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IEEE Std 802.11bb™-2023,
IEEE Std 802.11™-2020/Cor 2-2024,
and IEEE Std 802.11bc™-2024)

## Draft Standard for Information Technology—
## Telecommunications and Information Exchange between Systems
## Local and Metropolitan Area Networks—
## Specific Requirements

# Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications

**Prepared by the 802.11 Working Group of the**

**LAN/MAN Standards Committee**
**of the IEEE Computer Society**

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**Abstract:** Technical corrections and clarifications to IEEE Std 802.11 for wireless local area networks (WLANs) as well as enhancements to the existing medium access control (MAC) and physical layer (PHY) functions are specified in this revision. Amendments 1 to 7 published in 2021 to 2024 have also been incorporated into this revision.

**Keywords:** 2.4 GHz, 256-QAM, 3650 MHz, 4.9 GHz, 5 GHz, 5.9 GHz, 60 GHz, advanced encryption standard, AES, audio, beamforming, carrier sense multiple access/collision avoidance, CCMP, channel switching, clustering, contention based access period, Counter Mode with Cipher-block chaining Message authentication code Protocol, confidentiality, CSMA/CA, DFS, direct link, directional multi-gigabit, dynamic allocation of service period, dynamic extension of service period, dynamic frequency selection, dynamic truncation of service period, E911, EDCA, emergency alert system, emergency services, fast session transfer, forwarding, GCMP, generic advertisement service, high throughput, IEEE 802.11™, international roaming, interworking, interworking with external networks, LAN, local area network, MAC, management, measurement, medium access control, media-independent handover, medium access controller, mesh, MIS, millimeter-wave, MIMO, MIMO-OFDM, multi-band operation, multi-hop, multi-user MIMO, multiple input multiple output, network advertisement, network discovery, network management, network selection, noncontiguous frequency segments, OCB, path-selection, personal basic service set, PHY, physical layer, power saving, QoS, quality of service, quality-of-service management frame, radio, radio frequency, RF, radio resource, radio management, relay operation, spatial sharing, SSPN, subscriber service provider, television white spaces, TPC, transmit power control, video, wireless access in vehicular environments, wireless LAN, wireless local area network, WLAN, wireless network management, zero-knowledge proof

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# Introduction

This introduction is not part of IEEE P802.11-REVme/D7.0, August 2024, IEEE Standard for Information technology—Telecommunications and information exchange between systems—Local and metropolitan area network—Specific requirements—Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications.

This revision gives users, in one document, the IEEE 802.11 standard for wireless local area networks (WLANs) with all of the amendments that have been published to date.

## Incorporating published amendments

The original standard was published in 1997, revised in 1999 with MIB changes, and reaffirmed in 2003.

A revision was published in 2007, which incorporated into the 1999 edition the following amendments:

- IEEE Std 802.11a™-1999: High-speed Physical Layer in the 5 GHz Band (Amendment 1)
- IEEE Std 802.11b™-1999: Higher-Speed Physical Layer Extension in the 2.4 GHz Band (Amendment 2)
- IEEE Std 802.11b-1999/Corrigendum 1-2001: Higher-speed Physical Layer (PHY) extension in the 2.4 GHz band (Corrigendum 1 to Amendment 2)
- IEEE Std 802.11d™-2001: Specification for operation in additional regulatory domains (Amendment 3)
- IEEE Std 802.11g™-2003: Further Higher Data Rate Extension in the 2.4 GHz Band (Amendment 4)
- IEEE Std 802.11h™-2003: Spectrum and Transmit Power Management Extensions in the 5 GHz band in Europe (Amendment 5)
- IEEE Std 802.11i™-2004: Medium Access Control (MAC) Security Enhancements (Amendment 6)
- IEEE Std 802.11j™-2004: 4.9 GHz–5 GHz Operation in Japan (Amendment 7)
- IEEE Std 802.11e™-2005: Medium Access Control (MAC) Quality of Service Enhancements (Amendment 8)

A revision was published in 2012, which incorporated into the 2007 revision the following amendments:

- IEEE Std 802.11k™-2008: Radio Resource Measurement of Wireless LANs (Amendment 1)
- IEEE Std 802.11r™-2008: Fast Basic Service Set (BSS) Transition (Amendment 2)
- IEEE Std 802.11y™-2008: 3650–3700 MHz Operation in USA (Amendment 3)
- IEEE Std 802.11w™-2009: Protected Management Frames (Amendment 4)
- IEEE Std 802.11n™-2009: Enhancements for Higher Throughput (Amendment 5)
- IEEE Std 802.11p™-2010: Wireless Access in Vehicular Environments (Amendment 6)
- IEEE Std 802.11z™-2010: Extensions to Direct-Link Setup (DLS) (Amendment 7)
- IEEE Std 802.11v™-2011: Wireless Network Management (Amendment 8)
- IEEE Std 802.11u™-2011: Interworking with External Networks (Amendment 9)
- IEEE Std 802.11s™-2011: Mesh Networking (Amendment 10)

A revision was published in 2016, which incorporated into the 2012 revision the following amendments:

- IEEE Std 802.11ae™-2012: Prioritization of Management Frames (Amendment 1)
- IEEE Std 802.11aa™-2012: MAC Enhancements for Robust Audio Video Streaming (Amendment 2)


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- IEEE Std 802.11ad™-2012: Enhancements for Very High Throughput in the 60 GHz Band (Amendment 3)
- IEEE Std 802.11ac™-2013: Enhancements for Very High Throughput for Operation in Bands below 6 GHz (Amendment 4)
- IEEE Std 802.11af™-2013: Television White Spaces (TVWS) Operation (Amendment 5)

A revision was published in 2020, which incorporated into the 2016 revision the following amendments:

- IEEE Std 802.11ai™-2016 (second printing): Fast Initial Link Setup (Amendment 1)
- IEEE Std 802.11ah™-2016: Sub 1 GHz License Exempt Operation (Amendment 2)
- IEEE Std 802.11aj™-2018: Enhancements for Very High Throughput to Support Chinese Millimeter Wave Frequency Bands (60 GHz and 45 GHz) (Amendment 3)
- IEEE Std 802.11ak™-2018: Enhancements for Transit Links Within Bridged Networks (Amendment 4)
- IEEE Std 802.11aq™-2018: Preassociation Discovery (Amendment 5)

This revision is based on IEEE Std 802.11-2020, into which the following amendments have been incorporated:

- IEEE Std 802.11ax™-2021: Enhancements for High Efficiency WLAN (Amendment 1)
- IEEE Std 802.11ay™-2021: Enhanced Throughput for Operations in License-exempt Bands above 45 GHz (Amendment 2)
- IEEE Std 802.11ba™-2021: Wake-Up Radio Operation (Amendment 3)
- IEEE Std 802.11az™-2022: Enhancements for Positioning (Amendment 4)
- IEEE Std 802.11bd™-2022: Enhancements for Next Generation V2X (Amendment 5)
- IEEE Std 802.11bb™-2023: Light Communications (Amendment 6)
- IEEE Std 802.11bc™-2024: Enhanced Broadcast Services (Amendment 7)

## Technical corrections, clarifications, and enhancements

In addition, this revision specifies technical corrections and clarifications to IEEE Std 802.11 as well as enhancements to the existing medium access control (MAC) and physical layer (PHY) functions. In addition, this revision removes some features previously marked as obsolete and adds new indications of other obsolete features.

Generally, features that are marked deprecated or obsolete are not maintained; there might be technical errors in the material describing these features.

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## Renumbering of clauses and annexes

The numbering of certain clauses and annexes has been modified since IEEE Std 802.11-2012.

The evolution of this numbering is shown in Figure i (The evolution of numbering in IEEE Std 802.11).

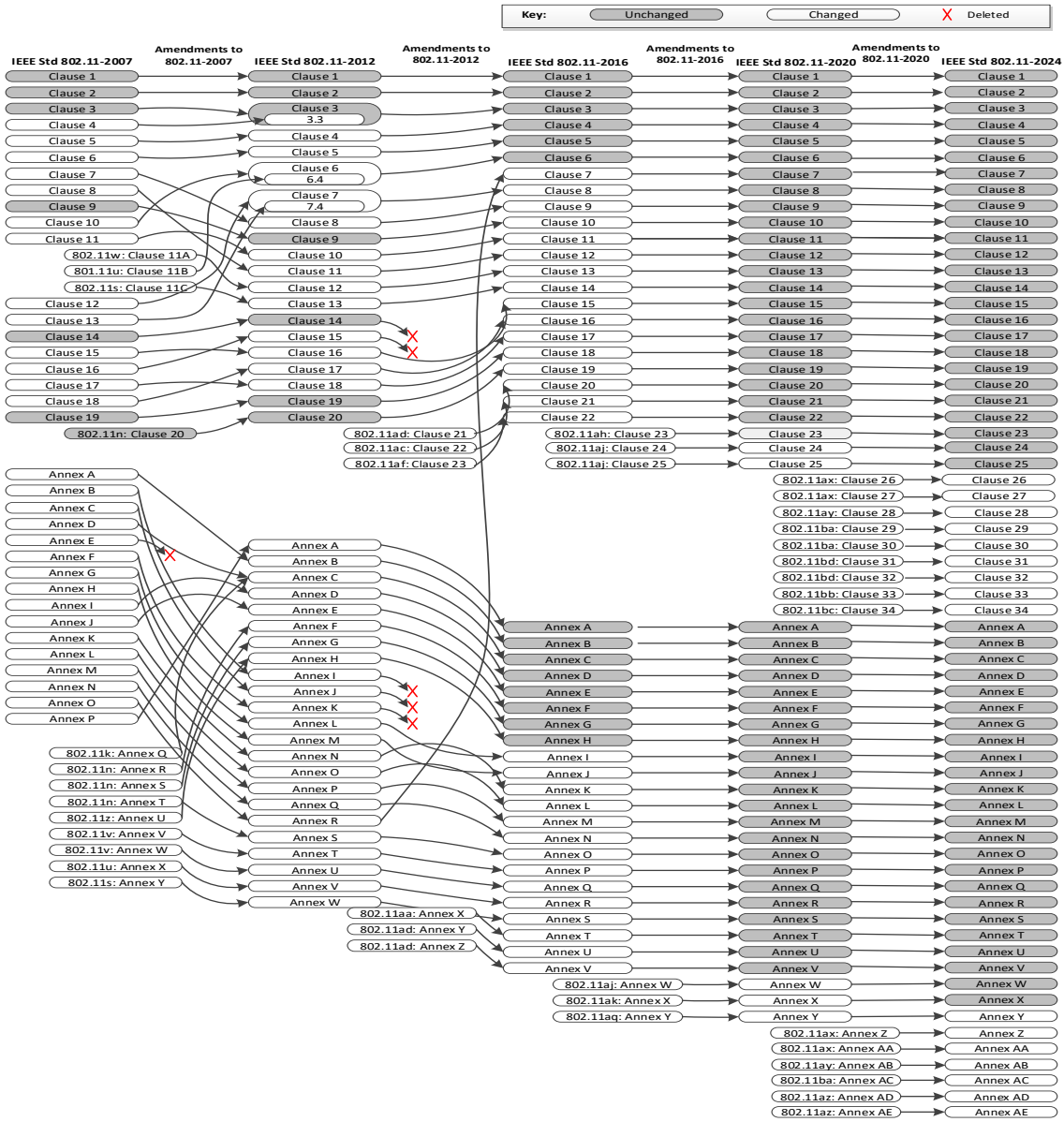


**Figure i—The evolution of numbering in IEEE Std 802.11**



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**Draft Standard for Information Technology—**
**Telecommunications and Information Exchange between Systems**
**Local and Metropolitan Area Networks—**
**Specific Requirements**

# Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications

## 1. Overview

### 1.1 Scope

The scope of this standard is to define one medium access control (MAC) and several physical layer (PHY) specifications for wireless connectivity for fixed, portable, and moving stations (STAs) within a local area.

### 1.2 Purpose

The purpose of this standard is to provide wireless connectivity for fixed, portable, and moving stations within a local area. This standard also offers regulatory bodies a means of standardizing access to one or more frequency bands for the purpose of local area communication.

### 1.3 Supplementary information on purpose

Specifically, in the context of IEEE 802.11™-compliant devices, this standard

- Describes the functions and services required by a device to operate within independent, personal, and infrastructure networks as well as the aspects of device mobility (transition) within those networks.
- Describes the functions and services that allow a device to communicate directly with another such device outside of an independent or infrastructure network.
- Defines the MAC procedures to support the MAC service data unit (MSDU) delivery services.
- Defines several PHY signaling techniques and interface functions that are controlled by the MAC.
- Permits the operation of a device within a wireless local area network (WLAN) that coexists with multiple overlapping IEEE 802.11 WLANs.
- Describes the requirements and procedures to provide data confidentiality of user information and MAC management information being transferred over the wireless medium (WM) and authentication of devices.
- Defines mechanisms for dynamic frequency selection (DFS) and transmit power control (TPC) that may be used to satisfy regulatory requirements for operation in any band.
- Defines the MAC procedures to support local area network (LAN) applications with quality-of-service (QoS) requirements, including the transport of voice, audio, and video.
- Defines mechanisms and services for wireless network management of devices that include BSS transition management, channel usage and coexistence, (#2210)colocated interference reporting, diagnostic, multicast diagnostic and event reporting, flexible multicast, efficient beacon


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mechanisms, proxy ARP advertisement, location, timing measurement, directed multicast, extended sleep modes, traffic filtering, and management notification.

- Defines functions and procedures aiding network discovery and selection by devices, information transfer from external networks using QoS mapping, and a general mechanism for the provision of emergency services.
- Defines the MAC procedures that are necessary for wireless multi-hop communication to support wireless LAN mesh topologies.
- Defines medium access control mechanisms to support the prioritization of Management frames.
- Defines mechanisms to improve audio video (AV) streaming QoS while maintaining data and voice performance.
- Defines the PHY signaling, MAC, and beamforming procedures required for operation with directional antenna patterns.
- Defines the PHY and MAC enhancements to enable operation in the Chinese millimeter wave frequency bands (60 GHz and 45 GHz).
- Defines the mechanisms for communications over the wireless medium used as a link in an IEEE 802.1Q™ bridged network.
- Defines mechanisms to enable delivery of preassociation service discovery information to IEEE 802.11 stations (STAs).
- Defines a mechanism to enable IEEE 802.11 STAs to operate at extremely low power consumption and to react to incoming traffic with low latency through a wake-up signal.(11ba)
- Defines mechanisms for the determination of absolute and relative position with secure measurement and measurement results exchange.(11az)
- Defines a mechanism to enable IEEE 802.11 stations to transmit and receive broadcast content, both in cases when the transmitter(s) and the receiver(s) are associated in an infrastructure BSS and when they are not; and a mechanism to enable uplink content to be relayed to a specified destination typically within an external network.(11bc)

## 1.4 Word usage

In this document, the word *shall* is used to indicate a mandatory requirement. The word *should* is used to indicate a recommendation. The word *may* is used to indicate a permissible action. The word *can* is used for statements of possibility and capability. The words *need(s) to* are used to indicate a requirement on an entity outside the scope of this standard.(#6401)

(#3703)The construction "between *x* and *y*", "*x* to *y*" or "*x*–*y*" represents an inclusive range (i.e., the range includes both values *x* and *y*). The construction "B*x*–B*y*" represents bits *x* to *y*; it is not the subtraction of bit *y* from bit *x*.(11ax)

The construction "up to *y*" represents an inclusive upper bound (i.e., the range includes the value *y).*

Any action specified as relating to a SAP primitive is to be interpreted as an action on an invocation or instance of that primitive.

If <x> represents a scalar field, scalar subfield, scalar parameter or scalar MIB attribute:

- if "<x> is" is used in a context that relates to the testing or setting the value of "<x>" this usage is to be interpreted as though written "the value of <x> is"
- "<x> indicate(s)" is to be interpreted as though written "the value of <x> indicate(s)"
- "indicated by <x>" is to be interpreted as though written "indicated by the value of <x>"
- "<x> that indicate" is to be interpreted as though written "<x> whose value indicates"

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If <x> represents a frame, element, subelement, structured field, structured subfield, structured parameter or structured MIB attribute:

— "<x> indicate(s)" is to be interpreted as though written "the contents of <x> indicate"
— "indicated by <x>" is to be interpreted as though written "indicated by the contents of <x>"
— "<x> that indicate" is to be interpreted as though written "<x> whose contents indicate"

(#2005)A reference to a value of a MIB attribute of the form "if <MIB attribute> is <x>" is to be interpreted as though written "if <MIB attribute> is present and is <x>". A reference to a value of a MIB attribute of the form "if <MIB attribute> is not <x>" is to be interpreted as though written "if <MIB attribute> is not present, or is present and is not <x>".

If <x> represents a SAP primitive:

— "<x> indicate(s)" is to be interpreted as though written "the (or an) invocation of <x> indicates"
— "indicated by <x>"(#323) is to be interpreted as though written "indicated by the (or an) invocation of <x>"

The construction of descriptions for uses of the SHA family of hash algorithms [HMAC-]SHA-<1,256,384>[-*n*] is used to refer to hash algorithms/HMACs where square brackets indicate optional information, and *n* is an integer indicating the length, in bits, of the output when truncating.

A construction of the form "the x element can be included in a, b and c frames" or "the x element can be present in a, b and c frames" is not to be understood as being a complete list of frames in which the element might be present.

Constructions of the form that a frame, MPDU or A-MPDU is transmitted with a certain TXVECTOR parameter, or received with a certain RXVECTOR parameter, are to be understood as referring to the TXVECTOR or RXVECTOR parameter, respectively, corresponding to the PSDU containing the frame, MPDU or A-MPDU. Similarly, constructions of the form that a PPDU is transmitted with a certain TXVECTOR parameter, or received with a certain RXVECTOR parameter, are to be understood as referring to the TXVECTOR or RXVECTOR parameter, respectively, corresponding to the PSDU contained in the PPDU.

References in this standard to a "<name> frame", where <name> corresponds to one of the Management frame subtypes, are to be understood as being to a "<name> MMPDU, where the MMPDU is carried in the frame body of one or more Management frames with the Subtype field value corresponding to <name>, plus information from the MPDU headers (the Management frame subtype and the addresses)".

(#3175)References in this standard to a "<name> Action frame", where <name> corresponds to a category identified in Table 9-81 (Category values), are to be understood as being to an "Action frame whose Category field indicates <name>", and references in this standard to a "<name> frame", where <name> corresponds to an Action frame subtype identified by the octet immediately after the Category field (the <something> Action field identified in the subclauses of 9.6 (Action frame format details)), are to be understood as being to "an Action frame with that <something> Action field (and the corresponding Category field)". For example, frames in the QoS category are called QoS Action frames, and frames in the QoS category with a QoS Action subfield of ADDTS Request are called ADDTS Request frames. Vendor Specific Public Action frames are a special case in that they use the "<name> Public Action frame" construction instead of the "<name> frame" above.(#4065)

References in this standard to a "<name> request", where <name> corresponds to one of the Measurement Types in Table 9-136 (Measurement type definitions for measurement requests) is equivalent to (according to context) a) "a Spectrum Measurement Request frame or Radio Measurement Request frame carrying a Measurement Request element with the Measurement Type field equal to <name>" or b) "a Measurement Request element with the measurement type field equal to <name>".


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References in this standard to a "<name> report", where <name> corresponds to one of the Measurement Types in Table 9-163 (Measurement Type field definitions for measurement reports) is equivalent to (according to context) a) "a Measurement Report frame or Radio Measurement Report frame carrying a Measurement Report element with the Measurement Type field equal to <name>" or b) "a Measurement Report element with the Measurement Type field equal to <name>".(#1687)

An ASCII or UTF-8 string is a sequence of ASCII or UTF-8 encoded code points, respectively, without a terminating null. ASCII refers to 7-bit US-ASCII per IETF RFC 20.(#1308)

References in this standard to "<adjective> STA" correspond to a specific instance of a STA implementation that can(M118) statically support and execute the <adjective> feature or role for the lifetime of the instance. Such a STA implementation may be capable of a different configuration where <adjective> is not supported (or even a mutually exclusive state is supported instead), but the switch from support to nonsupport of <adjective> is beyond the scope of this standard. The <adjective> support is to be understood as static for the lifetime of the instance, unless explicitly discussed otherwise.

References in this standard to "FILS authentication frame" or "SAE authentication frame" are to be understood as references to an Authentication frame that contains fields and elements for FILS or SAE (respectively) operation per Table 9-71 (Presence of fields and elements in Authentication frames).

(#4278)References in this standard to a "beacon" (with a lowercase initial letter) are to be understood as being to a Beacon, DMG Beacon or S1G Beacon frame, as the context permits.

(#1791)A construction of the form "silently discarding a frame" means that the STA shall discard the frame without further processing and without any externally observable notification that it has done so.

(#3181)References to the operating class of a BSS or STA are to be understood as being references to(#4376) the operating class pertaining to the channel on which the BSS or STA operates.

(#3266)A construction of the form "AKM [is] [not] 00-0F-AC:<n>" is to be interpreted as referring to the AKMP identified by AKM suite selector 00-0F-AC:<n>. A construction of the form "intended AKM" or "negotiated AKM" is to be interpreted as referring to the AKMP.

(#7159)Where a transition is shown a state machine figure, but no transition condition is shown, the transition occurs as soon as all the state actions have been performed.

## 1.5 Terminology for mathematical, logical, and bit operations

Floor ($x$), also written as $\lfloor x \rfloor$, is the largest integer smaller than or equal to $x$. For example, Floor (2.3) is 2 and Floor (–2.3) is –3. The two parameter form, Floor ($x$, $y$), is the largest multiple of $y$ smaller than or equal to $x$; this operator is not used in this standard if $y$ is negative. For example, Floor (3.3, 2) is 2 and Floor (–3.3, 2) is –4.

Ceil ($x$), also written as $\lceil x \rceil$ is the smallest integer larger than or equal to $x$. For example, Ceil (2.3) is 3 and Ceil (–2.3) is –2. The two parameter form, Ceil ($x$, $y$), is the smallest multiple of $y$ larger than or equal to $x$; this operator is not used in this standard if $y$ is negative. For example, Ceil (2.3, 2) is 4 and Ceil (–2.3, 2) is –2.

Round ($x$) is the integer closest to $x$, rounding values with a fractional part of 0.5 away from zero. For example, Round (2.3) is 2, Round (2.5) is 3, Round (–2.3) is –2 and Round (–2.5) is –3.

$x$ mod $y$ is the remainder when $x$ is divided by $y$; this operator is not used in this standard if $y$ is negative; the result is positive even if $x$ is negative. For example, 5 mod 3 is 2 and –5 mod 3 is 1.

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The symbol ⊕ represents bitwise exclusive OR (XOR).

log2 (*x*) is the logarithm of *x* to the base 2. For example, log2 (32) is 5.

log10 (*x*) is the logarithm of *x* to the base 10. For example, log10 (100) is 2.(11ax).

ln (*x*) is the logarithm of *x* to the base of natural logarithms. For example, ln (10) is approximately 2.3.(#315)

Re (*z*) is the real part of complex number *z*. Im (*z*) is the imaginary part of complex number *z* (not including the factor *i*). For example, Re (1 – 2*i*) is 1 and Im (1 – 2*i*) is –2.

*x* && *y* is the short-circuiting Boolean AND.

*x* || *y* is the concatenation of *x* and *y*, except in code, where it sometimes is the short-circuiting Boolean OR (as determined by the context).

!*x* is the Boolean NOT.

*x* >> *y* is *x* logically shifted right (i.e., zeros are inserted at the most significant end) by *y*; this operator is not used in this standard if *y* is negative.

*x* << *y* is *x* shifted left (i.e., zeros are inserted at the least significant end) by *y*; this operator is not used in this standard if *y* is negative.

x == y is Boolean equality.

x != y is(#1493) Boolean inequality.

*x* & *y*, where *x* and *y* are numbers, is the bitwise AND of *x* and *y*.

*x* | *y*, where *x* and *y* are numbers, is the bitwise OR of *x* and *y*.

0x introduces a hexadecimal number. For example, 0x12 is 18 decimal.

(#3506)ExtractBits(*S*, *F*, *N*) is bits *F* to *F*+*N*–1 of the bit string *S* starting from the left, using the IEEE 802.11 bit conventions from 9.2.2 (Conventions).

Truncate-*N*(*S*) is bits 0 to *N*–1 of the bit string *S* starting from the left, using the IEEE 802.11 bit conventions from 9.2.2 (Conventions)). Other bits are irretrievably deleted.

exp(*x*) is *e* to the power *x*, where *e* is the base of natural logarithms.

*A*[*b*:*c*] is the bit string consisting of bits *b* to *c* of *A*, where bit 0 of the output is the value of bit *b*. This operator is not used in this standard with *b* larger than *c*.

*int*(*S*) is the numeric value of bit string *S*, where bit 0 of S is the least significant bit, using the IEEE 802.11 bit conventions from 9.2.2 (Conventions).

NOTE—The *int* operator applied to a (portion of a) MAC address implies that octet 0 of the MAC address is the least significant octet under this operator.[1]

*bin*[*x*, *k*] is the operator that casts decimal value *x* into *k* bits binary vector, where *x* is less than $2^k$.

[1] NOTEs in text, tables, and figures of a standard are given for information only and do not contain requirements needed to implement the standard. Lettered footnotes to tables and figures, however, are normative.


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A construction of the form "*x* shall be ignored upon reception" (#6274)(and similar expressions) is to be understood as meaning that the state of any receiving STA is unaffected by *x*.(#4048)

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## 2. Normative references

The following referenced documents are indispensable for the application of this standard (i.e., they must be understood and used; therefore, each referenced document is cited in the text and its relationship to this document is explained). For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) at the time of publication of this standard applies.

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ETSI EN 301 893, Broadband Radio Access Networks (BRAN); 5 GHz high performance RLAN (latest Official Journal of the European Union published version).[3]

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IEC 60825-1 Ed. 3.0 b:2014, Safety of laser products—Part 1: Equipment classification and requirements.(11bb)

IEEE Std 754™-2008, IEEE Standard for Binary Floating-Point Arithmetic.[5,6]

IEEE Std 802®, IEEE Standards for Local and Metropolitan Area Networks: Overview and Architecture.

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IEEE Std 802.1AC™-2016, IEEE Standard for Local and Metropolitan Area Networks—Media Access Control (MAC) Service Definition.

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IEEE Std 802.3™-2018, IEEE Standard for Ethernet.

IEEE Std 802.21™-2017, IEEE Standard for Local and metropolitan area networks—Part 21: Media Independent Services Framework.

IEEE Std 802.21.1™-2017, IEEE Standard for Local and metropolitan area networks—Part 21.1: Media Independent Services.

[2] 3GPP™ documents are available from the 3rd Generation Partnership Project Web site (http://www.3gpp.org).
[3] ETSI documents are available from the European Telecommunications Standards Institute (http://www.etsi.org).
[4] FIPS publications are available from the National Technical Information Service (NTIS) (http://csrc.nist.gov).
[5] The IEEE standards or products referred to in this clause are trademarks owned by The Institute of Electrical and Electronics Engineers, Inc.
[6] IEEE publications are available from The Institute of Electrical and Electronics Engineers (http://standards.ieee.org/).


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ISO/IEC 8824-3:1995, Information technology — Abstract Syntax Notation One (ASN.1): Constraint specification.

ISO/IEC 8824-4:1995, Information technology — Abstract Syntax Notation One (ASN.1): Parameterization of ASN.1 specifications.

ISO/IEC 11802-5:1997, Information technology — Telecommunications and information exchange between systems—Local and metropolitan area networks — Technical reports and guidelines — Part 5: Medium Access Control (MAC) Bridging of Ethernet V2.0 in Local Area Networks (previously known as IEEE Std 802.1H, 1997 Edition [B18]).[11]

ISO/IEC 14888-3:2006, Information technology — Security techniques — Digital signatures with appendix — Part 3: Discrete logarithm based mechanisms.

ITU-T Recommendation Z.120 (2004), Programming Languages—Formal Description Techniques (FDT)—Message Sequence Chart (MSC).[12]

NIST Special Publication 800-38B, Recommendation for Block Cipher Modes of Operation: The CMAC Mode for Authentication, Dworkin, M.[13]

[8] ISO publications are available from the ISO Central Secretariat (http://www.iso.ch/).

[9] See http://www.currency-iso.org/en/home/tables/table-a1.html

[10] ISO/IEC publications are available from the ISO Central Secretariat (http://www.iso.ch/). ISO/IEC publications are also available in the United States from the American National Standards Institute (http://www.ansi.org/).

[11] The numbers in brackets correspond to the numbers of the bibliography in Annex A.

[12] ITU publications are available from the International Telecommunications Union (http://www.itu.int/).

[13] NIST publications are available from the National Institute of Standards and Technology (http://csrc.nist.gov/).

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NIST Special Publication 800-38D, Recommendation for Block Cipher Modes of Operation: Galois/ Counter Mode (GCM) and GMAC, Dworkin, M., Nov. 2007.

NIST Special Publication 800-56A R2, Recommendation for Pair-Wise Key Establishment Schemes Using Discrete Logarithm Cryptography, May 2013.

NIST Special Publication 800-57, Part 1 Rev 4, Recommendation for Key Management, Barker, E., Jan. 2016.

OASIS Standard EDXL-DE, "Emergency Data Exchange Language (EDXL) Distribution Element, v. 1.0." OASIS Emergency Management Technical Committee, May 2006.

OMA-TS-ULP-V2_0_1, UserPlane Location Protocol, Dec. 2012.[14]

[14] OMA publications are available from the Open Mobile Alliance (http://openmobilealliance.org/).


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# 3. Definitions, acronyms, and abbreviations

## 3.1 Definitions

For the purposes of this standard, the following terms and definitions apply. The *IEEE Standards Dictionary Online* should be referenced for terms not defined in this clause.[15]

**access control:** The prevention of unauthorized usage of resources.

**access point:** [AP](#3819) An entity that contains one station (STA) and provides access to the distribution system services, via the wireless medium (WM) for associated STAs. An AP comprises a STA and a distribution system access function (DSAF).

**access point (AP) reachability:** [AP reachability](#3819) An AP is reachable by a station (STA) if preauthentication messages can be exchanged between the STA and the target AP via the distribution system (DS).

NOTE—Preauthentication is defined in 12.6.8.2 (Preauthentication and RSNA key management).

**additional authentication data:** [AAD] Data that are not encrypted, but are cryptographically protected.

**admission control:** An algorithm intended to prevent the violation of parameterized service commitments made by the network to admitted flows by controlling the admittance of a new flow into a resource constrained network.

**aggregate medium access control (MAC) protocol data unit:** [A-MPDU] A structure that contains one or more MPDUs and is transported by a physical layer (PHY) as a single PHY service data unit (PSDU).

**aggregate medium access control (MAC) protocol data unit (A-MPDU) subframe:** [A-MPDU subframe] A portion of an A-MPDU that contains a delimiter and optionally contains an MPDU plus any necessary padding.

**aggregate medium access control (MAC) service data unit:** [A-MSDU] A structure that contains one or more MSDUs and is transmitted in one or more QoS Data frames with the same sequence number.(11ax)

**aggregate medium access control (MAC) service data unit (A-MSDU) subframe:** [A-MSDU subframe] A portion of an A-MSDU that contains a header and associated MSDU.

(#285)**antenna connector:** The measurement point of reference for radio frequency (RF) measurements in a station (STA). The antenna connector is the point in the STA architecture comprising a) a receive antenna connector representing the input of the receiver (output of the antenna) for radio reception and b) a transmit antenna connector representing the input of the antenna (output of the transmitter) for radio transmission. In systems using multiple antennas or antenna arrays, the antenna connector is a virtual point representing the aggregate output of (and input to) the multiple antennas. In systems using active antenna arrays with processing, the transmit antenna connector or receive antenna connector is respectively the input or output of the active array, which includes any processing gain of the active antenna subsystem. (11bb)In systems using light communications, the antenna connector is a virtual point representing the intermediate frequency (IF) interface of the light communication (LC) optical antenna. In the receive direction, the signal at this virtual point is the output of the LC optical receive (RX) antenna and includes any processing gain from the LC optical RX antenna.

[15] *IEEE Standards Dictionary Online* is available at http://dictionary.ieee.org/. An IEEE account is required for access to the dictionary, and one can be created at no charge on the dictionary sign-in page.

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(#285)NOTE 1—The receive antenna connector and transmit antenna connector might be the same measurement point.

(#285)NOTE 2—In contexts in which transmission or reception is the subject "antenna connector" is an implicit reference to the transmit antenna connector or receive antenna connector, respectively.

**antenna selection (ASEL) receiver:** [ASEL receiver] A station (STA) that (#3214)uses an antenna selection procedure to perform the mapping of signals at RF chains onto antenna elements when the number of RF chains is smaller than the number of antenna elements.

**antenna selection (ASEL) transmitter:** [ASEL transmitter] A station (STA) that performs transmit ASEL.

**antenna weight vector:** [AWV] A vector of weights describing the excitation (amplitude and phase) for each element of an antenna array.

**association:** The service used to establish a mapping between an access point (AP) or personal basic service set (PBSS) control point (PCP), and a station (STA) and enable STA invocation of the distribution system services (DSSs).

**authenticated encryption with associated data:** [AEAD] A cipher mode that performs authenticated encryption of a plaintext, with associated data that is authenticated but not encrypted.

**authentication:** The service used to establish the identity of one station (STA) as a member of the set of STAs authorized to associate with another STA.

**Authentication Server:** [AS] An entity that provides an authentication service to an Authenticator. This service determines, from the credentials provided by the Supplicant, whether the Supplicant is authorized to access the services provided by the Authenticator. ((#3469)IEEE Std 802.1X-2020[16])

**Authenticator:** An entity at one end of a point-to-point local area network (LAN) segment that facilitates (#441)Authentication of the entity attached to the other end of that link. ((#3469)IEEE Std 802.1X-2020)

**Authenticator**(#1380) **address:** [AA] The medium access control (MAC) address of the IEEE 802.1X Authenticator's station (STA).(#238)

**authorization:** The act of determining whether a particular right, such as access to a resource, is granted to an entity.

NOTE—See IETF RFC 2903 [B35].

**authorized:** To be explicitly allowed.

**average noise plus interference power indicator:** [ANIPI] A medium access control (MAC) indication of the average noise plus interference power measured on a channel that meets the two simultaneous conditions: 1) the station (STA) is not transmitting a frame, and 2) the station (STA) is not receiving a frame addressed to it.

**azimuth:** The horizontal orientation of the front surface of a station or of a radio antenna system's main lobe measured clockwise from true north.

**basic service area:** [BSA] (#7188)The area in which the members of a basic service set (BSS) are able to communicate with each other such that necessary services of the BSS can be provided, such as synchronization and data transfer.

[16] Information on references can be found in Clause 2 (Normative references).


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(#7188)NOTE—The extent of a given BSA is unlikely to be strictly definable, nor static. See 4.3.6 (Area concepts) for further discussion.

**basic service set:** [BSS] A set of stations (STAs) that have successfully synchronized using the MLME-JOIN.request service primitive and one STA that has used the MLME-START.request primitive. Alternatively, a set of STAs that have used the MLME-START.request primitive specifying matching mesh profiles where the match of the mesh profiles has been verified via the scanning procedure. Membership in a BSS does not imply that wireless communication with all other members of the BSS is possible.(#238)

**basic service set (BSS) max idle period:** [BSS max idle period] A time period during which the access point (AP) does not disassociate a station (STA) due to nonreceipt of frames from that STA.

**basic service set (BSS) transition:** [BSS transition] Change of association by a station (STA) from one BSS to another BSS in the same extended service set (ESS).

**beamformee:** A station (STA) that receives a physical layer (PHY) protocol data unit (PPDU) that was transmitted using a beamforming steering matrix.

**beamformer:** A station (STA) that transmits a physical layer (PHY) protocol data unit (PPDU) using a beamforming steering matrix.

**beamforming:** [BF](M118) A spatial filtering mechanism used at a transmitter to improve the received signal power or signal-to-noise ratio (SNR) at an intended receiver. *Syn:* **beam steering**.

**beamforming steering matrix:** A matrix determined using knowledge of the channel between a transmitter and an intended receiver that maps from space-time streams to transmit antennas with the goal of improving the signal power or signal-to-noise ratio (SNR) at the intended receiver.

**big endian:** The concept that, for a given multi-octet numeric representation, the most significant octet has the lowest address.

**broadcast address:** A unique group address that specifies all stations (STAs).

**calibration initiator:** A station (STA) that initiates a calibration sequence.

**calibration responder:** A station (STA) that transmits during a calibration sequence in response to a transmission by a calibration initiator.

**candidate peer mesh station (STA):** [candidate peer mesh STA] A neighbor mesh STA to which a mesh peering has not been established but meets eligibility requirements to become a peer mesh STA.

**certificate authority:** [CA] An entity that vouches for the binding between a device's identity, its public key, and associated keying material (such as key validity period and key usage).

**channel:** An instance of (#2253)use of the wireless medium (WM) for the purpose of passing physical layer (PHY) protocol data units (PDUs) between two or more stations (STAs).

**channel spacing:** The difference between the center frequencies of two nonoverlapping and adjacent channels of the radio transmitter.

**cipher suite:** A set of one or more algorithms, designed to provide data confidentiality, data authenticity or integrity, and/or replay protection.

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**clear channel assessment (CCA) function:** [CCA function] The logical function in the physical layer (PHY) that determines the current state of use of the wireless medium (WM).

**(#2210)colocated interference:** Interference that is caused by another radio or station (STA) emitting radio energy located in the same physical device as the reporting STA, where the reported characteristics of the interference are known a priori without interference detection, measurement, or characterization by the reporting STA.

**(#2210)colocated radio:** A radio capable of emitting radio-frequency energy located in the same physical device as the reporting station (STA), where the radio's type and some link characteristics are known without signal detection or measurement by the reporting STA.

**configuration profile:** A collection of parameters identified by a profile (#1310)nontransmitter identifier (ID) that represent a current or available configuration of a station (STA).

**contiguous transmission:** A transmission that uses only one frequency segment.

**coordination function:** The logical function that determines when a station (STA) is permitted to transmit protocol data units (PDUs) via the wireless medium (WM).

**(#1912)Counter Mode with cipher-block chaining message authentication code:** [CCM] A symmetric key block cipher mode providing confidentiality using (#1912)Counter Mode (CTR) and data origin authenticity using cipher-block chaining message authentication code (CBC-MAC).

NOTE—See IETF RFC 3610.

**cryptographic encapsulation:** The process of generating the cryptographic payload from the plaintext data. This comprises the cipher text as well as any associated cryptographic state required by the receiver of the data, e.g., initialization vectors (IVs), sequence numbers, message integrity codes (MICs), key identifiers.

**data confidentiality:** A property of information that prevents disclosure to unauthorized individuals, entities, or processes.

**deauthentication service:** The service that voids an existing authentication relationship.

**decapsulate:** To recover an unprotected frame from a protected one.

**decapsulation:** The process of generating plaintext data by decapsulating an encapsulated frame.

**dependent station (STA):** [dependent STA] A STA that is not registered and whose operational parameters are dictated by messages it receives from an enabling STA. Once enabled by the dynamic STA enablement (DSE) process, a dependent STA's continued operation becomes contingent upon being able to receive messages from its enabling STA over the wireless medium (WM).

**destination mesh station (STA):** [destination STA] A mesh STA that is the final destination of a (#238)medium access control (MAC) service data unit (MSDU). This mesh STA might reside in a proxy mesh gate that might forward the MSDU to a STA outside of the mesh basic service set (MBSS). A destination mesh STA might be an end station as defined in IEEE Std 802.

**direct link:** A bidirectional link from one quality-of-service (QoS) station (STA) to another QoS STA operating in the same (#1739)QoS independent basic service set (IBSS), or infrastructure QoS basic service set (BSS) that does not pass through a QoS access point (AP).(#562)(#1649)


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**directed multicast service:** [DMS] A service in which the access point (AP) transmits group addressed frames as individually addressed frames to the requesting non-AP station (STA).

**disassociation service:** The service that removes an existing association.

**distributed coordination function:** [DCF] A class of coordination function where the same coordination function logic is active in every station (STA) in the basic service set (BSS) whenever the network is in operation.

**distribution system:** [DS] A system used to interconnect a set of basic service sets (BSSs) and integrated local area networks (LANs) to create an extended service set (ESS).

**distribution system access function:** [DSAF] A function within an access point (AP) or mesh gate that uses the medium access control (MAC) service and distribution system service (DSS) to provide access between the distribution system (DS) and the wireless medium (WM). Within a general link (GLK) AP or GLK mesh station (STA), the DSAF also switches GLK traffic to the GLK convergence function and from there to the IEEE 802.1Q bridge port.

**distribution system medium:** [DSM] The medium or set of media used by a distribution system (DS) for communications between access points (APs), mesh gates, and the portal of an extended service set (ESS).

**distribution system service:** [DSS] The set of services provided by the distribution system (DS) that enable the medium access control (MAC) to transport MAC service tuples between stations (STAs) that are not in direct communication with each other over a single instance of the wireless medium (WM).

NOTE 1—These services include transport of MAC service tuples between the access points (APs) of basic service sets (BSSs) within an extended service set (ESS), transport of MAC service tuples between the portal and BSSs within an ESS, transport of MAC service tuples between mesh gates in the same or different mesh basic service sets (MBSSs), transport of MAC service tuples between mesh gates and APs, transport of MAC service tuples between mesh gates and a portal, and transport of MAC service tuples between STAs in the same BSS when the MAC service tuples has a group destination address or the destination is an individual address and the STA is associated with an AP.

NOTE 2—DSSs are provided between pairs of MACs not on the same instance of the WM.

**dynamic frequency selection:** [DFS] Facilities mandated to satisfy requirements in some regulatory domains for radar detection and uniform channel spreading in the 5 GHz band. These facilities might also be used for other purposes, such as automatic frequency planning.

**dynamic station (STA) enablement:** [DSE] The process by which an enabling STA grants permission and dictates operational procedures to STAs that are subject to its control.

**effective isotropic radiated power:** [EIRP] The equivalent power of a transmitted signal in terms of an isotropic (omnidirectional) radiator. The EIRP equals the product of the transmitter power and the antenna gain (reduced by any coupling losses between the transmitter and antenna).

**emergency alert system:** [EAS] A United States and its territories(#296) national public warning system.

**enabling station (STA):** [enabling STA] A registered STA that has the authority to control when and how a dependent STA can operate. An enabling STA communicates an enabling signal to its dependents over the wireless medium (WM). An enabling STA chooses whether other dynamic STA enablement (DSE) messages are exchanged over the air, over the distribution system (DS), or by mechanisms that rely on transport via higher layers.

**encapsulate:** To construct a protected frame from an unprotected frame.

**encapsulation:** The process of generating a protected frame by encapsulating plaintext data.

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**extended service area(#3782):** The area within which members of an extended service set (ESS) can communicate. An extended service area(#3782) is larger than or equal to a basic service area (BSA) and might involve several basic service sets (BSSs) in overlapping, disjointed, or both configurations.

**extended service set:** [ESS] A set of one or more basic service sets (BSSs) that are interconnected by a single distribution system (DS); an ESS appears as a single IEEE Std 802™ access domain to the logical link control (LLC) sublayer.(M12)

**extended service set (ESS) transition:** [ESS transition] Change of association by a station (STA) from one basic service set (BSS) in one ESS to another BSS in a different ESS.

**fast basic service set (BSS) transition:** [fast BSS transition, FT] Change of association by a station (STA) that is from one BSS in one extended service set (ESS) to another BSS in the same ESS and that minimizes the amount of time that the data connectivity is lost between the STA and the distribution system (DS).

**fast session transfer:** [FST] The transfer of a session from a channel to another channel, in the same or different frequency bands. The term "session" refers to non-physical layer state information kept by a pair of stations (STAs) that communicate directly (i.e., excludes forwarding).

**fixed station (STA):** [fixed STA] A STA that is physically attached to a specific location. In licensed bands, a fixed STA might be authorized to operate only at a specific location.

**forwarding information:** The information maintained by a mesh station (STA) that allows the mesh STA to perform its path selection and forwarding functions.

**(#14)frame:** A unit of data exchanged between medium access control (MAC) entities. *Syn:* **medium access control (MAC) protocol data unit (MPDU)**.

**(#109)frame exchange sequence:** A sequence of frames that maintains control of the wireless medium.

(#109)NOTE—Control of the wireless medium might be maintained across multiple frame exchange sequences through other mechanisms, see, for example, 10.23.2.8 (Multiple frame exchange sequences in an EDCA TXOP(#109)).

**frequency segment:** A contiguous block of spectrum used by a transmission or a block of spectrum used by a transmission that would be contiguous were it not punctured.(#1864)

**Gaussian frequency shift keying:** [GFSK] A modulation scheme in which the data are first filtered by a Gaussian filter in the baseband and then modulated with a simple frequency modulation.

**geolocation:** A location within an earth-centric frame of reference.

**group:** The entities in a wireless network, e.g., an access point (AP) and its associated stations (STAs), or all of the STAs in an independent basic service set (IBSS) network.

**group address:** A medium access control (MAC) address that has the group bit equal to 1. *Syn*: **multicast address**.

**group addressed:** When applied to a medium access control (MAC) service data unit (MSDU), it is an MSDU with a group address as the destination address (DA). When applied to a MAC protocol data unit (MPDU), it is an MPDU with a group address in the Address 1 field. *Syn*: **multicast**.

**HeSS**: A collection of basic service sets (BSSs) that provide access to a set of higher layer services using a given set of authentication credentials.(M12)


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NOTE 1—HeSS is an orthogonal concept to extended service set (ESS). Membership of a given BSS in an HeSS is independent of any ESS membership.

NOTE 2—"HeSS" is not an abbreviation for anything.

**hidden station (STA):** [hidden STA] A STA whose transmissions are not detected using carrier sense (CS) by a second STA, but whose transmissions interfere with transmissions from the second STA to a third STA. (M12)

**idle power indicator:** [IPI] A physical layer (PHY) indication of the total channel power (noise and interference) as measured in the channel at the receiving antenna connector while the station (STA) is idle, i.e., neither transmitting nor receiving a frame.

**IEEE 802.1X authentication:** Extensible Authentication Protocol (EAP) authentication transported by the IEEE 802.1X protocol.

**(M118)independent basic service set:** [IBSS] A basic service set (BSS) that forms a self-contained network, and in which no access to a distribution system (DS) is available.

**independent basic service set (IBSS) station (STA):** [IBSS STA] A STA that has started or joined an IBSS.

**individual address:** A medium access control (MAC) address in which the group bit is 0.(#1649)

**individually addressed:** When applied to a medium access control (MAC) service data unit (MSDU), it is an MSDU with an individual address as the destination address (DA). When applied to a MAC protocol data unit (MPDU), it is an MPDU with an individual address in the Address 1 field.(#1649)

**infrastructure:** An infrastructure comprises a distribution system (DS), one or more access points (APs), zero or one portals, and zero or more mesh gates. It is also the logical location of distribution and integration service functions of an extended service set (ESS).(#238)

**infrastructure authorization information:** The information that specifies the access rights of the user of a (#1295)non–access point (non-AP) station (STA). This information might include the rules for routing the user traffic, a set of permissions about services that a user is allowed to access, quality-of-service (QoS) configuration information, or the accounting policy to be applied by the infrastructure.

**infrastructure basic service set (BSS):** [infrastructure BSS] A BSS that includes an access point (AP), which enables access to a distribution system (DS).(#6070)

**integration service:** The service that enables delivery of medium access control (MAC) service data units (MSDUs) between the distribution system (DS) and a local area network (LAN) (via a portal).

**link margin:** Ratio of the received signal power to the minimum required by the station (STA). The STA might incorporate rate information and channel conditions, including interference, into its computation of link margin. The specific algorithm for computing the link margin is implementation dependent.

**link metric:** A criterion used to characterize the performance, quality, and eligibility of a link.

**little endian:** The concept that, for a given multi-octet numeric representation, the least significant octet has the lowest address.

**liveness:** A demonstration that the peer is actually participating in this instance of communication.

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**location subject local:** The term used when a location request is for the location of the requesting station (STA), i.e., when the requesting STA asks, "Where am I?"

**location subject remote:** The term used when a location request is for the location of the reporting station (STA), i.e., when the requesting STA asks, "Where are you?"

**location subject third party:** The term used when the location request is for the location of a station (STA) other than the requesting STA or the requested STA, (i.e., when the requesting STA asks, "Where is station A?")(#3246)

**master session key:** [MSK] Keying material that is derived between the Extensible Authentication Protocol (EAP) peer and exported by the EAP method to the Authentication Server (AS).

NOTE—In this standard, this key is at least 64 octets in length(#14).

**medium access control (MAC) protocol data unit:** [MPDU] The unit of data exchanged between two peer MAC entities using the services of the physical layer (PHY). *Syn:* **medium access control (MAC) frame**.

**medium access control (MAC) service data unit:** [MSDU] Information that is delivered as a unit between MAC service access points (SAPs).

**(#350)medium access control (MAC) service tuple:** [MAC service tuple] The collection of a MAC service data unit (MSDU) along with the associated source address, destination address, priority, drop eligibility, service class, station vector, and MSDU format, which are all passed as parameters across the MAC service access point (SAP) and are all except the station vector delivered across the distribution system between access points (APs), mesh gates, and the portal of an extended service set (ESS).

**mesh basic service set:** [MBSS] A basic service set (BSS) that forms a self-contained network of mesh stations (STAs) that use the same mesh profile. An MBSS contains zero or more mesh gates, and can be formed from mesh STAs that are not in direct communication.

**mesh facility:** The set of enhanced functions, channel access rules, frame formats, mutual authentication methods, and managed objects used to provide data transfer among autonomously operating stations (STAs) that might not be in direct communication with each other over a single instance of the wireless medium. Communication between STAs using the mesh facility takes place using only the wireless medium. The mesh facility transports a medium access control (MAC) service data unit (MSDU) between source and destination STAs over potentially multiple hops of the wireless medium without transiting the MAC service access point (SAP) at intermediate STAs.

**mesh gate:** Any entity that has a mesh station (STA) function and a distribution system access function (DSAF) to provide access to a single distribution system for the mesh basic service set (MBSS).

**mesh link:** A link from one mesh station (STA) to a neighbor mesh STA that have a mesh peering with each other.

**mesh neighborhood:** The set of all neighbor mesh stations (STAs) of a particular mesh STA.

**mesh path:** A concatenated set of mesh links from a source mesh station (STA) to a destination mesh STA.

**mesh path selection:** The process of selecting a mesh path.

**mesh peering:** A relationship between two mesh stations (STAs) that is required for direct communication over a single instance of the wireless medium (WM). A mesh peering is established with a mesh peering protocol.


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**mesh profile:** A set of values of parameters that identifies the attributes of the mesh basic service set (MBSS) and that is used in a single MBSS.

NOTE—The mesh profile consists of the identifiers that are the values for the parameters: mesh identifier (ID), active path selection protocol, active path selection metric, congestion control mode, synchronization method, and authentication protocol.

**mesh services:** The set of services that enable the creation and operation of a mesh basic service set (MBSS).

**mesh station (STA):** [mesh STA] A quality-of-service (QoS) STA that implements the mesh facility.

**message integrity code:** [MIC] A value generated by a cryptographic function. If the input data are changed, a new value cannot be correctly computed without knowledge of the cryptographic key(s) used by the cryptographic function.

NOTE—This is traditionally called a *message authentication code* (MAC), but the acronym MAC is already reserved for another meaning in this standard.

**mobile station (STA):** [mobile STA] A type of STA that uses network communications while in motion.(#4083)

**mobility domain:** A set of basic service sets (BSSs), within the same extended service set (ESS), that support fast BSS transitions between themselves and that are identified by the set's mobility domain identifier (MDID).

**mobility domain identifier:** [MDID] An identifier that names a mobility domain.

**multicast:** *See:* **group addressed**.

**multicast address:** *See:* **group address**.

**multicast-group address:** A medium access control (MAC) address associated by higher level convention with a group of logically related stations (STAs). (#3593)The group of STAs is referred to a multicast group.

**multi-level precedence and preemption:** [MLPP] A framework used with admission control for the treatment of traffic streams based on precedence, which supports the preemption of an active traffic stream by a higher precedence traffic stream when resources are limited. Preemption is the act of forcibly removing a traffic stream in progress in order to free up resources for another higher precedence traffic stream.

**multiple basic service set identifier (BSSID) capability:** [multiple BSSID capability] The capability to advertise information for multiple BSSIDs using a single Beacon or Probe Response frame instead of using multiple Beacon or Probe Response frames, each corresponding to a single BSSID, and the capability to indicate buffered frames for these multiple BSSIDs using a single traffic indication map (TIM) element in a single Beacon or TIM frame.

**multiple input, multiple output:** [MIMO] A physical layer (PHY) configuration in which (#3519)the transmitter uses multiple antennas and the receiver might use multiple antennas.(#4180)

**multiple medium access control (MAC) station management entity (SME):** [MM-SME] (M118)(#4084)Component of station management that manages multiple cooperating stations (STAs).

**multi-user multiple input, multiple output:** [MU-MIMO] A technique by which multiple stations (STAs), each with one or more antennas, either simultaneously transmit to a single STA or simultaneously receive from a single STA independent (#2056)PSDUs over the same subcarriers.(11ax)

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**neighbor access point (AP):** [neighbor AP] Any AP that is a potential service set transition candidate.

**neighbor station (STA):** [neighbor STA] A STA in the following relationship: STA A is a neighbor to STA B if STA A can both directly transmit to and receive from STA B over the wireless medium.

**network access identifier:** [NAI] The user identity submitted by the Supplicant during IEEE 802.1X authentication.

NOTE—See IETF RFC 4282.

**network access server (NAS) client:** [NAS client] The client component of a NAS that communicates with the Authentication Server (AS).

**network allocation vector:** [NAV] An indicator, maintained by each station (STA), of time periods when transmission onto the wireless medium (WM) is not initiated by the STA regardless of whether the STA's clear channel assessment (CCA) function senses that the WM is busy.

**next-hop mesh station (STA):** [next-hop mesh STA] The next peer mesh STA on the mesh path to the destination mesh STA.

**non–access point (non-AP)(#1295) station (STA):** [non-AP STA] A STA that is not contained within an access point (AP).

**nonce:** A (#4317)numeric value, used in cryptographic operations associated with a given cryptographic key, that is not to be reused with that key, including over all reinitializations of the system through all time.

**noncontiguous transmission:** A transmission that uses nonadjacent frequency segments.

**noninfrastructure basic service set (BSS):** [noninfrastructure BSS](M118) A BSS that is not an infrastructure BSS.(#3349)

**nonoperating channel:** A channel that is not the operating channel of the basic service set (BSS) of which the station (STA) is a member.

**non-quality-of-service (non-QoS) access point (AP):** [non-QoS AP] An AP that does not support the quality-of-service (QoS) facility.

**non-quality-of-service (non-QoS) basic service set (BSS):** [non-QoS BSS] A BSS that does not support the quality-of-service (QoS) facility.

**non-quality-of-service (non-QoS) station (STA):** [non-QoS STA] A STA that does not support the quality-of-service (QoS) facility.

**operating channel:** The operating channel is the channel in which beacons are transmitted.

NOTE—In IEEE Std 802.11, the serving access point (AP) of an infrastructure basic service set (BSS) or the dynamic frequency selection (DFS) owner of an independent basic service set (IBSS) (M118)transmit beacons.

**operating channel width:** The channel width in which the station (STA) is currently able to receive.

**optical front-end (OFE):** Optoelectronic module that, in a transmitter, converts an intermediate frequency (IF) electrical signal to an intensity modulated optical signal, and, in a receiver, converts the intensity modulated optical signal to an IF electrical signal.(11bb)


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**orthogonal frequency division multiple access:** [OFDMA] An orthogonal frequency division multiplexing(#2254) (OFDM)-based multiple access technique by which multiple stations (STAs) either simultaneously transmit to a single STA, or simultaneously receive from a single STA, independent (#2056)PSDUs over different groups of subcarriers.(11ax)(#2307)

**overlapping basic service set:** [OBSS] A basic service set (BSS) operating on the same channel as the station's (STA's) BSS and within (either partly or wholly) its basic service area (BSA).

**over-the-air fast basic service set (BSS) transition (FT):** [over-the-air fast BSS transition, over-the-air FT] An FT method in which the station (STA) communicates over a wireless medium (WM) link to the target access point (AP).

**over-the-distribution-system (over-the-DS) fast basic service set (BSS) transition (FT):** [over-the-DS fast BSS transition, over-the-DS FT] An FT method in which the station (STA) communicates with the target access point (AP) via the current AP.(#238)

**pairwise:** Referring to, or an attribute of, two entities that are associated with each other, e.g., an access point (AP) and an associated station (STA), or two STAs in an independent basic service set (IBSS) network. This term is used to refer to a type of encryption key hierarchy pertaining to keys shared by only two entities.

**pass-phrase:** A secret text string employed to corroborate the user's identity.

**password:** A shared, secret, and potentially low-entropy word, phrase, code, or key used as a credential for authentication purposes.

NOTE—The method of distribution of a password to the units in the system is outside the scope of this standard.

**path metric:** An aggregate multi-hop criterion used to characterize the performance, quality, and eligibility of a mesh path.

**peer mesh station (STA):** [peer mesh STA] A mesh STA to which a mesh peering has been established.

**peer-to-peer (PTP) link:** [PTP link] (M118)(#1752)A station-to-station (STA-to-STA) link between tunneled direct link(#2154) setup (TDLS) peer STAs in an infrastructure basic service set (BSS) or between STAs in a noninfrastructure BSS.(#3349)

**(M118)peer-to-peer (P2P) traffic specification (TSPEC):** [PTP TSPEC] The quality-of-service (QoS) characteristics of a data flow between non-access point (non-AP) QoS stations (STAs).

**perfect forward secrecy:** [PFS] A property of a key agreement protocol that protects a session key derived from a set of long-term public and private keys from being compromised if one of the (long-term) private keys is compromised in the future.

**per-frame encryption key:** A unique encryption key constructed for each medium access control (MAC) protocol data unit (MPDU)(#14).

**physical layer (PHY) protocol data unit:** [PPDU] The unit of data exchanged between PHY entities to provide the PHY data service.(11ax)

**piggyback:** The overloading of data with an acknowledgment of a previously received frame to the station (STA) to which the data is directed.

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**portable station (STA):** [portable STA] A type of station (STA) that might be moved from location to location, but that uses network communications only while at a fixed location.

**portal:** The logical point at which the integration service is provided.

NOTE—For the purposes of this Standard, there is at most one portal in a given extended service set's (ESS's) infrastructure. In an implementation, a single logical portal function might(M118) be provided by multiple devices that provide integration services for the ESS. How such multiple devices coordinate to appear as a single logical portal is implementation dependent.

**precursor mesh station (STA):** [precursor mesh STA] A neighbor peer mesh STA on the mesh path to the destination mesh STA, that identifies the mesh STA as the next-hop mesh STA.

**preshared key:** [PSK] A static key that is distributed to the units in the system by some out-of-band means.

**primary channel:** The common channel of operation for all stations (STAs) that are members of the basic service set (BSS). For example, in a 20 MHz, 40 MHz, 80 MHz, 160 MHz or 80+80 MHz BSS the primary channel is a primary 20 MHz channel.

**prioritized quality of service (QoS):** [prioritized QoS] The provisioning of service in which the medium access control (MAC) protocol data units (MPDUs) with higher priority are given a preferential treatment over MPDUs with a lower priority.

NOTE—Prioritized QoS is provided through the enhanced distributed channel access (EDCA) mechanism.

**protection mechanism:** Any procedure that attempts to update the network allocation vector (NAV) of all receiving stations (STAs) prior to the transmission of a frame that might or might not be detected as valid network activity by the physical layer (PHY) entities at those receiving STAs.

**protection mechanism frame:** Any frame that is sent as part of a protection mechanism procedure.

**protocol instance:** An execution of a particular protocol that consists of the state of the communicating parties as well as the messages exchanged.

**proxy mesh gate:** A mesh gate acting as an intermediary for IEEE 802 stations (STAs) outside the mesh basic service set (MBSS).

**pseudorandom function:** [PRF] A function that hashes various inputs to derive a pseudorandom value. In order to ensure liveness of a communication in which a pseudorandom value is used, a nonce is used as one of the inputs to the function.

**public safety answering point:** [PSAP] A physical location where emergency calls are received and routed to the appropriate emergency service dispatch center.

NOTE—See NENA 08-002 [B65].

**quadrature binary phase shift keying:** [QBPSK] A binary phase shift keying modulation in which the binary data is mapped onto the imaginary (Q) axis.

**quality-of-service (QoS) access point (AP):** [QoS AP] An AP that supports the QoS facility.

NOTE—In IEEE Std 802.11, the functions of a QoS AP are a superset of the functions of a non-QoS AP, and thus a QoS AP is able to function as a non-QoS AP to non-QoS stations (STAs).

**quality-of-service (QoS) basic service set (BSS):** [QoS BSS] A BSS that provides the QoS facility. An infrastructure QoS BSS contains a QoS access point (AP).


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**quality-of-service (QoS) facility:** [QoS facility] The set of enhanced functions, channel access rules, frame formats, frame exchange sequences and managed objects used to provide parameterized and prioritized QoS.

**quality-of-service (QoS) independent basic service set (IBSS):** [QoS IBSS] An IBSS in which one or more of its stations (STAs) support the QoS facility.

**quality-of-service (QoS) station (STA):** [QoS STA] A STA that implements the QoS facility.

NOTE—A QoS STA acts as a non-QoS STA when associated in a non-QoS basic service set (BSS).

**radio frequency (RF) chain:** [RF chain] The physical entity that is able to act as a receive chain or transmit chain, or both.

(M118)(11ay)**reassembly:** The process of combining a set of segmented medium access control (MAC) protocol data units (MPDUs) into a larger medium access control (MAC) service data unit (MSDU).

**reassociation service:** The service that enables an established association [between access point (AP) and station (STA)] to be transferred from one AP to another (or the same) AP.

(M118)**receive (RX) chain:** [RX chain] The physical entity that implements any necessary signal processing to provide the received signal to the digital baseband. Such signal processing includes filtering, amplification, down-conversion, and sampling.

(M118)**receive (RX) power:** [RX power] Mean power measured at the antenna connector.

(#14)**received channel power indicator:** [RCPI] An indication of the total channel power (signal, noise, and interference) of a received physical layer (PHY) protocol data unit (PPDU) measured on the channel and at the antenna connector used to receive the PPDU.

**received power indicator:** [RPI] A quantized measure of the received power level as seen at the antenna connector.

**registered location:** The geolocation of a station (STA) registered in accordance with the requirements for the regulatory domain.

**registered location query protocol:** [RLQP] The query protocol for registered location information that is received and transported by generic advertisement service (GAS) Public Action frames.

**registered location secure server:** [RLSS] An entity that accesses and manages a database that organizes storage of information by geographic location and securely holds the location and some operating parameters of one or more basic service sets (BSSs).

**registered station (STA):** [registered STA] A STA for which information needs to be submitted to an appropriate regulatory or coordination authority before it is allowed to transmit.

**remote request broker**: [RRB] The component of the station management entity (SME) of an access point (AP) that supports fast basic service set (BSS) transitions over the distribution system (DS).

**roaming consortium:** A group of subscription service providers (SSPs) having inter-SSP roaming agreements.

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**(11ay)segmentation:** The process of partitioning a large medium access control (MAC) service data unit (MSDU) into a sequence of MAC protocol data units (MPDUs), each carrying an MSDU segment. The inverse process of combining a set of segmented MPDUs into an MSDU is known as reassembly.

**service hash:** A value used for representing a service. This value is formed from a hash of the service name.

**service set identifier:** [SSID] A string used to identify the infrastructure basic service sets (BSSs) that comprise an extended service set (ESS), or to identify a noninfrastructure BSS(#3349).

NOTE—All BSSs in an ESS have the same SSID (see 4.3.5.2), but two BSSs with the same SSID might not be in the same ESS.(#6174)

**service set transition:** A station (STA) movement from one basic service set (BSS) to another BSS, i.e., either a BSS transition or an extended service set (ESS) transition.

**serving access point (AP):** [serving AP] The AP to which the station (STA) is associated.

**(#2255)(11ay)single input, single output:** [SISO] A physical layer (PHY) configuration in which both transmitter and receiver use a single antenna.

**single-user multiple input, multiple output:** [SU-MIMO] A technique by which a station (STA) with more than one antenna either transmits to or receives from a single STA independent space-time streams over the same radio frequencies.

**single-user (SU) physical layer (PHY) protocol data unit (PPDU):** [SU PPDU] A PPDU with a format that is capable of carrying only a single PHY service data unit (PSDU), or no PSDU.

**sounding:** The use of preamble training fields to measure the channel for purposes other than demodulation of the Data portion of the physical layer (PHY) protocol data unit (PPDU) containing the training fields.

NOTE—These uses include calculation of transmit steering, calculation of recommended modulation and coding scheme (MCS), and calculation of calibration parameters.

**source mesh station (STA):** [source mesh STA] A mesh STA from which a medium access control (MAC) service data unit (MSDU) enters the mesh basic service set (MBSS). A source mesh STA is either a mesh STA that is the source of an MSDU or a proxy mesh gate that receives an MSDU from a STA outside of the MBSS and forwards the MSDU on a mesh path.

**space-time stream:** [STS] Stream of modulation symbols created by applying a combination of spatial and temporal processing to one or more spatial streams of modulation symbols.

**spatial multiplexing:** [SM] A transmission technique in which data streams are transmitted on multiple spatial channels that are provided through the use of multiple antennas at the transmitter and the receiver.

**spatial stream:** One of several streams of bits or modulation symbols that might be transmitted over multiple spatial dimensions that are created by the use of multiple antennas at both ends of a communications link.

**station (STA):** [STA] A logical entity that is a singly addressable instance of a medium access control (MAC) and physical layer (PHY) interface to the wireless medium (WM).

NOTE—For IEEE 802.11 purposes, a station is any MAC/PHY entity providing the IEEE 802.11 MAC services. This differs from the IEEE 802 definition of ‘station,’ which includes bridges (or ‘end stations’) that are endpoints of link layer data traffic.


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**(#1296)station service:** The set of services that support transport of medium access control (MAC) service data units (MSDUs) between stations (STAs) within a basic service set (BSS)

**(#350)station vector:** A set of service_access_point_identifiers.

**subscription service provider:** [SSP] An organization (operator) offering connection to network services, perhaps for a fee.

**subscription service provider network:** [SSPN] The network controlled by a subscription service provider (SSP). The network maintains user subscription information.

**Supplicant:** An entity at one end of a point-to-point local area network (LAN) segment that is being authenticated by an Authenticator attached to the other end of that link. (#3469)IEEE Std 802.1X-2020)

**Supplicant address:** [SPA] The medium access control (MAC) address of the IEEE 802.1X Supplicant's station (STA).(#238)

**television white spaces:** [TVWS] The opportunistic use of allocated but not assigned spectrum—spectrum allocated for broadcast television, but with no assignment at a particular location.

**time unit:** [TU] A measurement of time equal to 1024 μs.

**traffic category:** [TC] A label for medium access control (MAC) service data units (MSDUs) that have a distinct user priority (UP), as viewed by higher layer entities, relative to other MSDUs provided for delivery over the same link. Traffic categories are meaningful only to MAC entities that support quality of service (QoS) within the MAC data service. These MAC entities determine the UP for MSDUs belonging to a particular traffic category using the priority value provided with those MSDUs at the MAC service access point (MAC SAP).

**traffic classification:** [TCLAS] The specification of one of several types of matching filter to classify protocol data units (PDUs) or medium access control (MAC) service data units (MSDUs) as belonging to a particular traffic stream (TS). Depending on the type of classification, the filter is applied within the MAC sublayer management entity (MLME), above the MAC, or within the MAC itself.

**traffic filter:** A set of traffic specifications defined by the use of traffic classification (TCLAS) elements that are utilized by the traffic filtering service (TFS) to identify specific allowed frames.

**traffic filtering service:** [TFS] A service provided by an access point (AP) to a non-AP station (STA) to reduce the number of frames sent to the non-AP STA by not forwarding individually addressed frames addressed to the non-AP STA that do not match traffic filters specified by the non-AP STA.

**traffic identifier:** [TID] Any of the identifiers usable by higher layer entities to distinguish medium access control (MAC) service data units (MSDUs) to MAC entities that support quality of service (QoS) within the MAC data service.

NOTE—There are 16 possible TID values; eight identify traffic categories (TCs), and the other eight identify parameterized traffic streams (TSs). The TID is assigned to an MSDU in the layers above the MAC.

**traffic specification:** [TSPEC] The quality-of-service (QoS) characteristics of a data flow to and from a QoS station (STA).

**traffic stream:** [TS] A set of medium access control (MAC) service data units (MSDUs) to be delivered subject to the quality-of-service (QoS) parameter values provided to the MAC in a particular traffic specification (TSPEC). TSs are meaningful only to MAC entities that support QoS within the MAC data service. These MAC entities determine the TSPEC applicable for delivery of MSDUs belonging to a

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particular TS using the priority parameter provided with those MSDUs at the MAC service access point (MAC SAP).

**transmission opportunity:** [TXOP] An interval of time during which a particular quality-of-service (QoS) station (STA) has the right to initiate frame exchange sequences onto the wireless medium (WM).

NOTE—A TXOP is defined by a starting time and a maximum duration.

(M118)**transmit (TX) chain:** [TX chain] The physical entity that implements any necessary signal processing to generate the transmit signal from the digital baseband. Such signal processing includes digital to analog conversion, filtering, amplification and upconversion.

**trusted third party**: [TTP] An entity that is relied upon to vouch for two parties in a pairwise authentication protocol.

**type/length/value:** [TLV] A format that consists of a type, a length, and a value.

**unauthorized disclosure:** The process of making information available to unauthorized individuals, entities, or processes.

**unauthorized resource use:** The use of a resource not consistent with the defined security policy.(#1649)

**uniform spreading:** A regulatory requirement for a channel selection mechanism that provides uniform usage across a minimum set of channels in the regulatory domain.

**unreachable destination:** A destination mesh station (STA) for which the link to the next hop of the mesh path to this destination mesh STA is no longer usable.

**user priority:** [UP] A value associated with an medium access control (MAC) service data unit (MSDU) that indicates how the MSDU is to be handled. The UP is assigned to an MSDU in the layers above the MAC.

**validated access point (AP):** [validated AP] An AP that has either been explicitly configured as a neighbor or learned through a mechanism such as the Beacon report.(#238)

**wildcard basic service set identifier (BSSID):** [wildcard BSSID] A BSSID value used to represent all BSSIDs.

NOTE—In IEEE Std 802.11, this is represented by all binary 1s.

**wildcard service set identifier (SSID):** [wildcard SSID] An SSID value used to represent all SSIDs.

NOTE—In IEEE Std 802.11, this is represented by the value “null”.

**wireless medium:** [WM] The medium used to implement the transfer of protocol data units (PDUs) between peer physical layer (PHY) entities of a wireless local area network (LAN).

## 3.2 Definitions specific to IEEE Std 802.11

The following terms and definitions are specific to terms or references in this standard and are not appropriate for inclusion in the *IEEE Standards Dictionary Online*.

**1 MHz mask physical layer (PHY) protocol data unit (PPDU):** [1 MHz mask PPDU] A PPDU that is transmitted using the 1 MHz transmit spectral mask defined in Clause 23 (Sub 1 GHz (S1G) PHY


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specification(#4095)) and that is a 1 MHz sub 1 GHz (S1G) PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW1).

**1 MHz physical layer (PHY) protocol data unit (PPDU):** [1 MHz PPDU] A Clause 23 (Sub 1 GHz (S1G) PHY specification(#4095)) 1 MHz sub 1 GHz (S1G) PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW1).

**2 MHz mask physical layer (PHY) protocol data unit (PPDU):** [2 MHz mask PPDU] A PPDU that is transmitted using the 2 MHz transmit spectral mask defined in Clause 23 (Sub 1 GHz (S1G) PHY specification(#4095)) and that is one of the following:

a) A 1 MHz sub 1 GHz (S1G) non-duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW1).

b) A 2 MHz S1G non-duplicate or S1G 1 MHz duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW2).

**2 MHz physical layer (PHY) protocol data unit (PPDU):** [2 MHz PPDU] A Clause 23 (Sub 1 GHz (S1G) PHY specification(#4095)) (#575)PPDU that is one of the following:

a) A 2 MHz sub 1 GHz (S1G) PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW2).

b) A 2 MHz S1G 1 MHz duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW2).

**(M118)(11ay)2.16 GHz mask physical layer (PHY) protocol data unit (PPDU)**: (#2305)[2.16 GHz mask PPDU] A PPDU defined in Clause 20 (Directional multi-gigabit (DMG) PHY specification) or Clause 28 (Enhanced directional multi-gigabit (EDMG) PHY specification(11ay)) that is transmitted using the transmit spectral mask defined in Clause 20 (Directional multi-gigabit (DMG) PHY specification).(#3769)

**(M118)(11ay)2.16 GHz physical layer (PHY) protocol data unit (PPDU)**: (#2305)[2.16 GHz PPDU] A PPDU that is one of the following:

a) A Clause 20 (Directional multi-gigabit (DMG) PHY specification) directional multi-gigabit (DMG) PPDU.

b) A Clause 28 (Enhanced directional multi-gigabit (EDMG) PHY specification(11ay)) 2.16-GHz enhanced directional multi-gigabit (EDMG) PPDU (TXVECTOR parameter FORMAT equal to EDMG).

c) A Clause 28 (Enhanced directional multi-gigabit (EDMG) PHY specification(11ay)) 2.16-GHz (#4106)nonenhanced directional multi-gigabit (non-EDMG) PPDU (TXVECTOR parameter FORMAT equal to NON_EDMG).

**(M118)(11ay)2.16+2.16 GHz mask physical layer (PHY) protocol data unit (PPDU)**: [2.16+2.16 mask PPDU] A PPDU defined in Clause 28 (Enhanced directional multi-gigabit (EDMG) PHY specification(11ay)) that is transmitted using the 2.16+2.16 GHz transmit spectral mask defined in the same clause.(#3769)

**(M118)(11ay)2.16+2.16 GHz physical layer (PHY) protocol data unit (PPDU)**: [2.16+2.16 PPDU] A PPDU that is one of the following:(#2305)

a) A Clause 28 (Enhanced directional multi-gigabit (EDMG) PHY specification(11ay)) 2.16+2.16 GHz enhanced directional multi-gigabit (EDMG) PPDU (TXVECTOR parameter FORMAT equal to EDMG).

b) A Clause 28 (Enhanced directional multi-gigabit (EDMG) PHY specification(11ay)) 2.16+2.16 GHz (#4106)nonenhanced directional multi-gigabit (non-EDMG) PPDU (TXVECTOR parameter FORMAT equal to NON_EDMG).

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**4 MHz mask physical layer (PHY) protocol data unit (PPDU):** [4 MHz mask PPDU] A PPDU that is transmitted using the 4 MHz transmit spectral mask defined in Clause 23 (Sub 1 GHz (S1G) PHY specification(#4095)) and that is one of the following:

a) A 1 MHz sub 1 GHz (S1G) non-duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW1).

b) A 2 MHz S1G non-duplicate or S1G 1 MHz duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW2).

c) A 4 MHz S1G non-duplicate, (#575)S1G 1 MHz duplicate, or S1G 2 MHz duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW4).

**4 MHz physical layer (PHY) protocol data unit (PPDU):** [4 MHz PPDU] A Clause 23 (Sub 1 GHz (S1G) PHY specification(#4095)) (#575)PPDU that is one of the following:

a) A 4 MHz sub 1 GHz (S1G) PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW4).

b) A 4 MHz S1G 1 MHz duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW4).

c) A 4 MHz S1G 2 MHz duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW4).

**4-way handshake:** A pairwise key management protocol defined by this standard. This handshake confirms mutual possession of a pairwise master key (PMK) by two parties, derives a pairwise transient key (PTK) and distributes one or more keys including a group temporal key (GTK).(#1701)

**(M118)(11ay)4.32 GHz mask physical layer (PHY) protocol data unit (PPDU)**: [4.32 GHz mask PPDU] A PPDU defined in Clause 28 (Enhanced directional multi-gigabit (EDMG) PHY specification(11ay)) that is transmitted using the 4.32 GHz transmit spectral mask defined in the same clause.(#3769)

**(M118)(11ay)4.32 GHz physical layer (PHY) protocol data unit (PPDU)**: [4.32 GHz PPDU] A PPDU that is one of the following:(#2305)

a) A Clause 28 (Enhanced directional multi-gigabit (EDMG) PHY specification(11ay)) 4.32-GHz enhanced directional multi-gigabit (EDMG) PPDU (TXVECTOR parameter FORMAT equal to EDMG).

b) A Clause 28 (Enhanced directional multi-gigabit (EDMG) PHY specification(11ay)) 4.32-GHz (#4106)nonenhanced directional multi-gigabit (non-EDMG) PPDU (TXVECTOR parameter FORMAT equal to NON_EDMG).

**(M118)(11ay)4.32+4.32 GHz mask physical layer (PHY) protocol data unit (PPDU)**: [4.32+4.32 GHz mask PPDU] A PPDU defined in Clause 28 (Enhanced directional multi-gigabit (EDMG) PHY specification(11ay)) that is transmitted using the 4.32+4.32 GHz transmit spectral mask defined in the same clause.(#3769)

**(M118)(11ay)4.32+4.32 GHz physical layer (PHY) protocol data unit (PPDU)**: [4.32+4.32 GHz PPDU] A PPDU that is one of the following:(#2305)

a) A Clause 28 (Enhanced directional multi-gigabit (EDMG) PHY specification(11ay)) 4.32+4.32 GHz enhanced directional multi-gigabit (EDMG) PPDU (TXVECTOR parameter FORMAT equal to EDMG).

b) A Clause 28 (Enhanced directional multi-gigabit (EDMG) PHY specification(11ay)) 4.32+4.32 GHz (#4106)nonenhanced directional multi-gigabit (non-EDMG) PPDU (TXVECTOR parameter FORMAT equal to NON_EDMG).

**(#3766)6 GHz band:** The frequency band between 5.925 GHz and 7.125 GHz.(#1061)


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(M118)(11ay)**6.48 GHz mask physical layer (PHY) protocol data unit (PPDU)**: [6.48 GHz mask PPDU] A PPDU defined in Clause 28 (Enhanced directional multi-gigabit (EDMG) PHY specification(11ay)) that is transmitted using the 6.48 GHz transmit spectral mask defined in the same clause.(#3769)

(M118)(11ay)**6.48 GHz physical layer (PHY) protocol data unit (PPDU)**: (#2305)[6.48 GHz PPDU] A PPDU that is one of the following:

a) A Clause 28 (Enhanced directional multi-gigabit (EDMG) PHY specification(11ay)) 6.48-GHz enhanced directional multi-gigabit (EDMG) PPDU (TXVECTOR parameter FORMAT equal to EDMG).

b) A Clause 28 (Enhanced directional multi-gigabit (EDMG) PHY specification(11ay)) 6.48-GHz (#4106)nonenhanced directional multi-gigabit (non-EDMG) PPDU (TXVECTOR parameter FORMAT equal to NON_EDMG).

**8 MHz mask physical layer (PHY) protocol data unit (PPDU):** [8 MHz mask PPDU] A PPDU that is transmitted using the 8 MHz transmit spectral mask defined in Clause 23 (Sub 1 GHz (S1G) PHY specification(#4095)) and that is one of the following:

a) A 1 MHz sub 1 GHz (S1G) non-duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW1).

b) A 2 MHz S1G non-duplicate or S1G 1 MHz duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW2).

c) A 4 MHz S1G non-duplicate, (#575)S1G 1 MHz duplicate, or S1G 2 MHz duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW4).

d) An 8 MHz S1G non-duplicate, (#575)S1G 1 MHz duplicate, or S1G 2 MHz duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW8).

**8 MHz physical layer (PHY) protocol data unit (PPDU):** [8 MHz PPDU] A Clause 23 (Sub 1 GHz (S1G) PHY specification(#4095)) (#575)PPDU that is one of the following:

a) An 8 MHz sub 1 GHz (S1G) PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW8).

b) An 8 MHz S1G 1 MHz duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW8).

c) An 8 MHz S1G 2 MHz duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW8).

(M118)(11ay)**8.64 GHz mask physical layer (PHY) protocol data unit (PPDU)**: [8.64 GHz mask PPDU] A PPDU defined in Clause 28 (Enhanced directional multi-gigabit (EDMG) PHY specification(11ay)) that is transmitted using the 8.64 GHz transmit spectral mask defined in the same clause.(#3769)

(M118)(11ay)**8.64 GHz physical layer (PHY) protocol data unit (PPDU)**: [8.64 GHz PPDU] A PPDU that is one of the following:(#2305)

a) A Clause 28 (Enhanced directional multi-gigabit (EDMG) PHY specification(11ay)) 8.64-GHz enhanced directional multi-gigabit (EDMG) PPDU (TXVECTOR parameter FORMAT equal to EDMG).

b) A Clause 28 (Enhanced directional multi-gigabit (EDMG) PHY specification(11ay)) 8.64-GHz (#4106)nonenhanced directional multi-gigabit (non-EDMG) PPDU (TXVECTOR parameter FORMAT equal to NON_EDMG).

**16 MHz mask physical layer (PHY) protocol data unit (PPDU):** [16 MHz mask PPDU] A PPDU that is transmitted using the 16 MHz transmit spectral mask defined in Clause 23 (Sub 1 GHz (S1G) PHY specification(#4095)) and that is one of the following:

a) A 1 MHz sub 1 GHz (S1G) non-duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW1).

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b) A 2 MHz S1G non-duplicate or S1G 1 MHz duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW2).

c) A 4 MHz S1G non-duplicate, (#575)S1G 1 MHz duplicate, or S1G 2 MHz duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW4).

d) An 8 MHz S1G non-duplicate, (#575)S1G 1 MHz duplicate, or S1G 2 MHz duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW8).

e) A 16 MHz S1G non-duplicate, (#575)S1G 1 MHz duplicate, or S1G 2 MHz duplicate (TXVECTOR parameter CH_BANDWIDTH equal to CBW16).

**16 MHz physical layer (PHY) protocol data unit (PPDU):** [16 MHz PPDU] A Clause 23 (Sub 1 GHz (S1G) PHY specification(#4095)) (#575)PPDU that is one of the following:

a) A 16 MHz sub 1 GHz (S1G) PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW16).

b) A 16 MHz S1G 1 MHz duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW16).

c) A 16 MHz S1G 2 MHz duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW16).

**20 MHz basic service set (BSS):** [20 MHz BSS] A BSS in which there is a primary 20 MHz channel and no secondary channel.

**20 MHz high throughput (HT)(#2297):** [20 MHz HT] A Clause 19 (High Throughput (HT) PHY specification(#2297)) transmission with the TXVECTOR parameter FORMAT equal to HT_MF or HT_GF and TXVECTOR parameter CH_BANDWIDTH equal to HT_CBW20.

**20 MHz mask physical layer (PHY) protocol data unit (PPDU):** [20 MHz mask PPDU] One of the following PPDUs:

a) A Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) PPDU transmitted using the 20 MHz transmit spectral mask defined in Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification).

b) A Clause 18 (Extended Rate PHY (ERP) specification) orthogonal frequency division multiplexing (OFDM) PPDU transmitted using the transmit spectral mask defined in Clause 18 (Extended Rate PHY (ERP) specification).

c) A (#2297)high throughput (HT) PPDU with the TXVECTOR parameter CH_BANDWIDTH equal to HT_CBW20 and the CH_OFFSET parameter equal to CH_OFF_20 transmitted using the 20 MHz transmit spectral mask defined in Clause 19 (High Throughput (HT) PHY specification(#2297)).

d) A very high throughput (VHT) PPDU with the TXVECTOR parameter CH_BANDWIDTH equal to CBW20 transmitted using the 20 MHz transmit spectral mask defined in Clause 21 (Very high throughput (VHT) PHY specification).

e) A Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) PPDU transmitted by a VHT station (STA)(#238) using the 20 MHz transmit spectral mask defined in Clause 21 (Very high throughput (VHT) PHY specification).

f) An HT PPDU with the TXVECTOR parameter CH_BANDWIDTH equal to HT_CBW20 and the CH_OFFSET parameter equal to CH_OFF_20 transmitted by a VHT STA using the 20 MHz transmit spectral mask defined in Clause 21 (Very high throughput (VHT) PHY specification).

g) A high-efficiency (HE) PPDU with TXVECTOR parameter CH_BANDWIDTH equal to CBW20 transmitted using the 20 MHz transmit spectral mask defined in Clause 27 (High-efficiency (HE) PHY specification(11ax)).(11ax)

h) A Clause 17 PPDU transmitted by an HE STA using the 20 MHz transmit spectral mask defined in Clause 27 (High-efficiency (HE) PHY specification(11ax)).(11ax)


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**20 MHz-only non–access point (non-AP)(#1295) high-efficiency station (HE STA):** 20 MHz-only non-AP HE STA] A non-AP HE STA that indicates in the Supported Channel Width Set subfield in the HE PHY Capabilities Information field in the HE Capabilities element that it does not support a channel width greater than 20 MHz.(11ax)(#2308)

**20 MHz operating non–access point (non-AP)(#1295) high-efficiency station (HE STA):** [20 MHz operating non-AP HE STA] A non-AP HE STA operating in a 20 MHz channel width mode, such as a 20 MHz-only non-AP HE STA or an HE STA that has reduced its operating channel width to 20 MHz using operating mode indication (OMI).(11ax)(#2309)

**20 MHz physical layer (PHY) protocol data unit (PPDU):** (#575)[20 MHz PPDU] A PPDU that is one of the following:

a) A Clause 15 (DSSS PHY specification for the 2.4 GHz band designated for ISM applications) PPDU.

b) A Clause 16 (High rate direct sequence spread spectrum (HR/DSSS) PHY specification) PPDU.

c) A Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) PPDU (when using 20 MHz channel spacing).

d) A Clause 18 (Extended Rate PHY (ERP) specification) orthogonal frequency division multiplexing (OFDM) PPDU.

e) A Clause 19 (High Throughput (HT) PHY specification(#2297)) 20 MHz (#2297)high throughput (HT) PPDU (TXVECTOR parameter CH_BANDWIDTH equal to HT_CBW20).

f) A Clause 21 (Very high throughput (VHT) PHY specification) 20 MHz very high throughput (VHT) PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW20).(11ax)

g) A Clause 27 (High-efficiency (HE) PHY specification(11ax)) (#2299)20 MHz high-efficiency (HE) PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW20).(11ax)

**20/40 MHz basic service set (BSS):** [20/40 MHz BSS] A BSS in which the supported channel width of the access point (AP) or dynamic frequency selection (DFS) owner (DO) station (STA) is 20 MHz and 40 MHz (Channel Width field is equal to 1) and the Secondary Channel Offset field is equal to a value of secondary channel above (SCA) or secondary channel below (SCB).

**40 MHz (#2297)high throughput (HT):** [40 MHz HT] A Clause 19 (High Throughput (HT) PHY specification(#2297)) transmission with the TXVECTOR parameter FORMAT equal to HT_MF or HT_GF and TXVECTOR parameter CH_BANDWIDTH equal to HT_CBW40.

**40 MHz mask physical layer (PHY) protocol data unit (PPDU):** [40 MHz mask PPDU] One of the following PPDUs:

a) A 40 MHz (#2297)high throughput (HT) PPDU (TXVECTOR parameter CH_BANDWIDTH equal to HT_CBW40) transmitted using the 40 MHz transmit spectral mask defined in Clause 19 (High Throughput (HT) PHY specification(#2297)).

b) A 40 MHz non-HT duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to NON_HT_CBW40) transmitted by a non-very high throughput (non-VHT) station (STA)(#238) using the 40 MHz transmit spectral mask defined in Clause 19 (High Throughput (HT) PHY specification(#2297)).

c) A 40 MHz non-HT duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW40) transmitted by a very high throughput (VHT) STA using the 40 MHz transmit spectral mask defined in Clause 21 (Very high throughput (VHT) PHY specification).

d) A 20 MHz HT PPDU with the TXVECTOR parameter CH_BANDWIDTH equal to HT_CBW20 and the CH_OFFSET parameter equal to either CH_OFF_20U or CH_OFF_20L transmitted using the 40 MHz transmit spectral mask defined in Clause 19 (High Throughput (HT) PHY specification(#2297)).

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e) A 20 MHz VHT PPDU with the TXVECTOR parameter CH_BANDWIDTH equal to CBW20 transmitted using the 40 MHz transmit spectral mask defined in Clause 21 (Very high throughput (VHT) PHY specification).

f) A 40 MHz VHT PPDU with the TXVECTOR parameter CH_BANDWIDTH equal to CBW40 transmitted using the 40 MHz transmit spectral mask defined in Clause 21 (Very high throughput (VHT) PHY specification).

g) A 40 MHz HT PPDU (TXVECTOR parameter CH_BANDWIDTH equal to HT_CBW40) transmitted by a VHT STA using the 40 MHz transmit spectral mask defined in Clause 21 (Very high throughput (VHT) PHY specification).

h) A 20 MHz non-HT PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW20) transmitted using the 40 MHz transmit spectral mask defined in Clause 19 (High Throughput (HT) PHY specification(#2297)).

i) A 20 MHz non-HT PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW20) transmitted by a VHT STA using the 40 MHz transmit spectral mask defined in Clause 21 (Very high throughput (VHT) PHY specification).

j) A 40 MHz high-efficiency (HE) PPDU with TXVECTOR parameter CH_BANDWIDTH equal to CBW40 transmitted using the 40 MHz transmit spectral mask defined in Clause 27 (High-efficiency (HE) PHY specification(11ax)).(11ax)

k) A 40 MHz VHT PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW40) transmitted by an HE STA using the 40 MHz transmit spectral mask defined in Clause 21 (Very high throughput (VHT) PHY specification).(11ax)

l) A 40 MHz non-HT duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW40) transmitted by an HE STA using the 40 MHz transmit spectral mask defined in Clause 19 (High Throughput (HT) PHY specification(#2297)).(11ax)

**40 MHz physical layer (PHY) protocol data unit (PPDU):** (#575)[40 MHz PPDU] A PPDU that is one of the following:

a) A 40 MHz (#2297)high throughput (HT) PPDU (TXVECTOR parameter CH_BANDWIDTH equal to HT_CBW40).

b) A 40 MHz non-HT duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to NON_HT_CBW40 or TXVECTOR parameter CH_BANDWIDTH equal to CBW40).

c) A 40 MHz very high throughput (VHT) PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW40).

d) A Clause 27 (High-efficiency (HE) PHY specification(11ax)) (#2300)40 MHz high-efficiency (HE) PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW40).(11ax)

**40-MHz-capable (40MC) (#2297)high throughput (HT) access point (AP):** [40MC HT AP] An HT AP that included a value of 1 in the Supported Channel Width Set subfield (indicating its capability to operate on a 40 MHz channel) of its most recent transmission of a frame containing an HT Capabilities element.

**40-MHz-capable (40MC) (#2297)high throughput (HT) access point (AP) 2G4:** [40MC HT AP 2G4] (#4085)An HT AP 2G4 that is also a 40MC HT AP.

**40-MHz-capable (40MC) (#2297)high throughput (HT) access point (AP) 5G:** [40MC HT AP 5G] An HT AP 5G that is also a 40MC HT AP.

**40-MHz-capable (40MC) (#2297)high throughput (HT) station (STA):** [40MC HT STA] An HT STA that included a value of 1 in the Supported Channel Width Set subfield (indicating its capability to operate on a 40 MHz channel) of its most recent transmission of a frame containing an HT Capabilities element.


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**40-MHz-capable (40MC) (#2297)high throughput (HT) station (STA) 2G4:** [40MC HT STA 2G4] An HT STA 2G4 that is also a 40MC HT STA.

**40-MHz-capable (40MC) (#2297)high throughput (HT) station (STA) 5G:** [40MC HT STA 5G] An HT STA 5G that is also a 40MC HT STA.

**80 MHz mask physical layer (PHY) protocol data unit (PPDU):** [80 MHz mask PPDU] One of the following PPDUs(11ax):

a) An 80 MHz very high throughput (VHT) PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW80) transmitted using the 80 MHz transmit spectral mask defined in Clause 21 (Very high throughput (VHT) PHY specification).(11ax)

b) An 80 MHz non-high-throughput (non-HT) duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW80) transmitted using the 80 MHz transmit spectral mask defined in Clause 21 (Very high throughput (VHT) PHY specification).(11ax)

c) A 20 MHz non-HT, (#2297)high throughput (HT), or VHT PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW20) transmitted using the 80 MHz transmit spectral mask defined in Clause 21 (Very high throughput (VHT) PHY specification).(11ax)

d) A 40 MHz non-HT duplicate, HT, or VHT PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW40) transmitted using the 80 MHz transmit spectral mask defined in Clause 21 (Very high throughput (VHT) PHY specification).(11ax)

e) An 80 MHz high-efficiency (HE) PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW80) transmitted using the 80 MHz transmit spectral mask defined in Clause 27 (High-efficiency (HE) PHY specification(11ax)).(11ax)

**80 MHz operating non–access point (non-AP)(#1295) high-efficiency station (HE STA):** [80 MHz operating non-AP HE STA] A non-AP HE STA that is operating in 80 MHz channel width mode, such as a non-AP STA (excluding the 20 MHz-only non-AP HE STA) (#1414)that is not capable of 160 MHz operation or a non-AP STA that has reduced its operating channel width to 80 MHz using (#2302)an operating mode indication (OMI).(11ax)

**80 MHz physical layer (PHY) protocol data unit (PPDU):** (#575)[80 MHz PPDU] A PPDU that is one of the following:

a) A Clause 21 (Very high throughput (VHT) PHY specification) 80 MHz very high throughput (VHT) PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW80).

b) A Clause 21 (Very high throughput (VHT) PHY specification) 80 MHz non-high-throughput (non-HT) duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW80).

c) A Clause 27 (High-efficiency (HE) PHY specification(11ax)) (#2298)80 MHz high-efficiency (HE) PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW80).(11ax)

**80+80 MHz mask physical layer (PHY) protocol data unit (PPDU):** [80+80 MHz mask PPDU] One of the following PPDUs(11ax):

a) An 80+80 MHz very high throughput (VHT) PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW80+80) transmitted using the 80+80 MHz transmit spectral mask defined in Clause 21 (Very high throughput (VHT) PHY specification).(11ax)

b) An 80+80 MHz non-high-throughput (non-HT) duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW80+80) transmitted using the 80+80 MHz transmit spectral mask defined in Clause 21 (Very high throughput (VHT) PHY specification).(11ax)

c) An 80+80 MHz high-efficiency (HE) PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW80+80) transmitted using the 80+80 MHz transmit spectral mask defined in Clause 27 (High-efficiency (HE) PHY specification(11ax)).(11ax)

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**80+80 MHz physical layer (PHY) protocol data unit (PPDU):** (#575)[80+80 MHz PPDU] A PPDU that is one of the following:

a) A Clause 21 (Very high throughput (VHT) PHY specification) 80+80 MHz very high throughput (VHT) PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW80+80).

b) A Clause 21 (Very high throughput (VHT) PHY specification) 80+80 MHz non-high-throughput (non-HT) duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW80+80).

c) A Clause 27 (High-efficiency (HE) PHY specification(11ax)) 80+80 MHz high-efficiency (HE) PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW80+80).(11ax)

**160 MHz mask physical layer (PHY) protocol data unit (PPDU):** [160 MHz mask PPDU] One of the following PPDUs(11ax):

a) A 160 MHz very high throughput (VHT) PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW160) transmitted using the 160 MHz transmit spectral mask defined in Clause 21 (Very high throughput (VHT) PHY specification).(11ax)

b) A 160 MHz non-high-throughput (non-HT) duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW160) transmitted using the 160 MHz transmit spectral mask defined in Clause 21 (Very high throughput (VHT) PHY specification).(11ax)

c) A 20 MHz non-HT, (#2297)high throughput (HT), or VHT PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW20) transmitted using the 160 MHz transmit spectral mask defined in Clause 21 (Very high throughput (VHT) PHY specification).(11ax)

d) A 40 MHz non-HT duplicate, HT, or VHT PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW40) transmitted using the 160 MHz transmit spectral mask defined in Clause 21 (Very high throughput (VHT) PHY specification).(11ax)

e) An 80 MHz non-HT duplicate or VHT PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW80) transmitted using the 160 MHz transmit spectral mask defined in Clause 21 (Very high throughput (VHT) PHY specification).(11ax)

f) A 160 MHz high-efficiency (HE) PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW160) transmitted using the 160 MHz transmit spectral mask defined in Clause 27 (High-efficiency (HE) PHY specification(11ax)).(11ax)

**160 MHz physical layer (PHY) protocol data unit (PPDU):** (#575)[160 MHz PPDU] A PPDU that is one of the following:

a) A Clause 21 (Very high throughput (VHT) PHY specification) 160 MHz very high throughput (VHT) PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW160).

b) A Clause 21 (Very high throughput (VHT) PHY specification) 160 MHz non-high- throughput (non-HT) duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW160).

c) A Clause 27 (High-efficiency (HE) PHY specification(11ax)) (#2301)160 MHz high-efficiency (HE) PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW160).(11ax)

**access category:** [AC] A label for the common set of enhanced distributed channel access (EDCA) parameters that are used by a quality-of-service (QoS) station (STA) to contend for the channel in order to transmit medium access control (MAC) service data units (MSDUs) with certain priorities.

**access network query protocol:** [ANQP] The query protocol for access network information retrieval transported by generic advertisement service (GAS) Public Action frames.

**access period:** A time period during a beacon interval established in a directional multi-gigabit (DMG) basic service set (BSS).

**access point (AP) path:** [AP path] Path between two tunneled direct link(#1356) setup (TDLS) peer stations (STAs) via the AP with which the STAs are currently associated.


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**ack-enabled single traffic identifier (TID) aggregate medium access control (MAC) protocol data unit (A-MPDU) (ack-enabled single-TID A-MPDU):** [ack-enabled single-TID A-MPDU] An A-MPDU that contains at least two A-MPDU subframes, where the TIDs differ and where only one of the A-MPDU subframes includes a tagged MPDU that solicits the acknowledgment context.(11ax)

NOTE—For the purpose of this definition, a Management frame is treated as if it had TID 15.(11ax)(#2303)(#6314)

**ack-enabled multi traffic identifier (TID) aggregate medium access control (MAC) protocol data unit (A-MPDU) (ack-enabled multi-TID A-MPDU):** [ack-enabled multi-TID A-MPDU] An A-MPDU where at least one tagged MPDU that solicits acknowledgment context is aggregated in the A-MPDU, and MPDUs from more than one TID that solicit Ack acknowledgment or Block Ack acknowledgment context are aggregated in the A-MPDU.(11ax)

NOTE—For the purpose of this definition, a Management frame is treated as if it had TID 15.(11ax)(#2304)(#6314)

(#1264)**active mode:** A power management mode of an associated station (STA) in which an access point (AP) might(M118) transmit physical layer (PHY) protocol data units (PPDUs) to an associated STA at any time. For a mesh STA, it is a mesh power management mode in which a neighbor peer mesh STA might(M118) transmit PPDUs to the mesh STA at any time.

(#1264)NOTE—This mode is equivalent to an associated STA or mesh STA being continuously in the awake state.

**advanced groupcast with retries (GCR):** [advanced GCR] A set of features comprising the GCR block acknowledgment retransmission policy and the GCR service period (GCR-SP) delivery method.

**advertisement protocol:** Access network query protocol (ANQP) and higher layer protocols defined external to this standard that are used for network and service discovery.

**advertisement server:** A logical server that provides the information repository for a specific advertisement protocol. The location of the physical server that instantiates the advertisement server is outside the scope of this standard.

(11ay)**aggregate physical layer (PHY) protocol data unit**: [A-PPDU] A sequence of two or more PPDUs transmitted without an interframe space (IFS). The PPDU(s) transmitted following the first PPDU in the sequence do not contain PHY preamble(s), only PHY header(s) and PHY service data unit(s) (PSDU(s)).

**aggregated schedule:** The aggregation of delivery and/or poll schedules by the quality-of-service (QoS) access point (AP) for a particular QoS station (STA) into a single service period (SP).

**attached bridge:** An IEEE 802.1Q bridge that has one or more bridge port Enhanced Internal Sublayer Service (EISS) interfaces supported by general links (GLKs) provided by a GLK access point (AP), GLK non-AP station (STA), GLK mesh STA, or GLK independent basic service set (IBSS) STA.

**authentication and key management (AKM) suite:** [AKM suite] A set of one or more algorithms designed to provide authentication and key management, either individually or in combination with higher layer authentication and key management algorithms outside the scope of this standard.

**average noise power indicator:** [ANPI] A medium access control (MAC) indication of the average noise plus interference power measured when the channel is idle as defined by three simultaneous conditions: 1) the virtual carrier sense (CS) mechanism indicates idle channel, 2) the station (STA) is not transmitting a frame, and 3) the STA is not receiving a frame.

**awake beacon interval:** [A-BI] In a directional multi-gigabit (DMG) basic service set (BSS) or personal basic service set (PBSS), a beacon interval of a power save mode wakeup schedule during which a station (STA) is expected to be in the awake state during several portions of the beacon interval.

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**bandwidth signaling transmitter address (TA):** [bandwidth signaling TA] A TA that is used by a very high throughput (VHT) station (STA), a high-efficiency (HE) STA(11ax), or a next generation vehicle-to-everything (NGV) STA(11bd) to indicate the presence of additional signaling related to the bandwidth to be used in subsequent transmission in an enhanced distributed channel access (EDCA) transmission opportunity (TXOP). (#1653)It is (11ax)the individual address of the transmitting (11ax)STA but with the Individual/Group bit set to 1.

**base channel:** Primary channel of the basic service set (BSS) of the access point (AP) with which the tunneled direct link(#1356) setup (TDLS) peer station (STA) is associated with an access point (AP).

**basic channel unit:** [BCU] For television very high throughput (TVHT) operation, 6 MHz, 7 MHz, or 8 MHz, depending on the regulatory domain.

(#97)**basic modulation and coding scheme (MCS):** [basic MCS] An MCS that belongs to the basic MCS set.

(#97)**basic modulation and coding scheme (MCS) set:** [basic MCS set] A set of MCSs designated by the station (STA) that started the basic service set (BSS) and fixed for the lifetime of the BSS. The basic MCS set is typically advertised in the element(s) (#1031)that contains the physical layer (PHY) operation parameters (among others), e.g., high throughput (HT) and very high throughput (VHT) Operation elements. All STAs in a BSS are capable of, or have signaled(#2256) that they are capable of, receiving and (#3078)transmitting using all MCSs in the basic MCS set.

(#97)**basic rate:** A data rate that belongs to the basic rate set.

(#97)**basic rate set:** A set of data rates designated by the station (STA) that started the basic service set (BSS) and fixed for the lifetime of the BSS. The basic rate set is advertised in the Supported Rates and BSS Membership Selectors element and, if present, the Extended Supported Rates and BSS Membership Selectors element. All STAs in a BSS are capable of, or have signaled that they are capable of, receiving and (#3078)transmitting using all rates in the basic rate set.

**basic service set (BSS) color:** [BSS color] An identifier for a BSS or for a set of BSSs belonging to a multiple basic service set identifier (BSSID) set or a co-hosted BSSID set.(11ax)

(#1311)**basic service set (BSS) identifier:** [BSSID] An identifier for a BSS.

**basic space-time block coding (STBC) modulation and coding scheme (MCS):** [basic STBC MCS] An An MCS value and STBC encoder specification used in the transmission of STBC-encoded Control frames and STBC-encoded group addressed frames.

**beacon header interval:** [BHI] The period of time that starts at the target beacon transmission time (TBTT) of a beacon interval of a directional multi-gigabit (DMG) basic service set (BSS) and that ends no later than the beginning of the data transfer interval (DTI) of the beacon interval.

**beacon integrity group temporal key:** [BIGTK] A random value, assigned by the access point (AP), that is used to protect Beacon frames from that AP.(#1521)

**beacon interval:** The time interval between two consecutive target beacon transmission times (TBTTs).

**beacon transmission interval:** [BTI] The time interval between the start of the first Directional Multi-gigabit (DMG) Beacon frame transmission by a DMG station (STA) in a beacon interval to the end of the last DMG Beacon frame transmission by the STA in the same beacon interval.


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**broadcast resource unit (RU):** [broadcast RU] A resource unit in a high-efficiency (HE) multi-user (MU) physical layer (PHY) protocol data unit (PPDU) transmitted by an access point (AP) that is intended for either unassociated STAs or more than one associated STA in the basic service set (BSS) or in any of the other BSSs in the multiple BSSID set to which the AP's BSS belongs.(11ax)

**broadcast target wake time (TWT):** [broadcast TWT] A specific time or set of times broadcast by an access point (AP) to multiple non-AP stations (STAs) at which the non-AP STAs are expected to be awake in order to exchange frames with the AP.(11ax)

**broadcast wake-up radio (WUR) wake-up frame:** [broadcast WUR wake-up frame] A WUR Wake-up frame with the ID field set to transmitter identifier (ID) or nontransmitter ID.(11ba)

**bufferable medium access control (MAC) management protocol data unit (MMPDU):** [bufferable MMPDU] An MMPDU that is eligible to be queued for delivery using a power saving mechanism(#3287).

**bufferable unit:** [BU] A medium access control (MAC) service data unit (MSDU), aggregate MAC service data unit (MSDU) [quality-of-service (QoS) stations (STAs) only], or bufferable MAC management protocol data unit (MMPDU).

**centralized authentication controlled (CAC) station (STA):** [CAC STA] A sub 1 GHz (S1G) non-access point (non-AP) STA that(#238) supports a CAC access point (AP) to alleviate wireless medium contention when a large number of STAs are trying to, or are expected to, reconnect to the AP at about the same time.

**centralized authentication controller (CAC) access point (AP):** [CAC AP] A sub 1 GHz (S1G) AP that(#238) is able to alleviate wireless medium contention when a large number of stations (STAs) are trying to, or are expected to, reconnect to the AP at about the same time.

**centralized coordination service root:** [CCSR] An entity that provides synchronization and configuration services to synchronization access points (S-APs).

**centralized coordination service set:** [CCSS] The collection of one centralized coordination service root (CCSR) and a set of one or more synchronization access points (S-APs) that are stationary with respect to their local environment while operating and are connected to the CCSR.

**channel-usage-aiding basic service set (BSS):** [channel-usage-aiding BSS] An infrastructure BSS whose AP performs channel coordination with at least one other non-co-hosted AP that has an overlapping BSS service area (BSA).(#6071)

**channel-usage-aidable basic service set (BSS):** [channel-usage-aidable BSS] A BSS that is not a channel-usage-aiding BSS.(#6071)

**China directional multi-gigabit:** [CDMG] Pertaining to directional multi-gigabit (DMG) operation and where the channel is contained within the Chinese 60 GHz frequency band.

**China directional multi-gigabit (CDMG) physical layer (PHY) protocol data unit (PPDU):** [CDMG PPDU] A Clause 24 (China directional multi-gigabit (CDMG) PHY specification) PPDU.

**China directional multi-gigabit small band beacon interval:** [CDMG SBBI] A value, in units of time units (TUs) represents the length of a beacon interval operating on a 1.08 GHz channel.

**China millimeter-wave multi-gigabit:** [CMMG] Pertaining to operation in a frequency band containing a channel in 42.3 GHz to 47.3 GHz or 47.2 GHz to 48.4 GHz frequency bands.

**China millimeter-wave multi-gigabit (CMMG) basic service set (BSS):** [CMMG BSS] A BSS in which directional multi-gigabit (DMG) Beacon frames are transmitted by CMMG stations (STAs).

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**China millimeter-wave multi-gigabit (CMMG) beamformee:** [CMMG beamformee] A CMMG station (STA) that receives a CMMG physical layer (PHY) protocol data unit (PPDU) that was transmitted using a beamforming steering matrix and that supports the CMMG transmit beamforming feedback mechanism as described in 10.32 (CMMG beamforming).

**China millimeter-wave multi-gigabit (CMMG) beamformer:** [CMMG beamformer] A CMMG station (STA) that transmits a CMMG physical layer (PHY) protocol data unit (PPDU) using a beamforming steering matrix.

**China millimeter-wave multi-gigabit (CMMG) duplicate physical layer (PHY) protocol data unit (PPDU) format:** [CMMG duplicate PPDU] A PPDU format that duplicates the transmission of a 540 MHz signal over two 540 MHz frequency segments.

**China millimeter-wave multi-gigabit (CMMG) physical layer (PHY) protocol data unit (PPDU):** [CMMG PPDU] A Clause 25 (China millimeter-wave multi-gigabit (CMMG) PHY specification) PPDU.

**China millimeter-wave multi-gigabit (CMMG) single medium access control (MAC) protocol data unit (CMMG single MPDU):** [CMMG single MPDU] An MPDU that is the only MPDU in an aggregate MPDU (A-MPDU) carried in a CMMG physical layer (PHY) protocol data unit (PPDU) and that is carried in an A-MPDU subframe with the EOF/Tag(#4367) subfield of the MPDU delimiter field equal to 1.

**co-hosted basic service set identifier (BSSID) set:** [co-hosted BSSID set] A collection of access points (APs) such that all APs use a common operating class, channel, receive antenna connector, and transmit antenna connector, and each AP advertises information for its BSSID using Beacon or Probe Response frames.(11ax)

**(#2210)colocated access point (AP) set:** [colocated AP set] A set of two or more APs in the same physical device.(11ax)

NOTE 1—APs in the colocated(#2210) set might be operating on the same or different channel.

NOTE 2—The APs that are part of a (#2210)colocated AP set and that are operating on the same channel might form a co-hosted basic service set identifier (BSSID) set or multiple BSSID set.

**compressed basic service set identifier (BSSID):** [compressed BSSID] A 32-bit Basic Service Set (BSS) identifier derived from a BSSID or a transmitted BSSID as defined in 29.5.2 (Compressed BSSID).(11ba)

**concealed groupcast with retries (GCR) frame:** [concealed GCR frame] A group addressed frame that is transmitted using the aggregate medium access control (MAC) service data unit (A-MSDU) format(#1996) with the destination address (DA) field set to the GCR concealment address.

**content identifier (ID):** An identifier of an enhanced broadcast services (EBCS) traffic stream.(11bc)

**contention based access period:** [CBAP] The time period in the data transfer interval (DTI) of a directional multi-gigabit (DMG) basic service set (BSS) during which enhanced distributed channel access (EDCA) is used.

**controlled access phase:** [CAP] A time period during which the hybrid coordinator (HC) maintains control of the medium. It might span multiple consecutive hybrid coordination function (HCF) controlled channel access (HCCA)(#238) transmission opportunities (TXOPs).

**data physical layer (PHY) protocol data unit (PPDU):** [data PPDU] A PPDU containing at least one medium access control (MAC) service data unit (MSDU) or fragment of an MSDU.

**deep sleep mode:** A mesh power management mode with respect to a neighbor peer mesh station (STA) in which a mesh STA alternates between awake and doze states and is not expected to receive beacons from this neighbor peer mesh STA.(#238)


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**(M118)delivery-enabled access category (AC):** [delivery-enabled AC] A quality-of-service (QoS) access point (AP) AC where the AP is allowed to use enhanced distributed channel access (EDCA) to deliver traffic from the AC to a QoS station (STA) in an unscheduled service period (SP) triggered by the STA.

**(#1000)delivery traffic indication map (DTIM) beacon:** [DTIM beacon] (#4097)A special case for a Beacon frame, (#4269)DMG Beacon or S1G Beacon frame, where the DTIM Count field in the TIM element is equal to zero. A DTIM beacon might be followed by buffered group addressed bufferable units (BUs).

**(#1000)delivery traffic indication map (DTIM) interval:** [DTIM interval] The interval between the consecutive target beacon transmission times (TBTTs) of DTIM beacons. The value, expressed in time units, is equal to the product of the value in the Beacon Interval field and the value in the DTIM Period field.

(#1000)NOTE 1—If the AP corresponds to a nontransmitted BSSID in a multiple BSSID set, the DTIM Period field is the one contained in the Multiple BSSID-Index element carried in the nontransmitted BSSID profile for that AP. Otherwise, the DTIM Period field is the one contained in the TIM element carried in the Beacon frame or S1G Beacon frame transmitted by that AP.

(#1000)NOTE 2—In a multiple BSSID set, the Beacon Interval field is the one contained in the Beacon frame transmitted by the AP corresponding to the transmitted BSSID in a multiple BSSID set.

**destination directional multi-gigabit (DMG) station (STA):** (11ay)[destination DMG STA] A DMG STA that is expected to receive during a time division duplex (TDD) slot, or a DMG STA identified by the destination association identifier (AID) field contained in a Grant frame or Extended Schedule element that caused the allocation of a service period (SP) or a contention based access period (CBAP). (#2310)

**differentiated initial link setup:** [DILS] A mechanism for restricting fast initial link setup (FILS) to certain categories of stations.

**direct sequence spread spectrum/complementary code keying:** [DSSS/CCK] A Clause 15 (DSSS PHY specification for the 2.4 GHz band designated for ISM applications) or Clause 16 (High rate direct sequence spread spectrum (HR/DSSS) PHY specification) transmission.

**direct sequence spread spectrum/complementary code keying (DSSS/CCK) physical layer (PHY) protocol data unit (PPDU):** [DSSS/CCK PPDU] A Clause 15 (DSSS PHY specification for the 2.4 GHz band designated for ISM applications) or Clause 16 (High rate direct sequence spread spectrum (HR/DSSS) PHY specification) PPDU.

**(M118)direct sequence spread spectrum (DSSS) physical layer (PHY) protocol data unit (PPDU):** [DSSS PPDU] A Clause 15 (DSSS PHY specification for the 2.4 GHz band designated for ISM applications) PPDU.

**directional multi-gigabit:** [DMG] Pertaining to operation in (11bb)a radio frequency (RF) frequency band containing a channel with the channel starting frequency above 45 GHz.

NOTE—The channel starting frequency for IEEE 802.11 stations (STAs) is defined in Annex E.

**(11ay)directional multi-gigabit (DMG) aggregate physical layer (PHY) protocol data unit (A-PPDU):** [DMG A-PPDU] An A-PPDU where all constituent PPDUs are DMG PPDUs.

**directional multi-gigabit (DMG) antenna:** [DMG antenna] A DMG antenna is a phased array, a single element antenna, or a set of switched beam antennas covered by a quasi-omni antenna pattern.

**directional multi-gigabit (DMG) basic service set (BSS):** [DMG BSS] A BSS in which DMG Beacon frames are transmitted by DMG stations (STAs).

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**directional multi-gigabit (DMG) frame:** [DMG frame] A frame transmitted or received within a DMG physical layer (PHY) protocol data unit (PPDU) (11ay)or within an enhanced directional multi-gigabit (EDMG) PPDU.

**directional multi-gigabit (DMG) physical layer (PHY) protocol data unit (PPDU):** [DMG PPDU] A Clause 20 (Directional multi-gigabit (DMG) PHY specification) PPDU.

**directional transmission:** A transmission that does not use an omnidirectional antenna pattern or quasi-omni antenna pattern.

**downlink:** A unidirectional link from an access point (AP) to one or more non-AP stations (STAs) or a unidirectional link from a non-AP destination directional multi-gigabit (DMG) STA to a non-AP source DMG STA.

**downlink (DL) high-efficiency (HE) multi-user (MU) physical layer (PHY) protocol data unit (PPDU):** [DL HE MU PPDU] An HE MU PPDU transmitted by an access point (AP). This PPDU carries one or more PHY service data units (PSDUs) for one or more users.(11ax)

**downlink multi-user multiple input, multiple output(#3367):** [DL MU-MIMO] A technique by which an access point (AP) with more than one antenna transmits a physical layer (PHY) protocol data unit (PPDU) to multiple receiving non-AP stations (STAs) over the same radio frequencies, wherein each non-AP STA simultaneously receives one or more distinct space-time streams.

**downlink multi-user multiple input, multiple output (DL MU-MIMO)(#3367) physical layer (PHY) protocol data unit (PPDU):** [DL MU-MIMO PPDU] A PPDU using the DL MU-MIMO(#3367) technique.

**doze beacon interval:** [D-BI] In a directional multi-gigabit (DMG) basic service set (BSS) or personal basic service set (PBSS), a beacon interval of a power save mode wakeup schedule during which a station (STA) is expected to be in the doze state for most of the portions of the beacon interval.

**dynamic bandwidth operation:** A feature of a very high throughput (VHT) station (STA) or a next generation vehicle-to-everything (NGV) STA in which the request-to-send/clear-to-send (RTS/CTS) exchange, using non-high-throughput (non-HT) duplicate physical layer (PHY) protocol data units (PPDUs or non-NGV duplicate PPDUs(11bd)), negotiates a potentially reduced channel width (compared to the channel width indicated by the RTS) for subsequent transmissions within the current transmission opportunity (TXOP).

**dynamic frequency selection (DFS) owner:** [DFS owner] A station (STA) in an independent basic service set (IBSS) or off-channel tunneled direct link setup (TDLS) direct link that takes responsibility for selecting the next channel after radar is detected operating in a channel. Due to the nature of IBSSs, it cannot be guaranteed that there is a single DFS owner at any particular time and the protocol is robust to this situation.

**EAPOL-Key frame:** A Data frame that carries all or part of an IEEE 802.1X Extensible Authentication Protocol (EAP) over local area network (LAN) (EAPOL) protocol data unit (PDU) of type EAPOL-Key.(#238)

**(#1571)EAPOL-Key request frame:** A Data frame that carries all or part of an IEEE 802.1X EAPOL-Key protocol data unit (PDU) with the Request bit in the Key Information field in the IEEE 802.11 Key Descriptor set to 1 and the Error bit set to 0.

**EAPOL-Start frame:** A Data frame that carries all or part of an IEEE 802.1X Extensible Authentication Protocol (EAP) over local area network (LAN) (EAPOL) protocol data unit (PDU) of type EAPOL-Start.(#238)(#1438)


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**emergency services association:** A robust security network association (RSNA) between an access point (AP) and a non-AP station (STA) without security credentials; the non-AP STA is granted access to emergency services using unprotected frames via this association.

**energy limited (EL) station (STA):** [EL STA] A sub 1 GHz (S1G) STA whose limited energy supply requires the STA to transmit or receive in certain intervals of time determined by an EL Operation element.

**enhanced broadcast services (EBCS)**: Services that enable the relaying of uplink broadcast traffic to a specified destination and enhanced broadcasting of downlink streams to both associated and unassociated stations (STAs).

**enhanced broadcast services (EBCS) access point (AP) group:** A group of one or more EBCS APs such that all EBCS APs in the group use common EBCS content identifiers (IDs). An EBCS AP group is a subgroup of an EBCS certificate group if the member APs use AP certificates.(11bc)

**enhanced broadcast services (EBCS) access point (AP) group identifier (ID):** An identifier (ID) of an EBCS AP group that can be used by EBCS receivers to filter EBCS traffic streams.(11bc)

**enhanced broadcast services (EBCS) certificate group:** A group of one or more EBCS access points (APs) such that all EBCS APs in the group use a common certificate for EBCS traffic streams.(11bc)

**enhanced broadcast services (EBCS) content MAC address:** A MAC address used in a frame header to identify an EBCS Data or EBCS uplink (UL) frame. See 34.2 (EBCS addressing).(11bc)

**enhanced broadcast services (EBCS) Data frame:** A Data frame used to carry data for an EBCS downlink traffic stream.(11bc)

**enhanced broadcast services (EBCS) downlink (DL):** A broadcast from an EBCS access point (AP) carrying an EBCS traffic stream.(11bc)

NOTE—This broadcast can be received by another EBCS AP.

**enhanced broadcast services (EBCS) downlink (DL) content server:** An entity reachable via the distribution system (DS) that is the source of an EBCS DL traffic stream.(11bc)

**enhanced broadcast services (EBCS) info MAC address:** A MAC address used in a frame header to identify an EBCS Info frame. See 34.2 (EBCS addressing).(11bc)

**enhanced broadcast services (EBCS) proxy:** A logical component affiliated with an EBCS relaying station (STA), which might be collocated with the EBCS relaying STA, that can relay a higher layer protocol (HLP) payload carried in an EBCS uplink (UL) frame received by the EBCS relaying STA to a destination specified in the frame, typically within an external network.(11bc)

**enhanced broadcast services (EBCS) receiver:** A station (STA) that can receive and process EBCS Data frames or EBCS uplink (UL) frames.(11bc)

**enhanced broadcast services (EBCS) relaying station:** An EBCS receiver that is affiliated with an EBCS proxy and provides a relaying service as described in 4.5.12.3 (EBCS relaying service) and 34.4 (EBCS UL procedure).(11bc)

NOTE—An EBCS relaying station (STA) can be an access point (AP) that has established its own infrastructure basic service set (BSS) or a STA that provides a relaying service without establishing an infrastructure BSS.

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**enhanced broadcast services (EBCS) service period:** A period of time during which an EBCS access point (AP) intends to conduct EBCS transmissions associated with one or more content identifiers (IDs).(11bc)

**enhanced broadcast services (EBCS) traffic stream:** A traffic stream that carries content on EBCS.(11bc)

**enhanced broadcast services (EBCS) transmitter:** A station (STA) that can transmit EBCS Data frames or EBCS uplink (UL) frames.(11bc)

**enhanced broadcast services (EBCS) uplink (UL):** A broadcast from an EBCS non-access point (non-AP) station (STA) carrying higher layer protocol (HLP) payload intended to be relayed by one or more EBCS relaying STAs to a destination specified in the broadcast.(11bc)

NOTE—An EBCS relaying STA might not be in range.

(11ay)**enhanced directional multi-gigabit**: [EDMG] Pertaining to an enhanced feature operation in directional multi-gigabit (DMG).

(11ay)**enhanced directional multi-gigabit (EDMG) aggregate physical layer (PHY) protocol data unit (A-PPDU)**: [EDMG A-PPDU] An A-PPDU where all constituent PPDUs are EDMG PPDUs.

(11ay)**enhanced directional multi-gigabit (EDMG) basic service set (BSS)**: [EDMG BSS] A directional multi-gigabit (DMG) BSS in which a DMG Beacon frame transmitted by an EDMG station (STA) has the EDMG Supported field equal to 1.

(11ay)**enhanced directional multi-gigabit (EDMG) physical layer (PHY) protocol data unit (PPDU)**: [EDMG PPDU] A Clause 28 (Enhanced directional multi-gigabit (EDMG) PHY specification(11ay)) PPDU transmitted with the TXVECTOR parameter FORMAT equal to EDMG.

**enhanced directional multi-gigabit (EDMG) secure ranging physical layer (PHY) protocol data unit (PPDU):** An EDMG single user (SU) PPDU that contains secure training (TRN) subfields in the training (TRN) field to enable secure ranging with physical layer (PHY) level security.(11az)

**enhanced distributed channel access:** [EDCA] The prioritized carrier sense multiple access with collision avoidance (CSMA/CA) access mechanism used by quality-of-service (QoS) stations (STAs) in a QoS basic service set (BSS) and STAs operating outside the context of a BSS. This access mechanism is also used by the QoS access point (AP) and operates concurrently with hybrid coordination function (HCF) controlled channel access (HCCA).

**enhanced distributed channel access function:** [EDCAF] A logical function in a quality-of-service (QoS) station (STA) that determines, using enhanced distributed channel access (EDCA), when a frame in the transmit queue with the associated access category (AC) is permitted to be transmitted via the wireless medium (WM). There is one EDCAF per AC.

**enhanced multiple basic service set identifier (BSSID) advertisement (EMA) access point (AP):** [EMA AP] An AP that uses enhancements related to the discovery of nontransmitted BSSIDs.(11ax)(#3730)

**extended centralized access point (AP) or personal basic service set (PBSS) control point (PCP) cluster:** [ECAPC] The collection of 1) a single centralized coordination service set (CCSS), 2) the set of centralized AP or PCP clusters such that each synchronization AP (S-AP) of a centralized AP or PCP cluster is within the CCSS, and 3) all stations (STAs) within the basic service sets (BSSs) of the S-APs and member APs and PCPs of the centralized AP or PCP clusters.


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**extended channel switching:** [ECS] A procedure that is used to announce a pending change of operating channel, operating class, or both.

**extended range (ER) beacon:** [ER beacon] A Beacon frame transmitted in a high-efficiency (HE) ER single-user (SU) physical layer (PHY) protocol data unit (PPDU) to form an ER basic service set (BSS).(11ax)

**extended rate physical layer (ERP):** [ERP] A physical layer (PHY) compliant with Clause 18 (Extended Rate PHY (ERP) specification).

**extended rate physical layer (ERP) physical layer (PHY) protocol data unit (PPDU):** [ERP PPDU] A Clause 18 (Extended Rate PHY (ERP) specification) PPDU that is not a Clause 16 (High rate direct sequence spread spectrum (HR/DSSS) PHY specification) PPDU.

**extended rate physical layer (PHY) using complementary code keying (CCK) modulation:** [ERP-CCK] A mode of operation of a PHY operating under Clause 18 (Extended Rate PHY (ERP) specification) rules, where the TXVECTOR parameter MODULATION is equal to ERP-CCK.(#238)

**extended rate physical layer (PHY) using direct sequence spread spectrum (DSSS) modulation:** [ERP-DSSS] A PHY operating under Clause 18 (Extended Rate PHY (ERP) specification) rules, where the TXVECTOR parameter MODULATION is equal to ERP-DSSS.(#238)

**extended rate physical layer (PHY) using direct sequence spread spectrum (DSSS) or complementary code keying (CCK) modulation:** [ERP-DSSS/CCK] A PHY operating under Clause 18 (Extended Rate PHY (ERP) specification) rules, where the TXVECTOR parameter MODULATION is equal to ERP-CCK or ERP-DSSS.(#238)

**extended rate physical layer (PHY) using orthogonal frequency division multiplexing (OFDM) modulation:** [ERP-OFDM] A mode of operation of a PHY operating under Clause 18 (Extended Rate PHY (ERP) specification) rules, where the TXVECTOR parameter MODULATION is equal to ERP-OFDM.(#238)

**extended service set (ESS) link:** [ESS link] In the context of an IEEE 802.11 medium access control (MAC) entity, a connection path through the wireless medium between a non–access point (non-AP)(#1295) station (STA) and one of the APs that is a member of the ESS.

**Extensible Authentication Protocol (EAP) reauthentication protocol (EAP-RP):** [EAP-RP] A protocol, using the EAP framework, that allows single round trip reauthentication with an Authentication Server after an initial EAP authentication.

NOTE—IETF RFC 6696 uses “ERP” for the abbreviation of EAP reauthentication protocol; IEEE Std 802.11 uses “EAP-RP” because “ERP” stands for “Extended Rate PHY” in IEEE Std 802.11.

**fast basic service set (BSS) transition (FT) 4-way handshake:** [FT 4-way handshake] A pairwise key management protocol used during FT initial mobility domain association. This handshake confirms mutual possession of a pairwise master key (PMK),(#238-Ed1) the PMK-R1, by two parties and distributes a group temporal key (GTK).

**fast basic service set (BSS) transition (FT) initial mobility domain association:** [fast BSS transition initial mobility domain association, FT initial mobility domain association] The first association or first reassociation procedure within a mobility domain, during which a station (STA) indicates its intention to use the FT procedures.

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**fast basic service set (BSS) transition (FT) originator:** (#4237)[FTO] A station (STA) that initiates the FT protocol by sending an FT Request frame or an Authentication frame with Authentication Algorithm Number field equal to Fast BSS Transition.

**fast initial link setup:** [FILS] A collection of mechanisms that enable IEEE Std 802.11 networks to minimize initial link setup time.

**fast initial link setup (FILS) access point (AP):** [FILS AP] An access point that implements FILS(#238).

**fast initial link setup (FILS) association:** [FILS association] A type of association used in fast initial link setup.

**fast initial link setup (FILS) authentication:** [FILS authentication] A type of authentication used in fast initial link setup.

**fast initial link setup (FILS) station (STA):** [FILS STA] A station that implements FILS(#238).

**fine timing measurement (FTM) procedure:** [FTM procedure] A procedure that allows a station (STA) to determine its distance from another STA.

**flexible multicast service:** [FMS] A service that enables a non–access point (non-AP)(#1295) station (STA) to request a multicast delivery interval longer than the delivery traffic indication map (DTIM) interval for the purposes of lengthening the period of time a STA can be in a power save state.

**flexible multicast service (FMS) stream:** [FMS stream] A succession of frames transmitted by the access point (AP) that correspond to a single flexible multicast stream identifier (FMSID).

**flexible multicast service (FMS) stream set:** [FMS stream set] A collection of FMS streams identified by the value of the FMS Token field, used during the FMS request procedure.(#238)

**flexible multicast stream (FMS) identifier:** [FMSID] An identifier assigned by the access point (AP) to a particular group addressed stream subsequent to a successful FMS request procedure.(#238)

**fragmentation:** The process of partitioning a medium access control (MAC) service data unit (MSDU), aggregate MAC service data unit (A-MSDU)(11ax) or MAC management protocol data unit (MMPDU) into a sequence of smaller MAC protocol data units (MPDUs) prior to transmission. The process of recombining a set of fragment MPDUs into an MSDU, A-MSDU,(11ax) or MMPDU is known as defragmentation.(#2190)

**future channel guidance:** future channel guidance communicates likely future channel information so that stations (STAs)(#238) can efficiently move their activity when the absence of Beacon frames is noticed.

**general link:** [GLK] A point-to-point connection between two instances of the IEEE 802.1AC(#51) Internal Sublayer Service that uses an IEEE 802.11 wireless link between stations (STAs). A general link is suitable for use in an IEEE 802.1Q bridged network.

**general link (GLK) convergence function:** [GLK convergence function] The convergence function defined in IEEE Std 802.1AC-2016 between an IEEE 802.11 medium access control (MAC) and an IEEE 802.1Q bridge.

**general link groupcast with retries:** [GLK-GCR] A variant of GCR that specifies the use of GCR for general link.

**general link (GLK) station (STA):** [GLK STA] A STA that implements GLK functionality.


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**generic advertisement service:** [GAS] An over-the-air transportation service that provides over-the-air transportation for frames of higher layer advertisements between stations (STAs) or between an advertisement server and a non–access point (non-AP)(#1295) STA. The protocol(s) used to relay frames between an AP, portal, and advertisement server is outside the scope of this standard. GAS supports higher layer protocols that employ a query/response mechanism.

**geolocation database:** [GDB] A database whose operation is mandated or authorized by a regulatory authority and that organizes storage of information by geographic location.

**geolocation database dependent:** [GDD] A modifier describing when station (STA) operation is dependent on information received from a geolocation database (GDB).

**geolocation database dependent (GDD) access point (AP):** [GDD AP] A station (STA) dependent on information received from a geolocation database (GDB) in order to initiate and maintain a network.

**geolocation database dependent (GDD) dependent station (STA):** [GDD dependent STA] A STA that is under the control of a GDD enabling STA.

**geolocation database dependent (GDD) enabling station (STA):** [GDD enabling STA] A STA that has the authority to control the operation of GDD dependent STAs after obtaining available spectrum for use at its own location.

**geolocation database dependent (GDD) fixed station (STA):** [GDD fixed STA] A STA whose geographical location information is fixed and maintained in a geolocation database (GDB) and whose operation depends on information received from that database.

**geolocation database dependent (GDD) geolocated non-access point (non-AP) station (STA):** [GDD geolocated non-AP STA] A STA that is not an AP and is authorized by a geolocation database (GDB) to operate at its current location.

**geolocation database dependent (GDD) non-access point (non-AP) station (STA):** [GDD non-AP STA] A STA that is not an AP but operates under the control of a GDD enabling STA.

**global operating class:** An operating class value that is any of the nonreserved values in Table E-4 (Global operating classes).(#258)

(M118)**group addressed quality-of-service (QoS) management frame:** [GQMF] A group addressed Management frame that is transmitted using the quality-of-service management frame (QMF) service.

**group addressed transmission service:** [GATS] A mechanism comprising directed multicast service (DMS) and groupcast with retries (GCR), for delivery of group addressed frames.

**group addressed wake-up radio (WUR) wake-up frame:** [group addressed WUR wake-up frame] A WUR Wake-up frame with the ID field set to group identifier (ID).(11ba)

**group key:** A key that is used to protect information exchanged in group addressed frames.(#1521)

**group key handshake:** A group key management protocol defined by this standard. It is used only to issue a new group temporal key (GTK) to peers with whom the local station (STA) has already formed security associations.

**group master key:** [GMK] An auxiliary key that might be used to derive a group temporal key (GTK).(#1521)

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**group temporal key:** [GTK] A temporal key that is used to protect information exchanged in group addressed Data frames.(#1521)

**group temporal key security association:** [GTKSA] The context resulting from a successful group temporal key (GTK) distribution exchange via either a group key handshake, a 4-way handshake, or fast initial link setup (FILS) authentication.

**groupcast with retries (GCR) active (GCR-A) delivery:** [GCR-A delivery] A delivery method for a group addressed stream subject to a GCR agreement wherein the frames are transmitted without regard to the power state of (#1295)non–access point (non-AP) stations (STAs).

**groupcast with retries (GCR) concealment address:** [GCR concealment address] A medium access control (MAC) address that is used to prevent group addressed frames transmitted via the GCR unsolicited retry or GCR block ack retransmission policies from being passed up the medium access control service access point (MAC SAP) of GCR-incapable stations (STAs).

**groupcast with retries (GCR) frame:** [GCR frame] A group addressed frame subject to a GCR agreement between the access point (AP) and at least one station (STA) within the infrastructure basic service set (BSS) or between peer mesh STAs in a mesh BSS.

**groupcast with retries (GCR) group address:** [GCR group address] A group address subject to a GCR agreement between the access point (AP) and at least one station (STA) within the basic service set (BSS) or between peer mesh STAs in a mesh BSS.

**groupcast with retries (GCR) service:** [GCR service] A means for transmission and retransmission of medium access control (MAC) service data units (MSDUs) to a destination that is a group address. The GCR service provides greater reliability by using group addressed retransmissions, concealed from GCR-incapable stations (STAs).

**groupcast with retries (GCR) service period (GCR-SP) aggregate medium access control (MAC) service data unit (A-MSDU):** [GCR-SP A-MSDU] An A-MSDU subject to the GCR service with the delivery method equal to GCR-SP.

**groupcast with retries (GCR) service period (GCR-SP) frame:** [GCR-SP frame] A frame subject to the GCR service when the delivery method is GCR-SP.

**groupcast with retries (GCR) service period (GCR-SP) medium access control (MAC) service data unit (MSDU):** [GCR-SP MSDU] An MSDU subject to the GCR service with the delivery method equal to GCR-SP.

**groupcast with retries (GCR) transmission opportunity (TXOP):** [GCR TXOP] An interval of time during which an access point (AP) or a mesh station (STA) has the right to initiate frame exchange sequences onto the wireless medium (WM) for the purpose of transmitting multiple frames that are subject to the GCR service.

**HE-LTF repetitions:** Multiple transmissions of HE-LTF symbols in an HE Ranging NDP or HE TB Ranging NDP, where an HE-LTF repetition value of 1 indicates no repetitions, and, for example, a value of 2 or 3 would indicate twice or three times as many HE-LTF symbols, respectively.(11az)

**high-efficiency (HE) basic service set (BSS):** [HE BSS] A BSS in which the transmitted Beacon frame includes an HE Operation element.(11ax)

**high-efficiency (HE) beacon:** [HE beacon] A Beacon frame transmitted in a HE single-user (SU) physical layer (PHY) protocol data unit (PPDU).(11ax)


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**high-efficiency (HE) beamformee:** [HE beamformee] An HE station (STA) that receives an HE physical layer (PHY) protocol data unit (PPDU) that was transmitted using a beamforming steering matrix.(11ax)

**high-efficiency (HE) beamformer:** [HE beamformer] An HE station (STA) that transmits an HE physical layer (PHY) protocol data unit (PPDU) using a beamforming steering matrix.(11ax)

**high-efficiency (HE) extended range (ER) single-user (SU) physical layer (PHY) protocol data unit (PPDU):** [HE ER SU PPDU] A PPDU transmitted with HE ER SU PPDU format. This PPDU carries a single PHY service data unit (PSDU).(11ax)

**high-efficiency (HE) masked HE-long training field (HE-LTF) sequence mode:** [HE masked HE-LTF sequence mode] An HE-LTF mode used in an HE TB PPDU. The masked HE-LTF sequence mode does not have any pilot subcarriers in the HE-LTF field and uses a masked HE-LTF sequence generated by multiplying an orthogonal code (distinct to each spatial stream) over groups of subcarriers.(11ax)

**high-efficiency (HE) modulation and coding scheme:** [HE-MCS] A specification of the HE physical layer (PHY) parameters that consists of modulation order (BPSK, QPSK, 16-QAM, 64-QAM, 256-QAM, 1024-QAM) and forward error correction (FEC) coding rate (1/2, 2/3, 3/4, 5/6) and that is used in an HE PHY protocol data unit (PPDU).(11ax)

**high-efficiency (HE) multi-user (MU) physical layer (PHY) protocol data unit (PPDU):** [HE MU PPDU] A PPDU transmitted with HE MU PPDU format.(11ax)

**high-efficiency (HE) no pilot HE-long training field (HE-LTF) mode:** [HE no pilot HE-LTF mode] An HE-LTF mode used in an HE triggered-based (TB) PPDU. The no pilot HE-LTF mode does not have any pilot subcarriers in the HE-LTF field and does not use a masked HE-LTF sequence. *See also:* **high-efficiency (HE) masked HE-long training field (HE-LTF) sequence mode**.(11ax)

**high-efficiency (HE) physical layer (PHY) protocol data unit (PPDU):** [HE PPDU] A Clause 27 PPDU that is not a Clause 21 PPDU.(11ax)

**high-efficiency (HE) single stream pilot:** [HE single stream pilot] The same pilot sequence is applied to all spatial time streams for a given resource allocation.(11ax)

**high-efficiency (HE) single stream pilot HE-long training field (HE-LTF) mode:** [HE single stream pilot HE-LTF mode] An HE-LTF mode used in an HE single-user (SU), HE extended range (ER) SU, HE multi-user (MU) and optionally HE trigger-based (TB) PPDU.(#3459)

**high-efficiency (HE) single-user (SU) physical layer (PHY) protocol data unit (PPDU):** [HE SU PPDU] A PPDU transmitted with HE SU PPDU format. This PPDU carries a single PHY service data unit (PSDU).(11ax)

**high-efficiency (HE) trigger-based (TB) physical layer (PHY) protocol data unit (PPDU):** [HE TB PPDU] A PPDU transmitted with HE TB PPDU format. This PPDU carries a single PHY service data unit (PSDU).(11ax)

**high rate direct sequence spread spectrum (HR/DSSS) physical layer (PHY) protocol data unit (PPDU):** [HR/DSSS PPDU] A Clause 16 (High rate direct sequence spread spectrum (HR/DSSS) PHY specification) PPDU that is not a Clause 15 (DSSS PHY specification for the 2.4 GHz band designated for ISM applications) PPDU.

(#2297)**high throughput (HT) basic service set (BSS):** [HT BSS] A BSS in which Beacon frames transmitted by an HT station (STA) include the HT Capabilities element.

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**(#2297)high throughput (HT) beamformee:** [HT beamformee] An HT station (STA) that receives an HT physical layer (PHY) protocol data unit (PPDU) that was transmitted using a beamforming steering matrix and that supports an HT transmit beamforming feedback mechanism.

**(#2297)high throughput (HT) beamformer:** [HT beamformer] An HT station (STA) that transmits an HT physical layer (PHY) protocol data unit (PPDU) using a beamforming steering matrix.

**(#2297)high throughput (HT) greenfield (HT-greenfield) format:** [HT-greenfield format] A physical layer (PHY) protocol data unit (PPDU) format of the HT PHY using the HT-greenfield format preamble.

**(#2297)high throughput (HT) immediate (HT-immediate) block acknowledgment (Ack):** [HT-immediate block ack] An immediate block ack mechanism that requires the use of the compressed BlockAck frame and an implicit block ack request and allows partial-state operation at the recipient. This block ack scheme is negotiated between two HT or directional multi-gigabit (DMG) stations (STAs).

**(#2297)high throughput (HT) mixed (HT-mixed) format:** [HT-mixed format] A physical layer (PHY) protocol data unit (PPDU) format of the HT PHY using the HT-mixed format preamble.

**(#2297)high throughput (HT) modulation and coding scheme:** [HT-MCS] A specification of the HT physical layer (PHY) parameters that consists of modulation order (e.g., BPSK, QPSK, 16-QAM, 64-QAM), forward error correction (FEC) coding rate (e.g., 1/2, 2/3, 3/4, 5/6), and number of spatial streams (NSS) and that is used in an HT PHY protocol data unit (PPDU).

**(#2297)(#6315)high throughput (HT) null data physical layer (PHY) protocol data unit (PPDU) (NDP) announcement:** [HT NDP announcement] A PPDU that contains one or more +HTC frames (i.e., frames with an HT Control field) that have the HT NDP Announcement subfield equal to 1.(#238)

**(#2297)high throughput (HT) physical layer (PHY) protocol data unit (PPDU):** [HT PPDU] A Clause 19 (High Throughput (HT) PHY specification(#2297)) PPDU that is not a Clause 15 (DSSS PHY specification for the 2.4 GHz band designated for ISM applications), Clause 16 (High rate direct sequence spread spectrum (HR/DSSS) PHY specification), Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification), or Clause 18 (Extended Rate PHY (ERP) specification) PPDU.

**(#2297)high throughput (HT) station (STA) 2G4:** [HT STA 2G4] An HT STA that is also a STA 2G4.

**(#2297)high throughput (HT) station (STA) 5G:** [HT STA 5G] An HT STA that is also a STA 5G.

**hybrid coordination function:** [HCF] A coordination function that combines and enhances aspects of the contention based and contention free access methods to provide quality-of-service (QoS) stations (STAs) with prioritized and parameterized QoS access to the wireless medium (WM), while continuing to support non-QoS STAs for best-effort transfer. The HCF includes the functionality provided by both enhanced distributed channel access (EDCA) and HCF controlled channel access (HCCA).

**hybrid coordination function (HCF) controlled channel access:** [HCCA] The channel access mechanism utilized by the hybrid coordinator (HC) to coordinate contention free media use by quality-of-service (QoS) stations (STAs) for downlink individually addressed, uplink, and direct link(#1356) transmissions.

**hybrid coordinator:** [HC] A type of coordinator, defined as part of the quality-of-service (QoS) facility, that implements the frame exchange sequences and medium access control (MAC) service data unit (MSDU) handling rules defined by the hybrid coordination function (HCF).

**identifier:** [ID] An identifier used by a wake-up radio (WUR) access point (AP) to identify broadcast WUR frames that are addressed to all WUR non-AP stations (STAs) associated with an AP corresponding to a


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nontransmitted basic service set identifier (BSSID) from the multiple BSSID set when multiple BSSID operation is supported.(11ba)

**IEEE 802.11 access network:** a network that provides access to an external network reachable via the basic service set (BSS).(#572)

**IEEE 802.11 station (STA):** [IEEE 802.11 STA] Any station that is compliant with IEEE Std 802.11. Any reference to the term station (STA) in this standard that is not qualified by the term *IEEE 802.11* implicitly refers to an IEEE 802.11 station.

(11ax)**individual target wake time (TWT):** [individual TWT] A specific time or set of times negotiated between two individual stations (STAs) at which the STAs are expected to be awake in order to exchange frames with each other.(11ax)

**individually addressed resource unit (RU):** [individually addressed RU] A resource unit in a high-efficiency (HE) multi-user (MU) physical layer (PHY) protocol data unit (PPDU) transmitted by an access point (AP) or a tunneled direct link setup (TDLS) peer station (STA) that is intended for a single associated non-AP STA or a TDLS peer STA, respectively.(11ax)(#258)

**individually addressed quality-of-service management frame:** [IQMF] An individually addressed Management frame that is transmitted using the quality-of-service management frame (QMF) service.

**integrity check key:** [ICK] A key used to integrity check FILS Authentication frames.

**integrity group temporal key:** [IGTK] A random value, assigned by the broadcast/multicast source station (STA), which is used to protect group addressed medium access control (MAC) management protocol data units (MMPDUs) from that source STA.(#1521)

**interworking service:** A service that supports use of an IEEE 802.11 network with non-IEEE-802.11 networks. Functions of the interworking service assist (#1295)non–access point (non-AP) stations (STAs) in discovering and selecting IEEE 802.11 networks, in using appropriate quality-of-service (QoS) settings for transmissions, in accessing emergency services, and in connecting to subscription service providers (SSPs).

(#4243)**key confirmation key:** [KCK] A key used to integrity check various frames related to key management.

**key counter:** A 256-bit (32-octet) counter that is used in the pseudorandom function (PRF) to generate initialization vectors (IVs). There is a single key counter per station (STA) that is global to that STA.

**key data encapsulation:** [KDE] A format for data other than elements in the EAPOL-Key Data field.

(#4243)**key encryption key:** [KEK] A key used to encrypt various fields related to key management.

**key management service:** A service to distribute and manage cryptographic keys within a robust security network (RSN).

**light communications station (LC STA):** A station (STA) that operates in the light band with wavelengths in the range 800 nm to 1000 nm.(11bb)

**light sleep mode:** A mesh power management mode with respect to a neighbor peer mesh station (STA) in which a mesh STA(#238) alternates between awake and doze states and is expected to receive beacons from this neighbor peer mesh STA.

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**link:** In the context of an IEEE 802.11 medium access control (MAC) entity, a physical path consisting of exactly one traversal of the wireless medium (WM) that is usable to transfer MAC service data units (MSDUs) between two stations (STAs) (#1379)that have established a relationship.

**link setup:** The process of discovering an extended service set (ESS), (secure) association and authentication, and gaining the ability to send higher layer [e.g., Internet Protocol (IP)] traffic with a valid higher layer address through an access point (AP).(#8216)

**location configuration information:** [LCI] As defined in IETF RFC 6225: includes latitude, longitude, and altitude, with uncertainty indicators for each.

**medium access control (MAC) management protocol data unit:** [MMPDU] The unit of data exchanged between two peer MAC entities, using services of the physical layer (PHY), to implement the MAC management protocol. The MMPDU is transported in one or more Management frames. The MMPDU might include a Mesh Control field, a (#1776)management message integrity code (MIC) element (MME)(#1517), (#6054)or a MIC element, but does not include a MAC header, a frame check sequence (FCS), or any other security encapsulation overhead.

**mesh awake window:** A period of time during which the mesh station (STA) operates in awake state after its Beacon or Probe Response frame transmission that contained the Mesh Awake Window element.

**mesh coordination function:** [MCF] A coordination function that combines aspects of the contention based and scheduled access methods. The MCF includes the functionality provided by both enhanced distributed channel access (EDCA) and MCF controlled channel access (MCCA).

**mesh coordination function (MCF) controlled channel access:** [MCCA] A coordination function for the mesh basic service set (MBSS).

**mesh coordination function (MCF) controlled channel access opportunity:** [MCCAOP] A period of time scheduled for frame transmissions between mesh stations (STAs) using MCF controlled channel access (MCCA).

**mesh data frame(#4340):** A Data frame that is transmitted by a mesh station (STA).

**mesh peer service period:** A period of time during which one or more individually addressed frames are transmitted between two peer mesh stations (STAs) with at least one of those mesh STAs operating in light sleep or deep sleep mode. A mesh peer service period is directional and might contain one or more transmission opportunities (TXOPs).

**mesh peer service period owner:** A mesh station (STA) that obtains transmission opportunities (TXOPs), transmits individually addressed frames to the recipient mesh STA in the mesh peer service period, and terminates the mesh peer service period.

**mesh peering management:** A group of protocols to facilitate mesh peering establishment and closure.

**mesh power management mode:** The activity level identifier of a mesh station (STA) set per mesh peering or for nonpeer neighbor STAs. A lower activity level enables a mesh STA to reduce its power consumption.

**mesh power management mode tracking:** Operation to observe the peering-specific mesh power management modes from the peer mesh stations (STAs)(#238) and to maintain the peering-specific mesh power management modes for each peer mesh STA.


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**message integrity code (MIC) key:** [MIC key] Temporal key integrity protocol (TKIP) only: The portion of a transient key used to validate the integrity of medium access control (MAC) service data units (MSDUs) or MAC protocol data units (MPDUs).

**method-specific service access point (SAP):** [MS SAP] The point at which an instance of the IEEE 802.11 method-specific medium access control (MAC) service is offered.

**michael:** The message integrity code (MIC) for the temporal key integrity protocol (TKIP).(#3263)

**modulation and coding scheme:** [MCS] A specification of the physical layer (PHY) parameters that consists of modulation order (e.g., BPSK, QPSK, 16-QAM, 64-QAM, and 256-QAM), forward error correction (FEC) coding rate (e.g., 1/2, 2/3, 3/4, 5/6), and, depending on the context, the number of space-time streams.

**modulation and coding scheme 32 (MCS 32) format:** [MCS 32 format] A physical layer (PHY) protocol data unit (PPDU) format of the (#2297)high throughput (HT) PHY in which signals in two halves of the occupied channel width contain the same information. This HT PPDU format supports the lowest rate.

**modulation and coding scheme (MCS) feedback (MFB) requester:** [MFB requester] A station (STA) that transmits a physical layer (PHY) protocol data unit (PPDU) containing an HT Control field in which the MCS request (MRQ) subfield is equal to 1.

**modulation and coding scheme (MCS) feedback (MFB) responder:** [MFB responder] A station (STA) that transmits a physical layer (PHY) protocol data unit (PPDU) containing an HT Control field with the MFB field containing an MCS index or the value 127 in response to a PPDU containing an HT Control field in which the MCS request (MRQ) subfield is equal to 1.

**multicarrier on-off keying (MC-OOK) symbol:** (#2242)[MC-OOK symbol] (#3458)A wake up receiver (WUR) OOK symbol generated using multiple carriers, either an (#7174)WUR OOK On symbol where a signal constructed from multiple subcarriers is present or an (#7174)WUR OOK Off symbol where no signal is present.(11ba)(#3771)

**multiple basic service set identifier (BSSID) set:** [BSSID set] A collection of (11ax)access points (APs), such that all of the APs use a common operating class, channel, receive antenna connector, and transmit antenna connector and advertise information for multiple BSSIDs using Beacon or Probe Response frames sent by the AP corresponding to the transmitted BSSID.(11ax)

**multiple medium access control (MAC) sublayers link:** [MMSL] A link between two stations (STAs), wherein one of the STAs is coordinated by a multiple MAC station management entity (MM-SME) that delivered (#1776)a multiple MAC sublayers (MMS) element to the peer STA.

**multiple medium access control (MAC) sublayers link (MMSL) cluster:** [MMSL cluster] The set of all MMSLs between a pair of stations (STAs).

**multi-band device:** A logical entity that supports operation over more than one frequency band or channel using fast session transfer (FST).(#4104)

**multi-user (MU) beamformee:** [MU beamformee] A (#1295)non–access point (non-AP) station (STA) that receives a physical layer (PHY) protocol data unit (PPDU) that was transmitted using a multi-user beamforming steering matrix and that supports the very high throughput (VHT) transmit beamforming feedback mechanism with a VHT null data PPDU (NDP) Announcement frame that includes more than one STA Info field.

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**multi-user (MU) beamformer:** [MU beamformer] An access point (AP) that transmits a physical layer (PHY) protocol data unit (PPDU) using a multi-user beamforming steering matrix.

**multi-user (MU) physical layer (PHY) protocol data unit (PPDU):** [MU PPDU] A PPDU that carries one or more PHY service data units (PSDUs) for one or more stations (STAs) using the downlink multi-user multiple input, multiple output (DL MU-MIMO)(#3367) technique, orthogonal frequency division multiple access (DL OFDMA) technique, or a combination of the two techniques, or that carries a PSDU for an AP(#4407), a TDLS STA on a direct link or an IBSS STA and is in high-efficiency (HE) MU PPDU format.(11ax)

**next generation vehicle-to-everything (V2X) (NGV) physical layer (PHY) protocol data unit (PPDU):** A Clause 32 (Next Generation V2X (NGV) PHY specification) PPDU with the TXVECTOR parameter FORMAT equal to NGV or NON_NGV_10.(11bd)

**no acknowledgment/no retry:** [No-Ack/No-Retry] A retransmission policy for group addressed frames in which each frame is transmitted once and without acknowledgment.

**non-40-MHz-capable (non-40MC) (#2297)high throughput (HT) station (STA):** [non-40MC HT STA] A STA that is not a 40-MHz-capable (40MC) HT STA.

**non-ack-enabled single traffic identifier (TID) aggregate medium access control (MAC) protocol data unit (A-MPDU):** [non-ack-enabled single-TID A-MPDU] A legacy A-MPDU with the exception that a Trigger frame can be aggregated.(11ax)

**non-ack-enabled multi traffic identifier (TID) aggregate medium access control (MAC) protocol data unit (A-MPDU) (non-ack-enabled multi-TID A-MPDU):** An A-MPDU where tagged MPDUs are not aggregated and the aggregated untagged MPDUs from at least two TIDs solicit block acknowledgment.(11ax)

**nonaggregate medium access control (MAC) protocol data unit (non-A-MPDU) frame:** [non-A-MPDU frame] A frame that is transmitted in a Clause 15 (DSSS PHY specification for the 2.4 GHz band designated for ISM applications) physical layer (PHY) protocol data unit (PPDU), Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) PPDU, Clause 16 (High rate direct sequence spread spectrum (HR/DSSS) PHY specification) PPDU, or Clause 18 (Extended Rate PHY (ERP) specification) orthogonal frequency division multiplexing (OFDM) PPDU; or is transmitted with the TXVECTOR AGGREGATION parameter present and equal to NOT_AGGREGATED; or is a single medium access control (MAC) protocol data unit (S-MPDU).

**nonbandwidth signaling transmitter address (TA):** [nonbandwidth signaling TA] An address in the TA field of an medium access control (MAC) protocol data unit (MPDU) in which the Individual/Group bit has the value 0.

**nonbufferable medium access control (MAC) management protocol data unit (MMPDU):** [nonbufferable MMPDU] An MMPDU that is not a bufferable MMPDU.

**nonconcealed groupcast with retries (GCR) frame:** [nonconcealed GCR frame] A group addressed frame that is not transmitted to the GCR concealment address.

(11ay)**nondirectional multi-gigabit**: [non-DMG] A modifier meaning not directional multi-gigabit (DMG), not enhanced directional multi-gigabit (EDMG), and not China directional multi-gigabit (CDMG).

(11ay)**nonenhanced directional multi-gigabit**: [non-EDMG] A modifier meaning directional multi-gigabit (DMG) and that includes neither EDMG enhancement nor CDMG enhancements.


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**(11ay)nonenhanced directional multi-gigabit (non-EDMG) duplicate transmission format**: [non-EDMG duplicate transmission format] A transmission format of the physical layer (PHY) that duplicates a 2.16 GHz non-EDMG transmission in two or more 2.16 GHz channels and allows a station (STA) in a DMG basic service set (BSS) on any one of the 2.16 GHz channels to receive the transmission. A non-EDMG duplicate format is one of the following:

- 4.32 GHz non-EDMG duplicate transmission format: A transmission format of the PHY that replicates a 2.16 GHz non-EDMG transmission in two adjacent 2.16 GHz channels.
- 6.48 GHz non-EDMG duplicate transmission format: A transmission format of the PHY that replicates a 2.16 GHz non-EDMG transmission in three adjacent 2.16 GHz channels.
- 8.64 GHz non-EDMG duplicate transmission format: A transmission format of the PHY that replicates a 2.16 GHz non-EDMG transmission in four adjacent 2.16 GHz channels.
- 2.16+2.16 GHz non-EDMG duplicate transmission format: A transmission format of the PHY that replicates a 2.16 GHz non-EDMG transmission in two, not necessarily adjacent, 2.16 GHz channels.
- 4.32+4.32 GHz non-EDMG duplicate transmission format: A transmission format of the PHY that replicates a 2.16 GHz non-EDMG transmission in two frequency segments of two adjacent 2.16 GHz channels where the two frequency segments of channels are not necessarily adjacent.

**(M118)nonextended rate physical layer (PHY):** [non-ERP] A physical layer (PHY) compliant with Clause 15 (DSSS PHY specification for the 2.4 GHz band designated for ISM applications) or Clause 16 (High rate direct sequence spread spectrum (HR/DSSS) PHY specification), but not with Clause 18 (Extended Rate PHY (ERP) specification).

**nongroupcast with retries:** [non-GCR] A method for delivering group addressed frames without using the groupcast with retries (GCR) unsolicited retry retransmission policy, the GCR block acknowledgment retransmission policy, or the GCR service period (GCR-SP) delivery method.

**(M118)nongroupcast with retries service period (SP):** [non-GCR-SP] A method for the delivery of group addressed frames without the use of a groupcast with retries service period (GCR-SP).

**(#1948)non-high-efficiency (non-HE) physical layer (PHY) protocol data unit (PPDU):** [non-HE PPDU] A PPDU that is transmitted using a PPDU format defined in Clause 15 (DSSS PHY specification for the 2.4 GHz band designated for ISM applications), Clause 16 (High rate direct sequence spread spectrum (HR/DSSS) PHY specification), Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification), Clause 18 (Extended Rate PHY (ERP) specification), Clause 19 (High Throughput (HT) PHY specification(#2297)) or Clause 21 (Very high throughput (VHT) PHY specification).(#4357)

**(M118)non-high-throughput:** [non-HT] A modifier meaning not high throughput (HT), not very high throughput (VHT), not high efficiency (HE), and not directional multi-gigabit (DMG).(11ay)(11ax)

**non-high-throughput (non-HT) duplicate:** [non-HT duplicate] A transmission format of the physical layer (PHY) that duplicates a 20 MHz non-HT transmission in two or more 20 MHz channels and allows a station (STA) in a non-HT basic service set (BSS) on any one of the 20 MHz channels to receive the transmission. A non-HT duplicate format is one of the following:

a) 40 MHz non-HT duplicate: A transmission format of the PHY that replicates a 20 MHz non-HT transmission in two adjacent 20 MHz channels.

b) 80 MHz non-HT duplicate: A transmission format of the PHY that replicates a 20 MHz non-HT transmission in four adjacent 20 MHz channels.

c) 160 MHz non-HT duplicate: A transmission format of the PHY that replicates a 20 MHz non-HT transmission in eight adjacent 20 MHz channels.

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d) 80+80 MHz non-HT duplicate: A transmission format of the PHY that replicates a 20 MHz non-HT transmission in two frequency segments of four adjacent 20 MHz channels where the two frequency segments of channels are not adjacent.

**non-high-throughput (non-HT) duplicate frame:** [non-HT duplicate frame] A frame transmitted in a non-HT duplicate physical layer (PHY) protocol data unit (PPDU).

**non-high-throughput (non-HT) duplicate in television white spaces (TVWS) band:** [non-HT duplicate in TVWS band] A transmission format of the physical layer (PHY) that duplicates a single basic channel unit (BCU) non-HT transmission in two or more BCUs and allows a station (STA) in a non-HT basic service set (BSS) on any one BCU to receive the transmission. A non-HT duplicate format is one of the following:

a) TVHT_W non-HT duplicate: A PHY transmission that replicates a non-HT PHY protocol data unit (PPDU) two times in a single BCU.

b) TVHT_2W non-HT duplicate: A PHY transmission that replicates a non-HT PPDU four times in two contiguous BCUs.

c) TVHT_4W non-HT duplicate: A PHY transmission that replicates a non-HT PPDU eight times in four contiguous BCUs.

d) TVHT_W+W non-HT duplicate: A PHY transmission that replicates a non-HT PPDU two times in each single BCU.

e) TVHT_2W+2W non-HT duplicate: A PHY transmission that replicates a non-HT PPDU four times in each of two contiguous BCUs.

**non-high-throughput (non-HT) duplicate physical layer (PHY) protocol data unit (PPDU):** [non-HT duplicate PPDU] A PPDU transmitted with the TXVECTOR FORMAT parameter equal to NON_HT and the NON_HT_MODULATION parameter equal to NON_HT_DUP_OFDM. (#4357)

**non-high-throughput (non-HT) duplicate physical layer (PHY) protocol data unit (PPDU) in television white spaces (TVWS) band:** [non-HT duplicate PPDU in TVWS band] A PPDU transmitted by a Clause 22 (Television very high throughput (TVHT) PHY specification) PHY with the TXVECTOR parameter FORMAT set to NON_HT and the TXVECTOR parameter CH_BANDWIDTH set to TVHT_W, TVHT_2W, TVHT_4W, TVHT_W+W, or TVHT_2W+2W.

**non-high-throughput (non-HT) physical layer (PHY) protocol data unit (PPDU):** [non-HT PPDU] A PPDU that is transmitted using (#4357)a PPDU format defined in Clause 15 (DSSS PHY specification for the 2.4 GHz band designated for ISM applications), Clause 16 (High rate direct sequence spread spectrum (HR/DSSS) PHY specification), Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) or Clause 18 (Extended Rate PHY (ERP) specification).(#3330)

**non-high-throughput (non-HT) (#4340)signal field (L-SIG) transmit opportunity (TXOP) protection:** [non-HT L-SIG TXOP protection] A protection mechanism in which protection is established by the non-HT SIG Length and Rate fields indicating a duration that is longer than the duration of the physical layer (PHY) protocol data unit (PPDU) itself.(#238)

**non-next generation vehicle-to-everything (V2X) (non-NGV) duplicate:** A transmission format of the physical layer (PHY) that duplicates a 10 MHz non-NGV transmission in two adjacent 10 MHz channels and allows a station (STA) communicating outside the context of a basic service set (BSS)(OCB) on either of the 10 MHz channels to receive the transmission.(11bd)

**non-next generation vehicle-to-everything (V2X) (non-NGV) physical layer (PHY) protocol data unit (PPDU):** A PPDU with 10 MHz channel width that is transmitted outside the context of a basic service set (BSS) (OCB) in the 5.9 GHz band and that is not a next generation V2X (NGV) PPDU.(11bd)


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**non-next generation vehicle-to-everything (V2X) (non-NGV) station (STA):** A STA that transmits or receives non-NGV physical layer (PHY) protocol data units (PPDUs) and that is not able to transmit next generation V2X (NGV) PPDUs.(11bd)

**non-orthogonal frequency division multiple access (non-OFDMA) high-efficiency (HE) physical layer (PHY) protocol data unit (PPDU):** [non-OFDMA HE PPDU] A 20 MHz HE PPDU with a 242-tone resource unit (RU), a 40 MHz HE PPDU with a 484-tone RU, an 80 MHz HE PPDU with a 996-tone RU, or a 160 MHz or 80+80 MHz HE PPDU with a 2×996-tone RU.(11ax)

**nonpeer mesh power management mode:** The activity level identifier of a mesh station (STA) toward nonpeer neighbor mesh STAs. Two nonpeer mesh power management modes are defined: active mode and deep sleep mode.

**non-personal basic service set (BSS) control point (non-PCP) station (STA):** [non-PCP STA] A STA that is not a personal BSS control point (PCP).

**nonprimary channel:** In a 40 MHz, 80 MHz, 160 MHz, or 80+80 MHz basic service set (BSS), any 20 MHz channel other than the primary 20 MHz channel.

**non-quality-of-service management frame (non-QMF) access point (AP):** [non-QMF AP] An AP that does not implement the quality-of-service management frame (QMF) service.

**non-quality-of-service management frame (non-QMF) station (STA):** [non-QMF STA] A STA that does not implement the quality-of-service management frame (QMF) service.

**non-sensor station (STA):** [non-sensor STA] A sub 1 GHz (S1G) non-access point (non-AP) STA transmitting or receiving Data frames not subject to limitation of payload size. A non-sensor STA might not have the power and traffic volume limitation expected for a sensor STA.

**non-space-time-block-coding (non-STBC) frame:** [non-STBC frame] A frame that is transmitted in a physical layer (PHY) protocol data unit (PPDU) that has the TXVECTOR STBC parameter equal to 0, or a frame that is received in a PPDU that has the RXVECTOR STBC parameter equal to 0.

(M118)**non-spatial reuse group:** [non-SRG] An adjective indicating the quality of not being a member of a particular spatial reuse group or the quality of not originating from a station (STA) that is a member of a basic service set (BSS) that is part of a particular spatial reuse group.(11ax)

**non-TB ranging:** A ranging measurement procedure that uses NDP, and is not initiated by a Ranging Trigger frame.(11az)

**non-traffic indication map (non-TIM) mode:** [non-TIM mode] A sub 1 GHz (S1G) non-access point (non-AP) station (STA) power save mode in which (#306)a non-AP S1G STA need not listen for traffic indication map (TIM) Beacon frames but transmits at least one PS-Poll or trigger frame to the associated access point (AP) every listen interval.

**non-traffic indication map (non-TIM) station (STA):** [non-TIM STA] A sub 1 GHz (S1G) non-access point (non-AP) STA that has entered the non-TIM mode.

**nontransmitted basic service set (BSS) identifier (BSSID):** [nontransmitted BSSID] A BSSID corresponding to one of the basic service sets (BSSs) when the multiple BSSID capability is supported(11ax) that is not transmitted explicitly, but that can be derived from the information encoded in Probe Response, Beacon and directional multi-gigabit (DMG) Beacon frames and neighbor reports.

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**null data physical layer (PHY) protocol data unit (PPDU):** [NDP] A PPDU that carries no Data field.(#238)

**null data physical layer (PHY) protocol data unit (PPDU) (NDP) 1M:** [NDP_1M] An NDP carrying medium access control (MAC) information (CMI) frame that is transmitted using the S1G_1M format.(#238)

**null data physical layer (PHY) protocol data unit (PPDU) (NDP) 2M:** [NDP_2M] An NDP carrying medium access control (MAC) information (CMI) frame that is transmitted using the S1G_SHORT format.

**null data physical layer (PHY) protocol data unit (PPDU) (NDP) carrying medium access control information (CMAC) PPDU:** [NDP CMAC PPDU] A PPDU with no Data field used by the PHY to provide to the medium access control (MAC) the service of carrying MAC information in the SIGNAL field of the sub 1 GHz (S1G) PPDU.(#238)

**Null-SAC-HE-LTF:** An HE-LTF present in an initiating STA (ISTA) to a responding STA (RSTA) null data PPDU (NDP), or RSTA to ISTA NDP in the ranging frame exchange, resulting from a mismatch of sequence authentication code (SAC) subfield in the STA Info field of a Ranging NDP Announcement frame, or the SAC subfield in the Trigger Dependent User Info field in the Ranging Secure Sounding Trigger frame, with either the value of the Validation SAC subfield in the Secure HE-LTF Parameters element in the last transmitted FTM frame, or the last transmitted (#8216)LMR frame to the ISTA, or is equal to 0. The TXVECTOR LTF_KEY and LTF_IV parameter corresponding to this LTF are set to generate any secure HE-LTF or null.(11az)

**(#3026)off-channel:** A channel used by a station (STA) that does not overlap with the channel(s) used by the BSS of which the STA is a member.

**operating class:** An E.1 (Country information and operating classes) index into a set of values for radio operation in one or more regulatory domains.

**operational modulation and coding scheme (MCS):** [operational MCS] An MCS that belongs to the operational MCS set.(#405)

**operational modulation and coding scheme (MCS) set:** [operational MCS set] The set of MCSs that a station (STA) is capable of receiving. The operational MCS set is typically advertised in the physical layer (PHY) capabilities element(s), e.g. HT and VHT Capabilities elements.

**operational rate:** A rate that belongs to the operational rate set.(#405)

**operational rate set:** The set of data rates that a station (STA) is capable of receiving. The operational rate set is advertised in the Supported Rates and BSS Membership Selectors element and, if present, the Extended Supported Rates and BSS Membership Selectors element.

**opportunistic power save (OPS) access point (AP):** [OPS AP] A high-efficiency (HE) AP that supports the OPS mechanism.(11ax)

**opportunistic power save (OPS) mechanism:** [OPS mechanism] A power save mechanism to allow OPS (#1295)non–access point (non-AP) stations (STAs) to opportunistically go to doze state or be unavailable for a defined period.(11ax)

**opportunistic power save (OPS) (#1295)non–access point (non-AP) station (STA):** [OPS non-AP STA] A non-AP high-efficiency (HE) STA that supports the OPS mechanism.(11ax)


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**opportunistic power save (OPS) period:** [OPS period] A period during which an OPS (#1295)non–access point (non-AP) station (STA) is allowed to go to doze state or be unavailable if it received an indication that it will not be scheduled by its associated OPS access point (AP).(11ax)

**orthogonal frequency division multiple access (OFDMA) high-efficiency (HE) physical layer (PHY) protocol data unit (PPDU):** [OFDMA HE PPDU] A 20 MHz HE PPDU with resource units (RUs) smaller than 242-tone, or a 40 MHz HE PPDU with RUs smaller than 484-tone, or an 80 MHz HE PPDU with RUs smaller than 996-tone, or a 160 MHz or 80+80 MHz HE PPDU with RUs smaller than 2×996-tone.(11ax)

**orthogonal frequency division multiplexing (OFDM) physical layer (PHY) protocol data unit (PPDU):** [OFDM PPDU] A Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) PPDU.

**outside the context of a basic service set (BSS):** [OCB] A mode of operation in which a station (STA) is not a member of a BSS and does not utilize IEEE 802.11 authentication, association, or data confidentiality services.

**outside the context of a basic service set (OCB) primary channel:** A 10 MHz channel that is designated by a higher layer (via medium access control (MAC) sublayer management entity (MLME) primitives and/or management information base (MIB) parameters). The OCB primary channel and OCB secondary channel are contiguous and together form a 20 MHz channel for transmission of 20 MHz next generation vehicle-to-everything (V2X) (NGV) physical layer (PHY) protocol data units (PPDUs).(11bd)

**outside the context of a basic service set (OCB) secondary channel:** A 10 MHz channel that is designated by a higher layer (via medium access control (MAC) sublayer management entity (MLME) primitives and/or management information base (MIB) parameters). The OCB secondary channel and the OCB primary channel are contiguous and together form a 20 MHz channel for the transmission of 20 MHz next generation vehicle-to-everything (V2X) (NGV) physical layer (PHY) protocol data units (PPDUs).(11bd)

**overlapping basic service set (OBSS) packet detect (PD):** [OBSS PD] A packet detection level used for (#2313)the spatial reuse procedure.(11ax)

**paged association identifier (AID):** [paged AID] An AID of a sub 1 GHz (S1G) non-access point (non-AP) station (STA) whose corresponding bit value in a transmitted traffic indication map (TIM) encoded in AID with differential encoding (ADE) mode is 1.

**pairwise master key:** [PMK] The key derived from a key generated by an Extensible Authentication Protocol (EAP) method or obtained directly from a preshared key (PSK).

**pairwise master key (PMK) R0:** [PMK-R0] The key at the first level of the fast basic service set (BSS) transition (FT) key hierarchy.

**pairwise master key (PMK) R0 (PMK-R0) name:** [PMKR0Name] An identifier that names the PMK-R0.(#238)

**pairwise master key (PMK) R1:** [PMK-R1] A key at the second level of the fast basic service set (BSS) transition (FT) key hierarchy.

**pairwise master key (PMK) R1 (PMK-R1) name:** [PMKR1Name] An identifier that names a PMK-R1.(#238)

**pairwise master key security association:** [PMKSA] The context resulting from a successful IEEE 802.1X authentication exchange between the peer and Authentication Server (AS) or from a preshared key (PSK).

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**pairwise transient key:** [PTK] A concatenation of session keys derived from the pairwise master key (PMK) or from the PMK R1 (PMK-R1)(#238), including a temporal key that is used to protect information exchanged in individually addressed frames.(#1521)

**pairwise transient key (PTK) name:** [PTKName] An identifier that names the PTK.

**pairwise transient key security association:** [PTKSA] The context resulting from a successful 4-way handshake between a peer and Authenticator or from a successful fast initial link setup (FILS) authentication.

**parameterized quality of service (QoS):** [parameterized QoS] The treatment of the medium access control (MAC) protocol data units (MPDUs) depends on the parameters associated with the MPDU. Parameterized QoS is primarily provided through the hybrid coordination function (HCF) controlled channel access (HCCA) mechanism, but is also provided by the enhanced distributed channel access (EDCA) mechanism if used with a traffic specification (TSPEC) for admission control.

**parameterized spatial reuse reception (PSRR) physical layer (PHY) protocol data unit (PPDU):** [PSRR PPDU] A PPDU that contains a Trigger frame that has a value in the UL Spatial Reuse subfield of the Common Info field that is neither PSR_DISALLOW nor PSR_AND_NON_SRG_OBSS_PD_PROHIBITED.(11ax)

**PASN Authentication frame:** Authentication frame used in preassociation security negotiation.(11az)

**Passive Sounding Ranging Trigger frame:** A Ranging Trigger frame of Passive Sounding subvariant.(11az)

**parameterized spatial reuse transmission (PSRT) physical layer (PHY) protocol data unit (PPDU) (PSRT PPDU):** [PSRT PPDU] A PPDU that is transmitted during a parameterized spatial reuse (PSR) opportunity by an HE STA when PSR conditions for PSR-based spatial reuse operation are satisfied and that has the SR PPDU subfield of the CAS Control field equal to 1.(11ax)

**payload protected (PP) aggregate medium access control (MAC) service data unit (A-MSDU):** [PP A-MSDU] A-MSDU that is protected with (#1912)Counter Mode (CTR) with cipher-block chaining message authentication code (CBC-MAC) protocol (CCMP) or (#1912)Galois/Counter Mode (GCM) protocol (GCMP) but does not include the A-MSDU Present field (bit 7 of the QoS Control field) in the construction of the additional authentication data (AAD).

**peer-specific mesh power management mode:** The activity level identifier of a mesh station (STA) set per mesh peering. Three peer-specific mesh power management modes are defined: active mode, light sleep mode, and deep sleep mode.(#1938)

**(M118)peer trigger frame:** (#419)A mesh Data or quality-of-service (QoS) Null frame that initiates a mesh peer service period.

**personal basic service set:** [PBSS] A directional multi-gigabit (DMG) basic service set (BSS) that includes one station (STA) that is in a PBSS control point (PCP), and in which access to a distribution system (DS) is not present.

**personal basic service set (PBSS) control point:** [PCP] An entity that contains one station (STA) and coordinates access to the wireless medium (WM) by STAs that are members of a PBSS.

**personal basic service set (PBSS) control point (PCP) or access point (AP) cluster:** [PCP or AP cluster] A single directional multi-gigabit (DMG) synchronization AP or synchronization PCP, plus zero or more


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neighboring DMG APs or PCPs (or a mixture of both) that join as member APs and PCPs to the synchronization AP or synchronization PCP.

**physical layer (PHY) header:** [PHY header] The portion of a PHY protocol data unit (PPDU) up to and excluding the first symbol that contains part of the PHY service data unit (PSDU).

**(M118)(#14)physical layer (PHY) protocol data unit (PPDU)[+SigExt]:** [PPDU[+SigExt]] A PPDU plus a signal extension that immediately follows the PPDU if the signal extension is present, and a PPDU otherwise.

**Poll Ranging Trigger frame:** A Ranging Trigger frame of Poll subvariant.(11az)

**power save (PS) mode:** [PS mode] A power management mode in which a nonmesh station (STA) alternates between awake and doze states.(#3263)

**power save (PS) station (STA):** [PS STA] A station that is in power save mode.

**preassociation security negotiation (PASN):** A mechanism to establish security association and allow management frame protection prior to association.(11az)

**preassociation security negotiation station (STA):** A STA that implements preassociation security negotiation (PASN).(11az)

**pre-robust security network association (pre-RSNA):** [pre-RSNA] The (#8140)type of association used by a pair of stations (STAs) if the procedure for establishing authentication or association between them did not include the 4-way handshake, was not fast initial link setup (FILS) authentication, and did not use the fast basic service set (BSS) transition (FT) protocol.

**pre-robust security network association (pre-RSNA) station (STA):** A STA that is not able to create robust security network associations (RSNAs).

**primary 1 MHz channel:** In a 2 MHz, 4 MHz, 8 MHz, or 16 MHz sub 1 GHz (S1G) basic service set (BSS), the 1 MHz channel that is used to transmit 1 MHz physical layer (PHY) protocol data units (PPDUs).

**primary 2 MHz channel:** In a 4 MHz, 8 MHz, or 16 MHz sub 1 GHz (S1G) basic service set (BSS), the 2 MHz channel that is used to transmit 2 MHz physical layer (PHY) protocol data units (PPDUs).

**primary 4 MHz channel:** In an 8 MHz or 16 MHz sub 1 GHz (S1G) basic service set (BSS), the 4 MHz channel that is used to transmit 4 MHz physical layer (PHY) protocol data units (PPDUs).

**primary 8 MHz channel:** In a 16 MHz sub 1 GHz (S1G) basic service set (BSS), the 8 MHz channel that is used to transmit 8 MHz physical layer (PHY) protocol data units (PPDUs).

**primary 20 MHz channel:** In a 20 MHz, 40 MHz, 80 MHz, 160 MHz, or 80+80 MHz basic service set (BSS), the 20 MHz channel that is used to transmit 20 MHz physical layer (PHY) protocol data units (PPDUs).(#3180)

**primary 40 MHz channel:** In an 80 MHz, 160 MHz, or 80+80 MHz basic service set (BSS), the 40 MHz channel that is used to transmit 40 MHz physical layer (PHY) protocol data units (PPDUs).

**primary 80 MHz channel:** In a 160 MHz or 80+80 MHz basic service set (BSS), the 80 MHz channel that is used to transmit 80 MHz physical layer (PHY) protocol data units (PPDUs).

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**primary access category (AC):** [primary AC] The AC that is the AC of(#2030) the enhanced distributed channel access function (EDCAF) that gains channel access.

NOTE—If an EDCAF gains channel access, and an RDG is granted to another STA, that STA is transmitting under the primary AC.(#2032)(#3108)

**protected frame:** A frame that has been encrypted and/or whose integrity can be verified cryptographically.

**protocol version 0 (PV0) medium access control (MAC) protocol data unit (MPDU):** [PV0 MPDU] An MPDU that has the Protocol Version field of the Frame Control field of the MPDU header equal to 0.

**protocol version 1 (PV1) medium access control (MAC) protocol data unit (MPDU):** [PV1 MPDU] An MPDU that has the Protocol Version field of the Frame Control field of the MPDU header equal to 1.

**quality-of-service (QoS) frame:** [QoS frame] A frame containing the QoS Control field.

(M118)**quality-of-service (QoS) management frame:** [QMF] A Management frame that is transmitted using the QMF service.

(M118)**quality-of-service (QoS) management frame (QMF) access point (AP):** [QMF AP] A quality-of-service AP that implements the QMF service.

(M118)**quality-of-service (QoS) management frame (QMF) policy:** [QMF policy] A policy defining the access category of Management frames. QMF stations (STAs) transmit their Management frames using the access category defined by the policy.

(M118)**quality-of-service (QoS) management frame (QMF) service:** [QMF service] A service in which the enhanced distributed channel access (EDCA) access category with which a Management frame is sent is determined according to a configured policy.

(M118)**quality-of-service (QoS) management frame (QMF) station (STA):** [QMF STA] A quality-of-service STA that implements the QMF service.

**quasi-omni antenna pattern:** A directional multi-gigabit (DMG) antenna operating mode with the widest beamwidth attainable.

**R0 key holder:** [R0KH] The component of robust security network association (RSNA) key management of the Authenticator that is authorized to derive and hold the pairwise master key (PMK) R0 (PMK-R0), derive the PMK R1s (PMK-R1s), and distribute the PMK-R1s to the R1 key holders (R1KHs).(#238)

**R0 key holder identifier:** [R0KH-ID] An identifier that names the holder of the pairwise master key (PMK) R0 (PMK-R0) in the Authenticator.(#238)

**R1 key holder:** [R1KH] The component of robust security network association (RSNA) key management of the Authenticator that receives a pairwise master key (PMK) R1 (PMK-R1) from the R0 key holder (R0KH), holds the PMK-R1, and derives the pairwise transient keys (PTKs).(#238)

**R1 key holder identifier:** [R1KH-ID] An identifier that names the holder of a pairwise master key (PMK) R1 (PMK-R1) in the Authenticator.(#238)

**random access resource unit:** [RA-RU] A resource unit (RU) allocated in a Trigger frame to support the uplink (UL) orthogonal frequency division multiple access (OFDMA) based random access (UORA) procedure.(11ax)


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**(M118)receive (RX) sector sweep (SSW):** [RXSS] Reception of (#4303)SSW frames via different sectors, in which a sweep is performed between consecutive receptions.

**received signal-to-noise indicator:** [RSNI] An indication of the signal-to-noise plus interference ratio of a received frame.

**Report Ranging Trigger frame:** A Ranging Trigger frame of Report subvariant.(11az)

**reported access point (AP):** [reported AP] An AP that is described in an element such as a Neighbor Report element or a Reduced Neighbor Report element.(11ax)

**reporting access point (AP):** [reporting AP] An AP that is transmitting an element, such as a Neighbor Report element or a Reduced Neighbor Report element, describing a reported AP.(11ax)

**resource information container (RIC):** [RIC] A sequence of elements that include resource request and response parameters.

**resource unit:** [RU] A group of 26, 52, 106, 242, 484, 996, or 2×996 subcarriers as an allocation of subcarriers for transmission.(11ax)

**restricted access window:** [RAW] A medium access interval for a group of stations (STAs) during which a STA in the RAW group indicated by the RAW parameter set (RPS) element is allowed to contend for access to the medium.

**reverse direction (RD) initiator:** [RD initiator] A station (STA) that is a transmit opportunity (TXOP) holder that transmits a medium access control (MAC) protocol data unit (MPDU) in which the reverse direction grant/more physical layer protocol data unit (RDG/More PPDU) subfield is equal to 1.

**reverse direction (RD) responder:** [RD responder] A station (STA) that is not the RD initiator and whose medium access control (MAC) address matches the value of the Address 1 field of a received MAC protocol data unit (MPDU) in which the RDG/More PPDU subfield is equal to 1.

**robust action frame(#4340):** An Action (#1738)or Action No Ack frame with a category value specified in 9.4.1.11 (Action field), in Table 9-81 (Category values) with Yes in the Robust column.(#160)

**robust Action No Ack frame:** An Action No Ack frame with a category value specified in 9.4.1.11 (Action field) (Table 9-81 (Category values)) of IEEE Std 802.11 with Yes in the Robust column.(11az)

**robust management frame(#4340):** A Management frame that is in the subset of Management frames that are eligible for management frame protection. See 12.2.7 (Requirements for management frame protection).(#7050)

NOTE—A Beacon frame is eligible for beacon protection, not management frame protection.(#7050).

**robust security network:** [RSN] A security network that allows only the creation of robust security network associations (RSNAs). An RSN can be identified by (#3056)the inclusion of the RSN element (RSNE) in Beacon frames.

**robust security network association:** [RSNA] The type of association used by a pair of stations (STAs) if the procedure to establish authentication or association between them includes the 4-way handshake or the fast basic service set (BSS) transition (FT) protocol, or is fast initial link setup (FILS) authentication. Note that existence of an RSNA between two STAs does not of itself provide robust security. Robust security is provided when all STAs in the network use RSNAs.

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**robust security network association (RSNA) key management:** [RSNA key management] Key management that includes the 4-way handshake, the group key handshake, authenticated mesh peering exchange, mesh group key handshake, and the (#1566)(#8167)tunneled direct link setup (TDLS) PeerKey (TPK) handshake. If fast basic service set (BSS) transition (FT) is enabled, the FT 4-way handshake and FT authentication sequence are also included. If fast initial link setup (FILS) is enabled, FILS authentication is also included.

**S0 key holder:** [S0KH] The component of robust security network association (RSNA) key management of the Supplicant that derives and holds the pairwise master key (PMK) R0 (PMK-R0), derives the PMK R1s (PMK-R1s), and provides the PMK-R1s to the S1 key holder (S1KH).(#238)

**S0 key holder identifier:** [S0KH-ID] An identifier that names the holder of the pairwise master key (PMK) R0 (PMK-R0) in the Supplicant.(#238)

**S1 key holder:** [S1KH] The component of robust security network association (RSNA) key management in the Supplicant that receives a pairwise master key (PMK) R1 (PMK-R1) from the S0 key holder (S0KH), holds the PMK-R1, and derives the pairwise transient keys (PTKs).(#238)

**S1 key holder identifier:** [S1KH-ID] An identifier that names the holder of the pairwise master key (PMK) R1 (PMK-R1) in the Supplicant.(#238)

**scheduled service period (SP):** [scheduled SP] An SP that is scheduled by a quality-of-service (QoS) access point (AP) or a personal basic service set (PBSS) control point (PCP).

**secondary 1 MHz channel:** In a 2 MHz sub 1 GHz (S1G) basic service set (BSS), the 1 MHz channel adjacent to the primary 1 MHz channel that with the primary 1 MHz channel forms the 2 MHz channel of the 2 MHz S1G BSS. In a 4 MHz, 8 MHz, and 16 MHz S1G BSS, the 1 MHz channel adjacent to the primary 1 MHz channel that together form the primary 2 MHz channel of the S1G BSS.

**secondary 2 MHz channel:** In a 4 MHz sub 1 GHz (S1G) basic service set (BSS), the 2 MHz channel adjacent to the primary 2 MHz channel that with the primary 2 MHz channel forms the 4 MHz channel of the 4 MHz S1G BSS. In an 8 MHz and 16 MHz S1G BSS, the 2 MHz channel adjacent to the primary 2 MHz channel that together form the primary 4 MHz channel of the S1G BSS.

**secondary 4 MHz channel:** In an 8 MHz sub 1 GHz (S1G) basic service set (BSS), the 4 MHz channel adjacent to the primary 4 MHz channel that with the primary 4 MHz channel forms the 8 MHz channel of the 8 MHz S1G BSS. In a 16 MHz S1G BSS, the 4 MHz channel adjacent to the primary 4 MHz channel that together form the primary 8 MHz channel.

**secondary 8 MHz channel:** In a 16 MHz sub 1 GHz (S1G) basic service set (BSS), the 8 MHz channel adjacent to the primary 8 MHz channel that with the primary 8 MHz channel forms the 16 MHz channel of the 16 MHz S1G BSS.

**secondary 20 MHz channel:** In a 40 MHz very high throughput (VHT) basic service set (BSS), the 20 MHz channel adjacent to the primary 20 MHz channel that together form the 40 MHz channel of the 40 MHz VHT BSS. In an 80 MHz VHT BSS, the 20 MHz channel adjacent to the primary 20 MHz channel that together form the primary 40 MHz channel of the 80 MHz VHT BSS. In a 160 MHz or 80+80 MHz VHT BSS, the 20 MHz channel adjacent to the primary 20 MHz channel that together form the primary 40 MHz channel of the 160 MHz or 80+80 MHz VHT BSS. In a VHT BSS, the secondary 20 MHz channel is also the secondary channel.

**secondary 40 MHz channel:** In an 80 MHz very high throughput (VHT) basic service set (BSS), the 40 MHz channel adjacent to the primary 40 MHz channel that together form the 80 MHz channel of the 80


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MHz VHT BSS. In a 160 MHz or 80+80 MHz VHT BSS, the 40 MHz channel adjacent to the primary 40 MHz channel that together form the primary 80 MHz channel.

**secondary 80 MHz channel:** In a 160 MHz or 80+80 MHz very high throughput (VHT) basic service set (BSS), the 80 MHz channel not including the primary 20 MHz channel, that together with the primary 80 MHz channel form the 160 MHz or 80+80 MHz channel of the 160 MHz or 80+80 MHz VHT BSS.

**secondary access category (AC):** [secondary AC] An AC that is not associated with the enhanced distributed channel access function (EDCAF) that gains channel access.

NOTE—Traffic associated with a secondary AC can be included in a multi-user (MU) physical layer (PHY) protocol data unit (MU PPDU) that includes traffic associated with the primary AC. There could be multiple secondary ACs at a given time(#3373).

**secondary channel:** A channel associated with a primary channel used to create a channel wider than the primary channel. In a 40 MHz, 80 MHz, 160 MHz or 80+80 MHz basic service set (BSS) the secondary channel is a secondary 20 MHz channel. (11ay)A 2.16 GHz channel associated with a primary channel used by enhanced directional multi-gigabit (EDMG) STAs for the purpose of creating a 4.32 GHz, 6.48 GHz, 8.64 GHz, 2.16+2.16 GHz, or 4.32+4.32 GHz channel.

**(M118)(11ay)secondary1 channel**: A 2.16 GHz channel associated with a primary channel and a secondary channel used by enhanced directional multi-gigabit (EDMG) stations (STAs) for the purpose of creating a 6.48 GHz, 8.64 GHz, 2.16+2.16 GHz, or 4.32+4.32 GHz channel.

**(M118)(11ay)secondary2 channel**: A 2.16 GHz channel associated with a primary channel, a secondary channel, and a secondary1 channel used by enhanced directional multi-gigabit (EDMG) stations (STAs) for the purpose of creating an 8.64 GHz channel, 2.16+2.16 GHz, or 4.32+4.32 GHz channel.

(11ay)NOTE—For the assignment and relationship of EDMG primary, secondary, secondary1, and secondary2 channels, refer to Table 8-6 (Definition of EDMG secondary, secondary1, and secondary2 channels(11ay)) and Figure 8-6 (Example channel-list parameter element for various BSS operating channels(11ay))

**sector:** A transmit or receive antenna pattern corresponding to a sector identifier (ID).

**Secure Sounding Ranging Trigger frame:** A Ranging Trigger frame of Secure Sounding subvariant.(11az)

**security network:** A basic service set (BSS) in which the station (STA) starting the BSS provides information about the security capabilities and configuration of the BSS by including the robust security network element (RSNE) in Beacon frames(#3079).

**sensor station (STA):** [sensor STA] A sub 1 GHz (S1G) non-access point (non-AP) STA that has certain traffic and device characteristics (e.g., limited payload size, limited traffic volume, battery operated device) and is allowed to associate with an access point (AP) that transmits an S1G Beacon, a Probe Response, or a PV1 Probe Response frame containing the S1G Capabilities element with the STA Type Support subfield indicating a sensor basic service set (BSS) or a mixed BSS.

**service information client:** [SIC] A logical entity that initiates station (STA) service discovery.

**service information registry:** [SIR] logical entity that contains caches of information about services that are available via the basic service set (BSS).

**service interval:** [SI] The interval between the starts of two successive scheduled service periods (SPs).

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**service period:** [SP] A period of time during which one or more downlink individually addressed frames are transmitted to a quality-of-service (QoS) station (STA) and/or one or more transmission opportunities (TXOPs) are granted to the same STA. SPs are either scheduled or unscheduled.

NOTE—A (#1295)non–access point (non-AP) STA can have at most one nongroupcast with retries SP (non-GCR-SP) active at any time.

**session key:** A key that is generated for a single session, to be used, e.g., for encryption and integrity protection, such as a temporal key (TK), group temporal key (GTK), (#4243)key encryption key (KEK) or key confirmation key (KCK).

NOTE—A session key is not necessarily a temporal key.

**shared bands:** Radio frequency bands in which dissimilar services are permitted.

**short beacon interval:** The interval between the consecutive target short beacon transmission times (TSBTTs) of beacons containing a minimal set of elements.

**(11ay)short sector sweep (SSW) (#4303)physical layer (PHY) protocol data unit (PPDU)**: [(#4303)Short SSW PPDU] A directional multi-gigabit (DMG) control mode physical layer (PHY) protocol data unit (PPDU) that has the Length field in the PHY header equal to 6 and the PPDU Type subfield within the Short SSW Payload field equal to 0.

**signaling and payload protected (SPP) aggregate medium access control (MAC) service data unit (A-MSDU):** [SSP A-MSDU] An A-MSDU that is protected with (#1912)Counter Mode (CTR) with cipher-block chaining message authentication code (CBC-MAC) protocol (CCMP) or (#1912)Galois/Counter Mode (GCM) protocol (GCMP) and that includes the A-MSDU Present field (bit 7 of the QoS Control field) in the construction of the additional authentication data (AAD).

**(11ay)single input, single output (SISO) identifier (ID) subset**: [SISO ID subset] A tuple comprising the values of the AWV feedback ID, TX antenna ID, RX antenna ID and BRP CDOWN subfields.

**single medium access control (MAC) protocol data unit (S-MPDU):** [S-MPDU] An MPDU that is the only MPDU in an aggregate MPDU (A-MPDU) and that is carried in an A-MPDU subframe with the EOF/ Tag(#4367) subfield of the MPDU delimiter field equal to 1.

**sounding physical layer (PHY) protocol data unit (PPDU):** [sounding PPDU] A PPDU that is intended by the transmitting station (STA) to enable the receiving STA to estimate the channel between the transmitting STA and the receiving STA. The Not Sounding field in the (#2297)high throughput SIGNAL field (HT-SIG) is equal to 0 in sounding PPDUs.

**Sounding Ranging Trigger frame:** A Ranging Trigger frame of Sounding subvariant.(11az)

**source directional multi-gigabit (DMG) station (STA):** [source DMG STA] A DMG STA (11ay)that is expected to transmit during a time division duplex (TDD) slot, or a DMG STA identified by the source association identifier (AID) field contained in a Grant frame or Extended Schedule element that caused the allocation of a service period (SP) or contention based access period (CBAP).

**space-time block coding (STBC) beacon:** [STBC beacon] A beacon that is transmitted using the basic STBC modulation and coding scheme (MCS) to enable discovery of the basic service set (BSS) by (#2297)high throughput (HT) stations (STAs) that support the HT STBC feature in order to extend the range of the BSS.

**(#8164)space-time block coding (STBC) delivery traffic indication map (DTIM) beacon:** [STBC DTIM beacon] An STBC beacon transmission that is a DTIM beacon(#3309).


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**space-time block coding (STBC) frame:** [STBC frame] A frame that is transmitted in a physical layer (PHY) protocol data unit (PPDU) that has a nonzero value of the TXVECTOR STBC parameter, or a frame that is received in a PPDU that has a nonzero value of the RXVECTOR STBC parameter.

(#3382)**spatial multiplexing (SM) power save:** [SM power save] A mode of operation that allows a station (STA) to listen using one radio frequency (RF) chain, then switch on additional RF chains for subsequent single-user multiple input, multiple output (SU-MIMO) operation.

**spatial reuse:** [SR] The transmission of a physical layer (PHY) protocol data unit (PPDU) on the medium under certain conditions when a PPDU has been detected that would otherwise have prevented the transmission.(11ax)

**spatial reuse group:** [SRG] A group of basic service sets (BSSs) identified by their BSS colors or partial basic service set identifiers (BSSIDs) for overlapping basic service set packet detect (OBSS PD) based spatial reuse operation with SRG OBSS PD level.(11ax)

**spatial sharing:** [SPSH] Use of a frequency channel by multiple stations (STAs) that are located in the same vicinity, and whose directional transmissions might overlap in time.

**staggered preamble:** A physical layer (PHY) preamble in a sounding PHY protocol data unit (PPDU) that is not a null data PPDU (NDP) and that includes one or more Data Long Training fields (DLTFs) and one or more Extension Long Training fields (ELTFs).

**staggered sounding:** The use of a sounding physical layer (PHY) protocol data unit (PPDU) that is not a null data PPDU (NDP) and that includes one or more Data Long Training fields (DLTFs) and one or more Extension Long Training fields (ELTFs).

**station (STA) 2G4:** [STA 2G4] A STA that is operating on a channel that belongs to any operating class that has a value of 25 or 40 for the entry in the Channel spacing column and that has a value of 2.407 or 2.414 for the entry in the Channel starting frequency column of any of the tables found in E.1 (Country information and operating classes).

**station (STA) 5G:** [STA 5G] A STA that is operating on a channel that belongs to any operating class that has a value of 20 or 40 for the entry in the Channel spacing column and that has a value of 5 for the entry in the Channel starting frequency column of any of the tables found in E.1 (Country information and operating classes).

**station (STA) 6G:** [STA 6G] A STA that is operating on a channel that belongs to any operating class that has a value of 5.925 or 5.950(#2333) for the entry in the (#4177)Channel starting frequency column of Table E-4 (Global operating classes).(11ax)

(M118)**sub 1 GHz (S1G) band:** [S1G band] Frequency band for which an S1G operating class is defined in Annex E.

**sub 1 GHz 1M (S1G_1M) physical layer (PHY) protocol data unit (PPDU):** [S1G_1M PPDU] A 1 MHz PPDU or 1 MHz duplicate PPDU that is transmitted with S1G_1M preamble.

**sub 1 GHz long (S1G_LONG) physical layer (PHY) protocol data unit (PPDU):** [S1G_LONG PPDU] A Clause 23 (Sub 1 GHz (S1G) PHY specification(#4095)) PPDU.

**sub 1 GHz modulation and coding scheme (S1G-MCS):** [S1G-MCS] A specification of the S1G physical layer (PHY) parameters that consists of modulation order (e.g., BPSK, QPSK, 16-QAM, 64-QAM, 256-QAM, 1024-QAM(M102)) and forward error correction (FEC) coding rate (e.g., 1/2 rep2, 1/2, 2/3, 3/4, 5/6) that is used in an S1G PHY protocol data unit (PPDU).

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**sub 1 GHz (S1G) physical layer (PHY) protocol data unit (PPDU):** [S1G PPDU] A PPDU transmitted with the TXVECTOR parameter FORMAT equal to S1G, S1G_DUP_1M, or S1G_DUP_2M. The PPDU is transmitted with the S1G_SHORT, S1G_LONG, or S1G_1M preamble.

**sub 1 GHz short (S1G_SHORT) physical layer (PHY) protocol data unit (PPDU):** [S1G_SHORT PPDU] A 2 MHz, 4 MHz, 8 MHz, 16 MHz, or 2 MHz duplicate PPDU with short preamble format.

**subchannel selective transmission (SST) channel:** [SST channel] A channel that is permitted for the subchannel selective transmission indicated by either an SST element or an RPS element.

**subscription service provider (SSP) roaming:** [SSP roaming] The use by a station (STA) of an SSP's IEEE 802.11 infrastructure, with which the terminal has no direct agreement, based on a subscription and formal agreement with the STA's own SSP.(#1601)

**successful transmission:** A transmission and the reception of its expected immediate response or a transmission for which no immediate response is expected.

**sweep:** A sequence of transmissions, separated by a short beamforming interframe space (SBIFS), in which the antenna configuration at the transmitter or receiver is changed between transmissions.

**synchronization access point (AP):** [S-AP] An AP that provides synchronization and other services to an AP cluster or personal basic service set (PBSS) control point (PCP).

**synchronization personal basic service set (PBSS) control point (PCP):** [S-PCP] A PCP that provides synchronization and other services to an access point (AP) cluster or PCP cluster.

**synchronizing access point (AP) or personal basic service set (PBSS) control point (PCP):** [synchronizing AP or PCP] A China directional multi-gigabit (CDMG) AP or PCP that is operating on a 1.08 GHz channel but still transmitting its DMG Beacon frames on the relevant 2.16 GHz channel with the AP or PCP Role subfield of the Dynamic Bandwidth Control element (9.4.2.219 (Dynamic Bandwidth Control element)) set to 0 and providing synchronization service to a synchronized AP or PCP on the relevant 2.16 GHz channel.

**synchronized access point (AP) or personal basic service set (PBSS) control point (PCP):** [synchronized AP or PCP] A (#238)China directional multi-gigabit (CDMG) AP or PCP that is operating on a 1.08 GHz channel but still transmitting its DMG Beacon frames on the relevant 2.16 GHz channel with the AP or PCP Role subfield of the Dynamic Bandwidth Control element (9.4.2.219 (Dynamic Bandwidth Control element)) set to 1 and synchronizing with the synchronizing AP or PCP on the relevant 2.16 GHz channel.

**synthetic receiver address:** [SYNRA] A constructed group address used by a general link (GLK) access point (AP) as a receiver address to forward frames to a subset of GLK non-AP stations (STAs), as required by IEEE 802.1Q bridges.

**tagged media access control (MAC) protocol data unit (MPDU):** [tagged MPDU] An MPDU carried in an aggregate MPDU (A-MPDU) subframe that has the EOF/Tag field in the MPDU delimiter set to 1.(11ax)

**target beacon transmission time (TBTT) scheduled station (STA):** [TBTT scheduled STA] A (#1295)non–access point (non-AP) STA that has negotiated the TBTT of the first Beacon frame and the wake interval between subsequent Beacon frames that it intends to receive.(11ax)

**target beacon transmission time (TBTT) scheduling access point (AP):** [TBTT scheduling AP] An AP that has negotiated with a non-AP station (STA) the TBTT of the first Beacon frame and the wake interval between subsequent Beacon frames that the non-AP STA intends to receive.(11ax)


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**target wake time (TWT) requester:** [TWT requester] A station (STA) that has had a requested TWT agreement accepted by another STA and that receives TWT service period (SP) start times from that STA.

**target wake time (TWT) responder:** [TWT responder] A station (STA) that has accepted a TWT agreement that was requested by another STA and that assigns TWT service period (SP) start times to the requesting STA.

**target wake time (TWT) scheduled station (STA)**: [TWT scheduled STA] A STA that follows the broadcast TWT schedules provided in a broadcast TWT element.(11ax)

**target wake time (TWT) scheduling access point (AP)**: [TWT scheduling AP] An AP that schedules broadcast TWTs and provides these broadcast TWT schedules in a broadcast TWT element.(11ax)

**target wake time (TWT) service period (SP):** [TWT SP] A period of time during which a TWT station (STA) is (#2212)expected to be awake to transmit and/or receive frames.

**target wake time (TWT) service period (SP) start time:** [TWT SP start time] The value of the timing synchronization function (TSF) at the beginning of a TWT SP.

**television very high throughput 2W:** [TVHT_2W] Two contiguous basic channel units (BCUs) in television white spaces (TVWS).

**television very high throughput 2W+2W:** [TVHT_2W+2W] Two noncontiguous frequency segments, each of which comprises two contiguous basic channel units (BCUs) in television white spaces (TVWS).

**television very high throughput 4W:** [TVHT_4W] Four contiguous basic channel units (BCUs) in television white spaces (TVWS).

**television very high throughput (TVHT) basic service set (BSS):** [TVHT BSS] A set of stations (STAs) that consists of a geolocation database dependent (GDD) enabling STA operating in television white spaces (TVWS) and one or more of its GDD STAs.

**television very high throughput W:** [TVHT_W] One basic channel unit in television white spaces (TVWS).

**television very high throughput W+W:** [TVHT_W+W] Two noncontiguous basic channel units (BCUs) in television white spaces (TVWS).

**temporal encryption key:** (#1521)A group temporal key (GTK) or the portion of a pairwise transient key (PTK) used directly or indirectly to encrypt data in medium access control (MAC) protocol data units (MPDUs).

**temporal key:** [TK] Temporal key integrity protocol (TKIP) only: The combination of temporal encryption key and a message integrity code (MIC) key. Non-TKIP only: A temporal encryption key.(#1505)When abbreviated this is, unless explicitly shown otherwise, specifically the key used to protect individually addressed frames, as distinct from e.g., the TK that is the group temporal key (GTK).(#1521)

NOTE—A temporal key is a session key.

**(11ay)time division duplex (TDD) service period (SP)**: [TDD SP] An SP that uses the TDD channel access within the SP.

(11ay)NOTE—TDD channel access is defined in 10.38.6.2.2 (SP with TDD channel access(11ay)).

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**time priority management frame(#4340):** A Management frame that is transmitted (#1524)outside of the normal MAC queueing process. See 10.2.3.1 (General).

**traffic indication map (TIM) broadcast:** [TIM broadcast] A service that enables a (#1295)non–access point (non-AP) station (STA) to request periodic transmission of a TIM frame by the AP. TIM frames have shorter duration than Beacon frames and can be transmitted at a higher physical layer (PHY) rate, which allows the STA to save additional power while periodically checking for buffered traffic in standby mode, relative to the power consumed if the station (STA) were to periodically transition to awake state(#6038) to receive a Beacon frame.

**traffic stream identifier:** [TSID] Any of the identifiers usable by higher layer entities to distinguish medium access control (MAC) service data units (MSDUs) to MAC entities for parameterized quality of service (QoS) [i.e., the traffic stream (TS) with a particular traffic specification (TSPEC)] within the MAC data service. The TSID is assigned to an MSDU in the layers above the MAC(#3056).

**transmission opportunity (TXOP) holder:** [TXOP holder] A quality-of-service (QoS) station (STA) that has either been granted a TXOP by the hybrid coordinator (HC) or successfully contended for a TXOP.

**transmission opportunity (TXOP) responder:** A station (STA) that transmits a frame in response to a frame received from a TXOP holder during a frame exchange sequence, but that does not acquire a TXOP in the process.

**(M118)transmit (TX) power:** [TX power] The effective isotropic radiated power (EIRP) when referring to the operation of an orthogonal frequency division multiplexing (OFDM) physical layer (PHY) in a country where so regulated.

**(M118)transmit (TX) sector sweep (SSW)(#4303-Ed):** [TXSS] Transmission of SSW or DMG(#4303) Beacon frames via different sectors, in which a sweep is performed between consecutive transmissions.

**(M118)transmit (TX) sector sweep (TXSS) contention based access period (CBAP):** [TXSS CBAP] A CBAP that is available to all stations (STAs) in an extended centralized personal basic service set (PBSS) control point (PCP) or access point (AP) cluster outside which TXSSs in the data transfer interval (DTI) can be prohibited.

**transmitted basic service set identifier (BSSID):** [transmitted BSSID] The BSSID included in the medium access control (MAC) header (#372)Address 2 field of a Beacon frame when the multiple BSSID capability is supported.

**transmitter identifier (ID):** [transmitter ID] An identifier that identifies a wake-up radio (WUR) access point (AP) and used in broadcast WUR frames that are addressed to all WUR non-AP stations (STAs) associated with the WUR AP when multiple BSSID operation is not supported or that are addressed to all WUR non-AP STAs associated with the transmitted basic service set identifier (BSSID) of a multiple BSSID set when multiple BSSID operation is supported or that are addressed to all WUR non-AP STAs that intend to discover or synchronize with the WUR AP.(11ba)

**(M118)trigger-enabled access category (AC):** [trigger-enabled AC] A quality-of-service (QoS) station (STA) AC where frames of subtype QoS Data and QoS Null from the STA that map to the AC trigger an unscheduled service period (SP) if one is not in progress.

**trigger frame:** A frame type or a frame transmission (#2213)intended to solicit the peer entity into a responding action.


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**triggered uplink access**: [TUA] A mechanism by which one or more (#1295)non–access point (non-AP) stations (STAs) simultaneously participate in an uplink (UL) transmission to an access point (AP) using resource units (RUs) allocated in the preceding Trigger frame.(11ax)

**triggering frame:** A Trigger frame or a frame carrying a TRS Control subfield.(11ax)

**triggering physical layer (PHY) protocol data unit (PPDU):** [triggering PPDU] A PPDU carrying a triggering frame.(11ax)

**tunneled direct link setup:** [TDLS] A protocol that uses a specific EtherType(#2186) encapsulation to tunnel frames(#3272) through an access point (AP) to establish a TDLS direct link.(#1356)

**tunneled direct link setup (TDLS) direct link:** [TDLS direct link] Direct link between two (#1295)non–access point (non-AP) stations (STAs) that has been established using the TDLS protocol.(#1356)

(#237)**tunneled direct link setup (TDLS) frame:** [TDLS frame] A Data frame carrying all or part of the encapsulation of a TDLS Action field (#3370)in an MSDU with (#2186)EtherType 89-0d.(#1356)

**tunneled direct link setup (TDLS) initiator station (STA):** [TDLS initiator STA] A STA that transmits a TDLS Setup Request frame or a TDLS Discovery Request frame.(#1356)

**tunneled direct link setup (TDLS) peer power save mode (PSM):** [TDLS peer PSM] A PSM that is based on periodically scheduled service periods (SPs), which can be used between two stations (STAs) that have set up a TDLS direct link.(#1356)

**tunneled direct link setup (TDLS) peer power save mode (PSM) initiator:** [TDLS peer PSM initiator] A station (STA) that transmits a TDLS Peer PSM Request frame.(#1356)

**tunneled direct link setup (TDLS) peer power save mode (PSM) responder:** [TDLS peer PSM responder] A station (STA) that transmits a TDLS Peer PSM Response frame.(#1356)

**tunneled direct link setup (TDLS) peer station (STA):** [TDLS peer STA] A STA with which another STA has, or is in the process of establishing, a TDLS direct link.(#1356)

**tunneled direct link setup (TDLS) peer unscheduled automatic power save delivery (U-APSD):** [TDLS peer U-APSD, TPU] A power save mode based on unscheduled service periods that can be used between two stations (STAs) that have set up a TDLS direct link.(#1356)

**tunneled direct link setup (TDLS) peer unscheduled automatic power save delivery (U-APSD) [TDLS peer U-APSD (TPU)] buffer station (STA):** [TPU buffer STA] A TDLS peer STA that buffers traffic for a TPU sleep STA.(#1356)

**tunneled direct link setup (TDLS) peer unscheduled automatic power save delivery (U-APSD) [TDLS peer U-APSD (TPU)] sleep station (STA):** [TPU sleep STA] A TDLS STA that entered power save mode on a TDLS direct link and that is using TPU for the delivery of buffered traffic.(#1356)

**tunneled direct link setup (TDLS) power save mode (PSM):** [TDLS PSM] TDLS peer PSM or peer unscheduled automatic power save delivery (U-APSD).(#1356)

**tunneled direct link setup (TDLS) responder station (STA):** [TDLS responder STA] A STA that receives or is the intended recipient of a TDLS Setup Request frame or TDLS Discovery Request frame.(#1356)

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**(#3772)TVHT_2W mask physical layer (PHY) protocol data unit (PPDU):** [TVHT_2W mask PPDU] One of the following PPDUs in Clause 22 (Television very high throughput (TVHT) PHY specification) transmitted using the TVHT_2W transmit spectral mask defined in 22.3.17.1 (Transmit spectrum mask):

a) A TVHT_2W very high throughput (VHT) PPDU (TXVECTOR parameter CH_BANDWIDTH set to TVHT_2W and TXVECTOR parameter FORMAT set to VHT).

b) A TVHT_2W non-high-throughput (non-HT) PPDU(#238) (TXVECTOR parameter CH_BANDWIDTH set to TVHT_2W, TXVECTOR parameter FORMAT set to NON_HT, and TXVECTOR parameter NON_HT_MODULATION set to NON_HT_DUP_OFDM).

c) A TVHT_W VHT PPDU (TXVECTOR parameter CH_BANDWIDTH set to TVHT_W and TXVECTOR parameter FORMAT set to VHT).

d) A TVHT_W non-HT PPDU(#238) (TXVECTOR parameter CH_BANDWIDTH set to TVHT_W, TXVECTOR parameter FORMAT set to NON_HT, and TXVECTOR parameter NON_HT_MODULATION set to NON_HT_DUP_OFDM).

**(#3772)TVHT_2W+2W mask physical layer (PHY) protocol data unit (PPDU):** [TVHT_2W+2W mask PPDU] One of the following PPDUs in Clause 22 (Television very high throughput (TVHT) PHY specification) transmitted using the TVHT_2W+2W transmit spectral mask defined in 22.3.17.1 (Transmit spectrum mask):

a) A TVHT_2W+2W very high throughput (VHT) PPDU (TXVECTOR parameter CH_BANDWIDTH set to TVHT_2W+2W and TXVECTOR parameter FORMAT set to VHT).

b) A TVHT_2W+2W non-high-throughput (non-HT) PPDU(#238) (TXVECTOR parameter CH_BANDWIDTH set to TVHT_2W+2W, TXVECTOR parameter FORMAT set to NON_HT, and TXVECTOR parameter NON_HT_MODULATION set to NON_HT_DUP_OFDM).

c) A TVHT_2W VHT PPDU (TXVECTOR parameter CH_BANDWIDTH set to TVHT_2W and TXVECTOR parameter FORMAT set to VHT).

d) A TVHT_2W non-HT PPDU(#238) (TXVECTOR parameter CH_BANDWIDTH set to TVHT_2W, TXVECTOR parameter FORMAT set to NON_HT, and TXVECTOR parameter NON_HT_MODULATION set to NON_HT_DUP_OFDM).

e) A TVHT_W VHT PPDU (TXVECTOR parameter CH_BANDWIDTH set to TVHT_W and TXVECTOR parameter FORMAT set to VHT).

f) A TVHT_W non-HT PPDU(#238) (TXVECTOR parameter CH_BANDWIDTH set to TVHT_W, TXVECTOR parameter FORMAT set to NON_HT, and TXVECTOR parameter NON_HT_MODULATION set to NON_HT_DUP_OFDM).

**(#3772)TVHT_4W mask physical layer (PHY) protocol data unit (PPDU):** [TVHT_4W mask PPDU] One of the following PPDUs in Clause 22 (Television very high throughput (TVHT) PHY specification) transmitted using the TVHT_4W transmit spectral mask defined in 22.3.17.1 (Transmit spectrum mask):

a) A TVHT_4W very high throughput (VHT) PPDU (TXVECTOR parameter CH_BANDWIDTH set to TVHT_4W and TXVECTOR parameter FORMAT set to VHT).

b) A TVHT_4W non-high-throughput (non-HT) PPDU(#238) (TXVECTOR parameter CH_BANDWIDTH set to TVHT_4W, TXVECTOR parameter FORMAT set to NON_HT, and TXVECTOR parameter NON_HT_MODULATION set to NON_HT_DUP_OFDM).

c) A TVHT_2W VHT PPDU (TXVECTOR parameter CH_BANDWIDTH set to TVHT_2W and TXVECTOR parameter FORMAT set to VHT).

d) A TVHT_2W non-HT PPDU(#238) (TXVECTOR parameter CH_BANDWIDTH set to TVHT_2W, TXVECTOR parameter FORMAT set to NON_HT, and TXVECTOR parameter NON_HT_MODULATION set to NON_HT_DUP_OFDM).

e) A TVHT_W VHT PPDU (TXVECTOR parameter CH_BANDWIDTH set to TVHT_W and TXVECTOR parameter FORMAT set to VHT).


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f) A TVHT_W non-HT PPDU(#238) (TXVECTOR parameter CH_BANDWIDTH set to TVHT_W, TXVECTOR parameter FORMAT set to NON_HT, and TXVECTOR parameter NON_HT_MODULATION set to NON_HT_DUP_OFDM).

**TVHT_MODE_1 physical layer (PHY) protocol data unit (PPDU):** [TVHT_MODE_1 PPDU] One of the following PPDUs: A Clause 22 (Television very high throughput (TVHT) PHY specification) TVHT_W Very High Throughput (VHT) PPDU or TVHT_W non-high-throughput (non-HT) PPDU.(#238)

**TVHT_MODE_2C physical layer (PHY) protocol data unit (PPDU):** [TVHT_MODE_2C PPDU] One of the following PPDUs: A Clause 22 (Television very high throughput (TVHT) PHY specification) TVHT_2W Very High Throughput (VHT) PPDU or TVHT_2W non-high-throughput (non-HT) PPDU.(#238)

**TVHT_MODE_2N physical layer (PHY) protocol data unit (PPDU):** [TVHT_MODE_2N PPDU] One of the following PPDUs: A Clause 22 (Television very high throughput (TVHT) PHY specification) TVHT_W+W Very High Throughput (VHT) PPDU or TVHT_W+W non-high-throughput (non-HT) PPDU.(#238)

**TVHT_MODE_4C physical layer (PHY) protocol data unit (PPDU):** [TVHT_MODE_4C PPDU] One of the following PPDUs: A Clause 22 (Television very high throughput (TVHT) PHY specification) TVHT_4W Very High Throughput (VHT) PPDU or TVHT_4W non-high-throughput (non-HT) PPDU.(#238)

**TVHT_MODE_4N physical layer (PHY) protocol data unit (PPDU):** [TVHT_MODE_4N PPDU] One of the following PPDUs: A Clause 22 (Television very high throughput (TVHT) PHY specification) TVHT_2W+2W Very High Throughput (VHT) PPDU or TVHT_2W+2W non-high-throughput (non-HT) PPDU.(#238)

(#3772)**TVHT_W mask physical layer (PHY) protocol data unit (PPDU):** [TVHT_W mask PPDU] One of the following PPDUs in Clause 22 (Television very high throughput (TVHT) PHY specification) transmitted using the TVHT_W transmit spectral mask defined in 22.3.17.1 (Transmit spectrum mask):

a) A TVHT_W very high throughput (VHT) PPDU (TXVECTOR parameter CH_BANDWIDTH set to TVHT_W and TXVECTOR parameter FORMAT set to VHT).

b) A TVHT_W non-high-throughput (non-HT) PPDU(#238) (TXVECTOR parameter CH_BANDWIDTH set to TVHT_W, TXVECTOR parameter FORMAT set to NON_HT, and TXVECTOR parameter NON_HT_MODULATION set to NON_HT_DUP_OFDM).

(#3772)**TVHT_W+W mask physical layer (PHY) protocol data unit (PPDU):** [TVHT_W+W mask PPDU] One of the following PPDUs in Clause 22 (Television very high throughput (TVHT) PHY specification) transmitted using the TVHT_W+W transmit spectral mask defined in 22.3.17.1 (Transmit spectrum mask):

a) A TVHT_W+W very high throughput (VHT) PPDU (TXVECTOR parameter CH_BANDWIDTH set to TVHT_W+W and TXVECTOR parameter FORMAT set to VHT).

b) A TVHT_W+W non-high-throughput (non-HT) PPDU(#238) (TXVECTOR parameter CH_BANDWIDTH set to TVHT_W+W, TXVECTOR parameter FORMAT set to NON_HT, and TXVECTOR parameter NON_HT_MODULATION set to NON_HT_DUP_OFDM).

c) A TVHT_W VHT PPDU (TXVECTOR parameter CH_BANDWIDTH set to TVHT_W and TXVECTOR parameter FORMAT set to VHT) .

d) A TVHT_W non-HT PPDU(#238) (TXVECTOR parameter CH_BANDWIDTH set to TVHT_W, TXVECTOR parameter FORMAT set to NON_HT, and TXVECTOR parameter NON_HT_MODULATION set to NON_HT_DUP_OFDM).

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**unassociated range negotiation and measurement management frame protection required (URNM-MFPR):** A security policy that specifies whether ranging frames are required to be protected without association.(11az)

**unassociated range negotiation and measurement management frame protection required exempt 20 MHz (URNM-MFPR-X20):** A security policy that specifies whether ranging frames are required to be protected without association if bandwidth greater than 20 MHz is used.(11az)

**unscheduled service period (SP):** [unscheduled SP] The period that is started when a quality-of-service (QoS) station (STA) transmits a trigger frame to the QoS access point (AP).

**untagged medium access control (MAC) protocol data unit (MPDU):** [untagged MPDU] An MPDU carried in an aggregate MPDU (A-MPDU) subframe that has the EOF/Tag field in the MPDU delimiter set to 0.(11ax)

**(M118)uplink:** [UL] A unidirectional link from a non-access point (non-AP) station (STA) to an access point (AP) or a unidirectional link from a non-AP source directional multi-gigabit (DMG) STA to a non-AP destination DMG STA.

**uplink (UL) high-efficiency (HE) multi-user (MU) physical layer (PHY) protocol data unit (PPDU):** [UL HE MU PPDU] An HE MU PPDU transmitted by a (#1295)non–access point (non-AP) station (STA) (#4407)intended for an AP. This PPDU carries a single PHY service data unit (PSDU).

NOTE—The UL HE MU PPDU has an HE-SIG-B field that contains additional information (e.g., the identifier of the transmitter) that can be used by the recipient of the UL HE MU PPDU to determine the transmitter of the PPDU even in cases where the Data field of the PPDU is not received. For example, this allows the originator of persistently failing PPDUs to be identified.(11ax)

**uplink (UL) orthogonal frequency division multiple access (OFDMA)-based random access:** [UORA] A random access mechanism for (#1295)non–access point (non-AP) high-efficiency (HE) stations (STAs) to participate in uplink OFDMA transmissions in one or more designated random access resource units (RUs).(11ax)

**upstream network:** An integrated local area network (LAN) to which an access point (AP) is connected through a portal.

**very high throughput (VHT) basic service set (BSS):** [VHT BSS] A BSS in which a Beacon frame transmitted by a VHT station (STA) includes the VHT Operation element.

**very high throughput (VHT) beamformee:** [VHT beamformee] A VHT station (STA) that receives a VHT physical layer (PHY) protocol data unit (PPDU) that was transmitted using a beamforming steering matrix and that supports the VHT transmit beamforming feedback mechanism.

**very high throughput (VHT) beamformer:** [VHT beamformer] A VHT station (STA) that transmits a VHT physical layer (PHY) protocol data unit (PPDU) using a beamforming steering matrix.

**very high throughput (VHT) modulation and coding scheme:** [VHT-MCS] A specification of the VHT physical layer (PHY) parameters that consists of modulation order (e.g., BPSK, QPSK, 16-QAM, 64-QAM, 256-QAM) and forward error correction (FEC) coding rate (e.g., 1/2, 2/3, 3/4, 5/6) and that is used in a VHT PHY protocol data unit (PPDU).

**very high throughput (VHT) multi-user (MU) physical layer (PHY) protocol data unit (PPDU):** [VHT MU PPDU] A VHT PPDU that is capable of carrying up to four PHY service data units (PSDUs) for up to four users and is transmitted using the downlink multi-user multiple input, multiple output (DL MU-MIMO)(#3367) technique.


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**very high throughput (VHT) physical layer (PHY) protocol data unit (PPDU):** [VHT PPDU] A Clause 21 (Very high throughput (VHT) PHY specification) PPDU that is not a Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) or Clause 19 (High Throughput (HT) PHY specification(#2297)) PPDU.

**very high throughput (VHT) single-user-only (SU-only) beamformee:** [VHT SU-only beamformee] A VHT beamformee that does not receive VHT multi-user (MU) physical layer (PHY) protocol data units (PPDUs).

**very high throughput (VHT) single-user-only (SU-only) beamformer:** [VHT SU-only beamformer] A VHT beamformer that does not transmit VHT multi-user (MU) physical layer (PHY) protocol data units (PPDUs).

(M118)**very high throughput (VHT) single-user (SU) physical layer (PHY) protocol data unit (PPDU):** [VHT SU PPDU] A VHT PPDU that carries one PHY service data unit (PSDU) for one user and is not transmitted using the downlink multi-user multiple input, multiple output (DL MU-MIMO)(#3367) technique.

**wake-up radio (WUR) 80 MHz channel:** [WUR 80 MHz channel] The 80 MHz channel that is used to transmit 80 MHz WUR Frequency Division Multiple Access (FDMA) physical layer (PHY) protocol data units (PPDUs).(11ba)

**wake-up radio (WUR) basic physical layer (PHY) protocol data unit (PPDU):** [WUR basic PPDU] A PPDU transmitted with the TXVECTOR parameter FORMAT equal to WUR_BASIC and TXVECTOR parameter CH_BANDWIDTH equal to WUR_CBW_20.(11ba)

**wake-up radio (WUR) channel:** [WUR channel] A channel in which a WUR access point (AP) transmits WUR Short Wake-up frames, WUR Wake-up frames, and WUR Vendor Specific frames.(11ba)

**wake-up radio (WUR) discovery channel:** [WUR discovery channel] The channel used by a WUR access point (AP) to transmit WUR Discovery frames.(11ba)

**wake-up radio (WUR) duty cycle period:** [WUR duty cycle period] The interval between the starting time of two successive WUR duty cycle service periods.(11ba)

(M118)**wake-up radio (WUR) duty cycle service period (SP):** [WUR duty cycle service period] A period of time of an established WUR duty cycle operation between a WUR access point (AP) and a WUR non-AP station (STA) during which one or more WUR frames can be transmitted to the WUR non-AP STA from the WUR AP.(11ba)

**wake-up radio (WUR) frequency division multiple access (FDMA) physical layer (PHY) protocol data unit (PPDU):** [WUR FDMA PPDU] A PPDU transmitted with the TXVECTOR parameter FORMAT equal to WUR_FDMA and TXVECTOR parameter CH_BANDWIDTH equal to WUR_CBW_40 or WUR_CBW_80 or WUR_CBW_PUNC80-PRI or WUR_CBW_PUNC80-SEC or WUR_CBW_PUNC80-PRI-SEC-1 or WUR_CBW_PUNC80-PRI-SEC-2.(11ba)

**wake-up radio (WUR) integrity group temporal key:** [WIGTK] A random value, assigned by a WUR access point (AP) that is used to protect broadcast and group addressed WUR frames from that AP.(11ba)

**wake-up radio (WUR) mode:** [WUR mode] A negotiation status between a WUR access point (AP) and a WUR non-AP station (STA) in which the WUR power state of the WUR non-AP STA in power save mode alternates between the WUR awake state and the WUR doze state or stays in the WUR awake state based on the negotiated WUR parameters.(11ba)

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**wake-up radio (WUR) primary 40 MHz channel:** [WUR primary 40 MHz channel] The 40 MHz channel that is used to transmit 40 MHz WUR Frequency Division Multiple Access (FDMA) physical layer (PHY) protocol data units (PPDUs).(11ba)

**wake-up radio (WUR) primary channel:** [WUR primary channel] The channel used by a WUR access point (AP) to transmit WUR Beacon frames.(11ba)

**wake-up radio (WUR) scanning:** [WUR scanning] The process of scanning WUR discovery channels for WUR Discovery frames. (11ba)

**wake-up radio (WUR) secondary 40 MHz channel:** [WUR secondary 40 MHz channel] 40 MHz channel adjacent to the WUR primary 40 MHz channel that together form the WUR 80 MHz channel. (11ba)

**wake-up radio (WUR) secondary channel:** [WUR secondary channel] The 20 MHz channel adjacent to the WUR primary channel that together form the WUR primary 40 MHz channel. (11ba)

**wake-up radio (WUR) temporal key:** [WTK] A temporal key used to protect individually addressed WUR Wake-up frames.(11ba)

**white space map:** [WSM] Information on identified available frequencies that is obtained from a geolocation database (GDB) and that is used by IEEE 802.11 stations (STAs)(#3056).

**wireless network management (WNM) sleep mode:** [WNM sleep mode] An extended power save mode for (#1295)non–access point (non-AP) stations (STAs) whereby a non-AP STA need not listen for every delivery traffic indication map (DTIM) beacon(#3309) and does not perform group temporal key/integrity group temporal key/beacon integrity group temporal key (GTK/IGTK/BIGTK) updates.

## 3.3 Definitions specific to IEEE 802.11 operation in some regulatory domains

ISO 3166-1 defines the international two-letter designation for country names, and these designations are included [in square brackets] at the end of each definition that has clear attribution to a regulatory domain. (#296)US is to be understood as also including the United States' territories, and EU is to be understood as including all CEPT member states.

**contact verification signal:** [CVS] A signal sent by a geolocation database dependent (GDD) enabling station (STA) to validate the list of available frequencies and to verify that the receiving GDD STA is within reception range of the master white space device (WSD) [US].

**personal/portable station (STA):** [personal/portable STA] A STA that uses network communications at unspecified locations [US].

**television band device:** [TVBD] An intentional radiator that operates on an unlicensed basis on available channels in the broadcast television frequency bands [US].

**white space device:** [WSD] An entity that employs cognitive facilities to use white space spectrum without causing harmful interference to protected services [EU].

## 3.4 Acronyms and abbreviations

| | |
|---|---|
| 3GPP | 3rd Generation Partnership Project |
| 40MC | 40-MHz-capable |
| 802.x LAN | IEEE 802-based local area networks such as IEEE Std 802.3 and IEEE Std 802.11 |


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| | |
|---|---|
| AA | Authenticator(#1441)(#1380) address |
| AAA | authentication, authorization, and accounting |
| AAD | additional authentication data |
| AAI | administratively assigned identifier |
| A-BFT | association beamforming training |
| A-BI | awake beacon interval |
| AC | access category |
| ACI | access category index |
| Ack | acknowledgment |
| ACM | admission control mandatory |
| A-Control | aggregated control(11ax) |
| ACU | admission control unit |
| ADDBA | add block acknowledgment |
| ADDTS | add traffic stream |
| ADE | AID with differential encoding |
| AEAD | authenticated encryption with associated data |
| AES | advanced encryption standard |
| AES-128-CMAC | advanced encryption standard (with 128-bit key) cipher-based message authentication code |
| AFC | automatic frequency control |
| AGC | automatic gain control |
| AID | association identifier |
| AIFS | arbitration interframe space |
| AIFSN | arbitration interframe space number |
| AKM | authentication and key management |
| AKMP | authentication and key management protocol |
| A-MPDU | aggregate MAC protocol data unit |
| AMPE | authenticated mesh peering exchange |
| A-MSDU | aggregate MAC service data unit |
| ANIPI | average noise plus interference power indicator |
| ANO | access network options |
| ANonce | Authenticator(#1441)(#1380) nonce |
| ANPI | average noise power indicator |
| ANQP | access network query protocol |
| AP | access point |
| AP-CSN | AP configuration sequence number |
| APSD | automatic power save delivery |
| A-PPDU | aggregate physical layer protocol data unit(11ay)(M118) |
| ARP | Address Resolution Protocol |
| AS | authentication server |
| ASEL | antenna selection |
| ASN.1 | Abstract Syntax Notation One |
| ASRA | additional step required for access |
| ATI | announcement transmission interval |
| ATIM | announcement traffic indication message |
| AV | audio video |

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| | |
|---|---|
| AWV | antenna weight vector |
| BA | block acknowledgment |
| BAR | block acknowledgment request |
| BAT | block acknowledgment TWT |
| BC | beam combining |
| BCC | binary convolutional code |
| BCE | broadcast/multicast integrity protocol (BIP) compact encapsulation(#6054) |
| BCU | basic channel unit |
| BDT | bidirectional TXOP |
| BF | beamforming |
| BFRP | beamforming report poll(11ax) |
| BHI | beacon header interval |
| BIGTK | beacon integrity group temporal key |
| BIGTKSA | beacon integrity group temporal key security association |
| BIP | broadcast/multicast integrity protocol(M118) |
| BIPN | BIGTK packet number |
| BPN | base packet number |
| BPSK | binary phase shift keying |
| BQR | bandwidth query report(11ax) |
| BQRP | bandwidth query report poll(11ax) |
| BRP | beam refinement protocol |
| BRPIFS | beam refinement protocol interframe space |
| BSA | basic service area |
| BSR | buffer status report(11ax) |
| BSRP | buffer status report poll(11ax) |
| BSS | basic service set |
| BSSID | basic service set identifier |
| BT | bit time |
| BTI | beacon transmission interval |
| BU | bufferable unit |
| BW | bandwidth |
| CA | certificate authority |
| CAC | centralized authentication controller (for access points) or controlled (for stations) |
| CAG | common advertisement group(#475) |
| CAP | controlled access phase |
| CAQ | channel availability query |
| CAS | command and status(11ax) |
| CBAP | contention based access period |
| CBC | cipher-block chaining |
| CBC-MAC | cipher-block chaining message authentication code |
| CBP | contention based protocol |
| CCA | clear channel assessment |
| CCDF | complementary cumulative distribution function(11ax) |
| CCK | complementary code keying |
| CCM | CTR with CBC-MAC |
| CCMP | CTR with CBC-MAC protocol(#475) |


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| | |
|---|---|
| CCSR | centralized coordination service root |
| CCSS | centralized coordination service set |
| CDMG | China directional multi-gigabit |
| CEF | channel estimation field |
| CF | contention free |
| CID | Company ID |
| CMMG | China millimeter-wave multi-gigabit |
| C-MPDU | coded MPDU |
| C-PSDU | coded PSDU |
| CQI | channel quality indication(11ax) |
| CRC | cyclic redundancy code |
| CS | carrier sense |
| CSD | cyclic shift diversity |
| CSI | channel state information |
| CSM | channel schedule management |
| CSMA/CA | carrier sense multiple access with collision avoidance |
| CTR | Counter Mode(#1912) |
| CTS | clear to send |
| CTS1 | clear to send 1 |
| CTS2 | clear to send 2 |
| CVS | contact verification signal |
| CW | contention window |
| DA | destination address |
| DBC | dynamic bandwidth control |
| D-BI | doze beacon interval |
| DBPSK | differential binary phase shift keying |
| DC | direct current(11bb) |
| DCF | distributed coordination function |
| DCLA | dc level adjustment |
| DCM | dual carrier modulation(11ax) |
| DCS | dynamic channel selection |
| DEI | drop eligibility indicator |
| DELBA | delete block acknowledgment |
| DELTS | delete traffic stream |
| DFS | dynamic frequency selection |
| DFT | discrete Fourier transform |
| DIFS | distributed (coordination function) interframe space |
| DILS | differentiated initial link setup |
| DL | downlink(11ax) |
| DLL | data link layer |
| DL MU | downlink multi-user(11ax) |
| DL MU-MIMO(#3367) | downlink multi-user multiple input, multiple output(#4124) |
| DLTF | Data Long Training field |
| DMG | directional multi-gigabit |
| DMS | directed multicast service |
| DMSID | directed multicast service identifier |

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| | |
|---|---|
| DN | destination network |
| DO | DFS owner |
| DQPSK | differential quadrature phase shift keying |
| DR | data rate |
| DS | distribution system |
| DSAF | distribution system access function |
| DSCP | differentiated services code point |
| DSE | dynamic station enablement |
| DSM | distribution system medium |
| DSS | distribution system service |
| DSSS | direct sequence spread spectrum |
| DST | daylight saving time |
| DTI | data transfer interval |
| DTIM | delivery traffic indication map |
| EAP | Extensible Authentication Protocol (IETF RFC 3748) |
| EAPOL | Extensible Authentication Protocol over LANs ((#3469)IEEE Std 802.1X-2020) |
| EAP-RP | EAP reauthentication protocol |
| EAS | emergency alert system |
| EBR | expedited bandwidth request |
| EBCS | enhanced broadcast services(11bc) |
| ECAPC | extended centralized AP or PCP cluster |
| ECS | extended channel switching |
| ED | energy detection |
| EDCA | enhanced distributed channel access |
| EDCAF | enhanced distributed channel access function |
| EDMG | enhanced directional multi-gigabit(11ay) |
| EDT | eastern daylight time |
| EHCC | extended hyperbolic congruence code |
| EIFS | extended interframe space |
| EIRP | equivalent isotropically radiated power |
| EL | energy limited |
| ELI | extended local identifier |
| ELTF | Extension Long Training field |
| EMA | enhanced multiple BSSID advertisement(#1004) |
| EOF | end-of-frame |
| EOM | end of multi-user |
| EOSP | end of service period |
| EPD | (#2186)EtherType Protocol Discrimination (IEEE Std 802) |
| ER | extended range(#1294) |
| ERP | extended rate PHY |
| ERP-CCK | extended rate PHY using CCK modulation |
| ERP-DSSS | extended rate PHY using DSSS modulation |
| ERP-DSSS/CCK | extended rate PHY using DSSS or CCK modulation |
| ERP-OFDM | extended rate PHY using OFDM modulation(#3782) |
| ESP | estimated service parameters |
| ESR | emergency services reachable |


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| | |
|---|---|
| ESS | extended service set |
| EST | eastern standard time |
| EVM | error vector magnitude |
| FCS | frame check sequence |
| FD | FILS discovery |
| FD-AF | full-duplex amplify-and-forward |
| FDMA | frequency division multiple access(11ba) |
| FEC | forward error correction(#14) |
| FFC | finite field cryptography |
| FFE | finite field element |
| FFT | Fast Fourier Transform |
| FIFO | first in first out |
| FILS | fast initial link setup |
| FL | fixed-length(11ba) |
| FMS | flexible multicast service |
| FMSID | flexible multicast stream identifier |
| FOV | field of view |
| FPBT | first path beamforming training(11az) |
| FSM | finite state machine |
| FST | fast session transfer |
| FSTS | fast session transfer session |
| FT | fast BSS transition |
| FTAA | fast BSS transition authentication algorithm |
| FTE | fast BSS transition element |
| FTM | fine timing measurement |
| FTMR | fine timing measurement request(11az) |
| FTO | fast BSS transition originator |
| GANN | gate announcement |
| GAS | generic advertisement service |
| GATS | group addressed transmission service |
| GCM | Galois/Counter Mode(#1912)(#475) |
| GCMP | Galois/Counter Mode protocol(#1912)(#475) |
| GCR | groupcast with retries |
| GCR-A | groupcast with retries active |
| GCR-SP | groupcast with retries service period |
| GDB | geolocation database |
| GDD | geolocation database dependent |
| GFSK | Gaussian frequency shift key or keying |
| GI | guard interval |
| GID | group identifier |
| GLK | general link |
| GLK-GCR | general link groupcast with retries |
| GMK | group master key |
| GNonce | group nonce |
| GP | grant period |
| GPRS | general packet radio service |

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| | |
|---|---|
| GPS | Global Positioning System |
| GQMF | group addressed quality-of-service Management frame |
| GTK | group temporal key |
| GTKSA | group temporal key security association |
| HC | hybrid coordinator |
| HCC | hyperbolic congruence code |
| HCCA | HCF controlled channel access |
| HCF | hybrid coordination function |
| HCFA | hash chain frame authentication(11bc) |
| HD-DF | half-duplex decode-and-forward |
| HDR | high data rate(11ba) |
| HE | high efficiency(11ax) |
| HEC | header error check |
| HELD | HTTP-enabled location delivery |
| HEMM | HCCA, EDCA mixed mode |
| HESSID | HeSS identifier(M12) |
| HIPERLAN | high-performance radio local area network |
| HLP | higher layer protocol |
| HLSA | higher layer source authentication(11bc) |
| HPA | high power amplifier |
| HR/DSSS | high rate direct sequence spread spectrum using the long preamble and header |
| HR/DSSS/short | high rate direct sequence spread spectrum using the optional short preamble and header mode |
| HT | high throughput(#2297) |
| HTC | high throughput(#2297) control |
| HT-GF-STF | high throughput(#2297) Greenfield Short Training field |
| HT-SIG | high throughput(#2297) SIGNAL field |
| HT-STF | high throughput(#2297) Short Training field |
| HTTP | hyptertext transfer protocol |
| HTTPS | hyptertext transfer protocol secure |
| HWMP | hybrid wireless mesh protocol |
| IBSS | independent basic service set |
| I2R | ISTA to RSTA(11az) |
| ICK | integrity check key |
| ICMP | Internet Control Message Protocol |
| ICV | integrity check value |
| IDFT | inverse discrete Fourier transform |
| IF | intermediate frequency(11bb) |
| IFFT | inverse Fast Fourier Transform |
| IFS | interframe space |
| IFTM | initial fine timing measurement(11az) |
| IFTMR | initial fine timing measurement request(11az) |
| IGTK | integrity group temporal key |
| IGTKSA | integrity group temporal key security association |
| IMp | intermodulation protection |
| INonce | initiator nonce |


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| | |
|---|---|
| IPI | idle power indicator |
| IPN | IGTK packet number |
| I/Q | in phase and quadrature |
| IQMF | individually addressed quality-of-service Management frame |
| ISM | industrial, scientific, and medical |
| ISS | initiator sector sweep |
| ISTA | initiating STA(11az) |
| IUT | implementation under test |
| IV | initialization vector |
| KCK | (#3743)(#4243)key confirmation key |
| KDE | key data encapsulation |
| KDF | key derivation function |
| KDK | key derivation key(11ba) |
| KEK | (#3743)(#4243)key encryption key |
| LAN | local area network |
| LBIFS | long beamforming interframe space |
| LC | light communications(11bb) |
| LCI | location configuration information |
| LDPC | low-density parity check |
| LDR | low data rate(11ba) |
| LFSR | linear feedback shift register |
| LGR | legendre symbol |
| LLC | logical link control |
| L-LTF | non-HT Long Training field |
| LME | layer management entity |
| LMR | Location Measurement Report(11az) |
| LNA | low noise amplifier |
| LP | low power |
| LPD | LLC Protocol Discrimination (IEEE Std 802) |
| LRC | long retry count |
| LSB | least significant bit |
| L-SIG | non-HT SIGNAL field |
| L-STF | non-HT Short Training field |
| LTF | Long Training field |
| MAC | medium access control |
| MAC_I | initiator MAC(#1558) address |
| MAC_P | peer MAC(#1558) address |
| MAD | maximum away duration |
| MAF | MCCA access fraction |
| MBCA | mesh beacon collision avoidance |
| MBIFS | medium beamforming interframe space |
| MBSS | mesh basic service set |
| MC-OOK | multicarrier on-off keying(11ba) |
| MCCA | MCF controlled channel access |
| MCCAOP | MCF controlled channel access opportunity |
| MCF | mesh coordination function |

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| | |
|---|---|
| MCS | modulation and coding scheme |
| MDE | (#1776)mobility domain element |
| MDID | mobility domain identifier |
| MFB | MCS feedback |
| MFPC | management frame protection capable |
| MFPR | management frame protection required |
| MFSI | MCS feedback sequence identifier |
| MGTK | mesh group temporal key |
| MIB | management information base |
| MIC | message integrity code |
| MID | multiple sector identifier |
| MIDC | multiple sector identifier capture |
| MIMO | multiple input, multiple output |
| MIS | media independent service |
| MLME | MAC sublayer management entity |
| MLPP | multi-level precedence and preemption |
| MME | (#1776)management MIC element |
| MMPDU | MAC management protocol data unit |
| MMS | multiple MAC sublayers |
| MMSL | multiple MAC sublayers link |
| MM-SME | multiple MAC station management entity |
| MPDU | MAC protocol data unit |
| MPM | mesh peering management |
| MRQ | MCS request |
| MSB | most significant bit |
| MSDU | MAC service data unit |
| MSGCF | MAC state generic convergence function |
| MSI | MRQ sequence identifier |
| MSK | master session key |
| MS SAP | method specific service access point |
| MTK | mesh temporal key |
| MU | multi-user |
| MU-BAR | multi-user block ack request(11ax) |
| MUEDCATimer | multi-user EDCA timer(11ax) |
| MU-MIMO | multi-user multiple input, multiple output |
| MU-RTS | multi-user request to send(11ax) |
| N/A | not applicable |
| NAI | network access identifier |
| NAS | network access server |
| NAV | network allocation vector |
| NCC | network channel control |
| NDP | null data PPDU |
| NFRP | NDP feedback report poll(11ax) |
| NGV | next generation vehicle-to-everything (V2X)(11bd) |
| non-ERP | nonextended rate PHY |
| NSS | number of spatial streams |


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| | |
|---|---|
| NTP | Network Time Protocol (IETF RFC 5905 [B49]) |
| NUC | nonuniform constellation(11ay) |
| OBSS | overlapping basic service set |
| OBO | orthogonal frequency division multiple access (OFDMA) random access backoff(11ax) |
| OCB | outside the context of a BSS |
| OCEF | OFDM channel estimation field |
| OCI | operating channel information |
| OCT | on-channel tunneling |
| OCVC | (#3505)operating channel validation capable or operating channel validation capability |
| OCW | orthogonal frequency division multiple access (OFDMA) contention window(11ax) |
| OFDM | orthogonal frequency division multiplexing |
| OFDMA | orthogonal frequency division multiple access(11ax) |
| OI | organization identifier |
| OLB | offset length bitmap |
| OM | operating mode(11ax) |
| OMI | operating mode indication(11ax) |
| OSI | Open Systems Interconnection (ISO/IEC 7498-1:1994) |
| OSTF | OFDM short training field |
| OUI | Organizationally Unique Identifier |
| PAD | preassociation discovery |
| PAE | port access entity ((#3469)IEEE Std 802.1X-2020) |
| PBAC | protected block ack agreement capable |
| PBSS | personal basic service set |
| PCP | PBSS control point |
| PCPS | PBSS control point service |
| PD | packet detect(11ax) |
| PDU | protocol data unit |
| PER | PSDU error ratio(#14) |
| PERR | path error |
| PFS | perfect forward secrecy |
| PHB | per-hop behavior |
| PHY | physical layer |
| PHYCS | PHY carrier sense |
| PHYED | PHY energy detection |
| PICS | protocol implementation conformance statement |
| PIFS | priority interframe space |
| PKFA | public key frame authentication(11bc) |
| PLME | physical layer management entity |
| PLW | PSDU length word |
| PMK | pairwise master key |
| PMKID | pairwise master key identifier |
| PMK-R0 | pairwise master key R0 (first level)(#238) |
| PMK-R1 | pairwise master key R1 (second level)(#238) |
| PMKSA | pairwise master key security association |

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| | |
|---|---|
| PN | packet number |
| PN | pseudonoise (code sequence) |
| PNonce | peer nonce |
| PP | polling period |
| PP A-MSDU | payload protected aggregate MAC service data unit |
| PPDU | PHY protocol data unit |
| PPE | physical layer (PHY) packet extension(11ax) |
| PPET | physical layer (PHY) packet extension threshold(11ax) |
| PPN | partial packet number(11ba) |
| PRAW | periodic restricted access window |
| PREP | path reply |
| PREQ | path request |
| PRF | pseudorandom function |
| PRNG | pseudorandom number generator |
| PS | power save (mode) |
| PSAP | public safety answering point |
| PSDU | PHY service data unit |
| PSF | PHY Signaling field |
| PSK | preshared key |
| PSM | power save mode(#3263) |
| PSR | parameterized spatial reuse(11ax) |
| PSTA | passive STA(11az) |
| PSTOA | phase shift time of arrival(11az) |
| PTI | peer traffic indication |
| PTID | partial TID (the 3 LSBs of a TID)(#36) |
| PTK | pairwise transient key |
| PTKSA | pairwise transient key security association |
| PTP | peer-to-peer |
| PV0 | protocol version 0 |
| PV1 | protocol version 1 |
| PWE | (#3131)password element of a finite cyclic group |
| PXU | proxy update |
| PXUC | proxy update confirmation |
| QAB | quieting adjacent BSS |
| QACM | QMF access category mapping |
| QAM | quadrature amplitude modulation |
| QBPSK | quadrature binary phase shift keying |
| QMF | quality-of-service Management frame |
| QoS | quality of service |
| (#1776)QoS-TU | QoS triggered unscheduled |
| QPSK | quadrature phase shift keying |
| QSRC | QoS STA retry count |
| QTP | quiet time period(11ax) |
| R0KH | R0 key holder (PMK-R0 key holder in the Authenticator)(#238) |
| R0KH-ID | R0 key holder identifier (PMK-R0 key holder identifier in the Authenticator)(#238) |


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| | |
|---|---|
| R1KH | R1 key holder (PMK-R1 key holder in the Authenticator)(#238) |
| R1KH-ID | R1 key holder identifier (PMK-R1 key holder identifier in the Authenticator)(#238) |
| R2I | RSTA to ISTA(11az) |
| RA | receiver address or receiving station address |
| RADIUS | remote authentication dial-in user service (IETF RFC 2865 [B33]) |
| RANN | root announcement |
| RA-RU | random access resource unit(11ax) |
| RAV | resource allocation vector |
| RAW | restricted access window |
| RCPI | received channel power indicator |
| RD | reverse direction |
| RDE | (#1776)RIC data element |
| RDG | reverse direction grant |
| RDP | reverse direction protocol(11ax) |
| RDS | relay DMG STA |
| REDS | relay endpoint DMG STA |
| RF | radio frequency |
| RFC | request for comments |
| RIC | resource information container |
| RID | response indication deferral |
| RIFS | reduced interframe space |
| RLAN | radio local area network |
| RLQP | registered location query protocol |
| RLS | relay link setup |
| RLSS | registered location secure server |
| ROC | relay operation type change |
| ROM | receive operating mode(11ax) |
| RPI | receive power indicator |
| RPL | received power level(11ax) |
| RPS | RAW parameter set |
| RRB | remote request broker |
| RSC | receive sequence counter |
| RSID | ranging session Identifier(11az) |
| RSN | robust security network |
| RSNA | robust security network association |
| RSNE | (#1776)RSN element |
| RSNI | received signal-to-noise indicator |
| RSNXE | (#1776)RSN extension element |
| RSPI | receiver service period initiated |
| RSS | responder sector sweep |
| RSSI | receive signal strength indicator |
| RSTA | responding STA(11az) |
| RTS | request to send |
| RTT | round trip time |
| RU | resource unit(11ax) |

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| | |
|---|---|
| RX | receive or receiver |
| RXASSI | receive antenna selection sounding indication |
| RXASSR | receive antenna selection sounding request |
| RXSS | receive sector sweep |
| S0KH | S0 key holder (PMK-R0 key holder in the Supplicant)(#238) |
| S0KH-ID | S0 key holder identifier (PMK-R0 key holder identifier in the Supplicant)(#238) |
| S1G | sub 1 GHz |
| S1KH | S1 key holder (PMK-R1 key holder in the Supplicant)(#238) |
| S1KH-ID | S1 key holder identifier (PMK-R1 key holder identifier in the Supplicant)(#238) |
| SA | source address |
| SAC | sequence authentication code(11az) |
| SAE | simultaneous authentication of equals |
| SAI | standard assigned identifier |
| S-AP | synchronization access point |
| SAP | service access point |
| S-APSD | scheduled automatic power save delivery |
| SA Query | security association query |
| SAR | segmentation and reassembly(11ay) |
| SBBI | small band beacon interval |
| SBIFS | short beamforming interframe space |
| SC | single carrier |
| SCA | secondary channel above |
| SCB | secondary channel below |
| SCEF | single carrier channel estimation field |
| SCN | no secondary channel |
| SCS | stream classification service |
| SCSID | stream classification service identifier |
| SDL | specification and description language |
| SDU | service data unit |
| SEMM | SPCA-EDCA mixed mode |
| SF | scaling factor(11ax) |
| SFD | start frame delimiter |
| SI | service interval |
| SIC | service information client |
| SID | short identifier |
| SIFS | short interframe space |
| SIR | service information registry |
| SISO | single input, single output(11ay) |
| SLAP | structured local address plan |
| SLRC | station long retry count |
| SLS | sector-level sweep |
| SM | spatial multiplexing |
| SMBT | single user multiple input, multiple output beamforming training(11ay) |
| SME | station management entity |
| S-MPDU | single MAC protocol data unit |
| SMT | station management |


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| | |
|---|---|
| SN | sequence number |
| SNAP | Sub-Network Access Protocol |
| SNonce | Supplicant(#1441)(#1380) nonce |
| SNR | signal-to-noise ratio |
| SP | service period |
| SPA | Supplicant(#1441)(#1380) address |
| SPCA | service period channel access |
| S-PCP | synchronization PBSS control point |
| SPP A-MSDU | signaling and payload protected aggregate MAC service data unit |
| SPR | service period request |
| SPSH | spatial sharing |
| SQ | signal quality (PN code correlation strength) |
| SR | spatial reuse(11ax) |
| SRC | short retry count |
| SRG | spatial reuse group(11ax) |
| SS | spatial stream(#1296) |
| SSID | service set identifier |
| SSP | subscription service provider |
| SSPN | subscription service provider network |
| SSRC | station short retry count |
| SST | subchannel selective transmission |
| SSW | sector sweep |
| STA | station |
| STACK | short TWT acknowledgment |
| STBC | space-time block coding |
| STF | Short Training field |
| STS | space-time stream |
| STT | selective translation table |
| SU | single-user |
| SU-MIMO | single-user multiple input, multiple output |
| SYNC | synchronization |
| SYNRA | synthetic receiver address |
| TA | transmitter address or transmitting station address |
| TACK | TWT acknowledgment |
| TAI | Temps Atomique International (International Atomic Time) |
| TB | trigger-based(11ax) |
| TBTT | target beacon transmission time |
| TC | traffic category |
| TCLAS | traffic classification |
| TDD | time division duplex(11ay) |
| TDDTI | time division data transfer interval |
| TDLS | tunneled direct link setup(#1356) |
| TFS | traffic filtering service |
| TID | traffic identifier |
| TIE | (#1776)timeout interval element |
| TIM | traffic indication map |

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| | |
|---|---|
| TK | temporal key |
| TKIP | temporal key integrity protocol |
| TLV | type/length/value |
| TMPTT | target measurement pilot transmission time |
| TOA | time of arrival |
| TOD | time of departure |
| TOM | transmit operating mode(11ax) |
| TPA | transmission time-point adjustment |
| TPC | transmit power control |
| TPK | TDLS PeerKey |
| TPKSA | TDLS PeerKey security association |
| TPK-TK | TPK transient key(#7161) |
| TPU | TDLS peer U-APSD |
| TRN-R | receive training |
| TRN-T | transmit training |
| TRQ | training request |
| TRS | triggered response scheduling(11ax) |
| TS | traffic stream |
| TSBTT | target short beacon transmission time |
| TSC | TKIP sequence counter |
| TSF | timing synchronization function |
| TSID | traffic stream identifier(#3056) |
| TSPEC | traffic specification |
| TTAK | TKIP-mixed transmitter address and key |
| TTL | time to live |
| TTP | trusted third party |
| TTTT | target TIM transmission time |
| TU | time unit |
| TUA | triggered uplink access(11ax) |
| TVHT | television very high throughput |
| TVWS | television white spaces |
| TWT | target wake time |
| TX | transmit or transmitter |
| TXASSI | transmit antenna selection sounding indication |
| TXASSR | transmit antenna selection sounding request |
| TXE | transmit enable |
| TXOP | transmission opportunity |
| TXSS | transmit sector sweep |
| U-APSD | unscheduled automatic power save delivery |
| UCT | unconditional transition |
| UESA | unauthenticated emergency service accessible |
| UL | uplink(11ax) |
| UL MU | uplink multi-user(11ax) |
| ULS | Universal Licensing System |
| U-NII | unlicensed national information infrastructure |
| UORA | uplink orthogonal frequency division multiple access (OFDMA) based random |


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| | |
|---|---|
| | access(11ax) |
| UP | user priority |
| UPH | uplink (UL) power headroom(11ax) |
| (#1776)U-PID | upper layer protocol identification |
| UPSIM | unscheduled power save indication map |
| URI | Uniform Resource Identifier |
| URL | Universal Resource Locator |
| URN | Uniform Resource Name |
| UTC | Coordinated Universal Time |
| V2X | vehicle-to-everything(11bd) |
| VHT | very high throughput |
| VL | variable-length(11ba) |
| VLAN | virtual local area network |
| VoIP | voice over Internet Protocol (IP)(#3056) |
| WIGTK | wake-up radio integrity group temporal key(11ba) |
| WIGTKSA | wake-up radio integrity group temporal key security association(11ba) |
| WIPN | wake-up radio IGTK packet number(11ba) |
| WLAN | wireless local area network |
| WM | wireless medium |
| WNM | wireless network management |
| WS | wakeup schedule |
| WSM | white space map |
| WTK | wake-up radio temporal key(11ba) |
| WTPN | wake-up radio TK packet number(11ba) |
| WUR | wake-up radio(11ba) |
| ZCZ | zero correlation zone |

## 3.5 Acronyms and abbreviations in some regulatory domains

ISO 3166-1 defines the international two-letter designation for country names, and these designations are included [in square brackets] at the end of each abbreviation that has clear attribution to a regulatory domain. (#296)US is to be understood as also including the United States' territories, and EU is to be understood as including all CEPT member states.

| | |
|---|---|
| PLMR/CRS | private land mobile radio/cellular radio service [US] |
| TVBD | television band device [US] |
| WSD | white space device [EU] |

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# 4. General description

## 4.1 General description of the architecture

This clause presents the concepts and terminology used within this standard. Specific terms are defined in Clause 3 (Definitions, acronyms, and abbreviations). Illustrations convey key IEEE 802.11 concepts and the interrelationships of the architectural components. IEEE Std 802.11(#3773) uses an architecture to describe functional components of an IEEE 802.11 LAN. The architectural descriptions are not intended to represent any specific physical implementation of IEEE Std 802.11.

## 4.2 How wireless local area networks (WLANs) are different

### 4.2.1 Introduction

Wireless networks have fundamental characteristics that make them significantly different from traditional wired LANs.

### 4.2.2 Wireless station (STA)

In the design of wired LANs it is implicitly assumed that an address is equivalent to a physical location. In wireless networks, this is not always the case. In IEEE Std 802.11, the addressable unit is a station (STA). Physical and operational characteristics are defined by modifiers that are placed in front of the term STA. For example, in the case of location and mobility, the addressable units are the fixed STA, the portable STA, and the mobile STA. The STA is an addressable destination, but not (in general) a fixed location.

A STA might take on multiple distinct characteristics, each of which shape its function. For example, a single addressable unit might simultaneously be a portable STA, a quality-of-service (QoS) STA, a dependent STA, and a hidden STA.

### 4.2.3 Media impact on design and performance

The PHYs used in IEEE Std 802.11 are fundamentally different from wired media. Thus IEEE 802.11 PHYs:

a) Use a medium that has neither absolute nor readily observable boundaries outside of which STAs with PHY transceivers are known to be unable to receive network frames
b) Are unprotected from other signals that are sharing the medium
c) Communicate over a medium significantly less reliable than wired PHYs
d) Have dynamic topologies
e) Lack full connectivity, and therefore the assumption normally made that every STA can hear every other STA is invalid (i.e., STAs might be “hidden” from each other)
f) Have time-varying and asymmetric propagation properties
g) Might experience interference from logically disjoint IEEE 802.11 networks operating in overlapping areas

Because of limitations on wireless PHY ranges, WLANs intended to cover reasonable geographic distances can be built from basic coverage building blocks. When providing QoS services, the MAC endeavors to provide QoS “service guarantees” within the limitations of the medium properties identified above. In other words, particularly in unlicensed spectrum, true guarantees are often not possible. However, gradations of service are always possible; and in sufficiently controlled environments, QoS guarantees are possible.


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#### 4.2.4 The impact of handling mobile STAs

One of the requirements of IEEE Std 802.11 is to handle *mobile* as well as *portable* STAs. A *portable* STA is one that is moved from location to location, but that is used only while at a fixed location. *Mobile* STAs access the LAN while in motion.

For technical reasons, it is not sufficient to handle only portable STAs. Propagation effects blur the distinction between portable and mobile STAs; stationary STAs often appear to be mobile due to propagation effects.

Mobile STAs typically are battery powered. Hence power management is an important consideration. For example, it cannot be presumed that a STA's receiver is always powered on.

#### 4.2.5 Interaction with other IEEE 802® layers

IEEE Std 802.11 is required to appear to higher layers [logical link control (LLC) sublayer] as a general-purpose IEEE 802 LAN. This requires that the IEEE 802.11 network handle STA mobility within the MAC sublayer. To meet reliability assumptions (that LLC makes about lower layers), it is necessary for IEEE Std 802.11 to incorporate functionality that is untraditional for MAC sublayers.

In a robust security network association (RSNA), IEEE Std 802.11 provides functions to protect Data frames, (#3469)IEEE Std 802.1X-2020 provides authentication and a Controlled Port, and IEEE Std 802.11 and (#3469)IEEE Std 802.1X-2020 collaborate to provide key management. All STAs in an RSNA have a corresponding IEEE 802.1X entity that handles these services. This standard defines how an RSNA utilizes (#3469)IEEE Std 802.1X-2020 to access these services. Within IEEE Std 802.11, EAPOL PDUs are carried as MSDUs within one or more Data frames, as described in Clause 12 of (#3469)IEEE Std 802.1X-2020. Within this standard, Data frames used for this purpose are generally referred to as *EAPOL-Key frames*, *EAPOL-Key request frames*, and *EAPOL-Start frames*.

When used to support applications that have QoS requirements, each IEEE 802.11 LAN provides a link within an end-to-end QoS environment that can be established between, and managed by, higher layer entities. To handle QoS traffic in a manner comparable to other IEEE 802 LANs, the IEEE 802.11 QoS facility requires the IEEE 802.11 MAC sublayers to incorporate functionality that is not traditional for MAC sublayers. In addition, it might be necessary for certain higher layer management entities to be "WLAN aware" at least to the extent of understanding that the available bandwidth and other QoS characteristics of a WLAN are subject to frequent, and sometimes substantial, dynamic changes due to causes other than traffic load and are outside the direct control of network management entities.

#### 4.2.6 Interaction with non-IEEE-802 protocols

An RSNA utilizes non-IEEE-802 protocols for its authentication and key management (AKM) services. Some of these protocols are defined by other standards organizations, such as the Internet Engineering Task Force (IETF).

### 4.3 Components of the IEEE 802.11 architecture

#### 4.3.1 General

The IEEE 802.11 architecture consists of several components that interact to provide a WLAN that supports STA mobility transparently to upper layers.

The basic service set (BSS) is the basic building block of an IEEE 802.11 LAN. Figure 4-1 (BSSs) shows two BSSs, each of which has two STAs that are members of the BSS.

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(#6332)It is useful to think of each oval depicting a BSS as the coverage area within which all the member STAs of the BSS can remain in communication. (The concept of area, while not precise, is often good enough.) This area is called the *basic service area (BSA)*. If a STA moves out of the BSA, it can no longer directly communicate with all the other STAs present in the BSA.

(#6332)NOTE—In the case of transmissions such as in a directional multi-gigabit (DMG) BSS, the individual coverage area of a transmission from one member STA to another can be thought of as a cone and hence is referred to as a *directional transmission*. The intersection of all possible directional transmissions by all the member STA defines the coverage area.

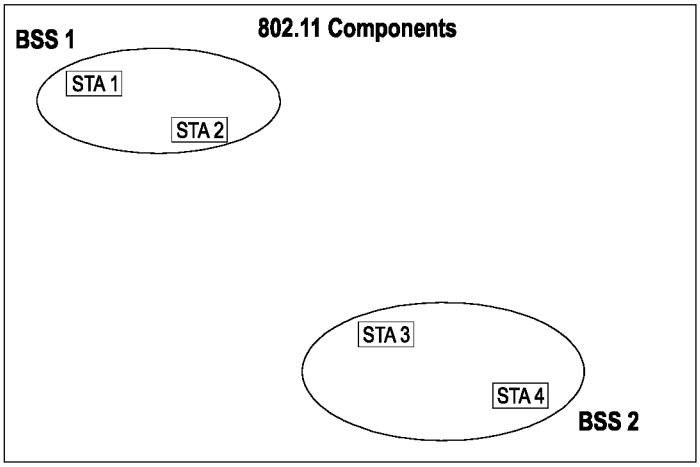


**Figure 4-1—BSSs**

### 4.3.2 Independent BSS (IBSS)

The IBSS is the most basic type of IEEE 802.11 LAN. Since the BSSs shown in Figure 4-1 (BSSs) are simple and lack other components (contrast this with Figure 4-2 (DSs and APs)), the two can be taken to be representative of two IBSSs.

This mode of operation is possible when IEEE 802.11 STAs are able to communicate directly. This type of IEEE 802.11 LAN is often formed without preplanning.

### 4.3.3 Personal BSS (PBSS)

Similar to the IBSS, the PBSS is a type of IEEE 802.11 LAN in which STAs communicate directly with each other.

In contrast to the IBSS, in the PBSS one STA assumes the role of the PBSS control point (PCP). The PCP provides the basic timing for the PBSS through DMG Beacon and Announce frames as well as allocation of service periods and contention based access periods.

A PBSS can be established only by DMG STAs. Not every DMG BSS is a PBSS. A DMG BSS can be a PBSS, an infrastructure BSS, or an IBSS.

### 4.3.4 STA membership in a BSS is dynamic

A STA's membership in a BSS is dynamic (STAs turn on, turn off, come within range, and go out of range). To become a member of an infrastructure BSS or an IBSS, a STA joins the BSS using the synchronization procedure described in 11.1.4.5 (Synchronizing with a BSS). To start a new mesh BSS or to become a member of a mesh BSS, a STA starts the transmission of Beacon frames and performs the synchronization


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maintenance procedure described in 14.14 (Synchronization and beaconing in MBSSs). To access all of the services of an infrastructure BSS, a STA becomes "associated." These associations are dynamic and involve the use of the distribution system service (DSS), which is described in 4.4.4 (DSS). A mesh STA does not become associated as there is no central entity in a mesh BSS (MBSS). Instead, a mesh STA peers with other mesh STAs.

### 4.3.5 Distribution system (DS) concepts

#### 4.3.5.1 Overview

(#3081)PHY limitations determine the direct station-to-station distance that is supported. For some networks this distance is sufficient; for other networks, increased coverage is required. Instead of existing independently, an infrastructure BSS might also form a component of an extended form of network that is built with multiple BSSs. The architectural component used to interconnect infrastructure BSSs is the DS for non-general link (non-GLK) operation. The DS and extended service set (ESS) are mechanisms for expanding connectivity for non-GLK operation. For GLK operation, an IEEE 802.1Q™ bridge might be used to form an extended network (see 4.3.31 (General link (GLK))).

IEEE Std 802.11 logically separates the WM from the distribution system medium (DSM). Each logical medium is used for different purposes, by a different component of the architecture. The IEEE 802.11 definitions neither preclude, nor demand, that the multiple media be either the same or different.

Recognizing that the multiple media are *logically* different is key to understanding the flexibility of the architecture. The IEEE 802.11 LAN architecture is specified independently of the physical characteristics of any specific implementation.

(M12)The DS enables mobile device support by providing the logical services necessary to handle address to destination mapping and seamless integration of multiple BSSs.

(M12)An access point (AP) is any entity that has STA functionality and a distribution system access function (DSAF), which enables access to the DS, via the WM for associated STAs. To access the DS, a non-AP STA joins a BSS and associates with the AP operating that BSS. (#2237)The AP notifies the DS at the completion of the association so that a destination mapping for that non-AP STA's address is established. The non-AP STA moves to another BSS operated by an AP connected to the same DS in another location by reassociating with this new AP. (#2237)The new AP notifies the DS at the completion of the reassociation so that the destination mapping for that non-AP STA's address is updated.

(M12)The STA's location information is internal to the DS, thus STA mobility is transparent to upper layers. See 4.3.5.2 (Extended service set (ESS): the large coverage network).

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Figure 4-2 (DSs and APs) adds the DS, DSM, and AP components to the IEEE 802.11 architecture picture.

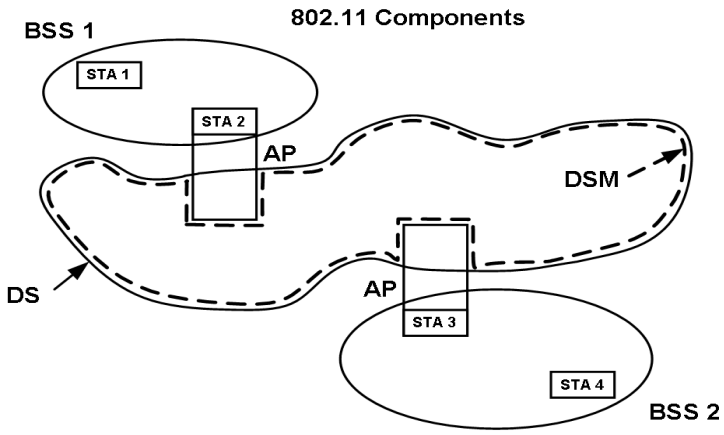


**Figure 4-2—DSs and APs**

Data move between a BSS and the DS via the DSAF in an AP. An AP contains a STA and is addressable on the WM using its STA address. The addresses used by an AP for communication on the WM and on the DSM are not necessarily the same.

Data sent to the AP's STA address by one of the STAs associated with it are always received at the (#1909)Uncontrolled Port for processing by the IEEE 802.1X port access entity. In addition, if the (#1909)Controlled Port is authorized, these frames conceptually transit the DS.

#### 4.3.5.2 Extended service set (ESS): the large coverage network

(M12)The DS and infrastructure BSSs allow IEEE Std 802.11 to create a wireless network of arbitrary size and complexity. IEEE Std 802.11 refers to this type of network as the ESS. An ESS is the union of the infrastructure BSSs with the same SSID connected by a single DS. All BSSs in an ESS have the same SSID. The ESS does not include the DS.

(M12)The key concept is that the ESS appears to be a single IEEE Std 802™ access domain to the LLC sublayer. STAs within an ESS can communicate and mobile STAs might move from one BSS to another (within the same ESS) transparently to the LLC sublayer.

(M12)If multiple BSSs are configured with the same SSID, but the APs are not interconnected by a common DS, there is no guarantee of seamless mobility for STAs between those BSSs. However, such a deployment (#1305)might have a common LLC sublayer interconnection, in which case(#1416) communication with location transparency to the LLC sublayer (a single access domain) is generally still possible, but such communication could be disrupted at times when a mobile STA moves between BSSs.

Owing to its distributed nature, a mesh BSS (MBSS) has no central entity like the AP of an infrastructure BSS. Instead, an MBSS forms a single set of independent mesh STAs. This set is indivisible and cannot be further unified. The ESS concept does not apply to the MBSS. However, it is possible to use a Mesh BSS as all or part of the DS that connects an ESS.

Nothing is assumed by IEEE Std 802.11 about the relative physical locations of the BSSs in Figure 4-3 (ESS).

All of the following are possible:


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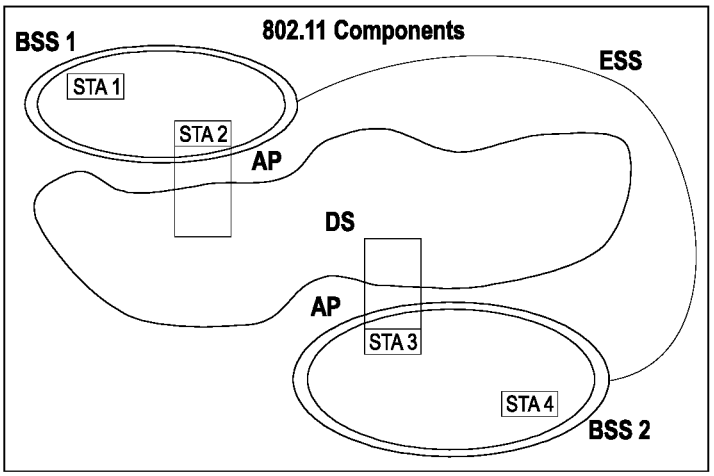


**Figure 4-3—ESS**

a) The BSSs partially overlap. This is commonly used to arrange coverage within a physical volume.

b) The BSSs could be physically disjoint. Logically there is no limit to the distance between BSSs.

c) The BSSs are physically (#2210)colocated. This could be done to provide redundancy.

d) One (or more) IBSSs or ESSs are physically present in the same location as one (or more) ESSs. This could arise for a number of reasons. Some examples are when an IBSS is operating in a location that also has an ESS, when physically overlapping IEEE 802.11 networks have been set up by different organizations, and when two or more different access and security policies are needed in the same location.

### 4.3.6 Area concepts

For wireless PHYs, well-defined coverage areas simply do not exist. Propagation characteristics are dynamic and unpredictable. Small changes in position or direction might produce dramatic differences in signal strength. Similar effects occur whether a STA is stationary or mobile (as moving objects might impact station-to-station propagation).

Figure 4-4 (A representative signal intensity map) shows a signal strength map for a simple square room with a standard metal desk and an open doorway. This figure is a static snapshot; the propagation patterns change dynamically as STAs and objects in the environment move. The dark (solid) blocks in the lower left are a metal desk and there is a doorway at the top right of the figure. The figure indicates relative differences in field strength with different intensities and indicates the variability of field strength even in a static environment. The difference between the greatest signal strength and the least signal strength in this figure is 50 dB.

While the architecture diagrams show sharp boundaries for BSSs, this is an artifact of the pictorial representation, not a physical reality. Because dynamic three-dimensional field strength pictures are difficult to draw, well-defined shapes are used by IEEE 802.11 architectural diagrams to represent the coverage of a BSS.

Further description difficulties arise when attempting to describe (#2210)colocated coverage areas. Consider Figure 4-5 ((#2210)Colocated coverage areas), in which STA 6 could belong to BSS 2 or BSS 3.

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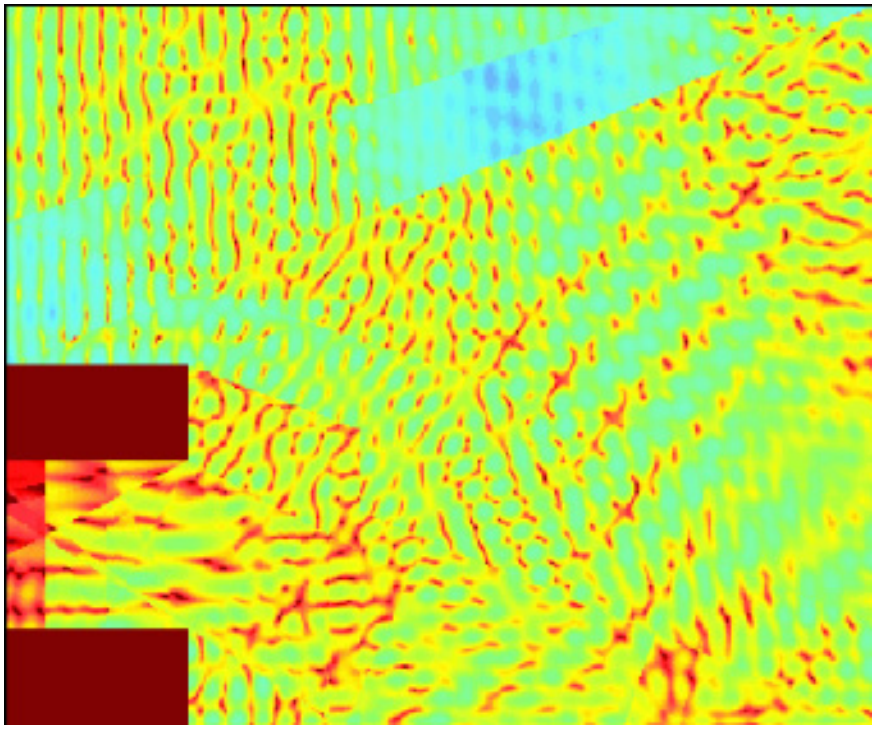

**Figure 4-4—A representative signal intensity map**

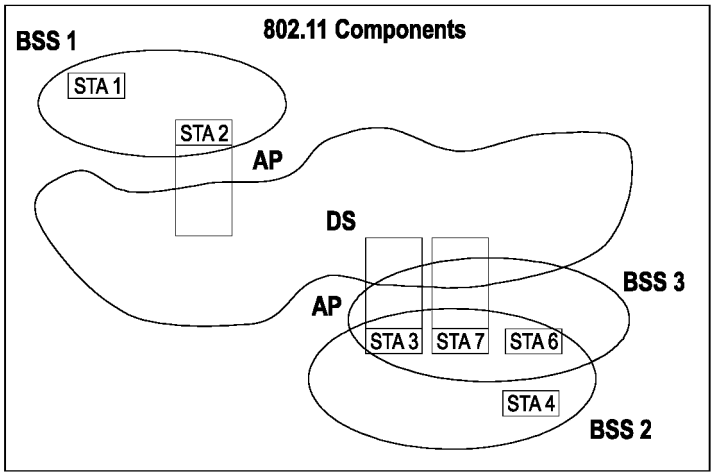


**Figure 4-5—(#2210)Colocated coverage areas**

While the concept of sets of STAs is correct, it is often convenient to talk about areas. For many topics the concept of area is sufficient. *Volume* is a more precise term than area, though still not technically correct. For historical reasons and convenience, this standard uses the common term *area*.


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### 4.3.7 Integration with non-IEEE-802.11 LANs

To integrate the IEEE 802.11 non-GLK architecture with a non-IEEE-802.11 LAN, including a traditional wired LAN, a final logical architectural component is introduced—a *portal*. The IEEE 802.11 GLK architecture (see 4.3.31 (General link (GLK))) does not include the concept of a portal.

A portal is the logical point at which the integration service is provided. All data from or to non-IEEE-802.11 LANs enter or leave the IEEE 802.11 architecture via a portal. The integration service is responsible for any addressing changes or other logical mappings that might be required when MSDUs pass between the DS and the integrated LAN. It is possible for one device to offer both the functions of an AP and a portal. For example, a portal to a wired IEEE 802 LAN is shown in Figure 4-6 (Connecting to other IEEE 802 LANs).

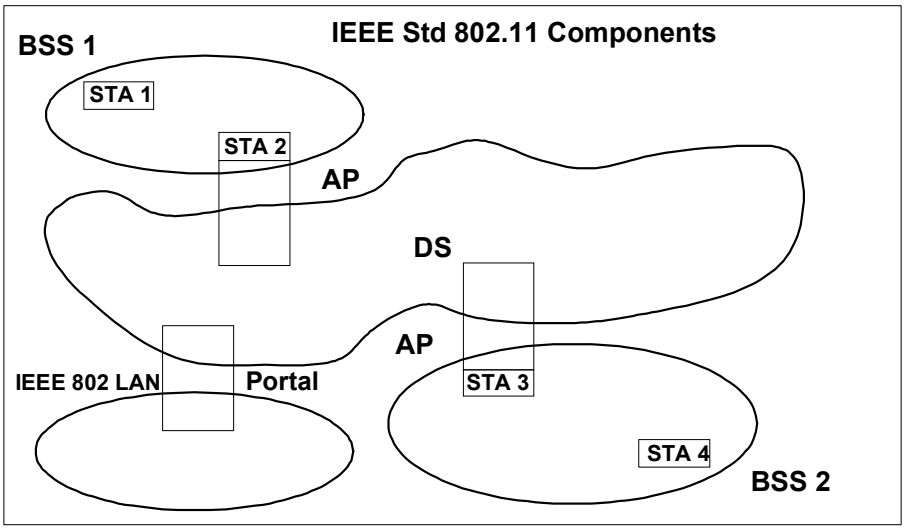


**Figure 4-6—Connecting to other IEEE 802 LANs**

### 4.3.8 Robust security network association (RSNA)

The following features are defined for an RSNA:

- Authentication mechanisms for STAs(#3203)
- Key management algorithms
- Cryptographic key establishment
- (#432)Cryptographic mechanisms, such as Counter Mode(#3112) with cipher-block chaining message authentication code protocol (CCMP) and Galois/Counter Mode(#3112) protocol (GCMP)
- Fast basic service set (BSS) transition (FT) mechanism
- Cryptographic encapsulation mechanisms for robust Management frames(#3203)

An RSNA might rely on components external to the IEEE 802.11 architecture.

The first component is an IEEE 802.1X port access entity (PAE). PAEs are present on all STAs in an RSNA and control the forwarding of data to and from the medium access control (MAC). An AP always implements the Authenticator PAE and Extensible Authentication Protocol (EAP) Authenticator roles, and a non-AP STA always implements the Supplicant PAE and EAP peer roles. In an IBSS or PBSS, each STA

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implements both the Authenticator PAE and Supplicant PAE roles and both EAP Authenticator and EAP peer roles.

A second component is the Authentication Server (AS). The AS authenticates the elements of the RSNA itself, i.e., the STAs provide material that the RSNA elements use to authenticate each other. The AS communicates through the IEEE 802.1X Authenticator with the IEEE 802.1X Supplicant on each STA, enabling the STA to be authenticated to the AS and vice versa. An RSNA depends upon the use of an EAP method that supports mutual authentication of the AS and the STA, such as those that meet the requirements in IETF RFC 4017. In certain applications, the AS might be integrated into the same physical device as the AP, or into a STA in an IBSS or PBSS.

In some applications, there is no need for a PAE or AS, and a STA and AP, or two IBSS STAs, or two mesh STAs in an MBSS, might authenticate each other using a password.

An RSNA using fast BSS transition relies on an external protocol to distribute keys between the pairwise master key (PMK) R0 key holder (R0KH) and PMK-R1 key holder (R1KH) Authenticator components. The requirements for this protocol are described in 13.2.2 (Authenticator key holders).

### 4.3.9 Centralized coordination service set (CCSS) and extended centralized AP or PCP clustering (ECAPC)

AP or PBSS control point (PCP) clustering is a protocol between a DMG synchronization AP or DMG synchronization PCP (S-AP or S-PCP) and other APs and PCPs within the cluster, known as member APs and PCPs. This protocol is used to improve spatial sharing and interference mitigation among the DMG BSSs of the S-AP or S-PCP and member APs and PCPs. AP or PCP clustering allows an AP or PCP within a cluster to schedule transmissions in nonoverlapping time periods with respect to other APs and PCPs that are in the same cluster. There are two types of clustering:

— In decentralized AP or PCP clustering, there is a single S-AP or S-PCP in the BSA of the S-AP or S-PCP.

— In centralized AP or PCP clustering, there can be multiple S-APs in the BSA of any one S-AP and all S-APs are coordinated via a single centralized coordination service set (CCSS).

A CCSS comprises a centralized coordination service root (CCSR) and a set of one or more synchronization APs that while operating are stationary with respect to their local environment and are connected to the CCSR via, for instance, one of the following:

— The DS to an AP (or beyond, to a STA associated to the AP)

— A combination of distribution system, portal, and external network

The CCSR provides coordination services for the CCSS, such as selecting the target beacon transmission time of S-APs within the CCSS to minimize interference. The CCSR might logically reside within an S-AP or in another entity as long as it has a globally administered MAC address. A CCSS is suited to an area and a frequency band having the following propagation characteristics:

— The BSAs of the S-APs within the CCSS cover the area, and

— Transmissions within the area are isolated to a high degree.

An extended centralized AP or PCP cluster (ECAPC) comprises a single CCSS and an accompanying set of centralized AP or PCP clusters. Each S-AP of one of the centralized AP or PCP clusters is inside the CCSS. The ECAPC also includes all STAs in the BSSs of the S-APs and member APs and PCPs of the centralized AP or PCP clusters. An example is shown in Figure 4-7 (CCSS and ECAPC), in which:

— STA3a and STA3b are two STAs coordinated by a one MM-SME component.

— STA4a and STA4b are two STAs coordinated by a second MM-SME component.


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— The CCSR happens to be located in an external network.

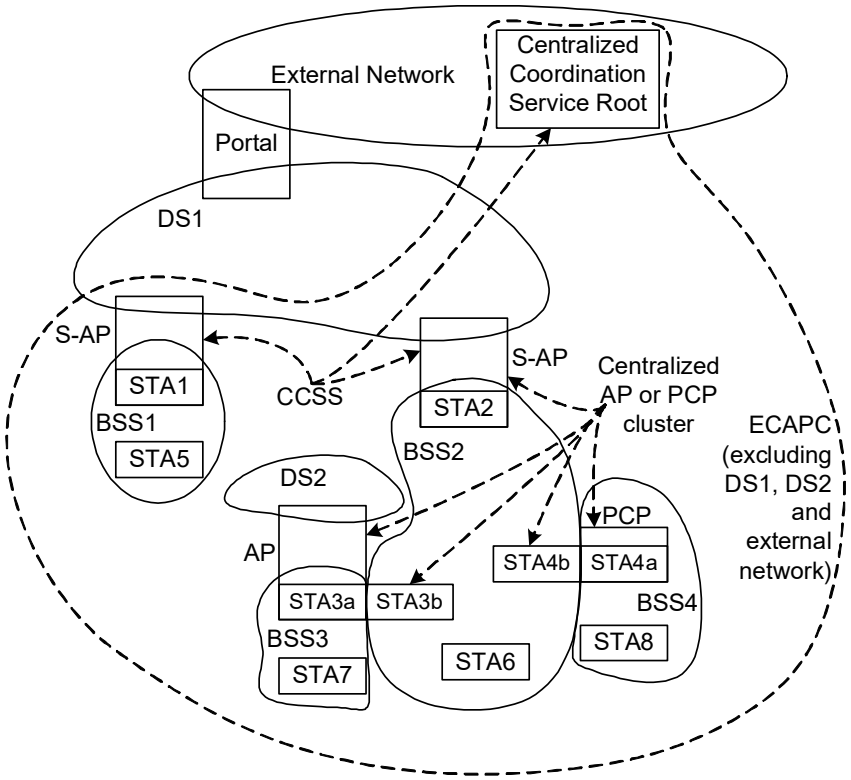


**Figure 4-7—CCSS and ECAPC**

The CCSS might contain whole ESSs, subsets of ESSs, or some combination of them.

Decentralized AP or PCP clustering can be employed without establishing a CCSS, CCSR, or ECAPC.

### 4.3.10 QoS BSS

The IEEE 802.11 QoS facility provides MAC enhancements to support LAN applications with QoS requirements. The QoS enhancements are available to QoS STAs associated with a QoS access point or PCP in a QoS BSS. A subset of the QoS enhancements is available for use between STAs that are members of the same QoS IBSS.

Similarly, a subset of the QoS enhancements is available for use between neighbor peer mesh STAs. A mesh BSS is one type of QoS BSS and it is described in 4.3.24 (Mesh BSS).

A QoS STA that is a non-DMG STA might associate with a non-QoS access point in a non-QoS BSS, to provide the non-QoS MAC data service, for example, when there is no QoS access point with which to associate.

As a mesh STA does not implement the necessary service, the mesh STA does not associate with any access point.

A DMG STA is a QoS STA. A DMG BSS is a QoS BSS.

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The enhancements that distinguish QoS STAs from non-QoS STAs and QoS APs from non-QoS APs are collectively termed the *QoS facility*. Which of the QoS-specific mechanisms a QoS STA supports might vary among QoS implementations, as well as between QoS STAs and QoS APs, over ranges specified in subsequent clauses. All service primitives, frame formats, coordination function and frame exchange rules, and management interface functions except for the block acknowledgment (block ack) function, and automatic power save delivery (APSD) are part of the core QoS facility. A QoS STA or QoS AP implements those core QoS facility necessary for its QoS functions to interoperate with other QoS STAs. Functions such as the block ack, and APSD are separate from the core QoS facility; and the presence of these functions is indicated by STAs separately from the core QoS facility.

For infrastructure BSS and IBSS, this standard provides four mechanisms for the support of applications with QoS requirements.

The first mechanism, designated the *enhanced distributed channel access* (EDCA), delivers traffic based on differentiating user priorities (UPs). This differentiation is achieved by varying the following for different UP values:

- Amount of time a STA senses the channel to be idle before backoff or transmission, or
- The length of the contention window to be used for the backoff, or
- The duration a STA transmits after it acquires the channel.

These transmissions might also be subject to certain channel access restrictions in the form of admission control. A DMG STA uses EDCA only within a contention based access period (CBAP). Details of EDCA are provided in 10.23.2 (HCF contention based channel access (EDCA)) and, for DMG STAs, additional details are provided in 10.38.4 (DTI transmission rules), 10.38.5 (Contention based access period (CBAP) transmission rules), and 10.38.6.3 (Contention based access period (CBAP) allocation).

The second mechanism, designated the *hybrid coordination function* (HCF) *controlled channel access* (HCCA), which is not applicable to DMG STAs, allows for the reservation of transmission opportunities (TXOPs) with the hybrid coordinator (HC). A STA requests the HC for TXOPs, both for its own transmissions as well as for transmissions from the AP to it.[17] The request is initiated by the station management entity (SME) of the STA. The HC, which is (#2210)colocated at the AP, either accepts or rejects the request based on an admission control policy. If the request is accepted, the HC schedules TXOPs for both STAs (both the AP and the non-AP STA). For transmissions from the non-AP STA, the HC polls the STA based on the parameters supplied by the STA at the time of its request. For transmissions to the STA, the AP directly obtains TXOPs from the (#2210)colocated HC and delivers the queued frames to the STA, again based on the parameters supplied by the STA. Details of the mechanism are provided in 10.23.3 (HCF controlled channel access (HCCA)) and 11.4 (TS operation). This mechanism might be used for applications such as voice and video, which need periodic service from the HC. If the application constraints dictate the use of this mechanism, the application initiates this mechanism by using the management service primitives.

The third mechanism, designated the *service period* (SP) *access* or *service period channel access* (SPCA), is applicable only to DMG STAs and allows for the reservation of channel time by the AP or PCP. A non-AP and non-PCP STA requests SPs from an AP or PCP. These SPs can be used for transmission to any other STA in the BSS. The request is initiated by the SME of the non-AP and non-PCP STA. The AP or PCP either accepts or rejects the request based on an admission control policy. If the request is accepted, the AP or PCP uses the Extended Schedule element to schedule SPs for communication between the source and destination DMG STAs indicated within the request. Details of this mechanism are provided in 10.38.6.2 (Service period (SP) allocation), 10.38.6.4 (Pseudo-static allocations), 10.38.6.6 (DMG and CMMG protected period), and 11.4 (TS operation).

[17] In the case of downlink traffic streams (TSs).


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The fourth mechanism, designated as *dynamic allocation*, is applicable only to DMG STAs and allows for near-real-time reservation of channel time with an AP or PCP. This type of access is used in addition to the service period and contention based access period mechanisms. An AP or PCP can poll a STA and receive requests for channel time allocation. Based on the received requests, the AP or PCP can accept a request and immediately allocate (within the same beacon interval) channel time for the STA to communicate with another STA by using a Grant frame. Details of this mechanism are provided in 10.38.7 (Dynamic allocation of service period), 10.38.8 (Dynamic truncation of service period), and 10.38.9 (Dynamic extension of service period).

The AP of a QoS BSS might allow non-QoS STAs to associate. All individually addressed frames that are sent to non-QoS STAs by an AP do not use the frame formats associated with the QoS facility.

A QoS STA associated in a non-QoS BSS acts as a non-QoS STA.

### 4.3.11 Wireless LAN radio measurements

#### 4.3.11.1 General

(#1192)Wireless LAN (WLAN) radio measurements enable STAs to observe and gather data on radio link performance and on the radio environment. A STA can choose to make measurements locally, request a measurement from another STA, or be requested by another STA to make one or more measurements and return the results. Radio measurement data is made available to STA management and upper protocol layers where it might be used for a range of applications. The measurements enable adjustment of STA operation to better suit the radio environment. The radio measurement service includes measurements that extend the capability, reliability, and maintainability of WLANs by providing standard measurements across vendors, and the service provides the resulting measurement data to upper layers in the communications stack.

In addition to featuring standard measurements and delivering measurement information to upper layers, there are applications that require quantifiable radio environment measurements in order to attain the necessary performance levels. These applications include VoIP, video over IP, location based applications, as well as applications requiring mitigation of harsh radio environments (e.g., multifamily dwellings, airplanes, factories, municipalities). Radio measurements address most of the existing issues in using unlicensed radio spectrum to meet the requirements of these emerging technologies.

To address the mobility requirements of technologies, such as VoIP and video streaming, radio measurements, such as Channel Load request/report and the Neighbor request/report, can be used to collect transition information, which can drastically speed up handoffs between BSSs within the same ESS. By accessing and using this information, the STAs (either in APs or in non-AP STAs) can make intelligent decisions about the most effective way to utilize the available spectrum, power, and bandwidth for their communications.

The request/report measurements are as follows:

- Beacon
- Frame
- Channel Load
- Noise Histogram
- STA Statistics
- LCI (location configuration information)
- Neighbor Report
- Link Measurement
- Transmit Stream/Category Measurement

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The request-only mechanism is as follows:

— Measurement Pause

The report-only mechanism is as follows:

— Measurement Pilot(#1193)

These measurement mechanisms provide the capability for a STA to manage and query its radio environment, and to make appropriate assessments about its health and efficiency. It is the first step in making WLAN smart and capable of making appropriate decisions for fast transition, for mesh connectivity, and for managing the radio environment for all wireless devices.

#### 4.3.11.2 Beacon

The Beacon request/report pair enables a STA to request from another STA a list of APs whose beacons it can receive on a specified channel or channels. The Beacon report request/response provides a means for a requesting STA to obtain received beacon, probe response, and measurement pilot information from a responding STA.

#### 4.3.11.3 Measurement pilot

The Measurement Pilot frame provides a subset of the information provided in a Beacon frame, is smaller than a Beacon frame, and is transmitted more often than a Beacon frame. The purpose of the Measurement Pilot frame is to assist a STA with scanning.

#### 4.3.11.4 Frame

The Frame request/report pair returns a picture of all of the channel traffic and a count of all of the frames received at the measuring STA. For each unique (#300)transmitter address, the STA reports the (#300)transmitter address, number of frames received from this transmitter, average power level (RCPI) for (#14)PPDUs containing these frames, and BSSID indicated by the transmitter.

#### 4.3.11.5 Channel load

The Channel Load request/report pair returns the channel utilization measurement as observed by the measuring STA.

#### 4.3.11.6 Noise histogram

The Noise Histogram request/report pair returns a power histogram measurement of non-IEEE-802.11 noise power by sampling the channel when virtual carrier sense indicates idle and the STA is neither transmitting nor receiving a frame.

#### 4.3.11.7 STA statistics

The STA Statistics request/report pair returns groups of values for STA counters and for BSS Average Access Delay. The STA counter group values include transmitted fragment counts, group addressed transmitted frame counts, failed counts, retry counts, multiple retry counts, frame duplicate counts, Request to Send (RTS) success counts, RTS failure counts, Acknowledgment (Ack) failure counts, received fragment counts, group addressed received frame counts, FCS error counts, and transmitted frame counts. BSS Average Access Delay group values include AP average access delay, average access delay for each access category, associated STA count, and channel utilization.


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#### 4.3.11.8 Location

The Location request/report pair returns a requested location in terms of latitude, longitude, and altitude. It includes types of altitude such as floors. A requested location can be the location of the requester (e.g., "Where am I?") or the location of the reporting STA (e.g., "Where are you?") or the location of another STA.

#### 4.3.11.9 Measurement pause

The Measurement Pause request is defined, but no report comes back from this request. The measurement pause permits the inclusion of a quantified delay between the execution of individual measurements that are provided in a series within a Radio Measurement Request frame. The measurement pause used as the last measurement in a frame provides control of the measurement period when Radio Measurement Request frames are to be repeated.

#### 4.3.11.10 Neighbor report

The neighbor report request is sent to an AP, which returns a neighbor report containing information about known neighbor APs that are candidates for a service set transition. This request/report pair enables a STA to gain information about the neighbors of the associated AP to be used as (#1600)potential BSS transition candidates.

#### 4.3.11.11 Link measurement

The link measurement request/report exchange provides measurements of the RF characteristics of a STA-to-STA link. This measurement indicates the instantaneous quality of a link.

#### 4.3.11.12 Transmit stream/category measurement

When two QoS STAs have an ongoing traffic stream between them, the Transmit Stream/Category Measurement request/report pair enables either STA to query the other about the conditions of the stream. The transmit stream/category measurement report provides the transmit-side performance metrics for the measured traffic stream. Trigger conditions included in the Transmit Stream/Category Measurement request can initiate triggered Transmit Stream/Category Measurement reports upon detection of the trigger condition.

### 4.3.12 Operation in licensed frequency bands

#### 4.3.12.1 General

IEEE 802.11 devices can operate on frequencies that are licensed by national regulatory bodies. Although this standard has been generalized so that it is independent of license type, band, and country of operation, only the bands and associated regulations listed in Annex D have been specifically considered.

#### 4.3.12.2 Dynamic STA enablement (DSE) in licensed bands

The DSE operating procedures are used to automate the channel provisioning and regulatory controls needed for unregistered IEEE 802.11 STAs to operate as dependent STAs in licensed spectrum.[18]

[18] In some licensed frequency bands, wireless equipment can be owned and operated by individuals who do not hold a license. In such instances, devices are permitted to operate only if they are either communicating with, or receiving permission to transmit from, a STA that is maintained by a licensed operator. The Japanese 4.9 GHz band and the United States and its territories(#296) 4.94–4.99 GHz public safety band are examples in which IEEE 802.11 STAs operate under such arrangements.

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#### 4.3.12.3 Contention based protocol (CBP) in nonexclusively licensed bands

The granting of licenses on a nonexclusive, uncoordinated basis in the same area leads to the possibility of overlapping networks. When overlapping networks cause co-channel interference, regulations, such as those governing the 3650 MHz band in the United States and its territories(#296), require the use of a CBP "by which a transmitter provides reasonable opportunities for other transmitters to operate."[19] IEEE 802.11 carrier sense multiple access with collision avoidance (CSMA/CA) is suitable for this purpose in most situations.

#### 4.3.12.4 Using DSE STA identification to resolve interference

When CSMA/CA is not able to sufficiently sense the presence of another licensee's STA (i.e., a hidden STA) or if a secondary licensee causes inference to a primary licensee, the secondary licensee is obliged to resolve complaints that result from interference caused by any STA under its control (including dependent STAs). In order to facilitate the interference resolution processes, all STAs operating in nonexclusively licensed spectrum use the DSE STA and location information procedures.

The STA identification and location information procedures are tied because, by default, registered STAs broadcast their actual location as their unique identifier. Dependent STAs broadcast the location of the STA that has enabled them as well as a unique code selected by the licensee. This method puts a victim of the interference in contact with the party responsible for rectifying the problem, and, at the same time, it protects the privacy of the dependent STA's operator.

#### 4.3.12.5 Further coexistence enhancements in nonexclusively licensed bands

While not explicitly required to meet specific rules, a number of optional IEEE 802.11 mechanisms, when used together, are able to meet general requirements for spectrum sharing, incumbent detection, and other cognitive radio functions in licensed bands. The specific mechanisms for each band are detailed in E.2 (Band-specific operating requirements).

### 4.3.13 High Throughput (HT) STA(#2297)

The IEEE 802.11 HT STA provides PHY and MAC features that can support a throughput of 100 Mb/s and greater, as measured at the MAC data service access point (SAP). An HT STA supports HT features as identified in Clause 10 (MAC sublayer functional description) and Clause 19 (High Throughput (HT) PHY specification(#2297)). An HT STA operating in the 5 GHz band supports transmission and reception of frames that are compliant with mandatory PHY specifications as defined in Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification). An HT STA operating in the 2.4 GHz band supports transmission and reception of frames that are compliant with mandatory PHY specifications as defined in Clause 16 (High rate direct sequence spread spectrum (HR/DSSS) PHY specification) and Clause 18 (Extended Rate PHY (ERP) specification). An HT STA is also a QoS STA. The HT features are available to HT STAs associated with an HT AP. A subset of the HT features is available for use between two HT STAs that are members of the same IBSS. Similarly, a subset of the HT features is available for use between two HT STAs that have established mesh peering (see 9.4.2.54 (HT Capabilities element) for details).

An HT STA has PHY features consisting of the modulation and coding scheme (MCS) set described in 19.3.5 (Modulation and coding scheme (MCS)) and physical layer (PHY) protocol data unit (PPDU) formats described in 19.1.4 (PPDU formats). Some PHY features that distinguish an HT STA from a non-HT STA are referred to as *multiple input, multiple output (MIMO)* operation; spatial multiplexing (SM); spatial mapping (including transmit beamforming); space-time block coding (STBC); low-density parity check (LDPC) encoding; and antenna selection (ASEL). The allowed PPDU formats are non-HT format, HT-

[19] Definition of CBP from FCC 05-56, Report and Order and Memorandum Opinion and Order, clause 58.


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mixed format, and HT-greenfield format (see 19.1.4 (PPDU formats)). The PPDUs can be transmitted with 20 MHz bandwidth and might be transmitted with 40 MHz bandwidth.

An HT STA has MAC features that include frame aggregation, some block ack features,(#3263) reverse direction (RD), and protection mechanisms supporting coexistence with non-HT STAs.

### 4.3.14 Sub 1 GHz (S1G) STA

#### 4.3.14.1 Overview

The IEEE 802.11 S1G STA operates in frequency bands below 1 GHz excluding the TV White Space bands.

An S1G STA supports S1G features identified in Clause 9 (Frame formats), Clause 10 (MAC sublayer functional description), Clause 11 (MLME), Clause 12 (Security), and Clause 23 (Sub 1 GHz (S1G) PHY specification(#4095)).

The main PHY features in an S1G STA are the following:

- Mandatory support for 1 MHz and 2 MHz channel width
- Mandatory support for S1G_1M PPDU
- Mandatory support for S1G_SHORT PPDU
- Mandatory support for S1G_LONG PPDU if ≥ 4 MHz channel width is supported
- Mandatory support for detection and decode of SIG-A field of the S1G_LONG preamble
- Mandatory support for single spatial stream S1G-MCS 0 to S1G-MCS 2 and S1G-MCS 10 (for 1 MHz PPDU only)
- Mandatory support for single spatial stream S1G-MCS 3 to S1G-MCS 7 in an S1G AP
- Mandatory support for binary convolutional code (BCC) coding
- Mandatory support for normal guard interval
- Mandatory support for fixed pilots
- Optional support for 2, 3, and 4 spatial streams (transmit and receive)
- Optional support for S1G_LONG PPDU if ≥ 4 MHz channel width is not supported
- Optional support for beamforming sounding (by sending an S1G NDP)
- Optional support for compressed beamforming feedback
- Optional support for STBC, LDPC (transmit and receive)
- Optional support for S1G MU PPDUs (transmit and receive)
- Optional support for 4 MHz, 8 MHz, or 16 MHz channel width
- Optional support for S1G-MCSs 8 and 9 (transmit and receive)
- Optional support for short guard interval
- Optional support for traveling pilots

The main MAC features supported for S1G STA are the following:

- Mandatory support for NDP Ack, NDP BlockAck, and NDP CTS frames; mandatory support for the reception of NDP Probe Request frame for S1G AP; optional support for other NDP CMAC PPDUs
- Mandatory support for the reception of PV1 MPDUs but optional support for the transmission of PV1 MPDUs
- Mandatory support for the second virtual carrier sensing mechanism, i.e., response indication deferral (RID)
- Mandatory support for the hierarchical structure of TIM element by an S1G AP

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- Mandatory support for extended BSS max idle periods and extended listen intervals with unified scaling factor
- Optional support for RAW
- Optional support for relay
- Optional support for grouping of non-AP STAs and group AID
- Optional support for TWT
- Optional support for BDT
- Optional support for sectorization
- Optional support for non-TIM mode
- Optional support for asymmetric BA, fragment BA
- Optional support for page slicing, dynamic AID assignment for an S1G AP
- Optional support for authentication control
- Optional support for SST
- Optional support for rescheduling STA's awake/doze(#6038)cycle
- Optional support for either a sensor STA or a non-sensor STA
- Optional support for an EL STA

NOTE—Some NDP CMAC PPDUs are mandatory under certain conditions as indicated in B.4.4.2 (MAC frames).

Most S1G features help either reduce a STA's energy consumption or increase the usable range between an AP and a non-AP STA.

An S1G STA is a nonmesh STA, and a QoS STA that does not support HCCA.

#### 4.3.14.2 S1G relay

The S1G relay is a mechanism for expanding the coverage area of an AP. The AP is referred to as the root AP. An S1G relay consists of an S1G relay AP and an S1G relay STA. An S1G relay forwards frames between STAs associated to its S1G relay AP and the AP to which its S1G relay STA is associated.

### 4.3.15 Very high throughput (VHT) STA

A VHT STA is an HT STA that, in addition to features supported as an HT STA, supports VHT features identified in Clause 9 (Frame formats), Clause 10 (MAC sublayer functional description), Clause 11 (MLME), Clause 14 (MLME mesh procedures), Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification), and Clause 21 (Very high throughput (VHT) PHY specification), but operates only in the 5 GHz band.(#362)

The main PHY features in a VHT STA that are not present in an HT STA are the following:

- Mandatory support for 40 MHz and 80 MHz channel widths
- Mandatory support for VHT single-user (SU) PPDUs
- Optional support for 160 MHz and 80+80 MHz channel widths
- Optional support for VHT sounding protocol to support beamforming
- Optional support for VHT multi-user (MU) PPDUs
- Optional support for VHT-MCSs 8 and 9

The main MAC features in a VHT STA that are not present in an HT STA are the following:

- Mandatory support for the A-MPDU padding of a VHT PPDU
- Mandatory support for S-MPDU


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- Mandatory support for responding to a bandwidth indication (provided by the RXVECTOR parameters CH_BANDWIDTH_IN_NON_HT and DYN_BANDWIDTH_IN_NON_HT) in a non-HT and non-HT duplicate RTS frame
- Optional support for MPDUs of up to 11 454 octets
- Optional support for A-MPDU pre-end-of-frame (pre-EOF) padding (see 9.7.1 (A-MPDU format)) of up to 1 048 575 octets
- Optional support for VHT link adaptation

Most VHT features, among other benefits, increase the maximum throughput achievable between two VHT STAs over that achievable using HT features alone. The VHT features are available to VHT STAs associated with a VHT AP. A subset of the VHT features is available for use between two VHT STAs that are members of the same IBSS. Similarly, a subset of the VHT features is available for use between two VHT STAs that have established mesh peering. A subset of the VHT features is available for use between two VHT STAs that have established a (#2152)TDLS direct link.

The support for VHT transmit beamforming sounding and VHT MU PPDUs in a VHT AP and more than one VHT STA within a VHT BSS enables the optional use of downlink MU multiple input, multiple output (DL MU-MIMO(#3367)). With DL MU-MIMO(#3367) the AP can create up to four A-MPDUs, each carrying MPDUs destined for an associated MU beamformee capable STA. The AP uses group identifiers (GIDs) to signal potential recipient STAs. The AP transmits the A-MPDUs simultaneously in separate space-time streams such that each recipient STA is able to demodulate the space-time streams carrying its A-MPDU. The simultaneous transmission of A-MPDUs in a single VHT MU PPDU provides a means to increase aggregate throughput over that achieved by sending the A-MPDUs in separate SU PPDUs.

The use of certain HT features, such as reduced interframe space (RIFS), is not permitted for VHT STAs.

### 4.3.16 High-efficiency (HE) STA(11ax)

The IEEE 802.11 HE STA operates in frequency bands between 1 GHz and 7.125 GHz.

In the 5 GHz and 6 GHz bands, the following apply:

- An HE STA is also a VHT STA if operating in the 5 GHz band, except that a 20 MHz-only HE STA does not support 40 MHz and 80 MHz channel widths
- An HE STA is also a STA that supports the OFDM PHY defined in Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) if operating in the 6 GHz band
- Support for 20 MHz operating channel width is mandatory in an HE STA
- Support for 40 MHz and 80 MHz operating channel width is mandatory in an HE STA that is not a 20 MHz-only non-AP HE STA
- Support for 160 MHz and 80+80 MHz operating channel width is optional in an HE STA

In the 2.4 GHz band, the following apply:

- An HE STA is also an HT STA
- Support for 20 MHz operating channel width is mandatory in an HE STA
- Support for 40 MHz operating channel width is optional in an HE STA

The main PHY features in an HE STA that are not present in VHT STA or HT STA are the following:

- Mandatory support for DL and UL OFDMA
- Mandatory support for DL MU-MIMO by an HE AP that supports 4 or more spatial streams when MU-MIMO is done on the entire PPDU bandwidth
- Mandatory support for DL MU-MIMO reception for a non-AP HE STA

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- Mandatory support for the HE sounding protocol to support beamforming for a non-AP STA beamformee and optional otherwise
- Optional support for HE-MCSs 10 and 11
- Optional support for UL MU-MIMO
- Optional support for preamble puncturing

NOTE—Preamble puncturing is a mechanism whereby OFDMA is used to avoid transmissions in certain subcarriers.

The main MAC features in an HE STA that are not present in VHT STA or HT STA are the following:

- In an AP, mandatory support for the role of operating mode indication (OMI) responder and optional support for the role of OMI initiator
- In an AP, mandatory support for individual target wake time (TWT) operation
- In a non-AP STA, mandatory support for two NAV operation
- In a non-AP STA, mandatory support for multiple BSSID operation
- In an AP, optional support for two NAV operation
- In a non-AP STA, optional support for the roles of OMI initiator and responder
- In a non-AP STA, optional support for individual TWT operation
- Optional support for dynamic fragmentation levels 1, 2, and 3
- Optional support for broadcast TWT
- Optional support for UL OFDMA-based random access (UORA)
- Optional support for spatial reuse operation
- Optional support for multi-TID A-MPDU operation
- Optional support for ER BSS
- Optional support for the NDP feedback report

An HE AP sends a Trigger frame to initiate UL MU operation using UL OFDMA or UL MU-MIMO transmissions or a frame containing a TRS Control subfield to initiate UL OFDMA transmissions. The frame initiating these transmissions in the uplink direction is a triggering frame. The triggering frame identifies non-AP STAs participating in UL MU operation and assigns RUs and/or spatial streams to these STAs. Multi-STA BlockAck frames can be used by the AP to acknowledge the frames transmitted by multiple non-AP STAs. The scheduling of these Trigger frames can be set up between a non-AP STA and the AP using TWT operation to save power and reduce collisions.

These features can reduce protocol overhead and increase aggregate network throughput (e.g., DL and UL OFDMA, DL/UL MU-MIMO), enhance peak link throughput (e.g., HE-MCS 10, 11), enhance dense network efficiency (e.g., spatial reuse), and/or enhance power conservation (e.g., TWT). These features can improve the average throughput per STA in a BSS by a factor of four, compared to VHT.

### 4.3.17 Wake-up radio (WUR) AP and WUR non-AP STA(11ba)

A WUR non-AP STA is a non-HT, HT, VHT, or HE non-AP STA that is capable of receiving WUR PPDUs and supports the WUR operation. A WUR non-AP STA has a capability to receive a WUR PPDU at a power consumption of less than 1 milliwatt.

A WUR AP is a non-HT, HT, VHT, or HE AP that is capable of transmitting WUR PPDUs and supports the WUR operation.

A WUR Basic PPDU carries a WUR frame. A WUR FDMA PPDU carries more than one WUR frame. A WUR AP transmits a WUR PPDU to an intended recipient WUR non-AP STA or multiple intended recipient WUR non-AP STAs. There are five types of WUR frames that provide the following functions:


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- WUR Beacon frames are transmitted by a WUR AP and used by a WUR non-AP STA to maintain timing synchronization to support the WUR duty cycle operation.
- WUR Wake-up frames provide notification to one or more WUR non-AP STA(s) that a WUR AP has buffered data and/or critical update of BSS parameters for the WUR non-AP STA(s), which enables the WUR non-AP STAs to remain in power save when there is no data to receive and enables the WUR non-AP STAs to react promptly to incoming traffic and critical update of BSS parameters.
- WUR Short Wake-up frames are shortened version of the WUR Wake-up frames.
- WUR Discovery frames support the discovery of WUR APs by a WUR non-AP STA at low power consumption.
- WUR Vendor Specific frames support vendor specific operations.

WUR PPDUs are either WUR Basic PPDUs or WUR FDMA PPDUs. The transmission and reception of WUR PPDUs is defined for the 2.4 GHz and 5 GHz bands. The transmission of 40 MHz WUR FDMA PPDUs is defined for the 2.4 GHz and 5 GHz bands and the transmission of 80 MHz WUR FDMA PPDUs is defined for the 5 GHz band.

The details of the WUR power management procedure are defined in 29.8 (WUR power management procedure).

A WUR AP has the following mandatory main features:

- Transmission of a WUR Basic PPDU on a 20 MHz channel at low data rate (LDR).
- Transmission of a WUR Basic PPDU on a 20 MHz channel at high data rate (HDR).
- Support of the WUR power management procedure.
- Support of the WUR wake-up operation.
- Support of the WUR duty cycle operation.
- Transmission of an individually addressed fixed-length (FL) WUR Wake-up frame.
- Transmission of a broadcast FL WUR Wake-up frame.
- WUR Beacon frame generation.

A WUR AP has the following optional main features:

- Transmission of a WUR FDMA PPDU on a 40 MHz or 80 MHz channel.
- Transmission of a variable-length (VL) WUR frame.
- Support for WUR frame protection.
- Transmission of a WUR Wake-up frame with a WUR group ID.
- Transmission of a WUR Short Wake-up frame.
- Support for WUR Discovery.

A WUR non-AP STA has the following mandatory main features:

- Reception of a WUR Basic PPDU on a 20 MHz channel at LDR.
- Support of the WUR power management procedure.
- Support of the WUR wake-up operation.
- Reception of an individually addressed FL WUR Wake-up frame.
- Reception of a broadcast FL WUR Wake-up frame.
- Synchronization using WUR Beacon frame.

A WUR non-AP STA has the following optional main features:

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- Reception of a WUR Basic PPDU on a 20 MHz channel at HDR.
- Support of the WUR FDMA operation (see 29.11 (WUR FDMA operation)).
- Support of the WUR duty cycle operation (see 29.7 (WUR duty cycle operation)).
- Reception of a VL WUR frame.
- Support for WUR frame protection.
- Reception of a WUR Wake-up frame with a WUR group ID.
- Reception of a WUR Short Wake-up frame.
- Support for WUR Discovery.

### 4.3.18 Television very high throughput (TVHT) STA

The IEEE 802.11 TVHT STA operates in television white spaces (TVWS) bands.

A TVHT STA supports all mandatory features of a VHT STA as mandatory features except for HT-mixed format PPDUs and 20 MHz, 40 MHz, and 80 MHz channel widths. A TVHT STA supports all optional features of a VHT STA as optional features except for HT-greenfield format PPDUs, 160 MHz or 80+80 MHz channel widths, more than 4 spatial streams, and Short GI (which is mandatory).

The 20 MHz, 40 MHz, 80 MHz, 160 MHz, or 80+80 MHz channel widths and more than 4 spatial streams are not used in STAs operating as TVHT STAs. The features and behaviors of VHT STAs specified in Clause 6 (Layer management), Clause 8 (PHY service specification), Clause 9 (Frame formats), Clause 10 (MAC sublayer functional description), Clause 11 (MLME), Clause 14 (MLME mesh procedures), and Annex G apply to TVHT STAs as well, unless stated otherwise.

For Clause 6 (Layer management), Clause 8 (PHY service specification), Clause 9 (Frame formats), Clause 10 (MAC sublayer functional description), Clause 11 (MLME), and Clause 14 (MLME mesh procedures), the following replacements are applied for TVHT STAs:

- “TVHT_W/TVHT_2W” replaces “20/40 MHz”.
- “TVHT_W/TVHT_2W/TVHT_4W” replaces “20/40/80/160 MHz”.
- “TVHT_W”, “TVHT_2W”, and “TVHT_4W” replace “20 MHz”, “40 MHz”, and “80 MHz,” respectively.
- “TVHT_W” replaces “CBW20”.
- “TVHT_2W” replaces “CBW40”.
- “TVHT_4W” replaces “CBW80” and “CBW80+80”.
- “secondaryTVHT_2W” replaces “secondary40”.
- “TVHT STA” replaces “VHT STA”.
- “TVHT AP” replaces “VHT AP”.
- “TVHT BSS” replaces “VHT BSS”.
- “TVHT-MCS” replaces “VHT-MCS”.
- “TVHT Operation” replaces “VHT Operation”.
- “dot11TVHTOptionImplemented” replaces “dot11VHTOptionImplemented”.
- “dot11TVHTControlFieldOptionImplemented” replaces both “dot11VHTControlFieldOptionImplemented” and “dot11HTControlFieldSupported”.
- “dot11TVHTShortGIOptionIn4WActivated” replaces “dot11VHTShortGIOptionIn80Activated”.
- “dot11TVHTSUBeamformerOptionImplemented” replaces “dot11VHTSUBeamformerOptionImplemented”.
- “dot11TVHTSUBeamformeeOptionImplemented” replaces “dot11VHTSUBeamformeeOptionImplemented”.


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- "dot11TVHTMUBeamformerOptionImplemented" replaces "dot11VHTMUBeamformerOptionImplemented".
- "dot11TVHTMUBeamformeeOptionImplemented" replaces "dot11VHTMUBeamformeeOptionImplemented".
- "dot11TVHTTXOPPowerSaveOptionImplemented" replaces "dot11VHTTXOPPowerSaveOptionImplemented".
- "dot11TVHTOBSSScanCount" replaces "dot11VHTOBSSScanCount".
- "dot11TVHTExtendedNSSBWCapable" replaces "dot11VHTExtendedNSSBWCapable".
- Reference to 9.4.1.48 (TVHT Compressed Beamforming Report field) replaces reference to 9.4.1.47 (VHT Compressed Beamforming Report field).
- Reference to 9.4.1.50 (TVHT MU Exclusive Beamforming Report field) replaces reference to 9.4.1.49 (MU Exclusive Beamforming Report field).
- Reference to 9.4.2.170 (TVHT Operation element) replaces reference to 9.4.2.157 (VHT Operation element).
- Reference to 11.41 (Basic TVHT BSS functionality) replaces reference to 11.38.1 (Basic VHT BSS functionality).
- Reference to Clause 22 (Television very high throughput (TVHT) PHY specification) and its subclauses replace reference to Clause 21 (Very high throughput (VHT) PHY specification) and its subclauses.

For Annex G, the following replacements are applied for TVHT STAs:

- "TVHT" replaces "VHT".
- "tvht" replaces "vht".

The main PHY features in a TVHT STA that are not present in a VHT STA are the following:

- Mandatory support for TVHT_W channel width.
- Optional support for TVHT_W+W channel width.
- Optional support for TVHT_2W channel width.
- Optional support for TVHT_4W channel width.
- Optional support for TVHT_2W+2W channel width.

These TVHT features are available to TVHT STAs associated with a TVHT AP. A subset of the TVHT features is available for use between two TVHT STAs that are members of the same IBSS.

### 4.3.19 STA transmission of Data frames outside the context of a BSS

In addition to defining procedures for STA communication within a BSS, this standard also defines procedures for a STA that is not a member of a BSS to transmit Data frames. Such Data frames are defined as being transmitted outside the context of a BSS (OCB). A STA transmits a Data frame outside the context of a BSS only if dot11OCBActivated is true.

NOTE—The specific frame subtypes that a STA is allowed to send when it has dot11OCBActivated true are specified in 11.18 (STAs communicating Data frames outside the context of a BSS).

When dot11OCBActivated is true, a Data frame can be sent to either an individual or a group destination MAC address. This type of communication is possible only between STAs that are able to communicate directly over the wireless medium. It allows immediate communication, avoiding the latency associated with establishing a BSS. When dot11OCBActivated is true, a STA is not a member of a BSS and it does not utilize the IEEE 802.11 authentication, association, or data confidentiality services. This capability is particularly well suited for use in rapidly varying communication environments such as those involving mobile STAs in which the interval over which the communication exchanges take place is of very short

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duration (e.g., on the order of tens or hundreds of milliseconds). Since IEEE 802.11 MAC sublayer authentication services are not used when dot11OCBActivated is true, any required authentication services are provided by the station management entity (SME) or by applications outside of the MAC sublayer, such as those described in the IEEE 1609 [B20] family of standards.

A STA whose MIB does not include dot11OCBActivated operates as if the attribute is false.

Communication of Data frames when dot11OCBActivated is true might take place in a frequency band that is dedicated for its use, and such a band might require licensing depending on the regulatory domain (see Annex E). A STA for which dot11OCBActivated is true initially transmits and receives on a channel known in advance, either through regulatory designation or some other out-of-band communication. A STA's SME determines PHY parameters, as well as any changes in the operating channel, e.g., using information obtained via out-of-band communication or over-the-air frame exchange. When dot11OCBActivated is true, a sending STA sets the BSSID field to the wildcard BSSID(#3522)(see 9.2.4.3.4 (BSSID field)).

(11bd)A STA with dot11OCBActivated equal to true might operate as a DMG STA. A DMG STA with dot11DMGOCBActivated equal to true supports the MAC and MLME functions defined in 31.3 (Operation in the 60 GHz band) in addition to the MAC functions defined in Clause 10 (MAC sublayer functional description) and the MLME functions defined in Clause 11 (MLME) for DMG STAs. A DMG STA operating OCB might support EDMG features.

(11bd)A STA whose MIB does not include the dot11DMGOCBActivated attribute operates as if the attribute is false.

The Vendor Specific Action(#4065) frame (see 9.6.5 (Vendor Specific Action frame and Vendor Specific Protected Action frame details(#3729)(#4065))) provides one means for STAs to exchange management information prior to communicating Data frames outside the context of a BSS.

### 4.3.20 Next generation vehicle-to-everything (V2X) (NGV) STA(11bd)

A next generation vehicle-to-everything (NGV) STA provides MAC and PHY features as defined in Clause 31 (Next Generation V2X (NGV) MAC specification) and Clause 32 (Next Generation V2X (NGV) PHY specification(11bd)). An NGV STA supports at least twice the throughput and at least 3 dB better receiver minimum input sensitivity than a non-NGV STA when operating OCB in high mobility channel environments in the 5.9 GHz band as defined in Annex E.2.3 and Annex E.2.4. The double throughput and higher receiver minimum input sensitivity might not be supported simultaneously. In an NGV STA dot11NGVOptionImplemented is true. In a non-NGV STA with dot11NGVOptionImplemented, the attribute is false. A STA whose MIB does not include the dot11NGVOptionImplemented attribute operates as if the attribute is false.

An NGV STA might be co-located with a DMG STA for which dot11DMGOCBActivated is true in the 60 GHz frequency band (57 GHz to 71 GHz) as defined in E.1. The NGV STA might assist the DMG STA in performing DMG discovery OCB by communicating with a peer NGV STA to exchange the higher layer information that contains information of a peer DMG STA with which the peer NGV STA is co-located. The information is provided from/to a DMG STA through the MLME SAP interface. The protocol to exchange this higher layer information is outside the scope of this standard.

An NGV STA supports interoperability, coexistence, backward compatibility, and fairness in contending for the medium with non-NGV STAs when operating OCB in the 5.9 GHz band. An NGV STA is also a non-NGV STA that supports transmission and reception of non-NGV PHY PPDUs when operating OCB in the 5.9 GHz band.

An NGV STA is capable of transmitting and receiving frames OCB as specified in 11.18 (STAs communicating Data frames outside the context of a BSS).


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The main PHY features of an NGV STA that are not present in a non-NGV STA are the following:

- Mandatory support for the 10 MHz NGV PPDU format and optional support for the 20 MHz NGV PPDU and 20 MHz non-NGV duplicate PPDU formats
- For the 20 MHz and 10 MHz NGV PPDU, mandatory support for LDPC coding, midambles, BPSK-DCM, and 256-QAM
- Mandatory support for transmit spectral mask C2 by a STA that transmits a 20 MHz NGV PPDU or 20 MHz non-NGV duplicate PPDU
- Mandatory support for repetitive NON_NGV_10 PPDU
- Mandatory support for coexistence with non-NGV STAs operating in the same channel
- Mandatory support for transmit spectral mask C by a STA that transmits a 10 MHz NGV PPDU and belongs to transmit power class C
- Optional support for transmission and reception of SU MIMO with two spatial streams

Additional NGV STA PHY features are:

- Mandatory support for a single spatial stream
- Mandatory support for Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) 10 MHz PPDU
- Optional support for Classes A, B, and D of spectrum mask requirement for 10 MHz bandwidth

The main MAC features of an NGV STA that are not present in a non-NGV STA are the following:

- Mandatory support for coexistence with non-NGV STAs operating in the same channel
- Mandatory support for extended MAC service interface to provide higher layers with the ability to control NGV transmissions and receive status regarding NGV receptions and the radio environment
- Mandatory support for NGV capability indication for non-NGV PPDUs encoded in the Duration/ID field of the MAC header
- Mandatory support for block ack
- Mandatory support for reception of frame aggregation when communicating OCB
- Optional support for transmission of frame aggregation when communicating OCB
- Optional support for 20 MHz OCB communication
- For optional 20 MHz OCB communication an NGV STA supports 20 MHz channel access with 10 MHz primary and 10 MHz secondary channels
- Optional support for 20 MHz non-NGV duplicate operation

Additional NGV STA MAC features are:

- Mandatory support for 10 MHz OCB communication

An NGV STA might support positioning based on NGV ranging, which consists of a subset of (#7065)fine timing measurement (FTM)(#8043) functionalities as defined in 11.21.6 (FTM procedure(#7065)) and Annex P.3:

- (#7065)FTM procedure negotiation and termination for non-TB ranging as defined in 11.21.6.3 (FTM procedure negotiation(11az)) and non-TB ranging as described in 11.21.6.4.4 (Non-TB ranging measurement exchange(11az))
- Differential distance computation as detailed in P.3 (Differential Distance Computation using FTM frames(#7223))(#8227)

An NGV STA might be co-located with a STA operating outside the 5.9 GHz band that supports the (#7065)FTM procedure as defined in 11.21.6 (FTM procedure(#7065)).

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### 4.3.21 Tunneled direct link setup(#1356)

Tunneled direct link(#1356) setup (TDLS) is characterized by the use of signaling frames that are encapsulated in Data frames so that the signaling frames are transmitted through an AP transparently. Therefore, the AP does not need to be (#2152)TDLS direct link(#1356) aware, nor does it have to support the same set of capabilities that are used on the (#2152)TDLS direct link, in order for TDLS to be used. To allow a STA to enter a TDLS power save mode, TDLS provides two power save mechanisms: TDLS peer unscheduled automatic power save delivery (U-APSD) (TPU) and TDLS peer power save mode (PSM). TDLS allows STAs to use the TDLS PeerKey (TPK) handshake to provide data confidentiality and message authentication. STAs that set up a TDLS direct link remain associated with the AP and transmit frames directly to the other TDLS peer STA.

### 4.3.22 Wireless network management

#### 4.3.22.1 Overview

Wireless network management (WNM) enables STAs to exchange information for the purpose of improving the overall performance of the wireless network. STAs use WNM protocols to exchange operational data so that each STA is aware of the network conditions, allowing STAs to be more cognizant of the topology and state of the network. WNM protocols provide a means for STAs to be aware of the presence of (#2210)colocated interference, and enable STAs to manage RF parameters based on network conditions.

In addition to providing information on network conditions, WNM also provides a means to exchange location information, provide support for the multiple BSSID capability on the same wireless infrastructure, support efficient delivery of group addressed frames, and enable a WNM sleep mode in which a STA can sleep for long periods of time without receiving frames from the AP.

The WNM service includes the following:

- BSS max idle period management
- BSS transition management
- Channel usage
- (#2210)Colocated interference reporting
- Diagnostic reporting
- Directed multicast service (DMS)
- Event reporting
- Flexible multicast service (FMS)
- Location services
- Multicast diagnostic reporting
- Multiple BSSID capability
- Proxy Address Resolution Protocol (ARP)
- QoS traffic capability
- SSID list
- Triggered STA statistics
- TIM broadcast
- Timing measurement
- Traffic filtering service
- U-APSD coexistence
- WNM notification


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— WNM sleep mode

#### 4.3.22.2 BSS max idle period management

BSS max idle period management enables an AP to indicate a time period during which the AP does not disassociate a STA due to nonreceipt of frames from the STA. This supports improved STA power saving and AP resource management.

(#7005)NOTE—The AP might disassociate the STA if, for example, that STA does not respond to group key handshake message 1. The STA might use WNM sleep mode (see 4.3.22.23 (WNM sleep mode)) to avoid getting disassociated in such a case.

#### 4.3.22.3 BSS transition management

BSS transition management enables an AP to request non-AP STAs to transition to a specific AP, or to indicate to a non-AP STA a set of preferred APs, due to network load balancing or BSS termination(#1676).

#### 4.3.22.4 Channel usage

Channel usage information is provided by the AP to the non-AP STA to recommend channels for BSSs that are not infrastructure BSSs or an off-channel TDLS direct link. The non-AP STAs can use the channel usage information as part of channel selection processing for a BSS that is not an infrastructure BSS or an off-channel TDLS direct link.

#### 4.3.22.5 (#2210)Colocated interference reporting

(#2210)Colocated interference reporting enables the requesting STA to obtain information on interference due to (#2210)colocated radios at the reporting STA. The requesting STA can use that information to schedule its transmissions to minimize the effects of the interference.

#### 4.3.22.6 Diagnostic reporting

Diagnostic requests enable a STA to request a non-AP STA to report information that might be helpful in diagnosing and resolving problems with the WLAN. Diagnostic reports include information on hardware, configuration, and STA capabilities.

#### 4.3.22.7 Directed multicast service (DMS)

The DMS enables a non-AP STA to request the AP to transmit group addressed frames destined to the requesting STA as individually addressed frames.

#### 4.3.22.8 Event reporting

Event requests enable a STA to request a non-AP STA to send particular real-time event reports. The types of events include transition, RSNA, WNM log, (11ax)BSS color collision, BSS color in use, and peer-to-peer link events. A transition event is transmitted after a non-AP STA successfully completes a BSS transition. Transition events are used to diagnose transition performance problems. An RSNA event report describes the type of Authentication used for the RSNA. RSNA events are used to diagnose security and authentication performance problems. A WNM log event report enables a non-AP STA to transmit a set of WNM log event messages to the requesting STA. WNM log event reports are used to access the contents of a STA's WNM log. (#2314)A BSS color collision event report enables a non-AP HE STA to signal BSS color collision to its associated AP. (11ax)A BSS color in use event report enables a non-AP HE STA to signal a BSS color in use by the non-AP HE STA to its associated AP. A peer-to-peer link event report enables a non-AP STA to inform the requesting STA that a peer-to-peer link has been established. Peer-to-peer link event reports are used to monitor the use of peer-to-peer links in the network.

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#### 4.3.22.9 Flexible multicast service (FMS)

The flexible multicast service enables a non-AP STA to request an alternate delivery traffic indication map (DTIM) (#8164)beacon delivery interval for one or more sets of group addressed streams that the non-AP STA receives. This enables the non-AP STA to transition to awake state(#6038) at the alternate DTIM interval rather than every DTIM (#8164)beacon and enables significant power saving when a non-AP STA receives group addressed traffic. The FMS also enables a STA to establish a data rate and delivery interval for group addressed traffic higher than the minimum data rate available(#1000).

#### 4.3.22.10 Location services

Location Configuration Request and Response frames enable STAs to configure a collection of location related parameters for Location Track Notification frames. The AP can indicate that it can provide location data to support applications such as emergency services. Location services also provide the ability for STAs to exchange location information using Radio Measurement Request and Radio Measurement Report frames. The protocol supports exchange-by-value and exchange-by-reference mechanisms. (#4198)Exchange-by-value can be performed in geospatial (LCI) and civic formats. (#6144)Exchange-by-reference can be performed using a URL that defines from where the location value is retrieved (in a location identifier report).

#### 4.3.22.11 Multicast Diagnostic report

Multicast Diagnostic reports enable a non-AP STA to report statistics for multicast traffic it received from a transmitting STA. This can be used by an AP to measure quality of multicast reception by a non-AP STA.

#### 4.3.22.12 Multiple BSSID capability

The Multiple BSSID capability enables the advertisement of information for BSSIDs using a single Beacon or Probe Response frame instead of multiple Beacon and Probe Response frames, each corresponding to a single BSSID. The Multiple BSSID capability also enables the indication of buffered frames for multiple BSSIDs using a single TIM element in a single beacon.

#### 4.3.22.13 Proxy ARP

(#1208)The IETF has defined a Proxy ARP function for IPv4 (IETF RFC 1027) and an IPv6 Neighbor Discovery (ND) Proxy function for IPv6 (IETF RFC 4389) where the proxy impersonates the target by replying to IPv4 ARP and IPv6 ND query respectively with its own MAC address for devices that are effectively reachable but not bridgeable beyond self. But those functions differ from the ones provided by the Proxy ARP service where the proxy would reply on behalf of the target. Therefore, the term Proxy ARP service in this standard does not refer to the functions defined in those RFCs. However, the Proxy ARP service in this standard for both IPv4 and IPv6 is similar to the function described in IETF RFC 7342.

(#1208)The Proxy ARP service enables an AP to avoid forwarding to the BSS broadcast ARP frames for IPv4 (IETF RFC 826) and IP layer multicast packets IPv6 ND messages for IPv6 (IETF RFC 4861 and IETF RFC 4862) which target not match the address of an associated STA. If the target matches the address of an associated non-AP STAs, the Proxy ARP service can either respond on behalf of the non-AP STA, or preferably send the frames as individually addressed frames(#6026) to the target STA(s) only. As a result, an associated STA that is not a target is not exposed to extraneous IPv4 ARP frames or IPv6 Neighbor Discovery packets. This way, the Proxy ARP service reduces the amount of broadcast transmissions and enables associated STAs to remain in power save for longer periods of time.

(#1208)For IPv6, the Proxy ARP service follows the recommendations in section 7 of IETF RFC 4389. In contrast to IPv4 ARP, IPv6 ND is still in evolution, and it might be hazardous for a proxy function to answer on behalf of the STA, when the STA might desire to use specific options in its own responses that the proxy


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ARP service is not aware of. For that reason, the Proxy ARP service for IPv6 effectively follows IETF RFC 8929 which recommended that the AP just turns the broadcast into a frame individually addressed to the targeted STA as suggested by IETF RFC 6085, rather than responds on its behalf.

#### 4.3.22.14 QoS traffic capability

QoS traffic capability procedures enable the QoS STA to indicate that it is capable of transmitting traffic belonging to the corresponding UP(#8044) from applications that require generation of such traffic. The QoS Traffic Capability might be used for example as an input to estimate the blocking probability of a voice application based on the number of voice capable non-AP STAs.

#### 4.3.22.15 SSID list

The SSID List element enables the non-AP STA to request information on a list of SSIDs. This is intended to reduce the number of Probe Request frames sent by the non-AP STA.

#### 4.3.22.16 Triggered STA statistics

The Triggered STA Statistics reporting capability enables generation of a STA statistics report (see 4.3.11.9 (Measurement pause)) when the statistics of interest reach a predefined threshold.

#### 4.3.22.17 TIM broadcast

The TIM broadcast protocol defines a mechanism to enable a STA to receive an indication of buffered individually addressed traffic, independent of the Beacon frame, reducing the wake time of the STA.

#### 4.3.22.18 Timing measurement

Timing Measurement frames allow a recipient STA to accurately measure the offset of its clock relative to a clock in the sending STA. With the regular transfer of Timing Measurement frames from one STA to another, it is possible for the recipient STA to track changes in the offset of its clock with respect to the sending STA over time and thus detect and compensate for any drift between the clocks.

#### 4.3.22.19 FTM(11az)(#7065)

(11az)The FTM procedure allows a STA to accurately measure the round trip time (RTT) between it and another STA. f used with multiple peer STAs, the STA can track changes in its relative position with those peer STAs. If the absolute position of the peer STAs is known, then the STA can determine its absolute position. A STA executes the FTM procedure with multiple peers and uses the resulting relative location estimates along with the absolute position of each of the peers to determine its position in geospatial coordinates.

(11az)The STA can also estimate the direction of the transmission (angle of departure) of frames transmitted to and reception (angle of arrival) of frames received from a peer STA, allowing for estimating position using measurements obtained from frame exchanges with a single peer.

(11az)An FTM session is negotiated to determine range estimates by executing one of the measurement exchanges listed below:

— EDCA based exchange of FTM frames where location estimates are based on time of departure and time of arrival of the exchanged FTM frames and their corresponding acknowledgments. When the negotiated FTM session is over EDMG, security parameters can be negotiated to ensure that the measurement exchange is executed with the intended peer.

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- Trigger-based (TB) measurement where location estimates are based on the execution of the trigger-based measurement exchange. This mode of operation allows for the execution of the measurement exchange between a responding STA (RSTA) and multiple initiating STAs (ISTAs) at the same time. Optionally, the TB measurement session can be negotiated to enable security parameters enabling mechanisms to ensure that the measurement exchange is executed with the intended peer.
- Non-Trigger-based (non-TB) measurement where location estimates are based on the execution of the non-TB measurement exchange. Optionally, the non-TB measurement session can be negotiated to enable security parameters enabling mechanisms to ensure that the measurement exchange is executed with the intended peer.
- A passive trigger-based (TB) Ranging measurement exchange is defined where a STA can determine its location based on periodic measurement reports from other STAs that execute the passive TB ranging measurement exchange amongst themselves.

(11az)The preassociation security negotiation protocol establishes a PTKSA for the exchange of protected frames without association, for example for establishing a secure FTM session and performing the corresponding secure measurement exchange between two unassociated peers.

#### 4.3.22.20 Traffic filtering service

The traffic filtering service enables an AP to determine if MSDUs and Management frames destined for a STA match a specific set of traffic filters that are enabled at the AP per the request of the STA. Individually addressed frames that do not match any of the traffic filters in the set are discarded. Individually addressed frames that do match at least one of the set of the enabled traffic filters are delivered to the STA. The STA can also negotiate to have a notification frame sent prior to the delivery of the frame matching the traffic filter.

#### 4.3.22.21 U-APSD coexistence

The U-APSD coexistence capability enables the non-AP STA to indicate a requested transmission duration to the AP for use of U-APSD service periods. Use of the transmission duration enables the AP to transmit frames during the service period and improve the likelihood that the non-AP STA receives the frames when the non-AP STA is experiencing interference. The U-APSD coexistence capability reduces the likelihood that the AP transmits frames during the service period that are not received.

#### 4.3.22.22 WNM notification

WNM notification provides a mechanism for a STA to notify another STA of a management event. The following events are defined:

- Firmware update notification
- Beacon protection failure

#### 4.3.22.23 WNM sleep mode

WNM sleep mode is an extended power save mode for non-AP STAs in which a non-AP STA need not listen for every DTIM beacon(#3309), and need not perform GTK/IGTK/BIGTK updates. WNM sleep mode enables a non-AP STA to signal to an AP that it might sleep for a specified length of time. This enables a non-AP STA to reduce power consumption and remain associated while the non-AP STA has no traffic to send to or receive from the AP.

### 4.3.23 Subscription service provider network (SSPN) interface

An AP can interact with external networks using a SSPN interface for the purpose of authenticating users and provisioning services, as shown in Figure 4-8 (SSPN interface service architecture). The exchange of


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authentication and provisioning information between the SSPN and the AP passes transparently through the portal. The protocol used to exchange this information is outside the scope of this standard. The logical SSPN interface provides the means for an AP to consult an SSPN for authenticating and authorizing a specific non-AP STA and to report statistics and status information to the SSPN. Authentication and provisioning information for non-AP STAs received from the SSPN are stored in the AP management information base (MIB) and are used to limit layer-2 services provided to that non-AP STA. Detailed interactions describing the SSPN interface are provided in 11.22.5 (Interworking procedures: interactions with SSPN).

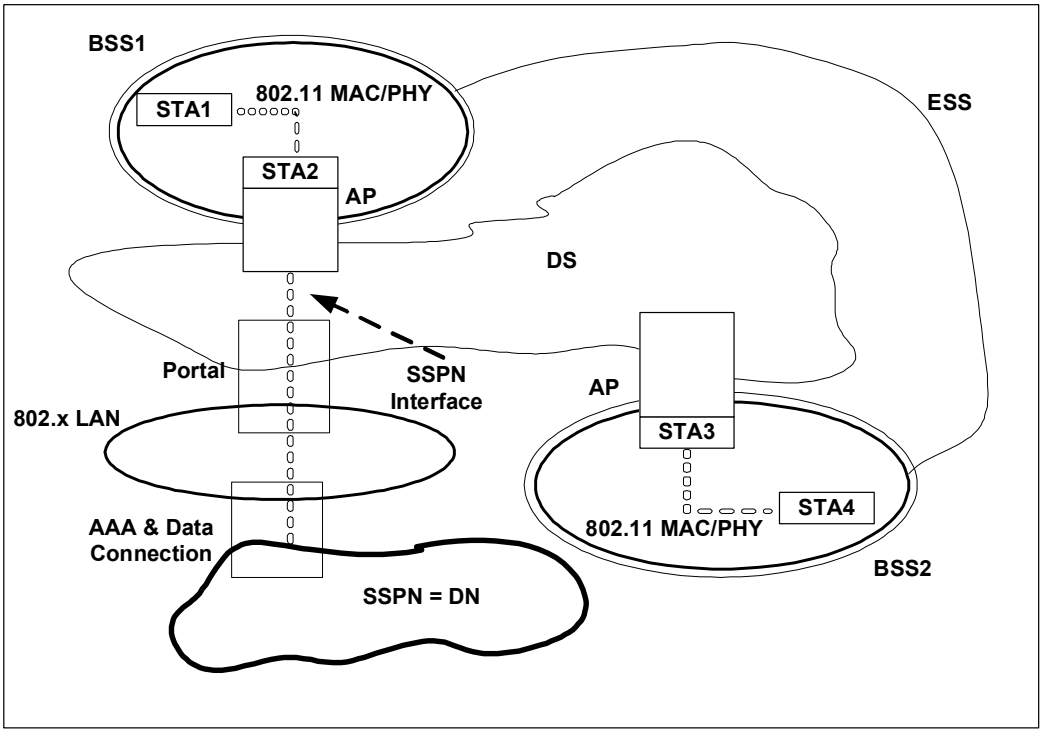


**Figure 4-8—SSPN interface service architecture**

The SSPN interface provides the non-AP STA access to the services provisioned in the SSPN via the currently associated BSS. Services might include virtual local area network (VLAN) mapping and tunnel establishment that are transparent to the non-AP STA and outside the scope of this standard. The SSPN interface also allows the non-AP STA to access services in destination networks (DNs) other than the SSPN. An example of a DN other than SSPN is the provision of Internet access via the IEEE 802 LAN, or an intermediary network that connects the IEEE 802.11 infrastructure and the SSPN.

NOTE—The SSPN Interface Service is not supported in an IBSS.

### 4.3.24 Mesh BSS

#### 4.3.24.1 General

The IEEE 802.11 mesh facility provides MAC enhancements to support wireless LAN mesh topologies. The mesh facilities are available to mesh STAs that belong to a mesh BSS (MBSS). Only the mesh discovery service is available to a mesh STA that has not become a member of an MBSS. The enhancements that distinguish mesh STAs from nonmesh STAs are collectively termed the “mesh facility.” The mesh-specific mechanisms vary among implementations.

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#### 4.3.24.2 Overview of the mesh BSS

A mesh BSS is an IEEE 802.11 LAN consisting of autonomous STAs. Inside the mesh BSS, all STAs establish wireless links with neighbor STAs to mutually exchange MSDUs. Further, using the multi-hop capability, MSDUs and Management frames can be transferred between STAs that are not in direct communication with each other over a single instance of the wireless medium. From the data delivery point of view, (#6268)the MAC service of a STA in an MBSS appears to provide the exchange of MSDUs directly to any other STA in the MBSS, even if the STAs are not within range of each other. The multi-hop capability enhances the range of the STAs and benefits wireless LAN deployments.

STAs in a mesh BSS might be sources, sinks, or propagators of traffic; some mesh STAs might propagate traffic for other STAs, but do not act as a source or sink of traffic. As described in 4.3.24.4 (IEEE 802.11 components and mesh BSS), a mesh BSS might have interfaces to external networks and can be a DSM for infrastructure BSSs.

Within a mesh BSS, STAs utilize the mesh coordination function (MCF) to access the channel. MCF is based on the core QoS facility described in 4.3.10 (QoS BSS), and a mesh BSS is categorized as one type of QoS BSS. MCF is specified in 10.24 (Mesh coordination function (MCF)).

#### 4.3.24.3 Mesh STA

A STA that belongs to a mesh BSS is termed a “mesh station” (mesh STA). Mesh STAs are QoS STAs that support mesh services, i.e., they participate in formation and operation of a mesh basic service set (MBSS). A mesh STA implements a subset of the QoS functionality:

— Use of QoS frame format
— EDCA (as a part of MCF)
— Block acknowledgment (optional)
— No acknowledgment (optional)
— Use of TSPEC, TCLAS, and TCLAS Processing elements to establish DMS or GCR agreements (optional)

A mesh BSS does not incorporate the full hybrid coordinator (HC) and BSS QoS functionality. MBSSs do not incorporate the following:

— HCCA
— Traffic stream (TS) management
— Admission control
— Automatic power save delivery (APSD)
— Tunneled direct link setup (TDLS)(#1356)

#### 4.3.24.4 IEEE 802.11 components and mesh BSS

Example mesh and infrastructure BSSs are illustrated in Figure 4-9 (Example MBSS containing mesh STAs, mesh gates, APs, and portals). Only mesh STAs participate in mesh functionalities such as formation of the mesh BSS, path selection, and forwarding. Accordingly, a mesh STA is not a member of an IBSS or an infrastructure BSS. Consequently, mesh STAs do not communicate with nonmesh STAs.

However, instead of existing independently, an MBSS might also interconnect with other BSSs through the distribution system (DS) or a bridged LAN. Then, mesh STAs can communicate with nonmesh STAs. A logical architectural component is introduced in order to integrate the non-GLK mesh STA with the DS: the mesh gate. Data move between a non-GLK MBSS and the DS via one or more mesh gates. Thus the mesh gate is the logical point at which MSDUs from a non-GLK MBSS enter the DS. In a GLK MBSS,


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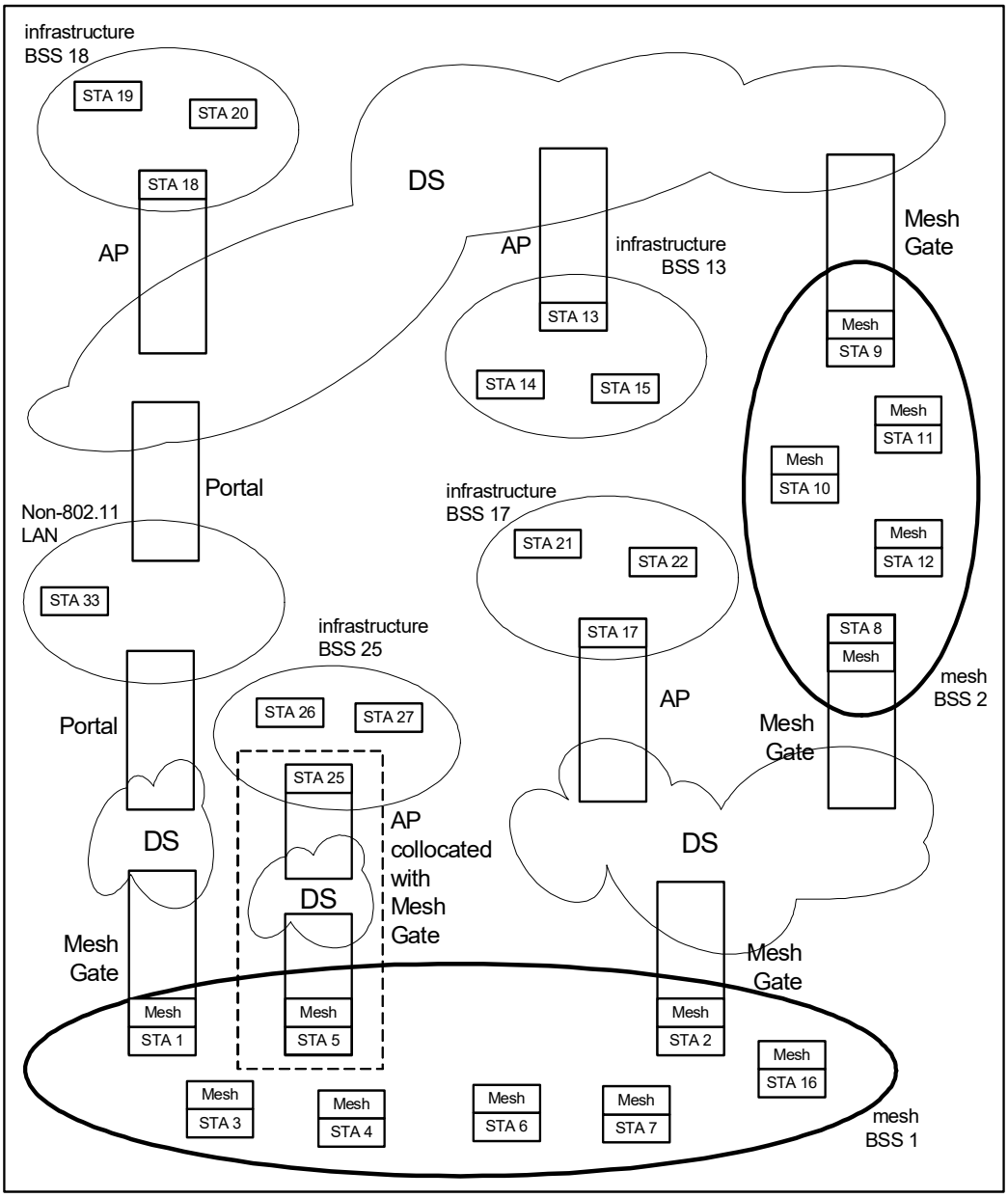


**Figure 4-9—Example MBSS containing mesh STAs, mesh gates, APs, and portals**

mesh STAs can communicate with nonmesh STAs via a GLK mesh STA with an attached bridge port and from there to the bridged LAN. Once an MBSS contains a mesh gate that connects it to the DS or a GLK mesh STA that connects it to (#3275)an attached bridge port, the MBSS can be integrated with other infrastructure BSSs, given that their APs connect to the same DS or bridged network. Several mesh gates are shown in Figure 4-9 (Example MBSS containing mesh STAs, mesh gates, APs, and portals) connecting different MBSSs to the DS.

When an MBSS accesses the DS or a bridged network, the MBSS can be integrated with a non-IEEE-802.11 LAN. To integrate the a DS to which this MBSS connects, the DS needs to contain a portal. See 4.3.7 (Integration with non-IEEE-802.11 LANs). Consequently, mesh gate and portal are different entities. The portal integrates the IEEE 802.11 architecture with a non-IEEE-802.11 LAN (e.g., a traditional wired LAN).

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The mesh gate integrates the MBSS with the DS. A GLK mesh STA integrates the MBSS with a bridged network.

It is possible for one device to offer any combination of the functions of an AP, a portal, and a mesh gate; see 14.12.5 (Mesh STA collocation). An example device combining the functions of an AP and a mesh gate is shown in Figure 4-10 (Example device consisting of mesh STA and AP STA to connect an MBSS and an infrastructure BSS). The implementation of such (#2210)colocated entities is beyond the scope of this standard. The configuration of a mesh gate that is (#2210)colocated with an access point allows the utilization of the mesh BSS as a distribution system medium. In this case, two different entities (mesh STA and access point) exist in the (#2210)colocated device and the mesh BSS is hidden to STAs that associate to the access point. The mesh STA collocation is outlined in 14.12.5 (Mesh STA collocation), which states that the usage of a distinct MAC address for each (#2210)colocated STA avoids ambiguities.

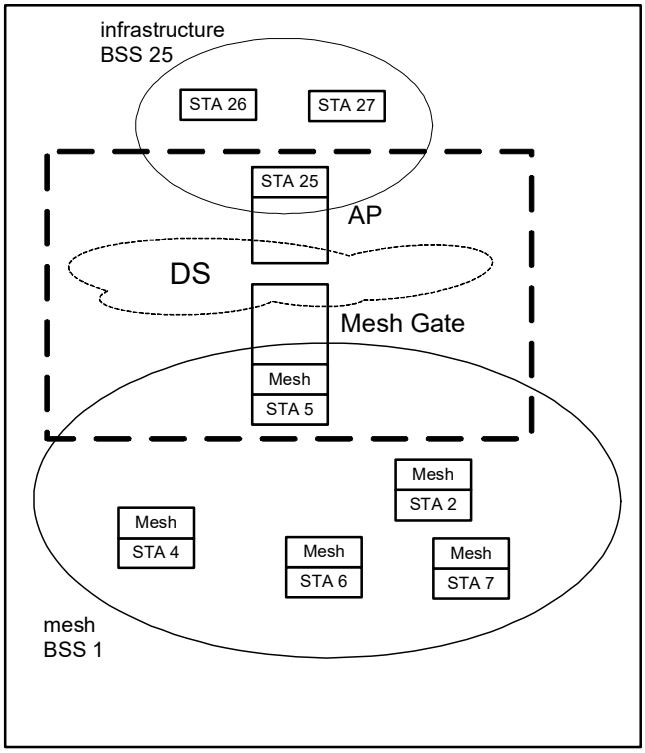


**Figure 4-10—Example device consisting of mesh STA and AP STA to connect an MBSS and an infrastructure BSS**

### 4.3.24.5 Introduction to mesh functions

#### 4.3.24.5.1 General

A mesh BSS is formed and operated by the set of services called *mesh services*. Mesh services are provided by the following major mesh facilities:

- Mesh discovery
- Mesh peering management
- Mesh security
- Mesh beaconing and synchronization
- Mesh coordination function


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- Mesh power management
- Mesh channel switching
- Three address, four address, and extended address frame formats
- Mesh path selection and forwarding
- Interworking with external networks
- Intra-mesh congestion control
- Emergency service support in mesh BSS

#### 4.3.24.5.2 Mesh discovery

A mesh STA performs either active scanning or passive scanning to discover an operating mesh BSS. Each mesh STA transmits Beacon frames periodically and responds with Probe Response frames when a Probe Request frame is received, so that neighbor mesh STAs can perform mesh discovery appropriately. The identification of the mesh BSS is given by the Mesh ID element contained in the Beacon and the Probe Response frames. The details for the mesh discovery facility are described in 14.3 (Mesh discovery).

#### 4.3.24.5.3 Mesh peering management (MPM)

Within a mesh BSS, direct communication between neighbor mesh STAs is allowed only when they are peer mesh STAs. After mesh discovery, two neighbor mesh STAs agree to establish a mesh peering to each other, and, after successfully establishing the mesh peering, they become peer mesh STAs. A mesh STA can establish a mesh peering with multiple neighbor mesh STAs. The mesh peering management (MPM) facilitates the mesh peering establishment and closure of the mesh peerings. The details of MPM are described in 14.4 (Mesh peering management (MPM)).

#### 4.3.24.5.4 Mesh security

In an MBSS, mesh link security protocols are used to authenticate a pair of mesh STAs and to establish session keys between them. Mesh authentication protocols establish a shared, common pairwise master key (PMK), and authenticate a peer mesh STA. The authenticated mesh peering exchange protocol relies on the existence of the PMK between the two mesh STAs to establish an authenticated peering and derive session keys. The details of mesh security are described in 12.4 (Authentication using a password), 14.4.3 (Mesh authentication), 14.6 (Authenticated mesh peering exchange (AMPE)), and 14.7 (Mesh group key handshake).

#### 4.3.24.5.5 Mesh beaconing and synchronization

In order to assist mesh discovery, mesh power management, and synchronization in a mesh BSS, all mesh STAs periodically transmit Beacon frames. Synchronization in a mesh BSS is maintained by the MBSS's active synchronization method. The default synchronization method is the neighbor offset synchronization method. Mesh beacon collision avoidance (MBCA) mitigates collisions of Beacon frames among hidden nodes. The details of mesh beaconing and synchronization are described in 14.14 (Synchronization and beaconing in MBSSs).

#### 4.3.24.5.6 Mesh coordination function (MCF)

A mesh STA uses the mesh coordination function (MCF) for channel access. MCF consists of EDCA (contention based channel access defined in 10.24.2 (MCF contention based channel access)) and MCCA (controlled channel access defined in 10.24.3 (MCF controlled channel access (MCCA))). MCCA is a reservation based channel access method and aims to optimize the efficiency of (#109)frame exchange sequences in a mesh BSS.

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#### 4.3.24.5.7 Mesh power management

A mesh STA can manage the activity level of its links per mesh peering. A mesh STA sets the activity level of each of its mesh peerings to either active mode, light sleep mode, or deep sleep mode. The mesh STA performs mesh power management mode tracking for each of its neighbor peer mesh STAs, and delivers the frames based on the rules defined in 14.15 (Power save in a mesh BSS).

#### 4.3.24.5.8 Mesh channel switching

When a mesh STA switches the operating channel, it uses the channel switching protocol defined in 11.8.8 (Selecting and advertising a new channel) and 11.9 (Extended channel switching (ECS)). The channel switching protocol enables the propagation of channel switch notifications throughout the mesh BSS, prior to the channel switch execution.

#### 4.3.24.5.9 Frame addressing in an MBSS

Three address, four address, and extended address frame formats enable the distribution of MSDUs over multiple instances of the wireless medium within a mesh BSS and integration to the ESS. Frame format details are described in Clause 9 (Frame formats) and 9.3.5 (Frame addressing in an MBSS).

#### 4.3.24.5.10 Mesh path selection and forwarding

Mesh path selection enables path discovery over multiple instances of the wireless medium within a mesh BSS. The overview of the mesh path selection framework is described in 14.9 (Mesh path selection and metric framework). The hybrid wireless mesh protocol (HWMP) is defined as the default path selection protocol for the mesh BSS. HWMP provides both proactive path selection and reactive path selection. The details of HWMP are described in 14.11 (Hybrid wireless mesh protocol (HWMP)). The path selection protocol uses link metrics in the assessment of a mesh path to the destination. The details of link metrics are described in Table 14.10 (Path selection link metric). The airtime link metric is the default link metric. The high PHY rate airtime link metric is another link metric intended for mesh STAs that are capable of transmitting frames with PHY rate higher than 54 Mb/s. The details of the airtime link metric and high PHY rate airtime link metric are described in 14.10.2 (Airtime link metric and high PHY rate airtime link metric).

Once the mesh path of a particular pair of the source mesh STA and the destination mesh STA is found through the mesh path selection function, mesh STAs propagate the data by the forwarding function. The details of the forwarding function are described in 10.37 (Mesh forwarding framework).

As a result of the mesh path selection and forwarding, MSDUs are transmitted among all of the mesh STAs in a mesh BSS, even if the mesh STAs are not neighbor STAs of each other. Figure 4-11 (MAC data transport over an MBSS) depicts the MSDU transfer within a mesh BSS.

#### 4.3.24.5.11 Interworking with the DS

A mesh BSS might contain one or more mesh gates that connect to one or more distribution systems. A mesh gate can announce its presence in the mesh BSS by sending Gate Announcement frames. Alternatively a mesh gate can announce its presence in the mesh BSS by sending HWMP Path Selection frames with the RANN element or the PREQ element indicating mesh gate announcement, when it is configured as a root mesh STA. Typically a mesh gate announces its presence when it is (#2210)colocated with a portal or it has access to a portal. Gate announcements allow mesh STAs to select the appropriate mesh gate and build a path toward it. Note that, when multiple mesh gates that have access to the same DS are present in the mesh BSS, proper configuration is necessary.


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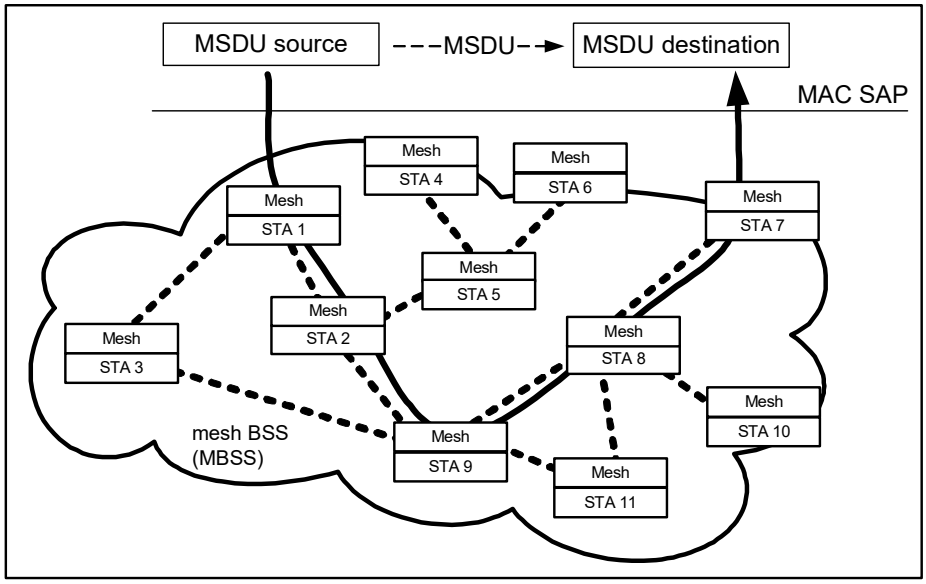


**Figure 4-11—MAC data transport over an MBSS**

When a mesh gate has access to IEEE 802 STAs outside the mesh BSS, the mesh gate acts as a proxy for the IEEE 802 STAs outside the MBSS. Such a mesh gate is called a *proxy mesh gate*. The details of the proxy functionality are described in 14.12.3 (Data forwarding at proxy mesh gates).

The details of the mesh BSS interworking are described in 14.12 (Interworking with the DS or an attached bridge).

#### 4.3.24.5.12 Intra-mesh congestion control

Intra-mesh congestion control is used to provide flow control over the multi-hop communication. Intra-mesh congestion control is useful to mitigate wasteful wireless medium utilization caused by buffer overflow at mesh STAs. Intra-mesh congestion control consists of three main mechanisms: local congestion monitoring and congestion detection, congestion control signaling, and local rate control. The details of the intra-mesh congestion control are described in 14.13 (Intra-mesh congestion control).

#### 4.3.24.5.13 Emergency service support in mesh BSS

Depending on regulations, emergency services support might be mandated over the mesh network. In this case the Beacon and Probe Response frames inform whether a mesh STA supports emergency services, advertising to other mesh STAs that mesh peering for emergency services is possible. If a mesh STA subsequently requires emergency services, an emergency indication is then set within the Mesh Peering Open frame. Mesh STAs that support emergency services, accept peering from other mesh STAs requiring emergency services, transferring frames to an emergency server (such as a PSAP).

### 4.3.25 DMG STA

The IEEE 802.11 DMG STA provides PHY and MAC features that can support a throughput of 1 Gb/s and greater, as measured at the MAC data service access point (SAP). A DMG STA supports DMG features as identified in Clause 10 (MAC sublayer functional description), Clause 11 (MLME), and Clause 20 (Directional multi-gigabit (DMG) PHY specification). (11bd)Optionally, a DMG STA with dot11DMGOCBActivated equal to true supports features as identified in 31.3 (Operation in the 60 GHz band). A DMG STA operates in a DMG BSS and supports transmission and reception of frames that are

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compliant with PHY specifications as defined in Clause 20 (Directional multi-gigabit (DMG) PHY specification). A DMG STA is also a QoS STA. The basic channel access of a DMG STA (see 10.38 (DMG and CMMG channel access)) allows it to operate in an Infrastructure BSS, in an IBSS, and in a PBSS. Certain DMG features such as service period allocation are available only to DMG STAs that are associated with an AP or with a PCP, while other DMG features such as EDCA operation in a PBSS and DMG STAs operating OCB(11bd) do not require association. A DMG STA supports beamforming (BF) as described in 10.41 (DMG beamforming) and 20.9 (Beamforming) and GCM encryption as described in 12.5.4 (GCM protocol (GCMP)).

A DMG STA supports the PHY signaling as described in 20.4 (DMG control mode), 20.5 (DMG SC mode), and 20.6 (DMG low-power SC mode). At a minimum, a DMG STA supports the mandatory modulation and coding scheme (MCS) and PHY protocol data unit (PPDU) formats described in 20.4 (DMG control mode) and 20.5 (DMG SC mode). A DMG STA has PHY features that include a low-density parity check (LDPC) encoding, a preamble making use of Golay sequences, and beamforming. The PPDUs are always transmitted with the same channel spacing as described in Annex E.

A DMG STA supports MAC features that provide channel access in an environment in which transmissions use a directional antenna pattern. (11ay)The MAC entity of a DMG STA provides frame aggregation, block acknowledgment(11bd), service periods, contention based access periods, DMG protected period, AP or PCP clustering, dynamic channel time management (see 10.38.7 (Dynamic allocation of service period), 10.38.8 (Dynamic truncation of service period), and 10.38.9 (Dynamic extension of service period)), reverse direction, spatial sharing, beamforming, discovery assistance, TDD channel access, and fast session transfer in a multi-band device,(11bd) transmission of Data frames OCB (see 11.18 (STAs communicating Data frames outside the context of a BSS)), and DMG discovery OCB (see 11.1.4.7 (DMG discovery outside the context of a BSS(11bd))). A DMG STA is not a mesh STA. A DMG STA does not use any of the following: HCCA, (#3263)TDLS, GCR.

#### 4.3.26 DMG relay

The IEEE 802.11 DMG relay function allows a source relay endpoint DMG STA (REDS) to transmit frames to a destination REDS with the assistance of another DMG STA, the relay DMG STA (RDS), as shown in Figure 4-12 (DMG relay in a DMG BSS). Relaying can improve the reliability of communication in a DMG BSS in the case the direct link between the source REDS and the destination REDS has poor quality or is disrupted. Following the DMG relay setup procedures, a source REDS can discover and select an appropriate RDS to act as the relay for a particular destination REDS, prior to Data frame transmission using the relay. A relay operating as a link switching type of relay uses the RDS to forward frames between the source and destination REDS if the direct link between the REDS is disrupted. In a link cooperation of relay operation, the RDS simultaneously repeats the transmission of frames between the source and destination REDS, which can possibly increase the signal quality received at the destination REDS.

#### 4.3.27 Robust audio video (AV) streaming

##### 4.3.27.1 Introduction

Robust AV streaming improves AV streaming performance when using IEEE Std 802.11 for consumer and enterprise applications.

##### 4.3.27.2 Groupcast with retries (GCR)

The GCR service allows a STA to request greater reliability for one or more group addressed streams that the STA receives. Greater reliability is provided via unsolicited retries or the block ack mechanism. A non-AP STA can request delivery so that the AP transmits the frames via EDCA within GCR service periods when all associated non-AP STAs are in active mode or the awake state of the PS mode.


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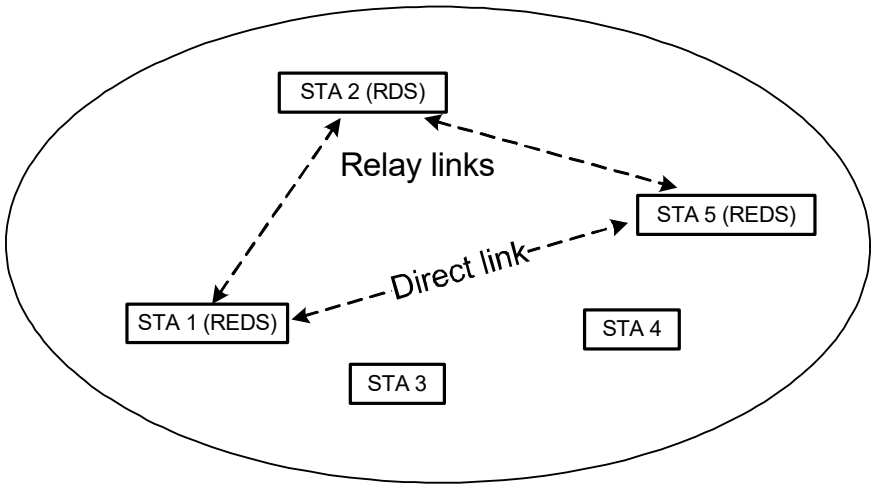


**Figure 4-12—DMG relay in a DMG BSS**

#### 4.3.27.3 Stream classification service (SCS)

SCS enables the establishment of a classification using layer 2 and/or layer 3 signaling to match incoming individually addressed MSDUs. Once classified, individually addressed MSDUs matching the classification are assigned to an access category and are tagged with their drop eligibility. When intra-access category prioritization is enabled (see 4.3.27.7 (Intra-access category prioritization)), SCS allows MSDUs matching the classification to be assigned to the primary or (#476)alternate EDCA transmit queues so that finer grained prioritization can be applied.

#### 4.3.27.4 Mirrored stream classification service (MSCS)

MSCS enables the establishment of classification using layer 2 and/or layer 3 signaling to classify incoming individually addressed MSDUs into streams. Once classified, individually addressed MSDUs in each stream are assigned to a user priority based on the user priority of MSDUs matching the stream in the reverse direction.

#### 4.3.27.5 Overlapping BSS (OBSS) management

The objective of OBSS management is to facilitate cooperative sharing of the medium between APs that operate in the same channel and that are able to receive or obtain frames from each other, including Beacon frames. These frames might be received directly or via associated STAs that support the Beacon request capability (see 11.10.10 (Usage of the neighbor report)).

OBSS management provides the means to

- Provide additional information for channel selection
- Extend the admission control mechanism to a distributed environment
- Enable the coordination of scheduled TXOPs between OBSSs

OBSS management enables stationary and portable APs to provide to neighboring APs information for the selection of a channel and for the cooperative sharing of that channel. The main component of OBSS management is the QLoad report that provides information on

- The reporting AP’s overlap situation
- The reporting AP’s QoS traffic load

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— The total QoS traffic load of BSSs directly overlapping the reporting AP's BSS

This information might be used to aid an AP when searching for a channel and also when sharing a channel in an overlap situation.

To coordinate the TXOPs of overlapping HCCA APs, OBSS management provides a means for an AP to advertise its TXOP allocations so another AP might schedule its own TXOPs to avoid those already scheduled.

#### 4.3.27.6 Interworking with IEEE 802.1Q Stream Reservation Protocol (SRP)

Support for SRP from IEEE Std 802.1Q enables integration of the TSPEC ADDTS request/response protocol with IEEE 802.1Q SRP to enable end-to-end SRP reservations when one or more IEEE 802.11 links are part of a path from IEEE 802.1Q Talker to IEEE 802.1Q Listener.

#### 4.3.27.7 Intra-access category prioritization

Intra-access category prioritization provides six transmit queues that map to four enhanced distributed channel access functions (EDCAFs) to enable differentiation between traffic streams that are in the same access category in order for finer grained prioritization to be applied between individual AV streams or voice streams.

### 4.3.28 Operation under geolocation database (GDB) control

Regulators designate television broadcast bands for the deployment of dynamic sharing technologies. Different schemes result in different times that elapse from the moment an authorized database is told to change access to a particular slice of spectrum and the time that sharing radios are required to change their operations.

One current system design allows the GDBs to utilize a fully populated map of all protected services, and the databases have precalculated maps that are effective on timescales of one to two days.

Another system design allows the protected services to negotiate with controllers of unlicensed devices so that both can share available broadcast channels and facilitate response times of less than an hour where necessary and even within minutes if desired.

Another system design has the GDB fully control all white space devices by requiring them to tell the database their intended location and emissions footprint and receive permission before any broadcast band transmission starts. Any change of intended frequencies or powers is told to the database, and permission is received before the change takes place.

The architectural role of components depends on the security and timeliness requirements in particular regulatory domains. Figure 4-13 (Multiple APs and multiple GDBs) shows two infrastructure BSSs in which


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APs are geolocation database dependent (GDD) enabling STAs and the other STAs are GDD dependent STAs.

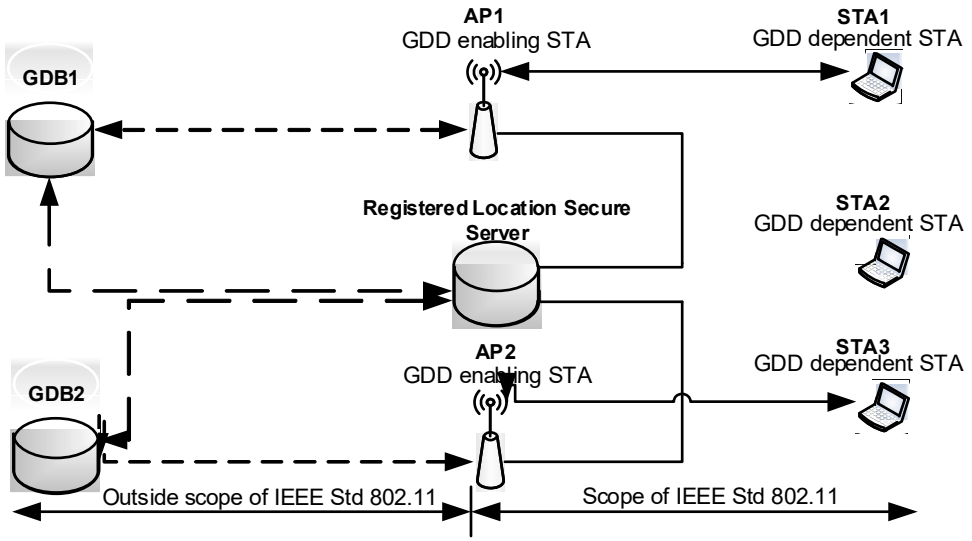


**Figure 4-13—Multiple APs and multiple GDBs**

In most regulatory domains, GDD enabling STAs are required to

- Securely communicate with GDBs
- Maintain the white space maps (WSMs) and other information received from GDBs
- Create and transmit a contact verification signal to inform GDD dependent STAs that the map they received is still valid

A registered location query protocol (RLQP) is provided to share the WSMs and current channel use among GDD enabling STAs in a neighborhood. GDD dependent STAs can query both their GDD enabling STA and the registered location secure server (RLSS) about WSMs and channel utilization. In some regulatory domains, a RLSS can provide GDBs with the current channel use information for all of the BSSs and IBSSs that communicate with it. In some regulatory domains, the RLSS communicates with controllers of other white space systems to coordinate emissions footprints of their services. By accessing and using this information, the STAs can make intelligent decisions about the most effective way to utilize the available spectrum, power, and bandwidth for their communications.

The specific mechanisms are as follows:

- Channel availability query, used to obtain one or more WSMs of available channels for an area or a geolocation
- Channel schedule management, used to obtain start and ending times for each available white space channel
- Contact verification signal, used by a GDD dependent STA to verify it is still receiving frames from its GDD enabling STA
- GDD enablement, the procedure where a GDD enabling STA forms a network and maintains the network under the control of a GDB
- Network channel control, used to inform a local channel controller that has a view of nearby transmitters and their emissions footprints
- WSM, used to retrieve the available white space channels and their transmit power restrictions

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The use of the mechanisms in a particular regulatory domain depends on the specific regulatory requirements. Table 4-1 (GDD mechanisms and timescales) gives a view of the use of specific mechanisms to meet regulatory requirements in terms of daily, hourly, and minute timescales. Implementers are referred to the regulatory sources in Table D.1 (External regulatory references) for further information. Operation in countries within defined regional regulatory domains might be subject to additional or alternative national regulations.

**Table 4-1—GDD mechanisms and timescales**

| Mechanism | Daily consultation required | Hourly consultation required | Minute responsiveness |
|---|---|---|---|
| Channel availability query | Informative | Informative | Not applicable |
| Channel schedule management | Informative | Informative | Not applicable |
| Contact verification signal | Required to be secure | Might be secure | Loss of consecutive signals requires action |
| GDD enablement | Required | Required | Required |
| Network channel control | Informative | Informative | Not applicable |
| WSM | Required for GDD enabling STA, might be translated for GDD dependent STA | Required for GDD enabling STA, might be translated for GDD dependent STA | Required for GDD enabling STA, might be translated for GDD dependent STA |

These mechanisms allow a BSS to manage and query its radio environment and a GDB to control the radio environment for all wireless services.

### 4.3.29 CDMG STA

An IEEE 802.11 CDMG STA is a DMG STA that supports CDMG operation in the Chinese 60 GHz frequency band, and has dot11CDMGOptionImplemented equal to true. In addition to CDMG features, a CDMG STA supports DMG features as described in 4.3.25 (DMG STA). A CDMG STA also supports CDMG features as identified in Clause 10 (MAC sublayer functional description), Clause 11 (MLME), and Clause 24 (China directional multi-gigabit (CDMG) PHY specification). A CDMG STA supports transmission and reception of frames that are compliant with PHY specifications as defined in Clause 24 (China directional multi-gigabit (CDMG) PHY specification). A CDMG STA is also a QoS STA. The basic channel access of a CDMG STA (see 10.38 (DMG and CMMG channel access) and 10.63 (DBC mechanism for CDMG STAs)) allows it to operate in an Infrastructure BSS or in an IBSS or in a PBSS.

Besides supporting DMG PHY features defined in Clause 20 (Directional multi-gigabit (DMG) PHY specification), a CDMG STA also supports the PHY signaling as described in 24.4 (CDMG control mode), 24.5 (CDMG SC mode), and 24.6 (CDMG low-power SC mode). At a minimum, a CDMG STA supports the mandatory modulation and coding scheme (MCS) and PHY protocol data unit (PPDU) formats described in 24.4 (CDMG control mode) and 24.5 (CDMG SC mode).

### 4.3.30 CMMG STA

The IEEE 802.11 CMMG STA operates in 42.3 GHz to 47.3 GHz or 47.2 GHz to 48.4 GHz frequency bands.


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The main PHY features in a CMMG STA are the following:

- 540 MHz channel width
- Control mode and SC mode (directional transmit and receive)
- Single spatial stream MCS 0 (control mode transmit and receive) in all supported channel widths
- Single spatial stream MCSs 1 to 3 (SC mode transmit and receive) in all supported channel widths
- LDPC coding with length 672
- Normal guard interval as defined in Table 25-3 (Timing-related parameters(#7171)(M118))
- Optional support for 1080 MHz channel width
- Optional support for CMMG-MCSs 4 to 8 (SC mode transmit and receive)
- Optional support for CMMG-MCSs 9 to 16 ((#7168)CMMG OFDM mode transmit and receive)
- Optional support for short guard interval (transmit and receive)
- Optional support for LDPC coding with length 2016
- Optional support MIMO transmission (#7168)CMMG SC mode and CMMG OFDM mode transmit and receive)
- Optional support for STBC (transmit and receive)
- Optional support for transmit beamforming sounding (by sending a CMMG NDP)
- Optional support for responding to transmit beamforming sounding

The CMMG STA provides PHY and MAC features that can support a throughput of 1 Gb/s and greater, as measured at the MAC data service access point (SAP). A CMMG STA supports CMMG features as identified in Clause 10 (MAC sublayer functional description), Clause 11 (MLME), and Clause 25 (China millimeter-wave multi-gigabit (CMMG) PHY specification). A CMMG STA operates in a CMMG BSS and supports transmission and reception of frames that are compliant with PHY specifications as defined in Clause 25 (China millimeter-wave multi-gigabit (CMMG) PHY specification). A CMMG STA is also a QoS STA. The basic channel access of a CMMG STA (see 10.38 (DMG and CMMG channel access)) allows it to operate in an Infrastructure BSS, in an IBSS, or in a PBSS. Certain CMMG features such as service period allocation are available only to CMMG STAs that are associated with an AP or with a PCP, while other CMMG features such as EDCA operation in a PBSS do not require association. A CMMG STA supports beamforming (BF) as described in 10.41 (DMG beamforming) and 20.10 (Golay sequences) and GCM encryption as described in 12.5.4 (GCM protocol (GCMP)).

A CMMG STA supports the PHY signaling as described in 25.4 (CMMG control mode), 25.5 (CMMG SC mode), and 25.6 (CMMG OFDM mode). At a minimum, a CMMG STA supports the mandatory modulation and coding scheme (MCS) and PHY protocol data unit (PPDU) formats described in 25.4 (CMMG control mode) and 25.5 (CMMG SC mode). A CMMG STA has PHY features that include a low-density parity check (LDPC) encoding, a preamble making use of zero correlation zone (ZCZ) sequences, and beamforming. The PPDUs are always transmitted with the same channel spacing as described in Annex E.

A CMMG STA supports MAC features that provide channel access in an environment in which transmissions use a directional antenna pattern or use multiple input multiple output antenna pattern. A CMMG STA has MAC features that include frame aggregation, block ack features, service periods, contention based access periods, CMMG protected period, AP or PCP clustering, dynamic channel time management, reverse direction, spatial sharing, beamforming, and fast session transfer in a multi-band device. A CMMG STA is not a mesh STA. A CMMG STA follows the same channel access rules irrespective of the type of BSS in which it operates.

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### 4.3.31 General link (GLK)

#### 4.3.31.1 General

GLK STAs establish general links with other GLK STAs. These general links are suitable to be used as links inside an IEEE 802.1Q network. For an infrastructure general link example, see Figure 4-15 (Example of infrastructure BSS with general links) (in 4.3.31.3.3 (Infrastructure BSS with general links)).

A GLK STA coordinates with a GLK convergence function to provide the Internal Sublayer Service, as defined in IEEE Std 802.1AC-2016, to an IEEE 802.1Q bridge for each peer GLK STA with which it is communicating. GLK STAs also provides link metrics for the use of external path selection protocols such as spanning tree protocol.

(M12)GLK operation does not involve a DS and does not involve an ESS. Instead, the general links formed with GLK operation are a point-to-point connection between pairs of instances of Internal Sublayer Service SAPs, which in turn can be used within an IEEE 802.1Q bridged network.

A GLK STA that starts a BSS uses membership selector values to set the BSS policy of requiring or not requiring general link or (#2186)EtherType protocol discrimination (EPD) support for any STA that joins the BSS.

A non-AP STA acts as either a GLK STA or a non-GLK STA. A GLK AP might permit associations from non-GLK STAs and acts as a non-GLK AP for those associated non-GLK STAs. GLK DMG STAs can establish a general link through a DMG relay. GLK S1G STAs cannot use or be an S1G relay.

The four-address MAC header can be used in GLK transmissions of Data frames. The use of the four-address MAC header or (#279)Basic A-MSDU format is necessary for such MPDUs if the frame's SA, TA, RA, and DA fields (source address, transmitter address, receiver address, and destination address, respectively) are all different from each other. The three-address frame format can be used, as defined by Table 9-3 (Combinations of To DS subfield and From DS subfield in Data frames(#278)), provided the addresses are consistent with Table 9-60 (Address field contents for Data frames transmitted by nonmesh STAs(#462)).

A SYNRA is an RA that is a group address used by a GLK AP to forward frames to a subset of GLK non-AP STAs, as required by IEEE 802.1Q bridges. The use of a SYNRA can improve bandwidth usage in some cases. SYNRAs are used in GLK AP transmissions.

As described in 4.3.31.2 (Selective reception of group addressed frames), when a GLK AP transmits a Data frame with a four-address MAC header whose RA field contains a group address, the RA is a synthetic receiver address (SYNRA), and therefore its RA and DA fields are not equal. A GLK non-AP STA supports selective reception of group addressed frames by supporting SYNRA reception.(#3522)

#### 4.3.31.2 Selective reception of group addressed frames

For the reasons given below, when transmitting a Data frame that has an RA that is a group address to a set of receiving STAs, the GLK transmitter needs to transmit those MSDUs so that they are accepted by a specified subset of the associated GLK STAs indicated by the IEEE 802.1Q bridge.

The reason for such selective reception is to support requirements of IEEE 802.1Q bridges and can include the MAC service requirements that, when an MSDU is sent, it is not subsequently received and processed by the transmitting station or to break loops in the network topology. When a GLK STA associated with a GLK AP sends an MSDU to that AP with a group address destination, the AP retransmits it and uses the selective reception facility to stop the originating GLK STA from accepting it. Also, since the AP Internal Sublayer Service SAPs are mapped to IEEE 802.1Q bridge ports, loop prevention might need the traffic to be blocked


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to one or more of the associated GLK STAs. Such blocking can be implemented by the selective reception facility.

Implementation of this selective reception facility in a BSS case includes use of an RA that is a synthetic group address (SYNRA addressing, see 9.3.2.1.2 (Address and BSSID fields)). As an alternative to the use of a SYNRA, selective reception includes sending a copy of the Data frame to each intended receiver using individually addressed MPDUs. In either case, an appropriate address format is needed because the DA is different from the RA (since the RA is either the SYNRA or a serial individual RA). SYNRA addressed MPDUs are transmitted by APs only.

All GLK non-AP STAs in an infrastructure BSS support receipt of SYNRAs (see 9.3.2.1.2 (Address and BSSID fields) and 10.64 (Addressing of GLK Data frame transmission)). A GLK AP that is requested to deliver an MPDU to multiple GLK STAs can choose to construct and transmit a SYNRA addressed MPDU, use a sequence of individually addressed MPDUs, or both.

Parameters exchanged during the association (or reassociation) of a GLK STA with a GLK AP determine the mechanism used by the GLK AP to enable selective reception at the GLK STA of group addressed frames transmitted by the GLK AP. One such mechanism is GLK-GCR, which is a subset of GCR customized for general links (see 11.21.16 (Group addressed transmission service)). In GLK-GCR the group address is a SYNRA. Features of GCR that do not apply to GLK-GCR are as follows:

a) DMS Request and DMS Response frame exchange to set up GLK-GCR service
b) ADDBA Request/Response frame exchange to setup block ack agreement
c) GCR-SP delivery method
d) Unsolicited DMS Response frame for “GCR Advertise”
e) Concealment address

#### 4.3.31.3 GLK Service Sets

##### 4.3.31.3.1 Provision of the MAC service

MAC service data unit (MSDU) delivery services in an IEEE 802.1Q network can be supported by the IEEE 802.1AC™ MAC service. GLK STAs coordinate with an IEEE 802.1AC-compliant GLK convergence function, to provide access to the WM via one or more Internal Sublayer Service SAPs. The routing of all MSDUs that are provided by an IEEE 802.1Q relay entity via GLK STAs is controlled by the routing protocols of the IEEE 802.1Q network to which the GLK STA is attached. This enables the routing protocols to use all the general links available to the GLK STA.

##### 4.3.31.3.2 GLK IBSS and PBSS

A GLK IBSS or GLK PBSS can provide access to the WM via general links that are suitable for use in an IEEE 802.1Q network. Figure 4-14 (Example of GLK IBSS or PBSS) shows an example of a GLK IBSS (or equivalently a PBSS) involving three GLK non-AP STAs. Each participating STA provides MAC services at the MS SAP, with the inclusion of a station vector that is then mapped to one or more Internal Sublayer Service SAPs by the IEEE 802.1AC GLK Convergence Function. Three general links are shown that connect three pairs of Internal Sublayer Service SAPs in a point-to-point manner. Each of the Internal Sublayer Service SAPs is then mapped to either an Enhanced Internal Sublayer Service (EISS) SAP or MAC SAP, by the IEEE 802.1Q Media Independent Function or the Internal Sublayer Service to MAC SAP function, respectively. The EISS SAP provides EISS services to the MAC relay entity of a VLAN bridge component (IEEE 802.1Q MAC Relay Entity). The MAC SAP provides services to the LLC Sublayer.

NOTE—IEEE Std 802.11 does not specify the details of the IEEE 802.1AC GLK Convergence Function, the IEEE 802.1Q Media Independent Function, the Internal Sublayer Service to MAC SAP function, the IEEE 802.1Q MAC Relay Entity, and the LLC Sublayer. These entities are specified in other documents such as IEEE Std 802.1AC-2016

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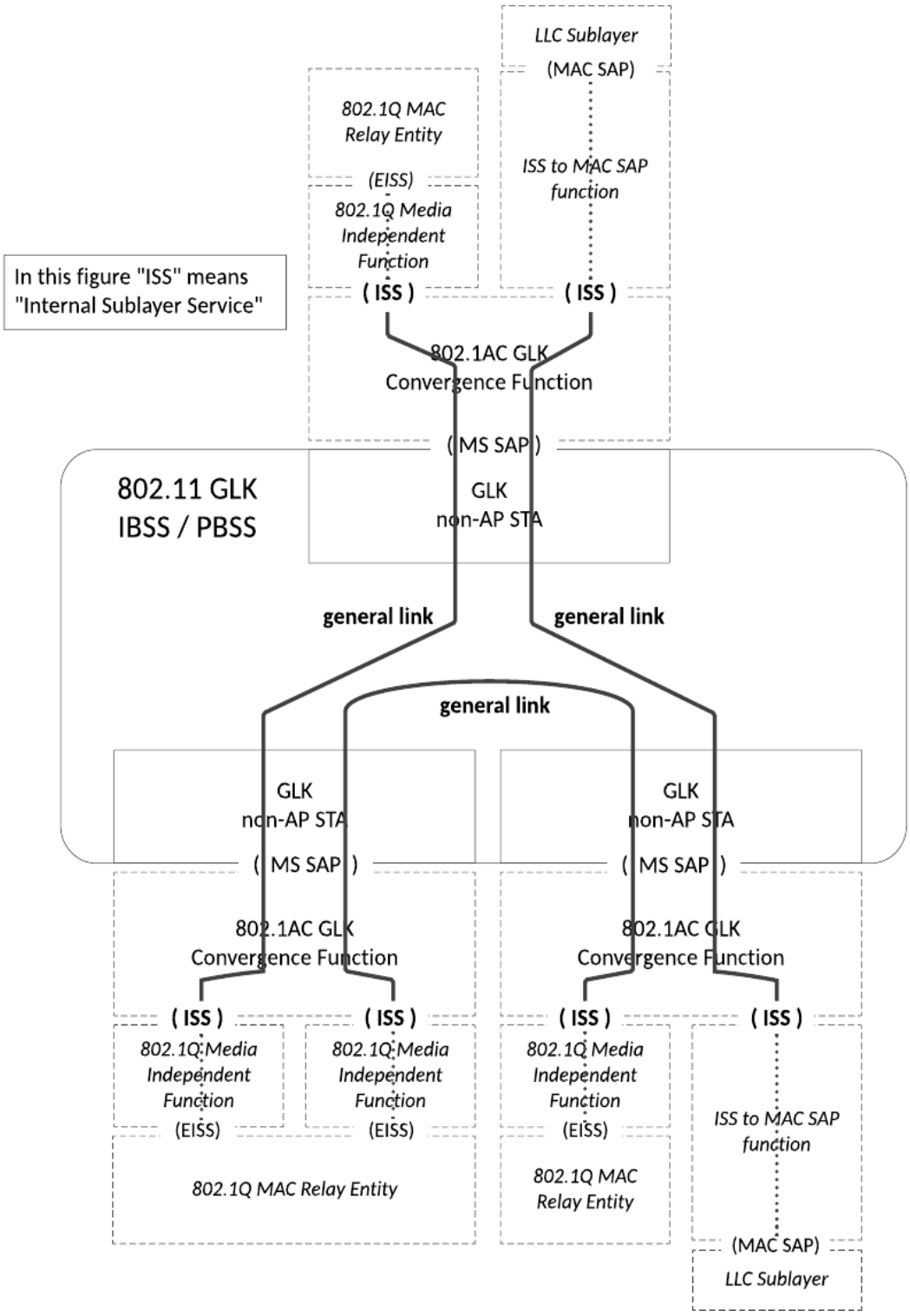


**Figure 4-14—Example of GLK IBSS or PBSS**

and IEEE Std 802.1Q-2018(#52). These entities are shown with dashed outlines in the figure. Entities that IEEE Std 802.11 does specify are shown with solid outlines and are within the box labeled “802.11 GLK IBSS/PBSS”.


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A difference from a non-GLK STA's IEEE 802.11 IBSS/PBSS is that either or both MAC SAPs could directly connect to an IEEE 802.1Q bridge.

For example, each of the STAs and attached bridges (including the IEEE 802.1Q MAC Relay Entities) shown could be at the top of a rack in a data center to provide inter-rack connectivity. The two MAC SAPs shown could even be safely connected to the same IEEE 802.1Q network, since such a network provides protection from loops.

Also, shown in the figure is the possibility to provide a point-to-point link between two LLC Sublayer entities that are each attached to a GLK non-AP STA. For example, this link could allow a computer attached to a GLK STA to directly connect to a network attached storage device attached to a GLK STA.

#### 4.3.31.3.3 Infrastructure BSS with general links

A GLK infrastructure BSS can provide access to the WM via general links that are suitable for use in an IEEE 802.1Q network. Figure 4-15 (Example of infrastructure BSS with general links) shows an example of a GLK infrastructure BSS with three GLK non-AP STAs and one GLK AP. Each participating STA provides MAC services at the MS SAP, with the inclusion of a station vector that is then mapped to one or more Internal Sublayer Service SAPs by the IEEE 802.1AC GLK Convergence Function. Four general links are shown that connect four pairs of Internal Sublayer Service SAPs in a point-to-point manner. Each of the Internal Sublayer Service SAPs is then mapped, by the IEEE 802.1Q Media Independent Function or the Internal Sublayer Service to MAC SAP function, to either an EISS SAP or a MAC SAP, respectively. The EISS SAP provides EISS services to the MAC relay entity of a VLAN bridge component (IEEE 802.1Q MAC Relay Entity). The MAC SAP provides services to the LLC Sublayer.

NOTE—IEEE Std 802.11 does not specify the details of the IEEE 802.1AC GLK Convergence Function, the IEEE 802.1Q Media Independent Function, the Internal Sublayer Service to MAC SAP function, the IEEE 802.1Q MAC Relay Entity, and the LLC Sublayer. These entities are specified in other documents such as IEEE Std 802.1AC-2016 and IEEE Std 802.1Q(#73-Ed1). These entities are shown with dashed outlines in the figure. Entities that IEEE Std 802.11 does specify are shown with solid outlines and are with in the box labeled "802.11 BSS".

Although transmissions by an AP are typically received by all STAs associated with that AP, the service provided by a GLK infrastructure BSS might be considered as separate point-to-point links between the corresponding Internal Sublayer Service SAPs. Provisioning of such apparent point-to-point links is natural for MPDUs with an RA that is an individual address. In order to provide such apparent point-to-point links for group addressed frames, the GLK AP can transmit them so that they are accepted by a subset of the associated GLK STAs. Such selective transmission can be provided through the GLK SYNRA addressing facility (see 4.3.31.2 (Selective reception of group addressed frames)) or by serial transmissions to the desired receivers.

Three types of example general links are shown in Figure 4-15 (Example of infrastructure BSS with general links):

— The first type is an infrastructure general link that connects a non-AP GLK STA attached bridge port of an IEEE 802.1Q MAC Relay Entity with an GLK AP attached bridge (two of these general links are shown in the figure). These links could be used to enhance the reliability and routing options of an IEEE 802.1Q-compliant LAN by providing redundant wireless links between the bridges in the LAN.

— The second type is a non-AP GLK STA to non-AP GLK STA link that connects the STAs' attached bridges (IEEE 802.1Q MAC Relay Entities). This type of general link is similar to the IBSS or PBSS STA to STA link.

— The third type of general link is a "leaf-node" type of general link that connects entities in the LLC layer attached to a non-AP GLK STA via a general link and an IEEE 802.1Q bridge attached to the GLK AP to another entity available via the IEEE 802.1Q network attached to the GLK AP. Such a

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general link could provide a connection between a network printer attached to the LAN and a computer attached to the non-AP GLK STA.

A difference between a GLK AP's IEEE 802.11 links and a non-GLK AP's IEEE 802.11 links, which can only be connected to an Internal Sublayer Service SAP via a DS and portal, is that an Internal Sublayer Service SAP could directly connect to an IEEE 802.1Q bridge.

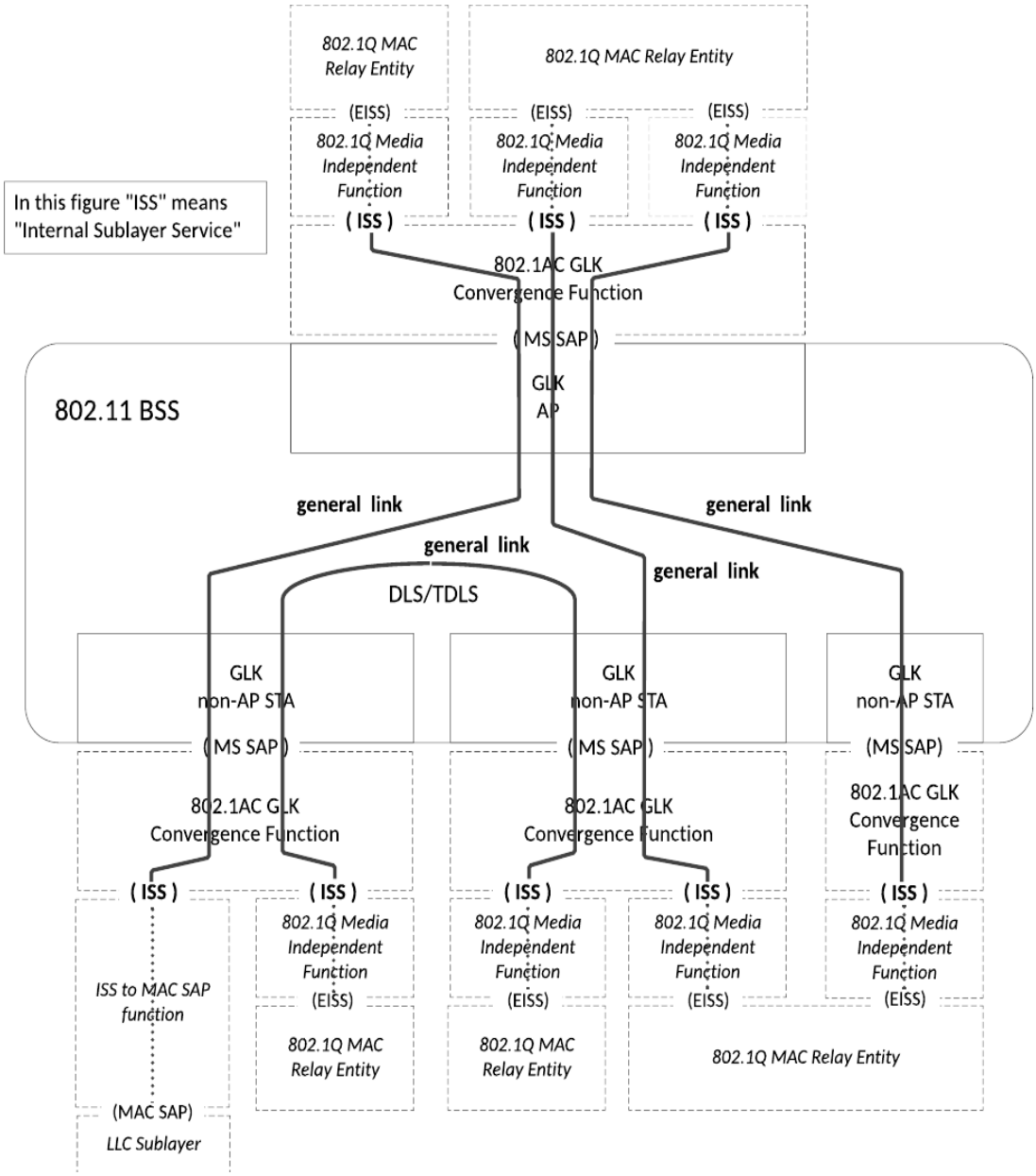


**Figure 4-15—Example of infrastructure BSS with general links**

#### 4.3.31.3.4 Infrastructure BSSs with general links in the presence of an ESS

BSSs that support general links can be components of an extended form of network by using the general links within an IEEE 802.1Q bridged network. In such a bridged network, the concept of the DS in (M12)an


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ESS is replaced by the other components of the IEEE 802.1Q network. However, such a GLK topology is more general than the non-GLK infrastructure mode. For example, Figure 4-16 (Example of an ESS and extended network with general links) shows a network consisting of three types of BSSs: a GLK infrastructure BSS (with only GLK STAs), an infrastructure BSS (with both GLK and non-GLK STAs), and an infrastructure BSS (containing only non-GLK STAs). The example ESS shown in the figure consists of all the non-GLK non-AP STAs, the non-GLK AP, and the portion of the GLK AP that has associated non-GLK non-AP STAs. In the ESS the portal that is connected to the DS does not show any additional connection because the portal could be connected to any type of bridge, switch, or LAN. Hence no specific interconnection is shown. The general links shown in Figure 4-16 (Example of an ESS and extended network with general links) are similar to those shown in Figure 4-15 (Example of infrastructure BSS with general links) and provide point-to-point links as described in 4.3.31.3.3 (Infrastructure BSS with general links). Also, shown in the figure is an example of the possible configuration of more than one IEEE 802.1Q MAC relay entity being attached to a GLK AP or GLK non-AP STA and the possible configuration of more than one GLK AP or GLK non-AP STA being attached to the same IEEE 802.1Q MAC relay entity. These configurations show the flexibility available with general links.

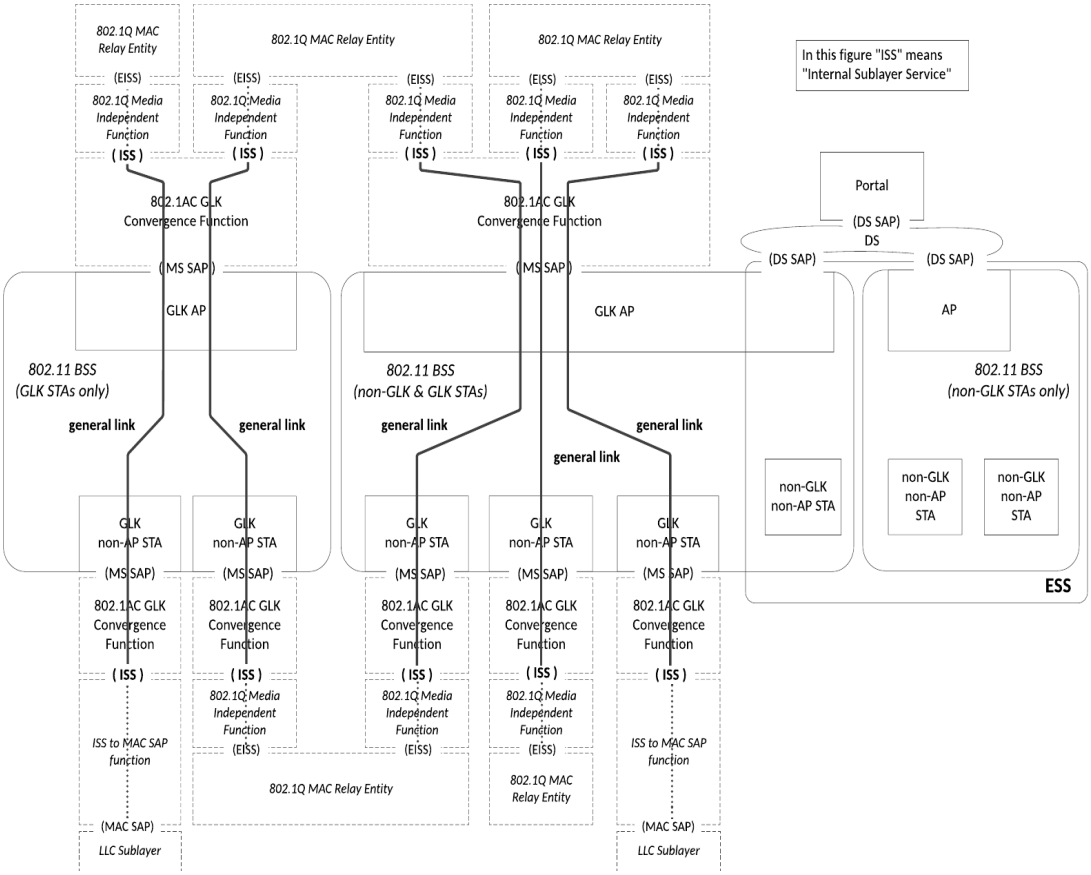


**Figure 4-16—Example of an ESS and extended network with general links**

NOTE—IEEE Std 802.11 explicitly does not specify the details of the IEEE 802.1AC GLK Convergence Function, the IEEE 802.1Q Media Independent Function, the Internal Sublayer Service to MAC SAP function, the IEEE 802.1Q MAC Relay Entity, and the LLC Sublayer. These entities are specified in other documents such as IEEE Std 802.1AC-2016 and IEEE Std 802.1Q-2018(#53). These entities are shown with dashed outlines in the figure. Entities that IEEE Std 802.11 does specify are shown with solid outlines.

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### 4.3.32 EtherType(#2186) protocol discrimination (EPD)

IEEE Std 802 describes the two LLC sublayer protocols: (#2186)EtherType protocol discrimination (EPD) and LLC protocol discrimination (LPD). LPD is the default for IEEE 802.11 MSDUs with the exception of the 5.9 GHz bands where EPD is used for the transmission of all MSDUs (see E.2.3 (5.9 GHz band in the United States and its territories (5.850–5.925 GHz)(#296)) and E.2.4 (5.9 GHz band in Europe (5.855–5.925 GHz))). While not the default, EPD might be used in other bands when it is known that the addressed STAs and the transmitting STA support EPD.

An EPD STA is a STA that supports EPD format MSDUs. EPD STAs, other than those operating in the 5.9 GHz bands, indicate their support through a bit in the Capability Information field, DMG STA Capability Information field, and Relay Capabilities element. An EPD STA, when transmitting an MPDU with an RA that is an individual address, uses EPD if the recipient supports EPD; otherwise, such individually addressed transmissions use LPD.

(#1653)In an MPDU transmitted with a group RA, the choice between of EPD or LPD format of MSDUs in the MPDU is controlled by the policy of the BSS (see 5.1.4 (MSDU format)).

### 4.3.33 EDMG STA(11ay)(#1179)

The IEEE 802.11 enhanced directional multi-gigabit (EDMG) STA is a DMG STA that provides PHY and MAC features that can support a throughput of at least 20 Gb/s, as measured at the MAC data service access point (SAP). An EDMG STA supports DMG and EDMG features as identified in Clause 10 (MAC sublayer functional description), Clause 11 (MLME), Clause 12 (Security), Clause 20 (Directional multi-gigabit (DMG) PHY specification), and Clause 28 (Enhanced directional multi-gigabit (EDMG) PHY specification(11ay)). An EDMG STA supports transmission and reception of frames that are compliant with PHY specifications as defined in Clause 20 (Directional multi-gigabit (DMG) PHY specification) and Clause 28 (Enhanced directional multi-gigabit (EDMG) PHY specification(11ay)).

The main features in an EDMG STA that are not present in a DMG STA are the following:

- Mandatory support of the EDMG format (transmit and receive) using SC modulation.
- Mandatory support of 4.32 GHz channel width.
- Mandatory support of single spatial stream (transmit and receive) in all supported channel widths.
- Mandatory support of non-EDMG duplicate format transmission of non-EDMG portion of EDMG format preamble.
- Mandatory support of the BRP transmit sector sweep.
- Mandatory support of the Short SSW PPDUs.
- Mandatory support of the EDMG power save enhancements.
- Optional support of EDMG SU PPDUs (transmit and receive) using OFDM modulation.
- Optional support of two or more spatial streams (transmit and receive) using SC or OFDM modulations.
- Optional support of EDMG MU PPDUs (transmit and receive) using SC or OFDM modulations.
- Optional support of 2.16+2.16 GHz channel width.
- Optional support of 4.32+4.32 GHz channel width.
- Optional support of 6.48 GHz channel width.
- Optional support of 8.64 GHz channel width.
- Optional support of a 64-point nonuniform constellation.
- Optional support for 8-PSK using SC modulation.
- Optional support of the beamforming for asymmetric links.


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— Optional support of the first path beamforming.
— Optional support of the EDMG multi-TID aggregation.

An EDMG STA is equipped with one or more DMG antennas. When the STA is equipped with more than one DMG antenna, each DMG antenna can be configured to cover overlapping or nonoverlapping spatial sectors (i.e., DMG antennas can be sectorized). Therefore, transmissions from different DMG antennas can reach different sets of STAs. Under the control of the MAC sublayer, transmissions from each DMG antenna can be synchronized to, for example, achieve MIMO communication (see 10.38.12.4 (MIMO channel access)).

#### 4.3.34 Light communication (LC) STA(11bb)

An LC STA operates in the light band with wavelengths in the range of 800 nm to 1000 nm.

An LC STA has one of three levels of support: HT, VHT, or HE. An LC STA with an LC PHY that has HT support is an HT STA (see 4.3.13 (High Throughput (HT) STA(#2297))) except that it operates in the light band. An LC STA with an LC PHY that has VHT support is a VHT STA (see 4.3.15 (Very high throughput (VHT) STA)) except that it operates in the light band. An LC STA with an LC PHY that has HE support is an HE STA (see 4.3.16 (High-efficiency (HE) STA(11ax))) except that it operates in the light band.

An LC STA has support for MAC features such as frame aggregation, block ack, beamforming, and fast session transfer in a multi-band device.

Simultaneous use of multiple transmit chains and multiple receive chains within the LC PHY is supported (see 33.2.3.5 (Multiple transmit chains and multiple receive chains)).

Channels defined for 2.4 GHz operation of HT and HE PHYs do not apply to an LC PHY with HT and HE support, respectively. The channels that apply to LC are defined in Table 33-1 (RF to LC IF mapping for channels in the 5 GHz and 6 GHz bands(11bb)).

## 4.4 Logical service interfaces

### 4.4.1 General

IEEE Std 802.11 explicitly does not specify the details of implementations. Instead, IEEE Std 802.11 specifies services to aid understanding how the architectural components are logically organized. The services are associated with different components of the architecture. There are three categories of IEEE 802.11 service—the station service(#1296), the PCP service (PCPS), and the distribution system service (DSS). These categories of service are used by the IEEE 802.11 MAC sublayer.

The complete set of IEEE 802.11 architectural services are as follows:

a) Authentication
b) Association
c) Deauthentication
d) Disassociation
e) Distribution
f) Integration
g) Data confidentiality
h) Reassociation
i) MSDU delivery

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j) DFS
k) TPC
l) Higher layer timer synchronization (QoS facility only)
m) QoS traffic scheduling (QoS facility only)
n) Radio measurement
o) DSE

This set of services is divided into three groups: the station service(#1296), the PCPS, and the DSS. The station service(#1296) is part of every STA. The PCPS is provided by the PCP of a PBSS. The DSS is provided by the DS.

### 4.4.2 Station service(#1296)

The service provided by STAs is known as the station service(#1296).

The station service(#1296) is present in every IEEE 802.11 STA (including APs, as APs include STA functionality). The station service(#1296) is specified for use by MAC sublayer entities. All STAs provide the station service(#1296).

The station service(#1296) is as follows:

a) Authentication (not used when dot11OCBActivated is true)
b) Deauthentication (not used when dot11OCBActivated is true)
c) Data confidentiality (not used when dot11OCBActivated is true)
d) MSDU delivery
e) DFS
f) TPC
g) Higher layer timer synchronization (QoS facility only)
h) QoS traffic scheduling (QoS facility only)
i) Radio measurement
j) DSE

### 4.4.3 PBSS control point service (PCPS)

The service provided by the PCP of a PBSS is known as the PCPS. Since each STA within a PBSS can operate as a PCP, each STA in the PBSS is capable of providing the PCPS, if it becomes the PCP of the PBSS. Non-PCP STAs do not provide the PCPS.

The services that comprise the PCPSs are the following:

a) Association
b) Disassociation
c) Reassociation
d) QoS traffic scheduling (optional)(#1931)

The PCPS is specified for use by MAC sublayer entities.

### 4.4.4 DSS

The service provided by the DS is known as the DSS. IEEE Std 802.11 explicitly does not specify the details of DS implementation structure. Instead, IEEE Std 802.11 specifies the services that are provided by a DS


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implementation. A DS can be created from many different technologies including current IEEE 802 wired LANs. IEEE Std 802.11 does not constrain the DS to be either data link or network layer based. Nor does IEEE Std 802.11 constrain a DS to be either centralized or distributed in nature.

This service is represented in the IEEE 802.11 architecture by arrows within APs and mesh gates, indicating that the service is used to cross media and possibly address space logical boundaries. An AP and a mesh gate are logical entities, and the functions described might be shared by one or more physical entities.

The services that comprise the DSS are as follows:

a) Association (not mesh facility)
b) Disassociation (not mesh facility)
c) Distribution
d) Integration
e) Reassociation (not mesh facility)
f) QoS traffic scheduling (QoS facility only)
g) DSE
h) Interworking with the DS (mesh facility only)

DSSs are specified for use by MAC sublayer entities.

Figure 4-17 (IEEE 802.11 architecture for infrastructure BSS and PBSS(#1296)) combines the components from previous figures with the three types of services to show the IEEE 802.11 architecture for infrastructure BSS and PBSS.

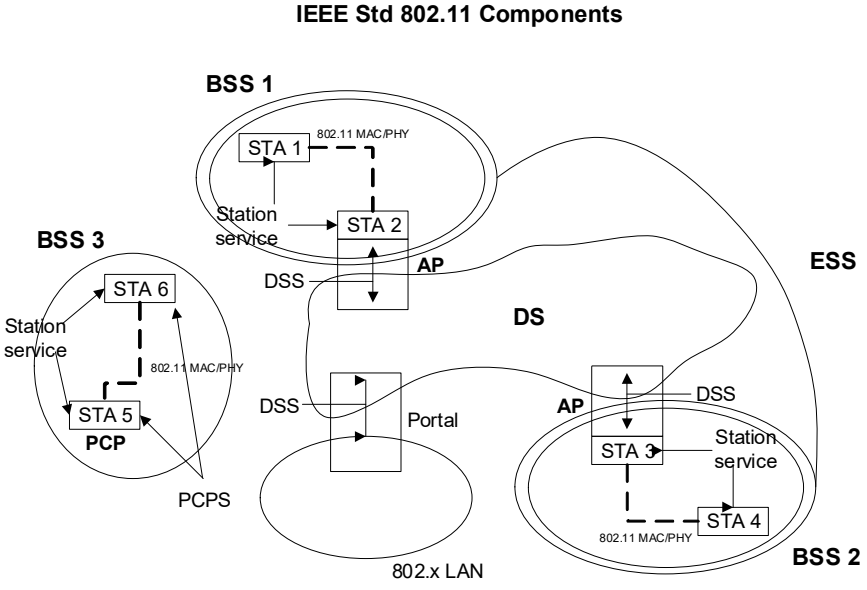


**Figure 4-17—IEEE 802.11 architecture for infrastructure BSS and PBSS(#1296)**

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## 4.5 Overview of the services

### 4.5.1 General

There are many services specified by IEEE Std 802.11. Six of the services are used to support medium access control (MAC) service data unit (MSDU) delivery between STAs. Three of the services are used to control IEEE 802.11 LAN access and confidentiality. Two of the services are used to provide spectrum management. One of the services provides support for LAN applications with QoS requirements. Another of the services provides support for higher layer timer synchronization. One of the services is used for radio measurement.

This subclause presents the services, an overview of how each service is used, and a description of how each service relates to other services and the IEEE 802.11 architecture. The services are presented in an order designed to help build an understanding of the operation of an IEEE 802.11 network. As a result, the services that comprise the station service(#1296) and DSS are intermixed in order (rather than being grouped by category). The services that comprise the PCPS are a subset of the services provided by the station service(#1296) and DSS.

Each of the services is supported by one or more MAC frame types. Some of the services are supported by MAC management PDUs, which are transported in (#8152)Management frames. The MSDU delivery service is supported by (#8152)Data frames. All of these frames gain access to the WM via the IEEE 802.11 MAC sublayer medium access method specified in Clause 10 (MAC sublayer functional description).

The IEEE 802.11 MAC sublayer uses four types of frame—*Data*, *Management*, *Extension,* and *Control* (see Clause 9 (Frame formats)). Data frames are handled by the MAC data plane (see Figure 5-1 (MAC data plane architecture (#7109)(#4149)(#1001)(11ay)(#3186)(#3185)(#4172)(#4192)(11bc))).

(#8152)Management frames and Extension frames (see 9.3.4 (Extension frames)) are handled via the MAC management plane.

(#8152)Control frames are used to support the delivery of IEEE 802.11 Data, Management, and Extension frames.

The examples here assume an ESS environment. The differences among the ESS, the PBSS, and the IBSS environments are discussed separately in 4.7 (Differences among ESS, PBSS, and IBSS LANs).

### 4.5.2 Distribution of MSDUs within a DS

#### 4.5.2.1 Distribution

This is the primary service used by IEEE 802.11 non-GLK STAs. It is conceptually invoked by every data message to or from an IEEE 802.11 non-GLK STA operating in an ESS (when the frame is sent via the DS). Distribution is via the DSS.

Refer to the ESS in Figure 4-18 (IEEE 802.11 Infrastructure model) and consider an MSDU being sent from STA 1 to STA 4. One or more frames containing the MSDU are sent from STA 1 and received by STA 2 (the “input” AP). The AP gives a MAC service tuple containing the MSDU to the DSS. It is the job of the distribution system to deliver the MAC service tuple within the DS in such a way that it arrives at the appropriate DS destination for the intended recipient. In this example, the MAC service tuple is distributed


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to STA 3 (the "output" AP) and STA 3 accesses the WM to send one or more frames containing the MSDU to STA 4 (the intended destination).

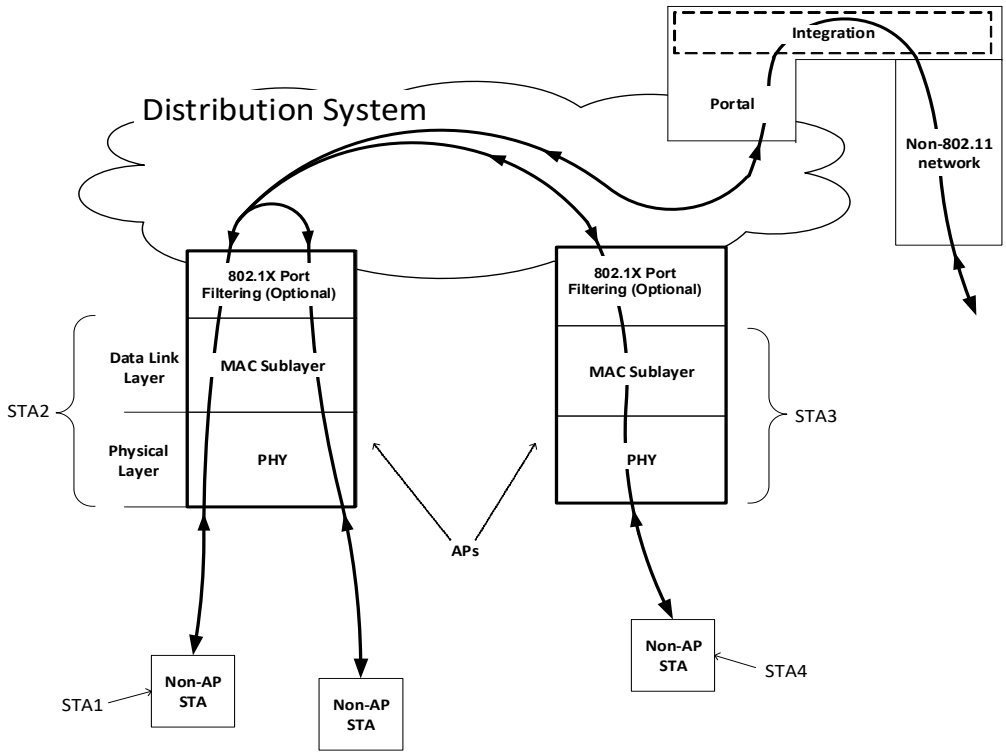


**Figure 4-18—IEEE 802.11 Infrastructure model**

The previous example was a case in which the AP that invoked the distribution system service was different from the AP that received the distributed MAC service tuple. If the MSDU had been intended for a STA that was a member of the same BSS as the sending STA, then the "input" and "output" APs for the MAC service tuple would have been the same.

If a MAC service tuple with a group addressed destination is provided to the DS, the DS is responsible for delivering that MAC service tuple to all appropriate APs in the ESS, including the "input" AP, to allow the AP to send frame(s) containing the MSDU to other associated non-AP STAs in its BSS. Generally, the DS delivers the MAC service tuple to all the APs in the ESS. Optionally, an (M118)implementation specific or higher layer filtering might be applied to restrict the delivery to a known subset of the APs in the ESS; such filtering is beyond the scope of this standard.

How the MAC service tuple is distributed within the DS is not specified by IEEE Std 802.11. All IEEE Std 802.11 is required to do is to provide the DS with enough information for the DS to be able to determine the "output" point that corresponds to the intended recipient. The necessary information is provided to the DS by the three association related services (association, reassociation, and disassociation).

In all the examples above, the distribution system service was logically invoked. Whether the MAC service tuple actually had to traverse the physical DSM or not is a DS implementation matter and is not specified by this standard.

While IEEE Std 802.11 does not specify DS implementations, it does recognize and support the use of the WM as one possible DSM. This is specifically supported by the IEEE 802.11 frame formats. (Refer to

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Clause 9 (Frame formats) for details.) A mesh BSS might form an entire DS or a part of a DS using the WM, as shown in Figure 4-9 (Example MBSS containing mesh STAs, mesh gates, APs, and portals). Mesh services are used to form a mesh BSS and distribute MSDUs. Clause 14 (MLME mesh procedures) defines how mesh BSSs are formed and how MSDUs are distributed through a mesh BSS.

#### 4.5.2.2 Integration

When the distribution system service determines that the intended recipient of an MSDU is a member of an integrated LAN, the "output" point of the DS is a portal instead of an AP.

MAC service tuples that are distributed to a portal cause the DS to invoke the Integration function (conceptually after the distribution system service). The Integration function is responsible for accomplishing whatever is needed to deliver a MAC service tuple from the DSM to the integrated LAN media (including any required media or address space translations).

MSDUs received from an integrated LAN invoke the Integration function before the MAC service tuple is distributed by the distribution system.

The details of an Integration function are dependent on a specific portal implementation and are outside the scope of this standard.

#### 4.5.2.3 QoS traffic scheduling

QoS traffic scheduling provides intra-BSS QoS frame transfers under the HCF, using either contention based or controlled channel access. At each TXOP, a traffic scheduling entity at the STA selects a frame for transmission, from the set of frames at the heads of a plurality of traffic queues, based on requested UP and/or parameter values in the traffic specification (TSPEC) for the requested MSDU. Additional information is available in 10.23 (HCF).

### 4.5.3 Connectivity-related services

#### 4.5.3.1 General

The primary purpose of a MAC sublayer is to transfer MSDUs between MAC sublayer entities. The information required for the distribution system service to operate is provided by the association services. Before an MSDU can be handled by the distribution system service, a STA is "associated."

To understand the concept of association, it is necessary first to understand the concept of mobility.

#### 4.5.3.2 Mobility types

(#6575)The two transition types that are supported within this standard that describe the mobility of (M12)non-GLK STAs within a network are as follows:

a) ***No-transition:*** In this type, two subclasses that are usually indistinguishable are identified:
   1) Static—no motion.
   2) Local movement—movement within the PHY range of the communicating STAs, i.e., movement within a basic service area (BSA).

b) ***BSS-transition:*** This type is defined as a STA movement from one BSS in one ESS to another BSS within the same ESS. A fast BSS transition is a BSS transition that establishes the state necessary for data connectivity before the reassociation rather than after the reassociation.(#6575)

NOTE—A nonmobility based transition from a BSS to the same BSS (same AP or PCP) is also supported. See 11.3.5.4 (Non-AP and non-PCP STA reassociation initiation procedures).(#4119)


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(#6575)A third type of transition is STA movement from a BSS in one ESS to a BSS in a different ESS. Maintenance of upper layer connections during transition between ESSs cannot be guaranteed by IEEE Std 802.11; disruption of service is likely to occur.

The FT protocol provides a mechanism for a STA to perform a BSS transition between access points (APs) in a robust security network (RSN) or when quality-of-service (QoS) admission control is enabled in the ESS.

The different association services support the different categories of (M12)non-GLK mobility.

(M12)In GLK operation, association services establish a general link between a pair of instances of Internal Sublayer Service SAPs. For these links there is no DS to provide the distribution service. Association services coordinate with higher layer services to create and maintain an IEEE 802.1Q network. Mobility of GLK links is managed (if supported at all) by the ability of the associated IEEE 802.1Q bridged network and the associated GLK convergence function (shim layer) to support remapping a general link from one IEEE 802.1Q bridge port to another. Such operation is outside the scope of IEEE 802.11, but see 4.5.3.4 (Reassociation) for some concepts used for GLK link mobility.

#### 4.5.3.3 Association

To deliver an MSDU within an ESS via the DS, the DS needs to know which AP within the ESS to deliver the MSDU to(#4387), so that the MSDU might ultimately be delivered to the addressed IEEE 802.11 STA. This information is provided to the DS by the concept of association. Association is necessary, but not sufficient, to support BSS-transition mobility. Association is sufficient to support no-transition mobility. Association is one of the services in the DSS.

Before a STA is allowed to send an MSDU via an AP, it first becomes associated with the AP.

For a non-GLK STA, the act of becoming associated invokes the association service, which provides the STA to AP mapping to the DS. How the information provided by the association service is stored and managed within the DS is not specified by this standard.

For a GLK STA, the act of becoming associated invokes the association service, which establishes a general link between two instances of the IEEE 802.1AC(#54) Internal Sublayer Service. This link provides a point-to-point link between the two Internal Sublayer Service SAPs. The GLK AP STA and the GLK non-AP STA each coordinate with higher layer services and each other to create the point-to-point link. The higher layer services create or enable the Internal Sublayer Service SAPs, inform the GLK convergence function of the mapping of the Internal Sublayer Service SAPs, and inform the network routing protocol of the existence of the general link. The GLK AP and the GLK non-AP STA each establish a service_access_point_identifier for each general link, for their respective MS SAPs. This process allows for the establishment of a point-to-point link suitable for use in an IEEE 802.1Q network.

Within a robust security network (RSN), association is handled differently. In an RSNA, the IEEE 802.1X Port determines when to allow data traffic across an IEEE 802.11 link. A single IEEE 802.1X Port maps to one association, and each association maps to an IEEE 802.1X Port. An IEEE 802.1X Port consists of an IEEE 802.1X Controlled Port and an IEEE 802.1X Uncontrolled Port. The IEEE 802.1X Controlled Port is blocked from passing general data traffic between two STAs until an IEEE 802.1X authentication procedure completes successfully over the IEEE 802.1X Uncontrolled Port. Once the AKM completes successfully, data protection is enabled to prevent unauthorized access, and the IEEE 802.1X Controlled Port unblocks to allow protected data traffic. IEEE 802.1X Supplicants and Authenticators exchange protocol information via the IEEE 802.1X Uncontrolled Port. It is expected that most other protocol exchanges use the IEEE 802.1X Controlled Ports. However, a given protocol might need to bypass the authorization function and make use of the IEEE 802.1X Uncontrolled Port.

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NOTE—See (#3469)IEEE Std 802.1X-2020 for a discussion of Controlled Port and Uncontrolled Port.

At any given instant, a STA is associated with no more than one AP. This allows the DS to determine a unique answer to the question, "Which AP is serving STA X?" Once an association is completed, a STA can make full use of a DS (via the AP) to communicate. Association is always initiated by the non-AP STA, not the AP.

An AP might be associated with many STAs at the same time.

A STA learns what APs are present and what operational capabilities are available from each of those APs and then invokes the association service to establish an association. A FILS STA is able to discover, authenticate and associate with the AP with a reduced number of frame transmissions. For details of how a STA learns about what APs are present, see 11.1.4 (Acquiring synchronization, scanning).

#### 4.5.3.4 Reassociation

Association is sufficient for no-transition MSDU delivery between IEEE 802.11 STAs. Additional functionality is needed to support BSS-transition mobility. The additional required functionality is provided by the reassociation service. Reassociation is one of the services in the DSS.

The reassociation service is invoked to "move" a current association of a non-AP STA from one AP to another. In an ESS(M12), the reassociation service informs the DS of the current mapping between AP and STA as the STA moves from BSS to BSS within the ESS. For a general link in an IEEE 802.1Q network, the reassociation service informs higher layer services how the link is reconfigured, commonly, with which BSS the GLK non-AP STA is a member of. The higher layer services will then destroy, disable, or maintain the existing Internal Sublayer Service SAPs, create or enable new Internal Sublayer Service SAPs, inform the GLK convergence function of the reconfigured general link mapping of the Internal Sublayer Service SAPs, and inform the network routing protocol of the updated general link. The GLK AP and GLK non-AP STA each then establish or maintain a service_access_point_identifier for the reconfigured general link, for their respective MS SAPs. Reassociation also enables changing association attributes of an established association while the non-AP STA remains associated with the same AP. Reassociation is always initiated by the non-AP STA.

Only the fast BSS transition facility can move an RSNA during reassociation. Therefore, if FT is not used, the old RSNA is deleted and a new RSNA is constructed.

#### 4.5.3.5 Disassociation

The disassociation service is invoked when an existing association is to be terminated. Disassociation is one of the services in the DSS.

For a non-GLK STA, the act of becoming disassociated invokes the disassociation service, which voids any existing STA to AP mapping known to the DS, for the disassociating STA. How the information provided by the disassociation service is managed within the DS is not specified by this standard. For a general link, disassociation removes or disables the corresponding Internal Sublayer Service SAPs that were configured for the general link. The IEEE 802.1Q bridge uses this information to update bridging for the GLK non-AP STA.

For an IEEE 802.11 link that is the basis of a general link, the disassociation service informs higher layer services of the IEEE 802.1Q network that the general link has been destroyed. The GLK AP and the GLK non-AP STA each coordinate with higher layer services and each other to destroy the point-to-point link. The higher layer services destroy or disable the Internal Sublayer Service SAPs, inform the GLK convergence function of the deletion of the mapping of the Internal Sublayer Service SAPs, and inform the


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network routing protocol of the destruction of the general link, for their respective MS SAPs. This process destroys the previously existing point-to-point link that was suitable for use in an IEEE 802.1Q network.

The disassociation service can be invoked by either party in an association (non-AP STA or AP). Disassociation is a notification, not a request. Disassociation cannot be refused by the receiving STA except when management frame protection is negotiated and the message integrity check fails.

An AP can disassociate STAs to enable the AP to be removed from a network for service or for other reasons.

STAs attempt to disassociate when they leave a network. However, the MAC protocol does not depend on STAs invoking the disassociation service. (MAC management is designed to accommodate loss of communication with an associated STA.)

### 4.5.4 Access control and data confidentiality services

#### 4.5.4.1 General

Two services are required for IEEE Std 802.11 to provide functionality equivalent to that which is inherent to wired LANs. The design of wired LANs assumes the physical attributes of wire. In particular, wired LAN design assumes the physically closed and controlled nature of wired media. The physically open medium nature of an IEEE 802.11 LAN violates those assumptions.

In a WLAN that does not support RSNA, two services, authentication and data confidentiality, are defined. IEEE 802.11 authentication is used instead of the wired media physical connection(#1266).

(#432)An RSNA uses the IEEE 802.1X authentication service along with RSNA mechanisms, such as CCMP and GCMP, to provide access control. The IEEE 802.11 station management entity (SME) provides key management via an exchange of (#1836)EAPOL-Key PDUs. (#432)Data confidentiality and data integrity are provided by RSN key management together with the RSNA mechanisms.

#### 4.5.4.2 Authentication

IEEE 802.11 authentication operates at the link level between IEEE 802.11 STAs. IEEE Std 802.11 does not provide either end-to-end (MSDU origin to MSDU destination) or user-to-user authentication.

IEEE Std 802.11 attempts to control LAN access via the authentication service. IEEE 802.11 authentication is a station service(#1296). This service might be used by all STAs to establish their identity to STAs with which they communicate, in both ESSs and IBSSs. If a mutually acceptable level of authentication has not been established between two STAs, an association is not established.

IEEE Std 802.11 defines (#3056)five(11az) IEEE 802.11 authentication methods: Open System authentication, FT authentication, simultaneous authentication of equals (SAE), FILS authentication and preassociation security negotiation (PASN) authentication.(11az) Open System authentication admits any STA to the DS. (#3056)FT authentication relies on keys derived during the initial mobility domain association to authenticate the stations as defined in Clause 13 (Fast BSS transition). SAE authentication uses finite field cryptography to prove knowledge of a shared password. FILS authentication allows for faster connection to the network for FILS non-AP STAs by providing authentication, association, and key confirmation information in an efficient number of frame exchanges (see 4.10.3.6 (AKM operations using FILS authentication)). (11az)PASN authentication allows for the protection of Management frames without association by establishing a PTKSA using authentication frames. The IEEE 802.11 authentication mechanism also allows definition of new authentication methods, (11az)or any combination of these authentication methods.

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An RSNA might support (11az)one or more of the following authentication methods: SAE authentication, FILS authentication, or PASN authentication(11az). An RSNA also supports authentication based on (#3469)IEEE Std 802.1X-2020, or preshared keys (PSKs) after Open System authentication. IEEE 802.1X authentication utilizes the EAP to authenticate STAs and the AS with one another. This standard does not specify an EAP method that is mandatory to implement. See 12.6.4 (RSNA policy selection in an IBSS) for a description of the IEEE 802.1X authentication and PSK usage within an IEEE 802.11 IBSS.

In an RSNA, IEEE 802.1X Supplicants and Authenticators exchange protocol information via the IEEE 802.1X Uncontrolled Port. The IEEE 802.1X Controlled Port is blocked from passing general data traffic between two STAs until an IEEE 802.1X authentication procedure completes successfully over the IEEE 802.1X Uncontrolled Port.

SAE authentication and Open System IEEE 802.11 authentication are used by STAs in an RSN for an infrastructure BSS. FILS authentication can be used by FILS STAs in an RSN for an infrastructure BSS. SAE authentication, Open System IEEE 802.11 authentication, or no IEEE 802.11 authentication is used in an RSN for an IBSS. SAE authentication is used for an MBSS. (#3056)In an RSN for DMG BSS, Open System IEEE 802.11 authentication is not used (12.2.4 (RSNA establishment)).

A STA might be authenticated with many other STAs at the same time.

Because the IEEE 802.1X authentication process could be time-consuming (depending on the authentication protocol in use), the authentication service can be invoked independently of the association service.

This type of preauthentication is typically done by a STA while it is already associated with an AP (with which it previously authenticated). IEEE Std 802.11 does not require that STAs preauthenticate with APs. However, authentication is required before an association establishment is complete.

If the authentication is left until reassociation time, this might impact the speed with which a STA reassociates between APs, limiting BSS-transition mobility performance. The use of preauthentication takes the authentication service overhead out of the time-critical reassociation process.

SAE authentication is performed prior to association and a STA can take advantage of the fact that it can be IEEE 802.11 authenticated to many APs simultaneously by completing the SAE protocol with any number of APs while still being associated to another AP. RSNA security can be established after association using the resulting shared key.

(11az)PASN authentication is used in an RSN for an infrastructure BSS when it is based on a PMKSA established by another RSN authentication protocol. Otherwise, it does not guarantee mutual authentication, and can be used as a non-RSN protocol in an infrastructure BSS.

#### 4.5.4.3 Deauthentication

The deauthentication service is invoked when an existing Open System, (#3056)FT, SAE, or FILS authentication is to be terminated. Deauthentication is a station service(#1296).

In an ESS, because authentication is a prerequisite for association, the act of deauthentication causes the STA to be disassociated. The deauthentication service can be invoked by either authenticated party (non-AP STA or AP). Deauthentication is not a request; it is a notification. The association at the transmitting STA is terminated when the STA sends a deauthentication notice to an associated STA. Deauthentication(#1418) cannot be refused by the receiving STA except when management frame protection is negotiated and the message integrity check fails (#1737)or there is no MIC to check, i.e., the frame is not protected.

In an RSN ESS, deauthentication results in termination of any association for the deauthenticated STA. It also results in the IEEE 802.1X Controlled Port for that STA, if used for this association, being disabled and


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deletes the pairwise transient key security association (PTKSA). The deauthentication notification is provided by the MLME to the SME. The SME then notifies the 802.1X Authenticator or Supplicant, and the 802.1X entity blocks the IEEE 802.1X Controlled Port from passing any further general data traffic.(#6268)

In an RSNA, deauthentication also deletes any related PTKSA(#7120), group temporal key security association (GTKSA), TPK security association (TPKSA), integrity group temporal key security association (IGTKSA), beacon integrity group temporal key security association (BIGTKSA), wake-up radio integrity group temporal key security association (WIGTKSA)(11ba), mesh GTKSA, and mesh PTKSA(#240) that exist in the STA and closes the associated IEEE 802.1X Controlled Port, if used for this association. If pairwise master key security association (PMKSA) caching is not enabled, deauthentication also deletes the PMKSA or mesh PMKSA.

In an RSN IBSS, Open System authentication is optional, but a STA is required to recognize Deauthentication frames. Deauthentication results in the IEEE 802.1X Controlled Port for that STA being disabled and deletes the PTKSA.

#### 4.5.4.4 Data confidentiality

In a wired LAN, only those STAs physically connected to the wire can send or receive LAN traffic. With a wireless shared medium, there is no physical connection, and all STAs and certain other RF devices in or near the LAN might be able to send, receive, and/or interfere with the LAN traffic. A STA receives traffic that is within range and transmits to any other STA within range. Thus, the connection of a single wireless link (without data confidentiality) to an existing wired LAN might seriously degrade the security level of the wired LAN.

To bring the security of the WLAN up to the level implicit in wired LAN design, IEEE Std 802.11 provides the ability to protect the contents of frames. This functionality is provided by the data confidentiality service. Data confidentiality is a station service.

(#1267)IEEE Std 802.11 provides several cryptographic algorithms to protect data traffic, including TKIP, CCMP, and GCMP. (#3442)IEEE Std 802.11 provides several cryptographic algorithms to protect management traffic, including CCMP, GCMP, BIP-CMAC, and BIP-GMAC.(#4252) TKIP is based on the (#3443) ARC4 algorithm, and CCMP and GCMP are based on the advanced encryption standard (AES). A means is provided for STAs to select the algorithm(s) to be used for a given association.

IEEE Std 802.11 provides the following security protocols for protection of individually addressed robust Management frames: CCMP and GCMP. This standard provides data confidentiality for certain Action frames as indicated in Table 9-81 (Category values).

IEEE Std 802.11 provides one security protocol, CCMP, for protection of individually addressed and group addressed Data frames between mesh STAs.

The default data confidentiality state for all IEEE 802.11 STAs is “in the clear,” i.e., without protection. If the data confidentiality service is not invoked, all frames are sent unprotected. If this policy is unacceptable to the sender, it does not send Data frames; and if the policy is unacceptable to the receiver, it discards any received Data frames. Unprotected Data frames and unprotected robust Management frames received at a STA configured for mandatory data confidentiality, as well as protected Data frames and protected robust Management frames using a key not available at the receiving STA, are discarded without an indication to LLC (or without indication to distribution system services in the case of “To DS” frames received at an AP). These frames are acknowledged on the WM [if received without frame check sequence (FCS) error] to avoid wasting WM bandwidth on retries of frames that are being discarded.

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#### 4.5.4.5 Key management

The enhanced data confidentiality, data authentication, and replay protection mechanisms require fresh cryptographic keys and corresponding security associations. The procedures defined in this standard provide fresh keys by means of protocols called the 4-way handshake, FT 4-way handshake, FT protocol, FT resource request protocol, group key handshake, and FILS authentication protocol.

#### 4.5.4.6 Data origin authenticity

The data origin authenticity mechanism defines a means by which a STA that receives a Data or robust Management frame can determine which STA transmitted the MAC protocol data unit (MPDU). This feature is required in an RSNA to prevent one STA from masquerading as a different STA.

Data origin authenticity is applicable only to individually addressed Data frames, individually addressed robust Management frames, and group addressed EBCS Data, EBCS Info, and EBCS UL frames. The protocols do not guarantee data origin authenticity for group addressed frames that are not EBCS Data, EBCS Info, or EBCS UL frames.(11bc)

#### 4.5.4.7 Replay detection

The replay detection mechanism defines a means by which a STA that receives a Data or robust Management frame from another STA can detect whether the received frame is an unauthorized retransmission. (#432)This replay protection mechanism is provided for Data frames for STAs that use RSNA mechanisms. The replay protection mechanism is also provided for robust Management frames for STAs that use CCMP, GCMP, and broadcast/multicast integrity protocol (BIP).

#### 4.5.4.8 Fast BSS transition

The FT mechanism defines a means for a STA to set up security and QoS parameters prior to reassociation to a new AP. This mechanism allows time-consuming operations to be removed from the time-critical reassociation process. During a handover across mobility domains, the overhead incurred during the FT initial mobility domain association in an RSN can be reduced using FILS authentication.

#### 4.5.4.9 Management frame protection

Robust Management frames are a subset of Management frames that can be protected by the management frame protection service (see 12.2.7 (Requirements for management frame protection) for a list of the robust Management frames)(#7050).

(#3305)Management frame protection protocols in an infrastructure BSS, IBSS or PBSS apply to transmission and reception of individually addressed robust Management frames after delivery of the PTK(#1509), transmission of group addressed robust Management frames, reception of group addressed robust Management frames after delivery of the IGTK, transmission of Beacon frames in an infrastructure BSS, and reception of Beacon frames in an infrastructure BSS after delivery of the BIGTK.(#1813)

(#1980)Management frame protection protocols in an MBSS apply to the following frames:

— Individually addressed robust Management frames, after establishment of the MTK,
— Group addressed Action and Action No Ack frames(#4339) of a category specified with Yes in the Group addressed privacy column of Table 9-81 (Category values), after establishment of the (#1509)MGTK, and
— Group addressed robust Management frames that are not Action and Action No Ack frames(#4339) of a category specified with Yes in the Group addressed privacy column of Table 9-81 (Category values), after establishment of the (#1509)IGTK.


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See 14.8 (Mesh security) for details.

Management frame protection is implemented by CCMP, GCMP, and BIP confidentiality protocols and the SA Query procedure.

#### 4.5.4.10 MAC privacy enhancements

When a non-AP STA searches for, and connects to, an infrastructure BSS, IBSS, or PBSS or attempts to discover services on a network preassociation, it (#6268)selects a MAC address for the particular connection. If the STA uses a fixed MAC address it is trivial to track the STA. An MSDU transmitted by a STA is assigned a sequence number that, if never reset, can also be used to track a device irrespective of the MAC address. If OFDM is used, the PHY DATA scrambler used can enable tracking of a device irrespective of the MAC address if it is not reseeded. The dynamic nature of BSS membership combined with this tracking information allows for construction of a network of connections, locations, and behavior. This network can be used to glean private and sensitive information regarding the individual behind the device.

Furthermore, even without establishing a connection, a mobile or portable STA that gratuitously transmits Probe Request frames containing SSIDs of favored infrastructure BSS networks, or announces the existence of IBSS networks, can reveal potentially sensitive information about its location and location history.

To mitigate this sort of traffic analysis a STA can support the ability to periodically and randomly change its MAC addresses and reset counters and seeds prior to association. While discovering networks, a STA can refrain from gratuitously transmitting Probe Request frames containing SSIDs of favored BSS networks.

### 4.5.5 Spectrum management services

#### 4.5.5.1 General

Two services are required to satisfy requirements in some regulatory domains (see Annex D and Annex E) for operation in the 5 GHz band. These services are called *transmit power control (TPC)* and *dynamic frequency selection (DFS)*.

#### 4.5.5.2 TPC

Regulations that apply to the 5 GHz band in certain regulatory domains require RLANs operating in the 5 GHz band to use transmitter power control, involving specification of a regulatory maximum transmit power and a mitigation requirement for each allowed channel. The TPC service is used to satisfy this regulatory requirement.

The TPC service provides for the following:

- Association of STAs with an AP based on the STAs' power capability
- Specification of regulatory and local maximum transmit power levels for the current channel
- Selection of a transmit power for each transmission in a channel within constraints imposed by regulatory requirements
- Adaptation of transmit power based on a range of information, including path loss and link margin estimates

#### 4.5.5.3 DFS

Regulations that apply to the 5 GHz band in certain regulatory domains require RLANs operating in the 5 GHz band to avoid co-channel operation with radar systems and to provide uniform utilization of available channels. The DFS service is used to satisfy these regulatory requirements.

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The DFS service provides for the following:

- Association of STAs with an AP based on the STAs' supported channels.
- Quieting the current channel so it can be tested for the presence of radar with less interference from other STAs.
- Testing channels for radar before using a channel and while operating in a channel.
- Discontinuing operations after detecting radar in the current channel to avoid interference with radar.
- Detecting radar in the current and other channels based on regulatory requirements.
- Requesting and reporting of measurements in the current and other channels.
- Selecting and advertising a new channel to assist the migration of a BSS after radar is detected.

### 4.5.6 Traffic differentiation and QoS support

#### 4.5.6.1 General

IEEE Std 802.11 uses a shared medium and provides differentiated control of access to the medium to handle data transfers with QoS requirements. The QoS facility (per MSDU traffic category and TSPEC negotiation) allows an IEEE 802.11 LAN to become part of a larger network providing end-to-end QoS delivery or to function as an independent network providing transport on a per-link basis with specified QoS commitments. The specifications regarding the integration and operability of the QoS facility with any other end-to-end QoS delivery mechanism like Resource Reservation Protocol (RSVP) are beyond the scope of this standard.

#### 4.5.6.2 Quality-of-service management frame support

When the quality-of-service management frame (QMF) service is enabled, some Management frames might be transmitted using an access category other than the access category assigned to voice traffic (access category AC_VO, see 9.4.2.27 (EDCA Parameter Set element)) in order to improve the quality of service of other traffic streams. This is achievable by the use of a QMF policy. A QMF policy defines the access categories of different Management frames. Only QoS STAs are able to implement QMF policy. A non-AP QMF STA uses the default QMF policy or the QMF policy accepted from a peer QMF STA to transmit Management frames to that peer QMF STA. A QMF AP sets its own QMF policy for the transmission of QMFs to its associated STAs. A QMF STA uses access category AC_VO to transmit Management frames to STAs that do not support the QMF service.

### 4.5.7 Support for higher layer timer synchronization

Some applications, e.g., the transport and rendering of audio or video streams, require synchronized timers shared among different STAs. Greater accuracy (in terms of jitter bounds) or finer timer granularity than that provided by a BSS timing synchronization function (TSF) might be an additional requirement. In support of such applications, this standard defines a MAC service that enables layers above the MAC to accurately synchronize application-dependent timers shared among STAs. The service is usable by more than one application at a time.

Although the timer synchronization methods and accuracy requirements are application-dependent and are beyond the scope of this standard, they rely on an indication from each MAC that is provided essentially simultaneously, via group addressed transmissions, to the STAs. The MAC accomplishes this by indicating the occurrence of the end of the (#14)PPDU[+SigExt] containing particular Data frames; the Data frames of interest are identified by their MAC header Address 1 field when it contains a group address previously registered with the MAC. (#14)The end of the PPDU[+SigExt] is observed[20] on the WM by STAs within a

[20] The synchronization indication (observed time) within the BSS varies slightly due to propagation.


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BSS while the delay between the observation and the delivery of the indication is known within a MAC by design (and communicated to the application by implementation dependent means). The common reference point in time provided by the end of (#14)the PPDU[+SigExt] indication is the essential building block upon which a variety of application-dependent timer synchronization methods might be based.

### 4.5.8 Radio measurement service

The Radio measurement service provides the following:

- The ability to request and report radio measurements in supported channels.
- The ability to perform radio measurements in supported channels.
- An interface for upper layer applications to retrieve radio measurements using MLME primitives and/or MIB access.
- Information about neighbor APs.

### 4.5.9 Interworking with external networks

#### 4.5.9.1 General

The interworking service allows non-AP STAs to access services provided by an external network according to the subscription or other characteristics of that external network. An IEEE 802.11 non-AP STA might have a subscription relationship with an external network, e.g., with an SSPN.

An overview of the interworking functions addressed in this standard is provided below:

- Network discovery and selection
  - Discovery of suitable networks through the advertisement of access network type, roaming consortium and venue information, via Management frames
  - Selection of a suitable IEEE 802.11 infrastructure using advertisement services (e.g., access network query protocol (ANQP) or an IEEE 802.21™ Information Server) in the BSS or in an external network reachable via the BSS.
  - Selection of an SSPN or external network with its corresponding IEEE 802.11 infrastructure
- Preassociation discovery (PAD)
  - Discovery of services offered by a BSS or an external network reachable via that BSS
- Emergency services
  - Emergency Call and Network Alert support at the link level
- QoS mapping distribution
- SSPN interface service between the AP and the SSPN

The generic advertisement service (GAS), described in 4.5.10 (Generic advertisement service (GAS)), provides both support for a STA's network discovery and selection, and support for a conduit for communication by a non-AP STA with other information resources in a network before joining the wireless LAN.

The interworking service supports emergency services by providing methods for users to access emergency services via the IEEE 802.11 infrastructure, advertising that emergency services are supported (see 11.22.6 (Interworking procedures: emergency services support)) and identifying that a traffic stream is used for emergency services.

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The interworking service provides QoS mapping for SSPNs and other external networks. Since each SSPN or other external network might have its own layer-3 end-to-end packet marking practice (e.g., differentiated services code point (DSCP) usage conventions), a means to remap the layer-3 service levels to a common over-the-air service level is necessary. The QoS Map service provides STAs a mapping of network-layer QoS packet marking to over-the-air QoS frame marking (i.e., user priority).

The SSPN Interface service supports service provisioning and transfer of user permissions from the SSPN to the AP. The method and protocol by which these permissions are transferred from the SSPN are outside the scope of this standard.

#### 4.5.9.2 Preassociation discovery (PAD)

##### 4.5.9.2.1 Introduction

PAD is an interworking function provided by a BSS to allow a non-AP and non-PCP STA, prior to association, to discover information concerning services that might be available to the STA when it is associated with the BSS. PAD provides a method for the STA to gather information to aid in the decision to select a BSS with which to become a member.

##### 4.5.9.2.2 Architecture

Figure 4-19 (Unsolicited PAD architecture) and Figure 4-20 (Solicited PAD architecture(#576)(#4113)) show the functional flow of MAC messaging and service information between a service information client (SIC) and a service information registry (SIR). These entities are described in 4.5.9.2.3 (Service information entities), 4.5.9.2.4 (Service information registry (SIR)), and 4.5.9.2.5 (Service information client (SIC)). The active components within the architecture differ depending upon whether unsolicited or solicited PAD is being used.


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NOTE—A SIR can be either (#2210)colocated with the AP or outside the AP. An SIR can only be (#2210)colocated with a PCP. The communications between the SIR and the AP, together with the SIR and the advertisement server(#576) are out of the scope of this standard.

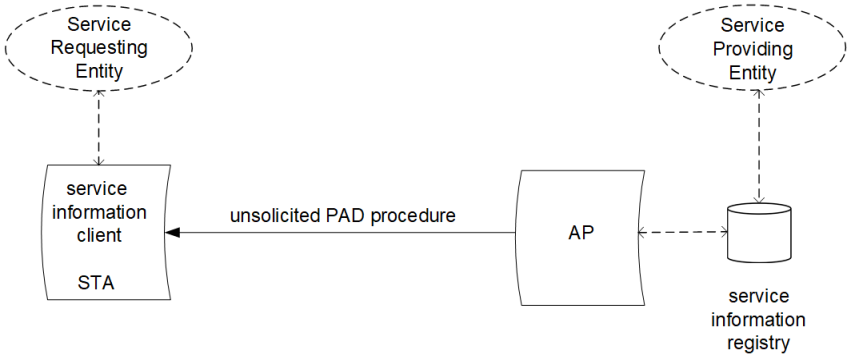


**Figure 4-19—Unsolicited PAD architecture**

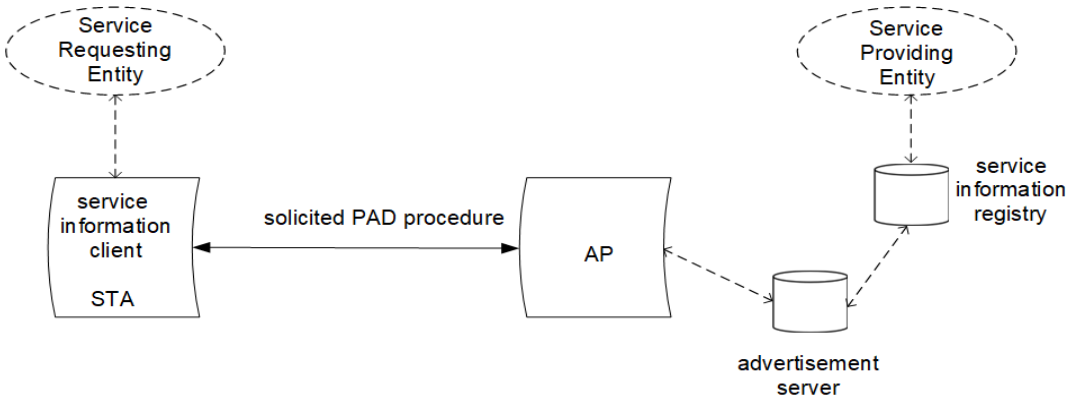


**Figure 4-20—Solicited PAD architecture(#576)(#4113)**

The unsolicited PAD procedure is described in 11.23.2 (Unsolicited PAD procedure) and solicited PAD procedure is described in 11.23.3 (Solicited PAD procedure).

#### 4.5.9.2.3 Service information entities

The SIC and SIR are used to exchange PAD service information. The PAD procedures operate between the SIC and SIR.

#### 4.5.9.2.4 Service information registry (SIR)

The SIR caches information about services that might be reachable via the BSS and therefore might be available to the STA once the STA is associated with that BSS. How the SIR obtains the information about services is outside the scope of this standard.

There is typically one SIR assigned to each ESS. It can be addressed by each AP and each service within that ESS. It includes supporting service discovery requests and responses from the BSS.

The SIR communicates with the advertisement server(#576) to respond to ANQP requests.

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#### 4.5.9.2.5 Service information client (SIC)

The SIC initiates service discovery. The SIC exchanges service discovery requests and responses between the SME and applications.

The SME determines whether to use unsolicited PAD or solicited PAD procedures. The SME also composes ANQP requests for solicited PAD procedures.

### 4.5.10 Generic advertisement service (GAS)

GAS provides functionality that enables STAs to discover the availability of information related to desired network services, e.g., information about services such as provided in an IBSS, local access services, available subscription service providers (SSPs) and/or SSPNs or other external networks. GAS uses a generic container to advertise network services' information over an IEEE 802.11 network. Public Action frames are used to transport this information.

While the specification of network services information is outside the scope of this standard, in an infrastructure BSS there is a need for STAs to query for information on network services provided by SSPNs or other external networks beyond an AP, before they associate with the wireless LAN. The exchange of information can also be performed after associating to the BSS.

In an IBSS/PBSS, GAS functionality enables a STA to access the availability and information related to desired services provided by other STAs in the IBSS/PBSS. Exchange of information using GAS can be performed either prior to joining an IBSS/PBSS or after joining the IBSS/PBSS.

There are a number of reasons why providing information to a STA in a preassociated state is beneficial:

— It supports more informed decision making about an IEEE 802.11 infrastructure BSS or PBSS of which to become a member. This is generally more efficient than requiring a non-AP and non-PCP STA to associate with an AP or PCP before discovering the information and then deciding whether to stay associated.
— It is possible for the non-AP and non-PCP STA to query multiple networks in parallel.
— The non-AP STA can discover information about APs that are not part of the same administrative group as the AP with which it is associated, supporting the selection of an AP belonging to a different IEEE 802.11 infrastructure that has an appropriate SSP roaming agreement in place.

### 4.5.11 Wake-up radio (WUR) services(11ba)

The WUR service allows non-AP STAs to have access to basic services provided by a BSS while operating at very low power. The basic WUR services that the BSS might provide to non-AP STAs include discovery, synchronization, and wake up instructions (scheduled or unscheduled).

### 4.5.12 Enhanced broadcast services(11bc)

#### 4.5.12.1 General

Enhanced broadcast services (EBCS) provide the enhanced transmission and reception of broadcast content, both while associated with an infrastructure BSS and while not associated with an infrastructure BSS. EBCS provides a service in which an EBCS proxy affiliated with an EBCS relaying STA can relay the contents of a higher layer protocol (HLP) payload received from an EBCS non-AP STA to a destination typically within an external network. The relaying EBCS proxy can embed additional information.

When there is an association, EBCS provides additional means for protecting broadcast traffic and the privacy of the stations receiving that traffic, including data origin authenticity.


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#### 4.5.12.2 EBCS DL service

##### 4.5.12.2.1 General

The EBCS DL service provides a mechanism for an EBCS AP to broadcast one or more EBCS traffic streams. The service allows the receiver of an EBCS traffic stream to authenticate the transmitter irrespective of whether the receiver and transmitter are associated with the EBCS AP.

##### 4.5.12.2.2 EBCS traffic stream mapper

The EBCS traffic stream mapper is used to map multicast traffic arriving from an EBCS DL content server to EBCS traffic streams. The EBCS traffic stream mapper exists only in an EBCS AP. The location of the EBCS traffic stream mapper is shown in Figure 5-1 (MAC data plane architecture (#7109)(#4149)(#1001)(11ay)(#3186)(#3185)(#4172)(#4192)(11bc)). It inspects the inbound traffic and assigns the content ID and the corresponding EBCS content MAC address according to dot11EBCSTrafficStreamTable.

##### 4.5.12.2.3 EBCS filter

The EBCS filter exists only in an EBCS receiver. The EBCS filter is located in the MAC data plane as shown in Figure 5-1 (MAC data plane architecture (#7109)(#4149)(#1001)(11ay)(#3186)(#3185)(#4172)(#4192)(11bc)). It filters the received EBCS traffic streams by their EBCS content MAC address according to dot11EBCSTrafficStreamTable. Details are described in 34.3.3 (EBCS DL procedure at an EBCS receiver).

##### 4.5.12.2.4 Example of EBCS DL operation

Figure 4-21 (Example of EBCS DL operation(11bc)) provides an example of EBCS DL operation.

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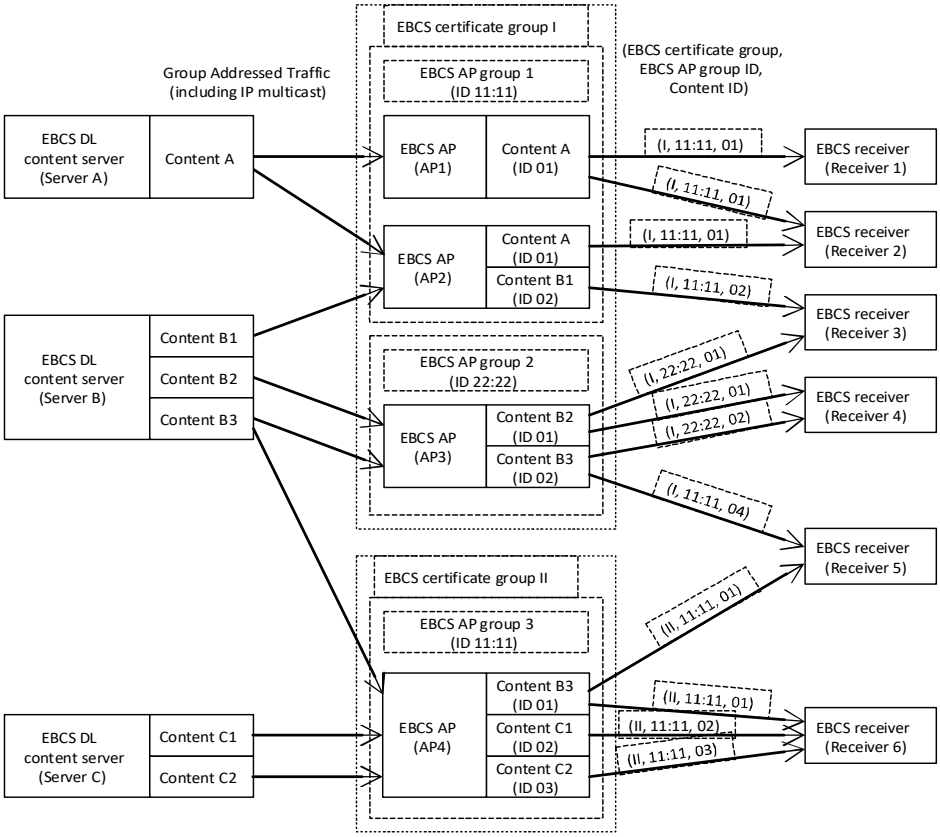


**Figure 4-21—Example of EBCS DL operation(11bc)**

EBCS DL content servers are distributing group addressed traffic streams. Each EBCS DL content server can distribute multiple traffic streams that can be identified by the source MAC address and the destination MAC address. If a traffic stream is an IP multicast traffic stream, the traffic stream is identified by the source IP address, the destination IP address, and the destination UDP port.

Server A in Figure 4-21 (Example of EBCS DL operation(11bc)) distributes Content A. Server B distributes Content B1, Content B2, and Content B3. Server C distributes Content C1 and Content C2.

An EBCS AP can receive multiple traffic streams from one or more EBCS DL content server(s). The SME in an EBCS AP selects traffic streams to be broadcast by setting the appropriate values in dot11EBCSTrafficStreamTable. An EBCS AP broadcasts the selected traffic streams as EBCS traffic streams. An EBCS AP can add authentication information to the streams.

AP1, AP2, and AP3 belong to the EBCS certificate group I. AP1 and AP2 belong to EBCS AP group 1 with an AP group ID of 11:11. AP3 belongs to the EBCS AP group 2 with a group ID of 22:22. AP4 belongs to the EBCS certificate group II and the EBCS AP group 3 with an AP group ID of 11:11. Although both the EBCS AP group 1 and EBCS AP group 3 use the EBCS AP group ID of 11:11, they are different EBCS AP groups as they belong to different EBCS certificate groups.

AP1 in Figure 4-21 (Example of EBCS DL operation(11bc)) receives and broadcasts Content A. AP2 receives and broadcasts Content A and Content B1. AP3 receives and broadcasts Content B2 and Content B3. AP4 receives and broadcasts Content B3, Content C1, and Content C2.


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An EBCS receiver can receive multiple EBCS traffic streams from one or more EBCS AP(s). An EBCS receiver filters EBCS traffic streams to be consumed using the EBCS filter. Each EBCS traffic stream can be authenticated if the transmitting EBCS AP adds authentication information.

Receiver 1 in Figure 4-21 (Example of EBCS DL operation(11bc)) can receive Content A from AP1. Receiver 2 can receive Content A from both AP1 and AP2. Receiver 3 can receive Content B1 from AP2 and Content B2 from AP3. Receiver 4 can receive both Content B2 and Content B3 from AP3. Receiver 5 can receive Content B3 from both AP3 and AP4. Receiver 6 can receive Content B3, Content C1, and Content C2 from AP4.

Receiver 2 can potentially recognize the presence of multiple copies of Content A by receiving from 2 APs as both EBCS traffic streams from AP1 and AP2 belong to the same EBCS certificate group and the same EBCS AP group, and have the same Content ID. Receiver 5 cannot recognize the presence of multiple copies of Content B3 as the EBCS traffic streams from AP3 and AP4 belong to the different EBCS certificate groups and different EBCS AP groups. Receiver 5 has to assume the two versions include different content.

#### 4.5.12.3 EBCS relaying service

##### 4.5.12.3.1 General

The EBCS relaying service facilitates EBCS UL operation (as described in 34.4 (EBCS UL procedure)) by providing a mechanism for an EBCS non-AP STA to transmit an EBCS UL frame containing an HLP payload that is intended to be relayed by one or more EBCS relaying STAs to a destination specified in the frame.

##### 4.5.12.3.2 EBCS proxy operation

An EBCS proxy, as a part of providing relaying service, evaluates certain criteria before relaying the HLP payload carried in an EBCS UL frame to the destination specified in the frame. Such criteria can include, but are not limited to, verifying the STA certificate, if present, to determine whether the STA transmitting the frame is authorized to send an HLP payload to the specified destination, performing replay checking, and limiting the per destination amount (e.g., octets) or per destination frequency (e.g., packets per second) of HLP payload that is relayed to the specified destination. The evaluation of the criteria can be based on local policies installed at the EBCS proxy and/or based on a relationship established with an entity at the specified destination. The establishment of such a relationship is out of scope of this standard.

An EBCS proxy can establish more than one relationship, each relationship with entities residing at a different destination and potentially requiring different evaluation criteria. An EBCS proxy can establish more than one relationship with the same entity, each matching a different destination URI and requiring evaluation of different criteria.

An EBCS proxy can also embed additional information before it relays the HLP payload. The format and content of the information embedded are based on the agreement with the specified destination. The relaying service is best effort and the EBCS proxy can decide not to relay the HLP payload if any of the implemented criteria for relaying are not satisfied or for any other reason.

For example, an AP vendor (or an operator) that has one or more APs deployed at a certain venue (such as an airport or a hotel) can establish a business relationship with one or more cloud providers (such as the one that specializes in baggage tracking or logging of sensor data). The AP vendor (or the operator) can configure (default) rules at an EBCS proxy (which is affiliated with the APs at the venue) for providing the relaying service while additional (destination specific) rules are set up based on the service agreement with the cloud provider. Based on these rules an EBCS proxy determines whether to relay the HLP payload carried in an EBCS UL frame that it receives. For example, if it receives an EBCS UL frame with a

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destination that is not part of any agreement, then based on local policies, it will not relay the HLP payload carried in the frame. Similarly, if the authentication of the EBCS UL frame fails, then based on the relationship with the entity at the specified destination, it will not relay the HLP payload carried in the frame.

NOTE 1 —The communication between an EBCS relaying STA and its affiliated EBCS proxy and the communication between an EBCS proxy and a specified destination are out of scope of this standard.

NOTE 2 —An EBCS proxy evaluating various criteria before it relays an HLP payload helps reduce the likelihood of a DoS attack on the specified destination.

NOTE 3—An operator can install one or more EBCS relaying STAs at a certain location with the intention of only providing relaying service. In such a deployment scenario, the EBCS relaying STAs will not beacon or establish an infrastructure BSS.

#### 4.5.12.3.3 Example configurations for EBCS proxy

The figures in this subclause show EBCS APs each affiliated with their respective EBCS proxy providing relaying service. However, the same explanation would apply if any of the EBCS APs is replaced with an EBCS relaying STA that does not transmit a Beacon frame.

Figure 4-22 (Illustration of relaying operation at EBCS APs with collocated EBCS proxy(11bc)) provides an example of the relaying service based on a relationship with a specified destination.

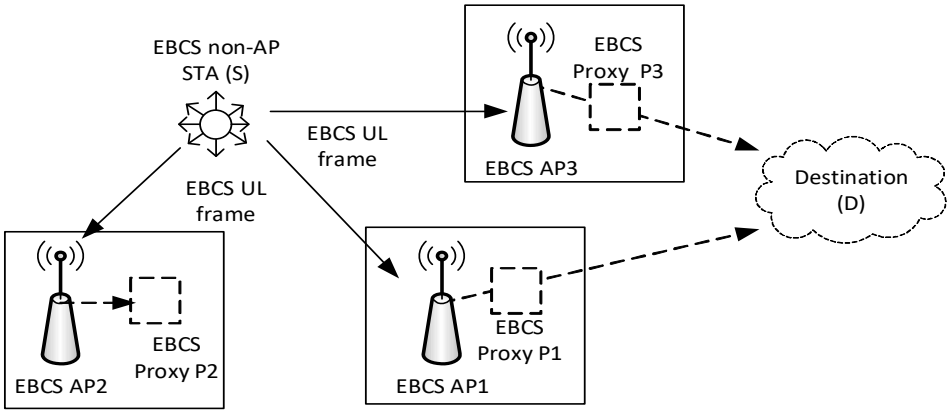


**Figure 4-22—Illustration of relaying operation at EBCS APs with collocated EBCS proxy(11bc)**

In this figure, EBCS proxies P1, P2 and P3 are collocated with EBCS APs A1, A2, and A3, respectively. EBCS proxy P1 and EBCS proxy P3 have established a relationship with a destination (D). An EBCS non-AP STA (S) transmits an EBCS UL frame that is received by EBCS APs in the neighborhood (i.e., AP1, AP2, and AP3). The EBCS UL frame carries the HLP payload, a field carrying the address of D and other fields for security. P1 and P3 verify the certificate of S based on their agreement with D and perform a replay check to determine whether the criteria for relaying the HLP payload to D are met. If the local policy or the agreement with D requires limiting the amount or frequency of payloads being sent to D, then P1 and P3 determine whether or not to relay their received payloads to D, based on whether or not prior transmissions have reached the limit. If the agreement with D requires the inclusion of additional information, P1 and P3 embed appropriate information, before relaying the HLP payload. In Figure 4-22 (Illustration of relaying operation at EBCS APs with collocated EBCS proxy(11bc)), EBCS AP2 discards the EBCS UL frame. This could be for any number of reasons such as that the AP does not provide a relaying service, that the AP's collocated proxy has not established a relationship with D, or that one or more criteria for relaying have not been satisfied.


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NOTE—If an entity at a destination has relationships with multiple EBCS proxies, it might, as part of the agreement with each proxy, set a relaying limit (e.g., amount or frequency of relaying per proxy) so that the aggregate from all the proxies is below a certain threshold. In addition, EBCS proxies might collaborate to limit the aggregate payload being relayed to the specified destination. Such mechanisms are out of scope of this standard.

In another example, depicted in Figure 4-23 (Illustration of relaying when EBCS proxy is not collocated within an EBCS AP(11bc)), the EBCS proxy (P) is not collocated with either EBCS AP1 or EBCS AP3, but resides on an entity (such as a network controller) in the LAN that AP1 and AP3 belong to. EBCS AP1 and EBCS AP3 send the contents of the EBCS UL frame to P, which evaluates whether the criteria for relaying are met before it relays a single copy of the HLP payload to the specified destination.

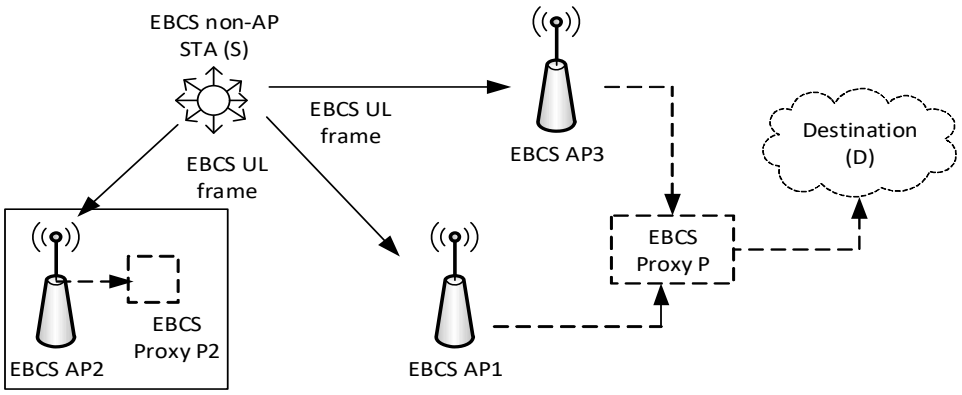


**Figure 4-23—Illustration of relaying when EBCS proxy is not collocated within an EBCS AP(11bc)**

The configuration shown in Figure 4-23 (Illustration of relaying when EBCS proxy is not collocated within an EBCS AP(11bc)) could be prevalent in commercial deployments, such as airports, train stations, malls, or a warehouse, where multiple EBCS APs are likely to be connected to a single entity on a common LAN (such as a network controller), which provides access to destinations outside the LAN. In such a configuration, the EBCS proxy resides on an entity in the LAN. On the other hand, the configuration shown in Figure 4-22 (Illustration of relaying operation at EBCS APs with collocated EBCS proxy(11bc)) could be prevalent in residential deployments where an EBCS AP has direct connectivity to destinations outside the LAN.

## 4.6 Multiple logical address spaces

Just as the IEEE 802.11 architecture allows for the possibility that the WM, DSM, and an integrated non-IEEE-802.11 LAN might all be different physical media, it also allows for the possibility that each of these components might be operating within different address spaces. IEEE Std 802.11 uses and specifies only the use of the WM address space.

Each IEEE 802.11 PHY operates in a single medium—the WM. The IEEE 802.11 MAC operates in a single address space. MAC addresses are used on the WM in the IEEE 802.11 architecture. Therefore, it is unnecessary for the standard to explicitly specify that its addresses are “WM addresses.” This is assumed throughout this standard.

IEEE Std 802.11 has chosen to use the IEEE 802 48-bit address space (see 9.2.4.3.2 (Address representation)). Thus IEEE 802.11 addresses are compatible with the address space used by the IEEE 802 LAN family.

The IEEE 802.11 choice of address space implies that for many instantiations of the IEEE 802.11 architecture, the non-IEEE-802.11 LAN MAC address space and the IEEE 802.11 MAC address space

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might be the same. In the situations where a DS that uses MAC-level IEEE 802 addressing is appropriate, all three of the logical address spaces used within a system could be identical. While this is a common case, it is not the only combination allowed by the architecture. The IEEE 802.11 architecture allows for all three logical address spaces to be distinct. In the GLK case, IEEE 802.1Q bridges are included in the network topology; therefore, the wired LAN MAC address space and IEEE 802.11 MAC address space are the same

A multiple address space example is one in which the DS implementation uses network layer addressing. In this case, the WM address space and the DS address space are different.

Note that IEEE 802.11 STAs within a single ESS share the same address space, fulfilling the transparency requirement from the definition of the DS. The DSS uses this same address space, even in the case where the DSM uses a different address space.

The ability of the architecture to handle multiple logical media and address spaces is key to the ability of IEEE Std 802.11 to be independent of the DS implementation and to interface cleanly with network layer mobility approaches. The implementation of the DS is unspecified and is beyond the scope of this standard.

## 4.7 Differences among ESS, PBSS, and IBSS LANs

In 4.3.2 (Independent BSS (IBSS)) the concept of the IBSS LAN was introduced, and in 4.3.3 (Personal BSS (PBSS)) the concept of the PBSS LAN was introduced. In an IBSS or PBSS, a STA communicates directly with one or more other STAs.

Consider the full IEEE 802.11 architecture as shown in Figure 4-24 (IEEE 802.11 architecture (again)(#1296)).

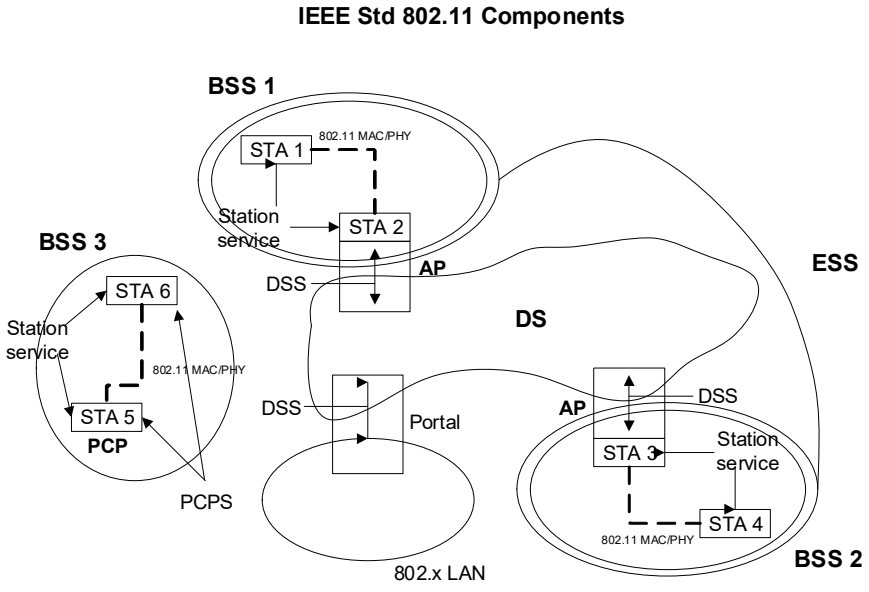


**Figure 4-24—IEEE 802.11 architecture (again)(#1296)**


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An IBSS consists of STAs that are directly connected. Thus there is (by definition) only one BSS. Further, because there is no physical DS, there is no portal, integrated non-IEEE-802.11 LAN, or DSS. The logical picture reduces to Figure 4-25 (Logical architecture of an IBSS(#1296)).

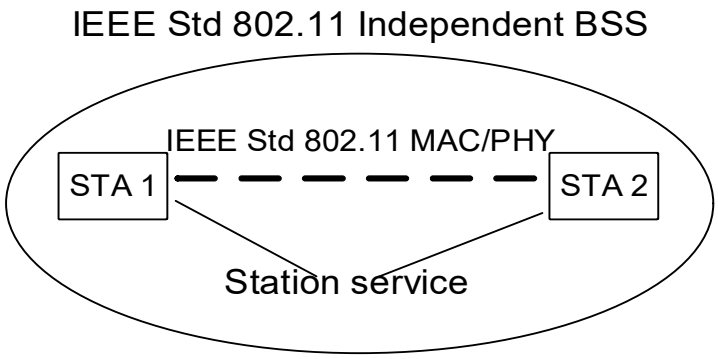


**Figure 4-25—Logical architecture of an IBSS(#1296)**

An important difference between the IBSS and the PBSS is that, within the PBSS, Beacon frames are not transmitted by every STA and instead only a single STA, namely the PCP, is responsible for DMG Beacon frame transmission. Within the IBSS, all STAs are responsible for Beacon frame transmission. When compared to the infrastructure BSS, the PBSS does not provide certain DSSs as described in 4.4.3 (PBSS control point service (PCPS)).

There can be more than one PBSS in the same BSA. One of the STAs within each PBSS assumes the role of the PCP. The logical picture of the PBSS reduces to Figure 4-26 (Logical architecture of a PBSS(#1296)).

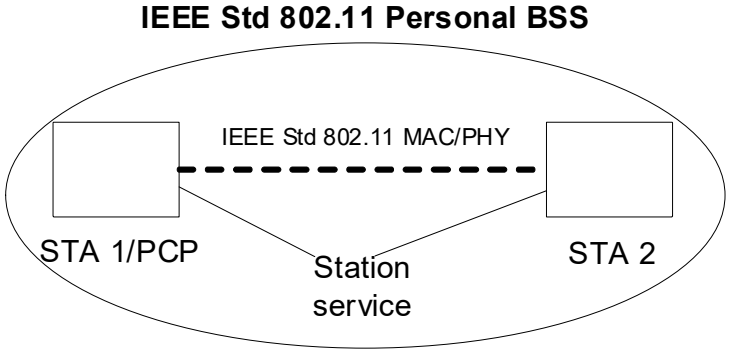


**Figure 4-26—Logical architecture of a PBSS(#1296)**

Only the minimum two STAs are shown in Figure 4-25 (Logical architecture of an IBSS(#1296)). An IBSS can have an arbitrary number of members. In an IBSS only Class 1 and Class 2 frames are allowed because there is no DS in an IBSS.

The services that apply to an IBSS are the SSs. A QoS IBSS supports operation under the HCF using TXOPs gained through the EDCA mechanism. The parameters that control differentiation of the delivery of MSDUs with different priority using EDCA are fixed. A QoS IBSS has no HC and does not support polled TXOP operation and setting up of TSPEC.

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The services that apply to the PBSS are the SSs and the PCPSs as described in 4.4.3 (PBSS control point service (PCPS)). A PBSS supports operation under the HCF using TXOPs gained through the EDCA mechanism. In a PBSS, the EDCA mechanism is used only within CBAPs. The parameters that control differentiation of traffic classes using EDCA can be configured by the PCP in a PBSS. The PCP of a PBSS has no HC, but can support TSPEC setup, DMG TSPEC setup, and service periods.

(#1705)In an IBSS, each STA enforces a uniform security policy across all STAs. In an infrastructure BSS or a PBSS, an AP or a PCP(#1514)(#3284), respectively, enforce a uniform security policy across all STAs, for all links to the AP or PCP.

## 4.8 Differences between ESS and MBSS LANs

In 4.3.24 (Mesh BSS), the concept of the MBSS LAN was introduced. It was noted that, using the multi-hop capability, (#6268)the MAC service of a STA in an MBSS appears to provide the exchange of MSDUs directly to any other STA in the MBSS, even if the STAs are not within range of each other. This is different from an IBSS, where STAs cannot communicate if they are not within range of each other.

Unlike the IBSS, an MBSS might have access to (#7098)one or more DSs. An MBSS connects through one or more mesh gates to (#7098)one or more DSs.

(#7099)Since in an MBSS it appears (#6268)at the MAC service interface as if all mesh STAs provide the direct exchange of MSDUs, the MBSS can be used as a DSM. APs, a portal, and mesh gates might use the MBSS as a DSM to provide the DSS. Thus, different infrastructure BSSs can unite over the MBSS to form an ESS for example.

An AP identifies the infrastructure BSS that it forms. This is different from the MBSS where no such central entity exists. Whereas infrastructure BSSs need the ESS and thus the DS to unite, the MBSS appears the same to an LLC layer without the need for access to a DS. However, if an MBSS has one or more mesh gates providing access (#7098)to the DS(s), the MBSS might exist in disjointed areas and yet form a single network.

## 4.9 Reference model

### 4.9.1 General

This standard presents the architectural view, emphasizing the separation of the system into two major parts: the MAC of the data link layer (DLL) and the PHY. These layers are intended to correspond closely to the lowest layers of the ISO/IEC basic reference model of Open Systems Interconnection (OSI) (ISO/IEC 7498-1:1994). The layers and sublayers described in this standard are shown in Figure 4-27 (Portion of the ISO/IEC basic reference model covered in this standard(#4114)).

There is an interface between the IEEE 802.1X Supplicant and Authenticator and the SME not shown in Figure 4-27 (Portion of the ISO/IEC basic reference model covered in this standard(#4114)). This interface is described in (#3469)IEEE Std 802.1X-2020.

### 4.9.2 Interworking reference model

The MAC state generic convergence function (MSGCF) provides services to higher layer protocols based on MAC state machines and interactions between the layers.

Interworking functions might require correlating information from multiple management entities. It is the function of the MSGCF to correlate information for higher layer entities. The MSGCF observes the


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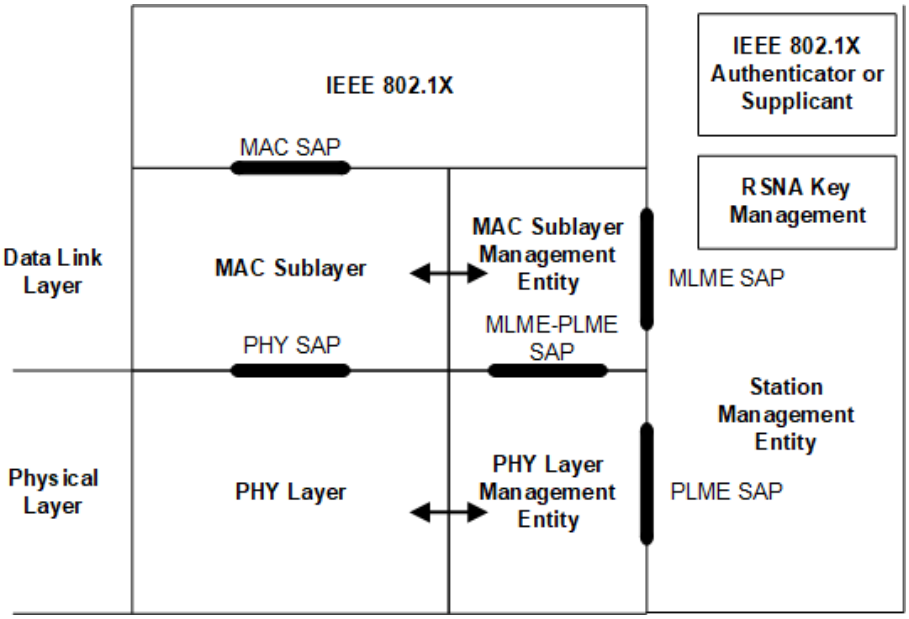


**Figure 4-27—Portion of the ISO/IEC basic reference model covered in this standard(#4114)**

interactions between the MLME and SME, and between the PLME and SME. After correlation of lower-layer MLME and PLME events, the MSGCF might synthesize indications to higher layer entities.

Figure 4-28 (Interworking reference model(#4114)) shows an entity, the MSGCF, defined in 6.4 (Table of MLME SAP interfaces(#1114)), that has access to all management information through exposure to the MAC sublayer and PHY management entities, and provides management information to higher level entities, such as Mobility Managers, supporting heterogeneous medium mobility.

An example of how the MSGCF interfaces to these higher layer entities, is provided by the media independent service (MIS) interface, as defined in IEEE Std 802.21-2017.

The MSGCF is designed to provide the status of the connection of a non-AP STA to a set of BSSs comprising a single ESS. Figure 4-29 (ESS link illustration) illustrates the concept of an ESS link. This reflects the state of a connection to an ESS independent of any particular access point. In Figure 4-29 (ESS link illustration), STA3 is associated with either AP1 or AP2. The state of the ESS link is up when STA3 is associated with any of the APs comprising an ESS.

### 4.9.3 Reference model for supporting multiple MAC sublayers

An MM-SME function interfaces with the SMEs of the coordinating STAs. STAs managed under the MM-SME share the same antennas and PHY and optionally unify power management. The reference model for supporting multiple MAC sublayers is shown in Figure 4-30 (Reference model for supporting multiple MAC sublayers).(#4086)

An MM-SME coordinates the management of multiple MAC sublayers. Each MAC sublayer has a separate MAC SAP and MLME SAP. A MAC SAP together with its corresponding MLME SAP is identified by a MAC address.

Even when coordinated by an MM-SME, each MAC retains its single MAC address, and each STA contains a single MAC; therefore, the MM-SME coordinates multiple STAs as well as multiple MACs.

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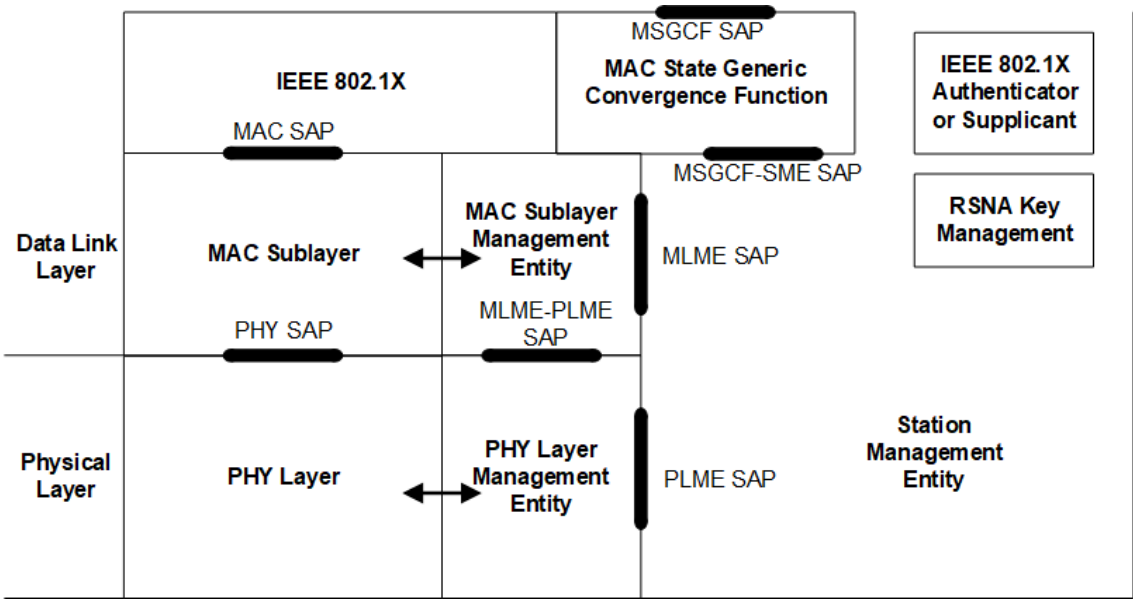


**Figure 4-28—Interworking reference model(#4114)**

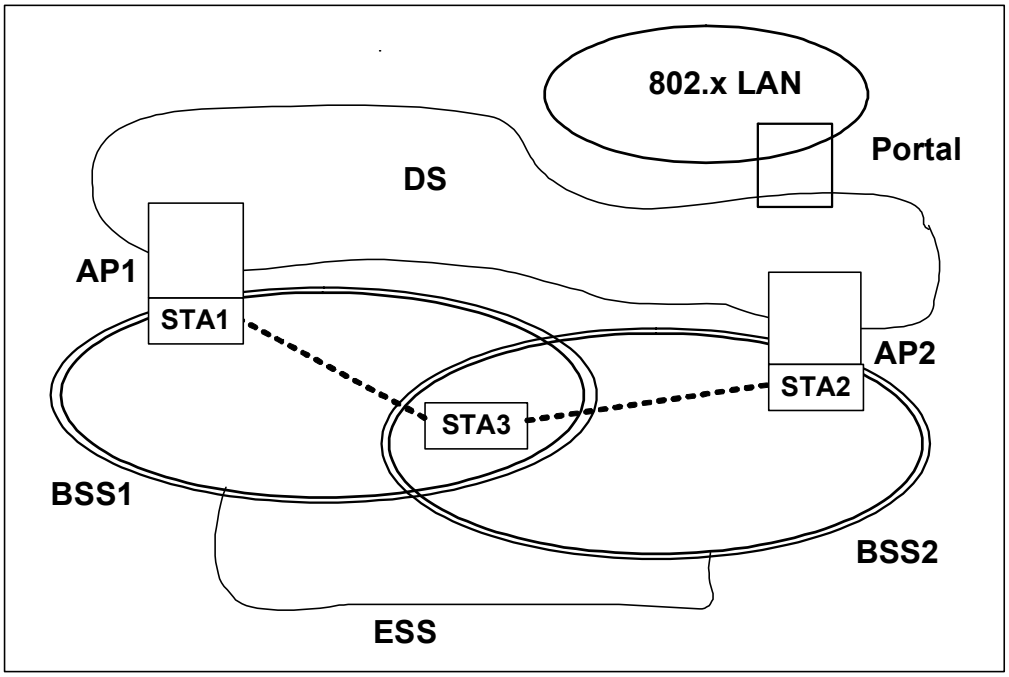


**Figure 4-29—ESS link illustration**

Multiple STAs coordinated by an MM-SME have a single PHY that is shared by the multiple MAC sublayers. Transmission attempts of different MAC sublayers can collide internally if the STAs share a single PHY, and a backoff procedure is invoked in this case. Since multiple STAs coordinated by the same MM-SME share the PHY, the STAs cannot directly exchange frames with each other.


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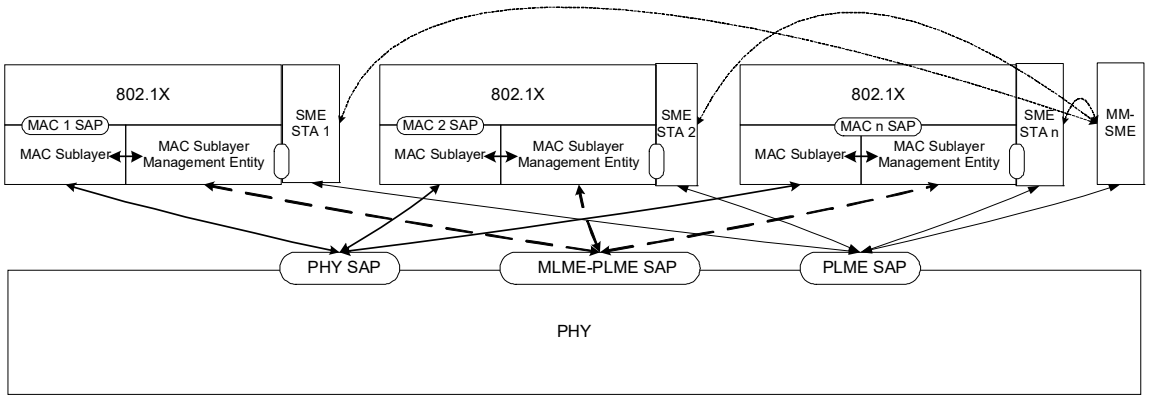


**Figure 4-30—Reference model for supporting multiple MAC sublayers**

NOTE—The multiple MAC reference model shown in Figure 4-30 (Reference model for supporting multiple MAC sublayers) defines how multiple STAs can share the same physical layer entity. If this model is used in conjunction with the reference model for multi-band operation (see 4.9.4 (Reference model for multi-band operation)), the multiple MAC reference model applies within each physical layer entity contained in the multi-band device, whereas the multi-band operation reference model applies to different physical layers.

The MM-SME accesses each of the MLME SAPs of the coordinated STAs separately to deliver MLME SAP primitives. STAs that are coordinated by the same MM-SME can establish a multiple MAC sublayers link (MMSL) with a peer STA. The set of all MMSLs between a pair of STAs creates an MMSL cluster.

An MM-SME controls the power management mode, DMG antenna configuration, and other parameters and states of the coordinated STAs to eliminate unnecessary duplication of functions. A change in the power management mode of the STAs coordinated by an MM-SME is signaled to a peer STA via any one of the STAs' MAC sublayer. Also, a beamforming link established between STAs can be used by all of the MAC sublayers of any of the STAs coordinated by the same MM-SME. For these purposes, (#1776)an MMS element is used.

The MMS element contains multiple MAC addresses of the MACs coordinated by the same MM-SME. The element can be included in any frame that advertises the MM-SME capabilities, such as Probe Request and Probe Response frames and Information Request and Information Response frames, and the frames that establish communication agreements, such as Association, ADDTS Request, ADDTS Response, BlockAckReq, and BlockAck.

### 4.9.4 Reference model for multi-band operation

The reference model of a device that is multi-band capable (see 11.31 (Multi-band operation)) and that supports transparent fast session transfer (FST) is shown in Figure 4-31 (Reference model for a multi-band capable device (transparent FST)). The reference model of a device that is multi-band capable and that supports nontransparent FST is shown in Figure 4-32 (Reference model for a multi-band capable device (nontransparent FST)).

A multi-band capable device can manage operation over more than one frequency band/channel. The operation across the different frequency bands/channels can be simultaneous or nonsimultaneous.

A multi-band capable device can also support multiple MAC sublayers; in this case, it is coordinated by an MM-SME.

NOTE—For simplicity, Figure 4-31 (Reference model for a multi-band capable device (transparent FST)) and Figure 4-32 (Reference model for a multi-band capable device (nontransparent FST)) depict the reference model when there is a

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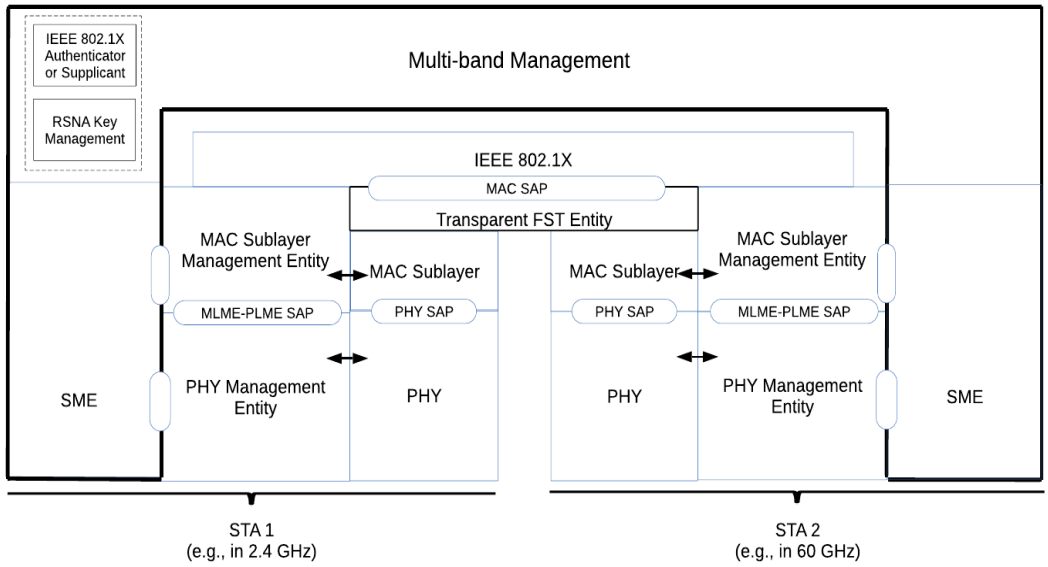


**Figure 4-31—Reference model for a multi-band capable device (transparent FST)**

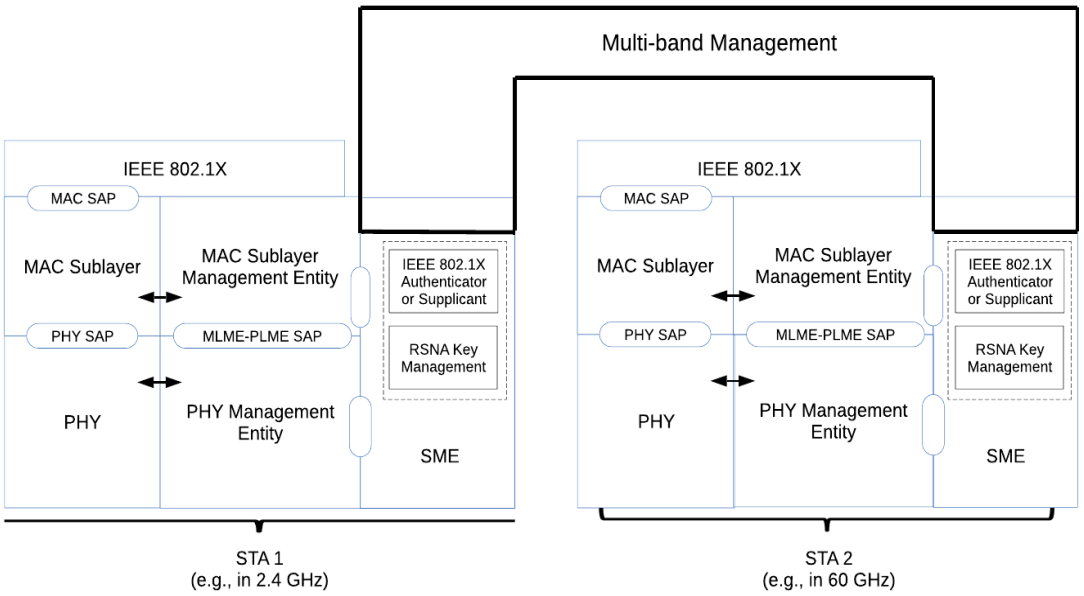


**Figure 4-32—Reference model for a multi-band capable device (nontransparent FST)**

one-to-one mapping between PHYs and MACs. However, the reference model for a multi-band capable device can be applied in conjunction with the reference model for STAs that support multiple MAC sublayers (see 4.9.3 (Reference model for supporting multiple MAC sublayers)).

When used in the context of FST, the term “session” refers to non-PHY state information that is kept in a pair of STAs that communicate directly (i.e., excludes forwarding) and that is available prior to and


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following a fast session transfer. This state information is different depending if transparent or nontransparent is used. For transparent FST, a shared multi-band management entity has access to the local information within each SME; and in this case the state information includes sequence numbers, block ack agreements, TSs, association state, RSNA, security keys, replay counters, and PN counters.(#1938) For nontransparent FST, the function of the multi-band management entity is restricted to coordinating the setup and teardown of a fast session transfer with no access to other local information within each SME. Therefore, with nontransparent FST, any information local to an SME needs to be reestablished for the new band/channel, and this can be done either prior to or following the fast session transfer (see 11.31 (Multi-band operation)).

The SME of a multi-band capable device contains a multi-band management entity that is responsible for coordinating the setup, configuration, teardown, and transfer of FST sessions from a band/channel to another band/channel supported by the multi-band capable device. If using nontransparent FST, the multi-band management entity can employ a combination of the source and destination MAC addresses in both the old and new band/channel to configure the routing of MSDUs and MLME primitives within the STA. If using transparent FST, in addition to the MAC addresses, the multi-band management entity can employ the TID of an FST session for this routing.

The multi-band procedures (see 11.31 (Multi-band operation)) allow a pair of multi-band capable devices to discover, synchronize, (de)authenticate, (re)associate, disassociate, and manage resources with each other on any common band/channel that is supported by both STAs.

By using the on-channel tunneling (OCT) multi-band procedure described in 11.31.5 (On-channel Tunneling (OCT) operation), the SME of a multi-band capable device can instruct one of its MLMEs to use the OCT services provided by another MLME of the same multi-band capable device to communicate with a peer MLME of a peer multi-band capable device. This enables the SMEs of a pair of multi-band capable devices to provide a seamless FST, including performing (de)authentication and (re)association across bands/channels. The MLMEs that use the OCT services provided by another MLME within the same multi-band capable device to communicate are referred to as being *over-the-WM disabled* with respect to each other. Following a frame exchange on the new band/channel (e.g., after FST), two peer over-the-WM disabled MLMEs can become over-the-WM enabled with respect to each other.

(11ay)By using the discovery assistance feature described in 11.31.7 (Multi-band discovery assistance procedure(11ay)), the SME of a multi-band capable device can trigger one of its MLMEs to start the discovery assistance procedure for its operating band upon reception of a multi-band discovery assistance request from another MLME of the same multi-band capable device. The multi-band discovery assistance request is an FST Setup Request frame including the DMG Discovery Assistance element. The SME of a multi-band capable device can trigger one of its MLMEs to start scanning its operating band upon reception of a multi-band discovery assistance response from another MLME of the same multi-band capable device. The multi-band discovery assistance response is an FST Setup Response frame including the DMG Discovery Assistance element. This enables multi-band capable devices to trigger the discovery assistance and scanning procedure on one band upon receiving the DMG Discovery Assistance element on another band. The multi-band discovery assistance procedure can be used to expedite the scanning procedure of a multi-band capable device that includes a DMG STA (see 11.31.1 (General)).

As described in 5.1.5 (MAC data service architecture), a MAC address is not unique within the multi-band capable device when transparent FST is intended to be used. When transparent FST is used, a single MAC SAP at each peer is presented to the higher layers of that peer for all of the frequency bands/channels that are identified by the same MAC address at that peer. When nontransparent FST is used, different MAC SAPs are presented to higher layers since different MAC addresses are used prior to and following an FST. Therefore, when nontransparent FST is used, higher layers are responsible for managing the FST.

Each MAC SAP is controlled by a separate and independent RSNA key management entity and IEEE 802.1X Authenticator or Supplicant unless transparent FST is used, in which case the multi-band

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management entity is responsible for coordinating with each of the SMEs to ensure that a single RSNA key management entity and IEEE 802.1X Authenticator or Supplicant are shared among the MACs and that a single IEEE 802.1X entity is controlled.

### 4.9.5 Reference model for co-channel coordinated management operation(11ay)

The reference model for a device that uses the co-channel coordinated management operation is shown in Figure 4-33 (Reference model for co-channel coordinated management operation(11ay)(#4098)). The reference model for co-channel coordinated management operation allows a device to operate on the same channel with more than one STA, where each STA is associated with a different antenna or DMG antenna configuration. Each STA can have its own PHY and MAC sublayer for channel access and MPDU processing.

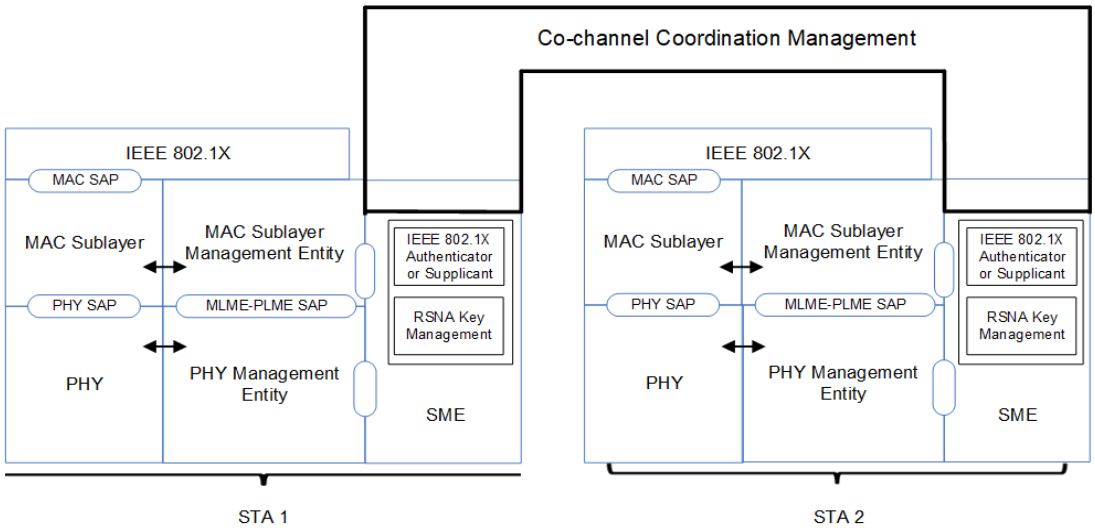


**Figure 4-33—Reference model for co-channel coordinated management operation(11ay)(#4098)**

The co-channel coordinated management operation reference model can be used by a device to provide TDD channel access as defined in11.54 (TDD channel access operation(11ay)) and in 10.38.6.2.2 (SP with TDD channel access(11ay)).

The SME of a device that uses the co-channel coordinated management operation contains a coordinated management entity that is responsible for coordinating the setup, configuration, time synchronization and scheduling of STAs belonging to the device.

Different MAC SAPs are presented to higher layers if different MAC addresses are used by each STA. Each MAC SAP is controlled by a separate and independent RSNA key management entity. The coordinated management entity is responsible for coordinating with each of the SMEs if a single IEEE 802.1X entity of the IEEE 802.1X Authenticator/Supplicant is shared among the MACs.


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## 4.10 IEEE Std 802.11 and IEEE Std 802.1X-2020(#3469)

### 4.10.1 General

An RSNA relies on (#3469)IEEE Std 802.1X-2020 to provide authentication services and uses the IEEE 802.11 key management scheme defined in 12.7 (Keys and key distribution). The IEEE 802.1X access control mechanisms apply to the association between a STA and an AP and to the relationship between the IBSS STA and STA peer. The AP's SME performs the Authenticator and, optionally, the Supplicant and AS roles. In an infrastructure BSS, a non-AP STA's SME performs the Supplicant role. In an IBSS the SME takes on both the Supplicant and Authenticator roles and might take on the AS role.

### 4.10.2 IEEE 802.11 usage of IEEE Std 802.1X-2020(#3469)

IEEE Std 802.11 depends upon (#3469)IEEE Std 802.1X-2020 to control the flow of MAC service data units (MSDUs) between the DS and STAs by use of the IEEE 802.1X Controlled/Uncontrolled Port model. IEEE 802.1X EAPOL PDUs are transmitted in one or more IEEE 802.11 Data frames and passed via the IEEE 802.1X Uncontrolled Port. The IEEE 802.1X Controlled Port is blocked from passing general data traffic between two STAs until an IEEE 802.1X authentication procedure completes successfully over the IEEE 802.1X Uncontrolled Port. It is the responsibility of both the Supplicant and the Authenticator to implement port blocking. Each association between a pair of STAs creates a unique pair of IEEE 802.1X Ports, and authentication takes place relative to those ports alone.

IEEE Std 802.11 depends upon (#3469)IEEE Std 802.1X-2020 and various IEEE 802.11 protocols and handshakes, described in Clause 12 (Security) and Clause 13 (Fast BSS transition), to establish and change cryptographic keys. Keys are established after authentication has completed. Keys might change for a variety of reasons, including expiration of an IEEE 802.1X authentication timer, key compromise, danger of compromise, or policy.

### 4.10.3 Infrastructure functional model overview

#### 4.10.3.1 General

This subclause summarizes the system setup and operation of an RSN, in three cases: when a password or PSK is used during IEEE 802.11 authentication, when an IEEE 802.1X AS is used after Open System authentication, and when a PSK is used after Open System authentication. In an RSN, an AP includes an Authenticator, and each associated STA includes a Supplicant.

#### 4.10.3.2 AKM operations with AS

The following AKM operations are carried out when an IEEE 802.1X AS is used:

a) Prior to any use of (#3469)IEEE Std 802.1X-2020, IEEE Std 802.11 assumes that the Authenticator and AS have established a secure channel. The security of the channel between the Authenticator and the AS is outside the scope of this standard.

   Authentication credentials are distributed to the Supplicant and AS prior to association.

b) A STA discovers the AP's security policy through passively monitoring Beacon frames or through active probing(#1349). If IEEE 802.1X authentication is used, the EAP authentication process starts when the Authenticator sends the EAP-Request(#1349) or (#1836)the Supplicant sends the EAPOL-Start PDU (in one or more EAPOL-Start frames). EAP messages pass between the Supplicant and AS via the Authenticator and Supplicant's Uncontrolled Ports (#1349)as described in 12.7 (Keys and key distribution).

c) The Supplicant and AS authenticate each other and generate a PMK. The PMK is sent from the AS to the Authenticator over the secure channel (#1349)as described in 12.7 (Keys and key distribution).

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A 4-way handshake or FT 4-way handshake utilizing (#1836)EAPOL-Key PDUs is initiated by the Authenticator to do the following:

- Confirm that a live peer holds the PMK.
- Confirm that the PMK is current.
- In the case of fast BSS transition, derive PMK-R0s and PMK-R1s.
- Derive a fresh pairwise transient key (PTK) from the PMK or, in the case of fast BSS transition, from the PMK-R1, the derived PTK including the key derivation key (KDK) if WUR frame protection is negotiated.(11ba)
- If WUR frame protection is negotiated, derive a fresh WTK from the KDK.(11ba)
- Install the pairwise encryption and integrity keys, and if WUR frame protection is negotiated, the WTK.(11ba)
- Transport the group (#1349)keys and sequence number from Authenticator to Supplicant and install the (#1349)group keys and sequence number in the STA and, if not already installed, in the AP.
- Verify that the RSN capabilities negotiated are valid as defined in 9.4.2.23.4 (RSN capabilities).
- Confirm the cipher suite selection.

Installing the PTK, and where applicable the (#1349)group keys GTK causes the MAC to encrypt and decrypt all subsequent MSDUs irrespective of their path through the (#1909)Controlled or Uncontrolled Ports. (11ba)Installing the WTK when WUR frame protection is negotiated (#1349)causes the MAC to integrity protect subsequent individually addressed WUR Wake-up frames at the AP or to validate subsequent individually addressed WUR Wake-up frames at the non-AP STA.

Upon successful completion of the 4-way handshake, the Authenticator and Supplicant have authenticated each other; and the IEEE 802.1X Controlled Ports are unblocked to permit general data traffic (#1349)as described in 12.7 (Keys and key distribution).

If the Authenticator later changes (#1349)one or more group keys, it sends the new group keys and sequence number to the Supplicant using the group key handshake to allow the Supplicant to continue to receive group addressed frames and, optionally, to transmit and receive individually addressed frames. (#1836)EAPOL-Key PDUs are used to carry out this exchange as described in 12.7 (Keys and key distribution).


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#### 4.10.3.3 AKM operations with a password or PSK

The following AKM operations are carried out when authentication is accomplished using a (#6316)password or PSK:

— A STA discovers the AP's security policy through passively monitoring the Beacon frames or through active probing. After discovery the STA performs SAE authentication using Authentication frames with the AP (see Figure 4-34 (Example using SAE authentication)).

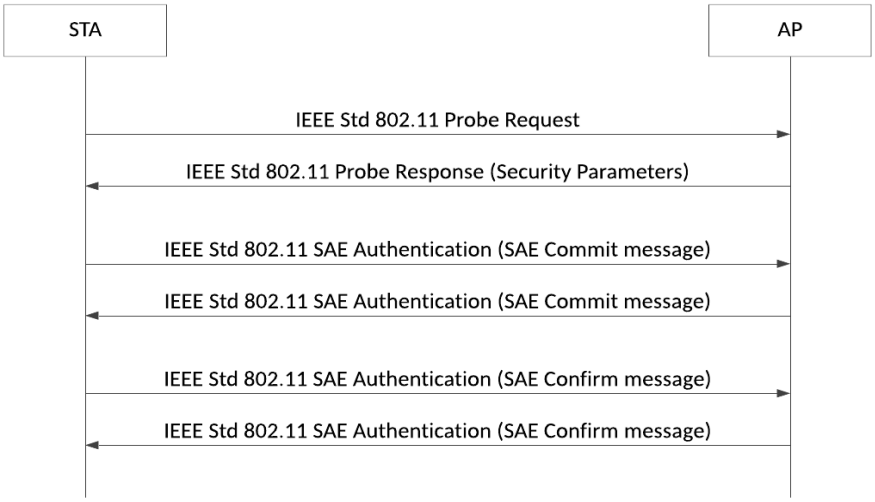


**Figure 4-34—Example using SAE authentication**

— Upon the successful conclusion of SAE, both the STA and AP generate a PMK. The STA then associates with(#1427) an AP and negotiates security policy. The AKM in the Association Request and Response frames is confirmed to be the AKM of SAE or of fast BSS transition.

— The PMK generated by SAE is used in a 4-way handshake using (#1836)EAPOL-Key PDUs, just as with IEEE 802.1X authentication when an AS is present.(#1349-Ed1)

— The GTK and GTK sequence number are sent from the Authenticator to the Supplicant just as in the AS case.(#1349-Ed1)

— If WUR frame protection is negotiated, the WIGTK and WIPN are sent from the Authenticator to the Supplicant just as in the AS case.(#1349-Ed1)

#### 4.10.3.4 Alternate operations with PSK

The following AKM operations represent an alternate operation of using a PSK. This operation has security vulnerabilities if used with a low-entropy key and is recommended to be used only after taking that into account. When this operation is carried out, the PMK is a PSK:

— A STA discovers the AP's security policy through passively monitoring Beacon frames or through active probing. (#1349-Ed1)A STA associates with an AP and negotiates a security policy. The PMK is the PSK.

— The 4-way handshake using (#1836)EAPOL-Key PDUs is used, just as with IEEE 802.1X authentication, when an AS is present.(#1349-Ed1)

— The GTK and GTK sequence number are sent from the Authenticator to the Supplicant just as in the AS case. (#1349-Ed1)

— If management frame protection is negotiated, the IGTK and IGTK packet number are sent from the Authenticator to the Supplicant just as in the AS case. If beacon protection is enabled, the BIGTK and BIPN are sent from the Authenticator to the Supplicant just as in the AS case.(#1349-Ed1)

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#### 4.10.3.5 Disassociation

Disassociation initiated by either STA in an RSNA causes the deletion of the PTKSA at both ends and the deletion of the GTKSA in a non-AP STA. The (#1909)Controlled and Uncontrolled Ports created for this association are also deleted.

#### 4.10.3.6 AKM operations using FILS authentication

##### 4.10.3.6.1 General

FILS authentication allows faster link setup to the network by performing authentication, association, and key confirmation using four frames—two Authentication frames, one (Re)Association Request frame, and one (Re)Association Response frame.

The following three FILS authentication methods are defined:

a) FILS Shared Key authentication performed without perfect forward security (PFS)

b) FILS Shared Key authentication performed with PFS

c) FILS Public Key authentication with PFS

FILS Shared Key authentication with and without PFS is described in 4.10.3.6.2 (AKM operations using FILS Shared Key authentication).

FILS Public Key authentication exchange is described in 4.10.3.6.3 (AKM operations using FILS Public Key authentication).

##### 4.10.3.6.2 AKM operations using FILS Shared Key authentication

A non-AP STA and a trusted third party (TTP) using FILS Shared Key authentication verify mutual possession of a shared key (rRK) (as defined in IETF RFC 5295 and IETF RFC 6696) using Extensible Authentication Protocol (EAP) reauthentication protocol (EAP-RP) signaling. EAP-RP signaling is encapsulated using (#7044)wrapped data in an Authentication frame as shown in Figure 4-35 (FILS authentication using TTP). A valid rRK is derived using a prior full authentication using the full EAP as


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defined in 4.10.3.2 (AKM operations with AS). This rRK can be used for multiple runs of EAP-RP authentications as specified in IETF RFC 5295 and IETF RFC 6696.

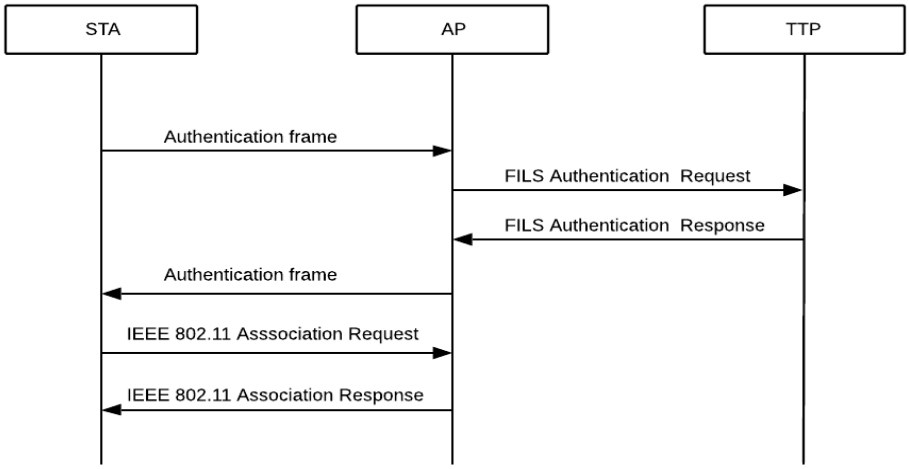


**Figure 4-35—FILS authentication using TTP**

#### 4.10.3.6.3 AKM operations using FILS Public Key authentication

When using FILS Public Key authentication, it is assumed that both STAs using FILS have either:

— Obtained a public key certificate from a certificate authority (CA) and are capable of verifying each other's certificate during execution of FILS authentication procedures; or

— A priori knowledge of, and trust in, an uncertified public key.

The manner in which trust is obtained in certificates is outside the scope of this standard.

#### 4.10.3.7 Opportunistic Wireless Encryption(#6088)

The following AKM operations are carried out when opportunistic encryption is accomplished using a Diffie-Hellman key exchange.

— The STA discovers the AP's security policy indicating support for Opportunistic Wireless Encryption through passively monitoring Beacon frames or through actively probing. After discovery in a non-DMG infrastructure BSS, the STA performs Open System Authentication with the AP.

— The STA (re)associates with the AP and provides an ephemeral Diffie-Hellman public key in its (Re)Association Request frame. The AP responds with an ephemeral Diffie-Hellman public key in its (Re)Association Response frame.

— The STA and AP complete the Diffie-Hellman key exchange and generate a PMK.

— The 4-way handshake using EAPOL-Key frames is used, just as with IEEE Std 802.1X authentication, when an AS is present.

### 4.10.4 IBSS functional model description

#### 4.10.4.1 General

This subclause summarizes the system setup and operation of an RSNA in an IBSS. An IBSS RSNA is specified in 12.6.9 (RSNA authentication in an IBSS).

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#### 4.10.4.2 Key usage

In an IBSS the individually addressed Data frames between two STAs are protected with a pairwise key. The key is part of the PTK, which is derived during a 4-way handshake. In an IBSS the 4-way handshake can follow IEEE 802.11 authentication of one STA to another. Such authentication might be used by the peer to cause deletion of the PTKSA and (#1405)block the Controlled Port, resetting any previous handshake.

In an IBSS group addressed Data frames are protected by a key, e.g., named B1, that is generated by the STA transmitting the group addressed frame. To allow other STAs to decrypt group addressed frames, B1 is sent to all of the other STAs in the IBSS. B1 is sent in an (#1836)EAPOL-Key PDU, encrypted under the (#3744)PTK key encryption key (PTK-KEK), and protected from modification by the PTK key confirmation key (PTK-KCK).

In an IBSS the SME responds to Deauthentication frames from a STA by deleting the PTKSA associated with that STA.

#### 4.10.4.3 Sample IBSS 4-way handshakes

In this example (see Figure 4-36 (Sample 4-way handshakes in an IBSS)), there are three STAs: S1, S2, S3. The group addressed frames sent by S1 are protected by B1; similarly B2 for S2, and B3 for S3.

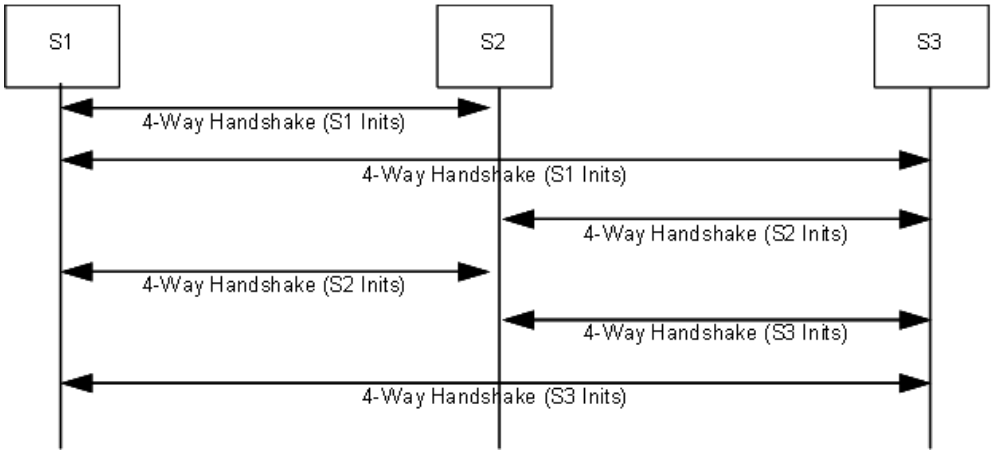


**Figure 4-36—Sample 4-way handshakes in an IBSS**

For STAs S2 and S3 to decrypt group addressed frames from S1, B1 is sent to S2 and S3. This is done using the 4-way handshake initially and using the group key handshake for GTK updates.

The 4-way handshake from S1 to S2 allows S1 to send group addressed frames to S2, but does not allow S2 to send group addressed frames to S1 because S2 has a different transmit GTK. Therefore, S2 needs to initiate a 4-way handshake to S1 to allow S1 to decrypt S2's group addressed frames. Similarly, S2 also needs to initiate a 4-way handshake to S3 to enable S3 to receive group addressed frames from S2.

In a similar manner S3 needs to complete the 4-way handshake with S1 and S2 to deliver B3 to S1 and S2.

In this example, there are six 4-way handshakes. In general, $N$ Supplicants require $N(N–1)$ 4-way handshakes.


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NOTE—In principle the (#3744)PTK-KCK and PTK-KEK from a single 4-way handshake can be used for the group key handshake in both directions, but using two 4-way handshakes means the Authenticator key state machine does not need to be different between IBSS and ESS.

The group key handshake can be used to send the GTKs to the correct STAs. The 4-way handshake is used to derive the pairwise key and to send the initial GTK. Because in an IBSS there are two 4-way handshakes between any two Supplicants and Authenticators, the pairwise key used between any two STAs is from the 4-way handshake initiated by the STA Authenticator with the higher MAC address (see 12.7.1 (Key hierarchy) for the notion of address comparison)(#3744).

In an IBSS a secure link exists between two STAs when both 4-way handshakes have completed successfully. The Supplicant and Authenticator 4-way handshake state machines interact so the IEEE 802.1X variable portValid is not set to 1 until both 4-way handshakes complete.

If a fourth STA comes within range and its SME decides to initiate a security association with the three peers, its Authenticator initiates 4-way handshakes with each of the other three Supplicants. Similarly, the original three STA Authenticators in the IBSS need to initiate 4-way handshakes to the fourth STA Supplicant. A STA learns that a peer STA is RSNA-enabled and the peer's security policy (e.g., whether the Authentication and Key Management Protocol (AKMP) is SAE, PSK, or IEEE 802.1X authentication) from the Beacon or Probe Response frame. The initiation might start for a number of reasons:

a) The fourth STA receives a Beacon or Probe Response frame from a MAC address with which it has not completed a 4-way handshake.

b) An SME receives an MLME-PROTECTEDFRAMEDROPPED.indication primitive from a MAC address with which it has not completed a 4-way handshake. This could be a group addressed Data frame transmitted by any of the STAs. In order to set up a security association to the peer STA, an SME that does not know the security policy of the peer can send a Probe Request frame to the peer STA to find its security policy before setting up a security association to the peer STA.

c) An SME receives message 1 of the 4-way handshake sent to a STA because the initiator received a broadcast Data frame, Beacon frame, or Probe Response frame from that STA. In order to set up a security association to the peer STA, a STA that received a 4-way handshake but does not know the security policy of the peer can send a Probe Request frame to the peer STA to find its security policy before setting up a security association to the peer STA.

#### 4.10.4.4 IBSS IEEE 802.1X example

When IEEE 802.1X authentication is used, each STA needs to include an IEEE 802.1X Authenticator and AS. A STA learns that a peer STA is RSNA-enabled and the peer's security policy (e.g., whether the AKMP is PSK or IEEE 802.1X authentication) from the Beacon or Probe Response frame.

(#1836)Each Supplicant sends an EAPOL-Start PDU (in one or more EAPOL-Start frames) to every other STA to which it intends to authenticate, and each STA's Authenticator responds with the identity of the credential it intends to use.

The EAPOL-Start and EAP-Request/Identity messages are initiated when a protected Data frame (indicated via an MLME-PROTECTEDFRAMEDROPPED.indication primitive), an IEEE 802.1X message, Beacon frame, or Probe Response frame is received from a MAC address with which the STA has not completed IEEE 802.1X authentication. In order to set up a security association to the peer STA, an SME that does not know the security policy of the peer can send a Probe Request frame to the peer STA to find its security policy before setting up a security association to the peer STA.

Although Figure 4-37 (Example using IEEE 802.1X authentication) shows the two IEEE 802.1X exchanges serialized, they might occur interleaved.

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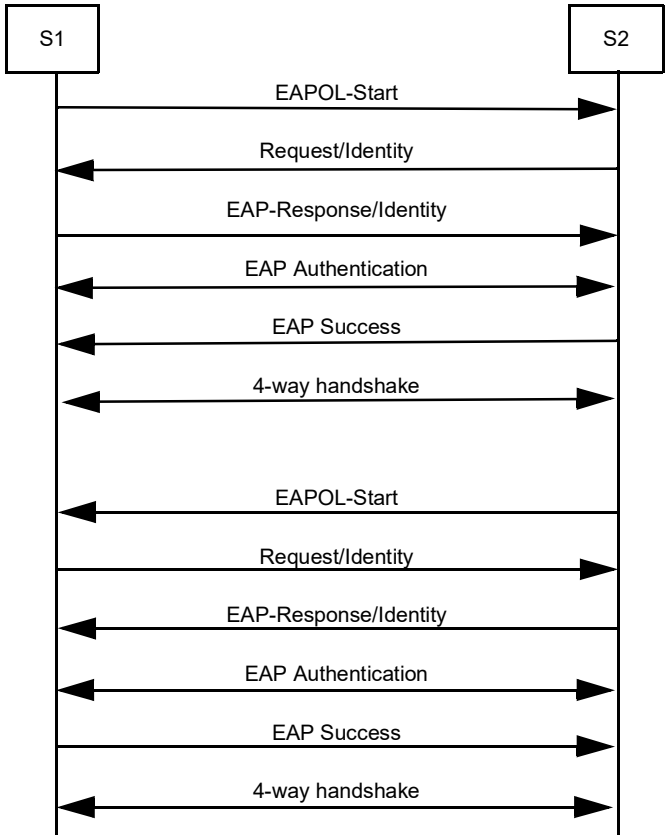


**Figure 4-37—Example using IEEE 802.1X authentication**

### 4.10.5 PBSS functional model description

This subclause summarizes the system setup and operation of an RSNA in a PBSS.

If a non-PCP STA chooses to associate with the PCP of the PBSS, the non-PCP STA establishes an RSNA with the PCP following the infrastructure functional model as specified in 4.10.3 (Infrastructure functional model overview).

If a non-PCP STA wants to establish an RSNA with the PCP without association or if the non-PCP STA wants to establish an RSNA with another non-PCP STA, it can directly initiate an RSNA authentication with the peer STA, followed by a 4-way handshake. One difference between this model and the IBSS functional model is that only one RSNA authentication and one 4-way handshake are performed between two STAs. If both STAs initiate an RSNA setup at the same time, the RSNA setup initiated by the STA with the lower MAC address is carried through, while the RSNA setup initiated by the STA with the higher MAC address is terminated.

Figure 4-38 (Example of RSNA setup in a PBSS) shows an example of the RSNA setup in a PBSS. An initiator STA discovers a peer STA's RSNA policies through the DMG Beacon frames from the peer STA if the peer STA is the PCP or through the Probe Response or Information Response frames from the peer STA. In this example, the initiator STA does not associate with the peer STA. The initiator STA performs RSNA authentication with the peer STA to derive a PMK. A 4-way handshake is then started to complete the RSNA setup.


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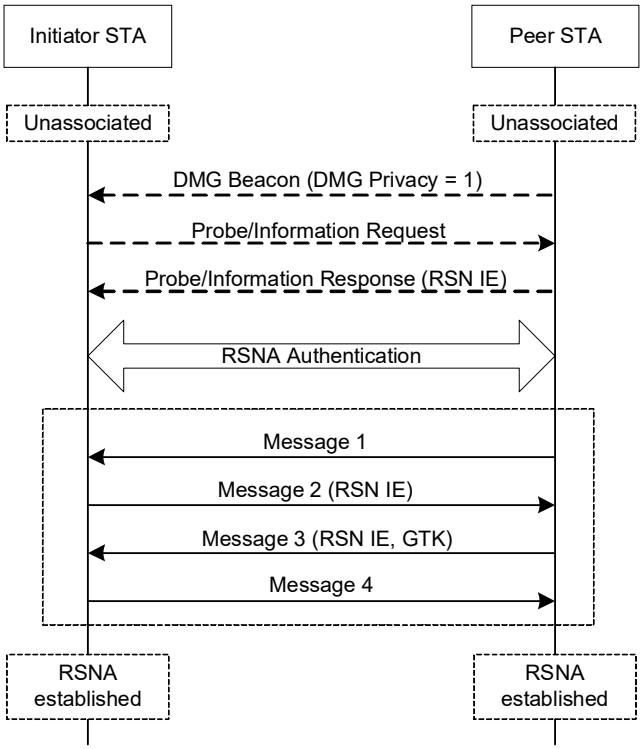


**Figure 4-38—Example of RSNA setup in a PBSS**

### 4.10.6 Authenticator-to-AS protocol

The Authenticator-to-AS authentication definition is out of the scope of this standard, but, to provide security assurances, the protocol needs to support the following functions:

a) Mutual authentication between the Authenticator and AS

b) A channel for the Supplicant and AS authentication

c) The ability to pass the generated key from the AS to the Authenticator in a manner that provides authentication of the key source, preserves integrity of the key transfer, and preserves data confidentiality of the key from all other parties

Suitable protocols include, but are not limited to, remote authentication dial-in user service (RADIUS) (IETF RFC 2865 [B33]) and Diameter (IETF RFC 3588 [B41]).

### 4.10.7 PMKSA caching

The Authenticator and Supplicant can cache PMKSAs, which include the IEEE 802.1X state. A PMKSA can be deleted from the cache for any reason and at any time.

A STA can supply a list of PMK identifiers in the (Re)Association Request frame or first FILS Authentication frame. Each (#3493)PMK identifier names a PMKSA. The Authenticator can specify the selected PMK identifier in message 1 of the 4-way handshake or the second FILS Authentication frame. The selection of the (#3493)PMK identifiers to be included by the STA and Authenticator is out of the scope of this standard.

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A FILS authentication exchange results in a PMKSA, which can be cached. A FILS STA can benefit from such caching, as a FILS STA performing subsequent authentications can supply a list of PMK identifiers in its initial Authentication frame. FILS APs that support PMK caching can identify themselves using a cache identifier. A FILS STA that has successfully established a PMKSA at an AP identifying a particular cache identifier can attempt to use PMK caching in a subsequent attempt with any AP that uses the same cache identifier.

### 4.10.8 Protection of group addressed robust Management frames

When management frame protection is negotiated, all group addressed robust Management frames are encapsulated using the procedures defined in 11.12 (Group addressed management frame protection procedures). This service provides integrity protection of group addressed robust Management frames using BIP.


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# 5. MAC service definition

## 5.1 Overview of MAC services

### 5.1.1 Data service

#### 5.1.1.1 General

This service provides peer LLC sublayer entities or IEEE 802.1Q bridge ports with the ability to exchange MSDUs. To support this service, the local MAC uses the underlying PHY-level services to transport an MSDU to a peer MAC entity, where it is delivered to the peer LLC sublayer or bridge port. Such asynchronous MSDU transport is performed on a connectionless basis. By default, MSDU transport is on a best-effort basis. However, the QoS facility uses a traffic identifier (TID) to specify differentiated services on a per-MSDU basis. The QoS facility also permits more synchronous behavior to be supported on a connection-oriented basis using TSPECs. There are no guarantees that the submitted MSDU will be delivered successfully. Group addressed transport is part of the data service provided by the MAC. Due to the characteristics of the WM, group addressed MSDUs might experience a lower QoS, compared to that of individually addressed MSDUs. All STAs support the data service, but only QoS STAs in a QoS BSS differentiate their MSDU delivery according to the designated traffic category or traffic stream (TS) of individual MSDUs. QoS STAs that support the QMF service differentiate their MMPDU delivery according to the MMPDU's access category. The access category of each MMPDU is designated by the transmitter's current QMF policy.

There are two service classes available in a QoS STA: QoSAck and QoSNoAck. The service classes are used to signal if the MSDU is to be transmitted with or without using the MAC-level acknowledgment.

In QoS STAs either associated in a BSS or having membership in an IBSS, the MAC uses a set of rules that tends to cause higher UP MSDUs in a BSS to be sent before lower UP MSDUs in the BSS. The MAC sublayer entities determine the UPs for MSDUs based on the TID values provided with those MSDUs. If a TSPEC has been provided for a TS, via the MAC sublayer management entity, the MAC attempts to deliver MSDUs belonging to that TS in accordance with the QoS parameter values contained in the TSPEC. In a BSS with some STAs supporting the QoS facility and others not supporting the QoS facility, in delivering an MSDU to a non-QoS STA, the QoS STA uses the access category (AC) corresponding to the UP of the MSDU.

#### 5.1.1.2 Determination of UP

The QoS facility supports eight priority values, referred to as UPs. The values a UP may take are the integer values from 0 to 7, which form an ordered sequence of priorities, with 1 being the lowest value, 7 the highest value, (#55)and 0 falling between 2 and 3. (#7209)An MSDU with a particular integer priority is said to belong to a traffic category (TC) with a numerically equal UP. The UP is provided with each MSDU at the medium access control service access point (MAC SAP) either directly, in the (#1334)priority parameter, or indirectly, in a TSPEC or SCS Descriptor element designated by the (#1334)priority parameter. For the transmission of an MSDU that was provided to the Internal Sublayer Service SAP associated with a general link, the UP is determined by the GLK convergence function based on the priority parameter of the (#1353)MA-UNITDATA.request primitive. (See Annex R for recommended mapping guidelines.)

#### 5.1.1.3 Interpretation of priority parameter in MAC service primitives

The value of the priority parameter in the MAC service primitives (see 5.2 (MAC data service specification)) may be a noninteger value of Contention or may be any integer value in the range 0 to 15.

When the priority parameter has an integer value, it is used in the TID subfields that appear in certain frames that are used to deliver and to control the delivery of QoS data across the WM.

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Priority parameter and TID subfield values 0 to 7 are interpreted as UPs for the MSDUs. Outgoing MSDUs with UP values 0 to 7 are handled by MAC entities at STAs in accordance with the UP.

Priority parameter and TID subfield values 8 to 15 specify TIDs that are also TS identifiers (TSIDs) and select the TSPEC for the TS designated by the TID. Outgoing MSDUs with priority parameter values 8 to 15 are handled by MAC entities at STAs in accordance with the UP value determined from the UP subfield as well as other parameter values in the selected TSPEC. When an MSDU arrives with a priority value between 8 and 15 and for which there is no TSPEC defined, then the MSDU shall be sent with priority parameter set to 0.

The noninteger value of the priority parameter is allowed at all non-QoS STAs. The integer values of the priority parameter (i.e., TID) are supported only at QoS STAs that are in a QoS BSS. (#1526)A range of 0 to 15 is supported by QoS STAs that are members of a QoS BSS that is not an IBSS; whereas a range of 0 to 7 is supported by QoS STAs that are members of a QoS IBSS. If a QoS STA is associated in a non-QoS BSS, the STA is functioning as a non-QoS STA, so the priority value is always Contention.

At QoS STAs associated in a QoS BSS, MSDUs with a priority of Contention are considered equivalent to MSDUs with TID 0. At STAs associated in a non-QoS BSS, all MSDUs with an integer priority are considered equivalent to MSDUs with a priority of Contention.

(#249)Data frames received by a QoS STA may be of:

a) Non-QoS subtypes, in which case the STA shall assign to them a priority of Contention.

b) QoS subtypes, in which case the STA shall infer the UP value from the TID in the QoS Control field directly for TID values between 0 and 7. For TID values between 8 and 15 the STA shall extract the UP value in the UP subfield of the TS Info field in the associated TSPEC or from the UP field in the associated (#1776)TCLAS element, as applicable.

QoS APs deliver the UP with the received MSDUs to the DS or bridge port.

#### 5.1.1.4 Interpretation of service class parameter in MAC service primitives in a STA

In QoS STAs, the value of the service class parameter in the MAC service primitive (see 5.2 (MAC data service specification)) may be a noninteger value of QoSAck or QoSNoAck.

When an MSDU is received from the MAC SAP with one of the following service class indications, and the recipient STA is a (#1489)single QoS STA or all recipient STAs are QoS STAs:

— QoSAck, the MSDU is transmitted using one or more QoS Data frame(s) with an ack policy other than No Ack.

— QoSNoAck, the MSDU is transmitted using one or more QoS Data frame(s) with an ack policy of No Ack.

(#1489)Otherwise, the MSDU is transmitted using one or more non-QoS Data frame(s).

When a QoS Data frame is received from another STA, the service class parameter in the MA-UNITDATA.indication primitive is set to

— QoSAck, if the frame is a QoS Data frame with an ack policy other than No Ack; this includes when the frame was delivered via the DMS or the GCR block ack retransmission policy.

— QoSNoAck, if the frame is a QoS Data frame with an ack policy of No Ack. This service class is also used when the DA parameter is a group address (#4107)unless the frame is received by an AP or PCP(#6259) or was delivered via DMS or the GCR block ack retransmission policy.


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When a non-QoS Data frame is received at a QoS STA, the service class parameter in the MA-UNITDATA.indication primitive is set to

— QoSAck, if the frame is an individually addressed (#393)frame (and so is acknowledged by the STA).

— QoSNoAck, if the frame is a group addressed (#393)frame (and so is not acknowledged by the STA).

NOTE—This includes a non-AP STA transmission of an MSDU with a group DA, at the AP.(#3515)

In non-QoS STAs, the value of the service class parameter in invoked MAC service primitives (see 5.2 (MAC data service specification)) is ignored. The value of the service class parameter in generated MAC service primitives is set to ReorderableGroupAddressed.

### 5.1.2 Security services

Security services in IEEE Std 802.11 are provided by the authentication service and the CCMP, GCMP, and BIP. The scope of the security services provided is limited to station-to-station data and robust Management frame transmissions. When CCMP or GCMP is used, the data confidentiality service is provided for Data frames and individually addressed robust Management frames. For the purposes of this standard, CCMP, GCMP, and BIP are viewed as logical services located within the MAC sublayer as shown in the reference model, Figure 4-27 (Portion of the ISO/IEC basic reference model covered in this standard(#4114)) (in 4.9 (Reference model)). Actual implementations of CCMP, GCMP, and BIP are transparent to the LLC sublayer and other layers above the MAC sublayer.

The security services provided by CCMP and GCMP in IEEE Std 802.11 are as follows:

a) Data Confidentiality;

b) Authentication; and

c) Access control in conjunction with layer management.

BIP provides message integrity and access control for group addressed robust Management frames.

During the authentication exchange, both parties exchange authentication information as described in Clause 12 (Security) and Clause 13 (Fast BSS transition).

The MAC sublayer security services provided by CCMP, GCMP, and BIP rely on information from non MAC sublayer management or system entities. Management entities communicate information to CCMP, GCMP, and BIP through a set of MAC sublayer management entity (MLME) interfaces and MIB attributes; in particular, the decision tree for CCMP, GCMP, and BIP is driven by MIB attributes(#3056).

The use of TKIP is (#1643)obsolete. The TKIP algorithm is unsuitable for the purposes of this standard.(#3133)

### 5.1.3 MSDU ordering

The services provided by the MAC sublayer permit, and might in certain cases require, the reordering of MSDUs.

In a non-QoS STA, the MAC does not intentionally reorder MSDUs except as might be necessary to improve the likelihood of successful delivery based on the current operational (“power management,” FMS, DMS) mode of the designated recipient STA(s). The sole effect of this reordering (if any), for the set of MSDUs received at the MAC service interface of any single STA, is a change in the delivery order of group addressed MSDUs, relative to individually addressed MSDUs, originating from a single source STA address.

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The MSDUs are reordered, not only to improve the likelihood of successful delivery based on the current operational mode of the designated recipient STA(s), but also to honor the priority parameters, specified in the MA-UNITDATA.request primitive, of the individual MSDUs. The effects of this reordering (if any), for the set of MSDUs received at the MAC service interface of any single STA, are:

a) A change in the delivery order of group addressed MSDUs, relative to individually addressed MSDUs, and

b) The reordering of MSDUs with different TID values, originating from a single source STA address.

There shall be no reordering of individually addressed MSDUs with the same TID value and addressed to the same destination.

STAs operating in a non-QoS BSS shall follow the reordering rules as defined for a non-QoS STA.

In order for the MAC to operate properly, (#6401)the DS needs to meet the MSDU ("object") reordering requirements of IEEE Std 802.1AC-2012 [B17].

Operational restrictions that provide the appropriate ordering of MSDUs are specified in 10.7 (MSDU transmission restrictions).

When MSDU or A-MSDU reordering is performed, the information in the MAC service tuple(s) for the MSDU(s) shall be maintained and reordered as a unit.

### 5.1.4 MSDU format

Logical Link Control (LLC) sublayer entities use the MAC sublayer service to exchange PDUs with peer LLC sublayer entities. These PDUs are termed MAC sublayer SDUs (MSDUs) when sent to the MAC sublayer. There are two LLC sublayer protocols used (see IEEE Std 802): LLC Protocol Discrimination (LPD) (see ISO/IEC 8802-2:1998) and (#2186)EtherType Protocol Discrimination (EPD) (see IEEE Std 802.3-2022(#6013)). MSDUs are formatted in accordance with LPD or with EPD, as determined by the first condition below that is true. After a true condition has been found, subsequent conditions are ignored.

a) In the 5.9 GHz band in the United States and its territories(#296) (see E.2.3 (5.9 GHz band in the United States and its territories (5.850–5.925 GHz)(#296))) use EPD.

b) For OCB communications outside of the 5.9 GHz bands, use LPD.

c) Within Data frames with RAs that are individual addresses, if both the transmitter and receiver are EPD STAs, use EPD.

d) Within Data frames with RAs that are individual addresses, if either the transmitter or the receiver are not EPD STAs, use LPD.

e) If the transmitting AP accepts association only from an EPD STA, use EPD.

f) If the transmitting mesh STA peers only with an EPD mesh STA, use EPD.

g) For EBCS transmissions, use EPD.(11bc)

h) For all other cases, use LPD.

When LPD is used, in order to achieve interoperability, implementers are recommended to apply the procedures described in (M118)ISO/IEC 11802-5:1997 (previously known as IEEE Std 802.1H, 1997 Edition [B18]), along with a selective translation table (STT) that handles a few specific network protocols, with specific attention to the operations required when passing MSDUs to or from LANs or operating system components that use the Ethernet frame format (EPD). Note that such translations might be required in a STA.


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### 5.1.5 MAC data service architecture

#### 5.1.5.1 General

When transparent FST is not being used, the MAC data plane architecture (i.e., processes that involve transport of all or part of an MSDU) is shown in Figure 5-1 (MAC data plane architecture (#7109)(#4149)(#1001)(11ay)(#3186)(#3185)(#4172)(#4192)(11bc)). When transparent FST is being used, the MAC data plane architecture is shown in Figure 5-2 (MAC data plane architecture (transparent FST)(11ay)(#1938)(#3158)(#4172)(#4192)).(#110)

The dotted line box labeled "Role-specific behaviors" is replaced by one of several options, depending on the role of the STA. See the following subclauses

During transmission, an MSDU goes through (#3185)some or all, as applicable, of the processes shown in the left-hand side of Figure 5-1 (MAC data plane architecture (#7109)(#4149)(#1001)(11ay)(#3186)(#3185)(#4172)(#4192)(11bc)). When transparent FST is used, an MSDU first goes, as shown in Figure 5-2 (MAC data plane architecture (transparent FST)(11ay)(#1938)(#3158)(#4172)(#4192)), through an additional transparent FST entity that contains a demultiplexing process that forwards the MSDU down to the selected TX MSDU Rate Limiting process and from there to MAC data plane processing as described in the previous sentence. (#3469)IEEE Std 802.1X-2020 may block the MSDU at the Controlled Port before the preceding processing occurs. Otherwise, at some point, the Data frames that contain all or part of the MSDU are queued per AC/TS.

During reception, a received Data frame goes through (#3185)some or all, as applicable, of the processes shown in the right-hand side of Figure 5-1 (MAC data plane architecture (#7109)(#4149)(#1001)(11ay)(#3186)(#3185)(#4172)(#4192)(11bc)). Then, one or more MSDUs are delivered to the MAC SAP or, via the DSAF, to either the DS or an IEEE 802.1Q bridge port. When transparent FST is used, MSDUs originating from different PHY SAPs go, as shown in Figure 5-2 (MAC data plane architecture (transparent FST)(11ay)(#1938)(#3158)(#4172)(#4192)), through a final step of a transparent FST entity that contains a multiplexing process before delivering the MSDU. The IEEE 802.1X Controlled/Uncontrolled Ports discard any received MSDU if the Controlled Port is not enabled and if the MSDU does not represent an EAPOL PDU(#3252).

NOTE—Many of the processes shown in Figure 5-1 (MAC data plane architecture (#7109)(#4149)(#1001)(11ay)(#3186)(#3185)(#4172)(#4192)(11bc)) also apply to MMPDU flows for the MAC control plane architecture, and the processes shown at the bottom also apply to Control and Extension frames.

(#1938)When transparent FST is used, the same security keys and PN counters are used by the MAC data plane to encrypt the MPDU prior to and following an FST, and the same security keys and replay counters are used to check the integrity and perform the protection of MPDUs. When nontransparent FST is used, independent RSNAs, security keys, replay counters, and PN counters have to be established for each MAC data plane to be used prior to and following an FST. When transparent FST is used, a single MAC SAP at each peer is presented to the higher layers of that peer for all of the frequency bands/channels that are identified by the same MAC address at that peer. When nontransparent FST is used, different MAC SAPs are presented to higher layers since different MAC addresses are used prior to and following an FST.

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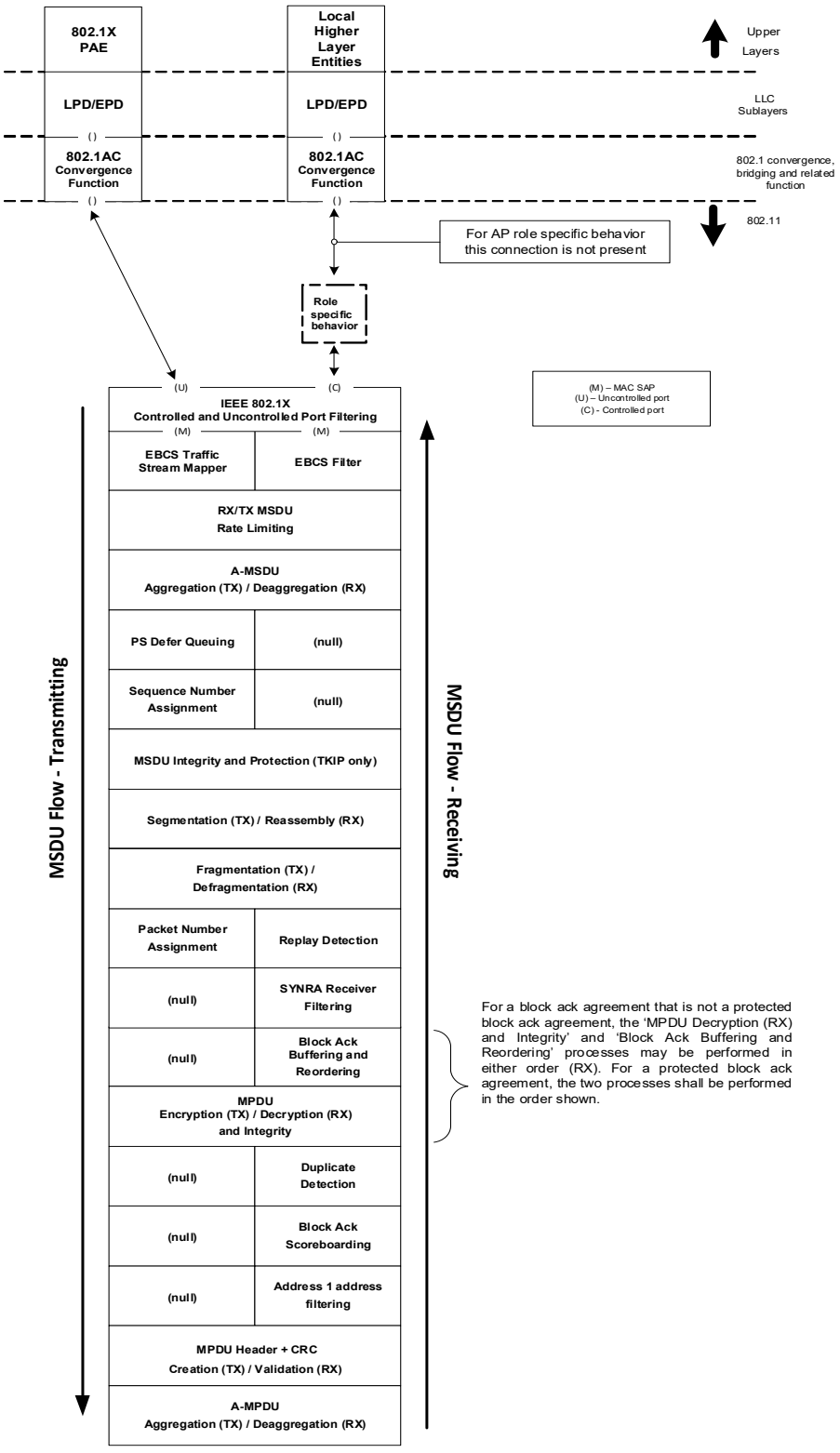


**Figure 5-1—MAC data plane architecture**
**(#7109)(#4149)(#1001)(11ay)(#3186)(#3185)(#4172)(#4192)(11bc)**


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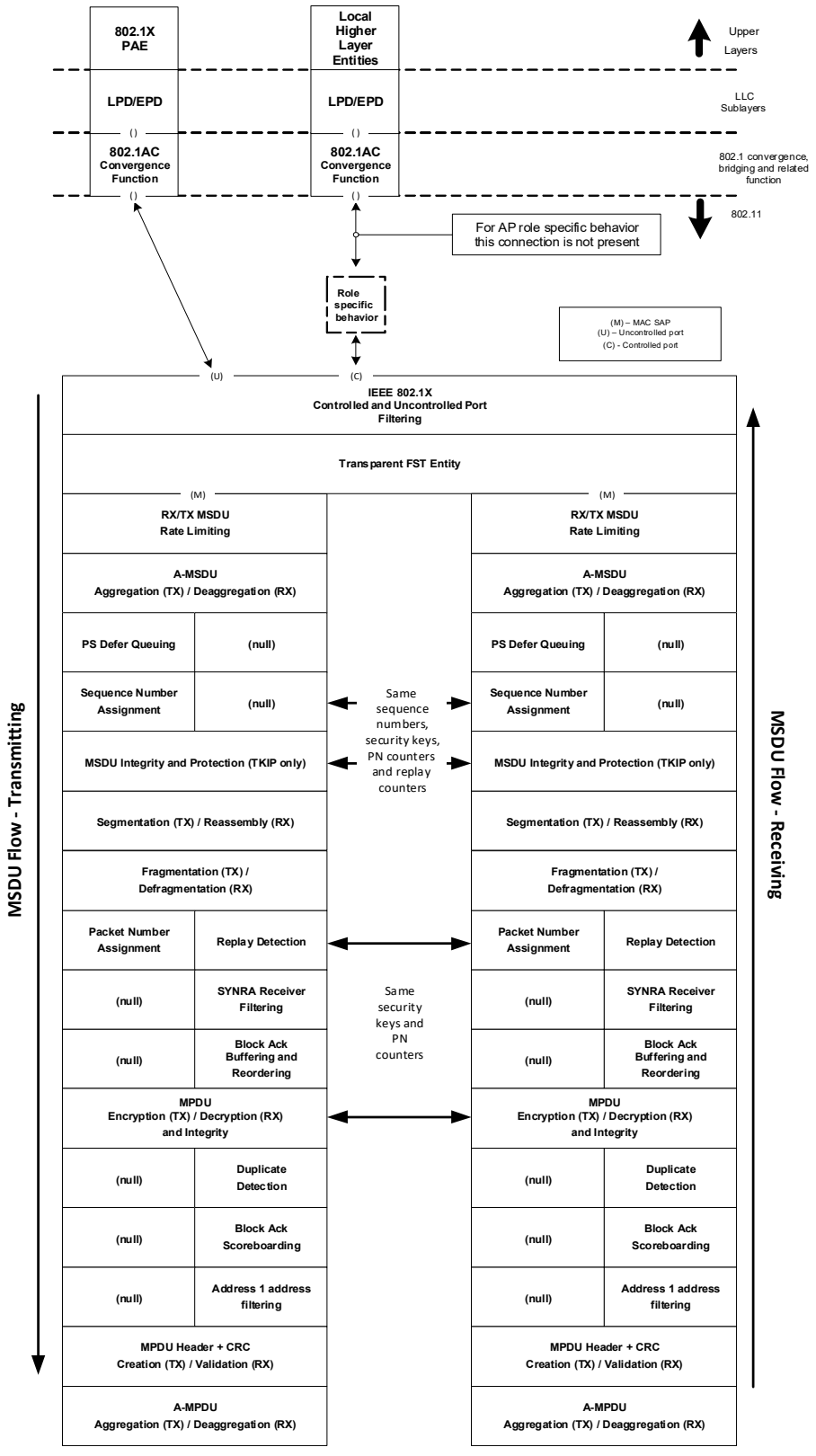


**Figure 5-2—MAC data plane architecture (transparent FST)(11ay)(#1938)(#3158)(#4172)(#4192)**

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### 5.1.5.2 Non-GLK non-AP STA role

The MAC data plane architecture of a non-GLK non-AP STA is completed by replacing the role-specific behavior block with (11bc)the block shown in Figure 5-3 (Role-specific behavior block for a non-GLK non-AP STA(#1429)). The function of this block in a non-AP STA is to perform destination address filtering as described in 10.2.8 (MAC data service).(#7111)

NOTE—In implementations, the (#1429)DA address filtering function might(M118) be done "lower in the stack." It is shown in the role-specific behavior block location for simplicity, and any implementation choice needs to provide equivalent behavior.(#7111)

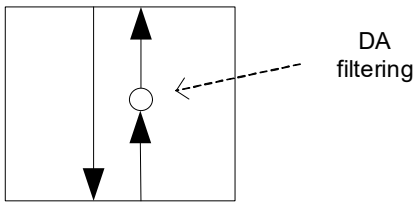


**Figure 5-3—Role-specific behavior block for a non-GLK non-AP STA(#1429)**

### 5.1.5.3 Non-GLK AP role

In a non-GLK AP, the MAC data plane architecture includes distribution system access in its role-specific behavior block, as shown in Figure 5-4 (Role-specific behavior block for a non-GLK AP(#7100)). This block provides access to the DS for associated non-AP STAs as described in 4.5.2.1 (Distribution).(#7110)

NOTE—This behavior block indicates that there is no access through the (#1909)Controlled Port to or from the local upper-layers (the LLC sublayer) at an AP. Any such access is logically achieved in the architecture via transition of the DS and Portal to an integrated LAN. In actual implementations, this is likely to be optimized, and Data frames appear to be delivered directly to one or more local LLC sublayer entities on the same physical device as the AP. Such optimization is effectively distributing the functions of the DS and Portal, and it is the responsibility of the implementation to ensure the logical behavior of these entities is maintained.(#7111)

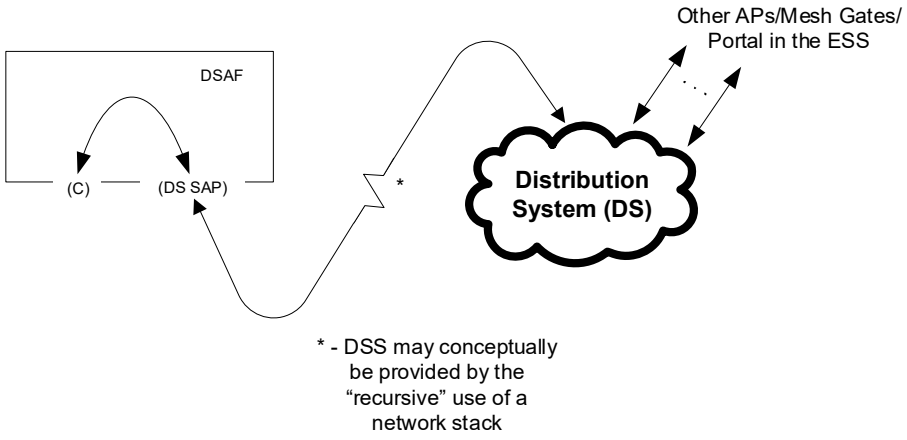


**Figure 5-4—Role-specific behavior block for a non-GLK AP(#7100)**

### 5.1.5.4 Non-GLK mesh STA role

The MAC data plane architecture of a mesh STA is completed by replacing the role-specific behavior block with that shown in Figure 5-5 (Role-specific behavior block for mesh STA). The function of this block in a


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mesh STA is described in 10.37 (Mesh forwarding framework). This role is not applicable when transparent FST is used, and does not apply to Figure 5-2 (MAC data plane architecture (transparent FST)(11ay)(#1938)(#3158)(#4172)(#4192)).

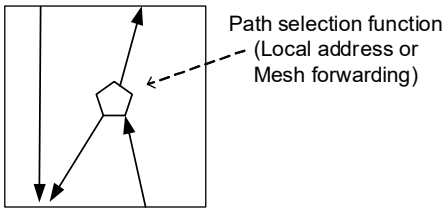


**Figure 5-5—Role-specific behavior block for mesh STA**

### 5.1.5.5 Mesh gate role

The MAC data plane architecture of a mesh gate is completed by replacing the role-specific behavior block with that shown in Figure 5-6 (Role-specific behavior block for mesh gate(#7100)). The function of this block in a mesh gate is described in 14.12 (Interworking with the DS or an attached bridge). This role is not applicable when transparent FST is used and does not apply to Figure 5-2 (MAC data plane architecture (transparent FST)(11ay)(#1938)(#3158)(#4172)(#4192)).

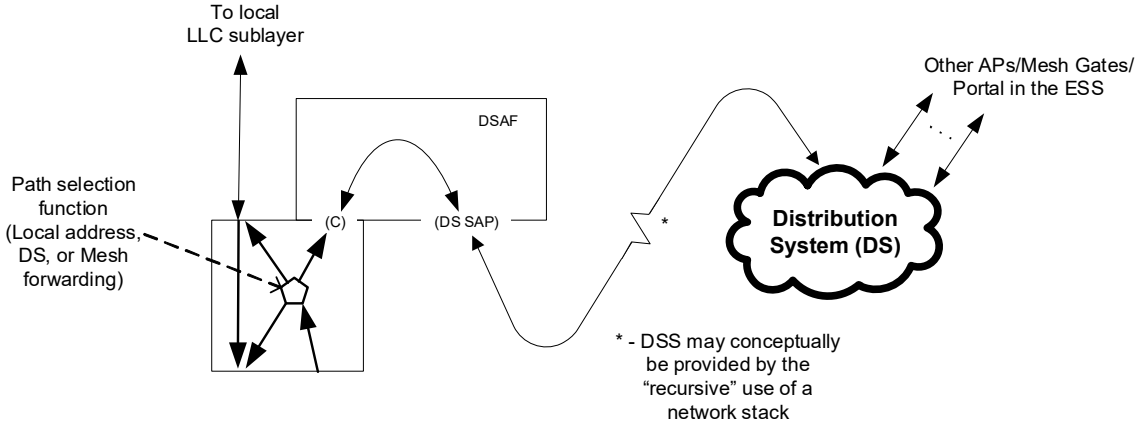


**Figure 5-6—Role-specific behavior block for mesh gate(#7100)**

### 5.1.5.6 S1G relay

An S1G relay comprises a relay AP, a relay STA and a relay function (see Figure 5-7 (S1G relay data plane architecture(#3185)(#4172)(#4192))).

A relay STA is a non-AP STA associated to a root AP or the relay AP of another relay. A relay AP is an AP that offers the relay function to its associated non-AP STAs, and provides access to the DS indirectly through the relay STA’s path to the root AP. The relay function performs local reception or selective forwarding of MSDUs between the relay STA and relay AP, based on the destination address, as described in 10.53 (S1G relay operation).

The MAC data plane architecture of an S1G relay is shown in Figure 5-7 (S1G relay data plane architecture(#3185)(#4172)(#4192)). (#3185)During transmission, an MSDU goes through some or all, as

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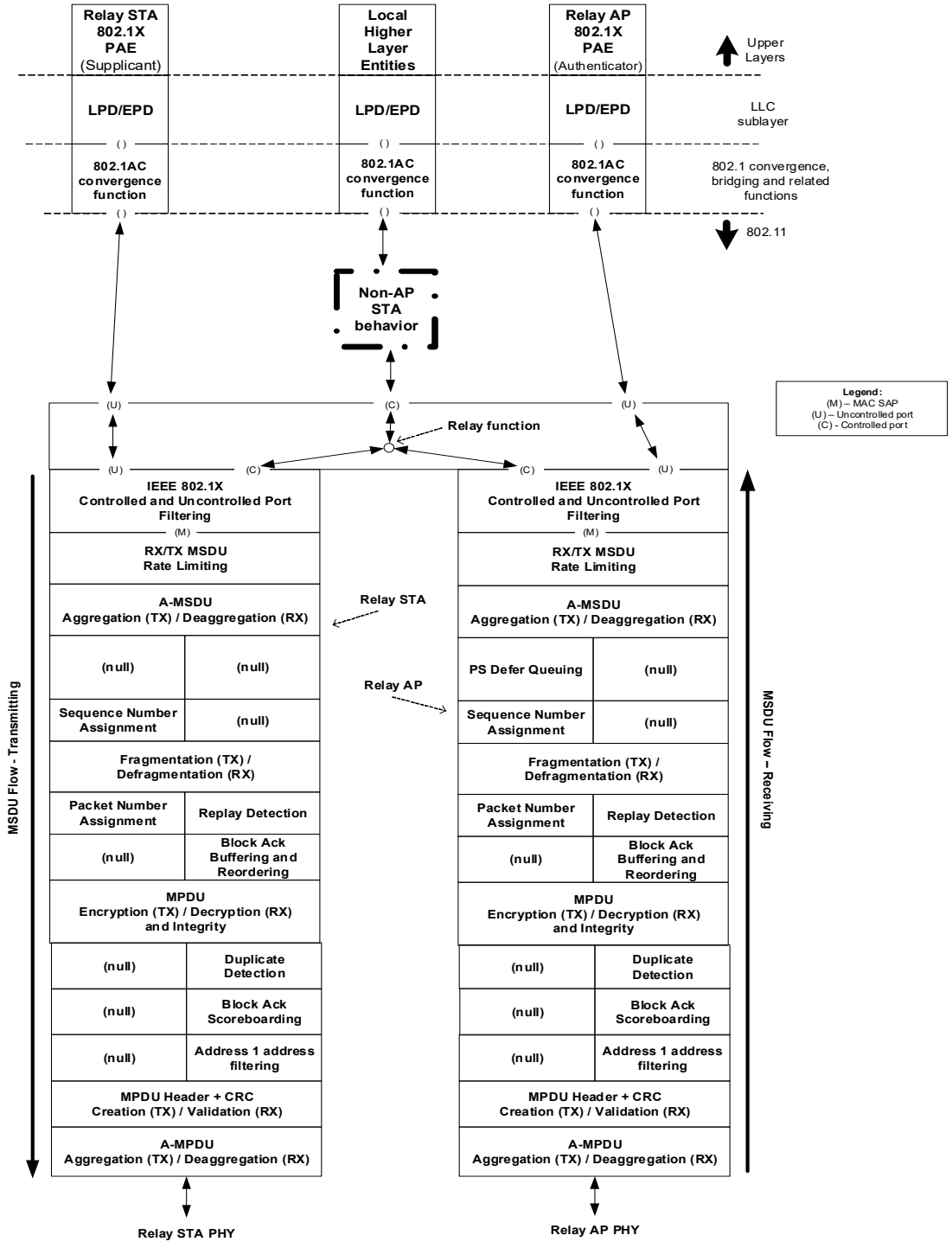


**Figure 5-7—S1G relay data plane architecture(#3185)(#4172)(#4192)**



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applicable, of the processes shown in the left-hand side of Figure 5-7 (S1G relay data plane architecture(#3185)(#4172)(#4192)). During reception, a received Data frame goes through some or all, as applicable, of the processes shown in the right-hand side of Figure 5-7 (S1G relay data plane architecture(#3185)(#4172)(#4192)).

#### 5.1.5.7 GLK STA role

In a GLK STA's MAC data plane architecture, the role-specific behavior block is as shown in Figure 5-8 (Role-specific behavior block for a GLK STA). The MAC service interface to this block includes a station vector, to provide the selective delivery service to a GLK convergence function. This block performs destination address filtering, as described in 10.2.8 (MAC data service), and provides access to the GLK convergence function and ultimately to the bridge ports.

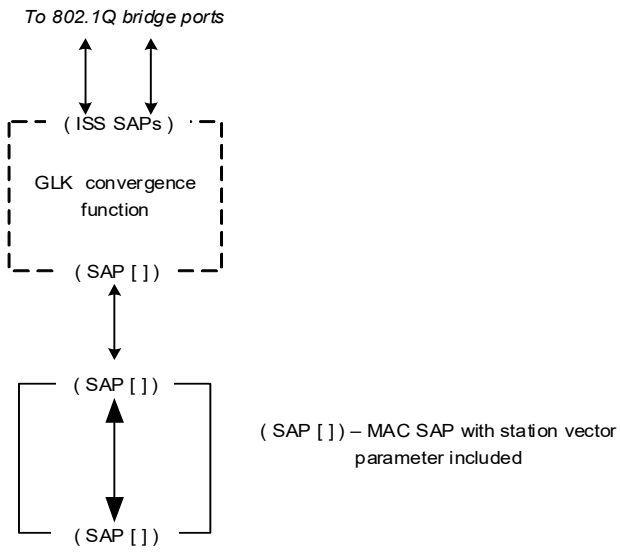


**Figure 5-8—Role-specific behavior block for a GLK STA**

#### 5.1.5.8 GLK AP role

A GLK AP that supports only general links (dot11GLKRequired is true) has the same general architectural structure as described in 5.1.5.7 (GLK STA role) for a general GLK STA.

A GLK AP that supports both general links and non-GLK links provides access between the bridge ports and general links, and between the DS and non-GLK links. The DSAF behavior of such an AP is extended by adding a switching function to direct received MSDUs to either the DS or toward a bridge port, as appropriate, as shown in Figure 5-9 (Role-specific behavior block for a mixed-mode GLK AP(#7100)).

#### 5.1.5.9 GLK mesh STA role

The only type of mesh STA that has explicit support for GLK is the GLK mesh STA, which is the equivalent of a mesh gate, except it is attached to a bridge rather than a DS. Other mesh STA types implicitly may support general links with the role specific structure shown in 5.1.5.4 (Non-GLK mesh STA role).

The MAC data plane architecture of a GLK mesh STA, like that for a non-GLK mesh STA, is completed by replacing the role-specific behavior block with that shown in Figure 5-10 (Role-specific behavior block for a GLK mesh STA). In a GLK mesh STA, the function of this block is described in 10.37 (Mesh forwarding

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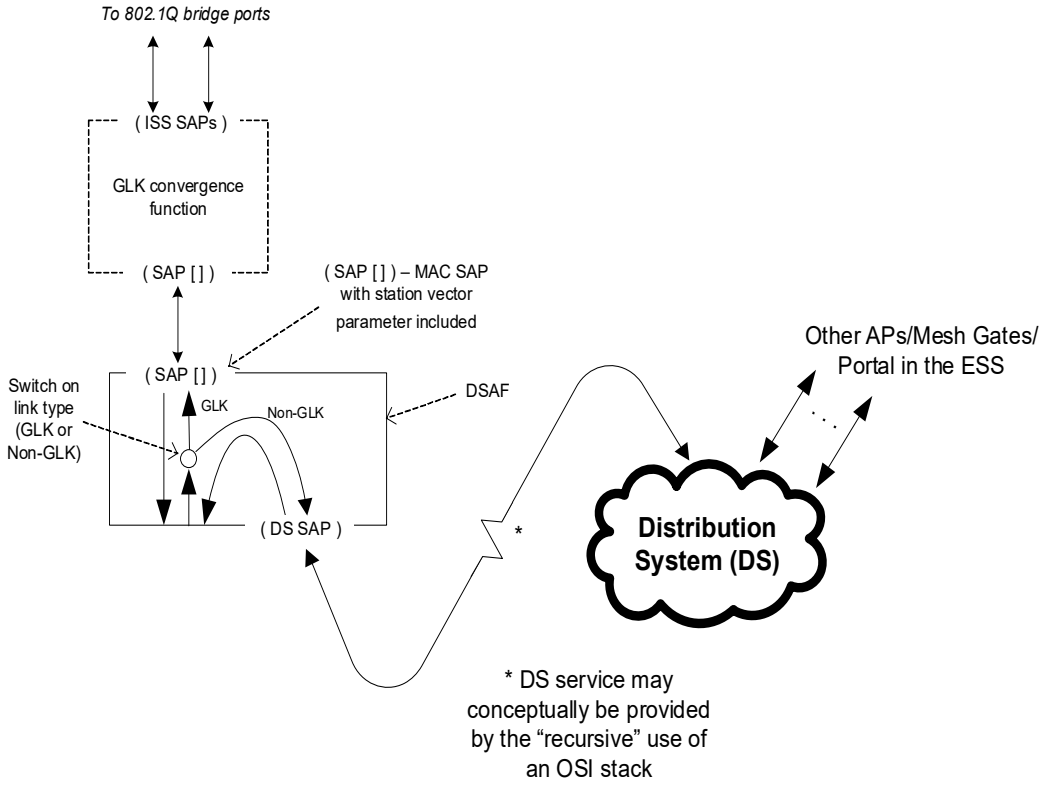


**Figure 5-9—Role-specific behavior block for a mixed-mode GLK AP(#7100)**

framework), to provide access to bridge ports, through provision of the station vector parameter, rather than access to only the local DA like a non-GLK mesh STA.

This role is not applicable when transparent FST is used and does not apply to Figure 5-2 (MAC data plane architecture (transparent FST)(11ay)(#1938)(#3158)(#4172)(#4192)).

## 5.2 MAC data service specification

### 5.2.1 General

The IEEE 802.11 MAC supports the following service primitives as defined in ISO/IEC 8802-2:1998:

- MA-UNITDATA.request
- MA-UNITDATA.indication
- MA-UNITDATA-STATUS.indication

IEEE Std 802.11 places restrictions and semantics on the parameter values for these primitives, as described in 5.2.4 (MA-UNITDATA.request) to 5.2.6 (MA-UNITDATA-STATUS.indication).

### 5.2.2 GLK MAC data service specification

A GLK STA coordinates with the GLK convergence function to create a virtual point-to-point LAN for each general link to an associated or peered GLK STA. This point-to-point LAN is presented by the convergence function as a unique Internal Sublayer Service SAP, which is ultimately mapped to an IEEE 802.1Q bridge port. Each such SAP is identified by a locally unique service_access_point_identifier (as defined in IEEE Std 802.1Q), generated by the STA and the convergence function.


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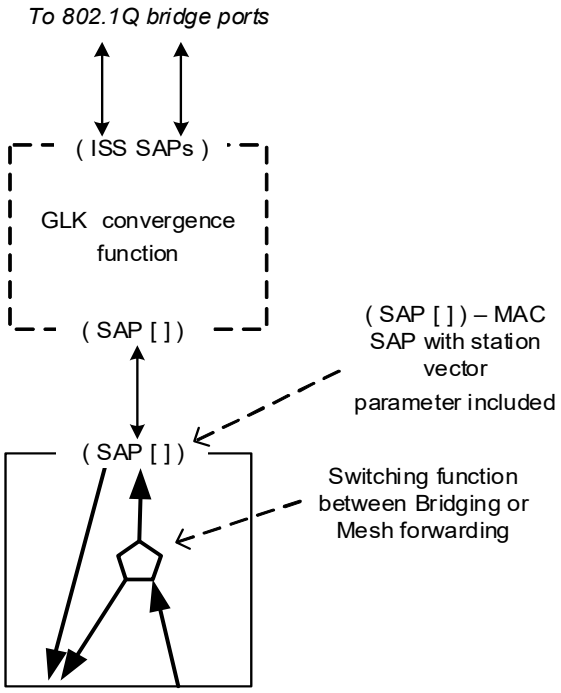


**Figure 5-10—Role-specific behavior block for a GLK mesh STA**

(#350)When GLK is in use, the MAC service makes use of the parameter station vector in the MA-UNITDATA primitives. In an MA-UNITDATA.request primitive, this parameter is a set of service_access_point_identifiers specifying the one or more general links that are to carry the MSDU. In an MA-UNITDATA.indication primitive, it is a set of exactly one service_access_point_identifier specifying the general link that carried the MSDU.

(#350)When GLK is in use, the MAC service also makes use of the MSDU format parameter. In an MA-UNITDATA.request primitive, this parameter indicates the format of the supplied MSDU (EPD or LPD). If the format is inappropriate for the transmission that carries this MSDU as described in 5.1.4 (MSDU format), the MAC service converts the format before transmission. In an MA-UNITDATA.indication primitive, this parameter indicates the format of the received MSDU, which is determined as described in 5.1.4 (MSDU format). The MAC service user uses this information to parse the MSDU correctly.

### 5.2.3 NGV MAC data service specification(11bd)

An NGV STA coordinates with higher layer ITS entities (e.g., IEEE 1609 [B20] family of standards) to provide wireless communications services via the LLC sublayer. The MA-UNITDATA primitives contain the radio environment request vector to facilitate the coordination.

### 5.2.4 MA-UNITDATA.request

#### 5.2.4.1 Function

This primitive requests a transfer of an MSDU from a local LLC sublayer entity to a single peer LLC sublayer entity or bridge port, or multiple peer LLC sublayer entities or bridge port in the case of group addresses.

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#### 5.2.4.2 Semantics of the service primitive

The parameters of the primitive are as follows:

```
MA-UNITDATA.request(
                        source address,
                        destination address,
                        routing information,
                        data,
                        priority,
                        drop eligible,
                        service class,
                        station vector,
                        MSDU format,
                        radio environment request vector(11bd)
                        )
```

The source address (SA) parameter specifies an individual MAC sublayer address of the sublayer entity from which the MSDU is being transferred.

The destination address (DA) parameter specifies either an individual or a group MAC sublayer entity address.

The routing information parameter specifies the route for the data transfer (a null value indicates source routing is not to be used). For IEEE Std 802.11, the routing information parameter shall be null.

The data parameter specifies the MSDU to be transmitted by the MAC sublayer entity. The length of the MSDU shall be less than or equal to the value shown in Table 9-34 (Maximum data unit sizes and durations(#1327)(#4013)).

The priority parameter specifies the requested priority of the (#3456)data transfer. The allowed values of priority are described in 5.1.1.3 (Interpretation of priority parameter in MAC service primitives).

NOTE—For a GLK STA, the bridge port provides the priority. That priority might have been derived from a priority tag in the frame arriving on another port of the bridge or from the configuration of that port if the frame arrived there untagged.

The drop eligible parameter is a Boolean that indicates whether this MSDU can be discarded in preference to other MSDUs when there are insufficient resources in a STA. If drop eligible is true, the MSDU can be discarded in preference to other MSDUs for which drop eligible is false.

The service class parameter specifies the requested service class of the (#3456)data transfer. The allowed values of service class are described in 5.1.1.4 (Interpretation of service class parameter in MAC service primitives in a STA) and 5.1.3 (MSDU ordering).

(#350)If dot11GLKImplemented is true, the station vector parameter is a set of service_access_point_identifiers (see 5.2.2 (GLK MAC data service specification)) that indicates the set of virtual point-to-point LANs for these data transfers, which are mapped to the set of general links over which the MSDU is transmitted; it is null otherwise.

(#350)In an EPD STA, the MSDU format parameter indicates the format of the supplied MSDU (EPD or LPD); it is ignored otherwise.

(11bd)The radio environment request vector parameter contains information that allows higher layer entities to configure the PPDU format, encoding, and MPDU handling for NGV transmission. This parameter is present when dot11NGVOptionImplemented is true or dot11NONNGVRadioEnvironmentImplemented is true, and absent otherwise.


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(11bd)The radio environment request vector parameter contains the following members pertaining to the transmission of the MPDU that contains the MSDU associated with the request containing the vector:

- PPDU format (non-NGV/NGV)
- data rate/NGV-MCS
- number of spatial streams
- permitted aggregation
- number of repetitions
- expiry time
- channel
- primary channel
- channel width
- fallback enabled
- transmit power spectral density

(11bd)The PPDU format member indicates the format of the PPDU as defined in Table 5-1 (PPDU format values(11bd)) that is used to transmit the MSDU.

**Table 5-1—PPDU format values(11bd)**

| PPDU format value | Description |
|---|---|
| 0 | Non-NGV PPDU |
| 1 | NGV PPDU |
| 2 | The PPDU format decided by the MAC sublayer(#7173) |

(11bd)The data rate/NGV-MCS member indicates the data rate of the PPDU carrying the MSDU if the PPDU format has value 0. The data rate can be either 0 (decided by MAC sublayer(#7173)), 3 Mb/s, 4.5 Mb/s, 6 Mb/s, 9 Mb/s, 12 Mb/s, 18 Mb/s, 24 Mb/s, or 27 Mb/s as defined in Table 17-4 (Modulation-dependent parameters). If the PPDU format has value 1, the data rate/NGV-MCS member indicates the NGV-MCS index as defined in 32.5 (Parameters for NGV-MCSs) with an exception that the value 14 means that the actual MCS is decided by the MAC sublayer(#7173).If the PPDU format has value 2, the data rate/NGV-MCS member is set to value 14 indicating that the actual data-rate/MCS is decided by the MAC sublayer(#7173).

(11bd)The number of spatial streams member with value 1 or 2 indicates the number of spatial streams being used to transmit the PPDU carrying the MSDU. The number of spatial streams member with value 0 means that the number of spatial streams is decided by the MAC sublayer(#7173). The permitted aggregation member indicates whether A-MPDU aggregation can be applied to the MSDU. The value 0 means that aggregation is not applied, the value 1 means that aggregation can be applied, while the value 2 means that it is up to the MAC sublayer(#7173) to decide whether the aggregation can be applied.

(11bd)The number of repetitions member indicates the maximal number of repetitions that can be used to transmit the MSDU in a broadcast MPDU of a non-NGV PPDU in a 10 MHz channel width where the values can be in the range 0 to 3 or 15. The value 15 means that it is up to the MAC sublayer(#7173) to decide whether the repetition is applied to the MSDU. This parameter is reserved when the MSDU is not in a broadcast MPDU in 10 MHz channel width.

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(11bd)The expiry time member indicates the time in milliseconds until the MSDU is discarded if still not transmitted, where the value 0 means that it is up to the MAC sublayer(#7173) to decide the expiry time of the MSDU.

NOTE 1—When an MSDU reaches its expiry time and is discarded, the CW state variable of the EDCAF associated with that MSDU is unchanged.(11bd)

(11bd)The channel member indicates the channel where the MSDU is transmitted in the 5.9 GHz band as defined in Annex E.2.3 and Annex E.2.4 with the exception for value 0, which means that the MAC sublayer(#7173) selects the channel.

(11bd)The primary channel indicates the primary 10 MHz channel where the MSDU is transmitted, where the value 0 means that the MAC sublayer(#7173) selects the primary channel. This member is present when dot11NGVOptionImplemented is true and when the channel width member is 20 MHz and is absent otherwise.

(11bd)The channel width member indicates either 10 MHz or 20 MHz channel width used to transmit the MSDU as defined in Table 5-2 (Channel width values(11bd)). When the channel width indicates 20 MHz, the primary channel member indicates the OCB primary channel.

NOTE 2—An NGV STA transmitting in a 20 MHz channel maintains a single primary channel at any given time(11bd).

**Table 5-2—Channel width values(11bd)**

| Channel width value | Description |
|---|---|
| 0 | 10 MHz |
| 1 | 20 MHz |
| 2 | The channel width is decided by the MAC sublayer(#7173) |

(11bd)The fallback enabled member indicates whether the transmission of a 10 MHz PPDU in the OCB primary channel is allowed by an NGV STA while the NGV STA performs channel access to transmit a 20 MHz NGV PPDU. The value 0 means that the fallback to 10 MHz can be applied to the MSDU, the value 1 means that the fallback to 10 MHz cannot be applied to the MSDU, while the value 3 means that it is up to the MAC sublayer(#7173) to decide whether the fallback is applied to the MSDU. This member is present when dot11NGVOptionImplemented is true and when the channel width member is 20 MHz and is absent otherwise.

(11bd)The transmit power spectral density member indicates the combined transmit power at the transmit antenna connector of all the antennas used to transmit the MSDU in units of dBm/10 MHz. The transmit power is described with a resolution of 1 dB, with values in the range 0 to 60 representing –20 dBm/10 MHz to 40 dBm/10 MHz, respectively. Values from 61 to 126 are reserved. The value 127 means that it is up to the MAC sublayer(#7173) to decide the transmit power of the MSDU.

#### 5.2.4.3 When generated

This primitive is generated by the LLC sublayer entity when an MSDU is to be transferred to a peer LLC sublayer entity or entities or to a peer bridge or bridges.


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#### 5.2.4.4 Effect of receipt

On receipt of this primitive, the MAC sublayer entity determines whether it is able to fulfill the request according to the requested parameters. A request that cannot be fulfilled according to the requested parameters is discarded, and this action is indicated to the LLC sublayer entity using an MA-UNITDATA-STATUS.indication primitive that describes why the MAC was unable to fulfill the request. If the request can be fulfilled according to the requested parameters, the MAC sublayer entity properly formats a frame and passes it to the lower layers for transfer to a peer MAC sublayer entity or entities (see 5.1.4 (MSDU format)), and indicates this action to the LLC sublayer entity or bridge port using an MA-UNITDATA-STATUS.indication primitive with transmission status set to Successful.

At an AP for which dot11SSPNInterfaceActivated is true, upon receipt of an MA-UNITDATA.request primitive having a destination address that is an individual address and a priority of Contention, the AP's MAC sublayer shall perform rate limiting to enforce the resource utilization limit in dot11NonAPStationMaxAuthBestEffortRate in the dot11InterworkingEntry identified by the destination MAC address of the frame to be transmitted. The specific mechanism to perform rate limiting is outside the scope of this standard.

— If the rate limiting mechanism does not discard the frame, then dot11NonAPStationBestEffortMSDUCount shall be incremented by 1 and dot11NonAPStationBestEffortOctetCount shall be incremented by the number of octets in the MSDU.

— If the rate limiting mechanism discards the frame, then dot11NonAPStationDroppedBestEffortMSDUCount shall be incremented by 1 and dot11NonAPStationDroppedBestEffortOctetCount shall be incremented by the number of octets in the MSDU.

At an AP for which dot11SSPNInterfaceActivated is true, upon receipt of an MA-UNITDATA.request primitive having a destination address that is an individual address for which the priority is an integer in the range 0 to 7, then the AP's MAC sublayer shall derive the access category from the priority using the mapping in Table 10-1 (UP-to-AC mappings(#68)). The AP's MAC sublayer shall retrieve the MIB attributes listed below from the dot11InterworkingEntry identified by the destination MAC address of the frame to be transmitted and perform the following operations:

— If the access category is AC_VO, then the AP's MAC sublayer shall perform rate limiting to enforce the resource utilization limit in dot11NonAPStationMaxAuthVoiceRate; the specific mechanism to perform rate limiting is outside the scope of this standard. If the rate limiting mechanism does not discard the frame, then dot11NonAPStationVoiceMSDUCount shall be incremented by 1 and dot11NonAPStationVoiceOctetCount shall be incremented by the number of octets in the MSDU. If the rate limiting mechanism discards the frame, then dot11NonAPStationDroppedVoiceMSDUCount shall be incremented by 1 and dot11NonAPStationDroppedVoiceOctetCount shall be incremented by the number of octets in the MSDU.

— If the access category is AC_VI, then the AP's MAC sublayer shall perform rate limiting to enforce the resource utilization limit in dot11NonAPStationMaxAuthVideoRate; the specific mechanism to perform rate limiting is outside the scope of this standard. If the rate-limiting mechanism does not discard the frame, then dot11NonAPStationVideoMSDUCount shall be incremented by 1 and dot11NonAPStationVideoOctetCount shall be incremented by the number of octets in the MSDU. If the rate limiting mechanism discards the frame, then dot11NonAPStationDroppedVideoMSDUCount shall be incremented by 1 and dot11NonAPStationDroppedVideoOctetCount shall be incremented by the number of octets in the MSDU.

— If the access category is AC_BE, then the AP's MAC sublayer shall perform rate limiting to enforce the resource utilization limit in dot11NonAPStationMaxAuthBestEffortRate; the specific mechanism to perform rate limiting is outside the scope of this standard. If the rate-limiting

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mechanism does not discard the frame, then dot11NonAPStationBestEffortMSDUCount shall be incremented by 1 and dot11NonAPStationBestEffortOctetCount shall be incremented by the number of octets in the MSDU. If the rate limiting mechanism discards the frame, then dot11NonAPStationDroppedBestEffortMSDUCount shall be incremented by 1 and dot11NonAPStationDroppedBestEffortOctetCount shall be incremented by the number of octets in the MSDU.

— If the access category is AC_BK, then the AP's MAC sublayer shall perform rate limiting to enforce the resource utilization limit in dot11NonAPStationMaxAuthBackgroundRate; the specific mechanism to perform rate limiting is outside the scope of this standard. If the rate-limiting mechanism does not discard the frame, then dot11NonAPStationBackgroundMSDUCount shall be incremented by 1 and dot11NonAPStationBackgroundOctetCount shall be incremented by the number of octets in the MSDU. If the rate limiting mechanism discards the frame, then dot11NonAPStationDroppedBackgroundMSDUCount shall be incremented by 1 and dot11NonAPStationDroppedBackgroundOctetCount shall be incremented by the number of octets in the MSDU.

At an AP for which dot11SSPNInterfaceActivated is true, upon receipt of an MA-UNITDATA.request primitive having a destination address that is an individual address whose priority is an integer in the range 8 to 15, then the AP's MAC sublayer shall perform rate limiting to enforce the resource utilization limit in dot11NonAPStationAuthMaxHCCAHEMMRate; the specific mechanism to perform rate limiting is outside the scope of this standard.

— If the rate-limiting mechanism does not discard the frame, then dot11NonAPStationHCCAHEMMMSDUCount shall be incremented by 1, and dot11NonAPStationHCCAHEMMOctetCount shall be incremented by the number of octets in the MSDU.

— If the rate limiting mechanism discards the frame, then dot11NonAPStationDroppedHCCAHEMMMSDUCount shall be incremented by 1 and dot11NonAPStationDroppedHCCAHEMMOctetCount shall be incremented by the number of octets in the MSDU.

### 5.2.5 MA-UNITDATA.indication

#### 5.2.5.1 Function

This primitive defines the transfer of an MSDU from the MAC sublayer entity to the LLC sublayer entity or bridge port, or entities or bridge ports in the case of group addresses. In the absence of error, the contents of the data parameter are logically complete and unchanged relative to the data parameter in the associated MA-UNITDATA.request primitive.

#### 5.2.5.2 Semantics of the service primitive

The parameters of the primitive are as follows:

```
MA-UNITDATA.indication(
                        source address,
                        destination address,
                        routing information,
                        data,
                        reception status,
                        priority,
                        drop eligible,
                        service class,
                        station vector,
                        MSDU format,
```


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radio environment status vector(11bd)
)

The SA parameter is an individual address as specified by the SA field of the incoming frame.

The DA parameter is either an individual or a group address as specified by the DA field of the incoming frame.

The routing information parameter specifies the route that was used for the data transfer. The MAC sublayer entity shall set this field to null.

The data parameter specifies the MSDU as received by the local MAC entity.

The reception status parameter indicates the success or failure of the received frame. The MAC always reports "success" because all failures of reception are discarded without generating MA-UNITDATA.indication primitive.

The drop eligible parameter is a Boolean that indicates whether the received MSDU was designated as drop eligible in the DEI subfield of the HT variant HT Control field of the incoming frame, if present. If no HT variant HT Control field was present, the parameter value is false.

The priority parameter specifies the receive processing priority that was used for the (#3456)data transfer. The allowed values of priority are described in 5.1.1.3 (Interpretation of priority parameter in MAC service primitives).

The service class parameter specifies the receive service class that was used for the (#3456)data transfer. The allowed values of service class are described in 5.1.1.4 (Interpretation of service class parameter in MAC service primitives in a STA) and 5.1.3 (MSDU ordering).

(#350)If dot11GLKImplemented is true, the station vector parameter is a set of service_access_point_identifiers (see 5.2.2 (GLK MAC data service specification)) that indicates the single virtual point-to-point LAN for this data transfer, which is mapped from the general link over which the MSDU was received; it is null otherwise.

(#350)In an EPD STA, the MSDU format parameter indicates the format of the received MSDU (EPD or LPD); it indicates LPD otherwise. (#7102)See 5.1.4 (MSDU format) for how the MSDU format is determined upon arrival of an MSDU.

(11bd)The radio environment status vector parameter provides information to higher layer entities about the current radio environment and the most recent reception. This parameter is present when dot11NGVOptionImplemented is true or dot11NONNGVRadioEnvironmentImplemented is true, and absent otherwise.

(11bd)The radio environment status vector parameter contains the following members pertaining to the reception of the MPDU that contained the MSDU associated with the indication containing the vector:

— PPDU format (non-NGV/NGV)
— data rate/NGV-MCS
— aggregation
— channel
— primary channel
— channel width
— RSSI

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(11bd)The PPDU format member indicates the format of the received PPDU that carries the MSDU as defined in Table 5-1 (PPDU format values(11bd)).

(11bd)The data rate/NGV-MCS member indicates the data rate of the PPDU carrying the MSDU if the PPDU format has value 0. The data rate can be one of 3 Mb/s, 4.5 Mb/s, 6 Mb/s, 9 Mb/s, 12 Mb/s, 18 Mb/s, 24 Mb/s, or 27 Mb/s as defined in Table 17-4 (Modulation-dependent parameters). If the PPDU format has value 1, the data rate/NGV-MCS member indicates the NGV-MCS index as defined in 32.5 (Parameters for NGV-MCSs).

(11bd)The aggregation member indicates whether A-MPDU aggregation is applied to the received MSDU. The value 0 means that aggregation is not applied, while the value 1 means that aggregation is applied.

(11bd)The channel member indicates the channel where the MSDU is transmitted in the 5.9 GHz band as defined in Annex E.2.3 and Annex E.2.4 with the exception for value 0, which means that the MAC sublayer(#7173) selects the channel.

(11bd)The primary channel member indicates the primary 10 MHz channel where the MSDU is received.

(11bd)The channel width member indicates either 10 MHz or 20 MHz channel width of the PPDU carrying the received MSDU as defined in Table 5-2 (Channel width values(11bd)). When the channel width indicates 20 MHz, the primary channel parameter indicates the OCB primary channel.

(11bd)The RSSI parameter indicates the receive signal power, measured at the STA's antenna connector and averaged over the antennas, for the NGV portion of the received NGV PPDU and is defined in Table 5-3 (RSSI values(11bd)).

**Table 5-3—RSSI values(11bd)**

| RSSI | Description |
|---|---|
| 0 to 90 | The RSSI, in units of dBm, is –113 + $F_{val}$ , where $F_{val}$ is the subfield value |
| 91 to 127 | Reserved |

#### 5.2.5.3 When generated

The MA-UNITDATA.indication primitive is passed from the MAC sublayer entity to the LLC sublayer entity or entities to, or bridge port or ports, indicate the arrival of an MSDU(#1806) at the local MAC sublayer entity. Frames are reported only if they are validly formatted at the MAC sublayer, received without error, received with valid (or null) security and integrity information, and their destination address designates the local MAC sublayer entity. The MA-UNITDATA.indication primitive might also be passed from the MAC sublayer entity, in coordination with the MAC sublayer management entity, to the LLC sublayer entity to indicate the arrival of a FILS higher layer protocol (HLP) Container element.

#### 5.2.5.4 Effect of receipt

The effect of receipt of this primitive by the LLC sublayer or bridge port is dependent on the content of the MSDU.

At an AP for which dot11SSPNInterfaceActivated is true, upon receipt of a frame with the Type subfield equal to Data having a group DA, the AP's MAC sublayer shall discard the frame if dot11NonAPStationAuthSourceMulticast is false in the dot11InterworkingEntry identified by the source


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MAC address of the received frame. If dot11NonAPStationAuthSourceMulticast is true, the AP's MAC sublayer shall perform rate limiting to enforce the resource utilization limit in dot11NonAPStationAuthMaxSourceMulticastRate in the dot11InterworkingEntry identified by the source MAC address of the received frame. The specific mechanism to perform rate limiting is outside the scope of this standard.

— If the rate limiting mechanism does not discard the frame, then dot11NonAPStationMulticastMSDUCount shall be incremented by 1 and dot11NonAPStationMulticastOctetCount shall be incremented by the number of octets in the MSDU.

— If the rate limiting mechanism discards the frame, then dot11NonAPStationDroppedMulticastMSDUCount. shall be incremented by 1 and dot11NonAPStationDroppedMulticastOctetCount. shall be incremented by the number of octets in the MSDU.

At an AP for which dot11SSPNInterfaceActivated is true, upon receipt of an individually addressed frame with the Type subfield equal to Data and a priority of Contention, then the AP's MAC sublayer shall perform rate limiting to enforce the resource utilization limit in dot11NonAPStationMaxAuthBestEffortRate in the dot11InterworkingEntry identified by the source MAC address of the received frame. The specific mechanism to perform rate limiting is outside the scope of this standard.

— If the rate limiting mechanism does not discard the frame, then dot11NonAPStationBestEffortMSDUCount shall be incremented by 1 and dot11NonAPStationBestEffortOctetCount shall be incremented by the number of octets in the MSDU.

— If the rate limiting mechanism discards the frame, then dot11NonAPStationDroppedBestEffortMSDUCount shall be incremented by 1 and dot11NonAPStationDroppedBestEffortOctetCount shall be incremented by the number of octets in the MSDU.

At an AP for which dot11SSPNInterfaceActivated is true, upon receipt of an individually addressed frame with the Type subfield equal to Data, for which the priority is an integer in the range 0 to 7, then the AP's MAC sublayer shall derive the access category from the priority using the mapping in Table 10-1 (UP-to-AC mappings(#68)). The AP's MAC sublayer shall retrieve the MIB attributes from the dot11InterworkingEntry identified by the source MAC address of the received frame and perform the following operations:

— If the access category is AC_VO, then the AP's MAC sublayer shall perform rate limiting to enforce the resource utilization limit in dot11NonAPStationMaxAuthVoiceRate; the specific mechanism to perform rate limiting is outside the scope of this standard. If the rate-limiting mechanism does not discard the frame, then dot11NonAPStationVoiceMSDUCount shall be incremented by 1 and dot11NonAPStationVoiceOctetCount shall be incremented by the number of octets in the MSDU. If the rate limiting mechanism discards the frame, then dot11NonAPStationDroppedVoiceMSDUCount shall be incremented by 1 and dot11NonAPStationDroppedVoiceOctetCount shall be incremented by the number of octets in the MSDU.

— If the access category is AC_VI, then the AP's MAC sublayer shall perform rate limiting to enforce the resource utilization limit in dot11NonAPStationMaxAuthVideoRate; the specific mechanism to perform rate limiting is outside the scope of this standard. If the rate-limiting mechanism does not discard the frame, then dot11NonAPStationVideoMSDUCount shall be incremented by 1 and dot11NonAPStationVideoOctetCount shall be incremented by the number of octets in the MSDU. If the rate limiting mechanism discards the frame, then dot11NonAPStationDroppedVideoMSDUCount shall be incremented by 1 and dot11NonAPStationDroppedVideoOctetCount shall be incremented by the number of octets in the MSDU.

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— If the access category is AC_BE, then the AP's MAC sublayer shall perform rate limiting to enforce the resource utilization limit in dot11NonAPStationMaxAuthBestEffortRate; the specific mechanism to perform rate limiting is outside the scope of this standard. If the rate-limiting mechanism does not discard the frame, then dot11NonAPStationBestEffortMSDUCount shall be incremented by 1 and dot11NonAPStationBestEffortOctetCount shall be incremented by the number of octets in the MSDU. If the rate limiting mechanism discards the frame, then dot11NonAPStationDroppedBestEffortMSDUCount shall be incremented by 1 and dot11NonAPStationDroppedBestEffortOctetCount shall be incremented by the number of octets in the MSDU.

— If the access category is AC_BK, then the AP's MAC sublayer shall perform rate limiting to enforce the resource utilization limit in dot11NonAPStationMaxAuthBackgroundRate; the specific mechanism to perform rate limiting is outside the scope of this standard. If the rate-limiting mechanism does not discard the frame, then dot11NonAPStationBackgroundMSDUCount shall be incremented by 1 and dot11NonAPStationBackgroundOctetCount shall be incremented by the number of octets in the MSDU. If the rate limiting mechanism discards the frame, then dot11NonAPStationDroppedBackgroundMSDUCount shall be incremented by 1 and dot11NonAPStationDroppedBackgroundOctetCount shall be incremented by the number of octets in the MSDU.

At an AP for which dot11SSPNInterfaceActivated is true, upon receipt of an individually addressed frame with the Type subfield equal to Data for which the priority is an integer in the range 8 to 15, the AP's MAC sublayer shall perform rate limiting to enforce the resource utilization limit in dot11NonAPStationAuthMaxHCCAHEMMRate; the specific mechanism to perform rate limiting is outside the scope of this standard.

— If the rate-limiting mechanism does not discard the frame, then dot11NonAPStationHCCAHEMMMSDUCount shall be incremented by 1, and dot11NonAPStationHCCAHEMMOctetCount shall be incremented by the number of octets in the MSDU.

— If the rate limiting mechanism discards the frame, then dot11NonAPStationDroppedHCCAHEMMMSDUCount shall be incremented by 1 and dot11NonAPStationDroppedHCCAHEMMOctetCount shall be incremented by the number of octets in the MSDU.

### 5.2.6 MA-UNITDATA-STATUS.indication

#### 5.2.6.1 Function

This primitive has local significance and provides the LLC sublayer or bridge port with status information for the corresponding preceding MA-UNITDATA.request primitive.

#### 5.2.6.2 Semantics of the service primitive

The parameters of the primitive are as follows:

MA-UNITDATA-STATUS.indication(
source address,
destination address,
transmission status,
provided priority,
provided service class,
radio environment request vector(11bd))

The SA parameter is an individual MAC sublayer entity address as specified in the associated MA-UNITDATA.request primitive.


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The DA parameter is either an individual or group MAC sublayer entity address as specified in the associated MA-UNITDATA.request primitive.

The transmission status parameter is used to pass status information back to the local requesting LLC sublayer entity or bridge port. IEEE Std 802.11 specifies the following values for transmission status:

a) Successful.
b) Undeliverable (excessive data length).
c) Undeliverable (non-null source routing).
d) Undeliverable: unsupported priority (for priorities other than Contention at a non-QoS STA; or for priorities other than Contention, or an integer in the range 0 to 15 at a QoS STA).
e) Undeliverable: unsupported service class (for service classes other than ReorderableGroupAddressed for non-QoS STAs and service classes other than QoSAck or QoSNoAck for QoS STAs).
f) Unavailable priority (for an integer in the range 1 to 15 at a STA that is associated in a non-QoS BSS, or an integer in the range 8 to 15 at an IBSS STA, in which case the MSDU is transmitted with a provided priority of Contention).
g) Undeliverable: unavailable service class.
h) Undeliverable (no BSS available).
i) Undeliverable (cannot encrypt with a null key).
j) In a STA in which dot11RejectUnadmittedTraffic is true, Undeliverable: unadmitted traffic (for a requested priority in the range 0 to 7 because there is no admitted TS for this priority and admission control is required for the AC).
k) In an AP in which dot11SSPNInterfaceActivated is true, Undeliverable (violation of limit specified by dot11NonAPStationMaxAuthVoiceRate in the dot11InterworkingTable for the non-AP STA identified by the destination address of the MA-UNITDATA.request primitive).
l) In an AP in which dot11SSPNInterfaceActivated is true, Undeliverable (violation of limit specified by dot11NonAPStationMaxAuthVideoRate in the dot11InterworkingTable for the non-AP STA identified by the destination address of the MA-UNITDATA.request primitive).
m) In an AP in which dot11SSPNInterfaceActivated is true, Undeliverable (violation of limit specified by dot11NonAPStationMaxAuthBestEffortRate in the dot11InterworkingTable for the non-AP STA identified by the destination address of the MA-UNITDATA.request primitive).
n) In an AP in which dot11SSPNInterfaceActivated is true, Undeliverable (violation of limit specified by dot11NonAPStationAuthMaxBackgroundRate in the dot11InterworkingTable for the non-AP STA identified by the destination address of the MA-UNITDATA.request primitive).
o) In an AP in which dot11SSPNInterfaceActivated is true, Undeliverable (violation of limit specified by dot11NonAPStationAuthMaxHCCAHEMMRate in the dot11InterworkingTable for the non-AP STA identified by the destination address of the MA-UNITDATA.request primitive).

If the transmission status parameter is Successful, the provided priority parameter specifies the priority used for the associated (#3456)data transfer (Contention or an integer in the range 0 to 15); otherwise the provided priority parameter is not present.

If the transmission status parameter is Successful, the provided service class parameter specifies the class of service for the associated (#3456)data transfer; otherwise the provided service class parameter is not present. In non-QoS STAs, the value of this parameter is ReorderableGroupAddressed. In QoS STAs, it is QoSAck or QoSNoAck.

(11bd)The radio environment request vector parameter (see 5.2.4.2 (Semantics of the service primitive)) contains information that is used by the MAC entity to report the used format, encoding, and MPDU handling for NGV transmission. This parameter is present when dot11NGVOptionImplemented is true or dot11NONNGVRadioEnvironmentImplemented is true, and absent otherwise.

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#### 5.2.6.3 When generated

The MA-UNITDATA-STATUS.indication primitive is passed from the MAC sublayer entity to the LLC sublayer entity or bridge port to indicate the status of the service provided for the corresponding MA-UNITDATA.request primitive.

#### 5.2.6.4 Effect of receipt

The effect of receipt of this primitive by the LLC sublayer or bridge port is dependent upon the type of operation employed by the LLC sublayer entity or bridge port.


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# 6. Layer management

## 6.1 Overview of management model

Both the MAC sublayer and PHY conceptually include management entities, called *MLME* and *PLME*, respectively. These entities provide the layer management service interfaces through which layer management functions are invoked.

In order to provide correct MAC operation, an SME is present within each STA. The SME is a layer-independent entity that resides in a separate management plane or resides "off to the side." Some of the functions of the SME are specified in this standard. Typically this entity is responsible for such functions as the gathering of layer-dependent status from the various layer management entities (LMEs), and similarly setting the value of layer-specific parameters. The SME typically performs such functions on behalf of general system management entities and would implement standard management protocols. Figure 4-27 (Portion of the ISO/IEC basic reference model covered in this standard(#4114)) (in 4.9 (Reference model)) depicts the relationship among management entities.

The various entities within this model interact in various ways. Certain of these interactions are defined explicitly within this standard, via a SAP across which defined primitives are exchanged. This definition includes the GET and SET operations between MLME, PLME and SME as well as other individually defined service primitives, represented as double arrows within Figure 6-1 (GET and SET operations). Other interactions are not defined explicitly within this standard, such as the interfaces between the MAC and MLME and between the PLME and PHY; the specific manner in which these MAC and PHY LMEs are integrated into the overall MAC sublayer and PHY is not specified within this standard. A STA includes only one instance of a PHY entity.

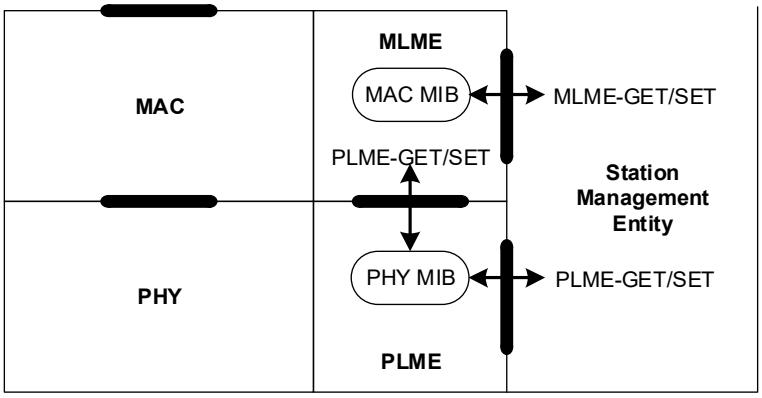


**Figure 6-1—GET and SET operations**

The management SAPs within this model are the following:

— SME-MLME SAP
— SME-PLME SAP
— MLME-PLME SAP

The latter two SAPs support identical primitives, and in fact might be viewed as a single SAP (called the *PLME SAP*) that is used either directly by MLME or by SME. In this fashion, the model reflects what is anticipated to be a common implementation approach in which PLME functions are controlled by the MLME (on behalf of SME).

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## 6.2 Generic management primitives

(#6320)The management information specific to each of the MAC sublayer and PHY layer is represented as a MIB for each. The MLME and PLME are viewed as "containing" the MIB for each. The generic model of (M118)MIB related management primitives exchanged across the management SAPs is to allow the SAP user-entity to either GET the value of a MIB attribute, or to SET the value of a MIB attribute. The invocation of a SET.request primitive might require that the entity perform certain defined actions.

Figure 6-1 (GET and SET operations) depicts these generic primitives.

The GET and SET primitives are represented as REQUESTs with associated CONFIRM primitives. These primitives are prefixed by MLME or PLME depending upon whether the MAC sublayer or PHY management SAP is involved. In the following, XX denotes MLME or PLME:

XX-GET.request(MIBattribute)

Requests the value of the given MIBattribute.

XX-GET.confirm(status, MIBattribute, MIBattributevalue)

Returns the appropriate MIB attribute value if status = "success," otherwise returns an error indication in the Status field. Possible error status values include "invalid MIB attribute" and "attempt to get write-only MIB attribute."

XX-SET.request(MIBattribute, MIBattributevalue)

Requests that the indicated MIB attribute be set to the given value. If this MIBattribute implies a specific action, then this requests that the action be performed.

XX-SET.confirm(status, MIBattribute)

If status = "success," this confirms that the indicated MIB attribute was set to the requested value; otherwise it returns an error condition in status field. If this MIBattribute implies a specific action, then this confirms that the action was performed. Possible error status values include "invalid MIB attribute" and "attempt to set read-only MIB attribute."

Additionally, there are certain requests that can be invoked across a given SAP that do not involve the setting or getting of a specific MIB attribute. One of these is supported by each SAP, as follows:

— XX-RESET.request: where XX is MLME or PLME as appropriate

This service is used to initialize the management entities, the MIBs, and the datapath entities. It might include a list of attributes for items to be initialized to nondefault values.

Other SAP-specific primitives are identified in 6.3 (MLME SAP interface(#1114)).

## 6.3 MLME SAP interface(#1114)

### 6.3.1 Introduction

The services provided by the MLME to the SME are specified in(#4127) Table 6-1 (MLME SAP interface(#1114)(#7082)). These services are described in an abstract way (following the model described in ITU-T Recommendation X.210 [B64]) and do not imply any particular implementation or exposed interface. MLME SAP primitives are of the general form ACTION.request primitive followed by ACTION.confirm primitive (for an exchange initiated by the SAP client) and ACTION.indication primitive followed by ACTION.response primitive (for an exchange initiated by the MLME). The SME uses the services provided by the MLME through the MLME SAP.


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The primitives generally include a STA Address or a Peer STA address parameter. The .response and .confirm primitives generally contain a ResultCode parameter. A high-level description of the primitives is provided in 6.4 (Table of MLME SAP interfaces(#1114)). The description in 6.4 (Table of MLME SAP interfaces(#1114)) is a guide to the detailed formats of the primitives and other parameters. Information that is known to the MLME is not passed in the primitive parameters.

There are seven general forms of MLME-SAP interface primitives.

### 6.3.2 Type 1

Figure 6-2 (Type 1 form of MLME SAP primitives for request/response process(#1114)) depicts Type 1. The Type 1 general form is used for the exchange of request/response frames between an initiating STA and a peer STA.

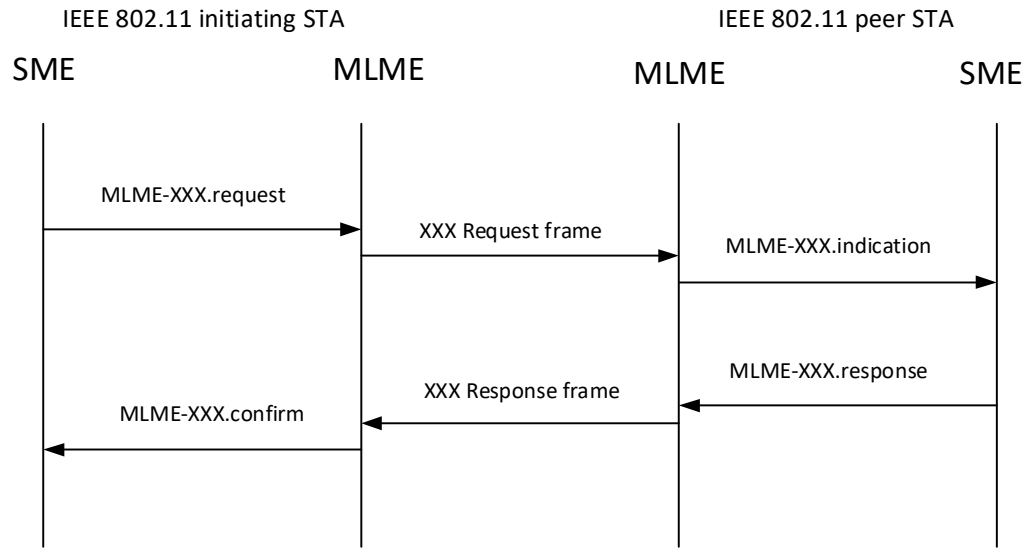


**Figure 6-2—Type 1 form of MLME SAP primitives for request/response process(#1114)**

The .request primitive is generated by the SME of the initiating STA to request that a request frame is sent to a peer STA.

The .indication primitive is generated by the MLME of the peer STA when the request frame is received.

The .response primitive is generated by the SME of the peer to request that a response frame be sent to the initiating STA.

The .confirm primitive includes a Result Code parameter reporting success or failure of the request, and is generated by the MLME of the initiating STA when either the response frame from the peer STA is acknowledged, or the (re)transmission of the request frame fails.

### 6.3.3 Type 2

Figure 6-3 (Type 2 form of MLME SAP primitives for frame transmission not requiring a response, but requiring a confirmation(#1114)) depicts Type 2. The Type 2 general form is used for the transmission of a

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frame from one STA to a peer STA that does not require a response from the peer STA but does require a confirmation that the frame was transmitted and either acknowledged or timed out.

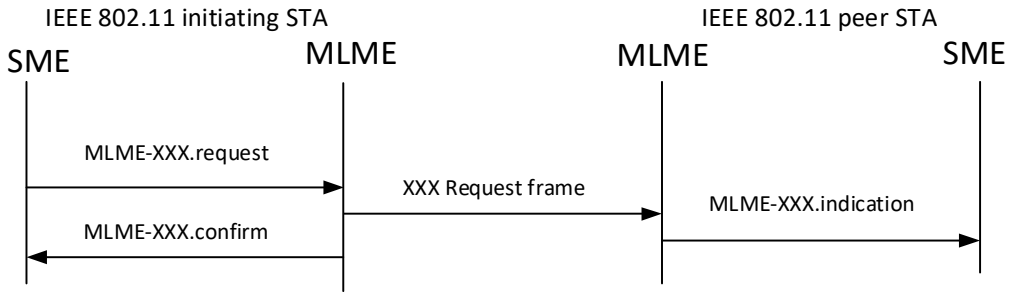


**Figure 6-3—Type 2 form of MLME SAP primitives for frame transmission not requiring a response, but requiring a confirmation(#1114)**

The .request primitive is generated by the SME of the initiating STA to request that a request frame is sent to a peer STA.

The .confirm primitive generally includes a Result Code parameter reporting success or failure of the request, and is generated by the MLME when the requested action or process is completed, or fails.

The .indication primitive is generated by the MLME of the peer STA when the request frame is received.

### 6.3.4 Type 3

Figure 6-4 (Type 3 form of MLME SAP primitives for frame transmission not requiring a response or a confirmation(#1114)) depicts Type 3. The Type 3 general form is used for the transmission of a frame from one STA to a peer STA that does not require a response from the peer STA or a confirmation.

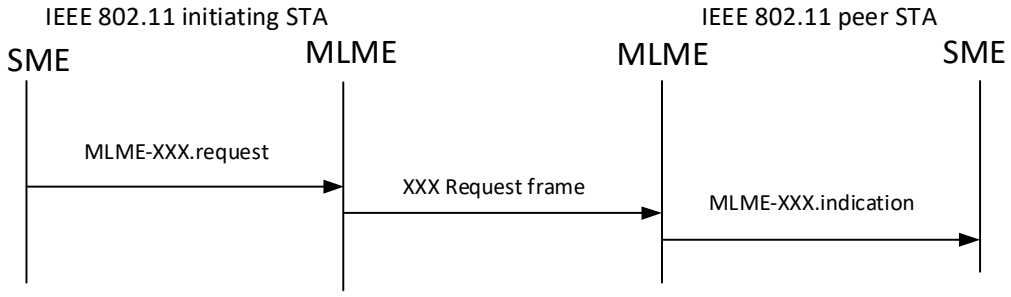


**Figure 6-4—Type 3 form of MLME SAP primitives for frame transmission not requiring a response or a confirmation(#1114)**

The .request primitive is generated by the SME of the initiating STA to request that a request frame is sent to a peer STA.

The .indication primitive is generated by the MLME of the peer STA when the request frame is received.


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### 6.3.5 Type 4

Figure 6-5 (Type 4 form of MLME SAP primitives for a frame transmission from a STA, but does require a confirmation that it was sent(#1114)) depicts Type 4. The Type 4 general form is used for the transmission of a frame that does not require a response, but does require a confirmation that it was sent.

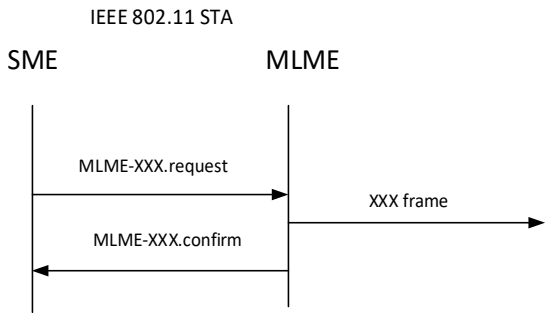


**Figure 6-5—Type 4 form of MLME SAP primitives for a frame transmission from a STA, but does require a confirmation that it was sent(#1114)**

The .request primitive is generated by the SME to request that the MLME transmits a frame.

The .confirm primitive generally includes a Result Code parameter reporting success or failure of the request, and is generated by the MLME when the requested frame transmission is completed, or fails.

### 6.3.6 Type 5

Figure 6-6 (Type 5 form of MLME SAP primitives for SME requesting MLME to perform a process(#1114)) depicts Type 5. The Type 5 general form is used when the SME requests a process to be initiated or information to be provided by the MLME.

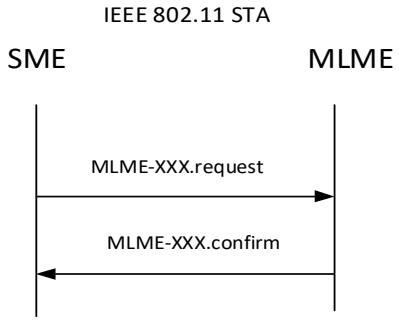


**Figure 6-6—Type 5 form of MLME SAP primitives for SME requesting MLME to perform a process(#1114)**

The .request primitive is generated by the SME to request that a process is initiated by the MLME or information is requested to be provided by the MLME.

The .confirm primitive generally includes a Result Code parameter reporting success or failure of the request, and is generated by the MLME when the request completes or fails.

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### 6.3.7 Type 6

Figure 6-7 (Type 6 form of MLME SAP primitives for SME requesting MLME to perform a process not requiring a confirmation(#1114)) depicts Type 6. The Type 6 general form is used when the SME requests a process to be initiated by the MLME and the SME does not require a confirmation.

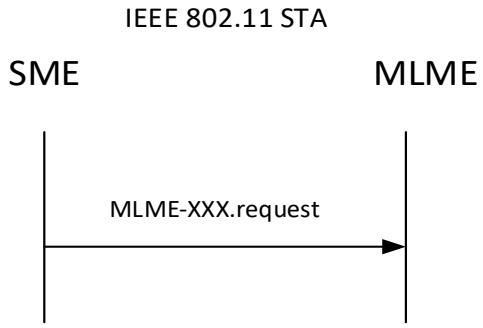


**Figure 6-7—Type 6 form of MLME SAP primitives for SME requesting MLME to perform a process not requiring a confirmation(#1114)**

The .request primitive is generated by the SME to request that a process is initiated by the MLME.

### 6.3.8 Type 7

Figure 6-8 (Type 7 form of MLME SAP primitives for MLME informing SME of an event(#1114)) depicts Type 7. The Type 7 general form is used when the MLME informs the SME of an event.

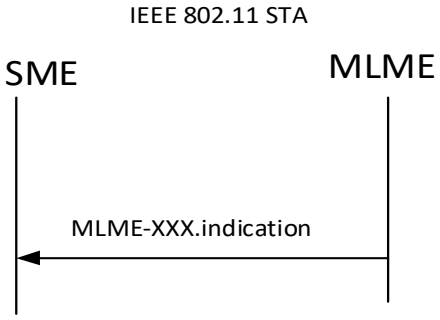


**Figure 6-8—Type 7 form of MLME SAP primitives for MLME informing SME of an event(#1114)**

The .indication primitive is generated by the MLME to inform the SME of an event.

## 6.4 Table of MLME SAP interfaces(#1114)

Table 6-1 (MLME SAP interface(#1114)(#7082))lists the service name, the MLME SAP interface name (MLME-XXX), the Type as defined in 6.3 (MLME SAP interface(#1114)), together with references that can be used to derive the primitive's parameters, triggers, and semantics.

(#4067)The Protected parameter is of Boolean type. If true or not present, this specifies that a Protected Dual of a Public Action frame is used; otherwise, a Public Action frame is used. The presence of the


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(#6295)Protected parameter is indicated in the Comments column of Table 6-1 (MLME SAP interface(#1114)(#7082)).

**Table 6-1— MLME SAP interface(#1114)(#7082)**

| Service Name | MLME-XXX | Type | References | Comments |
|---|---|---|---|---|
| Power management | POWERMGT | 5 | 6.5.2 (Power management) | See 11.2 (Power management) |
| Scan | SCAN | N/A | 6.5.3 (Scan) | See 11.1.4 (Acquiring synchronization, scanning) |
| | SCAN-STOP | 6 | (#3783)6.5.3.4 (MLME-SCAN-STOP.request) | (#3783)See 11.1.4.3 (Active scanning and probing procedures) |
| Synchronization | JOIN | 5 | 6.5.4 (Synchronization) | See 11.1 (Synchronization) |
| Authenticate | AUTHENTICATE(#4223) | 1 | 6.5.5 (Authenticate) | See 11.3.4 (Authentication and deauthentication) |
| Deauthenticate | DEAUTHENTICATE | 2 | 6.5.6 (Deauthenticate) | |
| Associate | ASSOCIATE | 1 | 6.5.7 (Associate) | See 11.3.5 (Association, reassociation, and disassociation) |
| Reassociate | REASSOCIATE | 1 | 6.5.8 (Reassociate) | |
| Disassociate | DISASSOCIATE | 2 | 6.5.9 (Disassociate) | |
| Reset | RESET | 6 | 6.5.10 (Reset) | (#3784)See 11.21.7.4 (BSS transition management response) |
| Start | START | 5 | 6.5.11 (Start) | (#3785)See Clause 10 (MAC sublayer functional description), Clause 11 (MLME), Clause 14 (MLME mesh procedures), 26.17 (HE BSS operation) |
| Stop | STOP | 6 | 6.5.12 (Stop) | |
| Measurement request | MREQUEST | 3 | 6.5.13 (Protocol layer model for spectrum management and radio measurement), 9.6.2 (Spectrum Management Action frame details(#3729)), 9.6.6 (Radio Measurement Action frame details(#3729)) | |
| Channel measurement | MEASURE | 2 | 6.5.13 (Protocol layer model for spectrum management and radio measurement), 9.4.2.19 (Measurement Request element), 9.4.2.20 (Measurement Report element) | |
| Measurement report | MREPORT | 3 | 6.5.13 (Protocol layer model for spectrum management and radio measurement), 9.4.2.20 (Measurement Report element) | |

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**Table 6-1— MLME SAP interface(#1114)(#7082)**

| Service Name | MLME-XXX | Type | References | Comments |
|---|---|---|---|---|
| Channel switch | CHANNELSWITCH | 1 | 6.5.13 (Protocol layer model for spectrum management and radio measurement), 9.6.2.6 (Channel Switch Announcement frame format), 9.4.2.17 (Channel Switch Announcement element) | |
| TPC request | TPCADAPT | 4 | 6.5.13 (Protocol layer model for spectrum management and radio measurement), 9.6.2.4 (TPC Request frame format), 9.6.2.5 (TPC Report frame format) | See 11.7.7 (Transmit power adaptation) |
| SetKeys | SETKEYS | 6 | 6.5.14 (SetKeys) | |
| DeleteKeys | DELETEKEYS | 6 | 6.5.15 (DeleteKeys) | |
| MIC (michael) failure event | MICHAELMICFAILURE | 7 | 12.5.2.4 (CCMP decapsulation), 12.7.2 (EAPOL-Key frames) | |
| EAPOL | EAPOL | 5 | 12.7.2 (EAPOL-Key frames) | |
| SetProtection | SETPROTECTION | 6 | 6.5.16 (SetProtection) | |
| Protected frame dropped | PROTECTEDFRAMEDROPPED | 7 | 12.6.16 (RSNA security association termination) | |
| TS management interface | ADDTS | 1 | 9.6.3.3 (Basic and DMG ADDTS Response frame format), 9.6.3.2 (Basic and DMG ADDTS Request frame format) | See 10.23.3 (HCF controlled channel access (HCCA)), 10.23.4 (Admission control at the HC) |
| | DELTS | 7 | 9.6.3.4 (DELTS frame format), 9.4.1.16 (DELBA Parameter Set field) | |
| | ADDTSRESERVE | 1 | 9.6.3.7 (ADDTS Reserve Request frame format), 9.6.3.8 (ADDTS Reserve Response frame format) | |
| Higher layer synchronization support | HL-SYNC | 3 | 11.6 (Higher layer timer synchronization) | |
| Block Ack | ADDBA | 1 | 9.3.1.7 (BlockAckReq frame format), 9.6.4.2 (ADDBA Request frame format), 9.6.4.3 (ADDBA Response frame format) | See 10.25 (Block acknowledgment (block ack)) |
| | DELBA | 3 | 9.6.4.4 (DELBA frame format), 9.4.1.16 (DELBA Parameter Set field) | |
| Schedule element management | SCHEDULE | 3 | 9.4.2.32 (Schedule element) | |


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**Table 6-1— MLME SAP interface(#1114)(#7082)**

| Service Name | MLME-XXX | Type | References | Comments |
|---|---|---|---|---|
| Vendor-specific action | VSPECIFIC | 3 | 9.6.5 (Vendor Specific Action frame and Vendor Specific Protected Action frame details(#3729)(#4065)) | Includes the Protected parameter.(#4067) |
| Neighbor report | NEIGHBORREPREQ | 3 | 9.6.6.6 (Neighbor Report Request frame format) | See 11.10.10 (Usage of the neighbor report) |
| | NEIGHBORREPRESP | 3 | 9.6.6.7 (Neighbor Report Response frame format) | |
| Link Measure Request | LINKMEASUREREQ | 3 | 9.6.6.4 (Link Measurement Request frame format) | See 11.10.11 (Link measurement) |
| | LINKMEASURERES | 3 | 9.6.6.5 (Link Measurement Report frame format) | |
| Resource request | RESOURCE-REQUEST | 1 | 13.9.1 (Introduction) | See 13.6.2 (Over-the-air fast BSS transition with resource request), 13.9 (FT security architecture state machines) |
| | RESOURCE-REQUEST-LOCAL | 5 | 13.11.2 (Resource information container (RIC)), 13.11.3.2 (AP procedures) | |
| Remote request | REMOTE-REQUEST | 3 | 9.6.8 (FT Action frame details) | See 13.5.3 (Over-the-DS FT protocol in an RSN), 13.9 (FT security architecture state machines), 13.10.1 (Overview) |
| Extended channel switch announcement | EXTCHANNELSWITCH | 1 | 9.6.7.7 (Extended Channel Switch Announcement frame format), 9.4.2.51 (Extended Channel Switch Announcement element) | See 11.8.8.4.3 (Processing channel switch announcement). Includes the Protected parameter.(#4067) |
| DSE power constraint announcement | DSETPC | 1 | 9.6.7.10 (DSE Power Constraint frame format) | See 11.11.5 (Dependent STA operation with DSE), 4.3.12 (Operation in licensed frequency bands). Includes the Protected parameter.(#4067) |
| Enablement | ENABLEMENT | 1 | 9.6.7.4 (DSE Enablement frame format) | See 11.11.2 (Enablement and deenablement). Includes the Protected parameter.(#4067) |
| Deenablement | DEENABLEMENT | 3 | 9.6.7.5 (DSE Deenablement frame format) | See 11.11.2 (Enablement and deenablement). Includes the Protected parameter.(#4067) |
| SA Query support | SA-QUERY | 1 | 9.6.9.2 (SA Query Request frame) | See 11.3.5.3 (AP or PCP association receipt procedures) |
| Get TSF timer | GETTSFTIME | 5 | 11.19.1 (Introduction) | |

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**Table 6-1— MLME SAP interface(#1114)(#7082)**

| Service Name | MLME-XXX | Type | References | Comments |
|---|---|---|---|---|
| Timing Advertisement | TIMING-ADVERTISEMENT | 3 | 9.4.2.59 (Time Advertisement element) | See 11.19.2 (Timing advertisement frame procedures) |
| TDLS Discovery | TDLSDISCOVERY | 1 | 9.6.12.12 (TDLS Discovery Request Action field format), 9.6.7.17 (TDLS Discovery Response frame format) | See 11.20.3 (TDLS discovery(#197)) |
| TDLS direct-link establishment(#3584) | TDLSSETUPREQUEST | 3 | 9.6.12.2 (TDLS Setup Request Action field format) | See 11.20 (Tunneled direct link setup(#1356)) |
| | TDLSSETUPRESPONSE | 3 | 9.6.12.3 (TDLS Setup Response Action field format) | |
| | TDLSCONFIRM | 3 | 9.6.12.4 (TDLS Setup Confirm Action field format) | |
| TDLS direct link teardown | TDLSTEARDOWN | 3 | 9.6.12.5 (TDLS Teardown Action field format) | See 11.20 (Tunneled direct link setup(#1356)) |
| TDLS peer U-APSD (TPU)(#4238) | TDLSSPTI | 1 | 9.6.12.6 (TDLS Peer Traffic Indication Action field format) | |
| TDLS channel switch | TDLSCHANNELSWITCH | 1 | 9.6.12.7 (TDLS Channel Switch Request Action field format), 9.6.12.8 (TDLS Channel Switch Response Action field format) | |
| TDLS peer PSM | TDLSPEERPSM | 1 | 9.6.12.9 (TDLS Peer PSM Request Action field format), 9.6.12.10 (TDLS Peer PSM Response Action field format) | |
| Event | EVLREQUEST | 3 | 6.5.18 (Event request) | See 11.21.2 (Event request and report procedures) |
| | EVLREPORT | 3 | 6.5.19 (Event report) | |
| | EVLOG | 5 | 6.5.20 (Event) | |
| Diagnostic request report | DIAGREQUEST | 3 | 9.6.13.4 (Diagnostic Request frame format), 9.4.2.68 (Diagnostic Report element) | See 11.21.3 (Diagnostic request and report procedures) |
| | DIAGREPORT | 3 | 9.6.13.5 (Diagnostic Report frame format), 9.4.2.68 (Diagnostic Report element) | |
| Location configuration request | LOCATIONCFG | 1 | 9.6.13.6 (Location Configuration Request frame format), 9.6.13.7 (Location Configuration Response frame format), 9.4.2.69 (Location Parameters element) | See 11.21.4 (Location track procedures) |
| Location track notification | LOCATIONTRACKNOTIF | 3 | 9.6.13.6 (Location Configuration Request frame format), 9.4.2.69 (Location Parameters element) | |


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**Table 6-1— MLME SAP interface(#1114)(#7082)**

| Service Name | MLME-XXX | Type | References | Comments |
|---|---|---|---|---|
| Timing measurement | TIMINGMSMTRQ | 3 | 9.6.13.28 (Timing Measurement Request frame format) | See 11.21.5 (Timing measurement procedure) |
| | TIMINGMSMT | 2 | 9.6.14.3 (Timing Measurement frame format) | |
| (#7065)FTM | FINETIMINGMSMTRQ | 3 | 9.6.7.32 (FTM(11az) Request frame format) | See 11.21.6 (FTM procedure(#7065)) |
| | FINETIMINGMSMT | 2 | 9.6.7.33 (FTM(11az) frame format) | |
| BSS transition management | BTMQUERY | 3 | 9.6.13.8 (BSS Transition Management Query frame format) | See 11.21.7.2 (BSS transition management query) |
| | BTM | 1 | 9.6.13.9 (BSS Transition Management Request frame format), 9.6.13.10 (BSS Transition Management Response frame format) | See 11.21.7.3 (BSS transition management request) and 11.21.7.4 (BSS transition management response) |
| FMS setup | FMS | 1 | 9.4.2.74 (FMS Request element), 9.4.2.75 (FMS Response element) | See 11.21.8 (FMS multicast rate processing) |
| Colocated Interference request report | CLINTERFERENCEREQUEST | 3 | 9.6.13.13 ((#2210)Colocated Interference Request frame format) | See 11.21.9 ((#2210)Colocated interference reporting) |
| | CLINTERFERENCEREPORT | 3 | 9.6.13.14 ((#2210)Colocated Interference Report frame format), 9.4.2.83 ((#2210)Colocated Interference Report element) | |
| TFS setup | TFS | 1 | 9.6.13.15 (TFS Request frame format), 9.6.13.16 (TFS Response frame format), 9.4.2.78 (TFS Request element), 9.4.2.79 (TFS Response element) | See 11.21.12 (TFS procedures) |
| WNM sleep mode request | SLEEPMODE | 1 | 9.4.2.78 (TFS Request element), 9.4.2.79 (TFS Response element) | See 11.2.3.15 (WNM sleep mode) |
| TIM broadcast setup | TIMBROADCAST | 1 | 9.4.2.81 (TIM Broadcast Request element), 9.4.2.82 (TIM Broadcast Response element) | See 11.2.3.14 (TIM Broadcast) |
| QoS traffic capability update | QOSTRAFFICCAPUPDATE | 3 | 9.6.13.23 (QoS Traffic Capability Update frame format) | See 11.21.10 (QoS Traffic capability procedure) |
| (#3311)Channel usage request | CHANNELUSAGE | 1 | 9.6.13.24 (Channel Usage Request frame format), , 9.6.13.25 (Channel Usage Response frame format), 9.4.2.84 (Channel Usage element) | See 11.21.15 (Channel usage procedures) |

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**Table 6-1— MLME SAP interface(#1114)(#7082)**

| Service Name | MLME-XXX | Type | References | Comments |
|---|---|---|---|---|
| DMS or GCR request and response procedure | GATS | 1 | 9.4.2.86 (DMS Request element), 9.4.2.87 (DMS Response element) | See 11.21.16 (Group addressed transmission service) |
| | GATS-TERM | 3 | 9.6.12.2 (TDLS Setup Request Action field format), 9.4.2.87 (DMS Response element) | |
| WNM notification request response | WNMNOTIFICATION REQUEST | 3 | 9.6.13.29 (WNM Notification Request frame format) | See 11.21.17 (WNM notification) |
| | WNMNOTIFICATION RESPONSE | 3 | 9.6.13.30 (WNM Notification Response frame format) | |
| Network discovery and selection support | GAS | 1 | 9.6.7.12 (GAS Initial Request frame format), 9.6.7.13 (GAS Initial Response frame format) | See 11.22.3 (Interworking procedures: generic advertisement service (GAS)), 11.23 (Preassociation discovery (PAD) procedures). Includes the Protected parameter.(#4067) |
| QoS Map element management | QOS-MAP | 3 | 9.6.3.6 (QoS Map Configure frame format) | See 11.22.9 (Interworking procedures: support for QoS mapping from external networks) |
| Mesh peering management | MESHPEERINGMANAGEMENT | 1 | 9.6.15.2 (Mesh Peering Open frame format), 9.6.15.3 (Mesh Peering Confirm frame format), 9.6.15.4 (Mesh Peering Close frame format) | See 14.4 (Mesh peering management (MPM)), 14.5 (Mesh peering management finite state machine (MPM FSM)) |
| Mesh power management | MESHPOWERMGT | 5 | 14.15.1 (General) | |
| Mesh neighbor offset synchronization | MESHNEIGHBOROFFSETSYNCSTART | 5 | 14.14 (Synchronization and beaconing in MBSSs) | |
| | MESHNEIGHBOROFFSETCALCULATE | 5 | | |
| | MESHNEIGHBOROFFSETSYNCSTOP | 5 | | |
| Mesh TBTT adjustment | MESHTBTTADJUSTMENT | 1 | 9.6.16.11 (TBTT Adjustment Request frame format), 9.6.16.12 (TBTT Adjustment Response frame format) | See 14.14.4 (Mesh beacon collision avoidance (MBCA)) |


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**Table 6-1— MLME SAP interface(#1114)(#7082)**

| Service Name | MLME-XXX | Type | References | Comments |
|---|---|---|---|---|
| MCCA management interface | ACTIVATEMCCA | 6 | 10.24.3.2 (MCCA activation) | |
| | MCCASETUP | 1 | 9.6.16.6 (MCCA Setup Request frame format), 9.6.16.7 (MCCA Setup Reply frame format) | See 10.24.3.6 (MCCAOP setup procedure) |
| | MCCAADVERTISEMENT | 1 | 9.6.16.8 (MCCA Advertisement Request frame format), 9.6.16.9 (MCCA Advertisement frame format) | See 10.24.3.7 (MCCAOP advertisement) |
| | MCCATEARDOWN | 3 | 9.6.16.10 (MCCA Teardown frame format) | See 10.24.3.8 (MCCAOP teardown) |
| MBSS congestion control | MBSSCONGESTIONCONTROL | 3 | 9.6.16.5 (Congestion Control Notification frame format) | See 14.13.2 (Congestion control signaling protocol) |
| MBSS proxy update | MBSSPROXYUPDATE | 1 | 9.6.17.2 (Proxy Update frame format), 9.6.17.3 (Proxy Update Confirmation frame format) | See 14.12.4.3 (Proxy update (PXU)) |
| MBSS mesh gate announcement | MBSSGATEANNOUNCEMENT | 3 | 9.6.16.4 (Gate Announcement frame format) | See 14.12.2 (Gate announcement (GANN)) |
| Mesh link metric | MESHLINKMETRICREAD | 5 | | See 14.10.2 (Airtime link metric and high PHY rate airtime link metric) |
| | MESHLINKMETRICREPORT | 3 | 9.6.16.2 (Mesh Link Metric Report frame format) | See 14.9.3 (Link metric reporting), 14.10 (Path selection link metric) |
| HWMP mesh path selection | HWMPMESHPATHSELECTION | 3 | 9.6.16.3 (HWMP Mesh Path Selection frame format) | See 14.11 (Hybrid wireless mesh protocol (HWMP)) |
| QMF policy | QMFPOLICY | 3 | 9.6.7.19 (QMF Policy frame format) | See 11.24.2 (QMF policy advertisement and configuration procedures) |
| | QMFPOLICYCHANGE | 3 | 9.6.7.20 (QMF Policy Change frame format) | |
| | QMFPOLICYSET | 6 | 11.24.2.2 (QMF policy change in an infrastructure BSS or in an MBSS) | |
| SCS request and response procedure | SCS | 1 | 9.6.18.2 (SCS Request frame format), 9.6.18.3 (SCS Response frame format) | See 11.25.2 (SCS procedures) |
| | SCS-TERM | 3 | 11.25.2 (SCS procedures) | |
| QLoad report management | QLOAD | 1 | 9.6.7.20 (QLoad Request frame format), 9.6.7.21 (QLoad Report frame format) | See 11.26.2 (QLoad Report element). Includes the Protected parameter.(#4067) |

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**Table 6-1— MLME SAP interface(#1114)(#7082)**

| Service Name | MLME-XXX | Type | References | Comments |
|---|---|---|---|---|
| HCCA TXOP advertisement management | TXOPADVERTISEMENT | 1 | 9.6.7.22 (HCCA TXOP Advertisement frame), 9.6.7.23 (HCCA TXOP Response frame) | See 11.26.3 (HCCA TXOP negotiation). Includes the Protected parameter.(#4067) |
| GCR group membership management | GROUP-MEMBERSHIP | 1 | 9.6.18.4 (Group Membership Request frame format), 9.6.18.5 (Group Membership Response frame format) | See 11.21.16.3.2 (GCR group membership procedures) |
| AP PeerKey management | APPEERKEY | 3 | 9.6.7.24 (Public Key frame) | See 12.10.2 (AP PeerKey protocol) |
| On-channel Tunneling operation | OCTunnel | N/A | 6.5.21 (On-channel Tunneling operation) | See 11.31.5 (On-channel Tunneling (OCT) operation) |
| Multi-band operation | FST-SETUP | 1 | 9.6.20.2 (FST Setup Request frame format), 9.6.20.3 (FST Setup Response frame format) | See 11.31.3 (FST setup protocol) |
| | FST-ACK | 1 | 9.6.20.5 (FST Ack Request frame format), 9.6.20.6 (FST Ack Response frame format) | See 11.31.3 (FST setup protocol) |
| | FST-TEARDOWN | 3 | 9.6.20.4 (FST Teardown frame format) | See 11.31.4 (FST teardown) |
| | FST-INCOMING | 6 | 11.31.3.2 (Transitioning between states) | |
| DMG relay operation | RELAY-SEARCH | 1 | 9.6.19.8 (Relay Search Request frame format), 9.6.19.9 (Relay Search Response frame format) | See 11.34.2 (Common relay setup procedures) |
| | RLS | 1 | 9.6.19.12 (RLS Request frame format), 9.6.19.13 (RLS Response frame format) | See 11.34.2.4 (RLS procedure) |
| | RLS-TEARDOWN | 3 | 9.6.19.15 (RLS Teardown frame format) | See 11.34.4 (Relay teardown) |
| Quieting adjacent BSS operation | QAB | 1 | 9.6.7.34 (QAB Request frame format), 9.6.7.35 (QAB Response frame format) | See 11.35 (Quieting adjacent DMG BSSs). Includes the Protected parameter.(#4067) |
| DMG beamforming | BF-TRAINING | N/A | 6.5.22 (DMG beamforming) | |
| | SU-MIMO-BF-TRAINING | | | |
| | MLME-MU-MIMO-BF-TRAINING | | | |
| | SU-MIMO-HYBRID-BF-PROTOCOL | | | |
| | MU-MIMO-HYBRID-BF-PROTOCOL | | | |


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**Table 6-1— MLME SAP interface(#1114)(#7082)**

| Service Name | MLME-XXX | Type | References | Comments |
|---|---|---|---|---|
| PN event report | PN-EXHAUSTION | 7 | 6.5.17 (PN event report) | See 12.5.2.3.2 (PN processing), 12.5.4.4 (GCMP decapsulation), 12.5.4.3.2 (PN processing), 12.6.16 (RSNA security association termination) |
| | PN-WARNING | 7 | | See 12.6.19 (RSNA rekeying) |
| Channel Availability Query | CHANNELAVAILABILITYQUERY | 1 | 9.6.7.25 (Channel Availability Query frame format) | See 11.42.4 (Channel availability query (CAQ) procedure). Includes the Protected parameter.(#4067) |
| Channel schedule management | CHANNELSCHEDULEMANAGEMENT | 1 | 9.6.7.26 (Channel Schedule Management frame format) | See 11.42.5 (Channel schedule management (CSM) procedures).Includes the Protected parameter.(#4067) |
| Contact verification signal | CVS | 3 | 9.6.7.27 (Contact Verification Signal frame format) | See 11.42.6 (Contact verification signal (CVS)). Includes the Protected parameter.(#4067) |
| GDD Enablement | GDDENABLEMENT | 1 | 9.6.7.28 (GDD Enablement Request frame format), 9.6.7.29 (GDD Enablement Response frame format) | See 11.42.2 (GDD enabling STA operation), 11.42.3 (GDD dependent STA operation). Includes the Protected parameter.(#4067) |
| Network channel control management | NETWORKCHANNELCONTROL | 1 | 9.6.7.30 (Network Channel Control frame format) | See 11.42.7 (Network channel control (NCC) procedures). Includes the Protected parameter.(#4067) |
| White space map (WSM) | WSM | 3 | 9.6.7.31 (White Space Map Announcement frame format) | See 11.42.8 (White space map (WSM)) |
| Estimated Throughput | ESTIMATED-THROUGHPUT | 5 | 6.5.23 (Estimated Throughput) | See 11.44 (Estimated throughput) |
| Get authentication and association state | GETAUTHASSOCSTATE | 5 | 11.3.1 (State variables) | |
| FILS Container | FILSContainer | 1 | 9.6.23.2 (FILS Container frame), 9.4.2.183 (FILS IP Address Assignment element) | See 11.45.3.3 (FILS IP address configuration) |

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**Table 6-1— MLME SAP interface(#1114)(#7082)**

| Service Name | MLME-XXX | Type | References | Comments |
|---|---|---|---|---|
| Dynamic AID assignment operation | AIDSWITCH | 1 | 9.6.24.2 (AID Switch Request frame format), 9.6.24.3 (AID Switch Response frame format) | See 10.20 (S1G dynamic AID assignment operation) |
| Sync Control | SYNCCONTROL | 3 | 9.6.24.4 (Sync Control frame format) | See 10.48 (Sync frame operation) |
| STA Information Announcement | STAINFORMATION | 3 | 9.6.24.5 (STA Information Announcement frame format) | See 10.20 (S1G dynamic AID assignment operation), 10.53.5.3 (Implicit Ack procedure) |
| EDCA Parameter Set update | EDCAPARAMETERSET | 3 | 9.6.24.6 (EDCA Parameter Set frame format) | See 10.2.3.2 (HCF contention based channel access (EDCA)) |
| EL Operation | ELOPERATION | 3 | 9.6.24.7 (EL Operation frame format) | See 10.61 (Energy limited STAs operation) |
| TWT Setup | TWTSETUP | 1 | 9.6.24.8 (TWT Setup frame format) | See 10.46.7 (TWT Sleep setup) |
| TWT Teardown | TWTTEARDOWN | 3 | 9.6.24.9 (TWT Teardown frame format) | See 10.46.8 (TWT teardown) |
| Sectorized Group ID List management | SECTORIZEDGROUPID | 3 | 9.6.24.10 (Sectorized Group ID List frame format) | See 10.52.3 (Group sectorization operation) |
| Header Compression procedure | HEADERCOMPRESSION | 1 | 9.6.25.5 (Header Compression frame format) | See 10.57 (Generation of PV1 MPDUs and header compression procedure) |
| Reachable Address Update | REACHABLEADDRESSUPDATE | 3 | 9.6.25.2 (Reachable Address Update frame format) | See 10.53.2 (S1G relay operation) |
| Control response MCS negotiation operation | CONTROLRESPONSEMCS | 1 | 9.6.27.2 (Control Response MCS Negotiation Request frame format), 9.6.27.3 (Control Response MCS Negotiation Response frame format) | See 10.6.5.4 (Rate selection for other group addressed Data and Management frames) |
| S1G relay (de)activation | S1GRELAYACTIVATE | 1 | 9.6.25.3 (Relay Activation Request frame format), 9.6.25.4 (Relay Activation Response frame format) | See 10.53.2 (S1G relay operation) |
| DCS procedure | DCSMEASUREMENT | 1 | 9.6.7.37 (DCS Measurement Request frame format), 9.6.7.38 (DCS Measurement Response frame format) | See 11.47 (DCS procedure for CDMG BSS) |
| Update | UPDATE | 5 | 6.5.24 (Update) | See 11.23.2 (Unsolicited PAD procedure) |


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**Table 6-1— MLME SAP interface(#1114)(#7082)**

| Service Name | MLME-XXX | Type | References | Comments |
|---|---|---|---|---|
| MSCS request and response procedure | MSCS | 1 | 9.6.18.6 (MSCS Request frame format), 9.6.18.7 (MSCS Response frame format) | See 11.25.3 (MSCS procedures) |
| | MSCS-TERM | 3 | 9.6.18.7 (MSCS Response frame format) | |
| MAC Address Update | UPDATEMACADDRESS | 5 | 12.2.11 (Requirements for support of MAC privacy enhancements) | |
| Quiet time period | QTP | 1 | 9.6.31.3 (Quiet Time Period action frame format) | See 26.17.5.2 (QTP Requesting STA procedure), 26.17.5.3 (Responding AP procedure) |
| TDD beamforming | TDD-BF-TRAINING | 2 | 10.41 (DMG beamforming) | See 11.36.2 (TDD beamforming(11ay)) |
| TDD sector switch | TDD-SECTOR-SWITCH | 2 | 11.36.3 (TDD sector switch procedure(11ay)) | |
| TDD beam measurement | TDD-BEAM-MEASUREMENT | 2 | 10.41.11 (TDD beamforming(11ay)) | See 11.36.4 (TDD beam measurement(11ay)) |
| TDD structure and schedule | TDD-SLOT-STRUCTURE | 5 | 9.4.2.280 (TDD Slot Structure element(11ay)) | See 10.38.6.2.2 (SP with TDD channel access(11ay)) |
| | TDD-SLOT-SCHEDULE | 5 | 9.4.2.281 (TDD Slot Schedule element(11ay)) | |
| | TDD-SLOT-ANNOUNCE | 2 | 9.4.2.280 (TDD Slot Structure element(11ay)), 9.4.2.281 (TDD Slot Schedule element(11ay)) | See 11.54 (TDD channel access operation(11ay)) |
| | TDD-BANDWIDTH | 2 | 9.4.2.284 (TDD Bandwidth Request element(11ay)) | |
| WUR mode setup | WURMODESETUP | 1 | 9.6.33.2 (WUR Mode Setup frame format) | See 29.8.2 (WUR mode setup) |
| WUR mode teardown | WURMODETEARDOWN | 3 | 9.6.33.3 (WUR Mode Teardown frame format) | See 29.8.2 (WUR mode setup) |
| WUR Discovery | WURDISCOVERY | 5 | 9.9.3.3 (WUR Discovery frame format), 6.5.25 (WUR Discovery(11ba)(#8139))(#8139) | See 29.12 (WUR discovery) |
| (#2362)MU EDCA Reset | MUEDCARESET | 3 | 9.6.32.3 (MU EDCA Reset frame format) | See 26.2.6.2 (MU-RTS Trigger frame transmission) |
| (#2363)HE BSS color change announcement | HEBSSCOLORCHANGEANNOUNCEMENT | 3 | 9.4.2.253 (BSS Color Change Announcement element(11ax)) | See 26.17.3.4 (Selecting and advertising a new BSS color) |
| (#7067)Cancel transmission of MSDUs | CANCELTX | 5 | 6.5.26 (Cancel transmissions of MSDUs(11bd)((#7067)) | See 10.2.3.2 (HCF contention based channel access (EDCA)) |

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**Table 6-1— MLME SAP interface(#1114)(#7082)**

| Service Name | MLME-XXX | Type | References | Comments |
|---|---|---|---|---|
| (#7082)NGV radio environment measurement | RADIOENVIRONMENT | 3 | 6.5.27 (NGV radio environment measurement(11bd)(#7082)) | See 31.6 (Radio environment measurement) |
| (#7077)DMG operation outside the context of a BSS | DMG-OCB-START | 4 | 9.3.4.2 (DMG Beacon), 9.4.2.127 (DMG Operation element), 9.4.2.265 (EDMG Operation element(11ay)), 9.4.2.279 (SAR Configuration element(11ay)), 9.4.2.25 (Extended Capabilities element) | See 11.1.4.7 (DMG discovery outside the context of a BSS(11bd)) |
| | DMG-OCB-STOP | 6 | | |
| | OCB-DMGDISCOVERY | 7 | 9.4.2.25 (Extended Capabilities element), 9.3.4.2 (DMG Beacon), 9.5.3 (SSW Feedback field(#4303)), 9.3.4.2 (DMG Beacon), 9.4.2.127 (DMG Operation element), 9.4.2.265 (EDMG Operation element(11ay)) | |
| | OCB-LINKSTATUS | 7 | 11.27.1.1 (General(11ay)), 9.4.2.25 (Extended Capabilities element) | See 11.27.1.1 (General(11ay)) |
| EBCS Info frames | EBCSININFO | 3 | 6.5.28 (MLME-EBCSINFO procedures(11bc)(#7067)) | See 9.6.7.54 (EBCS Info frame format(11bc)) |
| (#7067)EBCS Termination Notice | EBCSTERMINATION NOTICE | 3 | 9.6.7.55 (EBCS Termination Notice frame format(11bc)) | |
| (#7067)EBCS Content | EBCSCONTENT | 1 | 9.4.1.68 (EBCS Content Request field(11bc)), 9.4.1.69 (EBCS Content Response field(11bc)) | |
| (#7067)EBCS UL frame | ENCSUL | 3 | 6.5.29 (EBCS UL relaying(11bc)(#7067)) | See 9.6.7.53 (EBCS UL frame format(11bc)) |

## 6.5 MLME SAP primitives(#1114)

### 6.5.1 Introduction(#3138)

MLME SAP primitives are detailed in this clause when they do not directly correspond to frame exchanges described in subsequent clauses, where the primitive parameters differ significantly from the fields in the respective frames, or when the primitives might not (#7067)(M118)be clear from the descriptions in those clauses.

See 6.4 for a table of all MLME SAP primitives.



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### 6.5.2 Power management

#### 6.5.2.1 Introduction

This mechanism supports the process of establishment and maintenance of the power management mode of a STA.

#### 6.5.2.2 MLME-POWERMGT.request

##### 6.5.2.2.1 Function

This primitive requests a change in the power management mode.

##### 6.5.2.2.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-POWERMGT.request(
PowerManagementMode,
ReceiveDTIMBeacons(#4221) (#235)
)

| Name | Type | Valid range | Description |
|---|---|---|---|
| PowerManagementMode | Enumeration | ACTIVE, POWER_SAVE | An enumerated type that describes the requested power management mode of the STA. |
| ReceiveDTIMBeacons(#4221) | Boolean | true, false | Non-DMG BSS: When true, this parameter causes the STA to awaken to receive all DTIM beacons(#4221). When false, the STA is not required to awaken for every DTIM beacon(#3309).<br>DMG BSS: Not applicable |

##### 6.5.2.2.3 When generated

This primitive is generated by the SME to implement the power saving strategy of an implementation.

##### 6.5.2.2.4 Effect of receipt

This request sets the STA's power management parameters. The MLME subsequently issues an MLME-POWERMGT.confirm primitive that reflects the results of the power management change request.

#### 6.5.2.3 MLME-POWERMGT.confirm

##### 6.5.2.3.1 Function

This primitive confirms the change in power management mode.

##### 6.5.2.3.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-POWERMGT.confirm(
ResultCode
)

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| Name | Type | Valid range | Description |
|---|---|---|---|
| ResultCode | Enumeration | SUCCESS,<br>NOT_SUPPORTED | Indicates the result of the MLME-POWERMGT.request primitive. |

#### 6.5.2.3.3 When generated

This primitive is generated by the MLME as a result of an MLME-POWERMGT.request primitive to establish a new power management mode. It is not generated until the change has completed as defined in 11.2.3 (Power management in a non-DMG infrastructure network).

#### 6.5.2.3.4 Effect of receipt

The SME is notified of the change of power management mode.

### 6.5.3 Scan

#### 6.5.3.1 Introduction

This mechanism supports the process of determining the characteristics of the available BSSs.

#### 6.5.3.2 MLME-SCAN.request

#### 6.5.3.2.1 Function

This primitive requests a survey of potential BSSs that the STA can later elect to try to join.

#### 6.5.3.2.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-SCAN.request(
                                    BSSType,
                                    BSSID,
                                    SSID,
                                    ScanType,
                                    ActiveScanType,
                                    ProbeDelay,
                                    ChannelList,
                                    MinChannelTime,
                                    MaxChannelTime,
                                    RequestInformation,
                                    SSID List,
                                    ChannelUsage,
                                    AccessNetworkType,
                                    HESSID,
                                    MeshID,
                                    DiscoveryMode,
                                    FILSRequestParameters,
                                    ReportingOption,
                                    APConfigurationSequenceNumber,
                                    S1GRelayDiscovery,
                                    PV1ProbeResponseOption,
                                    S1GCapabilities,
                                    ChangeSequence,
```


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ELOperation,
MaxAwayDuration,
Multi-band local,
Multi-band peer,
GeneralLinkType,
OperationalRateSet,
HT Capabilities,
VHT Capabilities,
Short SSID List,(11ax)
HE Capabilities,(11ax)
HE 6 GHz Band Capabilities,(11ax)
ScanAntennaSectorList,(11ay)
SectorDwellTime,(11ay)
EDMG Capabilities,(11ay)
Unsolicited Block Ack Extension,(11ay)
WUR Capabilities,(11ba)
VendorSpecificInfo
)

| Name | Type | Valid range | Description |
|---|---|---|---|
| BSSType | Enumeration | INFRASTRUCTURE, PERSONAL, INDEPENDENT, MESH, ANY_BSS | Determines whether infrastructure BSS, PBSS, IBSS, MBSS, or all, are included in the scan. |
| BSSID | MAC address | Any valid individual address, or broadcast address | Identifies a specific or wildcard BSSID. |
| SSID | Octet string | 0–32 octets | Specifies the desired SSID or the wildcard SSID. |
| ScanType | Enumeration | ACTIVE, PASSIVE,TDD PASSIVE(11ay) | Indicates active, passive, or TDD passive scanning.(11ay) |
| ActiveScanType | Enumeration | FRAME, NDP | Indicates active scanning type by the transmission of either Probe Request frames or NDP Probe Request frames. This parameter is optionally present if dot11S1GOptionImplemented is true and if ScanType is ACTIVE; otherwise not present. |
| ProbeDelay | Integer | N/A | Delay (in microseconds) to be used prior to transmitting a probe request during active scanning.(#322) |
| ChannelList | Set of integers | Each channel is selected from the valid channel range for the appropriate PHY and carrier set. | Specifies a list of channels that are examined when scanning for a BSS. If the Multi-band local and Multi-band peer parameters are present in the primitive, the ChannelList parameter specifies the channels used by the TR-MLME and the Multi-band peer parameter contains the channels to be scanned (see 11.31.5 (On-channel Tunneling (OCT) operation)). |
| MinChannelTime | Integer | N/A | The minimum time (in TU) to spend on each channel when scanning. |
| MaxChannelTime | Integer | ≥ MinChannelTime | The maximum time (in TU) to spend on each channel when scanning. |

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| Name | Type | Valid range | Description |
|---|---|---|---|
| RequestInformation | A list of element identifiers | As defined in 9.4.2.8 (Request element) and 9.4.2.9 (Extended Request element). | This parameter is optionally present if dot11RadioMeasurementActivated is true and is placed in a Probe Request frame to request that the responding STA include the requested information in the Probe Response frame. |
| SSID List | A set of SSID element | As defined in 9.4.2.2 (SSID element). | One or more SSID elements that are optionally present when dot11SSIDListActivated is true. |
| ChannelUsage | A set of Channel Usage element | As defined in 9.4.2.84 (Channel Usage element) | Specifies request types for the (#3311)channel usage request. |
| AccessNetworkType | As defined in Table 9-276 (Access network type) | 0 to 15 | Specifies the target specific access network type or the wildcard access network type. This field is present when dot11InterworkingServiceActivated is true. |
| HESSID | MAC address | Any valid individual address or the broadcast address | Specifies the target specific HESSID network identifier or the wildcard network identifier. This field is present when dot11InterworkingServiceActivated is true. |
| Mesh ID | Octet string | 0–32 octets | Present only if BSSType = MESH or BSSType = ANY_BSS. Specifies the target mesh ID(#1755) or wildcard mesh ID(#1755). |
| DiscoveryMode | Integer | 0–1 | Indicates, if equal to 1, that a DMG Beacon frame is transmitted during active scanning with the Discovery Mode field set to 1 and, if equal to 0, that a DMG Beacon frame is not transmitted during active scanning. Present only when dot11DMGOptionImplemented is true. |
| FILSRequestParameters | As defined in 9.4.2.176 (FILS Request Parameters element(#2193)) | As defined in 9.4.2.176 (FILS Request Parameters element(#2193)) | Used in determining whether to transmit a Probe Response frame. This parameter is optionally present if dot11FILSActivated is true; otherwise not present. |
| ReportingOption | Enumeration | IMMEDIATE, CHANNEL_ SPECIFIC, AT_END | Indicates the result reporting mode as described in 11.1.4 (Acquiring synchronization, scanning). This parameter is optionally present if dot11FILSActivated is true; otherwise not present. |
| APConfigurationSequenceNumber | Integer | As defined in 9.4.2.180 (AP Configuration Sequence Number (AP-CSN) element) | Indicates the configuration sequence number for the static information fields and elements as described in 11.1.4.3.11 (Enhanced FILS active scanning to preferred AP). This parameter is optionally present if dot11FILSActivated is true and BSSID is (#1653)an individual address; otherwise not present. |
| S1GRelayDiscovery | S1G Relay Discovery element | As defined in 9.4.2.206 (S1G Relay Discovery element) | Indicates link budget information and QoS requirements for relay discovery. This element is optionally present if dot11RelaySTAImplemented is true; otherwise not present. |


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| Name | Type | Valid range | Description |
|---|---|---|---|
| PV1ProbeResponse Option | PV1 Probe Response Option element | As defined in 9.4.2.208 (PV1 Probe Response Option element) | Indicates which optional information is requested to be included in the PV1 Probe Response frame. This element is optionally present if dot11PV1ProbeResponseOptionImplemented is true; otherwise not present. |
| S1GCapabilities | S1G Capabilities element | As defined in 9.4.2.199 (S1G Capabilities element) | Indicates S1G capabilities of an S1G STA.<br>The S1G Capabilities element is present if dot11S1GOptionImplemented is true; otherwise not present. |
| ChangeSequence | Change Sequence element | As defined in 9.4.2.197 (Change Sequence element) | Specifies the parameters within the Change Sequence element that are supported by the MAC entity.<br>The parameter is optionally present if dot11S1GOptionImplemented is true; otherwise not present. |
| ELOperation | EL Operation element | As defined in 9.4.2.209 (EL Operation element) | Specifies the parameters within the EL Operation element that are supported by the MAC entity.<br>The parameter is present if dot11S1GELOperationActivated is true; otherwise not present. |
| MaxAwayDuration | Integer | 0–65 535 | Indicates the maximum duration, in TUs, that the AP is unavailable for communications with the STA.<br>The parameter is optionally present if dot11MaxAwayDuration is nonzero; otherwise not present. |
| Multi-band local | Multi-band element | As defined in 9.4.2.137 (Multi-band element) | Specifies the parameters within the Multi-band element that are supported by the local MAC entity. The parameter is present if dot11MultibandImplemented is true and is absent otherwise. |
| Multi-band peer | Multi-band element | As defined in 9.4.2.137 (Multi-band element) | Specifies the parameters within the Multi-band element that are used to deliver messages to the peer MAC entity. The parameter is present if OCT is being used and is absent otherwise. |
| GeneralLinkType | Enumeration | GLK_SUPPORTED, GLK_UNSPECIFIED | This parameter is present if dot11GLKImplemented is true. If GLK_SUPPORTED, a BSS in which the AP supports GLK is requested. If GLK_UNSPECIFIED, the GLK nature of the BSS is ignored. |
| OperationalRateSet | Non-DMG BSS: Set of integers<br><br>DMG BSS: Set of numbers | Non-DMG BSS: a value in dot11SupportedDataRatesRxTable, for each member of the set<br><br>DMG BSS: 0-12, 9.1, 12.1-12.6, or 25-31, for each member of the set | Non-DMG BSS: The set of data rates (in units of 500 kb/s) that the STA is able to use for communication within the BSS. The STA is able to receive at each of the data rates listed in the set. This set is a superset of the rates contained in the BSSBasicRateSet parameter of the SelectedBSS parameter.<br>DMG BSS: The set of MCS (#4136)indices that the STA uses for communication within the BSS.<br>Present only if ScanType = ACTIVE. |

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| Name | Type | Valid range | Description |
|---|---|---|---|
| HT Capabilities | As defined in frame format HT Capabilities element | As defined in 9.4.2.54 (HT Capabilities element); the HT-MCSs in the element are present in dot11SupportedHTMCSRxTable and the highest supported data rate in the element does not exceed dot11HighestSupportedDataRate | Specifies the parameters in the HT Capabilities element that are supported by the STA. The parameter is present if dot11HighThroughputOptionImplemented is true; otherwise, this parameter is not present.<br>Present only if ScanType = ACTIVE. |
| VHT Capabilities | As defined in VHT Capabilities element | As defined in 9.4.2.156 (VHT Capabilities element); the VHT-MCSs in the element are present in dot11VHTRxVHTMCSMap/ dot11VHTTxVHTMCSMap and the highest supported rates in the element do not exceed dot11VHTRxHighestDataRateSupported/ dot11VHTTxHighestDataRateSupported | Specifies the parameters in the VHT Capabilities element that are supported by the STA. The parameter is present if dot11VHTOptionImplemented is true and not present otherwise.<br>Present only if ScanType = ACTIVE. |
| Short SSID List(11ax) | A list of short SSIDs | As defined in 9.4.2.261 (Short SSID List element(11ax)) | (#7151)One or more short SSIDs that are optionally present if dot11ShortSSIDList is true. |
| HE Capabilities(11ax) | As defined in HE Capabilities element | As defined in 9.4.2.247 (HE Capabilities element(11ax)) | Specifies the parameters in the HE Capabilities element that are supported by the STA. The parameter is present if dot11HEOptionImplemented is true; otherwise, it is not present. |
| HE 6 GHz Band Capabilities(11ax) | As defined in HE 6 GHz Band Capabilities element | As defined in 9.4.2.262 (HE 6 GHz Band Capabilities element(11ax)) | Specifies the parameters in the HE 6 GHz Band Capabilities element that are supported by the STA. The parameter is present if dot11HE6GOptionImplemented is true; otherwise, it is not present. |
| ScanAntennaSectorIDList(11ay) | List of DMG antenna and sector configurations | Each DMG antenna and sector configuration is a valid configuration for the scanning STA. | Present if dot11TDDOptionImplemented is true and absent otherwise. Contains an ordered list of DMG antennas and sector configurations to be used during the scan using TDD beamforming (see 11.36.2 (TDD beamforming(11ay))). |
| SectorDwellTime(11ay) | Integer | N/A | Present if dot11TDDOptionImplemented is true and absent otherwise. The time (in microseconds) to dwell on each sector during TDD beamforming (see 11.36.2 (TDD beamforming(11ay))). |
| EDMG Capabilities(11ay) | EDMG Capabilities element | As defined in 9.4.2.264 (EDMG Capabilities element(11ay)) | Specifies the parameters within the EDMG Capabilities element that are supported by the MAC entity. The parameter is present if dot11EDMGOptionImplemented is true and is absent otherwise. |


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| Name | Type | Valid range | Description |
|---|---|---|---|
| Unsolicited Block Ack Extension(11ay) | Unsolicited Block Ack Extension element | As defined in 9.4.2.278 (Unsolicited Block Ack Extension element(11ay)) | Specifies the parameters within the Unsolicited Block Ack Extension element that are supported by the MAC entity. Optionally present if dot11UnsolicitedBAActivated is true and is absent otherwise. |
| WUR Capabilities(11ba) | As defined in WUR Capabilities element | As defined in 9.4.2.290 (WUR Capabilities element(11ba)) | Specifies the parameters within the WUR Capabilities element that are supported by the STA. The parameter is present if dot11WUROptionImplemented is true and ScanType = ACTIVE; otherwise, this parameter is not present. |
| VendorSpecificInfo | A set of elements | As defined in 9.4.2.24 (Vendor Specific element) | Zero or more elements. |

#### 6.5.3.2.3 When generated

This primitive is generated by the SME for a STA to determine if there are other BSSs that it can join.

#### 6.5.3.2.4 Effect of receipt

This request initiates the scan process when the current frame exchange sequence is completed.

### 6.5.3.3 MLME-SCAN.confirm

#### 6.5.3.3.1 Function

This primitive returns the descriptions of the set of BSSs detected by the scan process. Multiple MLME-SCAN.confirm primitives can be issued when the value of the ReportingOption parameter in the MLME-SCAN.request primitive is CHANNEL_SPECIFIC or IMMEDIATE. When the value of the ReportingOption parameter is AT_END, or the ReportingOption parameter is not present, a single MLME-SCAN.confirm primitive is issued.

#### 6.5.3.3.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-SCAN.confirm(
BSSDescriptionSet,
BSSDescriptionFromMeasurementPilotSet,
BSSDescriptionFromFDSet,
ResultCode,
Multi-band local,
Multi-band peer,
ScannedChannelList,
VendorSpecificInfo
)

| Name | Type | Valid range | Description |
|---|---|---|---|
| BSSDescriptionSet | Set of BSSDescriptions | N/A | The BSSDescriptionSet is returned to indicate the results of the scan request. It is a set containing zero or more instances of a BSSDescription. |

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| Name | Type | Valid range | Description |
|---|---|---|---|
| BSSDescriptionFromMeasurementPilotSet | Set of BSSDescriptionFromMeasurementPilots | N/A | The BSSDescriptionFromMeasurementPilotSet is returned to indicate the results of the scan request derived from Measurement Pilot frames. It is a set containing zero or more instances of a BSSDescriptionFromMeasurementPilot. Present if dot11RMMeasurementPilotActivated is nonzero; otherwise not present. |
| BSSDescriptionFromFDSet | Set of BSSDescriptionFromFDs | N/A | The BSSDescriptionFromFDSet is returned to indicate the results of the scan request derived from FILS Discovery frames. It is a set containing zero or more instances of a BSSDescriptionFromFD. Present if dot11FILSActivated is true; otherwise not present. |
| ResultCode | Enumeration | SUCCESS, INTERMEDIATE_SCAN_RESULT, NOT_SUPPORTED, PARTIAL_SCAN | Indicates the result of the MLME-SCAN.confirm primitive. The INTERMEDIATE_SCAN_RESULT is used to report the discovered BSSs when the value of the ReportingOption parameter in the MLME-SCAN.request primitive is CHANNEL_SPECIFIC or IMMEDIATE and is valid if dot11FILSActivated is true. The PARTIAL_SCAN is used to report that not all channels have been scanned as specified in the ChannelList parameter, if present, of the corresponding MLME-SCAN.request primitive. The ScannedChannelList parameter contains the list of scanned channels. |
| Multi-band local | Multi-band element | As defined in 9.4.2.137 (Multi-band element) | Specifies the parameters within the Multi-band element that are supported by the local MAC entity. The parameter is present if dot11MultibandImplemented is true and is absent otherwise. |
| Multi-band peer | Multi-band element | As defined in 9.4.2.137 (Multi-band element) | Specifies the parameters within the Multi-band element that are used to deliver messages to the peer MAC entity. The parameter is present if OCT is being used and is absent otherwise. |
| ScannedChannelList | Each channel is selected from the valid channel range for the appropriate PHY and carrier set | Each channel is selected from the valid channel range for the appropriate PHY and carrier set | This parameter is valid only if the ResultCode parameter has a value of PARTIAL_SCAN, and specifies a list of channels that were scanned. This list of channels is a subset of the channels present in the ChannelList parameter of the corresponding MLME-SCAN.request primitive. |
| VendorSpecificInfo | A set of elements | As defined in 9.4.2.24 (Vendor Specific element) | Zero or more elements. |


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Each BSSDescription consists of the parameters shown in the following table, in which the term *peer STA* refers to the STA transmitting the Beacon frame, S1G Beacon frame, Probe Response frame, or PV1 Probe Response frame from which the BSSDescription was determined and the term *local STA* refers to the STA performing the scan, and in which the (#4177)IBSS adoption column indicates whether

a) This parameter is adopted by a STA that is joining an IBSS.

b) This parameter is adopted by a STA that is a member of an IBSS that receives a beacon or S1G beacon from a STA that is a member of the same IBSS and that has a timestamp value that is greater than the local TSF value (see 11.1.5 (Adjusting STA timers)).

| Name | Type | Valid range | Description | IBSS adoption |
|---|---|---|---|---|
| BSSID | MAC address | N/A | The BSSID of the found BSS or the MAC address of the found mesh STA. | Adopt |
| SSID | Octet string | 0–32 octets | The SSID of the found BSS. | Adopt |
| BSSType | Enumeration | INFRASTRUCTURE, PERSONAL, INDEPENDENT, MESH | The type of the found BSS. | Adopt |
| Beacon Period | Integer | N/A | The beacon period (in TU) of the found BSS if the BSSType is not MESH, or of the found mesh STA if the BSSType = MESH. | Adopt |
| DTIM Period | Integer | As defined in 9.4.2.5 (TIM element) | The DTIM period (in beacon periods) of the BSS if the BSSType is not MESH, or of the mesh STA if the BSSType = MESH. | Adopt |
| Timestamp | Integer | N/A | The timestamp of the received frame (Probe Response/ Beacon or PV1 Probe Response/S1G Beacon) from the found BSS. When a PV1 Probe Response or an S1G Beacon frame is received, the timestamp is reconstructed as described in 11.1.3.10.3 (TSF timer accuracy with S1G Beacon frame). If the Multi-band local and Multi-band peer parameters are present in the MLME-SCAN.confirm primitive, the Timestamp parameter is reserved. | Adopt |
| Local Time | Integer | N/A | The value of the local STA's TSF timer at the start of reception of the first octet of the timestamp field of the received frame (Probe Response or Beacon) from the found BSS. | Do not adopt |

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| Name | Type | Valid range | Description | IBSS adoption |
|---|---|---|---|---|
| PHY Parameter Set | As defined in frame format or according to the relevant PHY clause. | As defined in frame format or according to the relevant PHY clause. | The parameter sets relevant to the PHY from the received Beacon or Probe Response frame. If no PHY Parameter Set element is present in the received frame, this parameter contains the channel number on which the frame was received. Valid channel numbers are defined in the relevant PHY clause. | Adopt |
| IBSS Parameter Set | IBSS Parameter Set element | As defined in 9.4.2.6 (IBSS Parameter Set element) | The parameter set for the IBSS, if found BSS is an IBSS. | Adopt |
| CapabilityInformation | Capability Information field | As defined in 9.4.1.4 (Capability Information field) | The advertised capabilities of the BSS. | Do not adopt |
| BSSBasicRateSet | Set of integers | Non-DMG BSS: 1–127 excluding values from Table 9-131 (BSS membership selector value encoding), for each member of the set | Non-DMG BSS: The set of data rates (in units of 500 kb/s) that all STAs in the BSS are able to use for communication. All STAs in the BSS are able to receive and transmit at each of the data rates listed in the set.<br><br>DMG BSS: Empty. | Adopt |
| OperationalRateSet | Non-DMG BSS: Set of integers<br><br>DMG BSS: Set of numbers | Non-DMG BSS: 1–127 excluding values from Table 9-131 (BSS membership selector value encoding), for each member of the set<br><br>DMG BSS: 0–12, 9.1, 12.1–12.6, or 25–31, for each member of the set | Non-DMG BSS: The set of data rates (in units of 500 kb/s) that the peer STA is able to use for communication within the BSS. The peer STA is able to receive at each of the data rates listed in the set. This set is a superset of the rates contained in the BSSBasicRateSet parameter.<br><br>DMG BSS: The set of MCS (#4136)indices that the peer STA uses for communication within the BSS. | Do not adopt |
| Country | As defined in the Country element | As defined in the Country element | The information required to identify the regulatory domain in which the peer STA is located and to configure its PHY for operation in that regulatory domain.<br>Present if TPC functionality is required, as specified in 11.7 (TPC procedures), or dot11MultiDomainCapability Activated is true or dot11RadioMeasurementActivated is true; otherwise not present. | Adopt |


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| Name | Type | Valid range | Description | IBSS adoption |
|---|---|---|---|---|
| IBSS DFS Recovery Interval | Integer | 1–255 | The time interval that is used for DFS recovery.<br><br>Present if DFS functionality is required, as specified in 11.8 (DFS procedures) and BSSType = INDEPENDENT; otherwise not present. | Adopt |
| RSN | RSNE | As defined in 9.4.2.23 (RSNE) | A description of the cipher suites and AKM suites supported in the BSS. | Do not adopt |
| BSS Load(#4134) | BSS Load element | As defined in 9.4.2.26 (BSS Load element) | The values from the BSS Load element(#4134). The parameter is present if dot11QoSOptionImplemented and dot11QBSSLoadImplemented are both true and a BSS Load element was present in the Probe Response or Beacon frame from which the BSSDescriptionSet was determined. Otherwise, the parameter is not present. | Do not adopt |
| Extended BSS Load(#4129)(#4134) | Extended BSS Load element | As defined in 9.4.2.158 (Extended BSS Load element) | The values from the Extended BSS Load element(#4134). The parameter is present if dot11QBSSLoadImplemented and dot11VHTOptionImplemented are both true and an Extended BSS Load element was present in the Probe Response or Beacon frame from which the BSSDescriptionSet was determined. Otherwise, the parameter is not present. | Do not adopt |
| EDCAParameterSet | EDCA Parameter Set element | As defined in 9.4.2.27 (EDCA Parameter Set element) | The values from the EDCA Parameter Set element if such an element was present in the Probe Response or Beacon frame, else null. | Adopt |
| QoSCapability | QoS Capability element | As defined in 9.4.2.33 (QoS Capability element) | The values from the QoS Capability element if such an element was present in the Probe Response, (#1413)PV1 Probe Response, S1G Beacon, DMG Beacon or Beacon frame, else null. | Adopt |
| AP Channel Report | Set of AP Channel Report elements | As defined in 9.4.2.34 (AP Channel Report element) | The values from the AP Channel Report element(s) if present in the Probe Response or Beacon frame, else null. | Adopt |
| BSS Average Access Delay | BSS Average Access Delay element | As defined in 9.4.2.37 (BSS Average Access Delay element) | The values from the BSS Average Access Delay element if such an element was present in Probe Response or Beacon frame, else null. | Adopt |

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| Name | Type | Valid range | Description | IBSS adoption |
|---|---|---|---|---|
| Antenna | Antenna element | As defined in 9.4.2.38 (Antenna element) | The values from the Antenna element if such an element was present in the Probe Response or Beacon frame, else null. | Adopt |
| BSS Available Admission Capacity | BSS Available Admission Capacity element | As defined in 9.4.2.41 (BSS Available Admission Capacity element) | The values from the BSS Available Admission Capacity element if such an element was present in the Probe Response or Beacon frame, else null. | Adopt |
| BSS AC Access Delay | BSS AC Access Delay element | As defined in 9.4.2.42 (BSS AC Access Delay element) | The values from the BSS AC Access Delay element if such an element was present in the Probe Response or Beacon frame, else null. | Adopt |
| Measurement Pilot Transmission Information | Measurement Pilot Transmission element | As defined in 9.4.2.40 (Measurement Pilot Transmission element) | The values from the Measurement Pilot Transmission element if such an element was present in the Probe Response or Beacon frame, else null. | Adopt |
| Multiple BSSID | (#488)A set of Multiple BSSID elements | As defined in 9.4.2.44 (Multiple BSSID element) | (#488)The values from the Multiple BSSID element(s) present in the Probe Response, Beacon, DMG Beacon or S1G Beacon frame, if any, else null. | Do not adopt |
| RM Enabled Capabilities | RM Enabled Capabilities element | As defined in 9.4.2.43 (RM Enabled Capabilities element) | The values from the RM Enabled Capabilities element if such an element was present in the Probe Response or Beacon frame, else null. | Adopt |
| RCPIMeasurement | Integer | As defined in 9.4.2.36 (RCPI element) | (#14)The RCPI of the received PPDU containing the frame. | Adopt |
| RSNIMeasurement | Integer | As defined in 9.4.2.39 (RSNI element) | (#14)The RSNI of the received PPDU containing the frame. | Adopt |
| Requested elements | Set of elements | As defined in 9.4.1.33 (Target Channel field(#3249)) | Elements requested by the Request element or Extended Request element of the Probe Request frame. | Adopt |
| DSERegisteredLocation | DSE Registered Location element | As defined in 9.4.2.50 (DSE Registered Location element) | The information from the DSE Registered Location element, if such a field is present in the Probe Response or Beacon frame, else null. Present if DSE functionality is required, as specified in 11.11 (DSE procedures), or dot11LCIDSERequired is true; otherwise not present. | Adopt |


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| Name | Type | Valid range | Description | IBSS adoption |
|---|---|---|---|---|
| HT Capabilities | As defined in frame format | As defined in 9.4.2.54 (HT Capabilities element) | The values from the HT Capabilities element if such an element was present in the Probe Response or Beacon frame, else null.<br>The parameter is optionally present if dot11HighThroughputOptionImplemented is true; otherwise not present. | Do not adopt |
| HT Operation | As defined in frame format | As defined in 9.4.2.55 (HT Operation element) | The values from the HT Operation element if such an element was present in the Probe Response or Beacon frame, else null.<br>The parameter is optionally present if dot11HighThroughputOptionImplemented is true; otherwise not present. | Adopt |
| BSSMembershipSelectorSet | Set of integers | A value from Table 9-131 (BSS membership selector value encoding) for each member of the set | The set of features that are supported by all STAs joining this BSS. | Adopt |
| Extended Capabilities | As defined in frame format | As defined in 9.4.2.25 (Extended Capabilities element) | Specifies the parameters within the Extended Capabilities element that are supported by the MAC entity. | Do not adopt |
| 20/40 BSS Coexistence | As defined in frame format | As defined in 9.4.2.58 (20/40 BSS Coexistence element) | Specifies the parameters within the 20/40 BSS Coexistence element that are indicated by the MAC entity.<br>The parameter is present if dot112040BSSCoexistence-ManagementSupport is true. | Do not adopt |
| Overlapping BSS Scan Parameters | As defined in frame format | As defined in 9.4.2.57 (Overlapping BSS Scan Parameters element) | Specifies the parameters within the Overlapping BSS Scan Parameters element that are indicated by the MAC entity.<br>This parameter is optionally present if dot11FortyMHzOptionImplemented is true and is not present if dot11FortyMHzOptionImplemented is false. | Adopt |
| FMSDescriptor | FMS Descriptor element | As defined in 9.4.2.73 (FMS Descriptor element) | The values from the FMS Descriptor element if such an element was present in the Probe Response or Beacon frame, else null. | Do not adopt |
| QoSTrafficCapability | QoS Traffic Capability element | As defined in 9.4.2.76 (QoS Traffic Capability element) | The values from the QoS Traffic Capability element if such an element was present in the Probe Response or Beacon frame, else null. | Do not adopt |

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| Name | Type | Valid range | Description | IBSS adoption |
|---|---|---|---|---|
| ChannelUsage | A set of Channel Usage element | As defined in 9.4.2.84 (Channel Usage element) | Specifies parameters for the (#3311)channel usage. | Do not adopt |
| TimeAdvertisement | Time Advertisement element | As defined in 9.4.2.59 (Time Advertisement element) | The values from the Time Advertisement element if such an element was present in the Probe Response or Beacon frame, else null. | Do not adopt |
| TimeZone | Time Zone element | As defined in 9.4.2.85 (Time Zone element) | The values from the Time Zone element if such an element was present in the Probe Response or Beacon frame, else null. | Do not adopt |
| MeshID | Mesh ID element | As defined in 9.4.2.97 (Mesh ID element) | The value of MeshID element if such element was present in the Probe Response or Beacon frame, else null. | Do not adopt |
| MeshConfiguration | Mesh Configuration element | As defined in 9.4.2.96 (Mesh Configuration element) | The values from the Mesh Configuration element if such an element was present in the Probe Response or Beacon frame, else null. | Do not adopt |
| Mesh Awake Window | Mesh Awake Window element | As defined in 9.4.2.102 (Mesh Awake Window element) | The values from the Mesh Awake Window element if such an element was present in the Probe Response or Beacon frame, else null. | Do not adopt |
| BeaconTiming | Beacon Timing element | As defined in 9.4.2.103 (Beacon Timing element) | The values from the Beacon Timing element if such an element was present in the Probe Response or Beacon frame, else null. | Do not adopt |
| MCCAOP Advertisement Overview | MCCAOP Advertisement Overview element | As defined in frame format | The values from the Beacon Timing element if such an element was present in the Probe Response or Beacon frame, else null. | Do not adopt |
| MCCAOP Advertisement | MCCAOP Advertisement | As defined in frame format | The values from the Beacon Timing element if such an element was present in the Probe Response or Beacon frame, else null. | Do not adopt |
| QMFPolicy | QMF Policy element | As defined in 9.4.2.118 (Quality-of-Service Management Frame Policy element) | The values from the QMF Policy element if such an element was present in the Probe Response or Beacon frame, else null. | Do not adopt |
| QLoad Report | As defined in frame format | As defined in 9.4.2.121 (QLoad Report element) | The values from the QLoad Report element if such an element was present in the Probe Response frame, else null. | Do not adopt. |


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| Name | Type | Valid range | Description | IBSS adoption |
|---|---|---|---|---|
| Sector Sweep | As defined in frame format | As defined in 9.3.4.2 (DMG Beacon) | The values from the SSW field(#4303) from the DMG Beacon frame, else null. The parameter is present only if dot11DMGOptionImplemented is true. | Adopt |
| Beacon Interval Control | As defined in frame format | As defined in 9.3.4.2 (DMG Beacon) | The values from the Beacon Interval Control field from the DMG Beacon frame, else null. The parameter is present only if dot11DMGOptionImplemented is true. | Adopt |
| DMG Parameters | As defined in frame format | As defined in 9.3.4.2 (DMG Beacon) | The values from the DMG Parameters field from the DMG Beacon frame, else null. The parameter is present only if dot11DMGOptionImplemented is true. | Adopt |
| Clustering Control | As defined in frame format | As defined in 9.3.4.2 (DMG Beacon) | The values from the Clustering Control field from the DMG Beacon frame, else null. The parameter is present only if dot11DMGOptionImplemented is true. | Do not adopt |
| DMG Capabilities | As defined in frame format | As defined in 9.4.2.126 (DMG Capabilities element) | The values from the DMG Capabilities element if such an element was present in the Probe Response or DMG Beacon frame, else null. The parameter is optionally present if dot11DMGOptionImplemented is true. | Do not adopt |
| DMG Operation | As defined in frame format | As defined in 9.4.2.126 (DMG Capabilities element) | The values from the DMG Operation element if such an element was present in the Probe Response or DMG Beacon frame, else null. The parameter is optionally present if dot11DMGOptionImplemented is true. | Adopt |
| Extended Schedule | As defined in frame format | As defined in 9.4.2.130 (Extended Schedule element) | The values from the Extended Schedule element if such an element was present in the Probe Response or DMG Beacon frame, else null. The parameter is optionally present if dot11DMGOptionImplemented is true. | Adopt |

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| Name | Type | Valid range | Description | IBSS adoption |
|---|---|---|---|---|
| Next DMG ATI | As defined in frame format | As defined in 9.4.2.134 (Next DMG ATI element) | The values from the Next DMG ATI element if such an element was present in the Probe Response or DMG Beacon frame, else null. The parameter is optionally present if dot11DMGOptionImplemented is true. | Adopt |
| DMG BSS Parameter Change | As defined in frame format | As defined in 9.4.2.125 (DMG BSS Parameter Change element) | The values from the DMG BSS Parameter Change element if such an element was present in the Probe Response or DMG Beacon frame, else null. The parameter is optionally present if dot11DMGOptionImplemented is true. | Adopt |
| Multi-band | As defined in frame format | As defined in 9.4.2.137 (Multi-band element) | The values from the Multi-band element if such an element was present in the Probe Response or DMG Beacon frame, else null. The Multi-band element is optionally present if dot11MultibandImplemented is true. | Adopt |
| DMG Wakeup Schedule | As defined in frame format | As defined in 9.4.2.129 (DMG Wakeup Schedule element) | The values from the DMG Wakeup Schedule element if such an element was present in the Probe Response or DMG Beacon frame, else null. The parameter is optionally present if dot11DMGOptionImplemented is true. | Adopt |
| Antenna Sector ID Pattern | As defined in frame format | As defined in 9.4.2.155 (Antenna Sector ID Pattern element) | The values from the Antenna Sector ID Pattern element if such an element was present in the Probe Response or DMG Beacon frame, else null. The parameter is optionally present if dot11DMGOptionImplemented is true. | Adopt |
| Relay Capabilities | As defined in frame format | As defined in 9.4.2.146 (Relay Capabilities element) | The values from the Relay Capabilities element if such an element was present in the Probe Response or DMG Beacon frame, else null. The parameter is optionally present if dot11RelayActivated is true. | Do not adopt |


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| Name | Type | Valid range | Description | IBSS adoption |
|---|---|---|---|---|
| VHT Capabilities | As defined in frame format | As defined in 9.4.2.156 (VHT Capabilities element) | The values from the VHT Capabilities element. The parameter is present if dot11VHTOptionImplemented is true and a VHT Capabilities element was present in the Probe Response or Beacon frame from which the BSSDescription was determined. The parameter is not present otherwise. | Do not adopt |
| VHT Operation | As defined in frame format | As defined in 9.4.2.157 (VHT Operation element) | The values from the VHT Operation element. The parameter is present if dot11VHTOptionImplemented is true and a VHT Operation element was present in the Probe Response or Beacon frame from which the BSSDescription was determined. The parameter is not present otherwise. | Adopt |
| TVHT Operation | As defined in frame format | As defined in 9.4.2.170 (TVHT Operation element) | The values from the TVHT Operation element if such an element was present in the Probe Response or Beacon frame; otherwise, null. The parameter is optionally present if dot11TVHTOptionImplemented is true. | Adopt |
| CAG Number | As defined in 9.4.2.175 (CAG Number element) | As defined in 9.4.2.175 (CAG Number element) | One or more Common Advertisement Group (CAG) tuples. Each CAG Tuple describes the CAG Version, Scope, and partial advertisement protocol ID. This parameter is optionally present when dot11FILSActivated is true; otherwise not present. | Do not adopt. |
| DILS | As defined in 9.4.2.185 (DILS element) | As defined in 9.4.2.185 (DILS element) | The values from the DILS element. It is optionally present when dot11FILSActivated is true and if such an element was present in the Probe Response or Beacon frame; otherwise not present. | Do not adopt |
| Short SSID(#8219) | Integer | N/A | The Short SSID(#8219) of the received frame (PV1 Probe Response or S1G Beacon) from the found BSS. This parameter is optionally present if dot11S1GOptionImplemented is true; otherwise not present. | Adopt |

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| Name | Type | Valid range | Description | IBSS adoption |
|---|---|---|---|---|
| Next TBTT | Integer | N/A | Highest 3 octets of the 4 least significant octets of the next TBTT. This parameter is optionally present if dot11S1GOptionImplemented is true; otherwise not present. | Adopt |
| S1G Relay Discovery | As defined in frame format | As defined in 9.4.2.206 (S1G Relay Discovery element) | The values from the S1G Relay Discovery element if such an element was present in the Probe Response, PV1 Probe Response, or S1G Beacon frame. More description is provided in 10.53.6 (S1G relay discovery procedure). | Do not adopt |
| RPS | RPS element | As defined in 9.4.2.190 (RPS element) | The parameter set for group-based restricted medium access, if such element was present in the S1G Beacon, PV1 Probe Response, or Probe Response frame, else null. The support of the feature is described on RAW-based medium access 10.23.5 (Restricted access window (RAW) operation). | Do not adopt |
| Page Slice | Page Slice element | As defined in 9.4.2.191 (Page Slice element) | The set of page slices present in DTIM interval, if such element was present in the S1G Beacon, or Probe Response, or PV1 Probe Response frame, else null. The support of the feature is described 10.50 (Page slicing). | Do not adopt |
| S1G Capabilities | As defined in frame format | As defined in 9.4.2.199 (S1G Capabilities element) | The values from the S1G Capabilities element. The parameter is present if dot11S1GOptionImplemented is true and an S1G Capabilities element was present in the S1G Beacon, or Probe Response, or PV1 Probe Response frame from which the BSSDescription was determined; otherwise not present. | Adopt |
| TSF Timer Accuracy | TSF Timer Accuracy element | As defined in 9.4.2.202 (TSF Timer Accuracy element) | The values from the TSF Timer Accuracy element if such an element was present in the Probe Response, PV1 Probe Response, or S1G Beacon frame, else null. The parameter is optionally present if dot11TSFTimerAccuracyImplemented is true; otherwise not present. | Adopt |


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| Name | Type | Valid range | Description | IBSS adoption |
|---|---|---|---|---|
| Change Sequence | As defined in frame format | As defined in 9.4.2.197 (Change Sequence element) | A Change Sequence element indicates the change of system information within a BSS. The support of the feature is described 10.45.2 (System information update procedure). | Do not adopt |
| S1GRelay | As defined in frame format | As defined in 9.4.2.203 (S1G Relay element) | The S1G Relay element is present in the S1G Beacon frame if dot11RelayAPOperationActivated is true or if dot11RelayAPImplemented is true; otherwise not present. The S1G Relay element is optionally present in Probe Response, or PV1 Probe Response, if dot11RelayAPImplemented is true. More description is provided in 10.53 (S1G relay operation). | Do not adopt |
| S1GOperation | As defined in frame format | As defined in 9.4.2.211 (S1G Operation element) | The values from the S1G Operation element if such an element was present in the Probe Response, PV1 Probe Response, or S1G Beacon frame, else null. The parameter is optionally present if dot11S1GOptionImplemented is true; otherwise not present. | Adopt |
| ShortBeaconPeriod | As defined in frame format | As defined in 9.4.2.196 (Short Beacon Interval element(#2194)) | The short beacon period, in TUs, of the found BSS if the Short Beacon Interval element was present in the Probe Response, PV1 Probe Response, or S1G Beacon frame, else null. The parameter is optionally present if dot11S1GOptionImplemented is true; otherwise not present. | Adopt |
| ShortBeaconDTIM Period | As defined in frame format | As defined in 9.4.2.5 (TIM element) | The values from the TIM element if such an element was present in the S1G Beacon frame, else null. The parameter is optionally present if dot11S1GOptionImplemented is true; otherwise not present. | Adopt |
| MaxAwayDuration | Integer | 0–65 535 | Indicates the maximum duration, in TUs, that the AP is unavailable for communications with the STA. The parameter is optionally present if dot11MaxAwayDuration is nonzero; otherwise not present. | Do not adopt |

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| Name | Type | Valid range | Description | IBSS adoption |
|---|---|---|---|---|
| CDMG Capabilities | CDMG Capabilities element | As defined in 9.4.2.218 (CDMG Capabilities element) | Specifies the parameters within the CDMG Capabilities element that are supported by the MAC entity.<br>The parameter is present if dot11CDMGOptionImplemented is true; otherwise not present. | Do not adopt |
| CMMG Capabilities | CMMG Capabilities element | As defined in 9.4.2.228 (CMMG Capabilities element) | Specifies the parameters within the CMMG Capabilities element that are supported by the MAC entity.<br>The parameter is present if dot11CMMGOptionImplemented is true; otherwise not present. | Do not adopt |
| CMMG Operation | CMMG Operation element | As defined in 9.4.2.229 (CMMG Operation element) | Specifies the parameters within the CMMG Operation element that are supported by the MAC entity.<br>The parameter is present if dot11CMMGOptionImplemented is true; otherwise not present. | Do not adopt |
| ServiceHint | Service Hint element | As defined in 9.4.2.236 (Service Hint element) | Provides an indication of the services advertised in Beacon frames and Probe Response frames.<br>The values from the Service Hint element, if such an element was present in the Beacon or Probe Response frame; else null. | Do not adopt |
| ServiceHash | Service Hash element | As defined in 9.4.2.237 (Service Hash element) | Specifies services advertised in Beacon and Probe Response frames.<br>The values from the Service Hash element, if such an element was present in the Beacon or Probe Response frame; else null. | Do not adopt |
| Reduced Neighbor Report(#469) | One or more Reduced Neighbor Report elements | As defined in 9.4.2.169 (Reduced Neighbor Report element) | The information of the Reduced Neighbor Information field of the received Beacon or Probe Response frame. This parameter is optional. | Do not adopt |
| TWT(11ax) | As defined in frame format | As defined in 9.4.2.198 (TWT element) | The value from the TWT element. The parameter is optionally present if dot11HEOptionImplemented is true, dot11TWTOptionActivated is true, and a TWT element was present in the broadcast Probe Response or Beacon frame from which the BSSDescriptionSet was determined. Otherwise, the parameter is not present. | Do not adopt |


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| Name | Type | Valid range | Description | IBSS adoption |
|---|---|---|---|---|
| HE Capabilities(11ax) | As defined in frame format | As defined in 9.4.2.247 (HE Capabilities element(11ax)) | The value from the HE Capabilities element. The parameter is present if dot11HEOptionImplemented is true and an HE Capabilities element was present in the Probe Response or Beacon frame from which the BSSDescription was determined. Otherwise, the parameter is not present. | Do not adopt |
| HE 6 GHz Band Capabilities(11ax) | As defined in frame format | As defined in 9.4.2.262 (HE 6 GHz Band Capabilities element(11ax)) | The value from the HE 6 GHz Band Capabilities element. The parameter is present if dot11HE6GOptionImplemented is true and an HE 6 GHz Band Capabilities element was present in the Probe Response or Beacon frame from which the BSSDescription was determined. Otherwise, the parameter is not present. | Do not adopt |
| HE Operation(11ax) | As defined in frame format | As defined in 9.4.2.248 (HE Operation element(11ax)) | The value from the HE Operation element. The parameter is present if dot11HEOptionImplemented is true and an HE Operation element was present in the Probe Response or Beacon frame from which the BSSDescriptionSet was determined. Otherwise, the parameter is not present. | Adopt |
| UORA Parameter Set(11ax) | As defined in frame format | As defined in 9.4.2.249 (UORA Parameter Set element(11ax)) | The value from the UORA Parameter Set element. The parameter is optionally present if dot11OFDMARandom-AccessOptionImlemented is true and a UORA Parameter Set element was present in the Probe Response or Beacon frame from which the BSSDescriptionSet was determined. Otherwise, the parameter is not present. | Do not adopt |
| MU EDCA Parameter Set(11ax) | As defined in frame format | As defined in 9.4.2.250 (MU EDCA Parameter Set element(11ax)) | The value from the MU EDCA Parameter Set element. The parameter is optionally present if dot11HEOptionImplemented is true and a MU EDCA Parameter Set element was present in the Probe Response or Beacon frame from which the BSSDescriptionSet was determined. Otherwise, the parameter is not present. | Do not adopt |

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| Name | Type | Valid range | Description | IBSS adoption |
|---|---|---|---|---|
| Spatial Reuse Parameter Set(11ax) | As defined in frame format | As defined in 9.4.2.251 (Spatial Reuse Parameter Set element(11ax)) | The value from the Spatial Reuse Parameter Set element. The parameter is optionally present if dot11HEOptionImplemented is true and a Spatial Reuse Parameter Set element was present in the Probe Response or Beacon frame from which the BSSDescriptionSet was determined. Otherwise, the parameter is not present. | Do not adopt |
| NDP Feedback Report Parameter Set(11ax) | As defined in frame format | As defined in 9.4.2.252 (NDP Feedback Report Parameter Set element(11ax)) | The value from the NDP Feedback Report Parameter Set element. The parameter is optionally present if dot11HEOptionImplemented is true and an NDP Feedback Report Parameter Set element was present in the Probe Response or Beacon frame from which the BSSDescriptionSet was determined. Otherwise, the parameter is not present. | Do not adopt |
| BSS Color Change Announcement(11ax) | As defined in frame format | As defined in 9.4.2.253 (BSS Color Change Announcement element(11ax)) | The value from the BSS Color Change Announcement element. The parameter is optionally present if dot11HEOptionImplemented is true and a BSS Color Change Announcement element was present in the Probe Response or Beacon frame from which the BSSDescriptionSet was determined. Otherwise, the parameter is not present. | Do not adopt |
| ESS Report(11ax) | As defined in frame format | As defined in 9.4.2.255 (ESS Report element(11ax)) | The value from the ESS Report element. The parameter is optionally present if an ESS Report element was present in the Probe Response or Beacon frame from which the BSSDescriptionSet was determined. Otherwise, the parameter is not present. | Do not adopt |
| HE BSS Load(11ax) | As defined in frame format | As defined in 9.4.2.258 (HE BSS Load element(11ax)) | The value from the HE BSS Load element. The parameter is (#4134)present if dot11QBSSLoadImplemented and dot11HEOptionImplemented are (#4134)both true and an HE BSS Load element was present in the Probe Response or Beacon frame from which the BSSDescriptionSet was determined. Otherwise, the parameter is not present. | Do not adopt |


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| Name | Type | Valid range | Description | IBSS adoption |
|---|---|---|---|---|
| Multiple BSSID Configuration(11ax) | As defined in frame format | As defined in 9.4.2.259 (Multiple BSSID Configuration element(11ax)) | The value from the Multiple BSSID Configuration element. The parameter is present if dot11MultiBSSIDImplemented is true and the Multiple BSSID Configuration element was present in the Probe Response or Beacon frame from which the BSSDescription was determined. Otherwise, the parameter is not present. | Do not adopt |
| WUR Capabilities(11ba) | As defined in frame format | As defined in 9.4.2.290 (WUR Capabilities element(11ba)) | The value from WUR Capabilities element. The parameter is present if dot11WUROptionImplemented is true and a WUR Capabilities element was present in the Probe Response or Beacon frame from which the BSSDescription was determined; otherwise, the parameter is not present. | Do not adopt |
| WUR Operation(11ba) | As defined in frame format | As defined in 9.4.2.291 (WUR Operation element(11ba)) | The value from WUR Operation element. The parameter is present if dot11WUROptionImplemented is true and a WUR Operation element was present in the Probe Response or Beacon frame from which the BSSDescriptionSet was determined; otherwise, the parameter is not present. | Do not adopt |
| WUR Discovery(11ba) | As defined in frame format | As defined in 9.4.2.293 (WUR Discovery element(11ba)) | The value from WUR Discovery element. The parameter is present if dot11WUROptionImplemented is true and a WUR Discovery element was present in the Probe Response or Beacon frame from which the BSSDescriptionSet was determined; otherwise, the parameter is not present. | Do not adopt |

Each BSSDescriptionFromMeasurementPilot consists of the following parameters, in which the term *peer STA* refers to the STA transmitting the Measurement Pilot frame from which the BSSDescription was determined and the term *local STA* refers to the STA performing the scan:

| Name | Type | Valid range | Description |
|---|---|---|---|
| BSSID | MAC address | N/A | The BSSID of the found BSS. |
| BSS Type | Enumeration | INFRASTRUCTURE | The type of the found BSS. |
| Local Time | Integer | N/A | The value of the local STA's TSF timer at the start of reception of the first octet of the timestamp field of the received frame from the found BSS. |

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| Name | Type | Valid range | Description |
|---|---|---|---|
| Condensed Capability Information | Condensed Capability Information field | As defined in 9.6.7.3 (Measurement Pilot frame format) | The advertised condensed capabilities of the BSS. |
| Condensed Country String | Condensed Country String field | As defined in 9.6.7.3 (Measurement Pilot frame format) | Together with the Operating Class, the information required to identify the regulatory domain in which the peer STA is located and to configure its PHY for operation in that regulatory domain. |
| Operating Class | Operating Class field | The field is defined in 9.6.7.3 (Measurement Pilot frame format), valid values for the field are defined in Annex E. | Together with the Condensed Country String, the information required to identify the regulatory domain in which the peer STA is located and to configure its PHY for operation in that regulatory domain. |
| Channel | Channel field | The field is defined in 9.6.7.3 (Measurement Pilot frame format), valid values for the field are defined in Annex E. | The operating channel of the BSS indicated in the received frame. |
| Measurement Pilot Interval | Measurement Pilot Interval field | As defined in 9.6.7.3 (Measurement Pilot frame format) | The measurement pilot interval of the BSS indicated in the received frame. |
| (#488)Multiple BSSID | (#488)A set of Multiple BSSID elements | As defined in 9.4.2.44 (Multiple BSSID element) | (#488)The values from the Multiple BSSID element(s) present in the Measurement Pilot frame, if any, else null. |
| PHY Type | Integer | As defined in Annex C | The dot11PHYType of the received frame. |
| RCPIMeasurement | Integer | As defined in 9.4.2.36 (RCPI element) | (#14)The RCPI of the received PPDU containing the frame. |
| RSNIMeasurement | Integer | As defined in 9.4.2.39 (RSNI element) | (#14)The RSNI of the received PPDU containing the frame. |


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The BSSDescriptionFromFDSet parameter is present if dot11FILSActivated is true; otherwise, it is not present. Each BSSDescriptionFromFD consists of the parameters shown in the following table:

| Name | Type | Valid range | Description |
|---|---|---|---|
| BSSID | MAC address | N/A | The BSSID of the found BSS. |
| SSID | Octet String | As defined in 9.4.2.2 (SSID element) | The SSID of the found BSS. This parameter is present if the Short SSID Indicator field in the received FILS Discovery frame is equal to 0. |
| Short SSID | Integer | As defined in the 9.4.2.169 (Reduced Neighbor Report element) | The short SSID of the found BSS. This parameter is present if the Short SSID Indicator field in the received FILS Discovery frame is equal to 1. |
| FD Capability | As defined in 9.6.7.36 (FILS Discovery frame format) | As defined in 9.6.7.36 (FILS Discovery frame format) | The FD Capability contains the capabilities and operational indications of the BSS. This parameter is optional. |
| Operating class | Integer | As defined in 9.4.1.34 (Operating Class field(#3249)) | The operating class of the advertised BSS. |
| Access Network Options | As defined in 9.4.2.90 (Interworking element) | As defined in 9.4.2.90 (Interworking element) | The advertised access network options of the BSS. This parameter is optional. |
| Primary Channel | Integer | 1–255 | The Primary Channel of the advertised BSS. The Primary Channel is defined within the indicated Operating Class as shown in Annex E. This parameter is optional. |
| FD RSN Information | As defined in 9.6.7.36 (FILS Discovery frame format) | As defined in 9.6.7.36 (FILS Discovery frame format) | The information for robust security network. This parameter is optional. |
| Channel Center Frequency Segment 1 | Integer | 1–255 | The channel number(#6420) of the 80 MHz channel of frequency segment 1 when the BSS operates on an 80+80 MHz operating channel width. This parameter is optional. |
| AP-CSN | Integer | As defined in 9.4.2.180 (AP Configuration Sequence Number (AP-CSN) element) | The value of the Configuration Sequence Number in the found BSS. This parameter is optional. |
| AP's next TBTT Offset | Integer | As defined in 9.6.7.36 (FILS Discovery frame format) | The information of next target beacon transmission time of the found BSS. This parameter is optional. |
| Reduced Neighbor Report | One or more Reduced Neighbor Report elements(11ax) | As defined in 9.4.2.169 (Reduced Neighbor Report element) | (11ax)The information related to APs in the neighborhood of the reporting AP or APs (#2210)colocated with the reporting AP. This parameter is optional. |
| FILS Indication | As defined in 9.4.2.181 (FILS Indication element) | As defined in 9.4.2.181 (FILS Indication element) | The information related to FILS authentication and upper layer set up capabilities of the found AP. This parameter is optional. |

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#### 6.5.3.3.3 When generated

This primitive is generated by the MLME to report the operating environment of the STA. It is issued after receiving an MLME-SCAN.request primitive or, if dot11FILSActivated is true, after receiving an MLME-SCAN-STOP.request primitive following an MLME-SCAN.request primitive.

#### 6.5.3.3.4 Effect of receipt

The SME is notified of the results of the scan procedure. If dot11FILSActivated is true, these results might be intermediate results, according to the value of ResultCode.

### 6.5.3.4 MLME-SCAN-STOP.request

#### 6.5.3.4.1 Function

This primitive terminates any ongoing scan.

#### 6.5.3.4.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-SCAN-STOP.request(
                                    Multi-band local,
                                    Multi-band peer
                                    )
```

| Name | Type | Valid range | Description |
|---|---|---|---|
| Multi-band local | Multi-band element | As defined in 9.4.2.137 (Multi-band element) | Specifies the parameters within the Multi-band element that are supported by the local MAC entity. The parameter is present if dot11MultibandImplemented is true and is absent otherwise. |
| Multi-band peer | Multi-band elemen | As defined in 9.4.2.137 (Multi-band element) | Specifies the parameters within the Multi-band element that are used to deliver messages to the peer MAC entity. The parameter is present if OCT is being used and is absent otherwise. |

#### 6.5.3.4.3 When generated

This primitive is generated by the SME in order to stop all ongoing active or passive scan processes in the STA.

#### 6.5.3.4.4 Effect of receipt

This request terminates all ongoing scan procedures.

### 6.5.4 Synchronization

#### 6.5.4.1 Introduction

This mechanism supports the process of selection of a peer in the authentication process.


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#### 6.5.4.2 MLME-JOIN.request

##### 6.5.4.2.1 Function

This primitive requests synchronization with (#3436)a nonmesh BSS.

##### 6.5.4.2.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-JOIN.request(
SelectedBSS,
JoinFailureTimeout,
NAVSyncDelay,
OperationalRateSet,
Capability Information,
HT Capabilities,
VHT Capabilities,
DMG Capabilities,
S1G Capabilities,
Extended Capabilities,
20/40 BSS Coexistence,
InterworkingInfo,
AdvertisementProtocolInfo,
HE Capabilities,(11ax)
HE 6 GHz Band Capabilities,(11ax)
EDMG Capabilities,(11ay)
WUR Capabilities,(11ba)
VendorSpecificInfo
)

| Name | Type | Valid range | Description |
|---|---|---|---|
| SelectedBSS | BSSDescription | N/A | The BSSDescription of the BSS to join. The SelectedBSS is a member of the set of descriptions that was returned as a result of an MLME-SCAN.request primitive. |
| JoinFailureTimeout | Integer | ≥ 1 | The time limit, in units of beacon intervals, after which the join procedure is terminated. |
| NAVSyncDelay | Integer | ≥ 0(#3418) | Delay (in microseconds) to be used prior to transmitting when changing from doze to awake state and when changing channel(#2079), if no frame is detected by which the network allocation vector (NAV) can be set. |
| OperationalRateSet | Non-DMG BSS: Set of integers<br><br>DMG BSS: Set of numbers | Non-DMG BSS: a value in dot11SupportedDataRatesRxTable, for each member of the set<br><br>DMG BSS: 0-12, 9.1, 12.1-12.6, or 25-31, for each member of the set | Non-DMG BSS: The set of data rates (in units of 500 kb/s) that the STA is able to use for communication within the BSS. The STA is able to receive at each of the data rates listed in the set. This set is a superset of the rates contained in the BSSBasicRateSet parameter of the SelectedBSS parameter.<br>DMG BSS: The set of MCS (#4136)indices that the STA uses for communication within the BSS. |

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| Name | Type | Valid range | Description |
|---|---|---|---|
| CapabilityInformation | Capability Information field | As defined in 9.4.1.4 (Capability Information field) | Specifies the parameters in the Capability Information field that are supported by the STA. |
| HT Capabilities | As defined in frame format HT Capabilities element | As defined in 9.4.2.54 (HT Capabilities element); the HT-MCSs in the element are present in dot11SupportedHTMCSRxTable and the highest supported data rate in the element does not exceed dot11HighestSupportedDataRate | Specifies the parameters in the HT Capabilities element that are supported by the STA. The parameter is present if dot11HighThroughputOptionImplemented is true; otherwise, this parameter is not present. |
| VHT Capabilities | As defined in VHT Capabilities element | As defined in 9.4.2.156 (VHT Capabilities element); the VHT-MCSs in the element are present in dot11VHTRxVHTMCSMap/ dot11VHTTxVHTMCSMap and the highest supported rates in the element do not exceed dot11VHTRxHighestDataRateSupported/ dot11VHTTxHighestDataRateSupported | Specifies the parameters in the VHT Capabilities element that are supported by the STA. The parameter is present if dot11VHTOptionImplemented is true and not present otherwise. |
| DMG Capabilities | DMG Capabilities element | As defined in 9.4.2.126 (DMG Capabilities element) | Specifies the parameters within the DMG Capabilities element that are supported by the MAC entity. The parameter is present if dot11DMGOptionImplemented is true and is absent otherwise. |
| S1G Capabilities | As defined in frame format | As defined in 9.4.2.199 (S1G Capabilities element) | Specifies the parameters in the S1G Capabilities element that are supported by the STA. The parameter is present if dot11S1GOptionImplemented is true; otherwise not present. |
| Extended Capabilities | As defined in frame format | As defined in 9.4.2.25 (Extended Capabilities element) | Specifies the parameters within the Extended Capabilities element that are supported by the MAC entity. |
| 20/40 BSS Coexistence | As defined in frame format | As defined in 9.4.2.58 (20/40 BSS Coexistence element) | Specifies the parameters within the 20/40 BSS Coexistence element that are indicated by the MAC entity. The parameter is present if dot112040BSSCoexistence-ManagementSupport is true. |
| InterworkingInfo | As defined in frame format | As defined in Interworking element in 9.4.2.90 (Interworking element) | Specifies (#2164)the interworking capabilities of STA. This field is present when dot11InterworkingServiceActivated is true. |


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| Name | Type | Valid range | Description |
|---|---|---|---|
| AdvertisementProtocolInfo | Integer or Sequence of integers | As defined in Advertisement Protocol element in Table 9-277 (Advertisement protocol ID definitions) | Identifies zero or more advertisement protocols and advertisement control to be used in the BSSs. This field is present when dot11InterworkingServiceActivated is true. |
| HE Capabilities(11ax) | As defined in HE Capabilities element | As defined in 9.4.2.247 (HE Capabilities element(11ax)) | Specifies the parameters within the HE Capabilities element that are supported by the STA. The parameter is present if dot11HEOptionImplemented is true; otherwise, this parameter is not present. |
| HE 6 GHz Band Capabilities(11ax) | As defined in HE 6 GHz Band Capabilities element | As defined in 9.4.2.262 (HE 6 GHz Band Capabilities element(11ax)) | Specifies the parameters within the HE 6 GHz Band Capabilities element that are supported by the STA. The parameter is present if dot11HE6GOptionImplemented is true; otherwise, this parameter is not present. |
| EDMG Capabilities(11ay) | EDMG Capabilities element | As defined in 9.4.2.264 (EDMG Capabilities element(11ay)) | Specifies the parameters within the EDMG Capabilities element that are supported by the MAC entity. The parameter is present if dot11EDMGOptionImplemented is true and is absent otherwise. |
| WUR Capabilities(11ba) | As defined in WUR Capabilities element | As defined in 9.4.2.290 (WUR Capabilities element(11ba)) | Specifies the parameters within the WUR Capabilities element that are supported by the STA. The parameter is present if dot11WUROptionImplemented is true; otherwise, this parameter is not present. |
| VendorSpecificInfo | A set of elements | As defined in 9.4.2.24 (Vendor Specific element) | Zero or more elements. |

#### 6.5.4.2.3 When generated

This primitive is generated by the SME for a STA to establish synchronization with a BSS.

#### 6.5.4.2.4 Effect of receipt

This primitive initiates a synchronization procedure once the current frame exchange sequence is complete. The MLME synchronizes its timing with the specified BSS based on the information provided in the SelectedBSS parameter. The MLME subsequently issues an MLME-JOIN.confirm primitive that reflects the results.

If the MLME of a non-DMG STA receives an MLME-JOIN.request primitive with the SelectedBSS parameter containing a BSSBasicRateSet parameter that contains any unsupported rates, the MLME response in the resulting MLME-JOIN.confirm primitive shall contain a ResultCode parameter that is not set to the value SUCCESS.

If the MLME of an HT STA receives an MLME-JOIN.request primitive with the SelectedBSS parameter containing a Basic HT-MCS Set field in the HT Operation parameter that contains any unsupported MCSs, the MLME response in the resulting MLME-JOIN.confirm primitive shall contain a ResultCode parameter that is not set to the value SUCCESS.

If the MLME of a VHT STA receives an MLME-JOIN.request primitive with a SelectedBSS parameter containing a Basic VHT-MCS And NSS Set field in the VHT Operation parameter that contains any

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unsupported <VHT-MCS, NSS> tuple, the MLME response in the resulting MLME-JOIN.confirm primitive shall contain a ResultCode parameter that is not set to the value SUCCESS.

If the MLME of a DMG STA receives an MLME-JOIN.request primitive with the SelectedBSS parameter containing a BSSBasicRateSet parameter that is not empty, or with the OperationalRateSet parameter containing any unsupported MCSs, the MLME response in the resulting MLME-JOIN.confirm primitive shall contain a ResultCode parameter that is not set to the value SUCCESS.

If the MLME of an S1G STA receives an MLME-JOIN.request primitive with a SelectedBSS parameter containing a Basic S1G-MCS and NSS Set field in the S1GOperation parameter that contains any unsupported <S1G-MCS, NSS> tuple, the MLME response in the resulting MLME-JOIN.confirm primitive shall contain a ResultCode parameter that is not set to the value SUCCESS.

If the MLME of an HE STA receives an MLME-JOIN.request primitive with a SelectedBSS parameter containing a Basic HE-MCS And NSS Set field in the HE Operation parameter that contains any unsupported <HE-MCS, NSS> tuple, then the MLME response in the resulting MLME-JOIN.confirm primitive shall contain a ResultCode parameter that is not set to the value SUCCESS.(11ax)

#### 6.5.4.3 MLME-JOIN.confirm

##### 6.5.4.3.1 Function

This primitive confirms synchronization with a BSS.

##### 6.5.4.3.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-JOIN.confirm(
                        ResultCode,
                        VendorSpecificInfo
                        )
```

| Name | Type | Valid range | Description |
|---|---|---|---|
| ResultCode | Enumeration | SUCCESS, JOIN_FAILURE_TIMEOUT | Indicates the result of the MLME-JOIN.request primitive. |
| VendorSpecificInfo | A set of elements | As defined in 9.4.2.24 (Vendor Specific element) | Zero or more elements. |

##### 6.5.4.3.3 When generated

This primitive is generated by the MLME as a result of an MLME-JOIN.request primitive to establish synchronization with a BSS.

##### 6.5.4.3.4 Effect of receipt

The SME is notified of the results of the synchronization procedure.

### 6.5.5 Authenticate

#### 6.5.5.1 Introduction

This mechanism supports the process of establishing an authentication relationship with a peer MAC entity.


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#### 6.5.5.2 MLME-AUTHENTICATE.request

##### 6.5.5.2.1 Function

This primitive requests authentication with a specified peer MAC entity.

##### 6.5.5.2.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-AUTHENTICATE.request(
PeerSTAAddress,
AuthenticationType,
AuthenticateFailureTimeout,
Content of FT Authentication elements,
Content of SAE Authentication frame,
Multi-band local,
Multi-band peer,
Content of FILS Authentication frame,
(#7121)Content of PASN Authentication frame,
VendorSpecificInfo
)

| Name | Type | Valid range | Description |
|---|---|---|---|
| PeerSTAAddress | MAC address | (#1653)Any valid individual address | Specifies the address of the peer MAC entity with which to perform the authentication process. |
| AuthenticationType | Enumeration | OPEN_SYSTEM, SHARED_KEY, FAST_BSS_TRANSITION, SAE, FILS_SHARED_KEY WITHOUT_PFS, FILS_SHARED KEY_WITH_PFS, FILS_PUBLIC_KEY | Specifies the type of authentication algorithm to use during the authentication process. |
| AuthenticateFailureTimeout | Integer | ≥ 1 | Specifies a time limit (in TU) after which the authentication procedure is terminated. |
| Content of FT Authentication elements | Sequence of elements | As defined in 13.8 (FT authentication sequence) | The set of elements to be included in the first message of the FT authentication sequence, as described in 13.8.2 (FT authentication sequence: contents of first message). Present if dot11FastBSSTransitionActivated is true; otherwise not present. |
| Content of SAE Authentication frame | Sequence of elements and fields | As defined in 9.4.1.35 (Send-Confirm field), 9.4.1.36 (Anti-Clogging Token field), 9.4.1.37 (Scalar field), 9.4.1.38 (FFE field), 9.4.1.39 (Confirm field), and 9.4.1.40 (Finite Cyclic Group field) | The set of elements and fields to be included in the SAE Commit message or SAE Confirm message. Present if AuthenticationType indicates SAE authentication; otherwise not present. |
| Multi-band local | Multi-band element | As defined in 9.4.2.137 (Multi-band element) | Specifies the parameters within the Multi-band element that are supported by the local MAC entity. The parameter is present if dot11MultibandImplemented is true and is absent otherwise. |

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| Name | Type | Valid range | Description |
|---|---|---|---|
| Multi-band peer | Multi-band element | As defined in 9.4.2.137 (Multi-band element) | Specifies the parameters within the Multi-band element that are used to deliver messages to the peer MAC entity. This parameter is present if OCT is being used and is absent otherwise. |
| Content of FILS Authentication frame | Sequence of elements and fields | As defined in 9.4.1.40 (Finite Cyclic Group field), 9.4.1.38 (FFE field), 9.4.2.23 (RSNE), 9.4.2.178 (FILS Session element), 9.4.2.186 ((11az)Wrapped Data element), and 9.4.2.188 (FILS Nonce element) | The set of elements and fields to be included in the first message of the FILS authentication sequence, as described in 12.11 (Authentication for FILS). Present if AuthenticationType indicates FILS SHARED KEY WITHOUT PFS, FILS SHARED KEY WITH PFS, or FILS PUBLIC KEY; otherwise not present. |
| Content of PASN Authentication frame (#7121) | Sequence of elements and fields | As defined in 12.13.3.2 (PASN frame construction and processing), 9.4.2.24 (Vendor Specific element), 9.4.2.48 (RDE(#1776)), 9.4.2.187 (Fragment element), 9.4.2.241 (TCLAS Mask element), and 9.4.2.303 (Multiple Best AWV ID element(11az)) | The set of elements and fields to be included in PASN Authentication frames. Present if AuthenticationType indicates PASN authentication and dot11PASNActivated is true, otherwise not present. |
| VendorSpecificInfo | A set of elements | As defined in 9.4.2.24 (Vendor Specific element) | Zero or more elements. |

#### 6.5.5.2.3 When generated

This primitive is generated by the SME for a STA to establish authentication with a specified peer MAC entity in order to permit Class 2 frames, or mesh peering Management frames for AMPE utilizing SAE authentication, to be exchanged between the two STAs. During the authentication procedure, the SME might generate additional MLME-AUTHENTICATE.request primitives.

If dot11S1GCentralizedAuthenticationControlActivated is true and a STA's MAC variable AuthenticationRequestTransmission is false, then the STA shall not invoke this primitive.

#### 6.5.5.2.4 Effect of receipt

This primitive initiates an authentication procedure. In the case that a response is received from the responder STA, the MLME subsequently issues an MLME-AUTHENTICATE.confirm primitive that reflects the results.

### 6.5.5.3 MLME-AUTHENTICATE.confirm

#### 6.5.5.3.1 Function

This primitive reports the results of an authentication attempt with a specified peer MAC entity.

#### 6.5.5.3.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-AUTHENTICATE.confirm(
                                PeerSTAAddress,
                                AuthenticationType,
```


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ResultCode,
Content of FT Authentication elements,
Content of SAE Authentication frame,
Multi-band local,
Multi-band peer,
Content of FILS Authentication frame,
(#7121)Content of PASN Authentication frame,
VendorSpecificInfo
)

| Name | Type | Valid range | Description |
|---|---|---|---|
| PeerSTAAddress | MAC address | (#1653)Any valid individual address | Specifies the address of the peer MAC entity with which the authentication process was attempted. This value matches the peerSTAAddress parameter specified in the corresponding MLME-AUTHENTICATE.request primitive. |
| AuthenticationType | Enumeration | OPEN_SYSTEM, SHARED_KEY FAST_BSS_TRANSITION, SAE, FILS_SHARED KEY_WITHOUT_PFS, FILS_SHARED_KEY_WITH_PFS, FILS_PUBLIC_KEY, (#7121)PASN | Specifies the type of authentication algorithm that was used during the authentication process. This value matches the AuthenticationType parameter specified in the corresponding MLME-AUTHENTICATE.request primitive. |
| ResultCode | Enumeration | SUCCESS, REFUSED_REASON_UNSPECIFIED,(#1780) ANTI_CLOGGING_TOKEN_REQUIRED, FINITE_CYCLIC_GROUP_NOT_SUPPORTED, AUTHENTICATION_REJECTED, AUTH_FAILURE_TIMEOUT | Indicates the result of the MLME-AUTHENTICATE.request primitive. |
| Content of FT Authentication elements | Sequence of elements | As defined in 13.8 (FT authentication sequence) | The set of elements included in the second message of the FT authentication sequence, as described in 13.8.3 (FT authentication sequence: contents of second message). Present if dot11FastBSSTransitionActivated is true; otherwise not present. |
| Content of SAE Authentication frame | Sequence of elements | As defined in 9.4.1.35 (Send-Confirm field), 9.4.1.36 (Anti-Clogging Token field), 9.4.1.37 (Scalar field), 9.4.1.38 (FFE field), 9.4.1.39 (Confirm field), and 9.4.1.40 (Finite Cyclic Group field) | The set of elements to be included in the SAE Commit message or SAE Confirm message. Present if AuthenticationType indicates SAE authentication; otherwise not present. |
| Multi-band local | Multi-band element | As defined in 9.4.2.137 (Multi-band element) | Specifies the parameters within the Multi-band element that identify the local MAC entity. This parameter is present if OCT is being used and is absent otherwise. |

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| Name | Type | Valid range | Description |
|---|---|---|---|
| Multi-band peer | Multi-band element | As defined in 9.4.2.137 (Multi-band element) | Specifies the parameters within the Multi-band element that are supported by the peer MAC entity. This parameter is present if OCT is being used and is absent otherwise. |
| Content of FILS Authentication frame | Sequence of elements and fields | As defined in 9.4.1.40 (Finite Cyclic Group field), 9.4.1.38 (FFE field), 9.4.2.23 (RSNE), 9.4.2.174 (Association Delay Info element), 9.4.2.178 (FILS Session element), 9.4.2.186 ((11az)Wrapped Data element), and 9.4.2.188 (FILS Nonce element) | The set of elements and fields included in the second message of the FILS authentication sequence, as described in 12.11 (Authentication for FILS). Present if AuthenticationType indicates FILS SHARED KEY WITHOUT PFS, FILS SHARED KEY WITH PFS, or FILS PUBLIC KEY; otherwise not present. |
| Content of PASN Authentication frame (#7121) | Sequence of elements and fields | As defined in 12.13.3.2 (PASN frame construction and processing), 9.4.2.24 (Vendor Specific element), 9.4.2.48 (RDE(#1776)), 9.4.2.187 (Fragment element), 9.4.2.241 (TCLAS Mask element), and 9.4.2.303 (Multiple Best AWV ID element(11az)) | The set of elements and fields to be included in PASN Authentication frames. Present if AuthenticationType indicates PASN authentication and dot11PASNActivated is true, otherwise not present. |
| VendorSpecificInfo | A set of elements | As defined in 9.4.2.24 (Vendor Specific element) | Zero or more elements. |

#### 6.5.5.3.3 When generated

This primitive is generated by the MLME as a result of an MLME-AUTHENTICATE.request primitive to authenticate with a specified peer MAC entity.

#### 6.5.5.3.4 Effect of receipt

The SME is notified of the results of the authentication procedure.

### 6.5.5.4 MLME-AUTHENTICATE.indication

#### 6.5.5.4.1 Function

This primitive indicates receipt of a request from a specific peer MAC entity to establish an authentication relationship with the STA processing this primitive.

#### 6.5.5.4.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-AUTHENTICATE.indication(
PeerSTAAddress,
AuthenticationType,
Content of FT Authentication elements,
Content of SAE Authentication frame,
Multi-band local,
Multi-band peer,
Content of FILS Authentication frame,
(#7121)Content of PASN Authentication frame,


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VendorSpecificInfo
)

| Name | Type | Valid range | Description |
|---|---|---|---|
| PeerSTAAddress | MAC address | (#1653)Any valid individual address | Specifies the address of the peer MAC entity (#4223)from which the authentication request was received. |
| AuthenticationType | Enumeration | OPEN_SYSTEM, SHARED_KEY, FAST_BSS_ TRANSITION, SAE, FILS_SHARED_KEY_WITHOUT_PFS, FILS_SHARED_KEY_WITH_PFS, FILS_PUBLIC_KEY, (#7121)PASN | Specifies the type of authentication algorithm that was used during the authentication process. |
| Content of FT Authentication elements | Sequence of elements | As defined in 13.8 (FT authentication sequence) | The set of elements included in the first message of the FT authentication sequence, as described in 13.8.2 (FT authentication sequence: contents of first message). Present if dot11FastBSSTransitionActivated is true; otherwise not present. |
| Content of SAE Authentication frame | Sequence of elements | As defined in 9.4.1.35 (Send-Confirm field), 9.4.1.36 (Anti-Clogging Token field), 9.4.1.37 (Scalar field), 9.4.1.38 (FFE field), 9.4.1.39 (Confirm field), and 9.4.1.40 (Finite Cyclic Group field) | The set of elements to be included in the SAE Commit message or SAE Confirm message. Present if AuthenticationType indicates SAE authentication; otherwise not present. |
| Multi-band local | Multi-band element | As defined in 9.4.2.137 (Multi-band element) | Specifies the parameters within the Multi-band element that identify and are supported by the local MAC entity. This parameter is present if OCT is being used and is absent otherwise. |
| Multi-band peer | Multi-band element | As defined in 9.4.2.137 (Multi-band element) | Specifies the parameters within the Multi-band element that identify and are supported by the peer MAC entity. This parameter is present if OCT is being used and is absent otherwise. |
| Content of FILS Authentication frame | Sequence of elements and fields | As defined in 9.4.1.40 (Finite Cyclic Group field), 9.4.1.38 (FFE field), 9.4.2.23 (RSNE), 9.4.2.174 (Association Delay Info element), 9.4.2.178 (FILS Session element), 9.4.2.186 ((11az)Wrapped Data element), and 9.4.2.188 (FILS Nonce element) | The set of elements and fields included in the first message of the FILS authentication sequence, as described in 12.11 (Authentication for FILS). Present if AuthenticationType indicates FILS SHARED KEY WITHOUT PFS, FILS SHARED KEY WITH PFS, or FILS PUBLIC KEY; otherwise not present. |

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| Name | Type | Valid range | Description |
|---|---|---|---|
| Content of PASN Authentication frame (#8045) | Sequence of elements and fields | As defined in 12.13.3.2 (PASN frame construction and processing), 9.4.2.24 (Vendor Specific element), 9.4.2.48 (RDE(#1776)), 9.4.2.187 (Fragment element), 9.4.2.241 (TCLAS Mask element), and 9.4.2.303 (Multiple Best AWV ID element(11az)) | The set of elements and fields to be included in PASN Authentication frames. Present if AuthenticationType indicates PASN authentication and dot11PASNActivated is true, otherwise not present. |
| VendorSpecificInfo | A set of elements | As defined in 9.4.2.24 (Vendor Specific element) | Zero or more elements. |

#### 6.5.5.4.3 When generated

This primitive is generated by the MLME as a result of the receipt of an authentication request from a specific peer MAC entity.

#### 6.5.5.4.4 Effect of receipt

The SME is notified of the receipt of the authentication request.

### 6.5.5.5 MLME-AUTHENTICATE.response

#### 6.5.5.5.1 Function

This primitive is used to send a response to a specific peer MAC entity that requested authentication with the STA that issued this primitive.

#### 6.5.5.5.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-AUTHENTICATE.response(
PeerSTAAddress,
ResultCode,
Content of FT Authentication elements,
Content of SAE Authentication frame,
Multi-band local,
Multi-band peer,
Content of FILS Authentication frame,
(#7121)Content of PASN Authentication frame,
VendorSpecificInfo
)

#### 6.5.5.5.3 When generated

This primitive is generated by the SME of a STA as a response to an MLME-AUTHENTICATE.indication primitive.

#### 6.5.5.5.4 Effect of receipt

This primitive initiates transmission of a response to the specific peer MAC entity that requested authentication.


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| Name | Type | Valid range | Description |
|---|---|---|---|
| PeerSTAAddress | MAC address | (#1653)Any valid individual address | Specifies the address of the peer MAC entity from which the authentication request was received. |
| ResultCode | Enumeration | SUCCESS, REFUSED_REASON_UNSPECIFIED,(#1780) ANTI_CLOGGING_TOKEN_REQUIRED, FINITE_CYCLIC_GROUP_NOT_SUPPORTED, AUTHENTICATION_REJECTED | Indicates the result response to the authentication request from the peer MAC entity. |
| Content of FT Authentication elements | Sequence of elements | As defined in 13.8 (FT authentication sequence) | The set of elements to be included in the second message of the FT authentication sequence, as described in 13.8.3 (FT authentication sequence: contents of second message). Present if dot11FastBSSTransitionActivated is true; otherwise not present. |
| Content of SAE Authentication frame | Sequence of elements | As defined in 9.4.1.35 (Send-Confirm field), 9.4.1.36 (Anti-Clogging Token field), 9.4.1.37 (Scalar field), 9.4.1.38 (FFE field), 9.4.1.39 (Confirm field), and 9.4.1.40 (Finite Cyclic Group field) | The set of elements to be included in the SAE Commit message or SAE Confirm message. Present if the AuthenticationType of the MLME-AUTHENTICATE.indication primitive that generated this response indicated SAE authentication; otherwise not present. |
| Multi-band local | Multi-band element | As defined in 9.4.2.137 (Multi-band element) | Specifies the parameters within the Multi-band element that are supported by the local MAC entity. The parameter is present if dot11MultibandImplemented is true and is absent otherwise. |
| Multi-band peer | Multi-band element | As defined in 9.4.2.137 (Multi-band element) | Specifies the parameters within the Multi-band element that are used to deliver messages to the peer MAC entity. This parameter is present if OCT is being used and is absent otherwise. |
| Content of FILS Authentication frame | Sequence of elements and fields | As defined in 9.4.1.40 (Finite Cyclic Group field), 9.4.1.38 (FFE field), 9.4.2.23 (RSNE), 9.4.2.178 (FILS Session element), 9.4.2.186 ((11az)Wrapped Data element), and 9.4.2.188 (FILS Nonce element) | The set of elements and fields to be included in the second message of the FILS authentication sequence, as described in 12.11 (Authentication for FILS). Present if AuthenticationType indicates FILS SHARED KEY WITHOUT PFS, FILS SHARED KEY WITH PFS, or FILS PUBLIC KEY; otherwise not present. |

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| Name | Type | Valid range | Description |
|---|---|---|---|
| Content of PASN Authentication frame (#7121) | Sequence of elements and fields | As defined in 12.13.3.2 (PASN frame construction and processing), 9.4.2.24 (Vendor Specific element), 9.4.2.48 (RDE(#1776)), 9.4.2.187 (Fragment element), 9.4.2.241 (TCLAS Mask element), and 9.4.2.303 (Multiple Best AWV ID element(11az)) | The set of elements and fields to be included in PASN Authentication frames. Present if AuthenticationType indicates PASN authentication and dot11PASNActivated is true, otherwise not present. |
| VendorSpecificInfo | A set of elements | As defined in 9.4.2.24 (Vendor Specific element) | Zero or more elements. |

### 6.5.6 Deauthenticate

#### 6.5.6.1 Introduction

This mechanism supports the process of invalidating an authentication relationship with a peer MAC entity.

#### 6.5.6.2 MLME-DEAUTHENTICATE.request

##### 6.5.6.2.1 Function

This primitive requests that the authentication relationship with a specified peer MAC entity be invalidated.

##### 6.5.6.2.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-DEAUTHENTICATE.request(
PeerSTAAddress,
ReasonCode,
VendorSpecificInfo
)

| Name | Type | Valid range | Description |
|---|---|---|---|
| PeerSTAAddress | MAC address | (#1653)Any valid individual address, or (#4223)the broadcast address(#3315) | Specifies the address of the peer MAC entity (#4223)or entities with which to perform the deauthentication process. |
| ReasonCode | Reason Code field | As defined in 9.4.1.7 (Reason Code field) | Specifies the reason for initiating the deauthentication procedure. |
| VendorSpecificInfo | A set of elements | As defined in 9.4.2.24 (Vendor Specific element) | Zero or more elements. |


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#### 6.5.6.2.3 When generated

This primitive is generated by the SME for a STA to invalidate authentication with a specified peer MAC entity in order to prevent the exchange of Class 2 frames, or mesh peering Management frames for AMPE utilizing SAE authentication, between the two STAs. During the deauthentication procedure, the SME might generate additional MLME-DEAUTHENTICATE.request primitives.

#### 6.5.6.2.4 Effect of receipt

This primitive initiates a deauthentication procedure. The MLME subsequently issues an MLME-DEAUTHENTICATE.confirm primitive that reflects the results.

### 6.5.6.3 MLME-DEAUTHENTICATE.confirm

#### 6.5.6.3.1 Function

This primitive reports the results of a deauthentication attempt with a specified peer MAC entity.

#### 6.5.6.3.2 Semantics of the service primitive

The primitive parameter is as follows:

MLME-DEAUTHENTICATE.confirm(
PeerSTAAddress
)

| Name | Type | Valid range | Description |
|---|---|---|---|
| PeerSTAAddress | MAC address | (#1653)Any valid individual address, or (#4223)the broadcast address(#3315) | Specifies the address of the peer MAC entity (#4223)or entities with which the deauthentication process was attempted. |

#### 6.5.6.3.3 When generated

This primitive is generated by the MLME as a result of an MLME-DEAUTHENTICATE.request primitive to invalidate the authentication relationship with a specified peer MAC entity.

#### 6.5.6.3.4 Effect of receipt

The SME is notified of the results of the deauthentication procedure.

### 6.5.6.4 MLME-DEAUTHENTICATE.indication

#### 6.5.6.4.1 Function

This primitive reports the invalidation of an authentication relationship with a specific peer MAC entity.

#### 6.5.6.4.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-DEAUTHENTICATE.indication(
PeerSTAAddress,
ReasonCode,
VendorSpecificInfo

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)

| Name | Type | Valid range | Description |
|---|---|---|---|
| PeerSTAAddress | MAC address | (#1653)Any valid individual address(#4223)(#3315) | Specifies the address of the peer MAC entity with which the authentication relationship was invalidated. |
| ReasonCode | Reason Code field | As defined in 9.4.1.7 (Reason Code field) | Specifies the reason the deauthentication procedure was initiated. |
| VendorSpecificInfo | A set of elements | As defined in 9.4.2.24 (Vendor Specific element) | Zero or more elements. |

#### 6.5.6.4.3 When generated

This primitive is generated by the MLME as a result of the invalidation of an authentication relationship with a specific peer MAC entity.

#### 6.5.6.4.4 Effect of receipt

The SME is notified of the invalidation of the specific authentication relationship.

### 6.5.7 Associate

#### 6.5.7.1 Introduction

The following primitives describe how a STA becomes associated with an AP.

#### 6.5.7.2 MLME-ASSOCIATE.request

#### 6.5.7.2.1 Function

This primitive requests association with a specified peer MAC entity that is within an AP.

#### 6.5.7.2.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-ASSOCIATE.request(
PeerSTAAddress(#1364),
ListenInterval,
Supported Channels,
RSN,
QoSCapability,
Content of FT Authentication elements,
SupportedOperatingClasses,
SM Power Save,
QoSTrafficCapability,
TIMBroadcastRequest,
EmergencyServices,
Multi-band local,
Multi-band peer,
MMS,
FILSHLPContainer,
FILSIPAddressAssignment,


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AID Request,
TWT,
MaxAwayDuration,
S1GRelayActivation,
ReachableAddress,
CDMG Capabilities,
CMMG Capabilities,
GLK-GCR Parameter Set,
MSCS Descriptor,
HE Capabilities,(11ax)
HE 6 GHz Band Capabilities,(11ax)
Channel Switch Timing,(11ax)
UL MU Power Capabilities,(11ax)
EDMG Capabilities,(11ay)
QoS Triggered Unscheduled,(11ay)
Unsolicited Block Ack Extension,(11ay)
TDD Slot Schedule,(11ay)
WUR Mode,(11ba)
Diffie-Hellman Parameter,(#1084)
VendorSpecificInfo
)

| Name | Type | Valid range | Description |
|---|---|---|---|
| PeerSTAAddress | MAC address | (#1653)Any valid individual address | Specifies the address of the peer MAC entity with which to perform the association process. |
| (#1364)ListenInterval | Integer | ≥ 0 | (#7058)Specifies how often the STA transitions to the awake state to listen for the next Beacon frame, if it enters power save mode. |
| Supported Channels | As defined in the Supported Channels element | As defined in the Supported Channels element | The list of channels in which the STA is capable of operating.<br>Present if DFS functionality is required, as specified in 11.8 (DFS procedures); otherwise (#3510)optionally present. |
| RSN | RSNE | As defined in 9.4.2.23 (RSNE) | A description of the cipher suites and AKM suites selected by the STA. |
| QoSCapability | QoS Capability element | As defined in 9.4.2.33 (QoS Capability element) | Specifies the parameters within the QoS Capability element that are supported by the MAC entity. The parameter is present if dot11QosOptionImplemented is true; otherwise not present. |
| Content of FT Authentication elements | Sequence of elements | As defined in 13.4 (FT initial mobility domain association) | The set of elements to be included in the initial mobility domain association request, as described in 13.4 (FT initial mobility domain association). Present if dot11FastBSSTransitionActivated is true; otherwise not present. |
| SupportedOperating Classes | As defined in the Supported Operating Classes element | As defined in 9.4.2.52 (Supported Operating Classes element) | Specifies the supported operating classes of the STA. This parameter is present if dot11ExtendedChannelSwitchActivated or dot11OperatingClassesRequired is true; otherwise not present. |

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| Name | Type | Valid range | Description |
|---|---|---|---|
| SM Power Save | Integer | As defined in Table 9-224 (Subfields of the HT Capability Information field) | Indicates the spatial multiplexing power save mode that is in operation immediately after association. |
| QoS Traffic Capability | As defined in the QoS Traffic Capability element | As defined in 9.4.2.76 (QoS Traffic Capability element) | Specifies the (#403)QoS traffic capability flags of the non-AP STA. This parameter is optionally present if dot11ACStationCountActivated is true and is not present otherwise. |
| TIMBroadcastRequest | As defined in the TIM Broadcast Request element | As defined in 9.4.2.81 (TIM Broadcast Request element) | Specifies the proposed service parameters for TIM Broadcast. This parameter is optionally present if dot11TIMBroadcastActivated is true and is not present otherwise. |
| EmergencyServices | Boolean | true, false | Specifies that the non-AP STA intends to associate for the purpose of unauthenticated access to emergency services. The parameter is optionally present if dot11InterworkingServiceActivated is true and is not present otherwise. |
| Multi-band local | Multi-band element | As defined in 9.4.2.137 (Multi-band element) | Specifies the parameters within the Multi-band element that are supported by the local MAC entity. The parameter is present if dot11MultibandImplemented is true and is absent otherwise. |
| Multi-band peer | Multi-band element | As defined in 9.4.2.137 (Multi-band element) | Specifies the parameters within the Multi-band element that are used to deliver messages to the peer MAC entity. The parameter is present if OCT is being used and is absent otherwise. |
| MMS | Multiple MAC Sublayers element | As defined in 9.4.2.151 (MMS element(#1776)) | Specifies the parameters within the Multiple MAC Sublayers element that are supported by the MAC entity. The parameter is present if dot11MultipleMACActivated is true and is absent otherwise. |
| FILSHLPContainer | As defined in 9.4.2.182 (FILS HLP Container element) | As defined in 9.4.2.182 (FILS HLP Container element) | A set of elements containing encapsulated data of higher layer protocol frames (e.g., DHCP message) that is transported in FILS association. The parameter is optionally present if dot11FILSActivated is true; otherwise not present. |
| FILSIPAddressAssignment | As defined in 9.4.2.183 (FILS IP Address Assignment element) | As defined in 9.4.2.183 (FILS IP Address Assignment element) | An explicit request for an IP address. The request is either for a new IP address or for a specified IP address. The parameter is optionally present if dot11FILSActivated is true; otherwise not present. |
| AID Request | AID Request element | As defined in 9.4.2.192 (AID Request element) | Indicates the device characteristic of the non-AP STA requesting AID assignment. This parameter is optionally present if dot11S1GOptionImplemented is true; otherwise not present. |


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| Name | Type | Valid range | Description |
|---|---|---|---|
| TWT | TWT element | As defined in 9.4.2.198 (TWT element) | Specifies the parameters in the TWT element.<br>This parameter is optionally present if dot11TWTOptionActivated is true; otherwise not present. |
| MaxAwayDuration | Integer | 0–65 535 | Indicates the maximum duration, in TUs, that the AP is unavailable for communications with the STA.<br>The parameter is optionally present if dot11MaxAwayDuration is nonzero; otherwise not present. |
| S1GRelayActivation | S1G Relay Activation element | As defined in 9.4.2.205 (S1G Relay Activation element) | (#221)Indicates if a STA with dot11RelaySTAImplemented equal to true requests to operate as a relay (in a request) and an AP with dot11RelayAPImplemented equal to true requests/confirms operation as a relay.<br>The parameter is optionally present if dot11RelaySTAImplemented is true; otherwise not present. |
| ReachableAddress | Reachable Address element | As defined in 9.4.2.204 (Reachable Address element) | The Reachable Address element is optionally present if dot11RelaySTAImplemented is true; otherwise not present. |
| CDMG Capabilities | CDMG Capabilities element | As defined in 9.4.2.218 (CDMG Capabilities element) | Specifies the parameters within the CDMG Capabilities element that are supported by the MAC entity.<br>The parameter is present if dot11CDMGOptionImplemented is true; otherwise not present. |
| CMMG Capabilities | CMMG Capabilities element | As defined in 9.4.2.228 (CMMG Capabilities element) | Specifies the parameters within the CMMG Capabilities element that are supported by the MAC entity. The parameter is present if dot11CMMGOptionImplemented is true; otherwise not present. |
| GLK-GCR Parameter Set | GLK-GCR Parameter Set element | As defined in 9.4.2.233 (GLK-GCR Parameter Set element) | This parameter is present if dot11GLKGCRImplemented is true and not present otherwise. Specifies the GLK-GCR capabilities supported by the STA. |
| MSCS Descriptor | As defined in the MSCS Descriptor element | As defined in 9.4.2.242 (MSCS Descriptor element) | The parameters used to classify streams using the procedures defined in 11.25.3 (MSCS procedures). Optionally present if dot11MSCSActivated is true; otherwise not present. |
| HE Capabilities(11ax) | As defined in HE Capabilities element | As defined in 9.4.2.247 (HE Capabilities element(11ax)) | Specifies the parameters in the HE Capabilities element that are supported by the STA. The parameter is present if dot11HEOptionImplemented is true; otherwise, it is not present. |
| HE 6 GHz Band Capabilities(11ax) | As defined in HE 6 GHz Band Capabilities element | As defined in 9.4.2.262 (HE 6 GHz Band Capabilities element(11ax)) | Specifies the parameters in the HE 6 GHz Band Capabilities element that are supported by the STA. The parameter is present if dot11HE6GOptionImplemented is true; otherwise, it is not present. |

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| Name | Type | Valid range | Description |
|---|---|---|---|
| Channel Switch Timing(11ax) | As defined in the Channel Switch Timing element | As defined in 9.4.2.62 (Channel Switch Timing element) | Provides information regarding the channel switch timing. The parameter is optionally present if dot11HESubchannelSelectiveTransmissionImplemented is true; otherwise, it is not present. |
| UL MU Power Capabilities(11ax) | As defined in UL MU Power Capabilities element | As defined in 9.4.2.263 (UL MU Power Capabilities element(11ax)) | Provides information regarding the UL MU power capabilities for the non-AP STA. The UL MU Power Capabilities element is optionally present if dot11HEOptionImplemented is true; otherwise, it is not present. |
| EDMG Capabilities(11ay) | EDMG Capabilities element | As defined in 9.4.2.264 (EDMG Capabilities element(11ay)) | Specifies the parameters within the EDMG Capabilities element that are supported by the MAC entity. The parameter is present if dot11EDMGOptionImplemented is true and is absent otherwise. |
| QoS Triggered Unscheduled(11ay) | QoS Triggered Unscheduled element | As defined in 9.4.2.277 (QoS-TU element(#1776)(11ay)) | Specifies the parameters within the QoS Triggered Unscheduled element that are supported by the MAC entity. The parameter is present if dot11EDMGOptionImplemented is true and is absent otherwise. |
| Unsolicited Block Ack Extension(11ay) | Unsolicited Block Ack Extension element | As defined in 9.4.2.278 (Unsolicited Block Ack Extension element(11ay)) | Specifies the parameters within the Unsolicited Block Ack Extension element that are supported by the MAC entity. Optionally present if dot11UnsolicitedBAActivated is true and is absent otherwise. |
| TDD Slot Schedule(11ay) | TDD Slot Schedule element | As defined in 9.4.2.281 (TDD Slot Schedule element(11ay)) | Present if dot11TDDOptionImplemented is true and absent otherwise. Specifies the TDD slot availability of the STA. |
| WUR Mode(11ba) | WUR Mode element | As defined in 9.4.2.292 (WUR Mode element(11ba)) | Specifies the proposed service parameters for the WUR Mode Setup request. The parameter is optionally present if dot11WUROptionImplemented is true; otherwise, this parameter is not present. |
| Diffie-Hellman Parameter(#1084) | Diffie-Hellman Parameter element | (#6088)As defined in 9.4.2.312 (Diffie-Hellman Parameter element(#6088)) | Provides a public key for use in the OWE exchange. Present if OWE is being performed; otherwise it is not present. |
| VendorSpecificInfo | A set of elements | As defined in 9.4.2.24 (Vendor Specific element) | Zero or more elements. |

Additional parameters needed to perform the association procedure are not included in the primitive parameter list since the MLME already has that data (maintained as internal state).

#### 6.5.7.2.3 When generated

This primitive is generated by the SME when a STA wishes to establish association with an AP or PCP.


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#### 6.5.7.2.4 Effect of receipt

This primitive initiates an association procedure. In the case that a response is received from the responder STA, the MLME subsequently issues an MLME-ASSOCIATE.confirm primitive that reflects the results.

### 6.5.7.3 MLME-ASSOCIATE.confirm

#### 6.5.7.3.1 Function

This primitive reports the results of an association attempt with a specified peer MAC entity that is in an AP or PCP.

#### 6.5.7.3.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-ASSOCIATE.confirm(
PeerSTAAddress(#4223)
ResultCode,
CapabilityInformation,
AssociationID,
EDCAParameterSet,
RCPI of Request,
RSNI of Request,
RCPI of Response,
RSNI of Response,
RMEnabledCapabilities,
Content of FT Authentication elements,
SupportedOperatingClasses,
Extended Capabilities,
20/40 BSS Coexistence,
TimeoutInterval,
BSSMaxIdlePeriod,
TIMBroadcastResponse,
QosMapSet,
QMFPolicy,
DMG Capabilities,
Multi-band local,
Multi-band peer,
MMS,
FILSHLPContainer,
FILSIPAddressAssignment,
KeyDelivery,
S1G Sector Operation,
S1G Capabilities,
AID Response,
TSF Timer Accuracy,
TWT,
Sectorized Group ID List,
MaxAwayDuration,
S1GRelayActivation,
S1GOperation,
SSTOperation,
S1GRelay,
HeaderCompression,

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CDMG Capabilities,
CMMG Capabilities,
GLK-GCR Parameter Set,
MSCS Descriptor,
HE Capabilities,(11ax)
HE 6 GHz Band Capabilities,(11ax)
HE Operation,(11ax)
UORA Parameter Set,(11ax)
MU EDCA Parameter Set,(11ax)
Spatial Reuse Parameter Set,(11ax)
NDP Feedback Report Parameter Set,(11ax)
BSS Color Change Announcement,(11ax)
ESS Report,(11ax)
EDMG Capabilities,(11ay)
EDMG Operation,(11ay)
QoS Triggered Unscheduled,(11ay)
Unsolicited Block Ack Extension,(11ay)
TDD Slot Structure,(11ay)
TDD Slot Schedule,(11ay)
WUR Capabilities,(11ba)
WUR Operation,(11ba)
WUR Mode,(11ba)
Diffie-Hellman Parameter,(#1084)
VendorSpecificInfo
)

| Name | Type | Valid range | Description |
|---|---|---|---|
| PeerSTAAddress (#4223) | MAC address | Any valid individual address | Specifies the address of the peer MAC entity to which the association request was sent. |
| ResultCode | Enumeration | SUCCESS, REFUSED_REASON_UNSPECIFIED, REFUSED_NOT_AUTHENTICATED, REFUSED_CAPABILITIES_MISMATCH, REFUSED_EXTERNAL_REASON, REFUSED_AP_OUT_OF_MEMORY, REFUSED_BASIC_RATES_MISMATCH, REJECTED_EMERGENCY_SERVICES_NOT_SUPPORTED, REFUSED_TEMPORARILY | Indicates the result of the MLME-ASSOCIATE.request primitive. |
| Capability-Information | Capability Information field | As defined in 9.4.1.4 (Capability Information field) | Specifies the operational capabilities advertised by the AP or PCP. |
| AssociationID | Integer | Non-DMG: 1–2007<br>DMG: 1–254 | If the association request result was SUCCESS, then AssociationID specifies the association ID value assigned by the AP or PCP. This parameter is not present if dot11S1GOptionImplemented is true. |


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| Name | Type | Valid range | Description |
|---|---|---|---|
| EDCAParameter Set | EDCA Parameter Set element | As defined in 9.4.2.27 (EDCA Parameter Set element) | Specifies the EDCA parameter set that the STA should use. The parameter is present if dot11QosOptionImplemented is true; otherwise not present. |
| RCPI of Request | Integer | As defined in 9.4.2.36 (RCPI element) | Indicates the RCPI value contained in the received Association Response frame. This value represents the RCPI that the AP or PCP measured (#14)of the receiving PPDU containing the corresponding Association Request frame. The element is optionally present if dot11RMRCPIMeasurementActivated is true; otherwise not present. |
| RSNI of Request | Integer | As defined in 9.4.2.39 (RSNI element) | Indicates the RSNI value contained in the received Association Response frame. This value represents the RSNI that the AP or PCP measured (#14)of the received PPDU containing the corresponding Association Request frame. The element is optionally present if dot11RMRSNIMeasurementActivated is true; otherwise not present. |
| RCPI of Response | Integer | As defined in 9.4.2.36 (RCPI element) | The RCPI value represents the measured RCPI (#14)of the received PPDU containing the corresponding Association Response frame. The element is optionally present if dot11RMRCPIMeasurementActivated is true; otherwise not present. |
| RSNI of Response | Integer | As defined in 9.4.2.39 (RSNI element) | RSNI at the time the corresponding Association Response frame was receive. The element is optionally present if dot11RMRSNIMeasurementActivated is true; otherwise not present. |
| RMEnabledCapabilities | RM Enabled Capabilities element | As defined in 9.4.2.43 (RM Enabled Capabilities element) | Specifies the RM enabled capabilities advertised by the AP or PCP. The element is present if dot11RadioMeasurementActivated is true; otherwise not present. |
| Content of FT Authentication elements | Sequence of elements | As defined in 13.4 (FT initial mobility domain association) | The set of elements included in the initial mobility domain association response, as described in 13.4 (FT initial mobility domain association). Present if dot11FastBSSTransitionActivated is true; otherwise not present. |

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| Name | Type | Valid range | Description |
|---|---|---|---|
| SupportedOperatingClasses | As defined in the Supported Operating Classes element | As defined in 9.4.2.52 (Supported Operating Classes element) | Indicates the supported operating classes of the AP or PCP. This parameter is optionally present if dot11ExtendedChannelSwitchActivated or dot11OperatingClassesRequired is true; otherwise not present. |
| Extended Capabilities | As defined in frame format | As defined in 9.4.2.25 (Extended Capabilities element) | Specifies the parameters within the Extended Capabilities element that are supported by the MAC entity. |
| 20/40 BSS Coexistence | As defined in frame format | As defined in 9.4.2.58 (20/40 BSS Coexistence element) | Specifies the parameters within the 20/40 BSS Coexistence element that are indicated by the MAC entity.<br>The parameter is present if dot112040BSSCoexistence-ManagementSupport is true. |
| TimeoutInterval | (#1776)TIE, as defined in frame format | As defined in 9.4.2.47 (TIE(#1776)) | This parameter is present when ResultCode is REFUSED_TEMPORARILY. |
| BSSMaxIdlePeriod | As defined in BSS Max Idle Period element | As defined in 9.4.2.77 (BSS Max Idle Period element) | Indicates the BSS max idle period parameters of the AP or PCP. This parameter is present if dot11WirelessManagementImplemented (#142)(#1428) and dot11BSSMaxIdlePeriodIndicationByNonAPSTA are true, or dot11S1GOptionImplemented (#139)is true and the BSS Max Idle Period element was present in the Association Response frame; is not present otherwise. |
| TIMBroadcastResponse | As defined in TIM Broadcast Response element | As defined in 9.4.2.82 (TIM Broadcast Response element) | Specifies the service parameters for TIM Broadcast. This parameter is optionally present if dot11TIMBroadcastActivated is true and the TIM Broadcast Request element is present in the corresponding Association Request frame; this parameter is not present otherwise. |
| QoSMapSet | As defined in frame format | As defined in 9.4.2.93 (QoS Map element) | Specifies the QoS Map the non-AP and non-PCP STA should use. |
| QMFPolicy | QMF Policy element | As defined in 9.4.2.118 (Quality-of-Service Management Frame Policy element) | The values from the QMF Policy element if such an element was present in the Association Response frame; otherwise, null. |
| DMG Capabilities | DMG Capabilities element | As defined in 9.4.2.126 (DMG Capabilities element) | Specifies the parameters within the DMG Capabilities element that are supported by the MAC entity. The parameter is present if dot11DMGOptionImplemented is true and is absent otherwise. |
| Multi-band local | Multi-band element | As defined in 9.4.2.137 (Multi-band element) | Specifies the parameters within the Multi-band element that identify and are supported by the local MAC entity. The parameter is present if OCT is being used and is absent otherwise. |


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| Name | Type | Valid range | Description |
|---|---|---|---|
| Multi-band peer | Multi-band element | As defined in 9.4.2.137 (Multi-band element) | Specifies the parameters within the Multi-band element that identify and are supported by the peer MAC entity. This parameter is present if OCT is being used and is absent otherwise. |
| MMS | Multiple MAC Sublayers element | As defined in 9.4.2.151 (MMS element(#1776)) | Specifies the parameters within the Multiple MAC Sublayers element that are supported by the MAC entity. The parameter is present if dot11MultipleMACActivated is true and is absent otherwise. |
| FILSHLPContainer | As defined in 9.4.2.182 (FILS HLP Container element) | As defined in 9.4.2.182 (FILS HLP Container element) | A set of elements containing encapsulated data of higher layer protocol (HLP) frames (e.g., DHCP message) that is transported in FILS association. The parameter is optionally present if dot11FILSActivated is true; otherwise not present. |
| FILSIPAddressAssignment | As defined in 9.4.2.183 (FILS IP Address Assignment element) | As defined in 9.4.2.183 (FILS IP Address Assignment element) | The IP address of a network layer entity associated with the STA. The parameter is optionally present if dot11FILSActivated is true; otherwise not present. |
| KeyDelivery | As defined in 9.4.2.184 (Key Delivery element) | As defined in 9.4.2.184 (Key Delivery element) | (#1406)KDE(s) and the current GTK RSC. The parameter is present if dot11FILSActivated is true; otherwise not present. |
| S1G Sector Operation | S1G Sector Operation element | As defined in 9.4.2.194 (S1G Sector Operation element) | Specifies the sectorization scheme, period, subperiod sector intervals, and sector training. |
| S1G Capabilities | As defined in frame format | As defined in 9.4.2.199 (S1G Capabilities element) | Specifies the parameters in the S1G Capabilities element that are supported by the AP. The parameter is present if dot11S1GOptionImplemented is true and the S1G Capabilities element is present in the Association Response frame received from the AP; otherwise not present. |
| AID Response | AID Response element | As defined in 9.4.2.193 (AID Response element) | Parameters describing an AID assignment.<br>This parameter is present if dot11S1GOptionImplemented is true; otherwise not present. |
| TSF Timer Accuracy | TSF Timer Accuracy element | As defined in 9.4.2.202 (TSF Timer Accuracy element) | Indicates the information about the TSF timer accuracy. The parameter is optionally present if dot11TSFTimerAccuracyImplemented is true; otherwise not present. |

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| Name | Type | Valid range | Description |
|---|---|---|---|
| TWT | TWT element | As defined in 9.4.2.198 (TWT element) | Specifies the parameters in the TWT element.<br>This parameter is optionally present if dot11TWTOptionActivated is true (11ax)and the TWT element is present in the Association Request frame that elicited the Association Response frame or the TWT Requester Support field in the HE Capabilities element in the Association Request frame that elicited the Association Response frame is 1; otherwise not present. |
| SectorizedGroup ID List | Sectorized Group ID List element | As defined in 9.4.2.210 (Sectorized Group ID List element) | Specifies the parameters in the Sectorized Group ID List element.<br>This parameter is optionally present if dot11S1GSectorizationActivated is true; otherwise not present. |
| MaxAwayDuration | Integer | 0–65 535 | Indicates the maximum duration, in TUs, that the AP is unavailable for communications with the STA.<br>The parameter is optionally present if dot11MaxAwayDuration is nonzero; otherwise not present. |
| S1GRelayActivation | S1G Relay Activation element | As defined in 9.4.2.205 (S1G Relay Activation element) | (#221)Indicates if a STA with dot11RelaySTAImplemented equal to true requests to operate as a relay (in a request) and an AP with dot11RelayAPImplemented equal to true requests/confirms operation as a relay.<br>The parameter is optionally present if dot11RelaySTAImplemented is true; otherwise not present. |
| S1GOperation | S1G Operation element | As defined in 9.4.2.211 (S1G Operation element) | The S1G Operation element is present if dot11S1GOptionImplemented is true; otherwise not present. |
| SSTOperation | SST Operation element | As defined in 9.4.2.213 (SST Operation element) | The SST Operation element is optionally present if dot11SelectiveSubchannelTransmissionPermitted is true; otherwise not present. |
| S1GRelay | S1G Relay element | As defined in 9.4.2.203 (S1G Relay element) | Indicates the support of the relay operation by the STA transmitting the element. |
| HeaderCompression | Header Compression element | As defined in 9.4.2.212 (Header Compression element) | The Header Compression element is present if dot11PV1MACHeaderOptionImplemented is true; otherwise not present. |


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| Name | Type | Valid range | Description |
|---|---|---|---|
| CDMG Capabilities | CDMG Capabilities element | As defined in 9.4.2.218 (CDMG Capabilities element) | Specifies the parameters within the CDMG Capabilities element that are supported by the MAC entity.<br>The parameter is present if dot11CDMGOptionImplemented is true; otherwise not present. |
| CMMG Capabilities | CMMG Capabilities element | As defined in 9.4.2.228 (CMMG Capabilities element) | Specifies the parameters within the CMMG Capabilities element that are supported by the MAC entity. The parameter is present if dot11CMMGOptionImplemented is true; otherwise not present. |
| GLK-GCR Parameter Set | GLK-GCR Parameter Set element | As defined in 9.4.2.233 (GLK-GCR Parameter Set element) | Specifies the values from the GLK-GCR Parameter Set element if such an element was present in the Association Response frame, otherwise null. |
| MSCS Descriptor | As defined in the MSCS Descriptor element | As defined in 9.4.2.242 (MSCS Descriptor element) | The parameters used to classify streams using the procedures defined in 11.25.3 (MSCS procedures). Optionally present if dot11MSCSActivated is true; otherwise not present. |
| HE Capabilities(11ax) | As defined in HE Capabilities element | As defined in 9.4.2.247 (HE Capabilities element(11ax)) | Specifies the parameters within the HE Capabilities element that are supported by the STA. The parameter is present if dot11HEOptionImplemented is true; otherwise, this parameter is not present. |
| HE 6 GHz Band Capabilities(11ax) | As defined in HE 6 GHz Band Capabilities element | As defined in 9.4.2.262 (HE 6 GHz Band Capabilities element(11ax)) | Specifies the parameters within the HE 6 GHz Band Capabilities element that are supported by the STA. The parameter is present if dot11HE6GOptionImplemented is true; otherwise, this parameter is not present. |
| HE Operation(11ax) | As defined in HE Operation element | As defined in 9.4.2.248 (HE Operation element(11ax)) | Provides additional information for operating the HE BSS. The parameter is present if dot11HEOptionImplemented is true; otherwise, it is not present. |
| UORA Parameter Set(11ax) | As defined in UORA Parameter Set element | As defined in 9.4.2.249 (UORA Parameter Set element(11ax)) | Indicates the metrics of the OFDMA-based random access mechanism. The parameter is optionally present if dot11OFDMARandomAccessOptionImlemented is true; otherwise, it is not present. |
| MU EDCA Parameter Set(11ax) | As defined in MU EDCA Parameter Set element | As defined in 9.4.2.250 (MU EDCA Parameter Set element(11ax)) | Indicates MU EDCA parameters. The parameter is optionally present if dot11HEOptionImplemented is true; otherwise, it is not present. |

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| Name | Type | Valid range | Description |
|---|---|---|---|
| Spatial Reuse Parameter Set(11ax) | As defined in Spatial Reuse Parameter Set element | As defined in 9.4.2.251 (Spatial Reuse Parameter Set element(11ax)) | Indicates parameters needed by STAs when performing OBSS PD-based spatial reuse. The parameter is optionally present if dot11HEOptionImplemented is true; otherwise, it is not present. |
| NDP Feedback Report Parameter Set(11ax) | As defined in NDP Feedback Report Parameter Set element | As defined in 9.4.2.252 (NDP Feedback Report Parameter Set element(11ax)) | Indicates NDP Feedback Report parameter values. The parameter is optionally present if dot11HEOptionImplemented is true; otherwise, it is not present. |
| BSS Color Change Announcement(11ax) | As defined in BSS Color Change Announcement element | As defined in 9.4.2.253 (BSS Color Change Announcement element(11ax)) | Indicates information on BSS Color Change. The parameter is optionally present if dot11HEOptionImplemented is true; otherwise, it is not present. |
| ESS Report(11ax) | As defined in ESS Report element | As defined in 9.4.2.255 (ESS Report element(11ax)) | Provides information on ESS to assist BSS transition. The parameter is optionally present. |
| EDMG Capabilities(11ay) | EDMG Capabilities element | As defined in 9.4.2.264 (EDMG Capabilities element(11ay)) | Specifies the parameters within the EDMG Capabilities element that are supported by the MAC entity. The parameter is present if dot11EDMGOptionImplemented is true and is absent otherwise. |
| EDMG Operation(11ay) | EDMG Operation element | As defined in 9.4.2.265 (EDMG Operation element(11ay)) | Specifies the parameters within the EDMG Operation element that are used in the BSS. The parameter is present if dot11EDMGOptionImplemented is true and is absent otherwise. |
| QoS Triggered Unscheduled(11ay) | QoS Triggered Unscheduled element | As defined in 9.4.2.277 (QoS-TU element(#1776)(11ay)) | Specifies the parameters within the QoS Triggered Unscheduled element that are supported by the MAC entity. The parameter is present if dot11EDMGOptionImplemented is true and is absent otherwise. |
| Unsolicited Block Ack Extension(11ay) | Unsolicited Block Ack Extension element | As defined in 9.4.2.278 (Unsolicited Block Ack Extension element(11ay)) | Specifies the parameters within the Unsolicited Block Ack Extension element that are supported by the MAC entity. Optionally present if dot11UnsolicitedBAActivated is true and is absent otherwise. |
| TDD Slot Structure(11ay) | TDD Slot Structure element | As defined in 9.4.2.280 (TDD Slot Structure element(11ay)) | Present if dot11TDDOptionImplemented is true and absent otherwise. Specifies the parameters within the TDD Slot Structure element corresponding to a target STA. |
| TDD Slot Schedule(11ay) | TDD Slot Schedule element | As defined in 9.4.2.281 (TDD Slot Schedule element(11ay)) | Present if dot11TDDOptionImplemented is true and absent otherwise. Specifies the TDD slot schedule of the STA. |


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| Name | Type | Valid range | Description |
|---|---|---|---|
| WUR Capabilities(11ba) | As defined in WUR Capabilities element | As defined in 9.4.2.290 (WUR Capabilities element(11ba)) | Specifies the parameters within the WUR Capabilities element that are supported by the WUR AP. The parameter is present if dot11WUROptionImplemented is true; otherwise, this parameter is not present. |
| WUR Operation(11ba) | As defined in WUR Operation element | As defined in 9.4.2.291 (WUR Operation element(11ba)) | Provides additional information for WUR operation. The parameter is present if dot11WUROptionImplemented is true; otherwise, this parameter is not present. |
| WUR Mode(11ba) | As defined in WUR Mode element | As defined in 9.4.2.292 (WUR Mode element(11ba)) | Specifies the proposed service parameters for the WUR Mode Setup request. The parameter is present if dot11WUROptionImplemented is true and the WUR Mode element is present in the Association Response frame received from the AP; otherwise, this parameter is not present. |
| Diffie-Hellman Parameter(#1084) | Diffie-Hellman Parameter element | (#6088)As defined in 9.4.2.312 (Diffie-Hellman Parameter element(#6088)) | Provides a public key for the AP from the Association Response frame that is used in the OWE exchange. Present if OWE is being performed; otherwise it is not present. |
| VendorSpecificInfo | A set of elements | As defined in 9.4.2.24 (Vendor Specific element) | Zero or more elements. |

#### 6.5.7.3.3 When generated

This primitive is generated by the MLME as a result of an MLME-ASSOCIATE.request primitive or receipt of an Association Response frame from the peer MAC entity to associate with a specified peer MAC entity that is in an AP or PCP.

#### 6.5.7.3.4 Effect of receipt

The SME is notified of the results of the association procedure.

### 6.5.7.4 MLME-ASSOCIATE.indication

#### 6.5.7.4.1 Function

This primitive indicates that a specific peer MAC entity is requesting association with the local MAC entity, which is in an AP or PCP.

#### 6.5.7.4.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-ASSOCIATE.indication(
PeerSTAAddress,
CapabilityInformation,

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BSSMaxIdlePeriod,
ListenInterval,
SSID,
OperationalRateSet,
BSSMembershipSelectorSet,
RSN,
QoSCapability,
RCPI,
RSNI,
RMEnabledCapabilities,
Content of FT Authentication elements,
SupportedOperatingClasses,
DSERegisteredLocation,
HT Capabilities,
Extended Capabilities,
20/40 BSS Coexistence,
QoSTrafficCapability,
TIMBroadcastRequest,
EmergencyServices,
DMG Capabilities,
Multi-band local,
Multi-band peer,
MMS,
VHT Capabilities,
FILSHLPContainer,
FILSIPAddressAssignment,
AID Request,
S1G Capabilities,
TWT,
MaxAwayDuration,
S1GRelayActivation,
ReachableAddress,
CDMG Capabilities,
CMMG Capabilities,
GLK-GCR Parameter Set,
MSCS Descriptor,
HE Capabilities,(11ax)
HE 6 GHz Band Capabilities,(11ax)
Channel Switch Timing,(11ax)
UL MU Power Capabilities,(11ax)
EDMG Capabilities,(11ay)
QoS Triggered Unscheduled,(11ay)
Unsolicited Block Ack Extension,(11ay)
TDD Slot Schedule,(11ay)
WUR Capabilities,(11ba)
WUR Mode,(11ba)
Diffie-Hellman Parameter,(#1084)
VendorSpecificInfo
)

#### 6.5.7.4.3 When generated

This primitive is generated by the MLME as a result of the receipt of an association request from a specific peer MAC entity.


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| Name | Type | Valid range | Description |
|---|---|---|---|
| PeerSTAAddress | MAC address | (#1653)Any valid individual address | Specifies the address of the peer MAC entity from which the association (#4223)request was received. |
| Capability-Information | Capability Information field | As defined in 9.4.1.4 (Capability Information field) | Specifies the operational capability definitions provided by the peer MAC entity as part of the association request. |
| BSSMaxIdlePeriod | BSS Max Idle Period element | As defined in 9.4.2.77 (BSS Max Idle Period element) | (#1365)Indicates the preferred BSS max idle period parameters. This parameter is present if the BSS Max Idle Period element was present in the Association Request frame and if dot11WirelessManagementImplemented and dot11BSSMaxIdlePeriodIndicationByNonAP STA are true, or dot11S1GOptionImplemented is true; is not present otherwise. |
| ListenInterval | Integer | ≥ 0 | Specifies the listen interval provided by the peer MAC entity as part of the association request. |
| SSID | Octet string | 0–32 octets | Specifies the SSID provided by the peer MAC entity as part of the association request. |
| OperationalRateSet | Non-DMG BSS: Set of integers<br><br>DMG BSS: Set of numbers | Non-DMG BSS: 1-127 excluding values from Table 9-131 (BSS membership selector value encoding) for each member of the set<br><br>DMG BSS: 0-12, 9.1, 12.1-12.6, or 25-31, for each member of the set | The set of data rates (in units of 500 kb/s) that the STA that is requesting association is able to use for communication within the BSS. The STA is able to receive at each of the data rates listed in the set. This set is a superset of the rates contained in the BSSBasicRateSet parameter.<br><br>DMG BSS: The set of MCS (#4136)indices that the AP or PCP uses for communication within the BSS. |
| BSSMembershipSelectorSet | Set of integers | A value from Table 9-131 (BSS membership selector value encoding), for each member of the set | The set of features that the STA that is requesting association is able to use for communication |
| RSN | RSNE | As defined in 9.4.2.23 (RSNE) | A description of the cipher suites and AKM suites selected by the STA. |
| QoSCapability | QoS Capability element | As defined in 9.4.2.33 (QoS Capability element) | Specifies the parameters within the QoSCapability that are supported by the peer MAC entity. The parameter is optionally present if dot11QosOptionImplemented is true; otherwise not present. |
| RCPI | Integer | As defined in 9.4.2.36 (RCPI element) | The RCPI value represents the measured RCPI (#14)of the received PPDU containing the corresponding Association Request frame. The element is optionally present if dot11RMRCPIMeasurementActivated is true; otherwise not present. |
| RSNI | Integer | As defined in 9.4.2.39 (RSNI element) | (#1236)The RSNI value represents the measured RSNI (#14)of the received PPDU containing the corresponding Association Request frame. The element is optionally present if dot11RMRSNIMeasurementActivated is true; otherwise not present. |

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| Name | Type | Valid range | Description |
|---|---|---|---|
| RMEnabledCapabilities | RM Enabled Capabilities element | As defined in 9.4.2.43 (RM Enabled Capabilities element) | Specifies the RM enabled capabilities advertised by the AP or PCP. The element is present if dot11RadioMeasurementActivated is true; otherwise not present. |
| Content of FT Authentication elements | Sequence of elements | As defined in 13.4 (FT initial mobility domain association) | The set of elements included in the initial mobility domain association, as described in 13.4 (FT initial mobility domain association). Present if dot11FastBSSTransitionActivated is true; otherwise not present. |
| SupportedOperatingClasses | As defined in the Supported Operating Classes element | As defined in 9.4.2.52 (Supported Operating Classes element) | Indicates the supported operating classes of the STA. This parameter is optionally present if dot11ExtendedChannelSwitchActivated or dot11OperatingClassesRequired is true; otherwise not present. |
| DSERegisteredLocation | As defined in the DSE Registered Location element | As defined in 9.4.2.50 (DSE Registered Location element) | Indicates the DSE registered location including the dependent enablement identifier assigned by the enabling STA. This parameter is optionally present if dot11LCIDSERequired is true; otherwise not present. |
| HT Capabilities | As defined in frame format | As defined in 9.4.2.54 (HT Capabilities element) | Specifies the parameters within the HT Capabilities element that are supported by the MAC entity.<br>The parameter is optionally present if dot11HighThroughputOptionImplemented is true; otherwise not present. |
| Extended Capabilities | As defined in frame format | As defined in 9.4.2.25 (Extended Capabilities element) | Specifies the parameters within the Extended Capabilities element that are supported by the MAC entity. |
| 20/40 BSS Coexistence | As defined in frame format | As defined in 9.4.2.58 (20/40 BSS Coexistence element) | Specifies the parameters within the 20/40 BSS Coexistence element that are indicated by the MAC entity.<br>The parameter is present if dot112040BSSCoexistenceManagementSupport is true. |
| QoS Traffic Capability | As defined in the QoS Traffic Capability element | As defined in 9.4.2.76 (QoS Traffic Capability element) | Specifies the (#403)QoS traffic capability flags of the non-AP and non-PCP STA. This parameter is optionally present if dot11ACStationCountActivated is true and is not present otherwise. |
| TIMBroadcastRequest | As defined in TIM Broadcast Request element | As defined in 9.4.2.81 (TIM Broadcast Request element) | Specifies the proposed service parameters for TIM Broadcast. This parameter is optionally present if dot11TIMBroadcastActivated is true and is not present otherwise. |
| EmergencyServices | Boolean | true, false | Specifies the setting of the UESA field received from the non-AP and non-PCP STA, if an Interworking element was present in the Association Request frame. The parameter is present if dot11InterworkingServiceActivated is true; otherwise not present. |
| DMG Capabilities | DMG Capabilities element | As defined in 9.4.2.126 (DMG Capabilities element) | Specifies the parameters within the DMG Capabilities element that are supported by the MAC entity. The parameter is present if dot11DMGOptionImplemented is true and is absent otherwise. |
| Multi-band local | Multi-band element | As defined in 9.4.2.137 (Multi-band element) | Specifies the parameters within the Multi-band element that identify and are supported by the local MAC entity. The parameter is present if OCT is being used and is absent otherwise. |


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| Name | Type | Valid range | Description |
|---|---|---|---|
| Multi-band peer | Multi-band element | As defined in 9.4.2.137 (Multi-band element) | Specifies the parameters within the Multi-band element that identify and are supported by the peer MAC entity. This parameter is present if OCT is being used and is absent otherwise. |
| MMS | Multiple MAC Sublayers element | As defined in 9.4.2.151 (MMS element(#1776)) | Specifies the parameters within the Multiple MAC Sublayers element that are supported by the MAC entity. The parameter is present if dot11MultipleMACActivated is true and is absent otherwise. |
| VHT Capabilities | As defined in VHT Capabilities element | As defined in 9.4.2.156 (VHT Capabilities element) | Specifies the parameters in the VHT Capabilities element that are supported by the STA. The parameter is present if dot11VHTOptionImplemented is true and the VHT Capabilities element is present in the Association Request frame received from the STA. The parameter is not present otherwise. |
| FILSHLPContainer | As defined in 9.4.2.182 (FILS HLP Container element) | As defined in 9.4.2.182 (FILS HLP Container element) | A set of elements containing encapsulated data of higher layer protocol frames (e.g., DHCP message) that is transported in FILS association. The parameter is optionally present if dot11FILSActivated is true; otherwise not present. |
| FILSIPAddressAssignment | As defined in 9.4.2.183 (FILS IP Address Assignment element) | As defined in 9.4.2.183 (FILS IP Address Assignment element) | An explicit request for an IP address. The request is for a new IP address or a specified IP address. The parameter is optionally present if dot11FILSActivated is true; otherwise not present. |
| AID Request | AID Request element | As defined in 9.4.2.192 (AID Request element) | Indicates the device characteristic of the non-AP STA requesting AID assignment. This parameter is optionally present if dot11S1GOptionImplemented is true; otherwise not present. |
| S1G Capabilities | As defined in frame format | As defined in 9.4.2.199 (S1G Capabilities element) | Specifies the parameters in the S1G Capabilities element that are supported by the STA. The parameter is present if dot11S1GOptionImplemented is true and the S1G Capabilities element is present in the Association Request frame received from the STA; otherwise not present. |
| TWT | TWT element | As defined in 9.4.2.198 (TWT element) | Specifies the parameters in the TWT element. This parameter is optionally present if dot11TWTOptionActivated is true; otherwise not present. |
| MaxAwayDuration | Integer | 0–65 535 | Indicates the maximum duration, in TUs, that the AP is unavailable for communications with the STA.<br>The parameter is optionally present if dot11MaxAwayDuration is nonzero; otherwise not present. |
| S1GRelayActivation | S1G Relay Activation element | As defined in 9.4.2.205 (S1G Relay Activation element) | (#221)Indicates if a STA with dot11RelaySTAImplemented equal to true requests to operate as a relay (in a request) and an AP with dot11RelayAPImplemented equal to true requests/confirms operation as a relay. The parameter is optionally present if dot11RelaySTAImplemented is true; otherwise not present. |

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| Name | Type | Valid range | Description |
|---|---|---|---|
| ReachableAddress | Reachable Address element | As defined in 9.4.2.204 (Reachable Address element) | The Reachable Address element is optionally present if dot11RelaySTAImplemented is true; otherwise not present. |
| CDMG Capabilities | CDMG Capabilities element | As defined in 9.4.2.218 (CDMG Capabilities element). | Specifies the parameters within the CDMG Capabilities element that are supported by the MAC entity.<br>The parameter is present if dot11CDMGOptionImplemented is true; otherwise not present. |
| CMMG Capabilities | CMMG Capabilities element | As defined in 9.4.2.228 (CMMG Capabilities element). | Specifies the parameters within the CMMG Capabilities element that are supported by the MAC entity. The parameter is present if dot11CMMGOptionImplemented is true; otherwise not present. |
| GLK-GCR Parameter Set | GLK-GCR Parameter Set element | As defined in 9.4.2.233 (GLK-GCR Parameter Set element) | Specifies the values from the GLK-GCR Parameter Set element if such an element was present in the Association Request frame, otherwise not present. |
| MSCS Descriptor | As defined in the MSCS Descriptor element | As defined in 9.4.2.242 (MSCS Descriptor element) | The parameters used to classify streams using the procedures defined in 11.25.3 (MSCS procedures). Optionally present if dot11MSCSActivated is true; otherwise not present. |
| HE Capabilities(11ax) | As defined in HE Capabilities element | As defined in 9.4.2.247 (HE Capabilities element(11ax)) | Specifies the parameters within the HE Capabilities element that are supported by the peer STA. The parameter is present if dot11HEOptionImplemented is true and the HE Capabilities element is present in the Association Request frame received from the STA; otherwise, this parameter is not present. |
| HE 6 GHz Band Capabilities(11ax) | As defined in HE 6 GHz Band Capabilities element | As defined in 9.4.2.262 (HE 6 GHz Band Capabilities element(11ax)) | Specifies the parameters within the HE 6 GHz Band Capabilities element that are supported by the peer STA. The parameter is present if dot11HE6GOptionImplemented is true and the HE 6 GHz Band Capabilities element is present in the Association Request frame received from the STA; otherwise, this parameter is not present. |
| Channel Switch Timing(11ax) | As defined in the Channel Switch Timing element | As defined in 9.4.2.62 (Channel Switch Timing element) | Provides information regarding the channel switch timing. The parameter is optionally present if dot11HESubchannelSelectiveTransmissionImplemented is true and the Channel Switch Timing element is present in the Association Request frame received from the STA; otherwise, it is not present. |
| UL MU Power Capabilities(11ax) | As defined in UL MU Power Capabilities element | As defined in 9.4.2.263 (UL MU Power Capabilities element(11ax)) | Provides information regarding the UL MU power capabilities for the non-AP STA. The UL MU Power Capabilities element is present if dot11HEOptionImplemented is true and the HE Capabilities element and UL MU Power Capabilities element is present in the Association Request frame received from the STA; otherwise, it is not present. |
| EDMG Capabilities(11ay) | EDMG Capabilities element | As defined in 9.4.2.264 (EDMG Capabilities element(11ay)) | Specifies the parameters within the EDMG Capabilities element that are supported by the MAC entity. The parameter is present if dot11EDMGOptionImplemented is true and is absent otherwise. |


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| Name | Type | Valid range | Description |
|---|---|---|---|
| QoS Triggered Unscheduled(11ay) | QoS Triggered Unscheduled element | As defined in 9.4.2.277 (QoS-TU element(#1776)(11ay)) | Specifies the parameters within the QoS Triggered Unscheduled element that are supported by the MAC entity. The parameter is present if dot11EDMGOptionImplemented is true and is absent otherwise. |
| Unsolicited Block Ack Extension(11ay) | Unsolicited Block Ack Extension element | As defined in 9.4.2.278 (Unsolicited Block Ack Extension element(11ay)) | Specifies the parameters within the Unsolicited Block Ack Extension element that are supported by the MAC entity. Optionally present if dot11UnsolicitedBAActivated is true and is absent otherwise. |
| TDD Slot Schedule(11ay) | TDD Slot Schedule element | As defined in 9.4.2.281 (TDD Slot Schedule element(11ay)) | Present if dot11TDDOptionImplemented is true and absent otherwise. Specifies the TDD slot schedule of the STA. |
| WUR Capabilities(11ba) | As defined in WUR Capabilities element | As defined in 9.4.2.290 (WUR Capabilities element(11ba)) | Specifies the parameters within the WUR Capabilities element that are supported by the peer STA. The parameter is present if it is present in the Association Request frame received from the STA; otherwise, this parameter is not present. |
| WUR Mode(11ba) | As defined in WUR Mode element | As defined in 9.4.2.292 (WUR Mode element(11ba)) | Specifies the proposed service parameters for the WUR Mode Setup request. The parameter is present if dot11WUROptionImplemented is true and the WUR Mode element is present in the Association Request frame received from the STA; otherwise, this parameter is not present. |
| Diffie-Hellman Parameter(#1084) | Diffie-Hellman Parameter element | (#6088)As defined in 9.4.2.312 (Diffie-Hellman Parameter element(#6088)) | Provides a public key from the peer MAC entity for use in the OWE exchange. Present if OWE is being performed; otherwise it is not present. |
| VendorSpecificInfo | A set of elements | As defined in 9.4.2.24 (Vendor Specific element) | Zero or more elements. |

#### 6.5.7.4.4 Effect of receipt

The SME is notified of the receipt of the association request.

### 6.5.7.5 MLME-ASSOCIATE.response

#### 6.5.7.5.1 Function

This primitive is used to send a response to a specific peer MAC entity that requested an association with the STA that issued this primitive, which is in an AP or PCP.

#### 6.5.7.5.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-ASSOCIATE.response(
                                    PeerSTAAddress,
                                    ResultCode,
                                    AssociationID,
                                    RCPI,
                                    RSNI,
```

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RMEnabledCapabilities,
Content of FT Authentication elements,
SupportedOperatingClasses,
TimeoutInterval,(#445)
TIMBroadcastResponse,
QoSMapSet,
Multi-band local,
Multi-band peer,
MMS,
FILSHLPContainer,
FILSIPAddressAssignment,
KeyDelivery,
S1G Sector Operation,
S1G Capabilities,
AID Response,
TSF Timer Accuracy,
TWT,
Sectorized Group ID List,
MaxAwayDuration,
S1GRelay,
S1GRelayActivation,
S1GOperation,
HeaderCompression,
SSTOperation,
CDMG Capabilities,
CMMG Capabilities,
GLK-GCR Parameter Set,
MSCS Descriptor,
HE Capabilities,(11ax)
HE 6 GHz Band Capabilities,(11ax)
HE Operation,(11ax)
UORA Parameter Set,(11ax)
MU EDCA Parameter Set,(11ax)
Spatial Reuse Parameter Set,(11ax)
NDP Feedback Report Parameter Set,(11ax)
BSS Color Change Announcement,(11ax)
ESS Report,(11ax)
EDMG Capabilities,(11ay)
EDMG Operation,(11ay)
QoS Triggered Unscheduled,(11ay)
Unsolicited Block Ack Extension,(11ay)
TDDSlotStructure,(11ay)
TDD Slot Schedule,(11ay)
WUR Capabilities,(11ba)
WUR Operation,(11ba)
WUR Mode,(11ba)
Diffie-Hellman Parameter,(#1084)
VendorSpecificInfo
)

| Name | Type | Valid range | Description |
|---|---|---|---|
| PeerSTAAddress | MAC address | (#1653)Any valid individual address | Specifies the address of the peer MAC entity from which the association request was received. |


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| Name | Type | Valid range | Description |
|---|---|---|---|
| ResultCode | Enumeration | SUCCESS, REFUSED_REASON_UNSPECIFIED, REFUSED_CAPABILITIES_MISMATCH, REFUSED_EXTERNAL_REASON, REFUSED_AP_OUT_OF_MEMORY, REFUSED_BASIC_RATES_MISMATCH, REJECTED_EMERGENCY_SERVICES_NOT_SUPPORTED, REFUSED_TEMPORARILY, GLK_NOT_AUTHORIZED | Indicates the result response to the association request from the peer MAC entity. |
| AssociationID | Integer | Non-DMG: 1–2007<br>DMG: 1–254 | If the association request result was SUCCESS and dot11S1GOptionImplemented is not true, then AssociationID specifies the association ID value assigned to the peer MAC entity by the AP or PCP; otherwise not present. |
| RCPI | Integer | As defined in 9.4.2.36 (RCPI element) | The RCPI value represents the measured RCPI (#14)of the received PPDU containing corresponding Association Request frame. The element is optionally present if dot11RMRCPIMeasurementActivated is true; otherwise not present. |
| RSNI | Integer | As defined in 9.4.2.39 (RSNI element) | The RSNI value represents the measured RSNI (#14)of the received PPDU containing the corresponding Association Request frame(#6107). The element is optionally present if dot11RMRSNIMeasurementActivated is true; otherwise not present. |
| RMEnabledCapabilities | RM Enabled Capabilities element | As defined in 9.4.2.43 (RM Enabled Capabilities element) | Specifies the RM enabled capabilities advertised by the AP or PCP. The element is present if dot11RadioMeasurementActivated is true; otherwise not present. |
| Content of FT Authentication elements | Sequence of elements | As defined in 13.4 (FT initial mobility domain association) | The set of elements to be included in the initial mobility domain association response, as described in 13.4 (FT initial mobility domain association). Present if dot11FastBSSTransitionActivated is true; otherwise not present. |
| SupportedOperatingClasses | As defined in the Supported Operating Classes element | As defined in 9.4.2.52 (Supported Operating Classes element) | Specifies the supported operating classes of the AP or PCP. This parameter is present if dot11ExtendedChannelSwitchActivated ot dot11OperatingClassesRequired is true; otherwise not present. |
| TimeoutInterval | (#1776)TIE, as defined in frame format | As defined in 9.4.2.47 (TIE(#1776)) | This parameter is present when ResultCode is REFUSED_TEMPORARILY.(#445) |

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| Name | Type | Valid range | Description |
|---|---|---|---|
| TIMBroadcastResponse | As defined in TIM Broadcast Response element | As defined in 9.4.2.82 (TIM Broadcast Response element) | Specifies the service parameters for TIM Broadcast. This parameter is optionally present if dot11TIMBroadcastActivated is true and the TIM Broadcast Request element is present in the corresponding Association Request frame; this parameter is not present otherwise. |
| QoSMapSet | As defined in frame format | As defined in 9.4.2.93 (QoS Map element) | Specifies the QoS Map the non-AP and non-PCP STA should use. |
| Multi-band local | Multi-band element | As defined in 9.4.2.137 (Multi-band element) | Specifies the parameters within the Multi-band element that are supported by the local MAC entity. The parameter is present if dot11MultibandImplemented is true and is absent otherwise. |
| Multi-band peer | Multi-band element | As defined in 9.4.2.137 (Multi-band element) | Specifies the parameters within the Multi-band element that are used to deliver messages to the peer MAC entity. The parameter is present if OCT is being used and is absent otherwise. |
| MMS | Multiple MAC Sublayers element | As defined in 9.4.2.151 (MMS element(#1776)) | Specifies the parameters within the Multiple MAC Sublayers element that are supported by the MAC entity, and negotiated for the association. The parameter is present if dot11MultipleMACActivated is true and is absent otherwise. |
| FILSHLPContainer | As defined in 9.4.2.182 (FILS HLP Container element) | As defined in 9.4.2.182 (FILS HLP Container element) | A set of elements containing encapsulated data of higher layer protocol frames (e.g., a DHCP message) transported in FILS association. The parameter is optionally present if dot11FILSActivated is true; otherwise not present. |
| FILSIPAddressAssignment | As defined in 9.4.2.183 (FILS IP Address Assignment element) | As defined in 9.4.2.183 (FILS IP Address Assignment element) | The IP address of a network layer entity associated with the STA. The parameter is optionally present if dot11FILSActivated is true; otherwise not present |
| KeyDelivery | As defined in 9.4.2.184 (Key Delivery element) | As defined in 9.4.2.184 (Key Delivery element) | KDE(s) and the current (#1406)GTK RSC. The parameter is present if dot11FILSActivated is true; otherwise not present. |
| S1G Sector Operation | S1G Sector Operation element | As defined in 9.4.2.194 (S1G Sector Operation element) | Specifies the sectorization scheme, period, subperiod sector intervals, and sector training. |
| S1G Capabilities | As defined in frame format | As defined in 9.4.2.199 (S1G Capabilities element) | Specifies the parameters in the S1G Capabilities element that are supported by the AP. The parameter is present if dot11S1GOptionImplemented is true and the S1G Capabilities element is present in the Association Response frame received from the AP; otherwise not present. |
| AID Response | AID Response element | As defined in 9.4.2.193 (AID Response element) | Parameters describing an AID assignment. This parameter is present if dot11S1GOptionImplemented is true; otherwise not present. |
| TSF Timer Accuracy | TSF Timer Accuracy element | As defined in 9.4.2.202 (TSF Timer Accuracy element) | Indicates the information about the TSF timer accuracy. The parameter is optionally present if dot11TSFTimerAccuracyImplemented is true; otherwise not present. |


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| Name | Type | Valid range | Description |
|---|---|---|---|
| TWT | TWT element | As defined in 9.4.2.198 (TWT element) | Specifies the parameters in the TWT element.<br>This parameter is optionally present if dot11TWTOptionActivated is true and the TWT element is present in the Association Request frame that elicited the Association Response frame or the TWT Requester Support field in the HE Capabilities element in the Association Request frame that elicited the Association Response frame is 1;(11ax) otherwise not present. |
| Sectorized Group ID List | Sectorized Group ID List element | As defined in 9.4.2.210 (Sectorized Group ID List element) | Specifies the parameters in the Sectorized Group ID List element.<br>This parameter is optionally present if dot11S1GSectorizationActivated is true; otherwise not present. |
| MaxAwayDuration | Integer | 0–65 535 | Indicates the maximum duration, in TUs, that the AP is unavailable for communications with the STA.<br>The parameter is optionally present if dot11MaxAwayDuration is nonzero; otherwise not present. |
| S1GRelay | S1G Relay element | As defined in 9.4.2.203 (S1G Relay element) | Indicates the support of the relay operation by the STA transmitting the element. |
| S1GRelayActivation | S1G Relay Activation element | As defined in 9.4.2.205 (S1G Relay Activation element) | (#221)Indicates if a STA with dot11RelaySTAImplemented equal to true requests to operate as a relay (in a request) and an AP with dot11RelayAPImplemented equal to true requests/confirms operation as a relay.<br>The parameter is optionally present if dot11RelaySTAImplemented is true; otherwise not present. |
| S1GOperation | S1G Operation element | As defined in 9.4.2.211 (S1G Operation element) | The S1G Operation element is present if dot11S1GOptionImplemented is true; otherwise not present. |
| HeaderCompression | Header Compression element | As defined in 9.4.2.212 (Header Compression element) | The Header Compression element is present if dot11PV1MACHeaderOptionImplemented is true; otherwise not present. |
| SSTOperation | SST Operation element | As defined in 9.4.2.213 (SST Operation element) | The SST Operation element is optionally present if dot11SelectiveSubchannelTransmissionPermitted is true; otherwise not present. |
| CDMG Capabilities | CDMG Capabilities element | As defined in 9.4.2.218 (CDMG Capabilities element). | Specifies the parameters within the CDMG Capabilities element that are supported by the MAC entity.<br>The parameter is present if dot11CDMGOptionImplemented is true; otherwise not present. |
| CMMG Capabilities | CMMG Capabilities element | As defined in 9.4.2.228 (CMMG Capabilities element). | Specifies the parameters within the CMMG Capabilities element that are supported by the MAC entity. The parameter is present if dot11CMMGOptionImplemented is true; otherwise not present. |

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| Name | Type | Valid range | Description |
|---|---|---|---|
| GLK-GCR Parameter Set | GLK-GCR Parameter Set element | As defined in 9.4.2.233 (GLK-GCR Parameter Set element) | This parameter is present only if the AP selects (#1653)GLK-GCR for group transmissions (either unsolicited retry or block ack) over the general link. Describes the parameters that define how GLK-GCR operates. |
| MSCS Descriptor | As defined in the MSCS Descriptor element | As defined in 9.4.2.242 (MSCS Descriptor element) | The parameters used to classify streams using the procedures defined in 11.25.3 (MSCS procedures). Optionally present if dot11MSCSActivated is true; otherwise not present. |
| HE Capabilities(11ax) | As defined in HE Capabilities element | As defined in 9.4.2.247 (HE Capabilities element(11ax)) | Specifies the parameters within the HE Capabilities element that are supported by the STA. The parameter is present if dot11HEOptionImplemented is true; otherwise, this parameter is not present. |
| HE 6 GHz Band Capabilities(11ax) | As defined in HE 6 GHz Band Capabilities element | As defined in 9.4.2.262 (HE 6 GHz Band Capabilities element(11ax)) | Specifies the parameters within the HE 6 GHz Band Capabilities element that are supported by the STA. The parameter is present if dot11HE6GOptionImplemented is true; otherwise, this parameter is not present. |
| HE Operation(11ax) | As defined in HE Operation element | As defined in 9.4.2.248 (HE Operation element(11ax)) | Provides additional information for operating the HE BSS. The parameter is present if dot11HEOptionImplemented is true; otherwise, it is not present. |
| UORA Parameter Set(11ax) | As defined in UORA Parameter Set element | As defined in 9.4.2.249 (UORA Parameter Set element(11ax)) | Indicates the metrics of the OFDMA-based random access mechanism. The parameter is optionally present if dot11OFDMARandomAccessOptionImlemented is true; otherwise, it is not present. |
| MU EDCA Parameter Set(11ax) | As defined in MU EDCA Parameter Set element | As defined in 9.4.2.250 (MU EDCA Parameter Set element(11ax)) | Indicates MU EDCA parameters. The parameter is optionally present if dot11HEOptionImplemented is true; otherwise, it is not present. |
| Spatial Reuse Parameter Set(11ax) | As defined in Spatial Reuse Parameter Set element | As defined in 9.4.2.251 (Spatial Reuse Parameter Set element(11ax)) | Indicates parameters needed by STAs when performing OBSS PD-based spatial reuse. The parameter is optionally present if dot11HEOptionImplemented is true; otherwise, it is not present. |
| NDP Feedback Report Parameter Set(11ax) | As defined in NDP Feedback Report Parameter Set element | As defined in 9.4.2.252 (NDP Feedback Report Parameter Set element(11ax)) | Indicates NDP Feedback Report parameter values. The parameter is optionally present if dot11HEOptionImplemented is true; otherwise, it is not present. |
| BSS Color Change Announcement(11ax) | As defined in BSS Color Change Announcement element | As defined in 9.4.2.253 (BSS Color Change Announcement element(11ax)) | Indicates information on BSS Color Change. The parameter is optionally present if dot11HEOptionImplemented is true; otherwise, it is not present. |
| ESS Report(11ax) | As defined in ESS Report element | As defined in 9.4.2.255 (ESS Report element(11ax)) | Provides information on ESS to assist BSS transition. The parameter is optionally present. |
| EDMG Capabilities(11ay) | EDMG Capabilities element | As defined in 9.4.2.264 (EDMG Capabilities element(11ay)) | Specifies the parameters within the EDMG Capabilities element that are supported by the MAC entity. The parameter is present if dot11EDMGOptionImplemented is true and is absent otherwise. |


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| Name | Type | Valid range | Description |
|---|---|---|---|
| EDMG Operation(11ay) | EDMG Operation element | As defined in 9.4.2.265 (EDMG Operation element(11ay)) | Specifies the parameters within the EDMG Operation element that are used in the BSS. The parameter is present if dot11EDMGOptionImplemented is true and is absent otherwise. |
| QoS Triggered Unscheduled(11ay) | QoS Triggered Unscheduled element | As defined in 9.4.2.277 (QoS-TU element(#1776)(11ay)) | Specifies the parameters within the QoS Triggered Unscheduled element that are supported by the MAC entity. The parameter is present if dot11EDMGOptionImplemented is true and is absent otherwise. |
| Unsolicited Block Ack Extension(11ay) | Unsolicited Block Ack Extension | As defined in 9.4.2.278 (Unsolicited Block Ack Extension element(11ay)) | Specifies the parameters within the Unsolicited Block Ack Extension element that are supported by the MAC entity. Optionally present if dot11UnsolicitedBAActivated is true and is absent otherwise. |
| TDDSlotStructure(11ay) | TDD Slot Structure element | As defined in 9.4.2.280 (TDD Slot Structure element(11ay)) | Present if dot11TDDOptionImplemented is true and absent otherwise. Specifies the parameters within the TDD Slot Structure element corresponding to a target STA. |
| TDD Slot Schedule(11ay) | TDD Slot Schedule element | As defined in 9.4.2.281 (TDD Slot Schedule element(11ay)) | Present if dot11TDDOptionImplemented is true and absent otherwise. Specifies the TDD slot schedule of the STA. |
| WUR Capabilities(11ba) | As defined in WUR Capabilities element | As defined in 9.4.2.290 (WUR Capabilities element(11ba)) | Specifies the parameters within the WUR Capabilities element that are supported by the STA. The parameter is present if dot11WUROptionImplemented is true; otherwise, this parameter is not present. |
| WUR Operation(11ba) | As defined in WUR Operation element | As defined in 9.4.2.291 (WUR Operation element(11ba)) | Provides additional information for WUR operation. The parameter is present if dot11WUROptionImplemented is true; otherwise not present. |
| WUR Mode(11ba) | As defined in WUR Mode element | As defined in 9.4.2.292 (WUR Mode element(11ba)) | Specifies the proposed service parameters for the WUR Mode Setup request. The parameter is optionally present if dot11WUROptionImplemented is true; otherwise, this parameter is not present. |
| Diffie-Hellman Parameter(#1084) | Diffie-Hellman Parameter element | (#6088)As defined in 9.4.2.312 (Diffie-Hellman Parameter element(#6088)) | Provides a public key for the STA that issued this primitive, it is used in the OWE exchange. Present if OWE is being performed; otherwise it is not present. |
| VendorSpecificInfo | A set of elements | As defined in 9.4.2.24 (Vendor Specific element) | Zero or more elements. |

Additional parameters needed to perform the association response procedure are not included in the primitive parameter list since the MLME already has that data (maintained as internal state).

#### 6.5.7.5.3 When generated

This primitive is generated by the SME of a STA that is in an AP or PCP as a response to an MLME-ASSOCIATE.indication primitive.

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#### 6.5.7.5.4 Effect of receipt

This primitive initiates transmission of an AssociationResponse to the specific peer MAC entity that requested association.

### 6.5.8 Reassociate

#### 6.5.8.1 Introduction

The following primitives describe how a STA becomes associated with another AP or PCP.

#### 6.5.8.2 MLME-REASSOCIATE.request

#### 6.5.8.2.1 Function

This primitive requests a change in association to a specified new peer MAC entity that is in an AP or PCP.

#### 6.5.8.2.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-REASSOCIATE.request(
NewPeerSTAAddress(#4223)(#1364),
ListenInterval,
Supported Channels
RSN,
QoSCapability,
Content of FT Authentication elements,
SupportedOperatingClasses,
SM Power Save,
QoSTrafficCapability,
TIMBroadcastRequest,
FMSRequest,
DMSRequest,
EmergencyServices,
Multi-band local,
Multi-band peer,
MMS,
FILSHLPContainer,
FILSIPAddressAssignment,
AID Request,
TWT,
Sectorized Group ID List,
MaxAwayDuration,
S1GRelayActivation,
ELOperation,
S1GRelay,
HeaderCompression,
ReachableAddress,
S1GOperation,
SSTOperation,
CDMG Capabilities,
CMMG Capabilities,
GLK-GCR Parameter Set,
MSCS Descriptor,


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HE Capabilities,(11ax)
HE 6 GHz Band Capabilities,(11ax)
Channel Switch Timing,(11ax)
UL MU Power Capabilities,(11ax)
EDMG Capabilities,(11ay)
QoS Triggered Unscheduled,(11ay)
Unsolicited Block Ack Extension,(11ay)
TDD Slot Schedule,(11ay)
WUR Mode,(11ba)
Diffie-Hellman Parameter,(#1084)
VendorSpecificInfo
)

| Name | Type | Valid range | Description |
|---|---|---|---|
| NewPeerSTAAddress(#4223) | MAC address | (#1653)Any valid individual address | Specifies the address of the peer MAC entity with which to perform the reassociation process. |
| (#1364)ListenInterval | Integer | ≥ 0 | (#7058)Specifies how often the STA transitions to the awake state to listen for the next Beacon frame,, if it enters power save mode. |
| Supported Channels | As defined in the Supported Channels element | As defined in the Supported Channels element | The list of channels in which the STA is capable of operating.<br>Present if DFS functionality is required, as specified in 11.8 (DFS procedures); otherwise (#3510)optionally present. |
| RSN | RSNE | As defined in 9.4.2.23 (RSNE) | A description of the cipher suites and AKM suites selected by the STA. |
| QoSCapability | QoS Capability element | As defined in 9.4.2.33 (QoS Capability element) | Specifies the parameters within the QoS Capability element that are supported by the MAC entity. The parameter is present if dot11QosOptionImplemented is true; otherwise not present. |
| Content of FT Authentication elements | Sequence of elements | As defined in 13.8 (FT authentication sequence) | The set of elements to be included in the third message of the FT authentication sequence, as described in 13.8.4 (FT authentication sequence: contents of third message). Present if dot11FastBSSTransitionActivated is true; otherwise not present. |
| SupportedOperating Classes | As defined in the Supported Operating Classes element | As defined in 9.4.2.52 (Supported Operating Classes element) | Specifies the supported operating classes of the STA. This parameter is present if dot11ExtendedChannelSwitchActivated or dot11OperatingClassesRequired is true; otherwise not present. |
| SM Power Save | Integer | As defined in Table 9-224 (Subfields of the HT Capability Information field) | Indicates the spatial multiplexing power save mode that is in operation immediately after reassociation. |
| QoS Traffic Capability | As defined in the QoS Traffic Capability element | As defined in 9.4.2.76 (QoS Traffic Capability element) | Specifies the (#403)QoS traffic capability flags of the non-AP and non-PCP STA. This parameter is optionally present if dot11ACStationCountActivated is true and is not present otherwise. |

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| Name | Type | Valid range | Description |
|---|---|---|---|
| TIMBroadcastRequest | As defined in TIM Broadcast Request element | As defined in 9.4.2.81 (TIM Broadcast Request element) | Specifies the proposed service parameters for TIM Broadcast. This parameter is optionally present if dot11TIMBroadcastActivated is true and is not present otherwise. |
| FMSRequest | As defined in FMS Request element | As defined in 9.4.2.74 (FMS Request element) | Specifies the proposed multicast parameters for FMS request procedure(#238). This parameter is optionally present if dot11FMSActivated is true and is not present otherwise. |
| DMSRequest | Sequence of DMS Request elements | As defined in 9.4.2.86 (DMS Request element) | Specifies the proposed multicast parameters for DMS Request. This parameter is optionally present if dot11DMSActivated is true and is not present otherwise. |
| EmergencyServices | Boolean | true, false | Specifies that the non-AP and non-PCP STA intends to reassociate for the purpose of unauthenticated access to emergency services. The parameter shall be present only if dot11InterworkingServiceActivated is true. |
| Multi-band local | Multi-band element | As defined in 9.4.2.137 (Multi-band element) | Specifies the parameters within the Multi-band element that are supported by the local MAC entity. The parameter is present if dot11MultibandImplemented is true and is absent otherwise. |
| Multi-band peer | Multi-band element | As defined in 9.4.2.137 (Multi-band element) | Specifies the parameters within the Multi-band element that are used to deliver messages to the peer MAC entity. The parameter is present if OCT is being used and is absent otherwise. |
| MMS | Multiple MAC Sublayers element | As defined in 9.4.2.151 (MMS element(#1776)) | Specifies the parameters within the Multiple MAC Sublayers element that are supported by the MAC entity. The parameter is present if dot11MultipleMACActivated is true and is absent otherwise. |
| FILSHLPContainer | As defined in 9.4.2.182 (FILS HLP Container element) | As defined in 9.4.2.182 (FILS HLP Container element) | A set of elements containing encapsulated data of higher layer protocol frames (e.g., a DHCP message) that is transported in FILS association. The parameter is optionally present if dot11FILSActivated is true; otherwise not present. |
| FILSIPAddressAssignment | As defined in 9.4.2.183 (FILS IP Address Assignment element) | As defined in 9.4.2.183 (FILS IP Address Assignment element) | An explicit request for an IP address. The request may be for a new IP address or a specified IP address. The parameter is optionally present if dot11FILSActivated is true; otherwise not present. |
| AID Request | AID Request element | As defined in 9.4.2.192 (AID Request element) | Indicates the device characteristic of the non-AP STA requesting AID assignment. This parameter is optionally present if dot11S1GOptionImplemented is true; otherwise not present. |
| TWT | TWT element | As defined in 9.4.2.198 (TWT element) | Specifies the parameters in the TWT element.<br>This parameter is optionally present if dot11TWTOptionActivated is true; otherwise not present. |


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| Name | Type | Valid range | Description |
|---|---|---|---|
| Sectorized Group ID List | Sectorized Group ID List element | As defined in 9.4.2.210 (Sectorized Group ID List element) | Specifies the parameters in the Sectorized Group ID List element.<br>This parameter is optionally present if dot11S1GSectorizationActivated is true; otherwise not present. |
| MaxAwayDuration | Integer | 0–65 535 | Indicates the maximum duration, in TUs, that the AP is unavailable for communications with the STA.<br>The parameter is optionally present if dot11MaxAwayDuration is nonzero; otherwise not present. |
| S1GRelayActivation | S1G Relay Activation element | As defined in 9.4.2.205 (S1G Relay Activation element) | (#221)Indicates if a STA with dot11RelaySTAImplemented equal to true requests to operate as a relay (in a request) and an AP with dot11RelayAPImplemented equal to true requests/confirms operation as a relay.<br>The parameter is optionally present if dot11RelaySTAImplemented is true; otherwise not present. |
| ELOperation | EL Operation element | As defined in 9.4.2.209 (EL Operation element) | The EL Operation element is optionally present if dot11S1GELOperationActivated is true; otherwise not present. |
| S1GRelay | S1G Relay element | As defined in 9.4.2.203 (S1G Relay element) | Specifies the parameters within the S1G Relay element that are supported by the MAC entity.<br>The parameter is present if dot11RelaySTAImplemented is true; otherwise not present. |
| HeaderCompression | Header Compression element | As defined in 9.4.2.212 (Header Compression element) | The Header Compression element is present if dot11PV1MACHeaderOptionImplemented is true; otherwise not present. |
| ReachableAddress | Reachable Address element | As defined in 9.4.2.204 (Reachable Address element) | The Reachable Address element is optionally present if dot11RelaySTAImplemented is true; otherwise not present. |
| S1GOperation | S1G Operation element | As defined in 9.4.2.211 (S1G Operation element) | The S1G Operation element is present if dot11S1GOptionImplemented is true; otherwise not present. |
| SSTOperation | SST Operation element | As defined in 9.4.2.213 (SST Operation element) | The SST Operation element is optionally present if dot11SelectiveSubchannelTransmissionPermitted is true; otherwise not present. |
| CDMG Capabilities | CDMG Capabilities element | As defined in 9.4.2.218 (CDMG Capabilities element) | Specifies the parameters within the CDMG Capabilities element that are supported by the MAC entity.<br>The parameter is present if dot11CDMGOptionImplemented is true; otherwise not present. |
| CMMG Capabilities | CMMG Capabilities element | As defined in 9.4.2.228 (CMMG Capabilities element) | Specifies the parameters within the CMMG Capabilities element that are supported by the MAC entity. The parameter is present if dot11CMMGOptionImplemented is true; otherwise not present. |

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| Name | Type | Valid range | Description |
|---|---|---|---|
| GLK-GCR Parameter Set | GLK-GCR Parameter Set element | As defined in 9.4.2.233 (GLK-GCR Parameter Set element) | This parameter is present if dot11GLKGCRImplemented is true and not present otherwise. Specifies the GLK-GCR capabilities supported by the STA. |
| MSCS Descriptor | As defined in the MSCS Descriptor element | As defined in 9.4.2.242 (MSCS Descriptor element) | The parameters used to classify streams using the procedures defined in 11.25.3 (MSCS procedures). Optionally present if dot11MSCSActivated is true; otherwise not present. |
| HE Capabilities(11ax) | As defined in HE Capabilities element | As defined in 9.4.2.247 (HE Capabilities element(11ax)) | Specifies the parameters in the HE Capabilities element that are supported by the STA. The parameter is present if dot11HEOptionImplemented is true; otherwise, it is not present. |
| HE 6 GHz Band Capabilities(11ax) | As defined in HE 6 GHz Band Capabilities element | As defined in 9.4.2.262 (HE 6 GHz Band Capabilities element(11ax)) | Specifies the parameters in the HE 6 GHz Band Capabilities element that are supported by the STA. The parameter is present if dot11HE6GOptionImplemented is true; otherwise, it is not present. |
| Channel Switch Timing(11ax) | As defined in the Channel Switch Timing element | As defined in 9.4.2.62 (Channel Switch Timing element) | Provides information regarding the channel switch timing. The parameter is optionally present if dot11HESubchannelSelectiveTransmissionImplemented is true; otherwise, it is not present. |
| UL MU Power Capabilities(11ax) | As defined in UL MU Power Capabilities element | As defined in 9.4.2.263 (UL MU Power Capabilities element(11ax)) | Provides information regarding the UL MU power capabilities for the non-AP STA. The UL MU Power Capabilities element is optionally present if dot11HEOptionImplemented is true; otherwise, it is not present. |
| EDMG Capabilities(11ay) | EDMG Capabilities element | As defined in 9.4.2.264 (EDMG Capabilities element(11ay)) | Specifies the parameters within the EDMG Capabilities element that are supported by the MAC entity. The parameter is present if dot11EDMGOptionImplemented is true and is absent otherwise. |
| QoS Triggered Unscheduled(11ay) | QoS Triggered Unscheduled element | As defined in 9.4.2.277 (QoS-TU element(#1776)(11ay)) | Specifies the parameters within the QoS Triggered Unscheduled element that are supported by the MAC entity. The parameter is present if dot11EDMGOptionImplemented is true and is absent otherwise. |
| Unsolicited Block Ack Extension(11ay) | Unsolicited Block Ack Extension | As defined in 9.4.2.278 (Unsolicited Block Ack Extension element(11ay)) | Specifies the parameters within the Unsolicited Block Ack Extension element that are supported by the MAC entity. Optionally present if dot11UnsolicitedBAActivated is true and is absent otherwise. |
| TDD Slot Schedule(11ay) | TDD Slot Schedule element | As defined in 9.4.2.281 (TDD Slot Schedule element(11ay)) | Present if dot11TDDOptionImplemented is true and absent otherwise. Specifies the TDD slot availability of the STA. |
| WUR Mode(11ba) | As defined in WUR Mode element | As defined in 9.4.2.292 (WUR Mode element(11ba)) | Specifies the proposed service parameters for the WUR Mode Setup request. The parameter is optionally present if dot11WUROptionImplemented is true; otherwise, this parameter is not present. |


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| Name | Type | Valid range | Description |
|---|---|---|---|
| Diffie-Hellman Parameter(#1084) | Diffie-Hellman Parameter element | (#6088)As defined in 9.4.2.312 (Diffie-Hellman Parameter element(#6088)) | Provides a public key for use in the OWE exchange. Present if OWE is being performed; otherwise it is not present. |
| VendorSpecificInfo | A set of elements | As defined in 9.4.2.24 (Vendor Specific element) | Zero or more elements. |

Additional parameters needed to perform the reassociation procedure are not included in the primitive parameter list since the MLME already has that data (maintained as internal state).

#### 6.5.8.2.3 When generated

This primitive is generated by the SME for a STA to change association to a specified new peer MAC entity that is in an AP or PCP.

#### 6.5.8.2.4 Effect of receipt

This primitive initiates a reassociation procedure. In the case that a response is received from the responder STA, the MLME subsequently issues an MLME-REASSOCIATE.confirm primitive that reflects the results.

### 6.5.8.3 MLME-REASSOCIATE.confirm

#### 6.5.8.3.1 Function

This primitive reports the results of a reassociation attempt with a specified peer MAC entity that is in an AP or PCP.

#### 6.5.8.3.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-REASSOCIATE.confirm(
PeerSTAAddress,(#4223)
ResultCode,
CapabilityInformation,
AssociationID,
EDCAParameterSet,
RCPI of Request,
RSNI of Request,
RCPI of Response,
RSNI of Response,
RMEnabledCapabilities,
Content of FT Authentication elements,
SupportedOperatingClasses,
Extended Capabilities,
20/40 BSS Coexistence,
TimeoutInterval,
BSSMaxIdlePeriod,
TIMBroadcastResponse,
FMSResponse,
DMSResponse,
QoSMapSet,
QMFPolicy,

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DMG Capabilities,
Multi-band local,
Multi-band peer,
MMS,
FILSHLPContainer,
FILSIPAddressAssignment,
KeyDelivery,
S1G Sector Operation,
S1G Capabilities,
AID Response,
TSF Timer Accuracy,
TWT,
MaxAwayDuration,
S1GRelayActivation,
ELOperation,
S1GRelay,
HeaderCompression,
S1GOperation,
SectorizedGroupIDList,
SSTOperation,
CDMG Capabilities,
CMMG Capabilities,
GLK-GCR Parameter Set,
MSCS Descriptor,
HE Capabilities,(11ax)
HE 6 GHz Band Capabilities,(11ax)
HE Operation,(11ax)
UORA Parameter Set,(11ax)
MU EDCA Parameter Set,(11ax)
Spatial Reuse Parameter Set,(11ax)
NDP Feedback Report Parameter Set,(11ax)
BSS Color Change Announcement,(11ax)
ESS Report,(11ax)
EDMG Capabilities,(11ay)
EDMG Operation,(11ay)
QoS Triggered Unscheduled,(11ay)
Unsolicited Block Ack Extension,(11ay)
TDD Slot Structure,(11ay)
TDD Slot Schedule,(11ay)
WUR Capabilities,(11ba)
WUR Operation,(11ba)
WUR Mode,(11ba)
Diffie-Hellman Parameter,(#1084)
VendorSpecificInfo
)

| Name | Type | Valid range | Description |
|---|---|---|---|
| PeerSTAAddress(#4223) | MAC address | Any valid individual address | Specifies the address of the peer MAC entity to which the reassociation request was sent. |


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| Name | Type | Valid range | Description |
|---|---|---|---|
| ResultCode | Enumeration | SUCCESS, REFUSED_REASON_UNSPECIFIED, REFUSED_NOT_AUTHENTICATED, REFUSED_CAPABILITIES_MISMATCH, REFUSED_EXTERNAL_REASON, REFUSED_AP_OUT_OF_MEMORY, REFUSED_BASIC_RATES_MISMATCH, REJECTED_EMERGENCY_SERVICES_NOT_SUPPORTED, REFUSED_TEMPORARILY | Indicates the result of the MLME-REASSOCIATE.request primitive. |
| Capability-Information | Capability Information field | As defined in 9.4.1.4 (Capability Information field) | Specifies the operational capabilities advertised by the AP or PCP. |
| AssociationID | Integer | Non-DMG: 1–2007<br>DMG: 1–254 | If the association request result was SUCCESS, then AssociationID specifies the association ID value assigned by the AP or PCP.<br>This parameter is not present if dot11S1GOptionImplemented is true. |
| EDCAParameterSet | EDCA Parameter Set element | As defined in 9.4.2.27 (EDCA Parameter Set element) | Specifies the EDCA parameter set that the STA should use. The parameter is present if dot11QosOptionImplemented is true; otherwise not present. |
| RCPI of Request | Integer | As defined in 9.4.2.36 (RCPI element) | Indicates the RCPI value contained in the received Reassociation Response frame. This value represents the RCPI that the AP or PCP measured (#14)of the received PPDU containing the corresponding Reassociation Request frame. The element is optionally present if dot11RMRCPIMeasurementActivated is true; otherwise not present. |
| RSNI of Request | Integer | As defined in 9.4.2.39 (RSNI element) | Indicates the RSNI value contained in the received Reassociation Response frame. This value represents the RSNI that the AP or PCP measured (#14)of the received PPDU containing the corresponding Reassociation Request frame. The element is optionally present if dot11RMRSNIMeasurementActivated is true; otherwise not present. |
| RCPI of Response | Integer | As defined in 9.4.2.36 (RCPI element) | The RCPI value represents the measured RCPI (#14)of the received PPDU containing the corresponding Reassociation Response frame. The element is optionally present if dot11RMRCPIMeasurementActivated is true; otherwise not present. |
| RSNI of Response | Integer | As defined in 9.4.2.39 (RSNI element) | RSNI at the time the corresponding Reassociation Response frame was received. The element is optionally present if dot11RMRSNIMeasurementActivated is true; otherwise not present. |

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| Name | Type | Valid range | Description |
|---|---|---|---|
| RMEnabledCapabilities | RM Enabled Capabilities element | As defined in 9.4.2.43 (RM Enabled Capabilities element) | Specifies the RM enabled capabilities advertised by the AP or PCP. The element is present if dot11RadioMeasurementActivated is true; otherwise not present. |
| Content of FT Authentication elements | Sequence of elements | As defined in 13.8 (FT authentication sequence) | The set of elements included in the fourth message of the FT authentication sequence, as described in 13.8.5 (FT authentication sequence: contents of fourth message). This includes an optional response to a resource request (RIC). Present if dot11FastBSSTransitionActivated is true; otherwise not present. |
| SupportedOperatingClasses | As defined in the Supported Operating Classes element | As defined in 9.4.2.52 (Supported Operating Classes element) | Indicates the supported operating classes of the AP or PCP. This parameter is optionally present if dot11ExtendedChannelSwitchActivated or dot11OperatingClassesRequired is true; otherwise not present. |
| Extended Capabilities | As defined in frame format | As defined in 9.4.2.25 (Extended Capabilities element) | Specifies the parameters within the Extended Capabilities element that are supported by the MAC entity. |
| 20/40 BSS Coexistence | As defined in frame format | As defined in 9.4.2.58 (20/40 BSS Coexistence element) | Specifies the parameters within the 20/40 BSS Coexistence element that are indicated by the MAC entity. The parameter is present if dot112040BSSCoexistenceManagementSupport is true. |
| TimeoutInterval | (#1776)TIE, as defined in frame format | As defined in 9.4.2.47 (TIE(#1776)) | This parameter is present when ResultCode is REFUSED_TEMPORARILY. |
| BSSMaxIdlePeriod | BSS Max Idle Period element | As defined in 9.4.2.77 (BSS Max Idle Period element) | Indicates the BSS max idle period parameters of the AP or PCP. This parameter is present if dot11WirelessManagementImplemented (#1428)and dot11BSSMaxIdlePeriodIndicationByNonAPSTA are true or dot11S1GOptionImplemented is true; otherwise not present. |
| TIMBroadcastResponse | As defined in TIM Broadcast Response element | As defined in 9.4.2.82 (TIM Broadcast Response element) | Specifies the service parameters for TIM Broadcast. This parameter is optionally present if dot11TIMBroadcastActivated is true and the TIM Broadcast Request element is present in the corresponding Association Request frame; this parameter is not present otherwise. |
| FMSResponse | As defined in FMS Response element | As defined in 9.4.2.75 (FMS Response element) | Specifies the multicast parameters for FMS Response. This parameter is optionally present if dot11FMSActivated is true and the FMS Request element is present in the corresponding Association Request frame; this parameter is not present otherwise. |


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| Name | Type | Valid range | Description |
|---|---|---|---|
| DMSResponse | Sequence of DMS Response elements | As defined in 9.4.2.87 (DMS Response element) | Specifies the multicast parameters for DMS Response. This parameter is optionally present if dot11DMSActivated is true and the DMS Request element is present in the corresponding Association Request frame; this parameter is not present otherwise. |
| QoSMapSet | As defined in frame format | As defined in 9.4.2.93 (QoS Map element) | Specifies the QoS Map the non-AP and non-PCP STA should use. |
| QMFPolicy | QMF Policy element | As defined in 9.4.2.118 (Quality-of-Service Management Frame Policy element) | Describes the QMF policy of the AP. This parameter is present when dot11QMFActivated is true and is not present otherwise. |
| DMG Capabilities | DMG Capabilities element | As defined in 9.4.2.126 (DMG Capabilities element) | Specifies the parameters within the DMG Capabilities element that are supported by the MAC entity. The parameter is present if dot11DMGOptionImplemented is true and is absent otherwise. |
| Multi-band local | Multi-band element | As defined in 9.4.2.137 (Multi-band element) | Specifies the parameters within the Multi-band element that identify and are supported by the local MAC entity. The parameter is present if OCT is being used and is absent otherwise. |
| Multi-band peer | Multi-band element | As defined in 9.4.2.137 (Multi-band element) | Specifies the parameters within the Multi-band element that identify and are supported by the peer MAC entity. This parameter is present if OCT is being used and is absent otherwise. |
| MMS | Multiple MAC Sublayers element | As defined in 9.4.2.151 (MMS element(#1776)) | Specifies the parameters within the Multiple MAC Sublayers element that are supported by the MAC entity. The parameter is present if dot11MultipleMACActivated is true and is absent otherwise. |
| FILSHLPContainer | As defined in 9.4.2.182 (FILS HLP Container element) | As defined in 9.4.2.182 (FILS HLP Container element) | A set of elements containing encapsulated data of higher layer protocol frames (e.g., a DHCP message) that is transported in FILS association. The parameter is present if dot11FILSActivated is true; otherwise not present. |
| FILSIPAddressAssignment | As defined in 9.4.2.183 (FILS IP Address Assignment element) | As defined in 9.4.2.183 (FILS IP Address Assignment element) | The IP address assigned to the STA for higher layer communication. The parameter is present if dot11FILSActivated is true; otherwise not present. |
| KeyDelivery | As defined in 9.4.2.184 (Key Delivery element) | As defined in 9.4.2.184 (Key Delivery element) | KDE(s) and the current (#1406)GTK RSC. The parameter is present if dot11FILSActivated is true; otherwise not present. |
| S1G Sector Operation | S1G Sector Operation element | As defined in 9.4.2.194 (S1G Sector Operation element) | Specifies the sectorization scheme, period, subperiod sector intervals, sector training. |

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| Name | Type | Valid range | Description |
|---|---|---|---|
| S1G Capabilities | As defined in frame format | As defined in 9.4.2.199 (S1G Capabilities element) | Specifies the parameters in the S1G Capabilities element that are supported by the AP. The parameter is present if dot11S1GOptionImplemented is true and the S1G Capabilities element is present in the (Re)Association Response frame received from the AP; otherwise not present. |
| AID Response | AID Response element | As defined in 9.4.2.193 (AID Response element) | Parameters describing an AID assignment.<br>This parameter is present if dot11S1GOptionImplemented is true; otherwise not present. |
| TSF Timer Accuracy | TSF Timer Accuracy element | As defined in 9.4.2.202 (TSF Timer Accuracy element) | Indicates the information about the TSF Timer Accuracy. The parameter is optionally present if dot11TSFTimerAccuracyImplemented is true; otherwise not present. |
| TWT | TWT element | As defined in 9.4.2.198 (TWT element) | Specifies the parameters in the TWT element.<br>This parameter is optionally present if dot11TWTOptionActivated is true and the TWT element is present in the Reassociation Request frame that elicited the Reassociation Response frame or the TWT Requester Support field in the HE Capabilities element in the Reassociation Request frame that elicited the Reassociation Response frame is 1;(11ax) otherwise not present. |
| MaxAwayDuration | Integer | 0–65 535 | Indicates the maximum duration, in TUs, that the AP is unavailable for communications with the STA.<br>The parameter is optionally present if dot11MaxAwayDuration is nonzero; otherwise not present. |
| S1GRelayActivation | S1G Relay Activation element | As defined in 9.4.2.205 (S1G Relay Activation element) | (#221)Indicates if a STA with dot11RelaySTAImplemented equal to true requests to operate as a relay (in a request) and an AP with dot11RelayAPImplemented equal to true requests/confirms operation as a relay.<br>The parameter is optionally present if dot11RelaySTAImplemented is true; otherwise not present. |
| ELOperation | EL Operation element | As defined in 9.4.2.209 (EL Operation element) | The EL Operation element is optionally present if dot11S1GELOperationActivated is true; otherwise not present. |
| S1GRelay | S1G Relay element | As defined in 9.4.2.203 (S1G Relay element) | Specifies the parameters within the S1G Relay element that are supported by the MAC entity.<br>The parameter is present if dot11RelaySTAImplemented is true; otherwise not present. |
| HeaderCompression | Header Compression element | As defined in 9.4.2.212 (Header Compression element) | The Header Compression element is present if dot11PV1MACHeaderOptionImplemented is true; otherwise not present. |


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| Name | Type | Valid range | Description |
|---|---|---|---|
| S1GOperation | S1G Operation element | As defined in 9.4.2.211 (S1G Operation element) | The S1G Operation element is present if dot11S1GOptionImplemented is true; otherwise not present. |
| SectorizedGroupID List | Sectorized Group ID List element | As defined in 9.4.2.210 (Sectorized Group ID List element) | Specifies the parameters in the Sectorized Group ID List element. This parameter is optionally present if dot11S1GSectorizationActivated is true; otherwise not present. |
| SSTOperation | SST Operation element | As defined in 9.4.2.213 (SST Operation element) | The SST Operation element is optionally present if dot11SelectiveSubchannelTransmissionPermitted is true; otherwise not present. |
| CDMG Capabilities | CDMG Capabilities element | As defined in 9.4.2.218 (CDMG Capabilities element) | Specifies the parameters within the CDMG Capabilities element that are supported by the MAC entity. The parameter is present if dot11CDMGOptionImplemented is true; otherwise not present. |
| CMMG Capabilities | CMMG Capabilities element | As defined in 9.4.2.228 (CMMG Capabilities element) | Specifies the parameters within the CMMG Capabilities element that are supported by the MAC entity. The parameter is present if dot11CMMGOptionImplemented is true; otherwise not present. |
| GLK-GCR Parameter Set | GLK-GCR Parameter Set element | As defined in 9.4.2.233 (GLK-GCR Parameter Set element) | Specifies the values from the GLK-GCR Parameter Set element if such an element was present in the Reassociation Response frame, otherwise not present. |
| MSCS Descriptor | As defined in the MSCS Descriptor element | As defined in 9.4.2.242 (MSCS Descriptor element) | The parameters used to classify streams using the procedures defined in 11.25.3 (MSCS procedures). Optionally present if dot11MSCSActivated is true; otherwise not present. |
| HE Capabilities(11ax) | As defined in HE Capabilities element | As defined in 9.4.2.247 (HE Capabilities element(11ax)) | Specifies the parameters within the HE Capabilities element that are supported by the STA. The parameter is present if dot11HEOptionImplemented is true; otherwise, this parameter is not present. |
| HE 6 GHz Band Capabilities(11ax) | As defined in HE 6 GHz Band Capabilities element | As defined in 9.4.2.262 (HE 6 GHz Band Capabilities element(11ax)) | Specifies the parameters within the HE 6 GHz Band Capabilities element that are supported by the STA. The parameter is present if dot11HE6GOptionImplemented is true; otherwise, this parameter is not present. |
| HE Operation(11ax) | As defined in HE Operation element | As defined in 9.4.2.248 (HE Operation element(11ax)) | Provides additional information for operating the HE BSS. The parameter is present if dot11HEOptionImplemented is true; otherwise, it is not present. |
| UORA Parameter Set(11ax) | As defined in UORA Parameter Set element | As defined in 9.4.2.249 (UORA Parameter Set element(11ax)) | Indicates the metrics of the OFDMA-based random access mechanism. The parameter is optionally present if dot11OFDMARandomAccessOptionImlemented is true; otherwise, it is not present. |
| MU EDCA Parameter Set(11ax) | As defined in MU EDCA Parameter Set element | As defined in 9.4.2.250 (MU EDCA Parameter Set element(11ax)) | Indicates MU EDCA parameters. The parameter is optionally present if dot11HEOptionImplemented is true; otherwise, it is not present. |

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| Name | Type | Valid range | Description |
|---|---|---|---|
| Spatial Reuse Parameter Set(11ax) | As defined in Spatial Reuse Parameter Set element | As defined in 9.4.2.251 (Spatial Reuse Parameter Set element(11ax)) | Indicates parameters needed by STAs when performing OBSS PD-based spatial reuse. The parameter is optionally present if dot11HEOptionImplemented is true; otherwise, it is not present. |
| NDP Feedback Report Parameter Set(11ax) | As defined in NDP Feedback Report Parameter Set element | As defined in 9.4.2.252 (NDP Feedback Report Parameter Set element(11ax)) | Indicates NDP Feedback Report parameter values. The parameter is optionally present if dot11HEOptionImplemented is true; otherwise, it is not present. |
| BSS Color Change Announcement(11ax) | As defined in BSS Color Change Announcement element | As defined in 9.4.2.253 (BSS Color Change Announcement element(11ax)) | Indicates information on BSS Color Change. The parameter is optionally present if dot11HEOptionImplemented is true; otherwise, it is not present. |
| ESS Report(11ax) | As defined in ESS Report element | As defined in 9.4.2.255 (ESS Report element(11ax)) | Provides information on ESS to assist BSS transition. The parameter is optionally present. |
| EDMG Capabilities(11ay) | EDMG Capabilities element | As defined in 9.4.2.264 (EDMG Capabilities element(11ay)) | Specifies the parameters within the EDMG Capabilities element that are supported by the MAC entity. The parameter is present if dot11EDMGOptionImplemented is true and is absent otherwise. |
| EDMG Operation(11ay) | EDMG Operation element | As defined in 9.4.2.265 (EDMG Operation element(11ay)) | Specifies the parameters within the EDMG Operation element that are used in the BSS. The parameter is present if dot11EDMGOptionImplemented is true and is absent otherwise. |
| QoS Triggered Unscheduled(11ay) | QoS Triggered Unscheduled element | As defined in 9.4.2.277 (QoS-TU element(#1776)(11ay)) | Specifies the parameters within the QoS Triggered Unscheduled element that are supported by the MAC entity. The parameter is present if dot11EDMGOptionImplemented is true and is absent otherwise. |
| Unsolicited Block Ack Extension(11ay) | Unsolicited Block Ack Extension element | As defined in 9.4.2.278 (Unsolicited Block Ack Extension element(11ay)) | Specifies the parameters within the Unsolicited Block Ack Extension element that are supported by the MAC entity. Optionally present if dot11UnsolicitedBAActivated is true and is absent otherwise. |
| TDD Slot Structure(11ay) | TDD Slot Structure element | As defined in 9.4.2.280 (TDD Slot Structure element(11ay)) | Present if dot11TDDOptionImplemented is true and absent otherwise. Specifies the parameters within the TDD Slot Structure element corresponding to a target STA. |
| TDD Slot Schedule(11ay) | TDD Slot Schedule element | As defined in 9.4.2.281 (TDD Slot Schedule element(11ay)) | Present if dot11TDDOptionImplemented is true and absent otherwise. Specifies the TDD slot schedule of the STA. |
| WUR Capabilities(11ba) | As defined in WUR Capabilities element | As defined in 9.4.2.290 (WUR Capabilities element(11ba)) | Specifies the parameters within the WUR Capabilities element that are supported by the WUR AP. The parameter is present if dot11WUROptionImplemented is true; otherwise, this parameter is not present. |


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| Name | Type | Valid range | Description |
|---|---|---|---|
| WUR Operation(11ba) | As defined in WUR Operation element | As defined in 9.4.2.291 (WUR Operation element(11ba)) | Provides additional information for WUR operation. The parameter is present if dot11WUROptionImplemented is true; otherwise not present. |
| WUR Mode(11ba) | As defined in WUR Mode element | As defined in 9.4.2.292 (WUR Mode element(11ba)) | Specifies the proposed service parameters for the WUR Mode Setup request. The parameter is present if dot11WUROptionImplemented is true and the WUR Mode element is present in the Reassociation Response frame received from the AP; otherwise, this parameter is not present. |
| Diffie-Hellman Parameter(#1084) | Diffie-Hellman Parameter element | (#6088)As defined in 9.4.2.312 (Diffie-Hellman Parameter element(#6088)) | Provides a public key for the AP from the Reassociation Response frame that is used in the OWE exchange. Present if OWE is being performed; otherwise it is not present. |
| VendorSpecificInfo | A set of elements | As defined in 9.4.2.24 (Vendor Specific element) | Zero or more elements. |

#### 6.5.8.3.3 When generated

This primitive is generated by the MLME as a result of an MLME-REASSOCIATE.request primitive to reassociate with a specified peer MAC entity that is in an AP or PCP.

#### 6.5.8.3.4 Effect of receipt

The SME is notified of the results of the reassociation procedure.

### 6.5.8.4 MLME-REASSOCIATE.indication

#### 6.5.8.4.1 Function

This primitive indicates that a specific peer MAC entity is requesting reassociation with the local MAC entity, which is in an AP or PCP.

#### 6.5.8.4.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-REASSOCIATE.indication(
                                    PeerSTAAddress,
                                    CurrentAPAddress,
                                    CapabilityInformation,
                                    BSSMaxIdlePeriod,
                                    ListenInterval,
                                    SSID,
                                    OperationalRateSet,
                                    BSSMembershipSelectorSet,
                                    RSN,
                                    QoSCapability,
                                    RCPI,
                                    RSNI,
                                    RMEnabledCapabilities,
```

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Content of FT Authentication elements,
SupportedOperatingClasses,
DSERegisteredLocation,
HT Capabilities,
Extended Capabilities,
20/40 BSS Coexistence,
QoSTrafficCapability,
TIMBroadcastRequest,
FMSRequest,
DMSRequest,
EmergencyServices,
DMG Capabilities,
Multi-band local,
Multi-band peer,
MMS,
VHT Capabilities,
FILSHLPContainer,
FILSIPAddressAssignment,
AID Request,
S1G Capabilities,
TWT,
Sectorized Group ID List,
MaxAwayDuration,
S1GRelayActivaton,
ELOperation,
S1GRelay,
HeaderCompression,
ReachableAddress,
S1GOperation,
SSTOperation,
CDMG Capabilities,
CMMG Capabilities,
GLK-GCR Parameter Set,
MSCS Descriptor,
HE Capabilities,(11ax)
HE 6 GHz Band Capabilities,(11ax)
Channel Switch Timing,(11ax)
UL MU Power Capabilities,(11ax)
EDMG Capabilities,(11ay)
QoS Triggered Unscheduled,(11ay)
Unsolicited Block Ack Extension,(11ay)
TDD Slot Schedule,(11ay)
WUR Capabilities,(11ba)
WUR Mode,(11ba)
Diffie-Hellman Parameter,(#1084)
VendorSpecificInfo
)

| Name | Type | Valid range | Description |
|---|---|---|---|
| PeerSTAAddress | MAC address | (#1653)Any valid individual address | Specifies the address of the peer MAC entity from which the reassociation request was received. |
| CurrentAPAddress | MAC address | (#1653)Any valid individual address | Specifies the address of the AP or PCP with which the peer STA is currently associated. |


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| Name | Type | Valid range | Description |
|---|---|---|---|
| Capability-Information | Capability Information field | As defined in 9.4.1.4 (Capability Information field) | Specifies the operational capability definitions provided by the peer MAC entity as part of the reassociation request. |
| BSSMaxIdlePeriod | BSS Max Idle Period element | As defined in 9.4.2.77 (BSS Max Idle Period element) | (#1365)Indicates the preferred BSS max idle period parameters. This parameter is present if the BSS Max Idle Period element was present in the Reassociation Request frame and if dot11WirelessManagementImplemented and dot11BSSMaxIdlePeriodIndicationByNonAPSTA are true, or dot11S1GOptionImplemented is true; is not present otherwise. |
| ListenInterval | Integer | ≥ 0 | Specifies the listen interval provided by the peer MAC entity as part of the reassociation request. |
| SSID | Octet string | 0–32 octets | Specifies the desired SSID provided by the peer MAC entity as part of the reassociation request. |
| OperationalRateSet | Non-DMG BSS: Set of integers<br><br>DMG BSS: Set of numbers | Non-DMG BSS: 1–127 excluding values from Table 9-131 (BSS membership selector value encoding) for each member of the set<br><br>DMG BSS: 0–12, 9.1, 12.1–12.6, or 25–31, for each member of the set | The set of data rates (in units of 500 kb/s) that the STA that is requesting association is able to use for communication within the BSS. The STA is able to receive at each of the data rates listed in the set. This set is a superset of the rates contained in the BSSBasicRateSet parameter.<br><br>DMG BSS: The set of MCS (#4136)indices that the AP or PCP uses for communication within the BSS. |
| BSSMembershipSelectorSet | Set of integers | A value from Table 9-131 (BSS membership selector value encoding), for each member of the set | The set of features that the STA that is requesting association is able to use for communication. |
| RSN | RSNE | As defined in 9.4.2.23 (RSNE) | A description of the cipher suites and AKM suites selected by the STA. |
| QoSCapability | QoS Capability element | As defined in 9.4.2.33 (QoS Capability element) | Specifies the parameters within the QoS Capability that are supported by the peer MAC entity. The parameter is present if dot11QosOptionImplemented is true; otherwise not present. |
| RCPI | Integer | As defined in 9.4.2.36 (RCPI element) | The RCPI value represents the measured RCPI (#14)of the received PPDU containing the corresponding Reassociation Request frame. The element is optionally present if dot11RMRCPIMeasurementActivated is true; otherwise not present. |
| RSNI | Integer | As defined in 9.4.2.39 (RSNI element) | (#1236)The RSNI value represents the measured RSNI (#14)of the received PPDU containing the corresponding Reassociation Request frame. The element is optionally present if dot11RMRSNIMeasurementActivated is true; otherwise not present. |

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| Name | Type | Valid range | Description |
|---|---|---|---|
| RMEnabledCapabilities | RM Enabled Capabilities element | As defined in 9.4.2.43 (RM Enabled Capabilities element) | Specifies the RM enabled capabilities advertised by the AP or PCP. The element is present if dot11RadioMeasurementActivated is true; otherwise not present. |
| Content of FT Authentication elements | Sequence of elements | As defined in 13.8 (FT authentication sequence) | The set of elements included in the third message of the FT authentication sequence, as described in 13.8.4 (FT authentication sequence: contents of third message). Present if dot11FastBSSTransitionActivated is true; otherwise not present. |
| SupportedOperatingClasses | As defined in the Supported Operating Classes element | As defined in 9.4.2.52 (Supported Operating Classes element) | Indicates the supported operating classes of the STA. This parameter is optionally present if dot11ExtendedChannelSwitchActivated or dot11OperatingClassesRequired is true; otherwise not present. |
| DSERegisteredLocation | As defined in the DSE Registered Location element | As defined in 9.4.2.50 (DSE Registered Location element) | Indicates the DSE registered location including the dependent enablement identifier assigned by the enabling STA. This parameter is optionally present if dot11LCIDSERequired is true; otherwise not present. |
| HT Capabilities | As defined in frame format | As defined in 9.4.2.54 (HT Capabilities element) | Specifies the parameters within the HT Capabilities element that are supported by the MAC entity.<br>The parameter is optionally present if dot11HighThroughputOptionImplemented is true. |
| Extended Capabilities | As defined in frame format | As defined in 9.4.2.25 (Extended Capabilities element) | Specifies the parameters within the Extended Capabilities element that are supported by the MAC entity. |
| 20/40 BSS Coexistence | As defined in frame format | As defined in 9.4.2.58 (20/40 BSS Coexistence element) | Specifies the parameters within the 20/40 BSS Coexistence element that are indicated by the MAC entity.<br>The parameter is present if dot112040BSSCoexistenceManagementSupport is true. |
| QoS Traffic Capability | As defined in the QoS Traffic Capability element | As defined in 9.4.2.76 (QoS Traffic Capability element) | Specifies the (#403)QoS traffic capability flags of the non-AP and non-PCP STA. This parameter is optionally present if dot11ACStationCountActivated is true and is not present otherwise. |
| TIMBroadcastRequest | As defined in TIM Broadcast Request element | As defined in 9.4.2.81 (TIM Broadcast Request element) | Specifies the proposed service parameters for TIM Broadcast. This parameter is optionally present if dot11TIMBroadcastActivated is true and is not present otherwise. |
| FMSRequest | As defined in FMS Request element | As defined in 9.4.2.74 (FMS Request element) | Specifies the proposed multicast parameters for the FMS request procedure(#238). This parameter is optionally present if dot11FMSActivated is true and is not present otherwise. |
| DMSRequest | Sequence of DMS Request elements | As defined in 9.4.2.86 (DMS Request element) | Specifies the proposed multicast parameters for DMS Request. This parameter is optionally present if dot11DMSActivated is true and is not present otherwise. |


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| Name | Type | Valid range | Description |
|---|---|---|---|
| EmergencyServices | Boolean | true, false | Specifies the setting of the UESA field received from the non-AP and non-PCP STA, if an Interworking element was present in the Reassociation Request frame. The parameter is present if dot11InterworkingServiceActivated is true; otherwise not present. |
| DMG Capabilities | DMG Capabilities element | As defined in 9.4.2.126 (DMG Capabilities element) | Specifies the parameters within the DMG Capabilities element that are supported by the MAC entity. The parameter is present if dot11DMGOptionImplemented is true and is absent otherwise. |
| Multi-band local | Multi-band element | As defined in 9.4.2.137 (Multi-band element) | Specifies the parameters within the Multi-band element that identify the local MAC entity. The parameter is present if dot11MultibandImplemented is true and is absent otherwise. |
| Multi-band peer | Multi-band element | As defined in 9.4.2.137 (Multi-band element) | Specifies the parameters within the Multi-band element that are supported by the peer MAC entity. This parameter is present if OCT is being used and is absent otherwise. |
| MMS | Multiple MAC Sublayers element | As defined in 9.4.2.151 (MMS element(#1776)) | Specifies the parameters within the Multiple MAC Sublayers element that are supported by the MAC entity. The parameter is present if dot11MultipleMACActivated is true and is absent otherwise. |
| VHT Capabilities | As defined in VHT Capabilities element | As defined in 9.4.2.156 (VHT Capabilities element) | Specifies the parameters in the VHT Capabilities element that are supported by the STA. The parameter is present if dot11VHTOptionImplemented is true and the VHT Capabilities element is present in the Reassociation Request frame received from the STA. The parameter is not present otherwise. |
| FILSHLPContainer | As defined in 9.4.2.182 (FILS HLP Container element) | As defined in 9.4.2.182 (FILS HLP Container element) | A set of elements containing encapsulated data of higher layer protocol frames (e.g., a DHCP message) that is transported in FILS reassociation. The parameter is optionally present if dot11FILSActivated is true; otherwise not present. |
| FILSIPAddressAssignment | As defined in 9.4.2.183 (FILS IP Address Assignment element) | As defined in 9.4.2.183 (FILS IP Address Assignment element) | An explicit request for an IP address. The request may be for a new IP address or a specified IP address. The parameter is optionally present if dot11FILSActivated is true; otherwise not present. |
| AID Request | AID Request element | As defined in 9.4.2.192 (AID Request element) | Indicates the device characteristic of the non-AP STA requesting AID assignment. This parameter is optionally present if dot11S1GOptionImplemented is true; otherwise not present. |
| S1G Capabilities | As defined in frame format | As defined in 9.4.2.199 (S1G Capabilities element) | Specifies the parameters in the S1G Capabilities element that are supported by the STA. The parameter is present if dot11S1GOptionImplemented is true and the S1G Capabilities element is present in the Reassociation Request frame received from the STA; otherwise not present. |

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| Name | Type | Valid range | Description |
|---|---|---|---|
| TWT | TWT element | As defined in 9.4.2.198 (TWT element) | Specifies the parameters in the TWT element.<br>This parameter is optionally present if dot11TWTOptionActivated is true; otherwise not present. |
| Sectorized Group ID List | Sectorized Group ID List element | As defined in 9.4.2.210 (Sectorized Group ID List element) | Specifies the parameters in the Sectorized Group ID List element.<br>This parameter is optionally present if dot11S1GSectorizationActivated is true; otherwise not present. |
| MaxAwayDuration | Integer | 0–65 535 | Indicates the maximum duration, in TUs, that the AP is unavailable for communications with the STA.<br>The parameter is optionally present if dot11MaxAwayDuration is nonzero; otherwise not present. |
| S1GRelayActivation | S1G Relay Activation element | As defined in 9.4.2.205 (S1G Relay Activation element) | (#221)Indicates if a STA with dot11RelaySTAImplemented equal to true requests to operate as a relay (in a request) and an AP with dot11RelayAPImplemented equal to true requests/confirms operation as a relay.<br>The parameter is optionally present if dot11RelaySTAImplemented is true; otherwise not present. |
| ELOperation | EL Operation element | As defined in 9.4.2.209 (EL Operation element) | The EL Operation element is optionally present if dot11S1GELOperationActivated is true; otherwise not present. |
| S1GRelay | S1G Relay element | As defined in 9.4.2.203 (S1G Relay element) | Specifies the parameters within the S1G Relay element that are supported by the MAC entity.<br>The parameter is present if dot11RelaySTAImplemented is true; otherwise not present. |
| HeaderCompression | Header Compression element | As defined in 9.4.2.212 (Header Compression element) | The Header Compression element is present if dot11PV1MACHeaderOptionImplemented is true; otherwise not present. |
| ReachableAddress | Reachable Address element | As defined in 9.4.2.204 (Reachable Address element) | The Reachable Address element is optionally present if dot11RelaySTAImplemented is true; otherwise not present. |
| S1GOperation | S1G Operation element | As defined in 9.4.2.211 (S1G Operation element) | The S1G Operation element is present if dot11S1GOptionImplemented is true; otherwise not present. |
| SSTOperation | SST Operation element | As defined in 9.4.2.213 (SST Operation element) | The SST Operation element is optionally present if dot11SelectiveSubchannelTransmissionPermitted is true; otherwise not present. |
| CDMG Capabilities | CDMG Capabilities element | As defined in 9.4.2.218 (CDMG Capabilities element) | Specifies the parameters within the CDMG Capabilities element that are supported by the MAC entity.<br>The parameter is present if dot11CDMGOptionImplemented is true; otherwise not present. |


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| Name | Type | Valid range | Description |
|---|---|---|---|
| CMMG Capabilities | CMMG Capabilities element | As defined in 9.4.2.228 (CMMG Capabilities element) | Specifies the parameters within the CMMG Capabilities element that are supported by the MAC entity.<br>The parameter is present if dot11CMMGOptionImplemented is true; otherwise not present. |
| GLK-GCR Parameter Set | GLK-GCR Parameter Set element | As defined in 9.4.2.233 (GLK-GCR Parameter Set element) | The GLK-GCR Parameter Set element from the received Reassociation Request frame. |
| MSCS Descriptor | As defined in the MSCS Descriptor element | As defined in 9.4.2.242 (MSCS Descriptor element) | The parameters used to classify streams using the procedures defined in 11.25.3 (MSCS procedures). Optionally present if dot11MSCSActivated is true; otherwise not present. |
| HE Capabilities(11ax) | As defined in HE Capabilities element. | As defined in 9.4.2.247 (HE Capabilities element(11ax)) | Specifies the parameters within the HE Capabilities element that are supported by the peer STA. The parameter is present if dot11HEOptionImplemented is true and the HE Capabilities element is present in the Reassociation Request frame received from the STA; otherwise, this parameter is not present. |
| HE 6 GHz Band Capabilities(11ax) | As defined in HE 6 GHz Band Capabilities element | As defined in 9.4.2.262 (HE 6 GHz Band Capabilities element(11ax)) | Specifies the parameters within the HE 6 GHz Band Capabilities element that are supported by the STA. The parameter is present if dot11HE6GOptionImplemented is true and the HE 6 GHz Band Capabilities element is present in the Reassociation Request frame received from the STA; otherwise, this parameter is not present. |
| Channel Switch Timing(11ax) | As defined in the Channel Switch Timing element | As defined in 9.4.2.62 (Channel Switch Timing element) | Provides information regarding the channel switch timing. The parameter is optionally present if dot11HESubchannelSelectiveTransmission Implemented is true and the Channel Switch Timing element is present in the Reassociation Request frame received from the STA; otherwise, it is not present. |
| UL MU Power Capabilities(11ax) | As defined in UL MU Power Capabilities element | As defined in 9.4.2.263 (UL MU Power Capabilities element(11ax)) | Provides information regarding the UL MU power capabilities for the non-AP STA. The UL MU Power Capabilities element is present if dot11HEOptionImplemented is true and the HE Capabilities element and UL MU Power Capabilities element is present in the Association Request frame received from the STA; otherwise, it is not present. |
| EDMG Capabilities(11ay) | EDMG Capabilities element | As defined in 9.4.2.264 (EDMG Capabilities element(11ay)) | Specifies the parameters within the EDMG Capabilities element that are supported by the MAC entity. The parameter is present if dot11EDMGOptionImplemented is true and is absent otherwise. |
| QoS Triggered Unscheduled(11ay) | QoS Triggered Unscheduled element | As defined in 9.4.2.277 (QoS-TU element(#1776)(11ay)) | Specifies the parameters within the QoS Triggered Unscheduled element that are supported by the MAC entity. The parameter is present if dot11EDMGOptionImplemented is true and is absent otherwise. |

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| Name | Type | Valid range | Description |
|---|---|---|---|
| Unsolicited Block Ack Extension(11ay) | Unsolicited Block Ack Extension element | As defined in 9.4.2.278 (Unsolicited Block Ack Extension element(11ay)) | Specifies the parameters within the Unsolicited Block Ack Extension element that are supported by the MAC entity. Optionally present if dot11UnsolicitedBAActivated is true and is absent otherwise. |
| TDD Slot Schedule(11ay) | TDD Slot Schedule element | As defined in 9.4.2.281 (TDD Slot Schedule element(11ay)) | Present if dot11TDDOptionImplemented is true and absent otherwise. Specifies the TDD slot schedule of the STA. |
| WUR Capabili-ties(11ba) | As defined in WUR Capabilities element | As defined in 9.4.2.290 (WUR Capabilities ele-ment(11ba)) | Specifies the parameters within the WUR Capabilities element that are supported by the peer STA. The parameter is present if it is present in the Association Request frame received from the STA; otherwise, this parameter is not present. |
| WUR Mode(11ba) | As defined in WUR Mode element | As defined in 9.4.2.292 (WUR Mode ele-ment(11ba)) | Specifies the proposed service parameters for the WUR Mode Setup request. The parameter is present if dot11WUROptionImplemented is true and the WUR Mode element is present in the Reassociation Request frame received from the STA; otherwise, this parameter is not present. |
| Diffie-Hellman Parameter(#1084) | Diffie-Hellman Parameter element | (#6088)As defined in 9.4.2.312 (Diffie-Hellman Parameter element(#6088)) | Provides a public key from the peer MAC entity for use in the OWE exchange. Pres-ent if OWE is being performed; otherwise it is not present. |
| VendorSpecificInf o | A set of elements | As defined in 9.4.2.24 (Vendor Specific element) | Zero or more elements. |

#### 6.5.8.4.3 When generated

This primitive is generated by the MLME as a result of the establishment of a reassociation with a specific peer MAC entity that resulted from a reassociation procedure that was initiated by that specific peer MAC entity.

#### 6.5.8.4.4 Effect of receipt

The SME is notified of the establishment of the reassociation.

### 6.5.8.5 MLME-REASSOCIATE.response

#### 6.5.8.5.1 Function

This primitive is used to send a response to a specific peer MAC entity that requested a reassociation with the STA that issued this primitive, which is in an AP or PCP.

#### 6.5.8.5.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-REASSOCIATE.response(
PeerSTAAddress,
ResultCode,


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AssociationID,
RCPI,
RSNI,
RMEnabledCapabilities,
Content of FT Authentication elements,
SupportedOperatingClasses,
TimeoutInterval,(#445)
TIMBroadcastResponse,
FMSResponse,
DMSResponse,
QoSMapSet,
Multi-band local,
Multi-band peer,
MMS,
FILSHLPContainer,
FILSIPAddressAssignment,
KeyDelivery,
S1G Sector Operation,
S1G Capabilities,
AID Response,
TSF Timer Accuracy,
TWT,
Sectorized Group ID List,
MaxAwayDuration,
S1GRelay,
S1GRelayActivation,
S1GOperation,
HeaderCompression,
SSTOperation,
CDMG Capabilities,
CMMG Capabilities,
GLK-GCR Parameter Set,
MSCS Descriptor,
HE Capabilities,(11ax)
HE 6 GHz Band Capabilities,(11ax)
HE Operation,(11ax)
UORA Parameter Set,(11ax)
MU EDCA Parameter Set,(11ax)
Spatial Reuse Parameter Set,(11ax)
NDP Feedback Report Parameter Set,(11ax)
BSS Color Change Announcement,(11ax)
ESS Report,(11ax)
EDMG Capabilities,(11ay)
EDMG Operation,(11ay)
QoS Triggered Unscheduled,(11ay)
Unsolicited Block Ack Extension,(11ay)
TDDSlotStructure,(11ay)
TDD Slot Schedule,(11ay)
WUR Capabilities,(11ba)
WUR Operation,(11ba)
WUR Mode,(11ba)
Diffie-Hellman Parameter,(#1084)
VendorSpecificInfo
)

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| Name | Type | Valid range | Description |
|---|---|---|---|
| PeerSTAAddress | MAC address | (#1653)Any valid individual address | Specifies the address of the peer MAC entity from which the reassociation request was received. |
| ResultCode | Enumeration | SUCCESS, REFUSED_REASON_UNSPECIFIED, REFUSED_CAPABILITIES_MISMATCH, REFUSED_EXTERNAL_REASON, REFUSED_AP_OUT_OF_MEMORY, REFUSED_BASIC_RATES_MISMATCH, REJECTED_EMERGENCY_SERVICES_NOT_SUPPORTED, REFUSED_TEMPORARILY | Indicates the result response to the reassociation request from the peer MAC entity. |
| AssociationID | Integer | Non-DMG: 1–2007<br>DMG: 1–254 | If the reassociation request result was SUCCESS, then AssociationID specifies the association ID value assigned to the peer MAC entity by the AP or PCP. This parameter is not present if dot11S1GOptionImplemented is true. |
| RCPI | Integer | As defined in 9.4.2.36 (RCPI element) | The RCPI value represents the measured RCPI (#14)of the received PPDU containing the corresponding Reassociation Request frame. The element is optionally present if dot11RMRCPIMeasurementActivated is true; otherwise not present. |
| RSNI | Integer | As defined in 9.4.2.39 (RSNI element) | The RSNI value represents the measured RSNI (#14)of the received PPDU containing the corresponding Reassociation Request frame(#6106). The element is optionally present if dot11RMRSNIMeasurementActivated is true; otherwise not present. |
| RMEnabledCapabilities | RM Enabled Capabilities element | As defined in 9.4.2.43 (RM Enabled Capabilities element) | Specifies the RM enabled capabilities advertised by the AP or PCP. The element is present if dot11RadioMeasurementActivated is true; otherwise not present. |
| Content of FT Authentication elements | Sequence of elements | As defined in 13.8 (FT authentication sequence) | The set of elements to be included in the fourth message of the FT authentication sequence, as described in 13.8.5 (FT authentication sequence: contents of fourth message). This includes an optional response to a resource request (RIC). Present if dot11FastBSSTransitionActivated is true; otherwise not present. |
| SupportedOperatingClasses | As defined in the Supported Operating Classes element | As defined in 9.4.2.52 (Supported Operating Classes element) | Specifies the supported operating classes of the AP or PCP. This parameter is present if dot11ExtendedChannelSwitchActivated or dot11OperatingClassesRequired is true; otherwise not present. |


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| Name | Type | Valid range | Description |
|---|---|---|---|
| TimeoutInterval | (#1776)TIE, as defined in frame format | As defined in 9.4.2.47 (TIE(#1776)) | This parameter is present when ResultCode is REFUSED_TEMPORARILY.(#445) |
| TIMBroadcastResponse | As defined in TIM Broadcast Response element | As defined in 9.4.2.82 (TIM Broadcast Response element) | Specifies the service parameters for TIM Broadcast. This parameter is optionally present if dot11TIMBroadcastActivated is true and the TIM Broadcast Request element is present in the corresponding Association Request frame; this parameter is not present otherwise. |
| FMSResponse | As defined in FMS Response element | As defined in 9.4.2.75 (FMS Response element) | Specifies the multicast parameters for FMS Response. This parameter is optionally present if dot11FMSActivated is true and the FMS Request element is present in the corresponding Association Request frame; this parameter is not present otherwise. |
| DMSResponse | Sequence of DMS Response elements | As defined in 9.4.2.87 (DMS Response element) | Specifies the multicast parameters for DMS Response. This parameter is optionally present if dot11DMSActivated is true and the DMS Request element is present in the corresponding Association Request frame; this parameter is not present otherwise. |
| QoSMapSet | As defined in frame format | As defined in 9.4.2.93 (QoS Map element) | Specifies the QoS Map the non-AP and non-PCP STA should use. |
| Multi-band local | Multi-band element | As defined in 9.4.2.137 (Multi-band element) | Specifies the parameters within the Multi-band element that are supported by the local MAC entity. The parameter is present if dot11MultibandImplemented is true and is absent otherwise. |
| Multi-band peer | Multi-band element | As defined in 9.4.2.137 (Multi-band element) | Specifies the parameters within the Multi-band element that are used to deliver messages to the peer MAC entity. The parameter is present if OCT is being used and is absent otherwise. |
| MMS | Multiple MAC Sublayers element | As defined in 9.4.2.151 (MMS element(#1776)) | Specifies the parameters within the Multiple MAC Sublayers element that are supported by the MAC entity, and negotiated for the association. The parameter is present if dot11MultipleMACActivated is true and is absent otherwise. |
| FILSHLPContainer | As defined in 9.4.2.182 (FILS HLP Container element) | As defined in 9.4.2.182 (FILS HLP Container element) | A set of elements containing encapsulated data of higher layer protocol frames (e.g., a DHCP message) that is transported in FILS reassociation. The parameter is optionally present if dot11FILSActivated is true; otherwise not present. |
| FILSIPAddressAssignment | As defined in 9.4.2.183 (FILS IP Address Assignment element) | As defined in 9.4.2.183 (FILS IP Address Assignment element) | The IP address of a network layer entity associated with the STA. The parameter is optionally present if dot11FILSActivated is true; otherwise not present. |

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| Name | Type | Valid range | Description |
|---|---|---|---|
| KeyDelivery | As defined in 9.4.2.184 (Key Delivery element) | As defined in 9.4.2.184 (Key Delivery element) | (#1406)KDE(s) and the current GTK RSC. The parameter is present if dot11FILSActivated is true; otherwise not present. |
| S1G Sector Operation | S1G Sector Operation element | As defined in 9.4.2.194 (S1G Sector Operation element) | Specifies the sectorization scheme, period, subperiod sector intervals, and sector training. |
| S1G Capabilities | As defined in frame format | As defined in 9.4.2.199 (S1G Capabilities element) | Specifies the parameters in the S1G Capabilities element that are supported by the STA. The parameter is present if dot11S1GOptionImplemented is true; otherwise not present. |
| AID Response | AID Response element | As defined in 9.4.2.193 (AID Response element) | Parameters describing an AID assignment.<br>This parameter is present if dot11S1GOptionImplemented is true; otherwise not present. |
| TSF Timer Accuracy | TSF Timer Accuracy element | As defined in 9.4.2.202 (TSF Timer Accuracy element) | Indicates the information about the TSF timer accuracy. The parameter is optionally present if dot11TSFTimerAccuracyImplemented is true; otherwise not present. |
| TWT | TWT element | As defined in 9.4.2.198 (TWT element) | Specifies the parameters in the TWT element.<br>This parameter is optionally present if dot11TWTOptionActivated is true and the TWT element is present in the Reassociation Request frame that elicited the Reassociation Response frame or the TWT Requester Support field in the HE Capabilities element in the Reassociation Request frame that elicited the Reassociation Response frame is 1;(11ax) otherwise not present. |
| Sectorized Group ID List | Sectorized Group ID List element | As defined in 9.4.2.210 (Sectorized Group ID List element) | Specifies the parameters in the Sectorized Group ID List element.<br>This parameter is optionally present if dot11S1GSectorizationActivated is true; otherwise not present. |
| MaxAwayDuration | Integer | 0–65 535 | Indicates the maximum duration, in TUs, that the AP is unavailable for communications with the STA.<br>The parameter is optionally present if dot11MaxAwayDuration is nonzero; otherwise not present. |
| S1GRelay | S1G Relay element | As defined in 9.4.2.203 (S1G Relay element) | Indicates the support of the relay operation by the STA transmitting the element. |
| S1GRelayActivation | S1G Relay Activation element | As defined in 9.4.2.205 (S1G Relay Activation element) | (#221)Indicates if a STA with dot11RelaySTAImplemented equal to true requests to operate as a relay (in a request) and an AP with dot11RelayAPImplemented equal to true requests/confirms operation as a relay.<br>The parameter is optionally present if dot11RelaySTAImplemented is true; otherwise not present. |


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| Name | Type | Valid range | Description |
|---|---|---|---|
| S1GOperation | S1G Operation element | As defined in 9.4.2.211 (S1G Operation element) | Provides additional information for operating the S1G BSS. The parameter is present if dot11S1GOptionImplemented is true; otherwise not present. |
| HeaderCompression | Header Compression element | As defined in 9.4.2.212 (Header Compression element) | The Header Compression element is present if dot11PV1MACHeaderOptionImplemented is true; otherwise not present. |
| SSTOperation | SST Operation element | As defined in 9.4.2.213 (SST Operation element) | The SST Operation element is optionally present if dot11SelectiveSubchannelTransmissionPermitted is true; otherwise not present. |
| CDMG Capabilities | CDMG Capabilities element | As defined in 9.4.2.218 (CDMG Capabilities element) | Specifies the parameters within the CDMG Capabilities element that are supported by the MAC entity.<br>The parameter is present if dot11CDMGOptionImplemented is true; otherwise not present. |
| CMMG Capabilities | CMMG Capabilities element | As defined in 9.4.2.228 (CMMG Capabilities element). | Specifies the parameters within the CMMG Capabilities element that are supported by the MAC entity.<br>The parameter is present if dot11CMMGOptionImplemented is true; otherwise not present. |
| GLK-GCR Parameter Set | GLK-GCR Parameter Set element | As defined in 9.4.2.233 (GLK-GCR Parameter Set element) | This parameter is present only if the AP selects (#1653)GLK-GCR for group transmissions (either unsolicited retry or block ack) over the general link. Describes the parameters that define how GLK-GCR operates. |
| MSCS Descriptor | As defined in the MSCS Descriptor element | As defined in 9.4.2.242 (MSCS Descriptor element) | The parameters used to classify streams using the procedures defined in 11.25.3 (MSCS procedures). Optionally present if dot11MSCSActivated is true; otherwise not present. |
| HE Capabilities(11ax) | As defined in HE Capabilities element | As defined in 9.4.2.247 (HE Capabilities element(11ax)) | Specifies the parameters within the HE Capabilities element that are supported by the STA. The parameter is present if dot11HEOptionImplemented is true; otherwise, this parameter is not present. |
| HE 6 GHz Band Capabilities(11ax) | As defined in HE 6 GHz Band Capabilities element | As defined in 9.4.2.262 (HE 6 GHz Band Capabilities element(11ax)) | Specifies the parameters within the HE 6 GHz Band Capabilities element that are supported by the STA. The parameter is present if dot11HE6GOptionImplemented is true; otherwise, this parameter is not present. |
| HE Operation(11ax) | As defined in HE Operation element | As defined in 9.4.2.248 (HE Operation element(11ax)) | Provides additional information for operating the HE BSS. The parameter is present if dot11HEOptionImplemented is true; otherwise, it is not present. |
| UORA Parameter Set(11ax) | As defined in UORA Parameter Set element | As defined in 9.4.2.249 (UORA Parameter Set element(11ax)) | Indicates the metrics of the OFDMA-based random access mechanism. The parameter is optionally present if dot11OFDMARandomAccessOptionImlemented is true; otherwise, it is not present. |

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| Name | Type | Valid range | Description |
|---|---|---|---|
| MU EDCA Parameter Set(11ax) | As defined in MU EDCA Parameter Set element | As defined in 9.4.2.250 (MU EDCA Parameter Set element(11ax)) | Indicates MU EDCA parameters. The parameter is optionally present if dot11HEOptionImplemented is true; otherwise, it is not present. |
| Spatial Reuse Parameter Set(11ax) | As defined in Spatial Reuse Parameter Set element | As defined in 9.4.2.251 (Spatial Reuse Parameter Set element(11ax)) | Indicates parameters needed by STAs when performing OBSS PD-based spatial reuse. The parameter is optionally present if dot11HEOptionImplemented is true; otherwise, it is not present. |
| NDP Feedback Report Parameter Set(11ax) | As defined in NDP Feedback Report Parameter Set element | As defined in 9.4.2.252 (NDP Feedback Report Parameter Set element(11ax)) | Indicates NDP Feedback Report parameter values. The parameter is optionally present if dot11HEOptionImplemented is true; otherwise, it is not present. |
| BSS Color Change Announcement(11ax) | As defined in BSS Color Change Announcement element | As defined in 9.4.2.253 (BSS Color Change Announcement element(11ax)) | Indicates information on BSS Color Change. The parameter is optionally present if dot11HEOptionImplemented is true; otherwise, it is not present. |
| ESS Report(11ax) | As defined in ESS Report element | As defined in 9.4.2.255 (ESS Report element(11ax)) | Provides information on ESS to assist BSS transition. The parameter is optionally present. |
| EDMG Capabilities(11ay) | EDMG Capabilities element | As defined in 9.4.2.264 (EDMG Capabilities element(11ay)) | Specifies the parameters within the EDMG Capabilities element that are supported by the MAC entity. The parameter is present if dot11EDMGOptionImplemented is true and is absent otherwise. |
| EDMG Operation(11ay) | EDMG Operation element | As defined in 9.4.2.265 (EDMG Operation element(11ay)) | Specifies the parameters within the EDMG Operation element that are used in the BSS. The parameter is present if dot11EDMGOptionImplemented is true and is absent otherwise. |
| QoS Triggered Unscheduled(11ay) | QoS Triggered Unscheduled element | As defined in 9.4.2.277 (QoS-TU element(#1776)(11ay)) | Specifies the parameters within the QoS Triggered Unscheduled element that are supported by the MAC entity. The parameter is present if dot11EDMGOptionImplemented is true and is absent otherwise. |
| Unsolicited Block Ack Extension(11ay) | Unsolicited Block Ack Extension | As defined in 9.4.2.278 (Unsolicited Block Ack Extension element(11ay)) | Specifies the parameters within the Unsolicited Block Ack Extension element that are supported by the MAC entity. Optionally present if dot11UnsolicitedBAActivated is true and is absent otherwise. |
| TDDSlotStructure(11ay) | TDD Slot Structure element | As defined in 9.4.2.280 (TDD Slot Structure element(11ay)) | Present if dot11TDDOptionImplemented is true and absent otherwise. Specifies the parameters within the TDD Slot Structure element corresponding to a target STA. |
| TDD Slot Schedule(11ay) | TDD Slot Schedule element | As defined in 9.4.2.281 (TDD Slot Schedule element(11ay)) | Present if dot11TDDOptionImplemented is true and absent otherwise. Specifies the TDD slot schedule of the STA. |
| WUR Capabilities(11ba) | As defined in WUR Capabilities element | As defined in 9.4.2.290 (WUR Capabilities element(11ba)) | Specifies the parameters within the WUR Capabilities element that are supported by the STA. The parameter is present if dot11WUROptionImplemented is true; otherwise, this parameter is not present. |


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| Name | Type | Valid range | Description |
|---|---|---|---|
| WUR Operation(11ba) | As defined in WUR Operation element | As defined in 9.4.2.291 (WUR Operation element(11ba)) | Provides additional information for WUR operation. The parameter is present if dot11WUROptionImplemented is true; otherwise not present. |
| WUR Mode(11ba) | As defined in WUR Mode element | As defined in 9.4.2.292 (WUR Mode element(11ba)) | Specifies the proposed service parameters for the WUR Mode Setup request. The parameter is optionally present if dot11WUROptionImplemented is true; otherwise, this parameter is not present. |
| Diffie-Hellman Parameter(#1084) | Diffie-Hellman Parameter element | (#6088)As defined in 9.4.2.312 (Diffie-Hellman Parameter element(#6088)) | Provides a public key for the STA that issued this primitive, it is used in the OWE exchange. Present if OWE is being performed; otherwise it is not present. |
| VendorSpecificInfo | A set of elements | As defined in 9.4.2.24 (Vendor Specific element) | Zero or more elements. |

Additional parameters needed to perform the reassociation response procedure are not included in the primitive parameter list since the MLME already has that data (maintained as internal state).

#### 6.5.8.5.3 When generated

This primitive is generated by the SME of a STA that is in an AP or PCP as a response to an MLME-REASSOCIATE.indication primitive.

#### 6.5.8.5.4 Effect of receipt

This primitive initiates transmission of a response to the specific peer MAC entity that requested reassociation.

### 6.5.9 Disassociate

#### 6.5.9.1 MLME-DISASSOCIATE.request

#### 6.5.9.1.1 Function

This primitive requests disassociation with a specified peer MAC entity.

#### 6.5.9.1.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-DISASSOCIATE.request(
                                    PeerSTAAddress,
                                    ReasonCode,
                                    VendorSpecificInfo
                                    )
```

| Name | Type | Valid range | Description |
|---|---|---|---|
| PeerSTAAddress | MAC address | (#1653)(#3315)Any valid individual address, or the broadcast address | Specifies the address of the peer MAC entity (#4223)or entities with which to perform the disassociation process. |

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| | | | |
|---|---|---|---|
| ReasonCode | Reason Code field | As defined in 9.4.1.7 (Reason Code field) | Specifies the reason for initiating the disassociation procedure. |
| VendorSpecificInfo | A set of elements | As defined in 9.4.2.24 (Vendor Specific element) | Zero or more elements. |

#### 6.5.9.1.3 When generated

This primitive is generated by the SME for a STA to disassociate from a STA with which it has an association.

#### 6.5.9.1.4 Effect of receipt

This primitive initiates a disassociation procedure. The MLME subsequently issues an MLME-DISASSOCIATE.confirm primitive that reflects the results.

### 6.5.9.2 MLME-DISASSOCIATE.confirm

#### 6.5.9.2.1 Function

This primitive reports the results of a disassociation procedure with a specific peer MAC entity.

#### 6.5.9.2.2 Semantics of the service primitive

The primitive parameters are as follows:

(#3316)MLME-DISASSOCIATE.confirm(
ResultCode,
VendorSpecificInfo
)

| Name | Type | Valid range | Description |
|---|---|---|---|
| ResultCode | Enumeration | SUCCESS, INVALID_PARAMETERS | Indicates the result of the MLME-DISASSOCIATE.request primitive |
| VendorSpecificInfo | A set of elements | As defined in 9.4.2.24 (Vendor Specific element) | Zero or more elements. |

#### 6.5.9.2.3 When generated

This primitive is generated by the MLME as a result of an MLME-DISASSOCIATE.request primitive to (#2234)disassociate from a specified peer MAC entity.

#### 6.5.9.2.4 Effect of receipt

The SME is notified of the results of the disassociation procedure.

### 6.5.9.3 MLME-DISASSOCIATE.indication

#### 6.5.9.3.1 Function

This primitive reports disassociation with a specific peer MAC entity.


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#### 6.5.9.3.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-DISASSOCIATE.indication(
                                    PeerSTAAddress,
                                    ReasonCode,
                                    VendorSpecificInfo
                                    )
```

| Name | Type | Valid range | Description |
|---|---|---|---|
| PeerSTAAddress | MAC address | (#1653)Any valid individual address | Specifies the address of the peer MAC entity with which the association relationship was invalidated. |
| ReasonCode | Reason Code field | As defined in 9.4.1.7 (Reason Code field) | Specifies the reason the disassociation procedure was initiated. |
| VendorSpecificInfo | A set of elements | As defined in 9.4.2.24 (Vendor Specific element) | Zero or more elements. |

#### 6.5.9.3.3 When generated

This primitive is generated by the MLME as a result of the invalidation of an association relationship with a specific peer MAC entity.

#### 6.5.9.3.4 Effect of receipt

The SME is notified of the invalidation of the specific association relationship.

### 6.5.10 Reset

#### 6.5.10.1 Introduction

This mechanism supports the process of resetting the MAC.

#### 6.5.10.2 MLME-RESET.request

#### 6.5.10.2.1 Function

This primitive requests that the MAC entity be reset.

#### 6.5.10.2.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-RESET.request(
                                    STAAddress,
                                    SetDefaultMIB
                                    )
```

| Name | Type | Valid range | Description |
|---|---|---|---|

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| | | | |
|---|---|---|---|
| STAAddress | MAC address | (#1653)Any valid individual address | Specifies the MAC address that is to be used by the MAC entity that is being reset. This value can be used to provide a locally administered STA address. |
| SetDefaultMIB | Boolean | true, false | If true, all MIB attributes are set to their default values. The default values are implementation dependent.<br>If false, the MAC is reset, but all MIB attributes retain the values that were in place prior to the generation of the MLME-RESET.request primitive. |

#### 6.5.10.2.3 When generated

This primitive is generated by the SME to reset the MAC to initial conditions. The MLME-RESET.request primitive shall be used prior to use of the MLME-START.request primitive. The MLME-RESET.request primitive shall be used prior to the first use of the MLME-JOIN.request primitive, or any time a STA's state is to be reinitialized.

#### 6.5.10.2.4 Effect of receipt

This primitive sets the MAC to initial conditions, clearing all MAC variables to the default values. MIB attributes can be reset to their implementation dependent default values by setting the SetDefaultMIB flag to true.

If dot11OCBActivated is true and if the SetDefaultMIB parameter is false, MAC operation shall resume in less than 2 TU after the STAAddress parameter is changed.

### 6.5.11 Start

#### 6.5.11.1 Introduction

This mechanism supports the process of starting a new BSS or becoming a member of an MBSS.

#### 6.5.11.2 MLME-START.request

#### 6.5.11.2.1 Function

This primitive requests that the MAC entity start a new BSS or become a member of an MBSS.

#### 6.5.11.2.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-START.request(
SSID,
BSSType,
BeaconPeriod,
DTIMPeriod,
PHY parameter set,
IBSS parameter set,
NAVSyncDelay,
CapabilityInformation,
BSSBasicRateSet,
OperationalRateSet,
Country,
IBSS DFS Recovery Interval,
EDCAParameterSet,


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DSERegisteredLocation,
HT Capabilities,
HT Operation,
BSSMembershipSelectorSet,
Extended Capabilities,
20/40 BSS Coexistence,
Overlapping BSS Scan Parameters,
(#488)Multiple BSSID,
InterworkingInfo,
AdvertisementProtocolInfo,
RoamingConsortiumInfo,
Mesh ID,
Mesh Configuration,
QMFPolicy,
DMG Capabilities,
Multi-band,
MMS,
DMG Operation,
Clustering Control,
CBAP Only,
PCP Association Ready,
VHT Capabilities,
VHT Operation,
Known OUIs,
S1G Capabilities,
S1GOperation,
ShortBeaconPeriod,
ShortBeaconDTIMPeriod,
CDMG Capabilities,
CMMG Capabilities,
CMMG Operation,
ServiceHint,
ServiceHash,
HE Capabilities,(11ax)
HE 6 GHz Band Capabilities,(11ax)
HE Operation,(11ax)
EDMG Capabilities,(11ay)
EDMG Operation,(11ay)
Unsolicited Block Ack Extension,(11ay)
TDDSlotStructure,(11ay)
TDD Slot Schedule,(11ay)
WUR Capabilities,(11ba)
WUR Operation,(11ba)
WUR Discovery,(11ba)
VendorSpecificInfo
)

| Name | Type | Valid range | Description |
|---|---|---|---|
| SSID | Octet string | 0–32 octets | The SSID of the BSS. |
| BSSType | Enumeration | INFRASTRUCTURE, INDEPENDENT, MESH, PERSONAL | The type of the BSS. |

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| Name | Type | Valid range | Description |
|---|---|---|---|
| Beacon Period | Integer | ≥ 1 | The beacon period (in TU) of the BSS if the BSSType is not MESH, or of the mesh STA if the BSSType is MESH. |
| DTIM Period | Integer | As defined in 9.4.2.5 (TIM element) | The DTIM Period (in beacon periods) of the BSS if the BSSType is not MESH, or of the mesh STA if the BSSType is MESH. |
| PHY parameter sets | DSSS Parameter Set element | As defined in 9.4.2.4 (DSSS Parameter Set element) | The parameter sets relevant to the PHY. |
| IBSS parameter set | IBSS Parameter Set element | As defined in 9.4.2.6 (IBSS Parameter Set element) | The parameter set for the IBSS, if BSS is an IBSS. |
| NAVSyncDelay | Integer | ≥ 0(#3418) | Delay (in microseconds) to be used, while the STA is a member of this BSS, prior to transmitting when changing from doze to awake state and when changing channel(#2079), if no frame is detected by which the NAV can be set. |
| CapabilityInformation | Capability Information field | As defined in 9.4.1.4 (Capability Information field) | The STA capabilities to be advertised for the BSS. |
| BSSBasicRateSet | Set of integers | Non-DMG BSS: a value in both dot11SupportedDataRatesRxTable and dot11SupportedDataRatesTxTable for each member of the set | Non-DMG BSS: The set of data rates (in units of 500 kb/s) that all STAs in the BSS are able to use for communication. All STAs in the BSS, including the STA that is starting the BSS, are able to receive and transmit at each of the data rates listed in the set.<br><br>DMG BSS: Empty. |
| OperationalRateSet | Non-DMG BSS: Set of integers<br><br>DMG BSS: Set of numbers | Non-DMG BSS: a value in dot11SupportedDataRatesRxTable for each member of the set<br><br>DMG BSS: 0-12, 9.1, 12.1-12.6, or 25-31, for each member of the set | Non-DMG BSS: The set of data rates (in units of 500 kb/s) that the STA is able to use for communication within the BSS. The STA is able to receive at each of the data rates listed in the set. This set is a superset of the rates contained in the BSSBasicRateSet parameter.<br><br>DMG BSS: The set of MCS (#4136)indices that the STA uses for communication within the BSS. |
| Country | As defined in the Country element | As defined in the Country element | The information required to identify the regulatory domain in which the STA is located and to configure its PHY for operation in that regulatory domain.<br>Present if TPC functionality is required, as specified in 11.7 (TPC procedures) or dot11MultiDomainCapabilityActivated is true; otherwise not present. |
| IBSS DFS Recovery Interval | Integer | 1–255 | The time interval that is used for DFS recovery.<br>Present if DFS functionality is required, as specified in 11.8 (DFS procedures) and BSSType = INDEPENDENT; otherwise not present. |
| EDCAParameterSet (QoS only) | EDCA Parameter Set element | As defined in 9.4.2.27 (EDCA Parameter Set element) | The initial EDCA parameter set values to be used in the BSS. The parameter is present if dot11QosOptionImplemented is true and dot11MeshActivated is true; otherwise not present. |


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| Name | Type | Valid range | Description |
|---|---|---|---|
| DSERegisteredLocation | As defined in the DSE Registered Location element | As defined in 9.4.2.50 (DSE Registered Location element) | The information for the DSE Registered Location element. The parameter is present if dot11LCIDSERequired is true. |
| HT Capabilities | As defined in frame format HT Capabilities element | As defined in 9.4.2.54 (HT Capabilities element); the HT-MCSs in the element are present in dot11SupportedHTMCSRxTable and the highest supported data rate in the element does not exceed dot11HighestSupportedDataRate | The STA's HT capabilities to be advertised for the BSS. The parameter is present if dot11HighThroughputOptionImplemented is true; otherwise, this parameter is not present. |
| HT Operation | As defined in frame format HT Operation element | As defined in 9.4.2.55 (HT Operation element); the HT-MCSs in the element are present in both dot11SupportedHTMCSRxTable and dot11SupportedHTMCSTxTable | Provides additional information for operating the HT BSS.<br>The parameter is present if dot11HighThroughputOptionImplemented is true; otherwise, this parameter is not present. |
| BSSMembershipSelectorSet | Set of integers | A value from Table 9-131 (BSS membership selector value encoding) for each member of the set | The set of features that are supported by all STAs in the BSS, including the STA that is starting the BSS. |
| Extended Capabilities | As defined in frame format | As defined in 9.4.2.25 (Extended Capabilities element) | Specifies the parameters within the Extended Capabilities element to be advertised for the BSS. |
| 20/40 BSS Coexistence | As defined in frame format | As defined in 9.4.2.58 (20/40 BSS Coexistence element) | Specifies the parameters within the 20/40 BSS Coexistence element that are indicated by the MAC entity.<br>The parameter is present if dot112040BSSCoexistence-ManagementSupport is true. |
| Overlapping BSS Scan Parameters | As defined in frame format | As defined in 9.4.2.57 (Overlapping BSS Scan Parameters element) | Specifies the parameters within the Overlapping BSS Scan Parameters element that are indicated by the MAC entity.<br>This parameter is optionally present if dot11FortyMHzOptionImplemented is true; otherwise, it is not present. |
| (#488)Multiple BSSID | (#488)A set of Multiple BSSID elements | (#488)As defined in 9.4.2.44 (Multiple BSSID element) | (#488)One or more elements are present if the AP is a member of a multiple BSSID set (see 11.10.14 (Multiple BSSID set)) with two or more members and any of the following conditions are true:<br>• dot11MultiBSSIDImplemented is true<br>• dot11MultiBSSIDImplemented is false and dot11RMMeasurementPilotActivated is between 2 and 7<br>• dot11FILSActivated is true<br>• dot11InterworkingServiceActivated is true and at least one dot11GASAdvertisementID exists |

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| Name | Type | Valid range | Description |
|---|---|---|---|
| InterworkingInfo | As defined in frame format | As defined in Interworking element in 9.4.2.90 (Interworking element) | Specifies (#2164)the interworking capabilities of STA. This field is present when dot11InterworkingServiceActivated is true. |
| AdvertisementProtocolInfo | Integer or Sequence of integers | As defined in Advertisement Protocol element in Table 9-277 (Advertisement protocol ID definitions) | Identifies zero or more advertisement protocols and advertisement control to be used in the BSSs. This field is present when dot11InterworkingServiceActivated is true. |
| RoamingConsortiumInfo | As defined in frame format | As defined in roaming consortium element in 9.4.2.94 (Roaming Consortium element) | Specifies identifying information for SSPs whose security credentials can be used to authenticate with the AP. This field is optionally present when dot11InterworkingServiceActivated is true. |
| Mesh ID | Octet string | 0–32 octets | The value of mesh ID(#1755). This element is present if the BSSType = MESH; otherwise not present. |
| Mesh Configuration | As defined in frame format | As defined in 9.4.2.96 (Mesh Configuration element) | Specifies the configuration of the mesh STA. This element is present if the BSSType = MESH; otherwise not present. |
| QMFPolicy | QMF Policy element | As defined in 9.4.2.118 (Quality-of-Service Management Frame Policy element) | This element is present when dot11QMFActivated is true and BSSType = INFRASTRUCTURE or MESH, and it is not present otherwise. The element is provided by the SME to signal to the MLME the QMF policy to be used for this BSS. |
| DMG Capabilities | DMG Capabilities element | As defined in 9.4.2.126 (DMG Capabilities element) | Specifies the parameters within the DMG Capabilities element to be advertised for the BSS.<br>The parameter is present if dot11DMGOptionImplemented is true and is absent otherwise. |
| Multi-band | Multi-band element | As defined in 9.4.2.137 (Multi-band element) | Specifies the parameters within the Multi-band element that are supported by the MAC entity.<br>The parameter is present if dot11MultibandImplemented is true and is absent otherwise. |
| MMS | Multiple MAC Sublayers element | As defined in 9.4.2.151 (MMS element(#1776)) | Specifies the parameters within the Multiple MAC Sublayers element that are supported by the MAC entity.<br>The parameter is present if dot11MultipleMACActivated is true and is absent otherwise. |
| DMG Operation | DMG Operation element | As defined in 9.4.2.126 (DMG Capabilities element) | Provides additional information for operating the DMG BSS.<br>The parameter is present if dot11DMGOptionImplemented is true and is absent otherwise. |
| Clustering Control | Clustering Control field | As defined in 9.3.4.2 (DMG Beacon) | Specifies the parameters within the Clustering Control field that are supported by the MAC entity.<br>The parameter is present if dot11ClusteringActivated is true and is absent otherwise. |
| CBAP Only | Integer | 0 or 1 | Specifies the setting of the CBAP Only field as defined in 9.3.4.2 (DMG Beacon) |


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| Name | Type | Valid range | Description |
|---|---|---|---|
| PCP Association Ready | Integer | 0 or 1 | Specifies the setting of the PCP Association Ready field as defined in 9.3.4.2 (DMG Beacon) |
| VHT Capabilities | As defined in VHT Capabilities element | As defined in 9.4.2.156 (VHT Capabilities element); the VHT-MCSs in the element are present in dot11VHTRxVHTMCSMap/ dot11VHTTxVHTMCSMap and the highest supported data rates in the element do not exceed dot11VHTRxHighestDataRateSupported/ dot11VHTTxHighestDataRateSupported | Specifies the parameters in the VHT Capabilities element to be advertised for the BSS. The parameter is present if dot11VHTOptionImplemented is true and not present otherwise. |
| VHT Operation | As defined in VHT Operation element | As defined in 9.4.2.157 (VHT Operation element); the VHT-MCSs in the element are present in both dot11VHTRxVHTMCSMap and dot11VHTTxVHTMCSMap | Provides additional information for operating the VHT BSS. The parameter is present if dot11VHTOptionImplemented is true and not present otherwise. |
| Known OUIs | A set of OUIs, each of which is defined in 9.4.1.29 (Organization Identifier field) | N/A | Zero or more OUIs that specify the OUIs considered known by the AP, in the context of determining if it should respond to certain Probe Request frames, as defined in 11.1.4.3.4 (Criteria for sending a response). |
| S1G Capabilities | As defined in frame format | As defined in 9.4.2.199 (S1G Capabilities element) | Specifies the parameters in the S1G Capabilities element to be advertised for the BSS. The parameter is present if dot11S1GOptionImplemented is true; otherwise not present. |
| S1GOperation | As defined in frame format | As defined in 9.4.2.211 (S1G Operation element) | Provides additional information for operating the S1G BSS. The parameter is present if dot11S1GOptionImplemented is true; otherwise not present. |
| ShortBeaconPeriod | As defined in frame format | As defined in 9.4.2.196 (Short Beacon Interval element(#2194)) | Provides the short beacon period of the S1G BSS. The parameter is present if dot11ShortBeaconInterval is true; otherwise not present. |
| ShortBeaconDTIMPeriod | As defined in frame format | As defined in 9.4.2.5 (TIM element) | Provides the DTIM period (in short beacon periods) of the S1G BSS. The parameter is present if dot11ShortBeaconInterval is true; otherwise not present. |
| CDMG Capabilities | CDMG Capabilities element | As defined in 9.4.2.218 (CDMG Capabilities element) | Specifies the parameters within the CDMG Capabilities element that are supported by the MAC entity.<br>The parameter is present if dot11CDMGOptionImplemented is true. |

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| Name | Type | Valid range | Description |
|---|---|---|---|
| CMMG Capabilities | CMMG Capabilities element | As defined in 9.4.2.228 (CMMG Capabilities element) | Specifies the parameters within the CMMG Capabilities element that are supported by the MAC entity. The parameter is present if dot11CMMGOptionImplemented is true and is absent otherwise. |
| CMMG Operation | CMMG Operation element | As defined in 9.4.2.229 (CMMG Operation element). | Specifies the parameters within the CMMG Operation element that are supported by the MAC entity. The parameter is present if dot11CMMGOptionImplemented is true; otherwise not present. |
| ServiceHint | Service Hint element | As defined in 9.4.2.236 (Service Hint element) | Provides an indication of the services advertised in Beacon and Probe Response frames. The element is optionally present if dot11UnsolicitedPADActivated is true and absent otherwise. |
| ServiceHash | Service Hash element | As defined in 9.4.2.237 (Service Hash element) | Specifies services advertised in Beacon and Probe Response frames. The element is optionally present if dot11UnsolicitedPADActivated is true and absent otherwise. |
| HE Capabilities(11ax) | As defined in HE Capabilities element. | As defined in 9.4.2.247 (HE Capabilities element(11ax)) | Specifies the parameters within the HE Capabilities element that are supported by the STA. The parameter is present if dot11HEOptionImplemented is true; otherwise, this parameter is not present. |
| HE 6 GHz Band Capabilities(11ax) | As defined in HE 6 GHz Band Capabilities element | As defined in 9.4.2.262 (HE 6 GHz Band Capabilities element(11ax)) | Specifies the parameters within the HE 6 GHz Band Capabilities element that are supported by the STA. The parameter is present if dot11HE6GOptionImplemented is true; otherwise, this parameter is not present. |
| HE Operation(11ax) | As defined in HE Operation element. | As defined in 9.4.2.248 (HE Operation element(11ax)) | Provides additional information for operating the HE BSS. The parameter is present if dot11HEOptionImplemented is true; otherwise, this parameter is not present. |
| EDMG Capabilities(11ay) | EDMG Capabilities element | As defined in 9.4.2.264 (EDMG Capabilities element(11ay)) | Specifies the parameters within the EDMG Capabilities element to be advertised for the BSS. The parameter is present if dot11EDMGOptionImplemented is true and is absent otherwise. |
| EDMG Operation(11ay) | EDMG Operation element | As defined in9.4.2.265 (EDMG Operation element(11ay)) | Provides additional information for operating the BSS. The parameter is present if dot11EDMGOptionImplemented is true and is absent otherwise. |
| Unsolicited Block Ack Extension(11ay) | Unsolicited Block Ack Extension element | As defined in 9.4.2.278 (Unsolicited Block Ack Extension element(11ay)) | Specifies the parameters within the Unsolicited Block Ack Extension element that are supported by the MAC entity. Optionally present if dot11UnsolicitedBAActivated is true and is absent otherwise. |
| TDDSlotStructure(11ay) | TDD Slot Structure element | As defined in 9.4.2.280 (TDD Slot Structure element(11ay)) | Present if dot11TDDOptionImplemented is true and absent otherwise. Specifies the parameters within the TDD Slot Structure element. |
| TDD Slot Schedule(11ay) | TDD Slot Schedule element | As defined in 9.4.2.281 (TDD Slot Schedule element(11ay)) | Present if dot11TDDOptionImplemented is true and absent otherwise. Specifies the parameters within the TDD Slot Schedule element. |


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| Name | Type | Valid range | Description |
|---|---|---|---|
| WUR Capabilities(11ba) | As defined in WUR Capabilities element | As defined in 9.4.2.290 (WUR Capabilities element(11ba)) | Specifies the parameters within the WUR Capabilities element that are supported by the STA. The parameter is present if dot11WUROptionImplemented is true; otherwise, this parameter is not present. |
| WUR Operation(11ba) | As defined in WUR Operation element | As defined in 9.4.2.291 (WUR Operation element(11ba)) | Provides additional information for WUR operation. The parameter is present if dot11WUROptionImplemented is true; otherwise not present. |
| WUR Discovery(11ba) | A defined in WUR Discovery element | As defined in 9.4.2.293 (WUR Discovery element(11ba)) | Specifies the parameters used for transmission of WUR Discovery frames. The parameter is present if dot11WUROptionImplemented is true and dot11WURDiscoveryImplemented is true; otherwise, this parameter is not present. |
| VendorSpecificInfo | A set of elements | As defined in 9.4.2.24 (Vendor Specific element) | Zero or more elements. |

#### 6.5.11.2.3 When generated

This primitive is generated by the SME to start an infrastructure BSS (with the MAC entity within an AP), an IBSS (with the MAC entity acting as the first STA in the IBSS), or an MBSS (with the MAC entity acting as the first mesh STA in the MBSS) or to become a member of an existing MBSS or a PBSS (with the MAC entity within a PCP). In an MBSS, this primitive starts the process of mesh beaconing.

The MLME-START.request primitive in an MBSS shall be generated before any synchronization or mesh peering have been attempted.

The MLME-START.request primitive shall not be used after successful use of the MLME-START.request primitive or successful use of the MLME-JOIN.request primitive without generating an intervening MLME-RESET.request primitive.

#### 6.5.11.2.4 Effect of receipt

This primitive initiates the BSS initialization procedure once the current frame exchange sequence is complete. The MLME subsequently issues an MLME-START.confirm primitive that reflects the results of the creation procedure.

If the MLME of a non-DMG STA receives an MLME-START.request primitive with a BSSBasicRateSet parameter containing any unsupported rates, the MLME response in the resulting MLME-START.confirm primitive shall contain a ResultCode parameter that is not set to the value SUCCESS.

If the MLME of an HT STA receives an MLME-START.request primitive with the Basic HT-MCS Set field of the HT Operation parameter containing any unsupported MCSs, the MLME response in the resulting MLME-START.confirm primitive shall contain a ResultCode parameter that is not set to the value SUCCESS.

If the MLME of a VHT STA receives an MLME-START.request primitive with a Basic VHT-MCS And NSS Set field in the VHT Operation parameter containing any unsupported <VHT-MCS, NSS> tuple, the MLME response in the resulting MLME-START.confirm primitive shall contain a ResultCode parameter that is not set to the value SUCCESS.

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If the MLME of a CMMG STA receives an MLME-START.request primitive with a Basic CMMG-MCS and NSS Set field in the CMMG Operation parameter containing any unsupported <CMMG-MCS, NSS> tuple, the MLME response in the resulting MLME-START.confirm primitive contains a ResultCode parameter that is not set to the value SUCCESS.

If the MLME of a DMG STA receives an MLME-START.request primitive with a BSSBasicRateSet parameter containing any rates, or with the OperationalRateSet parameter containing any unsupported MCSs, the MLME response in the resulting MLME-START.confirm primitive shall contain a ResultCode parameter that is not set to the value SUCCESS.

If the MLME of an S1G STA receives an MLME-START.request primitive with a Basic S1G-MCS and NSS Set field in the S1GOperation parameter containing any unsupported <S1G-MCS, NSS> tuple, the MLME response in the resulting MLME-START.confirm primitive shall contain a ResultCode parameter that is not set to the value SUCCESS.

(11ax)If the MLME of an HE STA receives an MLME-START.request primitive with a Basic HE-MCS And NSS Set field in the HE Operation parameter that contains any unsupported <HE-MCS, NSS> tuple, then the MLME response in the resulting MLME-START.confirm primitive shall not contain a ResultCode parameter that is set to SUCCESS.

#### 6.5.11.3 MLME-START.confirm

##### 6.5.11.3.1 Function

This primitive reports the results of a BSS creation procedure or a procedure to become a member of an MBSS.

##### 6.5.11.3.2 Semantics of the service primitive

The primitive parameter is as follows:

MLME-START.confirm(
ResultCode
)

| Name | Type | Valid range | resetDescription |
|---|---|---|---|
| ResultCode | Enumeration | SUCCESS, BSS_ALREADY_STARTED_OR_JOINED, RESET_REQUIRED_BEFORE_ START, NOT_SUPPORTED | Indicates the result of the MLME-START.request primitive. |

##### 6.5.11.3.3 When generated

This primitive is generated by the MLME as a result of an MLME-START.request primitive to create a new BSS or to become a member of an MBSS.

##### 6.5.11.3.4 Effect of receipt

The SME is notified of the results of the BSS creation procedure or a procedure to become a member of an MBSS.


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### 6.5.12 Stop

#### 6.5.12.1 General

This mechanism supports the process of terminating an existing BSS.

#### 6.5.12.2 MLME-STOP.request

##### 6.5.12.2.1 Function

This primitive requests that the MAC entity stop a BSS previously started by using an MLME-START.request primitive

##### 6.5.12.2.2 Semantics of the service primitive

The primitive parameter is as follows:

MLME-STOP.request(
SSID
)

| Name | Type | Valid range | Description |
|---|---|---|---|
| SSID | Octet string | 0–32 octets | The SSID of the BSS to be stopped. |

##### 6.5.12.2.3 When generated

This primitive is generated by the SME to terminate an infrastructure BSS (with the MAC entity within an AP) or a PBSS (with the MAC entity within the PCP). The MLME-STOP.request primitive shall be generated only after successful use of an MLME-START.confirm primitive.

The MLME-STOP termination procedure does not reset the MAC to initial conditions. An MLME-RESET.request primitive shall be issued prior to use of the MLME-START.request primitive and subsequent to the use of an MLME-STOP.request primitive.

The SME should notify associated non-AP STAs of imminent infrastructure BSS termination before issuing the MLME-STOP.request primitive. This can be done with the BSS transition management procedure, using the Termination information.

##### 6.5.12.2.4 Effect of receipt

This primitive initiates the termination of the BSS. All services provided by the AP to an infrastructure BSS, including Beacon and Probe Response frame transmissions and access to the DS, are stopped by the termination. All STAs in an infrastructure BSS are deauthenticated by the termination. In a PBSS, all of the services provided by the PCP, including DMG Beacon frames, are stopped by the termination. All of the STAs in a PBSS have their RSNA unestablished by the termination.

### 6.5.13 Protocol layer model for spectrum management and radio measurement

The layer management extensions for measurement, TPC, and channel switching assume a certain partition of functionality between the MLME and SME. This partitioning assumes that policy decisions (e.g., regarding measurement and channel switching) reside in the SME, while the protocol for measurement, switch timing, and the associated frame exchanges resides within the MLME (see Figure 6-9 (Layer management model)).

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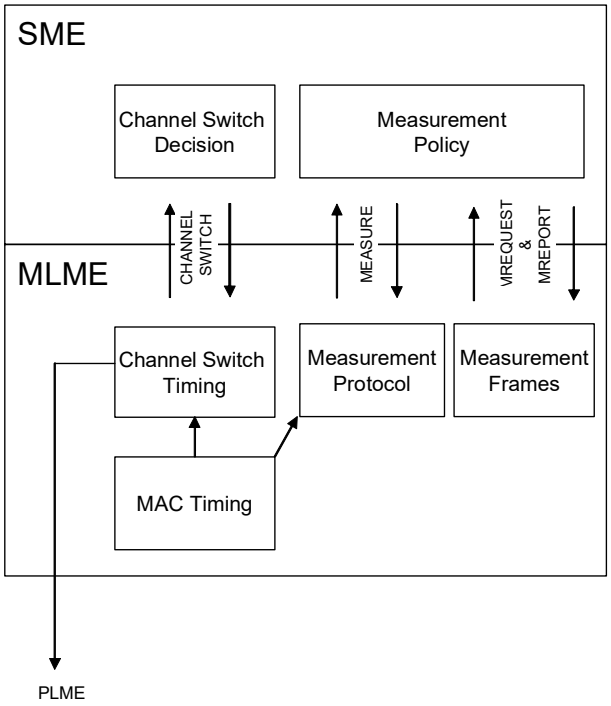


**Figure 6-9—Layer management model**

The diagrams within this subclause further illustrate the protocol layer model adopted. Figure 6-10 (Measurement request—accepted(#1114)) and Figure 6-11 (Measurement request—rejected(#1114)) depict the measurement process for a peer STA to accept and reject a measurement request, respectively. Figure 6-12 (TPC adaptation(#1114)) illustrates the TPC adaptation process. Lastly, Figure 6-13 (Channel switching(#1114)) depicts the management process for a channel switch using a Channel Switch Announcement frame.

Note that these diagrams are intended as examples and do not depict all possible protocol scenarios, e.g., a measurement request may result in more than one Spectrum or Radio Measurement Report frame as described in 11.8.7 (Requesting and reporting of measurements) and 11.10 (Radio measurement procedures).

### 6.5.14 SetKeys

#### 6.5.14.1 MLME-SETKEYS.request

##### 6.5.14.1.1 Function

This primitive causes the keys identified in the parameters of the primitive to be set in the MAC and enabled for use.


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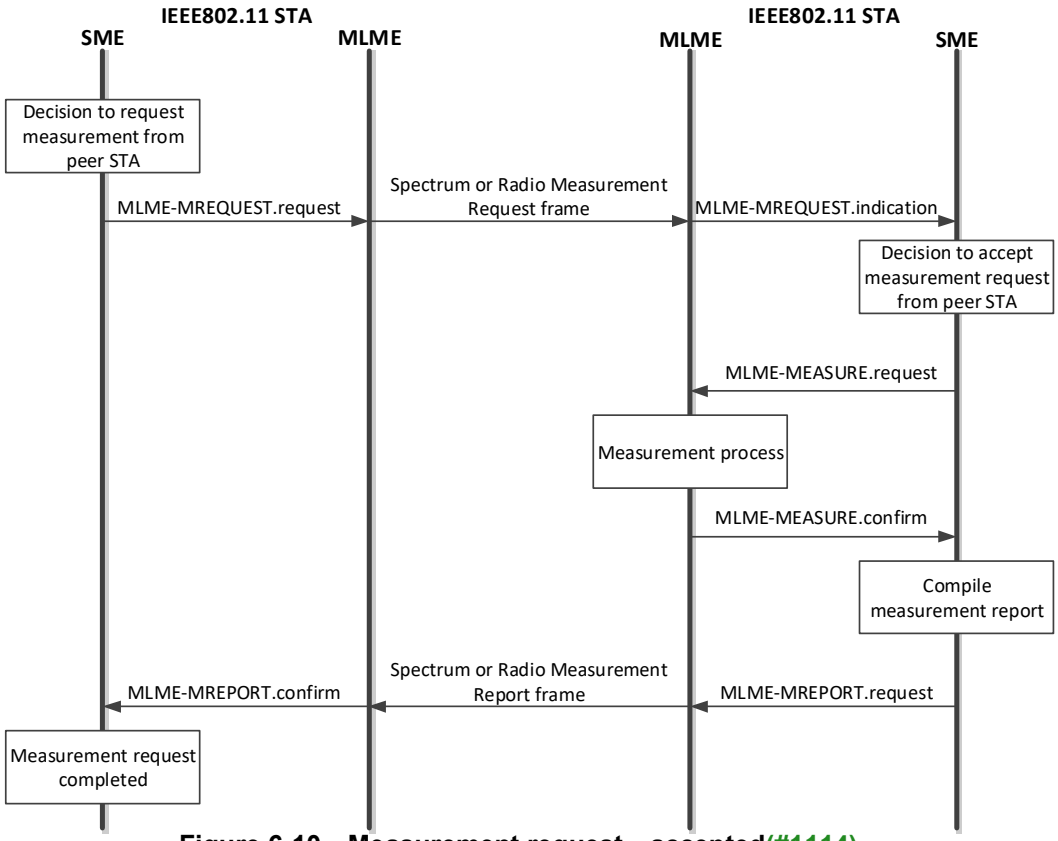


**Figure 6-10—Measurement request—accepted(#1114)**

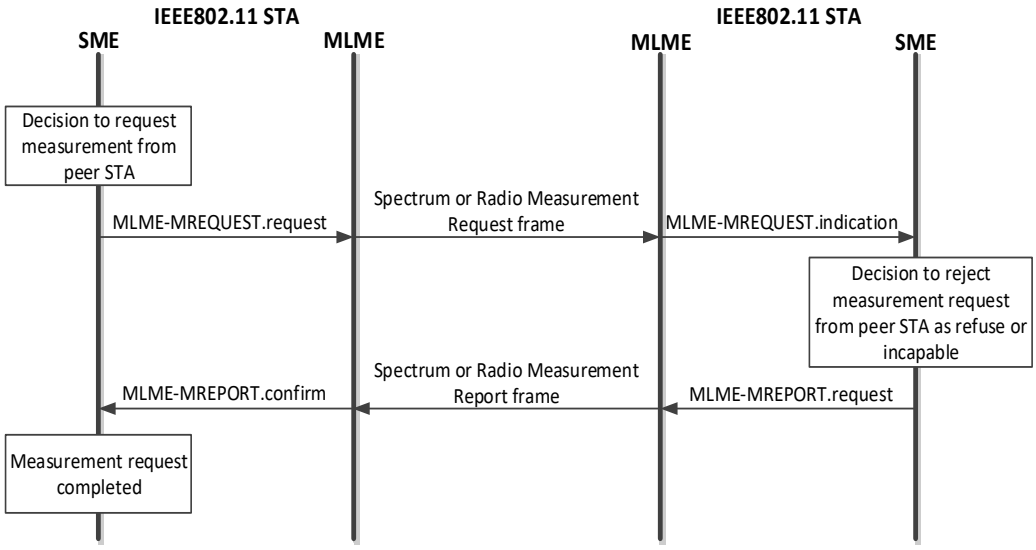


**Figure 6-11—Measurement request—rejected(#1114)**

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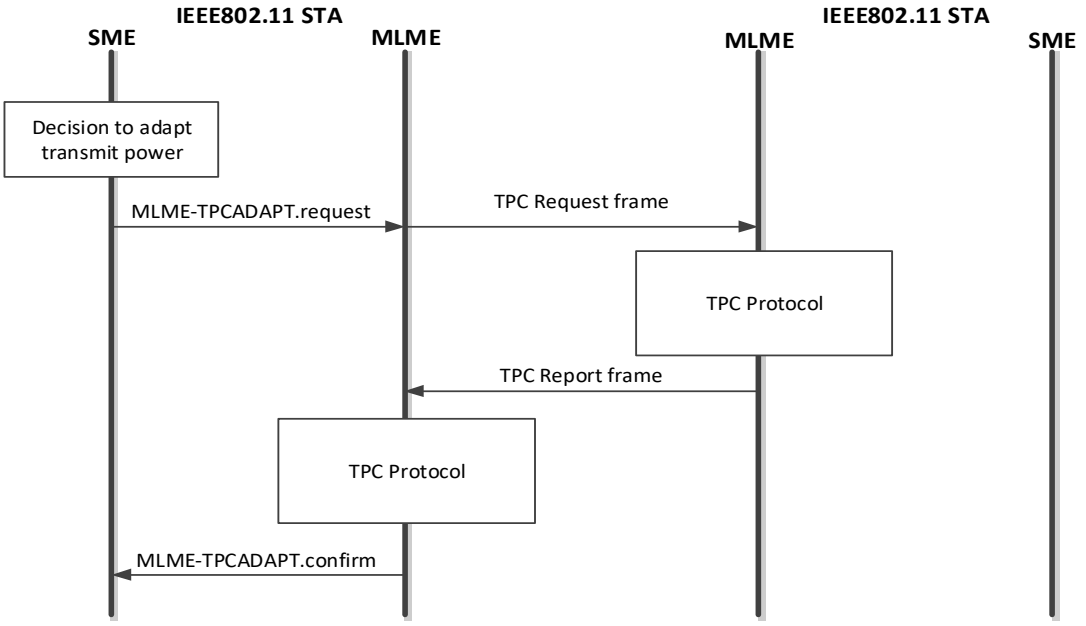


**Figure 6-12—TPC adaptation(#1114)**

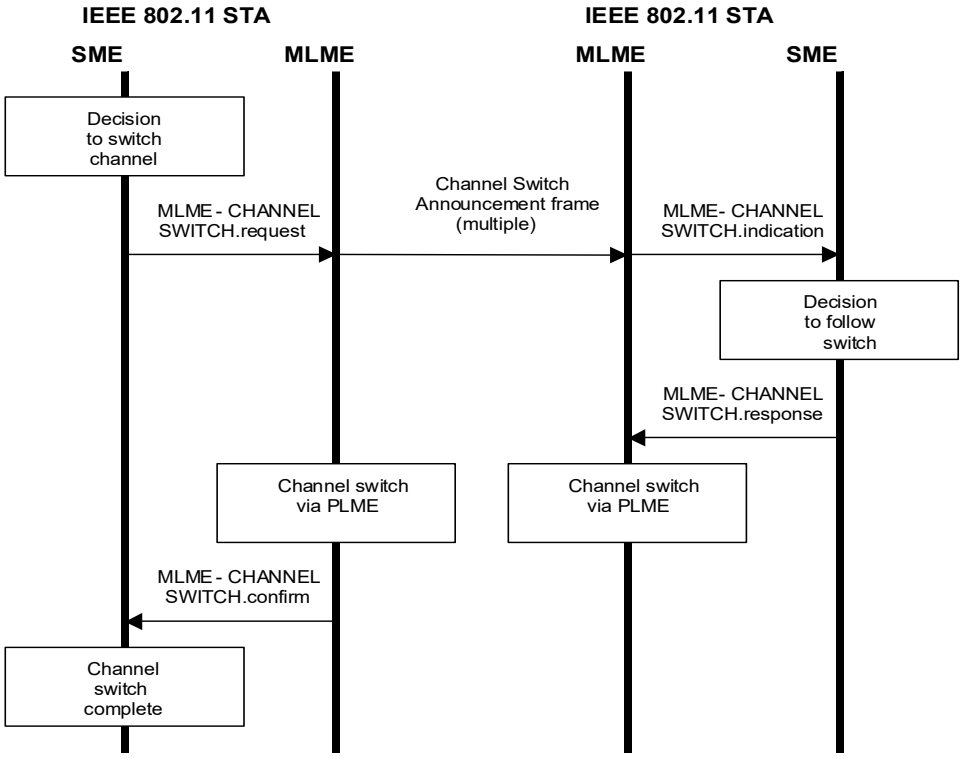


**Figure 6-13—Channel switching(#1114)**



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#### 6.5.14.1.2 Semantics of the service primitive

The primitive parameter is as follows:

MLME-SETKEYS.request(
Keylist
)

| Name | Type | Valid range | Description |
|---|---|---|---|
| Keylist | A set of SetKeyDescriptors | N/A | The list of keys to be used by the MAC. |

Each SetKeyDescriptor consists of the following parameters:

| Name | Type | Valid range | Description |
|---|---|---|---|
| Key | Bit string | N/A | The temporal key value |
| Length | Integer | N/A | The number of bits in the Key to be used. |
| Key ID | Integer | 0–3 shall be used with (#3056)TKIP, CCMP, and GCMP;<br>4–5 with BIP for IGTK; 6-7 with BIP for BIGTK;<br>(11ba)8–9 with BIP for WIGTK;<br>and 10–4095 are reserved | Key identifier |
| Key Type | Enumeration | Group, Pairwise, PeerKey, IGTK, BIGTK, WIGTK(11ba) | Defines whether this key is a GTK, TK, TPK-TK, IGTK, BIGTK, or WIGTK respectively.(11ba)(#1521) |
| Address | MAC address | (#1653)Any valid individual address | This parameter is valid only when the Key Type value is one of:(#1392)<br>— Pairwise,<br>— Group and the STA is in an IBSS or PBSS (but not an MBSS),<br>— PeerKey. |
| Receive Sequence Counter(#1406) | 8 octets | N/A | (#1406)Initialization value of the replay counter(s).<br>This parameter is valid only when the Key Type is Group, IGTK, BIGTK, or WIGTK.(11ba) |

#### 6.5.14.1.3 When generated

This primitive is generated by the SME at any time when one or more keys are to be set in the MAC.

#### 6.5.14.1.4 Effect of receipt

When the Key Type is Group, IGTK, BIGTK, or WIGTK(11ba), and the key matches the GTK, IGTK, BIGTK, or WIGTK(11ba), if any, installed as a result of (#1836)EAPOL-Key PDUs (see 12.7.7.4 (Group key handshake implementation considerations)) or exiting WNM sleep mode (see 11.2.3.15.1 (WNM sleep mode capability)) receipt of this primitive shall have no effect except updating the RSC(s) when they are greater than those currently stored. (#3407)Otherwise, irrespective of the Key Type parameter, when the Key parameter is the same as a key installed as a result of EAPOL-Key PDUs or exiting WNM sleep mode, receipt of this primitive shall have no effect.(#1679) Otherwise, receipt of this primitive causes the MAC to apply the keys as follows, subject to the MLME-SETPROTECTION.request primitive:

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— The MAC uses the key and key ID for the transmission of subsequent frames to which the key and key ID apply (as defined by the Key Type and Address parameters).(#3711)(#4332)

NOTE—If more than one key (and key ID) can be used for transmission for a particular key type and address, the MAC chooses the key and key ID to use.(#4332)

— The MAC installs the key with the associated (#3493)key ID such that received frames for that cipher, of the appropriate type, and containing the matching (#3493)key ID are processed using that key and its associated state information(#1661).

— When the Key Type parameter is Pairwise or PeerKey, and the Key, Key ID, and Address (where valid) parameters identify a new key to be set, the MAC shall initialize the transmitter TSC/PN counter and the receiver replay counter(s) to 0. When the Key Type parameter is not Pairwise, PeerKey, or BIGTK,(#6054) and the Key, Key ID, and Address (where valid) parameters identify a new key to be set, the MAC shall initialize, depending on the direction of the traffic, the transmitter TSC/PN/IPN/WIPN(#6054) counter to 0 or 1 (see Clause 12 (Security) and Clause 29 (Wake-Up Radio (WUR) MAC specification(11ba))) or the receiver replay counter(s) to the value in the Receive Sequence Count parameter. (#6054)When the Key Type parameter is BIGTK, and the Key and Key ID parameters identify a new key to be set, the MAC shall initialize, depending on the direction of the traffic, the transmitter BIPN counter as specified in 12.5.3.4 (BIP replay counters and packet numbers(#3573)) or the receiver replay counter to the value in the Receive Sequence Count parameter. When the Key Type, Key, Key ID, and Address (where valid) parameters identify an existing key, the MAC shall not change the transmitter TSC/PN/IPN/BIPN/WIPN counter or the receiver replay counter(s) associated with that key.(#1661)(#1505)

(#3292)NOTE—A new key is identified by virtue of having a different Key parameter than any of the currently configured keys used by the MAC. Additionally, it ought to have a different Key parameter than any key that has ever been used by the MAC for the current link.(#4272)

### 6.5.15 DeleteKeys

#### 6.5.15.1 MLME-DELETEKEYS.request

##### 6.5.15.1.1 Function

This primitive causes the keys identified in the parameters of the primitive to be deleted from the MAC and thus disabled for use.

##### 6.5.15.1.2 Semantics of the service primitive

The primitive parameter is as follows:

MLME-DELETEKEYS.request(
Keylist
)

| Name | Type | Valid range | Description |
|---|---|---|---|
| Keylist | A set of DeleteKeyDescriptors | N/A | The list of keys to be deleted from the MAC. |

Each DeleteKeyDescriptor consists of the following parameters:

##### 6.5.15.1.3 When generated

This primitive is generated by the SME at any time when keys for a security association are to be deleted in the MAC.


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| Name | Type | Valid range | Description |
|---|---|---|---|
| Key ID | Integer | 0–3 shall be used with (#3056)TKIP, CCMP, and GCMP; 4–5 with BIP for IGTK; 6-7 with BIP for BIGTK; (11ba)8–9 with BIP for WIGTK; and 10–4095 are reserved | Key identifier. |
| Key Type | Enumeration | Group, Pairwise, PeerKey, IGTK, BIGTK, WIGTK(11ba) | Defines whether this key is a GTK, TK, TPK-TK, IGTK, BIGTK, or WIGTK respectively.(11ba)(#1521) |
| Address | MAC address | (#1653)Any valid individual address | This parameter is valid only when the Key Type value is one of:(#1392)<br>— Pairwise,<br>— Group and the STA is in an IBSS or PBSS (but not an MBSS),<br>— PeerKey. |
| Encapsulation Mode(#6054) | Enumeration | Normal, BCE | This parameter is valid only when the Key Type value is BIGTK |

#### 6.5.15.1.4 Effect of receipt

Receipt of this primitive causes the MAC to delete all the temporal keys identified by each DeleteKeyDescriptor in the Keylist (as defined by the Key Type, Key ID and Address parameters), and to cease using them.

### 6.5.16 SetProtection

#### 6.5.16.1 MLME-SETPROTECTION.request

#### 6.5.16.1.1 Function

This primitive indicates whether protection is required for frames sent to and received from the indicated MAC address.

#### 6.5.16.1.2 Semantics of the service primitive

The primitive parameter is as follows:

MLME-SETPROTECTION.request(
Protectlist
)

| Name | Type | Valid range | Description |
|---|---|---|---|
| Protectlist | A set of ProtectDescriptors | N/A | The list of how each key is being used currently. |

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Each ProtectDescriptor consists of the following parameters:

| Name | Type | Valid range | Description |
|---|---|---|---|
| Address | MAC address | (#1653)Any valid individual address | This parameter is valid only when the Key Type value is one of:(#1392)<br>— Pairwise,<br>— Group and the STA is in an IBSS or PBSS (but not an MBSS),<br>— PeerKey. |
| ProtectType | Enumeration | None, Rx, Tx, Rx_Tx | The protection value for this MAC. |
| Key Type | Enumeration | Group, Pairwise, PeerKey, IGTK, BIGTK, WIGTK(11ba) | Defines whether this key is a GTK, TK, TPK-TK, IGTK, BIGTK, or WIGTK respectively.(11ba)(#1521) |

#### 6.5.16.1.3 When generated

This primitive is generated by the SME when protection is required for frames sent to and received from the indicated MAC address.

#### 6.5.16.1.4 Effect of receipt

Receipt of this primitive causes the MAC to set the protection and to protect Data frames as indicated in the ProtectType parameter of the Protectlist parameter:

— None: Specifies that Data frames to and from the MAC address are not protected.

— Rx: Specifies that Data frames from the MAC address are protected (i.e., any Data frames without protection received from the MAC address are discarded) but Data frames to the MAC address are not protected.

— Tx: Specifies that Data frames to the MAC address are protected but Data frames from the MAC address are not protected.

— Rx_Tx: Specifies that Data frames to and from the MAC address are protected.

Once Data frames are protected to and/or from the specified MAC address, the MLME-SETPROTECTION.request primitive is used to reset the prior setting. Invocation of the MLME-SETPROTECTION.request primitive with a ProtectType of None deletes a protection state.

### 6.5.17 PN event report

#### 6.5.17.1 General

This subclause describes the management procedures associated with PN event report.

#### 6.5.17.2 MLME-PN-EXHAUSTION.indication

#### 6.5.17.2.1 Function

This primitive indicates that the PN associated with a temporal key exceeds the threshold that is defined in dot11PNExhaustionThresholdLow and dot11PNExhaustionThresholdHigh.

#### 6.5.17.2.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-PN-EXHAUSTION.indication(


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Key ID,
Key Type,
Address
)

| Name | Type | Valid range | Description |
|---|---|---|---|
| Key ID | Integer | 0-3 shall be used with CCMP and GCMP; 4-5 with BIP for IGTK; 6-7 with BIP for BIGTK; (11ba)8–9 with BIP for WIGTK; and 10-4095 are reserved | Key identifier. |
| Key Type | Enumeration | Group, Pairwise, PeerKey, IGTK, BITGK, WIGTK(11ba) | Defines whether this key is a GTK, TK, TPK-TK, IGTK, BIGTK, or WIGTK respectively.(11ba)(#1521) |
| Address | MAC address | (#1653)Any valid individual address | This parameter is valid only when the Key Type value is one of:(#1392)<br>— Pairwise,<br>— Group and the STA is in an IBSS or PBSS (but not an MBSS),<br>— PeerKey. |

#### 6.5.17.2.3 When generated

This primitive is generated by the MLME when the PN associated with a temporal key exceeds the threshold that is defined in dot11PNExhaustionThresholdLow and dot11PNExhaustionThresholdHigh.

#### 6.5.17.2.4 Effect of receipt

On receipt of this primitive, the SME deletes the temporal key associated with the PN.

### 6.5.17.3 MLME-PN-WARNING.indication

#### 6.5.17.3.1 Function

This primitive indicates that the PN associated with a temporal key exceeds the threshold that is defined in dot11PNWarningThresholdLow and dot11PNWarningThresholdHigh.

#### 6.5.17.3.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-PN-WARNING.indication(
Key ID,
Key Type,
Address
)

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| Name | Type | Valid range | Description |
|---|---|---|---|
| Key ID | Integer | 0-3 shall be used with CCMP and GCMP; 4-5 with BIP for IGTK; 6-7 with BIP for BIGTK; (11ba)8–9 with BIP for WIGTK; and 10-4095 are reserved | Key identifier. |
| Key Type | Enumeration | Group, Pairwise, PeerKey, IGTK, BIGTK, WIGTK(11ba) | Defines whether this key is a GTK, TK, TPK-TK, IGTK, BIGTK, or WIGTK respectively.(11ba)(#1521) |
| Address | MAC address | (#1653)Any valid individual address | This parameter is valid only when the Key Type value is one of:(#1392)<br>— Pairwise,<br>— Group and the STA is in an IBSS or PBSS (but not an MBSS),<br>— PeerKey. |

#### 6.5.17.3.3 When generated

This primitive is generated by the MLME when the PN associated with a temporal key exceeds the threshold that is defined in dot11PNWarningThresholdLow and dot11PNWarningThresholdHigh.

#### 6.5.17.3.4 Effect of receipt

On receipt of this primitive, the SME can create a new temporal key before the PN space is exhausted.

### 6.5.18 Event request

#### 6.5.18.1 General

This set of primitives supports the exchange of Event Request and Event Report frames. The diagram in Figure 6-14 (Event protocol exchange(#1114)) shows the Event Request and Event Report process.

#### 6.5.18.2 MLME-EVLREQUEST.request

#### 6.5.18.2.1 Function

This primitive requests the transmission of an event request to a peer STA(#477).

#### 6.5.18.2.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-EVLREQUEST.request(
                        Peer MAC Address,
                        Dialog Token,
                        Event Request Set,
                        Destination URI,
                        VendorSpecificInfo
                        )
```


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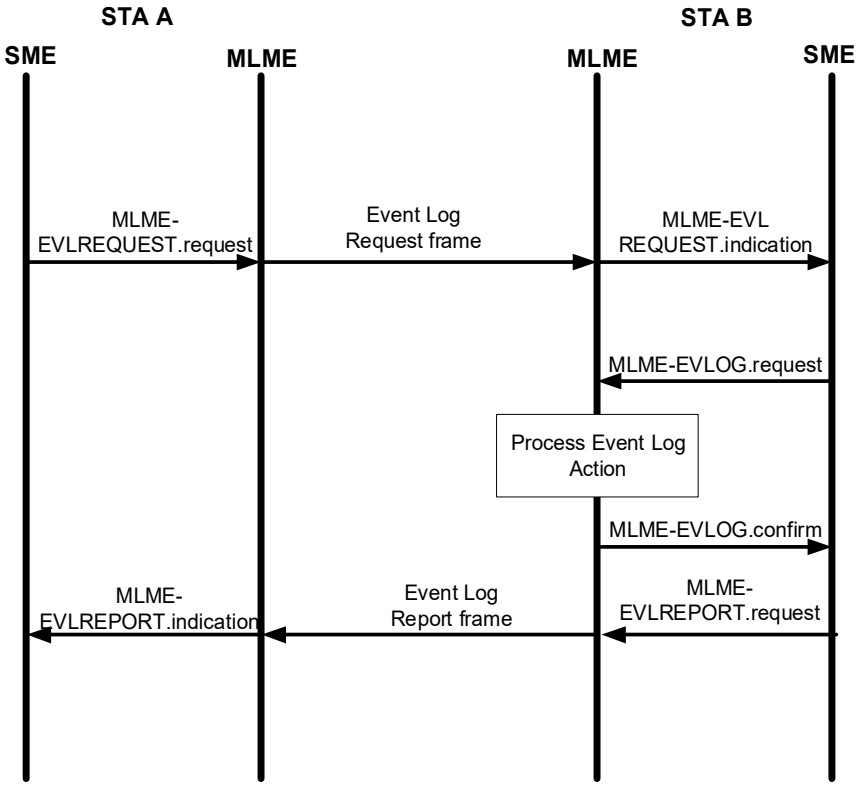


**Figure 6-14—Event protocol exchange(#1114)**

| Name | Type | Valid range | Description |
|---|---|---|---|
| Peer MAC Address | MAC address | (#1653)Any valid individual address | The address of the peer MAC entity to which the event request is sent. |
| Dialog Token | Integer | 1–255 | The dialog token to identify the event transaction. |
| Event Request Set | Set of event elements | Set of event elements | A set of event elements describing the requested event. |
| Destination URI | Destination URI element | Destination URI element | The Destination URI element as defined in 9.4.2.88 (Destination URI element). |
| VendorSpecificInfo | A set of elements | As defined in 9.4.2.24 (Vendor Specific element) | Zero or more elements. |

#### 6.5.18.2.3 When generated

This primitive is generated by the SME to request that an Event Request frame be sent to a peer STA(#477) to initiate one or more transactions.

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#### 6.5.18.2.4 Effect of receipt

On receipt of this primitive, the MLME constructs an Event Request frame containing the set of event elements specified. This frame is then scheduled for transmission.

### 6.5.18.3 MLME-EVLREQUEST.indication

#### 6.5.18.3.1 Function

This primitive indicates that an Event Request frame requesting an event transaction has been received.

#### 6.5.18.3.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-EVLREQUEST.indication(
Peer MAC Address,
Dialog Token,
Event Request Set,
Destination URI,
VendorSpecificInfo
)

| Name | Type | Valid range | Description |
|---|---|---|---|
| Peer MAC Address | MAC address | (#1653)Any valid individual address | The address of the peer MAC entity from which the event request was received. |
| Dialog Token | Integer | 1–255 | The dialog token to identify the event transaction. |
| Event Request Set | Set of event elements | Set of event elements | A set of event elements describing the requested event. |
| Destination URI | Destination URI element | Destination URI element | The Destination URI element as defined in 9.4.2.88 (Destination URI element). |
| VendorSpecificInfo | A set of elements | As defined in 9.4.2.24 (Vendor Specific element) | Zero or more elements. |

#### 6.5.18.3.3 When generated

This primitive is generated by the MLME when an Event Request frame is received.

#### 6.5.18.3.4 Effect of receipt

On receipt of this primitive, the SME either rejects the request or commences the event transaction.

### 6.5.19 Event report

#### 6.5.19.1 General

This set of primitives supports the signaling of event reports.


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#### 6.5.19.2 MLME-EVLREPORT.request

##### 6.5.19.2.1 Function

This primitive supports the signaling of event reports between peer SMEs.

##### 6.5.19.2.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-EVLREPORT.request(
Peer MAC Address,
Dialog Token,
Event Report Set,
VendorSpecificInfo
)

| Name | Type | Valid range | Description |
|---|---|---|---|
| Peer MAC Address | MAC address | (#1653)Any valid individual address | The address of the peer MAC entity to which the event report is sent. |
| Dialog Token | Integer | 1–255 | The dialog token to identify the event transaction. |
| Event Report Set | Set of event elements | Set of event elements | A set of event elements describing the response to the event request. |
| VendorSpecificInfo | A set of elements | As defined in 9.4.2.24 (Vendor Specific element) | Zero or more elements. |

##### 6.5.19.2.3 When generated

This primitive is generated by the SME to request that an Event Report frame be sent to a peer STA(#477) to report the results of one or more transactions.

##### 6.5.19.2.4 Effect of receipt

On receipt of this primitive, the MLME constructs an Event Report frame containing the set of event elements. This frame is then scheduled for transmission.

#### 6.5.19.3 MLME-EVLREPORT.indication

##### 6.5.19.3.1 Function

This primitive indicates that an Event Report frame has been received from a peer STA(#477).

##### 6.5.19.3.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-EVLREPORT.indication(
Peer MAC Address,
Dialog Token,
Event Report Set,
VendorSpecificInfo
)

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| Name | Type | Valid range | Description |
|---|---|---|---|
| Peer MAC Address | MAC address | (#1653)Any valid individual address | The address of the peer MAC entity from which the event report was received. |
| Dialog Token | Integer | 1–255 | The dialog token to identify the event transaction. |
| Event Report Set | Set of event elements | Set of event elements | A set of event elements describing the response to the event request. |
| VendorSpecificInfo | A set of elements | As defined in 9.4.2.24 (Vendor Specific element) | Zero or more elements. |

#### 6.5.19.3.3 When generated

This primitive is generated by the MLME when an Event Report frame is received.

#### 6.5.19.3.4 Effect of receipt

On receipt of this primitive, the event data can be made available for SME processes.

### 6.5.20 Event

#### 6.5.20.1 General

This set of primitives supports the requesting and reporting of event data.

#### 6.5.20.2 MLME-EVLOG.request

#### 6.5.20.2.1 Function

This primitive is generated by the SME to request that the MLME identify specific events.

#### 6.5.20.2.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-EVLOG.request(
                    Dialog Token,
                    Event Request Set
                    )
```

| Name | Type | Valid range | Description |
|---|---|---|---|
| Dialog Token | Integer | 1–255 | The dialog token to identify the event transaction. |
| Event Request Set | Set of event elements | Set of event elements | A set of event elements describing the response to the event request. |

#### 6.5.20.2.3 When generated

This primitive is generated by the SME to request that the MLME initiate the specified event.

#### 6.5.20.2.4 Effect of receipt

On receipt of this primitive, the MLME commences the identification of events.


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#### 6.5.20.3 MLME-EVLOG.confirm

##### 6.5.20.3.1 Function

This primitive reports the result of an event.

##### 6.5.20.3.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-EVLOG.confirm(
                    Dialog Token,
                    Event Report Set
                    )
```

| Name | Type | Valid range | Description |
|---|---|---|---|
| Dialog Token | Integer | 1–255 | The dialog token to identify the event transaction. |
| Event Report Set | Set of event report elements | Set of event report elements | A set of event report elements describing the reported event. |

##### 6.5.20.3.3 When generated

This primitive is generated by the MLME to report the results when event identification completes.

##### 6.5.20.3.4 Effect of receipt

On receipt of this primitive, the SME evaluates the result and, if appropriate, stores the events pending communication to the requesting entity or for local use.

### 6.5.21 On-channel Tunneling operation

#### 6.5.21.1 General

On-channel tunneling (OCT) primitives are used as part of multi-band operation (see 11.31 (Multi-band operation)). OCT frames are used to transport Management frames between peer MLME entities of multi-band capable devices.

The operation of the OCT is illustrated in Figure 6-15 (Operation of OCT(#1114)).

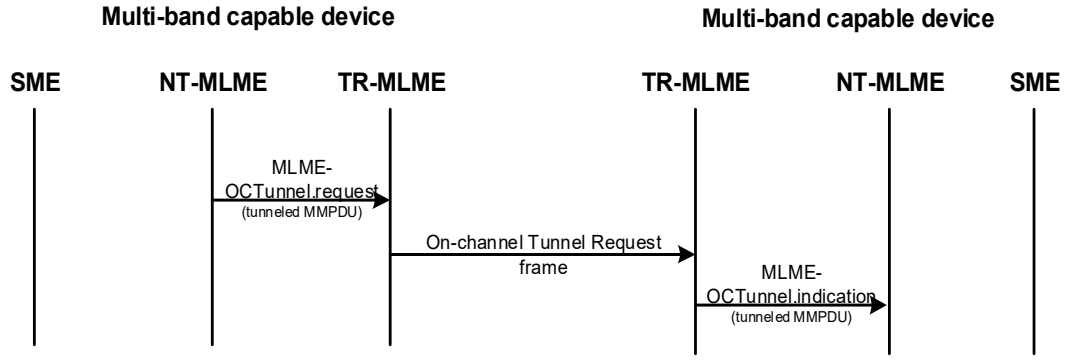


**Figure 6-15—Operation of OCT(#1114)**

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An initiator MLME of a STA that might not be currently enabled to transmit generates an MLME-OCTunnel.request primitive to a local MLME entity of a STA that is enabled to transmit. This request carries the contents of a Management frame and replaces transmission over the WM of that frame.

The recipient MLME generates the MLME-OCTunnel.indication primitive to the local MLME entity identified in the On-channel Tunnel Request frame.

The direct MLME-to-MLME primitive exchange should be viewed as shorthand for an exchange through the SMEs and multi-band entity, i.e., an MLME addresses another local MLME entity by sending that primitive through its SME and the multi-band entity to the SME of the MLME entity of a STA that is enabled to transmit, which reflects that primitive to the appropriate recipient.

#### 6.5.21.2 MLME-OCTunnel.request

##### 6.5.21.2.1 Function

This primitive requests transmission of an On-channel Tunnel Request frame.

##### 6.5.21.2.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-OCTunnel.request(
PeerSTAAddress,
OCT MMPDU,
Multi-band peer,
OCT source
)

| Name | Type | Valid range | Description |
|---|---|---|---|
| PeerSTAAddress | MAC address | (#1653)Any valid individual address | Specifies the MAC address of the STA to which the On-channel Tunnel Request frame is transmitted. |
| OCT MMPDU | OCT MMPDU Descriptor field | As defined in the On-channel Tunnel Request frame format (see 9.6.20.7 (On-channel Tunnel Request frame format)) | The OCT MMPDU carries the MMPDU to be tunneled to the specified MLME entity of the specified STA. |
| Multi-band peer | Multi-band element | As defined in the Multi-band element format (see 9.4.2.137 (Multi-band element)) | The Multi-band element identifies the peer MLME entity that should receive the OCT MMPDU. |
| OCT source | OCT Source element | As defined in the OCT Source element format (see 9.4.2.244 (OCT Source element)) | The OCT Source element identifies the MLME entity that generated (i.e., is the source) of the OCT MMPDU. |

##### 6.5.21.2.3 When generated

This primitive is generated by another MLME to request that an On-channel Tunnel Request frame be sent to another STA.

##### 6.5.21.2.4 Effect on receipt

On receipt of this primitive, the MLME constructs and attempts to transmit an On-channel Tunnel Request frame.


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#### 6.5.21.3 MLME-OCTunnel.indication

##### 6.5.21.3.1 Function

This primitive indicates that an On-channel Tunnel Request frame was received.

##### 6.5.21.3.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-OCTunnel.indication(
PeerSTAAddress,
OCT MMPDU,
Multi-band local,
OCT source,
Tunneled RXVECTOR
)

| Name | Type | Valid range | Description |
|---|---|---|---|
| PeerSTAAddress | MAC address | (#1653)Any valid individual address | Specifies the MAC address of the STA from which the On-channel Tunnel Request frame was received. |
| OCT MMPDU | OCT MMPDU Descriptor field | As defined in the On-channel Tunnel Request frame format (see 9.6.20.7 (On-channel Tunnel Request frame format)) | The OCT MMPDU carries the MMPDU that is being tunneled to the local MLME entity. |
| Multi-band local | Multi-band element | As defined in the Multi-band element format (see 9.4.2.137 (Multi-band element)) | The Multi-band element identifies the local MLME entity that should receive the OCT MMPDU. |
| OCT source | OCT Source element | As defined in the OCT Source element format (see 9.4.2.244 (OCT Source element)) | The OCT Source element identifies the MLME entity that generated (i.e., is the source) of the OCT MMPDU. |
| Tunneled RXVECTOR | RXVECTOR | As defined by the PHY of the STA | A copy of the RXVECTOR that the PHY passes to the MAC upon reception of the On-channel Tunnel Request frame. |

##### 6.5.21.3.3 When generated

This primitive is generated by the MLME to notify another MLME when an On-channel Tunnel Request frame is received.

##### 6.5.21.3.4 Effect on receipt

The recipient of this primitive is an MLME entity in a multi-band device.

On receipt of this primitive, the MLME retrieves the tunneled frame and processes it as though it were received over the WM.

#### 6.5.21.4 MLME-OCTunnel.confirm

##### 6.5.21.4.1 Function

This primitive reports the results of a request to transmit an On-channel Tunnel Request frame.

##### 6.5.21.4.2 Semantics of the service primitive

The primitive parameters are as follows:

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MLME-OCTunnel.confirm(
ResultCode
)

| Name | Type | Valid range | Description |
|---|---|---|---|
| ResultCode | Enumeration | SUCCESS, FAILURE | Indicates the result of the OCTunnel.request primitive. |

#### 6.5.21.4.3 When generated

This primitive is generated by the MLME as a result of an MLME-OCTunnel.request primitive to transmit an On-channel Tunnel Request frame.

#### 6.5.21.4.4 Effect of receipt

The MLME is notified of the results of the frame transmission.

### 6.5.22 DMG beamforming

### 6.5.22.1 SISO beamforming(11ay)

#### 6.5.22.1.1 General

This subclause describes the management procedures associated with DMG beamforming.

#### 6.5.22.1.2 MLME-BF-TRAINING.request

#### 6.5.22.1.2.1 Function

This primitive requests that beamforming training occur with a peer STA.

#### 6.5.22.1.2.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-BF-TRAINING.request(
PeerSTAAddress,
RequestBRP,
BRPRequest,(11ay)
DMGBeamRefinement,(11ay)
EDMGPartialSLS,(11ay)
EDMGBRPRequest(11ay)
)

| Name | Type | Valid range | Description |
|---|---|---|---|
| PeerSTAAddress | MAC address | (#1653)Any valid individual address | Specifies the address of the peer MAC entity with which to perform beamforming training. |
| RequestBRP | Boolean | true, false | If true, the beam refinement protocol (BRP) is performed as part of the beamforming training.<br>If false, only sector-level sweep (SLS) is performed. |
| BRPRequest(11ay) | A set of information subfields | As defined in 9.5.4 (BRP Request field) | Specifies the parameters of a BRP request |


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| Name | Type | Valid range | Description |
|---|---|---|---|
| DMGBeamRefinement(11ay) | A set of elements | As defined in 9.4.2.128 (DMG Beam Refinement element) | Zero or more elements |
| EDMGBRPRequest(11ay) | A set of elements | As defined in 9.4.2.269 (EDMG BRP Request element(11ay)) | Zero or more elements |
| EDMGPartialSLS(11ay) | A set of elements | As defined in 9.4.2.271 (EDMG Partial Sector Level Sweep element(11ay)) | Zero or more elements |

#### 6.5.22.1.2.3 When generated

This primitive is generated by the SME to request that beamforming training be performed with a peer STA.

#### 6.5.22.1.2.4 Effect on receipt

On receipt of this primitive, the MLME invokes the MAC sublayer beamforming training procedures defined in 10.41 (DMG beamforming).

### 6.5.22.1.3 MLME-BF-TRAINING.confirm

#### 6.5.22.1.3.1 Function

This primitive reports the outcome of a requested beamforming training procedure.

#### 6.5.22.1.3.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-BF-TRAINING.confirm(
                                PeerSTAAddress,
                                ResultCode,
                                DMGBeamRefinement,(11ay)
                                MeasFeedback,(11ay)
                                EDMGMeasFeedback(11ay)
                            )
```

| Name | Type | Valid range | Description |
|---|---|---|---|
| PeerSTAAddress | MAC address | (#1653)Any valid individual address | Specifies the address of the peer MAC entity with which beamforming training was performed or attempted. |
| ResultCode | Enumeration | SUCCESS, BF_TIMEOUT | Indicates the result of the beamforming procedure. |
| DMGBeamRefinement(11ay) | A set of elements | As defined in 9.4.2.128 (DMG Beam Refinement element) | Zero or more elements |
| MeasFeedback(11ay) | A set of elements | As defined in 9.4.2.135 (Channel Measurement Feedback element) | Zero or more elements |
| EDMGMeasFeedback(11ay) | A set of elements | As defined in 9.4.2.267 (EDMG Channel Measurement Feedback element(11ay)) | Zero or more elements |

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#### 6.5.22.1.3.3 When generated

This primitive is generated by the MLME to report the result of beamforming training with a peer STA.

#### 6.5.22.1.3.4 Effect on receipt

The SME is notified of the result of the procedure.

### 6.5.22.1.4 MLME-BF-TRAINING.indication

#### 6.5.22.1.4.1 Function

This primitive indicates that beamforming training with a peer STA, and at the request of that peer, has completed.

#### 6.5.22.1.4.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-BF-TRAINING.indication(
                                    PeerSTAAddress,
                                    ResultCode,
                                    DMGBeamRefinement,(11ay)
                                    MeasFeedback,(11ay)
                                    EDMGMeasFeedback(11ay)
                                )
```

| Name | Type | Valid range | Description |
|---|---|---|---|
| PeerSTAAddress | MAC address | (#1653)Any valid individual address | Specifies the address of the peer MAC entity with which beamforming training was performed (#4223)or attempted. |
| ResultCode | Enumeration | SUCCESS, BF_TIMEOUT | Indicates the result of the beamforming procedure. |
| DMGBeamRefinement(11ay) | A set of elements | As defined in 9.4.2.128 (DMG Beam Refinement element) | Zero or more elements |
| MeasFeedback(11ay) | A set of elements | As defined in 9.4.2.135 (Channel Measurement Feedback element) | Zero or more elements |
| EDMGMeasFeedback(11ay) | A set of elements | As defined in 9.4.2.267 (EDMG Channel Measurement Feedback element(11ay)) | Zero or more elements |

#### 6.5.22.1.4.3 When generated

This primitive is generated by the MLME to indicate successful completion of a beamforming training procedure requested by a peer STA.

#### 6.5.22.1.4.4 Effect on receipt

The SME is notified of the result of the procedure.


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#### 6.5.22.2 SU-MIMO beamforming(11ay)

##### 6.5.22.2.1 General

This subclause describes the management procedures associated with SU-MIMO beamforming.

##### 6.5.22.2.2 MLME-SU-MIMO-BF-TRAINING.request

###### 6.5.22.2.2.1 Function

This primitive requests that SU-MIMO beamforming training occurs with a peer STA.

###### 6.5.22.2.2.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-SU-MIMO-BF-TRAINING.request(
PeerSTAAddress,
RequestMIMOBRP,
MIMOSetupControl
)

| Name | Type | Valid range | Description |
|---|---|---|---|
| PeerSTAAddress | MAC address | (#1653)Any valid individual address | Specifies the address of the peer MAC entity with which to perform SU-MIMO beamforming training. |
| RequestMIMOBRP | Boolean | true, false(M118) | If true, the MIMO BRP procedure is performed as part of the SU-MIMO beamforming training.<br>If false, the SISO feedback procedure is performed as part of the SU-MIMO beamforming training. |
| MIMOSetupControl | A set of information fields | As defined in 9.4.2.272 (MIMO Setup Control element(11ay)) | Specifies the parameters of the SU-MIMO BF setup |

###### 6.5.22.2.2.3 When generated

This primitive is generated by the SME to request that SU-MIMO beamforming training be performed with a peer STA.

###### 6.5.22.2.2.4 Effect on receipt

On receipt of this primitive, the MLME invokes the MAC sublayer SU-MIMO beamforming training procedures defined in 10.41.10.2.2 (SU-MIMO beamforming).

##### 6.5.22.2.3 MLME-SU-MIMO-BF-TRAINING.confirm

###### 6.5.22.2.3.1 Function

This primitive reports the outcome of a requested SU-MIMO beamforming training procedure.

###### 6.5.22.2.3.2 Semantics of the service primitive

The primitive parameters are as follows:

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MLME-SU-MIMO-BF-TRAINING.confirm(
PeerSTAAddress,
ResultCode,
MIMOFeedbackControl,
MeasFeedback,
EDMGMeasFeedback
)

| Name | Type | Valid range | Description |
|---|---|---|---|
| PeerSTAAddress | MAC address | (#1653)Any valid individual address | Specifies the address of the peer MAC entity with which (#4223)SU-MIMO beamforming training was performed or attempted. |
| ResultCode | Enumeration | SUCCESS, FAILURE | Indicates the result of the beamforming procedure, i.e., SUCCESS in case BF was successfully performed and FAILURE otherwise. |
| MIMOFeedbackControl | MIMO Feedback Control element | As defined in 9.4.2.274 (MIMO Feedback Control element(11ay)) | Zero or more elements |
| MeasFeedback | Channel Measurement Feedback element | As defined in 9.4.2.135 (Channel Measurement Feedback element) | Zero or more elements |
| EDMGMeasFeedback | EDMG Channel Measurement Feedback element | As defined in 9.4.2.267 (EDMG Channel Measurement Feedback element(11ay)) | Zero or more elements |

#### 6.5.22.2.3.3 When generated

This primitive is generated by the MLME to report the result of SU-MIMO beamforming training with a peer STA.

#### 6.5.22.2.3.4 Effect on receipt

The SME is notified of the result of the procedure.

### 6.5.22.2.4 MLME-SU-MIMO-BF-TRAINING.indication

#### 6.5.22.2.4.1 Function

This primitive indicates that SU-MIMO beamforming training with a peer STA, and at the request of that peer, has completed.

#### 6.5.22.2.4.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-SU-MIMO-BF-TRAINING.indication(
PeerSTAAddress,
ResultCode,
MIMOFeedbackControl,
MeasFeedback,
EDMGMeasFeedback


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)

| Name | Type | Valid range | Description |
|---|---|---|---|
| PeerSTAAddress | MAC address | (#1653)Any valid individual address | Specifies the address of the peer MAC entity with which (#4223)SU-MIMO beamforming training was performed or attempted. |
| ResultCode | Enumeration | SUCCESS, FAILURE | Indicates the result of the beamforming procedure, i.e., SUCCESS in case BF was successfully performed and FAILURE otherwise. |
| MIMOFeedbackControl | MIMO Feedback Control element | As defined in 9.4.2.274 (MIMO Feedback Control element(11ay)) | Zero or more elements |
| MeasFeedback | Channel Measurement Feedback element | As defined in 9.4.2.135 (Channel Measurement Feedback element) | Zero or more elements |
| EDMGMeasFeedback | EDMG Channel Measurement Feedback element | As defined in 9.4.2.267 (EDMG Channel Measurement Feedback element(11ay)) | Zero or more elements |

#### 6.5.22.2.4.3 When generated

This primitive is generated by the MLME to indicate successful completion of a SU-MIMO beamforming training procedure requested by a peer STA.

#### 6.5.22.2.4.4 Effect on receipt

The SME is notified of the result of the procedure.

### 6.5.22.3 MU-MIMO beamforming(11ay)

#### 6.5.22.3.1 General

This subclause describes the management procedures associated with MU-MIMO beamforming.

#### 6.5.22.3.2 MLME-MU-MIMO-BF-TRAINING.request

#### 6.5.22.3.2.1 Function

This primitive requests that MU-MIMO beamforming training occurs with a group of peer STAs.

#### 6.5.22.3.2.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-MU-MIMO-BF-TRAINING.request(
                                    EDMGGroupID,
                                    RequestInitiatorTXSS,
                                    MIMOSetupControl
                                    )
```

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| Name | Type | Valid range | Description |
|---|---|---|---|
| EDMGGroupID | Integer | As defined in 9.4.2.268 (EDMG Group ID Set element(11ay)) | Specifies the group of peer MAC entities with which to perform MU-MIMO beamforming training. |
| RequestMIMOBRP | Boolean | true, false(M118) | If true, the initiator TXSS procedure is performed as part of the MU-MIMO beamforming training.<br>If false, the TXSS procedure is performed as part of the MU-MIMO beamforming training. |
| MIMOSetupControl | A set of information fields | As defined in 9.4.2.272 (MIMO Setup Control element(11ay)) | Specifies the parameters of the MU-MIMO BF setup |

#### 6.5.22.3.2.3 When generated

This primitive is generated by the SME to request that MU-MIMO beamforming training be performed with a group of peer STAs.

#### 6.5.22.3.2.4 Effect on receipt

On receipt of this primitive, the MLME invokes the MAC sublayer MU-MIMO beamforming training procedures defined in 10.41.10.2.3 (MU-MIMO beamforming).

### 6.5.22.3.3 MLME-MU-MIMO-BF-TRAINING.confirm

#### 6.5.22.3.3.1 Function

This primitive reports the outcome of a requested MU-MIMO beamforming training procedure.

#### 6.5.22.3.3.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-MU-MIMO-BF-TRAINING.confirm(
                                    EDMGGroupID,
                                    ResultCode,
                                    DMGBeamRefinement,
                                    MIMOFeedbackControl,
                                    MeasFeedback,
                                    EDMGMeasFeedback
                                    )
```

| Name | Type | Valid range | Description |
|---|---|---|---|
| EDMGGroupID | Integer | As defined in 9.4.2.268 | Specifies the group of peer MAC entities with which MU-MIMO beamforming training (#4223)was performed or attempted. |
| ResultCode | Enumeration | SUCCESS, FAILURE | Indicates the result of the MU-MIMO beamforming procedure, i.e., SUCCESS in case BF was successfully performed and FAILURE otherwise. |


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| Name | Type | Valid range | Description |
|---|---|---|---|
| DMGBeamRefinement | DMG Beam Refinement element | As defined in 9.4.2.128 (DMG Beam Refinement element) | Zero or more elements |
| MIMOFeedbackControl | MIMO Feedback Control element | As defined in 9.4.2.274 (MIMO Feedback Control element(11ay)) | Zero or more elements |
| MeasFeedback | Channel Measurement Feedback elements | As defined in 9.4.2.135 (Channel Measurement Feedback element) | Zero or more elements |
| EDMGMeasFeedback | EDMG Channel Measurement Feedback elements | As defined in 9.4.2.267 (EDMG Channel Measurement Feedback element(11ay)) | Zero or more elements |

#### 6.5.22.3.3.3 When generated

This primitive is generated by the MLME to report the result of MU-MIMO beamforming training with a group of peer STAs.

#### 6.5.22.3.3.4 Effect on receipt

The SME is notified of the result of the procedure.

### 6.5.22.3.4 MLME-MU-MIMO-BF-TRAINING.indication

#### 6.5.22.3.4.1 Function

This primitive indicates that MU-MIMO beamforming training with a peer STA, and at the request of that peer, has completed.

#### 6.5.22.3.4.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-MU-MIMO-BF-TRAINING.indication(
                                    PeerSTAAddress,
                                    ResultCode,
                                    MIMOSelectionControl,
                                    EDMGGroupIDSet
                                    )
```

| Name | Type | Valid range | Description |
|---|---|---|---|
| PeerSTAAddress | MAC address | (#1653)Any valid individual address | Specifies the address of the peer MAC entity with which (#4223)MU-MIMO beamforming training was performed or attempted. |
| ResultCode | Enumeration | SUCCESS, FAILURE | Indicates the result of the MU-MIMO beamforming procedure, i.e., SUCCESS in case BF was successfully performed and FAILURE otherwise. |

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| Name | Type | Valid range | Description |
|---|---|---|---|
| MIMOFeedbackControl | MIMO Feedback Control element | As defined in 9.4.2.274 (MIMO Feedback Control element(11ay)) | Zero or more elements |
| EDMGGroupIDSet | EDMG Group ID Set element | As defined in 9.4.2.268 (EDMG Group ID Set element(11ay)) | Zero or more elements |

#### 6.5.22.3.4.3 When generated

This primitive is generated by the MLME to indicate successful completion of an MU-MIMO beamforming training procedure requested by a peer STA.

#### 6.5.22.3.4.4 Effect on receipt

The SME is notified of the result of the procedure.

### 6.5.22.4 SU-MIMO hybrid beamforming(11ay)

#### 6.5.22.4.1 General

This subclause describes the management procedures associated with SU-MIMO hybrid beamforming.

#### 6.5.22.4.2 MLME-SU-MIMO-HYBRID-BF-PROTOCOL.request

##### 6.5.22.4.2.1 Function

This primitive requests that the SU-MIMO hybrid beamforming protocol occurs with a peer STA.

##### 6.5.22.4.2.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-SU-MIMO-HYBRID-BF-PROTOCOL.request(
                                        PeerSTAAddress,
                                        SoundingType,
                                        ControlTrailer
                                        )
```

| Name | Type | Valid range | Description |
|---|---|---|---|
| PeerSTAAddress | MAC address | (#1653)Any valid individual address | Specifies the address of the peer MAC entity with which (#4223)the SU-MIMO hybrid beamforming protocol was performed or attempted. |
| SoundingType | Boolean | true, false | If true, the BRP frames are used for the hybrid beamforming protocol. If false, tracking is used for the SU-MIMO hybrid beamforming protocol. |
| ControlTrailer | A set of information fields | As defined in 28.3.7 (Control trailer) | Specifies the parameters of an SU-MIMO hybrid beamforming announcement in the SU-MIMO hybrid beamforming protocol |


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#### 6.5.22.4.2.3 When generated

This primitive is generated by the SME to request that the SU-MIMO hybrid beamforming protocol be performed with a peer STA.

#### 6.5.22.4.2.4 Effect on receipt

On receipt of this primitive, the MLME invokes the MAC sublayer SU-MIMO hybrid beamforming protocol procedures defined in 10.41.10.2.4 (Hybrid beamforming for SU-MIMO and MU-MIMO).

### 6.5.22.4.3 MLME-SU-MIMO-HYBRID-BF-PROTOCOL.confirm

#### 6.5.22.4.3.1 Function

This primitive reports the outcome of a requested SU-MIMO hybrid beamforming protocol procedure.

#### 6.5.22.4.3.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-SU-MIMO-HYBRID-BF-PROTOCOL.confirm(
                                        PeerSTAAddress,
                                        ResultCode,
                                        MIMOFeedbackControl,
                                        MeasFeedback,
                                        EDMGMeasFeedback,
                                        DigitalBFFeedback
                                        )
```

| Name | Type | Valid range | Description |
|---|---|---|---|
| PeerSTAAddress | MAC address | (#1653)Any valid individual address | Specifies the address of the peer MAC entity with which (#4223)the SU-MIMO hybrid beamforming protocol was performed or attempted. |
| ResultCode | Enumeration | SUCCESS, FAILURE | Indicates the result of the SU-MIMO hybrid beamforming procedure, i.e., SUCCESS in case BF was successfully performed and FAILURE otherwise. |
| MIMOFeedbackControl | MIMO Feedback Control element | As defined in 9.4.2.274 (MIMO Feedback Control element(11ay)) | Zero or more elements |
| MeasFeedback | Channel Measurement Feedback element | As defined in 9.4.2.135 (Channel Measurement Feedback element) | Zero or more elements |
| EDMGMeasFeedback | EDMG Channel Measurement Feedback element | As defined in 9.4.2.267 (EDMG Channel Measurement Feedback element(11ay)) | Zero or more elements |
| DigitalBFFeedback | Digital BF Feedback elements | As defined in 9.4.2.283 (Digital BF Feedback element(11ay)) | Zero or more elements |

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#### 6.5.22.4.3.3 When generated

This primitive is generated by the MLME to report the result of the SU-MIMO hybrid beamforming protocol with a peer STA.

#### 6.5.22.4.3.4 Effect on receipt

The SME is notified of the result of the procedure.

### 6.5.22.4.4 MLME-SU-MIMO-HYBRID-BF-PROTOCOL.indication

#### 6.5.22.4.4.1 Function

This primitive indicates that the SU-MIMO hybrid beamforming protocol with a peer STA, and at the request of that peer, has completed.

#### 6.5.22.4.4.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-SU-MIMO-HYBRID-BF-PROTOCOL.indication(
                                    PeerSTAAddress,
                                    ResultCode,
                                    MIMOFeedbackControl,
                                    MeasFeedback,
                                    EDMGMeasFeedback,
                                    DigitalBFFeedback
                                    )
```

| Name | Type | Valid range | Description |
|---|---|---|---|
| PeerSTAAddress | MAC address | (#1653)Any valid individual address | Specifies the address of the peer MAC entity with which to perform the SU-MIMO hybrid beamforming protocol. |
| ResultCode | Enumeration | SUCCESS, FAILURE | Indicates the result of the SU-MIMO hybrid beamforming procedure, i.e., SUCCESS in case BF was successfully performed and FAILURE otherwise. |
| MIMOFeedbackControl | MIMO Feedback Control element | As defined in 9.4.2.274 (MIMO Feedback Control element(11ay)) | Zero or more elements |
| MeasFeedback | Channel Measurement Feedback element | As defined in 9.4.2.135 (Channel Measurement Feedback element) | Zero or more elements |
| EDMGMeasFeedback | EDMG Channel Measurement Feedback element | As defined in 9.4.2.267 (EDMG Channel Measurement Feedback element(11ay)) | Zero or more elements |
| DigitalBFFeedback | Digital BF Feedback elements | As defined in 9.4.2.283 (Digital BF Feedback element(11ay)) | Zero or more elements |


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#### 6.5.22.4.4.3 When generated

This primitive is generated by the MLME to indicate successful completion of an SU-MIMO hybrid beamforming protocol procedure requested by a peer STA.

#### 6.5.22.4.4.4 Effect on receipt

The SME is notified of the result of the procedure.

### 6.5.22.5 MU-MIMO hybrid beamforming(11ay)

#### 6.5.22.5.1 General

This subclause describes the management procedures associated with MU-MIMO hybrid beamforming.

#### 6.5.22.5.2 MLME-MU-MIMO-HYBRID-BF-PROTOCOL.request

#### 6.5.22.5.2.1 Function

This primitive requests that the MU-MIMO hybrid beamforming protocol occurs with a peer STA.

#### 6.5.22.5.2.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-MU-MIMO-HYBRID-BF-PROTOCOL.request(
                                        EDMGGroupID,
                                        ControlTrailer
                                        )
```

| Name | Type | Valid range | Description |
|---|---|---|---|
| EDMGGroupID | Integer | As defined in 9.4.2.268 (EDMG Group ID Set element(11ay)) | Specifies the group of peer MAC entities with which to perform the MU-MIMO hybrid beamforming protocol. |
| ControlTrailer | A set of information fields | As defined in 28.3.7 (Control trailer) | Specifies the parameters of an SU-MIMO hybrid beamforming announcement in the SU-MIMO hybrid beamforming protocol |

#### 6.5.22.5.2.3 When generated

This primitive is generated by the SME to request that the MU-MIMO hybrid beamforming protocol be performed with a group of STAs.

#### 6.5.22.5.2.4 Effect on receipt

On receipt of this primitive, the MLME invokes the MAC sublayer MU-MIMO hybrid beamforming protocol procedures defined in 10.41.10.2.4 (Hybrid beamforming for SU-MIMO and MU-MIMO).

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#### 6.5.22.5.3 MLME-MU-MIMO-HYBRID-BF-PROTOCOL.confirm

##### 6.5.22.5.3.1 Function

This primitive reports the outcome of a requested MU-MIMO hybrid beamforming protocol procedure.

##### 6.5.22.5.3.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-MU-MIMO-HYBRID-BF-PROTOCOL.confirm(
                                        EDMGGroupID,
                                        ResultCode,
                                        MIMOFeedbackControl,
                                        MeasFeedback,
                                        EDMGMeasFeedback,
                                        DigitalBFFeedback
                                        )
```

| Name | Type | Valid range | Description |
|---|---|---|---|
| EDMGGroupID | Integer | As defined in 9.4.2.268 (EDMG Group ID Set element(11ay)) | Specifies the group of peer MAC entities with which (#4223)the MU-MIMO hybrid beamforming protocol was performed or attempted. |
| ResultCode | Enumeration | SUCCESS, FAILURE | Indicates the result of the MU-MIMO hybrid beamforming procedure, i.e., SUCCESS in case BF was successfully performed and FAILURE otherwise. |
| MIMOFeedbackControl | MIMO Feedback Control element | As defined in 9.4.2.274 (MIMO Feedback Control element(11ay)) | Zero or more elements |
| MeasFeedback | Channel Measurement Feedback element | As defined in 9.4.2.135 (Channel Measurement Feedback element) | Zero or more elements |
| EDMGMeasFeedback | EDMG Channel Measurement Feedback element | As defined in 9.4.2.267 (EDMG Channel Measurement Feedback element(11ay)) | Zero or more elements |
| DigitalBFFeedback | Digital BF Feedback elements | As defined in 9.4.2.283 (Digital BF Feedback element(11ay)) | Zero or more elements |

##### 6.5.22.5.3.3 When generated

This primitive is generated by the MLME to report the result of the MU-MIMO hybrid beamforming protocol with a group of STAs.

##### 6.5.22.5.3.4 Effect on receipt

The SME is notified of the result of the procedure.


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#### 6.5.22.5.4 MLME-MU-MIMO-HYBRID-BF-PROTOCOL.indication

##### 6.5.22.5.4.1 Function

This primitive indicates that the MU-MIMO hybrid beamforming protocol with a peer STA, and at the request of that peer, has completed.

##### 6.5.22.5.4.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-MU-MIMO-HYBRID-BF-PROTOCOL.indication(
PeerSTAAddress,
ResultCode,
MIMOSelectionControl,
EDMGGroupIDSet,
DigitalBFFeedback
)

| Name | Type | Valid range | Description |
|---|---|---|---|
| PeerSTAAddress | MAC address | (#1653)Any valid individual address | Specifies the address of the peer MAC entity with which (#4223)the MU-MIMO hybrid beamforming protocol was performed or attempted. |
| ResultCode | Enumeration | SUCCESS, FAILURE | Indicates the result of the SU MIMO hybrid beamforming procedure, i.e., SUCCESS in case BF was successfully performed and FAILURE otherwise. |
| MIMOSelectionControl | MIMO Selection Control element | As defined in 9.4.2.275 (MIMO Selection Control element(11ay)) | Zero or more elements |
| EDMGGroupIDSet | EDMG Group ID Set element | As defined in 9.4.2.268 (EDMG Group ID Set element(11ay)) | Zero or more elements |
| DigitalBFFeedback | Digital BF Feedback elements | As defined in 9.4.2.283 (Digital BF Feedback element(11ay)) | Zero or more elements |

##### 6.5.22.5.4.3 When generated

This primitive is generated by the MLME to indicate successful completion of an MU-MIMO hybrid beamforming protocol procedure requested by a peer STA.

##### 6.5.22.5.4.4 Effect on receipt

The SME is notified of the result of the procedure.

### 6.5.23 Estimated Throughput

#### 6.5.23.1 General

The following set of MLME primitives support the transport of an estimate of the achievable throughput for a potential or an existing link between two STAs.

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### 6.5.23.2 MLME-ESTIMATED-THROUGHPUT.request

#### 6.5.23.2.1 Function

This primitive is generated by the SME to request that the MLME provide an estimate of the achievable throughput for a potential or an existing link between two STAs.

#### 6.5.23.2.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-ESTIMATED-THROUGHPUT.request (
                    PeerSTAAddress,
                    AverageMSDUSizeOutbound,
                    AverageMSDUSizeInbound
                    )
```

| Name | Type | Valid range | Description |
|---|---|---|---|
| PeerSTAAddress | MAC address | (#1653)Any valid individual address | Specifies the MAC address of the STA for which throughput is to be estimated assuming an association to that STA if an association with that STA does not currently exist. |
| AverageMSDUSizeInbound | An ordered set of integers | –1 to 7920, for each member of the set | A set of integers providing an estimate of the average number of octets per MSDU expected to be delivered over the wireless medium to this STA by the STA corresponding to the PeerMACAddress to this STA, specified per access category in the order AC_VO, AC_VI, AC_BE, AC_BK. A value of –1 means that the size is unspecified, a value of 0 means that no MSDUs are expected to be delivered for this access category. |
| AverageMSDUSizeOutbound | An ordered set of integers | –1 to 7920, for each member of the set | A set of integers providing an estimate of the average number of octets per MSDU expected to be delivered over the wireless medium by this STA to the STA corresponding to the PeerMACAddress, specified per access category in the order AC_VO, AC_VI, AC_BE, AC_BK. A value of –1 means that the size is unspecified, a value of 0 means that no MSDUs are expected to be delivered for this access category. |

#### 6.5.23.2.3 When generated

This primitive is generated by the SME to request that the MLME provide an estimate of throughput for MSDUs sent between this STA and (#1414)the STA that corresponds to the PeerMACAddress provided in the parameter list.


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#### 6.5.23.2.4 Effect of receipt(#146)

On receipt of this primitive, the MLME generates a set of estimates of throughput for MSDUs sent between (#1414)the STA that corresponds to the PeerMACAddress provided in the parameter list and this STA.

### 6.5.23.3 MLME-ESTIMATED-THROUGHPUT.confirm(#146)

#### 6.5.23.3.1 Function

This primitive reports the result of a request to provide a set of estimated throughput values for a potential or existing link.

#### 6.5.23.3.2 Semantics of the service primitive

The primitive uses the following parameters:

```
MLME-ESTIMATED-THROUGHPUT.confirm (
                    PeerSTAAddress,
                    EstimatedThroughputOutbound,
                    EstimatedThroughputInbound
                    )
```

| Name | Type | Valid range | Description |
|---|---|---|---|
| PeerSTAAddress | MAC address | (#1653)Any valid individual address | Specifies the MAC address of the STA for which throughput is to be estimated assuming a link with that STA if a link with that STA does not currently exist. |
| EstimatedThroughputOutbound | An ordered set of Real Numbers | Non-negative real numbers | The estimated throughput in the direction from this STA to the STA corresponding to the PeerMACAddress with units of MSDU b/s(#4148), specified per access category in the order AC_VO, AC_VI, AC_BE, AC_BK. A value of 0 means no estimate is available. |
| EstimatedThroughputInbound | An ordered set of Real Numbers | Non-negative real numbers | The estimated throughput in the direction from the STA corresponding to the PeerMACAddress to this STA with units of MSDU b/s(#4148), specified per access category in the order AC_VO, AC_VI, AC_BE, AC_BK. A value of 0 means no estimate is available. |

#### 6.5.23.3.3 When generated

This primitive is generated by the MLME to provide a set of estimates of throughput for MSDUs sent between (#1414)the STA that corresponds to the PeerMACAddress indicated in the parameter list and this STA.

#### 6.5.23.3.4 Effect of receipt

On receipt of this primitive, the SME may use the reported estimates to make link, association, and forwarding decisions.

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### 6.5.24 Update

#### 6.5.24.1 Introduction

This mechanism supports the process of updating one or more parameters used in the BSS without restarting the BSS.

#### 6.5.24.2 MLME-UPDATE.request

##### 6.5.24.2.1 Function

This primitive requests that the MAC entity to initiate a BSS update procedure to update one or more parameters used in the BSS without restarting the BSS.

##### 6.5.24.2.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-UPDATE.request(
ServiceHint,
ServiceHash,
VendorSpecificInfo)

| Name | Type | Valid range | Description |
|---|---|---|---|
| ServiceHint | Service Hint element | As defined in 9.4.2.236 (Service Hint element) | If null, requests that Service Hint element be removed from Beacon and Probe Response frames. Otherwise, provides an indication of the services advertised in Beacon and Probe Response frames. The parameter is optionally present if dot11UnsolicitedPADActivated is true and absent otherwise. |
| ServiceHash | Service Hash element | As defined in 9.4.2.237 (Service Hash element) | If null, requests that Service Hash element be removed from Beacon and Probe Response frames. Otherwise, specifies services advertised in Beacon and Probe Response frames. The parameter is optionally present if dot11UnsolicitedPADActivated is true and absent otherwise. |
| VendorSpecificInfo | A set of elements | As defined in 9.4.2.26 | Zero or more elements. |

##### 6.5.24.2.3 When generated

This primitive is generated by the SME of an AP or PCP STA when one or more parameters used in the BSS are to be changed without restarting the BSS.


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#### 6.5.24.2.4 Effect of receipt

If the MLME of an AP or PCP STA receives an MLME-UPDATE.request primitive with ServiceHint and or ServiceHash parameters, the AP or PCP STA shall use these parameters to update or remove the Service Hint element and/or Service Hash element in Beacon and Probe Response frames that the AP transmits or in DMG Beacon, Announce, and Probe Response frames that the PCP STA transmits.

### 6.5.24.3 MLME-UPDATE.confirm

#### 6.5.24.3.1 Function

This primitive reports the results of a BSS update procedure.

#### 6.5.24.3.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-UPDATE.confirm(
ResultCode
)

| Name | Type | Valid range | Description |
|---|---|---|---|
| ResultCode | Enumeration | SUCCESS, BSS_NOT_STARTED, NOT_SUPPORTED, UPDATE_FAILED | Indicates the result of the MLME-UPDATE.request primitive. |

#### 6.5.24.3.3 When generated

This primitive is generated by the MLME as a result of an MLME-UPDATE.request primitive to update one or more parameters used in the BSS without restarting the BSS.

#### 6.5.24.3.4 Effect of receipt

The SME is notified of the results of the BSS update procedure.

### 6.5.25 WUR Discovery(11ba)(#8139)

#### 6.5.25.1 General

The following MLME primitives support the WUR discovery procedure described in 29.12 (WUR discovery).

### 6.5.25.2 MLME-WURDISCOVERY.request

#### 6.5.25.2.1 Function

This primitive requests to initiate WUR scanning.

#### 6.5.25.2.2 Semantics of the service primitive

This primitive parameters are as follows:

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MLME-WURDISCOVERY.request(

WURDiscoveryChannelList,

MinChannelTime,

MaxChannelTime,

Transmitter ID,

CompressedBSSID_MSB,

Compressed SSID)

| Name | Type | Valid range | Description |
|---|---|---|---|
| WURDiscoveryChannel-List | A set of operating class and channel information as defined in 9.4.1.22 (Operating Class And Channel field(#6181)). | Each channel is selected from the valid channel range for the appropriate PHY and carrier set. | Specifies the WUR discovery channels that are examined when scanning for a WUR Discovery frame. |
| MinChannelTime | Integer | N/A | The minimum time (in TU) to spend on each WUR discovery channel when scanning for WUR Discovery frames. |
| MaxChannelTime | Integer | >=MinChannelTime | The maximum time (in TU) to spend on each WUR discovery channel when scanning for WUR Discovery frames. |
| Transmitter ID | Integer | As defined in 29.5.3 (Transmitter ID) | The Transmitter ID of the WUR AP to be discovered. This parameter is optionally present. |
| CompressedBSSID_MSB | Integer | As defined in 9.9.3.3 (WUR Discovery frame format) | The 12 MSBs of the compressed BSSID of the WUR AP to be discovered. This parameter is optionally present. |
| Compressed SSID | Integer | As defined in 9.9.3.3 (WUR Discovery frame format) | The 16 LSBs of the short SSID of the WUR AP to be discovered. This parameter is optionally present. |

#### 6.5.25.2.3 When generated

This primitive is generated by the SME for a WUR non-AP STA to determine if there are other BSSs that it can join.

#### 6.5.25.2.4 Effect of receipt

This request initiates the WUR discovery procedure.


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#### 6.5.25.3 MLME-WURDISCOVERY.confirm

##### 6.5.25.3.1 Function

This primitive indicates the receipt of a WUR Discovery frame during WUR discovery procedure.

##### 6.5.25.3.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-WURDISCOVERY.confirm(

BSSDescriptionFromWDSet,

ResultCode)

| Name | Type | Valid range | Description |
|---|---|---|---|
| BSSDescription-FromWDSet | Set of BSSDescription-FromWDs | N/A | The BSSDescriptionFromWDSet is returned to indicate the results of the WUR discovery derived from WUR Discovery frames. It is a set containing zero or more instances of a BSSDescriptionFromWD. Present if both dot11WUROptionImplemented and dot11WURDiscoveryImplemented are true; otherwise, not present. |
| ResultCode | Enumeration | SUCCESS, NOT_SUPPORTED | Indicates the result of the MLME-WURDISCOVERY.confirm primitive. |

Each BSSDescriptionFromWD consists of the parameters shown in the following table for a WUR AP discovered.

| Name | Type | Valid range | Description |
|---|---|---|---|
| Transmitter ID | Integer | As defined in 29.5.3 (Transmitter ID) | The Transmitter ID of the WUR AP carried in the ID field of the WUR Discovery frame. |
| CompressedBSSID_MSB | Integer | As defined in 9.9.3.3 (WUR Discovery frame format) | The 12 MSBs of the compressed BSSID of the WUR AP carried in the Type Dependent Control field of the WUR Discovery frame. |
| Compressed SSID | Integer | As defined in 9.9.3.3 (WUR Discovery frame format) | The 16 LSBs of the short SSID of the WUR AP. |
| Operating Channel | Operating class and channel information as defined in 9.4.1.22 (Operating Class And Channel field(#6181)) | As defined in 9.9.3.3 (WUR Discovery frame format) | Specifies the primary channel of the WUR AP. |

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| | | | |
|---|---|---|---|
| RSSI | Integer | 0 to 255 as defined in Table 30-1 (TXVECTOR and RXVECTOR parameters(11ba)). | Specifies the RSSI from the discovered WUR AP. |

#### 6.5.25.3.3 When generated

This primitive is generated by the MLME to report the operating environment of the STA. It is issued after receiving an MLME-WURDISCOVERY.request primitive.

#### 6.5.25.4 Effect of receipt

The SME is notified of the results of the WUR discovery procedure.

### 6.5.26 Cancel transmissions of MSDUs(11bd)((#7067)

#### 6.5.26.1 Introduction

This primitive allows higher layer entities (e.g., entities based on the IEEE 1609 [B22] family of standards) to cancel transmission of MSDUs that were previously sent to the STA and are still in the MAC entity's transmit queue.

#### 6.5.26.2 MLME-CANCELTX.request

#### 6.5.26.2.1 Function

Requests cancellation of transmission of all queued MSDUs belonging to the specified access category.

#### 6.5.26.2.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-CANCELTX.request(
                        AccessCategoryIndex
                        )
```

| Name | Type | Valid range | Description |
|---|---|---|---|
| AccessCategoryIndex | Integer | 0–4 | Specifies the access category index of the MSDUs that are to be removed from the transmit queue. Index 0–3 is the value of the access category in Table 9-276 (Access network type) and index 4 indicates all access categories. |

#### 6.5.26.2.3 When generated

This primitive is generated by the SME of an OCB STA when the SME receives a request (from a higher layer entity) to remove MSDUs from the transmit queue.

#### 6.5.26.2.4 Effect of receipt

The receipt of this primitive by the MAC entity causes the MAC entity to remove MSDUs of the specified access category index from the transmit queue.


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#### 6.5.26.3 MLME-CANCELTX.confirm

##### 6.5.26.3.1 Function

This primitive reports completion of the removal of MSDUs from the transmit queue.

##### 6.5.26.3.2 Semantics of the service primitive

This primitive has no parameters.

##### 6.5.26.3.3 When generated

The primitive is generated by the MLME to inform the SME that an MLME-CANCELTX.request primitive has been completed, so that the SME can inform the requesting entity (a higher layer entity).

##### 6.5.26.3.4 Effect of receipt

The SME is notified that the MAC entity has completed the requested removal of MSDUs of the specified access category, if any, from the transmit queue.

### 6.5.27 NGV radio environment measurement(11bd)(#7082)

#### 6.5.27.1 General

This primitive provides a report on the STA's radio environment.

#### 6.5.27.2 MLME-RADIOENVIRONMENT.request

##### 6.5.27.2.1 Function

This primitive is used to request the status information on the state of the STA's radio environment.

##### 6.5.27.2.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-RADIOENVIRONMENT.request (
RadioEnvironmentMeasurementPeriod,
StationMeasurementPeriod
)

| Name | Type | Valid range | Description |
|---|---|---|---|
| RadioEnvironmentMeasurementPeriod | Integer | 0 or 100–1000 | Specifies the amount of time in milliseconds during which the NGV STA measures the channel busy percentage measurement. When equal to 0, measurements are not made. |
| StationMeasurementPeriod | Integer | 0 or 100–1000 | Specifies the amount of time in milliseconds during which the NGV STA measures the number of neighboring STAs and the number of neighboring NGV STAs. When equal to 0, measurements are not made. |

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#### 6.5.27.2.3 When generated

The primitive is generated when a higher layer entity wants to acquire the status information on the state of the STA's radio environment.

### 6.5.27.3 MLME-RADIOENVIRONMENT.indication

#### 6.5.27.3.1 Function

This primitive provides status information on the state of the STA's radio environment.

#### 6.5.27.3.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-RADIOENVIRONMENT.indication(
StationCount,
NGVCapabilityPercentage,
ChannelBusyPercentage
)

| Name | Type | Valid range | Description |
|---|---|---|---|
| StationCount | Integer | 0–65 535 | Indicates the number of unique individual station MAC addresses detected during the most recent measurement period of duration dot11RadioEnvironmentMeasurementPeriod. |
| NGVCapabilityPercentage | Integer | 0–100 | Indicates the percentage of the stations indicated in StationCount whose transmissions contain indication of NGV capability. When StationCount is equal to 0, the NGVCapabilityPercentage shall be set to 0. |
| ChannelBusyPercentage | Integer | 0–100 | The percentage of time the channel was busy during the most recent measurement of duration dot11RadioEnvironmentMeasurementPeriod. The channel is busy when the NGV STA is either transmitting or its clear channel assessment function indicates the channel is busy. It is calculated as follows: $\frac{100 \times \text{duration as indicated channel busy}}{\text{dot11RadioEnvironmentMeasurementPeriod}}$ |

#### 6.5.27.3.3 When generated

The primitive is generated by the MAC entity every dot11RadioEnvironmentMeasurementPeriod if dot11NGVOptionImplemented is true.

### 6.5.28 MLME-EBCSINFO procedures(11bc)(#7067)

#### 6.5.28.1 General

This subclause describes the management procedures associated with EBCS Info frames.


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#### 6.5.28.2 MLME-EBCSINFO.request

##### 6.5.28.2.1 Function

This primitive requests the transmission of an EBCS Info frame. It is valid only at an EBCS transmitter.

##### 6.5.28.2.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-EBCSINFO.request(
EBCSInfoAuthenticationAlgorithm,
PrivateKey,
Certificate,
EBCSTIM,
ContentInformationSet
)

| Name | Type | Valid range | Description |
|---|---|---|---|
| EBCSInfoAuthenti-cationAlgorithm | Integer | As defined in 9.6.7.54 (EBCS Info frame format(11bc)) | Specifies the authentication algorithm of the EBCS Info frame. |
| PrivateKey | Sequence of octets | As defined in 12.14.1 (General) | Specifies the private key for signature generation. |
| Certificate | Sequence of octets | As defined in 9.6.7.54 (EBCS Info frame format(11bc)) | Specifies the certificate to be included in the EBCS Info frame. Present if the EBCS Info Authentication Algorithm subfield indicates that a certificate is present. |
| EBCSTIM | EBCS TIM element | As defined in 9.4.2.314 (EBCS TIM element(11bc)) | The information for the EBCS TIM. |
| ContentInforma-tionSet | Set of Content Information fields as defined in the EBCS Info frame format | As defined in 9.6.7.54 (EBCS Info frame format(11bc)) | A set of Content Information fields, each representing a content information EBCS transmitter advertised. |

##### 6.5.28.2.3 When generated

This primitive is generated by the SME to request the transmission of an EBCS Info frame.

##### 6.5.28.2.4 Effect of receipt

On receipt of this primitive, the MLME constructs an EBCS Info frame. The STA then attempts to broadcast this frame.

#### 6.5.28.3 MLME-EBCSINFO.indication

##### 6.5.28.3.1 Function

This primitive indicates that an EBCS Info frame was received. It is valid only at a STA with dot11EBCSSupportActivated equal to true.

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#### 6.5.28.3.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-EBCSINFO.indication(
PeerSTAAddress,
EBCSInfoSequenceNumber,
Timestamp,
EBCSInfoAuthenticationAlgorithm,
EBCSTIM,
ContentInformationSet
)

| Name | Type | Valid range | Description |
|---|---|---|---|
| PeerSTAAddress | MACAddress | Any valid individual MAC address | The MAC address of the STA from which an EBCS Info frame was received. |
| EBCSInfoSequen-ceNumber | Integer | $0 – 2^{32}–1$ | Indicates the EBCS Info sequence number of the EBCS Info frame. |
| Timestamp | Integer | $0 – 2^{64}–1$ | Indicates the timestamp of the EBCS Info frame. |
| EBCSInfoAuthenti-cationAlgorithm | Integer | As defined in 9.6.7.54 (EBCS Info frame format(11bc)) | Indicates the authentication algorithm of the EBCS Info frame. |
| EBCSTIM | EBCS TIM element | As defined in 9.4.2.314 (EBCS TIM element(11bc)) | Indicates the information for the EBCS TIM. |
| ContentInforma-tionSet | Set of Content Information fields as defined in the EBCS Info frame format | As defined in 9.6.7.54 (EBCS Info frame format(11bc)) | A set of Content Information fields, each representing a content information item advertised by the EBCS transmitter. |

#### 6.5.28.3.3 When generated

This primitive is generated by the MLME when an EBCS Info frame is received.

#### 6.5.28.3.4 Effect of receipt

On receipt of this primitive, the SME operates according to the procedure in 33.3.4 (EBCS Info frame generation and usage).

### 6.5.29 EBCS UL relaying(11bc)(#7067)

#### 6.5.29.1 General

The following MLME primitives support transmission and reception of the EBCS UL frame.

#### 6.5.29.2 MLME-EBCSUL.request

#### 6.5.29.2.1 Function

This primitive requests that an EBCS UL frame be sent. It is valid only at an EBCS non-AP STA.


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#### 6.5.29.2.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-EBCSUL.request(
DestinationURI,
HLPPayload,
STACertificate,
FrameTxTime,
FrameCount,
PrivateKey
)

| Name | Type | Valid range | Description |
|---|---|---|---|
| DestinationURI | Destination URI field as defined in 9.6.7.53 (EBCS UL frame format(11bc)) | As defined in 9.6.7.53 (EBCS UL frame format(11bc)) | Specifies the destination to which the HLP payload is to be relayed. |
| HLPPayload | Sequence of octets | As defined in 9.6.7.53 (EBCS UL frame format(11bc)) | Specifies the HLP payload to be relayed to the specified destination. |
| STACertificate | Sequence of octets | As defined in 9.6.7.53 (EBCS UL frame format(11bc)) | This parameter is optionally present; when present, specifies the certificate for the STA. |
| FrameTxTime | Frame Tx Time field as defined in 9.6.7.53 (EBCS UL frame format(11bc)) | As defined in 9.6.7.53 (EBCS UL frame format(11bc)) | This parameter is optionally present; when present, specifies the time when an EBCS UL frame is queued for transmission. |
| FrameCount | Frame Count field as defined in 9.6.7.53 (EBCS UL frame format(11bc)) | As defined in 9.6.7.53 (EBCS UL frame format(11bc)) | This parameter is optionally present; when present, specifies a count of the number of EBCS UL frame transmissions. |
| PrivateKey | Sequence of octets | As defined in 12.15.2.5 (Signature of the EBCS UL frame) | This parameter is optionally present; when present, specifies the private key for signature generation. |

#### 6.5.29.2.3 When generated

This primitive is generated by the SME to request an EBCS UL frame be sent.

#### 6.5.29.2.4 Effect of receipt

On receipt of this primitive, the MLME constructs an EBCS UL frame and then attempts to transmit it (also see 33.4.4 (EBCS UL procedure at an EBCS proxy)).

### 6.5.29.3 MLME-EBCSUL.indication

#### 6.5.29.3.1 Function

This primitive indicates that an EBCS UL frame was received. It is valid only at an EBCS relaying STA.

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#### 6.5.29.3.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-EBCSUL.indication(
DestinationURI,
HLPPayload,
FrameTxTime,
FrameCount
)

| Name | Type | Valid range | Description |
|---|---|---|---|
| DestinationURI | Destination URI field as defined in 9.6.7.53 (EBCS UL frame format(11bc)) | As defined in 9.6.7.53 (EBCS UL frame format(11bc)) | Specifies the destination to which the HLP payload is to be relayed. |
| HLPPayload | Sequence of octets | As defined in 9.6.7.53 (EBCS UL frame format(11bc)) | Specifies the HLP payload to be relayed to the specified destination. |
| FrameTxTime | Frame Tx Time field as defined in 9.6.7.53 (EBCS UL frame format(11bc)) | As defined in 9.6.7.53 (EBCS UL frame format(11bc)) | Present when Frame Tx Time subfield was present in the receive EBCS UL frame; when present, specifies the time when an EBCS UL frame is queued for transmission. |
| FrameCount | Frame Count field as defined in 9.6.7.53 (EBCS UL frame format(11bc)) | As defined in 9.6.7.53 (EBCS UL frame format(11bc)) | Present when Frame Count subfield was present in the receive EBCS UL frame; when present, specifies a count of the number of EBCS UL frame transmissions. |

#### 6.5.29.3.3 When generated

This primitive is generated by the MLME when an EBCS UL frame is received.

#### 6.5.29.3.4 Effect of receipt

On receipt of this primitive, the SME operates according to the procedure in 33.4.3 (EBCS UL procedure at an EBCS non-AP STA).

## 6.6 MAC state generic convergence function (MSGCF)

### 6.6.1 Overview of the convergence function

The MSGCF provides an abstraction of a link between a non-AP STA and an ESS (an ESS link) to its higher layer entity. The MSGCF provides control of an ESS link and generates events based on the state of an ESS link. A non-AP STA that transitions between two APs in the same ESS can operate transparently to the LLC sublayer, and does not change state in the state machine defined within 6.4 (Table of MLME SAP interfaces(#1114)).


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This clause defines interactions between the MSGCF and MLME and PLME through the MLME SAP and PLME SAP respectively, as well as with the SME via the MSGCF-SME SAP. The detailed manner in which the SAPs are implemented is not specified within this standard.

### 6.6.2 Overview of convergence function state machine

The convergence function maintains information on the state of the ESS, using the state machine shown in Figure 6-16 (MSGCF state machine(#1114)). Because Figure 6-16 (MSGCF state machine(#1114)) is defined in terms of ESS connectivity, it is not affected by changes in association provided that the transition was an intra-ESS transition.

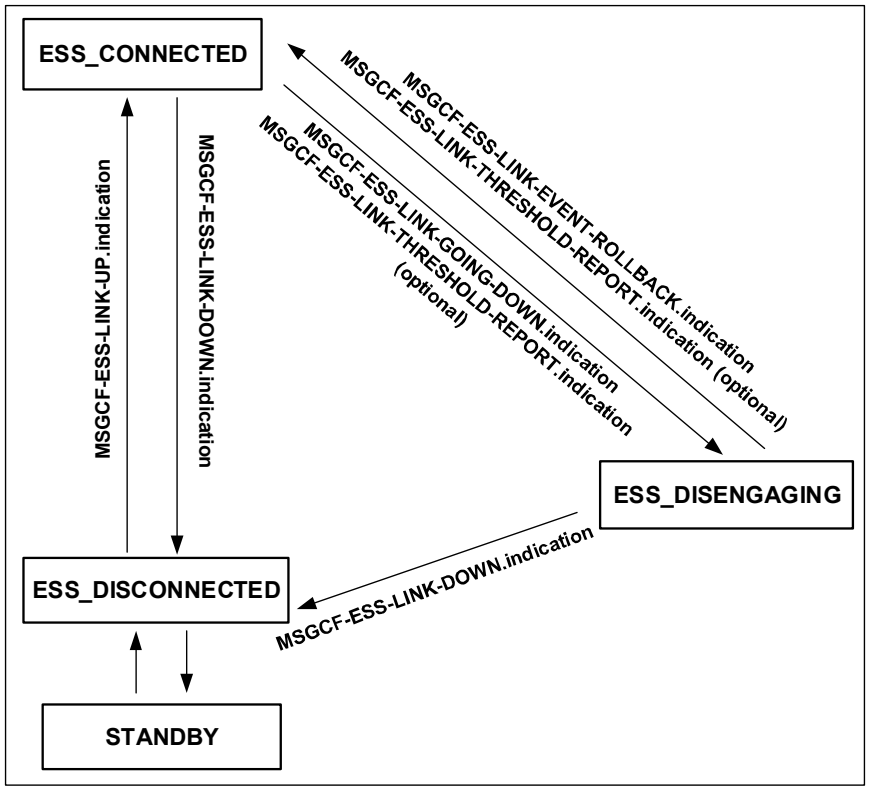


**Figure 6-16—MSGCF state machine(#1114)**

### 6.6.3 Convergence function state list

#### 6.6.3.1 ESS_CONNECTED

In the ESS_CONNECTED state, a non-AP STA has completed all layer 2 setup activities and is able to send Class 3 frames to peer LLC entities. A non-AP STA remains in this state as long as it is possible to send Class 3 frames through any AP within an ESS. A non-AP STA does not leave this state upon successful intra-ESS transitions.

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#### 6.6.3.2 ESS_DISCONNECTED

In the ESS_DISCONNECTED state, a non-AP STA is unable to send Class 3 frames to peer LLC entities. Higher layer network protocols are unavailable. In this state, a non-AP STA may use GAS to perform network discovery and selection.

#### 6.6.3.3 ESS_DISENGAGING

In the ESS_DISENGAGING state, the non-AP STA's SME anticipates that links to all APs within the ESS will be lost in a defined time interval, but the non-AP STA is still able to send Class 3 frames to peer LLC entities. The predictive failure of the link might be due to explicit disassociation by the peer, (#1938)the imminent invalidation of cryptographic keys because of usage limits (such as PN exhaustion), or predictive signal strength algorithms. In this state, it is recommended that a non-AP STA also initiate a search to find a new ESS.

#### 6.6.3.4 STANDBY

In the STANDBY state, the non-AP STA is powered down and unable to communicate with any other STAs.

### 6.6.4 Convergence function state transitions

#### 6.6.4.1 Transitions to ESS_CONNECTED

##### 6.6.4.1.1 From ESS_DISCONNECTED

To make this transition, a non-AP STA completes(M118) the network selection process and the relevant procedures to attach to the ESS, including IEEE 802.11 authentication, IEEE 802.11 association, and, if required, IEEE 802.11 RSN procedures. When this transition is completed, the MSGCF sends an MSGCF-ESS-LINK-UP.indication primitive to higher layers.

##### 6.6.4.1.2 From ESS_DISENGAGING

To make this transition, the SME cancels a previous event that predicted an ESS link failure. This might be due to network parameters indicating renewed link strength or a successful renewal of an expiring (#1382)security association (by rekeying; see 12.6.19 (RSNA rekeying)). When this transition is complete, the MSGCF sends an MSGCF-ESS-LINK-EVENT-ROLLBACK.indication primitive to indicate that a prior link failure predictive event is no longer valid. If the transition was due to network parameters crossing a threshold, the MSGCF also sends an MSGCF-ESS-LINK-THRESHOLD-REPORT.indication primitive to higher layers.

#### 6.6.4.2 Transitions to ESS_DISCONNECTED(#2191)

##### 6.6.4.2.1 From ESS_CONNECTED

This transition indicates that administrative action was taken to shut down the link, a sudden loss of signal strength or that (#1382)a security association expired and could not be renewed (by rekeying; see 12.6.19 (RSNA rekeying)). At the conclusion of this transition, the MSGCF sends an MSGCF-ESS-LINK-DOWN.indication primitive to higher layer protocols.

##### 6.6.4.2.2 From ESS_DISENGAGING

This transition indicates that the predictive link failure event has occurred. At the conclusion of this transition, the MSGCF issues an MSGCF-ESS-LINK-DOWN.indication primitive to higher layer protocols.


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#### 6.6.4.2.3 From STANDBY

This transition occurs when the non-AP STA is powered on and initialized. No event is issued by the MSGCF.

### 6.6.4.3 Transitions to ESS_DISENGAGING

#### 6.6.4.3.1 From ESS_CONNECTED

When the parameters as defined in Table 6-7 (ESS Link Parameter Set) change or imminent action is taken to bring down the link, the SME may predict an imminent link failure and initiate a transition. Upon completion of this transition, the MSGCF issues an MSGCF-ESS-LINK-GOING-DOWN event. If the cause of the transition was the degradation of network parameters beyond the thresholds stored in the MIB, an MSGCF-ESS-LINK-THRESHOLD-REPORT.indication primitive is also issued to higher layers.

### 6.6.4.4 Transitions to STANDBY

#### 6.6.4.4.1 From ESS_DISCONNECTED

When the non-AP STA has disconnected from an ESS, it may be administratively powered off to extend battery life. No events are issued by the MSGCF upon completion of this transition.

## 6.6.5 Convergence function informational events

Informational events may occur in any state. When they occur, the SME updates the convergence function MIB with new parameters. Informational events do not cause state changes in the MSGCF state machine (see Figure 6-16 (MSGCF state machine(#1114))). Informational events are generated when new potential ESS links are discovered, when the network parameter thresholds are set or read, and when higher layer protocols issue commands to the non-AP STA through the MSGCF-ESS-LINK-COMMAND.request primitive.

## 6.6.6 MAC state generic convergence SAP

The MAC state generic convergence SAP is the interface between the convergence function and higher layer protocols. It presents a standardized interface for higher layer protocols to access the state of the MAC, whether that state information is available in the MLME, PLME, or SME.

Some events on the MAC state generic convergence SAP require event identifiers for use as a dialog token in event sequencing and rollback. The EventID is an unsigned integer that is initialized to 1 when the non-AP STA leaves the STANDBY state.

## 6.6.7 ESS status reporting

### 6.6.7.1 MSGCF-ESS-LINK-UP.indication

#### 6.6.7.1.1 Function

This event is triggered when a new ESS has been made available for sending frames.

#### 6.6.7.1.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MSGCF-ESS-LINK-UP.indication(
                                    ESSIdentifier
                                    )
```

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| Name | Type | Valid range | Description |
|---|---|---|---|
| ESSIdentifier | String | N/A | An identifier composed of the string value of the SSID element concatenated with the value of the HESSID if it is in use. The HESSID is encoded in upper-case ASCII characters with the octet values separated by dash characters, as described in IETF RFC 3580 [B40]. |

#### 6.6.7.1.3 When generated

This primitive is generated when the ESS link to a network of APs is available to exchange Data frames. The generation of this primitive may vary depending on (#3056)the setting of dot11RSNAOptionImplemented.

(#3056)If dot11RSNAOptionImplemented is false, then the network does not use encryption. This event is generated upon receipt of an MLME-ASSOCIATE.confirm primitive with a result code of success.

(#3056) If dot11RSNAOptionImplemented is true, then the network requires the use of encryption on the link. Before declaring that the link is ready to exchange Data frames, the convergence function receives an MLME-ASSOCIATE.confirm primitive with a result code of success and the SME emits an MLME-SETKEYS.request primitive. The latter primitive is used to determine (#3056)that the RSN 4-way handshake has completed.

This event is not triggered by MLME-REASSOCIATE.confirm primitives because MLME-REASSOCIATE.confirm primitives are defined as transitions within the same ESS.

The MLME-ASSOCIATE.confirm primitive may be issued upon AP transitions. It is the objective of the MSGCF to generate this event only upon the initial connection to an IEEE 802.11 network, when the MSGCF state machine moves into the ESS_CONNECTED state.

#### 6.6.7.1.4 Effect of receipt

This event is made available to higher layer protocols by the convergence function. Actions taken by higher layers are outside of scope of this standard, but may include router discovery, IP configuration, and other higher layer protocol operations.

### 6.6.7.2 MSGCF-ESS-LINK-DOWN.indication

#### 6.6.7.2.1 Function

This event is triggered to indicate that the connection to an ESS is no longer available for sending frames.

#### 6.6.7.2.2 Semantics of the service primitive

The event's parameters are as follows:

```
MSGCF-ESS-LINK-DOWN.indication (
                                ESSIdentifier,
                                ReasonCode
                                )
```

| Name | Type | Valid range | Description |
|---|---|---|---|
| ESSIdentifier | String | N/A | An identifier composed of the string value of the SSID element concatenated with the value of the HESSID if it is in use. |


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| Name | Type | Valid range | Description |
|---|---|---|---|
| ReasonCode | Enumerated | EXPLICT_DISCONNECT, KEY_EXPIRATION, LOW_POWER, VENDOR_SPECIFIC | Reason code, drawn from Table 6-2 (Reason codes for network down). |

**Table 6-2—Reason codes for network down**

| Name | Description |
|---|---|
| EXPLICIT_DISCONNECT | An explicit disconnection operation (disassociation or deauthentication) was initiated by the non-AP STA or the non-AP STA's current serving AP (the AP with which the STA is associated) and the non-AP STA was unable to (re)associate with an alternate AP in the same ESS. |
| KEY_EXPIRATION | (#1382)A security association has expired due to time or traffic limitations, or TKIP countermeasures have invalidated the key hierarchy. |
| LOW_POWER | If the SME reports that the interface was shut down to conserve power, that event may be reported to higher level protocols. |
| VENDOR_SPECIFIC | Vendor-specific usage. |

#### 6.6.7.2.3 When generated

This event is generated when the SME declares that connectivity to an ESS is lost. It may be generated in the case of an explicit disconnection from the link peer, received as an MLME-DEAUTHENTICATE.indication or an MLME-DISASSOCIATE.indication primitive. The SME should wait for a period of dot11ESSDisconnectFilterInterval before declaring connectivity lost to confirm that a non-AP STA is unable to (re)associate with any alternate AP within the ESS.

#### 6.6.7.2.4 Effect of receipt

This event is made available to higher layer protocols by the convergence function. Actions taken by those higher layers are outside the scope of this standard, but may include removing entries from routing and forwarding tables, and attempting to initiate handover of open application connections to network interfaces that are still active.

### 6.6.7.3 MSGCF-ESS-LINK-GOING-DOWN.indication

#### 6.6.7.3.1 Function

This event is triggered to indicate the expectation that the connection to an ESS will no longer be available for sending frames in the near future.

#### 6.6.7.3.2 Semantics of the service primitive

The event parameters are as follows:

```
MSGCF-ESS-LINK-GOING-DOWN.indication(
                                    ESSIdentifier,
                                    EventID,
                                    TimeInterval,
                                    ReasonCode
                                    )
```

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| Name | Type | Valid range | Description |
|---|---|---|---|
| ESSIdentifier | String | N/A | An identifier composed of the string value of the SSID element concatenated with the value of the HESSID if it is in use. |
| EventID | Integer | N/A | An integer used to identify the event that is used in the case of event rollback. |
| TimeInterval | Integer | N/A | Time Interval, in time units, in which the link is expected to go down. Connectivity is expected to be available at least for time specified by TimeInterval. |
| Reason Code | Enumerated | EXPLICT_DISCONNECT, KEY_EXPIRATION, LOW_POWER, VENDOR_SPECIFIC | Indicates the reason the link is expected to go down, drawn from Table 6-3 (Reason codes for ESS link down). |

**Table 6-3—Reason codes for ESS link down**

| Name | Description |
|---|---|
| EXPLICIT_DISCONNECT | An explicit disconnection operation (Disassociation or Deauthentication) was initiated by the non-AP STA or the non-AP STA's current serving AP. |
| KEY_EXPIRATION | (#1382)A security association has expired due to time or traffic limitations, or TKIP countermeasures have invalidated the key hierarchy. |
| LOW_POWER | If the SME reports that the interface is going to be shut down to conserve power, that event may be reported to higher level protocols. |
| VENDOR_SPECIFIC | Vendor-specific usage. |

#### 6.6.7.3.3 When generated

This notification is generated by the MSGCF when the ESS link is currently established and is expected to go down within the specified time interval. The network can be expected to go down because of an event whose timing is well understood, such as an explicit disconnection event observed on the MLME SAP. It can also be expected as the result of a predictive algorithm that monitors link quality. The details of such a predictive algorithm used are beyond the scope of this standard.

The convergence function should attempt to deliver this event at least dot11ESSLinkDownTimeInterval time units before the link is predicted to go down. Different higher layer network protocols might need different levels of advance notice, and might configure dot11ESSLinkDownTimeInterval accordingly.

Not all thresholds in the dot11MACStateParameterTable are supported by every PHY. In the case when a threshold parameter is not supported it is not applied.

#### 6.6.7.3.4 Effect of receipt

This event is made available to higher layer protocols by the convergence function. Actions taken by those higher layers are outside the scope of this standard, but may include beginning preparations for handover.


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#### 6.6.7.4 MSGCF-ESS-LINK-EVENT-ROLLBACK.indication

##### 6.6.7.4.1 Function

This event is used to indicate that specific previous reports or events are no longer valid and should be disregarded.

##### 6.6.7.4.2 Semantics of the service primitive

The event parameters are as follows:

MSGCF-ESS-LINK-EVENT-ROLLBACK.indication(
ESSIdentifier,
EventID
)

| Name | Type | Valid range | Description |
|---|---|---|---|
| ESSIdentifier | String | N/A | An identifier for the network, composed of the string value of the SSID element used to identify the network, concatenated with the value of the HESSID if it is in use. |
| EventID | Integer | N/A | An integer used to identify the event that is used in the case of event rollback. |

##### 6.6.7.4.3 When generated

This event is generated when a previous predictive event is no longer valid within its expiration time.

The MSGCF-ESS-LINK-EVENT-ROLLBACK.indication primitive is used in conjunction with the MSGCF-ESS-LINK-GOING-DOWN.indication primitive. The MSGCF-ESS-LINK-EVENT-ROLLBACK.indication primitive is issued when the prediction of link failure is no longer valid. Algorithms used to determine that link failure predictions are beyond the scope of this standard.

##### 6.6.7.4.4 Effect of receipt

This event is made available to higher layer protocols by the convergence function to cancel any actions begun by the previous event. Actions taken by those higher layers are outside the scope of this standard, but may include canceling any handover procedures started by the MSGCF-ESS-LINK-GOING-DOWN event.

#### 6.6.7.5 MSGCF-ESS-LINK-DETECTED.indication

##### 6.6.7.5.1 Function

This event reports on the presence of a new ESS.

##### 6.6.7.5.2 Semantics of the service primitive

The primitive parameters are as follows:

MSGCF-ESS-LINK-DETECTED.indication(
ESSIdentifier,
ESSDescription
)

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| Name | Type | Valid range | Description |
|---|---|---|---|
| ESSIdentifier | String | N/A | An identifier for the network, composed of the string value of the SSID used to identify the network, concatenated with the value of the HESSID if it is in use. |
| ESSDescription | As defined in Table 6-4 (ESS description) | N/A | A set of information about the ESS. |

**Table 6-4—ESS description**

| Name | Syntax | Description |
|---|---|---|
| SSID | String | The SSID used by the ESS. |
| InformationServiceSupport | As described in Table 6-5 (Trigger support values) | A set of values indicating the type of information services supported on this network. |
| TriggerSupport | As described in Table 6-5 (Trigger support values) | A set of values indicating the support for the types of triggers that can be used to propose that the station take action. |
| RSN | As defined in 9.4.2.23 (RSNE) | The RSN configuration of the ESS. |
| Interworking | As defined in 9.4.2.90 (Interworking element) | Interworking configuration of the ESS. |

**Table 6-5—Trigger support values**

| Name | Description |
|---|---|
| MIS_CS_ES_Support | This network supports the IEEE 802.21 MIS Command Service and Event Service. |
| Vendor_Specific_Trigger_Support | This network supports a vendor-specific trigger service. |

#### 6.6.7.5.3 When generated

Support for MIS is indicated by the presence or absence of the relevant advertisement protocol IDs in the Advertisement Protocol element.To maintain the list of detected networks, the SME issues recurring MLME-SCAN.request primitives to the MLME. The SME may schedule these requests to avoid interruption of user traffic. Responses to these requests, received in the MLME-SCAN.confirm primitives, contain a list of detected networks. Each network is stored in dot11MACStateESSLinkDetectedTable. This table holds a list of networks, organized by Network Identifier. Each entry in the table contains a list of BSSIDs within the network, as well as indications of support for MIS. Support for MIS is indicated by the presence or absence of the relevant advertisement protocol IDs in the Advertisement Protocol element. Each entry in the table is held for at least dot11ESSLinkDetectionHoldInterval time units. When a non-AP STA has not observed an ESS for longer than dot11ESSLinkDetectionHoldInterval, it may be removed from the table.

This event is generated when a new entry is made into the dot11MACStateESSLinkDetectedTable. Modifications to existing entries in the list, such as an update to the BSSID list, do not trigger this event.


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#### 6.6.7.5.4 Effect of receipt

This event is made available to higher layer protocols by the convergence function. Actions taken by those higher layers are outside the scope of this standard.

### 6.6.7.6 MSGCF-ESS-LINK-SCAN.request

#### 6.6.7.6.1 Function

This function is used by higher layer protocols to request that the SME perform a scan operation for available ESSs.

#### 6.6.7.6.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MSGCF-ESS-LINK-SCAN.request(
                                SSID,
                                HESSID,
                                AccessNetworkType
                                )
```

| Name | Type | Valid range | Description |
|---|---|---|---|
| SSID | Octet string | 0–32 octets | Specific or wildcard. |
| HESSID | As defined in 9.4.2.90 (Interworking element) | As defined in 9.4.2.90 (Interworking element) | The HESSID to search for. It can be set to all 1s for use as a wildcard to match all available HESSID values. |
| AccessNetworkType | As defined in 9.4.2.90 (Interworking element) | As defined in 9.4.2.90 (Interworking element) | This may be a specific value to match one type of networks, or all 1s to match all access network types. |

#### 6.6.7.6.3 When generated

This request is generated when higher protocol layers request a list of available ESSs.

#### 6.6.7.6.4 Effect of receipt

The SME generates a corresponding MLME-SCAN.request primitive to find available networks.

### 6.6.7.7 MSGCF-ESS-LINK-SCAN.confirm

#### 6.6.7.7.1 Function

This function reports information on available ESSs to higher protocol layers.

#### 6.6.7.7.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MSGCF-ESS-LINK-SCAN.confirm(
                                ESSIdentifiers,
                                ESSDescriptions
                                )
```

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| Name | Type | Valid range | Description |
|---|---|---|---|
| ESSIdentifiers | Set of Strings | N/A | An identifier for the network composed of the string value of the SSID used to identify the network, concatenated with the value of the HESSID if it is in use. |
| ESSDescriptions | Set of ESSDescriptions, as defined in Table 6-4 (ESS description) | N/A | A set of information about each discovered ESS. |

#### 6.6.7.7.3 When generated

This primitive is generated when scan results are available for reporting to higher protocol layers, in response to an MSGCF-ESS-LINK-SCAN.request primitive.

#### 6.6.7.7.4 Effect of receipt

This event is made available to higher layer protocols by the convergence function. Actions taken by those higher layers are outside the scope of this standard.

### 6.6.8 Network configuration

#### 6.6.8.1 MSGCF-ESS-LINK-CAPABILITY.request

#### 6.6.8.1.1 Function

This primitive requests a list of the capabilities supported by a network.

#### 6.6.8.1.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MSGCF-ESS-LINK-CAPABILITY.request(
                                    ESSIdentifier
                                    )
```

| Name | Type | Valid range | Description |
|---|---|---|---|
| ESSIdentifier | String | N/A | An identifier for the network, composed of the string value of the SSID element used to identify the network, concatenated with the value of the HESSID if it is in use. |

#### 6.6.8.1.3 When generated

This primitive is issued to service higher layer protocols by reporting on the capabilities of a particular network.

#### 6.6.8.1.4 Effect of receipt

The convergence function retrieves the capabilities and reports them via the MSGCF-ESS-LINK-CAPABILITY.confirm primitive.


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#### 6.6.8.2 MSGCF-ESS-LINK-CAPABILITY.confirm

##### 6.6.8.2.1 Function

This primitive reports the convergence function capabilities of the network to higher layer protocols.

##### 6.6.8.2.2 Semantics of the service primitive

The primitive parameters are as follows:

MSGCF-ESS-LINK-CAPABILITY.confirm(
ESSIdentifier,
EssLinkParameterSet,
ReasonCode
)

| Name | Type | Valid range | Description |
|---|---|---|---|
| ESSIdentifier | String | N/A | An identifier for the network, composed of the string value of the SSID element used to identify the network, concatenated with the value of the HESSID if it is in use. |
| EventCapability Set | As defined in Table 6-6 (Event Capability Set) | N/A | list of supported events. |
| ReasonCode | Enumerated | SUCCESS, UNKNOWN_NETWORK, UNKNOWN_CAPABILITIES | An error code, if applicable. |

**Table 6-6—Event Capability Set**

| Name | Type | Valid range | Description |
|---|---|---|---|
| NonAPSTAMACAddress(#144) | MAC address | (#1653)Any valid individual address | The MAC address of the non-AP STA that is reporting the new network. |
| ESS-Link-Up | Boolean | true, false | Indicates whether the MSGCF-ESS-LINK-UP.indication primitive as defined in 6.6.7.1 (MSGCF-ESS-LINK-UP.indication) is supported. |
| ESS-Link-Down | Boolean | true, false | Indicates whether the MSGCF-ESS-LINK-DOWN.indication primitive as defined in 6.6.7.2 (MSGCF-ESS-LINK-DOWN.indication) is supported. |
| ESS-Link-Going-Down | Boolean | true, false | Indicates whether the MSGCF-ESS-LINK-GOING-DOWN primitive as defined in 6.6.7.3 (MSGCF-ESS-LINK-GOING-DOWN.indication) is supported. |
| ESS-Link-Event-Rollback | Boolean | true, false | Indicates whether the MSGCF-ESS-LINK-EVENT-ROLLBACK.indication primitive as defined in 6.6.7.4 (MSGCF-ESS-LINK-EVENT-ROLLBACK.indication) is supported. |

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**Table 6-6—Event Capability Set *(continued)***

| Name | Type | Valid range | Description |
|---|---|---|---|
| ESS-Link-Detected | Boolean | true, false | Indicates whether the MSGCF-ESS-LINK-DETECTED.indication primitive as defined in 6.6.7.5 (MSGCF-ESS-LINK-DETECTED.indication) is supported. |
| ESS-Link-Threshold-Report | Boolean | true, false | Indicates whether the MSGCF-ESS-LINK-THRESHOLD-REPORT.indication primitive as defined in 6.6.9.1 (MSGCF-ESS-LINK-THRESHOLD-REPORT.indication) is supported. |
| ESS-Link-Command | Boolean | true, false | Indicates whether the MSGCF-ESS-LINK-COMMAND.request primitive as defined in 6.6.10.1 (MSGCF-ESS-LINK-COMMAND.request) is supported. |

#### 6.6.8.2.3 When generated

This primitive is generated in response to the MSGCF-ESS-LINK-CAPABILITY.request primitive to report whether specific events are supported.

#### 6.6.8.2.4 Effect of receipt

This event is made available to higher layer protocols by the convergence function.

### 6.6.8.3 MSGCF-ESS-LINK-PARAMETERS.request

#### 6.6.8.3.1 Function

This primitive sets thresholds for reporting of network events.

#### 6.6.8.3.2 Semantics of the service primitive

The primitive parameters are as follows:

MSGCF-ESS-LINK-PARAMETERS.request(
ESSIdentifier,
EssLinkParameterSet
)

| Name | Type | Valid range | Description |
|---|---|---|---|
| ESSIdentifier | String | N/A | An identifier for the network, composed of the string value of the SSID element used to identify the network, concatenated with the value of the HESSID if it is in use. |
| ESSLinkParameterSet | As defined in Table 6-7 (ESS Link Parameter Set) | N/A | The EssLinkParameterSet is used to configure when event reports are sent to higher protocol layers. |

The ESSLinkParameterSet parameter is defined in Table 6-7 (ESS Link Parameter Set). It may include any or all of the parameters in Table 6-7 (ESS Link Parameter Set).


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**Table 6-7—ESS Link Parameter Set**

| Name | Type | Valid range | Description |
|---|---|---|---|
| PeakOperationalRate | Integer | As defined in 9.4.2.3 (Supported Rates and BSS Membership Selectors element) | The integer representing the target peak modulation data rate used for Data frame transmission. |
| MinimumOperationalRate | Integer | As defined in 9.4.2.3 (Supported Rates and BSS Membership Selectors element) | The integer encoding of the target minimum modulation data rate used in Data frame transmission. |
| NetworkDowntimeInterval | Integer | 0–65 535 | Target advance warning time interval, in TUs, for MSGCF-ESS-LINK-GOING-DOWN events.(#1717) |
| BeaconRSSI | Integer | –100 to 40 | The received signal strength in dBm of Beacon frames received on the channel. This may be time-averaged over recent history by a vendor-specific smoothing function. |
| BeaconSNR | Integer | 0–100 | The signal-to-noise ratio of the received (Ed1)Beacon frames, in dB. This may be time-averaged over recent history by a vendor-specific smoothing function. |
| DataFrameSNR | Integer | 0–100 | The signal-to-noise ratio of the received (Ed1)Data frames, in dB. This may be time-averaged over recent history by a vendor-specific smoothing function. |
| DataThroughput | Integer | 0–65 535 | The data throughput in Mb/s(#4148), rounded to the nearest megabit. This may be time-averaged over recent history by a vendor-specific smoothing function. |
| MissedBeaconRate | Real | N/A | The rate at which beacons have not been received in missed beacons per second. This may be time-averaged over recent history by a vendor-specific smoothing function. |
| FrameErrorRate | Real | N/A | The frame error rate of the network in errors per second. This may be time-averaged over recent history by a vendor-specific smoothing function. |
| VendorSpecific | Vendor Specific | As defined by 9.4.2.24 (Vendor Specific element) | Additional vendor-specific parameters may be included in this event. |

#### 6.6.8.3.3 When generated

This event is generated when higher protocol layers wish to set the performance parameters for a network. Higher protocol layers are responsible for ensuring that the set of configured network parameters is consistent with all subscribers to those higher layer protocols.

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#### 6.6.8.3.4 Effect of receipt

Parameters supplied in the event are stored in the MIB, either in the dot11MACStateConfigTable or the dot11MACStateParameterTable.

### 6.6.8.4 MSGCF-ESS-LINK-PARAMETERS.confirm

#### 6.6.8.4.1 Function

This primitive indicates whether network parameters were accepted.

#### 6.6.8.4.2 Semantics of the service primitive

The primitive parameters are as follows:

MSGCF-ESS-LINK-PARAMETERS.confirm(
ESSIdentifier,
EssLinkParameterSet,
)

| Name | Type | Valid range | Description |
|---|---|---|---|
| ESSIdentifier | String | N/A | An identifier for the network, composed of the string value of the SSID element used to identify the network, concatenated with the value of the HESSID if it is in use. |
| EssLinkParameterSet | As defined in Table 6-7 (ESS Link Parameter Set) | N/A | The EssLinkParameterSet is used to configure when event reports are sent to higher protocol layers. |

#### 6.6.8.4.3 When generated

This primitive is generated in response to the MSGCF-ESS-LINK-PARAMETERS.request primitive and is used to indicate whether the parameter set was accepted.

#### 6.6.8.4.4 Effect of receipt

The SME is notified of the new parameter set.

### 6.6.8.5 MSGCF-GET-ESS-LINK-PARAMETERS.request

#### 6.6.8.5.1 Function

This primitive retrieves the current network parameters for a specific network.

#### 6.6.8.5.2 Semantics of the service primitive

The primitive parameter is as follows:

MSGCF-GET-ESS-LINK-PARAMETERS.request(
ESSIdentifier
)


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| Name | Type | Valid range | Description |
|---|---|---|---|
| ESSIdentifier | String | N/A | An identifier for the network, composed of the string value of the SSID element used to identify the network, concatenated with the value of the HESSID if it is in use. |

#### 6.6.8.5.3 When generated

This primitive is used by higher layers to retrieve the currently stored parameters for a network.

#### 6.6.8.5.4 Effect of receipt

The SME retrieves the network parameters and makes them available through the MSGCF-GET-ESS-LINK-PARAMETERS.confirm primitive.

### 6.6.8.6 MSGCF-GET-ESS-LINK-PARAMETERS.confirm

#### 6.6.8.6.1 Function

This primitive reports the current network parameters.

#### 6.6.8.6.2 Semantics of the service primitive

The primitive parameters are as follows:

MSGCF-GET-ESS-LINK-PARAMETERS.confirm(
ESSIdentifier,
EssLinkParameterSet,
)

| Name | Type | Valid range | Description |
|---|---|---|---|
| ESSIdentifier | String | N/A | An identifier for the network, composed of the string value of the SSID element used to identify the network, concatenated with the value of the HESSID if it is in use. |
| EssLinkParameterSet | As defined 6.6.8.3 (MSGCF-ESS-LINK-PARAMETERS.request) | N/A | The EssLinkParameterSet is used to configure when event reports are sent to higher protocol layers. |

#### 6.6.8.6.3 When generated

This primitive is generated by the MSGCF as a result of the MSGCF-GET-ESS-LINK-PARAMETERS.request primitive.

#### 6.6.8.6.4 Effect of receipt

The higher layer protocols are notified of the current network parameters.

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### 6.6.9 Network events

#### 6.6.9.1 MSGCF-ESS-LINK-THRESHOLD-REPORT.indication

##### 6.6.9.1.1 Function

This event reports that the layer 2 network performance has crossed a threshold set by the operations described in Table 6-5 (Trigger support values).

##### 6.6.9.1.2 Semantics of the service primitive

The primitive parameters are as follows:

MSGCF-ESS-LINK-THRESHOLD-REPORT.indication(
ESSIdentifier,
EssLinkParameterSet,
ThresholdCrossingDirectionSet
)

| Name | Type | Valid range | Description |
|---|---|---|---|
| ESSIdentifier | String | N/A | An identifier for the network, composed of the string value of the SSID element used to identify the network, concatenated with the value of the HESSID if it is in use. |
| EssLinkParameterSet | As defined in Table 6-7 (ESS Link Parameter Set) | N/A | A list of EssLinkParameterSets and their current values that have crossed preset thresholds for alerts. |
| ThresholdCrossingDirectionSet | Set of ThresholdCrossing Directions, one for each value in the EssLinkParameterSet | UPWARD, DOWNWARD | Whether the parameter has crossed the threshold while rising or falling. |

##### 6.6.9.1.3 When generated

The convergence function is responsible for monitoring network performance. If the monitored parameters cross the configured threshold, this event is generated to inform higher layer protocols.

##### 6.6.9.1.4 Effect of receipt

This event is made available to higher layer protocols by the convergence function. Actions taken by those higher layers are outside the scope of this standard, but may include preparations for handover or assessing whether handover should be imminent.

### 6.6.10 Network command interface

#### 6.6.10.1 MSGCF-ESS-LINK-COMMAND.request

##### 6.6.10.1.1 Function

This primitive requests that a STA take action for a network.

##### 6.6.10.1.2 Semantics of the service primitive

The primitive parameters are as follows:

MSGCF-ESS-LINK-COMMAND.request(


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ESSIdentifier,
CommandType
)

| Name | Type | Valid range | Description |
|---|---|---|---|
| ESSIdentifier | String | N/A | An identifier for the network, composed of the string value of the SSID element used to identify the network, concatenated with the value of the HESSID if it is in use. |
| CommandType | Enumerated | DISCONNECT, LOW_POWER, POWER_UP, POWER_DOWN, SCAN | Type of command to perform on the link as described in the following subclauses. |

#### 6.6.10.1.3 When generated

This primitive is generated by a higher layer protocol.

#### 6.6.10.1.4 Effect of receipt

The convergence function issues commands to the SME to implement the requested action on behalf of higher layers.

When the DISCONNECT command type is specified, the higher layer is requesting that the STA disconnect from its peer. When the SME on a non-AP STA receives this command, the SME issues an MLME-DEAUTHENTICATE.request primitive to disconnect from the network, and the SME refrains from reconnecting to that network.

When the POWER_DOWN command type is specified, the SME powers down the non-AP STA. Before doing so, it may choose to notify the AP.

When the POWER_UP command type is specified, the SME starts the non-AP STA.

When the LOW_POWER command type is specified, the higher layer is requesting that the interface be placed in a low power mode. This action is accomplished by issuing an MLME-POWERMGT.request primitive with the PowerManagementMode parameter set to POWER_SAVE.

When the SCAN command type is specified, the higher layer is requesting that the STA search for networks. This action is accomplished by issuing an MLME-SCAN.request primitive. Detected networks are made available in the dot11MACStateESSLinkDetectedTable, as well as through the MSGCF-ESS-LINK-DETECTED.indication primitive.

### 6.6.11 MAC state SME SAP—mobility management

#### 6.6.11.1 MSSME-ESS-LINK-GOING-DOWN.indication

#### 6.6.11.1.1 Function

This primitive indicates that the SME is predicting a link failure.

#### 6.6.11.1.2 Semantics of the service primitive

The primitive parameters are as follows:

MSSME-ESS-LINK-GOING-DOWN.indication(

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NonAPSTAMACAddress,(#144)
ESSIdentifier,
TimeInterval,
ReasonCode
)

| Name | Type | Valid range | Description |
|---|---|---|---|
| NonAPSTAMACAddress(#144) | MAC address | (#1653)Any valid individual address | The MAC address of the non-AP STA that is reporting that an ESS is expected to go down. |
| ESSIdentifier | String | N/A | An identifier for the network, composed of the string value of the SSID element used to identify the network, concatenated with the value of the HESSID if it is in use. |
| TimeInterval | Integer | N/A | Time Interval, in time units, in which the link is expected to go down. Connectivity is expected to be available at least for time specified by *TimeInterval*. |
| Reason Code | Enumerated | EXPLICIT_DISCONNECT, LINK_PARAMETER_DEGRADATION, KEY_EXPIRATION, LOW_POWER, QOS_UNAVAILABLE, VENDOR_SPECIFIC | Indicates the reason the link is expected to go down. |

#### 6.6.11.1.3 When generated

This notification is generated by the SME when the network connection is currently established and is expected to go down. The details of the predictive algorithm used are beyond the scope of this standard. One method of implementing this function would be to generate this indication when link quality is fading and no better AP can be found.

#### 6.6.11.1.4 Effect of receipt

This indication is received by the MSGCF and is used to generate the MSGCF-ESS-LINK-DOWN.indication primitive due to link parameter degradation.

## 6.7 PLME SAP interface

### 6.7.1 General

The PHY management service interface consists of the generic PLMEGET and PLMESET primitives on PHY MIB attributes, as described previously, together with the PLME-RESET and PLME-CHARACTERISTICS primitives and the following specific primitives.

### 6.7.2 PLME-RESET.request

#### 6.7.2.1 Function

This primitive is a request by the SME to reset the PHY. The PHY is always reset to the receive state to avoid accidental data transmission.

#### 6.7.2.2 Semantics of the service primitive

This primitive has no parameters.


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#### 6.7.2.3 When generated

This primitive is generated at any time to reset the PHY.

#### 6.7.2.4 Effect of receipt

Receipt of this primitive by the PHY causes the PHY entity to reset both the transmit and the receive state machines and places the PHY into the receive state.

### 6.7.3 PLME-CHARACTERISTICS.request

#### 6.7.3.1 Function

This primitive is a request by the SME to provide (#3526)PHY operational characteristics.

#### 6.7.3.2 Semantics of the service primitive

This primitive has no parameters.

#### 6.7.3.3 When generated

This primitive is generated by the SME, at initialization time, to request the PHY entity to provide its operational characteristics.

#### 6.7.3.4 Effect of receipt

The effect of receipt of this primitive by the PHY entity is the generation of a PLME-CHARACTERISTICS. confirm primitive that conveys its operational characteristics.

### 6.7.4 PLME-CHARACTERISTICS.confirm

#### 6.7.4.1 Function

This primitive provides (#3276)(#3526)PHY operational characteristics.

#### 6.7.4.2 Semantics of the service primitive

The primitive provides the following parameters:

```
PLME-CHARACTERISTICS.confirm(
                                    aSlotTime,
                                    aSIFSTime,
                                    aSignalExtension,
                                    aCCATime,
                                    aCCAMidTime,
                                    aRxPHYStartDelay,
                                    aRxTxTurnaroundTime,
                                    aTxPHYDelay,
                                    aRxPHYDelay,
                                    aRxTxSwitchTime,
                                    aTxRampOnTime,
                                    aAirPropagationTime,
                                    aMACProcessingDelay,
                                    aRIFSTime,
                                    aSymbolLength,
```

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aPSDUMaxLength,
aPSDUMaxLengthWithNoAggregation,
aPPDUMaxTime,(#3263)
aCWmin,
aCWmax,
aMaxCSIMatricesReportDelay
aMaxTODError,
aMaxTOAError,
aTxPHYTxStartRFDelay,
aTxPHYTxStartRMS,
aMaxTODFineError,
aMaxTOAFineError,
aAPEPMaxLengthVHTMU20,
aAPEPMaxLengthVHTMU40,
aAPEPMaxLengthVHTMU80orMore,
aCMMGPPMinListeningTime(#2038)
)

The values assigned to the parameters are as specified in the PLME SAP interface specification contained within each PHY subclass of this standard. Not all parameters are used by all PHYs defined within this standard.

| Name | Type | Description |
|---|---|---|
| aSlotTime | Integer | The slot time (in microseconds) that the MAC uses for defining IFSs. See 10.3.7 (DCF timing relations). |
| aSIFSTime | Integer | (#14)The nominal time (in microseconds) that the MAC and PHY require from reception of the end of a PPDU[+SigExt] on the WM, until the MAC and PHY have processed (#2257)any frame(s) therein, and responded with the start on the WM of the PPDU containing the earliest possible response frame. See 10.3.7 (DCF timing relations). |
| aSignalExtension | Integer | Duration (in microseconds) of the signal extension (i.e., a period of no transmission) that is included (#14)immediately after certain PPDU formats; see 19.3.2 (PPDU format) and 10.3.8 (Signal extension). |
| aCCATime | Integer | For Clause 15 (DSSS PHY specification for the 2.4 GHz band designated for ISM applications) to Clause 18 (Extended Rate PHY (ERP) specification) PHYs and Clause 20 (Directional multi-gigabit (DMG) PHY specification) PHYs, the maximum time (in microseconds) the CCA mechanism has available to assess the medium to determine whether the medium is busy or idle.<br><br>For Clause 19 (High Throughput (HT) PHY specification(#2297)) and Clause 21 (Very high throughput (VHT) PHY specification) PHYs, the maximum time (in microseconds) that the CCA mechanism has available to detect the start of an IEEE 802.11 transmission within the primary channel and to assess the energy on the medium within the primary, secondary, secondary40 (Clause 21 (Very high throughput (VHT) PHY specification) PHY only), and secondary80 (Clause 21 (Very high throughput (VHT) PHY specification) PHY only) channels that fall inside the operating channel, in order to determine the values of the STATE and channel-list parameters of the PHY-CCA.indication primitive. |
| aCCAMidTime | Integer | For Clause 21 (Very high throughput (VHT) PHY specification) PHYs, the maximum time (in microseconds) the CCA mechanism has available to assess the medium to determine whether an IEEE 802.11 transmission is present on a nonprimary channel. |


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| Name | Type | Description |
|---|---|---|
| aRxPHYStartDelay | Integer(s)(#3038) | (#3038)One or more integer delay values for each supported PHY clause, where each delay, in microseconds, is from the start of the PPDU at the receiver's antenna to the issuance of earlier of the PHY-RXEARLYSIG.indication if sent or the PHY-RXSTART.indication primitive. |
| aRxTxTurnaroundTime | Integer | The maximum time (in microseconds) that the PHY requires to change from receiving to transmitting the start of the first symbol. See 10.3.7 (DCF timing relations). |
| aTxPHYDelay | Integer | (#1060)The nominal time (in microseconds) that the PHY uses from when a PHY-TXSTART.request primitive is issued until the PHY begins(#3351) transmission of the requested PPDU at the air interface. |
| aRxPHYDelay | Integer | (#14)The nominal time (in microseconds) that the PHY takes to generate the PHY-RXEND.indication for a received PPDU to the MAC from the end of the PPDU[+SigExt] on the WM.(#1058) |
| aRxTxSwitchTime | Integer | The nominal time (in microseconds) that the PHY takes to switch from receive to transmit.(#1405) |
| aTxRampOnTime | Integer | The maximum time (in microseconds) that the PHY takes to turn the transmitter on.(#1405) |
| aAirPropagationTime | Integer | Twice the propagation time (in microseconds) for a signal to cross the maximum distance between the most distant allowable STAs that are slot synchronized. |
| aMACProcessingDelay | Integer | The maximum time (in microseconds) available for the MAC to issue a PHY-TXSTART.request primitive pursuant to a PHY-RXEND.indication primitive (for response after a SIFS(#6587)) or PHY-CCA.indication(IDLE) primitive (for response at any slot boundary following a SIFS). This constraint on MAC performance is defined as a PHY-specific parameter because of its use, along with other PHY-specific time delays, in calculating the two PHY characteristics of primary concern to the MAC: aSlotTime and aSIFSTime. See 10.3.7 (DCF timing relations). |
| aRIFSTime | Integer | Value of the reduced interframe space (in microseconds), which is the time by which multiple transmissions from a single transmitter may be separated, when no SIFS-separated response transmission is expected. See 10.3.2.3.2 (RIFS). |
| aSymbolLength | Integer | The current PHY's Symbol length (in microseconds). If the actual value of the length is not an integer number of μs, the value is rounded up to the next higher value. |
| aPSDUMaxLength | Integer | The maximum number of octets in a PSDU that can be conveyed by a PPDU. |
| aPSDUMaxLengthWithNoAggregation | Integer | The maximum number of octets in a PSDU that can be conveyed by an S1G PPDU when the Aggregation field is 0. |
| aPPDUMaxTime | Integer | The maximum duration of a PPDU in milliseconds.(#3263) |
| aCWmin | Integer | The minimum size of the CW, in units of aSlotTime. |
| aCWmax | Integer | The maximum size of the CW, in units of aSlotTime. |
| aMaxCSIMatricesReportDelay | Integer | (#14)The maximum time (in milliseconds) between the reception of a PSDU containing a frame containing a CSI Feedback Request or an HT NDP announcement and the transmission of the PSDU containing a first CSI frame containing channel state information measured from the received Sounding Complete frame. See 10.33.2.4.4 (CSI reporting for calibration). |
| aMaxTODError | Integer | An estimate of the maximum error (in 10 ns units) in the TX_START_OF_FRAME_OFFSET value in the PHY-TXSTART.confirm primitive. The estimated maximum error includes any error due to implementation component and environmental (including temperature) variability. |
| aMaxTOAError | Integer | An estimate of the maximum error (in 10 ns units) in the RX_START_OF_FRAME_OFFSET value in the PHY-RXSTART.indication primitive. The estimated maximum error includes any error due to implementation component and environmental (including temperature) variability. |

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| Name | Type | Description |
|---|---|---|
| aTxPHYTxStartRFDelay | Integer | (#14)The delay (in units of 0.5 ns) between a PHY-TXSTART.request primitive being issued and the first PPDU energy sent by the transmitting port, for the current channel. |
| aTxPHYTxStartRMS | Integer | The RMS time of departure error (in units of 0.5 ns), where the time of departure error equals the difference between TIME_OF_DEPARTURE and the time of departure measured by a reference entity using a clock synchronized to the start time and mean frequency of the local PHY entity's clock. |
| aMaxTODFineError | Integer | An estimate of the maximum error (in units of picoseconds) in the TX_START_OF_FRAME_OFFSET value in the PHY-TXSTART.confirm primitive. The estimated maximum error includes any error due to implementation component and environmental (including temperature) variability. |
| aMaxTOAFineError | Integer | An estimate of the maximum error (in units of picoseconds) in the RX_START_OF_FRAME_OFFSET value in the PHY-RXSTART.indication primitive. The estimated maximum error includes any error due to implementation component and environmental (including temperature) variability. |
| aAPEPMaxLengthVHTMU20 | Integer | Maximum APEP_LENGTH value allowed for 20 MHz VHT MU PPDUs. |
| aAPEPMaxLengthVHTMU40 | Integer | Maximum APEP_LENGTH value allowed for 40 MHz VHT MU PPDUs. |
| aAPEPMaxLengthVHTMU80orMore | Integer | Maximum APEP_LENGTH value allowed for 80 MHz, 160 MHz, and 80+80 MHz VHT MU PPDUs. |
| aCMMGPPMinListeningTime(#2038) | Integer | The minimum time (in microseconds) CMMG STA moves to and stays in listening mode. |

#### 6.7.4.3 When generated

This primitive is issued by the PHY entity in response to a PLME-CHARACTERISTICS.request primitive.

#### 6.7.4.4 Effect of receipt

The receipt of this primitive provides (#3526)PHY operational characteristics. (#3038)The MAC determines aRxPHYStartDelay by excluding values of aRxPHYStartDelay for each supported PHY clause that are not allowed in the current context, then setting aRxPHYStartDelay to the maximum of the remaining values.

### 6.7.5 PLME-TXTIME.request

#### 6.7.5.1 Function

This primitive is a request for the PHY to calculate the time required to transmit onto the WM a PPDU containing a specified length PSDU, and using a specified format, data rate, and signaling.

#### 6.7.5.2 Semantics of the service primitive

This primitive provides the following parameter:

PLME-TXTIME.request(
TXVECTOR
)

The TXVECTOR represents a list of parameters that the MAC sublayer provides to the local PHY entity in order to transmit a PSDU. The minimum required PHY parameters are listed in 8.3.4.4 (Vector descriptions).


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#### 6.7.5.3 When generated

This primitive is issued by the MAC sublayer to the PHY entity when the MAC sublayer needs to determine the time required to transmit a particular PSDU.

#### 6.7.5.4 Effect of receipt

The effect of receipt of this primitive by the PHY entity is to generate a (#7074)PLME-TXTIME.confirm primitive that conveys the required transmission time.

### 6.7.6 PLME-TXTIME.confirm

#### 6.7.6.1 Function

This primitive indicates the time required to transmit the PPDU described in the corresponding PLME-TXTIME.request primitive.

When the TXVECTOR parameter FORMAT in the corresponding PLME-TXTIME.request primitive is VHT, the primitive also provides the number of octets, per user, required to fill the PPDU.

#### 6.7.6.2 Semantics of the service primitive

This primitive provides the following parameter:

```
PLME-TXTIME.confirm(
                        TXTIME,(#4087)
                        PSDU_LENGTH[]
                        )
```

The TXTIME represents the time, in microseconds, required to transmit the PPDU described in the corresponding PLME-TXTIME.request primitive. If the calculated time includes a fractional microsecond and the TXVECTOR parameter FORMAT in the corresponding PLME-TXTIME.request primitive is not HE_SU, HE_MU, HE_TB, or HE_ER_SU, a non-DMG STA rounds the TXTIME value to the next higher integer. A non-DMG STA does not round the TXTIME value up or down if the TXVECTOR parameter FORMAT in the corresponding PLME-TXTIME.request primitive is HE_SU, HE_MU, HE_TB, or HE_ER_SU. A DMG STA does not round the TXTIME value up or down.(11ax)(11ay)

The PSDU_LENGTH[] parameter is an array of size TXVECTOR parameter NUM_USERS if the TXVECTOR parameter FORMAT is VHT. If the TXVECTOR parameter FORMAT is HE_SU, HE_ER, or HE_TB, the size of the parameter PSDU_LENGTH[] array is always 1. If the TXVECTOR parameter FORMAT is HE_MU, the size of the parameter PSDU_LENGTH[] array is determined by TXVECTOR parameters RU_ALLOCATION and STA_ID. Each value in the array indicates the number of octets required to fill the PPDU for the user represented by that array index. The parameter is present only when the TXVECTOR parameter FORMAT is VHT, HE_SU, HE_ER_SU, HE_MU, or HE_TB.(11ax)

#### 6.7.6.3 When generated

This primitive is issued by the local PHY entity in response to a PLME-TXTIME.request primitive.

#### 6.7.6.4 Effect of receipt

The receipt of this primitive provides the MAC sublayer with the PPDU transmission time.

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### 6.7.7 PLME-MINPAYLOADSTAT.request(#7068)(11ay)

#### 6.7.7.1 Function

This primitive is a request for the PHY to start measuring the signal power of received PPDUs and compute metrics such as EVM, SNR and LDPC over iterations of PPDUs that exceed the prescribed PSDU length (see 10.42.5).

#### 6.7.7.2 Semantics of the service primitive

This primitive provides the following parameter:

```
PLME-MINPAYLOADSTAT.request(
                                    PSDU_MIN_LENGTH
                                    )
```

The PSDU_MIN_LENGTH parameter represents the smallest PSDU length, in octets, that PPDUs are required to have for the PHY to compute the required metrics.

#### 6.7.7.3 When generated

This primitive is issued by the SME to the PHY entity to require the PHY to proceed with parameters measurement of received PPDUs that have a PSDU length no less than PSDU_MIN_LENGTH. The SME also issues the primitive to change the value of PSDU_MIN_LENGTH.

#### 6.7.7.4 Effect on receipt

The effect of receipt of this primitive by the PHY entity is to start measuring signal power and to compute the metrics measured over PPDUs with a PSDU length no less than PSDU_MIN_LENGTH.

### 6.7.8 PLME-MINPAYLOADSTAT.confirm(11ay)

#### 6.7.8.1 Function

This primitive indicates that the PHY is ready to proceed with the measurement over received PPDUs and that the threshold has been set to PSDU_MIN_LENGTH.

#### 6.7.8.2 Semantics of the service primitive

This primitive provides the following parameter:

```
PLME-MINPAYLOADSTAT.confirm(
                                    PSDU_MIN_LENGTH
                                    )
```

The PSDU_MIN_LENGTH parameter represents the smallest PSDU length, in octets, that PPDUs are required to have for the PHY to compute the required metrics.

#### 6.7.8.3 When generated

This primitive is issued by the local PHY entity in response to a PLME-MINPAYLOADSTAT.request primitive.


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#### 6.7.8.4 Effect on receipt

The receipt of this primitive indicates to the SME that the PHY is ready to proceed with the measurement over received PPDUs that have a PSDU length no less than PSDU_MIN_LENGTH.

### 6.7.9 PLME- MINPAYLOADSTATRESET.request(11ay)

#### 6.7.9.1 Function

This primitive is a request by the SME to reset the PHY counters corresponding to the PLME-MINPAYLOADSTAT primitive. No other PHY functionality is impacted by the primitive.

#### 6.7.9.2 Semantics of the service primitive

This primitive has no parameters.

#### 6.7.9.3 When generated

This primitive is generated to reset the PHY measurements initiated by the PLME-MINPAYLOADSTAT.

#### 6.7.9.4 Effect on receipt

Receipt of this primitive by the PHY causes it to reset the PHY counters of received PPDUs.

### 6.7.10 PLME- MINPAYLOADSTATSTOP.request(11ay)

#### 6.7.10.1 Function

This primitive is a request by the SME for the PHY to stop all measurements corresponding to the PLME-MINPAYLOADSTAT primitive. No other PHY functionality is impacted by the primitive.

#### 6.7.10.2 Semantics of the service primitive

This primitive has no parameters.

#### 6.7.10.3 When generated

This primitive is generated to stop the PHY measurements initiated by the PLME-MINPAYLOADSTAT.

#### 6.7.10.4 Effect on receipt

Receipt of this primitive by the PHY causes it to stop the PHY measurements of received PPDUs.

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# 7. DS SAP specification

## 7.1 Introduction

The DS SAP is the interface between the DS SAP service users and the DS SAP service provider. The DS SAP service users are the connected APs, mesh gates, and the portal. The DS SAP service provider is the DS. Figure 7-1 (DS architecture) shows the location of the DS in the IEEE 802.11 architecture. The DS SAP is indicated in this Figure by the lines connecting the DS to its service users. In Figure 7-1 (DS architecture), the DS has four users, two APs, a mesh gate, and a portal, so the DS is shown passing behind the MAC/PHYs of the STAs.

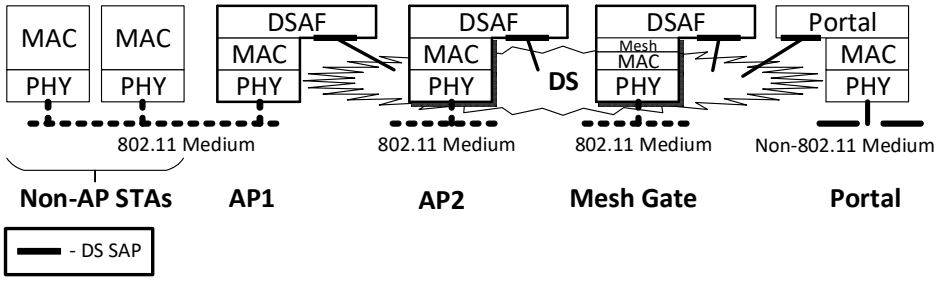


**Figure 7-1—DS architecture**

The DS SAP interface specification describes the primitives required to get MAC service tuples in and out of the DS and update the DS's mapping of STAs to APs or to mesh gates. Describing the DS itself or the functions thereof is out of scope of this standard.

The DS SAP actions are as follows:

a) Accept MSDUs (as part of MAC service tuples) from APs, mesh gates, and the portal.
b) Deliver MSDUs (as part of MAC service tuples) to APs, mesh gates, or the portal.
c) Accept STA-to-AP mapping updates from the APs.
d) Accept STA-to-mesh gate mapping updates from the mesh gates.

When the DS delivers the MAC service tuples to an AP, the AP then determines when and how to deliver the MAC service tuples to the AP's MAC (via the MAC SAP). When the DS delivers the MAC service tuples to a mesh gate, the mesh gate then determines when and how to deliver the MAC service tuples to the mesh gate's MAC (via the MAC SAP).

## 7.2 SAP primitives

### 7.2.1 General

The DS SAP service interface primitives are as follows:

a) DS-UNITDATA.request
b) DS-UNITDATA.indication
c) DS-STA-NOTIFY.request


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### 7.2.2 MSDU transfer

#### 7.2.2.1 General

The DS-UNITDATA primitives accept and deliver IEEE 802.11 MAC service tuples, including all of the parameters and data as defined in 5.2.4.2 (Semantics of the service primitive).

#### 7.2.2.2 DS-UNITDATA.request

##### 7.2.2.2.1 Function

This primitive requests distribution of a MAC service tuple across the DS.

##### 7.2.2.2.2 Semantics of the service primitive

The primitive parameters are as follows:

DS-UNITDATA.request(
MAC service tuple,
SourceType
)

| Name | Type | Valid range | Description |
|---|---|---|---|
| MAC service tuple | IEEE 802.11 MSDU | Any valid data unit according to 5.2.4.2 (Semantics of the service primitive), including data and all parameters | Specifies the MAC service tuple to be distributed via the DS. |
| SourceType | Enumeration | SRC_AP, SRC_MESH_GATE, SRC_PORTAL | Specifies the type of entity that is requesting distribution of a MAC service tuple. |

##### 7.2.2.2.3 When generated

This primitive is generated by an AP, mesh gate, or portal to submit a MAC service tuple to the DS for distribution.

##### 7.2.2.2.4 Effect of receipt

This primitive initiates distribution of the MAC service tuple through the DS. (#3422)A MAC service tuple with a destination that is an individual address from an AP, mesh gate, or portal is distributed through the DS to the corresponding AP, mesh gate, or portal. (#4140)(#3422)A MAC service tuple that has a destination address that is a group address and that is delivered to the DS from an AP or mesh gate is distributed to the portal, if any, and to all APs and mesh gates connected to the DS, including the originating AP or mesh gate. (#4140)(#3422)A MAC service tuple that has a destination address that is a group address and that is delivered to the DS from a portal is distributed to all APs and mesh gates connected to the DS.

#### 7.2.2.3 DS-UNITDATA.indication

##### 7.2.2.3.1 Function

This primitive indicates delivery of a MAC service tuple from the DS to an AP, mesh gate, or portal.

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#### 7.2.2.3.2 Semantics of the service primitive

The primitive parameters are as follows:

DS-UNITDATA.indication(
MAC service tuple
)

| Name | Type | Valid range | Description |
|---|---|---|---|
| MAC service tuple | IEEE 802.11 MSDU | Any valid data unit according to 5.2.4.2 (Semantics of the service primitive), including data and all parameters | Specifies the MAC service tuple that is being delivered by the DS. |

#### 7.2.2.3.3 When generated

This primitive is generated by the DS to deliver a MAC service tuple to an AP, mesh gate, or portal.

#### 7.2.2.3.4 Effect of receipt

This primitive delivers a MAC service tuple to an AP, mesh gate, or portal.

### 7.2.3 Mapping updates

#### 7.2.3.1 General

The DS-STA-NOTIFY primitive is used to maintain the STA-to-AP and mesh STA-to-mesh gate mapping data of the DS.

#### 7.2.3.2 DS-STA-NOTIFY.request

#### 7.2.3.2.1 Function

This primitive requests an update to the DS's STA-to-AP map or mesh STA-to-mesh gate map.

#### 7.2.3.2.2 Semantics of the service primitive

The primitive parameters are as follows:

DS-STA-NOTIFY.request(
STAAddress,
UpdateType
)

| Name | Type | Valid range | Description |
|---|---|---|---|
| STAAddress | MAC address(#376) | (#1653)Any valid individual address | When generated by an AP, specifies the address of the STA whose association status with the AP has changed.<br><br>When generated by a mesh gate, specifies the address of the mesh STA whose reachability status through the mesh gate has changed. |
| UpdateType | Enumeration | ADD, MOVE, DELETE | Specifies the DS mapping update operation to be performed. |


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#### 7.2.3.2.3 When generated

This primitive is generated by an AP or mesh gate to update the DS's STA-to-AP map or mesh STA-to-mesh gate map.

#### 7.2.3.2.4 Effect of receipt

When generated by an AP, this primitive updates the DS's STA-to-AP map, which controls to which AP the DS delivers MAC service tuples that are destined for a given STA.

When generated by a mesh gate, this primitive updates the DS's mesh STA-to-mesh gate map, which controls to which mesh gate the DS delivers MAC service tuples that are destined for a given mesh STA. The mesh STA-to-mesh gate map can be incomplete.

There are many mechanisms to implement this mapping update for the cases of ADD and MOVE. (#1834)One example mechanism, in the case where the DS is an IEEE 802 LAN, is to use an XID null frame (see ISO/IEC 8802-2:1998).

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# 8. PHY service specification

## 8.1 Scope of PHY services

The PHY services provided to the MAC are described in this clause. Different PHYs are defined as part of this standard. Each PHY can consist of the following protocol functions:

a) (#14)A function that defines a method of mapping the PSDUs into a PPDU format suitable for sending and receiving data, management, and control information between two or more STAs.

b) A function that defines the characteristics of, and method of transmitting and receiving data through, a WM between two or more STAs.

## 8.2 PHY functions

The protocol reference model for the IEEE 802.11 architecture is shown in Figure 4-27 (Portion of the ISO/IEC basic reference model covered in this standard(#4114)) (in 4.9 (Reference model)). Most PHY definitions contain two functional entities: the PHY function and the layer management function.

The PHY service is provided to the MAC entity at the STA through a SAP, called the *PHY SAP*, as shown in Figure 4-27 (Portion of the ISO/IEC basic reference model covered in this standard(#4114)).

## 8.3 Detailed PHY service specifications

### 8.3.1 Scope and field of application

The services provided by the PHY to the MAC are specified in this subclause. These services are described in an abstract way and do not imply any particular implementation or exposed interface.

### 8.3.2 Overview of the service

(#14)The function of the PHY is to provide a mechanism for transferring PSDUs between two or more STAs.

### 8.3.3 Overview of interactions

The primitives associated with communication between the MAC sublayer and the PHY fall into two basic categories:

a) Service primitives that support MAC peer-to-peer interactions

b) Service primitives that have local significance and (#6320)support interactions between the MAC sublayer and the PHY layer

### 8.3.4 Basic service and options

#### 8.3.4.1 PHY SAP peer-to-peer service primitives

Table 8-1 (PHY SAP peer-to-peer service primitives) indicates the primitives for peer-to-peer interactions.

#### 8.3.4.2 PHY SAP inter-(sub)layer service primitives

Table 8-2 (PHY SAP inter-(sub)layer service primitives) indicates (#6320)the primitives for interactions between the MAC sublayer and the PHY layer.


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**Table 8-1—PHY SAP peer-to-peer service primitives**

| Primitive | Request | Indication | Confirm |
|---|---|---|---|
| PHY-DATA | X | X | X |

**Table 8-2—PHY SAP inter-(sub)layer service primitives**

| Primitive | Request | Indication | Confirm |
|---|---|---|---|
| PHY-TXSTART | X | | X |
| PHY-TXEND | X | | X |
| PHY-CCARESET | X | | X |
| PHY-CCA | | X | |
| (#3038)PHY-RXEARLYSIG | | X | |
| PHY-RXSTART | | X | |
| PHY-RXEND | | X | |
| PHY-CONFIG | X | | X |
| PHY-TXHEADEREND | | X | |
| PHY-TRIGGER(11ax) | X | | |
| PHY-RXLTFSEQUENCE(11az) | X | | |
| PHY-RXTRNSEQUENCE(11az) | X | | |

### 8.3.4.3 PHY SAP service primitives parameters

Table 8-3 (PHY SAP service primitive parameters) shows the parameters used by one or more of the PHY SAP service primitives.

**Table 8-3—PHY SAP service primitive parameters**

| Parameter | Associated primitive | Value |
|---|---|---|
| DATA | PHY-DATA.request<br>PHY-DATA.indication | Octet value X'00'–X'FF' |
| TXVECTOR | PHY-TXSTART.request | A set of parameters |
| STATE | PHY-CCA.indication | (BUSY[, channel-list[, per20bitmap[, antenna-list]]])<br>(IDLE[, per20bitmap])(11ax)(11ay)(#4088) |
| RXVECTOR | PHY-RXSTART.indication | A set of parameters |

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**Table 8-3—PHY SAP service primitive parameters *(continued)***

| Parameter | Associated primitive | Value |
|---|---|---|
| RCPI | PHY-RXEND.indication | Clauses 15 (DSSS PHY specification for the 2.4 GHz band designated for ISM applications)–19 (High Throughput (HT) PHY specification(#2297)) and 21 (Very high throughput (VHT) PHY specification)–23 (Sub 1 GHz (S1G) PHY specification(#4095)): 0–255; Clauses 20 (Directional multi-gigabit (DMG) PHY specification), 24 (China directional multi-gigabit (CDMG) PHY specification), and 25 (China millimeter-wave multi-gigabit (CMMG) PHY specification): not present |
| RXERROR | PHY-RXEND.indication | NoError, FormatViolation, CarrierLost, UnsupportedRate, Filtered, IntegrityCheckError(11az) |
| IPI-STATE | PHY-CCARESET.request<br>PHY-CCARESET.confirm | IPI-ON, IPI-OFF |
| IPI-REPORT | PHY-CCA.indication<br>PHY-CCARESET.confirm | A set of IPI values for the preceding time interval |
| PHYCONFIG_VECTOR | PHY-CONFIG | A set of parameters |
| TXSTATUS | PHY-TXSTART.confirm | A set of parameters |
| USER_INDEX | PHY-DATA.request | 0 to TXVECTOR parameter NUM_USERS – 1 |
| TRIGVECTOR(11ax) | PHY-TRIGGER.request | A set of parameters |
| LTFVECTOR(11az) | PHY-RXLTFSEQUENCE.request | A set of parameters needed to receive and process the HE Ranging NDP and HE TB Ranging NDP (see Table 27-3 (LTFVECTOR parameters(11az))). |

### 8.3.4.4 Vector descriptions

Several service primitives include a parameter vector. This vector is a list of parameters that may vary depending on the PHY type. Table 8-4 (Vector descriptions(#4383)) lists the minimum parameter values required by the MAC or PHY in each of the parameter vectors.

**Table 8-4—Vector descriptions(#4383)**

| Parameter | Associated vector | Value |
|---|---|---|
| DATARATE | TXVECTOR, RXVECTOR | PHY dependent. The name of the field used to specify the Tx data rate and report the Rx data rate may vary for different PHYs. |
| LENGTH | TXVECTOR, RXVECTOR | PHY dependent. |


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**Table 8-4—Vector descriptions(#4383) *(continued)***

| Parameter | Associated vector | Value |
|---|---|---|
| ACTIVE_RXCHAIN_SET | PHYCONFIG_VECTOR | The ACTIVE_RXCHAIN_SET parameter indicates which receive chains of the available receive chains are active. |
| OPERATING_CHANNEL | PHYCONFIG_VECTOR | The operating channel the PHY is configured use. |
| SECONDARY_CHANNEL_OFFSET | PHYCONFIG_VECTOR | Enumerated type:<br>SECONDARY_CHANNEL_NONE indicates operation in 20 MHz HT STAs.<br>SECONDARY_CHANNEL_ABOVE indicates operation in 40 MHz with the secondary channel above the primary.<br>SECONDARY_CHANNEL_BELOW indicates operation in 40 MHz with the secondary channel below the primary. |
| ANT_CONFIG | PHYCONFIG_VECTOR | Indicates which antenna configuration(s) is to be used when receiving PPDUs and which configuration is to be used when switching configurations during the reception of a PPDU. Values are implementation dependent. |
| SECURE_TRN_SEQUENCE(11az) | TRNVECTOR | Indicates the Secure TRN bit sequences used in the EDMG secure ranging PPDU.<br>The Secure TRN bit sequences generation is defined in 12.2.12 (EDMG secure ranging sequences(11az)). |

The (11ax)HT PHY TXVECTOR and RXVECTOR contain additional parameters related to the operation of the (11ax)HT PHY modes of operation as described in 19.2 (HT PHY service interface). In certain modes of operation, the DATARATE parameter is replaced by MCS, CH_BANDWIDTH and GI_TYPE parameters. The mapping from these values to data rate is defined in 19.5 (Parameters for HT-MCSs).

The (11ax)VHT PHY TXVECTOR and RXVECTOR contain additional parameters related to the operation of the (11ax)VHT PHY modes of operation as described in 21.2 (VHT PHY service interface). In certain modes of operation, the DATARATE parameter is replaced by MCS, CH_BANDWIDTH, NUM_STS, STBC and GI_TYPE parameters. The mapping from these values to data rate is defined in 21.5 (Parameters for VHT-MCSs), where VHT-MCS is MCS and $N_{SS}$ is NUM_STS / (STBC + 1).

(11ax)The HE PHY TXVECTOR and RXVECTOR contain additional parameters related to the HE PHY modes of operation as described in 27.2 (HE PHY service interface). In certain modes of operation, the DATARATE parameter is replaced by MCS, CH_BANDWIDTH, RU_ALLOCATION, NUM_STS, STBC, GI_TYPE, and DCM values. The mapping from these values to data rate is defined in 27.5 (Parameters for HE-MCSs), where HE-MCS is MCS and $N_{SS}$ is NUM_STS / (STBC + 1).

(11ax)The HE PHY TRIGVECTOR contains parameters for UL MU operation (see Table 27-2 (TRIGVECTOR parameters(11ax))).

### 8.3.5 PHY SAP detailed service specification

#### 8.3.5.1 Introduction

Subclause 8.3.5 (PHY SAP detailed service specification) describes the services provided by each PHY primitive.

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#### 8.3.5.2 PHY-DATA.request

##### 8.3.5.2.1 Function

This primitive defines the transfer of an octet of data from the MAC sublayer to the local PHY entity.

##### 8.3.5.2.2 Semantics of the service primitive

The primitive provides the following parameter:

```
PHY-DATA.request(
                    DATA,
                    USER_INDEX,
                    STA_INDEX(11ax)
                    )
```

The DATA parameter is an octet of value X'00' to X'FF'.

The USER_INDEX parameter (typically identified as *u* for a VHT STA; (11ax)for MU usage, see the NOTE at the end of Table 21-1 (TXVECTOR and RXVECTOR parameters(#12))) is present for a VHT MU PPDU and indicates the index of the user in the TXVECTOR to which the accompanying DATA octet applies; otherwise, this parameter is not present.

(11ax)The STA_INDEX parameter (identified as the STA_ID parameter; see STA_ID parameter in Table 27-1 (TXVECTOR and RXVECTOR parameters(#12)(11ax)) and Table 26.11.1 (STA_ID)) is present for an HE MU PPDU; otherwise, this parameter is not present. If the TXVECTOR parameter UPLINK_FLAG is 0, this parameter indicates the STA or group of STAs that is the recipient of an RU to which the accompanying DATA octet applies. If the TXVECTOR parameter UPLINK_FLAG is 1, this parameter indicates the STA that is the transmitter of an RU to which the accompanying DATA octet applies.

##### 8.3.5.2.3 When generated

This primitive is generated by the MAC sublayer to transfer an octet of data to the PHY entity. This primitive can be issued only following a transmit initialization response (a PHY-TXSTART.confirm primitive) from the PHY.

##### 8.3.5.2.4 Effect of receipt

The receipt of this primitive by the PHY entity causes the PHY transmit state machine to transmit an octet of data. When the PHY entity receives the octet, it issues a PHY-DATA.confirm primitive to the MAC sublayer.

#### 8.3.5.3 PHY-DATA.indication

##### 8.3.5.3.1 Function

This primitive indicates the transfer of data from the PHY to the local MAC entity.

##### 8.3.5.3.2 Semantics of the service primitive

The primitive provides the following parameter:

```
PHY-DATA.indication(
                    DATA,
```


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STA_INDEX(11ax)
)

The DATA parameter is an octet of value X'00' to X'FF'.

(11ax)The STA_INDEX parameter (identified as an AID of the transmitter of the DATA contained in an HE TB PPDU; see STA_ID parameter in Table 27-1 (TXVECTOR and RXVECTOR parameters(#12)(11ax))) is present for an HE TB PPDU and indicates the STA of an RU from which the accompanying DATA octet applies; otherwise, this parameter is not present.

#### 8.3.5.3.3 When generated

The PHY-DATA.indication primitive is generated by a receiving PHY entity to transfer the received octet of data to the local MAC entity. The time between receipt of the last bit of the last provided octet from the WM and the receipt of this primitive by the MAC entity is aRxPHYDelay.

#### 8.3.5.3.4 Effect of receipt

The receipt of this primitive by the MAC entity causes the MAC to collect the data octet provided by the PHY in the current receive flow (see Figure 5-1 (MAC data plane architecture (#7109)(#4149)(#1001)(11ay)(#3186)(#3185)(#4172)(#4192)(11bc))).

### 8.3.5.4 PHY-DATA.confirm

#### 8.3.5.4.1 Function

This primitive is issued by the PHY to the local MAC entity to confirm the transfer of data from the MAC entity to the PHY.

#### 8.3.5.4.2 Semantics of the service primitive

The semantics of the primitive are as follows:
PHY-DATA.confirm

This primitive has no parameters.

#### 8.3.5.4.3 When generated

This primitive is issued by the PHY to the MAC entity when the transfer of data from the MAC entity to the PHY has completed. The PHY issues this primitive in response to every PHY-DATA.request primitive issued by the MAC sublayer.

#### 8.3.5.4.4 Effect of receipt

The receipt of this primitive by the MAC causes the MAC to start the next MAC entity request.

### 8.3.5.5 PHY-TXSTART.request

#### 8.3.5.5.1 Function

This primitive is a request by the MAC sublayer to the local PHY entity to start the transmission of a PSDU.

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#### 8.3.5.5.2 Semantics of the service primitive

The primitive provides the following parameter:

```
PHY-TXSTART.request(
                    TXVECTOR
                    )
```

The TXVECTOR represents a list of parameters that the MAC sublayer provides to the local PHY entity in order to transmit a PSDU. The minimum required PHY parameters are listed in 8.3.4.4 (Vector descriptions).

See 1.4 (Word usage) for interpretation of references to frames, MPDUs, A-MPDUs and PPDUs being transmitted with a certain TXVECTOR.

#### 8.3.5.5.3 When generated

This primitive is issued by the MAC sublayer to the PHY entity when the MAC sublayer needs to begin the transmission of a PSDU.

#### 8.3.5.5.4 Effect of receipt

The effect of receipt of this primitive by the PHY entity is to start the local transmit state machine.

The behavior expected by the MAC pursuant to the issuance of PHY-TXSTART.request primitive is shown in Figure 10-25 (DCF timing relationships(#14)(#1058)(#3297)) (in 10.3.7 (DCF timing relations)) and Figure 10-29 (EDCA mechanism timing relationships(#14)(#1058)).

### 8.3.5.6 PHY-TXSTART.confirm

#### 8.3.5.6.1 Function

This primitive is issued by the PHY to the local MAC entity to confirm the start of a transmission and to indicate parameters related to the start of the transmission. The PHY issues this primitive in response to every PHY-TXSTART.request primitive issued by the MAC sublayer.

#### 8.3.5.6.2 Semantics of the service primitive

The semantics of the primitive are as follows:

```
PHY-TXSTART.confirm(
                    TXSTATUS
                    )
```

The TXSTATUS represents a list of parameters that the local PHY entity provides to the MAC sublayer related to the transmission of a PPDU. The list of parameters is PHY-dependent.

#### 8.3.5.6.3 When generated

This primitive is issued by the PHY to the MAC entity once all of the following conditions are met:

— The PHY has received a PHY-TXSTART.request primitive from the MAC entity.
— The PHY is ready to begin accepting outgoing data octets from the MAC.

If dot11TODImplemented and dot11TODActivated are both true or dot11TimingMsmtActivated is true; and the parameter TIME_OF_DEPARTURE_REQUESTED in the TXVECTOR specified in the PHY-


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TXSTART.request primitive is true, then the PHY shall include the TIME_OF_DEPARTURE corresponding to the time when the first frame energy is sent by the transmitting port and TIME_OF_DEPARTURE_ClockRate parameters in the TXSTATUS, if the PHY includes these parameters in the TXSTATUS.

If dot11TimingMsmtActivated is true, then the PHY shall include TX_START_OF_FRAME_OFFSET in the TXSTATUS, if the PHY includes this parameter in the TXSTATUS.

(#14)NOTE—A more precise name for TX_START_OF_FRAME_OFFSET would be TX_START_OF_PPDU_TO_-PHY_TXSTART_PRIMITIVE_OFFSET. Similarly, a more precise name for RX_START_OF_FRAME_OFFSET would be RX_START_OF_PPDU_TO_PHY_RXSTART_PRIMITIVE_OFFSET.

#### 8.3.5.6.4 Effect of receipt

The receipt of this primitive by the MAC entity causes the MAC to start the transfer of data octets. (#14)Parameters in the TXSTATUS are returned to the MAC which can then include them in transmitted MPDUs. See Annex P for use of TXSTATUS parameters for timing.

### 8.3.5.7 PHY-TXEND.request

#### 8.3.5.7.1 Function

This primitive is a request by the MAC sublayer to the local PHY entity that the current transmission of the PSDU be completed.

#### 8.3.5.7.2 Semantics of the service primitive

The semantics of the primitive are as follows:

PHY-TXEND.request

This primitive has no parameters.

#### 8.3.5.7.3 When generated

This primitive is generated when the MAC sublayer has received the last PHY-DATA.confirm primitive from the local PHY entity for the PSDU currently being transferred.

#### 8.3.5.7.4 Effect of receipt

The effect of receipt of this primitive by the local PHY entity is to stop the transmit state machine.

### 8.3.5.8 PHY-TXEND.confirm

#### 8.3.5.8.1 Function

This primitive is issued by the PHY to the local MAC entity to confirm the completion of a transmission. The PHY issues this primitive in response to every PHY-TXEND.request primitive issued by the MAC sublayer.

#### 8.3.5.8.2 Semantics of the service primitive

The semantics of the primitive are as follows:

```
PHY-TXEND.confirm(
                        SCRAMBLER_OR_CRC
                        )
```

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The SCRAMBLER_OR_CRC parameter is present if dot11S1GOptionImplemented is true. The value of SCRAMBLER_OR_CRC parameter depends on the type of the transmitted frame:

- When transmitting a PPDU that is not an NDP CMAC PPDU, the value of the SCRAMBLER_OR_CRC parameter is the (#8126)scrambler initialization value in the (#3409)SERVICE field after scrambling (i.e., [B0:B6] of the (#3409)SERVICE field) (as defined in 23.3.9.2 (SERVICE field)) of the frame.
- When transmitting an NDP CMAC PPDU, the value of the SCRAMBLER_OR_CRC parameter is the calculated CRC value in the SIG/SIG-A field (as defined in 23.3.8.2.2.6 (CRC calculation for S1G SIG-A fields)) as follows:
  - When the frame is an NDP_1M CMAC PPDU(#1400), the value of SCRAMBLER_OR_CRC parameter is equal to [B26:B29] of the SIG field.
  - When the frame is an NDP_2M CMAC PPDU(#1400), the value of SCRAMBLER_OR_CRC parameter is equal to [B38:B41] of the ≥2 MHz SIG-A field.

#### 8.3.5.8.3 When generated

This primitive is issued by the PHY to the MAC entity when the PHY has received a PHY-TXEND.request primitive immediately after transmitting the end of the last bit of the last data octet indicating that the symbol containing the last data octet has been transferred and any signal extension has expired.

#### 8.3.5.8.4 Effect of receipt

The receipt of this primitive by the MAC entity provides the time reference for the contention backoff protocol.

### 8.3.5.9 PHY-TXHEADEREND.indication

#### 8.3.5.9.1 Function

This primitive indicates the transmission completion of the PHY header to the local MAC entity.

#### 8.3.5.9.2 Semantics of the service primitive

The semantics of the primitive are as follows:

PHY-TXHEADEREND.indication

This primitive has no parameters.

#### 8.3.5.9.3 When generated

The PHY-TXHEADEREND.indication primitive is generated by a transmitter PHY entity at the end of transmission of the last symbol containing the PHY header.

#### 8.3.5.9.4 Effect of receipt

The receipt of this primitive by the MAC entity causes the MAC to record the time when this primitive is received only if TIME_OF_DEPARTURE_REQUESTED is true in the corresponding PHY-TXSTART.request primitive.


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#### 8.3.5.10 PHY-CCARESET.request

##### 8.3.5.10.1 Function

This primitive is a request by the MAC sublayer to the local PHY entity to reset the PHY to the state appropriate for the end of a received frame and to turn IPI reporting on and off by means of the IPI-STATE parameter.

##### 8.3.5.10.2 Semantics of the service primitive

The primitive provides the following parameter:

```
PHY-CCARESET.request(
                        IPI-STATE
                        )
```

The IPI-STATE parameter is present if dot11RadioMeasurementActivated is true. The IPI-STATE parameter can be one of two values: IPI-ON or IPI-OFF. The parameter value is IPI-ON when the MAC sublayer is requesting the PHY entity to report IPI values when the PHY is neither receiving nor transmitting a PPDU. IPI-ON turns on IPI reporting in the PHY entity. IPI-OFF turns off IPI reporting in the PHY entity.

##### 8.3.5.10.3 When generated

This primitive is generated by the MAC sublayer for the local PHY entity at the end of a NAV and at a time indicated in 10.3.2.1 (CS mechanism) after each MAC slot boundary, which is described in 10.3.7 (DCF timing relations) and 10.23.2.4 (Obtaining an EDCA TXOP). This request can be used by some PHY implementations that may synchronize antenna diversity with slot timings.

(11ax)This primitive is also generated by the MAC sublayer for the local PHY entity when the spatial reuse conditions defined in 26.10 (HE spatial reuse operation(#2389)) are met.

##### 8.3.5.10.4 Effect of receipt

The effect of receipt of this primitive by the PHY entity is to reset the PHY to the state appropriate for the end of a received frame and to initiate a new CCA evaluation cycle. If IPI-STATE parameter is IPI-ON, the PHY entity collects IPI values when it is not transmitting or receiving and provides those values to the MAC sublayer using the IPI-REPORT parameter.

#### 8.3.5.11 PHY-CCARESET.confirm

##### 8.3.5.11.1 Function

This primitive is issued by the PHY to the local MAC entity to provide observed IPI values if IPI reporting was turned on prior to the receipt of the latest PHY-CCARESET.request primitive. This primitive is not issued by the PHY if IPI reporting was turned off prior to the receipt of the latest PHY-CCARESET.request primitive.

##### 8.3.5.11.2 Semantics of the service primitive

The primitive provides the following parameters:

```
PHY-CCARESET.confirm(
                        IPI-REPORT
                        )
```

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The IPI-REPORT parameter provides a set of IPI values for a time interval. The set of IPI values are recent values observed by the PHY entity since the generation of the most recent PHY-TXEND.confirm, PHY-RXEND.indication, PHY-CCARESET.confirm, or PHY-CCA.indication primitive, whichever occurred latest.

#### 8.3.5.11.3 When generated

This primitive is issued by the PHY to the MAC entity when IPI reporting was turned on prior to the receipt of the latest PHY-CCARESET.request primitive.

#### 8.3.5.11.4 Effect of receipt

The receipt of this primitive by the MAC entity causes the MAC to collect IPI values when IPI reporting was turned on prior to the receipt of the latest PHY-CCARESET.request primitive.

### 8.3.5.12 PHY-CCA.indication

#### 8.3.5.12.1 Function

This primitive is an indication by the PHY to the local MAC entity of the current state of the medium and to provide observed IPI values when IPI reporting is turned on.

#### 8.3.5.12.2 Semantics of the service primitive

The primitive provides the following parameters:

```
PHY-CCA.indication(
                    STATE,
                    IPI-REPORT,
                    channel-list,
                    per20bitmap,(11ax)(#4088)
                    RX-antenna-ID(11ay)
                    )
```

The STATE parameter can be one of two values: BUSY or IDLE. The parameter value is BUSY if the assessment of the channel(s) by the PHY determines that the channel(s) are not available. Otherwise, the value of the parameter is IDLE.

The IPI-REPORT parameter is present if dot11RadioMeasurementActivated is true and if IPI reporting has been turned on by the IPI-STATE parameter. The IPI-REPORT parameter provides a set of IPI values for a time interval. The set of IPI values may be used by the MAC sublayer for radio measurement purposes. The set of IPI values are recent values observed by the PHY entity since the generation of the most recent PHY-TXEND.confirm, PHY-RXEND.indication, PHY-CCARESET.confirm, or PHY-CCA.indication primitive, whichever occurred latest.

When STATE is IDLE or when, for the type of PHY in operation, CCA is determined by a single channel, the channel-list parameter is absent. Otherwise, it carries a set indicating which channels are busy. The channel-list parameter in a PHY-CCA.indication primitive generated by a VHT or S1G STA contains at most a single entry. Table 8-5 (The channel-list parameter entries) defines the members of this set. (11ay)For an EDMG STA, the channel-list parameter contains the primary and secondary channels and may contain the secondary1 and secondary2 channels, while the RX-antenna-ID parameter indicates a set of IDs of the DMG antennas in which the channel indication is provided.

The relationship of the channel-list parameter entries to the 40 MHz, 80 MHz, and 160 MHz BSS operating channel is illustrated by example in Figure 8-1 (The channel-list parameter entry for 40 MHz, 80 MHz, and


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**Table 8-5—The channel-list parameter entries**

| Channel-list parameter entry | Meaning |
|---|---|
| primary | In an HT STA that is neither a VHT STA nor an HE STA(11ax), indicates that the primary channel is busy according to the rules specified in 19.3.19.6 (CCA sensitivity).(#2364)<br>In a VHT STA that is not an HE STA(11ax), indicates that the primary 20 MHz channel is busy according to the rules specified in 21.3.18.5.3 (CCA sensitivity for signals occupying the primary 20 MHz channel).<br>In a TVHT STA, indicates that the primary channel is busy according to the rules specified in 22.3.18.6.2 (CCA sensitivity for signals occupying the primary channel).<br>(11ax)In an HE STA, indicates that the primary 20 MHz channel is busy according to the rules specified in 27.3.22.6.3 (CCA sensitivity for the primary 20 MHz channel).<br>(11ay)In an EDMG STA, indicates that the primary 2.16 GHz channel is busy according to the rules specified in 28.3.8 (CCA sensitivity). |
| secondary | In an HT STA that is neither a VHT STA nor an HE STA(11ax), indicates that the secondary channel is busy according to the rules specified in 19.3.19.6.5 (CCA sensitivity in 40 MHz).<br>In a VHT STA that is not an HE STA(11ax), indicates that the secondary 20 MHz channel is busy according to the rules specified in 21.3.18.5.4 (CCA sensitivity for signals not occupying the primary 20 MHz channel).<br>In a TVHT STA, indicates that the secondary channel is busy according to the rules specified in 22.3.18.6.3 (CCA sensitivity for signals not occupying the primary channel).<br>(11ax)In an HE STA, indicates that the secondary 20 MHz channel is busy according to the rules specified in 27.3.22.6.4 (CCA sensitivity for signals not occupying the primary 20 MHz channel).<br>(11ay)In an EDMG STA, indicates that the secondary 2.16 GHz channel is busy according to the rules specified in 28.3.8 (CCA sensitivity) |
| secondary40 | (11ax)In a VHT STA that is not an HE STA, indicates that the secondary 40 MHz channel is busy according to the rules specified in 21.3.18.5.4 (CCA sensitivity for signals not occupying the primary 20 MHz channel).<br>In a TVHT STA, indicates that the secondary TVHT_2W channel is busy according to the rules specified in 22.3.18.6.3 (CCA sensitivity for signals not occupying the primary channel).<br>(11ax)In an HE STA, indicates that the secondary 40 MHz channel is busy according to the rules specified in 27.3.22.6.3 (CCA sensitivity for the primary 20 MHz channel). |
| secondary80 | (11ax)In a VHT STA that is not an HE STA, indicates that the secondary 80 MHz channel is busy according to the rules specified in 21.3.18.5.4 (CCA sensitivity for signals not occupying the primary 20 MHz channel).<br>(11ax)In an HE STA, indicates that the secondary 80 MHz channel is busy according to the rules specified in 27.3.22.6.3 (CCA sensitivity for the primary 20 MHz channel). |
| primary1 | In an S1G STA, indicates that the primary 1 MHz channel is busy according to the rules specified in 23.3.18.5.3 (CCA sensitivity for signals occupying the primary 2 MHz and/or primary 1 MHz channel) |
| primary2 | In an S1G STA, indicates that the primary 2 MHz channel is busy according to the rules specified in 23.3.18.5.3 (CCA sensitivity for signals occupying the primary 2 MHz and/or primary 1 MHz channel). |
| (11ay)secondary1 | (11ay)In an EDMG STA, indicates that the second secondary 2.16 GHz channel is busy according to the rules specified in 28.3.8 (CCA sensitivity). |

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**Table 8-5—The channel-list parameter entries**

| | |
|---|---|
| secondary2 | In an S1G STA, indicates that the secondary 2 MHz channel is busy according to the rules specified in 23.3.18.5.4 (CCA sensitivity for signals not occupying the primary 2 MHz channel).<br>(11ay)In an EDMG STA, indicates that the third secondary 2.16 GHz channel is busy according to the rules specified in 28.3.8 (CCA sensitivity). |
| secondary4 | In an S1G STA, indicates that the secondary 4 MHz channel is busy according to the rules specified in 23.3.18.5.4 (CCA sensitivity for signals not occupying the primary 2 MHz channel). |
| secondary8 | In an S1G STA, indicates that the secondary 8 MHz channel is busy according to the rules specified in 23.3.18.5.4 (CCA sensitivity for signals not occupying the primary 2 MHz channel). |

160 MHz channel width). The relationship of the channel-list parameter entries to the 80+80 MHz BSS operating channel is illustrated by example in Figure 8-2 (The channel-list parameter entry for 80+80 MHz channel width).

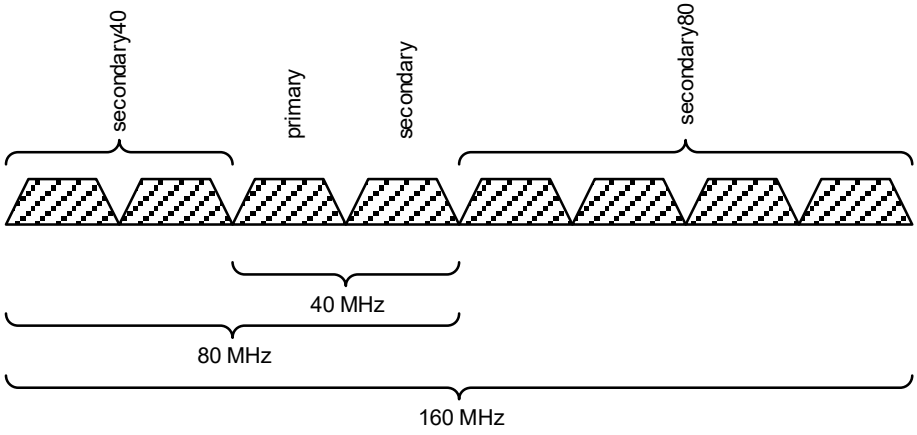


**Figure 8-1—The channel-list parameter entry for 40 MHz, 80 MHz, and 160 MHz channel width**

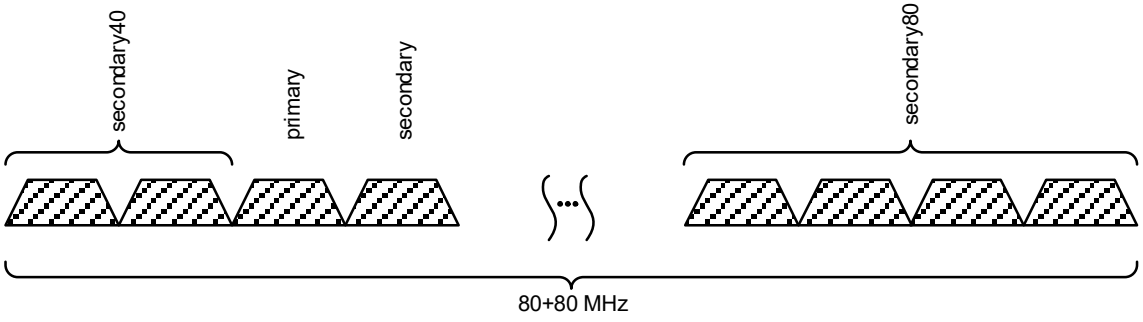


**Figure 8-2—The channel-list parameter entry for 80+80 MHz channel width**


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For a TVHT STA, the relationship of the channel-list parameter entries to the TVHT_W, TVHT_2W, and TVHT_W+W BSS operating channel is illustrated in Figure 8-3 (TVHT channel-list parameter entry and channel bandwidth for TVHT_W, TVHT_2W, and TVHT_W+W).

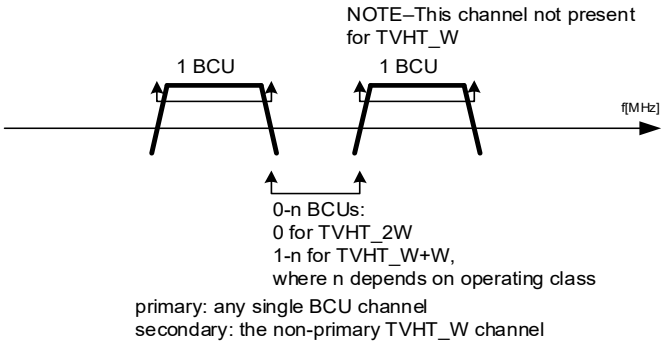


**Figure 8-3—TVHT channel-list parameter entry and channel bandwidth for TVHT_W, TVHT_2W, and TVHT_W+W**

For a TVHT STA, the relationship of the channel-list parameter entries to the TVHT_4W and TVHT_2W+2W BSS operating channel is illustrated in Figure 8-4 (TVHT channel-list parameter entry and channel bandwidth for TVHT_4W and TVHT_2W+2W).

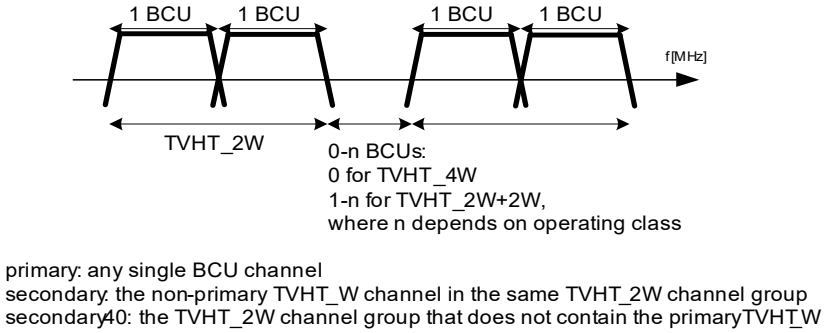


**Figure 8-4—TVHT channel-list parameter entry and channel bandwidth for TVHT_4W and TVHT_2W+2W**

For an S1G STA, the relationship of the channel-list parameter entries to the 1 MHz, 2 MHz, 4 MHz, 8 MHz, and 16 MHz BSS operating channel is illustrated by example Figure 8-5 (The channel-list parameter entries for the 1 MHz, 2 MHz, 4 MHz, 8 MHz, and 16 MHz channel width).

(11ax)If the STA is an HE STA with an operating channel width greater than 20 MHz, then the per20bitmap parameter is present; otherwise, it is absent. If present, the per20bitmap parameter is a bitmap where each bit represents the busy/idle status of a 20 MHz subchannel in the operating channel width as defined in 27.3.22.6.5 (Per 20 MHz CCA sensitivity).

(11ay)Table 8-6 (Definition of EDMG secondary, secondary1, and secondary2 channels(11ay)) defines the assignment of secondary, secondary1 and secondary2 channels in relation to the BSS Operating Channels field and Primary Channel field within the EDMG Operation element transmitted by an EDMG AP or an EDMG PCP. In Table 8-6 (Definition of EDMG secondary, secondary1, and secondary2 channels(11ay)), the following conventions are used:

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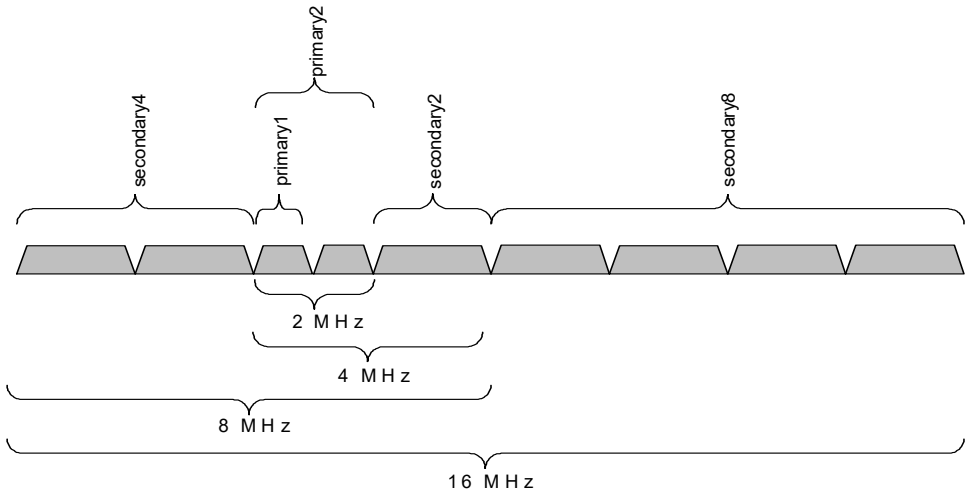


**Figure 8-5—The channel-list parameter entries for the 1 MHz, 2 MHz, 4 MHz, 8 MHz, and 16 MHz channel width**

— The BSS Operating Channels field is indicated as *Ch*(*i*), *Ch*(*k*), *Ch*(*l*), and *Ch*(*m*), where *Ch*(*i*) < *Ch*(*k*) < *Ch*(*l*) < *Ch*(*m*).

— The function *Ch*(*param*) returns a channel number, where *param* indicates a bit position (B0-B7), $0 \le param \le 7$, within the BSS Operating Channels field of the EDMG Operation element.

**Table 8-6—Definition of EDMG secondary, secondary1, and secondary2 channels(11ay)**

| Configuration indicated in the Primary Channel field and in the BSS Operating Channels field | | Channel definition | | | |
|---|---|---|---|---|---|
| **Number of channels** | **Channels set** | **Primary** | **Secondary** | **Secondary1** | **Secondary2** |
| 1 | *Ch*(*i*)<br><br>*i*=(0), (1), (2), (3), (4), (5), (6), (7) | *Ch*(*i*) | N/A | N/A | N/A |
| 2 | *Ch*(*i*), *Ch*(*k*)<br><br>(*i*,*k*) = (0,1),(0,2), (0,3), (0,4), (0,5), (0,6), (0,7), (1,2), (1,3), (1,4), (1,5), (1,6), (1,7), (2,3), (2,4), (2,5), (2,6), (2,7), (3,4), (3,5), (3,6), (3,7), (4,5), (4,6), (4,7), (5,6), (5,7), (6,7) | *Ch*(*i*) | *Ch*(*k*) | N/A | N/A |
| | | *Ch*(*k*) | *Ch*(*i*) | N/A | N/A |
| 3 | *Ch*(*i*), *Ch*(*k*), *Ch*(*l*)<br><br>(*i*,*k*,*l*) = (0,1,2), (1,2,3), (2,3,4), (3,4,5), (4,5,6), (5,6,7), (0,1,3), (0,1,4), (0,1,5), (0,1,6), (0,1,7), (1,2,4), (1,2,5), (1,2,6), (1,2,7), (2,3,5), (2,3,6), (2,3,7), (3,4,6), (3,4,7), (4,5,7) | *Ch*(*i*) | *Ch*(*k*) | *Ch*(*l*) | N/A |
| | | *Ch*(*k*) | *Ch*(*i*) | *Ch*(*l*) | N/A |
| | | *Ch*(*l*) | *Ch*(*k*) | *Ch*(*i*) | N/A |


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**Table 8-6—Definition of EDMG secondary, secondary1, and secondary2 channels(11ay) *(continued)***

| Configuration indicated in the Primary Channel field and in the BSS Operating Channels field | | Channel definition | | | |
|---|---|---|---|---|---|
| **Number of channels** | **Channels set** | **Primary** | **Secondary** | **Secondary1** | **Secondary2** |
| 3 | *Ch*(*i*), *Ch*(*k*), *Ch*(*l*)<br><br>(*i*,*k*,*l*) = (0,2,3), (0,3,4), (0,4,5), (0,5,6), (0,6,7), (1,3,4), (1,4,5), (1,5,6), (1,6,7), (2,4,5), (2,5,6), (2,6,7), (3,5,6), (3,6,7), (4,6,7), (0,2,4), (0,2,5), (0,2,6), (0,2,7), (0,3,5), (0,3,6), (0,3,7), (0,4,6), (0,4,7), (0,5,7), (1,3,5), (1,3,6), (1,3,7), (1,4,6), (1,4,7), (1,5,7), (2,4,6), (2,4,7), (2,5,7), (3,5,7) | *Ch*(*i*) | *Ch*(*k*) | *Ch*(*l*) | N/A |
| | | *Ch*(*k*) | *Ch*(*l*) | *Ch*(*i*) | N/A |
| | | *Ch*(*l*) | *Ch*(*k*) | *Ch*(*i*) | N/A |
| 4 | *Ch*(*i*), *Ch*(*k*), *Ch*(*l*), *Ch*(*m*)<br><br>(*i*,*k*,*l*.*m*) = (0,1,2,3), (1,2,3,4), (2,3,4,5), (3,4,5,6), (4,5,6,7), (0,1,3,4), (0,1,4,5), (0,1,5,6), (0,1,6,7), (1,2,4,5), (1,2,5,6), (1,2,6,7), (2,3,5,6), (2,3,6,7), (3,4,6,7), (0,1,3,5), (0,1,3,6), (0,1,3,7), (0,1,4,6), (0,1,4,7), (0,1,5,7), (1,2,4,6), (1,2,4,7), (1,2,5,7), (2,3,5,7) | *Ch*(*i*) | *Ch*(*k*) | *Ch*(*l*) | *Ch*(*m*) |
| | | *Ch*(*k*) | *Ch*(*i*) | *Ch*(*l*) | *Ch*(*m*) |
| | | *Ch*(*l*) | *Ch*(*m*) | *Ch*(*k*) | *Ch*(*i*) |
| | | *Ch*(*m*) | *Ch*(*l*) | *Ch*(*k*) | *Ch*(*i*) |
| 4 | *Ch*(*i*), *Ch*(*k*), *Ch*(*l*), *Ch*(*m*)<br><br>(*i*,*k*,*l*.*m*) = (0,1,2,4), (0,1,2,5), (0,1,2,6), (0,1,2,7), (1,2,3,5), (1,2,3,6), (1,2,3,7), (2,3,4,6), (2,3,4,7), (3,4,5,7) | *Ch*(*i*) | *Ch*(*k*) | *Ch*(*l*) | *Ch*(*m*) |
| | | *Ch*(*k*) | *Ch*(*i*) | *Ch*(*l*) | *Ch*(*m*) |
| | | *Ch*(*l*) | *Ch*(*k*) | *Ch*(*i*) | *Ch*(*m*) |
| | | *Ch*(*m*) | *Ch*(*l*) | *Ch*(*k*) | *Ch*(*i*) |
| 4 | *Ch*(*i*), *Ch*(*k*), *Ch*(*l*), *Ch*(*m*)<br><br>(*i*,*k*,*l*.*m*) = (0,2,3,4), (0,3,4,5), (0,4,5,6), (0,5,6,7), (1,3,4,5), (1,4,5,6), (1,5,6,7), (2,4,5,6), (2,5,6,7), (3,5,6,7), (0,2,4,5), (0,2,5,6), (0,2,6,7), (0,3,5,6), (0,3,6,7), (0,4,6,7), (1,3,5,6), (1,3,6,7), (1,4,6,7), (2,4,6,7), (0,2,4,6), (0,2,4,7), (0,2,5,7), (0,3,5,7), (1,3,5,7) | *Ch*(*i*) | *Ch*(*k*) | *Ch*(*l*) | *Ch*(*m*) |
| | | *Ch*(*k*) | *Ch*(*l*) | *Ch*(*m*) | *Ch*(*i*) |
| | | *Ch*(*l*) | *Ch*(*m*) | *Ch*(*k*) | *Ch*(*i*) |
| | | *Ch*(*m*) | *Ch*(*l*) | *Ch*(*k*) | *Ch*(*i*) |
| 4 | *Ch*(*i*), *Ch*(*k*), *Ch*(*l*), *Ch*(*m*)<br><br>(*i*,*k*,*l*.*m*) = (0,2,3,5), (0,2,3,6), (0,2,3,7), (0,3,4,6), (0,3,4,7), (0,4,5,7), (1,3,4,6), (1,3,4,7), (1,4,5,7), (2,4,5,7) | *Ch*(*i*) | *Ch*(*k*) | *Ch*(*l*) | *Ch*(*m*) |
| | | *Ch*(*k*) | *Ch*(*l*) | *Ch*(*i*) | *Ch*(*m*) |
| | | *Ch*(*l*) | *Ch*(*k*) | *Ch*(*i*) | *Ch*(*m*) |
| | | *Ch*(*m*) | *Ch*(*l*) | *Ch*(*k*) | *Ch*(*i*) |

(11ay)For an EDMG STA, the relationship of the channel-list parameter elements to the 4.32 GHz, 6.48 GHz, and 8.64 GHz BSS operating channel is illustrated by example in Figure 8-6 (Example channel-list parameter element for various BSS operating channels(11ay)).

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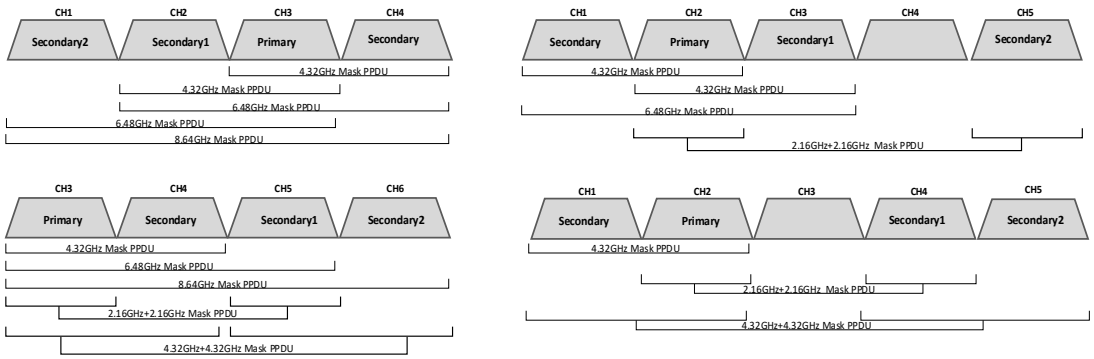


**Figure 8-6—Example channel-list parameter element for various BSS operating channels(11ay)**

### 8.3.5.12.3 When generated

For Clause 15 (DSSS PHY specification for the 2.4 GHz band designated for ISM applications) to Clause 20 (Directional multi-gigabit (DMG) PHY specification) PHYs, this primitive is generated within aCCATime of the occurrence of a change in the status of the primary channel from channel idle to channel busy or from channel busy to channel idle or when the entries of the channel-list parameter change. For Clause 21 (Very high throughput (VHT) PHY specification) and Clause 22 (Television very high throughput (TVHT) PHY specification) PHYs, this primitive is generated when the status of the channel(s) changes from channel idle to channel busy or from channel busy to channel idle or when the entries of the channel-list parameter change. This includes the period of time when the PHY is receiving data. (11ax)For (#1282)Clause 27 (High-efficiency (HE) PHY specification(11ax)) PHYs, this primitive is generated when the status of the channel(s) changes from channel idle to channel busy or from channel busy to channel idle, when the entries of the channel-list parameter change, or when the per20bitmap parameter changes. The timing of PHY-CCA.indication primitives related to transitions on secondary channel(s) is PHY specific. Refer to specific PHY clauses for details about CCA behavior for a given PHY.(11ax)

If the STA is an HT STA but not a VHT STA and the operating channel width is 20 MHz, the PHY maintains the channel busy indication until the period indicated by the LENGTH field has expired, where the LENGTH field is

— In a valid SIG field (#2095)if the PPDU is a non-HT PPDU
— In a valid HT-SIG field (#2095)if the PPDU is an HT PPDU

If the STA is an HT STA but not a VHT STA and the operating channel width is 40 MHz, the PHY maintains the channel busy indication until the period indicated by the LENGTH field has expired, where the LENGTH field is

— In a valid SIG field (#2095)if the PPDU is a non-HT PPDU and received in the primary channel
— In a valid HT-SIG field (#2095)if the PPDU is an HT PPDU and either a 20 MHz PPDU received in the primary channel or a 40 MHz PPDU

When the PHY is supporting one or more MAC entities that are coordinated by an MM-SME, this primitive is generated upon PHY-TXSTART or PHY-TXEND actions from those MAC entities. A PHY-CCA.indication primitive with STATE set to BUSY is generated when the PHY issues a PHY-TXSTART.confirm primitive to one of the MAC entities coordinated by an MM-SME, and it is generated to all coordinated MAC entities except to the one to which it responds with the PHY-TXSTART.confirm primitive. A PHY-CCA.indication primitive with STATE set to IDLE is generated when the PHY issues a PHY-TXEND.confirm primitive to one of the MAC entities coordinated by an MM-SME, and it is


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generated to all coordinated MAC entities except to the one to which it responds with the PHY-TXEND.confirm primitive. The ICI-REPORT parameter of the PHY-CCA.indication primitive is set as described above. The channel-list parameter is set to indicate the channels in use per the TXVECTOR of a PHY-TXSTART.request primitive from a coordinated MAC entity, or is not present when the PHY-CCA.indication primitive is generated in response to a PHY-TXEND.confirm primitive from a coordinated MAC entity.

#### 8.3.5.12.4 Effect of receipt

The receipt of this primitive by the MAC entity causes the MAC to update the physical CS state, and to collect IPI values when IPI reporting was turned on.

### 8.3.5.13 PHY-RXEARLYSIG.indication(#3038)

#### 8.3.5.13.1 Function

This primitive is an early indication by the PHY to the local MAC entity that the PHY has received a valid start of a PPDU.

NOTE—This primitive might be generated before the PHY has narrowed down the PPDU format to a single possibility, such as either of non-HT or VHT.

#### 8.3.5.13.2 Semantics of the service primitive

The primitive does not include any parameters:

PHY-RXEARLYSIG.indication(
)

#### 8.3.5.13.3 When generated

This primitive is generated by the local PHY entity to the MAC sublayer when the PHY has successfully validated an early SIG field in the PHY and the validation of the SIG field does not cause the issuance of the PHY-RXSTART.indication. The early SIG field is the first SIG field in the PPDU except:

— If the HT-SIG field is present in an HT_GF format PPDU, then the HT-SIG field is validated instead of the L-SIG field (and so the PHY-RXEARLYSIG.indication is not issued)

— If the RL-SIG field is present, then the pair of L-SIG and RL-SIG fields is validated instead of the L-SIG field

After generating a PHY-RXEARLYSIG.indication primitive, the PHY is expected to maintain physical medium busy status (not generating a PHY-CCA.indication (IDLE) primitive) until the issuance of the next PHY-RXSTART.indication or PHY-RXEND.indication.

#### 8.3.5.13.4 Effect of receipt

The receipt of this primitive by the MAC entity causes the MAC to determine that there is no NAV, CTS, Ack or similar timeout (see 10.3.2.4 (Setting and resetting the NAV), 10.3.2.9 (CTS and DMG CTS procedure), 10.3.2.11 (Acknowledgment procedure), 26.2.4 (Updating two NAVs), and 26.2.6.2 (MU-RTS Trigger frame transmission)).

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#### 8.3.5.14 PHY-RXSTART.indication

##### 8.3.5.14.1 Function

This primitive is an indication by the PHY to the local MAC entity that the PHY has received a valid start of a PPDU, including a valid PHY header.

NOTE—This primitive is not generated until the PHY has determined the PPDU format (e.g., a VHT PPDU, which starts with an HT PHY header).

##### 8.3.5.14.2 Semantics of the service primitive

The primitive provides the following parameter:

```
PHY-RXSTART.indication(
                        RXVECTOR
                        )
```

(#373)The RXVECTOR represents a list of parameters that the PHY provides the local MAC entity when receiving a PSDU. The required parameters are listed in 8.3.4.4 (Vector descriptions).

NOTE—The RXVECTOR is associated with a received PSDU, in the same way as the TXVECTOR is associated with a transmitted PSDU (see 8.3.5.5.2 (Semantics of the service primitive)).(#373)

See 1.4 (Word usage) for interpretation of references to frames, MPDUs, A-MPDUs and PPDUs being received with a certain RXVECTOR.

##### 8.3.5.14.3 When generated

This primitive is generated by the local PHY entity to the MAC sublayer when the PHY has successfully validated the PHY header at the start of a new PPDU.

After generating a PHY-RXSTART.indication primitive, the PHY is expected to maintain physical medium busy status (not generating a PHY-CCA.indication(IDLE) primitive) during the period required by that PHY to transfer a frame of the indicated LENGTH at the indicated DATARATE. This physical medium busy condition should be maintained even if a PHY-RXEND.indication(CarrierLost) primitive or a PHY-RXEND.indication(FormatViolation) primitive is generated by the PHY prior to the end of this period.

##### 8.3.5.14.4 Effect of receipt

The receipt of this primitive by the MAC entity causes the MAC to prepare for a new receive flow (see Figure 5-1 (MAC data plane architecture (#7109)(#4149)(#1001)(11ay)(#3186)(#3185)(#4172)(#4192)(11bc))).

#### 8.3.5.15 PHY-RXEND.indication

##### 8.3.5.15.1 Function

This primitive is an indication by the PHY to the local MAC entity that the PPDU currently being received is complete.

##### 8.3.5.15.2 Semantics of the service primitive

The primitive provides the following parameters:

```
PHY-RXEND.indication(
```



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RXERROR,
RCPI
)

The RXERROR parameter can convey NoError or one or more values indicating an error condition. A number of error conditions may occur after the PHY's receive state machine has detected what appears to be a valid preamble and SFD. The following describes the parameter returned for each of those error conditions:

— *NoError*. This value is used to indicate that no error occurred during the receive process in the PHY.

— *FormatViolation.* This value is used to indicate that the format of the received PPDU was in error.

— *CarrierLost.* This value is used to indicate that during the reception of the incoming PSDU, the carrier was lost and no further processing of the PSDU can be accomplished.

— *UnsupportedRate.* This value is used to indicate that during the reception of the incoming PPDU, a nonsupported date rate was detected.

— *Filtered*. This value is used to indicate that during the reception of the PPDU, the PPDU was filtered out due to a condition set in the PHYCONFIG_VECTOR.

NOTE 1—The filtered condition might occur(#4385):

- in a VHT STA due to (#6317)group ID or partial AID filtering in the PHY.
- in an HE STA due to BSS color filtering in the PHY.

— *IntegrityCheckError*. This value is used to indicate that during the reception of the HE Ranging NDP or HE TB Ranging NDP, an integrity check was performed and failed.(11az)

RCPI is a parameter included in the PHY-RXEND.indication primitive that the PHY provides the local MAC entity. (#14)If present, RCPI is a measure of the received RF power averaged over all of the receive chains in the data portion (#3475)of the received PPDU. RCPI is an included parameter only when dot11RadioMeasurementActivated is true and the PHY is not a DMG, CDMG, or CMMG PHY. The required parameters are listed in 8.3.4.4 (Vector descriptions).

NOTE 2—When dot11RadioMeasurementActiviated is true, for DMG, CDMG, or CMMG PHYs, RCPI is included in the RXVECTOR parameter of the PHY-RXSTART.indication primitive instead.

#### 8.3.5.15.3 When generated

This primitive is generated by the PHY (#3479)for the local MAC entity after the receive state machine has completed a reception with or without errors. (#1058)When reception is completed without error, the primitive is generated after the PHY has delivered the last bit of (#3478)all received PSDUs to the MAC. When a signal extension is present, the primitive is generated after the end of the signal extension.

In the case of an RXERROR value of NoError, the MAC uses the PHY-RXEND.indication primitive as reference for channel access timing, as shown in Figure 10-25 (DCF timing relationships(#14)(#1058)(#3297)) (in 10.3.7 (DCF timing relations)) and Figure 10-29 (EDCA mechanism timing relationships(#14)(#1058)).

#### 8.3.5.15.4 Effect of receipt

The effect of receipt of this primitive is for the MAC to begin interframe(#1460) space processing, as described in 10.3.7 (DCF timing relations) and 10.23.2.4 (Obtaining an EDCA TXOP).

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#### 8.3.5.16 PHY-CONFIG.request

##### 8.3.5.16.1 Function

This primitive is a request by the MAC sublayer to the local PHY entity to configure the PHY.

##### 8.3.5.16.2 Semantics of the service primitive

The primitive provides the following parameter:

```
PHY-CONFIG.request(
                        PHYCONFIG_VECTOR
                        )
```

##### 8.3.5.16.3 When generated

This primitive is generated by the MAC sublayer for the local PHY entity when it desires to change the configuration of the PHY.

##### 8.3.5.16.4 Effect of receipt

The effect of receipt of this primitive by the PHY is to apply the parameters provided with the primitive and to configure the PHY for future operation.

#### 8.3.5.17 PHY-TRIGGER.request(11ax)

##### 8.3.5.17.1 Function

This primitive is a request by the MAC sublayer to the local PHY entity to set parameters for the receipt of HE TB PPDU.

##### 8.3.5.17.2 Semantics of the service primitive

The primitive provides the following parameter:

```
PHY-TRIGGER.request (
                        TRIGVECTOR
                        )
```

The TRIGVECTOR parameter provides the PHY with the information needed to demodulate of the expected HE TB PPDUs.

##### 8.3.5.17.3 When generated

This primitive is issued by the MAC sublayer to the PHY entity after issuing PHY-TXSTART.request and before receiving HE TB PPDU.

##### 8.3.5.17.4 Effect of receipt

On receipt of this primitive, the PHY entity configures the receiver module for the expected arrival of the HE TB PPDUs.


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#### 8.3.5.17 PHY-ABORT.request(11ay)

##### 8.3.5.17.1 Function

This primitive is a request by the MAC to reset the PHY. The PHY is always reset to the receive state.

##### 8.3.5.17.2 Semantics of the service primitive

This primitive has no parameters.

##### 8.3.5.17.3 When generated

This primitive is generated at any time to reset the PHY.

##### 8.3.5.17.4 Effect of receipt

Receipt of this primitive by the PHY causes the PHY entity to reset both the transmit and the receive state machines and places the PHY into the receive state.

#### 8.3.5.18 PHY-RXLTFSEQUENCE.request(11az)

##### 8.3.5.18.1 Function

This primitive is a request by the MAC sublayer to the local PHY entity to provide the parameters shown in 27-3 (LTFVECTOR parameters(11az)) for the receipt of an HE Ranging NDP or HE TB Ranging NDP.

##### 8.3.5.18.2 Semantics of the service primitive

The primitive provides the following parameter:

```
PHY-RXLTFSEQUENCE.request(
                                LTFVECTOR
                                )
```

The LTFVECTOR represents a list of parameters needed to receive an HE Ranging NDP or HE TB Ranging NDP, including the HE-LTF configuration and information on how to generate the secure HE-LTF symbols as described in 27.3.20.6 (Construction of secure HE-LTF symbols(11az)).

##### 8.3.5.18.3 When generated

This primitive is issued by the MAC sublayer to the PHY entity before receiving HE Ranging NDP and HE TB Ranging NDP.

##### 8.3.5.18.4 Effect of receipt

The effect of receipt of this primitive by the PHY entity is to be aware of the number of spatial streams and HE-LTF repetitions that are not signaled in the HE SIG-A of the HE Ranging NDP and HE TB Ranging NDP, as well as to be able to generate the secure LTF symbols based on the parameters in the LTFVECTOR as described in 27.3.20.6 (Construction of secure HE-LTF symbols(11az)), if secure HE-LTF is used.

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#### 8.3.5.19 PHY-RXTRNSEQUENCE.request(11az)

##### 8.3.5.19.1 Function

This primitive is a request by the MAC sublayer to the local PHY entity with a TRNVECTOR parameter to provide the Secure TRN bit sequences for the receipt of the EDMG secure ranging PPDU.

##### 8.3.5.19.2 Semantics of the service primitive

The primitive provides the following parameter:

```
PHY-RXTRNSEQUENCE.request(
                                TRNVECTOR
                                )
```

The TRNVECTOR represents the Secure TRN bit sequences used in the EDMG secure ranging PPDU.

##### 8.3.5.19.3 When generated

This primitive is issued by the MAC sublayer to the PHY entity before receiving the secure TRN subfield of the EDMG secure ranging PPDU.

##### 8.3.5.19.4 Effect of receipt

The effect of receipt of this primitive by the PHY entity is to make a secure ranging waveform based on the TRNVECTOR.

## 8.4 PHY management

The MIB comprises the managed objects, attributes, actions, and notifications required to manage a STA. The definition of these managed objects, attributes, actions, and notifications, as well as their structure, is presented in Annex C.


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# 9. Frame formats

## 9.1 General requirements

The format of the MAC frames is specified in this clause. (#181)A STA shall properly construct a subset of the frames specified in this clause for transmission and decode a (potentially different) subset of the frames specified in this clause upon validation following reception. The particular subset of these frames that a STA constructs and decodes is determined by the functions supported by that particular STA. (#181)A STA shall validate every received frame using the frame check sequence (FCS) and (#8232)interpret certain fields from the MAC headers of all frames.

A STA shall transmit frames using only the frame formats described in Clause 9 (Frame formats).

## 9.2 MAC frame formats

### 9.2.1 Basic components

Each frame consists of the following basic components:

a) (#290)A *MAC header*, which comprises frame control, optional duration (not in PS-Poll frames), address, optional sequence control information, optional QoS Control information (only in QoS Data frames), and optional HT Control fields (only in +HTC frames);

b) A variable length *frame body*, which contains information specific to the frame *type* and *subtype*;

c) An *FCS*, which contains a 32-bit CRC based on ITU-T Recommendation V.42 [B63] (see 9.2.4.9 (FCS field)).

### 9.2.2 Conventions

Structures defined in the MAC sublayer are described as a sequence of components (e.g., fields, subfields, elements and subelements) in specific order. Each figure and table in Clause 9 (Frame formats) depicts the components as they appear in the MAC frame and in the order in which they are passed to the physical layer (PHY), from left to right and then from top to bottom.

Unless specified otherwise, a number in a field is encoded as an unsigned integer.

A field or subfield within the figure depiction of a frame format that includes a value (decimal, if numeric)(#4209) within parentheses indicates that this field or subfield is set to the indicated value upon transmission.

In figures, all bits within fields are numbered, from 0 to $k$, where the length of the field is $k + 1$ bits. Bits within numeric fields that are longer than a single bit are depicted in increasing order of significance, i.e., with the lowest numbered bit having the least significance. The octet boundaries within a field can be obtained by taking the bit numbers of the field modulo 8. Octets within numeric fields that are longer than a single octet are depicted in increasing order of significance, from lowest numbered bit to highest numbered bit. The octets in fields longer than a single octet are sent to the PHY in order from the octet containing the lowest numbered bits to the octet containing the highest numbered bits.

Any field containing a CRC is an exception to this convention and is transmitted commencing with the coefficient of the highest-order term. There are other exceptions; these are explicitly indicated in the description of the field in question.

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MAC addresses are assigned as ordered sequences of bits. The Individual/Group bit is always transferred first and is bit 0 of the MAC address. Bit 47 of the MAC address is always transferred last. This is illustrated in Figure 9-1 (Representation of a 48-bit MAC address). Also see Clause 8 of IEEE Std 802-2014.

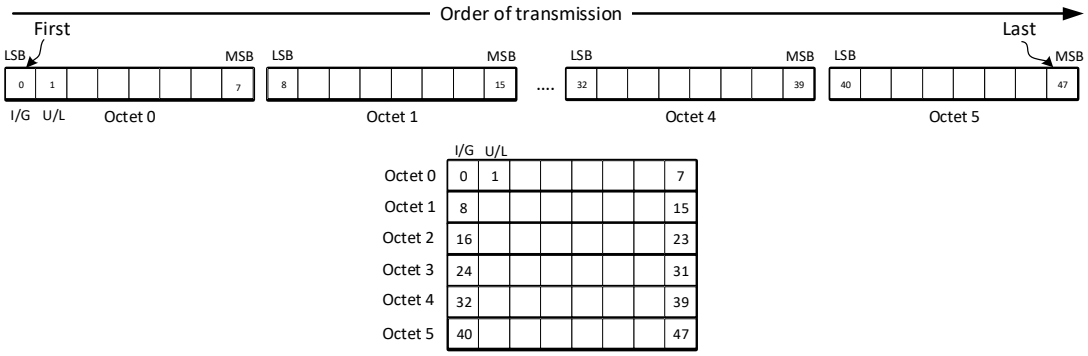


**Figure 9-1—Representation of a 48-bit MAC address**

A MAC address can be represented using hexadecimal values separated by hyphens, as described in IEEE Std 802.

Organizationally Unique Identifiers (OUIs), Company IDs (CIDs), and Organization Identifiers are specified in two forms: an ordered sequence of octets, and a numeric form. Treating the OUI, CID, or Organization Identifier as an ordered sequence of octets, the leftmost octet is always transferred first. This is equivalent to transmitting the most significant octet of the numeric form first.

(#1461)Values specified in decimal are coded with bit *n* representing $2^n$ unless otherwise stated. The values in Table 9-1 (Valid type and subtype combinations) (#1270)and Table 9-2 (Control Frame Extension) are in binary, with the bit assignments shown in the table. Values in other tables are shown in decimal notation, unless all the values in the table only contain the digits 0 and 1, in which case they are typically shown in binary notation.(#457)(3189)

ASCII and UTF-8 strings are defined in 1.4 (Word usage).

For evaluation purposes a nonce is interpreted as a sequence of octets with the most significant octet first and the most significant bit of an octet first.

Reception, in references to frames or fields within frames (e.g., received Beacon frames or a received Duration/ID field), applies to MPDUs indicated from the PHY without error and validated by FCS within the MAC sublayer.

Without further qualification, *reception* by the MAC sublayer implies that the frame contents are valid, and that the protocol version is supported (see 9.2.4.1.2 (Protocol Version subfield)), (#8148)with no implication regarding whether the frame type or other fields in the MAC header are meaningful to the MAC entity, where the frame is addressed to the STA (individually addressed or group addressed).(#6185)

Unless explicitly specified, a group addressed frame might or might not, depending on the context, be considered “addressed to” a particular STA. Additionally, in certain contexts a frame individually addressed to a STA might be considered “received” by another STA (see e.g., 10.3.2.4 (Setting and resetting the NAV)).(#7200)


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A frame that contains the HT Control field is referred to as a *+HTC frame*. A Control Wrapper frame is a +HTC frame.

A QoS Data frame that is transmitted by a mesh STA is referred to as a *mesh Data frame*.

NOTE 1—Subclause 9.2.4.1.4 (To DS and From DS subfields) constrains the setting of the From DS and To DS subfields in mesh Data frames.

Parentheses enclosing portions of names or acronyms are used to designate a set of related names that vary based on the inclusion of the parenthesized portion. For example,

- *QoS +CF-Poll frame* refers to the three QoS data subtypes that include "+CF-Poll": the QoS Data +CF-Poll frame, subtype 1010; QoS Data +CF-Ack +CF-Poll frame, subtype 1011; and QoS CF-Ack +CF-Poll frame, subtype 1111.
- *QoS CF-Poll frame* refers specifically to the QoS CF-Poll frame, subtype 1110.
- *QoS (+)CF-Poll frame* refers to all four QoS data subtypes with CF-Poll: the QoS CF-Poll frame, subtype 1110; the QoS CF-Ack +CF-Poll frame, subtype 1111; the QoS Data +CF-Poll frame, subtype 1010; and the QoS Data +CF-Ack +CF-Poll frame, subtype 1011.
- *QoS (+)Null frame* refers to all three QoS data subtypes with an empty frame body: the QoS Null frame, subtype 1100; the QoS CF-Poll frame, subtype 1110; and the QoS CF-Ack +CF-Poll frame, subtype 1111.
- *QoS +CF-Ack frame* refers to the three QoS data subtypes that include "+CF-Ack": the QoS Data +CF-Ack frame, subtype 1001; QoS Data +CF-Ack +CF-Poll frame, subtype 1011; and QoS CF-Ack +CF-Poll frame, subtype 1111.
- *(#3177)(NDP) CTS* refers to CTS and NDP CTS.
- *(#3177)(NDP) CF-End* refers to CF-End and NDP CF-End.
- *(#3177)(NDP) PS-Poll* refers to PS-Poll and NDP PS-Poll.
- *(#3177)(NDP) Ack* refers to Ack and NDP Ack.
- *(#3177)NDP (PS-Poll-)Ack* refers to NDP Ack and NDP PS-Poll-Ack.
- *(#3177)(NDP) Block Ack* refers to Block Ack and NDP Block Ack.
- *(#3177)PS-Poll(+BDT)* refers to PS-Poll and PS-Poll+BDT.

Reserved fields and subfields defined in this clause are set to 0 upon transmission and are ignored upon reception.

NOTE 2—This applies to reserved fields and subfields in MAC headers. Reserved fields and subfields in PHY headers might be set to a nonzero value upon transmission, and might not be ignored upon reception.

(#3000)During transmission, a field or a subfield is not set to a value that is reserved for that field or subfield. Upon reception of a reserved value in a field or subfield, the behavior is, unless otherwise specified, undefined.

### 9.2.3 General frame format

The MAC frame format comprises a set of fields that occur in a fixed order in all frames. Figure 9-2 (MAC frame format) depicts the general MAC frame format for protocol version 0 (PV0) MPDUs, and Figure 9-1330 (PV1 frame format(#1633)) (in 9.8.2 (General PV1 frame format)) depicts the general MAC frame format for protocol version 1 (PV1) frames. The first 2 bits of the first subfield (Protocol Version) of the Frame Control field and the last field (FCS) in Figure 9-2 (MAC frame format) are present in all PV0 MPDUs and PV1 MPDUs, including reserved types and subtypes. Figure 9-1346 (WUR frame format(11ba)) depicts the general MAC frame format for Wake-up Radio (WUR) frames.

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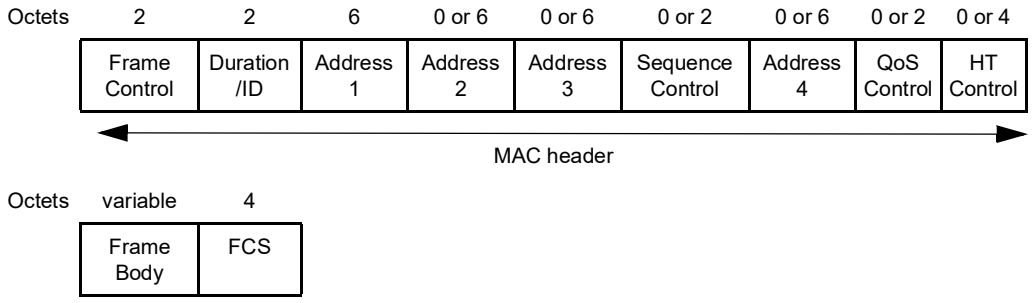


**Figure 9-2—MAC frame format**

For PV0 MPDUs, the first three fields (Frame Control, Duration/ID, and Address 1) and the last field (FCS) in Figure 9-2 (MAC frame format) constitute the minimal frame format and are present in all these frames, including reserved types and subtypes. The fields Address 2, Address 3, Sequence Control, Address 4, QoS Control, HT Control, and Frame Body are present only in certain frame types and subtypes. Each field is defined in 9.2.4 (Frame fields). For PV1 MPDUs, the fields constituting the minimal frame format are defined in 9.8.2 (General PV1 frame format). The format of each of the individual subtypes of each frame type is defined in 9.3 (Format of individual frame types), the format of each PV1 frame type is defined in 9.8 (MAC frame format for PV1 frames).(#1359) The components of (PV0) Management frame bodies are defined in 9.4 (Management and Extension frame body components). The formats of Action frame bodies (PV0 and PV1) are defined in 9.6 (Action frame format details).(#3059) The formats of WUR frames are defined in 9.9 (MAC frame format for WUR frames(11ba)).

The Frame Body field is of variable size, constrained as defined in 9.2.4.8.1 (General).

### 9.2.4 Frame fields

### 9.2.4.1 Frame Control field

#### 9.2.4.1.1 General

The first three subfields of the Frame Control field of a PV0 frame are Protocol Version, Type, and Subtype. The remaining subfields of the Frame Control field depend on the setting of the Type and Subtype subfields.

For a frame carried in (#1426)a non-S1G PPDU, when the Type subfield is not 1 or the Subtype subfield is not 6, the remaining subfields within the Frame Control field are To DS, From DS, More Fragments, Retry, Power Management, More Data, Protected Frame, and +HTC. In this case, the format of the Frame Control field is shown in Figure 9-3 (Frame Control field format in non-S1G PPDUs when Type subfield is not equal to 1 or Subtype subfield is not equal to 6).

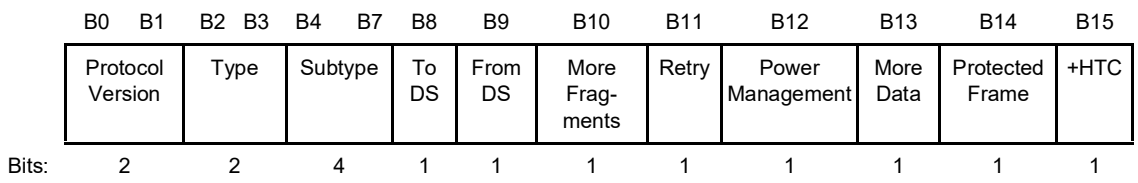


**Figure 9-3—Frame Control field format in non-S1G PPDUs when Type subfield is not equal to 1 or Subtype subfield is not equal to 6**

For a frame carried in a(#1426) non-S1G PPDU, when the Type subfield is 1 and the Subtype subfield is 6, the remaining subfields within the Frame Control field are the following: Control Frame Extension, Power


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Management, More Data, Protected Frame, and +HTC. In this case, the format of the Frame Control field is shown in Figure 9-4 (Frame Control field format in non-S1G PPDUs when Type subfield is equal to 1 and Subtype subfield is equal to 6).

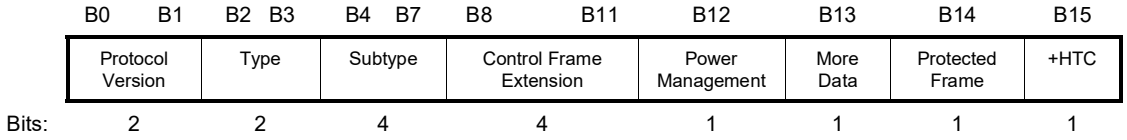


**Figure 9-4—Frame Control field format in non-S1G PPDUs when Type subfield is equal to 1 and Subtype subfield is equal to 6**

For a frame carried in an S1G PPDU, when the Type subfield is 0 or 2, the remaining subfields within the Frame Control field are: To DS, From DS, More Fragments, Retry, Power Management, More Data, Protected Frame, and +HTC. In this case, the format of the Frame Control field is shown in Figure 9-5 (Frame Control field format in S1G PPDUs when Type subfield is equal to 0 or 2)).

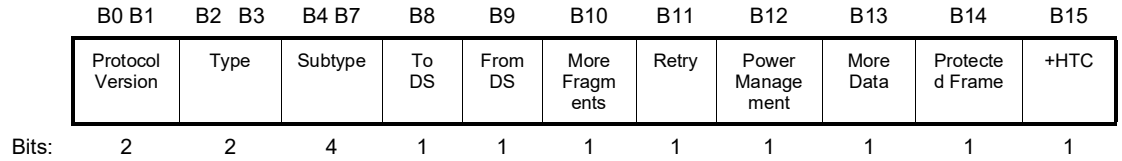


**Figure 9-5—Frame Control field format in S1G PPDUs when Type subfield is equal to 0 or 2**

When the Type subfield is equal to 3 and the Subtype subfield is equal to 1, the format of the Frame Control field is shown in Figure 9-6 (Frame Control field format when Type subfield is equal to 3 and Subtype subfield is equal to 1(#8219)).

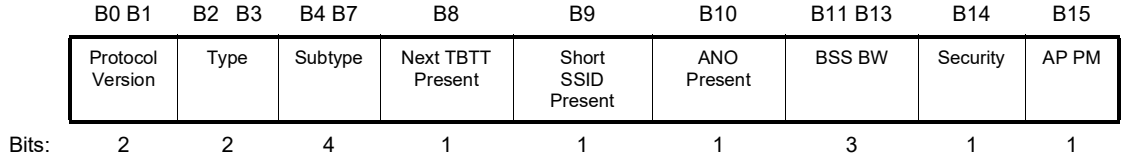


**Figure 9-6—Frame Control field format when Type subfield is equal to 3 and Subtype subfield is equal to 1(#8219)**

#### 9.2.4.1.2 Protocol Version subfield

The Protocol Version subfield is invariant in size and placement across all revisions of this standard. For this standard, the value of the protocol version is 0 for MAC frames as described in 9.2 (MAC frame formats) and 1 for PV1 MAC frames as described in 9.8 (MAC frame format for PV1 frames)(#1358). All other values are reserved. The revision level is incremented only when a fundamental incompatibility exists between a new revision and the prior edition of the standard. See 10.28.2 (Revision level field processing).

#### 9.2.4.1.3 Type and Subtype subfields

The Type and Subtype subfields together identify the function of the frame. There are three frame types: control, data, and management. Each of the frame types has several defined subtypes. In Data frames, the most significant bit (MSB) of the Subtype subfield, B7, is defined as the QoS subfield. Table 9-1 (Valid type and subtype combinations) defines the valid combinations of type and subtype.(#3190)

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**Table 9-1—Valid type and subtype combinations**

| Type value B3 B2 | Type description | Subtype value B7 B6 B5 B4 | Subtype description |
|---|---|---|---|
| 00 | Management | 0000 | Association Request |
| 00 | Management | 0001 | Association Response |
| 00 | Management | 0010 | Reassociation Request |
| 00 | Management | 0011 | Reassociation Response |
| 00 | Management | 0100 | Probe Request |
| 00 | Management | 0101 | Probe Response |
| 00 | Management | 0110 | Timing Advertisement |
| 00 | Management | 0111 | Reserved |
| 00 | Management | 1000 | Beacon |
| 00 | Management | 1001 | ATIM |
| 00 | Management | 1010 | Disassociation |
| 00 | Management | 1011 | Authentication |
| 00 | Management | 1100 | Deauthentication |
| 00 | Management | 1101 | Action |
| 00 | Management | 1110 | Action No Ack |
| 00 | Management | 1111 | Reserved |
| 01 | Control | 0000–0001(11ax) | Reserved |
| 01(11ax) | Control | 0010 | Trigger |
| 01 | Control | 0011 | TACK |
| 01 | Control | 0100 | Beamforming Report Poll |
| 01 | Control | 0101 | (11ax)VHT/HE NDP Announcement |
| 01 | Control | 0110 | Control Frame Extension |
| 01 | Control | 0111 | Control Wrapper |
| 01 | Control | 1000 | Block Ack Request (BlockAckReq) |
| 01 | Control | 1001 | Block Ack (BlockAck) |
| 01 | Control | 1010 | PS-Poll |
| 01 | Control | 1011 | RTS |
| 01 | Control | 1100 | CTS |
| 01 | Control | 1101 | Ack |
| 01 | Control | 1110 | CF-End |
| 01 | Control | 1111 | Reserved |
| 10 | Data | 0000 | Data |
| 10 | Data | 0001 | EBCS Data(11bc) |
| 10 | Data | 0010 | Reserved |
| 10 | Data | 0011 | Reserved |


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**Table 9-1—Valid type and subtype combinations *(continued)***

| Type value B3 B2 | Type description | Subtype value B7 B6 B5 B4 | Subtype description |
|---|---|---|---|
| 10 | Data | 0100 | Null |
| 10 | Data | 0101 | Reserved |
| 10 | Data | 0110 | Reserved |
| 10 | Data | 0111 | Reserved |
| 10 | Data | 1000 | QoS Data |
| 10 | Data | 1001 | QoS Data +CF-Ack |
| 10 | Data | 1010 | QoS Data +CF-Poll |
| 10 | Data | 1011 | QoS Data +CF-Ack +CF-Poll |
| 10 | Data | 1100 | QoS Null |
| 10 | Data | 1101 | Reserved |
| 10 | Data | 1110 | QoS CF-Poll |
| 10 | Data | 1111 | QoS CF-Ack +CF-Poll |
| 11 | Extension | 0000 | DMG Beacon |
| 11 | Extension | 0001 | S1G Beacon |
| 11 | Extension | 0010–1111 | Reserved |

Each Subtype subfield bit position is used to indicate a specific modification of the basic Data frame (subtype 0). Frame Control bit 4 is set to 1 in data subtypes that include +CF-Ack, bit 5 is set to 1 in data subtypes that include +CF-Poll, bit 6 is set to 1 in data subtypes that contain no Frame Body field, and bit 7 is set to 1 in the QoS data subtypes, which have QoS Control fields in their MAC headers.

The Control Frame Extension subtype is used to increase the subtype space by reusing (#465)B8–B11. These additional Control frames are defined in Table 9-2 (Control Frame Extension).

**Table 9-2—Control Frame Extension**

| Type value B3 B2 | Subtype value B7 B6 B5 B4 | Control Frame Extension value B11 B10 B9 B8 | Description |
|---|---|---|---|
| 01 | 0110 | 0000 | Sector Ack(11ay) |
| 01 | 0110 | 0001 | Block Ack Schedule(11ay) |
| 01 | 0110 | 0010 | Poll |
| 01 | 0110 | 0011 | SPR |
| 01 | 0110 | 0100 | Grant |
| 01 | 0110 | 0101 | DMG CTS |
| 01 | 0110 | 0110 | DMG DTS |
| 01 | 0110 | 0111 | Grant Ack |

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**Table 9-2—Control Frame Extension *(continued)***

| Type value B3 B2 | Subtype value B7 B6 B5 B4 | Control Frame Extension value B11 B10 B9 B8 | Description |
|---|---|---|---|
| 01 | 0110 | 1000 | SSW |
| 01 | 0110 | 1001 | SSW-Feedback |
| 01 | 0110 | 1010 | SSW-Ack |
| 01 | 0110 | 1011 | TDD Beamforming(11ay) |
| 01 | 0110 | (11ay)1100–1111 | Reserved |

#### 9.2.4.1.4 To DS and From DS subfields

The meaning of the combinations of values for the To DS and From DS subfields in Data frames are shown in Table 9-3 (Combinations of To DS subfield and From DS subfield in Data frames(#278)).

**Table 9-3—Combinations of To DS subfield and From DS subfield in Data frames(#278)**

| To DS subfield and From DS subfield values | Meaning |
|---|---|
| To DS = 0<br>From DS = 0 | A Data frame from one STA to another STA within the same IBSS or the same PBSS, a Data frame direct from one non-AP STA to another non-AP STA within the same infrastructure BSS, or a Data frame outside the context of a BSS.<br><br>This is the only valid combination for Data frames transmitted: a) by an IBSS or PBSS STA, b) on the direct path of a TDLS direct link, or c) outside the context of a BSS.(#574) |
| To DS = 1<br>From DS = 0 | A Data frame destined for the DS or being sent by a STA associated with an AP to the Port Access Entity in that AP. |
| To DS = 0<br>From DS = 1 | A Data frame exiting the DS or being sent by the Port Access Entity in an AP, or a group addressed mesh Data frame with the Mesh Control field present using the three-address MAC header format.<br><br>This is the only valid combination for Data frames transmitted by a non-GLK AP and group addressed Data frames transmitted by a mesh STA. |
| To DS = 1<br>From DS = 1 | (#462)A Data frame using the four-address MAC header format. This standard defines procedures for using this combination of field values in mesh BSSs (see 10.37 (Mesh forwarding framework)), by S1G relays (see 10.53 (S1G relay operation)) or by a GLK STA (see 10.64 (Addressing of GLK Data frame transmission)).(#1625)<br><br>This is the only valid combination for individually addressed Data frames transmitted by a mesh STA. |

The meanings of the combinations of values of the Management frame To DS and From DS subfields are shown in Table 9-4 (Combinations of To DS and From DS subfields in Management frames(#278)).

In Control frames, To DS and From DS subfields, when present, are both zero.


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**Table 9-4—Combinations of To DS and From DS subfields in Management frames(#278)**

| To DS subfield and From DS subfield values | Meaning |
|---|---|
| To DS = 0<br>From DS = 0 | All Management frames that are not QMFs(#4296). |
| To DS = 1<br>From DS = 0 | All QMFs(#4296) |
| To DS = 0<br>From DS = 1 | This combination is reserved. |
| To DS = 1<br>From DS = 1 | This combination is reserved. |

NOTE—In Control frames of subtype Control Frame Extension, the To DS and From DS subfields are not defined, and their bit positions are part of the Control Frame Extension field (see 9.2.4.1.3 (Type and Subtype subfields), Table 9-2 (Control Frame Extension)).

### 9.2.4.1.5 More Fragments subfield

The More Fragments subfield is set to 1 in all Data or Management frames that have another fragment of the current MSDU or current MMPDU to follow. It is set to 0 in all other frames in which the More Fragments subfield is present.

NOTE—In Control frames of subtype Control Frame Extension, the More Fragments subfield is not present, and its bit position is part of the Control Frame Extension field (see 9.2.4.1.3 (Type and Subtype subfields), Table 9-2 (Control Frame Extension)).

### 9.2.4.1.6 Retry subfield

The Retry subfield is set to 1 in any Data or Management frame that is a retransmission of an earlier frame. It is set to 0 in all other frames in which the Retry subfield is present. A receiving STA uses this indication to aid in the process of eliminating duplicate frames. These rules do not apply for frames that are not non-A-MPDUs and that are sent by a non-DMG STA under a block ack agreement.(#1652)(#3741)

NOTE—In Control frames of subtype Control Frame Extension, the Retry subfield is not present, and its bit position is part of the Control Frame Extension field (see 9.2.4.1.3 (Type and Subtype subfields), Table 9-2 (Control Frame Extension)).

### 9.2.4.1.7 Power Management subfield

The Power Management subfield is used to indicate the power management mode of a STA. The subfield is either reserved (as defined below) or remains constant in each frame from a particular STA within a frame exchange sequence(#109). The value indicates the mode of the STA after the successful completion of the frame exchange sequence.

In an infrastructure BSS or PBSS, the following applies:

— (#2022)In certain frame exchanges, as described in 11.2.3 (Power management in a non-DMG infrastructure network) and 11.2.7 (Power management in a PBSS and DMG infrastructure BSS), the Power Management subfield is set to 1 to indicate that the STA will be in PS mode and set to 0 to indicate that the STA will be in active mode.

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- The Power Management subfield is reserved in all Management frames transmitted by a STA to an AP or PCP with which it is not associated.
- The Power Management subfield is reserved in all frames transmitted by the AP.

In an IBSS, the Power Management subfield is valid only in certain frames as described in 11.2.4.4 (STA power state transitions). In such frames, the Power Management subfield set to 1 indicates that the STA will be in PS mode. The Power Management subfield set to 0 indicates that the STA will be in active mode.

In an MBSS, the Power Management subfield is valid only in frame exchanges as described per the mesh power management mode transitions rules in 14.15 (Power save in a mesh BSS). In such exchanges, the value indicates the STA's power management mode (see 14.15 (Power save in a mesh BSS)).

#### 9.2.4.1.8 More Data subfield

The More Data subfield is used differently by a DMG, an S1G STA, and a non-DMG non-S1G STA(#464).

A non-DMG and non-S1G STA uses the More Data subfield to indicate to a STA in PS mode that more BUs are buffered for that STA at the AP. The More Data subfield is valid in individually addressed Data or Management frames transmitted by an AP to a STA in PS mode. The More Data subfield is set to 1 to indicate that at least one additional buffered BU is present for the same STA.

(11ax)An AP optionally sets the More Data subfield to 1 in Ack frames sent to a non-DMG non-S1G non-HE STA and in Ack, BlockAck, and Multi-STA BlockAck frames sent to an HE STA. An HE AP indicates that it supports setting the More Data subfield to 1 in these control response frames by setting the More Data Ack subfield to 1 in the QoS Info field of elements it includes in frames transmitted to the STA.

(11ax)The AP can set the More Data subfield to 1 to indicate that it has a pending transmission for the STA if it has received a frame that contains a QoS Info field in which the More Data Ack subfield is equal to 1 from the STA and one of the following conditions is true:

- The STA is in PS mode and has one or more ACs that are delivery enabled (see 11.2.3.6 (AP operation)).
- The STA is in PS mode and is a TWT requester or a TWT scheduled STA (see 26.8 (TWT operation)).

(11ax)A TDLS peer STA optionally sets the More Data subfield to 1 in Ack frames sent to a non-HE STA and in Ack, BlockAck, and Multi-STA BlockAck frames sent to an HE STA. An HE TDLS peer STA indicates that it supports setting the More Data subfield to 1 in these control response frames by setting the More Data Ack subfield to 1 in the QoS Info field of the QoS Capability element it includes in frames transmitted to the STA.

(11ax)The TDLS peer STA can set the More Data subfield to 1 to indicate that it has a pending transmission for the STA if it has received from the STA a TDLS Setup Request frame or TDLS Setup Response frame that has the More Data Ack subfield equal to 1 in the QoS Info field of the QoS Capability element and one of the following conditions is true:

- The STA has TDLS peer PSM enabled (see 11.2.3.6 (AP operation)).
- The STA is in PS mode and is a TWT requester or a TWT scheduled STA (see 26.8 (TWT operation)).

The More Data subfield is 1 in individually addressed frames transmitted by a mesh STA to a peer mesh STA that is either in light sleep mode or in deep sleep mode for the corresponding mesh peering, when additional BUs remain to be transmitted to this peer mesh STA.


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The More Data subfield is set to 1 in individually addressed frames transmitted by a VHT AP to a VHT STA when both support the VHT TXOP power save feature (as determined from their VHT Capabilities elements) to indicate that at least one additional buffered BU is present for the STA. See 11.2.3.16 (VHT TXOP power save).

A non-DMG and non-S1G STA sets the More Data subfield to 0 in all other individually addressed frames.

A non-DMG and non-S1G STA sets the More Data subfield to 1 in non-GCR-SP group addressed frames transmitted by the AP when additional group addressed bufferable units (BUs) that are not part of an active GCR-SP remain to be transmitted by the AP during this beacon interval. The More Data subfield is set to 0 in non-GCR-SP group addressed frames transmitted by the AP when no more group addressed BUs that are not part of an active GCR-SP remain to be transmitted by the AP during this beacon interval and in all group addressed frames transmitted by non-AP STAs.

An S1G STA sets the More Data subfield to 1 in individually addressed frames to indicate that the S1G STA has MSDUs, MMPDU or A-MSDUs buffered for transmission to the frame's recipient during the current SP or TXOP. An S1G STA does not set the More Data subfield to 1 in individually addressed frames if it does not have any MSDUs, MMPDU or A-MSDUs buffered for transmission to the frame's recipient during the current SP or TXOP.

An S1G AP sets the More Data subfield to 1 in group addressed frames when additional group addressed BUs remain to be transmitted by the AP during this beacon interval or short beacon interval (see 11.1.3.10.2 (Generation of S1G Beacon frames)). The S1G AP sets the More Data subfield to 0 in group addressed frames transmitted by the AP when no more group addressed BUs remain to be transmitted by the AP during this beacon interval or short beacon interval.

The More Data subfield is set to 1 in GCR-SP group addressed frames transmitted by the AP when additional group addressed BUs that are part of an active GCR-SP remain to be transmitted by the AP during this GCR-SP. The More Data subfield is set to 0 in GCR-SP group addressed frames transmitted by the AP when no more group addressed BUs that are part of an active GCR-SP remain to be transmitted by the AP during this GCR-SP.

The More Data subfield is 1 in group addressed frames transmitted by a mesh STA when additional group addressed BUs remain to be transmitted. The More Data subfield is 0 in group addressed frames transmitted by a mesh STA when no more group addressed BUs remain to be transmitted.

A DMG STA sets the More Data subfield as follows:

— In individually addressed frames, it is set to 1 to indicate that the STA has MSDUs or A-MSDUs buffered for transmission to the frame's recipient during the current SP or TXOP.

— It is set to 1 in group addressed frames transmitted by the AP when additional group addressed BUs remain to be transmitted by the AP during this beacon interval. The More Data subfield is set to 0 in group addressed frames transmitted by the AP when no more group addressed BUs remain to be transmitted by the AP during this beacon interval.

A DMG STA does not set the More Data bit to 1 if it does not have any MSDUs or A-MSDUs buffered for transmission to the frame's recipient during the current SP or TXOP.

The More Data subfield is set to 1 in individually addressed frames transmitted by a CMMG AP to a CMMG STA when both support the CMMG TXOP power save feature (as determined from their CMMG Capabilities elements) to indicate that at least one additional buffered BU is present for the STA, see 11.2.3.18 (CMMG TXOP power save).

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#### 9.2.4.1.9 Protected Frame subfield

The Protected Frame subfield ((#6402)see 12.2.6 (Requirements for the Protected Frame field)) is set to 1 if the Frame Body field contains information that has been processed by a cryptographic encapsulation algorithm. The Protected Frame subfield is reserved in Control frames of subtype Control Frame Extension. When the Protected Frame subfield is equal to 1, the Frame Body field is protected utilizing the cryptographic encapsulation algorithm and expanded as defined in Clause 12 (Security). The Protected Frame subfield is set to 0 in Data frames of subtype Null, QoS Null, QoS CF-Poll, and QoS CF-Ack +CF-Poll (see, for example, 12.3.4.2 (TKIP MPDU formats) and 12.5.2.1 (General) that show that the frame body needs to be 1 octet or longer to apply the encapsulation).

#### 9.2.4.1.10 +HTC subfield

The +HTC subfield is set as follows:

— It is set to 1 in a QoS Data or Management frame transmitted with the FORMAT parameter of the TXVECTOR set to HT_GF, HT_MF, VHT or S1G to indicate that the frame contains an HT Control field.

— It is set to 1 in an RTS frame transmitted with the FORMAT parameter of the TXVECTOR set to S1G to indicate that the intended recipient of the frame has permission to extend the TXOP as described in 10.53.5.4 (Relay-shared TXOP protection mechanisms).

— It is set to 1 in a QoS Data or Management frame transmitted by a CMMG STA to indicate that the frame contains a CMMG variant HT Control field.

— It is set to 1 in a QoS Data, QoS Null, or Management frame transmitted by an HE STA to another HE STA to indicate that the frame contains an HT Control field.(11ax)

Otherwise, the +HTC subfield is set to 0.

NOTE—The +HTC subfield is always set to 0 for frames transmitted by a DMG STA.

#### 9.2.4.1.11 Bandwidth Indication and Dynamic Indication subfields

The Bandwidth Indication subfield identifies the bandwidth of the PPDU. The Bandwidth Indication and Dynamic Indication subfields are used to negotiate the bandwidth of PPDUs within a TXOP. Table 9-5 (Bandwidth Indication subfield encoding) defines the bandwidth used for exchanging PPDUs between a TXOP holder and a TXOP responder.

**Table 9-5—Bandwidth Indication subfield encoding**

| Bandwidth Indication encoding | Meaning |
|---|---|
| 0 | 1 MHz |
| 1 | 2 MHz |
| 2 | 4 MHz |
| 3 | 8 MHz |
| 4 | 16 MHz |
| 5–7 | Reserved |


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Table 9-6 (Dynamic Indication subfield encoding) indicates whether the bandwidth used for exchanging PPDUs in a TXOP is static or can change dynamically.

**Table 9-6—Dynamic Indication subfield encoding**

| Dynamic Indication encoding | Meaning |
|---|---|
| 0 | Static |
| 1 | Dynamic |

#### 9.2.4.1.12 Next TWT Info Present subfield

The Next TWT Info Present subfield is set to 1 if the Next TWT Info/Suspend Duration field is present in the frame. Otherwise, it is set to 0.

#### 9.2.4.1.13 Flow Control subfield

The Flow Control subfield is used for flow suspension signaling as described in 10.60 (S1G flow control).

#### 9.2.4.1.14 Poll Type subfield

The Poll Type subfield is defined in Table 9-7 (Poll Type subfield encoding) if the Power Management subfield is 1 in PS-Poll frame. Otherwise, the Poll Type subfield is reserved.

**Table 9-7—Poll Type subfield encoding**

| Poll Type subfield | Description |
|---|---|
| 0 | Request for a buffered frame without a request to reschedule the awake/doze cycle |
| 1 | Request for the information of change sequence of the beacon and partial timestamp |
| 2 | Request for a duration to a TBTT or Next TWT to reschedule awake/doze cycle |
| 3 | Request for a duration to a service period to reschedule awake/doze cycle |

#### 9.2.4.1.15 Next TBTT Present subfield

The Next TBTT Present subfield is set to 1 if the Next TBTT field is present; otherwise, it is set to 0.

#### 9.2.4.1.16 Short SSID Present subfield(#8219)

The (#8219)Short SSID Present subfield is set to 1 if the Short SSID field is present; otherwise, it is set to 0.

#### 9.2.4.1.17 ANO Present subfield

The ANO Present subfield is set to 1 if the Access Network Options field is present; otherwise, it is set to 0.

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#### 9.2.4.1.18 BSS BW subfield

The BSS BW subfield indicates the minimum and the maximum operating bandwidths of the BSS as defined in Table 9-8 (Frame Control field BSS BW setting).

**Table 9-8—Frame Control field BSS BW setting**

| BSS BW | Minimum BSS BW (MHz) | Maximum BSS BW (MHz) |
|---|---|---|
| 0 | 1 | 2 |
| 1 | Equal to the BW of the PPDU carrying the BSS BW field | Equal to the BW of the PPDU carrying the BSS BW field |
| 2 | 1 | 4 |
| 3 | 2 | 4 |
| 4 | 1 | 8 |
| 5 | 2 | 8 |
| 6 | 1 | 16 |
| 7 | 2 | 16 |

#### 9.2.4.1.19 Security subfield

The Security subfield is set to 1 if the AP is an RSNA AP.

#### 9.2.4.1.20 AP-PM subfield

The AP-PM subfield indicates whether the AP can go to Power Save mode until the next TBTT or TSBTT. If the AP-PM subfield is equal to 1, the AP can go to Power Save mode until the next TBTT or TSBTT unless otherwise is indicated by restricted access windows (RAWs) or TWTs. If the AP-PM subfield is equal to 0, the AP does not go to Power Save mode until the next TBTT or TSBTT.

### 9.2.4.2 Duration/ID field

The contents of the Duration/ID field vary with frame type and subtype, and with the QoS capabilities of the sending STA. The contents of the field are defined as follows:

a) In Control frames of subtype PS-Poll other than PS-Poll+BDT frames, and for broadcast transmissions in S1G PPDUs, the Duration/ID field carries the association identifier (AID) of the STA that transmitted the frame in the 14 least significant bits (LSB), and the 2 most significant bits (MSB) both set to 1.

b) In Data and Management frames sent by QoS STAs, the Duration/ID field contains a duration value as defined for each frame type in 9.2.5 (Duration/ID field (QoS STA)).(#485)

c) In Extension frames the Duration/ID field contains a duration value as defined in 9.3.4 (Extension frames).(#485)

d) In all other frames, the Duration/ID field contains a duration value as defined for each frame type in 9.3 (Format of individual frame types).(#485)

See 10.28.3 (Duration/ID field processing) on the processing of this field in received frames.

The encoding of the Duration/ID field is given in Table 9-9 (Duration/ID field encoding).


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**Table 9-9—Duration/ID field encoding**

| Bits 0–13 | Bit 14 | Bit 15 | Usage |
|---|---|---|---|
| 0–32 767 | | 0 | Duration value (in microseconds) within all frames except PS-Poll frames that are not PS-Poll+BDT |
| 0–16 383 | 0 | 1 | Reserved |
| 0 | 1 | 1 | AID 0 is used for broadcast transmission in S1G PPDU, reserved if not in S1G PPDU. |
| 1–2007 | 1 | 1 | AID in PS-Poll frames other than PS-Poll+BDT. |
| 2008–8191 | 1 | 1 | Additional AIDs in S1G PS-Poll frames other than PS-Poll+BDT. Reserved if not in S1G PS-Poll frames. |
| 8192–16 383 | 1 | 1 | Reserved |

See also 9.7.3 (A-MPDU contents) on the setting of the Duration/ID field of MAC headers of MPDUs in an A-MPDU.

### 9.2.4.3 Address fields

#### 9.2.4.3.1 General

There are four address fields in the MAC frame format. These fields are used to indicate the basic service set identifier (BSSID), source address (SA), destination address (DA), transmitting address (TA), and receiving address (RA). Certain frames might not contain some of the address fields.

Certain address field usage is specified by the relative position of the address field (1–4) within the MAC header, independent of the type of address present in that field. Specifically, the Address 1 field always identifies the intended receiver(s) of the frame, and the Address 2 field, where present, always identifies the transmitter of the frame.

NOTE—In the case of a bandwidth signaling TA the Address 2 field is not equal to the MAC address of the transmitter.(#100)

#### 9.2.4.3.2 Address representation

Each Address field (#4162)contains an address as defined in Clause 8 of IEEE Std 802-2014.

#### 9.2.4.3.3 Address designation

A MAC sublayer address is one of the following two types:

a) *Individual address.* The address assigned to a particular STA on the network.

b) *Group address.* A multidestination address, which might be in use by one or more STAs on a given network. The two kinds of group addresses are as follows:

   1) *Multicast-group address.* An address associated by higher level convention with a group of logically related STAs.

   2) *Broadcast address.* A distinguished, predefined group address that always denotes the set of all STAs on a given LAN. All 1s are interpreted to be the broadcast address. This group is predefined for each communication medium to consist of all STAs actively connected to that medium; it is used to broadcast to all of the active STAs on that medium.

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The address space is also partitioned into locally administered and universal (globally administered) addresses. The nature of a body and the procedures by which it administers these universal (globally administered) addresses is beyond the scope of this standard. See IEEE Std 802 for more information.

#### 9.2.4.3.4 BSSID field

The BSSID field is of the same format as a (#1893)MAC address. When dot11OCBActivated is false and dot11MeshActivated is false(#397), this field uniquely identifies each BSS.

(#396)This field, in an infrastructure BSS, is the MAC address currently in use by the STA in the AP of the BSS.

This field in a PBSS is set to the MAC address of the PCP.

This field in an IBSS is set to a locally administered (#1893)MAC address formed from a 46-bit random number generated according to the procedure defined in 11.1.4 (Acquiring synchronization, scanning). The Individual/Group bit of the address is set to 0. The Universal/Local bit of the address is set to 1. This mechanism is used to provide a high probability of selecting a unique BSSID.

(#397)This field in an MBSS is set to the MAC address of the mesh STA transmitting the frame containing the field.

NOTE—This means the BSSID field has the same value as the TA field (see 9.3.2.1.2 (Address and BSSID fields)).(#397)

This field is set to all 1s to indicate the wildcard BSSID. The wildcard value is not used in the BSSID field except where explicitly permitted in this standard. When dot11OCBActivated is true, the wildcard value is used in the BSSID field. When dot11OCBActivated is false and the BSSID field contains the wildcard value, the Address 1 (DA) field is also set to all 1s to indicate the broadcast address.

#### 9.2.4.3.5 DA field

The DA field contains a (#1893)MAC address that identifies the MAC entity or entities intended as the final recipient(s) of the MSDU (or fragment thereof) or A-MSDU (or fragment thereof),(11ax) as defined in 9.3.2.1 (Format of Data frames), contained in the frame body field.

#### 9.2.4.3.6 SA field

The SA field contains an (#1893)individual address that identifies the MAC entity from which the transfer of the MSDU (or fragment thereof) or A-MSDU, as defined in 9.3.2.1 (Format of Data frames), contained in the frame body field was initiated. The Individual/Group bit is always transmitted as a 0 in the source address.

#### 9.2.4.3.7 RA field

The RA field contains a (#1893)MAC address that identifies the intended immediate recipient STA(s), on the WM, for the information contained in the frame body field.

#### 9.2.4.3.8 TA field

The TA field contains a (#1893)MAC address that identifies the STA that has transmitted, onto the WM, the MPDU contained in the frame body field. If the Individual/Group bit is 0, then the TA field is the individual address of the STA; otherwise, the TA field is a bandwidth signaling TA, indicating that the frame carries additional information in the scrambling sequence (see 9.3.1.2 (RTS frame format), 9.3.1.5.1 (General), 9.3.1.7.1 (Overview), 9.3.1.8.1 (Overview), 9.3.1.19 (VHT/HE/Ranging NDP Announcement frame


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format(11ax)(11az)), 9.3.1.20 (Beamforming Report Poll frame format), 10.6.6.6 (Channel Width selection for Control frames), and 10.6.12 (Channel Width in non-HT and non-HT duplicate PPDUs)).

#### 9.2.4.4 Sequence Control field

##### 9.2.4.4.1 Sequence Control field structure when SAR is not used(11ay)

(#1092)If segmentation and reassembly (see 10.69 (DMG segmentation and reassembly operation(11ay))) is not established between the transmitting and receiving STA, the Sequence Control field has the format shown(#3242) in Figure 9-7 (Sequence Control field format when SAR is not used(#1092)).(#1892)

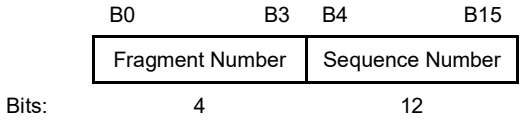


**Figure 9-7—Sequence Control field format when SAR is not used(#1092)**

##### 9.2.4.4.2 Sequence Control field structure when SAR is used(11ay)

If segmentation and reassembly (see 10.69) is established between the transmitting and receiving STA, the Sequence Control field has the format shown(#3242) in Figure 9-8 (Sequence Control field format when SAR is used(11ay)(#1092)).(#1892)

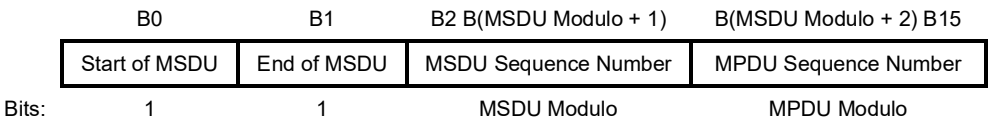


**Figure 9-8—Sequence Control field format when SAR is used(11ay)(#1092)**

The Start of MSDU subfield is set to 1 to indicate that the MPDU contains the first segment of an MSDU or A-MSDU. It is set to 0 otherwise.

The End of MSDU subfield is set to 1 to indicate that the MPDU contains the last segment of an MSDU or A-MSDU. It is set to 0 otherwise.

The MSDU Sequence Number subfield indicates the sequence number value associated with the respective MSDU or A-MSDU segment. The length of the MSDU Sequence Number subfield is equal to the value of the MSDU Modulo subfield within the SAR Configuration element contained in the intended recipient's ADDBA Response frame (see 10.25.2 (Setup and modification of the block ack parameters)).

The MPDU Sequence Number subfield indicates the MPDU sequence number that carries the MSDU or A-MSDU segment. The length of the MPDU Sequence Number subfield is equal to the value of the MPDU Modulo subfield within the SAR Configuration element contained in the intended recipient's ADDBA Response frame (see 10.25.2 (Setup and modification of the block ack parameters)).

##### 9.2.4.4.3 Sequence Number field

(#270)Each MSDU (if not in an A-MSDU), A-MSDU, or MMPDU is assigned a sequence number. See 10.3.2.14 (Duplicate detection and recovery).(#273)

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(#270)The Sequence Number field in Data frames indicates the sequence number of the MSDU (if not in an A-MSDU) or A-MSDU.

The Sequence Number field in QMFs comprises the QMF Sequence Number subfield and the AC Index (ACI) subfield. The QMF Sequence Number subfield indicates the sequence number of the frame. The ACI subfield indicates the ACI of the frame. The format of the Sequence Number field in QMFs is shown in Figure 9-9 (Sequence Number field format in QMFs).

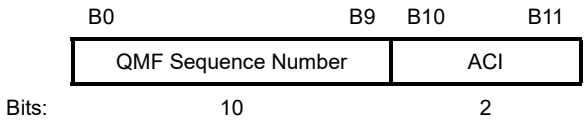


**Figure 9-9—Sequence Number field format in QMFs**

The ACI subfield represents the ACI of the frame as defined in 9.4.2.27 (EDCA Parameter Set element).

The Sequence Number field in Management frames that are not QMFs indicates the sequence number of the frame.

Each fragment of an MSDU (not in an A-MSDU), A-MSDU or MMPDU contains a copy of the sequence number assigned to that MSDU, A-MSDU or MMPDU. The sequence number remains constant in all retransmissions of the MSDU, A-MSDU, MMPDU, or fragment thereof, except when the MSDU is delivered via both DMS and group addressed delivery via NoAck, GCR unsolicited retry, or GCR block ack retransmission policies. In such cases, the sequence numbers assigned to the MSDUs (re)transmitted using group addressed delivery need not match the sequence number of the (#2004)corresponding A-MSDUs (re)transmitted using individually addressed delivery via DMS.(#1874)

#### 9.2.4.4.4 Fragment Number field

The Fragment Number field indicates the number of each fragment of an MSDU or MMPDU. The fragment number is set to 0 in the first or only fragment of an MSDU or MMPDU and is incremented by one for each successive fragment of that MSDU or MMPDU. The fragment number is set to 0 in an MPDU containing an A-MSDU, and in an MPDU containing an MSDU or MMPDU that is not fragmented. The fragment number remains constant in all retransmissions of the fragment.

### 9.2.4.5 QoS Control field

#### 9.2.4.5.1 QoS Control field structure

The QoS Control field identifies the TC or TS to which the frame belongs as well as various other QoS-related, A-MSDU related, and mesh-related information about the frame that varies by frame type, subtype, and type of transmitting STA. The QoS Control field is present in all Data frames in which the QoS subfield of the Subtype subfield is equal to 1 (see 9.2.4.1.3 (Type and Subtype subfields)).

When not transmitted within a DMG PPDU, each QoS Control field comprises five or eight subfields, as defined for the particular sender (HC or non-AP STA) and frame type and subtype. The usage of these subfields and the various possible layouts of the QoS Control field are described in 9.2.4.5.2 (TID subfield) to 9.2.4.5.12 (Receiver Service Period Initiated (RSPI) subfield) and shown in Table 9-10 (QoS Control field).

See 10.12.1 (A-MPDU contents) for constraints on the contents of the QoS Control field when present in an A-MPDU.


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**Table 9-10—QoS Control field**

| Applicable frame (sub)types | Bits 0–3 | Bit 4 | Bits 5–6 | Bit 7 | Bits 8 | Bit 9 | Bit 10 | Bits 11–15 |
|---|---|---|---|---|---|---|---|---|
| QoS CF-Poll and QoS CF-Ack +CF-Poll frames sent by HC | TID | EOSP | Ack Policy Indicator | Reserved | TXOP Limit | | | |
| QoS Data +CF-Poll and QoS Data +CF-Ack +CF-Poll frames sent by HC | TID | EOSP | Ack Policy Indicator | A-MSDU Present | TXOP Limit | | | |
| QoS Data and QoS Data +CF-Ack frames sent by HC | TID | EOSP | Ack Policy Indicator | A-MSDU Present | AP PS Buffer State | | | |
| QoS Null frames sent by HC | TID | EOSP | Ack Policy Indicator | Reserved | AP PS Buffer State | | | |
| QoS Data and QoS Data +CF-Ack frames sent in a nonmesh BSS by non-AP STAs that are not a TPU buffer STA or a TPU sleep STA | TID | 0 | Ack Policy Indicator | A-MSDU Present | TXOP Duration Requested | | | |
| | TID | 1 | Ack Policy Indicator | A-MSDU Present | Queue Size | | | |
| QoS Null frames sent in a nonmesh BSS by non-AP STAs that are not a TPU buffer STA or a TPU sleep STA | TID | 0 | Ack Policy Indicator | Reserved | TXOP Duration Requested | | | |
| | TID | 1 | Ack Policy Indicator | Reserved | Queue Size | | | |
| QoS Data and QoS Data +CF-Ack frames sent by TPU buffer STAs | TID | EOSP | Ack Policy Indicator | A-MSDU Present | Reserved | | | |
| QoS Null frames sent by TPU buffer STAs | TID | EOSP | Ack Policy Indicator | Reserved | Reserved | | | |
| QoS Data and QoS Data +CF-Ack frames sent by TPU sleep STAs | TID | Reserved | Ack Policy Indicator | A-MSDU Present | Reserved | | | |
| QoS Null frames sent by TPU sleep STAs | TID | Reserved | Ack Policy Indicator | Reserved | Reserved | | | |
| All frames sent by mesh STAs in a mesh BSS | TID | EOSP | Ack Policy Indicator | A-MSDU Present | Mesh Control Present | Mesh Power Save Level | RSPI | Reserved |

The format of the QoS Control field for MPDUs transmitted within a DMG PPDU is provided in Table 9-11 (QoS Control field for frames transmitted within a DMG PPDU). Data subtypes not shown in the table are not transmitted within a DMG PPDU.

#### 9.2.4.5.2 TID subfield

The TID subfield identifies the TC or TS to which the corresponding MSDU (or fragment thereof) or A-MSDU (or fragment thereof)(11ax) in the Frame Body field belongs. The TID subfield also identifies the TC or TS of traffic for which a TXOP is being requested, through the setting of TXOP duration requested or queue size. The encoding of the TID subfield depends on the access policy (see 9.4.2.28 (TSPEC element)) and is shown in Table 9-12 (TID subfield). Additional information on the interpretation of the contents of this field appears in 5.1.1.3 (Interpretation of priority parameter in MAC service primitives).

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**Table 9-11—QoS Control field for frames transmitted within a DMG PPDU**

| Applicable frame (sub)types | Bits 0–3 | Bit 4 | Bits 5–6 | Bit 7 | Bit 8 | Bit 9 | Bits 10–13 | Bit 14 | Bit 15 |
|---|---|---|---|---|---|---|---|---|---|
| QoS Data | TID | EOSP | Ack Policy Indicator | A-MSD U Present | A-MSD U Type | RDG/ More PPDU | Buffered AC | Reserved | AC Constraint |
| QoS Null | TID | EOSP | Ack Policy Indicator | Reserved | Reserved | RDG/ More PPDU | Buffered AC | Reserved | AC Constraint |

**Table 9-12—TID subfield**

| Access policy | Usage | Allowed values |
|---|---|---|
| EDCA | UP for either TC or TS, regardless of whether admission control is required | 0–7 |
| HCCA, SPCA | TSID | 8–15 |
| HEMM, SEMM | TSID, regardless of the access mechanism used | 8–15 |

In QoS Data +CF-Poll frames, the TID subfield in the QoS Control field indicates the TID of the data. In QoS (+)CF-Poll frames of subtype Null, the TID subfield in the QoS Control field indicates the TID for which the poll is intended. The requirement to respond to that TID is nonbinding, and a STA can respond with any frame (see 10.23.3.5.1 (General)). For STAs where dot11OCBActivated is true, traffic streams are not used and the TID always corresponds to a TC.

#### 9.2.4.5.3 EOSP (end of service period) subfield

The EOSP subfield is used by the HC to indicate the end of the current service period (SP) and by a DMG STA to indicate the end of the current SP or the end of the current allocated CBAP with a destination AID that is not the broadcast AID. The HC sets the EOSP subfield to 1 in its transmission and retransmissions of the SP's final frame to end an SP and sets it to 0 otherwise. To end an SP allocation or a CBAP allocation with a destination AID that is not the broadcast AID, the DMG STA sets the EOSP subfield to 1 in its final frame transmission and retransmissions within the allocation; otherwise, the DMG STA sets the EOSP subfield to 0.

The mesh STA uses the EOSP subfield to indicate the end of the current mesh peer service period in which it operates as the owner. The mesh STA sets the EOSP subfield to 1 in its transmission and retransmissions of the mesh peer service period's final frame to end a mesh peer service period, and sets it to 0 otherwise. See 14.15.9.4 (Termination of a mesh peer service period) for details.

If dot11RobustAVStreamingImplemented is true, then the HC sets the EOSP subfield to 1 in a GCR-SP group addressed frame in order to indicate that no more GCR-SP frames of that group address are to be transmitted by the AP until the next scheduled SP for this GCR-SP stream.

NOTE—As GCR frames sent using the GCR-A procedures are sent outside of any SP (see 11.21.16.3.8 (GCR-SP)), the EOSP subfield is set to 0 in such frames.(#1769)


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#### 9.2.4.5.4 Ack Policy Indicator subfield

The Ack Policy Indicator subfield, together with other information, as shown in Table 9-13 (Ack policy), identifies the ack policy, i.e. the behavior followed upon the delivery of the MPDU.

**Table 9-13—Ack policy**

| Ack policy | Ack Policy Indicator subfield | | Other conditions | Meaning |
|---|---|---|---|---|
| | Bit 0 | Bit 1 | | |
| Normal Ack | 0 | 0 | MPDU is a non-A-MPDU frame | Where the frame contains a fragment and both the originator and the addressed recipient support fragment BA :<br>The addressed recipient returns an NDP BlockAck or BAT frame after a SIFS, according to the procedures defined in 10.3.2.12 (Fragment BA procedure) and 10.46.2 (TWT acknowledgment procedure).<br><br>(11ay)The addressed recipient that is a DMG STA operating in an SP with TDD channel access (see 10.38.6.2.2 (SP with TDD channel access(11ay))) returns an Ack frame according to the procedures defined in 10.3.2.11 (Acknowledgment procedure).<br><br>Otherwise:<br>The addressed recipient returns an Ack, STACK, or QoS +CF-Ack frame after a short interframe space (SIFS)(#320), according to the procedures defined in 10.3.2.11 (Acknowledgment procedure), 10.46.2 (TWT acknowledgment procedure), and 10.23.3.5 (HCCA transfer rules). A non-DMG STA uses this ack policy for individually addressed QoS Null frames. |
| Implicit BAR | 0 | 0 | MPDU is not a non-A-MPDU frame<br>NOTE—This MPDU is sent under a block ack agreement. | The addressed recipient returns a BlockAck, TACK or BAT frame, either individually or as part of an A-MPDU starting a SIFS after the PPDU carrying the frame, according to the procedures defined in 10.3.2.11 (Acknowledgment procedure), 10.25.6.5 (Generation and transmission of BlockAck frames by an HT STA, DMG STA, or S1G STA), 10.29.3 (Rules for RD initiator), 10.29.4 (Rules for RD responder), 10.46.2 (TWT acknowledgment procedure), and 10.33.3 (Explicit feedback beamforming).<br><br>(11ay)The addressed recipient that is a DMG STA operating in an SP with TDD channel access (see 10.38.6.2.2 (SP with TDD channel access(11ay))) returns an BlockAck frame, either individually or as part of an A-MPDU according to the procedures defined in 10.25.6.5 (Generation and transmission of BlockAck frames by an HT STA, DMG STA, or S1G STA). |

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**Table 9-13—Ack policy *(continued)***

| Ack policy | Ack Policy Indicator subfield | | Other conditions | Meaning |
|---|---|---|---|---|
| | Bit 0 | Bit 1 | | |
| No Ack | 1 | 0 | None | The addressed recipient takes no action upon receipt of the frame. More details are provided in 10.26 (No Acknowledgment (No Ack)).<br><br>This ack policy is used in all frames in which the sender does not require any acknowledgment.(#1764)(#1593)<br>It is not used for QoS Data frames with a TID for which a block ack agreement exists. |
| No Explicit Acknowledgment | 0 | 1 | Bit 6 of the Frame Control field (see 9.2.4.1.3 (Type and Subtype subfields)) is equal to 1 (11ax)and the frame is not carried in an HE MU PPDU, HE SU PPDU, or HE ER SU PPDU that contains a frame that solicits a response in an HE TB PPDU | There might be a response frame to the frame that is received, but it is neither the Ack frame nor any Data frame of subtype +CF-Ack.<br>This ack policy is used for QoS CF-Poll and QoS CF-Ack +CF-Poll Data frames.<br><br>NOTE—Bit 6 of the Frame Control field (see 9.2.4.1.3 (Type and Subtype subfields)) indicates the absence of a Frame Body field in a QoS Data frame. When equal to 1, the QoS Data frame contains no Frame Body field, and any response is generated in response to a QoS CF-Poll or QoS CF-Ack +CF-Poll frame, but does not signify an acknowledgment of data. |
| (11ax)HETP Ack | 0 | 1 | The frame is carried in an HE MU PPDU, HE SU PPDU, or HE ER SU PPDU that contains a frame that solicits a response in an HE TB PPDU | The addressed recipient returns an Ack, Compressed BlockAck, or Multi-STA BlockAck frame carried in an HE TB PPDU a SIFS after the PPDU, subject to reception of a triggering frame in the PPDU, as defined in 10.3.2.13.2 (Acknowledgment procedure for DL MU PPDU in MU format(11ax))and 26.5.2 (UL MU operation). |
| Block Ack | 1 | 1 | None | The addressed recipient takes no action upon the receipt of the frame except for recording the state. The recipient can expect a BlockAckReq frame or implicit block ack request in the future to which it responds using the procedure described in 10.25 (Block acknowledgment (block ack)). |
| (11ay)Scheduled Ack | 0 | 1 | Bit 6 of the Frame Control field (see 9.2.4.1.3 (Type and Subtype subfields)) is equal to 0 | The acknowledgment for a frame indicating Scheduled Ack when it appears in an EDMG PPDU is to be received in a scheduled time slot as described in 10.3.2.13 (MU acknowledgment procedure), 10.29.4 (Rules for RD responder), and 10.29.5 (Reverse direction for EDMG DL MU-MIMO(11ay)). |

### 9.2.4.5.5 TXOP Limit subfield

The TXOP Limit subfield is present in QoS Data frames of subtypes that include CF-Poll and specifies the time limit on a TXOP granted by a QoS (+)CF-Poll frame from an HC in an infrastructure BSS. In QoS Data


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frames with subtypes that include CF-Poll, the addressed STA is granted a TXOP that begins a SIFS after this frame and lasts no longer than the number of 32 μs periods specified by the TXOP Limit subfield value. The range of time values is 32 μs to 8160 μs. A TXOP Limit subfield set to 0 indicates that only one MPDU or one QoS Null frame is to be transmitted immediately following the QoS (+)CF-Poll frame.

#### 9.2.4.5.6 Queue Size subfield

(11ax)(#1232)The Queue Size subfield (#4162)indicates the amount of buffered traffic for a given TC or TS:

— at a non-AP non-HE STA sending the frame that contains this subfield, or

— at a non-AP HE STA for transmission to the HE STA identified by the receiver address of the frame that contains this subfield.

The Queue Size subfield is present in QoS Data frames with bit 4 of the QoS Control field set to 1 sent by a non-AP STAs and in QoS Null frames with bit 4 of the QoS Control field set to 1 sent by a non-AP HE STA. The AP might use information contained in the Queue Size subfield to determine the TXOP duration assigned to the STA or to determine the UL resources assigned to the non-AP HE STA (see 26.5.2 (UL MU operation)).

(11ax)In a frame sent by a non-HE STA or sent to a non-HE STA, the following apply:

— The queue size value is the approximate total size, rounded up to the nearest multiple of 256 octets and expressed in units of 256 octets, of all MSDUs and A-MSDUs buffered at the STA (excluding the MSDU or A-MSDU of the present QoS Data frame) in the delivery queue used for MSDUs and A-MSDUs with TID values equal to the value in the TID subfield of this QoS Control field.

— A queue size value of 0 is used solely to indicate the absence of any buffered traffic in the queue used for the specified TID.

— A queue size value of 254 is used for all sizes greater than 64 768 octets.

— A queue size value of 255 is used to indicate an unspecified or unknown size.

(11ax)In a frame sent by a non-AP HE STA to an HE STA, the remainder of the subclause applies.

(11ax)The queue size, *QS*, is the approximate total size in octets, of all MSDUs and A-MSDUs buffered at the STA (including the MSDUs or A-MSDUs in the same PSDU as the frame containing the Queue Size subfield) in the delivery queue used for MSDUs and A-MSDUs with TID values equal to the value in the TID subfield of this QoS Control field.

NOTE 1—The queue size is based on data received by the STA at the MAC SAP (MA-UNITDATA.request).

NOTE 2—Buffered MSDUs are those that have been received in an MA-UNITDATA.request but that have not been successfully transmitted and have not been discarded.

(11ax)The Queue Size subfield consists of a Scaling Factor subfield in B14–B15 of the QoS Control subfield and an unscaled value, *UV*, in B8–B13 of the QoS Control subfield. The Scaling Factor subfield provides the scaling factor, *SF*, with an encoding that is shown in Table 9-33 (Scaling Factor subfield encoding(11ax)) (in 9.2.4.7.4 (BSR Control)). A non-AP HE STA sets the Queue Size subfield in a QoS frame it transmits as shown in Table 9-14 (Queue Size subfield encoding by a non-AP HE STA(11ax)).

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**Table 9-14—Queue Size subfield encoding by a non-AP HE STA(11ax)**

| Queue Size subfields | | Queue Size, *QS* |
|---|---|---|
| Scaling Factor | UV | |
| 0 | 0 | 0 |
| 0 | Ceil (*QS*, 16) / 16 | $0 < QS \leq 1008$ |
| 1 | 0 | $1008 < QS \leq 1024$ |
| 1 | Ceil (*QS* – 1024, 256) / 256 | $1024 < QS \leq 17\,152$ |
| 2 | 0 | $17\,152 < QS \leq 17\,408$ |
| 2 | Ceil (*QS* – 17 408, 2048) / 2048 | $17\,408 < QS \leq 146\,432$ |
| 3 | 0 | $146\,432 < QS \leq 148\,480$ |
| 3 | Ceil (*QS* – 148 480, 32 768) / 32 768 | $148\,480 < QS \leq 2\,147\,328$ |
| 3 | 62 | $QS > 2\,147\,328$ |
| 3 | 63 | Unspecified or unknown |

(11ax)An HE STA obtains the queue size, *QS*, from a received QoS Control field, which contains a scaling factor and an unscaled value, as follows:

$$QS = \begin{cases} 16 \times UV, \text{ if the Scaling Factor subfield is 0} \\ 1024 + 256 \times UV, \text{ if the Scaling Factor subfield is 1} \\ 17\,408 + 2048 \times UV, \text{ if the Scaling Factor subfield is 2} \\ 148\,480 + 32\,768 \times UV, \text{ if the Scaling Factor subfield is 3 and UV subfield is} < 62 \\ > 2\,147\,328, \text{ if the Scaling Factor subfield is 3 and UV subfield is 62} \\ \textit{Unspecified} \text{ or } \textit{Unknown}, \text{ if the Scaling Factor subfield is 3 and UV subfield is 63} \end{cases} \quad (9\text{-}1)$$

(11ax)The queue size value of QoS Data frames containing fragments might remain constant in all fragments even if the amount of queued traffic changes as successive fragments are transmitted (see 10.23.3.5.1 (General)). If the QoS Data frames containing fragments are carried in an A-MPDU, the queue size values of the MPDU containing the fragments are set according to the rules in 10.12.1 (A-MPDU contents).

#### 9.2.4.5.7 TXOP Duration Requested subfield

The TXOP Duration Requested subfield indicates the duration, in units of 32 μs, that the sending STA determines it needs for its next TXOP for the specified TID. The TXOP Duration Requested subfield is set to 0 to indicate that no TXOP is requested for the specified TID in the current SP. The TXOP Duration Requested subfield is set to a nonzero value to indicate a requested TXOP duration in the range 32 μs to 8160 μs in increments of 32 μs. See 10.23.3.5.2 (TXOP requests).

#### 9.2.4.5.8 AP PS Buffer State subfield

The AP PS Buffer State subfield, defined in Figure 9-10 (QoS AP PS Buffer State subfield format), indicates the PS buffer state at the AP for a STA. The AP PS Buffer State subfield is further subdivided into three subfields: Buffer State Indicated, Highest Priority Buffered AC, and AP Buffered Load.


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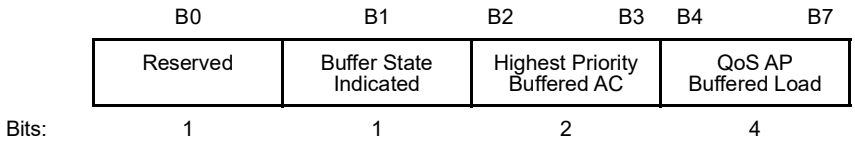


**Figure 9-10—QoS AP PS Buffer State subfield format**

The Buffered State Indicated subfield is used to indicate whether the AP PS buffer state is specified. This subfield is set to 1 to indicate that the AP PS buffer state is specified.

The Highest Priority Buffered AC subfield is used to indicate the AC of the highest priority traffic remaining that is buffered at the AP, excluding the MSDU or A-MSDU of the present frame.

The AP Buffered Load subfield is used to indicate the total buffer size, rounded up to the nearest multiple of 4096 octets and expressed in units of 4096 octets, of all MSDUs and A-MSDUs buffered at the QoS AP (excluding the MSDU or A-MSDU of the present QoS Data frame). An AP Buffered Load field set to 15 indicates that the buffer size is greater than 57 344 octets. An AP Buffered Load subfield set to 0 is used solely to indicate the absence of any buffered traffic for the indicated highest priority buffered AC when the Buffer State Indicated bit is 1.

When the Buffered State Indicated subfield is equal to 0, the Highest Priority Buffered AC subfield and the AP Buffered Load subfield are reserved.

#### 9.2.4.5.9 A-MSDU Present subfield

The A-MSDU Present subfield indicates the presence of an A-MSDU. The A-MSDU Present subfield is set to 1 to indicate that the Frame Body field contains an entire A-MSDU as defined in 9.3.2.2 (Aggregate MSDU (A-MSDU) format). The A-MSDU Present subfield is set to 0 to indicate that the Frame Body field contains an MSDU or fragment thereof as defined in 9.3.2.1 (Format of Data frames).

NOTE—A DMG STA, when the A-MSDU Present subfield is set to 1, can use one of two A-MSDU formats in the Frame Body. The specific A-MSDU format present is indicated by the A-MSDU Type subfield.

#### 9.2.4.5.10 Mesh Control Present subfield

The Mesh Control Present subfield indicates the presence of a Mesh Control field in the frame body. When the Mesh Control Present subfield is 1, the Frame Body field contains a Mesh Control field as defined in 9.2.4.8.3 (Mesh Control field). The mesh STA sets the Mesh Control Present subfield to 1 in the mesh Data frame containing an unfragmented MSDU, an A-MSDU, or the first fragment of an MSDU.

#### 9.2.4.5.11 Mesh Power Save Level subfield

The Mesh Power Save Level subfield indicates whether the mesh STA's peer-specific mesh power management mode will be deep sleep mode or light sleep mode after the successful completion of the frame exchange sequence.

When the Power Management subfield in the Frame Control field in the frame is 1, the following applies:

In individually addressed mesh Data frames, the Mesh Power Save Level subfield is set to of 0 to indicate that the mesh STA's peer-specific mesh power management mode for the recipient mesh STA will be light sleep mode (see 14.15.8.4 (Operation in light sleep mode for a mesh peering)). In individually addressed mesh Data frames, the Mesh Power Save Level subfield is set to 1 to indicate that the mesh STA's peer-specific mesh power management mode for the recipient mesh STA will be deep sleep mode (see 14.15.8.5 (Operation in deep sleep mode for a mesh peering)).

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In group addressed mesh Data frames, the Mesh Power Save Level subfield is set to 0 to indicate that none of the peer-specific mesh power management modes of the mesh STA are(M118) deep sleep mode. In group addressed mesh Data frames, the Mesh Power Save Level subfield is set to 1 to indicate that at least one of the peer-specific mesh power management modes of the mesh STA is deep sleep mode.

The Mesh Power Save Level subfield is reserved if the Power Management subfield in the Frame Control field is 0.

#### 9.2.4.5.12 Receiver Service Period Initiated (RSPI) subfield

The Receiver Service Period Initiated (RSPI) subfield is set to 0 to indicate that the mesh peer service period, of which the receiver of this frame is the owner, is not initiated. The subfield is set to 1 to indicate that the mesh peer service period, of which the receiver of this frame is the owner, is initiated. The use of the RSPI subfield is described in 14.15.9.2 (Initiation of a mesh peer service period). The RSPI subfield is reserved in group addressed frames.

#### 9.2.4.5.13 A-MSDU Type subfield

The A-MSDU Type subfield indicates the type of A-MSDU present in the Frame Body field. When the A-MSDU Type subfield is set to 0, the Frame Body field contains a Basic A-MSDU as defined in 9.3.2.2.2 (Basic A-MSDU subframe format). When the A-MSDU Type subfield is set to 1, the Frame Body field contains a Short A-MSDU as defined in 9.3.2.2.4 (Short A-MSDU subframe format). The A-MSDU Type subfield is reserved if the A-MSDU Present subfield is set to 0.

#### 9.2.4.5.14 RDG/More PPDU subfield

The RDG/More PPDU subfield of the QoS Control field for DMG frames is interpreted differently depending on whether it is transmitted by a reverse direction (RD) initiator or an RD responder, as defined in Table 9-17 (RDG/More PPDU subfield values).

#### 9.2.4.5.15 AC Constraint subfield

The AC Constraint subfield of the QoS Control field for DMG frames indicates whether the mapped AC of an RD Data frame is constrained to a single AC, as defined in Table 9-16 (AC Constraint subfield values).

#### 9.2.4.5.16 Buffered AC subfield

The Buffered AC subfield (#4162)indicates buffered traffic for four ACs as defined in Figure 9-11 (Buffered AC subfield format). At least one BU for the indicated AC is buffered if the related subfield is 1. The Buffered AC subfield is reserved except in QoS Data frames and QoS Null frames. A non-AP and non-PCP STA can use information contained in the Buffered AC subfield to determine the ACs for which BU are buffered for it.

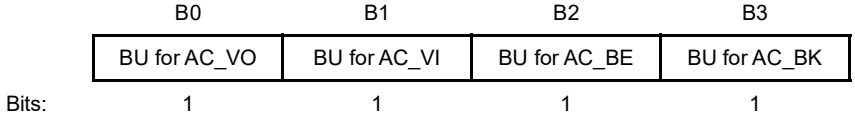


**Figure 9-11—Buffered AC subfield format**


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### 9.2.4.6 HT Control field

#### 9.2.4.6.1 General

The HT Control field is always present in a Control Wrapper frame and is present in QoS Data, (11ax)QoS Null, and Management frames as determined by the +HTC subfield of the Frame Control field as defined in 9.2.4.1.10 (+HTC subfield).

NOTE 1—The only control frame subtype for which HT Control field is present is the Control Wrapper frame. A Control frame that is described as +HTC (e.g., an RTS+HTC, CTS+HTC, BlockAck+HTC or BlockAckReq+HTC frame) implies the use of the Control Wrapper frame to carry that Control frame.

The format of the HT Control field transmitted by a non-CMMG STA is shown defined in Table 9-15 (HT Control field format(11ax)).(11ax)

**Table 9-15—HT Control field format(11ax)**

| Variant | B0 | B1 | B2–B29 | B30 | B31 |
|---|---|---|---|---|---|
| HT | 0 | HT Control Middle | | AC Constraint | RDG/More PPDU |
| VHT | 1 | 0 | VHT Control Middle | AC Constraint | RDG/More PPDU |
| HE | 1 | 1 | A-Control | | |

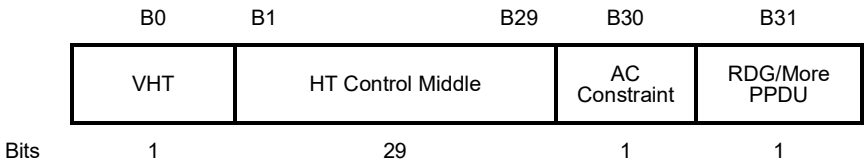


**Figure 9-12—Non-CMMG variant HT Control field format**

(11ax)The HT Control field transmitted by a non-CMMG STA has three variants: the HT variant, the VHT variant, and the HE variant. The variant formats are differentiated by the values of B0 and B1 as defined in Table 9-15 (HT Control field format(11ax)).

(11ax)The HT Control Middle subfield is defined in 9.2.4.6.2 (HT variant), and the VHT Control Middle subfield is defined in 9.2.4.6.3 (VHT variant). The A-Control subfield is defined in 9.2.4.6.4 (HE variant(11ax)).

The HT Control field transmitted by a CMMG STA has one form, the CMMG variant HT Control. The format of the HT Control field transmitted by a CMMG STA is shown in Figure 9-23 (CMMG variant HT Control field format).

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The AC Constraint subfield of the HT Control field indicates whether the mapped AC of an RD Data frame is constrained to a single AC, as defined in Table 9-16 (AC Constraint subfield values).

**Table 9-16—AC Constraint subfield values**

| Value | Description |
|---|---|
| 0 | The response to a reverse direction grant (RDG) contains Data frames from any TID; see 10.29.4 (Rules for RD responder). |
| 1 | The response to an RDG contains Data frames only from the same AC as the last Data frame received from the RD initiator; see 10.29.4 (Rules for RD responder). |

NOTE 2—The AC of the last Data frame received from the RD initiator is determined directly from the TID of the received frame if the TID is between 0 and 7 or from the UP field of the TSPEC identified by the TID of the received frame if the TID is between 8 and 15.

The RDG/More PPDU subfield of the HT Control field is interpreted differently depending on whether it is transmitted by an RD initiator or an RD responder, as defined in Table 9-17 (RDG/More PPDU subfield values).

**Table 9-17—RDG/More PPDU subfield values**

| Value | Role of transmitting STA | Interpretation of value |
|---|---|---|
| 0 | Not an RD responder | No reverse grant |
| | RD responder | The PPDU carrying the frame is the last transmission by the RD responder |
| 1 | RD initiator | An RDG is present |
| | RD responder | The PPDU carrying the frame is followed by another PPDU |

### 9.2.4.6.2 HT variant

The format of the HT Control Middle subfield of the HT variant HT Control field is shown in Figure 9-13 (HT Control Middle subfield of the HT variant HT Control field format).

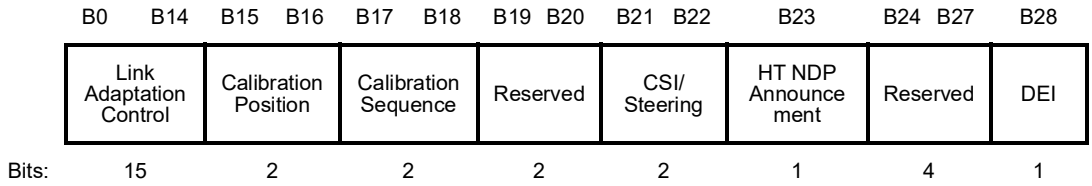


**Figure 9-13—HT Control Middle subfield of the HT variant HT Control field format**


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The format of the Link Adaptation Control subfield of the HT variant HT Control field is defined in Figure 9-14 (Link Adaptation Control subfield format).

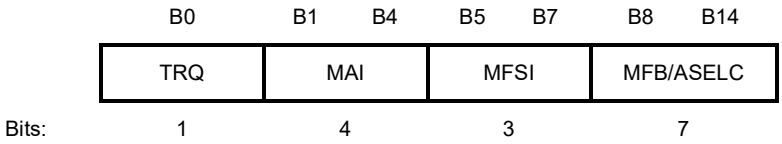


**Figure 9-14—Link Adaptation Control subfield format**

The subfields of the Link Adaptation Control subfield are defined in Table 9-18 (Subfields of Link Adaptation Control subfield).

**Table 9-18—Subfields of Link Adaptation Control subfield**

| Subfield | Meaning | Definition |
|---|---|---|
| TRQ | Training request | Set to 1 to request the responder to transmit a sounding PPDU.<br>Set to 0 to indicate that the responder is not requested to transmit a sounding PPDU.<br>See 10.33.2 (HT transmit beamforming with implicit feedback) and 10.35.2 (Transmission of an HT NDP). |
| MAI | MCS request (MRQ) or ASEL indication | Set to 14 (indicating ASELI) to indicate that the MFB/ASELC subfield is interpreted as ASELC. Otherwise, the MAI subfield is interpreted as shown in Figure 9-15 (MAI subfield format), and the MFB/ASELC subfield is interpreted as MCS feedback (MFB). |
| MFSI | MCS feedback sequence identifier | Set to the received value of MSI contained in the frame to which the MFB information refers.<br>Set to 7 for unsolicited MFB. |
| MFB/ASELC | MCS feedback and antenna selection command/data | When the MAI subfield is equal to the value ASELI, this subfield is interpreted as defined in Figure 9-16 (ASELC subfield format) and Table 9-20 (ASEL Command and ASEL Data subfields).<br><br>Otherwise, this subfield contains recommended MFB.<br>Set to 127 to indicate that no feedback is present. |

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(#4076)The structure of the MAI subfield of the Link Adaptation Control subfield is defined in Figure 9-15 (MAI subfield format). The subfields of the MAI subfield are defined in Table 9-19 (Subfields of the MAI subfield).

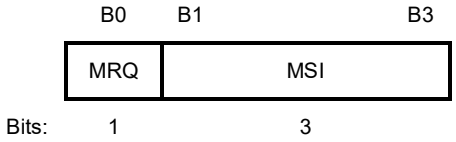


**Figure 9-15—MAI subfield format**

**Table 9-19—Subfields of the MAI subfield**

| Subfield | Meaning | Definition |
|---|---|---|
| MRQ | MCS request | Set to 1 to indicate that MFB is requested.<br>Set to 0 to indicate that no MFB is requested. |
| MSI | MRQ sequence identifier | When the MRQ subfield is equal to 1, the MSI subfield contains a sequence number in the range 0 to 6 that identifies the specific request.<br>When the MRQ subfield is equal to 0, the MSI subfield is reserved. |

The ASELC subfield of the Link Adaptation Control subfield contains the ASEL Command and ASEL Data subfields, as shown in Figure 9-16 (ASELC subfield format). The encoding of these subfields is shown in Table 9-20 (ASEL Command and ASEL Data subfields).

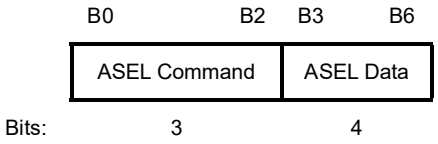


**Figure 9-16—ASELC subfield format**

**Table 9-20—ASEL Command and ASEL Data subfields**

| ASEL Command | Interpretation of ASEL Command | ASEL Data |
|---|---|---|
| 0 | Transmit Antenna Selection Sounding Indication (TXASSI) | Number of remaining sounding PPDUs to be transmitted<br><br>See NOTE |
| 1 | Transmit Antenna Selection Sounding Request (TXASSR) or Transmit ASEL Sounding Resumption | 0 when the command is Transmit ASEL Sounding Request<br>A number in the range 1 to 15, the number being the number of the first sounding PPDU to be transmitted when the command is Transmit ASEL Sounding Resumption, where 0 corresponds to the first sounding PPDU in the original ASEL training sequence |
| 2 | Receive Antenna Selection Sounding Indication (RXASSI) | Number of remaining sounding PPDUs to be received<br><br>See NOTE |
| 3 | Receive Antenna Selection Sounding Request (RXASSR) | Number of sounding PPDUs required |


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**Table 9-20—ASEL Command and ASEL Data subfields *(continued)***

| ASEL Command | Interpretation of ASEL Command | ASEL Data |
|---|---|---|
| 4 | Sounding Label | Sequence number of the sounding PPDU corresponding to a channel state information (CSI) frame in ASEL feedback |
| 5 | No Feedback Due to ASEL Training Failure or Stale Feedback | The number of the first sounding PPDU that was not received properly, where 0 corresponds to the first sounding PPDU in the ASEL training sequence, or 0 if no sounding PPDUs were received properly, or 0 if this is a request for a full retraining sequence |
| 6 | Transmit Antenna Selection Sounding Indication requesting feedback of explicit CSI (TXASSI-CSI) | Number of remaining sounding PPDUs to be transmitted<br><br>See NOTE |
| 7 | Reserved | Reserved |
| NOTE—If the HT variant HT Control field is carried in a sounding PPDU, then the ASEL Data field contains the remaining number of sounding frames following the current one. If null data PPDU (NDP) sounding PPDU(#3280) is used, then the ASEL Data field contains the number of NDPs following a non-NDP+HTC. The HT NDP Announcement subfield in the HT Control field is set to 1 to indicate NDP sounding. | | |

The Calibration Position and Calibration Sequence subfields of the HT variant HT Control field are defined in Table 9-21 (Calibration control subfields).

**Table 9-21—Calibration control subfields**

| Subfield | Meaning | Definition |
|---|---|---|
| Calibration Position | Position in calibration sounding frame exchange sequence(#109) | Set to 0 indicates this is not a calibration frame.<br>Set to 1 indicates calibration start.<br>Set to 2 indicates sounding response.<br>Set to 3 indicates sounding complete. |
| Calibration Sequence | Calibration sequence identifier | The field is included in each frame within the calibration procedure and its value is unchanged for the frame exchanges during one calibration procedure.<br>See 10.33.2.4.3 (Sounding exchange for calibration). |

The Calibration Sequence subfield identifies an instance of the calibration procedure. The subfield is included in each frame within a calibration procedure, and its value is unchanged for frames within the same calibration procedure.

The CSI/Steering subfield of the HT variant HT Control field indicates the type of feedback, as shown in Table 9-22 (CSI/Steering subfield values).

**Table 9-22—CSI/Steering subfield values**

| Value | Definition |
|---|---|
| 0 | No feedback required |

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**Table 9-22—CSI/Steering subfield values**

| | |
|---|---|
| 1 | CSI |
| 2 | Noncompressed beamforming |
| 3 | Compressed beamforming |

The HT NDP Announcement subfield of the HT variant HT Control field indicates that an NDP will be transmitted after the frame (according to the rules described in 10.35 (Null data PPDU (NDP) sounding)). It is set to 1 to indicate that an NDP will follow; otherwise, it is set to 0.

The DEI subfield of the HT Control field is set by the transmitting STA to indicate the suitability of the corresponding MSDU or A-MSDU to be discarded if there are insufficient resources at the receiving STA, per the value of the drop eligible parameter in the MA-UNITDATA.request. See 10.8 (HT Control field operation) and 11.25.2 (SCS procedures). In a Management frame, the DEI subfield is reserved.

### 9.2.4.6.3 VHT variant

In a non-S1G STA, the format of the (11ax)VHT Control Middle subfield of the VHT variant HT Control field is shown in Figure 9-17 (HT Control Middle subfield of the VHT variant HT Control field format(11ax)(#6022)).

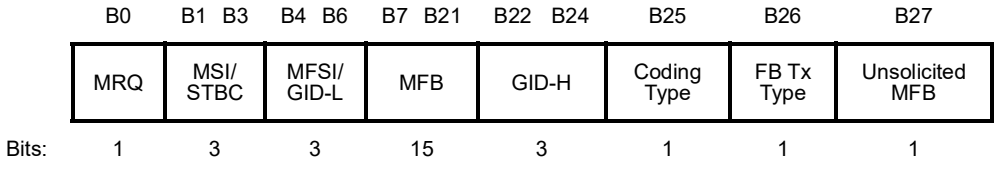


**Figure 9-17—HT Control Middle subfield of the VHT variant HT Control field format(11ax)(#6022)**


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The subfields of VHT variant HT Control field are defined in Table 9-23 (VHT variant HT Control field subfields).

**Table 9-23—VHT variant HT Control field subfields**

| Subfield | Meaning | Definition |
|---|---|---|
| MRQ | VHT-MCS feedback request | Set to 1 to request VHT-MCS feedback (solicited MFB); otherwise, set to 0. |
| MSI/STBC | MRQ sequence identifier/STBC indication | If the Unsolicited MFB subfield is 0 and the MRQ subfield is 1, the MSI/STBC subfield contains a sequence number in the range 0 to 6 that identifies the specific MCS feedback request.<br>If the Unsolicited MFB subfield is 0 and the MRQ subfield is 0, the MSI/STBC subfield is reserved.<br>If the Unsolicited MFB subfield is 1 and the MFB does not contain the value representing "no feedback is present," the MSI/STBC field contains the Compressed MSI and STBC Indication subfields as shown in Figure 9-18 (MSI/STBC subfield format when the Unsolicited MFB subfield is 1).<br>The STBC Indication subfield indicates whether the estimate in the MFB subfield is computed based on a PPDU using STBC encoding:<br>Set to 0 if the PPDU was not STBC encoded<br>Set to 1 if the PPDU was STBC encoded<br>The Compressed MSI subfield contains a sequence number that identifies the specific MCS feedback request. It is in the range 0 to 3 if STBC Indication equals 0 or in the range 0 to 2 if STBC Indication equals 1.<br>Otherwise, the MSI/STBC subfield is reserved. |
| MFSI/GID-L | MFB sequence identifier/LSBs of group ID | If the Unsolicited MFB subfield is 0, the MFSI/GID-L subfield contains the received value of MSI contained in the frame to which the MFB information refers.<br>If the Unsolicited MFB subfield is 1, the MFB does not contain the value representing "no feedback is present," and the MFB is estimated from a VHT MU PPDU, then the MFSI/GID-L subfield contains the lowest 3 bits of group ID of that PPDU from which the MFB was estimated (bit 0 of the group ID appears in the lowest numbered bit of the field MFSI/GID-L). If the unsolicited MFB is estimated from an SU PPDU, the MFSI/GID-L subfield is set to all 1s.<br>Otherwise, this subfield is reserved. |
| MFB | NUM_STS, VHT-MCS, BW and SNR feedback | MFB subfield is interpreted as defined in Table 9-24 (MFB subfield in the VHT variant HT Control field). This subfield contains the recommended MFB. The combination of VHT-MCS=15 and NUM_STS=7 indicates that no feedback is present. |
| GID-H | MSBs of group ID | If the Unsolicited MFB subfield is 1, the MFB does not contain the value representing "no feedback is present," and the unsolicited MFB is estimated from a VHT MU PPDU, then the GID-H subfield contains the highest 3 bits of group ID of the PPDU from which the unsolicited MFB was estimated (bit 3 of the group ID appears in the lowest numbered bit of the field GID-H). If the unsolicited MFB is estimated from an SU PPDU, the GID-H subfield is set to all 1s.<br>Otherwise, this subfield is reserved. |

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**Table 9-23—VHT variant HT Control field subfields *(continued)***

| Subfield | Meaning | Definition |
|---|---|---|
| Coding Type | Coding type of the measured PPDU | If the Unsolicited MFB subfield is 1 and the MFB does not contain the value representing "no feedback is present," the Coding Type subfield contains the Coding information (0 for BCC and 1 for LDPC) of the PPDU from which the unsolicited MFB was estimated.<br>Otherwise, this subfield is reserved. |
| FB Tx Type | Transmission type of the measured PPDU | If the Unsolicited MFB subfield is 1, the MFB does not contain the value representing "no feedback is present," and FB Tx Type subfield is 0, then the unsolicited MFB is estimated from a VHT PPDU with the RXVECTOR parameter BEAMFORMED equal to 0.<br><br>If the Unsolicited MFB subfield is 1, the MFB does not contain the value representing "no feedback is present," and the FB Tx Type subfield is 1, then the unsolicited MFB is estimated from a VHT PPDU with the RXVECTOR parameter BEAMFORMED equal to 1.<br><br>Otherwise, this subfield is reserved. |
| Unsolicited MFB | Unsolicited VHT-MCS feedback indicator | Set to 1 if the MFB is not a response to an MRQ.<br>Set to 0 if the MFB is a response to an MRQ. |

The format of the MSI/STBC subfield when the Unsolicited subfield is 1 is shown in Figure 9-18 (MSI/STBC subfield format when the Unsolicited MFB subfield is 1).

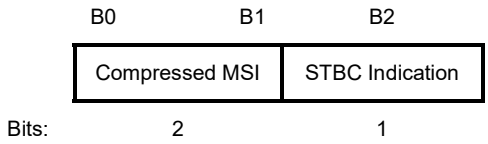


**Figure 9-18—MSI/STBC subfield format when the Unsolicited MFB subfield is 1**

The format of the MFB subfield in the VHT variant HT Control field is shown in Figure 9-19 (MFB subfield format in the VHT variant HT Control field).

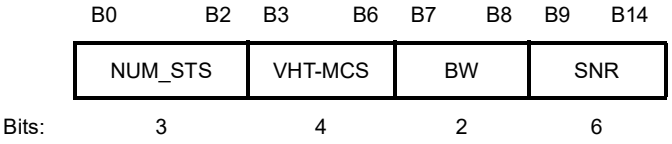


**Figure 9-19—MFB subfield format in the VHT variant HT Control field**


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In an S1G STA, the format of the MFB subfield in the VHT variant HT Control field is shown in Figure 9-20 (MFB subfield format in the VHT variant HT Control field when carried in S1G PPDU).

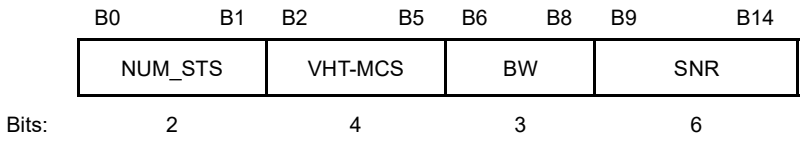


**Figure 9-20—MFB subfield format in the VHT variant HT Control field when carried in S1G PPDU**

The subfields of the MFB subfield in the VHT variant HT Control field are defined in Table 9-24 (MFB subfield in the VHT variant HT Control field).

**Table 9-24—MFB subfield in the VHT variant HT Control field**

| Subfield | Meaning | Definition |
|---|---|---|
| NUM_STS | Recommended NUM_STS | Indicates the recommended NUM_STS as defined in 10.31.3 (Link adaptation using the VHT variant HT Control field).<br>The NUM_STS subfield contains an unsigned integer representing the number of space-time streams minus 1. |
| VHT-MCS | Recommended VHT-MCS | Indicates the recommended VHT-MCS as defined in 10.31.3 (Link adaptation using the VHT variant HT Control field).<br>The VHT-MCS subfield contains an unsigned integer in the range 0 to 9 representing a VHT-MCS Index value (defined in 21.5 (Parameters for VHT-MCSs)). |

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**Table 9-24—MFB subfield in the VHT variant HT Control field *(continued)***

| | | |
|---|---|---|
| BW | Bandwidth of the recommended VHT-MCS or S1G-MCS | If the Unsolicited MFB subfield is 1, the BW subfield indicates the bandwidth for which the recommended VHT-MCS or S1G-MCS is intended, as defined in 10.31.3 (Link adaptation using the VHT variant HT Control field):<br><br>For a VHT STA:<br>Set to 0 for 20 MHz<br>Set to 1 for 40 MHz<br>Set to 2 for 80 MHz<br>Set to 3 for 160 MHz and 80+80 MHz.<br><br>For a TVHT STA:<br>Set to 0 for TVHT_W<br>Set to 1 for TVHT_2W and TVHT_W+W<br>Set to 2 for TVHT_4W and TVHT_2W+2W<br>The value 3 is reserved.<br><br>In an S1G STA:<br>Set to 0 for 1 MHz<br>Set to 1 for 2 MHz<br>Set to 2 for 4 MHz<br>Set to 3 for 8 MHz.<br>Set to 4 for 16 MHz.<br>The values 5 to 7 are reserved.<br><br>If the Unsolicited MFB subfield is 0, the BW subfield is reserved. |
| SNR | Average SNR | Indicates the average SNR, which is an SNR averaged over data subcarriers and space-time streams.<br><br>The SNR is averaged over all of the space-time streams and data subcarriers and is encoded as a 6-bit 2s complement number of SNR_average – 22, where SNR_average is the sum of the values of SNR per frequency subcarrier (in decibels) per space-time stream divided by the product of the number of space-time streams, as indicated in the NUM_STS subfield, and the number of frequency subcarriers represented in the bandwidth in which the MFB was estimated. This encoding covers the SNR range from –10 dB to 53 dB in 1 dB steps. |

### 9.2.4.6.4 HE variant(11ax)

The format of the A-Control subfield of the HE variant HT Control field is shown in Figure 9-21 (A-Control subfield of the HE variant HT Control field format(11ax)).

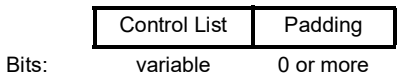


**Figure 9-21—A-Control subfield of the HE variant HT Control field format(11ax)**

(#1873)The Control List subfield contains one or more Control subfields. The format of each Control subfield is shown in Figure 9-22 (Control subfield format(11ax)).

The Control ID subfield indicates the type of information carried in the Control Information subfield. The length of the Control Information subfield is fixed for each value of the Control ID subfield that is not


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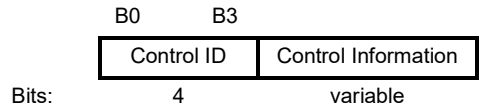


**Figure 9-22—Control subfield format(11ax)**

reserved. The values of the Control ID subfield and the associated length of the Control Information subfield are defined in Table 9-25 (Control ID subfield values(11ax)).

**Table 9-25—Control ID subfield values(11ax)**

| Control ID value | Meaning | Length of the Control Information subfield (bits) | Content of the Control Information subfield |
|---|---|---|---|
| 0 | Triggered response scheduling (TRS) | 26 | See 9.2.4.7.1 (TRS Control). |
| 1 | Operating mode (OM) | 12 | See 9.2.4.7.2 (OM Control). |
| 2 | HE link adaptation (HLA) | 26 | See 9.2.4.7.3 (HLA Control). |
| 3 | Buffer status report (BSR) | 26 | See 9.2.4.7.4 (BSR Control). |
| 4 | UL power headroom (UPH) | 8 | See 9.2.4.7.5 (UPH Control). |
| 5 | Bandwidth query report (BQR) | 10 | See 9.2.4.7.6 (BQR Control). |
| 6 | Command and status (CAS) | 8 | See 9.2.4.7.7 (CAS Control). |
| 7–14 | Reserved | | |
| 15 | Ones need expansion surely (ONES) | 26 | Set to all 1s. |

The Padding subfield, if present, follows the last Control subfield and is set to a sequence of 0s(M118) so that the length of the A-Control subfield carried in the HT Control field is 30 bits.

### 9.2.4.6.5 CMMG variant HT Control field

The format of the CMMG variant HT Control field is shown in Figure 9-23 (CMMG variant HT Control field format).

The link adaptation related subfields including the first six subfields are defined in Table 9-26 (Subfields corresponding to link adaptation).

The format of the MFB subfield in the CMMG variant HT Control field is shown in Figure 9-24 (MFB subfield in the CMMG variant HT Control field format(#1729)).

The subfields of the MFB subfield in the CMMG variant HT Control field are defined in Table 9-27 (MFB subfield in the CMMG variant HT Control field).

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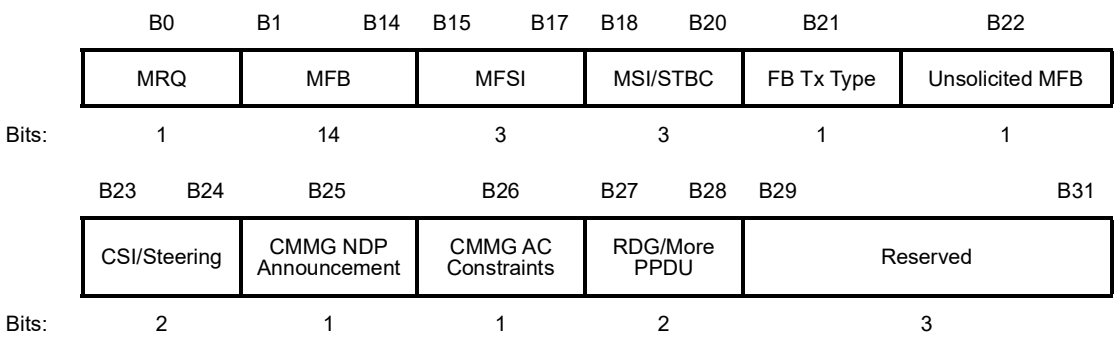


**Figure 9-23—CMMG variant HT Control field format**

**Table 9-26—Subfields corresponding to link adaptation**

| Subfield | Meaning | Definition |
|---|---|---|
| MRQ | CMMG-MCS Feedback request | Set to 1 to request CMMG-MCS feedback (solicited MFB); otherwise, set to 0. |
| MFB | NUM_STS, CMMG-MCS, BW and SNR feedback | MFB subfield is interpreted as defined in Table 9-27 (MFB subfield in the CMMG variant HT Control field). This subfield contains the recommended MFB. The combination of CMMG-MCS=31 and NUM_STS=3 indicates that no feedback is present. |
| MFSI | MFB sequence identifier | Set to the received value of MSI contained in the frame to which the MFB information refers. Set to 7 for unsolicited MFB. |
| MSI/STBC | MSI/STBC | If the Unsolicited MFB subfield is 0 and the MRQ subfield is 1, the MSI/STBC subfield contains a sequence number in the range 0 to 6 that identifies the specific MCS feedback request.<br>If the Unsolicited MFB subfield is 0 and the MRQ subfield is 0, the MSI/STBC subfield is reserved.<br>If the Unsolicited MFB subfield is 1 and the MFB does not contain the value representing "no feedback is present," the MSI/STBC field contains the Compressed MSI and STBC Indication subfields as shown in Figure 9-25 (MSI/STBC subfield format when the Unsolicited MFB subfield is 1).<br>The STBC Indication subfield indicates whether the estimate in the MFB subfield is computed based on a PPDU using STBC encoding:<br>Set to 0 if the PPDU was not STBC encoded.<br>Set to 1 if the PPDU was STBC encoded.<br>The Compressed MSI subfield contains a sequence number that identifies the specific MCS feedback request. It is in the range 0 to 3 if STBC Indication equals 0 or in the range 0 to 2 if STBC Indication equals 1.<br>Otherwise, the MSI/STBC subfield is reserved. |
| FB Tx Type | Transmission type of the measured PPDU | If the Unsolicited MFB subfield is 1 and FB Tx Type subfield is 0, then the unsolicited MFB is estimated from a CMMG PPDU with the RXVECTOR parameter BEAMFORMED equal to 0.<br>If the Unsolicited MFB subfield is 1, the MFB does not contain the value representing "no feedback is present," and the FB Tx Type subfield is 1, then the unsolicited MFB is estimated from a CMMG PPDU with the RXVECTOR parameter BEAMFORMED equal to 1.<br>Otherwise, this subfield is reserved. |
| Unsolicited MFB | Unsolicited CMMG-MCS feedback indicator | Set to 1 if the MFB is not a response to an MRQ.<br>Set to 0 if the MFB is a response to an MRQ. |


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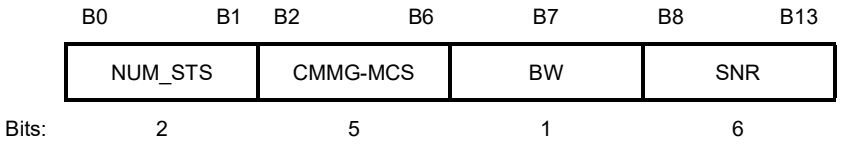


**Figure 9-24—MFB subfield in the CMMG variant HT Control field format(#1729)**

**Table 9-27—MFB subfield in the CMMG variant HT Control field**

| Subfield | Meaning | Definition |
|---|---|---|
| NUM_STS | Recommended NUM_STS | Indicates the recommended NUM_STS as defined in(#3263) 10.31.4 (Link adaptation using the CMMG variant HT Control field). The NUM_STS subfield contains an unsigned integer representing the number of space-time streams minus 1. |
| CMMG-MCS | Recommended CMMG-MCS | Indicates the recommended CMMG-MCS as defined in(#3263) 10.31.4 (Link adaptation using the CMMG variant HT Control field).<br>The CMMG-MCS subfield contains an unsigned integer representing a CMMG-MCS Index value (defined in 25.15 (Parameters for CMMG-MCSs)). |
| BW | Bandwidth of the recommended CMMG-MCS | If the Unsolicited MFB subfield is 1, the BW subfield indicates the bandwidth for which the recommended CMMG-MCS is intended, as defined in (#3263) 10.31.4 (Link adaptation using the CMMG variant HT Control field):<br>Set to 0 for 540 MHz.<br>Set to 1 for 1080 MHz.<br>If the Unsolicited MFB subfield is 0, the BW subfield is reserved. |
| SNR | Average SNR | The SNR subfield of the MFB subfield in the CMMG variant HT Control field is defined in Table 9-24 (MFB subfield in the VHT variant HT Control field). |

The format of the MSI/STBC subfield when the Unsolicited MFB subfield is 1 is shown in Figure 9-25 (MSI/STBC subfield format when the Unsolicited MFB subfield is 1).

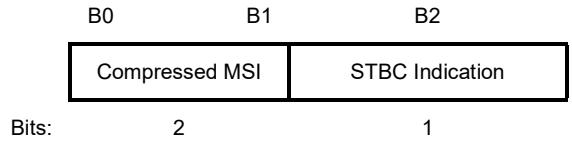


**Figure 9-25—MSI/STBC subfield format when the Unsolicited MFB subfield is 1**

The CSI/Steering subfield of the CMMG variant HT Control field is defined in Table 9-22 (CSI/Steering subfield values).

(#1989)(#177)(#6024)The CMMG NDP Announcement subfield of the CMMG variant HT Control field is set to 1 to indicate that a CMMG NDP frame will follow (according to the rules described in 10.36.1 (NDP rules)); otherwise, it is set to 0.

The CMMG AC Constraint subfield of the CMMG variant HT Control field is the same as defined in Table 9-16 (AC Constraint subfield values).

The RDG/More PPDU subfield of the CMMG variant HT Control field is defined in Table 9-17 (RDG/More PPDU subfield values).

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### 9.2.4.7 Control subfield variants of an A-Control subfield(11ax)

#### 9.2.4.7.1 TRS Control

The Control Information subfield in a TRS Control subfield contains triggered response scheduling (TRS) information for soliciting an HE TB PPDU that follows an HE MU PPDU, HE SU PPDU, or HE ER SU PPDU carrying the Control subfield (see 26.5.2.2 (Rules for soliciting UL MU frames)). See 26.5.2.4 (A-MPDU contents in an HE TB PPDU) for details on allowed content in an A-MPDU carried in an HE TB PPDU. The format of the subfield is shown in Figure 9-26 (Control Information subfield format in a TRS Control subfield(11ax)).

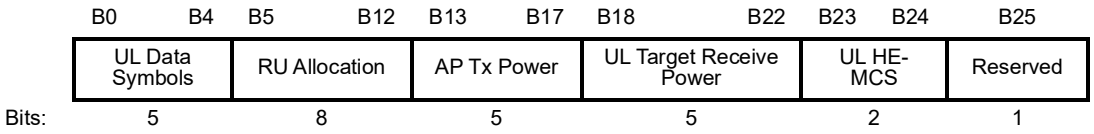


**Figure 9-26—Control Information subfield format in a TRS Control subfield(11ax)**

NOTE—A TRS Control subfield is not included in a non-HE PPDU.

The UL Data Symbols subfield indicates the number of OFDM symbols in the Data field of the HE TB PPDU response and is set to the number of OFDM symbols minus 1.

The RU Allocation subfield indicates the resource unit (RU) assigned for transmitting the HE TB PPDU response and the encoding is defined in 9.3.1.22.1 (General).

The AP Tx Power subfield indicates the AP's combined transmit power at the transmit antenna connector of all the antennas used to transmit the triggering PPDU in units of dBm/20 MHz. The transmit power in dBm/20 MHz, $P_{TX}$, is calculated as $P_{TX} = -20 + 2 \times F_{Val}$, where $F_{Val}$ is the value of the AP Tx Power subfield, except for the value 31, which is reserved.

The UL Target Receive Power subfield indicates the expected receive signal power, measured at the AP's antenna connector and averaged over the antennas, for the HE portion of the HE TB PPDU transmitted on the assigned RU as defined in Table 9-28 (UL Target Receive Power subfield in TRS Control field(11ax)).

**Table 9-28—UL Target Receive Power subfield in TRS Control field(11ax)**

| UL Target Receive Power subfield | Description |
|---|---|
| 0–30 | The expected receive signal power, in units of dBm, is $Target_{pwr} = -90 + 2 \times F_{val}$, where $F_{val}$ is the subfield value |
| 31 | The STA transmits the HE TB PPDU at the STA's maximum transmit power for the assigned HE-MCS.<br><br>NOTE—The expected receive signal power is then the STA's maximum transmit power for the assigned HE-MCS minus the path loss. |

(M118)The UL HE-MCS subfield indicates the HE-MCS, in the range HE-MCS 0 to 3, to be used by the receiving STA for the HE TB PPDU is set to the HE-MCS index (see 27.5 (Parameters for HE-MCSs)).


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#### 9.2.4.7.2 OM Control

The Control Information subfield in an OM Control subfield contains information related to the operating mode (OM) change of the STA transmitting the frame containing this information (see 26.9 (Operating mode indication)). The format of the subfield is shown in Figure 9-27 (Control Information subfield format in an OM Control subfield(11ax)).

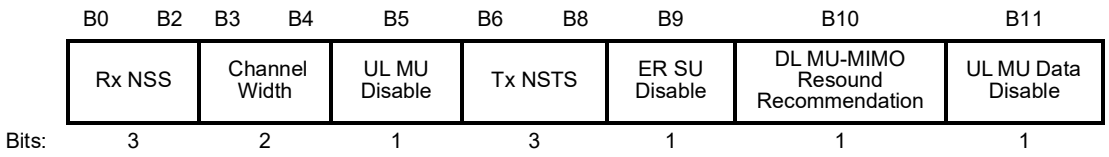


**Figure 9-27—Control Information subfield format in an OM Control subfield(11ax)**

If the operating channel width of the STA is greater than 80 MHz, then the Rx NSS subfield indicates the maximum number of spatial streams, $N_{SS}$, that the STA supports in reception for PPDU bandwidths less than or equal to 80 MHz and is set to $N_{SS} - 1$. If the operating channel width of the STA is less than or equal to 80 MHz, then the Rx NSS subfield indicates the maximum number of spatial streams, $N_{SS}$, that the STA supports in reception and is set to $N_{SS} - 1$.

If the operating channel width of the STA is greater than 80 MHz, then the maximum number of spatial streams that the STA supports in reception for PPDU bandwidths greater than 80 MHz is defined in 26.9 (Operating mode indication).

The Channel Width subfield indicates the operating channel width supported by the STA for both reception and transmission. It is set to 0 for 20 MHz, 1 for primary 40 MHz, 2 for primary 80 MHz, and 3 for 160 MHz and 80+80 MHz. The value 0 indicates a primary 20 MHz, unless the STA is an HE SST STA in which case it indicates any of the negotiated 20 MHz subchannels of the SST operation (see 26.8.7 (HE subchannel selective transmission)).

The allowed UL MU operations and frame types that can be transmitted as a response to a triggering frame are determined by the UL MU Disable subfield, UL MU Data Disable subfield and the recipient's setting of the OM Control UL MU Data Disable RX Support subfield in the HE Capabilities element, as indicated in Table 9-29 (UL MU Disable and UL MU Data Disable subfields encoding(11ax)).

If the OM Control field is transmitted by an HE AP, then the UL MU Disable and UL MU Data Disable subfields are reserved.

A non-AP STA sets the Tx NSTS subfield to $N_{STS} - 1$, where $N_{STS}$ is the maximum number of space-time streams that the non-AP STA supports in transmission. If the OM Control field is transmitted by an HE AP, then the Tx NSTS subfield is reserved.

A non-AP HE STA sets the ER SU Disable subfield to 1 to indicate that 242-tone HE ER SU PPDU reception is disabled and to 0 to indicate that 242-tone HE ER SU PPDU reception is enabled. If the OM Control field is transmitted by an HE AP, then the ER SU Disable subfield is reserved.

A non-AP HE STA sets the DL MU-MIMO Resound Recommendation subfield to 1 to indicate that the STA suggests that the AP either resound the channel or increase the channel sounding frequency with the STA. The subfield is set to 0 to indicate that the non-AP HE STA has no recommendation on the AP channel sounding frequency. If the OM Control field is transmitted by an HE AP, then the DL MU-MIMO Resound Recommendation subfield is reserved.

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**Table 9-29—UL MU Disable and UL MU Data Disable subfields encoding(11ax)**

| UL MU Disable subfield | UL MU Data Disable subfield | Interpretation by an AP that transmits a value of 0 in the OM Control UL MU Data Disable RX Support | Interpretation by an AP that transmits a value of 1 in the OM Control UL MU Data Disable RX Support |
|---|---|---|---|
| 0 | 0 | All trigger based UL MU transmissions are enabled by the STA as defined in 26.5.2 (UL MU operation). | All trigger based UL MU transmissions are enabled by the STA as defined in 26.5.2 (UL MU operation). |
| 0 | 1 | N/A | Trigger based UL MU Data frame transmissions in response to a Basic Trigger frame are suspended by the STA as defined in 26.9.3 (Transmit operating mode (TOM) indication).<br><br>Other trigger based UL MU transmissions remain enabled by the STA as defined in 26.9.3 (Transmit operating mode (TOM) indication). |
| 1 | 0 | All trigger based UL MU transmissions are suspended by the STA.<br><br>The STA will not respond to a received triggering frame. | All trigger based UL MU transmissions are suspended by the STA.<br><br>The STA will not respond to a received triggering frame. |
| 1 | 1 | Reserved | Reserved |

### 9.2.4.7.3 HLA Control

The Control Information subfield in an HLA Control subfield contains information related to the HE link adaptation (HLA) procedure (see 26.13 (Link adaptation using the HLA Control subfield)). The format of the subfield is shown in Figure 9-28 (Control Information subfield format in an HLA Control subfield(11ax)).

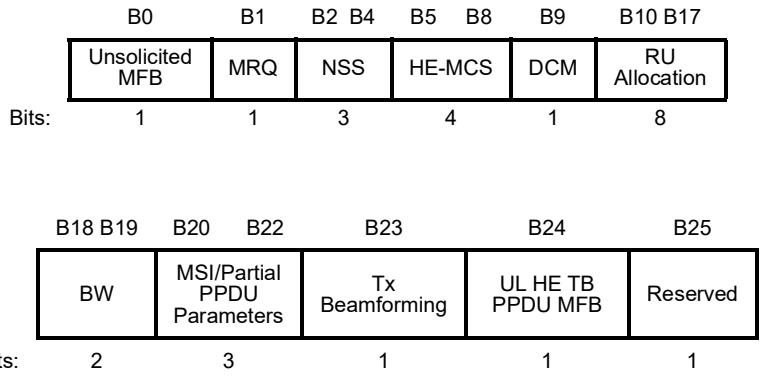


**Figure 9-28—Control Information subfield format in an HLA Control subfield(11ax)**



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The HLA Control subfields are defined in Table 9-30 (HLA Control subfields(11ax)).

**Table 9-30—HLA Control subfields(11ax)**

| Subfield | Meaning | Definition |
|---|---|---|
| Unsolicited MFB | Unsolicited MFB indicator | Set to 1 if the HLA Control is an unsolicited MFB.<br>Set to 0 if the HLA Control is an MRQ or a solicited MFB. |
| MRQ | HLA feedback request indicator | Set to 1 and set Unsolicited MFB subfield to 0 to request an HLA feedback.<br>Set to 0 and set Unsolicited MFB subfield to 0 to respond to an HLA request.<br><br>If the Unsolicited MFB subfield is 1, the MRQ subfield is reserved. |
| NSS | Recommended number of spatial stream | If the Unsolicited MFB subfield is 1 and the UL HE TB PPDU MFB subfield is 0 or if the Unsolicited MFB subfield is 0 and the MRQ subfield is 0, the NSS subfield indicates the recommended number of spatial streams to the PPDU sent to the STA, $N_{SS}$, and is set to $N_{SS} - 1$.<br><br>If the Unsolicited MFB subfield is 1 and the UL HE TB PPDU MFB subfield is 1, the NSS subfield indicates the recommended number of spatial streams to the HE TB PPDU sent from the STA, $N_{SS}$, and is set to $N_{SS} - 1$.<br><br>Otherwise, this subfield is reserved. |
| HE-MCS | Recommended HE-MCS | If the Unsolicited MFB subfield is 1 and the UL HE TB PPDU MFB subfield is 0 or if the Unsolicited MFB subfield is 0 and the MRQ subfield is 0, the HE-MCS subfield indicates the recommended HE-MCS of the PPDU sent to the STA, and is set to the HE-MCS index (see 27.5 (Parameters for HE-MCSs)).<br><br>If the Unsolicited MFB subfield is 1 and the UL HE TB PPDU MFB subfield is 1, the HE-MCS subfield indicates the recommended HE-MCS of the HE TB PPDU sent from the STA, and is set to the HE-MCS index (see 27.5 (Parameters for HE-MCSs)).<br><br>Otherwise, this subfield is reserved. |
| DCM | Recommended usage of dual carrier modulation (DCM) | If the Unsolicited MFB subfield is 1 and the UL HE TB PPDU MFB subfield is 0 or if the Unsolicited MFB subfield is 0 and the MRQ subfield is 0, the DCM subfield indicates the recommended usage of DCM. This subfield is set to 1 if DCM is recommended for(#1351) the PPDU sent to the STA and is set to 0 otherwise.<br><br>If the Unsolicited MFB subfield is 1 and the UL HE TB PPDU MFB subfield is 1, the DCM subfield indicates the recommended usage of DCM. This subfield is set to 1 if DCM is recommended to the HE TB PPDU sent from the STA and is set to 0 otherwise.<br><br>Otherwise, this subfield is reserved. |

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**Table 9-30—HLA Control subfields(11ax) *(continued)***

| Subfield | Meaning | Definition |
|---|---|---|
| RU Allocation | RU of the recommended HE-MCS/RU specified by MFB requester to get feedback | If the Unsolicited MFB subfield is 1 and the UL HE TB PPDU MFB subfield is 0, the RU Allocation subfield indicates the RU for which the recommended HE-MCS applies to the PPDU sent to the STA, as defined in 26.13 (Link adaptation using the HLA Control subfield).<br><br>If the Unsolicited MFB subfield is 0 and the MRQ subfield is 1, the RU subfield indicates the RU requested by the MFB requester to get feedback.<br><br>The RU Allocation subfield is interpreted with the BW subfield to specify the RU.<br><br>The RU index encoding is as defined in Table 9-53 (B7–B1 of the RU Allocation subfield(11ax)).<br><br>If the Unsolicited MFB subfield is 1 and the UL HE TB PPDU MFB subfield is 1, the RU Allocation subfield indicates the RU for which the recommended HE-MCS applies to the HE TB PPDU sent from the STA, as defined in 26.13 (Link adaptation using the HLA Control subfield) and that the actual allocation of the RU can be ignored by the recipient.<br><br>Otherwise, this subfield is reserved. |
| BW | Bandwidth of the recommended HE-MCS/Bandwidth specified by MFB requester to get feedback | If the Unsolicited MFB subfield is 1 and the UL HE TB PPDU MFB subfield is 0, the BW subfield indicates the bandwidth for which the recommended HE-MCS applies to the PPDU sent to the STA, as defined in 26.13 (Link adaptation using the HLA Control subfield).<br><br>If the Unsolicited MFB subfield is 1 and the UL HE TB PPDU MFB subfield is 1, the BW subfield indicates the bandwidth for which the recommended HE-MCS applies to the HE TB PPDU sent from the STA, as defined in 26.13 (Link adaptation using the HLA Control subfield).<br><br>If the Unsolicited MFB subfield is 0 and the MRQ subfield is 1, the BW subfield indicates the bandwidth requested by the MFB requester to get feedback.<br><br>Set to 0 for 20 MHz.<br>Set to 1 for 40 MHz.<br>Set to 2 for 80 MHz.<br>Set to 3 for 160 MHz or 80+80 MHz. |


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**Table 9-30—HLA Control subfields(11ax) *(continued)***

| Subfield | Meaning | Definition |
|---|---|---|
| MSI/Partial PPDU Parameters | Partial parameters of the measured PPDU/ MRQ sequence identifier | If the Unsolicited MFB subfield is 0 and the MRQ subfield is 1, the MSI/Partial PPDU Parameters subfield contains a sequence number in the range 0 to 6 that identifies the specific HE-MCS feedback request.<br><br>If the Unsolicited MFB subfield is 0 and the MRQ subfield is 0, the MSI/Partial PPDU Parameters subfield contains a sequence number in the range 0 to 6 that responds to the specific solicited HE-MCS feedback request.<br><br>If the Unsolicited MFB subfield is 1, the MSI/Partial PPDU Parameters subfield contains the PPDU Format and Coding Type subfields as shown in Figure 9-29 (MSI/ Partial PPDU Parameters subfield format if the Unsolicited MFB subfield is 1(11ax)). |
| Tx Beamforming | Transmission type of the measured PPDU | If the Unsolicited MFB subfield is 1 and the UL HE TB PPDU MFB subfield is 0, then the Tx Beamforming subfield indicates whether the PPDU from which the unsolicited MFB was estimated is beamformed.<br><br>Set to 0 for non-beamformed PPDU.<br>Set to 1 for beamformed PPDU.<br><br>Otherwise, this subfield is reserved. |
| UL HE TB PPDU MFB | UL HE TB PPDU MFB indication | If the Unsolicited MFB subfield is 1, a value of 1 in this subfield indicates that the NSS, HE-MCS, DCM, BW and RU Allocation fields represent the recommended MFB for the HE TB PPDU sent from the STA as defined in 26.13 (Link adaptation using the HLA Control subfield).<br><br>Otherwise, this subfield is reserved. |

The format of the MSI/Partial PPDU Parameters subfield is defined in Figure 9-29 (MSI/Partial PPDU Parameters subfield format if the Unsolicited MFB subfield is 1(11ax)).

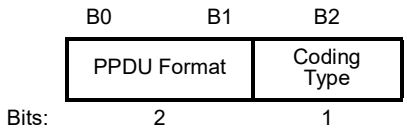


**Figure 9-29—MSI/Partial PPDU Parameters subfield format if the Unsolicited MFB subfield is 1(11ax)**

The PPDU Format subfield indicates the format of the PPDU from which the unsolicited MFB was estimated:

— Set to 0 for an HE SU PPDU.
— Set to 1 for an HE MU PPDU.
— Set to 2 for an HE ER SU PPDU.
— Set to 3 for an HE TB PPDU.

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The Coding Type subfield contains the coding information of the PPDU from which the unsolicited MFB was estimated:

— Set to 0 for BCC.

— Set to 1 for LDPC.

#### 9.2.4.7.4 BSR Control

The Control Information subfield in a BSR Control subfield contains buffer status information used for UL MU operation (see 26.5.2 (UL MU operation)). The format of the subfield is shown in Figure 9-30 (Control Information subfield format in a BSR Control subfield(11ax)).

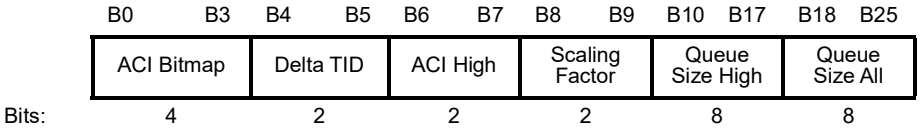


**Figure 9-30—Control Information subfield format in a BSR Control subfield(11ax)**

The ACI Bitmap subfield indicates the access categories for which the buffer status is reported and its encoding is shown in Table 9-31 (ACI Bitmap subfield encoding(11ax)). Each bit of the ACI Bitmap subfield is set to 1 to indicate that the buffer status of the corresponding AC is included in the Queue Size All subfield, and set to 0 otherwise, except that if the ACI Bitmap subfield is 0 and the Delta TID subfield is 3, then the buffer status of all 8 TIDs is included (see Table 9-32 (Delta TID subfield encoding(11ax))).

**Table 9-31—ACI Bitmap subfield encoding(11ax)**

| B0 | B1 | B2 | B3 |
|---|---|---|---|
| AC_BE | AC_BK | AC_VI | AC_VO |

The Delta TID subfield, together with the values of the ACI Bitmap subfield, indicate the number of TIDs for which the STA is reporting the buffer status. The encoding of the Delta TID subfield is defined in Table 9-32 (Delta TID subfield encoding(11ax)).

**Table 9-32—Delta TID subfield encoding(11ax)**

| Number of bits in the ACI Bitmap subfield that are set to 1 | Mapping of Delta TID subfield value and number of TIDs, $N_{TID}$ |
|---|---|
| 0 | Values 0 to 2 are not applicable;<br>Value 3 indicates 8 TIDs (i.e., all ACs have traffic). |
| 1 | Value 0 indicates 1 TID; Value 1 indicates 2 TIDs;<br>Values 2 to 3 are not applicable. |
| 2 | Value 0 indicates 2 TID; Value 1 indicates 3 TIDs;<br>Value 2 indicates 4 TIDs; Value 3 is not applicable. |


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**Table 9-32—Delta TID subfield encoding(11ax) *(continued)***

| Number of bits in the ACI Bitmap subfield that are set to 1 | Mapping of Delta TID subfield value and number of TIDs, $N_{TID}$ |
|---|---|
| 3 | Value 0 indicates 3 TID; Value 1 indicates 4 TIDs;<br>Value 2 indicates 5 TIDs; Value 3 indicates 6 TIDs. |
| 4 | Value 0 indicates 4 TID; Value 1 indicates 5 TIDs;<br>Value 2 indicates 6 TIDs; Value 3 indicates 7 TIDs. |

NOTE 1—The number of TIDs can be obtained as $N_{TID} = N_{ones} + D_{Val}$, where $N_{ones}$ is the number of bits set to one in the AC Bitmap subfield, and $D_{Val}$ is the value of the Delta TID subfield, except if $N_{ones}$ is equal to 0 for which there is the $N_{TID} = 8$ case.

NOTE 2—The Delta TID might be used by an AP to determine the setting of the TID Aggregation Limit field in the User Info field addressed to the STA in a subsequent Basic Trigger frame.

The ACI High subfield indicates the ACI of the AC for which the BSR is indicated in the Queue Size High subfield. The ACI to AC mapping is shown in 9-193 (ACI-to-AC coding).

NOTE 1—It is up to the non-AP STA that reports the buffer status to determine the queue that deserves higher priority with respect to the other queues. The determination might be based on the time the traffic has been outstanding, QoS delay requirements, amount of buffered traffic, etc., and is beyond the scope of this standard.

The Scaling Factor subfield indicates the unit *SF*, in octets, of the Queue Size High and Queue Size All subfields. The encoding of the Scaling Factor subfield is shown in Table 9-33 (Scaling Factor subfield encoding(11ax)).

**Table 9-33—Scaling Factor subfield encoding(11ax)**

| Scaling Factor subfield | Scaling factor, *SF* (octets) |
|---|---|
| 0 | 16 |
| 1 | 256 |
| 2 | 2 048 |
| 3 | 32 768 |

The Queue Size High subfield indicates the amount of buffered traffic, in units of *SF* octets, for the AC identified by the ACI High subfield that is intended for the STA identified by the receiver address of the frame containing the BSR Control subfield.

The Queue Size All subfield indicates the amount of buffered traffic, in units of *SF* octets, for all the ACs identified by the ACI Bitmap subfield that is intended for the STA identified by the receiver address of the frame containing the BSR Control subfield.

The queue size values in the Queue Size High and Queue Size All subfields are the total sizes, rounded up to the nearest multiple of *SF* octets, of all MSDUs and A-MSDUs buffered at the STA (including the MSDUs or A-MSDUs in the same PSDU as the frame containing the BSR Control subfield) in the delivery queues used for MSDUs and A-MSDUs with AC(s) that are specified in the ACI High and ACI Bitmap subfields, respectively.

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NOTE 2—The queue size is based on data received by the STA at the MAC SAP (MA-UNITDATA.request). Any data in layers above the MAC is not taken into account.

NOTE 3—Buffered MSDUs are those that have been received in an MA-UNITDATA.request but that have not been successfully transmitted and have not been discarded.

A queue size value of 254 in the Queue Size High and Queue Size All subfields indicates that the amount of buffered traffic is greater than 254 × *SF* octets. A queue size value of 255 in the Queue Size High and Queue Size All subfields indicates that the amount of buffered traffic is an unspecified or unknown size.

The queue size value of the QoS Data frames containing the fragments might remain constant in all fragments even if the amount of queued traffic changes as successive fragments are transmitted (see 10.23.3.5.1 (General)). If the QoS Data frames containing fragments are carried in the A-MPDU, the queue size values of the MPDUs containing the fragments are set according to the rules in 10.8 (HT Control field operation).

#### 9.2.4.7.5 UPH Control

The Control Information subfield in an UPH Control subfield contains the UL power headroom (UPH) used for power (M118)precorrection (see 26.5.2.4 (A-MPDU contents in an HE TB PPDU)). The format of the subfield is shown in Figure 9-31 (Control Information subfield format in a UPH Control subfield(11ax)).

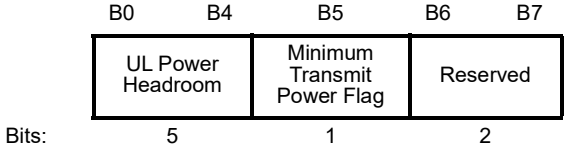


**Figure 9-31—Control Information subfield format in a UPH Control subfield(11ax)**

The UL Power Headroom subfield indicates the available UL power headroom, in units of dB, for the current HE-MCS (see 26.5.2.4 (A-MPDU contents in an HE TB PPDU)). The UL Power Headroom subfield carries a value 0 to 31 that maps to 0 dB to 31 dB.

The Minimum Transmit Power Flag subfield is set to 1 to indicate that the minimum transmit power for the current HE-MCS is reached by the STA and set to 0 otherwise.

#### 9.2.4.7.6 BQR Control

The Control Information subfield in a BQR Control subfield contains the bandwidth query report (BQR) used for bandwidth query report operation to assist HE MU transmission (see 26.5.2 (UL MU operation)). The format of the subfield is shown in Figure 9-32 (Control Information subfield format in a BQR Control subfield(11ax)).

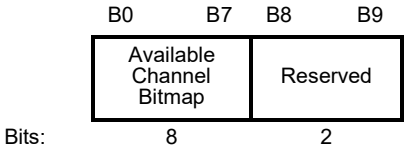


**Figure 9-32—Control Information subfield format in a BQR Control subfield(11ax)**


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The Available Channel Bitmap subfield contains a bitmap indicating the subchannels available at the STA transmitting the BQR. Each bit in the bitmap corresponds to a 20 MHz subchannel within the operating channel width of the BSS in which the STA is associated, with the LSB corresponding to the lowest numbered operating subchannel of the BSS. The bit in position $X$ in the bitmap is set to 1 to indicate that the subchannel $X+1$ is idle; otherwise, it is set to 0 to indicate that the subchannel is busy or unavailable. Availability of each 20 MHz subchannel is based on the ED-based CCA defined in 27.3.22.6.5 (Per 20 MHz CCA sensitivity) and is reported for the 20 MHz subchannels located in the operating channel of the reporting STA when the WM is idle as defined in 10.3.2.1 (CS mechanism) and in 26.5.2.5 (UL MU CS mechanism).

#### 9.2.4.7.7 CAS Control

The Control Information subfield in a CAS Control subfield contains the command and status (CAS) control. The format of the subfield frame is shown in Figure 9-33 (Control Information subfield format in a CAS Control subfield(11ax)).

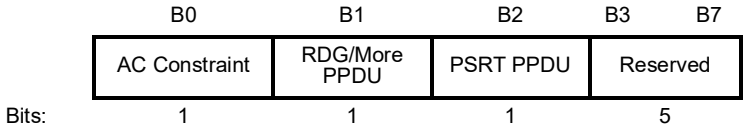


**Figure 9-33—Control Information subfield format in a CAS Control subfield(11ax)**

The AC Constraint subfield is defined in Table 9-16 (AC Constraint subfield values), except that a value of 1 indicates to an HE STA that the response can contain RD Data frames from the same AC or higher priority ACs as defined in 10.29.4 (Rules for RD responder).

The RDG/More PPDU subfield is defined in Table 9-17 (RDG/More PPDU subfield values).

The PSRT PPDU subfield indicates whether the PPDU carrying the frame with the CAS Control subfield is an PSRT PPDU. The PSRT PPDU subfield is set to 1 if the PPDU is an PSRT PPDU; otherwise, it is set to 0.

### 9.2.4.8 Frame Body field

#### 9.2.4.8.1 General

The Frame Body field is a variable length field that contains information specific to individual frame types and subtypes. The minimum length of the frame body is 0 octets. The maximum length of the frame body is constrained or affected by the following:

- The maximum MMPDU, MSDU, A-MSDU, and MPDU sizes supported by the recipient(s) for the PPDU format in use, as specified in Table 9-34 (Maximum data unit sizes and durations(#1327)(#4013)).
- The maximum PPDU duration [e.g., (#2095)HT-mixed format L-SIG L_LENGTH, HT-greenfield format, VHT, TVHT, S1G, or DMG aPPDUMaxTime (see Table 9-34 (Maximum data unit sizes and durations(#1327)(#4013))); any nonzero TXOP limit; any regulatory constraints (e.g., CS4-msBehavior)].
- The fields present in the MAC header (e.g., QoS Control, Address 4, HT Control).
- The presence of security encapsulation (e.g., TKIP, CCMP or GCMP header and MIC).
- The presence of Mesh Control fields (see 9.2.4.8.3 (Mesh Control field)).

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NOTE 1—In an A-MSDU, the Mesh Control field is located in the A-MSDU Subframe Header (see Figure 9-124 (Basic A-MSDU subframe structure when in a mesh Data frame(#462)(#419))). In an MMPDU, the Mesh Control field is located within the MMPDU (see 9.6.17 (Multihop Action frame details)). Such Mesh Control fields need to be taken into account if a maximum A-MSDU or MMPDU size constraint applies as well as if a maximum MPDU size constraint applies.

NOTE 2—TKIP is not allowed with A-MSDUs (see 12.2.5 (RSNA assumptions and constraints)) or MMPDUs (see 12.5.3.1 (BIP overview)) and, therefore, need not be taken into account if a maximum A-MSDU or MMPDU size constraint applies.(#2330)


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**Table 9-34—Maximum data unit sizes and durations(#1327)(#4013)**

| | Non-HT non-VHT non-HE(11ax) non-S1G non-DMG PPDU and non-HT duplicate PPDU | HT PPDU | VHT PPDU | HE PPDU(11ax) | S1G PPDU | DMG PPDU | EDMG PPDU(11ay) | NGV PPDU (11bd) |
|---|---|---|---|---|---|---|---|---|
| MMPDU size (in octets)(#4013) | 2304<br>See NOTE 10(#4014) and NOTE 12(#6413) | 2304<br>See NOTE 10(#4014) and NOTE 12(#6413) | See NOTE 1 | 2.4 GHz band: see NOTE 11; Otherwise: see NOTE 1(#4014) | See NOTE 1 and NOTE 12(#6413) | 2304<br>See NOTE 12(#6413) | 2304 | 2304 |
| MSDU size (in octets)(#4013) | 2304 | 2304 | 2304 | 2304 | 2304 | (11ay)Without SAR agreement: for the (#279)Basic A-MSDU format, it is equal to the value of A-MSDU size minus 14, or minus 2 for the short A-MSDU format, if the MPDU Limit subfield of the Extended MPDU Capability field of the DMG Capabilities element is valid; otherwise, it is equal to 7920.<br>With SAR agreement: see NOTE 8. | Without SAR agreement: for the (#279)Basic A-MSDU format, it is equal to the value of A-MSDU size minus 14, or minus 2 for the short A-MSDU format, if the MPDU Limit subfield of the Extended MPDU Capability field of the DMG Capabilities element is valid; otherwise, it is equal to 7920.<br>With SAR agreement: see NOTE 8. | 2304 |

**Table 9-34—Maximum data unit sizes and durations(#1327)(#4013) *(continued)***

| | Non-HT non-VHT non-HE(11ax) non-S1G non-DMG PPDU and non-HT duplicate PPDU | HT PPDU | VHT PPDU | HE PPDU(11ax) | S1G PPDU | DMG PPDU | EDMG PPDU(11ay) | NGV PPDU (11bd) |
|---|---|---|---|---|---|---|---|---|
| A-MSDU size (in octets)(#4013) | 3839 or 4065 (see NOTE 2) (HT STA, see also Table 9-224 (Subfields of the HT Capability Information field)), or N/A (non-HT STA, see also 10.11 (A-MSDU operation)) | 3839 (#1435)or 4065 (see NOTE 9) or 7935 (see also Table 9-224 (Subfields of the HT Capability Information field)) | See NOTE 3 | 2.4 GHz band: 3839 or 7935 (see also Table 9-224 (Subfields of the HT Capability Information field))<br><br>Otherwise: see NOTE 3 | See NOTE 3 | (11ay)Without SAR agreement: indirectly limited by the value of the MPDU Limit subfield in the Extended MPDU Capability field of the DMG Capabilities element, if the subfield is valid; otherwise, it is equal to 7935. With SAR agreement: see NOTE 8. | Without SAR agreement: indirectly limited by the value of the MPDU Limit subfield in the Extended MPDU Capability field of the DMG Capabilities element, if the subfield is valid; otherwise, it is equal to 7935. With SAR agreement: see NOTE 8 | 7935 |
| MPDU size (in octets)(#4013) | See NOTE 4 | See NOTE 5 | 3895 or 7991 or 11 454 (see also Table 9-313 (Subfields of the VHT Capabilities Information field)) and NOTE 10)(#4014) | 2.4 GHz band: see NOTE 5<br><br>Otherwise: 3895 or 7991 or 11 454 (see also Table 9-313 (Subfields of the VHT Capabilities Information field))<br><br>See NOTE 7 | 3895 or 7991 (see also Table 9-351 (Subfields of the S1G Capabilities Information field) | (11ay)The value indicated in the MPDU Limit subfield of the Extended MPDU Capability field of the DMG Capabilities element if the subfield is valid; otherwise, as in NOTE 5. | The value indicated in the MPDU Limit subfield of the Extended MPDU Capability field of the DMG Capabilities element if the subfield is valid; otherwise, as in NOTE 5. | 7991 |

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**Table 9-34—Maximum data unit sizes and durations(#1327)(#4013) *(continued)***

| | Non-HT non-VHT non-HE(11ax) non-S1G non-DMG PPDU and non-HT duplicate PPDU | HT PPDU | VHT PPDU | HE PPDU(11ax) | S1G PPDU | DMG PPDU | EDMG PPDU(11ay) | NGV PPDU (11bd) |
|---|---|---|---|---|---|---|---|---|
| PSDU size (in octets)(#4013) | $2^{12}$–1 (see Table 15-5 (DSSS PHY characteristics), Table 16-4 (HR/DSSS PHY characteristics), Table 17-24 (OFDM PHY characteristics), Table 18-5 (ERP characteristics)) | $2^{16}$–1 (see Table 19-25 (HT PHY characteristics)) | 4 692 480 (~$2^{22.16}$) (see Table 21-28 (VHT PHY characteristics)) | 6 500 631 (~$2^{22.63}$) (see Table 27-61 (HE PHY characteristics(11ax))) | 797 160 (~$2^{19.60}$) (see Table 23-41 (S1G PHY characteristics)) | $2^{18}$–1 (see Table 20-30 (DMG PHY characteristics)) | $2^{22}$–1 (see Table 28-12 (EDMG-Header-A field structure and definition for an SU PPDU(11ay)) and Table 28-19 (EDMG-Header-B field structure and definition(11ay))) | 244,800 |

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**Table 9-34—Maximum data unit sizes and durations(#1327)(#4013) *(continued)***

| | Non-HT non-VHT non-HE(11ax) non-S1G non-DMG PPDU and non-HT duplicate PPDU | HT PPDU | VHT PPDU | HE PPDU(11ax) | S1G PPDU | DMG PPDU | EDMG PPDU(11ay) | NGV PPDU (11bd) |
|---|---|---|---|---|---|---|---|---|
| PPDU duration (in microseconds) (#4013) | See NOTE 6 | 5484 ((#2095)HT-mixed format; see 10.27.4 (L_LENGTH and L_DATARATE parameter values for HT-mixed format PPDUs)) or 10 000 ((#2095)HT-greenfield format; see Table 19-25 (HT PHY characteristics)) | 5484 (see Table 21-28 (VHT PHY characteristics)) | 5484 (see Table 27-61 (HE PHY characteristics(11ax))) | 27 840 (see Table 23-41 (S1G PHY characteristics)) | 2000 (see Table 20-30 (DMG PHY characteristics)) | 2000 (see Table 20-30 (DMG PHY characteristics)) | 10,968 |

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**Table 9-34—Maximum data unit sizes and durations(#1327)(#4013) *(continued)***

| | Non-HT non-VHT non-HE(11ax) non-S1G non-DMG PPDU and non-HT duplicate PPDU | HT PPDU | VHT PPDU | HE PPDU(11ax) | S1G PPDU | DMG PPDU | EDMG PPDU(11ay) | NGV PPDU (11bd) |
|---|---|---|---|---|---|---|---|---|
| NOTE 1—No direct constraint on the maximum MMPDU size; indirectly constrained by the maximum MPDU size (see 9.3.3.1 (Format of (PV0) Management frames)). | | | | | | | | |
| NOTE 2—Indirect constraint from the maximum PSDU size: $2^{12}$–1 octets minus the minimum QoS Data frame overhead (26 octets for the MAC header and 4 octets for the FCS). | | | | | | | | |
| NOTE 3—No direct constraint on the maximum A-MSDU size; indirectly constrained by the maximum MPDU size. | | | | | | | | |
| NOTE 4—No direct constraint on the maximum MPDU size; indirectly constrained by the maximum MSDU, MMPDU or (for HT STAs only) A-MSDU(#4014) size. | | | | | | | | |
| NOTE 5—No direct constraint on the maximum MPDU size; indirectly constrained by the maximum A-MSDU/MMPDU(#4014) size. | | | | | | | | |
| NOTE 6—No direct constraint on the maximum duration, but an L_LENGTH value above 2332 might not be supported by some receivers (see NOTE 2 in 10.27.4 (L_LENGTH and L_DATARATE parameter values for HT-mixed format PPDUs)). | | | | | | | | |
| NOTE 7—The maximum MPDU size might be greater than the size declared as supported by the recipient if the MPDU is an HE Compressed Beamforming/CQI frame.(11ax) | | | | | | | | |
| NOTE 8—No direct constraint on the maximum MSDU or A-MSDU size; indirectly constrained by the maximum PSDU size. Each MPDU in an A-MPDU of the PSDU that contains the MSDU or A-MSDU generates an overhead of MPDU Header (26 octets(#8150)), FCS (4 octets(#8150)), GCMP Header (8 octets(#8150)), MIC (16 octets(#8150)), and MPDU delimiter (4 octets(#8150)).(11ay)(#2331) | | | | | | | | |
| NOTE 9—Indirect constraint from the maximum MPDU size in an A-MPDU in an HT PPDU: $2^{12}$–1 octets minus the minimum QoS Data frame overhead (26 octets for the MAC header and 4 octets for the FCS).(#1435) | | | | | | | | |
| NOTE 10—The maximum MMPDU or MPDU size can preclude the use of the corresponding PPDU format for certain sounding feedback configurations. See 10.33 (Transmit beamforming), 10.35 (Null data PPDU (NDP) sounding), and 26.7 (HE sounding operation(#2388)).(#4014) | | | | | | | | |
| NOTE 11—The maximum MMPDU size is:(#4014)<br>— if there is one recipient, then the size of the MPDU that contains an A-MSDU with size equal to the maximum size supported by the recipient less the shortest Management frame MAC header and FCS, or<br>— if there is more than one recipient, then the size of the MPDU that contains an A-MSDU with size equal to the smallest among the maximum sizes supported by the recipients less the shortest Management frame MAC header and FCS. | | | | | | | | |
| NOTE 12—Some implementations might not support 2304-octet Beacon frames.(#6413) | | | | | | | | |

#### 9.2.4.8.2 Overhead for encryption

The overhead for encryption is described in Clause 12 (Security). When the Mesh Control field is present in the frame body, the Mesh Control field is encrypted as a part of data.

#### 9.2.4.8.3 Mesh Control field

The Mesh Control field is present in a mesh Data frame containing an unfragmented MSDU or the first fragment of a fragmented MSDU and is present in a Multihop Action frame transmitted by a mesh STA.

In mesh Data frames, when the Mesh Control Present subfield in the QoS Control field is 1, the Mesh Control field is prepended to the MSDU and located as follows:

— When the frame body contains an MSDU (or a fragment thereof) and the frame is not encrypted, the Mesh Control field is located in the first octets of the frame body.

— When the frame body contains an MSDU (or a fragment thereof) and the frame is encrypted, the Mesh Control field is located in the first octets of the encrypted data portion.

— When the frame body contains an A-MSDU, the Mesh Control field is located in the A-MSDU subframe header as shown in Figure 9-124 (Basic A-MSDU subframe structure when in a mesh Data frame(#462)(#419)).

In the Multihop Action frame, the Mesh Control field is present as specified in 9.6.17 (Multihop Action frame details).

The Mesh Control field is of variable length (6, 12, or 18 octets). The structure of the Mesh Control field is defined in Figure 9-34 (Mesh Control field format).

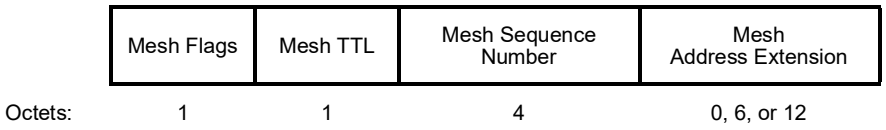


**Figure 9-34—Mesh Control field format**

The Mesh Flags subfield contains the Address Extension Mode subfield. The structure of the Mesh Flags subfield is shown in Figure 9-35 (Mesh Flags subfield format).

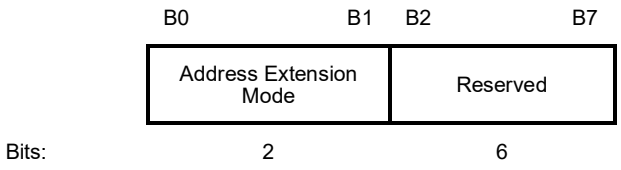


**Figure 9-35—Mesh Flags subfield format**

The Address Extension Mode subfield indicates the contents of the Mesh Address Extension subfield. Table 9-35 (Valid values for the Address Extension Mode subfield) defines valid values for the Address Extension Mode and describes the corresponding contents of the Mesh Address Extension subfield.

The Mesh TTL subfield contains a nonzero unsigned integer corresponding to the remaining number of hops the MSDU/MMPDU is forwarded. How the Mesh TTL is used in both individually and group addressed frames is described in 10.37.3 (Addressing and forwarding of individually addressed mesh Data frames) and 10.37.4 (Addressing and forwarding of group addressed mesh Data frames).


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**Table 9-35—Valid values for the Address Extension Mode subfield**

| Address extension mode value | Address extension mode name | Address extension mode description | Mesh Address Extension subfield length (octets) | Applicable frame types |
|---|---|---|---|---|
| 0 | None | No Mesh Address Extension subfield | 0 | Data, Management (Multihop Action, group addressed) |
| 1 | Address4 | Mesh Address Extension subfield contains Address 4 | 6 | Management (Multihop Action, individually addressed), Data (proxied, group addressed) |
| 2 | Address5&6 | Mesh Address Extension subfield contains Address 5 and Address 6 | 12 | Data (proxied, individually addressed) |
| 3 | | Reserved | — | — |

The Mesh Sequence Number subfield contains an unsigned integer sequence number counter value. Source mesh STAs assign mesh sequence numbers from a single modulo $2^{32}$ counter, starting at 0 and (#270)incrementing by 1 for each MSDU (if not in an A-MSDU), A-MSDU or MMPDU that is transmitted with a Mesh Control field. Usage of the Mesh Sequence Number is described in 10.37.6 (Detection of duplicate MSDUs/MMPDUs).

NOTE 1—It is believed that a 32-bit sequence number is sufficient as the rollover would occur after a period of 5 days assuming a source continuously transmitting at a rate of $10^4$ frames/s.(#1165)

The Mesh Address Extension subfield, shown in Figure 9-36 (Mesh Address Extension subfield format), is present only when the Address Extension Mode subfield of the Mesh Flags subfield is a nonzero nonreserved value. The Mesh Address Extension subfield provides additional address fields for mesh address extension as defined in Table 9-35 (Valid values for the Address Extension Mode subfield). The interpretation of the extended Address fields is described in 9.3.5 (Frame addressing in an MBSS).

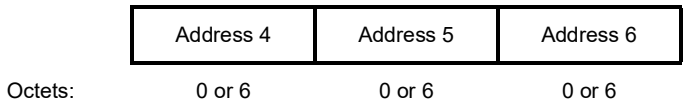


**Figure 9-36—Mesh Address Extension subfield format**

The Address 4 subfield is present when the Address Extension Mode subfield in the Mesh Flags subfield is 1. It carries a fourth address that is not included as a part of the MAC header for these frames.

The Address 5 subfield and Address 6 subfield are present when the Address Extension Mode subfield in the Mesh Flags subfield is 2. It carries the addresses of source and destination end station of the end-to-end IEEE 802 communication if either (or both) of the end stations are not mesh STAs at the beginning or end of a single mesh path. (See Figure 9-136 (Example addressing for a mesh Data frame).)

NOTE 2—This is useful, for example, when the end stations of IEEE 802 communication are nonmesh, external STAs that communicate over a mesh BSS via proxy mesh gates.

Details on the usage of these optional address fields are given in 14.11.8.4 (Forwarding information).

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#### 9.2.4.9 FCS field

The FCS field contains a 32-bit CRC. The FCS field value is calculated over all of the fields of the MAC header and the Frame Body field. These are referred to as the *calculation fields*.

The FCS field value is calculated using the following standard generator polynomial of degree 32:

$$G(x) = x^{32} + x^{26} + x^{23} + x^{22} + x^{16} + x^{12} + x^{11} + x^{10} + x^8 + x^7 + x^5 + x^4 + x^2 + x + 1$$

The FCS field value is the 1s complement of the sum (modulo 2) of the following:

a) The remainder of $x^k \times (x^{31} + x^{30} + x^{29} + \ldots + x^2 + x + 1)$ divided (modulo 2) by $G(x)$, where $k$ is the number of bits in the calculation fields, and

b) The remainder after multiplication of the contents (treated as a polynomial) of the calculation fields by $x^{32}$ and then division by $G(x)$.

The FCS field is transmitted commencing with the coefficient of the highest-order term.

As a typical implementation, at the transmitter, the initial remainder of the division is preset to all 1s and is then modified by division of the calculation fields by the generator polynomial $G(x)$. The 1s complement of this remainder is transmitted, with the highest-order bit first, as the FCS field.

At the receiver, the initial remainder is preset to all 1s and the serial incoming bits of the calculation fields and FCS, when divided by $G(x)$, results (in the absence of transmission errors) in a unique nonzero remainder value. The unique remainder value is the polynomial:

$$x^{31} + x^{30} + x^{26} + x^{25} + x^{24} + x^{18} + x^{15} + x^{14} + x^{12} + x^{11} + x^{10} + x^8 + x^6 + x^5 + x^4 + x^3 + x + 1$$

### 9.2.5 Duration/ID field (QoS STA)

#### 9.2.5.1 General

The value in the Duration/ID field within Poll, SPR, Grant, Grant Ack, DMG CTS, DMG DTS, SSW, SSW-Feedback, and SSW-Ack frames transmitted by a DMG STA are described in 9.3.1.10 (Poll frame format) to 9.3.1.18 (Grant Ack frame format). The value in the Duration/ID field within DMG Beacon frames transmitted by a DMG STA is described in 9.3.4.2 (DMG Beacon).

The value in the Duration/ID field in a frame transmitted by a QoS STA is defined in 9.2.5.2 (Setting for single and multiple protection under enhanced distributed channel access (EDCA)) to 9.2.5.7 (Setting for other response frames).

(#147)Unless stated otherwise, all times are calculated in μs. (#1490)If the value calculated for the Duration/ID field is not an integer, the value inserted in the Duration/ID field is rounded up to the next higher integer. If the value calculated for the Duration/ID field is negative, the value inserted in the Duration/ID field is 0.

The value in the Duration field of NDP Ack, and NDP CTS frames transmitted by an S1G STA is defined in 9.2.5.6 (Setting for control response frames). Setting the Duration field is additionally constrained by the same rules that apply to the Duration/ID field of Ack, and CTS frames as described in 9.2.5.2 (Setting for single and multiple protection under enhanced distributed channel access (EDCA)) and 9.2.5.7 (Setting for other response frames).

The value in the Duration field for the NDP_1M Ack frame when the Idle Indication field is 0, the NDP_1M CTS frame and the NDP_1M CF-End frame is calculated in multiples of 40 μs. (#148)(#149)See 23.3.12.2.4.2 (NDP_1M Ack) for the value in the Duration field for the NDP_1M Ack frame when the Idle


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Indication field is 1. See 23.3.12.2.5.2 (NDP_1M PS-Poll-Ack) for the value in the Duration field for the NDP_1M PS-Poll-Ack frame.

The value in the Duration field for the NDP_2M Ack frame when the Idle Indication field is 0, the NDP_2M PS-Poll-Ack frame when the Idle Indication field is 0, the NDP_2M CTS frame, and the NDP_2M CF-End frame is calculated in microseconds. (#148)(#149)See 23.3.12.2.4.3 (NDP_2M Ack) for the value in the Duration field for the NDP_2M Ack frame when the Idle Indication field is 1. See 23.3.12.2.5.3 (NDP_2M PS-Poll-Ack) for the value in the Duration field for the NDP_2M PS-Poll-Ack frame when the Idle Indication field is 1.

The value in the Duration/ID field in a frame transmitted by an NGV STA is further defined in 31.2.1 (Coexistence with non-NGV STAs).(11bd)

### 9.2.5.2 Setting for single and multiple protection under enhanced distributed channel access (EDCA)

In transmissions under EDCA by a STA that initiates a TXOP, there are two classes of duration settings: single protection and multiple protection. In single protection, the Duration/ID field of the frame can set a network allocation vector (NAV) value at receiving STAs that protects up to the end of any following Data, Management, or response frame plus any additional overhead frames as described below. In multiple protection, the Duration/ID field of the frame can set a NAV that protects up to the estimated end of a sequence of multiple frames.

The STA selects between single and multiple protection when it transmits the first frame of a TXOP. All subsequent frames transmitted by the STA in the same TXOP use the same class of duration settings. A STA always uses multiple protection in a TXOP that includes the following:

— Frames that have the RDG/More PPDU subfield equal to 1(#3263)
— VHT/HE NDP Announcement frames, Beamforming Report Poll frames, or BFRP Trigger frames(11ax)
— S1G Beacon frames
— Frames transmitted by an S1G STA with the TXVECTOR parameter RESPONSE INDICATION equal to Long Response

For S1G STAs, Duration/ID field determination rules are further specified in 10.3.2.15 (NAV distribution).

The Duration/ID field is set as follows:

a) Single protection settings.
   1) In an RTS frame that is not part of a dual clear-to-send (CTS) exchange and is not part of a BDT exchange, the Duration/ID field is set to the estimated time, in microseconds, required to transmit the pending frame, plus one CTS frame, plus one Ack or BlockAck frame if required, plus any NDPs required, plus explicit feedback if required, plus applicable IFSs.
   2) In an MU-RTS Trigger frame, the Duration/ID field is set to the estimated time, in microseconds, required to transmit the pending frame(s), plus one CTS frame, plus the time to transmit the solicited HE TB PPDU if required, plus the time to transmit the acknowledgment for the solicited HE TB PPDU if required, plus applicable IFSs.(11ax)

NOTE 1—The pending frame(s) include a triggering frame if required.

   3) In all CTS frames sent by STAs as the first frame in the exchange under EDCA and with the receiver address (RA) matching the MAC address of the transmitting STA, the Duration/ID field is set to one of the following:

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i) If there is a response frame, the estimated time required to transmit the pending frame, plus one SIFS, plus the response frame (Ack or BlockAck), plus any NDPs required, plus explicit feedback if required, plus an additional SIFS

ii) If there is no response frame, the time required to transmit the pending frame, plus one SIFS

4) In an MU-BAR Trigger frame, BSRP Trigger frame, GCR MU-BAR Trigger frame, BQRP Trigger frame, and NFRP Trigger frame, the Duration/ID field is set to the time required to transmit the solicited HE TB PPDU plus one SIFS.(11ax)

5) In a BlockAckReq frame, the Duration/ID field is set to the estimated time required to transmit one Ack or BlockAck frame, as applicable, plus one SIFS.

6) In a BlockAck frame that is not sent in response to a BlockAckReq frame or an implicit block ack request, the Duration/ID field is set to the estimated time required to transmit an Ack frame plus a SIFS.

7) In a Basic Trigger frame, the Duration/ID field is set to the estimated time required to transmit the solicited HE TB PPDU, plus the estimated time required to transmit the acknowledgment for the solicited HE TB PPDU if required, plus applicable SIFSs.(11ax)

8) In Management frames, non-QoS Data frames (i.e., with bit 7 of the(#4089) Frame Control field equal to 0), and individually addressed Data frames with an ack policy other than No Ack or Block Ack, the Duration/ID field is set to one of the following:

i) If the frame is the final frame of the TXOP, the estimated time required for the transmission of one Ack or BlockAck frame, as appropriate(#3664) (including appropriate IFSs)

ii) Otherwise, the estimated time required for the transmission of one Ack or BlockAck frame, as appropriate(#3664) plus the time required for the transmission of the following frame and its response if required, plus applicable IFSs.

9) In individually addressed QoS Data frames with an ack policy of No Ack or Block Ack, for Action No Ack frames, and for group addressed frames, the Duration/ID field is set to one of the following:

i) If the frame is the final frame of the TXOP, 0

ii) Otherwise, the estimated time required for the transmission of the following frame and its response frame, if required (including appropriate IFSs)

b) Multiple protection settings. The Duration/ID field is set to a value D as follows:

1) If $T_{TXOP} = 0$ and $T_{END\text{-}NAV} = 0$, then $D = T_{SINGLE\text{-}MSDU} - T_{\text{PPDU}}$

2) Else if $T_{TXOP} = 0$ and $T_{END\text{-}NAV} > 0$, then $D = \max(0, T_{END\text{-}NAV} - T_{PPDU})$

3) Else if $T_{END\text{-}NAV} = 0$, then $\min(T_{PENDING}, T_{TXOP} - T_{PPDU}) \le D \le T_{TXOP} - T_{PPDU}$

4) Else $T_{END\text{-}NAV} - T_{PPDU} \le D \le T_{TXOP\text{-}REMAINING} - T_{PPDU}$

where

$T_{SINGLE\text{-}MSDU}$ is the estimated time required for the transmission of the allowed frame exchange sequence defined in 10.23.2.9 (TXOP limits) (for a TXOP limit of 0), including applicable IFSs

$T_{PENDING}$ is the estimated time required for the transmission of

— Pending MPDUs(11ax)

— Any associated immediate response frames

— Any HT NDP, VHT NDP,(11ax) HE sounding NDP, or Beamforming Report Poll frame transmissions and explicit feedback response frames



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— Applicable IFSs
— Any RDG
— Any BDT
— Any pending QoS Null frame (#109)exchange sequences by paged STAs
— Any pending PS-Poll or NDP PS-Poll frame exchanges by paged STAs

| | |
|---|---|
| $T_{TXOP}$ | is the duration given by dot11EDCATableTXOPLimit (dot11QAPEDCATableTXOPLimit for the AP) for that AC |
| $T_{TXOP\text{-}REMAINING}$ | is $T_{TXOP}$ less the time already used within the TXOP |
| $T_{END\text{-}NAV}$ | is the remaining duration of any NAV set by the TXOP holder, or 0 if no NAV has been established |
| $T_{PPDU}$ | is the time required for transmission of the current PPDU |

NOTE 2—The rules allowing or disallowing the transmission of MPDUs with different ACs are described in 10.23.2.7 (Sharing an EDCA TXOP), 10.23.2.8 (Multiple frame exchange sequences in an EDCA TXOP(#109)), and 26.6.3 (Multi-TID A-MPDU and ack-enabled single-TID A-MPDU).(11ax)

NOTE 3—The estimated time to transmit an acknowledgment in response to the frames carried in a solicited HE TB PPDU might be inexact. The TXOP holder might use the maximum time required to transmit the acknowledgment as the estimated time.(11ax)

The estimated time required for transmission of a VHT Compressed Beamforming frame response is determined by assuming the following:

— All feedback segments (as defined in 10.35.5.3 (Rules for fragmented feedback in VHT sounding protocol sequences)) are transmitted, even if a Beamforming Report Poll frame is used and not all of the bits in the included Feedback Segment Retransmission Bitmap field are equal to 1.
— The subfield values of the VHT MIMO Control field are as follows:
  — The Feedback Type, Nr Index, and Channel Width fields are as specified in 10.35.5 (VHT sounding protocol).
  — The Nc Index field is as specified in 10.35.5 (VHT sounding protocol) if the Feedback Type field is MU, or to the greatest value allowed by 10.35.5 (VHT sounding protocol) if the Feedback Type field is SU.
  — The Grouping field indicates no grouping.
  — The Codebook Information field has the value 1.

NOTE 4—Estimated times might prove to be inexact, if the TXOP responder has a choice of PHY options (e.g., BCC v. LDPC, use of STBC, use of short GI, PHY header/preamble format options) or MAC options (e.g., use of HT Control). Heuristics such as the TXOP responder's previous choices and channel conditions might be used to minimize the inexactitude.

NOTE 5—If a TXOP includes the transmission of a VHT Compressed Beamforming frame by the TXOP responder, the TXOP holder can, if the duration estimates prove excessive, indicate truncation of the TXOP by using a CF-End frame, provided that the remaining duration of the TXOP after the transmission of the last frame can accommodate the CF-End frame (see 10.23.2.10 (Truncation of TXOP)).

In a PS-Poll+BDT frame or an RTS frame generated by an S1G STA as part of a BDT exchange the Duration/ID field is set as follows:

— In a PS-Poll+BDT frame, the Duration/ID field is set to the estimated time required for the transmission of one Ack frame, plus the estimated time required for the transmission of its following MPDUs and their responses if required, plus applicable IFS durations.
— In an RTS frame that is sent as a response to the PS-Poll+BDT frame, the Duration/ID field is set to a value D: min ($T_{END\text{-}NAV} + T_{PENDING} - T_{PPDU}$; $T_{TXOP\text{-}REMAINING} - T_{PPDU}$) $\leq D \leq T_{TXOP\text{-}REMAINING} - T_{PPDU}$.

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In any frame that includes a Duration/ID field, transmitted by an S1G STA as a response to PV1 frames that are not part of a BDT exchange, the Duration/ID field of the frame is set to 0. For any frame transmitted by a BDT initiator that is the TXOP holder as a response to PV1 frames, the Duration/ID field of the frame is set to the value of the TXNAV timer minus the estimated time required to transmit the frame. In any frame transmitted by a BDT initiator that is not the TXOP holder as a response to PV1 frames, the Duration/ID field of the frame is set to the remaining duration of the TXOP.

#### 9.2.5.3 Setting for QoS CF-Poll frames

Within a Data frame containing QoS CF-Poll, the Duration/ID field value is set to one of the following:

a) One SIFS plus the TXOP limit, if the TXOP limit is nonzero, or

b) The time required for the transmission of one MPDU of nominal MSDU size and the associated Ack frame plus two SIFSs, if the TXOP limit is 0.

#### 9.2.5.4 Setting for frames sent by a TXOP holder under HCCA

Within a frame sent by a TXOP holder under hybrid coordination function (HCF) controlled channel access (HCCA), to provide NAV protection for the entire controlled access phase (CAP), the Duration/ID field is set to one of the following values:

a) In an RTS frame
   1) If the pending frame is the final frame, the time required to transmit the pending frame, plus one CTS frame, plus one Ack frame if required, plus three SIFSs
   2) If the pending frame is not the final frame in the TXOP, the remaining duration of the TXOP

b) In a CTS frame
   1) If the pending frame is the sole frame in the TXOP, one of the following:
      i) If there is a response frame, the time required to transmit the pending frame, plus one SIFS, plus the response frame (Ack or BlockAck), plus an additional SIFS
      ii) If there is no response frame, the time required to transmit the pending frame, plus one SIFS
   2) If the pending frame is not the final frame in the TXOP, the remaining duration of the TXOP

c) Otherwise
   1) If the frame is a nonfinal frame in a TXOP with multiple frame exchanges, the remaining duration of the TXOP
   2) If the frame is the sole or final frame in the TXOP, the actual remaining time needed for this frame exchange sequence(#3263)

#### 9.2.5.5 Settings within a dual CTS sequence

Within a frame ("Frame1") (excluding a second CTS (CTS2) transmission, as defined in 10.3.2.10 (Dual CTS protection)) sent by a QoS STA that is not a TXOP holder in a PPDU that contains an immediate response or that is sent by an RD responder, the Duration/ID field is set to the Duration/ID value from the frame(s) ("Frames2") that elicited the response or that carried the RDG minus the time interval between the end of the PPDU that carried Frame1 and the end of the PPDU that carries Frames2.

Within a frame ("Frame1") (excluding a CTS2 transmission, as defined in 10.3.2.10 (Dual CTS protection)) sent by a QoS STA that is a TXOP holder, the Duration/ID field is set according to the rules in the following subclauses:

— 9.2.5.2 (Setting for single and multiple protection under enhanced distributed channel access (EDCA)) rule b) for multiple protection if Frame1 is not a QoS +CF-Poll frame and the TXOP holder is not operating under HCCA(#3263)


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- 9.2.5.3 (Setting for QoS CF-Poll frames) if Frame1 is a QoS +CF-Poll frame and the TXOP holder is not operating under HCCA(#3263)
- 9.2.5.4 (Setting for frames sent by a TXOP holder under HCCA) if the TXOP holder is operating under HCCA(#3263)

Within the CTS2 of a dual CTS exchange, defined in 10.3.2.10 (Dual CTS protection), the Duration/ID field is set to the value of the Duration/ID field of the RTS frame that initiated the exchange minus the time required to transmit the first clear-to-sent (CTS1), CTS2, and the applicable IFSs.

#### 9.2.5.6 Setting for control response frames

This subclause describes how to set the Duration/ID field for CTS, Ack, and BlockAck frames transmitted by a QoS STA.

In a CTS frame that is not part of a dual CTS sequence transmitted in response to an RTS frame, the Duration/ID field is set to the value obtained from the Duration/ID field of the RTS frame that elicited the response minus the time, in microseconds, between the end of the PPDU carrying the RTS frame and the end of the PPDU carrying the CTS frame.

In a CTS frame that is transmitted in response to an MU-RTS Trigger frame, the Duration/ID field is set to the value obtained from the Duration/ID field of the MU-RTS Trigger frame that elicited the CTS frame minus the time, in microseconds, between the end of the PPDU carrying the MU-RTS Trigger frame and the end of the PPDU carrying the CTS frame.(11ax)

In an Ack frame, the Duration/ID field is set to the value obtained from the Duration/ID field of the frame that elicited the response minus the time, in microseconds between the end of the PPDU carrying the frame that elicited the response and the end of the PPDU carrying the Ack frame.

In a BlockAck frame transmitted in response to a BlockAckReq frame, MU-BAR Trigger frame, frame containing an implicit block ack request, or frame carried in HE TB PPDU under single protection settings, the Duration/ID field is set to the value obtained from the Duration/ID field of the frame that elicited the response minus the time, in microseconds between the end of the PPDU carrying the frame that elicited the response and the end of the PPDU carrying the BlockAck frame.(11ax)

Under multiple protection settings, the Duration/ID field in a BlockAck frame transmitted in response to a frame carried in HE TB PPDU is set according to the multiple protection settings defined in 9.2.5.2 (Setting for single and multiple protection under enhanced distributed channel access (EDCA)).(11ax)

In an NDP CTS frame transmitted in response to an RTS frame, the Duration field is set to the value obtained from the Duration/ID field of the RTS frame that elicited the response minus the time, in microseconds, between the end of the PPDU carrying the RTS frame and the end of the NDP CTS frame except as described in 10.53.5.4 (Relay-shared TXOP protection mechanisms).

In an NDP Ack frame with the Idle Indication field equal to 0, the Duration field is set to the value obtained from the Duration/ID field of the frame that elicited the response minus the time, in microseconds, between the end of the PPDU carrying the frame that elicited the response and the end of the NDP Ack frame except when the eliciting frame is a PS-Poll frame in which case the Duration field can be set as described in 10.3.2.15 (NAV distribution).

In an NDP Ack frame with the Idle Indication field equal to 1, the Duration field is set to the duration of time, in milliseconds, during which an idle period is expected from the STA that elicited the response, starting from the end of NDP Ack frame response.

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In a TACK frame, the Duration/ID field is set to the value obtained from the Duration/ID field of the frame that elicited the response minus the time, in microseconds, between the end of the PPDU carrying the frame that elicited the response and the end of the PPDU carrying the TACK frame.

#### 9.2.5.7 Setting for other response frames

In any frame transmitted by a STA that is not the TXOP holder and is not specified by 9.2.5.1 (General) to 9.2.5.6 (Setting for control response frames), the Duration/ID field is set to the value obtained from the Duration/ID field of the frame that elicited the response minus the time, in microseconds, between the end of the PPDU carrying the frame that elicited the response and the end of the PPDU carrying the frame. If the frame is contained in an HE TB PPDU, the time is equal to SIFS plus the duration of the HE TB PPDU, where the duration of the HE TB PPDU is defined in Equation (27-147).(11ax)

## 9.3 Format of individual frame types

### 9.3.1 Control frames

#### 9.3.1.1 Format of Control frames

In the following descriptions, "immediately previous" frame means a frame whose reception concluded within the SIFS preceding the start of the current frame.

The Frame Control, Duration and Address 1 (RA) fields are present in all control frame subtypes. The Address 2 (TA) field is present in some control frame subtypes.

The subfields within the Frame Control field of Control frames carried in a non-S1G PPDU are set as shown in Figure 9-37 (Frame Control field subfield values within Control frames carried in a non-S1G PPDU).

| | B0 B1 | B2 B3 | B4 B7 | B8 | B9 | B10 | B11 | B12 | B13 | B14 | B15 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Protocol Version | Type (Control) | Subtype | To DS (0) | From DS (0) | More Frag (0) | Retry (0) | Power Man-age-ment | More Data | Protected Frame (0) | +HTC (0) |
| Bits: | 2 | 2 | 4 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

**Figure 9-37—Frame Control field subfield values within Control frames carried in a non-S1G PPDU**

In a Control frame carried in an S1G PPDU, when the Subtype subfield is not equal to 3 and not equal to 10, the format of the Frame Control field is shown in Figure 9-38 (Frame Control field format in Control frames carried in an S1G PPDU when Subtype subfield is not equal to 3 and not equal to 10).

| | B0 B1 | B2 B3 | B4 B7 | B8 B10 | B11 | B12 | B13 | B14 | B15 |
|---|---|---|---|---|---|---|---|---|---|
| | Protocol Version | Type | Subtype | Bandwidth Indication | Dynamic Indication | Power Manageme nt | More Data | Protected Frame | +HTC |
| Bits: | 2 | 2 | 4 | 3 | 1 | 1 | 1 | 1 | 1 |

**Figure 9-38—Frame Control field format in Control frames carried in an S1G PPDU when Subtype subfield is not equal to 3 and not equal to 10**


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In a Control frame carried in an S1G PPDU, when the Subtype subfield is equal to 3, the format of the Frame Control field is shown in Figure 9-39 (Frame Control field format in Control frames carried in an S1G PPDU when Subtype subfield is equal to 3).

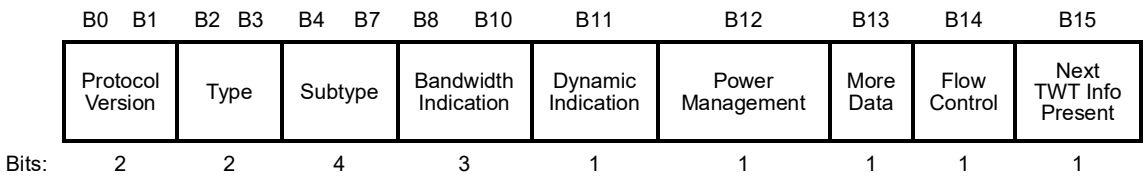


**Figure 9-39—Frame Control field format in Control frames carried in an S1G PPDU when Subtype subfield is equal to 3**

In a Control frame carried in an S1G PPDU, when the Subtype subfield is equal to 10, the format of the Frame Control field is shown in Figure 9-40 (Frame Control field format in Control frames carried in an S1G PPDU when Subtype subfield is equal to 10).

**Figure 9-40—Frame Control field format in Control frames carried in an S1G PPDU when Subtype subfield is equal to 10**

### 9.3.1.2 RTS frame format

The frame format for the RTS frame is defined in Figure 9-41 (RTS frame format).

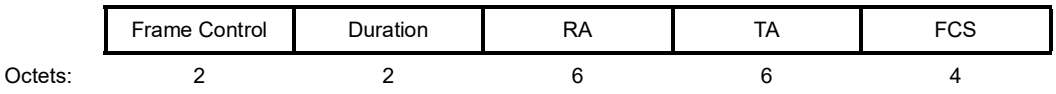


**Figure 9-41—RTS frame format**

The RA field of the RTS frame is the address of the STA that is the intended immediate recipient of a pending individually addressed frame.

The TA field is the address of the STA transmitting the RTS frame or the bandwidth signaling TA of the STA transmitting the RTS frame. In an RTS frame transmitted by a VHT STA or an HE STA(11ax) in a non-HT or non-HT duplicate format to another VHT STA or HE STA(11ax), the scrambling sequence carries the TXVECTOR parameters CH_BANDWIDTH_IN_NON_HT and DYN_BANDWIDTH_IN_NON_HT (see 10.3.2.7 (VHT and S1G RTS procedure)) and the TA field is a bandwidth signaling TA.

For all RTS frames sent by non-QoS STAs, the Duration field is the time, in microseconds, required to transmit the pending Data or Management frame, plus one CTS frame, plus one Ack frame, plus three SIFSs. If the calculated duration includes a fractional microsecond, that value is rounded up to the next higher integer. For RTS frames sent by QoS STAs, see 9.2.5 (Duration/ID field (QoS STA)).

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#### 9.3.1.3 CTS frame format

The frame format for the CTS frame is defined in Figure 9-42 (CTS frame format).

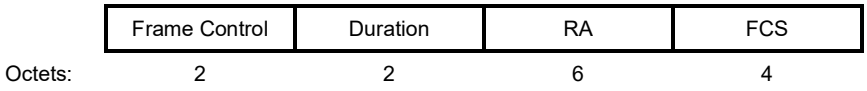


**Figure 9-42—CTS frame format**

If(11ax) the CTS frame is a response to an RTS frame, the RA field of the CTS frame is set to the address from the TA field of the RTS frame with the Individual/Group bit set to 0. If(11ax) the CTS frame is the first frame in a frame exchange, the RA field is set to the MAC address of the transmitter. If the CTS frame is a response to an MU-RTS Trigger frame, the RA field of the CTS frame is set to the address from the TA field of the MU-RTS Trigger frame.(11ax)

For all CTS frames transmitted by a non-QoS STA in response to RTS frames, the Duration field is the value obtained from the Duration field of the immediately previous RTS frame, minus the time, in microseconds, required to transmit the CTS frame and its SIFS. If the calculated duration includes a fractional microsecond, that value is rounded up to the next higher integer.

At a non-QoS STA, if the CTS frame is the first frame in the exchange and the pending Data or Management frame requires acknowledgment, the Duration field is the time, in microseconds, required to transmit the pending Data or Management frame, plus two SIFSs plus one Ack frame. At a non-QoS STA, if the CTS frame is the first frame in the exchange and the pending Data or Management frame does not require immediate acknowledgment, the Duration field is the time, in microseconds, required to transmit the pending Data or Management frame, plus one SIFS. If the calculated duration includes a fractional microsecond, that value is rounded up to the next higher integer.

For other CTS frame transmissions by a QoS STA, the Duration field is set as defined in 9.2.5 (Duration/ID field (QoS STA)).

A CTS-to-self frame is a CTS frame in which the RA field is equal to the transmitter's MAC address.

A CTS-to-AP frame is a CTS frame that is not transmitted in response to an RTS frame and in which the RA field is equal to the MAC address of the AP with which the STA is associated.

#### 9.3.1.4 Ack frame format

The frame format for the Ack frame is defined in Figure 9-43 (Ack frame format).

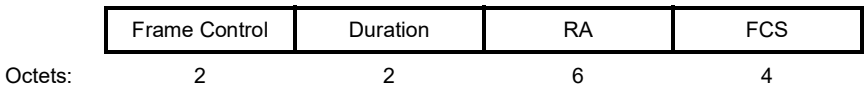


**Figure 9-43—Ack frame format**

The RA field of the Ack frame is the nonbandwidth signaling TA from the Address 2 field of the immediately previous individually addressed Data, Management, BlockAckReq, BlockAck, or PS-Poll frames.

For Ack frames sent by non-QoS STAs, if the More Fragments bit was equal to 0 in the Frame Control field of the immediately previous individually addressed Data or Management frame, the Duration field is set to 0. In other Ack frames sent by non-QoS STAs, the Duration field is the value obtained from the


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Duration/ID field of the immediately previous Data, Management, BlockAckReq, or BlockAck frame minus the time, in microseconds, required to transmit the Ack frame and its SIFS. If the calculated duration includes a fractional microsecond, that value is rounded up to the next higher integer.

In all other Ack frames, the Duration field is specified by 9.2.5 (Duration/ID field (QoS STA)).

#### 9.3.1.5 PS-Poll frame format

##### 9.3.1.5.1 General

The frame format for the PS-Poll frame is defined in Figure 9-44 (PS-Poll frame format).

| | Frame Control | Duration/ID | BSSID(RA) | TA | FCS |
|---|---|---|---|---|---|
| Octets: | 2 | 2 | 6 | 6 | 4 |

**Figure 9-44—PS-Poll frame format**

The BSSID (RA) field is set to the address of the STA contained in the AP. The TA field(#3522) is the address of the STA transmitting the frame or a bandwidth signaling TA. In a PS-Poll frame transmitted by a VHT STA or an HE STA(11ax) in a non-HT or non-HT duplicate format and where the scrambling sequence carries the TXVECTOR parameter CH_BANDWIDTH_IN_NON_HT, the TA field(#3522) is a bandwidth signaling TA.

##### 9.3.1.5.2 Non-BDT variant of the PS-Poll frame format

The Duration/ID field contains the AID value assigned to the STA transmitting the frame by the AP in the (Re)Association Response frame that established that STA's current association, with the two MSBs set to 1.

##### 9.3.1.5.3 BDT variant of the PS-Poll frame format

A PS-Poll frame with the Duration/ID field that contains a duration value as described in 9.2.5 (Duration/ID field (QoS STA)) is a BDT variant of the PS-Poll frame and is referred to as PS-Poll+BDT frame.

The Poll Type field in the Frame Control field of the PS-Poll+BDT frame is set to 0.

Bit 15 of the Duration/ID field of a PS-Poll+BDT frame is set to 0.

A non-S1G STA does not transmit PS-Poll+BDT frames.

#### 9.3.1.6 CF-End frame format

The frame format for the CF-End frame is defined in Figure 9-45 (CF-End frame format).

| | Frame Control | Duration | RA | BSSID(TA) | FCS |
|---|---|---|---|---|---|
| Octets: | 2 | 2 | 6 | 6 | 4 |

**Figure 9-45—CF-End frame format**

When transmitted by a non-DMG and non-S1G STA, the Duration field is set to 0. When transmitted by a DMG STA, the Duration field is set to the time required to complete the CF-End truncation sequence of which it is part (see 10.38.8 (Dynamic truncation of service period)): Duration = ($i$ – 1) × (TXTIME(CF-

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End) + SIFS), where *i* is in the range 1 to 3 and indicates the order of the CF-End frame in the truncation sequence in the reverse direction (i.e., *i*=1 corresponds to the last CF-End frame in the sequence). When transmitted by an S1G STA, the Duration field is set to either 0 or a truncated time as described in 10.23.2.9 (TXOP limits).

When transmitted by a non-DMG STA, the RA field is the broadcast address. When transmitted by a DMG STA, the RA field is the MAC address of the STA that is the intended immediate recipient of the individually addressed Data or Management frame, or the broadcast address.

If(11ax) transmitted by a non-DMG STA, the BSSID (TA) field is the address of the STA contained in the AP except that the Individual/Group bit of the BSSID (TA) field is set to 1 in a CF-End frame transmitted by a VHT STA to a VHT AP or an HE STA to an HE AP(11ax) in a non-HT or non-HT duplicate format to indicate that the scrambling sequence carries the TXVECTOR parameter CH_BANDWIDTH_IN_NON_HT. If(11ax) transmitted by a DMG STA, the TA field is the MAC address of the STA transmitting the frame.

### 9.3.1.7 BlockAckReq frame format

#### 9.3.1.7.1 Overview

The frame format of the BlockAckReq frame is defined in Figure 9-46 (BlockAckReq frame format).

| | Frame Control | Duration | RA | TA | BAR Control | BAR Information | FCS |
|---|---|---|---|---|---|---|---|
| Octets: | 2 | 2 | 6 | 6 | 2 | variable | 4 |

**Figure 9-46—BlockAckReq frame format**

The Duration field value is set as defined in 9.2.5 (Duration/ID field (QoS STA)).

The RA field of the BlockAckReq frame is the address of the recipient STA.

The TA field(#3522) is the address of the STA transmitting the BlockAckReq frame or a bandwidth signaling TA. In a BlockAckReq frame transmitted by a VHT STA or an HE STA(11ax) in a non-HT or non-HT duplicate format and where the scrambling sequence carries the TXVECTOR parameter CH_BANDWIDTH_IN_NON_HT, the TA field(#3522) is a bandwidth signaling TA.

The BAR (for block acknowledgment request) Control field is shown in Figure 9-47 (BAR Control field format(11ax)).

| | B0 | B1 B4 | B5 B11 | B12 B15 |
|---|---|---|---|---|
| | Reserved | BAR Type | Reserved | TID_INFO |
| Bits: | 1 | 4 | 7 | 4 |

**Figure 9-47—BAR Control field format(11ax)**


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(11ax)The BAR Type subfield indicates the BlockAckReq frame variant, as defined in Table 9-36 (BlockAckReq frame variant encoding(11ax)).

**Table 9-36—BlockAckReq frame variant encoding(11ax)**

| BAR Type | BlockAckReq frame variant |
|---|---|
| 0 | Reserved |
| 1 | Extended Compressed |
| 2 | Compressed |
| 3 | Multi-TID |
| 4–5 | Reserved |
| 6 | GCR |
| 7–9 | Reserved |
| 10 | GLK-GCR |
| 11–15 | Reserved |

DMG STAs use only the Compressed BlockAckReq variant and the Extended Compressed BlockAckReq variant.

The meaning of the TID_INFO subfield of the BAR Control field depends on the BlockAckReq frame variant type. The meaning of this subfield is explained within the subclause for each of the BlockAckReq frame variants.

The meaning of the BAR Information field of the BlockAckReq frame depends on the BlockAckReq frame variant type. The meaning of this field is explained within the subclause for each of the BlockAckReq frame variants.

NOTE—Reference to "a BlockAckReq" frame without any other qualification from other subclauses applies to any of the variants, unless specific exclusions are called out.

### 9.3.1.7.2 Compressed BlockAckReq variant

The TID_INFO subfield of the BAR Control field of the Compressed BlockAckReq frame contains the TID for which a BlockAck frame is requested.

The BAR Information field of the Compressed BlockAckReq frame contains the Block Ack Starting Sequence Control subfield, as shown in Figure 9-48 (Block Ack Starting Sequence Control subfield format). The Starting Sequence Number subfield of the Block Ack Starting Sequence Control subfield contains the sequence number of the first MSDU or A-MSDU for which this BlockAckReq frame is sent. The Fragment Number subfield of the Block Ack Starting Sequence Control subfield is set to 0.(#7201)

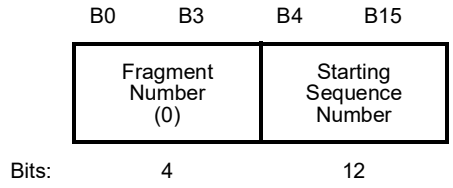


**Figure 9-48—Block Ack Starting Sequence Control subfield format**

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#### 9.3.1.7.3 Extended Compressed BlockAckReq variant

The TID_INFO subfield of the BAR Control field of the Extended Compressed BlockAckReq frame contains the TID for which a BlockAck frame is requested.

The BAR Information field of the Extended Compressed BlockAckReq frame contains the Block Ack Starting Sequence Control subfield, as shown in Figure 9-48 (Block Ack Starting Sequence Control subfield format). The Starting Sequence Number subfield of the Block Ack Starting Sequence Control subfield contains the sequence number of the first MSDU or A-MSDU for which this BlockAckReq frame is sent. The Fragment Number subfield of the Block Ack Starting Sequence Control subfield is set to 0(#4251).

#### 9.3.1.7.4 Multi-TID BlockAckReq variant(#6599)

The TID_INFO subfield of the BAR Control field of the Multi-TID BlockAckReq frame determines the number of TIDs present in the Multi-TID BlockAckReq frame as given by TID_INFO + 1, e.g., a 2 in the TID_INFO subfield means that three TID values are present in the Multi-TID BlockAckReq frame's BAR Information field.

The BAR Information field of the Multi-TID BlockAckReq frame comprises multiple sets of Per TID Info subfields and Block Ack Starting Sequence Control subfields, as shown in Figure 9-49 (BAR Information field format (Multi-TID BlockAckReq)(#6599)). The Per TID Info subfield is shown in Figure 9-50 (Per TID Info subfield format(#6599)). The Block Ack Starting Sequence Control subfield is shown in Figure 9-48 (Block Ack Starting Sequence Control subfield format). The Starting Sequence Number subfield of the Block Ack Starting Sequence Control subfield contains the sequence number of the first MSDU or A MSDU for which this BlockAckReq frame is sent. The Fragment Number subfield of the Block Ack Starting Sequence Control subfield is set to 0.

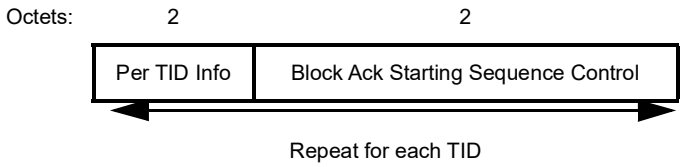


**Figure 9-49—BAR Information field format (Multi-TID BlockAckReq)(#6599)**

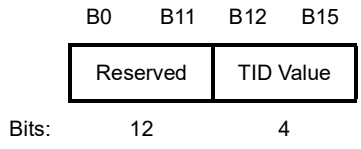


**Figure 9-50—Per TID Info subfield format(#6599)**

#### 9.3.1.7.5 GCR BlockAckReq variant

The TID_INFO subfield of the BAR Control field of the GCR BlockAckReq frame is set to 0.

The BAR Information field of the GCR BlockAckReq frame contains the Block Ack Starting Sequence Control subfield and GCR Group Address subfield, as shown in Figure 9-51 (BAR Information field format (GCR BlockAckReq)). The Block Ack Starting Sequence Control subfield is shown in Figure 9-48 (Block Ack Starting Sequence Control subfield format). The Starting Sequence Number subfield of the Block Ack Starting Sequence Control subfield contains the sequence number of the first MSDU or A-MSDU for which


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this BlockAckReq frame is sent. The Fragment Number subfield of the Block Ack Starting Sequence Control subfield is set to 0.

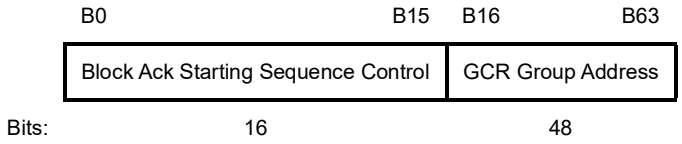


**Figure 9-51—BAR Information field format (GCR BlockAckReq)**

The GCR Group Address subfield contains the MAC address of the group for which reception status is being requested.

#### 9.3.1.7.6 GLK-GCR BlockAckReq variant

For the BlockAckReq(#1577) variant, the TID_INFO subfield in the BAR Control field in the GLK-GCR BlockAckReq frame is 0.

The BAR Information field in the GLK-GCR BlockAckReq frame contains the Block Ack Starting Sequence Control subfield as shown in Figure 9-48 (Block Ack Starting Sequence Control subfield format). The Starting Sequence Number subfield in the Block Ack Starting Sequence Control subfield contains the sequence number of the first MSDU or A-MSDU for which this GLK-GCR BlockAckReq frame is sent. The Fragment Number subfield in the Block Ack Starting Sequence Control subfield is 0.

### 9.3.1.8 BlockAck frame format

#### 9.3.1.8.1 Overview

The frame format of the BlockAck frame is defined in Figure 9-52 (BlockAck frame format).

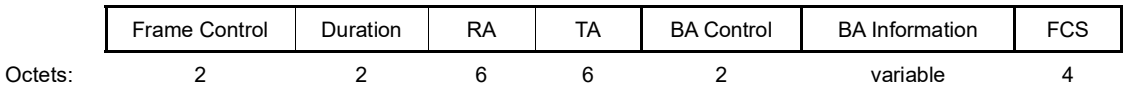


**Figure 9-52—BlockAck frame format**

The Duration field value is set as defined in 9.2.5 (Duration/ID field (QoS STA)).

The RA field of a BlockAck frame that is not a Multi-STA BlockAck variant is set to the TA field of the soliciting frame or the address of the recipient STA from which Data frames are acknowledged. The RA field of a Multi-STA BlockAck frame is set as described in Equation (9.3.1.8.6).(11ax)

The TA field(#3522) is the address of the STA transmitting the BlockAck frame.

The BA Control field is defined in Figure 9-53 (BA Control field format(11ax)(11ay)).

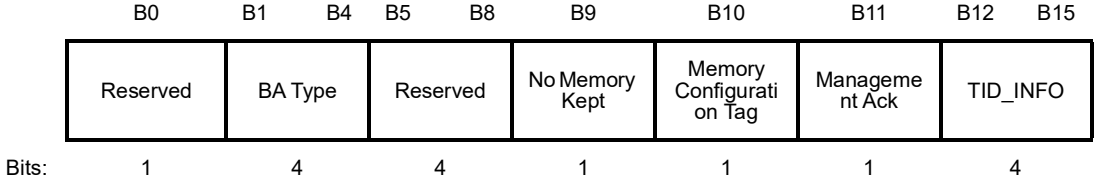


**Figure 9-53—BA Control field format(11ax)(11ay)**

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(11ax)The BA Type subfield in the BA Control field indicates the BlockAck frame variant, as defined in (#6291) Table 9-37 (BlockAck frame variant encoding(11ax)).

**Table 9-37—BlockAck frame variant encoding(11ax)**

| BA Type | BlockAck frame variant |
|---|---|
| 0 | Reserved |
| 1 | Extended Compressed |
| 2 | Compressed |
| 3 | Reserved(#6599) |
| 4–5 | Reserved |
| 6 | GCR |
| 7(11ay) | EDMG Multi-TID |
| 8(11ay) | EDMG Compressed |
| 9(11ay) | Reserved |
| 10 | GLK-GCR |
| 11 | Multi-STA |
| 12–15 | Reserved |

NOTE—Reference to "a BlockAck" frame without any other qualification from other subclauses applies to any of the variants, unless specific exclusions are called out.

The GCR BlockAck frame is used in response to a GCR BlockAckReq frame, and the GLK-GCR BlockAck frame is used in response to a GLK-GCR BlockAckReq frame.(11ax)

(11ay)An EDMG STA sets the No Memory Kept subfield to 1 to indicate that the free memory space indicated in the last RBUFCAP subfield might not be kept at the start of the next frame exchange sequence; otherwise, if set to 0, free memory space indicated by the RBUFCAP subfield is kept by the receiver for the next frame exchange sequence for the corresponding TID(s). The No Memory Kept subfield is reserved if transmitted by a STA that is not an EDMG STA.

(11ay)For an EDMG STA, the Memory Configuration Tag subfield indicates one out of two memory configurations as indicated in Memory Configuration Tag field in the recipient's EDMG Flow Control Extension Configuration element (9.4.2.276 (EDMG Flow Control Extension Configuration element(11ay))). For other types of STAs, this subfield is reserved.

(11ay)The Management Ack subfield is set to 1 to indicate that a frame of type Management and subtype that is not Action No Ack is acknowledged. This subfield is reserved if the BlockAck variant used is not the EDMG Multi-TID BlockAck variant.

The meaning of the TID_INFO subfield of the BA Control field depends on the BlockAck frame variant type. The meaning of this subfield is explained within the subclause for each of the BlockAck frame variants.

The meaning of the BA Information field depends on the BlockAck frame variant type. The meaning of this field is explained within the subclause for each of the BlockAck frame variants.


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#### 9.3.1.8.2 Compressed BlockAck variant

The TID_INFO subfield of the BA Control field of the Compressed BlockAck frame contains the TID for which this BlockAck frame is sent.

The BA Information field of the Compressed BlockAck frame (11ax)is shown in Figure 9-54 (BA Information field format (Compressed BlockAck)(11ax)). The Block Ack Starting Sequence Control subfield is shown in Figure 9-48 (Block Ack Starting Sequence Control subfield format). The Starting Sequence Number subfield of the Block Ack Starting Sequence Control subfield contains the sequence number of the first MSDU or A-MSDU for which this BlockAck frame is sent. This subfield is defined in 10.25.6.5 (Generation and transmission of BlockAck frames by an HT STA, DMG STA, or S1G STA).(11ax)

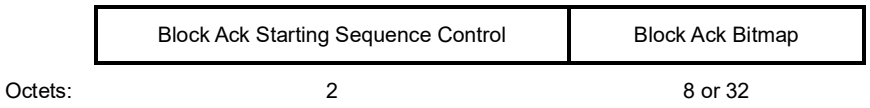


**Figure 9-54—BA Information field format (Compressed BlockAck)(11ax)**

(11ax)The Fragment Number subfield of the Block Ack Starting Sequence Control field is set as defined in Table 9-38 (Fragment Number subfield encoding for the Compressed BlockAck variant(11ax)). The Fragment Number subfield of the Block Ack Starting Sequence Control subfield is set to all 0s if the Compressed BlockAck frame is sent to or from a non-HE STA.

**Table 9-38—Fragment Number subfield encoding for the Compressed BlockAck variant(11ax)**

| Fragment Number subfield | | | Fragmentation level 3 (ON/OFF) | Block Ack Bitmap subfield length (octets) | Maximum number of MSDUs/A-MSDUs that can be acknowledged |
|---|---|---|---|---|---|
| B3 | B2–B1 | B0 | | | |
| 0 | 0 | 0 | OFF | 8 | 64 |
| 0 | 1 | 0 | | Reserved | Reserved |
| 0 | 2 | 0 | | 32 | 256 |
| 0 | 3 | 0 | | Reserved | Reserved |
| 0 | 0 | 1 | ON | 8 | 16 |
| 0 | 1 | 1 | | Reserved | Reserved |
| 0 | 2 | 1 | | 32 | 64 |
| 0 | 3 | 1 | | Reserved | Reserved |
| 1 | Any | Any | | Reserved | Reserved |

NOTE—A Compressed BlockAck frame with B0 of the Fragment Number subfield set to 1 is not sent to an HE STA whose Dynamic Fragmentation Support subfield in the HE Capabilities element it transmits is not set to 3 (see 26.3 (Fragmentation and defragmentation)).

(11ax)If B0 of the Fragment Number subfield is 0, the Block Ack Bitmap subfield of the BA Information field of the Compressed BlockAck frame indicates the receive status of up to 64 or 256 MSDUs and/or A-MSDUs depending upon the value of B2–B1 in the Fragment Number subfield as shown in Table 9-38

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(Fragment Number subfield encoding for the Compressed BlockAck variant(11ax)). Each bit that is equal to 1 in the compressed Block Ack Bitmap subfield acknowledges the reception of a single MSDU or A-MSDU in the order of sequence number, with the first bit of the Block Ack Bitmap subfield corresponding to the MSDU (or fragment thereof) or A-MSDU (or fragment thereof) with the sequence number that matches the Starting Sequence Number subfield of the Block Ack Starting Sequence Control subfield.

(11ax)If B0 of the Fragment Number subfield is 1, the Block Ack Bitmap subfield of the BA Information field of the Compressed BlockAck frame indicates the receive status of up to 16 or 64 MSDUs and/or A-MSDUs depending upon the value B2–B1 in the Fragment Number subfield as shown in Table 9-38 (Fragment Number subfield encoding for the Compressed BlockAck variant(11ax)). If bit position *n* of the Block Ack Bitmap subfield is 1, it acknowledges receipt of an MPDU with sequence number value *SN* and fragment number value *FN* with $n = 4 \times (SN - SSN) + FN$, where *SSN* is the value of the Starting Sequence Number subfield of the Block Ack Starting Sequence Control subfield and the operations on the sequence numbers are performed modulo 4096. If bit position *n* of the Block Ack Bitmap subfield is 0, it indicates that the MPDU has not been received.

NOTE—If the B0 of the Fragment Number subfield is equal to 1, then the Block Ack Bitmap subfield is split into (Block Ack Bitmap subfield length)/4 subbitmaps, each of which indicates receive status for 4 fragments of each of the MSDUs or A-MSDUs as indicated in Table 9-38 (Fragment Number subfield encoding for the Compressed BlockAck variant(11ax)).(#6599)

#### 9.3.1.8.3 Extended Compressed BlockAck variant

The TID_INFO subfield of the BA Control field of the Compressed BlockAck frame contains the TID for which a BlockAck frame is requested.

The BA Information field of the Extended Compressed BlockAck frame is shown in Figure 9-55 (BA Information field format (Extended Compressed BlockAck)). The Block Ack Starting Sequence Control subfield is shown in Figure 9-48 (Block Ack Starting Sequence Control subfield format). The Starting Sequence Number subfield of the Block Ack Starting Sequence Control subfield contains the sequence number of the first MSDU or A-MSDU for which this BlockAck frame is sent. This subfield is defined in 10.25.6.5 (Generation and transmission of BlockAck frames by an HT STA, DMG STA, or S1G STA). The Fragment Number subfield of the Block Ack Starting Sequence Control subfield is set to 0.

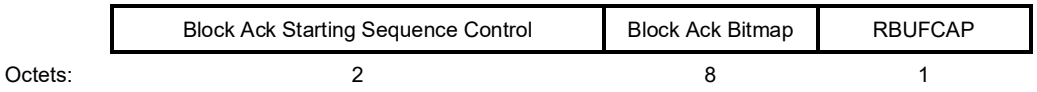


**Figure 9-55—BA Information field format (Extended Compressed BlockAck)**

The Block Ack Bitmap subfield of the BA Information field of the Extended Compressed BlockAck frame is used to indicate the received status of up to 64 entries, where each entry represents an MSDU or an A-MSDU. Each bit that is set to 1 in the Block Ack Bitmap subfield acknowledges the reception of a single MSDU or A-MSDU in the order of sequence number. The first bit of the Block Ack Bitmap subfield corresponds to the MSDU or A-MSDU with the sequence number that matches the Starting Sequence Number subfield of the Block Ack Starting Sequence Control subfield.

The RBUFCAP field contains an unsigned integer that is the number of MPDU buffers available to store received MPDUs at the time of transmission of the Extended Compressed BlockAck frame (10.41.9 (CDMG enhanced beam tracking)).

#### 9.3.1.8.4 GCR Block Ack variant

The TID_INFO subfield of the BA Control field of the GCR BlockAck frame contains the TID for which this BlockAck frame is sent.


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The BA Information field of the GCR BlockAck frame comprises the Block Ack Starting Sequence Control, GCR Group Address, and the Block Ack Bitmap subfields, as shown in Figure 9-56 (BA Information field format (GCR BlockAck)). The Block Ack Starting Sequence Control subfield is shown in Figure 9-48 (Block Ack Starting Sequence Control subfield format). The Starting Sequence Number subfield of the Block Ack Starting Sequence Control subfield contains the sequence number of the first A-MSDU for which this BlockAck frame is sent. This subfield is defined in 10.25.8 (GCR and GLK-GCR block ack). The Fragment Number subfield of the Block Ack Starting Sequence Control subfield is set to 0.

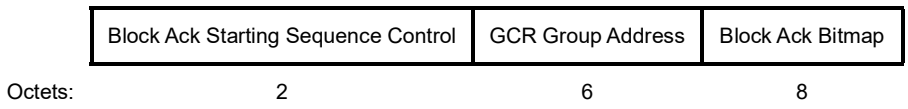


**Figure 9-56—BA Information field format (GCR BlockAck)**

The GCR Group Address subfield is set to the value from the Group Address subfield of the GCR BAR Information field in the BlockAckReq frame to which the BlockAck frame is sent in response. If the BlockAck frame is sent in response to a GCR MU-BAR Trigger frame, the GCR Group Address subfield is set to the value from the RA field in the GCR MU-BAR Trigger frame.(11ax)

The Block Ack Bitmap subfield is used to indicate the received status of up to 64 entries, where each entry represents an MSDU or an A-MSDU. Each bit that is equal to 1 in the Block Ack Bitmap subfield acknowledges the reception of a single MSDU or A-MSDU in the order of sequence number, with the first bit of the Block Ack Bitmap subfield corresponding to the MSDU or A-MSDU with the sequence number that matches the Starting Sequence Number subfield of the Block Ack Starting Sequence Control subfield.

#### 9.3.1.8.5 GLK-GCR BlockAck variant

The TID_INFO subfield in the BA Control field in the GLK-GCR BlockAck frame contains the TID for which this BlockAck frame is sent.

The BA Information field in the GLK-GCR BlockAck frame comprises the Block Ack Starting Sequence Control and the Block Ack Bitmap subfields, as shown in Figure 9-57 (BA Information field format (GLK-GCR BlockAck)). The Block Ack Starting Sequence Control subfield is shown in Figure 9-57 (BA Information field format (GLK-GCR BlockAck)) The Starting Sequence Number subfield in the Block Ack Starting Sequence Control subfield contains the sequence number of the first A-MSDU for which this BlockAck frame is sent. This subfield is defined in 10.25.8 (GCR and GLK-GCR block ack). The Fragment Number subfield in the Block Ack Starting Sequence Control subfield is 0.

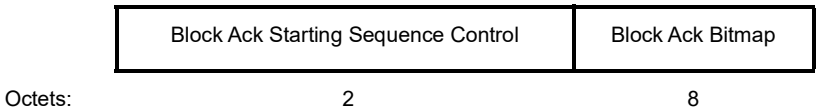


**Figure 9-57—BA Information field format (GLK-GCR BlockAck)**

The Block Ack Bitmap subfield is used to indicate the received status of up to 64 MSDUs and A-MSDUs. Each bit that is equal to 1 in the Block Ack Bitmap subfield acknowledges the reception of a single MSDU or A-MSDU in the order of sequence number, with the first bit of the Block Ack Bitmap subfield corresponding to the MSDU or A-MSDU with the sequence number that matches the Starting Sequence Number subfield in the Block Ack Starting Sequence Control subfield.

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#### 9.3.1.8.6 Multi-STA BlockAck variant(11ax)

The Multi-STA BlockAck frame is supported if either UL MU or multi-TID A-MPDU operation is supported and acknowledges MPDUs carried in an HE TB PPDU or multi-STA multi-TID, multi-STA single-TID, or single-STA multi-TID A-MPDUs.

An HE AP that sends a Multi-STA BlockAck frame where the Per AID TID Info fields are addressed to more than one STA sets the RA field to the broadcast address. An HE AP that sends a Multi-STA BlockAck frame where the Per AID TID Info fields are all addressed to a single recipient STA and that is sent in response to an HE TB PPDU sets the RA field of the Multi-STA BlockAck frame to either the address of the recipient STA or to the broadcast address. An HE AP that sends a Multi-STA BlockAck frame where the Per AID TID Info fields are all addressed to a single recipient STA and that is not sent in response to an HE TB PPDU sets the RA field of the Multi-STA BlockAck frame to the address of the recipient STA.

A non-AP HE STA sets the RA field to the TA field of the soliciting frame or to the address of the recipient STA whose Data or Management frames are acknowledged.

The TID_INFO subfield of the BA Control field of the Multi-STA BlockAck frame is reserved.

The BA Information field of the Multi-STA BlockAck frame comprises one or more Per AID TID Info subfields as defined in Figure 9-58 (BA Information field format (Multi-STA BlockAck)(11ax)).

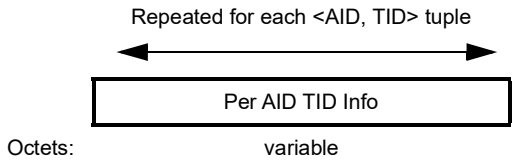


**Figure 9-58—BA Information field format (Multi-STA BlockAck)(11ax)**

The AID TID Info subfield is shown in Figure 9-59 (AID TID Info subfield format(11ax)).

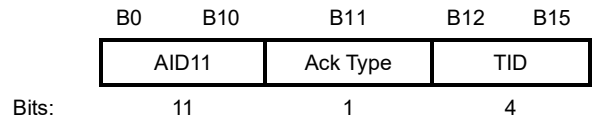


**Figure 9-59—AID TID Info subfield format(11ax)**

The AID11 subfield carries the 11 LSBs of the AID of the non-AP STA for which the Per AID TID Info subfield is intended. The format of the Per AID TID Info subfield depends on the value of the AID11 subfield. If the Multi-STA BlockAck frame is sent to an AP, the AID11 subfield is set to 0. A value of 2045 in the AID11 subfield is used as an identifier for any unassociated STA. If the AID11 subfield is set to 2045, then the Ack Type subfield and TID subfield are set to 0 and 15, respectively.

NOTE 1—More than one Per AID TID Info subfield with the same value in the AID11 subfield but different values in the TID subfield can be present in the Multi-STA BlockAck frame.


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If the AID11 subfield of the AID TID Info subfield is not 2045, then the Per AID TID Info subfield has the format shown in Figure 9-60 (Per AID TID Info subfield format if the AID11 subfield is not 2045(11ax)).

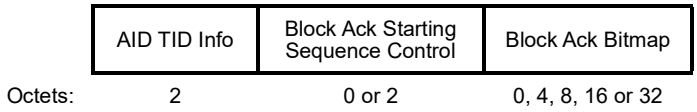


**Figure 9-60—Per AID TID Info subfield format if the AID11 subfield is not 2045(11ax)**

If the AID11 subfield is not 2045, then the context and the presence of each optional subfield in a Per AID TID Info subfield in a Multi-STA BlockAck frame is defined in Table 9-39 (Context of the Per AID TID Info subfield and presence of optional subfields if the AID11 subfield is not 2045(11ax)).

**Table 9-39—Context of the Per AID TID Info subfield and presence of optional subfields if the AID11 subfield is not 2045(11ax)**

| Ack Type subfield values | TID subfield values | Presence of Block Ack Starting Sequence Control subfield and Block Ack Bitmap subfields | Context of a Per AID TID Info subfield in a Multi-STA BlockAck frame |
|---|---|---|---|
| 0 | 0–7 | Present | Block acknowledgment context:<br>Sent as an acknowledgment to QoS Data frames that solicit a BlockAck frame response or to a BlockAckReq frame. |
| 1 | 0–7 | Not present | Acknowledgment context:<br>Sent as an acknowledgment to a QoS Data or QoS Null frame that solicits an Ack frame response. |
| 0 or 1 | 8–13 | N/A | Reserved |
| 0 | 14 | N/A | Reserved |
| 1 | 14 | Not present | All ack context:<br>Sent as an acknowledgment to an A-MPDU that contains an MPDU that solicits an immediate response and all MPDUs contained in the A-MPDU are received successfully. |
| 0 | 15 | N/A | Reserved |
| 1 | 15 | Not present | Management/PS-Poll frame acknowledgment context:<br>Sent as an acknowledgment to a Management or PS-Poll frame. |
| NOTE 1—Additional rules for acknowledgment, block acknowledgment and the all ack context are defined in 26.4.2 (Acknowledgment context in a Multi-STA BlockAck frame) for a multi-TID A-MPDU.<br>NOTE 2—As HE STAs do not use HCCA (see 10.23.1 (General)), TID values from 8 to 15 are not used in QoS Data frames. | | | |

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If the Ack Type subfield is 0, the Fragment Number subfield encoding indicates the length of the BlockAck bitmap subfield as defined in Table 9-40 (Fragment Number subfield encoding for the Multi-STA BlockAck variant (11ax)).

**Table 9-40—Fragment Number subfield encoding for the Multi-STA BlockAck variant (11ax)**

| Fragment Number subfield | | | Fragmentation level 3 (ON/OFF) | Block Ack Bitmap subfield length (octets) | Maximum number of MSDUs/A-MSDUs that can be acknowledged |
|---|---|---|---|---|---|
| B3 | B2–B1 | B0 | | | |
| 0 | 0 | 0 | OFF | 8 | 64 |
| 0 | 1 | 0 | | 16 | 128 |
| 0 | 2 | 0 | | 32 | 256 |
| 0 | 3 | 0 | | 4 | 32 |
| 0 | 0 | 1 | ON | 8 | 16 |
| 0 | 1 | 1 | | 16 | 32 |
| 0 | 2 | 1 | | 32 | 64 |
| 0 | 3 | 1 | | 4 | 8 |
| 1 | Any | Any | | Reserved | Reserved |

NOTE—A Multi-STA BlockAck frame with B0 of the Fragment Number subfield set to 1 cannot be sent to an HE STA, unless the HE Capabilities element received from the HE STA has the Dynamic Fragmentation Support subfield equal to 3 (see 26.3 (Fragmentation and defragmentation)).

If B0 of the Fragment Number subfield of the Block Ack Starting Sequence Control subfield is 0, the BA Information field of the Multi-STA BlockAck frame contains an 8-octet, 16-octet, 32-octet, or 4-octet Block Ack Bitmap subfield depending on B2–B1 of the Fragment Number subfield as defined in Table 9-40 (Fragment Number subfield encoding for the Multi-STA BlockAck variant (11ax)) indicating the receive status of up to 64, 128, 256, or 32 MSDUs (or fragments thereof) and/or A-MSDUs (or fragments thereof), respectively. Each bit that is equal to 1 in the Block Ack Bitmap subfield acknowledges the reception of a single MSDU (or fragment thereof) or A-MSDU (or fragment thereof) in the order of sequence number with the first bit of the Block Ack Bitmap subfield corresponding to the MSDU or A-MSDU with the sequence number that matches the value of the Starting Sequence Number subfield of the Block Ack Starting Sequence Control subfield.

If B0 of the Fragment Number subfield of the Block Ack Starting Sequence Control subfield is 1, the Block Ack Bitmap subfield of the BA Information field of the Multi-STA BlockAck frame indicates the receive status of up to 16, 32, 64, or 8 MSDUs and/or A-MSDUs depending on B2–B1 of the Fragment Number subfield as shown in Table 9-40 (Fragment Number subfield encoding for the Multi-STA BlockAck variant (11ax)). If bit position $n$ of the Block Ack Bitmap subfield is 1, it acknowledges receipt of an MPDU with sequence number value $SN$ and fragment number value $FN$ with $n = 4 \times (SN - SSN) + FN$, where $SSN$ is the value of the Starting Sequence Number subfield of the Block Ack Starting Sequence Control subfield and the operations on the sequence numbers are performed modulo 4096. If bit position $n$ of the Block Ack Bitmap subfield is 0, it indicates that the MPDU has not been received.

NOTE 2—If B0 of the Fragment Number subfield is 1, then the Block Ack Bitmap subfield is split into (Block Ack Bitmap subfield length)/4 subbitmaps, each of which indicates receive status for 4 fragments of each of the MSDUs or A-MSDUs as indicated in Table 9-40 (Fragment Number subfield encoding for the Multi-STA BlockAck


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variant (11ax)). For an A-MSDU, only the first bit of the subbitmap is used if fragmentation is not allowed in an A-MSDU.

If the AID11 subfield of the AID TID Info subfield is 2045, then the Per AID TID Info subfield has the format shown in Figure 9-61 (Per AID TID Info subfield format if the AID11 subfield is 2045(11ax)), where the RA subfield indicates the MAC address of an unassociated STA for which the Per AID TID Info subfield is intended.

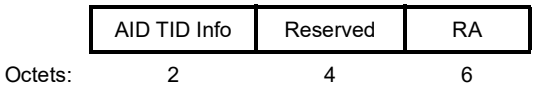


**Figure 9-61—Per AID TID Info subfield format if the AID11 subfield is 2045(11ax)**

NOTE 3—An associated non-AP HE STA that receives a Multi-STA BlockAck frame as a response from its AP and does not support the UORA procedure ignores the 10 octets following the AID TID Info subfield that are the remainder of the Per AID TID Info subfield if the AID11 subfield is 2045 and parses the following Per AID TID Info subfields if any.

### 9.3.1.8.7 EDMG Compressed BlockAck variant(11ay)

The TID_INFO subfield of the BA Control field of the EDMG Compressed BlockAck frame contains the TID for which a BlockAck frame is requested.

The BA Information field of the EDMG Compressed BlockAck frame variant is formatted as indicated in Figure 9-62 (BA Information field format (EDMG Compressed BlockAck)(11ay)).

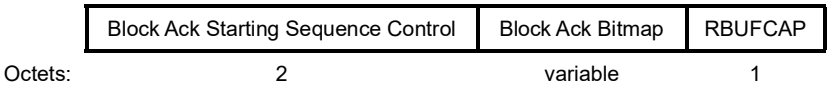


**Figure 9-62—BA Information field format (EDMG Compressed BlockAck)(11ay)**

For a block ack agreement that does not use segmentation and reassembly (see 10.69 (DMG segmentation and reassembly operation(11ay))), the Starting Sequence Number subfield of the Block Ack Starting Sequence Control subfield contains the sequence number of the first MSDU or A-MSDU for which this BlockAck frame is sent. The value of this subfield is defined in 10.25.6.5 (Generation and transmission of BlockAck frames by an HT STA, DMG STA, or S1G STA). The Fragment Number subfield of the Block Ack Starting Sequence Control subfield is reserved.

The Block Ack Bitmap subfield of the BA Information field is used to indicate the received status of MSDUs, where each entry represents an MSDU or an A-MSDU. The size of the Block Ack Bitmap subfield is negotiated during the block ack agreement(#6171) establishment (see 10.25 (Block acknowledgment (block ack))). Each bit that is set to 1 in the Block Ack Bitmap subfield acknowledges the successful reception of a single MSDU or A-MSDU in the order of sequence number. The first bit of the Block Ack Bitmap subfield corresponds to the MSDU or A-MSDU with the sequence number that matches the value of the Starting Sequence Number subfield of the Block Ack Starting Sequence Control subfield.

The RBUFCAP subfield is defined in Table 9-41 (RBUFCAP subfield encoding for the EDMG Compressed BlockAck variant(11ay)).

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**Table 9-41—RBUFCAP subfield encoding for the EDMG Compressed BlockAck variant(11ay)**

| RBUFCAP value | RBUFCAP value name | Definition |
|---|---|---|
| 0 | Receiver Buffer Empty | Indicates that the recipient's memory is not less than the length indicated by the Maximum A-MPDU Length Exponent subfield (Table 9-384 (A-MPDU Parameters field definition(11ay))). |
| 255 | Receiver Buffer Full | Indicates no space in the recipient's memory. |
| 1–254 | Receiver Buffer Available | Indicates the size of recipient's current memory that the originator can use to transmit MPDUs to the recipient; measured in units indicated by the Buffer Unit Size field (9.4.2.276 (EDMG Flow Control Extension Configuration element(11ay))). |

### 9.3.1.8.8 EDMG Multi-TID BlockAck variant(11ay)

The TID_INFO subfield of the BA Control field of the EDMG Multi-TID BlockAck frame contains the number of TIDs minus one for which information is reported in the BA Information field. For example, a value of two in the TID_INFO subfield means that information for three TIDs is present in the frame.

The BA Information field of the EDMG Multi-TID BlockAck frame comprises one or more instances of the Per TID Info, Block Ack Starting Sequence Control, Block Ack Bitmap subfields and RBUFCAP subfield. The BA Information field is formatted as indicated in Figure 9-63 (BA Information field format (EDMG Multi-TID BlockAck)(11ay)(#1348)).

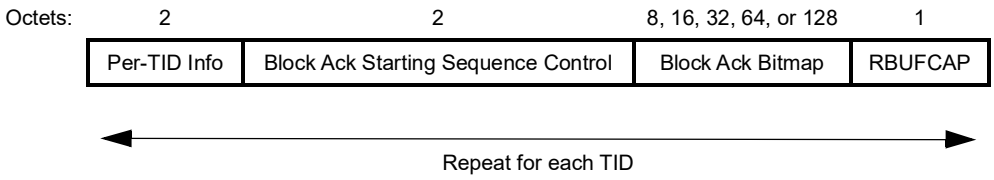


**Figure 9-63—BA Information field format (EDMG Multi-TID BlockAck)(11ay)(#1348)**

The Per-TID Info subfield is defined in Figure 9-64 (Per-TID Info subfield format(11ay)).

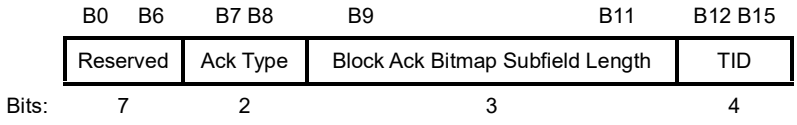


**Figure 9-64—Per-TID Info subfield format(11ay)**

If the Ack Type subfield is not 0, the Block Ack Bitmap Subfield Length field is reserved. The Ack Type subfield is defined in Table 9-42 (Ack Type subfield definition(11ay)).

The Block Ack Bitmap Subfield Length subfield is an integer in the range 0 to 4 that is used to calculate the number of octets of the bitmap represented by the Block Ack Bitmap subfield in the BA Information field. The bitmap length is equal to 2(3+ Block Ack Bitmap Subfield Length) octets, as negotiated during the block ack agreement(#6171) establishment (10.25 (Block acknowledgment (block ack))) for the TID indicated in the TID subfield of the Per-TID Info subfield.


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**Table 9-42—Ack Type subfield definition(11ay)**

| Ack Type subfield value | TID subfield value | Presence of Block Ack Starting Sequence Control subfield and Block Ack Bitmap subfields | Context of a Per TID Info subfield in a Multi-STA BlockAck frame |
|---|---|---|---|
| 0 | 0–15 | Present | Block acknowledgment context is sent in response:<br>— To MPDUs in an A-MPDU that solicits an immediate block acknowledgment or<br>— To a BlockAckReq frame or to A-MPDU with ack policy set to Scheduled Ack. |
| 1 | 0–15 | Not present | Ack context:<br>Sent as a response to an MPDU that has a TID that does not have BA agreement and with ack policy set to Scheduled Ack |
| 2 | 0–15 | Not present | All-ack context:<br>Sent as a response to an A-MPDU that contains an MPDU with Ack Policy set to Normal Ack or Scheduled Ack, and all MPDUs for a given TID contained in the A-MPDU are received successfully. |
| 3 | N/A | N/A | Reserved |

The TID subfield contains the value of the TID to which the value of the Block Ack Bitmap subfield carried in this BA Information field relates.

The Block Ack Starting Sequence Control subfield is shown in Figure 9-48 (Block Ack Starting Sequence Control subfield format). The Starting Sequence Number subfield of the Block Ack Starting Sequence Control subfield is the sequence number of the first MSDU or A-MSDU for which this BlockAck frame is sent. The value of this subfield is defined in 10.25.6.5 (Generation and transmission of BlockAck frames by an HT STA, DMG STA, or S1G STA)(#3046). The Fragment Number subfield of the Block Ack Starting Sequence Control subfield is reserved and set to 0.

The Block Ack Bitmap subfield of the BA Information field is used to indicate the received status of MSDUs, where each entry represents an MSDU or an A-MSDU. The size of the Block Ack Bitmap subfield is negotiated during the block ack agreement(#6171) establishment (see 10.25 (Block acknowledgment (block ack))) and can contain 8, 16, 32, 64, or 128 octets. Each bit that is set to 1 in the Block Ack Bitmap subfield acknowledges the successful reception of a single MSDU or A-MSDU in the order of sequence number. The first bit of the Block Ack Bitmap subfield corresponds to the MSDU or A-MSDU with the sequence number that matches the value of the Starting Sequence Number subfield of the Block Ack Starting Sequence Control subfield. The maximum size of all Block Ack Bitmap subfields appended for all TIDs in one EDMG Multi-TID BlockAck frame(#4301) is 256 octets.

The RBUFCAP subfield is defined in 9.3.1.8.7 (EDMG Compressed BlockAck variant(11ay)).

### 9.3.1.9 Control Wrapper frame format

The format of the Control Wrapper frame is shown in Figure 9-65 (Control Wrapper frame format).

The Control Wrapper frame is used to wrap any other Control frame (i.e., excluding the Control Wrapper frame) together with an HT Control field.

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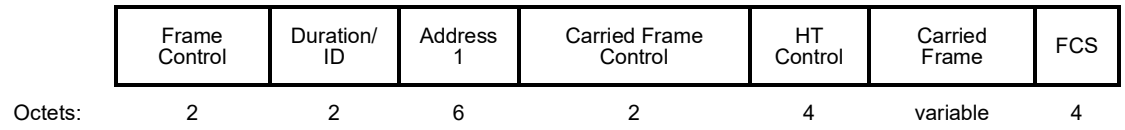


**Figure 9-65—Control Wrapper frame format**

The Duration/ID field of the Control Wrapper frame is generated by following the rules for the Duration/ID field of the Control frame that is being wrapped.

The Address 1 field of the Control Wrapper frame is generated by following the rules for the Address 1 field of the Control frame that is being wrapped.

The Carried Frame Control field contains the value of the Frame Control field of the wrapped Control frame.

The HT Control field is defined in 9.2.4.6 (HT Control field).

The Carried Frame field contains the fields that follow the Address 1 field of the Control frame that is being wrapped, excluding the FCS field.

The FCS field is defined in 9.2.4.9 (FCS field).

### 9.3.1.10 Poll frame format

The format of the Poll frame is shown in Figure 9-66 (Poll frame format).

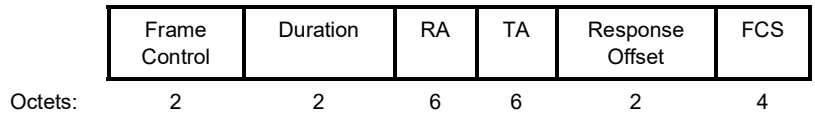


**Figure 9-66—Poll frame format**

The Duration field is set to include the duration, in microseconds, of the remaining Poll frame transmissions (see 10.38.7.2 (Polling period (PP))), plus all appropriate IFSs (10.3.2.3 (IFS)), plus the duration of the SPR frame transmissions.

The RA field contains the MAC address of the STA being polled.

The TA field contains the MAC address of the AP or PCP.

The Response Offset field indicates the offset, in units of 1 μs, beginning SIFS after the end of the Poll frame when the SPR frame in response to this Poll frame is transmitted.

### 9.3.1.11 SPR frame format(#4303)

The format of the service period request (SPR)(#4303) frame is shown in Figure 9-67 (SPR frame format).

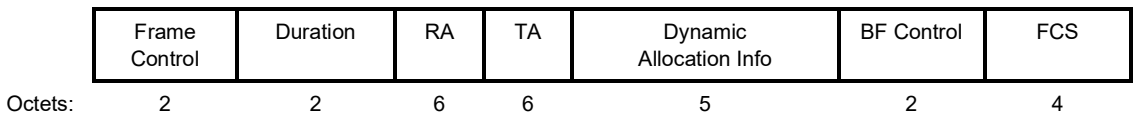


**Figure 9-67—SPR frame format**


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When an SPR frame is sent in response to a Poll frame (see 10.38.7 (Dynamic allocation of service period)), the Duration field in the SPR frame is set to the value of the Duration field contained in the Poll frame, minus the value of the Response Offset field contained in the Poll frame multiplied by its unit as specified in 9.3.1.10 (Poll frame format), minus SIFS, minus the time taken to transmit the SPR frame. When the SPR frame is not sent in response to a Poll frame (see 10.38.9 (Dynamic extension of service period) and 11.4.12 (DMG allocation formats)) and transmitted within an SP or a TXOP allocation, the Duration field is set to the time left in the allocation excluding the SPR transmission time. In all other cases, the Duration field is set to 0.

The RA field contains the MAC address of the AP or PCP.

The TA field contains the MAC address of the STA transmitting the SP request.

The Dynamic Allocation Info field is defined in 9.5.2 (Dynamic Allocation Info field).

The BF Control field is defined in 9.5.5 (Beamforming Control field).

### 9.3.1.12 Grant frame format

The format of the Grant frame is shown in Figure 9-68 (Grant frame format).

| | Frame Control | Duration | RA | TA | Dynamic Allocation Info | BF Control | FCS |
|---|---|---|---|---|---|---|---|
| Octets: | 2 | 2 | 6 | 6 | 5 | 2 | 4 |

**Figure 9-68—Grant frame format**

For individually addressed Grant frames:

— If the Grant frame is used to obtain a TXOP, the Duration field is set to a value subject to the TXOP limit as described in 10.23.2.9 (TXOP limits). In all other cases within a CBAP, the Duration field is set to the Duration field of the immediately preceding frame minus TXTIME(Grant frame) minus aSIFSTime.

— If the Grant frame is sent within an SP, the Duration field is set according to the rules in 10.38.7 (Dynamic allocation of service period), 10.38.8 (Dynamic truncation of service period), and 10.38.9 (Dynamic extension of service period) as appropriate depending on the Grant frame usage.

— If the Grant frame is sent within an ATI, the Duration field is set according to the rules in 10.38.3 (ATI transmission rules).

For group addressed Grant frames, the Duration field is set to the time between PHY-TXEND.indication primitive of the Grant frame and the start of the allocation as indicated by the Allocation Duration subfield within the Dynamic Allocation Info field.

The RA field contains the MAC address of the STA receiving the SP grant.

The TA field contains the MAC address of the STA that has transmitted the Grant frame.

The Dynamic Allocation Info field is defined in 9.5.2 (Dynamic Allocation Info field).

The BF Control field is defined in 9.5.5 (Beamforming Control field).

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#### 9.3.1.13 DMG CTS frame format

The frame format for the DMG CTS frame is defined in Figure 9-69 (DMG CTS frame format).

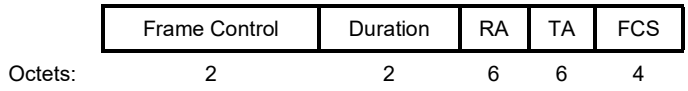


**Figure 9-69—DMG CTS frame format**

When the DMG CTS frame is a response to an RTS frame, the RA field of the DMG CTS frame is set to the address from the TA field of the RTS frame. When the DMG CTS frame is the first frame in a frame exchange, the RA field is set to the MAC address of the transmitter.

A DMG CTS-to-self frame is a DMG CTS frame in which the RA field is equal to the transmitter's MAC address.

For DMG CTS frames other than DMG CTS-to-self frames, the Duration field is set to the value of the Duration field of the immediately previous RTS frame, minus the time, in microseconds, required to transmit the DMG CTS frame and its SIFS. For DMG CTS-to-self frames, the Duration field is set to the remaining duration of the TXOP or SP.(#148)

For DMG CTS frames other than DMG CTS-to-self frames, the TA field is the MAC address of the STA transmitting the DMG CTS frame. For DMG CTS-to-self frames, the TA field is set to the individual address of the recipient or the group address of the recipients of the frame that the DMG STA intends to transmit after the DMG CTS-to-self frame.

#### 9.3.1.14 DMG DTS frame format

The frame format for the DMG Denial to Send (DTS) frame is defined in Figure 9-70 (DMG DTS frame format).

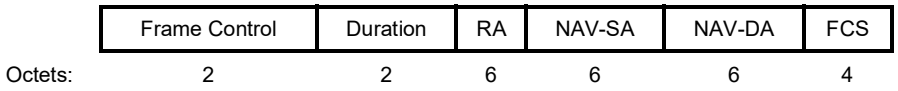


**Figure 9-70—DMG DTS frame format**

The Duration field is set to the value of the transmitting STA's NAV – (TXTIME(DMG DTS) + SIFS) or the remaining time in the SP at the end of the DMG DTS frame transmission, whichever is smaller. The transmitting STA's NAV is the value of its NAV at the start of the DMG DTS frame transmission.

The RA field of the frame is copied from the TA field of the immediately previous RTS frame to which the DMG DTS frame is a response.

The NAV-SA and the NAV-DA fields contain the MAC addresses of the source DMG STA and the destination DMG STA, respectively, whose exchange of an RTS and DMG CTS frame caused the last update to the NAV at the transmitting STA.

#### 9.3.1.15 SSW frame format(#4303)

The frame format for the sector sweep (SSW)(#4303) frame is defined in Figure 9-71 (SSW frame format).


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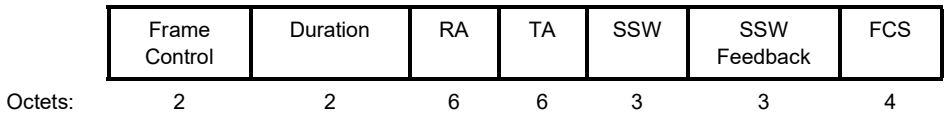


**Figure 9-71—SSW frame format**

The Duration field is set to the time until the end of the current SSW slot when the SSW frame is transmitted within an association beamforming training (A-BFT). Otherwise, it is set to the time until the end of the SSW frame transmission that has the CDOWN subfield within the SSW field equal to 0, plus MBIFS, or until the end of the current allocation (see 10.41 (DMG beamforming)), whichever comes first.

The RA field contains the MAC address of the STA that is the intended receiver of the SSW frame(#4303).

The TA field contains the MAC address of the transmitter STA of the SSW frame(#4303).

The SSW field is defined in 9.5.1 (SSW field(#4303)).

The SSW Feedback field is defined in 9.5.3 (SSW Feedback field(#4303)).

### 9.3.1.16 SSW-Feedback frame format(#4303)

The format of the sector sweep feedback (SSW-Feedback)(#4303) frame is shown in Figure 9-72 (SSW-Feedback frame format).

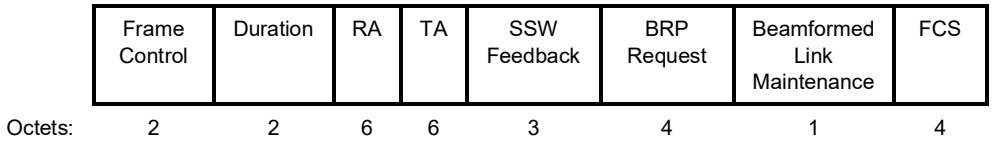


**Figure 9-72—SSW-Feedback frame format**

The Duration field is set to 0 when the SSW-Feedback frame is transmitted within an association beamforming training (A-BFT). When transmitted within a DTI, the Duration field is set to one of the following:

a) If a BRP phase is requested through the BRP Request field, the Duration field is set to the time, in microseconds, required to transmit an SSW-Ack frame plus 2×MBIFS (10.41.3.1 (General)).

b) If a BRP phase is not requested, the Duration field is set to the time, in microseconds, required to transmit an SSW-Ack frame, plus MBIFS (10.41.3.1 (General)) or the time until the end of the current allocation, whichever comes earlier.

The RA field contains the MAC address of the STA that is the intended destination of the SSW-Feedback frame.

The TA field contains the MAC address of the STA transmitting the SSW-Feedback frame.

The SSW Feedback field is defined in 9.5.3 (SSW Feedback field(#4303)).

The BRP Request field is defined in 9.5.4 (BRP Request field).

The Beamformed Link Maintenance field is defined in 9.5.6 (Beamformed Link Maintenance field).

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### 9.3.1.17 SSW-Ack frame format(#4303)

The format of the sector sweep acknowledgement (SSW-Ack) frame(#4303) is shown in Figure 9-73 (SSW-Ack frame format).

| | Frame Control | Duration | RA | TA | SSW Feedback | BRP Request | Beamformed Link Maintenance | FCS |
|---|---|---|---|---|---|---|---|---|
| Octets: | 2 | 2 | 6 | 6 | 3 | 4 | 1 | 4 |

**Figure 9-73—SSW-Ack frame format**

The Duration field is set to the value of the Duration field of the immediately preceding SSW-Feedback frame, minus MBIFS, minus the time required to transmit the SSW-Ack frame.

The RA field contains the MAC address of the STA that is the intended destination of the SSW-Ack frame.

The TA field contains the MAC address of the STA transmitting the SSW-Ack frame.

The SSW Feedback field is defined in 9.5.3 (SSW Feedback field(#4303)).

The BRP Request field is defined in 9.5.4 (BRP Request field).

The Beamformed Link Maintenance field is defined in 9.5.6 (Beamformed Link Maintenance field).

### 9.3.1.18 Grant Ack frame format

The format of the Grant Ack frame is shown in Figure 9-74 (Grant Ack frame format). The Grant Ack frame is sent as a response to the reception of a Grant frame.

| | Frame Control | Duration | RA | TA | Reserved | BF Control | FCS |
|---|---|---|---|---|---|---|---|
| Octets: | 2 | 2 | 6 | 6 | 5 | 2 | 4 |

**Figure 9-74—Grant Ack frame format**

The Duration field is set to the value obtained from the Duration field of the immediately previous Grant frame minus the time, in microseconds, required to transmit the Grant Ack frame and its SIFS.

The RA field of the Grant Ack frame is copied from the Address 2 field of the immediately previous Grant frame.

The TA field contains the MAC address of the STA that has transmitted the Grant Ack frame.

The BF Control field is defined in 9.5.5 (Beamforming Control field).

### 9.3.1.19 VHT/HE/Ranging NDP Announcement frame format(11ax)(11az)

(11az)(11ax)The VHT/HE/Ranging NDP Announcement frame has three variants, the VHT NDP Announcement frame, the HE NDP Announcement frame, and the Ranging NDP Announcement frame. The three formats are distinguished by the setting of the NDP Announcement Type subfield in the Sounding Dialog Token field.


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The frame format of the VHT NDP Announcement frame is shown in Figure 9-75 (VHT NDP Announcement frame format).

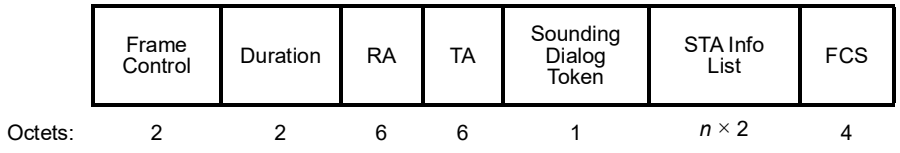


**Figure 9-75—VHT NDP Announcement frame format**

The Duration field is set as defined in 9.2.5 (Duration/ID field (QoS STA)).

The VHT/HE/Ranging NDP Announcement frame contains at least one STA Info field. If the VHT/HE/Ranging NDP Announcement frame contains only one STA Info field with AID/RSID equal or less than 2007, then in the case of VHT or HE NDP Announcement frames the RA field is set to the address of the STA that can provide feedback (see 10.35.5.2 (Rules for VHT sounding protocol sequences)), while in the case of Ranging NDP Announcement frames, the RA address is set to the address of the RSTA or ISTA that is the intended recipient of the frame. If the VHT/HE/Ranging NDP Announcement frame contains more than one STA Info field with AID/RSID equal or less than 2007, then the RA field is set to the broadcast address.(11ax)(11az)

The TA field is set to the address of the STA transmitting the VHT/HE/Ranging NDP Announcement frame or the bandwidth signaling TA of the STA transmitting the VHT/HE/Ranging NDP Announcement frame. In a VHT/HE/Ranging NDP Announcement frame transmitted by a VHT or HE STA in a non-HT or non-HT duplicate format and where the scrambling sequence carries the TXVECTOR parameter CH_BANDWIDTH_IN_NON_HT, the TA field is set to a bandwidth signaling TA. If a Ranging NDP Announcement frame is addressed to a set of ISTAs in which at least two ISTAs have a TB ranging measurement exchange with a different BSSID in the Multiple BSSID set of the RSTA, then the TA field is the transmitted BSSID.(11ax)(11az)

The format of the Sounding Dialog Token field is shown in Figure 9-76 (Sounding Dialog Token field format(11ax)(11az)).

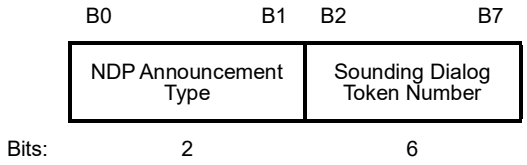


**Figure 9-76—Sounding Dialog Token field format(11ax)(11az)**

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(11az)(11ax)The NDP Announcement Type field in the Sounding Dialog Token field identifies the NDP Announcement frame variant as defined in Table 9-28f (NDP Announcement frame variant encoding).

**Table 9-43—NDP Announcement frame variant encoding(11az)**

| NDP Announcement Type subfield | NDP Announcement frame variant |
|---|---|
| 0 | VHT NDP Announcement frame |
| 1 | Ranging NDP Announcement frame |
| 2 | HE NDP Announcement frame |
| 3 | Reserved |

The Sounding Dialog Token Number subfield in the Sounding Dialog Token field contains a value selected by the beamformer to identify the VHT NDP Announcement frame.

The STA Info List field contains one or more (*n*) STA Info fields.

If the VHT NDP Announcement frame is transmitted by a non-S1G STA, then the format of the STA Info field is shown in Figure 9-77 (STA Info field format in a non-S1G STA).

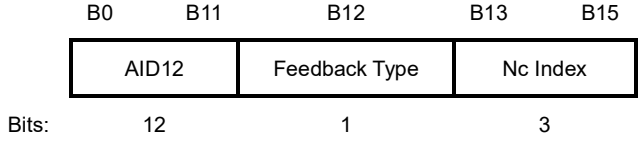


**Figure 9-77—STA Info field format in a non-S1G STA**

The subfields in the STA Info field are described in Table 9-44 (STA Info subfields).

**Table 9-44—STA Info subfields**

| Subfield | Description |
|---|---|
| AID12 | Contains the 12 least significant bits of the AID of a STA expected to process the following VHT NDP and prepare the sounding feedback. Equal to 0 if the STA is an AP, mesh STA, or IBSS STA. |
| Feedback Type | Indicates the type of feedback requested.<br>Set to 0 for SU.<br>Set to 1 for MU. |
| Nc Index | If the Feedback Type field indicates MU, then Nc Index indicates the number of columns minus 1, ($Nc - 1$),(#3453) in the compressed beamforming feedback matrix.<br>Reserved if the Feedback Type field indicates SU. |

If the VHT NDP Announcement frame is transmitted in an S1G PPDU, the frame is referred to as an S1G NDP Announcement frame, and the format of the STA Info field is shown in Figure 9-78 (STA Info field format in an S1G STA). The Feedback Type and Nc Index subfields are defined in Table 9-44 (STA Info subfields), wherein the Nc Index field does not indicate a value that is more than 4. The AID13 subfield


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contains the least significant bits of the AID of the STA that could process the following S1G NDP and prepare sounding feedback. The AID13 subfield is equal to 0 if the STA is an AP or is in an IBSS.

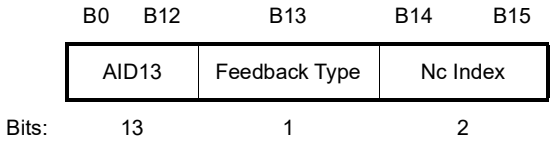


**Figure 9-78—STA Info field format in an S1G STA**

(11ax)The format of the HE NDP Announcement frame is shown in Figure 9-75 (VHT NDP Announcement frame format).

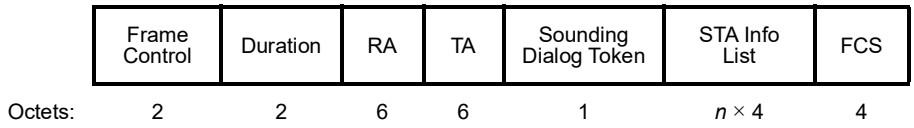


**Figure 9-79—HE NDP Announcement frame format(11ax)(#1096)(#1093)**

(11ax)The Duration, RA, and TA fields are set as in a VHT NDP Announcement frame.(11az)

(11ax)The Sounding Dialog Token Number field in the Sounding Dialog Token field contains a value selected by the beamformer to identify the HE NDP Announcement frame.

(#1093)The STA Info List field contains one or more (*n*) STA Info fields

(11ax)The format of the STA Info field in an HE NDP Announcement Frame if the AID11 subfield is not set to 2047 is defined in Figure 9-80 (STA Info field format in an HE NDP Announcement frame if the AID11 subfield is not 2047(11ax)).

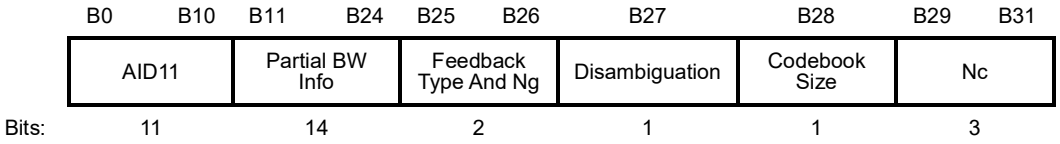


**Figure 9-80—STA Info field format in an HE NDP Announcement frame if the AID11 subfield is not 2047(11ax)**

(11ax)An HE NDP Announcement frame contains at most 1 STA Info field per STA.

(11ax)If the AID11 subfield is not 2047, then it contains an identifier of a STA expected to process the following HE sounding NDP and prepare the sounding feedback.

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(11ax)The Partial BW Info subfield is defined in Figure 9-81 (Partial BW Info subfield format(11ax)).

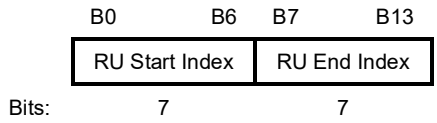


**Figure 9-81—Partial BW Info subfield format(11ax)**

(11ax)The RU Start Index subfield in the Partial BW Info subfield indicates the first 26-tone RU for which the HE beamformer is requesting feedback. The RU End Index subfield of the Partial BW Info subfield indicates the last 26-tone RU for which the HE beamformer is requesting feedback. The value of the RU Start Index subfield is less than or equal to the value of the RU End Index subfield. The RU Start Index subfield and RU End Index subfield depend(#3084) on (#2337)the bandwidth of the PPDU carrying the HE NDP Announcement frame, which is indicated by the TXVECTOR parameter CH_BANDWIDTH if the frame is carried in an HE, VHT, or HT PPDU and by the TXVECTOR parameter CH_BANDWIDTH_IN_NON_HT if the frame is carried in a non-HT duplicate PPDU, and is 20 MHz if the frame is carried in non-HT PPDU. The values of the RU Start Index subfield and RU End Index subfield are each selected from the following:

— Values 0 to 8 if (#2337)the bandwidth of the PPDU carrying the HE NDP Announcement frame is 20 MHz, where 0 indicates 26-tone RU 1 and 8 indicates 26-tone RU 9. Values 9–127 are reserved. See Table 27-8 (Data and pilot subcarrier indices for RUs in a 20 MHz HE PPDU and in a non-OFDMA 20 MHz HE PPDU(11ax)).

— Values 0 to 17 if (#2337)the bandwidth of the PPDU carrying the HE NDP Announcement frame is 40 MHz, where 0 indicates 26-tone RU 1 and 17 indicates 26-tone RU 18. Values 18–127 are reserved. See Table 27-9 (Data and pilot subcarrier indices for RUs in a 40 MHz HE PPDU and in a non-OFDMA 40 MHz HE PPDU(11ax)).

— Values 0 to 36 if (#2337)the bandwidth of the PPDU carrying the HE NDP Announcement frame is 80 MHz, where 0 indicates 26-tone RU 1 and 36 indicates 26-tone RU 37. Values 37–127 are reserved. See Table 27-10 (Data and pilot subcarrier indices for RUs in an 80 MHz HE PPDU and in a non-OFDMA 80 MHz HE PPDU(11ax)).

— Values 0 to 73 if (#2337)the bandwidth of the PPDU carrying the HE NDP Announcement frame is 160 MHz, where 0 indicates 26-tone RU 1 and 73 indicates 26-tone RU 74. Values 74–127 are reserved.

— Values 0 to 73 if (#2337)the bandwidth of the PPDU carrying the HE NDP Announcement frame is 80+80 MHz, where 0 indicates 26-tone RU 1 in the lower 80 MHz frequency segment, 36 indicates 26-tone RU 37 in the lower 80 MHz frequency segment, 37 indicates 26-tone RU 1 in the upper 80 MHz frequency segment, and 73 indicates 26-tone RU 37 in the upper 80 MHz frequency segment. Values 74–127 are reserved. For 80+80 MHz, feedback is not requested for the gap between the 80 MHz segments. See Table 27-10 (Data and pilot subcarrier indices for RUs in an 80 MHz HE PPDU and in a non-OFDMA 80 MHz HE PPDU(11ax)).


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(11ax)The Feedback Type And Ng and Codebook Size subfields for HE TB sounding are defined in Table 9-45 (Feedback Type And Ng subfield and Codebook Size subfield encoding for HE TB sounding(11ax)).

**Table 9-45—Feedback Type And Ng subfield and Codebook Size subfield encoding for HE TB sounding(11ax)**

| Feedback Type And Ng | | Codebook Size | Description |
|---|---|---|---|
| B25 | B26 | B28 | |
| 0 | 0 | 0 | SU, *Ng* = 4, quantization resolution (ϕ, ψ) = {4, 2} |
| 0 | 0 | 1 | SU, *Ng* = 4, quantization resolution (ϕ, ψ) = {6, 4} |
| 0 | 1 | 0 | SU, *Ng* = 16, quantization resolution (ϕ, ψ) = {4, 2} |
| 0 | 1 | 1 | SU, *Ng* = 16, quantization resolution (ϕ, ψ) = {6, 4} |
| 1 | 0 | 0 | MU, *Ng* = 4, quantization resolution (ϕ, ψ) = {7, 5} |
| 1 | 0 | 1 | MU, *Ng* = 4, quantization resolution (ϕ, ψ) = {9, 7} |
| 1 | 1 | 0 | CQI |
| 1 | 1 | 1 | MU, *Ng* = 16, quantization resolution (ϕ, ψ) = {9, 7} |

(11ax)The Feedback Type And Ng and Codebook Size subfields for HE non-TB sounding are defined in Table 9-46 (Feedback Type And Ng subfield and Codebook Size subfield encoding for HE non-TB sounding(11ax)).

**Table 9-46—Feedback Type And Ng subfield and Codebook Size subfield encoding for HE non-TB sounding(11ax)**

| Feedback Type And Ng | | Codebook Size | Description |
|---|---|---|---|
| B25 | B26 | B28 | |
| 0 | Reserved | Reserved | SU |
| 1 | 1 | 0 | CQI |

(11ax)The Disambiguation subfield is set to 1.

NOTE—Setting the Disambiguation subfield to 1 prevents a non-HE VHT STA from wrongly identifying its AID in the HE NDP Announcement frame. The Disambiguation subfield coincides with the MSB of the AID12 subfield of a VHT NDP Announcement frame if the HE NDP Announcement field is parsed as VHT NDP Announcement frame by a non-HE VHT STA. The MSB of the AID12 subfield is always 0 since the maximum AID is 2007.

(11ax)In a broadcast HE NDP Announcement frame that has more than one STA Info field with a value other than 2047 in the AID11 field the following applies to each STA Info subfield with a value other than 2047:

— (#2344)(#2338)If the Feedback Type And Ng subfield indicates SU or MU, the Nc subfield indicates the number of columns in the compressed beamforming feedback matrix minus one, *Nc* – 1

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— (#2344)(#2338)If the Feedback Type And Ng subfield indicates CQI, the Nc subfield indicates the number of space-time streams in the CQI report minus one, *Nc* – 1

(11ax)In an individually addressed HE NDP Announcement frame with a single STA Info field, the STA Info field having a value in the AID11 field other than 2047, the Nc subfield is reserved.

(11ax)The format of the STA Info field in an HE NDP Announcement frame if the AID11 subfield is set to 2047 is defined in Figure 9-82 (STA Info subfield format in an HE NDP Announcement frame if the AID11 subfield is 2047(11ax)).

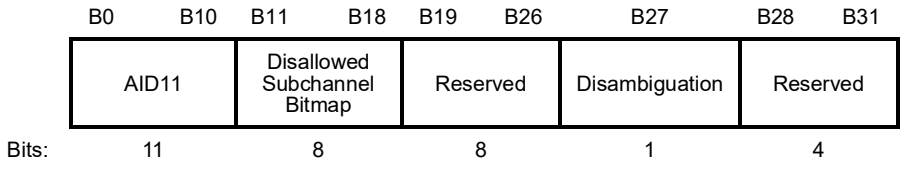


**Figure 9-82—STA Info subfield format in an HE NDP Announcement frame if the AID11 subfield is 2047(11ax)**

(11ax)The Disallowed Subchannel Bitmap subfield indicates the 20 MHz subchannels and the 242-tone RUs that are present in HE sounding NDPs announced by the HE NDP Announcement frame and the 242-tone RUs that are to be included in requested sounding feedback. A 20 MHz subchannel is as defined in Clause 17 for the portions of the PPDU that use a tone plan as specified in Clause 17 and a 242-tone RU is as defined in 27.3.2 (Subcarrier and resource allocation)). The lowest numbered bit of the Disallowed Subchannel Bitmap subfield corresponds to the 20 MHz subchannel that lies within the BSS bandwidth and that has the lowest frequency of the set of all 20 MHz subchannels within the BSS bandwidth. Each successive bit in the bitmap corresponds to the next higher frequency 20 MHz subchannel. A bit in the bitmap is set to 1 to indicate that for the corresponding 20 MHz subchannel, no energy is present in the HE sounding NDP associated with this HE NDP Announcement frame. For each disallowed 20 MHz subchannel, the 242-tone RU that is most closely aligned in frequency with the 20 MHz subchannel is disallowed for PPDUs that use a tone plan as specified in Clause 27 (High-efficiency (HE) PHY specification(11ax)). STAs addressed by the HE NDP Announcement frame do not include tones from disallowed 242-tone RUs when determining the average SNR of space time streams 1 to *Nc* and when generating requested sounding feedback. If a 20 MHz subchannel and its corresponding 242-tone RU is not disallowed, the corresponding bit in the bitmap is set to 0.

(11az)The Ranging NDP Announcement frame uses the same Frame Control subtype as the VHT NDP Announcement frame. The frame format of the Ranging NDP Announcement frame is the same as the HE NDP Announcement frame shown in Figure 9-79 (HE NDP Announcement frame format(11ax)(#1096)(#1093)).

(11az)The Duration, RA, and TA fields are set as in a VHT NDP Announcement frame.

(11az)The Sounding Dialog Token Number subfield in the Sounding Dialog Token (SDT) field contains a value in the range of 0 to 63, which identifies the Measurement Sounding phase of which this transmitted Ranging NDP Announcement frame is part; see 11.21.6.4.3 (TB ranging measurement exchange(11az)) and 11.21.6.4.4 (Non-TB ranging measurement exchange(11az)).

(11az)The format of the STA Info field in a Ranging NDP Announcement frame, when the AID11 subfield is equal or less than 2007, is defined in Figure 9-83 (STA Info field format in a Ranging NDP Announcement frame when the AID11 subfield is equal or less than 2007(11az)).


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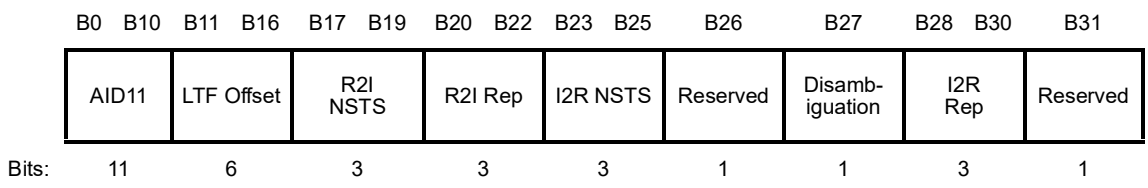


**Figure 9-83—STA Info field format in a Ranging NDP Announcement frame when the AID11 subfield is equal or less than 2007(11az)**

(11az)A Ranging NDP Announcement frame contains one STA Info field with AID11 subfield equal or less than 2007 per STA that is intended to receive this frame.

(11az)In the case of the non-TB ranging measurement exchange (see 11.21.6.4.4 (Non-TB ranging measurement exchange(11az))), there is always only one intended receiver and the RA field is set to the address of that STA.

(11az)In the case of the TB ranging measurement exchange (see 11.21.6.4.3 (TB ranging measurement exchange(11az))), the RA field is set to the broadcast address if more than one STA is intended to receive this frame; otherwise the RA field is set to the address of the STA that is intended to receive this frame.

(11az)If the AID11 subfield is equal or less than 2007, it identifies a STA that is intended to receive this frame and assigns the parameters within this STA Info field to this STA. In case of the TB ranging measurement exchange, see 11.21.6.4.3 (TB ranging measurement exchange(11az)), the AID11 subfield contains the 11 least significant bits of the AID of an associated STA, or the RSID of an unassociated STA, when it is expected to process the following NDP. In case of the non-TB ranging measurement exchange (see 11.21.6.4.4 (Non-TB ranging measurement exchange(11az))), the intended receiver is identified by the RA field and the AID11 subfield is set to 0.

(11az)When used as part of the TB ranging measurement exchange (see 11.21.6.4.3 (TB ranging measurement exchange(11az))), the LTF Offset, R2I NSTS, and R2I Rep subfields are used to indicate the following R2I NDP's HE-LTF configuration (see 27.3.19.1 (HE Ranging NDP(11az))); the I2R NSTS and the I2R Rep subfields are reserved.

(11az)When used as part of the non-TB ranging measurement exchange, the I2R NSTS and I2R Rep subfields are used to indicate the following I2R NDP's HE-LTF configuration, see 27.3.19.1 (HE Ranging NDP(11az)), while the R2I NSTS and R2I Rep subfields indicate the HE-LTF configuration of the R2I NDP sent in response by the RSTA, see 11.21.6.4.4 (Non-TB ranging measurement exchange(11az)).

(11az)The LTF Offset subfield is used in the TB ranging measurement exchange protocol with secure LTF see 11.21.6.4.5.2 (TB ranging measurement exchange with secure HE-LTF(11az)); it indicates the number of HE-LTF to skip when processing the following NDP. The LTF Offset subfield is set to 0 in all other cases.

(11az)The R2I NSTS and I2R NSTS subfields indicate the number of spatial streams of the corresponding NDP and is set to the number of spatial streams minus 1.

(11az)The R2I Rep and I2R Rep subfields are set to the number of HE-LTF repetitions of the corresponding HE Ranging NDP minus 1; see 27.3.19.1 (HE Ranging NDP(11az)). If the I2R and R2I Rep subfields have a value equal to 0, then there is no HE-LTF repetition in the I2R and R2I NDP respectively.

(11az)The Disambiguation subfield is set to 1 as in the STA Info field in an HE NDP Announcement frame regardless of the value of the AID11 subfield.

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(11az)The format of the STA Info field in a Ranging NDP Announcement frame when the AID is equal to 2043 is shown in Figure 9-84 (STA Info field format in a Ranging NDP Announcement frame if the AID11 subfield is 2043(11az)). It is used in the non-TB ranging measurement exchange with secure LTF to carry the sequence authentication code (SAC).

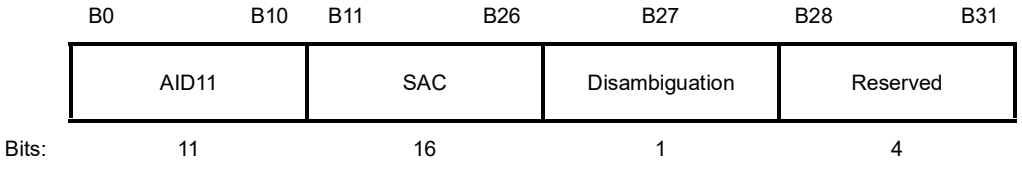


**Figure 9-84—STA Info field format in a Ranging NDP Announcement frame if the AID11 subfield is 2043(11az)**

(11az)The SAC subfield contains the 16-bit SAC used in the non-TB ranging measurement exchange with secure LTF; see 11.21.6.4.5.3 (Non-TB ranging measurement exchange with secure HE-LTF(11az)).

(11az)The format of the STA Info field in a Ranging NDP Announcement frame if the AID11 subfield is equal to 2044 as is shown in Figure 9-85 (STA Info field format in a Ranging NDP Announcement frame (if the AID11 subfield is equal to 2044)(11az)).

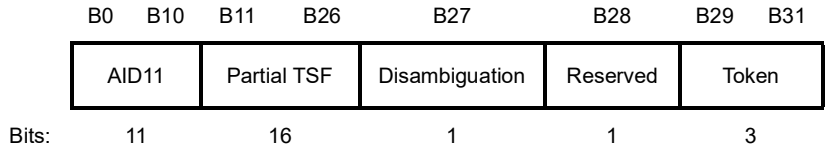


**Figure 9-85—STA Info field format in a Ranging NDP Announcement frame (if the AID11 subfield is equal to 2044)(11az)**

(11az)The STA Info field, with AID11 subfield equal to 2044, is present in Ranging NDP Announcement frames when part of the TB ranging measurement exchange. It is used to carry the Partial TSF subfield. The Partial TSF subfield contains 16 bits of the RSTA's TSF time, TSF[21:6], when the RSTA transmitted the TF Ranging Poll that preceded the Ranging NDP Announcement frame, carrying this STA Info field with AID subfield equal to 2044.

(11az)The Token subfield is set to the value of the Token subfield of the TF Ranging Poll whose partial transmission TSF time is carried.

(11az)The format of the STA Info field with AID11 subfield equal to 2045 is shown in Figure 9-86 (STA Info field format in a Ranging NDP Announcement frame if the AID11 subfield is 2045(11az)).

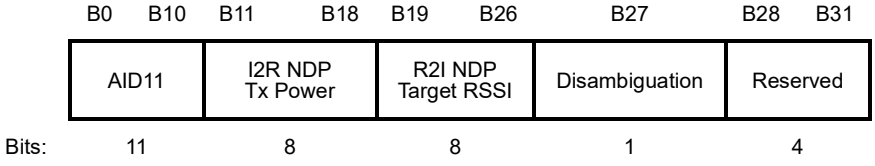


**Figure 9-86—STA Info field format in a Ranging NDP Announcement frame if the AID11 subfield is 2045(11az)**


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(11az)The STA Info field with AID11 subfield equal to 2045 is used in the non-TB ranging measurement exchange, see 11.21.6.4.4 (Non-TB ranging measurement exchange(11az)), to carry the I2R NDP Tx Power and R2I NDP Target RSSI subfields.

(11az)The I2R NDP Tx Power subfield indicates the combined average power per 20 MHz bandwidth referenced to the antenna connector, of all antennas used to transmit the following I2R NDP. The transmit power is reported with a resolution of 1 dB, with values in the range 0 to 60 representing –20 dBm to 40 dBm, respectively. Values above 60 are reserved.

(11az)The R2I NDP Target RSSI subfield indicates the preferred receive signal power, averaged over the ISTA's antenna connectors, for future R2I NDPs to be transmitted by the RSTA. The preferred receive signal power in units of dBm is TargetRSSI = –110 + FVal, where FVal is the value of the R2I NDP Target RSSI subfield, except that values above 90 indicate that the ISTA has no receive signal power preference for the R2I NDPs.

### 9.3.1.20 Beamforming Report Poll frame format

The Beamforming Report Poll frame is shown in Figure 9-87 (Beamforming Report Poll frame format).

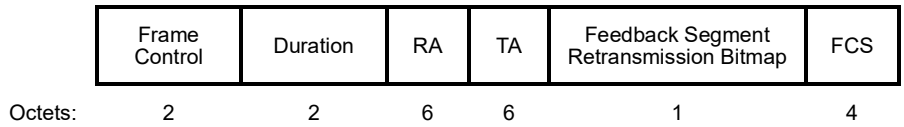


**Figure 9-87—Beamforming Report Poll frame format**

The Duration field is set as defined in 9.2.5 (Duration/ID field (QoS STA)).

The RA field is set to the address of the intended recipient.

The TA field is set to the address of the STA transmitting the Beamforming Report Poll or a bandwidth signaling TA. In a Beamforming Report Poll frame transmitted by a VHT STA in a non-HT or non-HT duplicate format and where the scrambling sequence carries the TXVECTOR parameter CH_BANDWIDTH_IN_NON_HT, the TA field is set to a bandwidth signaling TA.

The Feedback Segment Retransmission Bitmap field indicates the requested feedback segments of VHT compressed beamforming feedback(#4014)(#317) (see 10.35.5.3 (Rules for fragmented feedback in VHT sounding protocol sequences)). If the bit in position *n* (*n=0* for LSB and *n=7* for MSB) is 1, then the feedback segment with the Remaining Feedback Segments subfield in the VHT MIMO Control field equal to *n* is requested. If the bit in position *n* is 0, then the feedback segment with the Remaining Feedback Segments subfield in the VHT MIMO Control field equal to *n* is not requested.

### 9.3.1.21 TACK frame format

The frame format of the TACK frame is defined in Figure 9-88 (TACK frame format).

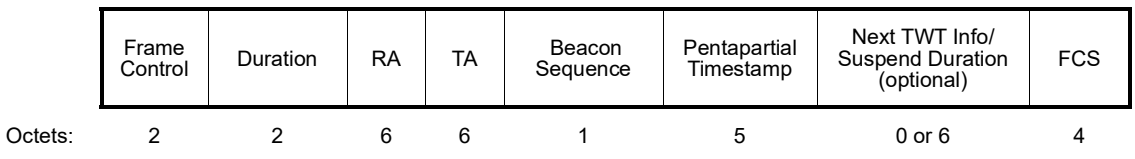


**Figure 9-88—TACK frame format**

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The Duration field is described in 9.2.5.6 (Setting for control response frames).

The RA field contains the address of the intended recipient of the frame.

The TA field contains the address of the transmitter sending the frame.

The Beacon Sequence field contains the value of the Change Sequence field from the most recently transmitted S1G Beacon frame.

The Pentapartial Timestamp field contains the value of the 5 least significant octets of the STA's TSF timer at the time that the start of the data symbol containing the first bit of the Pentapartial Timestamp field appears at the transmit antenna connector.

The format for the optional Next TWT Info/Suspend Duration field is defined in Figure 9-89 (Next TWT Info/Suspend Duration field format).

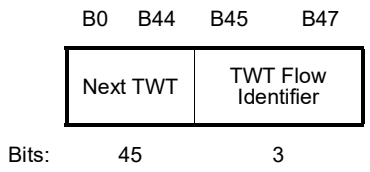


**Figure 9-89—Next TWT Info/Suspend Duration field format**

If the Next TWT Info Present field of the Frame Control field is equal to 1 and the Flow Control field of the Frame Control field is equal to 0, then the Next TWT Info/Suspend Duration field is present and is set to 0 or contains the 45 MSBs of the value of the 6 least significant octets of the TSF timer corresponding to the next scheduled TWT SP for the TWT agreement identified by the TWT Flow Identifier subfield for the STA that is the intended recipient of the frame. If the Next TWT Info/Suspend Duration field is 0, the transmitter does not currently have a Next TWT value available for transmission for the TWT agreement identified by the TWT Flow Identifier subfield for the STA that is the intended recipient of the frame.

If the Next TWT Info Present field of the Frame Control field is equal to 1 and the Flow Control field of the Frame Control field is equal to 1, then the Next TWT Info/Suspend Duration field is present and contains a flow suspension duration in microseconds during which the intended recipient TWT STA is not allowed to transmit Data frames to the STA identified by the TA field of the TACK frame.

If the Next TWT Info Present field is equal to 0 in the Frame Control field, the Next TWT Info/Suspend Duration field is not present in the TACK frame.

### 9.3.1.22 Trigger frame format(11ax)

#### 9.3.1.22.1 General

A Trigger frame allocates resources for and solicits one or more HE TB PPDU transmissions. The Trigger frame also carries other information required by the responding STA to send an HE TB PPDU.


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The format for the Trigger frame is defined in Figure 9-90 (Trigger frame format(11ax)(#1097)).

| | Frame Control | Duration | RA | TA | Common Info | User Info List | Padding | FCS |
|---|---|---|---|---|---|---|---|---|
| Octets: | 2 | 2 | 6 | 6 | 8 or more | variable | variable | 4 |

**Figure 9-90—Trigger frame format(11ax)(#1097)**

The Duration field is set as defined in 9.2.5 (Duration/ID field (QoS STA)).

The RA field is set as follows:

— For a Trigger frame that is not a GCR MU-BAR, NFRP or MU-RTS Trigger frame, and that has one User Info field and the AID12 subfield of the User Info field contains the AID of a non-AP STA, the RA field is set to the address of that STA

— For a Trigger frame that has at least one User Info field with the AID12 subfield that allocates an RA-RU, the RA field is set to the broadcast address

— For a Trigger frame that is not a GCR MU-BAR Trigger frame and that has more than one User Info field, the RA field is set to the broadcast address

— For a Trigger frame that is an NFRP Trigger frame or MU-RTS Trigger frame, the RA field is set to the broadcast address

— For a Trigger frame that is a GCR MU-BAR Trigger frame, the RA field is set to the MAC address of the group for which reception status is being requested

The TA field is the address of the STA transmitting the Trigger frame if the Trigger frame is addressed to STAs that belong to a single BSS. The TA field is the transmitted BSSID if the Trigger frame is addressed to STAs from at least two different BSSs of the multiple BSSID set. The rules for setting of the TA field are defined in 26.5.2.2.4 (Allowed settings of the Trigger frame fields and TRS Control subfield).

The Common Info field is defined in Figure 9-91 (Common Info field format(11ax)).

| | B0 B3 | B4 B15 | B16 | B17 | B18 B19 | B20 B21 | B22 | B23 B25 |
|---|---|---|---|---|---|---|---|---|
| | Trigger Type | UL Length | More TF | CS Required | UL BW | GI And HE-LTF Type | MU-MIMO HE-LTF Mode | Number Of HE-LTF Symbols And Midamble Periodicity |
| Bits: | 4 | 12 | 1 | 1 | 2 | 2 | 1 | 3 |

| | B26 | B27 | B28 B33 | B34 B35 | B36 | B37 B52 | B53 | B54 B62 |
|---|---|---|---|---|---|---|---|---|
| | UL STBC | LDPC Extra Symbol Segment | AP Tx Power | Pre-FEC Padding Factor | PE Disambiguity | UL Spatial Reuse | Doppler | UL HE-SIG-A2 Reserved |
| Bits: | 1 | 1 | 6 | 2 | 1 | 16 | 1 | 9 |

| | B63 | |
|---|---|---|
| | Reserved | Trigger Dependent Common Info |
| Bits: | 1 | variable |

**Figure 9-91—Common Info field format(11ax)**

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The Trigger Type subfield identifies the Trigger frame variant and its encoding is defined in Table 9-47 (Trigger Type subfield encoding(11ax)).

**Table 9-47—Trigger Type subfield encoding(11ax)**

| Trigger Type subfield value | Trigger frame variant |
|---|---|
| 0 | Basic |
| 1 | Beamforming Report Poll (BFRP) |
| 2 | MU-BAR |
| 3 | MU-RTS |
| 4 | Buffer Status Report Poll (BSRP) |
| 5 | GCR MU-BAR |
| 6 | Bandwidth Query Report Poll (BQRP) |
| 7 | NDP Feedback Report Poll (NFRP) |
| 8(11az) | Ranging |
| 9–15 | Reserved |

The UL Length subfield of the Common Info field indicates the value of the L-SIG LENGTH field of the solicited HE TB PPDU.

The More TF subfield of the Common Info field indicates whether (11az)or not a subsequent Trigger frame is scheduled for transmission. The More TF subfield is set as defined in 26.8.2 (Individual TWT agreements), 26.8.3.2 (Rules for TWT scheduling AP), and 11.21.6.4.3 (TB ranging measurement exchange(11az)).(11az)

The CS Required subfield of the Common Info field is set to 1 to indicate that the STAs identified in the User Info fields are required to use ED to sense the medium and to consider the medium state and the NAV in determining whether to respond. The CS Required subfield is set to 0 to indicate that the STAs identified in the User Info fields are not required to consider the medium state or the NAV in determining whether to respond. See 26.5.2.3 (Non-AP STA behavior for UL MU operation) and 26.5.2.5 (UL MU CS mechanism) for details.

The UL BW subfield of the Common Info field indicates the bandwidth in the HE-SIG-A field of the HE TB PPDU and is defined in Table 9-48 (UL BW subfield encoding(11ax)).

**Table 9-48—UL BW subfield encoding(11ax)**

| UL BW subfield value | Description |
|---|---|
| 0 | 20 MHz |


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**Table 9-48—UL BW subfield encoding(11ax)**

| | |
|---|---|
| 1 | 40 MHz |
| 2 | 80 MHz |
| 3 | 80+80 MHz or 160 MHz |

The GI And HE-LTF Type subfield of the Common Info field indicates the GI and HE-LTF type of the HE TB PPDU response. The GI And HE-LTF Type subfield encoding is defined in Table 9-49 (GI And HE-LTF Type subfield encoding(11ax)).

**Table 9-49—GI And HE-LTF Type subfield encoding(11ax)**

| GI And HE-LTF Type subfield value | Description |
|---|---|
| 0 | 1x HE-LTF + 1.6 μs GI |
| 1 | 2x HE-LTF + 1.6 μs GI |
| 2 | 4x HE-LTF + 3.2 μs GI |
| 3 | Reserved |

The MU-MIMO HE-LTF Mode subfield of the Common Info field indicates the HE-LTF mode for an HE TB PPDU that has an RU that spans the entire bandwidth and that is assigned to more than one non-AP STA (i.e., for UL MU-MIMO) when the GI And HE-LTF Type subfield of the Common Info field indicates either 2x HE-LTF + 1.6 μs GI or 4x HE-LTF + 3.2 μs GI, as defined in Table 9-49 (GI And HE-LTF Type subfield encoding(11ax)). Otherwise, this subfield is set to indicate HE single stream pilot HE-LTF mode. See Table 9-50 (MU-MIMO HE-LTF Mode subfield encoding(11ax)).

**Table 9-50—MU-MIMO HE-LTF Mode subfield encoding(11ax)**

| MU-MIMO HE-LTF subfield value | Description |
|---|---|
| 0 | HE single stream pilot HE-LTF mode |
| 1 | HE masked HE-LTF sequence mode |

If the Doppler subfield of the Common Info field is 0, then the Number Of HE-LTF Symbols And Midamble Periodicity subfield of the Common Info field indicates the number of HE-LTF symbols present in the HE TB PPDU and is encoded as follows:

— 0 for 1 HE-LTF symbol
— 1 for 2 HE-LTF symbols
— 2 for 4 HE-LTF symbols
— 3 for 6 HE-LTF symbols
— 4 for 8 HE-LTF symbols
— 5–7 are reserved

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If the Doppler subfield of the Common Info field is 1, then the Number Of HE-LTF Symbols And Midamble Periodicity subfield indicates the number of HE-LTF symbols and the periodicity of the midamble and is encoded as follows:

- 0 for 1 HE-LTF symbol and 10 symbol midamble periodicity
- 1 for 2 HE-LTF symbols and 10 symbol midamble periodicity
- 2 for 4 HE-LTF symbols and 10 symbol midamble periodicity
- 4 for 1 HE-LTF symbol and 20 symbol midamble periodicity
- 5 for 2 HE-LTF symbols and 20 symbol midamble periodicity
- 6 for 4 HE-LTF symbols and 20 symbol midamble periodicity
- 3 and 7 are reserved

The UL STBC subfield of the Common Info field indicates the status of STBC encoding for the solicited HE TB PPDUs. It is set to 1 to indicate STBC encoding and set to 0 otherwise.

The LDPC Extra Symbol Segment subfield of the Common Info field indicates the status of the LDPC extra symbol segment. It is set to 1 if the LDPC extra symbol segment is present in the solicited HE TB PPDUs and set to 0 otherwise.

The AP Tx Power subfield of the Common Info field indicates the AP's combined transmit power at the transmit antenna connector of all the antennas used to transmit the triggering PPDU in units of dBm/20 MHz. The transmit power in dBm/20 MHz, $P_{TX}$, is calculated as $P_{TX} = -20 + F_{Val}$, where $F_{Val}$ is the value of the AP Tx Power subfield, except for the values above 60, which are reserved.

The Pre-FEC Padding Factor and PE Disambiguity subfields are defined in Table 9-51 (Pre-FEC Padding Factor and PE Disambiguity subfields(11ax)) and have the same encoding as their respective subfields in HE SIG-A (see Table 27-21 (HE-SIG-A field of an HE MU PPDU(11ax))).

**Table 9-51—Pre-FEC Padding Factor and PE Disambiguity subfields(11ax)**

| Subfield | Description | Encoding |
|---|---|---|
| Pre-FEC Padding Factor | Indicates the pre-FEC padding factor | Set to 0 to indicate a pre-FEC padding factor of 4<br>Set to 1 to indicate a pre-FEC padding factor of 1<br>Set to 2 to indicate a pre-FEC padding factor of 2<br>Set to 3 to indicate a pre-FEC padding factor of 3 |
| PE Disambiguity | Indicates PE disambiguity | Set to 1 if the condition in Equation (27-118) is met; otherwise, it is set to 0 |

The UL Spatial Reuse subfield of the Common Info field carries the values to be included in the Spatial Reuse fields in the HE-SIG-A field of the solicited HE TB PPDUs. The format of the UL Spatial Reuse subfield is shown in Figure 9-92 (UL Spatial Reuse subfield format(11ax)), where each Spatial Reuse $n$ subfield, $1 \le n \le 4$, is set to the same value as its corresponding subfield in the HE-SIG-A field of the HE TB PPDU, which are defined in Table 27-22 (HE-SIG-A field of an HE TB PPDU(11ax)).

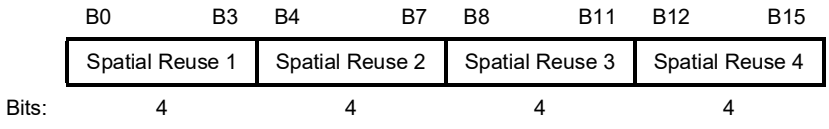


**Figure 9-92—UL Spatial Reuse subfield format(11ax)**


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The Doppler subfield of the Common Info field is set to 1 to indicate that a midamble is present in the HE TB PPDU and set to 0 otherwise.

The UL HE-SIG-A2 Reserved subfield of the Common Info field carries the value to be included in the Reserved field in the HE-SIG-A2 subfield of the solicited HE TB PPDUs. An HE AP sets the UL HE-SIG-A2 Reserved subfield to all 1s.

The Trigger Dependent Common Info subfield in the Common Info field is optionally present based on the value of the Trigger Type field (see 9.3.1.22.2 (Basic Trigger frame format) to 9.3.1.22.9 (NFRP Trigger frame format)).

The User Info List field contains zero or more User Info fields.

The User Info field is defined in Figure 9-93 (User Info field format(11ax)) for all Trigger frame variants, except the NFRP Trigger frame, which is defined in 9.3.1.22.9 (NFRP Trigger frame format) and the Ranging Trigger frame, which is defined in 9.3.1.22.10 (Ranging Trigger variant(11az))(11az).

| | B0 B11 | B12 B19 | B20 | B21 B24 | B25 | B26 B31 | B32 B38 | B39 | |
|---|---|---|---|---|---|---|---|---|---|
| | AID12 | RU Allocation | UL FEC Coding Type | UL HE-MCS | UL DCM | SS Allocation/ RA-RU Information | UL Target Receive Power | Reserved | Trigger Dependent User Info |
| Bits: | 12 | 8 | 1 | 4 | 1 | 6 | 7 | 1 | variable |

**Figure 9-93—User Info field format(11ax)**

The AID12 subfield in the User Info field is encoded as defined in Table 9-52 (AID12 subfield encoding(11ax)):

**Table 9-52—AID12 subfield encoding(11ax)**

| AID12 subfield | Description |
|---|---|
| 0 | User Info field allocates one or more contiguous RA-RUs for associated STAs |
| 1–2007 | User Info field is addressed to an associated STA whose AID is equal to the value in the AID12 subfield |
| 2008–2044 | Reserved |
| 2045 | User Info field allocates one or more contiguous RA-RUs for unassociated STAs |
| 2046 | Unallocated RU |
| 2047–4094 | Reserved |
| 4095 | Start of Padding field |

If the AID12 subfield is 2046, then the remaining subfields in the User Info field are reserved, except for the RU Allocation subfield, which indicates the RU location of the unallocated RU.

If the AID12 subfield is 4095, then the remaining subfields in the User Info field are not present.

The RU Allocation subfield along with the UL BW subfield in the Common Info field identifies the size and the location of the RU. If the UL BW subfield indicates 20 MHz, 40 MHz, or 80 MHz PPDU, then B0 of the

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RU Allocation subfield is set to 0. If the UL BW subfield indicates 80+80 MHz or 160 MHz, then B0 of the RU Allocation subfield is set to 0 to indicate that the RU allocation applies to the primary 80 MHz channel and set to 1 to indicate that the RU allocation applies to the secondary 80 MHz channel. The mapping of B7–B1 of the RU Allocation subfield for a Trigger frame that is not an MU-RTS Trigger frame is defined in Table 9-53 (B7–B1 of the RU Allocation subfield(11ax)).

**Table 9-53—B7–B1 of the RU Allocation subfield(11ax)**

| B7–B1 of the RU Allocation subfield | UL BW subfield | RU size | RU Index |
|---|---|---|---|
| 0–8 | 20 MHz, 40 MHz, 80 MHz, 80+80 MHz or 160 MHz | 26 | RU1 to RU9, respectively |
| 9–17 | 40 MHz, 80 MHz, 80+80 MHz or 160 MHz | | RU10 to RU18, respectively |
| 18–36 | 80 MHz, 80+80 MHz or 160 MHz | | RU19 to RU37, respectively |
| 37–40 | 20 MHz, 40 MHz, 80 MHz, 80+80 MHz or 160 MHz | 52 | RU1 to RU4, respectively |
| 41–44 | 40 MHz, 80 MHz, 80+80 MHz or 160 MHz | | RU5 to RU8, respectively |
| 45–52 | 80 MHz, 80+80 MHz or 160 MHz | | RU9 to RU16, respectively |
| 53, 54 | 20 MHz, 40 MHz, 80 MHz, 80+80 MHz or 160 MHz | 106 | RU1 and RU2, respectively |
| 55, 56 | 40 MHz, 80 MHz, 80+80 MHz or 160 MHz | | RU3 and RU4, respectively |
| 57–60 | 80 MHz, 80+80 MHz or 160 MHz | | RU5 to RU8, respectively |
| 61 | 20 MHz, 40 MHz, 80 MHz, 80+80 MHz or 160 MHz | 242 | RU1 |
| 62 | 40 MHz, 80 MHz, 80+80 MHz or 160 MHz | | RU2 |
| 63, 64 | 80 MHz, 80+80 MHz or 160 MHz | | RU3 and RU4, respectively |
| 65 | 40 MHz, 80 MHz, 80+80 MHz or 160 MHz | 484 | RU1 |
| 66 | 80 MHz, 80+80 MHz or 160 MHz | | RU2 |
| 67 | 80 MHz, 80+80 MHz or 160 MHz | 996 | RU1 |
| 68 | 80+80 MHz or 160 MHz | 2×996 | RU1 |

NOTE—If the UL BW subfield indicates 80+80 MHz or 160 MHz, the description indicates the RU index for the primary 80 MHz channel or secondary 80 MHz channel as indicated by B0 of the RU Allocation subfield.

See 9.3.1.22.5 (MU-RTS Trigger frame format) for the encoding of the RU Allocation subfield in an MU-RTS Trigger frame.


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If the UL BW subfield indicates 20 MHz, the mapping of the RU index to RU is defined in Table 27-8 (Data and pilot subcarrier indices for RUs in a 20 MHz HE PPDU and in a non-OFDMA 20 MHz HE PPDU(11ax)) in increasing order.

If the UL BW subfield indicates 40 MHz, the mapping of the RU index to RU is defined in Table 27-9 (Data and pilot subcarrier indices for RUs in a 40 MHz HE PPDU and in a non-OFDMA 40 MHz HE PPDU(11ax)) in increasing order.

If the UL BW subfield indicates 80 MHz, 160 MHz, or 80+80 MHz, the mapping of the RU index to RU is defined in Table 27-10 (Data and pilot subcarrier indices for RUs in an 80 MHz HE PPDU and in a non-OFDMA 80 MHz HE PPDU(11ax)) in increasing order.

If the UL BW subfield indicates 160 MHz or 80+80 MHz, B7–B1 of the RU Allocation subfield is set to 68 and B0 is set to 1 to indicate a 2×996-tone RU. A non-AP STA ignores B0 for 2×996-tone RU indication.

If the AID12 subfield is in the range 1 to 2007, then the RU Allocation subfield indicates the RU allocated to the STA identified by the AID12 subfield. If the AID12 subfield is 0 or 2045, then the RU Allocation subfield indicates the starting RU of one or more contiguous RA-RUs allocated by the User Info field. If the AID12 subfield is 2046, then the RU Allocation subfield indicates an unallocated RU.

If there is more than one RA-RU (i.e., the Number Of RA-RU subfield of this User Info field has a value greater than 0), then the allocated RUs are contiguous and the RU sizes of all RA-RUs are the same and equal to the size of the first RU. Further, all the remaining subfields of the User Info field apply to all the RA-RUs.

The UL FEC Coding Type subfield of the User Info field indicates the code type of the solicited HE TB PPDU. The UL FEC Coding Type subfield is set to 0 to indicate BCC and set to 1 to indicate LDPC.

The UL HE-MCS subfield of the User Info field indicates the HE-MCS of the solicited HE TB PPDU. The encoding of the UL HE-MCS subfield is defined in 27.3.7 (HE modulation and coding schemes (HE-MCSs)).

The UL DCM subfield of the User Info field indicates DCM of the solicited HE TB PPDU. The UL DCM subfield is set to 1 to indicate that DCM is used in the solicited HE TB PPDU as defined in 27.3.12.15 (Dual carrier modulation). The UL DCM subfield is set to 0 to indicate that DCM is not used. The UL DCM subfield is set to 0 if the UL STBC subfield of the Common Info field is set to 1.

If the AID12 subfield is either 0 or 2045, then B26–B31 of the User Info field is the RA-RU Information subfield; otherwise, B26–B31 of the User Info field is the SS Allocation subfield.

The SS Allocation subfield of the User Info field indicates the spatial streams of the solicited HE TB PPDU and the format is defined in Figure 9-94 (SS Allocation subfield format(11ax)(M118)).

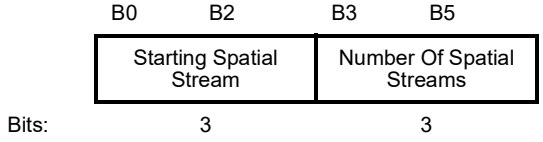


**Figure 9-94—SS Allocation subfield format(11ax)(M118)**

The Starting Spatial Stream subfield indicates the starting spatial stream and is set to the starting spatial stream minus 1 (see 26.5.2.3.3 (TXVECTOR parameters for HE TB PPDU response to Trigger frame)).

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The Number Of Spatial Streams subfield indicates the number of spatial streams, and is set to the number of spatial streams minus 1.

The RA-RU Information subfield of the User Info field indicates the RA-RU information and the format is defined in Figure 9-95 (RA-RU Information subfield format(11ax)(M118)).

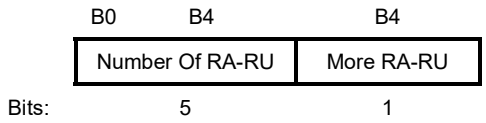


**Figure 9-95—RA-RU Information subfield format(11ax)(M118)**

The Number Of RA-RU subfield indicates the number of contiguous RUs allocated for UORA. The value of the Number Of RA-RU subfield is equal to the number of contiguous RA-RUs minus 1.

NOTE—The starting spatial stream and the number of spatial streams of the HE TB PPDU transmitted on each RA-RU are 1.

The More RA-RU subfield is set to 1 to indicate that RA-RUs of the type indicated by the AID12 subfield in this User Info field (see Table 9-52 (AID12 subfield encoding(11ax))) are allocated in subsequent Trigger frames that are sent until the end of the TWT SP in which the Trigger frame carrying this field is sent. Otherwise, the subfield is set to 0. The More RA-RU subfield is reserved if the More TF field in the Common Info field is set to 0.

The UL Target Receive Power subfield indicates the expected receive signal power, measured at the AP's antenna connector and averaged over the antennas, for the HE portion of the HE TB PPDU transmitted on the assigned RU and is defined in Table 9-54 (UL Target Receive Power subfield in Trigger frame(11ax)).

**Table 9-54—UL Target Receive Power subfield in Trigger frame(11ax)**

| UL Target Receive Power subfield | Description |
|---|---|
| 0–90 | The expected receive signal power, in units of dBm, is $Target_{pwr} = -110 + F_{val}$, where $F_{val}$ is the subfield value |
| 91–126 | Reserved |
| 127 | The STA transmits the HE TB PPDU at the STA's maximum transmit power for the assigned HE-MCS.<br>(11az)If the Trigger frame is a Sounding or Passive Sounding Ranging Trigger frame that does not assign an HE-MCS, then the STA's transmit power is that used for HE-MCS 0.<br>(11az)If the Trigger frame is a Secured Sounding Ranging Trigger frame that does not assign an HE-MCS, the assigned HE-MCS is assumed to be HE-MCS 6 in terms of setting the STA's transmit power.<br><br>(11az)NOTE—The expected receive signal power is then the STA's maximum transmit power for the assigned HE-MCS minus the path loss. |

The Trigger Dependent User Info subfield in the User Info field is optionally present based on the value of the Trigger Type field (see 9.3.1.22.2 (Basic Trigger frame format) to 9.3.1.22.9 (NFRP Trigger frame format)).


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The Padding field is optionally present in a Trigger frame to extend the frame length to give the recipient STAs enough time to prepare a response for transmission a SIFS after the frame is received. The Padding field, if present, is at least two octets in length and is set to all 1s. If the Padding field is present in a Trigger frame, its length is computed as described in 26.5.2.2.3 (Padding for a triggering frame).

#### 9.3.1.22.2 Basic Trigger frame format

The Trigger Dependent Common Info subfield is not present in the Basic Trigger frame. The Trigger Dependent User Info subfield of the Basic Trigger frame is defined in Figure 9-96 (Trigger Dependent User Info subfield format in the Basic Trigger frame(11ax)).

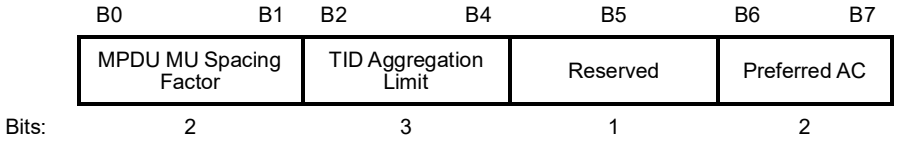


**Figure 9-96—Trigger Dependent User Info subfield format in the Basic Trigger frame(11ax)**

The MPDU MU Spacing Factor subfield is used for calculating the value by which the minimum MPDU start spacing is multiplied (see 10.12.3 (Minimum MPDU start spacing rules)).

The TID Aggregation Limit subfield indicates the MPDUs allowed in an A-MPDU carried in the HE TB PPDU and the maximum number of TIDs that can be aggregated by the STA in the A-MPDU and is set as defined in 26.5.2.2.4 (Allowed settings of the Trigger frame fields and TRS Control subfield).

The value in the TID Aggregation Limit subfield in Trigger frame is less than or equal to $MT + 1$, where $MT$ is the value indicated in the Multi-TID Aggregation Tx Support subfield in the HE MAC Capabilities Information field in the HE Capabilities element transmitted by the non-AP STA that is the intended receiver of the User Info field.

The Preferred AC subfield indicates the lowest AC that is recommended for aggregation of MPDUs in the A-MPDU contained in the HE TB PPDU sent as a response to the Trigger frame. The encoding of the Preferred AC subfield is as defined in Table 9-193 (ACI-to-AC coding).

#### 9.3.1.22.3 BFRP Trigger frame format

The Trigger Dependent Common Info subfield is not present in the BFRP Trigger frame. The Trigger Dependent User Info subfield of the BFRP Trigger frame is defined in Figure 9-97 (Trigger Dependent User Info subfield format in the BFRP Trigger frame(11ax)).

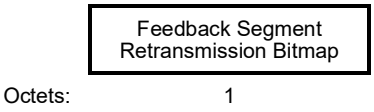


**Figure 9-97—Trigger Dependent User Info subfield format in the BFRP Trigger frame(11ax)**

The Feedback Segment Retransmission Bitmap subfield indicates the requested feedback segments of an HE compressed beamforming/CQI(#4014) report. If the bit in position $n$ ($n = 0$ for LSB and $n = 7$ for MSB) is 1, then the feedback segment with the Remaining Feedback Segments subfield in the HE MIMO Control field equal to $n$ is requested. If the bit in position $n$ is 0, then the feedback segment with the Remaining Feedback Segments subfield in the HE MIMO Control field equal to $n$ is not requested.

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#### 9.3.1.22.4 MU-BAR Trigger frame format

The Trigger Dependent Common Info subfield is not present in the MU-BAR Trigger frame. The Trigger Dependent User Info subfield for the MU-BAR Trigger frame is defined in Figure 9-98 (Trigger Dependent User Info subfield format in the MU-BAR Trigger frame(11ax)).

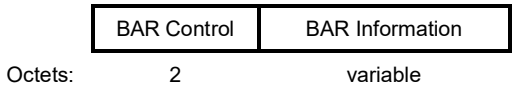


**Figure 9-98—Trigger Dependent User Info subfield format in the MU-BAR Trigger frame(11ax)**

The BAR Control subfield is defined in 9.3.1.7 (BlockAckReq frame format) and indicates either a Compressed BlockAckReq variant or a Multi-TID BlockAckReq variant.

The BAR Information subfield is defined in 9.3.1.7 (BlockAckReq frame format).

#### 9.3.1.22.5 MU-RTS Trigger frame format

The Trigger Dependent Common Info subfield and Trigger Dependent User Info subfield are not present in the MU-RTS Trigger frame.

The UL BW subfield in the Common Info field indicates the bandwidth of the PPDU carrying the MU-RTS Trigger frame and is defined in Table 9-48 (UL BW subfield encoding(11ax)).

The UL Length, GI And HE-LTF Type, MU-MIMO HE-LTF Mode, Number Of HE-LTF Symbols And Midamble Periodicity, UL STBC, LDPC Extra Symbol Segment, AP Tx Power, Pre-FEC Padding Factor, PE Disambiguity, UL Spatial Reuse, Doppler and UL HE-SIG-A2 Reserved subfields in the Common Info field are reserved.

The UL HE-MCS, UL FEC Coding Type, UL DCM, SS Allocation/RA-RU Information and UL Target Receive Power fields in the User Info field are reserved.

The RU Allocation subfield in the User Info field addressed to the STA indicates whether the CTS frame is transmitted on the primary 20 MHz channel, primary 40 MHz channel, primary 80 MHz channel, 160 MHz channel, or 80+80 MHz channel.

B0 of the RU Allocation subfield is set to 0 to indicate primary 20 MHz channel, primary 40 MHz channel and primary 80 MHz channel. For 160 MHz and 80+80 MHz indication, B0 of the RU Allocation subfield is set to 1. A non-AP STA ignores B0 for 160 MHz and 80+80 MHz indication.

B7–B1 of the RU Allocation subfield is set to indicate the primary 20 MHz channel as follows:

- 61 if the primary 20 MHz channel is the only 20 MHz channel or the lowest frequency 20 MHz channel in the primary 40 MHz channel or primary 80 MHz channel
- 62 if the primary 20 MHz channel is the second lowest frequency 20 MHz channel in the primary 40 MHz channel or primary 80 MHz channel
- 63 if the primary 20 MHz channel is the third lowest frequency 20 MHz channel in the primary 80 MHz channel
- 64 if the primary 20 MHz channel is the fourth lowest frequency 20 MHz channel in the primary 80 MHz channel


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B7–B1 of the RU Allocation subfield is set to indicate the primary 40 MHz channel as follows:

— 65 if the primary 40 MHz channel is the only 40 MHz channel or the lowest frequency 40 MHz channel in the primary 80 MHz channel

— 66 if the primary 40 MHz channel is the second lowest frequency 40 MHz channel in the primary 80 MHz channel

B7–B1 of the RU Allocation subfield is set to 67 to indicate the primary 80 MHz channel.

B7–B1 of the RU Allocation subfield is set to 68 to indicate the primary and secondary 80 MHz channel.

The settings for B7–B1 of the RU Allocation subfield are illustrated in Figure 9-99 (UL BW subfield and B7–B1 of RU Allocation subfield in MU-RTS Trigger frame(11ax)).

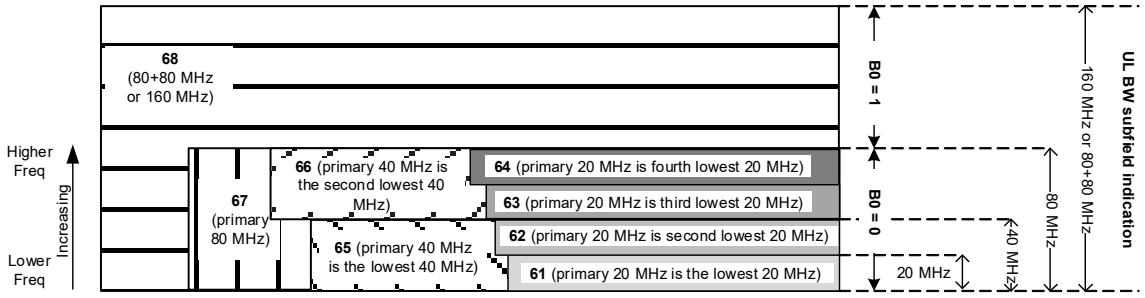


**Figure 9-99—UL BW subfield and B7–B1 of RU Allocation subfield in MU-RTS Trigger frame(11ax)**

### 9.3.1.22.6 BSRP Trigger frame format

The Trigger Dependent Common Info subfield and Trigger Dependent User Info subfield are not present in the BSRP Trigger frame.

### 9.3.1.22.7 GCR MU-BAR Trigger frame format

The Trigger Dependent Common Info subfield of the GCR MU-BAR Trigger frame is defined in Figure 9-100 (Trigger Dependent Common Info subfield format in the GCR MU-BAR Trigger frame(11ax)). The Trigger Dependent User Info subfield is not present in the GCR MU-BAR Trigger frame.

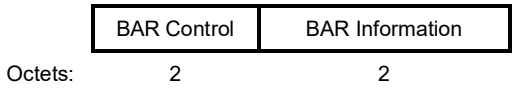


**Figure 9-100—Trigger Dependent Common Info subfield format in the GCR MU-BAR Trigger frame(11ax)**

The BAR Control subfield is defined in 9.3.1.7 (BlockAckReq frame format) and indicates a GCR BlockAckReq variant.

The BAR Information subfield is defined in 9.3.1.7.5 (GCR BlockAckReq variant), except that the GCR Group Address field is not present.

NOTE—A GCR MU-BAR Trigger frame is not a type of MU BAR Trigger frame.

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#### 9.3.1.22.8 BQRP Trigger frame format

The Trigger Dependent Common Info subfield and Trigger Dependent User Info subfield are not present in the BQRP Trigger frame.

#### 9.3.1.22.9 NFRP Trigger frame format

The UL BW subfield in the Common Info field indicates the bandwidth of the NDP feedback report response.

The UL STBC, LDPC Extra Symbol Segment, Pre-FEC Padding Factor, PE Disambiguity, UL Spatial Reuse, and Doppler subfields in the Common Info field are reserved.

The Number Of HE-LTF Symbols And Midamble Periodicity subfield in the Common Info field indicates the number of HE-LTF symbols present in the NDP feedback report response and is set to 1.

The GI And HE-LTF Type subfield in the Common Info field is set to 2.

The Trigger Dependent Common Info subfield is not present.

The User Info field for NFRP Trigger frame is defined in Figure 9-101 (User Info field format in the NFRP Trigger frame(11ax)(M118)).

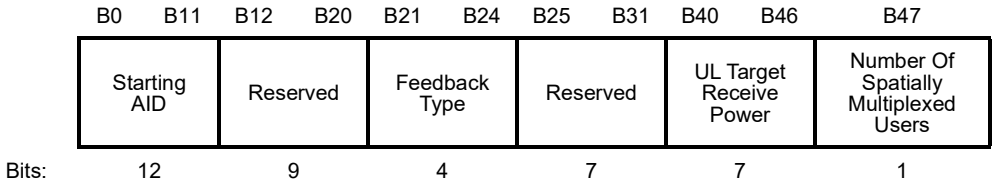


**Figure 9-101—User Info field format in the NFRP Trigger frame(11ax)(M118)**

The Feedback Type subfield encoding is defined in Table 9-55 (Feedback Type subfield encoding(11ax)).

**Table 9-55—Feedback Type subfield encoding(11ax)**

| Value | Description |
|---|---|
| 0 | Resource request |
| 1–15 | Reserved |

The scheduled non-AP HE STAs are identified by a range of AIDs. The Starting AID field defines the first AID of the range of AIDs that are scheduled to respond to the NFRP Trigger frame.

The UL Target Receive Power subfield indicates the expected receive signal power, measured at the AP's antenna connector and averaged over the antennas, for the HE portion of the HE TB PPDU transmitted on the assigned RU and is defined in Table 9-54 (UL Target Receive Power subfield in Trigger frame(11ax)).

The Number Of Spatially Multiplexed Users subfield indicates the number of STAs that are multiplexed on the same set of tones in the same RU, and is encoded as the number of STAs minus 1.


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The number of STAs, $N_{STA}$, that are scheduled to respond to the NFRP Trigger frame is calculated using Equation (9-2).

$$N_{STA} = 18 \times 2^{BW} \times (MultiplexingFlag + 1) \quad (9\text{-}2)$$

where *BW* is the value of the UL BW subfield in the Common Info field of the NFRP Trigger frame, and *MultiplexingFlag* is the value of the Number Of Spatially Multiplexed Users subfield.

#### 9.3.1.22.10 Ranging Trigger variant(11az)

The Ranging Trigger Subtype subfield value in the Trigger Dependent Common Info field of the Ranging Trigger frame, see Table 9-56 (Ranging Trigger Subtype subfield encoding(11az)), signals the Ranging Trigger frame subvariants, which can be one of five frame types: Poll, Sounding, Secure Sounding, Report, and Passive Sounding Ranging Trigger frame.

The format of the Trigger Dependent Common Info subfield for the Poll, Sounding, Secure Sounding, and Report Ranging Trigger frame, is shown in Figure 9-102 (Trigger Dependent Common Info subfield format for the Ranging Trigger subvariants Poll, Sounding, Secure Sounding, and Report(11az)). The Token field in the Trigger Dependent Common Info subfield is used in a Poll Ranging Trigger frame to match it with the partial TSF time in a following Ranging NDP Announcement frame. It is reserved in all other Ranging Trigger subvariants.

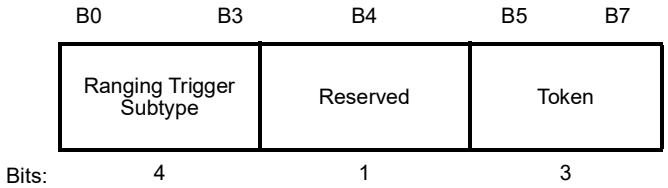


**Figure 9-102—Trigger Dependent Common Info subfield format for the Ranging Trigger subvariants Poll, Sounding, Secure Sounding, and Report(11az)**

The format of the Trigger Dependent Common Info subfield of Ranging Trigger frame of subvariant Passive Sounding is shown in Figure 9-103 (Trigger Dependent Common Info subfield format of the Passive Sounding Ranging Trigger frame(11az)). The Sounding Dialog Token Number subfield contains a value in the range of 0 to 63 which identifies a Measurement Sounding phase (I2RNDP and R2I NDP announced by a Sounding Trigger frame and the Ranging NDP Announcement frame, respectively), and the same value is included in the Sounding Dialog Token field of the Ranging NDP Announcement frame transmitted within the same availability window; see 9.3.1.19 (VHT/HE/Ranging NDP Announcement frame format(11ax)(11az)).

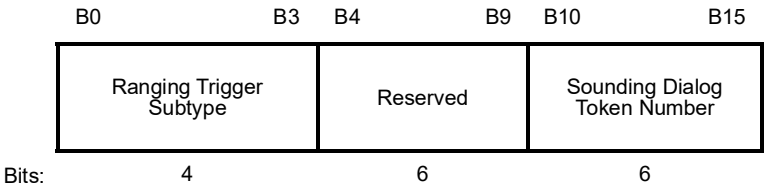


**Figure 9-103—Trigger Dependent Common Info subfield format of the Passive Sounding Ranging Trigger frame(11az)**

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The value of the Ranging Trigger Subtype subfield for the Ranging Trigger frame is defined in Table 9-56 (Ranging Trigger Subtype subfield encoding(11az)).

**Table 9-56—Ranging Trigger Subtype subfield encoding(11az)**

| Ranging Trigger Subtype subfield value | Ranging Trigger frame subvariant |
|---|---|
| 0 | Poll |
| 1 | Sounding |
| 2 | Secure Sounding |
| 3 | Report |
| 4 | Passive Sounding |
| 5–15 | Reserved |

The RA field, and the CS Required and UL BW subfields in the Common Info field of the Ranging Trigger frame are identical to the Basic Trigger frame described in 26.5.2 (UL MU operation) and 9.3.1.22 (Trigger frame format(11ax)), except that the RA field in Ranging Trigger frames with only one User Info field (#8240)is either an individual address or the broadcast address.(#6026)

The More TF subfield of the Common Info field of the Ranging Trigger frame indicates whether a subsequent Poll Ranging Trigger is scheduled for transmission within the availability window as defined in 11.21.6.4.3 (TB ranging measurement exchange(11az)).

When a Ranging Trigger frame is addressed to ISTAs that all have a TB ranging measurement exchange, see 11.21.6.4.3 (TB ranging measurement exchange(11az)), with the same RSTA's BSSID, the TA field of the Ranging Trigger frame is set to the RSTA's address. The TA field is set to the transmitted BSSID, if the Trigger frame is addressed to a set of ISTAs in which at least two ISTAs have a TB ranging measurement exchange with different BSSIDs in the Multiple BSSID set of the RSTA.

### 9.3.1.23 Subvariants of Ranging Trigger variant(11az)

#### 9.3.1.23.1 Poll subvariant

The format of the User Info field in the Poll Ranging Trigger frame is defined in Figure 9-104 (User Info field format for the Poll and Report Ranging Trigger(11az)).

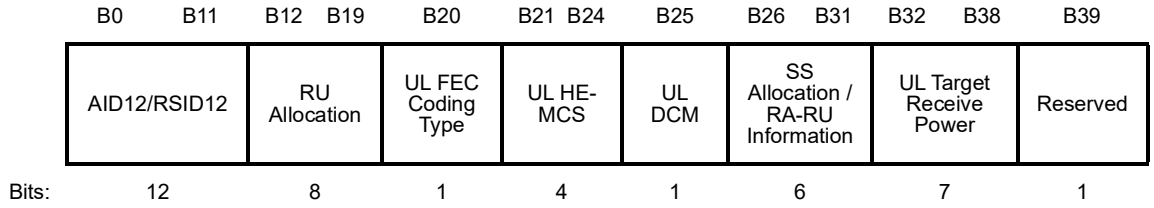


**Figure 9-104—User Info field format for the Poll and Report Ranging Trigger(11az)**

The AID12/RSID12 subfield carries either the 12 LSBs of the AID for an associated ISTA or the 12 LSBs of the RSID for an unassociated ISTA. The RU Allocation, UL FEC Coding Type, UL HE-MCS, UL DCM, SS


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Allocation/RA-RU Information, UL Target Receive Power subfields are identical to the corresponding subfield in the Basic Trigger frame; see 9.3.1.22 (Trigger frame format(11ax)).

The Trigger Dependent User Info subfield is not present in the Poll Ranging Trigger frame.

#### 9.3.1.23.2 Sounding subvariant

The format of the User Info field in the Sounding Ranging Trigger frame is defined in Figure 9-105 (User Info field format for Sounding subvariant(11az)).

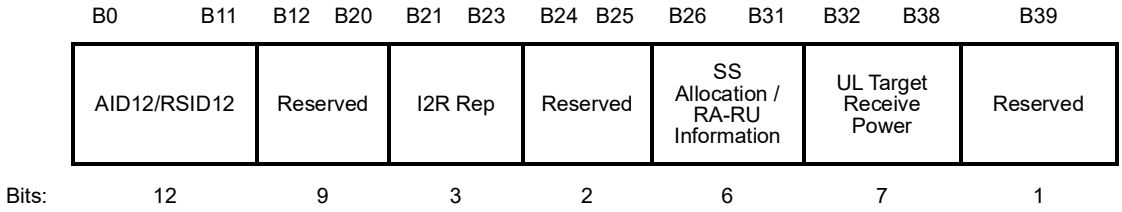


**Figure 9-105—User Info field format for Sounding subvariant(11az)**

The Trigger Dependent User Info subfield is not present in the Sounding Ranging Trigger frame.

The AID12/RSID12 subfield is identical to the corresponding subfield in the Poll Ranging Trigger frame.

The I2R Rep subfield indicates the number of HE-LTF repetitions in the corresponding HE TB Ranging NDP from the STA indicated in the AID12/RSID12 subfield; the I2R Rep subfield is set to the number of HE-LTF repetitions minus 1. The value of the I2R Rep subfield is the same in all User Info fields in a single Trigger frame. The SS Allocation/RA-RU Information and UL Target Receive Power subfields are identical to the corresponding subfields in the Basic Trigger frame; see 9.3.1.22 (Trigger frame format(11ax)).

In the Common Info field, the UL STBC, LDPC Extra Symbol Segment, Pre-FEC Padding Factor, and PE Disambiguity subfields are reserved.

The GI And HE-LTF Type subfield in the Common Info field is set to 1 (2x HE-LTF + 1.6 μs GI). The MU-MIMO HE-LTF Mode subfield in the Common Info field is set to 0 (HE single stream pilot HE-LTF mode).

The Doppler subfield in the Common Info field is set to 0.

NOTE—The UL Length subfield of a Trigger frame is computed using Equation (27-11) (see 26.5.2.2.4 (Allowed settings of the Trigger frame fields and TRS Control subfield)), which is based on the TXTIME computed in 27.4.3 (TXTIME and PSDU_LENGTH calculation). In case of Sounding Ranging Trigger frame, the resulting UL Length value is equivalent to $13 + 6 \times N_{LTF\_REP} \times N_{HE\text{-}LTF}$, where $N_{LTF\text{-}REP}$ is the number of HE-LTF repetitions (given by the I2R Rep subfield value plus 1) and $N_{HE\text{-}LTF}$ is the number of HE-LTF symbols (given by the Number Of HE-LTF Symbols And Midamble Periodicity subfield).

#### 9.3.1.23.3 Secure sounding subvariant

The format of the User Info field in the Secure Sounding Ranging Trigger is defined in Figure 9-106 (User Info field for Secure Sounding subvariant(11az)). There is a single User Info field in a Secure Sounding Ranging Trigger frame.

The AID12/RSID12 subfield is identical to the corresponding subfield in the Poll Ranging Trigger frame.

The I2R Rep subfield is identical to the corresponding subfield in the Sounding Ranging Trigger frame.

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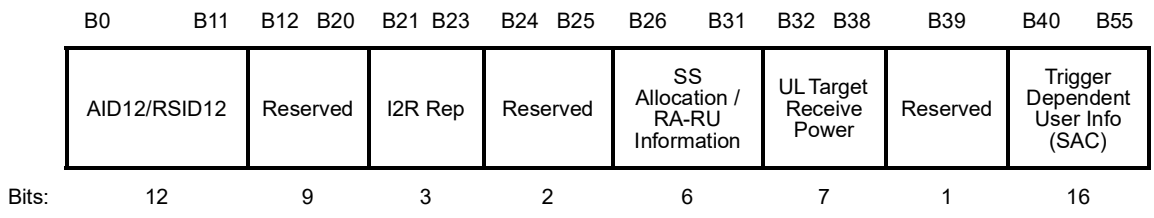


**Figure 9-106—User Info field for Secure Sounding subvariant(11az)**

The SS Allocation/RA-RU Information and UL Target Receive Power subfields are identical to the corresponding subfields in the Basic Trigger frame; see 9.3.1.22 (Trigger frame format(11ax)).

The Trigger Dependent User Info subfield is present in the Secure Sounding Ranging Trigger frame. The Trigger Dependent User Info subfield carries the Sequence Authentication Code (SAC) field. The SAC subfield provides the authentication information for the LTF Sequence Generation information used for the I2R sounding associated with the measurement instance; see 11.21.6.4.5 (Secure HE-LTF in the TB and non-TB ranging measurement exchange protocol(11az)). The length of this subfield is 16 bits.

NOTE—For measurement exchange with secure HE-LTF, the I2R Rep is set to the RSTA Assigned I2R Rep; see 11.21.6.3.4 (Negotiation for secure HE-LTF in the TB and non-TB ranging measurement exchange).

In the Common Info field, the MU-MIMO HE-LTF Mode, UL STBC, LDPC Extra Symbol Segment, Pre-FEC Padding Factor, and PE Disambiguity subfields are reserved. The GI And HE-LTF Type and Doppler subfields in the Common Info field are set as in the Sounding Ranging Trigger frame.

#### 9.3.1.23.4 Report subvariant

The format of the User Info field in the Report Ranging Trigger frame is defined in Figure 9-104 (User Info field format for the Poll and Report Ranging Trigger(11az)) and the subfields of the User Info field are identical to the corresponding subfields in the Poll Ranging Trigger frame.

The Trigger Dependent User Info subfield is not present in the Report Ranging Trigger frame.

#### 9.3.1.23.5 Passive sounding subvariant

The Passive Sounding Ranging Trigger frame follows the definition of the Sounding Ranging Trigger frame except that the RA field is always set to the broadcast address. There is a single User Info field in a Passive Sounding Ranging Trigger frame.

### 9.3.1.24 Sector Ack frame format(11ay)

The frame format for the Sector Ack frame is defined in Figure 9-107 (Sector Ack frame format(11ay)).

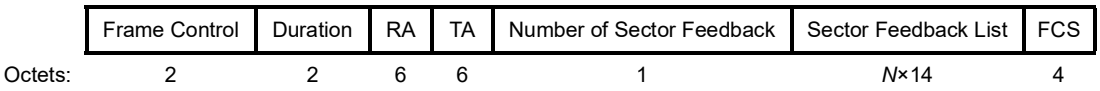


**Figure 9-107—Sector Ack frame format(11ay)**

The Duration field is set to the time until the end of the current beamforming training allocation (see 10.41.10.3.3 (Beamforming training allocation in DTI)).


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If the value of the Number of Sector Feedback field is 1, the RA field contains the MAC address of the STA that is the intended destination of the Sector Ack frame. If the value of the Number of Sector Feedback field is greater than 1, the RA field is set to the broadcast address.

The TA field contains the MAC address of the STA transmitting the Sector Ack frame.

The Number of Sector Feedback field indicates the number, *N*, of Sector Feedback fields within the Sector Feedback List field.

The Sector Feedback List field contains *N* Sector Feedback fields as defined in 9.5.9 (Sector Feedback field(11ay)).

### 9.3.1.25 Block Ack Schedule frame format(11ay)

The frame format for the Block Ack Schedule frame is defined in Figure 9-108 (Block Ack Schedule frame format(11ay)).

| | Frame Control | Duration | RA | TA | Block Ack Schedule Information | FCS |
|---|---|---|---|---|---|---|
| Octets: | 2 | 2 | 6 | 6 | 8 | 4 |

**Figure 9-108—Block Ack Schedule frame format(11ay)**

The Duration field is set to the time until the end of the TXOP or SP.

The RA field contains the MAC address of the STA that is the intended receiver of the Block Ack Schedule frame.

The TA field contains the MAC address of the STA transmitting the Block Ack Schedule frame.

The Block Ack Schedule Information field is defined in Figure 9-109 (Block Ack Schedule Information field format(11ay)).

| | B0 B15 | B16 B31 | B32 B47 | B48 B51 | B52 B53 | B54 B63 |
|---|---|---|---|---|---|---|
| | Response Offset | Response Duration | Next PPDU Start offset | TID Aggregation Limit | Preferred AC | Reserved |
| Bits: | 16 | 16 | 16 | 4 | 2 | 10 |

**Figure 9-109—Block Ack Schedule Information field format(11ay)**

The Response Offset subfield indicates the offset, in units of 1 μs, from the end of transmitted PPDU to the time when the response is expected to be transmitted by the intended responder.

The Response Duration subfield indicates the maximum duration of the responder transmission in units of 1 μs.(#1145)

The Next PPDU Start Offset subfield indicates the offset, in units of 1 μs, from the end of the transmitted PPDU to when the initiator is expected to start transmitting its next PPDU. If the transmitter does not intend to transmit its next PPDU to a responder, the Next PPDU Start Offset field is set to 0.

If the EDMG Multi-TID Aggregation Support subfield is greater than 0 in the STA's EDMG Capabilities element, the TID Aggregation Limit subfield indicates the maximum number of TIDs that can be aggregated

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in an A-MPDU by the RD responder as part of an RDG. Otherwise, the TID Aggregation Limit subfield is reserved.

If the EDMG Multi-TID Aggregation Support subfield is greater than 0 in the EDMG Capabilities element of the STA that is transmitting this element, the Preferred AC subfield indicates the lowest priority AC for aggregation of MPDUs in an A-MPDU sent as part of an RDG. Otherwise, the Preferred AC subfield is reserved. The Preferred AC subfield is reserved if the AC Constraint subfield is equal to 0. The Preferred AC subfield is encoded as the AC index (ACI) defined in Table 9-193 (ACI-to-AC coding).

### 9.3.1.26 TDD Beamforming frame format(11ay)

#### 9.3.1.26.1 Overview

The frame format for the TDD Beamforming frame is defined in Figure 9-110 (TDD Beamforming frame format(11ay)).

| | Frame Control | Duration | RA | TA | TDD Beamforming Control | TDD Beamforming Information | FCS |
|---|---|---|---|---|---|---|---|
| Octets: | 2 | 2 | 6 | 6 | 1 | variable | 4 |

**Figure 9-110—TDD Beamforming frame format(11ay)**

The Duration field is set to the time until the end of the current TDD slot.

The RA field is set to the MAC address of the intended receiver of the TDD Beamforming frame, or to the broadcast address when the intended receiver MAC address is unknown or there is more than one intended receiver.

The TA field is set to the MAC address of the transmitter STA of the TDD Beamforming frame.

The TDD Beamforming Control field is defined as shown in Figure 9-111 (TDD Beamforming Control field format(11ay)).

| | B0 | B1 | B2 B3 | B4 | B5 B7 |
|---|---|---|---|---|---|
| | TDD Group Beamforming | TDD Beam Measurement | TDD Beamforming Frame Type | End of Training | Reserved |
| Bits: | 1 | 1 | 2 | 1 | 3 |

**Figure 9-111—TDD Beamforming Control field format(11ay)**

Collectively, the TDD Group Beamforming, TDD Beam Measurement, and RA field values indicate a TDD Beamforming frame usage, as listed in Table 9-57 (TDD Beamforming frame usage(11ay)).

The TDD Beamforming Frame Type subfield is defined as shown in Table 9-58 (TDD Beamforming Frame Type subfield definition(11ay)).

The End of Training subfield is set as follows:

— The End of Training subfield is set to 1 in a TDD SSW frame to indicate that the initiator intends to end the TDD individual beamforming training or the TDD beam measurement after the transmission of the remaining TDD SSW frames with the current Sector ID; this subfield is set to 0 otherwise.

— The End of Training subfield is set to 1 in a TDD SSW Feedback frame sent as part of a TDD individual beamforming training if the TDD SSW Feedback frame is sent in response to a


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**Table 9-57—TDD Beamforming frame usage(11ay)**

| TDD Group Beamforming field value | TDD Beam Measurement field value | RA field value | Beamforming procedure |
|---|---|---|---|
| 0 | 0 | Individual address | TDD individual BF with a known STA |
| 0 | 0 | Broadcast address | TDD individual BF with an unknown STA |
| 0 | 1 | Individual address | TDD beam measurement with a known STA |
| 0 | 1 | Broadcast address | TDD beam measurement with all neighboring STAs |
| 1 | 0 | Individual address | Reserved |
| 1 | 0 | Broadcast address | TDD group BF with two or more STAs |
| 1 | 1 | Individual address | Reserved |
| 1 | 1 | Broadcast address | Reserved |

**Table 9-58—TDD Beamforming Frame Type subfield definition(11ay)**

| Value | Meaning |
|---|---|
| 0 | TDD SSW (Sector Sweep).<br><br>The TDD Beamforming Frame Type subfield is set to this value to indicate a TDD SSW frame (see 10.41.11 (TDD beamforming(11ay))). |
| 1 | TDD SSW Feedback.<br><br>The TDD Beamforming Frame Type subfield is set to this value to indicate a TDD SSW Feedback frame (see 10.41.11 (TDD beamforming(11ay))). |
| 2 | TDD SSW Ack.<br><br>The TDD Beamforming Frame Type subfield is set to this value to indicate a TDD SSW Ack frame (see 10.41.11 (TDD beamforming(11ay))). |
| 3 | Reserved |

TDD SSW frame in which its End of Training subfield was set to 1; this subfield is set to 0 otherwise.

— The End of Training subfield is set to 1 in a TDD SSW Ack frame to indicate that the TDD individual beamforming training has completed; otherwise, this subfield is set to 0.

For TDD group BF, the End of Training subfield is reserved.

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The definition of the TDD Beamforming Information field depends on the type of frame indicated by the TDD Beamforming Frame Type subfield and is specified in 9.3.1.26.2 (TDD SSW frame), 9.3.1.26.3 (TDD SSW Feedback frame), and 9.3.1.26.4 (TDD SSW Ack frame).

The length of the TDD Beamforming Information field is 6 octets when the TDD Group Beamforming subfield is 0 and is $5 + 4 \times R$ octets otherwise, where $R$ is the number of target responders. The length of the TDD Beamforming Information field does not change during TDD group BF, even after beamforming training with one or more of target responders has completed. For the target responder that has completed beamforming training, the corresponding Responder Info subfield that has the Responder Info Valid subfield equal to 0 is reserved.

### 9.3.1.26.2 TDD SSW frame

The TDD Beamforming Information field of a TDD SSW frame when TDD individual BF is used is shown in Figure 9-112 (TDD Beamforming Information field format (TDD individual BF)(11ay)). The TDD Beamforming Information field of a TDD SSW frame when TDD group BF is used is shown in Figure 9-113 (TDD Beamforming Information field format (TDD group BF)(11ay)). The TDD Beamforming Information field of a TDD SSW frame when TDD beam measurement is used is shown in Figure 9-114 (TDD Beamforming Information field format (TDD beam measurement)(11ay)).

| | B0 B8 | B9 B11 | B12 B14 | B15 B17 | B18 B25 | B26 B35 | B36 B45 | B46 B47 |
|---|---|---|---|---|---|---|---|---|
| | TX Sector ID | TX Antenna ID | Count Index | Beamforming Time Unit | Transmit Period | Responder Feedback Offset | Initiator Ack Offset | Number Of Requested Feedback |
| Bits: | 9 | 3 | 3 | 3 | 8 | 10 | 10 | 2 |

**Figure 9-112—TDD Beamforming Information field format (TDD individual BF)(11ay)**

| | B0 B8 | B9 B11 | B12 B14 | B15 B17 | B18 B25 | B26 B28 | B29 B36 | B37 B(37 + *N*×32 – 1) | B(37 + *N*×32) B(37 + *N*×32 + 2) |
|---|---|---|---|---|---|---|---|---|---|
| | TX Sector ID | TX Antenna ID | Count Index | Beamforming Time Unit | Transmit Period | Ack Count Index | Number of Responders | Responder Info List | Reserved |
| Bits: | 9 | 3 | 3 | 3 | 8 | 3 | 8 | *N*×32 | 3 |

**Figure 9-113—TDD Beamforming Information field format (TDD group BF)(11ay)**

| | B0 B8 | B9 B11 | B12 B14 | B15 B17 | B18 B25 | B26 B35 | B36 | B37 B47 |
|---|---|---|---|---|---|---|---|---|
| | TX Sector ID | TX Antenna ID | Count Index | Beamforming Time Unit | Transmit Period | TDD Slot CDOWN | Feedback Requested | Reserved |
| Bits: | 9 | 3 | 3 | 3 | 8 | 10 | 1 | 11 |

**Figure 9-114—TDD Beamforming Information field format (TDD beam measurement)(11ay)**

The TX Sector ID subfield is set to indicate the antenna sector through which the TDD SSW frame is transmitted.

NOTE—The size of sector ID fields in TDD beamforming frames are smaller than EDMG beamforming frames.


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The TX Antenna ID subfield indicates the DMG antenna ID through which the TDD SSW frame is transmitted.

The Count Index subfield indicates the index of TDD Beamforming frames transmitted by the initiator within a TDD slot, with the subfield set to 0 for the first transmission and increased by one for each successive transmission within a TDD slot.

The Beamforming Time Unit (BTU) subfield is defined in Table 9-59 (Beamforming Time Unit subfield(11ay)). The BTU subfield indicates the beamforming time unit for the Transmit Period, Responder Feedback Offset and Initiator Ack Offset subfields in the TDD Beamforming Information field of TDD SSW frames. The BTU subfield also defines the time unit for the Transmit Period, Initiator Transmit Offset and Responder Transmit Offset subfields in the TDD Beamforming Information field of TDD SSW Ack frames.

**Table 9-59—Beamforming Time Unit subfield(11ay)**

| Value | Time unit |
|---|---|
| 0 | 1 μs(#1098) |
| 1 | 100 μs(#1098) |
| 2 | 400 μs(#1098) |
| 3–7 | Reserved |

The Transmit Period subfield indicates the time interval, in units of BTUs, between TDD SSW transmissions with the same Count Index subfield value in different TDD slots. If the Transmit Period Offset subfield is 0, the transmission periodicity is unknown.

The Responder Feedback Offset subfield indicates the offset, in units of BTUs, from the beginning of the first TDD SSW frame in a TDD slot to when the first TDD SSW Feedback frame is to be transmitted by the responder. This subfield is reserved when the TDD SSW frame is transmitted exclusively for TDD beam measurement.

The Initiator Ack Offset subfield indicates the offset, in units of BTUs, from the beginning of the first TDD SSW frame in a TDD slot to when the first TDD SSW Ack frame is to be transmitted by the initiator. This subfield is reserved when the TDD SSW frame is transmitted exclusively for TDD beam measurement.

The Number Of Requested Feedback subfield indicates the number of TDD SSW Feedback frames the responder is required to transmit in response. Value of 0 indicates one frame to be sent, value of 1 indicates two frames and so on.

The Ack Count Index subfield indicates the number of the TDD SSW Ack frames that have been sent before the current TDD SSW frame within the same TDD slot. The Ack Count Index subfield is set to 0 if no TDD SSW Ack frame is transmitted before the current TDD SSW frame in the same TDD slot, and increases by one for each transmission of a TDD SSW Ack frame within the same TDD slot.

The Number of Responders subfield indicates the number of responders, *N*, with which the initiator intends to do TDD beamforming.

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The Responder Info List subfield contains *N* Responder Info subfields. Each Responder Info subfield is defined in Figure 9-115 (Responder Info subfield format(11ay)).

| | B0 B9 | B10 B19 | B20 B29 | B30 | B31 |
|---|---|---|---|---|---|
| | Responder ID | Responder Feedback Offset | Initiator Ack Offset | End of Training | Responder Info Valid |
| Bits: | 10 | 10 | 10 | 1 | 1 |

**Figure 9-115—Responder Info subfield format(11ay)**

The Responder ID subfield indicates the ID of the responder. The content of this subfield is derived from the responder's MAC address, based on the scheme in 10.41.11.4 (Initiator operation for TDD group beamforming).

The Responder Feedback Offset subfield and the Initiator Ack Offset subfield are as defined above in this subclause.

The End of Training subfield set to 1 in the Responder Info subfield of a TDD SSW frame for TDD Group beamforming training indicates that the initiator intends to end the TDD beamforming training with the corresponding responder after the transmission of the remaining TDD SSW frames with the current Sector ID; this subfield is set to 0 otherwise.

The Responder Info Valid subfield is set to 1 to indicate that the Responder Info subfield values are valid and is set to 0 otherwise.

The TDD Slot CDOWN subfield is a down counter indicating the number of remaining TDD SP slots to the end of the TDD beam measurement. This subfield is set to 0 in the last TDD SSW frame transmission.

The Feedback Requested subfield set to 1 requests that the responder(s) send a TDD Route element to the initiator as a feedback to the TDD beam measurement.

#### 9.3.1.26.3 TDD SSW Feedback frame

The TDD Beamforming Information field of a TDD SSW Feedback frame is shown in Figure 9-116 (TDD Beamforming Information field format(11ay)).

| | B0 B8 | B9 B11 | B12 B20 | B21 B23 | B24 B31 | B32 B33 | B34 B47 |
|---|---|---|---|---|---|---|---|
| | TX Sector ID | TX Antenna ID | Decoded TX Sector ID | Decoded TX Antenna ID | SNR Report | Feedback Count Index | Reserved |
| Bits: | 9 | 3 | 9 | 3 | 8 | 2 | 14 |

**Figure 9-116—TDD Beamforming Information field format(11ay)**

The TX Sector ID subfield is set to indicate the sector through which the TDD SSW Feedback frame is transmitted.

The TX Antenna ID subfield indicates the DMG antenna ID through which the TDD SSW Feedback frame is transmitted.

The Decoded TX Sector ID subfield contains the value of the TX Sector ID subfield from the TDD SSW frame that the feedback frame is sent in response to and that the TDD SSW frame was received from the initiator with the best quality.


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The Decoded TX Antenna ID subfield contains the value of the TX Antenna ID subfield from the TDD SSW frame that the feedback frame is sent in response to and that was received with the best quality.

The SNR Report subfield is set to the value of the SNR achieved while decoding the TDD SSW frame received with the best quality and which is indicated in the Decoded TX Sector ID subfield. The value of the SNR Report subfield is (#1727)referenced to a level of –8 dB. Each step is 0.25 dB. SNR values less than or equal to –8 dB are represented as 0. SNR values greater than or equal to 55.75 dB are represented as 0xFF.

The Feedback Count Index subfield is counter indicating the index of the TDD SSW Feedback frame transmission during a TDD slot. Value 0 is used in the first transmitted TDD SSW Feedback frame and this subfield value is increased by 1 for each subsequent transmitted frame.

### 9.3.1.26.4 TDD SSW Ack frame

The TDD Beamforming Information field of a TDD SSW Ack frame when TDD individual BF is used is shown in Figure 9-117 (TDD Beamforming Information field format (TDD individual BF)(11ay)). The TDD Beamforming Information field of a TDD SSW Ack frame when TDD group BF is used is shown in Figure 9-118 (TDD Beamforming Information field format (TDD group BF)(11ay)).

| | B0 B8 | B9 B11 | B12 B14 | B15 B22 | B23 B30 | B31 B38 | B39 B46 | B47 |
|---|---|---|---|---|---|---|---|---|
| | Decoded TX Sector ID | Decoded TX Antenna ID | Count Index | Transmit Period | SNR Report | Initiator Transmit Offset | Responder Transmit Offset | Reserved |
| Bits: | 9 | 3 | 3 | 8 | 8 | 8 | 8 | 1 |

**Figure 9-117—TDD Beamforming Information field format (TDD individual BF)(11ay)**

| | B0 B8 | B9 B11 | B12 B14 | B15 B22 | B23 B30 | B31 B38 | B39 B46 | B47 B49 | B50 B55 |
|---|---|---|---|---|---|---|---|---|---|
| | Decoded TX Sector ID | Decoded TX Antenna ID | Count Index | Transmit Period | SNR Report | Initiator Transmit Offset | Responder Transmit Offset | Ack Count Index | Reserved |
| Bits: | 9 | 3 | 3 | 8 | 8 | 8 | 8 | 3 | 6 |

**Figure 9-118—TDD Beamforming Information field format (TDD group BF)(11ay)**

The Decoded TX Sector ID subfield contains the value of the TX Sector ID subfield from the TDD SSW Feedback frame that was received from the responder.

The Decoded TX Antenna ID subfield contains the value of the TX Antenna ID subfield from the TDD SSW Feedback frame that was received from the responder.

The Count Index subfield indicates the index of the TDD Beamforming frame transmitted by the initiator within a TDD slot, with the subfield set to 0 for the first frame transmission and increased by one for each successive frame transmission within a TDD slot.

The Transmit Period subfield is reserved when the End of Training subfield in the TDD SSW Ack frame is 0. Otherwise, it indicates the interval, in units of BTUs, between successive transmit opportunities for the initiator to transmit frames other than TDD Beamforming frames to the responder, and also between successive transmit opportunities for the responder to transmit frames other than TDD Beamforming frames to the initiator, after completion of the unscheduled beamforming procedure, as defined in 10.41.11 (TDD beamforming(11ay)).

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The SNR Report subfield is set to the value of the SNR achieved while decoding the TDD SSW Feedback frame. The value of the SNR Report subfield is (#1727)referenced to a level of –8 dB. Each step is 0.25 dB. SNR values less than or equal to –8 dB are represented as 0. SNR values greater than or equal to 55.75 dB are represented as 0xFF.

The Initiator Transmit Offset subfield is reserved when the End of Training subfield in the TDD SSW Ack frame is 0. Otherwise, it indicates the offset, in units of BTUs, from the beginning of the first TDD Beamforming frame that is sent in the same TDD slot as the TDD SSW Ack frame (which can be the TDD SSW Ack frame itself), to the first transmit opportunity for the initiator to transmit a frame other than a TDD beamforming frame (i.e., a non-beamforming frame) to the responder. The Initiator Transmit Offset subfield is set to 0 to indicate that the initiator will transmit non-beamforming frames to the responder according to a TDD slot schedule available to the initiator and the responder.

The Responder Transmit Offset subfield is reserved when the End of Training subfield in the TDD SSW Ack frame is 0. Otherwise, it indicates the offset, in units of BTUs, from the beginning of the first TDD Beamforming frame that is sent in the same TDD slot as the TDD SSW Ack frame (which can be the TDD SSW Ack frame itself), to the first transmit opportunity for the responder to transmit a frame other than a TDD beamforming frame (i.e., a non-beamforming frame) to the initiator. The Responder Transmit Offset subfield is set to 0 to indicate that the responder will transmit non-beamforming frames to the initiator according to a TDD slot schedule available to the responder and the initiator.

The Ack Count Index subfield indicates the number of the TDD SSW Ack frames that have been sent before the current TDD SSW Ack frame within the same TDD slot. The Ack Count Index subfield is set to 0 if no TDD SSW Ack frame is transmitted before the current TDD SSW Ack frame in the same TDD slot, and increases by one for each transmission of a TDD SSW Ack frame within the same TDD slot.

### 9.3.2 Data frames

#### 9.3.2.1 Format of Data frames

##### 9.3.2.1.1 General

The format of a Data frame is defined in Figure 9-119 (Data frame format). The Frame Control, Duration, Address 1, Address 2, Address 3, and Sequence Control fields are present in all data frame subtypes. The presence of the Address 4 field is determined by the setting of the To DS and From DS subfields of the Frame Control field (see below). The presence of the QoS Control field is determined by the setting of the QoS subfield of the Subtype subfield (see 9.2.4.1.3 (Type and Subtype subfields) of the Frame Control field. The presence of the HT Control field is determined by the setting of the +HTC subfield of the Frame Control field (see 9.2.4.1.10 (+HTC subfield)).

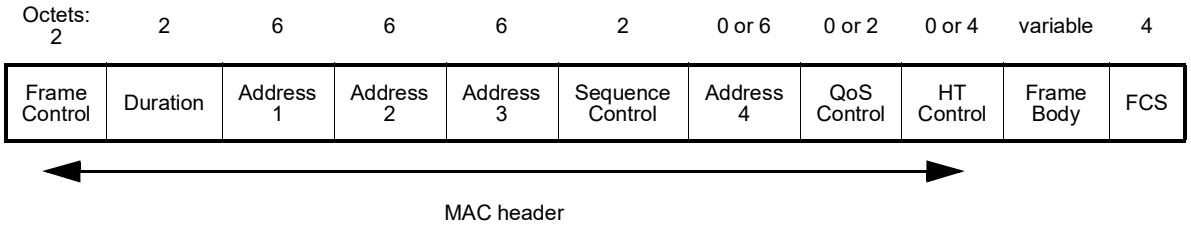


**Figure 9-119—Data frame format**

NOTE 1—The maximum frame body size shown in Figure 9-119 (Data frame format) is for GCMP encryption of a maximum-size A-MSDU (note that TKIP encryption is not allowed in this case and any Mesh Control fields are part of the A-MSDU subframes). The corresponding maximum for CCMP encryption is 7951 octets. The maximum frame body size if A-MSDUs are not used is 2346 octets for GCMP encryption of a maximum-size MSDU, 2338 octets for CCMP


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encryption of a maximum-size MSDU and 2342 octets for TKIP encryption of a maximum-size MSDU, including in both cases an 18-octet Mesh Control field. The frame body size might in all cases be greater if a vendor-specific cipher suite is used.

Data frames with the QoS subfield of the Subtype subfield (see 9.2.4.1.3 (Type and Subtype subfields)) set to 1 contain *QoS* in their names and contain a QoS Control field in the MAC header. Depending on the context, *QoS Data frame* either refers to any such frame, or refers specifically to the Data frame with subtype 1000. References nearby to other specific Data frames with *QoS* in their name (e.g., QoS Null or QoS Data +CF-Poll) typically suggest the latter interpretation.(#1670) A STA sets the QoS subfield as defined in 10.2.3.1 (General).(#1032)

### 9.3.2.1.2 Address and BSSID fields

The content of the address fields of Data frames is dependent upon the values of the To DS and From DS subfields in the Frame Control field and whether the Frame Body field contains either an MSDU (or fragment thereof) or an A-MSDU (or fragment thereof)(11ax), as determined by the A-MSDU Present subfield of the QoS Control field (see 9.2.4.5.9 (A-MSDU Present subfield)). The content of the address fields transmitted by nonmesh STAs is defined in Table 9-60 (Address field contents for Data frames transmitted by nonmesh STAs(#462)). The content of the address fields transmitted by mesh STAs is defined in 9.3.5 (Frame addressing in an MBSS), and the content of the fields transmitted by GLK STAs is defined in 10.64 (Addressing of GLK Data frame transmission). Where the content of a field is shown as not applicable (N/A), the field is omitted. Note that Address 1 always holds the receiver address of the intended receiver (or, in the case of group addressed frames, receivers) and that Address 2 always holds the address of the STA that is transmitting the frame. Note also that the address fields can be referred to by their contents, e.g., the Address 1 field can be referred to as the RA field and the Address 3 field for a Data frame transmitted by a nonmesh non-GLK STA with To DS and From DS subfields equal to 0 can be referred to as the BSSID field.(#3522)

A STA uses the contents of the Address 2 field to direct the acknowledgment if an acknowledgment is necessary.

The DA field contains the destination of the MSDU (or fragment thereof) or A-MSDU (or fragment thereof)(11ax) in the Frame Body field.

NOTE 1—A SYNRA is never the DA. When a GLK AP uses a SYNRA as the RA, the actual DA is carried in another field. See 10.64 (Addressing of GLK Data frame transmission).

The SA field contains the address of the MAC entity that initiated the MSDU (or fragment thereof) or A-MSDU (or fragment thereof)(11ax) in the Frame Body field.

When a Data frame carries an MSDU (or fragment thereof), the DA and SA(#3522) related to that MSDU are carried in the Address 1, Address 2, Address 3, and Address 4 fields (according to the setting of the To DS and From DS subfields) as defined in Table 9-60 (Address field contents for Data frames transmitted by nonmesh STAs(#462)).

When a Data frame carries a (#279)Basic A-MSDU (or fragment thereof)(11ax), the DA and SA(#3522) related to each MSDU carried by the A-MSDU are carried within the A-MSDU subframe header. Zero, one, or both of these fields are present in the Address 1 and Address 2 fields as indicated in Table 9-60 (Address field contents for Data frames transmitted by nonmesh STAs(#462)).

The RA field is the individual address of the STA that is the immediate intended receiver of the frame or the group address of the STAs that are the immediate intended receivers of the frame.

When a GLK Data frame is sent with (#1653)a four-address MAC header with a group RA(#1594), the RA is a SYNRA (see 10.64 (Addressing of GLK Data frame transmission)). A SYNRA is also used when the

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**Table 9-60—Address field contents for Data frames transmitted by nonmesh STAs(#462)**

| To DS | From DS | Address 1 | Address 2 | Address 3 | | Address 4 | |
|---|---|---|---|---|---|---|---|
| | | | | MSDU and Short A-MSDU case | Basic A-MSDU and Dynamic A-MSDU case | MSDU and Short A-MSDU case | Basic A-MSDU and Dynamic A-MSDU case |
| 0 | 0 | RA = DA | TA = SA | BSSID | BSSID | N/A | N/A |
| 0 | 1 | RA (see NOTE 1) | TA = BSSID | SA | BSSID | N/A | N/A |
| 1 | 0 | RA = BSSID | TA (see NOTE 2) | DA | BSSID | N/A | N/A |
| 1 | 1 | RA | TA | DA | BSSID | SA | BSSID |

NOTE 1—(#462)The Address 1 field of a frame with (#278)the To DS subfield equal to 0 and the From DS subfield equal to 1 is equal to the DA, except when a frame containing an A-MSDU is used (for DMS, DMG relay or S1G relay the frame is individually addressed; for GCR, it is (group) addressed to the GCR concealment address), (#274)in which case the destination address of the MSDU is indicated in the DA or Mesh DA field of the A-MSDU subframe (see 11.21.16 (Group addressed transmission service), 10.11 (A-MSDU operation), 10.44 (DMG relay operation), 10.53 (S1G relay operation), and 10.64 (Addressing of GLK Data frame transmission)). In an MBSS, this is the only combination used for group addressed Data frames, and a combination only used for group addressed Data frames (see Table 9-3 (Combinations of To DS subfield and From DS subfield in Data frames(#278)), Table 9-4 (Combinations of To DS and From DS subfields in Management frames(#278)), and Table 9-77 (Address field contents for mesh Data and Multihop Action frames(#462)(#419))).

NOTE 2—(#462)The Address 2 field of a frame with (#278)the To DS subfield equal to 1 and the From DS subfield equal to 0 is equal to the SA, except when an individually addressed frame containing an A-MSDU is used in GLK, DMG relay or S1G relay, (#274)in which case the source address of the MSDU is indicated in the SA or Mesh SA field of the A-MSDU subframe (see 10.11 (A-MSDU operation), 10.44 (DMG relay operation), 10.53 (S1G relay operation), and 10.64 (Addressing of GLK Data frame transmission)). In an MBSS, this combination is not used for Data frames (see Table 9-3 (Combinations of To DS subfield and From DS subfield in Data frames(#278)) and Table 9-77 (Address field contents for mesh Data and Multihop Action frames(#462)(#419))).

DA is not known by the corresponding IEEE 802.1Q bridge. The format of the RA field when it carries a SYNRA is shown in Figure 9-120 (Format of an RA field carrying a SYNRA).

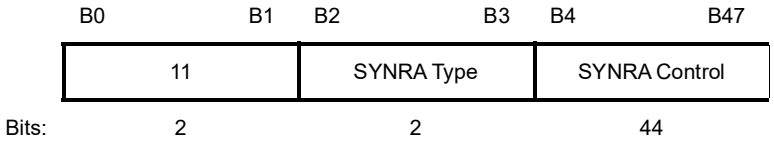


**Figure 9-120—Format of an RA field carrying a SYNRA**

NOTE 2—IEEE Std 802 and IEEE Std 802c-2017(#11) define (#1653)group addresses with a similar format to a SYNRA, but (#1653)group addresses are DAs in the context of IEEE Std 802.11. Since SYNRAs only occur in the RA field, the similar formats are disambiguated by virtue of being used within an RA or DA.

The SYNRA Type subfield is used to select between multiple possible SYNRA formats. The SYNRA types and the format of the SYNRA Control subfield for each type are listed in Table 9-61 (SYNRA Type field encoding).

The SYNRA Control subfield format is specified separately for each SYNRA type, as defined in Table 9-61 (SYNRA Type field encoding).

The AID Bitmap Offset subfield in a Basic SYNRA Control subfield is used to indicate the starting AID value, which is associated with bit 0 of the AID Bitmap subfield. Its value is multiplied by 4 to find the


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**Table 9-61—SYNRA Type field encoding**

| Value | Description | SYNRA Control subfield format |
|---|---|---|
| 0 | Basic SYNRA | See Figure 9-121 (Basic SYNRA Control subfield format). |
| 1–3 | Reserved | — |

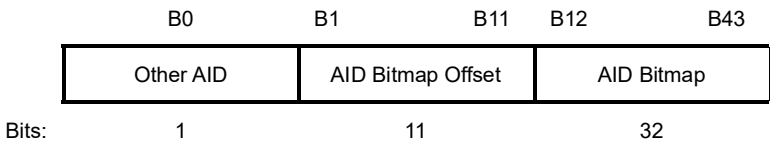


**Figure 9-121—Basic SYNRA Control subfield format**

starting AID value, and it has a value from 0 to 494 for a non-S1G STA, or 0 to 2040 for an S1G STA. Other values are reserved.

NOTE 3—These match the maximum AID values of 2007 (for non-S1G STAs) and 8191 (for S1G STAs).

The AID Bitmap subfield in a Basic SYNRA Control subfield provides the accept/discard indication for a range of 32 consecutive AIDs. (#465)B12 to B43 represent AID values in the range AID Bitmap Offset × 4 + 1 to AID Bitmap Offset × 4 + 32, respectively. For each bit in the AID Bitmap subfield, a 1 indicates acceptance, and a 0 indicates discarding.

The Other AID subfield in a Basic SYNRA Control subfield provides the accept/discard indication for AIDs outside the range of values covered by the AID Bitmap subfield. A 1 indicates acceptance, and a 0 indicates discarding.

The TA field is the address of the STA that is transmitting the frame.

The BSSID field of the Data frame is set as follows:

a) If the STA is contained within an AP or is associated with an AP, the BSSID is the address currently in use by the STA contained in the AP.
b) If the STA is an IBSS STA, the BSSID is that selected by the STA that started the IBSS.
c) If the STA is transmitting a Data frame when dot11OCBActivated is true, the BSSID is the wildcard BSSID.
d) If the STA is a member of an MBSS, the BSSID is the address of the transmitter and is equal to the Data frame's TA.
e) If the STA participates in a PBSS, the BSSID is the address of the STA contained in the PCP.

#### 9.3.2.1.3 Other MAC Header fields

The Sequence Control field is defined in 9.2.4.4 (Sequence Control field).

The QoS Control field is defined in 9.2.4.5 (QoS Control field). The presence of the QoS Control field is determined by the Subtype subfield of the Frame Control field, as specified in 9.2.4.1.3 (Type and Subtype subfields).

The HT Control field is defined in 9.2.4.6 (HT Control field). The presence of the HT Control field is determined by the +HTC subfield of the Frame Control field, as specified in 9.2.4.1.10 (+HTC subfield).

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#### 9.3.2.1.4 The frame body

The frame body consists of either of the following:

— The MSDU (or a fragment thereof), the Mesh Control field (present if the frame is transmitted by a mesh STA and the Mesh Control Present subfield of the QoS Control field is 1, otherwise absent), and a security header and trailer (present if the Protected Frame subfield in the Frame Control field is 1, otherwise absent)

— The A-MSDU and a security header and trailer (present if the Protected Frame subfield in the Frame Control field is 1, otherwise absent)

The presence of an A-MSDU in the frame body is indicated by setting the A-MSDU Present subfield of the QoS Control field to 1, as shown in Table 9-10 (QoS Control field).

For Data frames of subtype Null, QoS Null, QoS CF-Ack, QoS CF-Poll, and QoS CF-Ack +CF-Poll, the Frame Body field is null (i.e., has a length of 0 octets); these subtypes are used for MAC control purposes. For Data frames of subtype Data, the Frame Body field contains all of, or a fragment of, an MSDU after any encapsulation for security. For Data frames of subtypes QoS Data, QoS Data +CF-Ack, QoS Data +CF-Poll, and QoS Data +CF-Ack +CF-Poll, the Frame Body field contains an MSDU (or fragment thereof) or A-MSDU after any encapsulation for security. For Data frames of subtype QoS Data that are transmitted by a mesh STA, the Frame Body field also contains a Mesh Control field, as described in 9.2.4.8.3 (Mesh Control field). For Data frames of subtype EBCS Data, the Frame Body field contains an MSDU and fields for authentication in case of PKFA or HCFA, as described in 12.14.2.3 (PKFA MPDU format) or 12.14.3.3 (HCFA MPDU), respectively; in the case of HLSA, the Frame Body field contains an MSDU only.EQXX

The maximum length of the Frame Body field can be determined from the maximum MSDU length plus the length of the Mesh Control field (if present) plus any overhead from encapsulation for encryption (i.e., it is always possible to send a maximum length MSDU, with any encapsulations provided by the MAC(#6268) within a single Data frame). When the frame body carries an A-MSDU, the size of the Frame Body field is limited by:

— The PHY's maximum PHY service data unit (PSDU) length

— If A-MPDU aggregation is used by a non-VHT and non-DMG STA, a maximum MPDU length of 4095 octets (see 9.6.35 (EBCS Action frame details(11bc)))

#### 9.3.2.1.5 Duration field

Within all Data frames sent by the QoS STA, the Duration field contains a duration value as defined in 9.2.5 (Duration/ID field (QoS STA)). Within all Data frames sent by non-QoS STAs, the Duration field is set according to the following rules:

— If the Address 1 field contains a group address, the Duration field is set to 0.

— If the More Fragments bit is 0 in the Frame Control field of a frame and the Address 1 field contains an individual address, the Duration field is set to the time, in microseconds, required to transmit one Ack frame, plus one SIFS.

— If the More Fragments bit is 1 in the Frame Control field of a frame and the Address 1 field contains an individual address, the Duration field is set to the time, in microseconds, required to transmit the next fragment of this Data frame, plus two Ack frames, plus three SIFSs.

The Duration field calculation for the Data frame is based on the rules in 10.6 (Multirate support) that determine the data rate at which the Control frames in the frame exchange sequence are transmitted. If the calculated duration includes a fractional microsecond, that value is rounded up to the next higher integer. All STAs process Duration field(#3522) less than or equal to 32 767 from valid Data frames (without regard for the RA, DA, and/or BSSID fields(#3522) that might be present in these frames) to update their NAV settings as appropriate under the coordination function rules.


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NOTE 1—The QoS Data and QoS Null subtypes are the only Data subtypes transmitted by a DMG STA.

NOTE 2—The HT Control field is not present in frames transmitted by a DMG STA.

### 9.3.2.2 Aggregate MSDU (A-MSDU) format

#### 9.3.2.2.1 General

An A-MSDU is a sequence of A-MSDU subframes as shown in Figure 9-122 (A-MSDU structure). Each A-MSDU subframe consists of an A-MSDU subframe header followed by an MSDU and 0 to 3 octets of padding as shown in Figure 9-123 (Basic A-MSDU subframe structure when not in a mesh Data frame(#462)) (in 9.3.2.2.2 (Basic A-MSDU subframe format)), Figure 9-125 (Short A-MSDU subframe structure) (in 9.3.2.2.4 (Short A-MSDU subframe format)), and Figure 9-126 (Dynamic A-MSDU subframe structure) (in 9.3.2.2.5 (Dynamic A-MSDU format)).

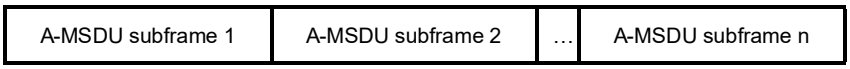


**Figure 9-122—A-MSDU structure**

Three A-MSDU subframe formats are defined: the Basic A-MSDU subframe described in 9.3.2.2.2 (Basic A-MSDU subframe format), the Short A-MSDU subframe described in 9.3.2.2.4 (Short A-MSDU subframe format), and the Dynamic A-MSDU subframe described in 9.3.2.2.5 (Dynamic A-MSDU format). Unless otherwise noted, in this standard, the term A-MSDU applies to any of the Basic A-MSDU, the Short A-MSDU, and the Dynamic A-MSDU. The Basic A-MSDU uses only the Basic A-MSDU subframe format, the Short A-MSDU uses only the Short A-MSDU subframe format, and the Dynamic A-MSDU uses only the Dynamic A-MSDU subframe format.

(#462)An A-MSDU contains only MSDUs whose DA and SA parameter values (in the MA-UNITDATA.request primitive) map to the same receiver address (RA) and same transmitter address (TA) field(#3522) (see 10.11 (A-MSDU operation)), respectively.

(#462)NOTE —The Address 1 (RA) and Address 2 (TA) fields in a Data frame identify the STA(s) receiving the frame and the STA transmitting the frame, respectively, whether or not the frame body carries an A-MSDU and, if it does, whether or not the source or destination of the MSDU(s) are those STAs.

#### 9.3.2.2.2 Basic A-MSDU subframe format

The structure of a Basic A-MSDU subframe (#462)when not in a mesh Data frame is shown in Figure 9-123 (Basic A-MSDU subframe structure when not in a mesh Data frame(#462)).

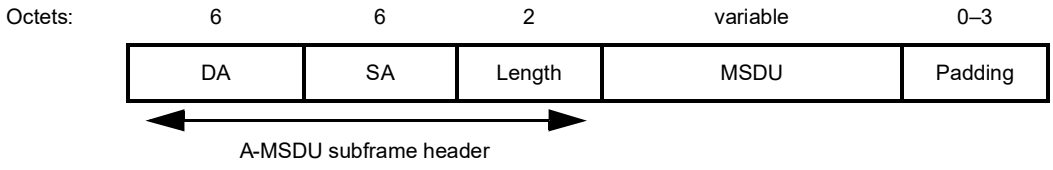


**Figure 9-123—Basic A-MSDU subframe structure when not in a mesh Data frame(#462)**

In the Basic A-MSDU subframe, each A-MSDU subframe (except the last) is padded so that its length is a multiple of 4 octets. The last A-MSDU subframe has no padding.

The A-MSDU subframe header contains three fields: DA, SA, and Length. The order of these fields and the bits within these fields are the same as the IEEE 802.3™ frame format. The DA and SA fields of the

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A-MSDU subframe header contain the values passed in the MA-UNITDATA.request and MA-UNITDATA.indication primitives. The Length field contains the length in octets of the MSDU(#462).

The MPDU containing the A-MSDU is carried in any of the following data frame subtypes: QoS Data, QoS Data +CF-Ack, QoS Data +CF-Poll, QoS Data +CF-Ack +CF-Poll. The A-MSDU structure is contained in the frame body of a single MPDU. If encrypted, the MPDU is encrypted as a single unit.

NOTE—The TID present in the QoS Control field of the MPDU carrying the A-MSDU indicates the TID for all MSDUs in the A-MSDU. Because this TID is common to all MSDUs in the A-MSDU, only MSDUs delivered to the MAC by an MA-UNITDATA.request primitive with an integer priority parameter that maps to the same TID can be aggregated together using A-MSDU.

#### 9.3.2.2.3 Mesh A-MSDU subframe format(#1340)

(#462)The structure of a Basic A-MSDU subframe when in a mesh Data frame is shown in Figure 9-124 (Basic A-MSDU subframe structure when in a mesh Data frame(#462)(#419)).

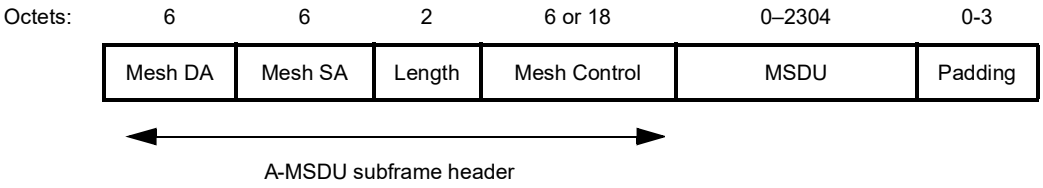


**Figure 9-124—Basic A-MSDU subframe structure when in a mesh Data frame(#462)(#419)**

The Mesh DA and Mesh SA fields contain the addresses of the destination mesh STA and the source mesh STA, respectively, determined in 9.3.5 (Frame addressing in an MBSS).

The Length field contains the length in octets of the MSDU.

NOTE—The octet order of the Length field is little endian in a mesh Data frame, which is different from the nonmesh Data frame case. Furthermore, the Mesh Control field following the Length field is not included in the length.(#4064)

The format of the Mesh Control field is described in 9.2.4.8.3 (Mesh Control field)(#462).

#### 9.3.2.2.4 Short A-MSDU subframe format

The Short A-MSDU subframe is shown in Figure 9-125 (Short A-MSDU subframe structure). In the Short A-MSDU subframe, each A-MSDU subframe (except the last) is padded so that its length excluding the A-MSDU subframe header is a multiple of 4 octets. The last A-MSDU subframe has no padding.

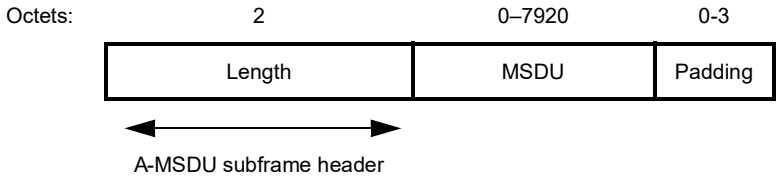


**Figure 9-125—Short A-MSDU subframe structure**

The Short A-MSDU subframe header consists of a Length field that contains the length in octets of the MSDU.

NOTE—The Short A-MSDU subframe format is not transmitted by non-DMG STAs.


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#### 9.3.2.2.5 Dynamic A-MSDU format

The structure of a Dynamic A-MSDU subframe is shown in Figure 9-126 (Dynamic A-MSDU subframe structure). In the Dynamic A-MSDU subframe, each A-MSDU subframe (except the last) is padded, so that its length is a multiple of 4 octets. The last A-MSDU subframe has no padding.

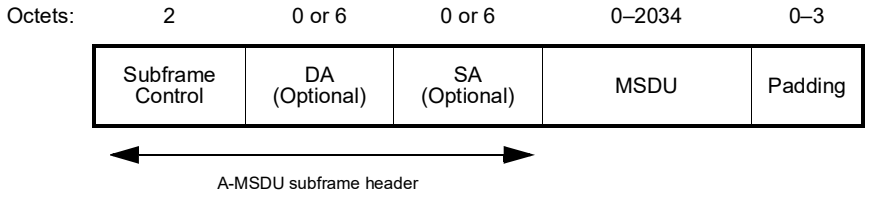


**Figure 9-126—Dynamic A-MSDU subframe structure**

The A-MSDU subframe header contains the Subframe Control field and optionally the DA and SA fields. A Dynamic A-MSDU subframe has 0, 1, or 2 addresses associated with it, as governed by the Subframe Control field.

The Subframe Control field is defined in Figure 9-127 (Subframe Control field format) and contains the Length, DA Present, and SA Present subfields.

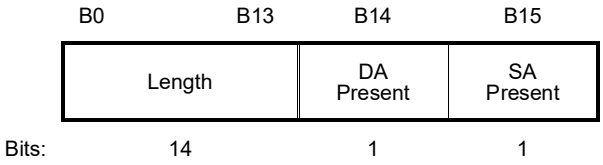


**Figure 9-127—Subframe Control field format**

The Length subfield contains the length in octets of the MSDU.

The DA Present field is set to 1 when the DA field is present in the Dynamic A-MSDU subframe header and is set to 0 when the DA field is not present.

The SA Present field is set to 1 when the SA field is present in the Dynamic A-MSDU subframe header and is set to 0 when the SA field is not present.

If present, the DA field of the Dynamic A-MSDU subframe header contains the destination address of the MSDU. When the DA field is not present, the DA of the MSDU is defined by the rules in 10.11 (A-MSDU operation).

If present, the SA field of the Dynamic A-MSDU subframe header contains the source address of the MSDU. When the SA field is not present in a Dynamic A-MSDU subframe, the SA is defined by the rules in 10.11 (A-MSDU operation).

The MSDU field contains the MSDU that is carried in the Dynamic A-MSDU subframe.

The Padding field contains 0 to 3 octets of padding, so that the length of the Dynamic A-MSDU subframe is a multiple of 4 octets, except for the last Dynamic A-MSDU subframe in a Dynamic A-MSDU, which has no padding.

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### 9.3.3 (PV0) Management frames

#### 9.3.3.1 Format of (PV0) Management frames

The format of a Management frame is defined in Figure 9-128 (Management frame format). The Frame Control, Duration, Address 1, Address 2, Address 3, and Sequence Control fields are present in all management frame subtypes. (#564)The maximum size of an MMPDU that is not carried in a VHT or S1G PPDU, or an HE PPDU not sent in the 2.4 GHz band(#4014) is defined in Table 9-34 (Maximum data unit sizes and durations(#1327)(#4013)). The presence of the HT Control field is determined by the setting of the +HTC subfield of the Frame Control field (see 9.2.4.1.10 (+HTC subfield). (#564)The maximum size of an MMPDU that is carried in one or more VHT or S1G PPDUs, or an HE PPDU not sent in the 2.4 GHz band (in whole or in part) is:(#4014)

— if there is one recipient, then the maximum MPDU size supported by the recipient less the shortest Management frame MAC header and FCS, or,

— if there is more than one recipient, then the smallest of the maximum MPDU sizes supported by the recipients less the shortest Management frame MAC header and FCS.

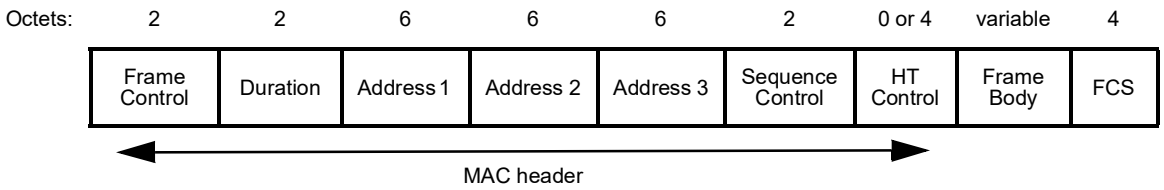


**Figure 9-128—Management frame format**

NOTE 1—In an MMPDU carried in one or more PPDUs, all of which are VHT or S1G PPDUs, the presence of encryption overhead (i.e., the MMPDU is transmitted in protected robust Management frames) or an HT Control field might cause an MMPDU to be fragmented that would not otherwise need to be fragmented.

A STA uses the contents of the Address 1 field to perform the address matching for receive decisions. In the case where the Address 1 field contains a group address and the frame subtype is other than Beacon or the frame subtype Action, Category Multihop Action (Multihop Action frame), the Address 3 field also is validated to verify that the group addressed frame originated from a STA in the BSS of which the receiving STA is a member or from a mesh STA to which mesh peering is maintained. Details of addressing and forwarding of the group addressed frame in an MBSS are defined in 10.37.4 (Addressing and forwarding of group addressed mesh Data frames). When the Address 1 field contains a group address and the frame subtype is either Probe Request or Action with Category Public, a wildcard BSSID(#3522) matches all receiving STA's (#4222)BSSs' BSSIDs. If the frame subtype is Beacon, other address matching rules apply, as specified in 11.1.3.7 (Beacon reception). Frames of subtype Probe Request are additionally processed as described in 11.1.4.3.2 (Active scanning procedure for a non-DMG STA) for non-DMG STAs and 11.1.4.3.3 (Active scanning procedure for a DMG STA) for DMG STAs. If the frame subtype is Action, the Category is Public, and the Action is 20/40 BSS Coexistence Management, then additional address matching rules for receive decisions apply as specified in 11.15 (20/40 MHz BSS operation) and 11.16 (20/40 BSS Coexistence Management frame usage).

The address fields for all Management frames except Multihop Action frames are as follows:

a) The Address 1 field of the Management frame is the RA (=DA) and is the destination of the frame.

b) The Address 2 field of the Management frame is the TA (=SA) and is the address of the STA transmitting the frame.


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1) If the STA is an AP with (#2078)dot11MultiBSSIDImplemented set to false, then this address is the BSSID.
2) If the STA is an AP with dot11MultiBSSIDImplemented set to true and the Address 1 field is not set to the broadcast address, then this address is the BSSID of the AP's BSS (which is either the transmitted BSSID or a nontransmitted BSSID).
3) If the STA is an AP with dot11MultiBSSIDImplemented set to true and the Address 1 field is set to the broadcast address, then this address is the transmitted BSSID.

c) The Address 3 field of the Management frame is set and determined as follows:

1) In Probe Request frames, the Address 3 field can be the wildcard BSSID as defined in the procedures specified in 11.1.4 (Acquiring synchronization, scanning). If Address 3 is not the wildcard BSSID, then it is (for a nonmesh STA) the BSSID of the BSS of the intended recipient(s), or (for a mesh STA) the MAC address of the intended recipient.

NOTE 2—Per 11.1.4.3.4 (Criteria for sending a response), a mesh STA does not examine the Address 3 field in Probe Request frames it receives. Using an individual address, however, might prevent unwanted responses from other STAs.

2) In Public Action frames, the Address 3 field is the BSSID,(#3522) set according to 11.17 (Public Action frame addressing).
3) If dot11OCBActivated is true, the Address 3 field is the wildcard BSSID.
4) Otherwise:
   i) If the STA is an AP or PCP, the Address 3 field is the same as the Address 2 field.
   ii) If the STA is transmitting the Management frame to an AP that is not in a multiple BSSID set or to a PCP, the Address 3 field is the BSSID, irrespective of whether the STA is associated with that AP or PCP.
   iii) If the STA is transmitting the Management frame to an AP that is in a multiple BSSID set, the Address 3 field is the BSSID of the AP's BSS (which is either the transmitted BSSID or a nontransmitted BSSID), irrespective of whether the STA is associated with that AP.
   iv) If the STA is transmitting the Management frame to one or more IBSS STAs, the Address 3 field is the BSSID.
   v) If the STA is a mesh STA, the Address 3 field is the TA.
   vi) If the STA is a TDLS STA transmitting the Management frame to a TDLS peer STA, and the AP to which they are associated is not in a multiple BSSID set, the Address 3 field is the BSSID.
   vii) If the STA is a TDLS STA transmitting the Management frame to a TDLS peer STA, and the AP to which they are associated is in a multiple BSSID set, the Address 3 field is the BSSID of the AP's BSS (which is either the transmitted BSSID or a nontransmitted BSSID).

The address fields for (#573)Multihop Action frames are described in 9.3.5 (Frame addressing in an MBSS).

Within all Management frames sent by the QoS STA, the Duration field contains a duration value as defined in 9.2.5 (Duration/ID field (QoS STA)). Within all Management frames sent by non-QoS STAs, the Duration field is set according to the following rules:

— If the DA field contains a group address, the Duration field is set to 0.
— If the More Fragments bit is 0 in the Frame Control field of a frame and the DA field contains an individual address, the Duration field is set to the time, in microseconds, required to transmit one Ack frame, plus one SIFS.
— If the More Fragments bit is 1 in the Frame Control field of a frame, and the DA field contains an individual address, the Duration field is set to the time, in microseconds, required to transmit the next fragment of this Management frame, plus two Ack frames, plus three SIFSs.

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The Duration field calculation for the Management frame is based on the rules in 10.6 (Multirate support) that determine the data rate at which the Control frames in the frame exchange sequence are transmitted. If the calculated duration includes a fractional microsecond, that value is rounded up to the next higher integer. All STAs process Duration field values less than or equal to 32 767 from valid Management frames to update their NAV settings as appropriate under the coordination function rules.

The HT Control field is defined in 9.2.4.6 (HT Control field). The presence of the HT Control field is determined by the +HTC subfield of the Frame Control field, as specified in 9.2.4.1.10 (+HTC subfield).

A Management frame is an IQMF when both

— The RA of the Management frame corresponds to (#1653)an individual address; and

— The To DS subfield is (#1539)equal to 1 and the From DS subfield of the Frame Control field is (#1539)equal to 0.

A Management frame is a GQMF when both

— The RA of the Management frame corresponds to (#1653)a group address; and

— The To DS subfield is (#1539)equal to 1 and the From DS subfield of the Frame Control field is equal(#1539) to 0.

The frame body consists of fields and elements as defined for each management frame subtype. All fields and elements are mandatory unless stated otherwise. Fields and elements appear in the specified, relative order, skipping fields or elements that are not present. STAs that encounter an element ID they do not recognize in the frame body of a received Management frame ignore that element and continue to parse the remainder of the management frame body (if any) for additional elements with recognizable element IDs. See 10.28.7 (Vendor specific element parsing).

### 9.3.3.2 Beacon frame format

The frame body of a Beacon frame contains the information shown in Table 9-62 (Beacon frame body).

**Table 9-62—Beacon frame body**

| Order | Information | Notes |
|---|---|---|
| 1 | Timestamp | See 9.4.1.10 (Timestamp field) for Timestamp field format. |
| 2 | Beacon Interval | See 9.4.1.3 (Beacon Interval field) for Beacon Interval field format. |
| 3 | Capability Information | See 9.4.1.4 (Capability Information field) for Capability Information field format. |
| 4 | Service Set Identifier (SSID) | If dot11MeshActivated is true, the SSID element is the wildcard value as described in 9.4.2.2 (SSID element). |
| 5 | Supported Rates and BSS Membership Selectors | |
| 6 | DSSS Parameter Set | The element is optionally present.<br>The DSSS Parameter Set element is present within Beacon frames generated by STAs using Clause 15 (DSSS PHY specification for the 2.4 GHz band designated for ISM applications), Clause 16 (High rate direct sequence spread spectrum (HR/DSSS) PHY specification), and Clause 18 (Extended Rate PHY (ERP) specification) PHYs.<br>The element is present within Beacon frames generated by STAs using a Clause 19 (High Throughput (HT) PHY specification(#2297)) PHY in the 2.4 GHz band. |


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**Table 9-62—Beacon frame body *(continued)***

| Order | Information | Notes |
|---|---|---|
| 7 | IBSS Parameter Set | The IBSS Parameter Set element is present only within Beacon frames generated by IBSS STAs. |
| 8 | Traffic indication map (TIM) | The TIM element is present only within Beacon frames generated by APs or mesh STAs. |
| 9 | Country | The Country element is present if dot11MultiDomainCapabilityActivated is true or dot11SpectrumManagementRequired is true or dot11RadioMeasurementActivated is true. |
| 10 | Power Constraint | The Power Constraint element is present if dot11SpectrumManagementRequired is true and is optionally present if dot11RadioMeasurementActivated is true. |
| 11 | Channel Switch Announcement | (#3085)The Channel Switch Announcement element is optionally present if dot11SpectrumManagementRequired is true or dot11ExtendedChannelSwitchActivated is true.(#511) |
| 12 | Quiet | The Quiet element is optionally present if dot11SpectrumManagementRequired is true or dot11RadioMeasurementActivated is true. |
| 13 | IBSS DFS | IBSS DFS element is present if dot11SpectrumManagementRequired is true in an IBSS. |
| 14 | TPC Report | The TPC Report element is present if dot11SpectrumManagementRequired is true or dot11RadioMeasurementActivated is true. |
| 15 | ERP | The ERP element is present within Beacon frames generated by STAs using extended rate PHYs (ERPs) defined in Clause 18 (Extended Rate PHY (ERP) specification) and is optionally present in other cases. |
| 16 | Extended Supported Rates and BSS Membership Selectors | (#3086)The Extended Supported Rates and BSS Membership Selectors element is present if the number of supported rates and BSS membership selectors(#1470) together exceed eight; it is optional otherwise. |
| 17 | RSN | The RSNE is present if dot11RSNAActivated is true; otherwise not present.(#3400) |
| 18 | BSS Load | The BSS Load element is present if dot11QosOptionImplemented and dot11QBSSLoadImplemented are both true. |
| 19 | EDCA Parameter Set | The EDCA Parameter Set element is present if dot11QosOptionImplemented is true, dot11MeshActivated is false, and the QoS Capability element is not present; otherwise, it is not present.(11ax) |
| 20 | QoS Capability | The QoS Capability element is present if dot11QosOptionImplemented is true, dot11MeshActivated is false, and neither the EDCA Parameter Set element nor the MU EDCA Parameter Set element is present; otherwise, it is not present.(11ax) |
| 21 | AP Channel Report | If dot11RMAPChannelReportActivated is true, one AP Channel Report element is present for each operating class that has at least 1 channel to report. |
| 22 | BSS Average Access Delay | The BSS Average Access Delay element is present if dot11RMBSSAverageAccessDelayActivated is true and the AP Average Access Delay field is not equal to 255 (measurement not available); otherwise, the BSS Average Access Delay element is optionally present if dot11RMBSSAverageAccessDelayActivated is true. |

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**Table 9-62—Beacon frame body *(continued)***

| Order | Information | Notes |
|---|---|---|
| 23 | Antenna | The Antenna element is present if dot11RMAntennaInformationActivated is true and the Antenna ID field is not equal to 0 (unknown antenna); otherwise, the Antenna element is optionally present if dot11RMAntennaInformationActivated is true. |
| 24 | BSS Available Admission Capacity | The BSS Available Admission Capacity element is present if dot11RMBSSAvailableAdmissionCapacityActivated is true with the following exceptions: 1) when Available Admission Capacity Bitmask equals 0 (Available Admission Capacity List contains no entries), or 2) when the BSS Load element is present and the Available Admission Capacity Bitmask states that only AC_VO is present in the Available Admission Capacity List field. |
| 25 | BSS AC Access Delay | The BSS AC Access Delay element is present if dot11RMBSSAverageAccessDelayActivated is true and at least one field of the element is not equal to 255 (measurement not available); otherwise, the BSS AC Access Delay element is optionally present if dot11RMBSSAverageAccessDelayActivated is true. |
| 26 | Measurement Pilot Transmission | The Measurement Pilot Transmission element is present if dot11RMMeasurementPilotActivated is a value between 2 and 7. |
| 27 | Multiple BSSID | (#488)One or more Multiple BSSID elements are present if the AP is a member of multiple BSSID set (see 11.10.14 (Multiple BSSID set)) with two or more members and any of the following conditions are true:<br>• dot11MultiBSSIDImplemented is true<br>• dot11MultiBSSIDImplemented is false and dot11RMMeasurementPilotActivated is between 2 and 7<br>• dot11FILSActivated is true<br>• dot11InterworkingServiceActivated is true and at least one dot11GASAdvertisementID exists |
| 28 | RM Enabled Capabilities | RM Enabled Capabilities element is present if dot11RadioMeasurementActivated is true. |
| 29 | Mobility Domain | The (#1776)MDE is present if dot11FastBSSTransitionActivated is true. |
| 30 | DSE registered location | The DSE Registered Location element is present if dot11LCIDSERequired is true. |
| 31 | Extended Channel Switch Announcement | The Extended Channel Switch Announcement element is optionally present if dot11ExtendedChannelSwitchActivated is true. |
| 32 | Supported Operating Classes | The Supported Operating Classes element is present if dot11ExtendedChannelSwitchActivated or dot11OperatingClassesRequired is true.<br>The Supported Operating Classes element is optionally present if dot11TVHTOptionImplemented is true. |
| 33 | HT Capabilities | The HT Capabilities element is present when dot11HighThroughputOptionImplemented is true and the STA is not a STA 6G.(11ax) |
| 34 | HT Operation | The HT Operation element is included by an AP and a mesh STA when dot11HighThroughputOptionImplemented is true and the AP or mesh STA is not a STA 6G.(11ax) |
| 35 | 20/40 BSS Coexistence | The 20/40 BSS Coexistence element is optionally present when dot112040BSSCoexistenceManagementSupport is true. |
| 36 | Overlapping BSS Scan Parameters | The Overlapping BSS Scan Parameters element is optionally present if dot11FortyMHzOptionImplemented is true. |


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**Table 9-62—Beacon frame body *(continued)***

| Order | Information | Notes |
|---|---|---|
| 37 | Extended Capabilities | The Extended Capabilities element is present if any of the fields in this element are nonzero. |
| 38 | FMS Descriptor | The FMS Descriptor element is present if dot11FMSActivated is true. |
| 39 | QoS Traffic Capability | The QoS Traffic Capability element is optionally present if dot11ACStationCountActivated is true. |
| 40 | Time Advertisement | The Time Advertisement element is present every dot11TimeAdvertisementDTIMInterval if dot11UTCTSFOffsetActivated is true. |
| 41 | Interworking | The Interworking element is present if dot11InterworkingServiceActivated is true. |
| 42 | Advertisement Protocol | Advertisement Protocol element is present if dot11InterworkingServiceActivated is true and at least one dot11GASAdvertisementID MIB attribute exists. |
| 43 | Roaming Consortium | The Roaming Consortium element is present if dot11InterworkingServiceActivated is true and the dot11RoamingConsortiumTable has at least one entry. |
| 44 | Emergency Alert Identifier | One or more Emergency Alert Identifier elements are present if dot11EASActivated is true and there are one or more EAS message(s) active in the network. |
| 45 | Mesh ID | The Mesh ID element is present if dot11MeshActivated is true. |
| 46 | Mesh Configuration | The Mesh Configuration element is present if dot11MeshActivated is true. |
| 47 | Mesh Awake Window | The Mesh Awake Window element is optionally present if dot11MeshActivated is true. |
| 48 | Beacon Timing | The Beacon Timing element is optionally present if both dot11MeshActivated and dot11MBCAActivated are true. |
| 49 | MCCAOP Advertisement Overview | The MCCAOP Advertisement Overview element is optionally present if both dot11MeshActivated and dot11MCCAActivated are true. |
| 50 | MCCAOP Advertisement | One or more MCCAOP Advertisement elements are optionally present if both dot11MeshActivated and dot11MCCAActivated are true. |
| 51 | Mesh Channel Switch Parameters | The Mesh Channel Switch Parameters element is present when dot11MeshActivated is true and either Channel Switch Announcement element or Extended Channel Switch Announcement element is present. |
| 52 | QMF Policy | Indicates the QMF policy parameters of the transmitting STA. The QMF Policy element is present when dot11QMFActivated is true and the transmitting STA is an AP or a mesh STA. This element is not present otherwise. |
| 53 | QLoad Report | The QLoad Report element is present every dot11QLoadReportIntervalDTIM DTIM intervals(#4221) if dot11QLoadReportActivated is true. |
| 54 | HCCA TXOP Update Count | The HCCA TXOP Update Count element is present if both dot11PublicHCCATXOPNegotiationActivated is true and an HC is (#2210)colocated with the AP. |
| 55 | Multi-band | The Multi-band element is optionally present if dot11MultibandImplemented is true. |

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**Table 9-62—Beacon frame body *(continued)***

| Order | Information | Notes |
|---|---|---|
| 56 | VHT Capabilities | The VHT Capabilities element is present in the 5 GHz band when dot11VHTOptionImplemented is true.(11ax)(#8181) |
| 57 | VHT Operation | The VHT Operation element is present when dot11VHTOptionImplemented is true and the STA is not a STA 6G and is optionally present if dot11HEOptionImplemented is true; otherwise, it is not present.(11ax) |
| 58 | Transmit Power Envelope(#474) | (11ax)One Transmit Power Envelope element is present for each distinct combination of values of the Maximum Transmit Power Interpretation subfield and Maximum Transmit Power Category subfield that is supported for the BSS if both of the following conditions are met:<br>Either dot11VHTOptionImplemented or dot11ExtendedSpectrumManagementImplemented is true.<br>Either dot11SpectrumManagementRequired is true or dot11RadioMeasurementActivated is true.<br>Otherwise, this element is not present.<br>NOTE—In a 6 GHz HE AP, both dot11VHTOptionImplemented (see 26.17.1 (Basic HE BSS operation)) and dot11SpectrumManagementRequired (see 26.17.2.1 (General)) are true. |
| 59 | Channel Switch Wrapper(#474) | The Channel Switch Wrapper element is optionally present if dot11VHTOptionImplemented or dot11ExtendedSpectrumManagementImplemented is true and at least one of a Channel Switch Announcement element or an Extended Channel Switch Announcement element is also present in the Beacon frame and the Channel Switch Wrapper element contains at least one subelement. |
| 60 | Extended BSS Load(#474) | The Extended BSS Load element is optionally present if dot11QBSSLoadImplemented and dot11VHTOptionImplemented are both true.(#3338)(#4130) |
| 61 | Quiet Channel | Either one Quiet Channel element containing an AP Quiet Mode field equal to 0 or, in an infrastructure BSS, one or more Quiet Channel elements each containing an AP Quiet Mode field equal to 1 are optionally present if dot11VHTOptionImplemented is true, and either dot11SpectrumManagementRequired or dot11RadioMeasurementActivated is true. |
| 62 | Operating Mode Notification | The Operating Mode Notification element is optionally present if dot11OperatingModeNotificationImplemented is true. |
| 63 | Reduced Neighbor Report | One or more Reduced Neighbor Report elements are optionally present if dot11TVHTOptionImplemented, dot11FILSActivated, or dot11ColocatedRNRImplemented is true; otherwise, they are not present.(11ax) |
| 64 | TVHT Operation | The TVHT Operation element is present for a (#4096)STA when dot11TVHTOptionImplemented is true; otherwise it is not present. |
| 65 | Estimated Service Parameters Inbound | The Estimated Service Parameters Inbound element is present if dot11EstimatedServiceParametersInboundOptionImplemented is true. |
| 66 | Future Channel Guidance | The Future Channel Guidance element is optionally present if dot11FutureChannelGuidanceActivated is true. |
| 67 | Common Advertisement Group (CAG) Number | The CAG Number element is optionally present if dot11FILSActivated is true; otherwise not present. |
| 68 | FILS Indication | The FILS Indication element is present if dot11FILSActivated is true; otherwise not present. |


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**Table 9-62—Beacon frame body *(continued)***

| Order | Information | Notes |
|---|---|---|
| 69 | AP-CSN | (#1776)The AP-CSN element is optionally present if dot11FILSActivated is true; otherwise not present. |
| 70 | DILS | The DILS element is optionally present if dot11FILSActivated is true; otherwise not present. |
| 71 | Max Channel Switch Time | The Max Channel Switch Time element is optionally present when a Channel Switch Announcement or an Extended Channel Switch Announcement element is also present. |
| 72 | Estimated Services Parameters Outbound | The Estimated Service Parameters Outbound element is optionally present if dot11EstimatedServiceParametersOutboundOptionImplemented is true. |
| 73 | Service Hint | The Service Hint element is optionally present if dot11UnsolicitedPADActivated is true. |
| 74 | Service Hash | The Service Hash element is optionally present if dot11UnsolicitedPADActivated is true. |
| 75 | RSN Extension | The RSNXE is present if any subfield of the Extended RSN Capabilities field in this element is nonzero, except the Field Length subfield. |
| 76(11ax) | Multiple BSSID Configuration | The Multiple BSSID Configuration element is optionally present if dot11MultiBSSIDImplemented is true. |
| 77(11ax) | HE Capabilities | The HE Capabilities element is present if dot11HEOptionImplemented is true; otherwise, it is not present. |
| 78(11ax) | HE Operation | The HE Operation element is present if dot11HEOptionImplemented is true; otherwise, it is not present. |
| 79(11ax) | TWT | The TWT element is optionally present if dot11TWTOptionActivated is true; otherwise, it is not present. |
| 80(11ax) | UORA Parameter Set | The UORA Parameter Set element is optionally present if dot11OFDMARandomAccessOptionImplemented is true; otherwise, it is not present. |
| 81(11ax) | BSS Color Change Announcement | The BSS Color Change Announcement element is optionally present if dot11HEOptionImplemented is true; otherwise, it is not present. |
| 82(11ax) | Spatial Reuse Parameter Set | The Spatial Reuse Parameter Set element is optionally present if dot11HEOptionImplemented is true; otherwise, it is not present. |
| 83 | MU EDCA Parameter Set | The MU EDCA Parameter Set element is present if dot11HEOptionImplemented is true, dot11MeshActivated is false, dot11MUEDCAParametersActivated is true, and the QoS Capability element is not present; otherwise, it is not present. |
| 84(11ax) | ESS Report | The ESS Report element is optionally present. |
| 85(11ax) | NDP Feedback Report Parameter Set | The NDP Feedback Report Parameter Set element is optionally present if dot11HEOptionImplemented is true; otherwise, it is not present. |
| 86(11ax) | HE BSS Load | The HE BSS Load element is optionally present if dot11QBSSLoadImplemented and dot11HEOptionImplemented are true. |
| 87(11ax) | HE 6 GHz Band Capabilities | The HE 6 GHz Band Capabilities element is present if dot11HEOptionImplemented and dot11HE6GOptionImplemented are true. |
| 88(11ax) | TWT Constraint Parameters | The TWT Constraint Parameters element is optionally present if dot11TWTOptionActivated is true; otherwise, it is not present. |

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**Table 9-62—Beacon frame body *(continued)***

| Order | Information | Notes |
|---|---|---|
| 89(11ba) | WUR Capabilities | The WUR Capabilities element is present when dot11WUROptionImplemented is true; otherwise it is not present. |
| 90(11ba) | WUR Operation | The WUR Operation element is present when dot11WUROptionImplemented is true; otherwise it is not present. |
| 91(11ba) | WUR Discovery | The WUR Discovery element is optionally present if dot11WUROptionImplemented is true and either dot11WURDiscoveryImplemented or dot11WURNeighborDiscoveryImplemented is true; otherwise it is not present. |
| 92(11az) | RSTA Availability Window | The RSTA Availability Window element is optionally present if dot11PassiveTBRangingResponderImplemented is true and a passive TB ranging availability window is present. |
| 93(11bc) | EBCS Parameters | This element is present if dot11EBCSSupportActivated is true and the length of dot11EBCSTrafficStreamTable is larger than 0, otherwise not present. |
| 94(11bc) | EBCS TIM | The EBCS TIM is present if dot11EBCSSupportActivated is true, dot11EBCSTIMInBeaconActivated is true, and one or more BUs for an EBCS traffic stream for which dot11EBCSTrafficStreamBuffered is true are buffered, otherwise not present. |
| Last – 1 | Vendor Specific | One or more Vendor Specific elements are optionally present.(#245) |
| Last | MME | The MME is present if dot11BeaconProtectionEnabled is true at the AP. |
| NOTE—The MME appears last in the frame body to protect the frames as specified in 12.5.3 (Broadcast/multicast integrity protocol (BIP)). Since it appears last and has a fixed size, it can readily be located without parsing all the elements in the frame.(#7154) | | |

### 9.3.3.3 ATIM frame format

The frame body of an ATIM frame is null.

### 9.3.3.4 Disassociation frame format

The frame body of a Disassociation frame contains the information shown in Table 9-63 (Disassociation frame body).

**Table 9-63—Disassociation frame body**

| Order | Information |
|---|---|
| 1 | Reason code |
| Last – 1 | One or more Vendor Specific elements are optionally present. |
| Last | The MME is present when management frame protection is enabled at the STA transmitting the frame(#1617)(#1549) and the frame is a group addressed frame. |
| NOTE—The MME appears last in the frame body to protect the frames as specified in 12.5.3 (Broadcast/multicast integrity protocol (BIP)). Since it appears last and has a fixed size, it can readily be located without parsing all the elements in the frame.(#7154) | |


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### 9.3.3.5 Association Request frame format

The frame body of an Association Request frame contains the information shown in Table 9-64 (Association Request frame body).

**Table 9-64—Association Request frame body**

| Order | Information | Notes |
|---|---|---|
| 1 | Capability Information | See 9.4.1.4 (Capability Information field) for Capability Information field format. |
| 2 | Listen Interval | |
| 3 | SSID | |
| 4 | Supported Rates and BSS Membership Selectors | (#1659)(#8229)See 11.1.4.6 (Operation of Supported Rates and BSS Membership Selectors element and Extended Supported Rates and BSS Membership Selectors element) for details on the inclusion of this element when dot11S1GOptionImplemented or dot11DMGOptionImplemented is true. |
| 5 | Extended Supported Rates and BSS Membership Selectors | (#3086)The Extended Supported Rates and BSS Membership Selectors element is present if the number of supported rates and BSS membership selectors(#1470) together exceed eight; it is optional otherwise.<br>(#1659)(#8229)See 11.1.4.6 (Operation of Supported Rates and BSS Membership Selectors element and Extended Supported Rates and BSS Membership Selectors element) for details on the inclusion of this element when dot11S1GOptionImplemented or dot11DMGOptionImplemented is true. |
| 6 | Power Capability | The Power Capability element is present if dot11SpectrumManagementRequired is true or dot11RadioMeasurementActivated is true. |
| 7 | Supported Channels | The Supported Channels element is present if dot11SpectrumManagementRequired is true and dot11ExtendedChannelSwitchActivated is false.<br>The Supported Channels element is optionally present, otherwise.(#3510) |
| 8 | RSN | The RSNE is present if dot11RSNAActivated is true; otherwise not present.(#3400) |
| 9 | QoS Capability | The QoS Capability element is present if dot11QosOptionImplemented is true. |
| 10 | RM Enabled Capabilities | RM Enabled Capabilities element is present if dot11RadioMeasurementActivated is true. |
| 11 | Mobility Domain | (#1776)The MDE is present in an Association Request frame if dot11FastBSSTransitionActivated is true and if the frame is being sent to an AP that advertised its FT capability in the MDE in its Beacon or Probe Response frame (i.e., AP also has dot11FastBSSTransitionActivated equal to true). |
| 12 | Supported Operating Classes | The Supported Operating Classes element is present if dot11ExtendedChannelSwitchActivated or dot11OperatingClassesRequired is true. |
| 13 | HT Capabilities | The HT Capabilities element is present when dot11HighThroughputOptionImplemented is true and the STA is not a STA 6G.(11ax) |

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**Table 9-64—Association Request frame body *(continued)***

| Order | Information | Notes |
|---|---|---|
| 14 | 20/40 BSS Coexistence | The 20/40 BSS Coexistence element is optionally present when dot112040BSSCoexistenceManagementSupport is true. |
| 15 | Extended Capabilities | The Extended Capabilities element is present if any of the fields in this element are nonzero. |
| 16 | QoS Traffic Capability | The QoS Traffic Capability element is present if dot11QoSTrafficCapabilityActivated is true. |
| 17 | TIM Broadcast Request | The TIM Broadcast Request element is present if dot11TIMBroadcastActivated is true. |
| 18 | Interworking | The Interworking element is present if dot11InterworkingServiceActivated is true and the non-AP STA is requesting unauthenticated access to emergency services (see 11.3.5 (Association, reassociation, and disassociation)). |
| 19 | Multi-band | The Multi-band element is optionally present if dot11MultibandImplemented is true. |
| 20 | DMG Capabilities | The DMG Capabilities element is present if dot11DMGOptionImplemented is true. |
| 21 | Multiple MAC Sublayers | The Multiple MAC Sublayers element is present if dot11MultipleMACActivated is true. |
| 22 | VHT Capabilities | The VHT Capabilities element is present in the 5 GHz band when dot11VHTOptionImplemented is true.(11ax)(#8181) |
| 23 | Operating Mode Notification | The Operating Mode Notification element is optionally present if dot11OperatingModeNotificationImplemented is true. |
| 24 | FILS Session | The FILS Session element is optionally present if dot11FILSActivated is true; otherwise not present. |
| 25 | FILS Public Key | The FILS Public Key element is present if dot11FILSActivated is true and FILS Public Key authentication is used; otherwise not present. |
| 26 | FILS Key Confirmation | The FILS Key Confirmation element is present if dot11FILSActivated is true and FILS authentication is used; otherwise not present. |
| 27 | FILS HLP Container | One or more FILS HLP Container elements are optionally present if dot11FILSActivated is true; otherwise not present. |
| 28 | FILS IP Address Assignment | The FILS IP Address Assignment element is optionally present if dot11FILSActivated is true; otherwise not present. |
| 29 | TWT | The TWT element is optionally present if dot11TWTOptionActivated is true; otherwise not present. |
| 30 | AID Request | The AID Request element is optionally present if dot11S1GOptionImplemented is true; otherwise not present. |
| 31 | S1G Capabilities | The S1G Capabilities element is present if dot11S1GOptionImplemented is true; otherwise not present. |
| 32 | EL Operation | The EL Operation element is optionally present if dot11S1GELOperationActivated is true; otherwise not present. |
| 33 | S1G Relay | The S1G Relay element is present if dot11RelaySTAImplemented is true; otherwise not present. |


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**Table 9-64—Association Request frame body *(continued)***

| Order | Information | Notes |
|---|---|---|
| 34 | BSS Max Idle Period | The BSS Max Idle Period element is optionally present if dot11WirelessManagementImplemented and dot11BSSMaxIdlePeriodIndicationByNonAPSTA are true, or if dot11S1GOptionImplemented is true; otherwise not present. |
| 35 | Header Compression | The Header Compression element is present if dot11PV1MACHeaderOptionImplemented is true. |
| 36 | MAD | The MAD element is optionally present if dot11S1GOptionImplemented is true; otherwise not present. |
| 37 | Reachable Address | The Reachable Address element is optionally present if dot11RelaySTAImplemented is true; otherwise not present. |
| 38 | S1G Relay Activation | The S1G Relay Activation element is optionally present if dot11RelaySTAImplemented is true; otherwise not present. |
| 39 | CDMG Capabilities | The CDMG Capabilities element is present if dot11CDMGOptionImplemented is true; otherwise not present. |
| 40 | CMMG Capabilities | The CMMG Capabilities element is present when dot11CMMGOptionImplemented is true; otherwise not present. |
| 41 | GLK-GCR Parameter Set | The GLK-GCR Parameter Set element is present if dot11GLKImplemented is true to indicate the number of reorder buffers the STA has to support GLK-GCR with GCR block ack and respond to corresponding GLK-GCR BlockAckReq frames. Otherwise this element is not present. |
| 42 | Fast BSS Transition | An FTE is present in an Association Request frame if dot11FastBSSTransitionActivated is true, dot11RSNAAuthenticationSuiteSelected is 00-0F-AC:16 or 00-0F-AC:17, and FT initial mobility domain association over FILS in an RSN is being performed. |
| 43 | RSN Extension | The RSNXE is present if any subfield of the Extended RSN Capabilities field in this element is nonzero, except the Field Length subfield. |
| 44 | Supplemental Class 2 Capabilities | The Supplemental Class 2 Capabilities element is present when dot11Class2CapabilitiesOptionImplemented is true; otherwise not present. |
| 45 | MSCS Descriptor | The MSCS Descriptor element is optionally present if dot11MSCSActivated is true; otherwise not present. |
| 46(11ax) | HE Capabilities | The HE Capabilities element is present if dot11HEOptionImplemented is true; otherwise, it is not present. |
| 47(11ax) | Channel Switch Timing | The Channel Switch Timing element is optionally present if dot11HESubchannelSelectiveTransmissionImplemented is true; otherwise, it is not present. |
| 48(11ax) | HE 6 GHz Band Capabilities | The HE 6 GHz Band Capabilities element is present if dot11HEOptionImplemented and dot11HE6GOptionImplemented are true; otherwise, it is not present. |
| 49(11ax) | UL MU Power Capabilities | The UL MU Power Capabilities element is optionally present if dot11HEOptionImplemented is true; otherwise, it is not present. |
| 50(11ax) | TWT Constraint Parameters | The TWT Constraint Parameters element is optionally present if dot11TWTOptionActivated is true; otherwise, it is not present. |
| 51(11ay) | EDMG Capabilities | The EDMG Capabilities element is present if dot11EDMGOptionImplemented is true. |

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**Table 9-64—Association Request frame body *(continued)***

| Order | Information | Notes |
|---|---|---|
| 52(11ay) | QoS Triggered Unscheduled | The QoS Triggered Unscheduled element is optionally present if dot11EDMGOptionImplemented is true. |
| 53(11ay) | Unsolicited Block Ack Extension | The Unsolicited Block Ack Extension element is optionally present if dot11UnsolicitedBAActivated is true and is absent otherwise. |
| 54(11ay) | TDD Slot Schedule | The TDD Slot Schedule element is optionally present if dot11DMGOptionImplemented is true. |
| 55(11ay) | TDD Route | This element is optionally present if dot11TDDOptionImplemented is true; otherwise, not present. If present, the element specifies the TDD beamforming results. |
| 56(11ba) | WUR Capabilities | The WUR Capabilities element is present when dot11WUROption-Implemented is true; otherwise it is not present. |
| 57(11ba) | WUR Mode | The WUR Mode element is optionally present when dot11WUROptionImplemented is true; otherwise, it is not present. |
| 58(#1084) | Diffie-Hellman Parameter | The Diffie-Hellman Parameter element is optionally present when performing OWE; otherwise it is not present. |
| 59(#4069) | Known STA Identification | The Known STA Identification element is optionally present if dot11RSNAActivated is true and the recipient of the frame has indicated support for this element in its Extended Capabilities field; otherwise not present. |
| 60(#6076) | Non-AP STA Regulatory Connectivity | The Non-AP STA Regulatory Connectivity element is optionally present if dot11ExtendedRegInfoSupport is true. |
| Last | Vendor Specific | One or more Vendor Specific elements are optionally present(#8128). |

### 9.3.3.6 Association Response frame format

The frame body of an Association Response frame contains the information shown in Table 9-65 (Association Response frame body).

**Table 9-65—Association Response frame body**

| Order | Information | Notes |
|---|---|---|
| 1 | Capability Information | See 9.4.1.4 (Capability Information field) for Capability Information field format. |
| 2 | Status Code(#1780) | |
| 3 | AID | This field is not present when dot11S1GOptionImplemented is true. |
| 4 | Supported Rates and BSS Membership Selectors | (#1659)(#8229)See 11.1.4.6 (Operation of Supported Rates and BSS Membership Selectors element and Extended Supported Rates and BSS Membership Selectors element) for details on the inclusion of this element when dot11S1GOptionImplemented or dot11DMGOptionImplemented is true. |


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**Table 9-65—Association Response frame body *(continued)***

| Order | Information | Notes |
|---|---|---|
| 5 | Extended Supported Rates and BSS Membership Selectors | (#3086)The Extended Supported Rates and BSS Membership Selectors element is present if the number of supported rates and BSS membership selectors(#1470) together exceed eight; it is optional otherwise. (#1659)(#8229)See 11.1.4.6 (Operation of Supported Rates and BSS Membership Selectors element and Extended Supported Rates and BSS Membership Selectors element) for details on the inclusion of this element when dot11S1GOptionImplemented or dot11DMGOptionImplemented is true. |
| 6 | EDCA Parameter Set | The EDCA Parameter Set element is present if dot11QosOptionImplemented is true; otherwise not present. |
| 7 | RCPI | The RCPI element is present if dot11RMRCPIMeasurementActivated is true. |
| 8 | RSNI | The RSNI element is present if dot11RMRSNIMeasurementActivated is true. |
| 9 | RM Enabled Capabilities | RM Enabled Capabilities element is present if dot11RadioMeasurementActivated is true. |
| 10 | RSN | The RSNE is present if dot11FILSActivated is true (#6088)or if performing OWE; otherwise not present. |
| 11 | Mobility Domain | An MDE is present in an Association Response frame when dot11FastBSSTransitionActivated is true and this frame is a response to an Association Request frame that contained an MDE (i.e., an FT initial mobility domain association exchange). |
| 12 | Fast BSS Transition | (#1776)An FTE is present in an Association Response frame when dot11FastBSSTransitionActivated is true, dot11RSNAActivated is true, and this frame is a response to an Association Request frame that contained an MDE (i.e., an FT initial mobility domain association exchange in an RSN). |
| 13 | DSE registered location | The DSE Registered Location element is present if dot11LCIDSERequired is true. |
| 14 | Timeout Interval (association comeback time(#3389)) | (#1776)A TIE containing the association comeback time(#3389) is present when dot11RSNAActivated is true, dot11RSNAProtectedManagementFramesActivated is true, and either the association request is rejected with a status code REFUSED_TEMPORARILY or the association request is accepted with a status code 0 and when dot11S1GOptionImplemented is true. |
| 15 | HT Capabilities | The HT Capabilities element is present when dot11HighThroughputOptionImplemented is true and the STA is not a STA 6G.(11ax) |
| 16 | HT Operation | The HT Operation element is included by an AP and a mesh STA when dot11HighThroughputOptionImplemented is true and the STA is not a STA 6G.(11ax) |
| 17 | 20/40 BSS Coexistence | The 20/40 BSS Coexistence element is optionally present when dot112040BSSCoexistenceManagementSupport is true. |
| 18 | Overlapping BSS Scan Parameters | The Overlapping BSS Scan Parameters element is optionally present if dot11FortyMHzOptionImplemented is true. |
| 19 | Extended Capabilities | The Extended Capabilities element is present if any of the fields in this element are nonzero. |

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**Table 9-65—Association Response frame body *(continued)***

| Order | Information | Notes |
|---|---|---|
| 20 | BSS Max Idle Period | The BSS Max Idle Period element is present if dot11WirelessManagementImplemented is true and the BSS max idle period is nonzero,(#138) or optionally present if dot11S1GOptionImplemented is true. |
| 21 | TIM Broadcast Response | The TIM Broadcast Response element is present if dot11TIMBroadcastActivated is true and the TIM Broadcast Request element is present in the Association Request frame that elicited this Association Response frame. |
| 22 | QoS Map | The QoS Map element is present if dot11QosMapActivated is true and the QoS Map field in the Extended Capabilities element of the corresponding Association Request frame is 1. |
| 23 | QMF Policy | The QMF Policy element is present if dot11QMFActivated is true and the QMFActivated subfield is 1 in the Extended Capabilities element in the Association Request frame that elicited this Association Response frame. |
| 24 | Multi-band | The Multi-band element is optionally present if dot11MultibandImplemented is true. |
| 25 | DMG Capabilities | The DMG Capabilities element is present if dot11DMGOptionImplemented is true. |
| 26 | DMG Operation | The DMG Operation element is present if dot11DMGOptionImplemented is true. |
| 27 | Multiple MAC Sublayers | The Multiple MAC Sublayers element is present if dot11MultipleMACActivated is true. |
| 28 | Neighbor Report | One or more Neighbor Report elements is present if the Status Code field is REJECTED_WITH_SUGGESTED_BSS_TRANSITION. |
| 29 | VHT Capabilities | The VHT Capabilities element is present in the 5 GHz band when dot11VHTOptionImplemented is true.(11ax)(#8181) |
| 30 | VHT Operation | The VHT Operation element is present when dot11VHTOptionImplemented is true and the STA is not a STA 6G and is optionally present if dot11HEOptionImplemented is true; otherwise, it is not present. (11ax) |
| 31 | Operating Mode Notification | The Operating Mode Notification element is optionally present if dot11OperatingModeNotificationImplemented is true. |
| 32 | Future Channel Guidance | The Future Channel Guidance element is optionally present if dot11FutureChannelGuidanceActivated is true. |
| 33 | FILS Session | The FILS Session element is present if dot11FILSActivated is true; otherwise not present. |
| 34 | FILS Public Key | The FILS Public Key element is present if dot11FILSActivated is true and FILS Public Key authentication is used; otherwise not present. |
| 35 | FILS Key Confirmation | The FILS Key Confirmation element is present if dot11FILSActivated is true and FILS authentication is used; otherwise not present. |
| 36 | FILS HLP Container | One or more FILS HLP Container elements are optionally present if dot11FILSActivated is true; otherwise not present. |
| 37 | FILS IP Address Assignment | The FILS IP Address Assignment element is optionally present if dot11FILSActivated is true; otherwise not present. |


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**Table 9-65—Association Response frame body *(continued)***

| Order | Information | Notes |
|---|---|---|
| 38 | Key Delivery | The Key Delivery element is present if dot11FILSActivated is true; otherwise not present. |
| 39 | S1G Sector Operation | The S1G Sector Operation element is optionally present if dot11S1GSectorizationActivated is true; otherwise not present. |
| 40 | TWT | The TWT element is present if dot11TWTOptionActivated is true, (#4005)dot11HEOptionImplemented is not true, and the TWT element is present in the Association Request frame that elicited this Association Response frame.<br><br>(11ax)The TWT element is optionally present if dot11TWTOptionActivated is true, dot11HEOptionImplemented is true, and the TWT Requester Support field in the HE Capabilities element in the Association Request frame that elicited this Association Response frame is 1.<br><br>(11ax)Otherwise, the TWT element is not present.(#4005) |
| 41 | TSF Timer Accuracy | The TSF Timer Accuracy element is optionally present when dot11TSFTimerAccuracyImplemented is true; otherwise not present. |
| 42 | S1G Capabilities | The S1G Capabilities element is present if dot11S1GOptionImplemented is true; otherwise not present. |
| 43 | S1G Operation | The S1G Operation element is present if dot11S1GOptionImplemented is true; otherwise not present. |
| 44 | AID Response | The AID Response element is present when dot11S1GOptionImplemented is true. |
| 45 | Sectorized Group ID List | The Sectorized Group ID List element is optionally present when dot11S1GSectorizationActivated is true; otherwise not present. |
| 46 | S1G Relay | The S1G Relay element is optionally present if dot11RelayAPImplemented is true; otherwise not present. |
| 47 | Header Compression | The Header Compression element is present if dot11PV1MACHeaderOptionImplemented is true. |
| 48 | SST Operation | The SST Operation element is present if dot11SelectiveSubchannelTransmissionPermitted is true. |
| 49 | MAD | The MAD element is optionally present if dot11S1GOptionImplemented is true; otherwise not present. |
| 50 | S1G Relay Activation | The S1G Relay Activation element is optionally present if dot11RelaySTAImplemented is true; otherwise not present. |
| 51 | CDMG Capabilities | The CDMG Capabilities element is present if dot11CDMGOptionImplemented is true; otherwise not present. |
| 52 | CMMG Capabilities | The CMMG Capabilities element is present when dot11CMMGOptionImplemented is true; otherwise not present. |
| 53 | CMMG Operation | The CMMG Operation element is present when dot11CMMGOptionImplemented is true; otherwise not present. |
| 54 | GLK-GCR Parameter Set | The GLK-GCR Parameter Set element is present if dot11GLKimplemented is true and the AP has set up a (#1653)GLK-GCR for group transmissions over the underlying general link. Otherwise this element is not present. |

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**Table 9-65—Association Response frame body *(continued)***

| Order | Information | Notes |
|---|---|---|
| 55 | RSN Extension | The RSNXE is present if any subfield of the Extended RSN Capabilities field in this element is nonzero, except the Field Length subfield. |
| 56 | MSCS Descriptor | The MSCS Descriptor element is optionally present if dot11MSCSActivated is true; otherwise not present. |
| 57(11ax) | HE Capabilities | The HE Capabilities element is present if dot11HEOptionImplemented is true; otherwise, it is not present. |
| 58(11ax) | HE Operation | The HE Operation element is present if dot11HEOptionImplemented is true; otherwise, it is not present. |
| 59(11ax) | BSS Color Change Announcement | The BSS Color Change Announcement element is optionally present if dot11HEOptionImplemented is true; otherwise, it is not present. |
| 60(11ax) | Spatial Reuse Parameter Set | The Spatial Reuse Parameter Set element is optionally present if dot11HEOptionImplemented is true; otherwise, it is not present. |
| 61(11ax) | MU EDCA Parameter Set | The MU EDCA Parameter Set element is present if dot11HEOptionImplemented and dot11MUEDCAParametersActivated are true; otherwise, it is not present. |
| 62(11ax) | UORA Parameter Set | The UORA Parameter Set element is optionally present if dot11HEOptionImplemented is true; otherwise, it is not present. |
| 63(11ax) | ESS Report | The ESS Report element is optionally present. |
| 64(11ax) | NDP Feedback Report Parameter Set | The NDP Feedback Report Parameter Set element is optionally present if dot11HEOptionImplemented is true; otherwise, it is not present. |
| 65(11ax) | HE 6 GHz Band Capabilities | The HE 6 GHz Band Capabilities element is present if dot11HEOptionImplemented and dot11HE6GOptionImplemented are true. |
| 66(11ax) | TWT Constraint Parameters | The TWT Constraint Parameters element is optionally present if dot11TWTOptionActivated is true; otherwise, it is not present. |
| 67(11ay) | EDMG Capabilities | The EDMG Capabilities element is present if dot11EDMGOptionImplemented is true. |
| 68(11ay) | EDMG Operation | The EDMG Operation element is present if dot11EDMGOptionImplemented is true. |
| 69(11ay) | QoS Triggered Unscheduled | The QoS Triggered Unscheduled element is optionally present if dot11EDMGOptionImplemented is true. |
| 70(11ay) | Unsolicited Block Ack Extension | The Unsolicited Block Ack Extension element is optionally present if dot11UnsolicitedBAActivated is true and is absent otherwise. |
| 71(11ay) | TDD Slot Structure | The TDD Slot Structure element is optionally present if dot11DMGOptionImplemented is true. |
| 72(11ay) | TDD Slot Schedule | The TDD Slot Schedule element is optionally present if dot11DMGOptionImplemented is true. |
| 73(11ay) | TDD Route | This element is optionally present if dot11TDDOptionImplemented is true; otherwise, not present. If present, the element specifies the TDD sector switch configuration. |


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**Table 9-65—Association Response frame body *(continued)***

| Order | Information | Notes |
|---|---|---|
| 74(11ba) | WUR Capabilities | The WUR Capabilities element is present when dot11WUROptionImplemented is true; otherwise it is not present. |
| 75(11ba) | WUR Operation | The WUR Operation element is present when dot11WUROptionImplemented is true; otherwise it is not present. |
| 76(11ba) | WUR Mode | The WUR Mode element is present when dot11WUROptionImplemented is true, and the WUR Mode element is present in the Association Request frame that solicited this Association Response frame; otherwise it is not present. |
| 77(#1084) | Diffie-Hellman Parameter | The Diffie-Hellman Parameter element is optionally present when performing OWE; otherwise it is not present. |
| Last | Vendor Specific | One or more Vendor Specific elements are optionally present(#8128). |

### 9.3.3.7 Reassociation Request frame format

The frame body of a Reassociation Request frame contains the information shown in Table 9-66 (Reassociation Request frame body).

**Table 9-66—Reassociation Request frame body**

| Order | Information | Notes |
|---|---|---|
| 1 | Capability Information | See 9.4.1.4 (Capability Information field) for Capability Information field format. |
| 2 | Listen Interval | |
| 3 | Current AP address | |
| 4 | SSID | |
| 5 | Supported Rates and BSS Membership Selectors | (#1659)(#8229)See 11.1.4.6 (Operation of Supported Rates and BSS Membership Selectors element and Extended Supported Rates and BSS Membership Selectors element) for details on the inclusion of this element when dot11S1GOptionImplemented or dot11DMGOptionImplemented is true. |
| 6 | Extended Supported Rates and BSS Membership Selectors | (#3086)The Extended Supported Rates and BSS Membership Selectors element is present if the number of supported rates and BSS membership selectors(#1470) together exceed eight; it is optional otherwise.<br>(#1659)(#8229)See 11.1.4.6 (Operation of Supported Rates and BSS Membership Selectors element and Extended Supported Rates and BSS Membership Selectors element) for details on the inclusion of this element when dot11S1GOptionImplemented or dot11DMGOptionImplemented is true. |
| 7 | Power Capability | The Power Capability element is present if dot11SpectrumManagementRequired is true or dot11RadioMeasurementActivated is true. |

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**Table 9-66—Reassociation Request frame body *(continued)***

| Order | Information | Notes |
|---|---|---|
| 8 | Supported Channels | The Supported Channels element is present if dot11SpectrumManagementRequired is true and dot11ExtendedChannelSwitchActivated is false.<br>The Supported Channels element is optionally present, otherwise.(#3510) |
| 9 | RSN | The RSNE is present if dot11RSNAActivated is true; otherwise not present. |
| 10 | QoS Capability | The QoS Capability element is present if dot11QosOptionImplemented is true. |
| 11 | RM Enabled Capabilities | RM Enabled Capabilities element is present if dot11RadioMeasurementActivated is true. |
| 12 | Mobility Domain | The MDE is present in a Reassociation Request frame if dot11FastBSSTransitionActivated is true and the frame is being sent to an AP that advertised its FT Capability in the MDE in its Beacon or Probe Response frame (i.e., AP also has dot11FastBSSTransitionActivated is true). |
| 13 | Fast BSS Transition | An FTE is present in a Reassociation Request frame if dot11FastBSSTransitionActivated is true and dot11RSNAAuthenticationSuiteSelected is equal to an AKM suite selector value for which the Authentication type column indicates FT authentication. See Table 9-190 (AKM suite selectors) (i.e., part of a fast BSS transition in an RSN). |
| 14 | Resource information container (RIC) | The set of elements that formulate a RIC-Request is optionally present in a Reassociation Request frame if<br>— dot11FastBSSTransitionActivated is true,<br>— The FT resource request protocol is not used,<br>— The frame is being sent to an AP that advertised its FT capability in the MDE in its Beacon or Probe Response frame (i.e., AP also has dot11FastBSSTransitionActivated is true), and<br>— (#8088)dot11RSNAAuthenticationSuiteSelected is equal to an AKM suite selector value for which the Authentication type column indicates FT authentication, or dot11RSNAActivated is flase (i.e., not in an RSN). See Table 9-190 (AKM suite selectors) (i.e., part of a fast BSS transition in an RSN). |
| 15 | Supported Operating Classes | The Supported Operating Classes element is present if dot11ExtendedChannelSwitchActivated or dot11OperatingClassesRequired is true. |
| 16 | HT Capabilities | The HT Capabilities element is present when dot11HighThroughputOptionImplemented is true and the STA is not a STA 6G.(11ax) |
| 17 | 20/40 BSS Coexistence | The 20/40 BSS Coexistence element is optionally present when dot112040BSSCoexistenceManagementSupport is true. |
| 18 | Extended Capabilities | The Extended Capabilities element is present if any of the fields in this element are nonzero. |
| 19 | QoS Traffic Capability | The QoS Traffic Capability element is present if dot11QoSTrafficCapabilityActivated is true. |
| 20 | TIM Broadcast Request | The TIM Broadcast Request element is present if dot11TIMBroadcastActivated is true. |


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**Table 9-66—Reassociation Request frame body *(continued)***

| Order | Information | Notes |
|---|---|---|
| 21 | FMS Request | The FMS Request element is optionally present if dot11FMSActivated is true. |
| 22 | DMS Request | The DMS Request element is optionally present if dot11DMSActivated is true. |
| 23 | Interworking | The Interworking element is present if dot11InterworkingServiceActivated is true and the non-AP STA is requesting unauthenticated access to emergency services (see 11.3.5 (Association, reassociation, and disassociation)). |
| 24 | Multi-band | The Multi-band element is optionally present if dot11MultibandImplemented is true. |
| 25 | DMG Capabilities | The DMG Capabilities element is present if dot11DMGOptionImplemented is true. |
| 26 | Multiple MAC Sublayers | The Multiple MAC Sublayers element is present if dot11MultipleMACActivated is true. |
| 27 | VHT Capabilities | The VHT Capabilities element is present in the 5 GHz band when dot11VHTOptionImplemented is true.(11ax)(#8181) |
| 28 | Operating Mode Notification | The Operating Mode Notification element is optionally present if dot11OperatingModeNotificationImplemented is true. |
| 29 | FILS Session | The FILS Session element is optionally present if dot11FILSActivated is true; otherwise not present. |
| 30 | FILS Public Key | The FILS Public Key element is present if dot11FILSActivated is true and FILS Public Key authentication is used; otherwise not present. |
| 31 | FILS Key Confirmation | The FILS Key Confirmation element is present if dot11FILSActivated is true and FILS authentication is used; otherwise not present. |
| 32 | FILS HLP Container | One or more FILS HLP Container elements are optionally present if dot11FILSActivated is true; otherwise not present. |
| 33 | FILS IP Address Assignment | The FILS IP Address Assignment element is optionally present if dot11FILSActivated is true; otherwise not present. |
| 34 | TWT | The TWT element is optionally present if dot11TWTOptionActivated is true; otherwise not present. |
| 35 | AID Request | The AID Request element is present when dot11S1GOptionImplemented is true. |
| 36 | S1G Capabilities | The S1G Capabilities element is present if dot11S1GOptionImplemented is true; otherwise not present. |
| 37 | EL Operation | The EL Operation element is present if dot11S1GELOperationActivated is true. |
| 38 | BSS Max Idle Period | The BSS Max Idle Period element is optionally present if dot11WirelessManagementImplemented and dot11BSSMaxIdlePeriodIndicationByNonAPSTA are true, or if dot11S1GOptionImplemented is true; otherwise not present. |
| 39 | S1G Relay | The S1G Relay element is optionally present if dot11RelaySTAImplemented is true; otherwise not present. |
| 40 | Header Compression | The Header Compression element is present if dot11PV1MACHeaderOptionImplemented is true. |

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**Table 9-66—Reassociation Request frame body *(continued)***

| Order | Information | Notes |
|---|---|---|
| 41 | MAD | The MAD element is optionally present if dot11S1GOptionImplemented is true; otherwise not present. |
| 42 | Reachable Address | The Reachable Address element is optionally present if dot11RelaySTAImplemented is true; otherwise not present. |
| 43 | S1G Relay Activation element | The S1G Relay Activation element is optionally present if dot11RelaySTAImplemented is true; otherwise not present. |
| 44 | CDMG Capabilities | The CDMG Capabilities element is present if dot11CDMGOptionImplemented is true; otherwise not present. |
| 45 | CMMG Capabilities | The CMMG Capabilities element is present when dot11CMMGOptionImplemented is true; otherwise not present. |
| 46 | OCI | OCI element is present if dot11FILSActivated and dot11RSNAOperatingChannelValidationActivated are both true; otherwise not present. |
| 47 | GLK-GCR Parameter Set | The GLK-GCR Parameter Set element is present if dot11GLKImplemented is true to indicate the number of reorder buffers the STA has to support GLK-GCR with GCR block ack and respond to corresponding GLK-GCR BlockAckReq frames. Otherwise this element is not present. |
| 48 | RSN Extension | The RSNXE is present if any subfield of the Extended RSN Capabilities field in this element is nonzero, except the Field Length subfield and, in the case of FT reassociation, the rules for FT reassociation in Table 13-1 (FT authentication elements) do not omit the RSNXE from the third message. |
| 49 | Supplemental Class 2 Capabilities | The Supplemental Class 2 Capabilities element is present when dot11Class2CapabilitiesOptionImplemented is true; otherwise not present. |
| 50 | MSCS Descriptor | The MSCS Descriptor element is optionally present if dot11MSCSActivated is true; otherwise not present. |
| 51(11ax) | HE Capabilities | The HE Capabilities element is present if dot11HEOptionImplemented is true; otherwise, it is not present. |
| 52(11ax) | Channel Switch Timing | The Channel Switch Timing element is optionally present if dot11HESubchannelSelectiveTransmissionImplemented is true; otherwise, it is not present. |
| 53(11ax) | HE 6 GHz Band Capabilities | The HE 6 GHz Band Capabilities element is present if dot11HEOptionImplemented and dot11HE6GOptionImplemented are true. |
| 54(11ax) | UL MU Power Capabilities | The UL MU Power Capabilities element is optionally present if dot11HEOptionImplemented is true; otherwise, it is not present. |
| 55(11ay) | EDMG Capabilities | The EDMG Capabilities element is present if dot11EDMGOptionImplemented is true. |
| 56(11ay) | QoS Triggered Unscheduled | The QoS Triggered Unscheduled element is optionally present if dot11EDMGOptionImplemented is true. |
| 57(11ay) | Unsolicited Block Ack Extension | The Unsolicited Block Ack Extension element is optionally present if dot11UnsolicitedBAActivated is true and is absent otherwise. |
| 58(11ay) | TDD Slot Schedule | The TDD Slot Schedule element is optionally present if dot11DMGOptionImplemented is true. |


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**Table 9-66—Reassociation Request frame body *(continued)***

| Order | Information | Notes |
|---|---|---|
| 59(11ay) | TDD Route | This element is optionally present if dot11TDDOptionImplemented is true; otherwise, not present. If present, the element specifies the TDD beamforming results. |
| 60(11ba) | WUR Capabilities | The WUR Capabilities element is present when dot11WUROptionImplemented is true; otherwise it is not present. |
| 61(11ba) | WUR Mode | The WUR Mode element is optionally present when dot11WUROptionImplemented is true; otherwise, it is not present. |
| 62(#1084) | Diffie-Hellman Parameter | The Diffie-Hellman Parameter element is optionally present when performing OWE; otherwise it is not present. |
| 63(#4069) | Known STA Identification | The Known STA Identification element is optionally present if dot11RSNAActivated is true and the recipient of the frame has indicated support for this element in its Extended Capabilities field; otherwise not present. |
| 64(#6076) | Non-AP STA Regulatory Connectivity | The Non-AP STA Regulatory Connectivity element is optionally present if dot11ExtendedRegInfoSupport is true. |
| Last | Vendor Specific | One or more Vendor Specific elements are optionally present(#8128). |

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### 9.3.3.8 Reassociation Response frame format

The frame body of a Reassociation Response frame contains the information shown in Table 9-67 (Reassociation Response frame body).

**Table 9-67—Reassociation Response frame body**

| Order | Information | Notes |
|---|---|---|
| 1 | Capability Information | See 9.4.1.4 (Capability Information field) for Capability Information field format. |
| 2 | Status Code(#3326) | |
| 3 | AID | This field is not present when dot11S1GOptionImplemented is true. |
| 4 | Supported Rates and BSS Membership Selectors | (#1659)(#8229)See 11.1.4.6 (Operation of Supported Rates and BSS Membership Selectors element and Extended Supported Rates and BSS Membership Selectors element) for details on the inclusion of this element when dot11S1GOptionImplemented or dot11DMGOptionImplemented is true. |
| 5 | Extended Supported Rates and BSS Membership Selectors | (#3086)The Extended Supported Rates and BSS Membership Selectors element is present if the number of supported rates and BSS membership selectors(#1470) together exceed eight; it is optional otherwise.<br>(#1659)(#8229)See 11.1.4.6 (Operation of Supported Rates and BSS Membership Selectors element and Extended Supported Rates and BSS Membership Selectors element) for details on the inclusion of this element when dot11S1GOptionImplemented or dot11DMGOptionImplemented is true. |
| 6 | EDCA Parameter Set | The EDCA Parameter Set element is present if dot11QosOptionImplemented is true; otherwise not present. |
| 7 | RCPI | The RCPI element is present if dot11RMRCPIMeasurementActivated is true. |
| 8 | RSNI | The RSNI element is present if dot11RMRSNIMeasurementActivated is true. |
| 9 | RM Enabled Capabilities | RM Enabled Capabilities element is present if dot11RadioMeasurementActivated is true. |
| 10 | RSN | An RSNE is present in a Reassociation Response frame if dot11FastBSSTransitionActivated is true, dot11RSNAActivated is true, and this frame is a response to a Reassociation Request frame that contained an FTE (i.e., part of a fast BSS transition in an RSN); or if dot11FILSActivated is true(#6088); or if performing OWE. Otherwise, not present. |
| 11 | Mobility Domain | An MDE is present in a Reassociation Response frame if dot11FastBSSTransitionActivated is true and this frame is a response to a Reassociation Request frame that contained an MDE (i.e., either an FT initial mobility domain association exchange or part of a fast BSS transition). |
| 12 | Fast BSS Transition | An FTE is present in a Reassociation Response frame if dot11FastBSSTransitionActivated is true, dot11RSNAActivated is true, and this frame is a response to a Reassociation Request frame that contained an MDE (i.e., either an FT initial mobility domain association exchange or part of a fast BSS transition in an RSN). |


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**Table 9-67—Reassociation Response frame body *(continued)***

| Order | Information | Notes |
|---|---|---|
| 13 | RIC | The set of elements that formulate a RIC-Response is present in a Reassociation Response frame if dot11FastBSSTransitionActivated is true and this frame is a response to a Reassociation Request frame that contained a RIC-Request. |
| 14 | DSE registered location | The DSE Registered Location element is present if dot11LCIDSERequired is true. |
| 15 | Timeout Interval (association comeback time(#3389)) | A TIE containing the association comeback time(#3389) is present when dot11RSNAActivated is true, dot11RSNAProtectedManagementFramesActivated is true, and either the reassociation is rejected with status code REFUSED_TEMPORARILY or the reassociation request is accepted with a status code 0 and when dot11S1GOptionImplemented is true. |
| 16 | HT Capabilities | The HT Capabilities element is present when dot11HighThroughputOptionImplemented is true and the STA is not a STA 6G.(11ax) |
| 17 | HT Operation | The HT Operation element is included by an AP when dot11HighThroughputOptionImplemented is true and the AP is not a STA 6G.(11ax) |
| 18 | 20/40 BSS Coexistence | The 20/40 BSS Coexistence element is optionally present when dot112040BSSCoexistenceManagementSupport is true. |
| 19 | Overlapping BSS Scan Parameters | The Overlapping BSS Scan Parameters element is optionally present if dot11FortyMHzOptionImplemented is true. |
| 20 | Extended Capabilities | The Extended Capabilities element is present if any of the fields in this element are nonzero. |
| 21 | BSS Max Idle Period | The BSS Max Idle Period element is present if dot11WirelessManagementImplemented is true or optionally present if dot11S1GOptionImplemented is true. |
| 22 | TIM Broadcast Response | The TIM Broadcast Response element is present if dot11TIMBroadcastActivated is true and the TIM Broadcast Request element is present in the Reassociation Request frame that elicited this Reassociation Response frame. |
| 23 | FMS Response | The FMS Response element is present if dot11FMSActivated is true and the FMS Request element is present in the Reassociation Request frame that elicited this Reassociation Response frame. |
| 24 | DMS Response | The DMS Response element is present if dot11DMSActivated is true and the DMS Request element is present in the Reassociation Request frame that elicited this Reassociation Response frame. |
| 25 | QoS Map | The QoS Map element is present if dot11QosMapActivated is true and the QoS Map field in the Extended Capabilities element of the corresponding Reassociation Request frame is 1. |
| 26 | QMF Policy | The QMF Policy element is present if dot11QMFActivated is true and the QMFActivated subfield is 1 in the Extended Capabilities element in the Reassociation Request that elicited this Reassociation Response frame. |
| 27 | Multi-band | The Multi-band element is optionally present if dot11MultibandImplemented is true. |
| 28 | DMG Capabilities | The DMG Capabilities element is present if dot11DMGOptionImplemented is true. |

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**Table 9-67—Reassociation Response frame body *(continued)***

| Order | Information | Notes |
|---|---|---|
| 29 | DMG Operation | The DMG Operation element is present if dot11DMGOptionImplemented is true. |
| 30 | Multiple MAC Sublayers | The Multiple MAC Sublayers element is present if dot11MultipleMACActivated is true. |
| 31 | Neighbor Report | One or more Neighbor Report elements is present if the Status Code field is REJECTED_WITH_SUGGESTED_BSS_TRANSITION. |
| 32 | VHT Capabilities | The VHT Capabilities element is present in the 5 GHz band when dot11VHTOptionImplemented is true.(11ax)(#8181) |
| 33 | VHT Operation | The VHT Operation element is present when dot11VHTOptionImplemented is true and the STA is not a STA 6G and is optionally present if dot11HEOptionImplemented is true; otherwise, it is not present.(11ax) |
| 34 | Operating Mode Notification | The Operating Mode Notification element is optionally present if dot11OperatingModeNotificationImplemented is true. |
| 35 | Future Channel Guidance | The Future Channel Guidance element is optionally present if dot11FutureChannelGuidanceActivated is true. |
| 36 | FILS Session | The FILS Session element is present if dot11FILSActivated is true and FILS authentication is used; otherwise not present. |
| 37 | FILS Public Key | The FILS Public Key element is present if dot11FILSActivated is true and FILS Public Key authentication is used; otherwise not present. |
| 38 | FILS Key Confirmation | The FILS Key Confirmation element is present if dot11FILSActivated is true and FILS authentication is used; otherwise not present. |
| 39 | FILS HLP Container | One or more FILS HLP Container elements are optionally present if dot11FILSActivated is true; otherwise not present. |
| 40 | FILS IP Address Assignment | The FILS IP Address Assignment element is optionally present if dot11FILSActivated is true; otherwise not present. |
| 41 | Key Delivery | The Key Delivery element is present if dot11FILSActivated is true and FILS authentication is used; otherwise not present. |
| 42 | S1G Sector Operation | The S1G Sector Operation element is optionally present if dot11S1GSectorizationActivated is true; otherwise not present. |
| 43 | TWT | The TWT element is present if dot11TWTOptionActivated is true, (#4005)dot11HEOptionImplemented is not true, and the TWT element is present in the Reassociation Request frame that elicited this Reassociation Response frame.<br><br>(11ax)The TWT element is optionally present if dot11TWTOptionActivated is true, dot11HEOptionImplemented is true, and the TWT Requester Support field in the HE Capabilities element in the Reassociation Request frame that elicited this Reassociation Response frame is 1.<br><br>(11ax)Otherwise, the TWT element is not present.(#4005) |
| 44 | TSF Timer Accuracy | The TSF Timer Accuracy element is optionally present when dot11TSFTimerAccuracyImplemented is true; otherwise not present. |


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**Table 9-67—Reassociation Response frame body *(continued)***

| Order | Information | Notes |
|---|---|---|
| 45 | S1G Capabilities | The S1G Capabilities element is present if dot11S1GOptionImplemented is true; otherwise not present. |
| 46 | S1G Operation | The S1G Operation element is present when dot11S1GOptionImplemented is true; otherwise not present. |
| 47 | AID Response | The AID Response element is present when dot11S1GOptionImplemented is true. |
| 48 | Sectorized Group ID List | The Sectorized Group ID List element is optionally present when dot11S1GSectorizationActivated is true; otherwise not present. |
| 49 | S1G Relay | The S1G Relay element is optionally present if dot11RelayAPImplemented is true; otherwise not present. |
| 50 | Header Compression | The Header Compression element is present if dot11PV1MACHeaderOptionImplemented is true. |
| 51 | SST Operation | The SST Operation element is present if dot11SelectiveSubchannelTransmissionPermitted is true. |
| 52 | MAD | The MAD element is optionally present if dot11S1GOptionImplemented is true; otherwise not present. |
| 53 | S1G Relay Activation | The S1G Relay Activation element is optionally present if dot11RelaySTAImplemented is true; otherwise not present. |
| 54 | CDMG Capabilities | The CDMG Capabilities element is present if dot11CDMGOptionImplemented is true; otherwise not present. |
| 55 | CMMG Capabilities | The CMMG Capabilities element is present when dot11CMMGOptionImplemented is true; otherwise not present. |
| 56 | CMMG Operation | The CMMG Operation element is present when dot11CMMGOptionImplemented is true; otherwise not present. |
| 56 | OCI | The OCI element is present if dot11FILSActivated and dot11RSNAOperatingChannelValidationActivated are both true; otherwise not present. |
| 58 | GLK-GCR Parameter Set | The GLK-GCR Parameter Set element is present if dot11GLKimplemented is true and the AP has set up a (#1653)GLK-GCR for group transmissions over the underlying general link. Otherwise this element is not present. |
| 59 | RSN Extension | The RSNXE is present if any subfield of the Extended RSN Capabilities field in this element is nonzero, except the Field Length subfield and, in the case of FT reassociation, the rules for FT reassociation in Table 13-1 (FT authentication elements) do not omit the RSNXE from the fourth message. |
| 60 | MSCS Descriptor | The MSCS Descriptor element is optionally present if dot11MSCSActivated is true; otherwise not present. |
| 61(11ax) | HE Capabilities | The HE Capabilities element is present if dot11HEOptionImplemented is true; otherwise, it is not present. |
| 62(11ax) | HE Operation | The HE Operation element is present if dot11HEOptionImplemented is true; otherwise, it is not present. |
| 63(11ax) | BSS Color Change Announcement | The BSS Color Change Announcement element is optionally present if dot11HEOptionImplemented is true; otherwise, it is not present. |
| 64(11ax) | Spatial Reuse Parameter Set | The Spatial Reuse Parameter Set element is optionally present if dot11HEOptionImplemented is true; otherwise, it is not present. |

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**Table 9-67—Reassociation Response frame body *(continued)***

| Order | Information | Notes |
|---|---|---|
| 65(11ax) | MU EDCA Parameter Set | The MU EDCA Parameter Set element is present if dot11HEOptionImplemented is true and dot11MUEDCAParametersActivated is true; otherwise, it is not present. |
| 66(11ax) | UORA Parameter Set | The UORA Parameter Set element is optionally present if dot11HEOptionImplemented is true; otherwise, it is not present. |
| 67(11ax) | ESS Report | The ESS Report element is optionally present. |
| 68(11ax) | NDP Feedback Report Parameter Set | The NDP Feedback Report Parameter Set element is optionally present if dot11HEOptionImplemented is true; otherwise, it is not present. |
| 69(11ax) | HE 6 GHz Band Capabilities | The HE 6 GHz Band Capabilities element is present if dot11HEOptionImplemented and dot11HE6GOptionImplemented are true. |
| 70(11ay) | EDMG Capabilities | The EDMG Capabilities element is present if dot11EDMGOptionImplemented is true. |
| 71(11ay) | EDMG Operation | The EDMG Operation element is present if dot11EDMGOptionImplemented is true. |
| 72(11ay) | QoS Triggered Unscheduled | The QoS Triggered Unscheduled element is optionally present if dot11EDMGOptionImplemented is true. |
| 73(11ay) | Unsolicited Block Ack Extension | The Unsolicited Block Ack Extension element is optionally present if dot11UnsolicitedBAActivated is true and is absent otherwise. |
| 74(11ay) | TDD Slot Structure | The TDD Slot Structure element is optionally present if dot11DMGOptionImplemented is true. |
| 75(11ay) | TDD Slot Schedule | The TDD Slot Schedule element is optionally present if dot11DMGOptionImplemented is true. |
| 76(11ay) | TDD Route | This element is optionally present if dot11TDDOptionImplemented is true; otherwise, not present. If present, the element specifies the TDD sector switch configuration. |
| 77(11ba) | WUR Capabilities | The WUR Capabilities element is present when dot11WUROptionImplemented is true; otherwise it is not present. |
| 78(11ba) | WUR Operation | The WUR Operation element is present when dot11WUROptionImplemented is true; otherwise it is not present. |
| 79(11ba) | WUR Mode | The WUR Mode element is present when dot11WUROptionImplemented is true, and the WUR Mode element is present in the Reassociation Request frame that solicited this Reassociation Response frame; otherwise it is not present. |
| 80(#1084) | Diffie-Hellman Parameter | The Diffie-Hellman Parameter element is optionally present when performing OWE; otherwise it is not present. |
| Last | Vendor Specific | One or more Vendor Specific elements are optionally present(#8128). |


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### 9.3.3.9 Probe Request frame format

The frame body of a Probe Request frame contains the information shown in Table 9-68 (Probe Request frame body).

**Table 9-68—Probe Request frame body**

| Order | Information | Notes |
|---|---|---|
| 1 | SSID | If dot11MeshActivated is true, the SSID element is the wildcard value as described in 9.4.2.2 (SSID element). |
| 2 | Supported Rates and BSS Membership Selectors | (#1659)(#8229)See 11.1.4.6 (Operation of Supported Rates and BSS Membership Selectors element and Extended Supported Rates and BSS Membership Selectors element) for details on the inclusion of this element when dot11S1GOptionImplemented or dot11DMGOptionImplemented is true. |
| 3 | Request | The Request element is optionally present(#1533). |
| 4 | Extended Supported Rates and BSS Membership Selectors | (#3086)The Extended Supported Rates and BSS Membership Selectors element is present if the number of supported rates and BSS membership selectors(#1470) together exceed eight; it is optional otherwise.<br>(#1659)(#8229)See 11.1.4.6 (Operation of Supported Rates and BSS Membership Selectors element and Extended Supported Rates and BSS Membership Selectors element) for details on the inclusion of this element when dot11S1GOptionImplemented or dot11DMGOptionImplemented is true. |
| 5 | DSSS Parameter Set | The element is optionally present.<br>The DSSS Parameter Set element is present within Probe Request frames generated by STAs using Clause 15 (DSSS PHY specification for the 2.4 GHz band designated for ISM applications), Clause 16 (High rate direct sequence spread spectrum (HR/DSSS) PHY specification), or Clause 18 (Extended Rate PHY (ERP) specification) PHYs if dot11RadioMeasurementActivated is true.<br>The DSSS Parameter Set element is present within Probe Request frames generated by STAs using a Clause 19 (High Throughput (HT) PHY specification(#2297)) PHY in the 2.4 GHz band if dot11RadioMeasurementActivated is true.<br><br>The DSSS Parameter Set element is optionally present within Probe Request frames generated by STAs using Clause 15 (DSSS PHY specification for the 2.4 GHz band designated for ISM applications), Clause 16 (High rate direct sequence spread spectrum (HR/DSSS) PHY specification), or Clause 18 (Extended Rate PHY (ERP) specification) PHYs if dot11RadioMeasurementActivated is false.<br>The DSSS Parameter Set element is optionally present within Probe Request frames generated by STAs using a Clause 19 (High Throughput (HT) PHY specification(#2297)) PHY in the 2.4 GHz band if dot11RadioMeasurementActivated is false. |
| 6 | Supported Operating Classes | The Supported Operating Classes element is present if dot11ExtendedChannelSwitchActivated or dot11OperatingClassesRequired is true.<br>The Supported Operating Classes element is optionally present if dot11TVHTOptionImplemented is true. |

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**Table 9-68—Probe Request frame body *(continued)***

| Order | Information | Notes |
|---|---|---|
| 7 | HT Capabilities | The HT Capabilities element is present when dot11HighThroughputOptionImplemented is true and the STA is not a STA 6G.(11ax) |
| 8 | 20/40 BSS Coexistence | The 20/40 BSS Coexistence element is optionally present when dot112040BSSCoexistenceManagementSupport is true. |
| 9 | Extended Capabilities | The Extended Capabilities element is present if any of the fields in this element are nonzero. |
| 10 | SSID List | The SSID List element is optionally present if dot11SSIDListActivated is true. |
| 11 | Channel Usage | One or more(#6072) Channel Usage elements are optionally present if dot11ChannelUsageActivated is true. |
| 12 | Interworking | The Interworking element is present if dot11InterworkingServiceActivated is true. |
| 13 | Mesh ID | The Mesh ID element is present if dot11MeshActivated is true. |
| 14 | Multi-band | The Multi-band element is optionally present if dot11MultibandImplemented is true. |
| 15 | DMG Capabilities | The DMG Capabilities element is present if dot11DMGOptionImplemented is true. |
| 16 | Multiple MAC Sublayers | The Multiple MAC Sublayers element is present if dot11MultipleMACActivated is true. |
| 17 | VHT Capabilities | The VHT Capabilities element is present in the 5 GHz band when dot11VHTOptionImplemented is true.(11ax)(#8181) |
| 18 | Estimated Service Parameters Inbound | The Estimated Service Parameters Inbound element is optionally present if dot11EstimatedServiceParametersInboundOptionImplemented is true. |
| 19 | Extended Request | (#1532)One or more Extended Request elements are optionally present (if more than one Extended Request element is present the Requested Element ID fields differ)(#1533). |
| 20 | FILS Request Parameters | The FILS Request Parameters element is optionally present if dot11FILSActivated is true; otherwise not present. |
| 21 | AP-CSN | The AP-CSN element is optionally present if dot11FILSActivated is true; otherwise not present. |
| 22 | Change Sequence | The Change Sequence element is optionally present if dot11S1GOptionImplemented is true; otherwise not present. |
| 23 | S1G Relay Discovery | The S1G Relay Discovery element is optionally present if dot11RelayDiscoveryOptionImplemented is true; otherwise not present. |
| 24 | PV1 Probe Response Option | The PV1 Probe Response Option element is optionally present if dot11PV1ProbeResponseOptionImplemented is true; otherwise not present. |
| 25 | S1G Capabilities | The S1G Capabilities element is present if dot11S1GOptionImplemented is true; otherwise not present. |
| 26 | EL Operation | The EL Operation element is present if dot11S1GELOperationActivated is true. |


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**Table 9-68—Probe Request frame body *(continued)***

| Order | Information | Notes |
|---|---|---|
| 27 | MAD | The MAD element is optionally present if dot11S1GOptionImplemented is true; otherwise not present. |
| 28 | Vendor Specific Request | The Vendor Specific Request element is optionally present. |
| 29 | CDMG Capabilities | The CDMG Capabilities element is present if dot11CDMGOptionImplemented is true; otherwise not present. |
| 30 | Cluster Probe | The Cluster Probe element is optionally present if dot11ClusteringActivated is true; otherwise not present. |
| 31 | CMMG Capabilities | The CMMG Capabilities element is present when dot11CMMGOptionImplemented is true; otherwise not present. |
| 32 | Estimated Services Parameters Outbound | The Estimated Service Parameters Outbound element is optionally present if dot11EstimatedServiceParametersOutboundOptionImplemented is true. |
| 33 | Supplemental Class 2 Capabilities | The Supplemental Class 2 Capabilities element is present when dot11Class2CapabilitiesOptionImplemented is true; otherwise not present. |
| 34(11ax) | HE Capabilities | The HE Capabilities element is present if dot11HEOptionImplemented is true; otherwise, it is not present. |
| 35(11ax) | Known BSSID | The Known BSSID element is optionally present if dot11MultiBSSIDImplemented is true. |
| 36(11ax) | HE 6 GHz Band Capabilities | The HE 6 GHz Band Capabilities element is present if dot11HEOptionImplemented and dot11HE6GOptionImplemented are true. |
| 37(11ax) | Short SSID List | The Short SSID List element is optionally present if dot11ShortSSIDListImplemented is true; otherwise, it is not present. |
| 38(11ax) | TWT Constraint Parameters | The TWT Constraint Parameters element is optionally present if dot11TWTOptionActivated is true; otherwise, it is not present. |
| 39(11ay) | EDMG Capabilities | The EDMG Capabilities element is present if dot11EDMGOptionImplemented is true. |
| 40(11ay) | Unsolicited Block Ack Extension | The Unsolicited Block Ack Extension element is optionally present if dot11UnsolicitedBAActivated is true and is absent otherwise. |
| 41(11ba) | WUR Capabilities | The WUR Capabilities element is present when dot11WUROptionImplemented is true; otherwise it is not present. |
| 42(#6076) | Non-AP STA Regulatory Connectivity | The Non-AP STA Regulatory Connectivity element is optionally present if dot11ExtendedRegInfoSupport is true. |
| Last | Vendor Specific | One or more Vendor Specific elements are optionally present(#8128). |

### 9.3.3.10 Probe Response frame format

The frame body of a Probe Response frame contains the information shown in Table 9-69 (Probe Response frame body). See additional details and procedures in 11.1.4 (Acquiring synchronization, scanning).

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**Table 9-69—Probe Response frame body**

| Order | Information | Notes |
|---|---|---|
| 1 | Timestamp | See 9.4.1.10 (Timestamp field) for Timestamp field format. |
| 2 | Beacon Interval | See 9.4.1.3 (Beacon Interval field) for Beacon Interval field format. |
| 3 | Capability Information | See 9.4.1.4 (Capability Information field) for Capability Information field format. |
| 4 | SSID | If dot11MeshActivated is true, the SSID element is the wildcard value as described in 9.4.2.2 (SSID element). |
| 5 | Supported Rates and BSS Membership Selectors | (#1659)(#8229)See 11.1.4.6 (Operation of Supported Rates and BSS Membership Selectors element and Extended Supported Rates and BSS Membership Selectors element) for details on the inclusion of this element when dot11S1GOptionImplemented or dot11DMGOptionImplemented is true. |
| 6 | DSSS Parameter Set | The element is optionally present.<br>The DSSS Parameter Set element is present within Probe Response frames generated by STAs using Clause 15 (DSSS PHY specification for the 2.4 GHz band designated for ISM applications), Clause 16 (High rate direct sequence spread spectrum (HR/DSSS) PHY specification), and Clause 18 (Extended Rate PHY (ERP) specification) PHYs.<br>The DSSS Parameter Set element is present within Probe Response frames generated by STAs using a Clause 19 (High Throughput (HT) PHY specification(#2297)) PHY in the 2.4 GHz band. |
| 7 | IBSS Parameter Set | The IBSS Parameter Set element is present only within Probe Response frames generated by IBSS STAs. |
| 8 | Country | The Country element is present if dot11MultiDomainCapabilityActivated is true or dot11SpectrumManagementRequired is true or dot11RadioMeasurementActivated is true. |
| 9 | Power Constraint | The Power Constraint element is present if dot11SpectrumManagementRequired is true and is optionally present if dot11RadioMeasurementActivated is true. |
| 10 | Channel Switch Announcement | (#3087)The Channel Switch Announcement element is optionally present if dot11SpectrumManagementRequired is true or dot11ExtendedChannelSwitchActivated is true.(#511) |
| 11 | Quiet | The Quiet element is optionally present if dot11SpectrumManagementRequired is true or if dot11RadioMeasurementActivated is true. |
| 12 | IBSS DFS | The IBSS DFS element is present if dot11SpectrumManagementRequired is true in an IBSS. |
| 13 | TPC Report | The TPC Report element is present if dot11SpectrumManagementRequired is true or dot11RadioMeasurementActivated is true. |
| 14 | ERP | The ERP element is present within Probe Response frames generated by STAs using ERPs and is optionally present otherwise. |


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**Table 9-69—Probe Response frame body *(continued)***

| Order | Information | Notes |
|---|---|---|
| 15 | Extended Supported Rates and BSS Membership Selectors | (#3086)The Extended Supported Rates and BSS Membership Selectors element is present if the number of supported rates and BSS membership selectors(#1470) together exceed eight; it is optional otherwise.<br>(#1659)(#8229)See 11.1.4.6 (Operation of Supported Rates and BSS Membership Selectors element and Extended Supported Rates and BSS Membership Selectors element) for details on the inclusion of this element when dot11S1GOptionImplemented or dot11DMGOptionImplemented is true. |
| 16 | RSN | The RSNE is present if dot11RSNAActivated is true; otherwise not present. |
| 17 | BSS Load | The BSS Load element is present if dot11QosOptionImplemented and dot11QBSSLoadImplemented are both true. |
| 18 | EDCA Parameter Set | The EDCA Parameter Set element is present if dot11QosOptionImplemented is true and dot11MeshActivated is false. |
| 19 | Measurement Pilot Transmission | The Measurement Pilot Transmission element is present if dot11RMMeasurementPilotActivated is between 2 and 7. |
| 20 | Multiple BSSID | (#488)One or more Multiple BSSID elements are present if the AP is a member of a multiple BSSID set (see 11.10.14 (Multiple BSSID set)) with two or more members and any of the following conditions are true:<br>• dot11MultiBSSIDImplemented is true<br>• dot11MultiBSSIDImplemented is false and dot11RMMeasurementPilotActivated is between 2 and 7<br>• dot11FILSActivated is true<br>• dot11InterworkingServiceActivated is true and at least one dot11GASAdvertisementID exists |
| 21 | RM Enabled Capabilities | The RM Enabled Capabilities element is present if dot11RadioMeasurementActivated is true. |
| 22 | AP Channel Report | If dot11RMAPChannelReportActivated is true, one AP Channel Report element is optionally present for each operating class that has at least 1 channel to report. |
| 23 | BSS Average Access Delay | The BSS Average Access Delay element is optionally present if dot11RMBSSAverageAccessDelayActivated is true and the AP Average Access Delay field is not equal to 255 (measurement not available). |
| 24 | Antenna | The Antenna element is optionally present if dot11RMAntennaInformationActivated is true and the Antenna ID field is not equal to 0 (unknown antenna). |
| 25 | BSS Available Admission Capacity | The BSS Available Admission Capacity element is optionally present if dot11RMBSSAvailableAdmissionCapacityActivated is true with the following exceptions: 1) when Available Admission Capacity Bitmask equals 0 (Available Admission Capacity List contains no entries), or 2) when the BSS Load element is present and the Available Capacity Bitmask equals 256 (Available Admission Capacity List contains only the AC_VO entry). |
| 26 | BSS AC Access Delay | The BSS AC Access Delay element is optionally present if dot11RMBSSAverageAccessDelayActivated is true and at least one field of the element is not equal to 255 (measurement not available). |
| 27 | Mobility Domain | The MDE is present if dot11FastBSSTransitionActivated is true. |

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**Table 9-69—Probe Response frame body *(continued)***

| Order | Information | Notes |
|---|---|---|
| 28 | DSE registered location | The DSE Registered Location element is present if dot11LCIDSERequired is true. |
| 29 | Extended Channel Switch Announcement | The Extended Channel Switch Announcement element is optionally present if dot11ExtendedChannelSwitchActivated is true. |
| 30 | Supported Operating Classes | The Supported Operating Classes element is present if dot11ExtendedChannelSwitchActivated or dot11OperatingClassesRequired is true.<br>The Supported Operating Classes element is optionally present if dot11TVHTOptionImplemented is true. |
| 31 | HT Capabilities | The HT Capabilities element is present when dot11HighThroughputOptionImplemented is true and the STA is not a STA 6G.(11ax) |
| 32 | HT Operation | The HT Operation element is included by an AP and a mesh STA when dot11HighThroughputOptionImplemented is true and the AP is not a STA 6G.(11ax) |
| 33 | 20/40 BSS Coexistence | The 20/40 BSS Coexistence element is optionally present when dot112040BSSCoexistenceManagementSupport is true. |
| 34 | Overlapping BSS Scan Parameters | The Overlapping BSS Scan Parameters element is optionally present if dot11FortyMHzOptionImplemented is true. |
| 35 | Extended Capabilities | The Extended Capabilities element is present if any of the fields in this element are nonzero. |
| 36 | QoS Traffic Capability | The QoS Traffic Capability element is optionally present if dot11ACStationCountActivated is true. |
| 37 | Channel Usage | One or more(#6072) Channel Usage elements are present if at least one Channel Usage element is present in the Probe Request frame and dot11ChannelUsageActivated is true. |
| 38 | Time Advertisement | The Time Advertisement element is present if dot11UTCTSFOffsetActivated is true. |
| 39 | Time Zone | The Time Zone element is present if dot11UTCTSFOffsetActivated is true. |
| 40 | Interworking | The Interworking element is present if dot11InterworkingServiceActivated is true. |
| 41 | Advertisement Protocol | Advertisement Protocol element is present if dot11InterworkingServiceActivated is true and at least one dot11GASAdvertisementID exists. |
| 42 | Roaming Consortium | The Roaming Consortium element is present if dot11InterworkingServiceActivated is true and the dot11RoamingConsortiumTable has at least one entry. |
| 43 | Emergency Alert Identifier | One or more Emergency Alert Identifier elements are present if dot11EASActivated is true and there are one or more EAS message(s) active in the network. |
| 44 | Mesh ID | The Mesh ID element is present if dot11MeshActivated is true. |
| 45 | Mesh Configuration | The Mesh Configuration element is present if dot11MeshActivated is true. |
| 46 | Mesh Awake Window | The Mesh Awake Window element is optionally present if dot11MeshActivated is true. |


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**Table 9-69—Probe Response frame body *(continued)***

| Order | Information | Notes |
|---|---|---|
| 47 | Beacon Timing | The Beacon Timing element is optionally present if both dot11MeshActivated and dot11MBCAActivated are true. |
| 48 | MCCAOP Advertisement Overview | The MCCAOP Advertisement Overview element is optionally present if both dot11MeshActivated and dot11MCCAActivated are true. |
| 49 | MCCAOP Advertisement | One or more MCCAOP Advertisement elements are optionally present if both dot11MeshActivated and dot11MCCAActivated are true. |
| 50 | Mesh Channel Switch Parameters | The Mesh Channel Switch Parameters element is present if dot11MeshActivated is true and either Channel Switch Announcement element or Extended Channel Switch Announcement element is present. |
| 51 | QMF Policy | The QMF Policy element is present if dot11QMFActivated is true and the QMFActivated subfield is 1 in the Extended Capabilities element in the Probe Request that elicited this Probe Response frame. |
| 52 | QLoad Report | The QLoad Report element is present if dot11QLoadReportActivated is true. |
| 53 | Multi-band | The Multi-band element is optionally present if dot11MultibandImplemented is true. |
| 54 | DMG Capabilities | The DMG Capabilities element is present if dot11DMGOptionImplemented is true. |
| 55 | DMG Operation | The DMG Operation element is present if dot11DMGOptionImplemented is true. |
| 56 | Multiple MAC Sublayers | The Multiple MAC Sublayers element is present if dot11MultipleMACActivated is true. |
| 57 | Antenna Sector ID Pattern | The Antenna Sector ID Pattern element is optionally present if dot11DMGOptionImplemented is true. |
| 58 | VHT Capabilities | The VHT Capabilities element is present in the 5 GHz band when dot11VHTOptionImplemented is true.(11ax)(#8181) |
| 59 | VHT Operation | The VHT Operation element is present when dot11VHTOptionImplemented is true and the STA is not a STA 6G and is optionally present if dot11HEOptionImplemented is true; otherwise, it is not present.(11ax) |
| 60 | Transmit Power Envelope element | (11ax)One Transmit Power Envelope element is present for each distinct<br>combination of values of the Maximum Transmit Power Interpretation subfield and Maximum Transmit Power Category subfield that is supported for the BSS if both of the following conditions are met:<br>Either dot11VHTOptionImplemented or dot11ExtendedSpectrumManagementImplemented is true.<br>Either dot11SpectrumManagementRequired is true or dot11RadioMeasurementActivated is true.<br>Otherwise, this element is not present.<br><br>NOTE—In a 6 GHz HE AP, both dot11VHTOptionImplemented (see 26.17.1 (Basic HE BSS operation)) and dot11SpectrumManagementRequired (see 26.17.2.1 (General)) are true. |

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**Table 9-69—Probe Response frame body *(continued)***

| Order | Information | Notes |
|---|---|---|
| 61 | Channel Switch Wrapper element | The Channel Switch Wrapper element is optionally present if dot11VHTOptionImplemented or dot11ExtendedSpectrumManagementImplemented is true and at least one of a Channel Switch Announcement element or an Extended Channel Switch Announcement element is also present in the Probe Response frame and the Channel Switch Wrapper element contains at least one subelement.<br>The Channel Switch Wrapper element is optionally present if dot11S1GOptionImplemented is true and Extended Channel Switch Announcement element is present in the Probe Response frame. |
| 62 | Extended BSS Load element | The Extended BSS Load element is optionally present if dot11QBSSLoadImplemented and dot11VHTOptionImplemented are both true.(#6311) |
| 63 | Quiet Channel | Either one Quiet Channel element containing an AP Quiet Mode field equal to 0 or, in an infrastructure BSS, one or more Quiet Channel elements each containing an AP Quiet Mode field equal to 1 are optionally present if dot11VHTOptionImplemented is true, and either dot11SpectrumManagementRequired or dot11RadioMeasurementActivated is true. |
| 64 | Operating Mode Notification | The Operating Mode Notification element is optionally present if dot11OperatingModeNotificationImplemented is true. |
| 65 | Reduced Neighbor Report | (11ax)One or more Reduced Neighbor Report elements are optionally present if dot11TVHTOptionImplemented, dot11FILSActivated, or dot11ColocatedRNRImplemented is true; otherwise, they are not present. |
| 66 | TVHT Operation | The TVHT Operation element is present for a TVHT STA when dot11TVHTOptionImplemented is true; otherwise it is not present. |
| 67 | Estimated Service Parameters Inbound | The Estimated Service Parameters Inbound element is optionally present if dot11EstimatedServiceParametersInboundOptionImplemented is true. |
| 68 | Relay Capabilities | The Relay Capabilities element is present if dot11RelayActivated is true; otherwise not present. |
| 69 | CAG Number | The CAG Number element is optionally present if dot11FILSActivated is true; otherwise not present. |
| 70 | FILS Indication | The FILS Indication element is present if dot11FILSActivated is true; otherwise not present. |
| 71 | AP-CSN | The AP-CSN element is optionally present if dot11FILSActivated is true; otherwise not present. |
| 72 | DILS | The DILS element is optionally present if dot11FILSActivated is true; otherwise not present. |
| 73 | RPS | The RPS element is optionally present if dot11RAWOperationActivated is true; otherwise not present. |
| 74 | Page Slice | The Page Slice element is optionally present if dot11PageSlicingActivated is true; otherwise not present. |
| 75 | Change Sequence | The Change Sequence element is optionally present if dot11S1GOptionImplemented is true; otherwise not present. |
| 76 | TSF Timer Accuracy | The TSF Timer Accuracy element is optionally present when dot11TSFTimerAccuracyImplemented is true; otherwise not present. |


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**Table 9-69—Probe Response frame body *(continued)***

| Order | Information | Notes |
|---|---|---|
| 77 | S1G Relay Discovery | The S1G Relay Discovery element is optionally present if dot11RelayDiscoveryOptionImplemented is true; otherwise not present. |
| 78 | S1G Capabilities | The S1G Capabilities element is present if dot11S1GOptionImplemented is true; otherwise not present. |
| 79 | S1G Operation | The S1G Operation element is present when dot11S1GOptionImplemented is true; otherwise not present. |
| 80 | MAD | The MAD element is optionally present if dot11S1GOptionImplemented is true; otherwise not present. |
| 81 | Short Beacon Interval | The Short Beacon Interval element is present if dot11ShortBeaconInterval is true. |
| 82 | S1G Open-Loop Link Margin Index | The S1G Open-Loop Link Margin Index element is optionally present if dot11S1GOptionImplemented is true; otherwise not present. |
| 83 | S1G Relay | The S1G Relay element is optionally present if dot11RelayAPImplemented is true; otherwise not present. |
| 84 | Max Channel Switch Time | The Max Channel Switch Time element is optionally present when a Channel Switch Announcement or an Extended Channel Switch Announcement element is also present. |
| 85 | CDMG Capabilities | The CDMG Capabilities element is present if dot11CDMGOptionImplemented is true; otherwise not present. |
| 86 | Extended Cluster Report | The Extended Cluster Report element is optionally present if dot11ClusteringActivated is true; otherwise not present. |
| 87 | CMMG Capabilities | The CMMG Capabilities element is present when dot11CMMGOptionImplemented is true; otherwise not present. |
| 88 | CMMG Operation | The CMMG Operation element is present when dot11CMMGOptionImplemented is true; otherwise not present. |
| 89 | Estimated Services Parameters Outbound | The Estimated Service Parameters Outbound element is optionally present if dot11EstimatedServiceParametersOutboundOptionImplemented is true. |
| 90 | Service Hint | The Service Hint element is optionally present if dot11UnsolicitedPADActivated is true. |
| 91 | Service Hash | The Service Hash element is optionally present if dot11UnsolicitedPADActivated is true. |
| 92(11ax) | RSN Extension | The RSNXE is present if any subfield of the Extended RSN Capabilities field in this element is nonzero, except the Field Length subfield. |
| 93(11ax) | Multiple BSSID Configuration | The Multiple BSSID Configuration element is optionally present if dot11MultiBSSIDImplemented is true. |
| 94(11ax) | HE Capabilities | The HE Capabilities element is present if dot11HEOptionImplemented is true; otherwise, it is not present. |
| 95(11ax) | HE Operation | The HE Operation element is present if dot11HEOptionImplemented is true; otherwise, it is not present. |

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**Table 9-69—Probe Response frame body *(continued)***

| Order | Information | Notes |
|---|---|---|
| 96(11ax) | TWT | The TWT element is optionally present within broadcast Probe Response frames if dot11TWTOptionActivated, dot11HEOptionImplemented and dot11FILSOmitReplicateProbeResponses are true; otherwise, it is not present. If the TWT element is present, then the Negotiation Type subfield of the TWT element is 2. |
| 97(11ax) | UORA Parameter Set | The UORA Parameter Set element is optionally present if dot11OFDMARandomAccessOptionImplemented is true; otherwise, it is not present. |
| 98(11ax) | BSS Color Change Announcement | The BSS Color Change Announcement element is optionally present if dot11HEOptionImplemented is true; otherwise, it is not present. |
| 99(11ax) | Spatial Reuse Parameter Set | The Spatial Reuse Parameter Set element is optionally present if dot11HEOptionImplemented is true; otherwise, it is not present. |
| 100(11ax) | MU EDCA Parameter Set | The MU EDCA Parameter Set element is present if dot11HEOptionImplemented is true and dot11MUEDCAParametersActivated is true; otherwise, it is not present. |
| 101(11ax) | ESS Report | The ESS Report element is optionally present. |
| 102(11ax) | NDP Feedback Report Parameter Set | The NDP Feedback Report Parameter Set element is optionally present if dot11HEOptionImplemented is true; otherwise, it is not present. |
| 103(11ax) | HE BSS Load | The HE BSS Load element is optionally present if dot11QBSSLoadImplemented and dot11HEOptionImplemented are true. |
| 104(11ax) | HE 6 GHz Band Capabilities | The HE 6 GHz Band Capabilities element is present if dot11HEOptionImplemented and dot11HE6GOptionImplemented are true. |
| 105(11ax) | TWT Constraint Parameters | The TWT Constraint Parameters element is optionally present if dot11TWTOptionActivated is true; otherwise, it is not present. |
| 106(11ay) | EDMG Capabilities | The EDMG Capabilities element is present if dot11EDMGOptionImplemented is true. |
| 107(11ay) | EDMG Operation | The EDMG Operation element is present if dot11EDMGOptionImplemented is true. |
| 108(11ay) | Unsolicited Block Ack Extension | The Unsolicited Block Ack Extension element is optionally present if dot11UnsolicitedBAActivated is true and is absent otherwise. |
| 109(11ba) | WUR Capabilities | The WUR Capabilities element is present when dot11WUROption-Implemented is true; otherwise it is not present. |
| 110(11ba) | WUR Operation | The WUR Operation element is present when dot11WUROption-Implemented is true; otherwise it is not present. |
| 111(11ba) | WUR Discovery | The WUR Discovery element is optionally present if dot11WUROptionImplemented is true and either dot11WURDis-coveryImplemented or dot11WURNeighborDiscoveryImple-mented is true; otherwise it is not present. |
| 112(#6050) | Authentication Control | The Authentication Control element is optionally present when dot11S1GCentralizedAuthenticationControlActivated is true or dot11S1GDistributedAuthenticationControlActivated is true; otherwise it is not present. |


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**Table 9-69—Probe Response frame body *(continued)***

| Order | Information | Notes |
|---|---|---|
| 113(11bc) | EBCS Parameters | This element is present if dot11EBCSSupportActivated is true and the length of dot11EBCSTrafficStreamTable is larger than 0, otherwise not present. |
| Last–1 | Vendor Specific | One or more Vendor Specific elements are optionally present(#8128). |
| Last | Requested elements | Elements requested by the Request element or Extended Request element(s) of the Probe Request frame are present if dot11MultiDomainCapabilityActivated or dot11EstimatedServiceParametersInboundOptionImplemented is true. See 11.1.4.3.2 (Active scanning procedure for a non-DMG STA) and 11.44 (Estimated throughput). |

### 9.3.3.11 Authentication frame format

The frame body of an Authentication frame contains the information shown in Table 9-70 (Authentication frame body). FT authentication is used when FT support is advertised by the AP and dot11FastBSSTransitionActivated is true in the STA. SAE authentication is used when dot11MeshActiveAuthenticationProtocol is sae (1). FILS authentication is used if support for FILS authentication is advertised by the AP and dot11FILSActivated is true in the STA.

**Table 9-70—Authentication frame body**

| Order | Information | Notes |
|---|---|---|
| 1 | Authentication algorithm number | |
| 2 | Authentication transaction sequence number | |
| 3 | Status Code(#3326) | The status code information is reserved in certain Authentication frames as defined in Table 9-71 (Presence of fields and elements in Authentication frames). |
| 4 | Finite Cyclic Group | An unsigned integer indicating a finite cyclic group as described in 9.4.1.40 (Finite Cyclic Group field). This is present only in certain Authentication frames as defined in Table 9-71 (Presence of fields and elements in Authentication frames). |
| 5 | Anti-Clogging Token | A random bit string used for anti-clogging purposes as described in 12.4.6 (Anti-clogging tokens). This is present only in certain Authentication frames as defined in Table 9-71 (Presence of fields and elements in Authentication frames). |
| 6 | Send-Confirm | A binary encoding of an integer used for anti-replay purposes as described in 12.4.7.4 (Encoding and decoding of SAE Confirm messages). This is present only in certain Authentication frames as defined in Table 9-71 (Presence of fields and elements in Authentication frames). |
| 7 | Scalar | An unsigned integer encoded as described in 12.4.7.3 (Encoding and decoding of SAE Commit messages). This is present only in certain Authentication frames as defined in Table 9-71 (Presence of fields and elements in Authentication frames). |

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**Table 9-70—Authentication frame body *(continued)***

| Order | Information | Notes |
|---|---|---|
| 8 | FFE(#312) | An element in a finite field encoded as described in 12.4.7.3 (Encoding and decoding of SAE Commit messages). This is present only in certain Authentication frames as defined in Table 9-71 (Presence of fields and elements in Authentication frames). |
| 9 | Confirm | An unsigned integer encoded as described in 12.4.7.4 (Encoding and decoding of SAE Confirm messages). This is present only in certain Authentication frames as defined in Table 9-71 (Presence of fields and elements in Authentication frames). |
| 10(#3056) | RSN | An RSNE is present only in certain Authentication frames as defined in Table 9-71 (Presence of fields and elements in Authentication frames). |
| 11(#3056) | Mobility Domain | An MDE is present only in certain Authentication frames as defined in Table 9-71 (Presence of fields and elements in Authentication frames). |
| 12(#3056) | Fast BSS Transition | An FTE is present only in certain Authentication frames as defined in Table 9-71 (Presence of fields and elements in Authentication frames). |
| 13(#3056) | Timeout Interval (reassociation deadline) | A TIE containing the reassociation deadline interval is present only in certain Authentication frames as defined in Table 9-71 (Presence of fields and elements in Authentication frames). |
| 14(#3056) | RIC | A resource information container, containing a variable number of elements, is present only in certain Authentication frames as defined in Table 9-71 (Presence of fields and elements in Authentication frames). |
| 15(#3056) | Multi-band | The Multi-band element is optionally present if dot11MultibandImplemented is true. |
| 16(#3056) | Neighbor Report | One or more Neighbor Report elements are present only in certain Authentication frames as defined in Table 9-71 (Presence of fields and elements in Authentication frames). |
| 17(#3056) | FILS Nonce | The FILS Nonce element is present in FILS Authentication frames as defined in Table 9-71 (Presence of fields and elements in Authentication frames). |
| 18(#3056) | FILS Session | The FILS Session element is present in FILS Authentication frames as defined in Table 9-71 (Presence of fields and elements in Authentication frames). |
| 19(#3056) | (#7044)Wrapped Data | The (#7044)Wrapped Data element is present in FILS Authentication frames as defined in Table 9-71 (Presence of fields and elements in Authentication frames). |
| 20(#3056) | Association Delay Info | The Association Delay Info element is present in FILS Authentication frames as defined in Table 9-71 (Presence of fields and elements in Authentication frames). |
| 21(#3056) | Password Identifier | The Password Identifier element is optionally present in certain Authentication frames as defined in Table 9-71 (Presence of fields and elements in Authentication frames). |
| 22(#7042) | RSNXE | The RSNXE is present only in certain Authentication frames as defined in Table 9-71 (Presence of fields and elements in Authentication frames) |


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**Table 9-70—Authentication frame body *(continued)***

| Order | Information | Notes |
|---|---|---|
| 23(#3056) | Rejected Groups | The Rejected Groups element is present only in certain Authentication frames as defined in Table 9-71 (Presence of fields and elements in Authentication frames). |
| 24(#3056) | Anti-Clogging Token Container | The Anti-Clogging Token Container element is present only in certain Authentication frames as defined in Table 9-71 (Presence of fields and elements in Authentication frames). |
| 25(M67)(#3056) | AKM Suite Selector | The AKM Suite Selector element is present only in certain Authentication frames as defined in Table 9-71 (Presence of fields and elements in Authentication frames). |
| 26(11az) | PASN Parameters | A PASN element is present only in certain Authentication frames as defined in Table 9-71 (Presence of fields and elements in Authentication frames). |
| 27(#7096) | Tunneled PASN | A Tunneled PASN element is present only in certain Authentication frames as defined in Table 9-71 (Presence of fields and elements in Authentication frames). |
| Last-1(#7045) | Vendor Specific | One or more Vendor Specific elements are optionally present. |
| Last(#7045) | MIC | A MIC element is present only in certain Authentication frames as defined in Table 9-71 (Presence of fields and elements in Authentication frames). |

**Table 9-71—Presence of fields and elements in Authentication frames**

| Authentication algorithm | Authentication transaction sequence number | Status Code(#3326) | Presence of fields and elements (#7043)indicated as conditional in Table 9-70 (Authentication frame body) |
|---|---|---|---|
| Open System | 1 | Reserved | Not present |
| Open System | 2 | Not REJECTED_WITH_SUGGESTED_BSS_TRANSITION | Not present |
| Open System | 2 | REJECTED_WITH_SUGGESTED_BSS_TRANSITION | One or more Neighbor Report element(s) is present |
| (#3056)FT | 1 | Reserved | The (#1776)MDE is present.<br><br>The (#1776)FTE and RSNE(s) are present if dot11RSNAActivated is true.<br><br>The RSNXE is present if any subfield of the Extended RSN Capabilities field in this element is nonzero, except the Field Length subfield.(#7041) |
| FT | 2 | Not REJECTED_WITH_SUGGESTED_BSS_TRANSITION | The (#1776)MDE is present if the Status Code field is 0.<br><br>The (#1776)FTE and RSNE(s) are present if the Status Code field is 0 and dot11RSNAActivated is true. |

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**Table 9-71—Presence of fields and elements in Authentication frames *(continued)***

| Authentication algorithm | Authentication transaction sequence number | Status Code(#3326) | Presence of fields and elements (#7043)indicated as conditional in Table 9-70 (Authentication frame body) |
|---|---|---|---|
| FT | 2 | REJECTED_WITH_SUGGESTED_BSS_TRANSITION | One or more Neighbor Report element(s) is present |
| FT | 3 | Reserved | The (#1776)MDE is present.<br><br>The (#1776)FTE and RSNE(s) are present if dot11RSNAActivated is true.<br><br>The RIC element is optionally present. |
| FT | 4 | Any | The (#1776)MDE is present if the Status Code field is 0.<br><br>The (#1776)FTE and RSNE(s) are present if dot11RSNAActivated is true.<br><br>The RIC element is optionally present if the Status Code field is 0.<br><br>The TIE (reassociation deadline) is present if a RIC element is present. |
| SAE | 1 | Any | The Scalar field is present if the Status Code field is zero or 126.<br>The FFE field is present if the Status Code field is zero or 126.<br>When the hunting-and-pecking method is used to drive the PWE, the Anti-Clogging Token field is present if the Status Code field is ANTI_CLOGGING_TOKEN_REQUIRED or if the Authentication frame is in response to a previous rejection with the Status Code field equal to ANTI_CLOGGING_TOKEN_REQUIRED.<br>The Finite Cyclic Group field is present if the Status Code field is zero, ANTI_CLOGGING_TOKEN_REQUIRED, 77 or 126.<br>The Password Identifier element is optionally present if the Status Code field is zero, 123 or 126.<br>(#288)If the Status Code field is 126, the Rejected Groups element is conditionally present as described in 12.4.7.3 (Encoding and decoding of SAE Commit messages); otherwise the Rejected Groups element is not present. When the hash-to-element method is used to derive the PWE, the Anti-Clogging Token Container element is present if the Status Code field is ANTI_CLOGGING_TOKEN_REQUIRED or if the Authentication frame is in response to a previous rejection with the Status Code field equal to ANTI_CLOGGING_TOKEN_REQUIRED.<br>(M67)The AKM Suite Selector element is present if (#3266)the intended AKM is 00-0F-AC:24 or 00-0F-AC:25 (see 12.4.5.3 (Construction of an SAE Commit message) and 12.4.5.4 (Processing of a peer's SAE Commit message)); otherwise, it is not present. |


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**Table 9-71—Presence of fields and elements in Authentication frames *(continued)***

| Authentication algorithm | Authentication transaction sequence number | Status Code(#3326) | Presence of fields and elements (#7043)indicated as conditional in Table 9-70 (Authentication frame body) |
|---|---|---|---|
| SAE | 2 | Not REJECTED_WITH_SUGGESTED_BSS_TRANSITION | The Send-Confirm field is present.<br>The Confirm field is present. |
| SAE | 2 | REJECTED_WITH_SUGGESTED_BSS_TRANSITION | One or more Neighbor Report element(s) are present |
| FILS Shared Key authentication without PFS | 1 | Reserved | The RSNE is present.<br><br>The MDE is present if the FILS authentication is used for FT initial mobility domain association.<br><br>The FILS Nonce element is present.<br><br>The FILS Session element is present.<br><br>The (#7044)Wrapped Data element is present. |
| FILS Shared Key authentication without PFS | 2 | Status | The RSNE is present.<br><br>The MDE and the FTE are present if the Status Code field is 0 and FILS authentication is used for FT initial mobility domain association.<br><br>The FILS Nonce element is present if the Status Code field is 0.<br><br>The FILS Session element is present if the Status Code field is 0.<br><br>The (#7044)Wrapped Data element is present if the Status Code field is 0.<br><br>The Association Delay Info element is present if the Status Code field is 0 and the AP expects that the (Re)Association Response frame will be transmitted more than 1 TU after the (Re)Association Request frame. |
| FILS Shared Key authentication with PFS | 1 | Reserved | The Finite Cyclic Group field is present.<br><br>The FFE field is present.<br><br>The RSNE is present.<br><br>The MDE is present if the FILS authentication is used for FT initial mobility domain association.<br><br>The FILS Nonce element is present.<br><br>The FILS Session element is present.<br><br>The (#7044)Wrapped Data element is present. |

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**Table 9-71—Presence of fields and elements in Authentication frames *(continued)***

| Authentication algorithm | Authentication transaction sequence number | Status Code(#3326) | Presence of fields and elements (#7043)indicated as conditional in Table 9-70 (Authentication frame body) |
|---|---|---|---|
| FILS Shared Key authentication with PFS | 2 | Status | The Finite Cyclic Group field(#313) is present if the Status Code field is 0.<br>The FFE field is present if the Status Code field is 0.<br>The RSNE is present.<br>The MDE and the FTE are present if the Status Code field is 0 and FILS authentication is used for FT initial mobility domain association.<br>The FILS Nonce element is present if the Status Code field is 0.<br>The FILS Session element is present if the Status Code field is 0.<br>The (#7044)Wrapped Data element is present if the Status Code field is 0.<br>The Association Delay Info element is present if the Status Code field is 0 and the AP expects that the (Re)Association Response frame will be transmitted more than 1 TU after the (Re)Association Request frame. |
| FILS Public Key authentication | 1 | Reserved | The Finite Cyclic Group field is present.<br><br>The FFE field is present.<br><br>The RSNE is present.<br><br>The MDE is present if the FILS authentication is used for FT initial mobility domain association.<br><br>The FILS Nonce element is present.<br><br>The FILS Session element is present. |
| FILS Public Key authentication | 2 | Status | The Finite Cyclic Group field(#313) is present if the Status Code field is 0.<br><br>The FFE field is present if the Status Code field is 0.<br><br>The RSNE is present.<br><br>The MDE and the FTE are present if the Status Code field is 0 and FILS authentication is used for FT initial mobility domain association.<br><br>The FILS Nonce element is present if the Status Code field is 0.<br><br>The FILS Session element is present if the Status Code field is 0.<br><br>The Association Delay Info element is present if the Status Code field is 0 and the AP expects that the (Re)Association Response frame will be transmitted more than 1 TU after the (Re)Association Request frame. |


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**Table 9-71—Presence of fields and elements in Authentication frames *(continued)***

| Authentication algorithm | Authentication transaction sequence number | Status Code(#3326) | Presence of fields and elements (#7043)indicated as conditional in Table 9-70 (Authentication frame body) |
|---|---|---|---|
| PASN Authentication(11az) | 1 | Reserved | RSNE is present.<br>RSNXE is present if any subfield of the Extended RSN Capabilities field in this element, except the Field Length subfield, is nonzero.<br>PASN Parameters element is present.<br>Timeout Interval element (#8241)is optionally present.<br>Wrapped Data element is present if wrapped data format in PASN Parameters element is nonzero and not reserved.<br>Fragment element (#8241)is optionally present if any of the elements are fragmented.<br>(#7096)Tunneled PASN element may be present. |
| PASN Authentication(11az) | 2 | Status | RSNE is present and PASN Parameters element is present if Status Code field is 0.<br>RSNXE is present if any subfield of the Extended RSN Capabilities field in this element, except the Field Length subfield, is nonzero.<br>Timeout Interval element (#8241)is optionally present.<br>Wrapped data element is present if wrapped data format in PASN Parameters element is nonzero and not reserved and Status Code field is 0.<br>MIC element is present.<br>Fragment element may be present if any of the elements are fragmented and Status Code field is 0.<br>(#7096)Tunneled PASN element (#8241)is optionally present. |
| PASN Authentication(11az) | 3 | Status | PASN Parameters element is present if Status Code field is 0.<br>Wrapped data element is present if wrapped data format in PASN Parameters element is nonzero and not reserved; and Status Code field is 0.<br>MIC element is present.<br>Fragment element may be present if any of the elements are fragmented and Status Code field is 0. |

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### 9.3.3.12 Deauthentication

The frame body of a Deauthentication frame contains the information shown in Table 9-72 (Deauthentication frame body).

**Table 9-72—Deauthentication frame body**

| Order | Information |
|---|---|
| 1 | Reason code |
| Last – 1 | One or more Vendor Specific elements are optionally present. |
| Last | The MME is present when management frame protection is enabled at the STA transmitting the frame(#1617) and the frame is a group addressed frame. |
| NOTE—The MME appears last in the frame body to protect the frames as specified in 12.5.3 (Broadcast/multicast integrity protocol (BIP)). Since it appears last and has a fixed size, it can readily be located without parsing all the elements in the frame.(#7154) | |

### 9.3.3.13 Action frame format

The frame body of an Action frame contains the information shown in Table 9-73 (Action frame body and Action No Ack frame body).

**Table 9-73—Action frame body and Action No Ack frame body**

| Order | Information |
|---|---|
| 1 | Action |
| Last – 3 | One or more Vendor Specific elements are optionally present.<br><br>These elements are absent when the Category subfield of the Action field is Vendor-Specific, Vendor-Specific Protected, (#125)or when the Category subfield of the Action field is VHT and the VHT Action subfield of the Action field is VHT Compressed Beamforming or when the Category subfield of the Action field is HE and the HE Action subfield of the Action field is HE Compressed Beamforming/CQI.(11ax) |
| Last – 2 | (#3410)The MME is present when management frame protection is enabled at the AP and the frame is a group addressed robust Action or Action No Ack frame(#4339) not of a category specified with Yes in the Group addressed privacy column of Table 9-81 (Category values); otherwise not present. |
| Last – 1(#125) | The MIC element is present in a Self-protected Action frame if a (#1900)shared PMK exists between the sender and recipient of this frame; otherwise not present. |
| Last | The Authenticated Mesh Peering Exchange element is present in a Self-protected Action frame if (#125)a (#1900)shared PMK exists between the sender and recipient of this frame; otherwise not present. |
| NOTE 1—The MME appears last in the frame body to protect the frames as specified in 12.5.3 (Broadcast/multicast integrity protocol (BIP)). Since it appears last and has a fixed size, it can readily be located without parsing all the elements in the frame.(#7154)<br>NOTE 2—The MIC element and the Authenticated Mesh Peering Exchange element appear after any fields that they protect in an individually addressed frame. Therefore, they appear last in the frame body. The Authenticated Mesh Peering Exchange element is encrypted and authenticated as specified in 14.6.3 (Construction and processing AES-SIV-protected mesh peering Management frames).(#125) | |


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#### 9.3.3.14 Action No Ack frame format

The frame body of an Action No Ack frame contains the information shown in Table 9-73 (Action frame body and Action No Ack frame body).

NOTE—The selection of Action or Action No Ack is made per frame that uses these formats.

Unless specified as allowing the use of the Action No Ack management frame subtype, a frame described as an "Action frame" uses only the Action subtype.

#### 9.3.3.15 Timing Advertisement frame format

The frame body of a Timing Advertisement frame contains the information shown in Table 9-74 (Timing Advertisement frame body).

**Table 9-74—Timing Advertisement frame body**

| Order | Information | Notes |
|---|---|---|
| 1 | Timestamp | See 9.4.1.10 (Timestamp field) for Timestamp field format. |
| 2 | Capability Information | See 9.4.1.4 (Capability Information field) for Capability Information field format. |
| 3 | Country | The Country element is present if dot11MultiDomainCapabilityActivated is true or dot11SpectrumManagementRequired is true. |
| 4 | Power Constraint | The Power Constraint element is optionally present if the Country element is present; otherwise not present. |
| 5 | Time Advertisement | The Time Advertisement element is optionally present. See 9.4.2.59 (Time Advertisement element). |
| 6 | Extended Capabilities | The Extended Capabilities element is present. |
| Last | Vendor specific | One or more Vendor Specific elements are optionally present(#8128). |

### 9.3.4 Extension frames

#### 9.3.4.1 Format of Extension frames

The format of Extension frames is defined in Figure 9-129 (Extension frame format). The MAC header of an Extension frame starts with the Frame Control field followed by the Duration field. The MAC header of different Extension frames can have different number and types of fields following the Duration field.

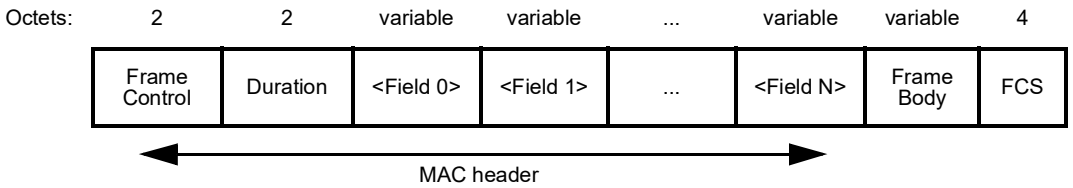


**Figure 9-129—Extension frame format**

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### 9.3.4.2 DMG Beacon

The format of the DMG Beacon frame is shown in Figure 9-130 (DMG Beacon frame format).

In addition to supporting functions such as network synchronization (see 11.1 (Synchronization)), the DMG Beacon frame can also be used as a training frame for beamforming (see 10.41 (DMG beamforming)).

| | Frame Control | Duration | BSSID | Frame Body | FCS |
|---|---|---|---|---|---|
| Octets: | 2 | 2 | 6 | variable(#213) | 4 |

**Figure 9-130—DMG Beacon frame format**

The Duration field is set to the time remaining until the end of the beacon transmission interval (BTI).

The BSSID field contains the BSSID.

The Frame Body field of the DMG Beacon frame contains the elements listed in Table 9-75 (DMG Beacon frame body).

**Table 9-75—DMG Beacon frame body**

| Order | Information | Notes |
|---|---|---|
| 1 | Timestamp | See 9.4.1.10 (Timestamp field) |
| 2 | Sector Sweep | See 9.5.1 (SSW field(#4303)) |
| 3 | Beacon Interval | See 9.4.1.3 (Beacon Interval field) |
| 4 | Beacon Interval Control | See Figure 9-131 (Beacon Interval Control field format when the Next A-BFT subfield is 0(11ay)(M118)). |
| 5 | DMG Parameters | See 9.4.1.44 (DMG Parameters field) |
| 6 | Clustering Control | Optional. See Figure 9-133 (Clustering Control field format if the Discovery Mode field is 0) and Figure 9-134 (Clustering Control field format if the Discovery Mode field is 1(11bd)). |
| 7 | DMG Capabilities | The DMG Capabilities element is optionally present. |
| 8 | Extended Schedule | The Extended Schedule element is optionally present. |
| 9 | RSN | The RSNE is optionally present if dot11RSNAActivated is true. |
| 10 | Multiple BSSID | (#488)One or more Multiple BSSID elements are present if the AP is a member of a multiple BSSID set (see 11.10.14 (Multiple BSSID set)) with two or more members and any of the following conditions are true:<br>• dot11MultiBSSIDImplemented is true<br>• dot11MultiBSSIDImplemented is false and dot11RMMeasurementPilotActivated is between 2 and 7<br>• dot11InterworkingServiceActivated is true and at least one dot11GASAdvertisementID exists |
| 11 | DMG Operation | The DMG Operation element is optionally present. |
| 12 | Next DMG ATI | The Next DMG ATI element is optionally present. |


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**Table 9-75—DMG Beacon frame body *(continued)***

| Order | Information | Notes |
|---|---|---|
| 13 | DMG BSS Parameter Change | The DMG BSS Parameter Change element is optionally present. |
| 14 | Multi-band | Zero or more Multi-band elements are present if dot11MultibandImplemented is true. |
| 15 | Awake Window | The Awake Window element is optionally present. If present, this element specifies the characteristics of the awake window of a CBAP (see 11.2.7 (Power management in a PBSS and DMG infrastructure BSS)). |
| 16 | DMG Wakeup Schedule | The DMG Wakeup Schedule element is optionally present (see 11.2.7.3.3 (PCP operation with a wakeup schedule). |
| 17 | UPSIM | The UPSIM element is optionally present (see 11.2.7.2.2 (Non-AP and non-PCP STA operation without a wakeup schedule)). |
| 18 | SSID | The SSID element is optionally present. |
| 19 | IBSS Parameter Set | The IBSS Parameter Set element is present only within DMG Beacon frames generated by IBSS STAs. |
| 20 | Country | The Country element is optionally present if dot11MultiDomainCapabilityActivated is true or dot11SpectrumManagementRequired is true or dot11RadioMeasurementActivated is true. |
| 21 | BSS Load | The BSS Load element is optionally present if dot11QBSSLoadImplemented is true(#3338); otherwise not present.(#1598-Ed1) |
| 22 | EDCA Parameter Set | The EDCA Parameter Set element is optionally present if the QoS Capability element is not present.(#316) |
| 23 | Power Constraint | The Power Constraint element is optionally present if dot11SpectrumManagementRequired is true and is optionally present if dot11RadioMeasurementActivated is true. |
| 24 | Neighbor Report | The Neighbor Report element is optionally present. |
| 25 | Quiet | The Quiet element is optionally present if dot11SpectrumManagementRequired is true or dot11RadioMeasurementActivated is true. |
| 26 | QoS Capability | The QoS Capability element is optionally present if the EDCA Parameter Set element is not present.(#316) |
| 27 | Extended Channel Switch Announcement | The Extended Channel Switch Announcement element is optionally present if dot11ExtendedChannelSwitchActivated is true. |
| 28 | BSS Average Access Delay | The BSS Average Access Delay element is optionally present. |
| 29 | RM Enabled Capabilities | The RM Enabled Capabilities element is optionally present if dot11RadioMeasurementActivated is true. |
| 30 | Nontransmitted BSSID Capability | The Nontransmitted BSSID Capability element is optionally present. |
| 31 | Interworking | The Interworking element is optionally present if dot11InterworkingServiceActivated is true. |

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**Table 9-75—DMG Beacon frame body *(continued)***

| Order | Information | Notes |
|---|---|---|
| 32 | Advertisement Protocol | The Advertisement Protocol element is optionally present if dot11InterworkingServiceActivated is true and at least one dot11GASAdvertisementID exists. |
| 33 | Roaming Consortium | The Roaming Consortium element is optionally present if dot11InterworkingServiceActivated is true and the dot11RoamingConsortiumTable has at least one entry. |
| 34 | STA Availability | The STA Availability element is optionally present. |
| 35 | Next PCP List | The Next PCP List element is optionally present. |
| 36 | PCP Handover | The PCP Handover element is optionally present. |
| 37 | Antenna Sector ID Pattern | The Antenna Sector ID Pattern element is optionally present. |
| 38 | CDMG Capabilities | The CDMG Capabilities element is present if dot11CDMGOptionImplemented is true; otherwise not present. |
| 39 | Dynamic Bandwidth Control | The Dynamic Bandwidth Control element is optionally present if a STA operates as an AP or PCP and dot11CDMGOptionImplemented is true; otherwise not present. |
| 40 | Cluster Probe | The Cluster Probe element is optionally present if dot11ClusteringActivated is true; otherwise not present. |
| 41 | Extended Cluster Report | The Extended Cluster Report element is optionally present if dot11ClusteringActivated is true; otherwise not present. |
| 42 | Cluster Switch Announcement | The Cluster Switch Announcement element is optionally present if dot11ClusteringActivated is true; otherwise not present. |
| 43 | Extended Cluster Report | The Extended Cluster Report element is optionally present if dot11ClusteringActivated is true; otherwise not present. |
| 44 | Cluster Switch Announcement | The Cluster Switch Announcement element is optionally present if dot11ClusteringActivated is true; otherwise not present. |
| 45 | SPSH Report | The SPSH Report element is optionally present if dot11ClusteringActivated is true; otherwise not present. |
| 46 | Clustering Interference Assessment | The Clustering Interference Assessment element is optionally present if dot11ClusteringActivated is true; otherwise not present. |
| 47 | CMMG Capabilities | The CMMG Capabilities element is present when dot11CMMGOptionImplemented is true; otherwise not present. |
| 48 | CMMG Operation | The CMMG Operation element is present if dot11CMMGOptionImplemented is true; otherwise not present. |
| 49 | Power Constraint | The Power Constraint element is present if dot11SpectrumManagementRequired is true and is optionally present if dot11RadioMeasurementActivated is true; otherwise not present. |
| 50 | TPC Report | The TPC Report element is present if dot11SpectrumManagementRequired is true or dot11RadioMeasurementActivated is true; otherwise not present.(#1598) |
| 51 | CDMG Extended Schedule | The CDMG Extended Schedule element is optionally present. |


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**Table 9-75—DMG Beacon frame body *(continued)***

| Order | Information | Notes |
|---|---|---|
| 52 | Service Hint | The Service Hint element is optionally present if dot11UnsolicitedPADActivated is true. |
| 53 | Service Hash | The Service Hash element is optionally present if dot11UnsolicitedPADActivated is true. |
| 54(11ax) | Multiple BSSID Configuration | The Multiple BSSID Configuration element is optionally present if dot11MultiBSSIDImplemented is true. |
| 55(11ay) | TDD Slot Structure | This element is optionally present if dot11TDDOptionImplemented is true. |
| 56(11ay) | TDD Slot Schedule | This element is optionally present if dot11TDDOptionImplemented is true. |
| 57(11ay) | EDMG Capabilities | This element is optionally present if dot11EDMGOptionImplemented is true. |
| 58(11ay) | EDMG Operation | This element is optionally present if dot11EDMGOptionImplemented is true. |
| 59(11ay) | EDMG Extended Schedule | This element is optionally present if dot11EDMGOptionImplemented is true. |
| 60(11ay) | EDMG Group ID Set | This element is optionally present if dot11EDMGOptionImplemented is true. |
| 61(11ay) | EDMG Training Field Schedule | This element is optionally present if dot11EDMGOptionImplemented is true. |
| 62(11ay) | Time Advertisement | This element is optionally present if dot11UTCTSFOffsetActivated is true. |
| 63(11bd) | DMG OCB | This element is present if dot11DMGOCBActivated is true; otherwise not present. |
| Last | Vendor Specific | One or more Vendor Specific elements are optionally present(#8128). |

(11ay)The format of the Beacon Interval Control field when the Next A-BFT subfield is 0 is shown in Figure 9-131 (Beacon Interval Control field format when the Next A-BFT subfield is 0(11ay)(M118)). The format of the Beacon Interval Control field when the Next A-BFT subfield is nonzero is shown in Figure 9-132 (Beacon Interval Control field format when the Next A-BFT subfield is nonzero(11ay)). The difference between the two formats is in the definition of the field occupying B14.

The CC Present subfield is set to 1 to indicate that the Clustering Control field is present in the DMG Beacon frame. Otherwise, the Clustering Control field is not present.

The Discovery Mode subfield is set to 1 if the STA is generating the DMG Beacon frame following the procedure described in 11.1.3.4 (DMG beacon generation before establishment of a BSS). Otherwise, this subfield is set to 0.

The Next Beacon subfield indicates the number of beacon intervals following the current beacon interval during which the DMG Beacon frame will not be transmitted.

The ATI Present subfield is set to 1 to indicate that the announcement transmission interval (ATI) is present in the current beacon interval. Otherwise, the ATI is not present.

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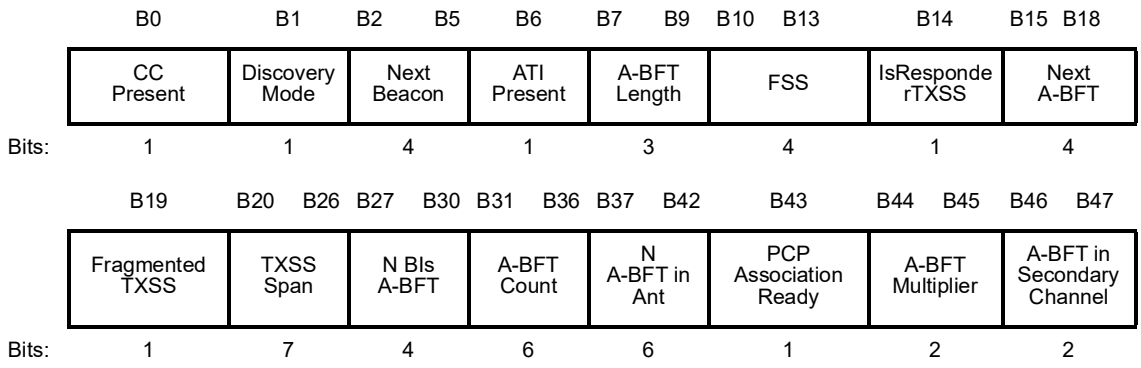


**Figure 9-131—Beacon Interval Control field format when the Next A-BFT subfield is 0(11ay)(M118)**

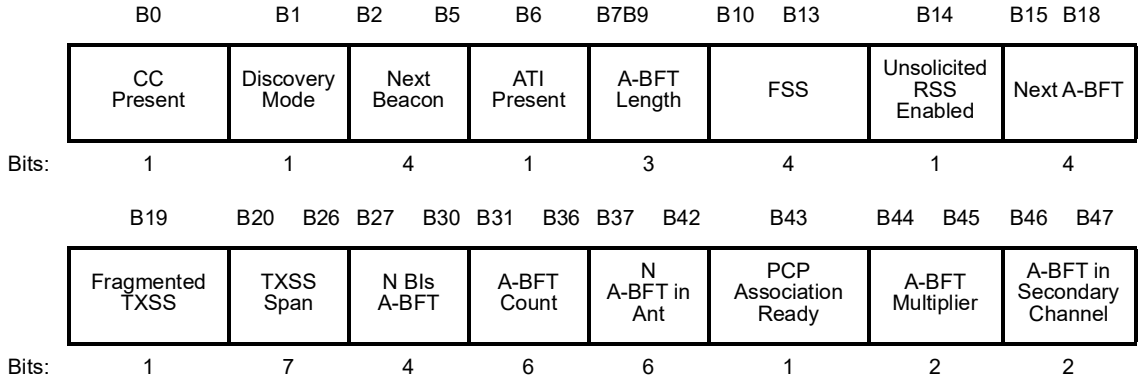


**Figure 9-132—Beacon Interval Control field format when the Next A-BFT subfield is nonzero(11ay)**

The A-BFT Length subfield indicates the number of sector sweep slots (10.41.5 (Beamforming in A-BFT)) in the A-BFT following the BTI, minus 1.

The FSS subfield indicates the number of SSW frames (11ay)or Short SSW PPDUs allowed per sector sweep slot (10.41.5 (Beamforming in A-BFT)). The subfield contains the number of SSW frames allowed minus one. The range of this subfield is 0 to 15.

The IsResponderTXSS subfield is (11ay)present when the Next A-BFT subfield is 0. The IsResponderTXSS is set to 1 to indicate the A-BFT following the BTI is used for responder transmit sector sweep (TXSS). This field is set to 0 to indicate responder receive sector sweep (RXSS). When this subfield is set to 0, the FSS subfield specifies the length of a complete receive sector sweep by the STA sending the DMG Beacon frame.

(11ay)The Unsolicited RSS Enabled subfield is present when the Next A-BFT subfield is nonzero. The Unsolicited RSS Enabled subfield is set to 1 to indicate that the STA is capable of receiving an unsolicited RSS in response to its BTI. This subfield is set to 0 otherwise. This subfield is ignored when received by a non-EDMG STA or when received from a non-EDMG STA.

The Next A-BFT subfield indicates the number of beacon intervals during which the A-BFT is not present. This subfield is set to 0 if the A-BFT immediately follows this BTI.


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The Fragmented TXSS subfield is set to 1 to indicate the TXSS is a fragmented sector sweep and is set to 0 to indicate the TXSS is a complete sector sweep.

The TXSS Span subfield indicates the number of beacon intervals it takes for the STA sending the DMG Beacon frame to complete the TXSS phase. This subfield is always greater than or equal to 1.

The N BIs A-BFT subfield indicates the interval, in number of beacon intervals, at which the STA sending the DMG Beacon frame allocates an A-BFT. The subfield is set to 1 if every beacon interval contains an A-BFT.

The A-BFT Count subfield indicates the number of A-BFTs since the STA sending the DMG Beacon frame last switched RX DMG antennas for an A-BFT. The subfield is set to 0 if the DMG antenna used in the forthcoming A-BFT differs from the DMG antenna used in the last A-BFT. This subfield is reserved if the Number of RX DMG Antennas field within the STA's DMG Capabilities element is 1.

The N A-BFT in Ant subfield indicates how many A-BFTs the STA sending the DMG Beacon frame receives from each DMG antenna in the DMG antenna receive rotation. This subfield is reserved if the Number of RX DMG Antennas field within the STA's DMG Capabilities element is 1.

The PCP Association Ready subfield is set to 1 to indicate that the PCP is ready to receive Association Request frames from non-PCP STAs and is set to 0 otherwise. This subfield is reserved when transmitted by a non-PCP STA.

(11ay)The A-BFT Multiplier subfield allows expanding the total length of the A-BFT. The total length of the A-BFT is equal to the value of the A-BFT Length subfield plus the multiplication of the value of the A-BFT Multiplier subfield and the value of the A-BFT Length subfield. This subfield is reserved if the value of the Next A-BFT subfield is nonzero.

(11ay)The A-BFT in Secondary Channel subfield indicates that the A-BFT is allocated on an adjacent secondary channel, in addition to being allocated on the primary channel. If set to 0, the A-BFT is not allocated on any secondary channel. If set to a nonzero value, the A-BFT is allocated on an adjacent secondary channel as follows:

— If set to 1, the A-BFT is also present on the lower secondary channel adjacent to the primary channel.
— If set to 2, the A-BFT is also present on the upper secondary channel adjacent to the primary channel.
— If set to 3, the A-BFT is also present on both the lower and upper secondary channels adjacent to the primary channel.

(11ay)The A-BFT in Secondary Channel subfield is reserved if the value of the Next A-BFT subfield is nonzero.

The DMG Parameters field is defined in 9.4.1.44 (DMG Parameters field).

If the Discovery Mode field is 0, the Clustering Control field is formatted as shown in Figure 9-133 (Clustering Control field format if the Discovery Mode field is 0). If the Discovery Mode field is 1, the

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Clustering Control field is formatted as shown in Figure 9-134 (Clustering Control field format if the Discovery Mode field is 1(11bd)).

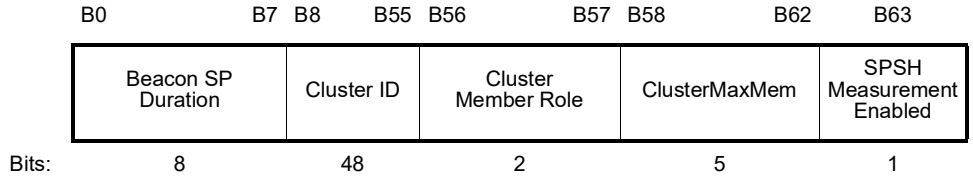


**Figure 9-133—Clustering Control field format if the Discovery Mode field is 0**

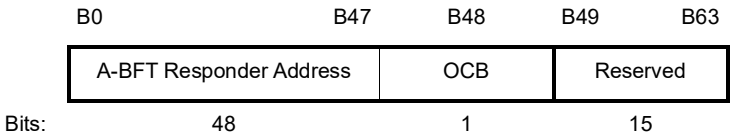


**Figure 9-134—Clustering Control field format if the Discovery Mode field is 1(11bd)**

If ECAPC Policy Enforced field is set to 0, the Beacon SP Duration subfield indicates the duration, in units of 8 μs, of the Beacon SPs in the cluster. If ECAPC Policy Enforced field is set to 1, the Beacon SP Duration subfield indicates the maximum duration, in units of 8 μs, of the beacon header interval (BHI) of the BSS, and the minimum duration of Beacon SPs in the cluster (see 10.39.2.2 (Centralized AP or PCP cluster formation)).

The cluster to which the transmitter of the Clustering Control field belongs is identified by the Cluster ID subfield. The MAC address of the S-AP or synchronization PCP (S-PCP) is the Cluster ID of the cluster.

The Cluster Member Role subfield identifies the role that the transmitting STA assumes within the cluster. A 0 means that the STA is currently not participating in clustering. A 1 means that the STA acts as the S-AP or S-PCP of the cluster. A 2 means that the STA participates in the cluster, but not as the S-AP or S-PCP. The value 3 is reserved.

The ClusterMaxMem subfield defines the maximum number of PCPs and/or APs, including the S-AP or S-PCP, that can participate in the cluster. The ClusterMaxMem subfield is computed in relation to the beacon interval value (10.41.2 (Sector-level sweep (SLS) phase)). The value 0 is reserved. Values 8 and above are reserved if the ECAPC Policy Enforced field is set to 0. The value 1 is assigned to the S-AP or S-PCP.

The SPSH Measurement Enabled subfield is used by a CDMG S-AP or S-PCP to indicate whether the member APs or member PCPs in an AP or PCP cluster are allowed to perform channel measurement to achieve spatial sharing. If the SPSH Measurement Enabled subfield is 1, a SPSH measurement period starts. In this period, the member APs or member PCPs in an AP or PCP cluster can perform channel measurement in its BSS and spatial reuse is not allowed. If the SPSH Measurement Enabled subfield is 0, SPSH measurement terminates and SP reuse is conducted in the following time interval, i.e., APs or PCPs of the AP or PCP cluster are allowed to allocate time-overlapping SPs among different BSSs. In a DMG Beacon frame transmitted by a non-CDMG S-AP or S-PCP, the SPSH Measurement Enabled subfield is reserved.

The A-BFT Responder Address subfield contains the MAC address of the STA that is allowed to transmit during the A-BFT, if present, that follows the BTI. (11bd)If all bits of the A-BFT Responder Address subfield are equal to 1 and the OCB subfield is equal to 1, any STA is allowed to transmit during the A-BFT, if present.


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(11bd)The OCB subfield is set to 1 to indicate the support of communication outside the context of a BSS by the STA transmitting the DMG Beacon frame.

### 9.3.4.3 S1G Beacon frame format

The format of the S1G Beacon is shown in Figure 9-135 (S1G Beacon frame format(#8219)).

| | Frame Control | Duration | SA | Time-stamp | Change Sequence | Next TBTT (optional) | Short SSID (optional) | Access Network Options (optional) | Frame Body | FCS |
|---|---|---|---|---|---|---|---|---|---|---|
| Octets: | 2 | 2 | 6 | 4 | 1 | 0 or 3 | 0 or 4 | 0 or 1 | variable | 4 |

**Figure 9-135—S1G Beacon frame format(#8219)**

The Duration field is set to the duration of time, in microseconds, required by the paged STAs to transmit any pending QoS Null, PS-Poll or NDP PS-Poll frames as specified in 9.2.5.2 (Setting for single and multiple protection under enhanced distributed channel access (EDCA)).

The SA field is the address of the STA transmitting the S1G Beacon frame.

The Timestamp field contains the value of the 4 least significant octets of the STA's TSF timer at the time that the start of the data symbol containing the first bit of the Timestamp field appears at the transmit antenna connector.

The Change Sequence field is defined as an unsigned integer, initialized to 0, that increments when a critical update to the Beacon frame has occurred (see 10.45.2 (System information update procedure)).

The Next TBTT field is present if the Next TBTT Present field in the Frame Control field is 1 and indicates the most significant 3 octets of the 4 least significant octets of the next TBTT. Otherwise, it is not present.

The (#8219)Short SSID field is present if the Short SSID Present field in the Frame Control is 1 and indicates a 32-bit CRC calculated over the SSID contained in the S1G Beacon frame (calculation is performed as defined in 9.2.4.9 (FCS field) where the SSID is the calculation fields). Otherwise, it is not present.

The Access Network Options field is present if the ANO field in the Frame Control field is 1 and it is defined in 9.4.2.90 (Interworking element) (see Figure 9-565 (Access Network Options field format)). Otherwise, it is not present.

The Frame Body field contains the optional elements listed in Table 9-76 (Minimum and full set of optional elements). The minimum set of optional elements is included in an S1G Beacon frame transmitted at a TSBTT that is not a TBTT and the full set of optional elements is included in an S1G Beacon frame that is

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transmitted at a TBTT (see 11.1.3.10.1 (General S1G synchronization)). See 10.28.6 (Element parsing) on the parsing of the elements.

**Table 9-76—Minimum and full set of optional elements**

| Order | Information | Notes | Allowed in minimum set | Allowed in full set |
|---|---|---|---|---|
| 1 | S1G Beacon Compatibility | The S1G Beacon Compatibility element is present within S1G Beacon frames generated at TBTTs. | No | Yes |
| 2 | Traffic indication map (TIM) | The TIM element is present within S1G Beacon frames generated by APs at TBTTs and is optionally present otherwise. | Yes | Yes |
| 3 | FMS Descriptor | The FMS Descriptor element is present if dot11FMSActivated is true. | Yes | Yes |
| 4 | RPS | The RPS element is optionally present if dot11RAWOperationActivated is true. | Yes | Yes |
| 5 | SST Operation | The SST Operation element is present if dot11SelectiveSubchannelTransmissionPermitted is true. | No | Yes |
| 6 | Subchannel Selective Transmission | (#1776)The SST element is optionally present if dot11SubchannelSelectiveTransmissionActivated is true. | Yes | Yes |
| 7 | S1G Relay | The S1G Relay element is optionally present if dot11RelayAPImplemented is true. | Yes | Yes |
| 8 | Page Slice | The Page Slice element is optionally present if dot11PageSlicingActivated is true. | Yes(#7008) | Yes |
| 9 | S1G Sector Operation | The S1G Sector Operation element is optionally present if dot11S1GSectorizationActivated is true. | No | Yes |
| 10 | Authentication Control | The Authentication Control element is optionally present when dot11S1GCentralizedAuthenticationControlActivated is true or dot11S1GDistributedAuthenticationControlActivated is true. | No | Yes |
| 11 | TSF Timer Accuracy | The TSF Timer Accuracy element is optionally present when dot11TSFTimerAccuracyImplemented is true. | No | Yes |
| 12 | S1G Relay Discovery | The S1G Relay Discovery element is optionally present if dot11RelayDiscoveryOptionImplemented is true. | No | Yes |
| 13 | S1G Capabilities | The S1G Capabilities element is present if dot11S1GOptionImplemented is true; otherwise not present. | No | Yes |
| 14 | S1G Operation | The S1G Operation element is present when dot11S1GOptionImplemented is true; otherwise not present. | No | Yes |


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**Table 9-76—Minimum and full set of optional elements**

| Order | Information | Notes | Allowed in minimum set | Allowed in full set |
|---|---|---|---|---|
| 15 | Short Beacon Interval | The Short Beacon Interval element is present if dot11ShortBeaconInterval is true. | No | Yes |
| 16 | Multiple BSSID | (#488)One or more Multiple BSSID elements are present if the AP is a member of a multiple BSSID set (see 11.10.14 (Multiple BSSID set)) with two or more members and any of the following conditions are true:<br>• dot11MultiBSSIDImplemented is true<br>• dot11MultiBSSIDImplemented is false and dot11RMMeasurementPilotActivated is between 2 and 7<br>• dot11InterworkingServiceActivated is true and at least one dot11GASAdvertisementID exists<br>Otherwise not present. | No | Yes |
| 17(11ax) | Multiple BSSID Configuration | The Multiple BSSID Configuration element is optionally present if dot11MultiBSSIDImplemented is true. | No | Yes |
| Last–2(#6054) | One or more elements can appear in this frame. | Optionally, element(s) that are not listed in this table, but are allowed in Beacon frame, in the order they appear in the Beacon frame (see Table 9-62 (Beacon frame body)).(#6091)(#246)(#1091) | No | Yes |
| Last–1(#6054) | Vendor Specific | One or more Vendor Specific elements are optionally present. | Yes(#7008) | Yes |
| Last(#6054) | MME or MIC element | The MIC element is present if dot11BIPCompactEncapsulation is true.<br>The MME is present if dot11BIPCompactEncapsulation is false and dot11BeaconProtectionEnabled is true.<br>Otherwise neither is present. | Yes | Yes |

### 9.3.5 Frame addressing in an MBSS

Mesh Data frames and Multihop Action frames enable multihop MSDU and MMPDU forwarding in an MBSS using the Mesh Control field described in 9.2.4.8.3 (Mesh Control field).

Table 9-77 (Address field contents for mesh Data and Multihop Action frames(#462)(#419)) shows the valid combinations of address fields in mesh Data frames and Multihop Action frames along with the corresponding value of the Address Extension Mode subfield in the Mesh Control field.

NOTE 1—To DS and From DS subfields are located in the Frame Control field (see 9.2.4.1.4 (To DS and From DS subfields)). The Address Extension Mode subfield is located in the Mesh Flags subfield in the Mesh Control field (see 9.2.4.8.3 (Mesh Control field)). Address 1, Address 2, and Address 3 fields are located in the MAC header (see 9.2.3 (General frame format)). The Address 4 field is located in the MAC header if both To DS and From DS subfields are 1; otherwise, the Address 4 field is located in the Mesh Address Extension subfield of the Mesh Control field (see 9.2.3 (General frame format) and 9.2.4.8.3 (Mesh Control field)). Address 5 and Address 6 fields are located in the Mesh Control field if they are present (see 9.2.4.8.3 (Mesh Control field)).

NOTE 2—Values for the Address Extension Mode subfield are defined in Table 9-35 (Valid values for the Address Extension Mode subfield).

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**Table 9-77—Address field contents for mesh Data and Multihop Action frames(#462)(#419)**

| Supported frames | To DS | From DS | Address extension mode | Address 1 | Address 2 | Address 3 | Address 4 | Address 5 | Address 6 |
|---|---|---|---|---|---|---|---|---|---|
| Mesh Data (individually addressed) | 1 | 1 | None | RA | TA | DA = Mesh DA | SA = Mesh SA | *Not Present* | *Not Present* |
| Mesh Data (group addressed) | 0 | 1 | None | DA | TA | SA = Mesh SA | *Not Present* | *Not Present* | *Not Present* |
| Mesh Data (proxied, individually addressed) | 1 | 1 | Address5&6 | RA | TA | Mesh DA | Mesh SA | DA | SA |
| Mesh Data (proxied, group addressed) | 0 | 1 | Address4 | DA | TA | Mesh SA | SA | *Not Present* | *Not Present* |
| Multihop Action (individually addressed) | 0 | 0 | Address4 | RA | TA | DA = Mesh DA | SA = Mesh SA | *Not Present* | *Not Present* |
| Multihop Action (group addressed) | 0 | 0 | None | DA | TA | SA = Mesh SA | *Not Present* | *Not Present* | *Not Present* |

In individually addressed (#419)mesh Data and Multihop Action frames, Address 1 and Address 2 correspond to the mesh STA receiver address (RA) and the mesh STA transmitter address (TA) for a particular mesh link. Address 3 and Address 4 correspond to the destination mesh STA and the source mesh STA of a mesh path. The Address Extension Mode subfield in the Mesh Control field indicates the presence of an optional Mesh Address Extension subfield in the Mesh Control field. When the Extension Mode subfield equals "Address5&6" (see Table 9-35 (Valid values for the Address Extension Mode subfield)), the Mesh Control field includes Address 5 and Address 6 that correspond to the end-to-end destination address (DA) and source address (SA) of STAs that communicate over the mesh path, for instance, external STAs that communicate over the mesh BSS via proxy mesh gates (see Figure 9-136 (Example addressing for a mesh Data frame)).

NOTE 3—The forwarding of individually addressed mesh Data frames uses only mesh STA addresses in fields Address 1, Address 2, Address 3, and Address 4. This allows intermediate mesh STAs to forward mesh Data frames without necessarily having any knowledge of the addresses of the source and destination end stations, which might be external addresses. Thus, proxy information only needs to be maintained by proxy mesh gates and by source mesh STAs.

The term source mesh STA refers to the first mesh STA on a mesh path. A source mesh STA is either a mesh STA that is the initial source of an MSDU/MMPDU or a mesh STA that receives an MSDU/MMPDU from a mesh path or from a STA outside the mesh BSS and translates and forwards the MSDU/MMPDU on the mesh path. The address of the source mesh STA is referred to as the *Mesh SA*.

The term destination mesh STA refers to the final mesh STA on a mesh path. A destination mesh STA is either a mesh STA that is the final destination of an MSDU/MMPDU or a mesh STA that receives an MSDU/MMPDU from a mesh path and translates and forwards the MSDU/MMPDU on another mesh path


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or to a STA outside of the mesh BSS. The address of the destination mesh STA is referred to as the *Mesh DA*.

In group addressed mesh Data frames, Address 1 and Address 2 correspond to the group address and the mesh STA transmitter address (TA). Address 3 corresponds to the mesh source address (mesh SA) of the group addressed mesh Data frame. The Address Extension Mode indicates the presence of an optional address extension field Address 4 in the Mesh Control field that corresponds to the source address (SA) of external STAs that communicate over the mesh BSS via proxy mesh gates.

NOTE 4—The reason for not using the four-address MAC header format for group addressed traffic is to avoid interactions with existing implementations. Earlier revisions of this standard defined the four-address MAC header format without defining procedures for its use. As a result there is a large number of deployed devices that use the four-address frame format in ways that would affect and be affected by mesh traffic if four-address group addressed frames were to be used.

Figure 9-136 (Example addressing for a mesh Data frame) illustrates the addressing of a mesh Data frame that contains an MSDU transmitted and forwarded on a mesh path from a mesh STA (#2210)colocated with a portal (STA 1) to a mesh STA (#2210)colocated with an AP (STA 2) where the source is a STA outside of the mesh BSS (STA 33) that is reachable via the portal and the destination is an IEEE 802.11 STA associated with the AP (STA 22).

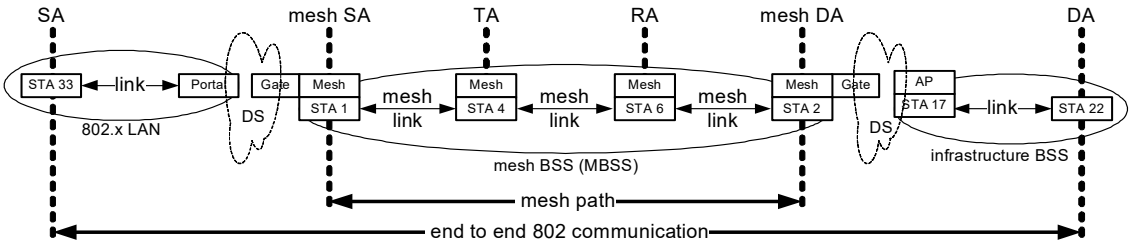


**Figure 9-136—Example addressing for a mesh Data frame**

Details on how these address mappings work in forwarding processing are described in 10.37.3 (Addressing and forwarding of individually addressed mesh Data frames) and 10.37.4 (Addressing and forwarding of group addressed mesh Data frames).

## 9.4 Management and Extension frame body components

### 9.4.1 Fields that are not elements

#### 9.4.1.1 Authentication Algorithm Number field

The Authentication Algorithm Number field indicates a single authentication algorithm. (M118)(#4170)The Authentication Algorithm Number field is shown in Figure 9-137 (Authentication Algorithm Number field format). The following values are defined for authentication algorithm number:

Authentication algorithm number = 0: Open System(#3056)
Authentication algorithm number = 2: Fast BSS Transition
Authentication algorithm number = 3: Simultaneous Authentication of Equals (SAE)
Authentication algorithm number = 4: FILS Shared Key authentication without PFS
Authentication algorithm number = 5: FILS Shared Key authentication with PFS
Authentication algorithm number = 6: FILS Public Key authentication
Authentication algorithm number = 7: PASN authentication(11az)
Authentication algorithm number = 65 535: vendor specific use

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NOTE—The use of this value implies that a Vendor Specific element is included with more information.

All other values of authentication algorithm number are reserved.

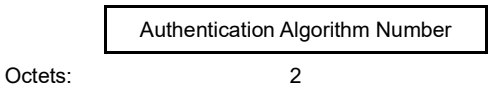


**Figure 9-137—Authentication Algorithm Number field format**

### 9.4.1.2 Authentication Transaction Sequence Number field

The Authentication Transaction Sequence Number field indicates the current state of progress through a multistep transaction. (M118)(#4170)The Authentication Transaction Sequence Number field is shown in Figure 9-138 (Authentication Transaction Sequence Number field format).

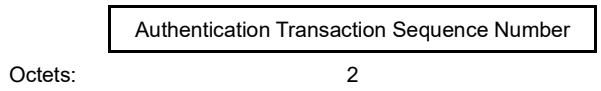


**Figure 9-138—Authentication Transaction Sequence Number field format**

### 9.4.1.3 Beacon Interval field

The Beacon Interval field represents the number of time units (TUs) between target beacon transmission times (TBTTs). (M118)(#4170)The Beacon Interval field is shown in Figure 9-139 (Beacon Interval field format).

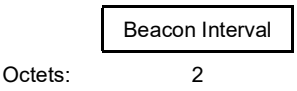


**Figure 9-139—Beacon Interval field format**

A 0 in the Beacon Interval field transmitted by a DMG STA indicates that the TBTT of the next BTI is unknown.

### 9.4.1.4 Capability Information field

The Capability Information field contains a number of subfields that are used to indicate requested or advertised optional capabilities.

(M118)(#4170)The format of the Capability Information field is defined in Figure 9-140 (Capability Information field format (non-DMG STA)(M118)) when transmitted by a non-DMG STA and in Figure 9-141 (Capability Information field format (DMG STA)) when transmitted by a DMG STA.

A DMG STA sets the Triggered Unscheduled PS subfield to 1 within the Capability Information field when it transmits a Capability Information field in which the Reverse Direction subfield is equal to 1 and is capable of delivering a BU as an RD responder on receipt of a PPDU containing an RDG MPDU with the Power Management subfield set to 1 and sets it to 0 otherwise. An EDMG AP always sets the Triggered Unscheduled PS subfield to 1.(11ay)

Each Capability Information subfield is interpreted according to the management frame subtype, as defined in this subclause.


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| | B0 | B1 | B2 | B3 | B4 | B5 | B6 | B7 |
|---|---|---|---|---|---|---|---|---|
| | ESS | IBSS | Reserved | Reserved | Privacy | Short Preamble | Reserved | Reserved |
| Bits: | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

| | B8 | B9 | B10 | B11 | B12 | B13 | B14 | B15 |
|---|---|---|---|---|---|---|---|---|
| | Spectrum Management | QoS | Short Slot Time | APSD | Radio Measurement | EPD | Reserved | Reserved |
| Bits: | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

**Figure 9-140—Capability Information field format (non-DMG STA)(M118)**

| | B0 | B7 | B8 | B9 | B10 B11 | B12 | B13 | B14 B15 |
|---|---|---|---|---|---|---|---|---|
| | DMG Parameters | Spectrum Management | Triggered Unscheduled PS | Reserved | Radio Measurement | EPD | Reserved | |
| Bits: | 8 | | 1 | 1 | 2 | 1 | 1 | 2 |

**Figure 9-141—Capability Information field format (DMG STA)**

An AP sets the ESS subfield to 1 and the IBSS subfield to 0 within transmitted Beacon or Probe Response frames. An IBSS STA sets the ESS subfield to 0 and the IBSS subfield to 1 in transmitted Beacon or Probe Response frames. A mesh STA sets the ESS and IBSS subfields to 0 in transmitted Beacon or Probe Response frames. Otherwise, the ESS and IBSS subfields are reserved.

An AP sets the Privacy subfield to 1 within transmitted Beacon, Probe Response, (Re)Association Response frames if data confidentiality is required for all Data frames exchanged within the BSS. If data confidentiality is not required, the Privacy subfield is set to 0.

In an RSNA, a non-AP STA in an infrastructure BSS sets the Privacy subfield to 0 within transmitted (Re)Association Request frames. The Privacy subfield is reserved in (Re)Association Request frames.

An IBSS STA sets the Privacy subfield to 1 in transmitted Beacon or Probe Response frames if data confidentiality is required for all Data frames exchanged within the IBSS. If data confidentiality is not required, An IBSS STA sets the Privacy subfield to 0 within these Management frames.

A mesh STA sets the Privacy subfield to 1 in transmitted Beacon or Probe Response frames if data confidentiality is required for all Data frames exchanged within the MBSS. If data confidentiality is not required, a mesh STA sets the Privacy subfield to 0 within these Management frames.

A STA that includes the RSNE in Beacon and Probe Response frames sets the Privacy subfield to 1 in any frame that includes the RSNE.

An AP sets the Short Preamble subfield to 1 in transmitted Beacon, Probe Response, Association Response, and Reassociation Response frames to indicate that the use of the short preamble, as described in 16.2.2.3 (Short PPDU format), is allowed within this BSS; an IBSS STA sets the Short Preamble subfield to 1 in transmitted Beacon when dot11ShortPreambleOptionImplemented is true. Otherwise an AP or an IBSS STA sets the Short Preamble subfield to 0.

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A mesh STA sets the Short Preamble subfield to 1 when dot11ShortPreambleOptionImplemented is true. Otherwise, a mesh STA sets the Short Preamble subfield to 0.

An ERP STA sets dot11ShortPreambleOptionImplemented to true as all ERP STAs support both long and short preamble formats.

A STA sets the Spectrum Management subfield in the Capability Information field to 1 if dot11SpectrumManagementRequired is true; otherwise, it is set to 0.

A STA sets the QoS subfield to 1 within the Capability Information field when dot11QosOptionImplemented is true and sets it to 0 otherwise.

(#2154)A non-AP STA sets the Short Slot Time subfield to 1 in transmitted Association Request, and Reassociation Request frames when dot11ShortSlotTimeOptionImplemented and dot11ShortSlotTimeOptionActivated are true. Otherwise, the STA sets the Short Slot Time subfield to 0.

An AP sets the Short Slot Time subfield to 1 in transmitted Beacon, Measurement Pilot, Probe Response, Association Response, and Reassociation Response frames to indicate the short slot time value is currently used within this BSS. Otherwise, the Short Slot Time subfield is set to 0. See 10.3.2.16 (Operation of aSlotTime) and 11.1.3.2 (Beacon generation in non-DMG infrastructure networks).(#1761)

See 10.3.2.16 (Operation of aSlotTime) for the operation of aSlotTime.

For IBSS and MBSS, the Short Slot Time subfield is set to 0.

An AP sets the APSD subfield to 1 within the Capability Information field when dot11APSDOptionImplemented is true and sets it to 0 otherwise. A non-AP STA always sets this subfield to 0.

A STA sets the Radio Measurement subfield in the Capability Information field to 1 when dot11RadioMeasurementActivated is true and sets it to 0 otherwise.

A STA sets the EPD subfield in the Capability Information field to 1 when dot11EPDImplemented is true and sets it to 0 otherwise.

The DMG Parameters field is defined in 9.4.1.44 (DMG Parameters field).

### 9.4.1.5 Current AP Address field

The Current AP Address field is the MAC address of the AP with which the STA is currently associated. (M118)The Current AP Address field is shown in Figure 9-142 (Current AP Address field format).

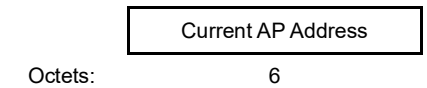


**Figure 9-142—Current AP Address field format**

### 9.4.1.6 Listen Interval field

The Listen Interval field is used to indicate to the AP how often an S1G STA with dot11NonTIMModeActivated equal to false or a non-S1G STA in power save mode wakes to listen to Beacon frames. It is also used to indicate to an AP the duration during which an S1G STA with dot11NonTIMModeActivated equal to true is required to transmit at least one frame that is addressed to the


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associated AP. This field is derived from the ListenInterval parameter when present as a parameter of an MLME primitive. The value is in units of beacon interval if dot11ShortBeaconInterval is false and in units of short beacon interval if dot11ShortBeaconInterval is true (see 11.1.3.10.2 (Generation of S1G Beacon frames)). (M118)(#4170)The Listen Interval field is shown in Figure 9-143 (Listen Interval field format carried in a non-S1G PPDU).

NOTE—The value 0 might be used by a STA that never enters power save mode.

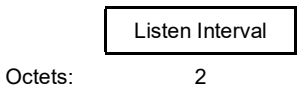


**Figure 9-143—Listen Interval field format carried in a non-S1G PPDU**

The Listen Interval field carried in an S1G PPDU is shown in Figure 9-144 (Listen Interval field format carried in an S1G PPDU).

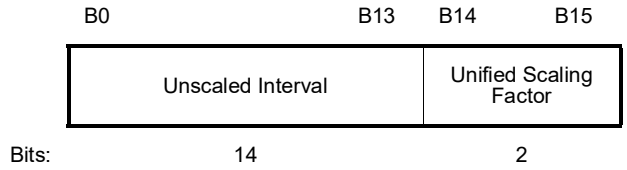


**Figure 9-144—Listen Interval field format carried in an S1G PPDU**

In an S1G STA, the ListenInterval parameter used by the MLME primitives is equal to the Unscaled Interval subfield multiplied by the scaling factor that corresponds to the value indicated in the Unified Scaling Factor subfield. The Unified Scaling Factor subfield encoding is defined in Table 9-78 (Unified Scaling Factor subfield encoding).

**Table 9-78—Unified Scaling Factor subfield encoding**

| Unified Scaling Factor | Scaling factor |
|---|---|
| 0 | 1 |
| 1 | 10 |
| 2 | 1000 |
| 3 | 10 000 |

An AP uses the listen interval in determining the lifetime of frames that it buffers for a STA.

### 9.4.1.7 Reason Code field

This Reason Code field is used to indicate the reason that an unsolicited notification Management frame (#1629)(#1628) was generated. It is contained in the Mesh Channel Switch Parameters element to indicate the reason for the channel switch. It is contained in the PERR element to indicate the reason for the path error. (M118)(#4170)The Reason Code field is shown in Figure 9-145 (Reason Code field format).

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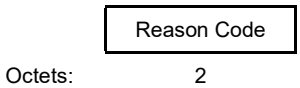


**Figure 9-145—Reason Code field format**

(#4044)The reason codes are defined in Table 9-79 (Reason codes).

**Table 9-79—Reason codes**

| Reason code | Name | Meaning |
|---|---|---|
| 0 | | Reserved |
| 1 | UNSPECIFIED_REASON | Unspecified reason |
| 2 | INVALID_AUTHENTICATION | Previous authentication no longer valid |
| 3 | LEAVING_NETWORK_DEAUTH | Deauthenticated because sending STA is leaving (or has left) the BSS |
| 4 | REASON_INACTIVITY | Disassociated due to inactivity |
| 5 | NO_MORE_STAS | Disassociated because AP is unable to handle all currently associated STAs |
| 6 | INVALID_CLASS2_FRAME | Class 2 frame received from nonauthenticated STA |
| 7 | INVALID_CLASS3_FRAME | Class 3 frame received from nonassociated STA |
| 8 | LEAVING_NETWORK_DISASSOC | Disassociated because sending STA is leaving (or has left) BSS |
| 9 | NOT_AUTHENTICATED | STA requesting (re)association is not authenticated with responding STA |
| 10 | UNACCEPTABLE_POWER_CAPABILITY | Disassociated because the information in the Power Capability element is unacceptable |
| 11 | UNACCEPTABLE_SUPPORTED_CHANNELS | Disassociated because the information in the Supported Channels element is unacceptable |
| 12 | BSS_TRANSITION_DISASSOC | Disassociated due to BSS transition management |
| 13 | REASON_INVALID_ELEMENT | Invalid element, i.e., an element defined in this standard for which the content does not meet the specifications in Clause 9 (Frame formats) |
| 14 | MIC_FAILURE | Message integrity code (MIC) failure |
| 15 | 4WAY_HANDSHAKE_TIMEOUT | 4-way handshake timeout |
| 16 | GK_HANDSHAKE_TIMEOUT | Group key handshake timeout |
| 17 | HANDSHAKE_ELEMENT_MISMATCH | Element in 4-way handshake different from (Re)Association Request/Probe Response/Beacon frame |
| 18 | REASON_INVALID_GROUP_CIPHER | Invalid group cipher |
| 19 | REASON_INVALID_PAIRWISE_CIPHER | Invalid pairwise cipher |
| 20 | REASON_INVALID_AKMP | Invalid AKMP |
| 21 | UNSUPPORTED_RSNE_VERSION | Unsupported RSNE version |


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**Table 9-79—Reason codes *(continued)***

| Reason code | Name | Meaning |
|---|---|---|
| 22 | INVALID_RSNE_CAPABILITIES | Invalid RSNE capabilities |
| 23 | 802_1_X_AUTH_FAILED | IEEE 802.1X authentication failed |
| 24 | REASON_CIPHER_OUT_OF_POLICY | Cipher suite rejected because of the security policy |
| 25 | TDLS_TEARDOWN_PEER_UNREACHABLE(#1692) | TDLS direct link(#1356) teardown due to TDLS peer STA unreachable via the TDLS direct link |
| 26 | TDLS_TEARDOWN_UNSPECIFIED_REASON(#1692) | TDLS direct link(#1356) teardown for unspecified reason |
| 27 | SSP_REQUESTED_DISASSOC | Disassociated because session terminated by SSP request |
| 28 | NO_SSP_ROAMING_AGREEMENT | Disassociated because of lack of SSP roaming agreement |
| 29 | BAD_CIPHER_OR_AKM | Requested service rejected because of SSP cipher suite or AKM requirement |
| 30 | NOT_AUTHORIZED_THIS_LOCATION | Requested service not authorized in this location |
| 31 | SERVICE_CHANGE_PRECLUDES_TS | TS deleted because QoS AP lacks sufficient bandwidth for this QoS STA due to a change in BSS service characteristics or operational mode (e.g., an HT BSS change from 40 MHz channel to 20 MHz channel) |
| 32 | UNSPECIFIED_QOS_REASON | Disassociated for unspecified, QoS-related reason |
| 33 | NOT_ENOUGH_BANDWIDTH | Disassociated because QoS AP lacks sufficient bandwidth for this QoS STA |
| 34 | MISSING_ACKS | Disassociated because excessive number of frames need to be acknowledged, but are not acknowledged due to AP transmissions and/or poor channel conditions |
| 35 | EXCEEDED_TXOP | Disassociated because STA is transmitting outside the limits of its TXOPs |
| 36 | STA_LEAVING | Requesting STA is leaving the BSS (or resetting) |
| 37 | END_TS<br>END_BA | Requesting STA is no longer using the stream or session |
| 38 | UNKNOWN_TS<br>UNKNOWN_BA | Requesting STA received frames using a mechanism for which a setup has not been completed |
| 39 | TIMEOUT | Requested from peer STA due to timeout |
| 40–45 | Reserved | |
| 46 | PEER_INITIATED | (#1693)Disassociated because authorized access limit reached |
| 47 | AP_INITIATED | (#1693)Disassociated due to external service requirements |
| 48 | REASON_INVALID_FT_ACTION_FRAME_COUNT | Invalid FT Action frame count |
| 49 | REASON_INVALID_PMKID | Invalid pairwise master key identifier (PMKID) |
| 50 | REASON_INVALID_MDE | Invalid MDE |
| 51 | REASON_INVALID_FTE | Invalid FTE |

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**Table 9-79—Reason codes *(continued)***

| Reason code | Name | Meaning |
|---|---|---|
| 52 | MESH-PEERING-CANCELED | Mesh peering canceled for unknown reasons |
| 53 | MESH-MAX-PEERS | The mesh STA has reached the supported maximum number of peer mesh STAs |
| 54 | MESH-CONFIGURATION-POLICY-VIOLATION | The received information violates the mesh configuration(#3437) policy configured in the mesh STA profile |
| 55 | MESH-CLOSE-RCVD | The mesh STA has received a Mesh Peering Close frame requesting to close the mesh peering. |
| 56 | MESH-MAX-RETRIES | The mesh STA has resent dot11MeshMaxRetries Mesh Peering Open frames, without receiving a Mesh Peering Confirm frame. |
| 57 | MESH-CONFIRM-TIMEOUT | The confirmTimer for the mesh peering instance times out. |
| 58 | MESH-INVALID-GTK | The mesh STA fails to unwrap the GTK or the values in the wrapped contents do not match |
| 59 | MESH-INCONSISTENT-PARAMETERS | The mesh STA receives inconsistent information about the mesh parameters between mesh peering Management frames |
| 60 | MESH-INVALID-SECURITY-CAPABILITY | The mesh STA fails the authenticated mesh peering exchange because due to failure in selecting either the pairwise (#3270)cipher suite or group cipher suite(#4090) |
| 61 | MESH-PATH-ERROR-NO-PROXY-INFORMATION | The mesh STA does not have proxy information for this external destination. |
| 62 | MESH-PATH-ERROR-NO-FORWARDING-INFORMATION | The mesh STA does not have forwarding information for this destination. |
| 63 | MESH-PATH-ERROR-DESTINATION-UNREACHABLE | The mesh STA determines that the link to the next hop of an active path in its forwarding information is no longer usable. |
| 64 | MAC-ADDRESS-ALREADY-EXISTS-IN-MBSS | The Deauthentication frame was sent because the MAC address of the STA already exists in the mesh BSS. See 11.3.6 (Additional mechanisms for an AP (#2210)colocated with a mesh STA). |
| 65 | MESH-CHANNEL-SWITCH-REGULATORY-REQUIREMENTS | The mesh STA performs channel switch to meet regulatory requirements. |
| 66 | MESH-CHANNEL-SWITCH-UNSPECIFIED | The mesh STA performs channel switching with unspecified reason. |
| 67 | TRANSMISSION_LINK_ESTABLISHMENT_FAILED(#1905) | Transmission link establishment in alternative channel failed. |
| 68 | (#1525)ALTERNATIVE_CHANNEL_OCCUPIED | The alternative channel is occupied. |
| 69(11ay) | TIME_SYNC_LOST | The STA is not able to maintain TSF. |
| 71(11ax) | POOR_RSSI_CONDITIONS | Disassociated due to poor RSSI. |
| 70;72–65 535 | | Reserved |



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### 9.4.1.8 AID field

In infrastructure BSS operation, the AID field contains a value assigned by an AP or PCP during association. The field represents the 16-bit ID of a STA. In mesh BSS operation, the AID field is a value that represents the 16-bit ID of a neighbor peer mesh STA, assigned during mesh peering. (M118)(#4170)The AID field is shown in Figure 9-146 (AID field format).

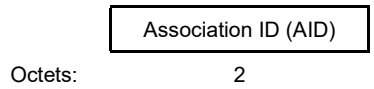


**Figure 9-146—AID field format**

The AID field for a non-DMG and non-S1G STA is in the range(#3482) 1 to 2007. This value is placed in the 14 LSBs of the AID field, with the two MSBs of the AID field set to 1.

The AID field for an S1G STA is in the range(#3482) 1 to 8191, and the 3 MSBs of the AID field are reserved.

The AID field for a DMG STA is in the range 1 to 254. (#1211)The value 255 corresponds to the Broadcast AID, and the value 0 corresponds to the AP or PCP. The 8 MSBs of the AID field are reserved.

### 9.4.1.9 Status Code field

(#4355)The Status Code field is used in a response Management frame to indicate the status of a requested operation. The Status Code field is shown in Figure 9-147 (Status Code field format). The values of the Status Code field are defined in Table 9-80 (Status codes).

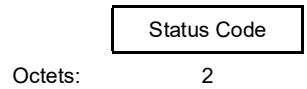


**Figure 9-147—Status Code field format**

**Table 9-80—Status codes**

| Status code | Name | Meaning |
|---|---|---|
| 0 | SUCCESS | Successful. |
| 1 | (#1780)REFUSED_REASON_UNSPECIFIED | Unspecified failure. |
| 2 | TDLS_REJECTED_ALTERNATIVE_PROVIDED | TDLS wakeup schedule rejected but alternative schedule provided. |
| 3 | TDLS_REJECTED | TDLS wakeup schedule rejected. |
| 4 | | Reserved. |
| 5 | SECURITY_DISABLED | Security disabled. |
| 6 | UNACCEPTABLE_LIFETIME | Unacceptable lifetime. |
| 7 | NOT_IN_SAME_BSS | Not in same BSS. |

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**Table 9-80—Status codes *(continued)***

| Status code | Name | Meaning |
|---|---|---|
| 8–9 | | Reserved. |
| 10 | REFUSED_CAPABILITIES_ MISMATCH | Cannot support all requested capabilities in the Capability Information field. |
| 11 | DENIED_NO_ASSOCIATION_EXIS TS | Reassociation denied due to inability to confirm that association exists. |
| 12 | DENIED_OTHER_REASON | Association denied due to reason outside the scope of this standard. |
| 13 | UNSUPPORTED_AUTH_ALGORIT HM | Responding STA does not support the specified authentication algorithm. |
| 14 | TRANSACTION_SEQUENCE_ERRO R | Received an Authentication frame with authentication transaction sequence number out of expected sequence. |
| 15 | CHALLENGE_FAILURE | Authentication rejected because of challenge failure. |
| 16 | REJECTED_SEQUENCE_TIMEOUT | Authentication rejected due to timeout waiting for next frame in sequence. |
| 17 | DENIED_NO_MORE_STAS | Association denied because AP is unable to handle additional associated STAs. |
| 18 | REFUSED_BASIC_RATES_ MISMATCH | Association denied due to requesting STA not supporting all of the data rates in the BSSBasicRateSet parameter, the Basic HT-MCS Set field of the HT Operation parameter, the Basic VHT-MCS And NSS Set field in the VHT Operation parameter, or the Basic HE-MCS And NSS Set field in the HE Operation parameter.(11ax) |
| 19 | DENIED_NO_SHORT_PREAMBLE_ SUPPORT | Association denied due to requesting STA not supporting the short preamble option. |
| 20 | | Reserved. |
| 21 | | Reserved. |
| 22 | REJECTED_SPECTRUM_MANAGE MENT_REQUIRED | Association request rejected because spectrum management capability is required. |
| 23 | REJECTED_BAD_POWER_CAPABI LITY | Association request rejected because the information in the Power Capability element is unacceptable. |
| 24 | REJECTED_BAD_SUPPORTED_CH ANNELS | Association request rejected because the information in the Supported Channels element is unacceptable. |
| 25 | DENIED_NO_SHORT_SLOT_TIME_ SUPPORT | Association denied due to requesting STA not supporting short slot time. |
| 26 | | Reserved. |
| 27 | DENIED_NO_HT_SUPPORT | Association denied because the requesting STA does not support HT features. |
| 28 | R0KH_UNREACHABLE | R0KH unreachable. |
| 29 | | Reserved |
| 30 | REFUSED_TEMPORARILY | Association request rejected temporarily; try again later. |
| 31 | ROBUST_MANAGEMENT_POLICY _VIOLATION | Robust management frame policy violation. |
| 32 | UNSPECIFIED_QOS_FAILURE | Unspecified, QoS-related failure. |


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**Table 9-80—Status codes *(continued)***

| Status code | Name | Meaning |
|---|---|---|
| 33 | DENIED_INSUFFICIENT_BANDWIDTH | Association denied because QoS AP or PCP has insufficient bandwidth to handle another QoS STA. |
| 34 | DENIED_POOR_CHANNEL_CONDITIONS | Association denied due to excessive frame loss rates and/or poor conditions on current operating channel. |
| 35 | DENIED_QOS_NOT_SUPPORTED | Association (with QoS BSS) denied because the requesting STA does not support the QoS facility. |
| 36 | | Reserved. |
| 37 | REQUEST_DECLINED | The request has been declined. |
| 38 | INVALID_PARAMETERS | The request has not been successful as one or more parameters have invalid values. |
| 39 | REJECTED_WITH_SUGGESTED_CHANGES | The allocation or TS has not been created because the request cannot be honored; however, a suggested TSPEC/DMG TSPEC is provided so that the initiating STA can attempt to set another allocation or TS with the suggested changes to the TSPEC/DMG TSPEC. |
| 40 | STATUS_INVALID_ELEMENT | Invalid element, i.e., an element defined in this standard for which the content does not meet the specifications in Clause 9 (Frame formats). |
| 41 | STATUS_INVALID_GROUP_CIPHER | Invalid group cipher. |
| 42 | STATUS_INVALID_PAIRWISE_CIPHER | Invalid pairwise cipher. |
| 43 | STATUS_INVALID_AKMP | Invalid AKMP. |
| 44 | UNSUPPORTED_RSNE_VERSION | Unsupported RSNE version. |
| 45 | INVALID_RSNE_CAPABILITIES | Invalid RSNE capabilities. |
| 46 | STATUS_CIPHER_OUT_OF_POLICY | Cipher suite rejected because of security policy. |
| 47 | REJECTED_FOR_DELAY_PERIOD | The TS or allocation has not been created; however, the HC or PCP might be capable of creating a TS or allocation, in response to a request, after the time indicated in the TS Delay element. |
| 48 | | Reserved. |
| 49 | NOT_PRESENT | The Destination STA is not present within this BSS. |
| 50 | NOT_QOS_STA | The Destination STA is not a QoS STA. |
| 51 | DENIED_LISTEN_INTERVAL_TOO_LARGE | Association denied because the listen interval is too large. |
| 52 | STATUS_INVALID_FT_ACTION_FRAME_COUNT | Invalid FT Action frame count. |
| 53 | STATUS_INVALID_PMKID | Invalid pairwise master key identifier (PMKID). |
| 54 | STATUS_INVALID_MDE | Invalid MDE. |
| 55 | STATUS_INVALID_FTE | Invalid FTE. |
| 56 | REQUESTED_TCLAS_NOT_SUPPORTED_BY_AP(#585) | Requested TCLAS processing is not supported by the AP.(#585) |

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**Table 9-80—Status codes *(continued)***

| Status code | Name | Meaning |
|---|---|---|
| 57 | INSUFFICIENT_TCLAS_ PROCESSING_RESOURCES | The AP or PCP has insufficient TCLAS processing resources to satisfy the request. |
| 58 | TRY_ANOTHER_BSS | The TS has not been created because the request cannot be honored; however, the HC or PCP suggests that the STA transition to a different BSS to set up the TS. |
| 59 | GAS_ADVERTISEMENT_ PROTOCOL_NOT_SUPPORTED | GAS advertisement protocol not supported. |
| 60 | NO_OUTSTANDING_GAS_ REQUEST | No outstanding GAS request. |
| 61 | GAS_RESPONSE_NOT_ RECEIVED_FROM _SERVER | GAS response not received from the advertisement server. |
| 62 | GAS_QUERY_TIMEOUT | STA timed out waiting for GAS query response. |
| 63 | GAS_QUERY_RESPONSE_ TOO_ LARGE | GAS response is larger than query response length limit. |
| 64 | REJECTED_HOME_WITH_ SUGGESTED_CHANGES | Request refused because home network does not support request. |
| 65 | SERVER_UNREACHABLE | Advertisement server in the network is not currently reachable. |
| 66 | | Reserved. |
| 67 | REJECTED_FOR_SSP_ PERMISSIONS | Request refused due to permissions received via SSPN interface. |
| 68 | REFUSED_UNAUTHENTICATED_A CCESS_NOT_SUPPORTED | Request refused because the AP or PCP does not support unauthenticated access. |
| 69–71 | | Reserved. |
| 72 | INVALID_RSNE | (#3488)Invalid RSNE, other than unsupported RSNE version or invalid RSNE capabilities, AKMP or pairwise cipher. |
| 73 | U_APSD_COEXISTENCE_NOT_SU PPORTED | U-APSD coexistence is not supported. |
| 74 | U_APSD_COEX_MODE_NOT_SUPP ORTED | Requested U-APSD coexistence mode is not supported. |
| 75 | BAD_INTERVAL_WITH_U_APS D_COEX | Requested interval/duration value cannot be supported with U-APSD coexistence. |
| 76 | ANTI_CLOGGING_TOKEN_REQUI RED | Authentication is rejected because an anti-clogging token is required. |
| 77 | UNSUPPORTED_FINITE_CYCLIC_ GROUP | Authentication is rejected because the offered finite cyclic group is not supported. |
| 78 | CANNOT_FIND_ALTERNATIVE_ TBTT | The TBTT adjustment request has not been successful because the STA could not find an alternative TBTT. |
| 79 | TRANSMISSION_FAILURE | Transmission failure. |
| 80 | REQUESTED_TCLAS_NOT_ SUPPORTED | Requested TCLAS not supported. |
| 81 | TCLAS_RESOURCES_EXHAUSTED | TCLAS resources exhausted. |


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**Table 9-80—Status codes *(continued)***

| Status code | Name | Meaning |
|---|---|---|
| 82 | REJECTED_WITH_SUGGESTED_ BSS_TRANSITION | Rejected with suggested BSS transition. |
| 83 | REJECT_WITH_SCHEDULE | Reject with recommended schedule. |
| 84 | REJECT_NO_WAKEUP_SPECIFIED | Reject because no wakeup schedule specified. |
| 85 | SUCCESS_POWER_SAVE_MODE | Success, the destination STA is in power save mode. |
| 86 | PENDING_ADMITTING_FST_SESSI ON | FST pending, in process of admitting FST session. |
| 87 | PERFORMING_FST_NOW | Performing FST now. |
| 88 | PENDING_GAP_IN_BA_WINDOW | FST pending, gap(s) in block ack window. |
| 89 | REJECT_U-PID_SETTING | Reject because of U-PID setting. |
| 90–91 | | Reserved. |
| 92 | REFUSED_EXTERNAL_REASON | (Re)Association refused for some external reason. |
| 93 | REFUSED_AP_OUT_OF_MEMORY | (Re)Association refused because of memory limits at the AP. |
| 94 | REJECTED_EMERGENCY_ SERVICES_NOT_SUPPORTED | (Re)Association refused because emergency services are not supported at the AP. |
| 95 | QUERY_RESPONSE_ OUTSTANDING | GAS query response not yet received. |
| 96 | REJECT_DSE_BAND | Reject since the request is for transition to a frequency band subject to DSE procedures and FST Initiator is a dependent STA. |
| 97 | TCLAS_PROCESSING_ TERMINATED | Requested TCLAS processing has been terminated by the AP. |
| 98 | TS_SCHEDULE_CONFLICT | The TS schedule conflicts with an existing schedule; an alternative schedule is provided. |
| 99 | DENIED_WITH_SUGGESTED_BAN D_AND_CHANNEL | The association has been denied; however, one or more Multi-band elements are included that can be used by the receiving STA to join the BSS. |
| 100 | MCCAOP_RESERVATION_ CONFLICT | The request failed due to a reservation conflict. |
| 101 | MAF_LIMIT_EXCEEDED | The request failed due to exceeded MAF limit. |
| 102 | MCCA_TRACK_LIMIT_EXCEEDED | The request failed due to exceeded MCCA track limit. |
| 103 | DENIED_DUE_TO_SPECTRUM_M ANAGEMENT | Association denied because the information in the Spectrum Management field is unacceptable. |
| 104 | DENIED_VHT_NOT_SUPPORTED | Association denied because the requesting STA does not support VHT features. |
| 105 | ENABLEMENT DENIED | Enablement denied. |
| 106 | RESTRICTION FROM AUTHORIZED GDB | Enablement denied due to restriction from an authorized GDB. |
| 107 | AUTHORIZATION DEENABLED | Authorization deenabled. |
| 108 | ENERGY_LIMITED_OPERATION_N OT_SUPPORTED | Re(association) refused or disassociated because energy limited operation is not supported at the AP. |

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**Table 9-80—Status codes *(continued)***

| Status code | Name | Meaning |
|---|---|---|
| 109 | REJECTED_NDP_BLOCK_ACK_SUGGESTED | BlockAck negotiation refused because, due to buffer constraints and other unspecified reasons, the recipient prefers to generate only NDP BlockAck frames. |
| 110 | REJECTED_MAX_AWAY_DURATION_UNACCEPTABLE | Association denied/disassociated because the suggested value for max away duration is unacceptable. |
| 111 | FLOW_CONTROL_OPERATION_SUPPORTED | Re(association) refused or disassociated because flow control operation is not supported by the non-AP STA. |
| 112 | FILS_AUTHENTICATION_FAILURE | Authentication rejected due to FILS authentication failure. |
| 113 | UNKNOWN_AUTHENTICATION_SERVER | Authentication rejected due to unknown Authentication Server. |
| 114–115 | | Reserved. |
| 116 | DENIED_NOTIFICATION_PERIOD_ALLOCATION | Request denied because the allocation of notification period is failed. |
| 117 | DENIED_CHANNEL_SPLITTING | Request denied because the request of channel splitting is failed. |
| 118 | DENIED_ALLOCATION | Request denied because the allocation request is failed. |
| 119 | CMMG_FEATURES_NOT_SUPPORTED | Association denied because the requesting STA does not support CMMG features. |
| 120 | GAS_FRAGMENT_NOT_AVAILABLE | The requested GAS fragment is not available. |
| 121 | SUCCESS_CAG_VERSIONS_MATCH | Success, the CAG Version provided by the requesting STA is the same as the latest CAG Version provided by the relevant server. |
| 122 | GLK_NOT_AUTHORIZED | The STA is not authorized to use GLK per local policy. |
| 123 | UNKNOWN_PASSWORD_IDENTIFIER | Authentication rejected because the password identifier is unknown. |
| 124 | DENIED_HE_NOT_SUPPORTED(11ax) | (11ax)Association denied because the requesting STA does not support HE features. |
| 125 | DENIED_LOCAL_MAC_ADDRESS_POLICY_VIOLATION | Request denied because source address of request is inconsistent with local MAC address policy. |
| 126 | SAE_HASH_TO_ELEMENT | SAE authentication uses the hash-to-element method(#344), instead of looping, to obtain the PWE. |
| 127 | | Reserved. |
| 128 | TCLAS_PROCESSING_TERMINATED_INSUFFICIENT_QOS | Requested TCLAS processing has been terminated by the AP due to insufficient QoS capacity. |
| 129 | TCLAS_PROCESSING_TERMINATED_POLICY_CONFLICT | Requested TCLAS processing has been terminated by the AP due to conflict with higher layer QoS policies. |
| 130–135 | | Reserved |
| 136(11az) | INVALID_PUBLIC_KEY | Public key format is invalid. |
| 137(11az) | PASN_BASE_AKMP_FAILED | Failure from (#7185)base AKMP processing during PASN. |
| 138(11az) | OCI_MISMATCH | OCI does not match received channel information. |


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**Table 9-80—Status codes *(continued)***

| Status code | Name | Meaning |
|---|---|---|
| 139–142 | | Reserved |
| 143(#6058) | GAS_QUERY_REQUEST_ TOO_ LARGE | GAS query request is larger than the dot11GASQueryRequestLengthLimit value. |
| 144–65 535 | | Reserved. |

### 9.4.1.10 Timestamp field

This field represents the timing synchronization function (TSF) timer (see 11.1 (Synchronization) and 11.19 (Timing advertisement)) of a frame's source. (M118)The Timestamp field is shown in Figure 9-148 (Timestamp field format).

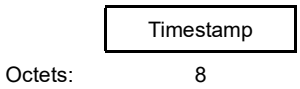


**Figure 9-148—Timestamp field format**

### 9.4.1.11 Action field

The Action field provides a mechanism for specifying extended management actions. The format of the Action field is shown in Figure 9-149 (Action field format).

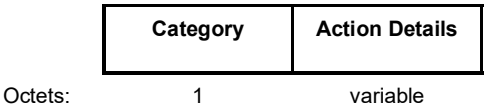


**Figure 9-149—Action field format**

The Category field is set to one of the nonreserved values shown in the Code column of Table 9-81 (Category values). Action frames of a given category are referred to as *<category name> Action frames*. For example, frames in the QoS category are called *QoS Action frames*(#3175).

The Action Details field contains the details of the action. The details of the actions allowed in each category are described in the appropriate subclause referenced in Table 9-81 (Category values). Robust Action frames

**Table 9-81—Category values**

| Code | Meaning | See subclause | Robust | Group addressed privacy |
|---|---|---|---|---|
| 0 | Spectrum Management | 9.6.2 (Spectrum Management Action frame details(#3729)) | Yes | No |
| 1 | QoS | 9.6.3 (QoS Action frame details) | Yes | No |

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**Table 9-81—Category values *(continued)***

| Code | Meaning | See subclause | Robust | Group addressed privacy |
|---|---|---|---|---|
| 2 | Reserved | | | |
| 3 | Block Ack | 9.6.4 (Block Ack Action frame details) | Yes | No |
| 4 | Public | 9.6.7 (Public Action frame details(#3729)) | No | No |
| 5 | Radio Measurement | 9.6.6 (Radio Measurement Action frame details(#3729)) | Yes | No |
| 6 | Fast BSS Transition | 9.6.8 (FT Action frame details) | Yes | No |
| 7 | HT | 9.6.11 (HT Action frame details) | No | No |
| 8 | SA Query | 9.6.9 (SA Query Action frame details) | Yes | No |
| 9 | Protected Dual of Public Action | 9.6.10 (Protected Dual of Public Action frame details(#3729)) | Yes | No |
| 10 | WNM | 9.6.13 (WNM Action frame details(#3729)) | Yes | No |
| 11 | Unprotected WNM | 9.6.14 (Unprotected WNM Action frame details(#3729)) | No | No |
| 12 | TDLS | 9.6.12 (TDLS Action field formats) | See NOTE | No |
| 13 | Mesh | 9.6.16 (Mesh Action frame details) | Yes | Yes |
| 14 | Multihop | 9.6.17 (Multihop Action frame details) | Yes | Yes |
| 15 | Self-protected | 9.6.15 (Self-protected Action frame details) | No | No |
| 16 | DMG | 9.6.19 (DMG Action frame details) | Yes | No |
| 17 | (#4220)*Allocated to the Wi-Fi Alliance®* [a] | | | |



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**Table 9-81—Category values *(continued)***

| Code | Meaning | See subclause | Robust | Group addressed privacy |
|---|---|---|---|---|
| 18 | Fast Session Transfer | 9.6.20 (FST Action frame details) | Yes | No |
| 19 | Robust AV Streaming | 9.6.18 (Robust AV Streaming Action frame details) | Yes | No |
| 20 | Unprotected DMG | 9.6.21 (Unprotected DMG Action frame details) | No | No |
| 21 | VHT | 9.6.22 (VHT Action frame details) | No | No |
| 22 | Unprotected S1G | 9.6.24 (Unprotected S1G Action frame details) | No | No |
| 23 | S1G | 9.6.25 (S1G Action frame details) | Yes | No |
| 24 | Flow control | 9.6.26 (Flow Control Action frame details) | Yes | No |
| 25 | Control Response MCS Negotiation | 9.6.27 (Control Response MCS Negotiation Action frame details(#3175)) | Yes | No |
| 26 | FILS | 9.6.23 (FILS Action frame details) | Yes | No |
| 27 | CDMG | 9.6.28 (CDMG Action frame details) | Yes | No |
| 28 | CMMG | 9.6.29 (CMMG Action frame details) | Yes | No |
| 29 | GLK | 9.6.30 (GLK Action frame details) | Yes | No(#1635) |
| 30(11ax) | HE | 9.6.31 (HE Action frame details(11ax)) | No | No |
| 31(11ax) | Protected HE | 9.6.32 (Protected HE Action frame details(11ax)) | Yes | No |

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**Table 9-81—Category values *(continued)***

| Code | Meaning | See subclause | Robust | Group addressed privacy |
|---|---|---|---|---|
| 32(11ba) | WUR | 9.6.33 (WUR Action frame details(#3175)(11ba)) | Yes | No |
| 33 | Reserved | | | |
| 34(11az) | Protected Fine Timing(#8156) | 9.6.34 (Protected Fine Timing Action frame details(11az)(#8155)) | Yes | No |
| 35–125 | Reserved | | | |
| 126 | Vendor-specific Protected | 9.6.5 (Vendor Specific Action frame and Vendor Specific Protected Action frame details(#3729)(#4065)) | Yes | No |
| 127 | Vendor-specific | 9.6.5 (Vendor Specific Action frame and Vendor Specific Protected Action frame details(#3729)(#4065)) | No | No |
| 128–255 | (#3128)Reserved | | | |
| NOTE—TDLS Action fields are always transported encapsulated within a Data frame (see 11.20.1 (General)), so there are no TDLS Action frames and in turn the question of whether these frames are robust is not applicable.(#1573) | | | | |

[a] See http://www.wi-fi.org.

are defined in 12.2.7 (Requirements for management frame protection) and group addressed privacy is defined in 11.12 (Group addressed management frame protection procedures).(#154)

### 9.4.1.12 Dialog Token field

The Dialog Token field is used for matching action responses with action requests when there are multiple, concurrent action requests. (M118)(#4170)The Dialog Token field is shown in Figure 9-150 (Dialog Token field format). See 10.28.5 (Operation of the Dialog Token field).

**Figure 9-150—Dialog Token field format**


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#### 9.4.1.13 Block Ack Parameter Set field

The Block Ack Parameter Set field is used in ADDBA Request or ADDBA Response frames to signal the parameters for setting up a block ack agreement and is used in a PBAC WinStart Update frame to identify the protected block ack agreement for which $WinStart_B$ and $WinStart_R$ at the recipient are being updated. (M118)(#4170)The Block Ack Parameter Set field is shown in Figure 9-151 (Block Ack Parameter Set field format). When carried in a PBAC WinStart Update frame all subfields except the TID subfield are reserved.(#3014)

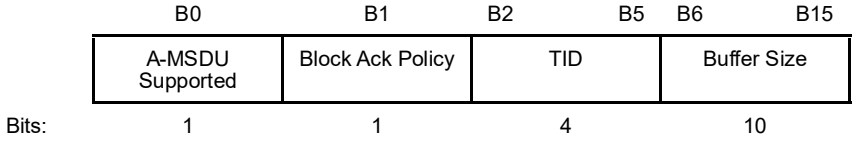


**Figure 9-151—Block Ack Parameter Set field format**

The A-MSDU Supported subfield is set to 1 by a STA to indicate that it supports an A-MSDU carried in a QoS Data frame sent under this block ack agreement. It is set to 0 otherwise.

The Block Ack Policy subfield is set to 1 (#4204)for a non-DMG STA.(#3170)

(#3014)When carried in an ADDBA Request frame or an ADDBA Response frame, the TID subfield contains the TC or TS for which the BlockAck frame is being requested. When carried in a PBAC WinStart Update frame, the TID subfield is used to identify the protected block ack agreement for which $WinStart_B$ and $WinStart_R$ are being updated.

The Buffer Size subfield indicates the number of buffers available for this particular TID.[21] When the A-MSDU Supported field is equal to 0 as indicated by the STA transmitting the Block Ack Parameter Set field, each buffer is capable of holding a number of octets equal to the maximum size of an MSDU. When the A-MSDU Supported field is equal to 1 as indicated by the STA, each buffer is capable of holding a number of octets equal to the maximum size of an A-MSDU that is supported by the STA.

In an ADDBA Request frame, the Buffer Size subfield provides guidance for the frame receiver to decide its reordering buffer size. If the Buffer Size subfield is equal to 0, (#6171)it implies that the block ack originator has no information to specify its value.

In an ADDBA Response frame, when the Status Code field is equal to SUCCESS, the Buffer Size subfield is set to at least 1.

#### 9.4.1.14 Block Ack Timeout Value field

The Block Ack Timeout Value field is used in the ADDBA Request and Response frames (11ay)and the Unsolicited Block Ack Extension element (#6172)to indicate the inactivity timeout for a block ack agreement. (M118)(#4170)The Block Ack Timeout Value field is shown in Figure 9-152 (Block Ack Timeout Value field format).

The Block Ack Timeout Value field contains the duration, in TUs, after which the block ack setup is terminated, if there are no (#109)frame exchange sequences (see 11.5.4 (Error recovery upon a peer failure)) within this duration using this block ack agreement. The field is set to 0 to disable the timeout.

[21] For buffer size, the recipient of data advertises a single scalar number that is the number of fragment buffers of the maximum MSDU or A-MSDU size (indicated by the A-MSDU Supported field) available for the block ack agreement that is being negotiated. Every buffered MPDU that is associated with this block ack agreement consumes one of these buffers regardless of whether the frame contains a whole MSDU (or a fragment thereof) or an A-MSDU. For example, ten maximum-size unfragmented MSDUs consumes the same amount of buffer space at the recipient as ten smaller fragments of a single MSDU of maximum size.

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**Figure 9-152—Block Ack Timeout Value field format**

### 9.4.1.15 Originator Preferred MCS field

The Originator Preferred MCS field is used in ADDBA Response frame to signal the preferred MCS used for eliciting A-MPDUs from the data originator. (M118)(#4170)The Originator Preferred MCS field is shown in Figure 9-153 (Originator Preferred MCS field format).

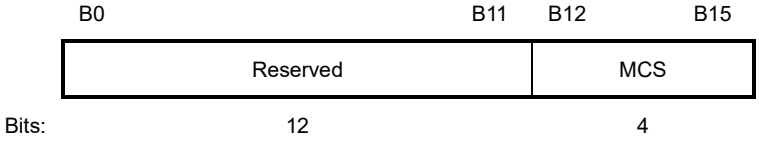


**Figure 9-153—Originator Preferred MCS field format**

The MCS subfield of the Originator Preferred MCS field is defined in Table 9-82 (MCS subfield of the Originator Preferred MCS field).

**Table 9-82—MCS subfield of the Originator Preferred MCS field**

| MCS subfield value | S1G-MCS Index | Description |
|---|---|---|
| 0–10 | 0–10 | The value represents the preferred S1G-MCS level |
| 11–14 | | Reserved |
| 15 | | The value represents that the asymmetric BA is not supported by either the originator or the intended recipient of the ADDBA Response that contains this value in the MCS subfield of the Originator Preferred MCS field. See 10.25.1 (Introduction) for asymmetric BA and 11.5.2.3 (Procedure at the recipient) on how to set the MCS subfield of the Originator Preferred MCS field in the ADDBA Response. |

### 9.4.1.16 DELBA Parameter Set field

The DELBA Parameter Set field is used in a DELBA frame to terminate an already set up block ack agreement. (M118)(#4170)The DELBA Parameter Set field is shown in Figure 9-154 (DELBA Parameter Set field format).

**Figure 9-154—DELBA Parameter Set field format**

The Initiator subfield indicates if the originator or the recipient of the data is sending this frame. It is set to 1 to indicate the originator and is set to 0 to indicate the recipient. The TID subfield indicates the TSID or the UP for which the block ack agreement(#6171) has been originally set up.


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### 9.4.1.17 QoS Info field

The QoS Info field contains capability information bits. The contents of the field are dependent on whether the STA is contained within an AP.

The format of the QoS Info field, when sent by the AP, is defined in Figure 9-155 (QoS Info field format when sent by an AP(11ax)).

| | B0 B3 | B4 | B5 | B6 | B7 |
|---|---|---|---|---|---|
| | EDCA Parameter Set Update Count | Q-Ack | Queue Request | TXOP Request | More Data Ack |
| Bits: | 4 | 1 | 1 | 1 | 1 |

**Figure 9-155—QoS Info field format when sent by an AP(11ax)**

The EDCA Parameter Set Update Count subfield indicates when the EDCA parameters, and for an HE BSS, the MU EDCA parameters have changed(see 10.2.3.2 (HCF contention based channel access (EDCA))).(11ax)

APs set the Q-Ack subfield to 1 when dot11QAckOptionImplemented is true and set it to 0 otherwise.

APs set the Queue Request subfield to 1 if they can process a nonzero Queue Size subfield in the QoS Control field in QoS Data frames and set it to 0 otherwise.

APs set the TXOP Request subfield to 1 if they can process a nonzero TXOP Duration Requested subfield in the QoS Control field in QoS Data frames and set it to 0 otherwise.

(11ax)An HE AP sets the More Data Ack subfield to 1 to indicate that it can generate individually addressed Ack and BlockAck frames with the More Data bit in the Frame Control field equal to 1; otherwise, the AP sets the More Data Ack subfield to 0. For a non-HE AP, the More Data Ack subfield is reserved.

The format of the QoS Info field, when sent by the non-AP STA, is defined in Figure 9-156 (QoS Info field format when set by a non-AP STA).

| | B0 | B1 | B2 | B3 | B4 | B5 B6 | B7 |
|---|---|---|---|---|---|---|---|
| | AC_VO U-APSD Flag | AC_VI U-APSD Flag | AC_BK U-APSD Flag | AC_BE U-APSD Flag | Q-Ack | Max SP Length | More Data Ack |
| Bits: | 1 | 1 | 1 | 1 | 1 | 2(#82) | 1 |

**Figure 9-156—QoS Info field format when set by a non-AP STA**

Each of the ACs U-APSD Flag subfields set to 1 in (Re)Association Request frames to indicate that the corresponding AC (AC_BE, AC_BK, AC_VI, or AC_VO) is both trigger-enabled and delivery-enabled. It is set to 0 in (Re)Association Request frames to indicate that the corresponding AC is neither trigger-enabled nor delivery-enabled. A TSPEC as described in 11.2.3.5 (Power management with APSD) is to be used to make a particular AC exclusively either trigger-enabled or delivery-enabled. These subfields are set to 0 when the APSD subfield in the Capability Information field received from the AP with which the non-AP STA is associating is equal to 0.

Non-AP STAs set the Q-Ack subfield to 1 when dot11QAckOptionImplemented is true and set it to 0 otherwise.

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The Max SP Length subfield indicates the maximum number of buffered BUs the STA is prepared to receive during any SP triggered by the STA. This subfield is reserved when the APSD subfield in the Capability Information field is equal to 0. If the APSD subfield in the Capability Information field is equal to 1, the settings of the values in the Max SP Length subfield are defined in Table 9-83 (Settings of the Max SP Length subfield).

**Table 9-83—Settings of the Max SP Length subfield**

| Bit 5 | Bit 6 | Usage |
|---|---|---|
| 0 | 0 | The STA is prepared to receive all buffered BUs. |
| 1 | 0 | The STA is prepared to receive a maximum of two BUs per SP. |
| 0 | 1 | The STA is prepared to receive a maximum of four BUs per SP. |
| 1 | 1 | The STA is prepared to receive a maximum of six BUs per SP. |

Non-AP non-HE STAs set the More Data Ack subfield to 1 to indicate that they can process Ack frames with the More Data bit in the Frame Control field equal to 1 and remain in the awake state. Non-AP HE STAs set the More Data Ack subfield to 1 to indicate that they can process Ack and BlockAck frames with the More Data bit in the Frame Control field equal to 1 and remain in the awake state. Non-AP STAs set the More Data Ack subfield to 0 otherwise.(11ax)

(11ax)An HE TDLS peer STA uses the More Data Ack subfield to indicate support for both processing and generating Ack and BlockAck frames.

### 9.4.1.18 Measurement Pilot Interval field

The Measurement Pilot Interval field represents the number of time units (TUs) between target measurement pilot transmission times (TMPTTs). (M118)The Measurement Pilot Interval field is shown in Figure 9-157 (Measurement Pilot Interval field format).

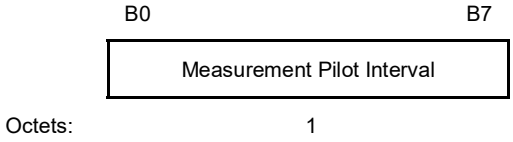


**Figure 9-157—Measurement Pilot Interval field format**

### 9.4.1.19 Max Transmit Power field

The Max Transmit Power field is a 2s complement signed integer. It provides an upper limit, in units of dBm, on the transmit power as measured at the antenna connector to be used by the transmitting STA on the current channel. The Max Transmit Power value has a tolerance of ± 5 dB. See 11.10.13 (Operation of the Max Transmit Power field). The Max Transmit Power field is shown in Figure 9-158 (Max Transmit Power field format).

**Figure 9-158—Max Transmit Power field format**


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#### 9.4.1.20 Transmit Power Used field

The Transmit Power Used field is a 2s complement signed integer. It is less than or equal to the Max Transmit Power and indicates the actual power used as measured at the antenna connector, in units of dBm, by a STA when transmitting the frame containing the Transmit Power Used field. The Transmit Power Used value is determined any time prior to sending the frame in which it is contained and has a tolerance of ± 5 dB. The Transmit Power Used field is shown in Figure 9-159 (Transmit Power Used field format).

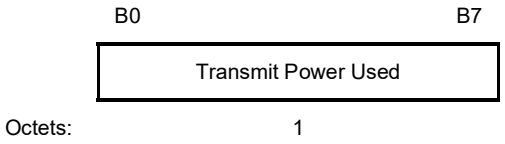


**Figure 9-159—Transmit Power Used field format**

#### 9.4.1.21 Channel Width field

The Channel Width field is used in a Notify Channel Width frame (see 9.6.11.2 (Notify Channel Width frame format)) to indicate the channel width on which the sending STA is able to receive. (M118)The Channel Width field is shown in Figure 9-160 (Channel Width field).

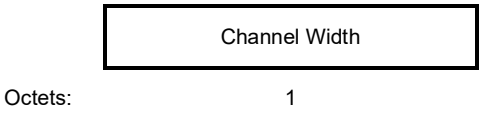


**Figure 9-160—Channel Width field**

If a STA transmitting or receiving this field is operating in an operating class that includes a value of PrimaryChannelLowerBehavior or PrimaryChannelUpperBehavior in the behavior limits set as specified in Annex E, then the Channel Width field is defined in Table 9-84 (Settings of the Channel Width field). If a STA transmitting or receiving this field is operating in an operating class that does not include a value of PrimaryChannelLowerBehavior or PrimaryChannelUpperBehavior in the behavior limits set as specified in Annex E, then this field is reserved.

**Table 9-84—Settings of the Channel Width field**

| Value | Meaning |
|---|---|
| 0 | 20 MHz channel width |
| 1 | Any channel width in the STA's Supported Channel Width Set subfield |
| 2–255 | Reserved |

#### 9.4.1.22 Operating Class And Channel field(#6181)

The Operating Class And Channel field(#6181) is used in the Location Indication Channels subelement of the Location Parameters element and in the Channel Usage element. The Operating Class And Channel field(#6181) indicates an operating class and channel. The format of the field is defined in Figure 9-161 (Operating Class And Channel field format(#6181)).

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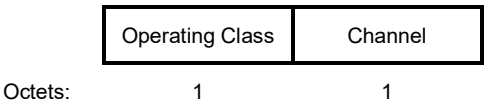


**Figure 9-161—Operating Class And Channel field format(#6181)**

The Operating Class field indicates an operating class value as defined in Annex E. The operating class is interpreted in the context of the country specified in the Beacon frame.

The Channel field indicates a channel number, which is interpreted in the context of the indicated operating class. Channel numbers are defined in Annex E.

### 9.4.1.23 SM Power Control field

The SM Power Control field is used in an SM Power Save frame (see 9.6.11.3 (SM Power Save frame format)) by a STA to communicate changes in its SM power saving state. The field is shown in Figure 9-162 (SM Power Control field format).

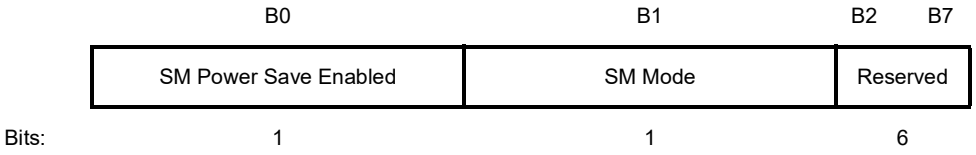


**Figure 9-162—SM Power Control field format**

The SM Power Save Enabled subfield indicates whether SM power saving is enabled at the STA. A 1 indicates enabled, and a 0 indicates disabled.

The SM Mode subfield indicates the mode of operation. A 1 indicates dynamic SM power save mode, a 0 indicates static SM power save mode. The modes are described in 11.2.6 (SM power save).(#3263)

### 9.4.1.24 MIMO Control field

The MIMO Control field is used to manage the exchange of MIMO channel state or transmit beamforming feedback information. It is used in the CSI (see 9.6.11.4 (CSI frame format)), Noncompressed Beamforming (see 9.6.11.5 (Noncompressed Beamforming frame format)), and Compressed Beamforming (see 9.6.11.6 (Compressed Beamforming frame format)) frames.

The MIMO Control field is defined in Figure 9-163 (MIMO Control field format).

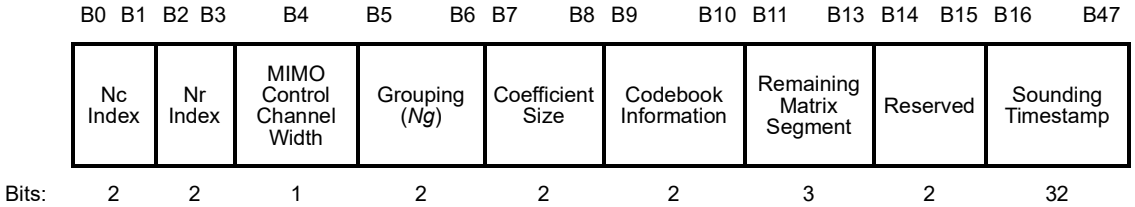


**Figure 9-163—MIMO Control field format**

The subfields of the MIMO Control field are defined in Table 9-85 (Subfields of the MIMO Control field).



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**Table 9-85—Subfields of the MIMO Control field**

| Subfield | Description |
|---|---|
| Nc Index | Indicates the number of columns in the compressed beamforming feedback matrix minus one. |
| Nr Index | Indicates the number of rows in the compressed beamforming feedback matrix minus one.<br>The value 0 is reserved. |
| MIMO Control Channel Width | Indicates the width of the channel in which a measurement was made:<br>Set to 0 for 20 MHz<br>Set to 1 for 40 MHz |
| Grouping (*Ng*) | Number of carriers grouped into one:<br>Set to 0 for *Ng* = 1 (No grouping)<br>Set to 1 for *Ng* = 2<br>Set to 2 for *Ng* = 4<br>The value 3 is reserved |
| Coefficient Size | Indicates the number of bits in the representation of the real and imaginary parts of each element in the matrix.<br><br>For CSI feedback:<br>Set to 0 for *Nb* = 4<br>Set to 1 for *Nb* = 5<br>Set to 2 for *Nb* = 6<br>Set to 3 for *Nb* = 8<br><br>For noncompressed beamforming feedback:<br>Set 0 for *Nb* = 4<br>Set 1 for *Nb* = 2<br>Set 2 for *Nb* = 6<br>Set 3 for *Nb* = 8 |
| Codebook Information | Indicates the size of codebook entries:<br>Set to 0 for 1 bit for $\psi$ , 3 bits for $\phi$<br>Set to 1 for 2 bits for $\psi$ , 4 bits for $\phi$<br>Set to 2 for 3 bits for $\psi$ , 5 bits for $\phi$<br>Set to 3 for 4 bits for $\psi$ , 6 bits for $\phi$ |
| Remaining Matrix Segment | Contains the remaining segment number for the associated measurement report. Set to 0 for the last segment of a segmented report or the only segment of an unsegmented report. |
| Sounding Timestamp | Contains the lower 4 octets of the TSF timer sampled at the instant that the MAC received the PHY-CCA.indication(IDLE) primitive that corresponds to the end of the reception of the sounding PPDU that was used to generate feedback information contained in the frame. |

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#### 9.4.1.25 CSI Report field

The CSI Report field is used by the CSI frame (see 9.6.11.4 (CSI frame format)) to carry explicit channel state information to a transmit HT beamformer, as described in 10.33.3 (Explicit feedback beamforming).

(#4076)The CSI Matrix subfields in the CSI Report field shown in Table 9-86 (CSI Report field (20 MHz)) and Table 9-87 (CSI Report field (40 MHz)) are matrices whose elements are taken from the CHAN_MAT parameter of RXVECTOR (see Table 19-1 (TXVECTOR and RXVECTOR parameters)).

**Table 9-86—CSI Report field (20 MHz)**

| Field | Size (bits) | Meaning |
|---|---|---|
| SNR in receive chain 1 | 8 | Signal-to-noise ratio in the first receive chain of the STA sending the report. |
| ... | | |
| SNR in receive chain *Nr* | 8 | Signal-to-noise ratio in the *Nr*'th receive chain of the STA sending the report. |
| CSI Matrix for carrier –28 | 3+2× *Nb*×*Nc*×*Nr* | CSI matrix (see Figure 9-164 (CSI matrix coding)) |
| ... | | |
| CSI Matrix for carrier –1 | 3+2× *Nb*×*Nc*×*Nr* | CSI matrix |
| CSI Matrix for carrier 1 | 3+2× *Nb*×*Nc*×*Nr* | CSI matrix |
| ... | | |
| CSI Matrix for carrier 28 | 3+2× *Nb*×*Nc*×*Nr* | CSI matrix |

The structure of the field depends on the value of the MIMO Control Channel Width subfield. The CSI Report field for 20 MHz has the structure defined in Table 9-86 (CSI Report field (20 MHz)) where

*Nb* is the number of bits determined by the Coefficients Size field of the MIMO Control field
*Nc* is the number of columns in a CSI matrix determined by the Nc Index field of the MIMO Control field
*Nr* is the number of rows in a CSI matrix determined by the Nr Index field of the MIMO Control field

The CSI Report field for 40 MHz has the structure defined in Table 9-87 (CSI Report field (40 MHz)).


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**Table 9-87—CSI Report field (40 MHz)**

| Field | Size (bits) | Meaning |
|---|---|---|
| SNR in receive chain 1 | 8 | Signal-to-noise ratio in the first receive chain of the STA sending the report. |
| ... | | |
| SNR in receive chain *Nr* | 8 | Signal-to-noise ratio in the *Nr*'th receive chain of the STA sending the report. |
| CSI Matrix for carrier –58 | 3+2× *Nb*×*Nc*×*Nr* | CSI matrix (see Figure 9-164 (CSI matrix coding)) |
| ... | | |
| CSI Matrix for carrier –2 | 3+2× *Nb*×*Nc*×*Nr* | CSI matrix |
| CSI Matrix for carrier 2 | 3+2× *Nb*×*Nc*×*Nr* | CSI matrix |
| ... | | |
| CSI Matrix for carrier 58 | 3+2× *Nb*×*Nc*×*Nr* | CSI matrix |

The signal-to-noise ratio (SNR) values in Table 9-86 (CSI Report field (20 MHz)) and Table 9-87 (CSI Report field (40 MHz)) are encoded as an 8-bit 2s complement value of 4 × (SNR_average – 22), where SNR_average is the decibel representation of linearly averaged values over the subcarriers represented. This encoding covers the SNR range from –10 dB to 53.75 dB in 0.25 dB steps.

Grouping is a method that reduces the size of the CSI Report field by reporting a single value for each group of *Ng* adjacent subcarriers. With grouping, the size of the CSI Report field is *Nr*×8+*Ns*×(3+2×*Nb*×*Nc*×*Nr)* bits, where the number of subcarriers sent, *Ns*, is a function of *Ng* and whether matrices for 40 MHz or 20 MHz are sent. The value of *Ns* and the specific carriers for which matrices are sent are shown in Table 9-88 (Number of matrices and carrier grouping). If the size of the CSI Report field is not an integer multiple of 8 bits, up to 7 0s are appended to the end of the report to make its size an integer multiple of 8 bits.

**Table 9-88—Number of matrices and carrier grouping**

| BW | Grouping *Ng* | *Ns* | Carriers for which matrices are sent |
|---|---|---|---|
| 20 MHz | 1 | 56 | (#515)All data and pilot carriers: –28, –27, …, –2, –1, 1, 2, …, 27, 28 |
| | 2 | 30 | –28,–26,–24,–22,–20,–18,–16,–14,–12,–10,–8,–6,–4,–2,–1, 1,3,5,7,9,11,13,15,17,19,21,23,25,27,28 |
| | 4 | 16 | –28,–24,–20,–16,–12,–8,–4,–1,1,5,9,13,17,21,25,28 |
| 40 MHz | 1 | 114 | All data and pilot carriers: –58, –57, …, –3, –2, 2, 3,…, 57, 58 |
| | 2 | 58 | –58,–56,–54,–52,–50,–48,–46,–44,–42,–40,–38,–36,–34,–32,–30,–28,–26,–24, –22,–20,–18,–16,–14,–12,–10,–8,–6,–4,–2, 2,4,6,8,10,12,14,16,18,20,22,24,26,28,30,32,34,36,38,40,42,44,46,48,50,52,54, 56,58 |
| | 4 | 30 | –58,–54,–50,–46,–42,–38,–34,–30,–26,–22,–18,–14,–10,–6, –2, 2,6,10,14,18,22,26,30,34,38,42,46,50,54,58 |

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The CSI matrix $H_{eff}$ for a single carrier has the structure defined in Figure 9-164 (CSI matrix coding). The encoding rules for the elements of the $H_{eff}$ matrix are given in 19.3.12.3.2 (CSI matrices feedback).

```
For each subcarrier include
{
    Carrier Matrix Amplitude of 3 bits
    For each of Nr rows in each CSI matrix in order: (1, …, Nr)
    {
        Include Nc complex coefficients of CSI matrix Heff in order: (1, …, Nc);
        each element of Heff includes the real part of the element (Nb bits) and
        imaginary part of the element (Nb bits) in that order
    }

}
```

**Figure 9-164—CSI matrix coding**

When operating with a 40 MHz channel width, CSI feedback with a bandwidth of 20 MHz corresponds to the subcarriers in the primary 20 MHz channel.

### 9.4.1.26 Noncompressed Beamforming Report field

The Noncompressed Beamforming Report field is used by the Noncompressed Beamforming frame to carry explicit feedback in the form of noncompressed beamforming feedback matrices *V* for use by a transmit HT beamformer to determine steering matrices Q, as described in 10.33.3 (Explicit feedback beamforming) and 19.3.12.3 (Explicit feedback beamforming).

The structure of the field is dependent on the value of the MIMO Control Channel Width subfield. The Noncompressed Beamforming Report field for 20 MHz has the structure defined in Table 9-89 (Noncompressed Beamforming Report field (20 MHz)) where

*Nb* is the number of bits determined by the Coefficients Size field of the MIMO Control field

*Nc* is the number of columns in a beamforming feedback matrix determined by the Nc Index field of the MIMO Control field

*Nr* is the number of rows in a beamforming feedback matrix determined by the Nr Index field of the MIMO Control field

**Table 9-89—Noncompressed Beamforming Report field (20 MHz)**

| Field | Size (bits) | Meaning |
|---|---|---|
| SNR for space-time stream 1 | 8 | Average signal-to-noise ratio in the STA sending the report for space-time stream 1. |
| ... | | |
| SNR for space-time stream *Nc* | 8 | Average signal-to-noise ratio in the STA sending the report for space-time stream *Nc*. |
| Beamforming Feedback Matrix for carrier –28 | 2× *Nb*×*Nc*×*Nr* | Beamforming feedback matrix *V* (see Figure 9-165 (V matrix coding (noncompressed beamforming))) |
| ... | | |
| Beamforming Feedback Matrix for carrier –1 | 2× *Nb*×*Nc*×*Nr* | Beamforming feedback matrix *V* |


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**Table 9-89—Noncompressed Beamforming Report field (20 MHz)**

| Field | Size (bits) | Meaning |
|---|---|---|
| Beamforming Feedback Matrix for carrier 1 | 2× *Nb*×*Nc*×*Nr* | Beamforming feedback matrix *V* |
| ... | | |
| Beamforming Feedback Matrix for carrier 28 | 2× *Nb*×*Nc*×*Nr* | Beamforming feedback matrix *V* |

The Noncompressed Beamforming Report field for 40 MHz has the structure defined in Table 9-90 (Noncompressed Beamforming Report field (40 MHz)).

**Table 9-90—Noncompressed Beamforming Report field (40 MHz)**

| Field | Size (bits) | Meaning |
|---|---|---|
| SNR for space-time stream 1 | 8 | Average signal-to-noise ratio in the STA sending the report for space-time stream 1. |
| ... | | |
| SNR for space-time stream *Nc* | 8 | Average signal-to-noise ratio in the STA sending the report for space-time stream *Nc*. |
| Beamforming Feedback Matrix for carrier –58 | 2× *Nb*×*Nc*×*Nr* | Beamforming feedback matrix *V* (see Figure 9-165 (V matrix coding (noncompressed beamforming))). |
| ... | | |
| Beamforming Feedback Matrix for carrier –2 | 2× *Nb*×*Nc*×*Nr* | Beamforming feedback matrix *V*. |
| Beamforming Feedback Matrix for carrier 2 | 2× *Nb*×*Nc*×*Nr* | Beamforming feedback matrix *V*. |
| ... | | |
| Beamforming Feedback Matrix for carrier 58 | +2× *Nb*×*Nc*×*Nr* | Beamforming feedback matrix *V*. |

The SNR values in Table 9-89 (Noncompressed Beamforming Report field (20 MHz)) and Table 9-90 (Noncompressed Beamforming Report field (40 MHz)) are encoded as an 8-bit 2s complement value of 4 × (SNR_average – 22), where SNR_average is the sum of the values of SNR per subcarrier (in decibels) divided by the number of subcarriers represented. This encoding covers the SNR range from –10 dB to 53.75 dB in 0.25 dB steps. The SNR in space-time stream *i* corresponds to the SNR associated with the column *i* of the beamforming feedback matrix *V*. Each SNR corresponds to the predicted SNR at the HT beamformee when the HT beamformer applies the matrix *V*.

Grouping is a method that reduces the size of the Noncompressed Beamforming Report field by reporting a single value for each group of *Ng* adjacent subcarriers. With grouping, the size of the Noncompressed Beamforming Report field is *Nc*×8+*Ns*×(2×*Nb*×*Nc*×*Nr*) bits. The number of subcarriers sent, *Ns*, is a function of *Ng* and whether matrices for 40 MHz or 20 MHz are sent. The value of *Ns* and the specific carriers for which matrices are sent is shown in Table 9-88 (Number of matrices and carrier grouping). If the size of the Noncompressed Beamforming Report field is not an integer multiple of 8 bits, up to 7 0s are appended to the end of the report to make its size an integer multiple of 8 bits.

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A beamforming feedback matrix *V* for a single carrier has the structure defined in Figure 9-165 (V matrix coding (noncompressed beamforming)).

```
For each subcarrier include
{
For each of Nr rows in the
        Noncompressed beamforming feedback matrix in order: (1, …, Nr)
    {
        Include Nc complex coefficients of the Noncompressed beamforming feedback
        matrix V in order: (1, …, Nc );  each element of V includes the real
        part of the element (Nb bits) and imaginary part of the element (Nb bits)
        in that order
    }
}
```

**Figure 9-165—*V* matrix coding (noncompressed beamforming)**

Encoding rules for elements of the *V* matrix are given in 19.3.12.3.5 (Noncompressed beamforming feedback matrix).

When operating with a 40 MHz channel width, noncompressed feedback with a bandwidth of 20 MHz corresponds to the subcarriers in the primary 20 MHz channel.

### 9.4.1.27 Compressed Beamforming Report field

The Compressed Beamforming Report field is used by the Compressed Beamforming frame (see 9.6.11.6 (Compressed Beamforming frame format)) to carry explicit feedback information in the form of angles representing compressed beamforming feedback matrices *V* for use by a transmit HT beamformer to determine steering matrices Q, as described in 10.33.3 (Explicit feedback beamforming) and 19.3.12.3 (Explicit feedback beamforming).

The size of the Compressed Beamforming Report field depends on the values in the MIMO Control field.

The Compressed Beamforming Report field contains the channel matrix elements indexed, first, by matrix angles in the order shown in Table 9-91 (Order of angles in the Compressed Beamforming Report field) and, second, by data subcarrier index from lowest frequency to highest frequency. The explanation on how these angles are generated from the beamforming feedback matrix *V* is given in 19.3.12.3.6 (Compressed beamforming feedback matrix).

**Table 9-91—Order of angles in the Compressed Beamforming Report field**

| Size of *V* (*Nr* × *Nc*) | Number of angles (*Na*) | The order of angles in the Quantized Beamforming Feedback Matrices Information field |
|---|---|---|
| 2×1 | 2 | $\phi_{11}$, $\psi_{21}$ |
| 2×2 | 2 | $\phi_{11}$, $\psi_{21}$ |
| 3×1 | 4 | $\phi_{11}$, $\phi_{21}$, $\psi_{21}$, $\psi_{31}$ |
| 3×2 | 6 | $\phi_{11}$, $\phi_{21}$, $\psi_{21}$, $\psi_{31}$, $\phi_{22}$, $\psi_{32}$ |
| 3×3 | 6 | $\phi_{11}$, $\phi_{21}$, $\psi_{21}$, $\psi_{31}$, $\phi_{22}$, $\psi_{32}$ |
| 4×1 | 6 | $\phi_{11}$, $\phi_{21}$, $\phi_{31}$, $\psi_{21}$, $\psi_{31}$, $\psi_{41}$ |


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**Table 9-91—Order of angles in the Compressed Beamforming Report field *(continued)***

| Size of *V* (*Nr* × *Nc*) | Number of angles (*Na*) | The order of angles in the Quantized Beamforming Feedback Matrices Information field |
|---|---|---|
| 4×2 | 10 | ϕ11, ϕ21, ϕ31, ψ21, ψ31, ψ41, ϕ22, ϕ32, ψ32, ψ42 |
| 4×3 | 12 | ϕ11, ϕ21, ϕ31, ψ21, ψ31, ψ41, ϕ22, ϕ32, ψ32, ψ42, ϕ33, ψ43 |
| 4×4 | 12 | ϕ11, ϕ21, ϕ31, ψ21, ψ31, ψ41, ϕ22, ϕ32, ψ32, ψ42, ϕ33, ψ43 |

The angles are quantized as defined in Table 9-92 (Quantization of angles).(#3237)

**Table 9-92—Quantization of angles**

| Quantized ψ | Quantized ϕ |
|---|---|
| $\psi = \frac{k\pi}{2^{b_\psi+1}} + \frac{\pi}{2^{b_\psi+2}}$ radians<br><br>where<br>$k = 0, 1, \ldots, 2^{b_\psi} - 1$<br><br>$b_\psi$ is the number of bits used to quantize ψ (defined by the Codebook Information field of the MIMO Control field; see 9.4.1.24 (MIMO Control field)); | $\phi = \frac{k\pi}{2^{b_\phi-1}} + \frac{\pi}{2^{b_\phi}}$ radians<br><br>where<br>$k = 0, 1, \ldots, 2^{b_\phi} - 1$<br><br>$b_\phi$ is the number of bits used to quantize ϕ (defined by the Codebook Information field of the MIMO Control field; see 9.4.1.24 (MIMO Control field)) |

The Compressed Beamforming Report field for 20 MHz has the structure defined in Table 9-93 (Compressed Beamforming Report field (20 MHz)), where *Na* is the number of angles used for beamforming feedback matrix *V* (see Table 9-91 (Order of angles in the Compressed Beamforming Report field)).

**Table 9-93—Compressed Beamforming Report field (20 MHz)**

| Field | Size (bits) | Meaning |
|---|---|---|
| SNR in space-time stream 1 | 8 | Average signal-to-noise ratio in the STA sending the report for space-time stream 1. |
| ... | | |
| SNR in space-time stream *Nc* | 8 | Average signal-to-noise ratio in the STA sending the report for space-time stream *Nc*. |
| Beamforming Feedback Matrix *V* for carrier –28 | $Na \times (b_\psi + b_\phi)/2$ | Beamforming feedback matrix *V*. |
| ... | | |
| Beamforming Feedback Matrix *V* for carrier –1 | $Na \times (b_\psi + b_\phi)/2$ | Beamforming feedback matrix *V*. |

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**Table 9-93—Compressed Beamforming Report field (20 MHz) *(continued)***

| Field | Size (bits) | Meaning |
|---|---|---|
| Beamforming Feedback Matrix *V* for carrier 1 | $Na\times(b_\psi+b_\phi)/2$ | Beamforming feedback matrix *V*. |
| ... | | |
| Beamforming Feedback Matrix *V* for carrier 28 | $Na\times(b_\psi+b_\phi)/2$ | Beamforming feedback matrix *V*. |

The Compressed Beamforming Report field for 40 MHz has the structure defined in Table 9-94 (Compressed Beamforming Report field (40 MHz)), where *Na* is the number of angles used for beamforming feedback matrix *V* (see Table 9-91 (Order of angles in the Compressed Beamforming Report field)).

**Table 9-94—Compressed Beamforming Report field (40 MHz)**

| Field | Size (bit) | Meaning |
|---|---|---|
| SNR in space-time stream 1 | 8 | Average signal-to-noise ratio in the STA sending the report for space-time stream 1. |
| ... | | |
| SNR in space-time stream *Nc* | 8 | Average signal-to-noise ratio in the STA sending the report for space-time stream *Nc*. |
| Beamforming Feedback Matrix *V* for carrier –58 | $Na\times(b_\psi+b_\phi)/2$ | Beamforming feedback matrix *V*. |
| Beamforming Feedback Matrix *V* for carrier –58 + *Ng* | $Na\times(b_\psi+b_\phi)/2$ | Beamforming feedback matrix *V*. |
| ... | | |
| Beamforming Feedback Matrix *V* for carrier –2 | $Na\times(b_\psi+b_\phi)/2$ | Beamforming feedback matrix *V*. |
| Beamforming Feedback Matrix *V* for carrier 2 | $Na\times(b_\psi+b_\phi)/2$ | Beamforming feedback matrix *V*. |
| Beamforming Feedback Matrix *V* for carrier 2 + *Ng* | $Na\times(b_\psi+b_\phi)/2$ | Beamforming feedback matrix *V*. |
| ... | | |
| Beamforming Feedback Matrix *V* for carrier 58 | $Na\times(b_\psi+b_\phi)/2$ | Beamforming feedback matrix *V*. |

The SNR values in Table 9-93 (Compressed Beamforming Report field (20 MHz)) and Table 9-94 (Compressed Beamforming Report field (40 MHz)) are encoded as an 8-bit 2s complement value of 4 × (SNR_average – 22), where SNR_average is the sum of the values of SNR per subcarrier (in decibels) divided by the number of subcarriers represented. This encoding covers the SNR range from –10 dB to 53.75 dB in 0.25 dB steps. Each SNR value per subcarrier in stream *i* (before being averaged) corresponds to the SNR associated with the column *i* of the beamforming feedback matrix *V* determined at the HT beamformee. Each SNR corresponds to the predicted SNR at the HT beamformee when the HT beamformer applies the matrix *V*.

Grouping is a method that reduces the size of the Compressed Beamforming Report field by reporting a single value for each group of *Ng* adjacent subcarriers. With grouping, the size of the Compressed Beamforming Report field is $Nc\times 8+Ns\times(Na\times(b_\psi+b_\phi)/2)$ bits, where the number of subcarriers sent, *Ns*, is


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a function of *Ng* and whether matrices for 40 MHz or 20 MHz are sent. The value of *Ns* and the specific carriers for which matrices are sent is defined in Table 9-88 (Number of matrices and carrier grouping). If the size of the Compressed Beamforming Report field is not an integer multiple of 8 bits, up to 7 0s are appended to the end of the report to make its size an integer multiple of 8 bits.

See Figure 9-166 (First example of Compressed Beamforming Report field encoding) and Figure 9-167 (Second example of Compressed Beamforming Report field encoding) for examples of this encoding.

| Bits | b0..b4 | b5..b7 | b8..b12 | b13..b15 | … | b440..b444 | b445..b447 |
|---|---|---|---|---|---|---|---|
| Data | $\phi_{11}(-28)$ | $\psi_{21}(-28)$ | $\phi_{11}(-27)$ | $\psi_{21}(-27)$ | … | $\phi_{11}(28)$ | $\psi_{21}(28)$ |

Conditions:
- 2 × 2 V
- $b_\psi = 3$, $b_\phi = 5$
- No grouping
- 20 MHz width
- The matrix *V* is encoded using 8 bits per subcarrier.

**Figure 9-166—First example of Compressed Beamforming Report field encoding**

| Bits | b0..b3 | b4..b7 | … | b26..b27 | b28..b29 | b30..b33 | … | b58..b59 | … | b870..b873 | … | b898..b899 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Data | $\phi_{11}(-58)$ | $\phi_{21}(-58)$ | … | $\psi_{32}(-58)$ | $\psi_{42}(-58)$ | $\phi_{11}(-54)$ | … | $\psi_{42}(-54)$ | … | $\phi_{11}(58)$ | … | $\psi_{42}(58)$ |

Conditions:
- 4 × 2 V
- $b_\psi = 2$, $b_\phi = 4$
- 4 subcarrier grouping
- 40 MHz width
- The matrix *V* is encoded using 30 bits per subcarrier .

**Figure 9-167—Second example of Compressed Beamforming Report field encoding**

When operating with a 40 MHz channel width, compressed feedback with a bandwidth of 20 MHz corresponds to the subcarriers in the primary 20 MHz channel.

### 9.4.1.28 Antenna Selection Indices field

The Antenna Selection Indices field is used within the Antenna Selection Indices Feedback frame to carry ASEL feedback, as described in 10.34 (Antenna selection (ASEL)).

The Antenna Selection Indices field is shown in Figure 9-168 (Antenna Selection Indices field format).

**Figure 9-168—Antenna Selection Indices field format**

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Bits 0 to 7 in the Antenna Selection Indices field correspond to antennas with indices 0 to 7, respectively. A 1 in a bit indicates the corresponding antenna is selected, and a 0 indicates the corresponding antenna is not selected.

### 9.4.1.29 Organization Identifier field

The Organization Identifier field contains a public unique identifier assigned by the IEEE Registration Authority as a 24-bit OUI, a 24-bit CID, or a 36-bit OUI-36, see IEEE Registration Authority [B15] and [B16]. The order of the Organization Identifier field is described in 9.2.2 (Conventions).

The length of the Organization Identifier field for a 24-bit OUI or a 24-bit CID identifier is 3 octets and for a 36-bit OUI-36 identifier is 5 octets (see Figure 9-169 (Organization Identifier field format(#7136))).(#7136)

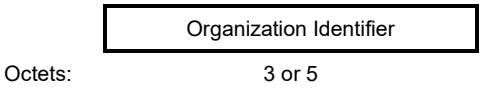


**Figure 9-169—Organization Identifier field format(#7136)**

If the length of the IEEE-assigned identifier is not an integer number of octets, the least significant bits of the last octet are specified by the organization identified.

NOTE—For example, for the IEEE-assigned identifier 0x0050C24A4, the Organization Identifier field would contain 0x0050C24A4*y* where *y* represents the four least significant bits of the fifth octet of the field. The value of *y* is specified by the organization whose identifier is 0x0050C24A4.

### 9.4.1.30 Rate Identification field

The Rate Identification field contains the rate identification information for a frame that is not the current frame transmitted or received by a STA. This information allows services to exchange frame rate information prior to use of the frames that use the rate specified by the Rate Identification field. The contents of the field is defined in Figure 9-170 (Identification field format).

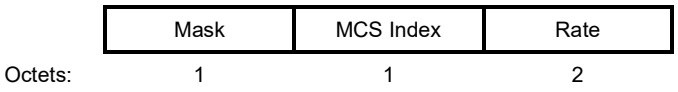


**Figure 9-170—Identification field format**

The Mask field specifies the other fields in the Rate Identification field that are used by a STA. The format of the Mask field is shown in Figure 9-171 (Mask field format).

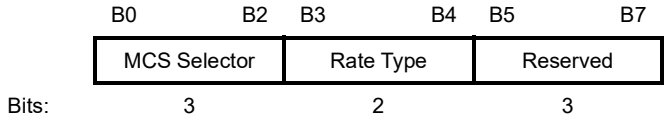


**Figure 9-171—Mask field format**

The MCS Selector field value 0 indicates that the MCS Index field is reserved. The MCS Selector field value 1 indicates the MCS Index field specifies an index value that is taken from Table 19-27 (MCS parameters for mandatory 20 MHz, $N_{SS}$ = 1, $N_{ES}$ = 1) to Table 19-30 (MCS parameters for optional 20 MHz, $N_{SS}$ = 4, $N_{ES}$ = 1, EQM) and Table 19-36 (MCS parameters for optional 20 MHz, $N_{SS}$ = 2, $N_{ES}$ = 1, UEQM) to Table 19-38 (MCS parameters for optional 20 MHz, $N_{SS}$ = 4, $N_{ES}$ = 1, UEQM) in 19.5 (Parameters for HT-MCSs).


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The MCS Selector field value 2 indicates that the MCS Index field specifies:

- Values that are taken from Table 19-31 (MCS parameters for optional 40 MHz, $N_{SS}$ = 1, $N_{ES}$ = 1) to Table 19-35 (MCS parameters for optional 40 MHz MCS 32 format, $N_{SS}$ = 1, $N_{ES}$ = 1) and Table 19-40 (MCS parameters for optional 40 MHz, $N_{SS}$ = 3, UEQM) to Table 19-41 (MCS parameters for optional 40 MHz, $N_{SS}$ = 4, UEQM) in 19.5 (Parameters for HT-MCSs), when carried in frames transmitted by a non-S1G STA.
- Values that are taken from Table 23-42 (S1G-MCSs for 1 MHz, Nss = 1) to Table 23-45 (S1G-MCSs for 1 MHz, Nss = 4), indicating an S1G-MCS for a 1 MHz channel width, when carried in frames transmitted by an S1G STA.

The MCS Selector field value 3 indicates that the MCS Index field specifies:

- Values that are taken from Table 21-29 (VHT-MCSs for mandatory 20 MHz, NSS = 1) to Table 21-36 (VHT-MCSs for optional 20 MHz, NSS = 8), indicating a VHT-MCS for a 20 MHz channel width, when carried in frames transmitted by a non-S1G STA.
- Values that are taken from Table 23-46 (S1G-MCSs for 2 MHz, Nss = 1) to Table 23-49 (S1G-MCSs for 2 MHz, Nss = 4), indicating an S1G-MCS for a 2 MHz channel width, when carried in frames transmitted by an S1G STA.

The MCS Selector field value 4 indicates that the MCS Index field specifies

- Values that are taken from Table 21-37 (VHT-MCSs for mandatory 40 MHz, NSS = 1) to Table 21-44 (VHT-MCSs for optional 40 MHz, NSS = 8), indicating a VHT-MCS for a 40 MHz channel width, when carried in frames transmitted by a non-TVHT and non-S1G STA.
- Values that are taken from Table 22-26 (TVHT-MCSs for TVHT_MODE_1, NSS = 1) to Table 22-29 (TVHT-MCSs for TVHT_MODE_1, NSS = 4), indicating a TVHT-MCS for a TVHT_W channel width, when carried in frames transmitted by a TVHT STA.
- Values that are taken from Table 23-50 (S1G-MCSs for 4 MHz, Nss = 1) to Table 23-53 (S1G-MCSs for 4 MHz, Nss = 4), indicating an S1G-MCS for a 4 MHz channel width, when carried in frames transmitted by an S1G STA.

The MCS Selector field value 5 indicates that the MCS Index field specifies

- Values that are taken from Table 21-45 (VHT-MCSs for mandatory 80 MHz, NSS = 1) to Table 21-52 (VHT-MCSs for optional 80 MHz, NSS = 8), indicating a VHT-MCS for an 80 MHz channel width, when carried in frames transmitted by a non-TVHT and non-S1G STA.
- Values that are taken from Table 22-30 (TVHT-MCSs for TVHT_MODE_2C and TVHT_MODE_2N, NSS = 1) to Table 22-33 (TVHT-MCSs for TVHT_MODE_2C and TVHT_MODE_2N, NSS = 4), indicating a TVHT-MCS for a TVHT_2W or TVHT_W+W channel width, when carried in frames transmitted by a TVHT STA.
- Values that are taken from Table 23-54 (S1G-MCSs for 8 MHz, Nss = 1) to Table 23-57 (S1G-MCSs for 8 MHz, Nss = 4), indicating an S1G-MCS for an 8 MHz channel width, when carried in frames transmitted by an S1G STA.

The MCS Selector field value 6 indicates that the MCS Index field specifies

- Values that are taken from Table 21-53 (VHT-MCSs for optional 160 MHz and 80+80 MHz, NSS = 1) to Table 21-60 (VHT-MCSs for optional 160 MHz and 80+80 MHz, NSS = 8), indicating a VHT-MCS for a 160 MHz or 80+80 MHz channel width, when carried in frames transmitted by a non-TVHT and non-S1G STA.
- Values that are taken from Table 22-34 (TVHT-MCSs for TVHT_MODE_4C and TVHT_MODE_4N, NSS = 1) to Table 22-37 (TVHT-MCSs for TVHT_MODE_4C and TVHT_MODE_4N, NSS = 4), indicating a TVHT-MCS for a TVHT_4W or TVHT_2W+2W channel width, when carried in frames transmitted by a TVHT STA.

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— Values that are taken from Table 23-58 (S1G-MCSs for 16 MHz, Nss = 1) to Table 23-61 (S1G-MCSs for 16 MHz, Nss = 4), indicating an S1G-MCS for a 16 MHz channel width, when carried in frames transmitted by an S1G STA.

The MCS Selector field value 7 is reserved.

The Rate Type field set to 0 indicates the Rate field is reserved. The Rate Type field set to 1 indicates the Rate field specifies a data rate that is in the basic rate set. The Rate Type field set to 2 indicates the Rate field specifies a data rate that is not in the basic rate set.

If MCS Selector is 1 or 2, the MCS Index field is a 1 octet unsigned integer that specifies the row index for one of the MCS parameter tables in 19.5 (Parameters for HT-MCSs).

If MCS Selector field is 3, 4, 5, or 6, the MCS Index field format is as shown in Figure 9-172 (MCS Index field format when the MCS Selector field is 3, 4, 5, or 6). In frames transmitted by an S1G STA, the MCS Index field format is also valid when MCS Selector field is 2. The NSS subfield indicates the number of spatial streams, and the VHT-MCS Index Row subfield indicates a value from the VHT-MCS Index column of Table 21-29 (VHT-MCSs for mandatory 20 MHz, NSS = 1) to Table 21-60 (VHT-MCSs for optional 160 MHz and 80+80 MHz, NSS = 8) in 21.5 (Parameters for VHT-MCSs) or from the MCS Index column of Table 22-26 (TVHT-MCSs for TVHT_MODE_1, NSS = 1) to Table 22-37 (TVHT-MCSs for TVHT_MODE_4C and TVHT_MODE_4N, NSS = 4) in 22.5 (Parameters for TVHT-MCSs) that corresponds to the channel width and $N_{SS}$ values, or from the MCS Idx column of Table 23-42 (S1G-MCSs for 1 MHz, Nss = 1) to Table 23-61 (S1G-MCSs for 16 MHz, Nss = 4) that corresponds to the channel width and NSS values.

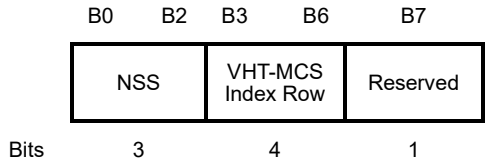


**Figure 9-172—MCS Index field format when the MCS Selector field is 3, 4, 5, or 6**

For non-S1G STAs, the Rate field contains an unsigned integer that specifies the PHY rate in 0.5 Mb/s units. For S1G STAs, it is reserved.

### 9.4.1.31 GAS Query Fragment ID field(#6058)

A GAS Query Fragment ID field is used by the STA to indicate when the Query Request or Query Response field spans multiple MMPDUs. STAs responding to the GAS query request use this field to inform the requesting STA of the GAS fragment number of the transmitted frames as well as identifying the last GAS fragment of the Query Response field. Requesting STAs use this field to determine if any fragments of the GAS query request or response are missing(#8185)(#8184)(#6058).

(#8184)The GAS Fragment ID field contains the GAS fragment number.

(#6058) The More GAS Fragments field is set to 1 in GAS Comeback Request Fragment or GAS Comeback Response frames, if another GAS fragment of the current GAS query request or GAS query response to follow; otherwise, it is set to 0. (#8184)The format of GAS Query Fragment ID field is shown in Figure 9-173 (GAS Query Fragment ID field format(#2306)(#6058)(#8184)).


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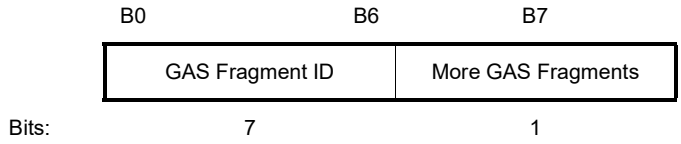


**Figure 9-173—GAS Query Fragment ID field format(#2306)(#6058)(#8184)**

### 9.4.1.32 Venue Info field

(#379)The format of Venue Info subfield is shown in Figure 9-174 (Venue Info field format).

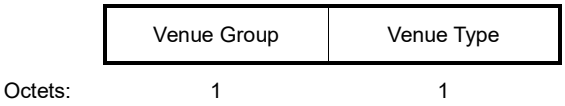


**Figure 9-174—Venue Info field format**

The Venue Group and Venue Type subfields are selected from Table 9-95 (Venue group codes and descriptions) and Table 9-96 (Venue type assignments(#1595)), respectively. The entries in Table 9-95 (Venue group codes and descriptions) and Table 9-96 (Venue type assignments(#1595)) are drawn from the *International Building Code*'s Use and Occupancy Classifications [B57].

**Table 9-95—Venue group codes and descriptions**

| Venue group code | Venue group description |
|---|---|
| 0 | Unspecified |
| 1 | Assembly |
| 2 | Business |
| 3 | Educational |
| 4 | Factory and Industrial |
| 5 | Institutional |
| 6 | Mercantile |
| 7 | Residential |
| 8 | Storage |
| 9 | Utility and Miscellaneous |
| 10 | Vehicular |
| 11 | Outdoor |
| 12(#93) | Credential |
| (#93)13–255 | Reserved |

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**Table 9-96—Venue type assignments(#1595)**

| Venue group code | Venue type code | Venue description |
|---|---|---|
| 0 | 0 | Unspecified |
| 0 | 1–255 | Reserved |
| 1 | 0 | Unspecified assembly |
| 1 | 1 | Arena |
| 1 | 2 | Stadium |
| 1 | 3 | Passenger terminal (e.g., airport, bus, ferry, train station) |
| 1 | 4 | Amphitheater |
| 1 | 5 | Amusement park |
| 1 | 6 | Place of worship |
| 1 | 7 | Convention center |
| 1 | 8 | Library |
| 1 | 9 | Museum |
| 1 | 10 | Restaurant |
| 1 | 11 | Theater |
| 1 | 12 | Bar |
| 1 | 13 | Coffee shop |
| 1 | 14 | Zoo or aquarium |
| 1 | 15 | Emergency coordination center |
| 1 | 16–255 | Reserved |
| 2 | 0 | Unspecified business |
| 2 | 1 | Doctor or dentist office |
| 2 | 2 | Bank |
| 2 | 3 | Fire station |
| 2 | 4 | Police station |
| 2 | 6 | Post office |
| 2 | 7 | Professional office |
| 2 | 8 | Research and development facility |
| 2 | 9 | Attorney office |
| 2 | 10–255 | Reserved |
| 3 | 0 | Unspecified educational |
| 3 | 1 | School, primary |
| 3 | 2 | School, secondary |
| 3 | 3 | University or college |
| 3 | 4–255 | Reserved |
| 4 | 0 | Unspecified factory and industrial |
| 4 | 1 | Factory |
| 4 | 2–255 | Reserved |


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**Table 9-96—Venue type assignments(#1595) *(continued)***

| Venue group code | Venue type code | Venue description |
|---|---|---|
| 5 | 0 | Unspecified institutional |
| 5 | 1 | Hospital |
| 5 | 2 | Long-term care facility (e.g., nursing home, hospice, etc.) |
| 5 | 3 | Alcohol and drug rehabilitation center |
| 5 | 4 | Group home |
| 5 | 5 | Prison or jail |
| 5 | 6–255 | Reserved |
| 6 | 0 | Unspecified mercantile |
| 6 | 1 | Retail store |
| 6 | 2 | Grocery market |
| 6 | 3 | Automotive service station |
| 6 | 4 | Shopping mall |
| 6 | 5 | Gas station |
| 6 | 6–255 | Reserved |
| 7 | 0 | Unspecified residential |
| 7 | 1 | Private residence |
| 7 | 2 | Hotel or motel |
| 7 | 3 | Dormitory |
| 7 | 4 | Boarding house |
| 7 | 5–255 | Reserved |
| 8 | 0 | Unspecified storage |
| 8 | 1–255 | Reserved |
| 9 | 0 | Unspecified utility and miscellaneous |
| 9 | 1–255 | Reserved |
| 10 | 0 | Unspecified vehicular |
| 10 | 1 | Automobile or truck |
| 10 | 2 | Airplane |
| 10 | 3 | Bus |
| 10 | 4 | Ferry |
| 10 | 5 | Ship or boat |
| 10 | 6 | Train |
| 10 | 7 | Motor bike |
| 10 | 8–255 | Reserved |
| 11 | 0 | Unspecified outdoor |
| 11 | 1 | Muni-mesh network |
| 11 | 2 | City park |
| 11 | 3 | Rest area |

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**Table 9-96—Venue type assignments(#1595) *(continued)***

| Venue group code | Venue type code | Venue description |
|---|---|---|
| 11 | 4 | Traffic control |
| 11 | 5 | Bus stop |
| 11 | 6 | Kiosk |
| 11 | 7–255 | Reserved |
| 12(#93) | 0 | Unspecified miscellaneous entities |
| 12(#93) | 1 | Service provider |
| 12(#93) | 2 | Cloud provider(#1596) |
| 12(#93) | 3 | Cable industry |
| 12(#93) | 4 | Government |
| 12 | 5 | Social media provider(#1596) |
| 12(#93) | 6–255 | Reserved |

### 9.4.1.33 Target Channel field(#3249)

The Target Channel field specifies the channel number of the target channel. (M118)The Target Channel field is shown in Figure 9-175 (Target Channel field format).

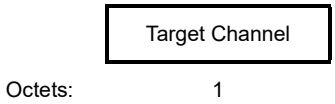


**Figure 9-175—Target Channel field format**

### 9.4.1.34 Operating Class field(#3249)

The Operating Class field specifies the operating class for the channel field included in the same frame. (M118)Operating classes are defined in Annex E. The Operating Class field is shown in Figure 9-176 (Operating Class field format).

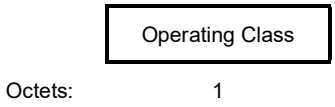


**Figure 9-176—Operating Class field format**

### 9.4.1.35 Send-Confirm field

The Send-Confirm field is used with SAE authentication as an anti-replay counter as specified in 12.4 (Authentication using a password). See Figure 9-177 (Send-Confirm field format).

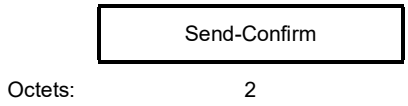


**Figure 9-177—Send-Confirm field format**


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#### 9.4.1.36 Anti-Clogging Token field

The Anti-Clogging Token field is used with SAE authentication for denial-of-service protection as specified in 12.4 (Authentication using a password). See Figure 9-178 (Anti-Clogging Token field format).

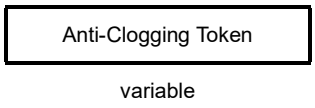


**Figure 9-178—Anti-Clogging Token field format**

#### 9.4.1.37 Scalar field

The Scalar field is used with SAE authentication to communicate cryptographic material as specified in 12.4 (Authentication using a password). See Figure 9-179 (Scalar field format).

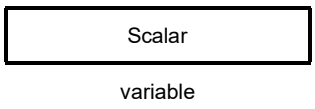


**Figure 9-179—Scalar field format**

#### 9.4.1.38 FFE field

The FFE field is used with SAE authentication and FILS authentication to communicate an element in a finite field as specified in 12.4 (Authentication using a password). See Figure 9-180 (FFE field format).

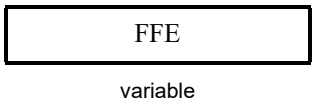


**Figure 9-180—FFE field format**

#### 9.4.1.39 Confirm field

The Confirm field is used with SAE authentication to authenticate and prove possession of a cryptographic key as specified in 12.4 (Authentication using a password). See Figure 9-181 (Confirm field format).

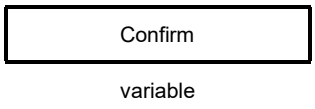


**Figure 9-181—Confirm field format**

#### 9.4.1.40 Finite Cyclic Group field

The Finite Cyclic Group field is used as specified in Clause 12 (Security) to indicate an unsigned integer, from a repository maintained by IANA as “Group Description” attributes for IETF RFC 2409 (IKE) [B14][B29] that specifies the cryptographic group to use in a cryptographic exchange. See Figure 9-182 (Finite Cyclic Group field format).

The Finite Cyclic Group field is used in SAE to indicate the cryptographic group to use in the SAE authentication as specified in 12.4 (Authentication using a password). This field is also used in FILS to

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indicate the cryptographic group to use in FILS authentication as specified in 12.11 (Authentication for FILS) . See Figure 9-182 (Finite Cyclic Group field format).

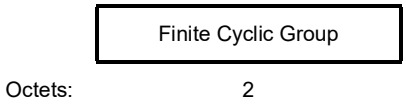


**Figure 9-182—Finite Cyclic Group field format**

#### 9.4.1.41 TXOP Reservation field

The format of the TXOP Reservation field is shown in Figure 9-183 (TXOP Reservation field format).

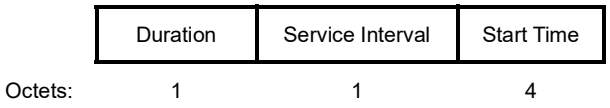


**Figure 9-183—TXOP Reservation field format**

The Duration subfield specifies the duration of the TXOP in units of 32 μs.

The Service Interval subfield contains an unsigned integer that specifies the service interval (SI) of the reservation in units of milliseconds.

The Start Time subfield is the offset from the next TBTT to the start of the first SP and indicates the anticipated start time, expressed in microseconds, of the first TXOP after the TBTT.

#### 9.4.1.42 Relay Capable STA Info field

The format of the Relay Capable STA Info field is defined in Figure 9-184 (Relay Capable STA Info field format).

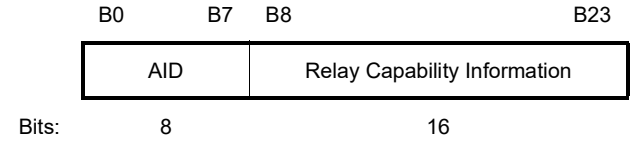


**Figure 9-184—Relay Capable STA Info field format**

The AID subfield contains the AID of the relay capable STA that is associated with the AP or PCP.

The Relay Capability Information subfield is defined in 9.4.2.146 (Relay Capabilities element).


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### 9.4.1.43 Band ID field

The Band ID field is defined in Table 9-97 (Band ID field).

**Table 9-97—Band ID field**

| Band ID value | Meaning |
|---|---|
| 0 | TV white spaces |
| 1 | Sub-1 GHz (excluding TV white spaces) |
| 2 | 2.4 GHz |
| 3 | 3.6 GHz |
| 4 | 4.9 and 5 GHz |
| 5 | 60 GHz |
| 6 | 45 GHz |
| 7(11ax) | 6 GHz |
| 8–255 | Reserved |

### 9.4.1.44 DMG Parameters field

The format of the DMG Parameters field is shown in Figure 9-185 (DMG Parameters field format(11ay)).

| | B0B1 | B2 | B3 | B4 | B5 | B6 | B7 |
|---|---|---|---|---|---|---|---|
| | BSS Type | CBAP Only | CBAP Source | DMG Privacy | ECAPC Policy Enforced | EDMG Supported | Reserved |
| Bits: | 2 | 1 | 1 | 1 | 1 | 1 | 1 |

**Figure 9-185—DMG Parameters field format(11ay)**

If the BSS Type field is transmitted as part of a DMG Beacon frame that has the Discovery Mode field within the Beacon Interval Control field (see Figure 9-131 (Beacon Interval Control field format when the Next A-BFT subfield is 0(11ay)(M118))) equal to 0, then the BSS Type subfield is defined in Table 9-98 (The BSS Type subfield when the Discovery mode field is 0) for specific types of frame cited below. An AP sets the BSS Type subfield to 3 within transmitted DMG Beacon, Probe Response, or (Re)Association Response frames. A PCP sets the BSS Type subfield to 2 within transmitted DMG Beacon, Probe Response, or (Re)Association Response frames. An IBSS STA or a STA that is not a member of a BSS sets the BSS Type subfield to 1 within transmitted DMG Beacon or Probe Response frames. The BSS Type subfield is reserved for all other types of frame.

**Table 9-98—The BSS Type subfield when the Discovery mode field is 0**

| Subfield value | BSS Type | Transmitted by DMG STA |
|---|---|---|
| 3 | Infrastructure BSS | AP |

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**Table 9-98—The BSS Type subfield when the Discovery mode field is 0**

| | | |
|---|---|---|
| 2 | PBSS | PCP |
| 1 | IBSS | Any non-AP and non-PCP DMG STA |
| 0 | Reserved | |

If the BSS Type field is transmitted as part of a DMG Beacon frame that has the Discovery Mode field within the Beacon Interval Control field (see Figure 9-131 (Beacon Interval Control field format when the Next A-BFT subfield is 0(11ay)(M118))) equal to 1, the BSS Type subfield is defined in Table 9-99 (The BSS Type subfield when the Discovery mode field is 1). Depending on the role of the STA that responds to the DMG Beacon frame (identified by the Responding STA role column of Table 9-99 (The BSS Type subfield when the Discovery mode field is 1)), the behavior is different and is defined in 10.41.5.2 (Operation during the A-BFT).

**Table 9-99—The BSS Type subfield when the Discovery mode field is 1**

| Subfield value | Responding STA role | Applicable BSS types |
|---|---|---|
| 3 | AP | Infrastructure BSS |
| 2 | PCP | PBSS |
| 1 | Non-AP STA | PBSS, IBSS, OCB(11bd) |
| 0 | Any | Infrastructure BSS, PBSS, IBSS, OCB(11bd) |
| NOTE—OCB is not a BSS Type, but rather an indication of communication outside the context of a BSS.(11bd) | | |

The CBAP Only, CBAP Source, and ECAPC Policy Enforced subfields are valid only when transmitted within a DMG Beacon, Probe Response, or (Re)Association Response frames and are set as follows:

— The CBAP Only subfield indicates the type of link access provided by the STA sending the DMG Beacon frame in the data transfer interval (DTI) (see 10.38.2 (Access periods within a beacon interval)) of the beacon interval. The CBAP Only subfield is set to 1 when the entirety of the DTI portion of the beacon interval is allocated as a CBAP. The CBAP Only subfield is set to 0 when the allocation of the DTI portion of the beacon interval is provided through the Extended Schedule element.

— The CBAP Source subfield is valid only if the CBAP Only subfield is 1. The CBAP Source subfield is set to 1 to indicate that the AP or PCP has higher priority to transmit during the CBAP than non-AP and non-PCP STAs. The CBAP Source subfield is set to 0 otherwise.

— The ECAPC Policy Enforced subfield is set to 1 to indicate that medium access policies specific to the centralized AP or PCP cluster are required as defined in 10.39.3.4 (Centralized AP or PCP cluster MAC requirements). The ECAPC Policy Enforced subfield is set to 0 to indicate that medium access policies specific to the centralized AP or PCP cluster are not required.

The DMG Privacy subfield is set to 1 if dot11RSNAActivated is true. Otherwise, this subfield is set to 0.

(11ay)The EDMG Supported subfield is set to 1 when transmitted by an EDMG STA. Otherwise, it is set to 0.


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### 9.4.1.45 CMMG Parameters field

The definition of the CMMG parameters field is the same as the definition of the DMG parameters field (see 9.4.1.44 (DMG Parameters field)).

### 9.4.1.46 VHT MIMO Control field

The VHT MIMO Control field is included in every VHT Compressed Beamforming frame (see 9.6.22.2 (VHT Compressed Beamforming frame format)). The VHT MIMO Control field is defined in Figure 9-186 (VHT MIMO Control field format).

| B0B2 | B3B5 | B6B7 | B8B9 | B10 | B11 | B12B14 | B15 | B16B17 | B18B23 |
|---|---|---|---|---|---|---|---|---|---|
| Nc Index | Nr Index | Channel Width | Grouping | Codebook Information | Feedback Type | Remaining Feedback Segments | First Feedback Segment | Reserved | Sounding Dialog Token Number |
| Bits: 3 | 3 | 2 | 2 | 1 | 1 | 3 | 1 | 2 | 6 |

**Figure 9-186—VHT MIMO Control field format**

The subfields of the VHT MIMO Control field are defined in Table 9-100 (Subfields of the VHT MIMO Control field).

**Table 9-100—Subfields of the VHT MIMO Control field**

| Subfield | Description |
|---|---|
| Nc Index | Indicates the number of columns, *Nc*, in the compressed beamforming feedback matrix minus 1.<br>In an S1G PPDU, the Nc Index field does not indicate an *Nc* that is greater than 4. |
| Nr Index | Indicates the number of rows, *Nr*, in the compressed beamforming feedback matrix minus 1.<br>The value 0 is reserved. In an S1G PPDU, the Nr Index field does not indicate an *Nr* that is greater than 4. |
| Channel Width | Indicates the width of the channel in which the measurement to create the compressed beamforming feedback matrix was made:<br>In a non-S1G PPDU:<br>Set to 0 for 20 MHz<br>Set to 1 for 40 MHz<br>Set to 2 for 80 MHz<br>Set to 3 for 160 MHz or 80+80 MHz<br>In an S1G PPDU:<br>Set to 0 for 2MHz<br>Set to 1 for 4 MHz<br>Set to 2 for 8 MHz<br>Set to 3 for 16 MHz |
| Grouping | Indicates the subcarrier grouping, *Ng*, used for the compressed beamforming feedback matrix:<br>Set to 0 for *Ng* = 1 (No grouping)<br>Set to 1 for *Ng* = 2<br>Set to 2 for *Ng* = 4<br>The value 3 is reserved |

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**Table 9-100—Subfields of the VHT MIMO Control field *(continued)***

| Subfield | Description |
|---|---|
| Codebook Information | Indicates the size of codebook entries:<br>If Feedback Type is SU in a VHT PPDU:<br>Set to 0 for 2 bits for ψ, 4 bits for ϕ<br>Set to 1 for 4 bits for ψ, 6 bits for ϕ<br>If Feedback Type is SU in an S1G PPDU with Nc Index field equal to 0:<br>Set to 0 for 2 bits for ϕ, and ψ is not fed back<br>Set to 1 for 2 bits for ψ, and 4 bits for ϕ<br>If Feedback Type is MU in a VHT PPDU:<br>Set to 0 for 5 bits for ψ, 7 bits for ϕ<br>Set to 1 for 7 bits for ψ, 9 bits for ϕ<br>If Feedback Type is MU in an S1G PPDU:<br>Set to 0 for 5 bits for ψ, 7 bits for ϕ<br>Set to 1 for 7 bits for ψ, 9 bits for ϕ |
| Feedback Type | Indicates the feedback type:<br>Set to 0 for SU<br>Set to 1 for MU |
| Remaining Feedback Segments | Indicates the number of remaining feedback segments for the associated VHT Compressed Beamforming frame:<br>Set to 0 for the last feedback segment of a segmented report or the only feedback segment of an unsegmented report.<br>Set to a value between 1 and 6 for a feedback segment that is neither the first nor the last of a segmented report.<br>Set to a value between 1 and 7 for a feedback segment that is not the last feedback segment of a segmented report.<br>In a retransmitted feedback segment, the field is set to the same value associated with the feedback segment in the original transmission. |
| First Feedback Segment | Set to 1 for the first feedback segment of a segmented report or the only feedback segment of an unsegmented report; set to 0 if it is not the first feedback segment or if the VHT Compressed Beamforming Report field and MU Exclusive Beamforming Report field are not present in the frame.<br>In a retransmitted feedback segment, the field is set to the same value associated with the feedback segment in the original transmission. |
| Sounding Dialog Token Number | The sounding dialog token from the VHT NDP Announcement frame soliciting feedback |

In a VHT Compressed Beamforming frame not carrying all or part of a VHT Compressed Beamforming report (see 10.35.5 (VHT sounding protocol) for a description of such a case), the Nc Index, Nr Index, Channel Width, Grouping, Codebook Information, Feedback Type and Sounding Dialog Token Number subfields are reserved, the First Feedback Segment subfield is set to 0 and the Remaining Feedback Segments subfield is set to 7.

### 9.4.1.47 VHT Compressed Beamforming Report field

The VHT Compressed Beamforming Report field is used by the VHT compressed beamforming feedback (see 9.6.22.2 (VHT Compressed Beamforming frame format)) to carry explicit feedback information in the form of angles representing compressed beamforming feedback matrices $V$ for use by a transmit beamformer to determine steering matrices $Q$, as described in 10.33.3 (Explicit feedback beamforming) and 19.3.12.3 (Explicit feedback beamforming).

The size of the VHT Compressed Beamforming Report field depends on the values in the VHT MIMO Control field. The VHT Compressed Beamforming Report field contains VHT Compressed Beamforming Report information or successive (possibly zero-length) portions thereof in the case of segmented VHT


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compressed beamforming feedback (see 10.35.5 (VHT sounding protocol)). VHT Compressed Beamforming Report information is always included in the VHT compressed beamforming feedback.

The VHT Compressed Beamforming Report information contains the channel matrix elements for each subcarrier from lowest frequency to highest frequency. For each subcarrier, the channel matrix element is represented by a sequence of angles. The order of the angles within each subcarrier when used in a non-S1G band is shown in Table 9-101 (Order of angles in the compressed beamforming feedback matrix when used in a non-S1G band). The order of the angles within each subcarrier when used in an S1G band for SU and MU type feedback are shown in Table 9-102 (Order of angles in the compressed beamforming feedback matrix for SU type feedback when used in an S1G band) and Table 9-103 (Order of angles in the compressed beamforming feedback matrix for MU type feedback when used in an S1G band), respectively. Explanation on how these angles are generated from the beamforming feedback matrix $V$ is given in 19.3.12.3.6 (Compressed beamforming feedback matrix).

In Table 9-101 (Order of angles in the compressed beamforming feedback matrix when used in a non-S1G band),

*Nc* is the number of columns in a compressed beamforming feedback matrix determined by the Nc Index field of the VHT MIMO Control field,

*Nr* is the number of rows in a compressed beamforming feedback matrix determined by the Nr Index field of the VHT MIMO Control field.

**Table 9-101—Order of angles in the compressed beamforming feedback matrix when used in a non-S1G band**

| Size of $V$ ($Nr \times Nc$) | Number of angles ($Na$) | The order of angles in the compressed beamforming feedback matrix |
|---|---|---|
| 2×1 | 2 | ϕ11, ψ21 |
| 2×2 | 2 | ϕ11, ψ21 |
| 3×1 | 4 | ϕ11, ϕ21, ψ21, ψ31 |
| 3×2 | 6 | ϕ11, ϕ21, ψ21, ψ31, ϕ22, ψ32 |
| 3×3 | 6 | ϕ11, ϕ21, ψ21, ψ31, ϕ22, ψ32 |
| 4×1 | 6 | ϕ11, ϕ21, ϕ31, ψ21, ψ31, ψ41 |
| 4×2 | 10 | ϕ11, ϕ21, ϕ31, ψ21, ψ31, ψ41, ϕ22, ϕ32, ψ32, ψ42 |
| 4×3 | 12 | ϕ11, ϕ21, ϕ31, ψ21, ψ31, ψ41, ϕ22, ϕ32, ψ32, ψ42, ϕ33, ψ43 |
| 4×4 | 12 | ϕ11, ϕ21, ϕ31, ψ21, ψ31, ψ41, ϕ22, ϕ32, ψ32, ψ42, ϕ33, ψ43 |
| 5×1 | 8 | ϕ11, ϕ21, ϕ31, ϕ41, ψ21, ψ31, ψ41, ψ51 |
| 5×2 | 14 | ϕ11, ϕ21, ϕ31, ϕ41, ψ21, ψ31, ψ41, ψ51, ϕ22, ϕ32, ϕ42, ψ32, ψ42, ψ52 |
| 5×3 | 18 | ϕ11, ϕ21, ϕ31, ϕ41, ψ21, ψ31, ψ41, ψ51, ϕ22, ϕ32, ϕ42, ψ32, ψ42, ψ52, ϕ33, ϕ43, ψ43, ψ53 |
| 5×4 | 20 | ϕ11, ϕ21, ϕ31, ϕ41, ψ21, ψ31, ψ41, ψ51, ϕ22, ϕ32, ϕ42, ψ32, ψ42, ψ52, ϕ33, ϕ43, ψ43, ψ53, ϕ44, ψ54 |
| 5×5 | 20 | ϕ11, ϕ21, ϕ31, ϕ41, ψ21, ψ31, ψ41, ψ51, ϕ22, ϕ32, ϕ42, ψ32, ψ42, ψ52, ϕ33, ϕ43, ψ43, ψ53, ϕ44, ψ54 |
| 6×1 | 10 | ϕ11, ϕ21, ϕ31, ϕ41, ϕ51, ψ21, ψ31, ψ41, ψ51, ψ61 |

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**Table 9-101—Order of angles in the compressed beamforming feedback matrix when used in a non-S1G band *(continued)***

| Size of $V$ ($Nr \times Nc$) | Number of angles ($Na$) | The order of angles in the compressed beamforming feedback matrix |
|---|---|---|
| 6×2 | 18 | $\phi 11, \phi 21, \phi 31, \phi 41, \phi 51, \psi 21, \psi 31, \psi 41, \psi 51, \psi 61, \phi 22, \phi 32, \phi 42, \phi 52, \psi 32, \psi 42, \psi 52, \psi 62$ |
| 6×3 | 24 | $\phi 11, \phi 21, \phi 31, \phi 41, \phi 51, \psi 21, \psi 31, \psi 41, \psi 51, \psi 61, \phi 22, \phi 32, \phi 42, \phi 52, \psi 32, \psi 42, \psi 52, \psi 62, \phi 33, \phi 43, \phi 53, \psi 43, \psi 53, \psi 63$ |
| 6×4 | 28 | $\phi 11, \phi 21, \phi 31, \phi 41, \phi 51, \psi 21, \psi 31, \psi 41, \psi 51, \psi 61, \phi 22, \phi 32, \phi 42, \phi 52, \psi 32, \psi 42, \psi 52, \psi 62, \phi 33, \phi 43, \phi 53, \psi 43, \psi 53, \psi 63, \phi 44, \phi 54, \psi 54, \psi 64$ |
| 6×5 | 30 | $\phi 11, \phi 21, \phi 31, \phi 41, \phi 51, \psi 21, \psi 31, \psi 41, \psi 51, \psi 61, \phi 22, \phi 32, \phi 42, \phi 52, \psi 32, \psi 42, \psi 52, \psi 62, \phi 33, \phi 43, \phi 53, \psi 43, \psi 53, \psi 63, \phi 44, \phi 54, \psi 54, \psi 64, \phi 55, \psi 65$ |
| 6×6 | 30 | $\phi 11, \phi 21, \phi 31, \phi 41, \phi 51, \psi 21, \psi 31, \psi 41, \psi 51, \psi 61, \phi 22, \phi 32, \phi 42, \phi 52, \psi 32, \psi 42, \psi 52, \psi 62, \phi 33, \phi 43, \phi 53, \psi 43, \psi 53, \psi 63, \phi 44, \phi 54, \psi 54, \psi 64, \phi 55, \psi 65$ |
| 7×1 | 12 | $\phi 11, \phi 21, \phi 31, \phi 41, \phi 51, \phi 61, \psi 21, \psi 31, \psi 41, \psi 51, \psi 61, \psi 71$ |
| 7×2 | 22 | $\phi 11, \phi 21, \phi 31, \phi 41, \phi 51, \phi 61, \psi 21, \psi 31, \psi 41, \psi 51, \psi 61, \psi 71, \phi 22, \phi 32, \phi 42, \phi 52, \phi 62, \psi 32, \psi 42, \psi 52, \psi 62, \psi 72$ |
| 7×3 | 30 | $\phi 11, \phi 21, \phi 31, \phi 41, \phi 51, \phi 61, \psi 21, \psi 31, \psi 41, \psi 51, \psi 61, \psi 71, \phi 22, \phi 32, \phi 42, \phi 52, \phi 62, \psi 32, \psi 42, \psi 52, \psi 62, \psi 72, \phi 33, \phi 43, \phi 53, \phi 63, \psi 43, \psi 53, \psi 63, \psi 73$ |
| 7×4 | 36 | $\phi 11, \phi 21, \phi 31, \phi 41, \phi 51, \phi 61, \psi 21, \psi 31, \psi 41, \psi 51, \psi 61, \psi 71, \phi 22, \phi 32, \phi 42, \phi 52, \phi 62, \psi 32, \psi 42, \psi 52, \psi 62, \psi 72, \phi 33, \phi 43, \phi 53, \phi 63, \psi 43, \psi 53, \psi 63, \psi 73, \phi 44, \phi 54, \phi 64, \psi 54, \psi 64, \psi 74$ |
| 7×5 | 40 | $\phi 11, \phi 21, \phi 31, \phi 41, \phi 51, \phi 61, \psi 21, \psi 31, \psi 41, \psi 51, \psi 61, \psi 71, \phi 22, \phi 32, \phi 42, \phi 52, \phi 62, \psi 32, \psi 42, \psi 52, \psi 62, \psi 72, \phi 33, \phi 43, \phi 53, \phi 63, \psi 43, \psi 53, \psi 63, \psi 73, \phi 44, \phi 54, \phi 64, \psi 54, \psi 64, \psi 74, \phi 55, \phi 65, \psi 65, \psi 75$ |
| 7×6 | 42 | $\phi 11, \phi 21, \phi 31, \phi 41, \phi 51, \phi 61, \psi 21, \psi 31, \psi 41, \psi 51, \psi 61, \psi 71, \phi 22, \phi 32, \phi 42, \phi 52, \phi 62, \psi 32, \psi 42, \psi 52, \psi 62, \psi 72, \phi 33, \phi 43, \phi 53, \phi 63, \psi 43, \psi 53, \psi 63, \psi 73, \phi 44, \phi 54, \phi 64, \psi 54, \psi 64, \psi 74, \phi 55, \phi 65, \psi 65, \psi 75, \phi 66, \psi 76$ |
| 7×7 | 42 | $\phi 11, \phi 21, \phi 31, \phi 41, \phi 51, \phi 61, \psi 21, \psi 31, \psi 41, \psi 51, \psi 61, \psi 71, \phi 22, \phi 32, \phi 42, \phi 52, \phi 62, \psi 32, \psi 42, \psi 52, \psi 62, \psi 72, \phi 33, \phi 43, \phi 53, \phi 63, \psi 43, \psi 53, \psi 63, \psi 73, \phi 44, \phi 54, \phi 64, \psi 54, \psi 64, \psi 74, \phi 55, \phi 65, \psi 65, \psi 75, \phi 66, \psi 76$ |
| 8×1 | 14 | $\phi 11, \phi 21, \phi 31, \phi 41, \phi 51, \phi 61, \phi 71, \psi 21, \psi 31, \psi 41, \psi 51, \psi 61, \psi 71, \psi 81$ |
| 8×2 | 26 | $\phi 11, \phi 21, \phi 31, \phi 41, \phi 51, \phi 61, \phi 71, \psi 21, \psi 31, \psi 41, \psi 51, \psi 61, \psi 71, \psi 81, \phi 22, \phi 32, \phi 42, \phi 52, \phi 62, \phi 72, \psi 32, \psi 42, \psi 52, \psi 62, \psi 72, \psi 82$ |
| 8×3 | 36 | $\phi 11, \phi 21, \phi 31, \phi 41, \phi 51, \phi 61, \phi 71, \psi 21, \psi 31, \psi 41, \psi 51, \psi 61, \psi 71, \psi 81, \phi 22, \phi 32, \phi 42, \phi 52, \phi 62, \phi 72, \psi 32, \psi 42, \psi 52, \psi 62, \psi 72, \psi 82, \phi 33, \phi 43, \phi 53, \varphi 63, \phi 73, \psi 43, \psi 53, \psi 63, \psi 73, \psi 83$ |
| 8×4 | 44 | $\phi 11, \phi 21, \phi 31, \phi 41, \phi 51, \phi 61, \phi 71, \psi 21, \psi 31, \psi 41, \psi 51, \psi 61, \psi 71, \psi 81, \phi 22, \phi 32, \phi 42, \phi 52, \phi 62, \phi 72, \psi 32, \psi 42, \psi 52, \psi 62, \psi 72, \psi 82, \phi 33, \phi 43, \phi 53, \phi 63, \phi 73, \psi 43, \psi 53, \psi 63, \psi 73, \psi 83, \phi 44, \phi 54, \phi 64, \phi 74, \psi 54, \psi 64, \psi 74, \psi 84$ |
| 8×5 | 50 | $\phi 11, \phi 21, \phi 31, \phi 41, \phi 51, \phi 61, \phi 71, \psi 21, \psi 31, \psi 41, \psi 51, \psi 61, \psi 71, \psi 81, \phi 22, \phi 32, \phi 42, \phi 52, \phi 62, \phi 72, \psi 32, \psi 42, \psi 52, \psi 62, \psi 72, \psi 82, \phi 33, \phi 43, \phi 53, \phi 63, \phi 73, \psi 43, \psi 53, \psi 63, \psi 73, \psi 83, \phi 44, \phi 54, \phi 64, \phi 74, \psi 54, \psi 64, \psi 74, \psi 84, \phi 55, \phi 65, \phi 75, \psi 65, \psi 75, \psi 85$ |


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**Table 9-101—Order of angles in the compressed beamforming feedback matrix when used in a non-S1G band *(continued)***

| Size of $V$ ($Nr \times Nc$) | Number of angles ($Na$) | The order of angles in the compressed beamforming feedback matrix |
|---|---|---|
| 8×6 | 54 | ϕ11, ϕ21, ϕ31, ϕ41, ϕ51, ϕ61, ϕ71, ψ21, ψ31, ψ41, ψ51, ψ61, ψ71, ψ81, ϕ22, ϕ32, ϕ42, ϕ52, ϕ62, ϕ72, ψ32, ψ42, ψ52, ψ62, ψ72, ψ82, ϕ33, ϕ43, ϕ53, ϕ63, ϕ73, ψ43, ψ53, ψ63, ψ73, ψ83, ϕ44, ϕ54, ϕ64, ϕ74, ψ54, ψ64, ψ74, ψ84, ϕ55, ϕ65, ϕ75, ψ65, ψ75, ψ85, ϕ66, ϕ76, ψ76, ψ86 |
| 8×7 | 56 | ϕ11, ϕ21, ϕ31, ϕ41, ϕ51, ϕ61, ϕ71, ψ21, ψ31, ψ41, ψ51, ψ61, ψ71, ψ81, ϕ22, ϕ32, ϕ42, ϕ52, ϕ62, ϕ72, ψ32, ψ42, ψ52, ψ62, ψ72, ψ82, ϕ33, ϕ43, ϕ53, ϕ63, ϕ73, ψ43, ψ53, ψ63, ψ73, ψ83, ϕ44, ϕ54, ϕ64, ϕ74, ψ54, ψ64, ψ74, ψ84, ϕ55, ϕ65, ϕ75, ψ65, ψ75, ψ85, ϕ66, ϕ76, ψ76, ψ86, ϕ77, ψ87 |
| 8×8 | 56 | ϕ11, ϕ21, ϕ31, ϕ41, ϕ51, ϕ61, ϕ71, ψ21, ψ31, ψ41, ψ51, ψ61, ψ71, ψ81, ϕ22, ϕ32, ϕ42, ϕ52, ϕ62, ϕ72, ψ32, ψ42, ψ52, ψ62, ψ72, ψ82, ϕ33, ϕ43, ϕ53, ϕ63, ϕ73, ψ43, ψ53, ψ63, ψ73, ψ83, ϕ44, ϕ54, ϕ64, ϕ74, ψ54, ψ64, ψ74, ψ84, ϕ55, ϕ65, ϕ75, ψ65, ψ75, ψ85, ϕ66, ϕ76, ψ76, ψ86, ϕ77, ψ87 |

**Table 9-102—Order of angles in the compressed beamforming feedback matrix for SU type feedback when used in an S1G band**

| Size of $V$ ($Nr \times Nc$) | Codebook Information field | Number of angles ($Na$) | The order of angles in the compressed beamforming feedback matrix |
|---|---|---|---|
| 2×1 | 0 | 1 | ϕ11 |
| 2×1 | 1 | 2 | ϕ11, ψ21 |
| 2×2 | 0 or 1 | 2 | ϕ11, ψ21 |
| 3×1 | 0 | 2 | ϕ11, ϕ21 |
| 3×1 | 1 | 4 | ϕ11, ϕ21, ψ21, ψ31 |
| 3×2 | 0 or 1 | 6 | ϕ11, ϕ21, ψ21, ψ31, ϕ22, ψ32 |
| 3×3 | 0 or 1 | 6 | ϕ11, ϕ21, ψ21, ψ31, ϕ22, ψ32 |
| 4×1 | 0 | 3 | ϕ11, ϕ21, ϕ31 |
| 4×1 | 1 | 6 | ϕ11, ϕ21, ϕ31, ψ21, ψ31, ψ41 |
| 4×2 | 0 or 1 | 10 | ϕ11, ϕ21, ϕ31, ψ21, ψ31, ψ41, ϕ22, ϕ32, ψ32, ψ42 |
| 4×3 | 0 or 1 | 12 | ϕ11, ϕ21, ϕ31, ψ21, ψ31, ψ41, ϕ22, ϕ32, ψ32, ψ42, ϕ33, ψ43 |
| 4×4 | 0 or 1 | 12 | ϕ11, ϕ21, ϕ31, ψ21, ψ31, ψ41, ϕ22, ϕ32, ψ32, ψ42, ϕ33, ψ43 |

The beamforming feedback matrix $V$ is formed by the beamformee as follows. The beamformer transmits an NDP with $N_{STS,NDP}$ space-time streams, where $N_{STS,NDP}$ takes a value between 2 and 8. Based on this NDP, the beamformee estimates the $N_{RX,\,BFEE} \times N_{STS,\,NDP}$ channel, and based on that channel it determines a $Nr \times Nc$ orthonormal matrix $V$, where $Nr$ and $Nc$ satisfy Equation (9-3).

$$Nr = N_{STS,\,NDP},\ Nc \leq min(N_{STS,\,NDP}, N_{RX,\,BFEE}) \tag{9-3}$$

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**Table 9-103—Order of angles in the compressed beamforming feedback matrix for MU type feedback when used in an S1G band**

| Size of $V$ ($Nr \times Nc$) | Codebook Information field | Number of angles ($Na$) | The order of angles in the compressed beamforming feedback matrix |
|---|---|---|---|
| 2×1 | 0 or 1 | 2 | $\phi 11, \psi 21$ |
| 2×2 | 0 or 1 | 2 | $\phi 11, \psi 21$ |
| 3×1 | 0 or 1 | 4 | $\phi 11, \phi 21, \psi 21, \psi 31$ |
| 3×2 | 0 or 1 | 6 | $\phi 11, \phi 21, \psi 21, \psi 31, \phi 22, \psi 32$ |
| 3×3 | 0 or 1 | 6 | $\phi 11, \phi 21, \psi 21, \psi 31, \phi 22, \psi 32$ |
| 4×1 | 0 or 1 | 6 | $\phi 11, \phi 21, \phi 31, \psi 21, \psi 31, \psi 41$ |
| 4×2 | 0 or 1 | 10 | $\phi 11, \phi 21, \phi 31, \psi 21, \psi 31, \psi 41, \phi 22, \phi 32, \psi 32, \psi 42$ |
| 4×3 | 0 or 1 | 12 | $\phi 11, \phi 21, \phi 31, \psi 21, \psi 31, \psi 41, \phi 22, \phi 32, \psi 32, \psi 42, \phi 33, \psi 43$ |
| 4×4 | 0 or 1 | 12 | $\phi 11, \phi 21, \phi 31, \psi 21, \psi 31, \psi 41, \phi 22, \phi 32, \psi 32, \psi 42, \phi 33, \psi 43$ |

Further restrictions on $Nc$ are described in 10.35.5 (VHT sounding protocol).

The angles are quantized as defined in Table 9-104 (Quantization of angles).

**Table 9-104—Quantization of angles**

| Quantized $\psi$ | Quantized $\phi$ |
|---|---|
| $\psi = \frac{k\pi}{2^{b_\psi+1}} + \frac{\pi}{2^{b_\psi+2}}$ radians<br>where<br>$k = 0, 1, \ldots, 2^{b_\psi} - 1$<br>$b_\psi$ is the number of bits used to quantize $\psi$ (defined by the Codebook Information field of the VHT MIMO Control field (see 9.4.1.46 (VHT MIMO Control field)) | $\phi = \frac{k\pi}{2^{b_\phi-1}} + \frac{\pi}{2^{b_\phi}}$ radians<br>where<br>$k = 0, 1, \ldots, 2^{b_\phi} - 1$<br>$b_\phi$ is the number of bits used to quantize $\phi$ (defined by the Codebook Information field of the VHT MIMO Control field (see 9.4.1.46 (VHT MIMO Control field)) |

The VHT Compressed Beamforming Report information has the structure defined in Table 9-105 (VHT Compressed Beamforming Report information), where $Na$ is the number of angles used for the compressed beamforming feedback matrix (see Table 9-101 (Order of angles in the compressed beamforming feedback matrix when used in a non-S1G band), Table 9-102 (Order of angles in the compressed beamforming


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feedback matrix for SU type feedback when used in an S1G band), and Table 9-103 (Order of angles in the compressed beamforming feedback matrix for MU type feedback when used in an S1G band)).

**Table 9-105—VHT Compressed Beamforming Report information**

| Field | Size (bits) | Meaning |
|---|---|---|
| Average SNR of Space-Time Stream 1 | 8 | Signal-to-noise ratio at the beamformee for space-time stream 1 averaged over all data subcarriers. See Table 9-107 (Average SNR of Space-Time Stream i subfield). |
| ... | … | … |
| Average SNR of Space-Time Stream *Nc* | 8 | Signal-to-noise ratio at the beamformee for space-time stream *Nc* averaged over all data subcarriers. See Table 9-107 (Average SNR of Space-Time Stream i subfield). |
| Compressed Beamforming Feedback Matrix *V* for subcarrier $k = scidx(0)$ | $Na \times (b_{\psi} + b_{\phi})/2$ | Compressed beamforming feedback matrix as defined in Table 9-101 (Order of angles in the compressed beamforming feedback matrix when used in a non-S1G band), Table 9-102 (Order of angles in the compressed beamforming feedback matrix for SU type feedback when used in an S1G band), or Table 9-103 (Order of angles in the compressed beamforming feedback matrix for MU type feedback when used in an S1G band) |
| Compressed Beamforming Feedback Matrix *V* for subcarrier $k = scidx(1)$ | $Na \times (b_{\psi} + b_{\phi})/2$ | Compressed beamforming feedback matrix as defined in Table 9-101 (Order of angles in the compressed beamforming feedback matrix when used in a non-S1G band), Table 9-102 (Order of angles in the compressed beamforming feedback matrix for SU type feedback when used in an S1G band), or Table 9-103 (Order of angles in the compressed beamforming feedback matrix for MU type feedback when used in an S1G band) |

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**Table 9-105—VHT Compressed Beamforming Report information *(continued)***

| Field | Size (bits) | Meaning |
|---|---|---|
| Compressed Beamforming Feedback Matrix $V$ for subcarrier $k = scidx(2)$ | $Na \times (b_\psi + b_\phi)/2$ | Compressed beamforming feedback matrix as defined in Table 9-101 (Order of angles in the compressed beamforming feedback matrix when used in a non-S1G band), Table 9-102 (Order of angles in the compressed beamforming feedback matrix for SU type feedback when used in an S1G band), or Table 9-103 (Order of angles in the compressed beamforming feedback matrix for MU type feedback when used in an S1G band) |
| ... | … | … |
| Compressed Beamforming Feedback Matrix $V$ for subcarrier $k = scidx(Ns - 1)$ | $Na \times (b_\psi + b_\phi)/2$ | Compressed beamforming feedback matrix as defined in Table 9-101 (Order of angles in the compressed beamforming feedback matrix when used in a non-S1G band), Table 9-102 (Order of angles in the compressed beamforming feedback matrix for SU type feedback when used in an S1G band), or Table 9-103 (Order of angles in the compressed beamforming feedback matrix for MU type feedback when used in an S1G band) |
| NOTE—*scidx()* is defined in Table 9-106 (Subcarrier indices for which a compressed beamforming feedback matrix is sent back). | | |

*Ns* is the number of subcarriers for which the compressed beamforming feedback matrix is sent back to the beamformer. A beamformee might choose to reduce *Ns* by using a method referred to as grouping, in which only a single Compressed Beamforming Feedback Matrix is reported for each group of *Ng* adjacent subcarriers. *Ns* is a function of the Channel Width and Grouping subfields in the VHT MIMO Control field (see 9.4.1.46 (VHT MIMO Control field)). Table 9-106 (Subcarrier indices for which a compressed beamforming feedback matrix is sent back) lists *Ns*, the exact subcarrier indices and their order for which the compressed beamforming feedback matrix is sent back. No padding is present between angles in the VHT Compressed Beamforming Report information, even if they correspond to different subcarriers. If the size of the VHT Compressed Beamforming Report information is not an integer multiple of 8 bits, up to seven 0s(M118) are appended to the end of the field to make its size an integer multiple of 8 bits.


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**Table 9-106—Subcarrier indices for which a compressed beamforming feedback matrix is sent back**

| Channel Width | *Ng* | *Ns* | Subcarrier indices for which Compressed Beamforming Feedback Matrix subfield is sent: *scidx*(0), *scidx*(1), …, *scidx*(*Ns*-1) |
|---|---|---|---|
| 20 MHz in a non-S1G band or 2 MHz in an S1G band | 1 | 52 | –28, –27, –26, –25, –24, –23, –22, –20, –19, –18, –17, –16, –15, –14, –13, –12, –11, –10, –9, –8, –6, –5, –4, –3, –2, –1, 1, 2, 3, 4, 5, 6, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 22, 23, 24, 25, 26, 27, 28<br>NOTE—Pilot subcarriers (± 21, ± 7) and DC subcarrier (0) are skipped |
| | 2 | 30 | –28, –26, –24, –22, –20, –18, –16, –14, –12, –10, –8, –6, –4, –2, –1, 1, 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28 |
| | 4 | 16 | –28, –24, –20, –16, –12, –8, –4, –1, 1, 4, 8, 12, 16, 20, 24, 28 |
| 40 MHz in a non-S1G band or 4 MHz in an S1G band | 1 | 108 | –58, –57, –56, –55, –54, –52, –51, –50, –49, –48, –47, –46, –45, –44, –43, –42, –41, –40, –39, –38, –37, –36, –35, –34, –33, –32, –31, –30, –29, –28, –27, –26, –24, –23, –22, –21, –20, –19, –18, –17, –16, –15, –14, –13, –12, –10, –9, –8, –7, –6, –5, –4, –3, –2, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 54, 55, 56, 57, 58<br>NOTE—Pilot subcarriers (± 53, ± 25, ± 11) and DC subcarriers (0, ± 1) are skipped. |
| | 2 | 58 | –58, –56, –54, –52, –50, –48, –46, –44, –42, –40, –38, –36, –34, –32, –30, –28, –26, –24, -22, –20, –18, –16, –14, –12, –10, –8, –6, –4,–2, 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30, 32, 34, 36, 38, 40, 42, 44, 46, 48, 50, 52, 54, 56, 58 |
| | 4 | 30 | –58, –54, –50, –46, –42, –38, –34, –30, –26, –22, –18, –14, –10, –6,–2, 2, 6, 10, 14, 18, 22, 26, 30, 34, 38, 42, 46, 50, 54, 58 |
| 80 MHz in a non-S1G band or 8 MHz in an S1G band | 1 | 234 | –122, –121, –120, –119, –118, –117, –116, –115, –114, –113, –112, –111, –110, –109, –108, –107, –106, –105, –104, –102, –101, –100, –99, –98, –97, –96, –95, –94, –93, –92, –91, –90, –89, –88, –87, –86, –85, –84, –83, –82, –81, –80, –79, –78, –77, –76, –74, –73, –72, –71, –70, –69, –68, –67, –66, –65, –64, –63, –62, –61, –60, –59, –58, –57, –56, –55, –54, –53, –52, –51, –50, –49, –48, –47, –46, –45, –44, –43, –42, –41, –40, –38, –37, –36, –35, –34, –33, –32, –31, –30, –29, –28, –27, –26, –25, –24, –23, –22, –21, –20, –19, –18, –17, –16, –15, –14, –13, –12, –10, –9, –8, –7, –6, –5, –4, –3, –2, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100, 101, 102, 104, 105, 106, 107, 108, 109, 110, 111, 112, 113, 114, 115, 116, 117, 118, 119, 120, 121, 122<br>NOTE—Pilot subcarriers (± 103, ± 75, ± 39, ± 11) and DC subcarriers (0, ± 1) are skipped. |
| 80 MHz in a non-S1G band or 8 MHz in an S1G band | 2 | 122 | –122, –120, –118, –116, –114, –112, –110, –108, –106, –104, –102, –100, –98, –96, –94, –92, –90, –88, –86, –84, –82, –80, –78, –76, –74, –72, –70, –68, –66, –64, –62, –60, –58, –56, –54, –52, –50, –48, –46, –44, –42, –40, –38, –36, –34, –32, –30, –28, –26, –24, –22, –20, –18, –16, –14, –12, –10, –8, –6, –4, –2, 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30, 32, 34, 36, 38, 40, 42, 44, 46, 48, 50, 52, 54, 56, 58, 60, 62, 64, 66, 68, 70, 72, 74, 76, 78, 80, 82, 84, 86, 88, 90, 92, 94, 96, 98, 100, 102, 104, 106, 108, 110, 112, 114, 116, 118, 120, 122 |
| | 4 | 62 | –122, –118, –114, –110, –106, –102, –98, –94, –90, –86, –82, –78, –74, –70, –66, –62, –58, –54, –50, –46, –42, –38, –34, –30, –26, –22, –18, –14, –10, –6, –2, 2, 6, 10, 14, 18, 22, 26, 30, 34, 38, 42, 46, 50, 54, 58, 62, 66, 70, 74, 78, 82, 86, 90, 94, 98, 102, 106, 110, 114, 118, 122 |

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**Table 9-106—Subcarrier indices for which a compressed beamforming feedback matrix is sent back *(continued)***

| Channel Width | *Ng* | *Ns* | Subcarrier indices for which Compressed Beamforming Feedback Matrix subfield is sent: *scidx*(0), *scidx*(1), …, *scidx*(*Ns*-1) |
|---|---|---|---|
| 160 MHz in a non-S1G band or 16 MHz in an S1G band | 1 | 468 | –250, –249, –248, –247, –246, –245, –244, –243, –242, –241, –240, –239, –238, –237, –236, –235, –234, –233, –232, –230, –229, –228, –227, –226, –225, –224, –223, –222, –221, –220, –219, –218, –217, –216, –215, –214, –213, –212, –211, –210, –209, –208, –207, –206, –205, –204, –202, –201, –200, –199, –198, –197, –196, –195, –194, –193, –192, –191, –190, –189, –188, –187, –186, –185, –184, –183, –182, –181, –180, –179, –178, –177, –176, –175, –174, –173, –172, –171, –170, –169, –168, –166, –165, –164, –163, –162, –161, –160, –159, –158, –157, –156, –155, –154, –153, –152, –151, –150, –149, –148, –147, –146, –145, –144, –143, –142, –141, –140, –138, –137, –136, –135, –134, –133, –132, –131, –130, –126, –125, –124, –123, –122, –121, –120, –119, –118, –116, –115, –114, –113, –112, –111, –110, –109, –108, –107, –106, –105, –104, -103, –102, –101, –100, –99, –98, –97, –96, –95, –94, –93, –92, –91, –90, –88, –87, –86, –85, –84, –83, –82, –81, –80, –79, –78, –77, –76, –75, –74, –73, –72, –71, –70, –69, –68, –67, –66, –65, –64, –63, –62, –61, –60, –59, –58, –57, –56, –55, –54, –52, –51, –50, –49, –48, –47, –46, –45, –44, –43, –42, –41, –40, –39, –38, –37, –36, –35, –34, –33, –32, –31, –30, –29, –28, –27, –26, –24, –23, –22, –21, –20, –19, –18, –17, –16, –15, –14, –13, –12, –11, –10, –9, –8, –7, –6, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100, 101, 102, 103, 104, 105, 106, 107, 108, 109, 110, 111, 112, 113, 114, 115, 116, 118, 119, 120, 121, 122, 123, 124, 125, 126, 130, 131, 132, 133, 134, 135, 136, 137, 138, 140, 141, 142, 143, 144, 145, 146, 147, 148, 149, 150, 151, 152, 153, 154, 155, 156, 157, 158, 159, 160, 161, 162, 163, 164, 165, 166, 168, 169, 170, 171, 172, 173, 174, 175, 176, 177, 178, 179, 180, 181, 182, 183, 184, 185, 186, 187, 188, 189, 190, 191, 192, 193, 194, 195, 196, 197, 198, 199, 200, 201, 202, 204, 205, 206, 207, 208, 209, 210, 211, 212, 213, 214, 215, 216, 217, 218, 219, 220, 221, 222, 223, 224, 225, 226, 227, 228, 229, 230, 232, 233, 234, 235, 236, 237, 238, 239, 240, 241, 242, 243, 244, 245, 246, 247, 248, 249, 250<br><br>NOTE—Pilot subcarriers (± 231, ± 203, ± 167, ± 139, ± 117, ± 89, ± 53, ± 25), DC subcarriers (0, ± 1, ± 2, ± 3, ± 4, ± 5) and subcarriers ± 127, ± 128, ± 129 are skipped. |


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**Table 9-106—Subcarrier indices for which a compressed beamforming feedback matrix is sent back *(continued)***

| Channel Width | *Ng* | *Ns* | Subcarrier indices for which Compressed Beamforming Feedback Matrix subfield is sent: *scidx*(0), *scidx*(1), …, *scidx*(*Ns*-1) |
|---|---|---|---|
| 160 MHz in a non-S1G band or 16 MHz in an S1G band | 2 | 244 | –250, –248, –246, –244, –242, –240, –238, –236, –234, –232, –230, –228, –226, –224, –222, –220, –218, –216, –214, –212, –210, –208, –206, –204, –202, –200, –198, –196, –194, –192, –190, –188, –186, –184, –182, –180, –178, –176, –174, –172, –170, –168, –166, –164, –162, –160, –158, –156, –154, –152, –150, –148, –146, –144, –142, –140, –138, –136, –134, –132, –130, –126, –124, –122, –120, –118, –116, –114, –112, –110, -108, –106, –104, –102, –100, –98, –96, –94, –92, –90, –88, –86, –84, –82, –80, –78, –76, –74, –72, –70, –68, –66, –64, –62, –60, –58, –56, –54, –52, –50, –48, –46, –44, –42, –40, –38, –36, –34, –32, –30, –28, –26, –24, –22, –20, –18, –16, –14, –12, –10, –8, –6, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30, 32, 34, 36, 38, 40, 42, 44, 46, 48, 50, 52, 54, 56, 58, 60, 62, 64, 66, 68, 70, 72, 74, 76, 78, 80, 82, 84, 86, 88, 90, 92, 94, 96, 98, 100, 102, 104, 106, 108, 110, 112, 114, 116, 118, 120, 122, 124, 126, 130, 132, 134, 136, 138, 140, 142, 144, 146, 148, 150, 152, 154, 156, 158, 160, 162, 164, 166, 168, 170, 172, 174, 176, 178, 180, 182, 184, 186, 188, 190, 192, 194, 196, 198, 200, 202, 204, 206, 208, 210, 212, 214, 216, 218, 220, 222, 224, 226, 228, 230, 232, 234, 236, 238, 240, 242, 244, 246, 248, 250<br>NOTE—DC subcarriers 0, ± 2, ± 4, and ± 128 are skipped. |
| | 4 | 124 | –250, –246, –242, –238, –234, –230, –226, –222, –218, –214, –210, –206, –202, –198, –194, –190, –186, –182, –178, –174, –170, –166, –162, –158, –154, –150, –146, –142, –138, –134, –130, –126, –122, –118, –114, –110, –106, –102, –98, –94, –90, –86, –82, –78, –74, –70, –66, –62, –58, –54, –50, –46, –42, –38, –34, –30, –26, –22, –18, –14, –10, –6, 6, 10, 14, 18, 22, 26, 30, 34, 38, 42, 46, 50, 54, 58, 62, 66, 70, 74, 78, 82, 86, 90, 94, 98, 102, 106, 110, 114, 118, 122, 126, 130, 134, 138, 142, 146, 150, 154, 158, 162, 166, 170, 174, 178, 182, 186, 190, 194, 198, 202, 206, 210, 214, 218, 222, 226, 230, 234, 238, 242, 246, 250<br>NOTE—DC subcarriers ± 2 are skipped. |

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**Table 9-106—Subcarrier indices for which a compressed beamforming feedback matrix is sent back *(continued)***

| Channel Width | *Ng* | *Ns* | Subcarrier indices for which Compressed Beamforming Feedback Matrix subfield is sent: *scidx*(0), *scidx*(1), …, *scidx*(*Ns*-1) |
|---|---|---|---|
| 80+80 MHz | 1 | 468 | –122(L), –121(L), –120(L), –119(L), –118(L), –117(L), –116(L), –115(L), –114(L), –113(L), –112(L), –111(L), –110(L), –109(L), –108(L), –107(L), –106(L), –105(L), -104(L), –102(L), –101(L), –100(L), –99(L), –98(L), –97(L), –96(L), –95(L), –94(L), –93(L), –92(L), –91(L), –90(L), –89(L), –88(L), –87(L), –86(L), –85(L), –84(L), –83(L), –82(L), –81(L), –80(L), –79(L), –78(L), –77(L), –76(L), –74(L), –73(L), –72(L), –71(L), –70(L), –69(L), –68(L), –67(L), –66(L), –65(L), –64(L), –63(L), –62(L), –61(L), –60(L), –59(L), –58(L), –57(L), –56(L), –55(L), –54(L), –53(L), –52(L), –51(L), –50(L), –49(L), –48(L), –47(L), –46(L), –45(L), –44(L), –43(L), –42(L), –41(L), –40(L), –38(L), –37(L), –36(L), –35(L), –34(L), –33(L), –32(L), –31(L), –30(L), –29(L), –28(L), –27(L), –26(L), –25(L), –24(L), –23(L), –22(L), –21(L), –20(L), –19(L), –18(L), –17(L), –16(L), –15(L), –14(L), –13(L), –12(L), –10(L), –9(L), –8(L), –7(L), –6(L), –5(L), –4(L), –3(L), –2(L), 2(L), 3(L), 4(L), 5(L), 6(L), 7(L), 8(L), 9(L), 10(L), 12(L), 13(L), 14(L), 15(L), 16(L), 17(L), 18(L), 19(L), 20(L), 21(L), 22(L), 23(L), 24(L), 25(L), 26(L), 27(L), 28(L), 29(L), 30(L), 31(L), 32(L), 33(L), 34(L), 35(L), 36(L), 37(L), 38(L), 40(L), 41(L), 42(L), 43(L), 44(L), 45(L), 46(L), 47(L), 48(L), 49(L), 50(L), 51(L), 52(L), 53(L), 54(L), 55(L), 56(L), 57(L), 58(L), 59(L), 60(L), 61(L), 62(L), 63(L), 64(L), 65(L), 66(L), 67(L), 68(L), 69(L), 70(L), 71(L), 72(L), 73(L), 74(L), 76(L), 77(L), 78(L), 79(L), 80(L), 81(L), 82(L), 83(L), 84(L), 85(L), 86(L), 87(L), 88(L), 89(L), 90(L), 91(L), 92(L), 93(L), 94(L), 95(L), 96(L), 97(L), 98(L), 99(L), 100(L), 101(L), 102(L), 104(L), 105(L), 106(L), 107(L), 108(L), 109(L), 110(L), 111(L), 112(L), 113(L), 114(L), 115(L), 116(L), 117(L), 118(L), 119(L), 120(L), 121(L), 122(L), –122(H), –121(H), –120(H), –119(H), –118(H), –117(H), –116(H), –115(H), –114(H), –113(H), –112(H), –111(H), –110(H), –109(H), –108(H), –107(H), –106(H), –105(H), –104(H), -102(H), -101(H), –100(H), –99(H), –98(H), –97(H), –96(H), –95(H), –94(H), –93(H), –92(H), –91(H), –90(H), –89(H), –88(H), –87(H), –86(H), –85(H), –84(H), –83(H), -82(H), –81(H), –80(H), –79(H), –78(H), –77(H), –76(H), –74(H), –73(H), –72(H), –71(H), –70(H), –69(H), –68(H), –67(H), –66(H), –65(H), –64(H), –63(H), –62(H), –61(H), –60(H), –59(H), –58(H), –57(H), –56(H), –55(H), –54(H), –53(H), –52(H), –51(H), –50(H), –49(H), –48(H), –47(H), –46(H), –45(H), –44(H), –43(H), –42(H), –41(H), –40(H), –38(H), –37(H), –36(H), –35(H), –34(H), –33(H), –32(H), –31(H), –30(H), –29(H), –28(H), –27(H), –26(H), –25(H), –24(H), –23(H), –22(H), –21(H), –20(H), –19(H), –18(H), –17(H), –16(H), –15(H), –14(H), –13(H), –12(H), –10(H), –9(H), –8(H), –7(H), –6(H), –5(H), –4(H), –3(H), –2(H), 2(H), 3(H), 4(H), 5(H), 6(H), 7(H), 8(H), 9(H), 10(H), 12(H), 13(H), 14(H), 15(H), 16(H), 17(H), 18(H), 19(H), 20(H), 21(H), 22(H), 23(H), 24(H), 25(H), 26(H), 27(H), 28(H), 29(H), 30(H), 31(H), 32(H), 33(H), 34(H), 35(H), 36(H), 37(H), 38(H), 40(H), 41(H), 42(H), 43(H), 44(H), 45(H), 46(H), 47(H), 48(H), 49(H), 50(H), 51(H), 52(H), 53(H), 54(H), 55(H), 56(H), 57(H), 58(H), 59(H), 60(H), 61(H), 62(H), 63(H), 64(H), 65(H), 66(H), 67(H), 68(H), 69(H), 70(H), 71(H), 72(H), 73(H), 74(H), 76(H), 77(H), 78(H), 79(H), 80(H), 81(H), 82(H), 83(H), 84(H), 85(H), 86(H), 87(H), 88(H), 89(H), 90(H), 91(H), 92(H), 93(H), 94(H), 95(H), 96(H), 97(H), 98(H), 99(H), 100(H), 101(H), 102(H), 104(H), 105(H), 106(H), 107(H), 108(H), 109(H), 110(H), 111(H), 112(H), 113(H), 114(H), 115(H), 116(H), 117(H), 118(H), 119(H), 120(H), 121(H), 122(H)<br><br>NOTE 1— *x*(L) denotes subcarrier index *x* in the frequency segment lower in frequency, and *x*(H) denotes subcarrier index *x* in the frequency segment higher in frequency.<br><br>NOTE 2—Pilot subcarriers (± 103, ± 75, ± 39, ± 11) and DC subcarriers (0, ± 1) are skipped in each frequency segment. |



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**Table 9-106—Subcarrier indices for which a compressed beamforming feedback matrix is sent back *(continued)***

| Channel Width | *Ng* | *Ns* | Subcarrier indices for which Compressed Beamforming Feedback Matrix subfield is sent: *scidx*(0), *scidx*(1), …, *scidx*(*Ns*-1) |
|---|---|---|---|
| 80+80 MHz | 2 | 244 | –122(L), –120(L), –118(L), –116(L), –114(L), –112(L), –110(L), –108(L), –106(L), -104(L), –102(L), –100(L), –98(L), –96(L), –94(L), –92(L), –90(L), –88(L), –86(L), –84(L), –82(L), –80(L), –78(L), –76(L), –74(L), –72(L), –70(L), –68(L), –66(L), –64(L), –62(L), –60(L), –58(L), –56(L), –54(L), –52(L), –50(L), –48(L), –46(L), –44(L), –42(L), –40(L), –38(L), –36(L), –34(L), –32(L), –30(L), –28(L), –26(L), –24(L), –22(L), –20(L), –18(L), –16(L), –14(L), –12(L), –10(L), –8(L), –6(L), –4(L), –2(L), 2(L), 4(L), 6(L), 8(L), 10(L), 12(L), 14(L), 16(L), 18(L), 20(L), 22(L), 24(L), 26(L), 28(L), 30(L), 32(L), 34(L), 36(L), 38(L), 40(L), 42(L), 44(L), 46(L), 48(L), 50(L), 52(L), 54(L), 56(L), 58(L), 60(L), 62(L), 64(L), 66(L), 68(L), 70(L), 72(L), 74(L), 76(L), 78(L), 80(L), 82(L), 84(L), 86(L), 88(L), 90(L), 92(L), 94(L), 96(L), 98(L), 100(L), 102(L), 104(L), 106(L), 108(L), 110(L), 112(L), 114(L), 116(L), 118(L), 120(L), 122(L), –122(H), –120(H), –118(H), –116(H), –114(H), –112(H), –110(H), –108(H), –106(H), –104(H), –102(H), –100(H), –98(H), –96(H), –94(H), –92(H), –90(H), –88(H), –86(H), –84(H), –82(H), –80(H), –78(H), –76(H), –74(H), –72(H), –70(H), –68(H), –66(H), –64(H), –62(H), –60(H), –58(H), –56(H), –54(H), –52(H), –50(H), –48(H), –46(H), –44(H), –42(H), –40(H), –38(H), –36(H), –34(H), –32(H), –30(H), –28(H), –26(H), –24(H), –22(H), –20(H), –18(H), –16(H), –14(H), –12(H), –10(H), –8(H), –6(H), -4(H), –2(H), 2(H), 4(H), 6(H), 8(H), 10(H), 12(H), 14(H), 16(H), 18(H), 20(H), 22(H), 24(H), 26(H), 28(H), 30(H), 32(H), 34(H), 36(H), 38(H), 40(H), 42(H), 44(H), 46(H), 48(H), 50(H), 52(H), 54(H), 56(H), 58(H), 60(H), 62(H), 64(H), 66(H), 68(H), 70(H), 72(H), 74(H), 76(H), 78(H), 80(H), 82(H), 84(H), 86(H), 88(H), 90(H), 92(H), 94(H), 96(H), 98(H), 100(H), 102(H), 104(H), 106(H), 108(H), 110(H), 112(H), 114(H), 116(H), 118(H), 120(H), 122(H) |
| | 4 | 124 | –122(L), –118(L), –114(L), –110(L), –106(L), –102(L), –98(L), –94(L), –90(L), –86(L), –82(L), –78(L), –74(L), –70(L), –66(L), –62(L), –58(L), –54(L), –50(L), –46(L), –42(L), –38(L), –34(L), –30(L), –26(L), –22(L), –18(L), –14(L), –10(L), –6(L), –2(L), 2(L), 6(L), 10(L), 14(L), 18(L), 22(L), 26(L), 30(L), 34(L), 38(L), 42(L), 46(L), 50(L), 54(L), 58(L), 62(L), 66(L), 70(L), 74(L), 78(L), 82(L), 86(L), 90(L), 94(L), 98(L), 102(L), 106(L), 110(L), 114(L), 118(L), 122(L), –122(H), –118(H), –114(H), –110(H), –106(H), –102(H), –98(H), –94(H), –90(H), -86(H), –82(H), –78(H), –74(H), –70(H), –66(H), –62(H), –58(H), –54(H), –50(H), –46(H), –42(H), –38(H), –34(H), –30(H), –26(H), –22(H), –18(H), –14(H), –10(H), –6(H), –2(H), 2(H), 6(H), 10(H), 14(H), 18(H), 22(H), 26(H), 30(H), 34(H), 38(H), 42(H), 46(H), 50(H), 54(H), 58(H), 62(H), 66(H), 70(H), 74(H), 78(H), 82(H), 86(H), 90(H), 94(H), 98(H), 102(H), 106(H), 110(H), 114(H), 118(H), 122(H) |

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The Average SNR of Space-Time Stream *i* subfield in (#6291)Table 9-105 (VHT Compressed Beamforming Report information) is a (#4162)2s complement integer whose definition is shown in Table 9-107 (Average SNR of Space-Time Stream i subfield).

**Table 9-107—Average SNR of Space-Time Stream *i* subfield**

| Average SNR of Space-Time Stream *i* subfield | $AvgSNR_i$ |
|---|---|
| –128 | ≤ –10 dB |
| –127 | –9.75 dB |
| –126 | –9.5 dB |
| … | … |
| +126 | 53.5 dB |
| +127 | ≥ 53.75 dB |

The $AvgSNR_i$ in Table 9-107 (Average SNR of Space-Time Stream i subfield) is found by computing the SNR per subcarrier in decibels for the subcarriers identified in Table 9-106 (Subcarrier indices for which a compressed beamforming feedback matrix is sent back), and then computing the arithmetic mean of those values. Each SNR value per subcarrier in stream *i* (before being averaged) corresponds to the SNR associated with the column *i* of the beamforming feedback matrix *V* determined at the beamformee. (#2335)Each SNR corresponds to the predicted SNR at the beamformee when the beamformer applies all columns of the $Nr \times Nc$ feedback matrix *V*

A STA with a 40 MHz, 80 MHz, or 160 MHz operating channel width and sending feedback for a 20 MHz channel width includes only subcarriers corresponding to the primary 20 MHz channel in the Compressed Beamforming Feedback Matrix subfield.

A STA with an 80 MHz or 160 MHz operating channel width and sending feedback for a 40 MHz channel width includes only subcarriers corresponding to the primary 40 MHz channel in the Compressed Beamforming Feedback Matrix subfield.

A STA with a 160 MHz or 80+80 MHz operating channel width and sending feedback for an 80 MHz channel width includes only subcarriers corresponding to the primary 80 MHz channel in the Compressed Beamforming Feedback Matrix subfield.

### 9.4.1.48 TVHT Compressed Beamforming Report field

The format of the TVHT Compressed Beamforming Report field is the same as the VHT Compressed Beamforming Report field in 9.4.1.47 (VHT Compressed Beamforming Report field) except for the following modifications.

The subcarriers for which Compressed Beamforming Feedback Matrix subfield is sent in Table 9-106 (Subcarrier indices for which a compressed beamforming feedback matrix is sent back) for 40 MHz are used for each basic channel unit (BCU) in TVHT_MODE_1 and TVHT_MODE_2N. See subcarrier location description in Table 22-9 (Tone location).

For TVHT_MODE_2C with 6 MHz and 8 MHz channelization, the subcarriers for which Compressed Beamforming Feedback Matrix subfield is sent in the Lower BCU are based on subtracting 72 from the


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values shown in Table 9-106 (Subcarrier indices for which a compressed beamforming feedback matrix is sent back) and for the Upper BCU by adding 72.

For TVHT_MODE_2C with 7 MHz channelization, the subcarriers for which Compressed Beamforming Feedback Matrix subfield is sent in the Lower BCU are based on subtracting 84 from the values shown in Table 9-106 (Subcarrier indices for which a compressed beamforming feedback matrix is sent back) and for the Upper BCU by adding 84.

For TVHT_MODE_4C with 6 MHz and 8 MHz channelization, the subcarriers for which Compressed Beamforming Feedback Matrix subfield is sent in the lowest, second to lowest, second to highest, and highest BCUs are based on subtracting 216, subtracting 72, adding 72, and adding 216 from the values shown in Table 9-106 (Subcarrier indices for which a compressed beamforming feedback matrix is sent back), respectively.

For TVHT_MODE_4C with 7 MHz channelization, the subcarriers for which Compressed Beamforming Feedback Matrix subfield is sent in the lowest, second to lowest, second to highest, and highest BCUs are based on subtracting 252, subtracting 84, adding 84, and adding 252 from the values shown in Table 9-106 (Subcarrier indices for which a compressed beamforming feedback matrix is sent back), respectively.

For TVHT_MODE_4N channelization, the subcarriers for which Compressed Beamforming Feedback Matrix subfield is sent in each of the two noncontiguous frequency segments are as described for TVHT_MODE_2C.

A STA with a TVHT_2W, TVHT_4W, TVHT_W+W, or TVHT_2W+2W operating channel width and sending feedback for a TVHT_W channel width includes a representation of the compressed beamforming feedback matrices of the subcarriers corresponding to the primary TVHT_W channel in the Compressed Beamforming Feedback Matrix subfield.

A STA with a TVHT_4W or TVHT_2W+2W operating channel width and sending feedback for a TVHT_2W channel width includes a representation of the compressed beamforming feedback matrices of the subcarriers corresponding to the primary TVHT_2W channel in the Compressed Beamforming Feedback Matrix subfield.

#### 9.4.1.49 MU Exclusive Beamforming Report field

The MU Exclusive Beamforming Report field is used by the VHT compressed beamforming feedback (see 9.6.22.2 (VHT Compressed Beamforming frame format)) to carry explicit feedback information in the form of delta SNRs. The information in the VHT Compressed Beamforming Report field and the MU Exclusive Beamforming Report field can be used by the transmit MU beamformer to determine steering matrices $Q$, as described in 10.33.3 (Explicit feedback beamforming), 19.3.12.3 (Explicit feedback beamforming), and 21.3.11 (SU-MIMO and (#3367)DL MU-MIMO Beamforming).

The size of the MU Exclusive Beamforming Report field depends on the values in the VHT MIMO Control field. The MU Exclusive Beamforming Report field contains MU Exclusive Beamforming Report information or successive (possibly zero-length) portions thereof in the case of segmented VHT compressed beamforming feedback (see 10.35.5 (VHT sounding protocol)). The MU Exclusive Beamforming Report information is included in the VHT compressed beamforming feedback if the Feedback Type subfield in the VHT MIMO Control field indicates MU (see 9.4.1.46 (VHT MIMO Control field)).

The MU Exclusive Beamforming Report information consists of Delta SNR subfields for each space-time stream (1 to $Nc$) of a subset of the subcarriers typically spaced $2Ng$ apart, where $Ng$ is signaled in the Grouping subfield of the VHT MIMO Control field, starting from the lowest frequency subcarrier and continuing to the highest frequency subcarrier. No padding is present between $\Delta SNR_{k,i}$ in the MU Exclusive Beamforming Report field, even if they correspond to different subcarriers. The subset of

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subcarriers included is determined by the values of the Channel Width and Grouping subfields of the VHT MIMO Control field as listed in Table 9-109 (Number of subcarriers and subcarrier mapping). For each subcarrier included, the deviation in dB of the SNR of that subcarrier for each column of $V$ relative to the average SNR of the corresponding space-time stream is computed using Equation (9-4).(#315)

$$\Delta SNR_{k,i} = min(max(\text{Round}(10\log 10\left(\frac{\left\|H_k V_{k,i}\right\|^2}{N}\right) - \overline{SNR_i}), -8), 7) \quad (9\text{-}4)$$

where

$k$ is the subcarrier index in the range $scidx(0)$, …, $scidx(Ns'-1)$

$i$ is the space-time stream index in the range 1, …, $Nc$

$H_k$ is the estimated MIMO channel for subcarrier $k$

$V_{k,i}$ is column $i$ of the beamforming matrix $V$ for subcarrier $k$

$N$ is the average noise plus interference power, measured at the beamformee, that was used to calculate $\overline{SNR_i}$

$\overline{SNR_i}$ is the average SNR of space-time stream $i$ reported in the VHT Compressed Beamforming Report information (Average SNR of Space-Time Stream $i$ field)

(#176)Each Delta SNR subfield is a 2s complement signed integer that contains the $\Delta SNR_{k,i}$ in dB (in the range -8 to 7 dB), computed using Equation (9-4). The structure of the MU Exclusive Beamforming Report field is shown in Table 9-108 (MU Exclusive Beamforming Report information).

**Table 9-108—MU Exclusive Beamforming Report information**

| Field | Size (bits) | Meaning |
|---|---|---|
| Delta SNR for space-time stream 1 for subcarrier $k$ = *scidx(0)* | 4 | $\Delta SNR_{scidx(0),1}$ as defined in Equation (9-4) |
| … | … | … |
| Delta SNR for space-time stream $Nc$ for subcarrier $k$ = *scidx(0)* | 4 | $\Delta SNR_{scidx(0),Nc}$ as defined in Equation (9-4) |
| Delta SNR for space-time stream 1 for subcarrier $k$ = *scidx(1)* | 4 | $\Delta SNR_{scidx(1),1}$ as defined in Equation (9-4) |
| … | … | … |
| Delta SNR for space-time stream $Nc$ for subcarrier $k$ = *scidx(1)* | 4 | $\Delta SNR_{scidx(1),Nc}$ as defined in Equation (9-4) |
| … | … | … |
| Delta SNR for space-time stream 1 for subcarrier $k$ = *scidx(Ns'–1)* | 4 | $\Delta SNR_{scidx(Ns'-1),1}$ as defined in Equation (9-4) |


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**Table 9-108—MU Exclusive Beamforming Report information *(continued)***

| Field | Size (bits) | Meaning |
|---|---|---|
| … | … | … |
| Delta SNR for space-time stream $Nc$ for subcarrier $k$ = *scidx(Ns'–1)* | 4 | $\Delta SNR_{scidx(Ns'-1),Nc}$ as defined in Equation (9-4) |

NOTE—*scidx*() is defined in Table 9-109 (Number of subcarriers and subcarrier mapping).

In Table 9-108 (MU Exclusive Beamforming Report information), *Ns*' is the number of subcarriers for which the Delta SNR subfield is sent back to the beamformer. Table 9-109 (Number of subcarriers and subcarrier mapping) shows *Ns*', the exact subcarrier indices and their order for which the Delta SNR is sent back.

**Table 9-109—Number of subcarriers and subcarrier mapping**

| Channel Width | *Ng* | *Ns*' | Subcarrier indices for which the Delta SNR subfield is sent: *scidx*(0), *scidx*(1), … *scidx*(*Ns*'–1) |
|---|---|---|---|
| 20 MHz | 1 | 30 | –28, –26, –24, –22, –20, –18, –16, –14, –12, –10, –8, –6, –4, –2, –1, 1, 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28 |
| | 2 | 16 | –28, –24, –20, –16, –12, –8, –4, –1, 1, 4, 8, 12, 16, 20, 24, 28 |
| | 4 | 10 | –28, –20, –12, –4, –1, 1, 4, 12, 20, 28 |
| 40 MHz | 1 | 58 | –58, –56, –54, –52, –50, –48, –46, –44, –42, –40, –38, –36, –34, –32, –30, –28, –26, –24, –22, –20, –18, –16, –14, –12, –10, –8, –6, –4,–2, 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30, 32, 34, 36, 38, 40, 42, 44, 46, 48, 50, 52, 54, 56, 58 |
| | 2 | 30 | –58, –54, –50, –46, –42, –38, –34, –30, –26, –22, –18, –14, –10, –6,–2, 2, 6, 10, 14, 18, 22, 26, 30, 34, 38, 42, 46, 50, 54, 58 |
| | 4 | 16 | –58, –50, –42, –34, –26, –18, –10, –2, 2, 10, 18, 26, 34, 42, 50, 58 |
| 80 MHz | 1 | 122 | –122, –120, –118, –116, –114, –112, –110, –108, –106, –104, –102, –100, –98, –96, –94, –92, –90, –88, –86, –84, –82, –80, –78, –76, –74, –72, –70, –68, –66, –64, –62, –60, –58, –56, –54, –52, –50, –48, –46, –44, –42, –40, –38, –36, –34, –32, –30, –28, –26, –24, –22, –20, –18, –16, –14, –12, –10, –8, –6, –4, –2, 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30, 32, 34, 36, 38, 40, 42, 44, 46, 48, 50, 52, 54, 56, 58, 60, 62, 64, 66, 68, 70, 72, 74, 76, 78, 80, 82, 84, 86, 88, 90, 92, 94, 96, 98, 100, 102, 104, 106, 108, 110, 112, 114, 116, 118, 120, 122 |
| | 2 | 62 | –122, –118, –114, –110, –106, –102, –98, –94, –90, –86, –82, –78, –74, –70, –66, –62, –58, –54, –50, –46, –42, –38, –34, –30, –26, –22, –18, –14, –10, –6, –2, 2, 6, 10, 14, 18, 22, 26, 30, 34, 38, 42, 46, 50, 54, 58, 62, 66, 70, 74, 78, 82, 86, 90, 94, 98, 102, 106, 110, 114, 118, 122 |
| | 4 | 32 | –122, –114, –106, –98, –90, –82, –74, –66, –58, –50, –42, –34, –26, –18, –10, –2, 2, 10, 18, 26, 34, 42, 50, 58, 66, 74, 82, 90, 98, 106, 114, 122 |

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**Table 9-109—Number of subcarriers and subcarrier mapping *(continued)***

| Channel Width | *Ng* | *Ns*' | Subcarrier indices for which the Delta SNR subfield is sent: *scidx*(0), *scidx*(1), … *scidx*(*Ns*'–1) |
|---|---|---|---|
| 160 MHz | 1 | 244 | –250, –248, –246, –244, –242, –240, –238, –236, –234, –232, –230, –228, –226, –224, –222, –220, –218, –216, –214, –212, –210, –208, –206, –204, –202, –200, –198, –196, –194, –192, –190, –188, –186, –184, –182, –180, –178, –176, –174, –172, –170, –168, –166, –164, –162, –160, –158, –156, –154, –152, –150, –148, –146, –144, –142, –140, –138, –136, –134, –132, –130, –126, –124, –122, –120, –118, –116, –114, –112, –110, –108, –106, –104, –102, –100, –98, –96, –94, –92, –90, –88, –86, –84, –82, –80, –78, –76, –74, –72, –70, –68, –66, –64, –62, –60, –58, –56, –54, –52, –50, –48, –46, –44, –42, –40, –38, –36, –34, –32, –30, –28, –26, –24, –22, –20, –18, –16, –14, –12, –10, –8, –6, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30, 32, 34, 36, 38, 40, 42, 44, 46, 48, 50, 52, 54, 56, 58, 60, 62, 64, 66, 68, 70, 72, 74, 76, 78, 80, 82, 84, 86, 88, 90, 92, 94, 96, 98, 100, 102, 104, 106, 108, 110, 112, 114, 116, 118, 120, 122, 124, 126, 130, 132, 134, 136, 138, 140, 142, 144, 146, 148, 150, 152, 154, 156, 158, 160, 162, 164, 166, 168, 170, 172, 174, 176, 178, 180, 182, 184, 186, 188, 190, 192, 194, 196, 198, 200, 202, 204, 206, 208, 210, 212, 214, 216, 218, 220, 222, 224, 226, 228, 230, 232, 234, 236, 238, 240, 242, 244, 246, 248, 250<br>NOTE—Subcarriers 0, ± 2, ± 4, and ± 128 are skipped. |
| 160 MHz | 2 | 124 | –250, –246, –242, –238, –234, –230, –226, –222, –218, –214, –210, –206, –202, –198, –194, –190, –186, –182, –178, –174, –170, –166, –162, –158, –154, –150, –146, –142, –138, –134, –130, –126, –122, –118, –114, –110, –106, –102, –98, –94, –90, –86, –82, –78, –74, –70, –66, –62, –58, –54, –50, –46, –42, –38, –34, –30, –26, –22, –18, –14, –10, –6, 6, 10, 14, 18, 22, 26, 30, 34, 38, 42, 46, 50, 54, 58, 62, 66, 70, 74, 78, 82, 86, 90, 94, 98, 102, 106, 110, 114, 118, 122, 126, 130, 134, 138, 142, 146, 150, 154, 158, 162, 166, 170, 174, 178, 182, 186, 190, 194, 198, 202, 206, 210, 214, 218, 222, 226, 230, 234, 238, 242, 246, 250<br>NOTE—Subcarriers ± 2 are skipped. |
| | 4 | 64 | –250, –242, –234, –226, –218, –210, –202, –194, –186, –178, –170, –162, –154, –146, –138, –130, –126, –118, –110, –102, –94, –86, –78, –70, –62, –54, –46, –38, –30, –22, –14, -6, 6, 14, 22, 30, 38, 46, 54, 62, 70, 78, 86, 94, 102, 110, 118, 126, 130, 138, 146, 154, 162, 170, 178, 186, 194, 202, 210, 218, 226, 234, 242, 250 |


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**Table 9-109—Number of subcarriers and subcarrier mapping *(continued)***

| Channel Width | *Ng* | *Ns*' | Subcarrier indices for which the Delta SNR subfield is sent: *scidx*(0), *scidx*(1), … *scidx*(*Ns*'–1) |
|---|---|---|---|
| 80+80 MHz | 1 | 244 | –122(L), –120(L), –118(L), –116(L), –114(L), –112(L), –110(L), –108(L), –106(L), –104(L), –102(L), –100(L), –98(L), –96(L), –94(L), –92(L), –90(L), –88(L), –86(L), –84(L), –82(L), –80(L), –78(L), –76(L), –74(L), –72(L), –70(L), –68(L), –66(L), –64(L), –62(L), –60(L), –58(L), –56(L), –54(L), –52(L), –50(L), –48(L), –46(L), –44(L), –42(L), –40(L), –38(L), –36(L), –34(L), –32(L), –30(L), –28(L), –26(L), –24(L), –22(L), –20(L), –18(L), –16(L), –14(L), –12(L), –10(L), –8(L), –6(L), –4(L), –2(L), 2(L), 4(L), 6(L), 8(L), 10(L), 12(L), 14(L), 16(L), 18(L), 20(L), 22(L), 24(L), 26(L), 28(L), 30(L), 32(L), 34(L), 36(L), 38(L), 40(L), 42(L), 44(L), 46(L), 48(L), 50(L), 52(L), 54(L), 56(L), 58(L), 60(L), 62(L), 64(L), 66(L), 68(L), 70(L), 72(L), 74(L), 76(L), 78(L), 80(L), 82(L), 84(L), 86(L), 88(L), 90(L), 92(L), 94(L), 96(L), 98(L), 100(L), 102(L), 104(L), 106(L), 108(L), 110(L), 112(L), 114(L), 116(L), 118(L), 120(L), 122(L), –122(H), –120(H), –118(H), –116(H), –114(H), –112(H), –110(H), –108(H), –106(H), –104(H), –102(H), –100(H), –98(H), –96(H), –94(H), –92(H), –90(H), –88(H), –86(H), –84(H), –82(H), –80(H), –78(H), –76(H), –74(H), –72(H), –70(H), –68(H), –66(H), –64(H), –62(H), –60(H), –58(H), –56(H), –54(H), –52(H), –50(H), –48(H), –46(H), –44(H), –42(H), –40(H), –38(H), –36(H), –34(H), –32(H), –30(H), –28(H), –26(H), –24(H), –22(H), –20(H), –18(H), –16(H), –14(H), –12(H), –10(H), –8(H), –6(H), –4(H), –2(H), 2(H), 4(H), 6(H), 8(H), 10(H), 12(H), 14(H), 16(H), 18(H), 20(H), 22(H), 24(H), 26(H), 28(H), 30(H), 32(H), 34(H), 36(H), 38(H), 40(H), 42(H), 44(H), 46(H), 48(H), 50(H), 52(H), 54(H), 56(H), 58(H), 60(H), 62(H), 64(H), 66(H), 68(H), 70(H), 72(H), 74(H), 76(H), 78(H), 80(H), 82(H), 84(H), 86(H), 88(H), 90(H), 92(H), 94(H), 96(H), 98(H), 100(H), 102(H), 104(H), 106(H), 108(H), 110(H), 112(H), 114(H), 116(H), 118(H), 120(H), 122(H) |
| | 2 | 124 | –122(L), –118(L), –114(L), –110(L), –106(L), –102(L), –98(L), –94(L), –90(L), –86(L), –82(L), –78(L), –74(L), –70(L), –66(L), –62(L), –58(L), –54(L), –50(L), –46(L), –42(L), –38(L), –34(L), –30(L), –26(L), –22(L), –18(L), –14(L), –10(L), –6(L), –2(L), 2(L), 6(L), 10(L), 14(L), 18(L), 22(L), 26(L), 30(L), 34(L), 38(L), 42(L), 46(L), 50(L), 54(L), 58(L), 62(L), 66(L), 70(L), 74(L), 78(L), 82(L), 86(L), 90(L), 94(L), 98(L), 102(L), 106(L), 110(L), 114(L), 118(L), 122(L), –122(H), –118(H), –114(H), –110(H), –106(H), –102(H), –98(H), –94(H), –90(H), –86(H), –82(H), –78(H), –74(H), –70(H), –66(H), –62(H), –58(H), –54(H), –50(H), –46(H), –42(H), –38(H), –34(H), –30(H), –26(H), –22(H), –18(H), –14(H), –10(H), –6(H), –2(H), 2(H), 6(H), 10(H), 14(H), 18(H), 22(H), 26(H), 30(H), 34(H), 38(H), 42(H), 46(H), 50(H), 54(H), 58(H), 62(H), 66(H), 70(H), 74(H), 78(H), 82(H), 86(H), 90(H), 94(H), 98(H), 102(H), 106(H), 110(H), 114(H), 118(H), 122(H) |
| 80+80 MHz | 4 | 64 | –122(L), –114(L), –106(L), –98(L), –90(L), –82(L), –74(L), –66(L), –58(L), –50(L), -42(L), –34(L), –26(L), –18(L), –10(L), –2(L), 2(L), 10(L), 18(L), 26(L), 34(L), 42(L), 50(L), 58(L), 66(L), 74(L), 82(L), 90(L), 98(L), 106(L), 114(L), 122(L), –122(H), –114(H), –106(H), –98(H), –90(H), –82(H), –74(H), –66(H), –58(H), –50(H), –42(H), –34(H), –26(H), –18(H), –10(H), –2(H), 2(H), 10(H), 18(H), 26(H), 34(H), 42(H), 50(H), 58(H), 66(H), 74(H), 82(H), 90(H), 98(H), 106(H), 114(H), 122(H) |

NOTE 1—*scidx*() is defined in Table 9-108 (MU Exclusive Beamforming Report information).

NOTE 2— *x*(L) denotes subcarrier index *x* in the frequency segment lower in frequency, and *x*(H) denotes subcarrier index *x* in the frequency segment higher in frequency.

### 9.4.1.50 TVHT MU Exclusive Beamforming Report field

See 9.4.1.49 with the following modifications:

— For each BCU in TVHT_MODE_1 and TVHT_MODE_2N, the subcarriers used in the Delta SNR subfield are defined in Table 9-109 (Number of subcarriers and subcarrier mapping) for 40 MHz. See the subcarrier location description in Table 22-9 (Tone location).

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- For TVHT_MODE_2C with 6 MHz and 8 MHz channelization, the subcarriers for which Delta SNR subfield is sent in the Lower BCU are based on subtracting 72 from the values shown in Table 9-109 (Number of subcarriers and subcarrier mapping) and for the Upper BCU by adding 72.
- For TVHT_MODE_2C with 7 MHz channelization, the subcarriers for which Delta SNR subfield is sent in the Lower BCU are based on subtracting 84 from the values shown in Table 9-109 (Number of subcarriers and subcarrier mapping) and for the Upper BCU by adding 84.
- For TVHT_MODE_4C with 6 MHz and 8 MHz channelization, the subcarriers for which Delta SNR subfield is sent in the lowest, second to lowest, second to highest, and highest BCUs are based on subtracting 216, subtracting 72, adding 72, and adding 216 from the values shown in Table 9-109 (Number of subcarriers and subcarrier mapping), respectively.
- For TVHT_MODE_4C with 7 MHz channelization, the subcarriers for which Delta SNR subfield is sent in the lowest, second to lowest, second to highest, and highest BCUs are based on subtracting 252, subtracting 84, adding 84, and adding 252 from the values shown in Table 9-109 (Number of subcarriers and subcarrier mapping), respectively.
- For TVHT_MODE_4N channelization, the subcarriers for which Delta SNR subfield is sent in each of the two noncontiguous frequency segments are as described for TVHT_MODE_2C.

#### 9.4.1.51 Operating Mode field

The Operating Mode field is present in the Operating Mode Notification frame (see 9.6.22.4 (Operating Mode Notification frame format)) and Operating Mode Notification element (see 9.4.2.164 (Operating Mode Notification element)).

The Operating Mode field for a non-S1G STA is shown in Figure 9-187 (Operating Mode field format when it is carried in a non-S1G PPDU).

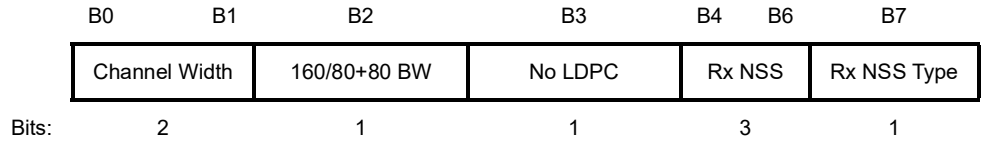


**Figure 9-187—Operating Mode field format when it is carried in a non-S1G PPDU**

The Operating Mode field in an S1G PPDU is shown in Figure 9-188 (Operating Mode field format when it is carried in an S1G PPDU).

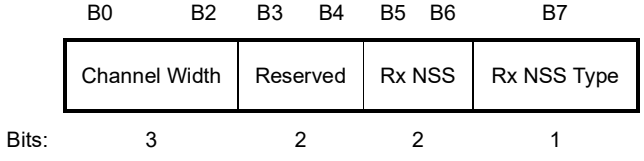


**Figure 9-188—Operating Mode field format when it is carried in an S1G PPDU**


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The STA transmitting this field indicates its current operating channel width and the number of spatial streams it can receive using the settings defined in Table 9-110 (Subfield values of the Operating Mode field).

**Table 9-110—Subfield values of the Operating Mode field**

| Subfield | Description |
|---|---|
| Channel Width | If the Rx NSS Type subfield is 0, indicates the supported channel width:<br><br>In a VHT STA, see Table 9-111 (Setting of the Channel Width subfield and 160/80+80 BW subfield at a VHT STA transmitting the Operating Mode field)<br><br>In a TVHT STA:<br>Set to 0 for TVHT_W<br>Set to 1 for TVHT_2W and TVHT_W+W<br>Set to 2 for TVHT_4W and TVHT_2W+2W<br>The value 3 is reserved.<br><br>In an S1G STA:<br>Set to 0 for 1 MHz<br>Set to 1 for 2 MHz<br>Set to 2 for 4 MHz<br>Set to 3 for 8 MHz<br>Set to 4 for 16 MHz<br>Reserved for values 5-7<br><br>Reserved if the Rx NSS Type subfield is 1. |
| 160/80+80 BW | This subfield, combined with the Channel Width subfield, the Supported Channel Width Set subfield and the Supported VHT-MCS and NSS Set subfield indicates whether 80+80 MHz and 160 MHz operation is supported.<br><br>In a VHT STA, see Table 9-111 (Setting of the Channel Width subfield and 160/80+80 BW subfield at a VHT STA transmitting the Operating Mode field).<br><br>In a TVHT STA, this field is reserved.<br>In a STA with dot11VHTExtendedNSSBWCapable either equal to false or not present, this field is set to 0. |
| No LDPC | Set to 1 to indicate that the STA transmitting this field prefers not to receive LDPC-encoded PPDUs; set to 0 otherwise. |

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**Table 9-110—Subfield values of the Operating Mode field *(continued)***

| Subfield | Description |
|---|---|
| Rx NSS | If the STA that transmits the Operating Mode field (STA1) and the receiver of the Operating Mode field (STA2) are not both HE STAs and if the Rx NSS Type subfield is 0, then this field, combined with other information described in 9.4.2.156.3 (Supported VHT-MCS and NSS Set field), indicates the maximum number of spatial streams that STA1 can receive.(11ax)<br><br>(11ax)If the STA that transmits the Operating Mode field (STA1) and the receiver of the Operating Mode field (STA2) are both HE STAs and if the Rx NSS Type subfield is 0, then the following apply:<br>— The value of this field, combined with other information described in 9.4.2.156.3 (Supported VHT-MCS and NSS Set field), indicates the maximum number of spatial streams that the HE STA can receive in a VHT PPDU.<br>— The value of this field, combined with other information described in 9.4.2.247.4 (Supported HE-MCS And NSS Set field), indicates the maximum number of spatial streams that STA1 can receive in an HE PPDU.<br><br>If the Rx NSS Type subfield is 1, this field indicates the maximum number of spatial streams that the STA can receive as a beamformee in an SU PPDU using a beamforming steering matrix derived from a VHT Compressed Beamforming report with Feedback Type subfield indicating MU in the corresponding VHT Compressed Beamforming frame sent by the STA.<br><br>In a non-S1G STA:<br>Set to 0 for $N_{SS} = 1$<br>Set to 1 for $N_{SS} = 2$<br>…<br>Set to 7 for $N_{SS} = 8$<br><br>In an S1G STA:<br>Set to 0 for $N_{SS} = 1$<br>Set to 1 for $N_{SS} = 2$<br>Set to 2 for $N_{SS} = 3$<br>Set to 3 for $N_{SS} = 4$<br><br>NOTE—In a STA with dot11VHTExtendedNSSBWCapable equal to true, NSS might be further modified for VHT PPDUs per Table 9-111 (Setting of the Channel Width subfield and 160/80+80 BW subfield at a VHT STA transmitting the Operating Mode field). In an HE STA with dot11VHTExtendedNSSBWCapable equal to true, NSS might be further modified for HE PPDUs per Equation (9-5).(11ax) |
| Rx NSS Type | Set to 0 to indicate that the Rx NSS subfield carries the maximum number of spatial streams that the STA can receive in any PPDU.<br><br>Set to 1 to indicate that the Rx NSS subfield carries the maximum number of spatial streams that the STA can receive as a beamformee in an SU PPDU using a beamforming steering matrix derived from a VHT Compressed Beamforming report with the Feedback Type subfield indicating MU in the corresponding VHT Compressed Beamforming frame sent by the STA.<br><br>NOTE—An AP always sets this field to 0. |



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**Table 9-111—Setting of the Channel Width subfield and 160/80+80 BW subfield at a VHT STA transmitting the Operating Mode field**

| Transmitted Operating Mode field | | VHT Capabilities of STA transmitting the Operating Mode field | | NSS support of STA transmitting the Operating Mode field as a function of the VHT PPDU (×Max VHT NSS) (see requirements R1 and R2) | | | | | Location of 160 MHz center frequency if BSS bandwidth is 160 MHz | Location of secondary 80 MHz center frequency if BSS bandwidth is 80+80 MHz |
|---|---|---|---|---|---|---|---|---|---|---|
| Channel width | 160/ 80+80 BW | Supported Channel Width Set | Extended NSS BW Support | 20 MHz | 40 MHz | 80 MHz | 160 MHz | 80 +80 MHz | | |
| 0 | 0 | 0-2 | 0-3 | 1 | | | | | | |
| 1 | 0 | 0-2 | 0-3 | 1 | 1 | | | | | |
| 2 | 0 | 0-2 | 0-3 | 1 | 1 | 1 | | | | |
| 2 | 1 | 0 | 1 | 1 | 1 | 1 | 1/2 | | CCFS2 | |
| 2 | 1 | 0 | 2 | 1 | 1 | 1 | 1/2 | 1/2 | CCFS2 | CCFS2 |
| 2 | 1 | 0 | 3 | 1 | 1 | 1 | 3/4 | 3/4 | CCFS2 | CCFS2 |
| 2 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | | CCFS1 | |
| 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1/2 | CCFS1 | CCFS2 |
| 2 | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 3/4 | CCFS1 | CCFS2 |
| 2 | 1 | 1 | 3 | 2 | 2 | 2 | 2 | 1 | CCFS1 | CCFS1 |
| 2 | 1 | 2 | 0 | 1 | 1 | 1 | 1 | 1 | CCFS1 | CCFS1 |
| 2 | 1 | 2 | 3 | 2 | 2 | 2 | 1 | 1 | CCFS1 | CCFS1 |

R1: NSS support is rounded down to the nearest integer.
R2: The maximum NSS supported is 8.

NOTE 1—Max VHT NSS is defined per MCS in 9.4.2.156.3 (Supported VHT-MCS and NSS Set field).

NOTE 2—1/2× or 3/4× Max VHT NSS support might end up being 0, indicating no support.

NOTE 3—Any other combination than the ones listed in this table is reserved.

NOTE 4—CCFS1 refers to the Channel Center Frequency Segment 1 field of the most recently transmitted VHT Operation element.

NOTE 5—CCFS2 refers to the Channel Center Frequency Segment 2 field of the most recently transmitted HT Operation element.

NOTE 6—CCFS1 is nonzero when the current BSS bandwidth is 160 MHz or 80+80 MHz and the NSS support is at least Max VHT NSS. CCFS2 is zero in this case.

NOTE 7—CCFS2 is nonzero when the current BSS bandwidth is 160 MHz or 80+80 MHz and the NSS support is less than Max VHT NSS. CCFS1 is zero in this case.

NOTE 8—At most one of CCFS1 and CCFS2 is nonzero.

NOTE 9—A supported multiple of Max VHT NSS applies to both transmit and receive.

NOTE 10—Some combinations of Supported Channel Width Set and Extended NSS BW support might not occur in practice.

NOTE 11—2× Max VHT NSS support might be used for 20 MHz or 40 MHz HT PPDU.

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(11ax)The maximum number of spatial streams that the STA supports in reception for a given HE-MCS as a function of the received HE PPDU bandwidth at an HE STA transmitting an Operating Mode field is defined as

$$\text{Floor}\,(\textit{Rx-NSS-from-OMF} \times (\textit{Max-HE-NSS-at-BW} \,/\, \textit{Max-HE-NSS-at-80})) \quad (9\text{-}5)$$

where

*Rx-NSS-from-OMF* is Rx NSS from the Operating Mode field transmitted by the STA

*Max-HE-NSS-at-BW* is the maximum NSS among all HE-MCS at *BW* MHz from the Supported HE-MCS And NSS Set field transmitted by the STA

*Max-HE-NSS-at-80* is the maximum $N_{SS}$ among all HE-MCS at 80 MHz from the Supported HE-MCS And NSS Set field transmitted by the STA

NOTE—For operating mode between two HE STAs, the Rx NSS subfield indicates the maximum number of spatial streams at channel widths less than or equal to 80 MHz.

### 9.4.1.52 Membership Status Array field

The Membership Status Array field is used in the Group ID Management frame (see 9.6.22.3 (Group ID Management frame format)).(#8141) A Membership Status Array field (indexed by the group ID) consists of a 1-bit Membership Status subfield for each of the 64 group IDs, as shown in Figure 9-189 (Membership Status Array field format).

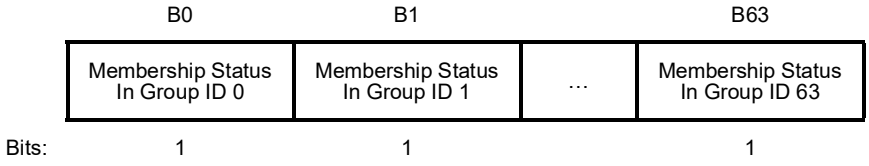


**Figure 9-189—Membership Status Array field format**

Within the Membership Status Array field, the 1-bit Membership Status subfield for each group ID is set as follows:

— Set to 0 if the STA is not a member of the group

— Set to 1 if STA is a member of the group

The Membership Status subfields for group ID 0 (transmissions to AP) and group ID 63 (downlink SU transmissions) are reserved.

### 9.4.1.53 User Position Array field

The User Position Array field is used in the Group ID Management frame (see 9.6.22.3 (Group ID Management frame format)).(#8141) A User Position Array field (indexed by the Group ID) consists of a 2-bit User Position subfield for each of the 64 group IDs, as shown in Figure 9-190 (User Position Array field format).

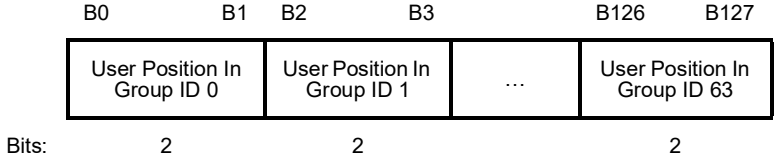


**Figure 9-190—User Position Array field format**


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If the Membership Status subfield for a particular group ID is 1, then the corresponding User Position subfield in the User Position Array field contains the group ID's User Position.

If the Membership Status subfield for a group ID is 0 (meaning the STA is not a member of that group), then the corresponding User Position subfield in the User Position Array field is reserved.

The User Position subfields for group ID 0 (transmissions to AP) and group ID 63 (downlink SU transmissions) are reserved.

#### 9.4.1.54 Device Location Information Body field

A Device Location Information Body field includes the location configuration information (LCI), which contains latitude, longitude, and altitude information.

The format of the Device Location Information Body field is shown in Figure 9-191 (Device Location Information Body field format).

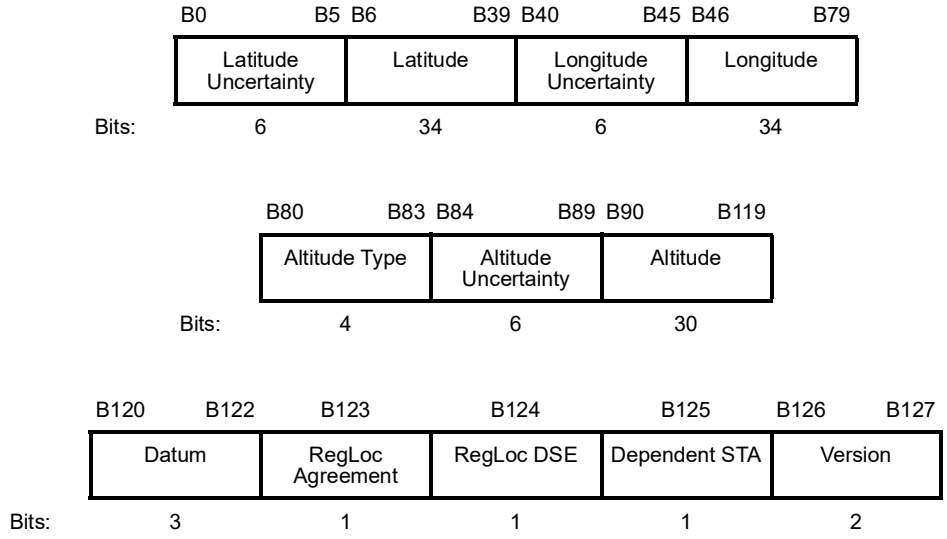


**Figure 9-191—Device Location Information Body field format**

The fields within the Device Location Information Body field are as defined in section 2.2 of IETF RFC 6225 except as defined in 9.4.2.50 (DSE Registered Location element), and RegLoc Agreement and RegLoc DSE are set to 0.

#### 9.4.1.55 WSM Type field and WSM Information field

The WSM Type field is set to a number that identifies the type of WSM information and the frequency band where the following WSM Information field is applicable. The values of WSM Types are shown in Table 9-112 (WSM Type definition). The WSM Type field set to 1 indicates the WSM Information field of the WSM element contains available frequency information for operation in the TVWS. Other values are reserved.

The WSM Information field indicates the available channel information as defined in 9.4.4.2.6 (WSM information values).

The WSM Information field corresponding to a TV band WSM is shown in Table 9-424 (WSM information values).

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**Table 9-112—WSM Type definition**

| Name | WSM Type |
|---|---|
| Reserved | 0 |
| TV band WSM | 1 |
| Reserved | 2–255 |

### 9.4.1.56 Sync Control field

The Sync Control field is present in the Sync Control frame (see 9.6.24.4 (Sync Control frame format)). The Sync Control field is shown in Figure 9-192 (Sync Control field format).

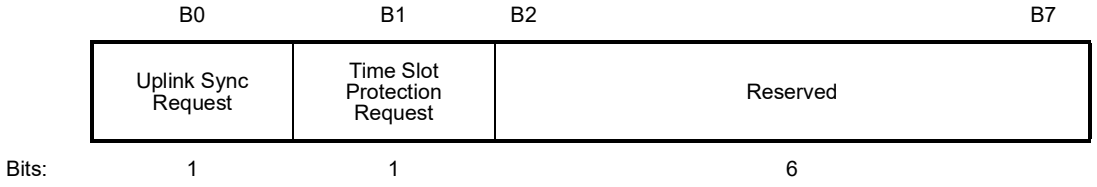


**Figure 9-192—Sync Control field format**

The non-AP STA transmitting this field indicates its mode of operation for the sync frame transmission. The subfields of the Sync Control field are defined in Table 9-113 (Subfields of the Sync Control field).

**Table 9-113—Subfields of the Sync Control field**

| Subfield | Definition | Encoding |
|---|---|---|
| Uplink Sync Request | This subfield indicates request for sync frame transmission for uplink. (see 10.48 (Sync frame operation)) | Set to 0 if not requested.<br>Set to 1 if requested. |
| Time Slot Protection Request | This subfield indicates request for a time slot protection during a time slot in a RAW (9.4.2.190 (RPS element)) or for a duration defined in the Nominal Minimum TWT Wake Duration field for a TWT time (9.4.2.198 (TWT element)), or for the duration of a TXOP after the expiration of wakeup timer. | Set to 0 if not requested.<br>Set to 1 if requested. |

### 9.4.1.57 Suspend Duration field

The format of the Suspend Duration field is shown in Figure 9-193 (Suspend Duration field format).

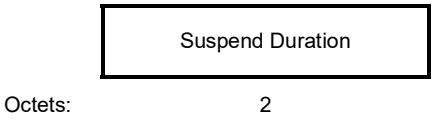


**Figure 9-193—Suspend Duration field format**


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The Suspend Duration field contains an unsigned integer. See 10.60 (S1G flow control) for the use of this field.

### 9.4.1.58 TWT Information field

The TWT Information field is present in the TWT Information frame (see 9.6.24.12 (TWT Information frame format)). The TWT Information field format is shown in Figure 9-194 (TWT Information field format(11ax)).

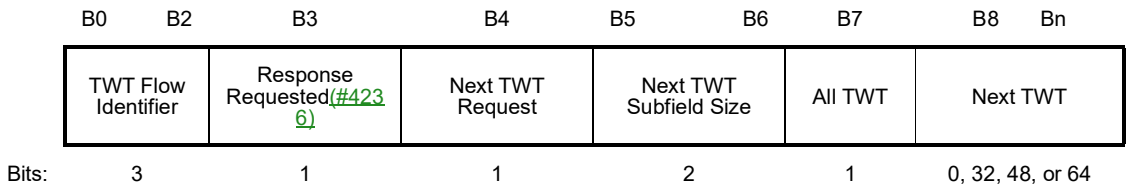


**Figure 9-194—TWT Information field format(11ax)**

The TWT Information field size is variable and depends on the Next TWT Size field.

The TWT Flow Identifier subfield contains the TWT flow identifier for which TWT information is requested or being provided.The TWT Flow Identifier subfield is reserved if the All TWT subfield is 1.(11ax)

The Response Requested subfield indicates whether the transmitter of the frame containing the TWT Information field is requesting a TWT Information frame to be transmitted in response to this frame. The Response Requested subfield is set to 0 to request the recipient to not transmit a TWT Information frame in response to the frame. The Response Requested subfield is set to 1 to request the recipient to transmit a TWT Information frame in response to the frame.

The Next TWT Request subfield is set to 1 to indicate that the TWT Information frame is a request for the delivery of a TWT Information frame containing a nonzero length Next TWT field. Otherwise, it is set to 0.

The Next TWT Subfield Size subfield describes the size of the Next TWT subfield according to Table 9-114 (Next TWT Subfield Size subfield encoding).

**Table 9-114—Next TWT Subfield Size subfield encoding**

| Next TWT Subfield Size subfield value | Size of the Next TWT subfield in bits |
|---|---|
| 0 | 0 |
| 1 | 32 |
| 2 | 48 |
| 3 | 64 |

(11ax)The All TWT subfield is set to 1 by an HE STA to indicate that the TWT Information frame reschedules all TWTs as defined in 26.8.4 (Use of TWT Information frames). Otherwise, it is set to 0.

The Next TWT subfield is of a variable size as determined by the Next TWT Subfield Size subfield value according to Table 9-114 (Next TWT Subfield Size subfield encoding). The value contained in the Next

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TWT subfield is the least significant portion of the TSF at the next TWT for the TWT specified by the TWT Flow Identifier subfield.

NOTE—The Next TWT subfield might carry only a portion of the target TSF time, and changes in the most significant octets of the corresponding target TSF time are not communicated to the receiving STA. Hence, the receiving STA must consider and account for a rollover of the corresponding most significant octets of the target TSF time that might happen at the receiving STA.(#7083)

### 9.4.1.59 CMMG MIMO Control field

The CMMG MIMO Control field is used to manage the exchange of CMMG MIMO channel state or transmit beamforming feedback information. It is used in the CMMG Compressed Beamforming (see 9.6.29.2 (CMMG Compressed Beamforming frame format)).

The CMMG MIMO Control field is defined in Figure 9-195 (CMMG MIMO Control field format).

| | B0B1 | B2B3 | B4 | B5 B6 | B7 B8 | B9 B11 | B12 B13 | B14 B37 | B38 B39 |
|---|---|---|---|---|---|---|---|---|---|
| | Nc Index | Nr Index | Channel Width | Grouping | Codebook Information | Remaining Matrix Segment | Reserved | Sounding Timestamp | Reserved |
| Bits: | 2 | 2 | 1 | 2 | 2 | 3 | 2 | 24 | 2 |

**Figure 9-195—CMMG MIMO Control field format**

The subfields of the CMMG MIMO Control field are defined in Table 9-115 (Subfields of the CMMG MIMO Control field).

**Table 9-115—Subfields of the CMMG MIMO Control field**

| Subfield | Description |
|---|---|
| *Nc* Index | Indicates the number of columns in the compressed beamforming feedback matrix minus 1. |
| *Nr* Index | Indicates the number of rows in the compressed beamforming feedback matrix minus 1. |
| Channel Width | Indicates the width of the channel in which a measurement was made:<br>Set to 0 for 540 MHz<br>Set to 1 for 1080 MHz |
| Grouping | Indicates the number of subcarriers grouped into one:<br>Set to 0 for $N_g = 1$ (No grouping)<br>Set to 1 for $N_g = 2$<br>Set to 2 for $N_g = 4$<br>Set to 3 for $N_g = 6$ |
| Codebook Information | Indicates the size of codebook entries:<br>Set to 0 for 2 bits for $\psi$ , 4 bits for $\phi$<br>Set to 1 for 3 bits for $\psi$ , 5 bits for $\phi$<br>The value 2 and 3 are reserved. |
| Remaining Matrix Segments | Contains the remaining segment number for the associated measurement report.<br>Set to 0 for the last segment of a segmented report or the only segment of an unsegmented report. |
| Sounding Timestamp | Contains the lower 3 octets of the TSF timer sampled at the instant that the MAC received the PHY-CCA.indication(IDLE) primitive that corresponds to the end of the reception of the sounding PPDU that was used to generate feedback information contained in the frame. |


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#### 9.4.1.60 CMMG Compressed Beamforming Report field

The CMMG Compressed Beamforming Report field is used by the CMMG Compressed Beamforming frame (see 9.6.29.2 (CMMG Compressed Beamforming frame format)) to carry explicit feedback information in the form of angles representing compressed beamforming feedback matrices V for use by a transmit CMMG beamformer to determine steering matrices Q, as described in 10.33.5 (Explicit feedback beamforming for CMMG STAs) and 25.6.8.13 (Beamforming).

The size of the CMMG Compressed Beamforming Report field depends on the values in the CMMG MIMO Control field.

The CMMG Compressed Beamforming Report field contains the channel matrix elements indexed, first, by matrix angles in the order shown in Table 9-116 (Order of angles in the CMMG Compressed Beamforming Report field), second, by data subcarrier index from lowest frequency to highest frequency. The explanation of how these angles are generated from the beamforming feedback matrix $V$ is given in 25.6.8.13.2 (Compressed Beamforming feedback matrix).

**Table 9-116—Order of angles in the CMMG Compressed Beamforming Report field**

| Size of $V$ ($Nr \times Nc$) | Number of angles ($Na$) | The order of angles in the compressed beamforming feedback matrix |
|---|---|---|
| 2 × 1 | 2 | $\varphi_{1,1}, \psi_{2,1}$ |
| 2 × 2 | 2 | $\varphi_{1,1}, \psi_{2,1}$ |
| 3 × 1 | 4 | $\varphi_{1,1}, \varphi_{2,1}, \psi_{2,1}, \psi_{3,1}$ |
| 3 × 2 | 6 | $\varphi_{1,1}, \varphi_{2,1}, \psi_{2,1}, \psi_{3,1}, \varphi_{2,2}, \psi_{3,2}$ |
| 3 × 3 | 6 | $\varphi_{1,1}, \varphi_{2,1}, \psi_{2,1}, \psi_{3,1}, \varphi_{2,2}, \psi_{3,2}$ |
| 4 × 1 | 6 | $\varphi_{1,1}, \varphi_{2,1}, \varphi_{3,1}, \psi_{2,1}, \psi_{3,1}, \psi_{4,1}$ |
| 4 × 2 | 10 | $\varphi_{1,1}, \varphi_{2,1}, \varphi_{3,1}, \psi_{2,1}, \psi_{3,1}, \psi_{4,1}, \varphi_{2,2}, \varphi_{3,2}, \psi_{3,2}, \psi_{4,2}$ |
| 4 × 3 | 12 | $\varphi_{1,1}, \varphi_{2,1}, \varphi_{3,1}, \psi_{2,1}, \psi_{3,1}, \psi_{4,1}, \varphi_{2,2}, \varphi_{3,2}, \psi_{3,2}, \psi_{4,2}, \varphi_{3,3}, \psi_{4,3}$ |
| 4 × 4 | 12 | $\varphi_{1,1}, \varphi_{2,1}, \varphi_{3,1}, \psi_{2,1}, \psi_{3,1}, \psi_{4,1}, \varphi_{2,2}, \varphi_{3,2}, \psi_{3,2}, \psi_{4,2}, \varphi_{3,3}, \psi_{4,3}$ |

The angles are quantized as defined in Table 9-117 (Quantization of angles).(#3237)

**Table 9-117—Quantization of angles**

| Quantized $\psi$ | Quantized $\varphi$ |
|---|---|
| $\psi = \frac{k\pi}{2^{b_\psi+1}} + \frac{\pi}{2^{b_\psi+2}}$ radians<br>where $k = 0, 1, \ldots, 2^{b_\psi} - 1$<br><br>$b_\psi$ is the number of bits used to quantize $\psi$ defined by the Codebook Information field of the CMMG MIMO Control field | $\varphi = \frac{k\pi}{2^{b_\varphi+1}} + \frac{\pi}{2^{b_\varphi+2}}$ radians<br>where $k = 0, 1, \ldots, 2^{b_\varphi} - 1$<br><br>$b_\varphi$ is the number of bits used to quantize $\varphi$ defined by the Codebook Information field of the CMMG MIMO Control field |

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The CMMG(#4014) Compressed Beamforming Report field has the structure defined in Table 9-118 (CMMG(#4014) Compressed Beamforming Report field), where *Na* is the number of angles used for the CMMG compressed beamforming feedback matrix.

**Table 9-118—CMMG(#4014) Compressed Beamforming Report field**

| Field | Size (bits) | Meaning |
|---|---|---|
| Average SNR of Space-Time Stream 1 | 8 | Signal-to-noise ratio at the beamformee for space-time stream 1 averaged over all data subcarriers |
| ... | ... | ... |
| Average SNR of Space-Time Stream *Nc* | 8 | Signal-to-noise ratio at the beamformee for space-time stream *Nc* averaged over all data subcarriers. |
| Compressed Beamforming Feedback Matrix *V* for Subcarrier $k = scidx(0)$ | $Na \times (b_{\varphi} + b_{\psi})/2$ | Compressed beamforming feedback matrix |
| Compressed Beamforming Feedback Matrix *V* for Subcarrier $k = scidx(1)$ | $Na \times (b_{\varphi} + b_{\psi})/2$ | Compressed beamforming feedback matrix |
| Compressed Beamforming Feedback Matrix *V* for Subcarrier $k = scidx(2)$ | $Na \times (b_{\varphi} + b_{\psi})/2$ | Compressed beamforming feedback matrix |
| ... | ... | ... |
| Compressed Beamforming Feedback Matrix *V* for Subcarrier $k = scidx(Ns - 1)$ | $Na \times (b_{\varphi} + b_{\psi})/2$ | Compressed beamforming feedback matrix |
| NOTE— *scidx()* is defined in Table 9-119 (Subcarrier indices for which a compressed beamforming feedback matrix is sent back). | | |

*Ns* is the number of subcarriers for which the CMMG compressed beamforming feedback matrix is sent back to the CMMG beamformer. *Ns* is a function of the Channel Width and Grouping subfields in the CMMG MIMO Control field. Table 9-119 (Subcarrier indices for which a compressed beamforming feedback matrix is sent back) lists *Ns*, the exact subcarrier indices and their order for which the CMMG (#4014)compressed beamforming feedback matrix is sent back. No padding is present between angles in the CMMG Compressed Beamforming Report field(#4014), even if they correspond to different subcarriers. If the length of the CMMG Compressed Beamforming Report field is not an integral multiple of 8 bits, up to 7 0s are appended to the end of the field to make its size an integral multiple of 8 bits.


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**Table 9-119—Subcarrier indices for which a compressed beamforming feedback matrix is sent back**

| Channel width | $N_g$ | $Ns$ | Subcarrier indices for which compressed beamforming feedback matrix is sent: *scidx*(0), *scidx*(1), …, *scidx*(*Ns*–1) |
|---|---|---|---|
| 540 MHz | 1 | 168 | –89, –88, –87, –86, –85, –84, –83, –82, –81, –80, –79, –78, –76, –75, –74, –73, –72, –71, –70, –69, –68, –67, –66, –65, –64, –63, –62, –61, –60, –59, –58, –57, –56, –54, –53, –52, –51, –50, –49, –48, –47, –46, –45, –44, –43, –42, –41, –40, –39, –38, –37, –36, –35, –34, –32, –31, –30, –29, –28, –27, –26, –25, –24, –23, –22, –21, –20, –19, –18, –17, –16, –15, –14, –13, –12, –10, –9, –8, –7, –6, –5, –4, –3, –2, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89<br>NOTE—Pilot subcarriers (± 77, ± 55, ± 33, ± 11) and DC subcarriers (0, ± 1) are skipped |
| | 2 | 90 | –89, –88, –86, –84, –82, –80, –78, –76, –74, –72, –70, –68, –66, –64, –62, –60, –58, –56 ,–54, –52, –50, –48, –46, –44, –42, –40, –38, –36, –34, –32, –30, –28, –26, –24, –22, –20, –18, –16, –14, –12, –10, –8, –6, –4, –2, 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30, 32, 34, 36, 38, 40, 42, 44, 46, 48, 50, 52, 54, 56, 58, 60, 62, 64, 66, 68, 70, 72, 74, 76, 78, 80, 82, 84, 86, 88, 89 |
| | 4 | 46 | –89, –86, –82, –78, –74, –70, –66, –62, –58, –54, –50, –46, –42, –38, –34, –30, –26, –22, –18, –14, –10, –6, –2, 2, 6, 10, 14, 18, 22, 26, 30, 34, 38, 42, 46, 50, 54, 58, 62, 66, 70, 74, 78, 82, 86, 89 |
| | 6 | 32 | –89, –86, –80, –74, –68, –62, –56, –50, –44, –38, –32, –26, –20, –14, –8, –2, 2, 8, 14, 20, 26, 32, 38, 44, 50, 56, 62, 68, 74, 80, 86, 89 |
| 1080 MHz | 1 | 336 | –177, –176, –175, –174, –173, –172, –171, –170, –169, –168, –167, –166, –164, –163, –162, –161, –160, –159, –158, –157, –156, –155, –154, –153, –152, –151, –150, –149, –148, –147, –146, –145, –144, –142, –141, –140, –139, –138, –137, –136, –135, –134, –133, –132, –131, –130, –126, –125, –124, –123, –122, –120, –119, –118, –117, –116, –115, –114, –113, –112, –111, –110, –109, –108, –107, –106, –105, –104, –103, –102, –101, –100, –98, –97, –96, –95, –94, –93, –92, –91, –90, –89, –88, –87, –86, –85, –84, –83, –82, –81, –80, –79, –78, –76, –75, –74, –73, –72, –71, –70, –69, –68, –67, –66, –65, –64, –63, –62, –61, –60, –59, –58, –57, –56, –54, –53, –52, –51, –50,–49, –48, –47, –46, –45, –44, –43, –42, –41, –40, –39, –38, –37, –36, –35, –34, –32, –31, –30, –29, –28, –27, –26, –25, –24, –23, –22, –21, –20, –19, –18, –17,–16, –15, –14, –13, –12, –10, –9, –8, –7, –6, –5, –4, –3, –2, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 56, 57, 58, 59, 60, 61,62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 78, 79, 80, 81, 82, 83,84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 100, 101, 102, 103, 104, 105, 106, 107, 108, 109, 110, 111, 112, 113, 114, 115, 116, 117, 118, 119, 120, 122, 123, 124, 125, 126, 130, 131, 132, 133, 134, 135, 136, 137, 138, 139, 140, 141, 142, 144, 145, 146, 147, 148, 149, 150, 151, 152, 153, 154, 155, 156, 157, 158, 159, 160, 161, 162, 163, 164, 166, 167, 168, 169, 170, 171, 172, 173, 174, 175, 176, 177<br>NOTE—Pilot subcarriers (± 165, ± 143, ± 121, ± 99, ± 77, ± 55, ± 33, ± 11) and DC subcarriers (0, ± 1) are skipped |

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**Table 9-119—Subcarrier indices for which a compressed beamforming feedback matrix is sent back *(continued)***

| Channel width | $N_g$ | *Ns* | Subcarrier indices for which compressed beamforming feedback matrix is sent: *scidx*(0), *scidx*(1), …, *scidx*(*Ns*–1) |
|---|---|---|---|
| 1080 MHz | 2 | 170 | –177, –176, –174, –172, –170, –168, –166, –164, –162, –160, –158, –156, –154, –152, –150, –148, –146, –144, –142, –140, –138, –136, –134, –132, –130, –128, –126, –124, –122, –120, –118, –116, –114, –112, –110, –108, –106, –104, –102, –100, –98, –96, –94, –92, –90, –88, –86, –84, –82, –80, –78, –76, –74, –72, –70, –68, –66, –64, –62, –60, –58, –56, –54, –52, –50, –48, –46, –44, –42, –40, –38, –36, –34, –32, –30, –28, –26, –24, –22, –20, –18, –16, –14, –12, –10, –8, –6, –4, –2, 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30, 32, 34, 36, 38, 40, 42, 44, 46, 48, 50, 52, 54, 56, 58, 60, 62, 64, 66, 68, 70, 72, 74, 76, 78, 80, 82, 84, 86, 88, 90, 92, 94, 96, 98, 100, 102, 104, 106, 108, 110, 112, 114, 116, 118, 120, 122, 124, 126, 128, 130, 132,134, 136, 138, 140, 142, 144, 146, 148, 150, 152, 154, 156, 158, 160, 162, 164, 166, 168, 170, 172, 174, 176, 177 |
| | 4 | 90 | –177, –174, –170, –166, –162, –158, –154, –150, –146, –142, –138, –134, –130, –126, –122, –118, –114, –110, –106, –102, –98, –94, –90, –86, –82, –78, –74, –70, –66, –62, –58, –54, –50, –46, –42, –38, –34, –30, –26, –22, –18, –14, –10, –6, –2, 2, 6, 10, 14, 18, 22, 26, 30, 34, 38, 42, 46, 50, 54, 58, 62, 66, 70, 74, 78, 82, 86, 90, 94, 98, 102, 106, 110, 114, 118, 122, 126, 130, 134, 138, 142, 146, 150, 154, 158, 162, 166, 170, 174, 177 |
| | 6 | 62 | –177, –176, –170, –164, –158, –152, –146, –140, –134, –128, –122, –116, –110, –104, –98, –92, –86, –80,–74,–68, –62, –56, –50, –44, –38, –32, –26, –20, –14, –8, –2, 2, 8, 14, 20, 26, 32, 38, 44, 50, 56, 62, 68, 74, 80, 86, 92, 98, 104, 110, 116, 122, 128, 134, 140, 146, 152, 158, 164, 170, 176, 177 |

The SNR values are encoded as an 8-bit 2s complement value of 4×(SNR_average-22), where SNR_average is the sum of the values of SNR per subcarrier (in decibels) divided by the number of subcarriers represented.

The Average SNR of Space-Time Stream *i* subfield is (#4162)a 2s complement integer whose definition is shown in Table 9-120 (Average SNR of Space-Time Stream i subfield).

**Table 9-120—Average SNR of Space-Time Stream *i* subfield**

| Average SNR of Space-Time Stream *i* subfield | $AvgSNR_i$ (dB) |
|---|---|
| –128 | ≤ –10 |
| –127 | –9.75 |
| –126 | –9.5 |
| … | … |
| +126 | 53.5 |
| +127 | 53.75 |


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#### 9.4.1.61 CMMG Operating Mode field

The CMMG Operating Mode field is present in the CMMG Operating Mode Notification frame (see 9.6.29.3 (CMMG Operating Mode Notification frame format)) and CMMG Operating Mode Notification element (see 9.4.2.230 (CMMG Operating Mode Notification element)).

The CMMG Operating Mode field is shown in Figure 9-196 (CMMG Operating Mode field format).

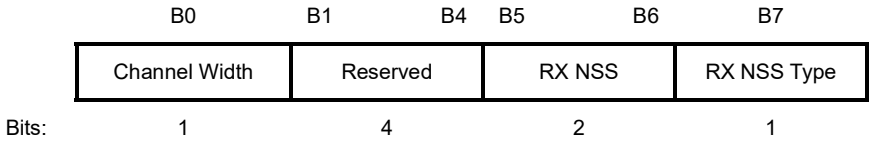


**Figure 9-196—CMMG Operating Mode field format**

The STA transmitting this field indicates its current operating channel width and the number of spatial streams it can receive using the settings defined in Table 9-121 (Subfield values of the CMMG Operating Mode field).

**Table 9-121—Subfield values of the CMMG Operating Mode field**

| Subfield | Description |
|---|---|
| Channel Width | If the RX NSS Type subfield is 0, indicates the supported channel width:<br>Set to 0 for 540 MHz<br>Set to 1 for 1080 MHz<br>Reserved if the Rx NSS Type subfield is 1 |
| RX NSS | If the RX NSS Type subfield is 0, indicates the maximum number of spatial streams that the STA can receive.<br>If the RX NSS Type subfield is 1, indicates the maximum number of spatial streams that the STA can receive as a beamformee in an SU PPDU using a beamforming steering matrix derived from a CMMG Compressed Beamforming Report field(#4014)(#317) with the Feedback Type subfield indicating SU in the corresponding CMMG Compressed Beamforming frame sent by the STA.<br>Set to 0 for NSS = 1<br>Set to 1 for NSS = 2<br>…<br>Set to 3 for NSS = 4 |
| RX NSS Type | Set to 0 to indicate that the RX NSS subfield carries the maximum number of spatial streams that the STA can receive.<br>Set to 1 to indicate that the RX NSS subfield carries the maximum number of spatial streams that the STA can receive in an SU PPDU using a beamforming steering matrix derived from a CMMG Compressed Beamforming Report field(#4014)(#317) with the Feedback Type subfield indicating SU in the corresponding CMMG Compressed Beamforming frame sent by the STA.<br>NOTE—An AP always sets this field to 0. |

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### 9.4.1.62 HE MIMO Control field(11ax)

The HE MIMO Control field is defined in Figure 9-197 (HE MIMO Control field format(11ax)).

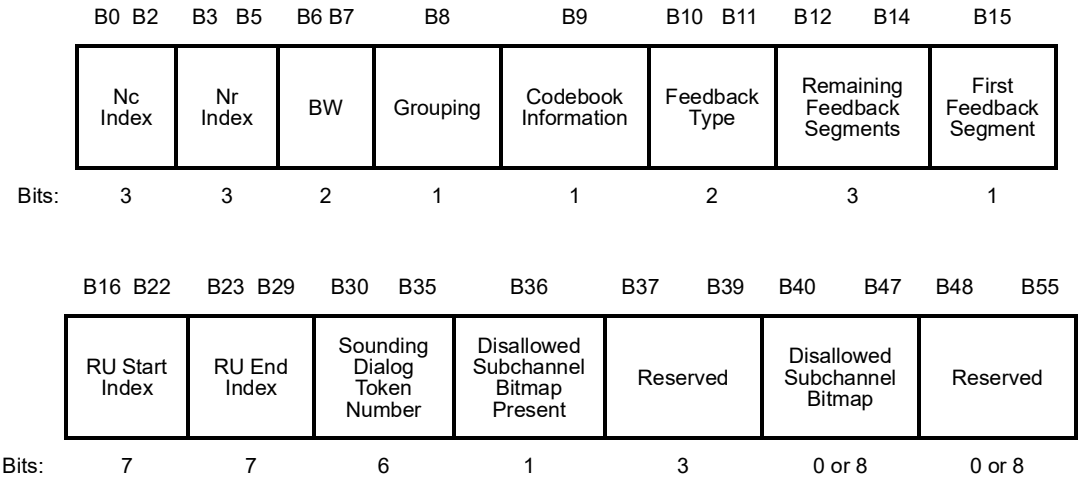


**Figure 9-197—HE MIMO Control field format(11ax)**

The subfields of the HE MIMO Control field are defined in Table 9-122 (HE MIMO Control field encoding(11ax)).

**Table 9-122—HE MIMO Control field encoding(11ax)**

| Subfield | Description |
|---|---|
| Nc Index | (#2339)If the Feedback Type subfield indicates SU or MU, the Nc Index subfield indicates the number of columns in the compressed beamforming feedback matrix minus 1, $Nc - 1$.<br><br>(#2339)If the Feedback Type subfield indicates CQI, the Nc Index subfield indicates the number of space time streams in the CQI Report minus 1, $Nc - 1$. |
| Nr Index | (#2340)If the Feedback Type subfield indicates SU or MU, then the Nr Index subfield indicates the number of rows in the compressed beamforming feedback matrix minus 1, $Nr - 1$.The value 0 is reserved.<br><br>If the Feedback Type subfield indicates CQI, then the Nr Index subfield is reserved. |
| BW | Indicates the channel width used to determine the starting and ending subcarrier indices when interpreting the RU Start Index and RU End Index subfields.<br><br>Set to 0 for 20 MHz.<br>Set to 1 for 40 MHz.<br>Set to 2 for 80 MHz.<br>Set to 3 for 160 MHz and 80+80 MHz. |
| Grouping | If the Feedback Type subfield indicates SU or MU, then the Grouping subfield indicates the subcarrier grouping, $Ng$, used for the compressed beamforming feedback matrix:<br>Set to 0 for $Ng = 4$.<br>Set to 1 for $Ng = 16$.<br><br>If the Feedback Type subfield indicates CQI, then the Grouping subfield is reserved. |


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**Table 9-122—HE MIMO Control field encoding(11ax)**

| Subfield | Description |
|---|---|
| Codebook Information | Indicates the size of codebook entries.<br><br>If the Feedback Type subfield indicates SU:<br>Set to 0 for 4 bits for ϕ and 2 bits for ψ.<br>Set to 1 for 6 bits for ϕ and 4 bits for ψ.<br><br>If the Feedback Type subfield indicates MU:<br>Set to 0 for 7 bits for ϕ and 5 bits for ψ.<br>Set to 1 for 9 bits for ϕ and 7 bits for ψ.<br><br>If the Feedback Type subfield indicates CQI, then the Codebook Information subfield is reserved.<br><br>NOTE—The codebook size for MU Feedback with *Ng* = 16 is limited to (ϕ, ψ) = {9, 7}. |
| Feedback Type | Indicates the feedback type:<br>Set to 0 for SU.<br>Set to 1 for MU.<br>Set to 2 for CQI.<br>3 is reserved. |
| Remaining Feedback Segments | Indicates the number of remaining feedback segments for the associated HE Compressed Beamforming/CQI frame:<br>Set to 0 for the last feedback segment of a segmented report or the only feedback segment of an unsegmented report.<br>Set to a value between 1 and 7 for a feedback segment that is not the last feedback segment of a segmented report.<br><br>In a retransmitted feedback segment, the subfield is set to the same value associated with the feedback segment in the original transmission. |
| First Feedback Segment | Set to 1 for the first feedback segment of a segmented report or the only feedback segment of an unsegmented report.<br>Set to 0 if not the first feedback segment or if the HE Compressed Beamforming Report field and HE MU Exclusive Beamforming Report field are not present in the frame.<br><br>In a retransmitted feedback segment, the subfield is set to the same value associated with the feedback segment in the original transmission.<br><br>NOTE—The First Feedback Segment subfield is always set to 0 if the Feedback Type subfield indicates CQI because the HE Compressed Beamforming/CQI frame(#7156) is always less than 11 454 octets in length. |
| RU Start Index | The starting RU index indicates the first 26-tone RU for which the HE beamformer is requesting feedback. |
| RU End Index | The ending RU index indicates the last 26-tone RU for which the HE beamformer is requesting feedback. |
| Sounding Dialog Token Number | Set to the same value as the Sounding Dialog Token Number field in the corresponding HE NDP Announcement frame. |

In an HE Compressed Beamforming/CQI frame (#6006)that does not include the HE Sounding Feedback Segment field (see 26.7 (HE sounding operation(#2388)) for a description of such a case), the Nc Index, Nr Index, BW, Grouping, Codebook Information, Feedback Type and Sounding Dialog Token Number subfields are reserved, the First Feedback Segment subfield is set to 0 and the Remaining Feedback Segments subfield is set to 7.

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The Disallowed Subchannel Bitmap Present subfield indicates whether a Disallowed Subchannel Bitmap subfield and a reserved field of 8 bits are present in the HE MIMO Control field. These subfields are present if the Disallowed Subchannel Bitmap Present subfield is equal to 1. These subfields are not present if the Disallowed Subchannel Bitmap Present subfield is equal to 0.

The Disallowed Subchannel Bitmap subfield is defined in 9.3.1.19 (VHT/HE/Ranging NDP Announcement frame format(11ax)(11az)).

#### 9.4.1.63 HE Compressed Beamforming Report field(11ax)

The HE Compressed Beamforming Report field carries the average SNR of each space-time stream and compressed beamforming feedback matrices *V* for use by a transmit beamformer to determine steering matrices *Q*, as described in 10.33.3 (Explicit feedback beamforming) and 19.3.12.3 (Explicit feedback beamforming).

The size of the HE Compressed Beamforming Report field depends on the values in the HE MIMO Control field. The HE Compressed Beamforming Report field contains HE Compressed Beamforming Report information. (#6006)The HE Compressed Beamforming Report field is included in the HE Compressed Beamforming/CQI Report field (see 9.4.1.66 (HE Compressed Beamforming/CQI Report field(#6006))) if the Feedback Type subfield in the HE MIMO Control field indicates SU or MU, and is not included otherwise. If the HE MIMO Control field contains a Disallowed Subchannel Bitmap subfield, then the HE Compressed Beamforming Report field does not include information for tones that are included within 242-tone RUs that are indicated as disallowed by the bitmap.

The HE Compressed Beamforming Report information contains the channel matrix elements indexed, first, by matrix angles in order shown in Table 9-101 (Order of angles in the compressed beamforming feedback matrix when used in a non-S1G band) and, second, by data and pilot subcarrier index from lowest frequency to highest frequency. An explanation of how these angles are generated from the beamforming feedback matrix *V* is given in 19.3.12.3.6 (Compressed beamforming feedback matrix), where *Nc* is the number of columns in a compressed beamforming feedback matrix determined by the Nc Index subfield of the HE MIMO Control field, and *Nr* is the number of rows in a compressed beamforming feedback matrix determined by the Nr Index subfield of the HE MIMO Control field.

The beamforming feedback matrix *V* is formed by the beamformee as follows. The beamformer transmits an HE sounding NDP with $N_{STS,NDP}$ space-time streams, where $N_{STS,NDP}$ takes a value between 2 and 8. Based on this HE sounding NDP, the beamformee estimates the $N_{RX,BFEE} \times N_{STS,NDP}$ channel, and based on that channel it determines a $Nr \times Nc$ orthogonal matrix *V*, where *Nr* and *Nc* satisfy Equation (9-3).(#1180) $N_{RX,BFEE}$ is the number of receiver chains used to receive the HE sounding NDP at the beamformee.

Further restrictions on *Nc* are described in 27.2 (HE PHY service interface). (#2341)The angles are quantized as defined in Table 9-104 (Quantization of angles) with $b_\psi$ and $b_\phi$ defined by the Codebook Information field of the HE MIMO Control field (see 9.4.1.62 (HE MIMO Control field(11ax))).

The HE Compressed Beamforming Report information has the structure and order defined in Table 9-123 (HE Compressed Beamforming Report information(11ax)), where *Na* is the number of angles used for the compressed beamforming feedback matrix (see Table 9-101 (Order of angles in the compressed beamforming feedback matrix when used in a non-S1G band)).

In Table 9-123 (HE Compressed Beamforming Report information(11ax)), *Ns* is the number of subcarriers for which a compressed beamforming feedback matrix is sent back to the beamformer. A beamformer or beamformee, depending upon which of the two determines the feedback parameters, reduces *Ns* by using a method referred to as grouping, in which only a single compressed beamforming feedback matrix is reported


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**Table 9-123—HE Compressed Beamforming Report information(11ax)**

| Field | Size (bits) | Meaning |
|---|---|---|
| Average SNR of Space-Time Stream 1 | 8 | Signal-to-noise ratio at the beamformee for space-time stream 1 averaged over all data subcarriers. See Table 9-107 (Average SNR of Space-Time Stream i subfield). |
| … | | … |
| Average SNR of Space-Time Stream Nc | 8 | Signal-to-noise ratio at the beamformee for space-time stream Nc averaged over all data subcarriers. See Table 9-107 (Average SNR of Space-Time Stream i subfield). |
| Compressed beamforming feedback matrix $V$ for subcarrier $k = scidx(0)$ | $Na \times (b_\phi + b_\psi)/2$ | Compressed beamforming feedback matrix defined in Table 9-101 (Order of angles in the compressed beamforming feedback matrix when used in a non-S1G band). |
| Compressed beamforming feedback matrix $V$ for subcarrier $k = scidx(1)$ | $Na \times (b_\phi + b_\psi)/2$ | Compressed beamforming feedback matrix defined in Table 9-101 (Order of angles in the compressed beamforming feedback matrix when used in a non-S1G band). |
| Compressed beamforming feedback matrix $V$ for subcarrier $k = scidx(2)$ | $Na \times (b_\phi + b_\psi)/2$ | Compressed beamforming feedback matrix defined inTable 9-101 (Order of angles in the compressed beamforming feedback matrix when used in a non-S1G band). |
| … | | … |
| Compressed beamforming feedback matrix $V$ for subcarrier $k = scidx(Ns - 1)$ | $Na \times (b_\phi + b_\psi)/2$ | Compressed beamforming feedback matrix defined in Table 9-101 (Order of angles in the compressed beamforming feedback matrix when used in a non-S1G band). |

for each group of *Ng* adjacent subcarriers. *Ns* is a function of the BW, RU Start Index, RU End Index and Grouping subfields in the HE MIMO Control field (see 9.4.1.62 (HE MIMO Control field(11ax))).

Subcarrier indices *scidx(0)* and *scidx(Ns – 1)* are identified by the RU Start Index and RU End Index subfields, respectively, together with the BW and Grouping subfields, as defined in Table 9-124 (Subcarrier indices scidx(0) and scidx(Ns – 1) for Ng = 4(11ax)) and Table 9-125 (Subcarrier indices scidx(0) and scidx(Ns – 1) for Ng = 16(11ax)).

**Table 9-124—Subcarrier indices *scidx*(0) and *scidx*(*Ns* – 1) for *Ng* = 4(11ax)**

| RU Index | 20 MHz | | 40 MHz | | 80 MHz | | 160 MHz | | 80+80 MHz | |
|---|---|---|---|---|---|---|---|---|---|---|
| | S | E | S | E | S | E | S | E | S | E |
| 0 | –122 | –96 | –244 | –216 | –500 | –472 | –1012 | –984 | –500(L) | –472(L) |
| 1 | –96 | –68 | –220 | –192 | –476 | –448 | –988 | –960 | –476(L) | –448(L) |
| 2 | –68 | –40 | –192 | –164 | –448 | –420 | –960 | –932 | –448(L) | –420(L) |
| 3 | –44 | –16 | –164 | –136 | –420 | –392 | –932 | –904 | –420(L) | –392(L) |

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**Table 9-124—Subcarrier indices *scidx*(0) and *scidx*(*Ns* – 1) for *Ng* = 4(11ax) *(continued)***

| RU Index | 20 MHz | | 40 MHz | | 80 MHz | | 160 MHz | | 80+80 MHz | |
|---|---|---|---|---|---|---|---|---|---|---|
| | S | E | S | E | S | E | S | E | S | E |
| 4 | –16 | 16 | –136 | –108 | –392 | –364 | –904 | –876 | –392(L) | –364(L) |
| 5 | 16 | 44 | –112 | –84 | –368 | –340 | –880 | –852 | –368(L) | –340(L) |
| 6 | 40 | 68 | –84 | –56 | –340 | –312 | –852 | –824 | –340(L) | –312(L) |
| 7 | 68 | 96 | –56 | –28 | –312 | –284 | –824 | –796 | –312(L) | –284(L) |
| 8 | 96 | 122 | –32 | –4 | –288 | –260 | –800 | –772 | –288(L) | –260(L) |
| 9 | | | 4 | 32 | –260 | –232 | –772 | –744 | –260(L) | –232(L) |
| 10 | | | 28 | 56 | –232 | –204 | –744 | –716 | –232(L) | –204(L) |
| 11 | | | 56 | 84 | –204 | –176 | –716 | –688 | –204(L) | –176(L) |
| 12 | | | 84 | 112 | –180 | –152 | –692 | –664 | –180(L) | –152(L) |
| 13 | | | 108 | 136 | –152 | –124 | –664 | –636 | –152(L) | –124(L) |
| 14 | | | 136 | 164 | –124 | –96 | –636 | –608 | –124(L) | –96(L) |
| 15 | | | 164 | 192 | –100 | –72 | –612 | –584 | –100(L) | –72(L) |
| 16 | | | 192 | 220 | –72 | –44 | –584 | –556 | –72(L) | –44(L) |
| 17 | | | 216 | 244 | –44 | –16 | –556 | –528 | –44(L) | –16(L) |
| 18 | | | | | –16 | 16 | –528 | –496 | –16(L) | 16(L) |
| 19 | | | | | 16 | 44 | –496 | –468 | 16(L) | 44(L) |
| 20 | | | | | 44 | 72 | –468 | –440 | 44(L) | 72(L) |
| 21 | | | | | 72 | 100 | –440 | –412 | 72(L) | 100(L) |
| 22 | | | | | 96 | 124 | –416 | –388 | 96(L) | 124(L) |
| 23 | | | | | 124 | 152 | –388 | –360 | 124(L) | 152(L) |
| 24 | | | | | 152 | 180 | –360 | –332 | 152(L) | 180(L) |
| 25 | | | | | 176 | 204 | –336 | –308 | 176(L) | 204(L) |
| 26 | | | | | 204 | 232 | –308 | –280 | 204(L) | 232(L) |
| 27 | | | | | 232 | 260 | –280 | –252 | 232(L) | 260(L) |
| 28 | | | | | 260 | 288 | –252 | –224 | 260(L) | 288(L) |
| 29 | | | | | 284 | 312 | –228 | –200 | 284(L) | 312(L) |
| 30 | | | | | 312 | 340 | –200 | –172 | 312(L) | 340(L) |
| 31 | | | | | 340 | 368 | –172 | –144 | 340(L) | 368(L) |
| 32 | | | | | 364 | 392 | –148 | –120 | 364(L) | 392(L) |
| 33 | | | | | 392 | 420 | –120 | –92 | 392(L) | 420(L) |
| 34 | | | | | 420 | 448 | –92 | –64 | 420(L) | 448(L) |
| 35 | | | | | 448 | 476 | –64 | –36 | 448(L) | 476(L) |
| 36 | | | | | 472 | 500 | –40 | –12 | 472(L) | 500(L) |


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**Table 9-124—Subcarrier indices *scidx*(0) and *scidx*(*Ns* – 1) for *Ng* = 4(11ax) *(continued)***

| RU Index | 20 MHz | | 40 MHz | | 80 MHz | | 160 MHz | | 80+80 MHz | |
|---|---|---|---|---|---|---|---|---|---|---|
| | S | E | S | E | S | E | S | E | S | E |
| 37 | | | | | | | 12 | 40 | –500(H) | –472(H) |
| 38 | | | | | | | 36 | 64 | –476(H) | –448(H) |
| 39 | | | | | | | 64 | 92 | –448(H) | –420(H) |
| 40 | | | | | | | 92 | 120 | –420(H) | –392(H) |
| 41 | | | | | | | 120 | 148 | –392(H) | –364(H) |
| 42 | | | | | | | 144 | 172 | –368(H) | –340(H) |
| 43 | | | | | | | 172 | 200 | –340(H) | –312(H) |
| 44 | | | | | | | 200 | 228 | –312(H) | –284(H) |
| 45 | | | | | | | 224 | 252 | –288(H) | –260(H) |
| 46 | | | | | | | 252 | 280 | –260(H) | –232(H) |
| 47 | | | | | | | 280 | 308 | –232(H) | –204(H) |
| 48 | | | | | | | 308 | 336 | –204(H) | –176(H) |
| 49 | | | | | | | 332 | 360 | –180(H) | –152(H) |
| 50 | | | | | | | 360 | 388 | –152(H) | –124(H) |
| 51 | | | | | | | 388 | 416 | –124(H) | –96(H) |
| 52 | | | | | | | 412 | 440 | –100(H) | –72(H) |
| 53 | | | | | | | 440 | 468 | –72(H) | –44(H) |
| 54 | | | | | | | 468 | 496 | –44(H) | –16(H) |
| 55 | | | | | | | 496 | 528 | –16(H) | 16(H) |
| 56 | | | | | | | 528 | 556 | 16(H) | 44(H) |
| 57 | | | | | | | 556 | 584 | 44(H) | 72(H) |
| 58 | | | | | | | 584 | 612 | 72(H) | 100(H) |
| 59 | | | | | | | 608 | 636 | 96(H) | 124(H) |
| 60 | | | | | | | 636 | 664 | 124(H) | 152(H) |
| 61 | | | | | | | 664 | 692 | 152(H) | 180(H) |
| 62 | | | | | | | 688 | 716 | 176(H) | 204(H) |
| 63 | | | | | | | 716 | 744 | 204(H) | 232(H) |
| 64 | | | | | | | 744 | 772 | 232(H) | 260(H) |
| 65 | | | | | | | 772 | 800 | 260(H) | 288(H) |
| 66 | | | | | | | 796 | 824 | 284(H) | 312(H) |
| 67 | | | | | | | 824 | 852 | 312(H) | 340(H) |
| 68 | | | | | | | 852 | 880 | 340(H) | 368(H) |
| 69 | | | | | | | 876 | 904 | 364(H) | 392(H) |

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**Table 9-124—Subcarrier indices *scidx*(0) and *scidx*(*Ns* – 1) for *Ng* = 4(11ax) *(continued)***

| RU Index | 20 MHz | | 40 MHz | | 80 MHz | | 160 MHz | | 80+80 MHz | |
|---|---|---|---|---|---|---|---|---|---|---|
| | S | E | S | E | S | E | S | E | S | E |
| 70 | | | | | | | 904 | 932 | 392(H) | 420(H) |
| 71 | | | | | | | 932 | 960 | 420(H) | 448(H) |
| 72 | | | | | | | 960 | 988 | 448(H) | 476(H) |
| 73 | | | | | | | 984 | 1012 | 472(H) | 500(H) |

NOTE 1—S denotes subcarrier index *scidx*(0), identified by the RU Start Index subfield; E denotes subcarrier index *scidx*(*Ns* – 1), identified by the RU End Index subfield.

NOTE 2—*x*(L) denotes subcarrier index *x* in the frequency segment lower in frequency, and *x*(H) denotes subcarrier index *x* in the frequency segment higher in frequency.

**Table 9-125—Subcarrier indices *scidx*(0) and *scidx*(*Ns* – 1) for *Ng* = 16(11ax)**

| RU Index | 20 MHz | | 40 MHz | | 80 MHz | | 160 MHz | | 80+80 MHz | |
|---|---|---|---|---|---|---|---|---|---|---|
| | S | E | S | E | S | E | S | E | S | E |
| 0 | –122 | –84 | –244 | –212 | –500 | –468 | –1012 | –980 | –500(L) | –468(L) |
| 1 | –100 | –68 | –228 | –180 | –484 | –436 | –996 | –948 | –484(L) | –436(L) |
| 2 | –68 | –36 | –196 | –164 | –452 | –420 | –964 | –932 | –452(L) | –420(L) |
| 3 | –52 | –4 | –164 | –132 | –420 | –388 | –932 | –900 | –420(L) | –388(L) |
| 4 | –20 | 20 | –148 | –100 | –404 | –356 | –916 | –868 | –404(L) | –356(L) |
| 5 | 4 | 52 | –116 | –84 | –372 | –340 | –884 | –852 | –372(L) | –340(L) |
| 6 | 36 | 68 | –84 | –52 | –340 | –308 | –852 | –820 | –340(L) | –308(L) |
| 7 | 68 | 100 | –68 | –20 | –324 | –276 | –836 | –788 | –324(L) | –276(L) |
| 8 | 84 | 122 | –36 | –4 | –292 | –260 | –804 | –772 | –292(L) | –260(L) |
| 9 | | | 4 | 36 | –260 | –228 | –772 | –740 | –260(L) | –228(L) |
| 10 | | | 20 | 68 | –244 | –196 | –756 | –708 | –244(L) | –196(L) |
| 11 | | | 52 | 84 | –212 | –164 | –724 | –676 | –212(L) | –164(L) |
| 12 | | | 84 | 116 | –180 | –148 | –692 | –660 | –180(L) | –148(L) |
| 13 | | | 100 | 148 | –164 | –116 | –676 | –628 | –164(L) | –116(L) |
| 14 | | | 132 | 164 | –132 | –84 | –644 | –596 | –132(L) | –84(L) |
| 15 | | | 164 | 196 | –100 | –68 | –612 | –580 | –100(L) | –68(L) |
| 16 | | | 180 | 228 | –84 | –36 | –596 | –548 | –84(L) | –36(L) |
| 17 | | | 212 | 244 | –52 | –4 | –564 | –516 | –52(L) | –4(L) |
| 18 | | | | | –20 | 20 | –532 | –492 | –20(L) | 20(L) |
| 19 | | | | | 4 | 52 | –508 | –460 | 4(L) | 52(L) |



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**Table 9-125—Subcarrier indices *scidx*(0) and *scidx*(*Ns* – 1) for *Ng* = 16(11ax) *(continued)***

| RU Index | 20 MHz | | 40 MHz | | 80 MHz | | 160 MHz | | 80+80 MHz | |
|---|---|---|---|---|---|---|---|---|---|---|
| | S | E | S | E | S | E | S | E | S | E |
| 20 | | | | | 36 | 84 | –476 | –428 | 36(L) | 84(L) |
| 21 | | | | | 68 | 100 | –444 | –412 | 68(L) | 100(L) |
| 22 | | | | | 84 | 132 | –428 | –380 | 84(L) | 132(L) |
| 23 | | | | | 116 | 164 | –396 | –348 | 116(L) | 164(L) |
| 24 | | | | | 148 | 180 | –364 | –332 | 148(L) | 180(L) |
| 25 | | | | | 164 | 212 | –348 | –300 | 164(L) | 212(L) |
| 26 | | | | | 196 | 244 | –316 | –268 | 196(L) | 244(L) |
| 27 | | | | | 228 | 260 | –284 | –252 | 228(L) | 260(L) |
| 28 | | | | | 260 | 292 | –252 | –220 | 260(L) | 292(L) |
| 29 | | | | | 276 | 324 | –236 | –188 | 276(L) | 324(L) |
| 30 | | | | | 308 | 340 | –204 | –172 | 308(L) | 340(L) |
| 31 | | | | | 340 | 372 | –172 | –140 | 340(L) | 372(L) |
| 32 | | | | | 356 | 404 | –156 | –108 | 356(L) | 404(L) |
| 33 | | | | | 388 | 420 | –124 | –92 | 388(L) | 420(L) |
| 34 | | | | | 420 | 452 | –92 | –60 | 420(L) | 452(L) |
| 35 | | | | | 436 | 484 | –76 | –28 | 436(L) | 484(L) |
| 36 | | | | | 468 | 500 | –44 | –12 | 468(L) | 500(L) |
| 37 | | | | | | | 12 | 44 | –500(H) | –468(H) |
| 38 | | | | | | | 28 | 76 | –484(H) | –436(H) |
| 39 | | | | | | | 60 | 92 | –452(H) | –420(H) |
| 40 | | | | | | | 92 | 124 | –420(H) | –388(H) |
| 41 | | | | | | | 108 | 156 | –404(H) | –356(H) |
| 42 | | | | | | | 140 | 172 | –372(H) | –340(H) |
| 43 | | | | | | | 172 | 204 | –340(H) | –308(H) |
| 44 | | | | | | | 188 | 236 | –324(H) | –276(H) |
| 45 | | | | | | | 220 | 252 | –292(H) | –260(H) |
| 46 | | | | | | | 252 | 284 | –260(H) | –228(H) |
| 47 | | | | | | | 268 | 316 | –244(H) | –196(H) |
| 48 | | | | | | | 300 | 348 | –212(H) | –164(H) |
| 49 | | | | | | | 332 | 364 | –180(H) | –148(H) |
| 50 | | | | | | | 348 | 396 | –164(H) | –116(H) |
| 51 | | | | | | | 380 | 428 | –132(H) | –84(H) |

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**Table 9-125—Subcarrier indices *scidx*(0) and *scidx*(*Ns* – 1) for *Ng* = 16(11ax) *(continued)***

| RU Index | 20 MHz | | 40 MHz | | 80 MHz | | 160 MHz | | 80+80 MHz | |
|---|---|---|---|---|---|---|---|---|---|---|
| | S | E | S | E | S | E | S | E | S | E |
| 52 | | | | | | | 412 | 444 | –100(H) | –68(H) |
| 53 | | | | | | | 428 | 476 | –84(H) | –36(H) |
| 54 | | | | | | | 460 | 508 | –52(H) | –4(H) |
| 55 | | | | | | | 492 | 532 | –20(H) | 20(H) |
| 56 | | | | | | | 516 | 564 | 4(H) | 52(H) |
| 57 | | | | | | | 548 | 596 | 36(H) | 84(H) |
| 58 | | | | | | | 580 | 612 | 68(H) | 100(H) |
| 59 | | | | | | | 596 | 644 | 84(H) | 132(H) |
| 60 | | | | | | | 628 | 676 | 116(H) | 164(H) |
| 61 | | | | | | | 660 | 692 | 148(H) | 180(H) |
| 62 | | | | | | | 676 | 724 | 164(H) | 212(H) |
| 63 | | | | | | | 708 | 756 | 196(H) | 244(H) |
| 64 | | | | | | | 740 | 772 | 228(H) | 260(H) |
| 65 | | | | | | | 772 | 804 | 260(H) | 292(H) |
| 66 | | | | | | | 788 | 836 | 276(H) | 324(H) |
| 67 | | | | | | | 820 | 852 | 308(H) | 340(H) |
| 68 | | | | | | | 852 | 884 | 340(H) | 372(H) |
| 69 | | | | | | | 868 | 916 | 356(H) | 404(H) |
| 70 | | | | | | | 900 | 932 | 388(H) | 420(H) |
| 71 | | | | | | | 932 | 964 | 420(H) | 452(H) |
| 72 | | | | | | | 948 | 996 | 436(H) | 484(H) |
| 73 | | | | | | | 980 | 1012 | 468(H) | 500(H) |

NOTE 1—S denotes subcarrier index *scidx*(0), identified by the RU Start Index subfield; E denotes subcarrier index *scidx*(*Ns* – 1), identified by the RU End Index subfield.

NOTE 2—*x*(L) denotes subcarrier index *x* in the frequency segment lower in frequency, and *x*(H) denotes subcarrier index *x* in the frequency segment higher in frequency.



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Subcarrier indices *scidx*(*i*), *i* = 0, …, *Ns* – 1 are the subset of the subcarrier indices identified by the BW and Grouping subfields, as defined in Table 9-126 (Subcarrier indices for compressed beamforming feedback matrix(11ax)), starting with *scidx*(0) and ending with *scidx*(*Ns* – 1), in the order given.

NOTE 1—This implicitly defines *Ns*.

NOTE 2—For full-bandwidth feedback, subcarrier indices *scidx*(*i*), *i* = 0, …, *Ns* – 1 are the entire superset shown in Table 9-126 (Subcarrier indices for compressed beamforming feedback matrix(11ax)), in the order given.

**Table 9-126—Subcarrier indices for compressed beamforming feedback matrix(11ax)**

| Channel width | *Ng* | Superset of subcarrier indices (*scidx*) |
|---|---|---|
| 20 MHz | 4 | –122, –120, –116, …, –8, –4, –2, 2, 4, 8, …, 116, 120, 122 |
| | 16 | –122, –116, –100, …, –20, –4, –2, 2, 4, 20, …, 100, 116, 122 |
| 40 MHz | 4 | –244, –240, …, –8, –4, 4, 8, …, 240, 244 |
| | 16 | –244, –228, …, –20, –4, 4, 20, …, 228, 244 |
| 80 MHz | 4 | –500, –496, …, –8, –4, 4, 8, …, 496, 500 |
| | 16 | –500, –484, …, –20, –4, 4, 20, …, 484, 500 |
| 160 MHz | 4 | –1012, –1008, …, –520, –516, –508, –504, …, –16, –12, 12, 16, …, 504, 508, 516, 520, …, 1008, 1012 |
| | 16 | –1012, –996, …, –532, –516, –508, –492, …, –28, –12, 12, 28, …, 492, 508, 516, 532, …, 996, 1012 |
| 80+80 MHz | 4 | –500(L), –496(L), …, –8(L), –4(L), 4(L), 8(L), …, 496(L), 500(L), –500(H), –496(H), …, –8(H), –4(H), 4(H), 8(H), …, 496(H), 500(H) |
| | 16 | –500(L), –484(L), …, –20(L), –4(L), 4(L), 20(L), …, 484(L), 500(L), –500(H), –484(H), …, –20(H), –4(H), 4(H), 20(H), …, 484(H), 500(H) |

NOTE 1—*x*(L) denotes subcarrier index *x* in the frequency segment lower in frequency, and *x*(H) denotes subcarrier index *x* in the frequency segment higher in frequency.

NOTE 2—"…" denotes an arithmetic progression in *Ng* increments.

NOTE 3—Pilot subcarriers are not skipped.

The Average SNR of Space-Time Stream *i* subfield in Table 9-123 (HE Compressed Beamforming Report information(11ax)) is (#4162)a 2s complement integer defined in Table 9-107 (Average SNR of Space-Time Stream i subfield).

The $AvgSNR_i$ in Table 9-107 (Average SNR of Space-Time Stream i subfield) is found by computing the SNR per subcarrier in decibels for the subcarriers identified in Table 9-124 (Subcarrier indices scidx(0) and scidx(Ns – 1) for Ng = 4(11ax)) for *Ng* = 4 and Table 9-125 (Subcarrier indices scidx(0) and scidx(Ns – 1) for Ng = 16(11ax)) for *Ng* = 16, and then computing the arithmetic mean of those values. Each SNR value per subcarrier in stream *i* (before being averaged) corresponds to the SNR associated with column *i* of the beamforming feedback matrix *V* determined at the beamformee. Each SNR corresponds to the predicted SNR at the beamformee when the beamformer applies all columns of the matrix V.

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The computation of the $AvgSNR_i$ values does not include channel information from subcarriers that lie within 242-tone RUs that are indicated as punctured by the Disallowed Subchannel Bitmap subfield, if present, of the HE NDP Announcement frame that solicited the feedback.

Padding is not present between angles in the HE Compressed Beamforming Report information, even if they correspond to different subcarriers. If the size of the HE Compressed Beamforming Report information is not an integer multiple of 8 bits, up to seven 0s are appended to the end of the field to make its size an integer multiple of 8 bits.

#### 9.4.1.64 HE MU Exclusive Beamforming Report field(11ax)

The HE MU Exclusive Beamforming Report field carries explicit feedback in the form of delta SNRs. The information in the HE Compressed Beamforming Report field and the HE MU Exclusive Beamforming Report field can be used by the transmit MU beamformer to determine the steering matrices *Q*, as described in 27.3.3.1 (DL MU-MIMO).

The size of the HE MU Exclusive Beamforming Report field depends on the values in the HE MIMO Control field. The HE MU Exclusive Beamforming Report field contains HE MU Exclusive Beamforming Report information. (#6006)The HE MU Exclusive Beamforming Report field is included in the HE Compressed Beamforming/CQI Report field (see 9.4.1.66 (HE Compressed Beamforming/CQI Report field(#6006))) (in addition to the HE Compressed Beamforming Report field) if the Feedback Type subfield in the HE MIMO Control field indicates MU, and is not included otherwise. If the HE MIMO Control field contains a Disallowed Subchannel Bitmap subfield, then the HE MU Exclusive Beamforming Report field does not include information for tones that are included within 242-tone RUs that are indicated as disallowed by the bitmap.

The HE MU Exclusive Beamforming Report information consists of Delta SNR subfields for each of the space-time streams, 1 to *Nc*, of a subset of subcarriers typically spaced *Ng* apart, where *Ng* is signaled in the Grouping subfield of the HE MIMO Control field. The subset of subcarriers starts from the lowest frequency subcarrier and continues to the highest frequency subcarrier. The subcarrier indices of the feedback for each Delta SNR subfield are identical to the subcarrier indices for the compressed beamforming feedback matrix *V*.

NOTE—The feedback subcarrier spacings are mostly equal to *Ng*, but there are a few exceptions, generally around the RU edge and the DC tone, where extra feedback subcarriers are added to improve the channel interpolation/extrapolation quality.

No padding is present between $\Delta SNR_{k,i}$, in the HE MU Exclusive Beamforming Report field, even if they correspond to different subcarriers. The subset of subcarriers included is determined by the values of the RU Start Index, RU End Index, and Grouping subfields of the HE MIMO Control field. For each subcarrier included, the deviation in dB of the SNR of that subcarrier for each column of *V* relative to the average SNR of the corresponding space-time stream is computed using Equation (9-4),(#1181) except that *k* is the subcarrier index in the range $scidx(0), \ldots, scidx(Ns-1)$ and $\overline{SNRi}$ is the average SNR of space-time stream *i* reported in the Average SNR of Space-Time Stream *i* field of the HE Compressed Beamforming Report information(#4014). In Equation (9-4),(#1181) the average SNR value is computed only for subcarriers that are not indicated as disallowed by a Disallowed Subchannel Bitmap subfield, when it is present.


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The HE MU Exclusive Beamforming Report information has the structure and order defined in Table 9-127 (HE MU Exclusive Beamforming Report information(11ax)).

**Table 9-127—HE MU Exclusive Beamforming Report information(11ax)**

| Field | Size (bits) | Meaning |
|---|---|---|
| Delta SNR for space-time stream 1 for subcarrier $k = scidx(0)$ | 4 | $\Delta SNR_{scidx(0),1}$ as defined in Equation (9-2) as modified above. |
| … | | … |
| Delta SNR for space-time stream $Nc$ for subcarrier $k = scidx(0)$ | 4 | $\Delta SNR_{scidx(0),Nc}$ as defined in Equation (9-2) as modified above. |
| Delta SNR for space-time stream 1 for subcarrier $k = scidx(1)$ | 4 | $\Delta SNR_{scidx(1),1}$ as defined in Equation (9-2) as modified above. |
| … | | … |
| Delta SNR for space-time stream $Nc$ for subcarrier $k = scidx(1)$ | 4 | $\Delta SNR_{scidx(1),Nc}$ as defined in Equation (9-2) as modified above. |
| … | | … |
| Delta SNR for space-time stream 1 for subcarrier $k = scidx(Ns - 1)$ | 4 | $\Delta SNR_{scidx(Ns-1),1}$ as defined in Equation (9-2) as modified above. |
| … | | … |
| Delta SNR for space-time stream $Nc$ for subcarrier $k = scidx(Ns - 1)$ | 4 | $\Delta SNR_{scidx(Ns-1),Nc}$ as defined in Equation (9-2) as modified above. |

In Table 9-127 (HE MU Exclusive Beamforming Report information(11ax)), *Ns* and *scidx()* are defined in 9.4.1.63 (HE Compressed Beamforming Report field(11ax)).

### 9.4.1.65 HE CQI Report field(11ax)

The HE CQI Report field carries the per-RU average SNRs of each space-time stream, where each per-RU average SNR is the arithmetic mean of the SNR in decibels over a 26-tone RU for which the feedback is being requested. The HE CQI Report field contains information about the quality of the link.

The size of the HE CQI Report field depends on the values in the HE MIMO Control field. The HE CQI Report field contains HE CQI Report information. HE CQI Report information is included in the (#6006)HE Compressed Beamforming/CQI Report field (see 9.4.1.66 (HE Compressed Beamforming/CQI Report field(#6006))) if the Feedback Type subfield in the HE MIMO Control field indicates CQI feedback, and is not included otherwise.(#6006) If the HE MIMO Control field contains a Disallowed Subchannel Bitmap subfield, then the HE CQI Report field does not include information for tones that are included within 26-tone RUs that are indicated as disallowed by the bitmap.

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The HE CQI Report field has the structure and order defined in Table 9-128 (HE CQI Report information(11ax)).

**Table 9-128—HE CQI Report information(11ax)**

| Field | Size (bits) | Meaning |
|---|---|---|
| Average SNR for space-time stream 1 for RU index $k$ = *ruidx*(0) | 6 | SNR at the beamformee for space-time stream 1 averaged over 26-tone RU. See Table 9-129 (Average SNR of RU index k for space-time stream i subfield(11ax)). |
| … | | … |
| Average SNR for space-time stream *Nc* for RU index $k$ = *ruidx*(0) | 6 | SNR at the beamformee for space-time stream *Nc* averaged over 26-tone RU. See Table 9-129 (Average SNR of RU index k for space-time stream i subfield(11ax)). |
| Average SNR for space-time stream 1 for RU index $k$ = *ruidx*(1) | 6 | SNR at the beamformee for space-time stream 1 averaged over 26-tone RU. See Table 9-129 (Average SNR of RU index k for space-time stream i subfield(11ax)). |
| … | | … |
| Average SNR for space-time stream *Nc* for RU index $k$ = *ruidx*(1) | 6 | SNR at the beamformee for space-time stream *Nc* averaged over 26-tone RU. See Table 9-129 (Average SNR of RU index k for space-time stream i subfield(11ax)). |
| … | | … |
| Average SNR for space-time stream 1 for RU index $k$ = *ruidx*(*Ncqi* – 1) | 6 | SNR at the beamformee for space-time stream 1 averaged over 26-tone RU. See Table 9-129 (Average SNR of RU index k for space-time stream i subfield(11ax)). |
| … | | … |
| Average SNR for space-time stream *Nc* for RU index $k$ = *ruidx*(*Ncqi* – 1) | 6 | SNR at the beamformee for space-time stream *Nc* averaged over 26-tone RU. See Table 9-129 (Average SNR of RU index k for space-time stream i subfield(11ax)). |

*Ncqi* is the number of RU indices for which the CQI report is sent back to the beamformer. *Ncqi* = (*ruidx*(*Ncqi* – 1) – *ruidx*(0)) + 1 – Disallowed # of RU26, where *ruidx*(0) and *ruidx*(*Ncqi* – 1) are equal to the RU Start Index and RU End Index subfields, respectively. The RU index *ruidx*($i$) = *ruidx*($i$ – 1) + 1, where $1 \le i \le Ncqi - 2$. The 26-tone RU subcarrier indices for 20 MHz, 40 MHz, and 80 MHz are defined in Table 27-8 (Data and pilot subcarrier indices for RUs in a 20 MHz HE PPDU and in a non-OFDMA 20 MHz HE PPDU(11ax)), Table 27-9 (Data and pilot subcarrier indices for RUs in a 40 MHz HE PPDU and in a non-OFDMA 40 MHz HE PPDU(11ax)), and Table 27-10 (Data and pilot subcarrier indices for RUs in an 80 MHz HE PPDU and in a non-OFDMA 80 MHz HE PPDU(11ax)), respectively.

The Average SNR of space-time stream $i$ for the RU index $k$ subfield in (#6291)Table 9-128 (HE CQI Report information(11ax)) is a 6-bit 2s complement integer whose definition is shown in Table 9-129 (Average SNR of RU index k for space-time stream i subfield(11ax)).


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**Table 9-129—Average SNR of RU index *k* for space-time stream *i* subfield(11ax)**

| Average SNR of RU index *k* for space-time stream *i* | $AvgSNR_{k,i}$ (dB) |
|---|---|
| –32 | ≤ –10 |
| –31 | –9 |
| –30 | –8 |
| … | … |
| 30 | 52 |
| 31 | ≥ 53 |

The $AvgSNR_{k,i}$ in Table 9-129 (Average SNR of RU index k for space-time stream i subfield(11ax)) is found by computing the arithmetic mean of the SNR per subcarrier in decibels for space-time stream *i* over the subcarriers in RU index *k* for which the feedback is being requested. The SNR per subcarrier calculation is defined in 9.4.1.63 (HE Compressed Beamforming Report field(11ax)).

Padding is not present between per-RU average SNRs of each space-time stream information, even if they correspond to different RUs and space-time streams. If the size of the HE CQI Report information is not an integer multiple of 8 bits, up to seven 0s are appended to the end of the field to make its size an integer multiple of 8 bits.

### 9.4.1.66 HE Compressed Beamforming/CQI Report field(#6006)

The HE Compressed Beamforming/CQI Report field carries the HE compressed beamforming/CQI report (see 26.7 (HE sounding operation(#2388))) and is defined in Figure 9-198 (HE Compressed Beamforming/ CQI Report field format(#6006)).

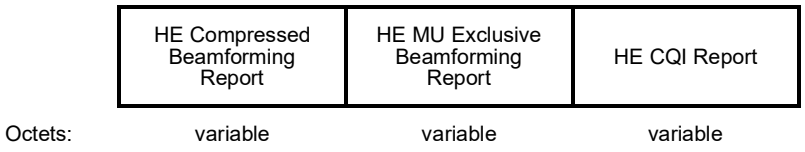


**Figure 9-198—HE Compressed Beamforming/CQI Report field format(#6006)**

The HE Compressed Beamforming Report field is defined in 9.4.1.63 (HE Compressed Beamforming Report field(11ax)).

The HE MU Exclusive Beamforming Report field is defined in 9.4.1.64 (HE MU Exclusive Beamforming Report field(11ax)).

The HE CQI Report field is defined in 9.4.1.65 (HE CQI Report field(11ax)).

NOTE —The presence of the HE Compressed Beamforming Report field, HE MU Exclusive Beamforming Report field and HE CQI Report field are dependent on the values of the Feedback Type subfield of the HE MIMO Control field in the HE Compressed Beamforming/CQI frame.

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### 9.4.1.67 HE Sounding Feedback Segment field(#6006)

The HE Sounding Feedback Segment field is defined in Figure 9-199 (HE Sounding Feedback Segment field format(#6006)).

**Figure 9-199—HE Sounding Feedback Segment field format(#6006)**

The Sounding Feedback Segment field consists of octets number *N*1 to *N*2, where the first octet is octet 1, of the HE Compressed Beamforming/CQI Report field, where *N*1 and *N*2 are determined by the HE MIMO Control field of the HE Compressed Beamforming/CQI frame containing the HE Sounding Feedback Segment field (see 26.7.4 (Rules for generating segmented feedback)).

### 9.4.1.68 EBCS Content Request field(11bc)

The EBCS Content Request field is included in an EBCS Content Request frame transmitted by an EBCS non-AP STA to request one or more EBCS traffic streams from its associated AP. The EBCS Content Request field is also included in an EBCS Content Request ANQP-element, transmitted by an EBCS non-AP STA to request one or more EBCS traffic streams from an unassociated AP. The format of the EBCS Content Request field is shown in Figure 9-200 (EBCS Content Request field format(11bc)).

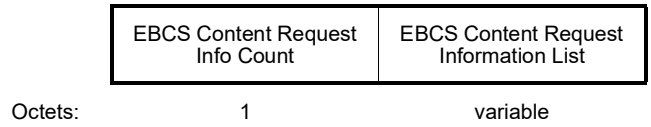


**Figure 9-200—EBCS Content Request field format(11bc)**

The EBCS Content Request Info Count field indicates the number of EBCS Content Request Info subfields contained in the EBCS Content Request field.

The EBCS Content Request Information List field contains one or more EBCS Content Request Info subfields.

The format of the EBCS Content Request Info subfield is shown in Figure 9-201 (EBCS Content Request Info subfield format(11bc)).

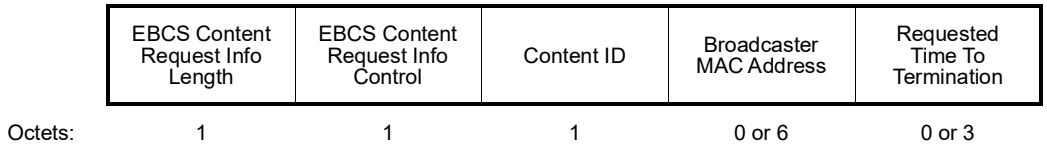


**Figure 9-201—EBCS Content Request Info subfield format(11bc)**

The EBCS Content Request Info Length field indicates the length in octets of the EBCS Content Request Info subfield including the EBCS Content Request Info Length field.

The format of the EBCS Content Request Info Control subfield is shown in Figure 9-202 (EBCS Content Request Info Control subfield format(11bc)).


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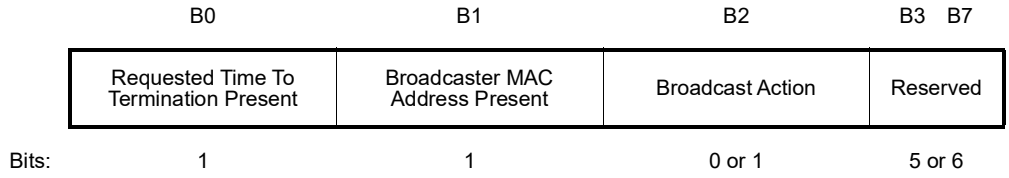


**Figure 9-202—EBCS Content Request Info Control subfield format(11bc)**

A value of 1 in the Requested Time To Termination Present subfield indicates that a Requested Time To Termination subfield is present in the EBCS Content Request Info subfield. A value of 0 in the Requested Time To Termination Present subfield indicates that a Requested Time To Termination subfield is not present in the EBCS Content Request Info subfield.

A value of 1 in the Broadcaster MAC Address Present subfield indicates that a Broadcaster MAC Address subfield is present in the EBCS Content Request Info subfield. A value of 0 in the Broadcaster MAC Address Present subfield indicates that a Broadcaster MAC Address subfield is not present in the EBCS Content Request Info subfield.

A value of 1 in the Broadcast Action subfield indicates a request for registration to receive the EBCS traffic stream identified by the Content ID subfield included in the same EBCS Content Request Info subfield. A value of 0 in the Broadcast Action subfield indicates a request for deregistration to stop receiving the ECBS traffic stream identified by the Content ID subfield included in the same EBCS Content Request Info subfield. The Broadcast Action subfield is present when the EBCS Content Request Info subfield is carried in an EBCS Content Request ANQP-element and otherwise is not present.

The Content ID subfield indicates the ID of the EBCS traffic stream being requested.

The Broadcaster MAC Address subfield contains the MAC address of the AP from which the EBCS traffic stream is currently being received, if any.

The Requested Time To Termination subfield indicates the requested subscription period in number of TBTTs after which the EBCS traffic stream identified by the Content ID subfield is terminated. The encoding of the Requested Time To Termination subfield is the same as defined for the Time to Termination field in 9.4.1.69 (EBCS Content Response field(11bc)). An EBCS STA does not include the Requested Time To Termination subfield in the EBCS Content Request Info subfield or in the EBCS Content Request ANQP-element if it does not request a specific time to termination for the EBCS traffic stream identified by the Content ID subfield in the EBCS Content Request Info subfield or in the EBCS Content Request ANQP-element.

### 9.4.1.69 EBCS Content Response field(11bc)

The EBCS Content Response field is included in an EBCS Content Response frame used by an EBCS AP to respond to a request for one or more EBCS traffic streams from an associated STA. The EBCS Content Request field is also included in an EBCS Content Response ANQP-element used by an EBCS AP to respond to a request for one or more EBCS traffic streams from an unassociated STA. The format of the EBCS Content Response field is shown in Figure 9-203 (EBCS Content Response field format(11bc)).

The EBCS Content Response Info Count field indicates the number of EBCS Content Response Info fields contained in the EBCS Content Response field.

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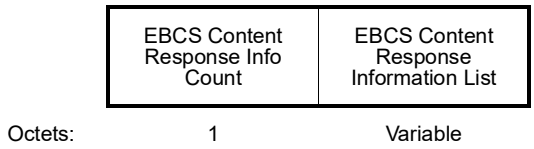


**Figure 9-203—EBCS Content Response field format(11bc)**

The EBCS Content Response Information List field contains one or more EBCS Content Response Info subfields. The format of the EBCS Content Response Info subfield is shown in Figure 9-204 (EBCS Content Response Info subfield format(11bc)).

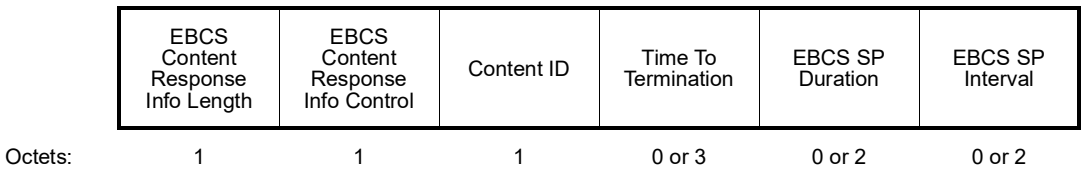


**Figure 9-204—EBCS Content Response Info subfield format(11bc)**

The EBCS Content Response Info Length field indicates the length in octets of the EBCS Content Response field including the EBCS Content Response Info Length field.

The format of the EBCS Content Response Info Control subfield is shown in Figure 9-205 (EBCS Content Response Info Control subfield format(11bc)).

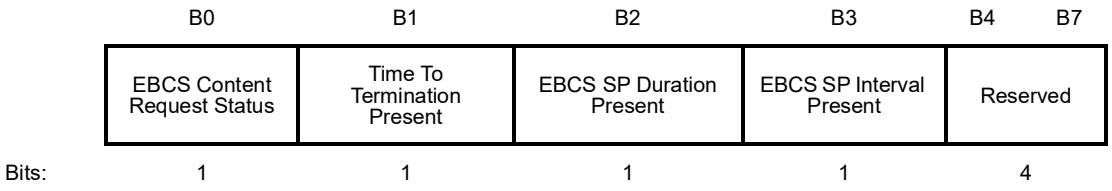


**Figure 9-205—EBCS Content Response Info Control subfield format(11bc)**

A value of 0 in the EBCS Content Request Status subfield indicates that the request for the EBCS traffic stream identified by the Content ID subfield included in the EBCS Content Response Info subfield is successful. A value of 1 in the EBCS Content Request Status subfield indicates that the request for the EBCS traffic stream identified by the Content ID subfield included in the EBCS Content Response Info subfield is refused.

A value 1 in the Time To Termination Present subfield indicates that a Time To Termination subfield is included in the EBCS Content Response Info subfield. A value 0 indicates that the EBCS Content Response Info subfield does not contain a Time To Termination subfield.

A value 1 in the EBCS SP Duration Present subfield indicates that an EBCS SP Duration subfield is included in the EBCS Content Response Info subfield. A value 0 indicates that the EBCS Content Response Info subfield does not contain an EBCS SP Duration subfield.

A value 1 in the EBCS SP Interval Present subfield indicates that an EBCS SP Interval subfield is included in the EBCS Content Response Info subfield. A value 0 indicates that the EBCS Content Response Info subfield does not contain an EBCS SP Interval subfield.

The Content ID subfield indicates the ID of the EBCS traffic stream.


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The Time To Termination subfield indicates the period in number of TBTTs after which the EBCS traffic stream identified by the Content ID subfield included in the EBCS Content Response Info subfield is terminated. The value 0 is reserved. An EBCS traffic stream identified by the Content ID subfield contained in an EBCS Content Response Info subfield has no specific termination time if the EBCS Content Response Info subfield contains no Time To Termination subfield.

The EBCS SP Duration subfield indicates the nominal duration of each EBCS service period in TUs.

The EBCS SP Interval subfield indicates the target interval between consecutive EBCS service periods for the EBCS traffic stream identified by the Content ID subfield in the EBCS Content Response Info subfield in TUs.

#### 9.4.1.70 EBCS Info Frame Tx Countdown field(11bc)

The EBCS Info Frame Tx Countdown field is shown in Figure 9-206 (EBCS Info Frame Tx Countdown field format(11bc)).

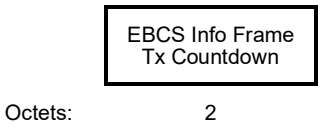


**Figure 9-206—EBCS Info Frame Tx Countdown field format(11bc)**

The EBCS Info Frame Tx Countdown field indicates the number of TBTTs until the transmission of the next EBCS Info frame. The value 1 indicates that the frame is transmitted following the next TBTT. The value 0 is reserved.

#### 9.4.1.71 Short SSID field(#7151)

The Short SSID field is used to carry a short SSID (see 9.4.2.169.3 (Calculating the short SSID)). The Short SSID field is shown in Figure 9-207 (Short SSID field format(#7151)); the short SSID is transmitted commencing with the coefficient of the highest order term of the short SSID.

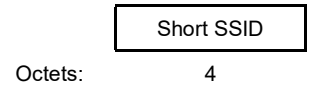


**Figure 9-207—Short SSID field format(#7151)**

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### 9.4.2 Elements

#### 9.4.2.1 General

Elements have a common general format shown in Figure 9-208 (Element format).

| | Element ID | Length | Element ID Extension | Information |
|---|---|---|---|---|
| Octets: | 1 | 1 | 0 or 1 | variable |

**Figure 9-208—Element format**

An element is identified by the Element ID field and, if present, the Element ID Extension field.

The set of valid elements is defined in Table 9-130 (Element IDs).

If an Element ID value has an entry in Table 9-130 (Element IDs) in the Element column of Element ID Extension present, then the Element ID Extension field is present. Otherwise, the Element ID Extension field is not present.

The Length field indicates the number of octets in the element excluding the Element ID and Length fields.

The Information field carries information specific to the element.

**Table 9-130—Element IDs**

| Element | Element ID | Element ID Extension | Extensible | Fragmentable |
|---|---|---|---|---|
| SSID (see 9.4.2.2 (SSID element)) | 0 | N/A | No | No |
| Supported Rates and BSS Membership Selectors (see 9.4.2.3 (Supported Rates and BSS Membership Selectors element)) | 1 | N/A | No | No |
| Reserved | 2 | | | |
| DSSS Parameter Set (see 9.4.2.4 (DSSS Parameter Set element)) | 3 | N/A | No | No |
| Reserved | 4 | | | |
| TIM (see 9.4.2.5 (TIM element)) | 5 | N/A | No | No |
| IBSS Parameter Set (see 9.4.2.6 (IBSS Parameter Set element)) | 6 | N/A | No | No |
| Country (see 9.4.2.7 (Country element)) | 7 | N/A | No | No |
| Reserved | 8 | | | |
| Reserved | 9 | | | |
| Request (see 9.4.2.8 (Request element)) | 10 | N/A | No | No |
| BSS Load (see 9.4.2.26 (BSS Load element)) | 11 | N/A | No | No |
| EDCA Parameter Set (see 9.4.2.27 (EDCA Parameter Set element)) | 12 | N/A | No | No |


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**Table 9-130—Element IDs *(continued)***

| Element | Element ID | Element ID Extension | Extensible | Fragmentable |
|---|---|---|---|---|
| TSPEC (see 9.4.2.28 (TSPEC element)) | 13 | N/A | In a non-DMG BSS: no<br>In a DMG BSS: yes | No |
| TCLAS (see 9.4.2.29 (TCLAS element)) | 14 | N/A | No | No |
| Schedule (see 9.4.2.32 (Schedule element)) | 15 | N/A | No | No |
| Reserved | (#3056)16–31 | | | |
| Power Constraint (see 9.4.2.12 (Power Constraint element)) | 32 | N/A | No | No |
| Power Capability (see 9.4.2.13 (Power Capability element)) | 33 | N/A | No | No |
| TPC Request (see 9.4.2.14 (TPC Request element)) | 34 | N/A | No | No |
| TPC Report (see 9.4.2.15 (TPC Report element)) | 35 | N/A | No | No |
| Supported Channels (see 9.4.2.16 (Supported Channels element)) | 36 | N/A | No | No |
| Channel Switch Announcement (see 9.4.2.17 (Channel Switch Announcement element)) | 37 | N/A | No | No |
| Measurement Request (see 9.4.2.19 (Measurement Request element)) | 38 | N/A | Subelements, for formats using 9.4.2.19.4 (RPI histogram request (Received power indicator histogram request)) to 9.4.2.19.12 (Measurement Pause request). | No |
| Measurement Report (see 9.4.2.20 (Measurement Report element)) | 39 | N/A | Subelements, for formats using 9.4.2.20.4 (RPI histogram report) to 9.4.2.20.11 (Transmit Stream/ Category Measurement report). | No |
| Quiet (see 9.4.2.21 (Quiet element)) | 40 | N/A | No | No |

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**Table 9-130—Element IDs *(continued)***

| Element | Element ID | Element ID Extension | Extensible | Fragmentable |
|---|---|---|---|---|
| IBSS DFS (see 9.4.2.22 (IBSS DFS element)) | 41 | N/A | No | No |
| ERP (see 9.4.2.10 (ERP element)) | 42 | N/A | Yes | No |
| TS Delay (see 9.4.2.30 (TS Delay element)) | 43 | N/A | No | No |
| TCLAS Processing (see 9.4.2.31 (TCLAS Processing element)) | 44 | N/A | No | No |
| HT Capabilities (see 9.4.2.54 (HT Capabilities element)) | 45 | N/A | Yes | No |
| QoS Capability (see 9.4.2.33 (QoS Capability element)) | 46 | N/A | No | No |
| Reserved | 47 | | | |
| RSN (see 9.4.2.23 (RSNE)) | 48 | N/A | No(#8103) | No |
| Reserved | 49 | | | |
| Extended Supported Rates and BSS Membership Selectors (see 9.4.2.11 (Extended Supported Rates and BSS Membership Selectors element)) | 50 | N/A | No | No |
| AP Channel Report (see 9.4.2.34 (AP Channel Report element)) | 51 | N/A | No | No |
| Neighbor Report (see 9.4.2.35 (Neighbor Report element)) | 52 | N/A | Subelements | No |
| RCPI (see 9.4.2.36 (RCPI element)) | 53 | N/A | Yes | No |
| (#1776)MDE (see 9.4.2.45 (MDE(#1776))) | 54 | N/A | No | No |
| (#1776)FTE (see 9.4.2.46 (FTE(#1776))) | 55 | N/A | No | No |
| (#1776)TIE (see 9.4.2.47 (TIE(#1776))) | 56 | N/A | No | No |
| (#1776)RDE (see 9.4.2.48 (RDE(#1776))) | 57 | N/A | No | No |
| DSE Registered Location (see 9.4.2.50 (DSE Registered Location element)) | 58 | N/A | No | No |
| Supported Operating Classes (see 9.4.2.52 (Supported Operating Classes element)) | 59 | N/A | No | No |
| Extended Channel Switch Announcement (see 9.4.2.51 (Extended Channel Switch Announcement element)) | 60 | N/A | No | No |
| HT Operation (see 9.4.2.55 (HT Operation element)) | 61 | N/A | Yes | No |
| Secondary Channel Offset (see 9.4.2.18 (Secondary Channel Offset element)) | 62 | N/A | No | No |
| BSS Average Access Delay (see 9.4.2.37 (BSS Average Access Delay element)) | 63 | N/A | Yes | No |
| Antenna (see 9.4.2.38 (Antenna element)) | 64 | N/A | Yes | No |



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**Table 9-130—Element IDs *(continued)***

| Element | Element ID | Element ID Extension | Extensible | Fragmentable |
|---|---|---|---|---|
| RSNI (see 9.4.2.39 (RSNI element)) | 65 | N/A | Yes | No |
| Measurement Pilot Transmission (see 9.4.2.40 (Measurement Pilot Transmission element)) | 66 | N/A | Subelements | No |
| BSS Available Admission Capacity (see 9.4.2.41 (BSS Available Admission Capacity element)) | 67 | N/A | Yes | No |
| BSS AC Access Delay (see 9.4.2.42 (BSS AC Access Delay element)) | 68 | N/A | Yes | No |
| Time Advertisement (see 9.4.2.59 (Time Advertisement element)) | 69 | N/A | Yes | No |
| RM Enabled Capabilities (see 9.4.2.43 (RM Enabled Capabilities element)) | 70 | N/A | Yes | No |
| Multiple BSSID (see 9.4.2.44 (Multiple BSSID element)) | 71 | N/A | Subelements | No |
| 20/40 BSS Coexistence (see 9.4.2.58 (20/40 BSS Coexistence element)) | 72 | N/A | Yes | No |
| 20/40 BSS Intolerant Channel Report (see 9.4.2.56 (20/40 BSS Intolerant Channel Report element)) | 73 | N/A | No | No |
| Overlapping BSS Scan Parameters (see 9.4.2.57 (Overlapping BSS Scan Parameters element)) | 74 | N/A | No | No |
| RIC Descriptor (see 9.4.2.49 (RIC Descriptor element)) | 75 | N/A | No | No |
| (#1776)MME (see 9.4.2.53 (MME(#1517))) | 76 | N/A | No | No |
| Reserved | 77 | | | |
| Event Request (see 9.4.2.65 (Event Request element)) | 78 | N/A | Subelements | No |
| Event Report (see 9.4.2.66 (Event Report element)) | 79 | N/A | No | No |
| Diagnostic Request (see 9.4.2.67 (Diagnostic Request element)) | 80 | N/A | Subelements | No |
| Diagnostic Report (see 9.4.2.68 (Diagnostic Report element)) | 81 | N/A | Subelements | No |
| Location Parameters (see 9.4.2.69 (Location Parameters element)) | 82 | N/A | Subelements | No |
| Nontransmitted BSSID Capability (see 9.4.2.70 (Nontransmitted BSSID Capability element)) | 83 | N/A | No | No |
| SSID List (see 9.4.2.71 (SSID List element)) | 84 | N/A | No | No |
| Multiple BSSID-Index (see 9.4.2.72 (Multiple BSSID-Index element)) | 85 | N/A | No | No |

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**Table 9-130—Element IDs *(continued)***

| Element | Element ID | Element ID Extension | Extensible | Fragmentable |
|---|---|---|---|---|
| FMS Descriptor (see 9.4.2.73 (FMS Descriptor element)) | 86 | N/A | No | No |
| FMS Request (see 9.4.2.74 (FMS Request element)) | 87 | N/A | Subelements | No |
| FMS Response (see 9.4.2.75 (FMS Response element)) | 88 | N/A | Subelements | No |
| QoS Traffic Capability (see 9.4.2.76 (QoS Traffic Capability element)) | 89 | N/A | Yes | No |
| BSS Max Idle Period (see 9.4.2.77 (BSS Max Idle Period element)) | 90 | N/A | Yes | No |
| TFS Request (see 9.4.2.78 (TFS Request element)) | 91 | N/A | Subelements | No |
| TFS Response (see 9.4.2.79 (TFS Response element)) | 92 | N/A | Subelements | No |
| WNM Sleep Mode (see 9.4.2.80 (WNM Sleep Mode element)) | 93 | N/A | Yes | No |
| TIM Broadcast Request (see 9.4.2.81 (TIM Broadcast Request element)) | 94 | N/A | Yes | No |
| TIM Broadcast Response (see 9.4.2.82 (TIM Broadcast Response element)) | 95 | N/A | Yes | No |
| (#2210)Colocated Interference Report (see 9.4.2.83 ((#2210)Colocated Interference Report element)) | 96 | N/A | Yes | No |
| Channel Usage (see 9.4.2.84 (Channel Usage element)) | 97 | N/A | Subelements | No |
| Time Zone (see 9.4.2.85 (Time Zone element)) | 98 | N/A | Yes | No |
| DMS Request (see 9.4.2.86 (DMS Request element)) | 99 | N/A | Subelements | No |
| DMS Response (see 9.4.2.87 (DMS Response element)) | 100 | N/A | Subelements | No |
| Link Identifier (see 9.4.2.60 (Link Identifier element)) | 101 | N/A | Yes | No |
| Wakeup Schedule (see 9.4.2.61 (Wakeup Schedule element)) | 102 | N/A | Yes | No |
| Reserved | 103 | | | |
| Channel Switch Timing (see 9.4.2.62 (Channel Switch Timing element)) | 104 | N/A | Yes | No |
| PTI Control (see 9.4.2.63 (PTI Control element)) | 105 | N/A | Yes | No |
| TPU Buffer Status (see 9.4.2.64 (TPU Buffer Status element)) | 106 | N/A | Yes | No |
| Interworking (see 9.4.2.90 (Interworking element)) | 107 | N/A | No | No |


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**Table 9-130—Element IDs *(continued)***

| Element | Element ID | Element ID Extension | Extensible | Fragmentable |
|---|---|---|---|---|
| Advertisement Protocol (see 9.4.2.91 (Advertisement Protocol element)) | 108 | N/A | No | No |
| Expedited Bandwidth Request (see 9.4.2.92 (Expedited Bandwidth Request element)) | 109 | N/A | No | No |
| QoS Map (see 9.4.2.93 (QoS Map element)) | 110 | N/A | Yes | No |
| Roaming Consortium (see 9.4.2.94 (Roaming Consortium element)) | 111 | N/A | Yes | No |
| Emergency Alert Identifier (see 9.4.2.95 (Emergency Alert Identifier element)) | 112 | N/A | No | No |
| Mesh Configuration (see 9.4.2.96 (Mesh Configuration element))(#3415) | 113 | N/A | Yes | No |
| Mesh ID (see 9.4.2.97 (Mesh ID element))(#3415) | 114 | N/A | No | No |
| Mesh Link Metric Report (see 9.4.2.98 (Mesh Link Metric Report element)) | 115 | N/A | No | No |
| Congestion Notification (see 9.4.2.99 (Congestion Notification element)) | 116 | N/A | Yes | No |
| Mesh Peering Management (see 9.4.2.100 (Mesh Peering Management element)) | 117 | N/A | Yes | No |
| Mesh Channel Switch Parameters (see 9.4.2.101 (Mesh Channel Switch Parameters element)) | 118 | N/A | Yes | No |
| Mesh Awake Window (see 9.4.2.102 (Mesh Awake Window element)) | 119 | N/A | Yes | No |
| Beacon Timing (see 9.4.2.103 (Beacon Timing element)) | 120 | N/A | No | No |
| MCCAOP Setup Request (see 9.4.2.104 (MCCAOP Setup Request element)) | 121 | N/A | Yes | No |
| MCCAOP Setup Reply (see 9.4.2.105 (MCCAOP Setup Reply element)) | 122 | N/A | No | No |
| MCCAOP Advertisement (see 9.4.2.107 (MCCAOP Advertisement element)) | 123 | N/A | Yes | No |
| MCCAOP Teardown (see 9.4.2.108 (MCCAOP Teardown element)) | 124 | N/A | Yes | No |
| GANN (see 9.4.2.109 (GANN element)) | 125 | N/A | Yes | No |
| RANN (see 9.4.2.110 (RANN element)) | 126 | N/A | Yes | No |
| Extended Capabilities (see 9.4.2.25 (Extended Capabilities element)) | 127 | N/A | Yes | No |
| Reserved | 128–129 | | | |
| PREQ (see 9.4.2.111 (PREQ element)) | 130 | N/A | Yes | No |
| PREP (see 9.4.2.112 (PREP element)) | 131 | N/A | Yes | No |

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**Table 9-130—Element IDs *(continued)***

| Element | Element ID | Element ID Extension | Extensible | Fragmentable |
|---|---|---|---|---|
| PERR (see 9.4.2.113 (PERR element)) | 132 | N/A | Yes | No |
| Reserved | 133–136 | | | |
| PXU (see 9.4.2.114 (PXU element)) | 137 | N/A | Yes | No |
| PXUC (see 9.4.2.115 (PXUC element)) | 138 | N/A | Yes | No |
| Authenticated Mesh Peering Exchange (see 9.4.2.116 (Authenticated Mesh Peering Exchange element)) | 139 | N/A | No | No |
| MIC (see 9.4.2.117 (MIC element)) | 140 | N/A | No | No |
| Destination URI (see 9.4.2.88 (Destination URI element)) | 141 | N/A | Yes | No |
| U-APSD Coexistence (see 9.4.2.89 (U-APSD Coexistence element)) | 142 | N/A | Subelements | No |
| DMG Wakeup Schedule (see 9.4.2.129 (DMG Wakeup Schedule element)) | 143 | N/A | Yes | No |
| Extended Schedule (see 9.4.2.130 (Extended Schedule element)) | 144 | N/A | Yes | No |
| STA Availability (see 9.8 (MAC frame format for PV1 frames)(#1358)) | 145 | N/A | Yes | No |
| DMG TSPEC (see 9.4.2.132 (DMG TSPEC element)) | 146 | N/A | Yes | No |
| Next DMG ATI (see 9.4.2.134 (Next DMG ATI element)) | 147 | N/A | Yes | No |
| DMG Capabilities (see 9.4.2.126 (DMG Capabilities element)) | 148 | N/A | Yes | No |
| Reserved | 149–150 | | | |
| DMG Operation (see 9.4.2.127 (DMG Operation element))(#3415) | 151 | N/A | Yes | No |
| DMG BSS Parameter Change (see 9.4.2.125 (DMG BSS Parameter Change element)) | 152 | N/A | Yes | No |
| DMG Beam Refinement (see 9.4.2.128 (DMG Beam Refinement element)) | 153 | N/A | Yes | No |
| Channel Measurement Feedback (see 9.4.2.135 (Channel Measurement Feedback element)) | 154 | N/A | Yes | No |
| Reserved | 155–156 | | | |
| Awake Window (see 9.4.2.136 (Awake Window element)) | 157 | N/A | Yes | No |
| Multi-band (see 9.4.2.137 (Multi-band element)) | 158 | N/A | Yes | No |
| ADDBA Extension (see 9.4.2.138 (ADDBA Extension element)) | 159 | N/A | Yes | No |


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**Table 9-130—Element IDs *(continued)***

| Element | Element ID | Element ID Extension | Extensible | Fragmentable |
|---|---|---|---|---|
| NextPCP List (see 9.4.2.139 (Next PCP List element)) | 160 | N/A | Yes | No |
| PCP Handover (see 9.4.2.140 (PCP Handover element)) | 161 | N/A | Yes | No |
| DMG Link Margin (see 9.4.2.141 (DMG Link Margin element)) | 162 | N/A | Yes | No |
| Switching Stream (see 9.4.2.143 (Switching Stream element)) | 163 | N/A | Yes | No |
| Session Transition (see 9.4.2.144 (Session Transition element)) | 164 | N/A | Yes | No |
| Reserved | 165 | | | |
| Cluster Report (see 9.4.2.145 (Cluster Report element)) | 166 | N/A | Yes | No |
| Relay Capabilities (see 9.4.2.146 (Relay Capabilities element)) | 167 | N/A | Yes | No |
| Relay Transfer Parameter Set (see 9.4.2.147 (Relay Transfer Parameter Set element)) | 168 | N/A | Yes | No |
| BeamLink Maintenance (see 9.4.2.150 (BeamLink Maintenance element)) | 169 | N/A | Yes | No |
| (#1776)MMS (see 9.4.2.151 (MMS element(#1776))) | 170 | N/A | Yes | No |
| U-PID (see 9.4.2.152 (U-PID element)) | 171 | N/A | Yes | No |
| DMG Link Adaptation Acknowledgment (see 9.4.2.142 (DMG Link Adaptation Acknowledgment element)) | 172 | N/A | Yes | No |
| Reserved | 173 | | | |
| MCCAOP Advertisement Overview (see 9.4.2.106 (MCCAOP Advertisement Overview element)) | 174 | N/A | Yes | No |
| Quiet Period Request (see 9.4.2.148 (Quiet Period Request element)) | 175 | N/A | Yes | No |
| Reserved | 176 | | | |
| Quiet Period Response (see 9.4.2.149 (Quiet Period Response element)) | 177 | N/A | Yes | No |
| Reserved | 178–180 | | | |
| QMF Policy (see 9.4.2.118 (Quality-of-Service Management Frame Policy element)) | 181 | N/A | No | No |
| ECAPC Policy (see 9.4.2.153 (ECAPC Policy element)) | 182 | N/A | Yes | No |
| Cluster Time Offset (see 9.4.2.154 (Cluster Time Offset element)) | 183 | N/A | Yes | No |

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**Table 9-130—Element IDs *(continued)***

| Element | Element ID | Element ID Extension | Extensible | Fragmentable |
|---|---|---|---|---|
| Intra-Access Category Priority (see 9.4.2.119 (Intra-Access Category Priority element)) | 184 | N/A | Yes | No |
| SCS Descriptor (see 9.4.2.120 (SCS Descriptor element)) | 185 | N/A | Subelements | No |
| QLoad Report (see 9.4.2.121 (QLoad Report element)) | 186 | N/A | Subelements | No |
| HCCA TXOP Update Count (see 9.4.2.122 (HCCA TXOP Update Count element)) | 187 | N/A | No | No |
| Higher Layer Stream ID (see 9.4.2.123 (Higher Layer Stream ID element)) | 188 | N/A | Yes | No |
| GCR Group Address (see 9.4.2.124 (GCR Group Address element)) | 189 | N/A | No | No |
| Antenna Sector ID Pattern (see 9.4.2.155 (Antenna Sector ID Pattern element)) | 190 | N/A | Yes | No |
| VHT Capabilities (see 9.4.2.156 (VHT Capabilities element)) | 191 | N/A | Yes | No |
| VHT Operation (see 9.4.2.157 (VHT Operation element)) | 192 | N/A | Yes | No |
| Extended BSS Load (see 9.4.2.158 (Extended BSS Load element)) | 193 | N/A | Yes | No |
| Wide Bandwidth Channel Switch (see 9.4.2.159 (Wide Bandwidth Channel Switch element)) | 194 | N/A | Yes | No |
| Transmit Power Envelope (see 9.4.2.160 (Transmit Power Envelope element)) | 195 | N/A | Yes | No |
| Channel Switch Wrapper (see 9.4.2.161 (Channel Switch Wrapper element)) | 196 | N/A | Subelements | No |
| AID (see 9.4.2.162 (AID element)) | 197 | N/A | No | No |
| Quiet Channel (see 9.4.2.163 (Quiet Channel element)) | 198 | N/A | Yes | No |
| Operating Mode Notification (see 9.4.2.164 (Operating Mode Notification element)) | 199 | N/A | Yes | No |
| UPSIM (see 9.4.2.165 (UPSIM element)) | 200 | N/A | Yes | No |
| Reduced Neighbor Report (see 9.4.2.169 (Reduced Neighbor Report element)) | 201 | N/A | Yes | No |
| TVHT Operation (see 9.4.2.170 (TVHT Operation element)) | 202 | N/A | Yes | No |
| Reserved | 203 | | | |
| Device Location (see 9.4.2.167 (Device Location element)) | 204 | N/A | Yes | No |
| White Space Map (see 9.4.2.168 (White Space Map element)) | 205 | N/A | Yes | No |


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**Table 9-130—Element IDs *(continued)***

| Element | Element ID | Element ID Extension | Extensible | Fragmentable |
|---|---|---|---|---|
| (11az)FTM Parameters (see 9.4.2.166 (FTM Parameters element(11az))) | 206 | N/A | Subelements(11az) | No |
| S1G Open-Loop Link Margin Index (see 9.4.2.189 (S1G Open-Loop Link Margin Index element)) | 207 | N/A | No | No |
| RPS (see 9.4.2.190 (RPS element)) | 208 | N/A | No | No |
| Page Slice (see 9.4.2.191 (Page Slice element)) | 209 | N/A | No | No |
| AID Request (see 9.4.2.192 (AID Request element)) | 210 | N/A | No | No |
| AID Response (see 9.4.2.193 (AID Response element)) | 211 | N/A | No | No |
| S1G Sector Operation (see 9.4.2.194 (S1G Sector Operation element)) | 212 | N/A | Yes | No |
| S1G Beacon Compatibility (see 9.4.2.195 (S1G Beacon Compatibility element)) | 213 | N/A | No | No |
| Short Beacon Interval (see 9.4.2.196 (Short Beacon Interval element(#2194))) | 214 | N/A | No | No |
| Change Sequence (see 9.4.2.197 (Change Sequence element)) | 215 | N/A | No | No |
| TWT (see 9.4.2.198 (TWT element)) | 216 | N/A | Yes | No |
| S1G Capabilities (see 9.4.2.199 (S1G Capabilities element)) | 217 | N/A | Yes | No |
| Reserved | 218–219 | | | |
| (#1776)SST (see 9.4.2.200 (SST element(#1776))) | 220 | N/A | No | No |
| Vendor Specific (see 9.4.2.24 (Vendor Specific element)) | 221 | N/A | Vendor defined | Vendor defined |
| Authentication Control (see 9.4.2.201 (Authentication Control element)) | 222 | N/A | Yes | No |
| TSF Timer Accuracy (see 9.4.2.202 (TSF Timer Accuracy element)) | 223 | N/A | No | No |
| S1G Relay (see 9.4.2.203 (S1G Relay element)) | 224 | N/A | Yes | No |
| Reachable Address (see 9.4.2.204 (Reachable Address element)) | 225 | N/A | Yes | No |
| S1G Relay Discovery (see 9.4.2.206 (S1G Relay Discovery element)) | 226 | N/A | No | No |
| Reserved | 227 | | | |
| AID Announcement (see 9.4.2.207 (AID Announcement element)) | 228 | N/A | No | No |
| PV1 Probe Response Option (see 9.4.2.208 (PV1 Probe Response Option element)) | 229 | N/A | No | No |

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**Table 9-130—Element IDs *(continued)***

| Element | Element ID | Element ID Extension | Extensible | Fragmentable |
|---|---|---|---|---|
| EL Operation (see 9.4.2.209 (EL Operation element)) | 230 | N/A | No | No |
| Sectorized Group ID List (see 9.4.2.210 (Sectorized Group ID List element)) | 231 | N/A | Yes | No |
| S1G Operation (see 9.4.2.211 (S1G Operation element)) | 232 | N/A | No | No |
| Header Compression (see 9.4.2.212 (Header Compression element)) | 233 | N/A | Yes | No |
| SST Operation (see 9.4.2.213 (SST Operation element)) | 234 | N/A | No | No |
| MAD (see 9.4.2.214 (MAD element)) | 235 | N/A | No | No |
| S1G Relay Activation (see 9.4.2.205 (S1G Relay Activation element)) | 236 | N/A | Yes | No |
| CAG Number (see 9.4.2.175 (CAG Number element)) | 237 | N/A | No | No |
| Reserved | 238 | | | |
| AP-CSN (see 9.4.2.180 (AP Configuration Sequence Number (AP-CSN) element)) | 239 | N/A | No | No |
| FILS Indication (see 9.4.2.181 (FILS Indication element)) | 240 | N/A | No | Yes |
| DILS (see 9.4.2.185 (DILS element)) | 241 | N/A | Yes | No |
| Fragment (see 9.4.2.187 (Fragment element)) | 242 | N/A | No | No |
| Reserved | 243 | | | |
| (#1776)RSNXE (see 9.4.2.240 (RSNXE(#1776))) | 244 | N/A | Yes | No |
| Reserved | 245–254 | | | |
| Element ID Extension present | 255 | | | |
| Reserved | 255 | 0 | | |
| Association Delay Info (see 9.4.2.174 (Association Delay Info element)) | 255 | 1 | No | No |
| FILS Request Parameters (see 9.4.2.176 (FILS Request Parameters element(#2193))) | 255 | 2 | No | No |
| FILS Key Confirmation (see 9.4.2.177 (FILS Key Confirmation element)) | 255 | 3 | No | Yes |
| FILS Session (see 9.4.2.178 (FILS Session element)) | 255 | 4 | No | No |
| FILS HLP Container (see 9.4.2.182 (FILS HLP Container element)) | 255 | 5 | No | Yes |


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**Table 9-130—Element IDs *(continued)***

| Element | Element ID | Element ID Extension | Extensible | Fragmentable |
|---|---|---|---|---|
| FILS IP Address Assignment (see 9.4.2.183 (FILS IP Address Assignment element)) | 255 | 6 | No | No |
| Key Delivery (see 9.4.2.184 (Key Delivery element)) | 255 | 7 | No | Yes |
| (#7044)Wrapped Data (see 9.4.2.186 ((11az)Wrapped Data element)) | 255 | 8 | No | Yes |
| FTM Synchronization Information (see 9.4.2.171 (FTM Synchronization Information element)) | 255 | 9 | Yes | No |
| Extended Request (see 9.4.2.9 (Extended Request element)) | 255 | 10 | No | No |
| Estimated Service Parameters Inbound (see 9.4.2.172 (Estimated Service Parameters Inbound element)) | 255 | 11 | Yes | No |
| FILS Public Key (see 9.4.2.179 (FILS Public Key element)) | 255 | 12 | No | Yes |
| FILS Nonce (see 9.4.2.188 (FILS Nonce element)) | 255 | 13 | No | No |
| Future Channel Guidance (see 9.4.2.173 (Future Channel Guidance element)) | 255 | 14 | No | No |
| Service Hint (see 9.4.2.236 (Service Hint element)) | 255 | 15 | No | No |
| Service Hash (see 9.4.2.237 (Service Hash element)) | 255 | 16 | No | No |
| CDMG Capabilities (see 9.4.2.218 (CDMG Capabilities element)) | 255 | 17 | Yes | No |
| Dynamic Bandwidth Control (see 9.4.2.219 (Dynamic Bandwidth Control element)) | 255 | 18 | Yes | No |
| CDMG Extended Schedule (see 9.4.2.220 (CDMG Extended Schedule element)) | 255 | 19 | Yes | Yes |
| SSW Report (see 9.4.2.221 (SSW Report element)) | 255 | 20 | Yes | Yes |
| Cluster Probe (see 9.4.2.222 (Cluster Probe element)) | 255 | 21 | Yes | No |
| Extended Cluster Report (see 9.4.2.223 (Extended Cluster Report element)) | 255 | 22 | Yes | No |
| Cluster Switch Announcement (see 9.4.2.224 (Cluster Switch Announcement element)) | 255 | 23 | Yes | No |
| Enhanced Beam Tracking (see 9.4.2.225 (Enhanced Beam Tracking element)) | 255 | 24 | Yes | No |
| SPSH Report (see 9.4.2.226 (SPSH Report element)) | 255 | 25 | Yes | Yes |

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**Table 9-130—Element IDs *(continued)***

| Element | Element ID | Element ID Extension | Extensible | Fragmentable |
|---|---|---|---|---|
| Clustering Interference Assessment (see 9.4.2.227 (Clustering Interference Assessment element)) | 255 | 26 | Yes | No |
| CMMG Capabilities (see 9.4.2.228 (CMMG Capabilities element)) | 255 | 27 | Yes | No |
| CMMG Operation (see 9.4.2.229 (CMMG Operation element)) | 255 | 28 | Yes | No |
| CMMG Operating Mode Notification (see 9.4.2.230 (CMMG Operating Mode Notification element)) | 255 | 29 | Yes | No |
| CMMG Link Margin (see 9.4.2.231 (CMMG Link Margin element)) | 255 | 30 | Yes | No |
| CMMG Link Adaptation Acknowledgment (see 9.4.2.232 (CMMG Link Adaptation Acknowledgment element)) | 255 | 31 | Yes | No |
| (#1084)(#1776)Diffie-Hellman Parameter (see 9.4.2.312 (Diffie-Hellman Parameter element(#6088)))(#6088) | 255 | 32 | No | No |
| Password identifier (see 9.4.2.215 (Password Identifier element)) | 255 | 33 | No | No |
| GLK-GCR Parameter Set (see 9.4.2.233 (GLK-GCR Parameter Set element)) | 255 | 34 | Yes | No |
| (11ax)HE Capabilities (see 9.4.2.247 (HE Capabilities element(11ax))) | 255 | 35 | Yes | No |
| (11ax)HE Operation (see 9.4.2.248 (HE Operation element(11ax))) | 255 | 36 | Yes | No |
| (11ax)(#1776)UORA Parameter Set (see 9.4.2.249 (UORA Parameter Set element(11ax))) | 255 | 37 | Yes | No |
| (11ax)MU EDCA Parameter Set (see 9.4.2.250 (MU EDCA Parameter Set element(11ax))) | 255 | 38 | Yes | No |
| (11ax)(#1776)Spatial Reuse Parameter Set (see 9.4.2.251 (Spatial Reuse Parameter Set element(11ax))) | 255 | 39 | Yes | No |
| GAS Extension (see 9.4.2.238 (GAS Extension element))(#3415) | 255 | 40 | Yes | Yes |
| (11ax)(#1776)NDP Feedback Report Parameter Set (see 9.4.2.252 (NDP Feedback Report Parameter Set element(11ax))) | 255 | 41 | Yes | No |
| (11ax)BSS Color Change Announcement (see 9.4.2.253 (BSS Color Change Announcement element(11ax))) | 255 | 42 | Yes | No |
| (11ax)Quiet Time Period (see 9.4.2.254 (Quiet Time Period element(11ax))) | 255 | 43 | Yes | No |


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**Table 9-130—Element IDs *(continued)***

| Element | Element ID | Element ID Extension | Extensible | Fragmentable |
|---|---|---|---|---|
| (#1776)Vendor Specific Request (see 9.4.2.217 (Vendor Specific Request element)) | 255 | 44 | No | No |
| (11ax)ESS Report (see 9.4.2.255 (ESS Report element(11ax))) | 255 | 45 | Yes | No |
| (11ax)OPS (see 9.4.2.256 (OPS element(11ax))) | 255 | 46 | Yes | No |
| (11ax)HE BSS Load (see 9.4.2.258 (HE BSS Load element(11ax))) | 255 | 47 | Yes | No |
| (11ba)WUR Capabilities (see 9.4.2.290 (WUR Capabilities element(11ba))) | 255 | 48 | Yes | No |
| (11ba)WUR Operation (see 9.4.2.291 (WUR Operation element(11ba))) | 255 | 49 | Yes | No |
| (11ba)WUR Mode (see 9.4.2.292 (WUR Mode element(11ba))) | 255 | 50 | Yes | No |
| (11ba)WUR Discovery (see 9.4.2.293 (WUR Discovery element(11ba))) | 255 | 51 | Yes | No |
| Max Channel Switch Time (see 9.4.2.216 (Max Channel Switch Time element)) | 255 | 52 | No | No |
| Estimated Service Parameters Outbound (see 9.4.2.234 (Estimated Service Parameters Outbound element)) | 255 | 53 | Yes | No |
| (#1776)OCI (see 9.4.2.235 (OCI element)) | 255 | 54 | Yes | No |
| (11ax)Multiple BSSID Configuration (see 9.4.2.259 (Multiple BSSID Configuration element(11ax))) | 255 | 55 | Yes | No |
| Non-Inheritance (see 9.4.2.239 (Non-Inheritance element)) | 255 | 56 | Yes | No |
| (11ax)Known BSSID (see 9.4.2.260 (Known BSSID element)) | 255 | 57 | No | No |
| (11ax)Short SSID List (see 9.4.2.261 (Short SSID List element(11ax))) | 255 | 58 | No | No |
| (11ax)HE 6 GHz Band Capabilities (see 9.4.2.262 (HE 6 GHz Band Capabilities element(11ax))) | 255 | 59 | Yes | No |
| (11ax)UL MU Power Capabilities (see 9.4.2.263 (UL MU Power Capabilities element(11ax))) | 255 | 60 | Yes | No |
| (11ay)EDMG Capabilities (see 9.4.2.264 (EDMG Capabilities element(11ay))) | 255 | 61 | Yes | No |
| (11ay)EDMG Operation (see 9.4.2.265 (EDMG Operation element(11ay))) | 255 | 62 | Yes | No |

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**Table 9-130—Element IDs *(continued)***

| Element | Element ID | Element ID Extension | Extensible | Fragmentable |
|---|---|---|---|---|
| (11ay)EDMG Extended Schedule (see 9.4.2.266 (EDMG Extended Schedule element(11ay))) | 255 | 63 | Yes | No |
| (11ay)EDMG Channel Measurement Feedback (see 9.4.2.267 (EDMG Channel Measurement Feedback element(11ay))) | 255 | 64 | Yes | No |
| (11ay)EDMG Group ID Set (see 9.4.2.268 (EDMG Group ID Set element(11ay))) | 255 | 65 | Yes | No |
| (11ay)EDMG BRP Request (see 9.4.2.269 (EDMG BRP Request element(11ay))) | 255 | 66 | Yes | No |
| (11ay)EDMG Training Field Schedule (see 9.4.2.270 (EDMG Training Field Schedule element(11ay))) | 255 | 67 | Yes | No |
| (11ay)EDMG Partial Sector Level Sweep (see 9.4.2.271 (EDMG Partial Sector Level Sweep element(11ay))) | 255 | 68 | Yes | No |
| (11ay)MIMO Setup Control (see 9.4.2.272 (MIMO Setup Control element(11ay))) | 255 | 69 | Yes | No |
| (11ay)MIMO Poll Control (see 9.4.2.273 (MIMO Poll Control element(11ay))) | 255 | 70 | Yes | No |
| (11ay)MIMO Feedback Control (see 9.4.2.274 (MIMO Feedback Control element(11ay))) | 255 | 71 | Yes | No |
| (11ay)MIMO Selection Control (see 9.4.2.275 (MIMO Selection Control element(11ay))) | 255 | 72 | Yes | No |
| (11ay)EDMG Flow Control Extension Configuration (see 9.4.2.276 (EDMG Flow Control Extension Configuration element(11ay))) | 255 | 73 | Yes | No |
| (11ay)(#1776)QoS-TU (see 9.4.2.277 (QoS-TU element(#1776)(11ay))) | 255 | 74 | Yes | No |
| (11ay)Unsolicited Block Ack Extension (see 9.4.2.278 (Unsolicited Block Ack Extension element(11ay))) | 255 | 75 | Yes | No |
| (11ay)SAR Configuration (see 9.4.2.279 (SAR Configuration element(11ay))) | 255 | 76 | Yes | No |
| (11ay)TDD Slot Structure (see 9.4.2.280 (TDD Slot Structure element(11ay))) | 255 | 77 | Yes | No |
| (11ay)TDD Slot Schedule (see 9.4.2.281 (TDD Slot Schedule element(11ay))) | 255 | 78 | Yes | No |
| (11ay)TDD Route (see 9.4.2.282 (TDD Route element(11ay))) | 255 | 79 | Yes | No |
| (11ay)Digital BF Feedback (see 9.4.2.283 (Digital BF Feedback element(11ay))) | 255 | 80 | Yes | No |


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**Table 9-130—Element IDs *(continued)***

| Element | Element ID | Element ID Extension | Extensible | Fragmentable |
|---|---|---|---|---|
| (11ay)TDD Bandwidth Request (see 9.4.2.284 (TDD Bandwidth Request element(11ay))) | 255 | 81 | Yes | No |
| (11ay)TDD Synchronization (see 9.4.2.285 (TDD Synchronization element(11ay))) | 255 | 82 | Yes | No |
| (11ay)EDMG Wide Bandwidth Channel Switch (see 9.4.2.286 (EDMG Wide Bandwidth Channel Switch element(11ay))) | 255 | 83 | Yes | No |
| (11ay)DMG Discovery Assistance (see 9.4.2.287 (DMG Discovery Assistance element(11ay))) | 255 | 84 | Yes | No |
| (11ay)Extended Link Measurement (see 9.4.2.288 (Extended Link Measurement element(11ay))) | 255 | 85 | Yes | No |
| (11ay)DMG STA Directional Transmit Activity Report (see 9.4.2.289 (DMG STA Directional Transmit Activity Report element(11ay))) | 255 | 86 | Yes | No |
| (11ba)WUR PN Update (see 9.4.2.294 (WUR PN Update element(11ba))) | 255 | 87 | Yes | No |
| (#1776)MSCS Descriptor (see 9.4.2.242 (MSCS Descriptor element)) | 255 | 88 | Yes | No |
| TCLAS Mask (see 9.4.2.241 (TCLAS Mask element)) | 255 | 89 | Yes | No |
| Supplemental Class 2 Capabilities (see 9.4.2.243 (Supplemental Class 2 Capabilities element)) | 255 | 90 | No | No |
| OCT Source (see 9.4.2.244 (OCT Source element)) | 255 | 91 | Yes | No |
| Rejected Groups (see 9.4.2.245 (Rejected Groups element)) | 255 | 92 | No | No |
| Anti-Clogging Token Container (see 9.4.2.246 (Anti-Clogging Token Container element)) | 255 | 93 | No | No |
| (11az)Secure HE-LTF Parameters (see 9.4.2.301 (Secure HE-LTF Parameters element(11az))) | 255 | 94 | Yes | No |
| (11az)ISTA Passive TB Ranging Measurement Report (see 9.4.2.306 (ISTA Passive TB Ranging Measurement Report element(11az))) | 255 | 95 | Yes | No |
| (11az)RSTA Passive TB Ranging Measurement Report (see 9.4.2.307 (RSTA Passive TB Ranging Measurement Report element(11az))) | 255 | 96 | Yes | No |

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**Table 9-130—Element IDs *(continued)***

| Element | Element ID | Element ID Extension | Extensible | Fragmentable |
|---|---|---|---|---|
| (11az)Passive TB Ranging LCI Table (see 9.4.2.308 (Passive TB Ranging LCI Table element(11az))) | 255 | 97 | Yes | No |
| (11az)ISTA Availability Window (see 9.4.2.298 (ISTA Availability Window element(11az))) | 255 | 98 | Yes | No |
| (11az)RSTA Availability Window (see 9.4.2.299 (RSTA Availability Window element(11az))) | 255 | 99 | Yes | No |
| (11az)PASN Parameters (see 9.4.2.305 (PASN Parameters element(11az))) | 255 | 100 | Yes | No |
| (11az)Ranging Parameters (see 9.4.2.300 (Ranging Parameters element(11az))) | 255 | 101 | Yes | No |
| (11az)Direction Measurement Results (see 9.4.2.302 (Direction Measurement Results element(11az))) | 255 | 102 | Yes | No |
| (11az)Multiple AOD Feedback (see 9.4.2.304 (Multiple AOD Feedback element(11az))) | 255 | 103 | Yes | No |
| (11az)Multiple Best AWV ID (see 9.4.2.303 (Multiple Best AWV ID element(11az))) | 255 | 104 | Yes | No |
| (11az)LOS Likelihood (see 9.4.2.309 (LOS Likelihood element(11az))) | 255 | 105 | Yes | No |
| Reserved | 255 | 106–110 | | |
| (11bc)EBCS Parameters (see 9.4.2.313 (EBCS Parameters element(11bc))) | 255 | 111 | Yes | No |
| (11bc)EBCS TIM (see 9.4.2.314 (EBCS TIM element(11bc))) | 255 | 112 | No | No |
| Reserved | 255 | 113 | | |
| (M67)AKM Suite Selector (#4333)(see 9.4.2.295 (AKM Suite Selector element(M67))) | 255 | 114 | Yes | Yes |
| (11bd)DMG OCB (see 9.4.2.310 (DMG OCB element(11bd))) | 255 | 115 | Yes | No |
| Originator Preferred MCS (see 9.4.2.296 (Originator Preferred MCS element(#1444)))(#1444) | 255 | 116 | Yes | No |
| Reserved | 255 | 117–135 | | |
| Known STA Identification (see 9.4.2.297 (Known STA Identification element(#4069)))(#4069) | 255 | 136 | Yes | No |
| (#6076)Non-AP STA Regulatory Connectivity (see 9.4.2.311 (Non-AP STA Regulatory Connectivity element(#6076))) | 255 | 137 | No | Ye(s |


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**Table 9-130—Element IDs *(continued)***

| Element | Element ID | Element ID Extension | Extensible | Fragmentable |
|---|---|---|---|---|
| Reserved | 255 | 138–141 | | |
| (#7057)TWT Constraint Parameters (see 9.4.2.257 (TWT Constraint Parameters element(11ax))) | 255 | 142 | Yes | No |
| (#7096)Tunneled PASN (see 9.4.2.315 (Tunneled PASN element(#7096))) | 255 | 143 | Yes | No |
| Reserved | 255 | 144–255 | | |
| NOTE—See 10.28.6 (Element parsing) on the parsing of elements. | | | | |

A Yes in the Extensible column of an element listed in Table 9-130 (Element IDs) indicates that the length of the element might be extended in future revisions or amendments of this standard. See 10.28.8 (Extensible element parsing). When the Extensible column of an element is set to Subelements, then the element might be extended in future revisions or amendments of this standard by defining additional subelements. See 10.28.9 (Extensible subelement parsing). The element is not extensible otherwise (i.e., if marked as No). An element that is not defined as extensible will not be extended in future revisions or amendments of this standard.

A Yes in the Fragmentable column listed in Table 9-130 (Element IDs) indicates that the element information might exceed the threshold that causes the element to be fragmented (see 10.28.11 (Element fragmentation)).

### 9.4.2.2 SSID element

The SSID element indicates the identity of an ESS or IBSS. See Figure 9-209 (SSID element format).

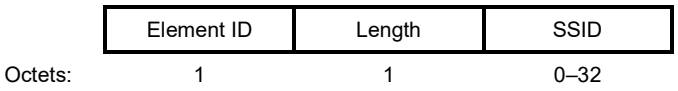


**Figure 9-209—SSID element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

(#8141)An SSID field of length 0 is used within Probe Request frames to indicate the wildcard SSID. The wildcard SSID is also used in Beacon and Probe Response frames transmitted by mesh STAs.

When the UTF-8 SSID subfield of the Extended Capabilities element is equal to 1 in the frame that includes the SSID element, or the Extended Capabilities element(#471) of the source of the SSID information is known to include the UTF-8 SSID capability based on a previously received Extended Capabilities element, the SSID is a sequence of UTF-8 encoded code points. Otherwise, the character encoding of the octets in this SSID element is unspecified.

NOTE—If the SSID is a sequence of UTF-8 encoded code points, a terminating null might or might not be present.

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### 9.4.2.3 Supported Rates and BSS Membership Selectors element

The Supported Rates and BSS Membership Selectors element specifies any combination of up to eight BSS membership selectors and rates in the OperationalRateSet parameter, as described in the MLME-JOIN.request and MLME-START.request primitives.

Each octet of the Supported Rates field describes a single supported rate or BSS membership selector (see Figure 9-210 (Supported Rates and BSS Membership Selectors element format)).

| | Element ID | Length | Supported Rates |
|---|---|---|---|
| Octets: | 1 | 1 | 1–8 |

**Figure 9-210—Supported Rates and BSS Membership Selectors element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

Within Beacon, Probe Response, Association Response, Reassociation Response, Mesh Peering Open, and Mesh Peering Confirm frames, each rate contained in the BSSBasicRateSet parameter is encoded as an octet with the MSB (bit 7) set to 1, and bits 6 to 0 are set to the data rate, if necessary rounded up to the next 500 kb/s, in units of 500 kb/s (e.g., a 2.25 Mb/s rate contained in the BSSBasicRateSet parameter is encoded as X'85'). Each rate in the OperationalRateSet parameter not contained in the BSSBasicRateSet parameter is encoded with the MSB set to 0, and bits 6 to 0 are set in the same way as for a rate contained in the BSSBasicRateSet parameter (e.g., a 2 Mb/s rate not contained in the BSSBasicRateSet parameter is encoded as X'04').

Within Beacon, Probe Response, Association Response, Reassociation Response, Mesh Peering Open, and Mesh Peering Confirm frames, each BSS membership selector contained in the BSSMembershipSelectorSet parameter is encoded as an octet with the MSB (bit 7) set to 1, and bits 6 to 0 are set to the encoded value for the selector as found in Table 9-131 (BSS membership selector value encoding) (e.g., an HT PHY BSS membership selector contained in the BSSMembershipSelectorSet parameter is encoded as X'FF'). A BSS membership selector that has the MSB (bit 7) set to 1 in the Supported Rates and BSS Membership Selectors element is defined to be basic.

The MSB of each octet in the Supported Rates field in other management frame types is ignored by receiving STAs.

The valid values for BSS membership selectors and their associated features are shown in Table 9-131 (BSS membership selector value encoding).

NOTE—Because the BSS membership selector and supported rates are carried in the same field, the BSS membership selector value cannot match the value corresponding to any valid supported rate. This allows any value to be determined as either a supported rate or a BSS membership selector.

See 11.1.4.6 (Operation of Supported Rates and BSS Membership Selectors element and Extended Supported Rates and BSS Membership Selectors element).

### 9.4.2.4 DSSS Parameter Set element

The DSSS Parameter Set element contains information to allow channel number identification for STAs. See Figure 9-211 (DSSS Parameter Set element format).

The Element ID and Length fields are defined in 9.4.2.1 (General).


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**Table 9-131—BSS membership selector value encoding**

| Value | Feature | Interpretation |
|---|---|---|
| 127 | HT PHY | Support for the mandatory features of Clause 19 (High Throughput (HT) PHY specification(#2297)) is required in order to join the BSS that was the source of the Supported Rates and BSS Membership Selectors element or Extended Supported Rates and BSS Membership Selectors element containing this value. |
| 126 | VHT PHY | Support for the mandatory features of Clause 21 (Very high throughput (VHT) PHY specification) is required in order to join the BSS that was the source of the Supported Rates and BSS Membership Selectors element or Extended Supported Rates and BSS Membership Selectors element containing this value, unless the STA is a 20 MHz-only non-AP HE STA and the BSS is an HE BSS.(11ax) |
| 125 | GLK | Indicates that support for the mandatory features of 11.50 (GLK operation) is required in order to join the BSS that was the source of the Supported Rates and BSS Membership Selectors element or Extended Supported Rates and BSS Membership Selectors element containing this value. |
| 124 | EPD | Indicates that support for EPD is required in order to join the BSS that was the source of the Supported Rates and BSS Membership Selectors element or Extended Supported Rates and BSS Membership Selectors element containing this value. |
| 123 | SAE Hash to Element Only | (#1915)Indicates that support for the SAE hash-to-element method(#344) is required in order to join the BSS that was the source of the Supported Rates and BSS Membership Selectors element or Extended Supported Rates and BSS Membership Selectors element containing this value.(#1797) |
| 122(11ax) | HE PHY | Support for the mandatory features of Clause 27 (High-efficiency (HE) PHY specification(11ax)) is required in order to join the BSS that was the source of the Supported Rates and BSS Membership Selectors element or Extended Supported Rates and BSS Membership Selectors element containing this value. |

| | Element ID | Length | Current Channel |
|---|---|---|---|
| Octets: | 1 | 1 | 1 |

**Figure 9-211—DSSS Parameter Set element format**

The Current Channel field is set to dot11CurrentChannel (see 15.4.4.3 (Channel Numbering of operating channels), 16.3.6.3 (Channel Numbering of operating channels), 17.3.8.4.2 (Channel numbering) and 19.3.15 (Channel numbering and channelization) for values).

### 9.4.2.5 TIM element

#### 9.4.2.5.1 General

The TIM element is used to signal the timing and availability of data for associated STAs. The format of this element is shown in Figure 9-212 (TIM element format).

| | Element ID | Length | DTIM Count | DTIM Period | Bitmap Control | Partial Virtual Bitmap |
|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 1 | 0 or 1 | 0 –251 |

**Figure 9-212—TIM element format**

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The Element ID and Length fields are defined in 9.4.2.1 (General).

The Length field for this element is constrained as described below.

The DTIM Count field indicates how many Beacon frames (including the current frame) appear before the next DTIM (#8164)beacon. A DTIM count of 0 indicates that the current (#8164)beacon is a DTIM beacon. The DTIM Count field is a single octet. When a TIM element is included in a TIM frame, the DTIM Count field is reserved.

The DTIM Period field indicates the number of beacon intervals or short beacon intervals between successive DTIM beacons(#4221). If all beacons are DTIM beacons(#4221)(#6593), the DTIM Period field has the value 1. The DTIM Period value 0 is reserved. The DTIM Period field is a single octet. If dot11ShortBeaconInterval is equal to true, the DTIM Period field is set to dot11ShortBeaconDTIMPeriod. If dot11ShortBeaconInterval is equal to false, the DTIM Period field is set to dot11DTIMPeriod (see 11.1.3.10.2 (Generation of S1G Beacon frames)).

(#7184)The Bitmap Control field for non-S1G STAs is shown in Figure 9-213 (Bitmap Control field format when TIM is carried in a non-S1G PPDU) and for S1G STAs is shown in Figure 9-214 (Bitmap Control field format when TIM is carried in an S1G PPDU). The Traffic Indicator field contains the traffic indication virtual bitmap bit associated with AID 0.

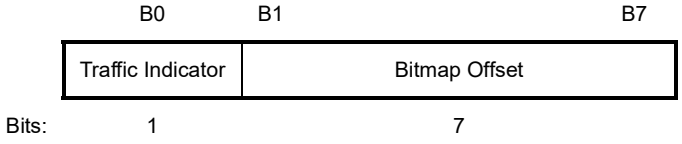


**Figure 9-213—Bitmap Control field format when TIM is carried in a non-S1G PPDU**

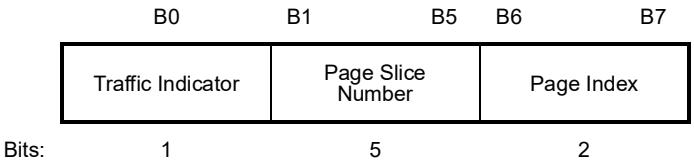


**Figure 9-214—Bitmap Control field format when TIM is carried in an S1G PPDU**

The Page Slice Number subfield indicates which page slice is encoded in the Partial Virtual Bitmap field (see 10.50 (Page slicing)) when the subfield is in the range(#3482) 0 to 30. If the Page Slice Number subfield is 31, then the entire page indicated by the Page Index subfield value is encoded in the Partial Virtual Bitmap field of the TIM elements with the same page index.

The Page Index subfield indicates the index of the page encoded in the Partial Virtual Bitmap field.

When the TIM is carried in a non-S1G PPDU, the traffic indication virtual bitmap, maintained by the AP or the mesh STA that generates a TIM, consists of 2008 bits, and it is organized into 251 octets such that bit number $N$ ($0 \le N \le 2007$) in the bitmap corresponds to bit number ($N$ mod 8) in octet number $\lfloor N / 8 \rfloor$ where the low order bit of each octet is bit number 0, and the high order bit is bit number 7. When the TIM is carried in an S1G PPDU, the traffic-indication virtual bitmap has the hierarchical structure shown in Figure 9-215 (Hierarchical structure of traffic-indication virtual bitmap carried in an S1G PPDU). Each bit in the traffic indication virtual bitmap corresponds to traffic buffered for a specific neighbor peer mesh STA within the MBSS that the mesh STA is prepared to deliver[22] or for a STA within the BSS that the AP is prepared to deliver at the time the Beacon frame is transmitted. Bit number $N$ indicates the status of


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buffered, individually addressed MSDUs/MMPDUs for the STA whose AID is *N*, or group addressed MSDUs/MMPDUs for the STAs whose group AID is *N*. It is set as follows:

— If the STA is not using APSD, and any individually addressed MSDUs/MMPDUs for that STA are buffered and the AP or the mesh STA is prepared to deliver them, then bit number *N* in the traffic indication virtual bitmap is 1.

— If the STA is using APSD, and any individually addressed MSDUs/MMPDUs for that STA are buffered in at least one nondelivery-enabled AC (if there exists at least one nondelivery-enabled AC), then bit number *N* in the traffic indication virtual bitmap is 1.

— If the STA is using APSD, all ACs are delivery-enabled, and any individually addressed MSDUs/MMPDUs for that STA are buffered in any AC, then bit number *N* in the traffic indication virtual bitmap is 1.

— Otherwise, bit number *N* in the traffic indication virtual bitmap is 0.

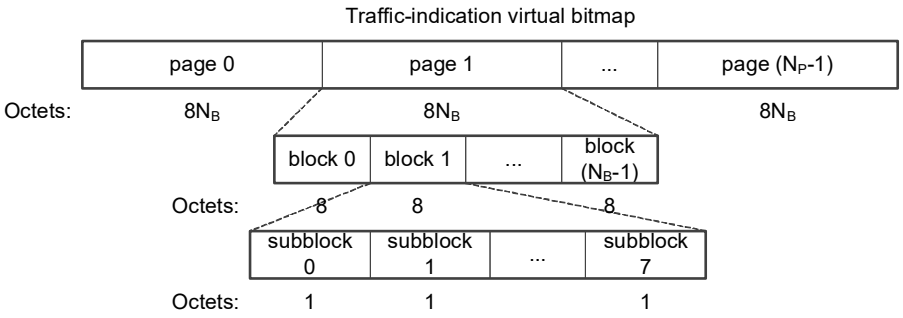


**Figure 9-215—Hierarchical structure of traffic-indication virtual bitmap carried in an S1G PPDU**

When dot11MultiBSSIDImplemented is false and the TIM is carried in a non-S1G PPDU, the Partial Virtual Bitmap field consists of octets numbered *N*1 to *N*2 of the traffic indication virtual bitmap, where *N*1 is the largest even number such that bits numbered 1 to (*N*1 × 8) – 1 in the traffic indication virtual bitmap are all 0 and *N*2 is the smallest number such that bits numbered (*N*2 + 1) × 8 to 2007 in the traffic indication virtual bitmap are all 0. In this case, the Bitmap Offset subfield value contains the number *N*1/2, and the Length field is set to (*N*2 – *N*1) + 4.

NOTE 1—When dot11MultiBSSIDImplemented is not true, (M165)the bit numbered 0 in the traffic indication virtual bitmap need not be included in the Partial Virtual Bitmap field even if that bit is set.

When the TIM is carried in a non-S1G PPDU, in the event that all bits other than bit 0 in the traffic indication virtual bitmap are 0, the Partial Virtual Bitmap field is encoded as a single octet equal to 0, the Bitmap Offset subfield is 0, and the Length field is 4. (#7205)When the TIM is carried in an S1G PPDU, if all bits in the virtual bitmap are 0, the Partial Virtual Bitmap field is not present in the TIM element.

(#7204)If all bits in the virtual bitmap are 0 and all the bits of the Bitmap Control field are 0, both the Partial Virtual Bitmap field and the Bitmap Control field are not present in the TIM element. The Bitmap Control field is present if the Partial Virtual Bitmap field is present.

When dot11MultiBSSIDImplemented is true, the Partial Virtual Bitmap field of the TIM element is constructed as follows, where the maximum possible number of BSSIDs is an integer power of 2, $n = \log2$ (maximum possible number of BSSIDs).

— The bits 1 to ($2^n$ – 1) of the bitmap are used to indicate that one or more group addressed frames are buffered for each AP corresponding to a nontransmitted BSSID(#8132). The bit position equals the

[22] How the AP or mesh STA determines the traffic it is prepared to deliver is outside the scope of this standard.

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value carried in the BSSID Index field of the Multiple BSSID-Index element carried in its nontransmitted BSSID profile (see 9.4.2.44 (Multiple BSSID element)). The AIDs from 1 to $(2^n - 1)$ are not allocated to a STA (in each page for an S1G STA). A bit position corresponding to an inactive nontransmitted BSSID is reserved and set to 0 (in each page for an S1G STA). The remaining AIDs are shared by the BSSs corresponding to the transmitted BSSID and all nontransmitted BSSIDs.

— When the DTIM Count field carried in a Multiple BSSID-Index element is 0 for a BSS that has a nontransmitted BSSID, and one or more group addressed frames are buffered at the AP for this BSS, the corresponding (#8132)bit is set to 1.

— Each bit starting from bit $2^n$ in the traffic indication virtual bitmap corresponds to individually addressed traffic buffered for a specific STA within any BSS corresponding to a transmitted or nontransmitted BSSID at the time the Beacon frame is transmitted. The correspondence is based on the AID of the STA.

— Based upon its knowledge of the capability of associated stations to support the multiple BSSID capability, as indicated by the corresponding field in the Extended Capabilities element and the content of the traffic indication virtual bitmap, an AP encodes the Partial Virtual Bitmap and the Bitmap Control fields(#8131) of the TIM element using one of the three following methods. Specifically, a non-S1G AP uses Method B when it determines that the bit for each associated non-AP STA in the traffic indication virtual bitmap that is reconstructed by each non-AP STA from the received TIM element encoded using Method B is set correctly. Otherwise, a non-S1G AP uses Method A and an S1G AP uses Method C.

Method A, Method B and Method C are described as follows:

a) Method A: The Partial Virtual Bitmap field consists of octets numbered 0 to $N2$ of the traffic indication virtual bitmap, where $N2$ is the smallest number such that bits numbered $(N2 + 1) \times 8$ to 2007 in the traffic indication virtual bitmap are all 0. If such a value $N2$ does not exist, that is, when not all bits in the last octet of the traffic indication virtual bitmap are equal to 0, $N2 = 250$. When using this method, the Bitmap Offset subfield value always contains the number 0, and the Length field is $N2 + 4$.

b) Method B: The Partial Virtual Bitmap field consists of a concatenation of octets numbered 0 to $N0 - 1$ and octets numbered $N1$ to $N2$ of the traffic indication virtual bitmap, where $N0$ is the largest positive integer such that $N0 \times 8 - 2^n < 8$. If $N0$ is an odd number, then $N1$ is the largest odd number such that $N0 < N1$ and(#2170) each of the bits $N0 \times 8$ to $(N1 \times 8 - 1)$ is equal to 0. When $N0$ is an even number, $N1$ is the largest even number such that $N0 < N1$ and each of the bits $N0 \times 8$ to $(N1 \times 8 - 1)$ is equal to 0. If such a value $N1 > N0$ does not exist, $N1 = N0$. Additionally, $N2$ is the smallest integer value for which the values for bit $(N2+1) \times 8$ to 2007 in the traffic indication virtual bitmap are all 0. If such a value $N2$ does not exist, that is, when not all bits in the last octet of the traffic indication virtual bitmap are equal to 0, $N2 = 250$. When using this method, the Bitmap Offset subfield contains $(N1 - N0)/2$, and the Length field is $N0 + N2 - N1 + 4$.

c) Method C: The Partial Virtual Bitmap field of the TIM that is carried in an S1G PPDU consists of a concatenation of Encoded Block subfields that contain (#8132)BSSID indices and Encoded Block subfields that contain AIDs. When using this method, the Page Slice Number subfield is equal to 31, and the Page Index subfield is equal to the page index of the TIM to which the AIDs belong.

NOTE 2—When $N1 = N0$, Method B reduces to Method A.

For both Method A and Method B, when there are no frames buffered for any BSS corresponding to a transmitted or nontransmitted BSSID supported, the Partial Virtual Bitmap field is encoded as a single octet equal to 0, the Bitmap Offset subfield is 0, and the Length field is 4. For Method C when the Partial Virtual Bitmap field is not present in the TIM element then the Length field is 3 and when both the Partial Virtual Bitmap field and the Bitmap Control field are not present in the TIM element then the Length field is 2. For both Method A and Method B, when there are no buffered individually addressed frames for any BSS


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corresponding to a transmitted or nontransmitted BSSID, but there are buffered group addressed frames for one or more of the BSSs, the Partial Virtual Bitmap field consists of the octets number 0 to $N0 - 1$ where $N0$ is the largest positive integer such that ($N0 \times 8 - 2^n < 8$). For Method C, the Partial Virtual Bitmap field consists of Encoded Block subfields that contain the (#8132)BSSID indices of the BSSs for which there are buffered group addressed frames. In this case for Method A and Method B, the Bitmap Offset subfield value contains the number 0, and the Length field is $N0+3$, while for Method C, the Length field is equal to 3 plus the size of the encoded blocks that carry the (#8132)BSSID indices, which are present in the TIM element.

When the TIM with a nonzero Partial Virtual Bitmap field is carried in an S1G PPDU, the Partial Virtual Bitmap field is constructed with one or more Encoded Block subfields as shown in Figure 9-216 (Partial Virtual Bitmap field format). The Encoded Block subfield consists of the Block Control subfield, the Block Offset subfield, and the Encoded Block Information subfield as shown in Figure 9-217 (Encoded Block subfield format). When dot11MultiBSSIDImplemented is true, the Partial Virtual Bitmap field contains zero or more Encoded Block subfields that contain (#8132)BSSID indices.

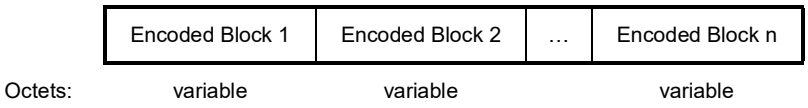


**Figure 9-216—Partial Virtual Bitmap field format**

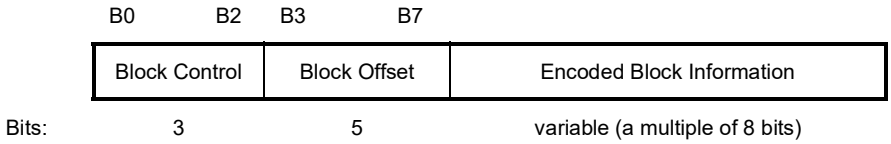


**Figure 9-217—Encoded Block subfield format**

The Block Control subfield indicates the encoding mode used in the Encoded Block subfield as shown in Table 9-132 (Block Control field encoding). The format of the Block Control subfield is as shown in Figure 9-218 (Block Control subfield format). The Block Control subfield consists of the Encoding Mode subfield and the Inverse Bitmap subfield.

**Table 9-132—Block Control field encoding**

| Bit 2 | Bit 1 | Bit 0 | Encoding mode |
|---|---|---|---|
| 0 | 0 | 0 | Block Bitmap |
| 0 | 0 | 1 | Single AID |
| 0 | 1 | 0 | OLB |
| 0 | 1 | 1 | ADE |
| 1 | 0 | 0 | Inverse Bitmap + Block Bitmap |
| 1 | 0 | 1 | Inverse Bitmap + Single AID |
| 1 | 1 | 0 | Inverse Bitmap + OLB |
| 1 | 1 | 1 | Inverse Bitmap + ADE |

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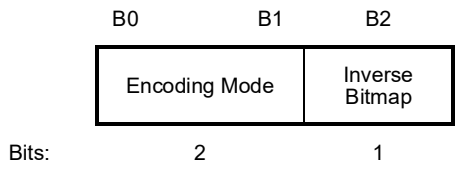


**Figure 9-218—Block Control subfield format**

The Inverse Bitmap subfield is set to 1, if the Encoded Block Information field is encoded based on the inverted version of the block, which inverts each bit value of the block. The Inverse Bitmap subfield is set to 0, otherwise.

The Encoding Mode subfield indicates one of the four encoding modes: the Block Bitmap mode, the Single AID mode, the offset length bitmap (OLB) mode, and the AID with differential encoding (ADE) mode. The four encoding modes are explained in the following subclauses.

The Block Offset field indicates the index of the block that is encoded in the Encoded Block subfield.

The Encoded Block Information subfield is defined depending on the Encoding Mode subfield and explained within the subclause for each of the encoding modes.

(11ax)If included in an OPS frame or a FILS Discovery frame by an OPS AP for aperiodic opportunistic power save (see 26.14.3 (Opportunistic power save)), the following apply:

- The DTIM Count field is reserved
- The DTIM Period field is reserved
- Bit *N* in the traffic indication virtual bitmap that corresponds to an OPS non-AP STA with AID *N* is determined as follows:
  - Bit *N* in the traffic indication virtual bitmap is set to 0 if the OPS AP does not intend to transmit to the OPS non-AP STA including to trigger the OPS non-AP STA for (#2318)a UL MU transmission during the OPS period.
  - Otherwise, bit *N* in the traffic indication virtual bitmap for the OPS non-AP STA is set to 1.
- Bit *N* in the traffic indication virtual bitmap that corresponds to a(#1426) non-OPS non-AP STA with AID *N* is determined as follows:
  - Bit *N* in the traffic indication virtual bitmap is set to 1 to indicate that AP has buffered frames for the STA and set to 0 otherwise.

(11ax)If included in a TIM frame or a FILS Discovery frame by an OPS AP for periodic opportunistic power save (see 26.14.3 (Opportunistic power save)), the following apply:

- The DTIM Count field is reserved
- The DTIM Period field is reserved
- Bit *N* in the traffic indication virtual bitmap that corresponds to an OPS non-AP STA with AID *N* is determined as follows:
  - Bit *N* in the traffic indication virtual bitmap is set to 0 if the OPS AP does not intend to transmit to the OPS non-AP STA including to trigger the OPS non-AP STA for (#2318)a UL MU transmission during the TWT SP and before the next TWT SP.
  - Otherwise, bit *N* in the traffic indication virtual bitmap for the OPS non-AP STA is set to 1.
- Bit *N* in the traffic indication virtual bitmap that corresponds to a(#1426) non-OPS non-AP STA with AID *N* is determined as follows:


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— Bit *N* in the traffic indication virtual bitmap is set to 1 to indicate that AP has buffered frames for the STA and set to 0 otherwise.

#### 9.4.2.5.2 Block Bitmap mode

The Encoded Block Information field consists of the Block Bitmap subfield and n Subblock subfields, where n is the number of bits equal to 1 in the Block Bitmap subfield. The format of the Encoded Block Information subfield is shown in Figure 9-219 (Encoded Block Information (Block Bitmap mode)).

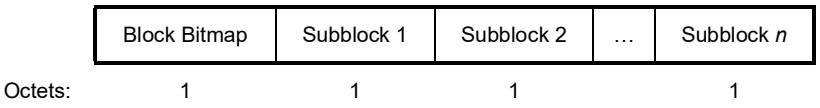


**Figure 9-219—Encoded Block Information (Block Bitmap mode)**

The bit in position *m* of the Block Bitmap subfield, if equal to 1, indicates that the subblock in position *m* of the Block is present in the Encoded Block Information subfield. The bit in position *m* of the Block Bitmap subfield, if equal to 0, indicates that the subblock in position *m* of the block is not present in the Encoded Block Information subfield. When *n* bits in the Block Bitmap subfield are equal to 1, *n* Subblock subfields follow the Block Bitmap field in ascending order of the subblock positions in the block.

Each Subblock subfield contains a subblock of the block, which has at least one bit position equal to 1. The bit in position *q* of the Subblock subfield, which contains the Subblock in position *m* of the block, indicates traffic buffered for the STA whose AID is *N*, where *N* is constructed by concatenating *q* (*N*[0:2]), *m* (*N*[3:5]), the Block Offset field (*N*[6:10]), and the Page Index field (*N*[11:12]) in sequence from LSB to MSB.

#### 9.4.2.5.3 Single AID mode

The Encoded Block Information subfield consists of the Single AID subfield as shown in Figure 9-220 (Encoded Block Information (Single AID mode)). The Single AID subfield contains the 6 LSBs of the single AID in the block. The rest of the bits of the Encoded Block Information subfield are reserved. The value in the Single AID subfield indicates traffic buffered for the STA whose AID is *N*, where *N* is constructed by concatenating the Single AID subfield(*N*[0:5]), the Block Offset field (*N*[6:10]), and the Page Index field (*N*[11:12]) in sequence from LSB to MSB.

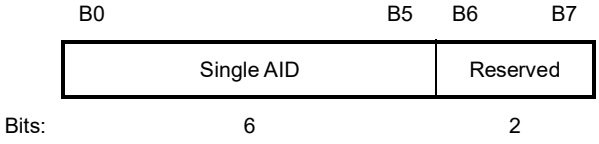


**Figure 9-220—Encoded Block Information (Single AID mode)**

#### 9.4.2.5.4 OLB mode

The Encoded Block Information field consists of the Length subfield and *n* Subblock subfields. The format of the Encoded Block Information field is shown in Figure 9-221 (Encoded Block Information (OLB mode)).

(M118)A Length subfield equal to *n* indicates that the Encoded Block Information field contains *n* contiguous subblocks in ascending order from multiple blocks starting from the first subblock of the block in position Block Offset.

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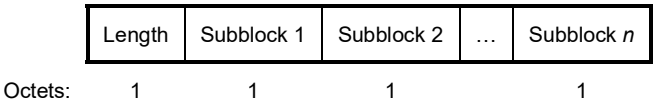


**Figure 9-221—Encoded Block Information (OLB mode)**

Each Subblock subfield contains a subblock of the Partial Virtual Map. A subblock *m* of the Encoded Block Information field is located in block *k* where *k* is obtained as Block Offset + $\lfloor m / 8 \rfloor$. The bit in position *q* of the subblock *m*, which is located in block *k*, when set to 1, indicates that there is traffic buffered for the STA whose AID is *N*, where *N* is constructed by concatenating *q* (*N*[0:2]), the subblock offset *m* mod 8 (*N*[3: 5]), the block *k* (*N*[6:10]), and the Page Index field (*N*[11:12]), in sequence from LSB to MSB.

#### 9.4.2.5.5 ADE mode

The Encoded Block Information field consists of the Encoding Word Length (EWL) subfield, Length subfield, *n* AID Differential Values (ΔAID) subfields and padding subfield, where *n* is the number of paged AIDs encoded in the ADE block. The format of the Encoded Block Information field is shown in Figure 9-222 (Encoded Block Information (ADE Block)).

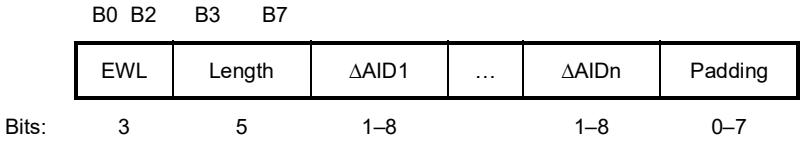


**Figure 9-222—Encoded Block Information (ADE Block)**

The length of each ΔAID subfields (*WL*) represents the encoded word length (the number of bits of each encoded words) of each AID. All *WL* have the same length. *WL* is indicated by EWL subfield.

The EWL subfield is 3 bits with B0 being LSB. The values of EWL subfield ranging from 0 to 7 represent *WL* being 1 to 8, respectively.

The Length subfield is 5 bits with B3 being LSB and it specifies the total length of the current ADE block in octets, excluding EWL and Length subfields.

The padding subfield contains 0–7 padding bits. The padding bits are set to 0.

To encode a list of paged AIDs, denoted as AID1, AID2 … AIDn, an AP can derive the *offset* value in the Block Offset field (9.4.2.5 (TIM element)) for the current ADE Block by $\lfloor (\mathrm{AID}_1 \bmod 2048) / 64 \rfloor$.

The encoding procedure is as follows:

If all AIDs in the ADE blocks are paged, AP sets the Inverse Bitmap subfield to 1 and ADE block consists only EWL and Length fields, where both EWL and Length Field are set to 0s.

If all but one AIDs in the ADE blocks are paged, AP sets the Inverse Bitmap subfield to 1 and ADE block consists only one ΔAID subfield. The AP sets the EWL to 7 and the Length subfield to one. ΔAID subfield is set to (AID – (*Page Index* × 2048 + *Block Offset* × 64)).

If only one AID is paged in the ADE blocks, AP sets the Inverse Bitmap subfield to 0 and uses the Single AID mode.


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For all other cases, AP sorts all AID*i*, *i* = 1, 2…*n* in an ascending order (AID1 < AID2 < … < AID*n*) and then calculates the AID differential values according to the following formulas:

$\Delta AID1 = AID1 - (Page\ Index \times 2048 + Block\ Offset \times 64)$

$\Delta AID_i = AID_i - AID_{i-1},\ i = 2 \ldots n$

Determine *WL* as the minimum bits that can represent the largest ΔAID*i* (or mathematically $\lfloor \log2(MAX)(\Delta AID_i) \rfloor + 1$ (#315)where $MAX(\Delta AID_i)$ denotes the largest $\Delta AID_i$), *i*=1,2,…,*n*. The EWL subfield is set to *WL*-1. For *n* AID differential values, a total of *WL* × *n* bits are required. The number of bits is less than or equal to 248 since maximum payload in an ADE block is 31 × 8=248 (31 is the maximum value in the 5-bit Length subfield). If the total number of bits *WL* × *n* is not a multiple of an octet, [*WL*×*n*/8]×8-*WL*×*n* zero bits are padded to make the ADE block end at octet boundary.

When decoding, if the Inverse Bitmap subfield is 1, and the EWL and Length subfield are 0s, then all AIDs in the ADE blocks are paged.

If the Inverse Bitmap subfield is 1, the EWL is 7 and the Length subfield is 1, then all AIDs except one in the ADE blocks are paged. The unpaged AID is ΔAID1 + *Block Offset* × 64 + *Page Index* × 2048.

For other cases, a STA can extract *Page Index* (9.4.2.5 (TIM element)) and *Block Offset* (9.4.2.5 (TIM element)), EWL and Length values from the respective fields. It derives *WL* by adding 1 to the value from EWL field. The paged AIDs are then derived with following formulas:

$AID1 = \Delta AID1 + (Page\ Index \times 2048 + Block\ Offset \times 64)$

$AID_i = \Delta AID_i + AID_i - 1,\ i = 2, \ldots, n$

The decoder stops the decoding of the current ADE block when either one of following conditions is satisfied:

— The number of bits left for decoding is less than WL.
— ΔAIDi is zero and *i* > 1.

AIDs from the same or different blocks can be encoded into one ADE block. A STA can derive the number of AIDs, including both paged and unpaged AIDs, encoded in one ADE block with following method:

If an ADE block is not the last encoded block in the TIM element, the decoder can derive the number of AIDs encoded by this ADE block based on the *Block offset* values in the current and the immediate next encoded blocks. For example, the offset values in the current ADE block and the next encoded block are *Offset*1 and *Offset*2. Then the AIDs encoded by this ADE block is [*Page Index* × 2048 + *Offset*1 × 64, *Page Index* × 2048 + *Offset*2×64), *Page Index*×2048 + *Offset*1 × 64 is included and *Page Index* × 2048 + *Offset*2 × 64 is excluded.

If an ADE block is the last one in the TIM element, the number of AIDs encoded by the last ADE block can be determined based on the offset value and page length or page slice length if its TIM page is sliced.

### 9.4.2.6 IBSS Parameter Set element

The IBSS Parameter Set element contains the set of parameters necessary to support an IBSS. See Figure 9-223 (IBSS Parameter Set element format).

The Element ID and Length fields are defined in 9.4.2.1 (General).

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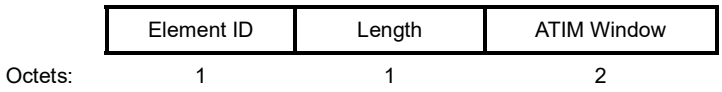


**Figure 9-223—IBSS Parameter Set element format**

The ATIM Window field contains the ATIM window length in TU(#3056).

### 9.4.2.7 Country element

The Country element contains the information required to allow a STA to identify the regulatory domain in which the STA is located and to configure its PHY for operation in that regulatory domain. The format of this element is as shown in Figure 9-224 (Country element format).

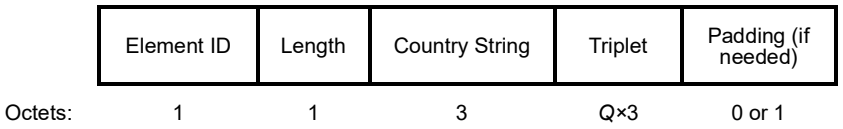


**Figure 9-224—Country element format**

The Element ID and Length fields are defined in 9.4.2.1 (General)(#22).

The AP and mesh STA set the Country String field to the value contained in dot11CountryString before transmission in a Beacon or Probe Response frame. Upon reception of this element, a STA sets the dot11CountryString to the value contained in this field. The three octets of the Country String have additional structure as defined by dot11CountryString (see Annex C).

If dot11OperatingClassesRequired is false, then the Triplet field is a single Subband Triplet Sequence field, as shown in Figure 9-225 (Subband Triplet Sequence format), that is composed of *Q* Subband Triplet fields, where *Q* is one or more. The format of the Subband Triplet field is shown in Figure 9-226 (Subband Triplet field format).

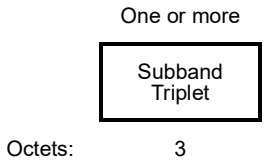


**Figure 9-225—Subband Triplet Sequence format**

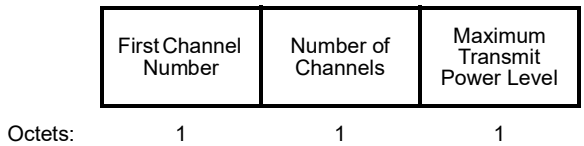


**Figure 9-226—Subband Triplet field format**

If dot11OperatingClassesRequired is true, then the Triplet field is composed of zero or more Subband Triplet fields followed by one or more Operating/Subband Sequence fields(#1481), as shown in Figure 9-227 (Triplet field format if dot11OperatingClassRequired is true). (11ax)If the Country element is included in a frame transmitted in the 6 GHz band, the Triplet field is composed of zero Subband Triplet fields and only has one or more Operating/Subband Sequence fields. Each Operating/Subband Sequence field(#1481)


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is composed of one Operating Triplet field followed by one Subband Triplet Sequence field, as shown in Figure 9-228 (Format of m-th Operating/Subband Sequence field). Each Subband Triplet Sequence field is composed of zero or more Subband Triplet fields. If dot11OperatingClassesRequired is true, the number of triplets in the Triplet field is $Q = N + \sum_{m=1}^{M} (1 + P(m))$, where $N$ is the total number of Subband Triplet fields and $M$ is the total number of Operating/Subband Sequence fields(#1481) contained in (#1484)the Country element and *P(m)* is the number of Subband Triplet fields making up Operating/Subband Sequence field *m*.

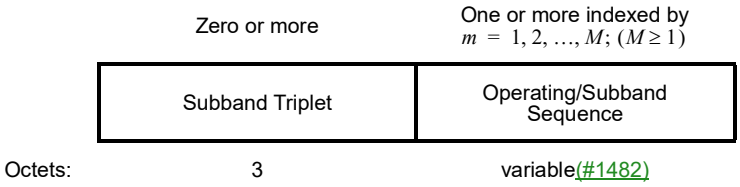


**Figure 9-227—Triplet field format if dot11OperatingClassRequired is true**

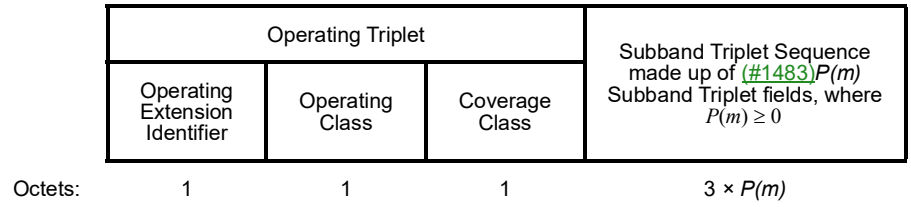


**Figure 9-228—Format of *m*-th Operating/Subband Sequence field**

The number $Q$ of Subband fields or Operating triplet fields in the element is determined by the Length field.

An operating class for an 80+80 MHz channel width is expressed by two consecutive Operating/Subband Sequence fields(#1481), where the first Operating/Subband Sequence field contains an Operating Triplet field indicating an 80 MHz channel spacing with an 80+ behavior limit and the second Operating/Subband Sequence field contains an Operating Triplet field indicating an 80 MHz channel spacing without an 80+ behavior limit.

Operating/Subband Sequence fields that contain an Operating Class field for which the Channel spacing (MHz) column in the appropriate table in Annex E equals 80 or 160 contain zero Subband Triplet fields.

NOTE 1—Any Operating Triplet field indicating 80 MHz, 160 MHz, and 80+80 MHz can be omitted from the Country element (see 10.22.3 (Operation with operating classes)).

NOTE 2—The Transmit Power Envelope element is always used for TPC for 80 MHz, 160 MHz, or 80+80 MHz operating classes instead of Subband Triplet fields (see 11.38.1 (Basic VHT BSS functionality)).

(11ax)An Operating/Subband Sequence field contains zero Subband Triplet fields if all the following conditions are true:

— The operating class table number indicated in the Country String field is Table E-4 (Global operating classes) (see dot11CountryString).

— (#3728)The value in the (#4177)Channel starting frequency (GHz) column in Table E-4 (Global operating classes) is greater than or equal to 5.925 and less than or equal to 7.125 for the operating class indicated in the Operating Class field.

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— (#3728)The value in the (#4177)Channel spacing (MHz) column in Table E-4 (Global operating classes) is greater than or equal to 40 MHz for the operating class indicated in the Operating Class field.

NOTE 3—Any Operating Triplet field for an operating class for which the (#4177)Channel starting frequency column in Table E-4 (Global operating classes) is greater than or equal to 5.925 and less than or equal to 7.125 can be omitted from the Country element (see 10.22.3 (Operation with operating classes)).

NOTE 4—The Transmit Power Envelope element is always used for TPC for operating classes in the 6 GHz band instead of Subband Triplet fields (see 26.15.8 (Additional rules for PPDUs sent in the 6 GHz band)).

(#22)The first octet in each Subband Triplet field or Operating Triplet field identifies the type of field. (#1988)If it is less than or equal to 200, then the field is a Subband Triplet field (see Figure 9-226 (Subband Triplet field format)). Otherwise, the field is an Operating Triplet field (see left half of Figure 9-228 (Format of m-th Operating/Subband Sequence field)).

The First Channel Number field indicates the lowest channel number in the Subband Triplet field. No channel is indicated by more than one pair of First Channel Number and Number of Channels fields within a Subband Triplet Sequence field. [For example, the (First Channel Number, Number of Channels) pairs (2,4) and (5,2) in 2.4 GHz each indicate channel 5, therefore are not used within the same Subband Triplet Sequence field.] The First Channel Numbers are monotonically increasing within a Subband Triplet Sequence field. The First Channel Number and the Number of Channels pairs in a Country element are used to describe channels only in the band on which the frame containing the element is transmitted.

(#1988)NOTE 5—It is not possible to indicate a first channel number above 200 in the 6 GHz band (i.e., a first channel above approximately 7 GHz), since this would be interpreted as the Operating Extension Identifier field of an Operating Triplet field.

Outside the 2.4 GHz band, the channel numbers that are included in a group of channels are separated by the BSS bandwidth. For Subband Triplet fields that are not within an Operating/Subband Sequence field, the BSS bandwidth is 20 MHz. For Subband Triplet fields that are within an Operating/Subband Sequence field, the BSS bandwidth is as indicated by the operating class in the same Operating/Subband Sequence field. In the 2.4 GHz band, the channel numbers that are included in a group of channels are separated by 5 MHz (for both 20 and 40 MHz BSS bandwidth), except that channel 14 is treated as if it were 5 MHz above channel 13.

NOTE 6—For example, the channels 1 to 11 in the 2.4 GHz band can be represented using one Subband Triplet field(#22) with First Channel Number = 1 and Number of Channels = 11. The channels 36, 40, 44, and 48 with 20 MHz BSS bandwidth in the 5 GHz band can be represented using one Subband Triplet field(#22) with First Channel Number = 36 and Number of Channels = 4. The six channels 183, 184, 185, 187, 188, and 189 (but not 186) with 10 MHz BSS bandwidth can be represented using three Subband Triplet (#22)fields: one with First Channel Number = 183 and Number of Channels = 4, one with First Channel Number = 184 and Number of Channels = 1 and one with First Channel Number = 188 and Number of Channels = 1.

The Maximum Transmit Power Level field is a 2s complement signed integer. The Maximum Transmit Power Level field indicates the maximum power, in dBm, allowed to be transmitted. As the method of measurement for maximum transmit power level differs by regulatory domain, the value in this field is interpreted according to the regulations applicable for the domain identified by the Country String.

(11ax)The Maximum Transmit Power Level field is reserved if it is within an Operating/Subband Sequence field with the operating class for which the (#4177)Channel starting frequency column in Table E-4 (Global operating classes) (#1868)is greater than or equal to 5.925 and less than or equal to 7.125.

NOTE 7—Maximum transmit power information for channels in the 6 GHz band is conveyed using the Transmit Power Envelope element (see 10.22.4 (Operation with the Transmit Power Envelope element)).

(#22)The Operating Extension Identifier field is an arbitrary value, subject to the minimum defined above for Operating Triplet fields.


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(#22)NOTE 8—The same value might be used in more than one Operating Triplet field within the Country element.

An operating class is an index into a set of values for radio equipment sets of rules.

(#22)(#1988)The Operating Class field specifies the operating class to which the immediately following Subband Triplet fields, if any, within the Operating/Subband Sequence field (see Figure 9-228 (Format of m-th Operating/Subband Sequence field)) pertain.

(#1988)NOTE 9—The Operating/Subchannel Sequence field ends at the next Operating Class field, if any.

A coverage class is an index into a set of values for aAirPropagationTime(#22).

The Coverage Class field (#22) is reserved in a DMG BSS. Otherwise, it specifies the aAirPropagationTime characteristic used in BSS operation, as shown in Table 9-133 (Coverage Class field parameters). The characteristic aAirPropagationTime describes variations in actual propagation time that are accounted for in a BSS and, together with maximum transmit power level, allow control of BSS diameter.

**Table 9-133—Coverage Class field parameters**

| Coverage class value | aAirPropagationTime (μs) |
|---|---|
| 0–31 | $n \times 3$ , where $n$ is the value of the coverage class |
| 32–255 | Reserved |

The Padding field is used to add, if needed, a single octet (with the value 0) to the Country element so that its length is evenly divisible by 2.

### 9.4.2.8 Request element

(#1529)This element is included in a frame to request that the responding STA include the requested elements in the response frame. The format of the element is as shown in Figure 9-229 (Request element format).

| | Element ID | Length | Requested Element IDs |
|---|---|---|---|
| Octets: | 1 | 1 | variable |

**Figure 9-229—Request element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The Requested Element IDs field is(M118) the list of elements that are requested to be included in the Probe Response or Information Response frame. The Requested Element IDs field is(M118) listed in order of increasing element ID. The Requested Element IDs field(M118) within a Request element transmitted in an Information Request frame does not include an element ID that corresponds to an element (M118)to be included in the Information Response frame even in the absence of the Request element, as shown in Table 9-572 (Information Response frame Action field format). A given element ID is included in at most once among the Requested Element IDs field(M118).

NOTE—Some implementations might unnecessarily include in a Probe Request frame a Request element that contains the element ID of an element (M118)to be included in the Probe Response frame even in the absence of the element ID in the Request element; see the notes in Table 9-69 (Probe Response frame body). Some implementations might include

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in a Probe Request frame a Request element that contains the element ID of an element that will not be included in the Probe Response frame even in the presence of the element ID in the Request element.

The Request element does not support elements that contain an Element ID Extension field.

See 11.1.4.3.9 (Contents of a probe response) for additional requirements.

### 9.4.2.9 Extended Request element

(#1529)This element is included in a frame to request that the responding STA include the requested elements in the response frame. The format of the element is as shown in Figure 9-230 (Extended Request element format).

| | Element ID | Length | Element ID Extension | Requested Element ID | Requested Element ID Extensions |
|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 1 | variable |

**Figure 9-230—Extended Request element format**

The Element ID, Element ID Extension, and Length fields are defined in 9.4.2.1 (General).

The Requested Element ID field contains one of the (M118)element IDs used to indicate an extended element.

The Requested Element ID Extensions field contains a list of 1-octet element ID extension values that, combined with the value of the Requested Element ID field, identify elements that are requested to be included in the Probe Response or Information Response frame. The values in this field are listed in increasing order. The requested elements within an Extended Request element transmitted in a Probe Request frame do not identify (M118)elements included in the Probe Response frame even in the absence of the Request element, or (M118)excluded from the Probe Response frame even in the presence of the Extended Request element as described by the notes in Table 9-69 (Probe Response frame body). The requested elements within an Extended Request (M118)element transmitted in an Information Request frame do not identify elements included in the Information Response frame even in the absence of the Extended Request element, as shown in Table 9-572 (Information Response frame Action field format). A given element ID extension value is included at most once in the Requested Element ID Extensions field.

See 11.1.4.3.9 (Contents of a probe response) for additional requirements.

### 9.4.2.10 ERP element

The ERP element contains information on the presence of Clause 15 (DSSS PHY specification for the 2.4 GHz band designated for ISM applications) or Clause 16 (High rate direct sequence spread spectrum (HR/DSSS) PHY specification) STAs in the BSS that are not capable of Clause 18 (Extended Rate PHY (ERP) specification) (ERP-OFDM) data rates. It also contains the requirement of the ERP element sender (AP, IBSS STA, or mesh STA) as to the use of protection mechanisms to optimize BSS performance and as to the use of long or short Barker preambles. See Figure 9-231 (ERP element format) for a definition of the frame element.

The ERP element has the form shown in Figure 9-231 (ERP element format).

The Element ID and Length fields are defined in 9.4.2.1 (General).

The ERP Parameters field is defined in Figure 9-232 (ERP Parameters field format).


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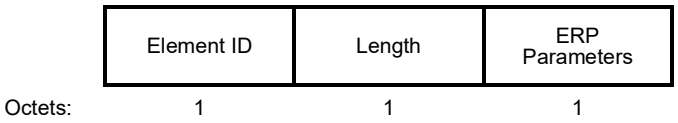


**Figure 9-231—ERP element format**

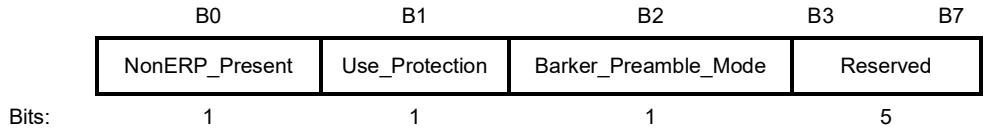


**Figure 9-232—ERP Parameters field format**

Recommended behavior for setting the Use_Protection bit is contained in 10.27 (Protection mechanisms).

### 9.4.2.11 Extended Supported Rates and BSS Membership Selectors element

The Extended Supported Rates and BSS Membership Selectors element specifies the rates in the OperationalRateSet parameter, as described in the MLME-JOIN.request and MLME-START.request primitives, and zero or more BSS membership selectors, where these are not carried in the Supported Rates and BSS Membership Selectors element. See Figure 9-233 (Extended Supported Rates and BSS Membership Selectors element format).

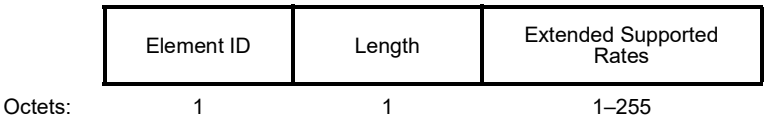


**Figure 9-233—Extended Supported Rates and BSS Membership Selectors element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The format and interpretation of each octet of the Extended Supported Rates field is the same as that of an octet in the Supported Rates field in a Supported Rates and BSS Membership Selectors element (see 9.4.2.3 (Supported Rates and BSS Membership Selectors element)).

### 9.4.2.12 Power Constraint element

The Power Constraint element contains the information necessary to allow a STA to determine the local maximum transmit power in the current channel. The format of the Power Constraint element is shown in Figure 9-234 (Power Constraint element format).

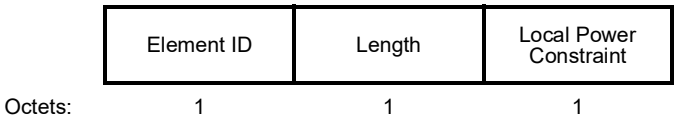


**Figure 9-234—Power Constraint element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The Local Power Constraint field is coded as an unsigned integer in units of decibels. The local maximum transmit power for a channel is thus defined as the maximum transmit power level specified for the channel

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in the Country element minus the local power constraint specified for the channel (from the MIB) in the Power Constraint element.

(#1099)The use of Power Constraint elements is described in 11.7.5 (Specification of regulatory and local maximum transmit power levels).

### 9.4.2.13 Power Capability element

The Power Capability element specifies the minimum and maximum transmit powers with which a STA is capable of transmitting in the current channel. The format of the Power Capability element is shown in Figure 9-235 (Power Capability element format).

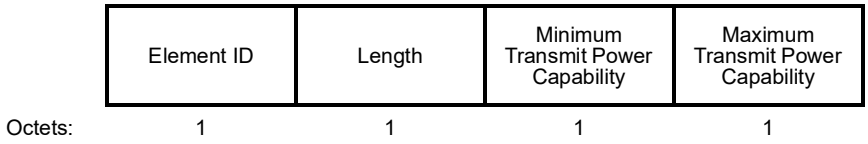


**Figure 9-235—Power Capability element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The Minimum Transmit Power Capability field is set to the nominal minimum transmit power with which the STA is capable of transmitting in the current channel, with a tolerance ± 5 dB. The field is coded as a 2s complement signed integer in units of decibels relative to 1 mW. Further interpretation of this field is defined in 11.7.4 (Interpretation of transmit power capability).

The Maximum Transmit Power Capability field is set to the nominal maximum transmit power with which the STA is capable of transmitting in the current channel, with a tolerance ± 5 dB. The field is coded as a 2s complement signed integer in units of decibels relative to 1 mW. Further interpretation of this field is defined in 11.7.4 (Interpretation of transmit power capability).

(#1100)The use of Power Capability elements is described in 11.7.2 (Association based on transmit power capability).

### 9.4.2.14 TPC Request element

The TPC Request element contains a request for a STA to report transmit power and link margin information using a TPC Report element. The format of the TPC Request element is shown in Figure 9-236 (TPC Request element format).

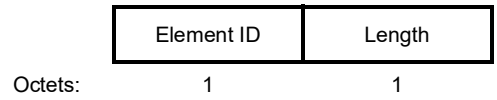


**Figure 9-236—TPC Request element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

(#1101)The use of TPC Request elements and frames is described in 11.7.7 (Transmit power adaptation).


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### 9.4.2.15 TPC Report element

The TPC Report element contains transmit power and link margin information sent in response to a TPC Request element or a Link Measurement Request frame. A TPC Report element is included in a Beacon frame or Probe Response frame without a corresponding request. The format of the TPC Report element is shown in Figure 9-237 (TPC Report element format).

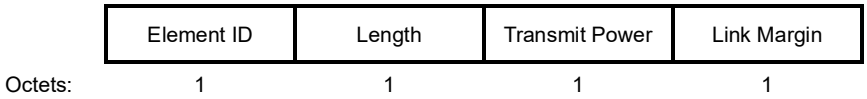


**Figure 9-237—TPC Report element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The Transmit Power field is set to the transmit power used to transmit the frame containing the TPC Report element. The field is coded as a 2s complement signed integer in units of decibels relative to 1 mW. The tolerance for the transmit power value reported in the TPC Response element is ± 5 dB. This tolerance is defined as the difference, in decibels, between the reported power value and the actual EIRP of the STA (when transmitting 1500 octet frames or maximum MPDU sized-frames, whichever is smaller).

The Link Margin field contains the link margin for the receive time and for the receive rate of the frame containing the TPC Request element or the Link Measurement Request frame. The field is coded as a 2s complement signed integer in units of decibels. The Link Margin field is reserved when a TPC Report element is included in a Beacon frame or Probe Response frame. The method used to measure the link margin is beyond the scope of this standard.

(#1102)The use of TPC Report elements and frames is described in 11.7.7 (Transmit power adaptation).

### 9.4.2.16 Supported Channels element

The Supported Channels element contains a list of channel subbands(#3510) in which a STA is capable of operating. The format of the Supported Channels element is shown in Figure 9-238 (Supported Channels element format).

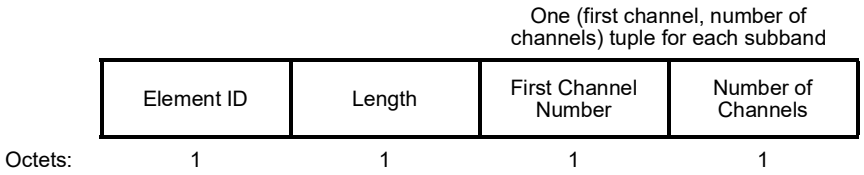


**Figure 9-238—Supported Channels element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The First Channel Number field is set to the first channel (as defined in 17.3.8.4.3 (Channelization)) in a subband of supported channels.

The Number of Channels field is set to the number of channels in a subband of supported channels.(#3510)

### 9.4.2.17 Channel Switch Announcement element

The Channel Switch Announcement element is used by a non-DMG AP, non-DMG IBSS STA, or mesh STA to advertise when it is changing to a new channel and the channel number of the new channel. The

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format of the Channel Switch Announcement element is shown in Figure 9-239 (Channel Switch Announcement element format).

**Figure 9-239—Channel Switch Announcement element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The Channel Switch Mode field indicates any restrictions on transmission until a channel switch. A non-DMG AP or non-DMG IBSS STA sets the Channel Switch Mode field to either 0 or 1 on transmission. In an MBSS, the Channel Switch Mode field is reserved. See 11.8.9 (Channel Switch Announcement element operation).

The New Channel Number field is set to the number of the channel to which the STA is moving (as defined in 17.3.8.4.3 (Channelization)).

For nonmesh STAs, the Channel Switch Count field is set to the number of TBTTs until the STA sending the Channel Switch Announcement element switches to the new channel. The value 1 indicates that the switch occurs at the next TBTT (the ensuing Beacon frame is created assuming the new channel), and the value 0 indicates that the switch occurs at any time after the frame containing the element is transmitted.

For mesh STAs, the Channel Switch Count field is encoded as an octet with bits 6 to 0 set to the time, in units of 2 TU when the MSB (bit 7) is 0, or in units of 100 TU when the MSB (bit 7) is 1, until the mesh STA sending the Channel Switch Announcement element switches to the new channel. An octet with bits 6 to 0 indicates that the switch occurs at any time after the frame containing the element is transmitted. For example, a 200 TU channel switch time is encoded as X'82' and a 10 TU channel switch time is encoded as X'05'.

(#1104)The use of Channel Switch Announcement elements and frames is described in 11.8.8 (Selecting and advertising a new channel).

### 9.4.2.18 Secondary Channel Offset element

The Secondary Channel Offset element is used by an AP, IBSS STA or mesh STA when changing to a new 40 MHz or wider channel. The format of the Secondary Channel Offset element is shown in Figure 9-240 (Secondary Channel Offset element format).(#3232)

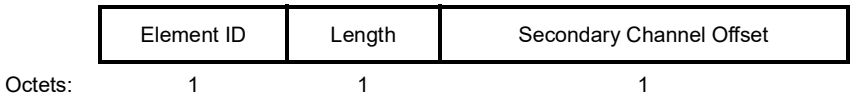


**Figure 9-240—Secondary Channel Offset element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The Secondary Channel Offset field of the Secondary Channel Offset element represents the position of the secondary channel relative to the primary channel. The values of the Secondary Channel Offset field are defined in Table 9-134 (Values of the Secondary Channel Offset field).


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**Table 9-134—Values of the Secondary Channel Offset field**

| Value | Name | Description |
|---|---|---|
| 0 | SCN - no secondary channel | Indicates that no secondary channel is present. |
| 1 | SCA - secondary channel above | Indicates that the secondary channel is above the primary channel. |
| 2 | | Reserved. |
| 3 | SCB - secondary channel below | Indicates that the secondary channel is below the primary channel. |
| 4–255 | | Reserved. |

### 9.4.2.19 Measurement Request element

#### 9.4.2.19.1 General

The Measurement Request element contains a request that the receiving STA undertake the specified measurement action. The Measurement Request element is included in Spectrum Measurement Request frames, as described in 9.6.2.2 (Spectrum Measurement Request frame format), or Radio Measurement Request frames, as described in 9.6.6.2 (Radio Measurement Request frame format). Measurement types 0, 1, and 2 are defined for spectrum management and are included only in Spectrum Measurement Request frames. The use of Measurement Request elements for spectrum management is described in 11.8.7 (Requesting and reporting of measurements). All other measurement types are included only in Radio Measurement Request frames. The use of Measurement Request elements for radio measurement is described in 11.10 (Radio measurement procedures).

The format of the Measurement Request element is shown in Figure 9-241 (Measurement Request element format).

| | Element ID | Length | Measurement Token | Measurement Request Mode | Measurement Type | Measurement Request |
|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 1 | 1 | variable |

**Figure 9-241—Measurement Request element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The Measurement Token is set to a nonzero number that is unique among the Measurement Request elements in a particular Spectrum or Radio Measurement Request frame.

The Measurement Request Mode field (shown in Figure 9-242 (Measurement Request Mode field format)) is a (#291)bitmap with the following bits defined:

— The Parallel subfield(#291) is used to request that more than one measurement is to be started in parallel. The Parallel subfield(#291) is set to 1 to request that the measurement is to start at the same time as the measurement described by the next Measurement Request element in the same Radio Measurement Request frame. The Parallel subfield(#291) is set to 0 if the measurements are to be performed in sequence. The Parallel subfield(#291) is reserved when the Enable subfield(#291) is 1, in the last or only Measurement Request element in the frame, or when the Measurement Type field is 0, 1, or 2 (spectrum management measurements). See 11.10.6 (Requesting and reporting of measurements).

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— The Enable subfield(#291) is used to differentiate between a request to make a measurement and a request to control the measurement requests and triggered or autonomous reports generated by the destination STA. The Enable subfield(#291) is further described in Table 9-135 (Summary of use of Enable, Request, and Report subfields(#291)).

— The Request subfield(#291) is described in Table 9-135 (Summary of use of Enable, Request, and Report subfields(#291)).

— The Report subfield(#291) is described in Table 9-135 (Summary of use of Enable, Request, and Report subfields(#291)).

— The Duration Mandatory subfield(#291) indicates whether the measurement duration contained within the measurement request is interpreted as mandatory by the STA receiving the request. A 0 indicates that the duration requested is a maximum duration, and the requesting STA accepts measurement results taken over any shorter duration. A 1 indicates that the duration requested is a mandatory duration. The Duration Mandatory subfield(#291) is reserved when the Enable subfield(#291) is 1, or when the Measurement Type field is 0, 1, 2, 8, or 255. See 11.10.4 (Measurement duration).

— All other bits are reserved.

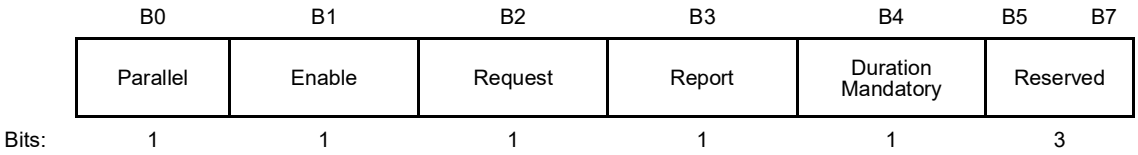


**Figure 9-242—Measurement Request Mode field format**

The use of the Enable, Request, and Report bits is summarized in Table 9-135 (Summary of use of Enable, Request, and Report subfields(#291)). See 11.8.7 (Requesting and reporting of measurements) and 11.10.6 (Requesting and reporting of measurements) for the description of how a STA handles requests to enable or disable measurement requests and autonomous reports. See 11.10.8 (Triggered autonomous reporting) for a description of the use of the Enable and Report bits in triggered reporting.

**Table 9-135—Summary of use of Enable, Request, and Report subfields(#291)**

| Subfields | | | Meaning of subfields |
|---|---|---|---|
| Enable | Request | Report | |
| 0 | Reserved | Reserved | The transmitting STA is requesting that the destination STA make a measurement of type indicated in the Measurement Type field. When Enable subfield(#291) is 0, Request and Report bits are reserved. |
| 1 | 0 | 0 | The transmitting STA is requesting that the destination STA not send any measurement requests or reports of the type indicated in the Measurement Type field. |
| 1 | 1 | 0 | The transmitting STA is indicating to the destination STA that it can accept measurement requests and is requesting the destination STA not send autonomous or triggered measurement reports of the type indicated in the Measurement Type field.<br><br>NOTE—This setting corresponds to the default STA behavior. |


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**Table 9-135—Summary of use of Enable, Request, and Report subfields(#291) *(continued)***

| Subfields | | | Meaning of subfields |
|---|---|---|---|
| Enable | Request | Report | |
| 1 | 0 | 1 | The transmitting STA is requesting that the destination STA not send measurement requests and indicating it accepts autonomous or triggered measurement reports of the type indicated in the Measurement Type field. |
| 1 | 1 | 1 | The transmitting STA is indicating to the destination STA that it can accept measurement requests and can accept autonomous or triggered measurement reports of the type indicated in the Measurement Type field. |

The Measurement Type field is set to a number that identifies a type of measurement request or measurement report. The measurement types that have been allocated for measurement requests are shown in Table 9-136 (Measurement type definitions for measurement requests) and measurement reports are shown in Table 9-163 (Measurement Type field definitions for measurement reports) (in 9.4.2.20 (Measurement Report element)).

**Table 9-136—Measurement type definitions for measurement requests**

| Name | Measurement type |
|---|---|
| Basic | 0 |
| Clear Channel Assessment (CCA) | 1 |
| Receive Power Indication (RPI) Histogram | 2 |
| Channel Load | 3 |
| Noise Histogram | 4 |
| Beacon | 5 |
| Frame | 6 |
| STA Statistics | 7 |
| LCI | 8 |
| Transmit Stream/Category Measurement | 9 |
| Multicast Diagnostics | 10 |
| Location Civic | 11 |
| Location Identifier | 12 |
| Directional Channel Quality | 13 |
| Directional Measurement | 14 |
| Directional Statistics | 15 |
| (#7065)FTM Range | 16 |
| Neighboring DMG APs(11az) | 17 |
| Reserved | 18–254 |
| Measurement Pause | 255 |

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When the Enable subfield(#291) is 0, the Measurement Request field contains the specification of a single measurement request corresponding to the measurement type, as described in 9.4.2.19.2 (Basic request) to 9.4.2.19.12 (Measurement Pause request). When the Enable subfield(#291) is 1, the Measurement Request field is present only when requesting a triggered measurement.

#### 9.4.2.19.2 Basic request

The Measurement Request field corresponding to a Basic request is shown in Figure 9-243 (Measurement Request field format for a Basic request). See 11.8.7 (Requesting and reporting of measurements).

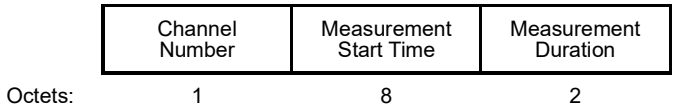


**Figure 9-243—Measurement Request field format for a Basic request**

The Channel Number field is set to the channel number for which the measurement request applies where the channel number is a value from the Channel set column in Table E-4 (Global operating classes), in a row having the same value in the Channel spacing (MHz) column as the width of the primary channel.

The Measurement Start Time field is set to the TSF timer at the time (± 32 μs) at which the requested Basic request measurement starts. A 0 indicates it starts immediately.

The Measurement Duration field is set to the duration of the requested measurement, expressed in TUs.

#### 9.4.2.19.3 CCA request (Clear channel access request)

The Measurement Request field corresponding to a CCA request is shown in Figure 9-244 (Measurement Request field format for a CCA request).

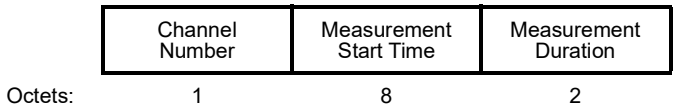


**Figure 9-244—Measurement Request field format for a CCA request**

The Channel Number field is set to the channel number for which the measurement request where the channel number is a value from the Channel set column in Table E-4 (Global operating classes), in a row having the same value in the Channel spacing (MHz) column as the width of the primary channel.

The Measurement Start Time field is set to the TSF at the time (± 32 μs) at which the requested CCA request measurement starts. A 0 indicates it starts immediately.

The Measurement Duration field is set to the duration of the requested measurement, expressed in TUs.

#### 9.4.2.19.4 RPI histogram request (Received power indicator histogram request)

The Measurement Request field corresponding to an RPI Histogram request is shown in Figure 9-245 (Measurement Request field format for an RPI Histogram request).

The Channel Number field is set to the channel number for which the measurement request where the channel number is a value from the Channel set column in Table E-4 (Global operating classes), in a row having the same value in the Channel spacing (MHz) column as the width of the primary channel.


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| | Channel Number | Measurement Start Time | Measurement Duration |
|---|---|---|---|
| Octets: | 1 | 8 | 2 |

**Figure 9-245—Measurement Request field format for an RPI Histogram request**

The Measurement Start Time field is set to the TSF at the time (± 32 μs) at which the requested RPI Histogram request measurement starts. A 0 indicates it starts immediately.

The Measurement Duration field is set to the duration of the requested measurement, expressed in TUs.

### 9.4.2.19.5 Channel Load request

The Measurement Request field corresponding to a Channel Load request is shown in Figure 9-246 (Measurement Request field format for Channel Load request).

| | Operating Class | Channel Number | Randomization Interval | Measurement Duration | Optional Subelements |
|---|---|---|---|---|---|
| Octets: | 1 | 1 | 2 | 2 | variable |

**Figure 9-246—Measurement Request field format for Channel Load request**

If the Wide Bandwidth Channel Switch subelement is not included, the Operating Class field indicates the operating class that identifies the channel set for which the measurement request applies. The Country, Operating Class, and Channel Number fields together specify the channel frequency and spacing for which the measurement request applies. Valid operating classes are listed in Annex E, excluding operating classes that encompass a primary channel but do not identify the location of the primary channel. The Channel Number field indicates the channel number for which the measurement request applies. Channel number is defined within an operating class as shown in Annex E.

NOTE—Examples of operating classes that encompass a primary channel but do not identify the location of the primary channel are operating classes with 80 or 160 in the Channel spacing (MHz) column in the applicable table in Annex E.

If the Wide Bandwidth Channel Switch subelement is included, the fields in the Wide Bandwidth Channel Switch subelement indicate the channel for which the measurement request applies, and the Operating Class field and Channel Number field together specify the primary channel and primary 40 MHz channel within the channel identified by the Wide Bandwidth Channel Switch subelement.

The Randomization Interval field specifies the upper bound of the random delay to be used prior to making the measurement, in units of TUs. See 11.10.3 (Measurement start time).

The Measurement Duration field is set to the preferred or mandatory duration of the requested measurement, in units of TUs. See 11.10.4 (Measurement duration).

The Optional Subelements field contains zero or more subelements. The subelement format and ordering of subelements are defined in 9.4.3 (Subelements).

The Subelement ID field values for the defined subelements are shown in Table 9-137 (Optional subelement IDs for Channel Load request).

The Channel Load Reporting subelement indicates the condition for issuing a Channel Load report. The Channel Load Reporting subelement Data field format is shown in Figure 9-247 (Channel Load Reporting subelement Data field format)(#1496). The Reporting Condition subfield is described in Table 9-138

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**Table 9-137—Optional subelement IDs for Channel Load request**

| Subelement ID | Name | Extensible |
|---|---|---|
| 0 | Reserved | |
| 1 | Channel Load Reporting | Yes |
| 2–162 | Reserved | |
| 163 | Wide Bandwidth Channel Switch | Yes |
| 164–220 | Reserved | |
| 221 | Vendor Specific | Vendor defined |
| 222–255 | Reserved | |

(Reporting Condition subfield for Channel Load report). The Channel Load Reference value is a Channel Load value as defined in 11.10.9.3 (Channel load report) and is the reference value for the indicated reporting condition.

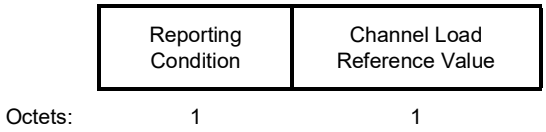


**Figure 9-247—Channel Load Reporting subelement Data field format**

**Table 9-138—Reporting Condition subfield for Channel Load report**

| Condition for report to be issued | Reporting Condition |
|---|---|
| Report to be issued after each measurement (default, used when the Channel Load Reporting subelement is not included in the Channel Load request). | 0 |
| Report to be issued when the measured Channel Load is greater than or equal to the reference value. | 1 |
| Report to be issued when the measured Channel Load is less than or equal to the reference value. | 2 |
| Reserved | 3–255 |

The Wide Bandwidth Channel Switch subelement has the same format as the corresponding element (see 9.4.2.159 (Wide Bandwidth Channel Switch element)), with the constraint that the New Channel Width field indicates an 80 MHz, 160 MHz, or 80+80 MHz BSS bandwidth.

The Vendor Specific subelements have the same format as their corresponding elements (see 9.4.2.24 (Vendor Specific element)). Zero or more Vendor Specific subelements are included in the list of optional subelements.

#### 9.4.2.19.6 Noise Histogram request

The Measurement Request field corresponding to a Noise Histogram request is shown in Figure 9-248 (Measurement Request field format for Noise Histogram request).


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| | Operating Class | Channel Number | Randomization Interval | Measurement Duration | Optional Subelements |
|---|---|---|---|---|---|
| Octets: | 1 | 1 | 2 | 2 | variable |

**Figure 9-248—Measurement Request field format for Noise Histogram request**

If the Wide Bandwidth Channel Switch subelement is not included, the Operating Class field indicates the operating class that identifies the channel set for which the measurement request applies. The Country, Operating Class, and Channel Number fields together specify the channel frequency and spacing for which the measurement request applies. Valid operating classes are listed in Annex E, excluding operating classes that encompass a primary channel but do not identify the location of the primary channel. The Channel Number field indicates the channel number for which the measurement request applies. Channel number is defined within an operating class as shown in Annex E.

If the Wide Bandwidth Channel Switch subelement is included, the fields in the Wide Bandwidth Channel Switch subelement indicate the channel for which the measurement request applies, and the Operating Class and Channel Number fields(#6181) together specify the primary channel and primary 40 MHz channel within the channel identified by the Wide Bandwidth Channel Switch subelement.

The Randomization Interval field specifies the upper bound of the random delay to be used prior to making the measurement, in units of TUs. See 11.10.3 (Measurement start time).

The Measurement Duration field is set to the preferred or mandatory duration of the requested measurement, in units of TUs. See 11.10.4 (Measurement duration).

The Optional Subelements field contains zero or more subelements. The subelement format and ordering of subelements are defined in 9.4.3 (Subelements).

The Subelement ID field values for the defined subelements are shown in Table 9-139 (Optional subelement IDs for Noise Histogram request).

**Table 9-139—Optional subelement IDs for Noise Histogram request**

| Subelement ID | Name | Extensible |
|---|---|---|
| 0 | Reserved | |
| 1 | Noise Histogram Reporting | Yes |
| 2–162 | Reserved | |
| 163 | Wide Bandwidth Channel Switch | Yes |
| 164–220 | Reserved | |
| 221 | Vendor Specific | Vendor defined |
| 222–255 | Reserved | |

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The Noise Histogram Reporting subelement indicates the condition for issuing a Noise Histogram report. The Noise Histogram Reporting subelement Data field format is shown in Figure 9-249 (Noise Histogram Reporting subelement Data field format)(#1496). The Reporting Condition subfield is described in Table 9-140 (Reporting Condition subfield for Noise Histogram report). The ANPI Reference Value is an ANPI value as defined in 11.10.9.4 (Noise Histogram report) and is the reference value for the indicated reporting condition.

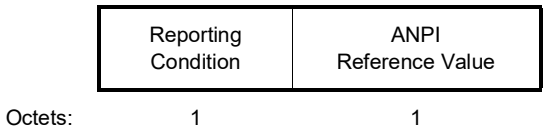


**Figure 9-249—Noise Histogram Reporting subelement Data field format**

**Table 9-140—Reporting Condition subfield for Noise Histogram report**

| Condition for report to be issued | Reporting Condition |
|---|---|
| Report to be issued after each measurement (default, used when Noise Histogram Reporting subelement is not included in a Noise Histogram request). | 0 |
| Noise Histogram report to be issued when measured ANPI is greater than or equal to the reference value. | 1 |
| Noise Histogram report to be issued when measured ANPI is less than or equal to the reference value. | 2 |
| Reserved | 3–255 |

The Wide Bandwidth Channel Switch subelement has the same format as the corresponding element (see 9.4.2.159 (Wide Bandwidth Channel Switch element)), with the constraint that the New Channel Width field indicates an 80 MHz, 160 MHz, or 80+80 MHz BSS bandwidth.

The Vendor Specific subelements have the same format as their corresponding elements (see 9.4.2.24 (Vendor Specific element)). Zero or more Vendor Specific subelements are included in the list of optional subelements.

### 9.4.2.19.7 Beacon request

The Measurement Request field corresponding to a Beacon request is shown in Figure 9-250 (Measurement Request field format for Beacon request).

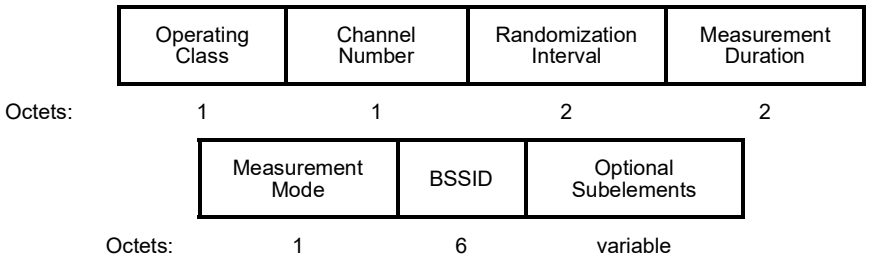


**Figure 9-250—Measurement Request field format for Beacon request**


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If the Wide Bandwidth Channel Switch subelement is not included, the Operating Class field indicates the operating class that identifies the channel set for which the measurement request applies. The Country, Operating Class, and Channel Number fields together specify the channel frequency and spacing for which the measurement request applies. Valid operating classes are listed in Annex E.

For operating classes that encompass a primary channel but do not identify the location of the primary channel, the Channel Number field value is either 0 or 255; otherwise, the Channel Number field value is 0, 255, or the channel number for which the measurement request applies and is defined within an operating class as shown in Annex E.

For operating classes that identify the location of the primary channel, a Channel Number field set to 0 indicates a request to make iterative measurements for all supported channels in the operating class where the measurement is permitted on the channel and the channel is valid for the current regulatory domain.

For operating classes that encompass a primary channel but do not identify the location of the primary channel, a Channel Number field set to 0 indicates a request to make iterative measurements for all primary channel positions within all requested and supported channels where the measurement is permitted on the channel and the channel is valid for the current regulatory domain.

For operating classes that identify the location of the primary channel, a Channel Number field set to 255 indicates a request to make iterative measurements for all supported channels in the current operating class listed in the latest AP Channel Report received from the serving AP.

A request frame is a request to make iterative measurements for all primary channel positions in all channels listed in the frame's AP Channel Report subelement when all of the following pertain:

- The operating class indicated by the Operating Class field in that frame encompasses a primary channel.
- The frame does not identify the location of that primary channel.
- The frame's Channel Number field is 255.
- The channel is supported.
- The measurement is permitted on the channel.
- The channel is permitted in the current regulatory domain.

If the Wide Bandwidth Channel Switch subelement is included, the fields in the Wide Bandwidth Channel Switch subelement indicate the channel for which the measurement request applies, and the Operating Class and Channel Number fields together specify the primary channel and primary 40 MHz channel within the channel identified by the Wide Bandwidth Channel Switch subelement.

The Randomization Interval field specifies the upper bound of the random delay to be used prior to making the measurement, in units of TUs. See 11.10.3 (Measurement start time).

The Measurement Duration field is set to the preferred or mandatory duration of the requested measurement, in units of TUs. See 11.10.4 (Measurement duration).

The Measurement Mode field indicates the mode to be used for the measurement. The valid measurement modes are listed in Table 9-141 (Measurement Mode definitions for Beacon request). The procedures for each mode are described in 11.10.9.1 (Beacon report).

The BSSID field indicates the BSSID of the BSS(s) for which a (#1685)Beacon report is requested. When requesting (#1685)Beacon reports for all BSSs on the channel, the BSSID field contains the wildcard BSSID; otherwise the BSSID field contains a specific BSSID for a single BSS.

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**Table 9-141—Measurement Mode definitions for Beacon request**

| Mode | Value |
|---|---|
| Passive | 0 |
| Active | 1 |
| Beacon Table | 2 |
| Reserved | 3–255 |

The Optional Subelements field contains zero or more subelements. The subelement format and ordering of subelements are defined in 9.4.3 (Subelements).

The Subelement ID field values for the defined subelements are shown in Table 9-142 (Optional subelement IDs for Beacon request).

**Table 9-142—Optional subelement IDs for Beacon request**

| Subelement ID | Name | Extensible |
|---|---|---|
| 0 | SSID | No |
| 1 | Beacon Reporting | Yes |
| 2 | Reporting Detail | Yes |
| 3–9 | Reserved | |
| 10 | Request | No |
| 11 | Extended Request | No |
| 12–50 | Reserved | |
| 51 | AP Channel Report | No |
| 52–162 | Reserved | |
| 163 | Wide Bandwidth Channel Switch | Yes |
| 164 | Last Beacon Report Indication Request | No |
| 165–220 | Reserved | |
| 221 | Vendor Specific | Vendor defined |
| 222–255 | Reserved | |

The SSID subelement indicates the ESS(s) or IBSS(s) for which a (#1685)Beacon report is requested. When SSID is not included in a Beacon request, the default “wildcard SSID” is used; otherwise the SSID is included in the Beacon request and contains a specific SSID for a single ESS or IBSS. The wildcard SSID is used to represent all possible SSIDs. The SSID element is described in 9.4.2.2 (SSID element).

The Beacon Reporting subelement indicates the condition for issuing a Beacon report. The Beacon Reporting subelement is optionally present in a Beacon request for repeated measurements; otherwise it is not present. The Beacon Reporting subelement Data field format is shown in Figure 9-251 (Beacon Reporting subelement Data field format)(#1496). The Reporting Condition subfield is described in Table 9-


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143 (Reporting Condition subfield for Beacon report). The Threshold/Offset Reference subfield contains either the threshold value or the offset value to be used for conditional reporting. For Reporting Condition subfield 1 and 2, the threshold value is a logarithmic function of the received signal power, as defined 9.4.2.36 (RCPI element). For Reporting Condition subfield 3 and 4, the threshold value is a logarithmic function of the signal-to-noise ratio, as described in 9.4.2.39 (RSNI element). For Reporting Condition subfield 5 to 10, the offset value is (#4162)a 2s complement integer units of 0.5 dBm. The indicated reporting condition applies individually to each measured Beacon, Measurement Pilot, or Probe Response frame. Reporting conditions are further described in 11.10.9.1 (Beacon report).

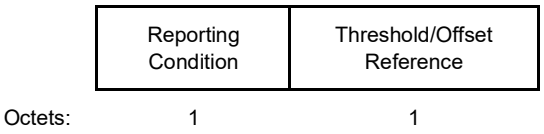


**Figure 9-251—Beacon Reporting subelement Data field format**

**Table 9-143—Reporting Condition subfield for Beacon report**

| Condition for report to be issued in Repeated Measurement | Reporting Condition |
|---|---|
| Report to be issued after each measurement (default, used when the Beacon Reporting subelement is not included in a Beacon request). | 0 |
| The measured RCPI level is greater than the threshold value contained in the Threshold/Offset Reference. | 1 |
| The measured RCPI level is less than the threshold value contained in the Threshold/ Offset Reference. | 2 |
| The measured RSNI level is greater than the threshold value contained in the Threshold/Offset Reference. | 3 |
| The measured RSNI level is less than the threshold value contained in the Threshold/ Offset Reference. | 4 |
| The measured RCPI level is greater than a threshold defined by an offset from the serving AP's reference RCPI, where the offset value is contained in the Threshold/ Offset Reference. | 5 |
| The measured RCPI level is less than a threshold defined by an offset from the serving AP's reference RCPI, where the offset value is contained in the Threshold/ Offset Reference. | 6 |
| The measured RSNI level is greater than a threshold defined by an offset from the serving AP's reference RSNI, where the offset value is contained in the Threshold/ Offset Reference. | 7 |
| The measured RSNI level is less than a threshold defined by an offset from the serving AP's reference RSNI, where the offset value is contained in the Threshold/ Offset Reference. | 8 |
| The measured RCPI level is in a range bound by the serving AP's reference RCPI and an offset from the serving AP's reference RCPI, where the offset value is contained in the Threshold/Offset Reference. | 9 |
| The measured RSNI level is in a range bound by the serving AP's reference RSNI and an offset from the serving AP's reference RSNI, where the offset value is contained in the Threshold/Offset Reference. | 10 |
| Reserved | 11–255 |

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(#1494)The Data field of the Reporting Detail subelement starts with a 1-octet Reporting Detail field that defines the level of detail per AP to be reported to the requesting STA. The Reporting Detail field(#1501) values are defined in Table 9-144 (Reporting Detail field(#1501) values). The indicated reporting detail applies individually to each measured Beacon, Measurement Pilot, or Probe Response frame. (#294)If the Reporting Detail field equals 1, a Request element and/or one or more Extended Request elements are optionally present in the list of optional subelements (if more than one Extended Request element is present the Requested Element ID fields differ).(#1530) If included, these identify elements requested to be reported in the Reported Frame Body subelement of the Beacon report.

**Table 9-144—Reporting Detail field(#1501) values**

| Level of detail requested | Reporting Detail |
|---|---|
| No fixed-length fields or elements | 0 |
| All fixed-length fields and any requested elements in the Request element (#294)and/ or Extended Request element(s)(#1530) if present | 1 |
| All fixed-length fields and elements (default, used when Reporting Detail subelement is not included in a Beacon request) | 2 |
| Reserved | 3–255 |

The Wide Bandwidth Channel Switch subelement has the same format as the corresponding element (see 9.4.2.159 (Wide Bandwidth Channel Switch element)) with the constraint that the New Channel Width field indicates an 80 MHz, 160 MHz, or 80+80 MHz BSS bandwidth.

The Last Beacon Report Indication Request subelement has the format defined in Figure 9-1075 (Subelement format), with a Length field set to 1. When included in a Beacon request with the Data field set to 1, it indicates that the requesting STA asks the responding STA to include an indication in the Beacon report to indicate the last frame of the sequence of frames generated as a response to a Beacon request. When included in a Beacon request with the Data field set to other than 1, it indicates that the requesting STA asks the responding STA not to include such an indication.(#1690)

The Request, Extended Request, AP Channel Report, and Vendor Specific subelements have the same format as their corresponding elements (see 9.4.2.8 (Request element), 9.4.2.9 (Extended Request element), 9.4.2.34 (AP Channel Report element), and 9.4.2.24 (Vendor Specific element), respectively). Zero or more AP Channel Report subelements and zero or more Vendor Specific subelements are included in the list of optional subelements. An AP Channel Report subelement containing an operating class with an 80+ behavior limit (as defined in Annex E) is interpreted in conjunction with following AP Channel Report elements as defined in 11.10.9.1 (Beacon report).

If one or more AP Channel Report elements are included, they indicate that iterative measurements are requested first on the channel(s) indicated by the Operating Class and Channel Number fields included in the Beacon request, and second on the channel(s) indicated by the Operating Class and Channel List fields of each AP Channel Report element included in the Beacon request. The procedures for iterative measurements on multiple channels are described in 11.10.9.1 (Beacon report).

#### 9.4.2.19.8 Frame request

The Measurement Request field corresponding to a Frame request is shown Figure 9-252 (Measurement Request field format for Frame request).


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| | Operating Class | Channel Number | Randomization Interval | Measurement Duration | Frame Request Type | MAC Address | Optional subelements |
|---|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 2 | 2 | 1 | 6 | variable |

**Figure 9-252—Measurement Request field format for Frame request**

If the Wide Bandwidth Channel Switch subelement is not included, the Operating Class field indicates the operating class that identifies the channel set for which the measurement request applies. The Country, Operating Class, and Channel Number fields together specify the channel frequency and spacing for which the measurement request applies. Valid operating classes are listed in Annex E, excluding operating classes that encompass a primary channel but do not identify the location of the primary channel. The Channel Number field indicates the channel number for which the measurement request applies. Channel number is defined within an operating class as shown in Annex E.

If the Wide Bandwidth Channel Switch subelement is included, the fields in the Wide Bandwidth Channel Switch subelement indicate the channel for which the measurement request applies, and the Operating Class and Channel Number fields together specify the primary channel and primary 40 MHz channel within the channel identified by the Wide Bandwidth Channel Switch subelement.

The Randomization Interval field specifies the upper bound of the random delay to be used prior to making the measurement, in units of TUs. See 11.10.3 (Measurement start time).

The Measurement Duration field is set to the preferred or mandatory duration of the requested measurement, in units of TUs. See 11.10.4 (Measurement duration).

The Frame Request Type indicates the subelements requested in the Frame report. A 1 signifies that a Frame Count Report is requested. The values 0 and 2 to 255 are reserved.

The MAC Address field indicates the TA field to match against Data and Management frames in order to count toward the Frame report generated in response to this Frame request.

The Optional Subelements field contains zero or more subelements. The subelement format and ordering of subelements are defined in 9.4.3 (Subelements).

The Subelement ID field values for the defined subelements are shown in Table 9-145 (Optional subelement IDs for Frame request).

**Table 9-145—Optional subelement IDs for Frame request**

| Subelement ID | Name | Extensible |
|---|---|---|
| 0–162 | Reserved | |
| 163 | Wide Bandwidth Channel Switch | Yes |
| 164–220 | Reserved | |
| 221 | Vendor Specific | Vendor defined |
| 222–255 | Reserved | |

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The Wide Bandwidth Channel Switch subelement has the same format as the corresponding element (see 9.4.2.159 (Wide Bandwidth Channel Switch element)), with the constraint that the New Channel Width field indicates an 80 MHz, 160 MHz, or 80+80 MHz BSS bandwidth.

The Vendor Specific subelements have the same format as their corresponding elements (see 9.4.2.24 (Vendor Specific element)). Zero or more Vendor Specific subelements are included in the list of optional subelements.

#### 9.4.2.19.9 STA Statistics request

The Measurement Request field corresponding to a STA Statistics request is shown in Figure 9-253 (Measurement Request field format for STA Statistics request).

| | Peer MAC Address | Randomization Interval | Measurement Duration | Group Identity | Optional Subelements |
|---|---|---|---|---|---|
| Octets: | 6 | 2 | 2 | 1 | variable |

**Figure 9-253—Measurement Request field format for STA Statistics request**

The Peer MAC Address field is the RA or TA MAC address for the frame statistics of this measurement.

The Randomization Interval field specifies the upper bound of the random delay to be used prior to making the measurement, in units of TUs. See 11.10.3 (Measurement start time).

The Measurement Duration field is set to the duration of the requested measurement in TUs except when triggered reporting is used. When triggered reporting is used, the measurement duration is 0.

The Group Identity field indicates the requested statistics group according to Table 9-146 (Group Identity for a STA Statistics request).

**Table 9-146—Group Identity for a STA Statistics request**

| Statistics Group Name | Group Identity |
|---|---|
| STA Counters from dot11CountersTable | 0 |
| STA Counters from dot11MacStatistics group | 1 |
| QoS STA Counters for UP0 from dot11QosCountersTable | 2 |
| QoS STA Counters for UP1 from dot11QosCountersTable | 3 |
| QoS STA Counters for UP2 from dot11QosCountersTable | 4 |
| QoS STA Counters for UP3 from dot11QosCountersTable | 5 |
| QoS STA Counters for UP4 from dot11QosCountersTable | 6 |
| QoS STA Counters for UP5 from dot11QosCountersTable | 7 |
| QoS STA Counters for UP6 from dot11QosCountersTable | 8 |
| QoS STA Counters for UP7 from dot11QosCountersTable | 9 |
| BSS Average Access Delays as described in 9.4.2.37 (BSS Average Access Delay element) and 9.4.2.42 (BSS AC Access Delay element) | 10 |
| STA Counters from dot11CountersGroup6(#3263) (A-MSDU) | 11 |
| STA Counters from dot11CountersGroup6(#3263) (A-MPDU) | 12 |


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**Table 9-146—Group Identity for a STA Statistics request *(continued)***

| Statistics Group Name | Group Identity |
|---|---|
| STA Counters from dot11CountersGroup6(#3263) (BlockAckReq, Channel Width(#3263)) | 13 |
| STA Counters from dot11CountersGroup6(#3263) (RD, dual CTS) | 14 |
| STA Counters from dot11CountersGroup6(#3263) (beamforming and STBC) | 15 |
| RSNA Counters | 16 |
| Reserved | 17–255 |

The Optional Subelements field contains zero or more subelements. The subelement format and ordering of subelements are defined in 9.4.3 (Subelements).

The Subelement ID field values for the defined subelements are shown in Table 9-147 (Optional subelement IDs for STA Statistics request).

**Table 9-147—Optional subelement IDs for STA Statistics request**

| Subelement ID | Name | Extensible |
|---|---|---|
| 0 | Reserved | |
| 1 | Triggered Reporting | No |
| 2–220 | Reserved | |
| 221 | Vendor Specific | Vendor defined |
| 222–255 | Reserved | |

The Triggered Reporting subelement is used to specify trigger conditions and thresholds for triggered STA Statistics measurements. It is present when setting up triggered reporting from STA Counters, QoS STA Counters, or RSNA Counters; see 11.10.9.5 (STA Statistics report).

The format of the Triggered Reporting subelement for STA Counters is shown in Figure 9-254 (Triggered Reporting subelement format for STA Counters). The fields marked as optional are only present if the appropriate bit in the STA Counter Trigger Condition field is 1.

| | Measurement Count | Trigger Timeout | STA Counter Trigger Condition | dot11FailedCount Threshold (optional) | dot11FCS ErrorCount Threshold (optional) |
|---|---|---|---|---|---|
| Octets: | 4 | 2 | 2 | 0 or 4 | 0 or 4 |

| | dot11Multiple RetryCount Threshold (optional) | dot11Frame DuplicateCount Threshold (optional) | dot11RTS FailureCount Threshold (optional) | dot11Ack FailureCount Threshold (optional) | dot11RetryCount Threshold (optional) |
|---|---|---|---|---|---|
| Octets: | 0 or 4 | 0 or 4 | 0 or 4 | 0 or 4 | 0 or 4 |

**Figure 9-254—Triggered Reporting subelement format for STA Counters**

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The value in the Measurement Count field specifies the number of MSDUs or MPDUs transmitted and/or received by the STA that are to be used to determine if one or more of the trigger conditions have been met.

The Trigger Timeout field contains a value in units of 100 TUs during which a measuring STA does not generate further triggered STA Statistics reports after a trigger condition has been met.

The STA Counter Trigger Condition field specifies trigger values used when requesting triggered STA Statistics reporting. The format of the STA Counter Trigger Condition field is shown in Figure 9-255 (STA Counter Trigger Condition field format).

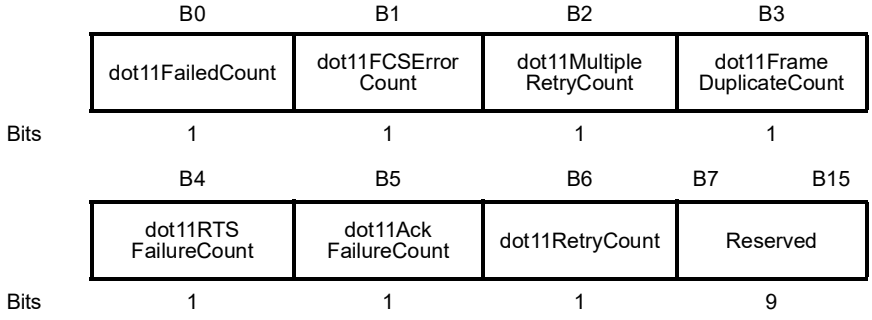


**Figure 9-255—STA Counter Trigger Condition field format**

For each bit in the STA Counter Trigger Condition field that is 1, a corresponding threshold value exists (defined in Figure 9-254 (Triggered Reporting subelement format for STA Counters)) in the Triggered Reporting subelement for STA Counters. With this, the STA Statistics request indicates that a STA Statistics report be generated when the corresponding STA counter defined in 9-304 (Measurement Report field format for dot11Counters Group) and 9-305 (Measurement Report field format for dot11MACStatistics Group) (in 9.4.2.20.9 (STA Statistics report)) exceeds the value of the specified threshold, within the total number of MSDUs or MPDUs indicated in the Measurement Count field. See 11.10.9.5 (STA Statistics report). One or more trigger conditions are set with specified thresholds. In the triggered STA Statistics request, the Group Identity field is either 0 or 1. When the Group Identity field of the triggered STA Statistics request is 0, B2–B6 in the STA Counter Trigger Condition field are set to 0. When the group identity of the triggered STA Statistics request is 1, B0 and B1 in the STA Counter Trigger Condition field are set to 0.


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The format of the Triggered Reporting subelement for QoS STA Counters is shown in Figure 9-256 (Triggered Reporting subelement format for QoS STA Counters). The fields marked as optional are only present if the appropriate bit in the QoS STA Counter Trigger Condition subfield is 1.

| | Measurement Count | Trigger Timeout | QoS STA Counter Trigger Condition | dot11QoSFailed Count Threshold (optional) | dot11QoSRetry Count Threshold (optional) |
|---|---|---|---|---|---|
| Octets: | 4 | 2 | 2 | 0 or 4 | 0 or 4 |

| | dot11QoSMultiple RetryCount Threshold (optional) | dot11QoSFrame DuplicateCount Threshold (optional) | dot11QoSRTSC ount Failure Threshold (optional) | dot11QoSAck FailureCount Threshold (optional) | dot11QoSDisca rdedCount Threshold (optional) |
|---|---|---|---|---|---|
| Octets: | 0 or 4 | 0 or 4 | 0 or 4 | 0 or 4 | 0 or 4 |

**Figure 9-256—Triggered Reporting subelement format for QoS STA Counters**

The UP of the QoS STA Counters for triggered QoS Statistics measurement is determined by the group identity of the Measurement Request field for a STA Statistics request as defined in 9-146 (Group Identity for a STA Statistics request).

The value in the Measurement Count field specifies the number of MSDUs or MPDUs transmitted and/or received by the STAs that are to be used to determine if one or more of the trigger conditions have been met.

The Trigger Timeout field contains a value in units of 100 TUs during which a measuring STA does not generate further triggered STA Statistics reports after a trigger condition has been met.

The QoS STA Counter Trigger Condition field specifies reporting triggers when requesting triggered STA Statistics reporting. The format of the QoS STA Counter Trigger Condition field is shown in Figure 9-257 (QoS STA Counter Trigger Condition field format).

| | B0 | B1 | B2 | B3 |
|---|---|---|---|---|
| | dot11QoS FailedCount | dot11QoS RetryCount | dot11QoSMultiple RetryCount | dot11QoSFrame DuplicateCount |
| Bits: | 1 | 1 | 1 | 1 |
| | B4 | B5 | B6 | B7-B15 |
| | dot11QoSRTS FailureCount | dot11QoSAck FailureCount | dot11QoS DiscardedCount | Reserved |
| Bits: | 1 | 1 | 1 | 9 |

**Figure 9-257—QoS STA Counter Trigger Condition field format**

For each bit in the QoS STA Counter Trigger Condition field that is 1, a corresponding threshold value exists (defined in Figure 9-256 (Triggered Reporting subelement format for QoS STA Counters)) in the Triggered Reporting subelement for QoS STA Counters. With this, the STA Statistics request indicates that a STA Statistics report be generated when the corresponding QoS STA counter defined in Figure 9-306 (Measurement Report field format for dot11QosCounters Group for UPx) (in 9.4.2.20.9 (STA Statistics report)) exceeds the value of the specified threshold, within the total number of MSDUs or MPDUs

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indicated in the Measurement Count field. See 11.10.9.5 (STA Statistics report). One or more trigger conditions are set with specified thresholds.

The format of the Triggered Reporting subelement for RSNA Counters is shown in Figure 9-258 (Triggered Reporting subelement format for RSNA Counters). The fields marked as optional are only present if the appropriate bit in the RSNA Trigger Condition subfield is 1.

| | Measurement Count | Trigger Timeout | RSNA Counter Trigger Condition | dot11RSNAStats CMACICVErrors Threshold (optional) | dot11RSNA StatsCMACReplays Threshold (optional) |
|---|---|---|---|---|---|
| Octets: | 4 | 2 | 2 | 0 or 4 | 0 or 4 |

| | dot11RSNA StatsRobustMgmt CCMPReplays Threshold (optional) | dot11RSNAStats TKIPICVErrors Threshold (optional) | dot11RSNAStats TKIPReplays Threshold (optional) | dot11RSNAStats CCMPDecryptErrors Threshold (optional) | dot11RSNAStats CCMPReplays Threshold (optional) |
|---|---|---|---|---|---|
| Octets: | 0 or 4 | 0 or 4 | 0 or 4 | 0 or 4 | 0 or 4 |

**Figure 9-258—Triggered Reporting subelement format for RSNA Counters**

The value in the Measurement Count field specifies the number of MPDUs transmitted and/or received by the STA that are to be used to determine if one or more of the trigger conditions have been met.

The Trigger Timeout field contains a value in units of 100 TUs during which a measuring STA does not generate further triggered STA Statistics reports after a trigger condition has been met.

The RSNA Counter Trigger Condition field specifies reporting triggers when requesting triggered STA Statistics reporting. The format of the RSNA Trigger Condition field is shown in Figure 9-259 (RSNA Trigger Condition field format).

| | B0 | B1 | B2 | B3 | B4 | B5 | B6 | B7 | B15 |
|---|---|---|---|---|---|---|---|---|---|
| | dot11RSNAStats CMACICVErrors | dot11RSNA StatsCMACReplays | dot11RSNAStats RobustMgmt CCMPReplays | dot11RSNAStats TKIPICVErrors | dot11RSNAStats TKIPReplays | dot11RSNAStats CCMPDecryptErrors | dot11RSNAStats CCMPReplays | Reserved | |
| Bits: | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 9 | |

**Figure 9-259—RSNA Trigger Condition field format**



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For each bit in the RSNA Trigger Condition field that is 1, a corresponding threshold value exists (defined in Figure 9-258 (Triggered Reporting subelement format for RSNA Counters)) in the Triggered Reporting subelement for RSNA Counters. With this, the STA Statistics request indicates that a STA Statistics report be generated when the corresponding RSNA counter defined in Figure 9-308 (Measurement Report field format for RSNA Counters Group) (in 9.4.2.20.9 (STA Statistics report)) exceeds the value of the specified threshold, within the total number of MPDUs indicated in the Measurement Count field. See 11.10.9.5 (STA Statistics report). One or more trigger conditions are set with specified thresholds.

The Vendor Specific subelements have the same format as their corresponding elements (see 9.4.2.24 (Vendor Specific element)). Zero or more Vendor Specific subelements are included in the list of optional subelements.

#### 9.4.2.19.10 LCI request (Location configuration information request)

The Measurement Request field corresponding to an LCI request is shown in Figure 9-260 (Measurement Request field format for LCI request).

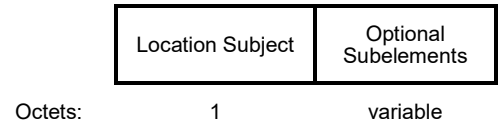


**Figure 9-260—Measurement Request field format for LCI request**

The Location Subject field of an LCI request is 1 octet. See Table 9-148 (Location Subject field definition).

**Table 9-148—Location Subject field definition**

| Value | Location Subject |
|---|---|
| 0 | Location Subject Local |
| 1 | Location Subject Remote |
| 2 | Location Subject Third Party |
| 3–255 | Reserved |

The term Local refers to the location of the requesting STA, and Remote refers to the location of the reporting STA.

NOTE 1—A measurement request with its Location Subject value Location Subject Local is used by a requesting STA to obtain its own location, asking “Where am I?” The Measurement Request with its Location Subject value Location Subject Remote is used by a requesting STA to obtain the location of the reporting STA, asking “Where are you?”

The Optional Subelements field contains zero or more subelements. The subelement format and ordering of subelements are defined in 9.4.3 (Subelements).

The Subelement ID field values for the defined subelements are shown in Table 9-149 (Optional subelement IDs for LCI request).

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**Table 9-149—Optional subelement IDs for LCI request**

| Subelement ID | Name | Extensible |
|---|---|---|
| 0 | Reserved | |
| 1 | Azimuth Request | Yes |
| 2 | Originator Requesting STA MAC Address | No |
| 3 | Target MAC Address | No |
| 4 | Maximum Age | Yes |
| 5–220 | Reserved | |
| 221 | Vendor Specific | Vendor defined |
| 222–255 | Reserved | |

The Azimuth Request subelement is present when requesting azimuth information. The Azimuth Request subelement is as shown in Figure 9-261 (Azimuth Request subelement format).

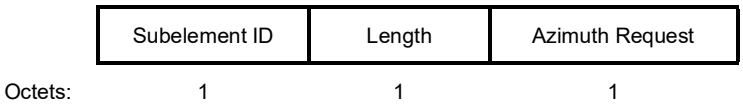


**Figure 9-261—Azimuth Request subelement format**

The Subelement ID field is defined in Table 9-149 (Optional subelement IDs for LCI request).

The Length field is defined in 9.4.3 (Subelements).

The Azimuth Request field of an Azimuth Request subelement is shown in Figure 9-262 (Azimuth Request field format).

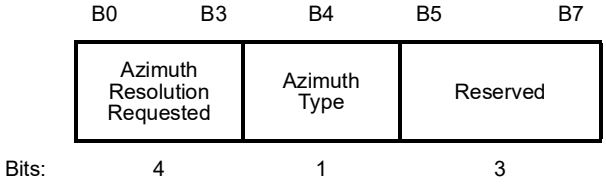


**Figure 9-262—Azimuth Request field format**

Azimuth Resolution Requested is the number of valid most significant bits requested for the fixed-point value of Azimuth, reported in integer degrees. Values above 9 are reserved.

Azimuth Type (bit 4) is set to 1 to request a report of the Azimuth of radio reception and is set to 0 to request a report of the Azimuth of front surface of the reporting STA.

NOTE 2—A geographic feature is an abstraction of a real-world phenomenon; it is a geographic feature if it is associated with a location relative to the Earth. The designation of a horizontal plane is relative to the Earth. The designation of the "front surface" of a station is arbitrary, but refers to an orientable surface (possessing a centerline) of the station. It is common to use a direction cosine matrix to convert from one coordinate system to another, i.e., body-centered coordinates to earth-centered coordinates.


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The Originator Requesting STA MAC Address subelement contains the MAC address of the STA requesting the Location Information and it is present whenever the Location Subject field is set to 2. The format of the Originator Requesting STA MAC Address subelement is shown in Figure 9-263 (Originator Requesting STA MAC Address subelement format).

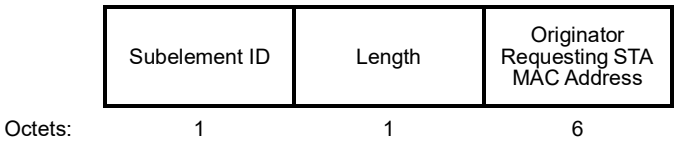


**Figure 9-263—Originator Requesting STA MAC Address subelement format**

The Target MAC Address subelement contains the MAC address of the STA whose Location Information is requested and it is present whenever the Location Subject field is set to 2. The format of the Target MAC Address subelement is shown in Figure 9-264 (Target MAC Address subelement format).

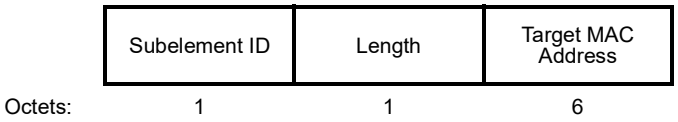


**Figure 9-264—Target MAC Address subelement format**

The Maximum Age subelement indicates the maximum age of the requested LCI. The format of the Maximum Age subelement is defined in Figure 9-265 (Maximum Age subelement format). The absence of a Maximum Age subelement indicates that an LCI determined at or after the LCI request is received is requested.

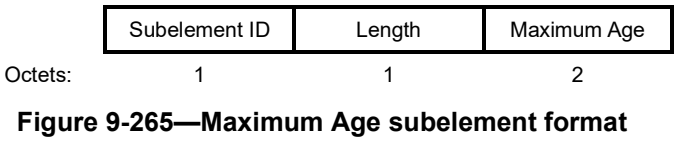


**Figure 9-265—Maximum Age subelement format**

The Length field is defined in 9.4.3 (Subelements).

The Maximum Age field of a Maximum Age subelement indicates the maximum elapsed time between when an LCI is determined and when an LCI request is received, within which the LCI satisfies the LCI request. The Maximum Age field is encoded as an unsigned integer with units of 0.1 s. The value of 0 is reserved. The value of 65 535 indicates that any LCI age is acceptable.

The Vendor Specific subelement has the same format as the Vendor Specific element (see 9.4.2.24 (Vendor Specific element)). Zero or more Vendor Specific subelements are included in the list of optional subelements.

### 9.4.2.19.11 Transmit Stream/Category Measurement request

The Transmit Stream/Category Measurement applies to TIDs for traffic streams associated with TSPECs and also to TIDs for traffic categories for QoS traffic without TSPECs. The Measurement Request field corresponding to a Transmit Stream/Category Measurement request is shown in Figure 9-266 (Measurement Request field format for Transmit Stream/Category Measurement Request).

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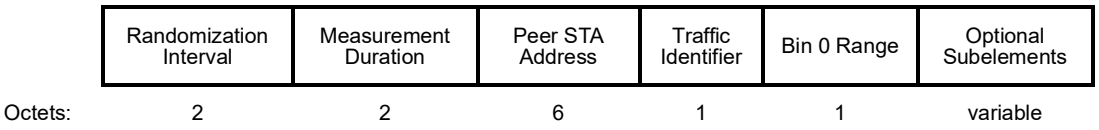


**Figure 9-266—Measurement Request field format for Transmit Stream/Category Measurement Request**

The Randomization Interval field is set to the maximum random delay in the measurement start time, in units of TUs. The use of the Randomization Interval field is described in 11.10.3 (Measurement start time). When requesting a triggered Transmit Stream/Category Measurement, the randomization interval is not used and the Randomization Interval field is reserved. See 11.10.9.8 (Transmit Stream/Category Measurement report).

The Measurement Duration is set to the duration of the requested measurement, in units of TUs except when setting up a triggered QoS measurement, when it is not used and is set to 0.

The Peer STA Address contains a MAC address indicating the RA in the MSDUs to be measured.

The Traffic Identifier field contains the TID subfield as shown in Figure 9-267 (Traffic Identifier field format).

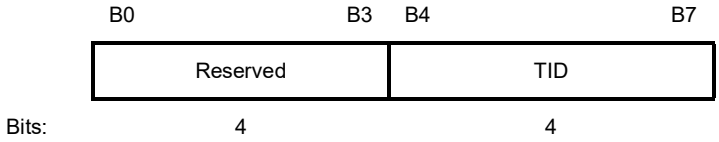


**Figure 9-267—Traffic Identifier field format**

The TID subfield indicates the TC or TS for which traffic is to be measured.

Bin 0 Range indicates the delay range of the first bin (Bin 0) of the Transmit Delay Histogram, in units of TUs. The Bin 0 Range value is used to calculate the delay ranges of the other 5 bins making up the histogram. The delay range for each bin increases in a binary exponential fashion as described in 9.4.2.20.11 (Transmit Stream/Category Measurement report).

The Optional Subelements field contains zero or more subelements. The subelement format and ordering of subelements are defined in 9.4.3 (Subelements).

The Subelement ID field values for the defined subelements are shown in Table 9-150 (Optional subelement IDs for Transmit Stream/Category Measurement Request).

**Table 9-150—Optional subelement IDs for Transmit Stream/Category Measurement Request**

| Subelement ID | Name | Extensible |
|---|---|---|
| 0 | Reserved | |
| 1 | Triggered Reporting | Yes |
| 2–220 | Reserved | |


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**Table 9-150—Optional subelement IDs for Transmit Stream/Category Measurement Request**

| Subelement ID | Name | Extensible |
|---|---|---|
| 221 | Vendor Specific | Vendor defined |
| 222–255 | Reserved | |

The Triggered Reporting subelement is used to specify measurement trigger thresholds. It is present only if requesting triggered transmit stream/category measurement reporting. The Triggered Reporting subelement format is shown in Figure 9-268 (Triggered Reporting subelement format).

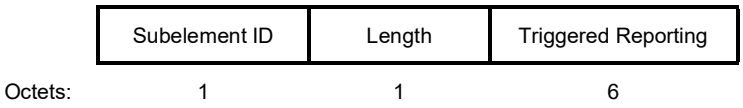


**Figure 9-268—Triggered Reporting subelement format**

The Subelement ID field is defined in Table 9-150 (Optional subelement IDs for Transmit Stream/Category Measurement Request).

The Length field is defined in 9.4.3 (Subelements).

The Triggered Reporting field is as shown in Figure 9-269 (Triggered Reporting field format).

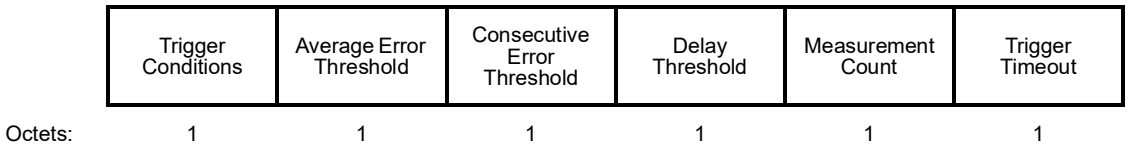


**Figure 9-269—Triggered Reporting field format**

Trigger Conditions is a (#291)subfield that specifies reporting triggers when requesting a triggered transmit stream/category measurement. The format of the Trigger Conditions (#291)subfield is shown in Figure 9-270 (Trigger Conditions subfield format(#291)).

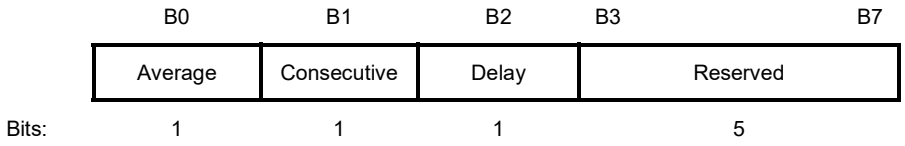


**Figure 9-270—Trigger Conditions subfield format(#291)**

— The Average (#291)subfield is set to 1 to request that a Transmit Stream/Category Measurement report be generated when the number of MSDUs for the TC or TS given by the TID that are discarded out of the number of preceding MSDUs specified in Measurement Count is greater than or equal to the value given in Average Error Threshold. MSDUs discarded due to the number of transmit attempts exceeding dot11ShortRetryLimit, or due to the MSDU lifetime having been reached, are counted.

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— The Consecutive (#291)subfield is set to 1 to request that a Transmit Stream/Category Measurement report be generated when the number of MSDUs for the TC or TS given by the TID that are discarded in succession is greater than or equal to the value given in Consecutive Error Threshold. MSDUs discarded due to the number of transmit attempts exceeding dot11ShortRetryLimit, or due to the MSDU lifetime having been reached, are counted.

— The Delay (#291)subfield is set to 1 to request that a Transmit Stream/Category Measurement report be generated when the number of consecutive MSDUs for the TC or TS given by the TID that experience a transmit delay greater than or equal to the value specified in the Delay Threshold subfield is greater than or equal to the value given in Delayed MSDU Count. Delay is measured from the time the MSDU is passed to the MAC until the point at which the entire MSDU has been successfully transmitted, including receipt of the final Ack frame from the peer STA if the QoSAck service class is being used.

The Average Error Threshold field contains a value representing the number of discarded MSDUs to be used as the threshold value for the average trigger condition(#291). The field is reserved if the Average Error Threshold subfield of the Trigger Conditions (#291)subfield is 0.

The Consecutive Error Threshold field contains a value representing the number of discarded MSDUs to be used as the threshold value for the consecutive trigger condition. The field is reserved if the Consecutive Error Threshold subfield of the Trigger Conditions (#291)subfield is 0.

The Delay Threshold field contains two subfields as shown in Figure 9-271 (Delay Threshold subfield format). The Delay Threshold field is reserved if the Delay Threshold subfield of the Trigger Conditions (#291)subfield is 0.

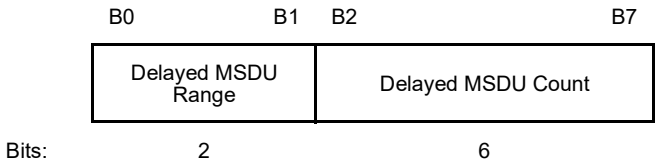


**Figure 9-271—Delay Threshold subfield format**

The Delayed MSDU Range field contains a value representing the MSDU transmit delay at or above which an MSDU is counted toward the Delayed MSDU Count threshold. The Delayed MSDU Range field is encoded as a value representing the lower bound of a bin in the Transmit Delay Histogram as shown in Table 9-151 (Delayed MSDU Range Definitions). The Transmit Delay Histogram is defined in 9.4.2.20.11 (Transmit Stream/Category Measurement report).

**Table 9-151—Delayed MSDU Range Definitions**

| Delayed MSDU Range | Condition |
|---|---|
| 0 | Transmit Delay = Lower Bound of Bin 2 |
| 1 | Transmit Delay = Lower Bound of Bin 3 |
| 2 | Transmit Delay = Lower Bound of Bin 4 |
| 3 | Transmit Delay = Lower Bound of Bin 5 |

The Delayed MSDU Count field contains a value representing the number of MSDUs to be used as the threshold value for the delay trigger condition.


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The Measurement Count field contains a number of MSDUs. This value is used to calculate an average discard count for the average trigger condition. It is also used in place of measurement duration in determining the scope of the reported results when a report is triggered; see 11.10.9.8 (Transmit Stream/ Category Measurement report).

The Trigger Timeout field contains a value, in units of 100 TU, during which a measuring STA does not generate further triggered transmit stream/category measurement reports after a trigger condition has been met. See 11.10.9.8 (Transmit Stream/Category Measurement report).

The Vendor Specific subelement has the same format as the Vendor Specific element (see 9.4.2.24 (Vendor Specific element)). Zero or more Vendor Specific subelements are included in the list of optional subelements.

#### 9.4.2.19.12 Measurement Pause request

The Measurement Request field corresponding to a Measurement Pause request is shown in Figure 9-272 (Measurement Request field format for Measurement Pause request). The Measurement Pause request cannot be processed in parallel with any other measurement request. See 11.10.9.7 (Measurement pause).

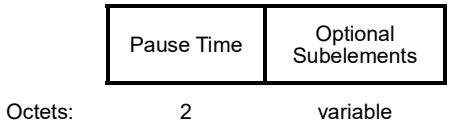


**Figure 9-272—Measurement Request field format for Measurement Pause request**

The Pause Time field contains a number between 1 and 65 535 representing the time period for which measurements are suspended or paused. The time unit for the Pause Time is 10 TUs. The Pause Time value 0 is reserved. Measurement Pause requests are used to provide time delays between the execution times of Measurement Request elements in a Radio Measurement Request frame.

The Optional Subelements field contains zero or more subelements. The subelement format and ordering of subelements are defined in 9.4.3 (Subelements).

The Subelement ID field values for the defined subelements are shown in Table 9-152 (Optional subelement IDs for Measurement Pause request).

**Table 9-152—Optional subelement IDs for Measurement Pause request**

| Subelement ID | Name | Extensible |
|---|---|---|
| 0–220 | Reserved | |
| 221 | Vendor Specific | Vendor defined |
| 222–255 | Reserved | |

The Vendor Specific subelements have the same format as their corresponding elements (see 9.4.2.24 (Vendor Specific element)). Zero or more Vendor Specific subelements are included in the list of optional subelements.

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#### 9.4.2.19.13 Multicast Diagnostics request

The Measurement Request field corresponding to a Multicast Diagnostics request is shown in Figure 9-273 (Measurement Request field format for a Multicast Diagnostics request). The response to a Multicast Diagnostics request is a Multicast Diagnostics report.

| | Randomization Interval | Measurement Duration | Group MAC Address | Optional Subelements |
|---|---|---|---|---|
| Octets: | 2 | 2 | 6 | variable |

**Figure 9-273—Measurement Request field format for a Multicast Diagnostics request**

The Randomization Interval field is the upper limit of random delay before the measurement begins, expressed in TUs. The use of the Randomization Interval field is described in 11.11.3 (Registered STA operation). When requesting a triggered multicast diagnostic report, the Randomization Interval field is reserved.

The Measurement Duration field is the duration of the requested measurement, expressed in TUs. When requesting a triggered multicast diagnostic report, the Measurement Duration field is reserved.

A Group MAC Address field with bit 0 set to 1 contains the MAC address of the group addressed frames to which the measurement request relates. A Group MAC Address field with bit 0 set to 0 indicates that all group addressed frames, apart from the broadcast address, are requested.

The Optional Subelements field contains zero or more subelements. The subelement format and ordering of subelements are defined in 9.4.3 (Subelements).

The Subelement ID field values for the defined subelements are shown in Table 9-153 (Optional subelement IDs for STA Multicast Diagnostics request).

**Table 9-153—Optional subelement IDs for STA Multicast Diagnostics request**

| Subelement ID | Name | Extensible |
|---|---|---|
| 0 | Reserved | |
| 1 | Multicast Triggered Reporting | No |
| 2–220 | Reserved | |
| 221 | Vendor Specific | Vendor defined |
| 222–255 | Reserved | |

The Multicast Triggered Reporting subelement is used to specify trigger conditions and thresholds. It is present only when requesting triggered multicast diagnostic reporting. The format of Multicast Triggered Reporting subelement is shown in Figure 9-274 (Multicast Triggered Reporting subelement format).

| | Subelement ID | Length | Multicast Trigger Condition | Inactivity Timeout | Reactivation Delay |
|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 1 | 1 |

**Figure 9-274—Multicast Triggered Reporting subelement format**


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The Multicast Trigger Condition field specifies reporting triggers for triggered management diagnostic reporting. The format of the Multicast Trigger Condition field is shown in Figure 9-275 (Multicast Trigger Condition field format).

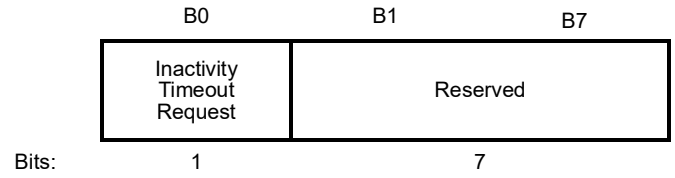


**Figure 9-275—Multicast Trigger Condition field format**

The Inactivity Timeout Request field is 1 to request that a multicast triggered report be generated when no group addressed frames with the monitored group address are received in a time equal to the value given in the Inactivity Timeout field. The Inactivity Timeout Request field is 0 when a multicast reception timeout is not requested.

The Inactivity Timeout field contains a time value in units of 100 TUs to be used as the threshold value for the inactivity timeout trigger condition.

The Reactivation Delay field contains a value in units of 100 TUs during which a measuring STA does not generate further multicast triggered reports after a trigger condition has been met.

The Vendor Specific subelement has the same format as the Vendor Specific element (see 9.4.2.24 (Vendor Specific element)).

The use of Multicast Diagnostics request is defined in 11.10.19 (Multicast diagnostic reporting).

#### 9.4.2.19.14 Location Civic request

The Measurement Request field corresponding to a Location Civic request is shown in Figure 9-276 (Location Civic Request field format). The response to a Location Civic request is a Location Civic report.

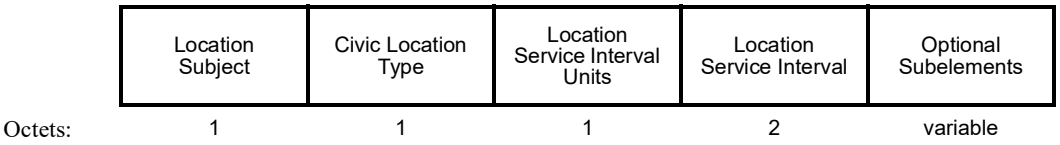


**Figure 9-276—Location Civic Request field format**

The Location Subject field is 1 octet and is defined in Table 9-148 (Location Subject field definition).

The Civic Location Type field contains the format of location information in the Location Civic report, as indicated in Table 9-154 (Civic Location Type field values).

When the Civic Location Type value is Vendor Specific, a Vendor Specific subelement is included in the list of optional subelements that identifies the Organization Identifier corresponding to the Civic Location Type field.

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**Table 9-154—Civic Location Type field values**

| Civic Location Type field value | Name | Description |
|---|---|---|
| 0 | IETF RFC 4776 | Starting at the country code field (i.e., excluding the GEOCONF_CIVIC/ OPTION_GEOCONF_CIVIC, N/option-len and what fields); includes all subsequent RFCs that define additional civic address Types |
| 1 | Vendor Specific | |
| 2–255 | Reserved | |

The Location Service Interval Units field contains the units for the Location Service Interval field, as indicated in Table 9-155 (Location Service Interval Units).

**Table 9-155—Location Service Interval Units**

| Location Service Interval Units value | Description |
|---|---|
| 0 | Seconds |
| 1 | Minutes |
| 2 | Hours |
| 3–255 | Reserved |

The Location Service Interval field is the time interval, expressed in the units indicated in the Location Service Interval Units field, at which the STA requests to receive Location Civic reports. A Location Service Interval of 0 indicates that only a single Location Civic report is requested.

The Optional Subelements field contains zero or more subelements. The subelement format and ordering of subelements are defined in 9.4.3 (Subelements).

The Subelement ID field values for the defined subelements are shown in Table 9-156 (Optional subelement IDs for Location Civic request).

**Table 9-156—Optional subelement IDs for Location Civic request**

| Subelement ID | Name | Extensible |
|---|---|---|
| 0 | Reserved | |
| 1 | Originator Requesting STA MAC Address | No |
| 2 | Target MAC Address | No |
| 3–220 | Reserved | |
| 221 | Vendor Specific | Vendor defined |
| 222–255 | Reserved | |


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The Originator Requesting STA MAC Address subelement contains the MAC address of the STA requesting for the Location Information and it is present whenever the Location Subject field is set to 2. The format of the Originator Requesting STA MAC Address subelement is shown in Figure 9-263 (Originator Requesting STA MAC Address subelement format).

The Target MAC Address subelement contains the MAC address of the STA whose Location Information is requested and it is present whenever the Location Subject field is set to 2. The format of the Target MAC Address subelement is shown in Figure 9-264 (Target MAC Address subelement format).

The Vendor Specific subelement has the same format as the Vendor Specific element (see 9.4.2.24 (Vendor Specific element)).

#### 9.4.2.19.15 Location Identifier request

The Measurement Request field corresponding to a Location Identifier request is shown in Figure 9-277 (Location Identifier request field format). The response to a Location Identifier request is a Location Identifier report.

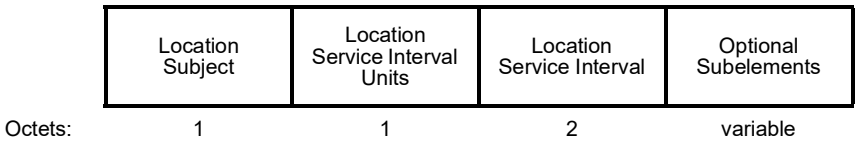


**Figure 9-277—Location Identifier request field format**

The Location Subject field is 1 octet and is defined in Table 9-148 (Location Subject field definition).

The Location Service Interval Units field is defined in Table 9-155 (Location Service Interval Units).

The Location Service Interval field is the time interval, expressed in the units indicated in the Location Service Interval Units field, at which the STA requests to receive Location Identifier reports. A Location Service Interval of 0 indicates that only a single Location Identifier report is requested.

The Optional Subelements field contains zero or more subelements. The subelement format and ordering of subelements are defined in 9.4.3 (Subelements).

The Subelement ID field values for the defined subelements are shown in Table 9-157 (Optional subelement IDs for Location Identifier request).

**Table 9-157—Optional subelement IDs for Location Identifier request**

| Subelement ID | Name | Extensible |
|---|---|---|
| 0 | Reserved | |
| 1 | Originator Requesting STA MAC Address | No |
| 2 | Target MAC Address | No |
| 3–220 | Reserved | |
| 221 | Vendor Specific | Vendor defined |
| 222–255 | Reserved | |

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The Originator Requesting STA MAC Address subelement contains the MAC address of the STA requesting the Location Information and it is present whenever the Location Subject field is set to 2. The format of the Originator Requesting STA MAC Address subelement is shown in Figure 9-263 (Originator Requesting STA MAC Address subelement format).

The Target MAC Address subelement contains the MAC address of the STA whose Location Information is requested and it is present whenever the Location Subject field is set to 2. The format of the Target MAC Address subelement is shown in Figure 9-264 (Target MAC Address subelement format).

The Vendor Specific subelement has the same format as the Vendor Specific element (see 9.4.2.24 (Vendor Specific element)).

#### 9.4.2.19.16 Directional Channel Quality request

The Measurement Request field corresponding to a Directional Channel Quality request is shown in Figure 9-278 (Measurement Request field format for Directional Channel Quality request). This Measurement Request is transmitted from a Requesting STA to a Requested STA to perform measurements toward a Target STA (see 11.30 (Spatial sharing and interference mitigation for DMG STAs)).

| | Operating Class | Channel Number | AID | Reserved | Measurement Method |
|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 1 | 1 |

| | Measurement Start Time | Measurement Duration | Number of Time Blocks | Optional Subelements |
|---|---|---|---|---|
| Octets: | 8 | 2 | 1 | variable(#213) |

**Figure 9-278—Measurement Request field format for Directional Channel Quality request**

The Operating Class field indicates the channel set for which the measurement request applies. The Operating Class and Channel Number fields(#6181) together specify the channel frequency and spacing for which the measurement request applies. Valid values of Operating Class are shown in Annex E.

The Channel Number field indicates the channel number for which the measurement request applies. Channel Number is defined within an Operating Class as shown in Annex E.

The AID field contains the AID assigned to the Target STA by the AP or PCP.

The Measurement Method field indicates the method that is to be used by the Requested STA to carry out this measurement request and report back in the measurement report. If this field is set to 0, it indicates ANIPI. If this field is set to 1, it indicates RSNI. (11ay)If this field is set to 2, it indicates ANIPI during the duration of the requested measurement, in units of 1 μs. If this field is set to 3, it indicates RSNI during the duration of the requested measurement, in units of 1 μs. Other values are reserved. Other values are reserved.

The Measurement Start Time field is set to the TSF timer at the time at which the requested measurement starts. A 0 indicates that the measurement starts immediately.

If the Measurement Method field is not 2 or 3, the Measurement Duration field is set to the preferred or mandatory duration of the requested measurement, in units of TUs. See 11.10.4 (Measurement duration). If the Measurement Method field is 2 or 3, the Measurement Duration field is set to the duration of the requested measurement, in units of 1 μs (TU/1024).(11ay)


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The Number of Time Blocks field indicates the number of time blocks within the Measurement Duration. The ratio (Measurement Duration/Number of Time Blocks) provides the duration of an individual measurement unit.

The Optional Subelements field contains zero or more subelements. The subelement format and ordering of subelements are defined in 9.4.3 (Subelements).

The Subelement ID field values for the defined subelements are shown in Table 9-158 (Optional subelement IDs for Directional Channel Quality request).

**Table 9-158—Optional subelement IDs for Directional Channel Quality request**

| Subelement ID | Name | Extensible |
|---|---|---|
| 0 | Reserved | |
| 1 | Directional Channel Quality Reporting | Yes |
| 2(11ay) | Measurement Configuration | Yes |
| 3(11ay) | Extended Measurement Configuration | Yes |
| 4–220 | Reserved | No |
| 221 | Vendor Specific | Vendor defined |
| 222–255 | Reserved | |

The Directional Channel Quality Reporting subelement indicates the condition for issuing a Directional Channel Quality report. The Directional Channel Quality Reporting subelement Data field format is shown in Figure 9-279 (Directional Channel Quality Reporting subelement Data field format)(#1496). The Reporting Condition subfield is described in Table 9-159 (Reporting Condition subfield for Directional Channel Quality report). The Directional Channel Quality Reference value is a Directional Channel Quality value and is the reference value for the indicated reporting condition.

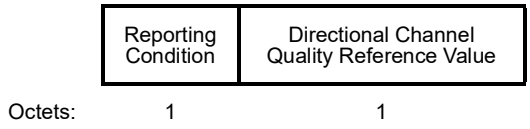


**Figure 9-279—Directional Channel Quality Reporting subelement Data field format**

**Table 9-159—Reporting Condition subfield for Directional Channel Quality report**

| Condition for report to be issued | Reporting condition |
|---|---|
| Report to be issued after each measurement (default, used when Directional Channel Quality Reporting subelement is not included in Directional Channel Quality Request). | 0 |
| Report to be issued when measured ANIPI or RSNI is greater than or equal to the reference value. | 1 |

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**Table 9-159—Reporting Condition subfield for Directional Channel Quality report *(contin-***

| Condition for report to be issued | Reporting condition |
|---|---|
| Report to be issued when measured ANIPI or RSNI is less than or equal to the reference value. | 2 |
| Reserved | 3–255 |

(11ay)The Measurement Configuration subelement indicates measurement configuration information for which the measurement request applies and is used between a pair of EDMG STAs. The Data field of the Measurement Configuration subelement is formatted as shown in Figure 9-280 (Data field format of the Measurement Configuration subelement(11ay)(M118)).

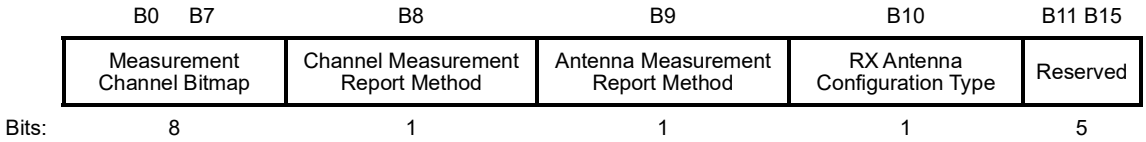


**Figure 9-280—Data field format of the Measurement Configuration subelement(11ay)(M118)**

(11ay)The Measurement Channel Bitmap subfield is a bitmap that indicates the 2.16 GHz channel(s) to which the measurement request applies and is formatted as shown in Figure 9-281 (Measurement Channel Bitmap subfield format(11ay)). In Figure 9-281 (Measurement Channel Bitmap subfield format(11ay)), Ch1 subfield corresponds to channel 1, Ch2 subfield corresponds to channel 2 and so on (channels are defined in Annex E). If a subfield is set to 1, the measurement request applies to the indicated channel; otherwise, if the subfield is set to 0, the measurement request does not apply to the indicated channel.

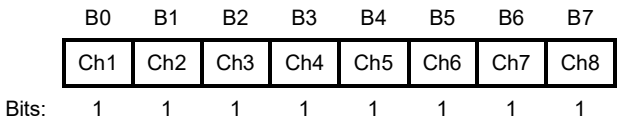


**Figure 9-281—Measurement Channel Bitmap subfield format(11ay)**

(11ay)The Channel Measurement Report Method subfield indicates the method that is to be used by the Requested STA to report the results of measurements over multiple 2.16 GHz channels in the measurement report. The Channel Measurement Report Method subfield sets to 0 to indicate the results of measurements over all the requested 2.16 GHz channels during each measurement time block are reported per 2.16 GHz channel. The Channel Measurement Report Method subfield sets to 1 to indicate the averaged results of concurrent measurements over all the requested 2.16 GHz channels during each measurement time block are reported. The Channel Measurement Report Method subfield is set to 0 when the Extended Measurement Configuration subelement is present.

(11ay)The Antenna Measurement Report Method subfield indicates the method that is to be used by the Requested STA to report the results of concurrent measurements using multiple RX DMG antennas in the measurement report. The Antenna Measurement Report Method subfield is set to 0 to indicate the results of concurrent measurements over each requested 2.16 GHz channel using multiple RX DMG antennas during a measurement time block are reported per DMG antenna. The Antenna Measurement Report Method subfield is set to 1 to indicate the averaged results of concurrent measurements over each requested 2.16 GHz channel using multiple RX DMG antennas during a measurement time block are reported.


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(11ay)The RX Antenna Configuration Type subfield is set to 0 to request that the RX antenna configuration used for SISO reception be used for measurements, and is set to 1 to request that the RX antenna configuration used for SU-MIMO reception be used for measurements.

(11ay)The Extended Measurement Configuration subelement is present if the Measurement Configuration subelement is present. The Extended Measurement Configuration subelement contains measurement timing information for the channels indicated in the Measurement Configuration subelement. If the Extended Measurement Configuration subelement is not present, the measurement timing information indicated in the Measurement Request field applies to all requested channels. If the Extended Measurement Configuration subelement is present, the measurement timing information indicated in the Measurement Request field applies to the first requested channel (i.e., the requested channel with the lowest channel number) and measurement timing information indicated in the Extended Measurement Configuration subelement applies to the remaining requested channels in ascending order in terms of channel number. The Data field of the Extended Measurement Configuration subelement is formatted as shown in Figure 9-282 (Data field format of the Extended Measurement Configuration subelement(11ay)(M118)).

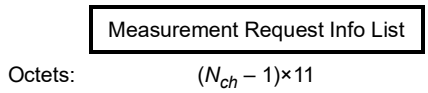


**Figure 9-282—Data field format of the Extended Measurement Configuration subelement(11ay)(M118)**

(11ay)The Measurement Request Info List field contains $(N_{ch} - 1)$ Measurement Request Info subfields, where $N_{ch}$ is the total number of the requested channels. Each Measurement Request Info subfield is defined in Figure 9-283 (Measurement Request Info subfield format(11ay)).

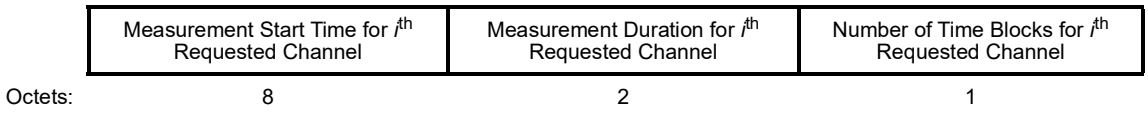


**Figure 9-283—Measurement Request Info subfield format(11ay)**

(11ay)The measurement timing information for the $i^{th}$ requested channel is indicated in the Measurement Start Time for $i^{th}$ Requested Channel subfield, the Measurement Duration subfield for $i^{th}$ Requested Channel and Number of Time Blocks for $i^{th}$ Requested Channel subfield, where $i = 2, 3, \ldots, N_{ch}$. The definition of these subfields is the same as the corresponding subfields in the Measurement Request field (Figure 9-278 (Measurement Request field format for Directional Channel Quality request)).

The Vendor Specific subelements have the same format as their corresponding elements (see 9.4.2.24 (Vendor Specific element)). Zero or more Vendor Specific subelements are included in the list of optional subelements.

### 9.4.2.19.17 Directional Measurement request

The Measurement Request field corresponding to a Directional Measurement request is shown in Figure 9-284 (Measurement Request field format for Directional Measurement request). This Measurement Request is transmitted from a Requesting STA to a Requested STA to perform directional channel measurements in all sectored receiving directions.

The Operating Class field indicates the channel set for which the measurement request applies. The Operating Class and Channel Number fields(#6181) together specify the channel frequency and spacing for which the measurement request applies. Valid values of Operating Class are shown in Annex E.

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| | Operating Class | Channel Number | Measurement Start Time | Measurement Duration per Direction | Measurement Method And Antenna Configuration | Optional Subelements |
|---|---|---|---|---|---|---|
| Octets | 1 | 1 | 8 | 2 | 1 | variable(#213) |

**Figure 9-284—Measurement Request field format for Directional Measurement request**

The Channel Number field indicates the channel number for which the measurement request applies. Channel Number is defined within an Operating Class as shown in Annex E.

The Measurement Start Time field is set to the TSF timer at the time at which the requested measurement starts. A 0 indicates that the measurement starts immediately.

The Measurement Duration per Direction field is set to the preferred or mandatory duration of the requested measurement in each receiving direction, in units of TUs.

(11ay)The Measurement Method And Antenna Configuration field is defined in Figure 9-285 (Measurement Method And Antenna Configuration field format(11ay)).

| | B0 B2 | B3 B4 | B5 B7 |
|---|---|---|---|
| | Measurement Method | Antenna Configuration | Reserved |
| Bits: | 3 | 2 | 3 |

**Figure 9-285—Measurement Method And Antenna Configuration field format(11ay)**

The Measurement Method field indicates the method that is to be used by the Requested STA to carry out this measurement request and report back in the measurement report. If this (11ay)subfield is set to 0, it indicates ANIPI. If this (11ay)subfield is set to 1, it indicates RCPI. If the (11ay)subfield is set to 2, it indicates Channel Load. Other values are reserved.

(11ay)The Antenna Configuration subfield indicates the configuration of the DMG antenna(s) used by the STA to carry out the measurement. If this subfield is set to 1, it indicates a quasi-omni antenna pattern. If this subfield is set to 2, it indicates directional antenna pattern. Other values are reserved.

The Optional Subelements field contains zero or more subelements. The subelement format and ordering of subelements are defined in 9.4.3 (Subelements).

The Subelement ID field values for the defined subelements are shown in Table 9-160 (Optional subelement IDs for Directional Measurement request).

**Table 9-160—Optional subelement IDs for Directional Measurement request**

| Subelement ID | Name | Extensible |
|---|---|---|
| 0–220 | Reserved | |
| 221 | Vendor Specific | Vendor defined |
| 222–255 | Reserved | |


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The Vendor Specific subelements have the same format as their corresponding elements (see 9.4.2.24 (Vendor Specific element)). Zero or more Vendor Specific subelements are included in the list of optional subelements.

### 9.4.2.19.18 Directional Statistics request

The Measurement Request field corresponding to a Directional Statistics request is shown in Figure 9-286 (Measurement Request field format for Directional Statistics request). This Measurement Request is transmitted from a Requesting STA to a Requested STA to perform directional channel measurements in all sectored receiving directions.

| | Operating Class | Channel Number | Measurement Start Time | Measurement Duration per Direction | Measurement Method | Directional Statistics Bitmap | Optional Subelements |
|---|---|---|---|---|---|---|---|
| Octets | 1 | 1 | 8 | 2 | 1 | 1 | variable(#213) |

**Figure 9-286—Measurement Request field format for Directional Statistics request**

The Operating Class field indicates the channel set for which the measurement request applies. The Operating Class and Channel Number fields(#6181) together specify the channel frequency and spacing for which the measurement request applies. Valid values of Operating Class are shown in Annex E.

The Channel Number field indicates the channel number for which the measurement request applies. Channel Number is defined within an Operating Class as shown in Annex E.

The Measurement Start Time field is set to the TSF timer at the time at which the requested measurement starts. A 0 indicates that the measurement starts immediately.

The Measurement Duration per Direction field is set to the preferred or mandatory duration of the requested measurement in each receiving direction, in units of TUs.

The Measurement Method field indicates the method that is to be used by the Requested STA to carry out this measurement request and report back in the measurement report. If this field is set to 0, it indicates ANIPI. If this field is set to 1, it indicates RCPI. If the field is set to 2, it indicates Channel Load. Other values are reserved.

The Directional Statistics Bitmap field format is shown in Figure 9-287 (Directional Statistics Bitmap field format). The Maximum field set to 1 indicates that the maximum measurement result among all directions is expected in the measurement report. The Minimum field set to 1 indicates that the minimum measurement result among all directions is expected in the measurement report. The Average field set to 1 indicates that the average measurement result among all directions is expected in the measurement report. The Variance field set to 1 indicates that the variance of measurement results among all directions is expected in the measurement report. Other bits are reserved.

| | B0 | B1 | B2 | B3 | B4 B7 |
|---|---|---|---|---|---|
| | Maximum | Minimum | Average | Variance | Reserved |
| Bits: | 1 | 1 | 1 | 1 | 4 |

**Figure 9-287—Directional Statistics Bitmap field format**

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The Optional Subelements field contains zero or more subelements. The subelement format and ordering of subelements are defined in 9.4.3 (Subelements).

The Subelement ID field values for the defined subelements are shown in Table 9-161 (Optional subelement IDs for Directional Statistics request).

**Table 9-161—Optional subelement IDs for Directional Statistics request**

| Subelement ID | Name | Extensible |
|---|---|---|
| 0–220 | Reserved | |
| 221 | Vendor Specific | Vendor defined |
| 222–255 | Reserved | |

The Vendor Specific subelements have the same format as their corresponding elements (see 9.4.2.24 (Vendor Specific element)). Zero or more Vendor Specific subelements are included in the list of optional subelements.

#### 9.4.2.19.19 FTM Range request(#7065)

The Measurement Request field corresponding to an (#7065)FTM Range request is shown in Figure 9-288 (Measurement Request field format for an FTM Range request(#8020)(#7065)).

| | Randomization Interval | Minimum AP Count | FTM Range Subelements |
|---|---|---|---|
| Octets: | 2 | 1 | variable |

**Figure 9-288—Measurement Request field format for an FTM Range request(#8020)(#7065)**

The Randomization Interval field specifies the upper bound of the random delay to be used prior to making the measurement, in units of TUs. See 11.10.3 (Measurement start time).

(#389)The Minimum AP Count field specifies the minimum number of APs to determine the range to, among the APs identified in the Neighbor Report subelements in the FTM Range Subelements field. The value 0 and values above 15 are reserved.

The FTM Range Subelements field contains one or more subelements. The subelement format and ordering of subelements are defined in 9.4.3 (Subelements). The FTM Range subelements are listed in Table 9-162 (FTM Range subelement IDs for FTM Range request(#7065)).

The Subelement IDs for subelements in the (#7065)FTM Range Request element(M118) are defined in Table 9-162 (FTM Range subelement IDs for FTM Range request(#7065)). The number of Neighbor Report subelements included in the FTM Range Subelements field is at least the value of the Minimum AP Count field. Each Neighbor Report subelement has the same format as the Neighbor Report element and contains the Wide Bandwidth Channel subelement. See Table 9-162 (FTM Range subelement IDs for FTM Range request(#7065)) and 9.4.2.35 (Neighbor Report element). The Neighbor Report subelements specify a set of nearby APs; the requested STA is requested to perform the FTM procedure with a subset of these APs (see 11.10.9.11 (FTM Range report(#7065))).


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**Table 9-162—FTM Range subelement IDs for FTM Range request(#7065)**

| Subelement ID | Name | Extensible |
|---|---|---|
| 0–3 | Reserved | |
| 4 | Maximum Age | Yes |
| 5–51 | Reserved | |
| 52 | Neighbor Report | Subelements |
| 53–220 | Reserved | |
| 221 | Vendor Specific | Vendor defined |
| 222–255 | Reserved | |

The Maximum Age subelement indicates the maximum age of the requested FTM ranges. The format of the Maximum Age subelement is defined in Figure 9-265 (Maximum Age subelement format). The absence of a Maximum Age subelement indicates that FTM ranges determined at or after the (#7065)FTM Range request is received are requested.

The Subelement ID field is defined in Table 9-162 (FTM Range subelement IDs for FTM Range request(#7065)).

The Length field is defined in 9.4.3 (Subelements).

The Maximum Age field of the Maximum Age subelement indicates the maximum elapsed time between when FTM ranges are determined and when an (#7065)FTM Range request is received, within which the FTM ranges satisfy the (#7065)FTM Range request. The Maximum Age field is encoded as an unsigned integer with units of 0.1 s. The value 0 is reserved. The value 65 535 indicates that FTM ranges determined at any time are acceptable.

The Vendor Specific subelement has the same format as the corresponding element (see 9.4.2.24 (Vendor Specific element)). Zero or more Vendor Specific subelements are included in the list of optional subelements.

### 9.4.2.20 Measurement Report element

#### 9.4.2.20.1 General

The Measurement Report element contains a measurement report. The format of the Measurement Report element is shown in Figure 9-289 (Measurement Report element format). The Measurement Report element is included in Measurement Report frames, as described in 9.6.2.3 (Spectrum Measurement Report frame format), or Radio Measurement Report frames, as described in 9.6.6.3 (Radio Measurement Report frame format). Measurement Types 0, 1, and 2 are used for spectrum management and are included only in Measurement Report frames. All other Measurement Types are included only in Radio Measurement Report frames. The use of Measurement Report elements and frames for spectrum management is described in

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11.8.7 (Requesting and reporting of measurements). The use of Measurement Report elements and frames for radio measurement is described in 11.10 (Radio measurement procedures).

| | Element ID | Length | Measurement Token | Measurement Report Mode | Measurement Type | Measurement Report |
|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 1 | 1 | variable |

**Figure 9-289—Measurement Report element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The Measurement Token field is set to the value of the Measurement Token field in the corresponding Measurement Request element. If the Measurement Report element is being sent autonomously, then the Measurement Token is set to 0. If the Measurement Report element is being sent in a Location Track Notification frame, then the Measurement Token field is set to the same value as the Location Configuration Request frame Dialog Token field that configured the STA to send the Location Track Notification frames.

The Measurement Report Mode field (shown in Figure 9-290 (Measurement Report Mode field format)) is used to indicate the reason for a failed or rejected measurement request. The Measurement Report Mode is a bit field with the following subfields(#291) defined:

— Late subfield(#291) indicates whether this STA is unable to carry out a measurement request because it received the request after the requested measurement time. The Late subfield(#291) is set to 1 to indicate the request was too late. The Late subfield(#291) is set to 0 to indicate the request was received in time for the measurement to be executed. The Late subfield(#291) only applies to spectrum management measurement and is set to 0 in all measurement report elements for radio measurement types (see Table 9-163 (Measurement Type field definitions for measurement reports)).

— Incapable subfield(#291) indicates whether this STA is incapable of generating a report of the type specified in the Measurement Type field that was previously requested by the destination STA of this Measurement Report element. The Incapable subfield(#291) is set to 1 to indicate the STA is incapable. The Incapable subfield(#291) is set to 0 to indicate the STA is capable or the report is autonomous.

— Refused subfield(#291) indicates whether this STA is refusing to generate a report of the type specified in the Measurement Type field that was previously requested by the destination STA of this Measurement Report element. The Refused subfield (#291)is set to 1 to indicate the STA is refusing. The Refused subfield(#291) is set to 0 to indicate the STA is not refusing or the report is autonomous.

— All other bits are reserved.

| | B0 | B1 | B2 | B3 | B7 |
|---|---|---|---|---|---|
| | Late | Incapable | Refused | Reserved | |
| Bits: | 1 | 1 | 1 | 5 | |

**Figure 9-290—Measurement Report Mode field format**

No more than one bit is set to 1 within a Measurement Report Mode field. All bits within the Measurement Mode field are set to 0 if the results of a successful measurement request or an autonomous measurement are being reported.


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The Measurement Type field is set to a number that identifies the measurement report. The Measurement Types that have been allocated are shown in Table 9-163 (Measurement Type field definitions for measurement reports).

**Table 9-163—Measurement Type field definitions for measurement reports**

| Name | Measurement Type |
|---|---|
| Basic | 0 |
| CCA | 1 |
| RPI Histogram | 2 |
| Channel Load | 3 |
| Noise Histogram | 4 |
| Beacon | 5 |
| Frame | 6 |
| STA Statistics | 7 |
| LCI | 8 |
| Transmit Stream/Category Measurement | 9 |
| Multicast Diagnostics | 10 |
| Location Civic | 11 |
| Location Identifier | 12 |
| Directional Channel Quality | 13 |
| Directional Measurement | 14 |
| Directional Statistics | 15 |
| (#7065)FTM Range | 16 |
| Reserved | 17–255 |

The Measurement Report field is not present when the Late subfield(#291) is equal to 1, the Incapable subfield(#291) is equal to 1, or the Refused subfield(#291) is equal to 1. Otherwise, it contains a single measurement report, as described in 9.4.2.20.2 (Basic report) to 9.4.2.20.11 (Transmit Stream/Category Measurement report).(#1687)

ANIPI is set to the average noise plus interference power value measured during the indicated Measurement Duration, using the same units and accuracy as defined for ANPI in 11.10.9.4 (Noise Histogram report).

RCPI is a logarithmic indication of the received channel power of the corresponding Link Measurement Request frame, as defined in 9.4.2.36 (RCPI element).

RSNI is the ratio of the received signal power to the noise plus interference power, as defined in 9.4.2.39 (RSNI element).

Channel Load is measured and reported as defined in 11.10.9.3 (Channel load report).

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#### 9.4.2.20.2 Basic report

The format of the Measurement Report field corresponding to a Basic report is shown in Figure 9-291 (Measurement Report field format for a Basic report).

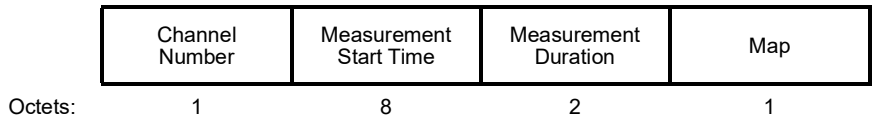


**Figure 9-291—Measurement Report field format for a Basic report**

The Channel Number field is set to the channel number to which the Basic report applies where the Channel Number is a value from the Channel set column in Table E-4 (Global operating classes), in a row having the same value in the Channel spacing (MHz) column as the width of the primary channel.

The Measurement Start Time field is set to the TSF at the time (± 32 μs) at which the Basic report measurement started.

The Measurement Duration field is set to the duration over which the Basic report was measured, expressed in TUs.

The Map field is coded as a bitmap(#291), as shown in Figure 9-292 (Map field format), and contains the following subfields(#291):

— BSS subfield(#291), which is set to 1 when at least one valid MPDU was received in the channel during the measurement period from another BSS. Otherwise, the BSS subfield(#291) is set to 0.

— OFDM Preamble subfield(#291), which is set to 1 when at least one sequence of short training symbols, as defined in 17.3.3 (PHY preamble (SYNC)), was detected in the channel during the measurement period without a subsequent valid SIGNAL field (see 17.3.4 (SIGNAL field)). This indicates the presence of an OFDM preamble, such as high-performance RLAN/2 (HIPERLAN/2). Otherwise, the OFDM Preamble subfield(#291) is set to 0.

— Unidentified Signal subfield(#291), which is set to 1 when, in the channel during the measurement period, there is significant power detected that is not characterized as radar, an OFDM preamble, or a valid MPDU. Otherwise, the Unidentified Signal subfield(#291) is set to 0. The definition of significant power is implementation dependent.

— Radar subfield(#291), which is set to 1 when radar was detected operating in the channel during the measurement period. The radar detection algorithm that satisfies regulatory requirements is outside the scope of this standard. Otherwise, the Radar subfield(#291) is set to 0.

— Unmeasured subfield(#291), which is set to 1 when this channel has not been measured. Otherwise, the Unmeasured subfield(#291) is set to 0. When the Unmeasured subfield is equal to 1, all of the other subfields(#291) are set to 0.

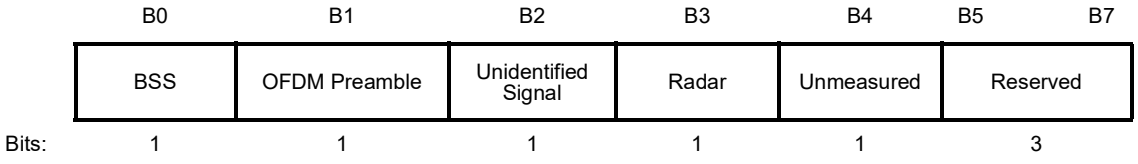


**Figure 9-292—Map field format**



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#### 9.4.2.20.3 CCA report

The format of the Measurement Report field corresponding to a CCA report is shown in Figure 9-293 (Measurement Report field format for a CCA report).

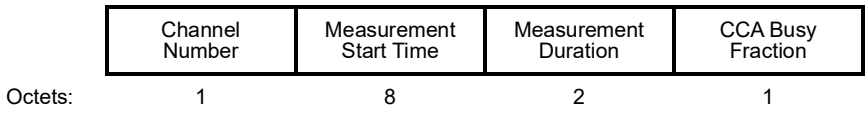


**Figure 9-293—Measurement Report field format for a CCA report**

The Channel Number field contains the channel number to which the CCA report applies where the Channel Number is a value from the Channel set column in Table E-4 (Global operating classes), in a row having the same value in the Channel spacing (MHz) column as the width of the primary channel.

The Measurement Start Time field is set to the TSF at the time (± 32 μs) at which the CCA report measurement started.

The Measurement Duration field is set to the duration over which the CCA report was measured, expressed in TUs.

The CCA Busy Fraction field contains the fractional duration over which CCA indicated the channel was busy during the measurement duration. The resolution of the CCA busy measurement is in microseconds. The CCA Busy Fraction value is defined as

$$\left\lceil \frac{255 \times t_{\text{busy}}}{1024 \times t_{\text{MD}}} \right\rceil$$

where

$t_{\text{busy}}$ is the duration CCA indicated channel was busy (μs)
$t_{\text{MD}}$ is the measurement duration (TUs)

#### 9.4.2.20.4 RPI histogram report

The format of the Measurement Report field corresponding to an RPI histogram report is shown in Figure 9-294 (Measurement Report field format for an RPI histogram report).

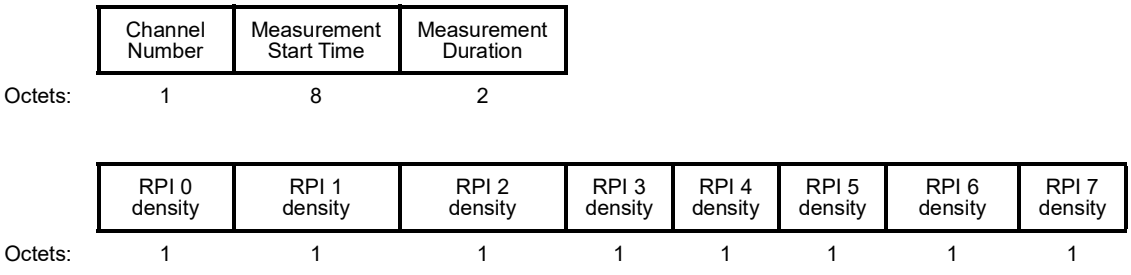


**Figure 9-294—Measurement Report field format for an RPI histogram report**

The Channel Number field is set to the channel number to which the RPI histogram report applies where the Channel Number is a value from the Channel set column in Table E-4 (Global operating classes), in a row having the same value in the Channel spacing (MHz) column as the width of the primary channel.

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The Measurement Start Time field is set to the TSF at the time (± 32 μs) at which the RPI histogram report measurement started.

The Measurement Duration field is set to the duration over which the RPI histogram report was measured, expressed in TUs.

The RPI histogram report contains the RPI densities observed in the channel for the eight RPI levels defined in Table 9-164 (RPI definitions for an RPI histogram report). See 11.10.12 (Measurement of the RPI histogram).

**Table 9-164—RPI definitions for an RPI histogram report**

| RPI | Power observed at the antenna connector (dBm) |
|---|---|
| 0 | Power ≤ –87 |
| 1 | –87 < Power ≤ –82 |
| 2 | –82 < Power ≤ –77 |
| 3 | –77 < Power ≤ –72 |
| 4 | –72 < Power ≤ –67 |
| 5 | –67 < Power ≤ –62 |
| 6 | –62 < Power ≤ –57 |
| 7 | –57 < Power |

The RPI histogram report provides an additional mechanism for a STA to gather information on the state of a channel from other STAs. The STA might use this information to assist in the choice of new channel, to help avoid false radar detections, and to assess the general level of interference present on a channel.

### 9.4.2.20.5 Channel Load report

The format of the Measurement Report field corresponding to a Channel Load report is shown in Figure 9-295 (Measurement Report field format for Channel Load report).

| | Operating Class | Channel Number | Actual Measurement Start Time | Measurement Duration | Channel Load | Optional Subelements |
|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 8 | 2 | 1 | variable |

**Figure 9-295—Measurement Report field format for Channel Load report**

If the Wide Bandwidth Channel Switch subelement is not included, the Operating Class field indicates the operating class that identifies the channel set for which the measurement report applies. The Country, Operating Class, and Channel Number fields together specify the channel frequency and spacing for which the measurement report applies. Valid operating classes are listed in Annex E, excluding operating classes that encompass a primary channel but do not identify the location of the primary channel. The Channel Number field indicates the channel number for which the measurement report applies. Channel number is defined within an operating class as shown in Annex E.


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NOTE—Examples of operating classes that encompass a primary channel but do not identify the location of the primary channel are operating classes with a value of 80 or 160 in the Channel Spacing (MHz) column of the applicable table in Annex E.

If the Wide Bandwidth Channel Switch subelement is included, the fields in the Wide Bandwidth Channel Switch subelement indicate the channel for which the measurement report applies, and the Operating Class and Channel Number fields together specify the primary channel and primary 40 MHz channel within the channel identified by the Wide Bandwidth Channel Switch subelement.

The Actual Measurement Start Time field is set to the value of the measuring STA's TSF timer at the time the measurement started.

The Measurement Duration field is set to the duration over which the Channel Load report was measured, in units of TUs.

The Channel Load field contains the proportion of measurement duration for which the measuring STA determined the channel to be busy. Procedure for Channel Load measurement and definition of channel load values are found in 11.10.9.3 (Channel load report).

The Optional Subelements field contains zero or more subelements. The subelement format and ordering of subelements are defined in 9.4.3 (Subelements).

The Subelement ID field values for the defined subelements are shown in Table 9-165 (Optional subelement IDs for Channel Load report).

**Table 9-165—Optional subelement IDs for Channel Load report**

| Subelement ID | Name | Extensible |
|---|---|---|
| 0–162 | Reserved | |
| 163 | Wide Bandwidth Channel Switch | Yes |
| 164–220 | Reserved | |
| 221 | Vendor Specific | Vendor defined |
| 222–255 | Reserved | |

The Wide Bandwidth Channel Switch subelement has the same format as the corresponding element (see 9.4.2.159 (Wide Bandwidth Channel Switch element)), with the constraint that the New Channel Width field indicates an 80 MHz, 160 MHz, or 80+80 MHz BSS bandwidth.

The Vendor Specific subelements have the same format as their corresponding elements (see 9.4.2.24 (Vendor Specific element)). Zero or more Vendor Specific subelements are included in the list of optional subelements.

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#### 9.4.2.20.6 Noise Histogram report

The format of the Measurement Report field of a Noise Histogram report is shown in Figure 9-296 (Measurement Report field format for Noise Histogram report).

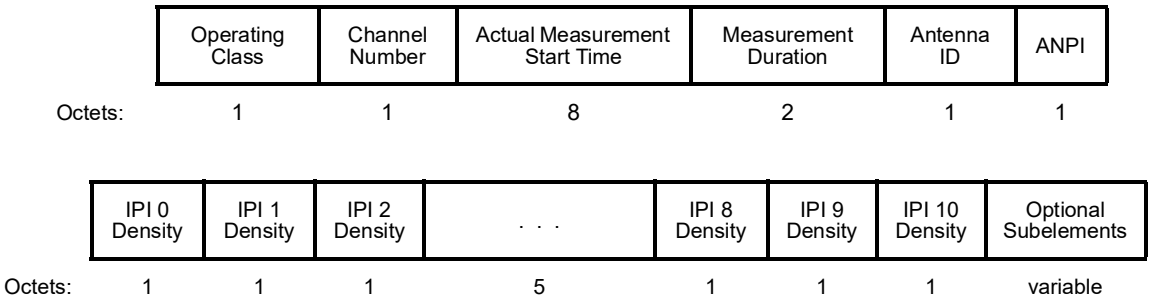


**Figure 9-296—Measurement Report field format for Noise Histogram report**

If the Wide Bandwidth Channel Switch subelement is not included, the Operating Class field indicates the operating class that identifies the channel set for which the measurement report applies. The Country, Operating Class, and Channel Number fields together specify the channel frequency and spacing for which the measurement report applies. Valid operating classes are listed in Annex E, excluding operating classes that encompass a primary channel but do not identify the location of the primary channel. The Channel Number field indicates the channel number for which the measurement report applies. Channel number is defined within an operating class as shown in Annex E.

If the Wide Bandwidth Channel Switch subelement is included, the fields in the Wide Bandwidth Channel Switch subelement indicate the channel for which the measurement report applies, and the Operating Class and Channel Number fields(#6181) together specify the primary channel and primary 40 MHz channel within the channel identified by the Wide Bandwidth Channel Switch subelement.

The Actual Measurement Start Time field is set to the value of the measuring STA's TSF timer at the time the measurement started.

The Measurement Duration field is set to the duration over which the Noise Histogram report was measured, in units of TUs.

The Antenna ID field is set to the identifying number for the antenna(s) or DMG antenna(s) used for this measurement. The antenna ID or DMG antenna ID is defined in 9.4.2.38 (Antenna element).

The ANPI field is set to the average noise plus interference power value measured during the indicated measurement duration while the indicated channel is idle as described in 11.10.9.4 (Noise Histogram report).

The Noise Histogram report contains the IPI densities, as defined in 11.10.9.4 (Noise Histogram report), observed in the channel for the eleven IPI levels defined in Table 9-166 (IPI Definitions for a Noise Histogram report).


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**Table 9-166—IPI Definitions for a Noise Histogram report**

| IPI Level | IPI Measured Power (dBm) |
|---|---|
| 0 | IPI ≤ –92 |
| 1 | –92 < IPI ≤ –89 |
| 2 | –89 < IPI ≤ –86 |
| 3 | –86 < IPI ≤ –83 |
| 4 | –83 < IPI ≤ –80 |
| 5 | –80 < IPI ≤ –75 |
| 6 | –75 < IPI ≤ –70 |
| 7 | –70 < IPI ≤ –65 |
| 8 | –65 < IPI ≤ –60 |
| 9 | –60 < IPI ≤ –55 |
| 10 | –55 < IPI |

The Optional Subelements field contains zero or more subelements. The subelement format and ordering of subelements are defined in 9.4.3 (Subelements).

The Subelement ID field values for the defined subelements are shown in Table 9-167 (Optional subelement IDs for Noise Histogram report).

**Table 9-167—Optional subelement IDs for Noise Histogram report**

| Subelement ID | Name | Extensible |
|---|---|---|
| 0–162 | Reserved | |
| 163 | Wide Bandwidth Channel Switch | Yes |
| 164–220 | Reserved | |
| 221 | Vendor Specific | Vendor defined |
| 222–255 | Reserved | |

The Wide Bandwidth Channel Switch subelement has the same format as the corresponding element (see 9.4.2.159 (Wide Bandwidth Channel Switch element)) with the constraint that the New Channel Width field indicates an 80 MHz, 160 MHz, or 80+80 MHz BSS bandwidth.

The Vendor Specific subelements have the same format as their corresponding elements (see 9.4.2.24 (Vendor Specific element)). Zero or more Vendor Specific subelements are included in the list of optional subelements.

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#### 9.4.2.20.7 Beacon report

The format of the Measurement Report field corresponding to a Beacon report is shown in Figure 9-297 (Measurement Report field format for Beacon report).

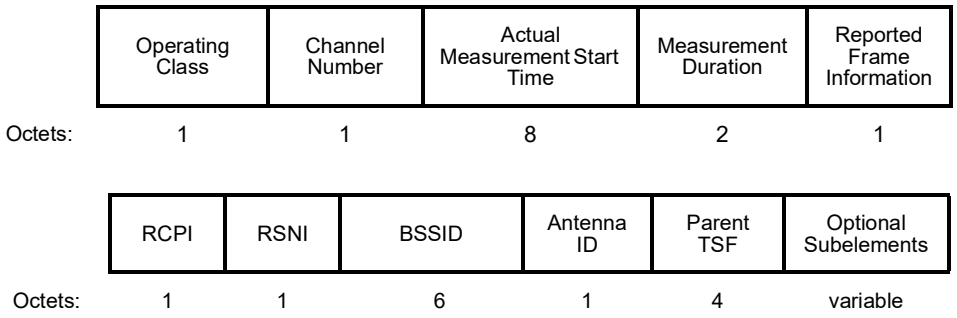


**Figure 9-297—Measurement Report field format for Beacon report**

The Operating Class field indicates the operating class that identifies the channel set of the received Beacon or Probe Response frame. The Country, Operating Class, and Channel Number fields together specify the channel frequency and spacing of the received Beacon or Probe Response frame. Valid operating classes are listed in Annex E.

The Channel Number field indicates the channel number of the received Beacon or Probe Response frame. Channel number is defined within an operating class as shown in Annex E.

If the PPDU carrying the received frame comprises noncontiguous frequency segments, the Operating Class and Channel Number fields identify the center frequency of frequency segment 0, and a Wide Bandwidth Channel Switch subelement is included to identify the center frequency of frequency segment 1 (the other fields in the subelement indicate 80+80 bandwidth and the same center frequency of frequency segment 0 as the Operating Class and Channel Number fields); otherwise the Wide Bandwidth Channel Switch subelement is not included.

The Actual Measurement Start Time field is set to the value of the measuring STA's TSF timer at the time the measurement started.

The Measurement Duration field is set to the duration over which the Beacon report was measured, in units of TUs.

The Reported Frame Information field contains two subfields as shown in Figure 9-298 (Reported Frame Information field format).

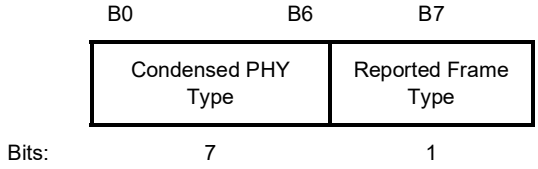


**Figure 9-298—Reported Frame Information field format**

The Condensed PHY Type subfield indicates the physical medium type on which the Beacon, Measurement Pilot, or Probe Response frame being reported was received. It has an integer value between 0 and 127 coded according to dot11PHYType.


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The Reported Frame Type subfield indicates the type of frame reported. A 0 indicates a Beacon or Probe Response frame; a 1 indicates a Measurement Pilot frame.

The RCPI field indicates the received channel power of the Beacon, Measurement Pilot, or Probe Response frame, which is a logarithmic function of the received signal power, as defined 9.4.2.36 (RCPI element).

The RSNI field indicates the received signal-to-noise indication for the Beacon, Measurement Pilot, or Probe Response frame, as described in 9.4.2.39 (RSNI element).

The BSSID field contains the BSSID from the Beacon, Measurement Pilot, or Probe Response frame being reported.

The Antenna ID field contains the identifying number for the antenna(s) or DMG antenna used for this measurement. The antenna ID or DMG antenna ID is defined in 9.4.2.38 (Antenna element).

The Parent TSF field contains the value of the 4 least significant octets of the measuring STA's TSF timer at the start of reception of the first octet of the Timestamp field of the reported Beacon, Measurement Pilot, or Probe Response frame at the time the Beacon, Measurement Pilot, or Probe Response frame being reported was received.

The Optional Subelements field contains zero or more subelements. The subelement format and ordering of subelements are defined in 9.4.3 (Subelements).

The Subelement ID field values for the defined subelements are shown in Table 9-168 (Optional subelement IDs for Beacon report).

**Table 9-168—Optional subelement IDs for Beacon report**

| Subelement ID | Name | Extensible |
|---|---|---|
| 0 | Reserved | |
| 1 | Reported Frame Body | No |
| 2 | Reported Frame Body Fragment ID | No |
| 3–162 | Reserved | |
| 163 | Wide Bandwidth Channel Switch | Yes |
| 164 | Last Beacon Report Indication | No |
| 165-220 | Reserved | |
| 221 | Vendor Specific | Vendor defined |
| 222–255 | Reserved | |

The Reported Frame Body subelement, if present, contains some or all of the fields and elements of the frame body of the reported Beacon, Measurement Pilot, or Probe Response frame. If the Reporting Detail field of the Reporting Detail subelement of the corresponding Beacon request equals 0, the Reported Frame Body subelement is not included in the Beacon report.(#294)

Some elements in the Reported Frame Body subelement, if present, or the Reported Frame Body subelement itself, might be large. In this case, some of the elements included in the Reported Frame Body subelement can be truncated or omitted, and the subelement itself can be truncated or fragmented over multiple Beacon

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reports (see 11.10.9.1.2 (Truncation and/or fragmentation of reported frame body in Beacon report(#294))).(#294)

NOTE—This is not element fragmentation as defined in 10.28.11 (Element fragmentation).(#294)

(#294)The Reported Frame Body Fragment ID subelement is present if a Reported Frame Body subelement is fragmented, and is not present otherwise. The format of the Data field of the Reported Frame Body Fragment ID subelement is shown in Figure 9-299 (Reported Frame Body Fragment ID subelement Data field format(#353)).

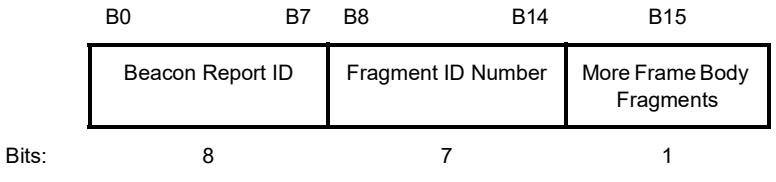


**Figure 9-299—Reported Frame Body Fragment ID subelement Data field format(#353)**

The Beacon Report ID field identifies the reported frame for which the Beacon reports are sent as a response to a Beacon request.(#294)

(#294)The Fragment ID Number field identifies the fragment of the fragmented Reported Frame Body subelement.

(#294)The More Frame Body Fragments field is set to 0 in the final fragment of the fragmented Reported Frame Body subelement, otherwise it is set to 1.

The Wide Bandwidth Channel Switch subelement has the same format as the corresponding element (see 9.4.2.159 (Wide Bandwidth Channel Switch element)) with the constraint that the New Channel Width field indicates an 80 MHz, 160 MHz, or 80+80 MHz BSS bandwidth.

The Last Beacon Report Indication subelement has the format defined in Figure 9-1075 (Subelement format), with a Length field set to 1. When the Data field is set to 1, it indicates that this Beacon report is the last frame sent as a response to a Beacon request. A 0 indicates that there are more frames expected.

The Vendor Specific subelements have the same format as their corresponding elements (see 9.4.2.24 (Vendor Specific element)). Zero or more Vendor Specific subelements are included in the list of optional subelements.

### 9.4.2.20.8 Frame report

The format of the Measurement Report field corresponding to a Frame report is shown in Figure 9-300 (Measurement Report field format for Frame report).

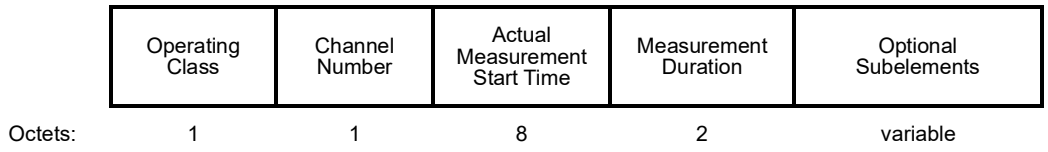


**Figure 9-300—Measurement Report field format for Frame report**

If the Wide Bandwidth Channel Switch subelement is not included, the Operating Class field indicates the operating class that identifies the channel set for which the measurement report applies. The Country,


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Operating Class, and Channel Number fields together specify the channel frequency and spacing for which the measurement report applies. Valid operating classes are listed in Annex E, excluding operating classes that encompass a primary channel but do not identify the location of the primary channel. The Channel Number field indicates the channel number for which the measurement report applies. Channel number is defined within an operating class as shown in Annex E.

If the Wide Bandwidth Channel Switch subelement is included, the fields in the Wide Bandwidth Channel Switch subelement indicate the channel for which the measurement report applies, and the Operating Class and Channel Number fields together specify the primary channel and primary 40 MHz channel within the channel identified by the Wide Bandwidth Channel Switch subelement.

The Actual Measurement Start Time field is set to the value of the measuring STA's TSF timer at the time the measurement started.

The Measurement Duration field is set to the duration over which the Frame report was measured, in units of TUs.

The Optional Subelements field contains zero or more subelements. The subelement format and ordering of subelements are defined in 9.4.3 (Subelements).

The Subelement ID field values for the defined subelements are shown in Table 9-169 (Optional subelement IDs for Frame report).

**Table 9-169—Optional subelement IDs for Frame report**

| Subelement ID | Name | Extensible |
|---|---|---|
| 0 | Reserved | |
| 1 | Frame Count Report | No |
| 2–162 | Reserved | |
| 163 | Wide Bandwidth Channel Switch | Yes |
| 164–220 | Reserved | |
| 221 | Vendor Specific | Vendor defined |
| 222–255 | Reserved | |

The Frame Count Report subelement is used to report information about frames sent by a transmitter. The Frame Count Report subelement is as shown in Figure 9-301 (Frame Count Report subelement format).

| | Subelement ID | Length | Frame Report Entries |
|---|---|---|---|
| Octets: | 1 | 1 | $n \times 19$ |

**Figure 9-301—Frame Count Report subelement format**

The Subelement ID field is defined in Table 9-169 (Optional subelement IDs for Frame report).

The Length field is defined in 9.4.3 (Subelements).

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The Frame Report Entries field contains zero or more (*n*) Frame Report Entry fields. The format of a Frame Report Entry field is shown in Figure 9-302 (Frame Report Entry field format).

| | Transmitter Address | BSSID | PHY Type | Average RCPI | Last RSNI | Last RCPI | Antenna ID | Frame Count |
|---|---|---|---|---|---|---|---|---|
| Octets: | 6 | 6 | 1 | 1 | 1 | 1 | 1 | 2 |

**Figure 9-302—Frame Report Entry field format**

The Transmitter Address field contains the transmitter address (TA) from the frames being reported.

The BSSID field contains the BSSID from the frames being reported.

The PHY Type field indicates the physical medium type for the frame(s) being reported. Valid entries are coded according to dot11PHYType.

The Average RCPI field indicates the average value for the received channel power of frames received and counted in this Frame Report Entry field, as described in 11.10.9.2 (Frame report). Average RCPI is a logarithmic function of the received signal power, as defined 9.4.2.36 (RCPI element).

The Last RSNI field indicates the received signal-to-noise indication of the most recently measured frame counted in this Frame Report Entry field, as described in 9.4.2.39 (RSNI element).

The Last RCPI field indicates the received channel power of the most recently measured frame counted in this Frame Report Entry field. Last RCPI is a logarithmic function of the received signal power, as defined in 9.4.2.36 (RCPI element).

The Antenna ID field contains the identifying number for the antenna(s) or DMG antenna used to receive the most recently measured frame counted in this Frame Report Entry field. The antenna ID or DMG antenna ID is defined in 9.4.2.38 (Antenna element).

The Frame Count field is a count of the Data and Management frames received with the indicated transmitter address and BSSID during the measurement duration. The value 65 535 indicates a count of 65 535 or more.

The Wide Bandwidth Channel Switch subelement has the same format as the corresponding element (see 9.4.2.159 (Wide Bandwidth Channel Switch element)), with the constraint that the New Channel Width field indicates an 80 MHz, 160 MHz, or 80+80 MHz BSS bandwidth.

The Vendor Specific subelement has the same format as the Vendor Specific element (see 9.4.2.24 (Vendor Specific element)). Zero or more Vendor Specific subelements are included in the list of optional subelements.


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#### 9.4.2.20.9 STA Statistics report

The format of the Measurement Report field of a STA Statistics report is shown in Figure 9-303 (Measurement Report field format for STA Statistics report).

| | Measurement Duration | Group Identity | Statistics Group Data | Optional Subelements |
|---|---|---|---|---|
| Octets: | 2 | 1 | variable | variable |

**Figure 9-303—Measurement Report field format for STA Statistics report**

The STA Statistics report reports the change in, or current values of, the requested statistics group data measured within the measurement duration.

The Measurement Duration field is set to the duration over which the change in statistics group data was measured and reported, in units of TUs. A Measurement Duration field set to 0 indicates a report of the current values of the statistics group data.

The Group Identity field indicates the requested statistics group describing the Statistics Group Data field according to Table 9-170 (Group Identity for a STA Statistics report).

The Statistics Group Data field contains the requested statistics from the MIB in Annex C related to the interface on which the request was received according to Table 9-170 (Group Identity for a STA Statistics report). Units used for reporting a statistic or change in statistic are the units used to define the statistic in Annex C. When the Measurement Duration field is nonzero, the reported data values for statistics that are not counters are the current values of the statistics data at the end of the measurement duration. When the Measurement Duration field is zero the current values of the requested statistics group data are reported, rather than the change.

**Table 9-170—Group Identity for a STA Statistics report**

| Group Identity Requested | Statistics Group Data field length (octets) | Statistics Returned |
|---|---|---|
| 0 | 28 | dot11Counters Group for the Interface on which the STA Statistics request was received (with the exception of (#3056)those counters listed in Group Identity 1):<br><br>dot11TransmittedFragmentCount (Counter32),<br>dot11GroupTransmittedFrameCount (Counter32),<br>dot11FailedCount (Counter32),<br>dot11ReceivedFragmentCount (Counter32),<br>dot11GroupReceivedFrameCount (Counter32),<br>dot11FCSErrorCount (Counter32),<br>dot11TransmittedFrameCount (Counter32) |

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**Table 9-170—Group Identity for a STA Statistics report *(continued)***

| Group Identity Requested | Statistics Group Data field length (octets) | Statistics Returned |
|---|---|---|
| 1 | 24 | dot11MACStatistics Group for the Interface on which the STA Statistics request was received:<br><br>dot11RetryCount (Counter32),<br>dot11MultipleRetryCount (Counter32),<br>dot11FrameDuplicateCount (Counter32),<br>dot11RTSSuccessCount (Counter32),<br>dot11RTSFailureCount (Counter32),<br>dot11AckFailureCount (Counter32) |
| 2 | 52 | dot11QosCounters Group for UP0 for the Interface on which the STA Statistics request was received:<br><br>dot11QosTransmittedFragmentCount (Counter32),<br>dot11QosFailedCount (Counter32),<br>dot11QosRetryCount (Counter32),<br>dot11QosMultipleRetryCount (Counter32),<br>dot11QosFrameDuplicateCount (Counter32),<br>dot11QosRTSSuccessCount (Counter32),<br>dot11QosRTSFailureCount (Counter32),<br>dot11QosAckFailureCount (Counter32),<br>dot11QosReceivedFragmentCount (Counter32),<br>dot11QosTransmittedFrameCount (Counter32),<br>dot11QosDiscardedFrameCount (Counter32),<br>dot11QosMPDUsReceivedCount (Counter32),<br>dot11QosRetriesReceivedCount (Counter32) |
| 3 | 52 | dot11QosCounters Group for UP1 for the Interface on which the STA Statistics request was received:<br><br>dot11QosTransmittedFragmentCount (Counter32),<br>dot11QosFailedCount (Counter32),<br>dot11QosRetryCount (Counter32),<br>dot11QosMultipleRetryCount (Counter32),<br>dot11QosFrameDuplicateCount (Counter32),<br>dot11QosRTSSuccessCount (Counter32),<br>dot11QosRTSFailureCount (Counter32),<br>dot11QosAckFailureCount (Counter32),<br>dot11QosReceivedFragmentCount (Counter32),<br>dot11QosTransmittedFrameCount (Counter32),<br>dot11QosDiscardedFrameCount (Counter32),<br>dot11QosMPDUsReceivedCount (Counter32),<br>dot11QosRetriesReceivedCount (Counter32) |


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**Table 9-170—Group Identity for a STA Statistics report *(continued)***

| Group Identity Requested | Statistics Group Data field length (octets) | Statistics Returned |
|---|---|---|
| 4 | 52 | dot11QosCounters Group for UP2 for the Interface on which the STA Statistics request was received:<br><br>dot11QosTransmittedFragmentCount (Counter32),<br>dot11QosFailedCount (Counter32),<br>dot11QosRetryCount (Counter32),<br>dot11QosMultipleRetryCount (Counter32),<br>dot11QosFrameDuplicateCount (Counter32),<br>dot11QosRTSSuccessCount (Counter32),<br>dot11QosRTSFailureCount (Counter32),<br>dot11QosAckFailureCount (Counter32),<br>dot11QosReceivedFragmentCount (Counter32),<br>dot11QosTransmittedFrameCount (Counter32),<br>dot11QosDiscardedFrameCount (Counter32),<br>dot11QosMPDUsReceivedCount (Counter32),<br>dot11QosRetriesReceivedCount (Counter32) |
| 5 | 52 | dot11QosCounters Group for UP3 for the Interface on which the STA Statistics request was received:<br><br>dot11QosTransmittedFragmentCount (Counter32),<br>dot11QosFailedCount (Counter32),<br>dot11QosRetryCount (Counter32),<br>dot11QosMultipleRetryCount (Counter32),<br>dot11QosFrameDuplicateCount (Counter32),<br>dot11QosRTSSuccessCount (Counter32),<br>dot11QosRTSFailureCount (Counter32),<br>dot11QosAckFailureCount (Counter32),<br>dot11QosReceivedFragmentCount (Counter32),<br>dot11QosTransmittedFrameCount (Counter32),<br>dot11QosDiscardedFrameCount (Counter32),<br>dot11QosMPDUsReceivedCount (Counter32),<br>dot11QosRetriesReceivedCount (Counter32) |
| 6 | 52 | dot11QosCounters Group for UP4 for the Interface on which the STA Statistics request was received:<br><br>dot11QosTransmittedFragmentCount (Counter32),<br>dot11QosFailedCount (Counter32),<br>dot11QosRetryCount (Counter32),<br>dot11QosMultipleRetryCount (Counter32),<br>dot11QosFrameDuplicateCount (Counter32),<br>dot11QosRTSSuccessCount (Counter32),<br>dot11QosRTSFailureCount (Counter32),<br>dot11QosAckFailureCount (Counter32),<br>dot11QosReceivedFragmentCount (Counter32),<br>dot11QosTransmittedFrameCount (Counter32),<br>dot11QosDiscardedFrameCount (Counter32),<br>dot11QosMPDUsReceivedCount (Counter32),<br>dot11QosRetriesReceivedCount (Counter32) |

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**Table 9-170—Group Identity for a STA Statistics report *(continued)***

| Group Identity Requested | Statistics Group Data field length (octets) | Statistics Returned |
|---|---|---|
| 7 | 52 | dot11QosCounters Group for UP5 for the Interface on which the STA Statistics request was received:<br><br>dot11QosTransmittedFragmentCount (Counter32),<br>dot11QosFailedCount (Counter32),<br>dot11QosRetryCount (Counter32),<br>dot11QosMultipleRetryCount (Counter32),<br>dot11QosFrameDuplicateCount (Counter32),<br>dot11QosRTSSuccessCount (Counter32),<br>dot11QosRTSFailureCount (Counter32),<br>dot11QosAckFailureCount (Counter32),<br>dot11QosReceivedFragmentCount (Counter32),<br>dot11QosTransmittedFrameCount (Counter32),<br>dot11QosDiscardedFrameCount (Counter32),<br>dot11QosMPDUsReceivedCount (Counter32),<br>dot11QosRetriesReceivedCount (Counter32) |
| 8 | 52 | dot11QosCounters Group for UP6 for the Interface on which the STA Statistics request was received:<br><br>dot11QosTransmittedFragmentCount (Counter32),<br>dot11QosFailedCount (Counter32),<br>dot11QosRetryCount (Counter32),<br>dot11QosMultipleRetryCount (Counter32),<br>dot11QosFrameDuplicateCount (Counter32),<br>dot11QosRTSSuccessCount (Counter32),<br>dot11QosRTSFailureCount (Counter32),<br>dot11QosAckFailureCount (Counter32),<br>dot11QosReceivedFragmentCount (Counter32),<br>dot11QosTransmittedFrameCount (Counter32),<br>dot11QosDiscardedFrameCount (Counter32),<br>dot11QosMPDUsReceivedCount (Counter32),<br>dot11QosRetriesReceivedCount (Counter32) |
| 9 | 52 | dot11QosCounters Group for UP7 for the Interface on which the STA Statistics request was received:<br><br>dot11QosTransmittedFragmentCount (Counter32),<br>dot11QosFailedCount (Counter32),<br>dot11QosRetryCount (Counter32),<br>dot11QosMultipleRetryCount (Counter32),<br>dot11QosFrameDuplicateCount (Counter32),<br>dot11QosRTSSuccessCount (Counter32),<br>dot11QosRTSFailureCount (Counter32),<br>dot11QosAckFailureCount (Counter32),<br>dot11QosReceivedFragmentCount (Counter32),<br>dot11QosTransmittedFrameCount (Counter32),<br>dot11QosDiscardedFrameCount (Counter32),<br>dot11QosMPDUsReceivedCount (Counter32),<br>dot11QosRetriesReceivedCount (Counter32) |



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**Table 9-170—Group Identity for a STA Statistics report *(continued)***

| Group Identity Requested | Statistics Group Data field length (octets) | Statistics Returned |
|---|---|---|
| 10 | 8 | dot11BSSAverageAccessDelay Group (only available at an AP):<br><br>dot11STAStatisticsAPAverageAccessDelay (INTEGER),<br>dot11STAStatisticsAverageAccessDelayBestEffort (INTEGER),<br>dot11STAStatisticsAverageAccessDelayBackGround (INTEGER),<br>dot11STAStatisticsAverageAccessDelayVideo (INTEGER),<br>dot11STAStatisticsAverageAccessDelayVoice (INTEGER),<br>dot11STAStatisticsStationCount (INTEGER),<br>dot11STAStatisticsChannelUtilization (INTEGER) |
| 11 | 40 | STA Counters from dot11CountersGroup6(#3263) (A-MSDU):<br>dot11TransmittedAMSDUCount (Counter32),<br>dot11FailedAMSDUCount (Counter32),<br>dot11RetryAMSDUCount (Counter32),<br>dot11MultipleRetryAMSDUCount (Counter32),<br>dot11TransmittedOctetsInAMSDUCount (Counter64),<br>dot11AMSDUAckFailureCount (Counter32),<br>dot11ReceivedAMSDUCount (Counter32),<br>dot11ReceivedOctetsInAMSDUCount (Counter64) |
| 12 | 36 | STA Counters from dot11CountersGroup6(#3263) (A-MPDU):<br>dot11TransmittedAMPDUCount (Counter32),<br>dot11TransmittedMPDUsInAMPDUCount (Counter32),<br>dot11TransmittedOctetsInAMPDUCount (Counter64),<br>dot11AMPDUReceivedCount (Counter32),<br>dot11MPDUInReceivedAMPDUCount (Counter32),<br>dot11ReceivedOctetsInAMPDUCount (Counter64),<br>dot11AMPDUDelimiterCRCErrorCount (Counter32) |
| 13 | 36 | STA Counters from dot11CountersGroup6(#3263) (BlockAckReq, Channel Width):<br>dot11ImplicitBARFailureCount (Counter32),<br>dot11ExplicitBARFailureCount (Counter32),<br>dot11ChannelWidthSwitchCount (Counter32),<br>dot11TwentyMHzFrameTransmittedCount (Counter32),<br>dot11FortyMHzFrameTransmittedCount (Counter32),<br>dot11TwentyMHzFrameReceivedCount (Counter32),<br>dot11FortyMHzFrameReceivedCount (Counter32),<br>8 reserved octets(#3263) |
| 14 | 36 | STA Counters from dot11CountersGroup6(#3263) (RD, dual CTS):<br>dot11GrantedRDGUsedCount (Counter32),<br>dot11GrantedRDGUnusedCount (Counter32),<br>dot11TransmittedFramesInGrantedRDGCount (Counter32),<br>dot11TransmittedOctetsInGrantedRDGCount (Counter64),<br>dot11DualCTSSuccessCount (Counter32),<br>dot11DualCTSFailureCount (Counter32),<br>dot11RTSLSIGSuccessCount (Counter32),<br>dot11RTSLSIGFailureCount (Counter32) |
| 15 | 20 | STA Counters from dot11CountersGroup6(#3263) (beamforming and STBC):<br>dot11BeamformingFrameCount (Counter32),<br>dot11STBCCTSSuccessCount (Counter32),<br>dot11STBCCTSFailureCount (Counter32),<br>dot11nonSTBCCTSSuccessCount (Counter32),<br>dot11nonSTBCCTSFailureCount (Counter32) |

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**Table 9-170—Group Identity for a STA Statistics report *(continued)***

| Group Identity Requested | Statistics Group Data field length (octets) | Statistics Returned |
|---|---|---|
| 16 | 28 | dot11RSNAStats Group for the Interface on which the STA Statistics request was received:<br><br>dot11RSNAStatsBIPMICErrors (Counter32)<br>dot11RSNAStatsCMACReplays (Counter32)<br>dot11RSNAStatsRobustMgmtCCMPReplays(Counter32)<br>dot11RSNAStatsTKIPICVErrors (Counter32)<br>dot11RSNAStatsTKIPReplays (Counter32)<br>dot11RSNAStatsCCMPDecryptErrors (Counter32)<br>dot11RSNAStatsCCMPReplays (Counter32) |
| 17–255 | | Reserved |

The format of the Measurement Report field for dot11Counters Group is shown in Figure 9-304 (Measurement Report field format for dot11Counters Group).

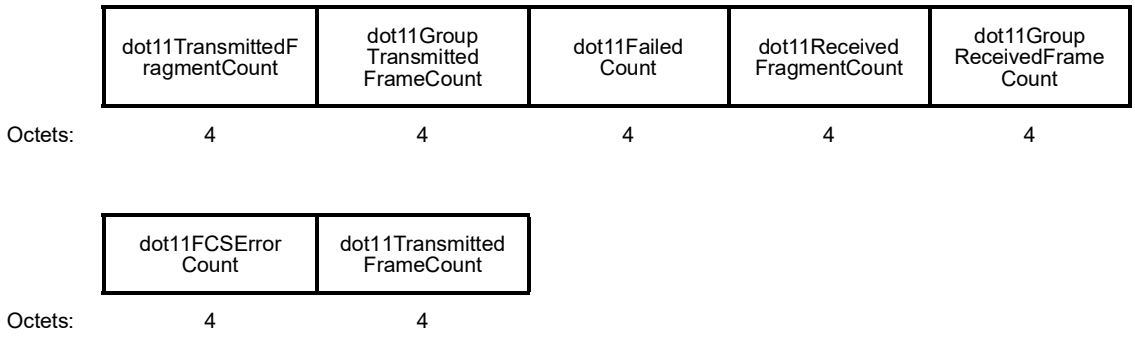


**Figure 9-304—Measurement Report field format for dot11Counters Group**

The format of the Measurement Report field for dot11MACStatistics is shown in Figure 9-305 (Measurement Report field format for dot11MACStatistics Group).

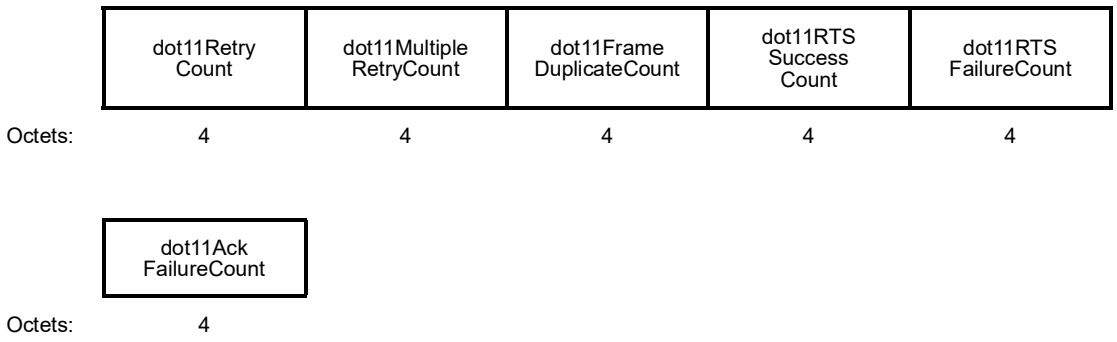


**Figure 9-305—Measurement Report field format for dot11MACStatistics Group**


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The format of the Measurement Report field for dot11QosCounters Group for UPx is shown in Figure 9-306 (Measurement Report field format for dot11QosCounters Group for UPx), where x is 0 – 7 and where the listed variables are obtained from the column of the QoS Counters Table indexed by x + 1. For example, the variables for dot11QosCounters Group for UP2 are from the third column of the dot11QosCountersTable, obtained from the dot11QosCountersEntry in which dot11QosCountersIndex is equal to 3.

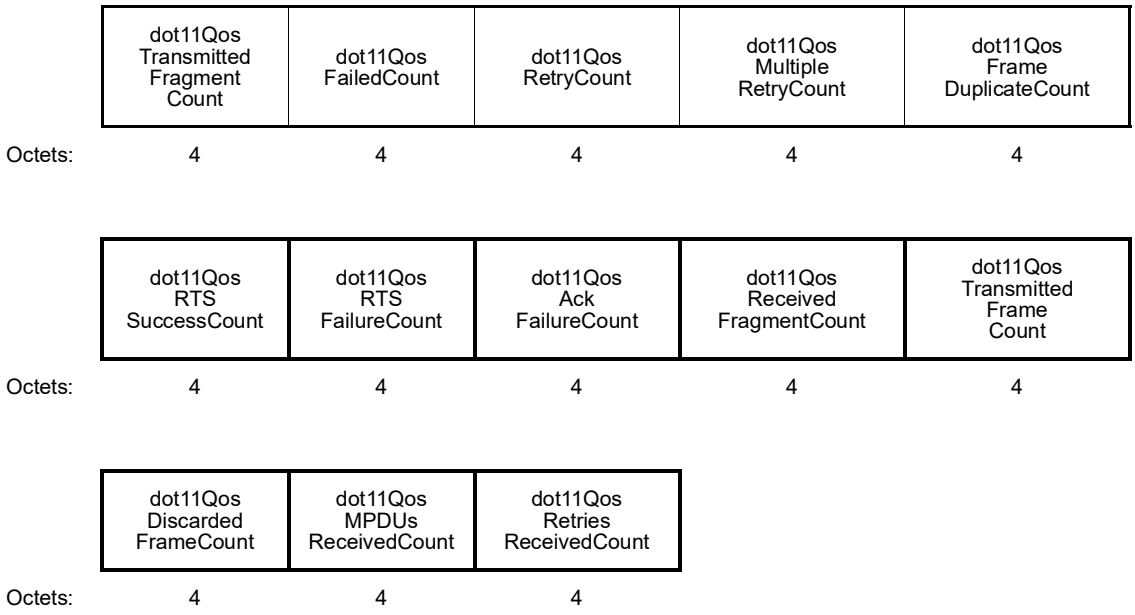


**Figure 9-306—Measurement Report field format for dot11QosCounters Group for UPx**

The format of the Measurement Report field for dot11BSSAverageAccessDelay Group is shown in Figure 9-307 (Measurement Report field format for dot11BSSAverageAccessDelay Group). Non-QoS APs set dot11STAStatisticsAverageAccessDelayBestEffort, dot11STAStatisticsAverageAccessDelayBackGround, dot11STAStatisticsAverageAccessDelayVideo, and dot11STAStatisticsAverageAccessDelayVoice to 255 (not available).

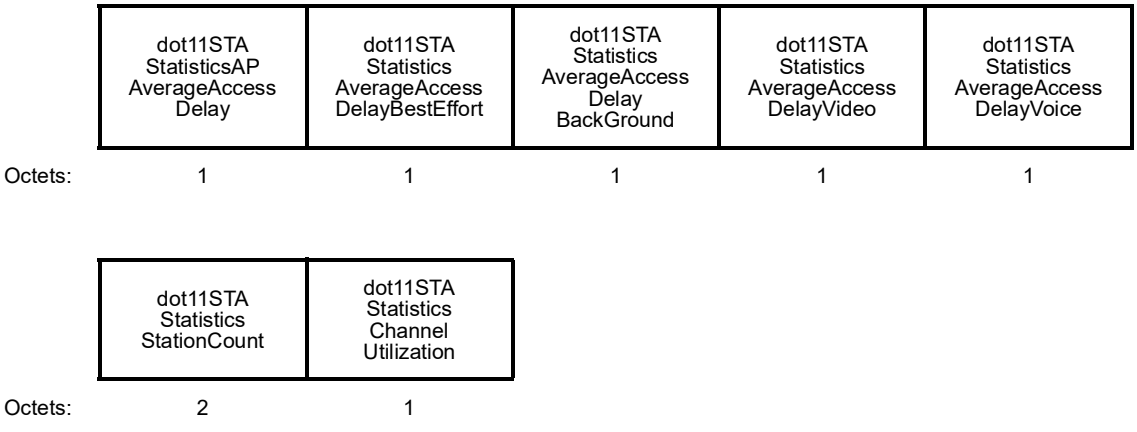


**Figure 9-307—Measurement Report field format for dot11BSSAverageAccessDelay Group**

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The Optional Subelements field contains zero or more subelements. The subelement format and ordering of subelements are defined in 9.4.3 (Subelements).

The Subelement ID field values for the defined subelements are shown in Table 9-171 (Optional subelement IDs for STA Statistics report).

**Table 9-171—Optional subelement IDs for STA Statistics report**

| Subelement ID | Name | Extensible |
|---|---|---|
| 0 | Reserved | |
| 1 | Reporting Reason | No |
| 2–220 | Reserved | |
| 221 | Vendor Specific | Vendor defined |
| 222–255 | Reserved | |

The format of the Measurement Report field for RSNA Counters Group is shown in Figure 9-308 (Measurement Report field format for RSNA Counters Group).

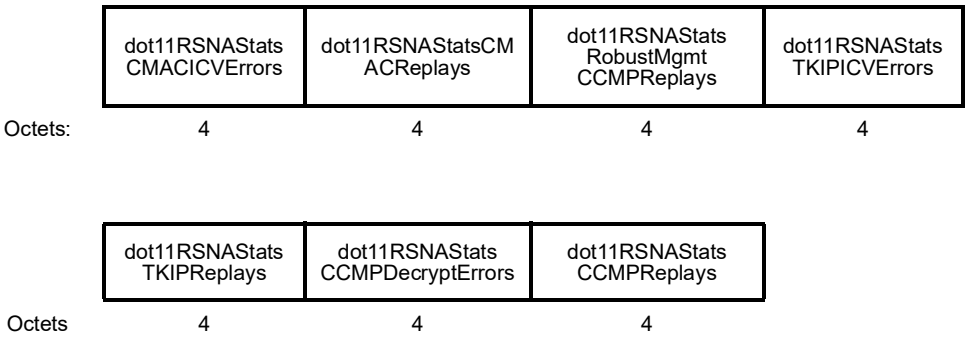


**Figure 9-308—Measurement Report field format for RSNA Counters Group**

The Reporting Reason subelement indicates the reason why the measuring STA sent the STA Statistics report. It is present if Statistics Group Name is from STA Counters, QoS STA Counters, or RSNA Counters (see 11.10.9.5 (STA Statistics report)).


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The Data field of the Reporting Reason subelement for STA Statistics Group Identities 0 or 1 (STA Counters) is shown in Figure 9-309 (Data field format of the Reporting Reason subelement for STA Counters).

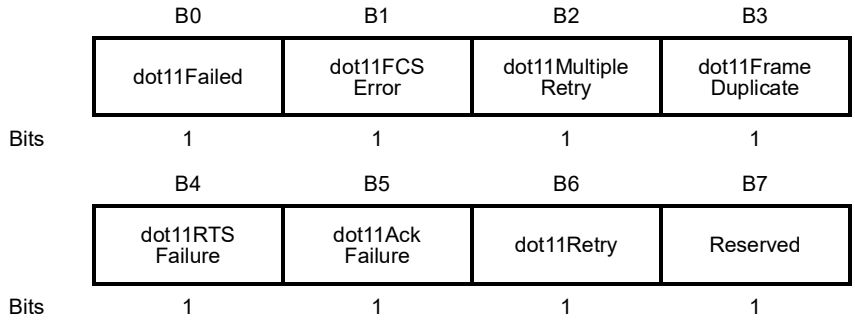


**Figure 9-309—Data field format of the Reporting Reason subelement for STA Counters**

The Data field of the Reporting Reason subelement for STA Statistics Group Identity 2 to 9 (QoS STA Counters) is shown in Figure 9-310 (Data field format of the Reporting Reason subelement for QoS STA Counters).

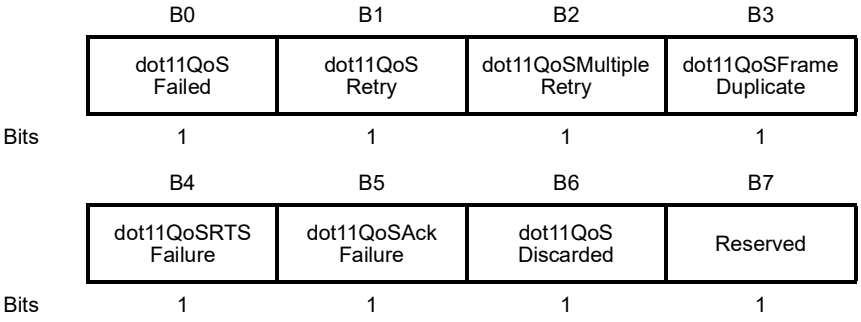


**Figure 9-310—Data field format of the Reporting Reason subelement for QoS STA Counters**

The Data field of the Reporting Reason subelement for STA Statistics Group Identity 16 (RSNA Counters) is shown in Figure 9-311 (Data field format of the Reporting Reason subelement for RSNA Counters).

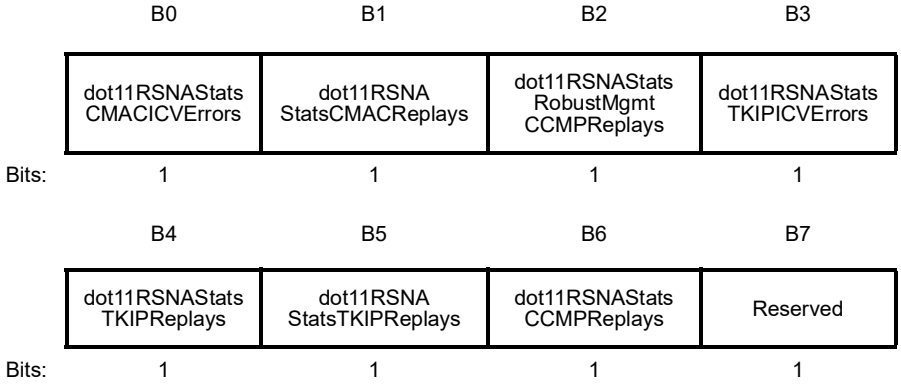


**Figure 9-311—Data field format of the Reporting Reason subelement for RSNA Counters**

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In a nontriggered STA Statistics report, all subfields of the Data field of the Reporting Reason subelement are set to 0.

The Vendor Specific subelements have the same format as their corresponding elements (see 9.4.2.24 (Vendor Specific element)). Zero or more Vendor Specific subelements are included in the list of optional subelements.

#### 9.4.2.20.10 LCI report (Location configuration information report)

An LCI report for a known LCI includes latitude, longitude, altitude, and related information. An unknown LCI is indicated by the Length field of the LCI subelement being set to 0 and there being no following subelements. The LCI report field format is shown in Figure 9-312 (Format of Location Configuration Information Report).

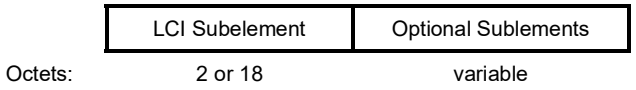


**Figure 9-312—Format of Location Configuration Information Report**

The subelements in the LCI report are defined in Table 9-172 (Subelement IDs for LCI Report).

**Table 9-172—Subelement IDs for LCI Report**

| Subelement ID | Name | Extensible |
|---|---|---|
| 0 | LCI | No |
| 1 | Azimuth Report | Yes |
| 2 | Originator Requesting STA MAC Address | No |
| 3 | Target MAC Address | No |
| 4 | Z | Subelements |
| 5 | Relative Location Error | Yes |
| 6 | Usage Rules/Policy | Yes |
| 7 | (#2210)Colocated BSSID List | Yes |
| 8 | (11az)Relative Compact LCI | No |
| 9 | (11az)Antenna Placement And Calibration | Yes |
| 10–220 | Reserved | |
| 221 | Vendor Specific | Vendor defined |
| 222–255 | Reserved | |


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The LCI Subelement field contains an LCI subelement. The LCI subelement is formatted as shown in Figure 9-313 (LCI subelement format).

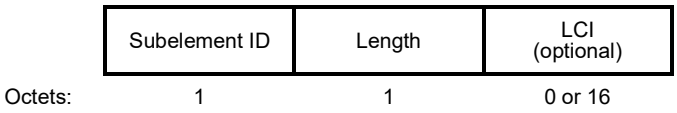


**Figure 9-313—LCI subelement format**

The Subelement ID field is equal to the value for LCI in Table 9-172 (Subelement IDs for LCI Report).

The Length field is defined in 9.4.3 (Subelements).

The LCI field is formatted as shown in Figure 9-314 (LCI field format).

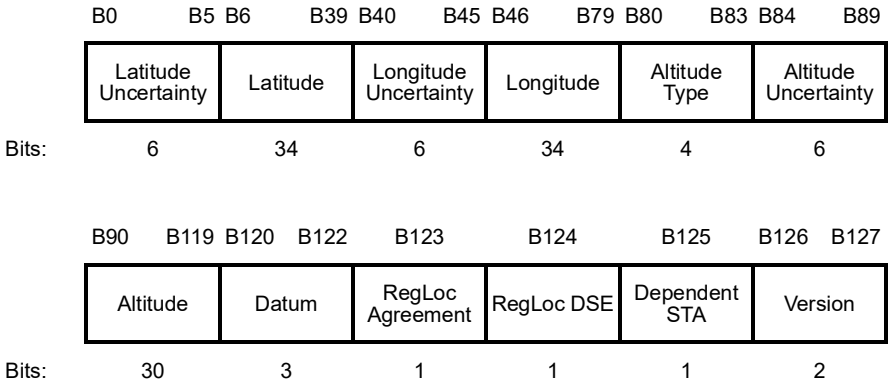


**Figure 9-314—LCI field format**

The definitions of fields within the LCI field are as specified in (#7193)section 2.2 of IETF RFC 6225(#7192) or as defined herein. This structure and information fields are based on the LCI format described in IETF RFC 6225.

NOTE 1—This example shows how to encode the coordinates of the Sydney Opera House using the encoding defined in IETF RFC 6225. The building is a polygon with the following (latitude, longitude) coordinates:

(–33.856 625°, +151.215 906°)
(–33.856 299°, +151.215 343°)
(–33.856 326°, +151.214 731°)
(–33.857 533°, +151.214 495°)
(–33.857 720°, +151.214 613°)
(–33.857 369°, +151.215 375°)

Latitude ranges from –33.857 720° to –33.856 299°; longitude ranges from +151.214 495° to +151.215 906°.

For this example, the point that is encoded is chosen by finding the middle of each range, that is (–33.857 009 5°, +151.215 200 5°), which is encoded as (11101111000100100100111011000001101,

01001011100110111000101110110000011) (2s complement, 9 bits before binary point, 25 after, MSB first).

These values can be derived as $2^{34}$ – Round (33.857 009 5 × $2^{25}$) and Round (151.215 200 5 × $2^{25}$), respectively.

The latitude uncertainty (LatUnc) is given by inserting the difference between the center value and the outer value into the formula from (#7193)section 2.3.2 of IETF RFC 6225. This gives:

LatUnc = $8 - \lceil \log2(-33.8570095 - (-33.857720)) \rceil$. The result is 18, which is encoded as 010010.

Similarly, longitude uncertainty (LongUnc) is given by the formula:

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LongUnc = 8 – ⌈log2(151.2152005 – 151.214495)⌉. The result is also 18, which is encoded as 010010.

The top of the building is 67.4 m above sea level, and a starting altitude of 0 m above sea level is assumed(#7198). At the GPS coordinates of the Sydney Opera House, the sea level is approximately 22.5 m below the WGS84 ellipsoid. Therefore, the lowest altitude of the building is –22.5 m, while the highest altitude is (67.4 – 22.5) = 44.9 m from the WGS84 ellipsoid. The middle of the range is (44.9 – 22.5)/2 = 11.2 m, which is encoded as 00000000000000000101100110011 (22 bits before binary point, 8 after, MSB first).

Altitude uncertainty is given by the height of the building. Since the building is 67.4 m above sea level and basement is assumed to be at sea level, the uncertainty to be encoded is half of 67.4 m.

Altitude uncertainty (AltUnc) uses the formula from (#7193)section 2.4.5 from IETF RFC 6225:

AltUnc = 21 – ⌈log2(33.7 – 0)⌉, the result is 15, which is encoded as 001111 (MSB first).

The Altitude Type field is set to 1, indicating that the altitude is specified in meters.

The Datum field is set to 1, indicating WGS84 coordinates.

The RegLoc Agreement field is set to 0 for this example.

The RegLoc DSE field is set to 0 for this example.

The Dependent STA field is set to 0 for this example.

The Version field is set to 1, as that is the only value currently defined in IETF RFC 6225.

The LCI configuration information report for this example is encoded as (where underscores are used as field or octet delimiters):

010010_1110111100010010010011011000001101_010010_0100101110011011100010111011000011_0001_001111_00000000000000000101100110011_001_0_0_0_01 (binary, MSB first per field)

010010_1011000001101100100100100011110111_010010_1100001101110100011101100111010010_1000_111100_1100110011010000000000000000000_100_0_0_0_10 (binary, LSB first per field)

01001010_11000001_10110010_01001000_11110111_01001011_00001101_11010001_11011001_11010010_10001111_00110011_00110100_00000000_00000000_10000010 (binary, rearranged into octets, with LSB first per octet)

01010010_10000011_01001101_00010010_11101111_11010010_10110000_10001011_10011011_01001011_11110001_11001100_00101100_00000000_00000000_01000001 (binary, MSB first, per octet)

52 83 4d 12 ef d2 b0 8b 9b 4b f1 cc 2c 00 00 41 (order over the PHY SAP, see 8.3.5 (PHY SAP detailed service specification) and 9.2.2 (Conventions))

The RegLoc Agreement field is set to 1 to report that the STA is operating within a national policy area or an international agreement area near a national border (see 11.11.3 (Registered STA operation)); otherwise, it is set to 0(#464).

The RegLoc DSE field is set to 1 to report that the enabling STA is enabling the operation of STAs with DSE; otherwise, it is set to 0(#464).

The Dependent STA field is set to 1 to report that the STA is operating with the enablement of the enabling STA whose LCI is being reported; otherwise, it is set to 0(#464).

The Version field is defined in IETF RFC 6225, and its(#464) use is described in IETF RFC 6225.

The Optional Subelements field contains zero or more subelements with subelement ID greater than or equal to 1 as listed in Table 9-172 (Subelement IDs for LCI Report). The subelement format and ordering of subelements are defined in 9.4.3 (Subelements).


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The Azimuth Report subelement is used to report an azimuth. The Azimuth Report subelement is as shown in Figure 9-315 (Azimuth Report subelement format).

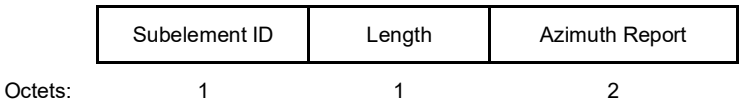


**Figure 9-315—Azimuth Report subelement format**

The Subelement ID field is defined in Table 9-172 (Subelement IDs for LCI Report).

The Length field is defined in 9.4.3 (Subelements).

The Azimuth Report field of an Azimuth Report subelement contains three subfields as shown in Figure 9-316 (Azimuth Report subfield format).

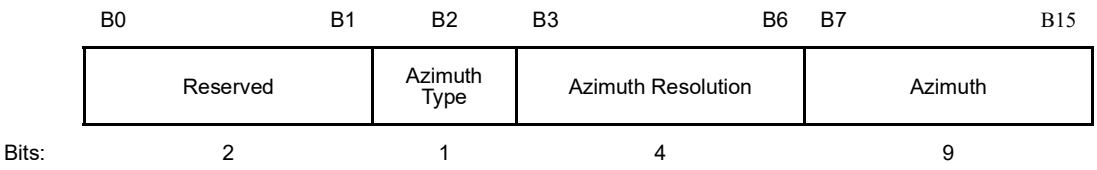


**Figure 9-316—Azimuth Report subfield format**

The Azimuth Type field is set to 1 to report the Azimuth of the bearing of the requester with respect to the responder and is set to 0 to report the Azimuth of front surface of the reporting STA.

The Azimuth Resolution field is 4 bits, indicating the number of valid most significant bits in the Azimuth.

The Azimuth field is (#1727)a value in degrees from true north, of the type defined by the Azimuth Type field.

The Originator Requesting STA MAC Address subelement contains the MAC address of the STA that requested the Location Information and it is present whenever the Location Subject field in the corresponding LCI request was set to 2. The format of the Originator Requesting STA MAC Address subelement is shown in Figure 9-263 (Originator Requesting STA MAC Address subelement format).

The Target MAC Address subelement contains the MAC address of the STA whose Location Information was requested and it is present whenever the Location Subject field in the corresponding LCI request was set to 2. The format of the Target MAC Address subelement is shown in Figure 9-264 (Target MAC Address subelement format).

The Z subelement is used to report the floor and location of the STA with respect to the floor level. The format of the Z subelement is shown in Figure 9-317 (Z subelement format).

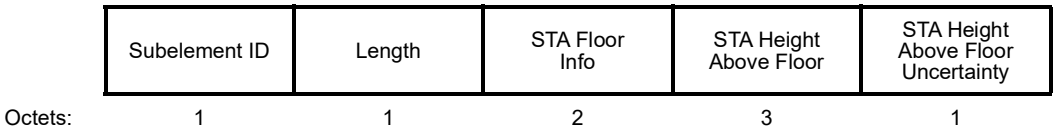


**Figure 9-317—Z subelement format**

The Subelement ID field is equal to the value for Z in Table 9-172 (Subelement IDs for LCI Report).

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The Length field is defined in 9.4.3 (Subelements).

The format of the STA Floor Info field is defined in Figure 9-317 (Z subelement format).

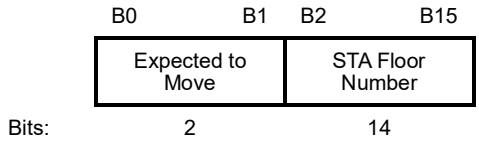


**Figure 9-318—STA Floor Info field format**

The Expected to Move field indicates whether the STA is expected to change its location. The value 1 indicates that the STA is expected to change its location. The value 0 indicates that the STA is not expected to change its location. The value 2 indicates that the STA's movement patterns are unknown. The value 3 is reserved.

NOTE 2—Examples of STAs that are expected to move include a) battery-powered STAs, b) STAs installed within trains/vehicles, c) STAs installed for temporary events.

The STA Floor Number field indicates the floor number of the STA. A higher value indicates a higher floor, and the integer approximates the floor number labels used at the venue (e.g., in stairwells and elevators, if present). The field is encoded as a 2s complement integer with units of $1/16^{th}$ of a floor. The value –8192 indicates an unknown floor number. The value 8191 indicates the STA's floor is 8191/16 floors or more. The value –8191 indicates the STA's floor is –8191/16 floors or less.

NOTE 3—For example, a building with floors labeled as Basement 1, Ground, Mezzanine, 1, and 2 might have the floors identified by STA Floor Number field values(M118) equal –16, 0, 8, 16 and 32 respectively.

The STA Height Above Floor field indicates the height of the STA above the floor. The field is coded as a 2s complement integer with units of 1/4096 m. The value –8 388 608 indicates an unknown STA height above floor. The value –8 388 607 indicates the height of the STA above the floor is –8 388 607/4096 m or less. The value 8 388 607 indicates the height of the STA above the floor is 8 388 607/4096 m or more.

A STA Height Above Floor Uncertainty field set to 0 indicates an unknown STA height above floor uncertainty. Values 25 or higher are reserved. A STA Height Above Floor Uncertainty field set from 1 to 24 indicates that the actual STA height above floor, $a$, is bounded according to:

$$h - 2^{11-u} \le a \le h + 2^{11-u}$$

where

$h$ is the value in units of 1/4096 m of the STA Height Above Floor field
$u$ is the value of the STA Height Above Floor Uncertainty field

If the STA Height Above Floor field indicates an unknown STA height above floor, the STA Height Above Floor Uncertainty field is set to 0.

The Relative Location Error subelement is used to report the location error of STAs with respect to a reference STA (rather than with respect to an absolute geographic location). The format of the Relative Location Error subelement is defined in Figure 9-319 (Relative Location Error subelement format).

The Subelement ID field is equal to the value for Relative Location Error in Table 9-172 (Subelement IDs for LCI Report).

The Length field is defined in 9.4.3 (Subelements).


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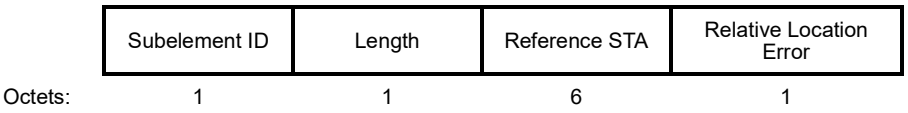


**Figure 9-319—Relative Location Error subelement format**

The Reference STA field contains the MAC address of the reference STA.

The format of the Relative Location Error field is defined in Figure 9-320 (Relative Location Error field format).

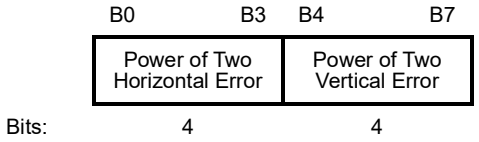


**Figure 9-320—Relative Location Error field format**

The Power Of Two Horizontal Error field contains an upper bound on the error between the horizontal location of the Reference STA and the Latitude and Longitude fields in the LCI subelement. The Power Of Two Horizontal Error field indicates a relative horizontal error of $2^{p-8}$ m, where $p$ is the value of the Power of Two Horizontal Error field in the range 0 to 13. The value 14 indicates a relative horizontal error of greater than 32 m. The value 15 indicates an unknown relative horizontal error.

The Power Of Two Vertical Error field contains an upper bound on the error between the vertical location of the Reference STA and the Altitude field in the LCI subelement. The Power Of Two Vertical Error field indicates a relative vertical error of $2^{p-8}$ m, where $p$ is the value of the Power Of Two Vertical Error field in the range 0 to 13. The value 14 indicates a relative vertical error of greater than 32 m. The value 15 indicates an unknown relative vertical error.

The Usage Rules/Policy subelement is used to report the usage rules of the reporting STA and whether additional STA or neighboring STA location information is available if the additional information can be transferred more securely. The format of the Usage Rules/Policy subelement is defined in Figure 9-321 (Usage Rules/Policy subelement format).

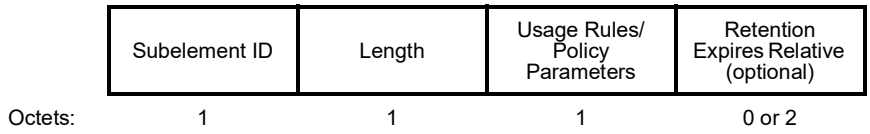


**Figure 9-321—Usage Rules/Policy subelement format**

The Subelement ID field is equal to the value for Usage Rules/Policy in Table 9-172 (Subelement IDs for LCI Report).

The Length field is defined in 9.4.3 (Subelements).

The Usage Rules/Policy Parameters field is defined in Figure 9-322 (Usage Rules/Policy Parameters field format).

The Retransmission Allowed field definition is the same as the definition for the retransmission-allowed element in IETF RFC 4119, except that the “no” and “yes” text encoding specified in IETF RFC 4119 is replaced by 0 and 1, respectively.

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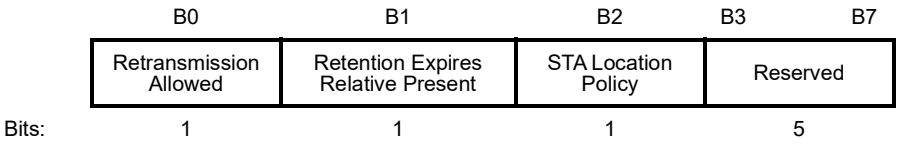


**Figure 9-322—Usage Rules/Policy Parameters field format**

The Retention Expires Relative Present field indicates whether Retention Expires Relative field is present. The value 1 indicates that the Retention Expires Relative field is present; otherwise the Retention Expires Relative field is not present. If the Retention Expires Relative field is not present, it indicates that the retention duration of the LCI report field is unbounded.

The STA Location Policy field indicates whether additional STA or neighboring STA location information is available if the additional information can be transferred more securely. The security of the transfer is (from lowest to highest): unassociated, associated without RSNA established, associated with RSNA established but without management frame protection negotiated, and associated with both RSNA established and management frame protection negotiated. The additional information might be one or more of (1) the STA's location with reduced uncertainty and (2) the location of additional neighbor APs, if the STA Location Policy field is carried within a Neighbor Report Response frame. A STA Location Policy field set to 1 indicates additional STA or neighboring STA location information is available. A STA Location Policy field set to 0 indicates no additional STA or neighboring STA location information is available.

The definition of the Retention Expires Relative field is the same as the definition for the retention-expires element in IETF RFC 4119, except that the absolute time text encoding specified in IETF RFC 4119 is replaced by a relative binary encoding: the Retention Expires Relative field is encoded as a number of hours in the future relative to the time of transmission of the Usage Rules/Policy subelement.

The Vendor Specific subelement has the same format as the Vendor Specific element (see 9.4.2.24 (Vendor Specific element)). Zero or more Vendor Specific subelements are included in the list of optional subelements.

The (#2210)Colocated BSSID List subelement is used to report the list of BSSIDs of the BSSs sharing the same antenna connector with the reporting STA if the subelement is contained within a Fine Time Measurement frame, otherwise the BSSs that are (#2210)colocated within the same physical device as the reporting STA.

The format of the (#2210)Colocated BSSID List subelement is shown in Figure 9-323 ((#2210)Colocated BSSID List subelement format).

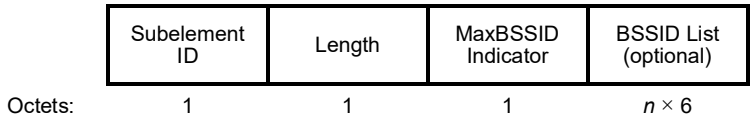


**Figure 9-323—(#2210)Colocated BSSID List subelement format**

The Subelement ID field is equal to the value for (#2210)Colocated BSSID list in Table 9-172 (Subelement IDs for LCI Report).

The Length field is defined in 9.4.3 (Subelements).


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The MaxBSSID Indicator field is defined in 9.4.2.44 (Multiple BSSID element). When set to a nonzero value, it indicates the maximum possible number of BSSs, including the reference BSS, which share the same antenna connector and have the same 48 bits (BSSID[0:(47-n)]) of the BSSIDs. When the BSSIDs of the (#2210)colocated BSSs are configured at the reporting STA but not represented by the MaxBSSID Indicator field, the BSSID List field is present in the (#2210)Colocated BSSID List subelement to provide an explicit list of such BSSID values.

When the MaxBSSID Indicator field is equal to 0, the BSSID List field contains one or more (*n*) BSSID values of the BSSs sharing the same antenna connector with the reporting STA.

NOTE 4—For example, if there are 4 BSSs sharing the same antenna connector and their BSSIDs end with 16, 24, 30, and 31, and the range of MAC addresses ending with 16-31 are not assigned to other BSSs using a different antenna connector, then this list of 4 BSSIDs can be indicated with a MaxBSSID Indicator field set to 5. Otherwise, the MaxBSSID Indicator field is set to 0 and the BSSIDs are listed separately.

(11az)The Relative Compact LCI field is formatted as shown in Figure 9-324 (Relative Compact LCI field format(11az)).

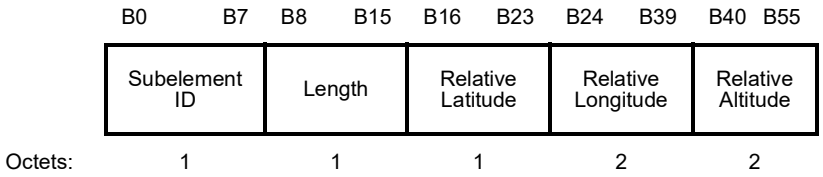


**Figure 9-324—Relative Compact LCI field format(11az)**

(11az)The Relative Compact LCI field is included in the Passive TB Ranging LCI Table Report element; see 9.4.2.308 (Passive TB Ranging LCI Table element(11az)) that contains an RSTA LCI Report field. The reported location of the RSTA serves as the reference location for the reporting of the Relative Latitude, Longitude, and Altitude subfields in the Relative Compact LCI field.

(11az)The Relative Latitude subfield contains a signed integer in 2s complement format indicating the latitude offset of the reported location in relation to the reference location, in units of $1.8 \times 10^{-7}$ deg. (Corresponds to approximately 2 cm at the equator.)

(11az)The Relative Longitude subfield contains a signed integer in 2s complement format indicating the longitude offset of the reported location in relation to the reference location, in units of $1.8 \times 10^{-7}$ deg. (Corresponds to approximately 2 cm at the equator.)

(11az)The Relative Altitude subfield contains a signed integer in 2s complement format indicating the elevation offset of the reported location in relation to the reference location, in units of 2 cm.

(11az)The Antenna Placement And Calibration subelement contains the antenna placement and the delay information for each of the transmit antennas. The format of the Antenna Placement And Calibration subelement is shown in Figure 9-325 (Antenna Placement And Calibration subelement format(11az)).

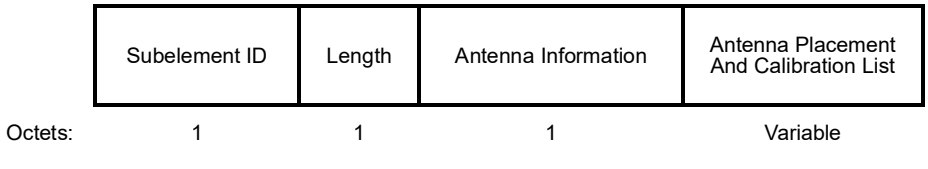


**Figure 9-325—Antenna Placement And Calibration subelement format(11az)**

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(11az)The Subelement ID field is equal to the value for Antenna Placement And Calibration in Table 9-172 (Subelement IDs for LCI Report).

(11az)The Length field is defined in 9.4.3 (Subelements).

(11az)The Antenna Information field is formatted as shown in Figure 9-326 (Antenna Information field format(11az)), where the Number of Selected Antennas subfield indicates the total number of the antennas selected for transmission minus one. The total number of the antennas selected for transmission is denoted as $N_{Tx\_sel}$, as shown in Figure 9-326 (Antenna Information field format(11az)) and Figure 9-327 (Antenna Placement And Calibration field format(11az)).

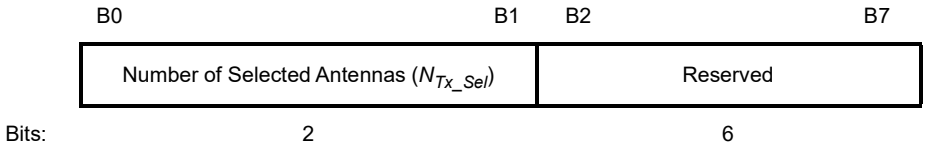
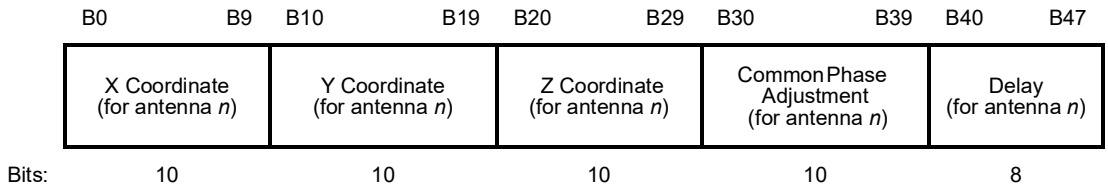



**Figure 9-326—Antenna Information field format(11az)**

(11az)The Antenna Placement And Calibration List field is composed of $N_{Tx\_Sel}$ Antenna Placement And Calibration fields, where $N_{Tx\_Sel}$ is greater than or equal to one. The format of the Antenna Placement And Calibration field is shown in Figure 9-327 (Antenna Placement And Calibration field format(11az)). The order of the antenna ports indicated in the Antenna Placement And Calibration List field matches the order of the rows in the P matrix applied to the space time streams spatial mapped to the antenna ports.




Where "(for antenna *n*)" represents the *n*th antenna in the range 1 to $N_{Tx\_Sel}$

**Figure 9-327—Antenna Placement And Calibration field format(11az)**

(11az)The X Coordinate field, Y Coordinate field, and Z Coordinate field contain the placement information of each antenna, where the origin of the axis that is defined by the Latitude, Longitude, and Altitude field values of the LCI subelement, the X axis points to the East, the Y axis points to the North, and the Z axis points up and is perpendicular to the plane formed by the X axis and the Y axis.

(11az)The values in the X, Y, and Z Coordinate field range from 0 to 1023, mapping to –512 to 511, in units of millimeters.

(11az)The value in the Common Phase Adjustment subfield indicates the additional phase rotation introduced in the RF chain that is common for all subcarriers. The value for this subfield, denoted $k$, ranges from 0 to 1023, and indicates a phase adjustment of $k \times \pi / 512$.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### 9.4.2.20.11 Transmit Stream/Category Measurement report

The Transmit Stream/Category Measurement report applies to TIDs for Traffic Streams associated with TSPECs and also to TIDs for Traffic Categories for QoS traffic without TSPECs. The format of the Measurement Report field corresponding to a Transmit Stream/Category Measurement report is shown in Figure 9-328 (Measurement Report field format for Transmit Stream/Category Measurement report).

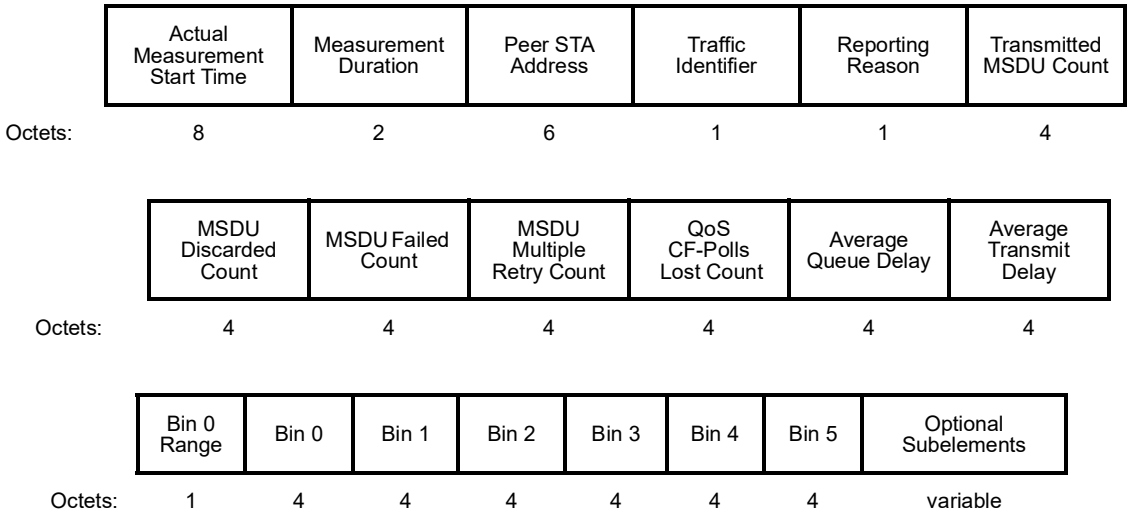


**Figure 9-328—Measurement Report field format for Transmit Stream/Category Measurement report**

The Actual Measurement Start Time field is set to the TSF at the time at which the measurement started, or for a triggered Transmit Stream/Category Measurement report, the TSF value at the reporting QoS STA when the trigger condition was met.

The Measurement Duration field is set to the duration over which the Transmit Stream/Category Measurement report was measured, in units of TUs. In a triggered Transmit Stream/Category Measurement report, metrics are reported over a number of transmitted MSDUs rather than a duration; hence Measurement Duration is set to 0; see 11.10.9.8 (Transmit Stream/Category Measurement report).

The Peer STA Address field contains a MAC address indicating the RA for the measured frames.

The Traffic Identifier field contains the TID subfield as shown in Figure 9-266 (Measurement Request field format for Transmit Stream/Category Measurement Request). The TID subfield indicates the TC or TS for which traffic was measured.

The Reporting Reason field is a bitmap(#291) indicating the reason that the measuring QoS STA sent the transmit stream/category measurement report. The Reporting Reason field is shown in Figure 9-329 (Reporting Reason field format).

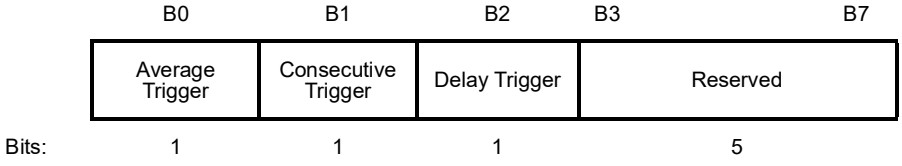


**Figure 9-329—Reporting Reason field format**

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- The Average Trigger subfield(#291) set to 1 indicates that the Transmit Stream/Category Measurement report was generated as a triggered report due to the average error trigger(#291).
- The Consecutive Trigger subfield(#291) set to 1 indicates that the Transmit Stream/Category Measurement report was generated as a triggered report due to the consecutive error trigger(#291).
- The Delay Trigger subfield(#291) set to 1 indicates that the Transmit Stream/Category Measurement report was generated as a triggered report due to the delay exceeding the delay threshold(#291).

When a Transmit Stream/Category Measurement report is sent as a direct response to a Transmit Stream/Category Measurement request and not as a triggered Transmit Stream/Category Measurement report, all subfields(#291) in the Reporting Reason field are set to 0. This is termed a requested Transmit Stream/Category Measurement report. Within a triggered Transmit Stream/Category Measurement report, more than one subfield(#291) in the Reporting Reason field might be set to 1 if more than one trigger condition was met.

The Transmitted MSDU Count, MSDU Failed Count, MSDU Discarded Count, MSDU Multiple Retry Count, QoS CF-Polls Lost Count, Average Queue Delay, Average Transmit Delay, and delay histogram fields relate to transmissions to the QoS STA given in the Peer STA Address field. Metrics are reported over the Measurement Duration, or for triggered transmit stream/category measurements, over the Measurement Count. Any counter that increments to a value of $2^{32}-1$ terminates the measurement.

The Transmitted MSDU Count field contains the number of MSDUs for the TC or the TS specified by the TID that were successfully transmitted.

The MSDU Discarded Count field contains the number of MSDUs for the TC or the TS specified by the TID that were discarded due either to the number of transmit attempts exceeding dot11ShortRetryLimit, or due to the MSDU lifetime having been reached.

The MSDU Failed Count field contains the number of MSDUs for the TC or the TS specified by the TID that were discarded due to the number of transmit attempts exceeding dot11ShortRetryLimit.

The MSDU Multiple Retry Count field contains the number of MSDUs for the TC or the TS specified by the TID that were successfully transmitted after more than one retransmission attempt.

The QoS CF-Polls Lost Count field contains the number of QoS (+)CF-Poll frames that were transmitted where there was no response from the QoS STA. QoS CF-Polls Lost Count are returned only if the reporting QoS STA is contained within an AP and the TID is for a TS. This field is set to 0 when QoS CF-Polls Lost Count is not returned.

The Average Queue Delay field is the average queuing delay of the frames (MSDUs) that are passed to the MAC for the indicated peer STA address and the indicated traffic identifier. Queue Delay is expressed in TUs and is measured from the time the MSDU is passed to the MAC until the point at which the first or only corresponding MPDU begins transmission.

The Average Transmit Delay field is the average delay of the frames (MSDUs) that are successfully transmitted for the indicated Peer STA Address and TID. Average Transmit Delay is measured from the time the MSDU is passed to the MAC until the point at which the entire MSDU has been successfully transmitted, including receipt of the final Ack frame from the peer STA if the QoSAck service class is being used. Average Transmit delay is expressed in units of TUs.


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The Bin 0 Range field value indicates the delay range of the first bin (Bin 0) of the Transmit Delay Histogram, in units of TUs. It is also used to calculate the delay ranges of the other five bins making up the histogram. The delay range for each bin increases in a binary exponential fashion as follows:

Bin 0 range: $0 \le \text{Delay} < B_0$ = Bin 0 Range field value

Bin i range: $2^{i-1} \times B_0 \le \text{Delay} < 2^i \times B_0$, for $1 \le i \le 4$

Bin 5 range: $16 \times B_0 \le \text{Delay}$

For example, if the Bin 0 Range field value is 10 TUs, the bin delay ranges are as defined in Table 9-173 (Delay definitions for a Transmit Stream/Category Measurement report for a Bin 0 Range field value of 10 TU).

**Table 9-173—Delay definitions for a Transmit Stream/Category Measurement report for a Bin 0 Range field value of 10 TU**

| Bin | Measured MSDU Transmit Delay (TUs) |
|---|---|
| 0 | Delay < 10 |
| 1 | 10 ≤ Delay < 20 |
| 2 | 20 ≤ Delay < 40 |
| 3 | 40 ≤ Delay < 80 |
| 4 | 80 ≤ Delay < 160 |
| 5 | 160 ≤ Delay |

To compute the value reported in Bin $i$ (i.e., $B_i$ for $i$ = 0, 1...5 of the Transmit Delay Histogram), the STA initializes all bin values to 0. For each MSDU successfully transmitted, the measured MSDU Transmit Delay determines the bin to be incremented. If the measured delay has a duration $t$ within Bin $i$, then Bin $i$ is increased by one. MSDU Transmit Delay is measured from the time the MSDU is passed to the MAC until the point at which the entire MSDU has been successfully transmitted, including receipt of the final Ack frame from the peer STA if the QoSAck service class is being used. The sum of the values in all six bins is equal to the value reported in the Transmitted MSDU Count.

The Optional Subelements field contains zero or more subelements. The subelement format and ordering of subelements are defined in 9.4.3 (Subelements).

The Subelement ID field values for the defined subelements are shown in Table 9-174 (Optional subelement IDs for Transmit Stream/Category Measurement report).

**Table 9-174—Optional subelement IDs for Transmit Stream/Category Measurement report**

| Subelement ID | Name | Extensible |
|---|---|---|
| 0–220 | Reserved | |

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**Table 9-174—Optional subelement IDs for Transmit Stream/Category Measurement report**

| | | |
|---|---|---|
| 221 | Vendor Specific | Vendor defined |
| 222–255 | Reserved | |

The Vendor Specific subelements have the same format as their corresponding elements (see 9.4.2.24 (Vendor Specific element)). Zero or more Vendor Specific subelements are included in the list of optional subelements.

### 9.4.2.20.12 Multicast Diagnostics report

The format of the Measurement Report field of a Multicast Diagnostics report is shown in Figure 9-330 (Measurement Report field format for a Multicast Diagnostics report).

| | Measurement Time | Measurement Duration | Group MAC Address | Multicast Reporting Reason | Multicast Received MSDU Count |
|---|---|---|---|---|---|
| Octets: | 8 | 2 | 6 | 1 | 4 |

| | First Sequence Number | Last Sequence Number | Multicast Rate | Optional Subelements |
|---|---|---|---|---|
| Octets: | 2 | 2 | 2 | variable |

**Figure 9-330—Measurement Report field format for a Multicast Diagnostics report**

The Measurement Time field is the value of the STA TSF timer at the time the measurement started. In a triggered Multicast Diagnostics report, this is the TSF value at the reporting STA when the trigger condition was met. When the reason for sending the report is Performance Measurement and the Multicast Received MSDU Count is nonzero, the Measurement Time field is the value of the STA TSF timer at the time of the first group addressed MSDU received during the measurement interval.

The Measurement Duration field specifies the period over which the Multicast Diagnostic report was generated, in units of TUs.

The Group MAC Address field contains the value from the Group MAC Address field from the Multicast Diagnostics request to which the report relates.

The Multicast Reporting Reason field indicates the reason why the measuring STA sent the Multicast Diagnostics report. The Multicast Reporting Reason field is shown in Figure 9-331 (Multicast Reporting Reason field format).

| | B0 | B1 | B2 B7 |
|---|---|---|---|
| | Inactivity Timeout Trigger | Measurement Result | Reserved |
| Bits: | 1 | 1 | 6 |

**Figure 9-331—Multicast Reporting Reason field format**


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The subfields of the Multicast Reporting Reason field are defined as follows:

— The Inactivity Timeout Trigger field set to 1 indicates that Multicast Diagnostics report was generated as a triggered report due to the timeout of the multicast diagnostic timer.

— The Measurement Result field set to 1 indicates that the Multicast Diagnostic report contains the result of completing a Multicast Diagnostic request that did not contain a Multicast Triggered Reporting subelement.

All of the bits in the Multicast Reporting Reason field are independent.

The Multicast Received MSDU Count field contains the total number of group addressed MSDUs with the indicated multicast MAC address that were received during the measurement duration. For a triggered multicast diagnostics measurement, the Multicast Received MSDU Count field contains the total number of group addressed MSDUs with the indicated multicast MAC address that were received between the acceptance of the multicast diagnostics measurement request and the occurrence of the trigger condition.

When bit 0 of the Multicast MAC address field in the Multicast Diagnostics request is 1, the twelve LSBs of the First Sequence Number field contain the sequence number of the first frame received with destination address equal to the value in the Multicast MAC address field during the measurement period. When bit 0 of the Multicast MAC address field in the Multicast Diagnostics request is 0, the twelve LSBs of the First Sequence Number field contain the sequence number of the first group addressed frame, that does not have the broadcast address as its destination, received during the measurement period. The four most significant bits of the First Sequence Number field are set to 0.

When bit 0 of the Multicast MAC address field in the Multicast Diagnostics request is 1, the twelve LSBs of the Last Sequence Number field contain the sequence number of the last frame received with destination address equal to the value in the Multicast MAC address field during the measurement period. When bit 0 of the Multicast MAC address field in the Multicast Diagnostics request is 0, the twelve LSBs of the Last Sequence Number field contain the sequence number of the last group addressed frame, that does not have the broadcast address as its destination, received during the measurement period. The four most significant bits of the Last Sequence Number field are set to 0.

The First Sequence Number field and the Last Sequence Number field are set to 0 if the Multicast Received MSDU Count is 0.

The Multicast Rate field specifies the highest data rate, in 0.5 Mb/s units, at which the STA has received a group addressed frame during the measurement period. The Multicast Rate field is encoded with the MSB set to 1 to indicate that the data rate is in the basic rate set, and set to 0 to indicate that the data rate is not in the basic rate set. The remaining 15 bit value is multiplied by 0.5 Mb/s to indicate the data rate. The Multicast Rate field is 0 by the STA to indicate that it has not received a group addressed frame during the measurement period.

The Optional Subelements field contains zero or more subelements. The subelement format and ordering of subelements are defined in 9.4.3 (Subelements).

The Subelement ID field values for the defined subelements are shown in Table 9-175 (Optional subelement IDs for Multicast Diagnostics report).

The Vendor Specific subelement has the same format as the Vendor Specific element (see 9.4.2.24 (Vendor Specific element)).

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**Table 9-175—Optional subelement IDs for Multicast Diagnostics report**

| Subelement ID | Name | Extensible |
|---|---|---|
| 0–220 | Reserved | |
| 221 | Vendor Specific | Vendor defined |
| 222–255 | Reserved | |

The summary of fields used in the STA Multicast Diagnostics report is shown in Table 9-176 (Summary of fields used in the STA Multicast Diagnostics report).

**Table 9-176—Summary of fields used in the STA Multicast Diagnostics report**

| Field | Measurement Result | Triggered Report |
|---|---|---|
| Measurement Time | Yes | Yes |
| Measurement Duration | Yes | Yes |
| Group MAC Address | Yes | Yes |
| Multicast Reporting Reason | Yes | Yes |
| Multicast Received MSDU Count | Yes | Yes |
| First Sequence Number | Yes | Yes |
| Last Sequence Number | Yes | Yes |
| Multicast Rate | Yes | Yes |
| Optional Subelements | Optional | Optional |

The use of Multicast Diagnostics report is defined in 11.10.19 (Multicast diagnostic reporting).

### 9.4.2.20.13 Location Civic report

The Location Civic report includes the location information defined in civic format for the location subject provided in the Location Civic request, as shown in Figure 9-332 (Location Civic report field format).

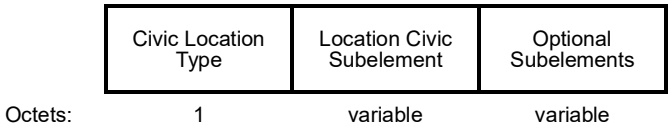


**Figure 9-332—Location Civic report field format**

The Civic Location Type field contains the format of location information in the (#4198)Location Civic Subelement field, as indicated in Table 9-154 (Civic Location Type field values).

The subelement IDs of the Location Civic report are defined in Table 9-177 (Subelement IDs for Location Civic report).


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**Table 9-177—Subelement IDs for Location Civic report**

| Subelement ID | Name | Extensible |
|---|---|---|
| 0 | Location Civic | No |
| 1 | Originator Requesting STA MAC Address | No |
| 2 | Target MAC Address | No |
| 3 | Location Reference(#4198) | No |
| 4 | Location Shape | No |
| 5 | Map Image | No |
| 6 | Reserved | |
| 7 | (#2210)Colocated BSSID List | Yes |
| (#4198)8 | Map Registration | No |
| 9–220 | Reserved | |
| 221 | Vendor Specific | Vendor defined |
| 222–255 | Reserved | |

The Location Civic Subelement field contains a Location Civic subelement. The Location Civic subelement of the Location Civic report (see Figure 9-332 (Location Civic report field format)) is formatted according to Figure 9-333 (Location Civic subelement format).

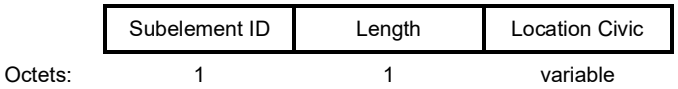


**Figure 9-333—Location Civic subelement format**

The Subelement ID field(M118) is equal to Location Civic as defined in Table 9-177 (Subelement IDs for Location Civic report).

The Location Civic field contains the location information in the format as indicated in the Civic Location Type field. When the Civic Location Type field is IETF RFC 4776:

— The Location Civic field is formatted according to IETF RFC 4776 starting at the country code field (i.e., excluding the GEOCONF_CIVIC/ OPTION_GEOCONF_CIVIC, N/option-len and what fields)

— An unknown civic location is indicated by(#3216)a zero-length Location Civic field

— The (#4198)Location Civic field follows the little-endian octet ordering

(#4198)The Optional Subelements field contains zero or more subelements with subelement ID greater than or equal to 1 as listed in Table 9-177 (Subelement IDs for Location Civic report). The subelement format and ordering of subelements are defined in 9.4.2 (Elements). The Optional Subelements field includes zero or one of each subelement, except that the Optional Subelements field includes zero or more Vendor Specific subelements.

(#4198)If the Civic Location Type field is IETF RFC 4776 and the Optional Subelements field includes

— a Map Image subelement (#6068)wherein the Map URL field does not include floor map georegistration parameters, then the Optional Subelements field also includes a Location Shape subelement

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- a Location Shape subelement, then the Optional Subelements field also includes a Location Reference subelement
- both a Map Image subelement (#6068)wherein the Map URL field does not include floor map georegistration parameters and a Location Reference subelement with nonzero Length field, then the Optional Subelements field also includes a Map Registration subelement
- a Location Reference subelement with Length field equal to 0, then the Optional Subelements field also includes a Map Image subelement (#6068)wherein the Map URL field does not include floor map georegistration parameters and optionally includes a Map Registration subelement.
- (#6068)a Map Image subelement wherein the Map URL field does include floor map georegistration parameters, then the Optional Subelements field does not include a Location Shape subelement, a Location Reference subelement nor a Map Registration subelement.

NOTE 1—In the case of a Map Image subelement wherein the Map URL field does include floor map georegistration parameters, a precise location can be conveyed separately via a Measurement Report element with the Measurement Type field set to LCI.(#6068)

(#4198)If the Civic Location Type field value is Vendor Specific, the Optional Subelements field includes at least one Vendor Specific subelement that identifies the Organization Identifier corresponding to the Civic Location Type field.

(#4198)The Originator Requesting STA MAC Address subelement contains the MAC address of the STA that requested the Location Information and it is present whenever the Location Subject field in the corresponding Location Civic request was set to 2. The format of the Originator Requesting STA MAC Address subelement is shown in Figure 9-263 (Originator Requesting STA MAC Address subelement format).

The Target MAC Address subelement contains the MAC address of the STA whose Location Information was requested and it is present whenever the Location Subject field in the corresponding Location Civic request was set to 2. The format of the Target MAC Address subelement is shown in Figure 9-264 (Target MAC Address subelement format).

(#4198)The format of the Location Reference subelement is shown in Figure 9-334 (Location Reference subelement format(#4198)).

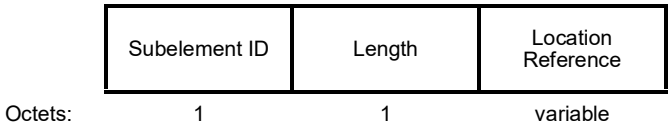


**Figure 9-334—Location Reference subelement format(#4198)**

(#4198)The Location Reference field is an ASCII string that defines the origin of the coordinate reference system and is used for the relative locations and offsets contained in the Location Shape subelement and in the Map Registration subelement. A Location Reference subelement with Length field (#6059)equal to 0 indicates that the origin is the point with the same X-coordinate as the most western feature in the floor map, with the same Y-coordinate as the most northern feature in the floor map, and with the same Z-coordinate as the feature with the lowest altitude in the floor map.

(#4198)NOTE 2—The floor map is identified by the Map Image subelement.


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The format of the Location Shape subelement is shown in Figure 9-335 (Location Shape subelement format).

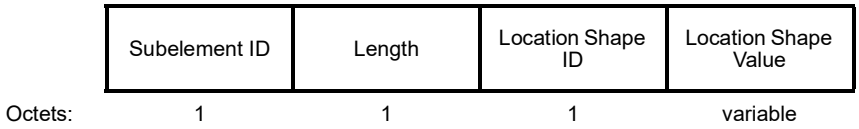


**Figure 9-335—Location Shape subelement format**

The Location Shape subelement defines the position in meters, including uncertainty, of the entity being located. A Shape is specified with respect to either (#4198)a 2-dimensional or 3-dimensional coordinate reference system where each point in the shape defines the direction from the point indicated by the Location Reference field. (#6060)Relative to the point indicated by the Location Reference field: a positive X-axis value corresponds to an easterly direction, a negative X-axis value corresponds to a westerly direction, a positive Y-axis value corresponds to a northerly direction, a negative Y-axis value corresponds to a southerly direction, a positive Z-axis value corresponds to an upward direction, and a negative Z-axis value corresponds to a downward direction.

The Location Shape ID field (#1496)defines the shape contained in the subelement and is one of the values defined in Table 9-178 (Location Shape IDs).

**Table 9-178—Location Shape IDs**

| Location Shape ID | Name |
|---|---|
| 0 | Reserved |
| 1 | 2-Dimension Point |
| 2 | 3-Dimension Point |
| 3 | Circle |
| 4 | Sphere |
| 5 | Polygon |
| 6 | Prism |
| 7 | Ellipse |
| 8 | Ellipsoid |
| 9 | Arcband |
| 10–255 | Reserved |

The Location Shape Value field contains the location shape value for each corresponding location shape ID. The formats of location shape values are described in the following text. (#4190)

(#1497)All shape fields that are 4-octet floating point values are in units of meters and are represented by binary32 floating point values as defined in IEEE Std 754-2008, with the least significant bit of the fraction occurring in bit 0 of the field. (#1497)All shape fields that are 2-octet angles are integers (see 9.2.2 (Conventions)) in degrees, between 0 and 359.

The format of the 2-Dimension Point Location Shape Value field is defined in Figure 9-336 (2-Dimension Point Location Shape Value format).

(#1497)The X-coordinate field contains the X-coordinate of the point, encoded as a floating point value.

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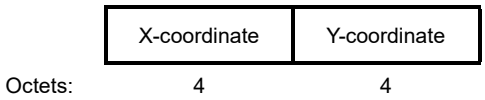


**Figure 9-336—2-Dimension Point Location Shape Value format**

(#1497)The Y-coordinate field contains the Y-coordinate of the point, encoded as a floating point value.

The format of the 3-Dimension Point Location Shape Value field is defined in Figure 9-337 (3-Dimension Point Location Shape Value format).

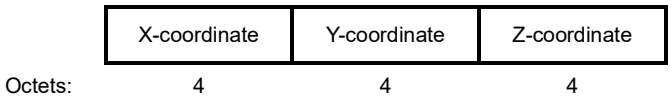


**Figure 9-337—3-Dimension Point Location Shape Value format**

(#1497)The X-coordinate field contains the X-coordinate of the point, encoded as a floating point value.

(#1497)The Y-coordinate field contains the Y-coordinate of the point, encoded as a floating point value.

(#1497)The Z-coordinate field contains the Z-coordinate of the point, encoded as a floating point value.

The format of the Circle Location Shape Value field is defined in Figure 9-338 (Circle Location Shape Value format).

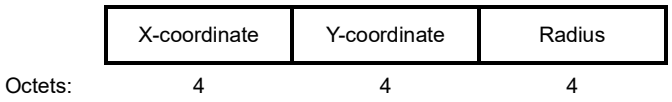


**Figure 9-338—Circle Location Shape Value format**

(#1497)The X-coordinate field contains the X-coordinate of the center of the circle, encoded as a floating point value.

(#1497)The Y-coordinate field contains the Y-coordinate of the center of the circle, encoded as a floating point value.

(#1497)The Radius field contains the radius of the circle, encoded as a floating point value.

The format of the Sphere Location Shape Value field is defined in Figure 9-339 (Sphere Location Shape Value format).

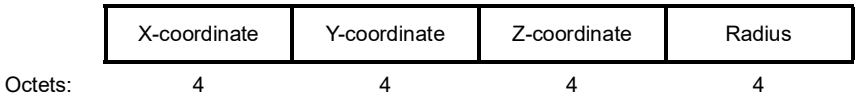


**Figure 9-339—Sphere Location Shape Value format**

(#1497)The X-coordinate field contains the X-coordinate of the center of the sphere, encoded as a floating point value.



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(#1497)The Y-coordinate field contains the Y-coordinate of the center of the sphere, encoded as a floating point value.

(#1497)The Z-coordinate field contains the Z-coordinate of the center of the sphere, encoded as a floating point value.

(#1497)The Radius field contains the radius of the sphere, encoded as floating point value.

The format of the Polygon Location Shape Value field is defined in Figure 9-340 (Polygon Location Shape Value format).

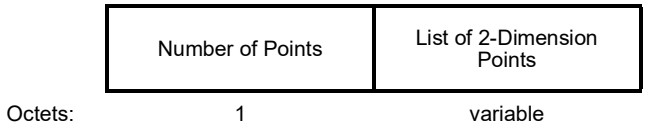


**Figure 9-340—Polygon Location Shape Value format**

The Number of Points field (#1727)specifies the number of points defined in the polygon. The value 0 is reserved.

The List of 2-Dimension Points field is a sequence of 2-Dimension Point Location Shape Value fields(#3215) that define the closed polygon.

The format of the Prism Location Shape Value field is defined in Figure 9-341 (Prism Location Shape Value format).

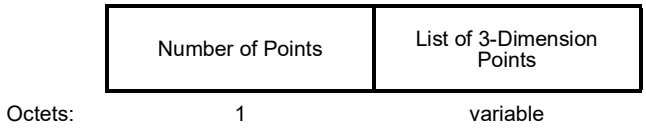


**Figure 9-341—Prism Location Shape Value format**

The Number of Points field (#1727)specifies the number of points defined in the prism. The value 0 is reserved.

The List of 3-Dimension Points field is a sequence of 3-Dimension Point Location Shape Value fields(#3215) that define the closed prism.

The format of the Ellipse Location Shape Value field is defined in Figure 9-342 (Ellipse Location Shape Value format).

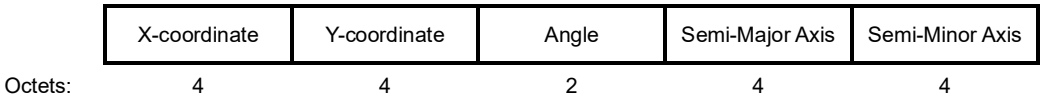


**Figure 9-342—Ellipse Location Shape Value format**

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(#1497)The X-coordinate field contains the X-coordinate of the center of the ellipse, encoded as a floating point value.

(#1497)The Y-coordinate field contains the Y-coordinate of the center of the ellipse, encoded as a floating point value.

(#1497)The Angle field contains the angle of the semi-major axis of the ellipse, measured clockwise from north (see IETF RFC 5491).(#3216)(#4379)

(#1497)The Semi-Major Axis field contains the semi-major axis of the ellipse, encoded as a floating point value.

(#1497)The Semi-Minor Axis field contains the semi-minor axis of the ellipse, encoded as a floating point value.

The format of the Ellipsoid Location Shape Value field is defined in Figure 9-343 (Ellipsoid Location Shape Value format).

| | X-coordinate | Y-coordinate | Z-coordinate | Angle | Semi-Major Axis | Semi-Minor Axis | Semi-Vertical Axis |
|---|---|---|---|---|---|---|---|
| Octets: | 4 | 4 | 4 | 2 | 4 | 4 | 4 |

**Figure 9-343—Ellipsoid Location Shape Value format**

(#1497)The X-coordinate field contains the X-coordinate of the center of the ellipsoid, encoded as a floating point value.

(#1497)The Y-coordinate field contains the Y-coordinate of the center of the ellipsoid, encoded as a floating point value.

(#1497)The Z-coordinate field contains the Z-coordinate of the center of the ellipsoid, encoded as a floating point value.

(#1497)The Angle field contains the angle of the semi-major axis of the ellipsoid, measured clockwise from north (see IETF RFC 5491).(#3216)(#4379)

NOTE 3—The semi-major axis lies in the XY-plane.(#3216)

(#1497)The Semi-Major Axis field contains the semi-major axis of the ellipsoid, encoded as a floating point value.

(#1497)The Semi-Minor Axis field contains the semi-minor axis of the ellipsoid, encoded as a floating point value.

(#1497)The Semi-Vertical Axis field contains the semi-vertical axis of the ellipsoid, encoded as a floating point value.

(#3216)An arcband is defined in IETF RFC 5491.(#4379)

The format of the Arcband Location Shape Value field is defined in Figure 9-344 (Arcband Location Shape Value format).


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| | X-coordinate | Y-coordinate | Inner Radius | Outer Radius | Start Angle | Opening Angle |
|---|---|---|---|---|---|---|
| Octets: | 4 | 4 | 4 | 4 | 2 | 2 |

**Figure 9-344—Arcband Location Shape Value format**

(#1497)The X-coordinate field contains the X-coordinate of the central point of the arcband, encoded as a floating point value.

(#1497)The Y-coordinate field contains the Y-coordinate of the central point of the arcband, encoded as a floating point value.

(#1497)The Inner Radius field contains the inner radius of the arcband, encoded as a floating point value.

(#1497)The Outer Radius field contains the outer radius of the arcband, encoded as a floating point value.

(#1497)The Start Angle field contains the start angle of the arcband, measured clockwise from north (see IETF RFC 5491).(#3216)(#4379)

(#1497)The Opening Angle field contains the opening angle of the arcband (see IETF RFC 5491).(#3216)(#4379)

The Map Image subelement contains a map reference that is used in combination with the Location Reference and Location Shape subelements. The format of the Map Image subelement is shown in Figure 9-345 (Map Image subelement format).

| | Subelement ID | Length | Map Type | Map URL |
|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | variable |

**Figure 9-345—Map Image subelement format**

The Map Type field (#1727)defines the type of map referred to by the Map URL field, as defined in Table 9-179 (Map types).

**Table 9-179—Map types**

| Map Type Value | Name |
|---|---|
| 0 | URL Defined |
| 1 | png |
| 2 | gif |
| 3 | jpeg |
| 4 | svg |
| 5 | dxf |
| 6 | dwg |
| 7 | dwf |
| 8 | cad |
| 9 | tiff |

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**Table 9-179—Map types *(continued)***

| Map Type Value | Name |
|---|---|
| 10 | gml |
| 11 | kml |
| 12 | bmp |
| 13 | pgm |
| 14 | ppm |
| 15 | xbm |
| 16 | xpm |
| 17 | ico |
| 18–255 | Reserved |

The Map Type field value "URL Defined" indicates the Map URL field value has a file extension, and that the type of map referred to by the Map URL field is to be determined from this.

NOTE 4—Other Map Type field values are intended for use when the Map URL field value does not have a file extension that allows the type of map to be determined.(#234)

The Map URL field is a variable length field formatted in accordance with IETF RFC 3986 and provides the retrieval location of (#4198)the floor map. (#6068)The Map URL field optionally includes floor map georegistration parameters as unordered query parameters in the URL's query string, where each of the following query parameters define string representations of numbers with arbitrary precision, with units of degrees:

- s_lat: the most southern feature in the floor map
- w_lng: the most western feature in the floor map
- n_lat: the most northern feature in the floor map
- e_lng: the most eastern feature in the floor map

NOTE 5—Seven decimal places of latitude and longitude provide sufficient resolution to achieve under 0.01 m of latitude error and longitude error throughout the globe. Considering the sizes of devices whose positions are being estimated and the use cases for the estimated positions, a map georegistration error of under 0.01 m is generally regarded as sufficient to avoid compromise of the estimated positions.(#6068)(#7198)

NOTE 6—Consider a floor map of the Sydney Opera House where the floor map is cropped to the minimal rectangle that encloses the building perimeter, and the building perimeter is described by a polygon with vertices having the following (latitude, longitude) coordinates:

- (-33.856 625 0°, +151.215 906 0°)
- (-33.856 299 0°, +151.215 343 0°)
- (-33.856 326 0°, +151.214 731 0°)
- (-33.857 533 0°, +151.214 495 0°)
- (-33.857 720 0°, +151.214 613 0°)
- (-33.857 369 0°, +151.215 375 0°)

Then, if the retrieval location for the floor map is http://www.example.com/floorMapImages/floorMapImage.png then the Map URL field that includes the floor map georegistration parameters could be http://www.example.com/floorMapImages/floorMapImage.png?w_lng=151.21449500&n_lat=-33.8562990&e_lng=151.2159060&s_lat=-33.8577200.(#6068)

The (#2210)Colocated BSSID List subelement is used to report the list of BSSIDs of the BSSs sharing the same antenna connector with the reporting STA if the subelement is contained within a Fine Time


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Measurement frame, otherwise the BSSs that are (#2210)colocated within the same physical device as the reporting STA. The (#2210)Colocated BSSID List subelement is described in 9.4.2.20.10 (LCI report (Location configuration information report)).

(#4198)The Map Registration subelement reports the registration of the floor map to the coordinate reference system.

| | Subelement ID | Length | X Min | Y Min | Z Min | X Max (Optional) | Y Max (Optional) | Z Max (Optional) |
|---|---|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 4 | 4 | 4 | 0 or 4 | 0 or 4 | 0 or 4 |

**Figure 9-346—Map Registration subelement format(#4198)**

(#4198)The Subelement ID field(M118) is equal to Map Registration as defined in Table 9-177 (Subelement IDs for Location Civic report).

(#4198)The X Min, Y Min, Z Min, X Max, Y Max, and Z Max fields, when present, contain floating point values represented by binary32 floating point values as defined in IEEE Std 754-2008, with the least significant bit of the fraction occurring in bit 0 of the field. These fields have units of meters and are defined with respect to the Location Reference subelement. For a rasterized floor map, these fields indicate the outermost edge (rather than the center) of the outermost pixels in the specified X or Y direction.

(#4198)The X Min field is the X-coordinate of the most western feature in the floor map.

(#4198)The Y Min field is the Y-coordinate of the most southern feature in the floor map.

(#4198)The Z Min field is the Z-coordinate of the lowest feature in the floor map.

(#4198)The X Max field, if other than NAN, is the X-coordinate of the most eastern feature in the floor map. The X Max field is optionally present. When present and other than NAN, the X Max field, together with the X Min field, is used to scale the floor map along the X-axis. When present and set to NAN, the X Max field is a padding field.

(#4198)The Y Max field is the Y-coordinate of the most northern feature in the floor map. The Y Max field is optionally present. When present, the Y Max field, together with the Y Min field, is used to scale the floor map along the Y-axis. If the Y Max field is present, then the X Max field is also present.

(#4198)The Z Max field is the Z-coordinate of the highest feature in the floor map. The Z Max field is optionally present. When present, the Z Max field, together with the Z Min field, is used to scale the floor map along the Z-axis. If the Z Max field is present, then the X Max and Y Max fields are also present. For a 2-dimensional floor map, the Z Max field is not present or set to the Z Min field.

(#4198)If the Length field of the Location Reference subelement contained in the Location Civic report is equal to 0 then the X Min and Z Min fields are equal to 0 and the Y Max field is present and equal to 0.

(#4198)NOTE 7—In this case, the X Max field is present and might be set to NAN or another value.

The Vendor Specific subelement has the same format as the Vendor Specific element (see 9.4.2.24 (Vendor Specific element)).

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#### 9.4.2.20.14 Location Identifier report

The Location Identifier report includes an indirect reference to the location information for the location subject provided in the Location Identifier request, as shown in Figure 9-347 (Location Identifier report field format).

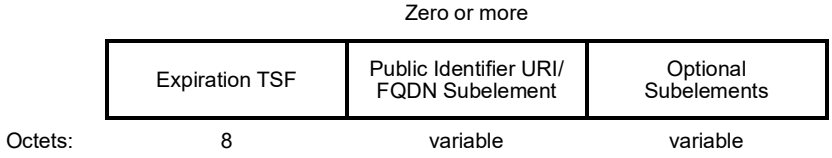


**Figure 9-347—Location Identifier report field format**

The Expiration TSF field is the value of the TSF when the Public Identifier URI/FQDN subelement(s) that indicate a location object are no longer valid. The Expiration TSF field set to 0 indicates the Public Identifier URI/FQDN subelement(s) that indicate a location object do not expire.

The Public Identifier URI/FQDN Subelement field contains zero or more Public Identifier URI/FQDN subelements.

The subelement IDs for the Location Identifier report are shown in Table 9-180 (Subelement IDs for Location Identifier report).

**Table 9-180—Subelement IDs for Location Identifier report**

| Subelement ID | Name | Extensible |
|---|---|---|
| 0 | Public Identifier URI/FQDN | No |
| 1 | Originator Requesting STA MAC Address | No |
| 2 | Target MAC Address | No |
| 3–220 | Reserved | |
| 221 | Vendor Specific | Vendor defined |
| 222–255 | Reserved | |

The Public Identifier URI/FQDN subelement of the Location Identifier report (see Figure 9-347 (Location Identifier report field format)) is formatted according to Figure 9-348 (Public Identifier URI/FQDN subelement format).

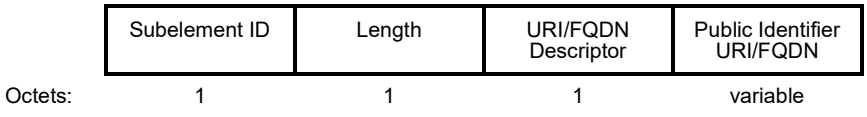


**Figure 9-348—Public Identifier URI/FQDN subelement format**


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The Subelement ID is equal to Public Identifier URI/FQDN as defined in Table 9-180 (Subelement IDs for Location Identifier report).

The URI/FQDN Descriptor field describes the Public Identifier URI/FQDN field. The URI/FQDN Descriptor field is defined in Table 9-181 (URI/FQDN Descriptor field values).

**Table 9-181—URI/FQDN Descriptor field values**

| Value | Usage |
|---|---|
| 0 | Reserved |
| 1 | The uniform resource locator (URI) of the Hypertext Transfer Protocol (HTTP) enabled location delivery (HELD) location object [IETF RFC 5985] |
| 2 | Fully qualified domain name of D-SLP SUPL server (excludes port number) [OMA-TS-ULP-V2_0_1 (or higher version)](#1732) |
| 3–255 | Reserved |

The Public Identifier URI/FQDN field contains a URI as a UTF-8 string, formatted in accordance with IETF RFC 3986, that points to a location object or an FQDN that identifies a location server.

A Public Identifier URI/FQDN field that points to a location object can be used to return the location value for the requesting STA. The format of the location value returned when the URI is dereferenced is dependent on the provider of the URI as indicated by the URI/FQDN Descriptor field. The Public Identifier URI field confirms the validity of the location estimate to an external agent when a STA forwards a location estimate to that agent. The protocol used to query the infrastructure for a location report based on the Public Identifier URI field is beyond the scope of this standard.

A Public Identifier URI/FQDN field that points to a location server can be used to discover the location server and establish communications with it. The protocol used with the location server is indicated by the URI/FQDN Descriptor field.

The Optional Subelements field contains zero or more subelements with subelement ID greater than or equal to 1 as listed in Table 9-180 (Subelement IDs for Location Identifier report). The subelement format and ordering of subelements are defined in 9.4.3 (Subelements).

The Originator Requesting STA MAC Address subelement contains the MAC address of the STA that requested the Location Information and it is present whenever the Location Subject field in the corresponding Location Identifier request was set to 2. The format of the Originator Requesting STA MAC Address subelement is shown in Figure 9-263 (Originator Requesting STA MAC Address subelement format).

The Target MAC Address subelement contains the MAC address of the STA whose Location Information was requested and it is present whenever the Location Subject field in the corresponding Location Identifier request was set to 2. The format of the Target MAC Address subelement is shown in Figure 9-264 (Target MAC Address subelement format).

The Vendor Specific subelement has the same format as the Vendor Specific element (see 9.4.2.24 (Vendor Specific element)).

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#### 9.4.2.20.15 Directional Channel Quality report

The format of the Measurement Report field of a Directional Channel Quality report is shown in Figure 9-349 (Measurement report field format for Directional Channel Quality report).

| | Operating Class | Channel Number | AID | Reserved | Measurement Method | Measurement Start Time |
|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 1 | 1 | 8 |

| | Measurement Duration | Number of Time Blocks | Measurement for Time Block List | Optional Subelements |
|---|---|---|---|---|
| Octets: | 2 | 1 | $n \times 1$ | variable(#213) |

**Figure 9-349—Measurement report field format for Directional Channel Quality report**

The Operating Class field indicates the channel set for which the measurement report applies. The Operating Class and Channel Number fields together specify the channel frequency and spacing for which the measurement report applies. Valid values of the Operating Class field are shown in Annex E.

The Channel Number field indicates the channel number for which the measurement report applies. The channel number is defined within an Operating Class as shown in Annex E.

The AID field contains the AID assigned to the Target STA by the AP or PCP.

The Measurement Method field indicates the method used by the STA to carry out this measurement request and the format of the Measurement for Time Block field(s). If this field is set to 0, it indicates that the Measurement for Time Block fields are expressed in ANIPI. If this field is set to 1, it indicates that the Measurement for Time Block fields are expressed in RSNI. (11ay)If this field is set to 2, it indicates that the Measurement for Time Block fields are expressed in ANIPI during the duration of the requested measurement, in units of 1 μs. If this field is set to 3, it indicates that the Measurement for Time Block fields are expressed in RSNI during the duration of the requested measurement, in units of 1 μs. Other values are reserved.

Measurement Start Time field is set to the value of the measuring STA's TSF timer at the time the measurement started.

(11ay)If the Measurement Method field is not 2 or 3, the Measurement Duration field is set to the duration of the measurement, in units of TUs. If the Measurement Method field is 2 or 3, the Measurement Duration field is set to the duration of the requested measurement, in units of 1 μs (TU/1024).

The Number of Time Blocks field indicates the number of time blocks, *n*, within the measurement duration. The ratio (Measurement Duration/Number of Time Blocks) provides the duration of an individual measurement unit.

The Measurement for Time Block List field contains one or more (*n*) Measurement for Time Block fields.

Each Measurement for Time Block field is set to the ANIPI or RSNI value measured during each (Measurement Duration/Number of Time Blocks) measurement units. The measurement units are set in the report in increasing order of start times.


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The Optional Subelements field contains zero or more subelements. The subelement format and ordering of subelements are defined in 9.4.3 (Subelements).

The Subelement ID field values for the defined subelements are shown in Table 9-182 (Optional subelement IDs for Directional Channel Quality report).

**Table 9-182—Optional subelement IDs for Directional Channel Quality report**

| Subelement ID | Name | Extensible |
|---|---|---|
| 0(11ay) | Measurement Configuration | Yes |
| (11ay)1 | Extended Measurement Configuration | Yes |
| (11ay)2 | Extended Measurement Report | Yes |
| 3–220 | Reserved | |
| 221 | Vendor Specific | Vendor defined |
| 222–255 | Reserved | |

(11ay)The Measurement Configuration subelement indicates measurement configuration information for which the measurement report applies and is used between a pair of EDMG STAs. The Data field of the Measurement Configuration subelement is formatted as shown in Figure 9-350 (Data field format of the Measurement Configuration subelement(11ay)(M118)).

| | B0 B7 | B8 | B9 | B10 | B11 B15 |
|---|---|---|---|---|---|
| | Measurement Channel Bitmap | Channel Measurement Report Method | Antenna Measurement Report Method | RX Antenna Configuration Type | Reserved |
| Bits: | 8 | 1 | 1 | 1 | 5 |

**Figure 9-350—Data field format of the Measurement Configuration subelement(11ay)(M118)**

(11ay)The Measurement Channel Bitmap subfield is a bitmap that indicates the 2.16 GHz channel(s) to which the measurement report applies and is formatted as shown in Figure 9-351 (Measurement Channel Bitmap subfield format(11ay)). In Figure 9-351 (Measurement Channel Bitmap subfield format(11ay)), Ch1 subfield corresponds to channel 1, Ch2 subfield corresponds to channel 2 and so on (channels are defined in Annex E). If a subfield is set to 1, the measurement report applies to the indicated channel; otherwise, if the subfield is set to 0, the measurement report does not apply to the indicated channel.

| | B0 | B1 | B2 | B3 | B4 | B5 | B6 | B7 |
|---|---|---|---|---|---|---|---|---|
| | Ch1 | Ch2 | Ch3 | Ch4 | Ch5 | Ch6 | Ch7 | Ch8 |
| Bits: | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

**Figure 9-351—Measurement Channel Bitmap subfield format(11ay)**

(11ay)The Channel Measurement Report Method subfield indicates the method that is to be used by the Reporting STA to report the results of measurements over multiple 2.16 GHz channels in the measurement report. The Channel Measurement Report Method subfield sets to 0 to indicate the results of measurements over all the requested 2.16 GHz channels during each measurement time block are reported per 2.16 GHz channel. The Channel Measurement Report Method subfield sets to 1 to indicate the averaged results of

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concurrent measurements over all the requested 2.16 GHz channels during each measurement time block are reported. The Channel Measurement Report Method subfield is set to 0 when the Extended Measurement Configuration subelement is present.

(11ay)The Antenna Measurement Report Method subfield indicates the method that is to be used by the Reporting STA to report the results of concurrent measurements using multiple RX DMG antennas in the measurement report. The Antenna Measurement Report Method subfield is set to 0 to indicate the results of concurrent measurements over each requested 2.16 GHz channel using multiple RX DMG antennas during a measurement time block are reported per DMG antenna. The Antenna Measurement Report Method subfield is set to 1 to indicate the averaged results of concurrent measurements over each requested 2.16 GHz channel using multiple RX DMG antennas during a measurement time block are reported.

(11ay)The RX Antenna Configuration Type subfield is set to 0 to indicate that the RX antenna configuration used for SISO reception is used for measurements, and is set to 1 to indicate that the RX antenna configuration used for SU-MIMO reception is used for measurements.

(11ay)The Extended Measurement Configuration subelement is present if the Measurement Configuration subelement is present. The Extended Measurement Configuration subelement contains measurement timing information for the channels indicated in the Measurement Configuration subelement. If the Extended Measurement Configuration subelement is not present, the measurement timing information indicated in the Measurement Report field applies to all reported channels. If the Extended Measurement Configuration subelement is present, the measurement timing information indicated in the Measurement Report field applies to the first reported channel (i.e., the reported channel with the lowest channel number) and measurement timing information indicated in the Extended Measurement Configuration subelement applies to the remaining reported channels in ascending order in terms of channel number. The Data field of the Extended Measurement Configuration subelement is formatted as shown in Figure 9-352 (Data field of the Extended Measurement Configuration subelement format(11ay)).

| Measurement Report Info List |
|---|
| Octets: $(N_{ch} - 1) \times 11$ |

**Figure 9-352—Data field of the Extended Measurement Configuration subelement format(11ay)**

(11ay)The Measurement Report Info List field contains $(N_{ch} - 1)$ Measurement Report Info subfields, where $N_{ch}$ is the total number of reported channels. Each Measurement Report Info subfield is defined in Figure 9-353 (Measurement Report Info subfield format(11ay)).

| | Measurement Start Time for $i^{th}$ Reported Channel | Measurement Duration for $i^{th}$ Reported Channel | Number of Time Blocks for $i^{th}$ Reported Channel |
|---|---|---|---|
| Octets: | 8 | 2 | 1 |

**Figure 9-353—Measurement Report Info subfield format(11ay)**

(11ay)The measurement timing information for the $i^{th}$ reported channels is indicated in the Measurement Start Time for $i^{th}$ Reported Channel subfield, the Measurement Duration for $i^{th}$ Reported Channel subfield and Number of Time Blocks for $i^{th}$ Reported Channel subfield, where $i = 2, 3, \ldots, N_{ch}$. The definition of these subfields is the same as the corresponding subfields in Measurement Report field (Figure 9-349 (Measurement report field format for Directional Channel Quality report)).

(11ay)The Extended Measurement Report subelement contains supplementary results of measurements performed by an EDMG STA over multiple 2.16 GHz channels using multiple RX DMG antennas. The


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format of the Extended Measurement Report data field depends on the values of the Channel Measurement Report Method subfield and the Antenna Measurement Report Method subfield. When both the Channel Measurement Report Method subfield and the Antenna Measurement Report Method subfield are 0, the results of measurements over the first 2.16 GHz channel using the first RX DMG antenna are carried in the Measurement for Time Blocks fields and the remaining results of measurements are carried in the Extended Measurement Report subelement. The Extended Measurement Report subelement data field format when both the Channel Measurement Report Method subfield and the Antenna Measurement Report Method subfield are 0 is shown in Figure 9-354 (Extended Measurement Report data field format when both the Channel Measurement Report Method subfield and the Antenna Measurement Report Method subfield are set to 0(11ay)). The Number of RX Antennas for the $j^{th}$ Reported Channel field ($j$ = 1, 2, …, $N_{ch}$) indicates the number of RX DMG antennas used by the reporting EDMG STA to perform measurements on the $j^{th}$ reported channel. The Measurement Results for 1st Reported Channel field consists of N1 Measurement for Time Block subfields for each of $N_{RX}$,1 RX DMG antennas excluding the first RX DMG antenna. The Measurement Results for $j^{th}$ Reported Channel field ($j$ = 2, 3, …, $N_{ch}$) consists of Nj Measurement for Time Block subfields for each of $N_{RX,j}$ RX DMG antenna.

| | Number of RX Antennas for 1st Reported Channel ($N_{RX,1}$) | Measurement Results for 1st Reported Channel | Number of RX Antennas for 2nd Reported Channel ($N_{RX,2}$) | Measurement Results for 2nd Reported channel | … | Number of RX Antennas for $N_{ch}^{th}$ Reported Channel ($N_{RX,Nch}$) | Measurement Results for $N_{ch}^{th}$ Reported channel |
|---|---|---|---|---|---|---|---|
| Octets: | 1 | $N_1 \times (N_{RX,1}-1)$ | 1 | $N_2 \times N_{RX,2}$ | | 1 | $N_{Nch} \times N_{RX,Nch}$ |

**Figure 9-354—Extended Measurement Report data field format when both the Channel Measurement Report Method subfield and the Antenna Measurement Report Method subfield are set to 0(11ay)**

(11ay)When the Channel Measurement Report Method subfield is 0 and the Antenna Measurement Report Method subfield is 1, the results of measurements over the first 2.16 GHz channel using multiple RX DMG antennas are carried in the Measurement for Time Blocks fields and the remaining results of measurements are carried in the Extended Measurement Report subelement. The Extended Measurement Report subelement data field format when the Channel Measurement Report Method subfield is 0 and the Antenna Measurement Report Method subfield is 1 is shown in Figure 9-355 (Extended Measurement Report data field format when the Channel Measurement Report Method subfield is set to 0 and the Antenna Measurement Report Method subfield is set to 1(11ay)). The Measurement Results for $j^{th}$ Requested Channel field ($j$ = 2, 3, …, $N_{ch}$) consists of Nj Measurement for Time Block subfields.

| | Measurement Results for 2nd Reported Channel | Measurement Results for 3rd Reported Channel | … | Measurement Results for $N_{ch}^{th}$ Reported Channel |
|---|---|---|---|---|
| Octets: | *N*2 | *N*3 | | $N_{Nch}$ |

**Figure 9-355—Extended Measurement Report data field format when the Channel Measurement Report Method subfield is set to 0 and the Antenna Measurement Report Method subfield is set to 1(11ay)**

(11ay)When the Channel Measurement Report Method subfield is 1 and the Antenna Measurement Report Method subfield is 0, the results of measurements over multiple 2.16 GHz channels using the first RX DMG antenna are carried in the Measurement for Time Blocks fields and the remaining results of measurements are carried in the Extended Measurement Report subelement. The Extended Measurement Report subelement data field format when the Channel Measurement Report Method subfield is 1 and the Antenna Measurement Report Method subfield is 0 as shown in Figure 9-356 (Extended Measurement Report data field format when the Channel Measurement Report Method subfield is set to 1 and the Antenna Measurement Report Method subfield is set to 0(11ay)).

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| | Number of Rx Antennas (NRX) | Measurement Results for 2nd RX DMG Antenna | Measurement Results for 3rd RX DMG Antenna | … | Measurement Results for NRX RX DMG Antenna |
|---|---|---|---|---|---|
| Octets: | 1 | *N* | *N* | | *N* |

**Figure 9-356—Extended Measurement Report data field format when the Channel Measurement Report Method subfield is set to 1 and the Antenna Measurement Report Method subfield is set to 0(11ay)**

(11ay)When the Channel Measurement Report Method subfield is 1 and the Antenna Measurement Report Method subfield is 1, the results of measurements over multiple 2.16 GHz channels using multiple RX DMG antennas are completely carried in the Measurement for Time Blocks fields.

The Vendor Specific subelements have the same format as their corresponding elements (see 9.4.2.24 (Vendor Specific element)). Zero or more Vendor Specific subelements are included in the list of optional subelements.

### 9.4.2.20.16 Directional Measurement report

The format of the Measurement Report field of a Directional Measurement report is shown in Figure 9-357 (Measurement Report field format for Directional Measurement report).

| | Operating Class | Channel Number | Measurement Start Time | Measurement Duration per Direction | Measurement Method And Antenna Configuration(11ay) | Measurement Results | Optional Subelements |
|---|---|---|---|---|---|---|---|
| Octets | 1 | 1 | 8 | 2 | 1 | variable(#213) | variable(#213) |

**Figure 9-357—Measurement Report field format for Directional Measurement report**

The Operating Class field indicates the channel set for which the measurement report applies. The Operating Class and Channel Number fields together specify the channel frequency and spacing for which the measurement report applies. Valid values of the Operating Class field are shown in Annex E.

The Channel Number field indicates the channel number for which the measurement report applies. The channel number is defined within an Operating Class as shown in Annex E.

The Measurement Start Time field is set to the value of the measuring STA's TSF timer at the time the measurement started.

The Measurement Duration per Direction field is set to the duration of the measurement in each receiving direction, in units of TUs.

(11ay)The Measurement Method And Antenna Configuration field is defined in Figure 9-358 (Measurement Method And Antenna Configuration field format(11ay)).

| | B0 B2 | B3 B4 | B5 B7 |
|---|---|---|---|
| | Measurement Method | Antenna Configuration | Reserved |
| Bits: | 3 | 2 | 3 |

**Figure 9-358—Measurement Method And Antenna Configuration field format(11ay)**


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The Measurement Method subfield indicates the method used by the STA to carry out the measurement request and the format of values in the Measurement for Direction fields. The Measurement Method subfield is defined in Table 9-183 (Measurement Method subfield definition(11ay)).(11ay)

**Table 9-183—Measurement Method subfield definition(11ay)**

| Measurement Method subfield value | Definition |
|---|---|
| 0 | Values in the Measurement for Direction fields are expressed in ANIPI as defined in 9.4.2.20.15 (Directional Channel Quality report). |
| 1 | Values in the Measurement for Direction fields are expressed in RCPI as defined in 9.4.2.36 (RCPI element). |
| 2 | Values in the Measurement for Direction fields are expressed in Channel Load as defined in 11.10.9.3 (Channel load report).(#3047) |
| 3–7 | Reserved. |

(11ay)The Antenna Configuration subfield indicates the configuration of the DMG antenna(s) used by the STA to carry out the measurement. If this subfield is set to 1, it indicates a quasi-omni antenna pattern. If this subfield is set to 2, it indicates a directional antenna pattern. Other values are reserved.

The format of the Measurement Results field is shown in Figure 9-359 (Measurement Results field format).

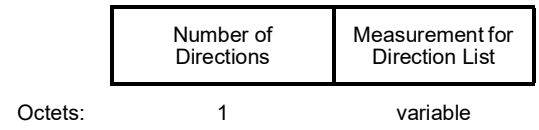


**Figure 9-359—Measurement Results field format**

The Number of Directions field is set to the number of measurement directions, *n*.

The Measurement for Direction List field contains one or more (*n*) Measurement for Direction fields.

Each Measurement for Direction field is set to the format of values specified in the Measurement Method subfield.(11ay)

(11ay)If the Antenna Configuration subfield is equal to 2, the Measurement for Direction 1 subfield contains the measurement results corresponding to the direction the reporting STA uses to receive frames from the requesting STA

The Optional Subelements field contains zero or more subelements. The subelement format and ordering of subelements are defined in 9.4.3 (Subelements).

The Subelement ID field values for the defined subelements are shown in Table 9-184 (Optional subelement IDs for Directional Measurement report).

The Vendor Specific subelements have the same format as their corresponding elements (see 9.4.2.24 (Vendor Specific element)). Zero or more Vendor Specific subelements are included in the list of optional subelements.

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**Table 9-184—Optional subelement IDs for Directional Measurement report**

| Subelement ID | Name | Extensible |
|---|---|---|
| 0–220 | Reserved | |
| 221 | Vendor Specific | Vendor defined |
| 222–255 | Reserved | |

### 9.4.2.20.17 Directional Statistics report

The format of the Measurement Report field of a Directional Statistics report is shown in Figure 9-360 (Measurement Report field format for Directional Statistics report).

| | Operating Class | Channel Number | Measurement Start Time | Measurement Duration per Direction | Measurement Method | Directional Statistics Bitmap | Measurement Results | Optional Subelements |
|---|---|---|---|---|---|---|---|---|
| Octets | 1 | 1 | 8 | 2 | 1 | 1 | variable(#213) | variable(#213) |

**Figure 9-360—Measurement Report field format for Directional Statistics report**

The Operating Class field indicates the channel set for which the measurement report applies. The Operating Class and Channel Number fields together specify the channel frequency and spacing for which the measurement report applies. Valid values of the Operating Class field are shown in Annex E.

The Channel Number field indicates the channel number for which the measurement report applies. The channel number is defined within an Operating Class as shown in Annex E.

The Measurement Start Time field is set to the value of the measuring STA's TSF timer at the time the measurement started.

The Measurement Duration per Direction field is set to the duration of the measurement in each receiving direction, in units of TUs.

The Measurement Method field indicates the method used by the STA to carry out the measurement request and the format of values in the Measurement Results field. If this field is set to 0, it indicates that the values in the Measurement Results field are expressed in ANIPI. If this field is set to 1, it indicates that the values in the Measurement Results field are expressed in RCPI. If this field is set to 2, it indicates that the values in the Measurement Results field are expressed in Channel Load. Other values are reserved.

The Directional Statistics Bitmap field format is described in 9.4.2.19.18 (Directional Statistics request). When the Maximum field is set, it indicates that the maximum measurement result among all directions is included in the Measurement Results field. When the Minimum field is set, it indicates that the minimum measurement result among all directions is included in the Measurement Results field. If the Average field is set, it indicates that the average measurement result among all directions is included in the Measurement Results field. If the Variance field is set, it indicates that the variance of measurement results among all directions is included in the Measurement Results field. Other bits are reserved.

The Measurement Results field is set based on the values in the Measurement Method field and the Directional Statistics Bitmap field. If two or more subfields in the Directional Statistics Bitmap are set to 1,


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the corresponding measurement results are included in the Measurement Results field in the same sequence as they appear in the Directional Statistics Bitmap field.

The Optional Subelements field contains zero or more subelements. The subelement format and ordering of subelements are defined in 9.4.3 (Subelements).

The Subelement ID field values for the defined subelements are shown in Table 9-185 (Optional subelement IDs for Directional Statistics report).

**Table 9-185—Optional subelement IDs for Directional Statistics report**

| Subelement ID | Name | Extensible |
|---|---|---|
| 0–220 | Reserved | |
| 221 | Vendor Specific | Vendor defined |
| 222–255 | Reserved | |

The Vendor Specific subelements have the same format as their corresponding elements (see 9.4.2.24 (Vendor Specific element)). Zero or more Vendor Specific subelements are included in the list of optional subelements.

#### 9.4.2.20.18 FTM Range report(#7065)

The format of the Measurement Report field corresponding to an (#7065)FTM Range report is shown in Figure 9-361 (Measurement Report field format for an FTM Range report(#7065)).

| | Range Entry Count | Range Entry | Error Entry Count | Error Entry | Optional Subelements |
|---|---|---|---|---|---|
| Octets: | 1 | *M* x 15 | 1 | *N* x 11 | variable |

**Figure 9-361—Measurement Report field format for an FTM Range report(#7065)**

The Range Entry Count field indicates the number of Range Entry fields (i.e., *M* in Figure 9-361 (Measurement Report field format for an FTM Range report(#7065))).

The Range Entry field indicates parameters relating to a successful range measurement with a single AP and is formatted according to Figure 9-362 (Range Entry field format).

| | Measurement Start Time | BSSID | Range | Max Range Error Exponent | Reserved |
|---|---|---|---|---|---|
| Octets: | 4 | 6 | 3 | 1 | 1 |

**Figure 9-362—Range Entry field format**

The Measurement Start Time field contains the least significant 4 octets of the TSF (synchronized with the associated AP) at the time (± 32 μs) at which the first FTM frame(#7223) within the first burst (FTM_2 in Figure 11-44 (Example negotiation and measurement frame exchange, ASAP=0, and FTMs Per Burst = 2(#109)(11az)). FTM_1 in Figure 11-45 (Example negotiation and measurement frame exchange, ASAP=1, and FTMs Per Burst = 2(#109)(11az)(#8031)) and FTM_1 in Figure 11-46 (Example negotiation and

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measurement frame exchange for a single burst instance, ASAP=1, and FTMs Per Burst = 3(#109))) was transmitted where the timestamps of both the frame and response frame were successfully measured.

The BSSID field contains the BSSID of the BSS of the AP whose range is being reported.

The Range field indicates the estimated range between the requested STA and the AP using the FTM procedure, in units of 1/4096 m. A value of $2^{24}$–1 indicates a range of ($2^{24}$–1)/4096 m or higher. See 11.10.9.11 (FTM Range report(#7065)).

The Max Range Error Exponent field contains an upper bound for the error in the value specified in the Range field. A Max Range Error Exponent field set to 0 indicates an unknown error. A nonzero value indicates a maximum range error of $2^{(Max\ Range\ Error\ Exponent\ -\ 13)}$ m. The Max Range Error Exponent field has a maximum value of 25. Values in the range 26–255 are reserved. A Max Range Error Exponent field set to 25 indicates a maximum range error of 4096 m or higher. For example, a Max Range Error Exponent field set to 14 indicates that the Range field has a maximum error of ± 2 m.

The Error Entry Count field indicates the number of Error Entry fields (i.e., *N* in Figure 9-361 (Measurement Report field format for an FTM Range report(#7065))).

The Error Entry field indicates parameters relating to a failed range measurement with a single AP and is formatted according to Figure 9-363 (Error Entry field format).

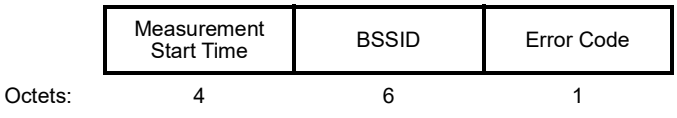


**Figure 9-363—Error Entry field format**

The Measurement Start Time field contains the least significant 4 octets of the TSF (synchronized with the associated AP) at the time (± 32 μs) at which the FTM failure was first detected.

The BSSID field contains the BSSID of the BSS of the AP whose range was attempted to be measured.

The Error Code field is defined in Table 9-186 (Error Code field values).

**Table 9-186—Error Code field values**

| Error code | Meaning |
|---|---|
| 0–1 | Reserved |
| 2 | AP reported “Request incapable” |
| 3 | AP reported “Request failed. Do not send new request for a specified period” |
| 4–7 | Reserved |
| 8 | Unable to successfully transmit to AP |
| 9–255 | Reserved |


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The Optional Subelements field contains zero or more subelements. The subelement format and ordering of subelements are defined in 9.4.3 (Subelements).

The Subelement ID field values for the defined subelements are shown in Table 9-187 (Optional subelement IDs for FTM Range report(#7065)).

**Table 9-187—Optional subelement IDs for FTM Range report(#7065)**

| Subelement ID | Name | Extensible |
|---|---|---|
| 0–220 | Reserved | |
| 221 | Vendor Specific | Vendor defined |
| 222–255 | Reserved | |

The Vendor Specific subelements have the same format as their corresponding elements (see 9.4.2.24 (Vendor Specific element)). Zero or more Vendor Specific subelements are included in the list of optional subelements.

### 9.4.2.21 Quiet element

The Quiet element defines an interval during which no transmission occurs in the current channel. This interval might be used to assist in making channel measurements without interference from other STAs in the BSS. The format of the Quiet element is shown in Figure 9-364 (Quiet element format).

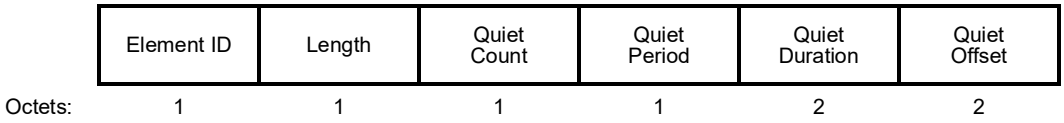


**Figure 9-364—Quiet element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The Quiet Count field is set to the number of TBTTs until the beacon interval during which the next quiet interval starts. The value of 0 is reserved.

The Quiet Period field is set to the number of beacon intervals between the start of regularly scheduled quiet intervals defined by this Quiet element. A Quiet Period field set to 0 indicates that no periodic quiet interval is defined.

The Quiet Duration field is set to the duration of the quiet interval, expressed in TUs.

The Quiet Offset field is set to the offset of the start of the quiet interval from the TBTT specified by the Quiet Count field, expressed in TUs. The value of the Quiet Offset field is less than one beacon interval.

The use of Quiet elements is described in 11.8.3 (Quieting channels for testing).(#557)

### 9.4.2.22 IBSS DFS element

The IBSS DFS element contains information for DFS operation in an IBSS. The format of the IBSS DFS element is shown in Figure 9-365 (IBSS DFS element format).

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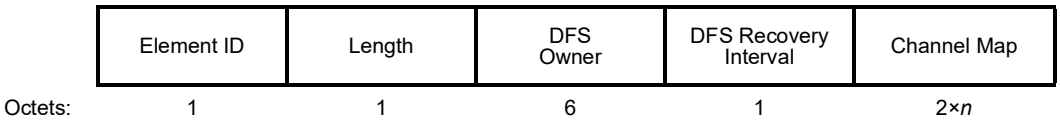


**Figure 9-365—IBSS DFS element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The DFS Owner field is set to the MAC (#1893)address of the STA that is the currently known DFS Owner in the IBSS.

The DFS Recovery Interval field indicates the time interval that is used for DFS owner recovery, expressed as an integer number of beacon intervals. The DFS Recovery Interval value is static throughout the lifetime of the IBSS and is determined by the STA that starts the IBSS.

The Channel Map field shown in Figure 9-366 (Channel Map field format) contains a Channel Number field and a Map field (see 9.4.2.20.2 (Basic report)) for each channel supported by the STA transmitting the IBSS DFS element. Note that *n* in Figure 9-365 (IBSS DFS element format) is the number of channels supported by the STA.

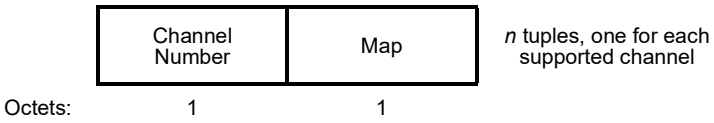


**Figure 9-366—Channel Map field format**

(#1105)The use of IBSS DFS elements is described in 11.8.8.3 (Selecting and advertising a new channel in an IBSS).

### 9.4.2.23 RSNE

#### 9.4.2.23.1 General

(#1776)The RSN element (RSNE) contains the information required to establish an RSNA. The format of the RSNE is defined in Figure 9-367 (RSNE format(#131)).

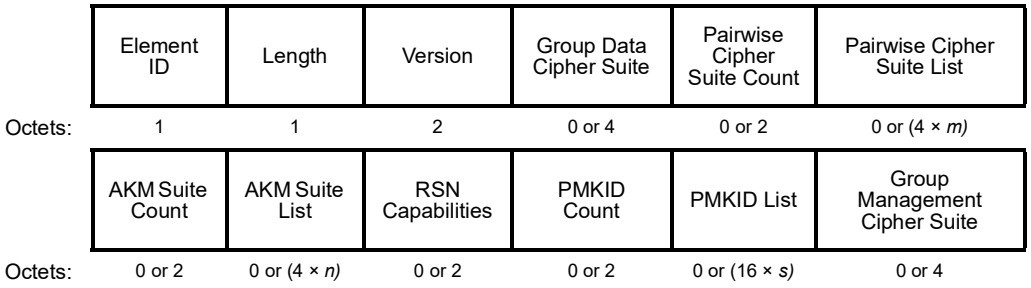


**Figure 9-367—RSNE format(#131)**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The size of (#1776)the RSNE is limited by the size of an element, which is 255 octets. Therefore, the number of pairwise cipher suites, AKM suites, and PMKIDs is limited.


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In Figure 9-367 (RSNE format(#131)), *m* denotes the pairwise cipher suite count, *n* the AKM suite count, and *s* the PMKID count.

All fields use the bit convention from 9.2.2 (Conventions). (#1776)(#6008)All fields after the Version field are optional. (#7227)(#8103)If the Group Data Cipher Suite, Pairwise Cipher Suite Count, AKM Suite Count, RSN Capabilities or PMKID Count field is absent, then all of the subsequent fields are also absent.

The Version field indicates the version number of the RSN protocol. Version 1 is defined in this standard. Other values are reserved.

NOTE 1—The following represent sample elements:

IEEE 802.1X authentication, CCMP-128 pairwise and group data cipher suites(#3056):

30, // Element ID(#6306), i.e., 48 in decimal(#1849)(#1850)
14, // Length in octets, i.e., 20 in decimal(#1849)(#1850)
01 00, // Version 1
00 0F AC 04, // CCMP-128 as group data cipher suite
01 00, // Pairwise cipher suite count(#1850)
00 0F AC 04, // CCMP-128 as pairwise cipher suite
01 00, // AKM suite count(#6265)(#1850)
00 0F AC 01, // IEEE 802.1X authentication(#339)
00 00 // No capabilities

IEEE 802.1X authentication, CCMP-128 pairwise and group data cipher suites(#3056), preauthentication supported:

30, // Element ID(#6306), i.e., 48 in decimal(#1849)(#1850)
14, // Length in octets, i.e., 20 in decimal(#1849)(#1850)
01 00, // Version 1
00 0F AC 04, // CCMP-128 as group data cipher suite
01 00, // Pairwise cipher suite count(#1850)
00 0F AC 04, // CCMP-128 as pairwise cipher suite
01 00, // AKM suite count(#6265)(#1850)
00 0F AC 01, // IEEE 802.1X authentication(#339)
01 00 // Preauthentication capabilities

IEEE 802.1X authentication, (#3056)CCMP-128 pairwise and group data cipher suites optional RSN Capabilities field omitted:

30, // Element ID(#6306), i.e., 48 in decimal(#1849)(#1850)
12, // Length in octets, i.e., 18 in decimal(#1849)(#1850)
01 00, // Version 1
00 0F AC (#3056)04, // CCMP-128 as group data cipher suite
01 00, // Pairwise cipher suite count(#1850)
00 0F AC (#3056)04, // CCMP-128 as pairwise cipher suite
01 00, // AKM suite count(#6265)(#1850)
00 0F AC 01 // IEEE 802.1X authentication

IEEE 802.1X authentication, CCMP-128 pairwise and group data cipher suites, preauthentication and two PMKIDs:(#1979)

30, // Element ID(#6306), i.e., 48 in decimal(#1849)(#1850)
(#1979)36, // Length in octets, i.e., (#1979)54 in decimal(#1849)(#1850)
01 00, // Version 1(#339)
00 0F AC 04, // CCMP-128 as group data cipher suite
01 00, // Pairwise cipher suite count(#1850)
00 0F AC 04, // CCMP-128 as pairwise cipher suite
01 00, // AKM suite count(#6265)(#1850)
00 0F AC 01, // IEEE 802.1X authentication(#339)
01 00, // Preauthentication capabilities(#339)
02 00, // PMKID count(#341)(#339)(#1979)
01 02 03 04 05 06 07 08 09 0A 0B 0C 0D 0E 0F 10, // PMKID
11 12 13 14 15 16 17 18 19 1A 1B 1C 1D 1E 1F 20 // PMKID(#1979)

(#340)(#1979)(FT-)PSK or (FT-)SAE authentication, CCMP-128 pairwise and group data cipher suites, GCMP-128 alternative pairwise data cipher suite and management frame protection with BIP-CMAC-128 as group management cipher suite.

30, // Element ID(#6306), i.e., 48 in decimal(#1849)(#1850)
(#1979)2A, // Length in octets, i.e., (#1979)42 in decimal(#1849)(#1850)
01 00, // Version 1

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00 0F AC 04, // CCMP-128 as group data cipher suite
02 00, // Pairwise cipher suite count(#1850)
00 0F AC 04, // CCMP-128 as pairwise cipher suite
00 0F AC 08, // GCMP-128 as pairwise cipher suite
(#1979)04 00, // AKM suite count(#6265)(#1850)
00 0F AC 02, // PSK authentication(#1979)
00 0F AC 04, // FT-PSK authentication(#1979)
00 0F AC 08, // SAE authentication(#1979)
00 0F AC 09, // FT-SAE authentication(#1979)
80 00, // Management frame protection is enabled but not required(#339)(#1850)
00 00, // PMKID count(#339)(#1979)
00 0F AC 06 // BIP-CMAC-128 as group management cipher suite(#339)

(#4071)NOTE 2—Preauthentication is deprecated.

### 9.4.2.23.2 Cipher suites

The Group Data Cipher Suite field contains the cipher suite selector used in the BSS to protect group addressed Data frames.

The Pairwise Cipher Suite Count field indicates the number of pairwise cipher suite selectors that are contained in the Pairwise Cipher Suite List field. The value 0 is reserved.

(#1929)(#1519)The Pairwise Cipher Suite List field contains a series of cipher suite selectors that indicate the pairwise cipher suite(s) that can be used to protect individually addressed Data frames and, (#2128)when management frame protection is negotiated, to protect individually addressed robust Management frames. (#2128)(#1929)(#3368)Use of BIP-CMAC-128, BIP-GMAC-128, BIP-GMAC-256, and BIP-CMAC-256 is not valid as a data cipher suite.

(#1929)The Group Management Cipher Suite field contains the cipher suite selector that indicates the cipher suite used (#2128)in the BSS to protect group addressed robust Management frames. Use of anything other than BIP-CMAC-128, BIP-GMAC-128, BIP-GMAC-256, and BIP-CMAC-256 is not valid as a group management cipher suite.(#3368)(#3369)

A suite selector has the format shown in Figure 9-368 (Suite selector format).

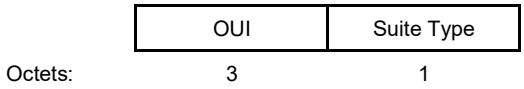


**Figure 9-368—Suite selector format**

The OUI field contains an OUI or CID. The order of the OUI field is described in 9.2.2 (Conventions).

Table 9-188 (Cipher suite selectors) provides the cipher suite selectors defined by this standard.

**Table 9-188—Cipher suite selectors**

| OUI | Suite type | Meaning |
|---|---|---|
| 00-0F-AC | 0 | Use group data cipher suite(#6020) |
| 00-0F-AC | 1 | (#3056)Reserved |
| 00-0F-AC | 2 | TKIP |


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**Table 9-188—Cipher suite selectors *(continued)***

| OUI | Suite type | Meaning |
|---|---|---|
| 00-0F-AC | 3 | Reserved |
| 00-0F-AC | 4 | CCMP-128 |
| 00-0F-AC | 5 | (#3056)Reserved |
| 00-0F-AC | 6 | BIP-CMAC-128 |
| 00-0F-AC | 7 | Group addressed traffic not allowed |
| 00-0F-AC | 8 | GCMP-128 |
| 00-0F-AC | 9 | GCMP-256 |
| 00-0F-AC | 10 | CCMP-256 |
| 00-0F-AC | 11 | BIP-GMAC-128 |
| 00-0F-AC | 12 | BIP-GMAC-256 |
| 00-0F-AC | 13 | BIP-CMAC-256 |
| 00-0F-AC | 14–255 | Reserved |
| Other OUI or CID | Any | Vendor-specific |

In non-DMG RSNA, the cipher suite selector 00-0F-AC:4 (CCMP-128) is the default group data cipher suite(#6020) when the Group Data Cipher Suite field is not included in the RSNE(#1776).

In non-DMG RSNA, the cipher suite selector 00-0F-AC:4 (CCMP-128) is the default pairwise cipher suite when the Pairwise Cipher Suite List field is not included in the RSNE(#1776).

In DMG RSNA, the cipher suite selector 00-0F-AC:8 (GCMP-128) is the default group data cipher suite(#6020) when the Group Data Cipher Suite field is not included in the RSNE(#1776).

In DMG RSNA, the cipher suite selector 00-0F-AC:8 (GCMP-128) is the default pairwise cipher suite when the Pairwise Cipher Suite List field is not included in the RSNE(#1776).

In an RSNA with management frame protection enabled, the cipher suite selector 00-0F-AC:6 (BIP-CMAC-128) is the default group management cipher suite(#6020) when the Group Management Cipher Suite field is not included in the RSNE(#1776).

(11ba)In an RSNA with WUR frame protection enabled, the cipher suite used for protecting WUR Wake-up frames is BIP-CMAC-128 and is not explicitly indicated in the RSNE(#3056).

NOTE—If the AKM Suite List field is present, the Group Data Cipher Suite field and the Pairwise Cipher Suite List field are present. If AKM 00-0F-AC:11, 00-0F-AC:12, or 00-0F-AC:13 is present in the AKM Suite List field, and the MFPC bit of the RSN Capabilities field is 1, the default group management cipher suite is not suitable.(#3760)

Use of any group data cipher suite(#6020) other than TKIP with TKIP as the pairwise cipher suite is not supported.

The cipher suite selector 00-0F-AC:0 (Use group data cipher suite(#6020)) is valid only as the pairwise cipher suite. An AP specifies the selector 00-0F-AC:0 (Use group data cipher suite(#6020)) for a pairwise cipher suite if it does not support any pairwise cipher suites. If an AP specifies 00-0F-AC:0 (Use group data

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cipher suite(#6020)) as the pairwise cipher selection, this is the only pairwise cipher selection the AP advertises.

(#387)If an AP advertises a group data cipher suite(#6020) other than TKIP(#3056), then the AP supports pairwise keys, and thus the pairwise suite selector 00-0F-AC:0 (Use group data cipher suite(#6020)) is not a valid option.

Table 9-189 (Cipher suite usage) indicates the circumstances under which each cipher suite is used. A cipher suite selector is not used in the Group Data Cipher Suite field if No is shown in the GTK column for that cipher suite. A cipher suite selector is not used in the Pairwise Cipher Suite List field if No is shown in the PTK column for that cipher suite. A cipher suite selector is not used in the Group Management Cipher Suite field if No is shown in the IGTK or BIGTK column for that cipher suite.(#1904)

**Table 9-189—Cipher suite usage**

| Cipher suite selector | GTK | PTK | IGTK or BIGTK |
|---|---|---|---|
| Use group data cipher suite(#6020) | No | Yes | No |
| (#3056)TKIP | Yes | Yes | No |
| CCMP-128 | Yes | Yes | No |
| BIP-CMAC-128 | No | No | Yes |
| GCMP-128 | Yes | Yes | No |
| GCMP-256 | Yes | Yes | No |
| CCMP-256 | Yes | Yes | No |
| BIP-GMAC-128 | No | No | Yes |
| BIP-GMAC-256 | No | No | Yes |
| BIP-CMAC-256 | No | No | Yes |

#### 9.4.2.23.3 AKM suites

The AKM Suite Count field indicates the number of AKM suite selectors that are contained in the AKM Suite List field. The value 0 is reserved.

The AKM Suite List field contains a series of AKM suite selectors. In an IBSS only a single AKMP(#3266) selector is specified because IBSS STAs use the same AKM suite and because there is no mechanism to negotiate the AKMP in an IBSS (see 12.6.4 (RSNA policy selection in an IBSS)).

Each AKM suite selector specifies an AKMP. Table 9-190 (AKM suite selectors) gives the AKM suite selectors defined by this standard. An AKM suite selector has the format shown in Figure 9-368 (Suite selector format).

(#3266)AKM 00-0F-AC:1 (i.e., Authentication negotiated over IEEE Std 802.1X with RSNA key management as defined in 12.7 (Keys and key distribution))(#1545) is the default AKMP(#3266) when the AKM Suite List field is not included in the RSNE.


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**Table 9-190—AKM suite selectors**

| OUI | Suite type | Meaning | | | Authentication algorithm numbers (see 9.4.1.1 (Authentication Algorithm Number field)) | Cipher suite selector restriction (M20) |
|---|---|---|---|---|---|---|
| | | Authentication type | Key management type | Key derivation type | | |
| 00-0F-AC | 0 | Reserved | Reserved | Reserved | Reserved | Reserved |
| 00-0F-AC | 1 | Authentication negotiated over IEEE Std 802.1X | RSNA key management as defined in 12.7 (Keys and key distribution) | Defined in 12.7.1.2 (PRF) | 0 (open) | None |
| 00-0F-AC | 2 | PSK | RSNA key management as defined in 12.7 (Keys and key distribution) | Defined in 12.7.1.2 (PRF) | 0 (open) | None |
| 00-0F-AC | 3 | FT authentication negotiated over IEEE Std 802.1X | FT key management as defined in 12.7.1.6 (FT key hierarchy) | Defined in 12.7.1.6.2 (Key derivation function (KDF)) using SHA-256 | 2 (FT) for FT protocol reassociation as defined in 13.5 (FT protocol)<br>0 (open) for FT Initial Mobility Domain Association over IEEE Std 802.1X or PMKSA caching | None |
| 00-0F-AC | 4 | FT authentication using PSK | FT key management as defined in 12.7.1.6 (FT key hierarchy) | Defined in 12.7.1.6.2 (Key derivation function (KDF)) using SHA-256 | 2 (FT) for FT protocol reassociation as defined in 13.5 (FT protocol)<br>0 (open) for FT Initial Mobility Domain Association using PSK | None |
| 00-0F-AC | 5 | Authentication negotiated over IEEE Std 802.1X | RSNA key management as defined in 12.7 (Keys and key distribution) | Defined in 12.7.1.6.2 (Key derivation function (KDF)) using SHA-256 | 0 (open) | None |

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**Table 9-190—AKM suite selectors *(continued)***

| OUI | Suite type | Meaning | | | Authentication algorithm numbers (see 9.4.1.1 (Authentication Algorithm Number field)) | Cipher suite selector restriction (M20) |
|---|---|---|---|---|---|---|
| | | Authentication type | Key management type | Key derivation type | | |
| 00-0F-AC | 6 | PSK | RSNA Key Management as defined in 12.7 (Keys and key distribution) | Defined in 12.7.1.6.2 (Key derivation function (KDF)) using SHA-256 | 0 (open) | None |
| 00-0F-AC | 7 | TDLS | TPK handshake | Defined in 12.7.1.6.2 (Key derivation function (KDF)) using SHA-256 | N/A | None |
| 00-0F-AC | 8 | SAE authentication | RSNA key management as defined in 12.7 (Keys and key distribution), or authenticated mesh peering exchange as defined in 14.6 (Authenticated mesh peering exchange (AMPE)) | Defined in 12.7.1.6.2 (Key derivation function (KDF)) using the hash algorithm specified in 12.4.2 (Assumptions on SAE) | 3 (SAE) for SAE Authentication<br>0 (open) for PMKSA caching | None |
| 00-0F-AC | 9 | FT authentication over SAE | FT key management defined in 12.7.1.6 (FT key hierarchy) | Defined in 12.7.1.6.2 (Key derivation function (KDF)) using the hash algorithm specified in 12.4.2 (Assumptions on SAE) | 3 (SAE) for FT Initial Mobility Domain Association<br>2 (FT) for FT protocol reassociation as defined in 13.5 (FT protocol)<br>0 (open) for FT Initial Mobility Domain Association over PMKSA caching | None |



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**Table 9-190—AKM suite selectors *(continued)***

| OUI | Suite type | Meaning | | | Authentication algorithm numbers (see 9.4.1.1 (Authentication Algorithm Number field)) | Cipher suite selector restriction (M20) |
|---|---|---|---|---|---|---|
| | | Authentication type | Key management type | Key derivation type | | |
| 00-0F-AC | 10 | APPeerKey Authentication with SHA-256 | RSNA key management as defined in 12.7 (Keys and key distribution) | Defined in 12.7.1.6.2 (Key derivation function (KDF)) using SHA-256 | N/A | None |
| 00-0F-AC | 11 | Authentication negotiated over IEEE Std 802.1X using a Suite B compliant EAP method supporting SHA-256 | RSNA key management as defined in 12.7 (Keys and key distribution) | Defined in 12.7.1.6.2 (Key derivation function (KDF)) using SHA-256 | 0 (open) | Used only with cipher suite selector values 00-0F-AC:8 (GCMP-128) and 00-0F-AC:11 (BIP-GMAC-128) |
| 00-0F-AC | 12 | Authentication negotiated over IEEE Std 802.1X using a CNSA Suite compliant EAP method | RSNA key management as defined in 12.7 (Keys and key distribution) | Defined in 12.7.1.6.2 (Key derivation function (KDF)) using SHA-384 | 0 (open) | Used only with cipher suite selector values 00-0F-AC:9 (GCMP-256), 00-0F-AC:10 (CCMP-256), 00-0F-AC:13 (BIP-CMAC-256), and 00-0F-AC:12 (BIP-GMAC-256) |
| 00-0F-AC | 13 | FT authentication negotiated over IEEE Std 802.1X | FT key management as defined in 12.7.1.6 (FT key hierarchy) | Defined in 12.7.1.6.2 (Key derivation function (KDF)) using SHA-384 | 2 (FT) for FT protocol reassociation as defined in 13.5 (FT protocol)<br>0 (open) for FT Initial Mobility Domain Association over IEEE Std 802.1X or PMKSA caching | Used only with cipher suite selector values 00-0F-AC:9 (GCMP-256), 00-0F-AC:10 (CCMP-256), 00-0F-AC:13 (BIP-CMAC-256), and 00-0F-AC:12 (BIP-GMAC-256) |

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**Table 9-190—AKM suite selectors *(continued)***

| OUI | Suite type | Meaning | | | Authentication algorithm numbers (see 9.4.1.1 (Authentication Algorithm Number field)) | Cipher suite selector restriction (M20) |
|---|---|---|---|---|---|---|
| | | Authentication type | Key management type | Key derivation type | | |
| 00-0F-AC | 14 | Key management over FILS using SHA-256 and AES-SIV-256, or authentication negotiated over IEEE Std 802.1X | FILS key management defined in 12.11.2.5 (Key establishment with FILS authentication) | Defined in 12.11.2.5 (Key establishment with FILS authentication) using SHA-256 | 4, 5 or 6 (FILS) for FILS Authentication<br>0 (open) for IEEE Std 802.1X | None |
| 00-0F-AC | 15 | Key management over FILS using SHA-384 and AES-SIV-512, or authentication negotiated over IEEE Std 802.1X | FILS key management defined in 12.11.2.5 (Key establishment with FILS authentication) | Defined in 12.11.2.5 (Key establishment with FILS authentication) using SHA-384 | 4, 5 or 6 (FILS) for FILS Authentication<br>0 (open) for IEEE Std 802.1X | None |
| 00-0F-AC | 16 | FT authentication over FILS with SHA-256 and AES-SIV-256 or authentication negotiated over IEEE Std 802.1X | FT key management as defined in 12.7.1.6 (FT key hierarchy) | Defined in 12.7.1.6.2 (Key derivation function (KDF)) using SHA-256 | 4, 5 or 6 (FILS) for FT Initial Mobility Domain Association over FILS<br>2 (FT) for FT protocol reassociation as defined in 13.5 (FT protocol)<br>0 (open) for FT Initial Mobility Domain Association over IEEE Std 802.1X or PMKSA caching | None |
| 00-0F-AC | 17 | FT authentication over FILS with SHA-384 and AES-SIV-512, or authentication negotiated over IEEE Std 802.1X | FT key management as defined in 12.7.1.6 (FT key hierarchy) | Defined in 12.7.1.6.2 (Key derivation function (KDF)) using SHA-384 | 4, 5 or 6 (FILS) for FT Initial Mobility Domain Association over FILS<br>2 (FT) for FT protocol reassociation as defined in 13.5 (FT protocol)<br>0 (open) for FT Initial Mobility Domain Association over IEEE Std 802.1X or PMKSA caching | None |



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**Table 9-190—AKM suite selectors *(continued)***

| OUI | Suite type | Meaning | | | Authentication algorithm numbers (see 9.4.1.1 (Authentication Algorithm Number field)) | Cipher suite selector restriction (M20) |
|---|---|---|---|---|---|---|
| | | Authentication type | Key management type | Key derivation type | | |
| 00-0F-AC(#1084) | 18 | None | RSNA key management as defined in 12.7 (Keys and key distribution) | (#6088)Defined in 12.7.1.6.2 (Key derivation function (KDF)) using the hash algorithm specified in Table 12-1 (Hash algorithm based on length of prime) | 0 (open) | None |
| 00-0F-AC | 19 | FT authentication using PSK | FT key management as defined in 12.7.1.6 (FT key hierarchy) | Defined in 12.7.1.6.2 (Key derivation function (KDF)) using SHA-384 | 2 (FT) for FT protocol reassociation as defined in 13.5 (FT protocol)<br>0 (open) for FT Initial Mobility Domain Association using PSK | None |
| 00-0F-AC | 20 | PSK | RSNA key management as defined in 12.7 (Keys and key distribution) | Defined in 12.7.1.6.2 (Key derivation function (KDF)) using SHA-384 | 0 (open) | None |
| 00-0F-AC(11az) | 21 | PASN(#8090) | PASN | PASN key management defined in 12.13 (Preassociation security negotiation(11az)) | Defined in 12.13.3 (Key establishment with PASN authentication) | None(#7069) |

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**Table 9-190—AKM suite selectors *(continued)***

| OUI | Suite type | Meaning | | | Authentication algorithm numbers (see 9.4.1.1 (Authentication Algorithm Number field)) | Cipher suite selector restriction (M20) |
|---|---|---|---|---|---|---|
| | | Authentication type | Key management type | Key derivation type | | |
| 00-0F-AC(M20) | 22 | FT authentication negotiated over IEEE Std 802.1X | FT key management as defined in 12.7.1.6 (FT key hierarchy) | Defined in 12.7.1.6.2 (Key derivation function (KDF)) using SHA-384 | 2 (FT) for FT protocol reassociation as defined in 13.5 (FT protocol)<br>0 (open) for FT Initial Mobility Domain Association over IEEE Std 802.1X or PMKSA caching | None |
| 00-0F-AC(M20) | 23 | Authentication negotiated over IEEE Std 802.1X | RSNA key management as defined in 12.7 (Keys and key distribution) | Defined in 12.7.1.6.2 (Key derivation function (KDF)) using SHA-384 | 0 (open) | None |
| 00-0F-AC(M21) | 24 | SAE authentication | RSNA key management as defined in 12.7 (Keys and key distribution), or authenticated mesh peering exchange as defined in 14.6 (Authenticated mesh peering exchange (AMPE)) | Defined in 12.7.1.6.2 (Key derivation function (KDF)) using the hash algorithm specified in 12.4.2 (Assumptions on SAE) | 3 (SAE) for SAE Authentication<br>0 (open) for PMKSA caching | None |
| 00-0F-AC(M21) | 25 | FT authentication over SAE | FT key management defined in 12.7.1.6 (FT key hierarchy) | Defined in 12.7.1.6.2 (Key derivation function (KDF)) using the hash algorithm specified in 12.4.2 (Assumptions on SAE) | 3 (SAE) for FT Initial Mobility Domain Association<br>2 (FT) for FT protocol reassociation as defined in 13.5 (FT protocol)<br>0 (open) for FT Initial Mobility Domain Association over PMKSA caching | None |



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**Table 9-190—AKM suite selectors *(continued)***

| OUI | Suite type | Meaning | | | Authentication algorithm numbers (see 9.4.1.1 (Authentication Algorithm Number field)) | Cipher suite selector restriction (M20) |
|---|---|---|---|---|---|---|
| | | Authentication type | Key management type | Key derivation type | | |
| 00-0F-AC | 26–255( M21) | Reserved | Reserved | Reserved | Reserved | Reserved |
| Other OUI or CID | Any | Vendor-specific | Vendor-specific | Vendor-specific | Vendor-specific | Vendor-specific |

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NOTE 1—(#3266)AKM 00-0F-AC:1 specifies only that (#3469)IEEE Std 802.1X-2020 is used as the authentication transport. IEEE Std 802.1X-2020 selects the authentication mechanism.

NOTE 2—(#3266)AKM 00-0F-AC:11 is deprecated.(M20)

NOTE 3—The usage of (#3266)AKM suite selector values with authentication algorithms is defined in the Authentication algorithm numbers column of Table 9-190 (AKM suite selectors); see 9.4.1.1 (Authentication Algorithm Number field).(M20)

NOTE 4—(#3266)AKMs 00-0F-AC:8 and 00-0F-AC:9 have the length of the PMK in bits equal to 256, the length of the (#3744)PTK-KCK in bits equal to 128, and the length of the PTK-KEK in bits equal to 128 (see 12.7.1.3 (Pairwise key hierarchy), and 12.7.3 (EAPOL-Key PDU construction and processing)). (#3266)AKMs 00-0F-AC:24 and 00-0F-AC:25 have the length of the PMK, the length of the (#8161)SAE key confirmation key, SAE-KCK, and PTK-KCK, and the length of PTK-KEK depending on the hash algorithm specified in 12.4.2 (Assumptions on SAE) (see 12.7.1.3 (Pairwise key hierarchy) and 12.7.3 (EAPOL-Key PDU construction and processing)). (M21)(M67)

(#3266)(#4397)SAE authentication (AKM 00-0F-AC:8 or 00-0F-AC:24)(#1545) is used when(#6183) a password is used with RSNA key management.

NOTE 5—(#3266)(#4397)AKMs 00-0F-AC:1 can simultaneously be enabled with AKM 00-0F-AC:8 or 00-0F-AC:24 or both by an Authenticator.

(#3266)AKM 00-0F-AC:2 (PSK) is used when an alternate form of PSK is used with RSNA key management.

NOTE 6—(#3266)AKMs 00-0F-AC:1 and 00-0F-AC:2 can simultaneously be enabled by an Authenticator.

(#8242)NOTE 7—(M20)A PMKSA established using a given AKM selector value might be cached and used in a subsequent (re)association as defined in 12.6.8.3 (Cached PMKSAs and RSNA key management).

### 9.4.2.23.4 RSN capabilities

The RSN Capabilities field indicates requested or advertised capabilities. If the RSN Capabilities field is not present, the default value of 0 is used for all of the capability subfields.

(#4170)The format of the RSN Capabilities field is as shown in Figure 9-369 (RSN Capabilities field format) and described after the figure.

| | B0 | B1 | B2 | B3 B4 | B5 | B6 | B7 |
|---|---|---|---|---|---|---|---|
| | Preauthentication | Reserved (#3056) | PTKSA Replay Counter | GTKSA Replay Counter | | MFPR | MFPC |
| Bits: | 1 | 1 | 2 | 2 | | 1 | 1 |

| | B8 | B9 | B10 | B11 | B12 | B13 | B14 | B15 |
|---|---|---|---|---|---|---|---|---|
| | Joint Multi-band RSNA | PeerKey Enabled | Reserved (#M57) | Reserved (#M57) | BIP Compact Encapsulation (#1002)(#6054)(#8101) | Extended Key ID for Individually Addressed Frames(#8100) | OCVC | Reserved |
| Bits: | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

**Figure 9-369—RSN Capabilities field format**

— Bit 0: Preauthentication. An AP sets the Preauthentication subfield(#1801) to 1 to signal it supports preauthentication (see 12.6.8.2 (Preauthentication and RSNA key management)) and sets the subfield to 0 when it does not support preauthentication. A non-AP STA sets the Preauthentication subfield to 0.


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(#4071)NOTE—Preauthentication is deprecated.

— Bit 1: (#3056)Reserved

— Bits 2–3: PTKSA Replay Counter. A STA sets the PTKSA Replay Counter subfield(#1801) to the value contained in dot11RSNAConfigNumberOfPTKSAReplayCounters(#1391). (#4175)(#4320)See 12.3.4.6 (TKIP replay protection procedures), 12.5.2.4.4 (PN and replay detection), and 12.5.4.4.4 (PN and replay detection). (#6148)The meaning of the value in the PTKSA Replay Counter subfield is defined in Table 9-191 (PTKSA/GTKSA/TPKSA replay counters usage).

**Table 9-191—PTKSA/GTKSA/TPKSA replay counters usage**

| Replay counter value | Meaning |
|---|---|
| 0 | 1 replay counter per PTKSA/GTKSA/TPKSA(#167)(#8177) |
| 1 | 2 replay counters per PTKSA/GTKSA/ TPKSA(#167)(#8177) |
| 2 | 4 replay counters per PTKSA/GTKSA/TPKSA(#167) |
| 3 | 16 replay counters per PTKSA/GTKSA/TPKSA(#167) |

— Bits 4–5: GTKSA Replay Counter. A STA sets the GTKSA Replay Counter subfield(#1801) to the value contained in dot11RSNAConfigNumberOfGTKSAReplayCounters(#1391). (#4175)(#4320)See 12.3.4.6 (TKIP replay protection procedures), 12.5.2.4.4 (PN and replay detection), and 12.5.4.4.4 (PN and replay detection). The meaning of the value in the GTKSA Replay Counter subfield is defined in Table 9-191 (PTKSA/GTKSA/TPKSA replay counters usage).

— Bit 6: MFPR. A STA sets this bit to 1 to advertise that protection of robust Management frames is mandatory; otherwise it sets this bit to 0.(#199)(#587-Ed1)

— Bit 7: MFPC. A STA sets this bit to 1 to advertise that protection of robust Management frames is enabled; otherwise it sets this bit to 0.(#587)(#199)

— Bit 8: Joint Multi-band RSNA. A STA sets the Joint Multi-band RSNA subfield to 1 to indicate that it supports the Joint Multi-band RSNA (12.6.20 (Multi-band RSNA)). Otherwise, this subfield is set to 0.

— Bits 9: PeerKey Enabled. (#1800)(Ed1)A STA sets the PeerKey Enabled subfield(#1801) to 1 to signal it supports (#1566)(#3221)the TPK handshake (see 12.7.8 (TDLS PeerKey (TPK) security protocol)). Otherwise, this subfield is set to 0.

NOTE 2—AP PeerKey support is not signaled.(#3346)

— Bit 10: Reserved(M57).

— Bit 11: Reserved(M57).

— Bit 12: BIP Compact Encapsulation.(#6054)(#1002)(#8101) An S1G AP sets this bit to 1 to indicate that it supports transmission of S1G Beacon frames protected using BCE and, if bit 7 (MFPC) is set to 1, that S1G Beacons will be protected using BCE. An S1G non-AP STA sets this bit to 1 to indicate that it supports reception of S1G Beacon frames protected using BCE. For non-S1G STAs, this bit is reserved.

— Bit 13: Extended Key ID for Individually Addressed Frames. This subfield is set to 1 to indicate that the STA supports (#3493)key ID values in the range 0 to 1 for a PTKSA when the cipher suite is CCMP or GCMP. Bit 13 set to 0 indicates that the STA only supports (#3493)key ID 0 for a PTKSA.

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— Bit 14: OCVC. This subfield is set to 1 to indicate that the STA supports operating channel validation by including Operating Channel Information (OCI) in RSNA exchanges and validates the information when received from another STA that indicated this capability. Otherwise, this subfield is set to 0. (#1527)

— Bits 15: Reserved.(#1520)

#### 9.4.2.23.5 PMKID

The PMKID Count field indicates the number of PMKIDs that are contained in the PMKID List field. The PMKID List field contains a series (possibly empty) of PMKIDs.

When one or more PMKIDs are included in a (Re)Association Request frame or FILS Authentication frame to an AP, they identify PMKSAs that the STA believes to be valid for the destination AP. When a PMKID is included in a FILS Authentication frame to a STA, it identifies a PMKID that the AP has selected.

A PMKID in the PMKID List field can refer to

a) The PMKID of a cached PMKSA that has been obtained through preauthentication with the target AP

b) The PMKID of a cached PMKSA from an EAP, FILS, or SAE authentication

c) The PMKID of a PMKSA derived from a PSK for the target AP

d) The PMKR0Name of a PMK-R0 security association derived as part of an FT initial mobility domain association

e) The PMKR1Name of a PMK-R1 security association derived as part of an FT initial mobility domain association or as part of a fast BSS transition.

See 12.7.1.3 (Pairwise key hierarchy) and 12.7.1.6.3 (PMK-R0) for the construction of the PMKID, 13.8 (FT authentication sequence) for the population of PMKID List for fast BSS transitions, 12.6.8.3 (Cached PMKSAs and RSNA key management) for the population of PMKID List when using PMKSA caching, 13.4 (FT initial mobility domain association) for the population of PMKID List for FT initial mobility domain association, 12.11.2 (FILS authentication protocol) for the population of PMKID List with FILS authentication, and 12.7.1.6 (FT key hierarchy) for the construction of PMKR0Name and PMKR1Name.

NOTE—A STA need not insert a PMKID in the PMKID List field if the STA (M118)is not using that PMKSA.

### 9.4.2.24 Vendor Specific element

The Vendor Specific element is used to carry information not defined in this standard within a single defined format, so that reserved element IDs are not usurped for nonstandard purposes and so that interoperability is more easily achieved in the presence of nonstandard information. The element is in the format shown in Figure 9-370 (Vendor Specific element format).

| | Element ID | Length | Organization Identifier | Vendor-specific content |
|---|---|---|---|---|
| Octets: | 1 | 1 | 3 or 5(#7136) | variable |

**Figure 9-370—Vendor Specific element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The Organization Identifier field contains the identity of the entity that has defined the content of the Vendor Specific element (see 9.4.1.29 (Organization Identifier field) for a description of the Organization Identifier field contents and length).(#7136)



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(#3376)The Vendor-specific content field contains vendor specific content.

### 9.4.2.25 Extended Capabilities element

The Extended Capabilities element carries information about the capabilities of a STA that augment the capabilities specified in the Capability Information field. The format of this element is shown in Figure 9-371 (Extended Capabilities element format).

| | Element ID | Length | Extended Capabilities |
|---|---|---|---|
| Octets: | 1 | 1 | variable |

**Figure 9-371—Extended Capabilities element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The Extended Capabilities field is a set of 1-bit fields(#291) indicating the extended capabilities being advertised by the STA transmitting the element. (#8141)If fewer bits are received in an Extended Capabilities field than shown in Table 9-192 (Extended Capabilities field), the rest of the Extended Capabilities field bits are assumed to be zero. The Extended Capabilities field is shown in Table 9-192 (Extended Capabilities field).

**Table 9-192—Extended Capabilities field**

| Bit | Information | Notes |
|---|---|---|
| 0 | 20/40 BSS Coexistence Management Support | The 20/40 BSS Coexistence Management Support field indicates support for the 20/40 BSS Coexistence Management frame and its use. The 20/40 BSS Coexistence Management Support field is set to 1 to indicate support for the communication of STA information through the transmission and reception of the 20/40 BSS Coexistence Management frame. The 20/40 BSS Coexistence Management Support field is set to 0 to indicate a lack of support for the communication of STA information through the transmission and reception of the 20/40 BSS Coexistence Management frame. |
| 1 | GLK | The STA sets the GLK field to 1 when dot11GLKImplemented is true and sets it to 0 otherwise. |
| 2 | Extended Channel Switching | The Extended Channel Switching field is 1 to indicate support for the communication of channel switching information through the transmission and reception of the Extended Channel Switch Announcement element and Management frame, as described in 9.6.7.7 (Extended Channel Switch Announcement frame format). The Extended Channel Switching field is 0 to indicate a lack of support for extended channel switching. |
| 3 | GLK-GCR | The STA sets the GLK-GCR field to 1 when dot11GLKGCRImplemented is true and sets it to 0 otherwise. |
| 4–6 | Reserved(#3263) | |
| 7 | Event | The STA sets the Event field to 1 when dot11EventsActivated is true, and sets it to 0 otherwise. See 11.21.2 (Event request and report procedures). |
| 8 | Diagnostics | The STA sets the Diagnostics field to 1 when dot11DiagnosticsActivated is true, and sets it to 0 otherwise. See 11.21.3 (Diagnostic request and report procedures). |
| 9 | Multicast Diagnostics | The STA sets the Multicast Diagnostics field to 1 when dot11MulticastDiagnosticsActivated is true, and sets it to 0 otherwise. See 11.21.3. |

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**Table 9-192—Extended Capabilities field *(continued)***

| Bit | Information | Notes |
|---|---|---|
| 10 | Location Tracking | The STA sets the Location Tracking field to 1 when dot11LocationTrackingActivated is true, and sets it to 0 otherwise. See 11.21.4 (Location track procedures). |
| 11 | FMS | The STA sets the FMS field to 1 when dot11FMSActivated is true, and sets it to 0 otherwise.<br>See 11.2.3.13 (FMS power management) and 11.21.8 (FMS multicast rate processing). |
| 12 | Proxy ARP Service | The AP sets the Proxy ARP Service field to 1 when dot11ProxyARPActivated is true, and sets it to 0 otherwise. See 11.21.14 (Proxy ARP service). A non-AP STA sets the Proxy ARP Service field to 0. |
| 13 | (#2210)Colocated Interference Reporting | The STA sets the (#2210)Colocated Interference Reporting field to 1 when dot11CoLocIntfReportingActivated is true, and sets it to 0 otherwise. See 11.21.9 ((#2210)Colocated interference reporting). |
| 14 | Civic Location | The STA sets the Civic Location field to 1 when dot11RMCivicConfigured is true, and sets it to 0 otherwise. See 11.10.9.9 (Location Civic report). |
| 15 | Geospatial Location | The STA sets the Geospatial Location field to 1 when dot11RMLCIConfigured is true, and sets it to 0 otherwise. See 11.10.9.6 (LCI report (Location configuration information report)). |
| 16 | TFS | The STA sets the TFS field to 1 when dot11TFSActivated is true, and sets it to 0 otherwise. See 11.21.12 (TFS procedures). |
| 17 | WNM Sleep Mode | The STA sets the WNM Sleep Mode field to 1 when dot11WNMSleepModeActivated is true, and sets it to 0 otherwise. See 11.2.3.15 (WNM sleep mode). |
| 18 | TIM Broadcast | The STA sets the TIM Broadcast field to 1 when dot11TIMBroadcastActivated is true, and sets it to 0 otherwise. See 11.2.3.14 (TIM Broadcast). |
| 19 | BSS Transition | The STA sets the BSS Transition field to 1 when dot11BSSTransitionActivated is true, and sets it to 0 otherwise. See 11.21.7 (BSS transition management(#556)). |
| 20 | QoS Traffic Capability | The STA sets the QoS Traffic Capability field to 1 when dot11QoSTrafficCapabilityActivated is true, and sets it to 0 otherwise. See 11.21.10 (QoS Traffic capability procedure). |
| 21 | AC Station Count | The STA sets the AC Station Count field to 1 when dot11ACStationCountActivated is true, and sets it to 0 otherwise. See 11.21.11 (AC Station Count). |
| 22 | Multiple BSSID | The STA sets the Multiple BSSID field to 1 when dot11MultiBSSIDImplemented is true, and sets it to 0 otherwise. See 11.10.14 (Multiple BSSID set) and 11.1.3.8 (Multiple BSSID procedure). |
| 23 | Timing Measurement | The STA sets the Timing Measurement field to 1 when dot11TimingMsmtActivated is true, and sets it to 0 otherwise. See 11.21.5 (Timing measurement procedure). |
| 24 | Channel Usage | The STA sets the Channel Usage field to 1 when dot11ChannelUsageActivated is true and sets it to 0 otherwise. See 11.21.15 (Channel usage procedures). |
| 25 | SSID List | The STA sets the SSID List field to 1 when dot11SSIDListActivated is true, and sets it to 0 otherwise. See 11.1.4 (Acquiring synchronization, scanning). |
| 26 | DMS | The STA sets the DMS field to 1 when dot11DMSActivated is true and sets it to 0 otherwise. See 11.21.16 (Group addressed transmission service). |


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**Table 9-192—Extended Capabilities field *(continued)***

| Bit | Information | Notes |
|---|---|---|
| 27 | UTC TSF Offset | The STA sets the UTC TSF Offset field to 1 when dot11UTCTSFOffsetActivated is true and sets it to 0 otherwise. See 11.19.3 (UTC TSF Offset procedures). |
| 28 | TPU Buffer STA Support | The TPU Buffer STA Support subfield indicates support for the TPU buffer STA function, as defined in 11.2.3.12 (TDLS peer U-APSD (TPU)). When dot11TDLSPeerUAPSDBufferSTAActivated is true, and to indicate support for TPU on this link, the TPU Buffer STA Support subfield is set to 1. Otherwise, the TPU Buffer STA Support subfield is set to 0 to indicate that this capability is not supported on this link. |
| 29 | TDLS Peer PSM Support | The TDLS Peer PSM Support subfield indicates support for TDLS peer PSM, as defined in 11.2.3.11 (TDLS peer power save mode).<br>(#3002)A non-AP STA that has dot11TDLSPeerPSMActivated equal to true indicates support for TDLS peer PSM by setting the TDLS Peer PSM Support subfield to 1. Otherwise, the TDLS Peer PSM Support subfield is set to 0 to indicate that this capability is not supported.<br>(#3002)This subfield is reserved for an AP. |
| 30 | TDLS Channel Switching(#3002) | (#3002)A non-AP STA that has dot11TDLSChannelSwitchingActivated equal to true indicates support for TDLS channel switching as described in 11.20 (Tunneled direct link setup(#1356)) by setting the TDLS Channel Switching subfield to 1. Otherwise, the TDLS Channel Switching subfield is set to 0 to indicate that this capability is not supported.<br>(#3002)This subfield is reserved for an AP. |
| 31 | Interworking | When dot11InterworkingServiceActivated is true, the Interworking field is set to 1 to indicate the STA supports interworking service as described in 11.22 (WLAN interworking with external networks procedures). When dot11InterworkingServiceActivated is false, the Interworking field is set to 0 to indicate the STA does not support this capability. |
| 32 | QoS Map | When dot11QosMapActivated is true, the QoS Map field is set to 1 to indicate the STA supports QoS Map service as described in 11.22.9 (Interworking procedures: support for QoS mapping from external networks). When dot11QosMapActivated is false, the QoS Map field is set to 0 to indicate the STA does not support this capability. |
| 33 | EBR | When dot11EBRActivated is true, the EBR field is set to 1 to indicate the STA supports EBR operation as described in 11.4 (TS operation). When dot11EBRActivated is false, the EBR field is set to 0 to indicate the STA does not support this capability. |
| 34 | SSPN Interface | When dot11SSPNInterfaceActivated is true, the SSPN Interface field is set to 1 to indicate the AP supports SSPN Interface service as described in 11.22.5 (Interworking procedures: interactions with SSPN). When dot11SSPNInterfaceActivated is false, the SSPN Interface is set to 0 to indicate the AP does not support this capability. Non-AP STAs set this field to 0. |
| 35 | Reserved | |
| 36 | MSGCF Capability | When dot11MSGCFActivated is true, the MSGCF Capability field is set to 1 to indicate the non-AP STA supports the MSGCF in 6.4 (Table of MLME SAP interfaces(#1114)). When dot11MSGCFActivated is false, the MSGCF Capability is set to 0 to indicate the non-AP STA does not support this capability. APs set this field to 0. |

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**Table 9-192—Extended Capabilities field *(continued)***

| Bit | Information | Notes |
|---|---|---|
| 37 | TDLS Support | (#3003)The TDLS Support subfield indicates support for TDLS, as defined in 11.20 (Tunneled direct link setup(#1356)).<br>A non-AP STA that has dot11TunneledDirectLinkSetupImplemented equal to true sets this subfield to 1 to indicate support for TDLS and is set to 0 to indicate that TDLS is not supported.<br>This subfield is reserved for an AP. |
| 38 | TDLS Prohibited | (#3004)The TDLS Prohibited subfield indicates whether the use of TDLS is prohibited.<br>An AP sets this subfield to 1 to indicate that TDLS is prohibited and to 0 to indicate that TDLS is allowed.<br>This subfield is reserved for a non-AP STA. |
| 39 | TDLS Channel Switching Prohibited | (#3004)The TDLS Channel Switching Prohibited subfield indicates whether the use of TDLS channel switching is prohibited.<br>An AP sets this subfield to 1 to indicate that TDLS channel switching is prohibited and to 0 to indicate that TDLS channel switching is allowed.<br>This subfield is reserved for a non-AP STA. |
| 40 | Reject Unadmitted Frame | When dot11RejectUnadmittedTraffic is true, the Reject Unadmitted Frame field(#3419) is set to 1 to indicate that the STA does not transmit frames belonging to an unadmitted TS.<br><br>When dot11RejectUnadmittedTraffic is false, the Reject Unadmitted Frame field(#3419) is set to 0 to indicate that the STA might transmit frames belonging to an unadmitted TS.<br><br>When dot11RejectUnadmittedTraffic is not present, the Reject Unadmitted Frame field(#3419) is set to 0. |
| 41-43 | Reserved(#3263) | |
| 44 | Identifier Location | The STA sets the Identifier Location field to 1 when dot11RMIdentifierMeasurementActivated is true, and sets it to 0 otherwise. See 11.10.9.10 (Location Identifier report). |
| 45 | U-APSD Coexistence | The STA sets the U-APSD Coexistence field to 1 when dot11UAPSDCoexistenceActivated is true and sets it to 0 otherwise. See 11.2.3.5.2 (U-APSD coexistence). |
| 46 | WNM Notification | The STA sets the WNM Notification field to 1 when dot11WNMNotificationActivated is true and sets it to 0 otherwise. See 11.21.17 (WNM notification). |
| 47 | QAB Capability | Set to 1 if AP supports QAB<br>Set to 0 otherwise |
| 48 | UTF-8 SSID | The SSID in this BSS is a sequence of UTF-8 encoded code points |
| 49 | QMFActivated | The STA sets the QMFActivated field to 1 when dot11QMFActivated is true and sets it to 0 otherwise. See 11.24 (Quality-of-service Management frame (QMF)). |
| 50 | QMFReconfigurationActivated | The STA sets the QMFReconfigurationActivated field to 1 when dot11QMFActivated is true and sets it to 0 otherwise. See 11.24 (Quality-of-service Management frame (QMF)). |
| 51 | Robust AV Streaming | The STA sets the Robust AV Streaming field to 1 when dot11RobustAVStreamingImplemented is true and sets it to 0 otherwise. See 11.25 (Robust AV streaming). |
| 52 | Advanced GCR | The STA sets the Advanced GCR field to 1 when dot11AdvancedGCRActivated is true and sets it to 0 otherwise. See 11.21.16.3 (GCR procedures). |


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**Table 9-192—Extended Capabilities field *(continued)***

| Bit | Information | Notes |
|---|---|---|
| 53 | Mesh GCR | The STA sets the mesh GCR field to 1 when dot11MeshGCRActivated is true and sets it to 0 otherwise. See 11.21.16.3 (GCR procedures). |
| 54 | SCS | The STA sets the SCS field to 1 when dot11SCSActivated is true and sets it to 0 otherwise. See 11.25.2 (SCS procedures). |
| 55 | QLoad Report | The STA sets the QLoad Report field to 1 when dot11QLoadReportActivated is true and sets it to 0 otherwise. See 11.26.2 (QLoad Report element). |
| 56 | Alternate EDCA | The STA sets the Alternate EDCA field to 1 when dot11AlternateEDCAActivated is true and sets it to 0 otherwise. See 10.2.3.2 (HCF contention based channel access (EDCA)). |
| 57 | Unprotected TXOP Negotiation | The STA sets the Unprotected TXOP Negotiation field to 1 when dot11PublicTXOPNegotiationActivated is true and sets it to 0 otherwise. See 11.26.3 (HCCA TXOP negotiation). |
| 58 | Protected TXOP Negotiation | The STA sets the Protected TXOP Negotiation field to 1 when dot11ProtectedTXOPNegotiationActivated is true and sets it to 0 otherwise. See 11.26.3 (HCCA TXOP negotiation). |
| 59 | Reserved | |
| 60 | Protected QLoad Report | The STA sets the Protected QLoad Report field to 1 when dot11ProtectedQLoadReportActivated is true and sets it to 0 otherwise. See 11.26.2 (QLoad Report element). |
| 61 | TDLS Wider Bandwidth | The TDLS Wider Bandwidth subfield indicates whether the STA supports a wider bandwidth than the BSS bandwidth for a TDLS direct link with a primary channel equal to the base channel. The field is set to 1 to indicate that the STA supports a wider bandwidth and to 0 to indicate that the STA does not support a wider bandwidth. A 160 MHz bandwidth is defined to be identical to an 80+80 MHz bandwidth (i.e., one is not wider than the other). |
| 62 | Operating Mode Notification | If dot11OperatingModeNotificationImplemented is true, the Operating Mode Notification field is set to 1 to indicate support for reception of the Operating Mode Notification element and the Operating Mode Notification frame.<br>If dot11OperatingModeNotificationImplemented is false or not present, the Operating Mode Notification field is set to 0 to indicate lack of support for reception of the Operating Mode Notification element and the Operating Mode Notification frame. |
| 63–64 | Max Number Of MSDUs In A-MSDU | Indicates the maximum number of MSDUs in an A-MSDU that the STA is able to receive from a VHT STA:<br>Set to 0 to indicate that no limit applies.<br>Set to 1 for 32.<br>Set to 2 for 16.<br>Set to 3 for 8<br>Reserved if A-MSDU is not supported or if the STA is not an HT STA. |
| 65 | Channel Schedule Management | The STA sets the Channel Schedule Management field to 1 when dot11ChannelScheduleManagementActivated is true and sets it to 0 otherwise. See 11.42.5 (Channel schedule management (CSM) procedures). |
| 66 | Geodatabase Inband Enabling Signal | The STA sets the Geodatabase Inband Enabling Signal field to 1 when dot11GDDActivated is true and the STA permits GDD dependent STAs to operate. See 11.42.2 (GDD enabling STA operation). |
| 67 | Network Channel Control | The STA sets the Network Channel Control field to 1 when dot11NetworkChannelControlActivated is true and sets it to 0 otherwise. See 11.42.7 (Network channel control (NCC) procedures). |

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**Table 9-192—Extended Capabilities field *(continued)***

| Bit | Information | Notes |
|---|---|---|
| 68 | White Space Map | The STA sets the White Space Map field to 1 when dot11WhiteSpaceMapActivated is true and sets it to 0 otherwise. See 11.42.8 (White space map (WSM)). |
| 69 | Channel Availability Query | The STA sets the Channel Availability Query field to 1 when dot11GDDActivated is true and sets it to 0 otherwise. See 11.42.4 (Channel availability query (CAQ) procedure). |
| 70 | (#7065)FTM Responder | The STA sets the (#7065)FTM Responder field to 1 when dot11FineTimingMsmtRespActivated is true and sets it to 0 otherwise. See 11.21.6 (FTM procedure(#7065)). |
| 71 | (#7065)FTM Initiator | The STA sets the (#7065)FTM Initiator field to 1 when dot11FineTimingMsmtInitActivated is true and sets it to 0 otherwise. See 11.21.6 (FTM procedure(#7065)). |
| 72 | FILS Capability | The FILS Capability field is set to 1 if dot11FILSActivated is true. Otherwise, the FILS Capability field is 0. |
| 73 | Extended Spectrum Management Capable | The STA sets the Extended Spectrum Management Capable field to 1 when dot11ExtendedSpectrumManagementImplemented is true and dot11VHTOptionImplemented is false, and sets it to 0 otherwise. |
| 74 | Future Channel Guidance | The STA sets the Future Channel Guidance field to 1 when dot11FutureChannelGuidanceActivated is true and sets it to 0 otherwise. See 11.8.10 (Future Channel Guidance operation). |
| 75 | PAD | Indicates support for PAD (see 11.23 (Preassociation discovery (PAD) procedures)). |
| 76(11ax) | Reserved | |
| 77(11ax) | TWT Requester Support | A STA sets the TWT Requester Support field to 1 if dot11TWTOptionActivated is true and TWT requester functionality is supported. Otherwise, the STA sets the TWT Requester Support field to 0. See 10.46 (Target wake time (TWT)). |
| 78(11ax) | TWT Responder Support | A STA sets the TWT Responder Support field to 1 if dot11TWTOptionActivated is true and TWT responder functionality is supported. Otherwise, the STA sets the TWT Responder Support field to 0. See 10.46 (Target wake time (TWT)). |
| 79(11ax) | OBSS Narrow Bandwidth RU In OFDMA Tolerance Support | An AP STA sets the OBSS Narrow Bandwidth RU In OFDMA Tolerance Support field to 1 if dot11OBSSNarrowBWRUinOFDMATolerated is true, and sets it to 0 otherwise.<br><br>A non-AP STA sets the OBSS Narrow Bandwidth RU In OFDMA Tolerance Support field to 0. |
| 80 | Complete List of NonTxBSSID Profiles | This field is reserved for a non-AP STA or when the AP has dot11MultiBSSIDImplemented set to false.<br><br>(11ax)Set to 1 to indicates that the frame carrying this element includes a complete list of nontransmitted BSSID profiles.<br>Set to 0 by a non-HE AP if there is no indication about the completeness of the list of nontransmitted BSSID profiles in the frame.<br>Set to 0 by an HE AP to indicate that the frame carrying this element does not include a complete list of nontransmitted BSSID profiles.<br><br>Also see 11.1.3.8 (Multiple BSSID procedure). |


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**Table 9-192—Extended Capabilities field *(continued)***

| Bit | Information | Notes |
|---|---|---|
| 81 | SAE Password Identifiers In Use | The AP sets the SAE Password Identifiers In Use field to 1 when any password in the dot11RSNAConfigPasswordValueTable has a password identifier and sets it to 0 otherwise. See 12.4.3 (Representation of a password). |
| 82 | SAE Password Identifiers Used Exclusively | The AP sets the SAE Password Identifiers Used Exclusively field to 1 when every password in the dot11RSNAConfigPasswordValueTable has a password identifier and sets it to 0 otherwise. See 12.4.3 (Representation of a password). |
| 83(11ax) | Enhanced Multi-BSSID Advertisement Support | This field is reserved for a non-AP STA or when the AP has dot11MultiBSSIDImplemented set to false.<br><br>Set to 1 to indicate that the AP supports enhancements related to discovery and advertisement of nontransmitted BSSIDs. Set to 0 otherwise.<br><br>Also see 11.1.3.8 (Multiple BSSID procedure). |
| 84 | Beacon Protection Enabled | The AP sets the Beacon Protection Enabled field to 1 when dot11BeaconProtectionEnabled is true. Otherwise, it is set to 0.<br>This field is reserved for a non-AP STA.<br>See 11.52 (Beacon protection procedures(#8133)). |
| 85 | Mirrored SCS | The STA sets the Mirrored SCS field to 1 when dot11MSCSActivated is true and sets it to 0 otherwise. |
| 86(11ax) | OCT | The non-AP STA sets the OCT field to 1 when dot11OCTOptionImplemented is true and sets it to 0 otherwise.<br><br>This field is reserved for an AP. |
| 87 | Local MAC Address Policy | When dot11LocalMACAddressPolicyActivated is true, the Local MAC Address Policy subfield is set to 1. When dot11LocalMACAddressPolicyActivated is false, the Local MAC Address Policy subfield is set to 0. |
| 88(#7061) | | *Allocated to the Wi-Fi Alliance* [a]. |
| 89(11ax) | TWT Parameters Range Support | Set to 1 to indicate support for reception of a TWT Setup frame that contains two TWT elements (see 10.46.9 (TWT parameter ranges(11ax))); otherwise, set to 0. |
| 90(11az) | Non-TB Ranging Responder | A STA sets the Non-TB Ranging Responder field to 1 if dot11NonTriggedBasedRangingRespImplemented is true. Otherwise the STA sets the Non-TB Ranging Responder field to 0; see 11.21.6 (FTM procedure(#7065)). |
| 91(11az) | TB Ranging Responder | A STA sets the TB Ranging Responder field to 1 if dot11TriggerBasedRangingRespImplemented is true. Otherwise the STA sets the TB Ranging Responder field to 0; see 11.21.6 (FTM procedure(#7065)). |
| 92(11az) | Passive TB Ranging Responder Measurement Support | A STA sets the Passive TB Ranging Responder Measurement Support field to 1 when dot11PassiveTBRangingResponderImplemented is true. Otherwise, the STA sets Passive TB Ranging Responder Measurement Support field to 0. See 11.21.6.4.8 (Measurement exchange in passive TB ranging mode(11az)). |
| 93(11az) | Passive TB Ranging Initiator Measurement Support | A STA sets the Passive TB Ranging Initiator Measurement Support field to 1 when dot11PassiveTBRangingInitiatorImplemented is true. Otherwise, the STA sets the Passive TB Ranging Initiator Measurement Support field to 0. See 11.21.6.4.8 (Measurement exchange in passive TB ranging mode(11az)). |
| 94(11az) | AOA Measurements Available | A STA sets the AOA Measurement Available field to 1 when dot11AOAMeasurementImplemented is true. Otherwise, the STA sets the AOA Measurement Available field to 0. |

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**Table 9-192—Extended Capabilities field *(continued)***

| Bit | Information | Notes |
|---|---|---|
| 95(11az) | Phase Shift Feedback Support | A STA sets the Phase Shift Feedback Support field to 1 or 0 as specified in 11.21.6.2 (FTM capabilities).<br>It indicates the LMR transmitted by the STA can carry Phase Shift Feedback. |
| 96(11az) | DMG/Location Supporting APs In The Area | An AP STA sets this field to 1 to indicate that APs providing location services using DMG are in the vicinity of the AP STA. Definition of vicinity is implementation dependent.<br>(#8243)NOTE—The AP might be capable of providing information about those DMG APs. |
| 97(11az) | I2R LMR Feedback Policy | A STA sets the I2R LMR Feedback Policy field to 1 if dot11I2RLMRFeedbackPolicy is true. Otherwise the STA sets the I2R LMR Feedback Policy field to 0. See 11.21.6.3.3 (Negotiation for TB and non-TB ranging measurement exchange).<br>The I2R LMR Feedback Policy field indicates the policy of the STA in the role of an RSTA, and it is reserved for a STA in the role of an ISTA. |
| 98(11bc) | EBCS Support | A STA sets the EBCS Support field to 1 when dot11EBCSSupportActivated is true. Otherwise, the STA sets the EBCS Support field to 0. |
| 99(11bc) | EBCS Relaying Supported | An EBCS relaying STA that has dot11EBCSRelayingServiceImplemented equal to true sets the EBCS Relaying Supported field to 1. Otherwise, an EBCS relaying STA sets the field to 0. |
| 100 (#1024) | Peer-to-peer TWT Support(#3150) | Set to 1 to indicate support for reception of a Channel Usage Request frame that includes one or more TWT elements. Set to 0 otherwise.(#3388) |
| 101(#3018) | Multiple BSSID Role Switch Support | A STA that has dot11MultiBSSIDImplemented equal to true sets this field to 1 to indicate support for the procedure described in 11.1.3.8.6 (Multiple BSSID Index Adjustment Procedure(#3018)). Otherwise, this field is set to 0. |
| 102(#4069) | Known STA Identification Enabled | Set to 1 to indicate that the AP has enabled use of Known STA Identification element. Set to 0 otherwise. This field is reserved for a non-AP STA. |
| 103 | Reserved | |
| 104(#6016) | Capability Notification Support | In an AP, set to 1 to indicate the AP supports reception of a Channel Usage Request frame that includes capabilities elements. Set to 0 otherwise.<br>In a non-AP STA, set to 1 to indicate the STA supports transmission of a Channel Usage Request frame that includes capabilities elements. Set to 0 otherwise. |
| 105 (#6058) | GAS Query Request Fragmentation | When dot11GASQueryRequestFragmentationActivated is true, the GAS Query Request Fragmentation field is set to 1 to indicate the STA supports GAS query request fragmentation as described in 11.22.3.2 (GAS Protocol). When dot11GASQueryRequestFragmentationActivated is false, the GAS Query Request Fragmentation field is set to 0 to indicate the STA does not support this capability. |
| 106–109 | Reserved | |
| 110 (#7096) | Tunneled PASN Support | Set to 1 to indicate that the AP supports the tunneled PASN feature. |
| 101–*n* (#4091) (#7096) | Reserved | |

[a] See http://www.wi-fi.org.



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If a STA does not support (#470)any of the capabilities defined in the Extended Capabilities element, then the STA is not required to transmit the Extended Capabilities element.

NOTE—The fields of the Extended Capabilities element are not dynamic. They are determined by the parameters of the MLME-START.request or MLME-JOIN.request primitive that caused the STA to start or join its current BSS, and they remain unchanged until the next MLME-START.request or MLME-JOIN.request primitive.

### 9.4.2.26 BSS Load element

The BSS Load element contains information on the current STA population and traffic levels in the BSS. The element information format is defined in Figure 9-372 (BSS Load element format). This element might be used by the STA for vendor-specific AP selection algorithm when performing BSS transition.(#1600)

| | Element ID | Length | Station Count | Channel Utilization | Available Admission Capacity |
|---|---|---|---|---|---|
| Octets: | 1 | 1 | 2 | 1 | 2 |

**Figure 9-372—BSS Load element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The Station Count field (#2047)indicates the total number of STAs currently associated with this BSS.

The Channel Utilization field is defined as the percentage of time, linearly scaled with 255 representing 100%, that the AP sensed the medium was busy, as indicated by either the physical or virtual carrier sense (CS) mechanism. When more than one channel is in use for the BSS, the Channel Utilization field value is calculated only for the primary channel. This percentage is computed using the following formula:

$$\text{Channel Utilization} = \left\lfloor \frac{\text{channel busy time}}{\text{dot11ChannelUtilizationBeaconIntervals} \times \text{dot11BeaconPeriod} \times 1024} \times 255 \right\rfloor$$

where

channel busy time is defined to be the number of microseconds during which the CS mechanism, as defined in 10.3.2.1 (CS mechanism), has indicated a channel busy indication,

dot11ChannelUtilizationBeaconIntervals represents the number of consecutive beacon intervals during which the channel busy time is measured.

The Available Admission Capacity field contains an unsigned integer that specifies the remaining amount of medium time available via explicit admission control, in units of 32 μs/s. The field is helpful for (#1600)BSS transitioning STAs to select an AP that is likely to accept future admission control requests, but it does not represent an assurance that the HC admits these requests.

### 9.4.2.27 EDCA Parameter Set element

The EDCA Parameter Set element provides information needed by STAs for proper operation of the QoS facility. The format of the EDCA Parameter Set element is defined in Figure 9-373 (EDCA Parameter Set element format).

The Element ID and Length fields are defined in 9.4.2.1 (General).

For an infrastructure BSS, the EDCA Parameter Set element is used by the AP to establish policy (by changing default MIB attribute values), to change policies when accepting new STAs or new traffic, or to

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| | Element ID | Length | QoS Info | Update EDCA Info | AC_BE Parameter Record | AC_BK Parameter Record | AC_VI Parameter Record | AC_VO Parameter Record |
|---|---|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 1 | 4 | 4 | 4 | 4 |

**Figure 9-373—EDCA Parameter Set element format**

adapt to changes in offered load. The most recent (#327)EDCA Parameter Set element received by a STA is used to update the appropriate MIB values.

The format of the QoS Info field is defined in 9.4.1.17 (QoS Info field).(11ax)

NOTE 1—The QoS Info field contains the EDCA Parameter Set Update Count subfield, which indicates when the EDCA parameters and, for an HE BSS, the MU EDCA parameters have changed (see 10.2.3.2 (HCF contention based channel access (EDCA))).

The Update EDCA Info field is reserved for non-S1G STAs. For S1G STAs, it is shown in Figure 9-374 (Update EDCA Info field format).

| | B0 | B1 B2 | B3 B4 | B5 B6 | B7 |
|---|---|---|---|---|---|
| | Override | PS-Poll ACI | RAW ACI | STA Type | Reserved |
| Bits: | 1 | 2 | 2 | 2 | 1 |

**Figure 9-374—Update EDCA Info field format**

The Override field is used by S1G APs to indicate to S1G STAs that this element overrides previously stored EDCA parameters as described in 10.2.3.2 (HCF contention based channel access (EDCA)).

The PS-Poll ACI field is used by S1G APs to inform the S1G STAs of the access category for sending a PS-Poll frame. The mapping between the PS-Poll ACI field and AC is identical to the one defined in Table 9-193 (ACI-to-AC coding).

The RAW ACI field is used by S1G APs to inform the S1G STAs of the access category for accessing the WM in the RAW as described in 10.23.5.5 (EDCA backoff procedure in generic RAW or triggering frame RAW). The mapping between the RAW ACI field and AC is identical to the one defined in Table 9-193 (ACI-to-AC coding).

The STA Type field indicates the type of STA for which the information in the element is provided. The S1G AP sets the STA Type field to

- 0 to indicate that the information provided by this element is valid for STAs (i.e., both sensor STAs and non-sensor STAs)
- 1 to indicate that the information is valid for sensor STAs
- 2 to indicate that the information provided by this element is valid for non-sensor STAs
- 3 to indicate a reserved value

NOTE 2—An S1G STA that transmits a (NDP) PS-Poll frame within a RAW uses the access category indicated by PS-Poll ACI subfield rather than the access category indicated by the RAW ACI subfield.

The formats of AC_BE, AC_BK, AC_VI, and AC_VO Parameter Record fields are identical and are shown in Figure 9-375 (AC_BE, AC_BK, AC_VI, and AC_VO Parameter Record field format).


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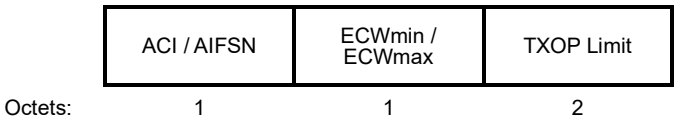


**Figure 9-375—AC_BE, AC_BK, AC_VI, and AC_VO Parameter Record field format**

The format of the ACI/AIFSN field is shown in Figure 9-376 (ACI/AIFSN field format).

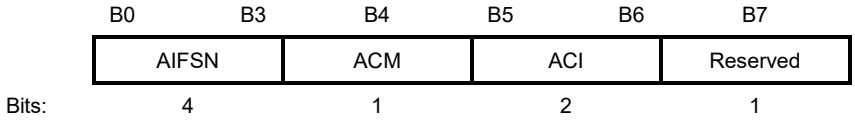


**Figure 9-376—ACI/AIFSN field format**

The value of the AC index (ACI) references the AC to which all parameters in this record correspond. The mapping between ACI and AC is defined in Table 9-193 (ACI-to-AC coding). The ACM (admission control mandatory) subfield indicates that admission control is required for the AC. If the ACM subfield is equal to 0, then there is no admission control for the corresponding AC. If the ACM subfield is set to 1, admission control has to be used prior to transmission using the access parameters specified for this AC. The AIFSN subfield indicates the number of slots after a SIFS a STA defers before either invoking a backoff or starting a transmission. The minimum value of the AIFSN subfield is 2.

**Table 9-193—ACI-to-AC coding**

| ACI | AC | Description |
|---|---|---|
| 0 | AC_BE | Best effort |
| 1 | AC_BK | Background |
| 2 | AC_VI | Video |
| 3 | AC_VO | Voice |

The ECWmin/ECWmax field is shown in Figure 9-377 (ECWmin/ECWmax field format).

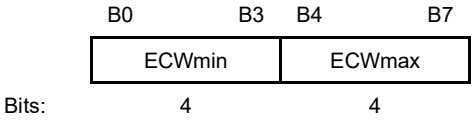


**Figure 9-377—ECWmin/ECWmax field format**

The ECWmin and ECWmax subfields encode the values of CWmin and CWmax, respectively, in an exponent form. The ECWmin and ECWmax values are defined so that

$$CWmin = 2^{ECWmin} - 1$$

$$CWmax = 2^{ECWmax} - 1$$

Hence the minimum encoded value of CWmin and CWmax is 0, and the maximum value is 32 767.

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The TXOP Limit field is specified as an unsigned integer, in units of 32 μs. A TXOP Limit field set to 0 has a special meaning (see 10.23.2.9 (TXOP limits)).

Table 9-194 (Default EDCA Parameter Set element (#1660)parameters if dot11OCBActivated is false and the STA is a non-sensor STA(#251)) defines the default EDCA parameters(#1660) used by a non-AP STA if dot11OCBActivated is false.[23]

**Table 9-194—Default EDCA Parameter Set element (#1660)parameters if dot11OCBActivated is false and the STA is a non-sensor STA(#251)**

| AC | CWmin | CWmax | AIFSN | TXOP limit | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | For PHYs defined in Clause 15 (DSSS PHY specification for the 2.4 GHz band designated for ISM applications) and Clause 16 (High rate direct sequence spread spectrum (HR/DSSS) PHY specification) | (#4101)For PHYs defined in Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification), Clause 18 (Extended Rate PHY (ERP) specification), Clause 19 (High Throughput (HT) PHY specification(#2297)), Clause 21 (Very high throughput (VHT) PHY specification), and Clause 27 (High-efficiency (HE) PHY specification(11ax)) | For PHY defined in Clause 22 (Television very high throughput (TVHT) PHY specification) | Clause 23 (Sub 1 GHz (S1G) PHY specification(#4095)) | Other PHYs |
| AC_BK | aCWmin | aCWmax | 7 | 3.264 ms | 2.528 ms | 0 | 15.008 ms | 0 |
| AC_BE | aCWmin | aCWmax | 3 | 3.264 ms | 2.528 ms | 0 | 15.008 ms | 0 |
| AC_VI | (aCWmin+1)/2 – 1 | aCWmin | 2 | 6.016 ms | 4.096 ms | 22.56 ms (BCU: 6 or 7 MHz), 16.92 ms (BCU: 8 MHz) | 15.008 ms | 0 |
| AC_VO | (aCWmin+1)/4 – 1 | (aCWmin+1)/2 – 1 | 2 | 3.264 ms | 2.080 ms | 11.28 ms (BCU: 6 or 7 MHz), 8.46 ms (BCU: 8 MHz) | 15.008 ms | 0 |

[23] The default values for TXOP limit are expressed in milliseconds and are multiples of 32 μs.


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If dot11OCBActivated is true, the default EDCA parameter set for STAs transmitting QoS frames is given in Table 9-195 (Default EDCA parameter set for STA operation if dot11OCBActivated is true).

**Table 9-195—Default EDCA parameter set for STA operation if dot11OCBActivated is true**

| AC | CWmin | CWmax | AIFSN | TXOP limit |
|---|---|---|---|---|
| AC_BK | aCWmin | aCWmax | 9 | 0 |
| AC_BE | aCWmin | aCWmax | 6 | 0 |
| AC_VI | aCWmin | aCWmax | 4 | 0 |
| AC_VO | (aCWmin+1)/4–1 | (aCWmin+1)/2–1 | 2 | 0 |

The default EDCA parameter set used by sensor STAs is given in Table 9-196 (Default EDCA Parameter Set element (#1660)parameters if the STA is a sensor STA).

**Table 9-196—Default EDCA Parameter Set element (#1660)parameters if the STA is a sensor STA**

| AC | CWmin | CWmax | AIFSN | TXOP limit |
|---|---|---|---|---|
| AC_BK | aCWmin | aCWmax | 7 | 0 |
| AC_BE | (aCWmin+1)/4 – 1 | aCWmin | 2 | 0 |
| AC_VI | (aCWmin+1)/2 – 1 | aCWmin | 5 | 0 |
| AC_VO | (aCWmin+1)/2 – 1 | aCWmin | 4 | 0 |

### 9.4.2.28 TSPEC element

(#1776)The traffic specification (TSPEC) element contains the set of parameters that define the characteristics and QoS expectations of a traffic flow, in the context of a particular STA, for use by the HC or PCP and STA(s) or a mesh STA and its peer mesh STAs in support of QoS traffic transfer using the procedures defined in 11.4 (TS operation) and 11.21.16.3 (GCR procedures), or for use by HE STAs in support of HE AP scheduling for EDCA or MU operations (see 26.5 (MU operation)).(11ax) The element information format comprises the items as defined in this subclause, and the structure is defined in Figure 9-378 (TSPEC element format).

The TSPEC element allows a set of parameters more extensive than might be needed, or might be available, for any particular instance of parameterized QoS traffic. Unless indicated otherwise, fields that follow the TS Info field are set to 0 for any unspecified parameter values. STAs set any parameters to unspecified if they have no information for setting that parameter.

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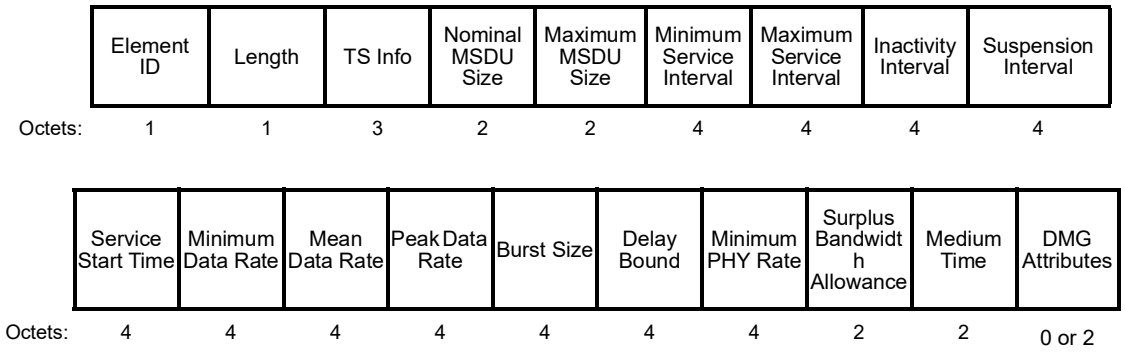


**Figure 9-378—TSPEC element format**

The structure of the TS Info field is defined in Figure 9-379 (TS Info field format).

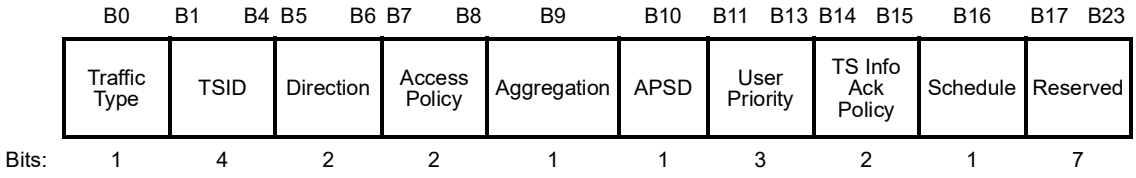


**Figure 9-379—TS Info field format**

The subfields of the TS Info field are defined as follows:

— The Traffic Type subfield is set to 1 for a periodic traffic pattern (e.g., isochronous TS of MSDUs or A-MSDUs, with constant or variable sizes, that are originated at fixed rate) or set to 0 for an aperiodic, or unspecified, traffic pattern (e.g., asynchronous TS of low-duty cycles).

— The TSID subfield contains a value that is a TSID. Note that the MSB (bit 4 in TS Info field) of the TSID subfield is always set to 1 when the TSPEC element is included within an ADDTS Response frame.

— The Direction subfield specifies the direction of data carried by the TS as defined in Table 9-197 (Direction subfield encoding).

**Table 9-197—Direction subfield encoding**

| Bit 5 | Bit 6 | Usage |
|---|---|---|
| 0 | 0 | Uplink, defined as follows:<br>— Non-DMG BSS: MSDUs or A-MSDUs are sent from the non-AP non-HE STA to HC or from the non-AP HE STA to the HE AP.(11ax)<br>— DMG BSS: MSDUs or A-MSDUs are sent by the originator of the ADDTS Request frame. |
| 1 | 0 | Downlink, defined as follows:<br>— Non-DMG BSS: MSDUs or A-MSDUs are sent from the HC to the non-AP non-HE STA or from the HE AP to the non-AP HE STA.(11ax)<br>— DMG BSS: MSDUs or A-MSDUs are sent by the recipient of the ADDTS Request frame. |



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**Table 9-197—Direction subfield encoding *(continued)***

| Bit 5 | Bit 6 | Usage |
|---|---|---|
| 0 | 1 | Direct link (MSDUs or A-MSDUs are sent from the non-AP STA to another non-AP STA) |
| 1 | 1 | Bidirectional link (equivalent to a downlink request plus an uplink request, each direction having the same parameters).<br>The fields in the TSPEC element specify resources for a single direction.<br>Double the specified resources are required to support both streams. |

— The Access Policy subfield specifies the access method to be used for the TS, and is defined in Table 9-198 (Access Policy subfield).

**Table 9-198—Access Policy subfield**

| Bit 7 | Bit 8 | Usage |
|---|---|---|
| 0 | 0 | Reserved |
| 1 | 0 | (11ax)For non-HE STAs: Contention based channel access (EDCA).<br>(11ax)For HE STAs: EDCA or MU based access (see 26.5 (MU operation)) |
| 0 | 1 | Controlled channel access (HCCA for non-DMG STAs and SPCA for DMG STAs) |
| 1 | 1 | Controlled and contention based channel access (HCCA, EDCA mixed mode (HEMM) for non-DMG STAs; SPCA, EDCA mixed mode (SEMM) for DMG STAs) |

— The Aggregation subfield is valid only when the access method is HCCA or SPCA or when the access method is EDCA and the Schedule subfield is equal to 1. It is set to 1 by a non-AP STA to indicate that an aggregate schedule is required. It is set to 1 by the AP if an aggregate schedule is being provided to the STA. It is set to 0 otherwise. In all other cases, the Aggregation subfield is reserved.

— The APSD subfield is set to 1 to indicate that automatic PS delivery is to be used for the traffic associated with the TSPEC and set to 0 otherwise.

— The UP subfield indicates the actual value of the UP to be used for the transport of MSDUs or A-MSDUs belonging to this TS (11ax)if relative prioritization is required. When the TCLAS element is present in the request, the UP subfield in TS Info field of the TSPEC element is reserved.

— The TS Info Ack Policy subfield indicates whether MAC acknowledgments are required for MPDUs or A-MSDUs belonging to this TSID and the form of those acknowledgments. The

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encoding of the TS Info Ack Policy subfield is shown in Table 9-199 (TS Info Ack Policy subfield encoding).

**Table 9-199—TS Info Ack Policy subfield encoding**

| Bit 14 | Bit 15 | Usage |
|---|---|---|
| 0 | 0 | Normal Ack.(11ax)<br>The addressed recipient returns an Ack or QoS +CF-Ack frame after a SIFS, according to the procedures defined in 10.3.2.11 (Acknowledgment procedure) and 10.23.3.5 (HCCA transfer rules). |
| 1 | 0 | No Ack: The recipient(s) do not acknowledge the transmission. |
| 0 | 1 | Reserved |
| 1 | 1 | Block Ack: A separate block ack mechanism described in 10.25 (Block acknowledgment (block ack)) is used. |

— The Schedule subfield specifies the requested type of schedule. The setting of the subfield when the access policy is EDCA is shown in Table 9-200 (Setting of Schedule subfield). When the Access Policy subfield is equal to any value other than EDCA, the Schedule subfield is reserved. When the Schedule and APSD subfields are equal to 1, the AP sets the Aggregation subfield to 1, indicating that an aggregate schedule is being provided to the STA.

**Table 9-200—Setting of Schedule subfield**

| APSD | Schedule | Usage |
|---|---|---|
| 0 | 0 | No Schedule |
| 1 | 0 | Unscheduled APSD |
| 0 | 1 | (#3263)GCR-SP |
| 1 | 1 | Scheduled APSD |

The Nominal MSDU Size field contains an unsigned integer that specifies the nominal size, in octets, of MSDUs or (where A-MSDU aggregation is employed) A-MSDUs belonging to the TS under this TSPEC element and is defined in Figure 9-380 (Nominal MSDU Size field format). If the Fixed subfield is equal to 1, then the size of the MSDU or A-MSDU is fixed and is indicated by the Size subfield. If the Fixed subfield is equal to 0, then the size of the MSDU or A-MSDU might not be fixed and the Size subfield indicates the nominal MSDU size. If both the Fixed and Size subfields are equal to 0, then the nominal MSDU or A-MSDU size is unspecified.

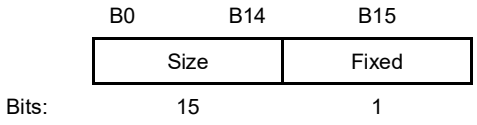


**Figure 9-380—Nominal MSDU Size field format**

The Maximum MSDU Size field contains an unsigned integer that specifies the maximum size, in octets, of MSDUs or A-MSDUs belonging to the TS under this TSPEC element.

The Minimum Service Interval field contains an unsigned integer that specifies the minimum interval, in microseconds, between the start of two successive SPs. If the TSPEC element is included within a GCR Request subelement that has the GCR delivery method equal to GCR-SP, a Minimum Service Interval field


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set to 0 indicates that SPs up to the maximum service interval are requested, including the continuous SP used by the GCR-A delivery method.

The Maximum Service Interval field contains an unsigned integer that, when the TSPEC element is for the admitting of HCCA streams, specifies the maximum interval, in microseconds, between the start of two successive SPs. If the TSPEC element is intended for EDCA Admission Control, the Maximum Service Interval field is used to indicate a latency limit, which limits the amount of aggregation (A-MSDU or A-MPDU) used, so that excessive latency does not occur (see K.4.3.1 (Scheduled traffic)). The Maximum Service Interval field is greater than or equal to the Minimum Service Interval field. If the TSPEC element is included within a GCR Request subelement that has the GCR delivery method equal to GCR-SP, a Maximum Service Interval field set to 0 indicates that the continuous SP used by the GCR-A delivery method is requested.

K.4.3.2 (Use of Maximum Service Interval with Aggregation of Packets) provides guidance on the use of the Maximum Service Interval field to determine the limit of aggregation of nominal MSDUs.

The Inactivity Interval field contains an unsigned integer that specifies the minimum amount of time, in microseconds, that can elapse without arrival or transfer of an MPDU belonging to the TS before this TS is deleted by the MAC entity at the HC for a non-HE STA or before the information provided in this TSPEC is considered invalid at HE STAs for HE STAs.(11ax)

For non-HE STAs, the Suspension Interval field contains an unsigned integer that specifies the minimum amount of time, in microseconds, that can elapse without arrival or transfer of an MSDU belonging to the TS before the generation of successive QoS(+)CF-Poll is stopped for this TS. A value of 4 294 967 295 ($= 2^{32} - 1$) disables the suspension interval, indicating that polling for the TS is not to be interrupted based on inactivity. The suspension interval is always less than or equal to the inactivity interval. The Suspension Interval field is reserved for HE STAs.(11ax)

The Service Start Time field contains an unsigned integer that specifies the time, expressed in microseconds, when the first scheduled SP starts. The service start time indicates to the AP the time when a STA first expects to be ready to send frames and a power saving STA needs to be awake to receive frames. This might help the AP to schedule service so that the MSDUs encounter small delays in the MAC and help the power saving STAs to reduce power consumption. The field represents the four lower order octets of the TSF timer at the start of the SP. If APSD and Schedule subfields are 0, this field is also set to 0 (unspecified).

NOTE—The Service Start Time field carries only a portion of the target TSF time, and changes in the most significant octets of the corresponding target TSF time are not communicated to the receiving STA. Hence, the receiving STA must consider and account for a rollover of the corresponding most significant octets of the target TSF time that might happen at the receiving STA.(#7083)

The Minimum Data Rate field indicates the lowest data rate specified at the MAC SAP, for transport of MSDUs or A-MSDUs belonging to this TS within the bounds of this TSPEC element. The field is encoded as a piecewise linear function described as follows:

$$R_{min} = \begin{cases} F_{min}, & F_{min} \le 2^{31} \\ 1024 \times (F_{min} - 2^{31}) + 2^{31}, & F_{min} > 2^{31} \end{cases}$$

where

$R_{min}$ is the minimum data rate (in units of b/s)(#1166)
$F_{min}$ is the value of the Minimum Data Rate field

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The Mean Data Rate[24] field indicates the average data rate specified at the MAC SAP, for transport of MSDUs or A-MSDUs belonging to this TS within the bounds of this TSPEC element. The field is encoded as a piecewise linear function described as follows:

$$R_{mean} = \begin{cases} F_{mean}, & F_{mean} \le 2^{31} \\ 1024 \times (F_{mean} - 2^{31}) + 2^{31}, & F_{mean} > 2^{31} \end{cases}$$

where

$R_{mean}$ is the mean data rate ((#1167)in units of b/s)
$F_{mean}$ is the value of the Mean Data Rate field

The Peak Data Rate field indicates the maximum allowable data rate specified at the MAC SAP for transport of MSDUs or A-MSDUs belonging to this TS within the bounds of this TSPEC element. The field is encoded as a piecewise linear function described as follows:

$$R_{peak} = \begin{cases} F_{peak}, & F_{peak} \le 2^{31} \\ 1024 \times (F_{peak} - 2^{31}) + 2^{31}, & F_{peak} > 2^{31} \end{cases}$$

where

$R_{peak}$ is the peak data rate ((#1168)in units of b/s)
$F_{peak}$ is the value of the Peak Data Rate field

If $p$ is the (#1169)peak rate in b/s, then the maximum amount of data, belonging to this TS, arriving in any time interval $[t1,t2]$, where $t1 < t2$ and $t2 - t1 > 1$ TU, does not exceed $p \times (t2 - t1)$ bits.

The Minimum, Mean and Peak Data Rates do not include the MAC and PHY overheads incurred in transporting the MSDUs or A-MSDUs, with the exception of the MAC overheads specific to A-MSDUs (A-MSDU subframe header and padding). K.4.4 (Minimum, Mean, and Peak Data Rate) provides guidance on how to determine the standard deviation of the TS and how to calculate the total traffic when there are multiple TSs.

The Burst Size field contains an unsigned integer that specifies the maximum burst, in octets, of the MSDUs or A-MSDUs belonging to this TS that arrive at the MAC SAP at the peak data rate. A Burst Size field set to 0 indicates that there are no bursts.

The Delay Bound field contains an unsigned integer that specifies the maximum amount of time, in microseconds, allowed to transport an MSDU or A-MSDU belonging to the TS in this TSPEC element, measured between the time marking the arrival of the MSDU, or the first MSDU of the MSDUs constituting an A-MSDU, at the local MAC sublayer from the local MAC SAP and the time of completion of the successful transmission or retransmission of the MSDU or A-MSDU to the destination. The completion of the MSDU or A-MSDU transmission includes the relevant acknowledgment frame transmission time, if present.

The Minimum PHY Rate field indicates the minimum PHY rate for transport of MSDUs or A-MSDUs belonging to this TS within the bounds of this TSPEC element.[25] See 11.4.2 (TSPEC construction) for

[24] The mean data rate, the peak data rate, and the burst size are the parameters of the token bucket model, which provides standard terminology for describing the behavior of a traffic source. The token bucket model is described in IETF RFC 2212 [B26], IETF RFC 2215 [B27], and IETF RFC 3290 [B36].


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constraints on the selection of this field. The field is encoded as a piecewise linear function described as follows:

$$R_{minphy} = \begin{cases} F_{minphy}, & F_{minphy} \le 2^{31} \\ 1024 \times (F_{minphy} - 2^{31}) + 2^{31}, & F_{minphy} > 2^{31} \end{cases}$$

where

$R_{minphy}$ is the minimum PHY rate ((#1170)in units of b/s)
$F_{minphy}$ is the value of the Minimum PHY Rate field

The Surplus Bandwidth Allowance field specifies the excess allocation of time (and bandwidth) over and above the stated application rates required to transport an MSDU or A-MSDU belonging to the TS in this TSPEC. This field is represented as an unsigned binary number and, when specified, is greater than 0. The 13 least significant bits (LSBs) indicate the decimal part while the three MSBs indicate the integer part of the number. This field takes into account the retransmissions, as the rate information does not include retransmissions. It represents the ratio of over-the-air bandwidth (i.e., time that the scheduler allocates for the transmission of MSDUs or A-MSDUs at the required rates) to bandwidth of the transported MSDUs or A-MSDUs required for successful transmission (i.e., time that would be necessary at the minimum PHY rate if there were no errors on the channel) to meet throughput and delay bounds under this TSPEC, when specified. As such, it should be greater than unity. A Surplus Bandwidth Allowance field set to 1 indicates that no additional allocation of time is requested. K.4.2 (Surplus Bandwidth Allocation) provides guidance on how to calculate the value for Surplus Bandwidth Allowance element.

The Medium Time field (#1727)contains the amount of time admitted to access the medium, in units of 32 μs/s. This field is reserved in the ADDTS Request frame and is set by the HC in the ADDTS Response frame. The derivation of this field is described in K.2.2 (Deriving medium time). This field is not used for controlled channel access.

The UP, Minimum Data Rate, Mean Data Rate, Peak Data Rate, Burst Size, Minimum PHY Rate, and Delay Bound fields in a TSPEC element express the QoS expectations requested by a STA, if this TSPEC element was issued by that STA, or provided by the HC, if this TSPEC element was issued by the HC, when these fields are specified with nonzero values. Unspecified parameters in these fields as indicated by a value of 0 indicate that the STA does not have specific requirements for these parameters if the TSPEC element was issued by that STA or that the HC does not provide any specific values for these parameters if the TSPEC element was issued by the HC. Annex K provides guidance on the use of the TSPEC element and the settings of values of the various fields.

The DMG Attributes field is defined in Figure 9-381 (DMG Attributes field format). The DMG Attributes field is present in a TSPEC element when the BSS to which the TSPEC element applies is a DMG BSS; otherwise absent.

— Traffic streams can share an allocation through TSPEC aggregation (see Annex V). The Allocation ID subfield is used as follows:
  — When setting up a TS, the DMG STA that transmits an ADDTS Request frame containing a TSPEC or PTP TSPEC element sets the Allocation ID subfield to a nonzero value to identify the allocation it requires to carry the TS. Alternatively, the same DMG STA sets the Allocation ID subfield to 0 to indicate any CBAP allocation with the broadcast AID as Source AID.

[25] This rate information is intended to confirm that the TSPEC parameter values resulting from an admission control negotiation are sufficient to provide the required throughput for the TS. In a typical implementation, a TS is admitted only if the defined traffic volume can be accommodated at the specified rate within an amount of WM occupancy time that the admissions control entity is willing to allocate to this TS.

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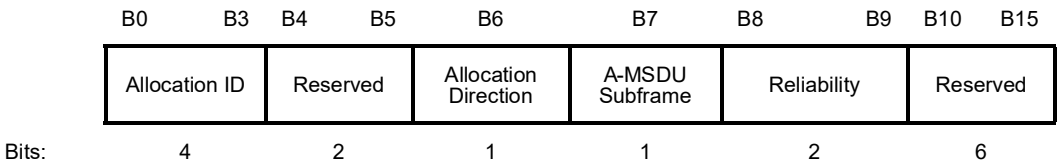


**Figure 9-381—DMG Attributes field format**

- When setting up a TS, the DMG STA that transmits the ADDTS Response frame containing the TSPEC or PTP TSPEC element sets the Allocation ID subfield to a nonzero value that identifies the allocation carrying the TS. Alternatively, the same DMG STA sets the Allocation ID subfield to 0 to indicate any CBAP allocation with the broadcast AID as Source AID and Destination AID.
- When deleting a TS, the DMG STA that transmits the DELTS frame containing a TSPEC or PTP TSPEC element sets the Allocation ID subfield to a nonzero value to identify the allocation that is carrying the TS to be deleted. Alternatively, the same DMG STA sets the Allocation ID subfield to 0 to indicate no allocation exists to carry the TS to be deleted.

— The Allocation Direction subfield is equal to 1 when the originator of the ADDTS request is also the source of the allocation identified by the Allocation ID subfield and is equal to 0 otherwise. The Allocation Direction subfield is equal to 0 when the Allocation ID subfield is equal to 0.

— The A-MSDU Subframe subfield contains a value that indicates the A-MSDU subframe structure to be used for this TS. The A-MSDU Subframe subfield is set to 0 to indicate the Basic A-MSDU subframe structure and set to 1 to indicate the Short A-MSDU subframe structure.

— The Reliability subfield contains an expected reliability index. The reliability index refers to the PHY PER (PSDU error rate as in 20.3.3.8 (Receive minimum input level sensitivity(#256))). The relation between the reliability index and the PER is shown in Table 9-201 (Reliability subfield values).

**Table 9-201—Reliability subfield values**

| Reliability index | PER |
|---|---|
| 0 | Not specified |
| 1 | $10^{-2}$ |
| 2 | $10^{-3}$ |
| 3 | $10^{-4}$ |

The Reliability subfield in an ADDTS Request frame that has the Direction subfield set to downlink or in an ADDTS Response frame that has the Direction field set to uplink indicates the expectation of the PER of the destination DMG STA for this TS. The Reliability subfield in an ADDTS Request frame that has the Direction subfield set to uplink or in an ADDTS Response frame that has the Direction field set to downlink is reserved. The reliability information is provided by the SME using the MLME-ADDTS.request primitive and MLME-ADDTS.response primitives. Together with the link margin (10.41.9 (CDMG enhanced beam tracking)) and other (M118)implementation specific information, this value can be used by the source DMG STA of this TS to estimate the MCS to be used for this particular TS.


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### 9.4.2.29 TCLAS element

(#1776)The traffic classification (TCLAS) element contains a set of parameters necessary to identify various kinds of PDU or incoming MSDU (from a higher layer in all STAs or from the DS in an AP) that belong to a particular TS. The TCLAS element is also used when the traffic does not belong to a TS, for example, by the FMS, DMS, and TFS services. If required, the TCLAS element is provided in ADDTS Request and ADDTS Response frames only for the downlink or bidirectional links. The TCLAS element is always included when a PTP TSPEC is transmitted to a peer STA via an AP or PCP. The structure of this element is shown in Figure 9-382 (TCLAS element format).

| | Element ID | Length | User Priority | Frame Classifier |
|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | variable |

**Figure 9-382—TCLAS element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

When the UP field contains a value that is less than or equal to 7, the value specifies the UP of the associated MSDUs. When the UP field contains a value that is greater than or equal to 8 and less than or equal to 11, the value specifies the access category of the associated MPDUs. The UP field value 255 is reserved and indicates that the UP of the MSDU and the access category of the MPDU are not compared as part of the traffic filter. The encoding of the contents of the User Priority field of an TCLAS element is specified in Table 9-202 (User Priority field of TCLAS element).

**Table 9-202—User Priority field of TCLAS element**

| User Priority | Meaning |
|---|---|
| 0–7 | The User Priority value of an MSDU. |
| 8 | The AC value of an MPDU is AC_VO.(#3211) |
| 9 | The AC value of an MPDU is AC_VI.(#3211) |
| 10 | The AC value of an MPDU is AC_BE.(#3211) |
| 11 | The AC value of an MPDU is AC_BK.(#3211) |
| 12–254 | Reserved. |
| 255 | The User Priority field is not used for comparison. |

The Frame Classifier field is defined in Figure 9-383 (Frame Classifier field format).

| | Classifier Type | Classifier Mask | Classifier Parameters |
|---|---|---|---|
| Octets: | 1 | 1 or 3 | variable |

**Figure 9-383—Frame Classifier field format**

The Frame Classifier field comprises the following subfields: Classifier Type, Classifier Mask, and Classifier Parameters. The Classifier Type subfield specifies the type of classifier parameters in this TCLAS element as defined in Table 9-203 (Frame classifier type).

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**Table 9-203—Frame classifier type**

| Classifier type | Classifier parameters |
|---|---|
| 0 | Ethernet parameters |
| 1 | TCP/UDP IP parameters |
| 2 | IEEE 802.1Q-2003 parameters (deprecated)(#56) |
| 3 | Filter Offset parameters |
| 4 | IP and higher layer parameters |
| 5 | IEEE 802.1Q parameters(#56) |
| 6 | IEEE 802.11 MAC header parameters |
| 7 | IEEE Std 802.11 downlink PV1 MPDU MAC header parameters (From DS field of the Frame Control field equal to 1) |
| 8 | IEEE Std 802.11 nondownlink PV1 MPDU MAC header parameters (From DS field of the Frame Control field equal to 0) |
| 9 | IEEE Std 802.11 PV1 MPDU Full Address MAC header parameters |
| 10 | IP extensions and higher layer parameters |
| 11–255 | Reserved |

When the classifier type is a value less than or equal to 5, but not equal to 3, the Classifier Mask subfield specifies a bitmap in which bits that have the value 1 identify a subset of the classifier parameters whose values need to match those of the corresponding parameters in a given MSDU for that MSDU to be classified to the TS of the affiliated TSPEC element. The bitmap is ordered from the LSB to the MSB, with each bit pointing to one of the classifier parameters of the same relative position as shown in this subclause based on classifier type. When there are more bits in the bitmap than classifier parameters that follow, the MSBs that do not point to any classifier parameters are reserved.

A Classifier Type subfield set to 6 applies only to frames with the Protocol Version subfield of the Frame Control field of the MAC header equal to 0.

A Classifier Type subfield set to 7 applies only to frames with the Protocol Version subfield of the Frame Control field of the MAC header equal to 1, the Type subfield of the Frame Control field of the MAC header equal to 0 or 1, and the From DS subfield of the Frame Control field of the MAC header equal to 1.

A Classifier Type subfield set to 8 applies only to frames with the Protocol Version subfield of the Frame Control field of the MAC header equal to 1, the Type subfield of the Frame Control field of the MAC header equal to 0 or 1, and the From DS subfield of the Frame Control field of the MAC header equal to 0.

A Classifier Type subfield set to 9 applies only to frames with the Protocol Version subfield of the Frame Control field of the MAC header equal to 1 and the Type subfield of the Frame Control field of the MAC header equal to 3.

When the Classifier Type subfield is equal to 6, 7, 8, or 9, the Classifier Mask subfield is 3 octets in length and contains a sequence of 2-bit Classifier Mask Control subfields. Each Classifier Mask Control subfield applies to a specific target field of the MAC header of an MPDU and determines whether the target field is included in the comparison and whether an additional bitmask (the target field filter mask) is present. When the target field filter mask is present, it determines the bits of the target field that are used in the comparison.


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The Classifier Mask Control subfield values are interpreted as follows:

— Setting the LSB of the two bits to 1 indicates the use of the corresponding MAC header(#3182) field for comparison, and setting the LSB of the two bits to 0 indicates the corresponding MAC header field is not used for comparison, and the corresponding match specification(#3183) is not included in the Classifier.

— Setting the MSB of the two bits to 1 indicates the inclusion of the corresponding MAC header(#3182) filter (a bitmask(#293)) in the corresponding match specification(#3183), and setting the MSB of the two bits to 0 indicates the MAC header(#3182) filter is not included in the corresponding match specification(#3183) and every bit of the match specification(#3183), if included in the Classifier Parameter, needs to be compared.

— If an optional MAC header(#3182) field needs to be compared, the LSB of the two bits in the Classifier Mask corresponding to the optional MAC header field is set to 1, and an MPDU that does not include the optional field is not a matching MPDU.

Table 9-204 (Classifier Mask for Classifier Type 6), Table 9-205 (Classifier Mask for Classifier Type 7), Table 9-206 (Classifier Mask for Classifier Type 8), and Table 9-207 (Classifier Mask for Classifier Type 9) specify the interpretation of the Classifier Mask Control subfield for each of the Classifier Type values 6, 7, 8, and 9, respectively.

**Table 9-204—Classifier Mask for Classifier Type 6**

| Octet index | Bits index | Classifier parameters |
|---|---|---|
| 0 | B1B0 | Frame Control |
| | B3B2 | Duration/ID |
| | B5B4 | Address 1 |
| | B7B6 | Address 2 |
| 1 | B1B0 | Address 3 |
| | B3B2 | Sequence Control |
| | B5B4 | Address 4 |
| | B7B6 | QoS Control |
| 2 | B1B0 | HT Control |
| | B3B2 | Reserved |
| | B5B4 | Reserved |
| | B7B6 | Reserved |

**Table 9-205—Classifier Mask for Classifier Type 7**

| Octet index | Bits index | Classifier parameters |
|---|---|---|
| 0 | B1B0 | Frame Control |
| | B3B2 | Address 1 (AID) |
| | B5B4 | Address 2 (BSSID) |
| | B7B6 | Sequence Control |

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**Table 9-205—Classifier Mask for Classifier Type 7**

| | | |
|---|---|---|
| 1 | B1B0 | Address 3 |
| | B3B2 | Address 4 |
| | B5B4 | Reserved |
| | B7B6 | Reserved |
| 2 | B1B0 | Reserved |
| | B3B2 | Reserved |
| | B5B4 | Reserved |
| | B7B6 | Reserved |

**Table 9-206—Classifier Mask for Classifier Type 8**

| Octet index | Bits index | Classifier parameters |
|---|---|---|
| 0 | B1B0 | Frame Control |
| | B3B2 | Address 1 (BSSID) |
| | B5B4 | Address 2 (AID) |
| | B7B6 | Sequence Control |
| 1 | B1B0 | Address 3 |
| | B3B2 | Address 4 |
| | B5B4 | Reserved |
| | B7B6 | Reserved |
| 2 | B1B0 | Reserved |
| | B3B2 | Reserved |
| | B5B4 | Reserved |
| | B7B6 | Reserved |

**Table 9-207—Classifier Mask for Classifier Type 9**

| Octet index | Bits index | Classifier parameters |
|---|---|---|


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**Table 9-207—Classifier Mask for Classifier Type 9**

| | | |
|---|---|---|
| 0 | B1B0 | Frame Control |
| | B3B2 | Address 1 |
| | B5B4 | Address 2 |
| | B7B6 | Sequence Control |
| 1 | B1B0 | Reserved |
| | B3B2 | Reserved |
| | B5B4 | Reserved |
| | B7B6 | Reserved |
| 2 | B1B0 | Reserved |
| | B3B2 | Reserved |
| | B5B4 | Reserved |
| | B7B6 | Reserved |

The map from the location of the Classifier Mask subfield to the target subfield is defined in Table 9-208 (Map from location of Classifier Mask subfield to target subfield).

**Table 9-208—Map from location of Classifier Mask subfield to target subfield**

| Bit number | Target field |
|---|---|
| 0–1 | Frame Control |
| 2–3 | Duration/ID |
| 4–5 | Address 1 |
| 6–7 | Address 2 |
| 8–9 | Address 3 |
| 10–11 | Sequence Control |
| 12–13 | Address 4 |
| 14–15 | QoS Control |
| 16–17 | HT Control |
| 18–23 | Reserved |

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For Classifier Type 0, the classifier parameters are the following parameters contained in an Ethernet frame header: Source Address, Destination Address, and Type ("Ethernet" [B9]). The endianness of the Type field is defined in "Ethernet" [B9]. The Frame Classifier field for Classifier Type 0 is defined in Figure 9-384 (Frame Classifier field format of Classifier Type 0). It has a length of 16 octets.

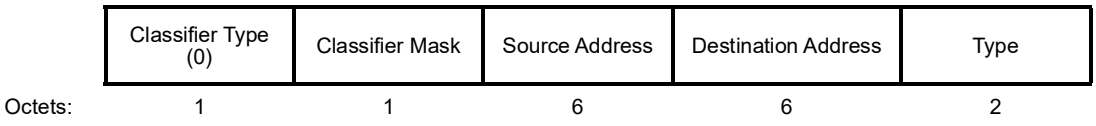


**Figure 9-384—Frame Classifier field format of Classifier Type 0**

For Classifier Type 1, frame classifier is defined for both IPv4 and IPv6, shown in Figure 9-385 (Frame Classifier field format of Classifier Type 1 for traffic over IPv4) and Figure 9-386 (Frame Classifier field format of Classifier Type 1 for traffic over IPv6), and distinguished by the Version field. Use of Classifier Type 1 for IPv6 is deprecated and replaced by Classifier Type 4. The subfields in the classifier parameters are represented and transmitted in the big-endian format. The classifier parameters are the following parameters:

- In the IP header: Source Address, Destination Address and Version.
- In a TCP or UDP header: Source Port and Destination Port, plus
- One of the following:
  - In an IPv4 header: Differentiated Services Code Point (DSCP) (IETF RFC 2474 [B29]) and Protocol, or
  - In an IPv6 header: Flow Label.

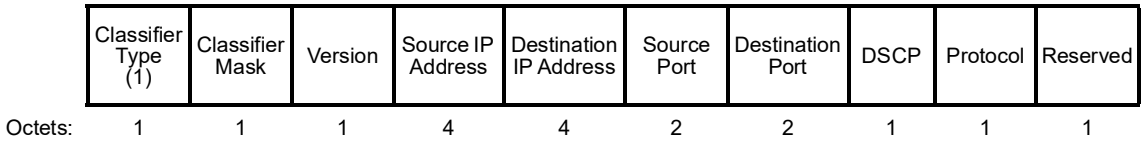


**Figure 9-385—Frame Classifier field format of Classifier Type 1 for traffic over IPv4**

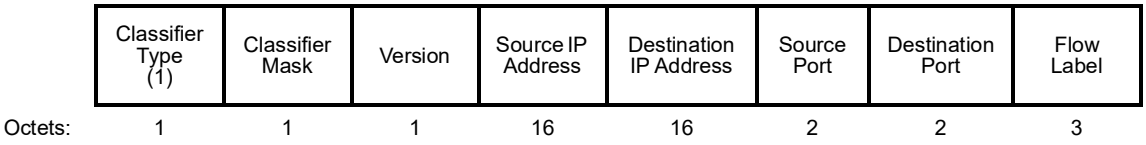


**Figure 9-386—Frame Classifier field format of Classifier Type 1 for traffic over IPv6**

The DSCP field contains a value in the 6 LSBs, and the 2 MSBs are set to 0. The 2 MSBs of the DSCP field are ignored for frame classification.

The value in the Version subfield is the value specified in IETF RFC 791 or IETF RFC 8200.

For Classifier Type 2, the Classifier Parameter is the IEEE 802.1Q-2003 VLAN Tag TCI. The endianness of the IEEE 802.1Q VLAN TCI field is defined in IEEE Std 802.1Q for the VLAN Tag TCI. The Frame Classifier field for Classifier Type 2 is defined in Figure 9-387 (Frame Classifier field format of Classifier Type 2). Classifier Type 2 is deprecated.


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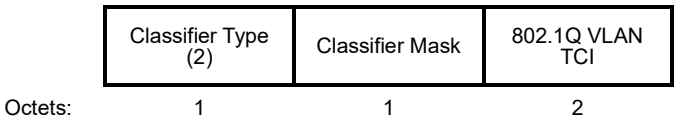


**Figure 9-387—Frame Classifier field format of Classifier Type 2**

For Classifier Type 3, the classifier parameters are defined by a Filter Offset subfield, a Filter Value subfield and a Filter Mask subfield. The Frame Classifier subfield of Classifier Type 3 is defined in Figure 9-388 (Frame Classifier field format of Classifier Type 3). It has a variable length.

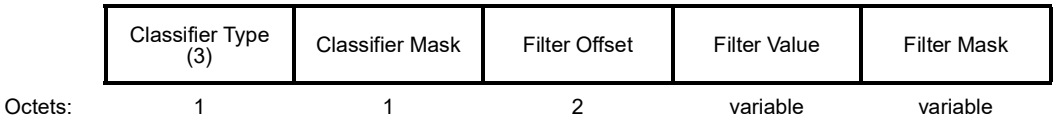


**Figure 9-388—Frame Classifier field format of Classifier Type 3**

The Classifier Mask subfield is reserved.

The Filter Offset subfield is set to the number of octets from the beginning of the MSDU or MMPDU at which the Filter Value is compared.

The length of the Filter Value and Filter Mask subfields is (*Length* – 5)/2, where *Length* is the value in the Length field of the TCLAS element.

The Filter Value subfield is an octet string that is compared to the MSDU or MMPDU content, beginning at the octet indicated by the Filter Offset.

The Filter Mask subfield is an octet string that is used to indicate the bits in the Filter Value subfield to be compared. The length of the Filter Mask subfield is equal to the length of the Filter Value subfield. A bit in the Filter Value subfield is compared only if the matching bit in the Filter Mask subfield is 1.

For Classifier Type 4, frame classifier is defined for both IPv4 and IPv6, shown in Figure 9-389 (Frame Classifier subfield format of Classifier Type 4 for traffic over IPv4) (with the Classifier Type subfield set to 4) and Figure 9-390 (Frame Classifier subfield format of Classifier Type 4 for traffic over IPv6), and distinguished by the Version subfield. The classifier parameters represent corresponding values in a received IPv4 or IPv6 frame and are defined in Table 9-209 (Classifier parameters for Classifier Type 4). The subfields in the classifier parameters are represented and transmitted in big-endian format.

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**Table 9-209—Classifier parameters for Classifier Type 4**

| Subfield | Included in IPv4 | IPv4 field length (octets) | Included in IPv6 | IPv6 field length (octets) |
|---|---|---|---|---|
| Version | Yes | 1 | Yes | 1 |
| Source IP Address | Yes | 4 | Yes | 16 |
| Destination IP Address | Yes | 4 | Yes | 16 |
| Source Port | Yes | 2 | Yes | 2 |
| Destination Port | Yes | 2 | Yes | 2 |
| DSCP | Yes | 1 | Yes | 1 |
| Protocol | Yes | 1 | No | n/a |
| Next Header | No | n/a | Yes | 1 |
| Flow Label | No | n/a | Yes | 3 |

The Frame Classifier subfield of Classifier Type 4 for traffic over IPv4 is shown in Figure 9-389 (Frame Classifier subfield format of Classifier Type 4 for traffic over IPv4).

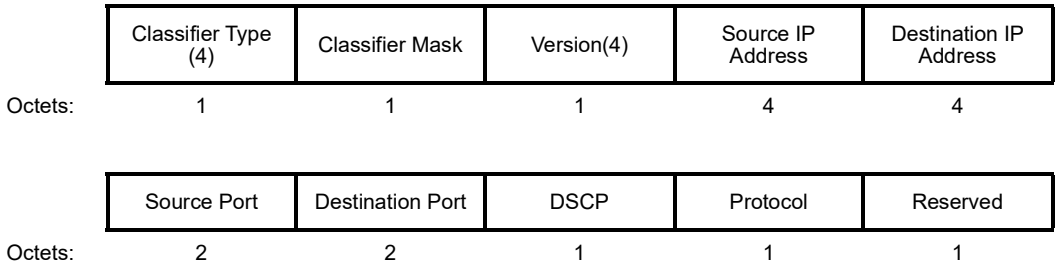


**Figure 9-389—Frame Classifier subfield format of Classifier Type 4 for traffic over IPv4**

The Frame Classifier subfield of Classifier Type 4 for traffic over IPv6 is shown in Figure 9-390 (Frame Classifier subfield format of Classifier Type 4 for traffic over IPv6).

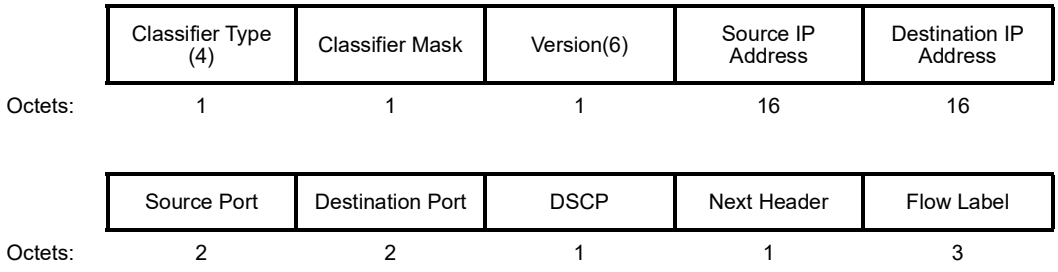


**Figure 9-390—Frame Classifier subfield format of Classifier Type 4 for traffic over IPv6**

NOTE 1—Frame classification when extension headers are used is supported only if the TCLAS does not classify on ports (Classifier Mask has the Source and Destination Port bits set to 0).


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The value in the Version subfield is the value specified in IETF RFC 791 or IETF RFC 8200.

The DSCP subfield contains the value as described in IETF RFC 2474 [B29] in the 6 least significant bits. The 2 most significant bits are reserved. For an IPv6 packet, this corresponds to the Traffic Class subfield of the IPv6 header.

The Source IP Address and Destination IP Address subfields(#414) correspond to the identically named fields of the IPv4 and IPv6 headers.

The Source Port and Destination Port subfields(#414) correspond to the identically named fields of various protocol headers that are encapsulated within an IPv4 or IPv6 packet.

The Next Header subfield contains the next encapsulated protocol which is either the value specified in the IPv4 header's Protocol field or the value in the Next Header field of the IPv6 header. In the presence of options in the IPv6 header, the Next Header field specifies the presence of one or more extension headers as registered in "IPv6 Extension Header Types" [B58] and defined by the corresponding IETF RFCs.

The Flow Label subfield contains the value in the 20 least significant bits. The 4 most significant bits are reserved.

NOTE 2—For example, the flow label 0x12345 is represented as the octet sequence 0x01, 0x23, 0x45.(#1860)

For Classifier Type 5 when used to match an IEEE 802.1Q tagged frame(#72-Ed1), the classifier parameters are: Priority Code Point, Drop Eligibility Indicator (DEI), and VLAN ID (VID).(#57)

The Frame Classifier field for Classifier Type 5 is defined in Figure 9-391 (Frame Classifier field format of Classifier Type 5).

| | Classifier Type (5) | Classifier Mask | (#58)802.1Q Priority Code Point | 802.1Q DEI | 802.1Q VID |
|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 1 | 2 |

**Figure 9-391—Frame Classifier field format of Classifier Type 5**

The subfields in the classifier parameters are represented and transmitted in big-endian format.

The (#60)802.1Q Priority Code Point subfield contains the value to be matched to the appropriate type frame header in the 4 LSBs; the 4 MSBs are reserved.

The 802.1Q DEI subfield contains the value to match against an IEEE 802.1Q tagged frame header, in the LSB; the 7 MSBs are reserved(#64)(#65).

The 802.1Q VID subfield contains the value to match against an IEEE 802.1Q tagged frame header, in the 12 LSBs; the 4 MSBs are reserved(#64)(#65).

For Classifier Type 6, the format of the Frame Classifier field of a TCLAS element is shown in Figure 9-392 (Frame Classifier field format of Classifier Type 6).

For Classifier Type 6, the formats of the Frame Control Match Specification subfield, Duration/ID Match Specification subfield, Address 1 Match Specification subfield, Address 2 Match Specification subfield, Address 3 Match Specification subfield, Sequence Control Match Specification subfield, Address 4 Match Specification subfield, QoS Control Match Specification subfield and HT Control Match Specification subfield of the Frame Classifier field of a TCLAS element are shown in Figure 9-393 (Frame Control Match

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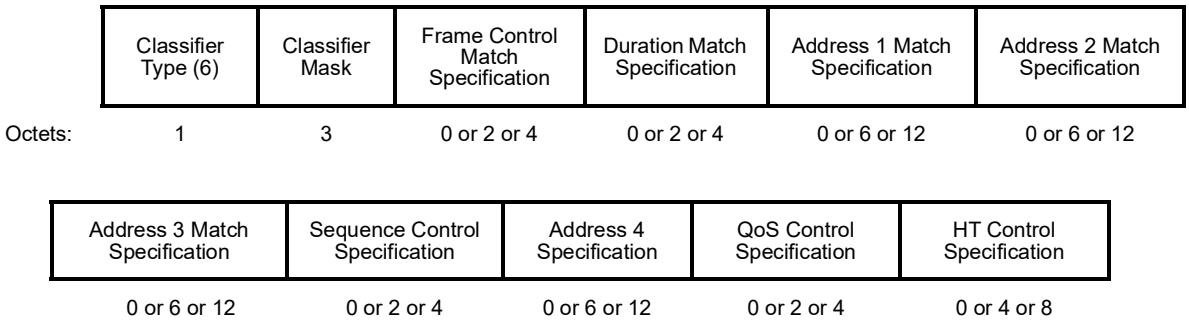


**Figure 9-392—Frame Classifier field format of Classifier Type 6**

Specification subfield format of Classifier Type 6, 7, 8, 9), Figure 9-394 (Duration/ID Match Specification subfield format of Classifier Type 6), Figure 9-395 (Address 1 Match Specification subfield format of Classifier Type 6, 8, 9), Figure 9-396 (Address 2 Match Specification subfield format of Classifier Type 6, 7, 9), Figure 9-397 (Address 3 Match Specification subfield format of Classifier Type 6, 7, 8), Figure 9-398 (Sequence Control Match Specification subfield format of Classifier Type 6, 7, 8, 9), Figure 9-399 (Address 4 Match Specification subfield format of Classifier Type 6, 7, 8), Figure 9-400 (QoS Control Match Specification subfield format of Classifier Type 6), and Figure 9-401 (HT Control Match Specification subfield format of Classifier Type 6), respectively. The Match Specification subfield contains the match specification (i.e., the parameters) of the corresponding MAC header field with which an MPDU is compared. When the corresponding Filter Mask is not present, every bit in a match specification(#3183) is compared; otherwise, only the bits with the same bit positions as the bits that are equal to 1 in the corresponding Filter Mask subfield are compared.

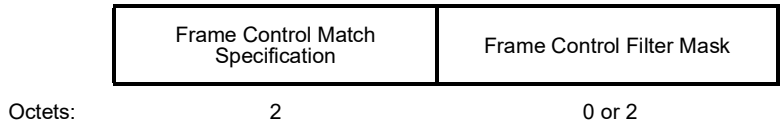


**Figure 9-393—Frame Control Match Specification subfield format of Classifier Type 6, 7, 8, 9**

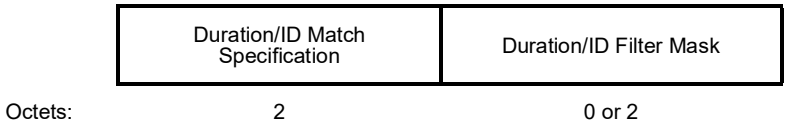


**Figure 9-394—Duration/ID Match Specification subfield format of Classifier Type 6**

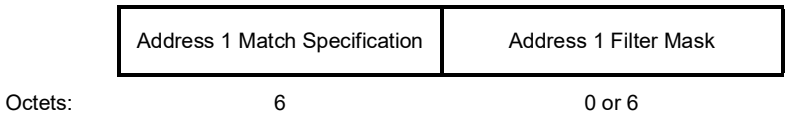


**Figure 9-395—Address 1 Match Specification subfield format of Classifier Type 6, 8, 9**

For Classifier Type 7, the format of the Frame Classifier field of a TCLAS element is shown in Figure 9-402 (Frame Classifier field format of Classifier Type 7).


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**Figure 9-396—Address 2 Match Specification subfield format of Classifier Type 6, 7, 9**

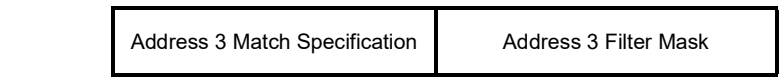


**Figure 9-397—Address 3 Match Specification subfield format of Classifier Type 6, 7, 8**

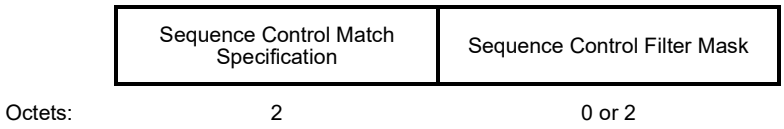


**Figure 9-398—Sequence Control Match Specification subfield format of Classifier Type 6, 7, 8, 9**

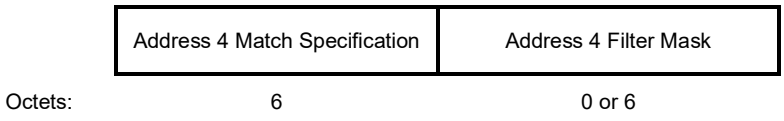


**Figure 9-399—Address 4 Match Specification subfield format of Classifier Type 6, 7, 8**

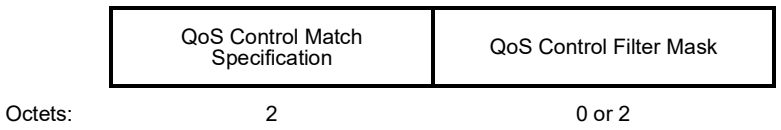


**Figure 9-400—QoS Control Match Specification subfield format of Classifier Type 6**

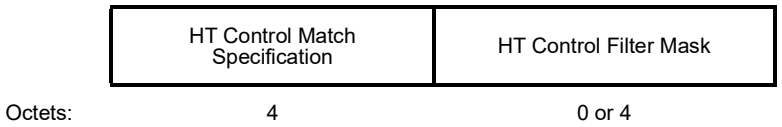


**Figure 9-401—HT Control Match Specification subfield format of Classifier Type 6**

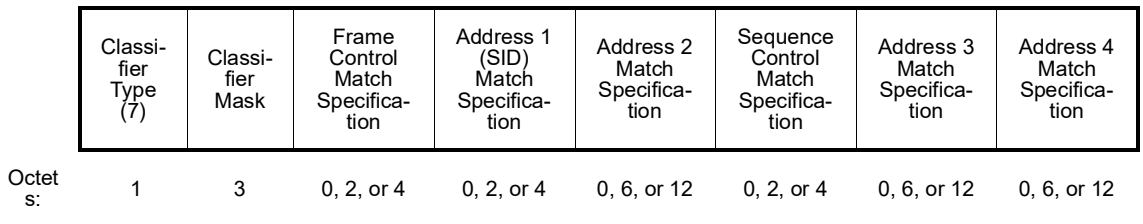


**Figure 9-402—Frame Classifier field format of Classifier Type 7**

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For Classifier Type 7, the formats of the Frame Control Match Specification subfield, Address 1 (SID) subfield, Address 2 (BSSID) subfield, Sequence Control subfield, Address 3 subfield, and Address 4 subfield of the Frame Classifier field of a TCLAS element are shown in Figure 9-393 (Frame Control Match Specification subfield format of Classifier Type 6, 7, 8, 9), Figure 9-403 (Address 1 (SID) Match Specification subfield format of Classifier Type 7), Figure 9-396 (Address 2 Match Specification subfield format of Classifier Type 6, 7, 9), Figure 9-398 (Sequence Control Match Specification subfield format of Classifier Type 6, 7, 8, 9), Figure 9-397 (Address 3 Match Specification subfield format of Classifier Type 6, 7, 8), and Figure 9-399 (Address 4 Match Specification subfield format of Classifier Type 6, 7, 8), respectively. The Match Specification subfield contains the match specification (i.e., the parameters) of the corresponding MAC header field with which an MPDU needs to be compared. When the corresponding Filter Mask subfield is not present, every bit in a Match Specification subfield needs to be compared; otherwise, only the bits with the same bit positions as the bits that are equal to 1 in the corresponding Filter Mask subfield are compared.

| | Address 1 (SID) Match Specification | Address 1 Filter Mask |
|---|---|---|
| Octets: | 2 | 0, or 2 |

**Figure 9-403—Address 1 (SID) Match Specification subfield format of Classifier Type 7**

For Classifier Type 8, the format of the Frame Classifier field of a TCLAS element is shown in Figure 9-404 (Frame Classifier field format of Classifier Type 8).

| | Classi-fier Type (8) | Classi-fier Mask | Frame Control Match Specifica-tion | Address 1 (BSSID) Match Specifica-tion | Address 2 (SID) Match Specifica-tion | Sequence Control Match Specifica-tion | Address 3 Match Specifica-tion | Address 4 Match Specifica-tion |
|---|---|---|---|---|---|---|---|---|
| Octets: | 1 | 3 | 0, 2, or 4 | 0, 6, or 12 | 0, 2, or 4 | 0, 2, or 4 | 0, 6, or 12 | 0, 6, or 12 |

**Figure 9-404—Frame Classifier field format of Classifier Type 8**

For Classifier Type 8, the formats of the Frame Control Match Specification subfield, Address 1 (BSSID) subfield, Address 2 (SID) subfield, Sequence Control subfield, and Address 3 subfield are shown in Figure 9-393 (Frame Control Match Specification subfield format of Classifier Type 6, 7, 8, 9), Figure 9-395 (Address 1 Match Specification subfield format of Classifier Type 6, 8, 9), Figure 9-405 (Address 2 (SID) Match Specification subfield format of Classifier Type 8), Figure 9-398 (Sequence Control Match Specification subfield format of Classifier Type 6, 7, 8, 9), Figure 9-397 (Address 3 Match Specification subfield format of Classifier Type 6, 7, 8), and Figure 9-399 (Address 4 Match Specification subfield format of Classifier Type 6, 7, 8), respectively. The Match Specification subfield contains the match specification (i.e., the parameters) of the corresponding MAC header field with which an MPDU needs to be compared. When the corresponding Filter Mask subfield is not present, every bit in a Match Specification subfield needs to be compared; otherwise, only the bits with the same bit positions as the bits that are equal to 1 in the corresponding Filter Mask subfield are compared.

| | Address 2(SID) Match Specification | Address 2 Filter Mask |
|---|---|---|
| Octets: | 2 | 0, or 2 |

**Figure 9-405—Address 2 (SID) Match Specification subfield format of Classifier Type 8**


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For Classifier Type 9, the format of the Frame Classifier field of a TCLAS element is shown in Figure 9-406 (Frame Classifier field format of Classifier Type 9).

| | Classifier Type (9) | Classifier Mask | Frame Control Match Specification | Address 1 Match Specification | Address 2 Match Specification | Sequence Control Match Specification |
|---|---|---|---|---|---|---|
| Octets: | 1 | 3 | 0, 2, or 4 | 0, 6, or 12 | 0, 6, or 12 | 0, 2, or 4 |

**Figure 9-406—Frame Classifier field format of Classifier Type 9**

For Classifier Type 9, the formats of the Frame Control Match Specification subfield, Address 1 subfield, Address 2 subfield, and Sequence Control subfield are shown in Figure 9-393 (Frame Control Match Specification subfield format of Classifier Type 6, 7, 8, 9), Figure 9-395 (Address 1 Match Specification subfield format of Classifier Type 6, 8, 9), Figure 9-396 (Address 2 Match Specification subfield format of Classifier Type 6, 7, 9), and Figure 9-398 (Sequence Control Match Specification subfield format of Classifier Type 6, 7, 8, 9), respectively. The Match Specification subfield contains the match specification (i.e., the parameters) of the corresponding MAC header field with which an MPDU needs to be compared. When the corresponding Filter Mask subfield is not present, every bit in a Match Specification subfield needs to be compared; otherwise, only the bits with the same bit positions as the bits that are set to 1 in the corresponding Filter Mask subfield are compared.

For Classifier Type 10, the Frame Classifier field for IP extensions and higher layer parameters is defined for packets using IPv4 and IPv6 as shown in Figure 9-407 (Frame Classifier field format of Classifier Type 10 for packets using IPv4 or IPv6(#1857)). The subfields in the classifier parameters are represented and transmitted in the big-endian format.

| | Classifier Type (10) | Protocol Instance | Protocol Number or Next Header | Filter Value | Filter Mask |
|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | variable | variable |

**Figure 9-407—Frame Classifier field format of Classifier Type 10 for packets using IPv4 or IPv6(#1857)**

The Protocol Instance subfield indicates the instance number of the protocol identified by the Protocol Number or Next Header subfield. A value of 0 in this field matches the first instance of the Protocol Number or Next Header. A value of 1 matches the second instance, and so on. The only value of Protocol Number or Next Header subfield that is allowed to appear more than once within an IP packet is the Destination Options extension header of IPv6.

The Protocol Number or Next Header subfield contains an IPv4 Protocol Number or an IPv6 Next Header value, which share a common interpretation also known as an IP Protocol Number. The Protocol Number or Next Header subfield value is compared against the Protocol field value of an IPv4 header and to all Next Header field values in an IPv6 packet. This is also true for an IPv6 packet that is encapsulated within an IPv4 packet. This matching operation is not maskable.

The lengths of the Filter Value and Filter Mask subfields are the same and are each equal to (Length – 4)/2 octets, where Length is the value in the Length field of the TCLAS element.

The Filter Value subfield is an octet string that is compared to the MSDU content, beginning at the first octet of the protocol information which is identified by the Protocol Number or Next Header subfield.

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The Filter Mask subfield is an octet string that is used to indicate which bits in the Filter Value subfield are compared. A bit in the Filter Value subfield is compared only if the matching bit in the Filter Mask subfield is 1.

Figure 9-408 (IPv4 packet example for Classifier Type 10) shows an example of how the Filter Value subfield is applied to an IPv4 packet.

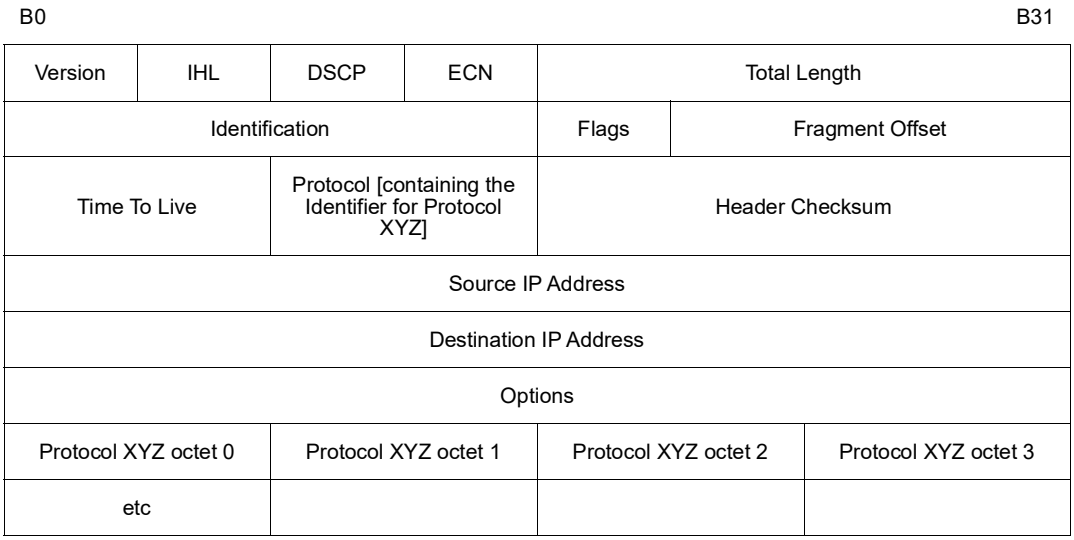


**Figure 9-408—IPv4 packet example for Classifier Type 10**

When the Protocol Number or Next Header subfield value of the Frame Classifier matches the value in the Protocol subfield of the IPv4 header, in this case the identifier that corresponds to protocol XYZ, then the first Filter Value octet is compared to Protocol XYZ octet 0 and so on.

Figure 9-409 (IPv6 packet example for Classifier Type 10) shows an example of how the Filter Value subfield is applied to an IPv6 packet that contains multiple extension headers.

When the Protocol Number or Next Header subfield value of the Frame Classifier matches the value of a Next Header field of any IPv6 Header or IPv6 Extension Header, then the first Filter Value octet is compared to the first octet of the header of of the payload that is identified by the matching Protocol Number or Next Header subfield value and so on. For example, if the Protocol Number or Next Header subfield value of a Frame Classifier of Classifier Type 10 contains the identifier for IPv6 Extension Header GHI, then this value matches the first entry of the seventh row in the figure and the Filter Value comparison begins at the first octet indicated on the ninth row of the figure. The comparison stops after the first match of a Next Header field.

(#6452)If a Classifier Mask field is not reserved and is present, at least one bit in the field that is not reserved is nonzero.

### 9.4.2.30 TS Delay element

The TS Delay element is used in an ADDTS Response frame transmitted by an HC and indicates the time after which the ADDTS can be retried; see 11.4.6 (Failed TS setup). The TS Delay element is defined in Figure 9-410 (TS Delay element format).

The Element ID and Length fields are defined in 9.4.2.1 (General).


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B0 B31

| | | | |
|---|---|---|---|
| Version | Traffic Class | Flow Label | |
| Payload Length | | Next Header [containing the identifier for Extension Header ABC] | Hop Limit |
| Source IP Address | | | |
| Destination IP Address | | | |
| Next Header [Extension Header ABC octet 0][containing the identifier for Extension Header DEF] | Extension Header ABC octet 1 | Extension Header ABC octet 2 | Extension Header ABC octet 3 |
| Extension Header ABC octet 4 | etc | | |
| Next Header [Extension Header DEF octet 0][ containing the identifier for Extension Header GHI] | Extension Header DEF octet 1 | Extension Header DEF octet 2 | Extension Header DEF octet 3 |
| Extension Header DEF octet 4 | etc | | |
| Next Header [Extension Header GHI octet 0] [ containing the identifier for Protocol XYZ] | Extension Header GHI octet 1 | Extension Header GHI octet 2 | Extension Header GHI octet 3 |
| Extension Header GHI octet 4 | etc | | |
| Protocol XYZ octet 0 | Protocol XYZ octet 1 | Protocol XYZ octet 2 | Protocol XYZ octet 3 |
| etc | | | |

**Figure 9-409—IPv6 packet example for Classifier Type 10**

| | Element ID | Length | Delay |
|---|---|---|---|
| Octets: | 1 | 1 | 4 |

**Figure 9-410—TS Delay element format**

The Delay field specifies the amount of time, in TUs, a STA should wait before it reinitiates setup of a TS.

The Delay field is set to 0 when an AP does not expect to serve any TSPECs for an indeterminate time and does not know this time a priori.

### 9.4.2.31 TCLAS Processing element

(#444)The TCLAS Processing element, together with the TCLAS element(s), if present, indicates how a PDU or MSDU should be processed by a classifier. The TCLAS Processing element is defined in Figure 9-411 (TCLAS Processing element format).

The Element ID and Length fields are defined in 9.4.2.1 (General).

The encoding of the (#2180)Processing field is shown in Table 9-210 (Encoding of Processing field(#2180)).

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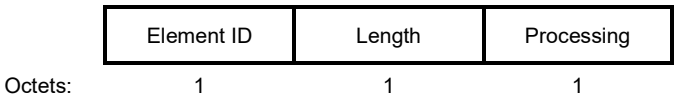


**Figure 9-411—TCLAS Processing element format**

**Table 9-210—Encoding of Processing field(#2180)**

| (#2180)Processing field value | Meaning |
|---|---|
| 0 | PDU contents or MSDU parameters have to match to the parameters in all of the associated TCLAS elements. |
| 1 | PDU contents or MSDU parameters have to match to at least one of the associated TCLAS elements. |
| 2 | PDUs or MSDUs that do not belong to any other TS are classified to the TS for which this TCLAS Processing element is used. In this case, there are no associated TCLAS elements. |
| 3–255 | Reserved |

### 9.4.2.32 Schedule element

The Schedule element is transmitted by the HC to a STA to announce the schedule that the HC follows for admitted streams originating from or destined to that STA, or GCR-SP streams destined to that STA, in the future. The information in this element might be used by the STA for power management, internal scheduling, or any other purpose. The element information format is shown in Figure 9-412 (Schedule element format).

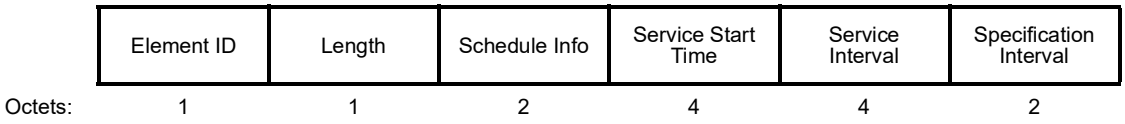


**Figure 9-412—Schedule element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The Schedule Info field is shown in Figure 9-413 (Schedule Info field format).

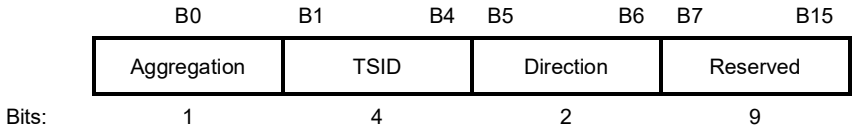


**Figure 9-413—Schedule Info field format**

The Aggregation subfield is set to 1 if the schedule is an aggregate schedule for all TSIDs associated with the STA to which the frame is directed. It is set to 0 otherwise. The TSID subfield contains a value allowed for a TSID, as defined in 9.2.4.5.2 (TID subfield), and indicates the TSID for which this schedule applies. The TSID subfield is reserved when the Schedule element is included within a GCR Response subelement. The Direction subfield is defined in 9.4.2.28 (TSPEC element) and defines the direction of the TSPEC associated with the schedule. In a Schedule element sent within a GCR Response subelement, the Direction


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subfield is set to "Downlink." The TSID and Direction subfields are valid only when the Aggregation subfield is 0. If the Aggregation subfield is 1, the TSID and Direction subfields are reserved.

The Service Start Time field indicates the anticipated time, expressed in microseconds, when service starts and represents the lower order 4 octets of the TSF timer value at the start of the first SP. The AP uses this field to confirm or modify the service start time indicated in the TSPEC request.

The Service Interval field indicates the time, expressed in microseconds, between two successive SPs and represents the measured time from the start of one SP to the start of the next SP. If the Schedule element is included within a GCR Response subelement that has the GCR delivery method equal to GCR-SP, the Service Interval field set to 0 indicates the delivery method is GCR-A.

The Specification Interval field contains an unsigned integer that specifies the time interval, in TUs, to verify schedule compliance.

The HC can set the Service Start Time field and the Service Interval field to 0 (unspecified) for nonpowersaving STAs, except when the Schedule element is included within a GCR Response subelement that has the GCR delivery method equal to GCR-SP (see 11.21.16.3.8 (GCR-SP)). When the Schedule element is included within a GCR Response subelement that has the GCR delivery method equal to GCR-SP, the Service Start Time field is not set to 0 and the Service Interval field might be set to 0.

### 9.4.2.33 QoS Capability element

The QoS Capability element contains a number of subfields that are used to advertise optional QoS capabilities at a QoS STA. The QoS Capability element is defined in Figure 9-414 (QoS Capability element format).

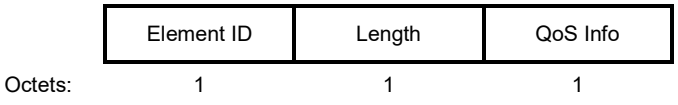


**Figure 9-414—QoS Capability element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The QoS Info field is defined in 9.4.1.17 (QoS Info field).

### 9.4.2.34 AP Channel Report element

The AP Channel Report element contains a list of channels where a STA is likely to find an AP. The format of the AP Channel Report element is shown in Figure 9-415 (AP Channel Report element format). See 11.10.18 (AP Channel Report) for details.

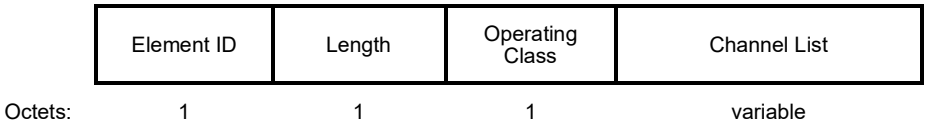


**Figure 9-415—AP Channel Report element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

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The Operating Class field contains an enumerated value from Annex E, specifying the operating class in which the Channel List field is valid. An AP Channel Report only reports channels for a single operating class. Multiple AP Channel Report elements are present when reporting channels in more than one operating class.

The Channel List field contains a variable number of octets, where each octet describes a single channel number. Channel numbering is dependent on Operating Class according to Annex E.

### 9.4.2.35 Neighbor Report element

The Neighbor Report element describes an AP. The format of the Neighbor Report element is shown in Figure 9-416 (Neighbor Report element format).

| | Element ID | Length | BSSID | BSSID Information | Operating Class | Channel Number | PHY Type | Optional Subelements |
|---|---|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 6 | 4 | 1 | 1 | 1 | variable |

**Figure 9-416—Neighbor Report element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The value of the BSSID field is the BSSID of the BSS being reported. The subsequent fields in the Neighbor Report element pertain to this BSS.

The BSSID Information field can be used to help determine neighbor service set transition candidates. The format of the BSSID Information field is shown in Figure 9-417 (BSSID Information field format(11ax)(M149)).

| | B0 B1 | B2 | B3 B4 | B5 B9 | B10 | B11 | B12 | B13 |
|---|---|---|---|---|---|---|---|---|
| | AP Reachability | Security | Key Scope | Capabilities | Mobility Domain | High Throughput | Very High Throughput | FTM |
| Bits: | 2 | 1 | 1 | 6 | 1 | 1 | 1 | 1 |

| | B14 | B15 | B16 | B17 | B18 | B19 | B20 | B21 |
|---|---|---|---|---|---|---|---|---|
| | High Efficiency | ER BSS | (#2210) Colocated AP | Unsolicited Probe Responses Active | Member Of ESS With 2.4/5 GHz Colocated AP(#2210) | OCT Supported With Reporting AP | (#2210) Colocated With 6 GHz AP | Reserved |
| Bits: | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

| | B22 | B23 B31 |
|---|---|---|
| | DMG Positioning | Reserved |
| Bits: | 1 | 9 |

**Figure 9-417—BSSID Information field format(11ax)(M149)**



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The AP Reachability field indicates whether the AP identified by this BSSID is reachable by the STA that requested the neighbor report. For example, the AP identified by this BSSID is reachable for the exchange of preauthentication frames as described in 12.6.8.2 (Preauthentication and RSNA key management). The values are shown in Table 9-211 (Reachability field).

**Table 9-211—Reachability field**

| Value | Reachability | Usage |
|---|---|---|
| 0 | Reserved | Not used. |
| 1 | Not Reachable | A station sending a preauthentication frame to the BSSID will not receive a response even if the AP indicated by the BSSID is capable of preauthentication. |
| 2 | Unknown | The AP is unable to determine if the value Reachable or Not Reachable is to be returned. |
| 3 | Reachable | The station sending a preauthentication frame to the BSSID can receive a response from an AP that is capable of preauthentication. |

The Security subfield(#291), if 1, indicates that the AP identified by this BSSID supports the same security provisioning as used by the STA in its current association. If the bit is 0, it indicates either that the AP does not support the same security provisioning or that the security information is not available at this time.

The Key Scope subfield(#291), when set, indicates the AP indicated by this BSSID has the same Authenticator(#1441)(#1380) as the AP sending the report. If this bit is 0, it indicates a distinct Authenticator(#1441)(#1380) or the information is not available.

The Capabilities subfield contains selected capability information for the AP indicated by this BSSID. The 1-bit subfields(#291) within this subfield have the same meaning and are set to the equivalent bits within the Capability Information field (see 9.4.1.4 (Capability Information field)) being sent in the beacons by the AP being reported. The format of the Capabilities subfield is shown in Figure 9-418 (Capabilities subfield format).

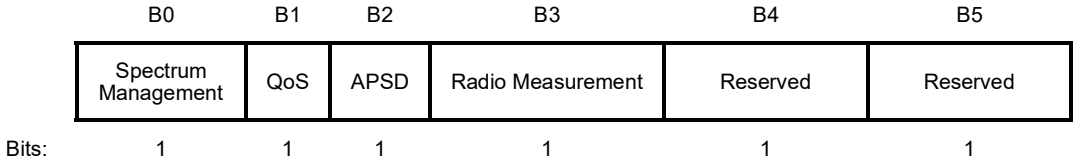


**Figure 9-418—Capabilities subfield format**

The Mobility Domain subfield(#291) is set to 1 to indicate that the AP represented by this BSSID is including an MDE in its Beacon frames and that the contents of that MDE are identical to the MDE advertised by the AP sending the report.

(11ax)The High Throughput subfield(#291) is set to 1 to indicate that the AP represented by this BSSID is an HT AP and that the HT Capabilities element (or HT Operation element), if included as a subelement in the report, is identical in content to the HT Capabilities element (or HT Operation element) included in the neighboring AP's Beacon. Otherwise, the High Throughput subfield is set to 0.

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(11ax)The Very High Throughput subfield(#291) is set to 1 to indicate that the AP represented by this BSSID is a VHT AP and that the VHT Capabilities element (or VHT Operation element), if included as a subelement in the report, is identical in content to the VHT Capabilities element (or VHT Operation element) included in the neighboring AP's Beacon frame. Otherwise, the Very High Throughput subfield is set to 0.

The FTM field is set to 1 to indicate that the AP represented by this BSSID is an AP that has set the (#7065)FTM Responder field of the Extended Capabilities element to 1. The FTM field is set to 0 to indicate either that the reporting AP has dot11FineTimingMsmtRespActivated equal to false, or the reported AP has not set the (#7065)FTM Responder field of the Extended Capabilities element to 1 or that the (#7065)FTM Responder field of the reported AP is not available to the reporting AP at this time.(11ax)

(11ax)The High Efficiency subfield is set to 1 to indicate that the AP represented by this BSSID is an HE AP and that the HE Capabilities element (or HE Operation element), if included as a subelement in the report, is identical in content to the HE Capabilities element (or HE Operation element) included in the neighboring AP's Beacon frame. Otherwise, the High Efficiency subfield is set to 0.

(11ax)The ER BSS subfield is set to 1 if the BSS corresponding to the HE AP representing this BSSID is an ER BSS transmitting Beacon frames using an HE ER SU PPDU (see 26.17.6 (ER beacon generation in an ER BSS)). Otherwise, the ER BSS subfield is set to 0.

(11ax)The (#2210)Colocated AP subfield is set to 1 to indicate that the AP reported in this Neighbor Report element is in the same (#2210)colocated AP set as the AP sending the Neighbor Report element.

(11ax)(#2310)The Unsolicited Probe Responses Active subfield is set to 1, if the reported AP is part of an ESS where all the APs operate in the same channel as the reported AP and are on the same channel and in range of a STA receiving this frame, have dot11UnsolicitedProbeResponseOptionActivated equal to true and are transmitting unsolicited Probe Response frames every 20 TUs or less (see 26.17.2.3 (Scanning in the 6 GHz band)). It is set to 0 otherwise or if the reporting AP does not have that information.

(11ax)The Member Of ESS With 2.4/5 GHz (#2210)Colocated AP subfield is set to 1 if the reported AP is part of an ESS where (#2310)all the APs in the ESS are operating in the same band as the reported AP (irrespective of the operating channel in that band) and are on the same channel and in the range of a STA receiving this frame have dot11MemberOfColocated6GHzESSOptionActivated equal to true and also have a corresponding AP operating in the 2.4 GHz or 5 GHz bands that is in the same (#2210)colocated AP set as that AP. It is set to 0 otherwise or if the reporting AP does not have that information. It is reserved if the reported AP is operating in the 2.4 GHz or 5 GHz bands.

NOTE—This subfield indicates that the reported AP is part of an ESS that has no 6 GHz-only APs that might be detected by a STA receiving this frame. This means that all APs operating in the 6 GHz band that are part of that ESS that might be detected by a STA receiving this frame can be discovered in the 2.4 GHz and/or 5 GHz bands.

(11ax)The OCT Supported With Reported AP subfield is set to 1 to indicate that OCT is supported to exchange MMPDUs with the AP reported in the Neighbor Report element (see 11.31.5 (On-channel Tunneling (OCT) operation)), through over-the-air transmissions with the AP sending the Neighbor Report element. It is set to 0 otherwise.

(11ax)The (#2210)Colocated With 6 GHz AP subfield is set to 1 to indicate that the AP reported by the Neighbor Report element is in the same (#2210)colocated AP set as a 6 GHz AP and that the 6 GHz AP can be discovered by receiving Management frames (as described in 26.17.2.3 (Scanning in the 6 GHz band) and 11.53 (Out-of-band discovery of a 6 GHz BSS(11ax))) sent by the reported AP. It is set to 0 otherwise.

(11az)The DMG Positioning field indicates that (#7108)the reported AP is a DMG AP and supports (#8113)FTM (see 11.21.6.4.2.2 (DMG general measurement exchange(11az))).


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The Operating Class and Channel Number fields(#6181) (and the Condensed Country String subelement, if present) together indicate the primary channel of the BSS being reported. Valid operating classes are listed in Annex E.(#2324)

The Channel Number field indicates the last known primary channel of the AP indicated by this BSSID. Channel number is defined within an operating class as shown in Annex E.

The PHY Type field indicates the PHY type of the AP indicated by this BSSID. It is an integer value coded according to the value of the dot11PHYType.

The Optional Subelements field contains zero or more subelements. The subelement format and ordering of subelements are defined in 9.4.3 (Subelements).

The Subelement ID field values for the defined subelements are shown in Table 9-212 (Optional subelement IDs for Neighbor Report).

**Table 9-212—Optional subelement IDs for Neighbor Report**

| Subelement ID | Name | Extensible |
|---|---|---|
| 0 | Reserved | |
| 1 | TSF Information | Yes |
| 2 | Condensed Country String | Yes |
| 3 | BSS Transition Candidate Preference | No |
| 4 | BSS Termination Duration | No |
| 5 | Bearing | No |
| 6 | Wide Bandwidth Channel | Yes |
| 7–38 | Reserved | |
| 39 | Measurement Report | Subelements |
| 40–44 | Reserved | |
| 45 | HT Capabilities subelement | Yes |
| 46–60 | Reserved | |
| 61 | HT Operation subelement | Yes |
| 62 | Secondary Channel Offset subelement | No |
| 63–65 | Reserved | |
| 66 | Measurement Pilot Transmission | Subelements |
| 67–69 | Reserved | |
| 70 | RM Enabled Capabilities | Yes |
| 71 | Multiple BSSID | Subelements |
| 72–190 | Reserved | |
| 191 | VHT Capabilities | Yes |
| 192 | VHT Operation | Yes |
| 193(11ax) | HE Capabilities | Yes |
| 194(11ax) | HE Operation | Yes |

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**Table 9-212—Optional subelement IDs for Neighbor Report *(continued)***

| Subelement ID | Name | Extensible |
|---|---|---|
| 195(11ax) | BSS Load | |
| 196(11ax) | HE BSS Load | Yes |
| 197(11ax) | SSID | |
| 198(#3005) | HE 6 GHz Band Capabilities | Yes |
| 199–220 | Reserved | |
| 221 | Vendor Specific | Vendor defined |
| 222–255 | Reserved | |

The TSF subelement contains TSF Offset and Beacon Interval subfields as shown in Figure 9-419 (TSF sub-element format).

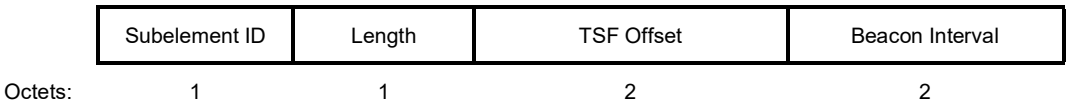


**Figure 9-419—TSF subelement format**

The Length field is defined in 9.4.3 (Subelements).

The TSF Offset subfield contains the neighbor AP's TSF timer offset. This is the time difference, in TUs, between the serving AP and a neighbor AP. This offset is given modulo the neighbor AP's Beacon Interval and rounded to the nearest TU boundary.

The Beacon Interval field is the beacon interval of the Neighbor AP indicated by this BSSID. This field is defined in 9.4.1.3 (Beacon Interval field) and in Figure 9-139 (Beacon Interval field format).

The Condensed Country String subelement's Data field contains the first two octets of the value contained in dot11CountryString. This subelement is present only if the country of the neighbor AP indicated by the BSSID differs from the country of the AP that sent this neighbor report.

The Measurement Pilot Transmission subelement has the same format as the Measurement Pilot Transmission element (see 9.4.2.40 (Measurement Pilot Transmission element)). The Measurement Pilot Transmission subelement is not included if the reported AP is not transmitting Measurement Pilot frames or if the measurement pilot interval of the reported AP is unknown.

A Measurement Report subelement with the Measurement Type field equal to LCI (see Table 9-163 (Measurement Type field definitions for measurement reports)) is optionally present. If present, the subelement has the same format as the Measurement Report element with Measurement Type field equal to LCI.The subelement indicates the LCI of the neighbor STA and further includes the Z subelement, or the subelement indicates an unknown LCI (see 11.21.6.7 (LCI and Location Civic retrieval using FTM procedure)). The Late, Incapable and Refused subfields(#291) in the Measurement Report Mode field are set to 0. The (#2210)Colocated BSSID List subelement is present in the Measurement Report subelement of the Neighbor Report element, when there is at least one other BSS that is (#2210)colocated within the same physical device as the reporting BSS.


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A Measurement Report subelement with the Measurement Type field equal to Location Civic (see Table 9-163 (Measurement Type field definitions for measurement reports)) is optionally present. If present, the subelement has the same format as the Measurement Report element with Measurement Type field equal to Location Civic, and the subelement indicates the civic address of the transmitting STA or an unknown civic address (see 11.21.6.7 (LCI and Location Civic retrieval using FTM procedure)). The Late, Incapable and Refused subfields(#291) in the Measurement Report Mode field are set to 0. The (#2210)Colocated BSSID List subelement is present in the Measurement Report subelement of the Neighbor Report element, when there is at least one other BSS which is (#2210)colocated within the same physical device as the reporting BSS. When a Measurement Report subelement with Measurement Type field equal to LCI that includes a (#2210)Colocated BSSID List subelement is present, the (#2210)Colocated BSSID List subelement is not present in the Measurement Report subelement with Measurement Type field equal to Location Civic.

The HT Capabilities subelement has the same format as the HT Capabilities element as defined in 9.4.2.54 (HT Capabilities element).(#3006)

The HT Operation subelement has the same format as the HT Operation element as defined in 9.4.2.55 (HT Operation element).(#3006)

The Secondary Channel Offset subelement has the same format as the Secondary Channel Offset element as defined in 9.4.2.18 (Secondary Channel Offset element).(#3006)

The RM Enabled Capabilities subelement has the same format as the RM Enabled Capabilities element (see 9.4.2.43 (RM Enabled Capabilities element)).

The Multiple BSSID subelement has the same format as the Multiple BSSID element (see 9.4.2.44 (Multiple BSSID element)). The reference BSSID for the Multiple BSSID subelement is the BSSID field in the Neighbor Report element. This subelement is not present if the neighbor AP is not a member of a multiple BSSID set with two or more members (#2163)or its membership is unknown (see 11.10.14 (Multiple BSSID set)).

The format of the BSS Transition Candidate Preference subelement is shown in Figure 9-420 (BSS Transition Candidate Preference subelement format).

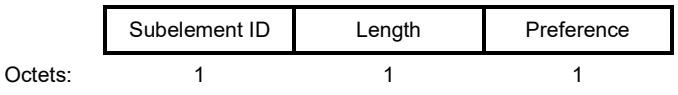


**Figure 9-420—BSS Transition Candidate Preference subelement format**

The Length field is defined in 9.4.3 (Subelements).

The Preference field indicates the network preference for BSS transition to the BSS listed in this BSS Transition Candidate List Entries field in the BSS Transition Management Request frame, BSS Transition Management Query frame, and BSS Transition Management Response frame. The Preference field value is a number ranging from 0 to 255, as defined in Table 9-213 (Preference field values), indicating an ordering of preferences for the BSS transition candidates for this STA. Additional details describing use of the Preference field are provided in 11.21.7 (BSS transition management(#556)).

The BSS Termination TSF field contained in the BSS Termination Duration subelement is the TSF time of the BSS transmitting the neighbor report that corresponds to the time when termination of the neighbor BSS occurs. How the BSS determines the neighbor BSS termination time is out of scope of the standard. The format of the BSS Termination Duration subelement is shown in Figure 9-421 (BSS Termination Duration subelement format).

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**Table 9-213—Preference field values**

| Preference field value | Description |
|---|---|
| 0 | Excluded BSS; reserved when present in the BSS Transition Management Query or BSS Transition Management Response frames. |
| 1–255 | Relative values used to indicate the preferred ordering of BSSs, with 255 indicating the most preferred candidate and 1 indicating the least preferred candidate. |

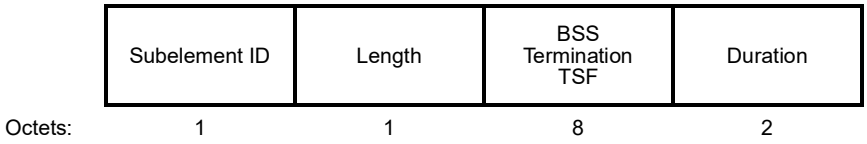


**Figure 9-421—BSS Termination Duration subelement format**

The Length field is defined in 9.4.3 (Subelements).

The BSS Termination TSF field indicates the value of the TSF timer when BSS termination will occur in the future. A BSS Termination TSF field set to 0 indicates that termination of the BSS will occur imminently. Prior to termination of the BSS, all associated STAs are disassociated by the AP.

The Duration field (#2047)indicates the number of minutes for which the BSS is not present. A Duration field set to 0 is reserved. A Duration field set to 65 535 when the BSS is terminated for a period longer than or equal to 65 535 minutes.

The format of the Bearing subelement is shown in Figure 9-422 (Bearing subelement format).

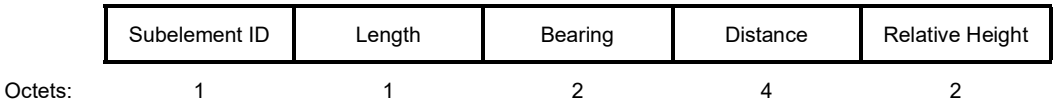


**Figure 9-422—Bearing subelement format**

The Length field is defined in 9.4.3 (Subelements).

The Bearing field specifies the direction that the neighbor, specified by the BSSID field in the Neighbor Report element, is positioned, relative to the reporting BSS and defined in relation to true north, increasing clockwise, measured in degrees from 0° to 359°. If the Bearing value is unknown, the subelement is not included.

The Distance field specifies the distance that the neighbor, specified by the BSSID field in the Neighbor Report element, is positioned relative to the reporting BSS as a floating point value, in meters.(#3432)

The Relative Height field, defined by a 2s complement signed integer, specifies the relative height in meters that the neighbor is positioned, relative to the reporting BSS. If the relative height is unknown or at the same height as the reporting BSS, the field is 0.

The format of the Wide Bandwidth Channel subelement is shown in Figure 9-423 (Wide Bandwidth Channel subelement format).

The Length field is defined in 9.4.3 (Subelements).


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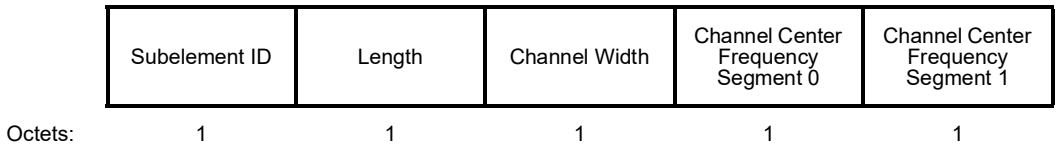


**Figure 9-423—Wide Bandwidth Channel subelement format**

The Channel Width, Channel Center Frequency Segment 0, and Channel Center Frequency Segment 1 subfields are defined in Table 9-214 (HT/VHT Operation Information subfields).

**Table 9-214—HT/VHT Operation Information subfields**

| Field | Definition | Encoding |
|---|---|---|
| Channel Width | This field defines the BSS bandwidth (see 11.38.1 (Basic VHT BSS functionality)). | Set to 0 for 20 MHz BSS bandwidth.<br>Set to 1 for 40 MHz BSS bandwidth.<br>Set to 2 for 80 MHz BSS bandwidth.<br>Set to 3 for 160 MHz BSS bandwidth.<br>Set to 4 for 80+80 MHz BSS bandwidth.<br>Values in the range 5 to 255 are reserved. |
| Channel Center Frequency Segment 0 | Defines the channel center frequency for an HT or VHT BSS or the frequency segment 0 channel center frequency for an 80+80 MHz VHT BSS. See 21.3.14 (Channelization). | For 20, 40, 80, or 160 MHz BSS bandwidth, indicates the channel number of the center frequency(#6420) for the channel on which the HT or VHT BSS operates.<br><br>For 80+80 MHz BSS bandwidth, indicates the channel number of the center frequency(#6420) for the 80 MHz channel of frequency segment 0 on which the VHT BSS operates. |
| Channel Center Frequency Segment 1 | Defines the frequency segment 1 channel center frequency for an 80+80 MHz VHT BSS. See 21.3.14 (Channelization). | For an 80+80 MHz BSS bandwidth, indicates the channel number of the center frequency(#6420) of the 80 MHz channel of frequency segment 1 on which the VHT BSS operates. The channel number of the center frequency(#6420) of segment 1 differs by more than 16 from the channel number of the center frequency(#6420) of segment 0 (i.e., the channel center frequencies are more than 80 MHz apart).<br>Reserved otherwise. |

The VHT Capabilities subelement has the same format as the VHT Capabilities element as defined in 9.4.2.156 (VHT Capabilities element).(#3006)

The VHT Operation subelement has the same formatas the VHT Operation element as defined in 9.4.2.157 (VHT Operation element).(#3006)

(11ax)The Data field of the HE Capabilities subelement has the same format as the Information field of the HE Capabilities element (see 9.4.2.247 (HE Capabilities element(11ax))).(#3006)

(11ax)The Data field of the HE Operation subelement has the same format as the Information field of HE Operation element (see 9.4.2.248 (HE Operation element(11ax))).(#3006)

(11ax)The BSS Load subelement has the same format as the BSS Load element (see 9.4.2.26 (BSS Load element)).

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(11ax)The Data field of the HE BSS Load subelement has the same format as the Information field of the HE BSS Load element (see 9.4.2.258 (HE BSS Load element(11ax))).(#3006)

(11ax)The SSID subelement has the same format as the SSID element (see 9.4.2.2 (SSID element)).

(#3005)The Data field of the HE 6 GHz Band Capabilities subelement has the same format as the Information field of the HE 6 GHz Band Capabilities element (see 9.4.2.262 (HE 6 GHz Band Capabilities element(11ax))).

The Vendor Specific subelement has the same format as the Vendor Specific element (see 9.4.2.24 (Vendor Specific element)). Zero or more Vendor Specific subelements are included in the list of optional subelements.

### 9.4.2.36 RCPI element

The RCPI element indicates the received frame power level at the receiving STA as shown in Figure 9-424 (RCPI element format).

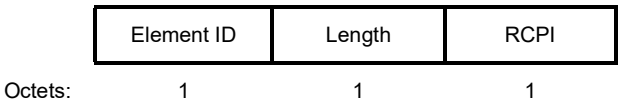


**Figure 9-424—RCPI element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The RCPI field contains an RCPI value, which is an indication of the received RF power in the selected channel for a received frame.

The value of the RCPI field is a monotonically increasing, logarithmic function of the received power level. The allowed values for the RCPI field are defined in Table 9-215 (RCPI values), where P is the received power level in dBm.

**Table 9-215—RCPI values**

| RCPI Value | Description |
|---|---|
| 0 | Represents $P < -109.5$ dBm |
| 1–219 | Power levels in the range $-109.5 \le P < 0$ are represented by RCPI $= \lfloor 2 \times (P + 110) \rfloor$ |
| 220 | Represents $P \ge 0$ dBm |
| 221–254 | Reserved |
| 255 | Measurement not available |


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### 9.4.2.37 BSS Average Access Delay element

The BSS Average Access Delay element contains the AP Average Access Delay, which is a measure of load in the BSS and is available in both QoS APs and non-QoS APs. The format of the BSS Average Access Delay element is defined in Figure 9-425 (BSS Average Access Delay element format).

**Figure 9-425—BSS Average Access Delay element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The AP Average Access Delay is a scalar indication of the relative level of loading at an AP. A low value indicates more available capacity than a higher value. If the AP is not currently transmitting any DCF or EDCAF traffic, the AP Average Access Delay is set to 255. The values between 1 and 252 are a scaled representation of the average medium access delay for all DCF and EDCAF transmitted frames measured from the time the DCF or EDCAF MPDU is ready for transmission (i.e., begins CSMA/CA access) until the actual frame transmission start time. Non-QoS APs average the access delays for all DCF transmitted frames. QoS APs average the access delays for all EDCA transmitted frames of all ACs. The AP Average Access Delay values are scaled as follows:

| | |
|---|---|
| 0: | Access Delay < 8 μs |
| 1: | 8 μs ≤ Access Delay < 16 μs |
| 2 ≤ n ≤ 14: | n × 8 μs ≤ Access Delay < (n + 1) × 8 μs |
| 15: | 120 μs ≤ Access Delay < 128 μs |
| 16: | 128 μs ≤ Access Delay < 144 μs |
| 17 ≤ n ≤ 106: | (n × 16) – 128 μs ≤ Access Delay < ((n + 1) × 16) – 128 μs |
| 107: | 1 584 μs ≤ Access Delay < 1 600 μs |
| 108: | 1 600 μs ≤ Access Delay < 1 632 μs |
| 109 ≤ n ≤ 246: | (n × 32) – 1 856 μs ≤ Access Delay < ((n + 1) × 32) – 1 856 μs |
| 247: | 6 048 μs ≤ Access Delay < 6 080 μs |
| 248: | 6 080 μs ≤ Access Delay < 8 192 μs |
| 249: | 8 192 μs ≤ Access Delay < 12 288 μs |
| 250: | 12 288 μs ≤ Access Delay < 16 384 μs |
| 251: | 16 384 μs ≤ Access Delay < 20 480 μs |
| 252: | 20 480 μs ≤ Access Delay < 24 576 μs |
| 253: | 24 576 μs ≤ Access Delay |
| 254: | Service unable to access channel |
| 255: | Measurement not available |

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The values 0–253 indicate the average access delay when one or more frames were transmitted during the measurement window. The value 254 indicates that the DCF is or the EDCAFs are currently unable to access the channel due to continuous carrier sense mechanism deferral and that no frames were transmitted during the measurement window. The AP measures and averages the medium access delay for all transmit frames using the DCF or the EDCAFs over a continuous 30 s measurement window. See 11.10.16 (Access delay measurement) for accuracy requirements.

#### 9.4.2.38 Antenna element

The Antenna element contains the Antenna ID field as shown in Figure 9-426 (Antenna element format).

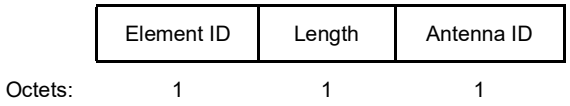


**Figure 9-426—Antenna element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The Antenna ID field contains the identifying number for the relevant antenna(s) or DMG antenna.

For a non-DMG STA, the antenna ID identifies the antenna(s) used to transmit the frame the Antenna element is contained in, or the antenna(s) used to receive an earlier frame, depending on the frame the antenna ID is contained in. A specific antenna has an antenna ID between 1 and 254. The value 0 indicates that the antenna ID is unknown. The value 255 indicates that this transmission was made with multiple antennas, i.e., antennas were switched during the transmission. If during frame reception different antennas are used to receive the preamble and body, the antenna ID identifies the antenna that receives the frame body. In these cases, the value 255 is not used. Antenna IDs are assigned to each antenna and each antenna configuration as consecutive integers starting with 1. Each antenna ID number represents a unique antenna or unique configuration of multiple antennas characterized by a fixed relative position, a fixed relative direction, and a fixed peak gain for that position and direction.

For a DMG STA, the DMG antenna ID identifies the DMG antenna used to transmit the frame the Antenna element is contained in, or the DMG antenna used to receive an earlier frame, depending on the frame the DMG antenna ID is contained in. A specific DMG antenna has a DMG antenna ID between 0 and 3. DMG antenna IDs are assigned to each DMG antenna as consecutive integers starting with 0.

#### 9.4.2.39 RSNI element

The RSNI element contains an RSNI value, as shown in Figure 9-427 (RSNI element format).

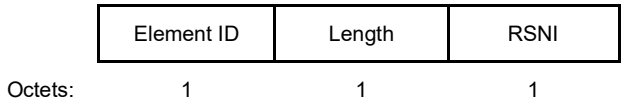


**Figure 9-427—RSNI element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The value of the RSNI field is in steps of 0.5 dB. RSNI is calculated by the ratio of the received signal power (RCPI-ANPI) to the noise plus interference power (ANPI) using the expression:


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$$RSNI = (10 \times \log10((RCPI_{power} - ANPI_{power}) / ANPI_{power})+10) \times 2$$

where $RCPI_{power}$ and $ANPI_{power}$ indicate power domain values for RCPI and ANPI and not dB domain values. RSNI in dB is scaled in steps of 0.5 dB to obtain 8-bit RSNI values, which cover the range from –10 dB to +117 dB. The value 255 indicates that RSNI is not available. See 11.10.9.4 (Noise Histogram report) for details and procedures for measuring ANPI.

### 9.4.2.40 Measurement Pilot Transmission element

The Measurement Pilot Transmission element contains a Measurement Pilot Transmission field as shown in Figure 9-428 (Measurement Pilot Transmission element format).

| | Element ID | Length | Measurement Pilot Transmission | Optional Subelements |
|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | variable |

**Figure 9-428—Measurement Pilot Transmission element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The Measurement Pilot Transmission field contains the measurement pilot interval as specified in 9.4.1.18 (Measurement Pilot Interval field).

The Optional Subelements field contains zero or more subelements. The subelement format and ordering of subelements are defined in 9.4.3 (Subelements).

The Subelement ID field values for the defined subelements are shown in Table 9-216 (Optional subelement IDs for Measurement Pilot Transmission).

**Table 9-216—Optional subelement IDs for Measurement Pilot Transmission**

| Subelement ID | Name | Extensible |
|---|---|---|
| 0–220 | Reserved | |
| 221 | Vendor Specific | Vendor defined |
| 222–255 | Reserved | |

The Vendor Specific subelements have the same format as their corresponding elements (see 9.4.2.24 (Vendor Specific element)). Zero or more Vendor Specific subelements are included in the list of optional subelements.

### 9.4.2.41 BSS Available Admission Capacity element

The BSS Available Admission Capacity element contains a list of Available Admission Capacity fields at different User Priorities and Access Categories as shown in Figure 9-429 (BSS Available Admission Capacity element format).

NOTE—The BSS Available Admission Capacity element is helpful for (#1600)BSS transitioning QoS STAs to select a QoS AP that is likely to accept future admission control requests, but it does not provide an assurance that the HC will admit these requests.

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| | Element ID | Length | Available Admission Capacity Bitmask | Available Admission Capacity List |
|---|---|---|---|---|
| Octets: | 1 | 1 | 2 | 2 × (total number of nonzero bits in Available Admission Capacity Bitmask) |

**Figure 9-429—BSS Available Admission Capacity element format**

The Element ID and Length fields are defined in 9.4.2.1 (General). The Length field is set to $2 + 2N_{nz}$, where $N_{nz}$ equals the total number of nonzero bits in Available Admission Capacity Bitmask.

The Available Admission Capacity Bitmask field indicates the UP values that have an Available Admission Capacity specified in the Available Admission Capacity List field. The format of the Available Admission Capacity Bitmask is defined in Table 9-217 (Available Admission Capacity Bitmask definition).

**Table 9-217—Available Admission Capacity Bitmask definition**

| Bit | Available Admission Capacity Reported |
|---|---|
| 0 | UP 0 |
| 1 | UP 1 |
| 2 | UP 2 |
| 3 | UP 3 |
| 4 | UP 4 |
| 5 | UP 5 |
| 6 | UP 6 |
| 7 | UP 7 |
| 8 | AC 0 |
| 9 | AC 1 |
| 10 | AC 2 |
| 11 | AC 3 |
| 12–15 | Reserved |

Each bit in the Available Admission Capacity Bitmask is set to 1 to indicate that the Available Admission Capacity for the corresponding traffic type is present in the Available Admission Capacity List field. The bit is set to 0 to indicate that the Available Admission Capacity for the corresponding traffic type is not present in the Available Admission Capacity List field.

The Available Admission Capacity List comprises a sequence of Available Admission Capacity fields corresponding respectively to the nonzero bits in the Available Admission Capacity Bitmask field.

Each Available Admission Capacity field is 2 octets long and contains an unsigned integer that specifies the amount of medium time available using explicit admission control for the corresponding UP or AC traffic, in units of 32 μs per 1 s. See 11.10.17 (BSS Available Admission Capacity) for furthers details.


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### 9.4.2.42 BSS AC Access Delay element

The BSS AC Access Delay element contains an Access Category Access Delay field, as shown in Figure 9-430 (BSS AC Access Delay element format).

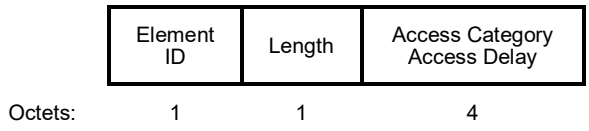


**Figure 9-430—BSS AC Access Delay element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The Access Category Access Delay field is formatted as four subfields as shown in Figure 9-431 (Access Category Access Delay subfield format). The value of the AC Access Delay field is a scalar indication of the average access delay at a QoS AP for services for each of the indicated access categories. If the QoS AP is not currently transmitting any traffic using the indicated AC, the value of Average Access Delay field for that AC is set to 255. The values between 1 and 252 are a scaled representation of the average medium access delay for transmitted frames in the indicated AC measured from the time the EDCA MPDU is ready for transmission (i.e., begins CSMA/CA access) until the actual frame transmission start time. The AC Access Delay values are scaled as follows:

| | |
|---|---|
| 0: | Access Delay < 8 μs |
| 1: | 8 μs ≤ Access Delay < 16 μs |
| $2 \le n \le 14$: | $n \times 8$ μs ≤ Access Delay < $(n + 1) \times 8$ μs |
| 15: | 120 μs ≤ Access Delay < 128 μs |
| 16: | 128 μs ≤ Access Delay < 144 μs |
| $17 \le n \le 106$: | $(n \times 16) - 128$ μs ≤ Access Delay < $((n + 1) \times 16) - 128$ μs |
| 107: | 1584 μs ≤ Access Delay < 1600 μs |
| 108: | 1600 μs ≤ Access Delay < 1632 μs |
| $109 \le n \le 246$: | $(n \times 32) - 1856$ μs ≤ Access Delay < $((n + 1) \times 32) - 1856$ μs |
| 247: | 6048 μs ≤ Access Delay < 6080 μs |
| 248: | 6080 μs ≤ Access Delay < 8192 μs |
| 249: | 8192 μs ≤ Access Delay < 12 288 μs |
| 250: | 12 288 μs ≤ Access Delay < 16 384 μs |
| 251: | 16 384 μs ≤ Access Delay < 20 480 μs |
| 252: | 20 480 μs ≤ Access Delay < 24 576 μs |
| 253: | 24 576 μs ≤ Access Delay |
| 254: | Service unable to access channel |
| 255: | Measurement not available |

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The values 0–253 indicate the average access delay when one or more frames were transmitted during the measurement window. The value 254 indicates that the EDCAF is currently unable to access the channel due to continuous carrier sense mechanism deferral to higher priority AC transmissions and that no frames were transmitted during the measurement window. The QoS AP measures and averages the medium access delay for all transmit frames of the indicated AC using EDCA mechanism over a continuous 30 s measurement window. See 11.10.16 (Access delay measurement) for accuracy requirements.

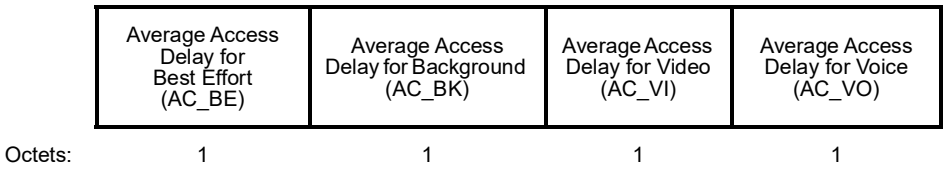


**Figure 9-431—Access Category Access Delay subfield format**

### 9.4.2.43 RM Enabled Capabilities element

The RM Enabled Capabilities element signals support for radio measurements in a STA. The element is shown in Figure 9-432 (RM Enabled Capabilities element format).

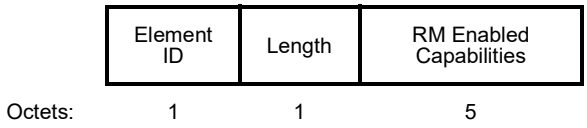


**Figure 9-432—RM Enabled Capabilities element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The RM Enabled Capabilities field is an octet string. Each subfield of this field indicates whether the corresponding capability listed in Table 9-218 (RM Enabled Capabilities definition) is enabled.

**Table 9-218—RM Enabled Capabilities definition**

| Bit position in the RM Enabled Capabilities field | Field name | Notes |
|---|---|---|
| 0 | Link Measurement Capability Enabled | A STA sets the Link Measurement Capability Enabled field to 1 when dot11RMLinkMeasurementActivated is true and sets it to 0 otherwise. |
| 1 | Neighbor Report Capability Enabled | A STA sets the Neighbor Report Capability Enabled field to 1 when dot11RMNeighborReportActivated is true and sets it to 0 otherwise. |
| 2 | Parallel Measurements Capability Enabled | A STA sets the Parallel Measurements Capability Enabled field to 1 when dot11RMParallelMeasurementsActivated is true and sets it to 0 otherwise. |
| 3 | Repeated Measurements Capability Enabled | A STA sets the Repeated Measurements Capability Enabled field to 1 when dot11RMRepeatedMeasurementsActivated is true and sets it to 0 otherwise. |
| 4 | Beacon Passive Measurement Capability Enabled | A STA sets the Beacon Passive Measurement Capability Enabled field to 1 when dot11RMBeaconPassiveMeasurementActivated is true and sets it to 0 otherwise. |


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**Table 9-218—RM Enabled Capabilities definition *(continued)***

| Bit position in the RM Enabled Capabilities field | Field name | Notes |
|---|---|---|
| 5 | Beacon Active Measurement Capability Enabled | A STA sets the Beacon Active Measurement Capability Enabled field to 1 when dot11RMBeaconActiveMeasurementActivated is true and sets it to 0 otherwise. |
| 6 | Beacon Table Measurement Capability Enabled | A STA sets the Beacon Table Measurement Capability Enabled field to 1 when dot11RMBeaconTableMeasurementActivated is true and sets it to 0 otherwise. |
| 7 | Beacon Measurement Reporting Conditions Capability Enabled | A STA sets the Beacon Measurement Reporting Conditions Capability Enabled field to 1 when dot11RMBeaconMeasurementReportingConditionsActivated is true and sets it to 0 otherwise. |
| 8 | Frame Measurement Capability Enabled | A STA sets the Frame Measurement Capability Enabled field to 1 when dot11RMFrameMeasurementActivated is true and sets it to 0 otherwise. |
| 9 | Channel Load Measurement Capability Enabled | A STA sets the Channel Load Measurement Capability Enabled field to 1 when dot11RMChannelLoadMeasurementActivated is true and sets it to 0 otherwise. |
| 10 | Noise Histogram Measurement Capability Enabled | A STA sets the Noise Histogram Measurement Capability Enabled field to 1 when dot11RMNoiseHistogramMeasurementActivated is true and sets it to 0 otherwise. |
| 11 | Statistics Measurement Capability Enabled | A STA sets the Statistics Measurement Capability Enabled field to 1 when dot11RMStatisticsMeasurementActivated is true and sets it to 0 otherwise. |
| 12 | LCI Measurement Capability Enabled | A STA sets the LCI Measurement Capability Enabled field to 1 when dot11RMLCIMeasurementActivated is true and sets it to 0 otherwise. |
| 13 | LCI Azimuth Capability Enabled | A STA sets the LCI Azimuth Capability Enabled field to 1 when dot11RMLCIAzimuthActivated is true and sets it to 0 otherwise. |
| 14 | Transmit Stream/ Category Measurement Capability Enabled | A STA sets the Transmit Stream/Category Measurement Capability Enabled field to 1 when dot11RMTransmitStreamCategoryMeasurementActivated is true and sets it to 0 otherwise. |
| 15 | Triggered Transmit Stream/Category Measurement Capability Enabled | A STA sets the Triggered Transmit Stream/Category Measurement Capability Enabled field to 1 when dot11RMTriggeredTransmitStreamCategoryMeasurementActivated is true and sets it to 0 otherwise. |
| 16 | AP Channel Report Capability Enabled | A STA sets the AP Channel Report Capability Enabled field to 1 when dot11RMAPChannelReportActivated is true and sets it to 0 otherwise. |
| 17 | RM MIB Capability Enabled | A STA sets the RM MIB Capability Enabled field to 1 when dot11RMMIBActivated is true and sets it to 0 otherwise. |
| 18–20 | Operating Channel Max Measurement Duration | A STA sets the Operating Channel Max Measurement Duration field to equal dot11RMMaxMeasurementDuration. See 11.10.4 (Measurement duration). |

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**Table 9-218—RM Enabled Capabilities definition *(continued)***

| Bit position in the RM Enabled Capabilities field | Field name | Notes |
|---|---|---|
| 21–23 | Nonoperating Channel Max Measurement Duration | A STA sets the Nonoperating Channel Max Measurement Duration field to equal dot11RMNonOperatingChannelMaxMeasurementDuration. See 11.10.4 (Measurement duration). |
| 24–26 | Measurement Pilot Capability | A STA sets the Measurement Pilot Capability field to equal dot11RMMeasurementPilotActivated. See Table 11-14 (Measurement pilot activated definition) in 11.10.15 (Measurement Pilot frame generation and usage). |
| 27 | Measurement Pilot Transmission Information Capability Enabled | A STA sets the Measurement Pilot Transmission Capability Enabled field to 1 when dot11RMMeasurementPilotTransmissionInformationActivated is true and sets it to 0 otherwise. |
| 28 | Neighbor Report TSF Offset Capability Enabled | A STA sets the Neighbor Report TSF Offset Capability Enabled field to 1 when dot11RMNeighborReportTSFOffsetActivated is true and sets it to 0 otherwise. |
| 29 | RCPI Measurement Capability Enabled | A STA sets the RCPI Measurement Capability Enabled field to 1 when dot11RMRCPIMeasurementActivated is true and sets it to 0 otherwise. |
| 30 | RSNI Measurement Capability Enabled | A STA sets the RSNI Measurement Capability Enabled field to 1 when dot11RMRSNIMeasurementActivated is true and sets it to 0 otherwise. |
| 31 | BSS Average Access Delay Capability Enabled | A STA sets the BSS Average Access Delay Capability Enabled field to 1 when dot11RMBSSAverageAccessDelayActivated is true and sets it to 0 otherwise (see NOTE). |
| 32 | BSS Available Admission Capacity Capability Enabled | A STA sets the BSS Available Admission Capacity Capability Enabled field to 1 when dot11RMBSSAvailableAdmissionCapacityActivated is true and sets it to 0 otherwise. |
| 33 | Antenna Capability Enabled | A STA sets the Antenna Capability Enabled field to 1 when dot11RMAntennaInformationActivated is true and sets it to 0 otherwise. |
| 34 | FTM Range Report Capability Enabled | A STA sets the FTM Range Report Capability Enabled field to 1 when dot11RMFineTimingMsmtRangeRepActivated is true and sets it to 0 otherwise. |
| 35 | Civic Location Measurement Capability Enabled | A STA sets the Civic Location Measurement Capability Enabled field to 1 when dot11RMCivicMeasurementActivated is true and sets it to 0 otherwise. |
| 36–39 | Reserved | |

NOTE—At a QoS AP dot11RMBSSAverageAccessDelayActivated is true indicates that the AP BSS AC Access Delay capability is also enabled.



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### 9.4.2.44 Multiple BSSID element

The format of the Multiple BSSID element is shown in Figure 9-433 (Multiple BSSID element format).

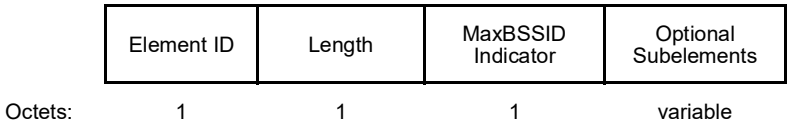


**Figure 9-433—Multiple BSSID element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The MaxBSSID Indicator field contains a value assigned to $n$, where $2^n$ is the maximum number of BSSIDs in the multiple BSSID set, including the reference BSSID (see 11.10.14 (Multiple BSSID set)). The maximum value of $n$ is 8.(11ax)(#1003)

(11ax)The actual number of BSSIDs in the multiple BSSID set is not explicitly signaled. BSSID($i$) corresponding to the $i^{th}$ BSSID in the multiple BSSID set is derived as follows:

A0-A1-A2-A3-A4-A5 = Reference BSSID

$B = A5 \bmod 2^n$

$A5(i) = A5 - B + ((B + i) \bmod 2^n)$

BSSID($i$) = A0-A1-A2-A3-A4-A5($i$)

NOTE 1—For example, for $n$ = 3 and Reference BSSID = 8c-fd-0f-7f-1e-f5:

A5 = f5
B = 5
A5(5) = f2 and BSSID(5) = 8c-fd-0f-7f-1e-f2
A5(2) = f7 and BSSID(2) = 8c-fd-0f-7f-1e-f7

NOTE 2—This definition uses the hexadecimal address representation defined in IEEE Std 802.

NOTE 3—The BSSID index as defined in 9.4.2.72 (Multiple BSSID-Index element) cannot be larger than 255, which effectively limits $n$ to 8.

When the Multiple BSSID element is transmitted in a Beacon, DMG Beacon, or Probe Response frame, the reference BSSID is the BSSID field of the frame. The AP or DMG STA determines the number of Multiple BSSID elements. The AP or DMG STA does not fragment a nontransmitted BSSID profile for a single BSSID across two Multiple BSSID elements, unless the contents of the nontransmitted BSSID profile are greater than the number of octets remaining in the Multiple BSSID element after taking into account the (#6001)size of the mandatory fields (i.e., the MaxBSSID Indicator field, and the Subelement ID and Length fields of the Nontransmitted BSSID Profile subelement) and any preceding Nontransmitted BSSID Profile subelement(s) carried in the element (see 11.1.3.8.2 (Nontransmitted BSSID profile(11ax))). When the Multiple BSSID element is transmitted as a subelement in a Neighbor Report element, the reference BSSID is the BSSID field in the Neighbor Report element.(11ax)

The Optional Subelements field contains zero or more subelements. The subelement format and ordering of subelements are defined in 9.4.3 (Subelements).

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The Subelement ID field values for the defined subelements are shown in Table 9-219 (Optional subelement IDs for Multiple BSSID).

**Table 9-219—Optional subelement IDs for Multiple BSSID**

| Subelement ID | Name | Extensible |
|---|---|---|
| 0 | Nontransmitted BSSID Profile | No |
| 1–220 | Reserved | |
| 221 | Vendor Specific | Vendor defined |
| 222–255 | Reserved | |

A nontransmitted BSSID profile (#4000)(see 11.1.3.8.2 (Nontransmitted BSSID profile(11ax))) carried in one or more Nontransmitted BSSID Profile subelements across one or more multiple BSSID elements in the same frame contains a list of elements for the AP or the DMG STA that has a nontransmitted BSSID and is defined as follows:(11ax)

— The Nontransmitted BSSID Capability element is the first element included followed by the SSID element and Multiple BSSID-Index element which are included as the second and third elements, respectively. This is followed by any element that is specific to the nontransmitted BSSID (see 11.1.3.8.4 (Inheritance of element values(11ax)) for details on the inheritance operation and what qualifies as an element specific to the nontransmitted BSSID).(#4000)

— The Timestamp and Beacon Interval fields, TIM, DSSS Parameter Set, IBSS Parameter Set, Country, Channel Switch Announcement, Extended Channel Switch Announcement, Wide Bandwidth Channel Switch, Transmit Power Envelope, Supported Operating Classes, IBSS DFS, ERP Information, HT Capabilities, HT Operation, VHT Capabilities, VHT Operation, S1G Beacon Compatibility, Short Beacon Interval, S1G Capabilities, S1G Operation, HE Capabilities, HE 6 GHz Band Capabilities, HE Operation, BSS Color Change Announcement, Spatial Reuse Parameter Set, Max Channel Switch Time, Quiet, Quiet Channel, and Multiple BSSID Configuration (#3007)(#2189) elements are not included in the Nontransmitted BSSID Profile subelement; the values of these elements for each nontransmitted BSSID are always the same as the corresponding transmitted BSSID element values.(11ax)

— When included in the Nontransmitted BSSID Profile subelement for this nontransmitted BSSID, the Non-Inheritance element (#4000)appears as the last element in the profile and carries a list of elements that are not inherited by this nontransmitted BSSID from the transmitted BSSID.

NOTE 5—A Reduced Neighbor Report element is not carried in the Nontransmitted BSSID Profile subelement. When present in the frame, the values of fields in the element, except the Same SSID subfield(s) apply to all the BSSs in the multiple BSSID set.(11ax)

(11ax)Each Nontransmitted BSSID Profile subelement contains only elements for a BSS with a nontransmitted BSSID.

The Vendor Specific subelements have the same format as their corresponding elements (see 9.4.2.24 (Vendor Specific element)). Zero or more Vendor Specific subelements are included in the list of optional subelements.

The Multiple BSSID element is included in Beacon frames (as described in 9.3.3.2 (Beacon frame format)), (#4001)in S1G Beacon frames (as described in 9.3.4.3 (S1G Beacon frame format)), in DMG Beacon frames (as described in 9.3.4.2 (DMG Beacon)), and Probe Response frames (as described in 9.3.3.10 (Probe Response frame format)). The use of the Multiple BSSID element is described in 11.10.14 (Multiple BSSID


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set). Nontransmitted BSSID advertisement procedures are described in 11.1.3.8 (Multiple BSSID procedure).

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### 9.4.2.45 MDE(#1776)

(#1776)The mobility domain element (MDE) contains the MDID (Mobility Domain Identifier) field and the FT Capability and Policy field. The AP uses the MDE to advertise that it is included in the group of APs that constitute a mobility domain, to advertise its support for FT capability, and to advertise its FT policy information. The format for this element is shown in Figure 9-434 (MDE format(#1776)).

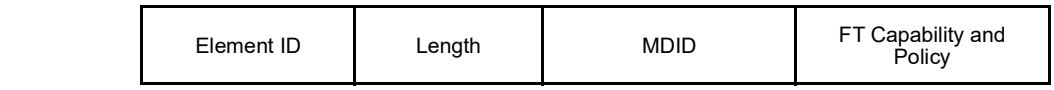


**Figure 9-434—MDE format(#1776)**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The MDID field (#2047)is an identifier that names a mobility domain.

The FT Capability and Policy field is 1 octet. The FT Capability and Policy field is defined in Figure 9-435 (FT Capability and Policy field format).

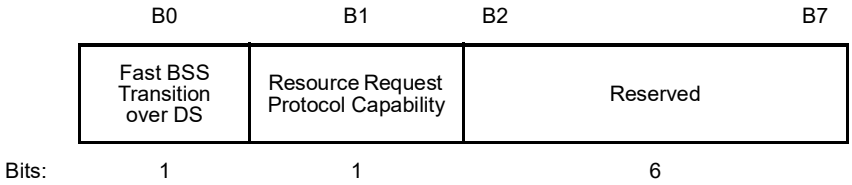


**Figure 9-435—FT Capability and Policy field format**

Bits 0–1 of the FT Capability and Policy field control the behavior of STAs performing fast BSS transitions (see 13.3 (Capability and policy advertisement)). The STA might use information from the MDE to determine the transition methods recommended by the AP and protocols supported by the AP. The choice of executing any specific transition method is outside the scope of this standard.

If the Resource Request Protocol Capability subfield is 1, then the STA might perform the FT resource request protocol as described in 13.6 (FT resource request protocol).

When sent by a STA to a target AP, the FT Capability and Policy field matches the value advertised by that target AP. See 13.8 (FT authentication sequence).

### 9.4.2.46 FTE(#1776)

(#1776)The fast BSS transition element (FTE) includes information needed to perform the FT authentication sequence or FILS authentication during a fast BSS transition in an RSN. This element is shown in Figure 9-436 (FTE format).

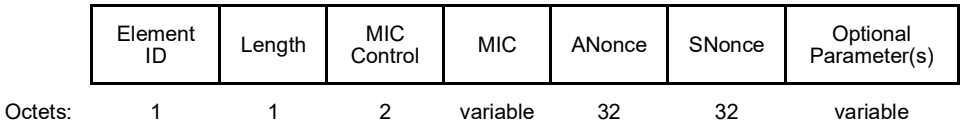


**Figure 9-436—FTE format**



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The Element ID and Length fields are defined in 9.4.2.1 (General).

The MIC Control field (#4170)is defined in Figure 9-437 (MIC Control field format(#3135)).

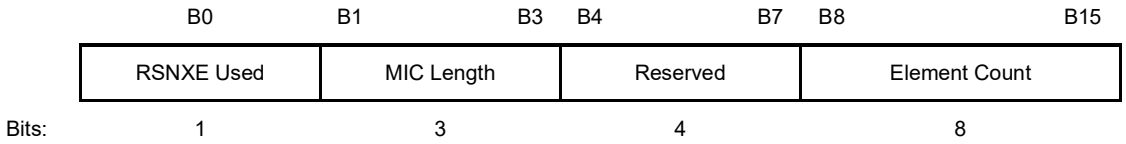


**Figure 9-437—MIC Control field format(#3135)**

The RSNXE Used subfield of the MIC Control field is used in the third and fourth messages of the FT authentication sequence to indicate whether the STA transmitting the frame containing the FTE includes an RSNXE in other frames. This subfield is set to 0 in other frames.

(#3135)When using AKM 00-0F-AC:25, the MIC Length subfield defines the length of the MIC field, as defined in Table 9-220 (MIC Length subfield values(#3135)). This subfield is reserved for other AKMs.

**Table 9-220—MIC Length subfield values(#3135)**

| Value | MIC field length in octets |
|---|---|
| 0 | 16 |
| 1 | 24 |
| 2 | 32 |
| 3–7 | Reserved |

The Element Count subfield of the MIC Control field contains the number of elements that are included in the message integrity code (MIC) calculation.

When the Element Count subfield has a value greater than 0, the MIC field contains a MIC. Otherwise, the MIC field is set to 0.(#118)

The length of the MIC field depends on the negotiated AKM selector (#3135)and the value of the MIC Length subfield, when not reserved, and is specified in Table 12-11 (Integrity and key wrap algorithms(#3244)).

The ANonce field contains a value chosen by the R1KH.

The SNonce field contains a value chosen by the S1KH.

(#3498)The Optional Parameter(s) field contains zero or more of the triplets shown in Figure 9-438 (Optional Parameter(s) field format).

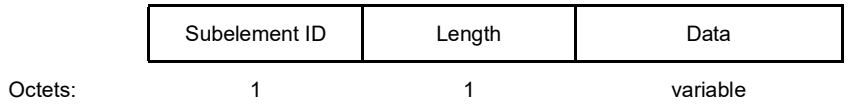


**Figure 9-438—Optional Parameter(s) field format**

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The Subelement ID field is defined in Table 9-221 (Subelement IDs):

**Table 9-221—Subelement IDs**

| Value | Subelement Name(#6388) |
|---|---|
| 0 | Reserved |
| 1 | R1KH-ID(#6388) |
| 2 | GTK |
| 3 | R0KH-ID(#6388) |
| 4 | IGTK |
| 5 | OCI(#6388) |
| 6 | BIGTK |
| 7(11ba) | WIGTK |
| 8–255 | Reserved |

R1KH-ID indicates the identity of the R1KH, which is used by the S0KH and the R0KH for deriving the PMK-R1s.

The GTK subelement contains the GTK, which is encrypted (see procedures in 13.8.5 (FT authentication sequence: contents of fourth message)) and is defined in Figure 9-439 (GTK subelement format).

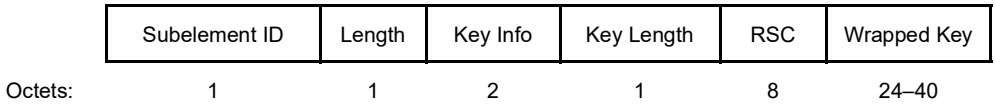


**Figure 9-439—GTK subelement format**

(#3493)The Key Info subfield is defined in Figure 9-440 (GTK subelement's Key Info subfield format).

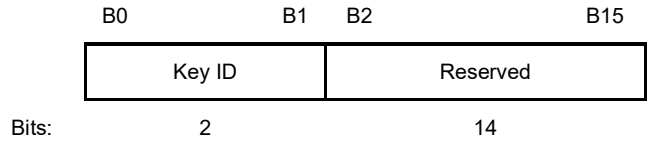


**Figure 9-440—GTK subelement's Key Info subfield format**

(#3493)The Key ID field contains the GTK key ID.

The Key Length field is the length of (#8145)the GTK in octets, not including any padding (see 13.8.5 (FT authentication sequence: contents of fourth message)).

The RSC field contains the current receive sequence counter (RSC) for the GTK being installed(#1928). If the RSC is less than 8 octets in length, it is stored in the first octets and the remaining octets are set to 0. The least significant octet of the RSC is in the first octet of the RSC field. The RSC for TKIP is the TKIP sequence counter (TSC); for CCMP and GCMP it is the packet number (PN); see Table 12-9 (RSC field(#1406))(#3056).


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(#394)The Wrapped Key field contains the wrapped GTK being distributed.

When sent by a non-AP STA, the R0KH-ID indicates the R0KH with which the S0KH negotiated the PMK-R0 it is using for this transition. When sent by an AP, the R0KH-ID indicates the R0KH that the S0KH will be using to generate a PMK-R0 security association. It is encoded following the conventions from 9.2.2 (Conventions).

The IGTK subelement contains the IGTK, used for protecting robust Management frames. The IGTK subelement format is shown in Figure 9-441 (IGTK subelement format).

| | Subelement ID | Length | Key ID | IPN | Key Length | Wrapped Key |
|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 2 | 6 | 1 | 24-40 |

**Figure 9-441—IGTK subelement format**

(#3493)The Key ID field contains the IGTK key ID.

The IPN field contains the current RSC for the IGTK being installed(#1928). The RSC for an IGTK is the IGTK packet number (IPN).

The Key Length field is the length of IGTK in octets, not including any padding (see 13.8.5 (FT authentication sequence: contents of fourth message)).

The Wrapped Key field contains the wrapped IGTK being distributed.

The OCI subelement contains the operating channel information that is integrity protected (see procedures in 13.7 (FT reassociation)) as defined in Figure 9-442 (OCI subelement format).

| | Subelement ID | Length | Operating Class | Primary Channel Number | Frequency Segment 1 Channel Number | OCT Operating Class (optional) | OCT Primary Channel Number (optional) | OCT Frequency Segment 1 Channel Number (optional) |
|---|---|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 1 | 1 | 0 or 1 | 0 or 1 | 0 or 1 |

**Figure 9-442—OCI subelement format**

The definitions of the Operating Class, Primary Channel Number, Frequency Segment 1 Channel Number, OCT Operating Class, OCT Primary Channel Number and OCT Frequency Segment 1 Channel Number fields are the same as those described in 9.4.2.235 (OCI element).

The OCT Operating Class, OCT Primary Channel Number and OCT Frequency Segment 1 fields are present if the OCI subelement is contained in a frame sent using the OCT procedure, i.e., an MMPDU included in an MLME-OCTunnel.request or MLME-OCTunnel.response primitive (see 11.31.5 (On-channel Tunneling (OCT) operation)); otherwise they are not present.

The BIGTK subelement contains the BIGTK, used for protecting Beacon frames. The BIGTK subelement format is shown in Figure 9-443 (BIGTK subelement format).

(#3493)The Key ID field contains the BIGTK key ID.

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| | Subelement ID | Length | Key ID | BIPN | Key Length | Wrapped Key |
|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 2 | 6 | 1 | 24-40 |

**Figure 9-443—BIGTK subelement format**

The BIPN field contains the current RSC for the BIGTK being installed(#1928). The RSC for a BIGTK is the BIGTK packet number (BIPN).

The Key Length field is the length of the BIGTK in octets, not including any padding (see 13.8.5 (FT authentication sequence: contents of fourth message)).

The Wrapped Key field contains the wrapped BIGTK being distributed.

(11ba)The WIGTK subelement contains the WIGTK, used for protecting broadcast and group addressed WUR Wake-up frames. The WIGTK subelement format is shown in Figure Figure 9-444 (WIGTK subelement format(11ba)).

| | Subelement ID | Length | Key ID | WIPN | Key Length | Wrapped Key |
|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 2 | 6 | 1 | 24 |

**Figure 9-444—WIGTK subelement format(11ba)**

(11ba)(#3493)The Key ID field contains the WIGTK key ID.

(11ba)The WIPN field (#1406)contains the current RSC for the WIGTK being installed(#1928). The RSC for a WIGTK is the WIGTK packet number (WIPN).(#3395)

(11ba)The Key Length field is the length of the WIGTK in octets, not including any padding (see 13.8.5 (FT authentication sequence: contents of fourth message)).

(11ba)The Wrapped Key field contains the wrapped WIGTK being distributed(#8146).

### 9.4.2.47 TIE(#1776)

(#1776)The timeout interval element (TIE) specifies time intervals and timeouts. Figure 9-445 (TIE format) shows this element.

| | Element ID | Length | Timeout Interval Type | Timeout Interval Value |
|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 4 |

**Figure 9-445—TIE format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The Timeout Interval Type field is defined in Table 9-222 (Timeout Interval Type field value).

The Timeout Interval Value field contains an unsigned 32-bit integer. It is encoded according to the conventions in 9.2.2 (Conventions).


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**Table 9-222—Timeout Interval Type field value**

| Timeout Interval Type | Meaning | Units |
|---|---|---|
| 0 | Reserved | |
| 1 | Reassociation deadline interval | Time units (TUs) |
| 2 | Key lifetime interval | Seconds |
| 3 | Association comeback time(#3389) | Time units (TUs) |
| 4 | Time-to-Start (see 11.31.3.1 (General)) | Time units (TUs) |
| (#1024)5 | Peer-to-peer TWT(#3150) agreement lifetime | Time units (TUs) |
| (#1024)6–255 | Reserved | |

A reassociation deadline interval set to 0 indicates no deadline exists. A key lifetime interval set to 0 is reserved.

### 9.4.2.48 RDE(#1776)

(#1776)The RIC data element (RDE) refers to a collection of elements that are used to express a resource request and to convey responses to the corresponding requests.

A RIC is a sequence of one or more Resource Requests, or a sequence of one or more Resource Responses. Each Resource Request or Response consists of an RDE, followed by one or more elements that describe that resource. See 13.11 (Resource request procedures) for examples and procedures.

The RDE format is shown in Figure 9-446 (RDE format).

| | Element ID | Length | RDE Identifier | Resource Descriptor Count | Status Code |
|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 1 | 2 |

**Figure 9-446—RDE format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The RDE Identifier field has an arbitrary 8-bit value, chosen by the resource requester to uniquely identify the RDE within the RIC.

The Resource Descriptor Count field indicates the number of alternative Resource Descriptors that follow this RDE.

The Status Code field is used in Resource Responses to indicate the result of the request. Valid values for the Status Code field are given in 9.4.1.9 (Status Code field). When an RDE is included in a Resource Request, the Status Code field is reserved.

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### 9.4.2.49 RIC Descriptor element

The RIC Descriptor element is used with an RDE during a fast BSS transition to negotiate resources that are not otherwise described by elements. See 13.11 (Resource request procedures) for procedures for including this element in a RIC.

Figure 9-447 (RIC Descriptor element format) shows the format of this element.

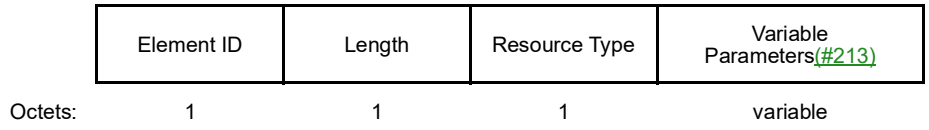


**Figure 9-447—RIC Descriptor element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The Resource Type field is defined in Table 9-223 (Resource type code in RIC Descriptor element).

**Table 9-223—Resource type code in RIC Descriptor element**

| Resource type value | Meaning | Variable parameters |
|---|---|---|
| 1 | Block Ack | Block Ack Parameter Set field value as defined in 9.4.1.13 (Block Ack Parameter Set field), (#6172)Block Ack Timeout Value field value as defined in 9.4.1.14 (Block Ack Timeout Value field), and Block Ack Starting Sequence Control subfield value as defined in 9.3.1.7 (BlockAckReq frame format). |
| 0, 2–255 | Reserved | |

The Variable Parameters field(#213) contain any additional data based on the resource type.

### 9.4.2.50 DSE Registered Location element

A DSE Registered Location element includes DSE location configuration information (LCI), which contains latitude, longitude, and altitude information. The DSE Registered Location element format is shown in Figure 9-448 (DSE Registered Location element format).

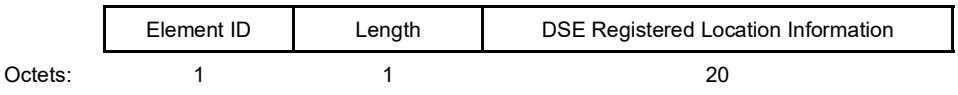


**Figure 9-448—DSE Registered Location element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The structure and information fields are based on the LCI format described in IETF RFC 6225.

The DSE Registered Location Information field is shown in Figure 9-449 (DSE Registered Location Information field format).


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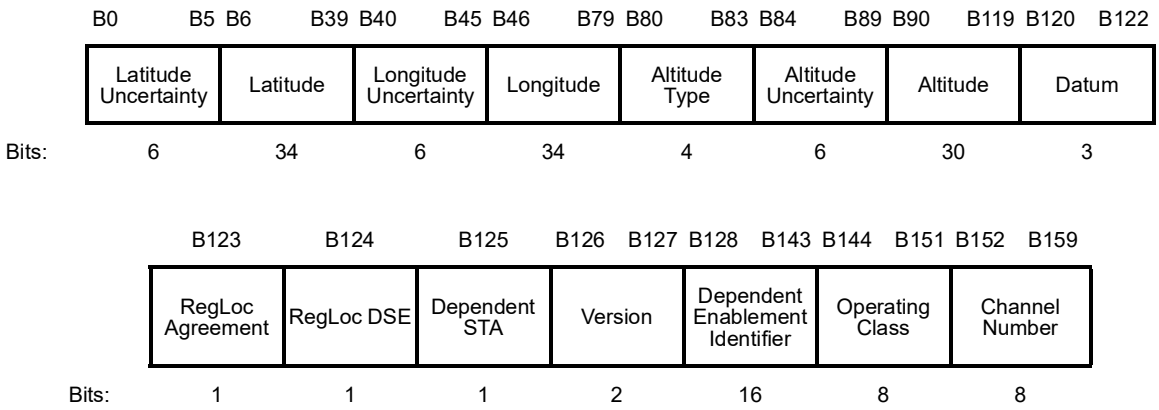


**Figure 9-449—DSE Registered Location Information field format**

The fields within the DSE Registered Location Information field are defined in section 2.2 of IETF RFC 6225(#7192) except as defined in this standard.

With an Altitude Type field set to 3(#8191), the altitude is defined to be in meters and is formatted in 2s complement, fixed-point, 22-bit integer part with 8-bit fraction.

The Datum field is defined in IETF RFC 6225, and the codes used are as defined in IETF RFC 6225.

The RegLoc Agreement subfield(#291) is set to 1 to report that the STA is operating within a national policy area or an international agreement area near a national border (see 11.11.3 (Registered STA operation)); otherwise, it is set to 0(#464).

The RegLoc DSE subfield(#291) is set to 1 to report that the enabling STA is enabling the operation of STAs with DSE; otherwise, it is set to 0(#464).

The Dependent STA subfield(#291) is set to 1 to report that the STA is operating with the enablement of the enabling STA whose LCI is being reported; otherwise, it is set to 0(#464).

The Version field is defined in IETF RFC 6225, and its(#464) use is described in IETF RFC 6225.

The Dependent Enablement Identifier field is a value set by the enabling STA via the DSE Enablement frame; otherwise, it is set to 0.

The Operating Class field indicates the channel set for which the enablement request, report, or announcement applies. The Operating Class and Channel Number fields together specify the channel frequency and channel bandwidth for which the report applies. Valid values for the Operating Class field are shown in Annex E.

The Channel Number field indicates the channel number for which the enablement request, report, or announcement applies. The channel number is defined within an operating class as shown in Annex E.

### 9.4.2.51 Extended Channel Switch Announcement element

The Extended Channel Switch Announcement element is used by an AP, PCP, IBSS STA, or mesh STA to advertise when the BSS is changing to a new channel in the same or a new operating class. The announcement includes both the operating class and the channel number of the new channel. The element is present only when an extended channel switch is pending. The format of the Extended Channel Switch

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Announcement element is shown in Figure 9-450 (Extended Channel Switch Announcement element format).

| | Element ID | Length | Channel Switch Mode | New Operating Class | New Channel Number | Channel Switch Count |
|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 1 | 1 | 1 |

**Figure 9-450—Extended Channel Switch Announcement element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The Channel Switch Mode field indicates any restrictions on transmission until a channel switch. An AP, PCP, or an IBSS STA sets the Channel Switch Mode field to either 0 or 1 on transmission as specified in 11.8.8.2 (Selecting and advertising a new channel in a non-DMG infrastructure BSS) and 11.8.8.3 (Selecting and advertising a new channel in an IBSS). The Channel Switch Mode field is reserved in an MBSS.

The New Operating Class field is set to the number of the operating class after the channel switch, as defined in Annex E.

If transmitted by a STA that is not an EDMG STA, the New Channel Number field is set to the number of the channel after the channel switch. The channel number is a channel from the STA's new operating class as defined in Annex E. If transmitted by an EDMG STA, the New Channel Number field is set to the channel number of the primary channel after the channel switch. The channel number is a channel from the STA's new operating class as defined in Annex E. (11ay)

For nonmesh STAs, the Channel Switch Count field indicates the number of target beacon transmission times (TBTTs) until the STA sending the Channel Switch Count field switches to the new channel. A Channel Switch Count field set to 1 indicates that the switch occurs immediately before the next TBTT. A Channel Switch Count field set to 0 indicates that the switch occurs any time after the frame containing the Channel Switch Count field is transmitted.

For mesh STAs, the Channel Switch Count field is encoded as an octet with bits 6 to 0 set to the time, in units of 2 TU when the MSB (bit 7) is 0, or in units of 100 TU when the MSB (bit 7) is 1, until the mesh STA sending the Channel Switch Count field switches to the new channel. Bits 6 to 0 set to 0 indicates that the switch occurs at any time after the frame containing the Channel Switch Count field is transmitted. For example, a 200 TU channel switch time is encoded as X'82' and a 10 TU channel switch time is encoded as X'05'.

### 9.4.2.52 Supported Operating Classes element

The Supported Operating Classes element is used by a STA to advertise the operating classes within which it is currently configured to operate. The format of the Supported Operating Classes element is shown in Figure 9-451 (Supported Operating Classes element format).

| | Element ID | Length | Current Operating Class | Operating Classes | Current Operating Class Extension Sequence (optional) | Operating Class Duple Sequence (optional) |
|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | variable | variable | variable |

**Figure 9-451—Supported Operating Classes element format**


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The Element ID and Length fields are defined in 9.4.2.1 (General).

The Current Operating Class field, concatenated with the Current Operating Class Extension field within the Current Operating Class Extension Sequence field if present, indicates the operating class in use for transmission and reception. If the operating class in use is a single octet, the Current Operating Class Extension Sequence field is not present. If the operating class in use is more than a single octet, then the Current Operating Class Extension Sequence field is present, and the concatenation of the Current Operating Class field with the Current Operating Class Extension Sequence field comprises $N$ (where $N \geq 0$) Operating Class octets with an 80+ behavior limit followed by one Operating Class octet without an 80+ behavior limit (as defined in Annex E). Channels using two nonadjacent frequency segments use 2-octet format to indicate the operating class (e.g., operating classes 128 and 130 are used to describe a 80+80 MHz channel).(#7040)

(#3429)(#7040)The Operating Classes field lists, in descending order of preference, all 1-octet operating classes within which the STA is currently configured to operate. The Operating Classes field terminates immediately before a OneHundredAndThirty Delimiter (see Figure 9-452 (Current Operating Class Extension Sequence field format)), a Zero Delimiter (see Figure 9-453 (Operating Class Duple Sequence field format)), or the end of the element.

The format of the optional Current Operating Class Extension Sequence field is shown in Figure 9-452 (Current Operating Class Extension Sequence field format).

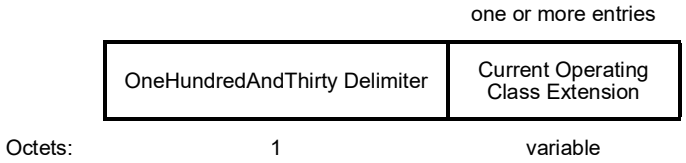


**Figure 9-452—Current Operating Class Extension Sequence field format**

The OneHundredAndThirty Delimiter field is set to 130.

The Current Operating Class Extension field comprises $N$ (where $N \geq 0$) Operating Class octets with an 80+ behavior limit followed by one Operating Class octet without an 80+ behavior limit (as defined in Annex E).

The format of the Operating Class Duple Sequence field is shown in Figure 9-453 (Operating Class Duple Sequence field format).

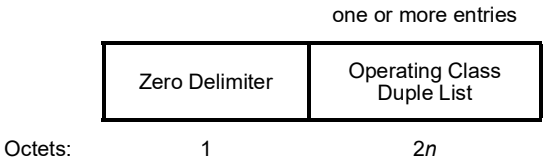


**Figure 9-453—Operating Class Duple Sequence field format**

The Zero Delimiter element is set to 0.

The Operating Class Duple List subfield lists all 2-octet operating classes within which the STA is currently configured to operate. Each operating class in the Operating Class Duple List subfield contains an Operating Class octet with an 80+ behavior limit followed by one Operating Class octet without an 80+ behavior limit (as defined in Annex E). Operating classes are transmitted in ascending order using the first octet in the operating class as the primary sort key and then the second octet in the operating class as the secondary sort key. If there are no 2-octet operating classes within which the STA is currently configured to operate, then the Operating Class Duple Sequence field is omitted from the Supported Operating Classes element. The

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Operating Class Duple List subfield terminates immediately before another zero octet or the end of the element.

The use of this element is described in 11.9.2 (Advertising supported operating classes) and 11.10.9.1 (Beacon report).

#### 9.4.2.53 MME(#1517)

(#1776)The management MIC element (MME) provides message integrity and protects group addressed robust Management frames and protected Beacon frames (#6054)which are not protected with BCE from forgery and replay. Figure 9-454 (MME(#1517) format) shows the MME format.

| | Element ID | Length | Key ID | IPN/BIPN | MIC |
|---|---|---|---|---|---|
| Octets: | 1 | 1 | 2 | 6 | 8 or 16 |

**Figure 9-454—MME(#1517) format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The Key ID field identifies the IGTK or BIGTK used to compute the MIC. Bits 0–11 define a value in the range 0–4095. Bits 12–15 are reserved. The IGTK (#3493)key ID is either 4 or 5. The BIGTK (#3493)key ID is either 6 or 7. The remaining (#3493)key IDs are reserved.

(#1496)The IPN/BIPN field is used to detect replay of protected group addressed robust Management frames and protected Beacon frames. For protected group addressed robust Management frames, the IPN/BIPN field contains the IPN. For protected Beacon frames, the IPN/BIPN field contains the BIPN.

The MIC field contains a message integrity code calculated over the robust Management frame or protected Beacon frame as specified in 12.5.3.5 (BIP transmission) and 12.5.3.6 (BIP reception). The length of the MIC field depends on the specific cipher negotiated and is either 8 octets (for BIP-CMAC-128) or 16 octets (for BIP-CMAC-256, BIP-GMAC-128, and BIP-GMAC-256).

#### 9.4.2.54 HT Capabilities element

##### 9.4.2.54.1 HT Capabilities element structure

An HT STA declares that it is an HT STA by transmitting the HT Capabilities element.

The HT Capabilities element contains a number of fields that are used to advertise optional HT capabilities of an HT STA. (#444)The HT Capabilities element is defined in Figure 9-455 (HT Capabilities element format).

| | Element ID | Length | HT Capability Information | A-MPDU Parameters | Supported MCS Set | HT Extended Capabilities | Transmit Beamforming Capabilities | ASEL Capabilities |
|---|---|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 2 | 1 | 16 | 2 | 4 | 1 |

**Figure 9-455—HT Capabilities element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).


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### 9.4.2.54.2 HT Capability Information field

The HT Capability Information field of the HT Capabilities element contains capability information bits. The structure of this field is defined in Figure 9-456 (HT Capability Information field format).

**Figure 9-456—HT Capability Information field format**

The subfields of the HT Capability Information field are defined in Table 9-224 (Subfields of the HT Capability Information field).

**Table 9-224—Subfields of the HT Capability Information field**

| Subfield | Definition | Encoding |
|---|---|---|
| LDPC Coding Capability | Indicates support for receiving LDPC coded PPDUs | Set to 0 if not supported<br>Set to 1 if supported |
| Supported Channel Width Set | Indicates the channel widths supported by the STA.<br>See 11.15 (20/40 MHz BSS operation). | Set to 0 if only 20 MHz operation is supported<br>Set to 1 if both 20 MHz and 40 MHz operation is supported<br><br>This field is reserved when the transmitting or receiving STA is operating in an operating class that includes 20 in the Channel spacing (MHz) column of the appropriate table in Annex E. |
| SM Power Save | Indicates the spatial multiplexing power save mode that is in operation immediately after (re)association.<br>See 11.2.6 (SM power save). | Set to 0 for static SM power save mode<br>Set to 1 for dynamic SM power save mode<br>Set to 3 for SM power save disabled or not supported<br><br>The value 2 is reserved<br><br>Only valid in a (Re)Association Request frame sent to an AP. Otherwise this subfield is set to 0 or 3 upon transmission and is ignored upon reception.<br><br>NOTE—This subfield indicates the operational state immediately after (re)association as well as (if not set to 3) a capability. |
| HT-Greenfield | Indicates support for the reception of PPDUs with HT-greenfield format.<br>See 19.1.4 (PPDU formats). | Set to 0 if not supported<br>Set to 1 if supported |

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**Table 9-224—Subfields of the HT Capability Information field *(continued)***

| Subfield | Definition | Encoding |
|---|---|---|
| Short GI for 20 MHz | Indicates short GI support for the reception of HT PPDUs transmitted with the TXVECTOR parameter CH_BANDWIDTH equal to HT_CBW20 and, for a VHT STA, for the reception of VHT PPDUs transmitted with the TXVECTOR parameter CH_BANDWIDTH equal to CBW20 | Set to 0 if not supported<br>Set to 1 if supported |
| Short GI for 40 MHz | Indicates short GI support for the reception of HT PPDUs transmitted with the TXVECTOR parameter CH_BANDWIDTH equal to HT_CBW40 and, for a VHT STA, for the reception of VHT PPDUs transmitted with the TXVECTOR parameter CH_BANDWIDTH equal to CBW40 | Set to 0 if not supported<br>Set to 1 if supported |
| Tx STBC | Indicates support for the transmission of PPDUs using STBC | Set to 0 if not supported<br>Set to 1 if supported<br>This field is reserved for a mesh STA. |
| Rx STBC | Indicates support for the reception of PPDUs using STBC | Set to 0 for no support<br>Set to 1 for support of one spatial stream<br>Set to 2 for support of one and two spatial streams<br>Set to 3 for support of one, two and three spatial streams<br>This field is reserved for a mesh STA. |
| Maximum A-MSDU Length | Indicates maximum A-MSDU length in an HT PPDU.(#1439) See 10.11 (A-MSDU operation). | Set to 0 for 3839 octets<br>Set to 1 for 7935 octets |


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**Table 9-224—Subfields of the HT Capability Information field *(continued)***

| Subfield | Definition | Encoding |
|---|---|---|
| DSSS/CCK Mode in 40 MHz | Indicates the BSS is operating in a mode that allows transmission of DSSS/CCK PPDUs, when the operating channel width is 40 MHz. See 11.15 (20/40 MHz BSS operation). | In Beacon and Probe Response frames:<br>Set to 0 if the BSS is operating in a mode that does not allow transmission of DSSS/CCK PPDUs<br>Set to 1 if the BSS is operating in a mode that allows transmission of DSSS/CCK PPDUs<br><br>Otherwise:<br>Set to 0 if the STA supports neither transmission nor reception of DSSS/CCK PPDUs when the operating channel width is 40 MHz<br>Set to 1 if the STA supports transmission and reception of DSSS/CCK PPDUs when the operating channel width is 40 MHz<br><br>See 11.15.8 (Support of DSSS/CCK in 40 MHz) for operating rules |
| Forty MHz Intolerant | Indicates whether APs receiving this information or reports of this information are required to prohibit 40 MHz transmissions (see 11.15.12 (Switching between 40 MHz and 20 MHz)). | Set to 1 by an HT STA to prohibit a receiving AP from operating that AP's BSS as a 20/40 MHz BSS; otherwise, set to 0. |

### 9.4.2.54.3 A-MPDU Parameters field

The structure of the A-MPDU Parameters field of the HT Capabilities element is shown in Figure 9-457 (A-MPDU Parameters field format).

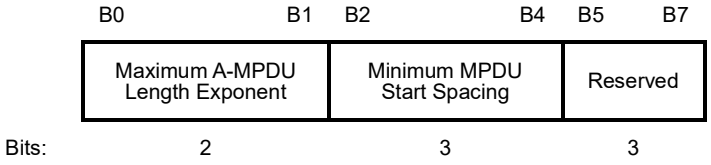


**Figure 9-457—A-MPDU Parameters field format**

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The subfields of the A-MPDU Parameters field are defined in Table 9-225 (Subfields of the A-MPDU Parameters field).

**Table 9-225—Subfields of the A-MPDU Parameters field**

| Subfield | Definition | Encoding |
|---|---|---|
| Maximum A-MPDU Length Exponent | Indicates the maximum length of A-MPDU that the STA can receive. | The length defined by this field is equal to $2^{(13 + \text{Maximum A-MPDU Length Exponent})} - 1$ octets. |
| Minimum MPDU Start Spacing | Determines the minimum time between the start of adjacent MPDUs within an A-MPDU that the STA can receive, measured at the PHY SAP. See 10.12.3 (Minimum MPDU start spacing rules). | Set to 0 for no restriction<br>Set to 1 for 1/4 μs<br>Set to 2 for 1/2 μs<br>Set to 3 for 1 μs<br>Set to 4 for 2 μs<br>Set to 5 for 4 μs<br>Set to 6 for 8 μs<br>Set to 7 for 16 μs |

### 9.4.2.54.4 Supported MCS Set field

The Supported MCS Set field of the HT Capabilities element indicates the HT-MCSs a STA supports.

An MCS is identified by an MCS index, which is represented by an integer in the range 0 to 76. The interpretation of the MCS index (i.e., the mapping from MCS to data rate) is PHY dependent. For the HT PHY, see 19.5 (Parameters for HT-MCSs).

The structure of the MCS Set field is defined in Figure 9-458 (Supported MCS Set field format).

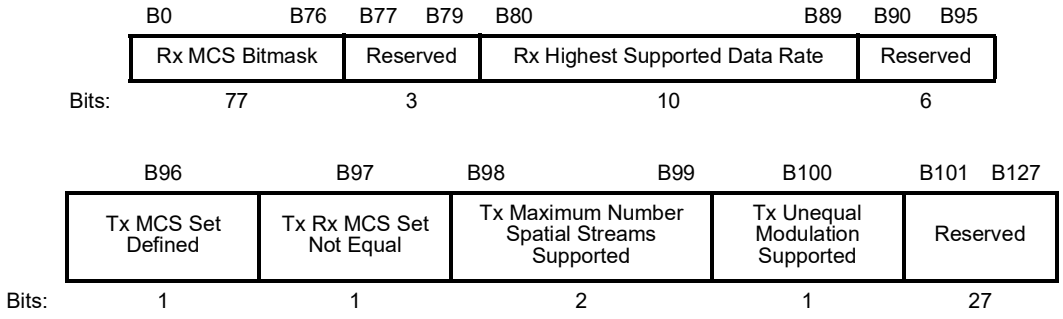


**Figure 9-458—Supported MCS Set field format**

The Rx MCS Bitmask subfield of the Supported MCS Set field defines a set of MCS index values, where (#465)B0 corresponds to MCS 0 and (#465)B76 corresponds to MCS 76.

NOTE—An HT STA includes the mandatory MCS values defined in 19.1 (Introduction) in the Rx MCS Bitmask subfield.

The Rx Highest Supported Data Rate subfield of the Supported MCS Set field defines the highest HT PPDU data rate that the STA is able to receive, in units of 1 Mb/s in the range 1 to 1023. If the maximum data rate expressed in Mb/s is not an integer, then the value is rounded down to the next integer. The value 0 indicates


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that this subfield does not specify the HT PPDU highest data rate that the STA is able to receive; see 10.6.6.5.3 (Control response frame MCS computation).

The Tx MCS Set Defined, Tx Rx MCS Set Not Equal, Tx Maximum Number Spatial Streams Supported, and Tx Unequal Modulation Supported subfields of the Supported MCS Set field indicate the transmit-supported MCS set, as defined in Table 9-226 (Transmit MCS Set).

**Table 9-226—Transmit MCS Set**

| Condition | Tx MCS Set Defined | Tx Rx MCS Set Not Equal | Tx Maximum Number Spatial Streams Supported | Tx Unequal Modulation Supported |
|---|---|---|---|---|
| No Tx MCS set is defined | 0 | 0 | 0 | 0 |
| The Tx MCS set is defined and is equal to the Rx MCS set | 1 | 0 | 0 | 0 |
| The Tx MCS set is defined and is not necessarily equal to the Rx MCS set | 1 | 1 | Indicates the maximum number of spatial streams supported when transmitting:<br>Set to 0 for 1 spatial stream<br>Set to 1 for 2 spatial streams<br>Set to 2 for 3 spatial streams<br>Set to 3 for 4 spatial streams | Indicates whether transmit unequal modulation (UEQM) is supported:<br>Set to 0 for UEQM not supported<br>Set to 1 for UEQM supported |

### 9.4.2.54.5 HT Extended Capabilities field

The structure of the HT Extended Capabilities field of the HT Capabilities element is defined in Figure 9-459 (HT Extended Capabilities field format).

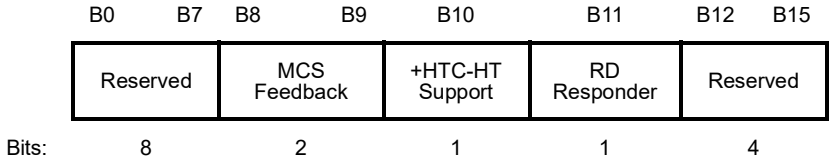


**Figure 9-459—HT Extended Capabilities field format**

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The subfields of the HT Extended Capabilities field are defined in Table 9-227 (Subfields of the HT Extended Capabilities field).

**Table 9-227—Subfields of the HT Extended Capabilities field**

| Subfield | Definition | Encoding |
|---|---|---|
| MCS Feedback | Indicates whether the STA can provide MFB | Set to 0 (No Feedback) if the STA does not provide MFB<br>Set to 2 (Unsolicited) if the STA provides only unsolicited MFB<br>Set to 3 (Both) if the STA can provide MFB in response to MRQ (either Delayed or Immediate, see 10.31.1 (Introduction)) as well as unsolicited MFB<br><br>The value 1 is reserved |
| +HTC-HT Support | Indicates support of the HT variant HT Control field.<br>See 10.8 (HT Control field operation) | Set to 0 if not supported<br>Set to 1 if supported |
| RD Responder | Indicates support for acting as a reverse direction responder, i.e., the STA might use an offered RDG to transmit data to an RD initiator using the reverse direction protocol described in 10.29 (Reverse direction protocol). | Set to 0 if not supported<br>Set to 1 if supported |


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#### 9.4.2.54.6 Transmit Beamforming Capabilities

The structure of the Transmit Beamforming Capabilities field is defined in Figure 9-460 (Transmit Beamforming Capabilities field format).

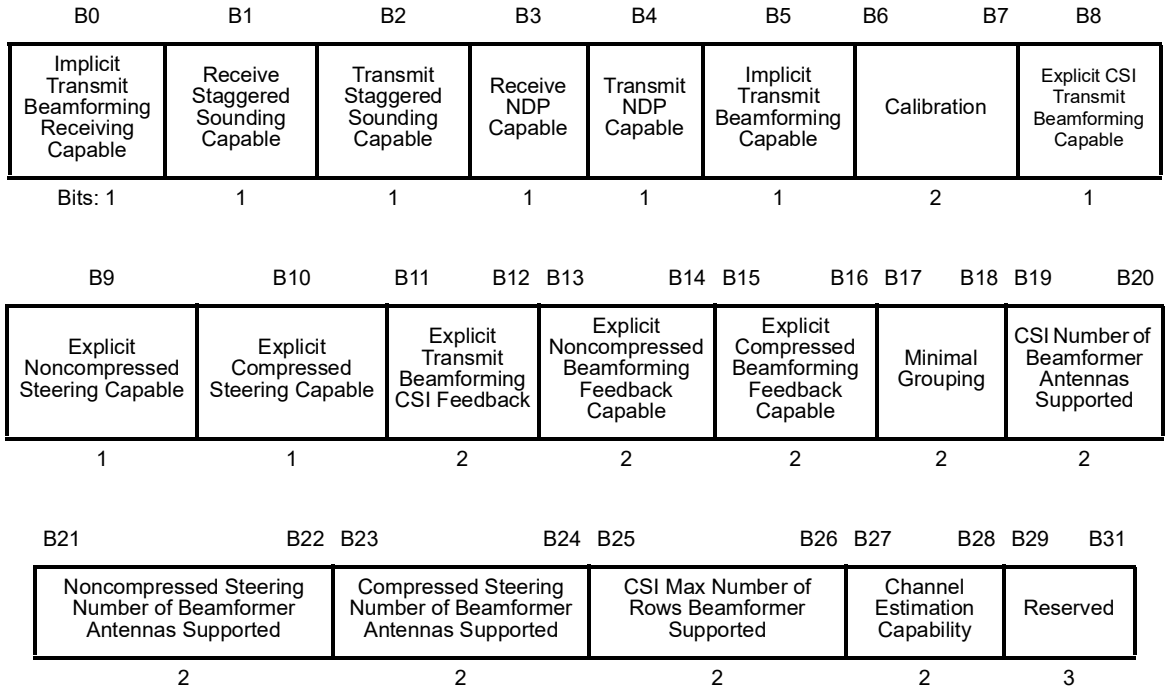


**Figure 9-460—Transmit Beamforming Capabilities field format**

The subfields of the Transmit Beamforming Capabilities field are defined in Table 9-228 (Subfields of the Transmit Beamforming Capabilities field).

**Table 9-228—Subfields of the Transmit Beamforming Capabilities field**

| Subfield | Definition | Encoding |
|---|---|---|
| Implicit Transmit Beamforming Receiving Capable | Indicates whether this STA can receive Transmit Beamforming steered frames using implicit feedback | Set to 0 if not supported<br>Set to 1 if supported |
| Receive Staggered Sounding Capable | Indicates whether this STA can receive staggered sounding frames. | Set to 0 if not supported<br>Set to 1 if supported |
| Transmit Staggered Sounding Capable | Indicates whether this STA can transmit staggered sounding frames. | Set to 0 if not supported<br>Set to 1 if supported |
| Receive NDP Capable | Indicates whether this receiver can interpret null data PPDUs as sounding frames. | Set to 0 if not supported<br>Set to 1 if supported |
| Transmit NDP Capable | Indicates whether this STA can transmit null data PPDUs as sounding frames. | Set to 0 if not supported<br>Set to 1 if supported |

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**Table 9-228—Subfields of the Transmit Beamforming Capabilities field *(continued)***

| Subfield | Definition | Encoding |
|---|---|---|
| Implicit Transmit Beamforming Capable | Indicates whether this STA can apply implicit transmit beamforming. | Set to 0 if not supported<br>Set to 1 if supported |
| Calibration | Indicates whether the STA can participate in a calibration procedure initiated by another STA that is capable of generating an immediate response sounding PPDU and can provide a CSI report in response to a sounding PPDU. | Set to 0 if not supported<br><br>Set to 1 if the STA can respond to a calibration request using the CSI report, but cannot initiate calibration<br><br>The value 2 is reserved<br><br>Set to 3 if the STA can both initiate and respond to a calibration request |
| Explicit CSI Transmit Beamforming Capable | Indicates whether this STA can apply transmit beamforming using CSI explicit feedback in its transmission | Set to 0 if not supported<br>Set to 1 if supported |
| Explicit Noncompressed Steering Capable | Indicates whether this STA can apply transmit beamforming using noncompressed beamforming feedback matrix explicit feedback in its transmission | Set to 0 if not supported<br>Set to 1 if supported |
| Explicit Compressed Steering Capable | Indicates whether this STA can apply transmit beamforming using compressed beamforming feedback matrix explicit feedback in its transmission | Set to 0 if not supported<br>Set to 1 if supported |
| Explicit Transmit Beamforming CSI Feedback | Indicates whether this receiver can return CSI explicit feedback. | Set to 0 if not supported<br>Set to 1 for delayed feedback<br>Set to 2 for immediate feedback<br>Set to 3 for delayed and immediate feedback |
| Explicit Noncompressed Beamforming Feedback Capable | Indicates whether this receiver can return noncompressed beamforming feedback matrix explicit feedback. | Set to 0 if not supported<br>Set to 1 for delayed feedback<br>Set to 2 for immediate feedback<br>Set to 3 for delayed and immediate feedback |
| Explicit Compressed Beamforming Feedback Capable | Indicates whether this receiver can return compressed beamforming feedback matrix explicit feedback. | Set to 0 if not supported<br>Set to 1 for delayed feedback<br>Set to 2 for immediate feedback<br>Set to 3 for delayed and immediate feedback |
| Minimal Grouping | Indicates the minimal grouping used for explicit feedback reports | Set to 0 if the STA supports groups of 1 (no grouping)<br>Set to 1 indicates groups of 1, 2<br>Set to 2 indicates groups of 1, 4<br>Set to 3 indicates groups of 1, 2, 4 |
| CSI Number of Beamformer Antennas Supported | Indicates the maximum number of beamformer antennas the HT beamformee can support when CSI feedback is required | Set to 0 for single Tx antenna sounding<br>Set to 1 for 2 Tx antenna sounding<br>Set to 2 for 3 Tx antenna sounding<br>Set to 3 for 4 Tx antenna sounding |
| Noncompressed Steering Number of Beamformer Antennas Supported | Indicates the maximum number of beamformer antennas the HT beamformee can support when noncompressed beamforming feedback matrix is required | Set to 0 for single Tx antenna sounding<br>Set to 1 for 2 Tx antenna sounding<br>Set to 2 for 3 Tx antenna sounding<br>Set to 3 for 4 Tx antenna sounding |


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**Table 9-228—Subfields of the Transmit Beamforming Capabilities field *(continued)***

| Subfield | Definition | Encoding |
|---|---|---|
| Compressed Steering Number of Beamformer Antennas Supported | Indicates the maximum number of beamformer antennas the HT beamformee can support when compressed beamforming feedback matrix is required | Set to 0 for single Tx antenna sounding<br>Set to 1 for 2 Tx antenna sounding<br>Set to 2 for 3 Tx antenna sounding<br>Set to 3 for 4 Tx antenna sounding |
| CSI Max Number of Rows Beamformer Supported | Indicates the maximum number of rows of CSI explicit feedback from the HT beamformee or calibration responder or transmit ASEL responder that an HT beamformer or calibration initiator or transmit ASEL initiator can support when CSI feedback is required. | Set to 0 for a single row of CSI<br>Set to 1 for 2 rows of CSI<br>Set to 2 for 3 rows of CSI<br>Set to 3 for 4 rows of CSI |
| Channel Estimation Capability | Indicates the maximum number of space-time streams (columns of the MIMO channel matrix) for which channel dimensions can be simultaneously estimated when receiving an NDP sounding PPDU or the extension portion of the HT Long Training fields (HT-LTFs) in a staggered sounding PPDU. See NOTE. | Set 0 for 1 space-time stream<br>Set 1 for 2 space-time streams<br>Set 2 for 3 space-time streams<br>Set 3 for 4 space-time streams |

NOTE—The maximum number of space-time streams for which channel coefficients can be simultaneously estimated using the HT-LTFs corresponding to the data portion of the PPDU is limited by the Rx MCS Bitmask subfield of the Supported MCS Set field and by the Rx STBC subfield of the HT Capability Information field. Both fields are part of the HT Capabilities element.

### 9.4.2.54.7 ASEL Capability field

The structure of the ASEL Capability field of the HT Capabilities element is defined in Figure 9-461 (ASEL Capability field format).

| | B0 | B1 | B2 | B3 | B4 | B5 | B6 | B7 |
|---|---|---|---|---|---|---|---|---|
| | Antenna Selection Capable | Explicit CSI Feedback Based Transmit ASEL Capable | Antenna Indices Feedback Based Transmit ASEL Capable | Explicit CSI Feed-back Capable | Antenna Indices Feedback Capable | Receive ASEL Capable | Transmit Sounding PPDUs Capable | Reserved |
| Bits: | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

**Figure 9-461—ASEL Capability field format**

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The subfields of the ASEL Capability field are defined in Table 9-229 (ASEL Capability field subfields).

**Table 9-229—ASEL Capability field subfields**

| Subfield | Definition | Encoding |
|---|---|---|
| Antenna Selection Capable | Indicates whether this STA supports ASEL | Set to 0 if not supported<br>Set to 1 if supported |
| Explicit CSI Feedback Based Transmit ASEL Capable | Indicates whether this STA supports transmit ASEL based on explicit CSI feedback | Set to 0 if not supported<br>Set to 1 if supported |
| Antenna Indices Feedback Based Transmit ASEL Capable | Indicates whether this STA supports transmit ASEL based on antenna indices feedback | Set to 0 if not supported<br>Set to 1 if supported |
| Explicit CSI Feedback Capable | Indicates whether this STA can compute CSI and provide CSI feedback in support of ASEL | Set to 0 if not supported<br>Set to 1 if supported |
| Antenna Indices Feedback Capable | Indicates whether this STA can compute an antenna indices selection and return an antenna indices selection in support of ASEL | Set to 0 if not supported<br>Set to 1 if supported |
| Receive ASEL Capable | Indicates whether this STA supports receive ASEL | Set to 0 if not supported<br>Set to 1 if supported |
| Transmit Sounding PPDUs Capable | Indicates whether this STA can transmit sounding PPDUs for ASEL training on request | Set to 0 if not supported<br>Set to 1 if supported |

### 9.4.2.55 HT Operation element

The operation of HT STAs in the BSS is controlled by the HT Operation element. The structure of this element is defined in Figure 9-462 (HT Operation element format).

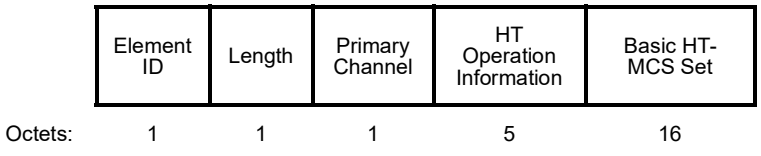


**Figure 9-462—HT Operation element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).


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The structure of the HT Operation Information field is shown in Figure 9-463 (HT Operation Information field format).

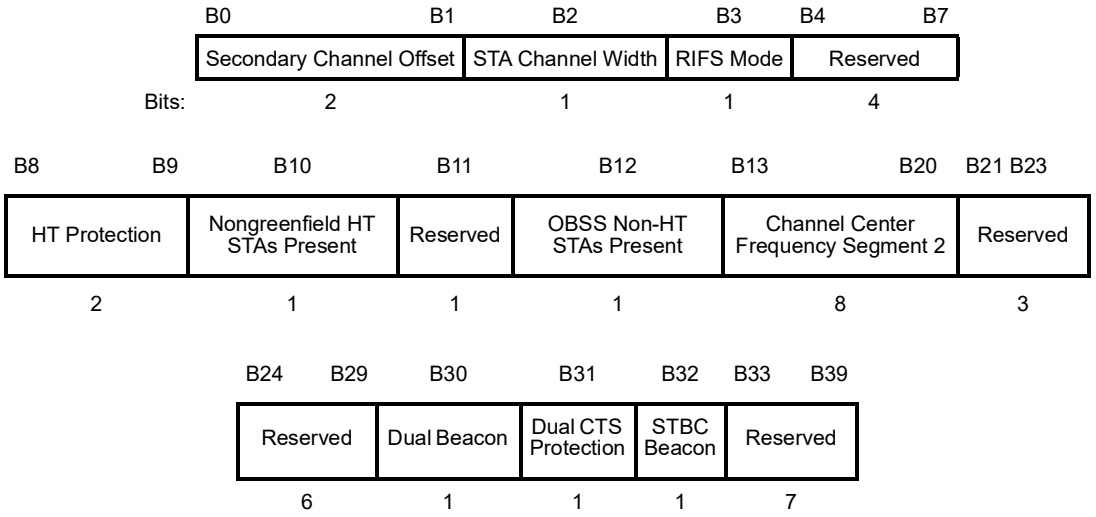


**Figure 9-463—HT Operation Information field format**

The Primary Channel field, subfields of the HT Operation Information field, and the Basic HT-MCS Set field are defined in Table 9-230 (HT Operation element fields and subfields). The (#4177)Reserved in IBSS? column indicates whether each field is reserved (Y) or not reserved (N) when this element is present in a frame transmitted within an IBSS. The (#4177)Reserved in MBSS? column indicates whether each field is reserved (Y) or not reserved (N) when this element is present in a frame transmitted within an MBSS.

**Table 9-230—HT Operation element fields and subfields**

| Field | Definition | Encoding | Reserved in IBSS? | Reserved in MBSS? |
|---|---|---|---|---|
| Primary Channel | Indicates the channel number of the primary channel. See 11.15.2 (Basic 20/40 MHz BSS functionality). | Channel number of the primary channel | N | N |
| Secondary Channel Offset | Indicates the offset of the secondary channel relative to the primary channel. | Set to 1 (SCA) if the secondary channel is above the primary channel<br>Set to 3 (SCB) if the secondary channel is below the primary channel<br>Set to 0 (SCN) if no secondary channel is present<br><br>The value 2 is reserved | N | N |

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**Table 9-230—HT Operation element fields and subfields *(continued)***

| Field | Definition | Encoding | Reserved in IBSS? | Reserved in MBSS? |
|---|---|---|---|---|
| STA Channel Width | Defines the channel widths that can be used to transmit to the STA.<br>See 11.15.12 (Switching between 40 MHz and 20 MHz) | Set to 0 for a 20 MHz channel width<br>Set to 1 allows use of any channel width in the Supported channel width set<br><br>This field is reserved when the transmitting or receiving STA is operating in an operating class that does not include a value of PrimaryChannelLowerBehavior or PrimaryChannelUpperBehavior in the behavior limits set as specified in Annex E.<br><br>See NOTE 1. | N | N |
| RIFS Mode | Indicates whether the use of reduced interframe space is permitted within the BSS.<br>See 10.3.2.3.2 (RIFS) and 10.27.3.3 (RIFS protection) | Set to 0 if use of RIFS is prohibited<br>Set to 1 if use of RIFS is permitted | Y | Y |
| HT Protection | Indicates protection requirements of HT transmissions.<br>See 10.27.3 (Protection mechanisms for transmissions of HT PPDUs). | Set to 0 for no protection mode<br>Set to 1 for nonmember protection mode<br>Set to 2 for 20 MHz protection mode<br>Set to 3 for non-HT mixed mode | Y | N |
| Nongreenfield HT STAs Present | AP indicates if any HT STAs that are not HT-greenfield capable have associated.<br><br>Mesh STA indicates if it establishes a mesh peering with an HT STA that is not HT-greenfield capable.<br><br>Determines when a non-AP STA should use HT-greenfield protection.<br>Present in Beacon and Probe Response frames transmitted by an AP or mesh STA. Otherwise reserved.<br>See 10.27.3.1 (General). | Set to 0 if all HT STAs that are associated are HT-greenfield capable or all HT peer mesh STAs are HT-greenfield capable<br><br>Set to 1 if one or more HT STAs that are not HT-greenfield capable are associated or one or more HT peer mesh STAs are not HT-greenfield capable | Y | N |


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**Table 9-230—HT Operation element fields and subfields *(continued)***

| Field | Definition | Encoding | Reserved in IBSS? | Reserved in MBSS? |
|---|---|---|---|---|
| OBSS Non-HT STAs Present | Indicates if the use of protection for non-HT STAs by overlapping BSSs is determined to be desirable.<br><br>If the BSS is operating in an operating class for which the behavior limits set listed in Annex E includes the DFS_50_100_Behavior, this field indicates if there exist any non-HT OBSSs and whether HT-greenfield transmissions are allowed.<br><br>Present in Beacon and Probe Response frames transmitted by an AP. Otherwise reserved.<br>See 10.27.3.4 (Use of OBSS Non-HT STAs Present field) and 11.8.8.5 (HT-greenfield transmissions in operating classes that include a behavior limit of DFS_50_100_Behavior). | If not operating in an operating class for which the behavior limits set listed in Annex E includes the value DFS_50_100_Behavior:<br><br>Set to 1 if the use of protection for non-HT STAs by OBSSs is determined to be desirable. See NOTE 2.<br><br>Set to 0 otherwise.<br><br>If operating in an operating class for which the behavior limits set listed in Annex E includes the value DFS_50_100_Behavior:<br><br>Set to 1 if there exists one or more non-HT OBSSs. Indicates that HT-greenfield transmissions are disallowed in the BSS.<br><br>Set to 0 otherwise. | Y | Y |
| Channel Center Frequency Segment 2 | Defines the channel center frequency for a 160 or 80+80 MHz BSS bandwidth with NSS support less than Max VHT NSS.<br><br>See 21.3.14 (Channelization), 11.38 (VHT BSS operation) and 9.4.2.156.3 (Supported VHT-MCS and NSS Set field). | For a STA with dot11VHTExtendedNSSBWCapable equal to true: See Table 9-314 (Setting of the Supported Channel Width Set subfield and Extended NSS BW Support subfield at a STA transmitting the VHT Capabilities Information field), otherwise this field is set to 0.<br><br>NOTE—This subfield is not used in a non-VHT HT STA. | N | N |
| Dual Beacon | Indicates whether the AP transmits an STBC beacon.<br><br>The use of the dual beacon mechanism is obsolete. | Set to 0 if no STBC beacon is transmitted<br>Set to 1 if an STBC beacon is transmitted by the AP | Y | Y |
| Dual CTS Protection | Dual CTS protection is used by the AP to set a NAV at STAs that do not support STBC and at STAs that can associate solely through the STBC beacon.<br>See 10.3.2.10 (Dual CTS protection).<br><br>The use of the dual CTS mechanism is obsolete. | Set to 0 if dual CTS protection is not required<br>Set to 1 if dual CTS protection is required | Y | Y |

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**Table 9-230—HT Operation element fields and subfields *(continued)***

| Field | Definition | Encoding | Reserved in IBSS? | Reserved in MBSS? |
|---|---|---|---|---|
| STBC Beacon | Indicates whether the beacon containing this element is a primary or an STBC beacon. The STBC beacon has half a beacon period shift relative to the primary beacon. Defined only in a Beacon frame transmitted by an AP. Otherwise reserved. See 11.1.3.2 (Beacon generation in non-DMG infrastructure networks). | Set to 0 in a primary beacon<br>Set to 1 in an STBC beacon | Y | Y |
| Basic HT-MCS Set | Indicates the HT-MCS values that are supported by all HT STAs in the BSS. Present in Beacon, Probe Response, Mesh Peering Open and Mesh Peering Confirm frames. Otherwise reserved. | A bitmap where a bit is set to 1 to indicate support for that MCS and 0 otherwise, where bit 0 corresponds to MCS 0.<br><br>MCS values are defined in 9.4.2.54.4 (Supported MCS Set field). | N | N |

NOTE 1—Any change of STA Channel Width field does not impact the HT Protection field.
NOTE 2—Examples of when this bit might be set to 1 include, but are not limited to, the following situations:
a) One or more non-HT STAs are associated
b) A non-HT BSS is overlapping (a non-HT BSS might be detected by the reception of a Beacon or Probe Response frame that does not include an HT Capabilities element)

### 9.4.2.56 20/40 BSS Intolerant Channel Report element

The 20/40 BSS Intolerant Channel Report element contains a list of channels on which a STA has found conditions that disallow the use of a 20/40 MHz BSS. The format of the 20/40 BSS Intolerant Channel Report element is shown in Figure 9-464 (20/40 BSS Intolerant Channel Report element format).

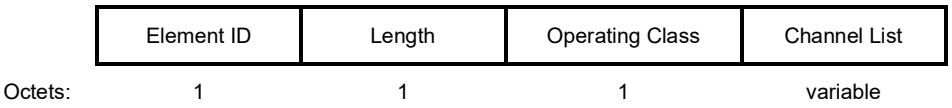


**Figure 9-464—20/40 BSS Intolerant Channel Report element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The Operating Class field of the 20/40 MHz BSS Intolerant Channel Report element contains an enumerated value from Annex E, encoded as an unsigned integer, specifying the operating class in which the Channel List field is valid. If the operating class is "unknown" as described in 11.15.12 (Switching between 40 MHz and 20 MHz), the Operating Class field is set to 0. A 20/40 BSS Intolerant Channel Report only reports channels for a single operating class. Multiple 20/40 BSS Intolerant Channel Report elements are used to report channels in more than one operating class.


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The Channel List field of the 20/40 MHz BSS Intolerant Channel Report element contains a variable number of octets, where each octet describes a single channel number. Channel numbering is dependent on operating class according to Annex E.

A 20/40 BSS Intolerant Channel Report element includes only channels that are valid for the regulatory domain in which the STA transmitting the element is operating and that are consistent with the Country element transmitted by the AP of the BSS of which it is a member.

### 9.4.2.57 Overlapping BSS Scan Parameters element

The Overlapping BSS Scan Parameters element is used by an AP to indicate the values to be used by BSS members when performing OBSS scan operations. The format of the Overlapping BSS Scan Parameters element is shown in Figure 9-465 (Overlapping BSS Scan Parameters element format).

| | Element ID | Length | OBSS Scan Passive Dwell | OBSS Scan Active Dwell | BSS Channel Width Trigger Scan Interval | OBSS Scan Passive Total Per Channel | OBSS Scan Active Total Per Channel | BSS Width Channel Transition Delay Factor | OBSS Scan Activity Threshold |
|---|---|---|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |

**Figure 9-465—Overlapping BSS Scan Parameters element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The OBSS Scan Passive Dwell field contains a value in TUs, encoded as an unsigned integer, that a receiving STA uses to set dot11OBSSScanPassiveDwell as described in 11.15.5 (Scanning requirements for 40MC HT STA 2G4).

The OBSS Scan Active Dwell field contains a value in TUs, encoded as an unsigned integer, that a receiving STA uses to set dot11OBSSScanActiveDwell as described in 11.15.5 (Scanning requirements for 40MC HT STA 2G4).

The BSS Channel Width Trigger Scan Interval field contains a value in seconds, encoded as an unsigned integer, that a receiving STA uses to set dot11BSSWidthTriggerScanInterval as described in 11.15.5 (Scanning requirements for 40MC HT STA 2G4).

The OBSS Scan Passive Total Per Channel field contains a value in TUs, encoded as an unsigned integer, that a receiving STA uses to set dot11OBSSScanPassiveTotalPerChannel as described in 11.15.5 (Scanning requirements for 40MC HT STA 2G4).

The OBSS Scan Active Total Per Channel field contains a value in TUs, encoded as an unsigned integer, that a receiving STA uses to set dot11OBSSScanActiveTotalPerChannel as described in 11.15.5 (Scanning requirements for 40MC HT STA 2G4).

The BSS Width Channel Transition Delay Factor field contains an integer value that a receiving STA uses to set dot11BSSWidthChannelTransitionDelayFactor as described in 11.15.5 (Scanning requirements for 40MC HT STA 2G4).

The OBSS Scan Activity Threshold field contains a value in hundredths of percent, encoded as an unsigned integer, that a receiving STA uses to set dot11OBSSScanActivityThreshold as described in 11.15.5 (Scanning requirements for 40MC HT STA 2G4).

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The use of each of these parameters is described in 11.15.5 (Scanning requirements for 40MC HT STA 2G4).

### 9.4.2.58 20/40 BSS Coexistence element

The 20/40 BSS Coexistence element is used by STAs to exchange information that affects 20/40 BSS coexistence.

The 20/40 BSS Coexistence element is formatted as shown in Figure 9-466 (20/40 BSS Coexistence element format).

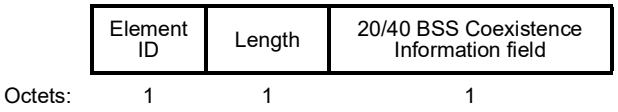


**Figure 9-466—20/40 BSS Coexistence element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The structure of the 20/40 BSS Coexistence Information field is shown in Figure 9-467 (20/40 BSS Coexistence Information field format).

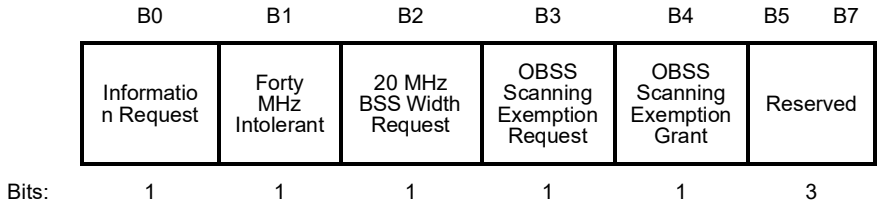


**Figure 9-467—20/40 BSS Coexistence Information field format**

The Information Request field is used to indicate that a transmitting STA is requesting the recipient to transmit a 20/40 BSS Coexistence Management frame with the transmitting STA as the recipient.

The Forty MHz Intolerant field is set to 1 to prohibit an AP that receives this information or reports of this information from operating a 20/40 MHz BSS. When equal to 0, it does not prohibit a receiving AP from operating a 20/40 MHz BSS. This field is used for inter-BSS communication. The definition of this field is the same as the definition of the Forty MHz Intolerant field in the HT Capabilities element (see 9.4.2.54 (HT Capabilities element)), and its operation is described in 11.15.11 (Signaling 40 MHz intolerance).

The 20 MHz BSS Width Request field is set to 1 to prohibit a receiving AP from operating its BSS as a 20/40 MHz BSS. Otherwise, it is set to 0. This field is used for intra-BSS communication. The operation of this field is described in 11.15.12 (Switching between 40 MHz and 20 MHz).

The OBSS Scanning Exemption Request field is set to 1 to indicate that the transmitting non-AP STA is requesting the BSS to allow the STA to be exempt from OBSS scanning. Otherwise, it is set to 0. The OBSS Scanning Exemption Request field is reserved when transmitted by an AP. The OBSS Scanning Exemption Request field is reserved when a 20/40 BSS Coexistence element is included in a group addressed frame.

The OBSS Scanning Exemption Grant field is set to 1 by an AP to indicate that the receiving STA is exempted from performing OBSS Scanning. Otherwise, it is set to 0. The OBSS Scanning Exemption Grant field is reserved when transmitted by a non-AP STA. The OBSS Scanning Exemption Grant field is reserved when a 20/40 BSS Coexistence element is included in a group addressed frame.


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### 9.4.2.59 Time Advertisement element

The Time Advertisement element, shown in Figure 9-468 (Time Advertisement element format), specifies fields describing the source of time corresponding to a time standard, an external clock (external time source), an estimate of the offset between that time standard and the TSF timer, and an estimate of the standard deviation of the error in the offset estimate. This information is used by a receiving STA to align its own estimate of the time standard based on that of another STA.

| | Element ID | Length | Timing Capabilities | Time Value (optional) | Time Error (optional) | Time Update Counter (optional) |
|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 0 or 10 | 0 or 5 | 0 or 1 |

**Figure 9-468—Time Advertisement element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The Timing Capabilities field specifies the STA's source and encoding of the Time Value field. The encoding of the Timing Capabilities field is specified in Table 9-231 (Encoding of the Timing Capabilities field).

**Table 9-231—Encoding of the Timing Capabilities field**

| Value | Usage |
|---|---|
| 0 | No standardized external time source |
| 1 | Timestamp offset based on UTC (see ITU-R Recommendation TF.460-6 (2002) [B61]). The Timestamp offset value in nanoseconds is defined to be 0 at the beginning of the first nanosecond of the first day of the year 1958. |
| 2 | UTC time at which the TSF timer is 0. |
| 3–255 | Reserved |

When the Timing Capabilities field is 0, only the Element ID, Length, and Timing Capabilities fields are included in the Time Advertisement element.

When the Timing Capabilities is 1, the following additional fields are included in the Time Advertisement element:

— Time Value field, a 2s complement integer in nanoseconds that, when added to the Timestamp present in the same transmitted frame, gives the receiving STA an estimate of the time standard at the time the frame was transmitted. The Timestamp is derived from the TSF Timer as defined in 11.19 (Timing advertisement).

— Time Error field, which is set to an unsigned integer in nanoseconds that defines the standard deviation of the error in the Time Value estimate. The Time Error field is set to all 1s to indicate that the error is unknown.

When the Timing Capabilities field is 2, the following fields are included in the Time Advertisement element:

— The Time Value field is the UTC time at which the TSF Timer is 0, given that the TSF Timer units are 1 μs(#8087) units(#7198) as defined in 11.1.3 (Maintaining synchronization). The format, including all subfields is shown in Table 9-232 (Time Value field format when Timing Capabilities is 2). For any subfield not known in the Time Value field, the subfield value is 0.

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— The Time Error field is an unsigned integer in milliseconds that defines the standard deviation of the error in the Time Value estimate.

— The Time Update Counter field is a modulo 256 counter that increments each time the AP updates the Time Value UTC at which the TSF Timer is 0.

**Table 9-232—Time Value field format when Timing Capabilities is 2**

| Octet | Description |
|---|---|
| 0–1 | Year (0–65 534) |
| 2 | Month (0–12) |
| 3 | Day of month (0–31) |
| 4 | Hours (0–23) |
| 5 | Minutes (0–59) |
| 6 | Seconds (0–59) |
| 7–8 | Milliseconds (0–999) |
| 9 | Reserved |

### 9.4.2.60 Link Identifier element

The Link Identifier element contains information that identifies a TDLS direct link. The element information format is defined in Figure 9-469 (Link Identifier element format).

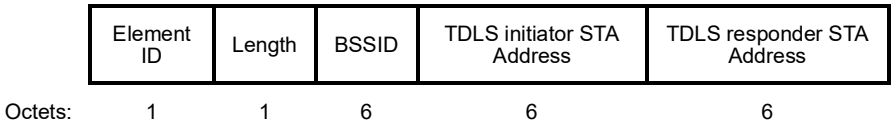


**Figure 9-469—Link Identifier element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The BSSID field is set to the BSSID of the BSS of which the TDLS initiator STA is a member.

The TDLS initiator STA Address field is set to the TDLS initiator STA's MAC address.

The TDLS responder STA Address field is set to the TDLS responder STA's MAC address.


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### 9.4.2.61 Wakeup Schedule element

The Wakeup Schedule element contains information regarding the periodic wakeup schedule for TDLS peer PSM. The element format is defined in Figure 9-470 (Wakeup Schedule element format).

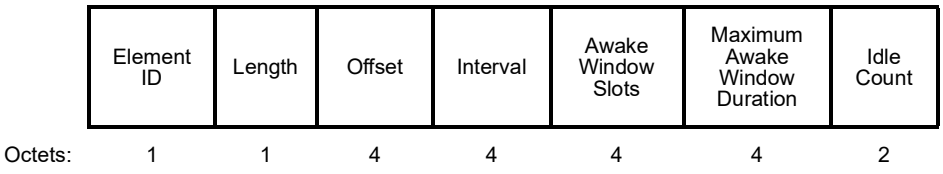


**Figure 9-470—Wakeup Schedule element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

(#3502)The Offset and Interval fields are in microseconds and define when awake windows begin. See Equation (11-1) in 11.2.3.11 (TDLS peer power save mode). The Interval field is nonzero and the Offset field is less than the Interval field.

The Awake Window Slots field is set to the duration of the awake window(#3110) in units of backoff slots (see 10.23.2.4 (Obtaining an EDCA TXOP)). See 11.2.3.11 (TDLS peer power save mode).

The Maximum Awake Window Duration field is set to the maximum duration of the awake window(#3110), in units of microseconds. See 11.2.3.11 (TDLS peer power save mode).

The Idle Count field is set to the number of consecutive awake windows(#3110) during which no individually addressed frame is received from the TDLS peer STA before a TDLS peer STA deletes the wakeup schedule. See 11.2.3.11 (TDLS peer power save mode).

### 9.4.2.62 Channel Switch Timing element

The Channel Switch Timing element contains information regarding the channel switch timing. The element is defined in Figure 9-471 (Channel Switch Timing element format(#8172)(#8173)).

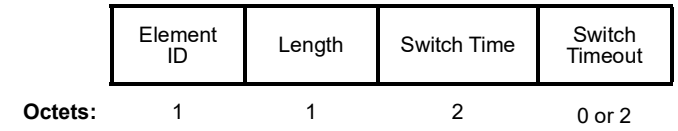


**Figure 9-471—Channel Switch Timing element format(#8172)(#8173)**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The Switch Time field is set to the time it takes for a STA sending the Channel Switch Timing element to switch channels, in units of microseconds.

The Switch Timeout field is set to a time in units of microseconds. The STA sending the Channel Switch Timing element waits for the first Data frame exchange on the off-channel for Switch Timeout microseconds before switching back to (#6222)the base channel. The time is measured from the end of the (#14)PPDU[+SigExt] containing the Ack frame that is transmitted in response to a(#375) TDLS Channel Switch Response frame, as seen on the WM. If transmitted in a (Re)Association Request frame, the Switch Timeout field is not present in the Channel Switch Timing element.(11ax)

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### 9.4.2.63 PTI Control element

The PTI Control element contains information regarding the traffic buffered at the TPU buffer STA for the TPU sleep STA at the time a TDLS Peer Traffic Indication frame is transmitted by the TPU buffer STA. The element is optionally included in the TDLS Peer Traffic Indication frame. The element is defined in Figure 9-472 (PTI Control element format).

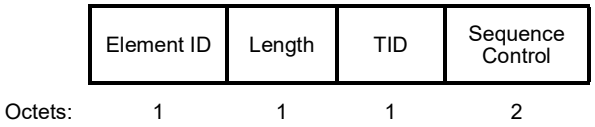


**Figure 9-472—PTI Control element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The TID field contained in the PTI Control element is set to the TID of the latest MPDU that has been transmitted over the TDLS direct link to the TPU sleep STA that is the destination of the TDLS Peer Traffic Indication frame that contains the PTI Control element. See 11.2.3.12 (TDLS peer U-APSD (TPU)).

The Sequence Control field is defined in 9.2.4.4 (Sequence Control field). The Sequence Control field contained in the PTI Control element is set to the sequence number of the latest MPDU that has been transmitted over the TDLS direct link to the TPU sleep STA that is the destination of the TDLS Peer Traffic Indication frame that contains the PTI Control element. See 11.2.3.12 (TDLS peer U-APSD (TPU)).

### 9.4.2.64 TPU Buffer Status element

The TPU Buffer Status element contains information regarding the traffic buffered at the TPU buffer STA for the TPU sleep STA at the time a TDLS Peer Traffic Indication frame is transmitted by the TPU buffer STA. The element is included in the TDLS Peer Traffic Indication frame. The element is defined in Figure 9-473 (TPU Buffer Status element format).

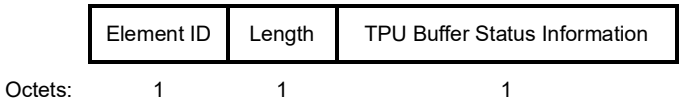


**Figure 9-473—TPU Buffer Status element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The TPU Buffer Status Information field is defined in Figure 9-474 (TPU Buffer Status Information field format)

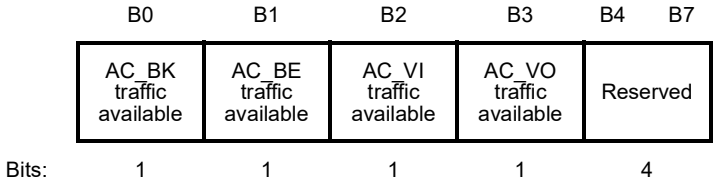


**Figure 9-474—TPU Buffer Status Information field format**

The AC_BK traffic available field is one bit in size and is set to 1 if AC_BK contains traffic buffered for the TPU sleep STA to which the TPU Buffer Status element will be transmitted and is set to 0 otherwise.


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The AC_BE traffic available field is one bit in size and is set to 1 if AC_BE contains traffic buffered for the TPU sleep STA to which the TPU Buffer Status element will be transmitted and is set to 0 otherwise.

The AC_VI traffic available field is one bit in size and is set to 1 if AC_VI contains traffic buffered for the TPU sleep STA to which the TPU Buffer Status element will be transmitted and is set to 0 otherwise.

The AC_VO traffic available field is one bit in size and is set to 1 if AC_VO contains traffic buffered for the TPU sleep STA to which the TPU Buffer Status element will be transmitted and is set to 0 otherwise.

### 9.4.2.65 Event Request element

#### 9.4.2.65.1 Event Request definition

The Event Request element contains a request to the receiving STA to perform the specified event action. The format of the Event Request element is shown in Figure 9-475 (Event Request element format).

| | Element ID | Length | Event Token | Event Type | Event Response Limit | Event Request |
|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 1 | 1 | variable |

**Figure 9-475—Event Request element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The Event Token field is a nonzero number that is unique among the Event Request elements sent to each destination MAC address for which a corresponding Event Report element has not been received.

The Event Type field is a number that identifies the type of event request. The values of the Event Type field are defined in Table 9-233 (Event Type field definitions for event requests and reports).

**Table 9-233—Event Type field definitions for event requests and reports**

| Name | Event Type |
|---|---|
| Transition | 0 |
| RSNA | 1 |
| Peer-to-peer link | 2 |
| WNM log | 3 |
| BSS Color Collision | 4(11ax) |
| BSS Color In Use | 5(11ax) |
| Reserved | 6–220 |
| Vendor Specific | 221 |
| Reserved | 222–255 |

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The Event Response Limit field contains the maximum number of requested Event Reports to be included in the Event Report element. The field is set to 0 to indicate that no limit is set on the number of Event Reports to be included in the Event Report element.

The Event Request field contains the event request corresponding to the event type, as described in 9.4.2.65.2 (Transition event request) to 9.4.2.65.4 (Peer-to-peer link event request). The Event Request field is not present when requesting a WNM log report.

The Event Request element is included in an Event Request frame, as described in 9.6.13.2 (Event Request frame format). The use of the Event Request element and Event Request frame is described in 11.21.2 (Event request and report procedures).

### 9.4.2.65.2 Transition event request

The Event Request field corresponding to the Transition event request contains zero or more Transition Event Request subelements. A transition event is a STA movement or attempted movement from one BSS (the source BSS) in one ESS to another BSS (the target BSS) within the same ESS.

The Transition Event subelements specify the conditions in which a Transition Event Report is sent by a STA. The set of valid Transition Event Request subelements is defined in Table 9-234 (Transition Event Request subelement).

**Table 9-234—Transition Event Request subelement**

| Transition Event Request subelement | Subelement ID |
|---|---|
| Transition Target BSSID | 0 |
| Transition Source BSSID | 1 |
| Transition Time Threshold | 2 |
| Transition Result | 3 |
| Frequent Transition | 4 |
| Reserved | 5–255 |

The Transition Target BSSID subelement is used to request that a Transition Event Report includes the transition event entry when the target BSSID is equal to the specific BSSID in the Target BSSID field. Excluding this subelement from the Event Request element indicates a request for transition events for all target BSSIDs. The format of the Transition Target BSSID subelement is shown in Figure 9-476 (Transition Target BSSID subelement format).

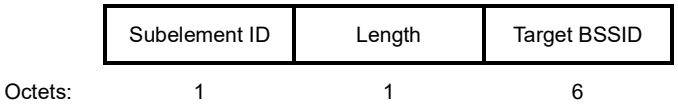


**Figure 9-476—Transition Target BSSID subelement format**

The Subelement ID field is equal to the Transition Target BSSID value in Table 9-234 (Transition Event Request subelement).


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The Length field is defined in 9.4.3 (Subelements).

The Target BSSID field contains a (#1496)BSSID.

The Transition Source BSSID subelement is used to request that a Transition Event Report includes the transition event entry when the source BSSID is equal to the BSSID specified in the Source BSSID field. Excluding this subelement from the Event Request element indicates a request for transition events for all source BSSIDs. The format of the Transition Source BSSID subelement is shown in Figure 9-477 (Transition Source BSSID subelement format).

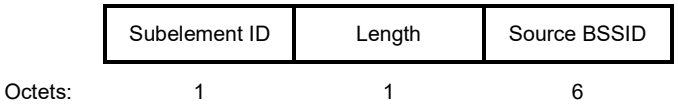


**Figure 9-477—Transition Source BSSID subelement format**

The Subelement ID field is equal to the Transition Source BSSID value in Table 9-234 (Transition Event Request subelement).

The Length field is defined in 9.4.3 (Subelements).

The Source BSSID field contains a (#1496)BSSID.

The Transition Time Threshold subelement is used to request that a Transition Event Report includes the transition event entry when the transition time is greater than or equal to the Transition Time Threshold value. The format of the Transition Time Threshold subelement is shown in Figure 9-478 (Transition Time Threshold subelement format).

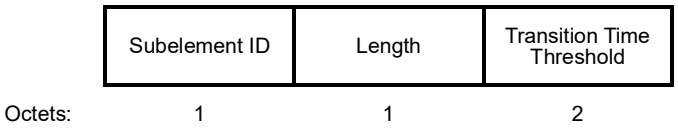


**Figure 9-478—Transition Time Threshold subelement format**

The Subelement ID field is equal to the Transition Time Threshold value in Table 9-234 (Transition Event Request subelement).

The Length field is defined in 9.4.3 (Subelements).

The Transition Time Threshold field contains a value representing the Transition Time to be used as the threshold value for the Transition Time condition in TUs. The Transition Time is defined in 11.21.2.2 (Transition event request and report).

The Transition Result subelement is used to request that a Transition Event Report includes the transition event entry that matches the transition result defined by this subelement. The format of Transition Result subelement is shown in Figure 9-479 (Transition Result subelement format).

The Subelement ID field is equal to the Transition Result value in Table 9-234 (Transition Event Request subelement).

The Length field is defined in 9.4.3 (Subelements).

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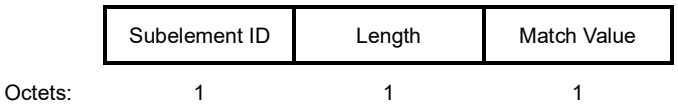


**Figure 9-479—Transition Result subelement format**

The Match Value field is set with each bit as defined in Figure 9-480 (Match Value field definitions(M118)) to request that the specified transition results that match the bit descriptions are included in the Transition Event report.

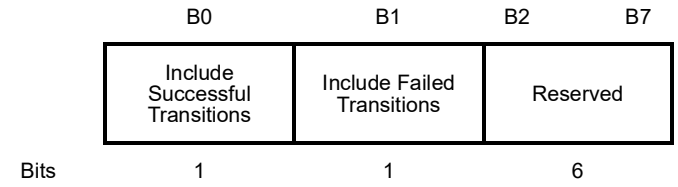


**Figure 9-480—Match Value field definitions(M118)**

The Frequent Transition subelement is used to request that an alerting Transition Event report be generated when the total transition count during the specified time period is greater than or equal to the value given in Frequent Transition Count Threshold field. The format of the Frequent Transition subelement is shown in Figure 9-481 (Frequent Transition subelement format).

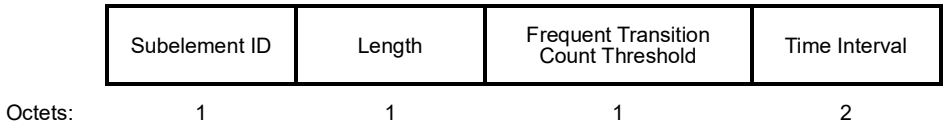


**Figure 9-481—Frequent Transition subelement format**

The Subelement ID field is equal to the Frequent Transition value in Table 9-234 (Transition Event Request subelement).

The Length field is defined in 9.4.3 (Subelements).

The Frequent Transition Count Threshold field containing the number of transitions in the measurement duration after which a Transition Event Report is generated.

The Time Interval field is the time interval in TUs during which the STA determines if the Frequent Transition Count Threshold is exceeded.

### 9.4.2.65.3 RSNA event request

The Event Request field corresponding to an RSNA event request contains zero or more RSNA Event Request subelements.

The subelement format and ordering of subelements are defined in 9.4.3 (Subelements). The set of valid RSNA Event Request subelements is defined in Table 9-235 (RSNA Event Request subelement).

The RSNA subelements specify reporting conditions for RSNA Event Reports.

The RSNA Target BSSID subelement identifies the BSS at which an RSNA Event establishment was attempted. Excluding this subelement from the Event Request element indicates a request for transition


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**Table 9-235—RSNA Event Request subelement**

| RSNA Event Request subelement | Subelement ID |
|---|---|
| RSNA Target BSSID | 0 |
| Authentication Type | 1 |
| EAP Method | 2 |
| RSNA Result | 3 |
| Reserved | 4–255 |

events for all source BSSIDs. The format of the RSNA Target BSSID subelement is shown in Figure 9-482 (RSNA Target BSSID subelement format).

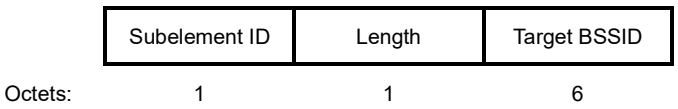


**Figure 9-482—RSNA Target BSSID subelement format**

The Subelement ID field is equal to the RSNA Target BSSID value in Table 9-235 (RSNA Event Request subelement).

The Length field is defined in 9.4.3 (Subelements).

The Target BSSID field contains a (#1496)BSSID.

The Authentication Type subelement is used to request that an RSNA Event Report includes the RSNA event entry when the Authentication Type is equal to the authentication type specified in the Authentication Type field. The format of the Authentication Type subelement is shown in Figure 9-483 (Authentication Type subelement format).

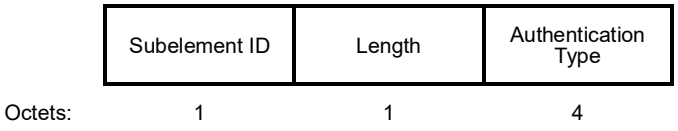


**Figure 9-483—Authentication Type subelement format**

The Subelement ID field is equal to the Authentication Type value in Table 9-235 (RSNA Event Request subelement).

The Length field is defined in 9.4.3 (Subelements).

The Authentication Type field contains one of the AKM suite selectors defined in Table 9-190 (AKM suite selectors) in 9.4.2.23.3 (AKM suites).

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The EAP Method subelement is used to request that an RSNA Event Report includes the RSNA event entry when the EAP Method is equal to the EAP method specified in the EAP Method field. The format of the EAP Method subelement is shown in Figure 9-484 (EAP Method subelement format).

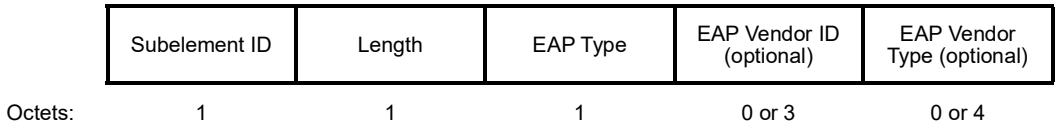


**Figure 9-484—EAP Method subelement format**

The Subelement ID field is equal to the EAP Method value in Table 9-235 (RSNA Event Request subelement).

The Length field is defined in 9.4.3 (Subelements).

The EAP Type field contains a value that identifies a single EAP method and is any valid IANA assigned EAP type.

The EAP Vendor ID field contains a value that identifies the EAP Vendor. The EAP Vendor ID field is included when EAP Type field is 254 and is excluded otherwise.

The EAP Vendor Type field contains a value that identifies the EAP Type as defined by the vendor. The EAP Vendor Type field is included when EAP Type field is 254 and is excluded otherwise.

The RSNA Result subelement is used to request that an RSNA Event Report includes the RSNA event entry that matches the transition result defined by this subelement. The format of RSNA Result subelement is shown in Figure 9-485 (RSNA Result subelement format).

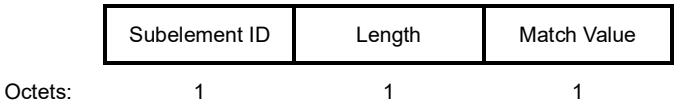


**Figure 9-485—RSNA Result subelement format**

The Subelement ID field is equal to the RSNA Result value in Table 9-235 (RSNA Event Request subelement).

The Length field is defined in 9.4.3 (Subelements).

The Match Value field bits are set as defined in Figure 9-486 (Match Value field definitions) to request that the specified RSNA results that match that bit descriptions are included in the RSNA Event report.

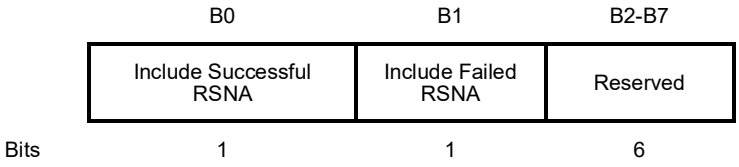


**Figure 9-486—Match Value field definitions**


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#### 9.4.2.65.4 Peer-to-peer link event request

The Event Request field corresponding to peer-to-peer link event request contains zero or more Peer-to-Peer Link Event Request subelements.

(#3427)The Optional Subelements field contains zero or more subelements. The subelement format and ordering of subelements are defined in 9.4.3 (Subelements). The set of valid Peer-to-Peer Link Event Request subelements is defined in Table 9-236 (Peer-to-Peer Link Event Request subelement).

**Table 9-236—Peer-to-Peer Link Event Request subelement**

| Peer-to-Peer Link Event Request subelement | Subelement ID |
|---|---|
| Peer Address | 0 |
| Channel Number | 1 |
| Reserved | 2–255 |

The Peer-to-Peer Link Event Request subelements specify reporting conditions for peer-to-peer link event reporting.

The Peer Address subelement identifies the peer STA, BSS, or IBSS of the peer-to-peer links to be reported. Excluding this subelement from the Event Request element indicates a request for peer-to-peer link events for any peer STA, any BSS, and any IBSS. The format of the Peer Address subelement is shown in Figure 9-487 (Peer Address subelement format).

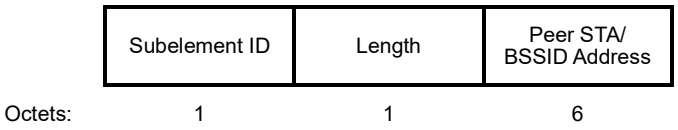


**Figure 9-487—Peer Address subelement format**

The Subelement ID field is equal to the Peer Address value in Table 9-236 (Peer-to-Peer Link Event Request subelement).

The Length field is defined in 9.4.3 (Subelements).

The Peer STA/BSSID Address field contains a (#1496)MAC address of a peer STA or a BSSID for peer-to-peer links in an IBSS. If the indicated address matches the Address 1 field of the MAC header contents (see Table 9-60 (Address field contents for Data frames transmitted by nonmesh STAs(#462))), then the address is a peer STA address for a TDLS peer STA or an IBSS STA. If the indicated address matches the Address 3 field of the MAC header contents, then the address is a BSSID for the TDLS (#1753)direct link or for the IBSS.(#1354)

The Channel Number subelement(s) identify the channel for the peer-to-peer links to be reported. Excluding this subelement from the Event Request element indicates a request for peer-to-peer link events for any channel. The format of the Channel Number subelement is shown in Figure 9-488 (Channel Number subelement format). The identified channel is indicated by *N*+1 Channel Number subelements where the

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first *N* subelements contain an Operating Class octet with an 80+ behavior limit and the last subelement contains an Operating Class octet without an 80+ behavior limit (as defined in Annex E).

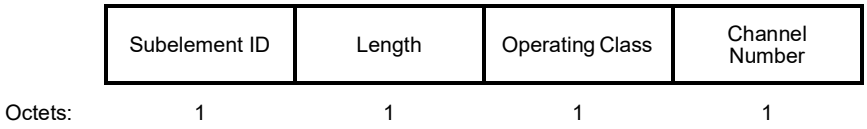


**Figure 9-488—Channel Number subelement format**

The Subelement ID field is equal to the Channel Number value in Table 9-236 (Peer-to-Peer Link Event Request subelement).

The Length field is defined in 9.4.3 (Subelements).

The Operating Class field indicates the channel set of the peer-to-peer link to be used for the peer-to-peer link event report. Operating Classes are defined in Annex E.

The Channel Number field indicates the channel number or (if the corresponding operating class in Annex E has "—" in the channel set column) the channel number of the center frequency(#6420) of the frequency segment containing the primary channel of the peer-to-peer link events requested and included in the peer-to-peer link event report. A Channel Number of 0 in all *N*+1 Channel Number subelements indicates a request to report any peer-to-peer link event for any supported channel in the specified filtering Operating Class.

#### 9.4.2.65.5 Vendor specific event request

The Event Request field corresponding to a vendor specific event request contains zero or more Vendor Specific subelements. The Vendor Specific subelement has the same format as the Vendor Specific element (see 9.4.2.24 (Vendor Specific element)).

### 9.4.2.66 Event Report element

#### 9.4.2.66.1 Event Report definition

The Event Report element is used by a STA to report an event. The format of the Event Report element is shown in Figure 9-489 (Event Report element format).

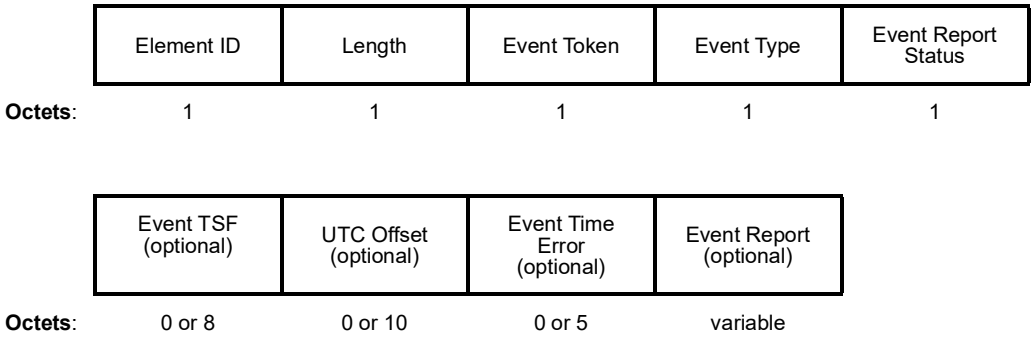


**Figure 9-489—Event Report element format**


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The Element ID and Length fields are defined in 9.4.2.1 (General).

The Event Token field is the Event Token in the corresponding Event Request element. If the Event Report element is being sent autonomously then the Event Token is 0.

The Event Type field is a number that identifies the type of event report. The values of the Event Type field are defined in Table 9-233 (Event Type field definitions for event requests and reports).

The Event Report Status field is a value in Table 9-237 (Event Report Status), indicating the STA's response to the Event Request.

**Table 9-237—Event Report Status**

| Event Report Status | Description |
|---|---|
| 0 | Successful |
| 1 | Request failed |
| 2 | Request refused |
| 3 | Request incapable |
| 4 | Detected frequent transition |
| 5–255 | Reserved |

If the Event Report Status field is 0 (Successful) and the Event Type field is neither 4 (BSS Color Collision) nor 5 (BSS Color In Use), then the Event TSF, UTC Offset, Event Time Error, and Event Report fields are present. If the Event Report Status field is 0 (Successful) and the Event Type field is either 4 (BSS Color Collision) or 5 (BSS Color In Use), then Event TSF and Event Report fields are present. Otherwise, the Event TSF, UTC Offset, Event Time Error, and Event Report fields are not present.(11ax)

The Event TSF field is TSF value when the STA logged the event.

The UTC Offset field is the UTC value that corresponds to the UTC time when the TSF timer is equal to 0. If the UTC Offset is unknown, the field is 0.

The Event Time Error field is the UTC standard deviation, as described in 9.4.2.59 (Time Advertisement element), that corresponds to the TSF value logged for the event. If the Event Time Error is unknown, the field is 0.

The Event Report field contains the specification of a single event report, as described in 9.4.2.66.2 (Transition event report) to 9.4.2.66.5 (WNM log event report), 9.4.2.66.7 (BSS color collision event report(11ax)), and 9.4.2.66.8 (BSS color in use event report(11ax)).(11ax)

The Event Report element is included in an Event Report frame, as described in 9.6.13.3 (Event Report frame format). The use of the Event Report element and frame is described in 11.21.2 (Event request and report procedures).

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#### 9.4.2.66.2 Transition event report

The format of the Event Report field corresponding to a Transition event report is shown in Figure 9-490 (Event Report format for Transition event).

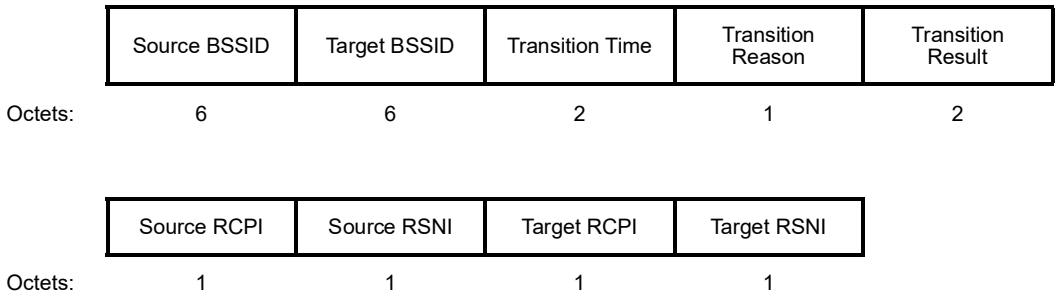


**Figure 9-490—Event Report format for Transition event**

The Source BSSID field contains the (#2047)(#365)MAC address of the associated AP prior to the attempted transition.

The Target BSSID field contains the (#2047)(#365)MAC address of the AP that is the target of the attempted transition.

The Transition Time field contains the transition time in TUs. The transition time is defined in 11.21.2.2 (Transition event request and report).

The Transition Reason field indicates the reason why a transition attempt occurred and contains one of the values in Table 9-238 (Transition and Transition Query reasons).

**Table 9-238—Transition and Transition Query reasons**

| Transition Reason value | Description |
|---|---|
| 0 | Unspecified |
| 1 | Excessive frame loss rates and/or poor conditions |
| 2 | Excessive delay for current traffic streams |
| 3 | Insufficient QoS capacity for current traffic streams (TSPEC rejected) |
| 4 | First association to ESS (the association initiated by an Association Request frame instead of a Reassociation Request frame) |
| 5 | Load balancing |
| 6 | Better AP found |
| 7 | Deauthenticated or Disassociated from the previous AP |
| 8 | AP failed IEEE 802.1X EAP Authentication |
| 9 | AP failed 4-way handshake |
| 10 | Received too many replay counter failures |
| 11 | Received too many data MIC failures |


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**Table 9-238—Transition and Transition Query reasons *(continued)***

| Transition Reason value | Description |
|---|---|
| 12 | Exceeded maximum number of retransmissions |
| 13 | Received too many broadcast disassociations |
| 14 | Received too many broadcast deauthentications |
| 15 | Previous transition failed |
| 16 | Low RSSI |
| 17 | Roam from a non-IEEE-802.11 system |
| 18 | Transition due to received BSS Transition Request frame |
| 19 | Preferred BSS transition candidate list included |
| 20 | Leaving ESS |
| 21–255 | Reserved |

The Transition Result field contains the result of the attempted transition and is one of the status codes specified in Table 9-80 (Status codes) in 9.4.1.9 (Status Code field).

The Source RCPI field indicates the received channel power of the most recently measured frame from the Source BSSID before the STA reassociates with(#1427) the Target BSSID. The Source RCPI is a logarithmic function of the received signal power, as defined in 9.4.2.36 (RCPI element).

The Source RSNI field indicates the received signal-to-noise indication of the most recently measured frame from the Source BSSID before the STA reassociates with(#1427) the Target BSSID. The Source RSNI is a logarithmic function of the signal-to-noise ratio, as defined in 9.4.2.39 (RSNI element).

The Source BSSID, Source RCPI, and Source RSNI fields are set to 0 if the transition is initiated by an Association Request frame.

The Target RCPI field indicates the received channel power of the first measured frame just after the STA reassociates with(#1427) the Target BSSID. If association with the Target BSSID failed, the Target RCPI field indicates the received channel power of the most recently measured frame from the Target BSSID. The Target RCPI is a logarithmic function of the received signal power, as defined in 9.4.2.36 (RCPI element).

The Target RSNI field indicates the received signal-to-noise indication of the first measured frame just after the STA reassociates with(#1427) the Target BSSID. If association with the Target BSSID failed, the Target RCPI field indicates the received signal-to-noise indication of the most recently measured frame from the Target BSSID. The Target RSNI is a logarithmic function of the signal-to-noise ratio, as defined in 9.4.2.39 (RSNI element).

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#### 9.4.2.66.3 RSNA event report

The format of the Event Report field corresponding to an RSNA event report is shown in Figure 9-491 (Event Report format for RSNA event).

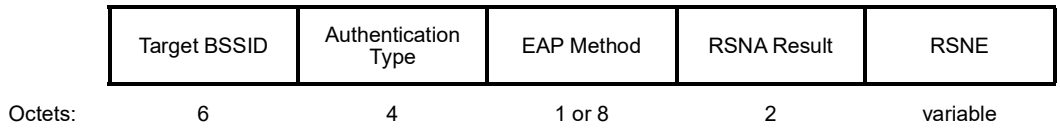


**Figure 9-491—Event Report format for RSNA event**

The Target BSSID field contains the (#2047)(#365)MAC address of the AP accepting the authentication attempt.

The Authentication Type field (#3266)identifies the AKMP in use at the time of the authentication attempt and is one of the AKM suite selectors defined in Table 9-190 (AKM suite selectors) in 9.4.2.23.3 (AKM suites).

When the Authentication Type field is either 00-0F-AC:1 (Authentication negotiated over IEEE Std 802.1X or using PMKSA caching as defined in 12.6.8.3 (Cached PMKSAs and RSNA key management)) or 00-0F-AC:3 (AKM suite selector for fast BSS transition as defined in 12.6.3 (RSNA policy selection in an infrastructure BSS)), the EAP Method field contains the IANA assigned EAP type. The EAP type contains either the legacy type (1 octet) or the expanded type (1 octet type = 254, 3-octet Vendor ID, 4-octet Vendor-Type). The EAP Method field is 0 otherwise. The EAP Method field is a single octet set to 0 otherwise.

The RSNA Result field contains the result of the RSNA establishment attempt and is one of the status codes specified in Table 9-80 (Status codes) in 9.4.1.9 (Status Code field).

The RSNE field contains the (#3488)Information field of (#4263)the RSNE in the (Re)Association Request frame that resulted in the current RSNA, truncated to the maximum length allowed for the RSNE field if necessary.

#### 9.4.2.66.4 Peer-to-peer link event report

The format of the Event Report field corresponding to a peer-to-peer link event report is shown in Figure 9-492 (Event Report format for peer-to-peer link event).

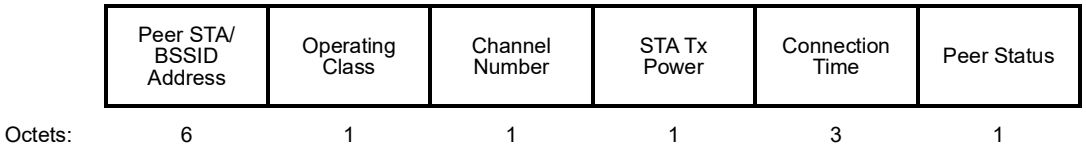


**Figure 9-492—Event Report format for peer-to-peer link event**

A peer-to-peer link is defined to be either a Direct Link within a QoS BSS, a TDLS, or a STA-to-STA communication in an IBSS.

The Peer STA/BSSID Address field contains a (#1496)MAC address. If this event is for a peer-to-peer link in an infrastructure BSS, this field contains the MAC address of the peer STA. If this event is for a peer-to-peer link in an IBSS, this field contains the BSSID.


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The Operating Class field indicates the channel set of the peer-to-peer link. Valid values of the Operating Class are shown in Annex E.

The Channel Number field indicates the peer-to-peer channel number of the peer-to-peer link. The Channel Number is defined within an Operating Class as shown in Annex E.

The STA Tx Power field indicates the target transmit power at the antenna (i.e., EIRP) in dBm with a tolerance of ± 5 dB of the lowest basic rate of the reporting STA.

The Connection Time field contains the connection time in seconds. If the Peer Status is 0, this field indicates the duration of the Direct Link. If the Peer Status field is 1, this field indicates the time difference from the time the Direct Link was established to the time at which the reporting STA generated the event report. If the Peer Status field is 2, this field indicates the duration of the IBSS membership. If the Peer Status is 3, this field indicates the time difference from the time the STA joined the IBSS to the time at which the reporting STA generated the event report. See 11.21.2.4 (Peer-to-peer link event request and report).

The Peer Status field indicates the Peer link connection status as indicated in Table 9-239 (Peer Status definitions).

**Table 9-239—Peer Status definitions**

| Peer Status | Description |
|---|---|
| 0 | Direct Link terminated |
| 1 | Direct Link active |
| 2 | IBSS membership terminated |
| 3 | IBSS membership active |
| 4–255 | Reserved |

### 9.4.2.66.5 WNM log event report

The format of the Event Report field corresponding to a WNM log event report is shown in Figure 9-493 (Event Report format for WNM log event).

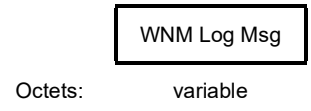


**Figure 9-493—Event Report format for WNM log event**

The WNM Log Msg field contains the entire syslog message, consisting of the PRI, HEADER, and MSG portion of a WNM log message as described in IETF RFC 5424. The TAG field of the MSG portion of the message is a 17-octet string containing the ASCII representation of the STA MAC address using hexadecimal notation with colons between octets. The octet containing the Individual/Group bit occurs last, and that bit is in the least significant position within that octet. See 11.21.2.5 (WNM log event request and report).

NOTE—For example, the TAG field for a STA with MAC address AC-DE-48-12-7B-80 is “80:7B:12:48:DE:AC” or “80:7b:12:48:de:ac”.

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#### 9.4.2.66.6 Vendor Specific event report

The Event Report field corresponding to Vendor Specific event report contains zero or more Vendor Specific subelements. The Vendor Specific subelement has the same format as the Vendor Specific element (see 9.4.2.24 (Vendor Specific element)).

#### 9.4.2.66.7 BSS color collision event report(11ax)

The Event Report field for a BSS color collision event report is 8 octets in length with each bit representing a BSS color value. A value of 1 at a bit position indicates that the BSS color value corresponding to that position is in use by OBSS as detected by the reporting non-AP HE STA.

#### 9.4.2.66.8 BSS color in use event report(11ax)

The Event Report field for a BSS color in use event report is 1 octet in length. If a reporting non-AP HE STA communicates with a peer STA with a BSS color that is different from the BSS color used by its associated AP, the Event Report field is set to the BSS color used in the communication with the peer STA.

A non-AP HE STA sets the Event Report field to 0 to cancel a previously sent BSS color in use event report. See 11.21.2.8 (BSS color in use event(11ax)).

### 9.4.2.67 Diagnostic Request element

#### 9.4.2.67.1 Diagnostic Request definition

The Diagnostic Request element contains a request that the receiving STA undertake the specified diagnostic action. The format of the Diagnostic Request element is shown in Figure 9-494 (Diagnostic Request element format).

| | Element ID | Length | Diagnostic Token | Diagnostic Request Type | Diagnostic Timeout | Diagnostic Subelements (optional) |
|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 1 | 2 | variable |

**Figure 9-494—Diagnostic Request element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The Diagnostic Token field is a number that is unique among the Diagnostic Request elements sent to each destination MAC address for which a corresponding Diagnostic Report element has not been received.

The Diagnostic Request Type field is a number that identifies a type of diagnostic request. The values of Diagnostic Request Types are shown in Table 9-240 (Diagnostic Request/Report Type definitions).

The Diagnostic Timeout field contains the time, in seconds, after which no response is returned.

The Diagnostic Subelements field contains zero or more diagnostic subelements depending on the specific Diagnostic Request Type, as defined in 9.4.2.67.2 (Association Diagnostic request) to 9.4.2.67.4 (Vendor Specific diagnostic request).

The Cancel Diagnostic Request, Manufacturer Information STA Report, and Configuration Profile Diagnostic Request elements carry no Diagnostic subelements.


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**Table 9-240—Diagnostic Request/Report Type definitions**

| Name | Diagnostic Type values |
|---|---|
| Cancel Diagnostic Request | 0 |
| Manufacturer Information STA Report | 1 |
| Configuration Profile | 2 |
| Association Diagnostic | 3 |
| IEEE 802.1X Authentication Diagnostic | 4 |
| Reserved | 5–220 |
| Vendor Specific | 221 |
| Reserved | 222–255 |

The Diagnostic Request element is included in a Diagnostic Request frame, as described in 9.6.13.4 (Diagnostic Request frame format). The use of Diagnostic Request element and frames is described in 11.21.3 (Diagnostic request and report procedures).

#### 9.4.2.67.2 Association Diagnostic request

The Diagnostic Subelements field corresponding to an Association Diagnostic request type is shown in Table 9-241 (Association Diagnostic request contents). The corresponding Diagnostic subelements are defined in 9.4.2.67.5 (Diagnostic subelement descriptions).

**Table 9-241—Association Diagnostic request contents**

| Order | Subelement |
|---|---|
| 1 | AP Descriptor |
| 2 | Profile ID |

#### 9.4.2.67.3 IEEE 802.1X Authentication Diagnostic request

The Diagnostic Subelements field corresponding to an IEEE 802.1X Authentication Diagnostic request type is shown in Table 9-242 (IEEE 802.1X Authentication Diagnostic request contents). The corresponding Diagnostic subelements are defined in 9.4.2.67.5 (Diagnostic subelement descriptions).

**Table 9-242—IEEE 802.1X Authentication Diagnostic request contents**

| Order | Subelement |
|---|---|
| 1 | AP Descriptor |
| 2 | EAP Method |
| 3 | Credential Type |
| 4 | Profile ID |

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#### 9.4.2.67.4 Vendor Specific diagnostic request

The Diagnostic Subelements field corresponding to a Diagnostic Request element of type Vendor Specific diagnostic request contains zero or more Vendor Specific subelements. The Vendor Specific subelements have the same format as their corresponding elements (see 9.4.2.24 (Vendor Specific element)).

#### 9.4.2.67.5 Diagnostic subelement descriptions

The following text describes the various subelements that are optionally included in Diagnostic Subelements field of a Diagnostic Request element (9.4.2.67) or a Diagnostic Report element (9.4.2.68). The format of a Diagnostic subelement is shown in Figure 9-495 (Diagnostic subelement format).

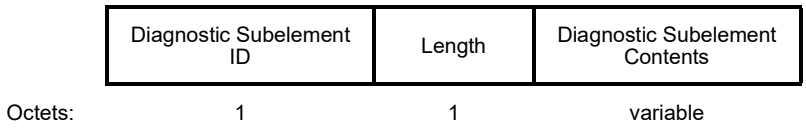


**Figure 9-495—Diagnostic subelement format**

The Diagnostic Subelement ID field indicates the Diagnostic subelement ID and is any allocated value in Figure 9-243 (Diagnostic subelement ID values).

**Table 9-243—Diagnostic subelement ID values**

| Subelement ID | Subelement name |
|---|---|
| 0 | Credential Type |
| 1 | AKM Suite |
| 2 | AP Descriptor |
| 3 | Antenna Type |
| 4 | Cipher Suite |
| 5 | (#2210)Colocated Radio Type |
| 6 | Device Type |
| 7 | EAP Method |
| 8 | Firmware Version |
| 9 | MAC Address |
| 10 | Manufacturer ID String |
| 11 | Manufacturer Model String |
| 12 | Manufacturer OI |
| 13 | Manufacturer Serial Number String |
| 14 | Power Save Mode |
| 15 | Profile ID |
| 16 | Supported Operating Classes |
| 17 | Status Code |
| 18 | SSID |
| 19 | Tx Power Capability |


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**Table 9-243—Diagnostic subelement ID values *(continued)***

| Subelement ID | Subelement name |
|---|---|
| 20 | Certificate ID |
| 21–220 | Reserved |
| 221 | Vendor Specific |
| 221–255 | Reserved |

The Length field is the length in octets of the Diagnostic Subelement Contents field.

The values of the Diagnostic Subelement Contents field are described in the following paragraphs.

The format for the Credential Type subelement is shown in Figure 9-496 (Credential Type subelement format).

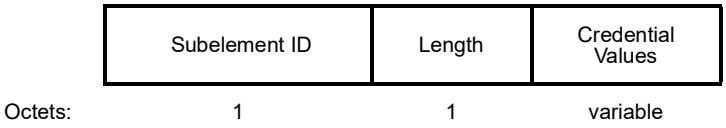


**Figure 9-496—Credential Type subelement format**

The Credentials Values field indicates one or more types of credential. Each value is chosen from those shown in Table 9-244 (Credentials values).

**Table 9-244—Credentials values**

| Value | Description |
|---|---|
| 0 | None |
| 1 | Preshared key |
| 2 | Username and password |
| 3 | X.509 certificate |
| 4 | Other certificate |
| 5 | One time password |
| 6 | Token |
| 7–255 | Reserved |

The format for the AKM Suite subelement is shown in Figure 9-497 (AKM Suite subelement format).

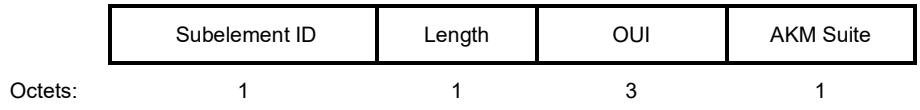


**Figure 9-497—AKM Suite subelement format**

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The OUI and AKM Suite fields identify the authentication method, and the AKM suite selector is one of the values in Table 9-190 (AKM suite selectors) in 9.4.2.23.3 (AKM suites).

The format of the AP descriptor subelement is shown in Figure 9-498 (AP Descriptor subelement format).

| | Subelement ID | Length | BSSID | Operating Class | Channel Number |
|---|---|---|---|---|---|
| Octets: | 1 | 1 | 6 | 1 | 1 |

**Figure 9-498—AP Descriptor subelement format**

The set of current operating classes and channel widths of the AP is indicated by *N*+1 AP descriptor subelements where the first *N* subelements contain an Operating Class octet with an 80+ behavior limit and the last subelement contains an Operating Class octet without an 80+ behavior limit (as defined in Annex E).

NOTE 1—An 80+80 MHz AP sends four AP descriptor subelements for 20/40 MHz, 80 MHz, 80+ MHz (for the secondary 80 MHz frequency segment), and 80 MHz (for the primary 80 MHz frequency segment).

The BSSID field identifies the BSS indicated in the AP Descriptor subelement, as described in 9.2.4.3.4 (BSSID field).

The Operating Class field contains an enumerated value from Annex E that identifies the mapping from Channel Number to frequency.

The Channel Number field indicates a current operating channel or (if the corresponding operating class in Annex E has "—" in the channel set column) the channel number of the center frequency(#6420) of the frequency segment containing the primary channel, of the AP identified by the BSSID in the AP Descriptor subelement.

The format for the Antenna Type subelement is shown in Figure 9-499 (Antenna Type subelement format).

| | Subelement ID | Length | Antenna Count | Antenna Gain | Antenna Type |
|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 1 | variable |

**Figure 9-499—Antenna Type subelement format**

The Antenna Count field contains the number of antennas of the indicated antenna type and antenna gain pair. The Antenna Count field value 0 is reserved.

The Antenna Gain field contains the peak gain, in dBi, of the antenna.

The Antenna Type field contains an ASCII string (truncated to 251 octets if required) describing the manufacturer's type information (i.e., a series of letters/numbers) of the antenna(s) or DMG antenna connected to the wireless adapter.

NOTE 2—Beamforming antennas for a non-DMG STA might have several antenna IDs, depending on antenna bearing.

The format for the Cipher Suite subelement is shown in Figure 9-500 (Cipher Suite subelement format).

The OUI and Suite Type fields identify the cipher suite, and the cipher suite selector is one of the values in Table 9-188 (Cipher suite selectors).


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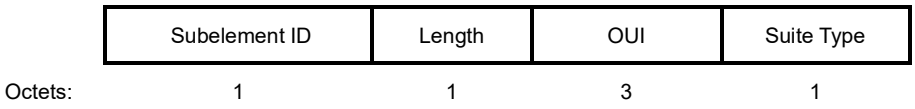


**Figure 9-500—Cipher Suite subelement format**

The format for the (#2210)Colocated Radio Type subelement is shown in Figure 9-501 ((#2210)Colocated Radio Type subelement format).

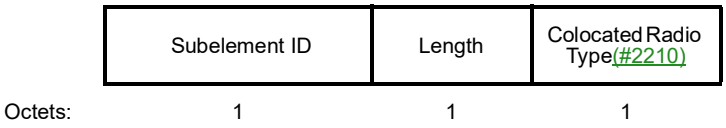


**Figure 9-501—(#2210)Colocated Radio Type subelement format**

The (#2210)Colocated Radio Type subelement indicates the type of (#2210)colocated radio and is one of the values in Table 9-245 ((#2210)Colocated Radio Type). The method that a STA uses to obtain the information on the (#2210)colocated radio is out of the scope of this standard.

**Table 9-245—(#2210)Colocated Radio Type**

| (#2210)Colocated Radio Type | Value |
|---|---|
| Reserved | 0 |
| Cellular | 1 |
| Cordless | 2 |
| GPS | 3 |
| IEEE 802.11™ | 4 |
| IEEE 802.15™ | 5 |
| IEEE 802.16™ | 6 |
| IEEE 802.20™ | 7 |
| IEEE 802.22™ | 8 |
| Digital Audio Broadcasting | 9 |
| Digital Video Broadcasting | 10 |
| Reserved | 11–255 |

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The Device Type subelement reports the type of device in which the IEEE 802.11 STA resides. The format of the Device Type subelement is shown in Figure 9-502 (Device Type subelement format).

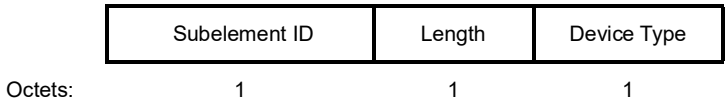


**Figure 9-502—Device Type subelement format**

The Device Type field indicates the category of device. The (#4317)numeric assignment to each device type category is defined in Table 9-246 (Device Type definitions).

**Table 9-246—Device Type definitions**

| Device Type | Value |
|---|---|
| Reserved | 0 |
| Reference Design | 1 |
| Access Point or Wireless Router for Home or Small Office | 2 |
| Enterprise Access Point | 3 |
| Cable, DSL, or Other Broadband Gateway | 4 |
| Digital Still Camera | 5 |
| Portable Video Camera | 6 |
| Networked Web Camera | 7 |
| Digital Audio—Stationary | 8 |
| Digital Audio—Portable | 9 |
| Set-Top Box, Media Extender, Media Server (includes players & recorders) | 10 |
| Display Device (television, monitor, picture frame) | 11 |
| Game Console or Game Console Adapter | 12 |
| Gaming Device—Portable | 13 |
| Media Server or Media Adapter | 14 |
| Network Storage Device | 15 |
| External Card | 16 |
| Internal Card | 17 |
| Ultra-Mobile PC | 18 |
| Notebook Computer | 19 |
| PDA (Personal Digital Assistant) | 20 |
| Printer or Print Server (includes scanner and/or fax capability) | 21 |
| Phone—Dual-Mode | 22 |


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**Table 9-246—Device Type definitions *(continued)***

| Device Type | Value |
|---|---|
| Phone—Single-Mode | 23 |
| Smartphone—Dual-Mode | 24 |
| Smartphone—Single-Mode | 25 |
| Reserved | 26-220 |
| Other devices | 221 |
| Reserved | 222–255 |

The format for the EAP Method subelement is shown in Figure 9-503 (EAP Method subelement format).

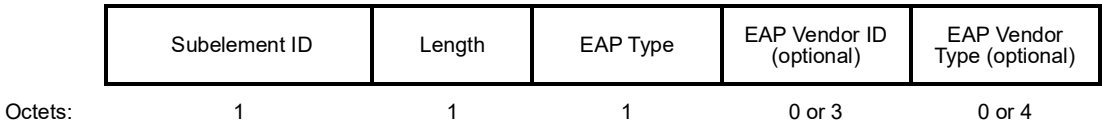


**Figure 9-503—EAP Method subelement format**

The EAP Type field contains a value that identifies a single EAP method and is any valid IANA assigned EAP type.

The EAP Vendor ID field contains a value that identifies the EAP Vendor. The EAP Vendor ID field is included when EAP Type field is 254 and is excluded otherwise.

The EAP Vendor Type field contains a value that identifies the EAP Type as defined by the vendor. The EAP Vendor Type field is included when EAP Type field is 254 and is excluded otherwise.

The format for the Firmware Version subelement is shown in Figure 9-504 (Firmware Version subelement format).

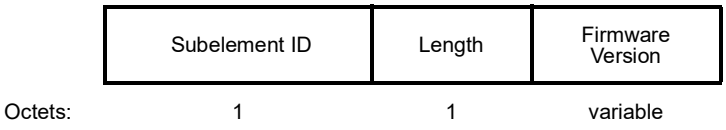


**Figure 9-504—Firmware Version subelement format**

This Firmware Version field contains an ASCII string identifying the version of firmware currently installed on the wireless network adaptor.

The format for the MAC Address subelement is shown in Figure 9-505 (MAC Address subelement format).

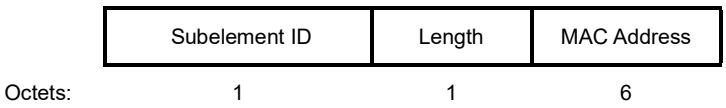


**Figure 9-505—MAC Address subelement format**

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The MAC Address field contains the (#1893)MAC address of the STA.(#2047)

The format for the Manufacturer ID String subelement is shown in Figure 9-506 (Manufacturer ID String subelement format).

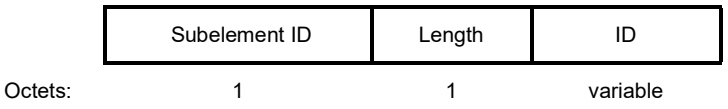


**Figure 9-506—Manufacturer ID String subelement format**

The ID field contains an ASCII string indicating the manufacturer identifier of the wireless network adaptor.

The format for the Manufacturer Model String subelement is shown in Figure 9-507 (Manufacturer Model String subelement format).

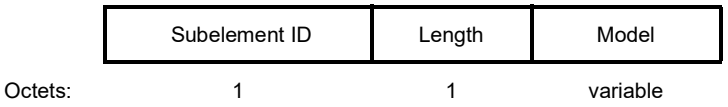


**Figure 9-507—Manufacturer Model String subelement format**

The Model field contains an ASCII string indicating the model of the wireless network adaptor.

The format for the Manufacturer OI subelement is shown in Figure 9-508 (Manufacturer OI subelement format).

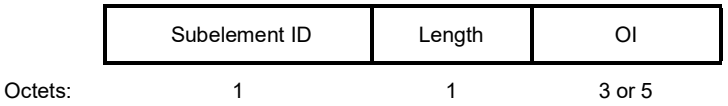


**Figure 9-508—Manufacturer OI subelement format**

The OI field contains an organization identifier, as defined in 9.4.1.29 (Organization Identifier field).

The format for the Manufacturer Serial Number String subelement is shown in Figure 9-509 (Manufacturer Serial Number String subelement format).

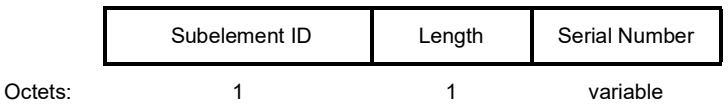


**Figure 9-509—Manufacturer Serial Number String subelement format**

The Serial Number field contains an ASCII string indicating the serial number of the wireless network adaptor.

The format for the Power Save Mode subelement is shown in Figure 9-510 (Power Save Mode subelement format).


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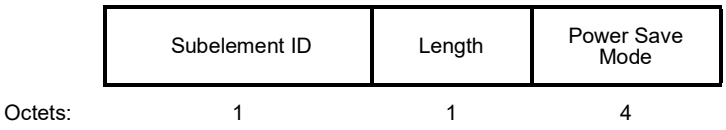


**Figure 9-510—Power Save Mode subelement format**

The Power Save Mode field is a bitmap field that indicates the power save mode(s) in use by the STA, as defined in Table 9-247 (Power Save Mode definition).

**Table 9-247—Power Save Mode definition**

| Power Save Mode | Bit |
|---|---|
| Unknown | 0 |
| None | 1 |
| PS mode (ReceiveDTIMBeacons(#4221) =1, see 11.2.3 (Power management in a non-DMG infrastructure network)) | 2 |
| PS mode (ReceiveDTIMBeacons(#4221)=0, see 11.2.3 (Power management in a non-DMG infrastructure network)) | 3 |
| U-APSD (see 11.2.3.5 (Power management with APSD)) | 4 |
| S-APSD (see 11.2.3.5 (Power management with APSD)) | 5 |
| Reserved(#3263) | 6–7 |
| SM power save (see 11.2.6 (SM power save)) | 8 |
| WNM sleep mode (see 11.2.3.15 (WNM sleep mode)) | 9 |
| FMS (see 11.2.3.13 (FMS power management)) | 10 |
| TIM broadcast (see 11.2.3.14 (TIM Broadcast)) | 11 |
| TFS (see 11.21.12 (TFS procedures)) | 12 |
| TPU (see 11.2.3.12 (TDLS peer U-APSD (TPU))) | 13 |
| TDLS peer PSM (see 11.2.3.11 (TDLS peer power save mode)) | 14 |
| TXOP power save mode | 15 |
| Reserved | 16–31 |

The format for the Profile ID subelement is shown in Figure 9-511 (Profile ID subelement format).

The Profile ID field contains a unique identifier for referencing a configuration profile available on a device. The identifier is uniquely associated to a single configuration profile on the device sending the identifier.

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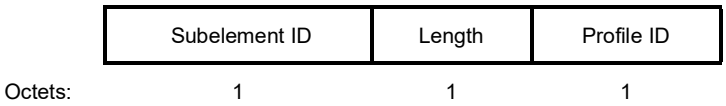


**Figure 9-511—Profile ID subelement format**

The format for the Supported Operating Classes subelement is shown in Figure 9-512 (Supported Operating Classes subelement format).

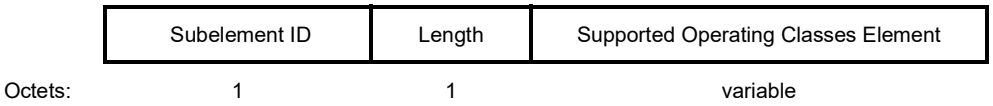


**Figure 9-512—Supported Operating Classes subelement format**

The Supported Operating Classes Element field contains a Supported Operating Classes element, as defined in 9.4.2.52 (Supported Operating Classes element), excluding the Element ID and Length fields.(#289)

The format for the Status Code subelement is shown in Figure 9-513 (Status Code subelement format).

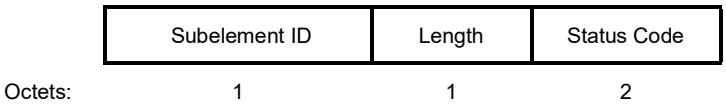


**Figure 9-513—Status Code subelement format**

(#3326)The Status Code field contains the status code, as defined in Table 9-80 (Status codes) in 9.4.1.9 (Status Code field), received at the end of the applicable operation.

The format for the SSID subelement is shown in Figure 9-514 (SSID subelement format).

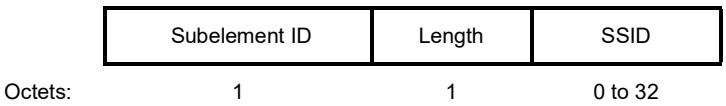


**Figure 9-514—SSID subelement format**

The SSID field contains a service set identifier with a maximum length of 32 octets, as defined in 9.4.2.2 (SSID element).

The format for the Tx Power Capability subelement is shown in Figure 9-515 (Tx Power Capability subelement format).

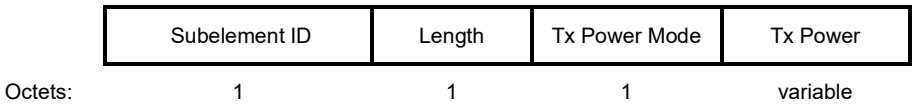


**Figure 9-515—Tx Power Capability subelement format**

The Tx Power Mode field identifies the transmit power mode of the non-AP STA and is one of the values in Table 9-248 (Tx Power Modes).


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**Table 9-248—Tx Power Modes**

| Tx Power Mode | Value |
|---|---|
| Discrete | 0 |
| Range | 1 |
| Reserved | 2–255 |

The Tx Power field indicates the target transmit power level(s) at the antenna(s) or DMG antenna(s) (i.e., EIRP), where the actual power is within ± 5 dB to the target. Each transmit power level is encoded in a single octet as a 2s complement value in dBm, rounded to the nearest integer. If the Tx Power Mode field is 0, then the Tx Power field contains one or more transmit power levels in increasing (#4317)numeric order. If the Tx Power Mode field is 1, the Tx Power field contains the STA's minimum and nonzero maximum transmit power levels, in that order.

The format for the Certificate ID subelement is shown in Figure 9-516 (Certificate ID subelement format).

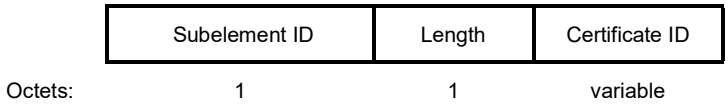


**Figure 9-516—Certificate ID subelement format**

The Certificate ID field contains a UTF-8 string indicating an identifier assigned to the STA in a manner outside the scope of the standard. The Certificate ID typically takes the form of "WFA3991" and might be used by a receiving STA to look up the certificate assigned to that ID.

The Vendor Specific subelements have the same format as their corresponding elements (see 9.4.2.24 (Vendor Specific element)).

### 9.4.2.68 Diagnostic Report element

#### 9.4.2.68.1 Diagnostic report definition

The Diagnostic Report element contains a Diagnostic report. The format of the Diagnostic Report element is shown in Figure 9-517 (Diagnostic Report element format).

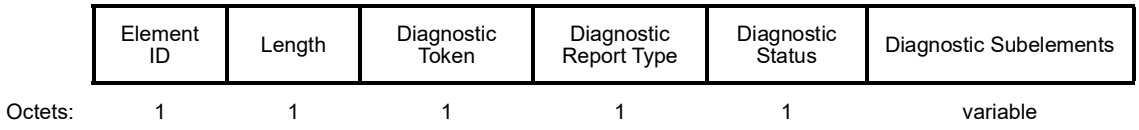


**Figure 9-517—Diagnostic Report element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The Diagnostic Token field is the Diagnostic Token in the corresponding Diagnostic Request element.

The Diagnostic Report Type field is a number that identifies the Diagnostic report. The Diagnostic Report Types are defined in Table 9-240 (Diagnostic Request/Report Type definitions).

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The Diagnostic Status field is a value in Table 9-237 (Event Report Status) (see 9.4.2.66 (Event Report element)), indicating the STA's response to the diagnostic request indicated by the diagnostic token.

The Diagnostic Subelements field contains the results of the diagnostic request.

The Diagnostic Subelements field contains the diagnostic subelement values, defined in 9.4.2.67.5 (Diagnostic subelement descriptions) corresponding to the Diagnostic Report Type field value.

The Diagnostic Report element is included in a Diagnostic Report frame, as described in 9.6.13.5 (Diagnostic Report frame format). The use of Diagnostic Report element and frames is described in 11.21.3 (Diagnostic request and report procedures).

#### 9.4.2.68.2 Manufacturer Information STA Report

The contents of the Diagnostic Subelements field of a Diagnostic Report element of type Manufacturer Information STA Report is shown in Table 9-249 (Manufacturer Information STA report contents). The corresponding Diagnostic subelements are defined in 9.4.2.67.5 (Diagnostic subelement descriptions).

**Table 9-249—Manufacturer Information STA report contents**

| Order | Subelement |
|---|---|
| 1 | Manufacturer OI |
| 2 | Manufacturer ID string |
| 3 | Manufacturer model string |
| 4 | Manufacturer serial number string |
| 6 | Firmware Version |
| 7 | Antenna Type |
| 8 | (#2210)Colocated Radio Type |
| 9 | Device Type |
| 10 | Certificate ID |

#### 9.4.2.68.3 Configuration Profile report

The contents of the Diagnostic Subelements field of a Diagnostic Report element of type Configuration Profile is shown in Table 9-250 (Configuration Profile report contents). The corresponding Diagnostic subelements are defined in 9.4.2.67.5 (Diagnostic subelement descriptions).


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**Table 9-250—Configuration Profile report contents**

| Order | Subelement |
|---|---|
| 1 | Profile ID |
| 2 | Supported Operating Classes |
| 3 | Tx Power |
| 4 | Cipher Suite |
| 5 | AKM Suite |
| 6 | EAP Method |
| 7 | Credential Type |
| 8 | SSID |
| 9 | Power Save Mode |

#### 9.4.2.68.4 Association Diagnostic report

The contents of the Diagnostic Subelements field of a Diagnostic Report element of type Association Diagnostic is shown in Table 9-251 (Association Diagnostic report contents). The corresponding Diagnostic subelements are defined in 9.4.2.67.5 (Diagnostic subelement descriptions).

**Table 9-251—Association Diagnostic report contents**

| Order | Subelement |
|---|---|
| 1 | AP Descriptor |
| 2 | Status Code |

#### 9.4.2.68.5 IEEE 802.1X Authentication Diagnostic report

The contents of the Diagnostic Subelements field of a Diagnostic Report element of type IEEE 802.1X Authentication Diagnostic is shown in Table 9-252 (IEEE 802.1X Authentication Diagnostic report contents). The corresponding Diagnostic subelements are defined in 9.4.2.67.5 (Diagnostic subelement descriptions).

**Table 9-252—IEEE 802.1X Authentication Diagnostic report contents**

| Order | Subelement |
|---|---|
| 1 | AP Descriptor |
| 2 | EAP Method |
| 3 | Credential Type |
| 4 | Status Code |

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#### 9.4.2.68.6 Vendor Specific diagnostic report

The contents of the Diagnostic subelements field of a Diagnostic Report element of type Vendor Specific contains zero or more Vendor Specific subelements that have the same formats as Vendor Specific elements in 9.4.2.24 (Vendor Specific element).

### 9.4.2.69 Location Parameters element

#### 9.4.2.69.1 Location Parameters definition

The Location Parameters element is used for location services. The format of this element is shown in Figure 9-518 (Location Parameters element format).

| | Element ID | Length | Location Subelements |
|---|---|---|---|
| Octets: | 1 | 1 | variable |

**Figure 9-518—Location Parameters element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The Location Subelements field contains one or more Location subelements described in Table 9-253 (Optional subelement IDs for Location Parameters).

**Table 9-253—Optional subelement IDs for Location Parameters**

| Subelement ID | Subelement name |
|---|---|
| 1 | Location Indication Parameters (see 9.4.2.69.2 (Location Indication Parameters subelement)) |
| 2 | Location Indication Channels (see 9.4.2.69.3 (Location Indication Channels subelement)) |
| 3 | Location Status (see 9.4.2.69.4 (Location Status subelement)) |
| 4 | Radio (see 9.4.2.69.5 (Radio subelement)) |
| 5 | Motion (see 9.4.2.69.6 (Motion subelement)) |
| 6 | Location Indication Broadcast Data Rate (see 9.4.2.69.7 (Location Indication Broadcast Data Rate subelement)) |
| 7 | Time of Departure (see 9.4.2.69.8 (Time of Departure subelement)) |
| 8 | Location Indication Options (see 9.4.2.69.9 (Location Indication Options subelement)) |
| 9–220 | Reserved |
| 221 | Vendor Specific (see 9.4.2.24 (Vendor Specific element)) |
| 222–255 | Reserved |


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The Location Parameters element is included in Location Configuration Request frames, as described in 9.6.13.6 (Location Configuration Request frame format); Location Configuration Response frames, as described in 9.6.13.7 (Location Configuration Response frame format); and Location Track Notification frames, as described in 9.6.7.18 (Location Track Notification frame format). The use of the Location Parameters element is described in 11.21.4 (Location track procedures).

The Vendor Specific subelements have the same format as their corresponding elements (see 9.4.2.24 (Vendor Specific element)). Zero or more Vendor Specific subelements are included in the list of optional subelements.

### 9.4.2.69.2 Location Indication Parameters subelement

The Location Indication Parameters subelement contains STA location reporting characteristics. The format of the Location Indication Parameters subelement is shown in Figure 9-519 (Location Indication Parameters subelement format).

| | Subelement ID | Length | Indication Multicast Address | Report Interval Units | Normal Report Interval | Normal Number of Frames per Channel |
|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 6 | 1 | 2 | 1 |

| | In-Motion Report Interval | In-Motion Number of Frames per Channel | Burst Interframe(#1460) Interval | Tracking Duration | ESS Detection Interval |
|---|---|---|---|---|---|
| Octets: | 2 | 1 | 1 | 1 | 1 |

**Figure 9-519—Location Indication Parameters subelement format**

The Subelement ID field is defined in Table 9-253 (Optional subelement IDs for Location Parameters).

The Length field is defined in 9.4.3 (Subelements).

Except in Location Track Notification frames sent in an IBSS, the Indication Multicast Address field specifies the destination address to which the Location Track Notification frames are sent. This field is a locally administered group address formed according to the procedure defined in 11.21.4.1 (Location track configuration procedures). The field is reserved when Location Track Notification frames are transmitted in an IBSS.

The Report Interval Units field contains the units used for the Normal Report Interval field and In-Motion Report Interval field, as indicated in Table 9-254 (Report Interval Units field).

The Normal Report Interval field is the time interval, expressed in the units indicated in the Report Interval Units field, at which the reporting STA is expected to transmit one or more Location Track Notification frames if either dot11MotionDetectionActivated is false or the STA is stationary. The STA does not transmit Location Track Notification frames when the value of the Normal Report Interval field is 0.

The Normal Number of Frames per Channel field is the number of Location Track Notification frames per channel sent or expected to be sent by the STA at each Normal Report Interval.

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**Table 9-254—Report Interval Units field**

| Report Interval Units | Description |
|---|---|
| 0 | Hours |
| 1 | Minutes |
| 2 | Seconds |
| 3 | Milliseconds |
| 4–255 | Reserved |

Motion is the act or process of moving, or a particular action or movement relative to the point at which the STA is configured to send Location Track Notification frames. Motion might be detected using one of the following criteria:

— Detection of speed that is greater or equal to 0.5 m/s.

— Detection of movement or vibration, for example by a ball-in-tube sensor or accelerometer or other means.

(#7142)The In-Motion Report Interval field is the time interval, expressed in the units indicated in the Report Interval Units field, at which the STA reports its location by sending a Location Track Notification frame when the reporting STA is in motion. If dot11MotionDetectionActivated is false, this field is 0.

The In-Motion Number of Frames per Channel field is the number of Location Track Notification frames per channel sent or expected to be sent by the STA at each In-Motion Report Interval. If dot11MotionDetectionActivated is false, this field is 0.

The Burst Interframe(#1460) Interval field is the target time interval, expressed in milliseconds, between the transmissions of each of the Normal or In-Motion frames on the same channel. The Burst Interframe(#1460) interval value is 0 to indicate that frames are transmitted with no target interframe(#1460) delay.

The Tracking Duration field is the amount of time, in minutes, that a STA sends the Location Track Notification frames. The duration starts as soon as the STA sends a Location Configuration Response frame with a Location Status value of Success. If the Tracking Duration value is a nonzero value the STA sends Location Track Notification frames, based on the Normal and In-Motion Report Interval field values, until the duration ends. If the Tracking Duration is 0 the STA continuously sends Location Track Notification frames as defined by Normal and In-Motion Report Interval field values until transmission is terminated based on the procedures detailed in 11.21.4.2 (Location track notification procedures).

The ESS Detection Interval field is the periodicity, in minutes, that a STA checks for beacons transmitted by one or more APs belonging to the same ESS that configured the STA. If no beacons from the ESS are received for this period, the STA terminates transmission of Location Track Notification frames, as described in the procedures detailed in 11.21.4.2 (Location track notification procedures). The ESS Detection Interval field is not used when the ESS Detection Interval field value is 0.

### 9.4.2.69.3 Location Indication Channels subelement

The Location Indication Channels subelement contains location reporting channel information. The format of the Location Indication Channels subelement format is shown in Figure 9-520 (Location Indication Channels subelement format).

The Subelement ID field is defined in Table 9-253 (Optional subelement IDs for Location Parameters).


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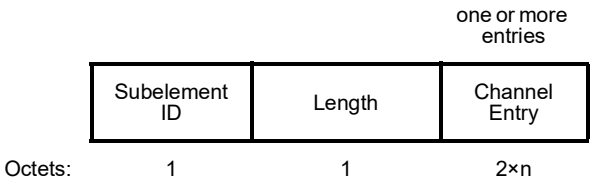


**Figure 9-520—Location Indication Channels subelement format**

The Length field is defined in 9.4.3 (Subelements).

The Channel Entry field includes one or more Operating Class And Channel fields(#6181) (see Figure 9-161 (Operating Class And Channel field format(#6181))).

The Operating Class subfield of the Operating Class And Channel field(#6181) indicates the frequency band on which a STA transmits Location Track Notification frames.

The Channel subfield of the Operating Class And Channel field(#6181) indicates a channel number on which a STA sends or an ESS expects to receive Location Track Notification frames.

The Operating Class And Channel fields(#6181) can be grouped together to identify a noncontiguous channel. A noncontiguous channel is indicated by a group of *N*+1 Operating Class And Channel fields(#6181) where the first *N* Operating Class And Channel fields(#6181) contain an Operating Class subfield with an 80+ behavior limit and the last Operating Class And Channel field(#6181) in the group contains an Operating Class subfield without an 80+ behavior limit (as defined in Annex E).

### 9.4.2.69.4 Location Status subelement

The Location Status subelement provides the result of a Location Request or Location Configuration Request frame. The format of the Location Status subelement is shown in Figure 9-521 (Location Status subelement format).

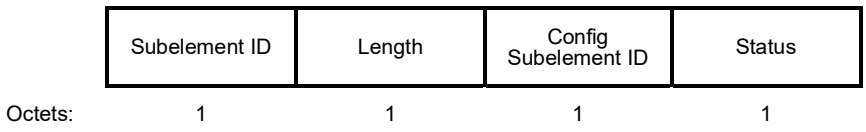


**Figure 9-521—Location Status subelement format**

The Subelement ID field is defined in Table 9-253 (Optional subelement IDs for Location Parameters).

The Length field is defined in 9.4.3 (Subelements).

The Config Subelement ID field is a specific Location Parameters subelement ID transmitted in a Location Configuration Request frame as defined in Table 9-253 (Optional subelement IDs for Location Parameters).

A Location Status subelement is included for each configuration subelement in the Location Configuration Request frame, except when all status values are the same. When all status values are the same, one Location Status subelement is included with the Config subelement ID set to 0 in the Location Configuration Response frame.

The Status field identifies the result of the Location Request frame and is one of the values in Table 9-237 (Event Report Status).

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#### 9.4.2.69.5 Radio subelement

The Radio subelement contains radio information. The format of the Radio subelement is shown in Figure 9-522 (Radio subelement format).

| | Subelement ID | Length | Transmit Power | Antenna ID | Antenna Gain | RSNI | RCPI |
|---|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

**Figure 9-522—Radio subelement format**

The Subelement ID field is defined in Table 9-253 (Optional subelement IDs for Location Parameters).

The Length field is defined in 9.4.3 (Subelements).

The Transmit Power field is the transmit power used to transmit the current Location Track Notification frame containing the Location Parameters element with the Radio subelement and is a 2s complement signed integer, reported as an EIRP in dBm. A Transmit Power field set to –128 indicates that the transmit power is unknown. The tolerance for the transmit power value reported in the Radio subelement is ± 5 dB. This tolerance is defined as the maximum possible difference, in decibels, between the reported power value and the total transmitted power across all antennas of the STA that were measured when transmitting Location Request frames.(#3444)

The Antenna ID field is the identifying number for the antenna or DMG antenna used to transmit the Location Request frame. The antenna ID or DMG antenna ID is defined in 9.4.2.38 (Antenna element).

The Antenna Gain field is the antenna gain of the antenna (or group of antennas) over which the Location Track Notification frame is transmitted and is a 2s complement signed integer, reported in dB. An Antenna Gain field set to –128 indicates that the antenna gain is unknown.

The RSNI field contains the RSNI value measured against the most recently received Location Configuration Request frame requesting that a Radio subelement be included in the Location Track Notification frame. The RSNI value is defined in 9.4.2.39 (RSNI element). A RSNI field set to 255 indicates that the RSNI value is unknown or is not used.

The RCPI field contains the RCPI value measured against the most recently received Location Configuration Request frame requesting that a Radio subelement be included in the Location Track Notification frame. The RCPI value is defined in 9.4.2.36 (RCPI element). A RCPI field set to 255 indicates that the RCPI value is unknown or is not used.

#### 9.4.2.69.6 Motion subelement

The Motion subelement contains motion information. The format of the Motion subelement is shown in Figure 9-523 (Motion subelement format).

| | Subelement ID | Length | Motion Indicator | Bearing | Speed Units | Horizontal Speed | Vertical Speed |
|---|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 2 | 1 | 2 | 2 |

**Figure 9-523—Motion subelement format**

The Subelement ID field is defined in Table 9-253 (Optional subelement IDs for Location Parameters).


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The Length field is defined in 9.4.3 (Subelements).

The Motion Indicator field is defined in Table 9-255 (Motion Indicator field). The mechanism that a STA uses to determine the value or transitions from one value to another of the Motion Indicator field is beyond the scope of the standard.

**Table 9-255—Motion Indicator field**

| Motion Indicator value | Description |
|---|---|
| 0 | Stationary: the device is stationary and not in motion. |
| 1 | Start of motion: the device was stationary and is now in motion. |
| 2 | In motion: the device is and has been in motion. |
| 3 | End of motion: the device was in motion and is now stationary. |
| 4 | Unknown: information related to motion is unknown. |
| 5–255 | Reserved |

The Bearing field(#2047) specifies the direction that the STA is traveling with relation to true north, increasing clockwise, measured in degrees from 0° to 359°. If the Bearing value is unknown, the field is 65 535.

The Speed Units field contains the units for both Horizontal and Vertical Speed field, as defined in Table 9-256 (Speed Units).

**Table 9-256—Speed Units**

| Speed Units value | Description |
|---|---|
| 0 | (#1171)cm/s |
| 1 | (#1172)m/s |
| 2–255 | Reserved |

The Horizontal Speed field contains the horizontal speed of the STA expressed in the units indicated in the Speed Units field. If the Horizontal Speed value is unknown, the field is 65 535.

The Vertical Speed field is a 2s complement signed integer indicating the vertical speed of the STA expressed in the units indicated in the Speed Units field. If the Vertical Speed value is unknown or greater than 32 766, the field is 32 767. If the Vertical Speed value is less than –32 767, the field is –32 768.

The Motion subelement field values are valid at the time of transmission of the Location Track Notification frame containing the subelement.

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#### 9.4.2.69.7 Location Indication Broadcast Data Rate subelement

The Location Indication Broadcast Data Rate subelement contains location reporting transmission rate information. The format of the Location Indication Broadcast Data Rate subelement format is shown in Figure 9-524 (Location Indication Broadcast Data Rate subelement format).

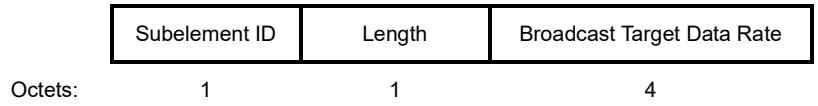


**Figure 9-524—Location Indication Broadcast Data Rate subelement format**

The Subelement ID field is defined in Table 9-253 (Optional subelement IDs for Location Parameters).

The Length field is defined in 9.4.3 (Subelements).

The Broadcast Target Data Rate field specifies the target data rate at which the STA transmits Location Track Notification frames. The Broadcast Target Data Rate field format is specified by the Rate Identification field defined in 9.4.1.30 (Rate Identification field). A Broadcast Target Data Rate field set to 0 indicates the STA transmits Location Track Notification frames at a rate chosen by the STA transmitting the Location Track Notification frames.

#### 9.4.2.69.8 Time of Departure subelement

The Time of Departure subelement contains time of departure information for the Location Track Notification frame including the subelement. The format of the Time of Departure subelement is shown in Figure 9-525 (Time of Departure subelement format).

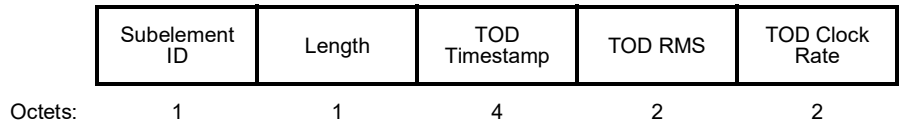


**Figure 9-525—Time of Departure subelement format**

The Subelement ID field is defined in Table 9-253 (Optional subelement IDs for Location Parameters).

The Length field is defined in 9.4.3 (Subelements).

The TOD Timestamp field specifies when the first frame energy is sent by the transmitting port in units equal to 1/TOD Clock Rate, where the TOD Clock Rate is specified in the TOD Clock Rate field. The reported TOD timestamp value is determined from the TIME_OF_DEPARTURE parameter within the PHY-TXSTART.confirm primitive.

The TOD RMS field specifies the RMS time of departure error in units equal to 1/TOD Clock Rate, where the TOD Clock Rate is specified in the TOD Clock Rate field, where the time of departure error equals the difference between the TOD Timestamp field and the time of departure measured by a reference entity using a clock synchronized to the start time and mean frequency of the local PHY entity's clock. The TOD RMS field is determined from aTxPHYTxStartRMS in units equal to 1/TOD Clock Rate, where the TOD Clock Rate is specified in the TOD Clock Rate field.

The TOD Clock Rate field contains the clock rate used to generate the TOD timestamp value reported in the TOD Timestamp field, and it is specified in units of MHz.


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### 9.4.2.69.9 Location Indication Options subelement

The Location Indication Options subelement contains the options for the STA when transmitting the Location Track Notification frame. The format of the Location Indication Options subelement is shown in Figure 9-526 (Location Indication Options subelement format).

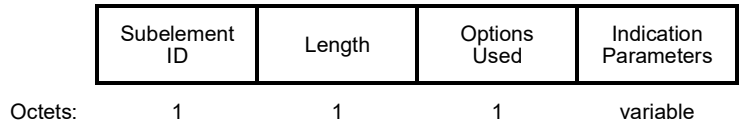


**Figure 9-526—Location Indication Options subelement format**

The Subelement ID field is defined in Table 9-253 (Optional subelement IDs for Location Parameters).

The Length field is defined in 9.4.3 (Subelements).

The Options Used field specifies the Indication Parameter fields in the Location Indication Options subelement that are used. The format of the Options Used field is shown in Figure 9-527 (Options Used field format).

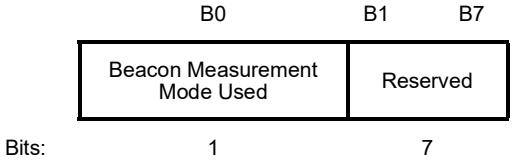


**Figure 9-527—Options Used field format**

The Indication Parameters field defines a sequence of optional fields that are included in the Location Indication Options subelement based on the Options Used field value. The value of the Indication Parameters field is defined in Table 9-257 (Indication Parameter values).

**Table 9-257—Indication Parameter values**

| Order | Field length | Field | Description |
|---|---|---|---|
| 1 | 1 | Beacon Measurement Mode | The Beacon Measurement Mode field is the mode of beacon measurement, as defined in Table 9-141 (Measurement Mode definitions for Beacon request). The results of the beacon measurement are included in the Location Track Notification frame, as described in 9.6.7.18 (Location Track Notification frame format) and 11.21.4.2 (Location track notification procedures). |
| 2–8 | | Reserved | |

### 9.4.2.70 Nontransmitted BSSID Capability element

The format of the Nontransmitted BSSID Capability element when transmitted by a non-DMG STA is shown in Figure 9-528 (Nontransmitted BSSID Capability element format (non-DMG STA)).

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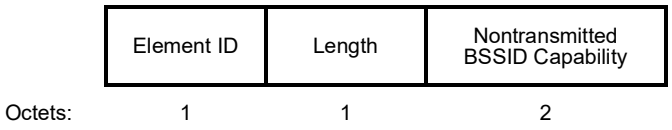


**Figure 9-528—Nontransmitted BSSID Capability element format (non-DMG STA)**

The format of the Nontransmitted BSSID Capability element when transmitted by a DMG STA is shown in Figure 9-529 (Nontransmitted BSSID Capability element format (DMG STA)).

**Figure 9-529—Nontransmitted BSSID Capability element format (DMG STA)**

When transmitted by a DMG STA, the Nontransmitted BSSID Capability element includes the DMG BSS Control and the Nontransmitted BSSID DMG Capabilities Element fields.

The Element ID and Length fields are defined in 9.4.2.1 (General).

The Nontransmitted BSSID Capability field has the same format as Capability Information field (defined in 9.4.1.4 (Capability Information field)), and indicates the capabilities of the nontransmitted BSS.(#3008)

The Nontransmitted BSSID Capability element is included in the Nontransmitted BSSID Profile subelement of the Multiple BSSID element defined in 9.4.2.44 (Multiple BSSID element). The use of the Multiple BSSID element is described in 11.10.14 (Multiple BSSID set) and Nontransmitted BSSID advertisement procedures are described in 11.1.3.8 (Multiple BSSID procedure).

The DMG BSS Control field is defined in Figure 9-530 (DMG BSS Control field format).

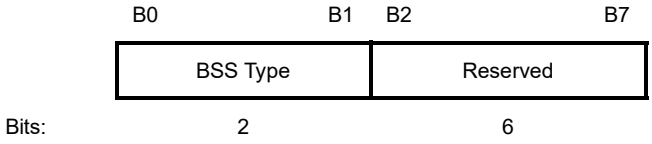


**Figure 9-530—DMG BSS Control field format**

The BSS Type field is defined in 9.4.1.44 (DMG Parameters field).

The Nontransmitted BSSID DMG Capabilities Element field contains the DMG Capabilities element of the DMG STA.

### 9.4.2.71 SSID List element

The format of the SSID List element is shown in Figure 9-531 (SSID List element format).

The Element ID and Length fields are defined in 9.4.2.1 (General).

The SSID List field is a list of SSID elements for which the STA is requesting information.


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| | Element ID | Length | SSID List |
|---|---|---|---|
| Octets: | 1 | 1 | variable |

**Figure 9-531—SSID List element format**

The SSID List element is included in Probe Request frames, as described in 9.3.3.9 (Probe Request frame format). The use of the SSID List element and frames is described in 11.1.4 (Acquiring synchronization, scanning).

### 9.4.2.72 Multiple BSSID-Index element

The format of the Multiple BSSID-Index element is shown in Figure 9-532 (Multiple BSSID-Index element format).

| | Element ID | Length | BSSID Index | DTIM Period (optional) | DTIM Count (optional) |
|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 0 or 1 | 0 or 1 |

**Figure 9-532—Multiple BSSID-Index element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The BSSID Index field is a value between 1 and $2^n - 1$ that identifies the nontransmitted BSSID, where $n$ is a nonzero, positive integer value.

The DTIM Period field indicates the DTIM period for the BSSID. This field is not present when the Multiple BSSID-Index element is included in the Probe Response frame.

The DTIM Count field indicates the DTIM count for the BSSID. This field is not present when the Multiple BSSID-Index element is included in the Probe Response frame.

The Multiple BSSID-Index element is included in the nontransmitted BSSID profile element, as described in 11.1.3.8 (Multiple BSSID procedure). The use of the Multiple BSSID element and frames is described in 11.10.14 (Multiple BSSID set).

### 9.4.2.73 FMS Descriptor element

The FMS Descriptor element defines information about group addressed BUs buffered at the AP. It is present in the Beacon frames when dot11FMSActivated is true. The format of the FMS Descriptor element is shown in Figure 9-533 (FMS Descriptor element format(M118)).

| | | | | zero or more FMS Counters | zero or more FMSIDs |
|---|---|---|---|---|---|
| | Element ID | Length | Number of FMS Counters | FMS Counters | FMSIDs |
| Octets: | 1 | 1 | 1 | *n* | *m* |

**Figure 9-533—FMS Descriptor element format(M118)**

The Element ID and Length fields are defined in 9.4.2.1 (General).

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The Number of FMS Counters field defines the number of FMS Counter fields that are contained in the FMS Counters field in the FMS Descriptor element.

The FMS Counters field contains zero or more FMS Counter fields. The format of the FMS Counter field is shown in Figure 9-534 (FMS Counter field format). When one or more FMS streams are accepted at the AP, at least one FMS counter is present in the FMS Descriptor element. A maximum of eight FMS counters are permitted. The FMS counters are used by the non-AP STA to identify the DTIM beacon after which group addressed BUs assigned to a particular delivery interval are transmitted. A single FMS counter is shared by all FMS streams that use the same delivery interval.

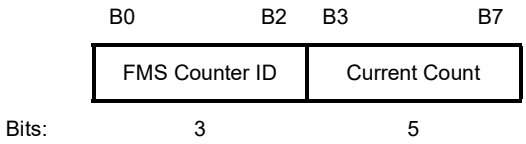


**Figure 9-534—FMS Counter field format**

The FMS Counter ID field (#4162)represents the counter ID assigned by the AP for a particular FMS stream.

The Current Count field indicates how many DTIM beacons(#3309) (including the current one) appear before the next DTIM beacon(#3309) after which the group addressed BUs assigned to a particular delivery interval are scheduled to be transmitted.

The FMSIDs field contains zero or more FMSIDs. Each FMSID is a 1-octet identifier assigned by the AP.

Inclusion of an FMSID indicates the AP has buffered BUs for the corresponding group addressed stream that is scheduled for transmission immediately after the DTIM beacon(#3309).

The FMS Descriptor element is included in Beacon frames, as described in 9.3.3.2 (Beacon frame format). The use of the FMS Descriptor element and frames is described in 11.2.3.13 (FMS power management).

### 9.4.2.74 FMS Request element

The FMS Request element defines information about the group addressed frames being requested by the non-AP STA. The format of FMS Request element is shown in Figure 9-535 (FMS Request element format).

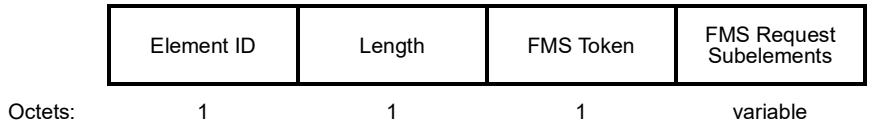


**Figure 9-535—FMS Request element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The FMS Token field contains a unique identifier for the FMS Stream Set that is the set of FMS subelements specified in the request. If this is a new request, then the FMS Token field is set to 0. Otherwise, the FMS Token field is set to the value assigned by the AP in the FMS Response element.

The FMS Request Subelements field contains one or more FMS Request subelements described in Table 9-258 (Optional subelement IDs for FMS Request subelements).


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**Table 9-258—Optional subelement IDs for FMS Request subelements**

| Subelement ID | Subelement name |
|---|---|
| 0 | Reserved |
| 1 | FMS subelement |
| 2–220 | Reserved |
| 221 | Vendor Specific subelement |
| 222–255 | Reserved |

The format of the FMS subelement is shown in Figure 9-536 (FMS subelement format).

| | | | | | | | one or more TCLAS Elements | |
|---|---|---|---|---|---|---|---|---|
| | Subelement ID | Length | Delivery Interval | Max Delivery Interval | Rate Identification | FMSID | TCLAS Elements | TCLAS Processing Element (optional) |
| Octets: | 1 | 1 | 1 | 1 | 4 | 1 | variable | 0 or 3 |

**Figure 9-536—FMS subelement format**

The Subelement ID field is 1 to uniquely identify this subelement as the FMS subelement.

The Length field is defined in 9.4.3 (Subelements).

The Delivery Interval field defines the periodicity of stream transmission in units of DTIM intervals(#4221).(#416) The value set to 0 indicates that requesting non-AP STA does not use the FMS stream identified by the TCLAS elements anymore.

The Max Delivery Interval field defines the maximum delivery interval the non-AP STA supports for the requested stream in units of DTIM intervals(#4221). The value set to 0 indicates that the non-AP STA is willing to accept any maximum delivery interval supported by the AP.

The Rate Identification field specifies the data rate as described in 9.4.1.30 (Rate Identification field), at which the STA requests to receive group addressed frames. If the STA does not request a particular multicast rate, the Rate Identification field is 0.

The FMSID field contains a unique identifier for this stream. If this is a new request, the FMSID field is reserved. Otherwise, the FMSID is set to the value assigned by the AP in the FMS Response element.

The TCLAS Elements field contains one or more TCLAS elements to specify the traffic filter as defined in 9.4.2.29 (TCLAS element). The number of TCLAS elements is limited and the total size of the FMS Request element is less than or equal to 255 octets.

The TCLAS Processing Element field is optionally present and defines how multiple TCLAS elements are processed as defined in 9.4.2.31 (TCLAS Processing element).

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(M118)The use of the FMS Request element and frames is described in 11.2.3.13 (FMS power management).

The Vendor Specific subelements have the same format as their corresponding elements (see 9.4.2.24 (Vendor Specific element)).

### 9.4.2.75 FMS Response element

The FMS Response element provides information about the delivery of group addressed frames. The format of the FMS Response element is shown in Figure 9-537 (FMS Response element format).

| | Element ID | Length | FMS Token | FMS Response Subelements |
|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | variable |

**Figure 9-537—FMS Response element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The FMS Token field is assigned by the AP for the set of FMS streams that share the counter identified by the (#3115)FMS counter ID maintained in the AP.

The FMS Response Subelements field contains one or more FMS Response subelements described in Table 9-259 (Optional subelement IDs for FMS Response subelements).

**Table 9-259—Optional subelement IDs for FMS Response subelements**

| Subelement ID | Subelement name |
|---|---|
| 0 | Reserved |
| 1 | FMS Status subelement |
| 2 | TCLAS Status subelement |
| 3–220 | Reserved |
| 221 | Vendor Specific subelement |
| 222–255 | Reserved |

The format of the FMS Status subelement is shown in Figure 9-538 (FMS Status subelement format).

| | Subelement ID | Length | Element Status | Delivery Interval | Max Delivery Interval | FMSID | FMS Counter | Rate Identification | Multicast Address |
|---|---|---|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 4 | 6 |

**Figure 9-538—FMS Status subelement format**

The Subelement ID field is 1 to uniquely identify this subelement as the FMS Status subelement.


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The Length field is defined in 9.4.3 (Subelements).

The Element Status field indicates the status of STA's requested delivery interval, as indicated in Table 9-260 (FMS Element Status and TFS Response Status definition), provided by the AP.

**Table 9-260—FMS Element Status and TFS Response Status definition**

| Value | Description |
|---|---|
| 0 | Accept |
| 1 | Deny, due to request format error or ambiguous classifier. |
| 2 | Deny, due to lack of resources on the AP. |
| 3 | Deny, due to requested classifier(s) matching 2 or more existing streams on different intervals. |
| 4 | Deny, by policy, requested stream or filter is not permitted to participate in the service. |
| 5 | Deny, reason unspecified. |
| 6 | Alternate proposed, due to existing stream with different delivery interval. |
| 7 | Alternate proposed, due to policy limits on the AP. |
| 8 | Alternate proposed, because the AP changed the delivery interval. |
| 9 | Multicast rate changes not allowed. |
| 10 | Terminate, due to an AP policy change. |
| 11 | Terminate, due to lack of resources of the AP. |
| 12 | Terminate, due to other FMS stream with higher priority. |
| 13 | Alternate proposed, because the AP changed the maximum delivery interval. |
| 14 | Alternate proposed, because the AP is unable to provide requested TCLAS-based classifiers. |
| 15–255 | Reserved |

The Delivery Interval field defines the minimum integer of DTIM periods between successive transmissions of frames for the stream corresponding to that FMSID.

The Max Delivery Interval field defines the maximum delivery interval the AP uses for the stream corresponding to FMSID. The value set to 0 indicates that the AP has no maximum delivery interval for the stream identified by FMSID.

The FMSID field is assigned by the AP and provides a unique identifier for this stream within the BSS.

The format of the FMS Counter field is shown in Figure 9-534 (FMS Counter field format). The FMS Counter ID field of the FMS Counter field is defined in 9.4.2.73 (FMS Descriptor element). The Current Count field of the FMS Counter field is reserved in the FMS Status subelement.

The Rate Identification field specifies the data rate as described in 9.4.1.30 (Rate Identification field) to be used for the multicast service. If the Rate Identification field is set to 0 then the data rate is undefined.

The Multicast MAC Address field contains the MAC address of the multicast traffic to which this FMS response relates.

The format of the TCLAS Status subelement is shown in Figure 9-539 (TCLAS Status subelement format).

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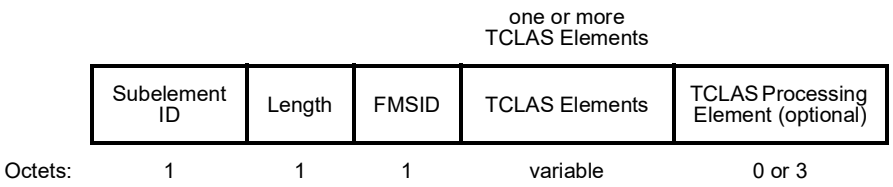


**Figure 9-539—TCLAS Status subelement format**

The Subelement ID field is 2 to uniquely identify this subelement as the TCLAS Status subelement.

The Length field is defined in 9.4.3 (Subelements).

The FMSID field is assigned by the AP and provides a unique identifier for this stream within the BSS.

The TCLAS Elements field contains one or more TCLAS elements to specify the traffic filter as defined in 9.4.2.29 (TCLAS element). The number of TCLAS elements is limited and the total size of the FMS Response element is less than or equal to 255 octets.

The TCLAS Processing Element field is optionally present and defines how multiple TCLAS elements are processed as defined in 9.4.2.31 (TCLAS Processing element).

(M118)The use of the FMS Response element and frames is described in 11.2.3.13 (FMS power management).

The Vendor Specific subelements have the same format as their corresponding elements (see 9.4.2.24 (Vendor Specific element)).

### 9.4.2.76 QoS Traffic Capability element

The QoS Traffic Capability element provides information about types of traffic generated by a non-AP QoS STA and is used by a QoS AP to indicate the access categories of associated non-AP QoS STAs. The format of the QoS Traffic Capability element is shown in Figure 9-540 (QoS Traffic Capability element format).

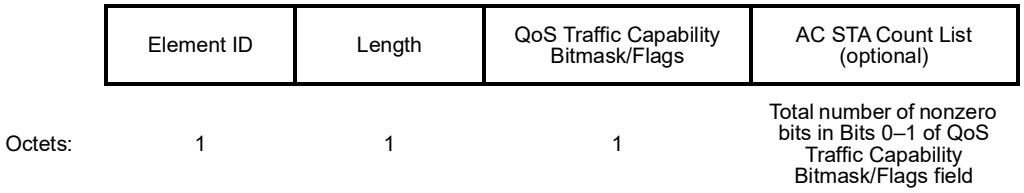


**Figure 9-540—QoS Traffic Capability element format**

The Element ID and Length fields are defined in 9.4.2.1 (General). The Length field is set to 1 + *n*, where *n* equals the total number of nonzero bits in Bits 0–1 of the QoS Traffic Capability Bitmask/Flags field.

The format of QoS Traffic Capability Bitmask/Flags field is defined in Table 9-261 (Definition of the QoS Traffic Capability Bitmask/Flags field(#403)).

Bits 0–1 serve as (#403)QoS traffic capability bitmask. The bitmask indicates the AC values that have the station count specified in the following AC STA Count List. An AP sets the bit to 1 to indicate that the station count for the corresponding AC is present in the AC STA Count List field. An AP sets the bit to 0 to


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**Table 9-261—Definition of the QoS Traffic Capability Bitmask/Flags field(#403)**

| Bit | Description |
|---|---|
| 0 | AC_VO |
| 1 | AC_VI |
| 2 | Reserved |
| 3 | Reserved |
| 4 | UP 4 Traffic |
| 5 | UP 5 Traffic |
| 6 | UP 6 Traffic |
| 7 | Reserved |

indicate that the station count for the corresponding AC is not present in the AC STA Count List field. Bits 0–1 are reserved in a transmission to an AP.

Bits 4–6 serve as (#403)QoS traffic capability flags. Each of Bits 4–6 serves as a flag for a non-AP STA to indicate application requirements about the user priorities of the traffic it generates. A non-AP STA sets the bit to 1 to indicate the existence of an application that requires generation of traffic belonging to the corresponding user priority (UP). A non-AP STA sets the bit to 0 to indicate that such application does not exist. Bits 4–6 are reserved in a transmission from an AP.

Bits 2–3 and Bit 7 are reserved.

The AC STA Count List field comprises a sequence of STA Count fields corresponding to the nonzero bits in the Bits 0–1 of the QoS Traffic Capability Bitmask/Flags field. Each STA Count field is 1 octet long and contains an unsigned integer. The STA Count field specifies the number of associated QoS STAs that have indicated QoS traffic capability of the corresponding AC. If the number of STAs is greater than 255, the STA Count field is 255. The AC STA Count List field is present only when the QoS AP transmits the QoS Traffic Capability element.(M118)

### 9.4.2.77 BSS Max Idle Period element

The BSS Max Idle Period element contains the time period a non-AP STA can refrain from transmitting frames to the AP before the AP disassociates the STA due to inactivity. The format of the BSS Max Idle Period element is shown in Figure 9-541 (BSS Max Idle Period element format).

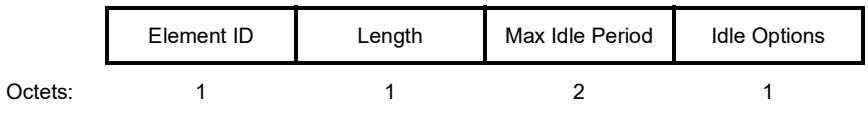


**Figure 9-541—BSS Max Idle Period element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

(#441)The Max Idle Period field indicates the BSS max idle period, as described in 11.21.13 (BSS max idle period management). The value 0 is reserved. In a non-S1G STA, it contains the BSS max idle period in units of 1000 TUs. In an S1G STA, it has the same format as the Listen Interval field (see Figure 9-144 (Listen Interval field format carried in an S1G PPDU)), and contains the BSS max idle period as the value of

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the Unscaled Interval subfield, multiplied by the scaling factor that corresponds to the value indicated in the Unified Scaling Factor subfield, in units of 1000 TUs.

The Idle Options field indicates the options associated with BSS max idle period management.(#392) The Idle Options field is shown in Figure 9-542 (Idle Options field format).

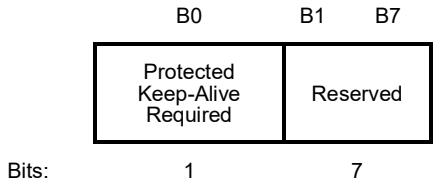


**Figure 9-542—Idle Options field format**

The Protected Keep-Alive Required subfield is set to 1 to indicate that only a protected frame indicates activity. The Protected Keep-Alive Required subfield is set to 0 to indicate that either an unprotected or a protected frame indicates activity.

The BSS Max Idle Period element is included in Association Request and Response frames, as described in 9.3.3.5 (Association Request frame format) and 9.3.3.6 (Association Response frame format), and Reassociation Request and Response frames, as described in 9.3.3.7 (Reassociation Request frame format) and 9.3.3.8 (Reassociation Response frame format). The use of the BSS Max Idle Period element and frames is described in 11.21.13 (BSS max idle period management).

### 9.4.2.78 TFS Request element

The TFS Request element defines information about the traffic filters that are enabled at the AP for the requesting non-AP STA. The format of the TFS Request element is defined in Figure 9-543 (TFS Request

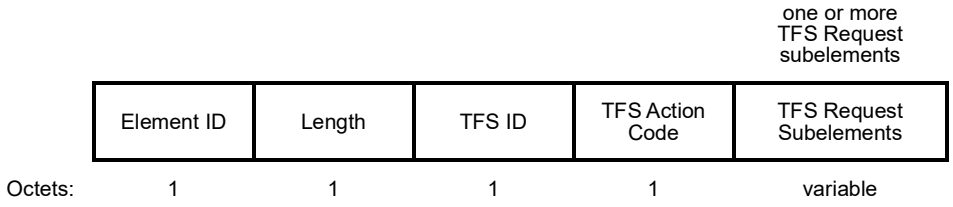


**Figure 9-543—TFS Request element format**

element format).

The Element ID and Length fields are defined in 9.4.2.1 (General).

The TFS ID field is assigned by the STA and provides a unique identifier for the traffic filter set specified by the TFS Request Subelements field.

The TFS Action Code field defines the actions taken at the AP when a frame matches a traffic filter set. The functions of the bits in this field are shown in Table 9-262 (TFS Action Code field values).

The TFS Request Subelements field contains one or more TFS Request subelements described in Table 9-263 (Optional subelement IDs for TFS Request parameters). The subelement format and ordering of subelements are defined in 9.4.3 (Subelements).


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**Table 9-262—TFS Action Code field values**

| Bit(s) | Name | Notes |
|---|---|---|
| 0 | Delete After Match | Setting this field to 1 for any traffic filter set indicates all traffic filter sets established at the AP for the non-AP STA are deleted when a frame matches any of the traffic filter sets established for the non-AP STA. Setting this field to 0 indicates no deletion of the traffic filter set upon a match. |
| 1 | Notify | (11ba)If a STA is a WUR non-AP STA:<br>— Setting this field to 1 indicates the STA is to be sent a WUR Short Wake-up frame or a WUR Wake-up frame as described in 29.9 upon the first frame matching to the traffic filter set or the first frame match after the AP receives a Notify Response frame containing the corresponding TFS ID. Setting this field to 0 indicates the AP does not send a WUR Short Wake-up frame or a WUR Wake-up frame to the requesting STA.<br>(11ba)If a STA is not a WUR non-AP STA:<br>— Setting this field to 1 indicates the STA requests to be sent a TFS Notify frame upon the first frame matching to the traffic filter set or the first frame match after the AP receives a Notify Response frame containing the corresponding TFS ID. Setting this field to 0 indicates the AP does not send a TFS Notify frame to the requesting STA. |
| 2–7 | Reserved | All other bits are reserved. |

The Subelement ID field values for the defined subelements are shown in Table 9-263 (Optional subelement IDs for TFS Request parameters). Each TFS Request subelement specifies one traffic filter. Using multiple TFS Request subelements in a TFS Request element is the equivalent to a logical AND operation on the match conditions of each TFS Request subelement.

**Table 9-263—Optional subelement IDs for TFS Request parameters**

| Subelement ID | Subelement name |
|---|---|
| 1 | TFS subelement |
| 221 | Vendor Specific subelement |
| 0, 2 to 220, 222 to 255 | Reserved |

In a TFS Response element, the number of the response subelements is the same as the number of the TFS Request subelements in the corresponding TFS Request element, where the TFS Response subelements appear in the same order as the corresponding TFS Request subelements in the corresponding TFS Request frame.

The format of the TFS subelement is shown in Figure 9-544 (TFS subelement format).

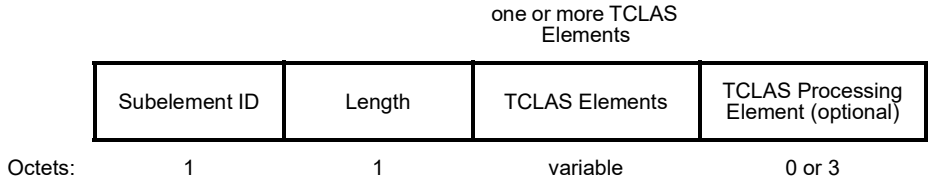


**Figure 9-544—TFS subelement format**

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The Subelement ID field uniquely identifies this subelement to be the TFS subelement.

The Length field is defined in 9.4.3 (Subelements).

The TCLAS Elements field contains one or more TCLAS elements, each specifying a set of filtering parameters as defined in 9.4.2.29 (TCLAS element). The number of TCLAS elements is limited and the total size of the TFS Request element is less than 255 octets.

The TCLAS Processing Element field is optionally present and defines how multiple TCLAS elements are processed as defined in 9.4.2.31 (TCLAS Processing element).

The format of the Vendor Specific subelement for a TFS Request element is shown in Figure 9-545 (TFS Request Vendor Specific subelement format).

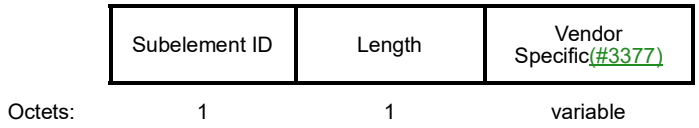


**Figure 9-545—TFS Request Vendor Specific subelement format**

The Subelement ID field uniquely identifies this subelement to be the TFS Request subelement.

The Length field is defined in 9.4.3 (Subelements).

The Vendor Specific field contains the vendor specific information.

(M118)The use of the TFS Request element and frames is described in 11.21.12 (TFS procedures).

### 9.4.2.79 TFS Response element

The TFS Response element defines information about the status of the requested filtering parameters. The format of the TFS Response element is defined in Figure 9-546 (TFS Response element format).

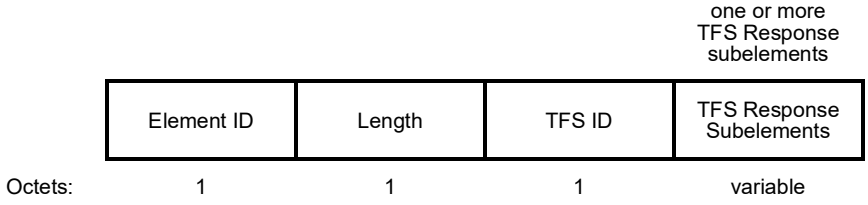


**Figure 9-546—TFS Response element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The TFS ID field indicates the unique ID for the TFS traffic filter set.

The TFS Response Subelements field contains one or more TFS Response subelements. The subelement format and ordering of subelements are defined in 9.4.3 (Subelements).

The Subelement ID field values for the defined subelements are shown in Table 9-264 (Optional subelement IDs for TFS Response parameters).


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In a TFS Response element, the number of the response subelements is the same as the number of the TFS Request subelements in the corresponding TFS Request element, where the TFS Response subelements appear in the same order as the corresponding TFS Request subelements in the corresponding TFS Request frame.

**Table 9-264—Optional subelement IDs for TFS Response parameters**

| Subelement ID | Subelement name |
|---|---|
| 1 | TFS Status subelement |
| 221 | Vendor Specific subelement |
| 0, 2–220, 222–255 | Reserved |

A TFS Status subelement contains the information as defined in Figure 9-547 (TFS Status subelement format).

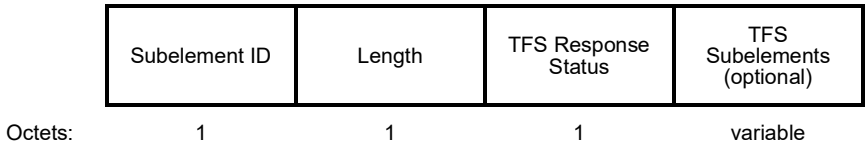


**Figure 9-547—TFS Status subelement format**

The Length field is defined in 9.4.3 (Subelements).

The TFS Response Status field indicates the status returned by the AP responding to the STA's requested traffic filter, as indicated in Table 9-260 (FMS Element Status and TFS Response Status definition).

If present, the TFS Subelements field contains one or more TFS Request subelements containing the alternative filtering parameters preferred by the AP.

The format of the Vendor Specific subelement for a TFS Response element is shown in Figure 9-548 (TFS Response Vendor Specific subelement format).

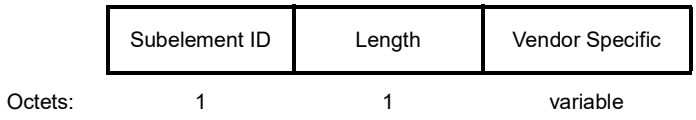


**Figure 9-548—TFS Response Vendor Specific subelement format**

The Subelement ID field uniquely identifies this subelement to be the TFS Response subelement.

The Length field is defined in 9.4.3 (Subelements).

The Vendor Specific field contains the vendor specific information.

(M118)The use of the TFS Response element and frames is described in 11.21.12 (TFS procedures).

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### 9.4.2.80 WNM Sleep Mode element

The WNM Sleep Mode element is used to enter and exit the WNM sleep mode. The format of the WNM Sleep Mode element is shown in Figure 9-549 (WNM Sleep Mode element format).

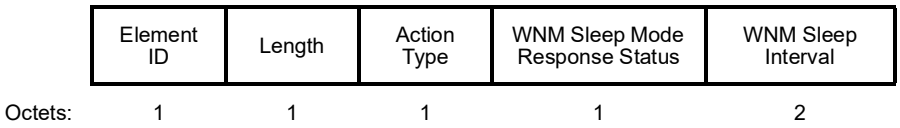


**Figure 9-549—WNM Sleep Mode element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The Action Type field is a number that identifies the type of WNM sleep mode request and response. The Action Types are shown in Table 9-265 (Action Type definitions).

**Table 9-265—Action Type definitions**

| Name | Action Type value |
|---|---|
| Enter WNM sleep mode | 0 |
| Exit WNM sleep mode | 1 |
| Reserved | 2–255 |

The WNM Sleep Mode Response Status field indicates the status returned by the AP responding to the non-AP STA's WNM sleep mode request as defined in Table 9-266 (WNM Sleep Mode Response Status definition). This field is valid only in the WNM Sleep Mode element in a WNM Sleep Mode Response frame and is reserved otherwise.

**Table 9-266—WNM Sleep Mode Response Status definition**

| Value | Description |
|---|---|
| 0 | Enter/Exit WNM sleep mode Accept. |
| 1 | Exit WNM sleep mode Accept, GTK/IGTK/BIGTK update required. |
| 2 | Denied. The AP is unable to perform the requested action. |
| 3 | Denied temporarily. The AP is unable to perform the requested action at the current time. The request can be submitted again at a later time. |
| 4 | Denied. Due to the pending key expiration. |
| 5 | Denied. The requested action was not granted due to other WNM services in use by the requesting STA. |
| 6–255 | Reserved |

The WNM Sleep Interval field is reserved if the Action Type field is 1.


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The WNM Sleep Interval field indicates to the AP how often a STA in WNM sleep mode wakes to receive Beacon frames, defined as the number of DTIM intervals. The value set to 0 indicates that the requesting non-AP STA does not transition to awake state(#6038) at any specific interval. In a non-S1G STA, the WNM Sleep Interval field is an unsigned integer. In an S1G STA, the two MSBs of the WNM Sleep Interval field contain the Unified Scaling Factor subfield and the remaining 14 bits contain the Unscaled Interval subfield (see Figure 9-144 (Listen Interval field format carried in an S1G PPDU)). In an S1G STA, the WNM sleep interval is equal to the value of the Unscaled Interval subfield, multiplied by the scaling factor that corresponds to the value indicated in the Unified Scaling Factor subfield. The Unified Scaling Factor subfield encoding is defined in Table 9-78 (Unified Scaling Factor subfield encoding).

(M118)The use of the WNM Sleep Mode element and frames is described in 11.2.3.15 (WNM sleep mode).

### 9.4.2.81 TIM Broadcast Request element

The TIM Broadcast Request element contains information about the periodic TIM broadcast being requested by the non-AP STA. The format of the TIM Broadcast Request element is shown in Figure 9-550 (TIM Broadcast Request element format).

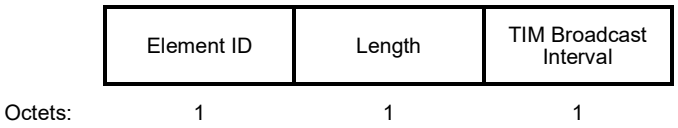


**Figure 9-550—TIM Broadcast Request element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The TIM Broadcast Interval field is the number of beacon periods between TIM frame transmissions. A TIM Broadcast Interval field set to 0 terminates the use of TIM Broadcast for the requesting station.

(M118)The use of the TIM Broadcast Request element and frames is described in 11.2.3.14 (TIM Broadcast).

### 9.4.2.82 TIM Broadcast Response element

The TIM Broadcast Response element contains information about the periodic TIM broadcast by the AP. The format of the TIM Broadcast Response element is shown in Figure 9-551 (TIM Broadcast Response element format).

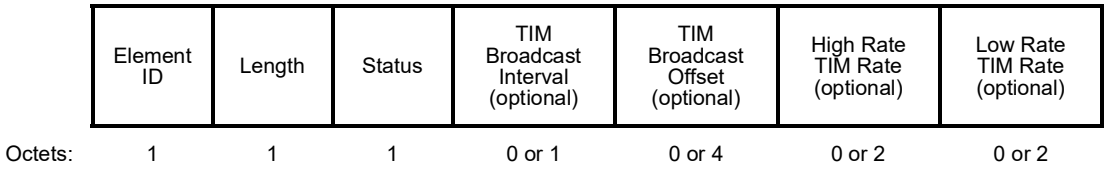


**Figure 9-551—TIM Broadcast Response element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The Status field indicates the status of the AP responding to the STA's requested delivery interval, as indicated in Table 9-267 (Status field values).

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**Table 9-267—Status field values**

| Field value | Description |
|---|---|
| 0 | Accept |
| 1 | Accept, timestamp present in TIM frames |
| 2 | Denied |
| 3 | Overridden |
| 4 | Overridden, timestamp present in TIM frames |
| 5–255 | Reserved |

When the Status field is 0, 1, 3 or 4, the TIM Broadcast Interval field, TIM Broadcast Offset field, High Rate TIM Rate field, and Low Rate TIM Rate field are included in the TIM Broadcast Response element.

The TIM Broadcast Interval field contains the number of beacon periods between scheduled TIM frame transmissions.

The TIM Broadcast Offset field contains the offset in microseconds with a tolerance of ± 4 μs relative to the TBTT for which a TIM frame is scheduled for transmission. The field contains a 2s complement signed integer.

The High Rate TIM Rate field provides an indication of the rate that is used to transmit the high data rate TIM frame, in units of 0.5 Mb/s. Setting this field to 0 indicates that the high data rate TIM frame is not transmitted.

The Low Rate TIM Rate field provides an indication of the rate that is used to transmit the low data rate TIM frame, in units of 0.5 Mb/s. The value 0 is reserved.

(M118)The use of the TIM Broadcast Response element and frames is described in 11.2.3.14 (TIM Broadcast).

### 9.4.2.83 (#2210)Colocated Interference Report element

The (#2210)Colocated Interference Report element contains some characteristics of the reported (#2210)colocated interference. The (#2210)Colocated Interference Report element is defined in Figure 9-552 ((#2210)Colocated Interference Report element format).

The Element ID and Length fields are defined in 9.4.2.1 (General).

The Report Period field contains an unsigned integer value in units of 200 TUs. If the Report Period field is a value that is greater than 0, then the reporting is periodic, and the field contains the period of sending the report. If the Report Period field is 0, then the reporting is not periodic, and a report is generated when the STA knows of a change in the (#2210)colocated interference. See 11.21.9 ((#2210)Colocated interference reporting) for further details.

The Interference Level field is a 2s complement signed integer indicating the maximum level of the (#2210)colocated interference power in units of dBm over all receive chains averaged over a 4 μs period during an interference period and across interference bandwidth. When the interference level is unknown, the field is +127 dBm. When the interference level is equal or greater than 126 dBm, the field is +126 dBm. If no (#2210)colocated interference is present the field is –128 dBm. When the interference level is equal or


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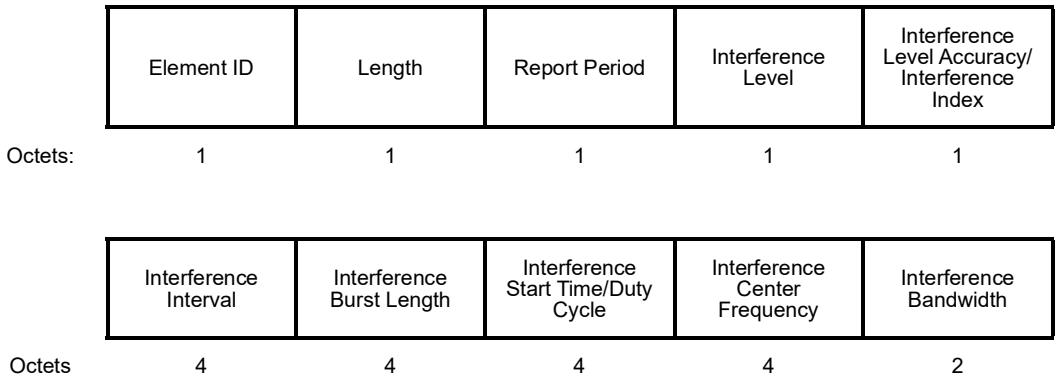


**Figure 9-552—(#2210)Colocated Interference Report element format**

lower than –127 dBm, the field is –127 dBm. The interference level is referenced to the antenna connector (see "antenna connector" in 3.1 (Definitions)) used for reception, like RCPI.

The Interference Level Accuracy/Interference Index field is shown in Figure 9-553 (Interference Level Accuracy/Interference Index field format).

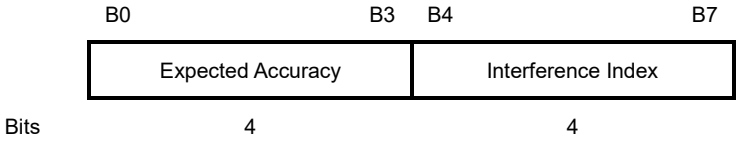


**Figure 9-553—Interference Level Accuracy/Interference Index field format**

The Expected Accuracy field represents an unsigned integer indicating the expected accuracy of the estimate of interference in dB with 95% confidence interval. If the Interference Level field is X (dBm) and the expected accuracy field is Y (dB), the actual interference level is in the range X – Y to X + Y with the probability of 95%. The range of expected accuracy is from 0 dB to 14 dB. If accuracy is unknown or greater than 14 dB, then the Expected Accuracy field is 15.

The Interference Index field indicates the interference index that is unique for each type of interference source. The field set to 0 indicates that no (#2210)colocated interference is present. See 11.21.9 ((#2210)Colocated interference reporting) for further details.

The Interference Interval field indicates the interval between two successive periods of interference in microseconds. When the interval between two successive periods of interference is variable the field is $2^{32}$–1. When the interval between two successive periods of interference is equal or greater than $2^{32}$– 2, the field is $2^{32}$– 2. If no (#2210)colocated interference is present, the field is 0.

The Interference Burst Length field indicates the duration of each period of interference in microseconds. When the duration of each period of interference is variable the field is $2^{32}$– 1. When the duration of each period of interference is equal or greater than $2^{32}$– 2, the field is $2^{32}$– 2. If no (#2210)colocated interference is present, the field is 0.

The Interference Start Time/Duty Cycle field contains the least significant 4 octets (i.e., B0–B31) of the TSF timer at the start of the interference burst. When either the Interference Interval or the Interference Burst Length fields are set to $2^{32}$– 1, this field indicates the average duty cycle. The average duty cycle value is defined as follows:

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$$\text{Average duty cycle} = \left\lfloor (2^{32} - 2) \times \frac{T_B}{T_I} + 0.5 \right\rfloor$$

where

$T_B$ is the average interference burst length
$T_I$ is the average interference interval

When the interference is nonperiodic or no (#2210)colocated interference is present, the Interference Start Time field is 0.

The Interference Center Frequency field indicates the center frequency of interference in units of 5 kHz. When center frequency is unknown, the center frequency of the STA's operating channel is reported. If no (#2210)colocated interference is present the field is 0.

The Interference Bandwidth field indicates the bandwidth in units of 5 kHz at the –3 dB roll-off point of the interference signal. When bandwidth of the interference signal is unknown, the field is 65 535. When bandwidth of the interference signal is equal or greater than 65 534 the field is 65 534. If no (#2210)colocated interference is present, the field is 0.

### 9.4.2.84 Channel Usage element

The Channel Usage element defines channel usage information for a list of channels used in a BSS or an (#7002)off-channel TDLS direct link.(#7063) The format of the Channel Usage element is shown in Figure 9-554 (Channel Usage element format).

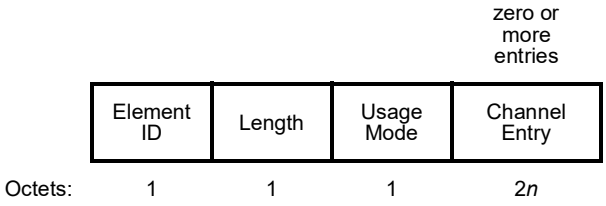


**Figure 9-554—Channel Usage element format**


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The Element ID and Length fields are defined in 9.4.2.1 (General).

The Usage Mode field is a number that identifies the usage of the recommended channels listed in the Operating Class/Channel Number pair fields. The Usage Mode definitions are shown in Table 9-268 (Usage Mode definitions).

**Table 9-268—Usage Mode definitions**

| Value | Usage Mode |
|---|---|
| 0 | (#6071)Channel-usage-aidable BSS(#3349) |
| 1 | Off-channel TDLS direct link |
| (#1024)2 | (#6071)Channel-usage-aidable BSS(#3349) in which none of the channel-usage-aiding BSSs that belong to the same ESS operate on the channels identified by the Channel Entry field |
| 3(#3145) | Unavailability indication(#6018) |
| 4(#4028) | (#6071)Channel-usage-aidable BSS channel switch request |
| 5(#6016) | Capability notification |
| 6–254 | Reserved |
| 255(#4006) | Unknown request |

The Channel Entry field includes zero or more Operating Class And Channel fields(#6181). The format of the Operating Class And Channel field(#6181) is defined in 9.4.1.22 (Operating Class And Channel field(#6181)). Operating Class And Channel fields(#6181) can be grouped together to identify a noncontiguous channel as described in 9.4.2.69.3 (Location Indication Channels subelement).

(M118)The use of the Channel Usage element and frames is described in 11.21.15 (Channel usage procedures).

### 9.4.2.85 Time Zone element

The Time Zone element contains the local time zone of the AP. The format of the Time Zone element is shown in Figure 9-555 (Time Zone element format).

| | Element ID | Length | Time Zone |
|---|---|---|---|
| Octets: | 1 | 1 | variable |

**Figure 9-555—Time Zone element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The format of the Time Zone field is as specified in 8.3 of IEEE Std 1003.1-2004:

stdoffset[dst[offset][,start[/time],end[/time]]]

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The length of the field is no less than 4 octets and no more than TZNAME_MAX, as defined in IEEE Std 1003.1-2004. The Time Zone field represents the time zone at the AP's location. The encoding of the field is in ASCII characters as shown in the following Example-1.

Example-1: EST5

Example-2: EST5EDT4,M3.2.0/02:00,M11.1.0/02:00

In the Example-2, the string is interpreted as a time zone that is normally five hours behind UTC, and four hours behind UTC during daylight saving time (DST), which runs from the second Sunday in March at 02:00 local time to the first Sunday in November at 02:00 local time. Normally, the time zone is abbreviated "EST" but during DST it is abbreviated "EDT."

### 9.4.2.86 DMS Request element

The DMS Request element defines information about the group addressed frames to be transmitted as individually(#1894) addressed frames. The format of the DMS Request element is shown in Figure 9-556 (DMS Request element format).

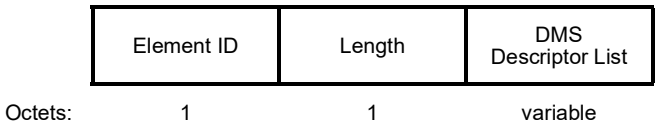


**Figure 9-556—DMS Request element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The DMS Descriptor List field contains one or more DMS Descriptors. The format of the DMS Descriptor is defined in Figure 9-557 (DMS Descriptor format).

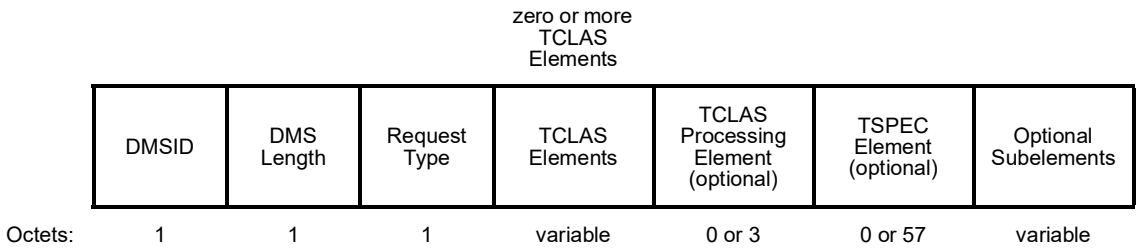


**Figure 9-557—DMS Descriptor format**

The DMSID field is set to 0 when the Request Type field is "Add" as defined in Table 9-269 (DMS Request Type field); otherwise, the DMSID field is set to the nonzero value assigned by the AP to identify the DMS traffic flow.

The DMS Length field is set to 1 + *n*, where *n* indicates the total length in octets of all of the TCLAS Elements, optional TCLAS Processing Element, optional TSPEC Element, and Optional Subelements fields contained in the DMS Descriptor field. The maximum value of the DMS Length field is 253.


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The Request Type field identifies the type of DMS request. The encoding of the Request Type field is shown in Table 9-269 (DMS Request Type field).

**Table 9-269—DMS Request Type field**

| Description | Request Type field value |
|---|---|
| Add | 0 |
| Remove | 1 |
| Change | 2 |
| Reserved | 3–255 |

When the Request Type field contains "Add," the TCLAS Elements field contains one or more TCLAS elements to specify group addressed frames as defined in 9.4.2.29 (TCLAS element). When a GCR Request subelement is included in the DMS Descriptor and the Request Type field is equal to "Add," the TCLAS Elements field contains at least a TCLAS element with frame classifier type set to 0 (Ethernet parameters) to specify a destination group address as defined in 9.4.2.29 (TCLAS element). When the Request Type field contains any value other than "Add," the TCLAS Elements field contains zero TCLAS elements.

When the Request Type field contains "Add" and when there are two or more TCLAS elements present, the TCLAS Processing Element field contains one TCLAS Processing element to define how these TCLAS elements are to be processed, as defined in 9.4.2.31 (TCLAS Processing element). Otherwise, the TCLAS Processing Element field contains zero TCLAS Processing elements.

When the Request Type field contains "Add" or "Change," the TSPEC Element field optionally contains one TSPEC element to specify the characteristics and QoS expectations of the corresponding traffic flow as defined in 9.4.2.28 (TSPEC element). When a GCR Request subelement is included in the DMS Descriptor and the Request Type field is equal to "Add" or "Change," the TSPEC Element field contains one TSPEC element. Otherwise, the TSPEC Element field contains zero TSPEC elements.

The Optional Subelements field contains zero or more subelements. The subelement format and ordering of subelements are defined in 9.4.3 (Subelements).

The Subelement ID field values for the defined subelements are shown in Table 9-270 (Optional subelement IDs for DMS Descriptor).

**Table 9-270—Optional subelement IDs for DMS Descriptor**

| Subelement ID | Name | Extensible |
|---|---|---|
| 0 | Reserved | |
| 1 | GCR Request | Yes |
| 2–220 | Reserved | |
| 221 | Vendor Specific | Vendor defined |
| 222–255 | Reserved | |

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Each DMS Descriptor contains zero or one GCR Request subelements. If present and the Request Type field is equal to "Add" or "Change," the GCR Request subelement indicates a request by a STA to respectively add or change the GCR service for a group addressed stream identified by the TCLAS element or by the DMSID in the DMS Descriptor. The format of the GCR Request subelement is shown in Figure 9-558 (GCR Request subelement format).

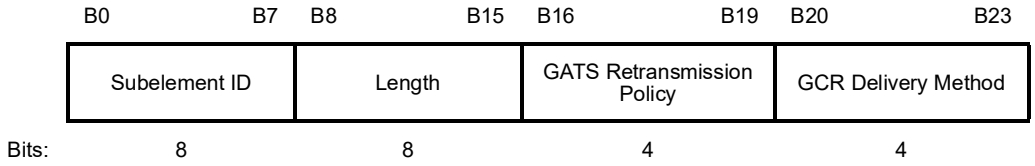


**Figure 9-558—GCR Request subelement format**

The Length field is defined in 9.4.3 (Subelements).

The GATS Retransmission Policy field is set to indicate the STA's preferred retransmission policy for the group address for which the GCR service is requested. The values are shown in Table 9-271 (GATS Retransmission Policy field values).

**Table 9-271—GATS Retransmission Policy field values**

| Value | GATS retransmission policy | Notes |
|---|---|---|
| 0 | No preference | |
| 1 | DMS | See 11.21.16.2 (DMS procedures). |
| 2 | GCR unsolicited retry | See 11.21.16.3.6 (GCR unsolicited retry). |
| 3 | GCR Block Ack | See 11.21.16.3.7 (GCR block ack). |
| 4–15 | Reserved | |

The GCR Delivery Method field is set to indicate the STA's preferred delivery method for the group address for which the GCR service is requested. The values are shown in Table 9-272 (GCR Delivery Method field values).

**Table 9-272—GCR Delivery Method field values**

| Value | GCR delivery method | Notes |
|---|---|---|
| 0 | No preference | |
| 1 | Non-GCR-SP | See 11.21.16.3.1 (Overview). |
| 2 | GCR-SP | See 11.21.16.3.8 (GCR-SP). |
| 3–15 | Reserved | |


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The DMS Request element is included in DMS Request frames, as described in 9.6.13.26 (DMS Request frame format), and Reassociation Request frames, as described in 9.3.3.7 (Reassociation Request frame format). The use of the DMS Request element and frames is described in 11.21.16 (Group addressed transmission service).

### 9.4.2.87 DMS Response element

The DMS Response element provides the status information about the requested group addressed frames. The format of the DMS Response element is shown in Figure 9-559 (DMS Response element format).

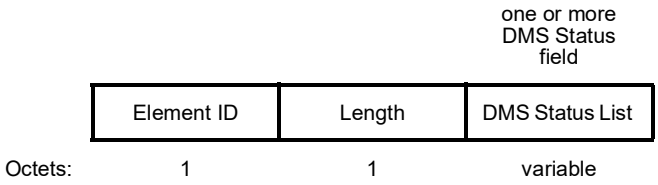


**Figure 9-559—DMS Response element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The DMS Status List field contains one or more DMS Status fields.(#1723) The format of a DMS Status field is defined in Figure 9-560 (DMS Status field format).

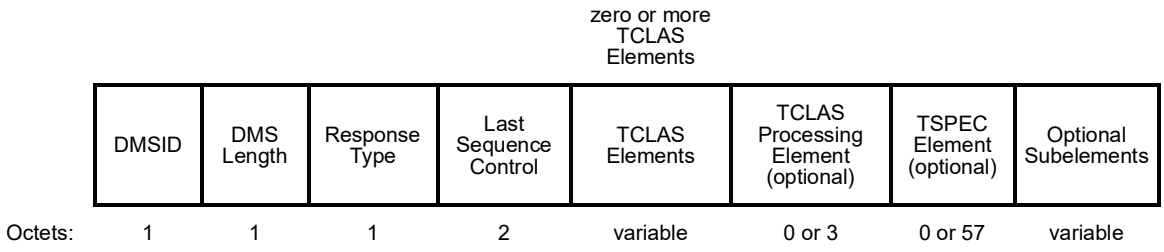


**Figure 9-560—DMS Status field format**

The DMSID is assigned by the AP and provides a unique identifier within the BSS for the DMS traffic flow identified by the TCLAS Elements, TCLAS Processing Element, and TSPEC Element fields. The uniqueness of the identifier is independent of the ordering of the TCLAS elements. In a mesh BSS, the DMSID is assigned by a mesh STA that responds to a GCR request and is unique among all existing DMSIDs used by the mesh STA for its current GCR agreements.

The DMS Length field is set to $3 + n$, where $n$ indicates the total length in octets of all of the TCLAS Elements, optional TCLAS Processing Element, optional TSPEC Element, and Optional Subelements fields contained in the DMS Status field. When the Response Type field is equal to "Terminate," the DMS Length field is set to 3. The maximum value of the DMS Length field is 253.

The Response Type field indicates the response type returned by the AP responding to the non-AP STA's request or by a mesh STA responding to its peer mesh STA's request or indicates the DMS status is an advertisement of an existing GCR service, as indicated in Table 9-273 (Response Type field values).

When the Last Sequence Control field is not supported the Last Sequence Control field is set to 65 535. When the Last Sequence Control field is supported and the Response Type field does not contain "Terminate" or "GCR Advertise," the Last Sequence Control field is reserved.

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**Table 9-273—Response Type field values**

| Field value | Description | Notes |
|---|---|---|
| 0 | Accept | STA accepts the DMS or GCR request |
| 1 | Denied | STA rejects the DMS or GCR request |
| 2 | Terminate | STA terminates DMS previously accepted DMS or GCR request |
| 3 | GCR Advertise | STA advertises a group addressed stream subject to an existing GCR agreement. |
| 4–255 | Reserved | |

When the Response Type field is "Terminate" and the Last Sequence Control field is supported, Bit 0 to Bit 3 of the Last Sequence Control field is 0, and Bit 4 to Bit 15 of the Last Sequence Control field contains the sequence number of the last group addressed frame that the AP delivered to the non-AP STA that is the recipient of the DMS Response frame. If the Response Type field is "Terminate" and the last frame received by the non-AP STA prior to DMS termination has not also been sent using a group addressed frame, the Last Sequence Control field is set to 65 534.

When the Response Type field contains "Accept" or "Denied" and a GCR Response subelement is not included in the DMS Status field, the TCLAS Elements field contains one or more TCLAS elements to specify group addressed frames as defined in 9.4.2.29 (TCLAS element). When the Response Type field is equal to "Accept," "Denied," or "GCR Advertise" and a GCR Response subelement is included in the DMS Status field, the TCLAS Elements field contains at least one TCLAS element with frame classifier type set to 0 (Ethernet parameters) to specify a destination group address as defined in 9.4.2.29 (TCLAS element). Otherwise, the TCLAS Elements field contains zero TCLAS elements.

When the Response Type field contains "Accept" or "Denied," the TCLAS Processing Element field optionally contains one TCLAS Processing element to define how these TCLAS elements are to be processed, as defined in 9.4.2.31 (TCLAS Processing element). When the Response Type field contains "Terminate" or when there is only one TCLAS element, the TCLAS Processing Element field contains zero TCLAS Processing elements.

When the Response Type field contains "Accept" or "Denied," the TSPEC Element field optionally contains one TSPEC element to specify the characteristics and QoS expectations of the corresponding traffic flow as defined in 9.4.2.28 (TSPEC element). When a GCR Response subelement is included in the DMS Status field and the Response Type field is equal to "Accept," "Denied," or "GCR Advertise," the TSPEC Element field contains one TSPEC element. Otherwise, the TSPEC Element field contains zero TSPEC elements.

The Optional Subelements field contains zero or more subelements. The subelement format and ordering of subelements are defined in 9.4.3 (Subelements).

The Subelement ID field values for the defined subelements are shown in Table 9-274 (Optional subelement IDs for DMS Status).

**Table 9-274—Optional subelement IDs for DMS Status**

| Subelement ID | Name | Extensible |
|---|---|---|
| 0 | Reserved | |
| 1 | GCR Response | Subelements |
| 2–220 | Reserved | |


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**Table 9-274—Optional subelement IDs for DMS Status**

| | | |
|---|---|---|
| 221 | Vendor Specific | Vendor defined |
| 222–255 | Reserved | |

The GCR Response subelement contains one of the following:

— A response by an AP to a GCR request by a non-AP STA for GCR service for a group address
— A response by a mesh STA to a GCR request by a peer mesh STA for GCR service for a group address
— An unsolicited advertisement for the parameters of a group addressed stream subject to the GCR service

The format of the GCR Response subelement is shown in Figure 9-557 (DMS Descriptor format).

| | Subelement ID | Length | GATS Retransmission Policy | GCR Delivery Method | GCR Concealment Address | Schedule Element |
|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 0 or 1 | 0 or 1 | 0 or 6 | 0 or 14 |

**Figure 9-561—GCR Response subelement format**

The GATS Retransmission Policy, GCR Delivery Method, and GCR Concealment Address fields are present when the Response Type field is not equal to “Denied”; otherwise, they are omitted. The Schedule Element field is optionally present when the Response Type field is not equal to “Denied.”

The GATS Retransmission Policy field is set to indicate the current GCR retransmission policy for the group address for which the GCR service is requested. The values are shown in Table 9-271 (GATS Retransmission Policy field values).

The GCR Delivery method field is set to indicate the current GCR Delivery method for the group address for which the GCR service is requested. The values are shown in Table 9-272 (GCR Delivery Method field values).

The GCR Concealment Address field, when present, indicates the GCR concealment address, as described in 11.21.16.3.5 (Concealment of GCR transmissions).

The Schedule Element field is present if the GCR delivery method is equal to GCR-SP. It indicates the current SP schedule for the group addressed stream (see 9.4.2.32 (Schedule element)).

The DMS Response element is included in DMS Response frames, as described in 9.6.13.27 (DMS Response frame format), and Reassociation Response frames, as described in 9.3.3.8 (Reassociation Response frame format). The use of the DMS Response element and frames is described in 11.21.16 (Group addressed transmission service).

### 9.4.2.88 Destination URI element

The Destination URI element contains URI and ESS detection interval(#1006) values from the requesting STA that the responding STA can (#1006)use to deliver Event or Diagnostic Report frames. The format of the Destination URI element is shown in Figure 9-562 (Destination URI element format).

The Element ID and Length fields are defined in 9.4.2.1 (General).

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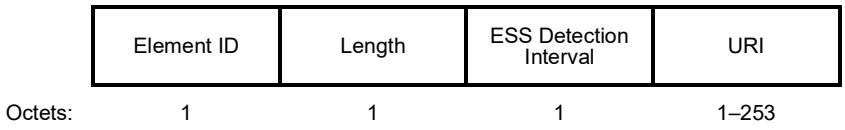


**Figure 9-562—Destination URI element format**

The ESS Detection Interval field is defined in 9.4.2.69.2 (Location Indication Parameters subelement) and its use for Event and Diagnostic requests is described in 11.21.2 (Event request and report procedures) and 11.21.3 (Diagnostic request and report procedures).

The URI field specifies the destination URI for Event and Diagnostic reports using the format defined in IETF RFC 3986. The URI field value is limited to 253 octets.(#1006)

Use of the Destination URI element in an Event Request frame is described in 11.21.2.1 (Event request and event report). Use of the Destination URI element in a Diagnostic Request frame is described in 11.21.3.1 (Diagnostic request and diagnostic report).

### 9.4.2.89 U-APSD Coexistence element

The (M118)U-APSD Coexistence element provides the duration of requested transmission during a U-APSD service period. The format of the U-APSD Coexistence element is shown in Figure 9-563 (U-APSD Coexistence element format).

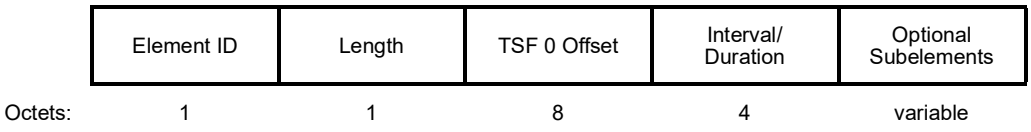


**Figure 9-563—U-APSD Coexistence element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The TSF 0 Offset field is set to the number of microseconds since TSF time 0 when the non-AP STA knew the start of interference. The AP uses the TSF 0 Offset field together with the Interval/Duration field to enqueue frames for transmission to the non-AP STA using the procedures as described in 11.2.3.5.2 (U-APSD coexistence).

Setting the TSF 0 Offset field to 0 indicates the non-AP STA requests the AP transmit frames to the non-AP STA using the procedure described in 11.2.3.5.2 (U-APSD coexistence) for the case where TSF 0 Offset is equal to 0.

The Interval/Duration field is defined as follows:

— When the TSF 0 Offset is 0, the Interval/Duration field is the number of microseconds during the U-APSD service period when the AP transmits frames to the non-AP STA as described in 11.2.3.5.2 (U-APSD coexistence).
— When the TSF 0 Offset is nonzero, the Interval/Duration field is the number of microseconds between the start of consecutive interference bursts.

The Interval/Duration field value of 0 is reserved.

The Optional Subelements field contains zero or more subelements. The subelement format and ordering of subelements are defined in 9.4.3 (Subelements).


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The Subelement ID field values for the defined subelements are shown in Table 9-275 (Optional subelement IDs for U-APSD coexistence).

**Table 9-275—Optional subelement IDs for U-APSD coexistence**

| Subelement ID | Name | Extensible |
|---|---|---|
| 0–220 | Reserved | |
| 221 | Vendor Specific | Vendor defined |
| 222–255 | Reserved | |

### 9.4.2.90 Interworking element

The Interworking element contains information about the interworking service capabilities of a STA as shown in Figure 9-564 (Interworking element format).

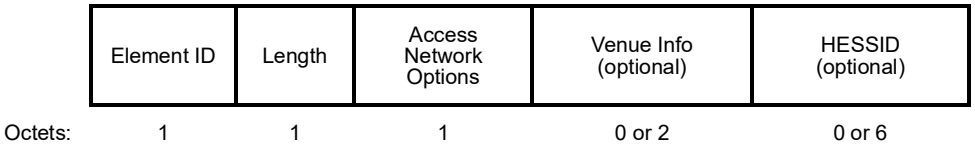


**Figure 9-564—Interworking element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The format of Access Network Options field is shown in Figure 9-565 (Access Network Options field format).

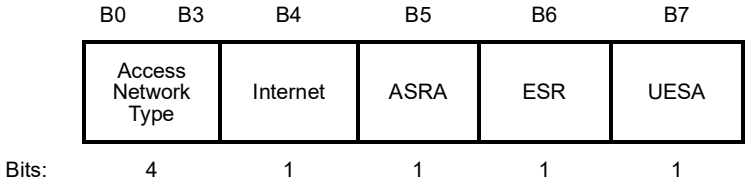


**Figure 9-565—Access Network Options field format**

A non-AP STA sets Internet, ASRA, ESR, and UESA fields to 0 when including the Interworking element in the Probe Request frame. A non-AP STA sets the Internet, ASRA and ESR bits to 0 when including the Interworking element in (Re)Association Request frames. A mesh STA sets the Internet bit to 0 when including the Interworking element in Mesh Peering Open frames. In (Re)Association Request frames, a non-AP STA sets the UESA bit according to the procedures in 11.3.5 (Association, reassociation, and disassociation). The access network types are shown in Table 9-276 (Access network type). The Access Network Type field is set by the AP or the mesh STA to advertise its access network type to non-AP STAs. A non-AP STA uses this field to indicate the desired access network type in an active scan. See R.2 (Network discovery and selection) for the usage of fields contained within the Interworking element.

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**Table 9-276—Access network type**

| Access network type | Meaning | Description |
|---|---|---|
| 0 | Private network | Nonauthorized users are not permitted on this network. Examples of this access network type are home networks and enterprise networks, which might employ user accounts. Private networks do not necessarily employ encryption. |
| 1 | Private network with guest access | Private network but guest accounts are available. Example of this access network type is enterprise network offering access to guest users. |
| 2 | Chargeable public network | The network is accessible to anyone, however, access to the network requires payment. Further information on types of charges might be available through other methods (e.g., IEEE Std 802.21-2017, http/https redirect, or DNS redirection). Examples of this access network type is a hotspot in a coffee shop offering internet access on a subscription basis or a hotel offering in-room internet access service for a fee. |
| 3 | Free public network | The network is accessible to anyone and no charges apply for the network use. An example of this access network type is an airport hotspot or municipal network providing free service. |
| 4 | Personal device network | A network of personal devices. An example of this type of network is a camera attaching to a printer, thereby forming a network for the purpose of printing pictures. |
| 5 | Emergency services only network | A network dedicated and limited to accessing emergency services. |
| 6 to 13 | Reserved | Reserved |
| 14 | Test or experimental | The network is used for test or experimental purposes only. |
| 15 | Wildcard | Wildcard access network type |

Bit 4 is the Internet field. The AP or mesh STA sets this field to 1 if the network provides connectivity to the Internet; otherwise it is set to 0 indicating that it is unspecified whether the network provides connectivity to the Internet.

Bit 5 is the Additional Step Required for Access (ASRA) field. It is set to 1 by the AP to indicate that the network requires a further step for access. For more information, refer to Network Authentication Type Information in 9.4.5.6 (Network Authentication Type ANQP-element). A mesh STA uses the ASRA field as an emergency indicator. If a mesh STA requires emergency services, the ASRA field is set to 1; otherwise it is set to 0. See 11.22.6 (Interworking procedures: emergency services support).

Bit 6 is the ESR (emergency services reachable) field. It is set to 1 by the AP or mesh STA to indicate that emergency services are reachable through the AP or mesh STA; otherwise it is set to 0 indicating that it is unable to reach the emergency services. See 11.22.6 (Interworking procedures: emergency services support).

Bit 7 is the UESA (unauthenticated emergency service accessible) field. When set to 0, this field indicates that no unauthenticated emergency services are reachable through this AP or mesh STA. When set to 1, this field indicates that higher layer unauthenticated emergency services are reachable through this AP or mesh STA. A STA uses the Interworking element with the UESA bit set to 1 to gain unauthenticated access to a BSS to access emergency services. A mesh STA uses the Interworking element with the UESA bit set to 1 to gain unauthenticated access to another mesh STA to access emergency services. See 11.3.5 (Association, reassociation, and disassociation).


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The Venue Info field is defined in 9.4.1.32 (Venue Info field).

(#8244)The HESSID field indicates the target HESSID when a STA is actively scanning. The HESSID field for an AP is set to dot11HESSID. This optional field is not used by mesh STAs.

### 9.4.2.91 Advertisement Protocol element

The Advertisement Protocol element contains information that identifies a particular advertisement protocol and its corresponding Advertisement Control. The Advertisement Protocol element format is shown in Figure 9-566 (Advertisement Protocol element format).

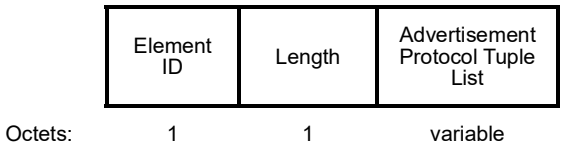


**Figure 9-566—Advertisement Protocol element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The Advertisement Protocol Tuple List field contains one or more Advertisement Protocol Tuple fields.

The format of an Advertisement Protocol Tuple field is shown in Figure 9-567 (Advertisement Protocol Tuple field format).

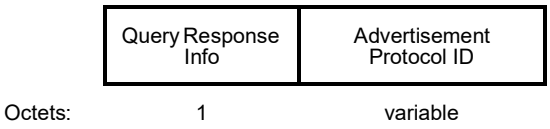


**Figure 9-567—Advertisement Protocol Tuple field format**

The format of Query Response Info field is shown in Figure 9-568 (Query Response Info field format).

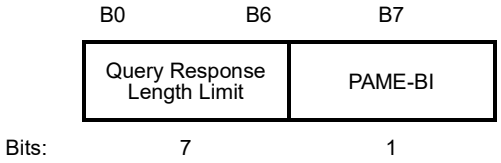


**Figure 9-568—Query Response Info field format**

The Query Response Info field is defined as follows:

— The Query Response Length Limit field indicates the maximum number of octets a STA will transmit in the Query Response field contained within one or more GAS Comeback Response frames. If the Query Response Length Limit field is larger than the maximum MMPDU size, the Query Response (M118)spans multiple MMPDUs. The Query Response Length Limit field is encoded as an integer number of 256 octet units. The value of 0 is reserved. The Query Response Length Limit field is set to 0x7F to indicate the maximum limit enforced is determined by the maximum allowable number of fragments in the GAS Query Response Fragment ID (see 9.4.1.31 (GAS Query Fragment ID field(#6058))). The Query Response Length Limit field is reserved in a transmission from the requesting STA to the responding STA.

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— Bit 7, the Preassociation Message Exchange BSSID Independent (PAME-BI) bit, is used by an AP to indicate whether the advertisement server(#571), which is the non-AP STA's peer for this advertisement protocol, returns a Query Response that is independent of the BSSID used for the GAS frame exchange. This bit is set to 1 to indicate the Query Response is independent of the BSSID; it is set to 0 to indicate that the Query Response (#8245)might be dependent on the BSSID. See 11.22.3.2 (GAS Protocol) for further information. Bit 7 is reserved for non-AP STAs.

The Advertisement Protocol ID field is a variable length field. When this field contains a vendor-specific advertisement protocol ID, then this field is(M118) structured per the Vendor Specific element defined in 9.4.2.24 (Vendor Specific element), where the Element ID of the Vendor Specific element of 9.4.2.24 (Vendor Specific element) is the first octet of the field and contains the vendor-specific value for advertisement protocol ID defined in Table 9-277 (Advertisement protocol ID definitions); otherwise its length is 1 octet and its value is one of the values in Table 9-277 (Advertisement protocol ID definitions). When one or more vendor-specific tuples are included in the Advertisement Protocol element, their total length needs to be constrained such that the total length of all of the Advertisement Protocol Tuple fields (both vendor specific and otherwise) is less than or equal to 255 octets.

— The ANQP supports information retrieval from an advertisement server(#571). ANQP is a protocol used by a requesting STA to query another STA (i.e., the receiving STA might respond to queries with or without proxying the query to a server in an external network). See 11.22.3.3 (ANQP procedures) for information on ANQP procedures.

— The MIS Information Service is a service defined in IEEE Std 802.21-2017 to support information retrieval from an information repository.

— The MIS Command and Event Services capability discovery is a mechanism defined in IEEE Std 802.21-2017 to support discovering capabilities of command service and event service entities in a STA or an external network.

— The EAS allows a network to disseminate emergency alert notifications from an external network to non-AP STAs. EAS uses the message format as defined in OASIS EDXL (see OASIS Standard EDXL-DE).

— The RLQP supports information retrieval from a RLSS. RLQP is a protocol used by a requesting STA to query another STA (i.e., the receiving STA can respond to queries with and without proxying the query to a server in an external network). 11.22 (WLAN interworking with external networks procedures) for information on RLQP procedures.

— (#4261)When the Advertisement Protocol ID field is equal to 221, the format of the Advertisement Protocol ID subfield follows the format of the Vendor Specific element in 9.4.2.24 (Vendor Specific element).

**Table 9-277—Advertisement protocol ID definitions**

| Name | Value |
|---|---|
| Access network query protocol (ANQP) | 0 |
| MIS Information Service | 1 |
| MIS Command and Event Services Capability Discovery | 2 |
| Emergency Alert System (EAS) | 3 |
| Registered location query protocol (RLQP) | 4 |
| Reserved | 5–220 |


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**Table 9-277—Advertisement protocol ID definitions**

| Name | Value |
|---|---|
| Vendor Specific | 221 |
| Reserved | 222–255 |

### 9.4.2.92 Expedited Bandwidth Request element

The Expedited Bandwidth Request element is transmitted from a non-AP STA to an AP in an ADDTS Request frame containing a TSPEC element and provides usage information for the bandwidth request. The Expedited Bandwidth Request element format is shown in Figure 9-569 (Expedited Bandwidth Request element format).

| | Element ID | Length | Precedence Level |
|---|---|---|---|
| Octets: | 1 | 1 | 1 |

**Figure 9-569—Expedited Bandwidth Request element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The Precedence Level field is provided in Table 9-278 (Precedence Level field description).

**Table 9-278—Precedence Level field description**

| Precedence level value | Description |
|---|---|
| 0–15 | Reserved |
| 16 | Emergency call, defined in NENA 08-002 [B65] |
| 17 | First responder (public) |
| 18 | First responder (private) |
| 19 | MLPP Level A |
| 20 | MLPP Level B |
| 21 | MLPP Level 0 |
| 22 | MLPP Level 1 |
| 23 | MLPP Level 2 |
| 24 | MLPP Level 3 |
| 25 | MLPP Level 4 |
| 26–255 | Reserved |

The precedence levels are derived from the 3rd Generation Partnership Project (3GPP) document 3GPP TS 22.067 [B2].

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The first responders (public) in Table 9-278 (Precedence Level field description) are government agencies or entities acting on behalf of the government, and the first responders (private) are private entities, such as individuals or companies.

### 9.4.2.93 QoS Map element

The QoS Map element is transmitted from an AP to a non-AP STA in a (Re)Association Response frame or a QoS Map Configure frame and provides the mapping of higher layer quality-of-service constructs to User Priorities defined by transmission of Data frames in this standard. This element maps the higher layer priority from the DSCP field used with the Internet Protocol to User Priority as defined by this standard. The QoS Map element is shown in Figure 9-570 (QoS Map element format).

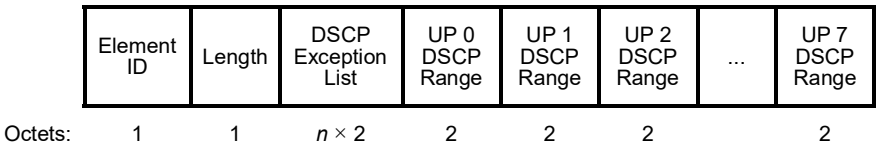


**Figure 9-570—QoS Map element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The DSCP Exception List field contains zero or more (*n*) DSCP Exception fields. The maximum value of *n* is 21. The format of each DSCP Exception field is shown in Figure 9-571 (DSCP Exception format).

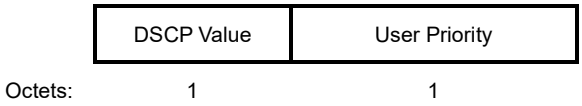


**Figure 9-571—DSCP Exception format**

The DSCP value in the DSCP Exception field is in the range 0 to 63, or 255; the User Priority value is in the range 0 to 7.

— When a non-AP STA begins transmission of a Data frame containing the Internet Protocol, it matches the DSCP field in the IP header to the corresponding DSCP value contained in this element. The non-AP STA first attempts to match the DSCP value to a DSCP exception field and uses the UP from the corresponding UP in the same DSCP exception field if successful; if no match is found then the non-AP STA attempts to match the DSCP field to a UP n DSCP Range field, and uses the n as the UP if successful; and otherwise uses a UP of 0.

— Each DSCP Exception field has a unique DSCP Value.

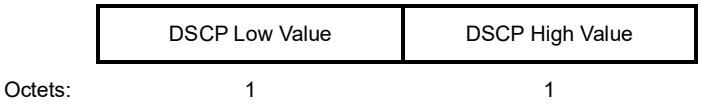


**Figure 9-572—DSCP Range description**

The QoS Map element has a DSCP Range field corresponding to each of the 8 user priorities. The format of the range field is shown in Figure 9-572 (DSCP Range description). The DSCP Range value is between 0 and 63, or 255.

— The DSCP range for each user priority is nonoverlapping.

— The DSCP High Value is greater than or equal to the DSCP Low Value.


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— If the DSCP Range high value and low value are both equal to 255, then the corresponding UP is not used.

### 9.4.2.94 Roaming Consortium element

The Roaming Consortium element contains information identifying the roaming consortium and/or SSP whose security credentials can be used to authenticate with the AP transmitting this element; see 11.22.8 (Interworking procedures: support for the advertisement of roaming consortiums). The element's format is shown in Figure 9-573 (Roaming Consortium element format).

| | Element ID | Length | Number of ANQP OIs | OI #1 and #2 Lengths | OI #1 | OI #2 (optional) | OI #3 (optional) |
|---|---|---|---|---|---|---|---|
| **Octets**: | 1 | 1 | 1 | 1 | variable | variable | variable |

**Figure 9-573—Roaming Consortium element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The format of the Number of ANQP OIs field is an unsigned integer whose value is the number of additional roaming consortium organization identifiers (OIs) obtainable via ANQP. The Number of ANQP OIs field is set to 0 to indicate that no additional OIs are returned in response to an ANQP request for the Roaming Consortium list. The Number of ANQP OIs field is set to 255 to indicate that 255 or more additional OIs are obtainable via ANQP.

The OI #1 and #2 Lengths field format is shown in Figure 9-574 (OI #1 and #2 Lengths field format).

— The OI #1 Length subfield is set to the length in octets of the OI #1 field.

— The OI #2 Length subfield is set to the length in octets of the OI #2 field. If the OI #2 field is not present, the OI #2 Length subfield is set to 0.

| | B0 B3 | B4 B7 |
|---|---|---|
| | OI #1 Length | OI #2 Length |
| Bits: | 4 | 4 |

**Figure 9-574—OI #1 and #2 Lengths field format**

NOTE—When there are three OIs, the OI #3 Length is calculated by subtracting sum of 2 plus the value of the OI #1 Length subfield plus the value of the OI #2 Length subfield from the value of the Length field.

The OI field is defined in 9.4.1.29 (Organization Identifier field). Each OI identifies a roaming consortium (group of SSPs with inter-SSP roaming agreement) or a single SSP. The OI(s) in this table are equal to the first 3 OIs in the dot11RoamingConsortiumTable. If fewer than 3 values are defined in the dot11RoamingConsortiumTable, then only as many OIs as defined in the table are populated in this element. The values of the OIs in this element are equal to the values of the first OIs, up to 3, from the table.

### 9.4.2.95 Emergency Alert Identifier element

The Emergency Alert Identifier element provides a hash to identify instances of the active EAS messages that are currently available from the network. The hash allows the non-AP STA to assess whether an EAS message advertised by an AP has been previously received and therefore whether it is

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necessary to download from the network. The format of the Emergency Alert Identifier element is shown in Figure 9-575 (Emergency Alert Identifier element format).

| | Element ID | Length | Alert Identifier Hash |
|---|---|---|---|
| **Octets**: | 1 | 1 | 8 |

**Figure 9-575—Emergency Alert Identifier element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The Alert Identifier Hash field(M118) contains a unique value used to indicate an instance of an EAS message. This field is set to the hash produced by the HMAC-SHA-1-64 hash algorithm operating on the EAS message.

AIH =HMAC-SHA-1-64("ES_ALERT", Emergency_Alert_Message)

where

"ES_ALERT" is an ASCII string.
Emergency_Alert_Message is the EAS message itself.

### 9.4.2.96 Mesh Configuration element

#### 9.4.2.96.1 General

The Mesh Configuration element shown in Figure 9-576 (Mesh Configuration element format) is used to advertise mesh services. It is contained in Beacon frames and Probe Response frames transmitted by mesh STAs and is also contained in Mesh Peering Open and Mesh Peering Confirm frames.

| | Element ID | Length | Active Path Selection Protocol Identifier | Active Path Selection Metric Identifier | Congestion Control Mode Identifier | Synchronization Method Identifier | Authentication Protocol Identifier | Mesh Formation Info | Mesh Capability |
|---|---|---|---|---|---|---|---|---|---|
| Octets | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

**Figure 9-576—Mesh Configuration element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The remainder of the fields are described in the following subclauses.


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#### 9.4.2.96.2 Active Path Selection Protocol Identifier

The Active Path Selection Protocol Identifier field indicates the path selection protocol that is currently activated in the MBSS. Table 9-279 (Active Path Selection Protocol Identifier field values) provides path selection protocol identifier values defined by this standard.

**Table 9-279—Active Path Selection Protocol Identifier field values**

| Value | Meaning |
|---|---|
| 0 | Reserved |
| 1 | Hybrid wireless mesh protocol (default path selection protocol) defined in 14.11 (Hybrid wireless mesh protocol (HWMP)) (default path selection protocol) |
| 2–254 | Reserved |
| 255 | Vendor specific<br>(The active path selection protocol is specified in a Vendor Specific element) |

When the Active Path Selection Protocol Identifier field is 255, the active path selection protocol is specified by a Vendor Specific element that is present in the frame. The content of the Vendor Specific element is beyond the scope of this standard. (See 9.4.2.24 (Vendor Specific element).)

#### 9.4.2.96.3 Active Path Selection Metric Identifier

The Active Path Selection Metric Identifier field indicates the path metric that is currently used by the active path selection protocol in the MBSS. Table 9-280 (Active Path Selection Metric Identifier field values) provides the path selection metric identifier values defined by this standard.

**Table 9-280—Active Path Selection Metric Identifier field values**

| Value | Meaning |
|---|---|
| 0 | Reserved |
| 1 | Airtime link metric defined in 14.10.2 (Airtime link metric and high PHY rate airtime link metric) (default path selection metric) |
| 2 | High PHY rate airtime link metric defined in 14.10.2 (Airtime link metric and high PHY rate airtime link metric) |
| 3–254 | Reserved |
| 255 | Vendor specific<br>(The active metric is specified in a Vendor Specific element) |

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When the Active Path Selection Metric Identifier field is 255, the active path metric is specified by a Vendor Specific element that is present in the frame. The content of the Vendor Specific element is beyond the scope of this standard. (See 9.4.2.24 (Vendor Specific element).)

#### 9.4.2.96.4 Congestion Control Mode Identifier

The Congestion Control Mode Identifier field indicates the congestion control protocol that is currently activated in the MBSS. Table 9-281 (Congestion Control Mode Identifier field values) provides the congestion control mode identifier values defined by this standard.

**Table 9-281—Congestion Control Mode Identifier field values**

| Value | Meaning |
|---|---|
| 0 | Congestion control is not activated (default congestion control mode) |
| 1 | Congestion control signaling protocol defined in 14.13.2 (Congestion control signaling protocol) |
| 2–254 | Reserved |
| 255 | Vendor specific<br>(The active congestion control protocol is specified in a Vendor Specific element) |

The Congestion Mode Identifier field set to 0 indicates the mesh STA has no active congestion control protocol and is set as the default value for the congestion control mode identifier in the MBSS.

When the Congestion Control Mode Identifier field is 255, the active congestion control protocol is specified by a Vendor Specific element that is present in the frame. The content of the Vendor Specific element is beyond the scope of this standard. (See 9.4.2.24 (Vendor Specific element).)

#### 9.4.2.96.5 Synchronization Method Identifier

The Synchronization Method Identifier field indicates the synchronization method that is currently activated in the MBSS. Table 9-282 (Synchronization Method Identifier field values) provides the synchronization method identifier values defined by this standard.

**Table 9-282—Synchronization Method Identifier field values**

| Value | Meaning |
|---|---|
| 0 | Reserved |
| 1 | Neighbor offset synchronization method defined in 14.14.2.2 (Neighbor offset synchronization method) (default synchronization method) |
| 2–254 | Reserved |
| 255 | Vendor specific<br>(The active synchronization method is specified in a Vendor Specific element) |


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The neighbor offset synchronization method is defined as the default synchronization method among mesh STAs. The details of the neighbor offset synchronization method are described in 14.14.2.2 (Neighbor offset synchronization method).

When the Synchronization Method Identifier field is 255, the active synchronization method is specified by a Vendor Specific element that is present in the frame. The content of the Vendor Specific element is beyond the scope of this standard. (See 9.4.2.24 (Vendor Specific element).)

#### 9.4.2.96.6 Authentication Protocol Identifier

The Authentication Protocol Identifier field indicates the type of authentication protocol that is currently used to secure the MBSS. Table 9-283 (Authentication Protocol Identifier field values) provides the authentication protocol identifier values defined by this standard.

**Table 9-283—Authentication Protocol Identifier field values**

| Value | Meaning |
|---|---|
| 0 | No authentication method is required to establish mesh peerings within the MBSS |
| 1 | SAE defined in 12.4 (Authentication using a password) |
| 2 | IEEE 802.1X authentication |
| 3–254 | Reserved |
| 255 | Vendor specific<br>(The active authentication protocol is specified in a Vendor Specific element) |

When the Authentication Protocol Identifier field is 255, the active authentication protocol is specified by a Vendor Specific element that is present in the frame. The content of the Vendor Specific element is beyond the scope of this standard. (See 9.4.2.24 (Vendor Specific element).)

#### 9.4.2.96.7 Mesh Formation Info

The format of the Mesh Formation Info field is shown in Figure 9-577 (Mesh Formation Info field format).

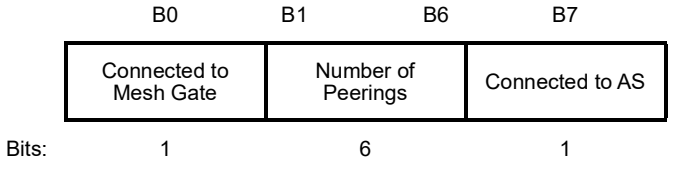


**Figure 9-577—Mesh Formation Info field format**

The Connected to Mesh Gate subfield is set to 1, if the mesh STA has a mesh path to a mesh gate that announces its presence using GANN elements, RANN elements, or PREQ elements, and set to 0 otherwise.

The Number of Peerings subfield contains an unsigned integer that indicates the number of mesh peerings currently maintained by the mesh STA or 63, whichever is smaller.

The Connected to AS subfield is set to 1 if the Authentication Protocol Identifier field in the Mesh Configuration element is equal to 2 (indicating IEEE 802.1X authentication) and the mesh STA has an active connection to an AS.

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NOTE—When an AS is (#2210)colocated with an IEEE 802.1X Authenticator an active connection is implicitly true.

### 9.4.2.96.8 Mesh Capability

The Mesh Capability field comprises a set of values indicating whether a mesh STA is a possible candidate for mesh peering establishment. The details of the Mesh Capability field are shown in Figure 9-578 (Mesh Capability field format).

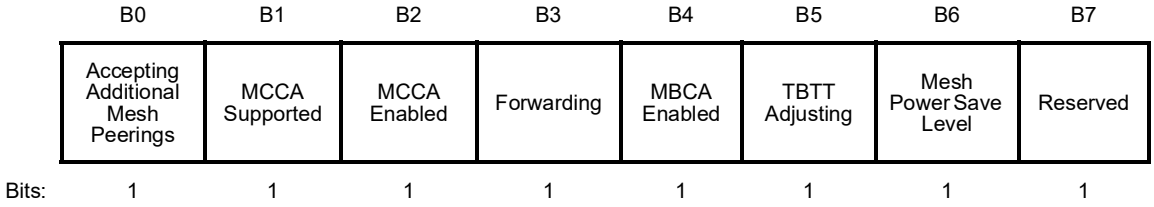


**Figure 9-578—Mesh Capability field format**

The Accepting Additional Mesh Peerings subfield is set to 1 if the mesh STA is willing to establish additional mesh peerings with other mesh STAs and set to 0 otherwise (i.e., the Accepting Additional Mesh Peerings subfield is set in accordance with dot11MeshAcceptingAdditionalPeerings). When the Mesh Configuration element is included in the Mesh Peering Open frame and in the Mesh Peering Confirm frame, the Accepting Additional Mesh Peerings subfield is set to 1.

The MCCA Supported subfield is set to 1 if the mesh STA implements MCCA and set to 0 otherwise (i.e., the MCCA Supported subfield is set in accordance with dot11MCCAImplemented).

The MCCA Enabled subfield is set to 1 if the mesh STA is using the MCCA and set to 0 otherwise (i.e., the MCCA Enabled subfield is set in accordance with dot11MCCAActivated).

The Forwarding subfield is set to 1 if the mesh STA forwards MSDUs and set to 0 otherwise (i.e., the Forwarding subfield is set in accordance with dot11MeshForwarding).

The MBCA Enabled subfield is set to 1 if the mesh STA is using MBCA and is set to 0 otherwise (i.e., the MBCA Enabled subfield is set in accordance with dot11MBCAActivated). (See 14.14.4 (Mesh beacon collision avoidance (MBCA)).)

The TBTT Adjusting subfield is set to 1 while the TBTT adjustment procedure is ongoing and is set to 0 otherwise. (See 14.14.4.4.3 (TBTT scanning and adjustment procedures).)

The Mesh Power Save Level subfield is set to 1 if at least one of the peer-specific mesh power management modes is deep sleep mode and set to 0 otherwise. The Mesh Power Save Level subfield is reserved when the Power Management subfield in the Frame Control field is set to 0. See 9.2.4.5.11 (Mesh Power Save Level subfield).

### 9.4.2.97 Mesh ID element

The Mesh ID element is used to advertise the identification of an MBSS and is described in 14.3.2 (Mesh identifier). The format of the Mesh ID element is shown in Figure 9-579 (Mesh ID element format). The Mesh ID element is transmitted in Mesh Peering Open frames, Mesh Peering Confirm frames, Mesh Peering Close frames, Beacon frames, and Probe Request and Response frames.

The Element ID and Length fields are defined in 9.4.2.1 (General).


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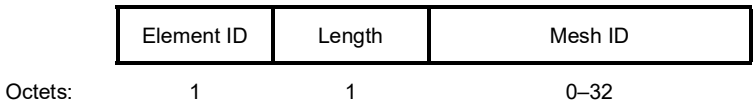


**Figure 9-579—Mesh ID element format**

A Mesh ID field of length 0 indicates the wildcard mesh ID(#1755), which is used within Probe Request frame.

Detailed usage of the Mesh ID element is described in 14.3.2 (Mesh identifier).

### 9.4.2.98 Mesh Link Metric Report element

The Mesh Link Metric Report element is transmitted by a mesh STA to a neighbor peer mesh STA to indicate the quality of the link between the transmitting mesh STA and the neighbor peer mesh STA. The format of the Mesh Link Metric Report element is shown in Figure 9-580 (Mesh Link Metric Report element format).

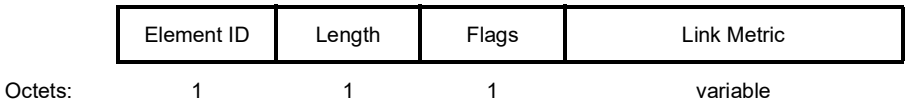


**Figure 9-580—Mesh Link Metric Report element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The format of the Flags field is shown in Figure 9-581 (Flags field format).

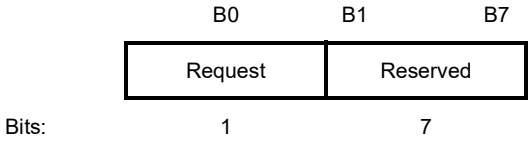


**Figure 9-581—Flags field format**

The Flags field is set as follows:

— Bit 0: Request subfield (0 = not a request, 1 = link metric report request). A Request subfield equal to 1 indicates that the recipient of Mesh Link Metric Report element is requested to send a link metric report to the transmitter of the Mesh Link Metric Report element.

— Bit 1–7: Reserved.

The Link Metric field indicates the link metric associated with the mesh link between the peer mesh STA transmitting the Mesh Link Metric Report and the neighbor mesh STA receiving the Mesh Link Metric report. The length and the data type of the Link Metric field are determined by the active path selection metric identifier (see 9.4.2.96.3 (Active Path Selection Metric Identifier)). The length and the data type for the airtime link metric are given in Table 14-5 (Parameters of the airtime link metric and high PHY rate airtime link metric for extensible path selection framework) in 14.10.2 (Airtime link metric and high PHY rate airtime link metric). The length and the data type for the airtime link metric and the high PHY rate airtime link metric are given in Table 14-5 (Parameters of the airtime link metric and high PHY rate airtime link metric for extensible path selection framework) in 14.10.2 (Airtime link metric and high PHY rate airtime link metric).

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### 9.4.2.99 Congestion Notification element

The Congestion Notification element is used to indicate the congestion status of the mesh STA per mesh destination and AC, and the duration for which the STA expects the congestion to last. The format of the Congestion Notification element is shown in Figure 9-582 (Congestion Notification element format). The Congestion Notification element is included in Congestion Control Notification frames, as described in 9.6.16.5 (Congestion Control Notification frame format).

| | Element ID | Length | Destination Mesh STA Address | Congestion Notification Duration (AC_BK) | Congestion Notification Duration (AC_BE) | Congestion Notification Duration (AC_VI) | Congestion Notification Duration (AC_VO) |
|---|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 6 | 2 | 2 | 2 | 2 |

**Figure 9-582—Congestion Notification element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The Destination Mesh STA Address field (#4162)is set to the address of the mesh destination for which the intra-mesh congestion control is applied. It is set to the broadcast address if the intra-mesh congestion control is applied to all destinations.

The element contains four Congestion Notification Duration fields for the four EDCA access categories to indicate the estimated congestion duration per AC at the mesh STA transmitting the congestion notification. The congestion notification duration values are encoded as unsigned integers in units of 100 μs.

### 9.4.2.100 Mesh Peering Management element

The Mesh Peering Management element is used to manage a mesh peering with a neighbor mesh STA. The format of the Mesh Peering Management element is shown in Figure 9-583 (Mesh Peering Management element format).

| | Element ID | Length | Mesh Peering Protocol Identifier | Local Link ID | Peer Link ID (optional) | Reason Code (optional) | Chosen PMK (optional) |
|---|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 2 | 2 | 0 or 2 | 0 or 2 | 0 or 16 |

**Figure 9-583—Mesh Peering Management element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The Mesh Peering Protocol Identifier field indicates the type of mesh peering protocol that is currently used to establish mesh peerings. Table 9-284 (Mesh Peering Protocol Identifier field values) provides the mesh peering protocol identifier values defined by this standard.

When the Mesh Peering Protocol Identifier field is 255, the active mesh peering protocol is specified by a Vendor Specific element that is present in the frame. The content of the Vendor Specific element is beyond the scope of this standard. (See 9.4.2.24 (Vendor Specific element).)

The Local Link ID field is the unsigned integer value generated by the local mesh STA to identify the mesh peering instance.


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**Table 9-284—Mesh Peering Protocol Identifier field values**

| Value | Meaning |
|---|---|
| 0 | Mesh peering management protocol |
| 1 | Authenticated mesh peering exchange protocol |
| 2–254 | Reserved |
| 255 | Vendor specific<br>(The active mesh peering protocol is specified in a Vendor Specific element) |
| 256–65 535 | Reserved |

The conditional components of the Mesh Peering Management element are present depending on the Action field of the frame in which the Mesh Peering Management element is conveyed.

The Peer Link ID field is the unsigned integer value generated by the peer mesh STA to identify the mesh peering instance. This field is not present for the Mesh Peering Open frame, is present for the Mesh Peering Confirm frame, and is optionally present for the Mesh Peering Close frame. The presence or absence of the Peer Link ID in a Mesh Peering Close is inferred by the Length field.

The Reason Code field enumerates reasons for sending a Mesh Peering Close. It is present for the Mesh Peering Close frame and is not present for Mesh Peering Open or Mesh Peering Confirm frames. The reason code is defined in 9.4.1.7 (Reason Code field).

The Chosen PMK field is present when dot11MeshSecurityActivated is true and a PMK is shared between the transmitter and receiver of the frame containing the element. It contains the PMKID that identifies the PMK used to protect the mesh peering Management frame.

Detailed usage of the Mesh Peering Management element is described in 14.4.6 (Mesh peering open), 14.4.7 (Mesh peering confirm), 14.4.8 (Mesh peering close), and 14.6.5 (Mesh peering Management frames for AMPE).

### 9.4.2.101 Mesh Channel Switch Parameters element

The Mesh Channel Switch Parameters element is used together with Channel Switch Announcement element and Extended Channel Switch Announcement element by a mesh STA to advertise to other mesh STAs when it is changing to a new operating channel and/or operating class. The format of the Mesh Channel Switch Parameters element is shown in Figure 9-584 (Mesh Channel Switch Parameters element format).

| | Element ID | Length | Time To Live | Flags | Reason Code | Precedence Value |
|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 1 | 2 | 2 |

**Figure 9-584—Mesh Channel Switch Parameters element format**

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The Element ID and Length fields are defined in 9.4.2.1 (General).

The Time To Live field is coded as an unsigned integer and indicates the remaining number of hops allowed for this element.

The Flags field indicates the attribute of this channel switch attempt. The format of the Flags field is shown in Figure 9-585 (Flags field format).

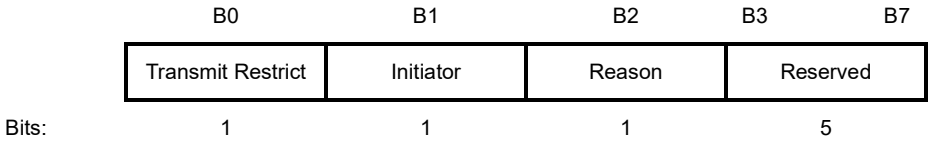


**Figure 9-585—Flags field format**

The Transmit Restrict subfield is set to 1 when the mesh STA asks neighboring peer mesh STAs not to transmit further frames except frames containing Mesh Channel Switch Parameters element on the current channel until the scheduled channel switch. The Transmit Restrict subfield is set to 0 otherwise.

The Initiator subfield is set to 1 when the mesh STA initiates this channel switch attempt. The Initiator subfield is set to 0 when this channel switch attempt is initiated by another mesh STA and propagated by the current mesh STA.

The Reason subfield indicates the validity of the Reason Code field. It is set to 1 if the Reason Code field is valid and is set to 0 otherwise. When the Reason subfield is 0, the content of the Reason Code field is reserved.

The Reason Code field specifies the reason for the mesh channel switch. The Reason Code is defined in 9.4.1.7 (Reason Code field). The content of the Reason Code field is valid only when Reason subfield of Flags field is set to 1 and is reserved otherwise.

The Precedence Value field is coded as unsigned integer and is set to a random value drawn from a uniform distribution in the range 0 to 65 535 determined by the initiator of this channel switch attempt.

The Mesh Channel Switch Parameters element is included in Channel Switch Announcement frames, as described in 9.6.2.6 (Channel Switch Announcement frame format), and Extended Channel Switch Announcement frames, as described in 9.6.7.7 (Extended Channel Switch Announcement frame format). During MBSS channel switching, the Mesh Channel Switch Parameters element is included in Beacon frames, as described in 9.3.3.2 (Beacon frame format), and Probe Response frames, as described in 9.3.3.10 (Probe Response frame format), until the scheduled channel switch.

### 9.4.2.102 Mesh Awake Window element

(#444)The format of the Mesh Awake Window element is shown in Figure 9-586 (Mesh Awake Window element format).

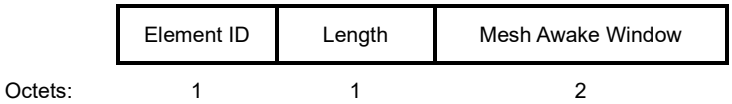


**Figure 9-586—Mesh Awake Window element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).


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The Mesh Awake Window field contains an unsigned integer that indicates the duration of the mesh awake window in TUs.

### 9.4.2.103 Beacon Timing element

The Beacon Timing element is used to advertise the beacon timing information of neighbor STAs (mesh STAs, IBSS APs, or IBSS STAs). The format of the Beacon Timing element is shown in Figure 9-587 (Beacon Timing element format).

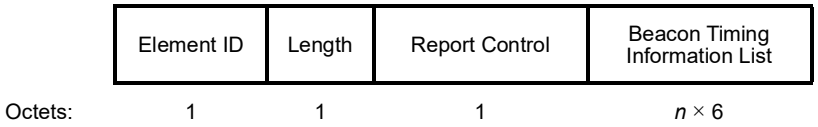


**Figure 9-587—Beacon Timing element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The Report Control field is used to signal information about the beacon timing information tuple contained in the Beacon Timing element. The structure of the Report Control field is defined in Figure 9-588 (Report Control field format).

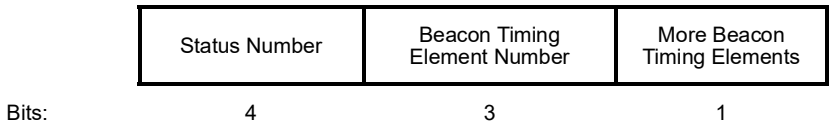


**Figure 9-588—Report Control field format**

The Status Number subfield is set to the status number of the beacon timing information set. The status number is managed as described in 14.14.4.2.4 (Maintenance of the status number).

The Beacon Timing Element Number subfield is an unsigned integer that indicates the index of the beacon timing information tuple contained in this Beacon Timing element. The Beacon Timing Element Number is set to 0 in the Beacon Timing element for the first or only tuple of the beacon timing information and is incremented by one for each successive tuple of the beacon timing information. The beacon timing information tuples are managed as described in 14.14.4.2.5 (Transmitter's procedure).

The More Beacon Timing Element subfield is set to 1 if a successive tuple of beacon timing information exists, and set to 0 otherwise.

The Beacon Timing Information List field contains one or more ($n$) Beacon Timing Information fields.

Each Beacon Timing Information field contains the beacon timing information of a neighbor STA. When the mesh STA reports multiple beacon timing information, multiple Beacon Timing Information fields are included in the Beacon Timing element. The structure of the Beacon Timing Information field is defined in Figure 9-589 (Beacon Timing Information field format).

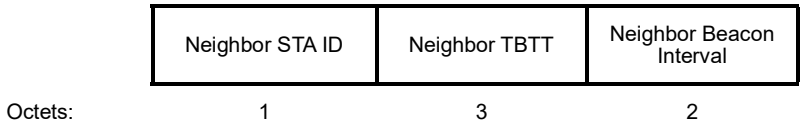


**Figure 9-589—Beacon Timing Information field format**

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The Neighbor STA ID subfield is an unsigned integer that indicates the identification of the neighbor STA corresponding to this beacon timing information. When a mesh peering is established with this neighbor STA, the MSB of this field is set to 0, and the rest of this field is set to the last 7 digits (7 LSBs) of the AID value assigned to this neighbor mesh STA. When a mesh peering is not established with this neighbor STA, the MSB of this field is set to 1, and the rest of this field is set to MAC_ADDR[42:47] of the (#6284)MAC address of this neighbor STA.

NOTE—Since the Neighbor STA ID subfield is provided in abbreviated form, it is possible that the same Neighbor STA ID value appears in multiple Beacon Timing Information fields.

The Neighbor TBTT subfield is an unsigned integer that indicates a TBTT of the corresponding neighbor STA, measured in the local TSF timer of the mesh STA. The value is indicated in multiples of 32 μs. When the active synchronization method is the neighbor offset synchronization method, the TBTT is calculated as described in 14.14.4.2.2 (Calculation of neighbor STA's TBTT). The B5 to the B28 (taking the B0 as the LSB) of the calculated TBTT are contained in this subfield.

The Neighbor Beacon Interval subfield is an unsigned integer that indicates the beacon interval being used by the corresponding neighbor STA. The unit of the Neighbor Beacon Interval subfield is TU.

Detailed usage of the Beacon Timing element is described in 14.14.4.2 (Beacon timing advertisement).

### 9.4.2.104 MCCAOP Setup Request element

#### 9.4.2.104.1 General

The MCCAOP Setup Request element is used to make an MCCAOP reservation. This element is transmitted in individually addressed MCCA Setup Request frames or in group addressed MCCA Setup Request frames. The mesh STA transmitting the MCCA Setup Request element is the MCCAOP owner of the MCCAOPs (M118)scheduled with this reservation setup request. The receivers of the MCCAOP Setup Request frame are the MCCAOP responders. The format of the element is shown in Figure 9-590 (MCCAOP Setup Request element format).

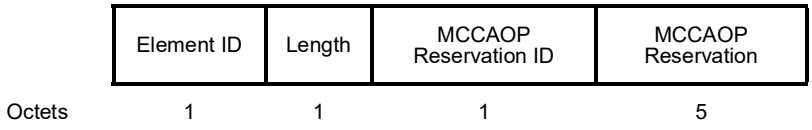


**Figure 9-590—MCCAOP Setup Request element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The MCCAOP Reservation ID field is an unsigned integer that represents the ID for the MCCAOP reservation. It is determined by the MCCAOP owner. When used in combination with the MAC address of the MCCAOP owner, the MCCAOP Reservation ID uniquely identifies the MCCAOP reservation. If this MCCAOP Setup Request element is for an individually addressed transmission, the MCCAOP Reservation ID is between 0 and 127 and the MCCAOP Setup Request element is transmitted in an individually addressed frame to the intended responder. If this MCCAOP Setup Request element is for a group addressed transmission, the MCCAOP Reservation ID is between 128 and 254 and the MCCAOP Setup Request element is transmitted in a group addressed frame. The value 255 is not used to identify a single MCCAOP reservation.

The MCCAOP Reservation field is described in 9.4.2.104.2 (MCCAOP Reservation field).


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#### 9.4.2.104.2 MCCAOP Reservation field

The MCCAOP Reservation field specifies(#2047) a schedule for frame transmissions called *MCCAOPs*. The MCCAOP Reservation field consists of three subfields and its format is shown in Figure 9-591 (MCCAOP Reservation field format).

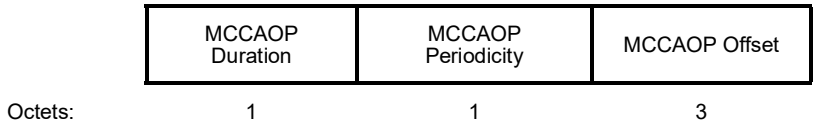


**Figure 9-591—MCCAOP Reservation field format**

The MCCAOP Duration subfield contains an unsigned integer. It specifies the duration of the MCCAOPs in multiples of 32 μs.

The MCCAOP Periodicity subfield contains a positive integer. It specifies the number of MCCAOPs scheduled in each DTIM interval.

The MCCAOP Offset subfield(#261) contains an unsigned integer. It specifies the beginning of the first MCCAOP in each DTIM interval. The value is specified in multiples of 32 μs. The sum of MCCAOP Offset plus MCCAOP Duration is constrained to be smaller than the duration of the DTIM interval divided by MCCAOP Periodicity.

#### 9.4.2.105 MCCAOP Setup Reply element

The MCCAOP Setup Reply element is used to reply to an MCCAOP Setup Request. This element is transmitted in individually addressed MCCA Setup Reply frames. The mesh STA transmitting the MCCA Setup Reply element is the MCCAOP responder of the MCCAOPs scheduled in this reservation setup. The receiver of the MCCAOP Setup Reply is the MCCAOP owner. The format of the element is shown in Figure 9-592 (MCCAOP Setup Reply element format).

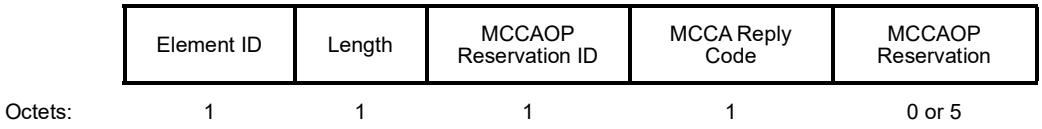


**Figure 9-592—MCCAOP Setup Reply element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The MCCAOP Reservation ID field is an unsigned integer that represents the ID for the requested series of MCCAOPs. It is determined by the MCCAOP owner and copied from the MCCAOP Setup Request element. When used in combination with the MAC address of the MCCAOP owner, the MCCAOP Reservation ID uniquely identifies the MCCAOP reservation.

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The MCCA Reply Code field (#2047)contains the reply code used in an MCCAOP Setup Reply element. The reply codes are defined in Table 9-285 (MCCA Reply Code field values).

**Table 9-285—MCCA Reply Code field values**

| MCCA reply code | Meaning |
|---|---|
| 0 | Accept |
| 1 | Reject: MCCAOP reservation conflict |
| 2 | Reject: MAF limit exceeded |
| 3 | (#1466)Reject: MCCAOP reservation track limit (dot11MCCATrack-StatesCapable) exceeded |
| 4–255 | Reserved |

The MCCAOP Reservation field includes an alternative to the MCCAOP reservation specified in the MCCAOP Setup Request frame. Its format is described in 9.4.2.104.2 (MCCAOP Reservation field). When the MCCA Reply Code is 1, the MCCAOP Reservation field might be present. When the MCCA Reply Code is set to other values, the MCCAOP Reservation field is not present.

### 9.4.2.106 MCCAOP Advertisement Overview element

The MCCAOP Advertisement Overview element is used by a mesh STA to advertise its MCCA Information and information about its MCCAOP Advertisement elements, representing its MCCAOP advertisement set, to its neighbors. This element is transmitted in MCCA Advertisement frames and optionally present in Beacon frames. The format of the MCCAOP Advertisement Overview element is shown in Figure 9-593 (MCCAOP Advertisement Overview element format).

| | Element ID | Length | Advertisement Set Sequence Number | Flags | MCCA Access Fraction | MAF Limit | Advertisement Elements Bitmap |
|---|---|---|---|---|---|---|---|
| Octets | 1 | 1 | 1 | 1 | 1 | 1 | 2 |

**Figure 9-593—MCCAOP Advertisement Overview element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The Advertisement Set Sequence Number field is coded as an unsigned integer. It is set to the advertisement set sequence number of the current MCCAOP advertisement set. The Advertisement Set Sequence Number, together with the MAC address of the transmitter of the MCCAOP Advertisement Overview element, identifies an MCCAOP advertisement set and provides an identifier and a chronological order of different MCCAOP advertisement sets of the same mesh STA.


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The format of the Flags field is shown in Figure 9-594 (Flags field format).

**Figure 9-594—Flags field format**

The Flags field is set as follows:

— Bit 0: Accept Reservations subfield. The Accept Reservations subfield is set to 1 if the mesh STA accepts additional reservations. It is set to 0 otherwise.

— Bit 1–7: Reserved

The MCCA Access Fraction field is an unsigned integer. The MCCA Access Fraction field is set to the current value of the MCCA access fraction at the mesh STA rounded down to the nearest multiple of (1/255) of the DTIM interval length.

The MAF Limit field is an unsigned integer. The MAF Limit field is set to the maximum MCCA access fraction allowed at the mesh STA rounded down to the nearest multiple of (1/255) of the DTIM interval length.

The Advertisement Elements Bitmap field indicates the MCCAOP Advertisement elements that are part of this MCCAOP advertisement set. The Advertisement Elements Bitmap field is a bitmap. Bit *i* in this bitmap equals 1 if the MCCAOP Advertisement element with MCCAOP Advertisement Element Index equal to *i* is part of this MCCAOP advertisement set, and it equals 0 otherwise.

### 9.4.2.107 MCCAOP Advertisement element

#### 9.4.2.107.1 General

The MCCAOP Advertisement element is used by a mesh STA to advertise MCCAOP reservations to its neighbors. This element is transmitted in MCCA Advertisement frames and optionally present in Beacon frames. The format of the element is shown in Figure 9-595 (MCCAOP Advertisement element format).

| | Element ID | Length | Advertisement Set Sequence Number | MCCAOP Advertisement Element Information | TX-RX Periods Report | Broadcast Periods Report | Interference Periods Report |
|---|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 1 | variable | variable | variable |

**Figure 9-595—MCCAOP Advertisement element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The Advertisement Set Sequence Number field is coded as an unsigned integer. It is set to the advertisement set sequence number of the current MCCAOP advertisement set. The Advertisement Set Sequence Number, together with the MAC address of the transmitter of the MCCAOP Advertisement element, identifies an MCCAOP advertisement set and provides an identifier and a chronological order of different MCCAOP advertisement sets of the same mesh STA.

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The MCCAOP Advertisement Element Information field is described in 9.4.2.107.2 (MCCAOP Advertisement Element Information field).

The TX-RX Periods Report field is a variable length field that contains an MCCAOP Reservation Report field, as described in 9.4.2.107.3 (MCCAOP Reservation Report field). This field is present when the TX-RX Report Present subfield of the MCCAOP Advertisement Element Information field is equal to 1; it is not present otherwise. The TX-RX Periods Report field is described in 10.24.3.7.2 (Construction of an MCCAOP advertisement set).

The Broadcast Periods Report field is a variable length field that contains an MCCAOP Reservation Report field, as described in 9.4.2.107.3 (MCCAOP Reservation Report field). This field is present when the Broadcast Report Present subfield of the MCCAOP Advertisement Element Information field is equal to 1; it is not present otherwise. The Broadcast Periods Report field is described in 10.24.3.7.2 (Construction of an MCCAOP advertisement set).

The Interference Periods Report field is a variable length field that contains an MCCAOP Reservation Report field, as described in 9.4.2.107.3 (MCCAOP Reservation Report field). This field is present when the Interference Report Present subfield of the MCCAOP Advertisement Element Information field is equal to 1; it is not present otherwise. The Interference Periods Report field is described in 10.24.3.7.2 (Construction of an MCCAOP advertisement set).

### 9.4.2.107.2 MCCAOP Advertisement Element Information field

The MCCA Information field(#261) provides information on the MCCAOP reservations. The field consists of four subfields and its format is shown in Figure 9-596 (MCCAOP Advertisement Element Information field format).

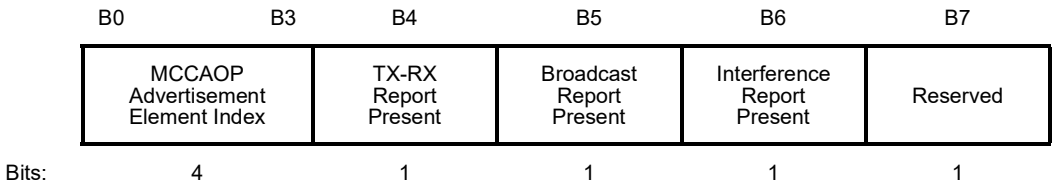


**Figure 9-596—MCCAOP Advertisement Element Information field format**

The MCCAOP Advertisement Element Index subfield is an unsigned integer. It identifies the MCCAOP Advertisement element.

The TX-RX Report Present subfield is set to 1 if the TX-RX Periods Report field is present in the MCCAOP Advertisement element and set to 0 if no TX-RX Periods Report field is present.

The Broadcast Report Present subfield is set to 1 if the Broadcast Periods Report field is present in the MCCAOP Advertisement element and set to 0 if no Broadcast Periods Report field is present.

The Interference Report Present subfield is set to 1 if the Interference Periods Report field is present in the MCCAOP Advertisement element and set to 0 if no Interference Periods Report field is present.

### 9.4.2.107.3 MCCAOP Reservation Report field

The MCCAOP Reservation Report field is of variable length and is used to report a number of MCCAOP reservations. The field consists of a variable number of subfields and its format is shown in Figure 9-597 (MCCAOP Reservation Report field format).


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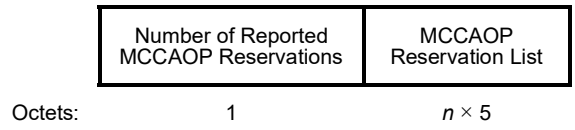


**Figure 9-597—MCCAOP Reservation Report field format**

The Number of Reported MCCAOP Reservations field is an unsigned integer that indicates the number, *n*, of MCCAOP Reservation fields reported in the MCCAOP Reservation List field.

The MCCAOP Reservation List field contains one or more (*n*) MCCAOP Reservation fields.

The MCCAOP Reservation fields specify the MCCAOP reservations reported. The format of each MCCAOP Reservation field is shown in Figure 9-591 (MCCAOP Reservation field format) in 9.4.2.104.2 (MCCAOP Reservation field).

### 9.4.2.108 MCCAOP Teardown element

The MCCAOP Teardown element is used to announce the teardown of an MCCAOP reservation. The MCCAOP Teardown element is transmitted in individually addressed MCCA Teardown frames or in group addressed MCCA Teardown frames. Its format is shown in Figure 9-598 (MCCAOP Teardown element format).

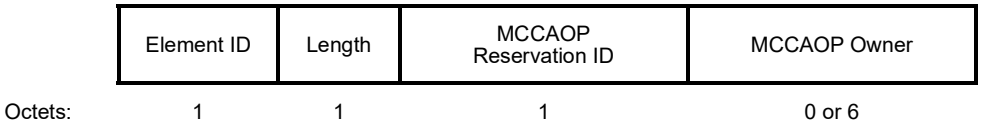


**Figure 9-598—MCCAOP Teardown element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

An MCCAOP Teardown element is transmitted by either the MCCAOP owner or the MCCAOP responder of an MCCAOP reservation to tear down the MCCAOP reservation.

The MCCAOP Reservation ID field is an unsigned integer that represents the ID for the MCCAOP reservation.

The MCCAOP Owner field, if present, indicates the (#6284)MAC address of the MCCAOP owner. This field is included if the element is transmitted by the MCCAOP responder; it is not included otherwise.

### 9.4.2.109 GANN element

The GANN (gate announcement) element is used for announcing the presence of a mesh gate in the MBSS. The GANN element is transmitted in a Gate Announcement frame (see 9.6.16.4 (Gate Announcement frame format)). The format of the GANN element is shown in Figure 9-599 (GANN element format).

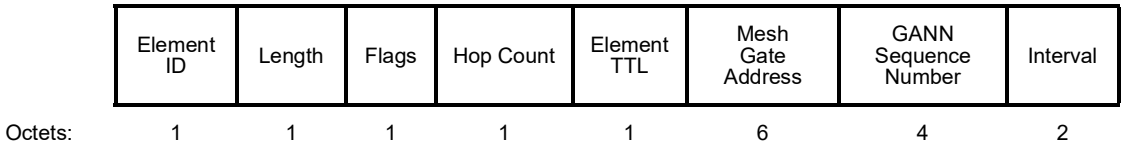


**Figure 9-599—GANN element format**

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The Element ID and Length fields are defined in 9.4.2.1 (General).

The Flags field is reserved.

The Hop Count field is coded as an unsigned integer and indicates the number of hops from the originating mesh gate to the mesh STA transmitting this element.

The Element TTL field is coded as an unsigned integer and indicates the remaining number of hops allowed for this element.

The Mesh Gate Address field (#6284)is set to the MAC address of the mesh gate.

The GANN Sequence Number field is coded as an unsigned integer and is set to a GANN Sequence Number specific for the originating mesh gate.

The Interval field is coded as an unsigned integer and is set to the number of seconds between the periodic transmissions of Gate Announcements by the mesh gate.

Detailed usage of the GANN element is described in 14.12.2 (Gate announcement (GANN)).

### 9.4.2.110 RANN element

The RANN (root announcement) element is used for announcing the presence of a mesh STA configured as root mesh STA with dot11MeshHWMProotMode set to rann (4). RANN elements are sent out periodically by such a root mesh STA. The RANN element is transmitted in an HWMP Mesh Path Selection frame (see 9.6.16.3 (HWMP Mesh Path Selection frame format)). The format of the RANN element is shown in Figure 9-600 (RANN element format).

| | Element ID | Length | Flags | Hop Count | Element TTL | Root Mesh STA Address | HWMP Sequence Number | Interval | Metric |
|---|---|---|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 1 | 1 | 6 | 4 | 4 | 4 |

**Figure 9-600—RANN element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The format of the Flags field is shown in Figure 9-601 (Flags field format).

| | B0 | B1 | B7 |
|---|---|---|---|
| | Gate Announcement | Reserved | |
| Bits: | 1 | 7 | |

**Figure 9-601—Flags field format**

The Flags field is set as follows:

— Bit 0: Gate Announcement subfield (0 = gate announcement protocol not activated, 1 = gate announcement protocol activated). A Gate Announcement subfield equal to 1 indicates that the Root Mesh STA Address is a mesh gate with dot11MeshGateAnnouncements equal to true.

— Bit 1–7: Reserved.


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The Hop Count field is coded as an unsigned integer and indicates the number of hops from the originating root mesh STA to the mesh STA transmitting this element.

The Element TTL field is coded as an unsigned integer and indicates the remaining number of hops allowed for this element.

The Root Mesh STA Address field is (#6284)set to the MAC address of the root mesh STA.

The HWMP Sequence Number field is coded as an unsigned integer and is set to the HWMP sequence number (SN) specific to the root mesh STA.

The Interval field is coded as an unsigned integer and is set to the number of TUs between the periodic transmissions of Root Announcements.

The Metric field is set to the cumulative metric from the originating root mesh STA to the mesh STA transmitting the announcement.

Detailed usage of the RANN element is described in 14.11.12 (Root announcement (RANN) mechanism).

### 9.4.2.111 PREQ element

The PREQ (path request) element is used for discovering a path to one or more target mesh STAs, maintaining a path (optional), building a proactive (reverse) path selection tree to the root mesh STA, and confirming a path to a target mesh STA (optional). The PREQ element is transmitted in an HWMP Mesh Path Selection frame (see 9.6.16.3 (HWMP Mesh Path Selection frame format)). The format of the PREQ element is shown in Figure 9-602 (PREQ element format).

| | Element ID | Length | Flags | Hop Count | Element TTL | Path Discovery ID | Originator Mesh STA Address |
|---|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 1 | 1 | 4 | 6 |

| Originator HWMP Sequence Number | Originator External Address | Lifetime | Metric | Target Count | Target Tuples |
|---|---|---|---|---|---|
| 4 | 0 or 6 | 4 | 4 | 1 | $n \times 11$ |

**Figure 9-602—PREQ element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The format of the Flags field is shown in Figure 9-603 (Flags field format).

| | B0 | B1 | B2 | B3 B5 | B6 | B7 |
|---|---|---|---|---|---|---|
| | Gate Announcement | Addressing Mode | Proactive PREP | Reserved | AE | Reserved |
| Bits | 1 | 1 | 1 | 3 | 1 | 1 |

**Figure 9-603—Flags field format**

The Flags field is set as follows:

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- Bit 0: Gate Announcement subfield (0 = gate announcement protocol not activated, 1 = gate announcement protocol activated). A Gate Announcement subfield equal to 1 indicates that the originator mesh STA address is a mesh gate with dot11MeshGateAnnouncements equal to true.
- Bit 1: Addressing Mode subfield (0 = group addressed, 1 = individually addressed). When the Addressing Mode subfield is 0, the PREQ element is sent in an HWMP Mesh Path Selection frame that is group addressed to all neighbor peer mesh STAs. When the Addressing Mode subfield is 1, the PREQ element is sent in an HWMP Mesh Path Selection frame that is individually addressed to a neighbor peer mesh STA. Detailed addressing information is provided in 14.11.7 (Addressing of HWMP Mesh Path Selection frame).
- Bit 2: Proactive PREP subfield (0 = off, 1 = on). The Proactive PREP subfield is of relevance only if the Target Address is the broadcast address (all 1s). If equal to 1, every recipient of a PREQ element with Target Address equal to the broadcast address replies with a PREP element. If equal to 0, a recipient replies only under certain conditions (see 14.11.4.2 (Proactive PREQ mechanism)) and does not reply otherwise.
- Bit 3–5: Reserved.
- Bit 6: AE (Address Extension) subfield (1= external address present, 0 = otherwise). An AE subfield equal to 1 indicates that the field Originator External Address is present, and that the originator mesh STA is a proxy for this external address.
- Bit 7: Reserved.

The Hop Count field is coded as an unsigned integer and is set to the number of hops from the originator to the mesh STA transmitting this element.

The Element TTL field is coded as an unsigned integer and indicates the remaining number of hops allowed for this element.

The Path Discovery ID field is coded as an unsigned integer and is set to some unique ID for this PathDiscovery.

The Originator Mesh STA Address field is represented as a (#6284)MAC address and is set to the originator MAC address.

The Originator HWMP Sequence Number field is coded as an unsigned integer and is set to the HWMP SN specific to the originator.

The Originator External Address field is the MAC address of an external STA proxied by the originator. This field is present only if the AE subfield in the Flags field is set to 1 (#6284)and is set to a MAC address.

The Lifetime field is coded as an unsigned integer and is set to the time for which mesh STAs receiving the PREQ element consider the forwarding information to be valid. The lifetime is measured in TUs.

The Metric field is set to the cumulative metric from the originator to the mesh STA transmitting the PREQ element.

The Target Count field is an unsigned integer and gives the number of targets (*n*) contained in this PREQ element. The maximum value of *n* is 20.

The Target Tuples field contains one or more Target Tuple fields. The format of a Target Tuple field is shown in Figure 9-604 (Target Tuple field format).

The format of the Per Target Flags field is shown in Figure 9-605 (Per Target Flags field format).


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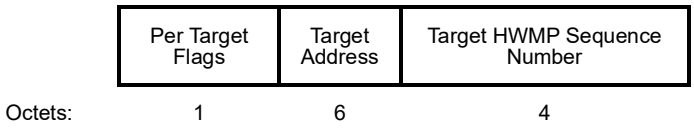


**Figure 9-604—Target Tuple field format**

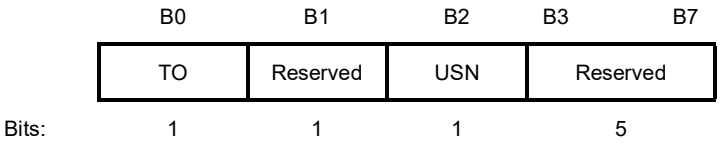


**Figure 9-605—Per Target Flags field format**

The Per Target Flags field is set as follows:

— Bit 0: TO (Target Only) subfield: The TO subfield defines the mesh STA to respond with a PREP element to the PREQ element containing an individual target address. If TO = 1, only the target mesh STA responds. If TO = 0, intermediate mesh STAs with active forwarding information to the target mesh STA also respond. See 14.11.10.3 (Conditions for generating and sending a PREP element).

— Bit 1: Reserved.

— Bit 2: USN (Unknown Target HWMP Sequence Number) subfield: The USN subfield indicates whether the Target HWMP Sequence Number field of the corresponding target is interpreted as HWMP SN (USN = 0) or not (USN = 1), the latter meaning that a target HWMP SN is unknown at the originator mesh STA.

— Bit 3–7: Reserved.

The Target Address field is (#6284)set to a MAC address.

The Target HWMP Sequence Number field is coded as an unsigned integer and is the latest known HWMP SN received in the past by the originator mesh STA for any path toward the target. If such a target HWMP SN is not known, the USN subfield is set to 1 and Target HWMP Sequence Number field is reserved.

Detailed usage of the PREQ element is described in 14.11.9 (Path request (PREQ) mechanism).

### 9.4.2.112 PREP element

The PREP (path reply) element is used to establish a forward path to a target and to confirm that a target is reachable. The PREP element is issued in response to a PREQ element. The PREP element is transmitted in an HWMP Mesh Path Selection frame (see 9.6.16.3 (HWMP Mesh Path Selection frame format)). The format of the PREP element is shown in Figure 9-606 (PREP element format).

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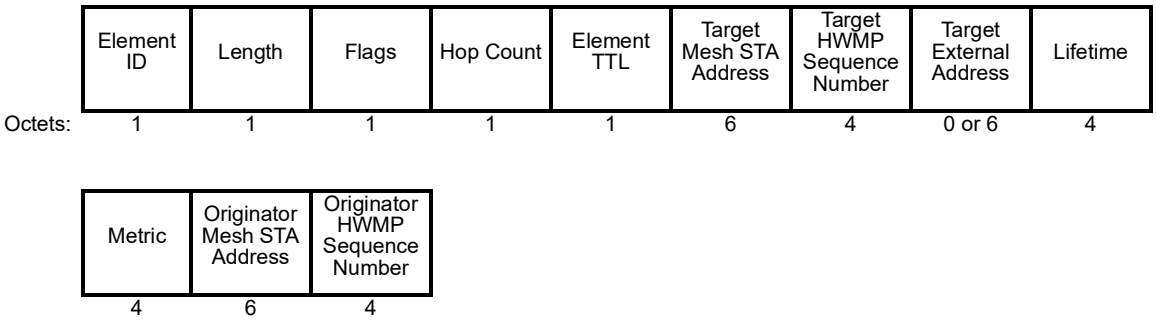


**Figure 9-606—PREP element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The format of the Flags field is shown in Figure 9-607 (Flags field format).

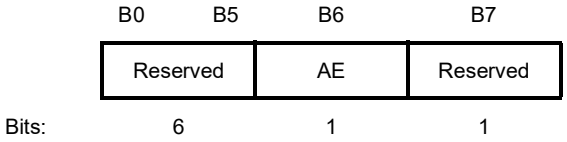


**Figure 9-607—Flags field format**

The Flags field is set as follows:

— Bit 0–5: Reserved.

— Bit 6: AE (Address Extension) subfield (1 = external address present, 0 = otherwise). An AE subfield equal to 1 indicates that the field Target External Address is present, and that the target mesh STA is a proxy for this external address.

— Bit 7: Reserved.

The Hop Count field is coded as an unsigned integer and is set to the number of hops from the path target to the mesh STA transmitting this element.

The Element TTL field is coded as an unsigned integer and indicates the remaining number of hops allowed for this element.

The Target Mesh STA Address is the MAC address of the target mesh STA or target proxy mesh gate and is represented as a (#6284)MAC address.

The Target HWMP Sequence Number field is coded as an unsigned integer and is set to the HWMP SN of the target mesh STA (if the AE subfield in the Flags field is equal to 0) or target proxy mesh gate (if the AE subfield in the Flags field is equal to 1).

The Target External Address field is set to the external address on behalf of which the PREP element is sent. This field is present only if Bit 6 (AE subfield) in Flags field equals 1 and is represented as a (#6284)MAC address.

The Lifetime field is coded as an unsigned integer and is set to the time for which mesh STAs receiving the PREP element consider the forwarding information to be valid. The lifetime is measured in TUs.


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The Metric field indicates the cumulative metric from the path target to the mesh STA transmitting this element.

The Originator Mesh STA Address field is represented as a (#6284)MAC address and is set to the MAC address of the originator, which is contained in the PREQ element.

The Originator HWMP Sequence Number field is coded as an unsigned integer and is set to the HWMP SN of the originator mesh STA contained in the PREQ element.

The detailed usage of the PREP element is described in 14.11.10 (Path reply (PREP) mechanism).

### 9.4.2.113 PERR element

The PERR (path error) element is used for announcing an unreachable destination. The PERR element is transmitted in an HWMP Mesh Path Selection frame (see 9.6.16.3 (HWMP Mesh Path Selection frame format)). The format of the PERR element is shown in Figure 9-608 (PERR element format).

| | Element ID | Length | Element TTL | Number of Destinations | Destination Tuples |
|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 1 | variable |

**Figure 9-608—PERR element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The Element TTL field is an unsigned integer that indicates the remaining number of hops allowed for this element.

The Number of Destinations field is an unsigned integer and indicates the number of announced destinations in PERR, *n*. The maximum value of *n* is 19.

The Destination Tuples field contains one or more Destination Tuple fields. The format of a Destination Tuple field is shown in Figure 9-609 (Destination Tuples field format).

| | Flags | Destination Address | HWMP Sequence Number | Destination External Address | Reason Code |
|---|---|---|---|---|---|
| Octets: | 1 | 6 | 4 | 0 or 6 | 2 |

**Figure 9-609—Destination Tuples field format**

The format of the Flags field is shown in Figure 9-610 (Flags field format).

| | B0 | B5 | B6 | B7 |
|---|---|---|---|---|
| | Reserved | | AE | Reserved |
| Bits: | 4 | | 1 | 1 |

**Figure 9-610—Flags field format**

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The Flags field is set as follows:

— Bit 0–5: Reserved.

— Bit 6: AE (Address Extension) subfield (1 = destination external address is present, 0 = otherwise).

— Bit 7: Reserved.

The Destination Address field is represented as a (#6284)MAC address and indicates the detected unreachable destination MAC address.

The HWMP Sequence Number field is coded as an unsigned integer and indicates the HWMP SN for the invalidated destination, if applicable. Otherwise, the HWMP Sequence Number field is reserved depending on the reason code.

The Destination External Address field is set to the external address, on behalf of which the PERR is sent. This field is present only if Bit 6 (AE subfield) in the Flags field equals 1 and is represented as a (#6284)MAC address.

The Reason Code field specifies the reason for sending a PERR element. The Reason Code is defined in 9.4.1.7 (Reason Code field).

The detailed usage of the PERR element is described in 14.11.11 (Path error (PERR) mechanism).

### 9.4.2.114 PXU element

The PXU (proxy update) element is used to inform the destination mesh STA of the proxy information at the originator mesh STA. The PXU element is transmitted in a Proxy Update frame (see 9.6.17.2 (Proxy Update frame format)). The format of the PXU element is shown in Figure 9-611 (PXU element format).

| | Element ID | Length | PXU ID | PXU Originator MAC Address | Number of Proxy Information | Proxy Information List |
|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 6 | 1 | variable |

**Figure 9-611—PXU element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The PXU ID field is an unsigned integer and is set to the sequence number of the PXU. The source mesh STA sets the PXU ID field in the PXU element to a value from a single modulo 256 counter that is incremented by 1 for each new PXU element.

The PXU Originator MAC Address field is represented as a (#6284)MAC address and is the MAC address of the mesh STA that originates this PXU element.

The Number of Proxy Information field is set to the number *n* of Proxy Information fields in the Proxy Information List field and that are reported to the destination mesh STA. The maximum value of *n* is 22.

The Proxy Information List field contains one or more (*n*) Proxy Information fields.

A Proxy Information field contains a single proxy information (see 14.12.4.2 (Proxy information)). The length of the Proxy Information field depends on the settings of the subfields in the Flags subfield and is 11, 15, 17, or 21 octets.



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The format of the Proxy Information field is defined in Figure 9-612 (Proxy Information field format).

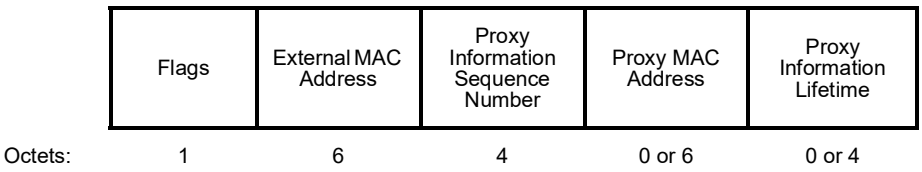


**Figure 9-612—Proxy Information field format**

The format of the Flags subfield is shown in Figure 9-613 (Flags subfield format).

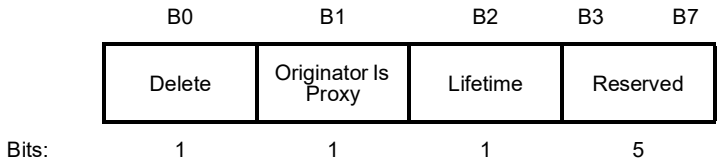


**Figure 9-613—Flags subfield format**

The Flags subfield is set as follows:

— Bit 0: The Delete subfield indicates whether this proxy information is to be deleted. It is set to 1 if the proxy information is to be deleted, and set to 0 otherwise.

— Bit 1: The Originator Is Proxy subfield indicates that the originator mesh STA of the PXU element is the proxy mesh gate of this proxy information when set to 1. In this case, there is no Proxy MAC Address subfield present in this Proxy Information field. When the Originator Is Proxy subfield is 0, the Proxy MAC Address subfield is present in this Proxy Information field.

— Bit 2: The Lifetime subfield indicates that the Proxy Information Lifetime subfield is present in this Proxy Information field when set to 1.

— Bit 3–7: Reserved.

The External MAC Address subfield is represented as a (#6284)MAC address and is the MAC address of the external STA proxied by the proxy mesh gate.

The Proxy Information Sequence Number field is coded as an unsigned integer and is set to the sequence number of the proxy information. The sequence number of the proxy information defines a chronological order of the proxy information for the external STA at this proxy mesh gate.

The Proxy MAC Address subfield is represented as a (#6284)MAC address and is set to the MAC address of the(#1425) proxy mesh gate. It is present if the Originator Is Proxy subfield of the Flags subfield is 0; it is not present otherwise.

The Proxy Information Lifetime subfield is coded as an unsigned integer and is set to the time for which the mesh STA receiving this PXU considers this proxy information to be valid. The proxy information lifetime is measured in TUs. It is present if the Lifetime subfield of the Flags subfield is 1; it is not present otherwise.

### 9.4.2.115 PXUC element

The PXUC (proxy update confirmation) element is used to confirm the previously received PXU. The PXUC element is transmitted in a Proxy Update Confirmation frame (see 9.6.17.3 (Proxy Update Confirmation frame format)). The format of PXUC element is shown in Figure 9-614 (PXUC element format).

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| | Element ID | Length | PXU ID | PXU Recipient MAC Address |
|---|---|---|---|---|
| Octets | 1 | 1 | 1 | 6 |

**Figure 9-614—PXUC element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The PXU ID field is coded as an unsigned integer and is the PXU ID of the received PXU that is being confirmed.

The PXU Recipient MAC Address is represented as a (#6284)MAC address and is set to the MAC address of the recipient of the PXU, i.e., the originator of the PXUC element.

### 9.4.2.116 Authenticated Mesh Peering Exchange element

The Authenticated Mesh Peering Exchange element includes information needed to perform the authentication sequence during an authenticated mesh peering exchange. This element is shown in Figure 9-615 (Authenticated Mesh Peering Exchange element format).

| | Element ID | Length | Selected Pairwise Cipher Suite | Local Nonce | Peer Nonce | Key Replay Counter (optional) | GTKdata (optional) | IGTKdata (optional) |
|---|---|---|---|---|---|---|---|---|
| Octets | 1 | 1 | 4 | 32 | 32 | 8 | variable | variable |

**Figure 9-615—Authenticated Mesh Peering Exchange element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The Selected Pairwise Cipher Suite field contains a pairwise cipher suite selector, as defined in 9.4.2.23.2 (Cipher suites), indicating a cipher suite to be used to secure the link.

The Local Nonce field contains a nonce value chosen by the mesh STA that is transmitting the element. It is encoded following the conventions from 9.2.2 (Conventions).

The Peer Nonce field contains a nonce value that was chosen by the peer mesh STA or candidate peer mesh STA to which the element is being sent. It is encoded following the conventions from 9.2.2 (Conventions).

The Key Replay Counter field is optional. It is used only for the Mesh Group Key Inform frame (see 14.7.3 (Mesh Group Key Inform frame construction and processing)) and the Mesh Group Key Acknowledge frame (see 14.7.4 (Mesh Group Key Acknowledge frame construction and processing)). It is represented as an unsigned integer.

The GTKdata field is optional. When present, it contains the bit string of {GTK || (#1406)RSC || GTKExpirationTime} as the GTK data material. When present, the GTKdata field is protected by the exchange in which it is contained (see 14.6 (Authenticated mesh peering exchange (AMPE))). The (#1406)RSC denotes the last TSC or PN sent using the GTK and is specified in Table 12-9 (RSC field(#1406)) of 12.7.2 (EAPOL-Key frames). GTKExpirationTime denotes the key lifetime of the GTK in seconds and the format is specified in Figure 12-42 (Lifetime KDE format) of 12.7.2 (EAPOL-Key frames).


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The IGTKdata field is optional.(#199) When present, it contains the (#3493)key ID, IPN and IGTK used with BIP for management frame protection. The format of the IGTKdata field is specified in Figure 12-44 (IGTK KDE format) of 12.7.2 (EAPOL-Key frames).

Detailed usage of the Authenticated Mesh Peering Exchange element is described in 14.6.5 (Mesh peering Management frames for AMPE) and in 14.7 (Mesh group key handshake).

### 9.4.2.117 MIC element

The MIC element provides integrity protection for Management frames.(#1462) The format of the MIC element is shown in Figure 9-616 (MIC element format).

| | Element ID | Length | MIC |
|---|---|---|---|
| Octets: | 1 | 1 | variable(11az) |

**Figure 9-616—MIC element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

(11az)In the mesh peering Management frame (as specified in 14.6 (Authenticated mesh peering exchange (AMPE))) and the mesh group key handshake frame (as specified in 14.7 (Mesh group key handshake)), the length of the MIC is 16 octets. (11az)In other frames, the MIC field is of variable length, depending on the context that specifies the computation of the MIC.

### 9.4.2.118 Quality-of-Service Management Frame Policy element

The Quality-of-Service Management Frame (QMF) Policy element defines a QMF access category mapping (QACM) of Management frames and is used to advertise and exchange QMF policy between STAs. The use of the QMF Policy element is given in 11.24 (Quality-of-service Management frame (QMF)). See Figure 9-617 (QMF Policy element format).

| | Element ID | Length | QACM #1 | ... | QACM #N |
|---|---|---|---|---|---|
| Octets: | 1 | 1 | variable | | variable |

**Figure 9-617—QMF Policy element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The QACM field specifies a group of Management frames and their associated access categories. See Figure 9-618 (QACM field format) and see 11.24.3 (Interpreting QMF access categories).

| | QACM Header | Action Frame Category (optional) | Action Value Bitmap (optional) |
|---|---|---|---|
| Octets: | 2 | 0 or 1 | variable |

**Figure 9-618—QACM field format**

The format of the QACM Header subfield of the QACM field is defined in Figure 9-619 (QACM Header subfield format).

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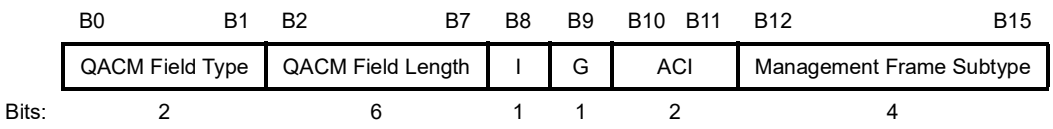


**Figure 9-619—QACM Header subfield format**

The QACM Field Type subfield defines the structure of the QACM field. Its value is 0. Values 1, 2, and 3 are reserved.

The QACM Field Length subfield defines the length in octets of the QACM field excluding the QACM Header subfield.

When the QACM applies to individually addressed Management frames, the Individually Addressed (I) subfield is set to 1. Otherwise, it is set to 0(#464).

When the QACM applies to group addressed Management frames, the Group Addressed (G) subfield is set to 1. Otherwise, it is set to 0(#464).

The combination of I = 0 and G = 0 is not allowed.

Each Management frame that is listed in the QACM Header subfield is transmitted using the access category identified by the accompanying ACI subfield.

The Management Frame Subtype subfield indicates the subtype of Management frames that are sent using the access category indicated in the ACI subfield. The valid values for this subfield are the subtypes in Table 9-1 (Valid type and subtype combinations) that correspond to Management frames.

The Action Frame Category subfield indicates the category of the Action frame, as defined in 9.4.1.1 (Authentication Algorithm Number field), of Action frames that are sent using the access category indicated in the ACI subfield. The Action Frame Category subfield is included only when the Management Frame Subtype subfield indicates Action or Action No Ack subtype as specified in 11.24.3 (Interpreting QMF access categories).

The Action Value Bitmap subfield is included when the QACM Policy is specified for a subset of Action frame types in a Action Frame Category. The Action Value Bitmap subfield is of variable length and indicates the action values, as defined in 9.5.7 (EDMG BRP field(11ay)), for the corresponding Action frame category that are sent using the access category indicated in the ACI subfield. The Action Value Bitmap subfield is included only when the Management Frame Subtype subfield indicates Action or Action No Ack subtype and the QACM Field Length subfield is greater than or equal to 2. Each bit in the Action Value Bitmap subfield is mapped to the corresponding action value. The Action Value Bitmap subfield is zero padded to complete any incomplete octet. When included, the size in octets of the Action Value Bitmap field is found by subtracting 1 from the value of the QACM Field Length subfield.

### 9.4.2.119 Intra-Access Category Priority element

The Intra-Access Category Priority element provides information from a non-AP STA to an AP on the relative priorities of streams within an AC, as described in 10.2.3.2 (HCF contention based channel access (EDCA)) and 11.25.2 (SCS procedures). This element is optionally present in ADDTS Request, QoS Map Configure, or SCS Request frames. The Intra-Access Category Priority element is defined in Figure 9-620 (Intra-Access Category Priority element format).

The Element ID and Length fields are defined in 9.4.2.1 (General).


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| Element ID | Length | Intra-Access Priority |
|---|---|---|
| Octets: 1 | 1 | 1 |

**Figure 9-620—Intra-Access Category Priority element format**

The Intra-Access Priority field is defined in Figure 9-621 (Intra-Access Priority field format).

| B0 B2 | B3 | B4 | B5 B7 |
|---|---|---|---|
| User Priority | Alternate Queue | Drop Eligibility | Reserved |
| Bits: 3 | 1 | 1 | 3 |

**Figure 9-621—Intra-Access Priority field format**

The User Priority subfield indicates the UP of MSDUs or A-MSDUs of the stream to which this Intra-Access Category Priority element relates.

The Alternate Queue subfield indicates the intended primary or alternate EDCA queue that is used for this stream. When dot11AlternateEDCAActivated is false, this subfield is reserved. When the Alternate Queue subfield is equal to 0, the primary EDCA queue for this AC is used. When the Alternate Queue subfield is equal to 1, the Alternate EDCA queue for this AC (see 10.2.3.2 (HCF contention based channel access (EDCA))) is used.

The Drop Eligibility subfield is used to indicate the suitability of this TS to be discarded if there are insufficient resources. If there are insufficient resources, a STA should discard the MSDUs or A-MSDUs of a TS with a Drop Eligibility subfield equal to 1, in preference to MSDUs or A-MSDUs of a TS whose Drop Eligibility subfield is equal to 0. See 11.24.2 (QMF policy advertisement and configuration procedures). The mechanisms for determining whether the resources are insufficient or when to discard MSDUs or A-MSDUs are beyond the scope of this standard.

### 9.4.2.120 SCS Descriptor element

The SCS Descriptor element defines information about the stream that is being classified using the procedures defined in 11.25.2 (SCS procedures). The format of the SCS Descriptor element is shown in Figure 9-622 (SCS Descriptor element format).

| | | | | | zero or more TCLAS Elements | | |
|---|---|---|---|---|---|---|---|
| Element ID | Length | SCSID | Request Type | Intra-Access Category Priority Element (optional) | TCLAS Elements (optional) | TCLAS Processing Element (optional) | Optional Subelements |
| Octets: 1 | 1 | 1 | 1 | 0 or 3 | variable | 0 or 3 | variable |

**Figure 9-622—SCS Descriptor element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The SCSID field is set to a nonzero value chosen by the non-AP STA identifying the SCS stream specified in this SCS Descriptor element.

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The Request Type field is set to a number to identify the type of SCS request. The Request Types are shown in Table 9-286 (SCS Request Type definitions).

**Table 9-286—SCS Request Type definitions**

| Name | Value |
|---|---|
| Add | 0 |
| Remove | 1 |
| Change | 2 |
| Reserved | 3–255 |

The Intra-Access Category Priority Element field is present when Request Type field is equal to "Add" or "Change" and is defined in 9.4.2.119 (Intra-Access Category Priority element).

The TCLAS Elements field contains zero or more TCLAS elements to specify how incoming MSDUs are classified as part of this SCS stream, as defined in 9.4.2.29 (TCLAS element). One or more TCLAS elements are present when Request Type field is equal to "Add" or "Change," and no TCLAS elements are present when Request Type field is equal to "Remove."

The TCLAS Processing Element field is present when more than one TCLAS element is present in the TCLAS Elements field and contains a TCLAS Processing element that defines how the multiple TCLAS elements are to be processed, as defined in 9.4.2.31 (TCLAS Processing element).

The Optional Subelements field contains zero or more subelements. The subelement format and ordering of subelements are defined in 9.4.3 (Subelements).

The Optional Subelement ID field values for the defined subelements are shown in Table 9-287 (Optional subelement IDs for SCS Descriptor element).

**Table 9-287—Optional subelement IDs for SCS Descriptor element**

| Subelement ID | Name | Extensible |
|---|---|---|
| 0–220 | Reserved | |
| 221 | Vendor Specific | Vendor defined |
| 222–255 | Reserved | |

The SCS Descriptor element is included in SCS Request frames, as described in 9.6.18.2 (SCS Request frame format). The use of the SCS Descriptor element and SCS Request frames is described in 11.25.2 (SCS procedures).


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### 9.4.2.121 QLoad Report element

#### 9.4.2.121.1 QLoad Report element format

The QLoad Report element contains the set of parameters necessary to support OBSS management. The format of the QLoad Report element is shown in Figure 9-623 (QLoad Report element format).

| | Element ID | Length | Potential Traffic Self | Allocated Traffic Self | Allocated Traffic Shared | EDCA Access Factor | HCCA Peak | HCCA Access Factor | Overlap | Sharing Policy | Optional Subelements |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 5 | 5 | 5 | 1 | 2 | 1 | 1 | 1 | variable |

**Figure 9-623—QLoad Report element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

Potential Traffic Self, Allocated Traffic Self, and Allocated Traffic Shared fields use the QLoad field format as described in 9.4.2.121.2 (QLoad field format).

The Potential Traffic Self field represents the peak composite QoS traffic for this BSS if all of the potential admission control and HCCA TSPECs from the non-AP STAs are active. The methods for gathering the total potential TSPEC information are described in 11.26.2 (QLoad Report element).

The Allocated Traffic Self field represents the composite QoS traffic for this BSS based upon all of the admission control and HCCA TSPECs admitted within the same BSS, as described in 11.26.2 (QLoad Report element).

The Allocated Traffic Shared field represents the sum of the Allocated Traffic Self field values that have been received or obtained from other APs whose beacons have been detected or obtained within the last 100 beacon periods, plus the Allocated Traffic Self field value of the AP itself. Computation of the values represented in the Allocated Traffic Shared field is described in 11.26.2 (QLoad Report element).

As described in 11.26.2 (QLoad Report element), the EDCA Access Factor field value is the sum of the Potential Traffic Self field values that have been received or obtained from other APs, plus the Potential Traffic Self field value of the AP itself, minus the sum of the HCCA Peak field values that have been received or obtained from overlapping APs, minus the HCCA Peak field value of the AP itself. The EDCA Access Factor field(M118) is expressed as a fraction rounded down to a multiple of 1/64. When the EDCA Access Factor field(M118) is greater than 254/64, the EDCA Access Factor field is set to 255.

The HCCA Peak field is the total peak HCCA TXOP requirement, over a period of 1 s, for the AP and BSS, for all of the HCCA TSPECs that are included in the QLoad. HCCA Peak is expressed in multiples of 32 μs over a period of 1 s. The HCCA Peak field is reserved if HCCA is not supported.

NOTE—Because the HCCA peak is calculated over 1 s periods, its value might be an underestimate of the instantaneous peak of interactive variable bit rate (VBR) flows.

The HCCA Access Factor field value is the sum of the HCCA Peak field values in the QLoad Report elements that have been received from the APs of OBSSs, plus the HCCA Peak field value of the AP itself, as described in 11.26.2 (QLoad Report element). It is expressed as a fraction rounded down to a multiple of 1/64. When the HCCA Access Factor is greater than 254/64, the HCCA Access Factor field is set to 255.

The Overlap field indicates the number of other APs that are sharing the same channel and whose beacons have been detected or obtained within the last 100 beacon periods by the AP issuing this beacon.

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The Sharing Policy field contains the currently active sharing policy. The values for the Sharing Policy field are described in Table 9-288 (Sharing Policy definitions).

**Table 9-288—Sharing Policy definitions**

| Sharing Policy field value | Current sharing policy |
|---|---|
| 0 | Not specified |
| 1 | Static |
| 2 | Dynamic |
| 3–220 | Reserved |
| 221 | Vendor Specific |
| 222–255 | Reserved |

The Optional Subelements field contains zero or more subelements. The subelement format and ordering of subelements are defined in 9.4.3 (Subelements).

The Subelement ID field values for the defined subelements are shown in Table 9-289 (Optional subelement IDs for QLoad Report element).

**Table 9-289—Optional subelement IDs for QLoad Report element**

| Subelement ID | Name | Extensible |
|---|---|---|
| 0–220 | Reserved | |
| 221 | Vendor Specific | Vendor defined |
| 222–255 | Reserved | |

### 9.4.2.121.2 QLoad field format

The QLoad field format is shown in Figure 9-624 (QLoad field format).

**Figure 9-624—QLoad field format**

The Mean subfield represents the amount of time admitted, or the amount of time scheduled traffic requires to access the medium, (#1173)in units of 32 μs/s. In the case of EDCA admission control, this value is the sum of the admitted medium times, and for HCCA it is the total TXOP time required per second (see T.2.2 (Calculating medium time)). If the mean medium time is larger than 2 097 088 μs (65 534 × 32), the Mean subfield is set to 0xFFFE. The Mean subfield is set to 0xFFFF to indicate that the mean medium time is unknown.


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The Standard Deviation subfield indicates the standard deviation from the mean medium time, (#1174)in units of 32 μs/s. If the standard deviation is larger than 8128 μs (254 × 32), the Standard Deviation subfield is set to 0x3FFE. The Standard Deviation subfield is set to 0x3FFF to indicate that the standard deviation from the mean is unknown.

The AC_VO Streams subfield indicates the number of TSs using explicit admission control for AC_VO in the QoS traffic load report. Bidirectional streams are counted as two streams. If the number of admitted AC_VO streams is larger than 14, the AC_VO Streams subfield is set to 0xE. The AC_VO Streams subfield is set to 0xF to indicate that the number of TSs using explicit admission control for AC_VO is unknown.

The AC_VI Streams subfield indicates the number of TSs using explicit admission control for AC_VI in the QoS traffic load report. Bidirectional streams are counted as two streams. If the number of TSs using explicit admission control for AC_VO is larger than 14, the AC_VI Streams subfield is set to 0xE. The AC_VI Streams subfield is set to 0xF to indicate that the number of TSs using explicit admission control for AC_VI is unknown.

See 11.26.2 (QLoad Report element) and Annex T.

### 9.4.2.122 HCCA TXOP Update Count element

The HCCA TXOP Update Count element is used by an AP to advertise its change in TXOP schedule. The format is shown in Figure 9-625 (HCCA TXOP Update Count element format).

| | Element ID | Length | Update Count |
|---|---|---|---|
| Octets: | 1 | 1 | 1 |

**Figure 9-625—HCCA TXOP Update Count element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The Update Count field is described in 11.26.3 (HCCA TXOP negotiation) and is used to indicate that a change has occurred in the number of active HCCA or HEMM TSs.

### 9.4.2.123 Higher Layer Stream ID element

The Higher Layer Stream ID element identifies a stream from a higher layer protocol. This element is used to bind messages that are exchanged in order to complete a procedure, e.g., messages exchanged in an AP-initiated TS setup procedure. See 11.4.4.3 (AP-initiated TS setup). The format is shown in Figure 9-626 (Higher Layer Stream ID element format).

| | Element ID | Length | Protocol ID | Organization Identifier | Higher Layer Stream ID |
|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 0, 3, or 5 | variable |

**Figure 9-626—Higher Layer Stream ID element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The Protocol ID field identifies the higher layer protocol to which the stream belongs. The values defined for the Protocol ID field are described in Table 9-290 (Protocol ID definitions).

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**Table 9-290—Protocol ID definitions**

| Protocol ID | Protocol | Description |
|---|---|---|
| 0 | Reserved | |
| 1 | IEEE 802.1Q SRP | Protocol is IEEE 802.1Q SRP, and the corresponding Stream ID is 8 octets long. |
| 2–220 | Reserved | |
| 221 | Vendor Specific | Corresponding Organization Identifier field is included in the element. |
| 222–255 | Reserved | |

The Organization Identifier field is present when the Protocol ID field is equal to 221 and contains a organization identifier assigned by IEEE. The identifier is specified in 9.4.1.29 (Organization Identifier field). The order of the Organization Identifier field is described in 9.2.2 (Conventions).

The Higher Layer Stream ID field is an octet string and is defined by the higher layer protocol specified in the Protocol ID field.

### 9.4.2.124 GCR Group Address element

The GCR Group Address element defines information about group addressed frames to be transmitted using the GCR service. The format of the GCR Group Address element is shown in Figure 9-627 (GCR Group Address element format).

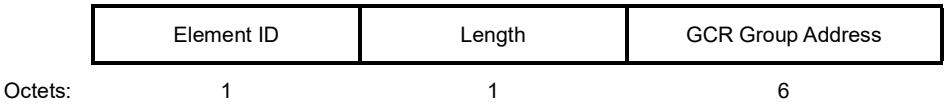


**Figure 9-627—GCR Group Address element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

GCR Group Address field is the MAC address of the GCR group.

### 9.4.2.125 DMG BSS Parameter Change element

The DMG BSS Parameter Change element is defined in Figure 9-628 (DMG BSS Parameter Change element format).

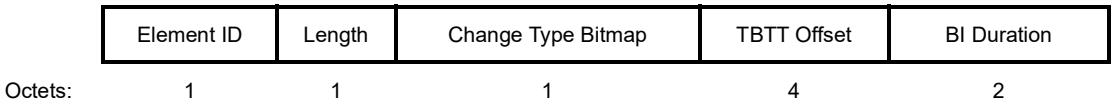


**Figure 9-628—DMG BSS Parameter Change element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The Change Type Bitmap field indicates the type of the parameter change to the BSS. This field is defined in Figure 9-629 (Change Type Bitmap field format).


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**Figure 9-629—Change Type Bitmap field format**

If the Move subfield is set to 1, it indicates a change in the TBTT of the BSS. The TBTT is not changed if the Move field is set to 0. If the Size subfield is set to 1, it indicates a change in the beacon interval duration. The beacon interval duration is not changed if the Size subfield is set to 0.

The TBTT Offset field contains a value expressed in microseconds. In any DMG BSS Parameter Change element included in the DMG Beacon and/or Announce frame, the TBTT Offset field represents the lower order 4 octets of the AP or PCP TSF timer of the first changed TBTT.

The BI Duration field value indicates the beacon interval, expressed in TUs, following the indicated DMG BSS parameter change. The BI Duration field is reserved if the Size bit of the Change Type Bitmap field is set to 0.

### 9.4.2.126 DMG Capabilities element

#### 9.4.2.126.1 General

The DMG Capabilities element contains a STA identifier and several fields that are used to advertise the support of optional DMG capabilities of a DMG STA. (#444)The DMG Capabilities element is formatted as defined in Figure 9-630 (DMG Capabilities element format).

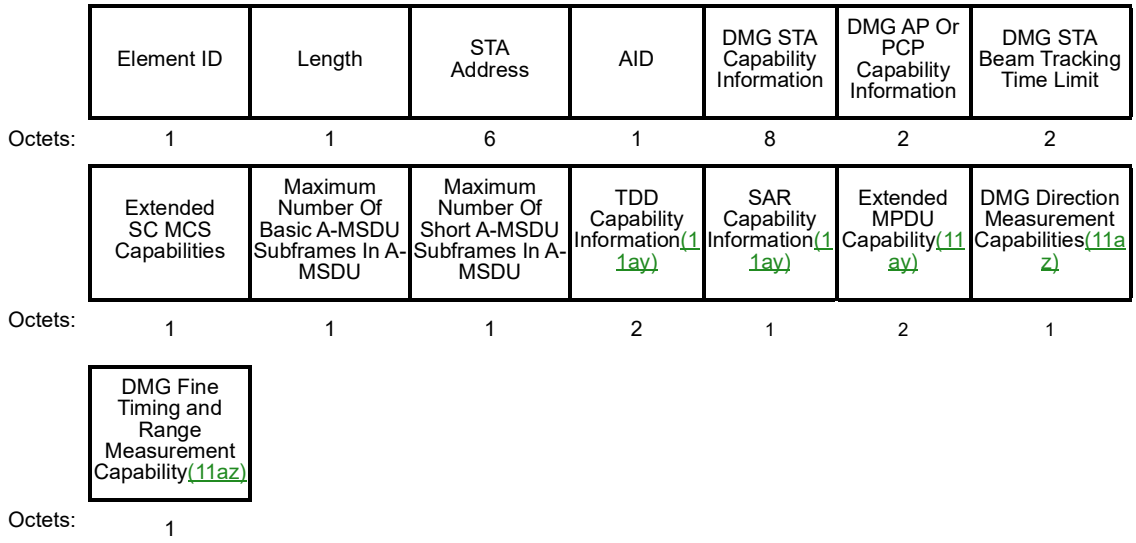


**Figure 9-630—DMG Capabilities element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

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The STA Address field contains the MAC address of the STA.

The AID field contains the AID assigned to the STA by the AP or PCP. The AID field is reserved in Association Request, Reassociation Request and Probe Request frames and when used in an IBSS.

#### 9.4.2.126.2 DMG STA Capability Information field

The DMG STA Capability Information field, shown in Figure 9-631 (DMG STA Capability Information field format(#1729)), represents the transmitting STA capabilities irrespective of the role of the STA.

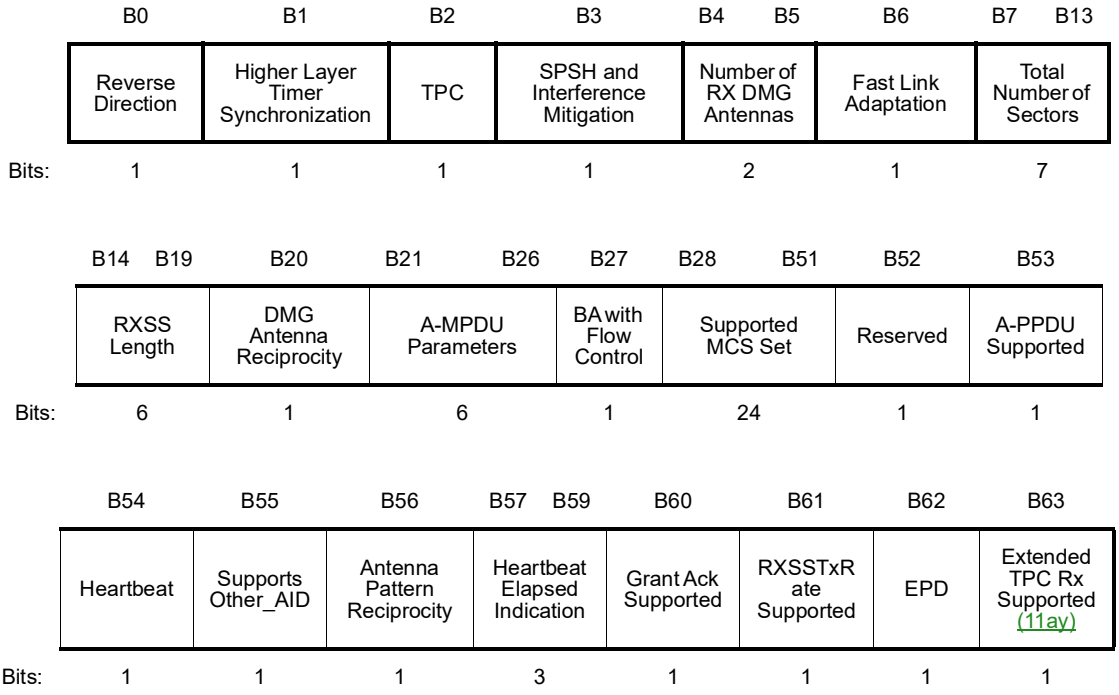


**Figure 9-631—DMG STA Capability Information field format(#1729)**

The Reverse Direction subfield is set to 1 if the STA supports RD as defined in 10.29 (Reverse direction protocol) and is set to 0 otherwise.

The Higher Layer Timer Synchronization subfield is set to 1 if the STA supports Higher Layer Timer Synchronization as defined in 11.6 (Higher layer timer synchronization) and is set to 0 otherwise.

The TPC subfield is set to 1 if the STA supports the TPC as defined in 11.7 (TPC procedures) and is set to 0 otherwise.

The SPSH (spatial sharing) and Interference Mitigation subfield is set to 1 if the STA is capable of performing the function of SPSH and Interference Mitigation and if dot11RadioMeasurementActivated is true and is set to 0 otherwise (see 11.30 (Spatial sharing and interference mitigation for DMG STAs)).

The Number of RX DMG Antennas subfield indicates the total number of receive DMG antennas of the STA minus 1.

The Fast Link Adaptation subfield is set to 1 to indicate that the STA supports the fast link adaptation procedure described in 10.42.3 (Fast link adaptation). Otherwise, it is set to 0.


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The Total Number of Sectors subfield indicates the total number of transmit sectors the STA uses in a transmit sector sweep combined over all DMG antennas, including any LBIFS required for DMG antenna switching (see 10.41 (DMG beamforming)), minus 1.

The value represented by the RXSS Length subfield specifies the total number of receive sectors combined over all receive DMG antennas of the STA, including any LBIFS required for DMG antenna switching (see 10.41 (DMG beamforming)). This subfield is set to (RXSS Length+1)×2, which ranges from 2 to 128.

The DMG Antenna Reciprocity subfield is set to 1 to indicate that the best transmit DMG antenna of the STA is the same as the best receive DMG antenna of the STA and vice versa. Otherwise, this subfield is set to 0.

The A-MPDU Parameters subfield is shown in Figure 9-632 (A-MPDU parameters subfield format).

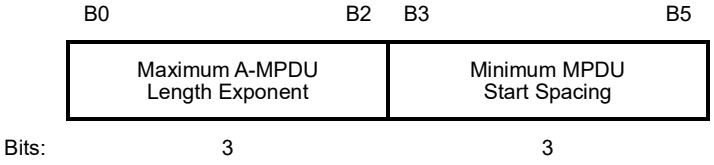


**Figure 9-632—A-MPDU parameters subfield format**

The subfields of the A-MPDU Parameters subfield are defined in Table 9-291 (Subfields of the A-MPDU Parameters subfield).

**Table 9-291—Subfields of the A-MPDU Parameters subfield**

| Subfield | Definition | Encoding |
|---|---|---|
| Maximum A-MPDU Length Exponent | Indicates the maximum length of A-MPDU that the STA can receive. | This subfield is an integer in the range 0 to 5. The length defined by this subfield is equal to $2^{(13 + \text{Maximum A-MPDU Length Exponent})} - 1$ octets. |
| Minimum MPDU Start Spacing | Determines the minimum time between the start of adjacent MPDUs within an A-MPDU that the STA can receive, measured at the PHY SAP. | Set to 0 for no restriction<br>Set to 1 for 16 ns<br>Set to 2 for 32 ns<br>Set to 3 for 64 ns<br>Set to 4 for 128 ns<br>Set to 5 for 256 ns<br>Set to 6 for 512 ns<br>Set to 7 for 1024 ns |

The BA with Flow Control subfield is set to 1 if the STA supports BA with flow control as defined in 10.41.9 (CDMG enhanced beam tracking) and is set to 0 otherwise.

The Supported MCS Set subfield indicates the MCSs a STA supports. An MCS is identified by an MCS index, which is represented by an integer in the range 0 to 12, or an integer in the range 25 to 31 or by one of the values 9.1, 12.1, 12.2, 12.3, 12.4, 12.5 and 12.6. The interpretation of the MCS index (i.e., the mapping from MCS to data rate) is PHY dependent. For the DMG PHY, see Clause 20 (Directional multi-gigabit (DMG) PHY specification). The structure of the Supported MCS Set subfield is defined in Figure 9-633 (Supported MCS Set subfield format).

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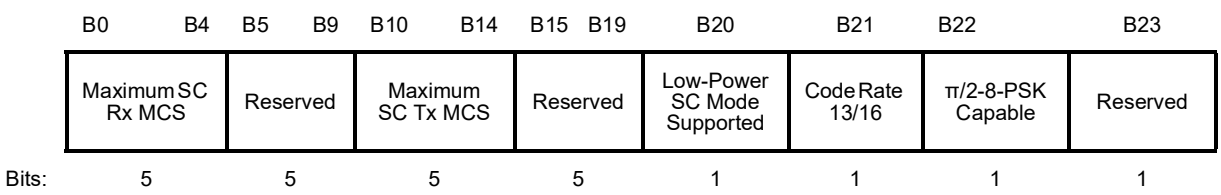


**Figure 9-633—Supported MCS Set subfield format**

The Maximum SC Rx MCS subfield contains the value of the maximum MCS index the STA supports for reception of single-carrier frames. Values 0-3 of this subfield are reserved. Possible values for this subfield are shown in Table 20-15 (DMG SC mode modulation and coding schemes). This subfield does not indicate support for MCSs 9.1, 12.1, 12.2, 12.3, 12.4, 12.5, and 12.6. Support for these MCSs is indicated using the Extended SC MCS Capabilities field; see 9.4.2.126.5 (Extended SC MCS Capabilities field).

The Maximum SC Tx MCS subfield contains the value of the maximum MCS index the STA supports for transmission of single-carrier frames. Values 0-3 of this subfield are reserved. Possible values for this subfield are shown in Table 20-15 (DMG SC mode modulation and coding schemes). This subfield does not indicate support for MCSs 9.1, 12.1, 12.2, 12.3, 12.4, 12.5, and 12.6. Support for these MCSs is indicated using the Extended SC MCS Capabilities field; see 9.4.2.126.5 (Extended SC MCS Capabilities field).

The Low-Power SC Mode Supported subfield is set to 1 to indicate that the STA supports the DMG low-power SC mode (20.6 (DMG low-power SC mode)). Otherwise, it is set to 0. If the STA supports the low-power SC mode, it supports all low-power SC mode MCSs indicated in Table 20-21 (DMG low-power SC mode modulation and coding schemes).

The Code Rate 13/16 subfield specifies whether the STA supports rate 13/16. It is set to 1 to indicate that the STA supports rate 13/16 and is set to 0 otherwise. If this subfield is 0, MCS with 13/16 code rate specified in Table 20-15 (DMG SC mode modulation and coding schemes) is not supported regardless of the value in Maximum SC Tx/Rx MCS subfields.

The π/2-8-PSK Capable subfield specifies whether the STA supports the use of π/2-8-PSK for MCS 10 and MCS 11. It is set to 1 to indicate the STA supports π/2-8-PSK for both transmission and reception and is set to 0 otherwise.

The A-PPDU Supported subfield is set to 1 to indicate that the STA supports A-PPDU aggregation as described in 10.14 (DMG A-PPDU and EDMG A-PPDU(11ay) operation). Otherwise, it is set to 0.

The Supports Other_AID subfield is set to 1 to indicate that the STA sets its AWV configuration according to the Other_AID subfield in the BRP Request field during the BRP procedure as described in 10.41.6.4.4 (Antenna configuration setting during a beam refinement transaction) and 20.9.2.2.6 (TRN field), if the value of the Other_AID subfield is different from zero. Otherwise, this subfield is set to 0.

The Heartbeat subfield is set to 1 to indicate that the STA expects to receive a frame from the AP or PCP during the ATI (10.38.3 (ATI transmission rules)) and expects to receive a frame with the DMG Control modulation from a source DMG STA at the beginning of an SP (10.38.6.2 (Service period (SP) allocation)) or TXOP (10.23.2 (HCF contention based channel access (EDCA))). Otherwise, it is set to 0.

The Antenna Pattern Reciprocity subfield is set to 1 to indicate that the transmit antenna pattern associated with an AWV is the same as the receive antenna pattern for the same AWV. Otherwise, this subfield is set to 0.


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The Heartbeat Elapsed Indication subfield is used to calculate the value of the Heartbeat Elapsed Time. The Heartbeat Elapsed Time is computed according to the following equation:

$$T_{HE} = \begin{cases} 0, & F_{HE} = 0 \\ \frac{2^{F_{HE}}}{4}, & F_{HE} > 0 \end{cases}$$

where

$T_{HE}$ is the Heartbeat Elapsed Time (in milliseconds)
$F_{HE}$ is the value of the Heartbeat Elapsed Indication subfield

The Grant Ack Supported subfield is set to 1 to indicate that the STA is capable of responding to a Grant frame with a Grant Ack frame. Otherwise, this subfield is set to 0.

The RXSSTxRate Supported subfield is set to 1 to indicate that the STA can perform an RXSS with SSW frames transmitted at MCS 1 of the DMG SC modulation class. Otherwise, it is set to 0.

A DMG STA sets the EPD subfield in the DMG STA Capability Information field to 1 when dot11EPDImplemented is true and sets it to 0 otherwise.

(11ay)The Extended TPC Rx Supported subfield is set to 1 to indicate that the STA supports extended TPC Rx on the receiver side described in 10.42.6 (Extended TPC(11ay)). This subfield is set to 0 otherwise.

### 9.4.2.126.3 DMG AP Or PCP Capability Information field

The DMG AP Or PCP Capability Information field, shown in Figure 9-634 (DMG AP Or PCP Capability Information field format(#1729)), represents the capabilities when the transmitting STA performs in the role of AP or PCP and that are in addition to the capabilities in the DMG STA Capability Information field.

| | B0 | B1 | B2 | B3 | B10 | B11 |
|---|---|---|---|---|---|---|
| | TDDTI | Pseudo-static Allocations | PCP Handover | MAX Associated STA Number | | Power Source |
| Bit: | 1 | 1 | 1 | 8 | | 1 |

| | B12 | B13 | B14 | B15 |
|---|---|---|---|---|
| | Decentralized AP or PCP Clustering | PCP Forwarding | Centralized AP or PCP Clustering | Reserved |
| Bits: | 1 | 1 | 1 | 1 |

**Figure 9-634—DMG AP Or PCP Capability Information field format(#1729)**

The TDDTI (time division data transfer interval) subfield is set to 1 if the STA, while operating as an AP or PCP, is capable of providing channel access as defined in 10.38.6 (Channel access in scheduled DTI) and 11.4 (TS operation) and is set to 0 otherwise.

The Pseudo-static Allocations subfield is set to 1 if the STA, while operating as an AP or PCP, is capable of providing pseudo-static allocations as defined in 10.38.6.4 (Pseudo-static allocations) and is set to 0

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otherwise. The Pseudo-static Allocations subfield is set to 1 only if the TDDTI subfield in the DMG AP Or PCP Capability Information field is set to 1. The Pseudo-static Allocations subfield is reserved if the TDDTI subfield in the DMG AP Or PCP Capability Information field is set to 0.

The PCP Handover subfield is set to 1 if the STA, while operating as a PCP, is capable of performing a PCP Handover as defined in 11.27.2 (PCP Handover) and is set to 0 if the STA does not support PCP Handover.

The MAX Associated STA Number subfield indicates the maximum number of STAs that the STA can perform association with if operating as an AP or PCP. This subfield includes the STAs, if any, that are (#2210)colocated with the AP or PCP.

The Power Source subfield is set to 0 if the STA is battery powered and is set to 1 otherwise.

The Decentralized AP or PCP Clustering subfield is set to 1 if the STA, when operating as an AP or PCP, is capable of performing decentralized AP or PCP clustering and is set to 0 otherwise.

The PCP Forwarding subfield is set to 1 if the STA, while operating as a PCP, is capable of forwarding frames it receives from a non-PCP STA and destined to another non-PCP STA in the PBSS. This subfield is set to 0 otherwise.

The Centralized AP or PCP Clustering subfield is set to 1 if the STA, when operating as an AP or PCP, is capable of performing centralized AP or PCP clustering and is set to 0 otherwise. An AP or PCP that is incapable of performing centralized AP or PCP clustering is subject to requirements as described in 10.39.2.2 (Centralized AP or PCP cluster formation).

#### 9.4.2.126.4 DMG STA Beam Tracking Time Limit field

The DMG STA Beam Tracking Time Limit field contains the value of dot11BeamTrackingTimeLimit. This field indicates the maximum time between a request for beam tracking feedback and the feedback response, such that the response will be considered valid. This use of this field is discussed in 10.41.7 (Beam tracking).

#### 9.4.2.126.5 Extended SC MCS Capabilities field

The Extended SC MCS Capabilities field (see Figure 9-635 (Extended SC MCS Capabilities field format)) advertises the support of the STA for MCSs 9.1, 12.1, 12.2, 12.3, 12.4, 12.5, and 12.6.

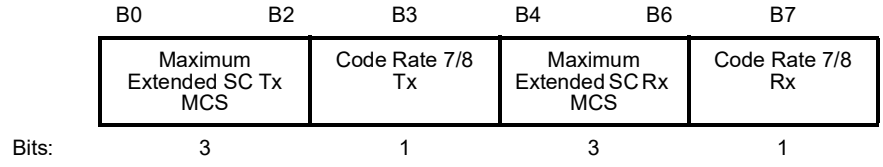


**Figure 9-635—Extended SC MCS Capabilities field format**

The Maximum Extended SC Tx MCS subfield indicates the maximum transmit extended SC MCS supported by the STA. The values in the subfield are ordered as shown in Table 9-292 (Mapping of Extended SC MCS to Maximum Supported Rx/Tx MCS subfield values).

A STA that indicates support for transmission of an extended SC MCS by setting the value in the Maximum Extended SC Tx MCS subfield to *k* supports the subset of MCSs {9.1, 12.1, 12.2, 12.3, 12.4, 12.5 12.6} that have a data rate lower than or equal to the data rate of the MCS indicated by *k*. A STA that indicates support for MCSs with a data rate higher than the data rate of MCS 9.1 in the Maximum Extended SC Tx MCS subfield sets the Maximum SC Tx MCS subfield of the Supported MCS Set subfield to 12.


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**Table 9-292—Mapping of Extended SC MCS to Maximum Supported Rx/Tx MCS subfield values**

| Extended MCS name | Value in Maximum Extended SC Rx/Tx MCS subfield |
|---|---|
| None | 0 |
| MCS 9.1 | 1 |
| MCS 12.1 | 2 |
| MCS 12.2 | 3 |
| MCS 12.3 | 4 |
| MCS 12.4 | 5 |
| MCS 12.5 | 6 |
| MCS 12.6 | 7 |

A STA that indicates support for transmission of an extended SC MCS by setting the value in the Maximum Extended SC Tx MCS subfield to *k* supports all extended SC MCSs with values lower than or equal to *k*.

The Maximum Extended SC Rx MCS subfield indicates the maximum receive extended SC MCS supported by the STA. The values in the subfield are ordered as shown in Table 9-292 (Mapping of Extended SC MCS to Maximum Supported Rx/Tx MCS subfield values).

A STA indicates support for transmission of code rate 7/8 by setting the Code Rate 7/8 Tx subfield to 1. If a STA indicates that it does not support code rate 7/8, then the STA does not support MCS 9.1 or 12.2 even if the value in the Maximum Extended SC Tx MCS subfield is greater than 1 or 3 respectively. A STA that indicates support for MCSs with a data rate higher than the data rate of MCS 9.1 in the Maximum Extended SC Rx MCS subfield sets the Maximum SC Rx MCS subfield of the Supported MCS Set subfield to 12.

A STA that indicates support for reception of an extended SC MCS by setting the Maximum Extended SC Rx MCS subfield to *k* supports the subset of MCSs {9.1, 12.1, 12.2, 12.3, 12.4, 12.5 12.6} that have a data rate lower than or equal to the data rate of the MCS indicated by *k*.

A STA indicates support for reception of code rate 7/8 by setting the Code Rate 7/8 Rx subfield to 1. If a STA indicates that it does not support code rate 7/8, the STA does not support MCS 9.1 or 12.2 even if the value in the Maximum Extended SC Rx MCS field is greater than 1 or 3 respectively.

#### 9.4.2.126.6 Maximum number of A-MSDU subframes in an A-MSDU

The Maximum Number Of Basic A-MSDU Subframes In A-MSDU subfield is defined in Table 9-293 (Maximum Number Of Basic A-MSDU Subframes In A-MSDU subfield) and indicates the maximum number of Basic A-MSDU subframes in an A-MSDU that the DMG STA is able to receive from another DMG STA.

The Maximum Number Of Short A-MSDU Subframes In A-MSDU subfield is defined in Table 9-294 (Maximum Number Of Short A-MSDU Subframes In A-MSDU subfield) and indicates the maximum number of Short A-MSDU subfields in an A-MSDU that the DMG STA is able to receive from another DMG STA.

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**Table 9-293—Maximum Number Of Basic A-MSDU Subframes In A-MSDU subfield**

| Value | Meaning |
|---|---|
| 0 | No limit on the maximum number of Basic A-MSDU subframes supported |
| 1 | A maximum of 4 Basic A-MSDU subframes are supported |
| 2 | A maximum of 8 Basic A-MSDU subframes are supported |
| 3 | A maximum of 16 Basic A-MSDU subframes are supported |
| 4 | A maximum of 32 Basic A-MSDU subframes are supported |
| 5 | A maximum of 64 Basic A-MSDU subframes are supported |
| 6 | A maximum of 128 Basic A-MSDU subframes are supported |
| 7 | A maximum of 256 Basic A-MSDU subframes are supported |
| 8–255 | Reserved |

**Table 9-294—Maximum Number Of Short A-MSDU Subframes In A-MSDU subfield**

| Value | Meaning |
|---|---|
| 0 | No limit on the maximum number of Short A-MSDU subframes supported |
| 1 | A maximum of 32 Short A-MSDU subframes are supported |
| 2 | A maximum of 64 Short A-MSDU subframes are supported |
| 3 | A maximum of 128 Short A-MSDU subframes are supported |
| 4 | A maximum of 256 Short A-MSDU subframes are supported |
| 5 | A maximum of 512 Short A-MSDU subframes are supported |
| 6 | A maximum of 1024 Short A-MSDU subframes are supported |
| 7–255 | Reserved |

### 9.4.2.126.7 TDD Capability Information field(11ay)

The TDD Capability Information field, shown in Figure 9-636 (TDD Capability Information field format(11ay)), indicates the transmitting STA capabilities in supporting TDD features.

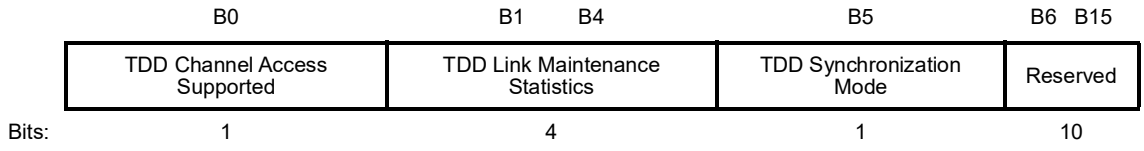


**Figure 9-636—TDD Capability Information field format(11ay)**


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The TDD Channel Access Supported subfield is set to 1 if dot11TDDOptionImplemented is true and indicates that the STA supports the TDD channel access described in 10.38.6.2.2 (SP with TDD channel access(11ay)). The subfield is set to 0 otherwise.

The TDD Link Maintenance Statistics subfield indicates the capabilities of reporting TDD rate adaptation statistics and is shown in Figure 9-637 (TDD Link Maintenance Statistics subfield format(11ay)).

**Figure 9-637—TDD Link Maintenance Statistics subfield format(11ay)**

The RX Chain Statistics Supported subfield is set to 1 to indicate the STA supports reporting the RX chain statistics in the DMG Link Margin element (see 9.4.2.141 (DMG Link Margin element)). Otherwise, this field is set to 0.

The PPDU Statistics Supported subfield is set to 1 to indicate the STA supports reporting the PPDU statistics in the DMG Link Margin element (see 9.4.2.141 (DMG Link Margin element)). Otherwise, this field is set to 0.

The LDPC Statistics Supported subfield is set to 1 to indicate the STA supports reporting the LDPC statistics in the DMG Link Margin element (see 9.4.2.141 (DMG Link Margin element)). Otherwise, this field is set to 0.

The SC/OFDM Statistics Supported subfield is set to 1 to indicate the STA supports reporting the parameters across SC blocks or OFDM symbols in the DMG Link Margin element (see 9.4.2.141 (DMG Link Margin element)). Otherwise, this field is set to 0.

The TDD Synchronization Mode subfield is set to 1 to indicate that the STA supports the TDD time synchronization described in 11.1.7 (TDD time synchronization(11ay)). This subfield is set to 0 otherwise.

### 9.4.2.126.8 SAR Capability Information field(11ay)

The SAR Capability Information field is defined in Figure 9-638 (SAR Capability Information field format(11ay)).

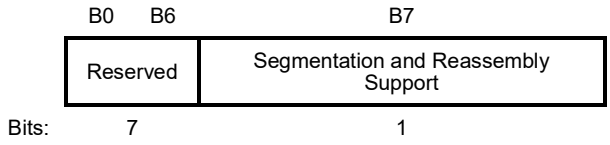


**Figure 9-638—SAR Capability Information field format(11ay)**

The Segmentation and Reassembly Support subfield indicates whether the STA supports the segmentation and reassembly mechanism as specified in 10.69 (DMG segmentation and reassembly operation(11ay)). A value of 0 indicates that segmentation and reassembly is not supported, indicated by dot11SAROptionImplemented equal to false. A value of 1 indicates that segmentation and reassembly is supported, indicated by dot11SAROptionImplemented equal to true.

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### 9.4.2.126.9 Extended MPDU Capability field(11ay)

The Extended MPDU Capability is defined in Figure 9-639 (Extended MPDU Capability field format(11ay)).

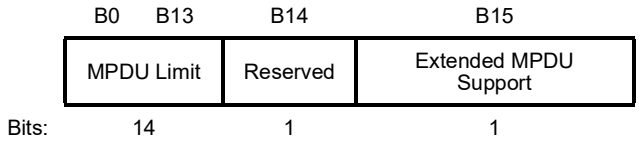


**Figure 9-639—Extended MPDU Capability field format(11ay)**

The MPDU Limit subfield indicates the maximum MPDU size, in octets, that the STA can receive when this subfield is valid. The subfield contains an integer between 7990 and 16383.

The Extended MPDU Support subfield indicates whether the MPDU Limit subfield is valid. When dot11DMGExtendedMPDULimitValid is true, the Extended MPDU Support subfield is set to 1 to indicate that the MPDU Limit subfield is valid. When dot11DMGExtendedMPDULimitValid is false, the Extended MPDU Support subfield is set to 0 to indicate that the MPDU Limit subfield is invalid.

### 9.4.2.126.10 DMG Direction Measurement Capabilities field(11az)

The DMG Direction Measurement Capabilities field, shown in Figure 9-640 (DMG Direction Measurement Capabilities field format(11az)), advertises capabilities for performing direction measurement as part of DMG or EDMG exchanges.

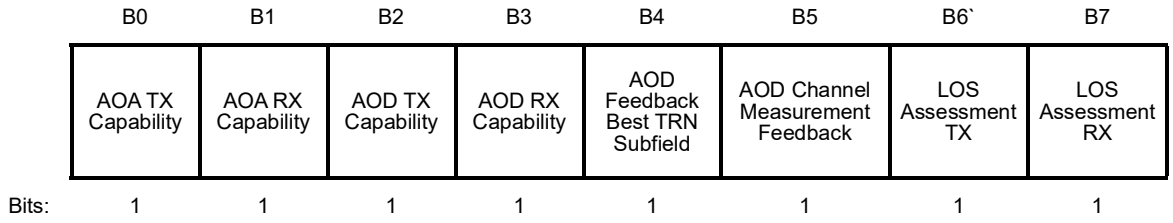


**Figure 9-640—DMG Direction Measurement Capabilities field format(11az)**

A DMG STA sets the AOA TX Capability subfield to 1 to indicate the ability to attach a TRN field to an FTM/Ack frame for the purpose of allowing the receiver of that frame to perform angle of arrival (AOA) estimation.

A DMG STA sets the AOA RX Capability subfield to 1 to indicate the ability to estimate the AOA based on a TRN field attached to an FTM/Ack frame.

A DMG STA sets the AOD TX Capability subfield to 1 to indicate the ability to attach a TRN field, possibly with different antenna settings to different TRN subfields, to an FTM/Ack frame, for the purpose of allowing the responder to estimate the angle of departure (AOD) of the PPDU.

A DMG STA sets the AOD RX Capability subfield to 1 to indicate the ability to estimate the AOD based on a TRN field attached to an FTM or Ack frame and send a report.


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A DMG STA sets the AOD Feedback Best TRN subfield to 1 to indicate the ability to send a best TRN subfield index, based on measurement on a TRN field sent by the receiver STA, for the purpose of AOD estimation.

A DMG STA sets the AOD Channel Measurement Feedback subfield to 1 to indicate the ability to send a Channel Measurement Feedback element based on measurement on a TRN field sent by the peer RSTA, for the purpose of AOD estimation.

The LOS Assessment TX subfield is set to 1 to indicate that the STA can participate as an RSTA in a LOS Assessment exchange by transmitting a LOS Assessment FTM PPDU; see 11.21.6.4.2.5 (DMG LOS assessment for EDCA based ranging measurement exchange(11az)).

The LOS Assessment RX subfield is set to 1 to indicate that the STA can participate in a LOS Assessment exchange as an RSTA by switching polarization at receiving an Ack with TRN field and responding with a Channel Measurement Feedback element in the next FTM frame to the ISTA.

### 9.4.2.126.11 DMG Fine Timing and Range Measurement Capability Information field(11az)

The DMG Fine Timing and Range Measurement Capability Information field, shown in Figure 9-641 (DMG Fine Timing And Range Measurement Capability Information field format(11az)(#7065)), advertises capabilities for performing FTMs and Range Measurements as part of DMG or EDMG exchanges.

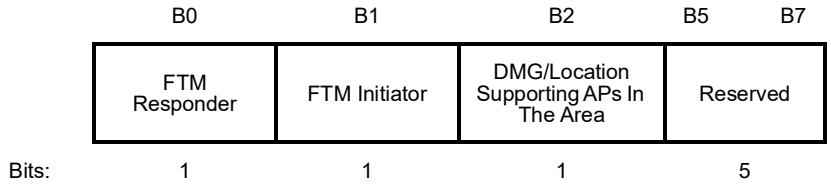


**Figure 9-641—DMG Fine Timing And Range Measurement Capability Information field format(11az)(#7065)**

The (#7065)FTM Responder field has the same meaning as the (#7065)FTM Responder field in the Extended Capabilities element (see 9.4.2.25 (Extended Capabilities element)). The (#7065)FTM Initiator field has the same meaning as the (#7065)FTM Initiator field in the Extended Capabilities element (see 9.4.2.25 (Extended Capabilities element)).

A DMG STA in the role of AP sets the DMG/Location Supporting APs In The Area field to 1 to indicate that APs providing location services using DMG are in the vicinity of the AP STA and sets it to 0 otherwise. Definition of vicinity is implementation dependent.

(#8242)NOTE—The AP might be capable of providing information about those DMG APs. The subfield is reserved if the DMG STA is not in the role of an AP.

### 9.4.2.127 DMG Operation element

The operational parameters of a BSS provided by the AP or PCP are determined by the DMG Operation element defined in Figure 9-642 (DMG Operation element format).

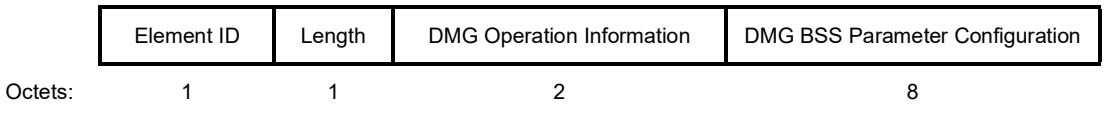


**Figure 9-642—DMG Operation element format**

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The Element ID and Length fields are defined in 9.4.2.1 (General).

The DMG Operation Information field is shown in Figure 9-643 (DMG Operation Information field format).

**Figure 9-643—DMG Operation Information field format**

The TDDTI subfield is set to 1 if the AP or PCP provides time division channel access as defined in 10.38.6 (Channel access in scheduled DTI) and is set to 0 otherwise.

The Pseudo-static allocations subfield is set to 1 if the AP or PCP provides pseudo-static allocations as defined in 10.38.6.4 (Pseudo-static allocations) and is set to 0 otherwise. The Pseudo-static allocations subfield is set to 1 only if the TDDTI subfield in the DMG Operation Information field is 1. The Pseudo-static allocations subfield is reserved if the TDDTI subfield in the DMG Operation Information field is 0.

The PCP Handover subfield is set to 1 if the PCP provides PCP Handover as defined in 11.27.2 (PCP Handover) and is set to 0 if the PCP does not provide PCP Handover.

The DMG BSS Parameter Configuration field is defined in Figure 9-644 (DMG BSS Parameter Configuration field format).

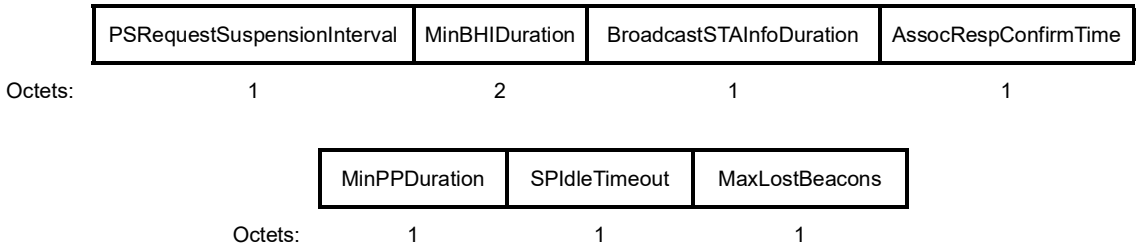


**Figure 9-644—DMG BSS Parameter Configuration field format**

The PSRequestSuspensionInterval subfield indicates the power save suspension interval and is specified in number of beacon intervals.

The MinBHIDuration subfield indicates the minimum duration of the BHI, which can include the BTI, A-BFT, and ATI and is specified in microseconds.

The BroadcastSTAInfoDuration subfield indicates the amount of time that the AP or PCP expects to take to transmit information about associated STAs and is specified in number of beacon intervals.

The AssocRespConfirmTime subfield indicates the amount of time that the AP or PCP expects to take to respond to association requests and is specified in units of 50 ms(#7198). A non-PCP and non-AP STA that receives a DMG Operation element can use the value of this field to set dot11AssociationResponseTimeOut.

The MinPPDuration subfield indicates the minimum duration of the PP and GP as part of the dynamic allocation of service period mechanism and is specified in microseconds.


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The SPIdleTimeout subfield indicates time during which a STA expects to receive a frame from its peer STA and is specified in microseconds.

The MaxLostBeacons subfield contains the value of dot11MaxLostBeacons.

### 9.4.2.128 DMG Beam Refinement element

The DMG Beam Refinement element is defined as shown in Figure 9-645 (DMG Beam Refinement element format).

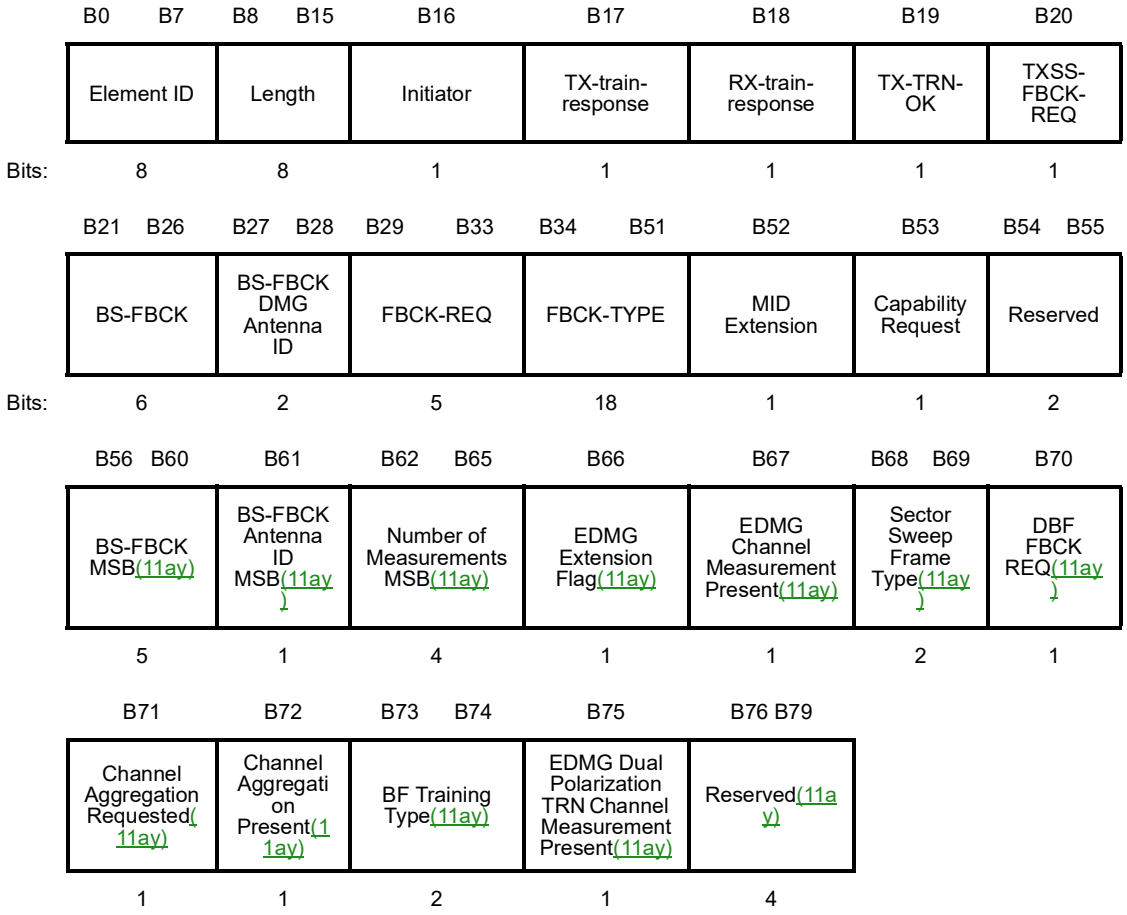


**Figure 9-645—DMG Beam Refinement element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

An Initiator field set to 1 indicates that the sender is the beam refinement initiator. Otherwise, this field is set to 0.

A TX-train-response field set to 1 indicates that this element is the response to a TX training request. Otherwise, this field is set to 0.

A RX-train-response field set to 1 indicates that the element serves as an acknowledgment for a RX training request. Otherwise, this field is set to 0.

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A TX-TRN-OK field set to 1 confirms a previous training request received by a STA. Otherwise, this field is set to 0.

A TXSS-FBCK-REQ field set to 1 indicates a request for transmit sector sweep feedback.

(11ay)The size in bits of the BS-FBCK field depends on the value of the EDMG Extension Flag field. If the EDMG Extension Flag field is set to 1, the BS-FBCK MSB field is prepended to the BS-FBCK field to form a single BS-FBCK field of size equal to 11 bits. Otherwise, the BS-FBCK MSB field is reserved and the BS-FBCK field remains with 6 bits in length.

If the EDMG Extension Flag field is set to 0, the BS-FBCK field indicates the index of the TRN-T subfield that was received with the best quality in the last received BRP-TX PPDU, where the first TRN-T subfield in the PPDU is defined as having an index equal to 1. If the EDMG Extension Flag field is set to 1, the BS-FBCK field indicates the AWV feedback ID of the TRN subfields transmitted with the same AWV that were received with the best quality in the last received EDMG BRP-TX PPDU or EDMG BRP-RX/TX PPDU as defined in 28.9.2.2 (EDMG BRP PPDU). If the EDMG Extension Flag field is set to 1 and the last received EDMG BRP-TX PPDU or EDMG BRP-RX/TX PPDU was transmitted using channel aggregation, the BS-FBCK field indicates the AWV feedback ID of the TRN subfields transmitted with the same AWV that were received with the best quality in the channel that includes the primary channel. If the last received PPDU from the same STA was not a BRP-TX PPDU, an EDMG BRP-TX PPDU or an EDMG BRP-RX/TX PPDU, this field is set to 0. The determination of best quality is implementation dependent.(11ay)

(11ay)The size in bits of the BS-FBCK Antenna ID field depends on the value of the EDMG Extension Flag field. If the EDMG Extension Flag field is set to 1, the BS-FBCK Antenna ID MSB field is prepended to the BS-FBCK Antenna ID field to form a single BS-FBCK Antenna ID field of size equal to 3 bits. Otherwise, the BS-FBCK Antenna ID MSB field is reserved and the BS-FBCK Antenna ID field remains at 2 bits in length.

The BS-FBCK DMG Antenna ID field specifies the DMG antenna ID corresponding to the sector indicated by the BF-FBCK field.

The FBCK-REQ field is defined in Figure 9-646 (FBCK-REQ field format) and is described in Table 9-295 (FBCK-REQ field description).

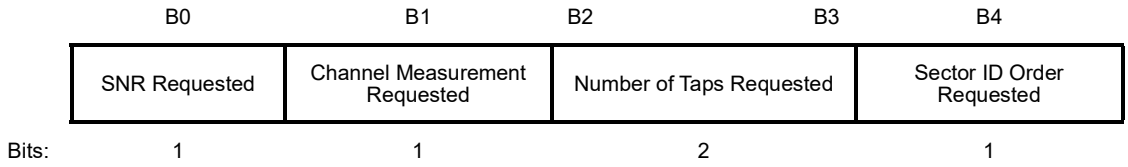


**Figure 9-646—FBCK-REQ field format**

**Table 9-295—FBCK-REQ field description**

| Subfield | Meaning |
|---|---|
| SNR Requested | If set to 1, the SNR subfield is requested as part of the returned Channel Measurement element(s). Otherwise, set to 0. |
| Channel Measurement Requested | If set to 1, the Channel Measurement subfield is requested as part of the returned Channel Measurement element(s). Otherwise, set to 0. |


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**Table 9-295—FBCK-REQ field description**

| | |
|---|---|
| Number of Taps Requested | Number of taps in each channel measurement:<br>0 x 0 – 1 tap<br>0 x 1 – 4×$N_{CB}$ + 1 taps(11ay)<br>0 x 2 – 14×$N_{CB}$ + 1 taps(11ay)<br>0 x 3 – 62×$N_{CB}$ + 1 taps(11ay)<br>where $N_{CB}$ is the integer number of contiguous 2.16 GHz channels over which the measurement is requested to be taken.(11ay) |
| Sector ID Order Requested | If this subfield is set to 1 and the EDMG Extension Flag field is set to 0, the Sector ID Order subfield is requested as part of the returned Channel Measurement element(s).<br>If this subfield is set to 1 and the EDMG Extension Flag field is set to 1, the EDMG Sector ID Order field is requested as part of the returned EDMG Channel Measurement Feedback element(s).<br>Otherwise, this subfield is set to 0. (11ay) |

The FBCK-TYPE field is defined in Figure 9-647 (FBCK-TYPE field format) and is described in Table 9-296 (FBCK-TYPE field description). When both $N_{meas}$ and $N_{beam}$ in this field are equal to 0, the Channel Measurement Feedback element is not present.

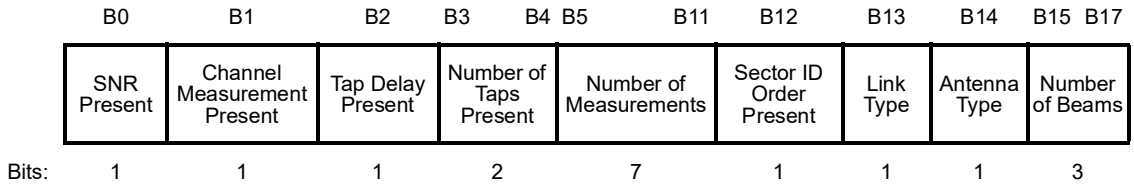


**Figure 9-647—FBCK-TYPE field format**

**Table 9-296—FBCK-TYPE field description**

| Subfield | Meaning |
|---|---|
| SNR Present | Set to 1 to indicate that the SNR subfield is present as part of the channel measurement feedback. Set to 0 otherwise. |
| Channel Measurement Present | Set to 1 to indicate that the Channel Measurement subfield is present as part of the channel measurement feedback. Set to 0 otherwise. |
| Tap Delay Present | If the EDMG Extension Flag field is set to 0, this subfield is set to 1 to indicate that the Tap Delay subfield is present as part of the channel measurement feedback. If the EDMG Extension Flag field is set to 1, this subfield is set to 1 to indicate that the Tap Delay subfield is present as part of the EDMG channel measurement feedback. This subfield is set to 0 in all other cases.(11ay) |
| Number of Taps Present | Number of taps in each channel measurement:<br>0 x 0 – 1 tap<br>0 x 1 – 4×$N_{CB}$ + 1 taps(11ay)<br>0 x 2 – 14×$N_{CB}$ + 1 taps(11ay)<br>0 x 3 – 62×$N_{CB}$ + 1 taps(11ay)<br>where $N_{CB}$ is the integer number of contiguous 2.16 GHz channels over which the measurement is requested to be taken.(11ay) |

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**Table 9-296—FBCK-TYPE field description *(continued)***

| Subfield | Meaning |
|---|---|
| Number of Measurements | The size in bits of the Number of Measurements subfield depends on the value of the EDMG Extension Flag field. If the EDMG Extension Flag field is set to 1, the Number of Measurements MSB field is prepended to the Number of Measurements subfield to form a single Number of Measurements field of size 11 bits. Otherwise, the Number of Measurements MSB field is reserved.(11ay)<br><br>The Number of Measurements subfield indicates the number of measurements in the SNR subfield and the Channel Measurement subfield. If the EDMG Extension Flag field is set to 0, the number of measurements is equal to the number of TRN-T subfields in the BRP-TX PPDU on which the measurement is based, or the number of received sectors if TXSS result is reported by setting the TXSS-FBCK-REQ subfield to 1. If the EDMG Extension Flag field is set to 1, the number of measurements is equal to the number of TX-RX AWV configurations trained with the EDMG BRP-TX or EDMG BRP-RX/TX PPDUs on which the measurement is based (see EDMG Channel Measurement Feedback element), or is equal to the number of received sectors if a TXSS result is reported by setting the TXSS-FBCK-REQ subfield to 1.(11ay) |
| Sector ID Order Present | Set to 1 to indicate<br>— That the Sector ID Order subfield is present as part of the channel measurement feedback when the EDMG Extension Flag field is set to 0; or<br>— That the EDMG Sector ID Order field is present as part of the EDMG Channel Measurement Feedback element when the EDMG Extension Flag field is set to 1.<br>Set to 0 otherwise.(11ay) |
| Link Type | Set to 0 for the initiator link and to 1 for the responder link |
| Antenna Type | Set to 0 for the transmitter antenna and to 1 for the receiver antenna |
| Number of Beams | Indicates the number of beams in the Sector ID Order subfield for the MIDC subphase |

A MID Extension field set to 1 indicates the intention to continue transmitting BRP-RX frames during the MID subphases. Otherwise, this field is set to 0.

A Capability Request field set to 1 indicates that the transmitter of the frame requests the intended receiver to respond with a BRP frame that includes the BRP Request field. Otherwise, this field is set to 0.

(11ay)The EDMG Channel Measurement Present field is set to 1 to indicate that at least one EDMG Channel Measurement Feedback element is present in the frame. Otherwise, this field is set to 0.

(11ay)The Sector Sweep Frame Type field is set to 0 to indicate that DMG Beacon frames or SSW frames are used in the last sector sweep. This field is set to 1 to indicate that Short SSW PPDUs are used in the last sector sweep. This field is set to 2 to indicate that BRP frames are used in the last sector sweep. The field is set to 3 to indicate that the BRP frame that contains this DMG Beam Refinement element carries a feedback for beam tracking.

(11ay)The definition of the DBF FBCK REQ field depends on the value of the Digital BF Request field within the EDMG BRP Request element contained in the same frame. If the Digital BF Request field is 1 and the DBF FBCK REQ is set to 1, digital beamforming matrix information is requested as part of a following MIMO BF Feedback frame. If the Digital BF Request field is 1 and the DBF FBCK REQ field is set to 0, MIMO channel measurement is present as part of a following MIMO BF Feedback frame. If the Digital BF Request field is 0, the DBF FBCK REQ field is reserved.

(11ay)The Channel Aggregation Requested field is set to 1 to indicate that the TRN field is transmitted over a 2.16+2.16 GHz or 4.32+4.32 GHz channel and to request the channel measurement feedback per channel


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in case of channel aggregation. Otherwise, it is set to 0. This field is reserved when the EDMG Extension Flag field is 0.

(11ay)The Channel Aggregation Present field is set to 1 to indicate, in case of channel aggregation, that channel measurement feedback per channel is present. Otherwise, it is set to 0. This field is reserved when the EDMG Extension Flag field is 0.

(11ay)The BF Training Type field is set to 0 to indicate SISO BF training, is set to 1 to indicate SU-MIMO BF training and is set to 2 to indicate MU-MIMO BF training. Other values are reserved.

(11ay)The EDMG Dual Polarization TRN Channel Measurement Present field is set to 1 to indicate that the EDMG Channel Measurement Feedback element contains the Dual Polarization TRN Measurement field. If the EDMG Dual Polarization TRN Channel Measurement Present field is set to 0, the EDMG Channel Measurement Feedback element does not contain the Dual Polarization TRN Measurement field.

### 9.4.2.129 DMG Wakeup Schedule element

The DMG Wakeup Schedule element is defined in Figure 9-648 (DMG Wakeup Schedule element format).

| | Element ID | Length | BI Start Time | Sleep Cycle | Number of Awake BIs |
|---|---|---|---|---|---|
| Octets: | 1 | 1 | 4 | 2 | 2 |

**Figure 9-648—DMG Wakeup Schedule element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The DMG Wakeup Schedule element is used to communicate the wakeup schedule (WS) of DMG STAs.

The BI Start Time field indicates the lower order 4 octets of the TSF timer at the start of the first A-BI in the WS defined by the DMG Wakeup Schedule element. A transmitted BI Start Time field points to a TBTT not more than $2^{31}$ μs minus aDMGDWSValidPeriod before, and not more than ($2^{31}$ – 1) μs after the TBTT of the beacon interval during which the BI Start Time field is transmitted.

NOTE—The delay between the moment a STA receives a DMG Wakeup Schedule element over the air and the moment the STA interprets the value of the BI Start Time field in the element can be large, to the extent that the beacon interval during which the BI Start Time filed is interpreted is different from the beacon interval during which the DMG Wakeup Schedule element is received. Excluding an interval from the range of BI Start Time field values at transmission enables the receiving STA to be able to correctly interpret any received value for the BI Start Time field of the DMG Wakeup Schedule element belonging to a STA in PS mode without having to remember the beacon interval during which the DMG Wakeup Schedule element was received, as long as the beginning of the beacon interval at the time of interpretation has not advanced more than aDMGDWSValidPeriod relative to the beginning of the beacon interval at the time of reception.

The Sleep Cycle field indicates the sleep cycle duration in beacon intervals, i.e., the sum of A-BIs and D-BIs that make up the sleep cycle.

The Number of Awake BIs field indicates the number of A-BIs at the beginning of each sleep cycle. A Number of Awake BIs field set to 0 indicates that all beacon intervals in the WS are D-BIs.

### 9.4.2.130 Extended Schedule element

The Extended Schedule element is defined in Figure 9-649 (Extended Schedule element format). Because the length parameter supports only 255 octets of information in an element, the AP or PCP can split the Allocation fields into more than one Extended Schedule element entry in the same DMG Beacon or

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Announce frame. Despite this splitting, the set of Extended Schedule element entries conveyed within a DMG Beacon and Announce frame is considered to be a single schedule for the beacon interval, and in this standard referred to simply as Extended Schedule element unless otherwise noted. The Allocation fields are ordered by increasing allocation start time with allocations beginning at the same time arbitrarily ordered.

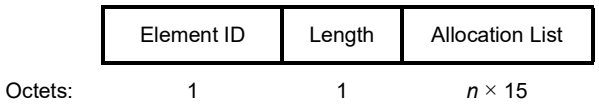


**Figure 9-649—Extended Schedule element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The Allocation List field contains one or more (*n*) Allocation fields. The Allocation fields are ordered by increasing allocation start time with allocations beginning at the same time arbitrarily ordered.

An Allocation field is formatted as shown in Figure 9-650 (Allocation field format).

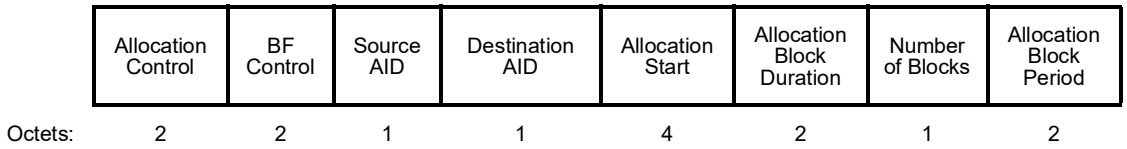


**Figure 9-650—Allocation field format**

The Allocation Control subfield is defined in Figure 9-651 (Allocation Control subfield format (DMG)) for a DMG STA and in Figure 9-652 (Allocation Control subfield format (CDMG)) for a CDMG STA.

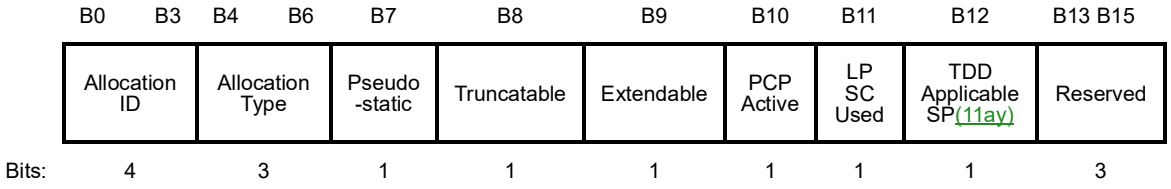


**Figure 9-651—Allocation Control subfield format (DMG)**

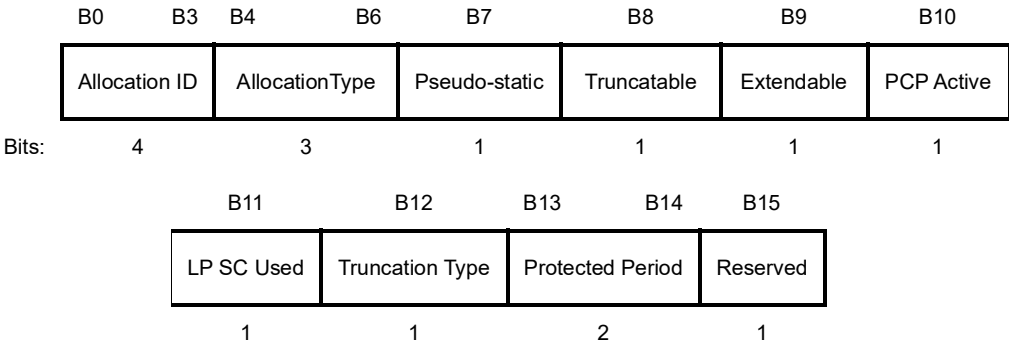


**Figure 9-652—Allocation Control subfield format (CDMG)**


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The Allocation ID subfield, when set to a nonzero value, identifies an airtime allocation from Source AID to Destination AID. Except for CBAP allocations with broadcast Source AID and broadcast Destination AID, the tuple (Source AID, Destination AID, Allocation ID) uniquely identifies the allocation. For CBAP allocations with broadcast Source AID and broadcast Destination AID, the Allocation ID subfield is set to 0.

The AllocationType subfield defines the channel access mechanism during the allocation, with possible values listed in Table 9-297 (AllocationType subfield values).

**Table 9-297—AllocationType subfield values**

| Bit 4 | Bit 5 | Bit 6 | Meaning |
|---|---|---|---|
| 0 | 0 | 0 | SP allocation |
| 1 | 0 | 0 | CBAP allocation |
| 0 | 1 | 0 | SP allocation on a 1.08 GHz channel |
| 1 | 1 | 0 | CBAP allocation on a 1.08 GHz channel |
| All other combinations | | | Reserved |

The Pseudo-static subfield is set to 1 to indicate that this allocation is pseudo-static (10.38.6.4 (Pseudo-static allocations)) and set to 0 otherwise.

For an SP allocation, the Truncatable subfield is set to 1 to indicate that the source DMG STA and destination DMG STA can request SP truncation and set to 0 otherwise. For a CBAP allocation, the Truncatable subfield is reserved.

For an SP allocation, the Truncatable subfield is set to 1 to indicate that the source CDMG STA and destination CDMG STA can request SP truncation, and the SP truncation type is determined by the Truncation Type subfield. Otherwise, it is set to 0, and the Truncation Type subfield is reserved. For a CBAP allocation, the Truncatable subfield is reserved

For an SP allocation, the Extendable subfield is set to 1 to indicate that the source DMG STA and destination DMG STA can request SP extension and set to 0 otherwise. For a CBAP allocation, the Extendable subfield is reserved.

For a PCP in active mode (see 11.2.7 (Power management in a PBSS and DMG infrastructure BSS)), or when applied to a CBAP or SP in a PCP A-BI, a PCP Active subfield set to 1 indicates that the PCP is available to transmit or receive during the CBAP or SP, and a PCP Active subfield set to 0 indicates the PCP is unavailable to transmit or receive. For a DMG PCP, the PCP Active subfield is set to 1 at least in the following cases:

— The PCP transmitting the subfield is the source or destination of the CBAP or SP
— At least one of the Truncatable or Extendable subfields is set to 1
— The subfield is transmitted by an AP

For a CDMG PCP, the PCP Active subfield is set to 1 at least in the following cases:

— The PCP transmitting the field is the source or destination of the CBAP or SP
— The Truncatable subfield is equal to 1, and the Truncation Type subfield is equal to 0
— The Extendable subfield is equal to 1
— The subfield is transmitted by an AP

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The PCP Active subfield is ignored when it applies to a CBAP or SP that resides in a PCP D- BI.

The BF Control subfield is defined in 9.5.5 (Beamforming Control field).

The Source AID subfield is set to the AID of the STA that initiates channel access during the SP or CBAP allocation or, in the case of a CBAP allocation, can also be set to the broadcast AID if all STAs are allowed to transmit during the CBAP allocation.

The Destination AID subfield is set to the AID of the STA that the source STA targets during the allocation, or to the broadcast AID if the source STA targets more than one STA during the allocation. If both Source AID and Destination AID subfields for an SP allocation are set to the broadcast AID, then during the SP a non-AP and non-PCP STA does not transmit unless it receives a Poll or Grant frame from the AP or PCP.

The Allocation Start subfield contains the lower 4 octets of the TSF at the time the SP or CBAP starts. The Allocation Start subfield can be specified at a future beacon interval when the pseudo-static subfield is set to 1.

The Allocation Block Duration subfield indicates the duration, in microseconds, of a time block for which the SP or CBAP allocation is made and cannot cross beacon interval boundaries. Possible values range from 1 to 32 767 for an SP allocation and 1 to 65 535 for a CBAP allocation.

The Number of Blocks subfield contains the number of time blocks making up the allocation.

The Allocation Block Period subfield contains the time, in microseconds, between the start of two consecutive time blocks belonging to the same allocation. The Allocation Block Period subfield is reserved when the Number of Blocks subfield is set to 1.

The LP SC Used subfield is set to 1 to indicate that the low-power SC mode described in 20.6 (DMG low-power SC mode) is used in this SP. Otherwise, it is set to 0.

If the Truncatable subfield is equal to 0, the Truncation Type subfield is reserved. Otherwise, a CDMG AP or a CDMG PCP sets the Truncation Type subfield to 0 to indicate that the CDMG STA is to return the time left in the SP to the CDMG AP or PCP, and it sets the Truncation Type subfield to 1 to indicate that the CDMG STA allocates any portion of its SP as a CBAP.

For CDMG STAs, the Protected Period subfield is used to indicate whether the source and destination STAs of the allocated SP are required to establish a protected period and on which channels the protected period is established. The Protected Period subfield is set to 0 to indicate the source and destination STAs of the SP are allowed to create a protected period, and the STA determines whether to establish a protected period. The Protected Period subfield is set to a nonzero value to indicate the source and destination STAs of the SP are required to create a protected period on the indicated channel(s). The values of the Protected Period subfield for a CDMG STA operating on a 2.16 GHz channel or a 1.08 GHz are listed in Table 9-298 (Protected Period subfield value for a CDMG STA operating on a 2.16 GHz channel) and Table 9-299 (Protected Period subfield value for a CDMG STA operating on a 1.08 GHz channel), respectively. For a CBAP allocation, the Protected Period subfield is reserved.

(11ay)If the Allocation Type subfield indicates an SP allocation, the TDD Applicable SP subfield set to 1 indicates that the SP allocation is using TDD channel access as described in 10.38.6.2.2 (SP with TDD channel access(11ay)); otherwise, it is set to 0. For other values of the Allocation Type subfield, the TDD Applicable SP subfield is reserved.


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**Table 9-298—Protected Period subfield value for a CDMG STA operating on a 2.16 GHz channel**

| Value | Meaning |
|---|---|
| 0 | The STA determines whether to establish a protected period. |
| 1 | The current channel needs a protected period. |
| 2 | Both the current 2.16 GHz channel and the low frequency channel 35 or channel 37 need a protected period. |
| 3 | Both the current 2.16 GHz channel and the high frequency channel 36 or channel 38 need a protected period. |

**Table 9-299—Protected Period subfield value for a CDMG STA operating on a 1.08 GHz channel**

| Value | Meaning |
|---|---|
| 0 | The STA determines whether to establish a protected period. |
| 1 | The current channel needs a protected period. |
| 2 | The current 1.08 GHz channel and the overlapping 2.16 GHz channel need a protected period. |
| 3 | Reserved. |

### 9.4.2.131 STA Availability element

The STA Availability element is used by a non-AP and non-PCP STA to inform an AP or PCP about the STA availability during the subsequent CBAPs (10.38.5 (Contention based access period (CBAP) transmission rules)) and to indicate participation in the dynamic allocation of service periods (10.38.7 (Dynamic allocation of service period)). The AP or PCP uses the STA Availability element to inform the non-AP and non-PCP STAs of other STAs availability during subsequent CBAPs and participation of other STAs in the Dynamic allocation of service periods.

The format of the STA Availability element is defined in Figure 9-653 (STA Availability element format).

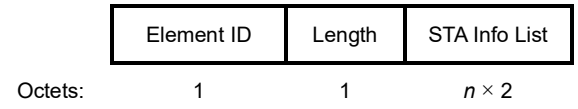


**Figure 9-653—STA Availability element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The STA Info List field contains one or more (*n*) STA Info fields.

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The format of the STA Info field is shown in Figure 9-654 (STA Info field format).

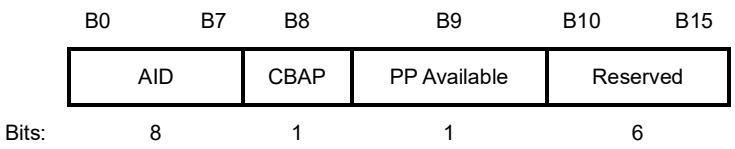


**Figure 9-654—STA Info field format**

The AID subfield contains the AID of the STA for which availability is indicated.

The CBAP subfield is set to 1 to indicate that the STA is available to receive transmissions during CBAPs and set to 0 otherwise.

The PP Available subfield is set to 1 to indicate that the STA is available during PPs (10.38.7 (Dynamic allocation of service period)) and is set to 0 otherwise.

### 9.4.2.132 DMG TSPEC element

The DMG TSPEC element (#444)sent by a non-AP and non-PCP DMG STA contains the set of parameters needed to create or modify an airtime allocation. The DMG TSPEC element (#444)sent by a DMG AP or PCP reflects the parameters, possibly modified, by which the allocation was created. The format of the DMG TSPEC element is shown in Figure 9-655 (DMG TSPEC element format).

| | Element ID | Length | DMG Allocation Info | BF Control | Allocation Period | Minimum Allocation |
|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 4 | 2 | 2 | 2 |

| | Maximum Allocation | Minimum Duration | Number of Constraints | Traffic Scheduling Constraint Set | BW Control(11ay) | BW(11ay) |
|---|---|---|---|---|---|---|
| Octets: | 2 | 2 | 1 | variable(#213) | 1 | 1 |

**Figure 9-655—DMG TSPEC element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The DMG Allocation Info field is formatted as shown in Figure 9-656 (DMG Allocation Info field format).

The Allocation ID subfield identifies an allocation if set to a nonzero value and is used as follows:

— The STA that transmits an ADDTS Request frame containing the DMG TSPEC element sets the Allocation ID subfield to a nonzero value to create a new allocation or modify an existing allocation.

— The STA that transmits an ADDTS Response frame containing the DMG TSPEC element sets the Allocation ID subfield to a nonzero value to identify a created or modified allocation or sets it to 0 if creating or modifying the allocation failed.


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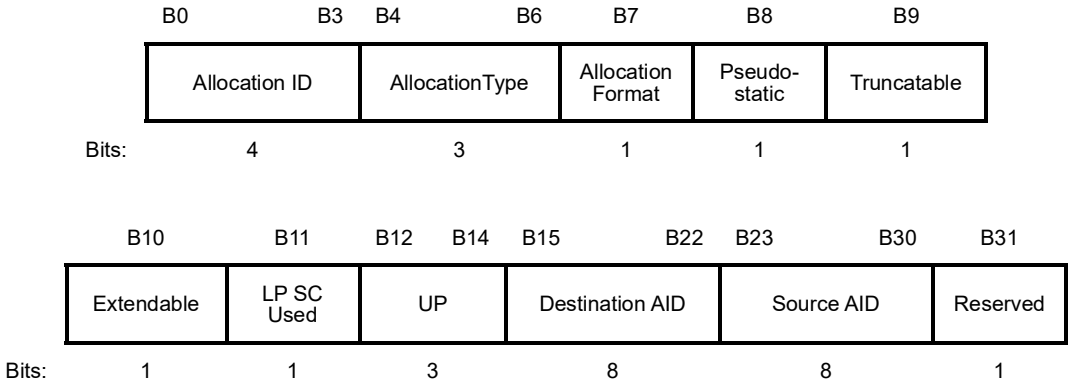


**Figure 9-656—DMG Allocation Info field format**

The AllocationType subfield defines the channel access mechanism used during the allocation, with values listed in Table 9-297 (AllocationType subfield values).

The Allocation Format field values are listed in Table 9-300 (Allocation Format subfield values).

**Table 9-300—Allocation Format subfield values**

| Allocation Format subfield value | Description |
|---|---|
| 1 | Isochronous allocation format |
| 0 | Asynchronous allocation format |

The Pseudo-static subfield is set to 1 for a pseudo-static allocation and set to 0 otherwise.

For an SP allocation, the Truncatable subfield is set to 1 if the STA expects to truncate the SP, as described in 10.38.8 (Dynamic truncation of service period). If the STA does not expect to truncate the SP, the Truncatable subfield is set to 0. The subfield is reserved for CBAP allocations.

For an SP allocation, the Extendable subfield is set to 1 if the STA expects to extend the SP, as described in 10.38.9 (Dynamic extension of service period). If the STA does not expect to extend the SP, the Extendable subfield is set to 0. The subfield is reserved for CBAP allocations.

The LP SC Used subfield is defined in 9.4.2.130 (Extended Schedule element).

The UP subfield indicates the lowest priority UP to be used for possible transport of MSDUs belonging to TCs with the same source and destination of the allocation.

The Destination AID subfield contains the AID of a STA that the requesting STA targets during the allocation.

The Source AID subfield contains the AID of the STA that initiates channel access during the allocation.

The BF Control subfield is defined in 9.5.5 (Beamforming Control field).

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The Allocation Period is specified as a fraction or multiple of the beacon interval as defined in Table 9-301 (Allocation Period field values).

**Table 9-301—Allocation Period field values**

| B0–B14 | B15 | Meaning |
|---|---|---|
| 0 | 0 | Reserved |
| 0 | 1 | Not periodic or periodicity unknown |
| 1–32 767 | 0 | The allocation period is a multiple of the beacon interval, i.e., allocation period = *n* x *bi* where *n* is the value represented by B0–B14 and *bi* is the beacon interval. |
| 1–32 767 | 1 | The allocation period is a fraction of the beacon interval, i.e., allocation period = *bi*/*n* where *n* is the value represented by B0–B14 and *bi* is the beacon interval. |

For isochronous allocation format requests the Allocation Period, Minimum Allocation and Maximum Allocation fields are set as follows:

— The Allocation Period field indicates the period over which the allocation repeats.

— The Minimum Allocation field is set to the minimum acceptable allocation in microseconds in each allocation period.

— The Maximum Allocation field is set to the requested allocation in microseconds in each allocation period.

For asynchronous allocation format requests the Maximum Allocation field is reserved, and the Allocation Period and Minimum Allocation fields are set as follows:

— The Allocation Period field indicates the period over which the minimum allocation applies. The Allocation Period is an integer multiple of the beacon interval.

— The Minimum Allocation field specifies the minimum allocation in microseconds that the STA expects within the allocation period.

The Minimum Duration field specifies the minimum acceptable duration in microseconds. Possible values range from 1 to 32 767 for an SP allocation and 1 to 65 535 for a CBAP allocation. This field is set to 0 to indicate no minimum specified.

The Number of Constraints field indicates the number of Constraint subfields contained in the element. The field ranges from 0 to 15. Other values are reserved.

The Traffic Scheduling Constraint Set field contains one or more Constraint subfields (see Figure 9-657 (Traffic Scheduling Constraint Set field format)).

Octets: variable(#213)

**Figure 9-657—Traffic Scheduling Constraint Set field format**

The Constraint subfield is defined as shown in Figure 9-658 (Constraint subfield format).


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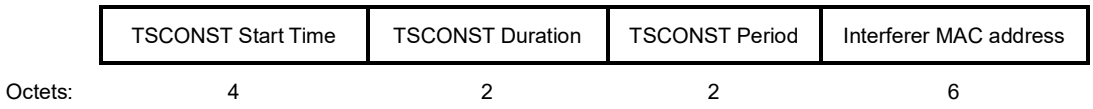


**Figure 9-658—Constraint subfield format**

The TSCONST Start Time subfield contains the lower 4 octets of the TSF at the time the scheduling constraint starts.

The TSCONST Duration subfield indicates the time, in microseconds, for which the scheduling constraint is specified.

The TSCONST Period subfield is specified as a fraction or multiple of the beacon interval as defined in Table 9-302 (TSCONST Period values). This subfield is used to indicate a periodic scheduling constraint by specifying the temporal gap between two consecutive scheduling constraints.

**Table 9-302—TSCONST Period values**

| B0–B14 | B15 | Meaning |
|---|---|---|
| 0 | 0 | Reserved |
| 0 | 1 | Not periodic or periodicity unknown |
| 1–32 767 | 0 | The TSCONST period is a multiple of the beacon interval, i.e., TSCONST period = *n* x *bi* where *n* is the value represented by B0–B14 and *bi* is the beacon interval.. |
| 1–32 767 | 1 | The TSCONST period is a fraction of the beacon interval, i.e., TSCONST period = *bi*/*n* where *n* is the value represented by B0–B14 and *bi* is the beacon interval.. |

The Interferer MAC Address subfield is set to the TA field within a frame received during the interval of time indicated by this Constraint subfield. If the value is unknown, the Interferer MAC Address subfield is set to the broadcast address.

(11ay)The BW Control field is defined in Figure 9-659 (BW Control field format(11ay)).

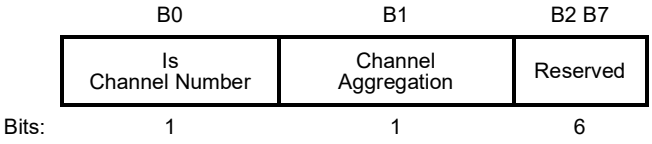


**Figure 9-659—BW Control field format(11ay)**

(11ay)The Is Channel Number subfield indicates whether the value in the BW field represents a channel width or channel number.

(11ay)The Channel Aggregation subfield is defined in Table 28-12 (EDMG-Header-A field structure and definition for an SU PPDU(11ay)).

(11ay)The BW field indicates the requested channel width or channel number of the allocation. If the Is Channel Number subfield is set to 1, the BW field uses the bitmap format of the BW field defined in Table 28-12 (EDMG-Header-A field structure and definition for an SU PPDU(11ay)) and, together with the

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Channel Aggregation subfield, are collectively used to derive a requested channel number for the allocation per the channel numbers defined in 9.4.2.264.5 (Supported Channels subelement). If the Is Channel Number subfield is set to 0, the BW field indicates a channel width using the bitmap format of the BW field defined in Table 28-12 (EDMG-Header-A field structure and definition for an SU PPDU(11ay)). In this case, the channel width can be allocated on any channel number. When transmitted in an ADDTS Response frame, the BW field indicates the allocated channel for the allocation using the bitmap format of the BW field defined in Table 28-12 (EDMG-Header-A field structure and definition for an SU PPDU(11ay)).

### 9.4.2.133 CMMG TSPEC element

The definition of the CMMG TSPEC element is similar with the definition of the DMG TSPEC element except for the specific change defined by Figure 9-660 (Constraint subfield format for CMMG STAs) and Figure 9-661 (Interferer Channel Bandwidth subfield format).

The Constraint subfield is defined in Figure 9-660 (Constraint subfield format for CMMG STAs) for CMMG STAs.

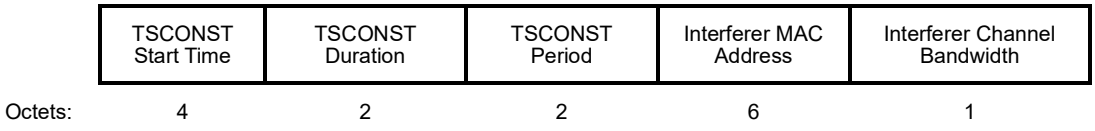


**Figure 9-660—Constraint subfield format for CMMG STAs**

The Interference Channel Bandwidth subfield is defined in Figure 9-661 (Interferer Channel Bandwidth subfield format).

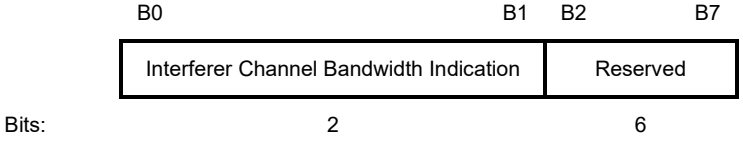


**Figure 9-661—Interferer Channel Bandwidth subfield format**

The Interferer Channel Bandwidth Indication subfield is present only when the operating channel bandwidth of the CMMG STA is 1080 MHz. The Interferer Channel Bandwidth Indication subfield indicates the part of the operating channel with interference during the time interval indicated by the TSCONST subfields. If the Interferer Channel Bandwidth Indication subfield is 0, interference occurred in the upper 540 MHz of the 1080 MHz operating channel. If the Interferer Channel Bandwidth Indication subfield is 1, interference occurred in the lower 540 MHz of the 1080 MHz operating channel. If the Interferer Channel Bandwidth Indication subfield is 2, interference occurred in over the total operating channel. A value of 3 for the Interferer Channel Bandwidth Indication subfield is reserved.

### 9.4.2.134 Next DMG ATI element

The Next DMG ATI element indicates the earliest start time for the next ATI in a subsequent beacon interval. See Figure 9-662 (Next DMG ATI element format).

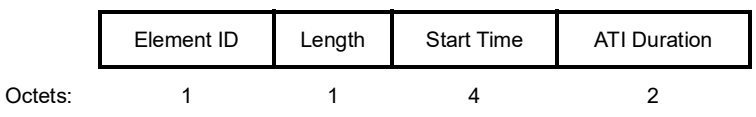


**Figure 9-662—Next DMG ATI element format**


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The Element ID and Length fields are defined in 9.4.2.1 (General).

The Start Time field contains the low order 4 octets of the TSF for the earliest time at which the next ATI in a subsequent beacon interval starts.

The ATI Duration field contains the duration, in microseconds, of the next ATI in a subsequent beacon interval.

### 9.4.2.135 Channel Measurement Feedback element

The Channel Measurement Feedback element is used to carry the channel measurement feedback in response to a request in the DMG Beam Refinement element of a BRP frame. (#8246)It contains data that the STA has measured on the TRN-T subfields of the BRP PPDU that contained the BRP frame, or a list of sectors identified during a sector sweep or during beam combination (10.41.6.3 (Multiple sector ID capture (MIDC) subphase)). The format and size of the Channel Measurement Feedback element are defined by the parameter values specified in the accompanying DMG Beam Refinement element.

The Channel Measurement Feedback element, as shown in Table 9-303 (Channel Measurement Feedback element format), is composed of 4 subfields: the SNR subfield, the Channel Measurement subfield, the Tap Delay subfield, and the Sector ID Order subfield.

**Table 9-303—Channel Measurement Feedback element format**

| Field | Size | | Meaning |
|---|---|---|---|
| Element ID | 8 bits | | |
| Length | 8 bits | | |
| SNR | $SNR_1$ | 8 bits | SNR as measured in the first TRN-T subfield or at the first sector from which SSW frame or Short SSW PPDU is received, or at the channel indicated by the first SISO ID subset |
| | $SNR_2$ | 8 bits | SNR as measured in the first TRN-T subfield or at the first sector from which SSW frame or Short SSW PPDU is received, or at the channel indicated by the first SISO ID subset. |
| | … | | |
| | $SNR_{N_{meas}}$ | 8 bits | SNR as measured in the $N_{meas}$ TRN-T subfield or at sector $N_{meas}$ from which SSW frame or Short SSW PPDU is received, or at the channel indicated by the $N_{meas}$ SISO ID subset. |
| Channel Measurement | Channel Measurement 1 | $N_{taps}$×16 bits | Channel measurement for the first TRN-T subfield or for the channel indicated by the first SISO ID subset. |
| | Channel Measurement 2 | $N_{taps}$×16 bits | Channel measurement for the second TRN-T subfield or for the channel indicated by the second SISO ID subset. |
| | … | | |
| | Channel Measurement $N_{meas}$ | $N_{taps}$×16 bits | Channel measurement for the $N_{meas}$ TRN-T subfield or for the channel indicated by the $N_{meas}$ SISO ID subset. |

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**Table 9-303—Channel Measurement Feedback element format *(continued)***

| Field | Size | | Meaning |
|---|---|---|---|
| Tap Delay | Relative Delay Tap #1 | 8 bits | The delay of Tap #1 in units of $T_c$ relative to the path with the shortest delay detected. |
| | Relative Delay Tap #2 | 8 bits | The delay of Tap #2 in units of $T_c$ relative to the path with the shortest delay detected. |
| | … | | |
| | Relative Delay Tap #$N_{taps}$ | 8 bits | The delay of Tap #$N_{taps}$ in units of $T_c$ relative to the path with the shortest delay detected. |
| Sector ID Order | Sector $ID_1$ | 6 bits | Sector ID for $SNR_1$ being obtained, or sector ID of the first detected beam. |
| | DMG Antenna $ID_1$ | 2 bits | DMG Antenna ID corresponding to sector $ID_1$. |
| | Sector $ID_2$ | 6 bits | Sector ID for $SNR_2$ being obtained, or sector ID of the second detected beam. |
| | DMG Antenna $ID_2$ | 2 bits | DMG Antenna ID corresponding to sector $ID_2$. |
| | … | | |
| | Sector $ID_{Nmeas}$ or sector $ID_{Nbeam}$ | 6 bits | Sector ID for $SNR_{Nmeas}$ being obtained, or sector ID of the detected beam $N_{beam}$. |
| | DMG Antenna $ID_{Nmeas}$ or DMG Antenna $ID_{Nbeam}$ | 2 bits | DMG Antenna ID corresponding to sector $ID_{Nmeas}$ or sector $ID_{Nbeam}$ |
| Additional SNR(11ay) | $SNR_1$ | 8 bits | SNR as measured in the first TRN-T field or at the channel indicated by the first SISO ID subset. |
| | $SNR_2$ | 8 bits | SNR as measured in the second TRN-T field or at the channel indicated by the second SISO ID subset. |
| | .<br>.<br>. | | |
| | $SNR_{Nmeas}$ | 8 bits | SNR as measured in the $N_{meas}$ TRN-T field or at the channel indicated by the $N_{meas}$ SISO ID subset. |
| Additional Channel Measurement(11ay) | Channel Measurement 1 | $N_{taps}$×16 bits | Channel measurement for the first TRN-T field or for the channel indicated by the first SISO ID subset. |
| | Channel Measurement 2 | $N_{taps}$×16 bits | Channel measurement for the second TRN-T field or for the channel indicated by the second SISO ID subset. |
| | .<br>.<br>. | | |
| | Channel Measurement $N_{meas}$ | $N_{taps}$×16 bits | Channel measurement for the $N_{meas}$ TRN-T field or for the channel indicated by the $N_{meas}$ SISO ID subset. |


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The Element ID and Length fields are defined in 9.4.2.1 (General).

The number of channel/SNR measurements reported, $N_{meas}$, is equal to the number of TRN-T subfields that were appended to the PPDU on which the measurements were performed. If the measurement reports the result of an SLS or of an MID, it is equal to the number of frames received during the sector sweep, or the number of PPDUs used during the MID subphase.

The SNR subfield levels are unsigned integers referenced to a level of –8 dB. Each step is 0.25 dB. SNR values less than or equal to –8 dB are represented as 0. SNR values greater than or equal to 55.75 dB are represented as 0xFF.

The format of each channel measurement is specified in Table 9-304 (Channel measurement).

**Table 9-304—Channel measurement**

| Field | Size | Meaning |
|---|---|---|
| Relative I Component Tap #1 | 8 bits | The in-phase component of impulse response for Tap #1, relative to the amplitude of the strongest tap measured. |
| Relative Q Component Tap #1 | 8 bits | The quadrature component of impulse response for Tap #1, relative to the amplitude of the strongest tap measured. |
| Relative I Component Tap #2 | 8 bits | The in-phase component of impulse response for Tap #2, relative to the amplitude of the strongest tap measured. |
| Relative Q Component Tap #2 | 8 bits | The quadrature component of impulse response for Tap #2, relative to the amplitude of the strongest tap measured. |
| … | | |
| Relative I Component Tap #$N_{taps}$ | 8 bits | The in-phase component of impulse response for Tap #$N_{taps}$, relative to the amplitude of the strongest tap measured. |
| Relative Q Component Tap #$N_{taps}$ | 8 bits | The quadrature component of impulse response for Tap #$N_{taps}$, relative to the amplitude of the strongest tap measured. |

Each channel measurement contains $N_{taps}$ channel impulse taps. The channel impulse response reported for all $N_{meas}$ measurements correspond to a common set of relative tap delays. If the Tap Delay subfield is not present, then the $N_{taps}$ channel taps is interpreted as consecutive time samples, separated by $T_c$. Selection of which taps are sent is implementation dependent. The delay values in the Tap Delay subfield, when present, correspond to the strongest taps and are unsigned integers, in increments of $T_c$, starting from 0. Each channel tap is reported as an in-phase and quadrature component pair, with each component value represented as a 2s complement number between –128 and 127. Unless all in-phase and quadrature component values are reported as zero, they are scaled such that the two most significant bits for at least one of the component values equal 01 or 10 (binary). The same scale applies to all measurements over all TRN subfields.

The Sector ID Order subfield indicates the TX sector IDs corresponding to the SNRs in the SNR subfield when the SNR Present subfield is set to 1 and Sector ID Order Present subfield is set to 1, in response to a BRP PPDU with the SNR Requested subfield set to 1. The Sector ID Order subfield indicates the TX sector IDs ranked in the decreasing order of link quality, as measured on a preceding sector sweep, MID, or BC phase, determined in an implementation dependent manner, when the SNR Present subfield is set to 0 and the Sector ID Order Present subfield is set to 1 in response to setting the SNR Requested subfield to 0 and the Sector ID Order Requested subfield to 1. The FBCK-REQ field and the FBCK TYPE field in the DMG

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Beam Refinement element are used by the transmitter and receiver to, respectively, request for and indicate the sector IDs and their order.

(11ay)If both the Channel Aggregation Present field and the EDMG Extension Flag field in the accompanying DMG Beam Refinement element are 1 or if the Channel Aggregation Present field in the accompanying MIMO Feedback Control element is 1, the following apply:

— The SNR and Channel Measurement fields are for the channel that includes the primary channel in case of channel aggregation. Otherwise, the SNR and Channel Measurement fields are for the channel in which the measurement is taken.

— The Additional SNR and Additional Channel Measurement fields are for the channel that does not include the primary channel in case of channel aggregation. Otherwise, the Additional SNR and Additional Channel Measurement fields are not present.

(11ay)If an EDMG Channel Measurement Feedback element is present in the same frame as a Channel Measurement Feedback element, the interpretation of each $SNR_i$, Channel $Measurement_i$, Tap $Delay_i$, Additional $SNR_i$ and Additional Channel $Measurement_i$ fields, $1 \le i \le N_{meas}$, is associated to the $i^{th}$ entry within the EDMG Sector ID Order field of the EDMG Channel Measurement Feedback element.

### 9.4.2.136 Awake Window element

The Awake Window element is defined as shown in Figure 9-663 (Awake Window element format).

| | Element ID | Length | Awake Window Duration | EDMG Awake Window Duration(11ay) |
|---|---|---|---|---|
| Octets: | 1 | 1 | 2 | 2 |

**Figure 9-663—Awake Window element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The Awake Window Duration field contains the duration of the awake windows(#3110) in microseconds.

(11ay)The EDMG Awake Window Duration field contains the duration, in microseconds, of the awake window for the CBAP allocations scheduled through the EDMG Extended Schedule element.

### 9.4.2.137 Multi-band element

The Multi-band element indicates that the STA transmitting this element (the transmitting STA) is within a multi-band device capable of operating in a frequency band or operating class or channel other than the one in which this element is transmitted. In addition, if used as part of a fast session transfer, this element indicates that the transmitting STA is able to accomplish a fast session transfer from the current channel to a channel using another STA in the same device, in the other or same band. The format of the Multi-band element is shown in Figure 9-664 (Multi-band element format).

| | Element ID | Length | Multi-band Control | Band ID | Operating Class | Channel Number | BSSID | Beacon Interval |
|---|---|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 1 | 1 | 1 | 6 | 2 |

The Element ID and Length fields are defined in 9.4.2.1 (General).



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| | TSF Offset | Multi-band Connection Capability | FSTSessionTimeout | STA MAC Address (optional) | Pairwise Cipher Suite Count (optional) | Pairwise Cipher Suite List (optional) |
|---|---|---|---|---|---|---|
| Octets: | 8 | 1 | 1 | 0 or 6 | 0 or 2 | 4 × *m* |

**Figure 9-664—Multi-band element format**

The format of the Multi-band Control field is shown in Figure 9-665 (Multi-band Control field format).

| | B0 B2 | B3 | B4 | B5 | B6 | B7 |
|---|---|---|---|---|---|---|
| | STA Role | STA MAC Address Present | Pairwise Cipher Suite Present | FST Not Supported | OCT Not Supported | Discovery Assistance Enabled(11av) |
| Bits: | 3 | 1 | 1 | 1 | 1 | 1 |

**Figure 9-665—Multi-band Control field format**

The STA Role subfield specifies the role the transmitting STA plays on the channel of the operating class indicated in this element. The possible values of the STA Role subfield are indicated in Table 9-305 (STA Role subfield values).

**Table 9-305—STA Role subfield values**

| STA role | Value |
|---|---|
| AP | 0 |
| TDLS STA | 1 |
| IBSS STA | 2 |
| PCP | 3 |
| Non-PCP and Non-AP STA | 4 |
| Reserved | 5–7 |

NOTE—A STA can perform in more than one role in a channel, and the STA Role subfield identifies the role that is most relevant for the STA for that channel.

The STA MAC Address Present subfield indicates whether the STA MAC Address subfield is present in the Multi-band element. If the present subfield is set to 1, the STA MAC Address subfield is present. If the STA MAC Address Present subfield is set to 0, the STA MAC Address subfield is not present.

The Pairwise Cipher Suite Present subfield indicates whether the Pairwise Cipher Suite Count field and the Pairwise Cipher Suite List field are present in the Multi-band element. If the Pairwise Cipher Suite Present subfield is set to 1, the Pairwise Cipher Suite Count field and the Pairwise Cipher Suite List field are present. If the Pairwise Cipher Suite Present subfield is set to 0, the Pairwise Cipher Suite Count field and the Pairwise Cipher Suite List field are not present.

The FST Not Supported subfield is set to 1 to indicate that FST protocol (see 11.31.3 (FST setup protocol)) is not supported. The FST protocol is supported otherwise.

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The OCT Not Supported subfield is set to 1 to indicate that OCT (see 11.31.5 (On-channel Tunneling (OCT) operation)) is not supported. OCT is supported otherwise.

(11ay)The Discovery Assistance Enabled subfield indicates whether the STA supports the multi-band discovery assistance procedure for the BSS defined by the BSSID field on the channel defined by the Band ID field, the Operating Class field, and the Channel Number field. The Discovery Assistance Enabled subfield is set to 1 if the BSS specified in the element is a DMG BSS and if dot11DiscoveryAssistanceActivated is true. The subfield is set to 0 otherwise.

The Band ID field provides the identification of the frequency band related to the Operating Class and Channel Number fields. The Band ID field is defined in 9.4.1.43 (Band ID field).

The Operating Class field indicates the channel set for which the Multi-band element applies. The Operating Class and Channel Number fields together specify the channel frequency and spacing for which the Multi-band element applies. Valid values of the Operating Class field are shown in Annex E. This field is set to 0 to indicate all operating classes within the frequency band specified by the Band ID field.

The Channel Number field is set to the number of the channel the transmitting STA is operating on or intends to operate on. This field is set to 0 to indicate all channels within the frequency band specified by the Band ID field.

The BSSID field specifies the BSSID of the BSS operating on the channel and frequency band indicated by the Channel Number and Band ID fields. When used as part of the on-channel tunneling operation (see 11.31.5 (On-channel Tunneling (OCT) operation)), this field can contain the wildcard BSSID.

The Beacon Interval field specifies the size of the beacon interval for the BSS operating on the channel and frequency band indicated by the Channel Number and Band ID fields. This field is set to 0 if no BSS is in operation in the indicated channel and frequency band.

If the transmitting STA is a member of a PBSS or infrastructure BSS on both the channel indicated in this element and the channel on which the element is transmitted, then the TSF Offset field contains the time offset of the TSF of the PBSS or infrastructure BSS of which the transmitting STA is member on the channel indicated in this element relative to the TSF of the PBSS or infrastructure BSS corresponding to the BSSID indicated in the Address 3 field of the MPDU in which this element is transmitted. The TSF Offset field is specified as a 2s complement integer in microsecond units. If the transmitting STA is not a member of an infrastructure BSS or PBSS on both the channel indicated in this element and the channel on which the element is transmitted, then the TSF Offset field contains the value 0.

The Multi-band Connection Capability field is defined in Figure 9-666 (Multi-band Connection Capability field format). The Multi-band Connection Capability field indicates the connection capabilities supported by the STA on the channel and band indicated in this element.

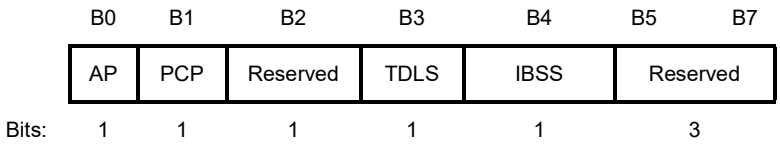


**Figure 9-666—Multi-band Connection Capability field format**


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The AP subfield specifies whether the STA can function as an AP on the channel and band indicated in the element. It is set to 1 when the STA is capable to function as an AP, and it is set to 0 otherwise.

The PCP subfield specifies whether the STA can function as a PCP on the channel and band indicated in the element. It is set to 1 when the STA is capable to function as a PCP, and it is set to 0 otherwise.

The TDLS subfield is set to 1 to indicate that the STA can perform a TDLS on the channel and band indicated in the element. Otherwise, it is set to 0.

The IBSS subfield is set to 1 to indicate that the STA is able to support IBSS on the channel and band indicated in the element. Otherwise, it is set to 0.

The FSTSessionTimeout field is used in the FST Setup Request frame to indicate the timeout value for FST session setup protocol as defined in 11.31.1 (General). The FSTSessionTimeout field contains the duration, in TUs, after which the FST setup is terminated. The FSTSessionTimeout field is reserved if the FST Not Supported subfield is 1.

The STA MAC Address field contains the MAC address that the transmitting STA uses while operating on the channel indicated in this element. The STA MAC Address field is not present in this element if the STA MAC Address Present field is set to 0.

The Pairwise Cipher Suite Count field and the Pairwise Cipher Suite List field are defined in 9.4.2.23 (RSNE). These fields are not present in this element if the Pairwise Cipher Suite Present subfield is set to 0.

### 9.4.2.138 ADDBA Extension element

The ADDBA Extension element is shown in Figure 9-667 (ADDBA Extension element format).

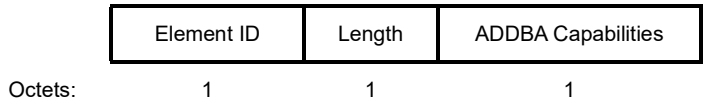


**Figure 9-667—ADDBA Extension element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The ADDBA Capabilities field is shown in Figure 9-668 (ADDBA Capabilities field format(11ax)).

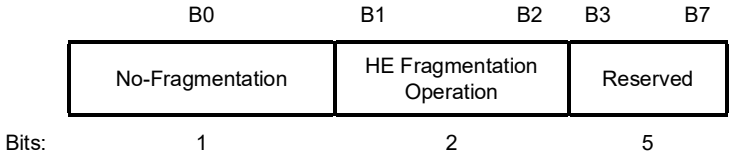


**Figure 9-668—ADDBA Capabilities field format(11ax)**

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The ADDBA Extension element can be included in the ADDBA Request and Response frames.

The No-Fragmentation subfield determines whether a fragmented MSDU can be carried in the MPDU sent under the block ack agreement. (#8202)If this subfield set to 1 in the ADDBA Request frame, it indicates that the non-HE originator is not fragmenting sent MSDUs. If this subfield set to 1 in the ADDBA Response frame, it indicates that the non-HE recipient is not capable of receiving fragmented MSDUs. The No-Fragmentation subfield is reserved when transmitted by (#8203)a non-DMG STA.(11ax)

(11ax) If transmitted by an HE STA, the HE Fragmentation Operation subfield indicates the level of dynamic fragmentation that is under negotiation for the TID indicated in the ADDBA frame as defined in Table 9-306 (HE Fragmentation Operation subfield(11ax)).

**Table 9-306—HE Fragmentation Operation subfield(11ax)**

| Value | Meaning in ADDBA Request frame | Meaning in ADDBA Response frame |
|---|---|---|
| 0 | The originator does not intend to send fragmented MSDUs or A-MSDUs (if supported by the transmitter) for the TID specified in the Block Ack Parameter Set field of the ADDBA Request frame. | The recipient does not support the reception fragmented MSDUs or A-MSDUs for the TID specified in the Block Ack Parameter Set field of the ADDBA Response frame. |
| 1 | The originator intends to send fragmented MSDUs or A-MSDU (if supported by the transmitter) under fragmentation level 1 (see 26.3.2.2 (Level 1 dynamic fragmentation)) for the TID specified in the Block Ack Parameter Set field of the ADDBA Request frame. | The recipient supports the reception of fragmented MSDUs or A-MSDU (if supported) under fragmentation level 1 only for the TID specified in the Block Ack Parameter Set field of the ADDBA Response frame. |
| 2 | The originator intends to send fragmented MSDUs or A-MSDUs (if supported by the transmitter) under fragmentation level 2 (see 26.3.2.3 (Level 2 dynamic fragmentation)) for the TID specified in the Block Ack Parameter Set field of the ADDBA Request frame. | The recipient supports the reception of receiving fragmented MSDUs or A-MSDU (if supported) under fragmentation levels 1 and 2 for the TID specified in the Block Ack Parameter Set field of the ADDBA Response frame. |
| 3 | The originator intends to send fragmented MSDUs or A-MSDUs (if supported by the transmitter) under fragmentation level 3 (see 26.3.2.4 (Level 3 dynamic fragmentation)) for the TID specified in the Block Ack Parameter Set field of the ADDBA Request frame. | The recipient supports the reception of fragmented MSDUs or A-MSDU (if supported) under fragmentation levels 1, 2 and 3 for the TID specified in the Block Ack Parameter Set field of the ADDBA Response frame. |

### 9.4.2.139 Next PCP List element

The Next PCP List element contains one or more AID of NextPCP *i* fields as shown in Figure 9-669 (Next PCP List element format).

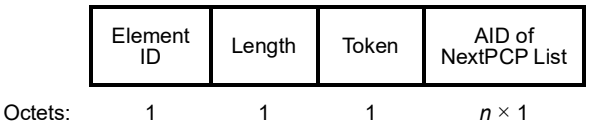


**Figure 9-669—Next PCP List element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).


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The Token field is set to 0 when the PBSS is initialized and incremented each time the sequence of AID of NextPCP *i* fields is updated.

The AID of NextPCP List field contains one or more (*n*) AID of NextPCP fields.

Each AID of NextPCP field contains the AID value of a STA. The AID values are listed in the order described in 11.27.2 (PCP Handover).

### 9.4.2.140 PCP Handover element

The PCP Handover element is used to indicate the STA becoming the new PCP following an explicit or implicit handover procedure. The PCP Handover element is defined in Figure 9-670 (PCP Handover element format).

| | Element ID | Length | Old BSSID | New PCP Address | Remaining BIs |
|---|---|---|---|---|---|
| Octets: | 1 | 1 | 6 | 6 | 1 |

**Figure 9-670—PCP Handover element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The Old BSSID field contains the BSSID of the PBSS from which control is being handed over.

The New PCP Address field indicates the MAC address of the new PCP following a handover.

The Remaining BIs field indicates the number of beacon intervals, from the beacon interval in which this element is transmitted, remaining until the handover takes effect.

### 9.4.2.141 DMG Link Margin element

#### 9.4.2.141.1 General

The format of the DMG Link Margin element is shown in Figure 9-671 (DMG Link Margin element format). The DMG Link Margin element is included in a Link Measurement Report frame.

| | Element ID | Length | Activity | MCS | Link Margin | SNR | Reference Timestamp |
|---|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 1 | 1 | 1 | 4 |

| | Rate Adaptation Control/ Extended TPC(11ay) | RX Chain Statistics(11ay) | PPDU Statistics(11ay) | LDPC Statistics(11ay) | SC/OFDM Statistics(11ay) | Extended TPC(11ay) |
|---|---|---|---|---|---|---|
| Octets: | 5 | 0 or $N_{RX}$ | 0 or 3×$N_{STS}$ | 0 or 8 | 0 or 4×$N_{STS}$ | 0 or 2×$N_{STS}$ |

**Figure 9-671—DMG Link Margin element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The Activity field is set to a preferred action that the STA sending this element recommends that the peer STA indicated in the RA field of the Link Measurement Report frame execute. The method by which the

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sending STA determines a suitable action for the peer STA is implementation specific. The Activity field is defined in 9.4.2.141.2 (Activity field).

The MCS field is set to an integer representation of the MCS that the STA sending this element recommends that the peer STA indicated in the RA field of the Link Measurement Report frame use to transmit frames to this STA. The reference PER for selection of the MCS is $10^{-2}$ for an MPDU length of 4096 octets. The method by which the sending STA determines a suitable MCS for the peer STA is implementation specific. Values 0–12 and values 25–31 indicate MCS 0 to MCS 12 and MCS 25 to MCS 31, respectively. Values 133, 134, 135, 136, 137, 138, and 140 indicate MCSs 12.1, 9.1, 12.3, 12.4, 12.5, 12.2, and 12.6, respectively. The MCS field is reserved when the value of the Number of Space-Time Streams Reported (NSTS) subfield within the Rate Adaptation Control/Extended TPC field is greater than 1.(11ay)

The Link Margin field contains the measured link margin of Data frames received from the peer STA indicated in the RA field of the Link Measurement Report frame and is coded as a 2s complement signed integer in units of decibels. This field is set to –128 to indicate that no link margin is provided. The method used to estimate the link margin is beyond the scope of this standard. The Link Margin field is reserved when the value of the Number of Space-Time Streams Reported (NSTS) subfield within the Rate Adaptation Control/Extended TPC field is greater than 1.(11ay)

The SNR field indicates the SNR measured during the reception of a PPDU. Values are from –13 dB to 50.75 dB in 0.25 dB steps. The SNR field is reserved when the value of the Number of Space-Time Streams Reported (NSTS) subfield within the Rate Adaptation Control/Extended TPC field is greater than 1.(11ay)

The Reference Timestamp field contains the lower 4 octets of the TSF timer value sampled at the instant that the MAC received the PHY-CCA.indication(IDLE) primitive that corresponds to the end of the reception of the PPDU that was used to generate the feedback information contained in the Link Measurement Report frame.

(11ay)The Rate Adaptation Control/Extended TPC field contains the number of space-time streams reported and indications of whether the element includes optional fields used for rate adaptation and TPC. The Rate Adaptation Control/Extended TPC field is defined in 9.4.2.141.3 (Rate Adaptation Control/Extended TPC field(11ay)).

(11ay)The RX Chain Statistics field is optionally present and is defined in 9.4.2.141.4 (RX Chain Statistics field(11ay)).

(11ay)The PPDU Statistics field is optionally present and is defined in 9.4.2.141.5 (PPDU Statistics field(11ay)).

(11ay)The LDPC Statistics field is optionally present and is defined in 9.4.2.141.6 (LDPC Statistics field(11ay)).

(11ay)The SC/OFDM Statistics field is optionally present and is defined in 9.4.2.141.7 (SC/OFDM Statistics field(11ay)).

(11ay)The Extended TPC field is optionally present and is defined in 9.4.2.141.8 (Extended TPC(11ay)).


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#### 9.4.2.141.2 Activity field

The Activity field values are defined in Table 9-307 (Activity field values).

**Table 9-307—Activity field values**

| Preferred Action value | Meaning |
|---|---|
| 0 | No change preferred |
| 1 | Change(d) MCS |
| 2 | Decrease(d) transmit power |
| 3 | Increase(d) transmit power |
| 4 | Fast session transfer (FST) |
| 5 | Power conserve mode |
| 6 | Perform SLS |
| 7–255 | Reserved |

#### 9.4.2.141.3 Rate Adaptation Control/Extended TPC field(11ay)

The Rate Adaptation Control/Extended TPC field format is defined in Figure 9-672 (Rate Adaptation Control/Extended TPC field format(11ay)).

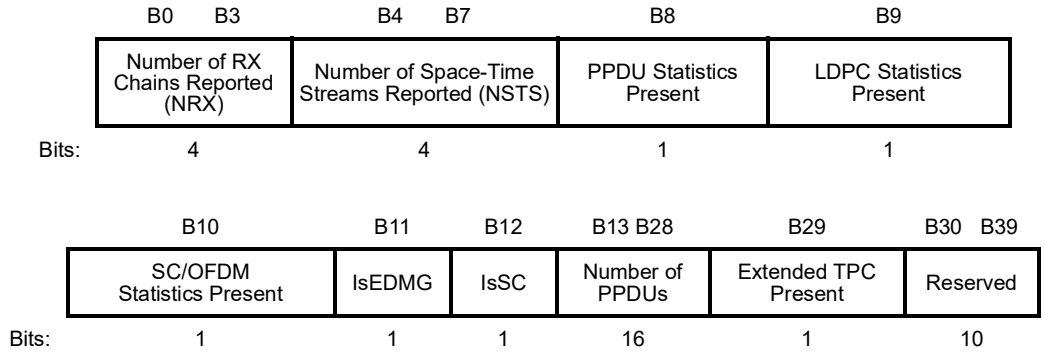


**Figure 9-672—Rate Adaptation Control/Extended TPC field format(11ay)**

The Number of RX Chains Reported (NRX) subfield indicates the number of RX chain entries being reported. Each entry, *i*, corresponds to an RX chain *i*.

The Number of Space-Time Streams Reported (NSTS) subfield indicates the number of space-time streams being reported. Each entry, *i*, corresponds to a space-time stream. If the value of this subfield is greater than 0, the MCS, Link Margin and SNR fields in the DMG Link Margin element are reserved. For a non-EDMG STA, the value of this subfield does not exceed 1.

The PPDU Statistics Present subfield is set to 1 if the DMG Link Margin element contains the PPDU Statistics field. It is set to 0 otherwise.

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The LDPC Statistics Present subfield is set to 1 if the DMG Link Margin element contains the LDPC Statistics field. It is set to 0 otherwise.

The SC/OFDM Statistics Present subfield is set to 1 if the DMG Link Margin element contains the SC/OFDM Statistics field. It is set to 0 otherwise.

The IsEDMG subfield is used to indicate whether the value in the MCS field in the DMG Link Margin element corresponds to the DMG PHY (20 (Directional multi-gigabit (DMG) PHY specification)) or the EDMG PHY (Clause 28 (Enhanced directional multi-gigabit (EDMG) PHY specification(11ay))). It is set to 1 for the EDMG PHY and to 0 for the DMG PHY.

The IsSC subfield is used to indicate whether the value in the MCS field corresponds to SC modulation or OFDM modulation. It is set to 1 for SC and to 0 for OFDM.

The Number of PPDUs subfield contains the number of PPDUs over which the reported statistics were measured.

The Extended TPC Present subfield is set to 1 if the DMG Link Margin element contains the Extended TPC field. It is set to 0 otherwise.

#### 9.4.2.141.4 RX Chain Statistics field(11ay)

The RX Chain Statistics field is defined in Figure 9-673 (RX Chain Statistics field format(11ay)). This field is present in the DMG Link Margin element when the Number of RX Chains Reported (NRX) subfield within the Rate Adaptation Control field is nonzero.

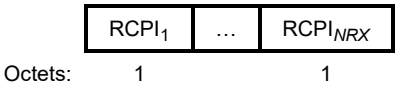


**Figure 9-673—RX Chain Statistics field format(11ay)**

Each $RCPI_i$ subfield, $1 \le i \le N_{RX}$, where $N_{RX}$ is the value of the Number of RX Chains Reported subfield within the Rate Adaptation Control/Extended TPC field, contains the RCPI (see 20.3.10 (Received channel power indicator (RCPI) measurement) and 28.3.9.2 (Received channel power indicator (RCPI) measurement)) for the $i^{th}$ RF chain averaged across all PSDUs received within a report interval intended for the STA, and where the PSDUs are transmitted using an MCS other than MCS 0 or EDMG MCS 0. The value of the subfield is found by computing the arithmetic mean of the RF power measurements in mW, converting the result to dBm, and encoding the dBm value as defined in 9.4.2.36 (RCPI element).

#### 9.4.2.141.5 PPDU Statistics field(11ay)

The PPDU Statistics field is defined in Figure 9-674 (PPDU Statistics field format(11ay)).

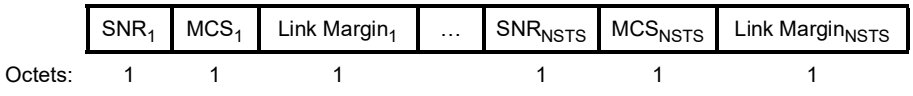


**Figure 9-674—PPDU Statistics field format(11ay)**

Each $SNR_i$ subfield, $1 \le i \le N_{STS}$, where $N_{STS}$ is the value of the Number of Space-Time Streams Reported subfield within the Rate Adaptation Control/Extended TPC field, contains the SNR of space-time stream $i$ averaged across all PSDUs received within a report interval intended for the STA, and where the PSDUs are


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transmitted using an MCS other than MCS 0 or EDMG MCS 0. The value of the subfield is found by computing the arithmetic mean of the PPDU signal-to-noise ratios with signal and noise power in mW, converting the result to dB, and encoding the dB value in the same way as the SNR field in the Channel Measurement Feedback element. If the Number of PPDUs subfield within the Rate Adaptation Control/ Extended TPC field is 0 and the PPDU Statistics field is present, the $SNR_i$ subfield is set to 0xFF.

Each MCS*i* subfield, $1 \le i \le N_{STS}$, where $N_{STS}$ is the value of the Number of Space-Time Streams Reported subfield within the Rate Adaptation Control/Extended TPC field, contains the MCS of space-time stream *i*. This subfield is used to indicate the MCS that was used to collect the values within the LDPC Statistics field or SC/OFDM Statistics field. If the Number of PPDUs subfield within the Rate Adaptation Control/ Extended TPC field is 0 and the PPDU Statistics field is present, the $MCS_i$ subfield is set to 0xFF.

Each Link $Margin_i$ subfield, $1 \le i \le N_{STS}$, where $N_{STS}$ is the value of the Number of Space-Time Streams Reported subfield within the Rate Adaptation Control/Extended TPC field, contains the link margin measured on space-time stream *i* and averaged across all PPDUs received within a report interval intended for the STA, and where all the PPDUs are transmitted using an MCS other than MCS 0 or EDMG MCS 0. The value of the subfield is found by computing the arithmetic mean of link margin values in decibels, and encoding the result as a 2s complement signed integer in units of decibels. A value of –128 indicates that no link margin is provided. The method used to estimate the link margin is beyond the scope of this standard. If the Number of PPDUs subfield within the Rate Adaptation Control/Extended TPC field is 0 and the PPDU Statistics field is present, the Link $Margin_i$ subfield is set to –128.

#### 9.4.2.141.6 LDPC Statistics field(11ay)

The LDPC Statistics field is defined in Figure 9-675 (LDPC Statistics field format(11ay)).

| | Average Iterations | Max Iterations | Nonzero Syndromes | Number of LDPC Codewords |
|---|---|---|---|---|
| Octets: | 1 | 1 | 3 | 3 |

**Figure 9-675—LDPC Statistics field format(11ay)**

The Average Iterations subfield indicates the average number of iterations used by the LDPC decoder on PSDUs received within a report interval intended for the STA, and where all PSDUs are transmitted using an MCS other than MCS 0 or EDMG MCS 0. One iteration includes processing of all rows. The value of the subfield is found by computing the arithmetic mean of number of iterations across all LDPC codewords in each PSDU, and across all PSDUs in the measurement set, and encoding as an 8 bit unsigned integer with 0 to 255 representing 0.0 to +25.5 iterations in 0.1 steps.

The Max Iteration subfield indicates the maximum number of iterations used by the LDPC decoder on PSDUs received with an MCS different from MCS 0 or EDMG MCS 0. One iteration includes processing of all rows. The value of the subfield is the maximum number of iterations across all LDPC codewords in each PSDU, and across all PSDUs in the measurement set, encoded as an 8 bit unsigned integer with 0 to 255 representing 0.0 to +25.5 iterations in 0.1 steps.

NOTE—The fractional part of the Max Iteration subfield represents the ratio of processed rows to total number of rows.

The Nonzero Syndromes subfield indicates the number of LDPC codewords with nonzero syndrome, summed across all PSDUs received within a report interval intended for the STA, and where the PSDUs are transmitted using an MCS other than MCS 0 or EDMG MCS 0.

The Number of LDPC Codewords subfield indicates the number of processed LDPC codewords using an MCS different from MCS 0 and included in the Average Iterations, Max Iterations and Nonzero Syndromes subfield statistics. The value is saturated to $2^{24} - 1$ if it overflows.

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### 9.4.2.141.7 SC/OFDM Statistics field(11ay)

The SC/OFDM Statistics field is defined in Figure 9-676 (SC/OFDM Statistics field format(11ay)).

| | $EVM_1$ | Number of SC Blocks/OFDM $Symbols_1$ | … | $EVM_{NSTS}$ | Number of SC Blocks/OFDM $Symbols_{NSTS}$ |
|---|---|---|---|---|---|
| Octets: | 1 | 3 | | 1 | 3 |

**Figure 9-676—SC/OFDM Statistics field format(11ay)**

Each $EVM_i$ subfield, $1 \le i \le N_{STS}$, where $N_{STS}$ is the value of the Number of Space-Time Streams Reported subfield within the Rate Adaptation Control/Extended TPC field, indicates the EVM of the SC data symbols or OFDM data subcarriers for PSDUs of space-time stream $i$ received within a report interval intended for the STA, and where the PSDUs are transmitted using an MCS other than MCS 0 or EDMG MCS 0. The value of the subfield is found by computing the arithmetic mean of EVM values in dB, across all SC data symbols or OFDM data subcarriers in each PSDU, and across all PSDUs in the measurement set, and encoding the result as an 8 bit unsigned integer with 0 to 255 representing –5.0 dB to +46.0 dB in 0.2 dB steps.

Each Number of SC Blocks/OFDM $Symbols_i$ subfield, $1 \le i \le N_{STS}$, where $N_{STS}$ is the value of the Number of Space-Time Streams Reported subfield within the Rate Adaptation Control/Extended TPC field, indicates the count of the SC blocks or OFDM symbols of space-time stream $i$ included in the average EVM value. The value is saturated to $2^{24} - 1$ if it overflows.

### 9.4.2.141.8 Extended TPC(11ay)

The Extended TPC field is defined in Figure 9-677 (Extended TPC field format(11ay)).

| | Extended $Activity_1$ | Extended Activity $Parameter_1$ | … | Extended $Activity_{NSTS}$ | Extended Activity $Parameter_{NSTS}$ |
|---|---|---|---|---|---|
| Octets: | 1 | 1 | | 1 | 1 |

**Figure 9-677—Extended TPC field format(11ay)**

The Extended $Activity_i$ subfield, $1 \le i \le N_{STS}$, where $N_{STS}$ is the value of the Number of Space-Time Streams Reported subfield within the Rate Adaptation Control/Extended TPC field, indicates the following:

— An action that the sending STA recommends that the peer STA performs for space-time stream $i$.

— Information about space-time stream $i$ that is helpful to the peer STA when performing TPC.

The method by which the sending STA determines a suitable action for the peer STA is implementation specific.

Each Extended Activity subfield is followed by an Extended Activity Parameter subfield. The Extended Activity and Extended Activity Parameter subfields are defined in Table 9-308 (Extended Activity and Extended Activity Parameter subfields definition(11ay)).

The sending STA should report link margin values through the PPDU Statistics field (see 9.4.2.141.5 (PPDU Statistics field(11ay))) if the field is present, and through the Extended TPC field otherwise.

NOTE—The link margin values in the PPDU Statistics field are calculated across PPDUs in a report interval and combined as described in 9.4.2.141.5 (PPDU Statistics field(11ay)). The link margin values in the Extended TPC field are implementation dependent.


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**Table 9-308—Extended Activity and Extended Activity Parameter subfields definition(11ay)**

| Extended Activity subfield value | Definition | Extended Activity Parameter subfield definition |
|---|---|---|
| 0 | No action | Reserved |
| 1 | Change MCS | Requested MCS for space-time stream *i*. |
| 2 | Increase/decrease transmit power | Change in transmit power for space-time stream *i* in units of 0.25 dB, and encoded as an 8-bit 2s complement signed integer. The encoding covers the range from –32 dB to 31.75 dB in 0.25 dB steps. |
| 3 | Link margin | Link margin for space-time stream *i* in units of dB, and encoded as 2s complement signed integer. The method used to estimate the link margin is beyond the scope of this standard. |
| 4–255 | Reserved | Reserved |

### 9.4.2.142 DMG Link Adaptation Acknowledgment element

The format of the DMG Link Adaptation Acknowledgment element is shown in Figure 9-678 (DMG Link Adaptation Acknowledgment element format). The DMG Link Adaptation Acknowledgment element is carried in the Optional Subelements field of the Link Measurement Report frame.

| | Element ID | Length | Activity | Reference Timestamp | Extended TPC Control(11ay) | Extended TPC Link Adaptation Acknowledgment(11ay) |
|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 4 | 1 | $2\times N_{STS}$ |

**Figure 9-678—DMG Link Adaptation Acknowledgment element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The Activity field is set to the action that the STA sending this element has executed following the reception of the recommended activity in a Link Measurement Report frame. The method by which the sending STA determines the action is described in 10.41.9 (CDMG enhanced beam tracking) and the Activity field is defined in 9.4.2.141.2 (Activity field).

The Reference Timestamp field contains the lower 4 octets of the TSF timer value sampled at the instant that the MAC received the PHY-CCA.indication(IDLE) primitive that corresponds to the end of the reception of the PPDU that was used to generate the feedback information contained in the Link Measurement Report frame.

(11ay)The format of the Extended TPC Control field is shown in Figure 9-679 (Extended TPC Control field format(11ay)).

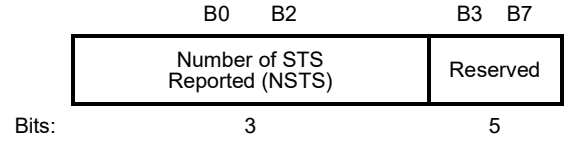


**Figure 9-679—Extended TPC Control field format(11ay)**

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(11ay)The Number of STS Reported (NSTS) subfield is optionally present. If present, it indicates the number of STS being reported in the Extended TPC Link Adaptation Acknowledgment field. If the value of this field is greater than 0, the Activity field in the DMG Link Adaptation Acknowledgment element is reserved.

(11ay)The Extended TPC Link Adaptation Acknowledgment field is present if the value of the Number of STS Reported (NSTS) subfield is greater than 0, and its format is shown in Figure 9-680 (Extended TPC Link Adaptation Acknowledgment field format(11ay)).

| | Extended Activity Acknowledgment$_1$ | Extended Activity Acknowledgment Parameter$_1$ | … | Extended Activity Acknowledgment$_{NSTS}$ | Extended Activity Acknowledgment Parameter$_{NSTS}$ |
|---|---|---|---|---|---|
| Octets: | 1 | 1 | | 1 | 1 |

**Figure 9-680—Extended TPC Link Adaptation Acknowledgment field format(11ay)**

(11ay)Each Extended Activity Acknowledgment$_i$ subfield, $1 \le i \le N_{STS}$, is set to the action that the STA sending this element has taken for the STS $i$ following the reception of the extended activity in a Link Measurement Report frame. The method by which the sending STA determines the action is described in 10.42 (DMG link adaptation).

(11ay)Each Extended Activity Acknowledgment Parameter$_i$ subfield, $1 \le i \le N_{STS}$, contains the parameter associated with the Extended Activity Acknowledgment$_i$ subfield for space-time stream $i$. If the Extended Activity Acknowledgment$_i$ subfield is 1, the Extended Activity Acknowledgment Parameter$_i$ subfield contains the transmit power change that was done for space-time stream $i$, in units of 0.25 dB and encoded as an 8-bit 2s complement signed integer. The encoding covers the range from –32 dB to 31.75 dB in 0.25 dB steps. If the Extended Activity Acknowledgment$_i$ subfield is 0, no change is indicated. All other values for Extended Activity Acknowledgment$_i$ subfield are reserved.

### 9.4.2.143 Switching Stream element

The Switching Stream element indicates the streams that the transmitting STA requests to be switched to a new frequency band or operating class or channel. The format of the Stream Switching element is shown in Figure 9-681 (Switching Stream element format).

| | Element ID | Length | Old Band ID | New Band ID | Non-QoS Data Frames | Number of Streams Switching | Switching Parameters |
|---|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 1 | 1 | 1 | 2 × Number of Streams Switching |

**Figure 9-681—Switching Stream element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The Old Band ID field specifies the frequency band to which the information carried in this element is related. This field is defined in 9.4.1.43 (Band ID field).

The New Band ID field specifies the frequency band to which the information contained in the Stream ID In New Band subfield of this element is related. This field is defined in 9.4.1.43 (Band ID field).

The Non-QoS Data Frames field specifies whether non-QoS Data frames can be transmitted in the frequency band indicated in the New Band ID field. If the Non-QoS Data Frames field is equal to 0, non-QoS Data


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frames cannot be transmitted in the frequency band indicated in the New Band ID field. If the Non-QoS Data Frames field is equal to 1, non-QoS Data frames can be transmitted in the frequency band indicated in the New Band ID field.

The Number of Streams Switching field specifies the number of streams to be switched.

The format of Switching Parameters field is shown in Figure 9-682 (Switching Parameters field format).

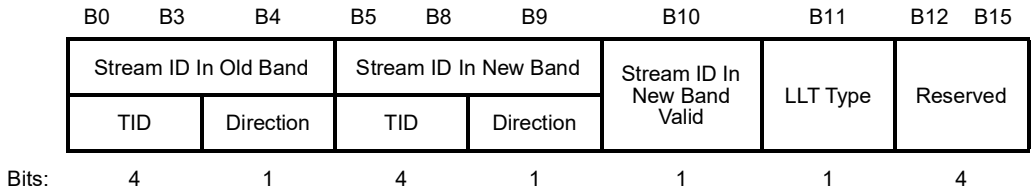


**Figure 9-682—Switching Parameters field format**

The Stream ID In Old Band and Stream ID In New Band subfields are comprised of the TID and Direction subfields. The subfields within the Stream ID In New Band subfield are reserved if the Stream ID In New Band Valid subfield is set to 0.

The TID subfield specifies the stream in the corresponding band.

The Direction subfield specifies whether the STA transmitting this element is the source or destination of the corresponding TID. It is set to 0 to indicate that the STA transmitting this element is the source of the TID, and it is set to 1 otherwise.

The Stream ID In New Band Valid subfield is set to 1 if the information contained in the Stream ID In New Band subfield is valid, that is, the TID specified within the Stream ID In New Band subfield has been established in the band identified in the New Band ID field. The Stream ID In New Band Valid subfield is set to 0 otherwise.

The LLT Type subfield is set to 1 to indicate that the streambased Link Loss Countdown is used for the stream identified by the Stream ID In Old Band subfield. The LLT Type subfield is set to 0 to indicate that the STA-based Link Loss Countdown is used for the stream identified by the Stream ID In Old Band subfield. This subfield is reserved when the LLT field within the FST Setup Request or FST Setup Response frame containing this element is set to 0.

### 9.4.2.144 Session Transition element

The Session Transition element is defined in Figure 9-683 (Session Transition element format).

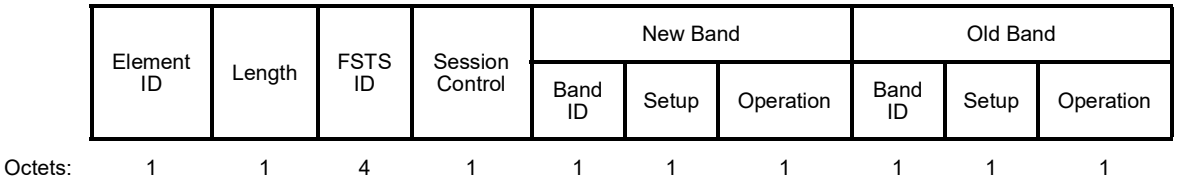


**Figure 9-683—Session Transition element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

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The FSTS ID (fast session transfer session identifier) field contains the identification of the FST session established between a pair of STAs as allocated by the initiator (11.31 (Multi-band operation)).

The Session Control field is defined in Figure 9-684 (Session Control field format(#1729)).

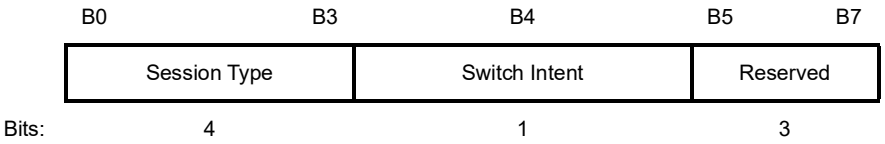


**Figure 9-684—Session Control field format(#1729)**

The Session Type subfield is defined as shown in Table 9-309 (Session Type subfield values) and indicates the type of connection/session that is intended to be set up in the new band for this FST session.

**Table 9-309—Session Type subfield values**

| Value | Session type |
|---|---|
| 0 | Infrastructure BSS |
| 1 | IBSS |
| 2 | Reserved |
| 3 | TDLS |
| 4 | PBSS |
| 5–255 | Reserved |

When the Session Type subfield is set to IBSS and the STA Role subfield within the Multi-band element is set to IBSS STA, the BSSID field within the Multi-band element contains the BSSID. This indicates that the transmitting STA is not associated with an AP on the band and channel indicated in the Multi-band element.

The Switch Intent subfield is set to 1 to indicate that the FST initiator that transmitted the FST Setup Request frame intends to switch to the band/channel indicated within the Band ID subfield of the FST Setup Request frame and in the Multi-band element, even if the fast session transfer does not succeed. Otherwise, this subfield is set to 0. This subfield is reserved when transmitted within an FST Setup Response frame.

The New Band and Old Band subfields are used for the signaling described in 11.31.1 (General). Both the New Band and Old Band subfields contain a Band ID subfield, a Setup subfield, and an Operation subfield.

The Band ID subfield is defined in 9.4.1.43 (Band ID field). If a Multi-band element is present in the frame containing this Session Transition element, the Band ID subfield refers to the Operating Class and Channel Number fields within the Multi-band element provided both of these fields are nonzero.

The Setup subfield is set to 1 to indicate that the STA transmitting this element has an FST session established with the STA that the frame containing this element is addressed and in the band indicated within the Band ID subfield. Otherwise, it is set to 0. Other values are reserved.

The Operation subfield is set to 1 to indicate that the STA is operating in the band indicated within the Band ID subfield. Otherwise, it is set to 0. Other values are reserved.


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### 9.4.2.145 Cluster Report element

The format of the Cluster Report element is shown in Figure 9-685 (Cluster Report element format). The Cluster Report element is included Action frames, such as Announce and Information Response frames, transmitted to the AP or PCP of the BSS. Because the Length field supports only 255 octets of information in an element, the STA can split the content of the Extended Schedule Element field, as described in 9.4.2.130 (Extended Schedule element), in different Cluster Report elements.

| | Element ID | Length | Cluster Report Control | Reported BSSID | Reference Timestamp | Clustering Control |
|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 0 or 6 | 0 or 4 | 0 or 8 |

| | ECAPC Policy Element | Extended Schedule Element | Number of Constraints | Traffic Scheduling Constraint Set |
|---|---|---|---|---|
| Octets: | 0, 13 or 17 | 0 or 17 – *n* | 1 | variable(#213) |

**Figure 9-685—Cluster Report element format**

The value of *n* in Figure 9-685 (Cluster Report element format) is given by the following equation:

$$n = 255 - (2 + S_{RB} + S_{RT} + S_{CC} + S_{EPE} + S_{TSCONST})$$

where

$S_{RB}$ is the size of the Reported BSSID field in octets
$S_{RT}$ is the size of the Reference Timestamp field in octets
$S_{CC}$ is the size of the Clustering Control field in octets
$S_{EPE}$ is the size of the ECAPC Policy Element field in octets
$S_{TSCONST}$ is the size of the Traffic Scheduling Constraint Set field in octets

The Element ID and Length fields are defined in 9.4.2.1 (General).

The Cluster Report Control field is defined in Figure 9-686 (Cluster Report Control field format).

| | B0 | B1 | B2 | B3 | B4 | B5 | B6 | B7 |
|---|---|---|---|---|---|---|---|---|
| | Cluster Request | Cluster Report | Schedule Present | TSCONST Present | ECAPC Policy Enforced | ECAPC Policy Present | Cluster Channel Number | |
| Bits: | 1 | 1 | 1 | 1 | 1 | 1 | 2 | |

**Figure 9-686—Cluster Report Control field format**

The Cluster Request subfield is set to 1 to indicate that the STA is requesting the AP or PCP to start AP or PCP clustering (10.39 (DMG and CMMG AP or PCP clustering)). Otherwise, it is set to 0.

The Cluster Report subfield is set to 1 to indicate that this element contains a cluster report. If this subfield is set to 1, the Reported BSSID, Reference Timestamp and Clustering Control fields are present in this element. Otherwise, if the Cluster Report subfield is set to 0, none of the Reported BSSID, Reference

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Timestamp, Clustering Control, Extended Schedule Element, and Traffic Scheduling Constraint Set fields is present in this element.

The Schedule Present subfield is valid only if the Cluster Report subfield is set to 1; otherwise, it is reserved. The Schedule present subfield is set to 1 to indicate that the Extended Schedule Element field is present in this element. Otherwise, the Extended Schedule Element field is not present in this element.

The TSCONST Present subfield is valid only if the Cluster Report subfield is set to 1; otherwise, it is reserved. The TSCONST Present subfield is set to 1 to indicate that the Number of Constraints field and the Traffic Scheduling Constraint Set field are present in this element. Otherwise, these fields are not present in this element.

The ECAPC Policy Enforced subfield is valid only if the Cluster Report subfield is set to 1; otherwise, it is reserved. The ECAPC Policy Enforced subfield is defined in 9.3.4.2 (DMG Beacon) and contains the ECAPC Policy Enforced subfield received in the DMG Beacon frame that generated this report.

The Cluster Channel Number subfield is set to 0 to indicate that the operating channel of the reported cluster is the common 2.16 GHz channel; it is set to 1 to indicate that the operating channel of the reported AP or PCP cluster is the low frequency 1.08 GHz channel 35 or 37 (see Annex E); it is set to 2 to indicate the operating channel of the reported AP or PCP cluster is the high frequency 1.08 GHz channel 36 or 38; and the value 3 is reserved.

The ECAPC Policy Present subfield is valid only if the Cluster Report subfield is set to 1; otherwise, it is reserved. The ECAPC Policy Present subfield is set to 1 to indicate that the ECAPC Policy Present Element field is present in this element. Otherwise, the ECAPC Policy Present Element field is not present in this element.

The Reported BSSID field contains the BSSID field of the DMG Beacon frame that triggered this report.

The Reference Timestamp field contains the lower 4 octets of the TSF timer value sampled at the instant that the STA's MAC received a DMG Beacon frame that triggered this report.

The Clustering Control field is defined in 9.3.4.2 (DMG Beacon) and contains the Clustering Control received in the DMG Beacon frame that triggered this report.

The ECAPC Policy Element field is defined in 9.4.2.149 (Quiet Period Response element) and contains the ECAPC Policy element obtained from the AP or PCP that sent the DMG Beacon frame that generated this report (see 10.39.4 (Cluster report and rescheduling)).

The Extended Schedule Element field is defined in 9.4.2.130 (Extended Schedule element) and contains a single Extended Schedule element received in the DMG Beacon frame that generated this report. If an Extended Schedule element is not present in the received DMG Beacon frame(#337), this field is set to all 0s.

The Number of Constraints field indicates the number of Constraint subfields contained in the Traffic Scheduling Constraint Set field. This field ranges from 0 to 15. Other values are reserved.

The Traffic Scheduling Constraint Set field contains one or more Constraint subfields as defined in 9.4.2.132 (DMG TSPEC element) and specifies periods of time with respect to the TBTT of the beacon interval of the BSS the STA participates where the STA experiences poor channel conditions, such as due to interference.


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### 9.4.2.146 Relay Capabilities element

(#111)A STA advertises its capabilities through the Relay Capabilities element prior to participation in a relay operation (11.34 (DMG relay procedures)). The Relay Capabilities element is defined in Figure 9-687 (Relay Capabilities element format).

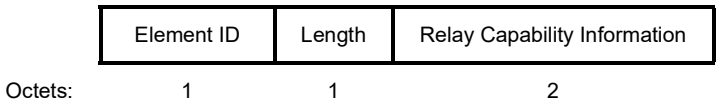


**Figure 9-687—Relay Capabilities element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The Relay Capability Information field is defined in Figure 9-688 (Relay Capability Information field format).

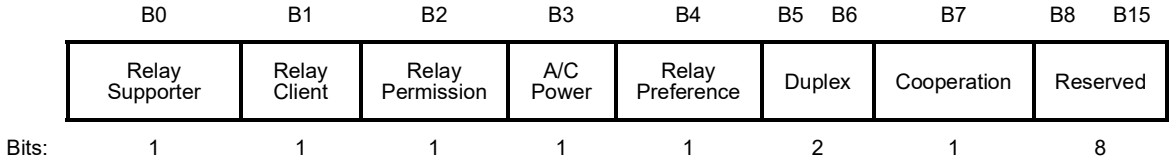


**Figure 9-688—Relay Capability Information field format**

The Relay Supporter subfield indicates whether the STA is capable of relaying by transmitting and receiving frames between a pair of other STAs. A STA capable of relaying is called a *relay* STA. This subfield is set to 1 if the STA supports relaying; otherwise, it is set to 0.

The Relay Client subfield indicates whether the STA is capable of using frame-relaying through a relay STA. It is set to 1 if the STA supports transmission and reception of frames through a relay STA; otherwise, it set to 0.

The Relay Permission subfield indicates whether the AP or PCP allows relay operation (11.34 (DMG relay procedures)) to be used within the AP's or PCP's BSS. It is set to 0 if relay operation is not allowed in the BSS; otherwise, it is set to 1. This subfield is reserved when transmitted by a non-AP and non-PCP STA.

The A/C Power subfield indicates whether the STA is power constrained or not. It is set to 1 if the STA is not power constrained, i.e., supplied by external power, including PoE, wall plug, etc.; otherwise, it is set to 0.

The Relay Preference subfield indicates whether the STA prefers to become RDS rather than REDS. It is set to 1 if a STA prefers to be RDS; otherwise, it is set to 0.

The Duplex subfield indicates whether the STA is capable of full-duplex/amplify-and-forward (FD-AF) or half-duplex/decode-and-forward (HD-DF). It is set to 1 if the STA is not capable of HD-DF but is capable of only FD-AF. It is set to 2 if the STA is capable of HD-DF but is not capable of FD-AF. It is set to 3 if the STA is capable of both HD-DF and FD-AF. The value 0 is reserved.

The Cooperation subfield indicates whether a STA is capable of supporting link cooperation. It is set to 1 if the STA supports both link cooperation and link switching. It is set to 0 otherwise.

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### 9.4.2.147 Relay Transfer Parameter Set element

(#111)A source REDS advertises the parameters for the relay operation with the transmission of a Relay Transfer Parameter Set element (11.34 (DMG relay procedures)) prior to transferring frames via an RDS. The Relay Transfer Parameter Set element is defined in Figure 9-689 (Relay Transfer Parameter Set element format).

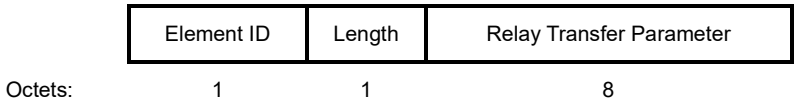


**Figure 9-689—Relay Transfer Parameter Set element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The Relay Transfer Parameter field is defined in Figure 9-690 (Relay Transfer Parameter field format).

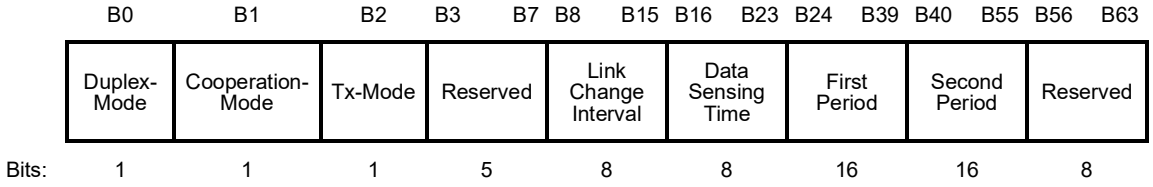


**Figure 9-690—Relay Transfer Parameter field format**

The Duplex-Mode subfield indicates that the source REDS set the duplex mode of the RDS involved in RLS. The Duplex-Mode subfield value is set to 0 if the RDS operates in HD-DF mode. It is set to 1 if the RDS operates in FD-AF mode.

The Cooperation-Mode subfield indicates whether the source REDS sets the link cooperation of the RDS involved in RLS. This subfield is valid only when the RDS is capable of link cooperation and Duplex-Mode subfield is set to 0. Otherwise, this subfield is reserved. The Cooperation-Mode subfield value is set to 0 if the RDS operates in link switching. It is set to 1 if the RDS operates in link cooperation.

The Tx-Mode subfield indicates that the source REDS sets the transmission mode of the RDS involved in RLS. This subfield is valid only when the RDS is capable of link switching and the Duplex-Mode subfield is set to 1. Otherwise, this subfield is reserved. The Tx-Mode subfield value is set to 0 if a group of three STAs involved in the RLS operates in Normal mode and is set to 1 if the group operates in Alternation mode.

The Link Change Interval subfield indicates when the link of frame transmission between source REDS and destination REDS is changed. From the start position of one reserved continuous SP, every time instant of link change interval can have an opportunity to change the link. Within one link change interval, only one link is used for frame transfer. The unit of this subfield is microseconds. This subfield is used only when the group involved in the RLS operates in link switching.

The Data Sensing Time subfield indicates the defer time offset from the time instant of the next link change interval when the link switching occurs. By default, it is set to SIFS plus SBIFS. This subfield is used only when the STAs involved in the RLS operate in link switching with Tx-Mode that is 0.

The First Period subfield indicates the period of the source REDS-RDS link in which the source REDS and RDS exchange frames. This subfield is used only when HD-DF RDS operates in link switching.


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The Second Period subfield indicates the period of the RDS-destination REDS link in which the RDS and destination REDS exchange frames and the following period of the RDS-source REDS link in which the RDS informs the source REDS of finishing one frame transfer. This subfield is used only when HD-DF RDS operates in link switching.

### 9.4.2.148 Quiet Period Request element

The Quiet Period Request element defines a periodic sequence of quiet intervals that the requester AP requests the responder AP to schedule. The format of the Quiet Period Request element is shown in Figure 9-691 (Quiet Period Request element format).

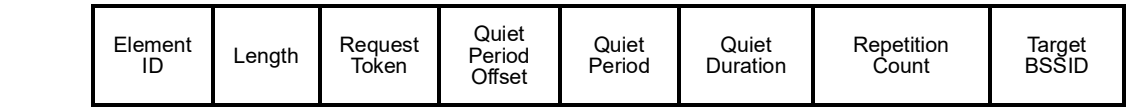


**Figure 9-691—Quiet Period Request element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The Request Token field is set to a nonzero value chosen by the requester AP.

The Quiet Period Offset field is set to the offset of the start of the first quiet interval from the QAB Request frame that contains this element, expressed in TUs. The reference time is the start of the preamble of the PPDU that contains this element.

The Quiet Period field is set to the spacing between the start of two consecutive quiet intervals, expressed in TUs.

The Quiet Duration field is set to duration of the quiet time, expressed in TUs.

The Repetition Count field is set to the number of requested quiet intervals.

NOTE—The periodic sequence of quiet intervals ends after the start of preamble of the PPDU containing the QAB IE + Quiet Period Offset + (Repetition Count-1)×Quiet Period + Quiet Duration (in TUs).

The Target BSSID field is set to the responder AP's MAC address.

### 9.4.2.149 Quiet Period Response element

The Quiet Period Response element defines the feedback information from the AP that received the Quiet Period Request element. The format of the Quiet Period Response element is shown in Figure 9-692 (Quiet Period Response element format).

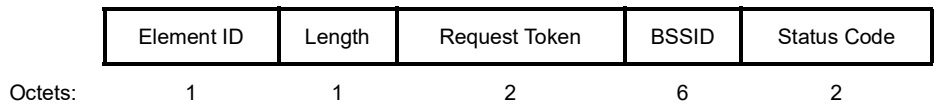


**Figure 9-692—Quiet Period Response element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

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The Request Token field is set to the value of the Request Token field of the corresponding received Quiet Period Request element.

The BSSID field is set to the value of the Target BSSID field of the corresponding received Quiet Period Request element.

The Status Code field is defined in 9.4.1.9 (Status Code field).

### 9.4.2.150 BeamLink Maintenance element

The format of the BeamLink Maintenance element is shown in Figure 9-693 (BeamLink Maintenance element format). The BeamLink Maintenance element is included in Action frames, such as Probe, Announce and the Information Request and Response frames, transmitted between a non-AP and non-PCP DMG STA and a DMG AP or PCP. The element is included in the Probe and Information Request and Response frames transmitted between non-AP and non-PCP DMG STAs.

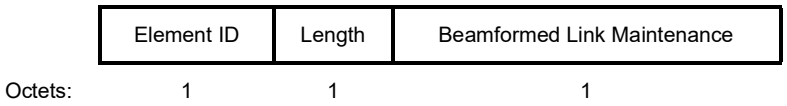


**Figure 9-693—BeamLink Maintenance element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The Beamformed Link Maintenance field is defined in 9.5.6 (Beamformed Link Maintenance field).

### 9.4.2.151 MMS element(#1776)

The format of (#1776)the multiple MAC sublayers (MMS) element is shown in Figure 9-694 (MMS element format). The MMS element is included in Action frames, such as Probe Request, Association Request, Information Request, Announce, and Information Response frames, transmitted to the peer STA and the AP or PCP of the BSS.

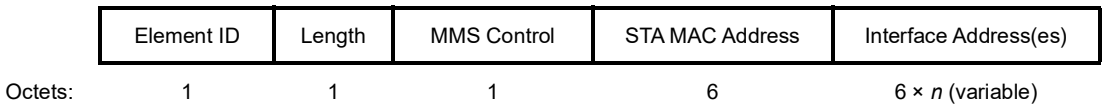


**Figure 9-694—MMS element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The MMS Control field is defined in Figure 9-695 (MMS Control field format(#1729)).

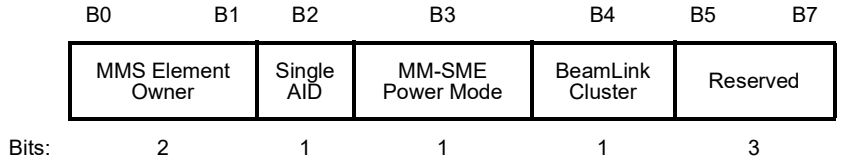


**Figure 9-695—MMS Control field format(#1729)**


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The MMS Element Owner subfield is encoded as shown in Table 9-310 (MMS Element Owner subfield definition). If the MMS Element Owner field is set to No Owner, then the Interface address(es) field in the MMS element is reserved.

**Table 9-310—MMS Element Owner subfield definition**

| MMS Element Owner subfield value | | Meaning |
|---|---|---|
| B0 | B1 | |
| 0 | 0 | No Owner |
| 1 | 0 | Non-AP and Non-PCP MMS element |
| 0 | 1 | PCP MMS element |
| 1 | 1 | AP MMS element |

The Single AID subfield(#261) is encoded as defined in Table 9-311 (Single AID subfield definition).

**Table 9-311—Single AID subfield definition**

| MMS element sent from | MMS element sent to | MMS Element Owner | | Single AID | Meaning |
|---|---|---|---|---|---|
| | | B0 | B1 | B2(#227) | |
| Non-AP and non-PCP STA | AP or PCP | 1 | 0 | 1 | Request to allocate single AID for MAC addresses included in the MMS element |
| Non-AP and non-PCP STA | AP or PCP | 1 | 0 | 0 | Do not allocate single AID for MAC addresses included in the MMS element |
| AP or PCP | Non-PCP, non-AP STA | 1 | 0 | 1 | Single AID is allocated for all MAC addresses in the MMS element |
| AP or PCP | Non-PCP, non-AP STA | 1 | 0 | 0 | Single AID is not allocated for all MAC addresses in the MMS element |
| Non-AP and non-PCP STA | Non-PCP, non-AP STA | 1 | 0 | 1 | Single AID is allocated for all MAC addresses in the MMS element |
| Non-AP and non-PCP STA | Non-PCP, non-AP STA | 1 | 0 | 0 | Single AID is not allocated for all MAC addresses in the MMS element |
| AP or PCP | Non-PCP, non-AP STA | 0 | 1 | 1 | Single AID is allocated for all MAC addresses in the non-AP and non-PCP STA MMS element |
| AP or PCP | Non-PCP, non-AP STA | 0 | 1 | 0 | Single AID is not allocated for all MAC addresses in the non-AP and non-PCP STA MMS element |

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The MM-SME Power Mode subfield(#261) is set to 1 to indicate that when a STA advertised in the MMS element sent by the STA coordinated by an MM-SME moves from the awake to the doze state, then all other STAs advertised in the MMS element sent by the STA move to the doze state. The STA coordinated by the MM-SME moves to the awake state only when all STAs advertised in the MMS element move to the awake state. The MM-SME Power Mode subfield is set to 0 to indicate that when a STA advertised in the MMS element sent by the STA moves from the doze to the awake state, then all other STAs advertised in the MMS element sent by the STA coordinated by the MM-SME move to the awake state. The STA coordinated by the MM-SME moves to the doze state only when all STAs advertised in the MMS element move to the doze state.

The BeamLink Cluster subfield(#261) is set to 1 if the DMG STA intends to maintain the same beamformed link for all of the links within the MMSL cluster. Otherwise, this subfield is set to 0.

The STA MAC Address field contains the MAC address of the STA.

When present in the element, the Interface Address(es) field contains one or more MAC addresses that can be used to identify the STAs in addition to the STA MAC address, coordinated by the same MM-SME (see 11.32 (MMSL cluster operation)).

### 9.4.2.152 U-PID element

(#1776)The format of the upper layer protocol identification (U-PID) element is shown in Figure 9-696 (U-PID element format).

| | Element ID | Length | LLC Header Removed | LLC Header Copy |
|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | variable(#213) |

**Figure 9-696—U-PID element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The LLC Header Removed field is set to 1 to indicate that MSDUs do not contain the LLC (Logical Link Control) header over the WM. It is set to 0 otherwise.

The content and corresponding size of the LLC Header Copy field are specified in Table 9-312 (LLC Header Copy field size).

**Table 9-312—LLC Header Copy field size**

| LLC Header Copy field contents | LLC Header Copy field size (octets) |
|---|---|
| LLC header with 8-bit control field without SNAP | 3 |
| LLC header with 8-bit control field with SNAP | 8 |
| LLC header with 16-bit control field without SNAP | 4 |
| LLC header with 16-bit content field with SNAP | 9 |


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NOTE—The structure of the LLC header is defined in ISO/IEC 8802-2:1998(#7153). The structure of the LLC with SNAP extension is defined in ISO/IEC 8802-2:1998(#1835).

### 9.4.2.153 ECAPC Policy element

The format of the ECAPC Policy element is shown in Figure 9-697 (ECAPC Policy element format).

| | Element ID | Length | ECAPC Policy Detail | CCSR ID | Available Cluster Time Offset Bitmap | TXSS CBAP Offset (optional) | TXSS CBAP Duration (optional) | TXSS CBAP MaxMem (optional) |
|---|---|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 6 | 4 | 0 or 2 | 0 or 1 | 0 or 1 |

**Figure 9-697—ECAPC Policy element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The ECAPC Policy Detail field is defined in Figure 9-698 (ECAPC Policy Detail field format).

| | B0 | B1 | B2 | B3 B7 |
|---|---|---|---|---|
| | BHI Enforced | TXSS CBAP Enforced | Protected Period Enforced | Reserved |
| Bits: | 1 | 1 | 1 | 5 |

**Figure 9-698—ECAPC Policy Detail field format**

The BHI Enforced subfield set to 1 indicates that an AP or PCP in a centralized AP or PCP cluster completes the BHI for the current beacon interval before TBTT + (8×Beacon SP duration), as described in 10.39.3.4 (Centralized AP or PCP cluster MAC requirements). The BHI Enforced subfield set to 0 indicates that an AP or PCP within a cluster does not have to complete the BHI for the current beacon interval before TBTT + (8×Beacon SP duration).

The TXSS CBAP Enforced subfield set to 1 indicates that a STA in a centralized AP or PCP cluster performs each of its TXSSs in the DTI within one or more TXSS CBAPs, as described in 10.39.3.4 (Centralized AP or PCP cluster MAC requirements). The TXSS CBAP Enforced subfield set to 0 indicates that a STA within a centralized AP or PCP cluster does not have to perform each of its TXSSs in the DTI within one or more TXSS CBAPs.

The Protected Period Enforced subfield indicates that every scheduled SP in the BSS is a DMG protected period as specified in 10.38.6.6 (DMG and CMMG protected period). The Protected Period Enforced subfield set to 0 indicates that a scheduled SP in the BSS does not have to be a DMG protected period.

The CCSR ID field is set to the MAC address of the CCSR within the ECAPC that the AP or PCP belongs to. The AP or PCP is the transmitter of the frame containing the ECAPC Policy element except when the ECAPC Policy element is transmitted in a Cluster Report element, where the AP or PCP is the transmitter that triggered the Cluster report.

The Available Time Cluster Offset Bitmap field is a bitmap where the bit $n$–1, $n$ = 1 to 32, indicates the availability of the $n^{th}$ Beacon SP. Values of $n$ = 1 and greater than ClusterMaxMem are reserved (i.e., bit 0 and bits ClusterMaxMem+1 to 31). Bit $n$–1 set to 0 indicates that $ClusterTimeOffset_{n-1}$ is determined to be already in use by a neighboring AP or PCP, excluding the recipient if sent within an individually addressed frame, in the ECAPC. Bit $n$–1 set to 1 indicates that $ClusterTimeOffset_{n-1}$ is not determined to be already in

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use by a neighboring AP or PCP, excluding the recipient if sent within an individually addressed frame, in the ECAPC.

If TXSS CBAP Enforced field is set to 0, then the TXSS CBAP Offset field, the TXSS CBAP Duration field, and the TXSS CBAP MaxMem field are not present in the element; otherwise, they are present in the element.

The TXSS CBAP Offset field is the delay of the first TXSS CBAP in a beacon interval from the TBTT, in units of 8 μs.

The TXSS CBAP Duration field indicates the duration of each TXSS CBAP, in units of 8 μs.

The TXSS CBAP MaxMem field is the number of TXSS CBAPs per beacon interval.

#### 9.4.2.154 Cluster Time Offset element

The format of the Cluster Time Offset element is shown in Figure 9-699 (Cluster Time Offset element format).

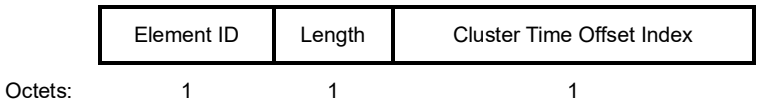


**Figure 9-699—Cluster Time Offset element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The Cluster Time Offset Index field is set to $n$–1 for a member AP or member PCP of a centralized AP or PCP cluster that adopted the $n^{th}$ Beacon SP (see 10.39 (DMG and CMMG AP or PCP clustering)). Values equal to 0 and greater than ClusterMaxMem are reserved.

#### 9.4.2.155 Antenna Sector ID Pattern element

The format of the Antenna Sector ID Pattern element is shown in Figure 9-700 (Antenna Sector ID Pattern element format).

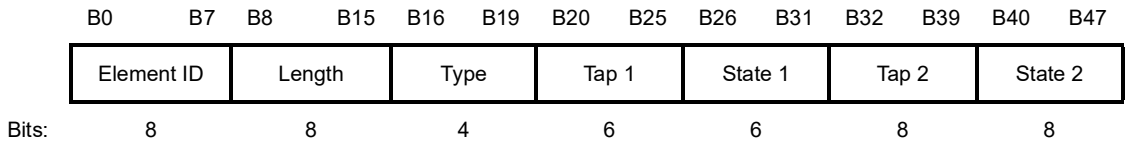


**Figure 9-700—Antenna Sector ID Pattern element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The Type field is set to 0 for Random Sequence Generator. Values 1 to 3 are reserved.

The Tap 1 field indicates the taps for Sequence Generator 1.

The State 1 field indicates the state for Sequence Generator 1.

The Tap 2 field indicates the taps for Sequence Generator 2.


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The State 2 field indicates the state for Sequence Generator 2.

Sequence Generator 1 is shown in Figure 9-701 (Sequence Generator 1) and is defined as follows:

— Generate the sector IDs for subsequent DMG Beacons by advancing the Sequence Generator 1, which is initialized using the values of the Tap 1 and State 1 fields contained in the Antenna Sector ID Pattern element received from the AP or PCP.

— Advance the Sequence Generator 1 by one shift for each anticipated DMG Beacon frame transmission thereafter.

— After advancing the Sequence Generator 1, if the next state equals the initial state for the second time, overwrite the state with an all-zero state. The next state following the state following all zero-state uses the first 6 bits of the state of Sequence Generator 2 as the initial state.

— If the STA's total number of transmit sectors is not equal to the period of the Sequence Generator 1, ignore state(s) greater than or equal total number of transmit sectors and continue advancing Sequence Generator 1 until the state is less than the total number of transmit sectors.

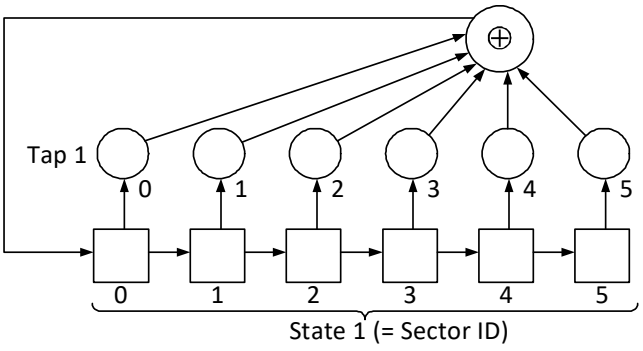


**Figure 9-701—Sequence Generator 1**

NOTE 1—The taps are selected from the set of sequences with maximal length property.

Sequence Generator 2 is shown in Figure 9-702 (Sequence Generator 2) and is defined as follows:

— Sequence Generator 2 is initiated with the value of the Tap 2 and State 2 fields contained in the Antenna Sector ID Pattern element received from the AP or PCP.

— Sequence Generator 2 is advanced by one shift when a new initial state is needed from Sequence Generator 1.

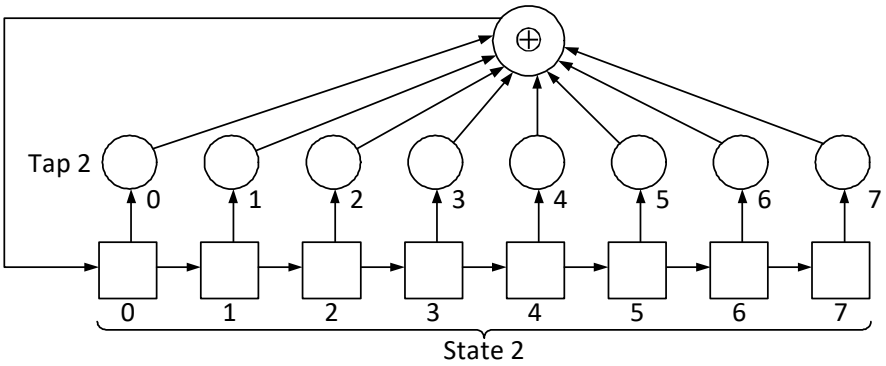


**Figure 9-702—Sequence Generator 2**

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NOTE 2—The taps are selected from the set of the sequences with maximal length property.

### 9.4.2.156 VHT Capabilities element

#### 9.4.2.156.1 VHT Capabilities element structure

A VHT STA declares that it is a VHT STA by transmitting the VHT Capabilities element.

The VHT Capabilities element contains a number of fields that are used to advertise the VHT capabilities of a VHT STA. The VHT Capabilities element is defined in Figure 9-703 (VHT Capabilities element format).

| | Element ID | Length | VHT Capabilities Info | Supported VHT-MCS and NSS Set |
|---|---|---|---|---|
| Octets: | 1 | 1 | 4 | 8 |

**Figure 9-703—VHT Capabilities element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

#### 9.4.2.156.2 VHT Capabilities Information field

The structure of the VHT Capabilities Information field is defined in Figure 9-704 (VHT Capabilities Information field format).

| B0 B1 | B2 B3 | B4 | B5 | B6 | B7 | B8 B10 | B11 | B12 | B13 B15 |
|---|---|---|---|---|---|---|---|---|---|
| Maximum MPDU Length | Supported Channel Width Set | Rx LDPC | Short GI for 80 MHz/ TVHT_MODE_4C | Short GI for 160 and 80+80 MHz | Tx STBC | Rx STBC | SU Beamformer Capable | SU Beamformee Capable | Beamformee STS Capability |
| Bits: 2 | 2 | 1 | 1 | 1 | 1 | 3 | 1 | 1 | 3 |

| B16 B18 | B19 | B20 | B21 | B22 | B23 B25 | B26 B27 | B28 | B29 | B30 B31 |
|---|---|---|---|---|---|---|---|---|---|
| Number Of Sounding Dimensions | MU Beamformer Capable | MU Beamformee Capable | TXOP PS | +HTC-VHT Capable | Maximum A-MPDU Length Exponent | VHT Link Adaptation Capable | Rx Antenna Pattern Consistency | Tx Antenna Pattern Consistency | Extended NSS BW Support |
| 3 | 1 | 1 | 1 | 1 | 3 | 2 | 1 | 1 | 2 |

**Figure 9-704—VHT Capabilities Information field format**


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The subfields of the VHT Capabilities Information field are defined in Table 9-313 (Subfields of the VHT Capabilities Information field).

**Table 9-313—Subfields of the VHT Capabilities Information field**

| Subfield | Definition | Encoding |
|---|---|---|
| Maximum MPDU Length | Indicates the maximum MPDU length that the STA is capable of receiving (see 10.11 (A-MSDU operation)), excepting that a higher maximum MPDU length might be required for the frames listed in NOTE 7 in Table 9-34 (Maximum data unit sizes and durations(#1327)(#4013)).(#4014) | Set to 0 for 3895 octets.<br>Set to 1 for 7991 octets.<br>Set to 2 for 11 454 octets.<br>The value 3 is reserved. |
| Supported Channel Width Set | Together with the Extended NSS BW Support subfield and Supported VHT-MCS and NSS Set field, indicates the channel widths and maximum NSS values per width supported by the STA. See 11.38 (VHT BSS operation). | In a non-TVHT STA, see Table 9-314 (Setting of the Supported Channel Width Set subfield and Extended NSS BW Support subfield at a STA transmitting the VHT Capabilities Information field). When the Channel Width subfield of the VHT Operation element is 2 or 3 (deprecated), the channel center frequency is defined in Table 11-30 (Setting of Channel Center Frequency Segment 0, Channel Center Frequency Segment 1, and Channel Center Frequency Segment 2 subfields).<br><br>In a TVHT STA, the field is structured into subfields as defined in Figure 9-705 (Supported Channel Width Set field format (TVHT)).<br>In a TVHT STA, set the TVHT_MODE_2C Support subfield to 1 if it supports TVHT_MODE_2C; otherwise set the subfield to 0.<br>In a TVHT STA, set the TVHT_MODE_2N Support subfield to 1 if it supports TVHT_MODE_2N; otherwise set the subfield to 0. |
| Rx LDPC | Indicates support for receiving LDPC encoded PPDUs. | Set to 0 if not supported.<br>Set to 1 if supported. |
| Short GI for 80 MHz/ TVHT_MODE_4C | In a non-TVHT STA, indicates short GI support for the reception of PPDUs transmitted with the TXVECTOR parameter FORMAT equal to VHT and CH_BANDWIDTH equal to CBW80.<br><br>In a TVHT STA, indicates support for TVHT_MODE_4C. | In a non-TVHT STA, set to 1 if Short GI for 80 MHz is supported.<br><br>In a TVHT STA, set to 1 if TVHT_MODE_4C is supported.<br><br>Otherwise set to 0. |
| Short GI for 160 and 80+80 MHz | Indicates short GI support for the reception of PPDUs transmitted with TXVECTOR parameters FORMAT equal to VHT and CH_BANDWIDTH equal to CBW160 or CBW80+80. | Set to 0 if not supported.<br>Set to 1 if supported.<br><br>In a TVHT STA, set to 1 if it supports TVHT_MODE_4N. |

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**Table 9-313—Subfields of the VHT Capabilities Information field *(continued)***

| Subfield | Definition | Encoding |
|---|---|---|
| Tx STBC | Indicates support for the transmission of at least 2×1 STBC. | Set to 0 if not supported.<br>Set to 1 if supported. |
| Rx STBC | Indicates support for the reception of PPDUs using STBC. | Set to 0 for no support.<br>Set to 1 for support of one spatial stream.<br>Set to 2 for support of one and two spatial streams.<br>Set to 3 for support of one, two, and three spatial streams.<br>Set to 4 for support of one, two, three, and four spatial streams.<br>The values 5, 6, 7 are reserved.<br>See NOTE 3. |
| SU Beamformer Capable | Indicates support for operation as an SU beamformer (see 10.35.5 (VHT sounding protocol)). | Set to 0 if not supported.<br>Set to 1 if supported. |
| SU Beamformee Capable | Indicates support for operation as an SU beamformee (see 10.35.5 (VHT sounding protocol)). | Set to 0 if not supported.<br>Set to 1 if supported. |
| Beamformee STS Capability | (#3694)Indicates the maximum number of space-time streams that the STA can receive in a VHT NDP, the maximum value for $N_{STS,total}$ that can be sent to the STA in a VHT MU PPDU if the STA is MU beamformee capable (subject to the Maximum NSTS, total field in the Supported VHT-MCS and NSS Set field) and the maximum value of *Nr* that the STA transmits in a VHT Compressed Beamforming frame. | If the SU Beamformee Capable field is set to 1, set to maximum number of space-time streams that the STA can receive in a VHT NDP minus 1.<br>Otherwise, reserved. |
| Number of Sounding Dimensions | Beamformer's capability indicating the maximum value of the TXVECTOR parameter NUM_STS for a VHT NDP. | If the SU Beamformer Capable field is set to 1, set to the maximum supported value of the TXVECTOR parameter NUM_STS minus 1.<br>Otherwise, reserved. |
| MU Beamformer Capable | Indicates support for operation as an MU beamformer (see 10.35.5 (VHT sounding protocol)). | Set to 0 if not supported or if SU Beamformer Capable is set to 0 or if sent by a non-AP STA.<br>Set to 1 if supported and SU Beamformer Capable is set to 1. |
| MU Beamformee Capable | Indicates support for operation as an MU beamformee (see 10.35.5 (VHT sounding protocol)). | Set to 0 if not supported or if SU Beamformee Capable is set to 0 or if sent by an AP.<br>Set to 1 if supported, SU Beamformee Capable is set to 1 and not sent by an AP. |
| TXOP PS | Indicates whether the AP supports TXOP power save mode or whether the non-AP STA has enabled TXOP power save mode. | Set to 0 if the AP does not support TXOP power save mode.<br>Set to 1 if the AP supports TXOP power save mode.<br>Set to 0 if the non-AP STA does not enable TXOP power save mode.<br>Set to 1 if the non-AP STA enables TXOP power save mode. |


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**Table 9-313—Subfields of the VHT Capabilities Information field *(continued)***

| Subfield | Definition | Encoding |
|---|---|---|
| +HTC-VHT Capable | Indicates whether the STA supports receiving a VHT variant HT Control field. | Set to 0 if not supported.<br>Set to 1 if supported. |
| Maximum A-MPDU Length Exponent | Indicates the maximum length of an A-MPDU pre-EOF padding that the STA can receive. | The length defined by this field is equal to $2^{(13 + \text{Maximum A-MPDU Length Exponent})} - 1$ octets. |
| VHT Link Adaptation Capable | Indicates whether the STA supports link adaptation using VHT variant HT Control field. | If +HTC-VHT Capable is 1:<br>Set to 0 (No Feedback) if the STA does not provide VHT MFB.<br>Set to 2 (Unsolicited) if the STA provides only unsolicited VHT MFB.<br>Set to 3 (Both) if the STA can provide VHT MFB in response to VHT MRQ and if the STA provides unsolicited VHT MFB.<br>The value 1 is reserved.<br>Reserved if +HTC-VHT Capable is 0. |
| Rx Antenna Pattern Consistency | Indicates the possibility of a receive antenna pattern change. | Set to 0 if the receive antenna pattern might change during the lifetime of the current association.<br>Set to 1 if the receive antenna pattern does not change during the lifetime of the current association.<br>See 11.38.6 (VHT STA antenna indication). |
| Tx Antenna Pattern Consistency | Indicates the possibility of a transmit antenna pattern change. | Set to 0 if the transmit antenna pattern might change during the lifetime of the current association.<br>Set to 1 if the transmit antenna pattern does not change during the lifetime of the current association.<br>See 11.38.6 (VHT STA antenna indication). |
| Extended NSS BW Support | Together with the Supported Channel Width Set subfield and Supported VHT-MCS and NSS Set field, indicates the channel widths and maximum NSS values per width supported by the STA (for non-TVHT VHT STAs). See 11.38 (VHT BSS operation). | In a non-TVHT STA, see Table 9-314 (Setting of the Supported Channel Width Set subfield and Extended NSS BW Support subfield at a STA transmitting the VHT Capabilities Information field).<br><br>In a TVHT STA, the field is reserved.<br><br>In a STA with dot11VHTExtendedNSSBWCapable equal to false or not present, this field is set to 0. |

NOTE 1—An AP that sets MU Beamformer Capable to 1 can transmit a VHT MU PPDU with only one nonzero TXVECTOR parameter NUM_STS[$p$], for $0 \le p \le 3$. However, a STA that sets MU Beamformee Capable to 0 is not required to be able to demodulate a VHT MU PPDU with only one nonzero RXVECTOR parameter NUM_STS[$p$], for $0 \le p \le 3$.

NOTE 2—The Maximum MPDU Length subfield of the VHT Capabilities Information field imposes a constraint on the allowed value in the Maximum MPDU Length subfield of the HT Capabilities element carried in the same frame (see 10.11 (A-MSDU operation)).

NOTE 3—Subject to any extended NSS BW support constraint.

In the context of Table 9-314 (Setting of the Supported Channel Width Set subfield and Extended NSS BW Support subfield at a STA transmitting the VHT Capabilities Information field):

— 1/2× or 3/4× Max VHT NSS support can be less than 1, indicating no support.

— A supported multiple of Max VHT NSS applies to both transmit and receive.

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— 2× Max VHT NSS support can be used for 20 MHz or 40 MHz HT PPDUs.
— Any other combination than the ones listed in this table is reserved.

**Table 9-314—Setting of the Supported Channel Width Set subfield and Extended NSS BW Support subfield at a STA transmitting the VHT Capabilities Information field**

| Transmitted VHT Capabilities Information field | | NSS support of STA transmitting the VHT Capabilities Information field as a function of the VHT PPDU (×Max VHT NSS) (see requirements R1 and R2) | | | | | Location of 160 MHz channel center frequency if BSS bandwidth is 160 MHz | Location of secondary 80 MHz channel center frequency if BSS bandwidth is 80+80 MHz |
|---|---|---|---|---|---|---|---|---|
| Supported Channel Width Set | Extended NSS BW Support | 20 MHz | 40 MHz | 80 MHz | 160 MHz | 80+80 MHz | | |
| 0 | 0 | 1 | 1 | 1 | | | | |
| 0 | 1 | 1 | 1 | 1 | 1/2 | | CCFS2 | |
| 0 | 2 | 1 | 1 | 1 | 1/2 | 1/2 | CCFS2 | CCFS2 |
| 0 | 3 | 1 | 1 | 1 | 3/4 | 3/4 | CCFS2 | CCFS2 |
| 1 | 0 | 1 | 1 | 1 | 1 | | CCFS1 | |
| 1 | 1 | 1 | 1 | 1 | 1 | 1/2 | CCFS1 | CCFS2 |
| 1 | 2 | 1 | 1 | 1 | 1 | 3/4 | CCFS1 | CCFS2 |
| 1 | 3 | 2 | 2 | 2 | 2 | 1 | CCFS1 | CCFS1 |
| 2 | 0 | 1 | 1 | 1 | 1 | 1 | CCFS1 | CCFS1 |
| 2 | 3 | 2 | 2 | 2 | 1 | 1 | CCFS1 | CCFS1 |

R1: NSS support is rounded down to the nearest integer.
R2: The maximum NSS supported is 8.

NOTE 1—Max VHT NSS is defined per MCS in 9.4.2.156.3 (Supported VHT-MCS and NSS Set field).

NOTE 2—CCFS1 refers to the Channel Center Frequency Segment 1 field of the most recently transmitted VHT Operation element.

NOTE 3—CCFS2 refers to the Channel Center Frequency Segment 2 field of the most recently transmitted HT Operation element.

NOTE 4—CCFS1 is nonzero when the current BSS bandwidth is 160 MHz or 80+80 MHz and the NSS support is at least Max VHT NSS. CCFS2 is zero in this case.See NOTE 7.

NOTE 5—CCFS2 is nonzero when the current BSS bandwidth is 160 MHz or 80+80 MHz and the NSS support is less than Max VHT NSS. CCFS1 is zero in this case. See NOTE 7.

NOTE 6—At most one of CCFS1 and CCFS2 is nonzero when the current BSS bandwidth is 160 MHz or 80+80 MHz. See NOTE 7.

NOTE 7—See Table 11-30 (Setting of Channel Center Frequency Segment 0, Channel Center Frequency Segment 1, and Channel Center Frequency Segment 2 subfields).

NOTE 8—A receiving STA in which dot11VHTExtendedNSSBWCapable is false ignores the Extended NSS BW Support subfield and effectively evaluates this table only at the entries where Extended NSS BW Support is 0.(M118)

NOTE 9—See also 11.38 (VHT BSS operation).


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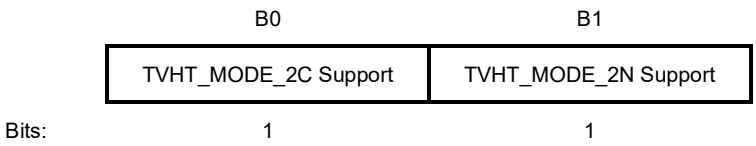


**Figure 9-705—Supported Channel Width Set field format (TVHT)**

Support for short GI for the reception of PPDUs with the TXVECTOR parameter CH_BANDWIDTH equal to CBW20 or CBW40 is indicated in the HT Capabilities Info field of the HT Capabilities element.

### 9.4.2.156.3 Supported VHT-MCS and NSS Set field

The Supported VHT-MCS and NSS Set field is used to convey the combinations of VHT-MCSs and spatial streams that a STA supports for reception and the combinations that it supports for transmission. The structure of the field is shown in Figure 9-706 (Supported VHT-MCS and NSS Set field format).

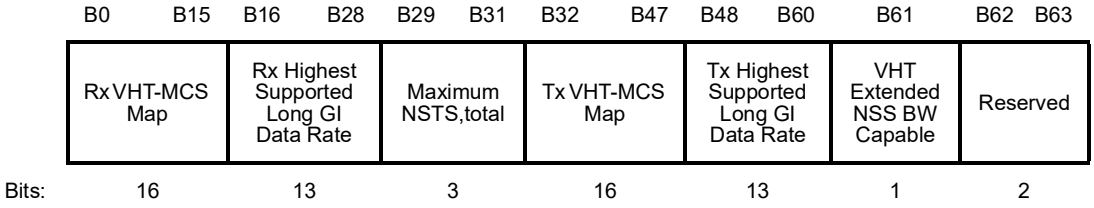


**Figure 9-706—Supported VHT-MCS and NSS Set field format**

The Supported VHT-MCS and NSS Set field's subfields are defined in Table 9-315 (Supported VHT-MCS and NSS Set subfields).

**Table 9-315—Supported VHT-MCS and NSS Set subfields**

| Subfield | Definition | Encoding |
|---|---|---|
| Rx VHT-MCS Map | If transmitted by a STA in which dot11VHTExtendedNSSBWCapable is not true, it indicates the maximum value of the RXVECTOR parameter MCS of a PPDU that can be received at all channel widths supported by this STA for each number of spatial streams.<br>If transmitted by a STA in which dot11VHTExtendedNSSBWCapable is true, this field combined with the Extended NSS BW Support subfield and the 160/80+80 BW subfield of the Operating Mode field determines the maximum value of the RXVECTOR parameter MCS of a PPDU as described in 9.4.2.156.2 (VHT Capabilities Information field) and 9.4.1.51 (Operating Mode field). | The format and encoding of this subfield are defined in Figure 9-707 (Rx VHT-MCS Map and Tx VHT-MCS Map subfields and Basic VHT-MCS And NSS Set field format) and the associated description. |

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**Table 9-315—Supported VHT-MCS and NSS Set subfields *(continued)***

| Subfield | Definition | Encoding |
|---|---|---|
| Rx Highest Supported Long GI Data Rate | Indicates the highest long GI VHT PPDU data rate that the STA is able to receive. | The largest integer value less than or equal to the highest long GI VHT PPDU data rate in Mb/s the STA is able to receive (see 10.6.13.1 (Rx Supported VHT-MCS and NSS Set)).<br><br>The value 0 indicates that this subfield does not specify the highest long GI VHT PPDU data rate that the STA is able to receive. |
| Maximum NSTS,total | Indicates the maximum value for $N_{STS,total}$ that can be sent to the STA in a VHT MU PPDU. | If MU beamformee capable and different from 0, indicates the maximum value for $N_{STS,total}$ minus 1 that can be sent to the STA in a VHT MU PPDU.<br><br>NOTE—This value is greater than or equal to the value in the Beamformee STS Capability subfield of the VHT Capabilities Information field.<br><br>(#3694)If MU beamformee capable and equal to 0, indicates that the maximum value for $N_{STS,total}$ is indicated by the Beamformee STS Capability subfield of the VHT Capabilities Information field.<br><br>Otherwise reserved. |
| Tx VHT-MCS Map | If transmitted by a STA in which dot11VHTExtendedNSSBWCapable is not true, indicates the maximum value of the TXVECTOR parameter MCS of a PPDU that can be transmitted at all channel widths supported by this STA for each number of spatial streams.<br><br>If transmitted by a STA in which dot11VHTExtendedNSSBWCapable is true, this field combined with the Extended NSS BW Support subfield and the 160/80+80 BW subfield of an Operating Mode field determines the maximum value of the TXVECTOR parameter MCS of a PPDU as described in 9.4.2.156.2 (VHT Capabilities Information field) and 9.4.1.51 (Operating Mode field). | The format and encoding of this subfield are defined in Figure 9-707 (Rx VHT-MCS Map and Tx VHT-MCS Map subfields and Basic VHT-MCS And NSS Set field format) and the associated description. |
| Tx Highest Supported Long GI Data Rate | Indicates the highest long GI VHT PPDU data rate at which the STA is able to transmit. | The largest integer value less than or equal to the highest long GI VHT PPDU data rate in Mb/s that the STA is able to transmit (see 10.6.13.2 (Tx Supported VHT-MCS and NSS Set)).<br><br>The value 0 indicates that this subfield does not specify the highest long GI VHT PPDU data rate that the STA is able to transmit. |


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**Table 9-315—Supported VHT-MCS and NSS Set subfields *(continued)***

| Subfield | Definition | Encoding |
|---|---|---|
| VHT Extended NSS BW Capable | Indicates whether the STA is capable of interpreting the Extended NSS BW Support subfield of the VHT Capabilities Information field. | If dot11VHTExtendedNSSBWCapable is true, then this field is set to 1 to indicate that the STA is capable of interpreting the Extended NSS BW Support subfield of the VHT Capabilities Information field.<br>Set to 0 otherwise. |

The Rx VHT-MCS Map subfield and the Tx VHT-MCS Map subfield have the structure shown in Figure 9-707 (Rx VHT-MCS Map and Tx VHT-MCS Map subfields and Basic VHT-MCS And NSS Set field format).

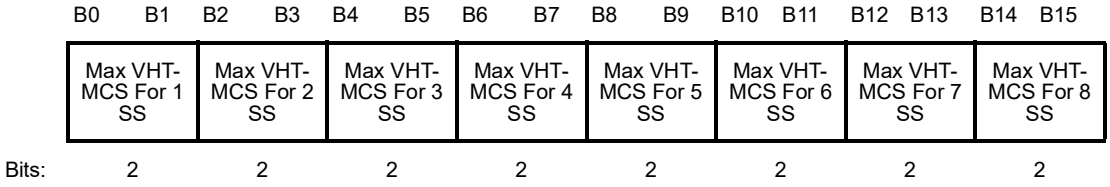


**Figure 9-707—Rx VHT-MCS Map and Tx VHT-MCS Map subfields and Basic VHT-MCS And NSS Set field format**

The Max VHT-MCS For *n* SS subfield (where *n* = 1, ..., 8) is encoded as follows:

— 0 indicates support for VHT-MCS 0-7 for *n* spatial streams

— 1 indicates support for VHT-MCS 0-8 for *n* spatial streams

— 2 indicates support for VHT-MCS 0-9 for *n* spatial streams

— 3 indicates that *n* spatial streams is not supported

The Max VHT NSS for a given MCS is equal to the smaller of the following:

— The maximum value of *n* for which the Max VHT-MCS for *n* SS has a value that indicates support for that VHT-MCS (0, 1 or 2 for VHT-MCS 0-7, 1 or 2 for VHT-MCS 8, 2 for VHT-MCS 9).

— The maximum supported NSS as indicated by the Rx NSS field of the Operating Mode Notification frame if the RX NSS Type is 0.

NOTE 1—A VHT-MCS indicated as supported in the VHT-MCS Map fields for a particular number of spatial streams might not be valid at all bandwidths (see 21.5 (Parameters for VHT-MCSs)), might be limited by the declaration of Tx Highest Supported Long GI Data Rates and Rx Highest Supported Long GI Data Rates, and might be affected by 10.6.13.3 (Additional rate selection constraints for VHT PPDUs) and the Extended NSS BW Support field of the VHT Capabilities Information field in 9.4.2.156.2 (VHT Capabilities Information field) and the 160/80+80 BW subfield of the Operating Mode field in 9.4.1.51 (Operating Mode field).

(11ax)The value of Max VHT NSS for a given MCS is equal to the smaller of

— The maximum value of *n* for which the Max VHT-MCS for *n* SS has a value that indicates support for that MCS or

— The maximum supported $N_{SS}$ as indicated (Ed1)by the value of the Rx NSS field of the OM Control subfield (and further defined in (#6291)Table 26-9 (Setting of VHT Channel Width and VHT NSS at an HE STA transmitting the OM Control subfield)).

NOTE 2—A VHT-MCS indicated as supported in the VHT-MCS Map fields for a particular number of spatial streams might not be valid at all bandwidths (see 21.5 (Parameters for VHT-MCSs)); might be limited by the declaration of Tx Highest Supported Long GI Data Rates and Rx Highest Supported Long GI Data Rates; and might be affected by

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additional rate selection constraints in 10.6.13.3 (Additional rate selection constraints for VHT PPDUs), the value of the Extended NSS BW Support field of the VHT Capabilities Information field (see 9.4.2.156.2 (VHT Capabilities Information field)), and the 160/80+80 BW subfield of the Operating Mode field (see 9.4.1.51 (Operating Mode field)).

### 9.4.2.157 VHT Operation element

The operation of VHT STAs in the BSS is controlled by the HT Operation element and the VHT Operation element. The format of the VHT Operation element is defined in Figure 9-708 (VHT Operation element format).

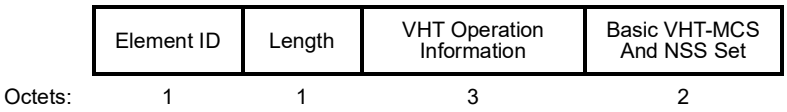


**Figure 9-708—VHT Operation element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The structure of the VHT Operation Information field is defined in Figure 9-709 (VHT Operation Information field format).

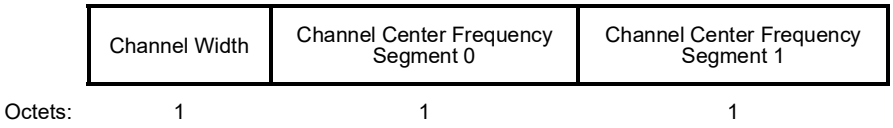


**Figure 9-709—VHT Operation Information field format**

The VHT STA gets the primary channel information from the HT Operation element. The subfields of the VHT Operation Information field are defined in Table 9-316 (VHT Operation Information subfields).

The Basic VHT-MCS And NSS Set field indicates the VHT-MCSs for each number of spatial streams in VHT PPDUs that are supported by all VHT STAs in the BSS (including IBSS and MBSS). The Basic VHT-MCS And NSS Set field is a bitmap of size 16 bits; each 2 bits indicates the supported VHT-MCS set for $N_{SS}$ from 1 to 8. The Basic VHT-MCS And NSS Set field is defined in Figure 9-707 (Rx VHT-MCS Map and Tx VHT-MCS Map subfields and Basic VHT-MCS And NSS Set field format).

### 9.4.2.158 Extended BSS Load element

The Extended BSS Load element reported by the AP contains information on MIMO spatial stream underutilization and bandwidth utilization. The element format is defined in Figure 9-710 (Extended BSS Load element format). A STA receiving the element might use the information it conveys in an (M118)implementation specific AP selection algorithm.

The Element ID and Length fields are defined in 9.4.2.1 (General).

The MU-MIMO Capable STA Count field indicates the total number of STAs currently associated with this BSS that have a 1 in the MU Beamformee Capable field of their VHT Capabilities element.

The Spatial Stream Underutilization field is defined as the percentage of time, linearly scaled with 255 representing 100%, that the AP has underutilized spatial domain resources for given busy time of the medium. The spatial stream underutilization is calculated only for the primary channel. This percentage is computed using the formula,


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**Table 9-316—VHT Operation Information subfields**

| Subfield | Definition | Encoding |
|---|---|---|
| Channel Width | This field, together with the HT Operation element STA Channel Width field, defines the BSS bandwidth (see 11.38.1 (Basic VHT BSS functionality)). | Set to 0 for 20 MHz or 40 MHz BSS bandwidth.<br>Set to 1 for 80 MHz, 160 MHz or 80+80 MHz BSS bandwidth.<br>Set to 2 for 160 MHz BSS bandwidth (deprecated).<br>Set to 3 for noncontiguous 80+80 MHz BSS bandwidth (deprecated).<br>Values in the range 4 to 255 are reserved. |
| Channel Center Frequency Segment 0 | Defines a channel center frequency for a 20, 40, 80, 160, or 80+80 MHz VHT BSS. See 21.3.14 (Channelization). | For 20, 40, or 80 MHz BSS bandwidth, indicates the channel number of the center frequency(#6420) for the 20, 40, or 80 MHz channel on which the VHT BSS operates.<br>For 160 MHz BSS bandwidth and the Channel Width subfield equal to 1, indicates the channel number of the center frequency(#6420) of the 80 MHz channel segment that contains the primary channel.<br>For 160 MHz BSS bandwidth and the Channel Width subfield equal to 2, indicates the channel number of the center frequency(#6420) of the 160 MHz channel on which the VHT BSS operates.<br>For 80+80 MHz BSS bandwidth and the Channel Width subfield equal to 1 or 3, indicates the channel number of the center frequency(#6420) for the primary 80 MHz channel of the VHT BSS.<br>Reserved otherwise. |
| Channel Center Frequency Segment 1 | Defines a channel center frequency for a 160 or 80+80 MHz VHT BSS. See 21.3.14 (Channelization). | For a 20, 40, or 80 MHz BSS bandwidth, this subfield is set to 0.<br>For a 160 MHz BSS bandwidth and the Channel Width subfield equal to 1, indicates the channel number of the center frequency(#6420) of the 160 MHz channel on which the VHT BSS operates.<br>For a 160 MHz BSS bandwidth and the Channel Width subfield equal to 2, this field is set to 0.<br>For an 80+80 MHz BSS bandwidth and the Channel Width subfield equal to 1 or 3, indicates the channel number of the center frequency(#6420) of the secondary 80 MHz channel of the VHT BSS.<br>See Table 9-317 (BSS bandwidth when the VHT Operation Information field Channel Width subfield is 1).<br>Reserved otherwise. |

$$\text{Spatial Stream Underutilization} = \left\lfloor \frac{N_{\text{max\_SS}} \times T_{\text{busy}} - T_{\text{utilized}}}{N_{\text{max\_SS}} \times T_{\text{busy}}} \times 255 \right\rfloor$$

where

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**Table 9-317—BSS bandwidth when the VHT Operation Information field Channel Width subfield is 1**

| Channel Center Frequency Segment 1 subfield value | BSS bandwidth |
|---|---|
| CCFS1 = 0 | 80 MHz or less |
| CCFS1 > 0 and \| CCFS1 – CCFS0 \| = 8 (40 MHz apart) | 160 MHz<br>(CCFS0: center frequency of the 80 MHz channel segment that contains the primary channel)<br>(CCFS1: center frequency of the 160 MHz channel) |
| CCFS1 > 0 and \| CCFS1 – CCFS0 \| > 16 (> 80 MHz apart) | 80+80 MHz<br>(CCFS0: center frequency of the primary 80 MHz channel)<br>(CCFS1: center frequency of the secondary 80 MHz channel) |
| CCFS1 > 0 and \| CCFS1 – CCFS0 \| < 8 (< 40 MHz apart) | Reserved |
| CCFS1 > 0 and 8 < \| CCFS1 – CCFS0 \| ≤ 16 (> 40 MHz and ≤ 80 MHz apart) | Reserved |
| NOTE 1—CCFS0 represents the Channel Center Frequency Segment 0 subfield.<br>NOTE 2—CCFS1 represents the Channel Center Frequency Segment 1 subfield. | |

| | Element ID | Length | MU-MIMO Capable STA Count | Spatial Stream Underutilization | Observable Secondary 20 MHz Utilization | Observable Secondary 40 MHz Utilization | Observable Secondary 80 MHz Utilization |
|---|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 2 | 1 | 1 | 1 | 1 |

**Figure 9-710—Extended BSS Load element format**

$N_{\text{max\_SS}}$ is the maximum number of spatial streams supported by the AP

$T_{\text{busy}}$ is the number of microseconds during which CCA indicated the channel was busy during the measurement duration. The resolution of the CCA busy measurement is in microseconds

$T_{\text{utilized}}$ is $\sum_{i=1}^{N} N_{SS,i} T_i$, where $T_i$ is the time interval, in units of microseconds, during which the primary 20 MHz channel is busy due to the transmission of one or more spatial streams by the AP to MU beamformee capable STAs; $N_{SS,i}$ is the number of spatial streams transmitted during the time interval $T_i$; and $N$ is the number of busy events that occurred during the total measurement time, which is less than or equal to dot11ChannelUtilizationBeaconIntervals consecutive beacon intervals

If $T_{\text{busy}}$ is 0, the Spatial Stream Underutilization field is reserved.

The measurement of the observable loading on each of the secondary 20 MHz channel, secondary 40 MHz channel, and secondary 80 MHz channel in conjunction with the measurement on the primary 20 MHz channel provides a STA with the loading on the 40 MHz, 80 MHz, 160 MHz, and 80+80 MHz channels.


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The Observable Secondary 20 MHz Utilization, Observable Secondary 40 MHz Utilization, and Observable Secondary 80 MHz Utilization fields are defined using Equation (9-6).

$$\text{Observable Secondary } W1 \text{ Utilization} = \left\lfloor \frac{T_{busy,\,W1}}{\text{dot11ChannelUtilizationBeaconIntervals} \times \text{dot11BeaconPeriod} \times 1024} \times 255 \right\rfloor \quad (9\text{-}6)$$

where

dot11ChannelUtilizationBeaconIntervals represents the number of consecutive beacon intervals during which the secondary channel busy time is measured

$T_{busy,W1}$ is computed as the sum of the times from PHY-CCA.indication(BUSY,{W2}, per20bitmap(11ax)) to the next issue of a PHY-CCA.indication primitive and that overlap the measurement interval, for W1 = 20, 40, or 80.(11ax)

For a VHT AP, for W1 = 20, 40, 80, W2 equals secondary, secondary40, or secondary80, respectively.(11ax)

For an HE AP, for W1 = 20, W2 equals secondary or per20bitmap has the bit corresponding to the primary 20 MHz channel equal to 0 and the bit corresponding to the secondary 20 MHz channel equal to 1; for W1 = 40, W2 equals secondary40 or per20bitmap has the bits corresponding to the primary 20 MHz and secondary 20 MHz channels equal to 0, and at least one bit corresponding to any 20 MHz subchannel in the secondary 40 MHz channel equal to 1; for W1 = 80, W2 equals secondary80 or per20bitmap has the bits corresponding to the primary 20 MHz, secondary 20 MHz, and secondary 40 MHz channels equal to 0, and at least one bit corresponding to any 20 MHz subchannel in the secondary 80 MHz channel is equal to 1.(11ax)

If the AP indicates a channel width of 20 MHz, 40 MHz, or 80 MHz in the STA Channel Width field in the HT Operation element and in the Channel Width field in the VHT Operation element, then the Observable Secondary 80 MHz Utilization field is reserved. If the AP indicates a channel width of 20 MHz or 40 MHz in the STA Channel Width field in the HT Operation element, then the Observable Secondary 40 MHz Utilization field is reserved. If the AP indicates a channel width of 20 MHz in the STA Channel Width field in the HT Operation element, then the Observable Secondary 20 MHz Utilization field is reserved.

### 9.4.2.159 Wide Bandwidth Channel Switch element

The Wide Bandwidth Channel Switch element is included in Channel Switch Announcement frames, as described in 9.6.2.6 (Channel Switch Announcement frame format), Extended Channel Switch Announcement frames, as described in 9.6.7.7 (Extended Channel Switch Announcement frame format), and TDLS Channel Switch Request frames, as described in 9.6.12.7 (TDLS Channel Switch Request Action field format). The format of the Wide Bandwidth Channel Switch element is shown in Figure 9-711 (Wide Bandwidth Channel Switch element format).

| Element ID | Length | New Channel Width | New Channel Center Frequency Segment 0 | New Channel Center Frequency Segment 1 |
|---|---|---|---|---|
| Octets: 1 | 1 | 1 | 1 | 1 |

**Figure 9-711—Wide Bandwidth Channel Switch element format**

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The Element ID and Length fields are defined in 9.4.2.1 (General).

If the New Operating Class field in the frame that contains this element does not indicate an S1G band, the subfields New Channel Width, New Channel Center Frequency Segment 0, and New Channel Center Frequency Segment 1 have the same definition, respectively, as Channel Width, Channel Center Frequency Segment 0, and Channel Center Frequency Segment 1 in the VHT Operation Information field, described in Table 9-316 (VHT Operation Information subfields). Otherwise, the subfields New Channel Width and New Channel Center Frequency Segment 0 have the same definition, respectively, as the Channel Width and the Channel Center Frequency in the S1G Operation Information field, described in Table 9-363 (S1G Operation Information field). The New Channel Center Frequency Segment 1 subfield is reserved.

### 9.4.2.160 Transmit Power Envelope element

The Transmit Power Envelope element conveys the local or regulatory maximum transmit powers for various transmission bandwidths or channels within the bandwidth of the BSS. The format of the Transmit Power Envelope element is shown in Figure 9-712 (Transmit Power Envelope element format(11ax)).(11ax)

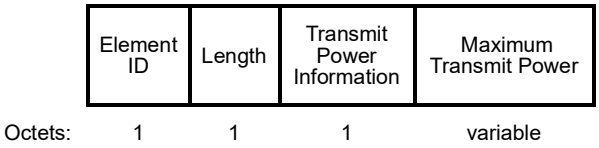


**Figure 9-712—Transmit Power Envelope element format(11ax)**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The format of the Transmit Power Information field is defined in Figure 9-713 (Transmit Power Information field format(11ax)).

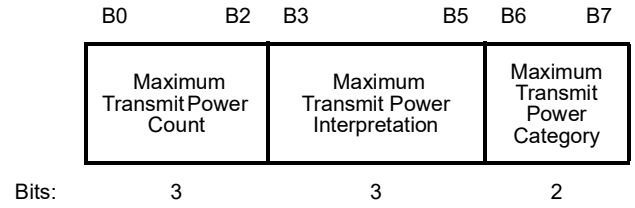


**Figure 9-713—Transmit Power Information field format(11ax)**

(11ax)The Maximum Transmit Power Interpretation subfield indicates the contents of the Maximum Transmit Power field and interpretation of the Maximum Transmit Power Count field and is defined in Table 9-318 (Maximum Transmit Power Interpretation subfield encoding(11ax)).

**Table 9-318—Maximum Transmit Power Interpretation subfield encoding(11ax)**

| Value | Interpretation of the Maximum Transmit Power field |
|---|---|
| 0 | Local EIRP |
| 1 | Local EIRP PSD (power spectral density) |
| 2 | Regulatory client EIRP |


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**Table 9-318—Maximum Transmit Power Interpretation subfield encoding(11ax) *(continued)***

| Value | Interpretation of the Maximum Transmit Power field |
|---|---|
| 3 | Regulatory client EIRP PSD |
| (#6076)4 | Additional regulatory client EIRP |
| (#6076)5 | Additional regulatory client EIRP PSD |
| (#6076)6–7 | Reserved |
| NOTE—This table is expected to be updated only if regulatory domains mandate the use of transmit power control with limits that cannot be converted into one of the currently defined interpretations. | |

(11ax)The Maximum Transmit Power Category subfield indicates a category for which the maximum transmit powers apply. A value of 0 indicates the default category. In the 6 GHz band, the interpretation of this subfield is defined in Table E-14 (Maximum Transmit Power Category subfield encoding(#600)) in E.2.7 (6 GHz band(11ax)(#600)).(#2322)

(11ax)If the Maximum Transmit Power Interpretation subfield (#6076)is 0, 2 or 4 (EIRP), the Maximum Transmit Power Count subfield indicates the number of Maximum Transmit Power For *X* MHz subfields (where *X* = 20, 40, 80, or 160/80+80) minus 1 in the Maximum Transmit Power field of the Transmit Power Envelope element, as shown in Table 9-319 (Meaning of Maximum Transmit Power Count subfield if the Maximum Transmit Power Interpretation subfield is 0, 2 or 4(#6076)(11ax)).

**Table 9-319—Meaning of Maximum Transmit Power Count subfield if the Maximum Transmit Power Interpretation subfield is 0, 2 or 4(#6076)(11ax)**

| Value | Field(s) present |
|---|---|
| 0 | Maximum Transmit Power For 20 MHz. |
| 1 | Maximum Transmit Power For 20 MHz and<br>Maximum Transmit Power For 40 MHz. |
| 2 | Maximum Transmit Power For 20 MHz,<br>Maximum Transmit Power For 40 MHz, and<br>Maximum Transmit Power For 80 MHz. |
| 3 | Maximum Transmit Power For 20 MHz,<br>Maximum Transmit Power For 40 MHz,<br>Maximum Transmit Power For 80 MHz, and<br>Maximum Transmit Power For 160/80+80 MHz.<br>For TVHT STAs, reserved. |
| 4–7 | Reserved |

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(11ax)If the Maximum Transmit Power Interpretation subfield (#6076)is 0, 2 or 4 (EIRP), the format of the Maximum Transmit Power field is defined in Figure 9-714 (Maximum Transmit Power field format if the Maximum Transmit Power Interpretation subfield is 0, 2 or 4(#6076)(11ax)).

| | Maximum Transmit Power For 20 MHz | Maximum Transmit Power For 40 MHz | Maximum Transmit Power For 80 MHz | Maximum Transmit Power For 160/ 80+80 MHz |
|---|---|---|---|---|
| Octets: | 1 | 0 or 1 | 0 or 1 | 0 or 1 |

**Figure 9-714—Maximum Transmit Power field format if the Maximum Transmit Power Interpretation subfield is 0, 2 or 4(#6076)(11ax)**

Maximum Transmit Power For *X* MHz fields (where *X* = 20, 40, 80, or 160/80+80) define the local maximum transmit power limit of *X* MHz PPDUs, except for an HE TB PPDU where X MHz is the bandwidth of the pre-HE modulated fields of the HE TB PPDU transmitted by a STA. Each Maximum Transmit Power For *X* MHz field is encoded as an 8-bit 2s complement signed integer in the range –64 dBm to 63 dBm with a 0.5 dB step. Setting this field to 63.5 dBm indicates 63.5 dBm or higher (i.e., no local maximum transmit power constraint).(11ax)

In frames transmitted by a TVHT STA, the Maximum Transmit Power For 20 MHz subfield indicates the local maximum transmit power for TVHT_W bandwidth; the Maximum Transmit Power For 40 MHz subfield indicates the local maximum transmit power for TVHT_2W or TVHT_W+W bandwidth; the Maximum Transmit Power For 80 MHz subfield indicates the local maximum transmit power for TVHT_4W or TVHT_2W+2W bandwidth; and the Maximum Transmit Power For 160/80+80 MHz subfield is not included in the Transmit Power Envelope element.(11ax)

(11ax)If the Maximum Transmit Power Interpretation subfield (#6076)is 1, 3 or 5 (EIRP PSD), the format of the Maximum Transmit Power field is shown in Figure 9-715 (Maximum Transmit Power field format if Maximum Transmit Power Interpretation subfield is 1, 3 or 5(#6076)(11ax)).

| | Maximum Transmit PSD 1 | Maximum Transmit PSD 2 | ... | Maximum Transmit PSD *N* |
|---|---|---|---|---|
| Octets: | 1 | 0 or 1 | | 0 or 1 |

**Figure 9-715—Maximum Transmit Power field format if Maximum Transmit Power Interpretation subfield is 1, 3 or 5(#6076)(11ax)**

(11ax)The Maximum Transmit Power Count subfield determines the value of an integer *N* as defined in Table 9-320 (Meaning of Maximum Transmit Power Count subfield if Maximum Transmit Power


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Interpretation subfield is 1, 3 or 5(#6076)(11ax)) which specifies the format and interpretation of the Maximum Transmit Power field as described below.

**Table 9-320—Meaning of Maximum Transmit Power Count subfield if Maximum Transmit Power Interpretation subfield is 1, 3 or 5(#6076)(11ax)**

| Value | *N* |
|---|---|
| 0 | 0 |
| 1 | 1 |
| 2 | 2 |
| 3 | 4 |
| 4 | 8 |
| 5–7 | Reserved to indicate values of *N* greater than 8 |

(11ax)If *N* is 0, then the Maximum Transmit Power field contains one Maximum Transmit PSD subfield that represents the maximum transmit PSD for a PPDU of any bandwidth within the BSS bandwidth.

(11ax)If *N* is greater than 0, then the Maximum Transmit Power field has *N* octets, with *N* representing the number of 20 MHz channels for which a maximum transmit PSD is indicated. The $X^{th}$ octet (*X* = integer ranging from 1 to *N*) of the Maximum Transmit Power field is the Maximum Transmit PSD *X* subfield, which indicates the maximum transmit PSD for the $X^{th}$ 20 MHz channel.

(11ax)If the BSS bandwidth is 20, 40, 80, or 160 MHz, then the Maximum Transmit PSD 1-*N* subfields correspond to 20 MHz channels from lowest to highest frequency, respectively, within the indicated bandwidth. If *N* is equal to 1, 2, 4, or 8 for 20, 40, 80, or 160 MHz BSS bandwidth, respectively, the indicated bandwidth is the BSS bandwidth. If *N* is greater than 0 and less than 2, 4, or 8 for 40, 80, or 160 MHz BSS bandwidth, respectively, then the indicated bandwidth is the primary 20 MHz, primary 40 MHz, or primary 80 MHz channel for *N* equal to 1, 2, or 4, respectively. If *N* is greater than 1, 2, or 4 for 20, 40, or 80 MHz BSS bandwidth, respectively, then the indicated bandwidth is wider than the BSS bandwidth. In this case, the Maximum Transmit PSD 1-*M* subfields correspond to the 20 MHz channels from lowest to highest frequency, respectively, within the BSS bandwidth where *M* is 1, 2, or 4 for 20, 40, or 80 MHz BSS bandwidth, respectively. The Maximum Transmit PSD (*M*+1)-*N* subfields are reserved for future use (see 10.22.4 (Operation with the Transmit Power Envelope element)).

(11ax)If the BSS bandwidth is 80+80 MHz, *N* is less than or equal to 8. If *N* is equal to 8 and the BSS bandwidth is 80+80 MHz, the Maximum Transmit PSD 1-4 subfields correspond to the 20 MHz channels from lowest to highest frequency, respectively, within the 80 MHz segment lower in frequency; the Maximum Transmit PSD 5-8 subfields correspond to the 20 MHz channels from lowest to highest frequency, respectively, within the 80 MHz segment higher in frequency. If *N* is greater than 0 and less than 8 for 80+80 MHz BSS bandwidth, then the bandwidth indicated by the Maximum Transmit PSD 1-*N* subfields is the primary 20 MHz, primary 40 MHz, or primary 80 MHz channel for *N* equal to 1, 2, or 4, respectively. In this case, the Maximum Transmit PSD 1-*N* subfields correspond to 20 MHz channels from lowest to highest frequency, respectively, within the indicated bandwidth.

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(11ax)Values of the Maximum Transmit Power Count field between 5 and 7 are reserved for future use to indicate values of *N* greater than 8. If *N* is greater than 8, the Maximum Transmit PSD 1-8 subfields correspond to the 20 MHz channels from lowest to highest frequency, respectively, within the 160 MHz channel containing the primary 20 MHz channel. See 10.22.4 (Operation with the Transmit Power Envelope element).

(11ax)The Maximum Transmit PSD *X* subfield is encoded as an 8-bit 2s complement signed integer. The value of –128 indicates that the corresponding 20 MHz channel cannot be used for transmission. The value of +127 indicates that no maximum PSD limit is specified for the corresponding 20 MHz channel. For all other values *Y* of the subfield (i.e., –127 to +126, inclusive), the maximum transmit PSD in the corresponding 20 MHz channel is *Y*/2 dBm/MHz (i.e., ranging from –63.5 to +63 dBm/MHz). (#6076)If an allowed PSD for the $X^{th}$ 20 MHz channel is known with finer resolution than 20 MHz, the Maximum Transmit PDF *X* subfield is set to the lowest allowed PSD within the $X^{th}$ 20 MHz channel.

### 9.4.2.161 Channel Switch Wrapper element

The Channel Switch Wrapper element contains subelements that indicate characteristics of the BSS after a channel switch. The format of the Channel Switch Wrapper element is defined in Figure 9-716 (Channel Switch Wrapper element format). Procedures related to the inclusion of subelements in the Channel Switch Wrapper element are defined in 11.38.4 (Channel switching methods for a VHT BSS).

| | Element ID | Length | New Country subelement (optional) | Wide Bandwidth Channel Switch subelement (optional) | New Transmit Power Envelope subelement (optional) |
|---|---|---|---|---|---|
| Octets: | 1 | 1 | variable | variable | variable |

**Figure 9-716—Channel Switch Wrapper element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The New Country subelement is present when an AP or mesh STA performs extended channel switching to a new Country, new Operating Class Table, or a changed set of operating classes relative to the contents of the Country element sent in the Beacon; otherwise, this subelement is not present. The format of the New Country subelement is defined to be the same as the format of the Country element (see 9.4.2.7 (Country element)), except that no Subband Triplet fields are present in the New Country subelement. The Country String field in the New Country subelement indicates the Country and Operating Class Table of the BSS after extended channel switching, and Operating Triplet fields within the New Country subelement indicate the operating classes of the BSS after extended channel switching (see 11.38.1 (Basic VHT BSS functionality)).

The Wide Bandwidth Channel Switch subelement is present under the following conditions:

— Channel switching to a BSS bandwidth of 40 MHz or wider

— Extended channel switching to a BSS bandwidth of 80 MHz or wider

The Wide Bandwidth Channel Switch subelement is optionally present if extended channel switching to a BSS bandwidth of 40 MHz. The Wide Bandwidth Channel Switch subelement is not present if channel switching to a 20 MHz BSS bandwidth.

The format of the Wide Bandwidth Channel Switch subelement is the same as the Wide Bandwidth Channel Switch element (see 9.4.2.159 (Wide Bandwidth Channel Switch element)) except for the following:

— A value 0 in the New Channel Width field signifies only a 40 MHz BSS bandwidth.


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— When switching to a 40 MHz BSS bandwidth, the New Channel Center Frequency Segment 0 field indicates the channel number of the center frequency(#6420) for the 40 MHz channel after the channel switch.

If present, the Wide Bandwidth Channel Switch subelement indicates the BSS bandwidth after channel switching (see 11.38.1 (Basic VHT BSS functionality)). For example, when switching to a 40 MHz BSS bandwidth on channel indices 36 and 40, the New Channel Width field is set to 0, and the New Channel Center Frequency Segment 0 field is set to 38.

Each New Transmit Power Envelope subelement that is present is defined to have the same format as the Transmit Power Envelope element (see 9.4.2.160 (Transmit Power Envelope element)) and includes a distinct value of the Local Maximum Transmit Power Unit Interpretation subfield. Each New Transmit Power Envelope subelement indicates the local maximum transmit powers for the BSS for the indicated bandwidths with an indicated unit interpretation after channel switching (see 11.38.1 (Basic VHT BSS functionality)).

If transmitted by a TVHT STA, the Wide Bandwidth Channel Switch subelement is present when the STA is switching channels to a BSS bandwidth of TVHT_2W or TVHT_W+W bandwidth or wider; if switching to a TVHT_W bandwidth BSS bandwidth then this subelement is not present.

### 9.4.2.162 AID element

(#8127)The AID element contains the AID assigned by the AP during association. The format of the AID element is shown in Figure 9-717 (AID element format).

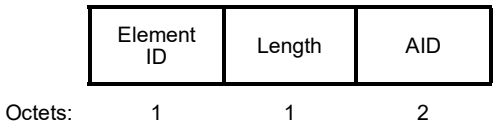


**Figure 9-717—AID element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The AID field is defined in 9.4.1.8 (AID field).

### 9.4.2.163 Quiet Channel element

The Quiet Channel element is used to indicate that the secondary 80 MHz channel of a VHT BSS is to be quieted during a quiet interval, and, in an infrastructure BSS, to indicate if the primary 80 MHz channel of a VHT BSS can be used during the quiet interval. A quiet interval is established using either a Quiet element (see 9.4.2.21 (Quiet element)) or, in an infrastructure BSS, the Quiet Channel element if its AP Quiet Mode field is equal to 1.

The Quiet Channel element is optionally present in Beacon frames, as described in 9.3.3.2 (Beacon frame format), and Probe Response frames, as described in 9.3.3.10 (Probe Response frame format). The use of Quiet Channel elements is described in 11.8.3 (Quieting channels for testing).

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The format of the Quiet Channel element is shown in Figure 9-718 (Quiet Channel element format).

| | Element ID | Length | AP Quiet Mode | Quiet Count (optional) | Quiet Period (optional) | Quiet Duration (optional) | Quiet Offset (optional) |
|---|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 0 or 1 | 0 or 1 | 0 or 2 | 0 or 2 |

**Figure 9-718—Quiet Channel element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The AP Quiet Mode field specifies STA behavior in an infrastructure BSS during the quiet intervals. When communications to the AP are allowed within the primary 80 MHz channel, then the AP Quiet Mode field is set to 1. Otherwise, the AP Quiet Mode field is set to 0.

If the AP Quiet Mode field is 1, then the Quiet Count field, Quiet Period field, Quiet Duration field, and Quiet Offset field are present in the Quiet Channel element; otherwise, these fields are not present in the Quiet Channel element.

The Quiet Count field, Quiet Period field, Quiet Duration field, and Quiet Offset field have the same definition as described in 9.4.2.21 (Quiet element).

### 9.4.2.164 Operating Mode Notification element

The Operating Mode Notification element is used to notify STAs that the transmitting STA is changing one or more of its operating channel width, the maximum number of spatial streams it can receive, and its LDPC receive preference. The format of the Operating Mode Notification element is defined in Figure 9-719 (Operating Mode Notification element format).

| | Element ID | Length | Operating Mode |
|---|---|---|---|
| Octets: | 1 | 1 | 1 |

**Figure 9-719—Operating Mode Notification element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The Operating Mode field is defined in 9.4.1.51 (Operating Mode field).

### 9.4.2.165 UPSIM element

The UPSIM element is defined as shown in Figure 9-720 (UPSIM element format).

| | Element ID | Length | UPSIM Flags | Partial Unsched-uled Power Save Bitmap |
|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 0-32 |

**Figure 9-720—UPSIM element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).


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The Length field for this element is constrained as described below.

The UPSIM Flags field is defined in Figure 9-721 (UPSIM Flags field format).

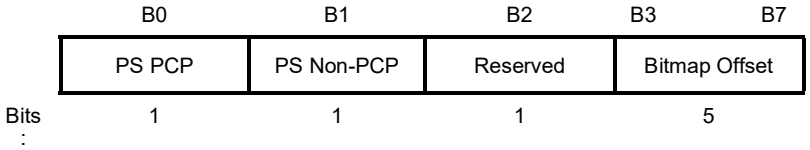


**Figure 9-721—UPSIM Flags field format**

The PS PCP field is set to 1 if the PCP is in unscheduled PS mode at the time of UPSIM element transmission and is set to 0 otherwise. The PS PCP field is set to 0 in infrastructure BSS. The PS Non-PCP field is set to 1 if all non-AP and non-PCP STAs are in unscheduled PS mode at the time of UPSIM element transmission and is set to 0 otherwise. The Bitmap Offset field defines the octet offset into a virtual bitmap maintained by the AP or PCP, as described below.

The AP or PCP maintains an unscheduled power save indication virtual bitmap that is 256 bits in length and is organized into 32 octets such that bit number $N$ ($0 \le N \le 255$) in the bitmap corresponds to bit number ($N$ mod 8) in octet number $\lfloor N / 8 \rfloor$, where the low order bit of each octet is bit number 0, and the high order bit is bit number 7. Bit $N$ in the bitmap is set to 1 if there is an associated DMG STA with AID equal to $N$ and the STA is in unscheduled PS mode and is set to 0 if there is no associated DMG STA with AID equal to $N$ or the STA is not in unscheduled PS mode. Bit 0 is set to 0 in the infrastructure BSS. Bit 255 is set to 0.

The Partial Unscheduled Power Save Bitmap field is not present when bits numbered 1 to 254 of the unscheduled power save indication virtual bitmap all have the same value at the time of UPSIM element transmission. In this case, the Length field is set to 1 and the Bitmap Offset field is set to 0.

When there are two bits in the unscheduled power save indication virtual bitmap with numbers between 1 and 254 and different values, the Partial Unscheduled Power Save Bitmap field consists of octets numbered $N1$ to $N2$ of the unscheduled power save indication virtual bitmap, where $N1$ is the largest integer such that bits numbered 1 to ($N1 \times 8$) - 1 in the unscheduled power save indication virtual bitmap are all 0, and $N2$ is the smallest number such that bits numbered ($N2 + 1$) × 8 to 255 in the unscheduled power save indication virtual bitmap are all 0. In this case, the Length field is set to ($N2 - N1$) + 2 and the Bitmap Offset subfield is set to $N1$.

NOTE—The Partial Unscheduled Power Save Bitmap field does not need to include bit 0 of the unscheduled power save indication virtual bitmap even if that bit is set.

### 9.4.2.166 FTM Parameters element(11az)

The (#7065)FTM Parameters element contains a number of subfields that are used to advertise the requested or allocated FTM configuration from one STA to another. The (#7065)FTM Parameters element is included in the IFTMR frame(#7223)(#7065), as described in 9.6.7.32 (FTM(11az) Request frame format), and the initial FTM frame(#7223), as described in 9.6.7.33 (FTM(11az) frame format). The use of the (#7065)FTM Parameters element is described in 11.21.6 (FTM procedure(#7065)).

The format of the (#7065)FMT Parameters element is shown in 9-722 (FTM(11az) Parameters element format).

The Element ID and Length fields are defined in 9.4.2.1 (General).

The format of the (#7065)FTM Parameters field is shown in 9-723 (FTM(11az) Parameters field format).

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**Figure 9-722—FTM(11az) Parameters element format**

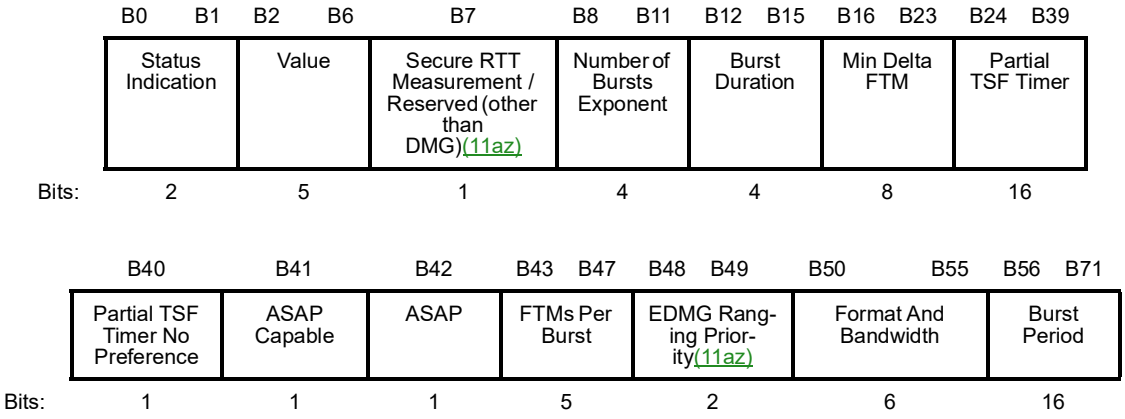


**Figure 9-723—FTM(11az) Parameters field format**

The Status Indication subfield indicates the responding STA's response to the IFTMR frame(#7223)(#7065). The encoding of the Status Indication subfield is shown in Table 9-321 (Status Indication subfield values).

**Table 9-321—Status Indication subfield values**

| Value | Description |
|---|---|
| 0 | Reserved |
| 1 | Successful (some requested parameters might have been overridden). Measurement exchanges are about to begin. |
| 2 | Request incapable. Do not send same request again. FTM session ends. |
| 3 | Request failed. Do not send new request for Value seconds. FTM session ends. |

The Status Indication subfield and Value subfield are reserved in the IFTMR frame(#7223)(#7065). When the Status Indication subfield is set to 3 by the responding STA, the Value subfield contains a duration in units of seconds; otherwise the Value subfield is reserved.

(11az)For secure EDMG ranging, the Secure RTT Measurement subfield is set to 1 by an ISTA to request a secure RTT measurement exchange between an ISTA and an RSTA; see 11.21.6.3.3 (Negotiation for TB and non-TB ranging measurement exchange). The Secure RTT Measurement subfield is set to 1 by an RSTA to acknowledge a secure RTT measurement exchange, and to 0 otherwise. In cases other than secure EDMG ranging, the Secure RTT Measurement subfield is reserved.

The Number of Bursts Exponent subfield indicates how many burst instances, defined in 11.21.6.4 (Measurement exchange), are requested for the FTM session if included in an IFTMR frame(#7065), or allocated for the FTM session if included in an initial FTM frame(#7223) respectively, where the number of burst instances is $2^{\text{Number of Bursts Exponent}}$. The value 15 in an IFTMR frame(#7223)(#7065) indicates no


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preference by the initiating STA and is valid (indicating $2^{15}$ burst instances) when set by the responding STA.

The Burst Duration subfield indicates the duration of a burst instance. The value 15 in the (#7065)IFTMR frame indicates no preference by the initiating STA and is not used by the responding STA. Table 9-322 (Burst Duration subfield encoding) shows the encoding of this subfield.

**Table 9-322—Burst Duration subfield encoding**

| Value | Represents |
|---|---|
| 0-1 | Reserved |
| 2 | 250 μs |
| 3 | 500 μs |
| 4 | 1 ms |
| 5 | 2 ms |
| 6 | 4 ms |
| 7 | 8 ms |
| 8 | 16 ms |
| 9 | 32 ms |
| 10 | 64 ms |
| 11 | 128 ms |
| 12–14 | Reserved |
| 15 | No preference |

The Min Delta FTM subfield indicates the minimum time between consecutive FTM frames(#7223). It is measured from the start of (#8020)an FTM frame(#7223) to the start of following FTM frame(#7223), in units of 100 μs. The value 0 indicates no preference by the initiating STA and is not used by the responding STA.

The value in the Partial TSF Timer subfield is the partial value of the responding STA's TSF at the start of the first burst instance. The Partial TSF Timer subfield value is derived as follows, so as to have units of TUs: from the 64 TSF timer bits at the start of the first burst instance of an FTM session, remove the most significant 38 bits and the least significant 10 bits.

The initiating STA indicates a preferred time for the start of the first burst instance by setting the Partial TSF Timer No Preference subfield to 0 and by setting the Partial TSF Timer subfield to indicate the preferred start of the first burst instance, in the FTMR frame(#7223). Otherwise the Partial TSF Timer No Preference subfield is set to 1 and the Partial TSF Timer subfield is reserved. The Partial TSF Timer No Preference subfield is reserved when the (#7065)FTM Parameters element is included in an initial FTM frame(#7223).

The value of the Partial TSF Timer subfield in an initial FTM frame(#7223) is the partial value of the responding STA's TSF timer at the start of the first burst instance of an FTM session.

NOTE 1—1024 TUs out of the full range of the Partial TSF Timer subfield are not used in order to allow the recipient to resolve ambiguity arising from 1) imperfect synchronization between the initiating and responding STAs, and 2) retries of the IFTMR frame(#7223)(#7065) or retransmissions of the initial FTM frame(#7223).

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The ASAP Capable subfield indicates that the responding STA is capable of capturing timestamps associated with an initial FTM frame(#7223) and its acknowledgment and sending them in the following FTM frame(#7223). This subfield is reserved in the IFTMR frame(#7223)(#7065).

The ASAP subfield indicates the initiating STA's request to start the first burst instance of the FTM session with the initial FTM frame(#7223) and capture timestamps corresponding to the transmission of the initial FTM frame(#7223) and the receipt of its acknowledgment. The responding STA sets the ASAP subfield to 1 to indicate the STA's intent to send (#8020)an FTM frame(#7223) as soon as possible and capture timestamps corresponding to the transmission of the initial FTM frame(#7223) and the receipt of its acknowledgment.

When the ASAP subfield is set to 0 and the Partial TSF Timer No Preference subfield is set to 0 by an initiating STA, the initiating STA requests the start of the first burst instance specified by the Partial TSF Timer subfield in the IFTMR frame(#7223)(#7065). When the ASAP subfield is set to 1 and the Partial TSF Timer No Preference subfield is set to 0 by an initiating STA, the Partial TSF Timer subfield in the FTMR frame(#7223) indicates the requested start of the first burst instance if the ASAP subfield is set to 0 in the corresponding initial FTM frame(#7223). The Partial TSF Timer subfield in both these frames is set to a value between 0 and 62/64 of 65 535 TUs.

Figure 9-724 (Calculation of the value of the Partial TSF Timer subfield(#7223)) describes how the value of the Partial TSF Timer subfield is determined based on the ASAP subfield and the Partial TSF Timer No Preference subfield at an initiating STA and on the ASAP subfield at the responding STA.

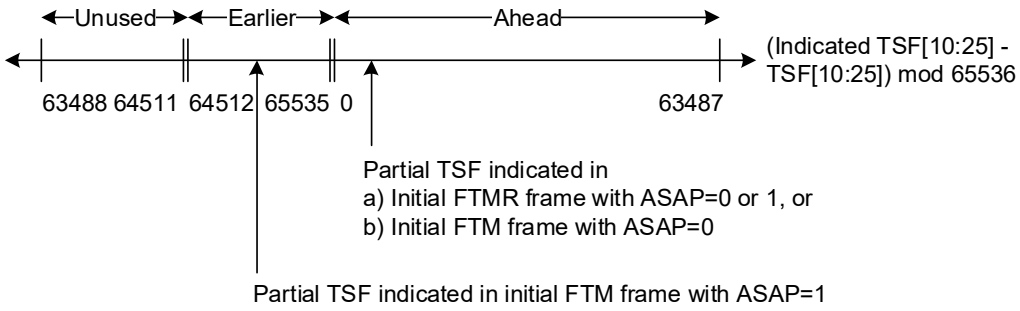


**Figure 9-724—Calculation of the value of the Partial TSF Timer subfield(#7223)**

The ASAP subfield is also used by the responding STA to signal whether that request has been honored or not. When the ASAP subfield is set to 0 by the responding STA, the Partial TSF Timer subfield in the initial FTM frame(#7223) indicates the start time of the first burst instance and the earliest time the FTMR frame(#7223) (see 11.21.6.4 (Measurement exchange)) should be sent by the initiating STA. The Partial TSF Timer subfield in both these frames is set to a value between 0 and 62/64 of 65 535 TUs.

When the ASAP subfield is set to 1 by the responding STA, the Partial TSF Timer subfield in the initial FTM frame(#7223) indicates the start time of the first burst instance and the earliest time the initial FTM frame(#7223) will be sent. The value in the Partial TSF Timer subfield in this case is set to a value less than 1/64 of 65 536 TUs (≥1024 TUs) from the responding STA's TSF timer.

The FTMs Per Burst subfield indicates how many successfully transmitted FTM frames(#7223) are requested per burst instance by the IFTMR frame(#7223)(#7065), or allocated by the initial FTM frame(#7223), respectively. The value 0 indicates no preference by the initiating STA and is not used by the responding STA.

(11az)For EDCA based ranging where the value of the Format And Bandwidth field indicates DMG or EDMG format, see Table 9-325 (Format And Bandwidth subfield), the EDMG Ranging Priority subfield of


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the FTM Parameters field of the FTM Parameters element in the IFTMR frame contains the ISTA's ranging priority request, which indicates the time sensitivity of a ranging operation, and it is set according to Table 9-323 (Definition of the EDMG Ranging Priority subfield when included in the IFTMR frame(11az)). In cases other than EDMG ranging, EDMG Ranging Priority subfield is reserved.

**Table 9-323—Definition of the EDMG Ranging Priority subfield when included in the IFTMR frame(11az)**

| Ranging Priority Request Value | Description | Definition |
|---|---|---|
| 0 | No priority | The ISTA does not know the time sensitivity of the ranging operation. |
| 1 | High | The results of the ranging operation is intended for emergency services (e.g., 911 calls) |
| 2 | Medium | The completion of the ranging operation impacts user experiences. |
| 3 | Low | The completion of the ranging operation is less sensitive to application performance. |

(11az)For EDCA based ranging where the value of the Format And Bandwidth field indicates DMG or EDMG format, see Table 9-325 (Format And Bandwidth subfield), the EDMG Ranging Priority subfield of the FTM Parameters field of the FTM Parameters element in the IFTM frame contains the RSTA's ranging priority response, which indicates whether the RSTA accommodates the ranging priority request of the ISTA, and it is set according to Table 9-324 (Definition of the EDMG Ranging Priority subfield when included in the IFTM frame(11az)).

**Table 9-324—Definition of the EDMG Ranging Priority subfield when included in the IFTM frame(11az)**

| Ranging Priority Response Value | Definition |
|---|---|
| 0 | The RSTA will be able to prioritize ranging operations to match the ranging priority requested by the ISTA. |
| 1 | The RSTA will not be able to prioritize ranging operations to match the ranging priority requested by the ISTA |
| 2 | Reserved |
| 3 | Reserved |

(11az)For EDCA based ranging where the value of the Format And Bandwidth field does not indicate DMG or EDMG format, see Table 9-325 (Format And Bandwidth subfield), the EDMG Ranging Priority subfield of the FTM Parameters field of the FTM Parameters element in the IFTM frame is reserved.

The Format And Bandwidth subfield indicates the requested or allocated PPDU format and bandwidth that can be used by FTM frames(#7223) in an FTM session and is shown in Table 9-325 (Format And Bandwidth subfield). The value 0 indicates no preference by the initiating STA in the associated state and is not used by the responding STA.The value 0 is not used by the initiating STA in the unassociated state.

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**Table 9-325—Format And Bandwidth subfield**

| Field value | Format | Bandwidth (MHz) |
|---|---|---|
| 0 | No preference | No preference |
| 1–3 | Reserved | Reserved |
| 4 | Non-HT | 5 |
| 5 | Reserved | Reserved |
| 6 | Non-HT | 10 |
| 7 | Reserved | Reserved |
| 8 | Non-HT, excluding Clause 15 (DSSS PHY specification for the 2.4 GHz band designated for ISM applications) and Clause 16 (High rate direct sequence spread spectrum (HR/ DSSS) PHY specification) | 20 |
| 9 | HT mixed | 20 |
| 10 | VHT | 20 |
| 11 | HT mixed | 40 |
| 12 | VHT | 40 |
| 13 | VHT | 80 |
| 14 | VHT | 80+80 |
| 15 | VHT (two separate RF LOs) | 160 |
| 16 | VHT (single RF LO) | 160 |
| 17(11az) | EDCA based HE | 20 |
| 18(11az) | EDCA based HE | 40 |
| 19(11az) | EDCA based HE | 80 |
| 20(11az) | EDCA based HE | 80+80 |
| 21(11az) | EDCA based HE (two separate RF LOs) | 160 |
| 22(11az) | EDCA based HE (single RF LO) | 160 |
| 23–30 | Reserved | Reserved |
| 31(11az) | DMG | 2160 |
| 32(11az) | EDMG (Single Carrier Mode) | 2160 |
| 33(11az) | EDMG (Single Carrier Mode) | 4320 |
| 34(11az) | EDMG (Single Carrier Mode) | 6480 |
| 35(11az) | EDMG (Single Carrier Mode) | 8640 |
| 36(11az) | EDMG (Single Carrier Mode) | 2160+2160 |
| 37(11az) | EDMG (Single Carrier Mode) | 4320+4320 |
| 38(11az) | EDMG (OFDM) | 2160 |
| 39(11az) | EDMG (OFDM) | 4320 |
| 40(11az) | EDMG (OFDM) | 6480 |
| 41(11az) | EDMG (OFDM) | 8640 |


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**Table 9-325—Format And Bandwidth subfield *(continued)***

| Field value | Format | Bandwidth (MHz) |
|---|---|---|
| 42(11az) | EDMG (OFDM) | 2160+2160 |
| 43(11az) | EDMG (OFDM) | 4320+4320 |
| 44–63 | Reserved | Reserved |

NOTE 2—See 21.3.17.3 (Transmit center frequency and symbol clock frequency tolerance) regarding the usage of two separate RF LOs.

The Burst Period subfield indicates the interval between two consecutive burst instances, in units of 100 ms. The value 0 indicates no preference by the initiating STA. This subfield is reserved when the Number of Bursts Exponent subfield is set to 0.

(11az)The Optional Subelements field contains zero or more subelements. The subelement format and ordering of subelements are defined in 9.4.3 (Subelements). The Subelement ID field values for the defined subelements are shown in Table 9-326 (Optional Subelement IDs for FTM Parameters(11az)).

**Table 9-326—Optional Subelement IDs for FTM Parameters(11az)**

| Subelement ID | Name | Extensible |
|---|---|---|
| 0 | DMG Direction Measurement Parameters | Yes |
| 1 | EDMG Specific Parameters | Yes |
| 2–220 | Reserved | |
| 221 | Vendor Specific | |
| 222–255 | Reserved | |

(11az)The DMG Direction Measurement Parameters subelement has the structure shown in Figure 9-725 (DMG Direction Measurement Parameters subelement format(11az)).

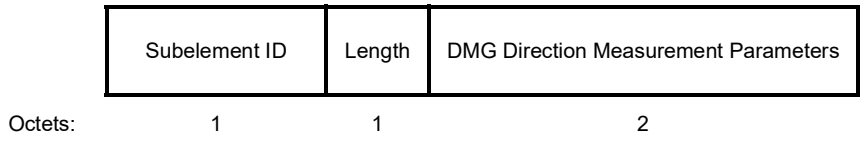


**Figure 9-725—DMG Direction Measurement Parameters subelement format(11az)**

(11az)The format of the DMG Direction Measurement Parameters field is shown in Figure 9-726 (DMG Direction Measurement Parameters field format(11az)).

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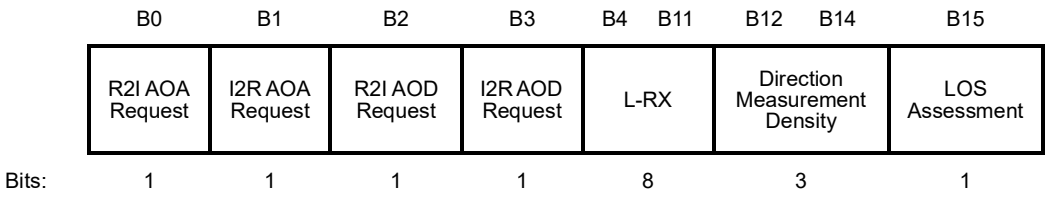


**Figure 9-726—DMG Direction Measurement Parameters field format(11az)**

(11az)A value of 1 in the R2I AOA Request subfield indicates a request for RSTA to ISTA angle of arrival measurement performed at the ISTA.

(11az)A value of 1 in the I2R AOA Request subfield indicates a request for ISTA to RSTA angle of arrival measurement performed at the RSTA.

(11az)A value of 1 in the R2I AOD Request subfield indicates a request for RSTA to ISTA angle of departure measurement performed at the ISTA.

(11az)A value of 1 in the I2R AOD Request subfield indicates a request for ISTA to RSTA angle of departure measurement performed at the RSTA.

(11az)The L-RX field indicates how many TRN-units are requested by the sender for angle of arrival measurements. The interpretation of this field is defined in 9.5.4 (BRP Request field). If either the initiator or the responder is a non-EDMG STA, the value of this field is limited to 32.

(11az)The Direction Measurement Density field indicates how often in a burst a direction measurement is performed. The interpretation of the values is defined in Table 9-327 (Direction Measurement Density field interpretation(11az)).

**Table 9-327—Direction Measurement Density field interpretation(11az)**

| Value | Interpretation |
|---|---|
| 0 | Only the first (#8113)FTM exchange in a burst is a direction measurement |
| 1 | Every measurement in a burst is a direction measurement |
| 2 | Every second measurement in a burst is a direction measurement |
| 3 | Every 4th measurement in a burst is a direction measurement |
| 4 | Every 8th measurement in a burst is a direction measurement |
| 5–7 | Reserved |

(11az)The LOS Assessment field is set to 1 in a DMG Direction Measurement Parameters field sent by an ISTA in an IFTMR frame to indicate a request for LOS assessment in the FTM session (see 11.21.6.4.8 (Measurement exchange in passive TB ranging mode(11az))).

(11az)The EDMG Specific Parameters subelement contains a number of fields that are used to advertise the requested or allocated operation configurations from one EDMG STA to another. The EDMG Specific Parameters subelement is included in the IFTMR frame, as described in 9.6.7.32 (FTM(11az) Request frame format), and the IFTM frame, as described in 9.6.7.33 (FTM(11az) frame format), if the Secure RTT


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Measurement subfield of the FTM Parameters field of these frames is equal to 1. The use of the EDMG Specific Parameters subelement is described in 11.21.6 (FTM procedure(#7065)).

(11az)The format of the EDMG Specific Parameters subelement is shown in Figure 9-727 (EDMG Specific Parameters subelement format(11az)).

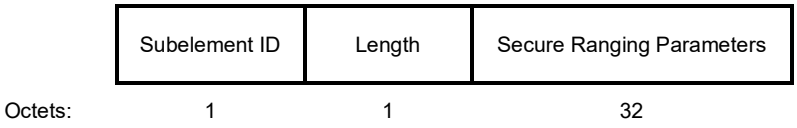


**Figure 9-727—EDMG Specific Parameters subelement format(11az)**

(11az)The format of the Secure Ranging Operation Parameters field is shown in Figure 9-728 (Secure Ranging Operation Parameters field format(11az)).

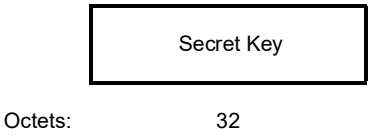


**Figure 9-728—Secure Ranging Operation Parameters field format(11az)**

(11az)The Secret Key subfield is used to carry the secret key, which is used along with Salt value (based on the PMKID), to generate the random sequence(s) as described in 12.2.12 (EDMG secure ranging sequences(11az)).

### 9.4.2.167 Device Location element

A Device Location element includes the location configuration information (LCI), which contains latitude, longitude, and altitude information. The Device Location element format is shown in Figure 9-729 (Device Location element format).

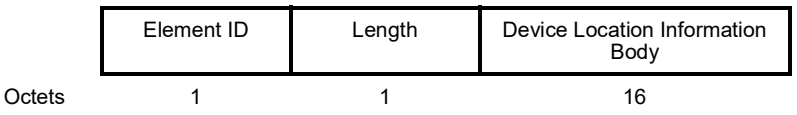


**Figure 9-729—Device Location element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The format of the Device Location Information Body field is defined in 9.4.1.54 (Device Location Information Body field).

### 9.4.2.168 White Space Map element

The White Space Map element includes available radio frequency information obtained from a GDB. The format of the WSM Information field is determined by the WSM Type field. The format of the White Space Map Announcement element is shown in Figure 9-730 (WSM element format).

The Element ID and Length fields are defined in 9.4.2.1 (General).

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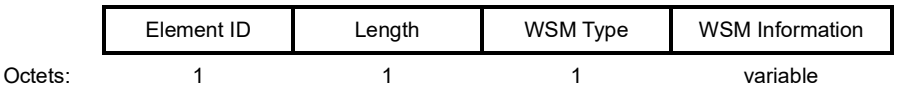


**Figure 9-730—WSM element format**

The format and values of WSM Type and WSM Information fields are defined in 9.4.1.55 (WSM Type field and WSM Information field).

### 9.4.2.169 Reduced Neighbor Report element

#### 9.4.2.169.1 General

The Reduced Neighbor Report element contains channel and other information related to neighbor APs. The format of the Reduced Neighbor Report element is shown in Figure 9-731 (Reduced Neighbor Report element format).

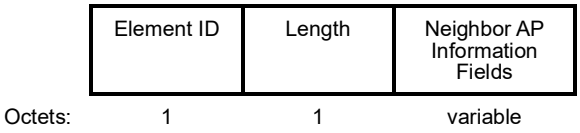


**Figure 9-731—Reduced Neighbor Report element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The Neighbor AP Information Fields field contains one or more of the Neighbor AP Information field described in 9.4.2.169.2 (Neighbor AP Information field).

#### 9.4.2.169.2 Neighbor AP Information field

The Neighbor AP Information field specifies TBTT and other information related to a group of neighbor APs on one channel. See Figure 9-732 (Neighbor AP Information field format).

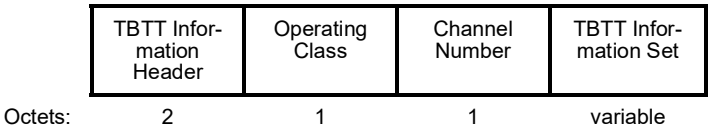


**Figure 9-732—Neighbor AP Information field format**

The format of TBTT Information Header subfield is defined in Figure 9-733 (TBTT Information Header subfield format).

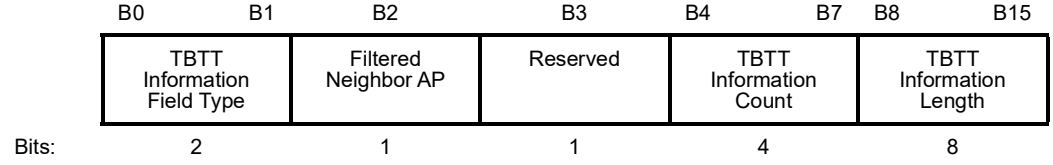


**Figure 9-733—TBTT Information Header subfield format**



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The TBTT Information Field Type subfield identifies, together with the TBTT Information Length subfield, the format of the TBTT Information field. It is set to 0 or 1(11bc).(#2218) Values (11bc)2, and 3 are reserved.

The Filtered Neighbor AP subfield is reserved except when the Reduced Neighbor Report element is carried in a Probe Response frame transmitted by a TVHT AP.

In a Probe Response frame transmitted by a TVHT AP, the Filtered Neighbor AP subfield is set to 1 if the specific SSID corresponding to every BSS of the APs in this Neighbor AP Information field matches the SSID in the corresponding Probe Request frame; otherwise it is set to 0.

The TBTT Information Count subfield contains the number of TBTT Information fields included in the TBTT Information Set field of the Neighbor AP Information field, minus one.

The TBTT Information Length subfield indicates the length of each TBTT Information field included in the TBTT Information Set field of the Neighbor AP Information field. If the TBTT Information Field Type subfield is 0, the TBTT Information Length subfield(11ax)

— Contains the length in octets of each TBTT Information field that is included in the TBTT Information Set field of the Neighbor AP Information field.
— Is set to 1, 2, 5, 6, 7, 8, 9, 11, 12, or 13; other values are reserved.(11ax)
— Indicates the TBTT Information field contents as shown in Table 9-328 (TBTT Information field contents when TBTT Information Field Type).

A TVHT AP sets the TBTT Information Length subfield to 1.

The TBTT Information Length subfield, when the TBTT Information Field Type subfield is equal to 0,(11bc) is interpreted as shown in Table 9-328 (TBTT Information field contents when TBTT Information Field Type).

**Table 9-328—TBTT Information field contents when TBTT Information Field Type**
**Table 9-329—subfield equal to 0(11bc)**

| TBTT Information Length subfield value | TBTT Information field contents |
|---|---|
| 0(#1005) | Reserved |
| 1 | The Neighbor AP TBTT Offset subfield |
| 2(11ax) | The Neighbor AP TBTT Offset subfield and the BSS Parameters subfield |
| 3(#1005) | Reserved |
| 4(#1005) | Reserved |
| 5 | The Neighbor AP TBTT Offset subfield and the Short SSID subfield |
| 6(11ax) | The Neighbor AP TBTT Offset subfield, the Short SSID subfield, and the BSS Parameters subfield |
| 7 | The Neighbor AP TBTT Offset subfield and the BSSID subfield |
| 8(11ax) | The Neighbor AP TBTT Offset subfield, the BSSID subfield, and the BSS Parameters subfield |
| 9(11ax) | The Neighbor AP TBTT Offset subfield, the BSSID subfield, the BSS Parameters subfield, and the 20 MHz PSD subfield |
| 10(#1005) | Reserved |

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**Table 9-328—TBTT Information field contents when TBTT Information Field Type Table 9-329—subfield equal to 0(11bc)**

| TBTT Information Length subfield value | TBTT Information field contents |
|---|---|
| 11 | The Neighbor AP TBTT Offset subfield, the BSSID subfield and the Short SSID subfield |
| 12(11ax) | The Neighbor AP TBTT Offset subfield, the BSSID subfield, the Short SSID subfield, and the BSS Parameters subfield |
| 13(11ax) | The Neighbor AP TBTT Offset subfield, the BSSID subfield, the Short SSID subfield, the BSS Parameters subfield, and the 20 MHz PSD subfield |
| 14–255(11ax) | The first 13 octets of the field contain the Neighbor AP TBTT Offset subfield, the BSSID subfield, the Short SSID subfield, the BSS Parameters subfield, and the 20 MHz PSD subfield (i.e., same contents as when the length of the TBTT Information field is 13). The remaining octets are reserved. |

(11bc)The TBTT Information Length subfield, when the TBTT Information Field Type subfield is equal to 1, is interpreted as shown in Table 9-330 (TBTT Information field contents when TBTT Information Field Type subfield equal to 1(11bc)).

**Table 9-330—TBTT Information field contents when TBTT Information Field Type subfield equal to 1(11bc)**

| TBTT Information Length subfield value | TBTT Information field contents |
|---|---|
| 0–1 | Reserved |
| 2 | The EBCS Info Frame Tx Countdown field as defined in 9.4.1.70 (EBCS Info Frame Tx Countdown field(11bc)) |
| 3–255 | Reserved |

The Operating Class field indicates a channel starting frequency that, together with the Channel Number field, indicates the primary channel of the BSSs of the APs in this Neighbor AP Information field.

NOTE 1—The Operating Class field and Channel Number tuple indicate the primary channel in order to assist with passive scanning.

The Channel Number field indicates the last known primary channel of the APs in this Neighbor AP Information field. Channel Number is defined within an Operating Class as shown in Table E-4 (Global operating classes).

The TBTT Information Set field contains one or more TBTT Information fields. The TBTT Information field is defined in Figure 9-734 (TBTT Information field format(11ax)).

(11ax)The Neighbor AP TBTT Offset subfield indicates the offset in TUs, rounded down to nearest TU, to the following:

— The next TBTT of the reported AP from the immediately prior TBTT of the AP that transmits this element if the reported AP is not part of a multiple BSSID set or is the transmitted BSSID of a multiple BSSID set.


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| | Neighbor AP TBTT Offset | BSSID (optional) | Short SSID (optional) | BSS parameters | 20 MHz PSD |
|---|---|---|---|---|---|
| Octets: | 1 | 0 or 6 | 0 or 4 | 0 or 1 | 0 or 1 |

**Figure 9-734—TBTT Information field format(11ax)**

— The next TBTT of the transmitted BSSID of the multiple BSSID set of the reported AP from the immediately prior TBTT of the AP that transmits this element if the reported AP is part of a multiple BSSID set and is a nontransmitted BSSID.

(11ax)The value 254 indicates an offset of 254 TUs or higher. The value 255 indicates an unknown offset value.

The BSSID field is defined in 9.2.4.3.4 (BSSID field).

(#7151)The Short SSID subfield is defined in 9.4.1.71 (Short SSID field(#7151)).

(11ax)The format of the BSS Parameters subfield is defined in Figure 9-734a (BSS Parameters subfield format(11ax)).

| | B0 | B1 | B2 | B3 | B4 | B5 | B6 | B7 |
|---|---|---|---|---|---|---|---|---|
| | OCT Recommended | Same SSID | Multiple BSSID | Transmitted BSSID | Member Of ESS With 2.4/5 GHz Colocated AP(#2210) | Unsolicited Probe Responses Active | Colocated AP(#2210) | Reserved |
| Bits: | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

**Figure 9-734a—BSS Parameters subfield format(11ax)**

(11ax)The OCT Recommended subfield is set to 1 to indicate that OCT is recommended to exchange MMPDUs with the AP identified in the TBTT Information field (see 11.31.5 (On-channel Tunneling (OCT) operation), through over-the-air transmissions with the AP sending the Reduced Neighbor Report element. It is set to 0 otherwise.

(11ax)The Same SSID subfield is set to 1 to indicate that the reported AP has the same SSID as the reporting AP. It is set to 0 otherwise.

(11ax)The Multiple BSSID subfield is set to 1 to indicate that the reported AP is part of a multiple BSSID set. It is set to 0 otherwise.

(11ax)The Transmitted BSSID subfield is set to 1 to indicate that the reported AP is a transmitted BSSID. It is set to 0 if the reported AP is a nontransmitted BSSID. It is reserved if the Multiple BSSID subfield is set to 0.

(11ax)(#2310)The Member Of ESS With 2.4/5 GHz (#2210)Colocated AP subfield is set to 1, if the reported AP is part of an ESS where all the APs in the ESS are operating in the same band as the reported AP (irrespective of the operating channel in that band) and are on the same channel and in range of a STA receiving this frame, have dot11MemberOfColocated6GHzESSOptionActivated equal to true and have a corresponding AP operating in the 2.4 GHz or 5 GHz bands that is in the same (#2210)colocated AP set as that AP. It is set to 0 otherwise or if the reporting AP does not have that information. It is reserved if the reported AP is operating in the 2.4 GHz or 5 GHz bands.

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NOTE 2—This subfield indicates that the reported AP is part of an ESS that has no 6 GHz-only APs that might be detected by a STA receiving this frame. This means that all APs operating in the 6 GHz band that are part of that ESS that might be detected by a STA receiving this frame can be discovered in the 2.4 GHz and/or 5 GHz bands.

(11ax)(#2310)The Unsolicited Probe Responses Active subfield is set to 1, if the reported AP is part of an ESS where all the APs are operating in the same channel as the reported AP and are on the same channel and in range of a STA receiving this frame, have dot11UnsolicitedProbeResponseOptionActivated equal to true and are transmitting unsolicited Probe Response frames every 20 TUs or less less (see 26.17.2.3 (Scanning in the 6 GHz band)). It is set to 0 otherwise or if the reporting AP does not have that information.

(11ax)The (#2210)Colocated AP subfield is set to 1 if the AP(#3010) is in the same (#2210)colocated AP set as the transmitting AP. It is set to 0 otherwise.

(11ax)The 20 MHz PSD subfield, if present, indicates a maximum transmit power for the Default category, with unit interpretation of PSD EIRP in dBm/MHz (see 9.4.2.160 (Transmit Power Envelope element) and 11.7.5), corresponding to the primary 20 MHz channel of the reported AP. The maximum transmit power is encoded as a 2s complement signed integer. The value –128 is reserved. The value +127 indicates that no maximum transmit power is specified for the corresponding 20 MHz channel. For all other values $Y$ of the subfield (i.e., –127 to +126), the maximum transmit power in the 20 MHz channel is $Y / 2$ dBm/MHz (i.e., ranging from –63.5 to +63 dBm/MHz).

NOTE 3—For example, suppose the reported AP transmits, in Beacon and Probe Response frames, one Transmit Power Envelope element with the Maximum Transmit Power For 20 MHz subfield indicating 20 dBm (regulatory client EIRP), then the 20 MHz PSD subfield indicates the equivalent PSD limit of 7 dBm/MHz with the value 14.

### 9.4.2.169.3 Calculating the short SSID

A short SSID is a 32-bit value calculated over an SSID. The SSID is referred to as the calculation fields. (#7151)The short SSID is calculated using the following standard generator polynomial of degree 32:

$$G(x) = x^{32} + x^{26} + x^{23} + x^{22} + x^{16} + x^{12} + x^{11} + x^{10} + x^8 + x^7 + x^5 + x^4 + x^2 + x + 1$$

(#7151)The short SSID is the 1s complement of the sum (modulo 2) of the following:

a) The remainder of $x^k \times (x^{31} + x^{30} + x^{29} + \ldots + x^2 + x + 1)$ divided (modulo 2) by $G(x)$, where $k$ is the number of bits in the calculation fields, and

b) The remainder after multiplication of the contents (treated as a polynomial) of the calculation fields by $x^{32}$ and then division by $G(x)$(#7151).

### 9.4.2.170 TVHT Operation element

The operation of TVHT STAs in the BSS is controlled by the TVHT Operation element. The format of the TVHT Operation element is defined in Figure 9-735 (TVHT Operation element format).

| | Element ID | Length | TVHT Operation Information | Basic VHT-MCS And NSS Set |
|---|---|---|---|---|
| Octets: | 1 | 1 | 4 | 2 |

**Figure 9-735—TVHT Operation element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The structure of the TVHT Operation Information field is defined in Figure 9-736 (TVHT Operation Information field format).


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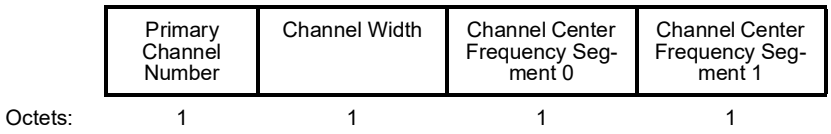


**Figure 9-736—TVHT Operation Information field format**

The subfields of the TVHT Operation Information field are defined in Table 9-331 (TVHT Operation Information subfields).

**Table 9-331—TVHT Operation Information subfields**

| Field | Definition | Encoding |
|---|---|---|
| Primary Channel Number | Indicates the channel number of the primary channel (see 11.41 (Basic TVHT BSS functionality)). | Channel number of the primary channel. |
| Channel Width | This field defines the BSS bandwidth (see 11.41 (Basic TVHT BSS functionality)). | Set to 0 for TVHT_W BSS bandwidth.<br>Set to 1 for TVHT_2W BSS bandwidth.<br>Set to 2 for TVHT_W+W BSS bandwidth.<br>Set to 3 for TVHT_4W BSS bandwidth.<br>Set to 4 for noncontiguous TVHT_2W+2W BSS bandwidth.<br>Values in the range 5 to 255 are reserved. |
| Channel Center Frequency Segment 0 | Defines the channel center frequency for a TVHT_W, TVHT_2W, and TVHT_4W TVHT BSS and the segment 0 channel center frequency for a TVHT_W+W and TVHT_2W+2W TVHT BSS. See 22.3.14 (Channelization). | For TVHT_W or TVHT_2W or TVHT_4W BSS bandwidth, indicates the center frequency of the lowest TV channel index for the TVHT_W or TVHT_2W or TVHT_4W channel on which the TVHT BSS operates.<br>For TVHT_W+W or TVHT_2W+2W BSS bandwidth, indicates the lowest TV channel index for the TVHT_W or TVHT_2W channel of frequency segment 0 on which the TVHT BSS operates.<br>Reserved otherwise. |
| Channel Center Frequency Segment 1 | Defines the segment 1 channel center frequency for a TVHT_W+W and TVHT_2W+2W TVHT BSS. See 22.3.14 (Channelization). | For TVHT_W+W or TVHT_2W+2W BSS bandwidth, indicates the lowest TV channel index in the segment for the TVHT_W or TVHT_2W channel of frequency segment 1 on which the TVHT BSS operates.<br>Reserved otherwise. |

The Basic VHT-MCS And NSS Set field indicates the MCSs for each spatial stream in VHT PPDU in TVWS bands that are supported by all TVHT STAs in the BSS (including IBSS). The Basic VHT-MCS And NSS Set field is a bitmap of size 16 bits; B8-B9, B10-B11, B12-B13, and B14-B15 are set to 3. For B0-B7, each 2 bits indicates the supported MCS set for $N_{SS}$ from 1 to 4. The Basic VHT-MCS And NSS Set field is defined as B0-B7 of Rx VHT-MCS Map subfield in 9.4.2.156.3 (Supported VHT-MCS and NSS Set field).

### 9.4.2.171 FTM Synchronization Information element

The format of the FTM Synchronization Information element is defined in Figure 9-737 (FTM Synchronization Information element format).

The Element ID, Length and Element ID Extension fields are defined in 9.4.2.1 (General).

The TSF Sync Info field is set to the 4 least significant octets of the TSF.

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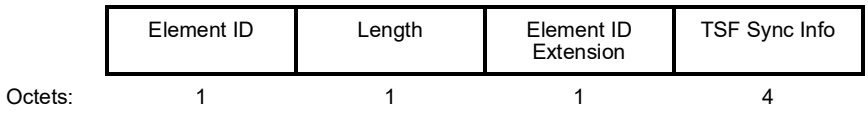


**Figure 9-737—FTM Synchronization Information element format**

### 9.4.2.172 Estimated Service Parameters Inbound element

The Estimated Service Parameters Inbound element is used by a STA to provide information to another STA that can then use the information as input to an algorithm to generate an estimate of inbound throughput between the two STAs.

The format of the Estimated Service Parameters Inbound element is shown in Figure 9-738 (Estimated Service Parameters Inbound element format).

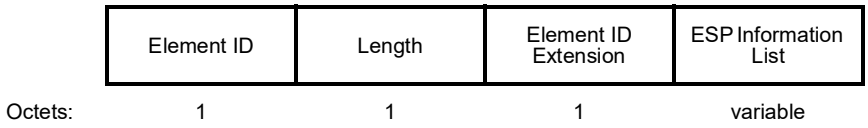


**Figure 9-738—Estimated Service Parameters Inbound element format**

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

The ESP Information List field contains from 1 to 4 ESP Information fields, each corresponding to an access category for which estimated service parameters information is provided.

The format of the ESP Information field is shown in Figure 9-739 (ESP Information field format).

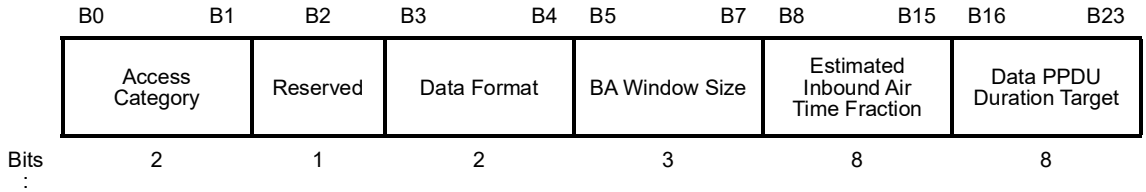


**Figure 9-739—ESP Information field format**

The Access Category subfield indicates the access category to which the remaining parameters of the ESP Information field apply. The encoding of the Access Category subfield is given in Table 9-332 (Access Category subfield encoding). When parameters for more than one access category are present in an Estimated Service Parameters Inbound element the ESP Information fields for the access categories appear in order of Access Category subfield value, with the ESP Information field with the lowest Access Category subfield value appearing first.

**Table 9-332—Access Category subfield encoding**

| Value | Access Category |
|---|---|
| 0 | AC_BK |
| 1 | AC_BE |



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**Table 9-332—Access Category subfield encoding**

| Value | Access Category |
|---|---|
| 2 | AC_VI |
| 3 | AC_VO |

The Data format subfield has the meaning indicated in Table 9-333 (Data Format subfield encoding).

**Table 9-333—Data Format subfield encoding**

| Value | Description |
|---|---|
| 0 | No aggregation is expected to be performed for MSDUs or MPDUs with the Type subfield equal to Data for the corresponding AC |
| 1 | A-MSDU aggregation is expected to be performed for MSDUs for the corresponding AC, but A-MPDU aggregation is not expected to be performed for MPDUs with the Type subfield equal to Data for the corresponding AC |
| 2 | A-MPDU aggregation is expected to be performed for MPDUs with the Type subfield equal to Data for the corresponding AC, but A-MSDU aggregation is not expected to be performed for MSDUs for the corresponding AC |
| 3 | A-MSDU aggregation is expected to be performed for MSDUs for the corresponding AC, and A-MPDU aggregation is expected to be performed for MPDUs with the Type subfield equal to Data for the corresponding AC |

The BA Window Size subfield is indicates the size of the Block Ack window that is expected for the corresponding access category as defined in Table 9-334 (BA Window Size subfield encoding). When the Block Ack window size expected to be used by the transmitter of the element does not match any of the values shown in the table, the transmitter uses the next lower value in the table.

**Table 9-334—BA Window Size subfield encoding**

| Value | Expected block ack window size |
|---|---|
| 0 | Block Ack not expected to be used |
| 1 | 2 |
| 2 | 4 |
| 3 | 6 |
| 4 | 8 |
| 5 | 16 |
| 6 | 32 |
| 7 | 64 |

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The Estimated Inbound Air Time Fraction subfield contains an unsigned integer that represents the predicted percentage of time, linearly scaled with 255 representing 100% and 0 representing 0%, that a new STA joining the BSS can expect to be available for the transmission of PPDUs to that STA, including overhead, where such PPDUs contain MPDUs with the Type subfield equal to Data that belong to the access category indicated in the Access Category subfield of the corresponding ESP Information field and any other MPDUs in the PPDU are considered to be overhead.

The Data PPDU Duration Target field is an unsigned integer that indicates the expected target duration of PPDUs transmitted to the STA that contain MPDUs with the Type subfield equal to Data that belong to the access category indicated in the Access Category subfield of the corresponding ESP Information field for the corresponding access category in units of 50 μs. This value is determined using a method that is beyond the scope of this standard.

### 9.4.2.173 Future Channel Guidance element

The Future Channel Guidance element is used by an AP, IBSS STA, mesh STA, or PCP to guide STAs about the likely future channel if the sending STA changes channels of operation. The format of the Future Channel Guidance element is shown in Figure 9-740 (Future Channel Guidance element format).

| | Element ID | Length | Element ID Extension | New Channel Number | Secondary Channel Offset element | Mesh Channel Switch Parameters element | Wide Bandwidth Channel Switch element | New Transmit Power Envelope element |
|---|---|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 4 | 0 or 3 | 0 or 8(#6142) | 0 or 5 | variable |

**Figure 9-740—Future Channel Guidance element format**

The Element ID, Length and Element ID Extension fields are defined in 9.4.2.1 (General).

The New Channel Number field is set to the number of the channel to which the STA will be moving in the event of a channel switch (as defined in 17.3.8.4.3 (Channelization)).

The Secondary Channel Offset element is defined in 9.4.2.18 (Secondary Channel Offset element). This element is present when switching to a 40 MHz or wider channel. It is optionally present when switching to a 20 MHz channel (in which case the Secondary Channel Offset field is set to SCN). See 11.38.4 (Channel switching methods for a VHT BSS).

The Mesh Channel Switch Parameters element is defined in 9.4.2.101 (Mesh Channel Switch Parameters element). This element is present when a mesh STA performs MBSS channel switch. Otherwise, the Mesh Channel Switch Parameters element is not present.

The Wide Bandwidth Channel Switch element is defined in 9.4.2.159 (Wide Bandwidth Channel Switch element). This element is present when switching to a channel width wider than 40 MHz.

Each New Transmit Power Envelope element that is present is defined to have the same format as the Transmit Power Envelope element (see 9.4.2.160 (Transmit Power Envelope element) and includes a distinct value of the Local Maximum Transmit Power Unit Interpretation subfield. If present, the New Transmit Power Envelope element indicates the local maximum transmit powers for the BSS for the BSS for the indicated bandwidths with an indicated unit interpretation after channel switching (see 11.38.1 (Basic VHT BSS functionality)).

The Future Channel Guidance procedure is defined in 11.8.10 (Future Channel Guidance operation).


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### 9.4.2.174 Association Delay Info element

The Association Delay Info element is used to identify the minimum (re)association response timeout to the non-AP STA. The format of the Association Delay Info element is shown in Figure 9-741 (Association Delay Info element format).

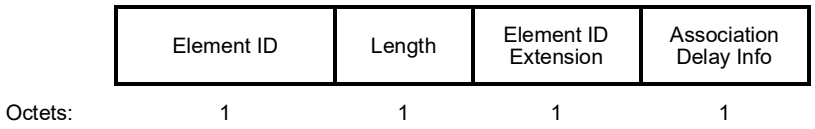


**Figure 9-741—Association Delay Info element format**

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

The Association Delay Info field contains an unsigned integer indicating the minimum association response delay in number of TUs.

### 9.4.2.175 CAG Number element

The Common Advertisement Group (CAG) is a group of elements that are defined by the same advertisement protocol and that do not change on a rapid basis within an AP. The CAG Number element provides one or more current version numbers of the CAG (CAG Version) associated with the AP, where each version number is associated with a specific advertisement protocol and server. The CAG Number element is optionally present in the Beacon or Probe Response frame to reduce GAS frame exchanges when dot11InterworkingServiceActivated is true. The CAG Number element is optionally present in the GAS Initial Request frame to indicate the CAG Version and the associated CAG Information Type cached by the non-AP STA when dot11SolicitedPADActivated is true.

The format of the CAG Number element is shown in Figure 9-742 (CAG Number element format).

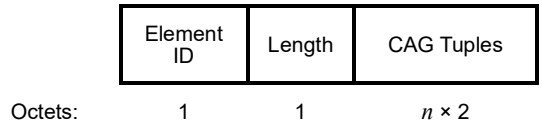


**Figure 9-742—CAG Number element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The CAG Tuples field contains one or more (#2047)CAG Tuple fields. The format of a CAG Tuple field is shown in Figure 9-743 (CAG Tuple field).

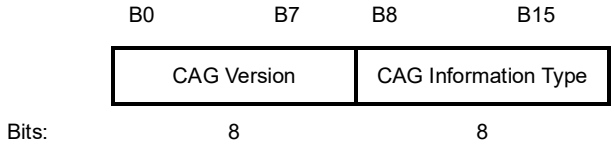


**Figure 9-743—CAG Tuple field**

The CAG Version subfield is an unsigned integer indicating the current version of the CAG of the associated advertisement protocol and server indicated by the CAG Information Type subfield in the same CAG Tuple field. The use of CAG Version is explained in 11.22.3.3 (ANQP procedures).

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The CAG Information Type subfield is indicates the type of information associated with the CAG Version in the same CAG Tuple field. The CAG Information Type is defined in Table 9-335 (CAG Information Type definitions).

**Table 9-335—CAG Information Type definitions**

| Name | Value |
|---|---|
| Access network query protocol (ANQP) | 0 |
| MIS Information Service | 1 |
| MIS Command and Event Services Capability Discovery | 2 |
| Emergency Alert System (EAS) | 3 |
| Registered location query protocol (RLQP) | 4 |
| Reserved | 5–127 |
| ANQP with Service Information Registry | 128 |
| Reserved | 129–220 |
| Vendor Specific | 221 |
| Reserved | 222–255 |

### 9.4.2.176 FILS Request Parameters element(#2193)

The contents of the FILS Request Parameters element in Probe Request frame are used in determining whether to transmit a Probe Response frame as described in 11.1.4.3.4 (Criteria for sending a response). The FILS Request Parameters element is defined in Figure 9-744 (FILS Request Parameters element format).

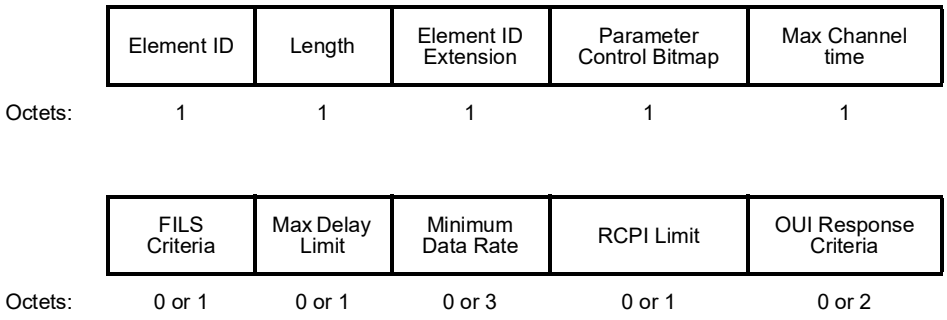


**Figure 9-744—FILS Request Parameters element format**

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

The Parameter Control Bitmap field is shown in Figure 9-745 (Parameter Control Bitmap field format).

Bits 0 to 4 of the Parameter Control Bitmap field correspond to the Parameter fields that are (#288)optionally present in the element. A 1 in a bit indicates the corresponding parameter is present, and 0 indicates the corresponding parameter is not present.

The FILS Criteria field is shown in Figure 9-746 (FILS Criteria field format).


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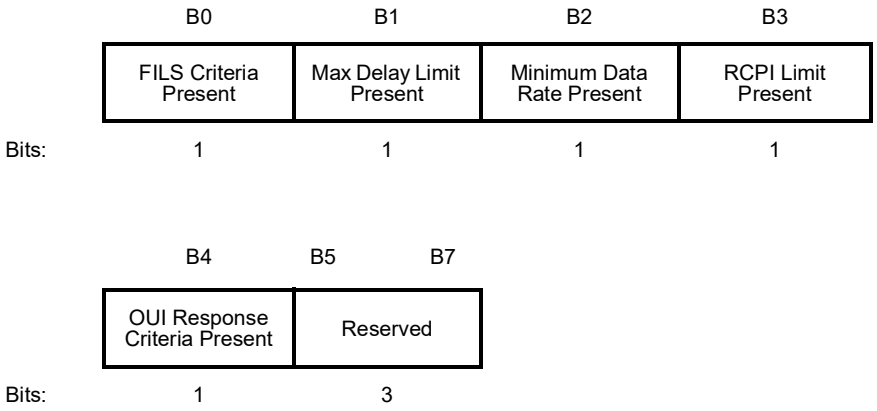


**Figure 9-745—Parameter Control Bitmap field format**

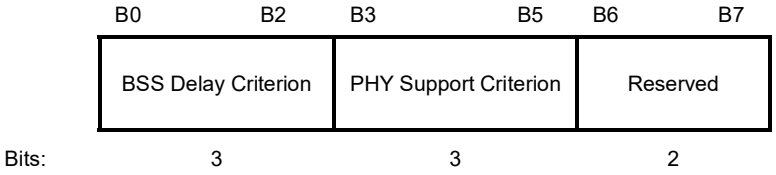


**Figure 9-746—FILS Criteria field format**

The BSS Delay Criterion subfield indicates the delay type that is applied in the decision to respond to the Probe Request frame as described in 11.1.4.3.4 (Criteria for sending a response). The delay type is selected as indicated in Table 9-336 (BSS Delay Criterion subfield).

**Table 9-336—BSS Delay Criterion subfield**

| Value | Explanation |
|---|---|
| 0 | Delay criterion is not in use. |
| 1 | Access delay is indicated as Average Access Delay for Background (AC_BK) subfield of the BSS AC Access Delay element as described in 9.4.2.42 (BSS AC Access Delay element). |
| 2 | Access delay is indicated as Average Access Delay for Best Effort (AC_BE) subfield of the BSS AC Access Delay element as described in 9.4.2.42 (BSS AC Access Delay element). |
| 3 | Access delay is indicated as Average Access Delay for Video (AC_VI) subfield of the BSS AC Access Delay element as described in 9.4.2.42 (BSS AC Access Delay element). |
| 4 | Access delay is indicated as Average Access Delay for Voice (AC_VO) subfield of the BSS AC Access Delay element as described in 9.4.2.42 (BSS AC Access Delay element). |
| 5 | Access Delay is indicated as Average Access Delay as described in 9.4.2.42 (BSS AC Access Delay element). |
| 6, 7 | Reserved |

The PHY Support Criterion subfield indicates the required PHY type of the responding STA.

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The indicated PHY type is used in the decision to respond to the Probe Request frame as described in 11.1.4.3.4 (Criteria for sending a response). The meaning of the values for the PHY Support Criterion is shown in Table 9-337 (PHY Support Criterion subfield).

**Table 9-337—PHY Support Criterion subfield**

| Value | Explanation |
|---|---|
| 0 | Indicates that PHY Support Criterion is not in use. |
| 1 | Indicates that a responding FILS STA is HT capable. |
| 2 | Indicates that a responding FILS STA is VHT capable. |
| 3(11ax) | Indicates that a responding FILS STA is HE capable. |
| 4–7 | Reserved |

The Max Delay Limit field (see 11.1.4.3.4 (Criteria for sending a response)) is an unsigned integer in units of 400 μs to indicate the maximum access delay as indicated by the BSS Delay Criterion subfield of the FILS Criteria of the FILS Request Parameters element. Value 0 is reserved. The use of the maximum access delay and the delay criterion are explained in 11.1.4.3.4 (Criteria for sending a response). Max Delay Limit is not present if FILS Criteria is not present or BSS Delay Criterion is not in use.

The Minimum Data Rate field (see 11.1.4.3.4 (Criteria for sending a response)), if present, contains an unsigned integer in units of Kb/s(#4148) that specifies the lowest total data rate specified at the MAC SAP for transport of MSDUs or A-MSDUs that the STA is going to transmit. The minimum MAC SAP data rate does not include the MAC and PHY overheads incurred in transferring the MSDUs or A-MSDUs.

The RCPI Limit field is an unsigned integer in units of 1 dB. The use of the RCPI Limit field is explained in 11.1.4.3.4 (Criteria for sending a response).

(#3011)The OUI Response Criteria field (see(#3011) 11.1.4.3.4 (Criteria for sending a response)) is a bitmap whose bits correspond to the Vendor Specific elements of the Probe Request frame in order of presence. Bit 0 corresponds to the first Vendor Specific element, bit 1 corresponds to the second, etc. A bit value of 1 in the OUI Response Criteria field indicates that the receiver identifies the Organization Identifier field of the corresponding Vendor Specific element in order to respond to the request and otherwise is 0. If the number of the Vendor Specific elements of the Probe Request frame is less than the number of bits of the OUI Response Criteria field, the remaining bits of the OUI Response Criteria field are 0. If the number of bits in the OUI Response Criteria field is less than the number of Vendor Specific elements in the Probe Request frame, the corresponding bits not present in the OUI Response Criteria field are assumed to be 0.

The Max Channel Time field (see(#3011) 11.1.4.3.4 (Criteria for sending a response)) contains the value of MaxChannelTime parameter of the MLME-SCAN.request primitive represented in units of TUs, as an unsigned integer. Setting the Max Channel Time field to 255 is used to indicate any duration of more than 254 TUs, or an unspecified or unknown duration.

### 9.4.2.177 FILS Key Confirmation element

The FILS Key Confirmation element is used to convey a cryptographic proof of authentication between a STA and an AP. The format of the FILS Key Confirmation element is shown in Figure 9-747 (FILS Key Confirmation element format).

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).


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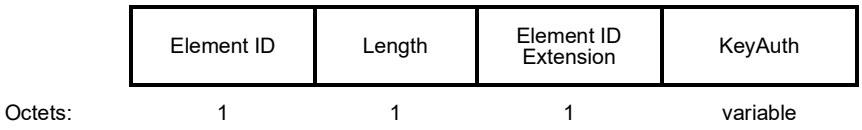


**Figure 9-747—FILS Key Confirmation element format**

The KeyAuth field contains the cryptographic authentication information (see 12.11.2.6 (Key confirmation with FILS authentication)).

### 9.4.2.178 FILS Session element

The FILS Session element is used to convey the (unique) identifier of an in-progress FILS authentication protocol session. The format of the FILS Session element is shown in Figure 9-748 (FILS Session element format).

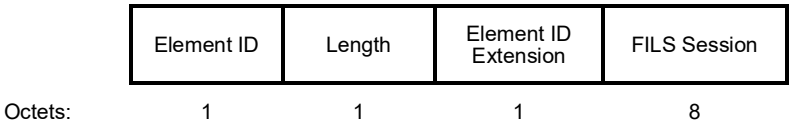


**Figure 9-748—FILS Session element format**

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

The FILS Session field is chosen randomly by the non-AP STA.

### 9.4.2.179 FILS Public Key element

The FILS Public Key element is used to communicate the device's (certified) public key for use with the FILS authentication exchange. The format of the FILS Public Key element is shown in Figure 9-749 (FILS Public Key element format).

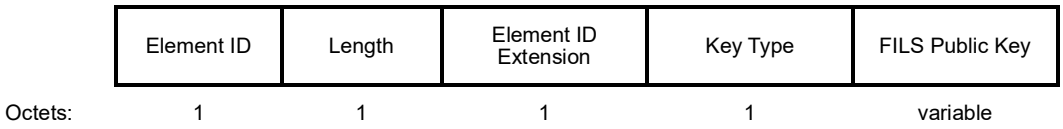


**Figure 9-749—FILS Public Key element format**

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

The Key Type field values are as follows:

0: Reserved.
1: FILS Public Key field contains an X.509v3 certificate encoded according to IETF RFC 5280.
2: FILS Public Key field contains an uncertified public key encoded according to IETF RFC 5480.
3: FILS Public Key field contains an uncertified public key encoded according to IETF RFC 3279.
4–255: Reserved.

### 9.4.2.180 AP Configuration Sequence Number (AP-CSN) element

An AP-CSN element indicates the change of system information within a BSS. The format of the AP-CSN element is shown in Figure 9-750 (AP-CSN element format).

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| | Element ID | Length | AP-CSN |
|---|---|---|---|
| Octets: | 1 | 1 | 1 |

**Figure 9-750—AP-CSN element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The AP-CSN contains the version number of the BSS configuration parameter set(#8158). This value increments when an update of the non-dynamic elements (all elements except dynamic elements indicated in 11.1.4.3.11 (Enhanced FILS active scanning to preferred AP)) inside a Beacon frame has occurred, as described in 11.1.4.3.11 (Enhanced FILS active scanning to preferred AP).

### 9.4.2.181 FILS Indication element

The FILS Indication element shown in Figure 9-751 (FILS Indication element format) contains information related to FILS authentication and higher layer setup capabilities of the AP.

| | Element ID | Length | FILS Information | Cache Identifier | HESSID | Realm Identifier | Public Key Identifiers (#3493) |
|---|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 2 | 0 or 2 | 0 or 6 | variable | variable |

**Figure 9-751—FILS Indication element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The FILS Information field provides information on the presence of the following optional fields in the FILS Indication element and the capability of the FILS authentication algorithms. The format of the FILS Information field is shown in Figure 9-752 (FILS Information field format).

| | B0 B2 | B3 B5 | B6 | B7 | B8 | B9 | B10 | B11 | B12 B15 |
|---|---|---|---|---|---|---|---|---|---|
| | Number of Public Key Identifi-ers | Number of Realm Identifi-ers | FILS IP Address Configu-ration | Cache Identifier Included | HESSID Included | FILS Shared Key Authentic ation without PFS Sup-ported | FILS Shared Key Authentic ation with PFS Sup-ported | FILS Public Key Authenti cation Sup-ported | Reserved |
| Bits: | 3 | 3 | 1 | 1 | 1 | 1 | 1 | 1 | 4 |

**Figure 9-752—FILS Information field format**

The Number of Public Key Identifiers subfield (#3493)contains the number of Public Key Identifier fields that are present in the Public Key Identifiers field in the FILS Indication element. When the Number of Public Key Identifiers subfield is 0, (#3493)the Public Key Identifiers field is not present in the FILS Indication element. Each Public Key Identifier (#3493)field is formatted per Figure 9-754 (Public Key Identifier field format)(#8247).

The Number of Realm Identifiers subfield lists the number of realm identifiers that are present in the Realm Identifier field in the FILS Indication element. When the Number of Realm Identifiers subfield is 0, the


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Realm Identifier field is not present in the FILS Indication element. Each realm identifier is formatted per Figure 9-753 (Realm Identifier field format)(#8247).

An AP sets the FILS IP Address Configuration bit to 1 if the AP supports FILS IP address configuration and is set to 0 otherwise.

The Cache Identifier Included bit is set in the FILS Information field when PMKSA caching is supported. When the Cache Identifier Included bit is 1, a (#2047)Cache Identifier field is present in the FILS Indication element. When the Cache Identifier Included bit is 0 the Cache Identifier field is not present in the FILS Indication element. The content of the Cache Identifier field is an opaque octet string that identifies the scope in which PMKSAs are cached. The assignment of the cache identifier is outside the scope of the standard but its value (#6025)is unique per Authenticator(#1441)(#1380) within an ESS. On the AP, dot11CacheIdentifier contains the value of the Cache Identifier.

When the HESSID Included bit is 1, a (#2047)HESSID field is present in the FILS Indication element. When the HESSID Included bit is 0, the HESSID field is not present in the FILS Indication element. The HESSID field is set to the value of dot11HESSID.

An AP sets the FILS Shared Key authentication without PFS Supported bit to 1 if the AP supports FILS Shared Key authentication without PFS and sets it to 0 otherwise. An AP sets the FILS Shared Key authentication with PFS Supported bit to 1 if the AP supports FILS Shared Key authentication with PFS and sets it to 0 otherwise. An AP sets the FILS Public Key Authentication Supported bit to 1 if the AP supports FILS Public Key authentication and sets it to 0 otherwise.

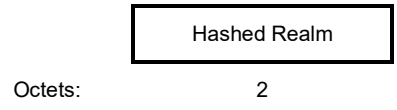


**Figure 9-753—Realm Identifier field format**

The Hashed Realm subfield of the Realm Identifier field entry is computed from the realm that is compliant with the preferred name syntax defined in IETF RFC 1035 (same as the domain name used in 9.4.5.15 (Domain Name ANQP-element)). The exact computation method for the hashed realm is given in 11.42.4 (Channel availability query (CAQ) procedure).

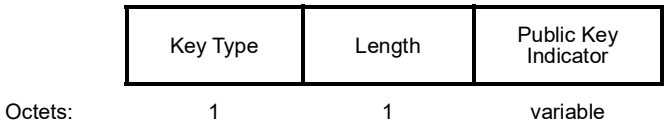


**Figure 9-754—Public Key Identifier field format**

The Key Type and Public Key Indicator subfields are described in Table 9-338 (Key Type and Public Key Indicator subfields). The Length subfield indicates the length in octets of the Public Key Indicator subfield.

**Table 9-338—Key Type and Public Key Indicator subfields**

| Key Type subfield | Public Key Indicator subfield |
|---|---|
| 0 | Reserved |
| 1 | The Issuer, per IETF RFC 5280, of the AP's certificate |

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**Table 9-338—Key Type and Public Key Indicator subfields**

| Key Type subfield | Public Key Indicator subfield |
|---|---|
| 2 | A SHA-256 hash of the AP's uncertified IETF RFC 5480 public key |
| 3 | A SHA-256 hash of the AP's uncertified IETF RFC 3279 public key |
| 4–255 | Reserved |

### 9.4.2.182 FILS HLP Container element

The FILS HLP Container element contains higher layer protocol (HLP) packets transported during FILS association. (#8248)This element is used for higher layer protocol packet encapsulation (11.45.3.2 (Higher layer protocol encapsulation)). The format of the FILS HLP Container element is shown in Figure 9-755 (FILS HLP Container element format).

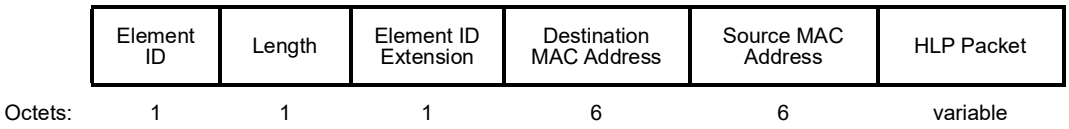


**Figure 9-755—FILS HLP Container element format**

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

The Destination MAC Address field and the Source MAC Address field are set as described in 11.45.3.2 (Higher layer protocol encapsulation).

The HLP Packet field contains the HLP packet.

### 9.4.2.183 FILS IP Address Assignment element

#### 9.4.2.183.1 General

The FILS IP Address Assignment element is used by a STA to request or to assign an IP address using (#479)FILS IP address configuration (11.45.3.3 (FILS IP address configuration)). (#8249)The format of the FILS IP Address Assignment element is shown in Figure 9-756 (FILS IP Address Assignment element format).

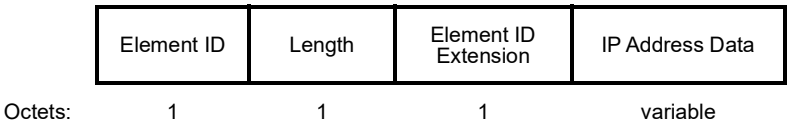


**Figure 9-756—FILS IP Address Assignment element format**

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

The IP Address Data field in (Re)Association Request and FILS Container frames from a non-AP STA to an AP is described in 9.4.2.183.2 (IP Address Data field for request). The IP Address Data field in (Re)Association Response frame and FILS Container frames from an AP to a non-AP STA is described in 9.4.2.183.3 (IP Address Data field for response).


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#### 9.4.2.183.2 IP Address Data field for request

The format of the IP Address Data field for request is shown in Figure 9-757 (IP Address Data field format for request).

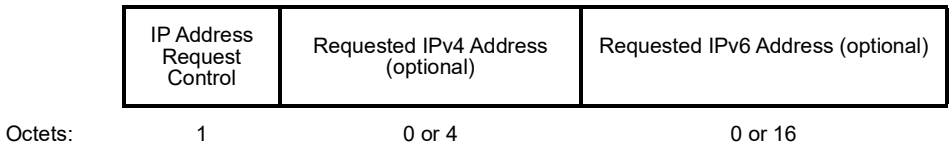


**Figure 9-757—IP Address Data field format for request**

The format of the IP Address Request Control subfield is shown in Figure 9-758 (IP Address Request Control subfield format).

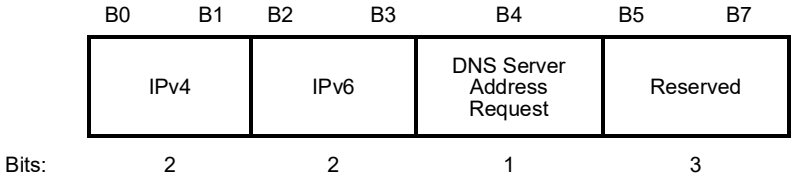


**Figure 9-758—IP Address Request Control subfield format**

The IPv4 subfields are set as shown in Table 9-339 (IPv4 subfield settings). The IPv6 subfields are set as shown in Table 9-340 (IPv6 subfield settings).

**Table 9-339—IPv4 subfield settings**

| IPv4 subfield | Explanation |
|---|---|
| 0 | STA is not requesting an IPv4 address |
| 1 | Reserved |
| 2 | STA is requesting a new IPv4 address |
| 3 | STA is requesting the IPv4 address present in the element |

**Table 9-340—IPv6 subfield settings**

| IPv6 subfield | Explanation |
|---|---|
| 0 | STA is not requesting an IPv6 address |
| 1 | Reserved |
| 2 | STA is requesting a new IPv6 address |
| 3 | STA is requesting the IPv6 address present in the element |

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The DNS Server Address Request subfield is 1 if the STA is requesting DNS server(s) address(es). The type of DNS server requested corresponds to the type of the IP address requested. If both IPv4 and IPv6 are requested, then DNS server addresses for both types are also requested by setting this bit to 1.

The Requested IPv4 Address field (4 octets) carries the specific IPv4 address that the non-AP STA is requesting, when the IPv4 field indicates the STA is requesting a specific IPv4 address.

The Requested IPv6 Address field (16 octets) carries the specific IPv6 address that the non-AP STA is requesting, when the IPv6 field indicates the STA is requesting a specific IPv6 address.

### 9.4.2.183.3 IP Address Data field for response

The format of the IP Address Data field for response is shown in Figure 9-759 (IP Address Data field format for response).

| | IP Address Response Control | DNS Info Control | Assigned IPv4 Address (optional) | Subnet Mask (optional) | IPv4 Gateway Address (optional) |
|---|---|---|---|---|---|
| Octets: | 1 | 1 | 0 or 4 | 0 or 4 | 0 or 4 |

| | IPv4 Gateway MAC Address (optional) | Assigned IPv6 Address (optional) | IPv6 Prefix Length (optional) | IPv6 Gateway Address (optional) |
|---|---|---|---|---|
| Octets: | 0 or 6 | 0 or 16 | 0 or 1 | 0 or 16 |

| | IPv6 Gateway MAC Address (optional) | Lifetime of the Assigned IPv4 Address (optional) | Lifetime of the Assigned IPv6 Address (optional) | DNS Server IPv4 Address (optional) |
|---|---|---|---|---|
| Octets: | 0 or 6 | 0 or 1 | 0 or 1 | 0 or 4 |

| | DNS Server IPv6 Address (optional) | IPv4 DNS Server MAC Address (optional) | IPv6 DNS Server MAC Address (optional) |
|---|---|---|---|
| Octets: | 0 or 16 | 0 or 6 | 0 or 6 |

**Figure 9-759—IP Address Data field format for response**

NOTE—IPv4 addressing is described in IETF RFC 791. IP Subnet and Subnet Mask is described IETF RFC 917. IPv6 addressing, IPv6 prefix and prefix-length is described in IETF RFC 4291. A default gateway in computer networking is a device that is assumed to know how to forward packets on to other networks or the Internet. IPv4 Gateway Address is the IPv4 address of the default gateway when IPv4 is used. IPv6 Gateway Address is the IPv6 address of the default gateway when IPv6 is used. The IPv6 Gateway MAC address is the MAC address of the IPv6 default gateway.

Subfields of the IP Address Response Control field(#2047) are interpreted dependent on the value of B0 (IP Address pending) as defined in Table 9-341 (IP Address Response Control subfield with B0 = 0) and Table 9-342 (IP Address Response Control subfield with B0 = 1).


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**Table 9-341—IP Address Response Control subfield with B0 = 0**

| Bit | Function of the subfield | Explanation |
|---|---|---|
| B0 | IP address pending | Set to 0 if an IP address assignment is included in the frame. B1 to B6 are set as shown below in this table when B0 = 0. |
| B1 | IPv4 assigned | Set to 1 if the Assigned IPv4 Address subfields are included in the element, and set to 0 otherwise. |
| B2 | IPv4 gateway included | Set to 1 if IPv4 Gateway Address and IPv4 Gateway MAC Address subfields are included in the element and set to 0 otherwise. See NOTE. |
| B3 | IPv6 assigned | Set to 1 if Assigned IPv6 Address and IPv6 Prefix Length subfields are included in the element and set to 0 otherwise. |
| B4 | IPv6 gateway included | Set( to 1 if IPv6 Gateway Address and IPv6 Gateway MAC Address subfields are included in the element and set to 0 otherwise. See NOTE. |
| B5 | Lifetime of the assigned IPv4 address included | Set to 1 if Assigned IPv4 Address subfield is present and the Lifetime of the Assigned IPv4 Address is included in the element. If this bit is 0, and if Assigned IPv4 Address subfield is present, then the assigned IPv4 address is valid during the entire time of association with the AP. |
| B6 | Lifetime of the assigned IPv6 address included | Set to 1 if Assigned IPv6 Address subfield is present and the Lifetime of the Assigned IPv6 Address is included in the element. If this bit is 0, and if Assigned IPv6 Address subfield is present, then the assigned IPv6 address is valid during the entire time of association with the AP. |
| B7 | Reserved | |

NOTE—A STA in a purely local network environment might be assigned an IP address without requiring a gateway address.

**Table 9-342—IP Address Response Control subfield with B0 = 1**

| Bit | Function of the subfield | Explanation |
|---|---|---|
| B0 | IP address pending | Set to 1 if an IP address is sent in a later transmission. An IP address is NOT present in the frame when set to 1. B1 to B6 are set as shown below in this table when B0 = 1. |
| B1–B6 | IP address request timeout | IP address request timeout value is the maximum estimated time in the unit of seconds within which an IP address (#8250)will be assigned and a DNS server address will be provided to the requesting STA. The value of 0 is reserved. |
| B7 | Reserved | |

The format of the DNS Info Control subfield is shown in Figure 9-760 (DNS Info Control subfield format) and the DNS Info Control subfield settings are shown in Table 9-343 (DNS Info Control subfield settings).

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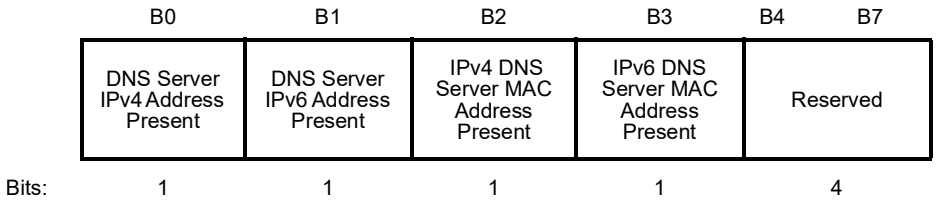


**Figure 9-760—DNS Info Control subfield format**

**Table 9-343—DNS Info Control subfield settings**

| Bit | Function of the subfield | Explanation |
|---|---|---|
| B0 | DNS server IPv4 address included | Set to 1 if the DNS Server IPv4 Address subfield is present in the element and set to 0 otherwise. The value of the DNS Server IPv4 Address subfield is the IPv4 address of the DNS server if the DNS Server IPv4 address Present bit of the DNS Info Control subfield is 1. |
| B1 | DNS server IPv6 address included | Set to 1 if the DNS Server IPv6 Address subfield is present in the element and set to 0 otherwise. The value of the DNS Server IPv6Address is the IPv6 address of the DNS server if the DNS Server IPv6 address Present bit of the DNS Info Control is 1. |
| B2 | IPv4 DNS server MAC address included | Set to 1 if the MAC address to which IPv4 based DNS queries can be sent is present in the element and set to 0 otherwise.<br>The value of the IPv4 DNS Server MAC Address subfield is the MAC address of the IPv4 DNS server if the IPv4 DNS Server MAC Address Present bit of the DNS Info Control subfield is 1. |
| B3 | IPv6 DNS server MAC address included | Set to 1 if the MAC address to which IPv6 based DNS queries can be sent is present in the element and set to 0 otherwise.<br>The value of the IPv6 DNS Server MAC Address subfield is the MAC address of the IPv6 DNS server if the IPv6 DNS Server MAC Address Present bit of the DNS Info Control subfield is 1. |

### 9.4.2.184 Key Delivery element

The Key Delivery element contains the current (#1406)RSC and one or more KDEs. The format of the Key Delivery element is shown in Figure 9-761 (Key Delivery element format).

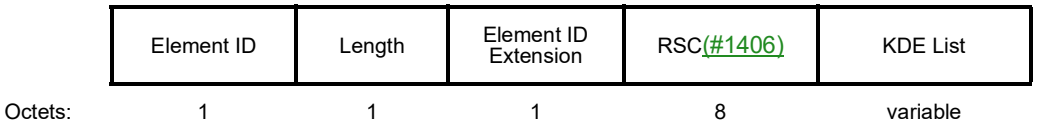


**Figure 9-761—Key Delivery element format**

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

The (#1406)RSC field contains the current (#1406)RSC for the GTK being installed. (#1394)If the RSC is less than 8 octets in length, it is stored in the first octets and the remaining octets are set to 0. The least significant octet of the RSC is in the first octet of the RSC field. The RSC for TKIP is the TKIP sequence counter (TSC); for CCMP and GCMP it is the packet number (PN); see Table 12-9 (RSC field(#1406)).


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The KDE List field contains one or more KDEs encapsulated using the format shown in Figure 12-37 (KDE format).

### 9.4.2.185 DILS element

The DILS element includes the conditions for a STA to determine whether it is allowed to attempt fast initial link setup for the duration specified in the element. The DILS element is optionally present in the Beacon and Probe Response frames. The DILS element is defined in Figure 9-762 (DILS element format).

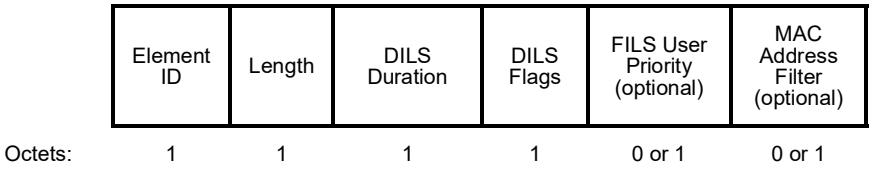


**Figure 9-762—DILS element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The DILS Duration field contains an unsigned integer that specifies the duration for the DILS restrictions (see 11.45.5.3 (Non-AP STA procedures for DILS)), expressed in units of 10 ms, starting from the beginning of the frame transmission of the DILS element.

The DILS Flags field (see Figure 9-763 (DILS Flags field format)) indicates the presence of optional fields following it.

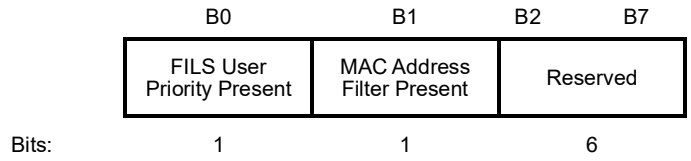


**Figure 9-763—DILS Flags field format**

Setting the FILS User Priority Present or MAC Address Filter Present subfields to 1 indicates that the corresponding field is present. At least one of the nonreserved bits in the DILS Flags field is set to 1.

The FILS User Priority field is defined in Figure 9-764 (FILS User Priority field format).

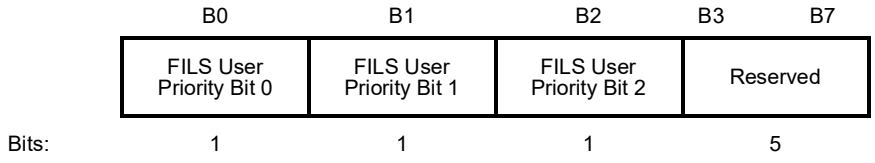


**Figure 9-764—FILS User Priority field format**

A value of 1 in the FILS User Priority Bit 0 subfield indicates FILS without additional delays for the STAs that have frames with User Priority 4–7 in their transmission queues, a value of 1 in the FILS User Priority Bit 1 subfield indicates high priority for the STAs that have frames with User Priority 0–3 in their transmission queues. A value of 1 in the FILS User Priority Bit 2 subfield indicates high priority for the STAs that have no frames in their transmission queues. See 11.45.5.2 (AP procedures for DILS).

The MAC Address Filter field is defined in Figure 9-765 (MAC Address Filter field format).

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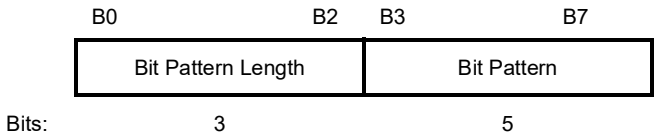


**Figure 9-765—MAC Address Filter field format**

The usage of the Bit Pattern Length subfield and Bit Pattern subfield is defined in Table 9-344 (MAC Address Filter field). The Bit Pattern Length subfield specifies the number of bits and the position of the bits in the Bit Pattern subfield that are used for MAC address filtering. The Bit Pattern subfield specifies the MAC addresses of the STAs that are allowed to attempt fast initial link setup. The details of MAC address filtering are described in 11.45.5.3 (Non-AP STA procedures for DILS).

**Table 9-344—MAC Address Filter field**

| Bit Pattern Length value B0 B1 B2 | Bit Pattern | | | | |
|---|---|---|---|---|---|
| | B3 | B4 | B5 | B6 | B7 |
| 1 | Reserved | Reserved | Reserved | Reserved | Used for MAC address filtering |
| 2 | Reserved | Reserved | Reserved | Used for MAC address filtering | |
| 3 | Reserved | Reserved | Used for MAC address filtering | | |
| 4 | Reserved | Used for MAC address filtering | | | |
| 5 | Used for MAC address filtering | | | | |
| 0 | Reserved | | | | |
| 6–7 | Reserved | | | | |

### 9.4.2.186 (11az)Wrapped Data element

The (11az)Wrapped Data element is used for the STA and AP to communicate data used by the RSNA protocols. The format of the Wrapped Data element is defined in Figure 9-766 ((11az)Wrapped Data element format).

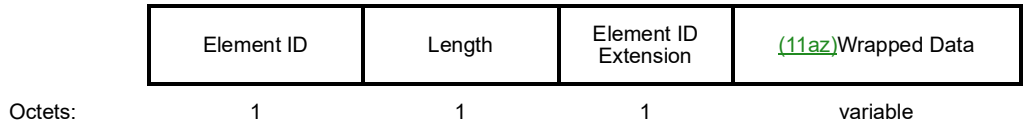


**Figure 9-766— (11az)Wrapped Data element format**

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

The (11az)Wrapped Data field is the data used by the FILS authentication algorithm (see 12.11 (Authentication for FILS)) and PASN authentication algorithm (see 12.13 (Preassociation security negotiation(11az))).(11az)


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### 9.4.2.187 Fragment element

Elements are defined to have a common general format, per 9.4.2.1 (General). The Length field of an Element is 1 octet, and thus limited to indicate 255 octets of payload in the Information field. However, since the Element ID Extension field is optional and included in the (#2047)Length count, the actual Information payload of an Element is limited to 254 octets if the Element ID Extension is present. If the information to be represented in an element is too large for this 255 or 254 octet limit, it is necessary to fragment the information as described in 10.28.11 (Element fragmentation) and 10.28.12 (Element defragmentation).

The format of the Fragment element is shown in Figure 9-767 (Fragment element format).

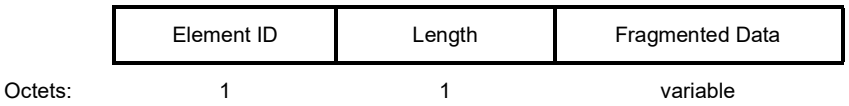


**Figure 9-767—Fragment element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The Fragmented Data field contains the data of the element that is fragmented as described in 10.28.11 (Element fragmentation).

For the information being fragmented, each Fragment element contains 255 octets, except the final Fragment element that contains 1 to 255 octets.

### 9.4.2.188 FILS Nonce element

The FILS Nonce element is used for exchanging an additional source of randomness in the FILS authentication exchange. The format of the FILS Nonce element is shown in Figure 9-768 (FILS Nonce element format).

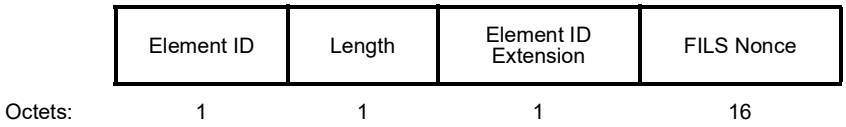


**Figure 9-768—FILS Nonce element format**

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

The FILS Nonce field contains randomly generated data.

### 9.4.2.189 S1G Open-Loop Link Margin Index element

The S1G Open-Loop Link Margin Index element contains the link margin information. The S1G Open-Loop Link Margin Index element is optionally included in an S1G Beacon frame or a Probe Response frame without a corresponding request. The format of the S1G Open-Loop Link Margin Index element is shown in Figure 9-769 (S1G Open-Loop Link Margin Index element format).

The Element ID and Length fields are defined in 9.4.2.1 (General).

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| Element ID | Length | Open-Loop Link Margin Index |
|---|---|---|
| Octets: 1 | 1 | 1 |

**Figure 9-769—S1G Open-Loop Link Margin Index element format**

The Open-Loop Link Margin $\Delta_{OPLM}$ is defined as the summation of transmit power $P_{tx}$ and the receiver sensitivity $RX_{sensitivity}$

$$\Delta_{OPLM} = P_{tx1} + RX_{sensitivity}$$

The transmit power $P_{tx1}$ indicates the actual power used as measured at the antenna connector, in units of dBm, by a STA when transmitting the frame containing the S1G Open-Loop Link Margin Index element. The receiver sensitivity $RX_{sensitivity}$ is the minimum required receive power for reception of MCS 10 for 1 MHz channel.

The S1G Open-Loop Link Margin $\Delta_{OPLM}$ is calculated as (–128 + $D$ × 0.5) dB, where $D$ is called Open-Loop Link Margin Index. $D$ is an unsigned integer value that is contained in S1G Open-Loop Link Margin Index field. For example, if the value $D$ shown in S1G Open-Loop Link Margin Index field is 0, then it indicates the S1G Open-Loop Link Margin $\Delta_{OPLM}$ is –128 dB. If the value $D$ shown in S1G Open-Loop Link Margin Index field is 255, then it indicates the S1G Open-Loop Link Margin $\Delta_{OPLM}$ is –0.5 dB.

The S1G Open-Loop Link Margin Index element can be used for open-loop link adaptation and open-loop transmit power control. When a STA receives the Open-loop link Margin index, it can calculate the S1G Open-Loop Link Margin $\Delta_{OPLM}$ by using (–128 + $D$ × 0.5) dB. Then the SNR margin over the MCS 10 can be derived at the STA that receives the frame that contains S1G Open-Loop Link Margin Index based on its own transmit power $P_{tx2}$ and the received RCPI(#1718) measured for the PPDU containing the S1G Open-Loop Link Margin Index.(#1718)

$$SNR_{Margin} = P_{tx2} - \Delta_{OPLM} + RCPI$$

### 9.4.2.190 RPS element

The RPS element contains one or more RAW Assignment subfields. Each RAW Assignment subfield contains parameters necessary to restrict medium access to one or multiple STAs within one RAW. The format of the RPS element is defined in Figure 9-770 (RPS element format).

| Element ID | Length | RAW Assignments |
|---|---|---|
| Octets: 1 | 1 | variable |

**Figure 9-770—RPS element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The RAW Assignments field contains one or more RAW Assignment subfields.

The format of the RAW Assignment subfield is shown in Figure 9-771 (RAW Assignment subfield format)(#288).


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| RAW Control | RAW Slot Definition | RAW Start Time | RAW Group | Channel Indication | Periodic Operation Parameters |
|---|---|---|---|---|---|
| Octets: 1 | 2 | 0 or 1 | 0 or 3 | 0 or 2 | 0 or 3 |

**Figure 9-771—RAW Assignment subfield format**

The format of the RAW Control subfield is shown in Figure 9-772 (RAW Control subfield format).

| B0 B1 | B2 B3 | B4 | B5 | B6 | B7 |
|---|---|---|---|---|---|
| RAW Type | RAW Type Options | Start Time Indication | RAW Group Indication | Channel Indication Presence | Periodic RAW Indication |
| Bits: 2 | 2 | 1 | 1 | 1 | 1 |

**Figure 9-772—RAW Control subfield format**

The value of the RAW Type field indicates the type of the RAW defined by the RAW assignment. The interpretation of the RAW Type subfields is shown in Table 9-345 (Interpretation of RAW Type and RAW Type Options).

**Table 9-345—Interpretation of RAW Type and RAW Type Options**

| RAW Type | Description | RAW Type Options subfield |
|---|---|---|
| 0 | Generic RAW | Bit 0 (Bit 2 of RAW Control subfield): Paged STA<br>Bit 1 (Bit 3 of RAW Control subfield): RA frame |
| 1 | Sounding RAW | 0: SST sounding RAW<br>1: SST report RAW<br>2: Sector sounding RAW<br>3: Sector report RAW |
| 2 | Simplex RAW | 0: AP PM RAW<br>1: Non-TIM RAW<br>2: Omni RAW<br>3: Reserved |
| 3 | Triggering frame RAW | EBCS UL RAW(11bc) |

The different types of RAWs are interpreted as follows:

— Generic RAW: used to provide restricted medium access only to a group of STAs.

— Sounding RAW: either used for SST sounding/SST report (SST RAW) or sector sounding/sector report (Sector RAW) as indicated by the RAW Type Options subfield as follows:

  — When the sounding RAW is used as an SST sounding RAW or a sector sounding RAW, non-AP STAs do not initiate a TXOP during the RAW but elect to listen to sector sounding (described in 10.52.5.2 (Procedure)) or SST sounding (described in 10.51 (Subchannel selective transmission (SST))). Non-AP STAs are allowed to transmit response frames during the RAW.

  — When the sounding RAW is used as an SST report RAW or a sector report RAW, as a response to the preceding SST sounding RAW or sector sounding RAW, STAs in the RAW Group can transmit a report frame to the AP during the SST report RAW as described in 10.51 (Subchannel

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selective transmission (SST)), or transmit sector ID feedback frame to the AP during the sector report RAW as described in 10.52.5 (Sector training operation) regardless of their corresponding TIM bits.

— Simplex RAW: the Slot Definition Format Indication, Cross Slot Boundary, and Number of Slots subfields of the Slot Definition field are set to 1, and the RAW is either used for AP Power Management (as described in 11.2.3.17 (AP power management)), for reserving channel time for S1G STAs in non-TIM mode, or for the omni RAW, (11bc)or for the EBCS UL RAW depending on the values of RAW Type Options subfield as follows:
  — When the RAW is used as the non-TIM RAW as indicated by the RAW Type Options subfield, the access is restricted to S1G STAs in non-TIM mode that have been previously scheduled within the RAW such as TWT STAs or awake/doze(#6038) rescheduled STAs (as described in 10.47.2 (Rescheduling of awake/doze cycle)). The RAW Assignment subfield for non-TIM RAW also conditionally contains the RAW Start Time, Channel Indication, and Periodic Operation Parameters subfields.
  — When the RAW is used as the AP PM RAW as indicated by the RAW Type Options subfield, the RAW Assignment subfield for AP PM RAW also conditionally contains the RAW Start Time and Periodic Operation Parameters subfields.
  — When the RAW is used as the omni RAW as indicated by the RAW Type Options subfield of the RAW Assignment subfield for omni RAW, the access is not restricted for any specific STA and this duration can be used by non-AP STAs to communicate with the AP that has scheduled the omni RAW to send the Probe Request frame or Association Request frame. The RAW assignment subfield of the omni RAW also conditionally contains the RAW Start Time, and Periodic Operation Parameters subfields.
  — When the RAW is used as the EBCS UL RAW as indicated by the RAW Type Options subfield of the RAW Assignment subfield for EBCS UL RAW, the access is not restricted for any specific STA, and this duration can be used by non-AP STAs to communicate with the AP that has scheduled the EBCS UL RAW to send the EBCS UL frame. The RAW assignment subfield of the EBCS UL RAW also conditionally contains the RAW Start Time, and Periodic Operation Parameters subfields.(11bc)

  NOTE—An EBCS non-AP STA that does not support RAW operation (see 10.23.5 (Restricted access window (RAW) operation)) can transmit an EBCS UL frame outside the RAW window.(11bc)

— Triggering Frame RAW: each paged STA belonging to the RAW group is allowed to send one specific trigger frame as described in 10.23.5.4 (Slotted channel access procedure in RAW) during its assigned RAW slot. The procedure of RAW slot assignment is described in 10.23.5.3 (Slot assignment procedure in RAW).

The Start Time Indication subfield indicates whether the RAW Start Time subfield is present in the RAW Assignment subfield or not. If it is equal to 0, the RAW Start Time subfield is not present. If it is equal to 1, the RAW Start Time subfield is present. In the first RAW assignment, the Start Time Indication subfield equal to 0 indicates that the RAW starts immediately after the S1G Beacon, the Probe Response frame, or the PV1 Probe Response that includes the RPS element. For other RAW assignments, the Start Time Indication subfield equal to 0 indicates that the current RAW starts immediately after the end of the previous RAW.

The RAW Group Indication subfield indicates whether the RAW Group subfield is present in the RAW Assignment subfield and is interpreted as follows:

— When the RAW type is generic RAW, sounding RAW, or triggering frame RAW, the RAW Group Indication subfield indicates whether the RAW group defined in the current RAW assignment is the same RAW group as defined in the previous RAW assignment. When the RAW Group Indication subfield is equal to 0, the RAW group defined in the current RAW assignment is the same as the RAW group defined in the previous RAW assignment and the RAW Group subfield is not present in this RAW assignment. When the RAW Group Indication subfield is equal to 1, the RAW Group


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subfield is present in this RAW assignment. The RAW Group Indication subfield in the first RAW assignment is set to 0 to indicate the RAW group in the first RAW assignment is the same as the range of AIDs in all the TIM bitmaps in the S1G Beacon frame.

— When the RAW is a non-TIM RAW, the RAW Group Indication subfield is set to 0 and the RAW Group subfield is not present.

— When the RAW is an AP PM RAW, the RAW Group Indication subfield equal to 0 indicates that the RAW group does not include any of the non-AP STAs, and the RAW Group subfield is not present. When the RAW Group Indication subfield is equal to 1, the RAW Group subfield is present.

The Channel Indication Presence subfield indicates whether the Channel Indication subfield in the current RAW assignment is present or not. If it is equal to 0, the Channel Indication subfield is not present. If it is equal to 1, the Channel Indication subfield is present.

The Periodic RAW Indication subfield indicates whether the RAW is periodic. When the Periodic RAW Indication subfield is equal to 1, the RAW is a periodic restricted access window (PRAW), and the Periodic Operation Parameters subfield is present. When the Periodic RAW Indication subfield is equal to 0, the Periodic Operation Parameters subfield is not present.

The definitions of RAW Type Options subfield are specified in Table 9-345 (Interpretation of RAW Type and RAW Type Options). The RAW Type Options subfield is interpreted as follows:

— For generic RAW, Bit 0 of the RAW Type Options (Bit 2 of the RAW Control subfield) is Paged STA indication. When it is equal to 0, the RAW can be accessed by any STA (paged or unpaged) within the RAW group specified by the RAW Group subfield. When it is equal to 1, the RAW can only be accessed by paged STAs within the RAW group specified by the RAW Group subfield. Bit 1 of the RAW Type Options (Bit 3 of the RAW Control subfield) is RA Frame Indication. If it is equal to 1, the AP transmits(M118) a Resource Allocation frame, as defined in 9.8.5.4 (Resource Allocation frame format), at the beginning of the RAW defined by the RAW Assignment subfield of the RPS element.

— For sounding RAW, the RAW Type Options subfield is treated as one subfield, the interpretation of which is defined in Table 9-345 (Interpretation of RAW Type and RAW Type Options). For Simplex RAW, the RAW Type Options subfield is treated as one subfield, the interpretation of which is defined in Table 9-345 (Interpretation of RAW Type and RAW Type Options).

— For Triggering Frame RAW, the RAW Type Options subfield is reserved.

The format of the RAW Slot Definition subfield is shown in Figure 9-773 (RAW Slot Definition subfield format).

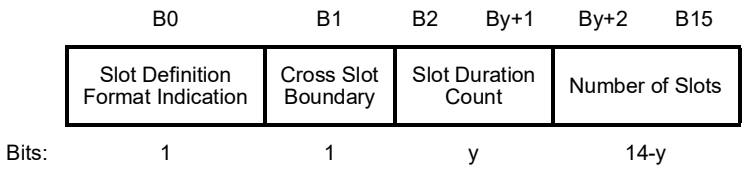


**Figure 9-773—RAW Slot Definition subfield format**

The Slot Definition Format Indication subfield indicates the number of bits used for the Slot Duration Count subfield, i.e., the value y in Figure 9-773 (RAW Slot Definition subfield format) of the Slot Duration Count subfield. If it is set 0, the Slot Duration Count subfield is 8 bits (y=8). If it is equal to 1, the Slot Duration Count subfield is 11 bits (y=11). When the RAW Type is sounding RAW, the Slot Duration Count subfield is 8 bits in length (y=8).

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The Cross Slot Boundary subfield indicates whether STAs are allowed to transmit after the assigned RAW slot boundary. If the bit is equal to 1, crossing a RAW slot boundary is allowed. If the bit is equal to 0, crossing a RAW slot boundary is not allowed for transmissions from STAs.

The Slot Duration Count subfield is an unsigned integer and it is used to calculate the duration of a RAW slot, or the RAW slot duration. The RAW slot duration, DSLOT, has time unit of microsecond and it is calculated as:

$$D_{SLOT} = 500 + C_{SLOT} \times 120$$

where

$C_{SLOT}$ is the value of the Slot Duration Count subfield

The Number of Slots subfield is an unsigned integer and indicates the number of RAW slots ($N_{RAW}$) in the RAW.

The Slot Definition subfield is used to calculate the RAW duration. The RAW duration indicates the duration, in units of microsecond, of the restricted medium access assigned to a RAW. The RAW duration, $D_{RAW,}$ indicated by the corresponding RAW assignment can be calculated as follows:

$$D_{RAW} = D_{SLOT} \times N_{RAW}$$

where

$D_{SLOT}$ is the RAW slot duration, in microseconds

$N_{RAW}$ is the value of the Number of Slots subfield

When the RAW Type is generic RAW or triggering frame RAW, the RAW Slot Definition subfield also provides the $N_{RAW}$ and slot duration information for RAW slot assignment. The procedure of RAW slot assignment is described in 10.23.5.3 (Slot assignment procedure in RAW).

The RAW Start Time subfield indicates the duration, in units of 2 TUs, from the end of the S1G Beacon, the Probe Response, or the PV1 Probe Response frame transmission that includes the RPS element to the start time of the RAW.

The format of the RAW Group subfield is shown in Figure 9-774 (RAW Group subfield format(#287)).

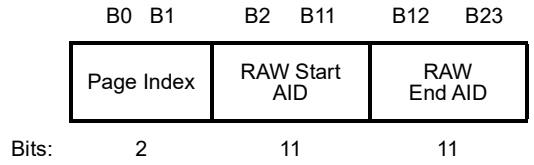


**Figure 9-774—RAW Group subfield format(#287)**

The RAW Group subfield indicates the STA AIDs that are allowed restricted access within the RAW period. The RAW Group subfield contains Page Index, RAW Start AID, and RAW End AID subfields according to the hierarchical addressing method of AIDs (see Figure 9-215 (Hierarchical structure of traffic-indication virtual bitmap carried in an S1G PPDU)). The Page Index subfield indicates the page index of the subset of AIDs.

The RAW Start AID field indicates the 11 LSBs of the AID of the STA with the lowest AID allocated in the RAW.


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The RAW End AID field indicates the 11 LSBs of the AID of the STA with the highest AID allocated in the RAW.

The RAW Group field is set to all 0s to indicate that all STAs are allowed to access within the RAW.

The format of the Channel Indication subfield is shown in Figure 9-775 (Channel Indication subfield format). The Channel Activity Bitmap subfield shows the allowed operating channels for the STAs indicated in the RAW, as defined in 10.23.5.1 (General). Each bit in the bitmap corresponds to one minimum width channel within the current BSS operating channels, with the least significant bit corresponding to the lowest numbered operating channel of the BSS. The Maximum Transmission Width, UL Activity, and DL Activity subfields are defined similarly as in 9.4.2.200 (SST element(#1776)).

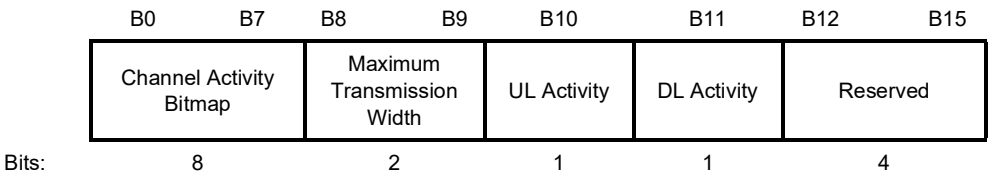


**Figure 9-775—Channel Indication subfield format**

The Periodic Operation Parameters subfield comprises the PRAW Periodicity, PRAW Validity, and PRAW Start Offset subfields. The format of the Periodic Operation Parameters subfield is shown in Figure 9-776 (Periodic Operation Parameters subfield format).

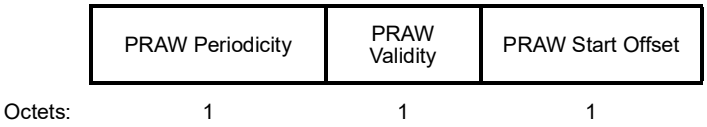


**Figure 9-776—Periodic Operation Parameters subfield format**

The PRAW Periodicity subfield indicates the period of current PRAW occurrence in the unit of beacon interval if dot11ShortBeaconInterval is false and in the unit of short beacon interval if dot11ShortBeaconInterval is true (see 11.1.3.10.2 (Generation of S1G Beacon frames)).

The PRAW Validity subfield indicates the number of periods that the PRAW repeats. A nonzero PRAW Validity subfield indicates the number of remaining PRAW occurrences, while a PRAW Validity subfield equal to 0 indicates that the PRAW validity is not determined.

The PRAW Start Offset subfield indicates the offset value from the end of the frame that carries the current RPS element to the S1G Beacon frame that the first window of the PRAW appears, in units of beacon interval or short beacon interval.

### 9.4.2.191 Page Slice element

The Page Slice element contains a subset of blocks from a single page, called a page slice. The STAs included in a page slice and indicated by the Page Slice element are served in the time intervals between Beacon frames within a page period, starting from the Beacon frame that carries the Page Slice element for the page (see 10.50 (Page slicing)). The frame format of the Page Slice element is defined in Figure 9-777 (Page Slice element format).

The Element ID and Length fields are defined in 9.4.2.1 (General).

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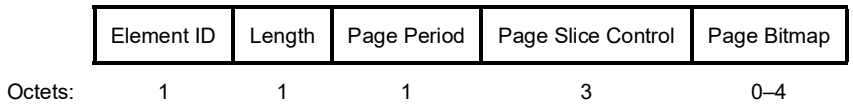


**Figure 9-777—Page Slice element format**

The Page Period field indicates the page period (see 10.50 (Page slicing)).(#7229)

The Page Slice Control field format is shown in Figure 9-778 (Page Slice Control field format).

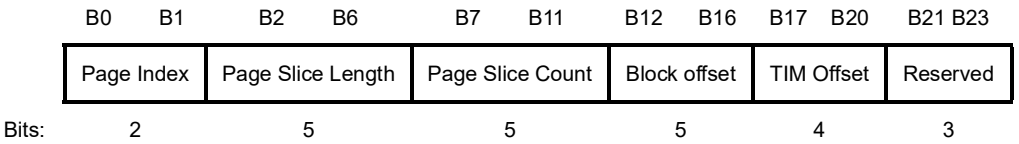


**Figure 9-778—Page Slice Control field format**

The Page Index subfield indicates the page whose slices are served during beacon intervals within a page period. Setting the Page Index subfield to 1 indicates the second page out of the four pages defined in the hierarchical AID addressing (see 9.4.2.5 (TIM element)).

The Page Slice Length subfield indicates the number of blocks included in each TIM for the associated page except for the last TIM. The Page Slice Length subfield is set to number of blocks in each page slice. The value 0 for the Page Slice Length subfield is reserved. For the last TIM, the size of the last page slice, $PS_{\text{last}}$, is computed as

$$PS_{\text{last}} = P_{\text{length}} - (PS_{\text{count}} - 1) \times PS_{\text{length}}$$

where

$P_{\text{length}}$ is the length (in bits) of a page indicated in the Page Bitmap field and is calculated as $P_{\text{length}} = 8 \times PB_{\text{length}}$

$PB_{\text{length}}$ is the length of the page (in octets) indicated in the Page Bitmap field

$PS_{\text{count}}$ is the value indicated in the Page Slice Count subfield

$PS_{\text{length}}$ is the value indicated in the Page Slice Length subfield

For example, with a Page Bitmap field of 2 octets, a value in the Page Slice Length subfield equal to 3, and a value in the Page Slice Count subfield equal to 5, the page slice consists of 4 (=16 – 3×4) blocks for the last TIM, i.e., a value greater than the value indicated in the Page Slice Length subfield. Again, for example, with a Page Bitmap field of 2 octets, a value in the Page Slice Length subfield equal to 6, and a value in the Page Slice Count subfield equal to 3, the page slice consists of 4 (=16 – 6×2) blocks for the last TIM, i.e., a value less than the value indicated in the Page Slice Length subfield.

The number of blocks assigned to all the TIMs, except the last TIM, within a DTIM interval, $P_{\text{rem}}$, is computed as

$$P_{\text{rem}} = P_{\text{length}} - PS_{\text{last}}$$

where

$P_{\text{length}}$ is the length of a page indicated in the Page Bitmap field

$PS_{\text{last}}$ is the size of the last page slice


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For every TIM, a STA computes the location of its block within a page slice, $SB_{STA}$, using the following equation:

$$SB_{STA} = AID[6:10] - BO$$

where

*AID* is the association identifier of the STA

*BO* is the value indicated in the Block Offset subfield of the Page Slice element

If the $SB_{STA}$ is greater than the $P_{length}$ or less than zero, the STA is not included in the page slice for the page period(#7181), otherwise:

— If $SB_{STA}$ is greater than $P_{rem}$, the page slice number for the STA indicated in the Page Slice Number field of the TIM element is equal to the value indicated in the Page Slice Count subfield of the Page Slice element

— Otherwise, the page slice number for the STA, $PS_{number}$, is computed as

$$PS_{number} = \lfloor SB_{STA} / PS_{length} \rfloor$$

The Page Slice Count subfield indicates the number of TIMs scheduled in one page period, except when the value is equal to 0. This field indicates a maximum of 31 TIMs that include page slices in a page period. The Page Slice Count subfield is set to 0 to indicate signaling that depends on the Page Slice Length subfield:

— If the Page Slice Length subfield is greater than 1, a 0 in the Page Slice Count field indicates that the 32nd TIM that is scheduled during this DTIM interval can contain DL BU information for non-AP STAs that do not support page slicing and for non-AP STAs whose AID is within the 32nd block of this page and do support page slicing.

— If the Page Slice Length subfield is equal to 1, a 0 in the Page Slice Count subfield indicates that all non-AP STAs for which the AP has DL BU are included in the only TIM that is scheduled within the DTIM interval.

The Block Offset subfield indicates the offset of the block in the first page slice from the first block in the page assigned within the page period. Setting the Block Offset field to 16 indicates that the first page slice starts at block 16, i.e., STAs in the second half of the page are assigned within this page period.

The TIM Offset subfield indicates the offset, in number of beacon intervals, from the DTIM beacon(#3309) that carries the Page Slice element of a page to the beacon that carries the first page slice of the page indicated by the corresponding Page Slice element in the DTIM beacon(#3309).

The Page Bitmap field indicates the presence of buffered data for each of the one or more blocks in a page slice or all the assigned page slices within a page period. A bit in the Page Bitmap field indicates information of buffered data for STAs in one block of a page slice corresponding to the location of the bit in the bitmap. The first block indicated in the Page Bitmap field is the block indicated in the Block Offset subfield. Based on the number of page slices assigned to the TIMs, this field is of variable length from 0 to 4 octets. For example, setting the Page Bitmap field to 129 indicates that there is buffered data for at least one STA in the first block and at least one STA in the last block. The bit sequence also indicates that only a page slice of 8 blocks is assigned within a page period. Further, the bit sequence indicates that there is no downlink buffered data for any STA in blocks 2 to 7. Hence these STAs can enter the doze state after receiving the group addressed BUs that are delivered by the AP following the DTIM beacon(#3309) as described in 11.2.3 (Power management in a non-DMG infrastructure network) and can avoid transitioning to awake state(#6038) for the assigned TIM in the following TBTTs or TSBTTs within the DTIM interval to check for downlink buffered data.

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### 9.4.2.192 AID Request element

The AID Request element contains information related to the characteristics of the device of the non-AP STA requesting an AID. The format of the AID Request element is shown in Figure 9-779 (AID Request element format).

| | Element ID | Length | AID Request Mode | AID Request Interval (Optional) | Peer STA Address (Optional) | Service Characteristic (Optional) | Group Address (Optional) |
|---|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 0 or 2 | 0 or 6 | 0 or 1 | 0 or 6 |

**Figure 9-779—AID Request element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The format of AID Request Mode field is shown in Figure 9-780 (AID Request Mode field format).

| | B0 | B1 | B2 | B3 | B4 | B5 | B6 B7 |
|---|---|---|---|---|---|---|---|
| | AID Request Interval Present | Peer STA Address Present | Service Characteristic Present | Non-TIM Mode Switch | TIM Mode Switch | Group Address Present | Reserved |
| Bits: | 1 | 1 | 1 | 1 | 1 | 1 | 2 |

**Figure 9-780—AID Request Mode field format**

The AID Request Interval Present subfield of the AID Request Mode field is set to 1 if the AID Request Interval field is present in the AID Request element and set to 0 if no AID Request Interval field is present.

The Peer STA Address Present subfield of the AID Request Mode field is set to 1 if the Peer STA Address field is present in the AID Request element and set to 0 if no Peer STA Address field is present.

The Service Characteristic Present subfield of the AID Request Mode field is set to 1 if the Service Characteristic field is present in the AID Request element and set to 0 if no Service Characteristic field is present.

The Non-TIM Mode Switch subfield of the AID Request Mode field is set to 1 if the non-AP STA requests to switch from the TIM mode to non-TIM mode. Otherwise, it is set to 0.

The TIM Mode Switch subfield of the AID Request Mode field is set to 1 if the non-AP STA requests to switch from the non-TIM mode to TIM mode. Otherwise, it is set to 0.

The Group Address Present subfield of the AID Request Mode field is set to 1 if the Group Address field is present in the AID Request element and is set to 0 if no Group Address field is present.

The AID Request Interval field indicates to the AP:

— The listen interval, in units of beacon interval or short beacon interval as defined in 9.4.1.6 (Listen Interval field), during which the S1G STA in TIM mode wakes to receive S1G Beacon frames when the Non-TIM Mode Switch field is equal to 0, TIM Mode Switch field is equal to 1, and the Group Address Present field is equal to 0.

— The listen interval, in units of beacon interval or short beacon interval as defined in 9.4.1.6 (Listen Interval field), during which the S1G STA in non-TIM mode is required to transmit at least one PS-


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Poll or trigger frame to the AP when the Non-TIM Mode Switch field is equal to 1, TIM Mode Switch is equal to 0, and the Group Address Present field is equal to 0.

— The group listen interval, in units of beacon interval or short beacon interval (see 11.1.3.10.2 (Generation of S1G Beacon frames)), during which the non-AP STA wakes up to receive the S1G Beacon frames that signal the presence of group addressed BUs for (#1653)the group address contained in the Group Address field. In this case the Group Address Present field is equal to 1 and the TIM Mode Switch field and Non-TIM Mode Switch field are equal to any value.

The AID Request Interval field contains a Unified Scaling Factor subfield (see Table 9-78 (Unified Scaling Factor subfield encoding)) and has a format as defined in Figure 9-144 (Listen Interval field format carried in an S1G PPDU). The AID Request Interval field is calculated as the value of the Unscaled Interval subfield multiplied by the scaling factor that corresponds to the value indicated in the Unified Scaling Factor subfield.

The Peer STA Address field indicates the MAC address of the peer STA for STA-to-STA communication.

The Service Characteristic field indicates the service characteristic provided by the non-AP STA so that the AP can assign a particular AID to the STA based on the service characteristic when the STA associates or requests AID switch. The format of the Service Characteristic field is shown in Figure 9-781 (Service Characteristic field format).

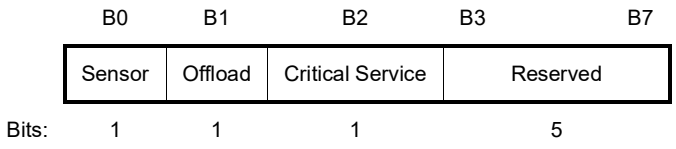


**Figure 9-781—Service Characteristic field format**

The Sensor subfield of the Service Characteristic field is set to 1 to indicate that the non-AP STA provides a sensor or a meter type services. Otherwise, it is set to 0. The Offload subfield of the Service Characteristic field is set to 1 to indicate that the non-AP STA provides a traffic offloading services. Otherwise, it is set to 0. The Critical Service subfield of the Service Characteristic field is set to 1 to indicate that it provides critical services such as health care, home, industrial, alarm monitoring or emergency services. Otherwise, it is set to 0.

(#7012)When the Group Address field is present in the AID Request element, the AID Request element is carried in an AID Switch Request frame to request a group AID. The Group Address field indicates the group address for which a group AID is being requested.

### 9.4.2.193 AID Response element

The AID Response element defines information about the AID assignment. The format of AID Response element is shown in Figure 9-782 (AID Response element format).

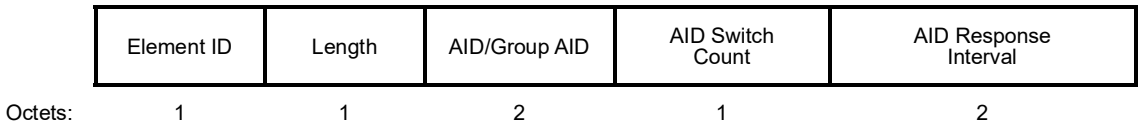


**Figure 9-782—AID Response element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

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The AID/Group AID field, which has the same format as the AID field described in 9.4.1.8 (AID field), indicates:

— The AID that is assigned to the non-AP STA if the AID Response element is not sent as a response to an AID Switch Request frame that contained a Group Address field. If the AP does not change the AID of the STA, this field indicates the current AID assigned to the non-AP STA. If the AP changes the AID of the STA, this field indicates the changed AID assigned to the non-AP STA.

— The group AID that is assigned to (#1653)a group address if the AID Response element is sent as a response to an AID Switch Request frame that contained a Group Address field carrying (#1653)the group address.

The AID Switch Count field indicates a countdown value, in units of beacon interval or short beacon interval, that the AP sets for the non-AP STA to switch to the new AID or to activate the group AID. The countdown value is expressed in units of beacon interval if dot11ShortBeaconInterval is false and in units of short beacon interval if dot11ShortBeaconInterval is true (see 11.1.3.10.2 (Generation of S1G Beacon frames)). The AID Switch Count field indicates the duration after which the (group) listen interval starts and the counter that corresponds to the AID Switch Count field starts upon transmission of the AID Response element. The AID Switch Count field is set to 0 in an AID Response element that is carried in a (Re)Association Response frame.

The AID Response Interval field indicates to the non-AP STA:

— The listen interval in units of beacon interval or short beacon interval as defined in 9.4.1.6 (Listen Interval field), during which the S1G STA in TIM mode wakes to receive S1G Beacon frames. The S1G Beacon frames that the S1G STA in TIM mode wakes up to listen either include a TIM element that can include their new AID or include a Page Slice element that indicates the assignment of the new AID in the corresponding page slices.

— The listen interval in units of beacon interval or short beacon interval as defined in 9.4.1.6 (Listen Interval field), during which the S1G STA in non-TIM mode is required to transmit at least one PS-Poll or trigger frame to the AP.

— The group listen interval, in units of beacon interval or short beacon interval (see 11.1.3.10.2 (Generation of S1G Beacon frames)), during which the non-AP STA is required to transition to awake state(#6038) for receiving the S1G Beacon frames that signal the presence of group addressed BUs for the group address contained in the Group Address field of the eliciting AID Switch Request frame. The (group) listen interval (M118)starts from the first TBTT or TSBTT that follows the expiration of the AID switch counter obtained from the AID Switch Count field of this element.

The AID Response Interval field contains a Unified Scaling Factor subfield (see Table 9-78 (Unified Scaling Factor subfield encoding)) and has a format as defined in Figure 9-144 (Listen Interval field format carried in an S1G PPDU). The AID Response Interval field is calculated as the value of the Unscaled Interval subfield multiplied by the scaling factor that corresponds to the value indicated in the Unified Scaling Factor subfield.

### 9.4.2.194 S1G Sector Operation element

The S1G Sector Operation element includes the information necessary for a receiving STA to determine the type of sector operation, if it is allowed to transmit during a specified sector time interval and if it can perform sector training. The S1G Sector Operation element is optionally present in Probe Response, Beacon or Association Response frames.

The format of the S1G Sector Operation element is presented in Figure 9-783 (S1G Sector Operation element format (sectorization type is group sectorization)) and later in this subclause in Figure 9-784 (S1G Sector Operation element format (sectorization type is TXOP-based sectorization operation)).


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| | B0 B7 | B8 B15 | B16 | B17B22 | B23 | B24B26 | B27 B30 | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Element ID | Length | Sectoriza-tion Type | Period | Omni | Sector ID | Number of Groups | Group IDs | Sector Duration | Pad |
| Bits: | 8 | 8 | 1 | 6 | 1 | 3 | 4 | variable | 6 | 1, 3, 5, or 7 |

**Figure 9-783—S1G Sector Operation element format (sectorization type is group sectorization)**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The Sectorization Type field indicates the type of sectorization. When the Sectorization Type field is equal to 0, it indicates that the format of the S1G Sector Operation element is structured for group sectorization operation.

NOTE 1—The Sectorization Type field can be set to 0 only when the Sectorized Beam-Capable field setting is either 2 or 3.

The Period field specifies the time interval, in units of 10 ms, until the next transmission of frames in the sector identified by the Sector ID field.

The Omni field indicates if the present transmission is sectorized or omnidirectional. When it is equal to 0, it indicates sectorized. When it is equal to 1, it indicates omnidirectional.

The Sector ID field identifies the ID of the active sector. It is reserved when Omni field is equal to 1.

The Number of Groups field indicates the number of Group ID subfields in the Group IDs field following this field.

Each Group ID subfield is 6 bits and identifies the group of STAs that are allowed to transmit during this sector interval.

The Sector Duration field indicates the duration of the current sector transmissions, in units of 10 ms.

The Pad field contains 1, 3, 5, or 7 bits of 0s to make the total number of bits in the S1G Sector Operation element equal to an integer number of octets.

The S1G Sector Operation element can be provided in Association Response frame when dot11S1GSectorizationActivated is true and it indicates the group ID allocated to that STA to be used during the sectorization purpose, the type of sectorization method, the value of the Period field, and the Sector Duration field if all the sector durations are equal. If the Sector Duration field is not equal for all sectors the Sector Duration field provided at the association time is 0. The values of the Sector ID and Omni fields are omitted by the STA in the Association Response frame. By default all the STAs that support group sectorization consider themselves in group ID 0 unless is specified otherwise via the Association Response frame. This way all the STAs can transmit at any time before their association. It is expected that during the association, STAs receive a nonzero group ID, which (M118)restricts their activity to a particular sector interval or during omnidirectional time interval. An AP can allow some STAs to have the group zero even after association, for instance public safety STAs or some high priority sensors.

The S1G Sector Operation element in the Beacon frame provides:

— Information related to the type of sectorization operation;

— Indication if the Beacon frame is sectorized or not;

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— The sector ID of the current sector;
— The group ID that identifies the group allowed transmitting during the current sector duration; and
— The duration of this sector.

A STA that receives a Beacon frame that includes an S1G Sector Operation element determines if the received Beacon frame is sectorized or omnidirectional. If the received Beacon frame is omnidirectional the STAs are allowed to transmit in all geographical sectors provided that their group ID is group zero or it is listed in S1G Sector Operation element. If the received Beacon frame is sectorized, the STAs with group zero from any sector are allowed to transmit and the STAs that receive the sectorized Beacon frame and have the group ID listed in the S1G Sector Operation element are allowed to transmit during the current sector duration. A Beacon frame that not carries an S1G Sector Operation element does not impose any sectorization restriction on the receiving STAs.

When the sectorization type is TXOP-based sectorization operation, the element is presented in Figure 9-784 (S1G Sector Operation element format (sectorization type is TXOP-based sectorization operation)).

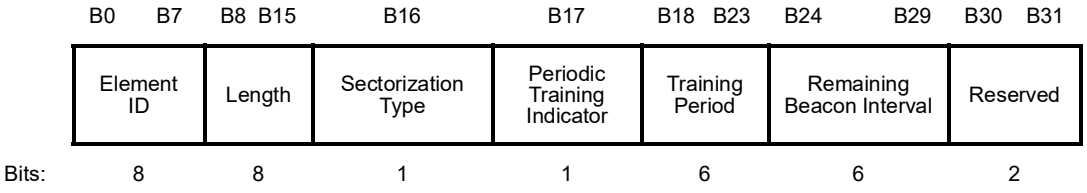


**Figure 9-784—S1G Sector Operation element format (sectorization type is TXOP-based sectorization operation)**

The Sectorization Type field is set to 1 to indicate that the format of the S1G Sector Operation element is structured for the TXOP-based sectorization operation.

NOTE 2—The Sectorization Type field can be set to 1 only when the Sectorized Beam-Capable field setting is 1 or 3.

The Periodic Training Indicator field is set to 1 to indicate periodic sector training is conducted by the AP and STAs can perform sector training. The Periodic Training Indicator field is set to 0 to indicate periodic sector training is not conducted by the AP.

The Training Period field is set to the number of beacon intervals in which the AP repeats the sector training.

The Remaining Beacon Interval field is set to the number of beacon intervals remaining before the next sector training commences. Setting the field to indicates the sector training is conducted in the current beacon interval.

### 9.4.2.195 S1G Beacon Compatibility element

The S1G Beacon Compatibility element carries the information that is shown in Figure 9-785 (S1G Beacon Compatibility element format).

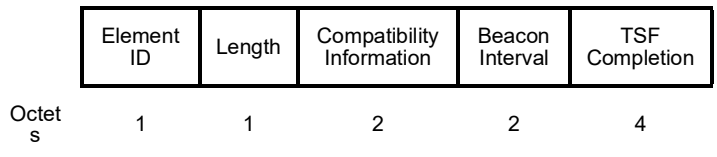


**Figure 9-785—S1G Beacon Compatibility element format**


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The Element ID and Length fields are defined in 9.4.2.1 (General).

The Compatibility Information field contains all the subfields defined in 9.4.1.4 (Capability Information field) except for the subfield located in B6 and B7 of the field. (#6054)B6 is defined as the TSF Rollover Flag subfield. An S1G AP sets the TSF Rollover Flag subfield to the value of the most significant bit of the 4 least significant octets of the TSF timer at the time the TSF timer is read for the purpose of creating the element carrying the Compatibility Information field. B7 is defined as the BIGTK Key ID Index subfield. When the S1G Beacon frame is protected with BCE, the S1G AP sets the field to 0 when the key ID used to protect the frame is 6, and sets the field to 1 when the key ID used to protect the frame is 7, i.e. *BIGTK Key ID Index* = *key ID* + 6.(#6054)

NOTE—Valid values for the BIGTK Key ID are 6 or 7 (see 6.5.14.1 (MLME-SETKEYS.request)).(#6054)

The Beacon Interval field in the element is defined in 9.4.1.3 (Beacon Interval field).

The TSF Completion field carries the 4 most significant octets of the TSF timer at the AP at the time of generation of the element carrying the TSF Completion field.

### 9.4.2.196 Short Beacon Interval element(#2194)

The Short Beacon Interval element carries the short beacon interval and its format is shown in Figure 9-786 (Short Beacon Interval element format).

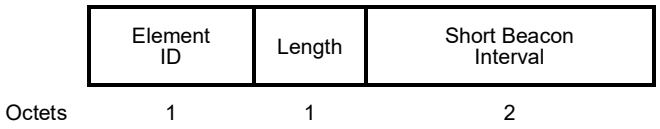


**Figure 9-786—Short Beacon Interval element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The Short Beacon Interval field represents the number of time units (TU)s between target short beacon transmission times (TSBTT)s.

### 9.4.2.197 Change Sequence element

The Change Sequence element indicates a change of system information within a BSS. The format of the Change Sequence element is shown in Figure 9-787 (Change Sequence element format).

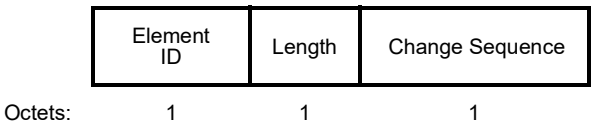


**Figure 9-787—Change Sequence element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The Change Sequence field is defined as an unsigned integer, initialized to 0, that increments when a critical update occurs to any of the elements inside an S1G Beacon frame; see 10.45.2 (System information update procedure).

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### 9.4.2.198 TWT element

The TWT element is shown in Figure 9-788 (TWT element format(11ax)).

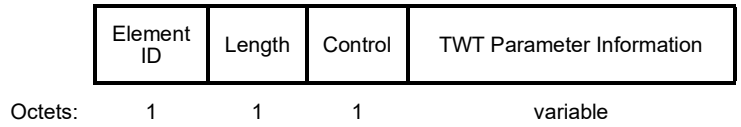


**Figure 9-788—TWT element format(11ax)**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The format of the Control field is shown in Figure 9-789 (Control field format(11ax)(#4010)).

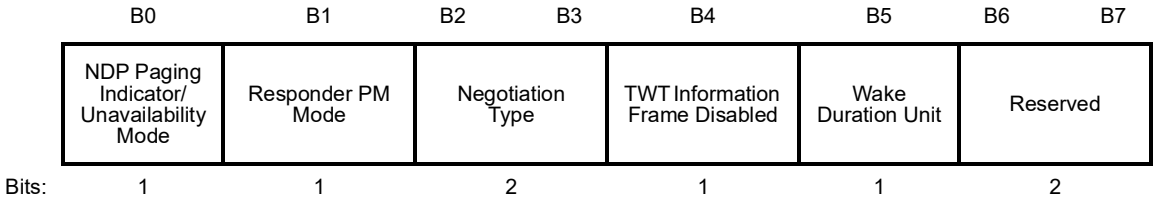


**Figure 9-789—Control field format(11ax)(#4010)**

(#4406)(#4010)The NDP Paging Indicator/Unavailability Mode subfield is set to 1 to indicate that the NDP Paging field is present if the STA sending the frame carrying the TWT element is an S1G STA. Otherwise, the NDP Paging field (#4406)is set to 0.

The Responder PM Mode subfield indicates the power management mode as defined in 11.2 (Power management).

(11ax)The Negotiation Type subfield indicates whether the information included in the TWT element is for the negotiation of parameters of broadcast or individual TWT(s) or a Wake TBTT interval. The MSB of the Negotiation Type subfield is the Broadcast field.

(11ax)The TWT Information Frame Disabled subfield is set to 1 to indicate that the reception of TWT Information frames is disabled by the STA; otherwise, it is set to 0.

(11ax)The Wake Duration Unit subfield indicates the unit of the Nominal Minimum TWT Wake Duration field. The Wake Duration Unit subfield is set to 0 if the unit is 256 μs(#1146) and is set to 1 if the unit is a TU. A non-HE STA sets the Wake Duration Unit subfield to 0.

(11ax)If the Broadcast field of the Negotiation Type subfield is 1, then one or more broadcast TWT parameter sets are contained in the TWT element (see Figure 9-791 (Broadcast TWT Parameter Set field format(11ax))). If the Broadcast field of the Negotiation Type subfield is 0, then only one Individual TWT parameter set is contained in the TWT element (see Figure 9-790 (Individual TWT Parameter Set field format(11ax))). An S1G STA sets the Negotiation Type subfield to 0.

(11ax)A TWT element that has the Broadcast field in the Control field set to 1 is referred to as broadcast TWT element.


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(11ax)The Negotiation Type subfield determines the interpretation of the Target Wake Time, TWT Wake Interval Mantissa, and TWT Wake Interval Exponent subfields of the TWT element as defined in Table 9-346 (Interpretation of Negotiation Type subfield and of Target Wake Time, TWT Wake Interval Mantissa, and TWT Wake Interval Exponent subfields(11ax)).

**Table 9-346—Interpretation of Negotiation Type subfield and of Target Wake Time, TWT Wake Interval Mantissa, and TWT Wake Interval Exponent subfields(11ax)**

| Negotiation Type subfield | Target Wake Time subfield | TWT Wake Interval Mantissa and TWT Wake Interval Exponent subfields | Description |
|---|---|---|---|
| 0 | A future Individual TWT SP start time | Interval between individual TWT SPs | Individual TWT negotiation between TWT requesting STA and TWT responding STA or individual TWT announcement by TWT responder. See 10.46 (Target wake time (TWT)) and 26.8.2 (Individual TWT agreements).<br><br>The TWT element contains one individual TWT parameter set. |
| 1 | Next Wake TBTT time | Interval between wake TBTTs | Wake TBTT and wake interval negotiation between TWT scheduled STA and TWT scheduling AP. See 26.8.6 (Negotiation of wake TBTT and wake interval).<br><br>The TWT element contains one individual TWT parameter set. |
| 2 | A future Broadcast TWT SP start time | Interval between broadcast TWT SPs | Provide broadcast TWT schedules to TWT scheduled STAs by including the TWT element in broadcast Management frames sent by TWT scheduling AP. See 26.8.3.2 (Rules for TWT scheduling AP).<br><br>The TWT element contains one or more broadcast TWT parameter sets. |
| 3 | A future Broadcast TWT SP start time | Interval between broadcast TWT SPs | Manage memberships in broadcast TWT schedules by including the TWT element in individually addressed Management frames sent by either a TWT scheduled STA or a TWT scheduling AP. See 26.8.3 (Broadcast TWT operation).<br><br>The TWT element contains one or more broadcast TWT parameter sets. |

(11ax)The TWT Parameter Information field contains a single Individual TWT Parameter Set field with format defined in Figure 9-790 (Individual TWT Parameter Set field format(11ax)) if the Broadcast subfield in the Control field is 0 and contains one or more Broadcast TWT Parameter Set fields with format defined in Figure 9-791 (Broadcast TWT Parameter Set field format(11ax)) if the Broadcast subfield of the Control field is 1. The number of Broadcast TWT Parameter Set fields present is determined by the values of the Last Broadcast Parameter Set subfields of the Request Type fields.

The format of the Request Type field of the Individual TWT Parameter Set field is shown in Figure 9-792 (Request Type field format Individual TWT Parameter Set field(11ax)) and of a Broadcast TWT Parameter Set field is shown in Figure 9-793 (Request Type field format in Broadcast TWT Parameter Set field(11ax)).(11ax)

A STA that transmits a TWT element with the TWT Request subfield equal to 1 is a TWT requesting STA or TWT scheduled STA. Otherwise, it is a TWT responding STA or TWT scheduling STA.(11ax)

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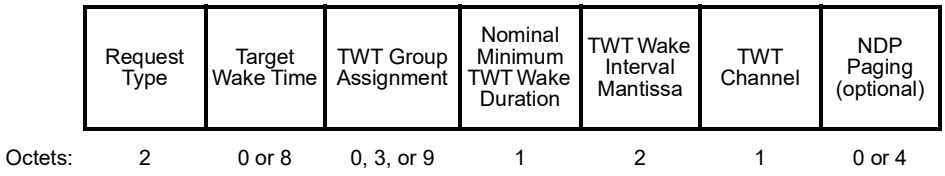


**Figure 9-790—Individual TWT Parameter Set field format(11ax)**

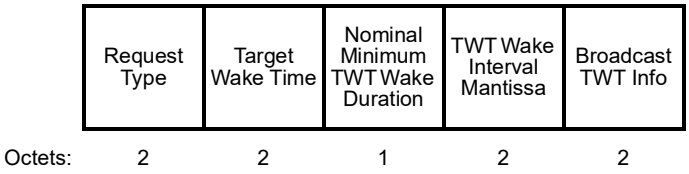


**Figure 9-791—Broadcast TWT Parameter Set field format(11ax)**

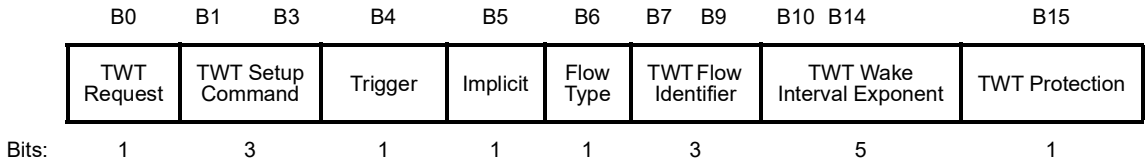


**Figure 9-792—Request Type field format Individual TWT Parameter Set field(11ax)**

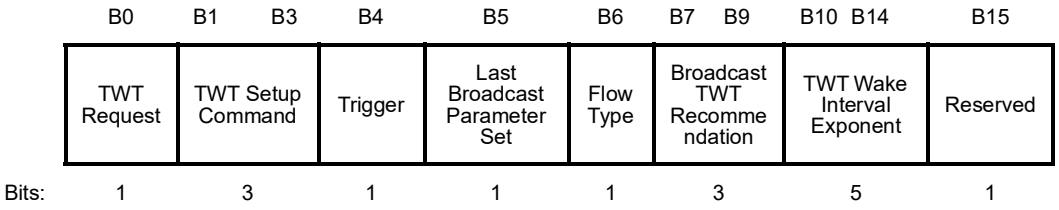


**Figure 9-793—Request Type field format in Broadcast TWT Parameter Set field(11ax)**

The TWT Setup Command subfield values indicate the type of TWT command. The use of the TWT Setup Command field for the negotiation of individual and broadcast TWT is described Table 9-347 (TWT Setup Command field values(11ax)). The entries in the table apply to cases where the Negotiation Type subfield is


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not 1. For TWT Setup Command field use when the Negotiation Type subfield is 1, see 26.8.6 (Negotiation of wake TBTT and wake interval).(11ax)

**Table 9-347—TWT Setup Command field values(11ax)**

| TWT Setup Command field value | Command name | Description(11ax) |
|---|---|---|
| 0 | Request TWT | (11ax)A TWT requesting or TWT scheduled STA requests to join a TWT without specifying a target wake time.<br>This command is valid if the TWT Request field is equal to 1; otherwise, the command is not applicable. |
| 1 | Suggest TWT | (11ax)A TWT requesting or TWT scheduled STA requests to join a TWT and specifies a suggested set of TWT parameters with the possibility that if the requested target wake time and/or other TWT parameters cannot be accommodated, then the TWT setup might still be accepted by the TWT requesting or TWT scheduled STA.<br><br>This command is valid if the TWT Request field is equal to 1; otherwise, it is not applicable. |
| 2 | Demand TWT | (11ax)A TWT requesting or TWT scheduled STA requests to join a TWT and specifies a demanded set of TWT parameters. If the demanded set of TWT parameters is not accommodated by the responding STA or TWT scheduling AP, then the TWT requesting STA or TWT scheduled STA (M118)rejects the TWT setup.<br><br>This command is valid if the TWT Request field is equal to 1; otherwise, it is not applicable. |
| 3 | TWT Grouping | (11ax)The TWT responding STA suggests TWT group parameters that are different from the suggested or demanded TWT parameters of the TWT requesting STA<br><br>This command is valid if the TWT Request field is 0 and the Negotiation Type subfield is 0 and sent by an S1G STA; otherwise, it is not applicable. |
| 4 | Accept TWT | (11ax)A TWT responding STA or TWT scheduling AP accepts the TWT request with the TWT parameters (see NOTE) indicated in the TWT element transmitted by the TWT requesting STA or TWT scheduled STA. This value is also used in unsolicited TWT responses.<br><br>This command is valid if the TWT Request field is 0; otherwise, it is not applicable. |
| 5 | Alternate TWT | (11ax)A TWT responding STA or TWT scheduling AP suggests TWT parameters that are different from those suggested by the TWT requesting STA or TWT scheduled STA.<br><br>This command is valid if the TWT Request field is 0; otherwise, it is not applicable. |

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**Table 9-347—TWT Setup Command field values(11ax) *(continued)***

| TWT Setup Command field value | Command name | Description(11ax) |
|---|---|---|
| 6 | Dictate TWT | (11ax)A TWT responding STA or TWT scheduling AP indicates TWT parameters that are different from those suggested by the TWT requesting STA or TWT scheduled STA.<br><br>This command is valid if the TWT Request field is 0; otherwise, it is not applicable. |
| 7 | Reject TWT | (11ax)A TWT responding STA or TWT scheduling AP rejects setup, or a TWT scheduling AP terminates an existing broadcast TWT, or a TWT scheduled STA terminates its membership in a broadcast TWT. |
| NOTE—TWT Parameters are TWT, Nominal Minimum TWT Wake Duration, TWT Wake Interval, and TWT Channel subfield values indicated in the TWT element. The Trigger subfield value indicated in the TWT element is also a TWT parameter for an HE STA.(11ax) | | |

(11ax)The Trigger field indicates whether or not the TWT SP indicated by the TWT element includes triggering frames as defined in 26.8. The Trigger field is set to 1 to indicate that at least one triggering frame is transmitted during the TWT SP. The Trigger field is set to 0 otherwise.

The Implicit subfield is set to 1 to indicate an implicit TWT and is set to 0 to indicate an explicit TWT.(11ax)

(11ax)The Last Broadcast Parameter Set subfield is set to 0 to indicate that another broadcast TWT Parameter set follows this set. The Last Broadcast Parameter Set subfield is set to 1 to indicate that this is the last broadcast TWT Parameter set in the broadcast TWT element.

The Flow Type subfield indicates the type of interaction between the TWT requesting STA or TWT scheduled STA and the TWT responding STA or TWT scheduling AP at a TWT. Setting the Flow Type subfield to 0 indicates an announced TWT in which the TWT requesting STA or TWT scheduled STA will send a PS-Poll or an APSD trigger frame (see 11.2.3.5 (Power management with APSD) to signal its awake state to the TWT responding STA or TWT scheduling AP before a frame that is not a Trigger frame is sent from the TWT responding STA or TWT scheduling AP to the TWT requesting STA or TWT scheduled STA. A TWT SP that is set up under an announced TWT agreement is an announced TWT SP. Setting the Flow Type subfield to 1 indicates an unannounced TWT in which the TWT responding STA or TWT scheduling AP will send a frame to the TWT requesting STA or TWT scheduled STA at TWT without waiting to receive a PS-Poll or an APSD trigger frame from the TWT requesting STA or TWT scheduled STA. A TWT SP that is set up under an unannounced TWT agreement is an unannounced TWT SP.(11ax)

NOTE—The TWT requesting STA is expected to send the PS-Poll or APSD trigger frame if the TWT is a trigger-enabled TWT.

The TWT Flow Identifier subfield contains a 3-bit value that identifies the specific information for this TWT request uniquely from other requests made between the same TWT requesting STA and TWT responding STA pair.

(#4007)The Broadcast TWT Recommendation subfield contains a value that indicates recommendations on the types of frames that are transmitted by TWT scheduled STAs and scheduling AP during the broadcast TWT SP, encoded according to the Broadcast TWT Recommendation field for a broadcast TWT element as


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defined in Table 9-348 (Broadcast TWT Recommendation field for a broadcast TWT element(11ax)). The Broadcast TWT Recommendation is reserved if transmitted by a TWT scheduled STA.(11ax)

**Table 9-348—Broadcast TWT Recommendation field for a broadcast TWT element(11ax)**

| Broadcast TWT Recommendation field value | Description when transmitted in a broadcast TWT element |
|---|---|
| 0 | No constraints on the frames transmitted during a broadcast TWT SP. |
| 1 | Frames transmitted during a broadcast TWT SP by a TWT scheduled STA are recommended to be limited to solicited status and solicited feedback:<br>— PS-Poll and QoS Null frames<br>— Feedback can be contained in the QoS Control field or in the HE variant HT Control field of the frame, if either is present (see 26.5.2 (UL MU operation), 26.9 (Operating mode indication), 26.13 (Link adaptation using the HLA Control subfield), etc.)<br>— Feedback in an HE TB feedback NDP, if solicited by the AP (see 26.5.7 (NDP feedback report procedure))<br>— BQRs (see 26.5.6 (Bandwidth query report operation))<br>— BSRs (see 26.5.5 (Buffer status report operation))<br>— Frames that are sent as part of a sounding feedback exchange (see 26.7 (HE sounding operation(#2388)))<br>— Management frames: Action or Action No Ack frames<br>— Control response frames<br>Trigger frames transmitted by the TWT scheduling AP during the broadcast TWT SP do not contain RUs for random access (see 26.8.3.2 (Rules for TWT scheduling AP) and 26.5.4 (UL OFDMA-based random access (UORA))), otherwise, there are no other restrictions on the frames transmitted by the TWT scheduling AP. |
| 2 | Frames transmitted during a broadcast TWT SP by a TWT scheduled STA are recommended to be limited to solicited status and solicited feedback:<br>— PS-Poll and QoS Null frames<br>— Feedback can be contained in the QoS Control field or in the HE variant HT Control field of the frame, if either is present (see 26.5.2 (UL MU operation), 26.9 (Operating mode indication), 26.13 (Link adaptation using the HLA Control subfield), etc.)<br>— BQRs (see 26.5.6 (Bandwidth query report operation))<br>— BSRs (see 26.5.5 (Buffer status report operation))<br>— Frames that are sent as part of a sounding feedback exchange (see 26.7 (HE sounding operation(#2388)))<br>— Management frames: Action, Action No Ack frames or (Re)Association Request<br>— Control response frames<br>Trigger frames transmitted by the TWT scheduling AP during the broadcast TWT SP contain at least one RU for random access (see 26.8.3.2 (Rules for TWT scheduling AP) and 26.5.4 (UL OFDMA-based random access (UORA))); otherwise, there are no restrictions on the frames transmitted by the TWT scheduling AP. |
| 3 | No constraints on the frames transmitted during a broadcast TWT SP, except that the AP transmits a TIM frame or a FILS Discovery frame including a TIM element at the beginning of each TWT SP (see 26.14.3.2 (AP operation for opportunistic power save)). |
| 4–7 | Reserved |

In a TWT element transmitted by a TWT requesting or TWT scheduled STA, the TWT wake interval is equal to the average time that the STA expects to elapse between successive TWT SPs start times (see Table 9-346 (Interpretation of Negotiation Type subfield and of Target Wake Time, TWT Wake Interval Mantissa, and TWT Wake Interval Exponent subfields(11ax))). In a TWT element transmitted by a TWT

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responding STA or TWT scheduling AP, the TWT wake interval is equal to the average time that the STA expects to elapse between successive TWT SPs start times. In a TWT element contained in a TWT request that is sent by the TWT scheduled STA to negotiate its wake intervals, the TWT wake interval indicates the value of the wake interval (see 26.8.6 (Negotiation of wake TBTT and wake interval)). The TWT Wake Interval Exponent subfield is set to the value of the exponent of the TWT wake interval value in microseconds, base 2. The TWT wake interval of the requesting STA is equal to (TWT Wake Interval Mantissa) × $2^{(\text{TWT Wake Interval Exponent})}$.(11ax)

If transmitted by a TWT requesting STA or a TWT scheduled STA and the TWT Setup Command subfield contains a value corresponding to the command "Suggest TWT" or "Demand TWT", the Target Wake Time field contains a positive an unsigned integer corresponding to a TSF time at which the STA requests to wake. If transmitted by a TWT requesting STA or a TWT scheduled STA and the TWT Setup Command subfield contains the value corresponding to the command "Request TWT", the Target Wake Time field contains the value 0. The Target Wake Time field is 8 octets if the Broadcast field is 0; otherwise, it is 2 octets with the lowest bit of the 2 octets corresponding to bit 10 of the relevant TSF value. If a TWT responding STA with dot11TWTGroupingSupport equal to 0 transmits a TWT element to the TWT requesting STA, the TWT element contains a value in the Target Wake Time field corresponding to a TSF time at which the TWT responding STA requests the TWT requesting STA to wake for the corresponding TWT SP and it does not contain the TWT Group Assignment field.(11ax)

When a TWT responding STA with dot11TWTGroupingSupport equal to 1 transmits the TWT element to the TWT requesting STA from which it received a frame containing an S1G Capabilities element with the TWT Grouping Support subfield equal to 1, the TWT element does not contain the Target Wake Time field and it does contain the TWT Group Assignment field in order to indicate the TWT group of the requesting STA and the assigned TWT value. The presence of the TWT Group Assignment field is indicated by a TWT responding STA by using the TWT Grouping command in the TWT Setup Command subfield (see Table 9-347 (TWT Setup Command field values(11ax))) within the TWT element.

The TWT Group Assignment field provides information to a requesting STA about the TWT group to which the STA is assigned. This field contains the TWT Group ID, Zero Offset of Group (optional), TWT Unit, and TWT Offset subfields. The TWT Group Assignment field and the corresponding subfields are depicted in Figure 9-794 (TWT Group Assignment field format).

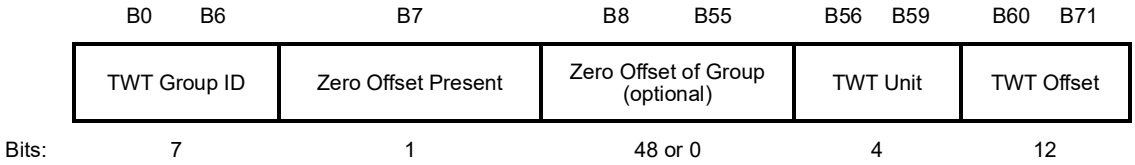


**Figure 9-794—TWT Group Assignment field format**

The TWT Group ID subfield is an unsigned integer and indicates the identifier of the TWT group to which the requesting STA is assigned. A TWT group is a group of STAs that have TWT values that lie within a specific interval of TSF values. The value zero in the TWT Group ID subfield is used to indicate the unique TWT group, which contains all STAs in the BSS.

The Zero Offset Present subfield indicates whether the following Zero Offset of Group subfield is included in the TWT Group Assignment field of the TWT element. Setting the Zero Offset Present subfield to 0 indicates that the Zero Offset of the Group subfield is not included in the TWT Group Assignment field.


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The Zero Offset of Group subfield indicates the initial TWT value for the TWT group identified by the TWT group ID. The Zero Offset of Group subfield (#1496)contains the initial TWT value for the TWT group with the given TWT group ID. When the Zero Offset of Group subfield is present, it contains the value of the 6 least significant octets of the TSF timer corresponding to the TWT group offset time. The Zero Offset of Group subfield is optionally present in the TWT Group Assignment field. If a STA transmits multiple TWT requests for multiple TWT flows, the next TWT Group Assignment field transmitted in a response to a TWT request can optionally exclude the Zero Offset of the Group subfield from an included TWT Group Assignment field provided that a previous response included a Zero Offset of the Group subfield. The receipt of a TWT response with a TWT Group Assignment field with no Zero Offset of the Group subfield implies that the Zero Offset of the Group subfield value for that TWT is the same as the Zero Offset of the Group subfield value for the most recently received Zero Offset of the Group subfield for the same TWT group ID from the TWT responding STA.

The TWT Unit subfield indicates the unit of increment of the TWT values within the TWT group identified by the TWT group ID. The TWT Unit subfield encoding is shown in Table 9-349 (TWT Unit subfield encoding).

**Table 9-349—TWT Unit subfield encoding**

| TWT Unit subfield value | TWT Unit time value |
|---|---|
| 0 | 32 μs |
| 1 | 256 μs |
| 2 | 1024 μs |
| 3 | 8.192 ms |
| 4 | 32.768 ms |
| 5 | 262.144 ms |
| 6 | 1.048576 s |
| 7 | 8.388608 s |
| 8 | 33.554432 s |
| 9 | 268.435456 s |
| 10 | 1073.741824 s |
| 11 | 8589.934592 s |
| 12–15 | Reserved |

The TWT Offset subfield indicates the position within the indicated group, of the STA corresponding to the RA of the frame containing the TWT element.

A non-AP STA uses the TWT Group ID, Zero Offset of Group, TWT Unit, and TWT Offset subfield values to compute its TWT value within the TWT group. A STA's TWT value is equal to the value of the Zero Offset of Group subfield plus TWT Offset subfield times the value of TWT Unit subfield.

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The Nominal Minimum TWT Wake Duration field indicates the minimum amount of time, in the unit indicated by the Wake Duration Unit subfield, that the TWT requesting STA or TWT scheduled STA is expected to be awake in order to complete the (#109)frame exchange sequences for the period of TWT wake interval, where TWT wake interval is the average time that the TWT requesting STA or TWT scheduled STA expects to elapse between successive TWT SPs.(11ax)

The TWT Wake Interval Mantissa subfield is set to the value of the mantissa of the TWT wake interval value in microseconds, base 2.

The Broadcast TWT Info subfield is defined in Figure 9-795 (Broadcast TWT Info subfield format(11ax)).

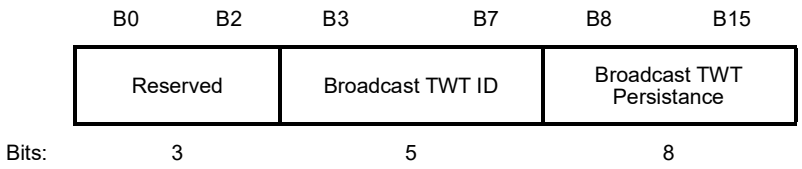


**Figure 9-795—Broadcast TWT Info subfield format(11ax)**

(11ax)Within a TWT element that includes a TWT setup command value of Request TWT, Suggest TWT, or Demand TWT, the Broadcast TWT ID, if present, indicates a specific Broadcast TWT in which the transmitting STA is requesting to participate. Within a TWT element that includes a TWT setup command value of Accept TWT, Alternate TWT, Dictate TWT, or Reject TWT, the Broadcast TWT ID, if present, indicates a specific Broadcast TWT for which the transmitting STA is providing TWT parameters. Within a TWT element that includes a TWT setup command value of TWT Grouping, the Broadcast subfield is 0 and the Broadcast TWT ID, is not present. The value 0 in the Broadcast TWT ID subfield indicates the broadcast TWT whose membership corresponds to all STAs that are members of the BSS corresponding to the BSSID of the Management frame carrying the TWT element and that is permitted to contain Trigger frames with RA-RUs for unassociated STAs.

(11ax)The Broadcast TWT Persistence subfield indicates the number of TBTTs during which the Broadcast TWT SPs corresponding to this broadcast TWT Parameter set are present. The number of beacon intervals during which the Broadcast TWT SPs are present is equal to the value in the Broadcast TWT Persistence subfield plus 1, except that the value 255 indicates that the Broadcast TWT SPs are present until explicitly terminated.

(11ax)The TWT Channel field includes a bitmap that provides the channel that is being negotiated by a STA as a temporary channel during a TWT SP. Each bit in the bitmap corresponds to one minimum width channel for the band in which the TWT responding STA's associated BSS is currently operating, with the least significant bit corresponding to the lowest numbered channel of the operating channels of the BSS. In an S1G BSS, the minimum width channel is equal to the SST Channel Unit field of the SST Operation element if such an element has been previously received or is equal to 1 MHz for a BSS with a BSS primary channel width of 1 MHz and 2 MHz for a BSS with a BSS primary channel width of 2 MHz if no such element has been previously received from the AP to which the SST STA is associated. In an HE BSS, the minimum width channel is equal to 20 MHz. Setting a position in the bitmap transmitted to 1 by a TWT requesting STA means that operation with that channel as the temporary channel is requested during a TWT SP. Setting a position in the bitmap transmitted to 1 by a TWT responding STA means that operation with that channel as the primary channel is allowed during the TWT SP. The TWT Channel field is used by an S1G STA as defined in 10.53 and is used by an HE STA as defined in 26.8.7 (HE subchannel selective transmission). If the TWT channel field is 0 then the STA operates as define in 10.46 (Target wake time (TWT)) or 26.8.2 (Individual TWT agreements).

(11ax)A TWT requesting STA sets the TWT Protection subfield to 1 to request the TWT responding STA to provide protection of the set of TWT SPs corresponding to the requested TWT flow identifier by


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— Allocating RAW(s) that restrict access to the medium during the TWT SP(s) for the TWTs that are set up within an S1G BSS.
— Enabling NAV protection during the TWT SP(s) for the TWTs that are set up within an HE BSS.

(11ax)A TWT requesting STA sets the TWT Protection subfield to 0 if TWT protection is not requested for the corresponding TWT(s).

(11ax)A TWT responding STA(#1207) sets the TWT Protection subfield to 1 to indicate that the TWT SP(s) corresponding to the TWT flow identifier(s) of the TWT element (M118)are protected by

— Allocating RAW(s) that restrict access to the medium during the TWT SP(s) for the TWT(s) where the TWT responding STA is an S1G STA.
— Enabling NAV protection during the TWT SP(s) for the TWTs where the TWT responding STE is an HE STA.

(11ax)A TWT responding STA sets the TWT Protection subfield to 0 to indicate that the TWT SP(s) identified in the TWT element might not be protected.

The format of the NDP Paging field is defined in Figure 9-796 (NDP Paging field format).

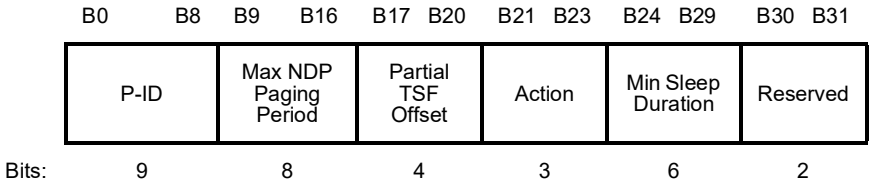


**Figure 9-796—NDP Paging field format**

The P-ID field is the identifier of the paged STA, as described in 10.46.6 (NDP paging setup).

The Max NDP Paging Period field indicates the maximum number of TWT wake intervals between two NDP Paging frames.

The Partial TSF Offset field includes timing indications, as described in 10.46.6 (NDP paging setup).

Upon reception of an NDP Paging frame with matching P-ID field as defined in 10.46.6 (NDP paging setup), the TWT STA that is an NDP (#8182)paging requester takes an action indicated by the Action field as described in Table 9-350 (Action field).

**Table 9-350—Action field**

| Action | Options |
|---|---|
| 0 | Send a PS-Poll or uplink trigger frame |
| 1 | Transition to awake state(#6038) at the time indicated by the Min Sleep Duration field |
| 2 | Transition to awake state(#6038) to receive the beacon |
| 3 | Transition to awake state(#6038) to receive the DTIM beacon |
| 4 | Transition to awake state(#6038) at the time indicated by the sum of the Min Sleep Duration field and the ASD subfield in the APDI field of the NDP Paging frame |
| 5–7 | Reserved |

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The Min Sleep Duration field(#8182) indicates in units of SIFS the minimum duration of the STA's(M118) doze state after receiving an NDP Paging frame with a matching P-ID.

### 9.4.2.199 S1G Capabilities element

#### 9.4.2.199.1 S1G Capabilities element structure

An S1G STA declares that it is an S1G STA by transmitting the S1G Capabilities element.

The S1G Capabilities element contains a number of fields that are used to advertise S1G capabilities of an S1G STA. The S1G Capabilities element is defined in Figure 9-797 (S1G Capabilities element format(M102)).

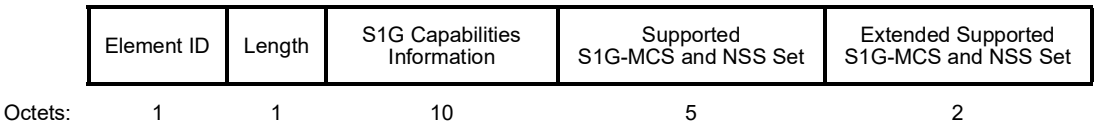


**Figure 9-797—S1G Capabilities element format(M102)**

The Element ID and Length fields are defined in 9.4.2.1 (General).


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### 9.4.2.199.2 S1G Capabilities Information field

The structure of the S1G Capabilities Information field is defined in Figure 9-798 (S1G Capabilities Information field format).

| | B0 | B1 | B2 | B3 | B4 | B5 | B6 | B7 |
|---|---|---|---|---|---|---|---|---|
| | S1G_LONG Support | Short GI for 1 MHz | Short GI for 2 MHz | Short GI for 4 MHz | Short GI for 8 MHz | Short GI for 16 MHz | Supported Channel Width | |
| Bits: | 1 | 1 | 1 | 1 | 1 | 1 | 2 | |

| | B8 | B9 | B10 | B11 | B12 | B13 | | B15 |
|---|---|---|---|---|---|---|---|---|
| | Rx LDPC | Tx STBC | Rx STBC | SU Beamformer Capable | SU Beamformee Capable | Beamformee STS Capability | | |
| Bits: | 1 | 1 | 1 | 1 | 1 | 3 | | |

| | B16 | | B18 | B19 | B20 | B21 | B22 | B23 |
|---|---|---|---|---|---|---|---|---|
| | Number Of Sounding Dimensions | | | MU Beamformer Capable | MU Beamformee Capable | +HTC-VHT Capable | Traveling Pilot Support | |
| Bits: | 3 | | | 1 | 1 | 1 | 2 | |

| | B24 | B25 | B26 | B27 | B28 | B29 | | B31 |
|---|---|---|---|---|---|---|---|---|
| | RD Responder | Reserved | Maximum MPDU Length | Maximum A-MPDU Length Exponent | | Minimum MPDU Start Spacing | | |
| Bits: | 1 | 1 | 1 | 2 | | 3 | | |

| | B32 | B33 | B34 | B35 | B36 | B37 | B38 | B39 |
|---|---|---|---|---|---|---|---|---|
| | Uplink Sync Capable | Dynamic AID | BAT Support | TIM ADE Support | Non-TIM Support | Group AID Support | STA Type Support | |
| Bits: | 1 | 1 | 1 | 1 | 1 | 1 | 2 | |

| | B40 | B41 | B42 | B43 | B44 | B45 | B46 | B47 |
|---|---|---|---|---|---|---|---|---|
| | Centralized Authentica-tion Control | Distributed Authentication Control | A-MSDU Supported | A-MPDU Supported | Asymmetric BA Supported | Flow Control Supported | Sectorized Beam-Capable | |
| Bits: | 1 | 1 | 1 | 1 | 1 | 1 | 2 | |

**Figure 9-798—S1G Capabilities Information field format**

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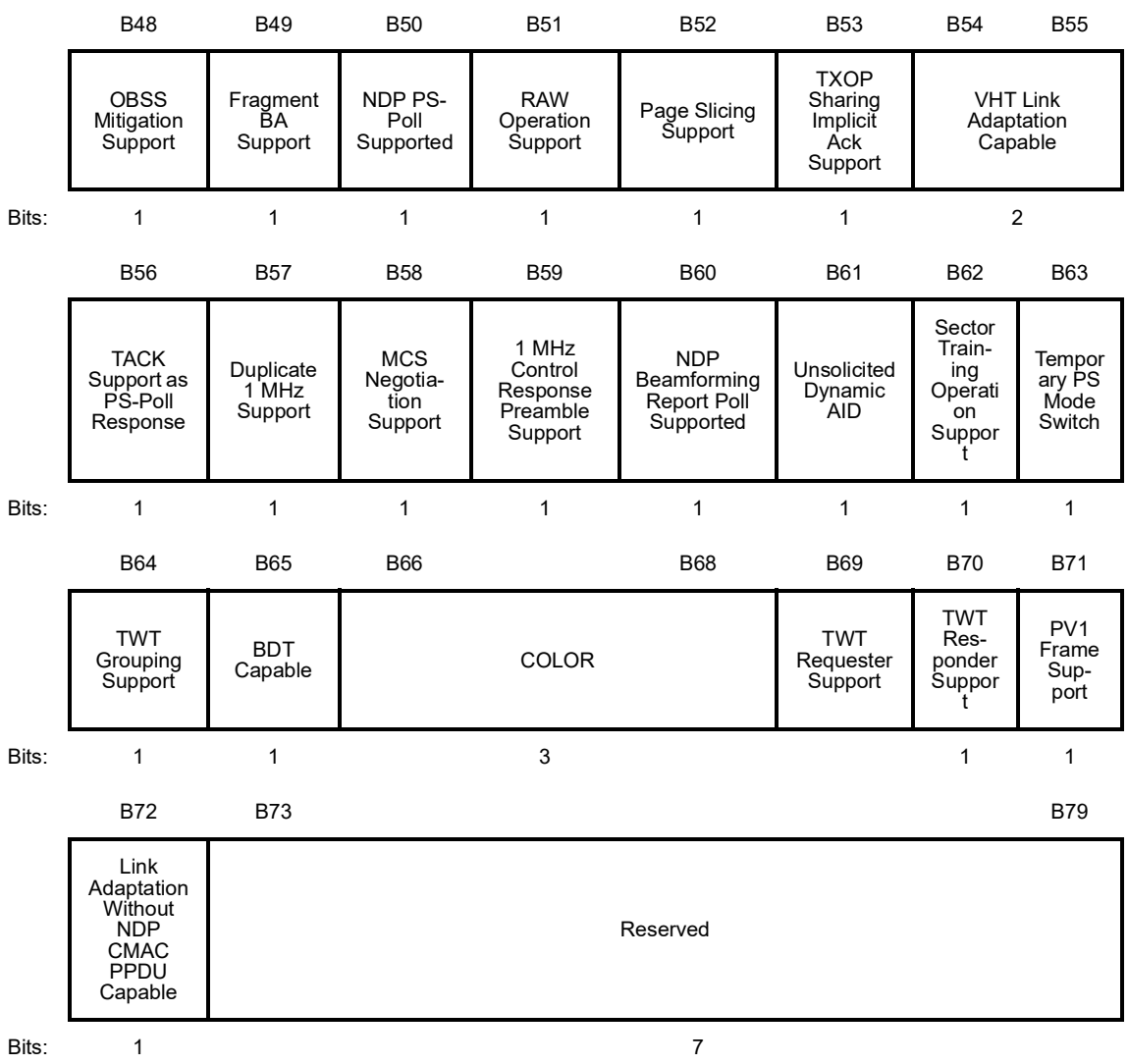


**Figure 9-798—S1G Capabilities Information field format *(continued)***



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The subfields of the S1G Capabilities Information field are defined in Table 9-351 (Subfields of the S1G Capabilities Information field).

**Table 9-351—Subfields of the S1G Capabilities Information field**

| Subfield | Definition | Encoding |
|---|---|---|
| S1G_LONG Support | Indicates support for the reception of S1G_LONG PPDUs.<br>See 23.3.2 (S1G PPDU format). | Set to 0 if not supported.<br>Set to 1 if supported. |
| Short GI for 1 MHz | Indicates short GI support for the reception of PPDUs transmitted with TXVECTOR parameters FORMAT equal to S1G and CH_BANDWIDTH equal to CBW1. | Set to 0 if not supported.<br>Set to 1 if supported. |
| Short GI for 2 MHz | Indicates short GI support for the reception of PPDUs transmitted with TXVECTOR parameters FORMAT equal to S1G and CH_BANDWIDTH equal to CBW2. | Set to 0 if not supported.<br>Set to 1 if supported. |
| Short GI for 4 MHz | Indicates short GI support for the reception of PPDUs transmitted with TXVECTOR parameters FORMAT equal to S1G and CH_BANDWIDTH equal to CBW4. | Set to 0 if not supported.<br>Set to 1 if supported. |
| Short GI for 8 MHz | Indicates short GI support for the reception of PPDUs transmitted with TXVECTOR parameters FORMAT equal to S1G and CH_BANDWIDTH equal to CBW8. | Set to 0 if not supported.<br>Set to 1 if supported. |
| Short GI for 16 MHz | Indicates short GI support for the reception of PPDUs transmitted with TXVECTOR parameters FORMAT equal to S1G and CH_BANDWIDTH equal to CBW16. | Set to 0 if not supported.<br>Set to 1 if supported. |
| Supported Channel Width | Indicates the channel widths supported by the STA.<br>See 10.45 (S1G BSS operation). | Set to 0 if the STA supports 1 MHz and 2 MHz operation.<br>Set to 1 if the STA supports 1 MHz, 2 MHz, and 4 MHz operation.<br>Set to 2 if the STA supports 1 MHz, 2 MHz, 4 MHz, and 8 MHz operation.<br>Set to 3 if the STA supports 1 MHz, 2 MHz, 4 MHz, 8 MHz, and 16 MHz operation. |
| Rx LDPC | Indicates support for receiving LDPC encoded PPDUs. | Set to 0 if not supported.<br>Set to 1 if supported. |
| Tx STBC | Indicates support for the transmission of at least 2×1 STBC. | Set to 0 if not supported.<br>Set to 1 if supported. |
| Rx STBC | Indicates support for the reception of PPDUs using STBC. | Set to 0 if not supported.<br>Set to 1 if supported. |
| SU Beamformer Capable | Indicates support for operation as an SU beamformer (see 10.35.5 (VHT sounding protocol)). | Set to 0 if not supported.<br>Set to 1 if supported. |
| SU Beamformee Capable | Indicates support for operation as an SU beamformee (see 10.35.5 (VHT sounding protocol)). | Set to 0 if not supported.<br>Set to 1 if supported. |

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**Table 9-351—Subfields of the S1G Capabilities Information field *(continued)***

| Subfield | Definition | Encoding |
|---|---|---|
| Beamformee STS Capability | The maximum number of space-time streams that the STA can receive in an S1G NDP, the maximum value for (#4359)$N_{STS,total}$ that can be sent to the STA in an S1G MU PPDU if the STA is MU beamformee capable and the maximum value of *Nr* that the STA transmits in a VHT Compressed Beamforming frame. | If SU beamformee capable, set to maximum number of space-time streams that the STA can receive in an S1G NDP minus 1.<br>Otherwise reserved. |
| Number Of Sounding Dimensions | Beamformer's capability indicating the maximum value of the TXVECTOR parameter NUM_STS for an S1G NDP. | If SU beamformer capable, set to the maximum supported value of the TXVECTOR parameter NUM_STS minus 1.<br>Otherwise reserved. |
| MU Beamformer Capable | Indicates support for operation as an MU beamformer (see 10.35.5 (VHT sounding protocol)). | Set to 0 if not supported or if SU Beamformer Capable is set to 0 or if sent by a non-AP STA.<br>Set to 1 if supported and SU Beamformer Capable is equal to 1. |
| MU Beamformee Capable | Indicates support for operation as an MU beamformee (see 10.35.5 (VHT sounding protocol)). | Set to 0 if not supported or if SU Beamformee Capable is set to 0 or if sent by an AP.<br>Set to 1 if supported and SU Beamformee Capable is equal to 1. |
| +HTC-VHT Capable | Indicates whether or not the STA supports receiving a VHT variant HT Control field. | Set to 0 if not supported.<br>Set to 1 if supported. |
| Traveling Pilot Support | Indicates support for the reception of PPDUs with a traveling pilots.<br>See 23.3.9.10 (Pilot subcarriers). | Set to 1 if dot11S1GTravelingPilotOptionActivated is true, and reception of traveling pilot for one space-time stream is supported but reception of traveling pilot for two space-time streams with STBC is not supported.<br>Set to 3 if dot11S1GTravelingPilotOptionActivated is true, and reception of traveling pilot for both one space-time stream and two space-time streams with STBC is supported.<br>Set to 0 if dot11S1GTravelingPilotOptionActivated is false.<br>Value 2 is reserved. |
| RD Responder | Indicates support for acting as a reverse direction responder, i.e., the STA can use an offered RDG to transmit data to an RD initiator using the reverse direction protocol described in 10.29 (Reverse direction protocol). | Set to 0 if not supported.<br>Set to 1 if supported. |
| Maximum MPDU Length | Indicates the maximum MPDU length (see 10.11 (A-MSDU operation)). | Set to 0 for 3895 octets.<br>Set to 1 for 7991 octets. |
| Maximum A-MPDU Length Exponent | Indicates the maximum length of A-MPDU that the STA can receive. EOF padding is not included in this limit. | The length defined by this field is equal to $2^{(13+\text{Maximum A-MPDU Length Exponent})} - 1$ octets. |


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**Table 9-351—Subfields of the S1G Capabilities Information field *(continued)***

| Subfield | Definition | Encoding |
|---|---|---|
| Minimum MPDU Start Spacing | Determines the minimum time between the start of adjacent MPDUs within an A-MPDU that the STA can receive, measured at the PHY SAP. See 10.12.3 (Minimum MPDU start spacing rules). | Set to 0 for no restriction.<br>Set to 1 for 1/4 μs.<br>Set to 2 for 1/2 μs.<br>Set to 3 for 1 μs.<br>Set to 4 for 2 μs.<br>Set to 5 for 4 μs.<br>Set to 6 for 8 μs.<br>Set to 7 for 16 μs. |
| Uplink Sync Capable | If sent by an AP, this subfield indicates support for sync frame transmission for uplink.<br><br>If sent by a non-AP STA, this subfield indicates request for sync frame transmission for uplink.<br><br>See 10.48 (Sync frame operation). | If sent by an AP:<br>Set to 0 if not supported.<br>Set to 1 if supported.<br><br>If sent by a non-AP STA:<br>Set to 0 if not requested.<br>Set to 1 if requested. |
| Dynamic AID | The STA sets the Dynamic AID field to 1 when dot11DynamicAIDActivated is true, and sets it to 0 otherwise. See 10.20 (S1G dynamic AID assignment operation). | Set to 1 if dot11DynamicAIDActivated is true.<br>Set to 0 otherwise. |
| BAT Support | The BAT Support subfield indicates support for the use of the Block Acknowledgment TWT (BAT) frame in block ack agreements(#3741). When dot11BATImplemented is true, this field is set to 1 to indicate support for BAT frames as both originator and recipient. | Set to 1 if dot11BATImplemented is true.<br>Set to 0 otherwise. |
| TIM ADE Support | This bit indicates support of the ADE mode of TIM bitmap encoding as described in 9.4.2.5.5 (ADE mode). | Set to 1 if dot11TIMADEImplemented is true.<br>Set to 0 otherwise. |
| Non-TIM Support | This bit indicates support of non-TIM mode. | In a non-AP STA:<br>Set to 0: The non-AP STA does not support non-TIM mode; it needs TIM entry as in legacy PS mode.<br>Set to 1: The non-AP STA supports non-TIM mode and does not need TIM entry when in non-TIM mode.<br><br>In an AP:<br>Set to 0: The AP does not support the STA's non-TIM mode.<br>Set to 1: The AP supports the STA's non-TIM mode. |
| Group AID Support | This bit indicates support of group traffic delivery using a group AID as described in 10.54 (Group AID). | Set to 1 if dot11GroupAIDActivated is true.<br>Set to 0 otherwise. |

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**Table 9-351—Subfields of the S1G Capabilities Information field *(continued)***

| Subfield | Definition | Encoding |
|---|---|---|
| STA Type Support | If sent by an AP, this subfield indicates the STA types that are supported by the AP.<br><br>If sent by a non-AP STA, this subfield indicates the STA type of the non-AP STA. | If sent by an AP:<br>Set to 0 if the AP supports both sensor STAs and non-sensor STAs.<br>Set to 1 if the AP supports only sensor STAs.<br>Set to 2 if the AP supports only non-sensor STAs.<br>3 is reserved.<br><br>If sent by a non-AP STA:<br>Set to 1 if the STA is a sensor STA.<br>Set to 2 if the STA is a non-sensor STA.<br>0 and 3 are reserved. |
| Centralized Authentication Control | This field indicates support of the centralized authentication control defined in 11.3.9.2 (Centralized authentication control). | Set to 1 if dot11S1GCentralizedAuthenticationControlActivated is true.<br>Set to 0 otherwise. |
| Distributed Authentication Control | This field indicates support of the distributed authentication control defined in 11.3.9.3 (Distributed authentication control). | Set to 1 if dot11S1GDistributedAuthenticationControlActivated is true.<br>Set to 0 otherwise. |
| A-MSDU Supported | This bit indicates support of Aggregated MSDU. | Set to 1 if dot11AMSDUImplemented is true.<br>Set to 0 otherwise. |
| A-MPDU Supported | This bit indicates support of Aggregated MPDU. | Set to 1 if dot11AMPDUImplemented is true.<br>Set to 0 otherwise. |
| Asymmetric BA Supported | This bit indicates support of Asymmetric BA. | Set to 1 if dot11AsymmetricBlockAckActivated is true.<br>Set to 0 otherwise. |
| Flow Control Supported | Indicates support for flow control operation. | Set to 0 if not supported<br>Set to 1 if supported |
| Sectorized Beam-Capable | The Sectorized Beam-Capable subfield indicates the type of sectorization operation supported by the STA. | If sent by an AP:<br>Set to 0 if sectorization operation is not supported,<br>Set to 1 if only TXOP-based sectorization operation is supported,<br>Set to 2 if only group sectorization operation is supported,<br>Set to 3 if both group sectorization and TXOP-based sectorization operations are supported.<br><br>If sent by a non-AP STA:<br>Set to 0 if not supported,<br>Set to 1 if supported<br>When equal to 1, a non-AP STA supports both group sectorization and TXOP-based sectorization operation. |
| OBSS Mitigation Support | The OBSS Mitigation Support subfield indicates whether the STA supports channel width reduction during a TXOP for OBSS mitigation. | Set to 1 to indicate that the STA supports channel width reduction during a TXOP for OBSS mitigation.<br>Set to 0 otherwise. |


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**Table 9-351—Subfields of the S1G Capabilities Information field *(continued)***

| Subfield | Definition | Encoding |
|---|---|---|
| Fragment BA Support | This bit indicates support for fragment BA. | Set to 1 if dot11FragmentBAOptionImplemented is true.<br>Set to 0 otherwise. |
| NDP PS-Poll Supported | This bit indicates support for NDP PS-Poll frames. | Set to 1 if dot11NDPPSPollSupport is true.<br>Set to 0 otherwise. |
| RAW Operation Support | This bit indicates support of RAW Participating as described in 10.23.5.1 (General). | Set to 1 if dot11RAWOperationImplemented is true.<br>Set to 0 otherwise. |
| Page Slicing Support | This bit indicates support of Page Slicing as described in 10.50 (Page slicing). | Set to 1 if dot11PageSlicingImplemented is true.<br>Set to 0 otherwise. |
| TXOP Sharing Implicit Ack Support | This bit indicates support of Implicit Ack in TXOP sharing. | Set to 1 if dot11TXOPSharingImplicitACKImplemented is true.<br>Set to 0 otherwise. |
| VHT Link Adaptation Capable | Indicates whether or not the STA supports link adaptation using VHT variant HT Control field. | If +HTC-VHT Capable is 1:<br>Set to 0 (No Feedback) if the STA does not provide VHT MFB.<br>Set to 2 (Unsolicited) if the STA provides only unsolicited VHT MFB.<br>Set to 3 (Both) if the STA can provide VHT MFB in response to VHT MRQ and if the STA provides unsolicited VHT MFB.<br>The value 1 is reserved.<br>Reserved if +HTC-VHT Capable is 0. |
| TACK Support as PS-Poll Response | This bit indicates whether the AP supports the using of TACK frame as the response to a PS-Poll frame with the Poll Type subfield equal to 1 as described in 10.47.2 (Rescheduling of awake/doze cycle). | Set to 1 if dot11PollTACKResponseImplemented is true.<br>Set to 0 otherwise. |
| Duplicate 1 MHz Support | This bit indicates support for transmission of S1G 1 MHz duplicate PPDUs. | Set to 1 if generation of a PPDU in duplicate 1 MHz format is supported as a response to an eliciting frame transmitted by the peer STA.<br>Set to 0 otherwise. |
| MCS Negotiation Support | Indicates if the STA supports control response MCS negotiation feature. | Set to 0 if not supported.<br>Set to 1 if supported. |
| 1 MHz Control Response Preamble Support | Indicates if the STA supports transmitting control response frames with 1 MHz preamble as the response of ≥2 MHz PPDUs. | Set to 0 if not supported.<br>Set to 1 if supported. |
| NDP Beamforming Report Poll Supported | Indicates support for reception of NDP Beamforming Report Poll frames. | Set to 0 if not supported.<br>Set to 1 if supported. |
| Unsolicited Dynamic AID | The STA sets the Unsolicited Dynamic AID field to 1 when dot11UnsolicitedDynamicAIDActivated is true, and sets it to 0 otherwise. See 10.20 (S1G dynamic AID assignment operation). | Set to 1 if dot11UnsolicitedDynamicAIDActivated is true.<br>Set to 0 otherwise. |

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**Table 9-351—Subfields of the S1G Capabilities Information field *(continued)***

| Subfield | Definition | Encoding |
|---|---|---|
| Sector Training Operation Supported | This bit indicates support of sector training operation described in 10.52.5 (Sector training operation). | Set to 0 if not supported.<br>Set to 1 if supported.<br>When equal to 1, a STA supports sector training operation. |
| Temporary PS Mode Switch | This bit indicates whether the STA supports the temporary PS Mode switch as described in 10.47.2 (Rescheduling of awake/doze cycle) while in non-TIM mode. | Set to 1 if supported.<br>Set to 0 otherwise. |
| TWT Grouping Support | This bit indicates support of TWT grouping described in 10.46.5 (TWT grouping). | Set to 0 if not supported.<br>Set to 1 if supported. |
| BDT Capable | Indicates the support of bidirectional TXOP operation described in 10.49 (Bidirectional TXOP). | Set to 0 if not supported.<br>Set to 1 if supported. |
| COLOR | Indicates the value that is used for the TXVECTOR parameter COLOR in frames transmitted by members of this BSS, as described in 10.21 (Group ID, partial AID, Uplink Indication, and COLOR in S1G PPDUs). | Set to an unsigned integer if sent by an AP. Otherwise reserved. |
| TWT Requester Support | This bit indicates support for the role of TWT requesting STA as described in 10.46 (Target wake time (TWT)). | Set to 1 if dot11TWTOptionActivated is true and the STA supports TWT requester STA functionality (see 10.46 (Target wake time (TWT))).<br>Set to 0 otherwise. |
| TWT Responder Support | This bit indicates support for the role of TWT responding STA | Set to 1 if dot11TWTOptionActivated is true and the STA supports TWT responding STA functionality (see 10.46 (Target wake time (TWT))).<br>Set to 0 otherwise. |
| PV1 Frame Support | Indicates support for PV1 MPDUs | Set to 0 if not supported.<br>Set to 1 if supported. |
| Link Adaptation Without NDP CMAC PPDU Capable | Indicate whether or not link adaptation through a Control frame that is not an NDP CMAC PPDU is allowed | Set to 0 if not supported.<br>Set to 1 if supported. |

### 9.4.2.199.3 Supported S1G-MCS and NSS Set field

The Supported S1G-MCS and NSS Set field and the Extended Supported S1G-MCS and NSS Set field are (M102) used to convey the combinations of S1G-MCSs and spatial streams that a STA supports for reception and the combinations that it supports for transmission. The structure of the field is shown in Figure 9-799 (Supported S1G-MCS and NSS Set field format).

NOTE 1—The Extended Supported S1G-MCS and NSS Set field not being present (M118)conveys that neither S1G-MCS 11 nor S1G-MCS 12 are supported. (see 9.4.2.199.4 (Extended Supported S1G-MCS and NSS Set field(M102))).(M102)


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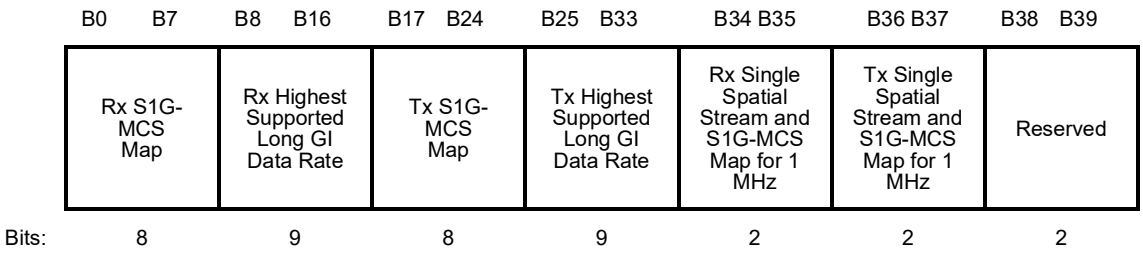


**Figure 9-799—Supported S1G-MCS and NSS Set field format**

The Supported S1G-MCS and NSS Set subfields are defined in Table 9-352 (Supported S1G-MCS and NSS Set subfields).

**Table 9-352—Supported S1G-MCS and NSS Set subfields**

| Subfield | Definition | Encoding |
|---|---|---|
| Rx S1G-MCS Map | Indicates the maximum value of the RXVECTOR parameter MCS of a PPDU that can be received at all channel widths supported by this STA for each number of spatial streams. | The format and encoding of this subfield are defined in Figure 9-800 (Rx S1G-MCS Map and Tx S1G-MCS Map subfields(M102)) and the associated description. If Rx Single Spatial Stream and S1G-MCS Map for 1 MHz subfield is greater than or equal to 1, then only the value of the Max S1G-MCS For 1 SS subfield that is indicated by the Rx Single Spatial Stream and S1G-MCS Map subfield is applicable for 1 MHz channel width. |
| Rx Highest Supported Long GI Data Rate | Indicates the highest long GI S1G data rate that the STA is able to receive. | The largest integer value less than or equal to the highest long GI S1G PPDU data rate in Mb/s the STA is able to receive (see 10.6.14.1 (RX Supported S1G-MCS and NSS Set)).<br><br>The value 0 indicates that this subfield does not specify the highest long GI S1G PPDU data rate that the STA is able to receive. |
| Tx S1G-MCS Map | Indicates the maximum value of the TXVECTOR parameter MCS of a PPDU that can be transmitted at all channel widths supported by this STA for each number of spatial streams. | The format and encoding of this subfield are defined in Figure 9-800 (Rx S1G-MCS Map and Tx S1G-MCS Map subfields(M102)) and the associated description. If Tx Single Spatial Stream and S1G-MCS Map for 1 MHz subfield is greater than or equal to 1, then only the value of the Max S1G-MCS For 1 SS subfield that is indicated by the Tx Single Spatial Stream and S1G-MCS Map subfield is applicable for 1 MHz channel width. |
| Tx Highest Supported Long GI Data Rate | Indicates the highest long GI S1G PPDU data rate at which the STA is able to transmit. | The largest integer value less than or equal to the highest long GI S1G PPDU data rate in Mb/s that the STA is able to transmit (see 10.6.14.2 (TX Supported S1G-MCS and NSS Set)).<br><br>The value 0 indicates that this subfield does not specify the highest long GI S1G PPDU data rate that the STA is able to transmit. |

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**Table 9-352—Supported S1G-MCS and NSS Set subfields**

| Subfield | Definition | Encoding |
|---|---|---|
| Rx Single Spatial Stream and S1G-MCS Map for 1 MHz | Indicates whether only a single spatial stream PPDU can be received at 1 MHz channel width by this STA. | 0: same number of spatial streams and same Max S1G-MCS as indicated by Rx S1G-MCS Map field.<br><br>1: single spatial stream only and with Max S1G-MCS as indicated by a 0 in the S1G-MCS for 1 SS subfield.<br><br>2: single spatial stream only and with Max S1G-MCS as indicated by a 1 in the S1G-MCS for 1 SS subfield.<br><br>3: single spatial stream only and with Max S1G-MCS as indicated by a 2 in the S1G-MCS for 1 SS subfield. |
| Tx Single Spatial Stream and S1G-MCS Map for 1 MHz | Indicates whether only a single spatial stream PPDU can be transmitted at 1 MHz channel width by this STA. | 0: same number of spatial streams and same Max S1G-MCS as indicated by Tx S1G-MCS Map field.<br><br>1: single spatial stream only and with Max S1G-MCS as indicated by a 0 in the S1G-MCS for 1 SS subfield.<br><br>2: single spatial stream only and with Max S1G-MCS as indicated by a 1 in the S1G-MCS for 1 SS subfield.<br><br>3: single spatial stream only and with Max S1G-MCS as indicated by a 2 in the S1G-MCS for 1 SS subfield. |

The Rx S1G-MCS Map subfield and the Tx S1G-MCS Map subfield have the structure shown in Figure 9-800 (Rx S1G-MCS Map and Tx S1G-MCS Map subfields(M102)).

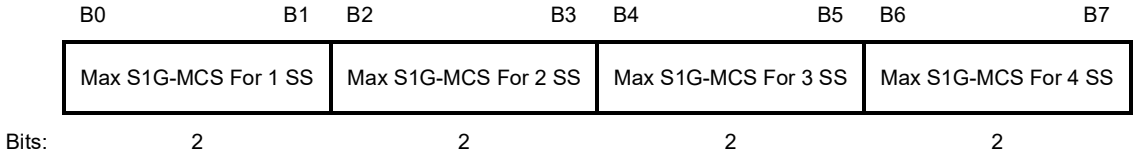


**Figure 9-800—Rx S1G-MCS Map and Tx S1G-MCS Map subfields(M102)**

The Max S1G-MCS for *n* SS subfield (where *n*=1,...,4) is encoded as follows:

— 0 indicates support for S1G-MCS 2 for n spatial streams

— 1 indicates support for S1G-MCS 7 for n spatial streams

— 2 indicates support for S1G-MCS 9 or more (see 9.4.2.199.4 (Extended Supported S1G-MCS and NSS Set field(M102)))(M102) for n spatial streams

— 3 indicates that n spatial streams is not supported

NOTE 2—An S1G-MCS indicated as supported in the S1G-MCS Map fields for a particular number of spatial streams might not be valid at all bandwidths (see 23.5 (Parameters for S1G-MCSs)) and might be limited by the declaration of Tx Highest Supported Long GI Data Rates and Rx Highest Supported Long GI Data Rates and might be affected by 10.6.14.3 (Additional rate selection constraints for S1G PPDUs).

NOTE 3—For 1 MHz, MCS 10 is always supported.


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#### 9.4.2.199.4 Extended Supported S1G-MCS and NSS Set field(M102)

The Extended Supported S1G-MCS and NSS Set field is used to convey the combinations of S1G-MCSs and spatial streams that a STA supports for reception and the combinations that it supports for transmission. The structure of the field is shown in Figure 9-801 (Extended Supported S1G-MCS and NSS Set field format(M102)).

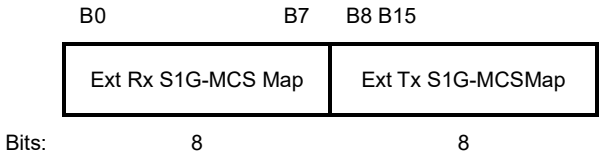


**Figure 9-801—Extended Supported S1G-MCS and NSS Set field format(M102)**

The Extended Supported S1G-MCS and NSS Set subfields are defined in Table 9-353 (Extended Supported S1G-MCS and NSS Set subfields(M102)).

**Table 9-353—Extended Supported S1G-MCS and NSS Set subfields(M102)**

| Subfield | Definition | Encoding |
|---|---|---|
| Ext Rx S1G-MCS Map | Indicates the maximum value of the RXVECTOR parameter MCS of a PPDU that can be received at all channel widths (#4391)where the MCS is valid for the channel width, supported by this STA for each number of spatial streams. | The format and encoding of this subfield are defined in Figure 9-802 (Ext Rx S1G-MCS Map and Ext Tx S1G-MCS Map subfields(M102)) and the associated description.(#4391) |
| Ext Tx S1G-MCS Map | Indicates the maximum value of the TXVECTOR parameter MCS of a PPDU that can be transmitted at all channel widths where the MCS is valid for the channel width, supported by this STA for each number of spatial streams.(#4391) | The format and encoding of this subfield are defined in Figure 9-802 (Ext Rx S1G-MCS Map and Ext Tx S1G-MCS Map subfields(M102)) and the associated description.(#4391) |

The Rx S1G-MCS Map subfield and the Tx S1G-MCS Map subfield have the structure shown in (#4391)Figure 9-802 (Ext Rx S1G-MCS Map and Ext Tx S1G-MCS Map subfields(M102)).

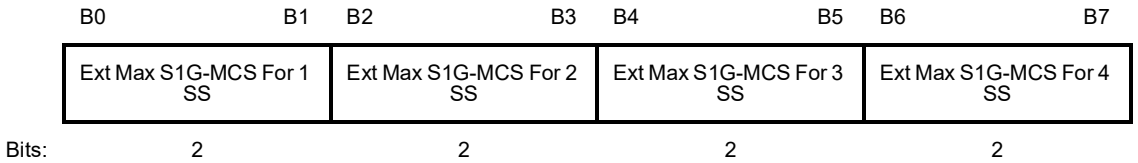


**Figure 9-802—Ext Rx S1G-MCS Map and Ext Tx S1G-MCS Map subfields(M102)**

The Max S1G-MCS for n SS subfield (where n=1,...,4) is encoded as follows:

— 0 indicates support for S1G-MCS 11 for n spatial streams

— 1 indicates support for S1G-MCS 12 for n spatial streams

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— 2 is reserved
— 3 indicates that n spatial streams is not supported for S1G-MCS 11

### 9.4.2.200 SST element(#1776)

(#1776)The subchannel selective transmission (SST) element is shown in Figure 9-803 (SST element format(#1776)).

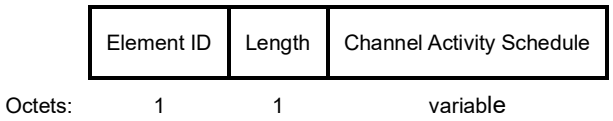


**Figure 9-803—SST element format(#1776)**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The Channel Activity Schedule subfield contains one or more channel activity schedules.

The format of the Channel Activity Schedule subfield is shown in Figure 9-804 (Channel Activity Schedule subfield format (Sounding Option = 0)) and Figure 9-805 (Channel Activity Schedule subfield format (Sounding Option = 1)).

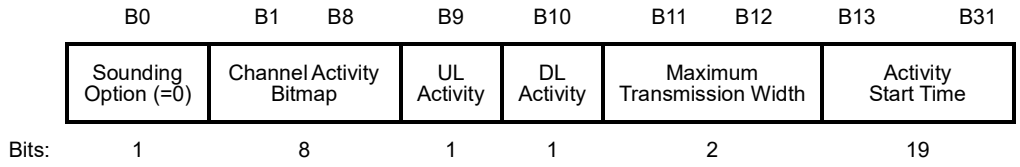


**Figure 9-804—Channel Activity Schedule subfield format (Sounding Option = 0)**

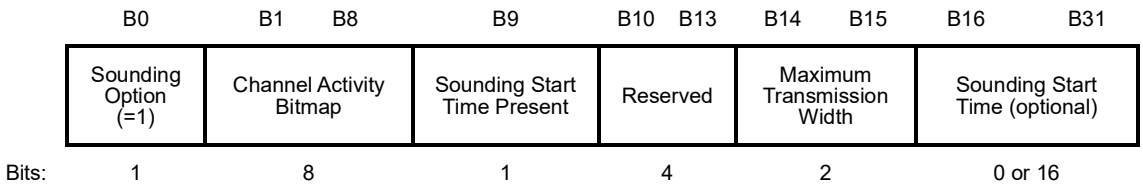


**Figure 9-805—Channel Activity Schedule subfield format (Sounding Option = 1)**


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The Sounding Option subfield is set to 0 to indicate that the Channel Activity Schedule field is the AP Activity schedule.

When the Sounding Option subfield is equal to 0, the Channel Activity Bitmap subfield contains a bitmap indicating on which channels transmission is either expected or permitted by the AP during a given time period. Each bit in the bitmap corresponds to one minimum width channel for the band of operation with the LSB corresponding to the lowest numbered operating channel of the BSS. A 1 in a bit position in the bitmap means that the AP expects activity and/or permits transmissions with bandwidth less than or equal to the bandwidth indicated in the Maximum Transmission Width subfield and that include that channel, after the time indicated in the Activity Start Time subfield. Only one bit in the bitmap can be set to 1 within each channel activity schedule. The minimum width channel is equal to the SST Channel Unit field of the SST Operation element if such an element has been previously transmitted or is equal to 2 MHz if no such element has been previously received from the AP to which the SST STA is associated.

The UL Activity subfield is set to 1 to indicate that the SST AP (that transmits the SST element) permits the STAs associated with it to transmit frames that are not immediate response frames on the channel(s) identified by the Channel Activity Bitmap and Maximum Transmission Width subfields at the time indicated in the Activity Start Time subfield. Otherwise it is set to 0.

The DL Activity subfield is set to 1 to indicate that the AP that transmits the SST element intends to transmit frames that are not immediate response frames on the channel(s) identified by the Channel Activity Bitmap and Maximum Transmission Width subfields at the time indicated in the Activity Start Time subfield. Otherwise it is set to 0.

The Maximum Transmission Width subfield indicates the maximum PPDU bandwidth permitted by the AP for a transmission on the indicated channel and cannot exceed the BSS operating channel width specified by the AP in a transmitted S1G Operation element. In order to abide by the rules of each regulatory domain, the maximum operating channel width is limited by the BSS operating channel width even if the Maximum Transmission Width field specifies otherwise. The maximum permitted PPDU bandwidth is in MHz and is determined based on the Maximum Transmission Width subfield as shown in Table 9-354 (Mapping between Maximum Transmission Width subfield and maximum permitted PPDU bandwidth).

**Table 9-354—Mapping between Maximum Transmission Width subfield and maximum permitted PPDU bandwidth**

| Maximum Transmission Width | Maximum permitted PPDU bandwidth (MHz) |
|---|---|
| 0 | channel width unit |
| 1 | 4 |
| 2 | 8 |
| 3 | 16 |

NOTE—The channel width unit is equal to 1 MHz if the SST Channel Unit field of the most recently received SST Operation element from the SST AP is equal to 1. If no SST Operation element has been received or the SST Channel Unit field of the received SST Operation element is equal to 0 then the channel width unit is equal to 2 MHz.

The Activity Start Time subfield contains a value that defines a start time for when the AP expects frame transmissions to begin on the channel(s) indicated in the corresponding Channel Activity Bitmap field. The start time is triggered when the 19 least significant bits of the TSF timer for the BSS match the value that is indicated in the Activity Start Time subfield of the SST element. The count down to the start time is initiated at the end of the transmission of the frame containing the SST element.

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The Sounding Option subfield is set to 1 in order to indicate that the Channel Activity Schedule field is the SST sounding schedule.

When the Sounding Option subfield is equal to 1, the Channel Activity Bitmap subfield contains a bitmap indicating on which channels there is an SST sounding transmission activity at a given time. Each bit in the bitmap corresponds to one minimum width channel for the band of operation with the LSB corresponding to the lowest numbered operating channel of the BSS. A 1 in a bit position in the bitmap means that the AP transmits one more PIFS-separated sounding NDPs.

The Sounding Start Time Present subfield indicates whether the Sounding Start Time subfield is present in the Channel Activity Schedule field. If the subfield is equal to 1, the Sounding Start Time subfield is present. If this subfield is equal to 0, the Sounding Start Time subfield is not present.

The Maximum Transmission Width subfield indicates the channel bandwidth of the sounding NDP and is shown in Table 9-354 (Mapping between Maximum Transmission Width subfield and maximum permitted PPDU bandwidth).

The Sounding Start Time subfield contains a value that defines a start time when the AP transmits one or more sounding NDPs on the channel(s) indicated in the corresponding Channel Activity Bitmap subfield. If the Sounding Start Time subfield is not present, the AP transmits one or more PIFS-separated sounding NDPs starting after the transmission of the Beacon frame containing the SST element. If the Sounding Start Time subfield is present, the AP transmits one or more PIFS-separated sounding NDPs starting at the time indicated in the Sounding Start Time field. The start time is triggered when the 16 least significant bits of the TSF timer for the BSS match the value that is indicated in the Sounding Start Time subfield of the SST element. The count down to the start time is initiated at the end of the transmission of the frame containing the SST element.

### 9.4.2.201 Authentication Control element

The notation of Authentication-Request and Authentication-Response refers to the definition in (#4139)13.1 (Overview).

The Authentication Control element contains the information required to mitigate contention among (#8189)Authentication-Request frames (see 11.3.9 (Authentication control)).

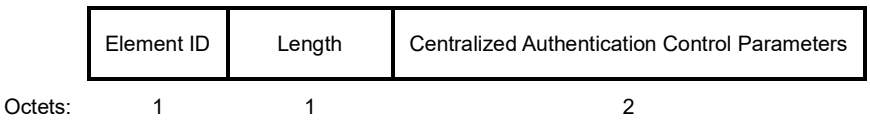


**Figure 9-806—Authentication Control element format (Control subfield equal to 0)**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The Information field starts with a 1-bit Control subfield.

When the Control subfield is equal to 0, the Authentication Control element format is as shown in Figure 9-806 (Authentication Control element format (Control subfield equal to 0)). The Authentication Control element indicates whether the recipient STA can transmit an Authentication-Request frame(#8189) to the AP that sends the element. The remaining part of the Centralized Authentication Control Parameters field Information field following the Control subfield contains the Deferral, Reserved and the Authentication Control Threshold subfields.


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The Centralized Authentication Control Parameters field format is shown in Figure 9-807 (Centralized Authentication Control Parameters format).

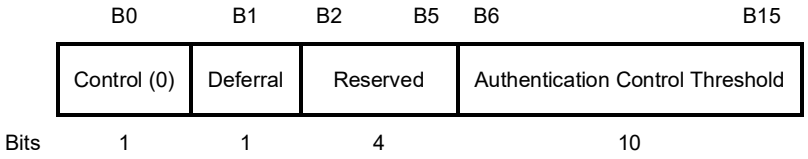


**Figure 9-807—Centralized Authentication Control Parameters format**

The Authentication Control Threshold subfield contains a number with a range from 0 to 1023. When the Deferral subfield is equal to 0, the value of the Authentication Control Threshold subfield is used by the recipient STA to determine whether or not the AP is allowing it to transmit an Authentication-Request frame(#8189). When the Deferral subfield is equal to 1, the Authentication Control Threshold subfield value is a time value, expressed in TUs, indicating a minimum amount of deferred time for channel access that is required before the transmission of an Authentication-Request frame and is set as described in 11.3.9.2 (Centralized authentication control).

When the Control subfield is equal to 1, the Authentication Control element contains the Distributed Authentication Control Parameters field as shown in Figure 9-808 (Authentication Control element format (Control subfield equal to 1)).

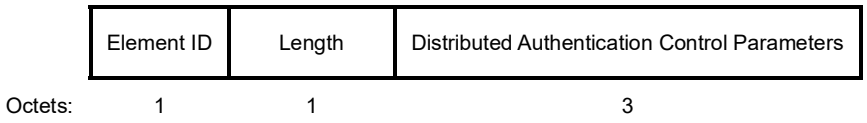


**Figure 9-808—Authentication Control element format (Control subfield equal to 1)**

The Distributed Authentication Control Parameters field format is shown Figure 9-809 (Distributed Authentication Control Parameters format).

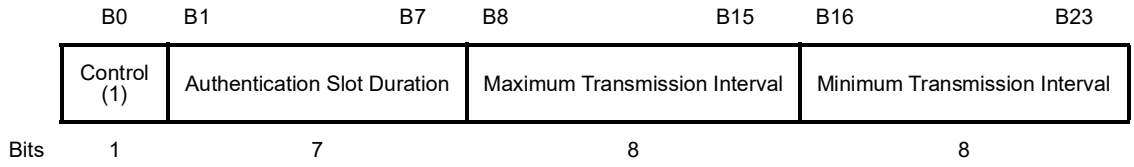


**Figure 9-809—Distributed Authentication Control Parameters format**

The Authentication Slot Duration subfield is expressed in units of TUs and indicates the authentication slot duration.

The Minimum Transmission Interval subfield is expressed in units of beacon intervals and indicates the minimum transmission interval (see 11.3.9.3 (Distributed authentication control)).

### 9.4.2.202 TSF Timer Accuracy element

The TSF Timer Accuracy element, shown in Figure 9-810 (TSF Timer Accuracy element format), specifies fields describing the accuracy of TSF timer. This information is used by a receiving STA to estimate the clock accuracy of the transmitting STA and to schedule the time to transition to awake state(#6038) for Beacon frame reception by taking this clock accuracy into account.

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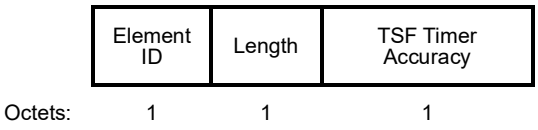


**Figure 9-810—TSF Timer Accuracy element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The TSF Timer Accuracy field (#2047)specifies the accuracy of the TSF timer of transmitting STA. The unit of the TSF Timer Accuracy field is ppm. The values between 125 and 255 are reserved for future expansion.

### 9.4.2.203 S1G Relay element

The S1G Relay element contains parameters necessary to support the relay operation and its format is shown in Figure 9-811 (S1G Relay element format).

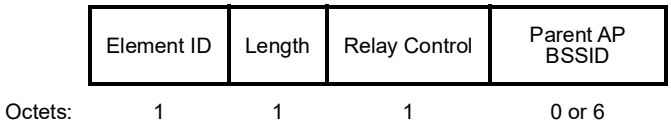


**Figure 9-811—S1G Relay element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The format of Relay Control field is shown in Figure 9-812 (Relay Control field format).

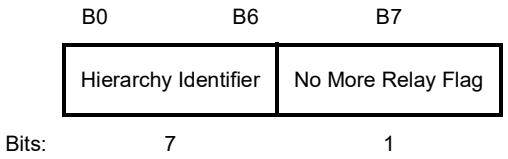


**Figure 9-812—Relay Control field format**

The Hierarchy Identifier subfield indicates whether the AP is a root AP or whether it relays an SSID, as specified in Table 9-355 (Hierarchy Identifier subfield).

**Table 9-355—Hierarchy Identifier subfield**

| Hierarchy Identifier | Meaning |
|---|---|
| 0 | Parent AP |
| 1 | S1G Relay AP that relays frames within the BSS identified by the BSSID contained in the RootAP BSSID field |
| 2–127 | Reserved |

The No More Relay Flag subfield is set to 1, to indicate that the AP does not accept any more requests for operating as relays from its associated non-AP STAs. Otherwise it is set to 0.


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The Parent AP BSSID field indicates the BSSID of the parent AP's BSS. The Parent AP BSSID field is present if the Hierarchy Identifier subfield is set to a nonzero value. Otherwise the Parent AP BSSID field is not present.

### 9.4.2.204 Reachable Address element

The format of the Reachable Address element is shown in Figure 9-813 (Reachable Address element format).

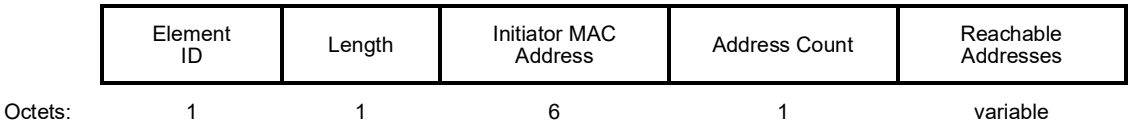


**Figure 9-813—Reachable Address element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The Initiator MAC Address field indicates the MAC address of the relay STA that transmits the Reachable Address element.

The Address Count field is an integer representing the number of addresses in the Reachable Addresses field.

The Reachable Addresses field contains one or more Reachable Address subfields

The Reachable Address subfields indicate the MAC addresses that can be reached through the relay STA. The format of the Reachable Address subfield is shown in Figure 9-814 (Reachable Address subfield format).

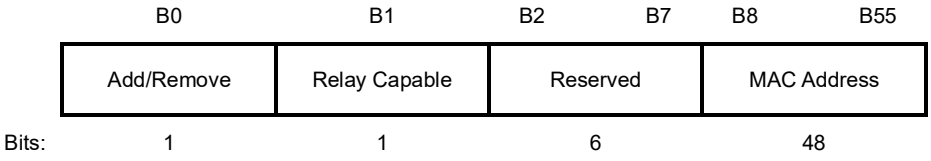


**Figure 9-814—Reachable Address subfield format**

The Add/Remove subfield is set to 1 if the MAC address is the address of a new STA joining the relay. Add/Remove subfield is set to 0 if the MAC address is the address of a STA leaving the relay. The Add/Remove subfield is set to 1 if the Reachable Address element is included within a (Re)Association Request frame.

The Relay Capable subfield is set to 1 if the STA is relay capable, otherwise it is set to 0.

The MAC Address subfield is set to the MAC address of the STA that joins or leaves the BSS.

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### 9.4.2.205 S1G Relay Activation element

The format of the S1G Relay Activation element is shown in Figure 9-815 (S1G Relay Activation element format).

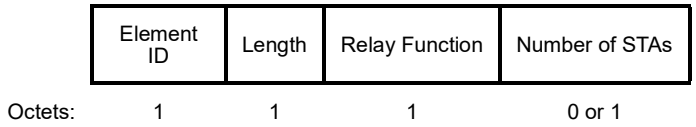


**Figure 9-815—S1G Relay Activation element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The format of the Relay Function field is shown in Figure 9-816 (Relay Function field format).

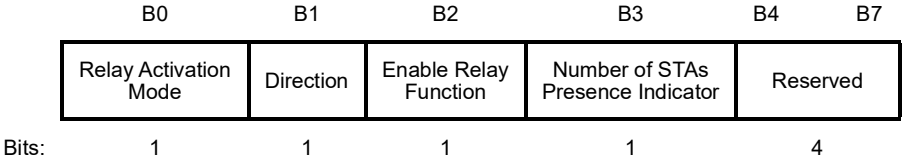


**Figure 9-816—Relay Function field format**

The Relay Activation Mode subfield is set to 1 to indicate that this element is a relay activation request. The Relay Activation Mode subfield is set to 0 to indicate the relay activation response.

The Direction subfield is set to 1 if the S1G Relay Activation element is sent by the AP. The Direction subfield is set to 0 if the S1G Relay Activation element is sent by the non-AP STA.

The Enable Relay Function subfield is set to a value based on the Direction and Relay Activation Mode subfield as described in Table 9-356 (Enable Relay Function subfield values).

**Table 9-356—Enable Relay Function subfield values**

| | **Relay Activation Mode=1 (Request)** | **Relay Activation Mode=0 (Response)** |
|---|---|---|
| **Direction=1 (from AP)** | If the Enable Relay Function subfield is set to 1, it indicates that the non-AP STA can operate as a relay and if it is set to 0 it indicates AP demands the non-AP STA to terminate the relay function. | If the Enable Relay Function subfield is set to 1, it indicates that the non-AP STA is allowed to operate as a relay and if it is set to 0, it indicates that the non-AP STA cannot operate as a relay. |
| **Direction=0 (from non-AP STA)** | If the Enable Relay Function subfield is set to 1, it indicates that the non-AP STA requests to activate its relay function and if it is set to 0, it indicates that the non-AP STA requests to terminate its relay function. | If the Enable Relay Function subfield is set to 1, it indicates that the non-AP STA activates its relay function and if it is set to 0, it indicates that the non-AP STA terminates its relay function. |

When the S1G Relay Activation element is sent by an AP, the Number of STAs Presence Indicator subfield is set to 1 to indicate that a Number of STAs field is included in the S1G Relay Activation element. Otherwise, it is set to 0.


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The Number of STAs field (#261)contains an unsigned integer. The Number of STAs field is used to calculate the maximum number of STAs, $N_{max}$, that an S1G relay AP is allowed to associate. $N_{max}$ is determined as follows:

$N_{max}$ = Number of STAs × 32

### 9.4.2.206 S1G Relay Discovery element

The S1G Relay Discovery element is shown in Figure 9-817 (S1G Relay Discovery element format).

| | Element ID | Length | Relay Discovery Control | UL/DL Data Rate (optional) | Delay Bound Requirement/ Channel Utilization (optional) | Min PHY Rate Requirement/ Relay Station Count (optional) |
|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 0 to 6 | 0 or 1 | 0 or 1 |

**Figure 9-817—S1G Relay Discovery element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The Relay Discovery Control field contains information indicating whether some or all following fields (see Figure 9-818 (UL/DL Data Rate field format)) are included in the S1G Relay Discovery element. The structure of Relay Discovery Control field is shown later in this subclause in Figure 9-819 (Relay Discovery Control field format).

| | UL Min Data Rate (optional) | UL Mean Data Rate (optional) | UL Max Data Rate (optional) | DL Min Data Rate (optional) | DL Mean Data Rate (optional) | DL Max Data Rate (optional) |
|---|---|---|---|---|---|---|
| Octets: | 0 or 1 | 0 or 1 | 0 or 1 | 0 or 1 | 0 or 1 | 0 or 1 |

**Figure 9-818—UL/DL Data Rate field format**

When UL Min Data Rate field is included in an S1G Relay Discovery element in a Probe Request frame, it indicates the UL minimum data rate of the direct link between the non-AP STA and AP in the unit of 100 kb/s. When UL Min Data Rate field is included in an S1G Relay Discovery element in a Probe Response or Beacon frame, it indicates the UL minimum data rate of the relay link between the relay and its associated AP in the unit of 100 kb/s.

When UL Mean Data Rate field is included in an S1G Relay Discovery element in a Probe Request frame, it indicates the UL mean data rate of the direct link between the non-AP STA and AP in the unit of 100 kb/s. When UL Mean Data Rate field is included in an S1G Relay Discovery element in a Probe Response or Beacon frame, it indicates the UL mean data rate of the relay link between the relay and its associated AP in the unit of 100 kb/s.

When UL Max Data Rate field is included in an S1G Relay Discovery element in a Probe Request frame, it indicates the UL maximum data rate of the direct link between the non-AP STA and AP in the unit of 100 kb/s. When UL Max Data Rate field is included in an S1G Relay Discovery element in a Probe Response or Beacon frame, it indicates the UL maximum data rate of the relay link between the relay and its associated AP in the unit of 100 kb/s.

When DL Min Data Rate field is included in an S1G Relay Discovery element in a Probe Request frame, it indicates the DL minimum data rate of the direct link between the non-AP STA and AP in the unit of

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100 kb/s. When DL Min Data Rate field is included in an S1G Relay Discovery element in a Probe Response or Beacon frame, it indicates the DL minimum data rate of the relay link between the relay and its associated AP in the unit of 100 kb/s.

When DL Mean Data Rate field is included in an S1G Relay Discovery element in a Probe Request frame, it indicates the DL mean data rate of the direct link between the non-AP STA and AP in the unit of 100 kb/s. When DL Mean Data Rate field is included in an S1G Relay Discovery element in a Probe Response or Beacon frame, it indicates the DL mean data rate of the relay link between the relay and its associated AP in the unit of 100 kb/s.

When DL Max Data Rate field is included in an S1G Relay Discovery element in a Probe Request frame, it indicates the DL maximum data rate of the direct link between the non-AP STA and AP in the unit of 100 kb/s. When DL Max Data Rate field is included in an S1G Relay Discovery element in a Probe Response or Beacon frame, it indicates the DL maximum data rate of the relay link between the relay and its associated AP in the unit of 100 kb/s.

When included in the S1G Relay Discovery element of a Probe Request frame and the Delay and Rate Requirement Included field in the Relay Discovery Control field of the S1G Relay Discovery element is equal to 1, the Delay Bound Requirement/Channel Utilization field indicates the delay bound requirement of the connection through the relay. When included in the S1G Relay Discovery element that is included in a Probe Response or a Beacon frame and the Utilization and Count Included field in the Relay Discovery Control field of the S1G Relay Discovery element is equal to 1, the Delay Bound Requirement/Channel Utilization field denotes the ratio of time that relay observes the busy level on the relay link between the relay and the AP, with value 100 indicating 100% busy level and value 0 indicating idle (values from 101 to 255 are reserved).

When included in the S1G Relay Discovery element of a Probe Request frame and the Delay and Min PHY Rate Requirement Included field in the Relay Discovery Control field of the S1G Relay Discovery element is equal to 1, the Min PHY Rate Requirement/Relay Station Count field indicates the minimum PHY data rate set required by the requesting STA. When included in the S1G Relay Discovery element of a Probe Response or a Beacon frame and the Utilization and Relay Count Included field in the Relay Discovery Control field of the S1G Relay Discovery element is equal to 1, the Min PHY Rate Requirement/Relay Station Count field denotes the number of non-AP STAs currently associated with the relay.

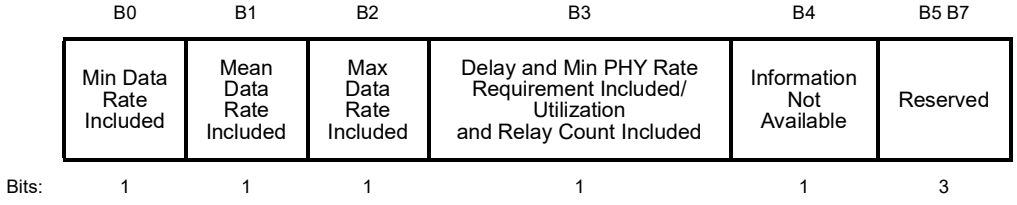


**Figure 9-819—Relay Discovery Control field format**

The Min Data Rate Included field is set to 1 if UL Min Data Rate field and DL Min Data Rate field are included in the S1G Relay Discovery element. Otherwise, the Min Data Rate Included field is set to 0.

The Mean Data Rate Included field is set to 1 if UL Mean Data Rate field and DL Mean Data Rate field are included in the S1G Relay Discovery element. Otherwise, the Mean Data Rate Included field is set to 0.

The Max Data Rate Included field is set to 1 if UL Max Data Rate field and DL Max Data Rate field are included in the S1G Relay Discovery element. Otherwise, the Max Data Rate Included field is set to 0.

The Delay and Rate Requirement Included/Utilization and Count Included field is set to 1 if Delay Bound Requirement/Channel Utilization field and Min PHY Rate Requirement/Relay Station Count field are


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included in the S1G Relay Discovery element. Otherwise, the Delay and Rate Requirement Included/ Utilization and Count Included field is set to 0.

The Information Not Available field is set to 1 if the relay does not provide the requested information. Otherwise, the Information Not Available field is set to 0.

### 9.4.2.207 AID Announcement element

The AID Announcement element is used to provide the mapping table between STAs' MAC addresses and AIDs.(#3296) The format of the AID Announcement element is shown in Figure 9-820 (AID Announcement element format).

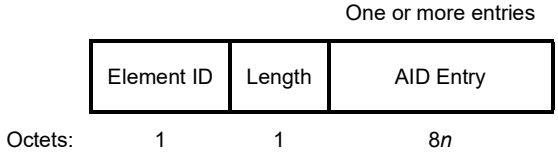


**Figure 9-820—AID Announcement element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The AID Entry field includes one or more STA MAC address and association ID pairs. The format of AID Entry field is shown in Figure 9-821 (AID Entry field format).

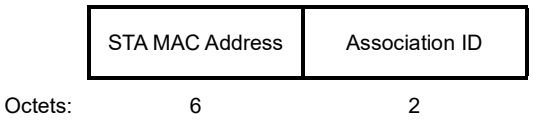


**Figure 9-821—AID Entry field format**

The STA MAC Address field indicates the MAC address of STA. The Association ID field, which has the same format as the AID field described in 9.4.1.8 (AID field), includes the AID for the corresponding STA. If AID Announcement element is included in a frame that is transmitted by a relay STA and the Association ID field equals to 0, the STA MAC Address field indicates the BSSID of the relay AP's BSS.

### 9.4.2.208 PV1 Probe Response Option element

The PV1 Probe Response Option element is included in the Probe Request frame to indicate the optional information requested to be included in the PV1 Probe Response frame that is transmitted by the responding STAs.

The optional information requested by the STA is indicated as bitmaps in the PV1 Probe Response Option element.

The format of the PV1 Probe Response Option element is shown in Figure 9-822 (PV1 Probe Response Option element format).

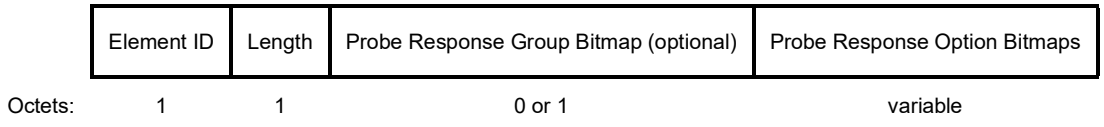


**Figure 9-822—PV1 Probe Response Option element format**

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The Element ID and Length fields are defined in 9.4.2.1 (General).

The Probe Response Group Bitmap field indicates the Probe Response Option Bitmap subfield(s) included in the PV1 Probe Response Option element. If Probe Response Option Bitmap subfield *i* is included in the PV1 Probe Response Option element, then *i*-th bit in the Probe Response Group Bitmap field is set to 1.

The Probe Response Option Bitmaps field contains one or more Probe Response Option Bitmap subfields.

Each Probe Response Option Bitmap subfield is 1 octet and indicates the optional information requested to be included in the PV1 Probe Response frame by the responding STAs. Setting a bit in a Probe Response Option Bitmap subfield to 1 indicates that the corresponding information is requested to be included in the PV1 Probe Response frame if the responding STA supports the indicated information.The bit is set to 0 to indicate that the information is not requested.

The optional information requested to be included in the PV1 Probe Response is categorized into 8 bitmaps (Probe Response Option bitmap 0 ~ 7).

Only Probe Response Option Bitmap subfields with at least one bit equal to 1 is included in the PV1 Probe Response Option element. For example, if only Probe Response Option Bitmap subfield 0 and 2 have bits that are equal to 1, then these two Probe Response Group Bitmap fields are included in the PV1 Probe Response Option element and the Probe Response Group Bitmap field is set to 10100000 to indicate that only the Probe Response Option Bitmap subfields 0 and 2 are included in the PV1 Probe Response Option element. When the Probe Response Group Bitmap field is included in the PV1 Probe Response Option element, at least one bit of the Probe Response Group Bitmap field is equal to 1.

Probe Response Option Bitmap subfield 0 is defined to be a default bitmap that indicates most frequently requested information. If the default bitmap is the only Probe Response Option Bitmap subfield that is included in the PV1 Probe Response Option element, then the Probe Response Group Bitmap field is omitted. In that case, only Element ID, Length, and the default bitmap (Probe Response Option Bitmap subfield 0) are included in the PV1 Probe Response Option element.

Table 9-357 (Probe Response Option Bitmap subfield 0 (Default Bitmap)) to Table 9-362 (Probe Response Option Bitmap subfield 5) define the Probe Response Option bitmap from 0 to 5, respectively.

NOTE—Probe Response Option bitmap 6 and 7 are reserved for future extension.

**Table 9-357—Probe Response Option Bitmap subfield 0 (Default Bitmap)**

| Bit position | Subfield | Item requested | Reference |
|---|---|---|---|
| 0 | Request Full SSID | (#8121)SSID element if the bit is set to 1, and (#8219)Short SSID field if the bit is set to 0 | 9.4.2.2 (SSID element) and 9.8.5.3 (PV1 Probe Response frame format) |
| 1 | Request Next TBTT | Next TBTT field | 9.8.5.3 (PV1 Probe Response frame format) |
| 2 | Request Access Network Options | Access Network Options field | 9.4.2.90 (Interworking element) |
| 3 | Request S1G Beacon Compatibility | S1G Beacon Compatibility element | 9.4.2.195 (S1G Beacon Compatibility element) |


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**Table 9-357—Probe Response Option Bitmap subfield 0 (Default Bitmap)**

| Bit position | Subfield | Item requested | Reference |
|---|---|---|---|
| 4 | Request Supported Rates | Supported Rates and BSS Membership Selectors element | 9.4.2.3 (Supported Rates and BSS Membership Selectors element) |
| 5 | Request S1G Capability | S1G Capabilities element | 9.4.2.199 (S1G Capabilities element) |
| 6 | Request S1G Operation | S1G Operation element | 9.4.2.211 (S1G Operation element) |
| 7 | Request RSN | RSNE(#1517) | 9.4.2.23 (RSNE) |

**Table 9-358—Probe Response Option Bitmap subfield 1**

| Bit position | Subfield | Item requested | Reference |
|---|---|---|---|
| 0 | Request RPS | RPS element | 9.4.2.190 (RPS element) |
| 1 | Request Page Slice | Page Slice element | 9.4.2.191 (Page Slice element) |
| 2 | Request TSF Timer Accuracy | TSF Timer Accuracy element | 9.4.2.202 (TSF Timer Accuracy element) |
| 3 | Request S1G Relay Discovery | S1G Relay Discovery element | 9.4.2.206 (S1G Relay Discovery element) |
| 4 | Request S1G Sector Operation | S1G Sector Operation element | 9.4.2.194 (S1G Sector Operation element) |
| 5 | Request Short Beacon Interval | Short Beacon Interval element | 9.4.2.196 (Short Beacon Interval element(#2194)) |
| 6–7 | Reserved | | |

**Table 9-359—Probe Response Option Bitmap subfield 2**

| Bit position | Subfield | Item requested | Reference |
|---|---|---|---|
| 0 | Request Country | Country element | 9.4.2.7 (Country element) |
| 1 | Request Power Constraint | Power Constraint element | 9.4.2.12 (Power Constraint element) |
| 2 | Request TPC Report | TPC Report element | 9.4.2.15 (TPC Report element) |
| 3 | Request Extended Supported Rates | Extended Supported Rates and BSS Membership Selectors element | 9.4.2.11 (Extended Supported Rates and BSS Membership Selectors element) |

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**Table 9-359—Probe Response Option Bitmap subfield 2**

| | | | |
|---|---|---|---|
| 4 | Request Extended Capabilities | Extended Capabilities element | 9.4.2.25 (Extended Capabilities element) |
| 5 | Request BSS Load | BSS Load element | 9.4.2.26 (BSS Load element) |
| 6 | Request EDCA Parameter Set | EDCA Parameter Set element | 9.4.2.27 (EDCA Parameter Set element) |
| 7 | Request Supported Operating Classes | Supported Operating Classes element | 9.4.2.52 (Supported Operating Classes element) |

**Table 9-360—Probe Response Option Bitmap subfield 3**

| Bit position | Subfield | Item requested | Reference |
|---|---|---|---|
| 0 | Request Measurement Pilot Transmission | Measurement Pilot Transmission element | 9.4.2.40 (Measurement Pilot Transmission element) |
| 1 | Request Multiple BSSID | Multiple BSSID element | 9.4.2.44 (Multiple BSSID element) |
| 2 | Request RM Enabled Capabilities | RM Enabled Capabilities element | 9.4.2.43 (RM Enabled Capabilities element) |
| 3 | Request AP Channel Report | AP Channel Report element | 9.4.2.34 (AP Channel Report element) |
| 4 | Request BSS Average Access Delay | BSS Average Access Delay element | 9.4.2.37 (BSS Average Access Delay element) |
| 5 | Request Antenna | Antenna element | 9.4.2.38 (Antenna element) |
| 6 | Request BSS Available Admission Capacity | BSS Available Admission Capacity element | 9.4.2.41 (BSS Available Admission Capacity element) |
| 7 | Request BSS AC Access Delay | BSS AC Access Delay element | 9.4.2.42 (BSS AC Access Delay element) |

**Table 9-361—Probe Response Option Bitmap subfield 4**

| Bit position | Subfield | Item requested | Reference |
|---|---|---|---|
| 0 | Request Mobility Domain | (#1776)MDE | 9.4.2.45 (MDE(#1776)) |
| 1 | Request QoS Traffic Capability | QoS Traffic Capability element | 9.4.2.76 (QoS Traffic Capability element) |
| 2 | Request Channel Usage | Channel Usage element | 9.4.2.84 (Channel Usage element) |
| 3 | Request Time Advertisement | Time Advertisement element | 9.4.2.59 (Time Advertisement element) |
| 4 | Request Time Zone | Request Time Zone element | 9.4.2.85 (Time Zone element) |


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**Table 9-361—Probe Response Option Bitmap subfield 4**

| | | | |
|---|---|---|---|
| 5 | Request IBSS Parameter Set | IBSS Parameter Set element | 9.4.2.6 (IBSS Parameter Set element) |
| 6(11bc) | Request EBCS Parameters | EBCS Parameters element | 9.4.2.313 (EBCS Parameters element(11bc)) |
| 7 | Reserved | | |

**Table 9-362—Probe Response Option Bitmap subfield 5**

| Bit position | Subfield | Item requested | Reference |
|---|---|---|---|
| 0 | Request Interworking | Interworking element | 9.4.2.90 (Interworking element) |
| 1 | Request Advertisement Protocol | Advertisement Protocol element | 9.4.2.91 (Advertisement Protocol element) |
| 2 | Request Roaming Consortium | Roaming Consortium element | 9.4.2.94 (Roaming Consortium element) |
| 3 | Request Emergency Alert Identifier | Emergency Alert Identifier element | 9.4.2.95 (Emergency Alert Identifier element) |
| 4 | Request QLoad Report | QLoad Report element | 9.4.2.121 (QLoad Report element) |
| 5 | Request Multi-band | Multi-band element | 9.4.2.137 (Multi-band element) |
| 6 | Request Multiple MAC Sublayers | Multiple MAC Sublayers element | 9.4.2.151 (MMS element(#1776)) |
| 7 | Request Reduced Neighbor Report | Reduced Neighbor Report element | 9.4.2.169 (Reduced Neighbor Report element) |

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### 9.4.2.209 EL Operation element

The EL Operation element is used by a STA to inform the associated AP or TDLS peer STA(#275) about operating limitations of the STA, in terms of the maximum continuous time the STA is capable of being in the awake state, and the minimum continuous time the STA stays in doze state in (#435)between awake periods. The format of the EL Operation element is presented in Figure 9-823 (EL Operation element format).

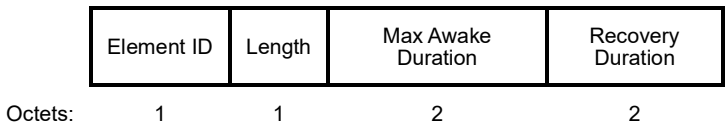


**Figure 9-823—EL Operation element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The Max Awake Duration field indicates a time in units of 40 μs, used as defined in 11.46 (Support for energy limited STAs); a value 0 indicates that no limit applies.

The Recovery Duration field indicates a time in units of 40 μs, used as defined in 11.46 (Support for energy limited STAs).

### 9.4.2.210 Sectorized Group ID List element

The Sectorized Group ID List element includes the information necessary for a receiving STA to determine its sectorization group membership. An example of group use is the sector operation. In sector operation, only a set of STA groups is allowed to transmit during the sector duration. The Sectorized Group ID List element can be provided in Probe Response or (Re)Association Response frame.

The format of the Sectorized Group ID List element is presented in Figure 9-824 (Sectorized Group ID List element format).

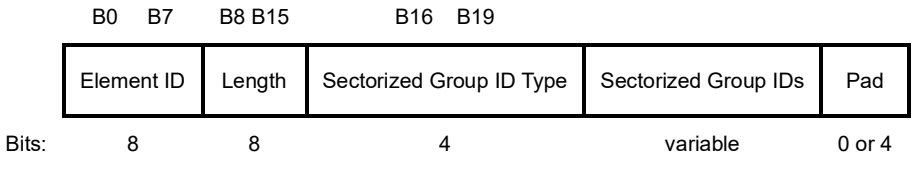


**Figure 9-824—Sectorized Group ID List element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The Sectorized Group ID Type field indicates the sectorized group IDs usage. Setting the Sectorized Group ID Type field to 0 indicates that the values in the Sectorized Group ID subfields refer to STAs in sectorization use. The values of the Sectorized Group ID Type field other than 0 are reserved for other purposes.

The Sectorized Group IDs field contains one or more Sectorized Group ID subfields.

Each Sectorized Group ID subfield is 4 bits and indicates a new sectorized group ID that is associated with the receiver STAs. A value of 15 in the Sectorized Group ID subfield is reserved for padding bits.


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The Pad field contains 0 or 4 bits of 1s to make the total number of bits in the Sectorized Group ID List element equal to an integer number of octets.

### 9.4.2.211 S1G Operation element

The operation of S1G STAs in the BSS is controlled by the S1G Operation element. The format of the S1G Operation element is defined in Figure 9-825 (S1G Operation element format).

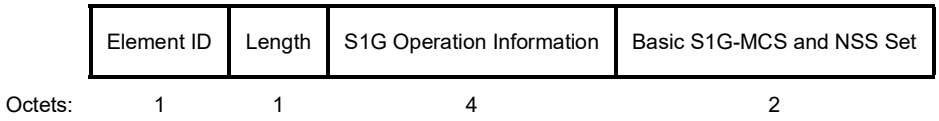


**Figure 9-825—S1G Operation element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The structure of the S1G Operation Information field is defined in Figure 9-826 (S1G Operation Information field format).

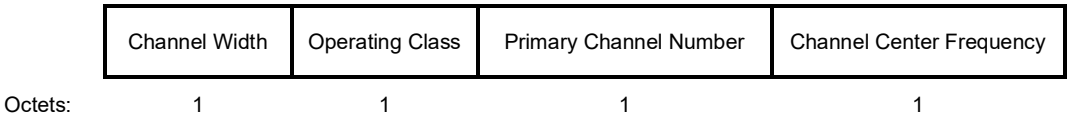


**Figure 9-826—S1G Operation Information field format**

The subfields of the S1G Operation Information field are defined in Table 9-363 (S1G Operation Information field).

**Table 9-363—S1G Operation Information field**

| Fields | Definition | Encoding |
|---|---|---|
| Channel Width | This field defines the BSS operating channel width (see Table 10-39 (S1G BSS operating channel width) in 10.45.1 (Basic S1G BSS functionality) also). | Bitmap of B0–B4 indicates the primary channel width, and the operating channel widths, 1/2/4/8/16 MHz.<br>The Primary Channel Width subfield, located in B0 of this field, and the BSS Operating Channel Width subfield, located in B1–B4 of this field, are defined in Table 10-39 (S1G BSS operating channel width).<br>(#465)B5 indicates the location of 1 MHz primary channel within the 2 MHz primary channel<br>— B5 is set to 0 to indicate that is located at the lower side of 2 MHz primary channel.<br>— B5 is set to 1 to indicate that is located at the upper side of 2 MHz primary channel.<br>B6 is reserved.<br>B7 is set to 1 to indicate that it is recommended that a STA does not use MCS 10. |
| Operating Class | This field defines the operating class in which the BSS is operating. | The operating class of the BSS. |

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**Table 9-363—S1G Operation Information field**

| Fields | Definition | Encoding |
|---|---|---|
| Primary Channel Number | Primary Channel Number field indicates the channel number of 2 MHz primary channel or 1 MHz primary channel. | Channel number of the primary channel. |
| Channel Center Frequency | Defines the channel center frequency. | Indicates the channel index of the BSS operating channel (see 23.3.14 (Channelization)). |

The Basic S1G-MCS and NSS Set field indicates the S1G-MCSs for each number of spatial streams in S1G PPDUs that are supported by all S1G STAs in the BSS. The format of the Basic S1G-MCS and NSS Set field is shown in Figure 9-827 (Basic S1G-MCS and NSS Set field format).

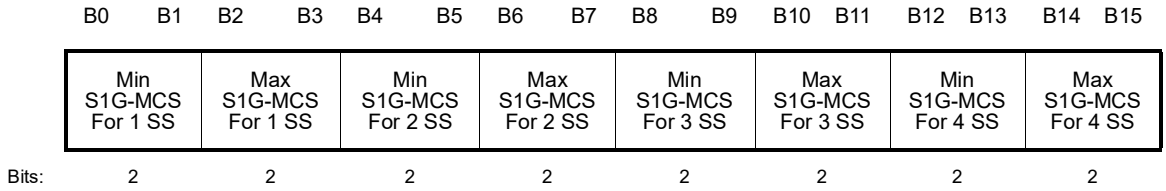


**Figure 9-827—Basic S1G-MCS and NSS Set field format**

Each Max S1G-MCS indicates the supported S1G-MCS set for NSS from 1 to 4 while each Min S1G-MCS indicates whether certain S1G-MCS values are not recommended for NSS from 1 to 4.

The Max S1G-MCS For *n* SS subfield (where *n* = 1,...,4) is same as the field with the same name that is defined in the S1G Capabilities element.

NOTE—Neither S1G-MCS 11 nor S1G-MCS 12 can be in the basic S1G-MCS and NSS set.(M102)

The Min S1G-MCS For *n* SS subfield (where *n* = 1,...,4) is encoded as follows:

— 0 indicates no minimum MCS restriction for n spatial streams.
— 1 indicates S1G-MCS 0 for *n* spatial streams is not recommended.
— 2 indicates S1G-MCS 0 and 1 for *n* spatial streams is not recommended.
— 3 is reserved.

### 9.4.2.212 Header Compression element

The Header Compression element is used by a STA to inform its intended receiver regarding frame header fields that (#6024)are compressed and that it needs to store. The format of the Header Compression element is shown in Figure 9-828 (Header Compression element format).

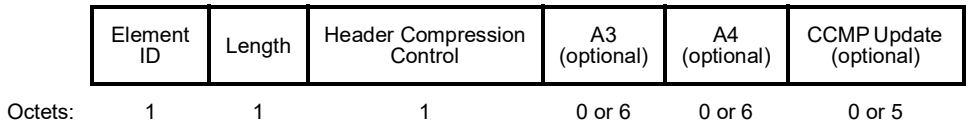


**Figure 9-828—Header Compression element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).


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The Header Compression Control field is shown in Figure 9-829 (Header Compression Control field format).

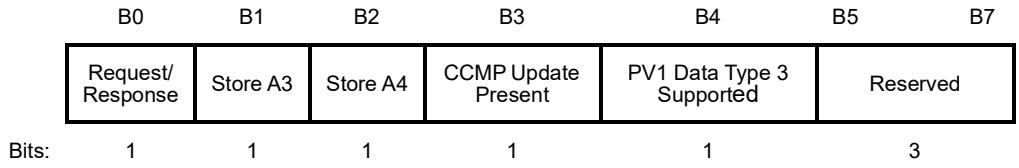


**Figure 9-829—Header Compression Control field format**

The Request/Response subfield is set to 0 to indicate a header compression request and set to 1 to indicate a header compression response.

The Store A3 subfield is set to 1 in the header compression request to request the intended receiver of the frame to store the A3 field and is set to 1 in the header compression response to confirm storage of the A3 field. Otherwise, it is set to 0 in the header compression request to indicate no storage request for the A3 field and is set to 0 in the header compression response to indicate unsuccessful storage or release of the stored A3 field.

The Store A4 subfield is set to 1 to request the intended receiver of the header compression request to store the A4 field and is set to 1 in the header compression response to confirm storing of the A4 field. Otherwise, it is set to 0 in the header compression request to indicate no storage request for the A4 field and is set to 0 in the header compression response to indicate unsuccessful storage or release of the stored A4 field.

The CCMP Update Present subfield is set to 1 to indicate the intended receiver of the header compression request to update the base packet number (BPN) and Key ID fields for the specified (#7012)sequence number (SN) space, as identified by the PTID subfield and Management subfield in the CCMP Update field and is set to 1 in the header compression response to confirm the update of the fields or to indicate decryption error for the specified (#7012)SN space. Otherwise, it is set to 0 in the header compression request to indicate no CCMP update request and is set to 0 in the header compression response to indicate no CCMP update confirmation.

(#7012)NOTE—See Table 10-5 (Transmitter sequence number spaces) for SN space selection.

The PV1 Data Type 3 Supported subfield is set to 1 to indicate that reception of PV1 frames with Type field equal to 3 is enabled. Otherwise, it is set to 0.

The A3 field in the Header Compression element is present if the Request/Response subfield is 0 and the Store A3 subfield is 1. Otherwise, it is not present.

The A4 field in the Header Compression element is present if the Request/Response subfield is 0 and the Store A4 subfield is 1. Otherwise, it is not present.

The CCMP Update field in the Header Compression element is present if the CCMP Update Present subfield is 1. Otherwise, it is not present.

The CCMP Update field contains the BPN and (#3493)key ID for (#7012)the specified SN space, as shown in Figure 9-830 (CCMP Update field format(#7012)).

The BPN subfield contains the BPN for the (#7012)specified SN space. The BPN subfield consists of the PN2, PN3, PN4, and PN5 octets, as shown in Figure 9-831 (BPN subfield format).

The Key ID subfield contains the (#3493)key ID for the (#7012)specified SN space.

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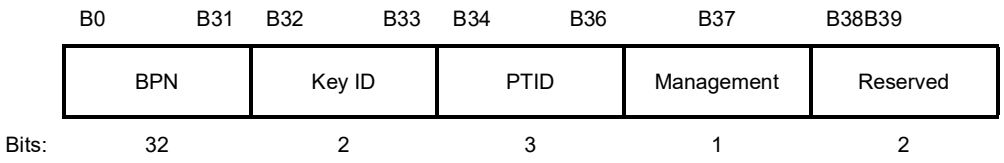


**Figure 9-830—CCMP Update field format(#7012)**

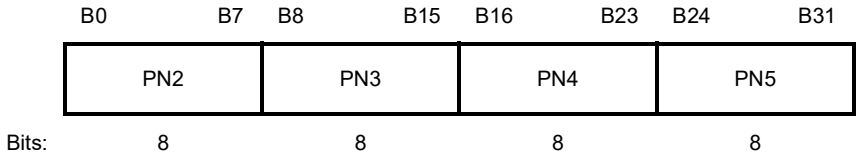


**Figure 9-831—BPN subfield format**

The (#7012)PTID subfield contains the PTID for the specified SN space when the Management subfield value is 0, and is set to 0 otherwise.

(#7012)The Management subfield is set to 1 to identify the specified SN space as SNS7, which is for individually addressed PV1 Management frames, and is set to 0 otherwise.

### 9.4.2.213 SST Operation element

The Subchannel Selective Transmission (SST) Operation element is shown in Figure 9-832 (SST Operation element format)

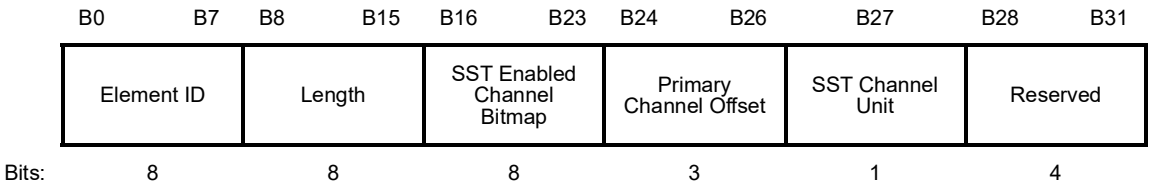


**Figure 9-832—SST Operation element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The SST Enabled Channel Bitmap field contains a bitmap indicating the channels that are enabled for SST operation. Each bit in the bitmap corresponds to one channel of width equal to the value of SST Channel Unit field, with the least significant bit corresponding to the lowest numbered subchannel in the SST Enabled Channel Bitmap field. The channel number of each of the channels in the SST Enabled Channel Bitmap field is equal to PCN minus OPC plus POS, where PCN is the value of the Primary Channel Number subfield in the most recently transmitted S1G Operation element, OPC is the offset of the primary channel relative to the lowest numbered subchannel in the bitmap as specified by the value of the Primary Channel Offset field and POS is the position of the channel in the bitmap. Setting a bit position in the bitmap to 1 indicates that the subchannel is enabled for SST operation but transmissions from SST STAs in that subchannel are allowed subject to the rules defined in 10.51 (Subchannel selective transmission (SST)). More than one bit in the bitmap can be equal to 1.

The Primary Channel Offset field indicates the relative position of the primary channel with respect to the lowest numbered channel in the SST Enabled Channel Bitmap field. For example, setting the Primary


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Channel Offset field to 2 indicates that the primary channel is the third subchannel in the SST Enabled Channel Bitmap.

The SST Channel Unit field indicates the channel width unit of each SST channel. Setting the field to 1 indicates that the channel width unit is 1 MHz and setting the field to 0 indicates that the channel width unit is 2 MHz.

### 9.4.2.214 MAD element

The MAD element is shown in Figure 9-833 (MAD element format).

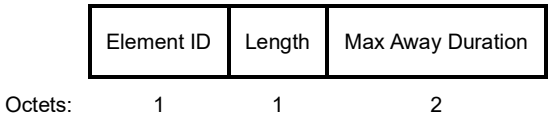


**Figure 9-833—MAD element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The Max Away Duration field indicates the maximum duration that the AP can be out of reach for the STA (operating in other channels, enter power save mode, or operating in other RAWs). The value of the Max Away Duration field is expressed in units of TU.

### 9.4.2.215 Password Identifier element

The Password Identifier element contains a string used to look up a password. The format of the element is defined in Figure 9-834 (Password Identifier element format).

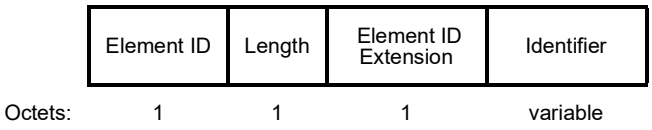


**Figure 9-834—Password Identifier element format**

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

The Identifier field is a variable-length string that identifies a password as specified in 12.4 (Authentication using a password).

### 9.4.2.216 Max Channel Switch Time element

The Max Channel Switch Time element indicates the time delta between the time the last beacon is transmitted by the AP in the current channel and the expected time of the first beacon transmitted by the AP in the new channel. The format of the element is defined in Figure 9-835 (Max Channel Switch Time element format).

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General)(#1715).

The Switch Time field indicates(#2047) the maximum time delta between the TBTT of the last Beacon frame transmitted by the AP in the current channel and the TBTT of the first Beacon frame in the new channel, expressed in TUs.(#3420)

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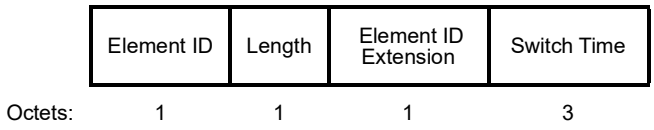


**Figure 9-835—Max Channel Switch Time element format**

This element is optionally present in Beacon and Probe Response frames when a Channel Switch Announcement or Extended Channel Switch Announcement element is also present.

### 9.4.2.217 Vendor Specific Request element

This element is placed in a Probe Request frame or Information Request frame to request that the responding STA include the requested information in the Probe Response frame or Information Response frame, respectively. It is used to make one or more requests to the responding STA using Vendor Specific Information. The format of the element is shown in Figure 9-836 (Vendor Specific(#1534) Request element format).

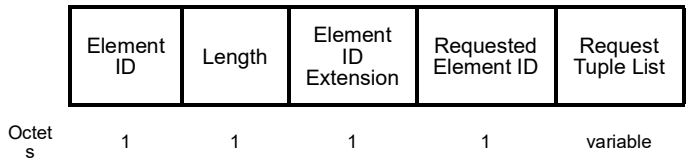


**Figure 9-836—Vendor Specific(#1534) Request element format**

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

The Requested Element ID field is set to 221 (Vendor Specific as defined in 9.4.2.1 (General)).

The Request Tuple List field contains one or more Request Tuple fields. The format of a Request Tuple field is shown in Figure 9-837 (Request Tuple field format).

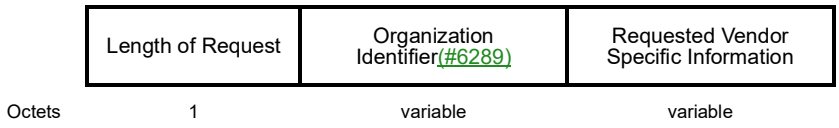


**Figure 9-837—Request Tuple field format**

(#6289)The Length of Request field is the length of the Organization Identifier and Requested Vendor Specific Information fields. The Organization Identifier field is described in 9.4.1.29 (Organization Identifier field). The Requested Vendor Specific Information field is a sequence of octets that comprise individual requests.

See 11.1.4.3.9 (Contents of a probe response) for additional requirements.

### 9.4.2.218 CDMG Capabilities element

#### 9.4.2.218.1 General

The capabilities of a CDMG STA include the capabilities indicated by both the DMG Capabilities element (9.4.2.126 (DMG Capabilities element)) and the CDMG Capabilities element (9.4.2.218 (CDMG Capabilities element)). The CDMG Capabilities element contains a STA identifier and several fields to


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indicate the capabilities that are applicable for a CDMG STA; they are not applicable for a DMG STA. A CDMG STA uses the CDMG Capabilities element to advertise the support of optional CDMG capabilities. The element is present in Association Request, Association Response, Reassociation Request, Reassociation Response, Probe Request, and Probe Response frames and is optionally present in DMG Beacon, Information Request, and Information Response frames. The CDMG Capabilities element is formatted as defined in Figure 9-838 (CDMG Capabilities element format).

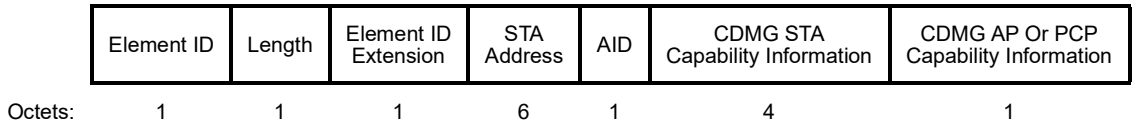


**Figure 9-838—CDMG Capabilities element format**

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

The STA Address field contains the MAC address of the STA.

The AID field contains the AID assigned to the STA by the AP or PCP(#443). The AID field is reserved in Association Request, Reassociation Request, and Probe Request frames and when used in an IBSS.

### 9.4.2.218.2 CDMG STA Capability Information field

The CDMG STA Capability Information field, shown in Figure 9-839 (CDMG STA Capability Information field format), represents the transmitting STA capabilities irrespective of the role of the STA.

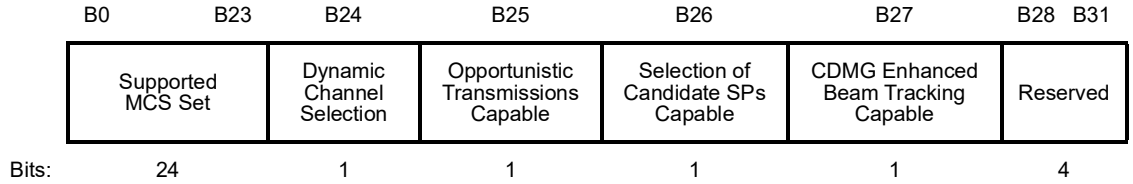


**Figure 9-839—CDMG STA Capability Information field format**

The Supported MCS Set subfield indicates the MCSs a CDMG STA supports. A MCS is identified by a MCS index, which is represented by an integer in the range 0 to 23. The interpretation of the MCS index (i.e., the mapping from MCS to data rate) is PHY dependent. For the CDMG PHY, see Clause 24 (China directional multi-gigabit (CDMG) PHY specification). The structure of the Supported MCS Set subfield is defined in Figure 9-840 (Supported MCS Set subfield format).

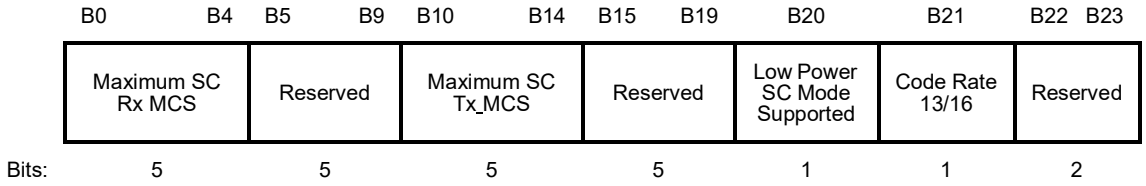


**Figure 9-840—Supported MCS Set subfield format**

The Maximum SC Rx MCS subfield contains the value of the maximum MCS index the CDMG STA supports for reception of single-carrier frames. Values 0-8 of this subfield are reserved. Possible values for this subfield are shown in Table 24-9 (CDMG SC mode modulation and coding schemes).

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The Maximum SC Tx MCS subfield contains the value of the maximum MCS index the CDMG STA supports for transmission of single-carrier frames. Values 0-8 of this subfield are reserved. Possible values for this subfield are shown in Table 24-9 (CDMG SC mode modulation and coding schemes).

The Low-Power SC Mode Supported subfield is set to 1 to indicate that the CDMG STA supports the low-power SC mode (24.6 (CDMG low-power SC mode)). Otherwise, it is set to 0. If the CDMG STA supports the low-power SC mode, it supports all low-power SC mode MCSs indicated in Table 24-11 (CDMG low-power SC mode modulation and coding schemes).

The Code Rate 13/16 subfield specifies whether the CDMG STA supports rate 13/16. It is set to 1 to indicate that the CDMG STA supports rate 13/16 and is set to 0 otherwise. If this subfield is 0, MCSs with 13/16 code rate specified in Table 24-9 (CDMG SC mode modulation and coding schemes) is not supported regardless of the value in Maximum SC Tx/Rx MCSMCS subfields.

The Dynamic Channel Selection subfield is set to 1 if the STA supports DCS procedures as defined in 11.47 (DCS procedure for CDMG BSS) and is set to 0 otherwise.

The Opportunistic Transmissions Capable subfield is set to 1 if the STA supports opportunistic transmission in alternative channels for CDMG STAs as defined in 10.38.11 (Opportunistic transmission in alternative channel for CDMG STAs) and is set to 0 otherwise.

The Selection of Candidate SPs Capable subfield is set to 1 if the STA supports selection of candidate SPs for spatial sharing as described in Annex W.1 and is set to 0 otherwise.

The CDMG Enhanced Beam Tracking Capable subfield is set to 1 if the STA supports CDMG enhanced beam tracking as defined in 10.41.9 (CDMG enhanced beam tracking) and Annex W.3 and is set to 0 otherwise.

#### 9.4.2.218.3 CDMG AP Or PCP Capability Information field

The CDMG AP Or PCP Capability Information field, defined in Figure 9-841 (CDMG AP Or PCP Capability Information field format), represents the capabilities, when the transmitting CDMG STA performs in the role of AP or PCP, that are in addition to the capabilities in the CDMG STA Capability Information field.

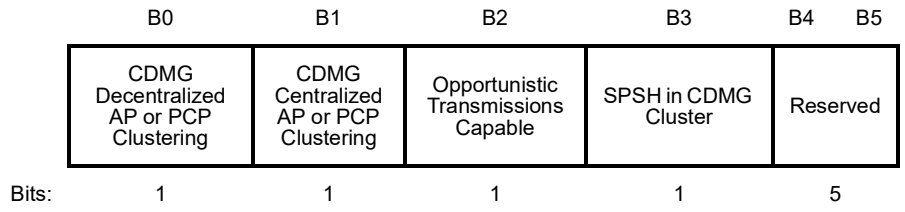


**Figure 9-841—CDMG AP Or PCP Capability Information field format**

The CDMG Decentralized AP or PCP Clustering subfield is set to 1 if the STA, when operating as an AP or PCP, is capable of performing decentralized AP or PCP clustering as described in 10.36 (Null data PPDU (NDP) sounding for CMMG STAs) and is set to 0 otherwise.

The CDMG Centralized AP or PCP Clustering subfield is set to 1 if the STA, when operating as an AP or PCP, is capable of performing centralized AP or PCP clustering and is set to 0 otherwise. An AP or PCP that is incapable of performing centralized AP or PCP clustering is subject to requirements as described in 10.36 (Null data PPDU (NDP) sounding for CMMG STAs).


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The SPSH in CDMG Cluster subfield is set to 1 if the STA supports spatial sharing in a CDMG AP or PCP cluster as defined in 10.40.6 (Spatial sharing in a CDMG AP or PCP cluster) and is set to 0 otherwise. If both the CDMG Decentralized AP or PCP Clustering subfield and the CDMG Centralized AP or PCP Clustering subfield are equal to 0, the SPSH in CDMG Cluster subfield is reserved.

### 9.4.2.219 Dynamic Bandwidth Control element

The Dynamic Bandwidth Control element defines the information from the CDMG AP or PCP to support the dynamic bandwidth control mechanism described in 10.63 (DBC mechanism for CDMG STAs) and the CDMG AP or PCP clustering mechanism described in 10.63 (DBC mechanism for CDMG STAs). The format of the Dynamic Bandwidth Control element is shown in Figure 9-842 (Dynamic Bandwidth Control element format).

| | Element ID | Length | Element ID Extension | DBC Control | Channel Number | BI Offset | TBTT Offset | NP/BHI Duration | Adjacent NP/BHI Duration |
|---|---|---|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 7 | 1 | 4 | 4 | 2 | 2 |

**Figure 9-842—Dynamic Bandwidth Control element format**

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

The format of the DBC Control field is shown in Figure 9-843 (DBC Control field format).

| | B0 | B1 | B2 | B3 | B4 B5 | B6 B53 | B54 B55 |
|---|---|---|---|---|---|---|---|
| | Channel Splitting | DBC Option | AP or PCP Role | Adjacent Channel Occupancy | Clustering Status | Synchronizing AP or PCP MAC Address | Reserved |
| Bits: | 1 | 1 | 1 | 1 | 2 | 48 | 2 |

**Figure 9-843—DBC Control field format**

The Channel Splitting subfield is set to 0 to indicate that an AP or PCP operates on a 2.16 GHz channel and the following subfields are reserved. Otherwise, this subfield is set to 1 to indicate that an AP or PCP operates on a 1.08 GHz channel.

The DBC Option subfield indicates the DBC option that an AP or PCP selects to operate on a 1.08 GHz channel. It is set to 0 to indicate that beacon intervals or BHIs are present on the 1.08 GHz channel and otherwise set to 1.

The AP or PCP Role subfield is set to 0 to indicate that the transmitting AP or PCP operating on a 1.08 GHz channel can provide a time reference to the AP or PCP operating on the adjacent 1.08 GHz channel. Otherwise, this subfield is set to 1 to indicate that the transmitting AP or PCP scans for DMG Beacon frames transmitted from the AP or PCP operating on the adjacent 1.08 GHz channel to maintain synchronization among them following the rules defined in 10.63.2.3 (Synchronization of CDMG infrastructure BSS or PBSSs on the adjacent 1.08 GHz channels within a 2.16 GHz channel).

The Adjacent Channel Occupancy subfield is set to 0 to indicate that the adjacent 1.08 GHz channel of the transmitting AP or PCP is occupied by another AP or PCP. Otherwise, this subfield is set to 1.

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The Clustering Status subfield indicates the cluster status of the two 1.08 GHz channel within the same 2.16 GHz channel. The first/second bit is set to 0 to indicate that a cluster starts in the current/adjacent 1.08 GHz channel. Otherwise, the first/second bit of this field is set to 1.

The Synchronizing AP or PCP MAC Address subfield indicates the MAC address of the AP or PCP that provides the time reference for the transmitting AP or PCP. If the AP or PCP Role subfield is 0, this subfield is set to the MAC address of itself. Otherwise, this subfield is set to the MAC address of the AP or PCP operating on the adjacent 1.08 GHz channel.

The Channel Number field is set to the number of the channel on which the transmitting STA is operating.

The BI Offset field contains the time offset of the TBTT of the first beacon interval that the transmitting AP or PCP starts on a 1.08 GHz channel relative to the TBTT of the beacon interval that the transmitting AP or PCP starts on the 2.16 GHz channel encompassing this 1.08 GHz channel. This field is reserved if the DBC Option subfield is 1.

The TBTT Offset field contains the time offset of the target starting time of the NP/BHI on a 2.16 GHz channel of the transmitting AP or PCP operating on one of the 1.08 GHz channels relative to that of another AP or PCP operating on the adjacent 1.08 GHz channel.

The NP/BHI Duration field is set to the length of the NP/BHI(#8144) duration on a 2.16 GHz channel by the transmitting AP or PCP operating on one of the 1.08 GHz channels.

The Adjacent NP/BHI Duration field is set to the length of the NP/BHI(#8144) duration on a 2.16 GHz channel by the AP or PCP operating on the adjacent 1.08 GHz channel of the transmitting AP or PCP.

### 9.4.2.220 CDMG Extended Schedule element

The CDMG Extended Schedule element is defined in Figure 9-844 (CDMG Extended Schedule element format). Like the Extended Schedule element (9.4.2.130 (Extended Schedule element)), the AP or PCP can split the Allocation fields in the CDMG Extended Schedule element into more than one CDMG Extended Schedule element entry in the same DMG Beacon frame or Announce frame. Despite this splitting, the set of CDMG Extended Schedule element entries conveyed within a DMG Beacon or Announce frame is considered to be a single schedule for the beacon interval and, in this standard, is referred to simply as CDMG Extended Schedule element unless otherwise noted.

| | Element ID | Length | Element ID Extension | Allocation List |
|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | $n \times 19$ |

**Figure 9-844—CDMG Extended Schedule element format**

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

The Allocation List field contains one or more ($n$) Allocation fields. The Allocation fields are ordered by increasing allocation start time with allocations beginning at the same time arbitrarily ordered.

The Allocation field is defined in Figure 9-845 (Allocation field format).

The Allocation Control subfield format is the same as defined in 9.4.2.130 (Extended Schedule element), including Allocation ID, AllcationType, Pseudo-static, Truncatable, Extendable, PCP Active, and LP SC Used subfields and reserved bits.


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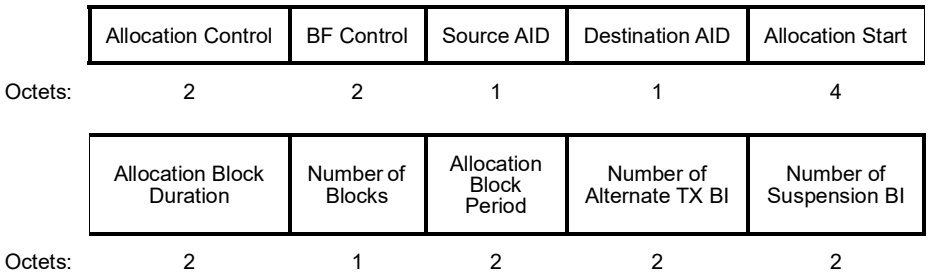


**Figure 9-845—Allocation field format**

The Allocation ID subfield is the same as defined in 9.4.2.130 (Extended Schedule element).

The AllocationType subfield defines the channel access mechanism during the allocation, with the possible values listed in Table 9-364 (AllocationType subfield values for CDMG STAs) for CDMG STAs:

**Table 9-364—AllocationType subfield values for CDMG STAs**

| Bit 4 | Bit 5 | Bit 6 | Meaning |
|---|---|---|---|
| 0 | 0 | 0 | SP allocation in dedicated channel |
| 1 | 0 | 0 | CBAP allocation in dedicated channel |
| 0 | 1 | 0 | SP allocation in alternative channel |
| 1 | 1 | 0 | CBAP allocation in alternative channel |
| All other combinations | | | Reserved |

The Pseudo-static, Truncatable, Extendable, PCP Active, and LP SC Used subfields are the same as defined in 9.4.2.130 (Extended Schedule element).

The BF Control subfield is defined in Figure 9-846 (BF Control field format when both IsInitiatorTXSS and IsResponderTXSS subfields are equal to 1 and the BF Control field is transmitted in Grant or Grant Ack frames) and Figure 9-847 (BF Control field format in all other cases).

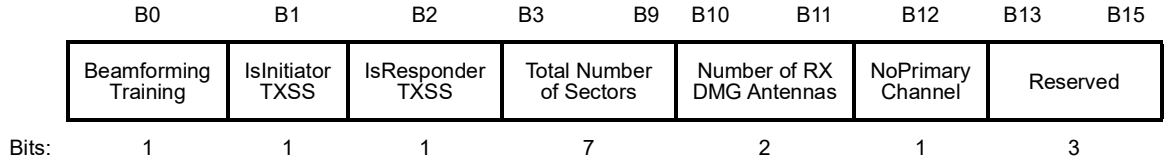


**Figure 9-846—BF Control field format when both IsInitiatorTXSS and IsResponderTXSS subfields are equal to 1 and the BF Control field is transmitted in Grant or Grant Ack frames**

The BeamformingTraining, IsInitiatorTXSS, IsResponderTXSS, Total Number of Sectors, Number of RX DMG Antennas, RXSS Length, RXSSTxRate subfields are the same as defined in 9.5.5 (Beamforming Control field).

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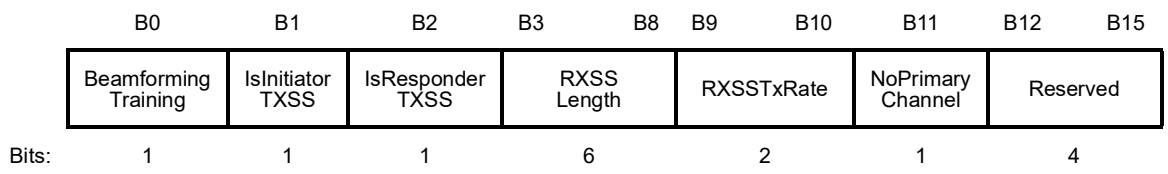


**Figure 9-847—BF Control field format in all other cases**

The NoPrimaryChannel subfield is set to 1 to indicate that the CDMG initiator does not need to perform SLS on the primary channel. It is set to 0 to indicate that the CDMG initiator needs to perform SLS on the primary channel. This subfield is reserved when it is transmitted by an AP or PCP.

The Source AID, Destination AID, Allocation Start, Allocation Block Duration, Number of Blocks, and Allocation Block Period subfields are the same as defined in 9.4.2.130 (Extended Schedule element).

The Number of Alternate TX BI subfield indicates the duration of transmission phase in the alternate channel in terms of number of beacon intervals.

The Number of Suspension BI subfield indicates the duration of the suspension phase in the alternate channel in terms of the number of beacon intervals.

### 9.4.2.221 SSW Report element

The SSW Report element is used by a non-AP and non-PCP CDMG STA to report beamforming training information to an CDMG AP or PCP (see 11.30.1 (General)) or used by a responder STA to deliver the backup sector information to an initiator STA. The SSW Report element is defined in Figure 9-848 (SSW Report element format).

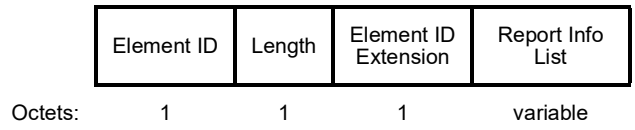


**Figure 9-848—SSW Report element format**

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

The Report Info List field contains one or more Report Info fields.

A Report Info field is formatted as defined in Figure 9-849 (Report Info field format when the SSW Report Control subfield is 1) when its SSW Report Control subfield is 1; otherwise, a Report Info field is formatted as defined in Figure 9-850 (Report Info field format when the SSW Report Control subfield is 0(#494)).

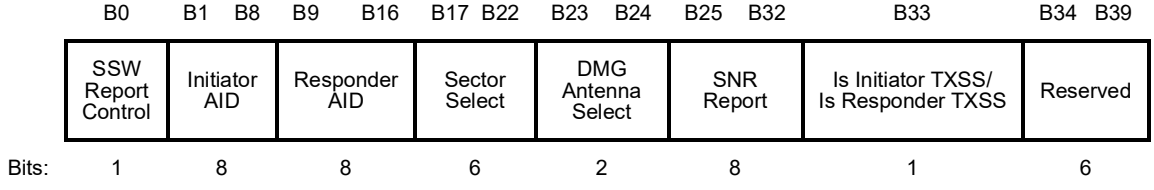


**Figure 9-849—Report Info field format when the SSW Report Control subfield is 1**


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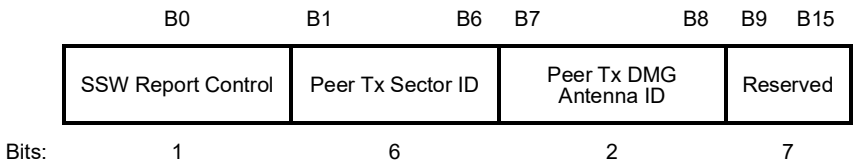


**Figure 9-850—Report Info field format when the SSW Report Control subfield is 0(#494)**

The SSW Report Control subfield indicates the format of the Report Info field.

The Initiator AID subfield identifies the STA that is the initiator of the beamforming training.

The Responder AID subfield identifies the STA that is the responder of the beamforming training.

The Sector Select subfield is defined in 9.5.3 (SSW Feedback field(#4303)).

The DMG Antenna Select subfield is defined in 9.5.3 (SSW Feedback field(#4303)).

The SNR Report subfield is defined in 9.5.3 (SSW Feedback field(#4303)).

The Is Initiator TXSS/Is Responder TXSS subfield is set to 1 to indicate that an initiator TXSS has been performed between the initiator and the responder. This subfield is set to 0 to indicate that a responder TXSS has been performed between the initiator and the responder.

If the SSW Report Control subfield is 0, the Peer Tx Sector ID(#494) subfield indicates the Sector ID of the alternative Tx sector of the peer STA. The determination of the alternative Tx sector is implementation dependent. Possible values of this subfield range from 0 to 63. Otherwise, the Peer Tx Sector ID(#494) subfield is reserved.

If the SSW Report Control subfield is 0, the Peer Tx DMG Antenna ID subfield indicates the alternative DMG antenna ID of the alternative Tx DMG antenna of the peer STA. The determination of the alternative Tx DMG antenna is implementation dependent. Otherwise, the Peer Tx DMG Antenna ID subfield is reserved.

### 9.4.2.222 Cluster Probe element

The Cluster Probe element is used to probe the presence of a CDMG AP or PCP cluster operating on the common 2.16 GHz channel by the CDMG AP or PCP operating on a 1.08 GHz channel. This element can be included in a DMG Beacon, Announce, or Probe Request frame. The Cluster Probe element is shown in Figure 9-851 (Cluster Probe element format).

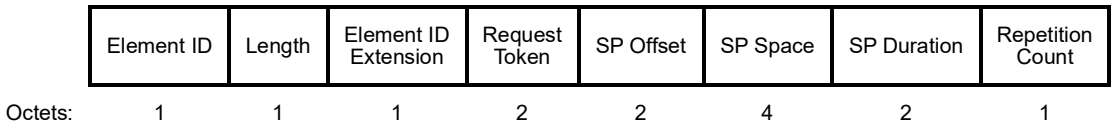


**Figure 9-851—Cluster Probe element format**

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The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

The Request Token field is set to a nonzero value chosen by the requesting AP or PCP.

The SP Offset field is set to the offset of the start of the first SP from the frame that contains this element, expressed in TUs. The reference time is the start of the preamble of the PPDU that contains this element.

The SP interval field is set to the spacing between the start of two consecutive SP intervals, expressed in TUs.

The SP Duration field is set to duration of a single SP, expressed in TUs.

The Repetition Count field is set to the number of requested SPs.

### 9.4.2.223 Extended Cluster Report element

The Extended Cluster Report element is used to report the cluster synchronization and control information to the cluster probe requesting CDMG AP or PCP by the S-AP or S-PCP of a CDMG AP or PCP cluster. (#111)The Extended Cluster Report element is also used by an S-AP to report the cluster information of the S-APs within the same CCSS for an AP or PCP. This element can be included in a DMG Beacon, Announce, or Probe Response frame transmitted by a CDMG AP or PCP. The Extended Cluster Report element is shown in Figure 9-852 (Extended Cluster Report element format).

| | Element ID | Length | Element ID Extension | Extended Cluster Report Control | Request Token | Next BTI Offset | Reported Clustering Control | Reported BI Duration | Cluster Channel Number | Available Cluster Offset Bitmap |
|---|---|---|---|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 1 | 0 or 2 | 4 | 8 | 0 or 2 | 0 or 1 | 0 or 4 |

**Figure 9-852—Extended Cluster Report element format**

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

If the Extended Cluster Report Control field is 0, this element is used in decentralized clustering mechanism, and the Reported BI Duration, Cluster Channel Number, and Available Cluster Offset Bitmap fields are not present in this element. Otherwise, this element is used in centralized clustering mechanism, and the Request Token field is not present in this element.

The Request Token field value is copied from the corresponding received Cluster Probe element.

The Next BTI Offset field contains the low order 4 octets of the TSF for the earliest time at which the next BTI in a subsequent beacon interval starts.

The Reported Clustering Control field is defined in 9.3.4.1 (Format of Extension frames) and contains the Clustering Control field in the last transmitted DMG Beacon frame of the S-AP or S-PCP or the reported S-AP.

The Reported BI Duration field is set to the beacon interval value of the reported S-AP, expressed in TUs.

The Cluster Channel Number field is set to the operating channel number of the reported S-AP.

The Available Cluster Time Offset Bitmap field is set to the Available Cluster Time Offset Bitmap field of the reported S-AP's ECAPC Policy element.


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### 9.4.2.224 Cluster Switch Announcement element

A CDMG AP or PCP transmits the Cluster Switch Announcement element to its original cluster before switching from a cluster to another. One of the synchronization pair APs or PCPs also transmits the Cluster Switch Announcement element to its peer CDMG AP or PCP before joining a cluster. The Cluster Switch Announcement element can be included in the DMG Beacon frame or Announce frame transmitted by a CDMG AP or PCP and received by other member CDMG APs or member CDMG PCPs. The format of the Cluster Switch Announcement element is shown in Figure 9-853 (Cluster Switch Announcement element format).

| | Element ID | Length | Element ID Extension | New Channel Number | Reference Timestamp | Reported Clustering Control | Reported BI Duration | Cluster Switch Count |
|---|---|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 2 | 2 | 4 | 2 | 1 |

**Figure 9-853—Cluster Switch Announcement element format**

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

The New Channel Number field is set to the operating channel number of the target cluster after cluster switching.

The Reference Timestamp field contains the lower 4 octets of the TSF timer value sampled at the instant that the STA's MAC received the DMG Beacon frame of the S-AP or S-PCP of the target cluster.

The Reported Clustering Control field contains the Clustering Control field included in the received DMG Beacon frame of the S-AP or S-PCP.

The Reported BI Duration field is set to the beacon interval value of the reported S-AP or S-PCP, expressed in TUs.

The Cluster Switch Count field either is set to the number of TBTTs until the AP or PCP sending the Cluster Switch Announcement element switches to the new cluster or is set to 0. This field is set to 1 to indicate that the switch occurs immediately before the next TBTT. It is set to 0 to indicate that the switch occurs at any time after the frame containing the element is transmitted.

### 9.4.2.225 Enhanced Beam Tracking element

The Enhanced Beam Tracking element is used to configure the alternative link of a CDMG STA, track the alternative link of the enhanced beam tracking initiator and responder, and switch to an alternative link from the current link. The element can be included in a BRP, DMG Beacon, Information Request, or Information Response frame transmitted by a CDMG STA.

The format of the Enhanced Beam Tracking element is shown in Figure 9-854 (Enhanced Beam Tracking element format).

| | Element ID | Length | Element ID Extension | E-BT Control | Peer Tx Antenna Parameter |
|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 1 | 1 |

**Figure 9-854—Enhanced Beam Tracking element format**

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The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.224 (Cluster Switch Announcement element).

The E-BT Control field is defined in Figure 9-855 (E-BT Control field format).

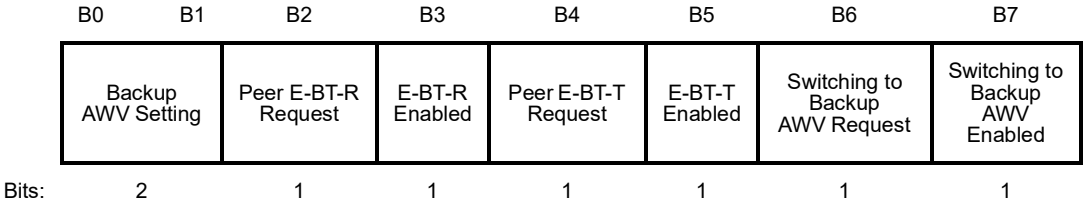


**Figure 9-855—E-BT Control field format**

The Backup AWV Setting subfield is used to set the alternative AWV of the peer STA. The default alternative AWV of the peer STA is set to omnidirectional. If the Backup AWV Setting subfield is 0, the peer STA does not update the alternative AWV. If the Backup AWV Setting subfield is 1, the peer STA set the alternative AWV according to the AWV specified by the Peer Tx Antenna Parameter field. If the Backup AWV Setting subfield is 2, the current received AWV of peer is used to update the alternative AWV; if the Backup AWV Setting subfield is 3, the last transmitted AWV of peer is used to update the alternative AWV.

The Peer E-BT-R Request subfield is set to 1 to indicate that the peer STA is requested to enable enhanced beam tracking to receive the e-TRN-R training sequences; otherwise, it is set to 0.

The E-BT-R Enabled subfield is set to 1 to indicate that the requested peer STA acknowledges that it has enabled enhanced receive beam tracking to receive the e-TRN-R training sequences; otherwise, it is set to 0.

The Peer E-BT-T Request subfield is set to 1 to indicate that the peer STA is requested to enable enhanced transmit beam tracking to transmit the e-TRN-T training sequences; otherwise, it is set to 0.

The E-BT-T Enabled subfield is set to 1 to indicate that the requested peer STA acknowledges that it has enabled enhanced transmit beam tracking to transmit the e-TRN-T training sequences; otherwise, it is set to 0.

The Switching to Backup AWV Request subfield is set to 1 to indicate that the peer STA is requested to switch to the alternative AWV; otherwise, it is set to 0.

The Switching to Backup AWV Enabled subfield is set to 1 to indicate that the requested STA acknowledges that its antenna setting is to be switched to the alternative AWV before the next frame and to set the AWV of the current link as the new alternative AWV; otherwise, it is set to 0.

The Peer TX Antenna Parameter field is defined in Figure 9-856 (Peer TX Antenna Parameter field format(#494)).

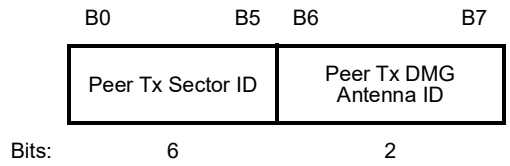


**Figure 9-856—Peer TX Antenna Parameter field format(#494)**


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If the Backup AWV Setting subfield is 1, the Peer Tx Sector ID(#494) field is set to the Sector ID of the alternative Tx AWV of the peer STA. Otherwise, the Peer Tx Sector ID(#494) field is reserved.

If the Backup AWV Setting subfield is 1, the Peer Tx DMG Antenna ID field indicates the DMG antenna ID of the alternative Tx AWV of the peer STA. Otherwise, the Peer Tx DMG Antenna ID field is reserved.

### 9.4.2.226 SPSH Report element

The SPSH Report element is used for an AP or PCP in a cluster to report the possibility of spatial sharing and coexistence between links in other BSSs and links in its own BSS. The SPSH Report element is transmitted in the DMG Beacon frame by a CDMG AP or PCP and is defined in Figure 9-857 (SPSH Report element format). Because the length parameter supports only 255 octets of payload in an element, the AP or PCP can split the SPSH List fields into more than one SPSH Report element entry in the same DMG Beacon or Announce frame.

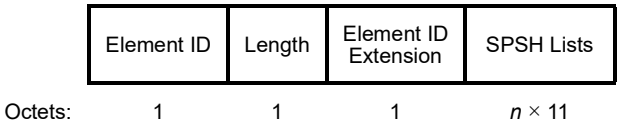


**Figure 9-857—SPSH Report element format**

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

The SPSH Lists field contains one or more (*n*) SPSH List fields.

The SPSH List field contains information of non-interfering links and is defined in Figure 9-858 (SPSH List field format).

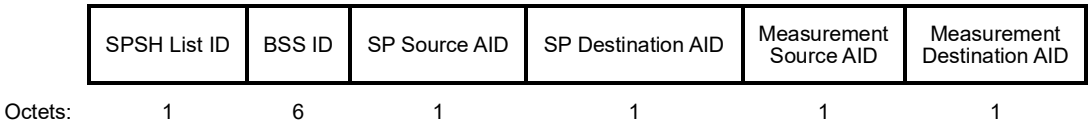


**Figure 9-858—SPSH List field format**

The SPSH List ID subfield indicates the identification of the SPSH List field, which is the same as the index of the corresponding field in the SPSH Report Element. It indicates that the channel measurement, between the two STAs indicated by the following Measurement Source AID subfield and the Measurement Destination AID subfield, shows no severe interference while the STA indicated by the SP Source AID subfield communicates with the STA indicated by the SP Destination AID subfield.

The BSS ID subfield indicates the identification of the measured infrastructure BSS or PBSS, which is the MAC address of the AP or PCP in the measured infrastructure BSS or PBSS.

The SP Source AID subfield indicates the AID of the transmitter STA of the link in the measured infrastructure BSS or PBSS.

The SP Destination AID subfield indicates the AID of the receiver STA of the link in the measured infrastructure BSS or PBSS. The SP Source AID and SP Destination AID subfields uniquely identify the link from the source AID STA to the destination AID STA in the BSS identified by the BSSID field.

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The Measuring Source AID subfield indicates the AID of the transmitter of the link that is conducting SPSH measurement in the measured infrastructure BSS or PBSS, and the measured link does not interfere with it.

The Measuring Destination AID subfield indicates the AID of the receiver of the link that is conducting SPSH measurement in the measured infrastructure BSS or PBSS, and the measured link does not interfere with it. The Measuring Source AID and Measuring Destination AID subfields uniquely identify the link from the measuring source AID STA to the measuring destination AID STA in the BSS.

### 9.4.2.227 Clustering Interference Assessment element

The S-AP or S-PCP in a CDMG AP or PCP cluster uses a Clustering Interference Assessment element to enable spatial sharing in the cluster and sets channel quality measurement and control parameters of spatial sharing for their member APs or member PCPs. The Clustering Interference Assessment element can be included in the DMG Beacon frames transmitted by the CDMG S-AP or S-PCP, as shown in Figure 9-859 (Clustering Interference Assessment element format).

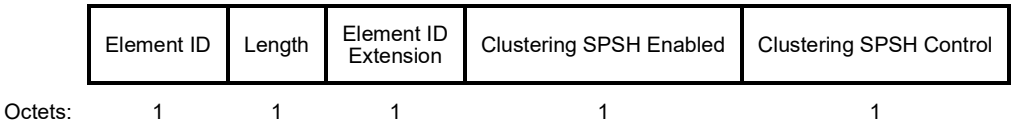


**Figure 9-859—Clustering Interference Assessment element format**

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

The Clustering SPSH Enabled field is set to 0 to indicate that a SPSH measurement phase starts. The Clustering SPSH Enabled field is set to 1 to indicate that the SPSH measurement phase for all member APs or member PCPs terminates and SP spatial sharing among BSSs starts. Other values are reserved. The Clustering SPSH Enabled field is set as the same as the SPSH Measurement Enabled subfield in the Clustering Control field defined in 9.3.4.2 (DMG Beacon).

The Clustering SPSH Control field is defined in Figure 9-860 (Clustering SPSH Control field format).

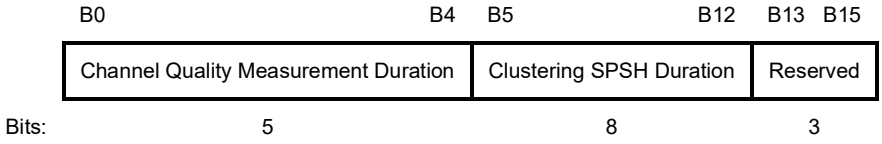


**Figure 9-860—Clustering SPSH Control field format**

The Channel Quality Measurement Duration subfield is set to a duration of directional channel quality measurement for all member APs or member PCPs in a CDMG AP or PCP cluster, in units of beacon intervals.

The Clustering SPSH Duration subfield is set to a duration of spatial sharing among BSSs for all member APs or member PCPs in a CDMG AP or PCP cluster, in units of beacon intervals.


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### 9.4.2.228 CMMG Capabilities element

#### 9.4.2.228.1 CMMG Capabilities element structure

The CMMG Capabilities element contains a number of fields that are used to advertise the CMMG capabilities of STA. The CMMG Capabilities element is defined in Figure 9-861 (CMMG Capabilities element format).

| | Element ID | Length | Element ID Extension | CMMG Capabilities Info | A-MPDU Parameters | Transmit Beamforming Capabilities | Supported CMMG-MCS and NSS Set | CMMG AP Or PCP Capability Information |
|---|---|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 6 | 1 | 4 | 8 | 2 |

**Figure 9-861—CMMG Capabilities element format**

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

#### 9.4.2.228.2 CMMG Capabilities Info field

The structure of the CMMG Capabilities Info field is defined in Figure 9-862 (CMMG Capabilities Info field format).

| B0 B1 | B2 | B3 | B4 B5 | B6 | B7 | B8 | B9 |
|---|---|---|---|---|---|---|---|
| Maximum MPDU Length | Supported Channel Width Set | Tx STBC | Rx STBC | Short GI for 540 MHz | Short GI for 1080 MHz | Supported MIMO | Heartbeat |
| Bits: 2 | 1 | 1 | 2 | 1 | 1 | 1 | 1 |

| B10 B11 | B12 | B13 | B14 | B15 | B16 | B17 | B18 B23 |
|---|---|---|---|---|---|---|---|
| TPC | Number of Sounding Dimensions CMMG | TXOP PS | Protected Block Ack | CMMG Link Adaptation Capable | Rx Antenna Pattern Consistency | Tx Antenna Pattern Consistency | Fast Link Adaptation |
| Bits: 2 | 1 | 1 | 1 | 1 | 1 | 1 | 6 |

| B24 B29 | B30 B31 | B32 | B33 B34 | B35 | B36 | B37 | B38 B44 |
|---|---|---|---|---|---|---|---|
| RXSS Length | Color | PSH and Interference Mitigation | Number of Rx Antennas | Supports Other_AID | RXSS Tx Rate Supported | Antenna Pattern Reciprocity | Total Number of Sectors |
| Bits: 6 | 2 | 1 | 2 | 1 | 1 | 1 | 7 |

| B45 B47 | B48 B50 | B51 | B52 B55 |
|---|---|---|---|
| Heartbeat Elapsed Indication | MCS Feedback | RD Responder | Reserved |
| Bits: 3 | 3 | 1 | 5 |

**Figure 9-862—CMMG Capabilities Info field format**

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The subfields of the CMMG Capabilities Info field are defined in Table 9-365 (Subfields of the CMMG Capabilities Info field).

**Table 9-365—Subfields of the CMMG Capabilities Info field**

| Subfield | Definition | Encoding |
|---|---|---|
| Maximum MPDU Length | Indicates the maximum MPDU length (see 10.12 (A-MPDU operation)). | Set to 0 for 3895 octets.<br>Set to 1 for 7991 octets.<br>Set to 2 for 11 454 octets.<br>The value 3 is reserved. |
| Supported Channel Width Set | Indicates the channel widths supported by the STA. See 11.47 (DCS procedure for CDMG BSS). | Set to 0 if the STA does not support 1080 MHz.<br>Set to 1 if the STA supports 1080 MHz. |
| Tx STBC | Indicates support for the transmission of at least 2x1 STBC. | Set to 0 if not supported.<br>Set to 1 if supported. |
| Rx STBC | Indicates support for the reception of PPDUs using STBC. | Set to 0 for no support.<br>Set to 1 for support of one spatial stream.<br>Set to 2 for support of one and two spatial streams.<br>The value 3 is reserved. |
| Short GI for 540 MHz | Indicates short GI support for the reception of PPDUs transmitted with the TXVECTOR parameter CH_BANDWIDTH set to (#7169)CBW540. | Set to 0 if not supported.<br>Set to 1 if supported. |
| Short GI for 1080 MHz | Indicates short GI support for the reception of PPDUs transmitted with the TXVECTOR parameter CH_BANDWIDTH set to (#7169)CBW1080. | Set to 0 if not supported.<br>Set to 1 if supported. |
| Supported MIMO | Indicates whether the STA supports MIMO. | The Supported MIMO field is set to 1 if the STA supports the SC and OFDM MIMO and is set to 0 otherwise. |
| Heartbeat | Indicate that whether the STA expects to receive a frame from the AP or PCP during the ATI and expects to receive a frame with the CMMG Control modulation from a source CMMG STA at the beginning of an SP or TXOP. | Set to 1 to indicate that the STA expects to receive a frame from the AP or PCP during the ATI and expects to receive a frame with the CMMG Control modulation from a source CMMG STA at the beginning of an SP or TXOP. Otherwise, this field is set to 0. |
| TPC | Indicates whether the STA supports TPC. | The TPC field is set to 1 if the STA supports the TPC as defined in 11.7 (TPC procedures) and is set to 0 otherwise. |
| Number of Sounding Dimensions | Beamformer's capability indicating the maximum value of the TXVECTOR parameter NUM_STS for a CMMG NDP. | If beamformer capable, set to the maximum supported value of the TXVECTOR parameter NUM_STS minus 1.<br>Otherwise, reserved. |


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**Table 9-365—Subfields of the CMMG Capabilities Info field *(continued)***

| Subfield | Definition | Encoding |
|---|---|---|
| TXOP PS | Indicates whether the AP supports CMMG TXOP power save mode or whether the non-AP STA has enabled CMMG TXOP power save mode. | Set to 0 if the AP does not support TXOP power save mode.<br>Set to 1 if the AP supports TXOP power save mode.<br>Set to 0 if the non-AP STA does not enable TXOP power save mode.<br>Set to 1 if the non-AP STA enables TXOP power save mode. |
| Protected Block Ack | Indicates support for protected block ack operation.<br>See 10.25.7 (Protected block ack agreement). | Set to 0 if not supported.<br>Set to 1 if supported.<br>Support indicates that the STA is able to accept an ADDBA request for protected block ack. |
| CMMG Link Adaptation Capable | Indicates whether the STA supports link adaptation using CMMG variant HT Control field. | Set to 0 (No Feedback) if the STA does not provide CMMG MFB.<br>Set to 2 (Unsolicited) if the STA provides only unsolicited CMMG MFB.<br>Set to 3 (Both) if the STA can provide CMMG MFB in response to CMMG MRQ and if the STA provides unsolicited CMMG MFB.<br>The value 1 is reserved. |
| Rx Antenna Pattern Consistency | Indicates the possibility of a receive antenna pattern change. | Set to 0 if the receive antenna pattern might change during the lifetime of the current association.<br>Set to 1 if the receive antenna pattern does not change during the lifetime of the current association.<br>See 11.48.6 (CMMG STAs antenna indication). |
| Tx Antenna Pattern Consistency | Indicates the possibility of a transmit antenna pattern change. | Set to 0 if the transmit antenna pattern might change during the lifetime of the current association.<br>Set to 1 if the transmit antenna pattern does not change during the lifetime of the current association.<br>See 11.48.6 (CMMG STAs antenna indication). |
| Fast Link Adaptation | Indicates whether the STA supports fast link adaptation. | The Fast Link Adaptation field is set to 1 to indicate that the STA supports the CMMG fast link adaptation procedure described in 10.43.3 (CMMG fast link adaptation). Otherwise, it is set to 0. |
| RXSS Length | Specifies the total number of receive sectors combined over all receive antennas of the STA. | The value represented by this field is in the range 2 to 128 and is given by (RXSS Length+1)×2. The maximum number of SSW frames transmitted during an RXSS is equal to the value of (RXSS Length+1)×2 times the total number of transmit antennas of the peer device. |
| Color | Indicates the value that is used for the TXVECTOR parameter COLOR in frames transmitted by members of this BSS, as described in 10.19 (Group ID and partial AID in VHT and CMMG PPDUs). | Set to an unsigned integer if sent by an AP.<br>Otherwise reserved. |
| SPSH and Interference Mitigation | Indicate whether the STA is capable of performing the function of SPSH and interference mitigation or not. | Set to 1 if the STA is capable of performing the function of SPSH and interference mitigation and if dot11RadioMeasurementActivated is true and is set to 0 otherwise (see 10.33 (Transmit beamforming)). |
| Number of Rx Antennas | Indicates the total number of receive antennas of the STA. | Set to the number of antennas minus 1. |

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**Table 9-365—Subfields of the CMMG Capabilities Info field *(continued)***

| Subfield | Definition | Encoding |
|---|---|---|
| Supports Other_AID | Indicate that the STA sets its AWV configuration according to the Other_AID subfield in the BRP Request field. | Set to 1 if the value of the Other_AID subfield is different from zero. Otherwise, this field is set to 0. |
| RXSSTxRate Supported | Indicate whether the STA can perform an RXSS with the SSW frames transmitted at MCS 1 of the CMMG SC modulation class or not. | Set to 1 to indicate that the STA can perform an RXSS with the SSW frames transmitted at MCS 1 of the CMMG SC modulation class. Otherwise, it is set to 0. |
| Antenna Pattern Reciprocity | Indicate whether the transmit antenna pattern associated with an AWV is the same as the receive antenna pattern for the same AWV or not. | Set to 1 to indicate that the transmit antenna pattern associated with an AWV is the same as the receive antenna pattern for the same AWV. Otherwise, this field is set to 0. |
| Total Number of Sectors | Indicates the total number of transmit sectors the STA uses in a transmit sector sweep combined over all antennas. | Set to the number of transmit sectors minus 1. |
| Heartbeat Elapsed Indication | Used to calculate the value of the heartbeat elapsed time. | The heartbeat elapsed time is computed according to the following equation:<br>$T_{HE} = \begin{cases} 0, F_{HE} = 0 \\ \frac{2^{F_{HE}}}{4}, F_{HE} > 0 \end{cases}$<br>where<br>$T_{HE}$ is the heartbeat elapsed time (in milliseconds);<br>$F_{HE}$ is the value of the Heartbeat Elapsed Indication subfield. |
| MCS Feedback | Indicates whether the STA can provide MFB. | Set to 0 (No Feedback) if the STA does not provide MFB.<br>Set to 2 (Unsolicited) if the STA provides only unsolicited MFB.<br>Set to 3 (Both) if the STA can provide MFB in response to MRQ (either Delayed or Immediate, see 10.31 (Link adaptation)) as well as unsolicited MFB<br>The value 1 is reserved. |
| RD Responder | Indicates support for acting as a reverse direction responder, i.e., the STA might use an offered RDG to transmit data to an RD initiator using the reverse direction protocol described in 10.27 (Protection mechanisms). | Set to 0 if not supported.<br>Set to 1 if supported. |
| NOTE—The value for the Maximum MPDU Length subfield in the CMMG Capabilities Info field imposes a constraint on the allowed value of the Maximum MPDU Length in the CMMG Capabilities Info field of the CMMG Capabilities element carried in the same frame (see 10.11 (A-MSDU operation)). | | |


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#### 9.4.2.228.3 A-MPDU Parameters field

The structure of the A-MPDU Parameters field of the CMMG Capabilities element is shown in Figure 9-863 (A-MPDU Parameters field format). The definition for the subfields of the A-MPDU Parameters field is shown in Table 9-366 (Subfields of the A-MPDU Parameters field).

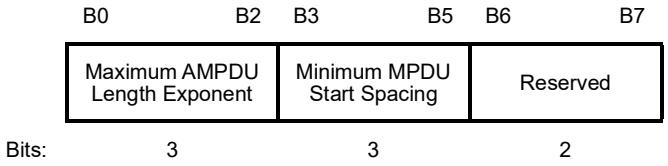


**Figure 9-863—A-MPDU Parameters field format**

**Table 9-366—Subfields of the A-MPDU Parameters field**

| Subfield | Definition | Encoding |
|---|---|---|
| Maximum AMPDU Length Exponent | Indicates the maximum length of A-MPDU that the STA can receive. EOF padding is not included in this limit. | The length defined by this field is equal to $2^{(13 + \text{Maximum AMPDU Lenght Exponent})}$ octets(#4363). |
| Minimum MPDU Start Spacing | Determines the minimum time between the start of adjacent MPDUs within an A-MPDU that the STA can receive, measured at the PHY SAP. See 9.7.3 (A-MPDU contents). | Set to 0 for no restriction.<br>Set to 1 for 16 ns.<br>Set to 2 for 32 ns.<br>Set to 3 for 64 ns.<br>Set to 4 for 128 ns.<br>Set to 5 for 256 ns.<br>Set to 6 for 512 ns.<br>Set to 7 for 1024 ns. |

#### 9.4.2.228.4 Supported CMMG-MCS and NSS Set field

The Supported CMMG-MCS and NSS Set field is used to convey the combinations of CMMG-MCSs and spatial streams that a STA supports for reception and the combinations that it supports for transmission. The structure of the field is shown in Figure 9-864 (Supported CMMG-MCS and NSS Set field format).

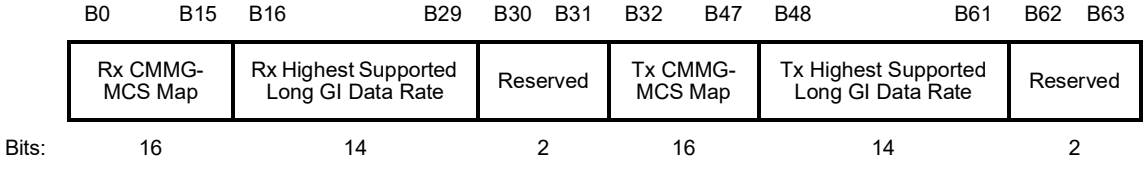


**Figure 9-864—Supported CMMG-MCS and NSS Set field format**

The Supported CMMG-MCS and NSS Set subfields are defined in Table 9-367 (Supported CMMG-MCS and NSS Set subfields).

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**Table 9-367—Supported CMMG-MCS and NSS Set subfields**

| Subfield | Definition | Encoding |
|---|---|---|
| Rx CMMG-MCS Map | Indicates the maximum value of the RXVECTOR parameter MCS of a PPDU that can be received at all channel widths supported by this STA for each number of spatial streams. | The format and encoding of this subfield are defined in Figure 9-865 (Rx CMMG-MCS Map and Tx CMMG-MCS Map subfields and Basic CMMG-MCS and NSS Set field format) and the associated description. |
| Rx Highest Supported Long GI Data Rate | Indicates the highest CMMG PPDU data rate that the STA is able to receive. | The largest integer value less than or equal to the highest CMMG PPDU data rate in Mb/s the STA is able to receive (see 10.6.15.1 (Rx supported CMMG-MCS and NSS set)).<br>The value 0 indicates that this subfield does not specify the highest CMMG PPDU data rate that the STA is able to receive. |
| Tx CMMG-MCS Map | Indicates the maximum value of the TXVECTOR parameter MCS of a PPDU that can be received at all channel widths supported by this STA for each number of spatial streams. | The format and encoding of this subfield are defined in Figure 9-865 (Rx CMMG-MCS Map and Tx CMMG-MCS Map subfields and Basic CMMG-MCS and NSS Set field format) and the associated description. |
| Tx Highest Supported Long GI Data Rate | Indicates the highest CMMG PPDU data rate at which the STA is able to transmit. | The largest integer value less than or equal to the highest CMMG PPDU data rate in Mb/s the STA is able to receive/transmit (see 10.6.15.2 (Tx supported CMMG-MCS and NSS set)).<br>The value 0 indicates that this subfield does not specify the highest CMMG PPDU data rate that the STA is able to receive transmit. |

The Rx CMMG-MCS Map subfield and the Tx CMMG-MCS Map subfield have the structure shown in Figure 9-865 (Rx CMMG-MCS Map and Tx CMMG-MCS Map subfields and Basic CMMG-MCS and NSS Set field format).

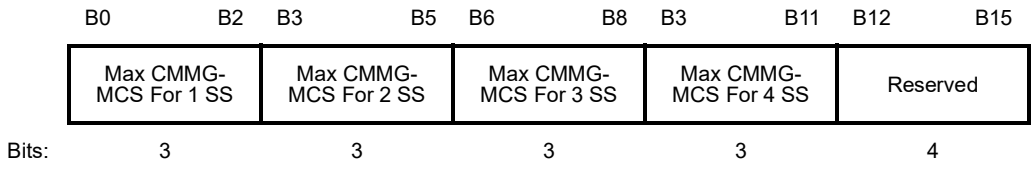


**Figure 9-865—Rx CMMG-MCS Map and Tx CMMG-MCS Map subfields and Basic CMMG-MCS and NSS Set field format**

The Max CMMG-MCS For *n* SS subfield (where *n* = 1, 2, 3, 4) is encoded as follows:

— 0 indicates support for SC CMMG-MCSs 1 to 5 or OFDM CMMG-MCSs 9 to 13 for *n* spatial streams
— 1 indicates support for SC CMMG-MCSs 1 to 6 or OFDM CMMG-MCSs 9 to 14 for *n* spatial streams
— 2 indicates support for SC CMMG-MCSs 1 to 7 or OFDM CMMG-MCSs 9 to 15 for *n* spatial streams
— 3 indicates support for SC CMMG-MCSs 1 to 8 or OFDM CMMG-MCSs 9 to 16 for *n* spatial streams
— 4–7 indicate that *n* spatial streams are not supported


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#### 9.4.2.228.5 Transmit Beamforming Capabilities field

The structure of the Transmit Beamforming Capabilities field is defined in Figure 9-866 (Transmit Beamforming Capabilities field format).

| B0 | B1 | B2 | B3 | B4 | B5 B7 |
|---|---|---|---|---|---|
| Receive Staggered Sounding Capable | Transmit Staggered Sounding Capable | Receive NDP Capable | Transmit NDP Capable | Explicit Compressed Steering Capable | Explicit Compressed Beamforming Feedback Capable |
| Bits: 1 | 1 | 1 | 1 | 1 | 3 |

| B8 B9 | B10 B11 | B12 B13 | B14 B15 | B16 B17 | B18 B23 |
|---|---|---|---|---|---|
| Minimal Grouping | CSI Number of Beamformer Antennas Supported | Compressed Steering Number of Beamformer Antennas Supported | CSI Max Number of Rows Beamformer Supported | CSI Max Number of Rows Beamformer Supported | Reserved |
| Bits: 2 | 2 | 2 | 2 | 2 | 6 |

**Figure 9-866—Transmit Beamforming Capabilities field format**

The subfields of the Transmit Beamforming Capabilities field are defined in Table 9-368 (Subfields of the Transmit Beamforming Capabilities field).

**Table 9-368—Subfields of the Transmit Beamforming Capabilities field**

| Subfield | Definition | Encoding |
|---|---|---|
| Receive Staggered Sounding Capable | Indicates whether this STA can receive staggered sounding frames. | Set to 0 if not supported.<br>Set to 1 if supported. |
| Transmit Staggered Sounding Capable | Indicates whether this STA can transmit staggered sounding frames. | Set to 0 if not supported.<br>Set to 1 if supported. |
| Receive NDP Capable | Indicates whether this receiver can interpret null data PPDUs as sounding frames. | Set to 0 if not supported.<br>Set to 1 if supported. |
| Transmit NDP Capable | Indicates whether this STA can transmit null data PPDUs as sounding frames. | Set to 0 if not supported.<br>Set to 1 if supported. |
| Explicit Compressed Steering Capable | Indicates whether this STA can apply transmit beamforming using compressed beamforming feedback matrix explicit feedback in its transmission. | Set to 0 if not supported.<br>Set to 1 if supported. |
| Explicit Compressed Beamforming Feedback Capable | Indicates whether this receiver can return compressed beamforming feedback matrix explicit feedback. | Set to 0 if not supported.<br>Set to 1 for delayed feedback.<br>Set to 2 for immediate feedback.<br>Set to 3 for delayed and immediate feedback. |

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**Table 9-368—Subfields of the Transmit Beamforming Capabilities field *(continued)***

| Subfield | Definition | Encoding |
|---|---|---|
| Minimal Grouping | Indicates the minimal grouping used for explicit feedback reports. | Set to 0 if the STA supports groups of 1 (no grouping).<br>Set to 1 indicates groups of 1, 2.<br>Set to 2 indicates groups of 1, 4.<br>Set to 3 indicates groups of 1, 2, 4.<br>Set to 4 indicates groups of 1, 6.<br>Set to 5 indicates groups of 1, 2, 6.<br>Set to 6 indicates groups of 1, 4, 6.<br>Set to 7 indicates groups of 1, 2, 4, 6. |
| CSI Number of Beamformer Antennas Supported | Indicates the maximum number of beamformer antennas the CMMG beamformee can support when CSI feedback is required. | Set to 0 for single Tx antenna sounding.<br>Set to 1 for 2 Tx antenna sounding.<br>Set to 2 for 3 Tx antenna sounding.<br>Set to 3 for 4 Tx antenna sounding. |
| Compressed Steering Number of Beamformer Antennas Supported | Indicates the maximum number of beamformer antennas the beamformee can support when compressed beamforming feedback matrix is required. | Set to 0 for single Tx antenna sounding.<br>Set to 1 for 2 Tx antenna sounding.<br>Set to 2 for 3 Tx antenna sounding.<br>Set to 3 for 4 Tx antenna sounding. |
| CSI Max Number of Rows Beamformer Supported | Indicates the maximum number of rows of CSI explicit feedback from the CMMG beamformee that a CMMG beamformer can support when CSI feedback is required. | Set to 0 for a single row of CSI.<br>Set to 1 for 2 rows of CSI.<br>Set to 2 for 3 rows of CSI.<br>Set to 3 for 4 rows of CSI. |
| Channel Estimation Capability | Indicates the maximum number of space-time streams (columns of the MIMO channel matrix) for which channel dimensions can be simultaneously estimated when receiving an NDP sounding PPDU or the extension portion of the MCTFs in a staggered sounding PPDU. | Set 0 for 1 space-time stream.<br>Set 1 for 2 space-time streams.<br>Set 2 for 3 space-time streams.<br>Set 3 for 4 space-time streams. |
| NOTE—The maximum number of space-time streams for which channel coefficients can be simultaneously estimated using the MCTFs corresponding to the data portion of the packet is limited by the Rx MCS Bitmask subfield of the Supported MCS Set field and by the Rx STBC subfield of the CMMG Capabilities Info field. Both fields are part of the CMMG Capabilities element. | | |

### 9.4.2.228.6 CMMG AP Or PCP Capability Information field

The CMMG AP Or PCP Capability Information field, defined in Figure 9-867 (CMMG AP Or PCP Capability Information field format), represents the capabilities, when the transmitting STA performs in the role of AP or PCP, that are in addition to the capabilities in the CMMG Capabilities Info field.

The TDDTI (time division data transfer interval) subfield is set to 1 if the STA, while operating as an AP or PCP, is capable of providing channel access as defined in 10.38.6 (Channel access in scheduled DTI) and 11.4 (TS operation) and is set to 0 otherwise.

The Pseudo-static Allocations subfield is set to 1 if the STA, while operating as an AP or PCP, is capable of providing pseudo-static allocations as defined in 10.38.6.4 (Pseudo-static allocations) and is set to 0 otherwise. The Pseudo-static Allocations subfield is set to 1 only if the TDDTI subfield in the CMMG AP Or PCP Capability Information field is equal to 1. The Pseudo-static Allocations subfield is reserved if the TDDTI subfield in the CMMG AP Or PCP Capability Information field is equal to 0.


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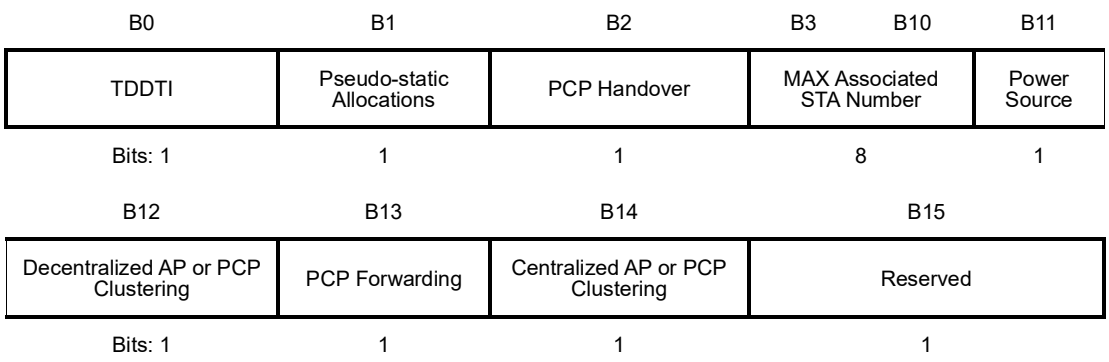


**Figure 9-867—CMMG AP Or PCP Capability Information field format**

The PCP Handover field is set to 1 if the STA, while operating as a PCP, is capable of performing a PCP handover as defined in 11.29.2 (Moving the TBTT) and is set to 0 if the STA does not support PCP handover.

The MAX Associated STA Number field indicates the maximum number of STAs that the STA can perform association with if operating as an AP or PCP. The value of this field includes the STAs, if any, that are (#2210)colocated with the AP or PCP.

The Power Source field is set to 0 if the STA is battery powered and is set to 1 otherwise.

The Decentralized AP or PCP Clustering field is set to 1 if the STA, when operating as an AP or PCP, is capable of performing decentralized AP or PCP clustering and is set to 0 otherwise.

The PCP Forwarding field is set to 1 if the STA, while operating as a PCP, is capable of forwarding frames it receives from a non-PCP STA and destined to another non-PCP STA in the PBSS. This field is set to 0 otherwise.

The Centralized AP or PCP Clustering field is set to 1 if the STA, when operating as an AP or PCP, is capable of performing centralized AP or PCP clustering and is set to 0 otherwise. An AP or PCP that is incapable of performing centralized AP or PCP clustering is subject to requirements as described in 10.39.2.2 (Centralized AP or PCP cluster formation).

### 9.4.2.229 CMMG Operation element

The operation of CMMG STAs in the BSS is controlled by the CMMG Operation element. The format of the CMMG Operation element is defined in Figure 9-868 (CMMG Operation element format).

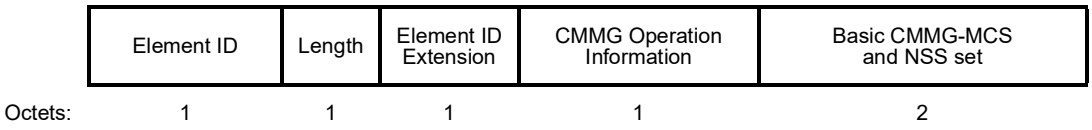


**Figure 9-868—CMMG Operation element format**

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

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The structure of the CMMG Operation Information field is defined in Figure 9-869 (CMMG Operation Information field format).

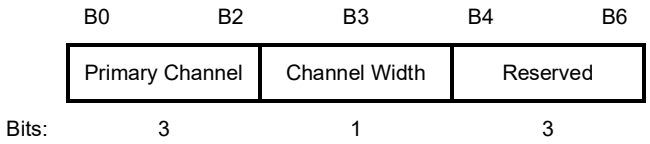


**Figure 9-869—CMMG Operation Information field format**

The subfields of the CMMG Operation Information field are defined in Table 9-369 (CMMG Operation Information field format).

**Table 9-369—CMMG Operation Information field format**

| Subfield | Definition | Encoding |
|---|---|---|
| Primary Channel | Indicates the channel number of the primary channel; see 25.10 (Channelization). | Channel number of the primary channel. |
| Channel Width | This field defines the BSS operating channel width. | Set to 0 for 540 MHz operating channel width.<br>Set to 1 for 1080 MHz operating channel width. |

The Basic CMMG-MCS and NSS Set field indicates the CMMG-MCSs for each number of spatial streams in CMMG PPDUs that are supported by all CMMG STAs in the BSS (including IBSS and MBSS). The Basic CMMG-MCS and NSS Set field is a bitmap of size 2 bits. The Basic CMMG-MCS and NSS Set field is defined in Figure 9-865 (Rx CMMG-MCS Map and Tx CMMG-MCS Map subfields and Basic CMMG-MCS and NSS Set field format).

### 9.4.2.230 CMMG Operating Mode Notification element

The CMMG Operating Mode Notification element is used to notify STAs that the transmitting STA is changing its operating channel width, the maximum number of spatial streams it can receive, or both. The format of the CMMG Operating Mode Notification element is defined in Figure 9-870 (CMMG Operating Mode Notification element format).

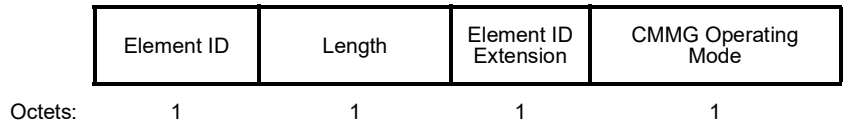


**Figure 9-870—CMMG Operating Mode Notification element format**

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

The CMMG Operating Mode field is defined in 9.4.1.61 (CMMG Operating Mode field).


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### 9.4.2.231 CMMG Link Margin element

#### 9.4.2.231.1 General

The format of the CMMG Link Margin element is shown in Figure 9-871 (CMMG Link Margin element format). The CMMG Link Margin element is included in a Link Measurement Report frame.

| | Element | Length | Element ID Extension | Activity | MCS | Link Margin | SNR | Reference Timestamp |
|---|---|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 4 |

**Figure 9-871—CMMG Link Margin element format**

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

The Activity field is set to a preferred action that the STA sending this element recommends that the peer STA indicated in the RA field of the Link Measurement Report frame execute. The method by which the sending STA determines a suitable action for the peer STA is implementation specific. The Activity field is defined in 9.4.2.231.2 (Activity field).

The MCS field is set to an MCS value that the STA sending this element recommends that the peer STA indicated in the RA field of the Link Measurement Report frame use to transmit frames to this STA. The reference PER for selection of the MCS is for an MPDU length of 4096 octets. The method by which the sending STA determines a suitable MCS for the peer STA is implementation specific. The Link Margin field contains the measured link margin of the Data frames received from the peer STA indicated in the RA field of the Link Measurement Report frame and is coded as a 2s complement signed integer in units of decibels. Setting the field to –128 indicates that no link margin is provided. The measurement method of link margin is beyond the scope of this standard.

The SNR field indicates the SNR measured during the reception of a PPDU. Values are from –13 dB to 50.75 dB in 0.25 dB steps.

The Reference Timestamp field contains the lower 4 octets of the TSF timer value sampled at the instant that the MAC received the PHY-CCA.indication(IDLE) primitive(#4122) that corresponds to the end of the reception of the PPDU that was used to generate the feedback information contained in the Link Measurement Report frame.

#### 9.4.2.231.2 Activity field

The Activity field values are defined in Table 9-370 (Activity field values).

**Table 9-370—Activity field values**

| Preferred Action value | Meaning |
|---|---|
| 0 | No change preferred |
| 1 | Change(d) MCS |
| 2 | Decrease(d) transmit power |
| 3 | Increase(d) transmit power |

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**Table 9-370—Activity field values *(continued)***

| Preferred Action value | Meaning |
|---|---|
| 4 | Fast session transfer (FST) |
| 5 | Power conserve mode |
| 6 | Perform SLS |
| 7–255 | Reserved |

### 9.4.2.232 CMMG Link Adaptation Acknowledgment element

The format of the CMMG Link Adaptation Acknowledgment element is shown in Figure 9-872 (CMMG Link Adaptation Acknowledgment element format). The CMMG Link Adaptation Acknowledgment element is carried in the Optional Subelements field of the Link Measurement Report frame.

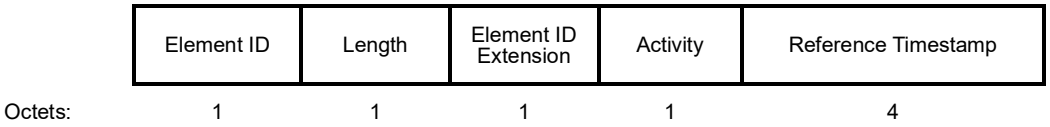


**Figure 9-872—CMMG Link Adaptation Acknowledgment element format**

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

The Activity field is set to the action that the STA sending this element has executed following the reception of the recommended activity in a Link Measurement Report frame. The method by which the sending STA determines the action is described in 10.31 (Link adaptation), and the Activity field is defined in 9.4.2.231.2 (Activity field).

The Reference Timestamp field contains the lower 4 octets of the TSF timer value sampled at the instant that the MAC received the PHY-CCA.indication(IDLE) primitive(#4122) that corresponds to the end of the reception of the PPDU that was used to generate the feedback information contained in the Link Measurement Report frame.

### 9.4.2.233 GLK-GCR Parameter Set element

The GLK-GCR Parameter Set element is included in an Association Request or a Reassociation Request frame transmitted by a non-AP STA to indicate its buffering capability to support GLK-GCR. The GLK-GCR Parameter Set element is included in the corresponding Association Response or Reassociation Response frame transmitted by an AP to define the parameters that are used when the GLK AP transmits (#1653)group addressed frames using GLK-GCR to the associated GLK non-AP STAs. Figure 9-873 (GLK-GCR Parameter Set element format) shows the fields that make up the GLK-GCR Parameter Set element.

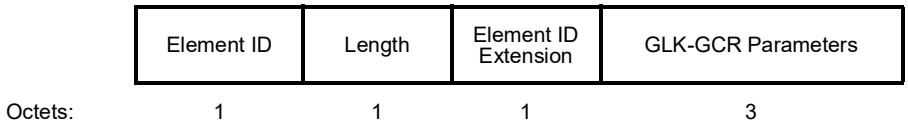


**Figure 9-873—GLK-GCR Parameter Set element format**


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The GLK-GCR Parameters field is shown in Figure 9-874 (GLK-GCR Parameters field format).

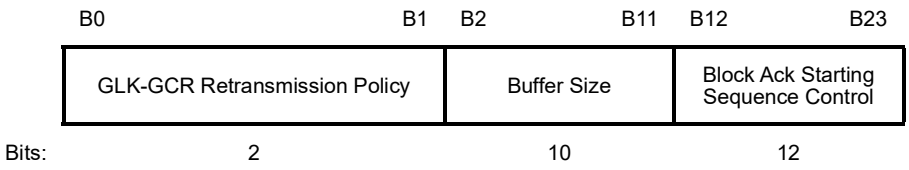


**Figure 9-874—GLK-GCR Parameters field format**

The GLK-GCR Retransmission Policy subfield is described in Table 9-371 (GLK-GCR Retransmission Policy subfield). This subfield is reserved when the corresponding GLK-GCR Parameters Set element is part of an Association Request or a Reassociation Request frame.

**Table 9-371—GLK-GCR Retransmission Policy subfield**

| B0 | B1 | Description of the corresponding GLK-GCR mode |
|---|---|---|
| 0 | 0 | Reserved |
| 0 | 1 | GLK-GCR not operational |
| 1 | 0 | Operating in GLK-GCR unsolicited retry mode |
| 1 | 1 | Operating in GLK-GCR block ack mode |

The Buffer Size subfield indicates the maximum number of buffers in the GLK-GCR block ack block. Each buffer is capable of holding a number of octets equal to the maximum size of an A-MSDU that is supported by the STA.

In an Association Request or a Reassociation Request frame, the Buffer Size subfield in a GLK-GCR Parameter Set element is intended to provide guidance for the recipient to decide its reordering buffer size. If the transmitter has no guidance for the receivers reordering buffer size it sets the Buffer Size subfield to 0.

In an Association Response or Reassociation Response frame, the Buffer Size subfield in a GLK-GCR Parameters field in the GLK-GCR Parameter Set element is set to a value greater than or equal to 1, if the GLK-GCR retransmission policy indicates GLK-GCR block ack mode. Otherwise this subfield is reserved.

The Block Ack Starting Sequence Control subfield indicates the sequence number of the first MSDU or A-MSDU for this GLK-GCR block ack agreement, and is defined in 9.3.1.8 (BlockAck frame format). This subfield is reserved when the corresponding GLK-GCR Parameters Set element is part of an Association Request or Reassociation Request frame.

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### 9.4.2.234 Estimated Service Parameters Outbound element

The Estimated Service Parameters Outbound element is used by a STA to provide information to another STA that can then use the information as input to an algorithm to generate an estimate of outbound throughput between the two STAs.

The format of the Estimated Service Parameters Outbound element is shown in Figure 9-875 (Estimated Service Parameters Outbound element format).

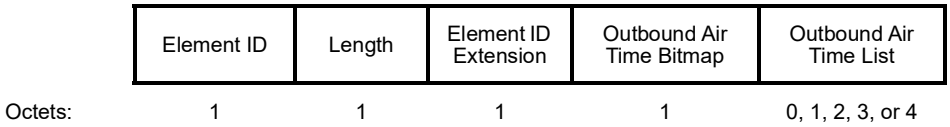


**Figure 9-875—Estimated Service Parameters Outbound element format**

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

The Outbound Air Time Bitmap field contains a bitmap indicating the presence or absence of an Outbound Air Time Information field for each of the four EDCA Access Categories. The format of the Outbound Air Time Bitmap field is shown in Figure 9-876 (Outbound Air Time Bitmap field format).

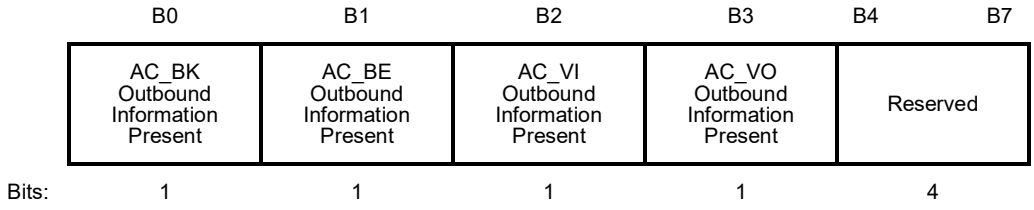


**Figure 9-876—Outbound Air Time Bitmap field format**

The Outbound Air Time List field contains from 0 to 4 Outbound Air Time Information fields, each corresponding to an access category for which estimated air time information for outbound traffic is provided. The Outbound Air Time Information field with the lowest numbered bits of the Outbound Air Time List field contains the outbound information corresponding to the AC of the lowest numbered bit of the Outbound Air Time Bitmap field that has a value of 1. The next Outbound Air Time Information field, if present, corresponds to the next higher numbered Outbound Air Time Bitmap field bit that has a value of 1, and so forth. If no Outbound Air Time Bitmap field bit has the value of 1, then no Outbound Air Time Information field is present. The format of the Outbound Air Time Information field is shown in Figure 9-877 (Outbound Air Time Information field format).

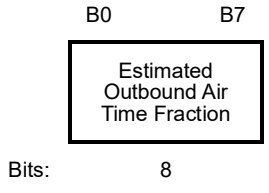


**Figure 9-877—Outbound Air Time Information field format**

The Estimated Outbound Air Time Fraction subfield of the Outbound Air Time Information field contains an unsigned integer that represents the predicted percentage of time, linearly scaled with 255 representing 100% and 0 representing 0%, that a new STA joining the BSS can expect to be available for the transmission of PPDUs by that STA, including overhead, where such PPDUs contain MPDUs with the Type subfield

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equal to Data that belong to the access category corresponding to the position of the Outbound Air Time Information field in the Outbound Air Time Bitmap field and any other MPDUs in the PPDU are considered to be overhead. A new STA joining the BSS might have a different view of the medium than the STA transmitting the Estimated Outbound Air Time Fraction, e.g. due to hidden nodes. In such cases, the new STA might experience a different actual outbound airtime fraction than that advertised in the element.

### 9.4.2.235 OCI element

The format of the OCI element is shown in Figure 9-878 (OCI element format).

| | Element ID | Length | Element ID Extension | Operating Class | Primary Channel Number | Frequency Segment 1 Channel Number | OCT Operating Class (optional) | OCT Primary Channel Number (optional) | OCT Frequency Segment 1 Channel Number (optional) |
|---|---|---|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 1 | 1 | 1 | 0 or 1 | 0 or 1 | 0 or 1 |

**Figure 9-878—OCI element format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The Operating Class field is set to the global operating class that corresponds to the widest bandwidth currently being used by the transmitting STA. See Annex E, Table E-4 (Global operating classes) for description of the global operating classes.

The Primary Channel Number field is set to the primary channel being used currently. The Primary Channel Number field is one of the channels from the row corresponding to the operating class as defined in Annex E or the primary 20 MHz (sub)channel allowed for HT or non-HT operation for operating classes that specify only channel center frequency indices.

(#3136)The Frequency Segment 1 Channel Number field is set to the channel number of the center frequency(#6420) of the secondary segment (frequency segment 1) being used currently, if operating in an 80+80 MHz operating class or set to 0 otherwise. The value of the Frequency Segment 1 Channel Number field is one of the center frequency indices from the row corresponding to the operating class as defined in Annex E(#3333), or 0 if not operating in an 80+80 MHz operating class.

(#4380)(#4393)The OCT Operating Class, OCT Primary Channel Number and OCT Frequency Segment 1 fields are present if the OCI element is contained in a frame sent using the OCT procedure, i.e. an MMPDU included in an MLME-OCTunnel.request or MLME-OCTunnel.response primitive (see 11.31.5 (On-channel Tunneling (OCT) operation)); otherwise they are not present. They have the same definition as the Operating Class, Primary Channel Number and Frequency Segment 1 fields, except that they pertain to the channel used by the STAs corresponding to the TR-MLMEs to transmit and receive PPDUs containing On-channel Tunnel Request frames.


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### 9.4.2.236 Service Hint element

The Service Hint element provides a probabilistic representation of a set of services that are available to the BSS. The format of the Service Hint element is shown in Figure 9-879 (Service Hint element format).

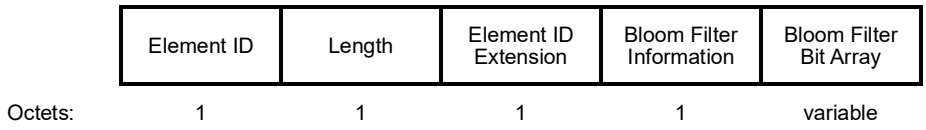


**Figure 9-879—Service Hint element format**

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

The Bloom Filter Information field represents the stochastic characteristics of a Bloom filter (Tarkoma et al. [B68]) that conveys the probabilistic data. The format of the Bloom Filter Information field is shown in Figure 9-880 (Bloom Filter Information field format).

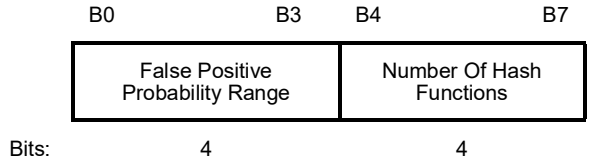


**Figure 9-880—Bloom Filter Information field format**

The False Positive Probability Range subfield represents the false positive probability range of the Bloom filter. The False Positive Probability Range subfield is shown in Table 9-372 (False Positive Probability Range subfield values).

**Table 9-372—False Positive Probability Range subfield values**

| Value | False positive probability range, $p$ |
|---|---|
| 0 | $p > 25\%$ |
| 1 | $20\% < p \leq 25\%$ |
| 2 | $15\% < p \leq 20\%$ |
| 3 | $10\% < p \leq 15\%$ |
| 4 | $5\% < p \leq 10\%$ |
| 5 | $1\% < p \leq 5\%$ |
| 6 | $0.5\% < p \leq 1\%$ |
| 7 | $0.1\% < p \leq 0.5\%$ |
| 8 | $0.05\% < p \leq 0.1\%$ |
| 9 | $0.01\% < p \leq 0.05\%$ |
| 10 | $p \leq 0.01\%$ |
| 11–15 | Reserved |

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The Number Of Hash Functions subfield is set to a value equal to $k$-1, where $k$ is the number of hash functions used by the Bloom filter as described in 11.23.5 (Bloom filter hash function operation).

The Bloom Filter Bit Array field provides an indication of the services offered by or through the AP or PCP with a target probability of false positive $p$. The length of the Bloom Filter Bit Array field in octets is $\lceil m/8 \rceil$ where $m$ is the size of the Bloom filter in bits. How the size of the Bloom filter is determined is out of the scope of this standard. The maximum length of the Bloom Filter Bit Array field is 128 octets.

### 9.4.2.237 Service Hash element

The Service Hash element contains one or more service hashes. The format of the Service Hash element is shown in Figure 9-881 (Service Hash element format).

| | Element ID | Length | Element ID Extension | Service Hashes |
|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | variable |

**Figure 9-881—Service Hash element format**

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

The Service Hashes field contains one or more 6-octet service hash values. See 11.23.4 (Service hash procedure) for procedures for generating a service hash used in the Service Hash element.

### 9.4.2.238 GAS Extension element

The GAS Extension element is defined in 9-882 (GAS Extension element format(#6058)). When present in the GAS Initial Request frame, the GAS Extension element indicates whether the STA is capable of:(#6058)

- Transmitting and receiving group addressed GAS frames
- Retransmitting a GAS query request or GAS query response fragment
- Indicating the size of the GAS query request or GAS query response in octets
- Establishing a maximum time to wait for a response to a GAS query request.

| | Element ID | Length | Element ID Extension | GAS Flags | Maximum Channel Time | Fragment ID | Number of Response Map Duples | Response Map Duples | GAS Query Size |
|---|---|---|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 0 or 1 | 0 or 1 | 0 or 1 | 0 or 1 | variable | 0 or 2 |

**Figure 9-882—GAS Extension element format(#6058)**

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

The GAS Flags field is defined in Figure 9-883 (GAS Flags field format(#6058)).

| | B0 | B1 | B2 | B3 | B4 | B5 | B6 B7 |
|---|---|---|---|---|---|---|---|
| | Group Addressed(#1293) GAS | Fragment Retransmission | Maximum Channel Time Flag | Fragment ID Flag | Response Map Flag | GAS Query Size Flag | Reserved |
| Bits: | 1 | 1 | 1 | 1 | 1 | 1 | 2 |

**Figure 9-883—GAS Flags field format(#6058)**



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The (#1293)Group Addressed GAS subfield is set to 1 to indicate that the STA is capable of receiving Group Addressed GAS Request and Group Addressed GAS Response frames and is set to 0 otherwise.

The Fragment Retransmission subfield, when present in a GAS Initial Request or GAS Initial Response frame, is set to 1 to indicate that the responding STA is capable of retransmitting a Query Request or Query Response fragment upon request and is set to 0 otherwise.(#6058)

The Maximum Channel Time Flag subfield is set to 1 to indicate that the Maximum Channel Time field is present in the element and is set to 0 otherwise.

The Fragment ID Flag subfield is set to 1 to indicate that Fragment ID field is present in the element and is set to 0 otherwise.

The Response Map Flag subfield is set to 1 to indicate that the Number of Response Map Duples field and the Response Map Duples field are present in the element and is set to 0 otherwise.

The GAS Query Size Flag subfield is set to 1 to indicate that the GAS Query Size field is present in the element and is set to 0 otherwise.(#6058)

The Maximum Channel Time field indicates the maximum duration the STA will, or needs to, remain on the channel to receive a GAS Initial Response, a GAS Comeback Response, or Group Addressed GAS Response frame(#6058), expressed as a multiple of 10 TUs beginning from the end of the PPDU carrying this element. The field has a valid range of 1–255.

The Fragment ID field, when present in the GAS Comeback Request Fragment or the GAS Comeback Response frames, indicates the fragment the STA is requesting. If it is present in the GAS Initial Request frame, it indicates that the GAS query request will be transmitted using GAS Comeback Request Fragment and GAS Comeback Response frames that support GAS fragmentation. It is present only when the Fragment ID Flag subfield is set to 1 in the GAS Flags field.(#6058)

The Number of Response Map Duples field indicates the number of Response Map Duple subfields contained in the Response Map Duples field. It is present only when the Response Map Flag subfield is set to 1 in the GAS Flags field. When present, the Number of Response Map Duples field is set to a nonzero value and the value of zero is reserved.

The Response Map Duples field is present only when the Number of Response Map Duples field is present and contains a nonzero value. The Response Map Duples field, when present, contains one or more Response Map Duple subfields as indicated by the Number of Response Map Duples field. The format of the Response Map Duple subfield is shown in Figure 9-884 (Response Map Duple subfield format). The Response Map Duples field is included in a Group Addressed GAS Response frame.

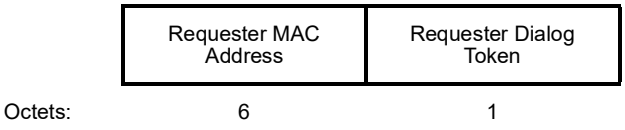


**Figure 9-884—Response Map Duple subfield format**

The Response Map Duple subfield contains a Requester MAC Address subfield and a Requester Dialog Token subfield. An AP or PCP includes one or more Response Map Duple subfields in a Group Addressed GAS Response frame.

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The GAS Query Size subfield contains the size of the GAS query request or GAS query response in octets.(#6058)

### 9.4.2.239 Non-Inheritance element

The Non-Inheritance element when present in the Nontransmitted BSSID Profile subelement of a Multiple BSSID element identifies one or more elements that are not inherited by the BSS corresponding to the nontransmitted BSSID profile that carried it. The identified elements are present in the Management frame of the transmitted BSSID that carried the Multiple BSSID element.

The format of the Non-Inheritance element is shown in Figure 9-885 (Non-Inheritance element format).

| | Element ID | Length | Element ID extension | List Of Element IDs | List of Element ID Extensions |
|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 1 or more | 1 or more |

**Figure 9-885—Non-Inheritance element format**

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

The format of the List Of Element IDs field is shown in Figure 9-886 (List Of Element IDs field format). The Length subfield of the List of Element IDs field is set to the number of elements listed in the Element ID List subfield. If the Element ID List subfield is not present, the Length subfield is set to 0. The Element ID List subfield consists of a list of Element ID values, each one octet in length. Element ID subfield values(M118) are in increasing order and no value occurs more than once. The List Of Element IDs field does not list elements that contain an Element ID Extension field (see 9.4.2.1 (General)).

| | Length | Element ID List |
|---|---|---|
| Octets: | 1 | 0 or more |

**Figure 9-886—List Of Element IDs field format**

The format of the List Of Element ID Extensions field is shown in Figure 9-887 (List Of Element ID Extensions field format). The Length subfield of the List Of Element ID Extensions field is set to the number of elements listed in the Element ID Extension List subfield. If the Element ID Extension List subfield is not present, the Length subfield is set to 0. The Element ID Extension List subfield consists of a list of Element ID Extension values, each one octet in length. Element ID Extension subfield values(M118) are in increasing order and no value occurs more than once. The List of Element ID Extensions field lists only elements that have (M118)an element ID value of 255 (see 9.4.2.1 (General)).

| | Length | Element ID Extension List |
|---|---|---|
| Octets: | 1 | 0 or more |

**Figure 9-887—List Of Element ID Extensions field format**

### 9.4.2.240 RSNXE(#1776)

(#1776)The RSN extension element (RSNXE) contains additional information required to establish an RSNA. The format of the RSNXE is defined in Figure 9-888 (RSNXE format).


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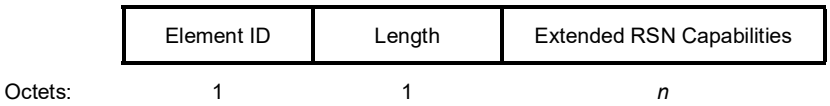


**Figure 9-888—RSNXE format**

The Element ID and Length fields are defined in 9.4.2.1 (General).

The Extended RSN Capabilities field, except its first 4 bits, is a set of 1-bit fields(#291) indicating the extended RSN capabilities being advertised by the STA transmitting the element. The length of the Extended RSN Capabilities field is a variable *n*, in octets, as indicated by the first 4 bits in the field. The Extended RSN Capabilities field is shown in Table 9-373 (Extended RSN Capabilities field).

**Table 9-373—Extended RSN Capabilities field**

| Bit | Information | Notes |
|---|---|---|
| 0–3 | Field length | The length of the Extended RSN Capabilities field, in octets, minus 1, i.e., $n - 1$. |
| 4 | Protected TWT Operations Support | (#3220)A STA sets the Protected TWT Operations Support field to 1 when dot11ProtectedTWTOperationsImplemented is true, and sets it to 0 otherwise. See 10.46.1 (TWT overview). |
| 5 | SAE Hash-to-element(#3178) | (#3220)A STA sets the (#4310)SAE Hash-to-element field to 1 when it supports the hash-to-element method to obtain the PWE instead of looping, and sets it to 0 otherwise.(#3168) See 12.4.4.2.3 (Hash-to-element(#331) generation of the password element with ECC groups) and 12.4.4.3.3 (Direct generation of the password element with FFC groups).<br><br>NOTE —If SAE is not negotiated, this field is ignored by the receiver.(#3223) |
| 6(M34) | | (#4220)*Allocated to the Wi-Fi Alliance* [a]. |
| 7(11ba) | Protected WUR Frame Support | (#3220)A STA sets the Protected WUR Frame Support field to 1 when dot11RSNAWURFrameProtectionActivated is true, and sets it to 0 otherwise. |
| 8(11az) | Secure HE-LTF Support | A STA sets the Secure HE-LTF Support field to 1 when dot11SecureLTFImplemented is true. Otherwise, the STA sets the Secure HE-LTF Support field to 0. See 11.21.6.4.5 (Secure HE-LTF in the TB and non-TB ranging measurement exchange protocol(11az)). |
| 9(11az) | Secure RTT Support(#7222) | A STA sets the Secure RTT Support(#7222) field to 1 if it supports Secure RTT Measurement exchange as defined in 11.21.6.4.2.7 (DMG secure measurement exchange for EDMG STAs(11az)). Otherwise, the field is set to 0. |
| 10(11az) | URNM-MFPR-X20 | A STA sets the URNM-MFPR-X20 field to 1 if dot11RSTARequiresPMFActivated is set to 1. Otherwise, it sets the field to 0. See 11.21.6.3.1 (General) and Annex C.3. |
| 11(11ay)(M34) | Protected Announce Support | (#3220)A non-EDMG STA sets the Protected Announce Support field to 1 when dot11ProtectedAnnounceImplemented is true, and sets it to 0 otherwise. See 12.6.18 (Robust management frame selection procedure). |

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**Table 9-373—Extended RSN Capabilities field**

| Bit | Information | Notes |
|---|---|---|
| 12 (#1002) | PBAC | A STA sets the PBAC field to indicate it can establish a protected block ack agreement and sets it to 0 otherwise. |
| 13 (#1276) | Extended S1G Action Protection | (#3220)A STA sets the Extended S1G Action Protection field to 1 when dot11ExtendedS1GActionProtectionOperationsImplemented is true and sets it to 0 otherwise. |
| 14 (M57) | SPP A-MSDU Capable(#8104) | A non-DMG STA sets the SPP A-MSDU Capable field(#3167)(#8104) to 1 if dot11SPPAMSDUCapable is true. Otherwise, this field(#3167) is set to 0. See 10.11 (A-MSDU operation). |
| 15(11az) | URNM-MFPR | A STA sets the URNM-MFPR field to 1 if dot11RSTARequiresPMFActivated is set to 2. Otherwise, it sets the field to 0. See 11.21.6.3.1 (General). |
| 21 (M166) | SSID Protection | A STA sets this field to 1 to indicate support for protected exchange of the SSID during the 4-way handshake. Otherwise, it sets the field to 0. |
| 22 (#7028) | QMF ACI Subfield Unmask Support | A STA sets the QMF ACI Subfield Unmask Support to 1 if the STA supports to unmask ACI subfield during AAD construction. Otherwise, this subfield is set to 0. |
| (M34)16–19, 20, 23–(8×*n* – 1) | Reserved | |

[a] See http://www.wi-fi.org.

If a STA does not support (#470)any of the capabilities defined in the RSNXE, then the RSNXE is not present.

### 9.4.2.241 TCLAS Mask element

The TCLAS Mask element contains a set of parameters necessary to classify incoming MSDUs into streams based on a classifier mask. The structure of this element is shown in Figure 9-889 (TCLAS Mask element format).

| | Element ID | Length | Element ID Extension | Frame Classifier |
|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | variable |

**Figure 9-889—TCLAS Mask element format**

The Element ID, Length and Element ID Extension fields are defined in 9.4.2.1 (General).

The Frame Classifier field specifies the parameters that are used to classify incoming MSDUs into streams. The field is defined in 9.4.2.29 (TCLAS element) (see Figure 9-383 (Frame Classifier field format)), except that, in the Classifier Parameters subfield, all subfields other than the following (if present) are reserved:

— Filter Offset subfield
— Filter Mask subfield(s) (including MAC header(#3182) filters in Match Specification subfields)
— Protocol Number or Next Header subfield


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### 9.4.2.242 MSCS Descriptor element

The MSCS Descriptor element defines information about the parameters used to classify streams using the procedures defined in 11.25.3 (MSCS procedures). The format of the MSCS Descriptor element is shown in Figure 9-890 (MSCS Descriptor element format).

| | Element ID | Length | Element ID Extension | Request Type | User Priority Control | Stream Timeout | TCLAS Mask Elements (Optional) | Optional subelements |
|---|---|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 1 | 2 | 4 | variable | variable |

**Figure 9-890—MSCS Descriptor element format**

The Element ID, Length and Element ID Extension fields are defined in 9.4.2.1 (General).

The Request Type field is defined in 9.4.2.120 (SCS Descriptor element).

The User Priority Control field is shown in Figure 9-891 (User Priority Control field format). This field is reserved when the Request Type field is "Remove", when the element is present in a (Re)Association Response frame with a value of "SUCCESS" in the Data field of the MSCS Status subelement, or when the element is present in a (Re)Association Response frame with a value other than "SUCCESS" in the Data field of the MSCS Status subelement and a value of "Add" in the Request Type field.

| | B0 B7 | B8 B10 | B11 B15 |
|---|---|---|---|
| | User Priority Bitmap | User Priority Limit | Reserved |
| Bits: | 8 | 3 | 5 |

**Figure 9-891—User Priority Control field format**

Each bit in the User Priority Bitmap subfield corresponds to a user priority (UP), with the least significant bit corresponding to UP value of 0, and the most significant bit corresponding to UP value of 7. A value of 1 in a bit position in the bitmap indicates that the corresponding UP is used when assigning a UP to streams classified by MSCS; a value of 0 in a bit position indicates that the corresponding UP is not used for this purpose.

The User Priority Limit subfield has a value between 0 and 7; it defines the maximum limit for the UP that is assigned to incoming MSDUs in the streams classified by MSCS.

The Stream Timeout subfield indicates the minimum timeout value, in TUs, for maintaining a variable *UP{tuple}* in the MSCS list. This subfield is reserved when the Request Type field is "Remove", when the element is present in a (Re)Association Response frame with a value of "SUCCESS" in the Data field of the MSCS Status subelement, or when the element is present in a (Re)Association Response frame with a value other than "SUCCESS" in the Data field of the MSCS Status subelement and a value of "Add" in the Request Type field.

The TCLAS Mask Elements field contains zero or more TCLAS Mask elements to specify how incoming MSDUs are classified into streams in MSCS, as defined in 9.4.2.241 (TCLAS Mask element). One or more TCLAS Mask elements are present when the Request Type field is "Add" or "Change"; no TCLAS Mask elements are present when the Request Type field is "Remove", when the element is present in a (Re)Association Response frame with a value of "SUCCESS" in the Data field of the MSCS Status subelement, or when the element is present in a (Re)Association Response frame with a value other than

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"SUCCESS" in the Data field of the MSCS Status subelement and a value of "Add" in the Request Type field.

The Optional Subelements field contains zero or more subelements. The subelement format and ordering of subelements are defined in 9.4.3 (Subelements). The subelements allowed in the MSCS Descriptor element are defined in Table 9-374 (Optional subelement IDs for MSCS Descriptor element).

**Table 9-374—Optional subelement IDs for MSCS Descriptor element**

| Subelement ID | Name | Extensible |
|---|---|---|
| 0 | Reserved | |
| 1 | MSCS Status | No |
| 2–220 | Reserved | |
| 221 | Vendor Specific | Vendor defined |
| 222–255 | Reserved | |

The MSCS Status subelement Data field has the same format as the Status Code field shown in Figure 9-147 (Status Code field format) and contains the status of the requested MSCS setup, as indicated in Table 9-80 (Status codes).

The use of the MSCS Descriptor element is described in 11.25.3 (MSCS procedures).

### 9.4.2.243 Supplemental Class 2 Capabilities element

The Supplemental Class 2 Capabilities element contains a number of fields that advertise supported rates of a Class 2 ERP or Class 2 HT STA. The Supplemental Class 2 Capabilities element is defined in Figure 9-892 (Supplemental Class 2 Capabilities element format).

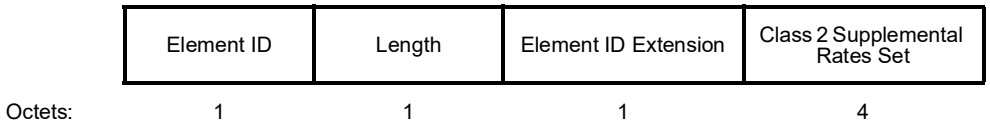


**Figure 9-892—Supplemental Class 2 Capabilities element format**

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

The format of the Class 2 Supplemental Rates Set field is defined in Figure 9-893 (Class 2 Supplemental Rates Set field format).

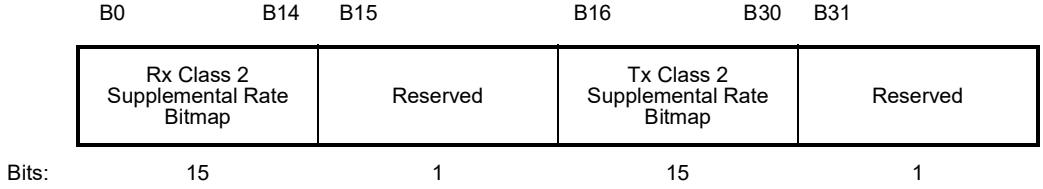


**Figure 9-893—Class 2 Supplemental Rates Set field format**

The Rx Class 2 Supplemental Rate Bitmap field is encoded as follows:


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a) (#465)B0–B1 represent support for receiving 1, 2 Mb/s (DSSS), respectively;
b) (#465)B2–B3 represent support for receiving 5.5, 11 Mb/s (HR/DSSS), respectively;
c) (#465)B4–B6 represent support for receiving 6, 12, 24 Mb/s (ERP-OFDM), respectively;
d) (#465)B7–B14 represent support for receiving 6.5, 13, 19.5, 26, 39, 52, 58.5, 65 Mb/s $N_{SS} = 1$ (HT), respectively.

The Tx Class 2 Supplemental Rate Bitmap field is encoded as follows:

a) (#465)B16–B17 represent support for transmitting 1, 2 Mb/s (DSSS), respectively;
b) (#465)B18–B19 represent support for transmitting 5.5, 11 Mb/s (HR/DSSS), respectively;
c) (#465)B20–B22 represent support for transmitting 6, 12, 24 Mb/s (ERP-OFDM), respectively;
d) (#465)B23–B30 represent support for transmitting 6.5, 13, 19.5, 26, 39, 52, 58.5, 65 Mb/s $N_{SS} = 1$ (HT), respectively.

### 9.4.2.244 OCT Source element

The OCT Source element is used to specify the MLME that is the source of an OCT MMPDU. The format of the OCT Source element is shown in Figure 9-894 (OCT Source element format).

| | Element ID | Length | Element ID Extension | Band ID | Channel Number | BSSID |
|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 1 | 1 | 6 |

**Figure 9-894—OCT Source element format**

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

The Band ID field identifies the band on which the source MLME operates, as defined in Table 9-97 (Band ID field).

The Channel Number field contains the channel number on which the source MLME operates.

The BSSID field contains the BSSID of the BSS in which the source MLME operates.

### 9.4.2.245 Rejected Groups element

The Rejected Groups element lists the finite cyclic groups, using the octet ordering conventions of 9.2.2 (Conventions), that have been rejected by a peer for use in SAE. The format of the Rejected Groups element is shown in Figure 9-895 (Rejected Groups element format).

| | Element ID | Length | Element ID Extension | Rejected Groups |
|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | variable |

**Figure 9-895—Rejected Groups element format**

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

The Rejected Groups field contains (#1592)one or more Finite Cyclic Group fields indicating all of the finite cyclic groups that have been rejected by a peer in a previous authentication attempt during the current SAE authentication instance.

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### 9.4.2.246 Anti-Clogging Token Container element

The Anti-Clogging Token Container element is used to carry an Anti-Clogging Token field in contexts where an information element is needed. The format of an Anti-Clogging Token Container element is shown in Figure 9-896 (Anti-Clogging Token Container element format).

| | Element ID | Length | Element ID Extension | Anti-Clogging Token |
|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | variable |

**Figure 9-896—Anti-Clogging Token Container element format**

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

The Anti-Clogging Token field is defined in 9.4.1.36 (Anti-Clogging Token field).

### 9.4.2.247 HE Capabilities element(11ax)

#### 9.4.2.247.1 General

An HE STA declares that it is an HE STA by transmitting the HE Capabilities element.

The HE Capabilities element contains a number of fields that are used to advertise the HE capabilities of an HE STA. The HE Capabilities element is defined in Figure 9-897 (HE Capabilities element format(11ax)).

| | Element ID | Length | Element ID Extension | HE MAC Capabilities Information | HE PHY Capabilities Information | Supported HE-MCS And NSS Set | PPE Thresholds (optional) |
|---|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 6 | 11 | 4, 8 or 12 | variable |

**Figure 9-897—HE Capabilities element format(11ax)**

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

The HE MAC Capabilities Information, HE PHY Capabilities Information, Supported HE-MCS And NSS Set, and PPE Thresholds fields are defined in the subclauses below.

#### 9.4.2.247.2 HE MAC Capabilities Information field

The format of the HE MAC Capabilities Information field is defined in Figure 9-898 (HE MAC Capabilities Information field format(11ax)).

| | B0 | B1 | B2 | B3 | B4 | B5 | B7 | B8 | B9 | B10 | B11 | B12 | B14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | +HTC HE Support | TWT Requester Support | TWT Responder Support | Dynamic Fragmentation Support | | Maximum Number Of Fragmented MSDUs/ A-MSDUs Exponent | | Minimum Fragment Size | | Trigger Frame MAC Padding Duration | | Multi-TID Aggregation Rx Support | |
| Bits: | 1 | 1 | 1 | 2 | | 3 | | 2 | | 2 | | 3 | |



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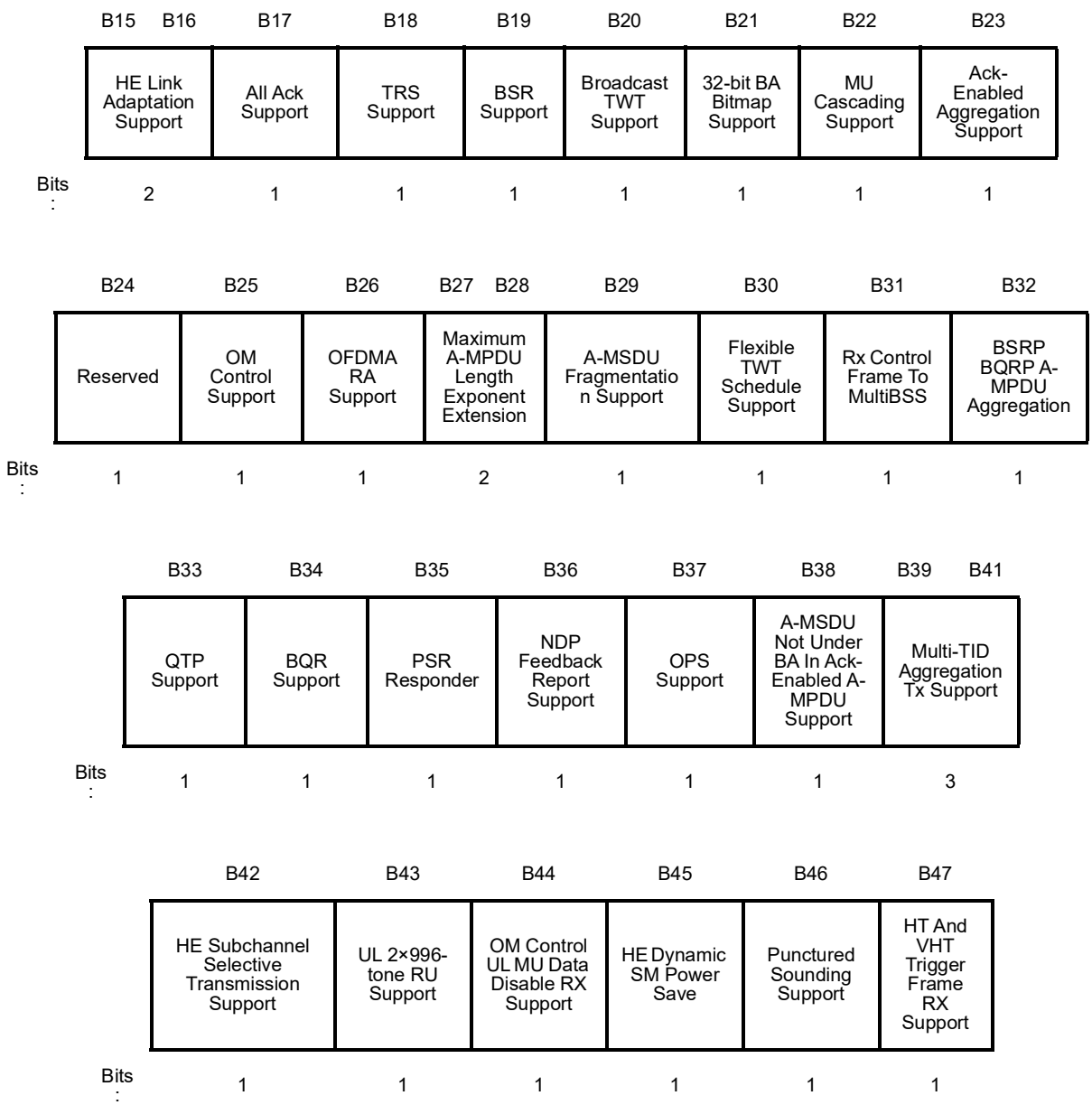


**Figure 9-898—HE MAC Capabilities Information field format(11ax)**

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The subfields of the HE MAC Capabilities Information field are defined in Table 9-375 (Subfields of the HE MAC Capabilities Information field(11ax)).

**Table 9-375—Subfields of the HE MAC Capabilities Information field(11ax)**

| Subfield | Definition | Encoding |
|---|---|---|
| +HTC-HE Support | Indicates support for the reception of a frame that carries an HE variant HT Control field. | For a non-AP STA:<br>Set to 1 if the STA supports reception of an HE variant HT Control field based on the description in 10.8 (HT Control field operation).<br>Set to 0 otherwise.<br><br>An AP sets the +HTC-HE Support subfield to 1. |
| TWT Requester Support | Indicates support for the role of TWT requesting STA as described in 26.8 (TWT operation). | Set to 1 if dot11TWTOptionActivated is true and the STA supports TWT requesting STA functionality (see 26.8 (TWT operation)).<br>Set to 0 otherwise. |
| TWT Responder Support | Indicates support for the role of TWT responder STA as described in 26.8 (TWT operation). | Set to 1 if dot11TWTOptionActivated is true and the STA supports TWT responder STA functionality (see 26.8 (TWT operation)).<br>Set to 0 otherwise.<br><br>An AP sets the TWT Responder Support subfield to 1. |
| Dynamic Fragmentation Support | Indicates the level of dynamic fragmentation that is supported by a STA as a recipient. | Set to 0 if the STA does not support dynamic fragmentation.<br>Set to 1 if the STA supports level 1 dynamic fragmentation (see 26.3.1 (General)).<br>Set to 2 if the STA supports level 2 dynamic fragmentation (see 26.3.1 (General)).<br>Set to 3 if the STA supports level 3 dynamic fragmentation (see 26.3.1 (General)). |
| Maximum Number Of Fragmented MSDUs/A-MSDUs Exponent | Indicates the maximum number of fragmented MSDUs and/or A-MSDUs (if supported by the recipient) that the STA is capable of receiving concurrently. | If the Dynamic Fragmentation Support subfield is greater than 0:<br>The maximum number of fragmented MSDUs and/or A-MSDUs, $N_{max}$, defined by this field is $N_{max} = 2^{\text{Maximum Number Of Fragmented MSDUs/A-MSDUs Exponent}}$, except that a value 7 in the Maximum Number Of Fragmented MSDUs/A-MSDUs Exponent subfield indicates that there is no restriction.<br><br>Reserved if the Dynamic Fragmentation Support subfield is 0. |


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**Table 9-375—Subfields of the HE MAC Capabilities Information field(11ax) *(continued)***

| Subfield | Definition | Encoding |
|---|---|---|
| Minimum Fragment Size | Indicates the minimum frame body size in octets of the first fragment of an MSDU, A-MSDU (if supported), or MMPDU that is supported by the recipient STA. | If the Dynamic Fragmentation Support subfield is greater than 0:<br>Set to 0 to indicate no minimum frame body size.<br>Set to 1 to indicate a minimum frame body size of 128 octets.<br>Set to 2 to indicate a minimum frame body size of 256 octets.<br>Set to 3 to indicate a minimum frame body size of 512 octets.<br><br>Reserved if the Dynamic Fragmentation Support subfield is 0. |
| Trigger Frame MAC Padding Duration | Indicates *MinTrigProcTime*, which is used in 26.5.2.2.3 (Padding for a triggering frame). | For a non-AP STA:<br>Set to 0 to indicate 0.<br>Set to 1 to indicate 8 μs.<br>Set to 2 to indicate 16 μs.<br>The value 3 is reserved.<br><br>Reserved for an AP. |
| Multi-TID Aggregation Rx Support | Indicates the number of TIDs of QoS Data frames that an HE STA can receive in a multi-TID A-MPDU as described in 26.6.3 (Multi-TID A-MPDU and ack-enabled single-TID A-MPDU). | Set to the number of TIDs minus 1 of QoS Data frames that an HE STA can receive in a multi-TID A-MPDU. |
| Multi-TID Aggregation Tx Support | Indicates the number of TIDs of QoS Data frames that an HE STA can transmit in a multi-TID A-MPDU as described in 26.6.3 (Multi-TID A-MPDU and ack-enabled single-TID A-MPDU). | Set to the number of TIDs minus 1 of QoS Data frames that an HE STA can transmit in a multi-TID A-MPDU. |
| HE Link Adaptation Support | Indicates support for link adaptation using the HLA Control subfield. | If the +HTC-HE Support subfield is 1:<br>Set to 0 (No Feedback) if the STA does not provide HE MFB.<br>Set to 2 (Unsolicited) if the STA can receive and provide only unsolicited HE MFB.<br>Set to 3 (Solicited and unsolicited) if the STA is capable of receiving and providing HE MFB in response to HE MRQ and if the STA can receive and provide unsolicited HE MFB.<br>The value 1 is reserved.<br><br>HE MFB and HE MRQ are MFB and MRQ using HLA Control subfield, respectively.<br><br>Reserved if the +HTC-HE Support subfield is 0. |
| All Ack Support | Indicates support for the reception of a Multi-STA BlockAck frame under the all ack context (see 26.4.2 (Acknowledgment context in a Multi-STA BlockAck frame)) | Set to 1 if supported.<br>Set to 0 otherwise. |

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**Table 9-375—Subfields of the HE MAC Capabilities Information field(11ax) *(continued)***

| Subfield | Definition | Encoding |
|---|---|---|
| TRS Support | For a non-AP STA, indicates support for receiving a frame with a TRS Control subfield. | For a non-AP STA that has set the +HTC-HE Support subfield to 1:<br>Set to 1 if the STA supports reception of the TRS Control subfield.<br>Set to 0 otherwise.<br><br>Reserved for an AP or if the +HTC-HE Support subfield is 0. |
| BSR Support | For an AP, indicates support for receiving a frame with a BSR Control subfield. For a non-AP STA, indicates support for generating a frame with a BSR Control subfield. | If the +HTC-HE Support subfield is 1:<br>Set to 1 if the STA supports the BSR Control subfield functionality.<br>Set to 0 otherwise.<br>Reserved if the +HTC-HE Support subfield is 0. |
| Broadcast TWT Support | For a non-AP STA, indicates support for the role of TWT scheduled STA. For an AP indicates support for the role of TWT scheduling AP as described in 26.8.3 (Broadcast TWT operation). | Set to 1 if the STA supports broadcast TWT functionality.<br>Set to 0 otherwise. |
| 32-bit BA Bitmap Support | Indicates support for the reception of a Multi-STA BlockAck frame that has a Per AID Info subfield addressed to it with a 32-bit Block Ack Bitmap subfield. | Set to 1 if the STA supports reception of a Multi-STA BlockAck frame that has a Per AID Info subfield addressed to it with a 32-bit Block Ack Bitmap subfield.<br>Set to 0 otherwise. |
| MU Cascading Support | Indicates support for participating in an MU cascading sequence (see 26.5.3 (MU cascading sequence)). | For an HE AP:<br>Set to 1 to indicate that the AP is capable of transmitting an A-MPDU that is constructed following the MU cascade sequence rules (see 26.5.3 (MU cascading sequence)) under MU cascade operation.<br>Set to 0 otherwise.<br><br>For a non-AP HE STA:<br>Set to 1 to indicate that the non-AP STA is capable of receiving an A-MPDU that is constructed following the MU cascade sequence rules (see 26.5.3 (MU cascading sequence)).<br>Set to 0 otherwise. |
| Ack-Enabled Aggregation Support | Indicates support by a STA to receive an A-MPDU that contains two or more frames at least one of which solicits an Ack frame or acknowledgment context in a Multi-STA BlockAck frame as described in 26.6.3 (Multi-TID A-MPDU and ack-enabled single-TID A-MPDU) and 26.5.1.1 (General). | Set to 1 if the STA supports reception of this A-MPDU format.<br>Set to 0 otherwise. |


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**Table 9-375—Subfields of the HE MAC Capabilities Information field(11ax) *(continued)***

| Subfield | Definition | Encoding |
|---|---|---|
| OM Control Support | Indicates support for receiving a frame with an OM Control subfield. | If the +HTC-HE Support subfield is 1 in a non-AP STA:<br>Set to 1 if the non-AP STA supports reception of the OM Control subfield.<br>Set to 0 otherwise.<br><br>Reserved if the +HTC-HE Support subfield is 0 in a non-AP STA.<br><br>An AP sets the OM Control Support subfield to 1. |
| OFDMA RA Support | For a non-AP STA, indicates support for the OFDMA random access procedure. For an AP, indicates support for sending Trigger frames that allocate RA-RUs. See 26.5.4 (UL OFDMA-based random access (UORA)). | Set to 1 if supported.<br>Set to 0 otherwise. |
| Maximum A-MPDU Length Exponent Extension | Indicates the exponent extension for the maximum A-MPDU length supported in reception (see 26.6 (A-MPDU operation in an HE PPDU)). | Set to the value of the maximum A-MPDU exponent extension value. |
| A-MSDU Fragmentation Support | Indicates support for the reception of fragmented A-MSDUs. | If the Dynamic Fragmentation Support subfield is not 0:<br>Set to 1 to indicate support for the receipt of fragmented A-MSDUs.<br>Set to 0 to indicate that reception of fragmented A-MSDUs is not supported.<br><br>Reserved if the Dynamic Fragmentation Support subfield is 0. |
| Flexible TWT Schedule Support | Indicates support for the reception of TWT Information frames with flexible TWT schedules as defined in 26.8.4.4 (TWT Information frame exchange for flexible wake time). | Set to 1 if the STA supports reception of a TWT Information frame with flexible TWT schedules.<br>Set to 0 otherwise. |
| Rx Control Frame To MultiBSS | For a non-AP STA associated with a BSS corresponding to a nontransmitted BSSID, indicates support for the reception of a Control frame with TA equal to the transmitted BSSID. | For a non-AP STA:<br>Set to 1 if supported.<br>Set to 0 otherwise.<br><br>Reserved for an AP. |
| BSRP BQRP A-MPDU Aggregation | For a non-AP STA, indicates whether the STA accepts a BSRP Trigger frame or BQRP Trigger frame that is aggregated with other Control, Data, and Management frames in an A-MPDU destined to the STA. | For a non-AP STA:<br>Set to 1 if supported.<br>Set to 0 otherwise.<br><br>Reserved for an AP. |

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**Table 9-375—Subfields of the HE MAC Capabilities Information field(11ax) *(continued)***

| Subfield | Definition | Encoding |
|---|---|---|
| QTP Support | Indicates support for quiet time period (QTP) operation as described in 26.17.5 (Quiet HE STAs in an HE BSS). | Set to 1 if supported.<br>Set to 0 otherwise. |
| BQR Support | For an AP, indicates support for receiving a frame with a BQR Control subfield. For a non-AP STA, indicates support for generating a frame with a BQR Control subfield. | If the +HTC-HE Support subfield is 1:<br>Set to 1 if the STA supports the BQR Control subfield functionality.<br>Set to 0 otherwise.<br><br>Reserved if the +HTC-HE Support subfield is 0. |
| PSR Responder | Indicates support for the role of PSR responder. | Set to 1 if the STA supports the role of PSR responder.<br>Set to 0 otherwise. |
| NDP Feedback Report Support | For an AP, indicates support for the NDP feedback report procedure.<br>For a non-AP STA, indicates support for responding to an NFRP Trigger frame. | Set to 1 if supported.<br>Set to 0 otherwise. |
| OPS Support | For an AP, indicates support for encoding OPS information in the TIM element of FILS Discovery frames, TIM frames or OPS frames as described in 26.14.3.2 (AP operation for opportunistic power save). For a non-AP STA, indicates support for receiving the opportunistic power save encoded TIM elements. | Set to 1 if supported.<br>Set to 0 otherwise. |
| A-MSDU Not Under BA In Ack-Enabled A-MPDU Support | Indicates support by a STA to receive an ack-enabled single-TID A-MPDU that carries an A-MSDU that is not under a block ack agreement. | Set to 1 if supported.<br>Set to 0 otherwise. |
| HE Subchannel Selective Transmission Support | Indicates whether an HE STA supports an HE subchannel selective transmission operation described in 26.8.7 (HE subchannel selective transmission). | Set to 1 if supported.<br>Set to 0 otherwise. |
| UL 2×996-tone RU Support | Indicates support by a non-AP STA to receive a TRS Control subfield or a Trigger frame with a User Info field addressed to the STA with the RU Allocation subfield of the TRS Control subfield or the User Info field indicating 2×996-tone RU. | For a non-AP STA:<br>Set to 1 if the STA supports reception of a TRS Control subfield with the RU Allocation subfield indicating a 2×996-tone RU or a Trigger frame with a User Info field addressed to the STA with the RU Allocation subfield indicating 2×996-tone RU.<br>Set to 0 otherwise.<br><br>Reserved for an AP. |


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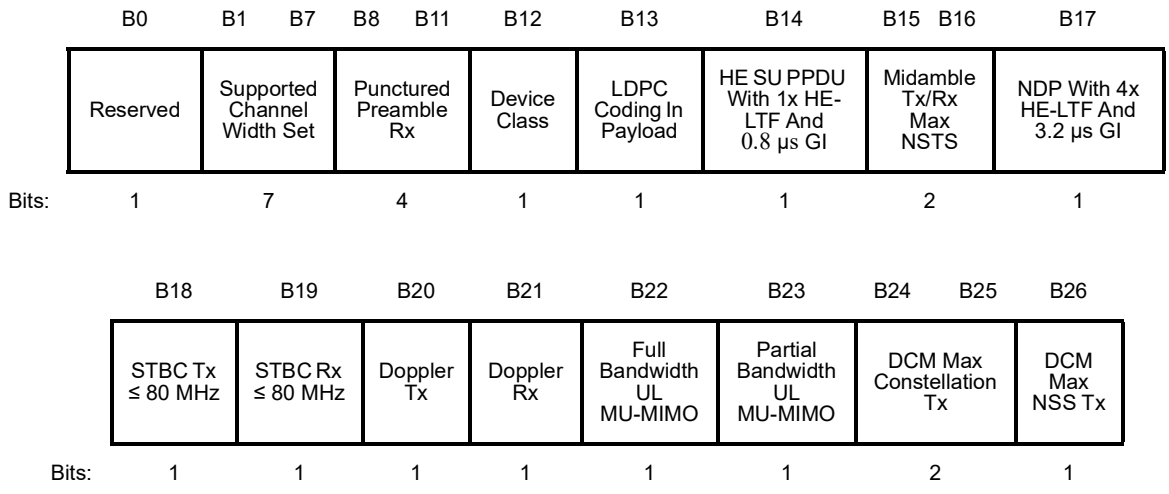
**Table 9-375—Subfields of the HE MAC Capabilities Information field(11ax) *(continued)***

| Subfield | Definition | Encoding |
|---|---|---|
| OM Control UL MU Data Disable RX Support | Indicates whether an AP supports interpretation of the UL MU Data Disable subfield of the OM Control subfield as described in 26.5.2 (UL MU operation). | For an AP:<br>Set to 1 if supported.<br>Set to 0 otherwise.<br><br>Reserved for a non-AP STA. |
| HE Dynamic SM Power Save | Indicates support for HE dynamic SM power save. See 26.14.4 (HE dynamic SM power save). | For a non-AP STA:<br>Set to 1 if supported.<br>Set to 0 if not supported.<br><br>Reserved for an AP. |
| Punctured Sounding Support | Indicates support for punctured sounding as described in 26.7 (HE sounding operation(#2388)). | Set to 1 if dot11HEPuncturedSoundingOptionImplemented is true (see 26.7 (HE sounding operation(#2388))).<br>Set to 0 otherwise. |
| HT And VHT Trigger Frame Rx Support | Indicates support for receiving a Trigger frame in an HT PPDU and receiving a Trigger frame in a VHT PPDU. | For a non-AP STA:<br>Set to 1 if supported.<br>Set to 0 otherwise.<br><br>Reserved for an AP. |

### 9.4.2.247.3 HE PHY Capabilities Information field

The format of the HE PHY Capabilities Information field is defined in Figure 9-899 (HE PHY Capabilities Information field format(11ax)).

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| B27 B28 | B29 | B30 | B31 | B32 | B33 | B34 B36 | B37 B39 |
|---|---|---|---|---|---|---|---|
| DCM Max Constellation Rx | DCM Max NSS Rx | Rx Partial BW SU In 20 MHz HE MU PPDU | SU Beamformer | SU Beamformee | MU Beamformer | Beamformee STS ≤ 80 MHz | Beamformee STS > 80 MHz |
| Bits: 2 | 1 | 1 | 1 | 1 | 1 | 3 | 3 |

*(continued)*

| B40 B42 | B43 B45 | B46 | B47 | B48 | B49 | B50 |
|---|---|---|---|---|---|---|
| Number Of Sounding Dimensions ≤ 80 MHz | Number Of Sounding Dimensions > 80 MHz | Ng = 16 SU Feedback | Ng = 16 MU Feedback | Codebook Size (ϕ, ψ) = {4, 2} SU Feedback | Codebook Size (ϕ, ψ) = {7, 5} MU Feedback | Triggered SU Beamforming Feedback |
| Bits: 3 | 3 | 1 | 1 | 1 | 1 | 1 |

| B51 | B52 | B53 | B54 | B55 | B56 | B57 | B58 |
|---|---|---|---|---|---|---|---|
| Triggered MU Beamforming Partial BW Feedback | Triggered CQI Feedback | Partial Bandwidth Extended Range | Partial Bandwidth DL MU-MIMO | PPE Thresholds Present | PSR-based SR Support | Power Boost Factor Support | HE SU PPDU And HE MU PPDU With 4x HE-LTF And 0.8 μs GI |
| Bits: 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

| B59 B61 | B62 | B63 | B64 | B65 | B66 | B67 | B68 |
|---|---|---|---|---|---|---|---|
| Max Nc | STBC Tx > 80 MHz | STBC Rx > 80 MHz | HE ER SU PPDU With 4x HE-LTF And 0.8 μs GI | 20 MHz In 40 MHz HE PPDU In 2.4 GHz Band | 20 MHz In 160/ 80+80 MHz HE PPDU | 80 MHz In 160/ 80+80 MHz HE PPDU | HE ER SU PPDU With 1x HE-LTF And 0.8 μs GI |
| Bits: 3 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

| B69 | B70 B71 | B72 | B73 | B74 | B75 | B76 | B77 |
|---|---|---|---|---|---|---|---|
| Midamble Tx/Rx 2x And 1x HE-LTF | DCM Max RU | Longer Than 16 HE-SIG-B OFDM Symbols Support | Non-Triggered CQI Feedback | Tx 1024-QAM < 242-tone RU Support | Rx 1024-QAM < 242-tone RU Support | Rx Full BW SU Using HE MU PPDU With Compressed HE-SIG-B | Rx Full BW SU Using HE MU PPDU With Non-Compressed HE-SIG-B |
| Bits: 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 |



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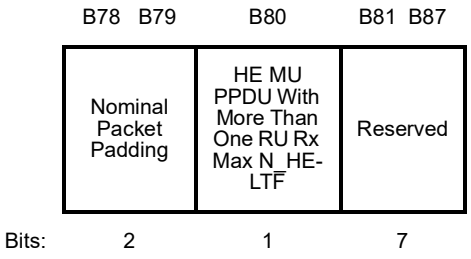


**Figure 9-899—HE PHY Capabilities Information field format(11ax)**

The subfields of the HE PHY Capabilities Information field are defined in Table 9-376 (Subfields of the HE PHY Capabilities Information field(11ax)).

**Table 9-376—Subfields of the HE PHY Capabilities Information field(11ax)**

| Subfield | Definition | Encoding |
|---|---|---|
| Supported Channel Width Set | In the 2.4 GHz band:<br>— B0 indicates support for a 40 MHz channel width.<br>— B1, B2, and B3 are reserved.<br>— B4 indicates support of 242-tone RUs in a 40 MHz HE MU PPDU if a non-AP STA operates with a 20 MHz channel width and the 20 MHz In 40 MHz HE PPDU In 2.4 GHz subfield is 1; otherwise, B4 is reserved.<br>— B5 and B6 are reserved.<br><br>In the 5 GHz and 6 GHz bands:<br>— B0 is reserved.<br>— B1 indicates support for a 40 MHz and 80 MHz channel width.<br>— B2 indicates support for a 160 MHz channel width.<br>— B3 indicates support for a 160/80+80 MHz channel width.<br>— B4 is reserved.<br>— B5 indicates support of 242-tone RUs in a<br>— 40 MHz and 80 MHz HE MU PPDU if a non-AP STA operates with 20 MHz channel width and the 20 MHz In 160/80+80 MHz HE PPDU subfield is set to 0, or<br>— 40 MHz, 80 MHz, 160 MHz, 80+80 MHz HE MU PPDU if a non-AP STA operates with 20 MHz channel width and the 20 MHz In 160/80+80 MHz HE PPDU subfield is set to 1;<br>— Otherwise, B5 is reserved.<br>— B6 is reserved. | B0 is set to 0 if not supported.<br>B0 is set to 1 if supported.<br><br>B1 is set to 0 if not supported.<br>B1 is set to 1 if supported.<br><br>B2 is set to 0 if not supported.<br>B2 is set to 1 if supported. If B2 is 1, then B1 is set to 1.<br><br>B3 is set to 0 if not supported.<br>B3 is set to 1 if supported. If B3 is 1, then B2 is set to 1.<br><br>B4 is set to 0 if not supported.<br>B4 is set to 1 if supported.<br><br>B5 is set to 0 if not supported.<br>B5 is set to 1 if supported.<br><br>NOTE 1—If a non-AP STA operates with 20 MHz channel width and the 20 MHz In 40 MHz HE PPDU In 2.4 GHz subfield is 0, then B4 is set to 0.<br><br>NOTE 2—If a non-AP STA operates with 20 MHz channel width and the 20 MHz In 160/80+80 MHz HE PPDU subfield is 0, then the 242-tone RU in a 160 MHz and 80+80 MHz HE MU PPDU in the 5 GHz band or 6 GHz band is not supported. |

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**Table 9-376—Subfields of the HE PHY Capabilities Information field(11ax) *(continued)***

| Subfield | Definition | Encoding |
|---|---|---|
| Punctured Preamble Rx | B0 indicates support for the reception of an 80 MHz preamble where the only punctured subchannel is the secondary 20 MHz channel.<br><br>B1 indicates support for the reception of an 80 MHz preamble where the only punctured subchannel is one of the two 20 MHz subchannels in the secondary 40 MHz channel.<br><br>B2 indicates support for the reception of a 160 MHz or 80+80 MHz preamble where the only punctured subchannels are the secondary 20 MHz channel and zero to two of the 20 MHz subchannels in the secondary 80 MHz channel. See Table 27-21 (HE-SIG-A field of an HE MU PPDU(11ax)) for allowed 20 MHz punctured subchannel combinations.<br><br>B3 indicates support for the reception of a 160 MHz or 80+80 MHz preamble where the only punctured subchannels are zero, one or both of the 20 MHz subchannels in the secondary 40 MHz channel and zero to two of the 20 MHz subchannels in the secondary 80 MHz channel; at least one 20 MHz subchannel is punctured. See Table 27-21 (HE-SIG-A field of an HE MU PPDU(11ax)) for allowed 20 MHz punctured subchannel combinations. | B0 is set to 0 if not supported.<br>B0 is set to 1 if supported.<br><br>B1 is set to 0 if not supported.<br>B1 is set to 1 if supported.<br><br>B2 is set to 0 if not supported.<br>B2 is set to 1 if supported.<br><br>B3 is set to 0 if not supported.<br>B3 is set to 1 if supported. |
| Device Class | For a non-AP STA, indicates whether the STA is a Class A or a Class B device. | For a non-AP STA:<br>Set to 1 for a Class A device.<br>Set to 0 for a Class B device.<br><br>Reserved for an AP. |
| LDPC Coding In Payload | Indicates support for the transmission and reception of LDPC encoded PPDUs. | Set to 0 if not supported.<br>Set to 1 if supported.<br><br>NOTE—Set to 1 by a STA that supports more than 4 spatial streams, an HE PPDU bandwidth greater than 20 MHz, HE-MCS 10, or HE-MCS 11. |
| HE SU PPDU With 1x HE-LTF And 0.8 μs GI | Indicates support of the reception of an HE SU PPDU with 1x HE-LTF and 0.8 μs guard interval duration. | Set to 0 if not supported.<br>Set to 1 if supported. |
| Midamble Tx/Rx Max NSTS | If the Doppler Rx subfield is 1, indicates the maximum number of space-time streams supported for reception when a midamble is present in the Data field.<br><br>If the Doppler Tx subfield is 1, indicates the maximum number of space-time streams supported for transmission when a midamble is present in the Data field.<br><br>If both Doppler Rx and Doppler Tx subfields are 1, indicates the maximum number of space-time streams supported for transmission and reception when a midamble is present in the Data field. | Set to 0 for 1 space-time stream.<br>Set to 1 for 2 space-time streams.<br>Set to 2 for 3 space-time streams.<br>Set to 3 for 4 space-time streams. |


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**Table 9-376—Subfields of the HE PHY Capabilities Information field(11ax) *(continued)***

| Subfield | Definition | Encoding |
|---|---|---|
| NDP With 4x HE-LTF And 3.2 µs GI | For a beamformee, indicates support for receiving an HE sounding NDP with 4x HE-LTF and 3.2 µs guard interval duration. | If the SU Beamformee field is 1:<br>Set to 0 if not supported.<br>Set to 1 if supported. |
| STBC Tx ≤ 80 MHz | Indicates support for the transmission of an HE TB PPDU using STBC that has a bandwidth less than or equal to 80 MHz. | For a non-AP STA:<br>Set to 0 if not supported.<br>Set to 1 if supported.<br><br>Reserved for an AP. |
| STBC Rx ≤ 80 MHz | Indicates support for the reception of an HE PPDU using STBC that has a bandwidth less than or equal to 80 MHz. | Set to 0 if not supported.<br>Set to 1 if supported. |
| Doppler Tx | Indicates support for transmitting HE PPDUs with midamble. | Set to 0 if not supported.<br>Set to 1 if supported. |
| Doppler Rx | Indicates support for receiving HE PPDUs with midamble. | Set to 0 if not supported.<br>Set to 1 if supported. |
| Full Bandwidth UL MU-MIMO | For an AP, indicates support for MU-MIMO reception of an HE TB PPDU on an RU that spans the entire PPDU bandwidth (UL MU-MIMO).<br><br>For a non-AP STA, indicates support for the transmission of an HE TB PPDU on an RU that spans the entire PPDU bandwidth (UL MU-MIMO). | Set to 0 if not supported.<br>Set to 1 if supported. |
| Partial Bandwidth UL MU-MIMO | For an AP, indicates support for receiving an HE TB PPDU on an RU where MU-MIMO is employed and where the RU does not span the entire PPDU bandwidth (UL MU-MIMO in OFDMA).<br><br>For a non-AP STA, indicates support for transmitting an HE TB PPDU on an RU where MU-MIMO is employed and where the RU does not span the entire PPDU bandwidth (UL MU-MIMO in OFDMA).<br><br>NOTE—The RU is a 106-tone or larger RU. | Set to 0 if not supported.<br>Set to 1 if supported. |
| DCM Max Constellation Tx | Indicates the maximum supported constellation for DCM in the Data field of an HE TB PPDU that the STA is capable of transmitting. | For a non-AP STA:<br>Set to 0 if DCM is not supported.<br>Set to 1 for BPSK.<br>Set to 2 for QPSK.<br>Set to 3 for 16-QAM.<br><br>Reserved for an AP. |
| DCM Max NSS Tx | Indicates the maximum number of spatial streams supported for transmission when DCM is used in the Data field of an HE TB PPDU. | For a non-AP STA, if the DCM Max Constellation Tx subfield is not 0:<br>Set to 0 for 1 spatial stream.<br>Set to 1 for 2 spatial streams.<br><br>Reserved for an AP or if the DCM Max Constellation Tx subfield is 0. |

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**Table 9-376—Subfields of the HE PHY Capabilities Information field(11ax) *(continued)***

| Subfield | Definition | Encoding |
|---|---|---|
| DCM Max Constellation Rx | Indicates the maximum supported constellation for DCM in both the Data field and HE-SIG-B field that the STA is capable of receiving. | Set to 0 if DCM is not supported.<br>Set to 1 for BPSK.<br>Set to 2 for QPSK.<br>Set to 3 for 16-QAM. |
| DCM Max NSS Rx | Indicates the maximum number of spatial streams supported for reception when DCM is used in the Data field. | Set to 0 for 1 spatial stream.<br>Set to 1 for 2 spatial streams. |
| Rx Partial BW SU In 20 MHz HE MU PPDU | For an AP, TDLS STA or IBSS STA, indicates support for the reception of a 20 MHz HE MU PPDU with just a 106-tone RU.<br><br>NOTE—It is mandatory for a non-AP HE STA to support reception of a 20 MHz HE MU PPDU with just a 106-tone RU. | For an AP, TDLS STA or IBSS STA:<br>Set to 0 if not supported.<br>Set to 1 if supported.<br><br>Reserved for a non-AP STA. |
| SU Beamformer | Indicates support for operation as an SU beamformer. | Set to 0 if not supported.<br>Set to 1 if supported.<br><br>NOTE—Set to 1 by an AP with support for 4 or more spatial streams. |
| SU Beamformee | Indicates support for operation as an SU beamformee. | For an AP:<br>Set to 0 if not supported.<br>Set to 1 if supported.<br><br>Set to 1 for a non-AP STA. |
| MU Beamformer | Indicates support for operation as an MU beamformer. | For an AP:<br>Set to 0 if not supported.<br>Set to 1 if the SU Beamformer field is 1 and operation as an MU beamformer is supported.<br><br>Set to 0 for a non-AP STA.<br><br>NOTE—Set to 1 by an AP with support for 4 or more spatial streams. |
| Beamformee STS ≤ 80 MHz | For a PPDU bandwidth less than or equal to 80 MHz, indicates the maximum number of space-time streams that the STA can receive in an HE sounding NDP, which is also the maximum total number of space-time streams over all the users that can be sent in a DL MU-MIMO transmission on an RU that includes that STA, where the RU might or might not span the entire PPDU bandwidth. | If the SU Beamformee subfield is 1:<br>Set to the maximum number of space-time streams that the STA is capable of receiving in an HE sounding NDP minus 1. The minimum value of this field is 3.<br><br>Reserved if the SU Beamformee field is 0. |


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**Table 9-376—Subfields of the HE PHY Capabilities Information field(11ax) *(continued)***

| Subfield | Definition | Encoding |
|---|---|---|
| Beamformee STS > 80 MHz | For a PPDU bandwidth greater than 80 MHz, indicates the maximum number of space-time streams that the STA can receive in an HE sounding NDP, which is also the maximum total number of space-time streams over all the users that can be sent in a DL MU-MIMO transmission on an RU that includes that STA, where the RU might or might not span the entire PPDU bandwidth. | If the SU Beamformee subfield is 1:<br>Set to the maximum number of space-time streams that the STA is capable of receiving in an HE sounding NDP minus 1. The minimum value of this field is 3.<br><br>Reserved if the SU Beamformee subfield is 0 or the Supported Channel Width Set field does not indicate support for bandwidths greater than 80 MHz. |
| Number Of Sounding Dimensions ≤ 80 MHz | For bandwidth less than or equal to 80 MHz, it indicates the beamformer's capability indicating the maximum value of the TXVECTOR parameter NUM_STS for an HE sounding NDP. | If the SU Beamformer subfield is 1:<br>Set to the supported maximum TXVECTOR parameter NUM_STS value minus 1.<br><br>Reserved if the SU Beamformer subfield is 0. |
| Number Of Sounding Dimensions > 80 MHz | For bandwidth greater than 80 MHz, indicates the beamformer's capability indicating the maximum value of the TXVECTOR parameter NUM_STS for an HE sounding NDP. | If the SU Beamformer subfield is 1:<br>Set to the supported maximum TXVECTOR parameter NUM_STS value minus 1.<br><br>Reserved if the SU Beamformer subfield is 0 or the Supported Channel Width Set field does not indicate support for bandwidths greater than 80 MHz. |
| Ng = 16 SU Feedback | Indicates HE beamformee support for a subcarrier grouping of 16 in the HE Compressed Beamforming Report field for SU feedback. | Set to 0 if not supported.<br>Set to 1 if supported. |
| Ng = 16 MU Feedback | Indicates HE beamformee support for a subcarrier grouping of 16 in the HE Compressed Beamforming Report field for MU feedback. | Set to 0 if not supported.<br>Set to 1 if supported. |
| Codebook Size ($\phi$, $\psi$) = {4, 2} SU Feedback | Indicates HE beamformee support for a codebook size ($\phi$, $\psi$) = {4, 2} in the HE Compressed Beamforming Report field for SU feedback. | Set to 0 if not supported.<br>Set to 1 if supported. |
| Codebook Size ($\phi$, $\psi$) = {7, 5} MU Feedback | Indicates HE beamformee support for a codebook size ($\phi$, $\psi$) = {7, 5} in the HE Compressed Beamforming Report field for MU feedback. | Set to 0 if not supported.<br>Set to 1 if supported. |
| Triggered SU Beamforming Feedback | For an AP, indicates support for the reception of partial- and full-bandwidth SU feedback in an HE TB sounding sequence.<br><br>For a non-AP STA, indicates support for the transmission of partial- and full-bandwidth SU feedback in an HE TB sounding sequence. | Set to 0 if not supported.<br>Set to 1 if supported. |

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**Table 9-376—Subfields of the HE PHY Capabilities Information field(11ax) *(continued)***

| Subfield | Definition | Encoding |
|---|---|---|
| Triggered MU Beamforming Partial BW Feedback | For an AP, indicates support for the reception of partial-bandwidth MU feedback in an HE TB sounding sequence.<br><br>For a non-AP STA, indicates support for the transmission of partial-bandwidth MU feedback in an HE TB sounding sequence. | Set to 0 if not supported.<br>Set to 1 if supported. |
| Triggered CQI Feedback | For an AP, indicates support for the reception of partial- and full-bandwidth CQI feedback in an HE TB sounding sequence.<br><br>For a non-AP STA, indicates support for the transmission of partial- and full-bandwidth CQI feedback in an HE TB sounding sequence. | Set to 0 if not supported.<br>Set to 1 if supported. |
| Partial Bandwidth Extended Range | Indicates support for the transmission and reception of an HE ER SU PPDU in which the HE modulated fields are transmitted over the higher frequency 106-tone RU within primary 20 MHz channel. | Set to 0 if not supported.<br>Set to 1 if supported. |
| Partial Bandwidth DL MU-MIMO | For a non-AP STA, indicates support for the reception of a DL MU-MIMO transmission on an RU in an HE MU PPDU where the RU does not span the entire PPDU bandwidth (DL MU-MIMO within OFDMA). | For a non-AP STA:<br>Set to 0 if not supported.<br>Set to 1 if supported.<br><br>NOTE—A non-AP STA that sets this field to 0 supports receiving a partial-bandwidth RU allocated to a single user within an HE MU PPDU where some other RU is employing DL MU-MIMO.<br><br>Reserved for an AP. |
| PPE Thresholds Present | Indicates whether the PPE Thresholds field is present.<br><br>NOTE—This field if set to 1 overrides the Nominal Packet Padding field.(#3236) | Set to 1 if PPE Thresholds field is present.<br>Set to 0 otherwise. |
| PSR-based SR Support | Indicates support for PSR-based SR operation. | Set to 0 if not supported.<br>Set to 1 if supported. |
| Power Boost Factor Support | Indicates that the STA supports a power boost factor for the RUs in an HE MU PPDU in the range [0.5, 2]. | Set to 0 if not supported.<br>Set to 1 if supported. |
| HE SU PPDU And HE MU PPDU With 4x HE-LTF And 0.8 μs GI | Indicates support for the reception of an HE SU PPDU and HE MU PPDU with 4x HE-LTF and 0.8 μs guard interval duration. | Set to 0 if not supported.<br>Set to 1 if supported.<br><br>This subfield is set to 1 if the HE ER SU PPDU With 4x HE-LTF And 0.8 μs GI subfield is 1. |
| Max Nc | Indicates the maximum supported *Nc* for an HE compressed beamforming/CQI report. | If the SU Beamformee subfield is 1:<br>Set to the maximum supported *Nc* for an HE compressed beamforming/CQI report minus 1.<br><br>Reserved if the SU Beamformee subfield is 0. |


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**Table 9-376—Subfields of the HE PHY Capabilities Information field(11ax) *(continued)***

| Subfield | Definition | Encoding |
|---|---|---|
| STBC Tx > 80 MHz | Indicates support for the transmission of an HE TB PPDU using STBC that has a bandwidth greater than 80 MHz. | For a non-AP STA:<br>Set to 0 if not supported.<br>Set to 1 if supported.<br><br>Reserved for an AP or if the Supported Channel Width Set field does not indicate support for bandwidths greater than 80 MHz. |
| STBC Rx > 80 MHz | Indicates support for the reception of an HE PPDU using STBC that has a bandwidth greater than 80 MHz. | Set to 0 if not supported.<br>Set to 1 if supported.<br><br>Reserved if the Supported Channel Width Set field does not indicate support for bandwidths greater than 80 MHz. |
| HE ER SU PPDU With 4x HE-LTF And 0.8 μs GI | Indicates support for the reception of an HE ER SU PPDU with 4x HE-LTF and 0.8 μs guard interval duration. | Set to 0 if not supported.<br>Set to 1 if supported. |
| 20 MHz In 40 MHz HE PPDU In 2.4 GHz Band | Indicates support for 26-, 52-, and 106-tone RU mapping for a 20 MHz operating non-AP HE STA that is the receiver of a 40 MHz HE MU PPDU in 2.4 GHz band, or the transmitter of a 40 MHz HE TB PPDU in 2.4 GHz band. | Set to 0 if not supported.<br>Set to 1 if supported.<br><br>NOTE—Set to 1 if B0 of the Supported Channel Width Set subfield is 1.<br><br>Reserved for an AP. |
| 20 MHz In 160/ 80+80 MHz HE PPDU | Indicates support for 26-, 52-, and 106-tone RU mapping for a 20 MHz operating non-AP HE STA that is the receiver of an 80+80 MHz or a 160 MHz HE MU PPDU, or the transmitter of an 80+80 MHz or 160 MHz HE TB PPDU. | Set to 0 if not supported.<br>Set to 1 if supported.<br><br>NOTE—Set to 1 if B2 of the Supported Channel Width Set subfield is 1.<br><br>Reserved for an AP. |
| 80 MHz In 160/ 80+80 MHz HE PPDU | Indicates supports of 160/80+80 MHz OFDMA for a non-AP HE STA that sets B1 of Supported Channel Width Set to 1, and sets B2 and B3 of Supported Channel Width Set each to 0, when operating with 80 MHz channel width. The capability bit is applicable while receiving an 80+80 MHz or a 160 MHz HE MU PPDU, or transmitting an 80+80 MHz or a 160 MHz HE TB PPDU. | Set to 0 if not supported.<br>Set to 1 if supported.<br><br>NOTE—Set to 1 if B2 of the Supported Channel Width Set subfield is 1.<br><br>Reserved for an AP. |
| HE ER SU PPDU With 1x HE-LTF And 0.8 μs GI | Indicates support of the reception of an HE ER SU PPDU with 1x HE-LTF and 0.8 μs guard interval duration. | Set to 0 if not supported.<br>Set to 1 if supported. |

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**Table 9-376—Subfields of the HE PHY Capabilities Information field(11ax) *(continued)***

| Subfield | Definition | Encoding |
|---|---|---|
| Midamble Tx/Rx 2x And 1x HE-LTF | If the Doppler Rx subfield is 1, indicates support for receiving midambles with 2x HE-LTF, 1x HE-LTF in HE SU PPDU if the HE SU PPDU With 1x HE-LTF And 0.8 µs GI subfield is 1, and 1x HE-LTF in HE ER SU PPDU if the HE ER SU PPDU With 1x HE-LTF And 0.8 µs GI subfield is 1.<br><br>If the Doppler Tx subfield is 1, indicates support for transmitting midambles with 2x HE-LTF, 1x HE-LTF in HE TB PPDU when allowed.<br><br>If both the Doppler Rx and Doppler Tx subfields are 1, indicates support for receiving midambles with 2x HE-LTF, 1x HE-LTF in HE SU PPDU if the HE SU PPDU With 1x HE-LTF And 0.8 µs GI subfield is 1, and 1x HE-LTF in HE ER SU PPDU if the HE ER SU PPDU With 1x HE-LTF And 0.8 µs GI subfield is 1; and also support for transmitting midambles with 2x HE-LTF, 1x HE-LTF in HE TB PPDU when allowed. | Set to 0 if not supported.<br>Set to 1 if supported. |
| DCM Max RU | If the DCM Max Constellation Tx subfield is greater than 0, then the DCM Max RU subfield indicates the maximum RU size that the STA might transmit with DCM applied.<br><br>If the DCM Max Constellation Rx subfield is greater than 0, then the DCM Max RU subfield indicates the maximum RU size with DCM applied that the STA can receive.<br><br>If both the DCM Max Constellation Tx subfield and DCM Max Constellation Rx subfield are 0, then this subfield is reserved. | Set to 0 for 242-tone RU<br>Set to 1 for 484-tone RU<br>Set to 2 for 996-tone RU<br>Set to 3 for 2×996-tone RU |
| Longer Than 16 HE-SIG-B OFDM Symbols Support | For a non-AP STA, indicates support for receiving a DL HE MU PPDU where the number of OFDM symbols in the HE-SIG-B field is greater than 16. | Set to 0 if not supported.<br>Set to 1 if supported.<br><br>A 20 MHz-only non-AP HE STA sets this to 0. |
| Non-Triggered CQI Feedback | For an AP, indicates support for the reception of full-bandwidth non-triggered CQI feedback.<br><br>For a non-AP STA, indicates support for the transmission of full-bandwidth non-triggered CQI feedback. | Set to 0 if not supported.<br>Set to 1 if supported. |
| Tx 1024-QAM < 242-tone RU Support | For a non-AP STA, indicates support for the transmission of 1024-QAM on a 26-, 52-, and 106-tone RU. | For a non-AP STA:<br>Set to 0 if not supported.<br>Set to 1 if supported.<br><br>Reserved for an AP. |
| Rx 1024-QAM < 242-tone RU Support | Indicates support for the reception of 1024-QAM on a 26-, 52-, and 106-tone RU. | Set to 0 if not supported.<br>Set to 1 if supported. |


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**Table 9-376—Subfields of the HE PHY Capabilities Information field(11ax) *(continued)***

| Subfield | Definition | Encoding |
|---|---|---|
| Rx Full BW SU Using HE MU PPDU With Compressed HE-SIG-B | Indicates support for reception of an HE MU PPDU with a single user allocated an RU spanning the entire PPDU bandwidth and a compressed HE-SIG-B field format. | Set to 0 if not supported.<br>Set to 1 if supported. |
| Rx Full BW SU Using HE MU PPDU With Non-Compressed HE-SIG-B | Indicates support for reception of an HE MU PPDU with a bandwidth less than or equal to 80 MHz, a single user allocated an RU spanning the entire PPDU bandwidth and a noncompressed HE-SIG-B field format. | Set to 0 if not supported.<br>Set to 1 if supported. |
| Nominal Packet Padding | Indicates the nominal packet padding to be used for all constellations, $N_{SS}$ and RU allocations the STA supports if the PPE Thresholds Present subfield is set to 0. | Set to 0 if the nominal packet padding is 0 μs for all constellations, $N_{SS}$ and RU allocations the STA supports.<br>Set to 1 if the nominal packet padding is 8 μs for all constellations, $N_{SS}$ and RU allocations the STA supports.<br>Set to 2 if the nominal packet padding is 16 μs for all constellations, $N_{SS}$ and RU allocations the STA supports.<br><br>The value 3 is reserved.<br><br>Reserved if the PPE Thresholds Present subfield is 1. |
| HE MU PPDU With More Than One RU Rx Max N_HE-LTF | Indicates the maximum number of HE-LTF symbols, $N_{\text{HE-LTF}}$, that the STA is capable of receiving in an HE MU PPDU with more than one RU. | For a non-AP STA:<br>Set to 0 if the number of HE-LTF symbols, $N_{\text{HE-LTF}}$, that the STA is capable of receiving in an HE MU PPDU equals $N_{\text{HE-LTF}}$(Beamformee STS + 1), where the $N_{\text{HE-LTF}}$(Beamformee STS + 1) is the lookup function shown in Table 21-13 with $N_{STS,total}$ taken as Beamformee STS + 1.<br><br>NOTE—For a PPDU bandwidth less than or equal to 80 MHz, use the value defined in the Beamformee STS ≤ 80 MHz subfield. For a PPDU bandwidth greater than 80 MHz, use the value defined in Beamformee STS > 80 MHz subfield.<br><br>Set to 1 if the maximum number of HE-LTF symbols, $N_{\text{HE-LTF}}$, that the STA is capable of receiving in an HE MU PPDU is 8.<br><br>Reserved for an AP. |

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### 9.4.2.247.4 Supported HE-MCS And NSS Set field

The Supported HE-MCS And NSS Set field indicates the combinations of HE-MCSs and spatial streams that a STA supports for reception and the combinations that it supports for transmission. The format of the field is shown in Figure 9-900 (Supported HE-MCS And NSS Set field format(11ax)).

| | Rx HE-MCS Map ≤ 80 MHz | Tx HE-MCS Map ≤ 80 MHz | Rx HE-MCS Map 160 MHz | Tx HE-MCS Map 160 MHz | Rx HE-MCS Map 80+80 MHz | Tx HE-MCS Map 80+80 MHz |
|---|---|---|---|---|---|---|
| Octets: | 2 | 2 | 0 or 2 | 0 or 2 | 0 or 2 | 0 or 2 |

**Figure 9-900—Supported HE-MCS And NSS Set field format(11ax)**

The subfields of the Supported HE-MCS And NSS Set field, and their presence, are defined in Table 9-377 (Subfields of the Supported HE-MCS And NSS Set field(11ax)).

**Table 9-377—Subfields of the Supported HE-MCS And NSS Set field(11ax)**

| Subfield | Definition | Encoding |
|---|---|---|
| Rx HE-MCS Map ≤ 80 MHz | If the operating channel width of the STA is greater than 80 MHz, indicates the maximum value of the RXVECTOR parameter MCS of a PPDU that can be received by the STA for a PPDU with bandwidth less than or equal to 80 MHz for each number of spatial streams.<br><br>If the operating channel width of this STA is less than or equal to 80 MHz, indicates the maximum value of the RXVECTOR parameter MCS for a PPDU that can be received by the STA for each number of spatial streams. | The format and encoding of this subfield are defined in Figure 9-900 (Supported HE-MCS And NSS Set field format(11ax)) and the associated description. |
| Tx HE-MCS Map ≤ 80 MHz | If the operating channel width of this STA is greater than 80 MHz, indicates the maximum value of the TXVECTOR parameter MCS of a PPDU that can be transmitted by the STA for a PPDU with bandwidth less than or equal to 80 MHz for each number of spatial streams.<br><br>If the operating channel width of this STA is less than or equal to 80 MHz, indicates the maximum value of the TXVECTOR parameter MCS for a PPDU that can be transmitted by the STA for each number of spatial streams. | The format and encoding of this subfield are defined in Figure 9-900 (Supported HE-MCS And NSS Set field format(11ax)) and the associated description. |


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**Table 9-377—Subfields of the Supported HE-MCS And NSS Set field(11ax) *(continued)***

| Subfield | Definition | Encoding |
|---|---|---|
| Rx HE-MCS Map 160 MHz | If the operating channel width of the STA is 160 MHz, indicates the maximum value of the RXVECTOR parameter MCS for a 160 MHz PPDU that can be received by this STA for each number of spatial streams. | The format and encoding of this subfield are defined in Figure 9-900 (Supported HE-MCS And NSS Set field format(11ax)) and the associated description.<br><br>The Rx HE-MCS Map 160 MHz subfield is present if B2 of the Supported Channel Width Set subfield of the HE PHY Capabilities Information field is 1; otherwise, it is not present. |
| Tx HE-MCS Map 160 MHz | If the operating channel width of the STA is 160 MHz, indicates the maximum value of the TXVECTOR parameter MCS for a 160 MHz PPDU that can be transmitted by this STA for each number of spatial streams. | The format and encoding of this subfield are defined in Figure 9-900 (Supported HE-MCS And NSS Set field format(11ax)) and the associated description.<br><br>The Tx HE-MCS Map 160 MHz subfield is present if B2 of the Supported Channel Width Set subfield of the HE PHY Capabilities Information field is 1; otherwise, it is not present. |
| Rx HE-MCS Map 80+80 MHz | If the operating channel width of the STA is 160 MHz, indicates the maximum value of the RXVECTOR parameter MCS for an 80+80 MHz PPDU that can be received by this STA for each number of spatial streams. | The format and encoding of this subfield are defined in Figure 9-900 (Supported HE-MCS And NSS Set field format(11ax)) and the associated description.<br><br>The Rx HE-MCS Map 80+80 MHz subfield is present if B3 of the Supported Channel Width Set subfield of the HE PHY Capabilities Information field is 1; otherwise, it is not present. |
| Tx HE-MCS Map 80+80 MHz | If the operating channel width of the STA is 160 MHz, indicates the maximum value of the TXVECTOR parameter MCS for an 80+80 MHz PPDU that can be transmitted by this STA for each number of spatial streams. | The format and encoding of this subfield are defined in Figure 9-900 (Supported HE-MCS And NSS Set field format(11ax)) and the associated description.<br><br>The Tx HE-MCS Map 80+80 MHz subfield is present if B3 of the Supported Channel Width Set subfield of the HE PHY Capabilities Information field is 1; otherwise, it is not present. |

The Rx HE-MCS Map and Tx HE-MCS Map subfields have the format shown in Table 9-378 (Rx HE-MCS Map subfield, Tx HE-MCS Map subfield, and Basic HE-MCS And NSS Set field format(11ax)).

| | B0 B1 | B2 B3 | B4 B5 | B6 B7 | B8 B9 | B10 B11 | B12 B13 | B14 B15 |
|---|---|---|---|---|---|---|---|---|
| | Max HE-MCS For 1 SS | Max HE-MCS For 2 SS | Max HE-MCS For 3 SS | Max HE-MCS For 4 SS | Max HE-MCS For 5 SS | Max HE-MCS For 6 SS | Max HE-MCS For 7 SS | Max HE-MCS For 8 SS |
| Bits: | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |

**Table 9-378—Rx HE-MCS Map subfield, Tx HE-MCS Map subfield, and Basic HE-MCS And NSS Set field format(11ax)**

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The Max HE-MCS For *n* SS subfield (where *n* = 1, …, 8) is encoded as follows:

— 0 indicates support for HE-MCS 0–7 for *n* spatial streams.
— 1 indicates support for HE-MCS 0–9 for *n* spatial streams.
— 2 indicates support for HE-MCS 0–11 for *n* spatial streams.
— 3 indicates that *n* spatial streams is not supported for HE PPDUs.

The maximum receive $N_{SS}$ for a given HE-MCS is equal to the smaller of

— The maximum value of *n* for which the Max HE-MCS For *n* SS has a value that indicates support for that HE-MCS or
— The maximum supported $N_{SS}$ as indicated by the value of the Rx NSS field of the Operating Mode Notification frame if the value of Rx NSS Type is 0 or of the OM Control subfield.

NOTE 1—An HE-MCS indicated as supported in the Rx HE-MCS Map fields for a particular number of spatial streams might not be valid at all bandwidths (see 27.5 (Parameters for HE-MCSs)) and might be affected by 26.15.4.3 (Additional rate selection constraints for HE PPDUs).

The maximum transmit $N_{SS}$ for a given HE-MCS is equal to the smaller of

— The maximum value of *n* for which the Max HE-MCS For *n* SS has a value that indicates support for that HE-MCS (0, 1, or 2 for HE-MCS 0-7, 1 or 2 for HE-MCS 8-9, 2 for HE-MCS 10-11) or
— The maximum supported NSTS as indicated by the value of the Tx NSTS field of the OM Control subfield sent by a non-AP STA.

NOTE 2—An HE-MCS indicated as supported in the Tx HE-MCS Map fields for a particular number of space-time streams might not be valid at all bandwidths (see 27.5 (Parameters for HE-MCSs)) and might be affected by 26.15.4.3 (Additional rate selection constraints for HE PPDUs).

### 9.4.2.247.5 PPE Thresholds field

The PPE Thresholds field determines the nominal packet padding value (see 26.12 (HE PPDU post-FEC padding and packet extension)) for an HE PPDU of a particular RU allocation size and NSTS value. The format of the PPE Thresholds field is defined in Figure 9-901 (PPE Thresholds field format(11ax)).

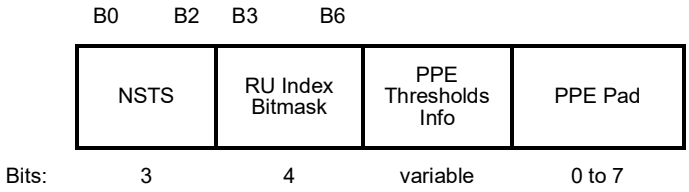


**Figure 9-901—PPE Thresholds field format(11ax)**

The NSTS subfield contains an unsigned integer that is the number of NSTS values minus 1 for which PPE threshold values are included in the PPE Thresholds Info(#2374) subfield.

The RU Index Bitmask subfield contains a bitmask that indicates whether the PPE Thresholds Info field contains PPET16 and PPET8 values for the four possible RU sizes indicated in Table 9-380 (RU allocation index(11ax)). The PPET16 and PPET8 values for RU allocation index *k* is present in the PPE Thresholds Info field only if bit *k* of the RU Index Bitmask subfield (bit 3 + *k* of the PPE Thresholds field) is 1. For example, if B0 of the RU Index Bitmask subfield (B3 of the PPE Thresholds field) is 1, PPET16 and PPET8 values are present in the PPE Thresholds Info field for the RU allocation size corresponding to RU allocation index 0 (242-tone RU). If B0 of the RU Index Bitmask subfield is 0, PPET16 and PPET8 values are not present in the PPE Thresholds Info field for the RU allocation size corresponding to RU allocation index 0.


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The PPE Thresholds Info(#2374) field contains 6 × (*NSTS* + 1) bits, where *NSTS* is the value in the NSTS field, for every bit in the RU Index Bitmask subfield that is nonzero. The format of the PPE Thresholds Info field is defined in Figure 9-902 (PPE Thresholds Info field format(11ax)(#3359)(#2374)).

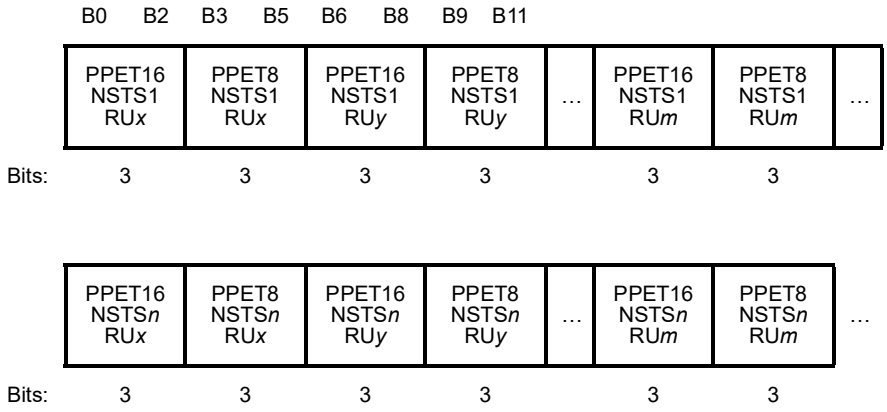


**Figure 9-902—PPE Thresholds Info field format(11ax)(#3359)(#2374)**

(#3359)NOTE—The figure assumes there are three or more RU sizes, fewer are possible.

The PPET16 and PPET8 subfields for various NSTS and RU values appear in increasing NSTS value and increasing RU index value order. Lower numbered PPE Thresholds Info field bits contain PPET16 and PPET8 subfields corresponding to lower numbered NSTS values. Within a set of PPET16 and PPET8 subfields corresponding to a single value of *NSTS*, lower numbered PPE Thresholds Info field bits contain PPET16 and PPET8 subfields corresponding to lower numbered RU index values. The PPET16 NSTS*n* RU*b* and PPET8 NSTS*n* RU*b* subfields are present for all values of *n* and *b* where $1 \le n \le (NSTS + 1)$ and where (#3359)*b* = [*x*, *y*, …, *m*] is the set of integers equal to the ordered list of bit positions of all bits that are set to 1 in the RU Index Bitmask subfield, with *x* being the lowest value.

Each PPET8 NSTS*n* RU*b* and PPET16 NSTS*n* RU*b* subfield contains an integer as defined in Table 9-379 (Constellation index(11ax)), which is used to compute the nominal packet padding value.

**Table 9-379—Constellation index(11ax)**

| Constellation Index | Corresponding Transmission Constellation |
|---|---|
| 0 | BPSK |
| 1 | QPSK |
| 2 | 16-QAM |
| 3 | 64-QAM |
| 4 | 256-QAM |
| 5 | 1024-QAM |
| 6 | Reserved |
| 7 | None |

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The value of the PPET8 NSTS*n* RU*b* subfield is always less than the value of the PPET16 NSTS*n* RU*b* subfield, except if the PPET8 subfield is 7.

The RU allocation index for each RU allocation size is defined in Table 9-380 (RU allocation index(11ax)).

**Table 9-380—RU allocation index(11ax)**

| RU allocation index | RU allocation size |
|---|---|
| 0 | 242 |
| 1 | 484 |
| 2 | 996 |
| 3 | 2×996 |

The PPE Pad field contains all 0s. The number of bits in the PPE Pad field is the least number of bits required to round the length of the PPE Thresholds Info field to an integer number of octets.

### 9.4.2.248 HE Operation element(11ax)

The operation of HE STAs in an HE BSS is controlled by the following:

— The HT Operation element and the HE Operation element if operating in the 2.4 GHz band.

— The HT Operation element, VHT Operation element (if present) and the HE Operation element if operating in the 5 GHz band.

— The HE Operation element if operating in the 6 GHz band.

The format of the HE Operation element is defined in Figure 9-903 (HE Operation element format(11ax)).

| | Element ID | Length | Element ID Extension | HE Operation Parameters | BSS Color Information | Basic HE-MCS And NSS Set | VHT Operation Information | Max Co-Hosted BSSID Indicator | 6 GHz Operation Information |
|---|---|---|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 3 | 1 | 2 | 0 or 3 | 0 or 1 | 0 or 5 |

**Figure 9-903—HE Operation element format(11ax)**

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

The format of the HE Operation Parameters field is defined in Figure 9-904 (HE Operation Parameters field format(11ax)).

| | B0 B2 | B3 | B4 B13 | B14 | B15 | B16 | B17 | B18 B23 |
|---|---|---|---|---|---|---|---|---|
| | Default PE Duration | TWT Required | TXOP Duration RTS Threshold | VHT Operation Information Present | Co-Hosted BSS | ER SU Disable | 6 GHz Operation Information Present | Reserved |
| Bits: | 3 | 1 | 10 | 1 | 1 | 1 | 1 | 6 |

**Figure 9-904—HE Operation Parameters field format(11ax)**



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The Default PE Duration subfield indicates the PE field duration in units of 4 μs for an HE TB PPDU that is solicited with a TRS Control subfield and its use is defined in 26.5.2.3 (Non-AP STA behavior for UL MU operation). Values 5–7 of the Default PE Duration subfield are reserved.

The TWT Required subfield is set to 1 to indicate that the AP requires its associated non-AP HE STAs that have declared support for TWT by setting any one of TWT Requester Support or TWT Responder Support or Broadcast TWT Support subfield in HE Capabilities element that it transmits to 1 to operate in the role of either TWT requesting STA by following the rules in 26.8.2 (Individual TWT agreements), or TWT scheduled STA by following the rules in 26.8.3 (Broadcast TWT operation) and set to 0 otherwise.

The TXOP Duration RTS Threshold subfield enables an HE AP to manage RTS/CTS usage by non-AP HE STAs that are associated with it (see 26.2.1 (TXOP duration-based RTS/CTS)). The TXOP Duration RTS Threshold subfield contains the TXOP duration RTS threshold in units of 32 μs, which enables the use of RTS/CTS, except for the value 1023. The value 1023 indicates that TXOP duration-based RTS is disabled. The value of 0 is allowed in Beacon and Probe Response frames and indicates that the previously announced TXOP duration RTS threshold remains in effect. In all other frames, the value of 0 is reserved.

The VHT Operation Information Present subfield is set to 1 to indicate that the VHT Operation Information field is present in the HE Operation element and set to 0 otherwise. The VHT Operation Information Present subfield is set as defined in 26.17 (HE BSS operation).

The Co-Hosted BSS subfield is set to 1 to indicate that the AP transmitting this element (#1086)has dot11MultiBSSIDImplemented false or not present and shares the same operating class, channel, receive antenna connector, and transmit antenna connector with at least one other AP that is providing its BSS information by transmitting Beacon and Probe Response frames. Otherwise, the subfield is set to 0. (#1086)A TDLS STA, an IBSS STA, or a mesh STA sets the subfield to 0.

NOTE—1 An AP operating in the 6 GHz band sets the Co-Hosted BSS subfield to 0 (see 26.17.2.1 (General)).(#1086)

The ER SU Disable subfield indicates whether 242-tone HE ER SU PPDU reception by the AP is disabled or enabled. The ER SU Disable subfield is set to 1 to indicate that it is disabled and set to 0 to indicate that it is enabled.

The 6 GHz Operation Information Present field is set to 1 to indicate that the 6 GHz Operation Information field is present and set to 0 otherwise. The 6 GHz Operation Information Present field is set to 1 by an AP operating in the 6 GHz band.

The BSS Color Information field is defined in Figure 9-905 (BSS Color Information field format(11ax)).

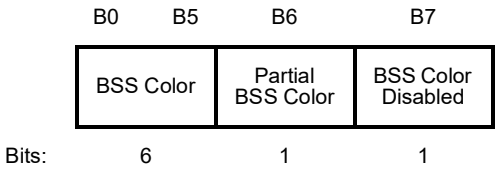


**Figure 9-905—BSS Color Information field format(11ax)**

The BSS Color subfield is an unsigned integer whose value is the BSS Color of the BSS corresponding to the AP, IBSS STA, mesh STA or TDLS STA that transmitted this element and is set as defined in 26.17.3 (BSS color).

The Partial BSS Color subfield is set to 1 to indicate that an AID assignment rule based on the BSS color as defined in 26.17.4 (AID assignment) is applied for the BSS. Otherwise, the Partial BSS Color subfield is set to 0.

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The BSS Color Disabled subfield is set to 1 to disable the use of color for the BSS as described in 26.17.3.3 (Disabling BSS color); otherwise, it is set to 0.

The Basic HE-MCS And NSS Set field indicates the HE-MCSs for each number of spatial streams in HE PPDUs that are supported by all HE STAs in the BSS (including IBSS and MBSS) in transmit and receive. The Basic HE-MCS And NSS Set field is defined in Table 9-378 (Rx HE-MCS Map subfield, Tx HE-MCS Map subfield, and Basic HE-MCS And NSS Set field format(11ax)).

The format of the VHT Operation Information field is defined in Figure 9-709 (VHT Operation Information field format) and its subfields are defined in Table 9-214 (HT/VHT Operation Information subfields). The VHT Operation Information field is present if the VHT Operation Info Present field is 1; otherwise, it is not present.

The Max Co-Hosted BSSID Indicator field contains a value assigned to $n$, where $2^n$ is the maximum number of BSSIDs in the co-hosted BSSID set as defined in 26.17.7 (Co-hosted BSSID set). This field is present if the Co-Hosted BSS subfield in HE Operation Parameters field is 1 and is not present otherwise.

NOTE 2—The Max Co-Hosted BSSID Indicator field does not provide the exact number or the identity of each co-hosted BSSID.

The 6 GHz Operation Information field provides channel and bandwidth information related to 6 GHz operation (see 27.3.25.2 (Channel allocation in the 6 GHz band)). The format of the 6 GHz Operation Information field is defined in Figure 9-906 (6 GHz Operation Information field format(11ax)).

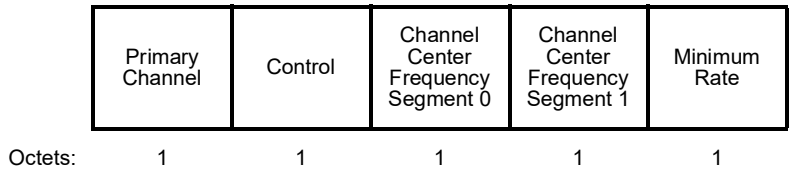


**Figure 9-906—6 GHz Operation Information field format(11ax)**

The Primary Channel field indicates the channel number of the primary channel in the 6 GHz band.

The Control field is defined in Figure 9-907 (Control field format(#6077)(11ax)).

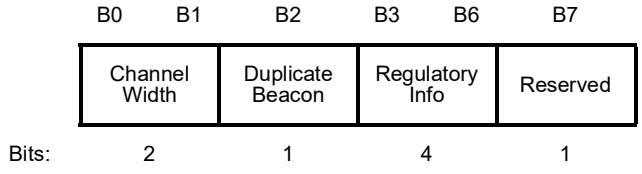


**Figure 9-907—Control field format(#6077)(11ax)**

The Channel Width field indicates the BSS channel width and is set to 0 for 20 MHz, 1 for 40 MHz, 2 for 80 MHz, and 3 for 80+80 or 160 MHz.

The Duplicate Beacon subfield is set to 1 if the AP transmits Beacon frames in non-HT duplicate PPDU with a TXVECTOR parameter CH_BANDWIDTH value that is up to the BSS bandwidth and is set to 0 otherwise.


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The Regulatory Info subfield carries information related to regulatory rules specific to the country in which the BSS is operating in, which is identified by the Country String field in the Country element. The interpretation of the Regulatory Info subfield is in E.2.7 (6 GHz band(11ax)(#600)).(#3789)

The Channel Center Frequency Segment 0 field indicates the channel number of the center frequency(#6420) for the 20 MHz, 40 MHz, 80 MHz, 160 MHz, or 80+80 MHz channel on which the BSS operates in the 6 GHz band. If the BSS channel width is 160 MHz or 80+80 MHz, then the Channel Center Frequency Segment 0 field indicates the channel number of the center frequency(#6420) of the primary 80 MHz.

The Channel Center Frequency Segment 1 field indicates the channel number of the center frequency(#6420) of the 160 MHz channel on which the BSS operates in the 6 GHz band. If the channel width is 80+80 MHz, then it indicates the channel number of the center frequency(#6420) of the secondary 80 MHz.

The Minimum Rate field indicates the minimum rate, in units of 1 Mb/s, that the non-AP STA is allowed to use for sending PPDUs (see 26.15.4.3 (Additional rate selection constraints for HE PPDUs)), where the rate is obtained with an $N_{SS}$ that is less than or equal to 3 and an MCS that is less than or equal to 3.

### 9.4.2.249 UORA Parameter Set element(11ax)

The metrics of the OFDMA-based random access mechanism (see 26.5.4 (UL OFDMA-based random access (UORA))) are signaled in the UORA Parameter Set element. The format of the UORA Parameter Set element is defined in Figure 9-908 (UORA Parameter Set element format(11ax)).

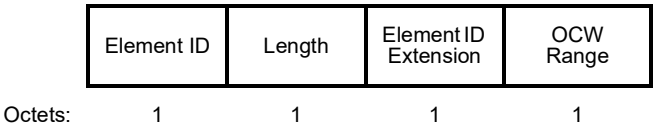


**Figure 9-908—UORA Parameter Set element format(11ax)**

The Element ID, Length, Element ID Extension fields are defined in 9.4.2.1 (General).

The OCW Range field indicates the minimum and maximum values of the OCW (OFDMA contention window) derived from the fields defined in Figure 9-909 (OCW Range field format(11ax)).

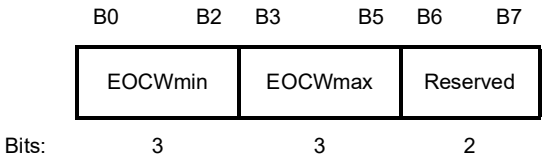


**Figure 9-909—OCW Range field format(11ax)**

The EOCWmin subfield indicates the minimum value of OCW for the initial HE TB PPDU transmission using UORA. The *OCWmin* parameter is used by a STA either for an initial transmission or following a successful HE TB PPDU transmission and is derived as follows:

$$OCWmin = 2^{EOCWmin} - 1$$

where

*EOCWmin* is the value in the EOCWmin subfield

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The EOCWmax subfield indicates the maximum value of OCW for UORA. The *OCWmax* parameter used by a STA for its retransmission attempts of UORA and is derived as follows:

$$OCWmax = 2^{EOCWmax} - 1$$

where
*EOCWmax* is the value in the EOCWmax subfield

### 9.4.2.250 MU EDCA Parameter Set element(11ax)

In an infrastructure BSS, the MU EDCA Parameter Set element is used by the AP to control the use of EDCA by non-AP HE STAs following particular UL MU HE TB PPDU transmissions, as defined in 26.2.7 (EDCA operation using MU EDCA parameters). The most recent MU EDCA Parameter Set element received by a non-AP HE STA is used to update the appropriate MIB values.

The format of the MU EDCA Parameter Set element is defined in Figure 9-910 (MU EDCA Parameter Set element format(11ax)).

| | Element ID | Length | Element ID Extension | QoS Info | MU AC_BE Parameter Record | MU AC_BK Parameter Record | MU AC_VI Parameter Record | MU AC_VO Parameter Record |
|---|---|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 1 | 3 | 3 | 3 | 3 |

**Figure 9-910—MU EDCA Parameter Set element format(11ax)**

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

The format of the QoS Info field is defined in 9.4.1.17 (QoS Info field) when sent by the AP.

NOTE—The QoS Info field contains the EDCA Parameter Set Update Count subfield, which indicates when the EDCA parameters and, for an HE BSS, the MU EDCA parameters have changed (see 10.2.3.2 (HCF contention based channel access (EDCA))).

The format of the MU AC_BE, MU AC_BK, MU AC_VI, and MU AC_VO Parameter Record fields are identical and defined in Figure 9-911 (MU AC Parameter Record field format(11ax)).

| | ACI/AIFSN | ECWmin/ ECWmax | MU EDCA Timer |
|---|---|---|---|
| Octets: | 1 | 1 | 1 |

**Figure 9-911—MU AC Parameter Record field format(11ax)**

The format of the ACI/AIFSN field is defined in Figure 9-262 and the encoding of its subfields is defined in 9.4.2.27 (EDCA Parameter Set element), except that the value 0 in the AIFSN field indicates that EDCA is disabled for the duration specified by the MUEDCATimer for the corresponding AC.

The format of the ECWmin/ECWmax field is defined in Figure 9-263, and the encoding of its subfields is defined in 9.4.2.27 (EDCA Parameter Set element).

The MU EDCA Timer field indicates the duration of time, in units of 8 TUs, during which the HE STA uses the MU EDCA parameters for the corresponding AC, as defined in 26.2.7 (EDCA operation using MU EDCA parameters), except that the value 0 is reserved.


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### 9.4.2.251 Spatial Reuse Parameter Set element(11ax)

The Spatial Reuse Parameter Set element provides information needed by STAs when performing OBSS PD-based spatial reuse as defined in 26.10.2 (OBSS PD-based spatial reuse operation) and PSR-based spatial reuse as defined in 26.10.3 (PSR-based spatial reuse operation). The format of the Spatial Reuse Parameter Set element is defined in Figure 9-912 (Spatial Reuse Parameter Set element format(11ax)).

| | Element ID | Length | Element ID Extension | SR Control | Non-SRG OBSS PD Max Offset | SRG OBSS PD Min Offset | SRG OBSS PD Max Offset | SRG BSS Color Bitmap | SRG Partial BSSID Bitmap |
|---|---|---|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 1 | 0 or 1 | 0 or 1 | 0 or 1 | 0 or 8 | 0 or 8 |

**Figure 9-912—Spatial Reuse Parameter Set element format(11ax)**

The Element ID, Element ID extension and Length fields are defined in 9.4.2.1 (General).

The SR Control field is defined in Figure 9-913 (SR Control field format(#3060)(11ax)).

| | B0 | B1 | B2 | B3 | B4 | B5 B7 |
|---|---|---|---|---|---|---|
| | PSR Disallowed | Non-SRG OBSS PD SR Disallowed | Non-SRG Offset Present | SRG Information Present | HESIGA Spatial Reuse Value15 Allowed | Reserved |
| Bits: | 1 | 1 | 1 | 1 | 1 | 3 |

**Figure 9-913—SR Control field format(#3060)(11ax)**

The PSR Disallowed subfield in the SR Control field indicates whether PSR-based SR transmissions are allowed at non-AP STAs that are associated with the AP that transmitted this element. PSR-based SR transmissions are disallowed when the PSR Disallowed subfield is 1. PSR-based SR transmissions are allowed when the PSR Disallowed subfield is 0. The PSR Disallowed subfield also affects the value of the SPATIAL_REUSE parameter of the TXVECTOR as described in 26.11.6 (SPATIAL_REUSE).

The Non-SRG OBSS PD SR Disallowed subfield in the SR Control field indicates whether non-SRG OBSS PD SR transmissions are allowed or not at non-AP STAs that are associated with the AP that transmitted this element. Non-SRG OBSS PD SR transmissions are disallowed when the Non-SRG OBSS PD SR Disallowed subfield is 1. Non-SRG OBSS PD SR transmissions are allowed when the Non-SRG OBSS PD SR Disallowed subfield is 0.

The Non-SRG Offset Present subfield in the SR Control field indicates whether the Non-SRG OBSS PD Max Offset field is present in the element. If the Non-SRG Offset Present subfield is 1, then the Non-SRG OBSS PD Max Offset field is present; otherwise, the Non-SRG OBSS PD Max Offset field is not present.

The SRG Information Present subfield in the SR Control field indicates whether the SRG OBSS PD Min Offset, SRG OBSS PD Max Offset, SRG BSS Color Bitmap, and SRG Partial BSSID Bitmap fields are present in the element. If the SRG Information Present subfield is 1, then the subfields are present; otherwise, the fields are not present.

The (#3060)HESIGA Spatial Reuse Value15 Allowed subfield in the SR Control field indicates whether non-AP STAs that are associated with the AP that transmitted this element can set the TXVECTOR

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parameter SPATIAL_REUSE to PSR_AND_NON_SRG_OBSS_PD_PROHIBITED. The subfield is set as described in 26.11.6 (SPATIAL_REUSE).

The Non-SRG OBSS PD Max Offset field contains an unsigned integer that is added to –82 dBm to generate the value of the Non-SRG OBSS PD Max parameter.

The SRG OBSS PD Min Offset field contains an unsigned integer that is added to –82 dBm to generate the value of the SRG OBSS PD Min parameter.

The SRG OBSS PD Max Offset field contains an unsigned integer that is added to –82 dBm to generate the value of the SRG OBSS PD Max parameter.

The SRG BSS Color Bitmap field is a bitmap that indicates the BSS color values used by members of the SRG of which the transmitting STA is a member. Each bit of the bitmap corresponds to one of the 64 BSS colors, where the lowest numbered bit corresponds to BSS color value 0 and the highest numbered bit corresponds to BSS color value 63. A BSS color value is used by at least one BSS that is a member of the same SRG of the transmitting STA if the corresponding bit of the bitmap is 1. If a bit in the bitmap is 0, then no BSS in the same SRG of the transmitting STA uses the corresponding BSS color value. The bit in the bitmap that corresponds to the BSS color value 0 is reserved.

The SRG Partial BSSID Bitmap field is a bitmap that indicates the Partial BSSID values used by members of the SRG of which the transmitting STA is a member. Each bit of the bitmap corresponds to one of the 64 possible values of BSSID[39:44], where the lowest numbered bit corresponds to Partial BSSID value 0 and the highest numbered bit corresponds to Partial BSSID value 63. A Partial BSSID value is used by at least one BSS that is a member of the same SRG of the transmitting STA if the corresponding bit of the bitmap is 1. If a bit in the bitmap is 0, then no BSS in the same SRG of the transmitting STA uses the corresponding Partial BSSID value.

### 9.4.2.252 NDP Feedback Report Parameter Set element(11ax)

The format of the NDP feedback report Parameter Set element is defined in Figure 9-914 (NDP Feedback Report Parameter Set element format(11ax)).

| | Element ID | Length | Element ID Extension | Resource Request Buffer Threshold Exponent |
|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 1 |

**Figure 9-914—NDP Feedback Report Parameter Set element format(11ax)**

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

The Resource Request Buffer Threshold Exponent field is used to calculate the buffer threshold between two different resource requests as defined in 26.5.7.4 (NDP feedback report for a resource request). The resource request buffer threshold value is equal to $2^{(\text{Resource Request Buffer Threshold Exponent})}$ octets.

The resource request buffer threshold is equal to 256 octets if no NDP Feedback Report Parameter Set element is sent by the AP.


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#### 9.4.2.253 BSS Color Change Announcement element(11ax)

The BSS Color Change Announcement element is used by an AP to advertise an upcoming BSS color change and (#6024)the corresponding new BSS color (see 26.17.3.4 (Selecting and advertising a new BSS color)). The format of the BSS Color Change Announcement element is shown in Figure 9-915 (BSS Color Change Announcement element format(11ax)).

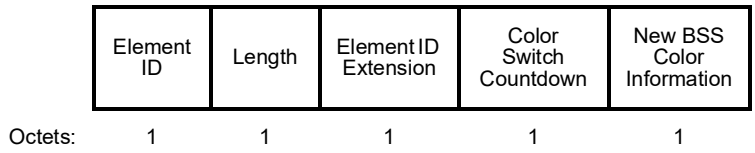


**Figure 9-915—BSS Color Change Announcement element format(11ax)**

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

The Color Switch Countdown field is set to the number of TBTTs until the HE AP sending the BSS Color Change Announcement element switches to the new BSS color. The value 1 indicates that the switch occurs at the next TBTT (the ensuing Beacon frame advertises in the BSS Color subfield of the BSS Color Information field the new BSS color). The value 0 is reserved.

The format of the New BSS Color Information field is defined in Figure 9-916 (New BSS Color Information field format(11ax)). The New BSS Color subfield is set to the new BSS color value that the HE AP intends to use starting from the TBTT at which the color switch countdown reaches 0.

**Figure 9-916—New BSS Color Information field format(11ax)**

#### 9.4.2.254 Quiet Time Period element(11ax)

##### 9.4.2.254.1 General

The format of the Quiet Time Period element is shown in Figure 9-917 (Quiet Time Period element format(11ax)).

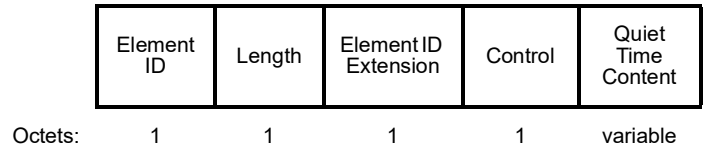


**Figure 9-917—Quiet Time Period element format(11ax)**

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

A one octet Control field specifies the subtype of the Quiet Time Period element. The two LSBs define the subtype and are referred to as the Quiet Time Period Subtype field. The remaining 6 bits are reserved.

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Table 9-381 (Quiet Time Period Subtype field encoding(11ax)) shows the encoding of the Quiet Time Period Subtype field.

**Table 9-381—Quiet Time Period Subtype field encoding(11ax)**

| Quiet Time Period Subtype field value | Meaning |
|---|---|
| 0 | Quiet Time Period Setup |
| 1 | Quiet Time Period Request |
| 2 | Quiet Time Period Response |
| 3 | Reserved |

The Quiet Time Content field is a variable length field and carries information of quiet time operation indicated by the value in the Control field.

### 9.4.2.254.2 Quiet Time Period Setup subtype

The Quiet Time Period Setup subtype defines a period of time for QTP (see 26.17.5 (Quiet HE STAs in an HE BSS)). The QTP can be used by an AP to mitigate interference by reducing the contention from HE STAs in a period that gives preference to HE STAs participating in the exchange of specific frames using peer-to-peer link.

The content of the Quiet Time Content subfield in the Quiet Time Period Setup subtype is shown Figure 9-918 (Quiet Time Content subfield format in Quiet Time Period Setup subtype(11ax)).

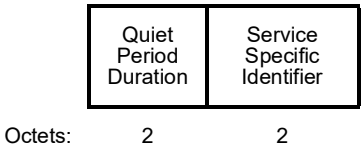


**Figure 9-918—Quiet Time Content subfield format in Quiet Time Period Setup subtype(11ax)**

The Quiet Period Duration field is set to the duration of the QTP, in units of 32 μs, that is no larger than the value indicated in the Quiet Period Interval subtype field of the Quiet Time Period Request subtype sent by the QTP requesting STA.

The Service Specific Identifier field contains an identifier assigned by a peer-to-peer application to identify specific (#109)frame exchange sequences using peer-to-peer links during which HE STAs that have requested participation of the specified (#109)frame exchange sequences might transmit frames during the quiet time period.

### 9.4.2.254.3 Quiet Time Period Request subtype

The Quiet Time Period Request subtype defines a periodic sequence of QTPs that the QTP requesting STA requests the QTP AP to schedule.


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The content of the Quiet Time Content subfield in the Quiet Time Period Request subtype is shown Figure 9-919 (Quiet Time Content subfield format in Quiet Time Period Request subtype(11ax)).

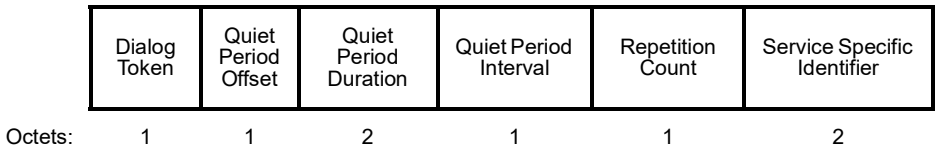


**Figure 9-919—Quiet Time Content subfield format in Quiet Time Period Request subtype(11ax)**

The Dialog Token field identifies the Quiet Time Period Response subtype to which the Quiet Time Period Request subtype corresponds.

The Quiet Period Offset field is set to the offset of the first QTP from the TBTT expressed in TUs.

The Quiet Period Interval field is set to the requested interval between the start of two consecutive QTPs, expressed in TUs.

The Quiet Period Duration field is set to the duration of the QTP in units of 32 μs.

The Repetition Count field is set to the number of requested QTPs. A repetition count equal to 0 indicates the setup time of the QTP is for an one time operation. Repetition count equals to 0xFF indicates the setup of the QTP is canceled.

The Service Specific Identifier field contains an identifier assigned by a peer-to-peer application to identify specific (#109)frame exchange sequences using peer-to-peer links during which HE STAs that have requested the participation of the specified (#109)frame exchange sequences might transmit frames during the quiet time period.

### 9.4.2.254.4 Quiet Time Period Response subtype

The Quiet Time Period Response subtype defines the feedback information from the AP that received the Quiet Time Period Request element. If an AP decides not to accept the value requested by the QTP requesting STA, the AP can set different values carried in the Quiet Period Response frame.

The content of the Quiet Time Content subfield in the Quiet Time Period Response subtype is shown in Figure 9-920 (Quiet Time Content subfield format in Quiet Time Period Response subtype(11ax)).

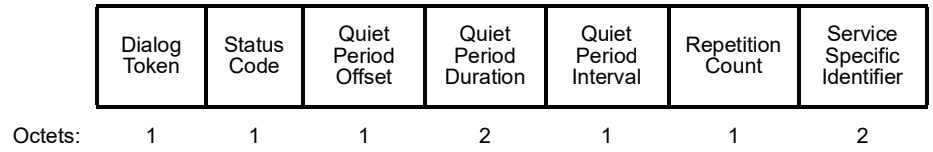


**Figure 9-920—Quiet Time Content subfield format in Quiet Time Period Response subtype(11ax)**

The Dialog Token field identifies the Quiet Time Period Request subtype to which this Quiet Time Period Response subtype corresponds.

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The Status Code field indicates the status of a requested operation. The value of the status code is shown in Table 9-382 (Status codes(11ax)).

**Table 9-382—Status codes(11ax)**

| Value | Meaning |
|---|---|
| 0 | Success |
| 1 | Reject |
| 2 | Counter |
| 3–255 | Reserved |

The Quiet Period Offset field is set to the offset of the first QTP from the TBTT expressed in TUs.

The Quiet Period Interval field is set to the interval between the start of two consecutive quiet time periods, expressed in TUs.

The Quiet Period Duration field is a one octet field with resolution of 32 μs.

The Repetition Count field is set to the number of requested QTPs.

The Service Specific Identifier field contains an identifier assigned by a peer-to-peer application to identify specific (#109)frame exchange sequences using peer-to-peer links which HE STAs that have requested the participation of the specific (#109)frame exchange sequences might transmit frames during the quiet time period.

### 9.4.2.255 ESS Report element(11ax)

The format of the ESS Report element is shown in Figure 9-921 (ESS Report element format(11ax)).

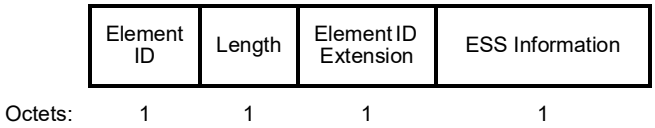


**Figure 9-921—ESS Report element format(11ax)**

The Element ID, Length and Element ID Extension fields are defined in 9.4.2.1 (General).

The format of the ESS Information field is defined in Figure 9-922 (ESS Information field format(11ax)).

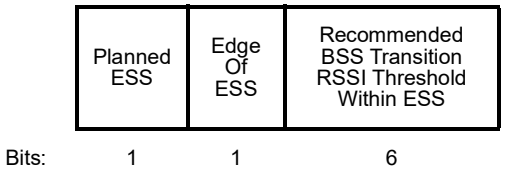


**Figure 9-922—ESS Information field format(11ax)**


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The Planned ESS subfield indicates whether the BSS is part of an ESS that is planned with several BSSs in an overlapping configuration. This subfield is set to 1 to indicate that the ESS is deployed to ensure blanket coverage over the extended service area(#3782). Otherwise, this subfield is set to 0 and the Edge Of ESS and Recommended BSS Transition RSSI Threshold Within ESS subfields are reserved.

The Edge Of ESS subfield indicates whether the BSS is at the edge of the ESS. This subfield is set to 1 to indicate the BSS is at the edge of the ESS. Otherwise, this subfield is set to 0.

The Recommended BSS Transition RSSI Threshold Within ESS subfield indicates the RSSI below which an associated STA is recommended to initiate BSS transition to a neighbor BSS belonging to the ESS.

The resolution for the Recommended BSS Transition RSSI Threshold Within ESS subfield is 1 dB. The encoding is defined in Table 9-383 (Recommended BSS Transition RSSI Threshold Within ESS subfield encoding(11ax)).

**Table 9-383—Recommended BSS Transition RSSI Threshold Within ESS subfield encoding(11ax)**

| Value | Description |
|---|---|
| 0–62 | –100 dBm to –38 dBm |
| 63 | No recommendation |

The use of the ESS Report element is described in 11.21.7.5 (Planned ESS(11ax)).

### 9.4.2.256 OPS element(11ax)

(#1776)The opportunistic power save (OPS) element provides information needed by STAs when operating with OPS as defined in 26.14.3 (Opportunistic power save). The format of the OPS element is shown in Figure 9-923 (OPS element format(11ax)).

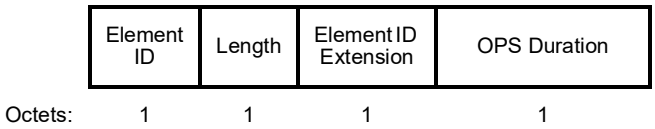


**Figure 9-923—OPS element format(11ax)**

The Element ID, Element ID extension and Length fields are defined in 9.4.2.1 (General).

If the OPS element is included in an OPS frame or a FILS Discovery frame, the OPS Duration field indicates the OPS period duration, during which a STA can go to doze state if it is explicitly not scheduled during that period, as defined in 26.14.3 (Opportunistic power save). The OPS Duration field is encoded in units of milliseconds.

### 9.4.2.257 TWT Constraint Parameters element(11ax)

The TWT Constraint Parameters element provides TWT constraint parameters that can be used during the establishment of individual TWT agreements and/or broadcast TWT schedules. The format of the TWT

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Constraint Parameters element is shown in Figure 9-924 (TWT Constraint Parameters element format(11ax)).

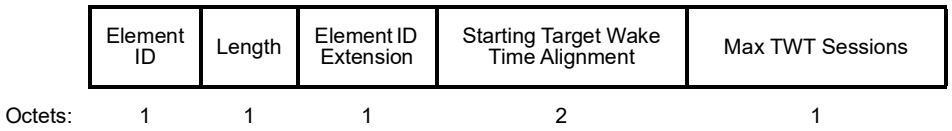


**Figure 9-924—TWT Constraint Parameters element format(11ax)**

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).(#7057)

The Starting Target Wake Time Alignment field contains a positive integer *n* that indicates a recommended time for the start of the first TWT SP of a TWT agreement. A value of *n* indicates that the first start time is recommended to be an integer multiple of *n* + 1 TUs [i.e., (Target Wake Time) mod (*n* + 1) = 0].

The Max TWT Sessions field contains the maximum number of TWT sessions that a STA is capable of establishing with a peer STA.

### 9.4.2.258 HE BSS Load element(11ax)

The HE BSS Load element reported by the AP contains information on utilization, frequency underutilization and spatial stream underutilization. The element format is defined in Figure 9-925 (HE BSS Load element format(11ax)). A STA receiving the element might use the information it conveys in an (M118)implementation specific AP selection algorithm.

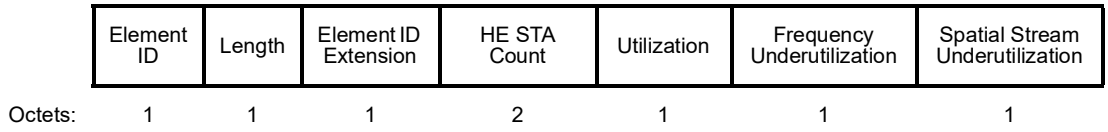


**Figure 9-925—HE BSS Load element format(11ax)**

The Element ID, Length and Element ID extension fields are defined in 9.4.2.1 (General).(#4188)

The HE STA Count field indicates the total number of STAs currently associated with this BSS that declare that they are HE STAs by transmitting their HE Capabilities elements.

The Utilization field is defined as the fraction of time, linearly scaled with 255 representing 100%, that the AP sensed the medium was busy due to a transmission between the AP and HE STAs, as indicated by the physical carrier sense (CS) mechanism. When more than one channels are in use for the BSS, the Utilization field value is calculated only for the primary channel. This field value is computed using Equation (9-7).

$$\text{Utilization} = \left\lfloor \frac{T_{busy}}{\text{dot11ChannelUtilizationBeaconInterval} \times \text{dot11BeaconPeriod} \times 1024} \times 255 \right\rfloor \quad (9\text{-}7)$$

The Frequency Underutilization field is defined as the fraction of time, linearly scaled with 255 representing 100%, that the AP has underutilized frequency domain resources for given busy time of the medium. This field value is computed using Equation (9-8).


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$$\text{Frequency Underutilization} = \left\lfloor \frac{T_{busy} - \sum_{i=1}^{N} \left\{ \left( \sum_{j=1}^{N_{RU}} B_{j,i} \times RU_j \right) \times T_i \right\}}{T_{busy}} \times 255 \right\rfloor \quad (9\text{-}8)$$

The Spatial Stream Underutilization field is defined as the fraction of time, linearly scaled with 255 representing 100%, that the AP has underutilized spatial domain resources for given busy time of the medium. This percentage is computed using Equation (9-9).

$$\text{Spatial Stream Underutilization} = \left\lfloor \frac{N_{maxSS} \times T_{busy} - \sum_{i=1}^{N} \left\{ \left( \sum_{j=1}^{N_{RUM}} N_{SS,j,i} \times RUM_j \right) \times T_i \right\}}{N_{maxSS} \times T_{busy}} \times 255 \right\rfloor \quad (9\text{-}9)$$

where

dot11ChannelUtilizationBeaconIntervals
: represents the number of consecutive beacon intervals during which the channel busy time is measured ((#4128)see 9.4.2.26 (BSS Load element)).

$T_{busy}$
: is the number of microseconds during which CCA indicated the channel was busy due to a transmission between the AP and HE STAs during the measurement duration. The resolution of the CCA busy measurement is in microseconds

$T_i$
: is the time interval, in units of microseconds, during which the primary 20 MHz channel is busy due to a transmission between the AP and HE STAs

$N$
: is the number of busy events that occurred during the total measurement time that is less than or equal to dot11ChannelUtilizationBeaconIntervals consecutive beacon intervals

$N_{RU}$
: is the number of RUs that are allocated within the BSS bandwidth during time interval $T_i$

$RU_j$
: is a normalizing factor depending on the RU size and equals the ratio of the $j^{th}$ RU size to the maximum RU size within the BSS bandwidth, i.e., if the $j^{th}$ RU is a 26-tone RU and the BSS bandwidth is 20 MHz, then $RU_j = 26/242$

$B_{j,i}$
: is 1 if the $j^{th}$ RU is occupied or interfered in the busy time $T_i$; otherwise, it is set to 0(#464). Any 20 MHz subchannels that are not occupied by a PPDU are regarded as interfered RUs if the bandwidth of PPDU is less than the BSS bandwidth.

$N_{maxSS}$
: is the maximum number of spatial streams supported by the AP

$N_{RUM}$
: is the number of RUs with a size of at least 106 tones and that are allocated within the BSS bandwidth during time interval $T_i$

$RUM_j$
: is a normalizing factor depending on the RU size. RUM is applied to RUs with a size of at least 106 tones and equals the ratio of the $j^{th}$ RU size to the maximum RUM size within the BSS bandwidth, i.e., if the $j^{th}$ RUM is a 106-tone RU and the BSS bandwidth is 20 MHz, then $RUM_j = 106/242$.

$N_{SS,j,i}$
: is the number of streams over the $j^{th}$ RUM in the busy time $T_i$.

If $T_{busy}$ is 0, the Utilization field, Frequency Underutilization field and Spatial Stream Underutilization field are reserved.

### 9.4.2.259 Multiple BSSID Configuration element(11ax)

The Multiple BSSID Configuration element is used to provide configuration information for a multiple (#6003)BSSID set (see 11.1.3.8.3 (Discovery of a nontransmitted BSSID profile(11ax))) or to carry information related to the index adjustment procedure (see 11.1.3.8.6 (Multiple BSSID Index Adjustment Procedure(#3018))) or both.(#6002)

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The format of the Multiple BSSID Configuration element is shown in Figure 9-926 (Multiple BSSID Configuration element format(11ax)).

| | Element ID | Length | Element ID Extension | BSSID Count | Full Set Rx Periodicity | Index Adjustment Factor(#3018) | Index Adjustment TBTT Count(#3018) |
|---|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 1 | 1 | 0 or 1 | 0 or 1 |

**Figure 9-926—Multiple BSSID Configuration element format(11ax)**

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

The BSSID Count field carries the total number of active BSSIDs in the multiple BSSID set.

The Full Set Rx Periodicity field indicates the minimum number of Beacon frames or DMG Beacon frames a non-AP STA performing scanning procedures needs to receive in order to discover all the active nontransmitted BSSIDs in the set.(M165)

NOTE—A non-AP STA is expected to know the profile periodicity of its associated AP. When its associated AP's profile is expected to be absent, the non-AP STA can choose to not process either the Beacon frame from the transmitted BSSID in the multiple BSSID set or the Multiple BSSID element within a Beacon frame from the transmitted BSSID.(M165)

(#3018)The Index Adjustment Factor field if present is set to the value by which the BSSID index of each BSSID in a multiple BSSID set will be adjusted according to the procedures defined in 11.1.3.8.6 (Multiple BSSID Index Adjustment Procedure(#3018)). The value 0 indicates there is no adjustment.

(#3018)(#4002)(#7220)The Index Adjustment TBTT Count field is present if the Index Adjustment Factor field is present and nonzero; otherwise it is not present. When present, the Index Adjustment Factor field is set to the number of TBTTs until a BSSID index adjustment occurs (as described in 11.1.3.8.6 (Multiple BSSID Index Adjustment Procedure(#3018))). A value of 1 indicates that the switch occurs at the next TBTT, and the corresponding Beacon, DMG Beacon or S1G Beacon frame is transmitted by the BSSID whose adjusted BSSID index value is 0 (i.e., the BSSID that takes on the transmitted BSSID role). The value 0 is reserved.

### 9.4.2.260 Known BSSID element

The Known BSSID element identifies the nontransmitted BSSIDs that a non-AP STA has discovered so far. A non-AP STA can include this element in a directed Probe Request frame to discover other nontransmitted BSSIDs not known to the requesting STA.

The format of the Known BSSID element is defined in Figure 9-927 (Known BSSID element format(11ax)).

| | Element ID | Length | Element ID Extension | BSSID Bitmap |
|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | variable |

**Figure 9-927—Known BSSID element format(11ax)**

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).


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The format of the BSSID Bitmap field is as defined in Figure 9-928 (BSSID Bitmap field format(11ax)).

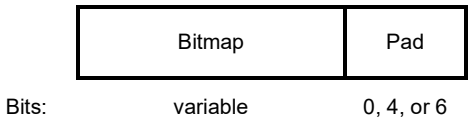


**Figure 9-928—BSSID Bitmap field format(11ax)**

The Bitmap subfield has a length of $2^n$ bits where $n$ is the value carried in the MaxBSSID Indicator field of the Multiple BSSID element advertised by the AP to which the Probe Request frame is being sent. Bit position 0 is reserved. The remainder of the bits represent one of $2^n - 1$ possible BSSID Index values (see 9.4.2.72 (Multiple BSSID-Index element)) in the multiple BSSID set. A value of 1 at bit position $k$ indicates that the non-AP STA has knowledge of nontransmitted BSSID with BSSID index $k$. Otherwise, the bit is set to 0.

The Pad subfield contains additional bits set to 0 to make the total number of bits in the BSSID Bitmap field equal to an integer number of octets.

### 9.4.2.261 Short SSID List element(11ax)

The format of the Short SSID List Element is shown in Figure 9-929 (Short SSID List element format(11ax)).

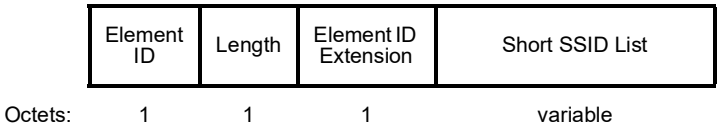


**Figure 9-929—Short SSID List element format(11ax)**

The Element ID, Length and Element ID Extension fields are defined in 9.4.2.1 (General).

The Short SSID List field contains the one or more Short SSID fields for which the STA is requesting information. The use of the Short SSID List element and frames is described in 11.1.4.3.2 (Active scanning procedure for a non-DMG STA). (#7151)The Short SSID field is defined in 9.4.1.71 (Short SSID field(#7151)).

### 9.4.2.262 HE 6 GHz Band Capabilities element(11ax)

An HE STA operating in the 6 GHz band declares its extended capabilities by transmitting the HE 6 GHz Band Capabilities element. The HE 6 GHz Band Capabilities element is defined in Figure 9-930 (HE 6 GHz Band Capabilities element format(11ax)).

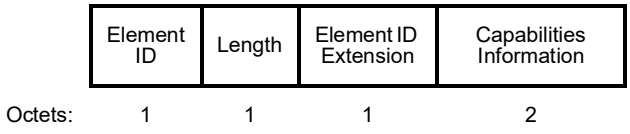


**Figure 9-930—HE 6 GHz Band Capabilities element format(11ax)**

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

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The Capabilities Information field is defined in Figure 9-931 (Capabilities Information field format(11ax)).

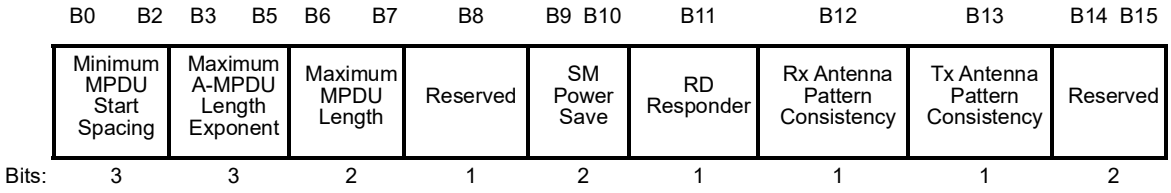


**Figure 9-931—Capabilities Information field format(11ax)**

The Minimum MPDU Start Spacing subfield is defined in 9.4.2.55.3.

The Maximum A-MPDU Length Exponent subfield and Maximum MPDU Length subfield are defined in (#2317)Table 9-313 (Subfields of the VHT Capabilities Information field)

The SM Power Save subfield is defined in defined in Table 9-224 (Subfields of the HT Capability Information field).

The RD Responder subfield is defined in defined in Table 9-227 (Subfields of the HT Extended Capabilities field).

The Rx Antenna Pattern Consistency subfield is defined in defined in Table 9-313 (Subfields of the VHT Capabilities Information field).

The Tx Antenna Pattern Consistency subfield is defined in defined in Table 9-313 (Subfields of the VHT Capabilities Information field).

### 9.4.2.263 UL MU Power Capabilities element(11ax)

The UL MU Power Capabilities element indicates the relative maximum transmit power that a STA is capable of transmitting an HE TB PPDU for each HE-MCS when using RU size greater than or equal to 242 subcarriers. The format of the UL MU Power Capabilities element is shown in Figure 9-932 (UL MU Power Capabilities element format(11ax)).

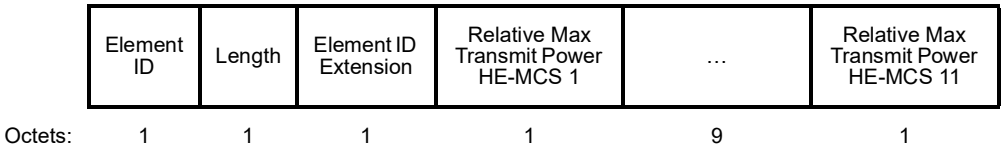


**Figure 9-932—UL MU Power Capabilities element format(11ax)**

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

The UL MU Power Capabilities element contains 11 Relative Max Transmit Power HE-MCS *n* fields in ascending order of HE-MCS from 1 to 11.

The Relative Max Transmit Power HE-MCS *n* field (where $n = 1, \ldots, 11$) is an unsigned integer in dB and contains the difference between the nominal maximum transmit power in dBm of an HE TB PPDU using an RU size greater than or equal to 242 subcarriers for HE-MCS 0 and that for HE-MCS *n*. The Relative Max Transmit Power HE-MCS *n* fields corresponding to HE-MCSs that are not supported by the HE STA that transmits this element are reserved.


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### 9.4.2.264 EDMG Capabilities element(11ay)

#### 9.4.2.264.1 General

A non-AP EDMG STA or a non-PCP EDMG STA declares that it is an EDMG STA by transmitting the EDMG Capabilities element.

The format of the EDMG Capabilities element is shown in Figure 9-933 (EDMG Capabilities element format(11ay))(M118).

| | Element ID | Length | Element ID Extension | Core Capabilities | Optional Subelements |
|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 6 | variable(M118) |

**Figure 9-933—EDMG Capabilities element format(11ay)**

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

The Core Capabilities field is defined in Figure 9-934 (Core Capabilities field format(11ay)).

| | B0 B6 | B7 B18 | B19 B42 | B43 B47 |
|---|---|---|---|---|
| | A-MPDU Parameters | TRN Parameters | Supported MCS | Reserved |
| Bits: | 7 | 12 | 24 | 5 |

**Figure 9-934—Core Capabilities field format(11ay)**

The A-MPDU Parameters field is defined in Figure 9-935 (A-MPDU Parameters field format(11ay)). The definition of the subfields of the A-MPDU Parameters field is shown in Table 9-384 (A-MPDU Parameters field definition(11ay)).

| | B0 B3 | B4 B6 |
|---|---|---|
| | Maximum A-MPDU Length Exponent | Minimum MPDU Start Spacing |
| Bits: | 4 | 3 |

**Figure 9-935—A-MPDU Parameters field format(11ay)**

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**Table 9-384—A-MPDU Parameters field definition(11ay)**

| Subfield | Definition | Encoding |
|---|---|---|
| Maximum A-MPDU Length Exponent | Indicates the maximum length of A-MPDU that the STA can receive. | This subfield is an integer in the range 0 to 9. The length defined by this subfield is equal to: $2^{(13 + \text{Maximum A-MPDU Length Exponent})} - 1$ octets. |
| Minimum MPDU Start Spacing | Determines the minimum time between the start of adjacent MPDUs within an A-MPDU that the STA can receive, measured at the PHY SAP. | Set to 0 for no restriction.<br>Set to 1 for 8 ns.<br>Set to 2 for 16 ns.<br>Set to 3 for 32 ns.<br>Set to 4 for 64 ns.<br>Set to 5 for 128 ns.<br>Set to 6 for 256 ns.<br>Set to 7 for 512 ns. |

The TRN Parameters field is defined in Figure 9-936 (TRN Parameters field format(11ay)).

| | B0 | B1 | B2 | B3 | B4 | B5 | B6 | B7 | B8 | B9 | B10 | B11 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | TP1 | TP4 | TN2 | TN4 | TN8 | RP1 | RP4 | RN2 | RN4 | RN8 | Short TRN | Long TRN |
| Bits: | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

**Figure 9-936—TRN Parameters field format(11ay)**

The TP1 subfield indicates that the STA is capable of transmitting an EDMG PPDU with TXVECTOR parameter EDMG_TRN_P equal to 1.

The TP4 subfield indicates that the STA is capable of transmitting an EDMG PPDU with TXVECTOR parameter EDMG_TRN_P equal to 4.

The TN2 subfield indicates that the STA is capable of transmitting an EDMG PPDU with TXVECTOR parameter EDMG_TRN_N equal to 2.

The TN4 subfield indicates that the STA is capable of transmitting an EDMG PPDU with TXVECTOR parameter EDMG_TRN_N equal to 4.

The TN8 subfield indicates that the STA is capable of transmitting an EDMG PPDU with TXVECTOR parameter EDMG_TRN_N equal to 8.

The RP1 subfield indicates that the STA is capable of receiving an EDMG PPDU with RXVECTOR parameter EDMG_TRN_P equal to 1.

The RP4 subfield indicates that the STA is capable of receiving an EDMG PPDU with RXVECTOR parameter EDMG_TRN_P equal to 4.

The RN2 subfield indicates that the STA is capable of receiving an EDMG PPDU with RXVECTOR parameter EDMG_TRN_N equal to 2.

The RN4 subfield indicates that the STA is capable of receiving an EDMG PPDU with RXVECTOR parameter EDMG_TRN_N equal to 4.


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The RN8 subfield indicates that the STA is capable of receiving an EDMG PPDU with RXVECTOR parameter EDMG_TRN_N equal to 8.

The Short TRN subfield is set to 1 to indicate that the STA is capable of receiving TRN subfields based on short Golay sequences (see 28.9.2.2.6 (TRN subfield definition for EDMG SC PPDUs and EDMG control mode PPDUs)) in SC mode or short TRN subfields (see 28.9.2.2.7 (TRN subfield definition for EDMG OFDM PPDUs)) in OFDM mode; otherwise, it is set to 0.

The Long TRN subfield is set to 1 to indicate that the STA is capable of receiving TRN subfields based on long Golay sequences (see 28.9.2.2.6 (TRN subfield definition for EDMG SC PPDUs and EDMG control mode PPDUs)) in SC mode or long TRN subfields (see 28.9.2.2.7 (TRN subfield definition for EDMG OFDM PPDUs)) in OFDM mode; otherwise, it is set to 0.

The Supported MCS field is defined in Figure 9-937 (Supported MCS field format(11ay)).

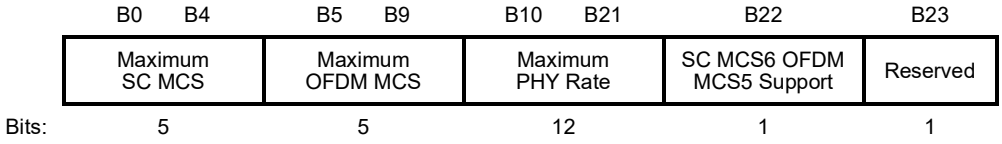


**Figure 9-937—Supported MCS field format(11ay)**

The Maximum SC MCS subfield contains the index of the highest supported receive EDMG SC mode MCS, including with NUC if supported.(#2327) The mandatory EDMG SC mode MCSs are not impacted by the value of this subfield.

The Maximum OFDM MCS subfield contains the index of the highest supported receive EDMG OFDM mode MCS. A value of zero indicates that the EDMG OFDM mode is not supported.

The Maximum PHY Rate subfield contains the maximum PHY data rate, in units of 100 Mb/s, that the STA supports in receive mode, over all supported channel bandwidths and number of spatial streams. This PHY data rate can be lower than the data rate provided by the maximum supported MCS when used with a combination of the largest supported channel bandwidth and the maximum number of supported spatial streams.

The SC MCS6 OFDM MCS5 Support subfield is set to 1 to indicate that MCS 6 of the EDMG SC mode and MCS 5 of the EDMG OFDM mode are supported in SISO. Otherwise, this subfield is set to 0.

The Optional Subelements field contains zero or more subelements. The subelement format and ordering of subelements are defined in 9.4.3 (Subelements).

The Subelement ID field values for the defined subelements are shown in Table 9-385 (Optional subelement IDs(11ay)). A subelement does not appear more than once in the EDMG Capabilities element. If a subelement corresponding to a Subelement ID is not present in a transmitted EDMG Capabilities element, the transmitting STA does not support any of the mechanisms defined within this subelement.

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**Table 9-385—Optional subelement IDs(11ay)**

| Subelement ID | Name | Extensible |
|---|---|---|
| 0 | Beamforming Capability | Yes |
| 1 | Antenna Polarization Capability | Yes |
| 2 | PHY Capabilities | Yes |
| 3 | Supported Channels | Yes |
| 4 | MAC Capabilities | Yes |
| 5–255 | Reserved | |

### 9.4.2.264.2 Beamforming Capability subelement

The Data field of the Beamforming Capability subelement is defined in Figure 9-938 (Data field of the Beamforming Capability subelement format(11ay)(11az)).

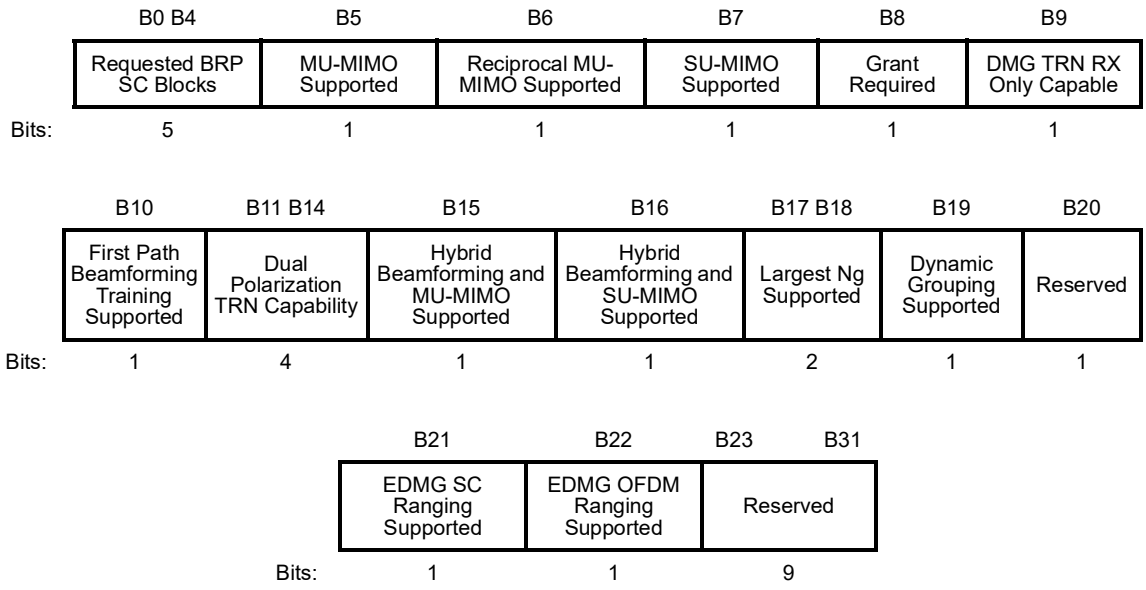


**Figure 9-938—Data field of the Beamforming Capability subelement format(11ay)(11az)**

The Requested BRP SC Blocks subfield indicates the minimum number of data SC blocks that the STA requests be included in a PPDU carrying a TRN field and transmitted to the STA. The value of this subfield is set to dot11RequestedBRPMinDataLength. If the PPDU is an OFDM mode PPDU, the minimum number of OFDM symbols is calculated as described in 28.9.2.2.4 (EDMG BRP PPDU duration).

The MU-MIMO Supported subfield indicates if the STA supports the DL MU-MIMO protocol including the MU-MIMO beamforming protocol described in 10.41.10.2.3 (MU-MIMO beamforming). This subfield is set to 1 if dot11EDMGMIMOSupport is either muAndSuMimo (2) or reciprocalMuMimoAndSuMimo (3), and is set to 0 otherwise.

The Reciprocal MU-MIMO Supported subfield indicates if the STA supports the reciprocal MU-MIMO protocol specified in 10.41.10.2.3 (MU-MIMO beamforming). This subfield is set to 1 if


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dot11EDMGMIMOSupport is reciprocalMuMimoAndSuMimo (3), and is set to 0 otherwise. This subfield is reserved if the MU-MIMO Supported field is 0.

The SU-MIMO Supported subfield indicates if the STA supports the SU-MIMO protocol including the SU-MIMO beamforming protocol described in 10.41.10.2.2 (SU-MIMO beamforming). This subfield is set to 1 if dot11EDMGMIMOSupport is suMimoOnly (1), and is set to 0 otherwise.

The Grant Required subfield indicates if the STA requires reception of a Grant frame to set up a MIMO configuration. This subfield is set to 1 if dot11EDMGBFGrantRequired is true, and is set to 0 otherwise. The Grant Required subfield is reserved if both the MU-MIMO Supported subfield and the SU-MIMO Supported subfield are set to 0.

The DMG TRN RX Only Capable subfield indicates if the STA is capable of receiving only DMG TRNs as defined in 20.9.2.2.2 (BRP PPDU structure), even when such TRNs are appended to an EDMG PPDU (see 28.9.2.2.3 (EDMG BRP PPDU Header field(#6409))). This subfield is set to 1 if dot11EDMGBFDMGTRNRXOnlyImplemented is true. Otherwise, this subfield is set to 0.

The First Path Training Supported subfield indicates if the STA supports the first path beamforming training procedure defined in 10.41.10.6 (First path beamforming training). This subfield is set to 1 if dot11FirstPathTrainingImplemented is true, and is set to 0 otherwise.

The Dual Polarization TRN Capability subfield is formatted as shown in Figure 9-939 (Dual Polarization TRN Capability subfield format(11ay)).

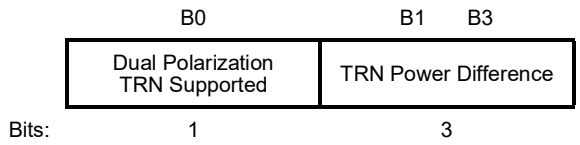


**Figure 9-939—Dual Polarization TRN Capability subfield format(11ay)**

The Dual Polarization TRN Supported subfield is set to 1 to indicate that the repetition of the same TRN subfield with different polarizations, as specified in 10.41.10.7 (Dual polarization TRN beamforming training), is supported by the STA both for transmit and receive. Otherwise, it is set to 0.

The TRN Power Difference subfield indicates the difference, in dB, between the radiated power of consecutive TRN subfields transmitted with the same AWV but with different polarizations. The encoding of the radiated power difference is shown in Table 9-386 (Encoding of TRN Power Difference subfield(11ay)).

**Table 9-386—Encoding of TRN Power Difference subfield(11ay)**

| TRN Power Difference subfield encoding | TRN power difference between the first TRN polarization and the second TRN polarization (dB) |
|---|---|
| 0(#1271) | 0 |
| 1(#1271) | 1 |
| 2(#1271) | 2 |
| 3(#1271) | 3 or higher |

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**Table 9-386—Encoding of TRN Power Difference subfield(11ay)**

| TRN Power Difference subfield encoding | TRN power difference between the first TRN polarization and the second TRN polarization (dB) |
|---|---|
| 5(#1271) | –1 |
| 6(#1271) | –2 |
| 7(#1271) | –3 |
| 4(#1271) | –4 or lower |

The MU-MIMO Supported subfield and the Hybrid Beamforming and MU-MIMO Supported subfield indicates if the STA supports the hybrid beamforming protocol during MU-MIMO transmission, including the hybrid beamforming protocol described in 10.41.10.2.4 (Hybrid beamforming for SU-MIMO and MU-MIMO). This subfield is set to 1 if dot11EDMGHybridMUMIMOImplemented is true, and is set to 0 otherwise. The Hybrid Beamforming and MU-MIMO Supported subfield is reserved if the MU-MIMO Supported subfield is 0.

The SU-MIMO Supported subfield and Hybrid Beamforming and SU-MIMO Supported subfield indicates if the STA supports hybrid beamforming protocol during SU-MIMO transmission, including the hybrid beamforming protocol described in 10.41.10.2.4 (Hybrid beamforming for SU-MIMO and MU-MIMO). This subfield is set to 1 if dot11EDMGHybridSUMIMOImplemented is true, and is set to 0 otherwise. The Hybrid Beamforming and SU-MIMO Supported subfield is reserved if the SU-MIMO Supported subfield is 0.

The Largest Ng Supported subfield indicates largest value of $N_g$ that the EDMG STA supports for the beamforming feedback matrix (see 9.4.2.283 (Digital BF Feedback element(11ay))). This subfield is set to the value of dot11EDMGBFGrantLargestNgSupported, i.e., 0 for $N_g = 2$, set to 1 for $N_g = 4$, and set to 2 for $N_g = 8$. Value of 3 is reserved.

The Dynamic Grouping Supported subfield indicates if the EDMG STA supports dynamic grouping. The field is set to 1 if dot11EDMGBFDynamicGroupingImplemented is true, and is set to 0 otherwise.

(11az)The EDMG SC Ranging Supported subfield is set to 1 to indicate that the EDMG STA is capable of performing range measurement based on FTM using EDMG SC PPDUs. This subfield is set to 0 otherwise.

(11az)The EDMG OFDM Ranging Supported subfield is set to 1 to indicate that the EDMG STA is capable of performing range measurement based on FTM using EDMG OFDM PPDUs. This subfield is set to 0 otherwise. This field is reserved if the Maximum OFDM MCS subfield of the Supported MCS field is set to 0.


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### 9.4.2.264.3 Antenna Polarization Capability subelement

The Data field of the Antenna Polarization Capability subelement allows a STA to share its antenna polarization characteristics with other stations. The Antenna Polarization Capability field is defined in Figure 9-940 (Data field of the Antenna Polarization Capability subelement format(11ay)).

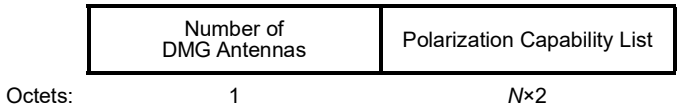


**Figure 9-940—Data field of the Antenna Polarization Capability subelement format(11ay)**

The value of the Number of DMG Antennas subfield plus one defines the combined total number, *N*, of RX and TX antennas of an EDMG STA.

The Polarization Capability List subfield contains *N* Polarization Capability subfields. Each Polarization Capability *i* subfield, $1 \le i \le N$, describes the polarization characteristics of the DMG antenna that is identified by index *i*. Each Polarization Capability *i* subfield is defined in Figure 9-941 (Polarization Capability subfield format(11ay)).

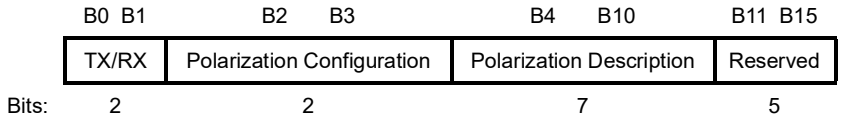


**Figure 9-941—Polarization Capability subfield format(11ay)**

The TX/RX subfield is set to 1 to indicate that the antenna is for both transmission and reception, is set to 2 to indicate that the antenna is for transmission only, and is set to 3 to indicate that the antenna is for reception only. Value 0 is reserved.

The Polarization Configuration subfield is set to 0 to indicate single polarization, is set to 1 to indicate polarization switch, is set to 2 to indicate synthesizable polarization, and is set to 3 to indicate MIMO dual polarization.

The definition of the Polarization Description subfield depends on the setting of the Polarization Configuration subfield.

If the value of the Polarization Configuration subfield is equal to single polarization or MIMO dual polarization, the Polarization Description subfield is set to 0 to indicate linear polarization, is set to 1 to indicate circular polarization and is set to 2 for mixed polarization. Other values are reserved.

If the value of the Polarization Configuration subfield is equal to synthesizable polarization, the Polarization Description subfield is set to 0 to indicate linear polarization, is set to 1 to indicate circular polarization, is set to 2 for mixed polarization, and is set to 3 to indicate support for both linear and circular polarization. Other values are reserved.

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If the value of the Polarization Configuration subfield is equal to polarization switch, the Polarization Description subfield is defined as shown in Figure 9-942 (Polarization Description subfield format(11ay)).

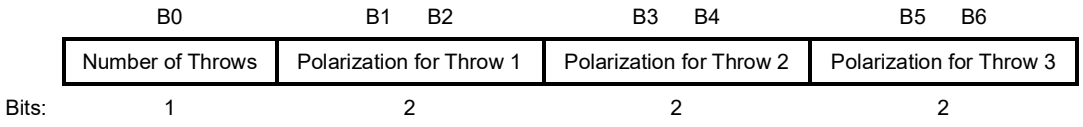


**Figure 9-942—Polarization Description subfield format(11ay)**

The Number of Throws subfield is set to 0 to indicate 2 throws and is set to 1 to indicate 3 throws. If the Number of Throws subfield is set to indicate 2 throws, the Polarization for Throw 3 subfield is reserved.

Each of Polarization for Throw 1 subfield, Polarization for Throw 2 subfield and Polarization for Throw 3 subfield is set to set to 0 to indicate linear polarization, is set to 1 to indicate circular polarization and is set to 2 for mixed polarization. Value of 3 is reserved.

### 9.4.2.264.4 PHY Capabilities subelement

The Data field of the PHY Capabilities subelement is defined in Figure 9-943 (Data field of the PHY Capabilities subelement format(11ay)).

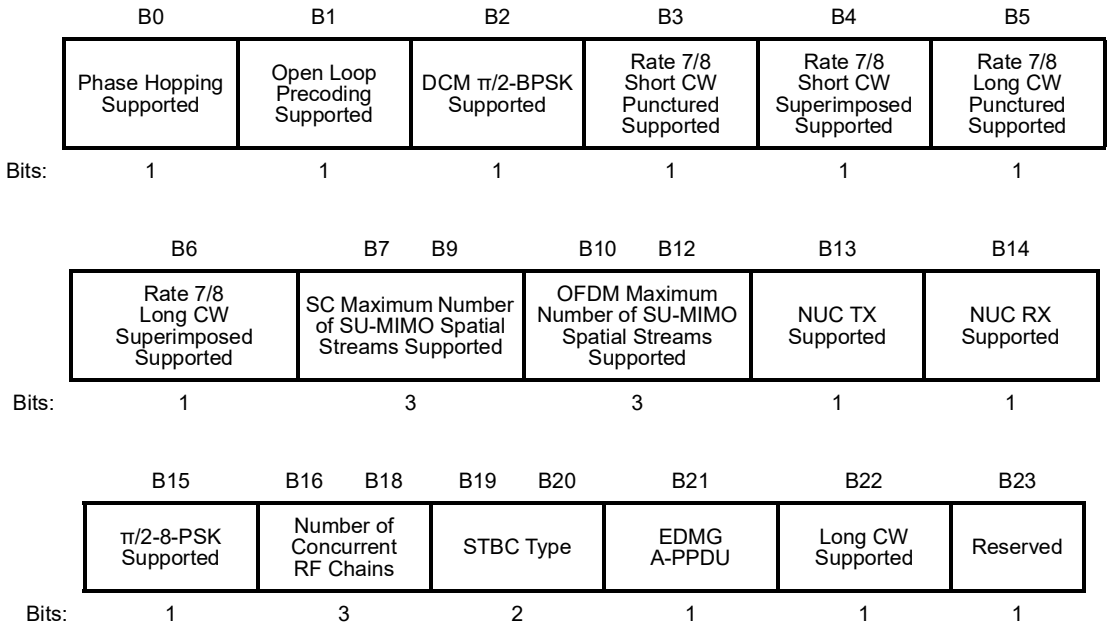


**Figure 9-943—Data field of the PHY Capabilities subelement format(11ay)**

The Phase Hopping Supported subfield indicates if the STA supports phase hopping as specified in 28.6.9.3 (Modulation mapping). The subfield is set to 1 if dot11EDMGPhaseHoppingImplemented is true, and is set to 0 otherwise.

The Open Loop Precoding Supported subfield indicates if the STA supports open loop precoding as specified in 28.6.9.3 (Modulation mapping). The subfield is set to 1 if dot11EDMGOpenLoopPrecodingImplemented is true, and is set to 1 otherwise.


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The DCM π/2-BPSK Supported subfield indicates if the STA supports DCM π/2-BPSK as specified in 28.5.9.5.3 (Dual carrier modulation (DCM) π/2-BPSK). The subfield is set to 1 if dot11EDMGDCMBPSKImplemented is true, and is set to 0 otherwise.

The Rate 7/8 Short CW Punctured Supported, Rate 7/8 Short CW Superimposed Supported, Rate 7/8 Long CW Punctured Supported and Rate 7/8 Long CW Superimposed Supported subfields indicate the support by an EDMG STA for LDPC code rate 7/8 with codeword length equal to 624, 672, 1248, and 1344 bits as follows:

— The Rate 7/8 Short CW Punctured Supported subfield is set to 1 if dot11EDMGShortCWPuncturedImplemented is true, and is set to 0 otherwise. The subfield indicates support for transmission and reception of LDPC code with short codeword length equal to 624 bits and code rate 7/8. The encoding procedure for short codeword length equal to 624 bits is defined in 20.5.3.2.3.3 (LDPC encoding process).

— The Rate 7/8 Short CW Superimposed Supported subfield is set to 1 if dot11EDMGShortCWSuperimposedImplemented is true, and is set to 0 otherwise. The subfield indicates support for transmission and reception of LDPC code with short codeword length equal to 672 bits and code rate 7/8. The encoding procedure for short codeword length equal to 672 bits is defined in 28.5.9.4 (Encoding), and parity check matrix is defined in 28.3.6.2 (Rate-7/8 LDPC code matrix H = 84 rows x 672 columns, Z = 42). This field is reserved if the Rate 7/8 Short CW Punctured Supported subfield is 0.

— The Rate 7/8 Long CW Punctured Supported subfield is set to 1 if dot11EDMGLongCWPuncturedImplemented is true, and is set to 0 otherwise. The subfield indicates support for transmission and reception of LDPC code with long codeword length equal to 1248 bits and code rate 7/8. The encoding procedure for long codeword length equal to 1248 bits is defined in 28.5.9.4.

— The Rate 7/8 Long CW Superimposed Supported subfield is set to 1 if dot11EDMGLongCWSuperimposedImplemented is true, and is set to 0 otherwise. The subfield indicates support for transmission and reception of LDPC code with long codeword length equal to 1344 bits and code rate 7/8. The encoding procedure for long codeword length equal to 1344 bits is defined in 28.5.9.4. This field is reserved if the Rate 7/8 Long CW Punctured Supported subfield is 0.

The SC Maximum Number of SU-MIMO Spatial Streams Supported subfield is set to dot11EDMGSCMaxSUSpatialStreams minus 1. The value of this subfield plus 1 indicates the maximum number of SU-MIMO spatial streams for the EDMG SC modulation class that the STA can demodulate.

The OFDM Maximum Number of SU-MIMO Spatial Streams Supported subfield is set to dot11EDMGOFDMMaxSUSpatialStreams minus 1. The value of this subfield plus 1 indicates the maximum number of SU-MIMO spatial streams for the EDMG OFDM modulation class that the STA can demodulate.

The NUC TX Supported subfield is set to 1 if dot11EDMGNUCTXImplemented is true, and is set to 0 otherwise. If equal to 1, this subfield indicates that the STA supports transmission of PPDUs using nonuniform constellation.

The NUC RX Supported subfield is set to 1 if dot11EDMGNUCRXImplemented is true, and is set to 0 otherwise. If equal to 1, this subfield indicates that the STA supports reception of PPDUs using nonuniform constellation.

The π/2-8-PSK Supported subfield is set to 1 if dot11EDMG8PSKImplemented is true, and is set to 0 otherwise. If equal to 1, this subfield indicates that the STA supports SC MCS 12 and SC MCS 13 using 8-PSK modulation.

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The Number of Concurrent RF Chains subfield is set to dot11EDMGNumConcurrentRFChains minus 1. The value of this subfield plus 1 indicates the maximum number of concurrent transmit or receive chains of the STA. The value of this field is less than or equal to the value of the Number of DMG Antennas subfield in the Antenna Polarization Capability field.

The STBC Type subfield is set to dot11EDMGSTBCType. If this subfield is 1, it indicates that the STA supports single stream STBC reception. If this subfield is 2, it indicates that the STA supports one or more spatial stream STBC reception; in this case, the maximum number of spatial streams that can be decoded is limited by the minimum of four and the value of the SC Maximum Number of SU-MIMO Spatial Streams Supported subfield for an EDMG SC PPDU and the value of the OFDM Maximum Number of SU-MIMO Spatial Streams Supported subfield for an EDMG OFDM PPDU. If this subfield is 0, the STA does not support STBC. Value of 3 is reserved.

The EDMG A-PPDU subfield is set to 1 if dot11EDMGAPPDUImplemented is true, and is set to 0 otherwise. If equal to 1, this subfield indicates that the STA supports EDMG A-PPDU as described in 10.14 (DMG A-PPDU and EDMG A-PPDU(11ay) operation).

The Long CW Supported subfield is set to 1 if dot11EDMGLongCWImplemented is true, and is set to 0 otherwise. If equal to 1, this subfield indicates that the STA supports LDPC codeword of length 1344 on code rates 1/2, 5/8, 3/4, and 13/16. If this subfield is 0, the Rate 7/8 Long CW Punctured Supported and Rate 7/8 Long CW Superimposed Supported subfields are set to 0.

#### 9.4.2.264.5 Supported Channels subelement

The Data field of the Supported Channels subelement is defined in Figure 9-944 (Data field of the Supported Channels subelement format(11ay)), where *N* is the integer number of channels and *M* is the integer number of channel aggregation combinations that the STA supports.

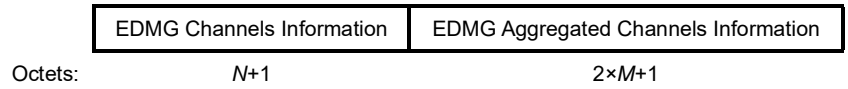


**Figure 9-944—Data field of the Supported Channels subelement format(11ay)**

NOTE—As specified in 28.3.4, support for at least one 2.16 GHz channel and one 4.32 GHz channel by an EDMG STA is mandatory.

The EDMG Channels Information subfield is defined in Figure 9-945 (EDMG Channels Information subfield format(11ay)).

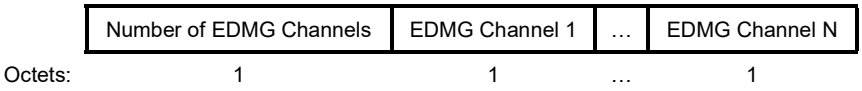


**Figure 9-945—EDMG Channels Information subfield format(11ay)**

The Number of EDMG Channels subfield defines the value of *N*.

Each EDMG Channel *i* subfield ($1 \le i \le N$) includes the channel number of a channel that is supported by the STA, as defined in Annex E.


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The EDMG Aggregated Channels Information subfield is defined in Figure 9-946 (EDMG Aggregated Channels Information subfield format(11ay)).

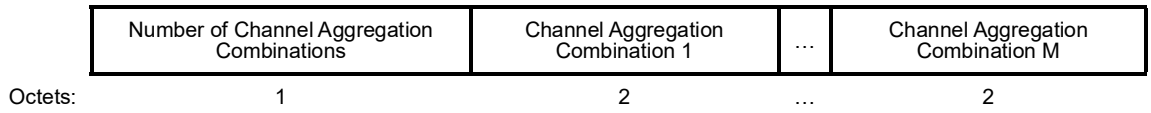


**Figure 9-946—EDMG Aggregated Channels Information subfield format(11ay)**

The Number of Channel Aggregation Combinations subfield defines the value of *M*.

Each Channel Aggregation Combination *i* subfield ($1 \leq i \leq M$) is defined in Figure 9-947 (Channel Aggregation Combination subfield format(11ay)). The channel numbers, as defined in Annex E, of the channels that are aggregated for each channel aggregation combination are included in the Aggregated Channel 1 and Aggregated Channel 2 subfields.

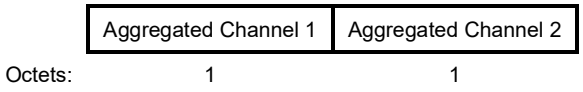


**Figure 9-947—Channel Aggregation Combination subfield format(11ay)**

### 9.4.2.264.6 MAC Capabilities subelement

The Data field of the MAC Capabilities subelement is defined in Figure 9-948 (Data field of the MAC Capabilities subelement format(11ay)).

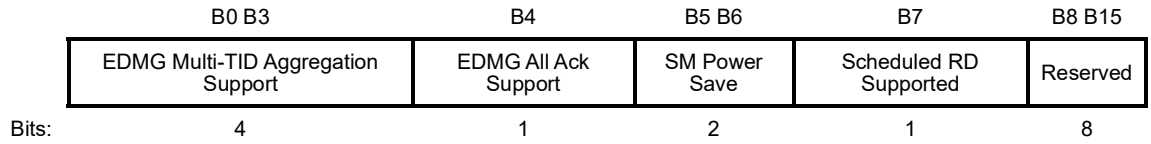


**Figure 9-948—Data field of the MAC Capabilities subelement format(11ay)**

The EDMG Multi-TID Aggregation Support field contains the number of TIDs minus one of QoS Data frames that the STA is able to receive or aggregate in a multi-TID A-MPDU as described in 10.70 (EDMG A-MPDU with multiple TIDs(11ay)). A value of zero indicates that the STA does not support EDMG multi-TID aggregation.

The EDMG All Ack Support field is set to 1 to indicate support for the reception of (#4251)an EDMG Multi-TID BlockAck frame under the all ack context when the Ack Type subfield value is 2 (see 10.70.2 (Acknowledgment context in an EDMG Multi-TID BlockAck frame(#4251))). The EDMG All Ack Support field is set to 0 otherwise.

The SM Power Save field indicates the support for spatial multiplexing power save for an EDMG STA (see 11.2.6 (SM power save)). It also indicates the spatial multiplexing power save mode that is in operation immediately after (re)association. This field is set to 0 for static SM power save mode, 1 for dynamic SM power save mode, and 3 for SM power save disabled or not supported (see 11.2.6 (SM power save)). The value of 2 is reserved. This field is valid in a (Re)Association Request frame sent to an AP or a PCP. Otherwise, this field is set to 0 or 3 upon transmission and it ignored upon reception.

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NOTE—This field indicates the operational state immediately after (re)association as well as (if not set to 3) a capability.

The Scheduled RD Supported field indicates if the EDMG STA supports the scheduling procedure of the RD protocol described in 10.29.3 (Rules for RD initiator) and 10.29.4 (Rules for RD responder). This field is set to 1 if dot11EDMGScheduledRDImplemented is true. Otherwise, this field is set to 0. When dot11EDMGMIMOSupport is either muAndSuMimo (2) or reciprocalMuMimoAndSuMimo (3), dot11EDMGScheduledRDImplemented is always true.

### 9.4.2.265 EDMG Operation element(11ay)

The operational parameters of an EDMG BSS provided by an EDMG AP or EDMG PCP are determined by the EDMG Operation element.

The format of the EDMG Operation element is shown in Figure 9-949 (EDMG Operation element format(11ay)).

| | Element ID | Length | Element ID Extension | Primary Channel | BSS AID | A-BFT Parameters | BSS Operating Channels | Operating Channel Width |
|---|---|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

**Figure 9-949—EDMG Operation element format(11ay)**

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

The Primary Channel field indicates a 2.16 GHz channel number, as defined in Annex E, of the primary channel of the BSS.

The BSS AID field contains a value in the range 1 to 254 assigned by an AP or PCP to identify the BSS. Other values are reserved.

The A-BFT Parameters field is defined in Figure 9-950 (A-BFT Parameters field format(11ay)(M118)).

| | B0 B1 | B2 B3 | B4 B7 |
|---|---|---|---|
| | RSS Retry Limit | RSS Backoff | Reserved |
| Bits: | 2 | 2 | 4 |

**Figure 9-950—A-BFT Parameters field format(11ay)(M118)**

The RSS Retry Limit subfield defines the value of the retry limit that a STA attempting to access the A-BFT of the BSS uses. If the RSS Retry Limit subfield is set to 0 it indicates 2 retries, if set to 1 it indicates 4 retries, if set to 2 it indicates 6 retries and if set to 3 it indicates 8 retries.

The RSS Backoff subfield defines the value of the backoff that a STA uses when the consecutive number of failed attempts to access the A-BFT of the BSS exceeds the retry limit specified by the RSS Retry Limit subfield. If the RSS Backoff subfield is set to 0 it indicates a backoff of 8, if set to 1 it indicates a backoff of 16, if set to 2 it indicates a backoff of 24 and if set to 4 it indicates a backoff of 32.

The BSS Operating Channels field is a bitmap that indicates the 2.16 GHz channel(s) that are allowed to be used for transmissions in the BSS and is formatted as shown in Figure 9-951 (BSS Operating Channels field format(11ay)). In Figure 9-951 (BSS Operating Channels field format(11ay)), Ch1 subfield corresponds to channel 1, Ch2 subfield corresponds to channel 2 and so on (channels are defined in Annex E). If a subfield


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is set to 1, transmission on the indicated channel is allowed; otherwise, if the subfield is set to 0, transmission on the indicated channel is not allowed. The subfield corresponding to the primary channel is always set to 1 and the total number of subfields set to 1 does not exceed four.

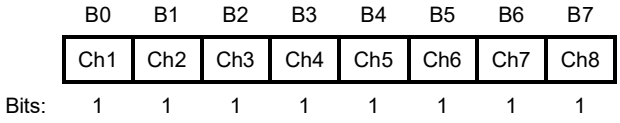


**Figure 9-951—BSS Operating Channels field format(11ay)**

The Operating Channel Width field is defined in Figure 9-952 (Operating Channel Width field format(11ay)) and indicates each possible bandwidth that a PPDU transmitted in the BSS can occupy.

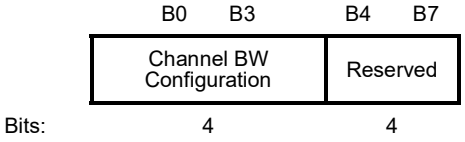


**Figure 9-952—Operating Channel Width field format(11ay)**

The Channel BW Configuration subfield encodes the allowed channel bandwidth configurations and is defined in Table 9-387 (Channel BW Configuration subfield definition(11ay)).

**Table 9-387—Channel BW Configuration subfield definition(11ay)**

| Channel BW Configuration subfield value | | PPDU masks that are allowed to be transmitted in the BSS per rules defined in 10.23.2.14 (EDCA channel access in an EDMG BSS(11ay)) and 10.38.12 (EDMG channel access(11ay)) | | | | | |
|---|---|---|---|---|---|---|---|
| | | 2.16 GHz | 4.32 GHz | 6.48 GHz | 8.64 GHz | 2.16+2.16 GHz | 4.32+4.32 GHz |
| Reserved | 0–3 | | | | | | |
| Operating on 2.16 GHz, 4.32 GHz, 6.48 GHz, and 8.64 GHz only | 4 | 1 | 0 | 0 | 0 | 0 | 0 |
| | 5 | 1 | 1 | 0 | 0 | 0 | 0 |
| | 6 | 1 | 1 | 1 | 0 | 0 | 0 |
| | 7 | 1 | 1 | 1 | 1 | 0 | 0 |
| Operating on 2.16 GHz, 4.32 GHz, 6.48 GHz, 8.64 GHz, and 2.16+2.16 GHz only | 8 | 1 | 0 | 0 | 0 | 1 | 0 |
| | 9 | 1 | 1 | 0 | 0 | 1 | 0 |
| | 10 | 1 | 1 | 1 | 0 | 1 | 0 |
| | 11 | 1 | 1 | 1 | 1 | 1 | 0 |

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**Table 9-387—Channel BW Configuration subfield definition(11ay)**

| Channel BW Configuration subfield value | | PPDU masks that are allowed to be transmitted in the BSS per rules defined in 10.23.2.14 (EDCA channel access in an EDMG BSS(11ay)) and 10.38.12 (EDMG channel access(11ay)) | | | | | |
|---|---|---|---|---|---|---|---|
| | | 2.16 GHz | 4.32 GHz | 6.48 GHz | 8.64 GHz | 2.16+2.16 GHz | 4.32+4.32 GHz |
| Operating on 2.16 GHz, 4.32 GHz, 6.48 GHz, 8.64 GHz, 2.16+2.16 GHz, and 4.32+4.32 GHz only | 12 | 1 | 0 | 0 | 0 | 1 | 1 |
| | 13 | 1 | 1 | 0 | 0 | 1 | 1 |
| | 14 | 1 | 1 | 1 | 0 | 1 | 1 |
| | 15 | 1 | 1 | 1 | 1 | 1 | 1 |
| NOTE—"1" denotes an allowed PPDU mask; "0" denotes a disallowed PPDU mask. | | | | | | | |

### 9.4.2.266 EDMG Extended Schedule element(11ay)

The EDMG Extended Schedule element defines the channel scheduling for an EDMG BSS, including an indication of which channels an allocation is scheduled on.

The format of the EDMG Extended Schedule element is shown in Figure 9-953 (EDMG Extended Schedule element format(11ay)).

| | Element ID | Length | Element ID Extension | EDMG Allocation Control | Number of Allocations | Channel Allocation 1 | … | Channel Allocation N |
|---|---|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 1 | 1 | 5 or 20 | | 5 or 20 |

**Figure 9-953—EDMG Extended Schedule element format(11ay)**

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

The EDMG Allocation Control field is defined in Figure 9-954 (EDMG Allocation Control field format(11ay)).

| | B0 | B1 B7 |
|---|---|---|
| | Distributed Scheduling Enabled | Reserved |
| Bits: | 1 | 7 |

**Figure 9-954—EDMG Allocation Control field format(11ay)**

The Distributed Scheduling Enabled subfield is set to 1 to indicate that the distributed scheduling mechanism (see 10.68 (EDMG AP or EDMG PCP distributed scheduling protocol operation(11ay))) is enabled. Otherwise, this subfield is set to 0.

The Number of Allocations field indicates the number, *N*, of Channel Allocation fields following it.



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Each Channel Allocation *i* subfield ($1 \leq i \leq N$)(#M118) starts with a Scheduling Type subfield, which defines the format of the remainder of the Channel Allocation field.

If the Scheduling Type subfield is 0, the Channel Allocation field contains supplemental allocation information (e.g., bandwidth that the allocation occupies) to the Allocation field in the Extended Schedule element for the same allocation. In this case, the Channel Allocation field is defined in Figure 9-955 (Channel Allocation field format when Scheduling Type is 0(11ay)).

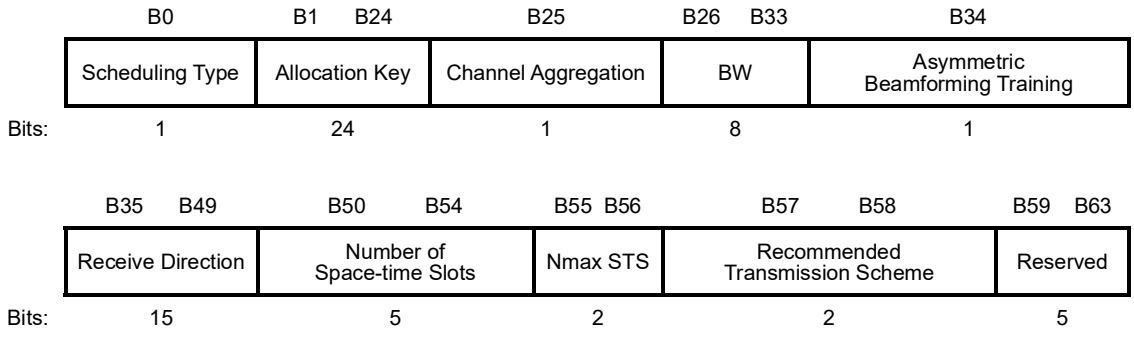


**Figure 9-955—Channel Allocation field format when Scheduling Type is 0(11ay)**

The contents of the Allocation Key subfield are used to identify the allocation. This is done by matching the contents of this subfield with the information obtained from the Extended Schedule element transmitted in the same frame containing the EDMG Extended Schedule element. The Allocation Key subfield is formatted as shown in Figure 9-956 (Allocation Key field format(11ay)).

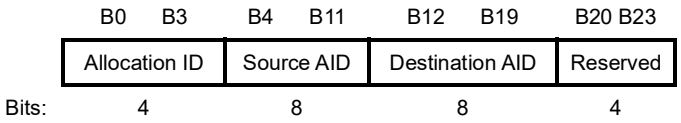


**Figure 9-956—Allocation Key field format(11ay)**

The Allocation ID, Source AID, and Destination AID subfields are collectively used to identify the allocation included as part of the Extended Schedule element.

The Channel Aggregation and BW subfields are defined in Table 28-12 (EDMG-Header-A field structure and definition for an SU PPDU(11ay)). These fields specify the channel(s) on which the allocation is scheduled.

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If the Scheduling Type subfield is 1, the Channel Allocation field contains the complete allocation scheduling information. In this case, the Channel Allocation field is defined in Figure 9-957 (Channel Allocation field format when Scheduling Type is 1(11ay)).

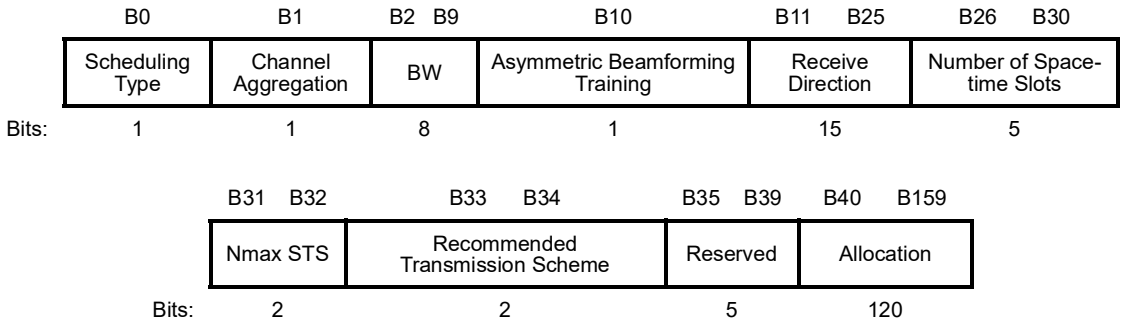


**Figure 9-957—Channel Allocation field format when Scheduling Type is 1(11ay)**

The Channel Aggregation and BW subfields are defined in Table 28-12 (EDMG-Header-A field structure and definition for an SU PPDU(11ay)). These fields specify the channel(s) on which the allocation is scheduled. The Channel Aggregation and BW subfields are reserved when the Asymmetric Beamforming Training subfield is set to 1.

The Asymmetric Beamforming Training subfield is set to 1 to indicate that this allocation is dedicated to performing the procedure specified in 10.41.10.3 (Beamforming for asymmetric links). Otherwise, this subfield is set to 0.

The Receive Direction subfield indicates the receive antenna configuration that the PCP or AP uses during the allocation and is formatted as shown in Figure 9-958 (Receive Direction subfield format(11ay)). The Receive Direction subfield is reserved if the Asymmetric Beamforming Training subfield is 1.

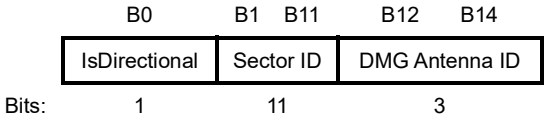


**Figure 9-958—Receive Direction subfield format(11ay)**

The IsDirectional subfield is set to 1 to indicate that the PCP or AP uses a directional, non quasi-omni antenna pattern to receive frames during the allocation, and is set to 0 otherwise.

The Sector ID subfield is reserved if the IsDirectional subfield is 0. Otherwise, the Sector ID subfield indicates the sector that the AP or PCP uses to receive frames during this allocation.

The DMG Antenna ID subfield is reserved if the IsDirectional subfield is 0. Otherwise, the DMG Antenna ID subfield indicates the DMG antenna that the AP or PCP uses to receive frames during this allocation.

The value of the Number of Space-time Slots subfield indicates the number of space-time slots allocated by the AP or PCP for asymmetric beamforming training. The Number of Space-time Slots subfield is reserved if the Asymmetric Beamforming Training subfield is 0. A space-time slot is a time slot in an asymmetric beamforming training allocation in which the AP or PCP listens on the combination of sector and DMG antenna as defined in 10.41.10.3.3 (Beamforming training allocation in DTI).


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The value $2^{STS}$, where STS is the value of the Nmax STS subfield, indicates the maximum number of consecutive space-time slots a responder can occupy within a listen period of asymmetric beamforming training. The Nmax STS subfield is reserved if the Asymmetric Beamforming Training subfield is 0. The value $2^{STS}$ is no more than the value of the Number of Space-time Slots subfield.

The Recommended Transmission Scheme subfield is set to 0 to indicate no transmission scheme for the allocation is recommended by the AP or the PCP. The subfield is set to 1 to indicate SISO transmission is recommended by the AP or the PCP for the allocation. The subfield is set to 2 to indicate SU-MIMO transmission is recommended by the AP or the PCP for the allocation. Value of 3 is reserved.

The Allocation subfield is defined in Figure 9-845 (Allocation field format). Other subfields are defined in the paragraphs above.

### 9.4.2.267 EDMG Channel Measurement Feedback element(11ay)

The EDMG Channel Measurement Feedback element is used to carry channel measurement feedback data that an EDMG STA has measured on DMG Beacon frames, SSW frames, Short SSW PPDUs or TRN fields of EDMG BRP PPDUs. This channel measurement feedback data is provided in addition to what is provided in the Channel Measurement Feedback element. The EDMG Channel Measurement Feedback element provides a list of sectors per transmit DMG antenna identified during sector sweep or during beam combination, or a list of TX sector combinations identified during SU-MIMO or MU-MIMO beamforming training and that can be used to establish a beamformed SISO, SU-MIMO, or MU-MIMO link, as well as AWV information obtained during beam tracking.

The format and size of the EDMG Channel Measurement Feedback element are defined by the parameter values specified in the accompanying DMG Beam Refinement element or MIMO Feedback Control element. The EDMG Channel Measurement Feedback element is shown in Table 9-388 (EDMG Channel Measurement Feedback element format(11ay)).

If the RXVECTOR parameter DUAL_POL_TRAINING of the PPDU over which the measurements were performed was 1 and the RXVECTOR parameter FIRST_PATH_TRAINING was 0, the Dual Polarization TRN Measurement field contains the measurements for all measured taps. If the RXVECTOR parameter DUAL_POL_TRAINING of the PPDU over which the measurements were performed was 1 and the RXVECTOR parameter FIRST_PATH_TRAINING was also 1, only the measurements corresponding to the tap #1 (shortest delay) are added to the Dual Polarization TRN Measurement field. The Relative I/Q Component Tap #N, polarization #1 or #2, represent the measured signal strength for the I or Q component for the tap #N and polarization #1 or #2, respectively.

**Table 9-388—EDMG Channel Measurement Feedback element format(11ay)**

| Field | Size (bits) | Meaning |
|---|---|---|
| Element ID | 8 | Defined in 9.4.2.1 (General) |
| Length | 8 | Defined in 9.4.2.1 (General) |
| Element ID Extension | 8 | Defined in 9.4.2.1 (General) |

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**Table 9-388—EDMG Channel Measurement Feedback element format(11ay) *(continued)***

| Field | Size (bits) | Meaning |
|---|---|---|
| EDMG Sector ID Order | | |
| Sector $ID_1$/$CDOWN_1$/AWV Feedback $ID_1$ | 11 | Sector $ID_k$/$CDOWN_k$/AWV Feedback $ID_k$ – Sector ID/CDOWN/ AWV feedback ID for $SNR_k$ being obtained, or Sector ID/CDOWN/ AWV feedback ID of the $k^{th}$ detected beam.<br><br>TX Antenna $ID_k$ – TX antenna ID corresponding to Sector $ID_k$/ $CDOWN_k$/AWV Feedback $ID_k$<br><br>RX Antenna $ID_k$ – RX antenna ID corresponding to Sector $ID_k$/ $CDOWN_k$/AWV Feedback $ID_k$ |
| TX Antenna $ID_1$ | 3 | |
| RX Antenna $ID_1$ | 3 | |
| Sector $ID_2$/$CDOWN_2$/AWV Feedback $ID_2$ | 11 | |
| TX Antenna $ID_2$ | 3 | |
| RX Antenna $ID_2$ | 3 | |
| … | … | |
| Sector $ID_{Nmeas}$/ $CDOWN_{Nmeas}$/ AWV Feedback $ID_{Nmeas}$ | 11 | |
| TX Antenna $ID_{Nmeas}$ | 3 | |
| RX Antenna $ID_{Nmeas}$ | 3 | |
| BRP CDOWN | | |
| BRP $CDOWN_1$ | 6 | BRP $CDOWN_k$: BRP CDOWN corresponding to AWV feedback $ID_k$ |
| BRP $CDOWN_2$ | 6 | |
| … | … | |
| BRP $CDOWN_{Nmeas}$ | 6 | |
| Tap Delay | | |
| Relative Delay Tap #1 | 12 | The delay of tap #1 in units of $T_c/N_{CB}$ relative to the path with the shortest delay detected, where $N_{CB}$ is the integer number of contiguous 2.16 GHz channels over which the measurement was taken. |
| Relative Delay Tap #2 | 12 | The delay of tap #2 in units of $T_c/N_{CB}$ relative to the path with the shortest delay detected, where $N_{CB}$ is the integer number of contiguous 2.16 GHz channels over which the measurement was taken. |
| … | … | |
| Relative Delay Tap #Ntaps | 12 | The delay of tap #Ntaps in units of $T_c/N_{CB}$ relative to the path with the shortest delay detected, where $N_{CB}$ is the integer number of contiguous 2.16 GHz channels over which the measurement was taken. |


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**Table 9-388—EDMG Channel Measurement Feedback element format(11ay) *(continued)***

| Field | Size (bits) | Meaning |
|---|---|---|
| Additional EDMG Sector ID Order | | |
| Sector $ID_1$/$CDOWN_1$/ AWV Feedback $ID_1$ | 11 | Sector $ID_k$/$CDOWN_k$/AWV Feedback $ID_k$ – Sector ID/CDOWN/ AWV feedback ID for $SNR_k$ being obtained, or Sector ID/CDOWN/ AWV feedback ID of the $k^{th}$ detected beam.<br><br>TX Antenna $ID_k$ – TX antenna ID corresponding to Sector $ID_k$/ $CDOWN_k$/AWV Feedback $ID_k$<br><br>RX Antenna $ID_k$ – RX antenna ID corresponding to Sector $ID_k$/ $CDOWN_k$/AWV Feedback $ID_k$ |
| TX Antenna $ID_1$ | 3 | |
| RX Antenna $ID_1$ | 3 | |
| Sector $ID_2$/$CDOWN_2$/ AWV Feedback $ID_2$ | 11 | |
| TX Antenna $ID_2$ | 3 | |
| RX Antenna $ID_2$ | 3 | |
| … | … | |
| Sector $ID_{Nmeas}$/ $CDOWN_{Nmeas}$/ AWV Feedback $ID_{Nmeas}$ | 11 | |
| TX Antenna $ID_{Nmeas}$ | 3 | |
| RX Antenna $ID_{Nmeas}$ | 3 | |
| Additional BRP CDOWN | | |
| BRP $CDOWN_1$ | 6 | Additional BRP $CDOWN_k$: BRP CDOWN corresponding to AWV feedback $ID_k$ |
| BRP $CDOWN_2$ | 6 | |
| … | … | |
| BRP $CDOWN_{Nmeas}$ | 6 | |
| Additional Tap Delay | | |
| Relative Delay Tap #1 | 12 | |
| Relative Delay Tap #2 | 12 | |
| … | … | |
| Relative Delay Tap #Ntaps | 12 | |
| Dual Polarization TRN Measurement | | |
| Relative I Component Tap #1 Polarization #1 | 8 | The in-phase component of impulse response for tap #1 (shortest delay), and polarization #1 in the dual polarization TRN |
| Relative Q Component Tap #1 Polarization #1 | 8 | The quadrature component of impulse response for tap #1 (shortest delay), and polarization #1 in the dual polarization TRN |
| Relative I Component Tap #1 Polarization #2 | 8 | The in-phase component of impulse response for Tap #1 (shortest delay), and polarization #2 in the dual polarization TRN |
| Relative Q Component Tap #1 Polarization #2 | 8 | The quadrature component of impulse response for tap #1 (shortest delay), and polarization #2 in the dual polarization TRN |
| Relative I Component Tap #2 Polarization #1 | 8 | The in-phase component of impulse response for tap #2 , and polarization #1 in the dual polarization TRN |
| Relative Q Component Tap #2 Polarization #1 | 8 | The quadrature component of impulse response for tap #2, and polarization #1 in the dual polarization TRN |

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**Table 9-388—EDMG Channel Measurement Feedback element format(11ay) *(continued)***

| Field | Size (bits) | Meaning |
|---|---|---|
| Relative I Component Tap #2 Polarization #2 | 8 | The in-phase component of impulse response for tap #2, and polarization #2 in the dual polarization TRN |
| Relative Q Component Tap #2 Polarization #2 | 8 | The quadrature component of impulse response for tap #2, and polarization #2 in the dual polarization TRN |
| | … | |
| Relative I Component Tap #N Polarization #1 | 8 | The in-phase component of impulse response for tap #N, and polarization #1 in the dual polarization TRN |
| Relative Q Component Tap #N Polarization #1 | 8 | The quadrature component of impulse response for tap #N, and polarization #1 in the dual polarization TRN |
| Relative I Component Tap #N Polarization #2 | 8 | The in-phase component of impulse response for tap #N, and polarization #2 in the dual polarization TRN |
| Relative Q Component Tap #N Polarization #2 | 8 | The quadrature component of impulse response for tap #N, and polarization #2 in the dual polarization TRN |
| Padding | 0–7 | Zero padding to make the EDMG Channel Measurement Feedback element length a multiple of 8 bits |

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

When the EDMG Channel Measurement Feedback element is included in a BRP frame, the EDMG Sector ID Order field indicates the TX sector IDs, TX antenna IDs and RX antenna IDs corresponding to the SNRs in the SNR field when the SNR Present subfield of the FBCK-TYPE field is equal to 1 and the Sector Sweep Frame Type field is equal to 0 (i.e., DMG Beacon frame or SSW frame) in the DMG Beam Refinement element contained in the frame. The EDMG Sector ID Order field indicates the CDOWN values and RX antenna IDs corresponding to the SNRs in the SNR field when the SNR Present subfield of the FBCK-TYPE field is equal to 1 and the Sector Sweep Frame Type field is equal to 1 (i.e., Short SSW PPDU) in the DMG Beam Refinement element contained in the frame. The TX Antenna ID subfields of the EDMG Sector ID Order field are reserved when the Sector Sweep Frame Type field is equal to 1 in the DMG Beam Refinement element contained in the frame.

When the EDMG Channel Measurement Feedback element is included in a MIMO BF Feedback frame or when the EDMG Channel Measurement Feedback element is included in a BRP frame with the Sector Sweep Frame Type field of the DMG Beam Refinement element contained in the frame equal to 2, the EDMG Sector ID Order field indicates AWV feedback IDs, TX antenna IDs and RX antenna IDs. The RX Antenna ID subfields of the EDMG Sector ID Order field are reserved when the EDMG Channel Measurement Feedback element is included in the MIMO BF Feedback frame. The BRP CDOWN field indicates BRP CDOWN values. The EDMG Sector ID Order field and the BRP CDOWN field can be divided into $N_{meas}$ SISO ID subsets. Specifically, the $i$ SISO ID subset ($i$ = 1, 2, …, $N_{meas}$) comprises the values of the AWV Feedback IDi, TX Antenna IDi, RX Antenna IDi and BRP CDOWNi subfields, where the AWV Feedback IDi subfield indicates the AWV for a TX DMG antenna having its TX antenna ID equal to the TX Antenna IDi subfield value, which is used to transmit an EDMG BRP-RX/TX PPDU or EDMG BRP-TX PPDU with the BRP CDOWN field set to the BRP CDOWNi subfield value.

Table 9-389 (Sector and DMG antenna interpretation based on the Sector Sweep Frame Type field value(11ay)) summarizes how the sector and DMG antenna are interpreted on the basis of the value of the Sector Sweep Frame Type field value.


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**Table 9-389—Sector and DMG antenna interpretation based on the Sector Sweep Frame Type field value(11ay)**

| Sector Sweep Frame Type field value | Basis for sector sweep result | TX sector ID interpretation | TX antenna ID interpretation |
|---|---|---|---|
| 0 | DMG Beacon or SSW frame | Sector ID field value in frame | DMG/CMMGAntenna ID subfield value in frame |
| 1 | Short SSW PPDU | CDOWN field value in PPDU | RF Chain ID field in PPDU |
| 2 | BRP frame | AWV Feedback ID field value in frame | TX Antenna Mask field in EDMG BRP Request element |
| 3 | TRN field as part of beam tracking | AWV Feedback ID field value in frame | N/A |

When the EDMG Channel Measurement Feedback element is carried within a MIMO BF Feedback frame, the number of measurements, $N_{meas}$, is equal to $N_{tsc} \times N_{TX} \times N_{RX}$, where $N_{tsc}$ is given by the Number of TX Sector Combinations Present field in the MIMO Feedback Control element within the MIMO BF Feedback frame, $N_{TX}$ refers to the value indicated by the Number of TX Antennas subfield in the MIMO Feedback Control element within the MIMO BF Feedback frame, and $N_{RX}$ refers to the value indicated by the Number of RX Antennas subfield in the MIMO Feedback Control element within the MIMO BF Feedback frame.

When the EDMG Channel Measurement Feedback element is carried within a MIMO BF Feedback frame, every $N_{TX} \times N_{RX}$ consecutive SISO ID subsets constitute a set that corresponds to a specific TX sector combination (or equivalently a specific TX-RX AWV configuration). Each TX sector combination comprises a single TX sector for each of $N_{TX}$ TX DMG antennas. $N_{tsc}$ TX sector combinations are ranked in the decreasing order of an implementation dependent metric. Specifically, the $j$ set ($j = 1, 2, \ldots, N_{tsc}$), which corresponds to the $j$ TX-RX AWV configuration, comprises the $((j-1) \times N_{TX} \times N_{RX} + 1)$ SISO ID subset to the $(j \times N_{TX} \times N_{RX})$ SISO ID subset. Assume that the MIMO channel corresponding to the $j$ TX-RX AWV configuration is defined by the following equation:

$$H_j = \begin{bmatrix} h_{1,1}^{(j)} & \cdots & h_{1,N_{RX}}^{(j)} \\ \vdots & \ddots & \vdots \\ h_{N_{TX},1}^{(j)} & \cdots & h_{N_{TX},N_{RX}}^{(j)} \end{bmatrix}$$

Here, $h_{m,n}^{(j)}$ ($m = 1, 2, \ldots, N_{TX}$ and $n = 1, 2, \ldots, N_{RX}$) represents the channel between the $m$ TX DMG antenna and the $n$ RX DMG antenna and is indicated by the $((j-1) \times N_{TX} \times N_{RX} + (m-1) \times N_{RX} + n)$ SISO ID subset. In particular, for the $j$ TX sector combination ($j = 1, 2, \ldots, N_{tsc}$), the AWV used by the $m$ TX antenna ($m = 1, 2, \ldots, N_{TX}$) is indicated by the values of the AWV feedback $ID_l$ and BRP $CDOWN_l$ subfields, where $l = (j-1) \times N_{TX} \times N_{RX} + (m-1) \times N_{RX} + n$ and $n$ is any integer between 1 and $N_{RX}$.

NOTE—Since a DMG Beacon frame, SSW frame or Short SSW PPDU transmitted through a TX sector, or a TRN subfield of an EDMG BRP-TX PPDU or an EDMG BRP-RX/TX PPDU transmitted using a TX AWV, can be received by several RX DMG antennas, reception of each DMG Beacon frame, SSW frame, Short SSW PPDU or TRN subfield of an EDMG BRP-TX PPDU or an EDMG BRP-RX/TX PPDU through an RX DMG antenna has an entry in the SNR field, the EDMG Sector ID Order field, the Additional SNR field (if present) and the Additional EDMG Sector ID Order field (if present).

If both the Channel Aggregation Present field and the EDMG Extension Flag field in the accompanying DMG Beam Refinement element are 1 or if the Channel Aggregation Present subfield of the MIMO FBCK-TYPE field in the accompanying MIMO Feedback Control element is 1, the following apply:

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— The EDMG Sector ID Order, BRP CDOWN and Tap Delay fields are for the channel that includes the primary channel in case of channel aggregation. Otherwise, the EDMG Sector ID Order, BRP CDOWN and Tap Delay fields are for the channel in which the measurement is taken.

— The Additional EDMG Sector ID Order, Additional BRP CDOWN and Additional Tap Delay fields are for the channel that does not include the primary channel in case of channel aggregation. Otherwise, the Additional EDMG Sector ID Order, Additional BRP CDOWN and Additional Tap Delay fields are not present.

### 9.4.2.268 EDMG Group ID Set element(11ay)

The EDMG Group ID Set element allows an AP or PCP to define groups of MU capable EDMG STAs to perform DL MU-MIMO beamforming training and transmissions.(M118)

The format of the EDMG Group ID Set element is shown in Figure 9-959 (EDMG Group ID Set element format(11ay)).

| | Element ID | Length | Element ID Extension | Number of EDMG Groups | EDMG Group Tuples |
|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 1 | variable(M118) |

**Figure 9-959—EDMG Group ID Set element format(11ay)**

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

The Number of EDMG Groups field indicates the number of EDMG Group fields.

The EDMG Group Tuples field contains one or more EDMG Group Tuple subfields. Each EDMG Group Tuple subfield has the structure shown in Figure 9-960 (EDMG Group Tuple subfield format(11ay)).

| | B0 B7 | B8 B12 | B13 B15 | B16 B23 | B24 B31 | | B(8×(*N*+1)) B(8×(*N*+2) – 1) |
|---|---|---|---|---|---|---|---|
| | EDMG Group ID | Group Size (*N*) | Reserved | AID0 | AID1 | … | AIDN-1 |
| Bits: | 8 | 5 | 3 | 8 | 8 | … | 8 |

**Figure 9-960—EDMG Group Tuple subfield format(11ay)**

The EDMG Group ID subfield is a unique, nonzero value that identifies the group.

The Group Size subfield indicates the number of EDMG STAs that belong to the group, i.e., the number of AID subfields following this subfield minus one.

Each AID subfield contains the AID of an EDMG STA that belongs to the group.


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### 9.4.2.269 EDMG BRP Request element(11ay)

The EDMG BRP Request element provides BRP configuration in addition to the BRP configuration provided in the BRP Request field. The EDMG BRP Request element is defined in Figure 9-961 (EDMG BRP Request element format(11ay)).

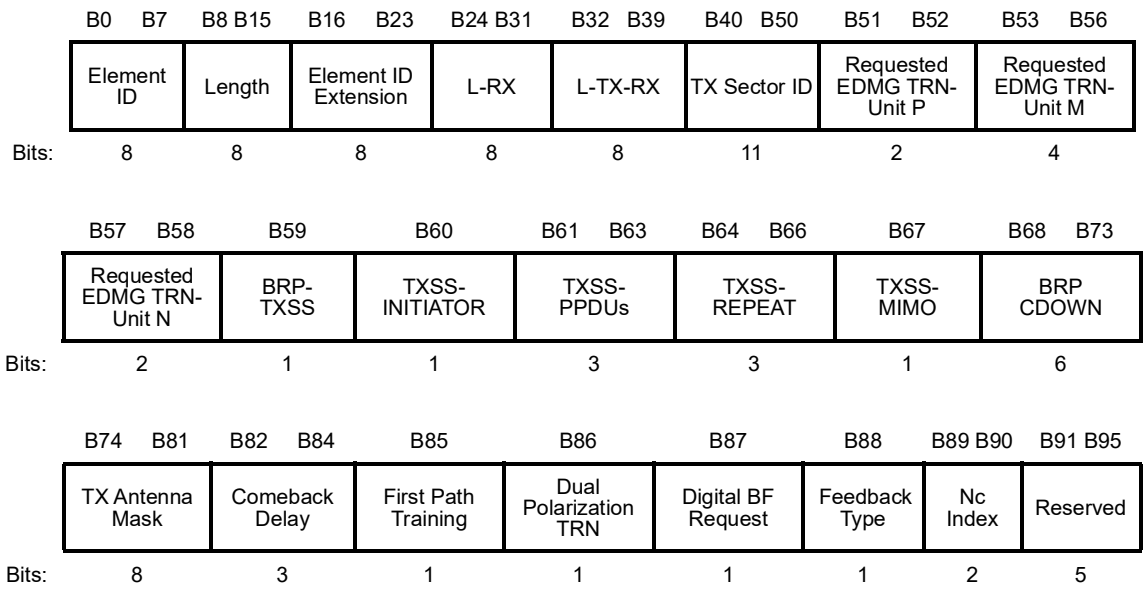


**Figure 9-961—EDMG BRP Request element format(11ay)**

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

The L-RX field indicates the number of TRN-Units requested by the transmitting STA as part of receive beam refinement. When the EDMG BRP Request element is present in a frame, the value of this field overrides the value of the subfield with the same name carried in the BRP Request field.

The L-TX-RX field indicates the requested number of consecutive TRN-Units for which the transmit AWV remains with the same AWV configuration as part of simultaneous receive and transmit beam refinement.

The TX Sector ID field indicates the sector ID that is used when transmitting the frame. If the frame is transmitted using a pattern that is not a sector that has been used in the sector sweep, the value of this field is set to 2047. When the EDMG BRP Request element is present in a frame, the value of this field overrides the value of the subfield with the same name carried in the BRP Request field.

The Requested EDMG TRN-Unit P field indicates the requested number of TRN subfields at the start of a TRN-Unit that use the same AWV, which is the same AWV used in the transmission of the preamble and Data fields of the PPDU, except for the case when the DMG antenna used in the transmission of the PPDU changes at the beginning of the TRN field (see 28.9.2.2.5 (TRN field definition)). A svalue of zero indicates zero requested TRN subfields, a value of one indicates one requested TRN subfield, a value of two indicates two requested TRN subfields and a value of three indicates four requested TRN subfields.

The value of the Requested EDMG TRN-Unit M field plus one indicates the requested number of TRN subfields within a TRN-Unit that can be used for transmit training, as defined in 28.9.2.2 (EDMG BRP PPDU). The value of this field plus one is an integer multiple of the value indicated in the Requested EDMG TRN-Unit N field.

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The Requested EDMG TRN-Unit N field indicates the requested number of consecutive TRN subfields within EDMG TRN-Unit M that are transmitted using the same AWV. A value of zero indicates one requested TRN subfield, a value of one indicates two requested TRN subfields, a value of two indicates three requested TRN subfields if the Requested EDMG TRN-Unit M field is equal to 2, 5, 8, 11, or 14, a value of two indicates eight requested TRN subfields if the Requested EDMG TRN-Unit M field is equal to 7 or 15, and a value of three indicates four requested TRN subfields.

The BRP-TXSS field is set to 1 to indicate either a request to perform BRP TXSS or to acknowledge a request to perform BRP TXSS, as defined in 10.41.10.5 (BRP transmit sector sweep (BRP TXSS)). Otherwise, this field is set to 0.

If the BRP-TXSS field is equal to 1, the TXSS-INITIATOR field set to 1 indicates that the transmitter of the BRP frame is the initiator of a BRP TXSS and the TXSS-INITIATOR field set to 0 indicates that the transmitter of the BRP frame is the responder of a BRP TXSS. If the BRP-TXSS field is equal to 0, the TXSS-INITIATOR field is reserved.

If the BRP-TXSS field and the TXSS-INITIATOR are both equal to 1, the value in the TXSS-PPDUs field plus one indicates the number of EDMG BRP-TX PPDUs necessary for the initiator to perform transmit training. If the BRP-TXSS field is equal to 1 and the TXSS-INITIATOR field is equal to 0, the value in the TXSS-PPDUs field plus one indicates the number of EDMG BRP-TX PPDUs necessary for the responder to perform transmit training if the procedure includes a Responder BRP TXSS (see 10.41.10.5 (BRP transmit sector sweep (BRP TXSS))). If the BRP-TXSS field is equal to 0, the TXSS-PPDUs field is reserved.

If the BRP-TXSS field and the TXSS-INITIATOR field are both equal to 1, the TXSS-REPEAT field plus one indicates the number of times that the EDMG BRP-TX PPDUs transmitted in the Responder BRP TXSS is repeated if the BRP TXSS includes a Responder BRP TXSS. If the BRP-TXSS field is equal to 1 and the TXSS-INITIATOR field is equal to 0, the TXSS-REPEAT field plus one indicates the number of times that the EDMG BRP-TX PPDUs transmitted in the Initiator BRP TXSS is repeated. If the BRP-TXSS field is equal to 0, the TXSS-REPEAT field is reserved.

If the BRP-TXSS field and the TXSS-INITIATOR field are both equal to 1, the TXSS-MIMO field set to 1 indicates that the requested BRP TXSS is a MIMO BRP TXSS (see 10.41.10.5 (BRP transmit sector sweep (BRP TXSS))), and the TXSS-MIMO field set to 0 indicates that the requested BRP TXSS is a SISO BRP TXSS (see 10.41.10.5 (BRP transmit sector sweep (BRP TXSS))). If the BRP-TXSS field and the TXSS-INITIATOR field are not both equal to 1, the TXSS-MIMO field is reserved.

The BRP CDOWN field is a down counter indicating the number of remaining EDMG BRP PPDU transmissions to the end of the BF training.

The TX Antenna Mask field is a bitmap that indicates whether each of eight TX DMG antennas is used in the transmission of the EDMG BRP PPDU. The first bit (i.e., the least significant bit) corresponds to the first TX DMG antenna, the second bit corresponds to the second TX DMG antenna, and so on. A bit is set to 1 to indicate the associated TX DMG antenna is used in the transmission of the EDMG BRP PPDU; otherwise, the bit is set to 0.

The Comeback Delay field indicates that the STA might not be ready with the feedback within BRPIFS. The value in the Comeback Delay field indicates when the device is ready with feedback. The interpretation of this field is defined according to Table 9-390 (Interpretation of the Comeback Delay field(11ay)).

The First Path training field set to 1 indicates that the BRP procedure is designated as a first path training procedure as specified in 10.41.10.6 (First path beamforming training). This field is set to 0 otherwise.


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**Table 9-390—Interpretation of the Comeback Delay field(11ay)**

| Value | Meaning |
|---|---|
| 0 | Feedback is ready within this frame. |
| 1 | 64 μs |
| 2 | 128 μs |
| 3 | 256 μs |
| 4 | 512 μs |
| 5 | 768 μs |
| 6 | 1024 μs |
| 7 | 2048 μs |

The Dual Polarization TRN field is set to 1 to request a BRP initiator to send TRN subfields with different polarizations for the same AWV as specified in 10.41.10.7 (Dual polarization TRN beamforming training). It is set to 0 otherwise.

The Digital BF Request field set to 1 indicates a request for performing digital beamforming. Otherwise, this field is set to 0.

The Feedback Type field indicates the type of feedback requested. Set to 0 for SU and set to 1 for MU.

If the Feedback Type field indicates MU, then the *Nc* Index field indicates the number of columns, *Nc*, in the compressed beamforming feedback matrix minus 1 for hybrid beamforming feedback in the EDMG OFDM mode. The interpretation of this field is defined according to Table 9-391 (Encoding of Nc Index field(11ay)).

**Table 9-391—Encoding of Nc Index field(11ay)**

| Value | Meaning |
|---|---|
| 0 | $Nc = 1$. |
| 1 | $Nc = 2$. |
| 2 | Reserved. |
| 3 | Reserved. |

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### 9.4.2.270 EDMG Training Field Schedule element(11ay)

The EDMG Training Field Schedule element allows an EDMG STA to announce BTIs in which TRN-R subfields are present in PPDUs containing DMG Beacon frames transmitted during the BTI.

The format of the EDMG Training Field Schedule element is shown in Figure 9-962 (EDMG Training Field Schedule element format(11ay)).

| | Element ID | Length | Element ID Extension | Next BTI With TRN | TRN Schedule Interval |
|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 1 | 1 |

**Figure 9-962—EDMG Training Field Schedule element format(11ay)**

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

The Next BTI With TRN field indicates the number of beacon intervals in which TRN-R subfields are not present in any PPDU transmitted in a BTI. The value of this field is this field is decreased by one at the start of every beacon interval until it reaches zero and is subsequently reset. If the Next BTI With TRN field is 0, TRN-R fields are present in the BTI.

The TRN Schedule Interval field indicates the periodic interval, in number of beacon intervals, at which TRN-R subfields are present in the BTI of one or more consecutive beacon intervals. If the value of this field is 0, there is no periodicity and the presence of TRN-R fields in a BTI is determined solely by the value of the Next BTI With TRN field.

### 9.4.2.271 EDMG Partial Sector Level Sweep element(11ay)

The EDMG Partial Sector Level Sweep element is used to exchange the length of a sector level sweep to be performed when the link is lost before the STA's resort to a complete sector level sweep. The format of the element is shown in Figure 9-963 (EDMG Partial Sector Level Sweep element format(11ay)).

| | Element ID | Length | Element ID Extension | Partial SLS Configuration |
|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 4 |

**Figure 9-963—EDMG Partial Sector Level Sweep element format(11ay)**

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

The Partial SLS Configuration field is defined in Figure 9-964 (Partial SLS Configuration field format(11ay)).

| | B0 B5 | B6 B16 | B17 B19 | B20 B22 | B23 B26 | B27 | B28 | B29 B31 |
|---|---|---|---|---|---|---|---|---|
| | Partial Number of Sectors | Total Number of Sectors | Partial Number of Rx Antennas | Total Number of Rx Antennas | Time to Switch to Full Sector Sweep | Agree to Change Initiator/ Responder Roles | Agree to Partial Sector Sweep | Reserved |
| Bits: | 6 | 11 | 3 | 3 | 4 | 1 | 1 | 3 |

**Figure 9-964—Partial SLS Configuration field format(11ay)**



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The Partial Number of Sector field indicates the number of sectors the sender intends to transmit per each of the peer STA's receive antennas as part of the partial sector level sweep.

The Total Number of Sector field indicates the number of sectors the sender intends to use as a transmitter per each of the peer STA's receive antennas as part of the complete sector level sweep.

The Partial Number of Rx antennas field indicates the number of RX antennas the sender intends to use when receiving the partial sector sweep.

The Total Number of Rx antennas field indicates the number of RX antennas the sender intends to use when receiving the complete sector level sweep.

When sent by the initiator of the partial sector level sweep exchange, the Time to Switch to (#4303)Full Sector Sweep field is the time, in units of one millisecond, after the expiration of the beamformed link maintenance timer (see 11.27.1.1 (General(11ay))) that the initiator of the exchange proposes to switch to a complete sector level sweep. This field is reserved when sent by the responder of this exchange.

When sent by the initiator of the partial sector level sweep exchange and set to 1, the Agree to Change Initiator/Responder Roles field indicates that the initiator requests to change the roles of initiator/responder in the sector level sweep starting with the expiration of the beamformed link maintenance timer. This field is reserved otherwise.

When sent by the initiator of the partial sector level sweep exchange, the Agree to Partial Sector Sweep field is set to 1. When sent by the responder of the partial sector level sweep exchange, the Agree to Partial Sector Sweep field is set to 1 to indicate agreement to the partial sector level sweep and is set to 0 to indicate disagreement to the partial sector level sweep.

### 9.4.2.272 MIMO Setup Control element(11ay)

The MIMO Setup Control element, defined in Table 9-392 (MIMO Setup Control element format(11ay)), is used to carry configuration information required for the SU-MIMO BF training and feedback subphases or the MU-MIMO BF training and feedback subphases.

**Table 9-392—MIMO Setup Control element format(11ay)**

| Field | Size (bits) | Meaning |
|---|---|---|
| Element ID | 8 | |
| Length | 8 | |
| Element ID Extension | 8 | |
| SU/MU | 1 | This field is set to 0 to indicate SU-MIMO beamforming and is set to 1 to indicate MU-MIMO beamforming. |
| Nonreciprocal/Reciprocal MIMO Phase | 1 | This field is set to 0 to indicate the nonreciprocal MIMO phase and is set to 1 to indicate the reciprocal MIMO phase. |
| EDMG Group ID | 8 | Indicates the EDMG Group ID of target MU group. This field is reserved when the SU/MU field is set to 0. |
| Group User Mask | 32 | |

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**Table 9-392—MIMO Setup Control element format(11ay) *(continued)***

| Field | Size (bits) | Meaning |
|---|---|---|
| L-TX-RX | 8 | Indicates the requested number of consecutive TRN-Units in which the same AWV is used in the transmission of the last *M* TRN subfields of each TRN-Unit. This field is reserved when the SU/MU field is set to 1 or when the SU/MU field is set to 0, the Nonreciprocal/Reciprocal MIMO phase field is set to 1 and the Initiator field is set to 1.<br><br>NOTE—*M* is equal to the value of the Requested EDMG TRN-Unit M field plus 1. |
| Requested EDMG TRN-Unit M | 4 | The value of this field plus one indicates the requested number of TRN subfields in a TRN-Unit that can be used for transmit training, as defined in 28.9.2.2. This field is reserved when the SU/MU field is set to 1 or when the SU/MU field is set to 0, the Nonreciprocal/Reciprocal MIMO phase field is set to 1 and the Initiator field is set to 1. |
| Initiator | 1 | This field is set to 1 to indicate the sender is the initiator and is set to 0 otherwise. This field is set to 1 when the SU/MU field is set to 1. |
| MIMO FBCK-REQ | 10 | Indicates requested channel measurement feedback. |
| Reserved | 7 | |

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

The Group User Mask field is a bitmap that indicates whether an EDMG STA in the target MU group is requested to engage in the subsequent MU-MIMO BF training. The order of EDMG STAs in the Group User Mask field follows the order in which they appear in the corresponding EDMG Group field of the EDMG Group ID Set element defining the target MU group. The first bit (i.e., the least significant bit) of the Group User Mask field corresponds to the first EDMG STA in the MU group, the second bit corresponds to the second EDMG STA, and so on. A bit is set to 1 to indicate that the corresponding EDMG STA is requested to engage in the subsequent MU-MIMO BF training; otherwise, the bit is set to 0. This Group User Mask field is reserved when the SU/MU field is set to 0. If the number of EDMG STAs in the target MU group is smaller than 32, the corresponding bits in the Group User Mask field are set to 0.

The MIMO FBCK-REQ field is defined in Figure 9-965 (MIMO FBCK-REQ field format(11ay)(M118)).

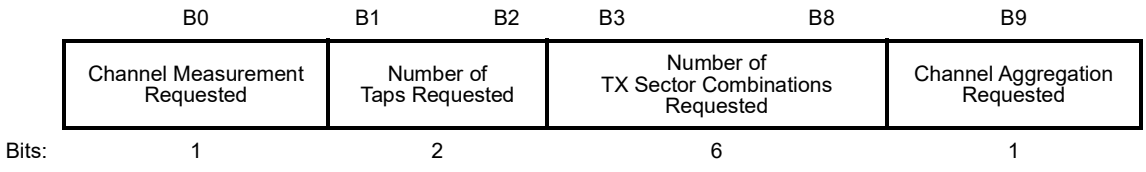


**Figure 9-965—MIMO FBCK-REQ field format(11ay)(M118)**

If the Channel Measurement Requested subfield is set to 1, the Channel Measurement subfield is requested as part of MIMO BF feedback. Otherwise, set to 0.

The Number of Taps Requested subfield indicates the number of taps requested in each channel measurement. The encoding for this subfield is specified in Table 9-296 (FBCK-TYPE field description).


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The value of the Number of TX Sector Combinations Requested subfield plus one indicates the number of TX sector combinations requested as part of MIMO BF feedback.

The Channel Aggregation Requested subfield is set to 1 to indicate that the TRN field is transmitted over a 2.16+2.16 GHz or 4.32+4.32 GHz channel and to request the channel measurement feedback per channel, in case channel aggregation is used as part of MIMO BF feedback. Otherwise, this subfield is set to 0.

#### 9.4.2.273 MIMO Poll Control element(11ay)

The MIMO Poll Control element is defined in Table 9-393 (MIMO Poll Control element format(11ay)).

**Table 9-393—MIMO Poll Control element format(11ay)**

| Field | Size (bits) | Meaning |
|---|---|---|
| Element ID | 8 | |
| Length | 8 | |
| Element ID Extension | 8 | |
| SU/MU | 1 | This field is set to 0 to indicate SU-MIMO beamforming and is set to 1 to indicate MU-MIMO beamforming. |
| Poll Type | 1 | This field is set to 1 to indicate training PPDU poll used in the reciprocal MU-MIMO beamforming or the MU-MIMO hybrid beamforming feedback phase. It is set to 0 to indicate MIMO BF feedback poll used in the SU-MIMO beamforming or the nonreciprocal MU-MIMO beamforming. |
| L-TX-RX | 8 | Indicates the requested number of consecutive TRN-Units in which the same AWV is used in the transmission of the last *M* TRN subfields of each TRN-Unit. This field is reserved when the Poll Type field is set to 0. |
| Requested EDMG TRN-Unit M | 4 | The value of this field plus one indicates the requested number of TRN subfields in a TRN-Unit can be used for transmit training, as defined in 28.9.2.2 (EDMG BRP PPDU). This field is reserved when the Poll Type field is set to 0. |
| Requested EDMG TRN-Unit P | 2 | Indicates the requested number of TRN subfields at the start of a TRN-Unit that use the same AWV. A value of zero indicates zero requested TRN subfields, a value of one indicates one requested TRN subfield, a value of two indicates two requested TRN subfields and a value of three indicates four requested TRN subfields. This field is reserved when the Poll Type field is set to 0. |
| Training Duration | 14 | Indicates the maximum duration, in microseconds, that can be used by the polled responder to transmit EDMG BRP-RX/TX PPDUs and starts following the reception of the MIMO BF Poll frame containing this element. Possible values range from 1 to 16383. This field is reserved when the Poll Type field is set to 0. |
| Reserved | 2 | |

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

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### 9.4.2.274 MIMO Feedback Control element(11ay)

The MIMO Feedback Control element, as shown in Table 9-394 (MIMO Feedback Control element format(11ay)), is used to carry configuration information for accompanying Channel Measurement Feedback element, EDMG Channel Measurement Feedback element and/or Digital BF Feedback element.

**Table 9-394—MIMO Feedback Control element format(11ay)**

| Field | Size (bits) | Meaning |
|---|---|---|
| Element ID | 8 | |
| Length | 8 | |
| Element ID Extension | 8 | |
| SU/MU | 1 | This field is set to 0 to indicate SU-MIMO beamforming and is set to 1 to indicate MU-MIMO beamforming. |
| Link Type | 1 | This field is set to 0 to indicate initiator link and is set to 1 otherwise. This field is set to 0 when the SU/MU field is set to 1. |
| Comeback Delay | 3 | This field indicates whether MIMO BF feedback is included in the MIMO BF Feedback frame containing the MIMO Feedback Control element or when the EDMG STA transmitting the MIMO Feedback Control element is ready with MIMO BF feedback. The encoding of this field is defined in Table 9-390 (Interpretation of the Comeback Delay field(11ay)). |
| MIMO FBCK-TYPE | 18 | |
| Digital Fbck Control | 30 | Defines the requirements for the digital feedback type. |
| Reserved | 3 | |

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

The MIMO FBCK-TYPE field is defined in Figure 9-966 (MIMO FBCK-TYPE field format(11ay)). This field is reserved when the Comeback Delay field is set to a nonzero value.

| | B0 | B1 | B2 B3 | B4 B9 | B10 | B11 | B12 B14 | B15 B17 |
|---|---|---|---|---|---|---|---|---|
| | Channel Measurement Present | Tap Delay Present | Number of Taps Present | Number of TX Sector Combinations Present | Precoder Information Present | Channel Aggregation Present | Number of TX Antennas | Number of RX Antennas |
| Bits: | 1 | 1 | 2 | 6 | 1 | 1 | 3 | 3 |

**Figure 9-966—MIMO FBCK-TYPE field format(11ay)**

If the Channel Measurement Present subfield is set to 1, the Channel Measurement subfield is present as part of the MIMO BF feedback. Otherwise, set to 0.



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If the Tap Delay Present subfield is set to 1, the Tap Delay subfield is present as part of the MIMO BF feedback. Otherwise, set to 0.

The Number of Taps Present subfield indicates the number of taps present in each channel measurement. This subfield has the same encoding as the Number of Taps Requested subfield specified in Table 9-296 (FBCK-TYPE field description).

The value of the Number of TX Sector Combinations Present subfield plus one indicates the number of TX sector combinations, $N_{tsc}$, for the MIMO BF feedback. The number of measurements, $N_{meas}$, is $N_{TX} \times N_{RX}$ multiples of the number of TX sector combinations, $N_{tsc}$ (see 9.4.2.267 (EDMG Channel Measurement Feedback element(11ay))).

The Precoder Information Present subfield is set to 1 to indicate that precoding information is present as part of the MIMO BF feedback. Otherwise, it is set to 0.

The Channel Aggregation Present subfield is set to 1 to indicate that, in case of channel aggregation, channel measurement feedback per channel is present. Otherwise, it is set to 0.

The Number of TX Antennas and the Number of RX Antennas subfields describe the $N_{TX}$ and $N_{RX}$ used in each of the $N_{tsc}$ sector combinations.

The Digital Fbck Control field defines the parameters of the accompanying digital BF feedback. The field is defined in Figure 9-967 (Digital Fbck Control field format(11ay)), and its subfields are described in Table 9-395 (Definition of subfields within Digital Fbck Control field(11ay)).

| | B0 B2 | B3 B5 | B6 B13 | B14 B15 | B16 B17 | B18 | B19 | B20 B29 |
|---|---|---|---|---|---|---|---|---|
| | Nc Index | Nr Index | Tx Antenna Mask | Ncb | Grouping | Codebook Information | Feedback Type | Number of Feedback Matrices or Feedback Taps |
| Bits: | 3 | 3 | 8 | 2 | 2 | 1 | 1 | 10 |

**Figure 9-967—Digital Fbck Control field format(11ay)**

**Table 9-395—Definition of subfields within Digital Fbck Control field(11ay)**

| Subfield | Meaning |
|---|---|
| Nc Index | Indicates the number of columns, *Nc*, in the beamforming feedback matrix minus one:<br>Set to 0 for *Nc* = 1.<br>Set to 1 for *Nc* = 2.<br>Set to 2 for *Nc* = 3.<br>Set to 3 for *Nc* = 4.<br>Set to 4 for *Nc* = 5.<br>Set to 5 for *Nc* = 6.<br>Set to 6 for *Nc* = 7.<br>Set to 7 for *Nc* = 8. |

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**Table 9-395—Definition of subfields within Digital Fbck Control field(11ay) *(continued)***

| Subfield | Meaning |
|---|---|
| Nr Index | Indicates the number of rows, Nr, in a beamforming feedback matrix minus one:<br>Set to 0 for Nr = 1.<br>Set to 1 for Nr = 2.<br>Set to 2 for Nr = 3.<br>Set to 3 for Nr = 4.<br>Set to 4 for Nr = 5.<br>Set to 5 for Nr = 6.<br>Set to 6 for Nr = 7.<br>Set to 7 for Nr = 8. |
| Tx Antenna Mask | Indicates the Tx Antennas reported in the accompanying Digital BF Feedback element. If the CSI for the $i^{th}$ Tx Antenna is included in the accompanying Digital BF Feedback element, the $i^{th}$ bit in Tx Antenna Mask is set to 1. Otherwise, the $i^{th}$ bit in Tx Antenna Mask is set to 0. |
| Ncb | Indicates the number of contiguous 2.16 GHz channels the measurement was made for minus one:<br>Set to 0 for 2.16 GHz.<br>Set to 1 for 4.32 GHz.<br>Set to 2 for 6.48 GHz.<br>Set to 3 for 8.64 GHz. |
| Grouping | Indicates the subcarrier grouping, Ng, used for beamforming feedback matrix<br>Set to 0 for $N_g = 2$.<br>Set to 1 for $N_g = 4$.<br>Set to 2 for $N_g = 8$.<br>Set to 3 for dynamic grouping; reserved if dynamic grouping is not supported.<br><br>If the Feedback Type subfield is 0, the Grouping subfield is reserved. |
| Codebook Information | Indicates the size of codebook entries.<br><br>If the SU/MU field in the MIMO Feedback Control element is 1:<br>Set to 0 for 6 bits for Ψ, 4 bits for ϕ.<br>Value 1 is reserved.<br><br>If the SU/MU field in the MIMO Feedback Control element is 0:<br>Set to 0 for 9 bits for Ψ , 7 bits for ϕ.<br>Value 1 is reserved. |
| Feedback Type | Indicates which type of feedback is provided. Set to 0 for uncompressed beamforming feedback in time domain (EDMG SC mode) and set to 1 for compressed using Givens-Rotation in frequency domain (EDMG OFDM mode). |
| Number of Feedback Matrices or Feedback Taps | This field is set to the value of the variable *Nsc*. The value 0 is reserved.<br><br>If the Feedback Type subfield is 0, *Nsc* is the number of feedback taps per element of the SC feedback matrix.<br><br>If the Feedback Type subfield is 1 and the Grouping subfield is less than 3, *Nsc* is determined by Table 9-403 (Subcarriers for which a compressed beamforming feedback matrix is sent back(11ay)).<br><br>If the Feedback Type subfield is 1 and the Grouping subfield is 3, *Nsc* specifies the number of subcarriers present in the Digital Beamforming Feedback Information field of the Digital BF Feedback element. |


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### 9.4.2.275 MIMO Selection Control element(11ay)

The MIMO Selection Control element is defined in Table 9-396 (MIMO Selection Control element format(11ay)).

**Table 9-396—MIMO Selection Control element format(11ay)**

| Field | Size (bits) | Meaning |
|---|---|---|
| Element ID | 8 | |
| Length | 8 | |
| Element ID Extension | 8 | |
| EDMG Group ID | 8 | Indicates the EDMG group ID of target MU group. |
| Number of MU-MIMO Transmission Configurations | 3 | Indicates the number of MU-MIMO transmission configurations, $N_{\text{conf}}$. |
| MU-MIMO Transmission Configuration Type | 1 | This field is set to 0 to indicate the MU-MIMO transmission configurations obtained from the nonreciprocal MU-MIMO BF training. This field is set to 1 to indicate the MU-MIMO transmission configurations obtained from the reciprocal MU-MIMO BF training. |
| Number of TX Antennas | 3 | Indicates the $N_{TX}$ used in each MU-MIMO transmission configuration. |
| Nonreciprocal MU-MIMO BF Training Based Transmission Configuration | | |
| Configuration 1 Group User Mask for Antenna 1 | 32 | Indicates the STA(s) in the target MU group associated with the first TX DMG antenna in the first MU-MIMO transmission configuration. |
| Configuration 1 User 1 SISO ID Subset Index/RX Antenna ID for Antenna 1 | 12 | Indicates the RX AWV, from a receiver's perspective, or RX DMG antenna of the first STA associated with the first TX DMG antenna in the first MU-MIMO transmission configuration. |
| ... | | |
| Configuration 1 User $N_{1,1}^{(u)}$ SISO ID Subset Index/RX Antenna ID for Antenna 1 | 12 | Indicates the RX AWV, from a receiver's perspective, or RX DMG antenna of the $N_{1,1}^{(u)}$ STA associated with the first TX DMG antenna in the first MU-MIMO transmission configuration. |
| ... | | |
| Configuration 1 Group User Mask for Antenna $N_{\text{TX}}$ | 32 | Indicates the STA(s) in the target MU group associated with the $N_{\text{TX}}$ TX DMG antenna in the first MU-MIMO transmission configuration. |
| Configuration 1 User 1 SISO ID Subset Index/RX Antenna ID for Antenna $N_{\text{TX}}$ | 12 | Indicates the RX AWV, from a receiver's perspective, or RX DMG antenna of the first STA associated with the $N_{\text{TX}}$ TX DMG antenna in the first MU-MIMO transmission configuration. |
| ... | | |
| Configuration 1 User $N_{1,N_{TX}}^{(u)}$ SISO ID Subset Index/RX Antenna ID for Antenna $N_{\text{TX}}$ | 12 | Indicates the RX AWV, from a receiver's perspective, or RX DMG antenna of the $N_{1,N_{TX}}^{(u)}$ STA associated with the $N_{\text{TX}}$ TX DMG antenna in the first MU-MIMO transmission configuration. |
| ... | | |

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**Table 9-396—MIMO Selection Control element format(11ay) *(continued)***

| Field | Size (bits) | Meaning |
|---|---|---|
| Configuration $N_{conf}$ Group User Mask for Antenna 1 | 32 | Indicates the STA(s) in the target MU group associated with the first TX DMG antenna in the $N_{conf}$ MU-MIMO transmission configuration. |
| Configuration $N_{conf}$ User 1 SISO ID Subset Index/RX Antenna ID for Antenna 1 | 12 | Indicates the RX AWV, from a receiver's perspective, or RX DMG antenna of the first STA associated with the first TX DMG antenna in the $N_{conf}$ MU-MIMO transmission configuration. |
| ... | | |
| Configuration $N_{conf}$ User $N^{(u)}_{N_{conf},1}$ SISO ID Subset Index/RX Antenna ID for Antenna $N_{TX}$ | 12 | Indicates the RX AWV, from a receiver's perspective, or RX DMG antenna of the $N^{(u)}_{N_{conf},1}$ STA associated with the first TX DMG antenna in the $N_{conf}$ MU-MIMO transmission configuration. |
| ... | | |
| Configuration $N_{conf}$ Group User Mask for Antenna $N_{TX}$ | 32 | Indicates the STA(s) in the target MU group associated with the $N_{TX}$ TX DMG antenna in the $N_{conf}$ MU-MIMO transmission configuration. |
| Configuration $N_{conf}$ User 1 SISO ID Subset Index/RX Antenna ID for Antenna $N_{TX}$ | 12 | Indicates the RX AWV, from a receiver's perspective, or RX DMG antenna of the first STA associated with the $N_{TX}$ TX DMG antenna in the $N_{conf}$ MU-MIMO transmission configuration. |
| ... | | |
| Configuration $N_{conf}$ User $N^{(u)}_{N_{conf},N_{TX}}$ SISO ID Subset Index/RX Antenna ID for Antenna $N_{TX}$ | 12 | Indicates the RX AWV, from a receiver's perspective, or RX DMG antenna of the $N^{(u)}_{N_{conf},N_{TX}}$ STA associated with the $N_{TX}$ TX DMG antenna in the $N_{conf}$ MU-MIMO transmission configuration. |
| Reciprocal MU-MIMO BF Training Based Transmission Configuration | | |
| Configuration 1 Group User Mask for Antenna 1 | 32 | Indicates the STA(s) in the target MU group associated with the first TX DMG antenna in the first MU-MIMO transmission configuration. |
| Configuration 1 User 1 AWV feedback ID for Antenna 1 | 11 | Indicates the RX AWV, from a receiver's perspective, or RX DMG antenna of the first STA associated with the first TX DMG antenna in the first MU-MIMO transmission configuration. |
| Configuration 1 User 1 BRP CDOWN for Antenna 1 | 6 | |
| Configuration 1 User 1 RX Antenna ID for Antenna 1 | 3 | |
| ... | | |
| Configuration 1 User $N^{(u)}_{1,1}$ AWV feedback ID for Antenna 1 | 11 | Indicates the RX AWV, from a receiver's perspective, or RX DMG antenna of the $N^{(u)}_{1,1}$ STA associated with the first TX DMG antenna in the first MU-MIMO transmission configuration. |
| Configuration 1 User $N^{(u)}_{1,1}$ BRP CDOWN for Antenna 1 | 6 | |
| Configuration 1 User $N^{(u)}_{1,1}$ RX Antenna ID for Antenna 1 | 3 | |
| ... | | |



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**Table 9-396—MIMO Selection Control element format(11ay) *(continued)***

| Field | Size (bits) | Meaning |
|---|---|---|
| Configuration 1 Group User Mask for Antenna $N_{TX}$ | 32 | Indicates the STA(s) in the target MU group associated with the $N_{TX}$ TX DMG antenna in the first MU-MIMO transmission configuration. |
| Configuration 1 User 1 AWV feedback ID for Antenna $N_{TX}$ | 11 | Indicates the RX AWV, from a receiver's perspective, or RX DMG antenna of the first STA associated with the $N_{TX}$ TX DMG antenna in the first MU-MIMO transmission configuration. |
| Configuration 1 User 1 BRP CDOWN for Antenna $N_{TX}$ | 6 | |
| Configuration 1 User 1 RX Antenna ID for Antenna $N_{TX}$ | 3 | |
| ... | | |
| Configuration 1 User $N^{(u)}_{1,N_{TX}}$ AWV feedback ID for Antenna $N_{TX}$ | 11 | Indicates the RX AWV, from a receiver's perspective, or RX DMG antenna of the $N^{(u)}_{1,N_{TX}}$ STA associated with the $N_{TX}$ TX DMG antenna in the first MU-MIMO transmission configuration. |
| Configuration 1 User $N^{(u)}_{1,N_{TX}}$ BRP CDOWN for Antenna $N_{TX}$ | 6 | |
| Configuration 1 User $N^{(u)}_{1,N_{TX}}$ RX Antenna ID for Antenna $N_{TX}$ | 3 | |
| ... | | |
| Configuration $N_{conf}$ Group User Mask for Antenna 1 | 32 | Indicates the STA(s) in the target MU group associated with the first TX DMG antenna in the $N_{conf}$ MU-MIMO transmission configuration. |
| Configuration $N_{conf}$ User 1 AWV feedback ID for Antenna 1 | 11 | Indicates the RX AWV, from a receiver's perspective, or RX DMG antenna of the first STA associated with the first TX DMG antenna in the $N_{conf}$ MU-MIMO transmission configuration. |
| Configuration $N_{conf}$ User 1 BRP CDOWN for Antenna 1 | 6 | |
| Configuration $N_{conf}$ User 1 RX Antenna ID for Antenna 1 | 3 | |
| ... | | |
| Configuration $N_{conf}$ User $N^{(u)}_{N_{conf},1}$ AWV feedback ID for Antenna 1 | 11 | Indicates the RX AWV, from a receiver's perspective, or RX DMG antenna of the $N^{(u)}_{N_{conf},1}$ STA associated with the first TX DMG antenna in the $N_{conf}$ MU-MIMO transmission configuration. |
| Configuration $N_{conf}$ User $N^{(u)}_{N_{conf},1}$ BRP CDOWN for Antenna 1 | 6 | |
| Configuration $N_{conf}$ User $N^{(u)}_{N_{conf},1}$ RX Antenna ID for Antenna 1 | 3 | |
| ... | | |

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**Table 9-396—MIMO Selection Control element format(11ay) *(continued)***

| Field | Size (bits) | Meaning |
|---|---|---|
| Configuration $N_{conf}$ Group User Mask for Antenna $N_{TX}$ | 32 | Indicates the STA(s) in the target MU group associated with the $N_{TX}$ TX DMG antenna in the $N_{conf}$ MU-MIMO transmission configuration. |
| Configuration $N_{conf}$ User 1 AWV feedback ID for Antenna $N_{TX}$ | 11 | Indicates the RX AWV, from a receiver's perspective, or RX DMG antenna of the first STA associated with the $N_{TX}$ TX DMG antenna in the $N_{conf}$ MU-MIMO transmission configuration. |
| Configuration $N_{conf}$ User 1 BRP CDOWN for Antenna $N_{TX}$ | 6 | |
| Configuration $N_{conf}$ User 1 RX Antenna ID for Antenna $N_{TX}$ | 3 | |
| ... | | |
| Configuration $N_{conf}$ User $N^{(u)}_{N_{conf},N_{TX}}$ AWV feedback ID for Antenna $N_{TX}$ | 11 | Indicates the RX AWV, from a receiver's perspective, or RX DMG antenna of the $N^{(u)}_{N_{conf},N_{TX}}$ STA associated with the $N_{TX}$ TX DMG antenna in the $N_{conf}$ MU-MIMO transmission configuration. |
| Configuration $N_{conf}$ User $N^{(u)}_{N_{conf},N_{TX}}$ BRP CDOWN for Antenna $N_{TX}$ | 6 | |
| Configuration $N_{conf}$ User $N^{(u)}_{N_{conf},N_{TX}}$ RX Antenna ID for Antenna $N_{TX}$ | 3 | |
| Padding | 0–7 | Zero padding to make the MIMO Selection Control element length a multiple of 8 bits |

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

The Configuration *i* Group User Mask for Antenna *j* field ($i$ = 1, 2, …, $N_{conf}$ and $j$ = 1, 2, …, $N_{TX}$) is a bitmap that indicates whether each of EDMG STAs in the target MU group is associated with the $j^{th}$ TX DMG antenna in the $i^{th}$ MU-MIMO transmission configuration. An MU-MIMO transmission configuration defines a specific subset of STAs in the target MU group and their respective RX AWVs to be used for receiving DL MU-MIMO data transmission. The order of EDMG STAs in the Configuration *i* Group User Mask for Antenna *j* field follows the order in which they appear in the corresponding EDMG Group field of the EDMG Group ID Set element containing the target MU group. The first bit (i.e., the least significant bit) corresponds to the first EDMG STA, and the second bit corresponds to the second EDMG STA, and so on. A bit is set to 1 to indicate the corresponding STA is associated with the $j^{th}$ TX DMG antenna in the $i^{th}$ MU-MIMO transmission configuration; otherwise, the bit is set to 0. If the number of EDMG STAs in the target MU group is smaller than 32, the corresponding bits in the Configuration *i* Group User Mask for Antenna *j* field ($i$ = 1, 2, …, $N_{conf}$ and $j$ = 1, 2, …, $N_{TX}$) is set to 0.

The Nonreciprocal MU-MIMO BF Training Based Transmission Configuration field is not present in the MIMO BF Selection frame when the MU-MIMO Transmission Configuration Type field is set to 1. The Reciprocal MU-MIMO BF Training Based Transmission Configuration field is not present in the MIMO BF Selection frame when the MU-MIMO Transmission Configuration Type field is set to 0.


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### 9.4.2.276 EDMG Flow Control Extension Configuration element(11ay)

The EDMG Flow Control Extension Configuration element is defined in Figure 9-968 (EDMG Flow Control Extension Configuration element format).

| | Element ID | Length | Element ID Extension | RBUFCAP | Flow Control Status | Advanced Recipient Memory Length Exponent | Recipient Memory Capabilities | Optional Subelements |
|---|---|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 1 | 1 | 1 | 1 | variable(M118) |

**Figure 9-968—EDMG Flow Control Extension Configuration element format**

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

When sent in an ADDBA Response frame, the RBUFCAP field is as defined in 9.3.1.8.7 (EDMG Compressed BlockAck variant(11ay)). This field is reserved when sent in an ADDBA Request frame.

When sent in an ADDBA Response frame, the Flow Control Status field is defined in Figure 9-969 (Flow Control Status field format(11ay)). This field is reserved when sent in an ADDBA Request frame.

| | B0 | B1 | B2 B7 |
|---|---|---|---|
| | No Memory Kept | Memory Configuration Tag | Reserved |
| Bits: | 1 | 1 | 6 |

**Figure 9-969—Flow Control Status field format(11ay)**

The No Memory Kept and Memory Configuration Tag subfields are defined in 9.3.1.8.1 (Overview).

When sent in an ADDBA Response frame, the Advanced Recipient Memory Length Exponent field indicates the amount of free space at the recipient's memory at the start of a TXOP or SP. This field is an integer in the range 0 to 9. The length defined by this subfield is equal to $2^{(13 + \text{Advanced Recipient Memory Length Exponent})} - 1$ octets. The value $2^{(13 + \text{Advanced Recipient Memory Length Exponent})}$ is smaller than or equal to the value $2^{(13 + \text{Maximum A-MPDU Length Exponent})}$ as advertised by the STA's EDMG Capabilities element. Only one value for the Advanced Recipient Memory Length Exponent field can be present in all Block Ack agreements. This field applies to all successfully established Block Ack agreements identified by the same pair of Address 1 and Address 2 fields. This field is reserved when sent in an ADDBA Request frame.

The Recipient Memory Capabilities field is defined in Figure 9-970 (Recipient Memory Capabilities field format(11ay)).

| | B0 | B1 | B2 | B3 | B4 | B5 B7 |
|---|---|---|---|---|---|---|
| | RBUFCAP Quantity Capable | Advanced Recipient Memory Length Capable | Recipient Memory Multiple Buffer Units Capable | TID Grouping Capable | Two Memory Config Tag Capable | Reserved |
| Bits: | 1 | 1 | 1 | 1 | 1 | 3 |

**Figure 9-970—Recipient Memory Capabilities field format(11ay)**

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The RBUFCAP Quantity Capable subfield is set to 1 to indicate support of RBUFCAP values in the range 1 through 254 and is set to 0 otherwise (Table 9-41 (RBUFCAP subfield encoding for the EDMG Compressed BlockAck variant(11ay))).

The Advanced Recipient Memory Length Capable subfield is set to 1 by the recipient to indicate its request to be supported with the Advanced Recipient Memory Length Exponent (Figure 9-968 (EDMG Flow Control Extension Configuration element format)) and is set to 0 otherwise.

The Recipient Memory Multiple Buffer Units Capable subfield is set to 1 to indicate support of Memory Unit Size, Maximum MPDU per Memory Unit, and MPDU Split in Buffer values (Figure 9-971 (Recipient Memory Configuration subelement format(11ay))) and is set to 0 otherwise.

The TID Grouping Capable subfield is set to 1 to indicate support of TID Grouping values (Figure 9-971 (Recipient Memory Configuration subelement format(11ay))) and set to 0 otherwise.

The Two Memory Config Tag Capable subfield is set to 1 to indicate the capability to support two Memory Configuration Tag values per TID or TID group (Figure 9-971 (Recipient Memory Configuration subelement format(11ay))) and is set to 0 otherwise.

The Optional Subelements field is defined in Table 9-397 (Optional subelement IDs for the EDMG Flow Control Extension Configuration element(11ay)). An EDMG Flow Control Extension Configuration element contains no more than two Recipient Memory Configuration subelements.

**Table 9-397—Optional subelement IDs for the EDMG Flow Control Extension Configuration element(11ay)**

| Subelement ID | Name | Extensible |
|---|---|---|
| 0 | Recipient Memory Configuration | Yes |
| 1–220 | Reserved | |
| 221 | Vendor specific | Vendor defined |
| 222–225 | Reserved | |

The Recipient Memory Configuration subelement is defined in Figure 9-971 (Recipient Memory Configuration subelement format(11ay)).

| | Subelement ID | Length | Memory Configuration Tag | Buffer Unit Size | Recipient Memory Multiple Buffer Units Parameters | | | TID Grouping |
|---|---|---|---|---|---|---|---|---|
| | | | | | Memory Unit Size | Maximum MPDU per Memory Unit | MPDU Split in Buffer | |
| Octets: | 1 | 1 | 1 | 2 | 2 | 1 | 1 | 2 |

**Figure 9-971—Recipient Memory Configuration subelement format(11ay)**

The Subelement ID field is defined in Table 9-397 (Optional subelement IDs for the EDMG Flow Control Extension Configuration element(11ay)).

The Length field is defined in 9.4.2.1 (General).


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The Memory Configuration Tag subfield indicates one of two recipient memory configurations indicated in ADDBA Response frame within which the EDMG Flow Control Extension Configuration element is included. Allowed values are 0 and 1.

The Buffer Unit Size subfield indicates the size, in octets, of the RBUFCAP to deliver information of the recipient's available memory space to the originator for MPDU delivery. This subfield is set to a value greater than 0 if the RBUFCAP Quantity Capable subfield is 1 and is set to 0 otherwise. The recipient's available memory space, in octets, is equal to RBUFCAP × Buffer Unit Size.

The subfields within the Recipient Memory Multiple Buffer Units Parameters indicate a recipient memory structure constructed from fixed size memory buffers used to store incoming MPDUs.

The Memory Unit Size subfield indicates the size, in octets, of each buffer unit in the recipient's memory.

The Maximum MPDU per Memory Unit subfield indicates the maximum number of MPDUs that can be held in a single buffer. Valid values are 1 through 255, where value 255 indicates that there is no limitation on the number of MPDUs that can be held in a single buffer.

The MPDU Split in Buffer subfield is set to 1 to indicate that an MPDU can be split between memory buffer units in the recipient's memory and is set to 0 otherwise.

The TID Grouping subfield is a bitmap where each bit corresponds to a TID (Figure 9-972 (TID Grouping subfield format(11ay))). By setting a bit to one in the TID Grouping subfield, it indicates the TID that correspond to a TID of an ADDBA Response frame within which the Recipient Memory Configuration subelement(s) is transmitted. The recipient memory configuration becomes applicable to all TIDs/TSIDs that have their bit in the TID Grouping subfield set to 1. The RBUFCAP field, No Memory Kept and Memory Configuration Tag subfields delivered in an EDMG Flow Control Extension Configuration element within an ADDBA Response frame and in a BlockAck frame are applicable to all TIDs/TSIDs that correspond to the TIDs/TSIDs of the ADDBA Response frame that contained the TID Grouping subfield. The Advanced Recipient Memory Length Exponent field delivered in an EDMG Flow Control Extension Configuration element of an ADDBA Response frame is applicable to all TIDs/TSIDs that correspond to the TIDs/TSIDs of the ADDBA Response frame that contained the TID Grouping subfield.

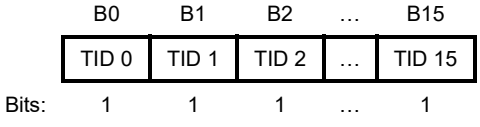


**Figure 9-972—TID Grouping subfield format(11ay)**

### 9.4.2.277 QoS-TU element(#1776)(11ay)

(#1776)The QoS triggered unscheduled (QoS-TU) element is used to communicate the QoS triggered unscheduled parameters between a non-AP and non-PCP EDMG STA and an EDMG AP or EDMG PCP.

(#1776)The QoS triggered unscheduled (QoS-TU) element is defined in Figure 9-973 (QoS Triggered Unscheduled element format(11ay)).

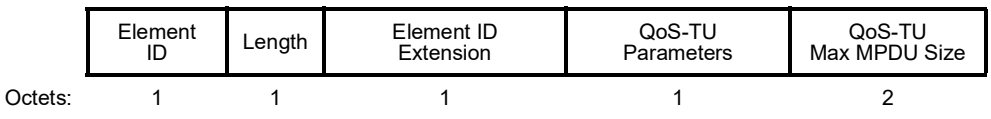


**Figure 9-973—QoS Triggered Unscheduled element format(11ay)**

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The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

The QoS-TU Parameters field contains the QoS-TU AC and the QoS-TU Max A-MPDU Length Exponent subfields as shown in Figure 9-974 (QoS-TU Parameters field format(11ay)).

| | B0 B3 | B4 | B5 | B6 | B7 |
|---|---|---|---|---|---|
| | QoS-TU Max A-MPDU Length Exponent | QoS-TU AC_VO Flag | QoS-TU AC_VI Flag | QoS-TU AC_BK Flag | QoS-TU AC_BE Flag |
| Bits: | 4 | 1 | 1 | 1 | 1 |

**Figure 9-974—QoS-TU Parameters field format(11ay)**

Each of the QoS-TU ACs Flag subfields is set to 1 to indicate that the corresponding AC (AC_BE, AC_BK, AC_VI, or AC_VO) is QoS triggered unscheduled enabled as described in 11.2.7.2.2 (Non-AP and non-PCP STA operation without a wakeup schedule); otherwise, it is set to 0.

When sent by a non-PCP and non-AP EDMG STA, the QoS-TU Max A-MPDU Length Exponent subfield is set according to the Maximum A-MPDU Length Exponent subfield described in Table 9-384 (A-MPDU Parameters field definition(11ay)). This subfield indicates the maximum A-MPDU size of buffered BUs the STA is prepared to receive during a QoS triggered unscheduled data transmission. When sent by an EDMG PCP or EDMG AP, this field is reserved.

When sent by a non-PCP and non-AP EDMG STA, the QoS-TU Max MPDU Size field indicates the maximum number of buffered BUs (MPDUs) that the STA is prepared to receive during a QoS triggered unscheduled data transmission. When sent by an EDMG PCP or EDMG AP, this field is reserved.

### 9.4.2.278 Unsolicited Block Ack Extension element(11ay)

The Unsolicited Block Ack Extension element includes information necessary to set up an unsolicited block ack extension agreement between a non-AP and non-PCP STA and an AP or PCP at the association establishment, or between a pair of non-AP and non-PCP STAs using an Information Request and Information Response frame exchange. The format of the element is shown in Figure 9-975 (Unsolicited Block Ack Extension element format(11ay)).

| | Element ID | Length | Element ID Extension | Unsolicited Block Ack Extension Parameters | Block Ack Timeout Value |
|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 2 | 2 |

**Figure 9-975—Unsolicited Block Ack Extension element format(11ay)**

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

The Unsolicited Block Ack Extension Parameters field is defined in Figure 9-976 (Unsolicited Block Ack Extension Parameters field format(11ay)).

| | B0 B7 | B8 | B9 B15 | B16 B26 | B27 | B28 B31 |
|---|---|---|---|---|---|---|
| | Reserved | A-MSDU Supported | Reserved | Buffer Size | Multi-TID Supported | Reserved |
| Bits: | 8 | 1 | 7 | 11 | 1 | 4 |

**Figure 9-976—Unsolicited Block Ack Extension Parameters field format(11ay)**



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The A-MSDU Supported subfield is set to 1 to indicate that the STA supports an A-MSDU carried in a QoS Data frame sent under the unsolicited block ack extension. It is set to 0 otherwise.

The Buffer Size subfield is an integer ranging from 1 to 1024 that indicates the number of buffers available for each unsolicited block ack extension agreement.

The Multi-TID Supported subfield is set to 1 to indicate that the STA supports multiple TIDs in unsolicited block ack agreements. An EDMG STA that supports multi-TID in unsolicited block ack agreements also sets the EDMG Multi-TID Aggregation Support field defined in 9.4.2.264.6 (MAC Capabilities subelement) to a nonzero value. An EDMG STA that does not support multi-TID as indicated by the EDMG Multi-TID Aggregation Support field defined in 9.4.2.264.6 (MAC Capabilities subelement), sets the Multi-TID Supported subfield to 0.

The Block Ack Timeout Value field is defined in 9.4.1.14 (Block Ack Timeout Value field).

### 9.4.2.279 SAR Configuration element(11ay)

The Segmentation and Reassembly (SAR) Configuration element is formatted as shown in Figure 9-977 (SAR Configuration element format(11ay)). The SAR Configuration element can be included in the ADDBA Request and Response frames in case the ADDBA originator requests the recipient to use segmentation and reassembly for a corresponding TID. The SAR Configuration element indicates the specific segmentation parameters for the TID.

| | Element ID | Length | Element ID Extension | SAR Parameters | MSDU Buffer Size | MPDU Buffer Size | Maximum Segmented MSDU Exponent |
|---|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 1 | 2 | 2 | 1 |

**Figure 9-977—SAR Configuration element format(11ay)**

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

The SAR Parameters field is defined in Figure 9-978 (SAR Parameters field format(11ay)).

| | B0 | B1 B3 | B4 B7 |
|---|---|---|---|
| | SAR Enabled | MSDU Modulo | MPDU Modulo |
| Bits: | 1 | 3 | 4 |

**Figure 9-978—SAR Parameters field format(11ay)**

The SAR Enabled subfield set to 1 indicates that segmentation and reassembly is to be used with the parameters indicated in this element for the corresponding TID.

The MSDU Modulo subfield indicates the number of bits to be allocated to the length of the MSDU Sequence Number subfield within the Sequence Control field. The MPDU Modulo subfield indicates the number of bits to be allocated to the length of the MPDU Sequence Number subfield within the Sequence Control field. The sum of the values of the MSDU Modulo subfield and the MPDU Modulo subfield is equal to 14(#6303).

The MSDU Buffer Size field indicates the number of buffers available for this particular TID. Each buffer is capable of holding the number of octets equal to the value defined by the Maximum Segmented MSDU Exponent subfield.

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The MPDU Buffer Size field indicates the number of buffers available for this particular TID. Each buffer is capable of holding a number of octets equal to the maximum MPDU size as indicated in Table 9-34 (Maximum data unit sizes and durations(#1327)(#4013)) for a DMG PPDU, or to the value of the last Maximum MSDU Size field of the TSPEC element agreed between the peers via an ADDTS Request and Response frame exchange for this TID, plus any security encapsulation overhead, MAC header and FCS.

The Maximum Segmented MSDU Exponent subfield specifies the maximum size of the segmented MSDU belonging to the TID under the BA agreement. This subfield is an integer in the range 0 to 9, occupying bit positions 0 through 3 in the Maximum Segmented MSDU Exponent subfield; other bit positions in the subfield are reserved. The maximum segmented MSDU size that is defined by this subfield is equal to $2^{(13 + \text{Maximum Segmented MSDU Exponent})} - 1$ octets.

### 9.4.2.280 TDD Slot Structure element(11ay)

The TDD Slot Structure element defines the structure of a TDD SP described in 10.38.6.2.2 (SP with TDD channel access(11ay)). The format of the TDD Slot Structure element is shown in Figure 9-979 (TDD Slot Structure element format(11ay)).

| | Element ID | Length | Element ID Extension | Slot Structure Control | Peer STA Address |
|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 2 | 6 |

| | Slot Structure Start Time | Number of TDD Intervals | TDD Interval Duration | Number of TDD Slots per TDD Interval (*M*) | Slot Structure |
|---|---|---|---|---|---|
| Octets: | 4 | 2 | 2 | 1 | 4×*M* |

**Figure 9-979—TDD Slot Structure element format(11ay)**

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

The Slot Structure Control field is defined in Figure 9-980 (Slot Structure Control field format(11ay)).

| | B0 B3 | B4 B11 | B12 B15 |
|---|---|---|---|
| | Allocation ID | Maximum Time Synchronization Error | Reserved |
| Bits: | 4 | 8 | 4 |

**Figure 9-980—Slot Structure Control field format(11ay)**

The Allocation ID subfield is set to the same value of the Allocation ID subfield in the Allocation Control field of the Extended Schedule element describing the TDD SP allocation.

The Maximum Time Synchronization Error subfield indicates the maximum time synchronization error, in microseconds, between a transmitter and receiver in either uplink or downlink direction.

The Peer STA Address field is any valid individual or broadcast address that specifies the MAC address of the STA that is the intended recipient of the TDD Slot Structure element. The broadcast address indicates that the TDD Slot Structure element is common for the entire BSS.


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The Slot Structure Start Time field indicates the lower 4 octets of the TSF timer at the start of the first TDD interval in which the slot structure takes effect.

The Number of TDD Intervals field indicates the time duration the slot structure holds, in units of TDD intervals.

The TDD Interval Duration field indicates the TDD interval duration in microseconds.

The Number of TDD Slots per TDD Interval field indicates the number of TDD slots in each TDD interval.

The Slot Structure field is defined in Figure 9-981 (Slot Structure field format(11ay)). The size of this field is 4×*M* octets, where *M* is equal to the value of the Number of TDD Slots per TDD Interval field.

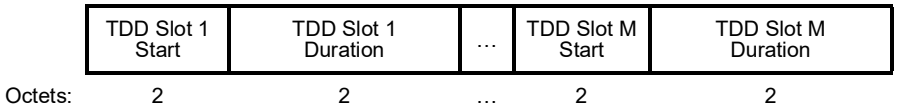


**Figure 9-981—Slot Structure field format(11ay)**

The TDD Slot *i* Start subfield, $1 \le i \le M$, indicates the start time, in microseconds, of the $i^{th}$ TDD slot relative to the beginning of each TDD interval.

The TDD Slot *i* Duration subfield, $1 \le i \le M$, indicates the duration, in microseconds, of the $i^{th}$ TDD slot in each TDD interval.

### 9.4.2.281 TDD Slot Schedule element(11ay)

The TDD Slot Schedule element defines the access assignment of DMG STAs to TDD slots within a TDD SP (see 10.38.6.2.2). The format of the TDD Slot Schedule element is shown in Figure 9-982 (TDD Slot Schedule element format(11ay)).

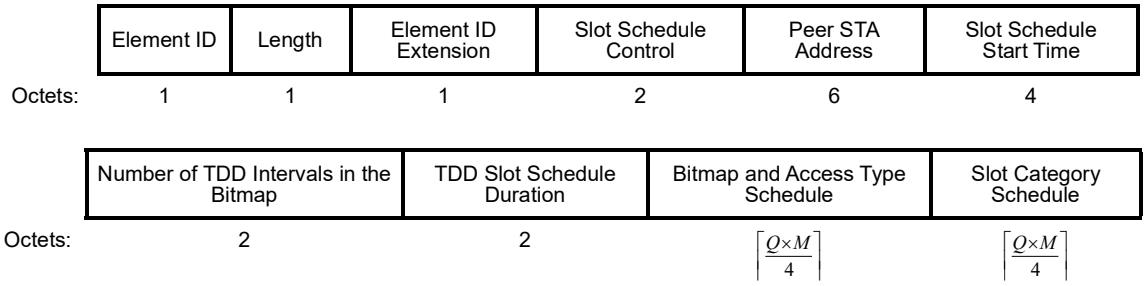


**Figure 9-982—TDD Slot Schedule element format(11ay)**

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

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The Slot Schedule Control field is defined in Figure 9-983 (Slot Schedule Control field format(11ay)).

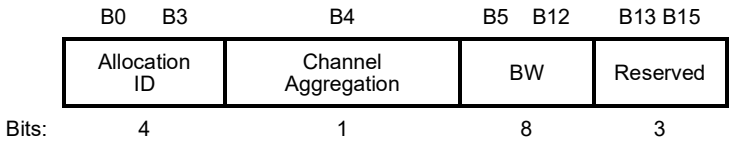


**Figure 9-983—Slot Schedule Control field format(11ay)**

The Allocation ID subfield is set to the same value of the Allocation ID subfield in Allocation Control field of the Extended Schedule element describing the SP allocation.

The Channel Aggregation and BW subfields are defined in Table 28-12 (EDMG-Header-A field structure and definition for an SU PPDU(11ay)).

The Peer STA Address field specifies the MAC address of the STA that is the intended recipient of the TDD Slot Structure element.

The Slot Schedule Start Time field indicates the lower 4 octets of the TSF timer at the start of the first TDD interval in which the schedule takes effect.

The Number of TDD Intervals in the Bitmap field indicates the number of TDD intervals described in the Bitmap and Access Type Schedule field following the time indicated by the Slot Schedule Start Time field.

The TDD Slot Schedule Duration field indicates the duration, in microseconds, from the start of the first TDD interval to the end of the last TDD interval in which the schedule takes effect.

The Bitmap and Access Type Schedule field defines the type of a TDD slot and the access permission of a DMG STA to the TDD slots covered by this bitmap. Each pair of consecutive 2 bits indicates the type and access permission of the TDD slot as specified in Table 9-398 (Bitmap and Access Type Schedule field encoding(11ay)) (see 10.38.6.2.2 (SP with TDD channel access(11ay)) and 11.2.7 (Power management in a PBSS and DMG infrastructure BSS)). The size of the Bitmap and Access Type Schedule field is a function of the value of the Number of TDD Slots per TDD Interval field in the TDD Slot Structure element, *M*, and the value of the Number of TDD Intervals in the Bitmap field, *Q*. If padding is required to make the size of this field an integer number, a TDD slot of type unassigned is used. The TDD slots defined by the Bitmap and Access Type Schedule field are repeated for the duration indicated by the TDD Slot Schedule Duration field value.

**Table 9-398—Bitmap and Access Type Schedule field encoding(11ay)**

| Encoding | Behavior of STA that transmits the TDD Slot Schedule element | Behavior of STA that receives the TDD Slot Schedule element |
|---|---|---|
| 0 | TDD slot unassigned | |
| 1 | Simplex TX | Simplex RX |
| 2 | Simplex RX | Simplex TX |
| 3 | Unavailable | |


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The Slot Category Schedule field defines the TDD slot category. Each pair of consecutive 2 bits indicates the frame type(s) that are allowed to be transmitted in the corresponding TDD slot defined by the Bitmap and Access Type Schedule field. A value of 0 indicates Basic TDD slot, a value of 1 indicates Data TDD slot and a value of 2 indicates a BF TDD slot. Value of 3 is reserved. The size of the Slot Category Schedule field is a function of the value of the Number of TDD Slots per TDD Interval field in the TDD Slot Structure element, *M*, and the value of the Number of TDD Intervals in the Bitmap field, *Q*. If padding is required to make the size of this field an integer number, a reserved TDD slot category is used.

### 9.4.2.282 TDD Route element(11ay)

The TDD Route element is used to communicate TDD beamforming results and sector switch configuration as described in 10.41.11 (TDD beamforming(11ay)) and 11.36 (DMG beamforming). The format of the TDD Route element is shown in Figure 9-984 (TDD Route element format(11ay)).

| | Element ID | Length | Element ID Extension | TDD Route Subelements |
|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | variable(M118) |

**Figure 9-984—TDD Route element format(11ay)**

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

The TDD Route Subelements field is defined in Table 9-399 (TDD Route Subelements field format(11ay)). The TDD Route element contains one or more of the subelements indicated in Table 9-399 (TDD Route Subelements field format(11ay)).

**Table 9-399—TDD Route Subelements field format(11ay)**

| Subelement ID | Name | Length |
|---|---|---|
| 0 | TDD Sector Feedback | Variable |
| 1 | TDD Sector Setting | 25 |
| 2 | TDD Sector Config | Variable |
| 3–220 | Reserved | |
| 221 | Vendor specific | Vendor defined |
| 222–225 | Reserved | |

The TDD Sector Feedback subelement is used to communicate all the initiator TX Sector IDs as received by the responder during a TDD beamforming training procedure described in 10.41.11. The format of the TDD Sector Feedback element is shown in Figure 9-985 (TDD Sector Feedback subelement format(11ay)).

| | Subelement ID | Length | Number of Tx Beams | Tx Beam Feedback$_1$ | … | Tx Beam Feedback$_N$ |
|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 2 | variable(M118) | | variable(M118) |

**Figure 9-985—TDD Sector Feedback subelement format(11ay)**

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The Subelement ID subfield is defined in Table 9-399 (TDD Route Subelements field format(11ay)).

The Length subfield is defined in 9.4.2.1 (General).

The Number of Tx Beams subfield indicates the number of Tx Beam Feedback subfields, *N*, included in the subelement.

Each Tx Beam Feedback subfield has a variable size and is defined in Figure 9-986 (Tx Beam Feedback subfield format(11ay)).

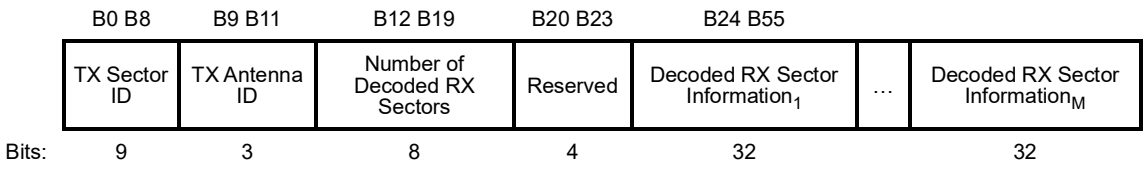


**Figure 9-986—Tx Beam Feedback subfield format(11ay)**

The TX Sector ID subfield contains the value of the TX Sector ID subfield in the TDD SSW frame to which the Tx Beam Feedback subfield applies.

The TX Antenna ID subfield contains the value of the TX Antenna ID subfield in the TDD SSW frame to which the Tx Beam Feedback subfield applies.

The Number of Decoded RX Sectors subfield indicates the number of Decoded RX Sector Information subfields, *M*, included in this subfield.

The Decoded RX Sectors Information subfield is defined in Figure 9-987 (Decoded RX Sectors Information subfield format(11ay)).

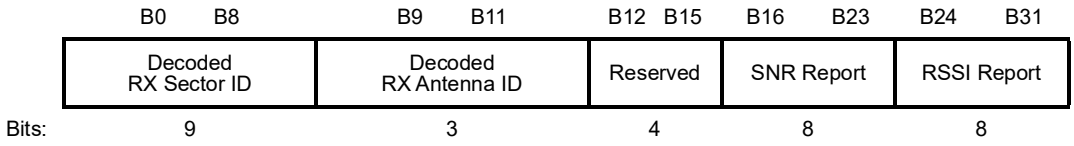


**Figure 9-987—Decoded RX Sectors Information subfield format(11ay)**

The Decoded RX Sector ID subfield indicates the receive sector index used by the responder when it decoded a TDD SSW frame with TX Sector ID and TX Antenna ID subfields matching the corresponding subfields in the Tx Beam Feedback subfield.

The Decoded RX Antenna ID subfield indicates the receive DMG antenna index used by the responder when it decoded a TDD SSW frame with TX Sector ID and TX Antenna ID subfields matching the corresponding subfields in the Tx Beam Feedback subfield.

The SNR Report subfield is set to the value of the SNR achieved while decoding TDD SSW frame(s) with TX Sector ID and TX Antenna ID subfields matching the corresponding subfields in the Tx Beam Feedback subfield. The SNR Report subfield is an unsigned integer referenced to a level of –8 dB. Each step is 0.25 dB. SNR values less than or equal to –8 dB are represented as 0. SNR values greater than or equal to 55.75 dB are represented as 0xFF.


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The RSSI Report subfield is set to the value of the received power while receiving the L-STF field of TDD SSW frame(s) with TX Sector ID and TX Antenna ID subfields matching the corresponding subfields in the Tx Beam Feedback subfield. The RSSI Report is a signed integer in the range –128 dBm to 127 dBm and is measured by the PHY as the power observed at the input of the antenna plus the antenna gain, or the equivalent antenna gain for phased array antennas, used to receive the TDD SSW frame(s).

NOTE—When multiple TDD SSW frames are received for the same combination of transmit and receive DMG antennas, and transmit and receive sectors, the SNR and RSSI values reported in the SNR Report and RSSI Report subfields can be a combination of measurements taken over any subset of the received TDD SSW frames.

The TDD Sector Setting subelement is used to request the peer to configure its antenna to a specific receive and transmit sector combination as described in 11.36 (DMG beamforming). The format of the TDD Sector Setting subelement is shown in Figure 9-988 (TDD Sector Setting subelement format(11ay)).

| | Subelement ID | Length | TDD Sector Setting Control | Switch Timestamp | Revert Timestamp | TDD Switch Sectors |
|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 8 | 8 | 6 |

**Figure 9-988—TDD Sector Setting subelement format(11ay)**

The Subelement ID subfield is defined in Table 9-399 (TDD Route Subelements field format(11ay)).

The Length subfield is defined in 9.4.2.1 (General).

The TDD Sector Setting Control subfield is defined in Figure 9-989 (TDD Sector Setting Control field format(11ay)).

| | B0 | B1 | B2 | B3 B7 |
|---|---|---|---|---|
| | Set Sector Request | Set Sector Response | Set Sector Acknowledge | Reserved |
| Bits: | 1 | 1 | 1 | 5 |

**Figure 9-989—TDD Sector Setting Control field format(11ay)**

The Set Sector Request subfield is set to 1 by the initiator to request the responder to change its receiver sector setting according to the Responder RX Sector ID subfield and its transmitter sector setting according to Responder TX Sector ID subfield, with both subfields indicated in the TDD Switch Sectors subfield.

The Set Sector Response subfield is set to 1 by the responder to indicate the reception of a successful TDD Sector Setting subelement with the Set Sector Request subfield equal to 1.

The Set Sector Acknowledge subfield is set to 1 by the initiator to acknowledge the reception of a successful TDD Sector Setting subelement with the Set Sector Response subfield equal to 1.

The Switch Timestamp subfield indicates a future TSF timer value in which the new sector configuration setting is to take effect.

The Revert Timestamp subfield indicates a future TSF timer value in which the previous sector configuration is restored in case sector switching fails.

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The TDD Switch Sectors subfield is defined in Figure 9-990 (TDD Switch Sectors field format(11ay)).

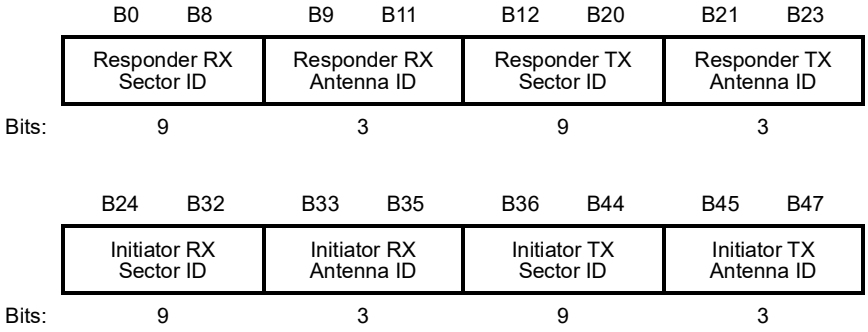


**Figure 9-990—TDD Switch Sectors field format(11ay)**

The Responder RX Sector ID subfield contains the value of the sector ID the responder uses to set its receive sector.

The Responder RX Antenna ID subfield contains the antenna ID the responder uses to set its receive DMG antenna.

The Responder TX Sector ID subfield contains the value of the sector ID the responder uses to set its transmit sector.

The Responder TX Antenna ID subfield contains the antenna ID the responder uses to set its transmit DMG antenna.

The Initiator RX Sector ID subfield contains the value of the sector index the initiator uses to set its receive sector.

The Initiator RX Antenna ID subfield contains the antenna ID the initiator uses to set its receive DMG antenna.

The Initiator TX Sector ID subfield contains the value of the sector index the initiator uses to set its transmit sector.

The Initiator TX Antenna ID subfield contains the antenna ID the initiator uses to set its transmit DMG antenna.

The TDD Sector Config subelement is used to communicate the RX Sector IDs and RX Antenna ID to be used by the responder during the next beam measurement procedure as described in 10.41.11 (TDD beamforming(11ay)). The format of the TDD Sector Config subelement is shown in Figure 9-991 (TDD Sector Config subelement format(11ay)).

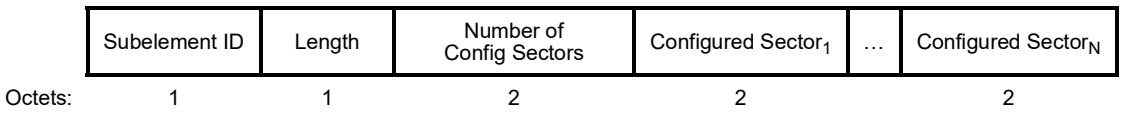


**Figure 9-991—TDD Sector Config subelement format(11ay)**

The Subelement ID subfield is defined in Table 9-399 (TDD Route Subelements field format(11ay)).


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The Length subfield is defined in 9.4.2.1 (General).

The Number of Config Sectors subfield indicates the number of Configured Sector subfields, *N*, included in the subelement.

Each Configured Sector subfield is defined as indicated in Figure 9-992 (Configured Sector subfield format(11ay)).

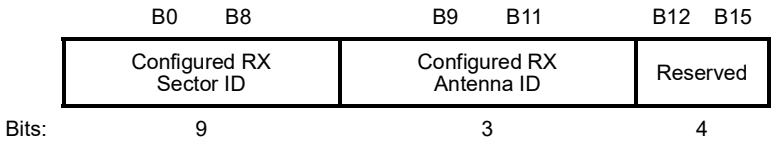


**Figure 9-992—Configured Sector subfield format(11ay)**

The Configured RX Sector ID subfield indicates the receive sector index to be used by the responder in the upcoming beam measurement procedure.

The Configured RX Antenna ID subfield indicates the receive DMG antenna index to be used by the responder in the upcoming beam measurement procedure.

### 9.4.2.283 Digital BF Feedback element(11ay)

The Digital BF Feedback element is transmitted in the MIMO BF Feedback frame and carries feedback information in the form of beamforming feedback matrices and differential SNRs. The feedback information (#2329)is used by a transmit beamformer to determine digital beamforming steering matrices, *Q*. This process is described in 10.41.10.2.4 (Hybrid beamforming for SU-MIMO and MU-MIMO). When the Digital BF Feedback element is transmitted in the MIMO BF Feedback frame, the SNR fields within the Channel Measurement Feedback element are interpreted as average SNR per stream, as defined in Table 9-264 (see 9.4.2.135 (Channel Measurement Feedback element)).

As specified in this subclause, the size and configuration of the Digital BF Feedback element depends on the field values in the MIMO Feedback Control element transmitted in the same frame that carries the Digital BF Feedback element. Therefore, all references to fields present in the MIMO Feedback Control element refer to the element transmitted in the same frame that carries the Digital BF Feedback element.

When the Feedback Type subfield within the Digital Fbck Control field is 0, the Digital Beamforming Feedback Information field in the Digital BF Feedback element contains $N_{SC}$ digital beamforming matrices. When $N_{SC} > 1$, a Tap Delay field indicating the tap to which each digital beamforming matrix corresponds to is additionally present. The digital beamforming information in time domain can be represented as a matrix function $V$ given by the following:

$$V\left(n\frac{T_c}{N_{CB}}\right)=\sum_{k=1}^{N_{SC}}\tilde{V}_k\delta\left(\frac{T_c}{N_{CB}}\left[n-n_k\right]\right)$$

where

$n_k$ is the delay of the $k^{\text{th}}$ tap and $n_k = 0$ for $k = 1$

$T_c/N_{CB}$ is defined in Table 28-47 (EDMG SC mode timing-related parameters(11ay))

$\tilde{V}_k$ is the digital beamforming matrix per tap

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$$\delta(n) = \begin{cases} 1 & n = 0 \\ 0 & n \neq 0 \end{cases}$$

The components of the digital beamforming matrix per tap $\tilde{V}_k$ are contained in the Digital Beamforming Feedback Matrix *k* subfield, in uncompressed form, indexed such that the $(i, j)^{\text{th}}$ element of $\tilde{V}_k$ is the $(j - 1) \times Nr + (i - 1)^{\text{th}}$ entry of the $k^{\text{th}}$ Digital Beamforming Feedback Matrix field, shown in Table 9-993 (Description of the Digital Beamforming Feedback Matrix k subfield in SC mode(11ay)), and $i = 1 \ldots Nr$, $j = 1 \ldots Nc$, where *Nr* and *Nc* are defined by the Nr Index and Nc Index subfields, respectively, in the Digital Fbck Control field. Each digital feedback component is represented as an 8 bit real part, followed by an 8 bit imaginary part. The taps $n_k > 0$ for which each of the beamforming feedback matrices are computed are indicated in the Tap Delay field.

**Figure 9-993—Description of the Digital Beamforming Feedback Matrix *k* subfield in SC mode(11ay)**

| Subfield | | Size (bits) | Meaning |
|---|---|---|---|
| Digital Beamforming Feedback Matrix *k* | Digital Feedback Component 1 | 16 | Digital beamforming coefficient(s) for stream 1 to TX transmit chain 1 |
| | Digital Feedback Component 2 | 16 | Digital beamforming coefficient(s) for stream 1 to TX transmit chain 2 |
| | … | … | … |
| | Digital Feedback Component *Nr* × *Nc* | 16 | Digital beamforming coefficient for stream *Nr* to TX transmit chain *Nc*. |

When the Feedback Type within the Digital Fbck Control field is 1, the Digital Beamforming Feedback Information field contains the digital beamforming feedback matrices in compressed form with elements indexed, first, by matrix angles in the order shown in Table 9-103 (Order of angles in the compressed beamforming feedback matrix for MU type feedback when used in an S1G band) and, second, by data subcarrier index from lowest frequency to highest frequency. The explanation on how these angles are generated from the beamforming feedback matrix *V* is given in 19.3.12.3.6 (Compressed beamforming feedback matrix). For channel aggregation where the total number of spatial streams is evenly divided between the primary and secondary channels (see 28.3.3.3.2.3 (Definition for EDMG SC mode and EDMG OFDM mode PPDUs)), the number of rows and columns in beamforming feedback matrix is an even number. The number of rows in each aggregated channel's beamforming feedback matrix is *Nr*/2 and the number of columns in each aggregated channel's beamforming feedback matrix is *Nc*/2, where *Nr* and *Nc* are the values, respectively, indicated by the Nr Index and Nc Index subfields within the Digital Fbck Control field.

The Digital BF Feedback element has the structure and order defined in Table 9-400 (Digital BF Feedback element format (11ay)), where the value of $n_{bit}$ is defined in Table 9-401 (Definition of nbit (11ay)) as a function of the value of the Feedback Type subfield within the Digital Fbck Control field. For channel aggregation, the value of $n_{bit}$ is composed of feedback bits for each aggregated channel.


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**Table 9-400—Digital BF Feedback element format (11ay)**

| Field | Size (bits) | Meaning |
|---|---|---|
| Element ID | 8 | |
| Length | 8 | |
| Element ID Extension | 8 | |
| Digital Beamforming Feedback Information | | |
| Digital Beamforming Feedback Matrix 1 | $n_{bit}$ | If the Feedback Type subfield is 0, represents the beamforming matrix in time domain for the 1st tap as described above.<br><br>If Feedback Type subfield is 1, represents the beamforming matrix for the 1st subcarrier, indexed by matrix angles in the order shown in Table 9-103 (Order of angles in the compressed beamforming feedback matrix for MU type feedback when used in an S1G band). |
| … | … | |
| Digital Beamforming Feedback Matrix $N_{SC}$ | $n_{bit}$ | If the Feedback Type subfield is 0, represents the beamforming matrix in time domain for the $N_{SC}$th tap as described above.<br><br>If Feedback Type subfield is 1, represents the beamforming matrix for the $N_{SC}$th subcarrier, indexed by matrix angles in the order shown in Table 9-103 (Order of angles in the compressed beamforming feedback matrix for MU type feedback when used in an S1G band). |
| Differential Subcarrier Index | | |
| Differential subcarrier index $scidx(0) - scidx(1)$ | 3 | When the Grouping subfield is 3, this field represents the number of subcarriers between $scidx(0)$ and $scidx(1)$. Otherwise, it is not present.<br>It is set to $j$ to indicate the distance between the $scidx(0)$ and $scidx(1)$ is $2^j$.<br><br>Set to 0 to indicate 1.<br>Set to 1 to indicate 2.<br>Set to 2 to indicate 4.<br>Set to 3 to indicate 8.<br>Set to 4 to indicate 16.<br>Set to 5 to indicate 32.<br>Values 6 and 7 are reserved. |
| … | … | |
| Differential subcarrier index $scidx(N_{SC} - 2) - scidx(N_{SC} - 1)$ | 3 | When the Grouping subfield is 3, this field represents the number of subcarriers between $scidx(N_{SC} - 2)$ and $scidx(N_{SC} - 1)$. Otherwise, it is not present.<br>It is set to $j$ to indicate the distance between the $scidx(N_{SC} - 2)$ and $scidx(N_{SC} - 1)$ is $2^j$. |

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**Table 9-400—Digital BF Feedback element format *(continued)*(11ay)**

| Field | Size (bits) | Meaning |
|---|---|---|
| Tap Delay | | |
| Relative Tap Delay 2 | 12 | When the Feedback Type subfield is 0 and $N_{SC} > 1$, this field represents the delay of tap #2 in units of $T_c/N_{CB}$ relative to Tap 1. Otherwise, it is not present. |
| … | ... | … |
| Relative Tap Delay $N_{SC}$ | 12 | When the Feedback Type subfield is 0 and $N_{SC} > 1$, this field represents the delay of tap #$N_{SC}$ in units of $T_c/N_{CB}$ relative to Tap 1. Otherwise, it is not present. |
| MU Exclusive Beamforming Report | | |
| Differential SNR for space-time stream 1 for subcarrier $k = scidx(0)$ | 8 | $D\_SNR_{scidx(0),1}$ as defined in Equation (9-11) |
| … | … | … |
| Differential SNR for space-time stream *Nc* for subcarrier $k = scidx(0)$ | 8 | $D\_SNR_{scidx(0),Nc}$ as defined in Equation (9-11) |
| Differential SNR for space-time stream 1 for subcarrier $k = scidx(1)$ | 4 | $D\_SNR_{scidx(1),1}$ as defined in Equation (9-10) |
| … | … | … |
| Differential SNR for space-time stream *Nc* for subcarrier $k = scidx(1)$ | 4 | $D\_SNR_{scidx(1),Nc}$ as defined in Equation (9-10) |
| … | … | … |
| Differential SNR for space-time stream 1 for subcarrier $k = scidx(N_{SC} - 1)$ | 4 | $D\_SNR_{scidx(Nsc-1),1}$ as defined in Equation (9-10) |
| … | … | … |
| Differential SNR for space-time stream *Nc* for subcarrier $k = scidx(N_{SC} - 1)$ | 4 | $D\_SNR_{scidx(Nsc-1),Nc}$ as defined in Equation (9-10) |
| Padding | 0–7 | Zero padding to make the Digital BF Feedback element length a multiple of 8 bits |

When the Grouping subfield within the Digital Fbck Control field is less than or equal to 2, the subcarrier indices for which the beamforming matrices are computed are defined in Table 9-403 (Subcarriers for which a compressed beamforming feedback matrix is sent back(11ay)). When the Grouping subfield within the Digital Fbck Control field is 3, the Digital BF Feedback element includes the Differential Subcarrier Index field marking the number of subcarriers between each two adjacent subcarriers within the feedback report. The subcarrier index set is constructed such that it is a subset of the subcarrier index set defined for *Ng*=2 and the corresponding $N_{CB}$ in Table 9-403 (Subcarriers for which a compressed beamforming feedback matrix is sent back(11ay)), such that the edge subcarriers and the subcarriers with indices –2 and 2 are present within the feedback report and the distance between subcarriers within the feedback report is one of the values in {1, 2, 4, 8, 16, 32}.


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**Table 9-401—Definition of $n_{bit}$ (11ay)**

| Feedback Type subfield value | $n_{bit}$ size (bits) | | |
|---|---|---|---|
| | 2.16 GHz, 4.32 GHz, 6.48 GHz, or 8.64 GHz channel | 2.16+2.16 GHz or 4.32+4.32 GHz channel | |
| 0 | $2\times 8\times N_c\times N_r$ | $2\times 8\times (N_c/2)\times (N_r/2)$ | 2.16 GHz or 4.32 GHz channel containing the primary channel |
| | | $2\times 8\times (N_c/2)\times (N_r/2)$ | 2.16 GHz or 4.32 GHz channel not containing the primary channel |
| 1 | $N_a\times (b_\psi + b_\varphi)/2$, with $N_\varphi = \left( N_r \times \frac{N_r+1}{2} - N_r \right)$ and $N_\psi = \left( N_r \times \frac{N_r-1}{2} \right)$, $N_a = N_\psi + N_\phi$ | $N_a\times (b_\psi + b_\varphi)/2$, with $N_\varphi = \left( (N_r/2)\times \frac{(N_r/2)+1}{2} - (N_r/2) \right)$ and $N_\psi = \left( (N_r/2)\times \frac{(N_r/2)-1}{2} \right)$, $N_a = N_\psi + N_\phi$ | 2.16 GHz or 4.32 GHz channel containing the primary channel |
| | | $N_a\times (b_\psi + b_\varphi)/2$ | 2.16 GHz or 4.32 GHz channel not containing the primary channel |

In Table 9-103 (Order of angles in the compressed beamforming feedback matrix for MU type feedback when used in an S1G band), *Nc* is the number of columns in a compressed beamforming feedback matrix determined by the Nc Index subfield within the Digital Fbck Control field, and *Nr* is the number of rows in a compressed beamforming feedback matrix determined by the Nr Index subfield within the Digital Fbck Control field.

The angles are quantized as defined in Table 9-402 (Quantization of angles(11ay)).

**Table 9-402—Quantization of angles(11ay)**

| Quantized Ψ | Quantized ϕ |
|---|---|
| $\psi = \frac{k\pi}{2^{b_\psi+1}} + \frac{\pi}{2^{b_\psi+2}}$ radians<br>where<br>$k = 0, 1, 2, \ldots, 2^{b_\psi} - 1$<br>$b_\psi$ is the number of bits used to quantize ψ (defined by the Codebook Information field of the MIMO Feedback Control element) | $\phi = \frac{k\pi}{2^{b_\phi-1}} + \frac{\pi}{2^{b_\phi}}$ radians<br>where<br>$k = 0, 1, 2, \ldots, 2^{b_\phi} - 1$<br>$b_\phi$ is the number of bits used to quantize ϕ (defined by the Codebook Information field of the MIMO Feedback Control element) |

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**Table 9-403—Subcarriers for which a compressed beamforming feedback matrix is sent back(11ay)**

| $N_{CB}$ | $Ng$ | $N_{SC}$ | Subcarriers for which compressed feedback beamforming matrix is sent: $scidx(0)$, $scidx(1)$, …, $scidx(N_{SC}-1)$ (Note that DC subcarriers (0, ±1) are skipped.) |
|---|---|---|---|
| 1 | 2 | 178 | –177,–176,–174,–172,–170,–168,–166,–164,–162,–160,–158,–156,–154,–152,–150,<br>–148,–146,–144,–142,–140,–138,–136,–134,–132,–130,–128,–126,–124,–122,–120,<br>–118,–116,–114,–112,–110,–108,–106,–104,–102,–100,–98,–96,–94,–92,–90,–88,–86,<br>–84,–82,–80,–78,–76,–74,–72,–70,–68,–66,–64,–62,–60,–58,–56,–54,–52,–50,–48,–46,<br>–44,–42,–40,–38,–36,–34,–32,–30,–28,–26,–24,–22,–20,–18,–16,–14,–12,–10,–8,–6,–4,–<br>2,2,4,6,8,10,12,14,16,18,20,22,24,26,28,30,32,34,36,38,40,42,44,46,48,50,52,54,56,58,60,62,64,66,68,70,72,74,76,78,80,82,84,86,88,90,92,94,96,98,100,102,104,106,108,110,112,114,116,118,120,122,124,126,128,130,132,134,136,138,140,142,144,146,148,150,152,154,156,158,160,162,164,166,168,170,172,174,176,177 |
| | 4 | 90 | –177,–174,–170,–166,–162,–158,–154,–150,–146,–142,–138,–134,–130,–126,–122,<br>–118,–114,–110,–106,–102,–98,–94,–90,–86,–82,–78,–74,–70,–66,–62,–58,–54,–50,<br>–46,–42,–38,–34,–30,–26,–22,–18,–14,–10,–6,–2,2,6,10,14,18,22,26, 30,34, 38,42,<br>46,50,54,58,62,66,70,74,78,82,86,90,94,98,102,106,110,114,118,122,126,130,134,138,<br>142,146,150,154,158,162,166,170,174,177 |
| | 8 | 46 | –177,–170,–162,–154,–146,–138,–130,–122,–114,–106,–98,–90,–82,–74,–66,–58,–50,<br>–42,–34,–26,–18,–10,–2,2,10,18,26,34,42,50,58,66,74,82,90,98,106,114,122,130,138,<br>146,154,162,170,177 |



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**Table 9-403—Subcarriers for which a compressed beamforming feedback matrix is sent back(11ay) *(continued)***

| $N_{CB}$ | $Ng$ | $N_{SC}$ | **Subcarriers for which compressed feedback beamforming matrix is sent: *scidx*(0), *scidx*(1), …, *scidx*($N_{SC}$ – 1)** (Note that DC subcarriers (0, ±1) are skipped.) |
|---|---|---|---|
| 2 | 2 | 388 | –386,–385,–383,–381,–379,–377,–375,–373,–371,–369,–367,–365,–363,–361,–359,<br>–357,–355,–353,–351,–349,–347,–345,–343,–341,–339,–337,–335,–333,–331,–329,<br>–327,–325,–323,–321,–319,–317,–315,–313,–311,–309,–307,–305,–303,–301,–299,<br>–297,–295,–293,–291,–289,–287,–285,–283,–281,–279,–277,–275,–273,–271,–269,<br>–267,–265,–263,–261,–259,–257,–255,–253,–251,–249,–247,–245,–243,–241,–239,<br>–237,–235,–233,–231,–229,–227,–225,–223,–221,–219,–217,–215,–213,–211,–209,<br>–207,–205,–203,–201,–199,–197,–195,–193,–191,–189,–187,–185,–183,–181,–179,<br>–177,–176,–174,–172,–170,–168,–166,–164,–162,–160,–158,–156,–154,–152,–150,<br>–148,–146,–144,–142,–140,–138,–136,–134,–132,–130,–128,–126,–124,–122,–120,<br>–118,–116,–114,–112,–110,–108,–106,–104,–102,–100,–98,–96,–94,–92,–90,–88,–86,<br>–84,–82,–80,–78,–76,–74,–72,–70,–68,–66,–64,–62,–60,–58,–56,–54,–52,–50,–48,–46,<br>–44,–42,–40,–38,–36,–34,–32,–30,–28,–26,–24,–22,–20,–18,–16,–14,–12,–10,–8,–6,–4,–<br>2,2,4,6,8,10,12,14,16,18,20,22,24,26,28,30,32,34,36,38,40,42,44,46,48,50,52,54,56,58,60,62,64,66,68,70,72,74,76,78,80,82,84,86,88,90,92,94,96,98,100,102,104,106,108,110,112,114,116,118,120,122,124,126,128,130,132,134,136,138,140,142,144,146,148,150,<br>152,154,156,158,160,162,164,166,168,170,172,174,176,177,179,181,183,185,187,189,<br>191,193,195,197,199,201,203,205,207,209,211,213,215,217,219,221,223,225,227,229,<br>231,233,235,237,239,241,243,245,247,249,251,253,255,257,259,261,263,265,267,269,<br>271,273,275,277,279,281,283,285,287,289,291,293,295,297,299,301,303,305,307,309,<br>311,313,315,317,319,321,323,325,327,329,331,333,335,337,339,341,343,345,347,349,<br>351,353,355,357,359,361,363,365,367,369,371,373,375,377,379,381,383,385,386 |
| | 4 | 196 | –386,–385,–381,–377,–373,–369,–365,–361,–357,–353,–349,–345,–341,–337,–333,<br>–329,–325,–321,–317,–313,–309,–305,–301,–297,–293,–289,–285,–281,–277,–273,<br>–269,–265,–261,–257,–253,–249,–245,–241,–237,–233,–229,–225,–221,–217,–213,<br>–209,–205,–201,–197,–193,–189,–185,–181,–177,–174,–170,–166,–162,–158,–154,<br>–150,–146,–142,–138,–134,–130,–126,–122,–118,–114,–110,–106,–102,–98,–94,–90,<br>–86,–82,–78,–74,–70,–66,–62,–58,–54,–50,–46,–42,–38,–34,–30,–26,–22,–18,–14,–10,<br>–6,–2,2,6,10,14,18,22,26,30,34,38,42,46,50,54,58,62,66,70,74,78,82,86,90,94,98,102,<br>106,110,114,118,122,126,130,134,138,142,146,150,154,158,162,166,170,174,177,181,<br>185,189,193,197,201,205,209,213,217,221,225,229,233,237,241,245,249,253,257,261,<br>265,269,273,277,281,285,289,293,297,301,305,309,313,317,321,325,329,333,337,341,<br>345,349,353,357,361,365,369,373,377,381,385,386 |
| | 8 | 101 | –386,–385,–377,–369,–361,–353,–345,–337,–329,–321,–313,–305,–297,–289,–281,<br>–273,–265,–257,–249,–241,–233,–225,–217, –209,–201,–193,–185, –177,–170,–162, –154,–146,–138,–130, –122,–114,–106,–98,–90,–82,–74,–66,–58,–50,–42,–34,–26, –18,<br>–10,–2,2,10,18,26,34,42,50,58,62,70,78,86,94,102,110,118,126,134,142,150,158,166,<br>174,177,185,193,201,209,217,225,233,241,249,257,265,273,281,289,297,305,313,321,<br>329,337,345,353,361,369,377,385,386 |

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**Table 9-403—Subcarriers for which a compressed beamforming feedback matrix is sent back(11ay) *(continued)***

| $N_{CB}$ | $Ng$ | $N_{SC}$ | **Subcarriers for which compressed feedback beamforming matrix is sent: *scidx*(0), *scidx*(1), …, *scidx*($N_{SC}$ – 1)** (Note that DC subcarriers (0, ±1) are skipped.) |
|---|---|---|---|
| 3 | 2 | 598 | –596,–594,–592,–590,–588,–586,–584,–582,–580,–578,–576,–574,–572,–570,–568,<br>–566,–564,–562,–560,–558,–556,–554,–552,–550,–548,–546,–544,–542,–540,–538,<br>–536,–534,–532,–530,–528,–526,–524,–522,–520,–518,–516,–514,–512,–510,–508,<br>–506,–504,–502,–500,–498,–496,–494,–492,–490,–488,–486,–484,–482,–480,–478,<br>–476,–474,–472,–470,–468,–466,–464,–462,–460,–458,–456,–454,–452,–450,–448,<br>–446,–444,–442,–440,–438,–436,–434,–432,–430,–428,–426,–424,–422,–420,–418,<br>–416,–414,–412,–410,–408,–406,–404,–402,–400,–398,–396,–394,–392,–390,–388,<br>–386,–385,–383,–381,–379,–377,–375,–373,–371,–369,–367,–365,–363,–361,–359,<br>–357,–355,–353,–351,–349,–347,–345,–343,–341,–339,–337,–335,–333,–331,–329,<br>–327,–325,–323,–321,–319,–317,–315,–313,–311,–309,–307,–305,–303,–301,–299,<br>–297,–295,–293,–291,–289,–287,–285,–283,–281,–279,–277,–275,–273,–271,–269,<br>–267,–265,–263,–261,–259,–257,–255,–253,–251,–249,–247,–245,–243,–241,–239,<br>–237,–235,–233,–231,–229,–227,–225,–223,–221,–219,–217,–215,–213,–211,–209,<br>–207,–205,–203,–201,–199,–197,–195,–193,–191,–189,–187,–185,–183,–181,–179,<br>–177,–176,–174,–172,–170,–168,–166,–164,–162,–160,–158,–156,–154,–152,–150,<br>–148,–146,–144,–142,–140,–138,–136,–134,–132,–130,–128,–126,–124,–122,–120,<br>–118,–116,–114,–112,–110,–108,–106,–104,–102,–100,–98,–96,–94,–92,–90,–88,–86,<br>–84,–82,–80,–78,–76,–74,–72,–70,–68,–66,–64,–62,–60,–58,–56,–54,–52,–50,–48,–46,<br>–44,–42,–40,–38,–36,–34,–32,–30,–28,–26,–24,–22,–20,–18,–16,–14,–12,–10,–8,–6,–4,–<br>2,2,4,6,8,10,12,14,16,18,20,22,24,26,28,30,32,34,36,38,40,42,44,46,48,50,52,54,56,58,60,62,64,66,68,70,72,74,76,78,80,82,84,86,88,90,92,94,96,98,100,102,104,106,108,110,112,114,116,118,120,122,124,126,128,130,132,134,136,138,140,142,144,146,148,150,<br>152,154,156,158,160,162,164,166,168,170,172,174,176,177,179,181,183,185,187,189,<br>191,193,195,197,199,201,203,205,207,209,211,213,215,217,219,221,223,225,227,229,<br>231,233,235,237,239,241,243,245,247,249,251,253,255,257,259,261,263,265,267,269,<br>271,273,275,277,279,281,283,285,287,289,291,293,295,297,299,301,303,305,307,309,<br>311,313,315,317,319,321,323,325,327,329,331,333,335,337,339,341,343,345,347,349,<br>351,353,355,357,359,361,363,365,367,369,371,373,375,377,379,381,383,385,386,388,<br>390,392,394,396,398,400,402,404,406,408,410,412,414,416,418,420,422,424,426,428,<br>430,432,434,436,438,440,442,444,446,448,450,452,454,456,458,460,462,464,466,468,<br>470,472,474,476,478,480,482,484,486,488,490,492,494,496,498,500,502,504,506,508,<br>510,512,514,516,518,520,522,524,526,528,530,532,534,536,538,540,542,544,546,548,<br>550,552,554,556,558,560,562,564,566,568,570,572,574,576,578,580,582,584,586,588,<br>590,592,594,596 |
| | 4 | 302 | –596,–594,–590,–586,–582,–578,–574,–570,–566,–562,–558,–554,–550,–546,–542,<br>–538,–534,–530,–526,–522,–518,–514,–510,–506,–502,–498,–494,–490,–486,–482,<br>–478,–474,–470,–466,–462,–458,–454,–450,–446,–442,–438,–434,–430,–426,–422,<br>–418,–414,–410,–406,–402,–398,–394,–390,–386,–385,–381,–377,–373,–369,–365,<br>–361,–357,–353,–349,–345,–341,–337,–333,–329,–325,–321,–317,–313,–309,–305,<br>–301,–297,–293,–289,–285,–281,–277,–273,–269,–265,–261,–257,–253,–249,–245,<br>–241,–237,–233,–229,–225,–221,–217,–213,–209,–205,–201,–197,–193,–189,–185,<br>–181,–177,–174, –170,–166,–162, –158,–154,–150,–146,–142,–138,–134,–130,–126, –122,–118,–114,–110,–106,–102,–98,–94,–90,–86,–82,–78,–74,–70,–66,–62,–58,–54,<br>–50,–46,–42,–38,–34,–30,–26,–22, –18,–14, –10,–6,–2,2,6,10,14,18,22, 26,30,34,38,42,<br>46,50,54,58,62,66,70,74,78,82,86,90,94,98,102,106,110,114,118,122,126,130,134,138,<br>142,146,150,154,158,162,166,170,174, 177, 181,185,189,193,197,201,205, 209,213,<br>217,221,225,229,233,237,241,245,249,253,257,261,265,269,273,277,281,285,289,293,<br>297,301,305,309,313,317,321,325,329,333,337,341,345,349,353,357,361,365,369,373,<br>377,381,385, 386, 390,394,398, 402,406,410,414, 418,422, 426,430,434,438,442,446,<br>450,454,458, 462, 466,470,474,478,482,486,490,494,498,502,506,510,514,518,522,526,<br>530,534,538,542, 546,550, 554, 558,562,566,570,574, 578,582,586,590,594,596 |



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**Table 9-403—Subcarriers for which a compressed beamforming feedback matrix is sent back(11ay) *(continued)***

| $N_{CB}$ | $Ng$ | $N_{SC}$ | **Subcarriers for which compressed feedback beamforming matrix is sent: *scidx*(0), *scidx*(1), …, *scidx*($N_{SC}$ – 1)** (Note that DC subcarriers (0, ±1) are skipped.) |
|---|---|---|---|
| 3 | 8 | 155 | –596,–594,–586,–578,–570,–562,–554,–546,–538,–530,–522,–514,–506,–498,–490, –482,–474,–466,–458,–450,–442,–434,–426,–418,–410,–402,–394,–386,–385,–377, –369,–361,–353,–345,–337,–329,–321,–313,–305,–297,–289,–281,–273,–265,–257, –249,–241,–233,–225,–217,–209,–201,–193,–185,–177,–170,–162,–154,–146,–138, –130,–122,–114,–106,–98,–90,–82,–74,–66,–58,–50,–42,–34,–26, –18, –10,–2,2,10,18, 26,34,42,50,58,62,70,78,86,94,102,110,118,126,134,142,150,158,166,174,177,185,193, 201, 209,217, 225,233,241,249,257,265,273,281,289,297,305,313,321,329,337,345,353, 361,369,377, 385, 386,394,402,410,418,426,434,442,450,458,466,474,482,490,498,506, 514, 522,530,538,546,554, 562,570, 578,586,594, 596 |

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**Table 9-403—Subcarriers for which a compressed beamforming feedback matrix is sent back(11ay) *(continued)***

| $N_{CB}$ | $Ng$ | $N_{SC}$ | **Subcarriers for which compressed feedback beamforming matrix is sent: *scidx*(0), *scidx*(1), …, *scidx*($N_{SC}$ – 1)** (Note that DC subcarriers (0, ±1) are skipped.) |
|---|---|---|---|
| 4 | 2 | 808 | –805,–804,–802,–800,–798,–796,–794,–792,–790,–788,–786,–784,–782,–780,–778,<br>–776,–774,–772,–770,–768,–766,–764,–762,–760,–758,–756,–754,–752,–750,–748,<br>–746,–744,–742,–740,–738,–736,–734,–732,–730,–728,–726,–724,–722,–720,–718,<br>–716,–714,–712,–710,–708,–706,–704,–702,–700,–698,–696,–694,–692,–690,–688,<br>–686,–684,–682,–680,–678,–676,–674,–672,–670,–668,–666,–664,–662,–660,–658,<br>–656,–654,–652,–650,–648,–646,–644,–642,–640,–638,–636,–634,–632,–630,–628,<br>–626,–624,–622,–620,–618,–616,–614,–612,–610,–608,–606,–604,–602,–600,–598,<br>–596,–594,–592,–590,–588,–586,–584,–582,–580,–578,–576,–574,–572,–570,–568,<br>–566,–564,–562,–560,–558,–556,–554,–552,–550,–548,–546,–544,–542,–540,–538,<br>–536,–534,–532,–530,–528,–526,–524,–522,–520,–518,–516,–514,–512,–510,–508,<br>–506,–504,–502,–500,–498,–496,–494,–492,–490,–488,–486,–484,–482,–480,–478,<br>–476,–474,–472,–470,–468,–466,–464,–462,–460,–458,–456,–454,–452,–450,–448,<br>–446,–444,–442,–440,–438,–436,–434,–432,–430,–428,–426,–424,–422,–420,–418,<br>–416,–414,–412,–410,–408,–406,–404,–402,–400,–398,–396,–394,–392,–390,–388,<br>–386,–385,–383,–381,–379,–377,–375,–373,–371,–369,–367,–365,–363,–361,–359,<br>–357,–355,–353,–351,–349,–347,–345,–343,–341,–339,–337,–335,–333,–331,–329,<br>–327,–325,–323,–321,–319,–317,–315,–313,–311,–309,–307,–305,–303,–301,–299,<br>–297,–295,–293,–291,–289,–287,–285,–283,–281,–279,–277,–275,–273,–271,–269,<br>–267,–265,–263,–261,–259,–257,–255,–253,–251,–249,–247,–245,–243,–241,–239,<br>–237,–235,–233,–231,–229,–227,–225,–223,–221,–219,–217,–215,–213,–211,–209,<br>–207,–205,–203,–201,–199,–197,–195,–193,–191,–189,–187,–185,–183,–181,–179,<br>–177,–176,–174,–172,–170,–168,–166,–164,–162,–160,–158,–156,–154,–152,–150,<br>–148,–146,–144,–142,–140,–138,–136,–134,–132,–130,–128,–126,–124,–122,–120,<br>–118,–116,–114,–112,–110,–108,–106,–104,–102,–100,–98,–96,–94,–92,–90,–88,–86,<br>–84,–82,–80,–78,–76,–74,–72,–70,–68,–66,–64,–62,–60,–58,–56,–54,–52,–50,–48,–46,<br>–44,–42,–40,–38,–36,–34,–32,–30,–28,–26,–24,–22,–20,–18,–16,–14,–12,–10,–8,–6,–4,–<br>2,2,4,6,8,10,12,14,16,18,20,22,24,26,28,30,32,34,36,38,40,42,44,46,48,50,52,54,56,58,60,62,64,66,68,70,72,74,76,78,80,82,84,86,88,90,92,94,96,98,100,102,104,106,108,110,112,114,116,118,120,122,124,126,128,130,132,134,136,138,140,142,144,146,148,150,<br>152,154,156,158,160,162,164,166,168,170,172,174,176,177,179,181,183,185,187,189,<br>191,193,195,197,199,201,203,205,207,209,211,213,215,217,219,221,223,225,227,229,<br>231,233,235,237,239,241,243,245,247,249,251,253,255,257,259,261,263,265,267,269,<br>271,273,275,277,279,281,283,285,287,289,291,293,295,297,299,301,303,305,307,309,<br>311,313,315,317,319,321,323,325,327,329,331,333,335,337,339,341,343,345,347,349,<br>351,353,355,357,359,361,363,365,367,369,371,373,375,377,379,381,383,385,386,388,<br>390,392,394,396,398,400,402,404,406,408,410,412,414,416,418,420,422,424,426,428,<br>430,432,434,436,438,440,442,444,446,448,450,452,454,456,458,460,462,464,466,468,<br>470,472,474,476,478,480,482,484,486,488,490,492,494,496,498,500,502,504,506,508,<br>510,512,514,516,518,520,522,524,526,528,530,532,534,536,538,540,542,544,546,548,<br>550,552,554,556,558,560,562,564,566,568,570,572,574,576,578,580,582,584,586,588,<br>590,592,594,596,598,600,602,604,606,608,610,612,614,616,618,620,622,624,626,628,<br>630,632,634,636,638,640,642,644,646,648,650,652,654,656,658,660,662,664,666,668,<br>670,672,674,676,678,680,682,684,686,688,690,692,694,696,698,700,702,704,706,708,<br>710,712,714,716,718,720,722,724,726,728,730,732,734,736,738,740,742,744,746,748,<br>750,752,754,756,758,760,762,764,766,768,770,772,774,776,778,780,782,784,786,788,<br>790,792,794,796,798,800,802,804,805 |



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**Table 9-403—Subcarriers for which a compressed beamforming feedback matrix is sent back(11ay) *(continued)***

| $N_{CB}$ | $Ng$ | $N_{SC}$ | **Subcarriers for which compressed feedback beamforming matrix is sent: *scidx*(0), *scidx*(1), …, *scidx*($N_{SC}$ – 1)** (Note that DC subcarriers (0, ±1) are skipped.) |
|---|---|---|---|
| 4 | 4 | 409 | –805,–804,–800,–796,–792,–788,–784,–780,–776,–772,–768,–764,–760,–756,–752, –748,–744,–740,–736,–732,–728,–724,–720,–716,–712,–708,–704,–700,–696,–692, –688,–684,–680,–676,–672,–668,–664,–660,–656,–652,–648,–644,–640,–636,–632, –628,–624,–620,–616,–612,–608,–604,–600,–596,–594,–590,–586,–582,–578,–574, –570,–566,–562,–558,–554,–550,–546,–542,–538,–534,–530,–526,–522,–518,–514, –510,–506,–502,–498,–494,–490,–486,–482,–478,–474,–470,–466,–462,–458,–454, –450,–446,–442,–438,–434,–430,–426,–422,–418,–414,–410,–406,–402,–398,–394, –390,–386,–385,–381,–377,–373,–369,–365,–361,–357,–353,–349,–345,–341,–337, –333,–329,–325,–321,–317,–313,–309,–305,–301,–297,–293,–289,–285,–281,–277, –273,–269,–265,–261,–257,–253,–249,–245,–241,–237,–233,–229,–225,–221,–217, –213,–209,–205,–201,–197,–193,–189,–185,–181,–177,–174,–170,–166,–162,–158, –154,–150,–146,–142,–138,–134,–130,–126,–122,–118,–114,–110,–106,–102,–98,–94, –90,–86,–82,–78,–74,–70,–66,–62,–58,–54,–50,–46,–42,–38,–34,–30,–26,–22, –18,–14, –10,–6,–2,2,6,10,14,18,22,26,30,34,38,42,46,50,54,58,62,66,70,74,78,82,86,90,94,98, 102,106, 110,114, 118, 122,126, 130, 134,138,142,146,150, 154,158,162,166,170,174, 177,181,185,189,193,197,201,205,209,213,217,221,225,229,233,237,241,245,249,253, 257,261,265,269, 273,277,281, 285,289,293, 297,301,305,309, 313, 317,321, 325,329, 333,337,341,345,349,353,357,361,365,369,373,377,381,385,386,390,394,398,402,406, 410,414, 418,422, 426,430,434,438,442,446,450,454,458,462,466,470,474,478,482,486, 490,494,498,502,506,510,514,518,522,526,530,534,538,542,546,550,554,558,562,566, 570,574,578,582,586,590,594,596,596,600,604,608,612,616,620,624,628,632,636,640, 644,648,652,656,660,664,668,672,676,680,684,688,692,696,700,704,708,712,716,720, 724,728,732,736,740,744,748,752,756,760,764,768,772,776,780,784,788,792,796,800, 804, 805 |
| | 8 | 209 | –805,–804,–796,–788,–780,–772,–764,–756,–748,–740,–732,–724,–716,–708,–700, –692,–684,–676,–668,–660,–652,–644,–636,–628,–620,–612,–604,596,–594,–586,– 578,–570,–562,–554,–546,–538,–530,–522,–514,–506,–498,–490,–482,–474,–466,–458, –450,–442,–434,–426,–418,–410,–402,–394,–386,–385,–377,–369,–361,–353,–345, –337,–329,–321,–313,–305,–297,–289,–281,–273,–265,–257,–249,–241,–233,–225, –217,–209,–201,–193,–185,–177,–170,–162,–154,–146,–138,–130,–122,–114,–106, –98,–90,–82,–74,–66,–58,–50,–42,–34,–26, –18, –10,–2,2,10,18, 26,34, 42, 50,58,62, 70,78,86, 94,102, 110, 118, 126, 134,142,150,158,166,174, 177, 185, 193,201,209,217, 225,233,241,249,257,265,273,281,289,297,305,313,321,329,337,345,353,361,369,377, 385,386,394,402,410,418,426,434,442,450,458,466,474,482,490,498,506,514,522,530, 538,546,554,562,570,578,586,594,596,604,612,620,628,636,644,652,660,668,676,684, 692, 700,708, 716,724,732,740,748, 756,764,772,780,788,796,804,805 |

The MU Exclusive Beamforming Report field carries explicit feedback information in the form of differential SNRs contained in the Differential SNR subfields. The MU Exclusive Beamforming Report field is included in the Digital BF Feedback element if the SU/MU field in MIMO Feedback Control element is 1 (MU transmission) and the Feedback Type subfield of the Digital Fbck Control field is 1 (EDMG OFDM mode).

The MU Exclusive Beamforming Report field consists of Differential SNR subfields for each space-time stream (1 to *Nc*) of a subset of the subcarriers spaced *Ng* apart, where *Ng* is the value of the Grouping subfield of the Digital Fbck Control field in the MIMO Feedback Control element, starting from the lowest frequency subcarrier and continuing to the highest frequency subcarrier. No padding is present between $D\_SNR_{k,i}$ in the MU Exclusive Beamforming Report field, even if they correspond to different subcarriers. The subset of subcarriers included is determined by the values of Table 9-403 (Subcarriers for which a compressed beamforming feedback matrix is sent back(11ay)). For each subcarrier included, the deviation

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in dB of the SNR of that subcarrier for each column of $V$ relative to the adjacent subcarrier spaced $Ng$ apart of the corresponding space-time stream is computed using Equation (9-10)(#3360).

$$D\_SNR_{k,j} = min\left(max\left(round\left(10\log10\left(\frac{\left\|H_k V_{k,i}\right\|^2}{N}\right) - 10\log10\left(\frac{\left\|H_{\tilde{k}} V_{\tilde{k},i}\right\|^2}{N}\right)\right), -8\right), -7\right) \quad (9\text{-}10)$$

where

$k$ is the subcarrier index in the range $scidx(1)$, …, $scidx(N_{SC} - 1)$

$\tilde{k}$ is the subcarrier index in the range $scidx(0)$, …, $scidx(N_{SC} - 2)$

$i$ is the space-time stream index in the range 1, …, $Nc$

$H_k$ is the estimated MIMO channel for subcarrier $k$

$V_{k,i}$ is column $i$ of the beamforming matrix $V$ for subcarrier $k$

$N$ is the average noise plus interference power, measured at the responder

Each Differential SNR subfield contains the $D\_SNR_{k,i}$ computed using Equation (9-10) and quantized to 4 bits in the range –8 dB to 7 dB with 1 dB granularity, except for $k = scidx(0)$. $D\_SNR_{scidx(0),i}$ is computed using Equation (9-11) and quantized to 8 bits in the range –8 dB to 55.75 dB with 0.25 dB granularity(#3360).

$$D\_SNR_{scidx(0),i} = 10\log10\left(\frac{\left\|H_{scidx(0)} V_{scidx(0),i}\right\|^2}{N}\right) \quad (9\text{-}11)$$

### 9.4.2.284 TDD Bandwidth Request element(11ay)

The TDD Bandwidth Request element contains the information needed for bandwidth reservation request during TDD SPs. The format of the TDD Bandwidth Request element is shown in Figure 9-994 (TDD Bandwidth Request element format(11ay)).

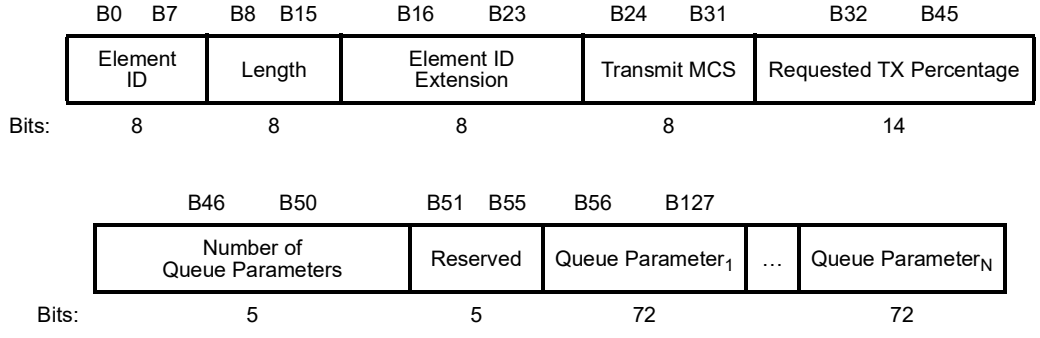


**Figure 9-994—TDD Bandwidth Request element format(11ay)**

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

The Transmit MCS field indicates the recommended MCS value to be used for the upcoming non-AP and non-PCP STA to AP or PCP transmission(s).


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The Requested TX Percentage field indicates the requested transmit percentage of airtime from the non-AP and non-PCP STA to the AP or PCP in relation to the airtime occupied by the bidirectional traffic between the STA and the AP or PCP. The value is in units of 0.01 percent.

The Number of Queue Parameters field defines the integer number, *N*, of subsequent Queue Parameter fields.

Each Queue Parameter field is defined as shown in Figure 9-995 (Queue Parameter field format(11ay)).

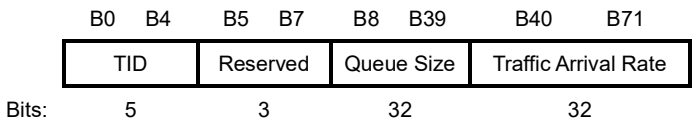


**Figure 9-995—Queue Parameter field format(11ay)**

For values from 0 to 15, the TID subfield indicates the TID corresponding to the queue. A value of 31 indicates that this field is not applicable. Other values are reserved.

The Queue Size subfield indicates the amount of queued traffic at the transmitter, in unit of octets(#8150), corresponding to the TID indicated by the TID subfield.

The Traffic Arrival Rate subfield indicates the arrival rate of the traffic since the last reporting event, in units of 1 kb/s. The method for computing the arrival rate is implementation dependent.

### 9.4.2.285 TDD Synchronization element(11ay)

The TDD Synchronization element contains the information needed for clock synchronization during TDD SPs. The format of the element is shown in Figure 9-996 (TDD Synchronization element format(11ay)).

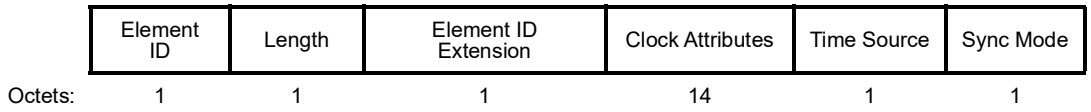


**Figure 9-996—TDD Synchronization element format(11ay)**

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

The Clock Attributes field format is shown in Figure 9-997 (Clock Attributes field format(11ay)).

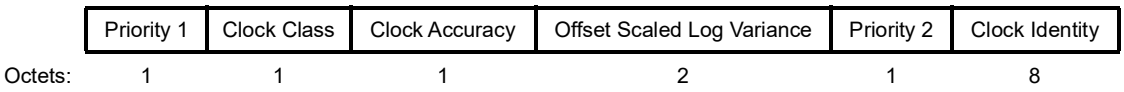


**Figure 9-997—Clock Attributes field format(11ay)**

The Priority 1, Clock Class, Clock Accuracy, Offset Scaled Log Variance, Priority 2 and Clock Identity subfields indicate attributes of the source of timing locally available to the STA that transmits the element, and are defined the same as priority1, clockClass, clockAccuracy, offsetSceledLogVariance, priority2, and clockIdentity attributes defined in 8.6.2 in IEEE Std 802.1AS-Rev/D8.0.

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The Time Source field indicates the type of clock available to the STA transmitting the element. It is defined the same as the timeSource attribute defined in 8.6.2 in IEEE Std 802.1AS-Rev/D8.0.

NOTE 1—The Clock Attributes field is defined similar to the IEEE 802.1AS systemIdentity attribute, as a metric to compare the local clock available to a STA and the clock available to the peer STA that transmits the TDD Clock Attributes element. While the comparison metric and logic are defined the same as IEEE 802.1AS for flexibility, using the IEEE 802.1AS protocol for TDD time synchronization is not required and is beyond the scope of this standard.

NOTE 2—DMG STAs that support TDD channel access can use external timing sources such as GNSS for accurate clock attributes. For example, for a STA with access to a clock that is synchronized to a primary reference time source such as GNSS (i.e., clockClass of 0x06), and has a precision of ±500 ps (i.e., clockAccuracy of 0x23) and a clock variance of 1.497e-22 $s^2$ (i.e., offsetScaledLogVariance 0x3780), the Clock Class, Clock Accuracy and Offset Scaled Log Variance fields are respectively set to 0x06, 0x23 and 0x3780. Refer to IEEE Std 802.1AS for details.

The Sync Mode field indicates access to a local source of timing (e.g., GNSS). The Sync Mode field is set to 1 to indicate that the STA does not have access to a local source of timing at the time of transmitting the element. The Sync Mode field is set to 0 to indicate that the local clock is used by the STA at the time of transmitting the element.

### 9.4.2.286 EDMG Wide Bandwidth Channel Switch element(11ay)

The EDMG Wide Bandwidth Channel Switch element is included in DMG Beacon frames, Announce frames, or Information Response frames, as defined in 11.8.8.7 (Selecting and advertising new channels in an EDMG BSS(11ay)). The format of the EDMG Wide Bandwidth Channel Switch element is shown in Figure 9-998 (EDMG Wide Bandwidth Channel Switch element format(11ay)).

| | Element ID | Length | Element ID Extension | EDMG New Operating Channel |
|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 2 |

**Figure 9-998—EDMG Wide Bandwidth Channel Switch element format(11ay)**

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

The EDMG New Operating Channel field is defined in Figure 9-999 (EDMG New Operating Channel field format(11ay)).

| | BSS Operating Channels | Operating Channel Width |
|---|---|---|
| Octets: | 1 | 1 |

**Figure 9-999—EDMG New Operating Channel field format(11ay)**

The BSS Operating Channels subfield and the Operating Channel Width subfield are defined in 9.4.2.265 (EDMG Operation element(11ay)).

### 9.4.2.287 DMG Discovery Assistance element(11ay)

The DMG Discovery Assistance element indicates parameters and attributes of the discovery assistance. This element is optionally present in FST Setup Request and FST Setup Response frames. The format of the


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DMG Discovery Assistance element is shown in Figure 9-1000 (EDMG Discovery Assistance element format(11ay)).

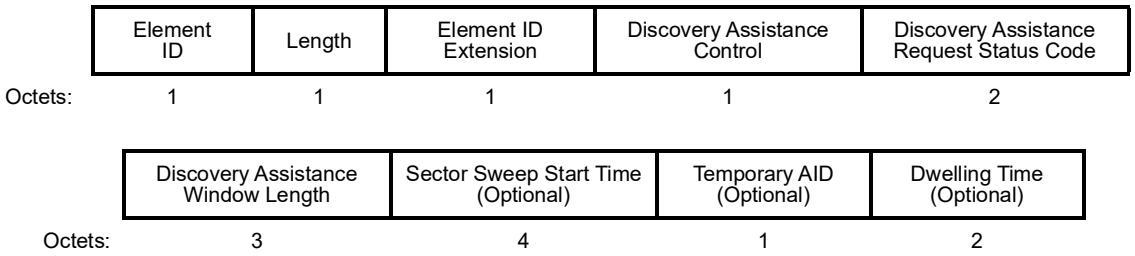


**Figure 9-1000—EDMG Discovery Assistance element format(11ay)**

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

The format of the Discovery Assistance Control field is shown in Figure 9-1001 (Discovery Assistance Control field format(11ay)). This field is reserved when the element is contained in an FST Setup Request frame.

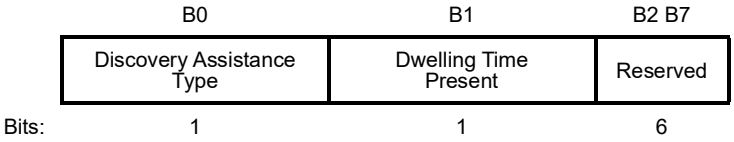


**Figure 9-1001—Discovery Assistance Control field format(11ay)**

The Discovery Assistance Type subfield is set to 0 to indicate that the Sector Sweep Start Time field is present in this element. When this field is set to 1, the schedule to perform discovery assistance is indicated in the Extended Schedule element and the Temporary AID field is present in this element. This field is reserved when the Discovery Assistance Request Status Code field is not equal to SUCCESS.

The Dwelling Time Present subfield is set to 1 to indicate that the Dwelling Time field is present in the element and is set to 0 otherwise.

The Discovery Assistance Request Status Code field contains the result of the discovery assistance request and is one of the status codes specified in Table 9-80 (Status codes) in 9.4.1.9 (Status Code field). This field is reserved when the element is contained in an FST Setup Request frame.

The Discovery Assistance Window Length field indicates the discovery assistance window length value, in microseconds, as confirmed by the STA transmitting this element. This field is reserved when the element is contained in an FST Setup Request frame.

The Sector Sweep Start Time field indicates the lower 4 octets of the TSF of the DMG BSS at the time the sector sweep transmission starts. This field is present if the Discovery Assistance Type subfield is 0. This field is reserved when the element is contained in an FST Setup Request frame.

The Temporary AID field indicates a temporary AID assigned by an AP or PCP to the STA receiving this element. The temporary AID is used for scheduling discovery assistance. This field is present if the Discovery Assistance Type subfield is 1.

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The Dwelling Time field indicates the recommended time, in microseconds, to sweep the receive sectors to scan for beamforming or discovery signals. This field is present if the Dwelling Time Present subfield is 1.

### 9.4.2.288 Extended Link Measurement element(11ay)

#### 9.4.2.288.1 General

The Extended Link Measurement element contains information used to solicit link measurement report and is optionally included in Link Measurement Request and Link Measurement Report frames. The format of Extended Link Measurement element is shown in Figure 9-1002 (Extended Link Measurement element format(11ay)).

| | Element ID | Length | Element ID Extension | Optional Subelements |
|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | variable(M118) |

**Figure 9-1002—Extended Link Measurement element format(11ay)**

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

The Optional Subelements field contains zero or more subelements. The subelement format and ordering of subelements are defined in 9.4.3 (Subelements).

The Subelement ID field values for the defined subelements are shown in Table 9-404 (Optional subelement IDs(11ay)). A subelement does not appear more than once in the Extended Link Measurement element.

**Table 9-404—Optional subelement IDs(11ay)**

| Subelement ID | Name | Extensible |
|---|---|---|
| 0 | Periodic Report Request | Yes |
| 1 | Extended TPC Configuration | Yes |
| 2 | EDMG Transmit Power | Yes |
| 3 | Periodic Report | Yes |
| 4–255 | Reserved | |

#### 9.4.2.288.2 Periodic Report Request subelement

The Periodic Report Request subelement contains information to solicit periodic link measurement report and is optionally included in Link Measurement Request frame. The format of the Data field of the Periodic Report Request subelement is shown in Figure 9-1003 (Data field of the Periodic Report Request subelement format(11ay)).

| | Report Start Time | Report Interval | Report Count |
|---|---|---|---|
| Octets: | 4 | 2 | 2 |

**Figure 9-1003—Data field of the Periodic Report Request subelement format(11ay)**


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The Report Start Time subfield indicates the lower 4 octets of the TSF timer at the start of the first report interval.

The Report Interval subfield indicates the interval of time, in microseconds, at which the responding STA needs to take measurements and send an unsolicited Link Measurement Report frame to the requesting STA. Value zero is reserved.

The Report Count subfield indicates the number of report intervals. A responding STA sends an unsolicited Link Measurement Report frame to the requesting STA for every report interval. Value zero is reserved.

### 9.4.2.288.3 Extended TPC Configuration subelement

The Extended TPC Configuration subelement contains information for EDMG transmit power control configuration and is optionally included in a Link Measurement Request frame. The format of the Data field of the Extended TPC Configuration subelement is shown in Figure 9-1004 (Data field of the Extended TPC Configuration subelement format(11ay)).

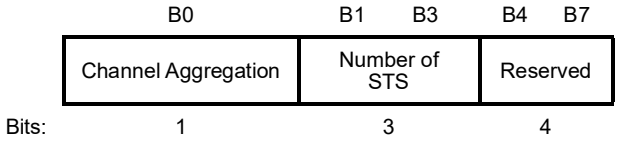


**Figure 9-1004—Data field of the Extended TPC Configuration subelement format(11ay)**

The Channel Aggregation field is set to 1 to indicate that the PPDU containing the Link Measurement Request frame is transmitted over a 2.16+2.16 GHz or a 4.32+4.32 GHz channel, and is set to 0 otherwise.

The Number of STS field indicates the number of STS used in the transmission of the PPDU containing the Link Measurement Request frame. If the Channel Aggregation field is 1, the Number of STS subfield is an even number.

### 9.4.2.288.4 EDMG Transmit Power subelement

The EDMG Transmit Power subelement contains information for transmit power in link measurement and is optionally included in a Link Measurement Request frame. The format of the Data field of the EDMG Transmit Power subelement is shown in Figure 9-1005 (Data field of the EDMG Transmit Power subelement format(11ay)).

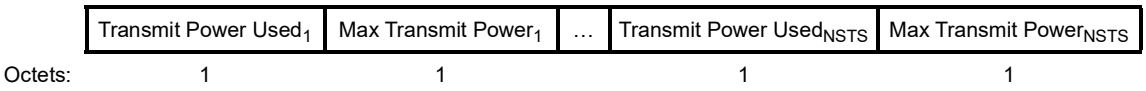


**Figure 9-1005—Data field of the EDMG Transmit Power subelement format(11ay)**

Each Transmit Power Used$_i$ field, $1 \le i \le N_{STS}$, indicates the transmit power used in the STS $i$ to transmit the PPDU containing the Link Measurement Request frame, as described in 9.4.1.20 (Transmit Power Used field). $N_{STS}$ represents the number of STS.

Each Max Transmit Power$_i$ field, $1 \le i \le N_{STS}$, indicates the upper limit on the transmit power of the STS $i$ measured at the output of the antenna connector to be used by the transmitting STA on its operating channel. This field is described in 9.4.1.19. (#1446)The value of each Max Transmit Power$_i$ field is equal to the

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minimum of the maximum powers at which the STA is permitted to transmit in the operating channel by device capability, policy, and regulatory authority.

### 9.4.2.288.5 Periodic Report subelement

The Periodic Report subelement contains information in response to a periodic link measurement request and is optionally included in a Link Measurement Report frame. The format of the Data field of the Periodic Report subelement is shown in Figure 9-1006 (Data field of the Periodic Report subelement format(11ay)).

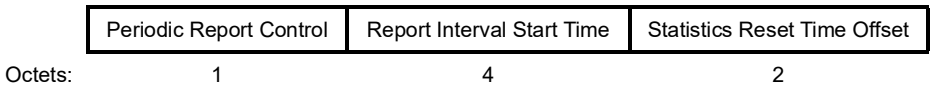


**Figure 9-1006—Data field of the Periodic Report subelement format(11ay)**

The Periodic Report Control field contains indications of whether the responding STA accepts or rejects the periodic link measurement request, and whether the Link Measurement Report frame includes optional fields used for periodic link measurement reports. The field is shown in Figure 9-1007 (Period Report Control field format(11ay)).

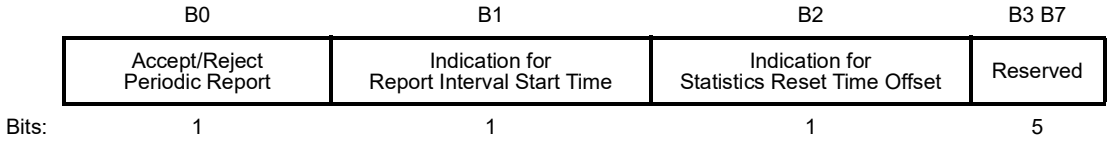


**Figure 9-1007—Period Report Control field format(11ay)**

The Accept/Reject Periodic Report subfield is set to 1 if the responding STA accepts periodic report, and is set to 0 if the responding STA rejects periodic report.

The Indication for Report Interval Start Time subfield is set to 1 if the Link Measurement Report frame contains the Report Interval Start Time field. It is set to 0 otherwise.

The Indication for Statistics Reset Time Offset subfield is set to 1 if the Link Measurement Report frame contains the Statistics Reset Time Offset field. It is set to 0 otherwise.

The Report Interval Start Time field is optionally present. If present, it indicates the lower 4 octets of the TSF timer at the start of the report interval of the corresponding Link Measurement Report frame.

The Statistics Reset Time Offset field is optionally present. If present, it indicates the relative time offset, in microseconds, of the last event when the reset condition (see 9.4.2.141.6 (LDPC Statistics field(11ay))) is met since the start of the corresponding report interval.


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### 9.4.2.289 DMG STA Directional Transmit Activity Report element(11ay)

The format of DMG STA Directional Transmit Activity Report element is shown in Figure 9-1008 (DMG STA Directional Transmit Activity Report element format(11ay)).

| | Element ID | Length | Element ID Extension | Control | Link ID | Observation Period Start Time | Observation Period Duration |
|---|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 2 | 1 | 4 | 4 |

| | Operating Class | Primary Channel | Operating Channels | Operating Channels Width | Optional Subelements |
|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 1 | variable(M118) |

**Figure 9-1008—DMG STA Directional Transmit Activity Report element format(11ay)**

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

The Control field is defined in Figure 9-1009 (Control field format(11ay)).

| | B0 B2 | B3 | B4 | B5 B7 |
|---|---|---|---|---|
| | Channel Access Type | TDD SP | Reciprocal Operation | Reserved |
| Octets: | 3 | 1 | 1 | 3 |

**Figure 9-1009—Control field format(11ay)**

The Channel Access Type subfield identifies the most used channel access mechanism during the observation period, i.e., the channel access mechanism used by one or more allocations with the largest total airtime inside the observation period. It has the same encoding as the Allocation Type subfield in the Extended Schedule element.

When the Channel Access Type subfield indicates SP channel access (0 or 2), the TDD SP field is set to 1 if majority of the airtime used by SP allocations during the observation period belongs to SPs with TDD Applicable SP subfield set to 1, and set to zero otherwise. The TDD SP subfield is reserved when the Channel Access Type subfield does not indicate SP channel access.

The Reciprocal Operation subfield is set to 1 to indicate that the transmitting STA is using or intends to use the same antenna pattern that it is using for transmission to also receive from other STAs, and is set to 0 otherwise.

The Link ID subfield is a locally unique identifier for data transmit activities targeting a given receiver, or a group of receivers, that are always transmitted data to through a common transmit antenna pattern and transmit power.

NOTE 1—Link ID helps a receiving STA correlate multiple DMG STA Directional Transmit Activity Report elements received through different frames. Specifically, elements with the same Link ID identify a unique transmit activity towards one or more intended receivers that are always using a common (not necessarily fixed) transmit antenna pattern. Link ID is independent of the specific antenna pattern used for transmission, i.e., changing the antenna pattern used to transmit data to the given receiver(s) does not change the Link ID associated with the DMG STA Directional Transmit Activity Report elements that are sent to report the corresponding transmit activity.

The Observation Period Start Time field is set to the lower 4 octets of the measuring STA's TSF timer at the beginning of the observation period.

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The Observation Period Duration field is set to the duration of the observation period that all reported metrics apply to, in μs.

The Operating Class field indicates an operating class value as defined in Annex E. The operating class is interpreted in the context of the country specified in the Country element included in the frame.

The Primary Channel field indicates the 2.16 GHz primary channel of the BSS to which the transmitting STA belongs.

The Operating Channels field indicates all 2.16 GHz channels occupied by PPDUs transmitted during the observation period, using the same DMG antenna and antenna pattern as the frame containing the element. The Operating Channels field has the same format as the BSS Operating Channels field in the EDMG Operation element.

The Operating Channels Width field indicates all bandwidths occupied by PPDUs transmitted during the observation period, using the same DMG antenna and antenna pattern as the frame containing the element. The Operating Channels Width field has the same format as the Operating Channels Width field in the EDMG Operation element.

The Optional Subelements field contains two or more subelements. The subelement format and ordering of subelements are defined in 9.4.3 (Subelements).

The Subelement ID field values for the defined subelements are listed in Table 9-405 (Optional subelement IDs(11ay)).

**Table 9-405—Optional subelement IDs(11ay)**

| Subelement ID | Name | Extensible |
|---|---|---|
| 0 | Directional Transmit Activity | Yes |
| 1 | Transceiver Parameters | Yes |
| 2–255 | Reserved | |

The Directional Transmit Activity subelement Data field format is shown in Figure 9-1010 (Directional Transmit Activity subelement Data field format(11ay)).

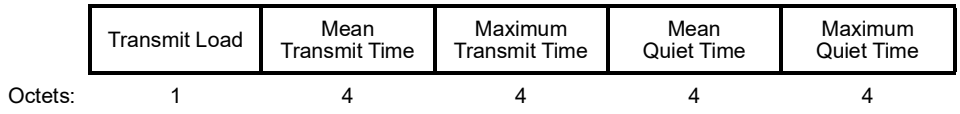


**Figure 9-1010—Directional Transmit Activity subelement Data field format(11ay)**

In the following, each 2.16 GHz channel that the frame containing the DMG STA Directional Transmit Activity Report element is transmitted on is referred to as a reported channel.

The Transmit Load subfield contains the percentage of time during the observation period that the local DMG PHY entity was in transmit state and was using the reported channel and Link ID. The subfield is encoded as an 8-bit unsigned integer, linearly scaled, with values of 0 and 255 representing 0% and 100%, respectively.


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The Mean Transmit Time and Maximum Transmit Time subfields respectively contain the arithmetic mean and maximum of all continuous transmission periods during the observation period, in μs. For the purpose of calculating these metrics, a continuous transmission period is a period during which the local DMG PHY entity was in transmit state using the reported channel and Link ID, except for short intervals not longer than SIFS.

The Mean Quiet Time and Maximum Quiet Time subfields contain, respectively, the arithmetic mean and maximum of all continuous quiet periods during the observation period, in μs. For the purpose of calculating these metrics, a continuous quiet period is a period longer than SIFS during which the local DMG PHY entity was not in transmit state using the reported channel and Link ID. In the absence of continuous quiet periods during the observation period both subfields are set to 0.

Figure 9-1011 (Examples of Maximum Transmit Time and Maximum Quiet Time: (a) operation during a TDD SP, (b) operation during other DMG allocations(11ay)) illustrates two examples of Maximum Transmit Time and Maximum Quiet Time calculation.

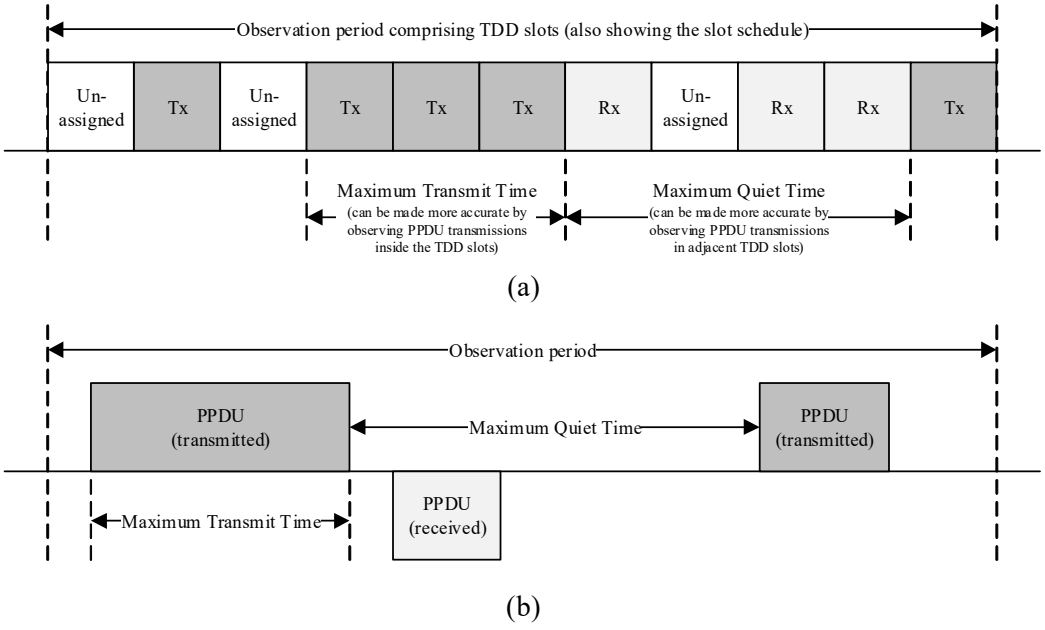


**Figure 9-1011—Examples of Maximum Transmit Time and Maximum Quiet Time: (a) operation during a TDD SP, (b) operation during other DMG allocations(11ay)**

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The Transceiver Parameters subelement Data field format is shown in Figure 9-1012 (Transceiver Parameters subelement Data field format(11ay)).

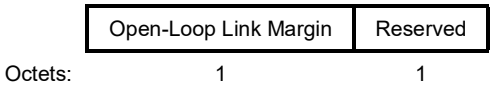


**Figure 9-1012—Transceiver Parameters subelement Data field format(11ay)**

The Open-Loop Link Margin field is calculated as follows:

$$OPLM = TRP + P_{sensitivity}$$

where

$TRP$ is the total radiated power, in dBm, used to transmit the PPDU that contains the element

$P_{sensitivity}$ is the actual receiver sensitivity for MCS 0, in dBm, and measured as defined in 20.3.3.8 (Receive minimum input level sensitivity(#256))

The Open-Loop Link Margin field is encoded as an 8-bit unsigned integer with values 0 through 255, representing –48 to 15.75 dBm in 0.25 dBm steps.

NOTE 2—A STA that receives a frame that contains the DMG STA Directional Transmit Activity Report element (activity report frame, for short) can use the TRP and Additional Sensitivity subfields in the frame to reduce the interference they cause to the frame transmitter. To illustrate, consider STA1 receiving an activity report frame transmitted by STA2, and assume the following definitions:

$G_{RX}^{STA1}(\phi)$ STA1 receive antenna gain in the direction $\phi$ towards STA2 when it received the activity report frame; if needed, STA1 can estimate $\phi$ using the TRN fields of the PPDU that contains the activity report frame.

$G_{TX}^{STA1}(\phi)$ STA1 transmit antenna gain in the direction $\phi$ towards STA2 for a given transmission, possibly using a different DMG antenna configuration from what STA1 was using when it received the activity report frame

$G_{RX}^{STA2}(\theta)$ STA2 receive antenna gain in the direction $\theta$ towards STA1, when STA2 uses the same DMG antenna configuration it was using when it transmitted the activity report frame

$G_{TX}^{STA2}(\theta)$ STA2 transmit antenna gain in the direction $\theta$ towards STA1

$TRP^{STA1}$ STA1 total radiated power

$TRP^{STA2}$ STA2 total radiated power, as indicated by the value of the TRP field

$P_{sensitivity}^{STA2}$ STA2 actual receiver sensitivity

$Loss$ Path loss between STA1 and STA2

The antenna gains are not necessarily the peak gains that STA1 and STA2 can achieve along $\phi$ and $\theta$ directions towards each other. The receive power at STA1 is $P_{RX}^{STA1} = TRP^{STA2} + G_{TX}^{STA2}(\theta) - Loss + G_{RX}^{STA1}(\phi)$. The receive power at STA2, if using the same DMG antenna configuration STA2 used to transmit the activity report frame, is $P_{RX}^{STA2} = TRP^{STA1} + G_{TX}^{STA1}(\phi) - Loss + G_{RX}^{STA2}(\theta)$. Assuming DMG antenna pattern reciprocity for STA2, and substituting $G_{RX}^{STA2}(\theta) - Loss = G_{TX}^{STA2}(\theta) - Loss = P_{RX}^{STA1} - TRP^{STA2} - G_{RX}^{STA1}(\phi)$, it is easy to see that STA1 can keep the receive power at STA2 below STA2 receiver sensitivity by limiting its total radiated power as $TRP^{STA1} \le (TRP^{STA2} + P_{sensitivity}^{STA2}) - (G_{TX}^{STA1}(\phi) - G_{RX}^{STA1}(\phi)) - P_{RX}^{STA1}$, where all parameters on the right-hand side of the inequality are known to STA1.


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### 9.4.2.290 WUR Capabilities element(11ba)

A WUR STA declares that it is a WUR STA by transmitting the WUR Capabilities element. The WUR Capabilities element contains a number of fields that are used to advertise WUR capabilities of a WUR STA. The WUR Capabilities element is defined in Figure 9-1013 (WUR Capabilities element format(11ba)).

| | Element ID | Length | Element ID Extension | Supported Bands | WUR Capabilities Information |
|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 1 | 2 |

**Figure 9-1013—WUR Capabilities element format(11ba)**

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

When the WUR Capabilities element is transmitted by a WUR AP, the Supported Bands field of the WUR capabilities element is reserved.

When the WUR Capabilities element is transmitted by a WUR non-AP STA, the Supported Bands field of the WUR capabilities element indicates the supported bands for the WUR operation. The format of the Supported Bands field is shown in Figure 9-1013a ( Supported Bands field format(11ba)).

| | B0 | B1 | B2 B7 |
|---|---|---|---|
| | 2.4 GHz | 5 GHz | Reserved |
| Bits: | 1 | 1 | 6 |

**Figure 9-1013a— Supported Bands field format(11ba)**

The 2.4 GHz subfield of the Supported Bands field is set to 1 to indicate the support of the 2.4 GHz band for the WUR operation. Otherwise, the 2.4 GHz subfield of the Supported Bands field is set to 0. The 5 GHz subfield of the Supported Bands field is set to 1 to indicate the support of the 5 GHz band for the WUR operation. Otherwise, the 5 GHz subfield of the Supported Bands field is set to 0.

The format of the WUR Capabilities Information field is defined in Figure 9-1014 (WUR Capabilities Information field format(11ba)).

| | B0 B7 | B8 | B9 B10 | B11 | B12 | B13 | B14 | B15 |
|---|---|---|---|---|---|---|---|---|
| | Transition Delay | VL WUR Frame Support | WUR Group IDs Support | Reserved | 20 MHz WUR Basic PPDU with HDR Support | WUR FDMA Support | WUR Short Wake-up Frame Support | Reserved |
| Bits: | 8 | 1 | 2 | 1 | 1 | 1 | 1 | 1 |

**Figure 9-1014—WUR Capabilities Information field format(11ba)**

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The subfields of the WUR Capabilities Information field is defined in Table 9-406 (Subfields of the WUR Capabilities Information field(11ba)).

**Table 9-406—Subfields of the WUR Capabilities Information field(11ba)**

| Subfield | Definition | Encoding |
|---|---|---|
| Transition Delay | Indicates the maximum time that the non-AP STA requires to transition from the doze state to the awake state. (see 11.2.1 (General)) | Set to (the indicated value minus 1)/256.<br><br>Reserved for a WUR AP. |
| VL WUR Frame Support | Indicates support for VL WUR frames. | For a WUR non-AP STA: Set to 1 to indicate support for the reception of VL WUR frames. Set to 0 otherwise.<br><br>For a WUR AP: Set to 1 to indicate support for the transmission of VL WUR frames. Set to 0 otherwise. |
| WUR Group IDs Support | Indicates WUR Group IDs support. | For a WUR non-AP STA:<br>— Set to 0 to indicate no support for WUR group IDs if the VL WUR Frame Support subfield is 0 and to indicate support for a single WUR group ID when the VL WUR Frame Support subfield is 1.<br>— Set to 1 to indicate support for 1 to 16 WUR group IDs.<br>— Set to 2 to indicate support for 1 to 32 WUR group IDs.<br>— Set to 3 to indicate support for 1 to 64 WUR group IDs.<br>NOTE—If the WUR Group IDs Support subfield is equal to a non-zero value, then it implies support of group addressed fixed-length (FL) WUR Wake-up frame.<br><br>For a WUR AP:<br>— Set to 0 to indicate no support for WUR group IDs if the variable-length (VL) WUR Frame Support subfield is 0 and to indicate support for single WUR group ID when the VL WUR Frame Support subfield is 1.<br>— Set to 1 to indicate support for WUR group IDs.<br>NOTE—If WUR Group IDs Support subfield is equal to 1, it also implies support of group addressed FL WUR Wake-up frame. |
| 20 MHz WUR Basic PPDU with HDR Support | Indicate support for the reception of 20 MHz WUR Basic PPDU with HDR. | Set to 1 to indicate support for the reception of 20 MHz WUR Basic PPDUs with HDR. Set to 0 otherwise.<br><br>Reserved for a WUR AP. |


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**Table 9-406—Subfields of the WUR Capabilities Information field(11ba) *(continued)***

| Subfield | Definition | Encoding |
|---|---|---|
| WUR FDMA Support | Indicates whether the WUR FDMA is supported or not (see 29.11 (WUR FDMA operation)). | For a WUR non-AP STA: Set to 1 if the WUR FDMA channel switching capability is supported. Set to 0 otherwise.<br><br>For a WUR AP: Set to 1 if the transmission of WUR FDMA PPDU is supported. Set to 0 otherwise. Set to 0 otherwise. |
| WUR Short Wake-up Frame Support | Indicates support for the WUR Short Wake-up frame. | For a WUR non-AP STA: Set to 1 to indicate support for the reception of WUR Short Wake-up frames. Set to 0 otherwise.<br><br>For a WUR AP: Set to 1 to indicate support for the transmission of WUR Short Wake-up frames. Set to 0 otherwise. |

### 9.4.2.291 WUR Operation element(11ba)

The WUR Operation element contains the set of parameters necessary to support the WUR operation. The format of the WUR Operation element is defined in Figure 9-1015 (WUR Operation element format(11ba)).

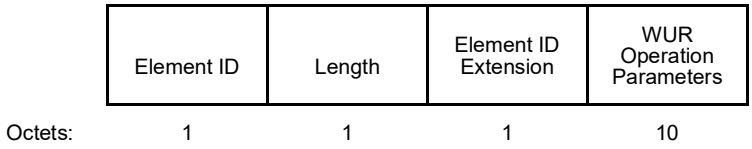


**Figure 9-1015—WUR Operation element format(11ba)**

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

The format of the WUR Operation Parameters field is defined in Figure 9-1016 (WUR Operation Parameters field format(11ba)).

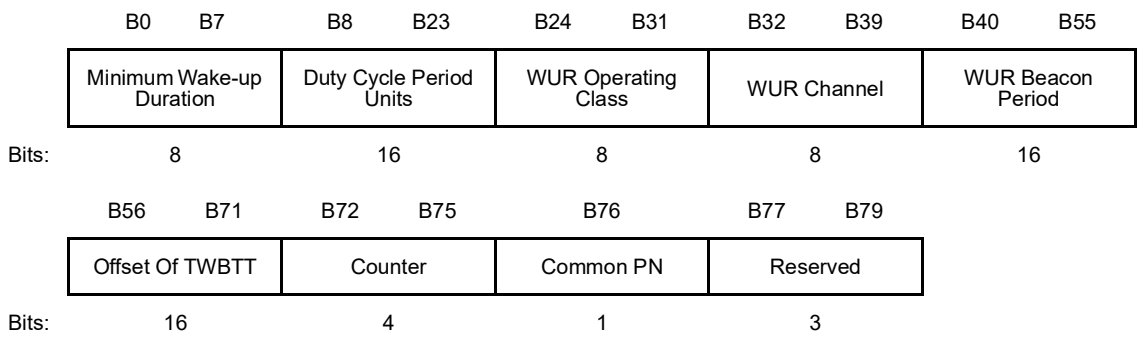


**Figure 9-1016—WUR Operation Parameters field format(11ba)**

The Minimum Wake-up Duration subfield indicates the minimum WUR duty cycle service period of the WUR duty cycle operation (see 29.7 (WUR duty cycle operation)) in units of 256 μs.

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The Duty Cycle Period Units subfield indicates the basic unit of the period of the WUR duty cycle operation (see 29.7 (WUR duty cycle operation)) in the unit of 4 μs.

The WUR Operating Class subfield indicates the operating class values of the WUR primary channel as defined in Annex E in use for transmission of WUR Beacon frames from the WUR AP to the WUR non-AP STA. The operating class is interpreted in the context of the country specified in the Beacon frame (see 29.2 (WUR channel, WUR primary channel, and WUR discovery channel)). The encoding is the same as the definition of Operating Class field in 9.4.1.22 (Operating Class And Channel field(#6181)).

The WUR Channel subfield indicates a channel number of the WUR primary channel, which is interpreted in the context of the indicated operating class as defined in Annex E in use for transmission of WUR Beacon frames from the WUR AP to the WUR non-AP STA (see 29.2 (WUR channel, WUR primary channel, and WUR discovery channel)). The encoding is the same as the definition of Channel field in 9.4.1.22 (Operating Class And Channel field(#6181)).

The WUR Beacon Period subfield represents the number of time units (TUs) between consecutive target WUR beacon transmission times (see 29.6.2 (WUR Beacon frame generation)).

The Offset Of TWBTT subfield indicates the time difference between the target WUR beacon transmission time with the smallest TSF time in units of TU and TSF 0 (see 29.6.2 (WUR Beacon frame generation)).

The Counter subfield indicates the current Counter subfield included in the broadcast WUR Wake-up frames (see 29.5.3 (Transmitter ID)) that are transmitted by the same AP.

The Common PN subfield indicates if a common PN is used for all protected WUR frames generated within the BSS. The Common PN subfield is set to 1 to indicate that a common PN is used for all protected WUR frames and is set to 0 to indicate that independent PNs are used for protected WUR frames addressed to different receivers (see 29.10.4 (Generation and construction of PN for WUR frames)).

### 9.4.2.292 WUR Mode element(11ba)

The WUR Mode element is used to negotiate the parameters related to WUR operation. The format of the WUR Mode element is shown in Figure 9-1017 (WUR Mode element format(11ba)).

| | Element ID | Length | Element ID Extension | Action Type | WUR Mode Response Status | WUR Parameters Control | WUR Parameters |
|---|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 1 | 1 | 1 | variable |

**Figure 9-1017—WUR Mode element format(11ba)**

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

The Action Type field contains a number that identifies the type of WUR mode operation. The Action Type values are shown in Table 9-407 (Action Type definitions(11ba)).

The WUR Mode Response Status field indicates the status returned by the WUR AP responding to the WUR non-AP STA's WUR mode request operation, and its values are defined in Table 9-408 (WUR Mode


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**Table 9-407—Action Type definitions(11ba)**

| Action Type value | Meaning |
|---|---|
| 0 | Enter WUR Mode Request |
| 1 | Enter WUR Mode Response |
| 2 | Enter WUR Mode Suspend Request |
| 3 | Enter WUR Mode Suspend Response |
| 4 | Enter WUR Mode Suspend |
| 5 | Enter WUR Mode |
| 6–255 | Reserved |

Response Status Definition(11ba)). This field is valid when the Action Type field is equal to "Enter WUR Mode Response" or "Enter WUR Mode Suspend Response" and is reserved otherwise.

**Table 9-408— WUR Mode Response Status Definition(11ba)**

| Value | Meaning |
|---|---|
| 0 | Accept. |
| 1 | Denied. Due to unspecified reason. |
| 2 | Denied. The preferred duty cycle period is too large. |
| 3 | Denied. Cannot satisfy the request of generating keep-alive WUR frames every WUR duty cycle service period. |
| 4–255 | Reserved |

NOTE 1—The threshold and duration of duty cycle period and detail operation of the WUR AP when the WUR mode Response Status field is equal to 2 are implementation dependent.

The WUR Parameters Control field indicates the configuration of the following WUR Parameters field. The format of the WUR Parameters Control field when the Action Type field is equal to "Enter WUR Mode Response" or "Enter WUR Mode Suspend Response" and the WUR Mode Response Status field is equal to "Accept" or when sent by a WUR non-AP STA is shown in Figure 9-1018 (WUR Parameters Control field format(11ba)). Otherwise, the field is reserved.

The WUR Duty Cycle Start Time Present subfield is set to 1 if the WUR Duty Cycle Start Time subfield is present in the following WUR Parameters field and is set to 0 otherwise.

NOTE 2—WUR non-AP STA always sets the WUR Duty Cycle Start Time Present subfield to 0 (see 29.7 (WUR duty cycle operation)).

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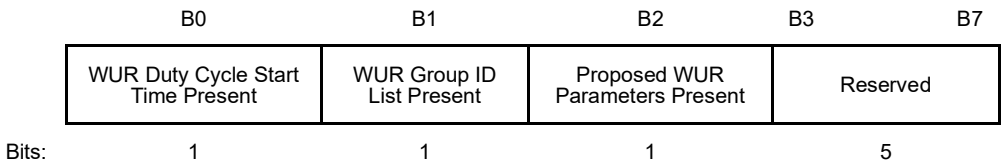


**Figure 9-1018—WUR Parameters Control field format(11ba)**

The WUR Group ID List Present subfield is set to 1 if the WUR Group ID List subfield is present in the following WUR Parameters field and is set to 0 otherwise. The WUR Group ID List Present subfield is reserved when the WUR Mode element is transmitted by a WUR non-AP STA.

The Proposed WUR Parameters Present subfield is set to 1 if the Proposed WUR Parameters subfield is present in the following WUR Parameters field and is set to 0 otherwise. The Proposed WUR Parameters Present subfield is reserved when the WUR Mode element is transmitted by a WUR AP.

The subfields of the WUR Parameters field sent from a WUR AP when the Action Type field is equal to "Enter WUR Mode Response" or "Enter WUR Mode Suspend Response" and the WUR Mode Response Status field is equal to "Accept" are defined in Figure 9-1019 (WUR Parameters field format if sent by a WUR AP(11ba)(#1729)(#1730)(M118)) and (#2317)Table 9-409 (Subfields of WUR Parameters field from WUR AP(11ba)). Otherwise, the WUR Parameters field sent from a WUR AP is reserved.

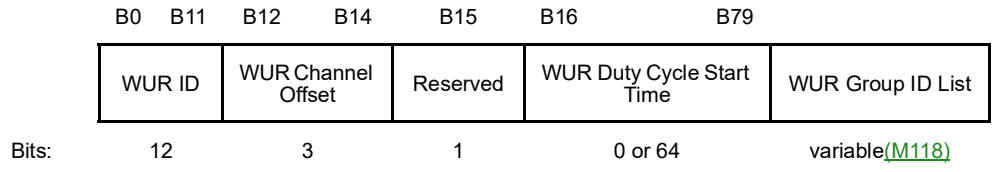


**Figure 9-1019—WUR Parameters field format if sent by a WUR AP(11ba)(#1729)(#1730)(M118)**

**Table 9-409—Subfields of WUR Parameters field from WUR AP(11ba)**

| Subfield | Definition | Encoding |
|---|---|---|
| WUR ID | A WUR identifier that uniquely identifies the WUR non-AP STA within the BSS of the AP | The size of the subfield is 12 bits. |
| WUR Channel Offset | Indicates the offset of the WUR channel on which WUR Short Wake-up frames or WUR Wake-up frames or WUR Vendor Specific frames are transmitted relative to the WUR primary channel (see 29.11 (WUR FDMA operation)). | The size of the subfield is 3 bits. The encoding is described in Table 9-410 (WUR Channel Offset subfield encoding(11ba)). |
| Reserved | Reserved field | The size of the subfield is 1 bit. |



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**Table 9-409—Subfields of WUR Parameters field from WUR AP(11ba)**

| Subfield | Definition | Encoding |
|---|---|---|
| WUR Duty Cycle Start Time | TSF time of the start point of the WUR duty cycle | The size of the subfield is 8 octets in units of μs. |
| WUR Group ID List | Indicates one or more WUR group IDs assigned to the WUR non-AP STA | The format is shown in Figure 9-1020 (WUR Group ID List subfield format(11ba)(M118)). This subfield is present if the WUR Group ID List Present subfield of the WUR Parameters Control field is equal to 1. Otherwise this subfield is not present. When this subfield is present, the size of this subfield in octets is 2, 4, 6 or 10 respectively when the WUR Group ID Bitmap Size field is 0, 1, 2 or 3. |

**Table 9-410—WUR Channel Offset subfield encoding(11ba)**

| WUR Channel Offset subfield | Meaning |
|---|---|
| 0 | The WUR Short Wake-up frames or the WUR Wake-up frames or the WUR Vendor Specific frames are to be transmitted in the WUR primary channel, which is indicated in the WUR Operation Class and the WUR Channel subfields in the WUR Operation element. |
| 1 | The WUR Short Wake-up frames or the WUR Wake-up frames or the WUR Vendor Specific frames are to be transmitted in first higher frequency 20 MHz channel relative to the WUR primary channel. |
| 2 | The WUR Short Wake-up frames or the WUR Wake-up frames or the WUR Vendor Specific frames are to be transmitted in first lower frequency 20 MHz channel relative to the WUR primary channel. |
| 3 | The WUR Short Wake-up frames or the WUR Wake-up frames or the WUR Vendor Specific frames are to be transmitted in second higher frequency 20 MHz channel relative to the WUR primary channel. |
| 4 | The WUR Short Wake-up frames or the WUR Wake-up frames or the WUR Vendor Specific frames are to be transmitted in second lower frequency 20 MHz channel relative to the WUR primary channel. |
| 5 | The WUR Short Wake-up frames or the WUR Wake-up frames or the WUR Vendor Specific frames are to be transmitted in third higher frequency 20 MHz channel relative to the WUR primary channel. |
| 6 | The WUR Short Wake-up frames or the WUR Wake-up frames or the WUR Vendor Specific frames are to be transmitted in third lower frequency 20 MHz channel relative to the WUR primary channel. |
| 7 | Reserved |

A WUR AP indicates the start time of a WUR duty cycle service period in the WUR Duty Cycle Start Time subfield of the WUR Parameters field in the WUR Mode element (see 29.7 (WUR duty cycle operation)).

The WUR Group ID Bitmap Size field is set to 0 to indicate that the WUR Group ID Bitmap field is not present. The WUR Group ID Bitmap Size field is set to 1 to indicate that the WUR Group ID Bitmap field contains a 16-bit bitmap. The WUR Group ID Bitmap Size field is set to 2 to indicate that the WUR Group

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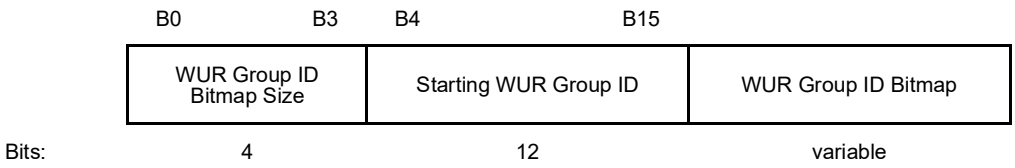


**Figure 9-1020—WUR Group ID List subfield format(11ba)(M118)**

ID Bitmap field contains a 32-bit bitmap.The WUR Group ID Bitmap Size field is set to 3 to indicate that the WUR Group ID Bitmap field contains a 64-bit bitmap. The values of 4 to 15 are reserved.

The Starting WUR Group ID field contains the starting WUR group ID of the WUR Group ID Bitmap field if the WUR Group ID Bitmap Size field is equal to a nonzero value. The Starting WUR Group ID field contains a single WUR group ID assigned by the WUR AP to the WUR non-AP STA if the WUR Group ID Bitmap Size field is equal to 0.

The WUR Group ID Bitmap field, if present, together with the Starting WUR Group ID field, indicates the WUR group IDs assigned by the WUR AP to the WUR non-AP STA. The first bit of the WUR Group ID Bitmap field corresponds to bit position 0. Bit position n of the WUR Group ID Bitmap field, if equal to 1, indicates the WUR group ID with a value equal to (the starting WUR group ID+ n) mod 4096 is assigned to the WUR non-AP STA. Bit position n of the WUR Group ID Bitmap field, if equal to 0, indicates the WUR group ID with a value equal to (the starting WUR group ID+ n) mod 4096 is not assigned to the WUR non-AP STA.

The subfields of the WUR Parameters field sent from a WUR non-AP STA when the Action Type field is equal to “Enter WUR Mode Request” or “Enter WUR Mode Suspend Request” are defined in 9-1021 (WUR Parameters field format if sent by a WUR non-AP STA(11ba)(M118)) and Table 9-411 (Subfields of the WUR Parameters field if sent by a WUR non-AP STA(11ba)(M118)). Otherwise, the WUR Parameters field sent from a WUR non-AP STA is reserved.

**Table 9-411—Subfields of the WUR Parameters field if sent by a WUR non-AP STA(11ba)(M118)**

| Subfield | Definition | Encoding |
|---|---|---|
| WUR Duty Cycle Service Period | Indicates the preferred WUR duty cycle service period that the WUR power state of the WUR non-AP STA is in the WUR awake state for each WUR duty cycle period (see 29.7 (WUR duty cycle operation)). | The size of the field is 4 octets. The unit of the field is 4 μs. |
| Duty Cycle Period | Indicates the preferred elapsed time between the start times of two successive WUR duty cycle service periods (see 29.7 (WUR duty cycle operation)). | The size of the field is 2 octets. The unit of the field is indicated by the Duty Cycle Period Units field in the most recently received WUR Operation element from the associated WUR AP. |
| Proposed WUR Parameters | Indicates one or more proposed WUR Parameters | The format is shown in Figure 9-1022 (Proposed WUR Parameters subfield format(11ba)). |


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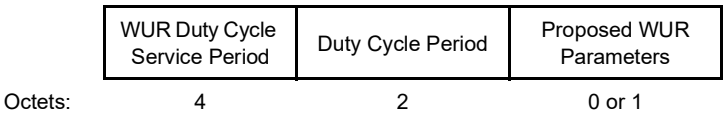


**Figure 9-1021—WUR Parameters field format if sent by a WUR non-AP STA(11ba)(M118)**

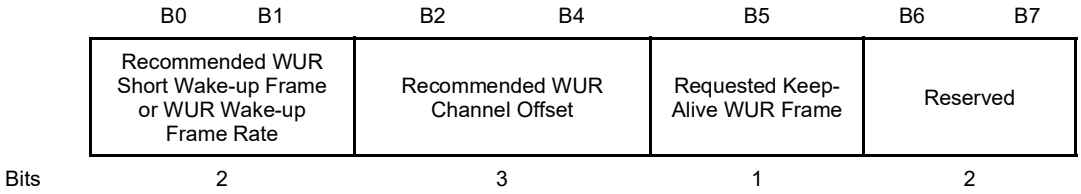


**Figure 9-1022—Proposed WUR Parameters subfield format(11ba)**

The format of the Proposed WUR Parameters subfield is shown in Figure 9-1022 (Proposed WUR Parameters subfield format(11ba)). This field is present if the Proposed WUR Parameters Present subfield of the WUR Parameter Control field is equal to 1. Otherwise this field is not present.

The Recommended WUR Short Wake-up Frame or WUR Wake-up Frame Rate field is set to 0 to indicate that the WUR non-AP STA has no recommendation on the data rate to be used for WUR Short Wake-up frames or WUR Wake-up frames. The Recommended WUR Short Wake-up Frame or WUR Wake-up Frame Rate field is set to 1 to indicate that LDR is recommended to be used for WUR Short Wake-up frames or individually or group addressed WUR Wake-up frames transmitted to the WUR non-AP STA. The Recommended WUR Short Wake-up Frame or WUR Wake-up Frame Rate field is set to 2 to indicate that HDR is recommended to be used for WUR Short Wake-up frames or individually or group addressed WUR Wake-up frames transmitted to the WUR non-AP STA. 3 is reserved.

The Recommended WUR Channel Offset field is used by a WUR non-AP STA to indicate a recommended value for the WUR Channel Offset field, with the same encoding as described in Table 9-410 (WUR Channel Offset subfield encoding(11ba)), except that the value 7 indicates that the WUR non-AP STA has no recommendation regarding the WUR channel assigned to the WUR non-AP STA.

The Requested Keep-Alive WUR Frame field is set to 1 if the WUR non-AP STA requests the WUR AP to transmit a keep-alive WUR frame during the WUR duty cycle service periods that are negotiated with the WUR non-AP STA. Otherwise, it is set to 0.

### 9.4.2.293 WUR Discovery element(11ba)

The WUR Discovery element is used to advertise the WUR discovery channels on which WUR APs transmit WUR Discovery frames. The format of the WUR Discovery element is shown in Figure 9-1023 (WUR Discovery element format(11ba)).

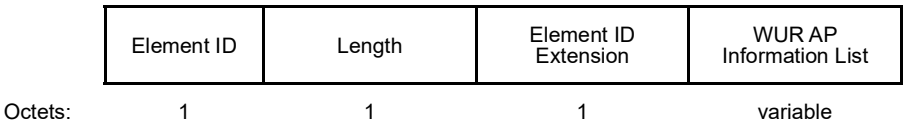


**Figure 9-1023—WUR Discovery element format(11ba)**

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

The WUR AP Information List field contains one or more WUR AP Information subfields. Each WUR AP Information subfield identifies the WUR APs that transmit WUR Discovery frames on a particular WUR

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Discovery channel. The format of the WUR AP Information subfield is shown in Figure 9-1024 (WUR AP Information subfield format(11ba)).

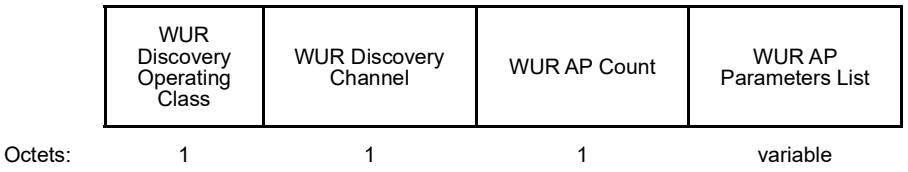


**Figure 9-1024—WUR AP Information subfield format(11ba)**

The WUR Discovery Operating Class field indicates the operating class in use for transmission of WUR Discovery frames by WUR APs listed in this subfield. The encoding is the same as the definition of Operating Class field in 9.4.1.22 (Operating Class And Channel field(#6181)).

The WUR Discovery Channel field indicates the channel in use for transmission of WUR Discovery frames by WUR APs listed in this subfield. The encoding is the same as the definition of Channel field in 9.4.1.22 (Operating Class And Channel field(#6181)).

The WUR AP Count field specifies the number of WUR AP Parameters subfields that are included in the WUR AP Parameters List field, minus one. 0 indicates that one WUR AP Parameters subfield is present.

The WUR AP Parameters List field contains one or more WUR AP Parameters subfields. Each WUR AP Parameters subfield identifies one WUR AP, which might be the WUR AP transmitting this WUR Discovery element itself or might be a neighboring WUR AP. The format of the WUR AP Parameters subfield is shown in Figure 9-1025 (WUR AP Parameters subfield format(11ba)).

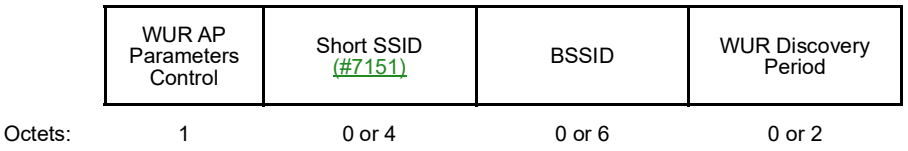


**Figure 9-1025—WUR AP Parameters subfield format(11ba)**

The WUR AP Parameters Control field indicates the presence of the (#7151)Short SSID field, the BSSID field, and the WUR Discovery Period field. The format of the WUR AP Parameters Control is shown in Figure 9-1026 (WUR AP Parameters Control field format(11ba)).

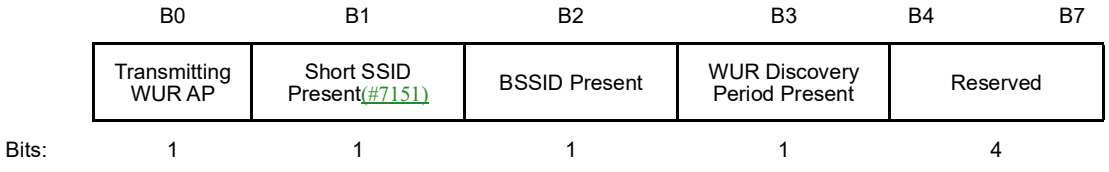


**Figure 9-1026—WUR AP Parameters Control field format(11ba)**

The Transmitting WUR AP subfield is set to 1 if the WUR AP Information subfield identifies the WUR AP's own WUR discovery channel and is set to 0, otherwise.

The (#7151)Short SSID Present subfield is set to 1 if the (#7151)Short SSID field is present in the WUR AP Parameters subfield and is set to 0, otherwise.


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The BSSID Present subfield is set to 1 if the BSSID field is present in the WUR AP Parameters subfield and is set to 0, otherwise.

The WUR Discovery Period Present subfield is set to 1 if the WUR Discovery Period is present in the WUR AP Parameters subfield. Otherwise, the WUR Discovery Period Present subfield is set to 0.

The (#7151)Short SSID field is defined in 9.4.1.71 (Short SSID field(#7151)) and contains the short SSID of the WUR AP identified by the WUR AP Parameters subfield.

The BSSID field contains the BSSID of the WUR AP identified by the WUR AP Parameters subfield as defined in 9.2.4.3.4 (BSSID field).

The WUR Discovery Period field contains the number of time units (TUs) between consecutive WUR Discovery frames transmitted by the WUR AP identified by the WUR AP Parameters subfield. 0 is reserved.

### 9.4.2.294 WUR PN Update element(11ba)

The WUR PN Update element is used to update the PN maintained by a WUR non-AP STA. The format of the WUR PN Update element is shown in Figure 9-1027 (WUR PN Update element format(11ba)).

| | Element ID | Length | Element ID Extension | Key Info | PN |
|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 1 | 0 or 6 |

**Figure 9-1027—WUR PN Update element format(11ba)**

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

(M118)The format of the Key Info field is shown in Figure Figure 9-1028 (Key Info field format(11ba)).

| | B0 B3 | B4 | B5 B7 |
|---|---|---|---|
| | Key ID | PN Present | Reserved |
| Bits: | 4 | 1 | 3 |

**Figure 9-1028—Key Info field format(11ba)**

The Key ID subfield contains the (#3493)key ID corresponding to the WTK or WIGTK.

The PN Present subfield is set to 1 if the PN field is present in the WUR PN Update element and is set to 0 otherwise.

(M118)The format of the PN field is shown in Figure 9-1029 (PN field format(11ba)).

| | B0 B7 | B8 B15 | B16 B23 | B24 B31 | B32 B39 | B40 B47 |
|---|---|---|---|---|---|---|
| | PN0 | PN1 | PN2 | PN3 | PN4 | PN5 |
| Bits: | 8 | 8 | 8 | 8 | 8 | 8 |

**Figure 9-1029—PN field format(11ba)**

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The PN field contains the PN corresponding to the integrity key indicated by the Key ID subfield in the Key Info field.

### 9.4.2.295 AKM Suite Selector element(M67)

The AKM Suite Selector element is used to indicate the intended AKM in SAE.

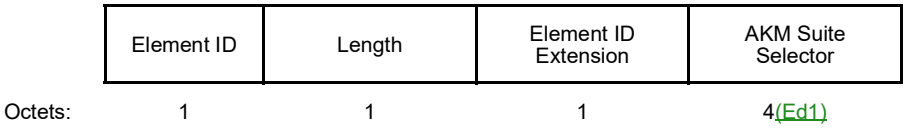


**Figure 9-1030—AKM Suite Selector element format(M67)**

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

The AKM Suite Selector field has the format shown in Figure 9-368 (Suite selector format), where the suite type is defined in Table 9-190 (AKM suite selectors).

### 9.4.2.296 Originator Preferred MCS element(#1444)

The Originator Preferred MCS element is used to signal the preferred MCS used for eliciting A-MPDUs from the data originator. The format of the Originator Preferred MCS element is shown in Figure 9-1031 (Originator Preferred MCSelement format(#1444)).

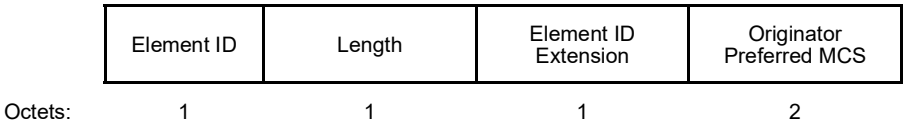


**Figure 9-1031—Originator Preferred MCSelement format(#1444)**

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

The Originator Preferred MCS field is defined in 9.4.1.15 (Originator Preferred MCS field).

### 9.4.2.297 Known STA Identification element(#4069)

The Known STA Identification element is used to demonstrate possession of a recently used PTK-KCK to allow a (re)associating STA to be identified in an RSN. The format of the Known STA Identification element is shown in Figure 9-1032 (Known STA Identification element format(#4069)).

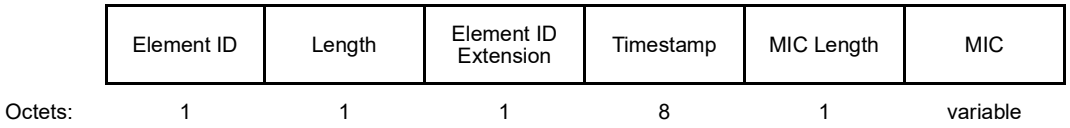


**Figure 9-1032—Known STA Identification element format(#4069)**

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

The Timestamp field contains the value of the most recently received Timestamp field from the AP to which the Known STA Identification element is being sent.


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The MIC Length field contains the length of the MIC field in octets.

The MIC field contains a MIC calculated as specified in 11.13 (SA Query procedures).

### 9.4.2.298 ISTA Availability Window element(11az)

The format of the ISTA Availability Window element is shown in Figure 9-1033 (ISTA Availability Window element format(11az)).

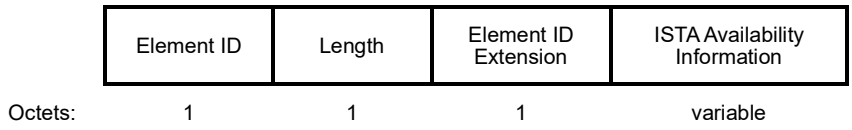


**Figure 9-1033—ISTA Availability Window element format(11az)**

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

The ISTA Availability Information field format is shown in Figure 9-1034 (ISTA Availability Information field format(11az)).

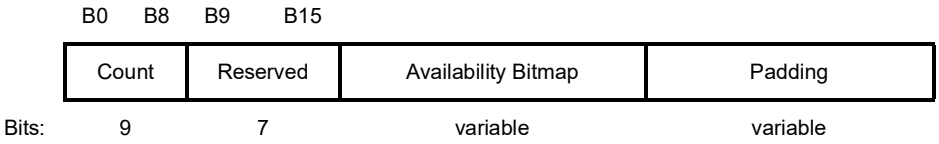


**Figure 9-1034—ISTA Availability Information field format(11az)**

The Count subfield in the ISTA Availability Information field indicates the size in bits of the Availability Bitmap subfield. The value of this subfield is denoted as "count".

Each Availability Bit in the Availability Bitmap subfield indicates the ISTA's availability for TB ranging with the recipient RSTA. The value indicated by each bit in the Availability Bitmap subfield is in units of 10 TUs. Bit $B_k$ (where $0 \le k \le \text{count} - 1$) represents the ISTA's periodic availability for TB ranging with the RSTA in the interval $[t_{start,k}, t_{end,k}]$ repeated every $N$ TUs; see Equation (9-12):

$$\begin{aligned} t_{start,k} &= t_{start,0} + 10k \text{ TU} \\ t_{end,k} &= t_{start,0} + 10(k+1) \text{ TU} \\ t_{start,0} &= \text{time 0 per RSTA's TSF} \\ N &= 10 \times \text{count} \end{aligned} \tag{9-12}$$

A value of 1 in an Availability Bit indicates the ISTA's availability at time $t_{start,k}$ for a duration of 10 TUs, while a value of 0 indicates the ISTA's unavailability at time $t_{start,k}$ for a duration of 10 TUs.

The Padding subfield (#8251)is optionally present to render the length of the Availability Bitmap subfield to be a multiple of eight. The value of the bits in the Padding field is reserved.

### 9.4.2.299 RSTA Availability Window element(11az)

The format of the RSTA Availability Window element is shown in Figure 9-1035 (RSTA Availability Window element format(11az)).

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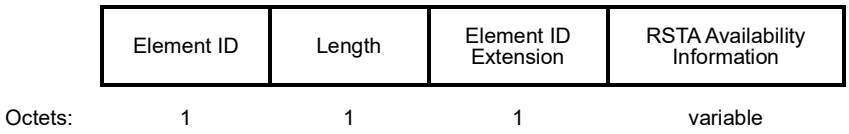


**Figure 9-1035—RSTA Availability Window element format(11az)**

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

The RSTA Availability Information field format is shown in Figure 9-1036 (RSTA Availability Information field format(11az)).

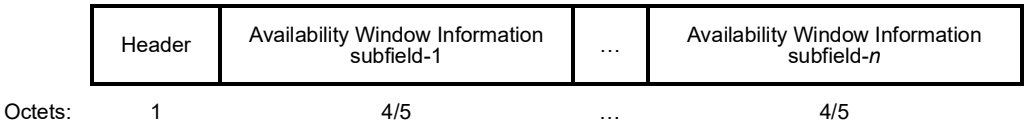


**Figure 9-1036—RSTA Availability Information field format(11az)**

The Header subfield format in the RSTA Availability Information field is shown in Figure 9-1037 (Header subfield format(11az)).

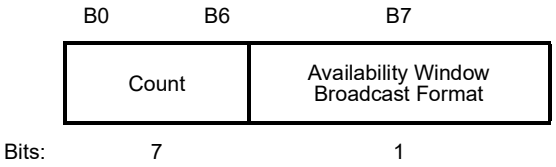


**Figure 9-1037—Header subfield format(11az)**

The Count subfield in the Header subfield indicates the number of Availability Window Information subfields included in the RSTA Availability information field.

The Availability Window Broadcast Format subfield indicates the format of the Availability Window Information subfields.

When the Availability Window Broadcast Format subfield is set to 0, the format of each Availability Window Information subfield is shown in Figure 9-1038 (Availability Window Information field format when the Availability Window Broadcast Format subfield is set to 0(11az)).

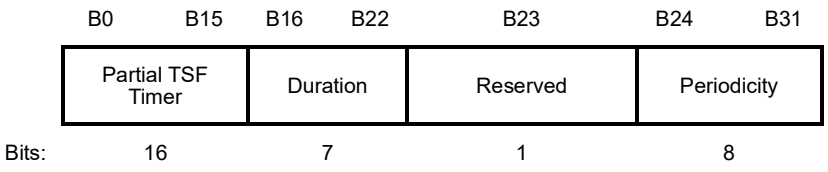


**Figure 9-1038—Availability Window Information field format when the Availability Window Broadcast Format subfield is set to 0(11az)**

The Partial TSF Timer subfield is derived as described in 9.4.2.166 (FTM Parameters element(11az)) and indicates the TSF timer of the RSTA at the start of first availability window.


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The Duration subfield in the Availability Window Information field indicates the duration of the corresponding availability window in units of 100 μs (giving it a value from 0 to ~12.7 ms). The value 0 is Reserved.

The Periodicity subfield in an Availability Window Information subfield indicates the periodicity of that availability window in units of 100 TU (Giving it a value from 0 to ~26.1 s).

When the Availability Window Broadcast Format subfield is set to one, the format of each Availability Window Information subfield is shown in Figure 9-1039 (Availability Window Information field format when the Availability Window Broadcast Format subfield is set to 1(11az)).

**Figure 9-1039—Availability Window Information field format when the Availability Window Broadcast Format subfield is set to 1(11az)**

The format of the Partial TSF Timer, Duration, and Periodicity subfields when the Availability Window Broadcast Format subfield is set to 1 are the same as the formats of the subfields when the Availability Window Broadcast Format subfield is set to 0. The Passive TB Ranging Parameters subfield format is shown in Figure 9-1040 (Passive TB Ranging Parameters subfield format(11az)).

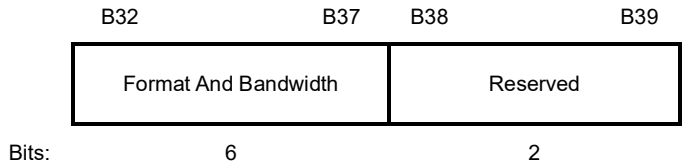


**Figure 9-1040—Passive TB Ranging Parameters subfield format(11az)**

The Format And Bandwidth subfield is defined in Table 9-412 (Format And Bandwidth subfield(11az)), and indicates the requested or allocated PPDU format and nominal bandwidth used to transmit the I2R/R2I NDP exchange as part of the passive TB ranging measurement exchange in the passive TB ranging availability window. Depending on the medium availability, the bandwidth used for the exchanged frames is equal to or smaller than the nominal bandwidth.

### 9.4.2.300 Ranging Parameters element(11az)

The Ranging Parameters element is optionally included in the IFTMR frame, as described in 9.6.7.32 (FTM(11az) Request frame format), and the IFTM frame, as described in 9.6.7.33 (FTM(11az) frame format). The use of the Ranging Parameters element is described in 11.21.6 (FTM procedure(#7065)).

The format of the Ranging Parameters element is shown in Figure 9-1041 (Ranging Parameters element format(11az)).

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

The format of the Ranging Parameters field is shown in Figure 9-1042 (Ranging Parameters field format(11az)).

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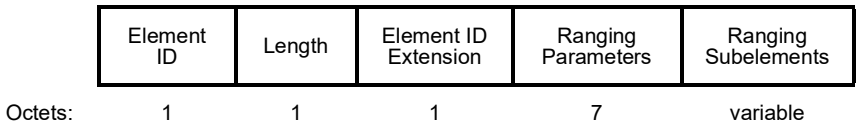


**Figure 9-1041—Ranging Parameters element format(11az)**

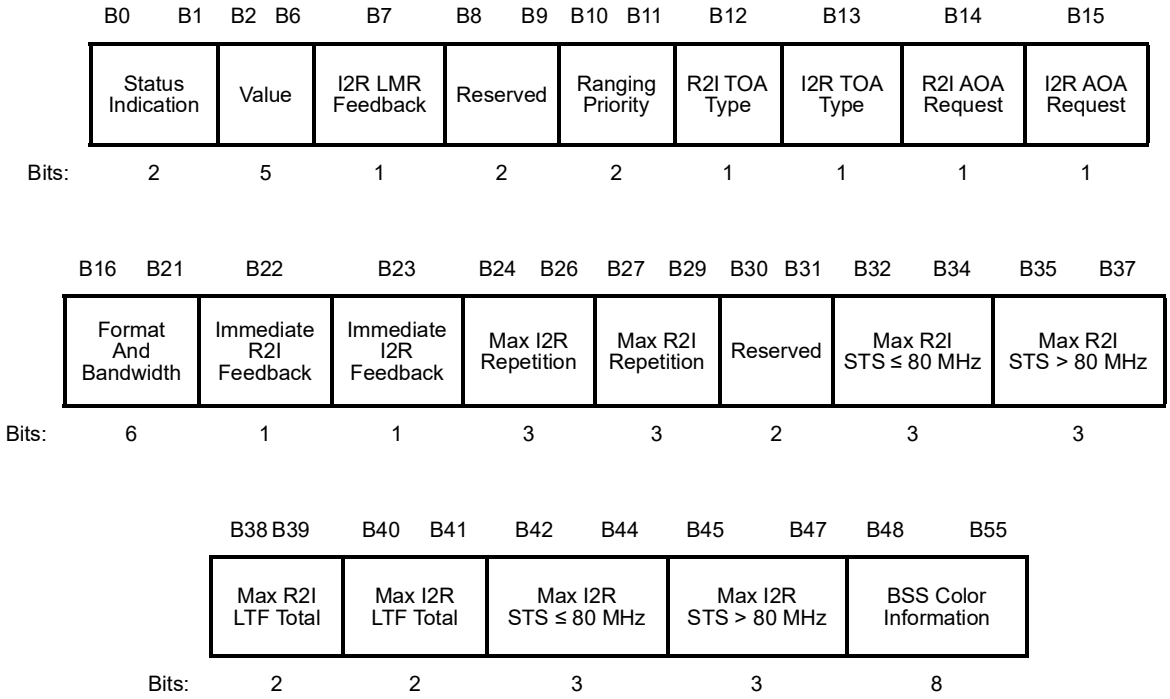


**Figure 9-1042—Ranging Parameters field format(11az)**

The Status Indication subfield indicates the RSTA's response to the Fine Timing Request. The encoding of the Status Indication subfield is shown in Table 9-321 (Status Indication subfield values).

The Status Indication subfield and Value subfield are reserved in the IFTMR frame. When the Status Indication subfield is set to 3 by the RSTA, the Value subfield contains a duration in units of seconds; otherwise the Value subfield is reserved.

The I2R LMR Feedback subfield in the Ranging Parameters element in the IFTMR frame is set to indicate whether it transmits I2R LMR feedback to the RSTA, if requested by the RSTA; (see 11.21.6.3.3 (Negotiation for TB and non-TB ranging measurement exchange)).

The RSTA sets the I2R LMR Feedback subfield in the Ranging Parameters element in the IFTM frame to 1 to indicate it requests the ISTA to transmit I2R LMR feedback to the RSTA and sets it to 0 otherwise (see 11.21.6.3.3 (Negotiation for TB and non-TB ranging measurement exchange), 11.21.6.4.3.4 (Reporting phase of TB ranging measurement(11az)), and 11.21.6.4.4.3 (Non-TB ranging measurement reporting phase(11az))).

The R2I TOA Type subfield is set to 1 in the IFTMR frame by the ISTA to indicate that it requests phase shift TOA feedback in the R2I LMR and is set to 0 otherwise. The R2I TOA Type subfield is set to 1 in the


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IFTM frame by the RSTA to indicate that it reports phase shift TOA feedback in the R2I LMR and is set to 0 otherwise; see 11.21.6.3.3 (Negotiation for TB and non-TB ranging measurement exchange).

The I2R TOA Type subfield is set to 1 in the IFTMR frame by the ISTA to indicate that it supports phase shift TOA feedback in the I2R LMR and is set to 0 otherwise. The I2R TOA type subfield is set to 1 in the IFTM frame by the RSTA to assign phase shift TOA feedback in the I2R LMR and is set to 0 otherwise; see 11.21.6.3.3 (Negotiation for TB and non-TB ranging measurement exchange).

The R2I AOA Requested subfield is set to 1 in the IFTMR frame by the ISTA when it requests the RSTA to include AOA measurements in the AOA Feedback field of the R2I LMR. The R2I AOA Requested subfield is set to 1 in the IFTM frame to indicate that the RSTA includes the AOA measurements in the R2I LMR.

The I2R AOA Requested subfield in the IFTMR frame is set to 1 to indicate that the ISTA supports AOA measurement feedback in the I2R LMR. The I2R AOA Requested subfield in the IFTM frame is set to 1 to request the ISTA to include the AOA measurement feedback in the I2R LMR and is set to 0 otherwise.

The Format And Bandwidth subfield indicates the requested or allocated PPDU format and bandwidth used to transmit the I2R/R2I NDP exchange as part of the non-TB ranging, or TB ranging measurement exchange; see 11.21.6.4.3 (TB ranging measurement exchange(11az)) and 11.21.6.4.4 (Non-TB ranging measurement exchange(11az)). The encoding of this subfield is given in Table 9-412 (Format And Bandwidth subfield(11az)).

**Table 9-412—Format And Bandwidth subfield(11az)**

| Field value | Format | Bandwidth |
|---|---|---|
| 0 | HE | 20 |
| 1 | HE | 40 |
| 2 | HE | 80 |
| 3 | HE | 80+80 |
| 4 | HE (two separate RF LOs) | 160 |
| 5 | HE (single RF LO) | 160 |
| 6(11bd) | NGV | 10 |
| 7(11bd) | NGV | 20 |
| 8–63 | Reserved | Reserved |
| NOTE—Values 6 and 7 are supported only when dot11NGVOptionImplemented is true.(11bd) | | |

The values of 3, 4, and 5 indicate STA support for 160 MHz operation as either 80+80, 160 two-LO, or 160 single-LO, respectively in addition to supporting 80 MHz, 40 MHz, and 20 MHz bandwidths (e.g., a field value of 5 does not mean the device supports all 160 MHz options but rather 160 MHz single LO).

The Max I2R Repetition subfield indicates the maximum number of HE-LTF repetitions that the ISTA uses in the preamble of the I2R NDP and is set to the number of HE-LTF repetitions minus 1.

The Max R2I Repetition subfield indicates the maximum number of HE-LTF repetitions that the RSTA uses in the preamble of the R2I NDP and is set to the number of HE-LTF repetitions minus 1.

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NOTE—The values of 0 to 7 contained in the Max I2R Repetition and Max R2I Repetition subfields are mapped to the values 1 to 8 for the number of HE-LTF repetitions, respectively.

The Ranging Priority subfield of the Ranging Parameters field of the Ranging Parameters element in the IFTMR frame contains the ISTA's ranging priority request, which indicates the time sensitivity of a ranging operation, and it is set according to Table 9-323 (Definition of the EDMG Ranging Priority subfield when included in the IFTMR frame(11az)).

For TB ranging, the Ranging Priority subfield of the Ranging Parameters field of the Ranging Parameters element in the IFTM frame contains the RSTA's ranging priority response, which indicates whether the RSTA accommodates the ranging priority request of the ISTA, and it is set according to Table 9-324 (Definition of the EDMG Ranging Priority subfield when included in the IFTM frame(11az)) in 9.4.2.166 (FTM Parameters element(11az)).

For non-TB ranging, the Ranging Priority subfield of the Ranging Parameters field of the Ranging Parameters element in the IFTM frame is reserved.

The Immediate R2I Feedback and Immediate I2R Feedback subfields indicate if the measurement results from the current measurement exchange are reported immediately by setting it to 1 (from the current measurement) or delayed by setting it to 0 (from the previous measurement) in the R2I and I2R LMR frame respectively.

The Immediate R2I Feedback subfield is reserved in the IFTMR frame. In the IFTM frame the Immediate R2I Feedback field is set to 1 to indicate that the R2I LMR will be immediate feedback and to 0 to indicate delayed feedback.

The Immediate I2R Feedback field in the IFTMR frame is set to 1 to indicate immediate feedback in the I2R LMR and is set to 0 to indicate delayed feedback. In the IFTM frame the Immediate I2R Feedback field is set to the same value as in the IFTMR frame.

The Max R2I STS ≤ 80 MHz subfield indicates for bandwidths less than or equal to 80 MHz the maximum number of space-time streams to be used in the R2I NDP in the session.

The Max R2I STS > 80 MHz subfield indicates for bandwidths greater than 80 MHz the maximum number of space-time streams to be used in the R2I NDP in the session.

The BSS Color Information subfield has the same format as in the BSS Color Information field in the HE Operation element. Each subfield of the BSS Color Information field is set to the same value, as in the HE Operation element transmitted by an RSTA. The BSS Color Information subfield is reserved in the IFTMR frame.

The Max R2I LTF Total and Max I2R LTF Total subfields indicate the maximum number of HE-LTFs to be destined to an ISTA in the R2I NDP and an RSTA in an I2R NDP, respectively, the encoding is given in Table 9-413 (Max R2I/I2R LTF Total subfields(11az)). The maximum number of HE-LTFs limits the allowed combinations of number of space-time streams and HE-LTF repetitions.

**Table 9-413—Max R2I/I2R LTF Total subfields(11az)**

| Field value | Max number of HE-LTFs |
|---|---|
| 0 | 4 |
| 1 | 8 |


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**Table 9-413—Max R2I/I2R LTF Total subfields(11az)**

| Field value | Max number of HE-LTFs |
|---|---|
| 2 | 16 |
| 3 | 64 |

The Max I2R STS ≤ 80 MHz subfield indicates for bandwidths less than or equal to 80 MHz the maximum number of space-time streams to be used in the I2R NDP in the session.

The Max I2R STS > 80 MHz subfield indicates for bandwidths greater than 80 MHz the maximum number of space-time streams to be used in the I2R NDP in the session.

The Ranging Subelements field contains one or more subelements. The format and ordering of the subelements are defined in 9.4.3 (Subelements). The Subelement ID field values for the defined subelements are shown in Table 9-414 (Ranging Subelement IDs for Ranging Parameters(11az)).

**Table 9-414—Ranging Subelement IDs for Ranging Parameters(11az)**

| Subelement ID field | Name | Extensible |
|---|---|---|
| 0 | Non-TB Specific subelement | Yes |
| 1 | TB-specific subelement | Yes |
| 2 | Secure HE-LTF subelement | Yes |
| 3–220 | Reserved | |
| 221 | Vendor Specific | |
| 222–255 | Reserved | |

If the initiator and the responder successfully negotiate an FTM session, and the negotiated ranging protocol is non-TB, then the Non-TB Specific subelement is included in both the IFTMR frame, to describe the requested set of parameters that the initiator proposes to use, and in the IFTM frame.

The format of the Non-TB Specific subelement is as shown in Figure 9-1043 (Non-TB Specific subelement format(11az)).

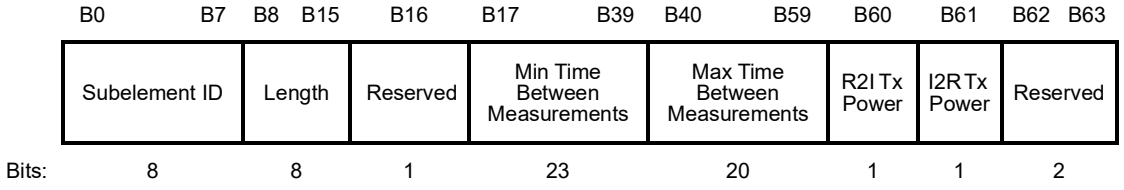


**Figure 9-1043—Non-TB Specific subelement format(11az)**

The Subelement ID and Length fields are defined in 9.4.3 (Subelements).

The R2I Tx Power field in the IFTMR frame is set to 1 to indicate that the ISTA requests the RSTA to report the TX power of the R2I NDPs in the (#8066)R2I NDP Tx Power field in the following LMR, and 0

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otherwise. In the IFTM frame, the R2I Tx Power field is set to 1 by the RSTA to indicate that it will report the TX power of the R2I NDPs in the (#8066)R2I NDP Tx Power field of the following LMR, and 0 otherwise.

The I2R Tx Power field in the IFTMR frame is set to 1 to indicate that the ISTA supports announcing the TX power of the I2R NDPs in the STA Info field with the AID11 subfield set to 2045 of the preceding NDP Announcement frame, and 0 otherwise. In the IFTM frame, the I2R Tx Power field is set to 1 by the RSTA to request the ISTA to announce the TX power of the I2R NDPs in the STA Info field with the AID11 subfield set to 2045 of the preceding NDP Announcement frame, and 0 otherwise.

The Min Time Between Measurements field is requested by the ISTA in the IFTMR frame and assigned by RSTA in the IFTM frame, and indicates the minimum time between two consecutive range measurements initiated by an ISTA, in units of 100 μs.

The Max Time Between Measurements field is requested by the ISTA in the IFTMR frame and assigned by RSTA in the IFTM frame, and indicates the latest time by which the ISTA needs to complete the next round of measurements, in units of 10 ms.

If the initiator and the responder successfully negotiate an FTM session where the negotiated ranging protocol is TB, then the TB Specific subelement is included in both the IFTMR frame, to describe the requested set of parameters that the initiator proposes to use, and in the IFTM frame.

The format of the TB Specific subelement is as shown in Figure 9-1044 (TB Specific subelement format(11az)).

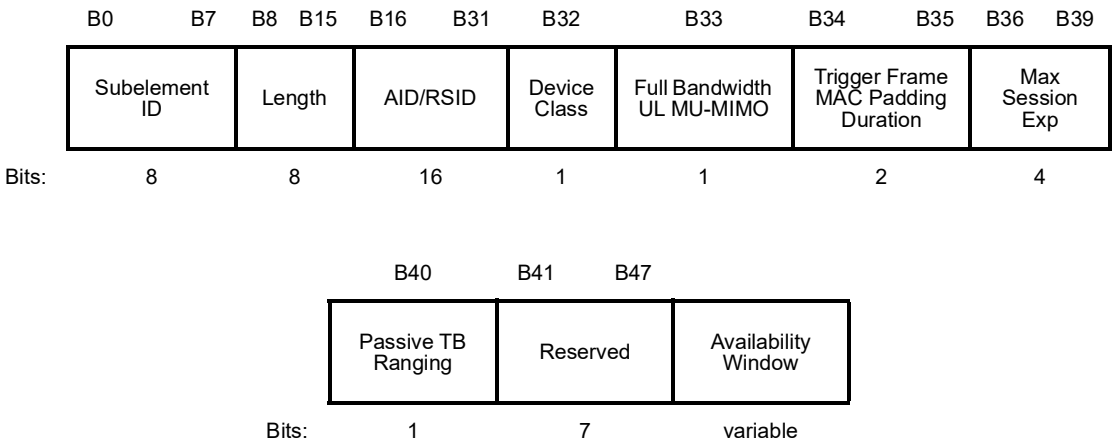


**Figure 9-1044—TB Specific subelement format(11az)**

The Subelement ID and Length fields are defined in 9.4.3 (Subelements).

The AID/RSID field is reserved in the IFTMR frame. In the IFTM frame it contains an identifier for the ISTA for the duration of the FTM session. If the ISTA is associated with the RSTA, the value is set to the ISTA's AID. If the ISTA is not associated with the RSTA, the AID/RSID field is set to the RSID, which is assigned by the responder to identify the unassociated ISTA, and has the same length as the AID.

The Device Class and Full Bandwidth UL MU-MIMO fields correspond to the Device Class and Full Bandwidth UL MU-MIMO fields defined in Table 9-376 (Subfields of the HE PHY Capabilities Information field(11ax)). For associated STAs, the values of the Device Class and Full Bandwidth UL MU-


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MIMO subfields are equal to the values of the Device Class and Full Bandwidth UL MU-MIMO fields, respectively, that are exchanged during association.

The Trigger Frame MAC Padding Duration field correspond to the Trigger Frame MAC Padding Duration field defined in Table 9-375 (Subfields of the HE MAC Capabilities Information field(11ax)). For associated STAs, the value of the Trigger Frame MAC Padding Duration field is equal to the value that was exchanged during association.

The Max Session Exp field indicates the time before which a new measurement exchange between the ISTA and RSTA should be initiated and completed. This value is computed as $2^{(\text{Max Session Exp} + 8)}$ ms. The Max Session Exp field is reserved in an IFTMR frame.

The Passive TB Ranging field is set to 1 by the initiator to request passive TB ranging operation, otherwise it is set to 0. The Passive TB Ranging field is set to 1 by the Responder to grant passive TB ranging operation, otherwise it is set to 0.

The Availability Window field (#8252)contains either an ISTA Availability Window element, see Figure 9-1033 (ISTA Availability Window element format(11az)), when the containing Ranging Parameters element is in an IFTMR frame; or an RSTA Availability Window element, see Figure 9-1035 (RSTA Availability Window element format(11az)), when the containing Ranging Parameters element is in an FTM frame.

Figure 9-1045 (Example of a bitmap with 200 TU periodicity signaled in the ISTA Availability Window element(11az)), Figure 9-1046 (Example of mapping of ISTA's availability bitmap to RSTA's TSF(11az)), and Figure 9-1047 (Example of how an RSTA assigns an Availability Window to an ISTA(11az)) together show an example of how an RSTA assigns an availability window from the received Availability Window element of the ISTA. Figure 9-1045 (Example of a bitmap with 200 TU periodicity signaled in the ISTA Availability Window element(11az)) shows the bitmap in the ISTA Availability Information field of the ISTA Availability Window element included with an IFTMR frame. The bitmap has periodicity of 200 TUs and the RSTA Beacon Interval is 100 TUs. Figure 9-1046 (Example of mapping of ISTA's availability bitmap to RSTA's TSF(11az)) shows how the RSTA calculates ISTA's periodic availability from this bitmap relative to RSTA TSF. Finally, Figure 9-1047 (Example of how an RSTA assigns an Availability Window to an ISTA(11az)) shows how the RSTA constructs an availability window with periodicity of 200 TUs

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requested by the ISTA and with a window duration of 10 TUs. The shaded region indicates the location of the assigned availability windows.

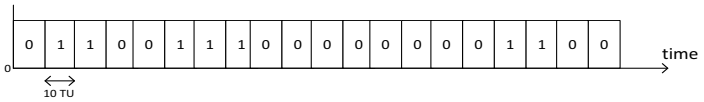


**Figure 9-1045—Example of a bitmap with 200 TU periodicity signaled in the ISTA Availability Window element(11az)**

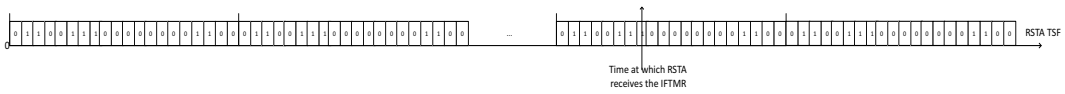


**Figure 9-1046—Example of mapping of ISTA's availability bitmap to RSTA's TSF(11az)**

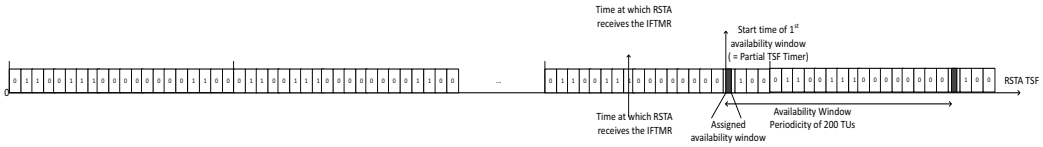


**Figure 9-1047—Example of how an RSTA assigns an Availability Window to an ISTA(11az)**

The Ranging Parameters element in the IFTMR frame includes a Non-TB Specific subelement and/or a TB specific subelement; and the Ranging Parameters element in the corresponding IFTM frame includes either a Non-TB Specific subelement or a TB specific subelement, if the Status Indication subfield in the Ranging Parameters field is set to Success to indicate the range measurement protocol selected by the responder for the negotiated FTM session.

The Secure HE-LTF subelement is included in the IFTMR frame to indicate that the initiator supports use of secure HE-LTF and the associated parameters; it is included in the IFTM, if the initiator and the responder successfully negotiate an FTM session where secure HE-LTF is used.

The format of the Secure HE-LTF subelement is as shown in Figure 9-1048 (Secure HE-LTF subelement format(11az)).

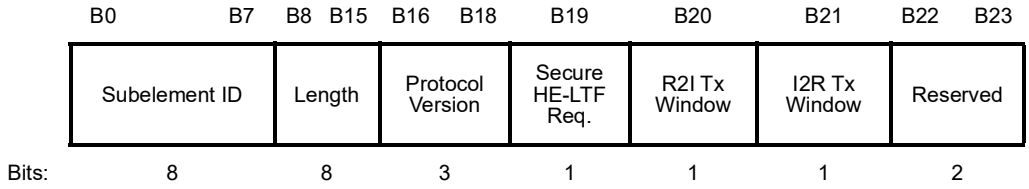


**Figure 9-1048—Secure HE-LTF subelement format(11az)**


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The Subelement ID and Length fields are defined in Figure 9.4.3 (Subelements).

The Protocol Version field in the IFTMR frame is set to the value 0 by the ISTA, with values 1 to 7 reserved for future use; see Table 9-415 (Secure HE-LTF protocol section identifier(11az)). In the IFTM frame the Version field is set to the value 0 by the RSTA, with values 1 to 7 reserved for future use. The interpretation of the version field in the IFTMR frame and IFTM frame, and the possible resulting actions, are described in 11.21.6.3.4 (Negotiation for secure HE-LTF in the TB and non-TB ranging measurement exchange).

The Secure HE-LTF Required field is set to 1 by the ISTA to indicate it requires secure HE-LTF to be enabled and is set to 1 by the RSTA to enable a secure HE-LTF measurement exchange between an ISTA and an RSTA. Otherwise the Secure HE-LTF Required field is set to 0.

The R2I Tx Window field in the IFTMR frame is set to 1 to indicate the ISTA requests use of the optional frequency domain Tx Window in the R2I NDPs, and 0 to indicate the default frequency domain Tx window. In the IFTM frame, the R2I Tx Window field is set to 1 to indicate the RSTA will use the optional frequency domain Tx window in the R2I NDPs, and 0 to indicate the default frequency domain Tx window; see Table 9-415 (Secure HE-LTF protocol section identifier(11az)).

The I2R Tx Window field in the IFTMR frame is set to 1 to indicate that the ISTA supports use of the optional frequency domain Tx window in the I2R NDPs, and 0 to indicate the default frequency domain Tx window. In the IFTM frame, the I2R Tx Window field is set to 1 by the RSTA to request that the ISTA use the optional frequency domain Tx window in the I2R NDPs, and 0 to indicate the default frequency domain Tx window; see Table 9-415 (Secure HE-LTF protocol section identifier(11az)).

**Table 9-415—Secure HE-LTF protocol section identifier(11az)**

| Protocol Version | Secure HE-LTF PHY sections |
|---|---|
| 0 | 27.3.19 (HE Ranging NDP and HE TB Ranging NDP(11az))(#7104) |
| 1–7 | Reserved |

### 9.4.2.301 Secure HE-LTF Parameters element(11az)

The Secure HE-LTF Parameters element is optionally included in the IFTM frame, as described in 9.6.7.33 (FTM(11az) frame format), and the LMR frame, as described in 9.6.7.49 (LMR frame format(11az)(#8216)) for a secure HE-LTF measurement exchange mode of the non-TB ranging and TB ranging measurement exchange (see 11.21.6.4.5 (Secure HE-LTF in the TB and non-TB ranging measurement exchange protocol(11az))). The use of the Secure HE-LTF Parameters element is described in 11.21.6 (FTM procedure(#7065)).

The format of the Secure HE-LTF Parameters element is shown in Figure 9-1049 (Secure HE-LTF Parameters element format(#8016)(11az)).

| | Element ID | Length | Element ID Extension | Secure LTF Counter | Validation SAC | Measurement SAC | Measurement Result LTF Offset |
|---|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 6 | 2 | 2 | 1 |

**Figure 9-1049—Secure HE-LTF Parameters element format(#8016)(11az)**

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The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

The (#8016)Secure LTF Counter field is used to determine the randomized LTF sequence of an I2R NDP and R2I NDP in one of the following secure HE-LTF measurement exchange sequences:

— An I2R NDP and an R2I NDP immediately following a Ranging NDP Announcement frame, in a non-TB ranging measurement exchange (11.21.6.4.4 (Non-TB ranging measurement exchange(11az))).

— A sequence of an I2R NDP, a Ranging NDP Announcement frame, an R2I NDP, in a TB ranging measurement exchange (11.21.6.4.3 (TB ranging measurement exchange(11az))).

The (#8016)Secure LTF Counter field is used in the IFTM frame and the R2I LMR frame when part of a secure HE-LTF measurement exchange; it is reserved otherwise.

The Validation SAC field is a nonzero value associated with the (#8016)secure LTF counter carried in the same Secure HE-LTF Parameters element and validates the randomized LTF sequence; see 11.21.6.3.4 (Negotiation for secure HE-LTF in the TB and non-TB ranging measurement exchange). This field is used in the initial protected FTM frame, the R2I protected LMR frame and is reserved otherwise.

The Measurement SAC field is used to verify that range measurement results contained in the LMR frame are calculated using the same LTF sequence between ISTA and RSTA. The Measurement SAC field is the same value as the SAC subfield in the STA Info field with AID equal to 2043 in the Ranging NDP Announcement frame that solicited the I2R NDP and the R2I NDP in the non-TB ranging measurement exchange or the SAC subfield in the Trigger Dependent User Info of the Secure Sounding Ranging Trigger frame in the TB ranging measurement exchange; see 11.21.6.4.5 (Secure HE-LTF in the TB and non-TB ranging measurement exchange protocol(11az)). This field is reserved in the IFTM frame.

The Measurement Results LTF Offset field is used in TB ranging to verify that the measurement results contained in the LMR frame are calculated using the same LTF Offset for the R2I NDP between RSTA and ISTA. The Measurement Result LTF Offset field has the same value as the LTF Offset subfield in the corresponding STA Info field of the Ranging NDP Announcement frame preceding the R2I NDP, which was used for estimating the measurement results contained in the LMR frame. The Measurement Result LTF Offset field is structured as shown in Figure 9-1050 (Measurement Result LTF Offset field format(11az)). This field is not used in the IFTM frame nor in the LMR frames in non-TB ranging.

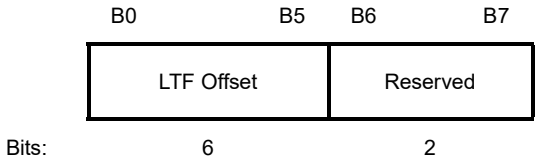


**Figure 9-1050—Measurement Result LTF Offset field format(11az)**

### 9.4.2.302 Direction Measurement Results element(11az)

The Direction Measurement Results element is used to send angle of arrival (AOA) and angle of departure (AOD) measurement results and is defined in Figure 9-1051 (Direction Measurement Results element(11az)).

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

The AOA Results field is as shown in Figure 9-1052 (AOA Results field format(11az)).


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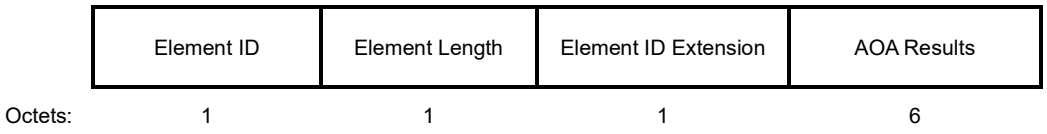


**Figure 9-1051—Direction Measurement Results element(11az)**

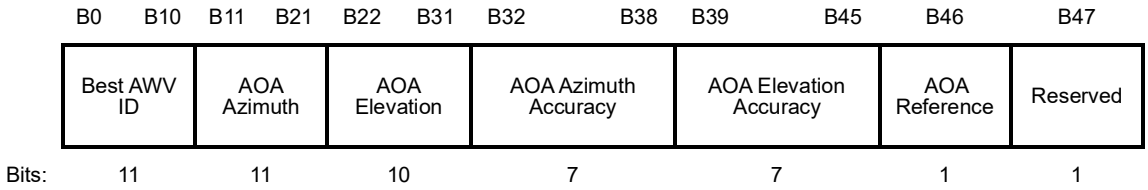


**Figure 9-1052—AOA Results field format(11az)**

The AOA Azimuth subfield contains the AOA azimuth result in 360º/2048 resolution. This subfield is an unsigned 2s complement number taking values between 0 and 2047. When the AOA Reference subfield is set to 1, the AOA Azimuth subfield is in earth coordinates (i.e., direction 0 is north). When the AOA Reference subfield is set to 0, the AOA Azimuth subfield is in coordinates relative to the orientation of the STA measuring the AOA azimuth.

The AOA Elevation subfield contains the AOA elevation result in 180º/1024 resolution. This subfield is a signed 2s complement number taking values between –512 and 511.

The AOA Azimuth Accuracy subfield contains the AOA azimuth result's estimated accuracy in 360º/2048 resolution. An accuracy larger than 125 × 360º/2048 is represented by the value of 125. A value of 126 indicates no azimuth measurement. A value of 127 indicates no ability to estimate azimuth accuracy.

The AOA Elevation Accuracy subfield contains the AOA elevation result's estimated accuracy in 360º/2048 resolution. An accuracy larger than 125 × 360º/2048 is represented by the value 125. A value of 126 indicates no elevation measurement. A value of 127 indicates no ability to estimate elevation accuracy.

When the AOA Reference subfield is set to 1, the AOA Elevation subfield is in earth coordinates (i.e., elevation 0 is the horizon). When the AOA Reference subfield is set to 0, the AOA elevation is in coordinates relative to the orientation of the STA measuring the AOA elevation.

If the STA sending the frame containing the element is a DMG STA, and the frame containing the Direction Measurement Result element follows an ISTA PPDU that enabled AOD by containing TRN-T subfields, the Best AWV ID subfield contains the index of the TRN-T subfield that was received with the highest SNR. If the ISTA PPDU that enabled AOD contained EDMG TRN-T subfields, then the AWV ID field contains the AWV ID (see 28.9.2.2.5) of the TRN subfields that were received with the highest SNR. If the STA sending the frame containing the element is a non-DMG STA, the Best AWV ID subfield is reserved.

### 9.4.2.303 Multiple Best AWV ID element(11az)

The Multiple Best AWV ID element is used to send multiple TRN subfields indices/AWV IDs from an ISTA to an RSTA and is defined in Figure 9-1053 (Multiple Best AWV ID element(11az)). The Multiple Best AWV ID element is carried in an FTM frame.

The Number Of Best AWV ID field indicates the number of attached Best AWV ID fields. Each Best AWV ID field is 16 bits long. Bits B0–B4 are reserved. It indicates the index of either the TRN subfield index or the AWV ID of the TRN subfield(s) received with highest SNR. The choice of whether TRN subfield index

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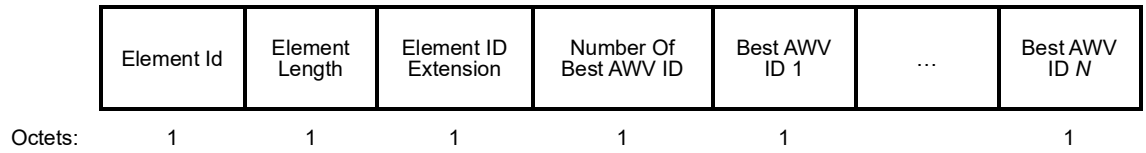


**Figure 9-1053—Multiple Best AWV ID element(11az)**

or AWV ID is used depends on whether the PPDU over which the TRN subfield(s) were selected contained a DMG TRN field or an EDMG TRN field.

### 9.4.2.304 Multiple AOD Feedback element(11az)

The Multiple AOD Feedback element is used to send multiple angle of departure (AOD) results from an RSTA to an ISTA and is defined in Figure 9-1054 (Multiple AOD Feedback element(11az)). The Multiple AOD Feedback element is carried in an FTM frame.

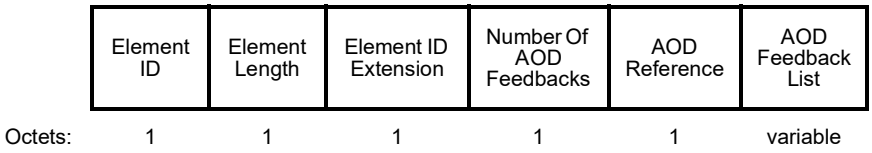


**Figure 9-1054—Multiple AOD Feedback element(11az)**

The value contained in the Number Of AOD Feedbacks field indicates the number of AOD Feedback fields present in the AOD Feedback List field, and is set to the Number Of Best AWV ID fields present in the last received Multiple Best AWV ID element from the ISTA.

When the AOD Reference field is set to 1, the AOD Elevation subfield is in earth coordinates (i.e., elevation 0 is horizon). When the AOD Reference field is set to 0, the AOD Elevation subfield is in coordinates relative to the orientation of the STA transmitting the measurement signal. When the AOD Reference field is set to 1, the AOD Azimuth subfield is in earth coordinates (i.e., direction 0 is north). When the AOD Reference field is set to 0, the AOD Azimuth subfield is in coordinates relative to the orientation of the STA transmitting the measurement signal.

The AOD Feedback List field is composed of a set of AOD Feedback fields. Each AOD Feedback field has the structure in Figure 9-1055 (AOD Feedback field format(11az)).

**Figure 9-1055—AOD Feedback field format(11az)**

The AOD Azimuth subfield contains the angle of departure (AOD) azimuth result in 360º/2048 resolution. This subfield is an unsigned 2s complement number taking values between 0 and 2047.

The AOD Azimuth Accuracy subfield contains the AOD azimuth result's estimated accuracy in 360º/2048 resolution. An accuracy larger than 125 × 360º/2048 is represented by the value of 125. A value of 126 indicates no azimuth measurement. A value of 127 indicates no ability to estimate azimuth accuracy.


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The AOD Elevation subfield contains the AOD elevation result in 180º/1024 resolution. This subfield is a signed 2s complement number taking values between –512 and 511.

The AOD Elevation Accuracy subfield contains the AOD elevation result's estimated accuracy in 360º/2048 resolution. An accuracy larger than 125 × 360º/2048 is represented by the value of 125. A value of 126 indicates no elevation measurement. A value of 127 indicates no ability to estimate elevation accuracy.

### 9.4.2.305 PASN Parameters element(11az)

The Control field, see Figure 9-1057 (PASN Parameters element Control Info field format(11az)), indicates the presence or absence of other fields in the PASN Parameters element; see Figure 9-1056 (PASN Parameters element format(11az)).

| | Element ID | Length | Element ID Extension | Control | Wrapped Data Format | Comeback Info | Finite Cyclic Group ID | Ephemeral Public Key Length | Ephemeral Public Key |
|---|---|---|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 1 | 1 | variable | 0 or 2 | 0 or 1 | variable |

**Figure 9-1056—PASN Parameters element format(11az)**

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

| | B0 | B1 | B2 B7 |
|---|---|---|---|
| | Comeback Info Present | Group and Key Present | Reserved |
| Bits: | 1 | 1 | 6 |

**Figure 9-1057—PASN Parameters element Control Info field format(11az)**

The Comeback Info Present subfield indicates if the Comeback Info field is included in the PASN Parameters element. The Group and Key Present subfield indicates if the PASN Parameters element includes the Finite Cyclic Group ID, the Ephemeral Public Key Length, and the Ephemeral Public Key fields.

The Wrapped Data Format field indicates the format of data in the Wrapped Data element included along with the PASN Parameters element. The values defined for this format are:

- 0: No wrapped data
- 1: Fast BSS Transition Wrapped Data; see 12.13.6 (PASN authentication with FT)
- 2: FILS Shared Key authentication without PFS Wrapped Data; see 12.13.4 (PASN authentication with FILS shared key)
- 3: SAE Wrapped Data; see 12.13.5 (PASN authentication with SAE)
- 4–255: Reserved

The Comeback Info field, present only when the corresponding Comeback Info Present subfield in the Control field is set to 1, is of variable length and is formatted as shown in Figure 9-1058 (Comeback Info field format(11az)).

The Comeback After subfield value is the time in TUs after which the non-AP STA is requested to retry the PASN authentication. The Comeback After subfield is set to 0 to indicate that the operation can be retried

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| | Comeback After | Cookie Length | Cookie |
|---|---|---|---|
| Octets: | 2 | 1 | variable |

**Figure 9-1058—Comeback Info field format(11az)**

with a cookie of nonzero length in the Cookie subfield. The Comeback After subfield is reserved in PASN Authentication frames from a non-AP STA.

The Cookie Length subfield (#7224)contains the length in octets of the Cookie subfield. If the Cookie Length subfield is 0, it indicates that there is no Cookie subfield.

The Cookie subfield contains a cookie, which is an opaque sequence of octets generated by an AP STA in an implementation dependent manner; see 12.13.10 (Comeback cookies).

The Finite Cyclic Group ID, Ephemeral Public Key Length, and Ephemeral Public Key fields are present if the Group and Key Present subfield in the Control field is set to 1.

The Finite Cyclic Group ID field indicates the group used in PASN authentication. It has the same semantics as the field Finite Cyclic Group field (9.4.1.40 (Finite Cyclic Group field)).

The Ephemeral Public Key Length field is set to the length in octets of the Ephemeral Public Key field.

(#8253)The Ephemeral Public Key field contains the public key encoded using IETF RFC 5480 conventions, in either compressed or uncompressed form.

### 9.4.2.306 ISTA Passive TB Ranging Measurement Report element(11az)

The ISTA Passive TB Ranging Measurement Report element, defined in Figure 9-1059 (ISTA Passive TB Ranging Measurement Report element format(11az)), is used to convey measurement results and associated parameters from an ISTA to the RSTA in a passive TB ranging exchange.

| | Element ID | Element Length | Element ID Extension | Sounding Dialog Token Number | CFO | More & N Timestamp Measurement Reports | Timestamp Measurement Reports |
|---|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 1 | 2 | 1 | variable |

**Figure 9-1059—ISTA Passive TB Ranging Measurement Report element format(11az)**

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

The value of the Sounding Dialog Token Number field is the value of the Sounding Dialog Token Number subfield in the Ranging NDP Announcement frame of the corresponding measurement sounding phase in which the reported ISTA's timestamps were measured; see 11.21.6.4.3 (TB ranging measurement exchange(11az)) and 11.21.6.4.8 (Measurement exchange in passive TB ranging mode(11az)).

The CFO field indicates the reporting ISTA's carrier frequency offset with respect to the RSTA, as a signed integer in 2s complement format in units of 0.01 ppm.

The More & N Timestamp Measurement Reports field is defined as depicted in Figure 9-1060 (More & N Timestamp Measurement Reports field format(11az)).


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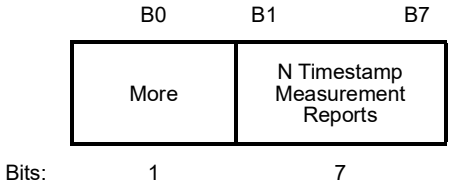


**Figure 9-1060—More & N Timestamp Measurement Reports field format(11az)**

The More subfield is used to indicate that the ISTA has more timestamps ready to report but is not able to fit them in its allocated resources as given by the RSTA.

The N Timestamp Measurement Reports subfield is an unsigned integer indicating the number of Timestamp Measurement Report subfields present in the Timestamp Measurement Reports field. The value 0 of the N Timestamp Measurement Reports field is reserved.

The Timestamp Measurement Reports field contains one or more Timestamp Measurement Report subfields defined as in Figure 9-1061 (Timestamp Measurement Report subfield format(11az)).

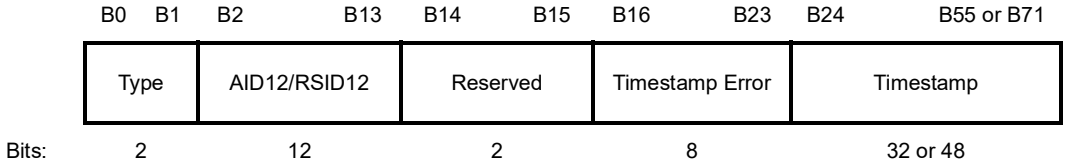


**Figure 9-1061—Timestamp Measurement Report subfield format(11az)**

The Type subfield is set according to Table 9-416 (Type subfield(11az)).

**Table 9-416—Type subfield(11az)**

| Field value | Timestamp type | Description |
|---|---|---|
| 00 | TOD | Time of departure timestamp |
| 01 | TOA | Time of arrival timestamp |
| 10 | PSTOA | Phase shift TOA |
| 11 | Reserved | Reserved |

The AID12/RSID12 subfield contains the 12 LSBs of the AID, for an associated ISTA, or the 12 LSBs of the RSID, for an unassociated ISTA, of the STA that transmitted the NDP that the timestamp is reported for. When the STA that transmitted the NDP is the RSTA the value zero is reported in the AID12/RSID12 subfield.

The Timestamp Error field is structured as shown in Figure 9-1062 (Timestamp Error subfield format(11az)).

The maximum errors in the timestamp values are represented using the function defined in Equation (9-13).

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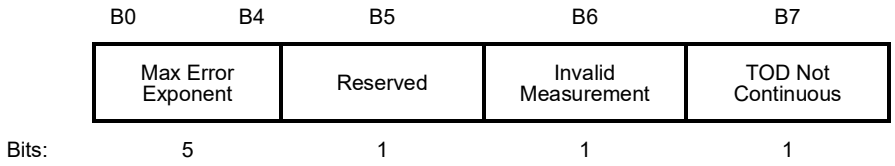


**Figure 9-1062—Timestamp Error subfield format(11az)**

$$E_{max} = \begin{cases} \text{unknown}, & F = 0 \\ 2^{F-1}, & 1 \le F \le 30 \\ \ge 2^{30}, & F = 31 \end{cases} \quad (9\text{-}13)$$

where

$F$ is the Max Error Exponent

$E_{max}$ is the maximum timestamp error, respectively, in units of picoseconds

The Max Error Exponent subfield contains the Max Error Exponent, $F$, in Equation (9-13) for the value specified in the Timestamp subfield.

The Invalid Measurement field is set to 1 to indicate that the timestamp is invalid and set to 0 to indicate that the timestamp is valid.

For a timestamp of type TOD, the TOD Not Continuous subfield indicates that the TOD value is with respect to a different underlying time base than the last transmitted TOD value. It is set to 1 when a discontinuity is present. Otherwise, it is set to 0. For other timestamp types, this field is reserved.

The Timestamp subfield contains a TOD, TOA, or a PSTOA timestamp. The TOD timestamps are represented with 48 bits in units of 1 ps. The TOA and PSTOA timestamps are represented with 32 bits in units of 16 ps.

The TOD timestamp represents the time, with respect to the ISTA's time base, at which the start of the preamble of the NDP in question appeared at the transmit antenna connector.

The TOA timestamp represents the time, with respect to the ISTA's time base, at which the start of preamble of the NDP in question arrived at the receive antenna connector.

The PSTOA timestamp represents the time, with respect to the ISTA's time base, at which the start of preamble of the NDP in question arrived at the receive antenna connector, calculated based on the average linear phase shift between two adjacent tones normalized by the tone spacing. An example of calculation of the phase shift is shown in Annex AD.

### 9.4.2.307 RSTA Passive TB Ranging Measurement Report element(11az)

The RSTA Passive TB Ranging Measurement Report element, defined in Figure 9-1062a (RSTA Passive TB Ranging Measurement Report element format), is used to broadcast measurement results and associated parameters from an RSTA to STAs that want to use this information.

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

The value of the Sounding Dialog Token Number field is the value of the Sounding Dialog Token Number subfield in the Ranging NDP Announcement frame corresponding to the measurement sounding phase in


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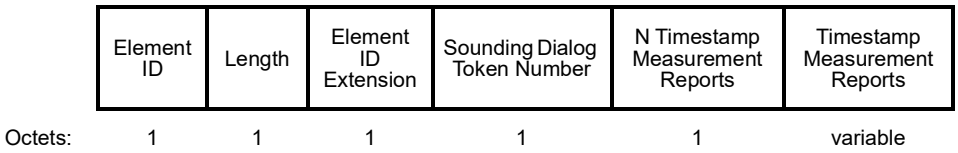


**Figure 9-1062a—RSTA Passive TB Ranging Measurement Report element format**

which the reported RSTA timestamps were measured; see 11.21.6.4.3 (TB ranging measurement exchange(11az)) and 11.21.6.4.8 (Measurement exchange in passive TB ranging mode(11az)).

The N Timestamp Measurement Reports field is an unsigned integer indicating the number of Timestamp Measurement Reports. The value 0 of the N Timestamp Measurement Reports field is reserved.

The Timestamp Measurement Reports field contains one or more Timestamp Measurement Report fields defined as in Figure 9-1061 (Timestamp Measurement Report subfield format(11az)) with definitions as detailed in 9.4.2.308 (Passive TB Ranging LCI Table element(11az)).

### 9.4.2.308 Passive TB Ranging LCI Table element(11az)

The Passive TB Ranging LCI Table Report element, defined in Figure 9-1063 (Passive TB Ranging LCI Table Report element format(11az)), is used by an RSTA to broadcast LCI data for the ISTAs participating in its passive TB ranging exchanges.

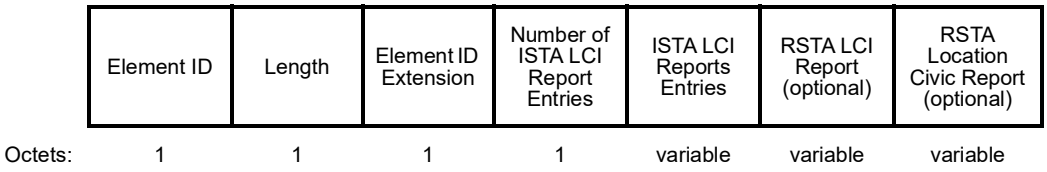


**Figure 9-1063—Passive TB Ranging LCI Table Report element format(11az)**

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

The number of ISTA LCI Reports contained in the ISTA LCI Reports field is indicated by the Number of ISTA LCI Reports ISTA LCI Report field. The format of the ISTA LCI Report field is defined in Figure 9-1064 (ISTA LCI Report Entry field format(11az)).

The RSTA LCI Report field is present if the RSTA has never transmitted it before or its content has changed, and it is periodically present otherwise. If present, it contains a Measurement Report element with Measurement Type field equal to LCI, see Table 9-163 (Measurement Type field definitions for measurement reports), which either indicates the LCI of the RSTA and can include the Z subelement, Usage Rules/Policy subelement, and Antenna Placement And Calibration subelement, or indicates an unknown LCI; see 11.21.6.7 (LCI and Location Civic retrieval using FTM procedure).

The RSTA Location Civic Report field is optionally present. If present, it contains a Measurement Report element with Measurement Type field equal to Location Civic, see Table 9-163 (Measurement Type field definitions for measurement reports), which either indicates the Civic address of the ISTA or an unknown Civic address; see 11.21.6.7 (LCI and Location Civic retrieval using FTM procedure).

The ISTA RSID/AID subfield contains the ranging ID of the ISTA reported on.

The ISTA MAC ADDRESS subfield contains the MAC address of the ISTA reported on.

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| | ISTA RSID/AID | ISTA MAC ADDRESS | ISTA LCI Report (optional) | ISTA Location Civic Report (optional) |
|---|---|---|---|---|
| Octets: | 2 | 6 | variable | variable |

**Figure 9-1064—ISTA LCI Report Entry field format(11az)**

The ISTA LCI Report subfield is present if the RSTA has never transmitted it before or its content has changed and it is periodically present otherwise. If present, it contains a Measurement Report element with Measurement Type field equal to LCI (see Table 9-163 (Measurement Type field definitions for measurement reports)), which either indicates the LCI of the ISTA and can include the Z subelement, Usage Rules/Policy subelement, and Antenna Placement And Calibration subelement, or indicates an unknown LCI; see 11.21.6.7 (LCI and Location Civic retrieval using FTM procedure).

The ISTA Location Civic Report field is optionally present. If present, it contains a Measurement Report element with Measurement Type field equal to Location Civic (see Table 9-163 (Measurement Type field definitions for measurement reports)), which either indicates the Civic address of the ISTA or an unknown Civic address; see 11.21.6.7 (LCI and Location Civic retrieval using FTM procedure).

An ISTA LCI Report Entry includes at least one of ISTA LCI Report or ISTA Location Civic Report.

NOTE—To shorten the LCI reporting, the 'Relative Compact LCI' Measurement Type can be used in the ISTA's LCI reporting. In this case the ISTA's location is reported in relation to the location reported for the RSTA in the Passive TB Ranging LCI Table Report within which the ISTA's LCI report is contained. See 9.4.2.20.10 (LCI report (Location configuration information report)).

### 9.4.2.309 LOS Likelihood element(11az)

The LOS Likelihood field contains the estimated log likelihood that measurements contained in the Direction Measurement Results element or in the TOD field of the same FTM frame, are line of sight (LOS) measurements. The method to estimate the likelihood is implementation dependent. The format of the LOS Likelihood element is shown in Figure 9-1065 (LOS Likelihood element format(11az)).

| | Element ID | Element Length | Element ID Extension | LOS Log Likelihood Ratio |
|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 1 |

**Figure 9-1065—LOS Likelihood element format(11az)**

The LOS Log Likelihood Ratio field is a signed 2s complement 8-bit number containing $40 \times \log_{10}$ of the estimated ratio between the probability that measurement is on a LOS path and the probability is on a non-LOS path. This covers the range –31.75 dB to +31.75 dB. If this field has a value equal to 255, it indicates that the LOS Log Likelihood Ratio is not available.

### 9.4.2.310 DMG OCB element(11bd)

The format of the DMG OCB element is shown in Figure 9-1066 (DMG OCB element format(11bd)).

| | Element ID | Length | Element ID Extension | DMG OCB Parameters |
|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 1 |

**Figure 9-1066—DMG OCB element format(11bd)**


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The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

The DMG OCB Parameters field is defined in Figure 9-1067 (DMG OCB Parameters field format(11bd)).

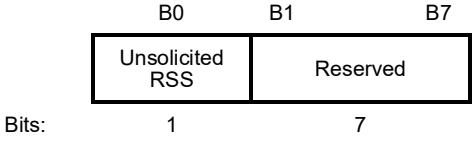


**Figure 9-1067—DMG OCB Parameters field format(11bd)**

The Unsolicited RSS subfield is defined in 9.5.5 (Beamforming Control field).

### 9.4.2.311 Non-AP STA Regulatory Connectivity element(#6076)

The format of the Non-AP STA Regulatory Connectivity element is defined in Figure 9-1068 (Non-AP STA Regulatory Connectivity element format(#6076)).

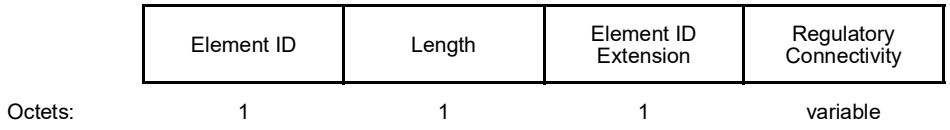


**Figure 9-1068—Non-AP STA Regulatory Connectivity element format(#6076)**

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

The Regulatory Connectivity field indicates certain regulatory capabilities of the non-AP STA transmitting the element. The Regulatory Connectivity field is defined in Table 9-417 (Regulatory Connectivity field(#6076)).

NOTE—The length of the Regulatory Connectivity field is variable and is liable to increase as additional connectivity capabilities are defined.

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**Table 9-417—Regulatory Connectivity field(#6076)**

| Subfield bit or bits | Subfield name | Interpretation |
|---|---|---|
| 0 | Connectivity With Indoor AP Valid | Indicates whether the Connectivity With Indoor AP subfield is reserved or not:<br>Set to 0 if the Connectivity With Indoor AP subfield is reserved.<br>Set to 1 if the Connectivity With Indoor AP subfield is valid. |
| 1 | Connectivity With Indoor AP | Indicates whether operating under the control of an indoor AP and an indoor standard power AP is implemented (see E.2.7 (6 GHz band(11ax)(#600))).<br><br>For a non-SP STA:<br>Set to 0 if not implemented.<br>Set to 1 if implemented.<br><br>Reserved for a non-AP STA that is incapable of operating as a STA 6G in the current regulatory domain and for an AP.<br><br>Reserved if the Connectivity With Indoor AP Valid subfield is set to 0.<br><br>See NOTE. |
| 2 | Connectivity With SP AP Valid | Indicates whether the Connectivity With SP AP subfield is reserved or not:<br>Set to 0 if the Connectivity With SP AP subfield is reserved.<br>Set to 1 if the Connectivity With SP AP subfield is valid. |
| 3 | Connectivity With SP AP | Indicates whether at least one of the following is implemented: operating under the control of an SP AP and an indoor standard power AP and operating as a fixed client device (see E.2.7 (6 GHz band(11ax)(#600))).<br><br>For a non-AP STA:<br>Set to 0 if not implemented.<br>Set to 1 if implemented.<br><br>Reserved for a non-AP STA that is incapable of operating as a STA 6G in the current regulatory domain and for an AP.<br><br>Reserved if the Connectivity With SP AP Valid subfield is set to 0.<br><br>See NOTE. |
| 4 to<br>8 × (Length – 1) – 1 | Pad | Reserved |
| NOTE—This field is informative (e.g., for troubleshooting), has no regulatory purpose, and does not imply a need for any action by a peer STA. | | |


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### 9.4.2.312 Diffie-Hellman Parameter element(#6088)

The Diffie-Hellman Parameter element contains a Diffe-Hellman public value and an indicator of the finite cyclic group from which it was obtained. See Figure 9-1069 (Diffie-Hellman Parameter element format(#6088)).

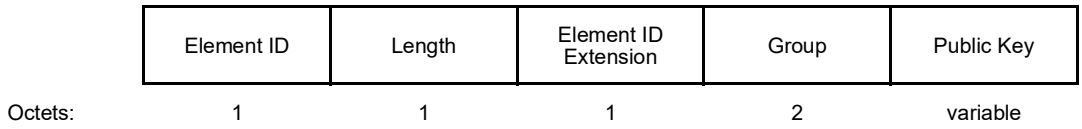


**Figure 9-1069—Diffie-Hellman Parameter element format(#6088)**

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

The Group field is a 16-bit unsigned integer that maps an identifying number from the "Group Description" registry maintained by IANA for IETF RFC 2409 (IKE) to a complete domain parameter set.

The Public Key field is a Diffie-Hellman public key, an element in the group described by the domain parameter set indicated by the value in the Group field.

### 9.4.2.313 EBCS Parameters element(11bc)

An EBCS AP advertises its EBCS operational parameters in the EBCS Parameters element.

The format of the EBCS Parameters element is shown in Figure 9-1070 (EBCS Parameters element format(11bc)).

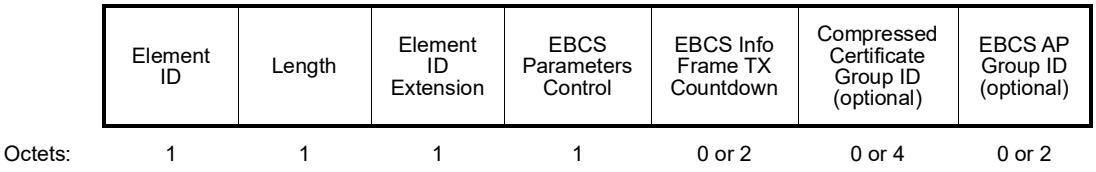


**Figure 9-1070—EBCS Parameters element format(11bc)**

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

The format of the EBCS Parameters Control field is shown in Figure 9-1071 (EBCS Parameters Control field format(11bc)).

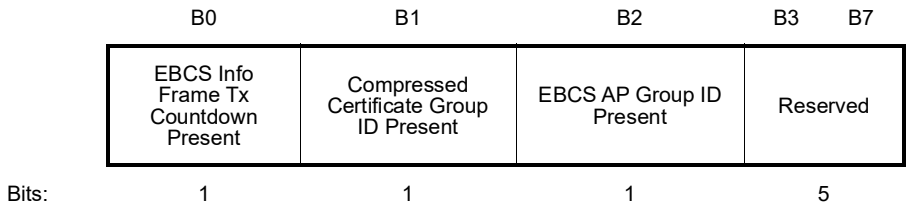


**Figure 9-1071—EBCS Parameters Control field format(11bc)**

The EBCS Info Frame Tx Countdown Present subfield is set to 1 if the EBCS Info Frame Tx Countdown subfield is present and is set to 0 otherwise.

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The Compressed Certificate Group ID Present subfield is set to 1 if the Compressed Certificate Group ID field is present and is set to 0 otherwise.

The EBCS AP Group ID Present subfield is set to 1 if the EBCS AP Group ID field is present and is set to 0 otherwise.

The EBCS Info Frame Tx Countdown field is defined in 9.4.1.70 (EBCS Info Frame Tx Countdown field(11bc)).

The Compressed Certificate Group ID field indicates a 32-bit CRC calculated over the certificate of the AP.

The EBCS AP Group ID field contains the EBCS AP Group ID of the AP.

### 9.4.2.314 EBCS TIM element(11bc)

The EBCS TIM element is used to signal the availability of EBCS traffic stream frames. The format of this element is shown in Figure 9-1072 (EBCS TIM element format(11bc)).

| | Element ID | Length | Element ID Extension | Content ID Bitmap Control | Content ID Bitmap |
|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 1 | 1-32 |

**Figure 9-1072—EBCS TIM element format(11bc)**

The Element ID, Length and Element ID Extension fields are defined in 9.4.2.1 (General).

The format of the Content ID Bitmap Control field is shown in Figure 9-1073 (Content ID Bitmap Control field format(11bc)).

| | B0 | B1 | B5 | B6 | B7 |
|---|---|---|---|---|---|
| | Bitmap Mode | Bitmap Offset | | Reserved | |
| Bits | 1 | 5 | | 2 | |

**Figure 9-1073—Content ID Bitmap Control field format(11bc)**

The EBCS traffic indication virtual bitmap, maintained by the EBCS AP that generates an EBCS TIM, consists of 256 bits and is organized into 32 octets such that bit number $N$ ($0 \le N \le 255$) in the bitmap corresponds to bit number $N$ mod 8 in octet number, $\lfloor N/8 \rfloor$, where the low order bit of each octet is bit number 0, and the high order bit is bit number 7. A bit value 1 means the corresponding EBCS traffic stream is buffered at the AP.

The format of the Content ID Bitmap field is identified by the Bitmap Mode subfield.

If the Bitmap Mode subfield is 0, the Content ID Bitmap field consists of octets numbered $N_1$ to $N_2$ of the EBCS traffic indication virtual bitmap, where $N_1$ is the largest integer such that each of the bits 0 to $((N_1 \times 8) - 1)$ is equal to 0. If such a value does not exist, $N_1 = 0$. Additionally, $N_2$ is the smallest integer such that each of the bits $(N_2 + 1) \times 8$ to 255 is equal to 0. If such a value does not exist, that is, when not all bits in the last octet of the EBCS traffic indication virtual bitmap are equal to 0, $N_2 = 31$. The Bitmap Offset subfield contains $N_1$, and the Length field is set to $(N_2 - N_1) + 4$.



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If the Bitmap Mode subfield is 1, the Bitmap Offset subfield is set to 0 and the Content ID Bitmap field contains a set of octets indicating the content IDs of EBCS traffic streams buffered at the AP.

### 9.4.2.315 Tunneled PASN element(#7096)

The Tunneled PASN element is present in tunneled PASN frames (12.13.7 (Tunneled PASN(#7096))). The format of the Tunneled PASN element is shown in Figure 9-1074 (Tunneled PASN element format(#7096)).

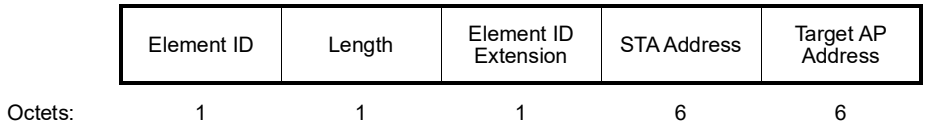


**Figure 9-1074—Tunneled PASN element format(#7096)**

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

The STA address is the address that the STA intends to use with the target AP. The Target AP Address field is the BSSID of the BSS of the AP with which the STA performs tunneled PASN.

### 9.4.3 Subelements

(#3428)Subelements have a common general format shown in Figure 9-1075 (Subelement format). Each subelement is assigned a subelement ID that is unique within the containing element or subelement. The Length field specifies the number of octets in the Data field.

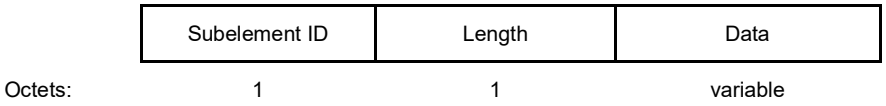


**Figure 9-1075—Subelement format**

At the location in this standard that a subelement is defined, the definition might indicate if the subelement is extensible, typically using a table column called Extensible in the table in which subelement IDs are defined. A subelement that is indicated as extensible (typically with Yes in the Extensible column) might be extended in future revisions or amendments of this standard. A subelement that is indicated as extensible through subelements (typically with Subelements in the Extensible column) might be extended in future revisions or amendments of this standard by defining (additional) subelements within the subelement.

If the definition of a subelement does not indicate whether it is extensible (e.g., there is no Extensible column in a table defining it) that subelement is not extensible.

A subelement that is not defined as extensible will not be extended in future revisions or amendments of this standard.

(#524)Subelements within an element and subelements in a field outside of an element are in each case ordered by nondecreasing Subelement ID. See 10.28.9 (Extensible subelement parsing).

Unless stated otherwise, no more than one subelement with the same Subelement ID, apart from Vendor Specific subelements, is present within an element.

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### 9.4.4 TLV encodings

#### 9.4.4.1 General

The following TLV encodings are used to convey parameters within (#8152)Management frames (9.3.3 ((PV0) Management frames), 9.4 (Management and Extension frame body components), and 9.5.7 (EDMG BRP field(11ay))). TLV tuples with type values that are unknown, not specified in this subclause, or specified as "reserved" are discarded upon receipt. The form of TLVs is shown in Table 9-418 (General TLV format).

**Table 9-418—General TLV format**

| Name | Type | Length (octets) | Value | Scope/ Country code |
|---|---|---|---|---|
| The name of the TLV | 1 | variable | Single Octet, Single Value, or Compound TLV tuples. | |

NOTE—This standard is complete regarding the endianness of multi-octet fields as they are covered by 9.2.2 (Conventions). Be aware that most protocols above the MAC operate in the opposite endianness.

The Name field is the name of the TLV tuple.

The '*m.n*' syntax in the Type field means that the TLV has type *n*, an unsigned 1-octet integer, and is embedded in the Value field of a TLV of type *m*. The length of the Type field is 1 octet.

The format of the Length field is an unsigned number of size 1 octet, and the value in the Length field specifies the number of octets in the Value field.

A single octet TLV has a Value field that is 1 octet, a single value TLV has a Value field larger than 1 octet(#3431), and a compound TLV has a Value field that represents more than 1-octet fields.

When a Scope field entry contains two characters, it identifies the country or other entity to which the STA's operation is bound. If the two-character value stands for a country or other entity, then the value matches a code defined in ISO 3166-1. When a Scope field entry contains more than two characters, it identifies a scope for the TLV tuple.

#### 9.4.4.2 Common TLVs

##### 9.4.4.2.1 General

The general form of common TLVs is shown in Table 9-418 (General TLV format) and is used in 9.4.4.2.2 (Device Class) to 9.4.4.2.6 (WSM information values).

##### 9.4.4.2.2 Device Class

This parameter contains the intended class of device for operation in TVWS band after it receives the available channel list at its location. The Device Class field format is shown in Table 9-419 (Device Class field definition).


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**Table 9-419—Device Class field definition**

| Name | Type | Length (octets) | Value | Scope/ Country code |
|---|---|---|---|---|
| Device Class | 2 | 1 | The Device Class field contains an integer that indicates the device's TVWS band mode of operation as follows:<br>0: GDD non-AP STA<br>1: GDD geolocated non-AP STA<br>2: GDD AP<br>3: GDD fixed STA<br>4–255: Reserved | CAQ, GDDENABLEMENT, WSM |

#### 9.4.4.2.3 Device Identification Information

This parameter contains the identification information of the device initiating the channel availability query. The Device Identification Information field format is shown in Table 9-420 (Device Identification Information field definition) and related Device Identification Information Value fields tables in E.2 (Band-specific operating requirements) for specific regulatory domains.

**Table 9-420—Device Identification Information field definition**

| Name | Type | Length (octets) | Value | Scope/ Country code |
|---|---|---|---|---|
| Device Identification Information | 3 | variable | One or more TLV fields as defined in Table E-9 (Device Identification Information Value fields) for a specific regulatory domain. | CAQ, GDDENABLEMENT, CSM |

#### 9.4.4.2.4 Device Location Information

This parameter contains the location information of the device initiating the channel availability query. The Device Location Information field format is shown in Table 9-421 (Device Location Information field definition).

**Table 9-421—Device Location Information field definition**

| Name | Type | Length (octets) | Value | Scope/ Country code |
|---|---|---|---|---|
| Device Location Information | 10 | 16 | The Device Location Information field contains the latitude, longitude, and altitude information of the device in the format specified by the Device Location Information Body fields in Figure 9-191 (Device Location Information Body field format). When the Device Type subfield (see Table 9-419 (Device Class field definition)) is not GDD fixed STA, the altitude information (Altitude Type, Altitude Uncertainty, and Altitude subfields) of the Device Location Information field remain unused. | CAQ |

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#### 9.4.4.2.5 Channel Schedule Descriptor

This parameter contains the channel number associated with channel schedule information used for channel schedule management. The Channel Schedule Descriptor Tuple attribute format is shown in Table 9-422 (Channel Schedule Descriptor Tuple attribute definition) and Table 9-423 (Channel Schedule Descriptor Value fields). Channel Schedule Descriptor field is constructed with either Channel Availability Starting Time field or Channel Availability Starting Timestamp field present or neither of these two fields present.

**Table 9-422—Channel Schedule Descriptor Tuple attribute definition**

| Name | Type | Length (octets) | Value | Scope/ Country code |
|---|---|---|---|---|
| Channel Schedule Descriptor | 11 | variable | Compound TLVs in Table 9-423 (Channel Schedule Descriptor Value fields). | CSM |

**Table 9-423—Channel Schedule Descriptor Value fields**

| Name | Subtype | Length (octets) | Value | Scope/ Country code |
|---|---|---|---|---|
| Operating Class | 1 | 1 | The Operating Class field is the number of the operating class of the channel, which is defined in E.1 (Country information and operating classes). | CSM |
| Channel Number | 2 | 1 | The Channel Number field is the number of the channel, which is the subject of the value of Channel Schedule Management Mode field. If the Channel Schedule Management Mode field indicates the schedule information is based on WLAN channels, the Channel Number is a channel from the operating class of the STA(#3181) as defined in E.1 (Country information and operating classes); otherwise, the Operating Class compound TLV is not present, and the Channel Number is a positive integer value as defined in D.1 (External regulatory references) to indicate the available TV channel for WLAN operation. | CSM |
| Channel Availability Starting Time | 3 | 8 | The Channel Availability Starting Time field indicates the starting time in Coordinated Universal Time (UTC) from when the channel indicated in the Channel Number field is available for operation. When neither this field nor a Channel Availability Starting Timestamp is present, the STA takes the time that the response element is received as the starting time of the channel availability.<br>NOTE—The Channel Availability Starting Time field follows the UTC time definition of the Time Value field of the Time Advertisement element in 9.4.2.59 (Time Advertisement element), and the first 6 octets are used to indicate the UTC time until minutes. The left 2 octets are reserved. | CSM |


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**Table 9-423—Channel Schedule Descriptor Value fields *(continued)***

| Name | Subtype | Length (octets) | Value | Scope/ Country code |
|---|---|---|---|---|
| Channel Availability Starting Timestamp | 4 | 8 | The Channel Availability Starting Timestamp field indicates the starting timestamp from when the channel indicated in the Channel Number field is available for operation. When neither this field nor a Channel Availability Starting Time field is present, the STA takes the time that the response element is received as the starting time of the channel availability. | CSM |
| Channel Availability Offset Time | 5 | 2 | The Channel Availability Offset Time field indicates the offset of channel availability time with respect to the time that the Channel Schedule Descriptor is received. This field is present when the Channel Availability Starting Time field is not present in the response TLV and the channel is not available at the moment the TLV is received. | CSM |
| Channel Availability Duration | 6 | 2 | The Channel Availability Duration field indicates the duration in minutes of the availability of the channel that indicated in the Channel Number field. | CSM |

#### 9.4.4.2.6 WSM information values

The format of the WSM information values is shown in Table 9-424 (WSM information values). If the WSM Type field of the White Space Map element (9.4.1.55 (WSM Type field and WSM Information field)) is set to 1, the WSM Information field specifies available channel information for TVWS, which is country-specific.

**Table 9-424—WSM information values**

| Name | Type | Length (octets) | Value | Scope/ Country code |
|---|---|---|---|---|
| WSM Information | 12 | variable | Single value TLV comprising fields in related table in E.2 (Band-specific operating requirements) for a specific regulatory domain. | WSM |

The format of the WSM Information Value fields is shown in Table 9-425 (WSM Information Value fields).

The Device Class field is defined in 9.4.4.2.2 (Device Class) and identifies the device class used by the WSM. It determines the length of the channel availability tuple consisting of the Channel Number, Maximum Power Level, and Validity fields, which is repeated as indicated by the Length field of the WSM element. If the Device Class field is 0, the Validity field in WSM Information Value field is not present. Otherwise, the Validity field exists in the WSM Information Value field.

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**Table 9-425—WSM Information Value fields**

| Name | Length (octets) | Value | Scope/ Country code |
|---|---|---|---|
| Device Class | 1 | Single octet TLV comprising fields in Table 9-419 (Device Class field definition). | WSM |
| Map ID | 1 | Bit 0: Type bit indicates whether the following channel list is a full channel list or a partial channel list. If the Type bit is 1, the following channel list is a full channel list; and if the Type bit is 0, the following channel list is a partial channel list.<br>Bits 1–7: Map version identifies the version of the WSM. | WSM |
| Channel Number | 1 | Channel Number field in related WSM Information Value fields table in E.2 (Band-specific operating requirements). | WSM |
| Maximum Power Level | 1 | Maximum Power Level field in related WSM Information Value fields table in E.2 (Band-specific operating requirements). | WSM |
| Validity | 1 | The Validity field indicates the duration in minutes for which the Channel Number is available with the allowed maximum power level, where the Validity field is provided for each available Channel Number. | WSM, UK |
| Maximum Channel Bandwidth | 2 | Limits on the maximum contiguous and maximum noncontiguous instantaneous bandwidths of STA specified as $n \times 0.1$ MHz, where $n > 0$. | WSM, UK |


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### 9.4.5 Access network query protocol (ANQP)-elements(M118)

#### 9.4.5.1 General

(#3428)ANQP-elements have a common format shown in Figure 9-1076 (ANQP-element format). Each element is assigned a unique Info ID as defined in this standard. See R.2 (Network discovery and selection) for the ANQP usage.

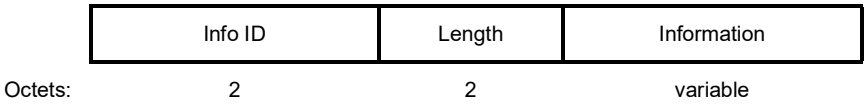


**Figure 9-1076—ANQP-element format**

Each ANQP-element in 9.4.5 (Access network query protocol (ANQP)-elements(M118)) is assigned a unique 2-octet Info ID. The set of valid Info IDs are defined in Table 9-426 (ANQP-element definitions).

**Table 9-426—ANQP-element definitions**

| ANQP-element name | Info ID(#6161) | ANQP-element (subclause) |
|---|---|---|
| Reserved | 0–255 | — |
| Query List | 256 | 9.4.5.2 (Query List ANQP-element) |
| Capability List | 257 | 9.4.5.3 (Capability List ANQP-element) |
| Venue Name | 258 | 9.4.5.4 (Venue Name ANQP-element) |
| Emergency Call Number | 259 | 9.4.5.5 (Emergency Call Number ANQP-element) |
| Network Authentication Type | 260 | 9.4.5.6 (Network Authentication Type ANQP-element) |
| Roaming Consortium | 261 | 9.4.5.7 (Roaming Consortium ANQP-element) |
| IP Address Type Availability | 262 | 9.4.5.9 (IP Address Type Availability ANQP-element) |
| NAI Realm | 263 | 9.4.5.10 (NAI Realm ANQP-element) |
| 3GPP Cellular Network | 264 | 9.4.5.11 (3GPP Cellular Network ANQP-element) |
| AP Geospatial Location | 265 | 9.4.5.12 (AP Geospatial Location ANQP-element) |
| AP Civic Location | 266 | 9.4.5.13 (AP Civic Location ANQP-element) |
| AP Location Public Identifier URI/ FQDN | 267 | 9.4.5.14 (AP Location Public Identifier URI/FQDN ANQP-element) |
| Domain Name | 268 | 9.4.5.15 (Domain Name ANQP-element) |
| Emergency Alert Identifier URI | 269 | 9.4.5.16 (Emergency Alert URI ANQP-element) |

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**Table 9-426—ANQP-element definitions *(continued)***

| ANQP-element name | Info ID(#6161) | ANQP-element (subclause) |
|---|---|---|
| TDLS Capability | 270 | 9.4.5.18 (TDLS Capability ANQP-element) |
| Emergency NAI | 271 | 9.4.5.17 (Emergency NAI ANQP-element) |
| Neighbor Report | 272 | 9.4.5.19 (Neighbor Report ANQP-element) |
| Query AP List | 273 | 9.4.5.24 (Query AP List ANQP-element) |
| AP List Response | 274 | 9.4.5.25 (AP List Response ANQP-element) |
| Reserved | 275 | — |
| CAG | 276 | 9.4.5.26 (CAG ANQP-element) |
| Venue URL | 277 | 9.4.5.20 (Venue URL ANQP-element) |
| Advice of Charge | 278 | 9.4.5.21 (Advice of Charge ANQP-element) |
| Local Content | 279 | 9.4.5.22 (Local Content ANQP-element) |
| Network Authentication Type with Timestamp | 280 | 9.4.5.23 (Network Authentication Type with Timestamp ANQP-element) |
| Service Information Request | 281 | 9.4.5.27 (Service Information Request ANQP-element) |
| Service Information Response | 282 | 9.4.5.28 (Service Information Response ANQP-element) |
| Local MAC Address Policy | 283 | 9.4.5.29 (Local MAC Address Policy ANQP-element) |
| EBCS Content Request(11bc) | 284 | 9.4.5.31 (EBCS Content Request ANQP-element(11bc)) |
| EBCS Content Response(11bc) | 285 | 9.4.5.32 (EBCS Content Response ANQP-element(11bc)) |
| EBCS(11bc) | 286 | 9.4.5.30 (EBCS ANQP-element(11bc)) |
| Credential Types(#93) | 287(Ed-MDR) | 9.4.5.33 (Credential Types ANQP-element(#93)) |
| Service Level Agreement(#93) | 288(Ed-MDR) | 9.4.5.34 (Service Level Agreement ANQP-element(#93)(#1090)) |
| Excluded NAI Realm(#93) | 289(Ed-MDR) | 9.4.5.35 (Excluded NAI Realm ANQP-Element(#93)) |
| Reserved | 290 –56 796 | — |
| Vendor Specific | 56 797 | 9.4.5.8 (Vendor Specific ANQP-element) |
| Reserved | 56 798–65 535 | — |

The Length field specifies the number of octets in the Information field.



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(#4066)The ANQP-elements with type S in Table 11-20 (ANQP usage) can be configured. If information is not configured for a particular ANQP-element with type S, then that ANQP-element is not included in the response.

NOTE—Some STAs might return a queried ANQP-element for which information is not configured with all optional fields not present.(#4066)

### 9.4.5.2 Query List ANQP-element

The Query List ANQP-element provides a list of identifiers of ANQP-elements for which the requesting STA is querying; see 11.22.3.3.2 (Query list procedure).

The format of the Query List ANQP-element is shown in Figure 9-1077 (Query List ANQP-element format(#1363)).

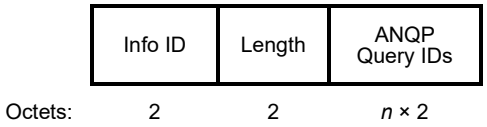


**Figure 9-1077—Query List ANQP-element format(#1363)**

The Info ID and Length fields are defined in 9.4.5.1 (General).

The ANQP Query IDs field contains one or more 2-octet ANQP Query ID subfields.

Each ANQP Query ID subfield value is an Info ID drawn from Table 9-426 (ANQP-element definitions). Including an Info ID in the Query List ANQP-element declares that the STA performing the ANQP request is requesting the ANQP-element corresponding to that Info ID be returned in the ANQP response. The Info IDs included in the Query List ANQP-element are ordered by monotonically increasing Info ID value. The ANQP response is defined in 11.22.3.3.1 (General).

### 9.4.5.3 Capability List ANQP-element

The Capability List ANQP-element provides a list of information/capabilities that has been configured on a STA. The Capability List ANQP-element is returned in response to a Query List ANQP-element containing the Info ID of the Capability List ANQP-element.

The format of the Capability List ANQP-element is shown in Figure 9-1078 (Capability List ANQP-element format).

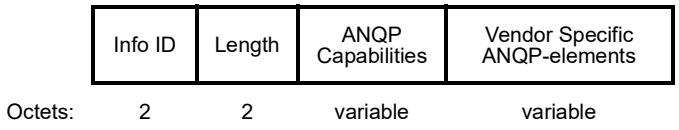


**Figure 9-1078—Capability List ANQP-element format**

The Info ID and Length fields are defined in 9.4.5.1 (General).

The ANQP Capabilities field contains one or more 2-octet ANQP Capability subfields.

Each ANQP Capability subfield value is an Info ID drawn from Table 9-426 (ANQP-element definitions). If included in the Capability List ANQP-element, it declares that a Query List ANQP-element including that

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Info ID will return the requested ANQP-element. The Info ID for Capability List ANQP-element is always included in the Capability List ANQP-element returned in a GAS query response(#7054). The list does not include any duplicate Info IDs, except possibly the Info ID for each Vendor Specific ANQP-element. The Info IDs returned in the Capability List ANQP-element are ordered by nondecreasing Info ID value.

The Vendor Specific ANQP-elements field contains one or more variable length Vendor Specific ANQP-elements.

The Vendor Specific ANQP-element is defined in 9.4.5.8 (Vendor Specific ANQP-element). The Vendor Specific ANQP-element is structured such that the first 2 octets of the Vendor Specific ANQP-element is the Info ID whose value corresponds to the Vendor Specific ANQP-element (see Table 9-426 (ANQP-element definitions)). When a Vendor Specific ANQP-element is present in the Capability List ANQP-element, the Vendor Specific ANQP-element contains the capabilities of that vendor-specific query protocol.

### 9.4.5.4 Venue Name ANQP-element

The Venue Name ANQP-element provides zero or more venue names associated with the BSS. The format of the Venue Name ANQP-element is shown in Figure 9-1079 (Venue Name ANQP-element format). The Venue Name ANQP-element might be used to provide additional metadata on the BSS. For example, the information might be used to assist a user in selecting the appropriate BSS of which to become a member.

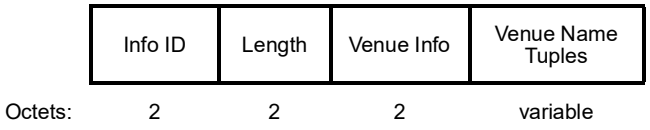


**Figure 9-1079—Venue Name ANQP-element format**

The Info ID and Length fields are defined in 9.4.5.1 (General).

The Venue Info field is defined in 9.4.1.32 (Venue Info field).

The Venue Name Tuples field contains zero or more variable length Venue Name Tuple subfields.

The format of the Venue Name Tuple subfield is shown in Figure 9-1080 (Venue Name Tuple subfield).

— The Length field is equal to 3 plus the number of octets in the Venue Name field.
— The Language Code field contains an ASCII-encoded language code selected from ISO 639, and defines the language used in the Venue Name field. A two character language code has 0 (ASCII NUL) appended.
— The Venue Name field is a UTF-8 string containing the venue's name. The maximum length of this field is 252 octets.

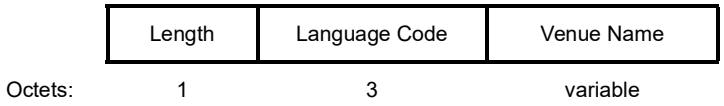


**Figure 9-1080—Venue Name Tuple subfield**

A URL associated with the Venue Name field can be specified by the Venue URL ANQP-element defined in 9.4.5.20 (Venue URL ANQP-element).


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### 9.4.5.5 Emergency Call Number ANQP-element

The Emergency Call Number ANQP-element provides a list of emergency phone numbers to an emergency responder, such as directed by a public safety answering point (PSAP), that is used in the geographic location of the STA. The format of the Emergency Call Number ANQP-element is shown in Figure 9-1081 (Emergency Call Number ANQP-element format).

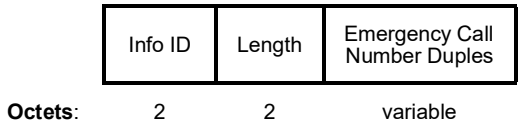


**Figure 9-1081—Emergency Call Number ANQP-element format**

The Info ID and Length fields are defined in 9.4.5.1 (General).

The Emergency Call Number Duples field contains zero or more variable length Emergency Call Number Duple subfields.

Each Emergency Call Number Duple subfield has the structure shown in Figure 9-1082 (Emergency Call Number Duple subfield format).

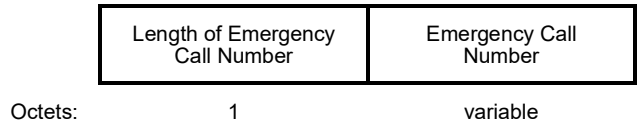


**Figure 9-1082—Emergency Call Number Duple subfield format**

The Length of Emergency Call Number field (#7224)contains the length in octets of the Emergency Call Number field.

The Emergency Call Number field is a UTF-8 string containing information, used to reach emergency services, from the network [e.g., dialed digits, emergency service URN label (IETF RFC 5031 [B46])]. When this field is transmitted by an AP, with the intention of the field being received by a STA in a 3GPP capable device, the recommended format and content of this field is defined in Annex I of 3GPP TS 24.302.

### 9.4.5.6 Network Authentication Type ANQP-element

The Network Authentication Type ANQP-element provides a list of authentication types when ASRA is set to 1. The format of the Network Authentication Type ANQP-element is shown in Figure 9-1083 (Network Authentication Type ANQP-element format).

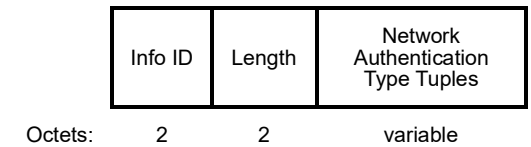


**Figure 9-1083—Network Authentication Type ANQP-element format**

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The Info ID and Length fields are defined in 9.4.5.1 (General).

The Network Authentication Type Tuples field contains zero or more variable length Network Authentication Type Tuple subfields.

Each Network Authentication Type Tuple subfield has the structure shown in Figure 9-1084 (Network Authentication Type Tuple subfield format).

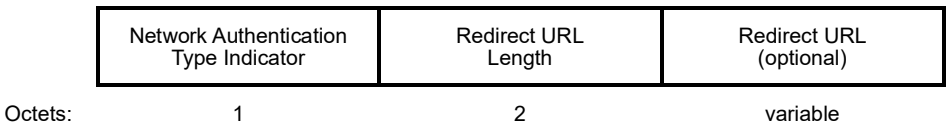


**Figure 9-1084—Network Authentication Type Tuple subfield format**

The Network Authentication Type Indicator field is set to one of the values shown in Table 9-427 (Network Authentication Type Indicator definitions).

**Table 9-427—Network Authentication Type Indicator definitions**

| Value | Meaning |
|---|---|
| 0 | Acceptance of terms and conditions |
| 1 | On-line enrollment supported |
| 2 | http/https redirection |
| 3 | DNS redirection |
| 4–255 | Reserved |

Each Network Authentication Type Indicator field defines additional information that can be communicated.

(#8097)The Redirect URL Length field contains the length (#7224)in octets of the Redirect URL field. The Redirect URL Length field is set to 0 whenever the Redirect URL field(#8098) is not present.

(#8097)(#8099)The Redirect URL field is a variable length field that is optionally included if the Network Authentication Type Indicator field is either 0 or 2; otherwise, it is not included. The URL is formatted in accordance with IETF RFC 3986.

If the Network Authentication Type Indicator field is 0, the network requires the user to accept terms and conditions. The (#7224)Redirect URL field can be used by the non-AP STA to obtain the terms and conditions.(#8098)

If the Network Authentication Type Indicator field is 1, the network supports on-line enrollment. Higher layer protocols on the non-AP STA might indicate to the user that accounts might be created. When the Network Authentication Type Indicator is 1, (#8097)the (#7224)Redirect URL field is not present.

If the Network Authentication Type Indicator field is 2, the network infrastructure performs http/https redirect. The (#7224)Redirect URL field is used by the non-AP STA to perform additional steps required for network access.


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If the Network Authentication Type Indicator field is 3, the network supports DNS redirection. Higher layer software on the non-AP STA exchanges credentials with the network, (#8097)the (#7224)Redirect URL field is not present.

### 9.4.5.7 Roaming Consortium ANQP-element

The Roaming Consortium ANQP-element provides a list of information about the Roaming Consortium and/or SSPs whose networks are accessible via this AP. This list can be returned in response to a GAS query request(#7052) using procedures in 11.22.3.3.3 (Roaming Consortium procedure). The format of the Roaming Consortium ANQP-element is shown in Figure 9-1085 (Roaming Consortium ANQP-element format).

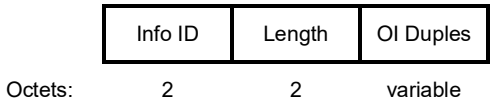


**Figure 9-1085—Roaming Consortium ANQP-element format**

The Info ID and Length fields are defined in 9.4.5.1 (General).

OIs contained within the Roaming Consortium element (see 9.4.2.94 (Roaming Consortium element)) are also included in this ANQP-element. The value of the OI subfield(s) in this ANQP-element are equal to the values of the OI(s) in the dot11RoamingConsortiumTable.

The OI Duples field contains zero or more variable length OI Duple subfields.

The format of the OI Duple subfield is shown in Figure 9-1086 (OI Duple subfield format).

— The OI Length field is set to the number of octets in the OI field.

— The OI field is defined in 9.4.1.29 (Organization Identifier field). Each OI identifies a roaming consortium (group of SSPs with inter-SSP roaming agreement) or a single SSP.

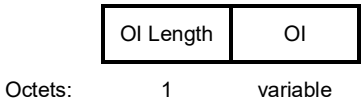


**Figure 9-1086—OI Duple subfield format**

### 9.4.5.8 Vendor Specific ANQP-element

The Vendor Specific ANQP-element is used to query for information not defined in this standard within a single defined format, so that reserved Info IDs are not usurped for nonstandard purposes and interoperability is more easily achieved in the presence of nonstandard information. The ANQP-element is in the format shown in Figure 9-1087 (Vendor Specific ANQP-element format).

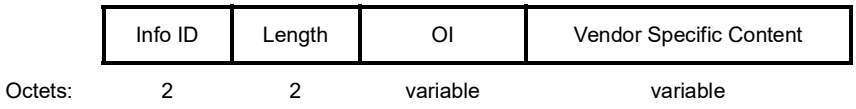


**Figure 9-1087—Vendor Specific ANQP-element format**

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The Info ID and Length fields are defined in 9.4.5.1 (General).

The OI field is defined in 9.4.1.29 (Organization Identifier field).

The Vendor Specific Content field is a variable length field whose content is defined by the entity identified in the OI field.

### 9.4.5.9 IP Address Type Availability ANQP-element

The IP Address Type Availability ANQP-element provides STA with the information about the availability of IP address version and type that could be allocated to the STA after successful association. The format of the IP Address Type Availability ANQP-element is shown in Figure 9-1088 (IP Address Type Availability ANQP-element).

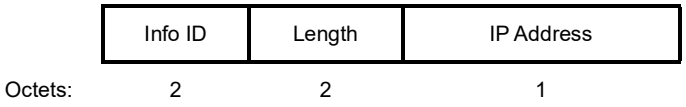


**Figure 9-1088—IP Address Type Availability ANQP-element**

The Info ID and Length fields are defined in 9.4.5.1 (General).

The format of the IP Address field shown in Figure 9-1089 (IP Address field format).

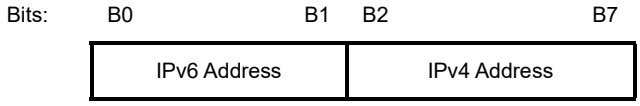


**Figure 9-1089—IP Address field format**

The IPv6 Address field values are shown in Table 9-428 (IPv6 Address field values).

**Table 9-428—IPv6 Address field values**

| Address value | Meaning |
|---|---|
| 0 | Address type not available |
| 1 | Address type available |
| 2 | Availability of the address type not known |
| 3 | Reserved |


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The IPv4 Address field values are shown in Table 9-429 (IPv4 Address field values).

**Table 9-429—IPv4 Address field values**

| Address value | Meaning |
|---|---|
| 0 | Address type not available |
| 1 | Public IPv4 address available |
| 2 | Port-restricted IPv4 address available |
| 3 | Single NATed private IPv4 address available |
| 4 | Double NATed private IPv4 address available |
| 5 | Port-restricted IPv4 address and single NATed IPv4 address available |
| 6 | Port-restricted IPv4 address and double NATed IPv4 address available |
| 7 | Availability of the address type is not known |
| 8–63 | Reserved |

### 9.4.5.10 NAI Realm ANQP-element

The NAI Realm ANQP-element provides a list of network access identifier (NAI) realms corresponding to SSPs or other entities whose networks or services are accessible via this AP; optionally included for each NAI realm is a list of one or more EAP Method subfields, which that NAI realm uses for authentication. The format of the NAI Realm ANQP-element is shown in Figure 9-1090 (NAI Realm ANQP-element format).

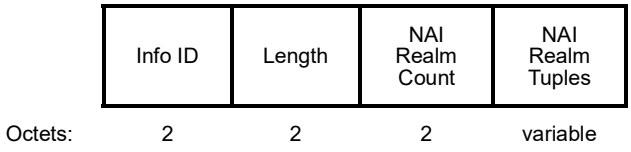


**Figure 9-1090—NAI Realm ANQP-element format**

The Info ID and Length fields are defined in 9.4.5.1 (General).

(#1612)The NAI Realm Count field specifies the number of NAI Realm Tuple subfields included in the NAI Realm ANQP-element.

The NAI Realm Tuples field contains zero or more variable length NAI Realm Tuple subfields.

The format of the NAI Realm Tuple subfield is shown in Figure 9-1091 (NAI Realm Tuple subfield format).

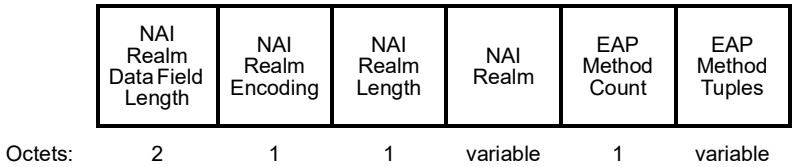


**Figure 9-1091—NAI Realm Tuple subfield format**

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The NAI Realm Data Field Length subfield is equal to 3 plus the length (#7224)in octets of the NAI Realm subfield plus the length in octets of the EAP Method Tuples subfield.(#1611)

The NAI Realm Encoding subfield is shown in Figure 9-1092 (NAI Realm Encoding subfield format).

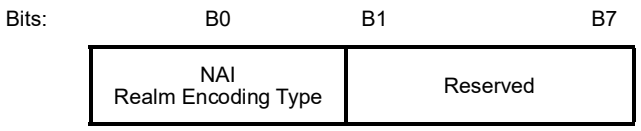


**Figure 9-1092—NAI Realm Encoding subfield format**

The NAI Realm Encoding Type subfield is set to 0 to indicate that each NAI realm in the NAI Realm subfield is formatted in accordance with IETF RFC 4282. It is set to 1 to indicate that each NAI realm is a UTF-8 string that (#1624)might not be formatted in accordance with IETF RFC 4282.(#1613)

NOTE—This encoding is to facilitate roaming consortium or other entities that use nonstandard NAI realm(#3235) formats.

The NAI Realm Length subfield is the length in octets of the NAI Realm subfield.

The NAI Realm subfield is one or more NAI realms(#3235) formatted as defined in the NAI Realm Encoding Type subfield(#1610) of the NAI Realm Encoding subfield. If there is more than one NAI realm(#3235) in this subfield, the NAI realms are delimited by a semicolon character (i.e., ";", which is encoded in UTF-8 as 0x3B). All of the realms included in the NAI Realm subfield support all of the EAP methods identified by the EAP Method subfields, if present. The maximum length of this subfield is 255 octets.

The EAP Method Count subfield specifies the number of EAP methods subfields for the NAI realm. If the count is 0, there is no EAP method information provided for the NAI realm.

The EAP Method Tuples field contains zero or more variable length EAP Method Tuple subfields.

The format of the optional EAP Method Tuple subfield is shown in Figure 9-1093 (EAP Method Tuple subfield format). Each EAP Method subfield contains a set of Authentication Parameters associated with the EAP-Method.

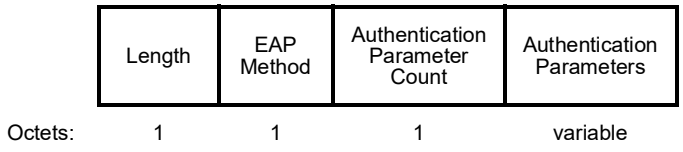


**Figure 9-1093—EAP Method Tuple subfield format**

The Length subfield is 2 plus the length (#7224)in octets of the Authentication Parameters subfield.

The EAP method subfield is set to the EAP Type value as given in IANA EAP Method Type Numbers.

The Authentication Parameter Count indicates how many additional Authentication Parameter subfields are specified for the supported EAP Method. If the Authentication Parameters Count subfield is 0, there are no Authentication Parameters subfields present, meaning no additional Authentication Parameters are specified for the EAP Method.


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The Authentication Parameters field contains zero or more variable length Authentication Parameter subfields.

The format of the Authentication Parameter subfield is shown in Figure 9-1094 (Authentication Parameter subfield format).

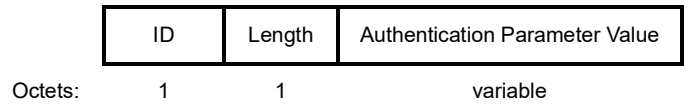


**Figure 9-1094—Authentication Parameter subfield format**

The ID subfield indicates the type of authentication information provided.

The Length subfield indicates the length (#7224)in octets of the Authentication Parameter Value subfield.

The Authentication Parameter Value subfield is a variable length subfield containing the value of the parameter indicated by the ID.

The ID and its associated formats are specified in Table 9-430 (Authentication Parameter types). Each ID indicates a different type of information. Use of multiple Authentication Parameter subfields allows all of the required authentication parameter requirements to be provided.

**Table 9-430—Authentication Parameter types**

| Authentication information | ID | Description | Length (octets) |
|---|---|---|---|
| Reserved | 0 | | |
| Expanded EAP Method | 1 | Expanded EAP Method Subfield | 7 |
| Non-EAP Inner Authentication Type | 2 | Enum (0 - Reserved, 1 - PAP, 2 - CHAP, 3 - MSCHAP, 4 - MSCHAPV2) | 1 |
| Inner Authentication EAP Method Type | 3 | Value drawn from IANA EAP Method Type Numbers | 1 |
| Expanded Inner EAP Method | 4 | Expanded EAP Method Subfield | 7 |
| Credential Type | 5 | Enum (1 - SIM, 2 - USIM, 3 - NFC Secure Element, 4 - Hardware Token, 5 - Softoken, 6 - Certificate, 7 - username/password, 8 - none (#4181)(see NOTE), 9 - Reserved, 10 - Vendor Specific) | 1 |
| Tunneled EAP Method Credential Type | 6 | Enum (1 - SIM, 2 - USIM, 3 - NFC Secure Element, 4 - Hardware Token, 5 - Softoken, 6 - Certificate, 7 - username/password, 8 - Reserved, 9 - Anonymous, 10 - Vendor Specific) | 1 |
| Reserved | 7–220 | | |
| Vendor Specific | 221 | Variable | variable |
| Reserved | 222–255 | | |
| NOTE—None means server-side authentication only. | | | |

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If the EAP Method type is an Expanded EAP type (the EAP Method value is 254), the Authentication Parameter is used to specify additional information on the EAP method. Table 9-431 (Authentication Parameter format for the Expanded EAP method) describes the Authentication Parameter format for the Expanded EAP method; values for the Vendor ID and Vendor Type are specified in IETF RFC 3748. The Vendor ID and Vendor Type fields are expressed in big endian octet order.

**Table 9-431—Authentication Parameter format for the Expanded EAP method**

| Parameters | Length (octets) |
|---|---|
| ID | 1 |
| Length | 1 |
| Vendor ID | 3 |
| Vendor Type | 4 |

The Non-EAP Inner Authentication Type is specified as a single enumerated value given in Table 9-430 (Authentication Parameter types). This Authentication Information type is used for non-EAP Inner Authentication methods. The possible values are PAP (as specified in IETF RFC 1334 [B23]), CHAP (as specified in IETF RFC 1994 [B24]), MSCHAP (as specified in IETF RFC 2433 [B28]), and MSCHAPv2 (as specified in IETF RFC 2759 [B32]).

The Inner Authentication EAP Method Type is specified as the EAP number as defined in IANA EAP Method Type Numbers. This Authentication Information type is used when the Inner Authentication method is an EAP method. If the Inner Authentication EAP Method Type is equal to 254 indicating an Expanded EAP Type, then the Expanded EAP Method Authentication Parameter is included.

A Credential Type is specified as a single enumerated value as shown in Table 9-430 (Authentication Parameter types). If the value is equal to the "Vendor Specific" value, then a Vendor-Specific Authentication Parameter is included.

Vendor-Specific Authentication Parameters are specified as shown in Table 9-432 (Vendor Specific Authentication Parameters).

**Table 9-432—Vendor Specific Authentication Parameters**

| Parameters | Length (octets) |
|---|---|
| ID | 1 |
| Length | 1 |
| OI | variable |
| Authentication Parameter Value | variable(#1726) |


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#### 9.4.5.11 3GPP Cellular Network ANQP-element

The 3GPP Cellular Network ANQP-element contains cellular information such as network advertisement information e.g., network codes and country codes to assist a non-AP STA in selecting an AP to access 3GPP networks. The format of the 3GPP Cellular Network ANQP-element is shown in Figure 9-1095 (3GPP Cellular Network ANQP-element format).

**Figure 9-1095—3GPP Cellular Network ANQP-element format**

The Info ID and Length fields are defined in 9.4.5.1 (General).

The Payload field is a variable length field and is a generic container. An example of the format and content is defined in Annex H of 3GPP TS 24.302.

#### 9.4.5.12 AP Geospatial Location ANQP-element

The AP Geospatial Location ANQP-element provides the AP's location in LCI format; see 9.4.2.20.10 (LCI report (Location configuration information report)). This information is taken from dot11APLCITable.

The format of the AP Geospatial Location ANQP-element is shown in Figure 9-1096 (AP Geospatial Location ANQP-element format).

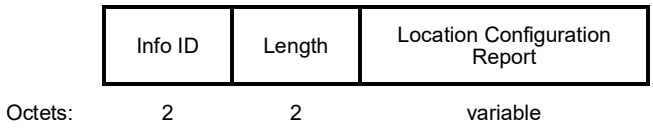


**Figure 9-1096—AP Geospatial Location ANQP-element format**

The Info ID and Length fields are defined in 9.4.5.1 (General).

The Location Configuration Report field is of variable length and defined in 9.4.2.20.10 (LCI report (Location configuration information report)). The Z and Usage Rules/Policy subelements are optionally present in the Location Configuration Report field, when it is used in the AP Geospatial Location ANQP element. The (#2210)Colocated BSSID List subelement is present when there is at least one other BSS that is (#2210)colocated within the same physical device as the reporting BSS.

#### 9.4.5.13 AP Civic Location ANQP-element

The AP Civic Location ANQP-element provides the AP's location in civic format. The format of the AP Civic Location ANQP-element is shown in Figure 9-1097 (AP Civic Location ANQP-element format).

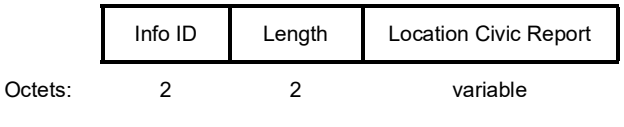


**Figure 9-1097—AP Civic Location ANQP-element format**

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The Info ID and Length fields are defined in 9.4.5.1 (General).

The Location Civic Report field is a variable length field and the format is provided in 9.4.2.20.13 (Location Civic report). This information is taken from dot11APCivicLocationTable. The Colocated BSSID List subelement is present when there is at least one other BSS that is (#2210)colocated within the same physical device as the reporting BSS and the (#2210)Colocated BSSID List subelement is not present in the (#7176)AP Geospatial Location ANQP-element; this subelement is not present otherwise.

### 9.4.5.14 AP Location Public Identifier URI/FQDN ANQP-element

The AP Location Public Identifier URI/FQDN ANQP-element provides an indirect reference to the location information for the AP. This list element can be returned in response to a GAS query request(#7052) using the procedures in 11.22.3.3 (ANQP procedures). The format of the AP Location Public Identifier URI/FQDN ANQP-element is shown in Figure 9-1098 (AP Location Public Identifier URI/FQDN ANQP-element format).

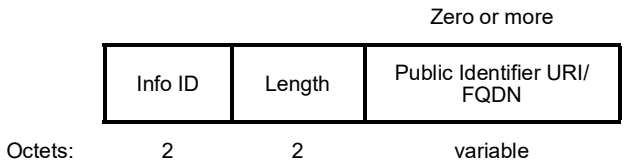


**Figure 9-1098—AP Location Public Identifier URI/FQDN ANQP-element format**

The Info ID and Length fields are defined in 9.4.5.1 (General).

The Public Identifier URI/FQDN field is a variable length field containing zero or more Public Identifier URI/FQDN subelements, as defined in 9.4.2.20.14 (Location Identifier report).

### 9.4.5.15 Domain Name ANQP-element

The Domain Name ANQP-element provides a list of one or more domain names of the entity operating the IEEE 802.11 access network. Domain Names in this ANQP-element are taken from dot11DomainNameTable. The format of the Domain Name ANQP-element is shown in Figure 9-1099 (Domain Name ANQP-element format).

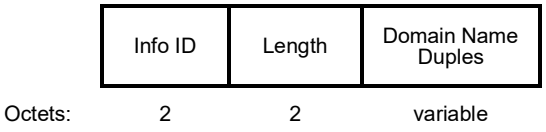


**Figure 9-1099—Domain Name ANQP-element format**

The Info ID and Length fields are defined in 9.4.5.1 (General).

The Domain Name Duples field contains zero or more variable length Domain Name Duple subfields.


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The format of the Domain Name Duple subfield is shown in Figure 9-1100 (Domain Name Duple subfield format).

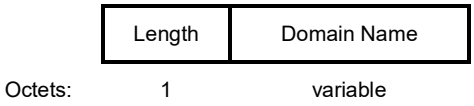


**Figure 9-1100—Domain Name Duple subfield format**

The Length subfield indicates the length in octets of the Domain Name subfield.

The Domain Name subfield is of variable length and contains a domain name compliant with the "Preferred Name Syntax" as defined in IETF RFC 1035. The maximum length of this field is 255 octets.

#### 9.4.5.16 Emergency Alert URI ANQP-element

The Emergency Alert URI ANQP-element provides a URI for EAS message retrieval.

The format of the Emergency Alert URI ANQP-element is shown in Figure 9-1101 (Emergency Alert URI ANQP-element format).

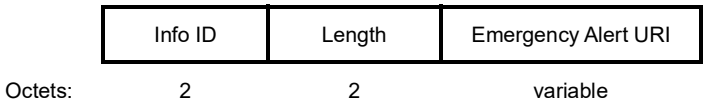


**Figure 9-1101—Emergency Alert URI ANQP-element format**

The Info ID and Length fields are defined in 9.4.5.1 (General).

The Emergency Alert URI field is a variable length field used to indicate the URI at which an EAS message can be retrieved as described in 11.22.7 (Interworking procedures: emergency alert system (EAS) support). The Emergency Alert URI field is formatted in accordance with IETF RFC 3986.

#### 9.4.5.17 Emergency NAI ANQP-element

The Emergency NAI ANQP-element contains an emergency string that is available for use by a STA as its identity to indicate emergency access request. The format of the Emergency NAI ANQP-element is shown in Figure 9-1102 (Emergency NAI ANQP-element format).

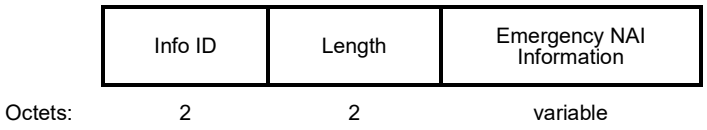


**Figure 9-1102—Emergency NAI ANQP-element format**

The Info ID and Length fields are defined in 9.4.5.1 (General).

The Emergency NAI Information field is a UTF-8 string formatted in accordance with IETF RFC 4282.

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### 9.4.5.18 TDLS Capability ANQP-element

The TDLS Capability ANQP-element is used by a STA to discover the TDLS capabilities of a peer STA. The format of the TDLS Capability ANQP-element is shown in Figure 9-1103 (TDLS Capability ANQP-element format).

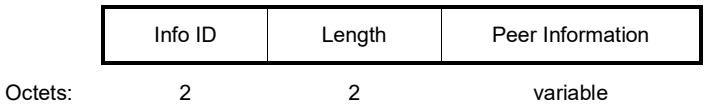


**Figure 9-1103—TDLS Capability ANQP-element format**

The Info ID and Length fields are defined in 9.4.5.1 (General).

The Peer Information field is a variable length field containing information that a STA can use to establish a (#2152)TDLS direct link and is defined as an XML schema (see R.6 (Peer information)). An example of the peer information is described in 11.22.3.3.10 (TDLS Capability procedure).

### 9.4.5.19 Neighbor Report ANQP-element

The Neighbor Report ANQP-element provides zero or more neighbor reports about neighboring APs. This is of benefit to a STA in a preassociated state. The format of the Neighbor Report ANQP-element is defined in Figure 9-1104 (Neighbor Report ANQP-element format).

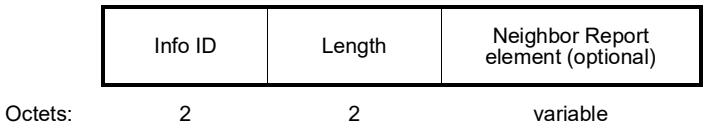


**Figure 9-1104—Neighbor Report ANQP-element format**

The Info ID and Length fields are defined in 9.4.5.1 (General).

The format of the Neighbor Report element is shown in Figure 9-416 (Neighbor Report element format) defined in 9.4.2.35 (Neighbor Report element). The (#2210)Colocated BSSID List subelement is present in the Measurement Report subelement when there is at least one other BSS that is (#2210)colocated within the same physical device as the reporting BSS.

### 9.4.5.20 Venue URL ANQP-element

The Venue URL ANQP-element provides a list of one or more URLs that can be used for web page advertising services or providing information, particular to a venue's BSS, to a STA. The format of the Venue URL ANQP-element is defined in Figure 9-1105 (Venue URL ANQP-element format).

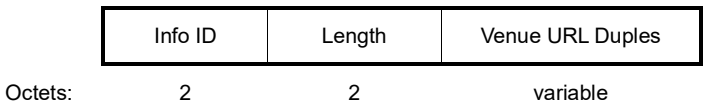


**Figure 9-1105—Venue URL ANQP-element format**

The Info ID and Length fields are defined in 9.4.5.1 (General).


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The Venue URL Duples field contains one or more Venue URL Duple fields as shown in Figure 9-1106 (Venue URL Duple field).

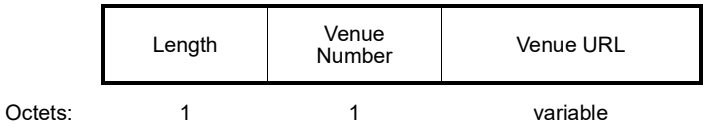


**Figure 9-1106—Venue URL Duple field**

The Length field is set to 1 plus the number of octets in the Venue URL field.

The Venue Number field identifies the position (1 = 1st, 2 = 2nd, and so on) of the corresponding Venue Name Tuple subfield in the Venue Name ANQP-element from the same STA, as defined in 9.4.5.4 (Venue Name ANQP-element). If that same STA does not advertise a Venue Name ANQP-element, or does not advertise any Venue Name Tuple subfields in the Venue Name ANQP-element, then the Venue Number field is set to 0.

The Venue URL field is a variable length field that indicates the URL at which information relevant to the corresponding Venue Name Tuple subfield, indicated by the Venue Number, might be retrieved. This is further described in 11.22.3.3.11 (Venue URL procedure). If no Venue URL is provided this field is left empty. The Venue URL field is formatted in accordance with IETF RFC 3986.

### 9.4.5.21 Advice of Charge ANQP-element

The Advice of Charge ANQP-element provides a list of one or more financial advice of charges related to access to a BSS. The format of the Advice of Charge ANQP-element is defined in Figure 9-1107 (Advice of Charge ANQP-element format).

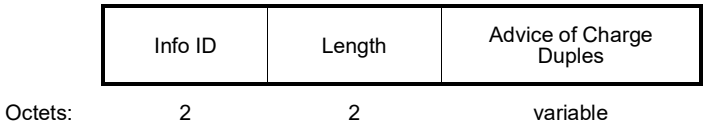


**Figure 9-1107—Advice of Charge ANQP-element format**

The Info ID and Length fields are defined in 9.4.5.1 (General).

The Advice of Charge Duples field contains one or more Advice of Charge Duple fields as shown in Figure 9-1108 (Advice of Charge Duple field).

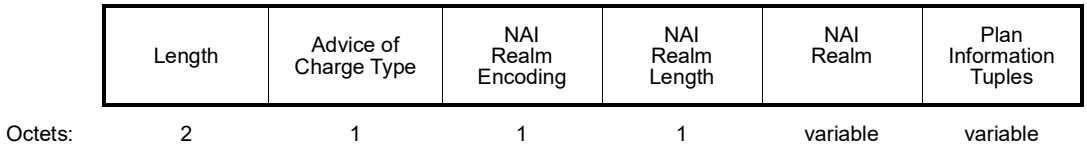


**Figure 9-1108—Advice of Charge Duple field**

The Length field is set to 3 plus the number of octets in the NAI Realm and Plan Information Tuples fields.

The Advice of Charge Type field is set to one of the values defined in Table 9-433 (Advice of Charge Type field values).

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**Table 9-433—Advice of Charge Type field values**

| Advice of Charge Type Value | Description |
|---|---|
| 0 | Time-based |
| 1 | Data-volume-based |
| 2 | Time-and-data-volume-based |
| 3 | Unlimited |
| 4–255 | Reserved |

The NAI Realm Encoding and NAI Realm Length are defined in 9.4.5.10 (NAI Realm ANQP-element). The NAI Realm subfield is one or more NAI realms(#3235) formatted as defined in 9.4.5.10 (NAI Realm ANQP-element).

The format of the Plan Information Tuples field is defined in Figure 9-1109 (Plan Information Tuple field format).

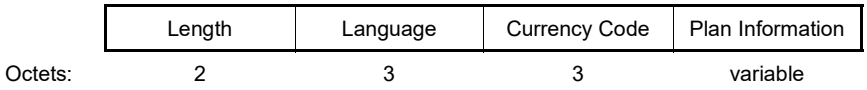


**Figure 9-1109—Plan Information Tuple field format**

The Length field is set to the number of octets in the Language, Currency Code, and Plan Information fields.

The Language Code field contains an ASCII-encoded language code selected from ISO 639, and defines the language used in the Cost Information field. A two character language code has 0 (ASCII NUL) appended.

The Currency Code field is an(#2047) ASCII string representing an ISO 4217 currency alphabetic or numeric code (e.g., “USD”).(#366)

The Plan Information field is a UTF-8 string that carries an XML description of an (#338)advice of charge plan. The schema and semantics of this description are outside the scope of this standard.

### 9.4.5.22 Local Content ANQP-element

The Local Content ANQP-element provides a list of one or more URLs that can be used to display local content related to the BSS. The format of the Local Content ANQP-element is defined in Figure 9-1110 (Local Content ANQP-element format).

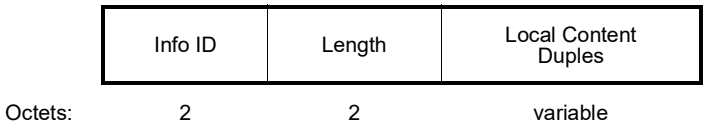


**Figure 9-1110—Local Content ANQP-element format**

The Info ID and Length fields are defined in 9.4.5.1 (General).


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The Local Content Duples field contains one or more Local Content Duple fields as shown in Figure 9-1111 (Local Content Duple field format).

| | Length | State | Local Content URL Length | Local Content URL | Label Length (optional) | Label (optional) |
|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | variable | 0 or 1 | variable |

**Figure 9-1111—Local Content Duple field format**

The Length field is set to 2 plus the number of octets in the Local Content URL, Label Length and Label fields.

The State field is defined in Table 9-434 (Local Content State values).

**Table 9-434—Local Content State values**

| State | Name |
|---|---|
| 0 | Not authenticated |
| 1 | Authenticated |
| 2 | Failure during authentication |
| 3 | Incorrect credentials |
| 4 | Credentials expired |
| 5–255 | Reserved |

The Local Content URL Length field contains the length of the Local Content URL field in octets.

The Local Content URL field is a variable length field containing a URL that is used for directing the device to local content. The Local Content URL field is formatted in accordance with IETF RFC 3986.

The Label Length field contains the value of the length of the Label field in octets. If the Label field is not present, this field is not present.

The Label field is a UTF-8 string containing a text description of the URL suitable for display on a user interface. It provides the type and potential usage of the URL.

### 9.4.5.23 Network Authentication Type with Timestamp ANQP-element

The Network Authentication Type with Timestamp ANQP-element provides similar information to that of the Network Authentication Type as defined in 9.4.5.6 (Network Authentication Type ANQP-element). In addition, a timestamp field is optionally provided to indicate to the requesting STA a timestamp corresponding to the time at which the received terms and conditions were most recently modified. With this timestamp, the requesting STA can determine if previously received information is stale.

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The format of the Network Authentication Type with Time ANQP-element is shown in Figure 9-1112 (Network Authentication Type with Timestamp ANQP-element format).

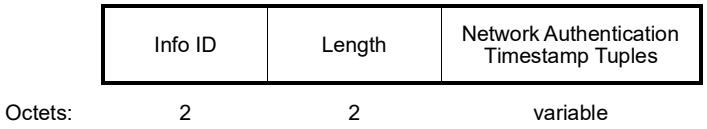


**Figure 9-1112—Network Authentication Type with Timestamp ANQP-element format**

The Info ID and Length fields are defined in 9.4.5.1 (General).

The Network Authentication Timestamp Tuples field contains zero or more variable length Network Authentication Timestamp Tuple subfields.

Each Network Authentication Timestamp Tuple subfield has the structure shown in Figure 9-1113 (Network Authentication Timestamp Tuple subfield format).

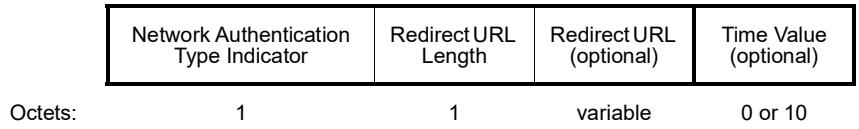


**Figure 9-1113—Network Authentication Timestamp Tuple subfield format**

The Network Authentication Type Indicator field is defined in 9.4.5.6 (Network Authentication Type ANQP-element)

The Redirect URL Length field and the Redirect URL field are defined in 9.4.5.6 (Network Authentication Type ANQP-element).

The Time Value field is defined in Table 9-232 (Time Value field format when Timing Capabilities is 2) using the Timing Capability equal to 2 encoding. This field is used by the responding STA to set a time of the ANQP response.

### 9.4.5.24 Query AP List ANQP-element

The Query AP List ANQP-element provides a list of APs and a list of Info IDs of ANQP-elements that the requesting STA is requesting from each AP in the list. The Query AP List ANQP-element declares that the STA performing the ANQP request is requesting that the ANQP-element corresponding to each Info ID be returned in the AP List Response ANQP-element. This element allows an optimization of the single ANQP request procedure (see 9.4.5.2 (Query List ANQP-element)) by having multiple ANQP requests in a single ANQP-element thus reducing the time necessary for network discovery and selection. See 11.22.3.3.14 (Query AP List procedure) for information on the Query AP list procedure.

The format of the Query AP List ANQP-element is shown in Figure 9-1114 (Query AP List ANQP-element format).

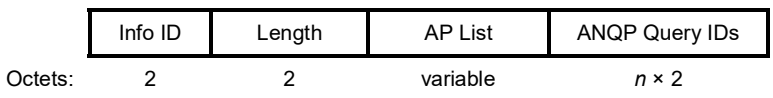


**Figure 9-1114—Query AP List ANQP-element format**


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The Info ID and Length fields are defined in 9.4.5.1 (General).

The AP List field is a variable length field defined in Figure 9-1115 (AP List field format) that contains the list of BSSIDs for requested information.

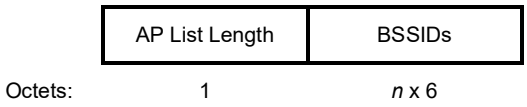


**Figure 9-1115—AP List field format**

The AP List Length field indicates the length (#7224)in octets of the BSSIDs field.

The BSSIDs field contains one or more BSSID fields. Each BSSID field(#261) indicates the BSSID of the BSS of an AP that the requesting STA wants to query.

The ANQP Query IDs field contains one or more ANQP Query ID fields that are ordered by increasing info ID value. Each ANQP Query ID field is an unsigned integer of length two octets.

The ANQP Query ID field value is drawn from Table 9-426 (ANQP-element definitions).

### 9.4.5.25 AP List Response ANQP-element

The AP List Response ANQP-element provides the response to the Query AP List ANQP-element request. The ANQP response is defined in 11.22.3.3 (ANQP procedures). The format of the AP List Response ANQP-element is defined in Figure 9-1116 (AP List Response ANQP-element format).

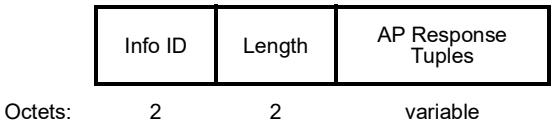


**Figure 9-1116—AP List Response ANQP-element format**

The Info ID and Length fields are defined in 9.4.5.1 (General).

The AP Response Tuples field contains zero or more AP Response Tuple fields.

The format of the AP Response Tuple field is defined in Figure 9-1117 (AP Response Tuple field format).

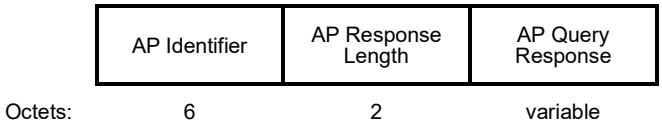


**Figure 9-1117—AP Response Tuple field format**

The AP Identifier field indicates the BSSID of the BSS of the AP that the requesting STA queries.

The AP Response Length field indicates the number of octets in the following AP Query Response field.

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The AP Query Response field contains an ANQP response corresponding to the ANQP Query ID in the received Query AP List ANQP-element as specified in 9.4.5.24 (Query AP List ANQP-element). Each ANQP response comprises one or more ANQP-elements (Table 9-426 (ANQP-element definitions)).

### 9.4.5.26 CAG ANQP-element

The CAG ANQP-element provides the info IDs for the ANQP-elements contained within a CAG associated with ANQP, or ANQP with Service Information Registry, and the current value of the ANQP CAG version, indicating the version of information within the CAG associated with ANQP, or ANQP with Service Information Registry. The format of the CAG ANQP-element is defined in Figure 9-1118 (CAG ANQP-element format). The selection of the specific number of info IDs and the specific values of info IDs in a CAG associated with ANQP is left to the implementation and is beyond the scope of this standard.

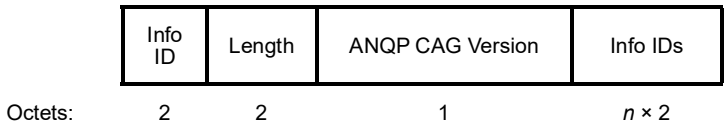


**Figure 9-1118—CAG ANQP-element format**

The Info ID and Length fields are defined in 9.4.5.1 (General).

The ANQP CAG Version field indicates the current version of the CAG associated with ANQP, or ANQP with Service Information Registry.

The Info IDs field contains zero or more Info ID fields. (#1496)The Info ID field contains the info ID of an ANQP-element Info ID specified in Table 9-343 (DNS Info Control subfield settings).

### 9.4.5.27 Service Information Request ANQP-element

The Service Information Request ANQP-element contains a generic request for service information associated with the service hash(es) provided.

The format of the Service Information Request ANQP-element is shown in Figure 9-1119 (Service Information Request ANQP-element format).

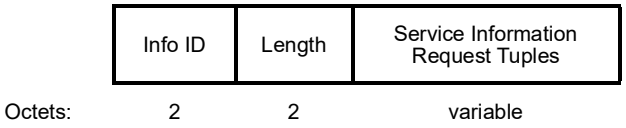


**Figure 9-1119—Service Information Request ANQP-element format**

The Info ID and Length fields are defined in 9.4.5.1 (General).

The Service Information Request Tuples field contains one or more Service Information Request Tuple subfields. The format of the Service Information Request Tuple subfield is shown in Figure 9-1120 (Service Information Request Tuple subfield format).

The Service Hash field contains a (#1496)service hash value. See 11.23.4 (Service hash procedure) for procedures for generating a service hash.


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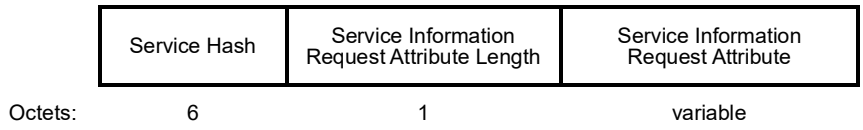


**Figure 9-1120—Service Information Request Tuple subfield format**

The Service Information Request Attribute Length subfield indicates the length (#7224)in octets of the Service Information Request Attribute subfield.

The Service Information Request Attribute subfield contains a service-specific query. The value of this subfield is out of the scope of this standard.

### 9.4.5.28 Service Information Response ANQP-element

The Service Information Response ANQP-element contains the detailed service information in response to a Service Information Request ANQP-element.

The format of the Service Information Response ANQP-element is shown in Figure 9-1121 (Service Information Response ANQP-element format).

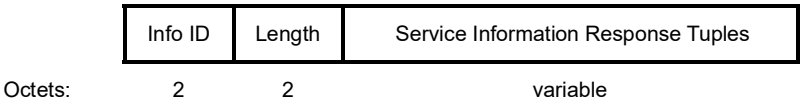


**Figure 9-1121—Service Information Response ANQP-element format**

The Info ID and Length fields are defined in 9.4.5.1 (General).

The Service Information Response Tuples field contains zero or more Service Information Response Tuple subfields.

The format of the Service Information Response Tuple subfield is shown in Figure 9-1122 (Service Information Response Tuple subfield format).

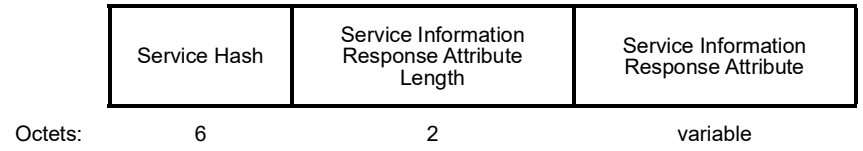


**Figure 9-1122—Service Information Response Tuple subfield format**

The Service Hash field contains a (#1496)service hash value. See 11.23.4 (Service hash procedure) for procedures for generating a service hash.

The Service Information Response Attribute Length subfield indicates the length (#7224)in octets of the Service Information Response Attribute subfield.

The content of the Service Information Response Attribute subfield is service specific based on the corresponding Service Information Request Attribute subfield in the Service Information Request Tuples of the Service Information Request ANQP-element as described in 9.4.5.27 (Service Information Request ANQP-element).

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### 9.4.5.29 Local MAC Address Policy ANQP-element

The Local MAC Address Policy ANQP-element provides an indication of the local MAC address policy of the ESS.

The format of the Local MAC Address Policy ANQP-element is specified in Figure 9-1123 (Local MAC Address Policy ANQP-element format).

| | Info ID | Length | Local MAC Address Policy | Number Of Restricted Prefixes | Restricted Address Prefix |
|---|---|---|---|---|---|
| Octets: | 2 | 2 | 1 | 1 | variable |

**Figure 9-1123—Local MAC Address Policy ANQP-element format**

The Info ID and Length fields are specified in 9.4.5.1 (General).

The Local MAC Address Policy field is a bitmap advertising policies supported by the ESS regarding its support for local MAC address. The values of the bits are specified in Table 9-435 (Local MAC Address Policy field bits).

**Table 9-435—Local MAC Address Policy field bits**

| Bitmap value | Description |
|---|---|
| Bit 0 (MSB) | Reserved |
| Bit 1 | Randomization subject to Restricted Address Prefixes supported in SLAP Quadrant 00 |
| Bit 2 | Randomization subject to Restricted Address Prefixes supported in SLAP Quadrant 01 |
| Bit 3 | Randomization subject to Restricted Address Prefixes supported in SLAP Quadrant 10 |
| Bit 4 | Randomization subject to Restricted Address Prefixes supported in SLAP Quadrant 11 |
| Bit 5 | Reserved |
| Bit 6 | Reserved |
| Bit 7 | Reserved |

The bitmap values provided in Table 9-435 (Local MAC Address Policy field bits) indicate, to the receiving STA, aspects of the local MAC address policy of the ESS. The bits are independent and not mutually exclusive. They make reference to the Structured Local Address Plan (SLAP) introduced into IEEE Std 802 via the amendment IEEE Std 802c-2017. The bit value indications are as follows:

— Bit 0 is reserved.

— Bit 1, when set to 1, indicates the support of an address chosen by the STA randomly, in SLAP Quadrant 00 (i.e., the SLAP AAI quadrant, with 0100 as the M, X, Y, and Z bits, respectively) but avoiding addresses beginning with any prefix specified in the Restricted Address Prefix field. Bit 1,


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when set to 0, indicates that the ESS provides no rules on MAC address use within SLAP Quadrant 00.

— Bit 2, when set to 1, represents the support of an address chosen by the STA randomly, in SLAP Quadrant 01 (i.e., the SLAP ELI quadrant, with 0101 as the M, X, Y, and Z bits, respectively) but avoiding addresses beginning with any prefix specified in the Restricted Address Prefix field. Bit 2, when set to 0, indicates that the ESS provides no rules on MAC address use within SLAP Quadrant 01.

— Bit 3, when set to 1, represents the support of an address chosen by the STA randomly, in SLAP Quadrant 10 (i.e., the SLAP Reserved quadrant, with 0110 as the M, X, Y, and Z bits, respectively) but avoiding addresses beginning with any prefix specified in the Restricted Address Prefix field. Bit 3, when set to 0, indicates that the ESS provides no rules on MAC address use within SLAP Quadrant 10.

— Bit 4, when set to 1, represents the support of an address chosen by the STA randomly, in SLAP Quadrant 11 (i.e., the SLAP SAI quadrant, with 0111 as the M, X, Y, and Z bits, respectively) but avoiding addresses beginning with any prefix specified in the Restricted Address Prefix field. Bit 4, when set to 0, indicates that the ESS provides no rules on MAC address use within SLAP Quadrant 11.

The Number Of Restricted Prefixes field specifies the number of Restricted Address Prefix subfields in the Restricted Address Prefix field.

NOTE 1—If Local MAC Address Policy field bits 1-4 are set to 1 and Number Of Restricted Prefixes to 0, the Local MAC Address Policy ANQP-element indicates that the ESS supports randomized address throughout local address range. In this case, the AP STA sets the Local MAC Address Policy field in the Extended Capabilities field to 0, indicating that local MAC addresses are not restricted, and consequently the Local MAC Address Policy ANQP-element is redundant.

The Restricted Address Prefix field contains zero or more Restricted Address Prefix subfields, each specifying the prefix of local MAC addresses supported in the ESS. Each such prefix indicates support for MAC addresses assigned as extensions of the indicated prefix, provided that the assignment is made according to the procedures specified for the use of that prefix, or, in the case that a MAC address is an extension of multiple indicated prefixes, the longest of those prefixes.

NOTE 2—The detailed specification of the use of local MAC addresses is provided in IEEE Std 802. Per its amendment IEEE Std 802c-2017, an SAI is assigned by a protocol specified in an IEEE 802 standard, and specification of the use of ELI addresses is provided by the assignee of a CID duly assigned by the IEEE Registration Authority.

The format of the Restricted Address Prefix subfield is described in Figure 9-1124 (Restricted Address Prefix subfield format).

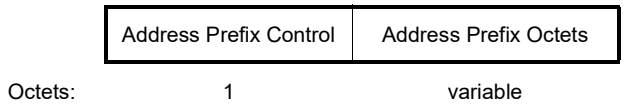


**Figure 9-1124—Restricted Address Prefix subfield format**

The format of the Address Prefix Control subfield is described in Figure 9-1125 (Address Prefix Control subfield format).

The Length Of Address Prefix Octets subfield indicates the length (in octets) of the Address Prefix Octets field. Values 0 and 7 are reserved.

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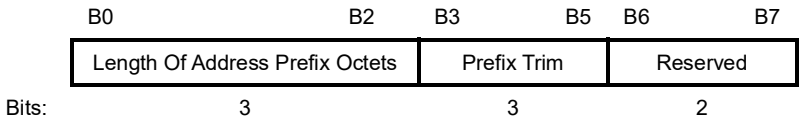


**Figure 9-1125—Address Prefix Control subfield format**

The Prefix Trim subfield indicates the number of bits to be truncated from the end of the value of the Address Prefix Octets subfield in order to obtain the MAC address prefix. In other words, the MAC address prefix is the value of the Address Prefix Octets subfield after truncation of some of the most significant bits of the last octet, with the number of truncated bits equal to the value of the Prefix Trim subfield. If the Length of Address Prefix Octets subfield is set to 1, then the value of the Prefix Trim subfield is not be set to 7; this provides that the length of the MAC address prefix is at least two bits. The bit and octet ordering of the MAC address prefix is per Figure 9-1 (Representation of a 48-bit MAC address).

### 9.4.5.30 EBCS ANQP-element(11bc)

The EBCS ANQP-element provides a list of zero or more enhanced broadcast services that are available from the STA transmitting this element. The format of the EBCS ANQP-element is defined in Figure 9-1126 (EBCS ANQP-element format(11bc)).

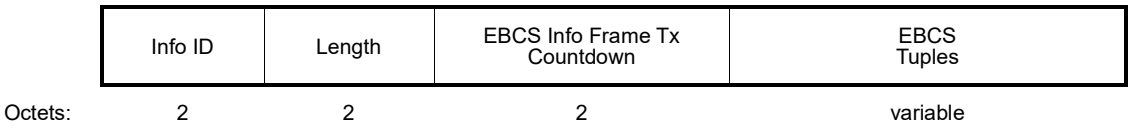


**Figure 9-1126—EBCS ANQP-element format(11bc)**

The Info ID and Length fields are defined in 9.4.5.1 (General).

The EBCS Info Frame Tx Countdown field is defined in 9.4.1.70 (EBCS Info Frame Tx Countdown field(11bc)).

If present, the EBCS Tuples field contains one or more EBCS Tuple fields as defined in Figure 9-1127 (EBCS Tuple field format(11bc))..

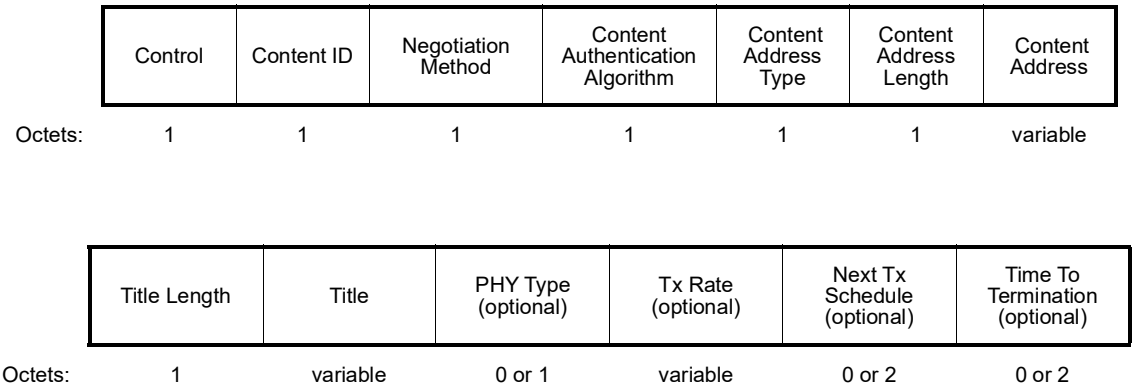


**Figure 9-1127—EBCS Tuple field format(11bc)**

The Control field defines which of the optional fields are present in the EBCS Tuple field and is defined in Figure 9-1128 (Control field format(11bc)).


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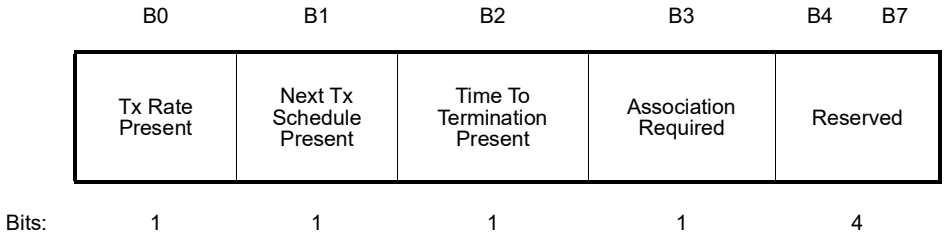


**Figure 9-1128—Control field format(11bc)**

The Tx Rate Present subfield is set to 1 if the PHY Type subfield and the Tx Rate subfield are present and is set to 0 otherwise.

The Next Tx Schedule Present subfield is set to 1 by a STA to indicate that the EBCS Tuple field contains a Next Tx Schedule field. This subfield is set to 0 to indicate that there is no Next Tx Schedule field.

The Time To Termination Present subfield is set to 1 by a STA to indicate that the EBCS Tuple field contains a Time To Termination field. This subfield is set to 0 to indicate that there is no Time To Termination field.

A value of 1 in the Association Required subfield indicates that association is required to consume the EBCS traffic stream identified by the content ID contained in the Content ID subfield. A value of 0 indicates that association is not required to consume the EBCS traffic stream identified by the content ID contained in the Content ID subfield.

The Content ID subfield indicates the identifier of the content.

The format of the Negotiation Method subfield is shown in Figure 9-1129 (Negotiation Method subfield format(11bc)).

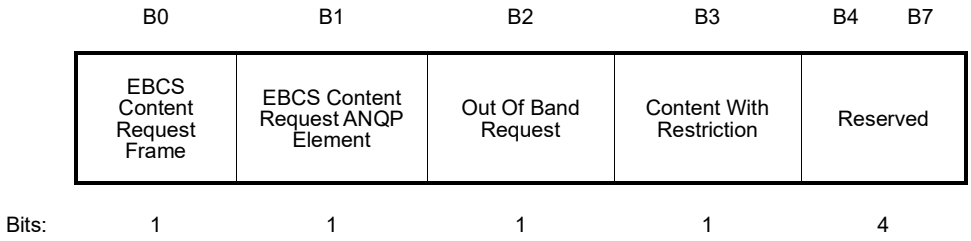


**Figure 9-1129—Negotiation Method subfield format(11bc)**

The EBCS Content Request Frame subfield is set to 1 if the EBCS traffic stream identified by the Content ID subfield included in the same EBCS Tuple field can be requested using EBCS Content Request frames, otherwise it is set to 0.

The EBCS Content Request ANQP Element subfield is set to 1 if the EBCS traffic stream identified by the Content ID subfield included in the same EBCS Tuple field can be requested using the EBCS Content Request ANQP-element, otherwise it is set to 0.

The Out Of Band Request subfield is set to 1 if the EBCS traffic stream, identified by the Content ID subfield included in the same EBCS Tuple field, can be requested using an out of band method, otherwise it is set to 0. The URL to be used for the out of band negotiation method is contained in the EBCS Info frame.

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If the Association Required bit in the Control field included in the same EBCS Tuple field is equal to 1, the only allowed request method is through EBCS Content Request/Response frames, therefore the EBCS Content Request Frame bit is set to 1 and EBCS Content Request ANQP Element bit is set to 0.

The Content With Restriction subfield is set to 1 if the content requires offline registration to be consumed and is set to 0 otherwise. The registration process is outside of the scope of this standard. The URL used for offline registration is contained in the Service URL subfield in the EBCS Info frame.

When the EBCS Content Request Frame subfield, the EBCS Content Request ANQP Element subfield, and the Out Of Band Request subfield are all set to 0, the EBCS traffic stream will be transmitted without any STA requesting it.

The Content Authentication Algorithm field indicates the authentication algorithm used for this EBCS traffic stream.

The Content Authentication Algorithm subfield is defined in Table 9-436 (Content Authentication Algorithms(11bc)).

**Table 9-436—Content Authentication Algorithms(11bc)**

| Value | Content Authentication Algorithms |
|---|---|
| 0 | HLSA (see 12.15.4 (No frame authentication with mandatory higher layer source authentication (HLSA))) |
| 1 | PKFA (see 12.15.2 (EBCS public key frame authentication (PKFA))) |
| 2 | HCFA without instant authentication (see 12.15.3 (EBCS hash chain frame authentication (HCFA))) |
| 3 | HCFA with instant authentication (see 12.15.3 (EBCS hash chain frame authentication (HCFA))) |
| 4–255 | Reserved |

The Content Address Type subfield is defined in Table 9-437 (Content Address Type subfield(11bc)).

**Table 9-437—Content Address Type subfield(11bc)**

| Value | Address Type |
|---|---|
| 0 | UDP/IPv4 |
| 1 | UDP/IPv6 |
| 2 | MAC address |
| 3–255 | Reserved |

The Content Address Length subfield contains the length of the Content Address subfield in octets.

The Content Address subfield contains the addresses and the port to select the content, encoded as follows.


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If the Content Address Type subfield indicates UDP/IPv4, the format of the Content Address subfield is shown in Figure 9-1130 (Content Address subfield format for UDP/IPv4(11bc)).

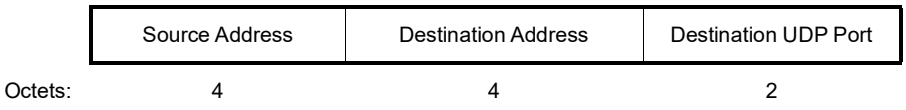


**Figure 9-1130—Content Address subfield format for UDP/IPv4(11bc)**

The Source Address subfield contains the source IPv4 address of the content. If the value of the Source Address subfield is 0, the source address of the content is not specified.

The Destination Address subfield indicates the IPv4 address used as the destination address (typically a multicast IPv4 address) in the broadcast frames for the EBCS traffic stream identified by the Content ID field. The Destination Port subfield indicates the UDP port associated with the IPv4 address indicated in the Destination Address subfield.

NOTE—The UDP port is encoded per the conventions defined in 9.2.2 (Conventions). IPv4 addresses correspond to the identically named fields of the IPv4 header.

If the Content Address Type subfield indicates UDP/IPv6, the format of the Content Address subfield is shown in Figure 9-1131 (Content Address subfield format for UDP/IPv6(11bc)).

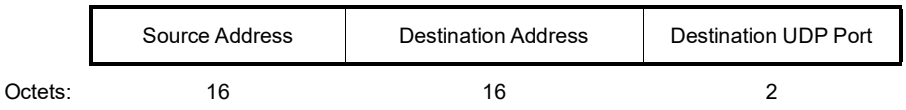


**Figure 9-1131—Content Address subfield format for UDP/IPv6(11bc)**

The Source Address subfield contains the source IPv6 address of the content. If the value of the Source Address subfield is 0, the source address of the content is not specified.

The Destination Address subfield indicates the IPv6 address used as the destination address (typically a multicast IPv6 address) in the broadcast frames for the EBCS traffic stream identified by the Content ID field. The Destination Port subfield indicates the UDP port associated with the IPv6 address indicated in the Destination Address subfield.

NOTE—The UDP port is encoded per the conventions defined in 9.2.2 (Conventions). IPv6 addresses correspond to the identically named fields of the IPv6 header.

If the Content Address Type subfield indicates MAC address, the format of the Content Address subfield is shown in Figure 9-1132 (Content Address subfield format for MAC Address(11bc)). The Content Address subfields contain MAC addresses.

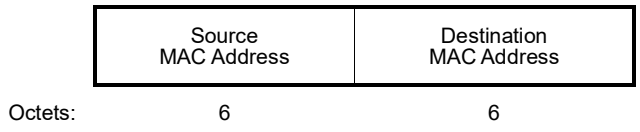


**Figure 9-1132—Content Address subfield format for MAC Address(11bc)**

The Source MAC Address subfield contains the source MAC address of the content. If the value of the Source MAC Address subfield is 0, the source MAC address of the content is not specified.

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The Destination MAC Address subfield contains the destination MAC address of the content that is a group address.

The Title Length field indicates the length of the Title field in octets.

The Title field is a human readable title of the content as a UTF-8 string.

The PHY Type subfield indicates the PHY type of the EBCS Data frames of the EBCS traffic stream. The PHY type is encoded as defined in Table 9-438 (PHY Type subfield(11bc)).

**Table 9-438—PHY Type subfield(11bc)**

| Value | Operating band | | | |
|---|---|---|---|---|
| | Sub 1 GHz | 2.4 GHz | 5 GHz | 6 GHz |
| 0 | S1G | DSSS / HR/DSSS / OFDM / ERP | OFDM | Reserved |
| 1 | Reserved | HT | HT | Reserved |
| 2 | Reserved | Reserved | VHT | Reserved |
| 3 | Reserved | HE | HE | HE |
| 4–255 | Reserved | Reserved | Reserved | Reserved |

The PHY Type subfield value depends on the operating band of the EBCS AP. If the PHY Type subfield is not present, the PHY type and the transmission rate of the EBCS Data frames of the EBCS traffic stream is same as the PHY type and the transmission rate of the EBCS Info frame (dot11EBCSInfoTxRate).

The Tx Rate subfield indicates the transmission rate of the EBCS Data frames of the EBCS traffic stream.

The format of the TX Rate subfield for DSSS, HR/DSSS, OFDM, or ERP is shown in Figure 9-1133 (DSSS / HR/DSSS / OFDM / ERP TX Rate subfield format(11bc)). The Data Rate subfield indicates the transmission rate multiplied by 2 in units of megabits per second.

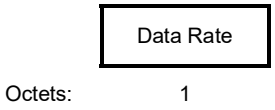


**Figure 9-1133—DSSS / HR/DSSS / OFDM / ERP TX Rate subfield format(11bc)**

The format of the TX Rate subfield for HT is defined in Figure 9-1134 (HT TX Rate subfield format(11bc)).

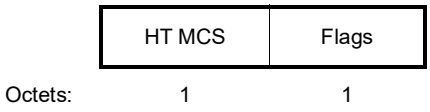


**Figure 9-1134—HT TX Rate subfield format(11bc)**

The MCS subfield indicates the HT MCS index. The format of the Flags subfield is shown in Figure 9-1135 (Flags subfield format(11bc)).


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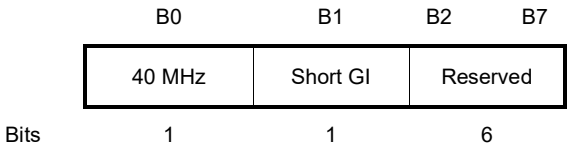


**Figure 9-1135—Flags subfield format(11bc)**

The 40 MHz subfield is set to 1 when the channel bandwidth is 40 MHz. Otherwise, the subfield is set to 0. The Short GI subfield is set to 1 when a short GI is used. Otherwise the subfield is set to 0.

The format of the TX Rate subfield for VHT is defined in Figure 9-1136 (VHT TX Rate subfield format(11bc)).

**Figure 9-1136—VHT TX Rate subfield format(11bc)**

The format of the VHT MCS subfield is defined in Figure 9-1137 (VHT MCS subfield format(11bc)).

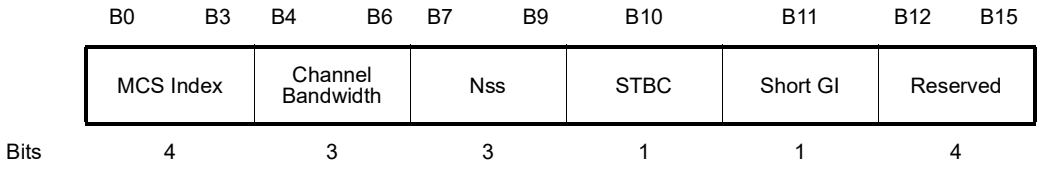


**Figure 9-1137—VHT MCS subfield format(11bc)**

The MCS Index subfield indicates the VHT MCS index.

The Channel Bandwidth subfield value is encoded as defined in Table 9-439 (VHT Channel Bandwidth subfield(11bc)).

**Table 9-439—VHT Channel Bandwidth subfield(11bc)**

| Value | Channel bandwidth |
|---|---|
| 0 | 20 MHz |
| 1 | 40 MHz |
| 2 | 80 MHz |
| 3 | 160 MHz |
| 4 | 80+80 MHz |
| 5–7 | Reserved |

The Nss subfield value indicates the $N_{ss}$ minus 1.

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The STBC subfield is set to 1 when STBC is used. Otherwise, the subfield is set to 0.

The Short GI subfield is set to 1 when a short GI is used. Otherwise, the subfield is set to 0.

The format of the TX Rate subfield for TVHT is shown in Figure 9-1138 (TVHT TX Rate subfield format(11bc)).

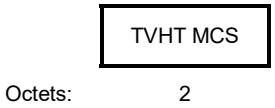


**Figure 9-1138—TVHT TX Rate subfield format(11bc)**

The format of the TVHT MCS subfield is shown in Figure 9-1139 (TVHT MCS Subfield format(11bc)).

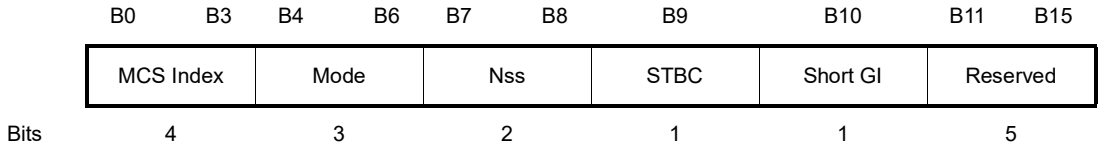


**Figure 9-1139—TVHT MCS Subfield format(11bc)**

The MCS Index subfield indicates the TVHT MCS index.

The Mode subfield value is encoded as defined in Table 9-440 (Mode subfield values(11bc)).The Nss

**Table 9-440—Mode subfield values(11bc)**

| Value | Mode |
|---|---|
| 0 | TVHT MODE 1 |
| 1 | TVHT MODE 2C |
| 2 | TVHT MODE 2N |
| 3 | TVHT MODE 4C |
| 4 | TVHT MODE 4N |
| 5–7 | Reserved |

subfield value indicates the $N_{ss}$ minus 1.

The STBC subfield is set to 1 when STBC is used. Otherwise, the subfield is set to 0.

The Short GI subfield is set to 1 when a short GI is used. Otherwise, the subfield is set to 0.

The format of the TX Rate subfield for S1G is shown in Figure 9-1140 (S1G TX Rate subfield format(11bc)).


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**Figure 9-1140—S1G TX Rate subfield format(11bc)**

The format of the S1G MCS subfield is shown in Figure 9-1141 (S1G MCS Subfield format(11bc)).

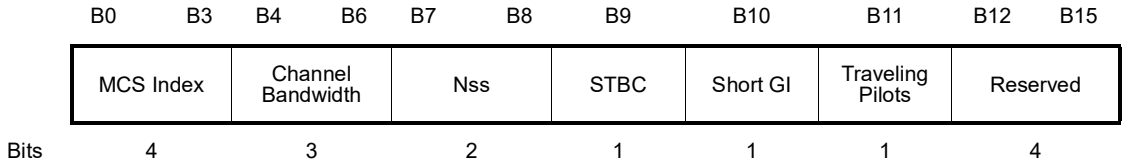


**Figure 9-1141—S1G MCS Subfield format(11bc)**

The MCS Index subfield indicates the S1G MCS index.

The Channel Bandwidth subfield value is encoded as defined in Table 9-441 (S1G Channel Bandwidth subfield values(11bc)).

**Table 9-441—S1G Channel Bandwidth subfield values(11bc)**

| Value | Channel Bandwidth |
|---|---|
| 0 | 1 MHz |
| 1 | 2 MHz |
| 2 | 4 MHz |
| 3 | 8 MHz |
| 4 | 16 MHz |
| 5–7 | Reserved |

The Nss subfield value indicates the $N_{ss}$ minus 1.

The STBC subfield is set to 1 when STBC is used. Otherwise, the subfield is set to 0.

The Short GI subfield is set to 1 when a short GI is used. Otherwise, the subfield is set to 0.

The Traveling Pilots subfield is set to 1 when traveling pilots are used. Otherwise, the subfield is set to 0.

The format of the TX Rate subfield for CMMG is defined in Figure 9-1142 (CMMG TX Rate subfield format(11bc)).

The format of the CMMG MCS subfield is shown in Figure 9-1143 (CMMG MCS subfield format(11bc)).

The MCS Index subfield indicates the CMMG MCS index.

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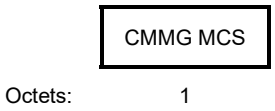


**Figure 9-1142—CMMG TX Rate subfield format(11bc)**

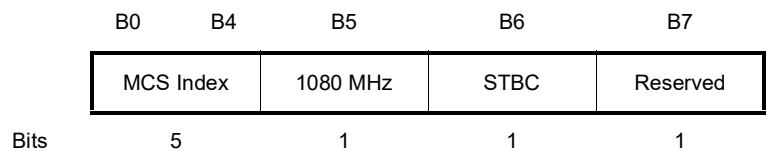


**Figure 9-1143—CMMG MCS subfield format(11bc)**

The 1080 MHz subfield is set to 1 when the channel bandwidth is 1080 MHz. Otherwise, the subfield is set to 0.

The STBC subfield is set to 1 when STBC is enabled. Otherwise, the subfield is set to 0.

The format of the HE TX Rate subfield is defined in Figure 9-1144 (HE TX Rate subfield format(11bc)).

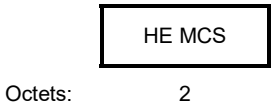


**Figure 9-1144—HE TX Rate subfield format(11bc)**

The format of the HE MCS subfield is defined in Figure 9-1145 (HE MCS Subfield format(11bc)).

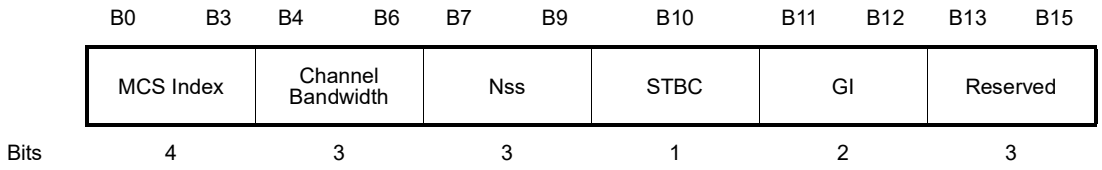


**Figure 9-1145—HE MCS Subfield format(11bc)**

The MCS Index subfield indicates the HE MCS index.

The Channel Bandwidth subfield value is encoded as shown in Table 9-439 (VHT Channel Bandwidth subfield(11bc)).

The Nss subfield value indicates the $N_{SS}$ minus 1.

The STBC subfield is set to 1 when STBC is used. Otherwise, the subfield is set to 0.

The GI subfield value is encoded as defined in Table 9-442 (HE GI subfield values(11bc)).

The Channel Configuration subfield indicates the channel configuration number.

The Time To Termination subfield is defined in 9.4.1.69 (EBCS Content Response field(11bc)).


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**Table 9-442—HE GI subfield values(11bc)**

| Value | Guard interval |
|---|---|
| 0 | 0.8 μs |
| 1 | 1.6 μs |
| 2 | 3.2 μs |
| 3 | Reserved |

The Next Tx Schedule subfield indicates the number of TBTTs until the beacon interval in which the next frame belonging to the EBCS traffic stream, identified by the Content ID subfield, is transmitted. A value of 0 indicates that this transmission occurs in the beacon interval that starts at the next TBTT. A value of 1 indicates that it occurs in the beacon interval that follows that beacon interval. A value of 65 535 indicates that there is no specific transmission starting time.

### 9.4.5.31 EBCS Content Request ANQP-element(11bc)

The EBCS Content Request ANQP-element transmits a register (or unregister) request from a STA to a peer STA to receive (or stop receiving) enhanced broadcast services that are available from the peer STA. The format of the EBCS Content Request ANQP-element is defined in Figure 9-1146 (EBCS Content Request ANQP-element format(11bc)).

**Figure 9-1146—EBCS Content Request ANQP-element format(11bc)**

The Info ID and Length fields are defined in 9.4.5.1 (General).

The EBCS Content Request Info subfield is defined in 9.4.1.68 (EBCS Content Request field(11bc)).

### 9.4.5.32 EBCS Content Response ANQP-element(11bc)

The EBCS Content Response ANQP-element provides a list of zero or more enhanced broadcast services that are available from a peer STA. The format of the EBCS Content Response ANQP-element is defined in Figure 9-1147 (EBCS Content Response ANQP-element format(11bc)).

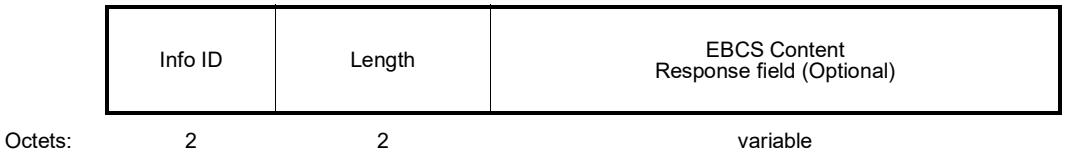


**Figure 9-1147—EBCS Content Response ANQP-element format(11bc)**

The Info ID and Length fields are defined in 9.4.5.1 (General).

The EBCS Content Response field is defined in 9.4.1.69 (EBCS Content Response field(11bc)).

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### 9.4.5.33 Credential Types ANQP-element(#93)

The Credential Types ANQP-element provides a STA with information about the types of credentials accepted via that AP. The format of the Credential Types ANQP-element is shown in Figure 9-1148 (Credential Types ANQP-element format(#93)).

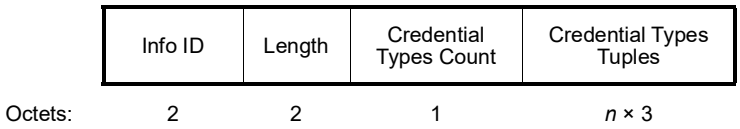


**Figure 9-1148—Credential Types ANQP-element format(#93)**

The Info ID and Length fields are defined in 9.4.5.1 (General).

The Credential Types Count field specifies the number *n* of Credential Types Tuple subfields.

The Credential Types Tuples subfield contains zero or more Credential Types Tuple subfields.

The format of the(M118) Credential Types Tuple subfield is shown in Figure 9-1149 (Credential Types Tuple subfield format(#93)).

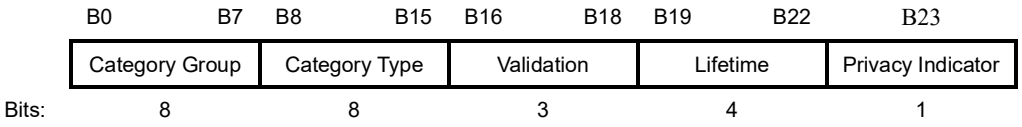


**Figure 9-1149—Credential Types Tuple subfield format(#93)**

The Category Group and Category Type subfields specify the credential issuer(s) accepted via the AP, mapped to the Venue group code and the Venue type code in Table 9-96 (Venue type assignments(#1595)), respectively.

The Validation subfield indicates the minimum type of credential validation (M118)for the credentials to be deemed valid. The values of the subfield are defined in Table 9-443 (Validation subfield values(#93)).

**Table 9-443—Validation subfield values(#93)**

| Value | Validation method | Notes |
|---|---|---|
| 0 | No verification | Credentials do not need to be verified |
| 1 | Any method allowed | |
| 2 | Email verification | |
| 3 | SMS verification | |
| 4 | Government ID | e.g., account obtained by showing a government ID |
| 5 | Government issued credentials | e.g., a certificate issued by a government |
| 6–7 | Reserved | |


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The Lifetime subfield indicates the minimum age required for the credentials to be acceptable, in units of year quarters.

The Privacy Indicator subfield is set to 1 if this AP requires the user to expose a contactable identity to the AP (usually for legal purposes). It is set to 0 if this AP accepts anonymous roaming.

### 9.4.5.34 Service Level Agreement ANQP-element(#93)(#1090)

The Service Level Agreement ANQP-element provides a STA with information about the type of roaming supported by the AP, and the service level agreement (SLA) offered by the AP for a given roaming type. The format of the SLA ANQP-element is shown in Figure 9-1150 (Service Level Agreement ANQP-element format(#93)).

| | Info ID | Length | Venue SLA Policy Count | Venue SLA Policy Tuples |
|---|---|---|---|---|
| Octets: | 2 | 2 | 1 | variable |

**Figure 9-1150—Service Level Agreement ANQP-element format(#93)**

The Info ID and Length fields are defined in 9.4.5.1 (General).

The Venue SLA Policy Count field specifies the number of Venue SLA Policy Tuple subfields.

The Venue SLA Policy Tuples subfield contains zero or more Venue SLA Policy Tuple subfields.

The format of a Venue SLA Policy Tuple subfield is shown in Figure 9-1151 (Venue SLA Policy Tuple subfield format(#93)(#1090)).

| | Length | Indicators | SLA Details |
|---|---|---|---|
| Octets: | 2 | 1 | variable |

**Figure 9-1151—Venue SLA Policy Tuple subfield format(#93)(#1090)**

The Length field contains the length of the remaining fields in octets.(#1090)

The Indicators subfield indicates the roaming services accepted by the venue and their associated SLAs. The format of the Indicators subfield is shown in Figure 9-1152 (Indicators subfield format(#93)).

| | B0 B1 | B2 B3 | B4 B5 | B6 B7 |
|---|---|---|---|---|
| | First Settlement Indicator | First SLA Indicator | Second Settlement Indicator | Second SLA Indicator |
| Bits: | 2 | 2 | 2 | 2 |

**Figure 9-1152—Indicators subfield format(#93)**

The First Settlement Indicator and Second Settlement Indicator subfields each indicate a type of roaming service accepted by the venue. The values of the First Settlement Indicator and Second Settlement Indicator subfields are specified in Table 9-444 (Settlement indicator values(#93)).

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**Table 9-444—Settlement indicator values(#93)**

| Value | Settlement Type |
|---|---|
| 0 | All |
| 1 | Free services |
| 2 | Paid services |
| 3 | Reserved |

The First SLA Indicator and Second SLA Indicator subfields each indicate the SLA that the AP offers for the respective settlement type. The values of the First SLA Indicator and Second SLA Indicator subfields are specified in Table 9-445 (SLA indicator values(#93)) and follow the Olympic model defined in IETF RFC 2597([B31]).

**Table 9-445—SLA indicator values(#93)**

| Value | SLA |
|---|---|
| 0 | No Olympic SLA |
| 1 | Bronze |
| 2 | Silver |
| 3 | Gold |

If the First SLA Indicator subfield is set to 0, the Second Settlement Indicator and Second SLA Indicator subfields are reserved. Otherwise, the First SLA Indicator and Second SLA Indicator subfields differ, and a nonzero value in the First SLA Indicator subfield takes precedence over a value of 0 in the Second SLA Indicator subfield, for the settlement type indicated by the First SLA Indicator subfield.

The SLA Details subfield is an optional vendor specific UTF-8 string that can be used to indicate the details of the SLA (e.g., minimum bandwidth, max jitter or delay, etc.). The content of this subfield is beyond the scope of this standard(#1560).

### 9.4.5.35 Excluded NAI Realm ANQP-Element(#93)

The Excluded NAI Realm ANQP-element provides a list of network access identifier (NAI) realms corresponding to SSPs or other entities whose networks or services are not accessible via this AP, even if they are members of a roaming consortium advertised by this AP. The format of the Excluded NAI Realm ANQP-element is shown in Figure 9-1153 (Excluded NAI Realm ANQP-element format(#93)).

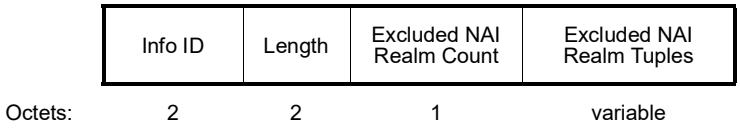


**Figure 9-1153—Excluded NAI Realm ANQP-element format(#93)**

The Info ID and Length fields are defined in 9.4.5.1 (General).

The Excluded NAI Realm Count field specifies the number of Excluded NAI Realm Tuple subfields.


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The Excluded NAI Realm Tuples field contains zero or more Excluded NAI Realm Tuple subfields.

The format of an Excluded NAI Realm Tuple subfield is shown in Figure 9-1154 (Excluded NAI Realm Tuples subfield format(#93)).

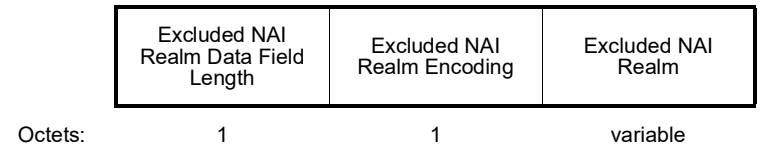


**Figure 9-1154—Excluded NAI Realm Tuples subfield format(#93)**

The Excluded NAI Realm Data Field Length subfield is equal to 1 plus the length in octets of the Excluded NAI Realm subfield.(#7224)

The Excluded NAI Realm Encoding subfield is shown in Figure 9-1155 (Excluded NAI Realm Encoding subfield format(#93)).

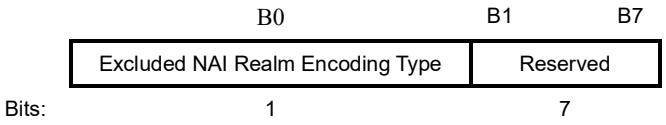


**Figure 9-1155—Excluded NAI Realm Encoding subfield format(#93)**

The Excluded NAI Realm Encoding Type subfield is set to 0 to indicate that the NAI realm(s) in the Excluded NAI Realm subfield is/are formatted in accordance with IETF RFC 4282. It is set to 1 to indicate that it/they might not be formatted in accordance with IETF RFC 4282.

The Excluded NAI Realm subfield contains one NAI realm formatted as defined in the Excluded NAI Realm Encoding Type subfield.

### 9.4.6 Registered location query protocol (RLQP) elements

#### 9.4.6.1 General

(#3428)RLQP-elements have a common format shown in Figure 9-1156 (RLQP-element format). Each element is assigned a unique Info ID as defined in this standard.

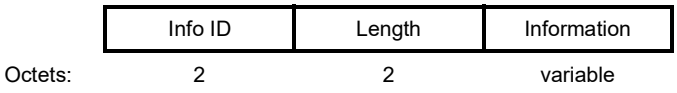


**Figure 9-1156—RLQP-element format**

Each RLQP-element in 9.4.6 (Registered location query protocol (RLQP) elements) is assigned a unique 2-octet Info ID. The set of valid Info IDs is defined in Figure 9-1156 (RLQP-element format).

The Length field indicates the number of octets in the Information field.

The RLQP-elements are shown in Table 9-446 (RLQP-element definitions).(#3380)

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**Table 9-446—RLQP-element definitions**

| RLQP-element name | Info ID | RLQP-element (subclause) |
|---|---|---|
| Reserved | 0–272 | N/A |
| Channel Availability Query | 273 | 9.4.6.2 (Channel Availability Query RLQP-element) |
| Channel Schedule Management | 274 | 9.4.6.3 (Channel Schedule Management RLQP-element) |
| Network Channel Control | 275 | 9.4.6.4 (Network Channel Control RLQP-element) |
| Reserved | 276–56 796 | N/A |
| Vendor Specific | 56 797 | 9.4.6.5 (Vendor Specific RLQP-element) |
| Reserved | 56 798–65 535 | N/A |

### 9.4.6.2 Channel Availability Query RLQP-element

The Channel Availability Query element is used to exchange the requests and responses for the channel availability query process using the GAS protocol. The Channel Availability Query RLQP-element is included in a GAS query request(#7052) or returned in a response to a GAS query request(#7052).

The element is in the format shown in Figure 9-1157 (Channel Availability Query RLQP-element format).

| | Info ID | Length | Requester STA Address | Responder STA Address | Reason Result Code | Channel Query Info | Device Class | Device Identification Information | Device Location Information | WSM Information |
|---|---|---|---|---|---|---|---|---|---|---|
| Octets: | 2 | 2 | 6 | 6 | 1 | 1 | variable | variable | variable | variable |

**Figure 9-1157—Channel Availability Query RLQP-element format**

The Info ID and Length fields are defined in 9.4.6.1 (General).

The RequesterSTAAddress field is the MAC address of the requesting STA that initiates the channel query process(#6293).

The ResponderSTAAddress field is the MAC address of the responding STA that responds to the channel query requesting STA(#6293).

The Reason Result Code field is used to indicate the reason that a channel availability query was generated. It also indicates the result of the query as successful or not and the reason when the query is not successful. (#8141)The Reason Result Code field values that have been allocated are shown in Table 9-447 (Reason Result Code field values).


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**Table 9-447—Reason Result Code field values**

| Reason Result Code field value | Name | Description |
|---|---|---|
| 0 | | Reserved. |
| 1 | | Channel availability list requested. |
| 2 | SUCCESS | Success with the available channel list result for a Device Location Information field. |
| 3 | SUCCESS_MULTIPLE | Success with an available channel list result for a bounded geographic area defined by multiple Device Location Information fields. |
| 4 | REFUSED | Request declined. |
| 5 | DEVICE_VERIFICATION_FAILURE | Request not successful because of device identification verification failure.<br>NOTE—Failure of providing an authorized identification of the corresponding regulatory organization can cause the responding STA to reject the query and return such a Reason Result Code. |
| 6 | Continuation frame | This frame continues the fields from the previous CAQ frame. |
| 7–255 | | Reserved. |

The Channel Query Info field is used to indicate the type of Channel Query request and associated parameters. The format of the Channel Query Info field is shown in Figure 9-1158 (Channel Query Info field format).

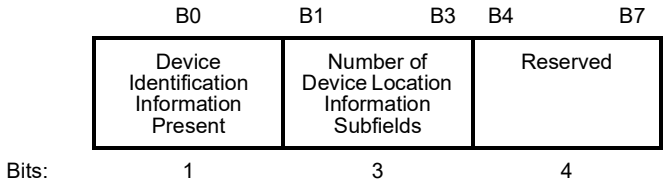


**Figure 9-1158—Channel Query Info field format**

The Device Identification Information Present subfield value is set to 1 to indicate that the Device Identification Information field is present in the Channel Availability Query element; otherwise it is set to 0 to indicate that the Device Identification Information field is not provided.

The Number of Device Location Information Subfields subfield indicates the number of device location information subfields presented in the Channel Availability Query element. When no device location is present, the Number of Device Location Information Subfields subfield is set to 0.

The Device Class field is used to indicate the characteristics of STA requesting the channel availability query. The format of the Device Class field is specified in 9.4.4.2.2 (Device Class). The Device Class field is present only when the Reason Result Code field value is 1.

The Device Identification Information field is used to indicate the identification of the STA requesting the channel availability query. The format of the Device Identification Information field is specified in 9.4.4.2.3 (Device Identification Information).

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The Device Location Information field is used to provide the location of the STA requesting the channel availability query, which is provided in the format specified in 9.4.4.2.4 (Device Location Information).

The WSM Information field is defined in the White Space Map element (see 9.4.2.168 (White Space Map element)). The WSM Information field is present only when the Reason Result Code field value is 2 or 3, as the successful result of the query.

### 9.4.6.3 Channel Schedule Management RLQP-element

The Channel Schedule Management element is used by an GDD enabling STA to query the RLSS or another GDD enabling STA for channel schedule information. The element is in the format shown in Figure 9-1159 (Channel Schedule Management RLQP-element format).

| | Info ID | Length | Requester STA Address | Responder STA Address | Reason Result Code | Channel Schedule Management Mode | Device Identification Information | Channel Schedule Descriptor |
|---|---|---|---|---|---|---|---|---|
| Octets: | 2 | 2 | 6 | 6 | 1 | 1 | variable | variable |

**Figure 9-1159—Channel Schedule Management RLQP-element format**

The Info ID and Length fields are defined in 9.4.6.1 (General).

The Requester STA Address field is the MAC address of the requesting STA that initiates the channel schedule management process.

The Responder STA Address field is the MAC address of the STA that responds to the STA that requested channel schedule management.

The remaining fields are as defined in the Channel Schedule Management element (see 9.6.7.26 (Channel Schedule Management frame format)).

### 9.4.6.4 Network Channel Control RLQP-element

The Network Channel Control element is used to request network channel control and respond to network channel requests using the GAS protocol. The element is in the format shown in Figure 9-1160 (Network Channel Control RLQP-element format).

| | | | | | | | a Network Channel Control triplet | | |
|---|---|---|---|---|---|---|---|---|---|
| | Info ID | Length | Requester STA Address | Responder STA Address | Reason Result Code | Number of Network Channel Control Triplets | Operating Class | Channel Number | Maximum Transmit Power |
| Octets: | 2 | 2 | 6 | 6 | 1 | 1 | 1 | 1 | 1 |

**Figure 9-1160—Network Channel Control RLQP-element format**

The Info ID and Length fields are defined in 9.4.6.1 (General).

The RequesterSTAAddress field is the MAC address of the requesting STA that initiates the network channel control process.


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The ResponderSTAAddress field is the MAC address of the STA that responds to the STA that requested network channel control.

The Reason Result Code field is used to indicate the reason that a Network Channel Control frame was generated. (#8141)The encoding of the Reason Result Code field is shown in Table 9-448 (Reason Result Code field values).

**Table 9-448—Reason Result Code field values**

| Reason Result Code field value | Name | Description |
|---|---|---|
| 0 | REQUEST | Network channel request. |
| 1 | SUCCESS | Success. |
| 2 | REFUSED | Request declined. |
| 3 | TOO_MANY_SIMULTANEOUS_REQUESTS | Network channel request denied because the GDD enabling STA is unable to handle additional GDD dependent STAs. |
| 4 | Continuation frame | This frame continues the fields from the previous NCC frame. |
| 5–255 | | Reserved. |

The Number of Network Channel Control Triplets field indicates the number of triplets of Operating Class, Channel Number, and Transmit Power Constraint fields.

The Operating Class field indicates the channel set for which the network channel control request applies. The Operating Class field and Channel Number field are used together to specify the channel frequency and channel bandwidth for which the network channel control applies. Values for the Operating Class field are shown in E.1 (Country information and operating classes).

In a request, the Channel Number field of a Network Channel Control frame indicates the channel that the requesting STA intends to operate on. In a response, the Channel Number field in the Network Channel Control frame indicates the channels that the responding STA permits the requesting STA to operate on. The Channel Number is defined within an Operating Class as shown in E.1 (Country information and operating classes).

The Maximum Transmit Power field gives the intended maximum transmit power in dBm for operation in the request frame and indicates the maximum allowable transmit power in dBm for operation in the response frame. The field is coded as a 2s complement signed integer in units of 0.5 dBm. The field is set to –128 when a requesting STA requests a responding STA to provide a network channel control response without specifying in the request the intended maximum transmit power.

### 9.4.6.5 Vendor Specific RLQP-element

The Vendor Specific RLQP-element is used to carry information not defined in this standard within a single defined format, so that reserved Info IDs are not usurped for nonstandard purposes and so that interoperability is more easily achieved in the presence of nonstandard information. The RLQP-element is in the format shown in Figure 9-1161 (Vendor Specific RLQP-element format).

The Info ID and Length fields are defined in 9.4.6.1 (General).

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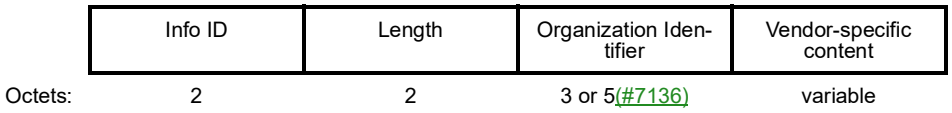


**Figure 9-1161—Vendor Specific RLQP-element format**

The Organization Identifier field contains the identity of the entity that has defined the content of the Vendor Specific RLQP-element (see 9.4.1.29 (Organization Identifier field) for a description of the Organization Identifier field contents and length).(#7136)

(#3376)The Vendor-specific content field contains vendor specific content.

## 9.5 Fields used in Management and Extension frame bodies and Control frames

### 9.5.1 SSW field(#4303)

(11ay)When the SSW field(#4303) is not transmitted in a DMG Beacon frame, the format of the SSW field is shown in Figure 9-1162 (SSW field format when not transmitted in a DMG Beacon frame(11ay)).

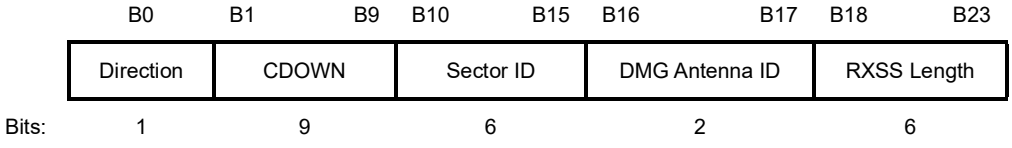


**Figure 9-1162—SSW field format when not transmitted in a DMG Beacon frame(11ay)**

(11ay)The format of the field when transmitted in a DMG Beacon frame is shown in Figure 9-1163 (SSW field format when transmitted in a DMG Beacon frame(11ay)).

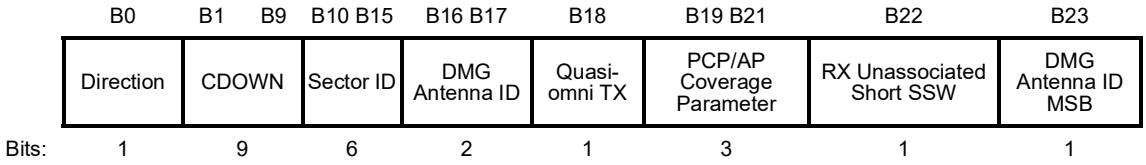


**Figure 9-1163—SSW field format when transmitted in a DMG Beacon frame(11ay)**

The Direction subfield is set to 0 to indicate that the frame is transmitted by the beamforming initiator and set to 1 to indicate that the frame is transmitted by the beamforming responder.

The CDOWN subfield is a down counter indicating the number of remaining DMG Beacon frame transmissions to the end of the TXSS, or the number of remaining SSW frame transmissions to the end of the TXSS/RXSS. This subfield is set to 0 in the last frame DMG Beacon and SSW frame transmission. Possible values range from 0 to 511.

The Sector ID subfield is set to indicate the sector number through which the frame containing this SSW field is transmitted.

The DMG Antenna ID subfield indicates the antenna (for a CMMG STA) or DMG antenna (for a DMG STA) the transmitter is currently using for this transmission.


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The RXSS Length subfield is valid only when transmitted in a CBAP and is reserved otherwise. The RXSS Length subfield specifies the length of a receive sector sweep as required by the transmitting STA and is defined in units of an SSW frame. The length of the sector sweep is given by $(\text{RXSS Length} + 1) \times 2$.

(11ay)The Quasi-omni TX subfield is set to 1 to indicate that the frame containing the SSW field(#4303) is transmitted with a quasi-omni antenna pattern and is set to 0 to indicate that the frame is not transmitted with a quasi-omni antenna pattern.

(11ay)The PCP/AP Coverage Parameter subfield contains the composite value describing the PCP or AP related link budget parameter specific for the sector and DMG antenna defined in Sector ID and DMG Antenna ID fields. For values 1 through 7, the value of this field is interpreted as (4×PCP/AP Coverage Parameter + 14) and is measured in dBm. This covers a range from 18 dBm to 42 dBm in 4 dBm steps. A value of 0 in the PCP/AP Coverage Parameter subfield indicates that this field to be ignored. The usage of PCP/AP Coverage Parameter subfield is described in 10.38.12.6 (“Near-Far” self classification).

NOTE—An EDMG PCP or EDMG AP can set the PCP/AP Coverage Parameter subfield to EIRP – $G_{omni\_rx}$ – $G_{add\_gain}$, where (a) EIRP is equal to $P + G_{tx}$, and $P$ and $G_{tx}$ are the transmit power and antenna gain, respectively, used in the DMG Beacon frame transmission; (b) $G_{omni\_rx}$ is the antenna gain of the AP or PCP receiver when in quasi-omni receive mode; and (c) $G_{add\_gain}$ is equal to $P_{min\_sensitivity} - P_{sensitivity}$, where $P_{min\_sensitivity}$ is the receiver sensitivity for MCS 0 defined in Table 20-3 and $P_{sensitivity}$ is the actual PCP or AP receiver sensitivity. Since the values of $G_{omni\_rx}$ and $G_{tx}$ can change for different directions, the value of the PCP/AP Coverage Parameter subfield in DMG Beacon frames transmitted through different sectors can be different.

(11ay)The RX Unassociated Short SSW subfield is set to 1 to indicate that the EDMG STA supports reception of Short SSW PPDUs from unassociated STAs during a CBAP. Otherwise, it is set to 0.

(11ay)The DMG Antenna ID MSB subfield is prepended to the DMG Antenna ID subfield to create a single 3-bit field.

### 9.5.2 Dynamic Allocation Info field

The format of the Dynamic Allocation Info field is shown in Figure 9-1164 (Dynamic Allocation Info field format).

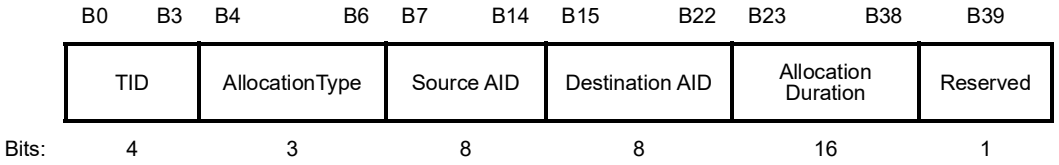


**Figure 9-1164—Dynamic Allocation Info field format**

The TID subfield identifies the TC or TS for the allocation request or grant.

NOTE—Unlike pseudo-static allocations, nonpseudo-static allocations are not labeled with an allocation ID, and are associated to a TID.

The AllocationType subfield is defined in 9.4.2.130 (Extended Schedule element).

The Source AID subfield identifies the STA that is the source of the allocation.

The Destination AID subfield identifies the STA that is the destination of the allocation.

When the Dynamic Allocation Info field is transmitted within an SPR frame, the Allocation Duration subfield contains the requested duration in microseconds. When the Dynamic Allocation Info subfield is transmitted within a Grant frame by an AP or PCP in an ATI or GP, the Allocation Duration subfield

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contains the granted duration of the SP or CBAP allocation in microseconds (see 10.38.3 (ATI transmission rules), 10.38.7 (Dynamic allocation of service period), 10.38.8 (Dynamic truncation of service period), and 10.38.9 (Dynamic extension of service period)). Possible values range from 0 to 32 767 for an SP allocation and a CBAP allocation. Setting the Allocation Duration subfield transmitted to 0 within a Grant frame means that the STA can transmit one PPDU followed by any relevant acknowledgment plus one RTS/DMG CTS handshake.

When the Dynamic Allocation Info subfield is transmitted within a Grant frame in a CBAP, the value of the Allocation Duration field indicates the purpose of the Grant frame transmission. Two purposes are possible:

a) Beyond current TXOP: in this case, the Allocation Duration subfield values range from 0 to 32 767. The value of the Allocation Duration field plus the Duration field of the Grant frame indicates the time offset from the PHY-TXEND.indication primitive of the Grant frame when the STA transmitting the Grant frame will attempt to initiate access for communication with the STA indicated by the RA field of the Grant frame.

b) Within current TXOP: in this case, the Allocation Duration subfield is set to 32 768.

When the Dynamic Allocation Info subfield is transmitted within a Grant frame with RA set to broadcast address by a source or destination STA of an SP, the Allocation Duration subfield values range from 0 to 32 767.

When the Dynamic Allocation Info subfield is transmitted within a Grant frame with RA set to individual address by a source STA of an SP, the Allocation Duration subfield is set to 32 768.

### 9.5.3 SSW Feedback field(#4303)

When the SSW Feedback field is transmitted as part of an ISS, the format of the field is as shown in Figure 9-1165 (SSW Feedback field format when transmitted as part of an ISS). Otherwise, the format of the SSW Feedback field is as shown in Figure 9-1166 (SSW Feedback field format when not transmitted as part of an ISS and the EDMG Extension Flag subfield is 1(11ay)) (11ay)when the EDMG Extension Flag subfield is 1 and in Figure 9-1167 (SSW Feedback field format when not transmitted as part of an ISS and the EDMG Extension Flag subfield is 0(11ay)) when the EDMG Extension Flag subfield is 0(#3061).

| | B0 B8 | B9 B10 | B11 B15 | B16 | B17 | B18 B21 | B22 | B23 |
|---|---|---|---|---|---|---|---|---|
| | Total Sectors in ISS | Number of RX DMG Antennas | Reserved | Poll Required | OCB(11bd) | Reserved | Unsolicited RSS Enabled(11ay) | Reserved |
| Bits: | 9 | 2 | 5 | 1 | 1 | 4 | 1 | 1 |

**Figure 9-1165—SSW Feedback field format when transmitted as part of an ISS**

| | B0B5 | B6B7 | B8B15 | B16 | B17 B21 | B22 | B23 |
|---|---|---|---|---|---|---|---|
| | Sector Select | DMG Antenna Select | SNR Report | Poll Required | Sector Select MSB(11ay) | DMG Antenna Select MSB(11ay) | EDMG Extension Flag(11ay) |
| Bits: | 6 | 2 | 8 | 1 | 5 | 1 | 1 |

**Figure 9-1166—SSW Feedback field format when not transmitted as part of an ISS and the EDMG Extension Flag subfield is 1(11ay)**



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| | B0 B5 | B6 B7 | B8 B15 | B16 | B17 | B18 B21 | B22 | B23 |
|---|---|---|---|---|---|---|---|---|
| | Sector Select | DMG Antenna Select | SNR Report | Poll Required | OCB(11bd) | Reserved | Unsolicited RSS Enabled | EDMG Extension Flag |
| Bits: | 6 | 2 | 8 | 1 | 1 | 4 | 1 | 1 |

**Figure 9-1167—SSW Feedback field format when not transmitted as part of an ISS and the EDMG Extension Flag subfield is 0(11ay)**

The Total Sectors in ISS subfield indicates the total number of sectors that the initiator uses in the ISS, including any repetition performed as part of multi-antenna beamforming. Possible values range from 0 to 511, representing 1 to 512 sectors.

The Number of RX DMG Antennas subfield indicates the number of receive DMG antennas the initiator uses during the following RSS. This subfield is set to the number of receive DMG antennas used minus 1.

(11ay)The EDMG Extension Flag subfield is 0 when the (#4303)SSW Feedback field is transmitted within an SSW frame, and when transmitted within an SSW-Feedback and SSW-Ack frame sent in response to an ISS or an RSS that used the SSW frame. Otherwise, the EDMG Extension Flag subfield is 1.

(11ay)The selected sector depends on the value of the EDMG Extension Flag subfield.

(11ay)If the EDMG Extension Flag subfield is 0, the Sector Select subfield contains the value of the Sector ID subfield of the SSW field within the frame that was received with best quality in the immediately preceding sector sweep. The determination of which frame was received with best quality is implementation dependent.

(11ay)If the EDMG Extension Flag subfield is 1, the Sector Select MSB subfield is prepended to the Sector Select subfield to form a single 11-bit subfield representing the value of the CDOWN field within the Short SSW PPDU that was received with the best quality in the immediately preceding sector sweep. The determination of which PPDU was received with the best quality is implementation dependent.

(11ay)The interpretation of the DMG Antenna Select subfield depends on the value of the EDMG Extension Flag subfield.

(11ay)If the EDMG Extension Flag subfield is 0, the DMG Antenna Select subfield indicates the value of the DMG Antenna ID subfield of the SSW field within the frame that was received with best quality in the immediately preceding sector sweep. The determination of which frame was received with best quality is implementation dependent.

(11ay)If the EDMG Extension Flag subfield is 1, the DMG Antenna Select MSB subfield is prepended to the DMG Antenna Select subfield to form a single 3-bit subfield representing the value of the RF Chain ID field within the Short SSW PPDU that was received with the best quality in the immediately preceding sector sweep. The determination of which PPDU was received with the best quality is implementation dependent.

(11ay)The Unsolicited RSS Enabled subfield is set to 1 to indicate that the STA is capable of receiving an unsolicited RSS and completing the SLS with any other STA that opportunistically receives this ISS or RSS, but that is not the STA addressed by this ISS or RSS (see 10.41.6.4 (BRP phase execution)). This subfield is set to 0 otherwise.

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The SNR Report subfield is set to the value of the SNR from the frame that was received with best quality during the immediately preceding sector sweep and is indicated in the Sector Select field. This subfield is encoded as 8-bit 2s complement value of 4×(SNR-19), where SNR is measured in dB. This covers from –13 dB to 50.75 dB in 0.25 dB steps.

The Poll Required subfield is set to 1 by a non-AP and non-PCP STA to indicate that it requires the AP or PCP to initiate communication with the non-AP and non-PCP. This subfield is set to 0 to indicate that the non-AP and non-PCP has no preference about whether the AP or PCP initiates the communication. This subfield is reserved when transmitted by an AP or PCP.

(11bd)The OCB subfield is set to 1 if dot11DMGOCBActivated is true, and is set to 0 otherwise. If equal to 1, this subfield indicates that the STA is operating outside the context of a BSS.

### 9.5.4 BRP Request field

The BRP Request field is defined in Figure 9-1168 (BRP Request field format).

| | B0 B4 | B5 | B6 | B7 | B8 | B9 | B10 | B11 B16 |
|---|---|---|---|---|---|---|---|---|
| | L-RX | TX-TRN-REQ | MID-REQ | BC-REQ | MID-Grant | BC-Grant | Chan-FBCK-CAP | TX Sector ID |
| Bits: | 5 | 1 | 1 | 1 | 1 | 1 | 1 | 6 |

| | B17 B24 | B25 B26 | B27 | B28 | B29 B31 |
|---|---|---|---|---|---|
| | Other_AID | TX DMG Antenna ID | EDMG-SHORT-BRP(11ay) | EDMG-SHORT-FBCK(11ay) | Reserved |
| Bits: | 8 | 2 | 1 | 1 | 3 |

**Figure 9-1168—BRP Request field format**

If the MID-REQ subfield is set to 0, the L-RX subfield indicates the number of TRN units requested by the transmitting STA for RX training as part of beam refinement. The L-RX subfield contains an unsigned integer between 0 and 16. Values outside this range are reserved. The number of requested TRN-R subfields is equal to the value of the L-RX subfield multiplied by 4. Other values are reserved. If the subfield is set to 0, the transmitting STA does not request receive training as part of beam refinement. If the MID-REQ subfield is set to 1, the L-RX subfield indicates the number of TRN units the STA uses during the MID phase for each TX sector/AWV.

The TX-TRN-REQ subfield is set to 1 to indicate that the STA requests transmit training as part of beam refinement. Otherwise, it is set to 0.

A STA sets the MID-REQ subfield to 1 in SSW-Feedback or BRP frames to indicate a request for an I-MID subphase or R-MID subphase; otherwise, the STA sets the subfield to 0 to indicate it is not requesting an I-MID subphase or R-MID subphase. In case an R-MID subphase is requested, the STA can include information on the TX sector IDs to be used by the STA receiving this request. The STA receiving this request sets the MID-grant subfield in SSW-Ack or BRP frames to 1 to grant this request or otherwise sets it to 0.

A STA sets the BC-REQ subfield to 1 in SSW-Feedback or BRP frames to indicate a request for an I/R-BC subphase; otherwise, the STA sets the subfield to 0 to indicate it is not requesting an I/R-BC subphase. In case an R-BC subphase is requested, the STA can include information on the TX sector IDs to be used by


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the STA receiving this request. The STA receiving this request sets the BC-grant subfield in SSW-Ack or BRP frames to 1 to grant this request; otherwise, the STA sets it to 0 to reject the request.

The Chan-FBCK-CAP subfield is set to 1 to indicate the STA is capable to return channel measurement during beam refinement. The Chan-FBCK-CAP subfield is set to 0 to indicate the STA is able to return only BS-FBCK during beam refinement.

NOTE—Regardless of the value of the Chan-FBCK-CAP subfield, 10.41.6.4 (BRP phase execution) requires a DMG STA to return the SNR values from the last TXSS if it receives a BRP frame with the TXSS-FBCK-REQ field and the SNR Requested subfield within the FBCK-REQ field both set to 1.

The TX Sector ID subfield indicates the sector ID that is used when transmitting the PPDU. If the PPDU is transmitted using a pattern that is not a sector that has been used in the sector sweep, this subfield is set to 0x63. This subfield is reserved if the BRP Request field is transmitted within an SSW-Feedback frame with the EDMG Extension Flag subfield set to 1 or within an SSW-Ack frame with the EDMG Extension Flag subfield set to 1.(11ay)

The Other_AID subfield is set to the AID of an additional STA referenced in the BRP procedure as described in 10.41.6.4.4 (Antenna configuration setting during a beam refinement transaction) and 20.9.2.2.6 (TRN field). Otherwise, if the additional STA is not used, this subfield is set to 0.

The TX DMG Antenna ID subfield indicates the DMG antenna ID that is used when transmitting the PPDU.This subfield is reserved if the BRP Request field is transmitted within an SSW-Feedback frame with the EDMG Extension Flag subfield set to 1 or within an SSW-Ack frame with the EDMG Extension Flag subfield set to 1.(11ay)

(11ay)The EDMG-SHORT-BRP subfield is set to 1 to indicate that an EDMG BRP field is present following the BRP Request field. Otherwise, this field is set to 0.

(11ay)The EDMG-SHORT-FBCK subfield is set to 1 to indicate that an EDMG Short FBCK field is present in the frame following the EDMG BRP field. Otherwise, this field is set to 0. This subfield is reserved if the EDMG-SHORT-BRP subfield is 0.

### 9.5.5 Beamforming Control field

The Beamforming Control field is formatted as shown in Figure 9-1169 (BF Control field format when both IsInitiatorTXSS and IsResponderTXSS subfields are equal to 1 and the BF Control field is transmitted in Grant or Grant Ack frames(#1729)) when both the IsInitiatorTXSS and IsResponderTXSS subfields are equal to 1, and the Beamforming Control field is transmitted in either a Grant or Grant Ack frames. In all other cases, the Beamforming Control field is formatted as shown in Figure 9-1170 (BF Control field format in all other cases(#1729)).

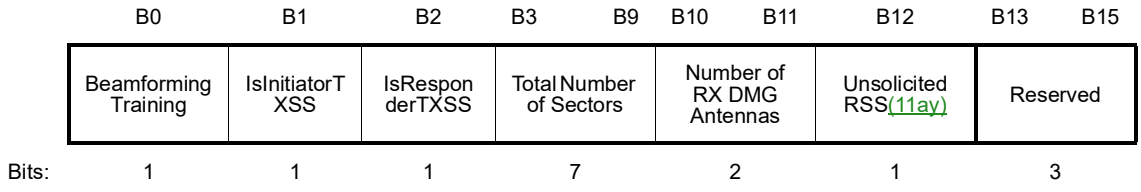


**Figure 9-1169—BF Control field format when both IsInitiatorTXSS and IsResponderTXSS subfields are equal to 1 and the BF Control field is transmitted in Grant or Grant Ack frames(#1729)**

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| | B0 | B1 | B2 | B3 B8 | B9 | B10 B11 | B12 | B13 B15 |
|---|---|---|---|---|---|---|---|---|
| | Beamforming Training | IsInitiatorTXSS | IsResponderTXSS | RXSS Length | RXSSTxRate | Reserved | Unsolicited RSS(11ay) | Reserved |
| Bits: | 1 | 1 | 1 | 6 | 1 | 2 | 1 | 3 |

**Figure 9-1170—BF Control field format in all other cases(#1729)**

The Beamforming Training subfield is set to 1 to indicate that the source DMG STA intends to initiate beamforming training with the destination DMG STA at the start of the allocation and is set to 0 otherwise. If the Beamforming Training subfield is set to 0, all other subfields of the Beamforming Control field are reserved.

The IsInitiatorTXSS subfield is set to 1 to indicate that the source DMG STA starts the beamforming training with an initiator TXSS. This subfield is set to 0 to indicate that the source DMG STA starts the BF training with an initiator RXSS. The IsInitiatorTXSS subfield is ignored if the Unsolicited RSS field is set to 1.(11ay)

The IsResponderTXSS subfield is set to 1 to indicate that the destination DMG STA, or the source EDMG STA if the Unsolicited RSS subfield is set to 1, starts the RSS with a responder TXSS. This subfield is set to 0 to indicate that the destination DMG STA, or the source EDMG STA if the Unsolicited RSS subfield is set to 1, is to initiate the RSS with a responder RXSS.(11ay)

(11ay)The Unsolicited RSS subfield is set to 1 to indicate the source EDMG STA intends to initiate an unsolicited RSS at the start of the TXOP or SP. This subfield is set to 0 to indicate the source EDMG STA intends to initiate an SLS with the ISS at the start of the allocation.

(11ay)The interpretation of the IsInitiatorTXSS, IsResponderTXSS, and Unsolicited RSS subfields are indicated in Table 9-449 (IsInitiatorTXSS, IsResponderTXSS, and Unsolicited RSS subfields(11ay)).

**Table 9-449—IsInitiatorTXSS, IsResponderTXSS, and Unsolicited RSS subfields(11ay)**

| Bit 1 | Bit 2 | Bit 12 | Meaning |
|---|---|---|---|
| 1 | 0 | 0 | Initiator TXSS and Responder RXSS |
| 0 | 1 | 0 | Initiator RXSS and Responder TXSS |
| 1 | 1 | 0 | Initiator TXSS and Responder TXSS |
| 0 | 0 | 0 | Initiator RXSS and Responder RXSS |
| N/A | 1 | 1 | Responder TXSS only (no ISS) |
| N/A | 0 | 1 | Responder RXSS only (no ISS) |

When the Beamforming Control field is transmitted within an Extended Schedule element, either the IsInitiatorTXSS subfield or the IsResponderTXSS subfield is set to 0, but not both.

The RXSS Length subfield is valid only if at least one of IsInitiatorTXSS subfield or IsResponderTXSS subfield is equal to 0 and is reserved otherwise. The value represented by the RXSS Length subfield specifies the total number of receive sectors combined over all receive DMG antennas of the STA, including any LBIFS as necessary for DMG antenna switching. The value represented by this subfield is in the range 2 to 128 and is given by (RXSS Length+1)×2.


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The RXSSTxRate subfield is valid only if the RXSS Length subfield is valid and the value of the RXSS Length subfield is greater than 0. Otherwise, the RXSSTxRate subfield is reserved. The RXSSTxRate subfield is set to 0 to indicate that all frames transmitted as part of the RXSS use the DMG Control modulation class (10.6.7.1 (Usage of DMG Control modulation class)). The RXSSTxRate subfield is set to 1 to indicate that only the first frame transmitted as part of the RXSS use the DMG Control modulation class and the remaining frames use MCS 1 of the DMG SC modulation class. If both the IsInitiatorTXSS and IsResponderTXSS subfields are set to 0 and the BF Control field is sent within a Grant frame, the RXSSTxRate subfield refers to the RSS only. If both the IsInitiatorTXSS and IsResponderTXSS subfields are set to 0 and the BF Control field is sent within a Grant Ack frame, the RXSSTxRate subfield refers to the ISS only.

When the BF Control field is transmitted in a Grant frame, the Total Number of Sectors subfield indicates the total number of sectors the initiator uses during the ISS, including any LBIFS required for DMG antenna switching (see 10.41 (DMG beamforming)). When the BF Control field is transmitted in a Grant Ack frame, the Total Number of Sectors subfield indicates the total number of sectors the responder uses during the RSS. In both cases, this field is set to the total number of sectors used minus 1.

When the BF Control field is transmitted in a Grant frame, the Number of RX DMG Antennas subfield indicates the number of receive DMG antennas the initiator uses during the RSS. When the BF Control field is transmitted in a Grant Ack frame, the Number of RX DMG Antennas subfield indicates the number of receive DMG antennas the responder uses during the ISS. In both cases, this subfield is set to the number of receive DMG antennas used minus 1.

When the BF Control field is transmitted in a Grant Ack frame in response to a Grant frame with the Beamforming Training field equal to 0, the following fields are reserved: IsInitiatorTXSS, IsResponderTXSS, Total Number of Sectors, and Number of RX DMG Antennas.

### 9.5.6 Beamformed Link Maintenance field

The Beamformed Link Maintenance field is shown in Figure 9-1171 (Beamformed Link Maintenance field format) and provides a DMG STA with the value of dot11BeamLinkMaintenanceTime.

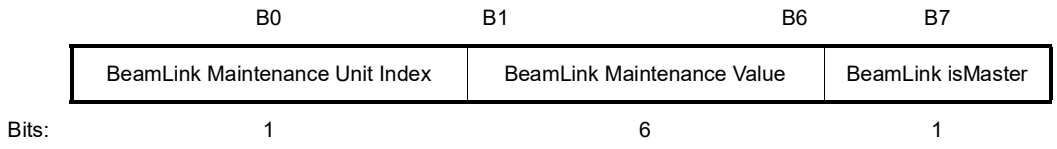


**Figure 9-1171—Beamformed Link Maintenance field format**

The encoding of the BeamLink Maintenance Unit Index subfield is specified in Table 9-450 (Encoding of BeamLink Maintenance Unit Index).

**Table 9-450—Encoding of BeamLink Maintenance Unit Index**

| BeamLink Maintenance Unit Index | BeamLink Maintenance Unit (μs) |
|---|---|
| 0 | 32 |
| 1 | 2000 |

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If the content of the BeamLink Maintenance Value subfield is greater than 0, it is used to calculate dot11BeamLinkMaintenanceTime as follows:

$$dot11BeamLinkMaintenanceTime = BLMU \times BLMV$$

where

*BLMU* is the value of the BeamLink Maintenance Unit corresponding to the value of the BeamLink Maintenance Unit Index subfield (see Table 9-450 (Encoding of BeamLink Maintenance Unit Index))

*BLMV* is the value of the BeamLink Maintenance Value subfield

Otherwise, if the BeamLink Maintenance Value subfield is set to 0, the dot11BeamLinkMaintenanceTime is left undefined. An undefined value of the dot11BeamLinkMaintenanceTime indicates that the STA does not participate in beamformed link maintenance.

The BeamLink isMaster subfield is set to 1 to indicate that the STA is the master of the data transfer and set to 0 otherwise. The STAs use the BeamLink isMaster subfield to negotiate the dot11BeamLinkMaintenanceTime as specified in Table 9-451 (The Beamformed Link Maintenance negotiation).

NOTE—In Table 9-451 (The Beamformed Link Maintenance negotiation), STA-A and STA-B refer to any of the STAs performing the Beamformed Link Maintenance negotiation procedure in no particular order.

**Table 9-451—The Beamformed Link Maintenance negotiation**

| BeamLink isMaster subfield (STA-A) | BeamLink isMaster subfield (STA-B) | dot11BeamLinkMaintenanceTime (STA-A) vs. dot11BeamLinkMaintenanceTime (STA-B) | Result |
|---|---|---|---|
| 0 | 0 | ≥ | dot11BeamLinkMaintenanceTime (STA-A) |
| 1 | 0 | >, <, = | dot11BeamLinkMaintenanceTime (STA-A) |
| 1 | 1 | = | dot11BeamLinkMaintenanceTime (STA-A) |
| 0 or 1 | 0 or 1 | If either dot11BeamLinkMaintenanceTime (STA-A) or dot11BeamLinkMaintenanceTime (STA-B) is undefined | Undefined |


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### 9.5.7 EDMG BRP field(11ay)

The EDMG BRP field combines the EDMG BRP Request element and the DMG Beam Refinement element into a fixed size field for use in a fixed sized version of the BPR frame (see 9.6.21.3 (BRP frame format)). The EDMG BRP field is defined in Figure 9-1172 (EDMG BRP field format(11ay)).

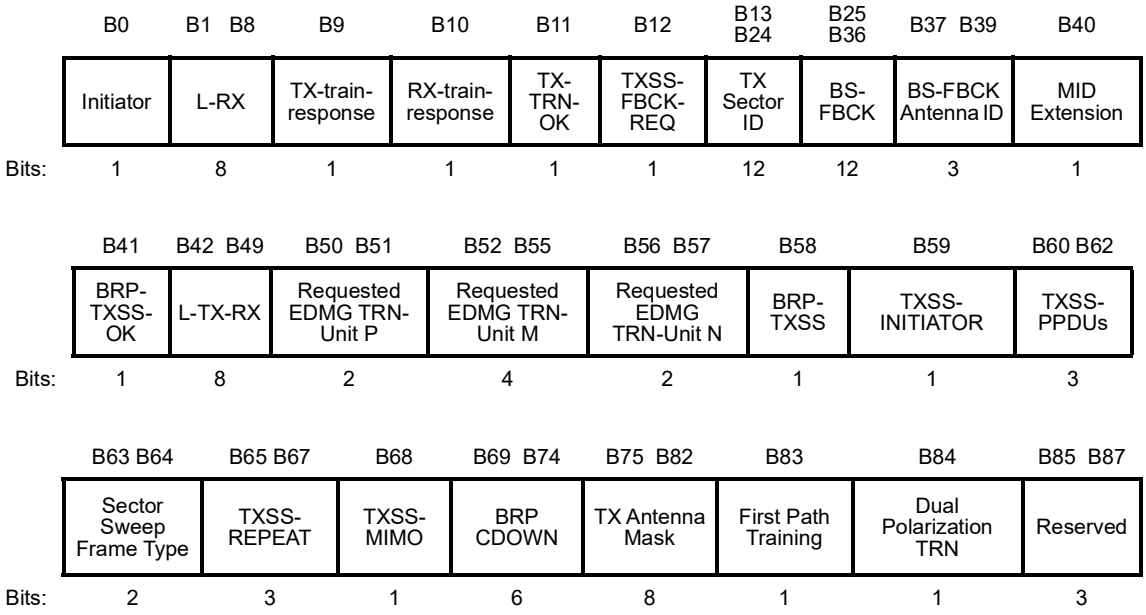


**Figure 9-1172—EDMG BRP field format(11ay)**

The Initiator, TX-train-response, RX-train-response, TX-TRN-OK, TXSS-FBCK-REQ, BS-FBCK, BS-FBCK Antenna ID, Sector Sweep Frame Type, and MID Extension subfields are defined in 9.4.2.128 (DMG Beam Refinement element).

The L-RX, TX Sector ID, L-TX-RX, Requested EDMG TRN-Unit P, Requested EDMG TRN-Unit M, Requested EDMG TRN-Unit N, BRP-TXSS, TXSS-INITIATOR, TXSS-PPDUs, TXSS-REPEAT, TXSS-MIMO, BRP CDOWN, TX Antenna Mask, First Path Training, and Dual Polarization TRN subfields are defined in 9.4.2.269 (EDMG BRP Request element(11ay)).

### 9.5.8 Short BRP Feedback field(11ay)

The Short BRP Feedback field carries feedback information of up to 16 sectors and is defined in Figure 9-1173 (Short BRP Feedback field format(11ay)).

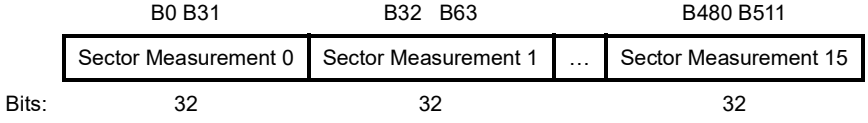


**Figure 9-1173—Short BRP Feedback field format(11ay)**

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Each Sector Measurement *i* subfield, $0 \le i \le 15$, has the same format and is defined in Figure 9-1174 (Sector Measurement subfield format(11ay)).

| | B0 B10 | B11 B16 | B17 B19 | B20 B22 | B23 B30 | B31 |
|---|---|---|---|---|---|---|
| | Sector ID/CDOWN/AWV ID | BRP CDOWN | TX Antenna ID | RX Antenna ID | SNR | Reserved |
| Bits: | 11 | 6 | 3 | 3 | 8 | 1 |

**Figure 9-1174—Sector Measurement subfield format(11ay)**

If the Sector Measurement subfield contains the feedback for a sector sweep performed using SSW frames, or Short SSW PPDUs, or DMG Beacon frames, the Sector ID/CDOWN/AWV ID subfield indicates the Sector ID of a PPDU received in the sector sweep, the TX Antenna ID subfield indicates the DMG antenna ID indicated in the PPDU, and the RX Antenna ID subfield indicates the receive DMG antenna through which the SNR contained in the SNR subfield was measured.

If the Sector Measurement subfield contains the feedback for a sector sweep performed using BRP-TX PPDUs, the Sector ID/CDOWN/AWV ID subfield contains the AWV feedback ID of the TRN subfields over which the SNR in the SNR subfield was measured. The BRP CDOWN field contains the value of the BRP CDOWN field in the BRP frame through in which the SNR in the SNR subfield was measured. The TX Antenna ID subfield has the value of the TX Antenna Mask field in the received BRP frame and the RX Antenna ID subfield indicates the receive DMG antenna through which the SNR in the SNR subfield was measured.

The encoding of the SNR subfield is defined in 9.4.2.135 (Channel Measurement Feedback element). A value of 254 in the SNR subfield indicates SNR values greater than or equal to 55.5 dB. A value of 255 indicates that this Sector Measurement subfield is invalid.

### 9.5.9 Sector Feedback field(11ay)

The Sector Feedback field is defined in Figure 9-1175 (Sector Feedback field format(11ay)).

| | RA | SSW Feedback | BRP Request | Beamformed Link Maintenance |
|---|---|---|---|---|
| Octets: | 6 | 3 | 4 | 1 |

**Figure 9-1175—Sector Feedback field format(11ay)**

The RA field contains the MAC address of the STA that is the intended destination of the Sector Feedback field.

The SSW Feedback field is defined in Figure 9-1165 (SSW Feedback field format when transmitted as part of an ISS).

The BRP Request field is defined in 9.5.4 (BRP Request field).

The Beamformed Link Maintenance field is defined in 9.5.6 (Beamformed Link Maintenance field).


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## 9.6 Action frame format details

### 9.6.1 General(11ax)

Subclause 9.6 (Action frame format details)(#1623) describes the Action field formats allowed in each of the action categories defined in Table 9-81 (Category values) in 9.4.1.11 (Action field). The frames defined in this subclause are Action frames, unless stated explicitly to be Action No Ack frames.

In the Action field formats defined in 9.6 (Action frame format details)(#1623), the fields and elements listed are always present unless stated otherwise.

### 9.6.2 Spectrum Management Action frame details(#3729)

#### 9.6.2.1 Spectrum Management Action field(#3729)

Five Action frame formats are defined for spectrum management. A Spectrum Management Action field, in the field immediately after the Category field, differentiates the five formats. The Spectrum Management Action field values associated with each frame format are defined in Table 9-452 (Spectrum Management Action field values).

**Table 9-452—Spectrum Management Action field values**

| Spectrum Management Action field value | Description |
|---|---|
| 0 | Spectrum Measurement Request |
| 1 | Spectrum Measurement Report |
| 2 | TPC Request |
| 3 | TPC Report |
| 4 | Channel Switch Announcement |
| 5–255 | Reserved |

#### 9.6.2.2 Spectrum Measurement Request frame format

The Spectrum Measurement Request frame is transmitted to request another STA to measure one or more channels. The format of the Spectrum Measurement Request frame Action field is shown in Figure 9-1176 (Spectrum Measurement Request frame Action field format).

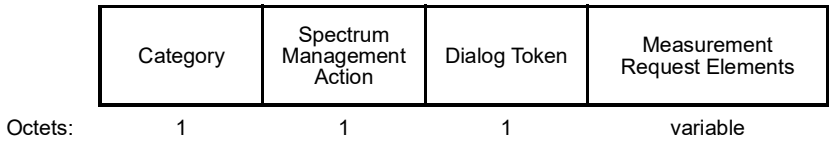


**Figure 9-1176—Spectrum Measurement Request frame Action field format**

The Category field is defined in 9.4.1.11 (Action field).

The Spectrum Management Action field is defined in 9.6.2.1 (Spectrum Management Action field(#3729)).

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(#417)The Dialog Token field is defined in 9.4.1.12 (Dialog Token field). It is set to a nonzero value chosen by the STA sending the measurement request to identify the request/report transaction.

The Measurement Request Elements field contains one or more of the Measurement Request elements described in 9.4.2.19 (Measurement Request element). The number and length of the Measurement Request elements in a Spectrum Measurement Request frame are limited by the maximum allowed MMPDU size.

### 9.6.2.3 Spectrum Measurement Report frame format

The Spectrum Measurement Report frame is transmitted in response to a Spectrum Measurement Request frame or transmitted autonomously providing measurement information. The format of the Spectrum Measurement Report frame Action field is shown in Figure 9-1177 (Spectrum Measurement Report frame Action field format).

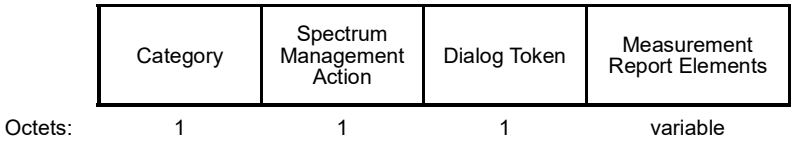


**Figure 9-1177—Spectrum Measurement Report frame Action field format**

The Category field is defined in 9.4.1.11 (Action field).

The Spectrum Management Action field is defined in 9.6.2.1 (Spectrum Management Action field(#3729)).

(#417)The Dialog Token field is defined in 9.4.1.12 (Dialog Token field). It is set to the same value as the Dialog Token field of the corresponding Spectrum Measurement Request frame. If the Spectrum Measurement Report frame is not being transmitted in response to a Spectrum Measurement Request frame, then the dialog token is set to 0.

The Measurement Report Elements field contains one or more of the Measurement Report elements described in 9.4.2.20 (Measurement Report element). The number and length of the Measurement Report elements in a Spectrum Measurement Report frame are limited by the maximum allowed MMPDU size.

### 9.6.2.4 TPC Request frame format

The TPC Request frame is transmitted requesting another STA for transmit power and link margin information. The format of the TPC Request frame Action field is shown in Figure 9-1178 (TPC Request frame Action field format).

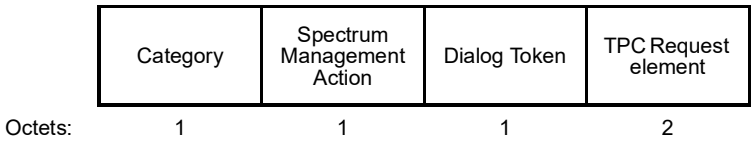


**Figure 9-1178—TPC Request frame Action field format**

The Category field is defined in 9.4.1.11 (Action field).

The Spectrum Management Action field is defined in 9.6.2.1 (Spectrum Management Action field(#3729)).

(#417)The Dialog Token field is defined in 9.4.1.12 (Dialog Token field). It is set to a nonzero value chosen by the STA sending the request to identify the transaction.


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The TPC Request element is set as described in 9.4.2.14 (TPC Request element).

### 9.6.2.5 TPC Report frame format

The TPC Report frame is transmitted in response to a TPC Request frame. The format of the TPC Report frame Action field is shown in Figure 9-1179 (TPC Report frame Action field format).

| | Category | Spectrum Management Action | Dialog Token | TPC Report element |
|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 4 |

**Figure 9-1179—TPC Report frame Action field format**

The Category field is defined in 9.4.1.11 (Action field).

The Spectrum Management Action field is defined in 9.6.2.1 (Spectrum Management Action field(#3729)).

(#417)The Dialog Token field is defined in 9.4.1.12 (Dialog Token field). It is set to the value of the Dialog Token field in the corresponding TPC Request frame.

The TPC Report element is set as described 9.4.2.15 (TPC Report element).

### 9.6.2.6 Channel Switch Announcement frame format

The Channel Switch Announcement frame is transmitted by a non-DMG AP, non-DMG IBSS STA, or mesh STA to advertise a channel switch. The format of the Channel Switch Announcement frame Action field is shown in Figure 9-1180 (Channel Switch Announcement frame Action field format).

| | Category | Spectrum Management Action | Channel Switch Announcement element | Secondary Channel Offset element |
|---|---|---|---|---|
| Octets: | 1 | 1 | 5 | 0 or 3 |
| | | Optional | Zero or more | Zero or one |
| | Mesh Channel Switch Parameters element | Wide Bandwidth Channel Switch element | New Transmit Power Envelope Element (M118) | Max Channel Switch Time Element (#7160) |
| Octets: | 0 or 8 | 0 or 5 | variable | 0 or 6 |

**Figure 9-1180—Channel Switch Announcement frame Action field format**

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The Category field is defined in 9.4.1.11 (Action field).

The Spectrum Management Action field is defined in 9.6.2.1 (Spectrum Management Action field(#3729)).

The Channel Switch Announcement element is set as described 9.4.2.17 (Channel Switch Announcement element).

The Secondary Channel Offset element is defined in 9.4.2.18 (Secondary Channel Offset element). This element is present when switching to a 40 MHz or wider channel. It can be present when switching to a 20 MHz channel (in which case the Secondary Channel Offset field is set to SCN); see 11.38.4 (Channel switching methods for a VHT BSS).

The Mesh Channel Switch Parameters element is defined in 9.4.2.101 (Mesh Channel Switch Parameters element). This element is present when a mesh STA performs MBSS channel switching. Otherwise, the Mesh Channel Switch Parameters element is not present.

The Wide Bandwidth Channel Switch element is defined in 9.4.2.159 (Wide Bandwidth Channel Switch element). This element is present when switching to a channel width wider than 40 MHz.

Each New Transmit Power Envelope element that is present is defined to have the same format as the Transmit Power Envelope element (see 9.4.2.160 (Transmit Power Envelope element)) and includes a distinct value of the Local Maximum Transmit Power Unit Interpretation subfield. If present, the New Transmit Power Envelope element indicates the local maximum transmit powers for the BSS for the indicated bandwidths with an indicated unit interpretation after channel switching (see 11.38.1 (Basic VHT BSS functionality)).

(#7160)(#8094)The Max Channel Switch Time Element field, if present, contains a Max Channel Switch Time element as defined in 9.4.2.216 (Max Channel Switch Time element).

### 9.6.3 QoS Action frame details

#### 9.6.3.1 QoS Action field(#3729)

Several Action frame formats are defined for QoS purposes. These frames are identified by the single octet QoS Action field, which follows immediately after the Category field. The values of the QoS Action field are defined in Table 9-453 (QoS Action field values).

**Table 9-453—QoS Action field values**

| QoS Action field value | Meaning |
|---|---|
| 0 | ADDTS Request |
| 1 | ADDTS Response |
| 2 | DELTS |
| 3 | Schedule |
| 4 | QoS Map Configure |
| 5 | ADDTS Reserve Request |
| 6 | ADDTS Reserve Response |
| 7–255 | Reserved |


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Two variants are defined for the ADDTS frames: a Basic ADDTS frame variant and a DMG ADDTS frame variant. These variants use different TSPEC formats. The variant of the frame is indicated by the Element ID in the fourth field of the ADDTS Request frame Action field format (see Table 9-456 (Basic ADDTS Request frame variant Action field format) and Table 9-457 (DMG ADDTS Request frame variant Action field format)) and sixth field of the ADDTS Response frame Action field format (see Table 9-458 (Basic ADDTS Response frame variant Action field format) and Table 9-459 (DMG ADDTS Response frame variant Action field format)). The Element ID is the first octet of each of these fields. The encoding of the ADDTS frame variants is shown in Table 9-454 (Encoding of the ADDTS Request frame variant) and Table 9-455 (Encoding of the ADDTS Response frame variant).

**Table 9-454—Encoding of the ADDTS Request frame variant**

| Element ID of fourth field of ADDTS Request frame | ADDTS Request frame variant |
|---|---|
| 13 (TSPEC) | Basic ADDTS Request frame |
| 146 (DMG TSPEC) | DMG ADDTS Request frame |

**Table 9-455—Encoding of the ADDTS Response frame variant**

| Element ID of sixth field of ADDTS Response frame | ADDTS Response frame variant |
|---|---|
| 13 (TSPEC) | Basic ADDTS Response frame |
| 146 (DMG TSPEC) | DMG ADDTS Response frame |

### 9.6.3.2 Basic and DMG ADDTS Request frame format

#### 9.6.3.2.1 Basic ADDTS Request frame variant

The ADDTS frames are used to carry TSPEC and optionally TCLAS elements to set up and maintain TSs using the procedures defined in 11.4 (TS operation).

The Action field of the ADDTS Request frame contains the information shown in Table 9-456 (Basic ADDTS Request frame variant Action field format).

**Table 9-456—Basic ADDTS Request frame variant Action field format**

| Order | Information | Notes |
|---|---|---|
| 1 | Category | |
| 2 | QoS Action | |
| 3 | Dialog token | |
| 4 | TSPEC | |
| 5 | TCLAS | Optional |
| 6 | TCLAS Processing | Optional |
| 7 | U-APSD Coexistence | Optional |

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**Table 9-456—Basic ADDTS Request frame variant Action field format**

| | | |
|---|---|---|
| 8 | Expedited Bandwidth Request | Optional |
| 9 | Intra-Access Category Priority | Optional |
| 10 | Higher Layer Stream ID | Only in AP-initiated TS setup |
| 11 | Multi-band | Optional |
| 12 | U-PID | Optional |
| 13 | Multiple MAC Sublayers | Optional |

The Category field is defined in 9.4.1.11 (Action field).

The QoS Action field is defined in 9.6.3.1 (QoS Action field(#3729)).

The values of the Dialog Token, TCLAS, and subsequent fields of this frame are the same as the values of the corresponding parameters in the invocation of the MLME-ADDTS.request primitive that causes the frame to be sent. Some of the TSPEC parameters have the same values as the corresponding parameters in the invocation of the MLME-ADDTS.request primitive, while the values of the other fields (i.e., Surplus Bandwidth Allowance, Minimum Service Interval, Maximum Service Interval, and Minimum PHY Rate) are generated within the MAC.

The TSPEC element, defined in 9.4.2.28 (TSPEC element), and the optional TCLAS element, defined in 9.4.2.29 (TCLAS element), contain the QoS parameters that define the TS. The TS is identified by the TSID and Direction fields within the TSPEC element. The TCLAS element is optional at the discretion of the STA that sends the ADDTS Request frame, regardless of the setting of the access policy (EDCA, SPCA, or HCCA). There are zero or more TCLAS elements in the ADDTS frame. The TCLAS Processing element is present when there is more than one TCLAS element and is defined in 9.4.2.31 (TCLAS Processing element). An Expedited Bandwidth Request element is optionally present, which is defined in 9.4.2.92 (Expedited Bandwidth Request element).

The U-APSD Coexistence element, defined in 9.4.2.89 (U-APSD Coexistence element), contains the coexistence parameters requested by the non-AP STA when using the U-APSD coexistence capability as described in 11.2.3.5.2 (U-APSD coexistence). The U-APSD Coexistence element is optionally present.

An Intra-Access Category Priority element is optionally present, which is defined in 9.4.2.119 (Intra-Access Category Priority element) and described in 11.4.1 (Introduction).

The Higher Layer Stream ID element (9.4.2.123 (Higher Layer Stream ID element)) provides the stream identifier from a higher layer protocol. The Higher Layer Stream ID element is present only in the AP-initiated TS setup (11.4.4.3 (AP-initiated TS setup)).

When present in an ADDTS Request frame, the Multi-band element indicates the frequency band, operating class, and channel number to which the ADDTS Request frame applies and contains band-specific information.

When present in the ADDTS Request frame, the U-PID element indicates the upper layer protocol associated with the TID/TSID specified within the TSPEC element contained in this frame.

When present in the ADDTS Request frame, the Multiple MAC Sublayers element is used to establish an MMSL cluster.


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#### 9.6.3.2.2 DMG ADDTS Request frame variant

The DMG ADDTS Request frame is used by DMG STAs in a PBSS and in an infrastructure BSS. The Action field of the DMG ADDTS Request frame contains the information shown in Table 9-457 (DMG ADDTS Request frame variant Action field format).

**Table 9-457—DMG ADDTS Request frame variant Action field format**

| Order | Information | Notes |
|---|---|---|
| 1 | Category | |
| 2 | Action | |
| 3 | Dialog Token | |
| 4 | DMG TSPEC | |
| 5 | TSPEC | Optional |
| 6 | TCLAS | Optional |
| 7 | TCLAS Processing | Optional |
| 8 | Multi-band | Optional |
| 9 | U-PID | Optional |
| 10 | Multiple MAC Sublayers | Optional |
| 11 | Higher Layer Stream ID | Optional |

The values of the Dialog Token, DMG TSPEC, TSPEC, TCLAS, and subsequent fields of this frame are the same as the values of the corresponding parameters in the invocation of the MLME-ADDTS.request primitive that causes the frame to be sent.

The DMG TSPEC element contains the parameters that define an allocation. The allocation uniquely identified by the Source AID, Allocation ID, and Destination AID subfields within the DMG TSPEC element.

The optional TSPEC element defines a TS that can use the allocation if the allocation is created successfully.

The optional TCLAS element is used to identify the destination non-AP and non-PCP DMG STA of the ADDTS Request frame. If a TSPEC element is not present, then the TCLAS element is not present. There can be one or more TCLAS elements in the DMG ADDTS Request frame. The TCLAS Processing element is present if there is more than one TCLAS element.

When present in a DMG ADDTS Request frame, the Multi-band element indicates the frequency band, operating class, and channel number to which the TS identified by the optional TSPEC element applies.

When present in the DMG ADDTS Request frame, the U-PID element indicates the upper layer protocol associated with the TS identified by the optional TSPEC element contained in this frame. If a TSPEC element is not present in the frame, the U-PID element is not present in the frame.

When present in the DMG ADDTS Request frame, the Multiple MAC Sublayers element is used to establish an MMSL cluster.

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### 9.6.3.3 Basic and DMG ADDTS Response frame format

#### 9.6.3.3.1 Basic ADDTS Response frame variant

The ADDTS Response frame is transmitted in response to an ADDTS Request frame. The Action field of the ADDTS Response frame contains the information shown in Table 9-458 (Basic ADDTS Response frame variant Action field format).

**Table 9-458—Basic ADDTS Response frame variant Action field format**

| Order | Information | Notes |
|---|---|---|
| 1 | Category | |
| 2 | QoS Action | |
| 3 | Dialog Token | |
| 4 | Status Code | |
| 5 | TS Delay | |
| 6 | TSPEC | |
| 7 | TCLAS | Optional |
| 8 | TCLAS Processing | Optional |
| 9 | Schedule | Optionally present if the status code is equal to SUCCESS; otherwise not present |
| 10 | Expedited Bandwidth Request | Optional |
| 11 | Higher Layer Stream ID | Only in AP-initiated TS setup |
| 12 | Multi-band | Optional |
| 13 | U-PID | Optional |
| 14 | Multiple MAC Sublayers | Optional |

The Category field is defined in 9.4.1.11 (Action field).

The QoS Action field is defined in 9.6.3.1 (QoS Action field(#3729)).

The Status Code field is defined in 9.4.1.9 (Status Code field).

The values the Dialog Token, TS Delay, TSPEC, TCLAS, and subsequent fields in this frame are the same as the values of the corresponding parameters in the invocation of the MLME-ADDTS.response primitive that causes the frame to be sent. The TS Delay element is present in an ADDTS Response frame only if the status code is equal to REJECTED_FOR_DELAY_PERIOD.

The Schedule element, defined in 9.4.2.32 (Schedule element), is present in an ADDTS Response frame only if the status code is equal to SUCCESS(i.e., when the TS is admitted).

The Higher Layer Stream ID element is present only in AP-initiated TS setup. The Higher Layer Stream ID element (9.4.2.123 (Higher Layer Stream ID element)) contains the stream identifier provided by a higher layer protocol.


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When present in an ADDTS Response frame, the Multi-band element indicates the frequency band, operating class, and channel number to which the ADDTS Response frame applies and contains band-specific information.

When present in the ADDTS Response frame, the U-PID element indicates the upper layer protocol associated with the TID/TSID specified within the TSPEC contained in this frame.

When present in the ADDTS Response frame, the Multiple MAC Sublayers element is used to establish an MMSL cluster (see 11.32 (MMSL cluster operation)).

#### 9.6.3.3.2 DMG ADDTS Response frame variant

The DMG ADDTS Response frame is used by DMG STAs in a PBSS and in an infrastructure BSS. The Action field of the DMG ADDTS Response frame contains the information shown in Table 9-459 (DMG ADDTS Response frame variant Action field format).

**Table 9-459—DMG ADDTS Response frame variant Action field format**

| Order | Information | Notes |
|---|---|---|
| 1 | Category | |
| 2 | Action | |
| 3 | Dialog Token | |
| 4 | Status Code(#3326) | |
| 5 | TS Delay | |
| 6 | DMG TSPEC | |
| 7 | TSPEC | Optional |
| 8 | TCLAS | Optional |
| 9 | TCLAS Processing | Optional |
| 10 | Multi-band | Optional |
| 11 | U-PID | Optional |
| 12 | Multiple MAC Sublayers | Optional |
| 13 | Higher Layer Stream ID | Optional |

The values of the Dialog Token, TS Delay, DMG TSPEC, TSPEC, TCLAS, and subsequent fields in this frame are the same as the values of the corresponding parameters in the invocation of the MLME-ADDTS.response primitive that causes the frame to be sent. The TS Delay element is present in a DMG ADDTS Response frame only if the status code is set to REJECTED_FOR_DELAY_PERIOD (9.4.1.9 (Status Code field)).

When present in a DMG ADDTS Response frame, the Multi-band element indicates the frequency band, operating class, and channel number to which the TS identified by the optional TSPEC element applies.

When present in the DMG ADDTS Response frame, the U-PID element indicates the upper layer protocol associated with the TS identified by the optional TSPEC contained in this frame. If a TSPEC element is not present in the frame, the U-PID element is not present in the frame.

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When present in the DMG ADDTS Response frame, the Multiple MAC Sublayers element is used to establish an MMSL cluster (see 11.32 (MMSL cluster operation)).

#### 9.6.3.4 DELTS frame format

The DELTS frame is used to delete a TS or an allocation using the procedures defined in 11.4.8 (TS deletion).

The Action field of a DELTS frame contains the information shown in Table 9-460 (DELTS frame Action field format).

**Table 9-460—DELTS frame Action field format**

| Order | Information |
|---|---|
| 1 | Category |
| 2 | QoS Action |
| 3 | TS Info |
| 4 | Reason Code |
| 5 | DMG Allocation Info (optional) |
| 6 | Multi-band (optional) |

The Category field is defined in 9.4.1.11 (Action field).

The QoS Action field is defined in 9.6.3.1 (QoS Action field(#3729)).

The TS Info field is defined in 9.4.2.28 (TSPEC element). Either the field identifies an existing TS created using the TSPEC element, or all its subfields are set to 0. The DMG Allocation Info field, defined in 9.4.2.132 (DMG TSPEC element), is present when an existing DMG allocation is being deleted. When a DMG allocation is being deleted, the DMG Allocation Info field identifies an existing allocation created using the DMG TSPEC element. When a DMG allocation is not being deleted, all subfields in the DMG Allocation Info field are set to 0.

The Reason Code field is defined in 9.4.1.7 (Reason Code field).

A DELTS frame is used to delete a TS characterized by the TS Info field or to delete a DMG allocation identified by the DMG Allocation Info field in the frame. A DELTS frame can be sent from the HC or PCP to the source STA of that TS, or vice versa, to indicate an imperative request, to which no response is required from the recipient STA.

When present in an DELTS frame, the Multi-band element indicates the frequency band, operating class, and channel number to which the DELTS frame applies.

#### 9.6.3.5 Schedule frame format

The Schedule frame is transmitted by the HC to announce the schedule of delivery of data and polls. The Action field of the Schedule frame contains the information shown in Table 9-461 (Schedule frame Action field format).

The Category field is defined in 9.4.1.11 (Action field).


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**Table 9-461—Schedule frame Action field format**

| Order | Information |
|---|---|
| 1 | Category |
| 2 | QoS Action |
| 3 | Schedule |

The QoS Action field is defined in 9.6.3.1 (QoS Action field(#3729)).

The Schedule element is defined in 9.4.2.32 (Schedule element).

### 9.6.3.6 QoS Map Configure frame format

The QoS Map Configure frame is used by an AP to provide the QoS Map information to a non-AP STA using the procedures defined in 11.22.9 (Interworking procedures: support for QoS mapping from external networks).

The Action field of the QoS Map Configure frame contains the information shown in Table 9-462 (QoS Map Configure frame Action field format).

**Table 9-462—QoS Map Configure frame Action field format**

| Order | Information |
|---|---|
| 0 | Category |
| 1 | QoS Action |
| 2 | QoS Map |
| 3 | Intra-Access Category Priority elements (optional) |

The Category field is defined in 9.4.1.11 (Action field).

The QoS Action field is defined in 9.6.3.1 (QoS Action field(#3729)).

The QoS Map element is defined in 9.4.2.93 (QoS Map element).

Zero or more Intra-Access Category Priority elements are present, which are defined in 9.4.2.119 (Intra-Access Category Priority element).

### 9.6.3.7 ADDTS Reserve Request frame format

The ADDTS Reserve Request frame is transmitted by an AP to a non-AP STA in response to a higher layer protocol. See 11.4.4.3 (AP-initiated TS setup).

The Action field of the ADDTS Reserve Request frame contains the information shown in Table 9-463 (ADDTS Reserve Request frame Action field format).

The Category field is defined in 9.4.1.11 (Action field).

The QoS Action field is defined in 9.6.3.1 (QoS Action field(#3729)).

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**Table 9-463—ADDTS Reserve Request frame Action field format**

| Order | Information |
|---|---|
| 1 | Category |
| 2 | QoS Action |
| 3 | TSPEC |
| 4 | Schedule |
| 5 | Higher Layer Stream ID |

The TSPEC element contains the QoS parameters that define the TS. The QoS parameters in the TSPEC are equivalent to the QoS parameters of the higher level stream identified by the Higher Level Stream ID. The TS is identified by the TSID and Direction fields within the TSPEC element.

The Schedule element is defined in 9.4.2.32 (Schedule element) and set to reflect schedule information corresponding to the TSPEC specification.

The Higher Layer Stream ID element (defined in 9.4.2.123 (Higher Layer Stream ID element)) provides the stream identifier from a higher layer protocol.

### 9.6.3.8 ADDTS Reserve Response frame format

An ADDTS Reserve Response frame is used by a non-AP STA to indicate the completion of an AP-initiated TS setup procedure (11.4.4.3 (AP-initiated TS setup)). The Action field of the ADDTS Reserve Response frame contains the information shown in Table 9-464 (ADDTS Reserve Response frame Action field format).

**Table 9-464—ADDTS Reserve Response frame Action field format**

| Order | Information |
|---|---|
| 1 | Category |
| 2 | QoS Action |
| 3 | Higher Layer Stream ID |
| 4 | Status Code |

The Category field is defined in 9.4.1.11 (Action field).

The QoS Action field is defined in 9.6.3.1 (QoS Action field(#3729)).

The Higher Layer Stream ID field contains a Higher Layer Stream ID element (see 9.4.2.123 (Higher Layer Stream ID element)).

The Status Code field is defined in 9.4.1.9 (Status Code field).


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### 9.6.4 Block Ack Action frame details

#### 9.6.4.1 Block Ack Action field(#3729)

ADDBA Request and ADDBA Response frames are used to set up or to modify block ack operation(#3518) for a specific TC, TS, or GCR group address. (#4341)A Block Ack Action field, in the octet immediately after the Category field, differentiates the Block Ack Action frame formats. The Block Ack Action frames are used to negotiate several parameters of a block ack agreement and the type of BlockAck frames that are used: BlockAck, NDP BlockAck and Block Acknowledgment TWT frames (see 10.25.2 (Setup and modification of the block ack parameters)). The Block Ack Action field values associated with each frame format within the Block Ack category are defined in Table 9-465 (Block Ack Action field values).

**Table 9-465—Block Ack Action field values**

| Block Ack Action field values | Meaning |
|---|---|
| 0 | ADDBA Request |
| 1 | ADDBA Response |
| 2 | DELBA |
| 3(#3014) | PBAC WinStart Update |
| 4–127 | Reserved |
| 128 | NDP ADDBA Request |
| 129 | NDP ADDBA Response |
| 130 | NDP DELBA |
| 131 | Reserved |
| 132 | BAT ADDBA Request |
| 133 | BAT ADDBA Response |
| 134 | BAT DELBA |
| 135–255 | Reserved |

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### 9.6.4.2 ADDBA Request frame format

An ADDBA Request frame is sent by an originator of block ack to another STA. The Action field of an ADDBA Request frame contains the information shown in Table 9-466 (ADDBA Request frame Action field format).

**Table 9-466—ADDBA Request frame Action field format**

| Order | Information |
|---|---|
| 1 | Category |
| 2 | Block Ack Action |
| 3 | Dialog Token |
| 4 | Block Ack Parameter Set |
| 5 | Block Ack Timeout Value |
| 6 | Block Ack Starting Sequence Control |
| 7 | GCR Group Address element (optional) |
| 8 | Multi-band (optional) |
| 9 | TCLAS (optional) |
| 10 | ADDBA Extension (optional) |
| 11(11ay) | EDMG Flow Control Extension Configuration (optional) |
| 12(11ay) | SAR Configuration (optional) |

The Category field is defined in 9.4.1.11 (Action field).

The Block Ack Action field is defined in 9.6.4.1 (Block Ack Action field(#3729)) for each of the ADDBA request variants.(#4199)

(#417)The Dialog Token field is defined in 9.4.1.12 (Dialog Token field). For an unsolicited block ack extension agreement, the Dialog Token field is set to 0. Otherwise, it is set to a nonzero value chosen by the STA. (11ay)

The Block Ack Parameter Set field is defined in 9.4.1.13 (Block Ack Parameter Set field).

The Block Ack Timeout Value field is defined in 9.4.1.14 (Block Ack Timeout Value field).

The Starting Sequence Number subfield of the Block Ack Starting Sequence Control field (see Figure 9-48 (Block Ack Starting Sequence Control subfield format)) contains the sequence number of the first or next (in the case of a renegotiation of a block ack agreement) (#4194)MSDU (not in an A-MSDU) or A-MSDU to be sent under this block ack agreement. The Fragment Number subfield is set to 0.

If the GCR Group Address element is present, the TID field within the Block Ack Parameter Set field is reserved.

The GCR Group Address element contains the group address for which a block ack agreement is requested.


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When present in an ADDBA Request frame, the Multi-band element indicates the frequency band, operating class, and channel number to which the ADDBA Request frame applies and contains band-specific information.

The ADDBA Extension element is defined in 9.4.2.138 (ADDBA Extension element).

(11ay)The EDMG Flow Control Extension Configuration element is defined in 9.4.2.276 (EDMG Flow Control Extension Configuration element(11ay)).

(11ay)The SAR Configuration element is defined in 9.4.2.279 (SAR Configuration element(11ay)).

### 9.6.4.3 ADDBA Response frame format

The ADDBA Response frame is sent in response to an ADDBA Request frame. The Action field of an ADDBA Response frame contains the information shown in Table 9-467 (ADDBA Response frame Action field format).

**Table 9-467—ADDBA Response frame Action field format**

| Order | Information |
|---|---|
| 1 | Category |
| 2 | Block Ack Action |
| 3 | Dialog Token |
| 4 | Status Code |
| 5 | Block Ack Parameter Set |
| 6 | Block Ack Timeout Value |
| 7 | GCR Group Address element (optional) |
| 8 | Multi-band (optional) |
| 9 | TCLAS (optional) |
| 10 | ADDBA Extension (optional) |
| 11(#1444) | Reserved |
| 12(11ay) | EDMG Flow Control Extension Configuration (optional) |
| 13(11ay) | SAR Configuration (optional) |
| 14(#1444) | Originator Preferred MCS element (optional) |

The Category field is defined in 9.4.1.11 (Action field).

The Block Ack Action field is defined in 9.6.4.1 (Block Ack Action field(#3729)) for each of the ADDBA response variants.(#4199)

The Dialog Token field value is copied from the corresponding received ADDBA Request frame.

The Status Code field is defined in 9.4.1.9 (Status Code field).

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The Block Ack Parameter Set field is defined in 9.4.1.13 (Block Ack Parameter Set field).

The Block Ack Timeout Value field is defined in 9.4.1.14 (Block Ack Timeout Value field).

If the GCR Group Address element is present, the TID field within the Block Ack Parameter Set field is reserved.

The GCR Group Address element contains the group address for which a block ack agreement is requested.

When present in an ADDBA Response frame, the Multi-band element indicates the frequency band ID, operating class, and channel number to which the ADDBA Response frame applies and contains band-specific information.

The ADDBA Extension element is defined in 9.4.2.138 (ADDBA Extension element).(#8255)

(#1444)The Originator Preferred MCS field element (#8254)is optionally present if dot11S1GOptionImplemented is true, and the Block Ack Action field is 1. Otherwise, it is not present.

(11ay)The EDMG Flow Control Extension Configuration element is defined in 9.4.2.276 (EDMG Flow Control Extension Configuration element(11ay)).

(11ay)The SAR Configuration element is defined in 9.4.2.279 (SAR Configuration element(11ay)) and is included in the frame if a SAR Configuration element was included in the corresponding ADDBA Request frame.

### 9.6.4.4 DELBA frame format

The DELBA frame is sent by either the originator of the traffic or the recipient to terminate the block ack agreement(#6171). The Action field of a DELBA frame contains the information shown in Table 9-468 (DELBA frame Action field format).

**Table 9-468—DELBA frame Action field format**

| Order | Information |
|---|---|
| 1 | Category |
| 2 | Block Ack Action |
| 3 | DELBA Parameter Set |
| 4 | Reason Code |
| 5 | DELBA GCR Group Address |
| 6 | Multi-band (optional) |
| 7 | TCLAS (optional) |


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The Category field is defined in 9.4.1.11 (Action field).

The Block Ack Action field is defined in 9.6.4.1 (Block Ack Action field(#3729)) for each of the DELBA variants.(#4199)

The DELBA Parameter Set field is defined in 9.4.1.16 (DELBA Parameter Set field).

The Reason Code field is defined in 9.4.1.7 (Reason Code field).

The DELBA GCR Group Address field is defined in 9.4.2.124 (GCR Group Address element) and contains the GCR group address whose block ack agreement is being terminated.

When present in an DELBA frame, the Multi-band element indicates the frequency band, operating class, and channel number to which the DELBA frame applies.

#### 9.6.4.5 PBAC WinStart Update frame format(#3014)

The PBAC WinStart Update frame is sent by an originator to update(#6304) $WinStart_B$ and $WinStart_R$ at the recipient for a protected block ack agreement (see 10.25.7 (Protected block ack agreement)). The Action field of a PBAC WinStart Update frame contains the information shown in Table 9-469 (PBAC WinStart Update frame Action field format(#3014)).

**Table 9-469—PBAC WinStart Update frame Action field format(#3014)**

| Order | Information |
|---|---|
| 1 | Category |
| 2 | Block Ack Action |
| 3 | Block Ack Parameter Set |
| 4 | Block Ack Starting Sequence Control |

The Category field is defined in 9.4.1.11 (Action field).

The Block Ack Action field is defined in 9.6.4.1 (Block Ack Action field(#3729)).(#4199)

The Block Ack Parameter Set field is defined in 9.4.1.13 (Block Ack Parameter Set field).

The Starting Sequence Number subfield of the Block Ack Starting Sequence Control field (see Figure 9-48 (Block Ack Starting Sequence Control subfield format)) contains the sequence number of the next (#4194)MSDU (not in an A-MSDU) or A-MSDU to be sent under this block ack agreement. The Fragment Number subfield is set to 0.

### 9.6.5 Vendor Specific Action frame and Vendor Specific Protected Action frame details(#3729)(#4065)

(#4065)Vendor Specific Action and Vendor Specific Protected Action frames are defined for vendor-specific signaling. The format of the Action field of these frames is shown in Figure 9-1181 (Action field format of Vendor Specific Action and Vendor Specific Protected Action frames(#4065-Ed)).

NOTE—If management frame protection is negotiated, then Vendor Specific Protected Action frames (see Table 9-81 (Category values)) are protected; otherwise they are unprotected.

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| Category | Organization Identifier | Vendor Specific Content |
|---|---|---|
| Octets: 1 | 3 or 5(#7136) | variable |

**Figure 9-1181—Action field format of Vendor Specific Action and Vendor Specific Protected Action frames(#4065-Ed)**

The Category field is defined in 9.4.1.11 (Action field).

The Organization Identifier field contains(#4065) the identity of the entity that has defined the content of the Vendor Specific Action and Vendor Specific Protected Action frames (see 9.4.1.29 (Organization Identifier field) for a description of the Organization Identifier field contents and length).(#7136)

The Vendor Specific Content field contains vendor-specific field(s). The length of the vendor specific content in a (#4065)Vendor Specific Action and Vendor Specific Protected Action frame is limited by the maximum allowed MMPDU size.

### 9.6.6 Radio Measurement Action frame details(#3729)

#### 9.6.6.1 Radio Measurement Action field(#3729)

Several Action frame formats are defined for radio measurement purposes. A Radio Measurement Action field, in the field immediately after the Category field, differentiates the formats. The Radio Measurement Action field values associated with each frame format are defined in Table 9-470 (Radio Measurement Action field values).

**Table 9-470—Radio Measurement Action field values**

| Radio Measurement Action field value | Description |
|---|---|
| 0 | Radio Measurement Request |
| 1 | Radio Measurement Report |
| 2 | Link Measurement Request |
| 3 | Link Measurement Report |
| 4 | Neighbor Report Request |
| 5 | Neighbor Report Response |
| 6–255 | Reserved |

#### 9.6.6.2 Radio Measurement Request frame format

The Radio Measurement Request frame is transmitted to another STA to request that it makes one or more measurements on one or more channels. The format of the Action field in the Radio Measurement Request frame is shown in Figure 9-1182 (Radio Measurement Request frame Action field format).

The Category field is defined in 9.4.1.11 (Action field).

The Radio Measurement Action field is defined in 9.6.6.1 (Radio Measurement Action field(#3729)).


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**Figure 9-1182—Radio Measurement Request frame Action field format**

(#417)The Dialog Token field is defined in 9.4.1.12 (Dialog Token field). It is set to a nonzero value chosen by the STA sending the radio measurement request to identify the request/report transaction.

The Number of Repetitions field contains the requested number of repetitions for all of the Measurement Request elements in this frame. Setting the Number of Repetitions field to 0 indicates Measurement Request elements are executed once without repetition. Setting the Number of Repetitions field to 65 535 indicates Measurement Request elements are repeated until the measurement is canceled or superseded.

The Measurement Request Elements field contains zero or more of the Measurement Request elements described in 9.4.2.19 (Measurement Request element). The number and length of the Measurement Request elements in a Measurement Request frame are limited by the maximum allowed MMPDU size.

### 9.6.6.3 Radio Measurement Report frame format

The Radio Measurement Report frame is transmitted in response to a Radio Measurement Request frame or by a STA providing a triggered autonomous measurement report. The format of the Action field in the Radio Measurement Report frame is shown in Figure 9-1183 (Radio Measurement Report frame Action field format).

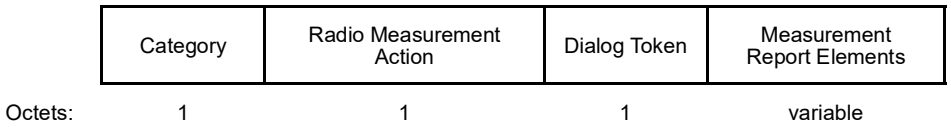


**Figure 9-1183—Radio Measurement Report frame Action field format**

The Category field is defined in 9.4.1.11 (Action field).

The Radio Measurement Action field is defined in 9.6.6.1 (Radio Measurement Action field(#3729)).

(#417)The Dialog Token field is defined in 9.4.1.12 (Dialog Token field). It is set to the value in the corresponding Radio Measurement Request frame. If the Radio Measurement Report frame is not being transmitted in response to a Radio Measurement Request frame then the dialog token is set to 0.

The Measurement Report Elements field contains one or more Measurement Report elements described in 9.4.2.20 (Measurement Report element). The number and length of the Measurement Report elements in a single Radio Measurement Report frame are limited by the maximum allowed MMPDU size. Subclause 11.10.6 (Requesting and reporting of measurements) describes the required behavior for multiframe Radio Measurement Report frame responses.

### 9.6.6.4 Link Measurement Request frame format

The Link Measurement Request frame is transmitted by a STA to request another STA to respond with a Link Measurement Report frame to enable measurement of link path loss and estimation of link margin. In a non-DMG BSS, a Link Measurement Request frame is an Action frame and in a DMG BSS, a Link Measurement Request frame is an Action or an Action No Ack frame. The format of the Action field in the

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Link Measurement Request frame is shown in Figure 9-1184 (Link Measurement Request frame Action field format).

| | Category | Radio Measurement Action | Dialog Token | Transmit Power Used | Max Transmit Power | Extended Link Measurement(11ay) |
|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 1 | 1 | variable |

**Figure 9-1184—Link Measurement Request frame Action field format**

The Category field is defined in 9.4.1.11 (Action field).

The Radio Measurement Action field is defined in 9.6.6.1 (Radio Measurement Action field(#3729)).

(#417)The Dialog Token field is defined in 9.4.1.12 (Dialog Token field). It is set to a nonzero value chosen by the STA sending the request to identify the transaction.

The Transmit Power Used field is set to the transmit power used to transmit the frame containing the Link Measurement Request, as described in 9.4.1.20 (Transmit Power Used field).

The Max Transmit Power field provides the upper limit on the transmit power as measured at the antenna connector to be used by the transmitting STA on its operating channel. This field is described in 9.4.1.19 (Max Transmit Power field). (#1446)The Max Transmit Power field is set to the minimum of the maximum powers at which the STA is permitted to transmit in the operating channel by device capability, policy, and regulatory authority.

(11ay)The Extended Link Measurement field is optionally present. When present, it contains an Extended Link Measurement element.

### 9.6.6.5 Link Measurement Report frame format

The Link Measurement Report frame is transmitted in response to a Link Measurement Request frame. In a non-DMG BSS, a Link Measurement Report frame is an Action frame and in a DMG BSS, a Link Measurement Report frame is an Action or an Action No Ack frame. The format of the Action field in the Link Measurement Report frame is shown in Figure 9-1185 (Link Measurement Report frame Action field format).

| | Category | Radio Measurement Action | Dialog Token | TPC Report element | Receive Antenna ID | Transmit Antenna ID | RCPI |
|---|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 4 | 1 | 1 | 1 |

| | RSNI | DMG Link Margin | DMG Link Adaptation Acknowledgment | Extended Link Measurement(11ay) |
|---|---|---|---|---|
| Octets: | 1 | variable | variable | variable |

**Figure 9-1185—Link Measurement Report frame Action field format**


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The Category field is defined in 9.4.1.11 (Action field).

The Radio Measurement Action field is defined in 9.6.6.1 (Radio Measurement Action field(#3729)).

(#417)The Dialog Token field is defined in 9.4.1.12 (Dialog Token field). It is set to the value of the Dialog Token field in the last received(11ay) corresponding Link Measurement Request frame.

The TPC Report element is set as described in 9.4.2.15 (TPC Report element).

The Receive Antenna ID field contains the identifying number for the antenna(s) or DMG antenna used to receive the corresponding Link Measurement Request frame or the last received frame from the requesting STA within the corresponding report interval.(11ay) The antenna ID or DMG antenna ID is defined in 9.4.2.38 (Antenna element).

The Transmit Antenna ID field contains the identifying number for the antenna(s) or DMG antenna used to transmit this Link Measurement Report frame. The antenna ID or DMG antenna ID is defined in 9.4.2.38 (Antenna element).

The RCPI field indicates the received channel power of the corresponding Link Measurement Request frame, which is a logarithmic function of the received signal power or the last received frame from the requesting STA within the corresponding report interval,(11ay) as defined in 9.4.2.36 (RCPI element).

The RSNI field indicates the received signal-to-noise indication for the corresponding Link Measurement Request frame or the last received frame from the requesting STA within the corresponding report interval,(11ay) as described in 9.4.2.39 (RSNI element).

The DMG Link Margin field is optionally present. When present, it contains a DMG Link Margin element (see 9.4.2.141 (DMG Link Margin element)).

The DMG Link Margin Adaptation Acknowledgment field is optionally present. When present, it contains a DMG Link Margin Adaptation Acknowledgment element (see 9.4.2.141.3 (Rate Adaptation Control/ Extended TPC field(11ay))).

(11ay)The Extended Link Measurement field is optionally present. When present, it contains an Extended Link Measurement element.

### 9.6.6.6 Neighbor Report Request frame format

The Neighbor Report Request frame is transmitted requesting information in the neighbor report about neighboring APs. The format of the Action field in the Neighbor Report Request frame is shown in Figure 9-1186 (Neighbor Report Request frame Action field format).

| | Category | Radio Measurement Action | Dialog Token | SSID (optional) | LCI Measurement Request (optional) | Location Civic Measurement Request (optional) | Neighbor DMG Request (optional)(11az) |
|---|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | variable | variable | variable | variable |

**Figure 9-1186—Neighbor Report Request frame Action field format**

The Category field is defined in 9.4.1.11 (Action field).

The Radio Measurement Action field is defined in 9.6.6.1 (Radio Measurement Action field(#3729)).

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(#417)The Dialog Token field is defined in 9.4.1.12 (Dialog Token field). It is set to a nonzero value chosen by the STA sending the measurement request to identify the request/report transaction.

The SSID field is optionally present. If present, it contains an SSID element. The presence of an SSID element in a Neighbor Report Request frame indicates a request for a list of neighbor reports for the specified SSID in the SSID element. The absence of an SSID element indicates the request is for the ESS of which the transmitting STA is a member.

The LCI Measurement Request field is optionally present. If present, it contains a Measurement Request element with Measurement Type field equal to LCI (see Table 9-136 (Measurement type definitions for measurement requests)), which indicates a request for a Measurement Report subelement with Measurement Type field equal to LCI for each Neighbor Report element (see 11.10.10.2 (Requesting a neighbor report)). The Enable subfield(#291) in the Measurement Request Mode field in the Measurement Request element is set to 0. The Location Subject field in the Measurement Request field of the Measurement Request element is set to Location Subject Remote (see Table 9-148 (Location Subject field definition)). The Request, Report and Duration Mandatory subfield(#291) within the Measurement Request Mode field in the Measurement Request element are reserved (see 9.4.2.19.1 (General)).

The Location Civic Measurement Request field is optionally present. If present, it contains a Measurement Request element with Measurement Type field equal to Location Civic (see Table 9-136 (Measurement type definitions for measurement requests)). The element indicates a request for a Measurement Report subelement with Measurement Type field equal to Location Civic for each Neighbor Report element (see 11.10.10.2 (Requesting a neighbor report)). The Enable subfield(#291) in the Measurement Request Mode field within the Measurement Request element is set to 0. The Location Subject field in the Measurement Request field of the Measurement Request element is equal to Location Subject Remote (see Table 9-148 (Location Subject field definition)). The Location Service Interval Units field in the Measurement Request field of the Measurement Request element is set to 0. The Request, Report and Duration Mandatory subfield(#291) in the Measurement Request Mode field in the Measurement Request element are reserved (see 9.4.2.19.1 (General)).

(11az)The Neighbor DMG Request field is optionally present. If present, it contains a Measurement Request element with Measurement Type field equal to neighboring DMG APs; see Table 9-136 (Measurement type definitions for measurement requests). The element indicates a request for Neighbor Report elements containing information about neighboring DMG APs supporting location services. The Enable bit in the Measurement Request Mode field within the Measurement Request element is set to 0.

### 9.6.6.7 Neighbor Report Response frame format

The Neighbor Report Response frame is transmitted in response to a Neighbor Report Request frame. The format of the Action field in the Neighbor Report Response frame is shown in Figure 9-1187 (Neighbor Report Response frame Action field format).

| | Category | Radio Measurement Action | Dialog Token | Neighbor Report Elements |
|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | variable |

**Figure 9-1187—Neighbor Report Response frame Action field format**

The Category field is defined in 9.4.1.11 (Action field).

The Radio Measurement Action field is defined in 9.6.6.1 (Radio Measurement Action field(#3729)).


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The Dialog Token field set to the value in the corresponding Neighbor Report Request frame. If the Neighbor Report Response frame is not being transmitted in response to a Neighbor Report Request frame, then the dialog token is set to 0.

The Neighbor Report Elements field contains the Neighbor Report elements for validated APs described in 9.4.2.35 (Neighbor Report element). If the STA has no information in response to the Neighbor Report Request, the Neighbor Report elements are omitted. The number and length of the Neighbor Report elements in a Neighbor Report Response frame is limited by the maximum allowed MMPDU size.

NOTE—Under some circumstances, a Neighbor Report element is included for the STA transmitting the frame. See 11.10.10.3 (Responding to a neighbor report request).

### 9.6.7 Public Action frame details(#3729)

#### 9.6.7.1 Public Action field(#3729)

The Public Action frame is defined to allow the following:

— Inter-BSS and AP to unassociated-STA communications
— Intra-BSS communication
— GAS

A Public Action field, in the octet immediately after the Category field, differentiates the Public Action frame formats. The defined Public Action frames are listed in Table 9-471 (Public Action field values).

**Table 9-471—Public Action field values**

| Public Action field value | Description |
|---|---|
| 0 | 20/40 BSS Coexistence Management |
| 1 | DSE Enablement |
| 2 | DSE Deenablement |
| 3 | DSE Registered Location Announcement |
| 4 | Extended Channel Switch Announcement |
| 5 | DSE Measurement Request |
| 6 | DSE Measurement Report |
| 7 | Measurement Pilot |
| 8 | DSE Power Constraint |
| 9 | Vendor Specific |
| 10 | GAS Initial Request |
| 11 | GAS Initial Response |
| 12 | GAS Comeback Request |
| 13 | GAS Comeback Response |
| 14 | TDLS Discovery Response |
| 15 | Location Track Notification |

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**Table 9-471—Public Action field values *(continued)***

| Public Action field value | Description |
|---|---|
| 16 | QAB Request frame |
| 17 | QAB Response frame |
| 18 | QMF Policy |
| 19 | QMF Policy Change |
| 20 | QLoad Request |
| 21 | QLoad Report |
| 22 | HCCA TXOP Advertisement |
| 23 | HCCA TXOP Response |
| 24 | Public Key |
| 25 | Channel Availability Query |
| 26 | Channel Schedule Management |
| 27 | Contact Verification Signal |
| 28 | GDD Enablement Request |
| 29 | GDD Enablement Response |
| 30 | Network Channel Control |
| 31 | White Space Map Announcement |
| 32 | (#7065)FTM Request |
| 33 | (#7065)FTM |
| 34 | FILS Discovery |
| 35 | DCS Measurement Request |
| 36 | DCS Measurement Report |
| 37 | DCS Request |
| 38 | DCS Response |
| 39 | Extended Notification Period Request |
| 40 | Extended Notification Period Response |
| 41 | Extended Channel Splitting Request |
| 42 | Extended Channel Splitting Response |
| 43 | Group Addressed GAS Request |
| 44 | Group Addressed GAS Response |
| 45 | On-channel Tunnel Request |
| 46(11ay) | DMG STA Directional Transmit Activity Report |
| 47(11az) | LMR |
| 48(11az) | ISTA Passive TB Ranging Measurement Report |


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**Table 9-471—Public Action field values *(continued)***

| Public Action field value | Description |
|---|---|
| 49(11az) | Primary RSTA Broadcast Passive TB Ranging Measurement Report |
| 50(11az) | Secondary RSTA Broadcast Passive TB Ranging Measurement Report |
| 51(11bc) | EBCS UL (see 9.6.7.53 (EBCS UL frame format(11bc))) |
| 52(11bc) | EBCS Info (see 9.6.7.54 (EBCS Info frame format(11bc))) |
| 53(11bc) | EBCS termination notice (see 9.6.7.55 (EBCS Termination Notice frame format(11bc))) |
| 54–59 | Reserved |
| 60(#6058) | GAS Comeback Request Fragment |
| 61–255 | Reserved |

### 9.6.7.2 20/40 BSS Coexistence Management frame format

The format of the 20/40 BSS Coexistence Management frame Action field is defined in Table 9-472 (20/40 BSS Coexistence Management frame Action field format).

**Table 9-472—20/40 BSS Coexistence Management frame Action field format**

| Order | Information | Notes |
|---|---|---|
| 1 | Category | |
| 2 | Public Action | |
| 3 | 20/40 BSS Coexistence (see 9.4.2.58 (20/40 BSS Coexistence element)) | |
| 4 | 20/40 BSS Intolerant Channel Report (see 9.4.2.56 (20/40 BSS Intolerant Channel Report element)) | Appears zero or more times |

The Category field is defined in 9.4.1.11 (Action field).

The Public Action field is defined in 9.6.7.1 (Public Action field(#3729)).

### 9.6.7.3 Measurement Pilot frame format

The format of the Action field of the Measurement Pilot frame is shown in Figure 9-1188 (Measurement Pilot frame Action field format).

The Category field is defined in 9.4.1.11 (Action field).

The Public Action field is defined in 9.6.7.1 (Public Action field(#3729)).

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| | Category | Public Action | Condensed Capability Information | Condensed Country String | Operating Class | Channel | Measurement Pilot Interval | Optional Subelements |
|---|---|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 2 | 1 | 1 | 1 | variable |

**Figure 9-1188—Measurement Pilot frame Action field format**

The Condensed Capability Information field contains two subfields as shown in Figure 9-1189 (Condensed Capability Information field).

| | B0 | B1 | B2 | B7 |
|---|---|---|---|---|
| | Spectrum Management | Short Slot Time | Reserved | |
| Bits: | 1 | 1 | 6 | |

**Figure 9-1189—Condensed Capability Information field**

The Spectrum Management subfield is set to 1 if dot11SpectrumManagementRequired is true; otherwise, it is set to 0.

The Short Slot Time subfield is set to 1 to indicate the short slot time value is currently used within this BSS. Otherwise, the Short Slot Time subfield is set to 0. See 10.3.2.16 (Operation of aSlotTime) and 11.1.3.2 (Beacon generation in non-DMG infrastructure networks).(#1761)

The Condensed Country String field is set to the first two octets of the value contained in dot11CountryString.

If the Wide Bandwidth Channel Switch subelement is not included, the Operating Class field indicates the operating class value for the operating channel. The Country, Operating Class, and Channel Number fields together specify the channel frequency and spacing for the operating channel. Valid operating classes are listed in Annex E, excluding Operating Classes that encompass a primary channel but do not identify the location of the primary channel. The Channel Number field indicates the operating channel. Channel number is defined within an operating class as shown in Annex E.

If the Wide Bandwidth Channel Switch subelement is included, the fields in the Wide Bandwidth Channel Switch subelement indicate the operating channel, and the Operating Class and Channel Number fields(#6181) together specify the primary channel and primary 40 MHz channel within the channel identified by the Wide Bandwidth Channel Switch subelement.

The Measurement Pilot Interval field is set to the value contained in dot11RMMeasurementPilotPeriod.

(#524)The Optional Subelements field contains zero or more subelements. The subelement format and ordering of subelements are defined in 9.4.3 (Subelements).

The Subelement ID field values for the defined subelements are shown in Table 9-473 (Optional subelement IDs for Measurement Pilot frame).

The Wide Bandwidth Channel Switch subelement has the same format as the corresponding element (see 9.4.2.159 (Wide Bandwidth Channel Switch element)) with the constraint that the New Channel Width field indicates an 80 MHz, 160 MHz, or 80+80 MHz BSS bandwidth.


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**Table 9-473—Optional subelement IDs for Measurement Pilot frame**

| Subelement ID | Name | Extensible |
|---|---|---|
| 0–70 | Reserved | |
| 71 | Multiple BSSID | Subelements |
| 72–162 | Reserved | |
| 163 | Wide Bandwidth Channel Switch | Yes |
| 164–220 | Reserved | |
| 221 | Vendor Specific | Vendor defined |
| 222–255 | Reserved | |

The Multiple BSSID and Vendor Specific subelements have the same format as the Multiple BSSID and Vendor Specific elements (see 9.4.2.44 (Multiple BSSID element) and 9.4.2.24 (Vendor Specific element), respectively). Zero or more Vendor Specific subelements are included in the list of optional subelements.

### 9.6.7.4 DSE Enablement frame format

The DSE Enablement frame is transmitted as part of enablement. The format of the DSE Enablement frame Action field is shown in Figure 9-1190 (DSE Enablement frame Action field format).

| | Category | Public Action | Requester STA Address | Responder STA Address | Reason Result Code | Enablement Identifier |
|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 6 | 6 | 1 | 2 |

**Figure 9-1190—DSE Enablement frame Action field format**

The Category field is defined in 9.4.1.11 (Action field).

The Public Action field is defined in 9.6.7.1 (Public Action field(#3729)).

The RequesterSTAAddress field is the MAC address of the requesting STA that initiates the enablement process(#6293).

The ResponderSTAAddress field is the MAC address of the enablement responder(#6293).

The Reason Result Code field is used to indicate the reason that a DSE Enablement frame was generated. (#8141)The reason result codes that have been allocated are shown in Table 9-474 (Reason Result Code field values).

**Table 9-474—Reason Result Code field values**

| Reason Result Code field value | Name | Description |
|---|---|---|
| 0 | | Reserved |
| 1 | | Reserved |

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**Table 9-474—Reason Result Code field values *(continued)***

| Reason Result Code field value | Name | Description |
|---|---|---|
| 2 | | Enablement requested |
| 3 | SUCCESS | Success |
| 4 | REFUSED | Request declined |
| 5 | INVALID_PARAMETERS | Request not successful as one or more parameters have invalid values |
| 6 | TOO_MANY_ SIMULTANEOUS_REQUESTS | Enablement denied because the enabling STA is unable to handle additional dependent STAs |
| 7–255 | | Reserved |

The Enablement Identifier field is (#4162)assigned by an enabling STA to a dependent STA; otherwise, it is 0, set using the procedures defined in 11.11 (DSE procedures).

### 9.6.7.5 DSE Deenablement frame format

The DSE Deenablement frame is transmitted as part of deenablement. The format of the DSE Deenablement frame Action field is shown in Figure 9-1191 (DSE Deenablement frame Action field format).

| | Category | Public Action | Requester STA Address | Responder STA Address | Reason Result Code |
|---|---|---|---|---|---|
| Octets: | 1 | 1 | 6 | 6 | 1 |

**Figure 9-1191—DSE Deenablement frame Action field format**

The Category field is defined in 9.4.1.11 (Action field).

The Public Action field is defined in 9.6.7.1 (Public Action field(#3729)).

The RequesterSTAAddress field is the MAC address of the requesting STA that initiates the deenablement process(#6293).

The ResponderSTAAddress field is the MAC address of the responding STA that becomes deenabled.(#6293)

The Reason Result Code field is used to indicate the reason that a DSE Deenablement frame was generated. (#8141)The reason result codes that have been allocated are shown in Table 9-475 (Reason Result Code field values).

**Table 9-475—Reason Result Code field values**

| Reason Result Code field value | Description |
|---|---|
| 0 | Reserved |
| 1 | Reserved |


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**Table 9-475—Reason Result Code field values**

| Reason Result Code field value | Description |
|---|---|
| 2 | Deenablement requested |
| 3–255 | Reserved |

### 9.6.7.6 DSE Registered Location Announcement frame format

The DSE Registered Location Announcement frame is transmitted by a dependent STA to advertise the registered location of its enabling STA. The format of the DSE Registered Location Announcement frame Action field is shown in Figure 9-1192 (DSE Registered Location Announcement frame Action field format).

| | Category | Public Action | DSE Registered Location Information |
|---|---|---|---|
| Octets: | 1 | 1 | 20 |

**Figure 9-1192—DSE Registered Location Announcement frame Action field format**

The Category field is defined in 9.4.1.11 (Action field).

The Public Action field is defined in 9.6.7.1 (Public Action field(#3729)).

The DSE Registered Location Information field is defined in 9.4.2.50 (DSE Registered Location element).

### 9.6.7.7 Extended Channel Switch Announcement frame format

The Extended Channel Switch Announcement frame is transmitted by an AP, IBSS STA, or mesh STA to advertise a channel switch. The format of the Extended Channel Switch Announcement frame Action field is shown in Figure 9-1193 (Extended Channel Switch Announcement frame Action field format).

| | Category | Public Action | Channel Switch Mode | New Operating Class | New Channel Number | Channel Switch Count |
|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 1 | 1 | 1 |
| | | Zero or one | Zero or one | Zero or more | Zero or one | |

| | Mesh Channel Switch Parameters element | New Country element | Wide Bandwidth Channel Switch element | New Transmit Power Envelope element | Max Channel Switch Time element (#7160) |
|---|---|---|---|---|---|
| Octets: | 0 or 8 | variable | variable | variable | 0 or 6 |

**Figure 9-1193—Extended Channel Switch Announcement frame Action field format**

The Category field is defined in 9.4.1.11 (Action field).

The Public Action field is defined in 9.6.7.1 (Public Action field(#3729)).

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The Channel Switch Mode, New Operating Class, New Channel Number, and Channel Switch Count fields are as described in the Extended Channel Switch Announcement element (see 9.4.2.51 (Extended Channel Switch Announcement element)).

The Mesh Channel Switch Parameters element is defined in 9.4.2.101 (Mesh Channel Switch Parameters element). This element is present when a mesh STA performs MBSS channel switching. The Mesh Channel Switch Parameters element is not included for channel switching other than for an MBSS channel switch.

The New Country element is present when an AP or mesh STA performs extended channel switching to a new Country, new Operating Class Table, or a changed set of operating classes relative to the contents of the Country element sent in the Beacon; otherwise, this element is not present. The format of the New Country element is defined to be the same as the format of the Country element (see 9.4.2.7 (Country element)), except that no Subband Triplet fields are present in the New Country element. The Country String field in the New Country element indicates the Country and Operating Class Table of the BSS after extended channel switching and Operating Triplet fields within the New Country element indicate the operating classes of the BSS after extended channel switching (see 11.38.1 (Basic VHT BSS functionality)).

This Wide Bandwidth Channel Switch element is present when extended channel switching to a channel width wider than 40 MHz, or when extended channel switching is to a channel width wider than 1 MHz and the frame carrying the element is an S1G PPDU; otherwise, this element is not present. The Wide Bandwidth Channel Switch element is defined in 9.4.2.159 (Wide Bandwidth Channel Switch element). The Wide Bandwidth Channel Switch element indicates the BSS bandwidth after extended channel switching (see 11.38.1 (Basic VHT BSS functionality) and 10.45.1 (Basic S1G BSS functionality)).

Each New Transmit Power Envelope element that is present is defined to have the same format as the Transmit Power Envelope element (see 9.4.2.160 (Transmit Power Envelope element)) and includes a distinct value of the Local Maximum Transmit Power Unit Interpretation subfield. If present, the New Transmit Power Envelope element indicates the maximum transmit powers for the BSS for the indicated bandwidths with an indicated unit interpretation after extended channel switching (see 11.38.1 (Basic VHT BSS functionality)).

(#7160)(#8094)The Max Channel Switch Time Element field, if present, cotnains a Max Channel Switch Time element as defined in 9.4.2.216 (Max Channel Switch Time element).

### 9.6.7.8 DSE Measurement Request frame format

The DSE Measurement Request frame requests a DSE measurement report. It is transmitted using the procedures defined in 11.11 (DSE procedures). The format of the DSE Measurement Request frame Action field is shown in Figure 9-1194 (DSE Measurement Request frame Action field format).

| | Category | Public Action | Requester STA Address | Responder STA Address | Operating Class | Channel Number | Measurement Start Time | Measurement Duration |
|---|---|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 6 | 6 | 1 | 1 | 8 | 2 |

**Figure 9-1194—DSE Measurement Request frame Action field format**

The Category field is defined in 9.4.1.11 (Action field).

The Public Action field is defined in 9.6.7.1 (Public Action field(#3729)).

The RequesterSTAAddress field is the MAC address of the STA that requests the DSE measurement report(#6293).


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The ResponderSTAAddress field is the MAC address of the responding STA that operates based on the enablement(#6293).

The Operating Class field indicates the channel set for which the measurement request applies. The Operating Class and Channel Number fields together specify the channel frequency and channel bandwidth for which the measurement request applies. Valid values for the Operating Class field are shown in Annex E.

The Measurement Start Time field is set to the timing synchronization function (TSF) at the time (± 1 TU) at which the requested DSE request measurement starts. Setting the field to 0 indicates it starts immediately.

The Measurement Duration field is set to the duration of the requested measurement, expressed in number of time units (TUs).

### 9.6.7.9 DSE Measurement Report frame format

The DSE Measurement Report frame is transmitted using the procedures defined in 11.11 (DSE procedures). The format of the DSE Measurement Report frame Action field is shown in Figure 9-1195 (DSE Measurement Report frame Action field format).

| | Category | Public Action | Requester STA Address | Responder STA Address | Length | Operating Class | Channel Number | Measurement Report Mode | Actual Measurement Start Time | Measurement Duration | Reported DSE LCI fields |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 6 | 6 | 2 | 1 | 1 | 1 | 8 | 2 | n × 26 |

**Figure 9-1195—DSE Measurement Report frame Action field format**

The Category field is defined in 9.4.1.11 (Action field).

The Public Action field is defined in 9.6.7.1 (Public Action field(#3729)).

The RequesterSTAAddress field is the MAC address of the STA that requested the DSE measurement report(#6293).

The ResponderSTAAddress field is the MAC address of the responding STA that operates based on the enablement(#6293).

The Length field indicates the length of the remaining frame fields in octets, and the value is variable. The minimum value of the Length field is 13.

The Operating Class field indicates the channel set for which the measurement report applies. The Operating Class and Channel Number fields together specify the channel frequency and spacing for which the measurement request applies. Valid values for the Operating Class field are shown in Annex E.

The Measurement Report Mode field is defined in 9.4.2.20 (Measurement Report element) (see Figure 9-290 (Measurement Report Mode field format)).

The Actual Measurement Start Time field is set to the value of the measuring STA's TSF timer at the time (± 1 TU) at which the DSE measurement started.

The Measurement Duration field is set to the duration over which the requested measurement was measured, expressed in number of TUs.

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The reported DSE LCI fields contain the DSE LCI received at the measuring STA. If the reported DSE LCI fields would cause the frame to exceed the maximum MAC management protocol data unit (MMPDU) size, then the reported DSE LCI fields are truncated so that the last reported DSE LCI field is complete. The DSE LCI field format is shown in Figure 9-1196 (DSE LCI field format).

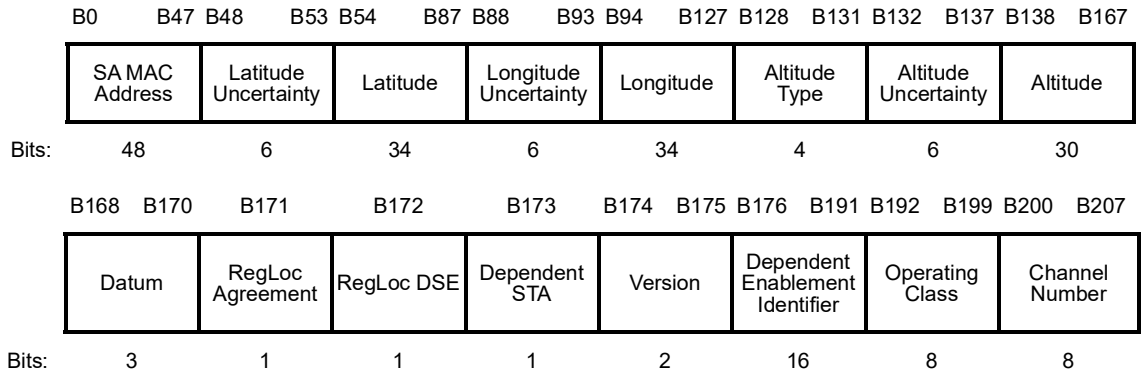


**Figure 9-1196—DSE LCI field format**

The SA MAC Address field contains the SA MAC address from the Beacon or Public Action frame containing a DSE Registered Location element being reported.

The remaining fields are as defined in the DSE Registered Location Information field (see 9.4.2.50 (DSE Registered Location element)).

### 9.6.7.10 DSE Power Constraint frame format

The DSE Power Constraint frame requests that a dependent STA constrain transmit power below the regulatory limit. It is transmitted by an enabling STA as part of enablement. The format of the DSE Power Constraint frame Action field is shown in Figure 9-1197 (DSE Power Constraint frame Action field format).

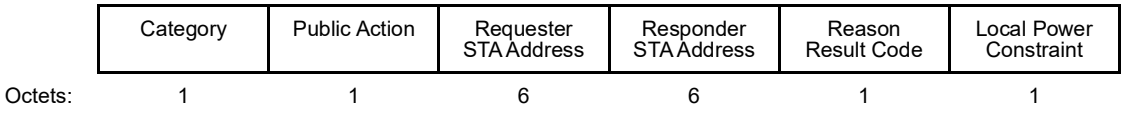


**Figure 9-1197—DSE Power Constraint frame Action field format**

The Category field is defined in 9.4.1.11 (Action field).

The Public Action field is defined in 9.6.7.1 (Public Action field(#3729)).

The RequesterSTAAddress field is the MAC address of the STA that requests the DSE power constraint(#6293).

The ResponderSTAAddress field is the MAC address of the responding STA that initiates the enablement(#6293).

The Reason Result Code field is used to indicate the reason that a DSE Power Constraint frame was generated. (#8141)The reason result codes that have been allocated are shown in Table 9-476 (Reason Result Code field values).


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**Table 9-476—Reason Result Code field values**

| Reason Result Code field value | Name | Description |
|---|---|---|
| 0 | | Reserved |
| 1 | | Reserved |
| 2 | | Power constraint requested |
| 3 | SUCCESS | Success |
| 4 | REFUSED | Refused — no reason specified |
| 5 | INVALID_PARAMETERS | Request not successful as one or more parameters have invalid values |
| 6–255 | | Reserved |

The Local Power Constraint field is coded as an unsigned integer in units of decibels relative to 1 mW. The local maximum transmit power for a channel is thus defined as the maximum transmit power level specified for the channel in the Country element minus the local power constraint specified for the channel in the DSE Power Constraint frame.

### 9.6.7.11 Vendor Specific Public Action frame format

The Vendor Specific Public Action frame is defined for vendor-specific signaling between unassociated STAs. The format of the Action field of the Vendor Specific Public Action frame is shown in Figure 9-1198 (Vendor Specific Public Action frame Action field format).

| | Category | Public Action | Organization Identifier | Vendor Specific Content |
|---|---|---|---|---|
| Octets: | 1 | 1 | variable | variable |

**Figure 9-1198—Vendor Specific Public Action frame Action field format**

The Category field is defined in 9.4.1.11 (Action field).

The Public Action field is defined in 9.6.7.1 (Public Action field(#3729)).

The Organization Identifier field contains a organization identifier assigned by the IEEE and is specified in 9.4.1.29 (Organization Identifier field). The order of the Organization Identifier field is described in 9.2.2 (Conventions). The length of the Organization Identifier field is variable, as specified in 9.4.1.29 (Organization Identifier field).

The Vendor Specific Content field contains vendor-specific field(s). The length of the vendor specific content in a Vendor Specific Public Action(#4065) frame is limited by the maximum allowed MMPDU size.

### 9.6.7.12 GAS Initial Request frame format

The GAS Initial Request frame is transmitted by a requesting STA to request information from another STA. The format of the GAS Initial Request frame Action field is shown in Table 9-477 (GAS Initial Request frame Action field format).

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**Table 9-477—GAS Initial Request frame Action field format**

| Order | Information |
|---|---|
| 0 | Category |
| 1 | Public Action |
| 2 | Dialog Token |
| 3 | Advertisement Protocol element |
| 4 | Query Request Length |
| 5 | Query Request |
| 6 | Multi-band (optional) |
| 7 | CAG Number (optional) |
| 8 | GAS Extension (optional) |

The Category field is defined in 9.4.1.11 (Action field).

The Public Action field is defined in 9.6.7.1 (Public Action field(#3729)).

The Dialog Token field is defined in 9.4.1.12 (Dialog Token field) and set by the requesting STA.

The Advertisement Protocol element is defined in 9.4.2.91 (Advertisement Protocol element). The Advertisement Protocol element includes exactly one advertisement protocol ID.

The Query Request Length field is defined in Figure 9-1199 (Query Request Length field). The value of the Query Request Length field is set to the total number of octets in the Query Request field.

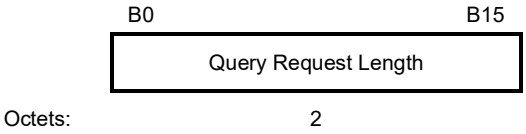


**Figure 9-1199—Query Request Length field**

The Query Request field is defined in Figure 9-1200 (Query Request field). The Query Request field is a generic container whose value is formatted in accordance with the protocol identified in the Advertisement Protocol element.

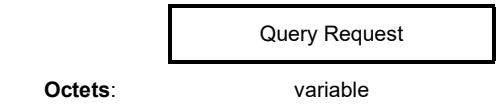


**Figure 9-1200—Query Request field**

When present in a GAS Initial Request frame, the Multi-band element indicates the frequency band, operating class, and channel number to which the GAS Initial Request frame applies.

When present in a GAS Initial Request frame, the CAG Number element includes one or more Common Advertisement Group (CAG) tuples. Each CAG tuple specifies a pair of CAG Version and CAG


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Information Type cached by the requesting STA and associated with the query request contained in the Query Request field.

The GAS Extension element indicating the STA support for GAS extension in GAS frame exchanges is optionally present if dot11GASExtensionImplemented is true.

### 9.6.7.13 GAS Initial Response frame format

The GAS Initial Response frame is transmitted in response to a GAS Initial Request frame or a Group Addressed GAS Request frame. The format of the GAS Initial Response frame Action field is shown in Table 9-478 (GAS Initial Response frame Action field format).

**Table 9-478—GAS Initial Response frame Action field format**

| Order | Information |
|---|---|
| 0 | Category |
| 1 | Public Action |
| 2 | Dialog Token |
| 3 | Status Code |
| 4 | GAS Comeback Delay |
| 5 | Advertisement Protocol element |
| 6 | Query Response Length |
| 7 | Query Response (optional) |
| 8 | Multi-band (optional) |
| 9 | GAS Extension (optional) |

The Category field is defined in 9.4.1.11 (Action field).

The Public Action field is defined in 9.6.7.1 (Public Action field(#3729)).

(#417)The Dialog Token field is defined in 9.4.1.12 (Dialog Token field). It is copied from the corresponding GAS Initial Request frame or Group Addressed GAS Request frame.

(#3326)The Status Code field values are defined in Table 9-80 (Status codes).

The GAS Comeback Delay field specifies the delay time value in TUs. The GAS Comeback Delay field format is shown in Figure 9-1201 (GAS Comeback Delay field format). The behavior is described in 11.22.3.2 (GAS Protocol). The value 0 (M118)is returned by the STA when a Query Response is provided in this frame.

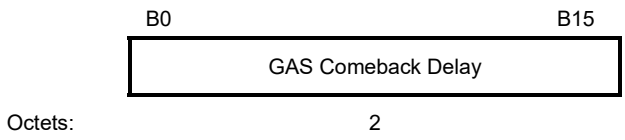


**Figure 9-1201—GAS Comeback Delay field format**

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The Advertisement Protocol element is defined in 9.4.2.91 (Advertisement Protocol element). The Advertisement Protocol element includes exactly one advertisement protocol ID.

The Query Response Length field is defined in Figure 9-1202 (Query Response Length field format). The Query Response Length field is set to the total number of octets in the Query Response field. If the Query Response Length field is set to 0, then there is no Query Response included in this Action frame.

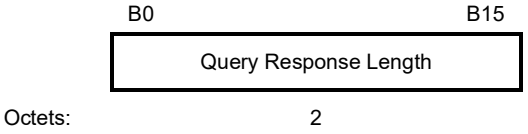


**Figure 9-1202—Query Response Length field format**

The Query Response field is defined in Figure 9-1203 (Query Response field format). The Query Response field is a generic container whose value is formatted in accordance with the protocol specified in the Advertisement Protocol element.

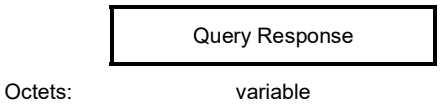


**Figure 9-1203—Query Response field format**

When present in a GAS Initial Response frame, the Multi-band element indicates the frequency band, operating class, and channel number to which the GAS Initial Response frame applies.

The GAS Extension element indicating the STA support for GAS extension in GAS frame exchanges is optionally present if dot11GASExtensionImplemented is true. It is included as a response to a GAS Initial Request frame containing a GAS Extension element.

### 9.6.7.14 GAS Comeback Request frame format

The GAS Comeback Request frame is transmitted by a requesting STA to a responding STA. The format of the GAS Comeback Request frame Action field is shown in Table 9-479 (GAS Comeback Request frame Action field format(#4092)).

**Table 9-479—GAS Comeback Request frame Action field format(#4092)**

| Order | Information |
|---|---|
| 0 | Category |
| 1 | Public Action |
| 2 | Dialog Token |
| 3 | Multi-band (optional) |
| 4 | GAS Extension (optional) |


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The Category field is defined in 9.4.1.11 (Action field).

The Public Action field is defined in 9.6.7.1 (Public Action field(#3729)).

(#417)The Dialog Token field is defined in 9.4.1.12 (Dialog Token field). It is copied from the corresponding GAS Initial Request frame.

When present in a GAS Comeback Request frame, the Multi-band element indicates the frequency band, operating class, and channel number to which the GAS Comeback Request frame applies.

When present in a GAS Comeback Request frame, the GAS Extension element indicates a request to retransmit a GAS query response(#7054) fragment.

### 9.6.7.15 GAS Comeback Request Fragment frame format(#6058)

The GAS Comeback Request Fragment frame is transmitted by a requesting STA to a responding STA. The format of the GAS Comeback Request Fragment frame Action field is shown in Table 9-480 (GAS Comeback Request Fragment frame Action field format(#6058)).

**Table 9-480—GAS Comeback Request Fragment frame Action field format(#6058)**

| Order | Information |
|---|---|
| 0 | Category |
| 1 | Public Action |
| 2 | Dialog Token |
| 3 | Status Code |
| 4 | GAS Query Fragment ID |
| 5 | Query Request Length |
| 6 | Query Request |
| 7 | Multi-band (optional) |
| 8 | GAS Extension (optional) |

The Category field is defined in 9.4.1.11 (Action field).

The Public Action field is defined in 9.6.7.1 (Public Action field(#3729)).

The Dialog Token field is defined in 9.4.1.12 (Dialog Token field). It is copied from the corresponding GAS Initial Request frame. The same value of the Dialog Token field is present in all fragments of a multi-fragment query request.

The Status Code field values are defined in Table 9-80 (Status codes).

The GAS Query Fragment ID field is defined in 9.4.1.31 (GAS Query Fragment ID field(#6058)). When there is more than one Query Request fragment, the requesting STA sets the GAS Query Fragment ID field to 0 for the initial fragment and increments it by 1 for each subsequent fragment in a multi-fragment query request. The More GAS Fragments field is set to 0 whenever the final fragment of a GAS query request is

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being transmitted. A GAS Query Fragment ID field having a nonzero (#8184)GAS Fragment ID field and the More GAS Fragments field set to 1 indicates to the responding STA that another GAS Comeback Request and GAS Comeback Response frame exchange should be performed to continue the retrieval of the GAS query request.

The Query Request Length field is defined in 9.6.7.12 (GAS Initial Request frame format).

The Query Request field is defined in 9.6.7.12 (GAS Initial Request frame format).

When present in a GAS Comeback Request Fragment frame, the Multi-band element indicates the frequency band, operating class, and channel number to which the GAS Comeback Request Fragment frame applies.

### 9.6.7.16 GAS Comeback Response frame format

The GAS Comeback Response frame is transmitted by a responding STA to a requesting STA. The format of the GAS Comeback Response frame Action field is shown in Table 9-481 (GAS Comeback Response frame Action field format).

**Table 9-481—GAS Comeback Response frame Action field format**

| Order | Information |
|---|---|
| 0 | Category |
| 1 | Public Action |
| 2 | Dialog Token |
| 3 | Status Code |
| 4 | GAS Query Fragment ID(#6058) |
| 5 | GAS Comeback Delay |
| 6 | Advertisement Protocol element |
| 7 | Query Response Length |
| 8 | Query Response (optional) |
| 9 | Multi-band (optional) |
| 10(#6058) | GAS Extension (optional) |

The Category field is defined in 9.4.1.11 (Action field).

The Public Action field is defined in 9.6.7.1 (Public Action field(#3729)).

(#417)The Dialog Token field is defined in 9.4.1.12 (Dialog Token field). It is copied from the Dialog Token field of the corresponding GAS Comeback Request or (#6058)GAS Comeback Request Fragment frame. The same value of the Dialog Token field is present in all fragments of a multi-fragment query response.

(#3326)The Status Code field values are defined in Table 9-80 (Status codes). The same status code value is present in all fragments of a multi-fragment query response.


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The GAS Query Fragment ID field is defined in 9.4.1.31 (GAS Query Fragment ID field(#6058)). If the responding STA has not received a response to the query that it posted on behalf of a requesting STA, then the responding STA sets the GAS Query Fragment ID field to 0. When there is more than one query response fragment, the responding STA sets the GAS Query Fragment ID field to 0 for the initial fragment and increments it by 1 for each subsequent fragment in a multi-fragment query response. The More GAS Fragments field is set to 0 whenever the final fragment of a query response is being transmitted. A GAS Query Fragment ID field having a nonzero (#8184)GAS Fragment ID field and the More GAS Fragments field set to 1 indicates to the requesting STA that another GAS Comeback Request and GAS Comeback Response frame exchange should be performed to continue the retrieval of the query response.(#6058)

The GAS Comeback Delay field format is shown in Figure 9-1201 (GAS Comeback Delay field format). A nonzero GAS Comeback Delay field(#4356) is returned by the responding STA in this frame to indicate that the GAS query request(#7052) being carried out on behalf of the requesting STA is still in progress.

— A nonzero value indicates to the requesting STA that another GAS Comeback Request and GAS Comeback Response frame(#6058) exchange should be performed after the expiration of the GAS comeback delay(#4356) timer in order to retrieve the query response.

— This field is set to 0 for all GAS Comeback Response frames containing a query response or a fragment of a multi-fragment query response.

The Advertisement Protocol element is defined in 9.4.2.91 (Advertisement Protocol element). The Advertisement Protocol element includes exactly one advertisement protocol ID.

The Query Response Length field is defined in Figure 9-1202 (Query Response Length field format). The Query Response Length field is set to the total number of octets in the Query Response field. If the Query Response Length field is set to 0, then there is no Query Response included in this Action frame.

The Query Response field is defined in Figure 9-1203 (Query Response field format). The Query Response field is a generic container dependent on the advertisement protocol specified in the Advertisement Protocol element and the query itself. In a multi-fragment (#6058)GAS query response, the response to the (#6058)GAS query request posted on behalf of a requesting STA is fragmented such that each fragment to be transmitted fits within the MMPDU size limitation.

When present in a GAS Comeback Response frame, the Multi-band element indicates the frequency band, operating class, and channel number to which the GAS Comeback Response frame applies.

### 9.6.7.17 TDLS Discovery Response frame format

The format of the TDLS Discovery Response frame Action field is shown in Table 9-482 (TDLS Discovery Response frame Action field format). (#1751)

**Table 9-482—TDLS Discovery Response frame Action field format**

| Order | Information | Notes |
|---|---|---|
| 1 | Category | The Category field is defined in 9.4.1.11 (Action field). |
| 2 | Public Action | The Public Action field is defined in 9.6.7.1 (Public Action field(#3729)). |
| 3 | Dialog Token | The dialog token is copied from the corresponding TDLS Discovery Request frame. The dialog token is specified in 9.4.1.12 (Dialog Token field). |

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**Table 9-482—TDLS Discovery Response frame Action field format**

| Order | Information | Notes |
|---|---|---|
| 4 | Capability | The Capability field indicates the capabilities of the STA. The Capability field is defined in 9.4.1.4 (Capability Information field). |
| 5 | Supported Rates and BSS Membership Selectors | The Supported Rates and BSS Membership Selectors element indicates the rates supported by the STA. The Supported Rates and BSS Membership Selectors element is defined in 9.4.2.3 (Supported Rates and BSS Membership Selectors element). |
| 6 | Extended Supported Rates and BSS Membership Selectors | (#3086)The Extended Supported Rates and BSS Membership Selectors element is present if the number of supported rates and BSS membership selectors(#1470) together exceed eight; it is optional otherwise.<br>The Extended Supported Rates and BSS Membership Selectors element is defined in 9.4.2.11 (Extended Supported Rates and BSS Membership Selectors element). |
| 7 | Supported Channels | The Supported Channels element is present if the TDLS Channel Switching subfield is equal to 1.<br>The Supported Channels element is defined in 9.4.2.16 (Supported Channels element). |
| 8 | RSNE | The RSNE is present if security is required on the TDLS direct link (see 12.7.8.1 (General)); otherwise not present.(#3400)<br>The RSNE is defined in 9.4.2.23 (RSNE). |
| 9 | Extended Capabilities | The Extended Capabilities element is present if any of the fields in this element are nonzero. The Extended Capabilities element is defined in 9.4.2.25 (Extended Capabilities element). |
| 10 | Timeout Interval (TPK key lifetime) | The (#1776)TIE contains the TPK key lifetime.<br>It is present if security is required on the TDLS direct link (see 12.7.8.1 (General)).<br>The (#1776)TIE is defined in 9.4.2.47 (TIE(#1776)). |
| 11 | Supported Operating Classes | The Supported Operating Classes element is present if the TDLS Channel Switching subfield is equal to 1. |
| 12 | HT Capabilities | The HT Capabilities element is present when dot11HighThroughputOptionImplemented is true.<br>The HT Capabilities element is defined in 9.4.2.54 (HT Capabilities element). |
| 13 | 20/40 BSS Coexistence | The 20/40 BSS Coexistence element is present when dot112040BSSCoexistenceManagementSupport is true. The 20/40 BSS Coexistence element is defined in 9.4.2.58 (20/40 BSS Coexistence element). |
| 14 | Link Identifier | The Link Identifier element is defined in 9.4.2.60 (Link Identifier element). |
| 15 | Multi-band | The Multi-band element is optionally present if dot11MultibandImplemented is true. |
| 16 | VHT Capabilities | VHT Capabilities element (optional). The VHT Capabilities element is present in the 5 GHz band if dot11VHTOptionImplemented is true.(#8181) The VHT Capabilities element is defined in 9.4.2.156 (VHT Capabilities element). |


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**Table 9-482—TDLS Discovery Response frame Action field format**

| Order | Information | Notes |
|---|---|---|
| 18(Ed1)(11ax) | HE Capabilities | The HE Capabilities element is present if dot11HEOptionImplemented is true; otherwise, it is not present, The HE Capabilities element is defined in 9.4.2.247 (HE Capabilities element(11ax)). |
| 19(#3013) | HE 6 GHz Band Capabilities | The HE 6 GHz Band Capabilities element is present if dot11HEOptionImplemented and dot11HE6GOptionImplemented are true; otherwise, it is not present. |

### 9.6.7.18 Location Track Notification frame format

The Location Track Notification frame is transmitted to allow remote location determination to occur by another STA. The format of the Location Track Notification frame Action field is shown in Figure 9-1204 (Location Track Notification frame Action field format).

| | Category | Public Action | Location Parameters Element | Measurement Report Element (optional) |
|---|---|---|---|---|
| Octets: | 1 | 1 | variable | variable |

**Figure 9-1204—Location Track Notification frame Action field format**

The Category field is defined in 9.4.1.11 (Action field).

The Public Action field is defined in 9.6.7.1 (Public Action field(#3729)).

The Location Parameters Element field contains the Location Parameters subelements, described in Table 9-253 (Optional subelement IDs for Location Parameters). Table 9-483 (Location Parameters Element field for Location Track Notification frame) defines the allowed Location Parameters subelements for a Location Parameters element that is included in the frame.

**Table 9-483—Location Parameters Element field for Location Track Notification frame**

| Allowed subelements | Subelement ID | Notes |
|---|---|---|
| Location Indication Channels | 2 | The Location Indication Channels subelement is included in the Location Track Notification frame. |
| Radio Information | 4 | The Radio subelement is included in the Location Track Notification frame. |
| Motion | 5 | The Motion subelement is included in the Location Track Notification frame if dot11MotionDetectionActivated is true. |
| Time of Departure | 7 | The Time of Departure subelement is included in the Location Track Notification frame if dot11TODActivated is true. |
| Location Indication Options | 8 | The Location Indication Options subelement is included in the Location Track Notification frame if the successful Location Configuration Request frame that configured the STA included a Location Indication Options subelement. |

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The Measurement Report Element field contains a Measurement Report element of type Beacon report as defined in 9.4.2.20.7 (Beacon report). The Measurement Report Element field is included in the Location Track Notification frame if the Location Parameters Element field contains a Location Indication Options subelement. The Measurement Report element Measurement Token field is set to the same value of the dialog token in the Location Configuration Request frame that configured the STA.

### 9.6.7.19 QMF Policy frame format

The QMF Policy frame is transmitted by a requesting STA to a receiving STA with the included QMF policy. It is either sent unsolicited by the requesting STA or in response to a QMF Policy Change frame from a receiving STA. The format of the Action field of the QMF Policy frame is shown in Figure 9-1205 (QMF Policy frame Action field contents).

| | Category | Public Action | Dialog Token | Status Code | QMF Policy element (optional) |
|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 2 | 0 or 3-257 |

**Figure 9-1205—QMF Policy frame Action field contents**

The Category field is defined in 9.4.1.11 (Action field).

The Public Action field is defined in 9.6.7.1 (Public Action field(#3729)).

(#417)The Dialog Token field is defined in 9.4.1.12 (Dialog Token field). It is set to the value in the corresponding QMF Policy Change frame. If the QMF Policy frame is not being transmitted in response to a QMF Policy Change frame, then the Dialog Token field is set to 0.

The Status Code field is defined in Table 9.4.1.9 (Status Code field).

The QMF Policy element is set as described in 9.4.2.118 (Quality-of-Service Management Frame Policy element). It indicates the new access categories configured for Management frame(s). This field is included if the (#7190)status code is SUCCESS and this frame is not being transmitted in response to a QMF Policy Change frame, and optionally included if the Status Code field(M118) is REQUEST_DECLINED.

### 9.6.7.20 QMF Policy Change frame format

The QMF Policy Change frame is transmitted by a requesting STA to request a change to the QMF policy it most recently received from the destination STA. The format of the Action field of the QMF Policy Change frame is shown in Figure 9-1206 (QMF Policy Change frame Action field contents).

| | Category | Public Action | Dialog Token | QMF Policy element |
|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 3-257 |

**Figure 9-1206—QMF Policy Change frame Action field contents**

The Category field is defined in 9.4.1.11 (Action field).

The Public Action field is defined in 9.6.7.1 (Public Action field(#3729)).

(#417)The Dialog Token field is defined in 9.4.1.12 (Dialog Token field). It is set to a nonzero value chosen by the STA sending the QMF Policy Change frame to identify the transaction.


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The QMF Policy element is set as described in 9.4.2.118 (Quality-of-Service Management Frame Policy element). It indicates the access categories requested for Management frame(s), including any changes to the QMF policy it most recently received from the destination STA.

### 9.6.7.20 QLoad Request frame format

The QLoad Request frame is transmitted by an AP to request information from another AP. The format of the Action field of the QLoad Request frame is shown in Table 9-484 (QLoad Request frame Action field format).

**Table 9-484—QLoad Request frame Action field format**

| Order | Information |
|---|---|
| 1 | Category |
| 2 | Public Action |
| 3 | Dialog Token |
| 4 | QLoad Report element |

The Category field is defined in 9.4.1.11 (Action field).

The Public Action field is defined in 9.6.7.1 (Public Action field(#3729)).

The Dialog Token field is defined in 9.4.1.12 (Dialog Token field) and set by the requesting STA to a nonzero value that is used for matching action responses with action requests. See 10.28.5 (Operation of the Dialog Token field).

The QLoad Report element is defined in 9.4.2.121 (QLoad Report element) and contains the QLoad report corresponding to the AP sending the request.

### 9.6.7.21 QLoad Report frame format

The QLoad Report frame is transmitted by an AP responding to a QLoad Request frame. The format of the Action field of the QLoad Report frame is shown in Table 9-485 (QLoad Report frame Action field format).

**Table 9-485—QLoad Report frame Action field format**

| Order | Information |
|---|---|
| 1 | Category |
| 2 | Public Action |
| 3 | Dialog Token |
| 4 | QLoad Report element |

The Category field is defined in 9.4.1.11 (Action field).

The Public Action field is defined in 9.6.7.1 (Public Action field(#3729)).

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The Dialog Token field is defined in 9.4.1.12 (Dialog Token field) and set by the requesting STA to a nonzero value that is used for matching action responses with action requests. See 10.28.5 (Operation of the Dialog Token field). The Dialog Token field is set to 0 when an unsolicited QLoad Report frame is sent by the AP.

The QLoad Report element is defined in 9.4.2.121 (QLoad Report element).

### 9.6.7.22 HCCA TXOP Advertisement frame

The HCCA TXOP Advertisement frame is transmitted by an AP to another AP to inform it of active and pending TXOP reservations. The format of the Action field of the HCCA TXOP Advertisement frame is shown in Figure 9-1207 (HCCA TXOP Advertisement frame Action field format).

| | Category | Public Action | Dialog Token | Number of Reported TXOP Reservations | Number of Pending TXOP Reservations | Active TXOP Reservations | Pending TXOP Reservations |
|---|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 1 | 1 | variable | variable |

**Figure 9-1207—HCCA TXOP Advertisement frame Action field format**

The Category field is defined in 9.4.1.11 (Action field).

The Public Action field is defined in 9.6.7.1 (Public Action field(#3729)).

The Dialog Token field is defined in 9.4.1.12 (Dialog Token field) and is set by the AP to a nonzero value that is used for matching action responses with action requests. See 10.28.5 (Operation of the Dialog Token field).

The Number of Reported TXOP Reservations field contains a positive integer that specifies the number of active TXOP reservations reported in this frame. Setting the field to 0 indicates that no TXOP reservations are active.

The Number of Pending Reported TXOP Reservations field contains a positive integer that specifies the number of pending TXOP reservations reported in this frame. Setting the field to 0 indicates that no TXOP reservations are in the process of being activated.

The Active TXOP Reservation field contains zero or more TXOP Reservation fields as defined in 9.4.1.41 (TXOP Reservation field). This field indicates active HCCA TXOPs that the AP has scheduled. The Start Time subfield of the TXOP Reservation field is relative to the TSF of the sending AP.

The Pending TXOP Reservation field contains zero or more TXOP Reservation fields as defined in 9.4.1.41 (TXOP Reservation field). This field indicates new HCCA TXOPs that the AP is scheduling. The Start Time subfield of the TXOP Reservation field is relative to the TSF of the sending AP.

The use of the HCCA TXOP Advertisement frame is described in 11.26.3 (HCCA TXOP negotiation).

### 9.6.7.23 HCCA TXOP Response frame

The HCCA TXOP Response frame is transmitted by an AP to another AP to respond to an HCCA TXOP Advertisement frame. The format of the Action field of the HCCA TXOP Response frame is shown in Figure 9-1208 (HCCA TXOP Response frame Action field format).


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| | Category | Public Action | Dialog Token | Status Code | Schedule Conflict | Alternate Schedule | Avoidance Request |
|---|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 2 | 0 or 1 | 0 or 6 | 0 or 6 |

**Figure 9-1208—HCCA TXOP Response frame Action field format**

The Category field is defined in 9.4.1.11 (Action field).

The Public Action field is defined in 9.6.7.1 (Public Action field(#3729)).

(#417)The Dialog Token field is defined in 9.4.1.12 (Dialog Token field). It is set to the value of the Dialog Token field from the corresponding HCCA TXOP Advertisement frame.

The Status Code field is defined in 9.4.1.9 (Status Code field) and is set to either the value SUCCESS or TS_SCHEDULE_CONFLICT.

The Schedule Conflict field is present only when the Status Code field is not SUCCESS. The Schedule Conflict field indicates the TXOP reservation from the HCCA TXOP Advertisement frame that conflicts with an existing or in-progress schedule. Its value is between 1 and the summation of the values from the Number of Reported TXOP Reservations and Number of Pending TXOP Reservations fields of the HCCA TXOP Advertisement frame. Setting the field to 1 indicates the first TXOP reservation in the HCCA TXOP Advertisement frame, setting the field to 2 indicates the second TXOP reservation in the HCCA TXOP Advertisement frame, and so on. The value of zero is reserved.

The optional Alternate Schedule field contains a TXOP Reservation field, as defined in 9.4.1.41 (TXOP Reservation field) and is present only when the Status Code field is not SUCCESS. When the Alternate Schedule field is present, it contains an alternate to the TXOP reservation given in the corresponding HCCA TXOP Advertisement frame. The Start Time subfield of the Alternate Schedule field is relative to the TSF of the destination AP.

The optional Avoidance Request field contains a TXOP Reservation field, as defined in 9.4.1.41 (TXOP Reservation field) and is optionally present when the Status Code field is not SUCCESS. When the Avoidance Request field is present, it indicates a TXOP schedule that the AP sending the TXOP Response frame is requesting to be avoided by the AP that is the destination of the TXOP Response frame. The Start Time subfield of the Avoidance Request field is relative to the TSF of the destination AP.

The use of the HCCA TXOP Response frame is described in 11.26.3 (HCCA TXOP negotiation).

### 9.6.7.24 Public Key frame

The Public Key frame is transmitted by an AP to provide its public key to peer APs and to request the peer's public key. The format of the Public Key frame Action field is defined in Figure 9-1209 (Public Key frame Action field format).

| | Category | Public Action | Public Key Frame Usage | Finite Cyclic Group | Public Key (optional) |
|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 2 | variable |

**Figure 9-1209—Public Key frame Action field format**

The Category field is defined in 9.4.1.11 (Action field).

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The Public Action field is defined in 9.6.7.1 (Public Action field(#3729)).

The Public Key Frame Usage field is set to a number to signify the usage mode of this frame. The Request Types are shown in Table 9-486 (Public Key Frame Usage field values).

**Table 9-486—Public Key Frame Usage field values**

| Public Key Frame Usage | Value |
|---|---|
| Request | 0 |
| Response | 1 |
| NAK | 2 |
| Refused | 3 |
| Reserved | 4–255 |

The Public Key Frame Usage field is set to "Request" to indicate that a public key is being requested from a peer AP.

The Public Key Frame Usage field is set to "Response" to indicate that this frame is in response to a Public Key frame.

The Public Key Frame Usage field is set to "NAK" to indicate rejection of a received Public Key frame.

The Finite Cyclic Group field is used to indicate the cryptographic group used when generating the public key and is defined in 9.4.1.40 (Finite Cyclic Group field)), or the preferred group when the Public Key Frame Usage field is set to "NAK".

When the Public Key Frame Usage field is set to "NAK" or "Refused", the Public Key field is not included. In all other cases, the Public Key field contains the public key of the AP that is sending this Public Key frame encoded as an octet string according to 12.4.7.2.5 (Octet string to element conversion).

The use of the Public Key frame is described in 12.10 (AP PeerKey support).

### 9.6.7.25 Channel Availability Query frame format

The Channel Availability Query frame is transmitted as part of a channel query. The format of the Channel Availability Query frame Action field is shown in Figure 9-1210 (Channel Availability Query frame Action field format).

| | Category | Public Action | Requester STA Address | Responder STA Address | Reason Result Code | Length | Channel Query Info | Device Class | Device Identification Information | Device Location Information | WSM Information |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 6 | 6 | 1 | 1 | 1 | variable | variable | variable | variable |

**Figure 9-1210—Channel Availability Query frame Action field format**

The Category field is defined in 9.4.1.11 (Action field).

The Public Action field is defined in 9.6.7.1 (Public Action field(#3729)).


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The Length field indicates the length of the remaining frame fields in octets, and the value is variable.

The remaining fields are as defined in the Channel Availability Query element (see 9.4.6.2 (Channel Availability Query RLQP-element)) and White Space Map element (see 9.4.2.168 (White Space Map element)).

### 9.6.7.26 Channel Schedule Management frame format

The Channel Schedule Management frame is transmitted to exchange the channel schedule information as part of the channel schedule management procedure. The format of the Channel Schedule Management frame Action field is shown in Figure 9-1211 (Channel Schedule Management frame Action field format).

| | Category | Public Action | Requester STA Address | Responder STA Address | Length | Reason Result Code | Channel Schedule Management Mode | Device Identification Information | Channel Schedule Descriptor |
|---|---|---|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 6 | 6 | 1 | 1 | 1 | variable | variable |

**Figure 9-1211—Channel Schedule Management frame Action field format**

The Category field is defined in 9.4.1.11 (Action field).

The Public Action field is defined in 9.6.7.1 (Public Action field(#3729)).

The Requester STA Address field is the MAC address of the requesting STA that initiates the Channel Schedule Management process.

The Responder STA Address field is the MAC address of the STA that responds to the STA that requested channel schedule management.

The Length field indicates the length of the remaining fields in octets, and the value is variable.

The Reason Result Code field indicates the reason for transmitting a query request for channel schedule information. It also indicates the result of a query as successful or not and the reason when the query is not successful. This field is defined in Table 9-487 (Reason Result Code field values).

**Table 9-487—Reason Result Code field values**

| Reason Result Code field values | Description |
|---|---|
| 0 | Request for channel schedule information from a RLSS. |
| 1 | Request for channel schedule information from a GDD enabling STA. |
| 2 | Success, returning full channel schedule information on the requested channels. |
| 3 | Success, returning additional timeslots from the list of the last query on the requested channels. |
| 4 | Success, returning timeslots deleted from the list of last query on the requested channels. |
| 5 | Success, returning deleted and added timeslots from the list of last query on the requested channels. |

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**Table 9-487—Reason Result Code field values *(continued)***

| Reason Result Code field values | Description |
|---|---|
| 6 | Success, returning no channel schedule changes from last query. |
| 7 | Request declined by the GDD enabling STA for unspecified reason. |
| 8 | Request declined by the GDD enabling STA because of no capability for providing schedule information on WLAN channels. |
| 9 | Request declined by RLSS for unspecified reason. |
| 10 | Request declined by RLSS because of no capability for providing schedule information on WLAN channels. |
| 11 | Unknown reason. |
| 12 | Continuation frame. This frame continues the fields from the previous CSM frame. |
| 13–63 | Reserved. |

The Channel Schedule Management Mode field indicates if the schedule information of the channel availability is based on TV channels or WLAN channels. If the schedule information is based on WLAN channels, the optional Operating Class field is present in the Channel Schedule Descriptor field as defined in E.1 (Country information and operating classes). This field also indicates whether the optional Channel Availability Starting Time field is present in the Channel Schedule Descriptor field. This field is defined in Table 9-488 (Channel Schedule Management Mode field values).

**Table 9-488—Channel Schedule Management Mode field values**

| Channel Schedule Management Mode value | Description |
|---|---|
| 0 | The channel schedule information is based on TV channels. The Reason Result Code field is set to either 0 or 1. |
| 1 | The channel schedule information is based on WLAN channels. The Reason Result Code field is set to either 0 or 1. |
| 2–3 | Reserved. |

The Device Identification Information field indicates the regulatory identification of the STA that is requesting the schedule information. The Device Identification Information field is present only when Reason Result Code is either 0 or 1. The field is defined in 9.4.4.2.3 (Device Identification Information).

The Channel Schedule Descriptor field indicates the channels for which the schedule information is requested, and the channel schedule information is provided in the response. The field is defined in 9.4.4.2.5 (Channel Schedule Descriptor). The Channel Schedule Descriptor field is repeated, as determined by the Length field.


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### 9.6.7.27 Contact Verification Signal frame format

The Contact Verification Signal frame is transmitted by a GDD enabling STA to notify whether the available channel information from the GDB has been updated. The format of the Contact Verification Signal frame Action field is shown in Figure 9-1212 (Contact Verification Signal frame Action field format).

| | Category | Public Action | Map ID |
|---|---|---|---|
| Octets: | 1 | 1 | 1 |

**Figure 9-1212—Contact Verification Signal frame Action field format**

The Category field is defined in 9.4.1.11 (Action field).

The Public Action field is defined in 9.6.7.1 (Public Action field(#3729)).

The Map ID field is set to a number that is equal to the Map ID of the recently received WSM. The WSM is defined in Table 9-424 (WSM information values) in 9.4.4.2.6 (WSM information values).

### 9.6.7.28 GDD Enablement Request frame format

The format of the Action field of the GDD Enablement Request frame is shown in Figure 9-1213 (GDD Enablement Request frame Action field format).

| | Category | Public Action | Dialog Token | Device Class | Device Identification Information |
|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 1 | variable |

**Figure 9-1213—GDD Enablement Request frame Action field format**

The Category field is defined in 9.4.1.11 (Action field).

The Public Action field is defined in 9.6.7.1 (Public Action field(#3729)).

(#417)The Dialog Token field is defined in 9.4.1.12 (Dialog Token field). It is a nonzero value chosen by the STA sending the GDD Enablement Request frame to identify the request/response transaction.

The Device Class field is used to indicate the characteristic of the STA requesting the GDD Enablement Request frame. The format of the Device Class field is specified in 9.4.4.2.2 (Device Class).

The Device Identification Information field is used to indicate the identification of the STA requesting the GDD Enablement Request frame. The format of the Device Identification Information field is specified in 9.4.4.2.3 (Device Identification Information).

### 9.6.7.29 GDD Enablement Response frame format

The format of the Action field of the GDD Enablement Response frame is shown in Figure 9-1214 (GDD Enablement Response frame Action field format).

The Category field is defined in 9.4.1.11 (Action field).

The Public Action field is defined in 9.6.7.1 (Public Action field(#3729)).

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| | Category | Public Action | Dialog Token | Status Code | WSM Information |
|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 2 | variable |

**Figure 9-1214—GDD Enablement Response frame Action field format**

(#417)The Dialog Token field is defined in 9.4.1.12 (Dialog Token field). It is a nonzero value of the corresponding GDD Enablement Request frame. If a GDD Enablement Response frame is being transmitted other than in response to an GDD Enablement Request frame, then the Dialog Token field is 0.

The Status Code field contains the status code in response to a GDD Enablement Request frame as defined in Table 9-80 (Status codes).

The remaining field is defined in the WSM element (see 9.4.2.168 (White Space Map element)).

### 9.6.7.30 Network Channel Control frame format

The Network Channel Control frame is transmitted by a GDD dependent STA and a GDD enabling STA as part of the procedure that allows a GDD enabling STA to control the frequency usage of a GDD dependent STA's WLAN channels. The format of the Network Channel Control frame is shown in Figure 9-1215 (Network Channel Control frame Action field format).

| | | | | | | | | a Network Channel Control triplet | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Category | Public Action | Length | Requester STA Address | Responder STA Address | Reason Result Code | Number of Network Channel Control Triplets | Operating Class | Channel Number | Maximum Transmit Power |
| Octets: | 1 | 1 | 1 | 6 | 6 | 1 | 1 | 1 | 1 | 1 |

**Figure 9-1215—Network Channel Control frame Action field format**

The Category field is defined in 9.4.1.11 (Action field).

The Public Action field is defined in 9.6.7.1 (Public Action field(#3729)).

The Length field indicates the length of the remaining frame fields in octets, and the value is variable. The minimum value of the Length field is 14.

The Requester STA Address field is the MAC address of the requesting STA that initiates the network channel control process.

The Responder STA Address field is the MAC address of the STA that responds to the STA that requested network channel control.

The Reason Result Code field is used to indicate the reason that a Network Channel Control frame was generated. (#8141)The encoding of the Reason Result Code field is shown in Table 9-448 (Reason Result Code field values).

The Number of Network Channel Control Triplets field indicates the number of triplets of Operating Class, Channel Number, and Maximum Transmit Power fields.

The Operating Class field indicates the channel set for which the network channel control request applies. The Operating Class and Channel Number fields together specify the channel frequency and channel


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bandwidth for which the network channel control applies. Values for the Operating Class field are shown in E.1 (Country information and operating classes).

In a request, the Channel Number field of the Network Channel Control frame indicates the channel that the requesting STA intends to operate on. In the response, the Channel Number field in the Network Channel Control frame indicates the channels that the responding STA permits the requesting STA to operate on. The Channel Number is defined within an Operating Class as shown in E.1 (Country information and operating classes).

The Maximum Transmit Power field gives the intended maximum transmit power in dBm for operation in the request frame and indicates the maximum allowable transmit power in dBm for operation in the response frame. The field contains EIRP per channel bandwidth and is coded as a 2s complement signed integer in units of 0.5 dBm. The field is set to 0 when a requesting STA requests a responding STA to provide a network channel control response without specifying in the request the intended maximum transmit power.

### 9.6.7.31 White Space Map Announcement frame format

The format of the Action field of the White Space Map Announcement frame is shown in Figure 9-1216 (White Space Map Announcement frame Action field format).

| | Category | Public Action | Reason Result Code | White Space Map |
|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | variable |

**Figure 9-1216—White Space Map Announcement frame Action field format**

The Category field is defined in 9.4.1.11 (Action field).

The Public Action field is defined in 9.6.7.1 (Public Action field(#3729)).

Setting the Reason Result Code field to 1 indicates the Public Action frame is a continuation of the previous WSM Public Action frame, and any other value indicates this is not a continuation of the previous WSM Public Action frame.

The White Space Map field contains a White Space Map element (see 9.4.2.168 (White Space Map element)).

### 9.6.7.32 FTM(11az) Request frame format

The format of the FTMR frame(#7223) Action field is shown in Figure 9-1217 (FTM Request frame Action field format(11az)(#7065)).

| | Category | Public Action | Trigger | LCI Measurement Request (optional) | Location Civic Measurement Request (optional) | FTM Parameters (optional) |
|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | variable | variable | variable |

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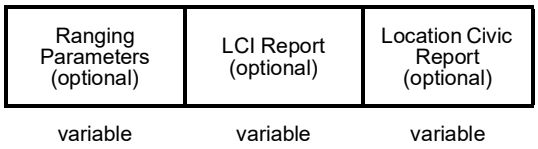


**Figure 9-1217—FTM Request frame Action field format(11az)(#7065)**

The Category field is defined in 9.4.1.11 (Action field).

The Public Action field is defined in 9.6.7.1 (Public Action field(#3729)).

(11az)When the Trigger field is set to 1, the ISTA requests that the RSTA start or continue sending FTM frames (see 11.21.6 (FTM procedure(#7065))). When the Trigger field is set to 0, indicates that the ISTA requests that the RSTA stop sending FTM frames.

(11az)When the Trigger field is set to 2, an EDMG ISTA initiates an (#8113)FTM exchange using the first path AWV; see 11.21.6.4.2.6 (DMG first path AWV for EDCA based ranging measurement exchange(11az)). (#8259)When the Trigger field is set to 3, an EDMG ISTA indicates that the following FTM burst is requested to contain LOS assessment measurements. If the FTM burst is performed over the first path AWV and is requested to contain LOS assessment measurements, the Trigger field is set to 4. Trigger field values (11az)5–255 are reserved.

The LCI Measurement Request field is optionally present. If present, it contains a Measurement Request element with Measurement Type field equal to LCI (see Table 9-136 (Measurement type definitions for measurement requests)), which indicates a request for a Measurement Report element with Measurement Type field equal to LCI (see 11.21.6.7 (LCI and Location Civic retrieval using FTM procedure)). The Enable subfield(#291) in the Measurement Request Mode field in the Measurement Request element is set to 0. The Location Subject field in the Measurement Request field of the Measurement Request element is set to Location Subject Remote (see Table 9-148 (Location Subject field definition)). The Request, Report and Duration Mandatory subfield(#291) in the Measurement Request Mode field in the Measurement Request element are reserved (see 9.4.2.19.1 (General)).

The Location Civic Measurement Request field is optionally present. If present, it contains a Measurement Request element with Measurement Type field equal to Location Civic (see Table 9-136 (Measurement type definitions for measurement requests)), which indicates a request for a Measurement Report element with Measurement Type field equal to Location Civic (see 11.21.6.7 (LCI and Location Civic retrieval using FTM procedure)). The Enable subfield(#291) in the Measurement Request Mode field in the Measurement Request element is set to 0. The Location Subject field in the Measurement Request field of the Measurement Request element is set to Location Subject Remote (see Table 9-148 (Location Subject field definition)). The Location Service Interval Units field in the Measurement Request field of the Measurement Request element is set to 0. The Request, Report and Duration Mandatory subfield(#291) in the Measurement Request Mode field within the Measurement Request element are reserved (see 9.4.2.19.1 (General)).

(11az)The FTM Parameters field is optionally present. It is present in an IFTMR frame and its retransmissions when negotiating EDCA based ranging; see 11.21.6.3.2 (Negotiation for EDCA based ranging measurement exchange).

(11az)The Ranging Parameters field is present in the IFTMR frame, and its retransmissions, when the initiator requires negotiation of parameters with the responder in order to perform non-TB ranging, or TB ranging measurement exchange, see 11.21.6.3 (FTM procedure negotiation(11az)). If present, it contains a Ranging Parameters element as defined in 9.4.2.300 (Ranging Parameters element(11az)).


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(11az)The LCI Report field is optional in an IFTMR frame and is present if the frame contains a TB specific subelement with the Passive TB Ranging field set to 1. The Location Civic Report field is optional in an IFTMR frame and can be present if the frame contains a TB specific subelement with the Passive TB Ranging field set to 1. The LCI Report and Location Civic Report fields are not present in IFTMR frames without a TB specific subelement with the Passive TB Ranging field set to 1. The format of the LCI Report is defined in 9.4.2.20.1 (General) and 9.4.2.20.10 (LCI report (Location configuration information report)). The LCI Report contains the Antenna Placement And Calibration subelement if the ISTA has dot11PassiveTBRangingAoDImplemented equal to true, and does not contain the Antenna Placement And Calibration subelement if the ISTA has dot11PassiveTBRangingAoDImplemented equal to false. The format of the Location Civic Report is defined in 9.4.2.20.1 (General) and 9.4.2.20.13 (Location Civic report).

### 9.6.7.33 FTM(11az) frame format

(11az)The FTM frame is an Action frame, except when transmitted in an A-MPDU, where it is an Action No Ack frame. The FTM is used to support the FTM procedure described in 11.21.6 (FTM procedure(#7065)). The format of the (11az)FTM frame Action field is shown in Figure 9-1218 (FTM frame Action field format(11az)(#7065)).

| | TOD Error | TOA Error | LCI Report (optional) | Location Civic Report (optional) | FTM Parameters (optional) | FTM Synchronization Information (optional) | Ranging Parameters (optional) |
|---|---|---|---|---|---|---|---|
| Octets: | 2 | 2 | variable | variable | variable | variable | variable |

| | Secure HE-LTF Parameters (optional) | Channel Measurement Feedback Type (optional) | Channel Measurement Feedback (optional) | Direction Measurement Results (optional) | Multiple Best AWV ID (optional) | Multiple AOD Feedback (optional) | LOS Likelihood (optional) |
|---|---|---|---|---|---|---|---|
| Octets: | 14 | 2 | variable | 9 | variable | variable | 4 |

**Figure 9-1218—FTM frame Action field format(11az)(#7065)**

The Category field is defined in 9.4.1.11 (Action field).

The Public Action field is defined in 9.6.7.1 (Public Action field(#3729)).

The TOD Error field format is shown in Figure 9-1219 (TOD Error field format(11az)).

| | B0 B4 | B5 B14 | B15 |
|---|---|---|---|
| | Max TOD Error Exponent | Reserved | TOD Not Continuous |
| Bits: | 5 | 10 | 1 |

**Figure 9-1219—TOD Error field format(11az)**

The TOA Error field format is shown in Figure 9-1220 (TOA Error field format(11az)).

(#417)The Dialog Token field is defined in 9.4.1.12 (Dialog Token field). It is a nonzero value chosen by the responding STA to identify the (11az)FTM frame as the first of a pair, with the second or followup(#1665) (11az)FTM frame to be sent later. The Dialog Token field is set to 0 to indicate the end of the FTM session (see 11.21.6.6 (FTM session termination(11az)) and 11.21.6.4 (Measurement exchange)).

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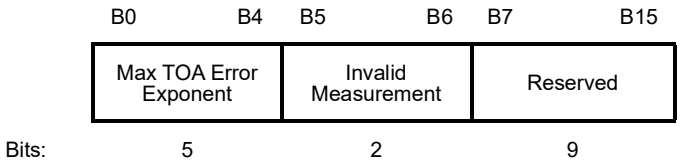


**Figure 9-1220—TOA Error field format(11az)**

The Follow Up Dialog Token field is the nonzero value of the Dialog Token field of the last transmitted (11az)FTM frame to indicate that it is the follow up (11az)FTM frame and that the TOD, TOA, Max TOD Error Exponent and Max TOA Error Exponent fields contain the values of the timestamps captured with the first (11az)FTM frame of the pair. The Follow Up Dialog Token field is 0 to indicate that the (11az)FTM frame is not a follow up to a last transmitted (11az)FTM frame. The value 0 in this field also indicates that TOD, TOA, TOD Error, and TOA Error fields are reserved. See 11.21.6 (FTM procedure(#7065)).

The TOD and TOA fields are expressed in units of picoseconds.

The maximum errors in the TOD and TOA values are represented using the function defined in Equation (9-14).

$$E_{max} = \begin{cases} \text{unknown}, & F = 0 \\ 2^{F-1}, & 1 \le F \le 30 \\ \ge 2^{30}, & F = 31 \end{cases} \quad (9\text{-}14)$$

where

$F$ is the Max Error Exponent

$E_{max}$ is the maximum TOD or TOA error, respectively, in units of picoseconds

The TOD field contains a timestamp that represents the time, with respect to a time base, at which the start of the preamble of the last transmitted (11az)FTM frame appeared at the transmit antenna connector.

The TOA field contains a timestamp that represents the time, with respect to a time base, at which the start of the preamble of the Ack frame to the last transmitted (11az)FTM frame arrived at the receive antenna connector.

NOTE 1—The values specified in the TOD and TOA fields are described in (#8109)(#8108)MLME-FINETIMINGMSMT.request MLME-FINETIMINGMSMT.confirm and MLME-FINETIMINGMSMT.indication primitives.

The Max TOD Error Exponent field contains an upper bound for the error exponent in the value specified in the TOD field.

NOTE 2—For instance, setting the Max TOD Error Exponent field to 2 indicates that the value in the TOD field has a maximum error of ± 2 ps.

The TOD Not Continuous field indicates that the TOD value is with respect to a different underlying time base than the last transmitted TOA value. It is set to 1 when a discontinuity is present. Otherwise, it is set to 0.

The Max TOA Error Exponent field contains an upper bound for the error exponent in the value specified in the TOA field.


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Setting the Max TOD Error Exponent or the Max TOA Error Exponent field to 1 indicates that the upper bound on the error in the corresponding TOD or TOA value is unknown. Setting either field to 31 indicates that the upper bound on the error is greater than or equal to 1.073 741 824 ms.

(11az)The Invalid Measurement field contains an indication of an invalid TOA field. The Invalid Measurement field is set to 1 to indicate that the TOA value is invalid, and is set to 0 to indicate that the TOA value is valid; values of 2 and 3 are reserved.

The LCI Report field is optionally present. If present, it contains a Measurement Report element with Measurement Type field equal to LCI (see Table 9-163 (Measurement Type field definitions for measurement reports)), which either indicates the LCI of the transmitting STA and includes the Z and Usage Rules/Policy subelement or indicates an unknown LCI (see 11.21.6.7 (LCI and Location Civic retrieval using FTM procedure)). The Late, Incapable and Refused bits in the Measurement Report Mode field are set to 0. The (#2210)Colocated BSSID List subelement is present in the Measurement Report element with Measurement Type field equal to LCI, when there is at least one other BSS that shares the same antenna connector with the reporting BSS.

The Location Civic Report field is optionally present. If present, it contains a Measurement Report element with Measurement Type field equal to Location Civic (see Table 9-163 (Measurement Type field definitions for measurement reports)), which either indicates the Civic address of the transmitting STA or an unknown Civic address (see 11.21.6.7 (LCI and Location Civic retrieval using FTM procedure)). The Late, Incapable and Refused bits in the Measurement Report Mode field are set to 0. The (#2210)Colocated BSSID List subelement is present in the Measurement Report element with Measurement Type field equal to LCI, when there is at least one other BSS that shares the same antenna connector with the reporting BSS. When the LCI Report field contains a (#2210)Colocated BSSID List subelement, the (#2210)Colocated BSSID List subelement is not present in the Location Civic Report field.

(11az)The FTM Parameters field is optionally present. It is present in an IFTM frame and its retransmissions when negotiating EDCA based ranging; see 11.21.6.3.2 (Negotiation for EDCA based ranging measurement exchange).

The FTM Synchronization Information field is present in the initial FTM frame(#7223) and its retransmissions if any, and in the first (11az)FTM frame within each burst and its retransmissions if any; otherwise it is not present. If present, it contains an FTM Synchronization Information element with a TSF Sync Info field containing the 4 least significant octets of the TSF at the responding STA corresponding to the time the responding STA received the last (11az)FTM Request frame with the Trigger field equal to 1.

(11az)The Ranging Parameters element is optionally present. It is present in an IFTM frame and its retransmissions, when negotiating non-TB ranging; see 11.21.6.4.4 (Non-TB ranging measurement exchange(11az)) or 11.21.6.4.3 (TB ranging measurement exchange(11az)). If present, it contains a Ranging Parameters element as defined in 9.4.2.300 (Ranging Parameters element(11az)).

(11az)The Secure HE-LTF Parameters element is optionally present. It is present in an IFTM frame, if the IFTMR frame contained a Ranging Parameters element that included a Secure HE-LTF subelement. If present, it contains a Secure HE-LTF Parameters element as defined in 9.4.2.301 (Secure HE-LTF Parameters element(11az)).

(11az)The Channel Measurement Feedback Type field is present in the FTM frame if the Channel Measurement Feedback field is present. It describes the content of the Channel Measurement Feedback element contained in that field. The format of the Channel Measurement Feedback Type field is shown in Figure 9-1221 (Channel Measurement Feedback Type field format(11az)). Each of the subfields is described in Table 9-296 (FBCK-TYPE field description).

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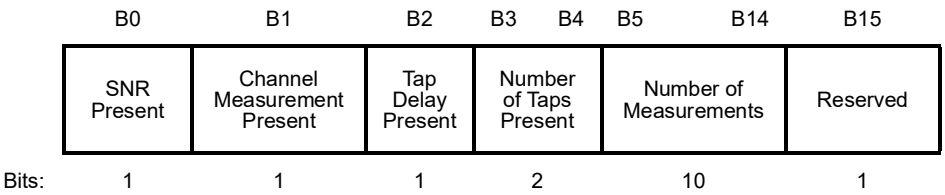


**Figure 9-1221—Channel Measurement Feedback Type field format(11az)**

(11az)The Channel Measurement Feedback element is present in the FTM frame if the frame is sent after a LOS Assessment Ack PPDU and optionally in response to an ISTA to RSTA angle of departure TRN field on an Ack frame. This field contains the Channel Measurement Feedback element (see 9.4.2.135 (Channel Measurement Feedback element)).

(11az)The Direction Measurement Results field is present in the FTM frame when the frame is sent from an RSTA to an ISTA following an FTM exchange that included ISTA to RSTA AOA measurement. This field contains the Direction Measurement Results element.

(11az)The Multiple Best AWV ID field is present in the FTM frame when the frame is sent from an ISTA as part of an AOD feedback exchange after an FTM exchange; see 11.21.6.4.2.4 (DMG AOD feedback exchange after an FTM exchange(11az)). It contains the Multiple Best AWV ID elements.

(11az)The Multiple AOD Feedback element is present in the FTM frame when the frame is sent from an RSTA to an ISTA as part of an AOD feedback exchange after an FTM exchange; see 11.21.6.4.2.4 (DMG AOD feedback exchange after an FTM exchange(11az)). It contains the Multiple AOD Feedback element.

(11az)The LOS Likelihood element (#8256)is optionally present in any FTM frame that contain TOA and TOD or Direction Measurement Results on measurements performed over DMG or EDMG PPDUs.

### 9.6.7.34 QAB Request frame format

The QAB Request frame is transmitted by an AP to another AP to schedule quiet periods that facilitate the detection of other system operating in the same band. The format of the QAB Request frame Action field is shown in Table 9-489 (QAB Request frame Action field format).

**Table 9-489—QAB Request frame Action field format**

| Order | Information |
|---|---|
| 1 | Category |
| 2 | Public Action |
| 3 | Dialog Token |
| 4 | RequesterAP Address |
| 5 | ResponderAP Address |
| 6 | Quiet Period Request element |

The Category field is defined in 9.4.1.11 (Action field).

The Public Action field is defined in 9.6.7.1 (Public Action field(#3729)).


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(#417)The Dialog Token field is defined in 9.4.1.12 (Dialog Token field). It is set to a nonzero value chosen by the AP.

The RequesterAP Address field is the MAC address of the AP that initiates the process. The length of this field is 6 octets.

The ResponderAP Address field is the MAC address of the responding AP. The length of this field is 6 octets. This field can be set to the broadcast address if the request is sent to multiple APs.

The Quiet Period Request element is defined in 9.4.2.148 (Quiet Period Request element).

### 9.6.7.35 QAB Response frame format

A QAB Response frame is sent in response to a QAB Request frame. The format of a QAB Response frame Action field contains the information shown in Table 9-490 (QAB Response frame Action field format).

**Table 9-490—QAB Response frame Action field format**

| Order | Information |
|---|---|
| 1 | Category |
| 2 | Public Action |
| 3 | Dialog Token |
| 4 | RequesterAP Address |
| 5 | ResponderAP Address |
| 6 | Quiet Period Response element |

The Category field is defined in 9.4.1.11 (Action field).

The Public Action field is defined in 9.6.7.1 (Public Action field(#3729)).

The Dialog Token field value is copied from the corresponding received QAB Request frame.

The RequesterAP Address field is the MAC address of the AP that initiates the process. The length of this field is 6 octets.

The ResponderAP Address field is the MAC address of the responding AP. The length of this field is 6 octets.

The Quiet Period Response element is defined in 9.4.2.149 (Quiet Period Response element).

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### 9.6.7.36 FILS Discovery frame format

The format of the FILS Discovery frame Action field is defined in Table 9-491 (FILS Discovery frame format).

**Table 9-491—FILS Discovery frame format**

| Order | Information | Notes |
|---|---|---|
| 1 | Category | |
| 2 | Public Action | |
| 3 | FILS Discovery Information field | |
| 4 | Reduced Neighbor Report element | One or more Reduced Neighbor Report elements are optionally present if dot11FILSActivated or dot11ColocatedRNRImplemented is true; otherwise, they are not present.(11ax) |
| 5 | FILS Indication element | The FILS Indication element is optionally present if dot11FILSActivated is true; otherwise, it is not present.(11ax) |
| 6 | Roaming Consortium element | The Roaming Consortium element is optionally present if dot11FILSActivated is true; otherwise, it is not present.(11ax) |
| 7(11ax) | TIM element | The TIM element is optionally present if dot11HEOptionImplemented is true; otherwise, it is not present. |
| 8(11ax) | TWT element | The TWT element is optionally present if dot11HEOptionImplemented is true, otherwise, it is not present. If present, the Broadcast field of the TWT element is 1. |
| 9(11ax) | OPS element | The OPS element is optionally present if dot11HEOptionImplemented is true; otherwise, it is not present. |
| 10(11ax) | Transmit Power Envelope element | One Transmit Power Envelope element is optionally present for each distinct combination of values of the Maximum Transmit Power Interpretation subfield and Maximum Transmit Power Category subfield that is supported for the BSS if both of the following conditions are met:<br>— Either dot11VHTOptionImplemented or dot11ExtendedSpectrumManagementImplemented is true.<br>— Either dot11SpectrumManagementRequired or dot11RadioMeasurementActivated is true.<br><br>NOTE—In a 6 GHz HE AP, both dot11VHTOptionImplemented (see 26.17.1 (Basic HE BSS operation)) and dot11SpectrumManagementRequired (see 26.17.2.1 (General)) are true. |
| 11(11bc) | EBCS Parameters element | The EBCS Parameters element is optionally present if the transmitting STA has dot11EBCSSupport Activated set to true and a nonzero dot11EBCSTrafficStreamTable length. It is otherwise not present. |


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The Category field indicates the public category specified in Table 9-81 (Category values).

The Public Action field indicates the value of the FILS Discovery frame, as specified in Table 9-471 (Public Action field values) in Table 9.6.7.1 (Public Action field(#3729)).

The FILS Discovery Information field is shown in Figure 9-1222 (FILS Discovery Information field format).

| | FILS Discovery Frame Control | Timestamp | Beacon Interval | SSID/Short SSID | Length | FD Capability |
|---|---|---|---|---|---|---|
| Octets: | 2 | 8 | 2 | 1-32 | 0 or 1 | 0 or 2 |

| | Operating Class | Primary Channel | AP Configuration Sequence Number | Access Network Options | FD RSN Information | Channel Center Frequency Segment 1 | Mobility Domain |
|---|---|---|---|---|---|---|---|
| Octets: | 0 or 1 | 0 or 1 | 0 or 1 | 0 or 1 | 0 or 5 | 0 or 1 | 0 or 3 |

**Figure 9-1222—FILS Discovery Information field format**

The format of the FILS Discovery Frame Control subfield is shown in Figure 9-1223 (FILS Discovery Frame Control subfield format).

| | B0 – B4 | B5 | B6 | B7 |
|---|---|---|---|---|
| | SSID Length | Capability Presence Indicator | Short SSID Indicator | AP-CSN Presence Indicator |
| Bits: | 5 | 1 | 1 | 1 |

| | B8 | B9 | B10 | B11 | B12 | B13 | B14 B15 |
|---|---|---|---|---|---|---|---|
| | ANO Presence Indicator | Channel Center Frequency Segment 1 Presence Indicator | Primary Channel Presence Indicator | RSN Info Presence Indicator | Length Presence Indicator | MD Presence Indicator | (#4220)*Allocated to the Wi-Fi Alliance*[a] |
| Bits: | 1 | 1 | 1 | 1 | 1 | 1 | 2 |

[a] See(#6323) http://www.wi-fi.org.

**Figure 9-1223—FILS Discovery Frame Control subfield format**

The SSID Length subfield of the FILS Discovery Frame Control subfield indicates the length, in octets, of the SSID/Short SSID subfield in the FILS Discovery frame. This subfield is equal to the length of the SSID/Short SSID subfield in octets minus 1.

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NOTE 1—When the Short SSID Indicator subfield is equal to 1, the SSID Length subfield is equal to 3.

When the Capability Presence Indicator subfield is set to 1, it indicates that the FILS Discovery (FD) Capability subfield is present in the FILS Discovery frame. Setting the subfield to 0 indicates that the FD capability subfield is not present in the FILS Discovery frame.

A value of 1 in the Short SSID Indicator subfield indicates that a short SSID is contained in the SSID/Short SSID field of the FILS Discovery frame. A value of 0 indicates that an SSID is contained in the SSID/Short SSID field of the FILS Discovery frame.

A value of 1 in the AP-CSN Presence Indicator subfield indicates that the AP Configuration Sequence Number subfield is present in the FILS Discovery frame. Setting the subfield to 0 indicates that the AP-CSN subfield is not present in the FILS Discovery frame.

A value of 1 in the Access Network Options (ANO) Presence Indicator subfield indicates that the Access Network Options subfield is present in the FILS Discovery frame. Setting the subfield to 0 indicates that the ANO subfield is not present in the FILS Discovery frame.

A value of 1 in the Channel Center Frequency Segment 1 Presence Indicator subfield indicates that the Channel Center Frequency Segment 1 subfield is present in the FILS Discovery frame. Setting the subfield to 0 indicates that Channel Center Frequency Segment 1 subfield is not present.

A value of 1 in the Primary Channel Presence Indicator subfield indicates that the Primary Channel and the Operating Class subfields are present in the FILS Discovery frame. Setting the subfield to 0 indicates that the Primary Channel and the Operating Class subfields are not present in the FILS Discovery frame.

A value of 1 in the (#3248)RSN Info Presence Indicator subfield indicates that the FD RSN Information subfield is present in the FILS Discovery frame. Setting the subfield to 0 indicates that the FD RSN Information subfield is not present in the FILS Discovery frame.

A value of 1 in the Length Presence Indicator subfield indicates that the Length field is present in the FILS Discovery frame. Setting the subfield to 0 indicates that the Length field is not present in the FILS Discovery frame.

Setting the MD Presence Indicator subfield to 1 indicates that the Mobility Domain subfield is present in the FILS Discovery frame. Setting the subfield to 0 indicates that the Mobility Domain subfield is not present in the FILS Discovery frame.

The Timestamp subfield carries the value of the TSF timer at the time that the start of the data symbol containing the first bit of the Timestamp field appears at the transmit antenna connector.

The Beacon Interval subfield carries the beacon interval in TUs.

(#7151)When the Short SSID Indicator subfield is 1, the SSID/Short SSID field contains a Short SSID field (see 9.4.1.71 (Short SSID field(#7151))). Otherwise, the SSID/Short SSID field contains the SSID, whose length in octets is specified by the SSID Length subfield in the FILS Discovery Frame Control of the FILS Discovery frame(#8137).

The Length subfield indicates the length of the remaining fields in the FILS Discovery Information field in octets. Its value is variable.

NOTE 2—The Length field is used to facilitate STAs parsing the FILS Discovery frame in case of future expansions of the FILS Discovery Information field; STAs can determine the end of the FILS Discovery Information field using the value indicated in the Length field even if they do not recognize one or more subfields in the FILS Discovery Information field.


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The FD Capability subfield contains the information that advertises the capabilities and operational indications of the STA transmitting the FILS Discovery frame. Its presence is indicated by the Capability Presence Indicator subfield in the FILS Discovery Frame Control subfield being equal to 1. The format of the FD Capability subfield is shown in Figure 9-1224 (FD Capability subfield format).

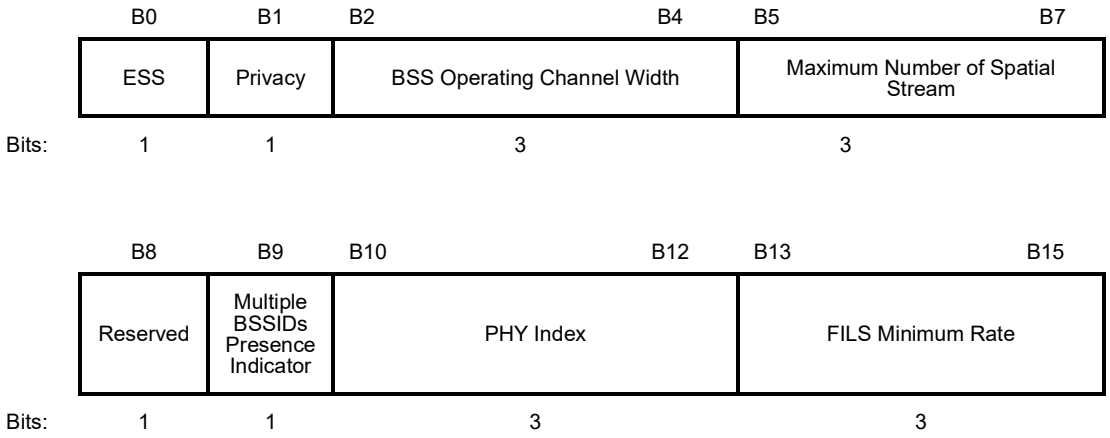


**Figure 9-1224—FD Capability subfield format**

The ESS and Privacy subfields are interpreted as specified in 9.4.1.4 (Capability Information field).

The BSS Operating Channel Width subfield indicates the BSS operating channel width as defined in Table 9-492 (BSS Operating Channel Width).

**Table 9-492—BSS Operating Channel Width**

| BSS Operating Channel Width field | HR/DSSS, OFDM, ERP, HT, VHT, HE BSS operating channel width | TVHT BSS operating channel width |
|---|---|---|
| 0 | 20 MHz or 22 MHz | TVHT_W |
| 1 | 40 MHz | TVHT_W+W |
| 2 | 80 MHz | TVHT_2W |
| 3 | 160 MHz or 80+80 MHz | TVHT_4W or TVHT_2W+2W |
| 4–7 | Reserved | Reserved |

The Maximum Number of Spatial Streams subfield indicates the number of the spatial streams supported by the AP. The Maximum Number of Spatial Streams subfield is coded per Table 9-493 (Maximum Number of Spatial Streams).

**Table 9-493—Maximum Number of Spatial Streams**

| Number of Spatial Streams subfield | Maximum Number of Spatial Streams subfield |
|---|---|
| 0 | 1 |
| 1 | 2 |

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**Table 9-493—Maximum Number of Spatial Streams**

| Number of Spatial Streams subfield | Maximum Number of Spatial Streams subfield |
|---|---|
| 2 | 3 |
| 3 | 4 |
| 4 | 5–8 |
| 5–7 | Reserved |

The Multiple BSSIDs Presence Indicator subfield is set to 1 to indicate that the Multiple BSSID element is present in the Beacon and Probe Response frames. It is set to 0 to indicate that the Multiple BSSID element is not present in the Beacon and Probe Response frames.

The PHY Index subfield is defined as in Table 9-494 (PHY Index subfield).

**Table 9-494—PHY Index subfield**

| PHY Index subfield | PHY |
|---|---|
| 0 | HR/DSSS (see Clause 16 (High rate direct sequence spread spectrum (HR/DSSS) PHY specification)) |
| 1 | ERP-OFDM (see Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) and Clause 18 (Extended Rate PHY (ERP) specification)) |
| 2 | HT (see Clause 19 (High Throughput (HT) PHY specification(#2297))) |
| 3 | VHT (see Clause 21 (Very high throughput (VHT) PHY specification)) or TVHT (see Clause 22 (Television very high throughput (TVHT) PHY specification)) |
| 4(11ax) | HE (see Clause 27 (High-efficiency (HE) PHY specification(11ax))) |
| 5–7 | Reserved |

The FILS Minimum Rate subfield indicates the minimum rate to be used by the AP transmitting the FILS Discovery frame and by FILS STAs in subsequent transmissions between the AP and FILS STAs. Depending on the PHY Index subfield of the received FILS Discovery frame, the minimum rate is represented as a bit rate value or as an MCS value as shown in Table 9-495 (FILS Minimum Rate). If an MCS value is provided, then the minimum rate is derived from the MCS value and the PHY Index in the FD Capability subfield.

(#1011)The Operating Class and Primary Channel subfields are present if the FILS Discovery frame is transmitted in a non-HT duplicate PPDU. Otherwise, the subfields are not present.

When present, the subfields indicate the following:

— If the operating class has a channel spacing other than 80 MHz
  - BSS bandwidth, equals the channel spacing
  - Center frequency of the channel on which the BSS operates


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**Table 9-495—FILS Minimum Rate**

| FILS Minimum Rate subfield | PHY Index subfield is 0 (HR/DSSS) | PHY Index subfield is 1 (ERP-OFDM) | PHY Index subfield is 2 (HT) | PHY Index subfield is 3 (VHT or TVHT) | PHY Index subfield is 4 (HE)(11ax) |
|---|---|---|---|---|---|
| 0 | 1 Mb/s | 6 Mb/s | HT-MCS 0 | VHT-MCS 0 | HE-MCS 0 |
| 1 | 2 Mb/s | 9 Mb/s | HT-MCS 1 | VHT-MCS 1 | HE-MCS 1 |
| 2 | 5.5 Mb/s | 12 Mb/s | HT-MCS 2 | VHT-MCS 2 | HE-MCS 2 |
| 3 | 11 Mb/s | 18 Mb/s | HT-MCS 3 | VHT-MCS 3 | HE-MCS 3 |
| 4 | Reserved | 24 Mb/s | HT-MCS 4 | VHT-MCS 4 | HE-MCS 4 |
| 5–7 | Reserved | Reserved | Reserved | Reserved | Reserved |

- Center frequency of the primary channel

— If the operating class has a channel spacing of 80 MHz

- BSS bandwidth, either 80 MHz or 80+80 MHz
- Center frequency of the channel on which the BSS operates, if BSS bandwidth is 80 MHz
- Center frequency of the primary 80 MHz channel, if BSS bandwidth is 80+80 MHz
- Center frequency of the primary channel

NOTE 3—If a received FILS Discovery frame does not include the Primary Channel subfield, the primary channel is the channel on which the PPDU was received.

NOTE 4—A STA that receives a FILS Discovery frame containing an Operating Class subfield indicating a channel spacing of 80 MHz can determine the BSS bandwidth by receiving a Beacon or a Probe Response frame on the primary channel indicated in the FILS Discovery frame.

The AP Configuration Sequence Number (AP-CSN) subfield format is defined in 9.4.2.180 (AP Configuration Sequence Number (AP-CSN) element).

The Access Network Options (ANO) subfield format is defined in Figure 9-565 (Access Network Options field format) (in 9.4.2.90 (Interworking element)).

(#1012)The FD RSN Information subfield is defined in Figure 9-1225 (FD RSN Information subfield format).

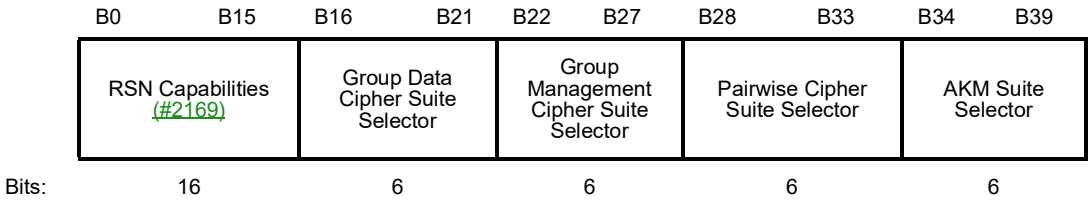


**Figure 9-1225—FD RSN Information subfield format**

The FD RSN Information subfield contains an RSN Capabilities) subfield, as specified in Figure 9-369 (RSN Capabilities field format) (in 9.4.2.23.4 (RSN capabilities)).

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The FD RSN Information subfield also contains three cipher suite selectors. The Group Data Cipher Suite Selector subfield contains one group data cipher suite selector. The Group Management Cipher Suite Selector subfield contains one group management cipher suite selector. The Pairwise Cipher Suite Selector subfield contains one pairwise cipher suite selector. Each of these subfields contains a code identifying a Cipher Suite Type as specified in Table 9-188 (Cipher suite selectors). The definition of the cipher suite selectors is shown in Table 9-496 (Cipher suite selector definitions).

**Table 9-496—Cipher suite selector definitions**

| Cipher suite selector | Cipher suite type |
|---|---|
| 0–13 | Cipher suite type 0 to 13 in Table 9-188 (Cipher suite selectors) |
| 14–61 | Reserved |
| 62 | Vendor Specific |
| 63 | No cipher suite selected |

The FD RSN Information subfield also contains one AKM suite selector. An AKM suite selector is a code identifying (#3266)an AKMP as specified in Table 9-190 (AKM suite selectors). The definition of the AKM suite selectors is shown in Table 9-497 (AKM suite selector definitions).

**Table 9-497—AKM suite selector definitions**

| AKM suite selector | AKMP(#3266) |
|---|---|
| 0 | Use AKM from RSN IE Beacon/Probe Response frame |
| 1 | Set (#3266)AKM 00-0F-AC: 14 of Table 9-190 (AKM suite selectors) |
| 2 | Set (#3266)AKM 00-0F-AC: 15 of Table 9-190 (AKM suite selectors) |
| 3 | Set (#3266)AKM 00-0F-AC: 14 or 00-0F-AC: 15 of Table 9-190 (AKM suite selectors) |
| 4 | Set (#3266)AKM 00-0F-AC: 17 of Table 9-190 (AKM suite selectors) |
| 5–61 | Reserved |
| 62 | Vendor Specific |
| 63 | No (#3266)AKMP selected |

The Channel Center Frequency Segment 1 subfield is set to the index of the channel center frequency of the frequency segment 1 for an 80+80 MHz VHT (11ax)or HE BSS if the FILS Discovery frame is transmitted as a non-HT duplicate PPDUs at an 80+80 MHz channel bandwidth; otherwise, the subfield is not present.

The format of the Mobility Domain subfield is shown in Figure 9-1226 (Mobility Domain subfield format).

The MDID field is defined in 9.4.2.45 (MDE(#1776)).


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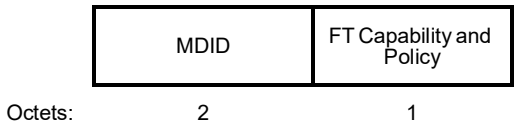


**Figure 9-1226—Mobility Domain subfield format**

The FT Capability and Policy field is defined in 9.4.2.45 (MDE(#1776)).

The Reduced Neighbor Report element is defined in 9.4.2.169 (Reduced Neighbor Report element).

The FILS Indication element is defined in 9.4.2.181 (FILS Indication element).

(#1010)The Roaming Consortium element is defined in 9.4.2.94 (Roaming Consortium element).

(11ax)The TIM element is defined in 9.4.2.5 (TIM element) and is included for operation as defined in 26.14.3 (Opportunistic power save).

(11ax)The TWT element is defined in 9.4.2.198 (TWT element) and is included with the Broadcast field set to 1 to aid an unassociated STA determine the target transmission time of Trigger frames that contain at least one User Info field that allocates RA-RUs for unassociated STAs (see 26.5.4.5 (Additional considerations for unassociated STAs) and 26.8.3.1 (General)).

(11ax)The OPS element is defined in 9.4.2.256 (OPS element(11ax)).

(11ax)The Transmit Power Envelope element is defined in 9.4.2.160 (Transmit Power Envelope element).

(11bc)The EBCS Parameters element is defined in 9.4.2.313 (EBCS Parameters element(11bc)). When included in FILS Discovery frames, the element carries the EBCS Info Frame Tx Countdown field and can include the Compressed Certificate Group ID field and the EBCS AP Group ID field.

### 9.6.7.37 DCS Measurement Request frame format

The DCS Measurement Request frame is transmitted by a DCS requesting CDMG AP or PCP to a DCS responder CDMG AP or PCP to request all of the STAs in the DCS responder AP's infrastructure BSS or PCP's PBSS to measure a specified channel or all other channels within the supported operating class (as defined in 9.4.2.52 (Supported Operating Classes element)). The format of the DCS Measurement Request frame Action field is shown in Figure 9-1227 (DCS Measurement Request frame Action field format).

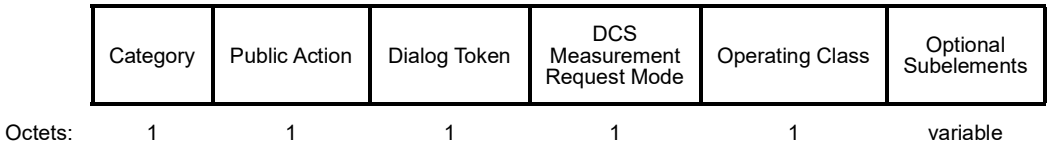


**Figure 9-1227—DCS Measurement Request frame Action field format**

The Category field is defined in 9.4.1.11 (Action field).

The Public Action field is defined in 9.6.7.1 (Public Action field(#3729)).

The Dialog Token field is defined in 9.4.1.12 (Dialog Token field) and set by the requesting STA.

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The Measurement Request Mode field is set to 1 to indicate that the DCS requesting AP or PCP requests all STAs within the DCS responder AP's or PCP's infrastructure BSS or PBSS to measure all channels within the operating class specified in the following Operating Class field. The Measurement Request Mode field is set to 2 to indicate that the DCS requesting AP or PCP requests all STAs within the DCS responder AP's infrastructure BSS or PCP's PBSS to measure the specified channel(s) indicated within the list of optional subelements. Other values are reserved.

The Operating Class field is valid when the Measurement Request Mode field is 1. In all other cases, the Operating Class field is reserved. The Operating Class and Channel Number fields together specify the channel frequency and channel bandwidth for which the DCS procedure applies. Valid values of the Operating Class field are shown in Annex E.

The Optional Subelements field is present when the Measurement Request Mode field is 2. The Optional Subelements field contains zero or more subelements. The subelement format and ordering of subelements are defined in 9.4.3 (Subelements). The optional subelements are ordered by nondecreasing subelement ID.

The Subelement ID field values for the defined optional subelements are shown in Table 9-498 (Optional subelement IDs for DCS Measurement Request frame).

**Table 9-498—Optional subelement IDs for DCS Measurement Request frame**

| Subelement ID | Name | Extensible |
|---|---|---|
| 0 | Reserved | |
| 1 | Channel Measurement Request | Yes |
| 2–220 | Reserved | |
| 221 | Vendor Specific | Vendor defined |
| 222–255 | Reserved | |

The Channel Measurement Request subelement is used to specify the channel(s) to be measured. The format of the DCS Channel Measurement Request subelement is shown in Figure 9-1228 (DCS Channel Measurement Request subelement format).

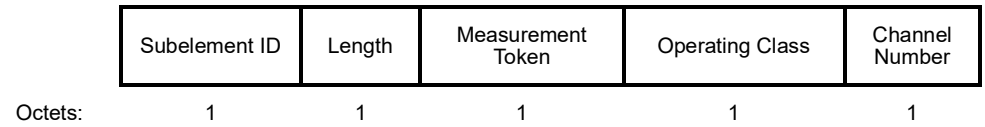


**Figure 9-1228—DCS Channel Measurement Request subelement format**

The Subelement ID field is defined in Figure 9-498 (Optional subelement IDs for DCS Measurement Request frame).

The Length field is defined in 9.4.3 (Subelements).

The Measurement Token field is set to a nonzero value that is unique among the Channel Measurement Request subelements in a particular DCS Measurement Request frame.


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The Operating Class and Channel Number fields together specify the channel frequency and channel bandwidth for which the DCS procedure applies. Valid values of the Operating Class field are shown in Annex E (Country elements and operating classes).

The Channel Number field is set to the channel number for which the Channel Measurement Request applies (as defined in 17.3.8.4.3 (Channelization)).

### 9.6.7.38 DCS Measurement Response frame format

The DCS Measurement Response frame is transmitted by a DCS responder AP or PCP to a DCS requesting AP or PCP to report the results of measuring one or more channels. The format of the DCS Measurement Response frame Action field is shown in Figure 9-1229 (DCS Measurement Response frame Action field format).

| | Category | Public Action | Dialog Token | DCS Measurement Report Mode | Operating Class | Optional Subelements |
|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 1 | 1 | variable |

**Figure 9-1229—DCS Measurement Response frame Action field format**

The Category field is defined in 9.4.1.11 (Action field).

The Public Action field is defined in 9.6.7.1 (Public Action field(#3729)).

(#417)The Dialog Token field is defined in 9.4.1.12 (Dialog Token field). It is copied from the corresponding DCS Measurement Request frame.

The Measurement Report Mode field is set to 0 to indicate no clear channel to which the DCS responder AP's or PCP's BSS can move within the operating class specified in the following Operating Class field, or the DCS request has been declined by the DCS responder AP or PCP. The Measurement Report Mode field is set to 1 to indicate that all other channels within the operating class specified in the following Operating Class field are available for the DCS responder AP's or PCP's BSS. The Measurement Report Mode field is set to 2 to indicate that the clear channel for the DCS responder AP's or PCP's BSS is indicated by the Optional Subelement field in the DCS Measurement Response frame. Other values are reserved.

The Operating Class field is valid when the Measurement Report Mode field is 1. In all other cases, the Operating Class field is reserved. The Operating Class and Channel Number fields together specify the channel frequency and channel bandwidth for which the DCS procedure applies. Valid values of the Operating Class field are shown in Annex E.

The Optional Subelements field is present when the Measurement Report Mode field is 2. The Optional Subelements field contains zero or more subelements. The subelement format and ordering of subelements are defined in 9.4.3 (Subelements). The optional subelements are ordered by nondecreasing subelement ID.

The Subelement ID field values for the defined optional subelements are shown in Table 9-499 (Optional subelement IDs for DCS Measurement Response frame).

The Channel Measurement Report subelement is used to report the number of available channel to which the DCS responder AP's or PCP's BSS can move. The DCS Channel Measurement Report subelement format is as shown in Figure 9-1230 (DCS Channel Measurement Report subelement format).

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**Table 9-499—Optional subelement IDs for DCS Measurement Response frame**

| Subelement ID | Name | Extensible |
|---|---|---|
| 0 | Reserved | |
| 1 | Channel Measurement Report | Yes |
| 2–220 | Reserved | |
| 221 | Vendor Specific | Vendor defined |
| 222–255 | Reserved | |

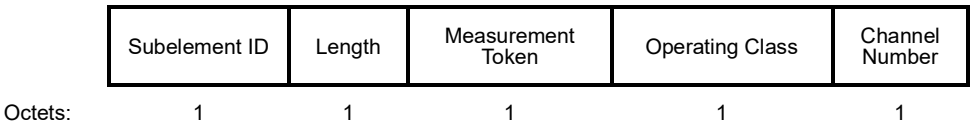


**Figure 9-1230—DCS Channel Measurement Report subelement format**

The Subelement ID field is defined in Table 9-499 (Optional subelement IDs for DCS Measurement Response frame).

The Length field is defined in 9.4.3 (Subelements).

The Measurement Token field is copied from the corresponding Channel Measurement Request subelement in the received DCS Measurement Request frame.

The Operating Class and Channel Number fields together specify the channel frequency and channel bandwidth for which the DCS procedure applies. Valid values of the Operating Class field are shown in Annex E.

The Channel Number field is set to the channel number to which the DCS responder AP's or PCP's BSS can move (as defined in 17.3.8.4.3 (Channelization)).

### 9.6.7.39 DCS Request frame format

The DCS Request frame is transmitted by a DCS requesting AP or PCP to a DCS responder AP or PCP to request the DCS responder AP's or PCP's BSS to move to an available channel indicated in the DCS Measurement Response frame. The format of the DCS Request frame Action field is shown in Figure 9-1231 (DCS Request frame Action field format).

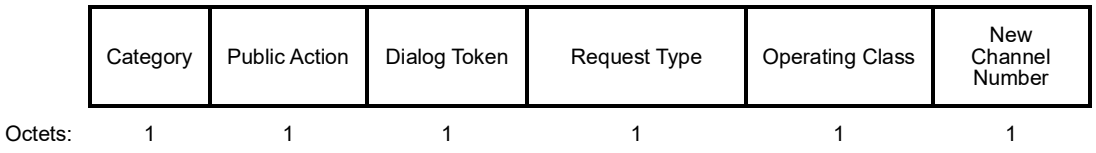


**Figure 9-1231—DCS Request frame Action field format**

The Category field is defined in 9.4.1.11 (Action field).

The Public Action field is defined in 9.6.7.1 (Public Action field(#3729)).


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The Dialog Token field value is copied from the corresponding DCS Measurement Response frame.

The Request Type field value is set to 0 to indicate that the requesting AP or PCP requests the responder AP or PCP to tear down the DCS procedure or the DCS request is refused by the responder AP or PCP; then the following Operation Class field and New Channel Number field are reserved. The Request Type field value is set to 1 to indicate that the DCS requesting AP or PCP to request the DCS responder AP's or PCP's BSS to move to an available channel indicated by the following Operating Class field and New Channel Number field. Other values are reserved.

The Operating Class and Channel Number fields together specify the channel frequency and channel bandwidth for which the DCS procedure applies. Valid values of the Operating Class field are shown in Annex E. This field is valid when the Request Type field is set to 1; otherwise, it is reserved.

The New Channel Number field is set to the channel number to which the DCS requesting AP or PCP request the DCS responder AP's or PCP's BSS to move (as defined in 17.3.8.4.3 (Channelization)). This field is valid when the Request Type field is set to 1; otherwise, it is reserved.

### 9.6.7.40 DCS Response frame format

The DCS Response frame is transmitted by a DCS responder AP or PCP to a DCS requesting AP or PCP to confirm that the DCS responder AP's or PCP's BSS is moving to the channel specified in the DCS request frame. The format of the DCS Response frame Action field is shown in Figure 9-1232 (DCS Response frame Action field format).

| | Category | Public Action | Dialog Token | Responder Type | Operating Class | New Channel Number | Channel Switch Count |
|---|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 1 | | 1 | 1 |

**Figure 9-1232—DCS Response frame Action field format**

The Category field is defined in 9.4.1.11 (Action field).

The Public Action field is defined in 9.6.7.1 (Public Action field(#3729)).

(#417)The Dialog Token field is defined in 9.4.1.12 (Dialog Token field). It is copied from the corresponding DCS Request frame.

The Operating Class and Channel Number fields together specify the channel frequency and channel bandwidth for which the DCS procedure applies. Valid values of the Operating Class field are shown in Annex E.

The New Channel Number field is set to the channel number copied from the corresponding received DCS Request frame.

The Channel Switch Count field either is set to the number of TBTTs until the DCS responder AP or PCP sending the Channel Switch Announcement frame or element within its BSS switches to the new channel or is set to 0. It is set to 1 to indicate that the switch occurs immediately before the next TBTT. It is set to 0 to indicate that the switch occurs at any time after the frame containing the element is transmitted.

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### 9.6.7.41 Extended Notification Period Request frame format

The format of the Extended Notification Period Request frame Action field is defined in Table 9-500 (Extended Notification Period Request frame Action field format).

**Table 9-500—Extended Notification Period Request frame Action field format**

| Order | Information |
|---|---|
| 0 | Category |
| 1 | Public Action |
| 2 | Dialog Token |
| 3 | NP/BHI Duration |

The Category field is defined in 9.4.1.11 (Action field).

The Public Action field is defined in 9.6.7.1 (Public Action field(#3729)).

The Dialog Token field is defined in 9.4.1.12 (Dialog Token field) and set by the requesting STA.

The NP/BHI Duration field is set to the length of the NP/BHI duration requested by the STA intending to establish its BSS on a free 1.08 GHz channel to the peer STA operating on the adjacent 1.08 GHz channel. The length of this field is 2 octets.

### 9.6.7.42 Extended Notification Period Response frame format

The format of the Extended Notification Period Response frame Action field is defined in Table 9-501 (Extended Notification Period Response frame Action field format).

**Table 9-501—Extended Notification Period Response frame Action field format**

| Order | Information |
|---|---|
| 0 | Category |
| 1 | Public Action |
| 2 | Dialog Token |
| 3 | Status Code |
| 4 | Dynamic Bandwidth Control |

The Category field is defined in 9.4.1.11 (Action field).

The Public Action field is defined in 9.6.7.1 (Public Action field(#3729)).

(#417)The Dialog Token field is defined in 9.4.1.12 (Dialog Token field). It is copied from the corresponding Extended Notification Period Response frame.


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The Status Code field indicates the result of the notification period allocation request and is defined in 9.4.1.9 (Status Code field).

The Dynamic Bandwidth Control element specifies the information of the STA operating on a 1.08 GHz channel after channel splitting and is defined in 9.4.2.219 (Dynamic Bandwidth Control element). This element is present if the Status Code field indicates successful; otherwise, it is not present.

### 9.6.7.43 Extended Channel Splitting Request frame format

The format of the Extended Channel Splitting Request frame Action field is defined in Table 9-502 (Extended Channel Splitting Request frame Action field format).

**Table 9-502—Extended Channel Splitting Request frame Action field format**

| Order | Information |
|---|---|
| 0 | Category |
| 1 | Public Action |
| 2 | Dialog Token |
| 3 | NP/BHI Duration |

The Category field is defined in 9.4.1.11 (Action field).

The Public Action field is defined in 9.6.7.1 (Public Action field(#3729)).

The Dialog Token field is defined in 9.4.1.12 (Dialog Token field) and set by the requesting STA.

The NP/BHI Duration field is set to the length of the NP/BHI duration requested by the STA intending to establish its BSS on a free 1.08 GHz channel to the peer STA operating on the adjacent 1.08 GHz channel. The length of this field is 2 octets.

### 9.6.7.44 Extended Channel Splitting Response frame format

The format of the Extended Channel Splitting Response frame Action field is defined in Table 9-503 (Extended Channel Splitting Response frame Action field format).

**Table 9-503—Extended Channel Splitting Response frame Action field format**

| Order | Information |
|---|---|
| 0 | Category |
| 1 | Public Action |
| 2 | Dialog Token |
| 3 | Status Code |
| 4 | Channel Switch Announcement |

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**Table 9-503—Extended Channel Splitting Response frame Action field format *(continued)***

| Order | Information |
|---|---|
| 5 | Beacon Interval |
| 6 | Dynamic Bandwidth Control |

The Category field is defined in 9.4.1.11 (Action field).

The Public Action field is defined in 9.6.7.1 (Public Action field(#3729)).

(#417)The Dialog Token field is defined in 9.4.1.12 (Dialog Token field). It is copied from the corresponding Extended Channel Splitting Response frame.

The Status Code field indicates the result of the notification period allocation request and is defined in 9.4.1.9 (Status Code field).

The Channel Switch Announcement element is defined in 9.4.2.17 (Channel Switch Announcement element). This element is present if the Status Code field indicates successful; otherwise, it is not present.

The Beacon Interval field specifies the beacon interval length on a 2.16 GHz channel set by the STA operating on one of the 1.08 GHz channel after channel splitting and is defined in 9.4.1.3 (Beacon Interval field). This field is present if the Status Code field indicates successful; otherwise, it is not present.

The Dynamic Bandwidth Control element specifies the information of the STA operating on a 1.08 GHz channel after channel splitting and is defined in 9.4.2.219 (Dynamic Bandwidth Control element). This element is present if the Status Code field indicates successful; otherwise, it is not present.

### 9.6.7.45 Group Addressed GAS Request frame format

The Group Addressed GAS Request frame is transmitted by a requesting STA to request information from another STA. The format of the Group Addressed GAS Request frame Action field is defined in Table 9-504 (Group Addressed GAS Request frame Action field format).

**Table 9-504—Group Addressed GAS Request frame Action field format**

| Order | Information |
|---|---|
| 0 | Category |
| 1 | Public Action |
| 2 | Dialog Token |
| 3 | Advertisement Protocol element |
| 4 | Query Request Length |
| 5 | Query Request |
| 6 | Multi-band (optional) |
| 7 | GAS Extension |


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The Category field is defined in 9.4.1.11 (Action field).

The Public Action field is defined in 9.6.7.1 (Public Action field(#3729)).

The Dialog Token field is defined in 9.4.1.12 (Dialog Token field) and set by the requesting STA.

The Advertisement Protocol element is defined in 9.4.2.91 (Advertisement Protocol element). The Advertisement Protocol element includes exactly one advertisement protocol ID.

The Query Request Length field format is provided in Figure 9-1199 (Query Request Length field). The Query Request Length field is set to the total number of octets in the Query Request field.

The Query Request field format is provided in Figure 9-1200 (Query Request field). The Query Request field is a generic container whose value is formatted in accordance with the protocol identified in the Advertisement Protocol element.

When present in a Group Addressed GAS Request frame, the Multi-band element indicates the frequency band, operating class, and channel number to which the Group Addressed GAS Request frame applies.

The GAS Extension element indicates parameters that the (#8257)STA transmitting the request is requesting the responder to use while processing this request.

### 9.6.7.46 Group Addressed GAS Response frame format

The Group Addressed GAS Response frame is transmitted in response to a GAS Initial Request frame or Group Addressed GAS Request frame. The format of the Group Addressed GAS Response frame Action field is defined in Table 9-505 (Group Addressed GAS Response frame Action field format).

**Table 9-505—Group Addressed GAS Response frame Action field format**

| Order | Information |
|---|---|
| 0 | Category |
| 1 | Public Action |
| 2 | Dialog Token |
| 3 | Status Code |
| 4 | Advertisement Protocol element |
| 5 | Query Response Length |
| 6 | Query Response |
| 7 | Multi-band (optional) |
| 8 | GAS Extension |

The Category field is defined in 9.4.1.11 (Action field).

The Public Action field is defined in 9.6.7.1 (Public Action field(#3729)).

(#417)The Dialog Token field is defined in 9.4.1.12 (Dialog Token field). It is copied from the corresponding GAS Initial Request frame or Group Addressed GAS Request frame.

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The Status Code values are defined in 9.4.1.9 (Status Code field).

The Advertisement Protocol element is defined in 9.4.2.91 (Advertisement Protocol element). The Advertisement Protocol element includes exactly one advertisement protocol ID.

The Query Response Length field format is provided in Figure 9-1202 (Query Response Length field format). The value of the Query Response Length field is set to the total number of octets in the Query Response field.

The Query Response field format is provided in Figure 9-1203 (Query Response field format). The Query Response field is a generic container whose value is formatted in accordance with the protocol specified in the Advertisement Protocol element.

When present in a Group Addressed GAS Response frame, the Multi-band element indicates the frequency band, operating class, and channel number to which the GAS Initial Response frame applies.

When present in a Group Addressed GAS Response frame, the GAS Extension element indicates parameters to which STA and which Query Request of the STA the response is responding.

### 9.6.7.47 On-channel Tunnel Request frame format

The On-channel Tunnel Request frame allows nonrobust STA-STA communications of the same information that is conveyed in the robust On-channel Tunnel Request frame (see 9.6.20.7 (On-channel Tunnel Request frame format)).

The format of the robust and nonrobust On-channel Tunnel Request frame is the same and defined in 9.6.20.7 (On-channel Tunnel Request frame format). The Category field value differentiates whether an On-channel Tunnel Request frame is robust or not.

### 9.6.7.48 DMG STA Directional Transmit Activity Report frame format(11ay)

The DMG STA Directional Transmit Activity Report frame is transmitted by a DMG STA to describe the transmit activity of the STA for a given antenna pattern and over a given observation period. The information included in the frame can help a receiving STA take actions to eliminate or mitigate both the interference caused by the STA transmitting the frame, and the interference caused by the receiving STA to the transmitting STA. The format of the DMG STA Directional Transmit Activity Report frame Action field is shown in Figure 9-1233 (DMG STA Directional Transmit Activity Report frame Action field format(11ay)).

| | Category | Public Action | Timestamp | Country element | DMG STA Directional Transmit Activity Report element |
|---|---|---|---|---|---|
| Octets: | 1 | 1 | 8 | variable(M118) | variable(M118) |

**Figure 9-1233—DMG STA Directional Transmit Activity Report frame Action field format(11ay)**

The Category field is defined in 9.4.1.11 (Action field).

The Public Action field is defined in 9.6.7.1 (Public Action field(#3729)).

The Timestamp field is defined in 9.4.1.10 (Timestamp field).

The Country element is defined in 9.4.2.7 (Country element).


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The DMG STA Directional Transmit Activity Report element is defined in 9.4.2.289 (DMG STA Directional Transmit Activity Report element(11ay)).

### 9.6.7.49 LMR frame format(11az)(#8216)

The LMR frame is an Action No Ack frame of category Public. The LMR frame is used to support the non-TB and TB ranging mechanisms of the FTM procedure described in 11.21.6 (Fine timing measurement (FTM) procedure). The format of the LMR Action field is shown in Figure 9-1234 (LMR frame Action field format(11az)(#8216)).

| | Category | Public Action | Dialog Token | TOD | TOA | TOD Error | TOA Error |
|---|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 6 | 6 | 1 | 1 |

| | CFO Parameter | R2I NDP Tx Power | I2R NDP Target RSSI | Secure HE-LTF Parameters (optional) | AOA Feedback (optional) |
|---|---|---|---|---|---|
| Octets: | 2 | 1 | 1 | 14 | 9 |

**Figure 9-1234—LMR frame Action field format(11az)(#8216)**

The Category field is defined in 9.4.1.11 (Action field).

The Public Action field is defined in 9.6.7.1 (Public Action field(#3729)).

The Dialog Token field is used to link the LMR to the Measurement Sounding phase that was used for the reported measurement.

The TOD and TOA fields are expressed in units of picoseconds.

The TOD field contains a timestamp that represents the time, with respect to a time base, at which the start of the preamble of the corresponding NDP appeared at the transmit antenna connector. The corresponding NDP in an R2I LMR frame(#8216) is an R2I NDP, while in an I2R LMR frame it is an I2R NDP. In both cases the corresponding NDP refers to a measurement exchange that included a Ranging NDP Announcement frame, which carried the matching dialog token that is also included in this LMR.

The TOA field contains a timestamp that represents the time, with respect to a time base, at which the start of the preamble of the corresponding NDP arrived at the receive antenna connector. The corresponding NDP in an R2I LMR frame is an I2R NDP, while in an I2R LMR frame it is an R2I NDP. In both cases the corresponding NDP refers to a measurement exchange that included a Ranging NDP Announcement frame, which carried the matching dialog token that is also included in this LMR.

The TOD Error field format is defined in Figure 9-1235 (TOD Error field format(11az)).

The TOA Error field format is defined in Figure 9-1236 (TOA Error field format(11az)).

The maximum errors in the TOD and TOA values are represented using the function defined in Equation (9-15).

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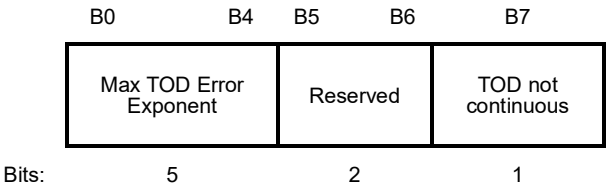


**Figure 9-1235—TOD Error field format(11az)**

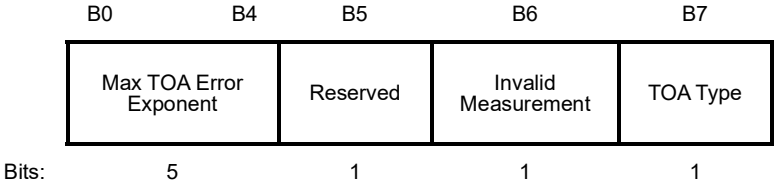


**Figure 9-1236—TOA Error field format(11az)**

$$E_{max} = \begin{cases} \text{unknown}, & F = 0 \\ 2^{F-1}, & 1 \le F \le 30 \\ \ge 2^{30}, & F = 31 \end{cases} \quad (9\text{-}15)$$

where

$F$ is the Max Error Exponent

$E_{max}$ is the maximum TOD or TOA error, respectively, in units of picoseconds

The Max TOD Error Exponent subfield contains an upper bound for the error exponent in the value specified in the TOD field.

The TOD Not Continuous subfield indicates that the TOD value is with respect to a different underlying time base than the last transmitted TOD value. It is set to 1 when a discontinuity is present. Otherwise, it is set to 0.

The Max TOA Error Exponent subfield contains an upper bound for the error exponent in the value specified in the TOA field.

A value of 0 for the Max TOD Error Exponent or the Max TOA Error Exponent subfield indicates that the upper bound on the error in the corresponding TOD or TOA value is unknown. A value of 31 indicates that the upper bound on the error is greater than or equal to 1.073741824 ms.

The Invalid Measurement subfield indicates whether the TOA field contains a valid value. It is set to 1 to indicate that the TOA value is invalid and the value 0 in this subfield indicates that the TOA value is valid.

The TOA Type subfield indicates if the TOA timestamp was calculated based on the first arrival path of the channel impulse response or the average linear phase across the subcarriers.

In the I2R LMR, the CFO Parameter field indicates the clock rate difference between the ISTA and RSTA; the format is a signed value in units of 0.01 ppm. In the R2I LMR, the value of the CFO Parameter field is reserved.


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When negotiated, the (#8066)R2I NDP Tx Power and I2R NDP Target RSSI fields are used in the in R2I LMR as part of the non-TB ranging measurement exchange, see 11.21.6.4.4 (Non-TB ranging measurement exchange(11az)), otherwise their values are reserved.

The R2I NDP Tx Power field indicates the combined average power per 20 MHz bandwidth referenced to the antenna connector, of all antennas used to transmit the preceding R2I NDP. The transmit power is reported with a resolution of 1 dB, with values in the range 0 to 60 representing –20 dBm to 40 dBm, respectively. Values above 60 are reserved.

The I2R NDP Target RSSI field indicates the preferred receive signal power, averaged over the RSTA's antenna connectors, for future I2R NDPs transmitted by the ISTA. The preferred receive signal power in units of dBm is TargetRSSI = –110 + FVal, where FVal is the value of the Target RSSI field, except that values above 90 indicate that the RSTA has no preferred receive signal power for the I2R NDPs(#8066).

The Secure HE-LTF Parameters element is present if an ISTA and RSTA have negotiated an FTM session with secure HE-LTF measurement exchange mode; see 11.21.6.3.4 (Negotiation for secure HE-LTF in the TB and non-TB ranging measurement exchange). If present, it contains a Secure HE-LTF Parameters element as defined in 9.4.2.301 (Secure HE-LTF Parameters element(11az)).

The AOA Feedback field is optionally present. If present, it contains a Direction Measurement Results element as defined in 9.4.2.302 (Direction Measurement Results element(11az)).

### 9.6.7.50 ISTA Passive TB Ranging Measurement Report frame format(11az)

The ISTA Passive TB Ranging Measurement Report frame is an Action No Ack frame of category Public. The ISTA Passive TB Ranging Measurement Report frame is used to support the passive TB ranging mechanisms of the FTM procedure described in 11.21.6 (Fine timing measurement (FTM) procedure). The format of the ISTA Passive TB Ranging Measurement Report frame is shown in Figure 9-1237 (ISTA Passive TB Ranging Measurement Report frame format(11az)).

| | Category | Public Action | ISTA Passive TB Ranging Measurement Report |
|---|---|---|---|
| Octets: | 1 | 1 | variable |

**Figure 9-1237—ISTA Passive TB Ranging Measurement Report frame format(11az)**

The Category field is defined in 9.4.1.11 (Action field).

The Public Action field is defined in 9.6.7.1 (Public Action field(#3729)).

The ISTA Passive TB Ranging Measurement Report field is defined in 9.4.2.306 (ISTA Passive TB Ranging Measurement Report element(11az)).

### 9.6.7.51 Primary RSTA Broadcast Passive TB Ranging Measurement Report frame format(11az)

The Primary RSTA Broadcast Passive TB Ranging Measurement Report frame is an Action No Ack frame of category Public. The Primary RSTA Broadcast Passive TB Ranging Measurement Report frame is used to support the passive TB ranging mechanisms of the FTM procedure described in 11.21.6 (FTM procedure(#7065)). The format of the Primary RSTA Broadcast Passive TB Ranging Measurement Report Action field is shown in Figure 9-1238 (Primary RSTA Broadcast Passive TB Ranging Measurement Report Action field format(11az)).

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| Category | Public Action | Passive TB Ranging LCI Table Counter | Passive TB Ranging LCI Table Countdown Info | RSTA Passive TB Ranging Measurement Report | Passive TB Ranging LCI Table (optional) |
|---|---|---|---|---|---|
| Octets: 1 | 1 | 1 | 1 | variable | variable |

**Figure 9-1238—Primary RSTA Broadcast Passive TB Ranging Measurement Report Action field format(11az)**

The Category field is defined in 9.4.1.11 (Action field).

The Public Action field is defined in 9.6.7.1 (Public Action field(#3729)).

The Passive TB Ranging LCI Table Counter field contains a number serving as a reference to the version of the latest Passive TB Ranging LCI Table element transmitted by the RSTA transmitting the Primary RSTA Broadcast Passive TB Ranging Measurement Report frame.

The Passive TB Ranging LCI Table Countdown Info field contains two subfields as shown in Figure 9-1239 (Passive TB Ranging LCI Table Countdown Info field format(11az)).

| | B0 | B1 ... B7 |
|---|---|---|
| | New LCI Table | Passive TB Ranging LCI Table Countdown |
| Bits: | 1 | 7 |

**Figure 9-1239—Passive TB Ranging LCI Table Countdown Info field format(11az)**

The New LCI Table subfield is set to 0 if the current LCI table and LCI table to be transmitted at the end of the countdown are the same, otherwise it is set to 1.

The Passive TB Ranging LCI Table Countdown subfield is an index pointing to the next passive TB ranging availability window where the Passive LCI Table element will be contained in the Primary RSTA Broadcast Passive TB Ranging Measurement Report frame. If the Passive TB Ranging LCI Table element is contained in the current availability window, then the index has the value 0, if the Passive TB Ranging LCI Table element is contained in the next availability window the index has the value 1, if the Passive TB Ranging LCI Table element is contained in the availability window after that the index has value 2, and so on.

The RSTA Passive TB Ranging Measurement Report element is defined in 9.4.2.307 (RSTA Passive TB Ranging Measurement Report element(11az)).

The Passive TB Ranging LCI Table field is defined in 9.4.2.308 (Passive TB Ranging LCI Table element(11az)).

### 9.6.7.52 Secondary RSTA Broadcast Passive TB Ranging Measurement Report frame format(11az)

The Secondary Broadcast RSTA Passive TB Ranging Measurement Report frame is an Action No Ack frame of category Public. The Secondary RSTA Broadcast Passive TB Ranging Measurement Report frame is used to support the passive TB ranging mechanisms of the FTM procedure described in 11.21.6 (FTM procedure(#7065)). The format of the Secondary RSTA Broadcast Passive TB Ranging Measurement


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Report Action field is shown in Figure 9-1240 (Secondary RSTA Broadcast Passive TB Ranging Measurement Report Action field format(11az)).

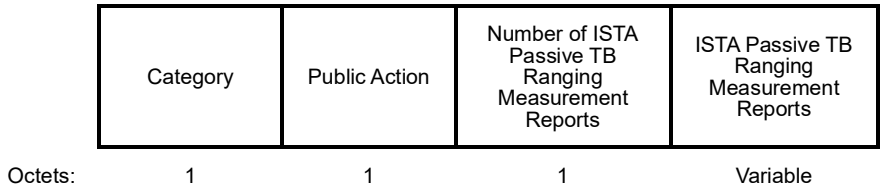


**Figure 9-1240—Secondary RSTA Broadcast Passive TB Ranging Measurement Report Action field format(11az)**

The Category field is defined in 9.4.1.11 (Action field).

The Public Action field is defined in 9.6.7.1 (Public Action field(#3729)).

The Number of ISTA Passive TB Ranging Measurement Reports field indicates the number of following ISTA Passive TB Ranging Measurement Report fields.

The ISTA Passive TB Ranging Measurement Reports field contains the number of ISTA Passive TB Ranging Measurement Reports in the ISTA Passive TB Ranging Measurement Report elements. The ISTA Passive TB Ranging Measurement Reports element is defined in 9.4.2.306 (ISTA Passive TB Ranging Measurement Report element(11az)).

### 9.6.7.53 EBCS UL frame format(11bc)

The EBCS UL frame is transmitted by an EBCS non-AP STA and carries an HLP payload intended for a destination specified within the frame. The format of the EBCS UL frame Action field is defined in Figure 9-1241 (EBCS UL frame Action field format(11bc)).

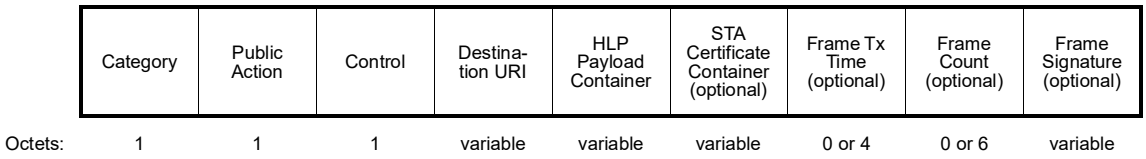


**Figure 9-1241—EBCS UL frame Action field format(11bc)**

The Category field is defined in 9.4.1.11 (Action field).

The Public Action field is defined in 9.6.7.1 (Public Action field(#3729)).

The format of Control field is shown in Figure 9-1242 (Control field format(11bc)).

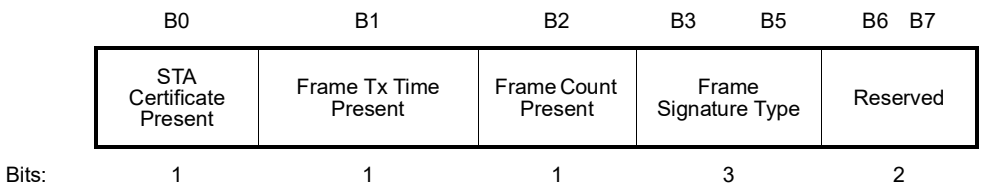


**Figure 9-1242—Control field format(11bc)**

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The STA Certificate Present subfield is set to 1 when the STA Certificate Container field is carried in the frame. Otherwise, the subfield is set to 0.

The Frame Tx Time Present subfield is set to 1 when the Frame Tx Time field is carried in the frame. Otherwise, the subfield is set to 0.

The Frame Count Present subfield is set to 1 when the Frame Count field is carried in the frame. Otherwise, the subfield is set to 0.

The encoding of the Frame Signature Type subfield is shown in Table 9-506 (Encoding of Frame Signature Type subfield(11bc)).

**Table 9-506—Encoding of Frame Signature Type subfield(11bc)**

| Value | Algorithm | Frame signature length (octets) | Encoding |
|---|---|---|---|
| 0 | HLSA | — | The authentication of the HLP payload is provided by a higher layer and is included in the HLP Payload field. |
| 1 | RSASSA-PSS-2048 | 256 | See 12.15.2.5 (Signature of the EBCS UL frame) |
| 2 | RSASSA-PSS-4096 | 512 | |
| 3 | ECDSA-P256 | variable | |
| 4 | ECDSA-P521 | variable | |
| 5–7 | Reserved | | |

The format of the Destination URI field is shown in Figure 9-1243 (Destination URI field format(11bc)).

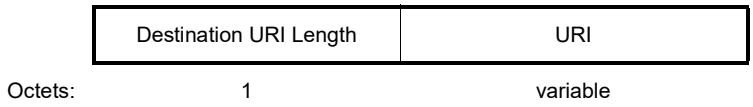


**Figure 9-1243—Destination URI field format(11bc)**

The Destination URI Length subfield indicates the length of the URI subfield in octets.

The URI subfield carries the destination URI using the format defined in IETF RFC 3986.

The format of the HLP Payload Container field is shown in Figure 9-1244 (HLP Payload Container field format(11bc)).

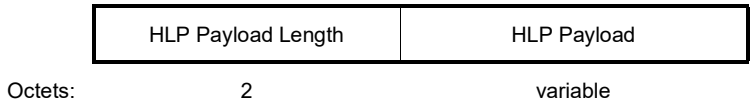


**Figure 9-1244—HLP Payload Container field format(11bc)**


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The HLP Payload Length subfield indicates the length of the HLP Payload subfield in octets.

The HLP Payload subfield carries the HLP payload.

The format of the STA Certificate Container field is shown in Figure 9-1245 (STA Certificate Container field format(11bc)).

| | STA Certificate Length | STA Certificate |
|---|---|---|
| Octets: | 2 | variable |

**Figure 9-1245—STA Certificate Container field format(11bc)**

The STA Certificate Length subfield carries a nonzero value that indicates the length of the STA Certificate subfield in octets.

The STA Certificate subfield carries the X.509v3 certificate of the STA encoded according to IETF RFC 5280.

The Frame Tx Time subfield, if present, carries the time expressed as the number of seconds since 2020-01-01 00:00:00 UTC, when the frame is queued for transmission.

The Frame Count field, if present, carries a numeric value that is incremented for each EBCS UL frame transmission.

The Frame Signature field is not present if the Frame Signature Type subfield indicates HLSA. Otherwise, the Frame Signature field carries a signature of the EBCS UL frame (generated as described in 12.15.2.5 (Signature of the EBCS UL frame)). The length of the Frame Signature field is determined as defined in Table 9-506 (Encoding of Frame Signature Type subfield(11bc)). In case of ECDSA, the Signature field contains the value *r* and *s* encoded in DER-encoded ASN.1 structure (a SEQUENCE of two INTEGERS, for *r* and *s*, in that order) that includes the length.

### 9.6.7.54 EBCS Info frame format(11bc)

The format of the Action field of the EBCS Info frame is shown in Figure 9-1246 (EBCS Info frame Action field format(11bc)).

| | Category | Public Action | EBCS Info Sequence Number | EBCS Info Time-stamp | EBCS Info Control | EBCS Info Authentica-tion Algorithm | EBCS Info Interval |
|---|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 4 | 8 | 1 | 1 | 1 |

| | EBCS TIM Length | EBCS TIM | Fragment Hash Values | Certificate Length | Certificate | Content Informa-tion Number | Content Informa-tion List | Signature |
|---|---|---|---|---|---|---|---|---|
| Octets: | 0 or 1 | variable | $n \times 32$ | 0 or 2 | variable | 1 | variable | variable |

**Figure 9-1246—EBCS Info frame Action field format(11bc)**

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The Category field is defined in 9.4.1.11 (Action field).

The Public Action field is defined in 9.6.7.1 (Public Action field(#3729)).

The EBCS Info Sequence Number field contains the sequence number of the EBCS Info frame.

The EBCS Info Timestamp field is the elapsed time from 2020-01-01 00:00 UTC in milliseconds.

The EBCS Info Control field is shown in Figure 9-1247 (EBCS Info Control field format(11bc)).

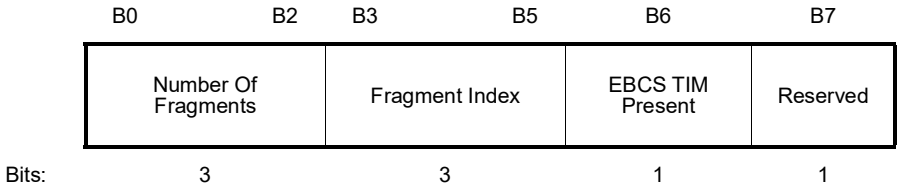


**Figure 9-1247—EBCS Info Control field format(11bc)**

The Number Of Fragments subfield indicates the number of the EBCS Info frame fragments minus 1.

The Fragment Index subfield indicates the EBCS Info frame fragment number (see 33.3.5 (EBCS Info frame fragmentation)). The first fragment is fragment 0.

The EBCS TIM Present subfield is set to 1 if the EBCS TIM Length field and the EBCS TIM field are present and is set to 0 otherwise.

The EBCS Info Authentication Algorithm field indicates the algorithm used to authenticate the EBCS Info frame. This field is defined in Table 9-507 (EBCS Info Authentication Algorithm field(11bc)).

**Table 9-507—EBCS Info Authentication Algorithm field(11bc)**

| Value | Algorithm | Certificate present |
|---|---|---|
| 0 | None | No |
| 1 | Prenegotiated | No |
| 2 | Digital signature | Yes |
| 3–255 | Reserved | - |

Details of each algorithm are described in 12.15.2.1 (Signature of an EBCS Info frame).

The EBCS Info Interval field indicates the EBCS Info frame transmission interval (from dot11EBCSInfoInterval), in units of a beacon interval.

NOTE—Even if PKFA is used, the EBCS Info frames are transmitted periodically to advertise EBCS availability.

The EBCS TIM Length field indicates the length (#7224)in octets of the EBCS TIM field.


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The EBCS TIM field contains an EBCS TIM element (9.4.2.314 (EBCS TIM element(11bc))) excluding the Element ID field, the Length field and the Element ID Extension field.

The EBCS TIM Length field and the EBCS TIM field are present if dot11EBCSSupportActivated is true and one or more EBCS traffic streams have dot11EBCSTrafficStreamBufferableActivated set to true, otherwise not present.

The Fragment Hash Values field is only present if the Number Of Fragments subfield, *n*, is nonzero. It contains a sequence of *n* Fragment Hash Value subfields.

The Certificate Length field, the Certificate field and the Signature field are present if the EBCS Info Authentication Algorithm subfield indicates that a certificate is present, and are not present otherwise. The Certificate Length field indicates the length of the Certificate field in octets.

The Certificate field contains the X.509v3 certificate of the EBCS transmitter encoded according to IETF RFC 5280.

The Content Information Number field indicates the number of Content Information subfields included in the Content Information List field.

The Content Information List field contains one or more Content Information subfields. The format of each Content Information subfield is shown in Figure 9-1248 (Content Information field format(11bc)).

| | Content ID | Content Authentication Algorithm | Content Information Control | Content Address Type | Content Address Length | Content Address | Title Length | Title |
|---|---|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 1 | 1 | variable | 1 | variable |

| | Negotiation Method | Time To Termination (optional) | Next TX Schedule (optional) | Service URL Length (optional) | Service URL (optional) | Vendor Specific Data Length (optional) | Vendor Specific Data (optional) | Content Authentication Parameters (optional) |
|---|---|---|---|---|---|---|---|---|
| Octets: | 1 | 0 or 2 | 0 or 2 | 0 or 1 | variable | 0 or 1 | variable | variable |

**Figure 9-1248—Content Information field format(11bc)**

The Content ID subfield contains the content ID.

The Content Authentication Algorithm subfield is defined in Table 9-436 (Content Authentication Algorithms(11bc)).

The Content Information Control subfield is shown in Figure 9-1249 (Content Information Control subfield format(11bc)).

The Time To Termination Present subfield indicates whether the Time To Termination field is present.

The Next Tx Schedule Present subfield indicates whether the Next Tx Schedule field is present.

The Service URL Present subfield is set to 1 if the Service URL Length subfield and the Service URL subfield are present and is set to 0 otherwise.

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| | B0 | B1 | B2 | B3 | B4 | B6 | B7 |
|---|---|---|---|---|---|---|---|
| | Time To Termination Present | Next Tx Schedule Present | Service URL Present | Vendor Specific Data Present | Bufferable Traffic | Content Transmit-ted | Reserved |
| Bits: | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

**Figure 9-1249—Content Information Control subfield format(11bc)**

The Vendor Specific Data Present subfield is set to 1 if the Vendor Specific Data Length subfield and the Vendor Specific Data subfield are present and is set to 0 otherwise.

The Bufferable Traffic subfield is set to 1 if frames for the EBCS traffic stream are bufferable at the AP. This subfield is set to 0 otherwise.

The Content Transmitted subfield is set to 1 if the content is being transmitted at the moment (no request is needed), and it is set to 0 otherwise.

The Content Address Type subfield, the Content Address subfield, the Time To Termination subfield, and the Negotiation Method subfield are defined in 9.4.5.30 (EBCS ANQP-element(11bc)).

The Title Length subfield indicates the length of the following Title subfield in octets. The Title subfield is a human readable title of the content as a UTF-8 string.The Next TX Schedule subfield indicates the number of TBTTs until the next expected broadcast of the EBCS traffic stream identified by the Content ID subfield. A value of 1 indicates that the transmission of the content identified by the Content ID subfield will begin in the beacon interval that starts at the following TBTT. A value of 0 is reserved. If the content identified by the Content ID subfield has no specific transmission starting time, the Next TX Schedule subfield is not included.

The Content Authentication Parameters subfield depends on the content authentication algorithm.

In case of PKFA, the Content Authentication Parameters subfield is present and its format is shown in Figure 9-1250 (Content Authentication Parameters subfield format for PKFA(11bc)).

| | Allowable Time Difference |
|---|---|
| Octets: | 2 |

**Figure 9-1250—Content Authentication Parameters subfield format for PKFA(11bc)**

The Allowable Time Difference subfield indicates the allowable time differencein milliseconds between the value in the EBCS Info Timestamp field and the reception time recorded by an EBCS receiver.

In case of HCFA, the Content Authentication Parameters subfield is present and its format is shown in Figure 9-1251 (Content Authentication Parameters subfield format for HCFA(11bc)).

The Allowable Time Difference subfield indicates the allowable time difference in milliseconds between the value in the EBCS Info Timestamp field and the reception time recorded by an EBCS receiver.

The HCFA Base Key subfield contains the first HCFA base key of the HCFA period that starts from this EBCS Info frame.


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| | Allowable Time Difference | HCFA Base Key | Previous Period HCFA Base Key 0 Sequence | Previous Period HCFA Base Key 0 | Previous Period HCFA Base Key 1 Sequence | Previous Period HCFA Base Key 1 | HCFA Change Interval | Number of Instant Authenti-cators (optional) | Instant Authenti-cator List (optional) |
|---|---|---|---|---|---|---|---|---|---|
| Octets: | 2 | 32 | 1 | 32 | 1 | 32 | 1 | 0 or 1 | *n* x 33 |

**Figure 9-1251—Content Authentication Parameters subfield format for HCFA(11bc)**

The Previous Period HCFA Base Key 0 Sequence subfield and the Previous Period HCFA Base Key 1 Sequence subfield indicate the key sequence number of the Previous Period HCFA Base Key 0 subfield and the Previous Period HCFA Base Key 1 subfield, respectively. The Previous Period HCFA Base Key 0 subfield and the Previous Period HCFA Base Key 1 subfield contain the HCFA base key to be disclosed for the previous HCFA period.

If the previous HCFA period does not exist, e.g., at the start of the EBCS transmission, the Previous Period HCFA Base Key 0 Sequence subfield, the Previous Period HCFA Base Key 0 subfield, the Previous Period HCFA Base Key 1 Sequence subfield, and the Previous Period HCFA Base Key 1 subfield are set to 0.

The HCFA Key Change Interval subfield indicates the EBCS HCFA key change interval in units of 10 ms (see dot11EBCSHCFAKeyChangeInterval).

The Number Of Instant Authenticators subfield and the Instant Authenticator List subfield are present if the Content Authentication Algorithm field indicates HCFA with instant authentication, and are not present otherwise.

The Number Of Instant Authenticators subfield, if present, indicates the number of Instant Authenticator subfields contained in the Instant Authenticator List subfield.

The Instant Authenticator List subfield, if present, contains one or more Instant Authenticator subfields.

The format of each Instant Authenticator subfield is shown in Figure 9-1252 (Instant Authenticator subfield format(11bc)).

| | Hash Distance | Hash Value |
|---|---|---|
| Octets: | 1 | 32 |

**Figure 9-1252—Instant Authenticator subfield format(11bc)**

The Hash Distance subfield indicates the hash distance of the instant authenticator. The Hash Value subfield contains the instant authenticator of the following EBCS Data frame of the hash distance that is indicated in the Hash Distance subfield.

In case of HLSA, the Content Authentication Parameters subfield is not present.

The Service URL Length subfield indicates the number of octets in the Service URL subfield.

The Service URL subfield indicates the URL at which information relevant to the corresponding EBCS traffic stream might be retrieved, including negotiation or registration for the service, formatted in accordance with IETF RFC 3986.

The Vendor Specific Data Length subfield indicates the number of octets in the Vendor Specific Data subfield.

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The Vendor Specific Data subfield is defined by application specific requirements and its contents are outside the scope of this standard.

The Signature field is the digital signature of the EBCS Info frame (see 12.15.2.1 (Signature of an EBCS Info frame)). The length of the Signature field is determined by the value of the EBCS Info Authentication Algorithm field as defined in Table 9-507 (EBCS Info Authentication Algorithm field(11bc)). In case of ECDSA, the Signature field contains the values *r* and *s* encoded in DER-encoded ASN.1 structure (a SEQUENCE of two INTEGERs, for *r* and *s*, in that order) that includes the length. In case of Prenegotiated, the length of the Signature field is negotiated beforehand between the EBCS AP and the EBCS receiver. The Signature field is not present if the Fragment Index subfield is nonzero.

### 9.6.7.55 EBCS Termination Notice frame format(11bc)

The EBCS Termination Notice frame is transmitted by a STA to announce the termination of one or more of the EBCS traffic streams transmitted by the STA. The format of the EBCS Termination Notice frame Action field is shown in Figure 9-1253 (EBCS Termination Notice frame Action Field format(11bc)).

| | Category | Public Action | EBCS Termination Info Count | EBCS Termination Information Set |
|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | variable |

**Figure 9-1253—EBCS Termination Notice frame Action Field format(11bc)**

The Category field is defined in 9.4.1.11 (Action field).

The Public Action field is defined in 9.6.7.1 (Public Action field(#3729)).

The EBCS Termination Info Count field indicates the number of EBCS Termination Info subfields contained in the EBCS Termination Information Set field.

The EBCS Termination Information Set field contains one or more EBCS Termination Info subfields.

The format of an EBCS Termination Info subfield is shown in Figure 9-1254 (EBCS Termination Info subfield format(11bc)).

| | EBCS Termination Info Length | EBCS Termination Info Control | Content ID | Title Length | Title | Time To Termination | Negotiation Method | Negotiation Address Type | Negotiation Address |
|---|---|---|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 0 or 1 | variable | 2 | 1 | 0 or 1 | variable |

**Figure 9-1254—EBCS Termination Info subfield format(11bc)**

The EBCS Termination Info Length field indicates the length in octets of the EBCS Termination Info subfield including the EBCS Termination Info Length field.

The format of the EBCS Termination Info Control subfield is shown in Figure 9-1255 (EBCS Termination Info Control subfield format(11bc)).

A value of 1 in the Title Presence Indicator subfield indicates that a Title Length subfield and a Title subfield are present in the EBCS Termination Info subfield. A value of 0 indicates that a Title Length subfield and a Title subfield are not present in the EBCS Termination Info subfield.


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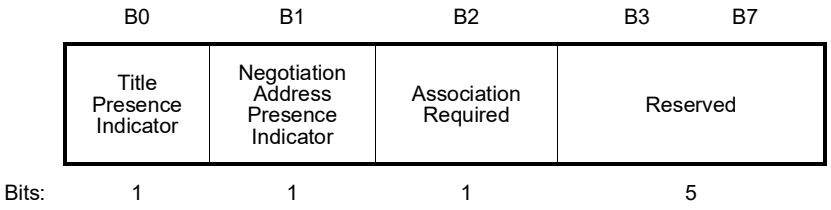


**Figure 9-1255—EBCS Termination Info Control subfield format(11bc)**

A value of 1 in the Negotiation Address Presence Indicator subfield indicates that a Negotiation Address Type subfield and a Negotiation Address subfield are present in the EBCS Termination Info subfield. The value of 0 indicates that a Negotiation Address Type subfield and a Negotiation Address subfield are not present in the EBCS Termination Info subfield.

A value of 1 in the Association Required subfield indicates that an association is required to consume the EBCS traffic stream identified by the content ID contained in the Content ID subfield. A value of 0 indicates that an association is not required to consume the EBCS traffic stream identified by the content ID contained in the Content ID subfield.

The Content ID subfield indicates the ID of the EBCS traffic stream to be terminated.

The Title Length subfield indicates the length of the Title subfield in octets.

The Title subfield indicates the title in a UTF-8 string of the EBCS traffic stream identified by the content ID contained in the Content ID subfield.

The Time To Termination subfield is defined in 9.4.1.69 (EBCS Content Response field(11bc)).

NOTE—The Time To Termination subfield indicates the termination time for the transmitter STA of the EBCS traffic stream and does not indicate the termination time of the content associated with the EBCS traffic stream.

The Negotiation Method subfield indicates the negotiation method to request an extension of the EBCS traffic stream identified by the content ID contained in the Content ID subfield. The encoding of the Negotiation Method subfield is defined in Table 9-508 (Negotiation Method subfield encoding(11bc)).

**Table 9-508—Negotiation Method subfield encoding(11bc)**

| Negotiation Method subfield value | Meaning | Notes |
|---|---|---|
| 0 | No negotiation | |
| 1 | Request through EBCS Content Request frames | EBCS traffic stream request by STAs that are associated with the broadcaster. |
| 2 | Request through EBCS Content Request ANQP-element / Request through EBCS Content Request frame | (#8258)EBCS traffic stream extensions by STAs that are not associated with the broadcaster are requested using an EBCS Content Request ANQP-element. EBCS traffic stream extensions by STAs that are associated with the broadcaster are requested using either an EBCS Content Request ANQP-element or using an EBCS Content Request frame. |

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**Table 9-508—Negotiation Method subfield encoding(11bc)**

| | | |
|---|---|---|
| 3 | Request through IP request | Out of band IP request. |
| 4–255 | Reserved | |

The Negotiation Address Type subfield indicates the type of the address included in the Negotiation Address subfield. The encoding of the Negotiation Address Type subfield is defined in Table 9-509 (Negotiation Address Type subfield encoding(11bc)).

The Negotiation Address subfield indicates the address to be used for negotiating for the extension of the EBCS traffic stream identified by the content ID contained in the Content ID subfield. The format and the length of the Negotiation Address subfield depends on the value contained in the Negotiation Address Type subfield.

The Negotiation Address subfield contains a MAC address if the Negotiation Address Type subfield is equal to 0.

**Table 9-509—Negotiation Address Type subfield encoding(11bc)**

| Destination Address Type value | Meaning |
|---|---|
| 0 | MAC address |
| 1 | UDP/IPv4 address |
| 2 | UDP/IPv6 address |
| 3 | UDP/hostname |
| 4–255 | Reserved |

The format of the Negotiation Address subfield when the Negotiation Address Type subfield is equal to 1 is shown in Figure 9-1256 (Negotiation Address subfield format for a Negotiation Address Type of 1(11bc)).

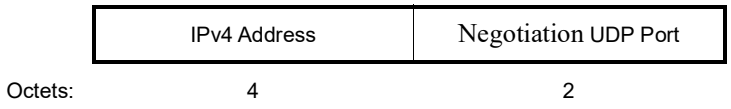


**Figure 9-1256—Negotiation Address subfield format for a Negotiation Address Type of 1(11bc)**

The IPv4 Address subfield indicates an IPv4 address used for negotiating the extension of the EBCS traffic stream.

The Negotiation UDP Port subfield indicates the UDP port associated with the IPv4 address indicated in the IPv4 Address subfield in little endian format.

The format of the Negotiation Address subfield when the Negotiation Address Type subfield is equal to 2 is shown in Figure 9-1257 (Negotiation Address subfield format for a Negotiation Address Type of 2(11bc)).


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**Figure 9-1257—Negotiation Address subfield format for a Negotiation Address Type of 2(11bc)**

The IPv6 Address subfield indicates an IPv6 address used for negotiating the extension of the EBCS traffic stream.

The Negotiation UDP Port subfield indicates the UDP port associated with the IPv6 address indicated in the IPv6 Address subfield in little endian format.

The format of the Negotiation Address subfield when the Negotiation Address Type subfield is equal to 3 is shown in Figure 9-1258 (Negotiation Address subfield format for a Negotiation Address Type of 3(11bc)).

**Figure 9-1258—Negotiation Address subfield format for a Negotiation Address Type of 3(11bc)**

The Hostname Length subfield indicates the length of the Hostname subfield in octets.

The Hostname subfield indicates the host name for negotiating the extension of the EBCS traffic stream in a UTF-8 string.

The Negotiation UDP Port subfield indicates the UDP port associated with the host name indicated in the Hostname subfield in little endian format.

### 9.6.8 FT Action frame details

#### 9.6.8.1 FT Action field(#3729)

Four Action frame formats are defined to support fast BSS transitions over the DS, which are initiated through the currently associated AP. The FT Action frames are sent over the air between the STA and the current AP. The Action frame is used as a transport mechanism for data that are destined for the target AP. An FT Action field, in the octet immediately after the Category field, differentiates the FT Action frame formats. The FT Action field values associated with each FT Action frame format are defined in Table 9-510 (FT Action field values).

#### 9.6.8.2 FT Request frame

The FT Request frame is sent by the STA to its associated AP to initiate an over-the-DS fast BSS transition.

Figure 9-1259 (FT Request frame Action field format) shows the format of the FT Request frame Action field.

The Category field is defined in 9.4.1.11 (Action field).

The FT Action field is defined in 9.6.8.1 (FT Action field(#3729)).

The STA Address field is set to the (#4237)FTO's MAC address.

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**Table 9-510—FT Action field values**

| FT Action field value | Description |
|---|---|
| 0 | Reserved |
| 1 | FT Request frames |
| 2 | FT Response frames |
| 3 | FT Confirm frames |
| 4 | FT Ack frames |
| 5–255 | Reserved |

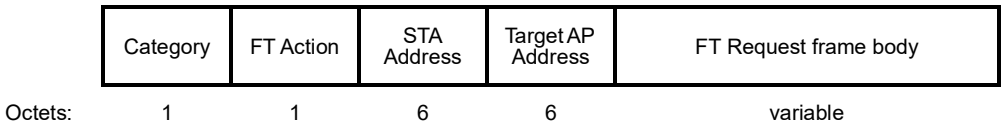


**Figure 9-1259—FT Request frame Action field format**

The Target AP Address field is set to the BSSID of the target AP's BSS.(#3522)

The FT Request frame body contains the information shown in Table 9-511 (FT Request frame body).

**Table 9-511—FT Request frame body**

| Order | Information | Notes |
|---|---|---|
| 1 | RSN | A RSNE is present if dot11RSNAActivated is true. |
| 2 | Mobility Domain | The MDE is present. |
| 3 | Fast BSS Transition | An FTE is present if dot11RSNAActivated is true. |
| (#4070)4 | RSN Extension | An RSNXE is present if any subfield of the Extended RSN Capabilities field in this element is nonzero, except the Field Length subfield; otherwise, not present. |

The usage of these elements is defined in 13.8.2 (FT authentication sequence: contents of first message).

### 9.6.8.3 FT Response frame

The FT Response frame is transmitted by the currently associated AP as a response to the STA's FT Request frame. Figure 9-1260 (FT Response frame Action field format) shows the format of the FT Response frame Action field.

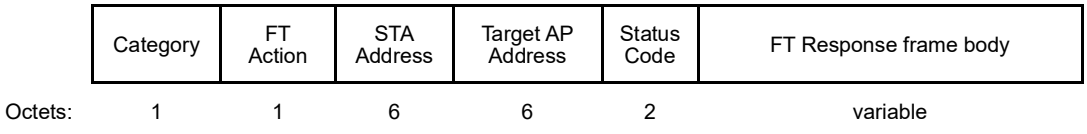


**Figure 9-1260—FT Response frame Action field format**


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The Category field is defined in 9.4.1.11 (Action field).

The FT Action field is defined in 9.6.8.1 (FT Action field(#3729)).

The STA Address field is set to the FTO's MAC address.

The Target AP Address field is set to the BSSID of the target AP's BSS.(#3522)

The Status Code field is a value from the options listed in 9.4.1.9 (Status Code field).

If the Status Code field is SUCCESS, then the FT Response frame body contains the information shown in Table 9-512 (FT Response frame body).

**Table 9-512—FT Response frame body**

| Order | Information | Notes |
|---|---|---|
| 1 | RSN | The RSNE is present if dot11RSNAActivated is true; otherwise not present.(#3400) |
| 2 | Mobility Domain | The MDE is present. |
| 3 | Fast BSS Transition | An FTE is present if dot11RSNAActivated is true. |

The usage of these elements is defined in 13.8.3 (FT authentication sequence: contents of second message).

### 9.6.8.4 FT Confirm frame

The FT Confirm frame in an RSN is confirmation to the target AP of receipt of the ANonce and indicates the liveness of the PTKSA. The FT Confirm frame is optionally used by the FTO to request resources. Figure 9-1261 (FT Confirm frame Action field format) shows the FT Confirm frame Action field format.

| | Category | FT Action | STA Address | Target AP Address | FT Confirm frame body |
|---|---|---|---|---|---|
| Octets: | 1 | 1 | 6 | 6 | variable |

**Figure 9-1261—FT Confirm frame Action field format**

The Category field is defined in 9.4.1.11 (Action field).

The FT Action field is defined in 9.6.8.1 (FT Action field(#3729)).

The STA Address field is set to the FTO's MAC address.

The Target AP Address field is set to the BSSID of the target AP's BSS.(#3522)

The FT Confirm frame body contains the information shown in Table 9-513 (FT Confirm frame body).

The usage of these elements is defined in 13.8.4 (FT authentication sequence: contents of third message).

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**Table 9-513—FT Confirm frame body**

| Order | Information | Notes |
|---|---|---|
| 1 | RSN | The RSNE is present if dot11RSNAActivated is true; otherwise not present.(#3400) |
| 2 | Mobility Domain | The MDE is present. |
| 3 | Fast BSS Transition | An FTE is present if dot11RSNAActivated is true. |
| 4 | RIC | The RIC Request field is present if resources are being requested. |

### 9.6.8.5 FT Ack frame

The FT Ack frame is transmitted by the currently associated AP as a response to the STA's FT Confirm frame. Figure 9-1262 (FT Ack frame Action field format) shows the FT Ack frame Action field format.

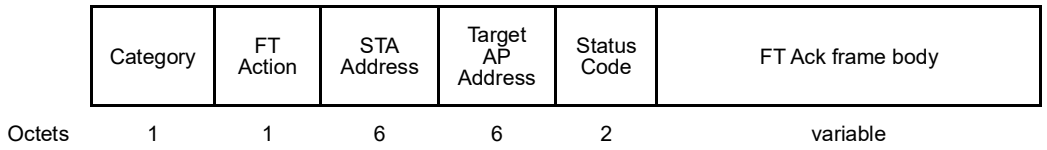


**Figure 9-1262—FT Ack frame Action field format**

The Category field is defined in 9.4.1.11 (Action field).

The FT Action field is defined in 9.6.8.1 (FT Action field(#3729)).

The STA Address field is set to the FTO's MAC address.

The Target AP Address field is set to the BSSID of the target AP's BSS.(#3522)

The Status Code field is a value from the options listed in 9.4.1.9 (Status Code field).

If the Status Code field is SUCCESS, then the FT Ack frame body contains the information shown in Table 9-514 (FT Ack frame body).

**Table 9-514—FT Ack frame body**

| Order | Information | Notes |
|---|---|---|
| 1 | RSN | The RSNE is present if dot11RSNAActivated is true; otherwise not present.(#3400) |
| 2 | Mobility Domain | The MDE is present. |
| 3 | Fast BSS Transition | An FTE is present if dot11RSNAActivated is true. |
| 4 | Timeout Interval (reassociation deadline) | A TIE containing the reassociation deadline interval is present if resources were requested in the FT Confirm frame and dot11RSNAActivated is false. |
| 5 | RIC | The RIC Response field is present if resources were requested in the FT Confirm frame. |


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The usage of these elements is defined in 13.8.5 (FT authentication sequence: contents of fourth message).

### 9.6.9 SA Query Action frame details

#### 9.6.9.1 SA Query Action field(#3729)

Two Action frame formats are defined for the SA Query procedure. An SA Query Action field, in the field immediately after the Category field, differentiates the formats. The Action field values associated with each frame format are defined in Table 9-515 (SA Query Action field values).

NOTE—The SA query functionality defined in this standard is used to prevent the Association Lockout problem (defined in 11.3 (STA authentication and association)).

**Table 9-515—SA Query Action field values**

| SA Query Action field value | Description |
|---|---|
| 0 | SA Query Request |
| 1 | SA Query Response |

#### 9.6.9.2 SA Query Request frame

The SA Query Request frame is used to request an SA Query Response from the receiving STA. The format of the Action field of the SA Query Request frame is shown in Figure 9-1263 (SA Query Request frame Action field format).

| | Category | SA Query Action | Transaction Identifier | OCI Element |
|---|---|---|---|---|
| Octets: | 1 | 1 | 2 | 6 |

**Figure 9-1263—SA Query Request frame Action field format**

The Category field is defined in 9.4.1.11 (Action field).

The SA Query Action field is defined in 9.6.9.1 (SA Query Action field(#3729)).

The Transaction Identifier field is a (#1395)counter value set by the STA sending the SA Query Request frame to identify any outstanding request/response transaction.

The OCI Element field includes the OCI element (see 9.4.2.235 (OCI element)) and is included if dot11RSNAOperatingChannelValidationActivated is true.

#### 9.6.9.3 SA Query Response frame

The SA Query Response frame is used to respond to an SA Query Request frame from another STA. The format of the Action field of the SA Query Response frame is shown in Figure 9-1264 (SA Query Response frame Action field format).

The Category field is defined in 9.4.1.11 (Action field).

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| | Category | SA Query Action | Transaction Identifier | OCI Element |
|---|---|---|---|---|
| Octets: | 1 | 1 | 2 | 6 |

**Figure 9-1264—SA Query Response frame Action field format**

The SA Query Action field is defined in 9.6.9.1 (SA Query Action field(#3729)).

The Transaction Identifier field is set to the same value as the Transaction Identifier field in the corresponding SA Query Request frame.

The OCI Element field includes the OCI element (see 9.4.2.235 (OCI element)) and is included if dot11RSNAOperatingChannelValidationActivated is true.

### 9.6.10 Protected Dual of Public Action frame details(#3729)

The Protected Dual of Public Action frame is defined to allow robust STA-STA communications of the same information that is conveyed in (#3108)Public Action frames. A Public Action field, in the octet immediately after the Category field, differentiates the Protected Dual of Public Action frame formats. The defined Protected Dual of Public Action frames are listed in Table 9-516 (Public Action field values defined for Protected Dual of Public Action frames).

(#1631)The Action fields of Protected Dual of Public Action frames have the same format as those of the corresponding nonprotected Public Action frames.

**Table 9-516—Public Action field values defined for Protected Dual of Public Action frames**

| Public Action field value | Description | Defined in |
|---|---|---|
| 0 | Reserved | |
| 1 | Protected DSE Enablement | 9.6.7.4 (DSE Enablement frame format) |
| 2 | Protected DSE Deenablement | 9.6.7.5 (DSE Deenablement frame format) |
| 3 | Reserved | |
| 4 | Protected Extended Channel Switch Announcement | 9.6.7.7 (Extended Channel Switch Announcement frame format) |
| 5 | Protected Measurement Request | 9.6.7.8 (DSE Measurement Request frame format) |
| 6 | Protected Measurement Report | 9.6.7.9 (DSE Measurement Report frame format) |
| 7 | Reserved | |


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**Table 9-516—Public Action field values defined for Protected Dual of Public Action frames *(continued)***

| Public Action field value | Description | Defined in |
|---|---|---|
| 8 | Protected DSE Power Constraint | 9.6.7.10 (DSE Power Constraint frame format) |
| 9 | Protected Vendor Specific | 9.6.7.11 (Vendor Specific Public Action frame format) |
| 10 | Protected GAS Initial Request | 9.6.7.12 (GAS Initial Request frame format) |
| 11 | Protected GAS Initial Response | 9.6.7.13 (GAS Initial Response frame format) |
| 12 | Protected GAS Comeback Request | 9.6.7.14 (GAS Comeback Request frame format) |
| 13 | Protected GAS Comeback Response | 9.6.7.16 (GAS Comeback Response frame format) |
| 14–15 | Reserved | |
| 16 | QAB Request | 9.6.7.34 (QAB Request frame format) |
| 17 | QAB Response | 9.6.7.35 (QAB Response frame format) |
| 18 | Protected QMF Policy | 9.6.7.19 (QMF Policy frame format) |
| 19 | Protected QMF Policy Change | 9.6.7.20 (QMF Policy Change frame format) |
| 20 | Protected QLoad Request | 9.6.7.20 (QLoad Request frame format) |
| 21 | Protected QLoad Report | 9.6.7.21 (QLoad Report frame format) |
| 22 | Protected HCCA TXOP Advertisement | 9.6.7.22 (HCCA TXOP Advertisement frame) |
| 23 | Protected HCCA TXOP Response | 9.6.7.23 (HCCA TXOP Response frame) |
| 24 | Reserved | |

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**Table 9-516—Public Action field values defined for Protected Dual of Public Action frames *(continued)***

| Public Action field value | Description | Defined in |
|---|---|---|
| 25 | Protected Channel Availability Query | 9.6.7.25 (Channel Availability Query frame format) |
| 26 | Protected Channel Schedule Management | 9.6.7.26 (Channel Schedule Management frame format) |
| 27 | Protected Contact Verification Signal | 9.6.7.27 (Contact Verification Signal frame format) |
| 28 | Protected GDD Enablement Request | 9.6.7.28 (GDD Enablement Request frame format) |
| 29 | Protected GDD Enablement Response | 9.6.7.29 (GDD Enablement Response frame format) |
| 30 | Protected Network Channel Control | 9.6.7.30 (Network Channel Control frame format) |
| 31 | Protected White Space Map Announcement | 9.6.7.31 (White Space Map Announcement frame format) |
| 32(11ay) | Protected DMG STA Directional Transmit Activity Report | 9.6.7.48 (DMG STA Directional Transmit Activity Report frame format(11ay)) |
| 33(11bc) | EBCS Termination Notice | 9.6.7.55 (EBCS Termination Notice frame format(11bc)) |
| 34(#6058) | Protected GAS Comeback Request Fragment | 9.6.7.15 (GAS Comeback Request Fragment frame format(#6058)) |
| 35–255 | Reserved | |


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## 9.6.11 HT Action frame details

### 9.6.11.1 HT Action field

Several Action frame formats are defined to support HT features. An HT Action field, in the octet immediately after the Category field, differentiates the HT Action frame formats. The HT Action field values associated with each frame format within the HT category are defined in Table 9-517 (HT Action field values). The frame formats are defined in 9.6.11.2 (Notify Channel Width frame format) to 9.6.11.7 (Antenna Selection Indices Feedback frame format).

**Table 9-517—HT Action field values**

| HT Action field value | Meaning | Time priority |
|---|---|---|
| 0 | Notify Channel Width | No |
| 1 | SM Power Save | No |
| (#3263)2–3(#1707) | Reserved | |
| 4 | CSI | Yes |
| 5 | Noncompressed Beamforming | Yes |
| 6 | Compressed Beamforming | Yes |
| 7 | ASEL Indices Feedback | Yes |
| 8–255(#1707) | Reserved | |

### 9.6.11.2 Notify Channel Width frame format

A STA sends the Notify Channel Width frame to another STA if it wants to change the channel width of frames that the other STA sends to it. See definition in 11.15.2 (Basic 20/40 MHz BSS functionality).

The format of the Notify Channel Width frame Action field is defined in Table 9-518 (Notify Channel Width frame Action field format).

**Table 9-518—Notify Channel Width frame Action field format**

| Order | Information |
|---|---|
| 1 | Category |
| 2 | HT Action |
| 3 | Channel Width (see 9.4.1.21 (Channel Width field)) |

This frame can be sent by both non-AP STA and AP.

The Category field is defined in 9.4.1.11 (Action field).

The HT Action field is defined in 9.6.11.1 (HT Action field).

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### 9.6.11.3 SM Power Save frame format

The SM Power Save frame is of category HT. The SM Power Save frame is used to manage SM power-saving state transitions as defined in 11.2.6 (SM power save).

The Action field of the SM Power Save frame is defined in Table 9-519 (SM Power Save frame Action field format).

**Table 9-519—SM Power Save frame Action field format**

| Order | Information |
|---|---|
| 1 | Category |
| 2 | HT Action |
| 3 | SM Power Control (see 9.4.1.23 (SM Power Control field)) |

The Category field is defined in 9.4.1.11 (Action field).

The HT Action field is defined in 9.6.11.1 (HT Action field).(#3263)

### 9.6.11.4 CSI frame format

The CSI frame is an Action or an Action No Ack frame of category HT. The format of its Action field is defined in Table 9-520 (CSI frame Action field format).

**Table 9-520—CSI frame Action field format**

| Order | Information |
|---|---|
| 1 | Category |
| 2 | HT Action |
| 3 | MIMO Control (see 9.4.1.24 (MIMO Control field)) |
| 4 | CSI Report (see 9.4.1.25 (CSI Report field)) |

The Category field is defined in 9.4.1.11 (Action field).

The HT Action field is defined in 9.6.11.1 (HT Action field).

In a CSI frame, the fields of the MIMO Control field (see 9.4.1.24 (MIMO Control field)) are used as described in Table 9-85 (Subfields of the MIMO Control field). The Codebook Information subfield is reserved in this frame.

### 9.6.11.5 Noncompressed Beamforming frame format

The Noncompressed Beamforming frame is an Action or an Action No Ack frame of category HT. The format of its Action field is defined in Table 9-521 (Noncompressed Beamforming frame Action field format).


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**Table 9-521—Noncompressed Beamforming frame Action field format**

| Order | Information |
|---|---|
| 1 | Category |
| 2 | HT Action |
| 3 | MIMO Control (see 9.4.1.24 (MIMO Control field)) |
| 4 | Noncompressed Beamforming Report (see 9.4.1.26 (Noncompressed Beamforming Report field)) |

The Category field is defined in 9.4.1.11 (Action field).

The HT Action field is defined in 9.6.11.1 (HT Action field).

In a Noncompressed Beamforming frame, the fields of the MIMO Control field (see 9.4.1.24 (MIMO Control field)) are used as described in Table 9-85 (Subfields of the MIMO Control field). The Codebook Information subfield is reserved in this frame.

### 9.6.11.6 Compressed Beamforming frame format

The Compressed Beamforming frame is an Action or an Action No Ack frame of category HT. The format of its Action field is defined in Table 9-522 (Compressed Beamforming frame Action field format).

**Table 9-522—Compressed Beamforming frame Action field format**

| Order | Information |
|---|---|
| 1 | Category |
| 2 | HT Action |
| 3 | MIMO Control (see 9.4.1.24 (MIMO Control field)) |
| 4 | Compressed Beamforming Report (see 9.4.1.27 (Compressed Beamforming Report field)) |

The Category field is defined in 9.4.1.11 (Action field).

The HT Action field is defined in 9.6.11.1 (HT Action field).

In a Compressed Beamforming frame, the fields of the MIMO Control field (see 9.4.1.24 (MIMO Control field)) are used as described in Table 9-85 (Subfields of the MIMO Control field). The Coefficient Size subfield is reserved in this frame.

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### 9.6.11.7 Antenna Selection Indices Feedback frame format

The Antenna Selection Indices Feedback frame is an Action or Action No Ack frame of category HT. The format of its Action field is defined in Table 9-523 (Antenna Selection Indices Feedback frame Action field format).

**Table 9-523—Antenna Selection Indices Feedback frame Action field format**

| Order | Information |
|---|---|
| 1 | Category |
| 2 | HT Action |
| 3 | Antenna Selection Indices (see 9.4.1.28 (Antenna Selection Indices field)) |

The Category field is defined in 9.4.1.11 (Action field).

The HT Action field is defined in 9.6.11.1 (HT Action field).

## 9.6.12 TDLS Action field formats

### 9.6.12.1 TDLS Action field(#3729)

Several Action field formats are defined to support TDLS. A TDLS Action field, in the octet immediately after the Category field, differentiates the TDLS Action field formats. The TDLS Action field values associated with each Action field format within the TDLS category are defined in Table 9-524 (TDLS Action field values).

**Table 9-524—TDLS Action field values**

| Action field value | Meaning |
|---|---|
| 0 | TDLS Setup Request |
| 1 | TDLS Setup Response |
| 2 | TDLS Setup Confirm |
| 3 | TDLS Teardown |
| 4 | TDLS Peer Traffic Indication |
| 5 | TDLS Channel Switch Request |
| 6 | TDLS Channel Switch Response |
| 7 | TDLS Peer PSM Request |
| 8 | TDLS Peer PSM Response |
| 9 | TDLS Peer Traffic Response |
| 10 | TDLS Discovery Request |
| 11–255 | Reserved |


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References to one of the TDLS Action field values as a frame, e.g., "TDLS Setup Request frame," denote a Data frame carrying a TDLS Action field and any Vendor Specific elements tunneled as described in 11.20.2 (TDLS payload).(#1680)

NOTE—There is no TDLS Discovery Response TDLS Action field; the TDLS Discovery Response frame is not a Data frame but a Public Action frame.(#1546)

### 9.6.12.2 TDLS Setup Request Action field format

The Action field of a TDLS Setup Request Action field contains the information shown in Table 9-525 (Information for TDLS Setup Request Action field).

**Table 9-525—Information for TDLS Setup Request Action field**

| Order | Information | Notes |
|---|---|---|
| 1 | Category | The Category field is defined in 9.4.1.11 (Action field). |
| 2 | TDLS Action | The TDLS Action field is defined in 9.6.12.1 (TDLS Action field(#3729)). |
| 3 | Dialog Token | The Dialog Token field contains a unique nonzero value for the conversation between the STAs involved in this request. The dialog token is specified in 9.4.1.12 (Dialog Token field). |
| 4 | Capability | The Capability field indicates the capabilities of the STA. The Capability field is defined in 9.4.1.4 (Capability Information field). |
| 5 | Supported Rates and BSS Membership Selectors | The Supported Rates and BSS Membership Selectors element indicates the rates that are supported by the STA. The Supported Rates and BSS Membership Selectors element is defined in 9.4.2.3 (Supported Rates and BSS Membership Selectors element). |
| 6 | Country | The Country element is present when dot11MultiDomainCapabilityActivated is true or dot11SpectrumManagementRequired is true. The Country element is defined in 9.4.2.7 (Country element). |
| 7 | Extended Supported Rates and BSS Membership Selectors | (#3086)The Extended Supported Rates and BSS Membership Selectors element is present if the number of supported rates and BSS membership selectors(#1470) together exceed eight; it is optional otherwise. The Extended Supported Rates and BSS Membership Selectors element is defined in 9.4.2.11 (Extended Supported Rates and BSS Membership Selectors element). |
| 8 | Supported Channels | The Supported Channels element is present if the TDLS Channel Switching subfield is equal to 1.<br>The Supported Channels element is defined in 9.4.2.16 (Supported Channels element). |
| 9 | RSNE | The RSNE is present if security is required on the TDLS direct link (see 12.7.8.1 (General)); otherwise not present. (#3400)The RSNE is defined in 9.4.2.23 (RSNE). |
| 10 | Extended Capabilities | The Extended Capabilities element is present if any of the fields in this element are nonzero. The Extended Capabilities element is defined in 9.4.2.25 (Extended Capabilities element). |

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**Table 9-525—Information for TDLS Setup Request Action field *(continued)***

| Order | Information | Notes |
|---|---|---|
| 11 | QoS Capability | The QoS Capability element is present when dot11QosOptionImplemented is true and not present otherwise. The QoS Capability element is defined in 9.4.2.33 (QoS Capability element). |
| 12 | FTE | The FTE is present if security is required on the TDLS direct link (see 12.7.8.1 (General)). The FTE is defined in 9.4.2.46 (FTE(#1776)). |
| 13 | Timeout Interval (TPK key lifetime) | The (#1776)TIE contains the TPK key lifetime and is present if security is required on the TDLS direct link (see 12.7.8.1 (General)).<br>The (#1776)TIE is defined in 9.4.2.47 (TIE(#1776)). |
| 14 | Supported Operating Classes | The Supported Operating Classes element is present if the TDLS Channel Switching subfield is equal to 1. |
| 15 | HT Capabilities | The HT Capabilities element is defined in 9.4.2.54 (HT Capabilities element).<br>The HT Capabilities element is present when dot11HighThroughputOptionImplemented is true. |
| 16 | 20/40 BSS Coexistence | The 20/40 BSS Coexistence element is defined in 9.4.2.58 (20/40 BSS Coexistence element).<br>The 20/40 BSS Coexistence element is optionally present. |
| 17 | Link Identifier | The Link Identifier element is specified in 9.4.2.60 (Link Identifier element). |
| 18 | Multi-band | The Multi-band element is optionally present if dot11MultibandImplemented is true. |
| 19 | AID | The AID element containing the AID of the STA sending the frame is present if dot11VHTOptionImplemented, dot11HEOptionImplemented, or dot11S1GOptionImplemented is true.(11ax) |
| 20 | VHT Capabilities | The VHT Capabilities element is present in the 5 GHz band if dot11VHTOptionImplemented is true.(#8181) |
| 21 | S1G Capabilities | S1G Capabilities element is optionally present if dot11S1GOptionImplemented is true. |
| 22 | EL Operation | EL Operation element is present if dot11S1GELOperationActivated is true. |
| 23(11ax) | HE Capabilities | The HE Capabilities element is present if dot11HEOptionImplemented is true; otherwise, it is not present. The HE Capabilities element is defined in 9.4.2.247 (HE Capabilities element(11ax)). |
| 24(11ax) | TWT | The TWT element is optionally present if dot11TWTOptionActivated is true; otherwise, it is not present.<br>The Trigger subfield and the Negotiation Type subfield of the TWT element are set to 0. |
| 25(11ax) | HE 6 GHz Band Capabilities | The HE 6 GHz Band Capabilities element is present if dot11HEOptionImplemented and dot11HE6GOptionImplemented are true; otherwise, it is not present. |


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The TDLS Setup Request Action field is encapsulated in a Data frame and transmitted to the recipient STA through the AP to request the setup of a TDLS direct link. See 11.20 (Tunneled direct link setup(#1356)).

### 9.6.12.3 TDLS Setup Response Action field format

The Action field of a TDLS Setup Response Action field contains the information shown in Table 9-526 (Information for TDLS Setup Response Action field).

**Table 9-526—Information for TDLS Setup Response Action field**

| Order | Information | Notes |
|---|---|---|
| 1 | Category | The Category field is defined in 9.4.1.11 (Action field). |
| 2 | TDLS Action | The TDLS Action field is defined in 9.6.12.1 (TDLS Action field(#3729)). |
| 3 | Status Code | The Status Code is defined in 9.4.1.9 (Status Code field). |
| 4 | Dialog Token | The dialog token is copied from the corresponding TDLS Setup Request. The dialog token is specified in 9.4.1.12 (Dialog Token field). |
| 5 | Capability | The Capability field indicates the capabilities of the STA and is present when the (#7190)status code is SUCCESS and is not present otherwise. The Capability field is defined in 9.4.1.4 (Capability Information field). |
| 6 | Supported Rates and BSS Membership Selectors | The Supported Rates and BSS Membership Selectors element indicates the rates that are supported by the STA and is present when the (#7190)status code is SUCCESS and is not present otherwise.The Supported Rates and BSS Membership Selectors element is defined in 9.4.2.3 (Supported Rates and BSS Membership Selectors element). |
| 7 | Country | The Country element is present when Status Code is SUCCESS and either dot11MultiDomainCapabilityActivated is true or dot11SpectrumManagementRequired is true and is not present otherwise.<br>The Country element is defined in 9.4.2.7 (Country element). |
| 8 | Extended Supported Rates and BSS Membership Selectors | The Extended Supported Rates and BSS Membership Selectors element is present when there are more than 8 supported rates and Status Code is SUCCESS. It is optionally present when there are less than 8 supported rates and Status Code is SUCCESS. Otherwise it is not present. The Extended Supported Rates and BSS Membership Selectors element is defined in 9.4.2.11 (Extended Supported Rates and BSS Membership Selectors element). |
| 9 | Supported Channels | The Supported Channels element is defined in 9.4.2.16 (Supported Channels element). It is present if the TDLS Channel Switching subfield is equal to 1 and the (#7190)status code is SUCCESS, and not present otherwise. |
| 10 | RSNE | The RSNE is present if security is required on the TDLS direct link (see 12.7.8.1 (General)) and the (#7190)status code is SUCCESS, and not present otherwise. The RSNE is defined in 9.4.2.23 (RSNE). |
| 11 | Extended Capabilities | The Extended Capabilities element is present if any of the fields in this element are nonzero and the (#7190)status code is SUCCESS, and not present otherwise. The Extended Capabilities element is defined in 9.4.2.25 (Extended Capabilities element). |

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**Table 9-526—Information for TDLS Setup Response Action field *(continued)***

| Order | Information | Notes |
|---|---|---|
| 12 | QoS Capability | The QoS Capability element is present when dot11QosOptionImplemented is true and the (#7190)status code is SUCCESS and not present otherwise. The QoS Capability element is defined in 9.4.2.33 (QoS Capability element). |
| 13 | FTE | The FTE is present if security is required on the TDLS direct link (see 12.7.8.1 (General)) and the (#7190)status code is SUCCESS, and not present otherwise.<br>The FTE is defined in 9.4.2.46 (FTE(#1776)). |
| 14 | Timeout Interval (TPK key lifetime) | The (#1776)TIE, containing the TPK key lifetime, is present if security is required on the TDLS direct link (see 12.7.8.1 (General)) and the (#7190)status code is SUCCESS, and not present otherwise.<br>The (#1776)TIE is defined in 9.4.2.47 (TIE(#1776)). |
| 15 | Supported Operating Classes | The Supported Operating Classes element is present if the TDLS Channel Switching subfield is equal to 1 and the (#7190)status code is SUCCESS and not present otherwise. |
| 16 | HT Capabilities | The HT Capabilities element is present if dot11HighThroughputOptionImplemented is true and the (#7190)status code is SUCCESS and is not present otherwise.<br>The HT Capabilities element is defined in 9.4.2.54 (HT Capabilities element). |
| 17 | 20/40 BSS Coexistence | The 20/40 BSS Coexistence element is optionally present if the (#7190)status code is SUCCESS and not present otherwise.<br>The 20/40 BSS Coexistence element is defined in 9.4.2.58 (20/40 BSS Coexistence element). |
| 18 | Link Identifier | The Link Identifier element is present if the (#7190)status code is SUCCESS and not present otherwise.<br>The Link Identifier is specified in 9.4.2.60 (Link Identifier element). |
| 19 | Multi-band | The Multi-band element is optionally present if dot11MultibandImplemented is true and the (#7190)status code is SUCCESS and not present otherwise. |
| 20 | AID | The AID element containing the AID of the STA sending the frame is present if dot11VHTOptionImplemented, (11ax)dot11HEOptionImplemented, or dot11S1GOptionImplemented is true and the (#7190)status code is SUCCESS and not present otherwise. |
| 21 | VHT Capabilities | The VHT Capabilities element is present in the 5 GHz band if dot11VHTOptionImplemented is true(#8181) and the (#7190)status code is SUCCESS and not present otherwise. |
| 22 | Operating Mode Notification | The Operating Mode Notification element is optionally present if the TDLS Setup Request frame contained an Extended Capabilities element with the Operating Mode Notification field is equal to 1. |
| 23 | S1G Capabilities | S1G Capabilities element is optionally present if dot11S1GOptionImplemented is true. |
| 24 | EL Operation | EL Operation element is present if dot11S1GELOperationActivated is true. |


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**Table 9-526—Information for TDLS Setup Response Action field *(continued)***

| Order | Information | Notes |
|---|---|---|
| 25(11ax) | HE Capabilities | The HE Capabilities element is present if dot11HEOptionImplemented is true and the (#7190)status code is SUCCESS; otherwise, it is not present. The HE Capabilities element is defined in 9.4.2.247 (HE Capabilities element(11ax)). |
| 26(11ax) | TWT | The TWT element is present if dot11TWTOptionActivated is true and the TWT element is present in the TDLS Setup Request frame that elicited this TDLS Setup Response frame. The TWT element is optionally present if dot11TWTOptionActivated is true and the TWT Requester Support field or the TWT Responder Support field is equal to 1 in the HE Capabilities in the TDLS Setup Request frame that elicited this TDLS Setup Response frame. Otherwise, the TWT element is not present.<br><br>The Trigger subfield and the Negotiation Type subfield of the TWT element are set to 0. |
| 27(11ax) | HE 6 GHz Band Capabilities | The HE 6 GHz Band Capabilities element is present if dot11HEOptionImplemented and dot11HE6GOptionImplemented are true; otherwise, it is not present. |

The TDLS Setup Response Action field is encapsulated in a Data frame and transmitted to the TDLS initiator STA through the AP in response to a TDLS Setup Request Action field. See 11.20 (Tunneled direct link setup(#1356)).

### 9.6.12.4 TDLS Setup Confirm Action field format

The Action field of a TDLS Setup Confirm Action field contains the information shown in Table 9-527 (Information for TDLS Setup Confirm Action field).

**Table 9-527—Information for TDLS Setup Confirm Action field**

| Order | Information | Notes |
|---|---|---|
| 1 | Category | The Category field is defined in 9.4.1.11 (Action field). |
| 2 | TDLS Action | The TDLS Action field is defined in 9.6.12.1 (TDLS Action field(#3729)). |
| 3 | Status Code | The Status Code is defined in 9.4.1.9 (Status Code field). |
| 4 | Dialog Token | The dialog token is copied from the corresponding TDLS Setup Response. The dialog token is specified in 9.4.1.12 (Dialog Token field). |
| 5 | RSNE | The RSNE is present if security is required on the TDLS direct link (see 12.7.8.1 (General)) and the (#7190)status code is SUCCESS, and not present otherwise. The RSNE is defined in 9.4.2.23 (RSNE). |
| 6 | EDCA Parameter Set | The EDCA parameter set is present if QoS is supported on the TLDS direct link (see 12.7.8.1 (General)) . The EDCA Parameter Set element is specified in 9.4.2.27 (EDCA Parameter Set element). It is present for Status Code SUCCESS. |

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**Table 9-527—Information for TDLS Setup Confirm Action field *(continued)***

| Order | Information | Notes |
|---|---|---|
| 7 | FTE | The FTE is defined in 9.4.2.46 (FTE(#1776)).<br>The FTE is present if security is required on the TDLS direct link (see 12.7.8.1 (General)) and the (#7190)status code is SUCCESS, and not present otherwise. |
| 8 | Timeout Interval (TPK key lifetime(#7162)) | The (#1776)TIE is defined in 9.4.2.47 (TIE(#1776)).<br>The (#1776)TIE, containing the TPK key lifetime(#7162), is present if security is required on the (#2152)TDLS direct link and the (#7190)status code is SUCCESS, and not present otherwise. |
| 9 | HT Operation | The HT Operation element is present if dot11HighThroughputOptionImplemented is true, the TDLS Setup Response frame contained an HT Capabilities element, the (#7190)status code is SUCCESS.<br>The HT Operation element is defined in 9.4.2.55 (HT Operation element). |
| 10 | Link Identifier | The Link Identifier is specified in 9.4.2.60 (Link Identifier element). It is present if the (#7190)status code is SUCCESS. |
| 11 | VHT Operation | VHT Operation element (optional). The VHT Operation element is present if dot11VHTOptionImplemented is true, the TDLS Setup Response frame contained a VHT Capabilities element, the status code is SUCCESS, and the TDLS direct link is not established in the 2.4 GHz band. The VHT Operation element is defined in 9.4.2.157 (VHT Operation element). |
| 12 | Operating Mode Notification | The Operating Mode Notification element is optionally present if the TDLS Setup Request frame contained an Extended Capabilities element with the Operating Mode Notification field is equal to 1. |
| 13 | S1G Operation | The S1G Operation element is present if dot11S1GOptionImplemented is true and the status code is 0 (Successful). The S1G Operation element is defined in 9.4.2.211 (S1G Operation element). |
| 14(11ax) | HE Operation | The HE Operation element is present when dot11HEOptionImplemented is true, the TDLS Setup Response frame contains an HE Capabilities element, and the (#7190)status code is SUCCESS; otherwise, it is not present.<br>The HE Operation element is defined in 9.4.2.248 (HE Operation element(11ax)). |

The TDLS Setup Confirm Action field is encapsulated in a Data frame and transmitted to the TDLS responder STA through the AP in response to a TDLS Setup Response Action field. See 11.20 (Tunneled direct link setup(#1356)).


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#### 9.6.12.5 TDLS Teardown Action field format

The Action field of a TDLS Teardown Action field contains the information shown in Table 9-528 (Information for TDLS Teardown Action field).

**Table 9-528—Information for TDLS Teardown Action field**

| Order | Information | Notes |
|---|---|---|
| 1 | Category | The Category field is defined in 9.4.1.11 (Action field). |
| 2 | TDLS Action | The TDLS Action field is defined in 9.6.12.1 (TDLS Action field(#3729)). |
| 3 | Reason Code | The Reason Code is defined in 9.4.1.7 (Reason Code field). |
| 4 | FTE | The FTE is present if a TPK handshake was successful for this session.<br>The FTE is defined in 9.4.2.46 (FTE(#1776)). |
| 5 | Link Identifier | The Link Identifier is specified in 9.4.2.60 (Link Identifier element). |

The TDLS Teardown Action field is encapsulated in a Data frame and transmitted to the TDLS peer STA directly or through the AP to tear down a TDLS direct link. See 11.20 (Tunneled direct link setup(#1356)).

#### 9.6.12.6 TDLS Peer Traffic Indication Action field format

The Action field of a TDLS Peer Traffic Indication Action field contains the information shown in Table 9-529 (Information for TDLS Peer Traffic Indication Action field).

**Table 9-529—Information for TDLS Peer Traffic Indication Action field**

| Order | Information | Notes |
|---|---|---|
| 1 | Category | The Category field is defined in 9.4.1.11 (Action field). |
| 2 | TDLS Action | The TDLS Action field is defined in 9.6.12.1 (TDLS Action field(#3729)). |
| 3 | Dialog Token | The dialog token is specified in 9.4.1.12 (Dialog Token field). |
| 4 | Link Identifier | The Link Identifier is specified in 9.4.2.60 (Link Identifier element). |
| 5 | PTI Control | The PTI Control element is optionally present. It is defined in 9.4.2.63 (PTI Control element). |
| 6 | TPU Buffer Status | The TPU Buffer Status element is defined in 9.4.2.64 (TPU Buffer Status element). |

The TDLS Peer Traffic Indication Action field indicates the state of the power save buffer at the STA supporting TPU that is buffering data for a TDLS peer STA in power save mode.

The TPU Buffer Status element indicates the status of the AC buffers at the TPU buffer STA.

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The PTI Control element is optionally included in the TDLS Peer Traffic Indication Action field (see 11.2.3.12 (TDLS peer U-APSD (TPU))) to identify the latest MPDU transmitted to the TPU sleep STA that is the destination of the TDLS Peer Traffic Indication Action field.

The TDLS Peer Traffic Indication Action field is encapsulated in a Data frame and transmitted to the TDLS peer STA through the AP. See 11.2.3.12 (TDLS peer U-APSD (TPU)).

### 9.6.12.7 TDLS Channel Switch Request Action field format

The Action field of the TDLS Channel Switch Request Action field contains the information shown in Table 9-530 (Information for TDLS Channel Switch Request Action field).

**Table 9-530—Information for TDLS Channel Switch Request Action field**

| Order | Information | Notes |
|---|---|---|
| 1 | Category | The Category field is defined in 9.4.1.11 (Action field). |
| 2 | TDLS Action | The TDLS Action field is defined in 9.6.12.1 (TDLS Action field(#3729)). |
| 3 | Target Channel | 1-octet field that specifies the channel number of the target channel. See 9.4.1.33 (Target Channel field(#3249)). |
| 4 | Operating Class | 1-octet field that specifies the operating class for the target channel. The Operating Channel field is defined in 9.4.1.34 (Operating Class field(#3249)). |
| 5 | Secondary Channel Offset | The secondary channel offset is present if a switch to a (#2152)40 MHz TDLS direct link is indicated and is absent otherwise. See 9.4.2.18 (Secondary Channel Offset element). |
| 6 | Link Identifier | The Link Identifier element is specified in 9.4.2.60 (Link Identifier element). |
| 7 | Channel Switch Timing | The Channel Switch Timing element is specified in 9.4.2.62 (Channel Switch Timing element). |
| 8 | Wide Bandwidth Channel Switch | Wide Bandwidth Channel Switch element (optional). The Wide Bandwidth Channel Switch element is included when a switch to an 80 MHz, 160 MHz, or 80+80 MHz (#2152)TDLS direct link is indicated. See 9.4.2.159 (Wide Bandwidth Channel Switch element). |
| 9 | Country | Country element (optional). The Country element is included to change operating classes when a switch to a (#2152)TDLS direct link is indicated. The Country element indicates the same country as the BSS and includes zero Subband Triplet fields. |
| 10 | Transmit Power Envelope | Transmit Power Envelope element (zero or more). Each Transmit Power Envelope element that is present includes a distinct value of the Local Maximum Transmit Power Unit Interpretation subfield. If present, the New Transmit Power Envelope element indicates the maximum transmit powers for the (#2152)TDLS direct link for the indicated bandwidths with an indicated unit interpretation after a switch to a (#2152)TDLS direct link (see 11.20.6.5.1 (General)). |


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The TDLS Channel Switch Request Action field is encapsulated in a Data frame and transmitted directly to the TDLS peer STA to request for the TDLS direct link to be switched to another channel. See 11.20 (Tunneled direct link setup(#1356)).

### 9.6.12.8 TDLS Channel Switch Response Action field format

The Action field of the TDLS Channel Switch Response Action field contains the information shown in Table 9-531 (Information for TDLS Channel Switch Response Action field).

**Table 9-531—Information for TDLS Channel Switch Response Action field**

| Order | Information | Notes |
|---|---|---|
| 1 | Category | The Category field is defined in 9.4.1.11 (Action field). |
| 2 | TDLS Action | The TDLS Action field is defined in 9.6.12.1 (TDLS Action field(#3729)). |
| 3 | Status Code | The Status Code is defined in 9.4.1.9 (Status Code field). |
| 5 | Link Identifier | The Link Identifier element is specified in 9.4.2.60 (Link Identifier element). It is present if the (#7190)status code is SUCCESS. |
| 6 | Channel Switch Timing | The Channel Switch Timing element is specified in 9.4.2.62 (Channel Switch Timing element). |

The TDLS Channel Switch Response Action field is encapsulated in a Data frame and transmitted directly to the TDLS peer STA in response to a TDLS Channel Switch Request Action field. See 11.20 (Tunneled direct link setup(#1356)).

### 9.6.12.9 TDLS Peer PSM Request Action field format

The TDLS Peer PSM Request Action field contains the information shown in Table 9-532 (Information for TDLS Peer PSM Request Action field).

**Table 9-532—Information for TDLS Peer PSM Request Action field**

| Order | Information | Notes |
|---|---|---|
| 1 | Category | The Category field is defined in 9.4.1.11 (Action field). |
| 2 | TDLS Action | The TDLS Action field is defined in 9.6.12.1 (TDLS Action field(#3729)). |
| 3 | Dialog Token | The Dialog Token field contains a value that is unique among TDLS Peer PSM Request Action fields for which a corresponding TDLS Peer PSM Response Action field has not been received. The dialog token is specified in 9.4.1.12 (Dialog Token field). |
| 4 | Link Identifier | The Link Identifier element is specified in 9.4.2.60 (Link Identifier element). |
| 5 | Wakeup Schedule | The Wakeup Schedule element is specified in 9.4.2.61 (Wakeup Schedule element). |

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The TDLS Peer PSM Request Action field is encapsulated in a Data frame and transmitted to the TDLS peer STA, directly or through the AP, to set up or change a periodic wakeup schedule on the TDLS direct link. See 11.2.3.11 (TDLS peer power save mode).

### 9.6.12.10 TDLS Peer PSM Response Action field format

The TDLS Peer PSM Response Action field contains the information shown in Table 9-533 (Information for TDLS Peer PSM Response Action field).

**Table 9-533—Information for TDLS Peer PSM Response Action field**

| Order | Information | Notes |
|---|---|---|
| 1 | Category | The Category field is defined in 9.4.1.11 (Action field). |
| 2 | TDLS Action | The TDLS Action field is defined in 9.6.12.1 (TDLS Action field(#3729)). |
| 3 | Dialog Token | The dialog token is set to the value contained in the corresponding TDLS Peer PSM Request Action field. The dialog token is specified in 9.4.1.12 (Dialog Token field). |
| 4 | Status Code | The Status Code is specified in 9.4.1.9 (Status Code field). |
| 5 | Link Identifier | The Link Identifier element is specified in 9.4.2.60 (Link Identifier element). It is present if the (#7190)status code is SUCCESS. |
| 6 | Wakeup Schedule | The Wakeup Schedule element is present is present if the status code is set to TDLS_REJECTED_ALTERNATIVE_PROVIDED and is not present otherwise. The Wakeup Schedule element is specified in 9.4.2.61 (Wakeup Schedule element). |

The TDLS Peer PSM Response Action field is encapsulated in a Data frame and transmitted to the TDLS peer STA directly in response to a TDLS Peer PSM Request Action field. See 11.2.3.11 (TDLS peer power save mode).

### 9.6.12.11 TDLS Peer Traffic Response Action field format

The Action field of a TDLS Peer Traffic Response Action field contains the information shown in Table 9-534 (Information for TDLS Peer Traffic Response Action field).

**Table 9-534—Information for TDLS Peer Traffic Response Action field**

| Order | Information | Notes |
|---|---|---|
| 1 | Category | The Category field is defined in 9.4.1.11 (Action field). |
| 2 | TDLS Action | The TDLS Action field is defined in 9.6.12.1 (TDLS Action field(#3729)). |
| 3 | Dialog Token | The dialog token is specified in 9.4.1.12 (Dialog Token field). |
| 4 | Link Identifier | The Link Identifier element is specified in 9.4.2.60 (Link Identifier element). |


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The TDLS Peer Traffic Response Action field indicates the receipt of the corresponding TDLS Peer Traffic Indication Action field.

(#417)The Dialog Token field is defined in 9.4.1.12 (Dialog Token field). It is set to the nonzero value of the corresponding TDLS Peer Traffic Indication Action field.

The Link Identifier field is set to identify the TDLS direct link in relation to which the TDLS Peer Traffic Response Action field is transmitted.

The TDLS Peer Traffic Response Action field is encapsulated in a Data frame and transmitted to the TDLS peer STA directly. See 11.2.3.12 (TDLS peer U-APSD (TPU)).

#### 9.6.12.12 TDLS Discovery Request Action field format

The TDLS Discovery Request Action field contains the information shown in Table 9-535 (Information for TDLS Discovery Request Action field).

**Table 9-535—Information for TDLS Discovery Request Action field**

| Order | Information | Notes |
|---|---|---|
| 1 | Category | The Category field is defined in 9.4.1.11 (Action field). |
| 2 | TDLS Action | The TDLS Action field is defined in 9.6.12.1 (TDLS Action field(#3729)). |
| 3 | Dialog Token | The Dialog Token field can be used to match TDLS Discovery Response frames to the corresponding TDLS Discovery Request frame. The dialog token is specified in 9.4.1.12 (Dialog Token field). |
| 4 | Link Identifier | The Link Identifier element is specified in 9.4.2.60 (Link Identifier element). |
| 5 | Multi-band | The Multi-band element is optionally present if dot11MultibandImplemented is true. |

The TDLS Discovery Request Action field is encapsulated in a Data frame and transmitted to a TDLS peer STA through the AP, to request TDLS STAs in the same BSS to respond with a TDLS Discovery Response frame. See 11.20 (Tunneled direct link setup(#1356)).

### 9.6.13 WNM Action frame details(#3729)

#### 9.6.13.1 WNM Action field(#3729)

Several Action frame formats are defined for wireless network management (WNM) purposes. A WNM Action field, in the field immediately after the Category field, differentiates the formats. The WNM Action field values associated with each frame format are defined in Table 9-536 (WNM Action field values).

#### 9.6.13.2 Event Request frame format

The Event Request frame is transmitted to request another STA to report one or more events. The format of the Event Request frame Action field is shown in Figure 9-1265 (Event Request frame Action field format).

The Category field is defined in 9.4.1.11 (Action field).

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**Table 9-536—WNM Action field values**

| WNM Action field value | Description |
|---|---|
| 0 | Event Request |
| 1 | Event Report |
| 2 | Diagnostic Request |
| 3 | Diagnostic Report |
| 4 | Location Configuration Request |
| 5 | Location Configuration Response |
| 6 | BSS Transition Management Query |
| 7 | BSS Transition Management Request |
| 8 | BSS Transition Management Response |
| 9 | FMS Request |
| 10 | FMS Response |
| 11 | (#2210)Colocated Interference Request |
| 12 | (#2210)Colocated Interference Report |
| 13 | TFS Request |
| 14 | TFS Response |
| 15 | TFS Notify |
| 16 | WNM Sleep Mode Request |
| 17 | WNM Sleep Mode Response |
| 18 | TIM Broadcast Request |
| 19 | TIM Broadcast Response |
| 20 | QoS Traffic Capability Update |
| 21 | Channel Usage Request |
| 22 | Channel Usage Response |
| 23 | DMS Request |
| 24 | DMS Response |
| 25 | Timing Measurement Request |
| 26 | WNM Notification Request |
| 27 | WNM Notification Response |
| 28–255 | Reserved |

The WNM Action field is defined in 9.6.13.1 (WNM Action field(#3729)).

(#417)The Dialog Token field is defined in 9.4.1.12 (Dialog Token field). It is a nonzero value chosen by the STA sending the event request to identify the request/report transaction.


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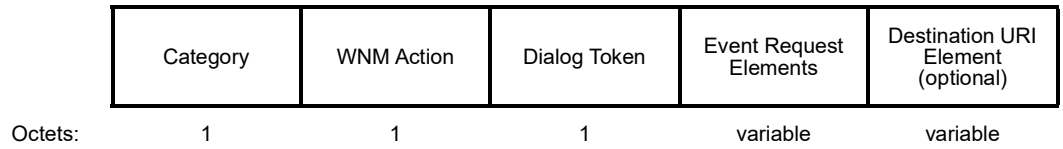


**Figure 9-1265—Event Request frame Action field format**

The Event Request Elements field contains one or more of the Event Request elements described in 9.4.2.65 (Event Request element).

The Destination URI element field contains zero or one Destination URI elements described in 9.4.2.88 (Destination URI element).

### 9.6.13.3 Event Report frame format

The Event Report frame is transmitted in response to an Event Request frame, or autonomously. The format of the Event Report frame Action field is shown in Figure 9-1266 (Event Report frame Action field format).

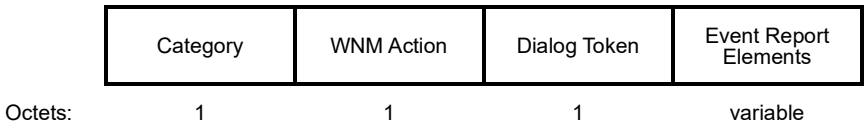


**Figure 9-1266—Event Report frame Action field format**

The Category field is defined in 9.4.1.11 (Action field).

The WNM Action field is defined in 9.6.13.1 (WNM Action field(#3729)).

(#417)The Dialog Token field is defined in 9.4.1.12 (Dialog Token field). It is the nonzero value of the corresponding Event Request frame. If the Event Report frame is being transmitted other than in response to an Event Request frame, then the dialog token is 0.

The Event Report Elements field contains one or more of the Event Report elements described in 9.4.2.66 (Event Report element).

### 9.6.13.4 Diagnostic Request frame format

The Diagnostic Request frame is transmitted requesting the receiving STA to execute a diagnostic test. The format of the Diagnostic Request frame Action field is shown in Figure 9-1267 (Diagnostic Request frame Action field format).

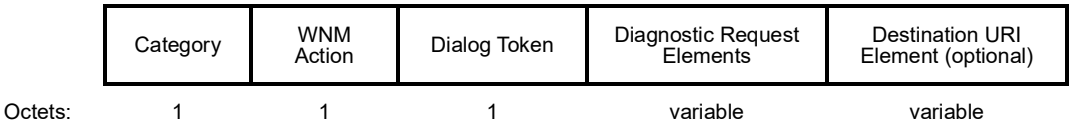


**Figure 9-1267—Diagnostic Request frame Action field format**

The Category field is defined in 9.4.1.11 (Action field).

The WNM Action field is defined in 9.6.13.1 (WNM Action field(#3729)).

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(#417)The Dialog Token field is defined in 9.4.1.12 (Dialog Token field). It is a nonzero value chosen by the STA sending the Diagnostic Request frame to identify the request/report transaction.

The Diagnostic Request Elements field contains one or more of the Diagnostic Request elements described in 9.4.2.67 (Diagnostic Request element). The number and length of the Diagnostic Request elements in a Diagnostic Request frame is limited by the maximum MMPDU size (see 9.3.3.1 (Format of (PV0) Management frames)).

The Destination URI element field contains zero or one Destination URI elements described in 9.4.2.88 (Destination URI element).

### 9.6.13.5 Diagnostic Report frame format

The Diagnostic Report frame is transmitted by a STA in response to a Diagnostic Request frame. The format of the Diagnostic Report frame Action field is shown in Figure 9-1268 (Diagnostic Report frame Action field format).

| | Category | WNM Action | Dialog Token | Diagnostic Report Elements |
|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | variable |

**Figure 9-1268—Diagnostic Report frame Action field format**

The Category field is defined in 9.4.1.11 (Action field).

The WNM Action field is defined in 9.6.13.1 (WNM Action field(#3729)).

(#417)The Dialog Token field is defined in 9.4.1.12 (Dialog Token field). It is the nonzero value in any corresponding Diagnostic Request frame.

The Diagnostic Report Elements field contains one or more of the Diagnostic Report elements described in 9.4.2.68 (Diagnostic Report element). The number and length of the Diagnostic Report elements in a Diagnostic Report frame is limited by the maximum MMPDU size (see 9.3.3.1 (Format of (PV0) Management frames)).

### 9.6.13.6 Location Configuration Request frame format

The Location Configuration Request frame is transmitted to configure another STA to send a Location Track Notification frame on a set of channels periodically for the purposes of determining location of the STA. The format of the Location Configuration Request frame Action field is shown in Figure 9-1269 (Location Configuration Request frame Action field format).

| | Category | WNM Action | Dialog Token | Location Parameters Element |
|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | variable |

**Figure 9-1269—Location Configuration Request frame Action field format**

The Category field is defined in 9.4.1.11 (Action field).

The WNM Action field is defined in 9.6.13.1 (WNM Action field(#3729)).


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(#417)The Dialog Token field is defined in 9.4.1.12 (Dialog Token field). It is a nonzero value that is unique among the Location Configuration Request frames sent to each destination MAC address for which a corresponding Location Configuration Response frame has not been received.

The Location Parameters Element field contains the location parameters subelements, described in 9.4.2.69 (Location Parameters element). Table 9-537 (Location Parameters Element field for Location Configuration Request frame) defines the allowed Location Parameters subelements for a Location Parameters element that is included in the Location Configuration Request frame.

**Table 9-537—Location Parameters Element field for Location Configuration Request frame**

| Allowed subelements | Subelement ID | Notes |
|---|---|---|
| Location Indication Parameters | 1 | The Location Indication Parameters subelement is included in the Location Configuration Request frame. |
| Location Indication Channels | 2 | The Location Indication Channels subelement is included in the Location Configuration Request frame. |
| Location Indication Broadcast Data Rate | 6 | The Location Indication Broadcast Data Rate subelement is included in the Location Configuration Request frame. |
| Location Indication Options | 8 | The Location Indication Options subelement is optionally included in the Location Configuration Request frame. |
| Vendor Specific Information | 221 | Zero or more Vendor Specific subelements are included in the Location Configuration Request frame. |

### 9.6.13.7 Location Configuration Response frame format

The Location Configuration Response frame is transmitted in response to a Location Configuration Request frame. The format of the Location Configuration Response frame Action field is shown in Figure 9-1270 (Location Configuration Response frame Action field format).

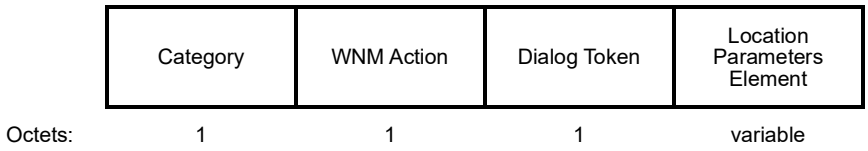


**Figure 9-1270—Location Configuration Response frame Action field format**

The Category field is defined in 9.4.1.11 (Action field).

The WNM Action field is defined in 9.6.13.1 (WNM Action field(#3729)).

(#417)The Dialog Token field is defined in 9.4.1.12 (Dialog Token field). It is the nonzero value received in the Location Configuration Request frame to identify the request/response transaction.

The Location Parameters Element field contains the location parameters subelements, described in 9.4.2.69 (Location Parameters element). Table 9-538 (Location Parameters Element field for Location Configuration Response frame) defines the allowed Location Parameters subelements for a Location Parameters element that is included in the Location Configuration Response frame.

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**Table 9-538—Location Parameters Element field for Location Configuration Response frame**

| Allowed subelements | Subelement ID | Notes |
|---|---|---|
| Location Indication Parameters | 1 | The Location Indication Parameters subelement is optionally included in the Location Configuration Response frame. |
| Location Indication Channels | 2 | The Location Indication Channels subelement is optionally included in the Location Configuration Response frame. |
| Location Indication Broadcast Data Rate | 6 | The Location Indication Broadcast Data Rate subelement is optionally included in the Location Configuration Response frame. |
| Location Indication Options | 8 | The Location Indication Options subelement is optionally included in the Location Configuration Response frame. |
| Location Status | 3 | The Location Status subelement is included in the Location Configuration Response frame. If all configuration of the subelements contained in a Location Configuration Request frame was successful, then a single Location Status subelement is included in the Location Configuration Response frame. For each subelement contained in the Location Configuration Request frame that is not successful a Location Status subelement is included in the Location Configuration Response frame that indicates the subelement ID and the unsuccessful status code for that subelement ID. |
| Vendor Specific Information | 221 | Zero or more Vendor Specific subelements are included in the Location Configuration Response frame. |

### 9.6.13.8 BSS Transition Management Query frame format

The BSS Transition Management Query frame is transmitted to request or provide information on BSS transition candidate APs. The format of the BSS Transition Management Query frame Action field is shown in Figure 9-1271 (BSS Transition Management Query frame Action field format).

| | Category | WNM Action | Dialog Token | BSS Transition Query Reason | BSS Transition Candidate List Entries (Optional) |
|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 1 | variable |

**Figure 9-1271—BSS Transition Management Query frame Action field format**

The Category field is defined in 9.4.1.11 (Action field).

The WNM Action field is defined in 9.6.13.1 (WNM Action field(#3729)).

(#417)The Dialog Token field is defined in 9.4.1.12 (Dialog Token field). It is a nonzero value chosen by the STA sending the BSS Transition Management Query frame to identify the query/request/response transaction.


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The BSS Transition Query Reason field contains the reason code for a BSS transition management query as defined in Table 9-238 (Transition and Transition Query reasons).

The BSS Transition Candidate List Entries field contains zero or more Neighbor Report elements, as described in 9.4.2.35 (Neighbor Report element). The Neighbor Report elements are collected by the STA as part of its scanning procedures and provided to the AP as described in 11.21.7.2 (BSS transition management query). The length of the BSS Transition Candidate List Entries field in a BSS Transition Management Query frame is limited by the maximum MMPDU size (see 9.3.3.1 (Format of (PV0) Management frames)).

### 9.6.13.9 BSS Transition Management Request frame format

The BSS Transition Management Request frame is transmitted by an AP in response to a BSS Transition Management Query frame, or autonomously. The format of the BSS Transition Management Request frame Action field is shown in Figure 9-1272 (BSS Transition Management Request frame Action field format(#554)).

| | Category | WNM Action | Dialog Token | Request Mode | Disassociation Timer |
|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 1 | 2 |

| | Validity Interval | BSS Termination Duration (optional) | Session Information URL (optional) | BSS Transition Candidate List Entries (optional) |
|---|---|---|---|---|
| Octets: | 1 | 0 or 12 | variable | variable |

**Figure 9-1272—BSS Transition Management Request frame Action field format(#554)**

The Category field is defined in 9.4.1.11 (Action field).

The WNM Action field is defined in 9.6.13.1 (WNM Action field(#3729)).

(#417)The Dialog Token field is defined in 9.4.1.12 (Dialog Token field). It is the nonzero value received in the BSS Transition Management Query frame if the BSS Transition Management Request frame is being transmitted in response to a BSS Transition Management Query frame. If the BSS Transition Management Request frame is being transmitted other than in response to a BSS Transition Management Query frame, then the Dialog Token field is a nonzero value chosen by the AP sending the BSS Transition Management Request frame to identify the request/response transaction.

The (#554)Request Mode field is defined in Figure 9-1273 (Request Mode field format(#130)).

| | B0 | B1 | B2 | B3 | B4 | B5 | B7 |
|---|---|---|---|---|---|---|---|
| | Preferred Candidate List Included | Abridged | Disassociation Imminent | BSS Termination Included | ESS Disassociation Imminent | Reserved | |
| Bits: | 1 | 1 | 1 | 1 | 1 | 3 | |

**Figure 9-1273—Request Mode field format(#130)**

— The Preferred Candidate List Included (bit 0) field indicates whether the BSS transition candidate list included in this frame is a preferred candidate list or a list of known BSS transition candidates. The Preferred Candidate List Included bit set to 0 indicates that the receiving STA can ignore the

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BSS Transition Candidate List Entries field (see 11.21.7.3 (BSS transition management request)). The Preferred Candidate List Included bit set to 1 indicates that the sender expects the receiving STA to process this frame.

— The Abridged (bit 1) field indicates to the recipient of the frame the intended treatment of all BSSIDs not listed in the BSS Transition Candidate List Entries field. The AP sets the Abridged bit in the Request Mode field to 1 when a preference value of 0 is assigned to all BSSIDs that do NOT appear in the BSS Transition Candidate List. The AP sets the Abridged bit in the Request Mode field to 0 when the AP has no recommendation for or against any BSSID not present in the BSS Transition Candidate List Entries field.

— The Disassociation Imminent (bit 2) field indicates whether the STA will be disassociated from the current AP. The value 1 in the Disassociation Imminent bit in the Request Mode field indicates that the STA is to be disassociated from the current AP, while the value 0 indicates that disassociation from the AP is not imminent.

— The BSS Termination Included (bit 3) field indicates that the BSS Termination Duration field is included, the BSS is shutting down and the STA will be disassociated. The AP sets the BSS Termination Included bit in the (#554)Request Mode field to 1 to indicate that the BSS is shutting down. The BSS Termination Included bit is 0 if no BSS Termination Duration information is included in the BSS Transition Management Request frame.

— The ESS Disassociation Imminent (bit 4) field indicates that the Session Information URL field is included, and that the STA will be disassociated from the ESS. The value 1 in the ESS Disassociation Imminent bit in the Request Mode field indicates that the STA is to be disassociated from the ESS, while the value 0 indicates that disassociation from the ESS is not imminent. When the ESS Disassociation Imminent bit value is 1, a Session Information URL field is included in the BSS Transition Management Request frame.

The Disassociation Timer indicates the time after which the AP issues a Disassociation frame to this STA. The Disassociation Timer field contains the number of (#2227)target beacon transmission times (TBTTs) until the AP sends a Disassociation frame to this STA. Setting the field to 0 indicates that the AP has not determined when it will send a Disassociation frame to this STA. If the Disassociation Imminent field is 0, the Disassociation Timer field is reserved. The format of the Disassociation Timer field is shown in Figure 9-1274 (Disassociation Timer field format).

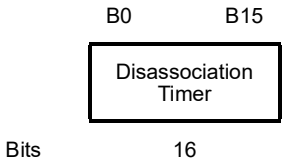


**Figure 9-1274—Disassociation Timer field format**

The Validity Interval field is the number of (#2228)target beacon transmission times (TBTTs) until the BSS transition candidate list is no longer valid. A value of 0 is reserved.

The BSS Termination Duration field contains the BSS Termination Duration subelement (see 9.4.2.35 (Neighbor Report element)) for the current BSS and is present only when the BSS Termination Included field is 1 in the (#554)Request Mode field.

The format of the optional Session Information URL field is shown in Figure 9-1275 (Session Information URL field format). This field is present when the ESS Disassociation Imminent field is 1.

The URL Length field is (#7224)the length in octets of the URL field. The URL Length field is 0 when the URL field is not present.


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| URL Length | URL (optional) |
|---|---|
| 1 | variable |

Octets:

**Figure 9-1275—Session Information URL field format**

The URL field is a variable length field formatted in accordance with IETF RFC 3986.

The BSS Transition Candidate List Entries field contains zero or more Neighbor Report elements described in 9.4.2.35 (Neighbor Report element). If the STA has no information in response to the BSS Transition Management Query frame or in an unsolicited BSS Transition Management Request frame, the Neighbor Report elements are omitted and the Preferred Candidate List Included bit is 0. The length of the BSS Transition Candidate List Entries in a BSS Transition Management Request frame is limited by the maximum MMPDU size (see 9.3.3.1 (Format of (PV0) Management frames)).

### 9.6.13.10 BSS Transition Management Response frame format

The BSS Transition Management Response frame is optionally transmitted by a STA in response to a BSS Transition Management Request frame. The format of the BSS Transition Management Response frame Action field is shown in Figure 9-1276 (BSS Transition Management Response frame Action field format).

| Category | WNM Action | Dialog Token | BTM Status Code | BSS Termination Delay | Target BSSID (Optional) | BSS Transition Candidate List Entries (Optional) |
|---|---|---|---|---|---|---|
| 1 | 1 | 1 | 1 | 1 | 0 or 6 | variable |

Octets:

**Figure 9-1276—BSS Transition Management Response frame Action field format**

The Category field is defined in 9.4.1.11 (Action field).

The WNM Action field is defined in 9.6.13.1 (WNM Action field(#3729)).

(#417)The Dialog Token field is defined in 9.4.1.12 (Dialog Token field). It is the value in the corresponding BSS Transition Management Request frame. The BSS Transition Management Response frame is transmitted in response to a BSS Transition Management Request frame.

The BTM Status Code field contains the status code in response to a BSS Transition Management Request frame as defined in Table 9-539 (BTM status code definitions). If the STA will transition to another BSS, then the status code is 0 (i.e., Accept). If the STA intends to retain the association with the current BSS, the status code is one of the “Reject” status codes.

The BSS Termination Delay field is the number of minutes that the responding STA requests the BSS to delay termination. This field is reserved if the BTM Status Code field is not 5.(#3326)

The Target BSSID field is the BSSID of the BSS that the non-AP STA transitions to. This field is present (#3326)if the BTM Status Code field is 0, and not present otherwise.

The BSS Transition Candidate List Entries field contains zero or more Neighbor Report elements described in 9.4.2.35 (Neighbor Report element). The Neighbor Report elements are collected by the STA as part of its scanning procedures and provided to the AP as described in 11.21.7.4 (BSS transition management response). The length of the BSS Transition Candidate List Entries field in a BSS Transition Management

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**Table 9-539—BTM status code definitions**

| Status code | Status code description |
|---|---|
| 0 | Accept |
| 1 | Reject—Unspecified reject reason. |
| 2 | Reject—Insufficient Beacon or Probe Response frames received from all candidates. |
| 3 | Reject—Insufficient available capacity from all candidates. |
| 4 | Reject—BSS termination undesired. |
| 5 | Reject—BSS termination delay requested. |
| 6 | Reject—STA BSS Transition Candidate List provided. |
| 7 | Reject—No suitable BSS transition candidates. |
| 8 | Reject—Leaving ESS. |
| 9–255 | Reserved |

Response frame is limited by the maximum MMPDU size (see 9.3.3.1 (Format of (PV0) Management frames)).

### 9.6.13.11 FMS Request frame format

The FMS Request frame is sent by a non-AP STA to the AP to request the specified FMS and to propose delivery intervals for a set of group addressed streams. The FMS Request frame is also sent by a non-AP STA to request a modification to an existing FMS(#238). The format of the Action field of the FMS Request frame is shown in Figure 9-1277 (FMS Request frame Action field format).

| | Category | WNM Action | Dialog Token | FMS Request Element |
|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | variable |

**Figure 9-1277—FMS Request frame Action field format**

The Category field is defined in 9.4.1.11 (Action field).

The WNM Action field is defined in 9.6.13.1 (WNM Action field(#3729)).

(#417)The Dialog Token field is defined in 9.4.1.12 (Dialog Token field). It is a nonzero value that is unique among the FMS Request frame sent to each destination MAC address for which a corresponding FMS Report frame has not been received.

The FMS Request Element field indicates the group addressed traffic streams that are requested by the non-AP STA. The FMS Request Element field contains one FMS Request element described in 9.4.2.74 (FMS Request element).


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### 9.6.13.12 FMS Response frame format

The FMS Response frame is sent by an AP in response to an FMS Request frame, or sent by the AP to the STA to instruct the non-AP STA to change the delivery interval or data rate. The format of the Action field of the FMS Response frame is shown in Figure 9-1278 (FMS Response frame Action field format).

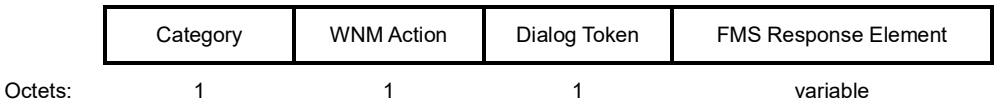


**Figure 9-1278—FMS Response frame Action field format**

The Category field is defined in 9.4.1.11 (Action field).

The WNM Action field is defined in 9.6.13.1 (WNM Action field(#3729)).

(#417)The Dialog Token field is defined in 9.4.1.12 (Dialog Token field). It is the nonzero value received in the FMS Request frame to identify the request/response transaction. If an FMS Response frame is being transmitted other than in response to an FMS Request frame, then the Dialog Token field is 0.

The FMS Response Element indicates the group addressed traffic streams that the AP supports and the corresponding delivery intervals. The FMS Response Element field contains one FMS Response elements, described in 9.4.2.75 (FMS Response element).

### 9.6.13.13 (#2210)Colocated Interference Request frame format

The (#2210)Colocated Interference Request frame is transmitted to request (#2210)colocated interference reports, sent using (#2210)Colocated Interference Report frames. The format of the (#2210)Colocated Interference Request frame Action field is shown in Figure 9-1279 ((#2210)Colocated Interference Request frame Action field format).

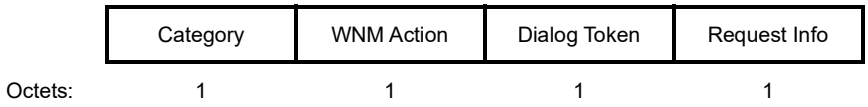


**Figure 9-1279—(#2210)Colocated Interference Request frame Action field format**

The Category field is defined in 9.4.1.11 (Action field).

The WNM Action field is defined in 9.6.13.1 (WNM Action field(#3729)).

(#417)The Dialog Token field is defined in 9.4.1.12 (Dialog Token field). It is any nonzero value to identify the request/response transaction.

The Request Info field is shown in Figure 9-1280 (Request Info field format).

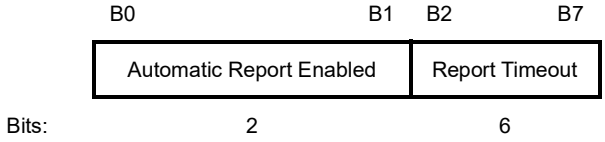


**Figure 9-1280—Request Info field format**

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The Automatic Report Enabled subfield contains an unsigned integer value.

The Automatic Report Enabled subfield set to 0 indicates that the requesting STA cancels the previous requests so that the receiving STA stops sending (#2210)colocated interference reports.

The Automatic Report Enabled subfield set to 1 indicates that the requesting STA requests the receiving STA to send a (#2210)colocated interference report when the STA knows of a change in the (#2210)colocated interference, subject to meeting the Report Timeout requirement.

The Automatic Report Enabled subfield set to 2 indicates that the requesting STA requests the receiving STA to send a (#2210)colocated interference report periodically using the period included in the Report Period field in the (#2210)Colocated Interference Report element; see 9.4.2.83 ((#2210)Colocated Interference Report element).

The Automatic Report Enabled subfield set to 3 indicates that the requesting STA requests the receiving STA to send (#2210)colocated interference reports periodically using the period included in the Report Period field in the (#2210)Colocated Interference Report element; see 9.4.2.83 ((#2210)Colocated Interference Report element), or send a (#2210)colocated interference report when the STA knows of a change in the (#2210)colocated interference, subject to meeting the Report Timeout requirement.

The Report Timeout field contains a value in units of 200 TUs and indicates the minimum duration between two consecutive (#2210)Colocated Interference Report frames from the reporting STA. When the Automatic Report Enabled subfield is 0, the Report Timeout field is reserved.

### 9.6.13.14 (#2210)Colocated Interference Report frame format

The (#2210)Colocated Interference Report frame is transmitted in response to a(#375) (#2210)Colocated Interference Request frame. The format of the (#2210)Colocated Interference Report frame Action field is shown in Figure 9-1281 ((#2210)Colocated Interference Report frame Action field format).

| | Category | WNM Action | Dialog Token | (#2210) Colocated Interference Report Elements |
|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | variable |

**Figure 9-1281—(#2210)Colocated Interference Report frame Action field format**

The Category field is defined in 9.4.1.11 (Action field).

The WNM Action field is defined in 9.6.13.1 (WNM Action field(#3729)).

(#417)The Dialog Token field is defined in 9.4.1.12 (Dialog Token field). It is the nonzero value received in the corresponding (#2210)Colocated Interference Request frame to identify the request/response transaction.

The (#2210)Colocated Interference Report Elements field contains one or more (#2210)Colocated Interference Report elements to indicate the characteristics of the reported (#2210)colocated interferences, as defined in 9.4.2.83 ((#2210)Colocated Interference Report element).


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### 9.6.13.15 TFS Request frame format

The TFS Request frame is sent by a non-AP STA to the AP to request the specified traffic filtering. The format of the TFS Request frame Action field is defined in Figure 9-1282 (TFS Request frame Action field format).

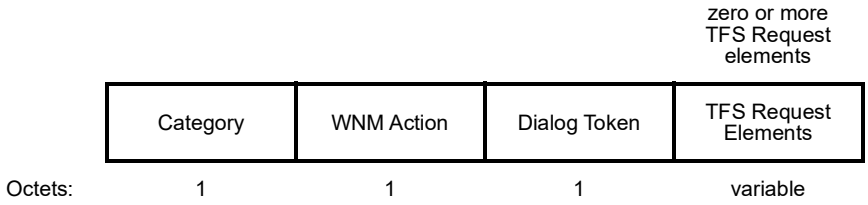


**Figure 9-1282—TFS Request frame Action field format**

The Category field is defined in 9.4.1.11 (Action field).

The WNM Action field is defined in 9.6.13.1 (WNM Action field(#3729)).

(#417)The Dialog Token field is defined in 9.4.1.12 (Dialog Token field). It is a value chosen by the STA sending the TFS Request frame to identify the request/response transaction.

The TFS Request Elements field contains one or more TFS Request elements to specify one or more traffic filter sets that are requested by the non-AP STA, as defined in 9.4.2.78 (TFS Request element), or zero TFS Request elements to cancel all of the existing traffic filter sets (see 11.21.12.2 (TFS non-AP STA operation)).

### 9.6.13.16 TFS Response frame format

The TFS Response frame is sent by an AP in response to a TFS Request frame. The format of the TFS Response frame Action field is defined in Figure 9-1283 (TFS Response frame Action field format).

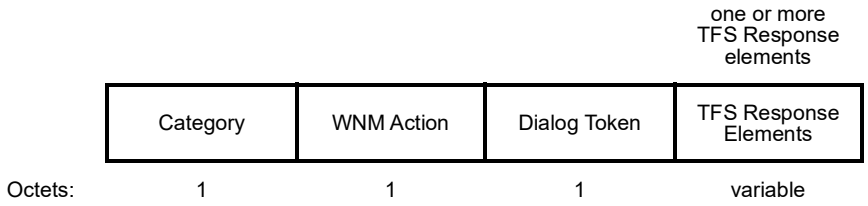


**Figure 9-1283—TFS Response frame Action field format**

The Category field is defined in 9.4.1.11 (Action field).

The WNM Action field is defined in 9.6.13.1 (WNM Action field(#3729)).

(#417)The Dialog Token field is defined in 9.4.1.12 (Dialog Token field). It is the value in the corresponding TFS Request frame.

The TFS Response Elements field contains one or more TFS Response elements to indicate the status of the filtering parameters that the AP is requested to support, as defined in 9.4.2.79 (TFS Response element). The number of TFS Response elements in a TFS Response frame is the same as the number of the TFS Request elements in the TFS Request frame with the same dialog token, where the TFS Response elements appear in

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the same order as the corresponding TFS Request elements in the TFS Request frame with the same dialog token.

### 9.6.13.17 TFS Notify frame format

The TFS Notify frame is sent by an AP to a STA when a frame matching a traffic filter is encountered. The format of the TFS Notify frame Action field is defined in Figure 9-1284 (TFS Notify frame Action field format).

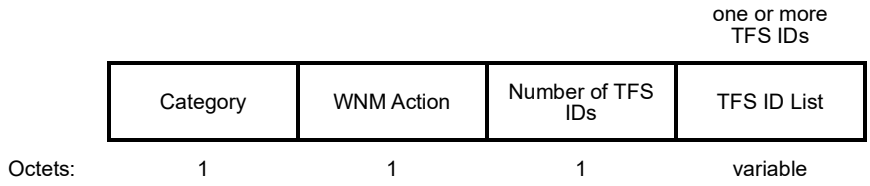


**Figure 9-1284—TFS Notify frame Action field format**

The Category field is defined in 9.4.1.11 (Action field).

The WNM Action field is defined in 9.6.13.1 (WNM Action field(#3729)).

The Number of TFS IDs field indicates the number of 1-octet TFS IDs present in the TFS ID List field.

The TFS ID field indicates the traffic filter set containing the matched TCLAS element.

### 9.6.13.18 TFS Notify Response frame format

A TFS Notify Response frame is transmitted by a non-AP STA to an AP to request the AP to resume generation of the TFS Notify frame when a frame matches any traffic filter set identified by the TFS ID(s) included in the TFS Notify Response frame. The format of the TFS Notify Response frame Action field is shown in Figure 9-1285 (TFS Notify Response frame Action field format).

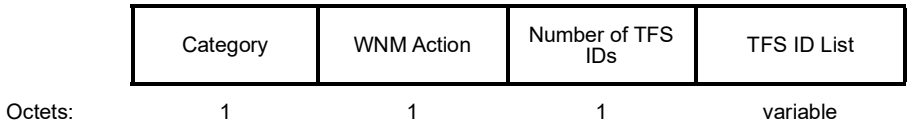


**Figure 9-1285—TFS Notify Response frame Action field format**

The Category field is defined in 9.4.1.11 (Action field).

The WNM Action field is defined in 9.6.13.1 (WNM Action field(#3729)).

The Number of TFS IDs field indicates the number of 1-octet TFS IDs present in the TFS ID List field.

The TFS ID List field indicates the identifiers of the traffic filter sets.

### 9.6.13.19 WNM Sleep Mode Request frame format

The WNM Sleep Mode Request frame is sent by a non-AP STA to the AP to enter the WNM sleep mode. The format of the WNM Sleep Mode Request frame Action field is defined in Figure 9-1286 (WNM Sleep Mode Request frame Action field format(#7025)).


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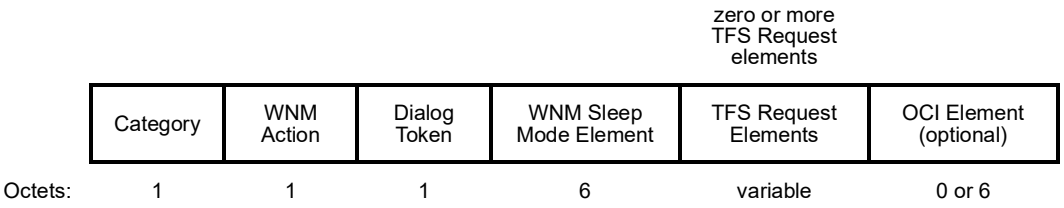


**Figure 9-1286—WNM Sleep Mode Request frame Action field format(#7025)**

The Category field is defined in 9.4.1.11 (Action field).

The WNM Action field is defined in 9.6.13.1 (WNM Action field(#3729)).

(#417)The Dialog Token field is defined in 9.4.1.12 (Dialog Token field). It is a nonzero value chosen by the non-AP STA sending the WNM Sleep Mode Request frame to identify the request/response transaction.

The WNM Sleep Mode Element field contains a WNM Sleep Mode element that is requested by a non-AP STA, as described in 9.4.2.80 (WNM Sleep Mode element).

The TFS Request Elements field contains (#7025)zero or more TFS Request elements to specify the traffic filters that are requested by a non-AP STA, as defined in 9.4.2.78 (TFS Request element).

The OCI Element field is optionally present, and contains an OCI element as defined in 9.4.2.235 (OCI element).

### 9.6.13.20 WNM Sleep Mode Response frame format

The WNM Sleep Mode Response frame is sent by an AP in response to a WNM Sleep Mode Request frame or is sent without solicitation by an AP to a non-AP STA upon the AP's deletion of all traffic filter sets established according to the traffic filtering agreement between the AP and the non-AP STA. The format of the WNM Sleep Mode Response frame Action field is defined in Figure 9-1287 (WNM Sleep Mode Response frame Action field format(#7025)).

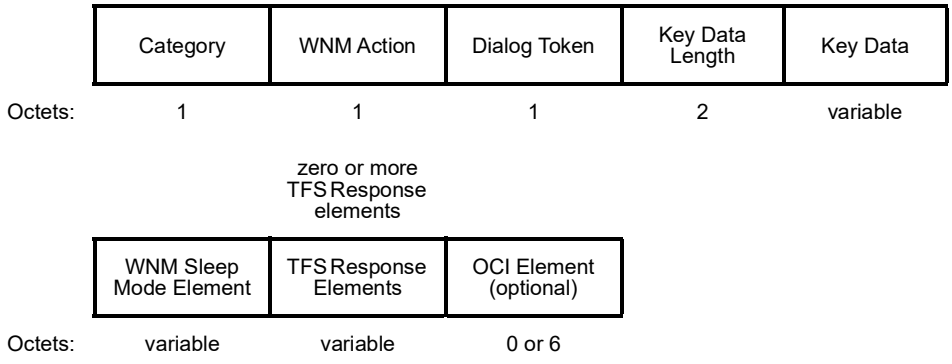


**Figure 9-1287—WNM Sleep Mode Response frame Action field format(#7025)**

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The Category field is defined in 9.4.1.11 (Action field).

The WNM Action field is defined in 9.6.13.1 (WNM Action field(#3729)).

(#417)The Dialog Token field is defined in 9.4.1.12 (Dialog Token field).(Ed1) When the WNM Sleep Mode Response frame is transmitted as a response to a WNM Sleep Mode Request frame, the Dialog Token field is the value in the corresponding WNM Sleep Mode Request frame. When the WNM Sleep Mode Response frame is transmitted as an unsolicited response, the Dialog Token field is set to 0.

The Key Data Length field is the length (#7224)in octets of the Key Data field. If (#1722)management frame protection was not negotiated for the current association(#7049), this field is 0.

The Key Data field contains zero or more subelements that provide the current GTK, IGTK and BIGTK to the STA. The format of these subelements is shown in Figure 9-1288 (WNM Sleep Mode GTK subelement format), Figure 9-1289 (WNM Sleep Mode IGTK subelement format), and Figure 9-1290 (WNM Sleep Mode BIGTK subelement format).(#155) The subelement IDs for these subelements are defined in Table 9-540 (Optional subelement IDs for WNM Sleep Mode parameters). When management frame protection was not negotiated for the current association(#7049), the Key Data field is not present.

**Table 9-540—Optional subelement IDs for WNM Sleep Mode parameters**

| Value | Contents of subelement |
|---|---|
| 0 | GTK |
| 1 | IGTK |
| 2 | BIGTK |
| 3–255 | Reserved |

The GTK subelement contains the GTK as shown in Figure 9-1288 (WNM Sleep Mode GTK subelement format).

| | Subelement ID | Length | Key Info | Key Length | RSC | Key |
|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 2 | 1 | 8 | 5 to 32 |

**Figure 9-1288—WNM Sleep Mode GTK subelement format**

The Length field is defined in 9.4.3 (Subelements).

The Key Info field is defined in Figure 9-440 (GTK subelement's Key Info subfield format).

The Key Length field is the length of the Key field in octets.

The RSC field contains the current (#1406)RSC for the GTK being installed(#1928). If the RSC is less than 8 octets in length, it is stored in the first octets and the remaining octets are set to 0. The least significant octet of the RSC is in the first octet of the RSC field. The RSC for TKIP is the TKIP sequence counter (TSC); for CCMP and GCMP it is the packet number (PN); see Table 12-9 (RSC field(#1406)).

The Key field is the GTK being distributed.


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The IGTK subelement contains the IGTK as shown in Figure 9-1289 (WNM Sleep Mode IGTK subelement format).

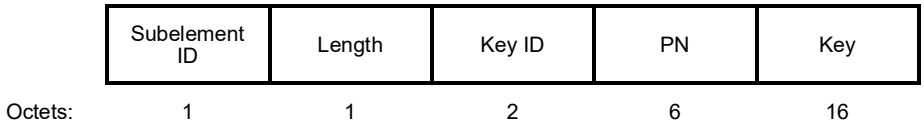


**Figure 9-1289—WNM Sleep Mode IGTK subelement format**

The Length field is defined in 9.4.3 (Subelements).

(#3493)The Key ID field contains the IGTK key ID.

The PN field contains the current RSC (#1406)for the IGTK being installed(#1928). The RSC for an IGTK is the IGTK packet number (IPN).

The Key field is the IGTK being distributed.

The BIGTK subelement contains the BIGTK as shown in Figure 9-1290 (WNM Sleep Mode BIGTK subelement format).

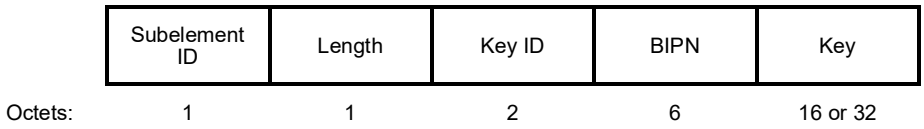


**Figure 9-1290—WNM Sleep Mode BIGTK subelement format**

The Subelement ID field is defined in 9.6.13.20 (WNM Sleep Mode Response frame format).

The Length field is defined in 9.4.3 (Subelements).

(#3493)The Key ID field contains the BIGTK key ID.

The BIPN field contains the current RSC for the BIGTK being installed.(#1928) The RSC for a BIGTK is the BIGTK packet number (BIPN).

The Key field is the BIGTK being distributed.

NOTE 1—There might be multiple GTK, multiple IGTK, and multiple BIGTK subelements if (#1273)GTK rekeying is in progress(#3392) when the non-AP STA wakes up from WNM sleep mode.

NOTE 2—Management frame protection is used to provide confidentiality, replay, and integrity protection for GTK/IGTK/BIGTK update in WNM Sleep Mode Response frames.

The WNM Sleep Mode Element field contains a WNM Sleep Mode element, as described in 9.4.2.80 (WNM Sleep Mode element).

The TFS Response Elements field contains (#7025)zero or more TFS Response elements to specify the traffic filters, as defined in 9.4.2.79 (TFS Response element).

The OCI Element field is optionally present, and contains an OCI element as defined in 9.4.2.235 (OCI element).

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### 9.6.13.21 TIM Broadcast Request frame format

The format of the TIM Broadcast Request frame Action field is shown in Figure 9-1291 (TIM Broadcast Request frame Action fieldformat).

| | Category | WNM Action | Dialog Token | TIM Broadcast Request Element |
|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 3 |

**Figure 9-1291—TIM Broadcast Request frame Action fieldformat**

The Category field is defined in 9.4.1.11 (Action field).

The WNM Action field is defined in 9.6.13.1 (WNM Action field(#3729)).

(#417)The Dialog Token field is defined in 9.4.1.12 (Dialog Token field). It is a nonzero value chosen by the STA sending the TIM Broadcast Request frame to identify the request/response transaction.

The TIM Broadcast Request Element field contains a TIM Broadcast Request Element as specified in 9.4.2.81 (TIM Broadcast Request element).

### 9.6.13.22 TIM Broadcast Response frame format

The format of the TIM Broadcast Response frame Action field is shown in Figure 9-1292 (TIM Broadcast Response frame Action field format).

| | Category | WNM Action | Dialog Token | TIM Broadcast Response Element |
|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 3 or 12 |

**Figure 9-1292—TIM Broadcast Response frame Action field format**

The Category field is defined in 9.4.1.11 (Action field).

The WNM Action field is defined in 9.6.13.1 (WNM Action field(#3729)).

(#417)The Dialog Token field is defined in 9.4.1.12 (Dialog Token field). It is the nonzero value of the corresponding TIM Broadcast Request frame. If the TIM Broadcast Response frame is being transmitted other than in response to a TIM Broadcast Request frame, then the dialog token is 0.

The TIM Broadcast Response Element field contains a TIM Broadcast Response Element as specified in 9.4.2.82 (TIM Broadcast Response element).

### 9.6.13.23 QoS Traffic Capability Update frame format

The QoS Traffic Capability Update frame is sent by a non-AP STA to the AP to update QoS Traffic Capability information. The format of the Action field of the QoS Traffic Capability Update frame is shown in Figure 9-1293 (QoS Traffic Capability Update frame Action field format).


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| | Category | WNM Action | QoS Traffic Capability Flags |
|---|---|---|---|
| Octets: | 1 | 1 | 1 |

**Figure 9-1293—QoS Traffic Capability Update frame Action field format**

The Category field is defined in 9.4.1.11 (Action field).

The WNM Action field is defined in 9.6.13.1 (WNM Action field(#3729)).

The QoS Traffic Capability Flags field is defined in Table 9-541 (Definition of the QoS Traffic Capability Flags field(#403)). The QoS Traffic Capability Flags field comprises 1 octet, with the bits 4–6 serving as (#403)QoS traffic capability flags. Each of the bits 4–6 serves as a flag for one of the three user priorities, UP 4–6. The field is 1 to indicate the expectation of generating traffic belonging to the corresponding user priority (UP). The field is 0 to indicate that such expectation does not exist. The use of the QoS Traffic Capability Update frame is described in 11.21.10 (QoS Traffic capability procedure).

**Table 9-541—Definition of the QoS Traffic Capability Flags field(#403)**

| Bit | Description |
|---|---|
| 0–3 | Reserved |
| 4 | UP 4 Traffic |
| 5 | UP 5 Traffic |
| 6 | UP 6 Traffic |
| 7 | Reserved |

### 9.6.13.24 Channel Usage Request frame format

The Channel Usage Request frame is sent by a non-AP STA to the AP to request the specified (#3311)channel usage information. The format of the Channel Usage Request frame Action field is defined in Figure 9-1294 (Channel Usage Request frame Action field format(#6016)).

| | Category | WNM Action | Dialog Token | Channel Usage Elements | Supported Operating Classes Element | TWT Elements (optional) (#1024) | Timeout Interval Element (optional)( #3155) |
|---|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | variable | variable | variable | 0 or 7 |

| | HT Capabilities Element (optional) | VHT Capabilities Element (optional) | HE Capabilities Element (optional) | HE 6 GHz Band Capabilities Element (optional) |
|---|---|---|---|---|
| Octets: | variable | variable | variable | variable |

**Figure 9-1294—Channel Usage Request frame Action field format(#6016)**

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The Category field is defined in 9.4.1.11 (Action field).

The WNM Action field is defined in 9.6.13.1 (WNM Action field(#3729)).

(#417)The Dialog Token field is defined in 9.4.1.12 (Dialog Token field). It is a nonzero value chosen by the non-AP STA sending the Channel Usage Request frame to identify the request/response transaction.

The Channel Usage Elements field includes one or more Channel Usage elements described in 9.4.2.84 (Channel Usage element) to identify the request channel usage.(#3310) If the Usage Mode field in a Channel Usage element indicates Channel-usage-aidable BSS channel switch request or Capability notification, no other Channel Usage element is included in the Channel Usage Request frame.(#6016)

The Supported Operating Classes Element field contains a Supported Operating Classes element to indicate the supported operating classes for the requested network type, consistent with the Country element advertised by the AP. The Supported Operating Classes is described in 9.4.2.52 (Supported Operating Classes element). This field is not present if the Usage Mode field in the Channel Usage element is Capability notification.(#6016)

(#1024)The TWT Elements field includes zero or more TWT elements each containing only one individual TWT parameter set (see Figure 9-790 (Individual TWT Parameter Set field format(11ax))). (#3146)When included in a Channel Usage Request frame, the TWT Elements field contains only one TWT element, except if used for the establishment of a peer-to-peer TWT agreement with a range of TWT parameter values (see 10.46.9 (TWT parameter ranges(11ax))). In this case, an additional TWT element is present. The subfields of the Individual TWT Parameter Set field are set as described in 11.21.15 (Channel usage procedures).

(#3155)The Timeout Interval Element field is present when the TWT Elements field contains at least one TWT element; if present it contains a TIE. Otherwise, the Timeout Interval Element field is not present in this frame. The subfields of the TIE are set as described in 11.21.15 (Channel usage procedures).

(#6016)The HT Capabilities Element field, if present, contains an HT Capabilities element. It specifies the HT capabilities of the STA in the operating class and channel specified in the Channel Entry field of the Channel Usage element. It is optionally present when the Usage Mode field in the Channel Usage element indicates Channel-usage-aidable BSS channel switch request or Capability notification; not present otherwise.

(#6016)The VHT Capabilities Element field, if present, contains a VHT Capabilities element. It specifies the VHT capabilities of the STA for the operating class and channel specified in the Channel Entry field of the Channel Usage element. It is optionally present when the Usage Mode field in the Channel Usage element indicates Channel-usage-aidable BSS channel switch request or Capability notification; not present otherwise.

(#6016)The HE Capabilities Element field, if present, contains an HE Capabilities element. It specifies the HE capabilities of the STA for the operating class and channel specified in the Channel Entry field of the Channel Usage element. It is optionally present when the Usage Mode field in the Channel Usage element indicates Channel-usage-aidable BSS channel switch request or Capability notification; not present otherwise.

(#6016)The HE 6 GHz Band Capabilities Element field, if present, contains an HE 6 GHz Band Capabilities element. It specifies the HE capabilities of the STA for the operating class and channel in the 6 GHz band that is specified in the Channel Entry field of the Channel Usage element. It is optionally present when the Usage Mode field in the Channel Usage element indicates Channel-usage-aidable BSS channel switch request or Capability notification; not present otherwise.


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### 9.6.13.25 Channel Usage Response frame format

The Channel Usage Response frame is sent by an AP in response to a Channel Usage Request frame, or autonomously. The format of the Channel Usage Response frame Action field is shown in Figure 9-1295 (Channel Usage Response frame Action field format).

| | Category | WNM Action | Dialog Token | Channel Usage Elements | Country String | Power Constraint Element (optional) | EDCA Parameter Set Element (optional) | Transmit Power Envelope Element (optional) (#7001) | TWT Elements (optional) (#1024) | Timeout Interval Element (optional) (#1024) |
|---|---|---|---|---|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | variable | 3 | 0 or 3 | 0 or 20 | variable | variable | 0 or 7 |

**Figure 9-1295—Channel Usage Response frame Action field format**

The Category field is defined in 9.4.1.11 (Action field).

The WNM Action field is defined in 9.6.13.1 (WNM Action field(#3729)).

(#417)The Dialog Token field is defined in 9.4.1.12 (Dialog Token field). It is the nonzero value received in the Channel Usage Request frame if the Channel Usage Response frame is being transmitted in response to a Channel Usage Request frame. The Dialog Token field is 0 if the Channel Usage Response frame is being transmitted other than in response to a Channel Usage Request frame.

The Channel Usage Element field includes zero or more Channel Usage elements described in 9.4.2.84 (Channel Usage element).

The Country String field is the value contained in the dot11CountryString attribute.

The Power Constraint Element field includes zero or one Power Constraint elements described in 9.4.2.12 (Power Constraint element). The use of the Power Constraint element included in the Power Constraint Element field is described in 11.21.15 (Channel usage procedures).

The EDCA Parameter Set Element field includes zero or one EDCA Parameter Set elements described in 9.4.2.27 (EDCA Parameter Set element). The use of the EDCA Parameter Set element included in the EDCA Parameter Set Element field is described in 11.21.15 (Channel usage procedures).

The Transmit Power Envelope Element field includes zero or one Transmit Power Envelope element described in 9.4.2.160 (Transmit Power Envelope element). The use of the Transmit Power Envelope element included in the Transmit Power Envelope Element field is described in 11.21.15 (Channel usage procedures).(#7001)

(#1024)The TWT Elements field includes zero or more TWT elements each containing only one individual TWT parameter set (see Figure 9-790 (Individual TWT Parameter Set field format(11ax))). (#3146)When included in a Channel Usage Request frame, the TWT Elements field contains only one TWT element, except if used for the establishment of a peer-to-peer TWT agreement with a range of TWT parameter values (see 10.46.9 (TWT parameter ranges(11ax))). In this case, an additional TWT element is present. The subfields of the Individual TWT Parameter Set field are set as described in 11.21.15 (Channel usage procedures).

(#1024)The Timeout Interval Element field is present when the TWT Elements field contains at least one TWT element; if present it contains a TIE(#3390). Otherwise, the Timeout Interval Element field is not

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present in this frame. The subfields of the TIE(#3390) are set as described in 11.21.15 (Channel usage procedures).

### 9.6.13.26 DMS Request frame format

The DMS Request frame is sent by a non-AP STA to the AP to define information about a DMS request to the AP. The format of the DMS Request frame Action field is defined in Figure 9-1296 (DMS Request frame Action field format).

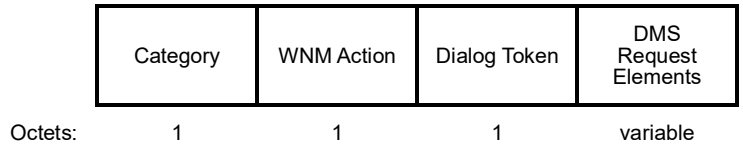


**Figure 9-1296—DMS Request frame Action field format**

The Category field is defined in 9.4.1.11 (Action field).

The WNM Action field is defined in 9.6.13.1 (WNM Action field(#3729)).

(#417)The Dialog Token field is defined in 9.4.1.12 (Dialog Token field). It is a nonzero value chosen by the non-AP STA sending the DMS Request frame to identify the request/response transaction.

The DMS Request Elements field contains one or more DMS Request elements as specified in 9.4.2.86 (DMS Request element).

### 9.6.13.27 DMS Response frame format

The DMS Response frame is sent by an AP or a mesh STA in response to a DMS Request frame, or autonomously to terminate a requested DMS stream, or to advertise the current parameters for one or more GCR streams. The format of the DMS Response frame Action field is shown in Figure 9-1297 (DMS Response frame Action field format).

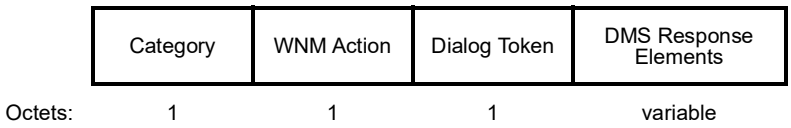


**Figure 9-1297—DMS Response frame Action field format**

The Category field is defined in 9.4.1.11 (Action field).

The WNM Action field is defined in 9.6.13.1 (WNM Action field(#3729)).

(#417)The Dialog Token field is defined in 9.4.1.12 (Dialog Token field). It is the nonzero value received in the DMS Request frame if the DMS Response frame is being transmitted in response to a DMS Request frame. The Dialog Token field is 0 if the DMS Response frame is being transmitted autonomously, and not in response to a DMS Request frame.

The DMS Response Elements field contains one or more DMS Response elements as specified in 9.4.2.87 (DMS Response element).


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### 9.6.13.28 Timing Measurement Request frame format

The format of the Timing Measurement Request frame Action field is shown in Figure 9-1298 (Timing Measurement Request frame Action field format).

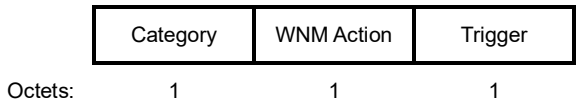


**Figure 9-1298—Timing Measurement Request frame Action field format**

The Category field is defined in 9.4.1.11 (Action field).

The WNM Action field is defined in 9.6.13.1 (WNM Action field(#3729)).

The Trigger field set to the value 1 indicates that the sending STA requests a timing measurement procedure at the receiving STA as defined in 11.21.5 (Timing measurement procedure). The Trigger field set to the value 0 indicates that the sending STA requests that the receiving STA stop sending Timing Measurement frames. Trigger field values 2–255 are reserved.

### 9.6.13.29 WNM Notification Request frame format

The format of the WNM Notification Request frame Action field is shown in Figure 9-1299 (WNM Notification Request frame Action field format).

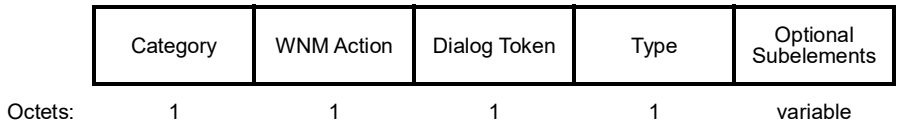


**Figure 9-1299—WNM Notification Request frame Action field format**

The Category field is defined in 9.4.1.11 (Action field).

The WNM Action field is defined in 9.6.13.1 (WNM Action field(#3729)).

(#417)The Dialog Token field is defined in 9.4.1.12 (Dialog Token field). It is set to a nonzero value chosen by the STA sending the WNM notification request to identify the request/response transaction.

The Type field indicates the type of WNM notification, as defined in Table 9-542 (WNM notification type).

(#524)The Optional Subelements field contains zero or more subelements. The subelement format and ordering of subelements are defined in 9.4.3 (Subelements).

The Subelement ID field values for the defined subelements are shown in Table 9-543 (Optional subelement IDs for WNM Notification Request).

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**Table 9-542—WNM notification type**

| Value | Description |
|---|---|
| 0 | Firmware Update Notification |
| 1 | Reserved |
| 2 | Beacon Protection Failure |
| 3–220 | Reserved |
| 221 | Vendor Specific |
| 222–255 | Reserved |

**Table 9-543—Optional subelement IDs for WNM Notification Request**

| Subelement ID | Name | Extensible |
|---|---|---|
| 0 | AP Descriptor | No |
| 1 | Firmware Version—Current | No |
| 2 | Firmware Version—New | No |
| 3–220 | Reserved | |
| 221 | Vendor Specific | Vendor defined |
| 222–255 | Reserved | |

When the Type field is 0, the AP Descriptor, Firmware Version—Current, and Firmware Version—New optional subelements are included in the WNM Notification Request frame. The AP descriptor field format is defined in Figure 9-498 (AP Descriptor subelement format). The Firmware Version—Current subelement contains the current firmware version, in the Firmware Version subelement format defined in Figure 9-504 (Firmware Version subelement format). The Firmware Version—New subelement contains the new firmware version, in the Firmware Version subelement format defined in Figure 9-504 (Firmware Version subelement format).

When the Type field is 2, the AP Descriptor, Firmware Version—Current, and Firmware Version—New optional subelements are not included in the WNM Notification Request frame.

### 9.6.13.30 WNM Notification Response frame format

The format of the WNM Notification Response frame Action field is shown in Figure 9-1300 (WNM Notification Response frame Action field format).

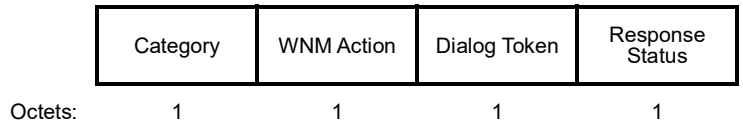


**Figure 9-1300—WNM Notification Response frame Action field format**

The Category field is defined in 9.4.1.11 (Action field).


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The WNM Action field is defined in 9.6.13.1 (WNM Action field(#3729)).

(#417)The Dialog Token field is defined in 9.4.1.12 (Dialog Token field). It is set to the nonzero value of the corresponding WNM Notification Request frame.

The Response Status field indicates the Response Status value, as defined in Table 9-544 (WNM Notification Response Status).

**Table 9-544—WNM Notification Response Status**

| Value | Description |
|---|---|
| 0 | Notification Acknowledged |
| 1–255 | Reserved |

### 9.6.14 Unprotected WNM Action frame details(#3729)

#### 9.6.14.1 Unprotected WNM Action field(#3729)

Unprotected WNM Action frames are not encapsulated using mechanisms defined for robust Management frames. An Unprotected WNM Action field, in the field immediately after the Category field, differentiates the formats. The Unprotected WNM Action field values associated with each frame format is defined in Table 9-545 (Unprotected WNM Action field values).

**Table 9-545—Unprotected WNM Action field values**

| Action field value | Description |
|---|---|
| 0 | TIM |
| 1 | Timing Measurement |
| 2–255 | Reserved |

#### 9.6.14.2 TIM frame format

The format of the TIM frame Action field is shown in Figure 9-1301 (TIM frame Action field format).

| | Category | Unprotected WNM Action | Check Beacon | Timestamp | TIM Element |
|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 8 | 4–256 |

**Figure 9-1301—TIM frame Action field format**

The Category field is defined in 9.4.1.11 (Action field).

The Unprotected WNM Action field is defined in 9.6.14.1 (Unprotected WNM Action field(#3729)).

The Check Beacon field is defined as an unsigned integer initialized to 0, that increments when a critical update to the Beacon frame has occurred; see 11.2.3.14 (TIM Broadcast).

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The Timestamp field is defined in 9.4.1.10 (Timestamp field). The field contains a TSF timestamp when the TIM Broadcast Response frame contained a Status field set to "Accept, timestamp present in TIM frames" or "Overridden, timestamp present in TIM frames." The field is reserved otherwise.

The TIM Element field contains a TIM element as specified in 9.4.2.5 (TIM element). The bit corresponding to buffered group addressed frames is reserved for all BSSIDs.

### 9.6.14.3 Timing Measurement frame format

The Timing Measurement frame is used to support the timing measurement procedure described in 11.21.5 (Timing measurement procedure). The format of the Timing Measurement frame Action field is shown in Figure 9-1302 (Timing Measurement frame Action field format).

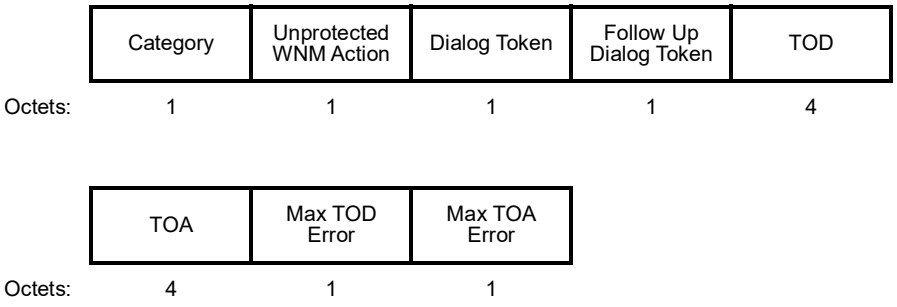


**Figure 9-1302—Timing Measurement frame Action field format**

The Category field is defined in 9.4.1.11 (Action field).

The Unprotected WNM Action field is defined in 9.6.14.1 (Unprotected WNM Action field(#3729)).

(#417)The Dialog Token field is defined in 9.4.1.12 (Dialog Token field). It is a nonzero value chosen by the sending STA to identify the Timing Measurement frame as the first of a pair, with the second or followup(#1665) Timing Measurement frame to be sent later. The Dialog Token field is set to 0 to indicate that the Timing Measurement frame will not be followed by a subsequent followup(#1665) Timing Measurement frame.

The Follow Up Dialog Token field is the nonzero value of the Dialog Token field of the previously transmitted Timing Measurement frame to indicate that it is the follow up Timing Measurement frame and that the TOD, TOA, Max TOD Error and Max TOA Error fields contain the values of the timestamps captured with the first Timing Measurement frame of the pair. The Follow Up Dialog Token field is 0 to indicate that the Timing Measurement frame is not a follow up to a previously transmitted Timing Measurement frame. The value 0 in this field also indicates that the TOD, TOA, Max TOD Error, and Max TOA Error fields are reserved. See 11.21.5 (Timing measurement procedure).

The TOD, TOA, Max TOD Error, and Max TOA Error fields are expressed in units of 10 ns.

The TOD field contains a timestamp that represents the time at which the start of the preamble of the previously transmitted Timing Measurement frame appeared at the transmit antenna connector.

The TOA field contains a timestamp that represents the time at which the start of the preamble of the Ack frame to the previously transmitted Timing Measurement frame arrived at the receive antenna connector.


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NOTE—The values specified in the TOD and TOA fields are described in (#8109)(#8108)MLME-TIMINGMSMT.request MLME-TIMINGMSMT.confirm and MLME-TIMINGMSMT.indication primitives.(#1114-Ed1)

The Max TOD Error field contains an upper bound for the error in the value specified in the TOD field. For instance, a 2 in the Max TOD Error field indicates that the TOD field has a maximum error of ± 20 ns.

The Max TOA Error field contains an upper bound for the error in the value specified in the TOA field. For instance, a 2 in the Max TOA Error field indicates that the TOA field has a maximum error of ± 20 ns.

Setting the Max TOD Error or the Max TOA Error field to 0 indicates that the upper bound on the error in the corresponding TOD or TOA value is unknown. Setting either field to 255 indicates that the upper bound on the error is greater than or equal to 2.55 μs.

### 9.6.15 Self-protected Action frame details

#### 9.6.15.1 Self-protected Action field(#3729)(#125)

The Self-protected Action frame is defined to allow robust STA-STA communications of the Action frames that are not robust (see 9.4.1.11 (Action field)). The protocols that use these Action frames are responsible for deciding whether to protect these frames and supporting protection mechanisms for these frames as needed.

Self-protected Action frames have a different nature than Public Action frames and robust Action frames. Robust Action frames assume the existence of a completely established security association. Self-protected Action frames typically exist to manage the creation and deletion of security associations, regardless of whether they are completely established.

Public Action frames are defined as public for all STAs, including those that are not in the BSS and MBSS. Self-protected Action frames, however, are used for relationship creation and maintenance between two specific STAs. Their public nature is incidental.

(#125)The Mesh Peering Open frame, the Mesh Peering Confirm frame, and the Mesh Peering Close frame are referred to as *mesh peering Management frames*.

A Self-protected Action field, in the field immediately after the Category field, differentiates the formats. The defined Self-protected Action frames are listed in Table 9-546 (Self-protected Action field values).

**Table 9-546—Self-protected Action field values**

| Self-protected Action field value | Description |
|---|---|
| 0 | Reserved |
| 1 | Mesh Peering Open |
| 2 | Mesh Peering Confirm |
| 3 | Mesh Peering Close |
| 4 | Mesh Group Key Inform |
| 5 | Mesh Group Key Acknowledge |
| 6–255 | Reserved |

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NOTE—A Self-protected Action frame is not necessarily protected. When it is, the MIC element and the Authenticated Mesh Peering Exchange element are present after the Action field (see 9.3.3.13 (Action frame format)).(#125)(#1637)

### 9.6.15.2 Mesh Peering Open frame format

#### 9.6.15.2.1 Mesh Peering Open frame self protection

Protection of this frame is provided when authenticated mesh peering exchange (AMPE) is enabled. AMPE provides integrity protection of Mesh Peering Open frames.

When the Mesh Peering Open frame is used by the mesh peering management (MPM) protocol, integrity protection on the frame is not enabled.

#### 9.6.15.2.2 Mesh Peering Open frame details

The Mesh Peering Open frame is used to open a mesh peering using the procedures defined in 14.4.6 (Mesh peering open) and in 14.6.5 (Mesh peering Management frames for AMPE). (#125)It is also used for HCCA TXOP negotiation between APs (see 11.26.3 (HCCA TXOP negotiation)). The format of the Mesh Peering Open frame Action field is shown in Table 9-547 (Mesh Peering Open frame Action field format).

**Table 9-547—Mesh Peering Open frame Action field format**

| Order | Information | Notes |
|---|---|---|
| 1 | Category | The Category field is defined in 9.4.1.11 (Action field).(#125) |
| 2 | Self-protected Action | The Self-protected Action field is defined in 9.6.15.1 (Self-protected Action field(#3729)(#125)).(#125) |
| 3 | Capability | The Capability field is defined in 9.4.1.4 (Capability Information field).(#125) |
| 4 | Supported Rates and BSS Membership Selectors | The Supported Rates and BSS Membership Selectors element is defined in 9.4.2.3 (Supported Rates and BSS Membership Selectors element).(#125) |
| 5 | Extended Supported Rates and BSS Membership Selectors | (#3086)The Extended Supported Rates and BSS Membership Selectors element is present if the number of supported rates and BSS membership selectors(#1470) together exceed eight; it is optional otherwise. |
| 6 | Power Capability | The Power Capability element is present if dot11SpectrumManagementRequired is true. |
| 7 | Supported Channels | The Supported Channels element is present if dot11SpectrumManagementRequired is true and dot11ExtendedChannelSwitchActivated is false.<br>The Supported Channels element is optionally present, otherwise.(#3510) |
| 8 | RSN | The RSNE is present if dot11MeshSecurityActivated, dot11ProtectedQLoadReportActivated, or dot11ProtectedTXOPNegotiationActivated is true; otherwise not present. |
| 9 | Mesh ID | The Mesh ID element is defined in 9.4.2.97 (Mesh ID element) and is present when dot11MeshActivated is true; otherwise it is not present.(#125) |


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**Table 9-547—Mesh Peering Open frame Action field format *(continued)***

| Order | Information | Notes |
|---|---|---|
| 10 | Mesh Configuration | The Mesh Configuration element is defined in 9.4.2.96 (Mesh Configuration element) and is present when dot11MeshActivated is true; otherwise it is not present.(#125) |
| 11 | Mesh Peering Management | The Mesh Peering Management element is (#125)defined in 9.4.2.100 (Mesh Peering Management element). |
| 12 | ERP Information | The ERP element is present if ERP mesh STA detects non-ERP STAs in its vicinity and is optionally present otherwise. |
| 13 | Supported Operating Classes | The Supported Operating Classes element is present if dot11ExtendedChannelSwitchActivated is true, or for a mesh STA if dot11OperatingClassesImplemented is true and the STA is capable of operation in more than one operating class. |
| 14 | HT Capabilities | The HT Capabilities element is present when dot11HighThroughputOptionImplemented is true. |
| 15 | HT Operation | The HT Operation element is included when dot11HighThroughputOptionImplemented is true. |
| 16 | 20/40 BSS Coexistence element | The 20/40 BSS Coexistence element is optionally present when dot112040BSSCoexistenceManagementSupport is true. |
| 17 | Extended Capabilities element | The Extended Capabilities element is present if any of the fields in this element are nonzero. |
| 18 | Interworking | The Interworking element is present if dot11InterworkingServiceActivated is true. |
| 19 | VHT Capabilities | The VHT Capabilities element is present in the 5 GHz band if dot11VHTOptionImplemented is true.(#8181) |
| 20 | VHT Operation | The VHT Operation element is present when dot11VHTOptionImplemented is true. |
| 21 | Operating Mode Notification | The Operating Mode Notification element is optionally present if dot11OperatingModeNotificationImplemented is true. |
| 22(11ax) | HE Capabilities | The HE Capabilities element is present when dot11HEOptionImplemented is true; otherwise, it is not present. |
| 23(11ax) | HE Operation | The HE Operation element is present when dot11HEOptionImplemented is true; otherwise, it is not present. |
| 24(#125) | OCI | The OCI element is present when dot11RSNAOperatingChannelValidationActivated is true; otherwise, it is not present. |

### 9.6.15.3 Mesh Peering Confirm frame format

#### 9.6.15.3.1 Mesh Peering Confirm frame self protection

Protection of this frame is provided when authenticated mesh peering exchange (AMPE) is enabled. AMPE provides integrity protection of Mesh Peering Confirm frames.

When the Mesh Peering Confirm frame is used by the mesh peering management (MPM) protocol, integrity protection on the frame is not enabled.

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#### 9.6.15.3.2 Mesh Peering Confirm frame details

The Mesh Peering Confirm frame is used to confirm a mesh peering using the procedures defined in 14.4.7 (Mesh peering confirm) and 14.6.5 (Mesh peering Management frames for AMPE). (#125)It is also used for HCCA TXOP negotiation between APs (see 11.26.3 (HCCA TXOP negotiation)). The format of the Mesh Peering Confirm frame Action field is shown in Table 9-548 (Mesh Peering Confirm frame Action field format).

**Table 9-548—Mesh Peering Confirm frame Action field format**

| Order | Information | Notes |
|---|---|---|
| 1 | Category | The Category field is defined in 9.4.1.11 (Action field).(#125) |
| 2 | Self-protected Action | The Self-protected Action field is defined in 9.6.15.1 (Self-protected Action field(#3729)(#125)).(#125) |
| 3 | Capability | The Capability field is defined in 9.4.1.4 (Capability Information field).(#125) |
| 4 | AID | The AID field is defined in 9.4.1.8 (AID field).(#125) |
| 5 | Supported Rates and BSS Membership Selectors | The Supported Rates and BSS Membership Selectors element is defined in 9.4.2.3 (Supported Rates and BSS Membership Selectors element).(#125) |
| 6 | Extended Supported Rates and BSS Membership Selectors | (#3086)The Extended Supported Rates and BSS Membership Selectors element is present if the number of supported rates and BSS membership selectors(#1470) together exceed eight; it is optional otherwise. |
| 7 | RSN | The RSNE is present when dot11MeshSecurityActivated, dot11ProtectedQLoadReportActivated, or dot11ProtectedTXOPNegotiationActivated is true; otherwise not present.(#1621) |
| 8 | Mesh ID | The Mesh ID element is defined in 9.4.2.97 (Mesh ID element) and is present when dot11MeshActivated is true; otherwise it is not present.(#125) |
| 9 | Mesh Configuration | The Mesh Configuration element is defined in 9.4.2.96 (Mesh Configuration element) and is present when dot11MeshActivated is true; otherwise it is not present.(#125) |
| 10 | Mesh Peering Management | The Mesh Peering Management element is (#125)defined in 9.4.2.100 (Mesh Peering Management element). |
| 11 | HT Capabilities | The HT Capabilities element is present when dot11HighThroughputOptionImplemented is true. |
| 12 | HT Operation | The HT Operation element is included when dot11HighThroughputOptionImplemented is true. |
| 13 | 20/40 BSS Coexistence element | The 20/40 BSS Coexistence element is optionally present when dot112040BSSCoexistenceManagementSupport is true. |
| 14 | Extended Capabilities element | The Extended Capabilities element is present if any of the fields in this element are nonzero. |
| 15 | VHT Capabilities | The VHT Capabilities element is present in the 5 GHz band if dot11VHTOptionImplemented is true.(#8181) |
| 16 | VHT Operation | The VHT Operation element is present when dot11VHTOptionImplemented is true. |


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**Table 9-548—Mesh Peering Confirm frame Action field format *(continued)***

| Order | Information | Notes |
|---|---|---|
| 17 | Operating Mode Notification | The Operating Mode Notification element is optionally present if dot11OperatingModeNotificationImplemented is true. |
| 18(11ax) | HE Capabilities | The HE Capabilities element is present when dot11HEOptionImplemented is true; otherwise, it is not present. |
| 19(11ax) | HE Operation | The HE Operation element is present when dot11HEOptionImplemented is true; otherwise, it is not present. |
| 20(#125) | OCI | The OCI element is present when dot11RSNAOperatingChannelValidationActivated is true; otherwise, it is not present. |

### 9.6.15.4 Mesh Peering Close frame format

#### 9.6.15.4.1 Mesh Peering Close frame self protection

Protection of this frame is provided when authenticated mesh peering exchange (AMPE) is enabled. AMPE provides integrity protection of Mesh Peering Close frames.

When the Mesh Peering Close frame is used by the mesh peering management (MPM) protocol, integrity protection on the frame is not enabled.

#### 9.6.15.4.2 Mesh Peering Close frame details

The Mesh Peering Close frame is used to close a mesh peering using the procedures defined in 14.4.8 (Mesh peering close) and in 14.6.5 (Mesh peering Management frames for AMPE). (#125)It is also used for HCCA TXOP negotiation between APs (see 11.26.3 (HCCA TXOP negotiation)). The format of the Mesh Peering Close frame Action field is shown in Table 9-549 (Mesh Peering Close frame Action field format).

**Table 9-549—Mesh Peering Close frame Action field format**

| Order | Information | Notes |
|---|---|---|
| 1 | Category | The Category field is defined in 9.4.1.11 (Action field).(#125) |
| 2 | Self-protected Action | The Self-protected Action field is defined in 9.6.15.1 (Self-protected Action field(#3729)(#125)).(#125) |
| 3 | Mesh ID | The Mesh ID element is defined in 9.4.2.97 (Mesh ID element) and is present when dot11MeshActivated is true; otherwise it is not present.(#125) |
| 4 | Mesh Peering Management | The Mesh Peering Management element is (#125)defined in 9.4.2.100 (Mesh Peering Management element). |

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#### 9.6.15.5 Mesh Group Key Inform frame format

##### 9.6.15.5.1 Mesh Group Key Inform frame self protection

The protection of the frames is provided by the mesh group key handshake protocol (see 14.7 (Mesh group key handshake)) that uses Mesh Group Key Inform frames.

##### 9.6.15.5.2 Mesh Group Key Inform frame details

The Mesh Group Key Inform frame is used to update a mesh GTK (MGTK) with a peer (#125)(see 14.7.2 (Protection on mesh group key handshake frames)). The format of the Mesh Group Key Inform frame Action field is shown in Table 9-550 (Mesh Group Key Inform frame Action field format).

**Table 9-550—Mesh Group Key Inform frame Action field format**

| Order | Information | Notes |
|---|---|---|
| 1 | Category | The Category field is defined in 9.4.1.11 (Action field).(#125) |
| 2 | Self-protected Action | The Self-protected Action field is defined in 9.6.15.1 (Self-protected Action field(#3729)(#125)).(#125) |

#### 9.6.15.6 Mesh Group Key Acknowledge frame format

##### 9.6.15.6.1 Mesh Group Key Acknowledge frame self protection

The protection of the frames is provided by the mesh group key handshake protocol (see 14.7 (Mesh group key handshake)) that uses Mesh Group Key Acknowledge frames.

##### 9.6.15.6.2 Mesh Group Key Acknowledge frame details

The Mesh Group Key Acknowledge frame is used to acknowledge receipt and processing of a Mesh Group Key Inform frame (#125)(see 14.7.2 (Protection on mesh group key handshake frames)). The format of the Mesh Group Key Acknowledge frame Action field is shown in Table 9-551 (Mesh Group Key Acknowledge frame Action field format).

**Table 9-551—Mesh Group Key Acknowledge frame Action field format**

| Order | Information | Notes |
|---|---|---|
| 1 | Category | The Category field is defined in 9.4.1.11 (Action field).(#125) |
| 2 | Self-protected Action | The Self-protected Action field is defined in 9.6.15.1 (Self-protected Action field(#3729)(#125)).(#125) |


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### 9.6.16 Mesh Action frame details

#### 9.6.16.1 Mesh Action field(#3729)

Several Mesh Action frame formats are defined for mesh BSS operation. A Mesh Action field, in the field immediately after the Category field, differentiates the formats. The Mesh Action field values associated with each frame format are defined in Table 9-552 (Mesh Action field values).

**Table 9-552—Mesh Action field values**

| Mesh Action field value | Description |
|---|---|
| 0 | Mesh Link Metric Report |
| 1 | HWMP Mesh Path Selection |
| 2 | Gate Announcement |
| 3 | Congestion Control Notification |
| 4 | MCCA Setup Request |
| 5 | MCCA Setup Reply |
| 6 | MCCA Advertisement Request |
| 7 | MCCA Advertisement |
| 8 | MCCA Teardown |
| 9 | TBTT Adjustment Request |
| 10 | TBTT Adjustment Response |
| 11–255 | Reserved |

#### 9.6.16.2 Mesh Link Metric Report frame format

The Mesh Link Metric Report frame is transmitted by a mesh STA to a neighbor peer mesh STA to report metric information on the link between the two mesh STAs. It is also transmitted by a mesh STA to a neighbor peer mesh STA to request metric information on the link between the two mesh STAs from the recipient. This frame is transmitted using an individually addressed frame. The format of the Mesh Link Metric Report frame Action field is shown in Table 9-553 (Mesh Link Metric Report frame Action field format).

**Table 9-553—Mesh Link Metric Report frame Action field format**

| Order | Information | Notes |
|---|---|---|
| 1 | Category | |
| 2 | Mesh Action | |
| 3 | Mesh Link Metric Report element | |

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The Category field is defined in 9.4.1.11 (Action field).

The Mesh Action field is defined in 9.6.16.1 (Mesh Action field(#3729)).

The Mesh Link Metric Report element is set as described in 9.4.2.98 (Mesh Link Metric Report element).

### 9.6.16.3 HWMP Mesh Path Selection frame format

The HWMP Mesh Path Selection frame is transmitted by a mesh STA to establish, update or delete paths to other mesh STAs using the HWMP defined in 14.11 (Hybrid wireless mesh protocol (HWMP)). This frame is transmitted in an individually or group addressed frame depending on the contained elements and as defined in 14.11.7 (Addressing of HWMP Mesh Path Selection frame). The format of the HWMP Mesh Path Selection frame Action field is shown in Table 9-554 (HWMP Mesh Path Selection frame Action field format).

The HWMP Mesh Path Selection frame contains one or more of the elements indicated in Table 9-554 (HWMP Mesh Path Selection frame Action field format). Usage of the HWMP Mesh Path Selection frame is described in 14.11.7 (Addressing of HWMP Mesh Path Selection frame).

**Table 9-554—HWMP Mesh Path Selection frame Action field format**

| Order | Information | Notes |
|---|---|---|
| 1 | Category | |
| 2 | Mesh Action | |
| 3 | PREQ element | A PREQ element is optionally present |
| 4 | PREP element | A PREP element is optionally present |
| 5 | PERR element | A PERR element is optionally present |
| 6 | RANN element | A RANN element is optionally present |

The Category field is defined in 9.4.1.11 (Action field).

The Mesh Action field is defined in 9.6.16.1 (Mesh Action field(#3729)).

The PREQ element is set as described in 9.4.2.111 (PREQ element). It is present in an HWMP Mesh Path Selection frame as described in 14.11.9 (Path request (PREQ) mechanism).

The PREP element is set as described in 9.4.2.112 (PREP element).

The PERR element is set as described in 9.4.2.113 (PERR element).

The RANN element is set as described in 9.4.2.110 (RANN element).

### 9.6.16.4 Gate Announcement frame format

The Gate Announcement frame is transmitted by a mesh gate to announce its presence in the MBSS. This frame is transmitted using group addresses. The format of the Gate Announcement frame Action field is shown in Table 9-555 (Gate Announcement frame Action field format).


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**Table 9-555—Gate Announcement frame Action field format**

| Order | Information | Notes |
|---|---|---|
| 1 | Category | |
| 2 | Mesh Action | |
| 3 | GANN element | |

The Category field is defined in 9.4.1.11 (Action field).

The Mesh Action field is defined in 9.6.16.1 (Mesh Action field(#3729)).

The GANN element is set as described in 9.4.2.109 (GANN element).

### 9.6.16.5 Congestion Control Notification frame format

A mesh STA uses the Congestion Control Notification frame to indicate its congestion status to its neighbor peer mesh STA(s). This frame is transmitted using individual addresses or group addresses. The format of the Congestion Control Notification frame Action field is shown in Table 9-556 (Congestion Control Notification frame Action field format).

**Table 9-556—Congestion Control Notification frame Action field format**

| Order | Information | Notes |
|---|---|---|
| 1 | Category | |
| 2 | Mesh Action | |
| 3 | Congestion Notification element | One or more Congestion Notification elements (9.4.2.99 (Congestion Notification element)) are present. Repeated *N* times (*N* is the number of Congestion Notification elements contained in the frame). |

The Category field is defined in 9.4.1.11 (Action field).

The Mesh Action field is defined in 9.6.16.1 (Mesh Action field(#3729)).

The Congestion Notification element is set as described in 9.4.2.99 (Congestion Notification element).

### 9.6.16.6 MCCA Setup Request frame format

The MCCA Setup Request frame is used to set up an MCCAOP reservation. A mesh STA (with dot11MCCAActivated equal to true) transmits the MCCA Setup Request frame to one or more neighbor mesh STAs (with dot11MCCAActivated equal to true too). This frame is transmitted using individual addresses or group addresses. The format of the MCCA Setup Request frame Action field is shown in Table 9-557 (MCCA Setup Request frame Action field format).

The Category field is defined in 9.4.1.11 (Action field).

The Mesh Action field is defined in 9.6.16.1 (Mesh Action field(#3729)).

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**Table 9-557—MCCA Setup Request frame Action field format**

| Order | Information | Notes |
|---|---|---|
| 1 | Category | |
| 2 | Mesh Action | |
| 3 | MCCAOP Setup Request element | |

The MCCAOP Setup Request element is described in 9.4.2.104 (MCCAOP Setup Request element).

### 9.6.16.7 MCCA Setup Reply frame format

The MCCA Setup Reply frame is used to reply to an MCCA Setup Request frame. It is transmitted by a mesh STA with dot11MCCAActivated equal to true to a neighbor peer mesh STA with dot11MCCAActivated equal to true. This frame is transmitted using individual addresses. The format of the MCCA Setup Reply frame Action field is shown in Table 9-558 (MCCA Setup Reply frame Action field format).

**Table 9-558—MCCA Setup Reply frame Action field format**

| Order | Information | Notes |
|---|---|---|
| 1 | Category | |
| 2 | Mesh Action | |
| 3 | MCCAOP Setup Reply element | |

The Category field is defined in 9.4.1.11 (Action field).

The Mesh Action field is defined in 9.6.16.1 (Mesh Action field(#3729)).

The MCCAOP Setup Reply element is described in 9.4.2.105 (MCCAOP Setup Reply element).

### 9.6.16.8 MCCA Advertisement Request frame format

The MCCA Advertisement Request frame is transmitted by a mesh STA with dot11MCCAActivated equal to true to a neighbor peer mesh STA with dot11MCCAActivated equal to true in order to request MCCAOP advertisements from the neighbor peer mesh STA. This frame is transmitted using individual addresses. The format of the MCCA Advertisement Request frame Action field is shown in Table 9-559 (MCCA Advertisement Request frame Action field format).

The Category field is defined in 9.4.1.11 (Action field).

The Mesh Action field is defined in 9.6.16.1 (Mesh Action field(#3729)).

The MCCAOP Advertisement Overview element is described in 9.4.2.106 (MCCAOP Advertisement Overview element).


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**Table 9-559—MCCA Advertisement Request frame Action field format**

| Order | Information | Notes |
|---|---|---|
| 1 | Category | |
| 2 | Mesh Action | |
| 3 | MCCAOP Advertisement Overview element | An MCCAOP Advertisement Overview element is optionally present. |

### 9.6.16.9 MCCA Advertisement frame format

The MCCA Advertisement frame is transmitted by a mesh STA with dot11MCCAActivated equal to true to one or more neighbor peer mesh STAs with dot11MCCAActivated equal to true. This frame is transmitted using group addresses or individual addresses. The format of the MCCA Advertisement frame Action field is shown in Table 9-560 (MCCA Advertisement frame Action field format).

**Table 9-560—MCCA Advertisement frame Action field format**

| Order | Information | Notes |
|---|---|---|
| 1 | Category | |
| 2 | Mesh Action | |
| 3 | MCCAOP Advertisement Overview element | An MCCAOP Advertisement Overview element is optionally present. |
| 4 | MCCAOP Advertisement elements | If an MCCAOP Advertisement Overview element is present, zero or more MCCAOP Advertisement elements are present. If an MCCAOP Advertisement Overview element is not present, one or more MCCAOP Advertisement elements are present. |

The Category field is defined in 9.4.1.11 (Action field).

The Mesh Action field is defined in 9.6.16.1 (Mesh Action field(#3729)).

The MCCAOP Advertisement Overview element is described in 9.4.2.106 (MCCAOP Advertisement Overview element).

The MCCAOP Advertisement element is described in 9.4.2.107 (MCCAOP Advertisement element).

### 9.6.16.10 MCCA Teardown frame format

The MCCA Teardown frame is transmitted by a mesh STA with dot11MCCAActivated equal to true to one or more neighbor peer mesh STAs with dot11MCCAActivated equal to true. This frame is transmitted using group addresses or individual addresses. The format of the MCCA Teardown frame Action field is shown in Table 9-561 (MCCA Teardown frame Action field format).

The Category field is defined in 9.4.1.11 (Action field).

The Mesh Action field is defined in 9.6.16.1 (Mesh Action field(#3729)).

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**Table 9-561—MCCA Teardown frame Action field format**

| Order | Information | Notes |
|---|---|---|
| 1 | Category | |
| 2 | Mesh Action | |
| 3 | MCCAOP Teardown element | |

The MCCAOP Teardown element is described in 9.4.2.108 (MCCAOP Teardown element).

### 9.6.16.11 TBTT Adjustment Request frame format

The TBTT Adjustment Request frame is used to request a particular neighbor peer mesh STA to adjust its TBTT. This frame is transmitted using individual addresses. The format of the TBTT Adjustment Request frame Action field is shown in Table 9-562 (TBTT Adjustment Request frame Action field format).

**Table 9-562—TBTT Adjustment Request frame Action field format**

| Order | Information | Notes |
|---|---|---|
| 1 | Category | |
| 2 | Mesh Action | |
| 3 | Beacon Timing element | Repeated *N_Info* times (*N_Info* is a number of beacon timing information tuples as described in 14.14.4.2.5 (Transmitter's procedure)). |

The Category field is defined in 9.4.1.11 (Action field).

The Mesh Action field is defined in 9.6.16.1 (Mesh Action field(#3729)).

The Beacon Timing element is set as described in 9.4.2.103 (Beacon Timing element). When not all beacon timing information is included in a Beacon Timing element due to the maximum element size limit, multiple Beacon Timing elements are present. The elements are present in the order of Beacon Timing Element Number field value in the Report Control field of the Beacon Timing element.

### 9.6.16.12 TBTT Adjustment Response frame format

The TBTT Adjustment Response frame is used to respond to a TBTT adjustment request. This frame is transmitted using individual addresses. The format of the TBTT Adjustment Response frame Action field is shown in Table 9-563 (TBTT Adjustment Response frame Action field format).

**Table 9-563—TBTT Adjustment Response frame Action field format**

| Order | Information | Notes |
|---|---|---|
| 1 | Category | |
| 2 | Mesh Action | |


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**Table 9-563—TBTT Adjustment Response frame Action field format *(continued)***

| Order | Information | Notes |
|---|---|---|
| 3 | Status Code | |
| 4 | Beacon Timing element (optional) | Repeated *N_Info* times (*N_Info* is a number of beacon timing information tuples as described in 14.14.4.2.5 (Transmitter's procedure)). |

The Category field is defined in 9.4.1.11 (Action field).

The Mesh Action field is defined in 9.6.16.1 (Mesh Action field(#3729)).

The Status Code field is set as described in 14.14.4.4.2 (Requested TBTT adjustment).

The Beacon Timing element is set as defined in 9.4.2.103 (Beacon Timing element). It is present only if the (#7190)status code is set to CANNOT_FIND_ALTERNATIVE_TBTT (i.e., when the request is not successful due to the neighbor constraint). When not all beacon timing information is included in a Beacon Timing element due to the maximum element size limit, multiple Beacon Timing elements are present. The elements are present in the order of Beacon Timing Element Number field value in the Report Control field of the Beacon Timing element.

### 9.6.17 Multihop Action frame details

#### 9.6.17.1 Multihop Action field(#3729)

Several Multihop Action frame formats are defined for mesh BSS operation. A Multihop Action field, in the field immediately after the Category field, differentiates the formats. The Multihop Action field values associated with each frame format are defined in Table 9-564 (Multihop Action field values). The Mesh Control field is present immediately after the Multihop Action field in all Multihop Action frames.

**Table 9-564—Multihop Action field values**

| Multihop Action field value | Description |
|---|---|
| 0 | Proxy Update |
| 1 | Proxy Update Confirmation |
| 2–255 | Reserved |

#### 9.6.17.2 Proxy Update frame format

The Proxy Update frame is used to inform the recipient about new, updated, or deleted proxy information. This frame is transmitted using individual addresses. The format of the Proxy Update frame Action field is shown in Table 9-565 (Proxy Update frame Action field format).

The Category field is defined in 9.4.1.11 (Action field).

The Multihop Action field is defined in 9.6.17.1 (Multihop Action field(#3729)).

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**Table 9-565—Proxy Update frame Action field format**

| Order | Information | Notes |
|---|---|---|
| 1 | Category | |
| 2 | Multihop Action | |
| 3 | Mesh Control | |
| 4 | PXU element | Repeated *N* times (*N* is the number of PXU elements contained in the frame). |

The Mesh Control field is set as defined in 9.2.4.8.3 (Mesh Control field).

The PXU element is described in 9.4.2.114 (PXU element). The Proxy Update frame allows the inclusion of multiple PXU elements.

### 9.6.17.3 Proxy Update Confirmation frame format

The Proxy Update Confirmation frame is transmitted by a mesh STA in response to a Proxy Update frame. This frame is used to inform that the corresponding PXU element has been properly received and is transmitted using individual addresses. The format of the Proxy Update Confirmation frame Action field is shown in Table 9-566 (Proxy Update Confirmation frame Action field format).

**Table 9-566—Proxy Update Confirmation frame Action field format**

| Order | Information | Notes |
|---|---|---|
| 1 | Category | |
| 2 | Multihop Action | |
| 3 | Mesh Control | |
| 4 | PXUC element | Repeated *N* times (*N* is the number of PXUC elements contained in the frame). |

The Category field is defined in 9.4.1.11 (Action field).

The Multihop Action field is defined in 9.6.17.1 (Multihop Action field(#3729)).

The Mesh Control field is set as defined in 9.2.4.8.3 (Mesh Control field).

The PXUC element is described in 9.4.2.115 (PXUC element). The Proxy Update Confirmation frame allows the inclusion of one or more PXUC elements.

## 9.6.18 Robust AV Streaming Action frame details

### 9.6.18.1 Robust AV Streaming Action field(#3729)

Several Action frame formats are defined to support robust AV streaming. The Robust Action field values associated with each frame format within the robust AV streaming category are defined in Table 9-567


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(Robust AV streaming Robust Action field values). The frame formats are defined in 9.6.18.2 (SCS Request frame format) to 9.6.18.7 (MSCS Response frame format).

**Table 9-567—Robust AV streaming Robust Action field values**

| Robust Action field value | Meaning |
|---|---|
| 0 | SCS Request |
| 1 | SCS Response |
| 2 | Group Membership Request |
| 3 | Group Membership Response |
| 4 | MSCS Request |
| 5 | MSCS Response |
| 6–255 | Reserved |

### 9.6.18.2 SCS Request frame format

SCS Request frames are used to request the creation, modification, or deletion of a stream classification using the procedures defined in 11.25.2 (SCS procedures).

The Action field of the SCS Request frame contains the information shown in Figure 9-1303 (SCS Request frame Action field format).

| | Category | Robust Action | Dialog Token | SCS Descriptor List |
|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | variable |

**Figure 9-1303—SCS Request frame Action field format**

The Category field is defined in 9.4.1.11 (Action field).

The Robust Action field is defined in 9.6.18.1 (Robust AV Streaming Action field(#3729)).

The Dialog Token field is defined in 9.4.1.12 (Dialog Token field) and set by the requesting STA to a nonzero value that is used for matching action responses with action requests. See 10.28.5 (Operation of the Dialog Token field).

The SCS Descriptor List field contains one or more SCS Descriptor elements, as defined in 9.4.2.120 (SCS Descriptor element).

### 9.6.18.3 SCS Response frame format

The SCS Response frame is sent in response to an SCS Request frame using the procedures defined in 11.25.2 (SCS procedures). The Action field of an SCS Response frame contains the information shown in Figure 9-1304 (SCS Response frame Action field format).

The Category field is defined in 9.4.1.11 (Action field).

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| | Category | Robust Action | Dialog Token | Count(#49) | SCS Status List |
|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 1 | variable |

**Figure 9-1304—SCS Response frame Action field format**

The Robust Action field is defined in 9.6.18.1 (Robust AV Streaming Action field(#3729)).

(#417)The Dialog Token field is defined in 9.4.1.12 (Dialog Token field). It is set to the nonzero value of the corresponding SCS Request frame. If the SCS Report frame is being transmitted for a reason other than in response to an SCS Request frame, then the Dialog Token field is set to 0.

(#49)The Count field is set to the value of the number of SCS Status duples in the SCS Status List field.

The SCS Status List field contains one or more SCS Status duples. The format of the SCS Status duple is defined in Figure 9-1305 (SCS Status duple format).

| | SCSID | Status |
|---|---|---|
| Octets: | 1 | 2 |

**Figure 9-1305—SCS Status duple format**

The SCSID field identifies an SCS stream.(#586)

The Status field indicates the status of the SCS stream(#586), as (#3326)defined in Table 9-80 (Status codes).

### 9.6.18.4 Group Membership Request frame format

The Group Membership Request frame is sent to a STA to request the contents of its dot11GroupAddressesTable. The Action field of a Group Membership Request frame contains the information shown in Figure 9-1306 (Group Membership Request frame Action field format).

| | Category | Robust Action | Dialog Token |
|---|---|---|---|
| Octets: | 1 | 1 | 1 |

**Figure 9-1306—Group Membership Request frame Action field format**

The Category field is defined in 9.4.1.11 (Action field).

The Robust Action field is defined in 9.6.18.1 (Robust AV Streaming Action field(#3729)).

The Dialog Token field is defined in 9.4.1.12 (Dialog Token field) and set by the requesting STA to a nonzero value that is used for matching action responses with action requests. See 10.28.5 (Operation of the Dialog Token field).

Usage of the Group Membership Request frame is described in 11.21.16.3.2 (GCR group membership procedures).


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### 9.6.18.5 Group Membership Response frame format

The Group Membership Response frame is sent in response to a Group Membership Request frame or upon a change in the dot11GroupAddressesTable object, using the procedures defined in 11.21.16.3.2 (GCR group membership procedures). The Action field of a Group Membership Response frame contains the information shown in Figure 9-1307 (Group Membership Response frame Action field format(#261)).

| | Category | Robust Action | Dialog Token | Address Count | Group Address List |
|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 1 | *n* × 6 |

**Figure 9-1307—Group Membership Response frame Action field format(#261)**

The Category field is defined in 9.4.1.11 (Action field).

The Robust Action field is defined in 9.6.18.1 (Robust AV Streaming Action field(#3729)).

(#417)The Dialog Token field is defined in 9.4.1.12 (Dialog Token field). It is set to the nonzero value of the corresponding Group Membership Request frame. If the Group Membership Report frame is being transmitted for a reason other than in response to a Group Membership Request frame, the Dialog Token field is set to 0.

The Address Count field specifies the number of MAC addresses that are in the Group Address List field.

The Group Address List field contains zero or more MAC addresses to indicate the set of (#1653)group addresses for which the STA receives frames.(#261)

### 9.6.18.6 MSCS Request frame format

MSCS Request frames are used to request the creation, modification, or deletion of mirrored stream classification using the procedures defined in 11.25.3 (MSCS procedures).

The Action field of the MSCS Request frame contains the information shown in Figure 9-1308 (MSCS Request frame Action field format).

| | Category | Robust Action | Dialog Token | MSCS Descriptor element |
|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | variable |

**Figure 9-1308—MSCS Request frame Action field format**

The Category field is defined in 9.4.1.11 (Action field).

The Robust Action field is defined in 9.6.18.1 (Robust AV Streaming Action field(#3729)).

The Dialog Token field is defined in 9.4.1.12 (Dialog Token field) and set by the requesting STA to a nonzero value that is used for matching action responses with action requests. See 10.28.5 (Operation of the Dialog Token field).

The MSCS Descriptor element is defined in 9.4.2.242 (MSCS Descriptor element).

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### 9.6.18.7 MSCS Response frame format

The MSCS Response frame is sent in response to an MSCS Request frame using the procedures defined in 11.25.3 (MSCS procedures). The Action field of an MSCS Response frame contains the information shown in Figure 9-1309 (MSCS Response frame Action field format).

| | Category | Robust Action | Dialog Token | Status | MSCS Descriptor element (optional) |
|---|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 2 | variable |

**Figure 9-1309—MSCS Response frame Action field format**

The Category field is defined in 9.4.1.11 (Action field).

The Robust Action field is defined in 9.6.18.1 (Robust AV Streaming Action field(#3729))

(#417)The Dialog Token field is defined in 9.4.1.12 (Dialog Token field). It is set to the nonzero value of the corresponding MSCS Request frame. If the MSCS Report frame is being transmitted for a reason other than in response to an MSCS Request frame, then the Dialog Token field is set to 0.

The Status field indicates the status of the request, as (#3326)defined in Table 9-80 (Status codes).

The MSCS Descriptor element is defined in 9.4.2.242 (MSCS Descriptor element). When the Status field is SUCCESS the element is not present; otherwise it is optionally present as described in 11.25.3 (MSCS procedures).

## 9.6.19 DMG Action frame details

### 9.6.19.1 DMG Action field

Several Action frame formats are defined to support DMG features. A DMG Action field, in the octet immediately after the Category field, differentiates the DMG Action frame formats. The DMG Action field values associated with each frame format within the DMG category are defined in Table 9-568 (DMG Action field values).

**Table 9-568—DMG Action field values**

| DMG Action field value | Meaning |
|---|---|
| 0 | Power Save Configuration Request |
| 1 | Power Save Configuration Response |
| 2 | Information Request |
| 3 | Information Response |
| 4 | Handover Request |
| 5 | Handover Response |
| 6 | Reserved |
| 7 | Reserved |
| 8 | Relay Search Request |


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**Table 9-568—DMG Action field values *(continued)***

| DMG Action field value | Meaning |
|---|---|
| 9 | Relay Search Response |
| 10 | Multi-Relay Channel Measurement Request |
| 11 | Multi-Relay Channel Measurement Report |
| 12 | RLS Request |
| 13 | RLS Response |
| 14 | RLS Announcement |
| 15 | RLS Teardown |
| 16 | Relay Ack Request |
| 17 | Relay Ack Response |
| 18 | TPA Request |
| 19 | TPA Response |
| 20 | TPA Report |
| 21 | ROC Request |
| 22 | ROC Response |
| 23(11ay) | Protected Announce |

### 9.6.19.2 Power Save Configuration Request frame format

The format of the Power Save Configuration Request (PSC-REQ) frame Action field is shown in Table 9-569 (Power Save Configuration Request frame Action field format).

**Table 9-569—Power Save Configuration Request frame Action field format**

| Order | Information |
|---|---|
| 1 | Category |
| 2 | DMG Action |
| 3 | Dialog Token |
| 4 | DMG Power Management |
| 5 | DMG Wakeup Schedule element (optional) |
| 6(11ay) | QoS Triggered Unscheduled element (optional) |

The Category field is defined in 9.4.1.11 (Action field).

The DMG Action field is defined in 9.6.19.1 (DMG Action field).

(#417)The Dialog Token field is defined in 9.4.1.12 (Dialog Token field). It is set to a value chosen by the STA sending the frame to uniquely identify the transaction.

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The length of the DMG Power Management (DPM) field is 1 octet. Setting the DPM field to 0 indicates a transition from power save mode to active mode. Setting the DPM field to 1 indicates a transition from active mode to power save mode. All other values are reserved.

The DMG Wakeup Schedule element is defined in 9.4.2.129 (DMG Wakeup Schedule element) (11.2.7.2 (Non-AP and non-PCP STA power management mode)).

(11ay)The QoS Triggered Unscheduled element is defined in 9.4.2.277 (QoS-TU element(#1776)(11ay)).

### 9.6.19.3 Power Save Configuration Response frame format

The format of the Power Save Configuration Response (PSC-RSP) frame Action field is shown in Table 9-570 (Power Save Configuration Response frame Action field format).

**Table 9-570—Power Save Configuration Response frame Action field format**

| Order | Information |
|---|---|
| 1 | Category |
| 2 | DMG Action |
| 3 | Dialog Token |
| 4 | Status Code |
| 5 | DMG Wakeup Schedule element (optional) |
| 6 | Antenna Sector ID Pattern element (optional) |
| 7(11ay) | QoS Triggered Unscheduled element (optional) |

The Category field is defined in 9.4.1.11 (Action field).

The DMG Action field is defined in 9.6.19.1 (DMG Action field).

(#417)The Dialog Token field is defined in 9.4.1.12 (Dialog Token field). It is set to the value of the Dialog Token field in the corresponding PSC-REQ frame.

The Status Code field is defined in 9.4.1.9 (Status Code field).

The DMG Wakeup Schedule element is defined in 9.4.2.129 (DMG Wakeup Schedule element).

The Antenna Sector ID Pattern element is defined in 9.4.2.155 (Antenna Sector ID Pattern element).

(11ay)The QoS Triggered Unscheduled element is defined in 9.4.2.277 (QoS-TU element(#1776)(11ay)).

### 9.6.19.4 Information Request frame format

The format of an Information Request frame Action field is shown in Table 9-571 (Information Request frame Action field format).

The Category field is defined in 9.4.1.11 (Action field).

The DMG Action field is defined in 9.6.19.1 (DMG Action field).


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**Table 9-571—Information Request frame Action field format**

| Order | Information |
|---|---|
| 1 | Category |
| 2 | DMG Action |
| 3 | Subject Address |
| 4 | Request element |
| 5 | Zero or more DMG Capabilities elements |
| 6 | Zero or more provided elements |
| 7 | Zero or more Extended Request elements |
| 8 | Zero or more Vendor Specific Request elements |

The Subject Address field contains the MAC address of the STA whose information is being requested. If this frame is sent to the PCP and the Subject Address field is the broadcast address, then the STA is requesting information regarding all associated STAs.

The Request element field is described in 9.4.2.8 (Request element).

The DMG Capabilities element carries information about the transmitter STA and other STAs known to the transmitter STA. The format of this element is defined in 9.4.2.126 (DMG Capabilities element).

Each provided element is an element as specified in 9.4.2 (Elements), that the transmitter of this frame is providing to the destination of the frame.

The Extended Request element is described in 9.4.2.9 (Extended Request element).

The Vendor Specific Request element is described in 9.4.2.217 (Vendor Specific Request element).

### 9.6.19.5 Information Response frame format

The format of an Information Response frame Action field is shown in Table 9-572 (Information Response frame Action field format).

This frame is individually addressed to a STA in response to an Information Request frame or it is sent unsolicited and individually addressed to a STA or broadcast to all STAs in the PBSS/infrastructure BSS. If this frame is sent as a broadcast, then this frame is an Action No Ack frame.

**Table 9-572—Information Response frame Action field format**

| Order | Information |
|---|---|
| 1 | Category |
| 2 | DMG Action |
| 3 | Subject Address |
| 4 | One or more DMG Capabilities elements |

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**Table 9-572—Information Response frame Action field format**

| | |
|---|---|
| 5 | Zero or more requested elements |
| 6 | Zero or more provided elements |

The Category field is defined in 9.4.1.11 (Action field).

The DMG Action field is defined in 9.6.19.1 (DMG Action field).

The Subject Address field contains the MAC address of the STA whose information is being provided. If this field is set to the broadcast address, then the STA is providing information regarding all associated STAs.

The DMG Capabilities element carries information about the transmitter STA and other STAs known to the transmitter STA. The DMG Capabilities element is described in 9.4.2.126 (DMG Capabilities element).

The requested elements are those returned in response to an Information Request frame, as described in 11.28.1 (Information Request and Response).

The provided elements are elements, as described in 9.4.2 (Elements), that the transmitter of this frame provides to the destination of the frame, either in addition to the requested elements, or in an unsolicited Information Response frame.

### 9.6.19.6 Handover Request frame format

The format of the Handover Request frame Action field is shown in Table 9-573 (Handover Request frame Action field format).

**Table 9-573—Handover Request frame Action field format**

| Order | Information |
|---|---|
| 1 | Category |
| 2 | DMG Action |
| 3 | Handover Reason |
| 4 | Handover Remaining BI |

The Category field is defined in 9.4.1.11 (Action field).

The DMG Action field is defined in 9.6.19.1 (DMG Action field).

The Handover Reason field is 1 octet in length and indicates the reason that the current PCP intends to do the PCP handover. The Handover Reason field is set to 0 to indicate the PCP is leaving the PBSS, it is set to 1 to indicate low power in the PCP, is set to 2 to indicate that a more qualified PCP handover capable STA is available, and is set to 3 to indicate that the PCP handover capable STA wishes to become a PCP. The other values are reserved.


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The Handover Remaining BI field is 1 octet in length and indicates the number of beacon intervals, excluding the beacon interval in which this frame is transmitted, remaining until the handover takes effect.

### 9.6.19.7 Handover Response frame format

The format of the Handover Response frame Action field is shown in Table 9-574 (Handover Response frame Action field format).

**Table 9-574—Handover Response frame Action field format**

| Order | Information |
|---|---|
| 1 | Category |
| 2 | DMG Action |
| 3 | Handover Result |
| 4 | Handover Reject Reason |

The Category field is defined in 9.4.1.11 (Action field).

The DMG Action field is defined in 9.6.19.1 (DMG Action field).

The Handover Result field is 1 octet in length and indicates whether the STA accepted the handover request. Setting this field to 0 indicates that the STA accepts the handover request. Setting this field to 1 indicates that the STA does not accept the handover request.

If the Handover Result field is set to 0, the Handover Reject Reason field is reserved and set to 0. If the Handover Result field is set to 1, the Handover Reject Reason field indicates the reason the STA rejected the handover request and can be one of the following: 0 for low power, 1 for handover in progress with another STA, 2 for invalid value for Handover Remaining BI field, and 3 for unspecified reason. The length of Handover Reject Reason field is 1 octet.

### 9.6.19.8 Relay Search Request frame format

The Relay Search Request frame is transmitted by a non-AP and non-PCP STA to the AP or PCP to request a list of RDSs in the BSS. The format of the Relay Search Request frame Action field is shown in Table 9-575 (Relay Search Request frame Action field format).

**Table 9-575—Relay Search Request frame Action field format**

| Order | Information |
|---|---|
| 1 | Category |
| 2 | DMG Action |
| 3 | Dialog Token |
| 4 | Destination REDS AID |

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The Category field is defined in 9.4.1.11 (Action field).

The DMG Action field is defined in 9.6.19.1 (DMG Action field).

(#417)The Dialog Token field is defined in 9.4.1.12 (Dialog Token field). It is set to a nonzero value chosen by the STA sending the Relay Search Request frame to identify the request/response transaction.

The Destination REDS AID field is set to the AID of the target destination REDS. The structure of the field is defined in 9.4.1.8 (AID field).

### 9.6.19.9 Relay Search Response frame format

The Relay Search Response frame is sent by an AP or PCP in response to a Relay Search Request frame. The format of a Relay Search Response frame Action field is shown in Table 9-576 (Relay Search Response frame Action field format).

**Table 9-576—Relay Search Response frame Action field format**

| Order | Information |
|---|---|
| 1 | Category |
| 2 | DMG Action |
| 3 | Dialog Token |
| 4 | Status Code |
| 5 | Number of Relay Capable STAs |
| 6 | Zero or more Relay Capable STA Info fields |

The Category field is defined in 9.4.1.11 (Action field).

The DMG Action field is defined in 9.6.19.1 (DMG Action field).

(#417)The Dialog Token field is defined in 9.4.1.12 (Dialog Token field). It is set to the value in the corresponding Relay Search Request frame that generated this response.

The Status Code field is defined in 9.4.1.9 (Status Code field).

The Number of Relay Capable STAs field is 1 octet in length and indicates the number of STAs in the BSS that are relay capable. This field is set to 0 if the (#7190)status code does not indicate success.

The Relay Capable STA Info field is defined in 9.4.1.42 (Relay Capable STA Info field). This information is included only if the status code indicates successful. The number of Relay Capable STA Info fields that appear in the frame is indicated by the value of the Number of Relay Capable STAs field.

### 9.6.19.10 Multi-relay Channel Measurement Request frame format

The Multi-Relay Channel Measurement Request frame is transmitted by a STA initiating relay operation to the recipient STA in order to obtain Channel Measurements between the recipient STA and the other STA participating in the relay operation. The format of the Multi-Relay Channel Measurement Request frame


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Action field is shown in Table 9-577 (Multi-relay Channel Measurement Request frame Action field format).

**Table 9-577—Multi-relay Channel Measurement Request frame Action field format**

| Order | Information |
|---|---|
| 1 | Category |
| 2 | DMG Action |
| 3 | Dialog Token |

The Category field is defined in 9.4.1.11 (Action field).

The DMG Action field is defined in 9.6.19.1 (DMG Action field).

(#417)The Dialog Token field is defined in 9.4.1.12 (Dialog Token field). It is set to a nonzero value chosen by the STA sending the Multi-Relay Channel Measurement Request frame to identify the request/report transaction.

### 9.6.19.11 Multi-relay Channel Measurement Report frame format

The Multi-Relay Channel Measurement Report frame is sent in response to a Multi-Relay Channel Measurement Request. The format of the Multi-Relay Channel Measurement Report frame Action field is shown in Table 9-578 (Multi-relay Channel Measurement Report frame Action field format).

**Table 9-578—Multi-relay Channel Measurement Report frame Action field format**

| Order | Information |
|---|---|
| 1 | Category |
| 2 | DMG Action |
| 3 | Dialog Token |
| 4 | Number of Channel Measurement Info |
| 5 | One or more Channel Measurement Info fields |

The Category field is defined in 9.4.1.11 (Action field).

The DMG Action field is defined in 9.6.19.1 (DMG Action field).

(#417)The Dialog Token field is defined in 9.4.1.12 (Dialog Token field). It is set to the value in any corresponding Multi-Relay Channel Measurement Request frame. If the Multi-Relay Channel Measurement Report frame is not being transmitted in response to a Multi-Relay Channel Measurement Request frame, then the dialog token is set to 0.

The Number of Channel Measurement Info field is 1 octet in length and indicates the number of Channel Measurements Info fields included in the frame.

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The format of the Channel Measurement Info field is defined in Figure 9-1310 (Channel Measurement Info field format). The number of Channel Measurement Info fields included in the frame is indicated by the Number of Channel Measurement Info field. More than one Multiple Channel Measurement Info field is included if the reporting STA measures the channel for multiple RDSs.

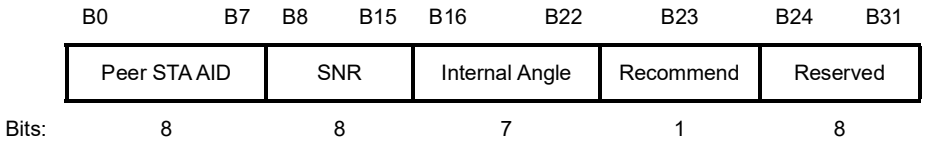


**Figure 9-1310—Channel Measurement Info field format**

The Peer STA AID subfield contains the AID of the STA toward which the reporting STA measures link.

The SNR subfield indicates the SNR measured in the link toward the STA corresponding to Peer STA AID. This subfield is encoded as 8-bit 2s complement value of 4x(SNR-19), where SNR is measured in dB. This covers from –13 dB to 50.75 dB in 0.25 dB steps.

The Internal Angle subfield indicates the angle between directions toward the other STAs involved in the relay operation. This covers from 0° to 180° in 2° steps. This subfield uses the degree of the direction from the sector that the feedbacks indicates has highest quality during TXSS if SLS phase of BF is performed and RXSS is not included.

The Recommend subfield indicates whether the responding STA recommends relay operation based on the channel measurement with the Peer STA. This subfield is set to 1 when the relay operation is recommended and otherwise is set to 0.

### 9.6.19.12 RLS Request frame format

The RLS Request frame is used to set up a relay link. The format of the RLS Request frame Action field is shown in Table 9-579 (RLS Request frame Action field format).

**Table 9-579—RLS Request frame Action field format**

| Order | Information |
|---|---|
| 1 | Category |
| 2 | DMG Action |
| 3 | Dialog Token |
| 4 | Destination AID |
| 5 | Relay AID |
| 6 | Source AID |
| 7 | Destination Capability Information |
| 8 | Relay Capability Information |
| 9 | Source Capability Information |
| 10 | Relay Transfer Parameter Set |


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The Category field is defined in 9.4.1.11 (Action field).

The DMG Action field is defined in 9.6.19.1 (DMG Action field).

(#417)The Dialog Token field is defined in 9.4.1.12 (Dialog Token field). It is set to a nonzero value chosen by the STA sending the RLS Request frame to identify the request/response transaction.

The Destination AID field value is the AID of the target destination formatted per 9.4.1.8 (AID field).

The Relay AID field value is the AID of the selected RDS formatted per 9.4.1.8 (AID field).

The Source AID field value is the AID of the initiating STA formatted per 9.4.1.8 (AID field).

The Destination Capability Information field indicates the Relay Capability Information field within the Relay Capabilities element of the target destination REDS as defined in 9.4.2.146 (Relay Capabilities element).

The Relay Capability Information field indicates the Relay Capability Information field within the Relay Capabilities element of the selected RDS as defined in 9.4.2.146 (Relay Capabilities element).

The Source Capability Information field indicates the Relay Capability Information field within the Relay Capabilities element of the originator of the request as defined in 9.4.2.146 (Relay Capabilities element).

The Relay Transfer Parameter Set element is defined in 9.4.2.147 (Relay Transfer Parameter Set element).

### 9.6.19.13 RLS Response frame format

The RLS Response frame is sent in response to an RLS Request frame. The format of an RLS Response frame Action field is shown in Table 9-580 (RLS Response frame Action field format).

**Table 9-580—RLS Response frame Action field format**

| Order | Information |
|---|---|
| 1 | Category |
| 2 | DMG Action |
| 3 | Dialog Token |
| 4 | Destination Status Code |
| 5 | Relay Status Code (optional) |

The Category field is defined in 9.4.1.11 (Action field).

The DMG Action field is defined in 9.6.19.1 (DMG Action field).

(#417)The Dialog Token field is defined in 9.4.1.12 (Dialog Token field). It is set to the value in any corresponding RLS Request frame.

The Destination Status Code field is included when the destination REDS transmits an RLS Response frame as a result of RLS Request. It is defined in 9.4.1.9 (Status Code field).

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The Relay Status Code field is included when the relay REDS transmits an RLS Response frame as a result of RLS Request. It is defined in 9.4.1.9 (Status Code field).

### 9.6.19.14 RLS Announcement frame format

The RLS Announcement frame is sent to announce the successful RLS. The format of an RLS Announcement frame Action field is shown in Table 9-581 (RLS Announcement frame Action field format).

**Table 9-581—RLS Announcement frame Action field format**

| Order | Information |
|---|---|
| 1 | Category |
| 2 | DMG Action |
| 3 | Status Code |
| 4 | Destination AID |
| 5 | Relay AID |
| 6 | Source AID |

The Category field is defined in 9.4.1.11 (Action field).

The DMG Action field is defined in 9.6.19.1 (DMG Action field).

The Status Code field is defined in 9.4.1.9 (Status Code field).

The Destination AID field value is the AID of the target destination formatted per 9.4.1.8 (AID field).

The Relay AID field value is the AID of the RDS formatted per 9.4.1.8 (AID field).

The Source AID field value is the AID of the initiating STA formatted per 9.4.1.8 (AID field).

### 9.6.19.15 RLS Teardown frame format

The RLS Teardown frame is sent to terminate a relay operation. The format of the RLS Teardown frame Action field is shown in Table 9-582 (RLS Teardown frame Action field format).

**Table 9-582—RLS Teardown frame Action field format**

| Order | Information |
|---|---|
| 1 | Category |
| 2 | DMG Action |
| 3 | Destination AID |
| 4 | Relay AID |


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**Table 9-582—RLS Teardown frame Action field format**

| | |
|---|---|
| 5 | Source AID |
| 6 | Reason Code |

The Category field is defined in 9.4.1.11 (Action field).

The DMG Action field is defined in 9.6.19.1 (DMG Action field).

The Destination AID field value is the AID of the destination REDS formatted per 9.4.1.8 (AID field).

The Relay AID field value is the AID of the RDS formatted per 9.4.1.8 (AID field).

The Source AID field value is the AID of the source REDS formatted per 9.4.1.8 (AID field).

The Reason Code field is defined in 9.4.1.7 (Reason Code field).

### 9.6.19.16 Relay Ack Request frame format

The Relay Ack Request frame is sent by a source REDS to an RDS participating in a relay operation in order to determine whether all frames forwarded through the RDS were received by the destination REDS also participating in the relay operation. This frame is used only when the RDS is operated in HD-DF mode and relay operation is link switching. The format of the Relay Ack Request frame Action field is shown in Table 9-583 (Relay Ack Request frame Action field format).

**Table 9-583—Relay Ack Request frame Action field format**

| Order | Information |
|---|---|
| 1 | Category |
| 2 | DMG Action |
| 3 | BAR Control |
| 4 | (#4200)Block Ack Starting Sequence Control |

The Category field is defined in 9.4.1.11 (Action field).

The DMG Action field is defined in 9.6.19.1 (DMG Action field).

The BAR Control and (#4200)Block Ack Starting Sequence Control fields are defined in 9.3.1.7 (BlockAckReq frame format).

### 9.6.19.17 Relay Ack Response frame format

The Relay Ack Response frame is sent by an RDS to a source REDS participating in a relay operation in order to report the frames received by the destination REDS also participating in the relay operation. This frame is used only when the RDS is operated in HD-DF mode and relay operation is link switching. The format of the Relay Ack Response frame Action field is shown in Table 9-584 (Relay Ack Response frame Action field format).

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**Table 9-584—Relay Ack Response frame Action field format**

| Order | Information |
|---|---|
| 1 | Category |
| 2 | DMG Action |
| 3 | BA Control |
| 4 | (#4200)Block Ack Starting Sequence Control |
| 5 | BlockAck Bitmap |

The Category field is defined in 9.4.1.11 (Action field).

The DMG Action field is defined in 9.6.19.1 (DMG Action field).

(#6322)The BA Control, (#4200)Block Ack Starting Sequence Control, and BlockAck Bitmap fields are defined in 9.3.1.8 (BlockAck frame format).(#7201)

The BlockAck Bitmap field is defined in 9.3.1.8 (BlockAck frame format).

### 9.6.19.18 TPA Request frame format

The TPA Request frame is sent by a destination REDS participating in operation based on link cooperation to both the RDS and source REDS that belong to the same group as the destination REDS in order for them to send back their own TPA Response frames at the separately predefined times. Also, a source REDS sends a TPA Request frame to the RDS that is selected by the source REDS in order for the RDS to feedback its own TPA Response frame at the predefined time.

The format of the TPA Request frame Action field is shown in Table 9-585 (TPA Request frame Action field format).

**Table 9-585—TPA Request frame Action field format**

| Order | Information |
|---|---|
| 1 | Category |
| 2 | DMG Action |
| 3 | Dialog Token |
| 4 | Timing Offset |
| 5 | Sampling Frequency Offset |


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The Category field is defined in 9.4.1.11 (Action field).

The DMG Action field is defined in 9.6.19.1 (DMG Action field).

(#417)The Dialog Token field is defined in 9.4.1.12 (Dialog Token field). It is set to a nonzero value chosen by the STA sending the TPA Request frame to identify the request/response transaction.

The Timing Offset field is 2 octets in length and indicates the amount of time, in nanoseconds, that the STA identified in the RA of the frame is required to change the timing offset of its transmissions so that they arrive at the expected time at the transmitting STA.

The Sampling Frequency Offset field is 2 octets in length and indicates the amount by which to change the sampling frequency offset of the burst transmission so that bursts arrive at the destination DMG STA with no sampling frequency offset. The unit is 0.01 ppm.

### 9.6.19.19 TPA Response frame format

The TPA Response frame is sent by an RDS or a source REDS participating in relay operation in response to a TPA Request frame from a destination REDS or a source REDS. The RDS or the source REDS that receives a TPA Request frame responds to the destination REDS or the source REDS, as appropriate, with a TPA Response frame at a predetermined time from the end of the TPA Request frame (see 11.34 (DMG relay procedures)). The format of the TPA Response frame Action field is shown in Table 9-586 (TPA Response frame Action field format).

**Table 9-586—TPA Response frame Action field format**

| Order | Information |
|---|---|
| 1 | Category |
| 2 | DMG Action |
| 3 | Dialog Token |

The Category field is defined in 9.4.1.11 (Action field).

The DMG Action field is defined in 9.6.19.1 (DMG Action field).

(#417)The Dialog Token field is defined in 9.4.1.12 (Dialog Token field). It is set to the value of the Dialog Token field of the TPA Request frame that generated this response.

### 9.6.19.20 TPA Report frame format

The TPA Report frame is sent to announce whether a TPA procedure is successful. The format of the TPA Report frame Action field is shown in Table 9-587 (TPA Report frame Action field format).

**Table 9-587—TPA Report frame Action field format**

| Order | Information |
|---|---|
| 1 | Category |

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**Table 9-587—TPA Report frame Action field format**

| | |
|---|---|
| 2 | DMG Action |
| 3 | Status Code(#3326) |

The Category field is defined in 9.4.1.11 (Action field).

The DMG Action field is defined in 9.6.19.1 (DMG Action field).

The Status Code field indicates the result of the current TPA procedure and is defined in 9.4.1.9 (Status Code field).

### 9.6.19.21 ROC Request frame format

The ROC Request frame is sent by the source REDS participating in a relay operation in order to request a change in the current relay operation type. The format of the ROC Request frame Action field is shown in Table 9-588 (ROC Request frame Action field format).

**Table 9-588—ROC Request frame Action field format**

| Order | Information |
|---|---|
| 1 | Category |
| 2 | DMG Action |
| 3 | Dialog Token |
| 4 | Relay Operation Type |

The Category field is defined in 9.4.1.11 (Action field).

The DMG Action field is defined in 9.6.19.1 (DMG Action field).

(#417)The Dialog Token field is defined in 9.4.1.12 (Dialog Token field). It is set to a nonzero value chosen by the STA sending the ROC Request frame to identify the request/response transaction.

The format of the Relay Operation Type field is defined in Figure 9-1311 (Relay Operation Type field format).

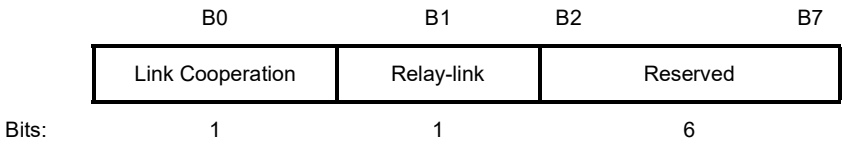


**Figure 9-1311—Relay Operation Type field format**

The Link Cooperation subfield is set to 0 to request the operation to be changed to link switching and is set to 1 to request the operation to be changed to link cooperation.


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The Relay-link subfield is set to 0 to indicate that the link switching operation starts at the direct link between the source REDS and destination REDS and set to 1 to indicate that the link switching operation starts with the RDS. If the Link Cooperation subfield is set to 1, the Relay-link subfield is reserved.

#### 9.6.19.22 ROC Response frame format

The ROC Response frame is sent by the RDS or the destination DMG STA participating in a relay operation in response to a ROC Request frame from the source DMG STA. The format of the ROC Response frame Action field is shown in Table 9-589 (ROC Response frame Action field format).

**Table 9-589—ROC Response frame Action field format**

| Order | Information |
|---|---|
| 1 | Category |
| 2 | DMG Action |
| 3 | Dialog Token |
| 4 | Status Code |

The Category field is defined in 9.4.1.11 (Action field).

The DMG Action field is defined in 9.6.19.1 (DMG Action field).

(#417)The Dialog Token field is defined in 9.4.1.12 (Dialog Token field). It is set to the value received in the corresponding ROC Request frame that generated this response.

The Status Code field is defined in 9.4.1.9 (Status Code field).

#### 9.6.19.23 Protected Announce frame format(11ay)

The Protected Announce frame allows robust STA-STA communications of the same information that is conveyed in the nonrobust Announce frame (see 9.6.21.2 (Announce frame format)).

The format of the robust Protected Announce and nonrobust Announce frame is the same and defined in 9.6.21.2 (Announce frame format). The Category field value differentiates whether the frame is robust or not.

### 9.6.20 FST Action frame details

#### 9.6.20.1 FST Action field

The FST Action field values are defined in Table 9-590 (FST Action field values).

**Table 9-590—FST Action field values**

| FST Action field value | Meaning |
|---|---|
| 0 | FST Setup Request |

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**Table 9-590—FST Action field values**

| | |
|---|---|
| 1 | FST Setup Response |
| 2 | FST Teardown |
| 3 | FST Ack Request |
| 4 | FST Ack Response |
| 5 | On-channel Tunnel Request |

### 9.6.20.2 FST Setup Request frame format

The FST Setup Request frame allows an initiating STA to announce to a peer STA whether the initiating STA intends to enable FST for the session between the initiating STA and the peer STA (11.31 (Multi-band operation)). The format of the FST Setup Request frame Action field is shown in Table 9-591 (FST Setup Request frame Action field format).

**Table 9-591—FST Setup Request frame Action field format**

| Order | Information |
|---|---|
| 1 | Category |
| 2 | FST Action |
| 3 | Dialog Token |
| 4 | LLT |
| 5 | Session Transition |
| 6 | Multi-band (optional) |
| 7 | DMG Wakeup Schedule (optional) |
| 8 | Awake Window (optional) |
| 9 | Switching Stream (optional) |
| 10 | Zero or more additional elements are present, as defined in 11.31.1 (General). Each of these elements is not present more than once in the frame. |

The Category field is defined in 9.4.1.11 (Action field).

The FST Action field is defined in 9.6.20.1 (FST Action field).

(#417)The Dialog Token field is defined in 9.4.1.12 (Dialog Token field). It is set to a nonzero value chosen by the STA.

The Link loss timeout (LLT) field is 32 bits and indicates the compressed maximum duration counted from the last time an MPDU was received by the initiating STA from the peer STA until the initiating STA decides to initiate FST. The use of this field is described in 11.31 (Multi-band operation).

The Session Transition field contains the Session Transition element as defined in 9.4.2.144 (Session Transition element).


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The Multi-band field contains the Multi-Band element as defined in 9.4.2.137 (Multi-band element). The regulatory information contained in the Multi-band element is applicable to all of the fields and elements contained in the frame.

The DMG Wakeup Schedule element is defined in 9.4.2.129 (DMG Wakeup Schedule element).

The Awake Window element is defined in 9.4.2.136 (Awake Window element).

The Switching Stream element is defined in 9.4.2.143 (Switching Stream element).

### 9.6.20.3 FST Setup Response frame format

The FST Setup Response frame is transmitted in response to an FST Setup Request frame. The format of the frame Action field is shown in Table 9-592 (FST Setup Response frame Action field format).

**Table 9-592—FST Setup Response frame Action field format**

| Order | Information |
|---|---|
| 1 | Category |
| 2 | FST Action |
| 3 | Dialog Token |
| 4 | Status Code |
| 5 | Session Transition |
| 6 | Multi-band (optional) |
| 7 | DMG Wakeup Schedule (optional) |
| 8 | Awake Window (optional) |
| 9 | Switching Stream (optional) |
| 10 | (#1776)TIE (optional) |
| 11 | Zero or more additional elements are present, as defined in 11.31.1 (General). Each of these elements is not present more than once in the frame. |

The Category field is defined in 9.4.1.11 (Action field).

The FST Action field is defined in 9.6.20.1 (FST Action field).

The Dialog Token field value is copied from the corresponding received FST Setup Request frame.

The Status Code field is defined in 9.4.1.9 (Status Code field).

The Session Transition field contains the Session Transition element as defined in 9.4.2.144 (Session Transition element).

The Multi-band element is defined in 9.4.2.137 (Multi-band element).

The DMG Wakeup Schedule element is defined in 9.4.2.129 (DMG Wakeup Schedule element).

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The Awake Window element is defined in 9.4.2.136 (Awake Window element)

The Switching Stream element is defined in 9.4.2.143 (Switching Stream element).

The (#1776)TIE is defined in 9.4.2.47 (TIE(#1776)).

### 9.6.20.4 FST Teardown frame format

The FST Teardown frame is transmitted to delete an established FST session between STAs. The format of the frame Action field is shown in Table 9-593 (FST Teardown frame Action field format).

**Table 9-593—FST Teardown frame Action field format**

| Order | Information |
|---|---|
| 1 | Category |
| 2 | FST Action |
| 3 | FSTS ID |

The Category field is defined in 9.4.1.11 (Action field).

The FST Action field is defined in 9.6.20.1 (FST Action field).

The FSTS ID field contains the identification of the FST session established between the STAs identified by the TA and RA fields of this frame. The format of the FSTS ID field is as specified 9.4.2.144 (Session Transition element).

### 9.6.20.5 FST Ack Request frame format

The FST Ack Request frame is transmitted in the frequency band an FST session is transferred to and confirms the FST. The format of the frame Action field is shown in Table 9-594 (FST Ack Request frame Action field format).

**Table 9-594—FST Ack Request frame Action field format**

| Order | Information |
|---|---|
| 1 | Category |
| 2 | FST Action |
| 3 | Dialog Token |
| 4 | FSTS ID |


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The Category field is defined in 9.4.1.11 (Action field).

The FST Action field is defined in 9.6.20.1 (FST Action field).

(#417)The Dialog Token field is defined in 9.4.1.12 (Dialog Token field). It is set to a nonzero value chosen by the STA sending the FST Ack request to identify the request/report transaction.

The FSTS ID field contains the identification of the FST session established between the STAs identified by the TA and RA fields of this frame. The format of the FSTS ID field is as specified in 9.4.2.144 (Session Transition element).

### 9.6.20.6 FST Ack Response frame format

The FST Ack Response frame is transmitted in response to an FST Ack Request frame. The format of the frame Action field is shown in Table 9-595 (FST Ack Response frame Action field format).

**Table 9-595—FST Ack Response frame Action field format**

| Order | Information |
|---|---|
| 1 | Category |
| 2 | FST Action |
| 3 | Dialog Token |
| 4 | FSTS ID |

The Category field is defined in 9.4.1.11 (Action field).

The FST Action field is defined in 9.6.20.1 (FST Action field).

(#417)The Dialog Token field is defined in 9.4.1.12 (Dialog Token field). It is set to the value in any corresponding FST Ack Request frame. If the FST Ack Response frame is not being transmitted in response to an FST Ack Request frame, then the dialog token is set to 0.

The FSTS ID field contains the identification of the FST session established between the STAs identified in the TA and RA fields of this frame. The format of the FSTS ID field is as specified in 9.4.2.144 (Session Transition element).

### 9.6.20.7 On-channel Tunnel Request frame format

The On-channel Tunnel Request frame allows a STA of a multi-band device to encapsulate an MMPDU for transmission to an MLME of a peer STA within the same multi-band device (11.31 (Multi-band operation)), which can be used to perform multi-band association and multi-band authentication.

The format of the On-channel Tunnel Request frame Action field is shown in Table 9-596 (On-channel Tunnel Request frame Action field format).

The Category field is defined in 9.4.1.11 (Action field).

The FST Action field is defined in 9.6.20.1 (FST Action field).

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**Table 9-596—On-channel Tunnel Request frame Action field format**

| Order | Information |
|---|---|
| 1 | Category |
| 2 | FST Action |
| 3 | OCT MMPDU Descriptor |
| 4 | Multi-band |
| 5 | OCT Source |

The OCT MMPDU Descriptor field is defined in Figure 9-1312 (Definition of the OCT MMPDU Descriptor field).

| | MMPDU Length | MMPDU Frame Control | MMPDU Frame Body |
|---|---|---|---|
| Octets: | 2 | 2 | variable(#213) |

**Figure 9-1312—Definition of the OCT MMPDU Descriptor field**

The MMPDU Length subfield contains the length in octets of the MMPDU Frame Body subfield.

The MMPDU Frame Control subfield carries the content of the Frame Control field of an MMPDU that would be constructed if the MMPDU for the corresponding management frame type were transmitted over the air.

The MMPDU Frame Body subfield carries the content of the Frame Body field of an MPDU carrying the MMPDU that would be constructed if the MMPDU for the corresponding management frame type were transmitted unencrypted over the air (i.e., all of the octets after the MAC header and up to, but not including, the FCS).

The Multi-band field contains the Multi-band element (see 9.4.2.137 (Multi-band element)) of the peer MLME to which the OCT MMPDU is destined to. The values of the Band ID, Channel Number and BSSID fields contained in this element are used to deliver the OCT MMPDU to the correct MLME within the peer STA.

The OCT Source field contains an OCT Source element that identifies the MLME that is the source of an OCT MMPDU.

### 9.6.21 Unprotected DMG Action frame details

#### 9.6.21.1 Unprotected DMG Action field

Unprotected DMG Action frames are not encapsulated using mechanisms defined for robust Management frames. An Unprotected DMG Action field, in the field immediately after the Category field, differentiates the formats. The Action field values associated with each frame format are defined in Table 9-597 (Unprotected DMG Action field values).


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**Table 9-597—Unprotected DMG Action field values**

| Unprotected DMG Action field value | Meaning |
|---|---|
| 0 | Announce |
| 1 | BRP |
| 2(11ay) | MIMO BF Setup |
| 3(11ay) | MIMO BF Poll |
| 4(11ay) | MIMO BF Feedback |
| 5(11ay) | MIMO BF Selection |

### 9.6.21.2 Announce frame format

The Announce frame is an Action or an Action No Ack frame of category Unprotected DMG. The format of an Announce frame Action field is shown in Table 9-598 (Announce frame Action field format).

Announce frames can be transmitted during the ATI of a beacon interval and can perform functions including of a DMG Beacon frame, but since this frame does not have to be transmitted as a sector sweep to a STA, it can provide much more spectrally efficient access than using a DMG Beacon frame.

**Table 9-598—Announce frame Action field format**

| Order | Information | Notes |
|---|---|---|
| 1 | Category | The Category field is defined in 9.4.1.11 (Action field). |
| 2 | Unprotected DMG Action or DMG Action(11ay-Ed1) | The Unprotected DMG Action field is defined in 9.6.21.1 (Unprotected DMG Action field) and is sent when the Announce frame is transmitted unprotected.(11ay)<br>The DMG Action field is defined in(#4199) 9.6.19.1 (DMG Action field) and is sent when the Announce frame is transmitted protected. (11ay) |
| 3 | Timestamp | The Timestamp field is defined in 9.4.1.10 (Timestamp field). |
| 4 | Beacon Interval | The Beacon Interval field is defined in 9.4.1.3 (Beacon Interval field) and specifies the duration of the beacon interval of the BSS. |
| 5 | SSID | The SSID element is defined in 9.4.2.2 (SSID element). The SSID element is optionally present. If present, the SSID element specifies the SSID of the BSS. |
| 6 | Extended Schedule | The Extended Schedule element is defined in 9.4.2.130 (Extended Schedule element). The Extended Schedule element is optionally present. If present, the Extended Schedule element specifies the schedule of the BSS. |
| 7 | DMG Capabilities | The DMG Capabilities element is defined in 9.4.2.126 (DMG Capabilities element). The DMG Capabilities element is optionally present. If present, the DMG Capabilities element specifies capabilities of the transmitting STA. |

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**Table 9-598—Announce frame Action field format *(continued)***

| Order | Information | Notes |
|---|---|---|
| 8 | RSN | The RSNE is defined in 9.4.2.23 (RSNE). The RSNE is optionally present. If present, the RSNE indicates that security is required in the BSS. |
| 9 | Multiple BSSID | (#488)One or more Multiple BSSID elements are present if the AP is a member of a multiple BSSID set (see 11.10.14 (Multiple BSSID set)) with two or more members and any of the following conditions are true:<br>• dot11MultiBSSIDImplemented is true<br>• dot11MultiBSSIDImplemented is false and dot11RMMeasurementPilotActivated is between 2 and 7<br>• dot11InterworkingServiceActivated is true and at least one dot11GASAdvertisementID exists<br>Otherwise not present. |
| 10 | DMG Operation | The DMG Operation element is defined in 9.4.2.126.7 (TDD Capability Information field(11ay)). The DMG Operation element is optionally present. If present, the DMG Operation element specifies the operational parameters of the BSS. |
| 11 | Next DMG ATI | The Next DMG ATI element is defined in 9.4.2.134 (Next DMG ATI element). The Next DMG ATI element is optionally present. If present, the Next DMG ATI element specifies the start time of the next ATI at a subsequent beacon interval. |
| 12 | Multi-band | The Multi-band element is defined in 9.4.2.137 (Multi-band element). The Multi-band element is optionally present. |
| 13 | Awake Window | The Awake Window element is defined in 9.4.2.136 (Awake Window element). The Awake Window element is optionally present. |
| 14 | DMG BSS Parameter Change | The DMG BSS Parameter Change element is defined in 9.4.2.125 (DMG BSS Parameter Change element). The DMG BSS Parameter Change element is optionally present. |
| 15 | BeamLink Maintenance | The BeamLink Maintenance element is defined in 9.4.2.150 (BeamLink Maintenance element). The BeamLink Maintenance element is optionally present. |
| 16 | Multiple MAC Sublayers | The Multiple MAC Sublayers element is defined in 9.4.2.151 (MMS element(#1776)). The Multiple MAC Sublayers element is optionally present. |
| 17 | ECAPC Policy | The ECAPC Policy element is defined in 9.4.2.153 (ECAPC Policy element). The ECAPC Policy element is optionally present. |
| 18 | Cluster Report | The Cluster Report element is defined in 9.4.2.145 (Cluster Report element). The Cluster Report element is optionally present. |
| 19 | Next PCP List | The Next PCP List element is defined in 9.4.2.139 (Next PCP List element). The Next PCP List element is optionally present. |
| 20 | PCP Handover | The PCP Handover element is defined in 9.4.2.140 (PCP Handover element). The PCP Handover element is optionally present. |
| 21 | STA Availability | The STA Availability element is defined in 9.8 (MAC frame format for PV1 frames).(#1358) The STA Availability element is optionally present. |


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**Table 9-598—Announce frame Action field format *(continued)***

| Order | Information | Notes |
|---|---|---|
| 22 | UPSIM | The UPSIM element is defined in 9.4.2.165 (UPSIM element). The UPSIM element is optionally present. |
| 23 | Extended Channel Switch Announcement | The Extended Channel Switch Announcement element is defined in 9.4.2.51 (Extended Channel Switch Announcement element). The Extended Channel Switch Announcement element is optionally present if dot11ExtendedChannelSwitchActivated is true. |
| 24 | Cluster Probe | The Cluster Probe element is defined in 9.4.2.222 (Cluster Probe element). The Cluster Probe element is optionally present. |
| 25 | Extended Cluster Report | The Extended Cluster Report element is defined in 9.4.2.223 (Extended Cluster Report element). The Extended Cluster Report element is optionally present. |
| 26 | Cluster Switch Announcement | The Cluster Switch Announcement element is defined in 9.4.2.224 (Cluster Switch Announcement element). The Cluster Switch Announcement element is optionally present. |
| 27 | CDMG Extended Schedule | The Extended Schedule element is optionally present if dot11OpportunisticTransmissionsImplemented is true; otherwise not present. |
| 28 | Service Hash | The Service Hash element is optionally present if dot11UnsolicitedPADActivated is true; otherwise not present. |
| 29 | Service Hint | The Service Hint element is optionally present if dot11UnsolicitedPADActivated is true; otherwise not present. |
| 30(11ay) | TDD Slot Structure | This element is optionally present if dot11TDDOptionImplemented is true; otherwise, not present. If present, the element specifies the TDD slot timing. |
| 31(11ay) | TDD Slot Schedule | This element is optionally present if dot11TDDOptionImplemented is true; otherwise, not present. If present, the element specifies the type of the TDD slot and the access permission. |
| 32(11ay) | TDD Route | This element is optionally present if dot11TDDOptionImplemented is true; otherwise, not present. If present, the element specifies the TDD beamforming results and sector switch configuration. |
| 33(11ay) | DMG Link Margin | This element is optionally present. If present, the element specifies the parameters needed for link maintenance. |
| 34(11ay) | TDD Bandwidth Request | This element is optionally present if dot11TDDOptionImplemented is true; otherwise, not present. If present, the element specifies the parameters needed for bandwidth reservation during TDD SPs. |
| 35(11ay) | TDD Synchronization | This element is optionally present if dot11TDDOptionImplemented is true; otherwise, not present. If present, the element specifies the information needed for clock synchronization during TDD SPs. |
| 36(11ay) | EDMG Capabilities | This element is optionally present if dot11EDMGOptionImplemented is true. |
| 37(11ay) | EDMG Operation | This element is optionally present if dot11EDMGOptionImplemented is true. |
| 38(11ay) | EDMG Extended Schedule | This element is optionally present if dot11EDMGOptionImplemented is true. |

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**Table 9-598—Announce frame Action field format *(continued)***

| Order | Information | Notes |
|---|---|---|
| 39(11ay) | EDMG Group ID Set | This element is optionally present if dot11EDMGOptionImplemented is true. |
| 40(11ay) | EDMG Training Field Schedule | This element is optionally present if dot11EDMGOptionImplemented is true. |
| 41(11ay) | Time Advertisement | Optionally present if dot11UTCTSFOffsetActivated is true |
| 42(#4137) | BSS Load | The BSS Load element is present if dot11QBSSLoadImplemented is true. |

### 9.6.21.3 BRP frame format

The BRP frame is an Action No Ack frame. The BRP frame Action field format is one of two variants depending upon the value of the EDMG-SHORT-BRP subfield within the BRP Request field. If the value of the EDMG-SHORT-BRP subfield is 1, the format of the BRP frame Action field is shown in Table 9-600 (BRP frame Action field format when the EDMG-SHORT-BRP subfield is 1(11ay)). In all other cases, the format of a BRP frame Action field is shown in Table 9-599 (BRP frame Action field format).

**Table 9-599—BRP frame Action field format**

| Order | Information |
|---|---|
| 1 | Category |
| 2 | Unprotected DMG Action |
| 3 | Dialog Token |
| 4 | BRP Request field |
| 5 | DMG Beam Refinement element |
| 6 | Zero or more Channel Measurement Feedback elements |
| 7 | Enhanced Beam Tracking element |
| 8 | SSW Report element |
| 9(11ay) | EDMG Partial Sector Level Sweep element (optional) |
| 10(11ay) | EDMG BRP Request element (optional) |
| 11(11ay) | Zero or more EDMG Channel Measurement Feedback elements |

**Table 9-600—BRP frame Action field format when the EDMG-SHORT-BRP subfield is 1(11ay)**

| Order | Information |
|---|---|
| 1 | Category |
| 2 | Unprotected DMG Action |
| 3 | Dialog Token |


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**Table 9-600—BRP frame Action field format when the EDMG-SHORT-BRP subfield is 1(11ay)**

| Order | Information |
|---|---|
| 4 | BRP Request field |
| 5 | EDMG BRP field |
| 6 | Short BRP Feedback field (optional) |

The Category field is defined in 9.4.1.11 (Action field).

The Unprotected DMG Action field is defined in 9.6.21.1 (Unprotected DMG Action field).

(#417)The Dialog Token field is defined in 9.4.1.12 (Dialog Token field). It is set to a value chosen by the STA sending the frame to uniquely identify the transaction.

The BRP Request field is defined in 9.5.4 (BRP Request field).

The DMG Beam Refinement element is defined in 9.4.2.128 (DMG Beam Refinement element).

The Channel Measurement Feedback element is defined in 9.4.2.135 (Channel Measurement Feedback element).

The BRP frame contains more than one Channel Measurement Feedback element if the measurement information exceeds 255 octets. The content of each Channel Measurement Feedback element that follows the first one in a single BRP frame is a continuation of the content in the previous element. The Channel Measurement, Tap Delay, and Sector ID Order subfields can be split between several elements. Each Channel Measurement Feedback element that is not the last Channel Measurement Feedback element in the frame is 257 octets long. Channel measurement information for a single channel measurement is always contained within a single BRP frame.

NOTE—The length of a BRP frame can limit the choice of channel measurement parameters such as the number of measurements and the number of taps.

The EDMG Partial Sector Level Sweep element is defined in 9.4.2.271.

(11ay)The EDMG BRP Request element is defined in 9.4.2.269 (EDMG BRP Request element(11ay)). If this element is present in the frame, the value of a field within this element overrides the value of the field with the same name in the BRP Request field contained in the frame.

(11ay)The EDMG Channel Measurement Feedback element is defined in 9.4.2.267 (EDMG Channel Measurement Feedback element(11ay)). If an EDMG Channel Measurement Feedback element appears in the frame, then at least one Channel Measurement Feedback element is also included in the frame.

(11ay)The EDMG BRP field is defined in 9.5.7 (EDMG BRP field(11ay)).

(11ay)The Short BRP Feedback field is defined in 9.5.8 (Short BRP Feedback field(11ay)).

(11ay)The Enhanced Beam Tracking element is defined in 9.4.2.225 (Enhanced Beam Tracking element).

(11ay)The SSW Report element is defined in 9.4.2.221 (SSW Report element).

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### 9.6.21.4 MIMO BF Setup frame format(11ay)

The MIMO BF Setup frame is an Action No Ack frame. The format of a MIMO BF Setup frame Action field is shown in Table 9-601 (MIMO BF Setup frame Action field format(11ay)).

**Table 9-601—MIMO BF Setup frame Action field format(11ay)**

| Order | Information |
|---|---|
| 1 | Category |
| 2 | Unprotected DMG Action |
| 3 | Dialog Token |
| 4 | MIMO Setup Control element |

The Category field is defined in 9.4.1.11 (Action field).

The Unprotected DMG Action field is defined in 9.6.21.1 (Unprotected DMG Action field).

The Dialog Token field is set to a value chosen by the STA sending the frame to uniquely identify the transaction.

The MIMO Setup Control element is defined in 9.4.2.272 (MIMO Setup Control element(11ay)).

### 9.6.21.5 MIMO BF Poll frame format(11ay)

The MIMO BF Poll frame is an Action No Ack frame. The format of a MIMO BF Poll frame Action field is shown in Table 9-602 (MIMO BF Poll frame Action field format(11ay)).

**Table 9-602—MIMO BF Poll frame Action field format(11ay)**

| Order | Information |
|---|---|
| 1 | Category |
| 2 | Unprotected DMG Action |
| 3 | Dialog Token |
| 4 | MIMO Poll Control element |

The Category field is defined in 9.4.1.11 (Action field).

The Unprotected DMG Action field is defined in 9.6.21.1 (Unprotected DMG Action field).

The Dialog Token field is set to a value chosen by the STA sending the frame to uniquely identify the transaction.

The MIMO Poll Control element is defined in 9.4.2.273 (MIMO Poll Control element(11ay)).


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### 9.6.21.6 MIMO BF Feedback frame format(11ay)

The MIMO BF Feedback frame is an Action No Ack frame. The format of a MIMO BF Feedback frame Action field is shown in Table 9-603 (MIMO BF Feedback frame Action field format(11ay)).

**Table 9-603—MIMO BF Feedback frame Action field format(11ay)**

| Order | Information |
|---|---|
| 1 | Category |
| 2 | Unprotected DMG Action |
| 3 | Dialog Token |
| 4 | MIMO Feedback Control element |
| 5 | Zero or more Channel Measurement Feedback elements |
| 6 | Zero or more EDMG Channel Measurement Feedback elements |
| 7 | Zero or more Digital BF Feedback elements |

The Category field is defined in 9.4.1.11 (Action field).

The Unprotected DMG Action field is defined in 9.6.21.1 (Unprotected DMG Action field).

The Dialog Token field is set to a value chosen by the STA sending the frame to uniquely identify the transaction.

The MIMO Feedback Control element is defined in 9.4.2.274 (MIMO Feedback Control element(11ay)).

The Channel Measurement Feedback element is defined in 9.4.2.135 (Channel Measurement Feedback element).

The EDMG Channel Measurement Feedback element is defined in 9.4.2.267 (EDMG Channel Measurement Feedback element(11ay)).

The Digital BF Feedback element is defined in 9.4.2.283 (Digital BF Feedback element(11ay)).

The MIMO BF Feedback frame contains more than one Channel Measurement Feedback element if the measurement information exceeds 255 octets. The content of each Channel Measurement Feedback element that follows the first one in a single MIMO BF Feedback frame is a continuation of the content in the previous element. The SNR, Channel Measurement, Additional SNR and Additional Channel Measurement subfields can be split between several elements. Each Channel Measurement Feedback element that is not the last Channel Measurement Feedback element in the frame is 257 octets long. Channel measurement information for a single channel measurement is always contained within a single MIMO BF Feedback frame.

The MIMO BF Feedback frame contains more than one EDMG Channel Measurement Feedback element if the measurement information exceeds 254 octets. The content of each EDMG Channel Measurement Feedback element that follows the first one in a single MIMO BF Feedback frame is a continuation of the content in the previous element. The EDMG Sector ID Order, BRP CDOWN, Tap Delay, Additional EDMG Sector ID Order, Additional BRP CDOWN and Additional Tap Delay fields can be split between several elements. Each EDMG Channel Measurement Feedback element that is not the last EDMG Channel

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Measurement Feedback element in the frame is 257 octets long. Channel measurement information for a single channel measurement is always contained within a single MIMO BF Feedback frame.

NOTE—The length of a MIMO BF Feedback frame can limit the choice of channel measurement parameters such as the number of measurements and the number of taps.

### 9.6.21.7 MIMO BF Selection frame format(11ay)

The MIMO BF Selection frame is an Action No Ack frame. The format of a MIMO BF Selection frame Action field is shown in Table 9-604 (MIMO BF Selection frame Action field format(11ay)).

**Table 9-604—MIMO BF Selection frame Action field format(11ay)**

| Order | Information |
|---|---|
| 1 | Category |
| 2 | Unprotected DMG Action |
| 3 | Dialog Token |
| 4 | MIMO Selection Control element |
| 5 | EDMG Group ID Set element (optional) |

The Category field is defined in 9.4.1.11 (Action field).

The Unprotected DMG Action field is defined in 9.6.21.1 (Unprotected DMG Action field).

The Dialog Token field is set to a value chosen by the STA sending the frame to uniquely identify the transaction.

The MIMO Selection Control element is defined in 9.4.2.275 (MIMO Selection Control element(11ay)).

The EDMG Group ID Set element is defined in 9.4.2.268 (EDMG Group ID Set element(11ay)). The element contains the updated list of MU groups following completion of the MU MIMO beamforming training.

## 9.6.22 VHT Action frame details

### 9.6.22.1 VHT Action field

Several Action frame formats are defined to support VHT functionality and S1G functionality. A VHT Action field, in the octet immediately after the Category field, differentiates the VHT Action frame formats. The VHT Action field values associated with each frame format within the VHT category are defined in Table 9-605 (VHT Action field values).


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**Table 9-605—VHT Action field values**

| Value | Meaning | Time priority |
|---|---|---|
| 0 | VHT Compressed Beamforming | Yes |
| 1 | Group ID Management | No |
| 2 | Operating Mode Notification | No |
| 3–255 | Reserved | |

### 9.6.22.2 VHT Compressed Beamforming frame format

The VHT Compressed Beamforming frame is an Action No Ack frame of category VHT. The Action field of a VHT Compressed Beamforming frame contains the information shown in Table 9-606 (VHT Compressed Beamforming frame Action field format).

**Table 9-606—VHT Compressed Beamforming frame Action field format**

| Order | Information |
|---|---|
| 1 | Category |
| 2 | VHT Action |
| 3 | VHT MIMO Control (see 9.4.1.46 (VHT MIMO Control field)) |
| 4 | VHT Compressed Beamforming Report (see 9.4.1.47 (VHT Compressed Beamforming Report field)) |
| 5 | MU Exclusive Beamforming Report (see 9.4.1.49 (MU Exclusive Beamforming Report field)) |

The Category field is defined in 9.4.1.11 (Action field).

The VHT Action field is defined in 9.6.22.1 (VHT Action field).

The VHT MIMO Control field is always present in the frame. The presence and contents of the VHT Compressed Beamforming Report field and the MU Exclusive Beamforming Report field are dependent on the values of the Feedback Type, Remaining Feedback Segments, and First Feedback Segment subfields of the VHT MIMO Control field (see 9.4.1.46 (VHT MIMO Control field), 9.4.1.47 (VHT Compressed Beamforming Report field), 9.4.1.49 (MU Exclusive Beamforming Report field), and 10.35.5 (VHT sounding protocol)).

No Vendor Specific elements are present in a VHT Compressed Beamforming frame.

When carried in an S1G PPDU, a VHT Compressed Beamforming frame is referred to as an S1G Compressed Beamforming frame, and a VHT MIMO Control field is referred to as an S1G MIMO Control field.

When carried in an S1G PPDU, a VHT NDP Announcement frame is referred to as an S1G NDP Announcement frame.

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### 9.6.22.3 Group ID Management frame format

The Group ID Management frame is transmitted by the AP to assign or change the user position of a STA for one or more group IDs. The Action field of a Group ID Management frame contains the information shown in Table 9-607 (Group ID Management frame Action field format).

**Table 9-607—Group ID Management frame Action field format**

| Order | Information |
|---|---|
| 1 | Category |
| 2 | VHT Action |
| 3 | Membership Status Array (see 9.4.1.52 (Membership Status Array field))(#4383) |
| 4 | User Position Array (see 9.4.1.53 (User Position Array field)) |

The Category field is defined in 9.4.1.11 (Action field).

The VHT Action field is defined in 9.6.22.1 (VHT Action field).

### 9.6.22.4 Operating Mode Notification frame format

The Operating Mode Notification frame is used to notify STAs that the transmitting STA is changing one or more of its operating channel width, the maximum number of spatial streams it can receive, and its LDPC receive preference.

The Action field of the Operating Mode Notification frame contains the information shown in Table 9-608 (Operating Mode Notification frame Action field format).

**Table 9-608—Operating Mode Notification frame Action field format**

| Order | Information |
|---|---|
| 1 | Category |
| 2 | VHT Action |
| 3 | Operating Mode (see 9.4.1.51 (Operating Mode field)) |

The Category field is defined in 9.4.1.11 (Action field).

The VHT Action field is defined in 9.6.22.1 (VHT Action field).

## 9.6.23 FILS Action frame details

### 9.6.23.1 FILS Action field(#3729)

The FILS Action frame is used for FILS operation after the non-AP STA has associated with the AP. The defined FILS Action frames are listed in Table 9-609 (FILS Action field(#4199) values).


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**Table 9-609—FILS Action field(#4199) values**

| Action field value | Description |
|---|---|
| 0 | FILS Container(#4199) |
| 1–255 | Reserved |

### 9.6.23.2 FILS Container frame

The FILS Container frame is used to exchange FILS IP Address Assignment elements (see 9.4.2.183 (FILS IP Address Assignment element)). The format of the Action field of the FILS Container frame is shown in Figure 9-1313 (FILS Container frame Action field format).

| | Category | FILS Action | FILS IP Address Assignment Elements |
|---|---|---|---|
| Octets: | 1 | 1 | variable |

**Figure 9-1313—FILS Container frame Action field format**

The Category field is set to the value for FILS defined in Table 9-81 (Category values).

The FILS Action field is defined in 9.6.23.1 (FILS Action field(#3729)).(#4199)

The FILS IP Address Assignment Elements field contains one or more FILS IP Address Assignment elements as defined in 9.4.2.183 (FILS IP Address Assignment element).

### 9.6.24 Unprotected S1G Action frame details

### 9.6.24.1 Unprotected S1G Action field

(11ax)An Unprotected S1G Action field, in the octet immediately after the Category field, differentiates the Unprotected S1G Action frame formats. The Unprotected S1G Action field values associated with each frame format within the Unprotected S1G category are defined in Table 9-610 (Unprotected S1G Action field values(#1707)).

**Table 9-610—Unprotected S1G Action field values(#1707)**

| Value | Meaning |
|---|---|
| 0 | AID Switch Request |
| 1 | AID Switch Response |
| 2 | Sync Control |
| 3 | STA Information Announcement |
| 4 | EDCA Parameter Set |
| 5 | EL Operation |
| 6 | TWT Setup |
| 7 | TWT Teardown |

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**Table 9-610—Unprotected S1G Action field values(#1707)**

| Value | Meaning |
|---|---|
| 8 | Sectorized Group ID List |
| 9 | Sector ID Feedback |
| 10 | Reserved |
| 11 | TWT Information |
| 12–255 | Reserved |

### 9.6.24.2 AID Switch Request frame format

A STA that is changing its device characteristic as defined in 9.4.2.192 (AID Request element) uses the AID Switch Request frame to request the frame's recipient to change its AID or to request a group AID from an AP. The Action field of the AID Switch Request frame contains the information shown in Table 9-611 (AID Switch Request frame Action field format).

**Table 9-611—AID Switch Request frame Action field format**

| Order | Information |
|---|---|
| 1 | Category |
| 2 | Unprotected S1G Action |
| 3 | Dialog Token |
| 4 | AID Request (see 9.4.2.192 (AID Request element)) |

The Category field is defined in 9.4.1.11 (Action field).

The Unprotected S1G Action field is defined in 9.6.24.1 (Unprotected S1G Action field).

(#417)The Dialog Token field is defined in 9.4.1.12 (Dialog Token field). It is a value chosen by the non-AP STA sending the AID Switch Request frame to identify the request/response transaction.

The AID Request field contains an AID Request element as specified in 9.4.2.192 (AID Request element).

### 9.6.24.3 AID Switch Response frame format

The AID Switch Response frame is sent by an AP in response to an AID Switch Request frame, or sent by an AP to a non-AP STA to instruct the STA to change its AID or wakeup interval and it is sent by an AP to assign a group AID to a requesting STA. The Action field of the AID Switch Response frame contains the information shown in Table 9-612 (AID Switch Response frame Action field format).

The Category field is defined in 9.4.1.11 (Action field).

The Unprotected S1G Action field is defined in 9.6.24.1 (Unprotected S1G Action field).


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**Table 9-612—AID Switch Response frame Action field format**

| Order | Information |
|---|---|
| 1 | Category |
| 2 | Unprotected S1G Action |
| 3 | Dialog Token |
| 4 | AID Response (see 9.4.2.193 (AID Response element)) |

(#417)The Dialog Token field is defined in 9.4.1.12 (Dialog Token field). It is the value in the corresponding AID Switch Request frame. If the AID Switch Response frame is not being transmitted in response to an AID Switch Request frame, then the Dialog token is set to 0.

The AID Response field contains an AID Response element as specified in 9.4.2.193 (AID Response element).

### 9.6.24.4 Sync Control frame format

The Sync Control frame is transmitted by a non-AP STA to a UL-Sync capable AP to enable or disable sync frame transmission for uplink traffic (see 10.48 (Sync frame operation)). The Action field of a Sync Control frame contains the information shown in Table 9-613 (Sync Control frame Action field format).

**Table 9-613—Sync Control frame Action field format**

| Order | Information |
|---|---|
| 1 | Category |
| 2 | Unprotected S1G Action |
| 3 | Sync Control (see 9.4.1.56 (Sync Control field)) |

The Category field is defined in 9.4.1.11 (Action field).

The Unprotected S1G Action field is defined in 9.6.24.1 (Unprotected S1G Action field).

The Sync Control field is defined in 9.4.1.56 (Sync Control field).

### 9.6.24.5 STA Information Announcement frame format

The STA Information Announcement frame is either used by a non-AP STA to inform the peer STAs of the updated AID when a STA's AID is changed or used by a relay STA to inform the AP of a newly associated STA's AID or the updated AID when a STA's AID is changed. The Action field of the STA Information Announcement frame contains the information shown in Table 9-614 (STA Information Announcement frame Action field format).

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**Table 9-614—STA Information Announcement frame Action field format**

| Order | Information |
|---|---|
| 1 | Category |
| 2 | Unprotected S1G Action |
| 3 | AID Announcement (9.4.2.207 (AID Announcement element)) |

The Category field is defined in 9.4.1.11 (Action field).

The Unprotected S1G Action field is defined in 9.6.24.1 (Unprotected S1G Action field).

The AID Announcement field contains an AID Announcement element as specified in 9.4.2.207 (AID Announcement element).

### 9.6.24.6 EDCA Parameter Set frame format

The EDCA Parameter Set frame is used to update the EDCA Parameter Set at the recipient STA, as defined in 10.2.3.2 (HCF contention based channel access (EDCA))). The Action field of the EDCA Parameter Set frame contains the information shown in Table 9-615 (EDCA Parameter Set frame Action field format).

**Table 9-615—EDCA Parameter Set frame Action field format**

| Order | Information |
|---|---|
| 1 | Category |
| 2 | Unprotected S1G Action |
| 3 | EDCA Parameter Set (9.4.2.27 (EDCA Parameter Set element)) |

The Category field is defined in 9.4.1.11 (Action field).

The Unprotected S1G Action field is defined in 9.6.24.1 (Unprotected S1G Action field).

The EDCA Parameter Set field contains an EDCA Parameter Set element as specified in 9.4.2.27 (EDCA Parameter Set element).

### 9.6.24.7 EL Operation frame format

The EL Operation frame is used to carry the EL Operation element (9.4.2.209 (EL Operation element)). The Action field of the EL Operation frame contains the information shown in Table 9-616 (EL Operation Action field format)

The Category field is defined in 9.4.1.11 (Action field).

The Unprotected S1G Action field is defined in 9.6.24.1 (Unprotected S1G Action field).

The EL Operation field contains an EL Operation element as specified in 9.4.2.209 (EL Operation element).


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**Table 9-616—EL Operation Action field format**

| Order | Information |
|---|---|
| 1 | Category |
| 2 | Unprotected S1G Action |
| 3 | EL Operation (9.4.2.209 (EL Operation element)) |

### 9.6.24.8 TWT Setup frame format

The TWT Setup frame is sent by a STA to request the setup of a TWT SP and it is sent by a responding STA to indicate the status of a requested TWT SP. The Action field of the TWT Setup frame contains the information shown in Table 9-617 (TWT Setup frame Action field format).

**Table 9-617—TWT Setup frame Action field format**

| Order | Information |
|---|---|
| 1 | Category |
| 2 | Unprotected S1G Action |
| 3 | Dialog Token |
| 4 | (11ax)One or two TWT (9.4.2.198 (TWT element)) |

The Category field is defined in 9.4.1.11 (Action field).

The Unprotected S1G Action field is defined in 9.6.24.1 (Unprotected S1G Action field).

(#417)(Ed1)The Dialog Token field is defined in 9.4.1.12 (Dialog Token field). In a TWT Setup frame with a TWT Request field that is set to 1, the Dialog Token field is set to a nonzero value chosen by the transmitting STA to identify the request/response transaction. In a TWT Setup frame with a TWT Request field set to 0 that is sent in response to a TWT Setup frame with a TWT Request field that is equal to 1, the Dialog Token field is set to the value copied from the corresponding received TWT Setup frame with a TWT Request field equal to 1. In a TWT Setup frame with a TWT Request field set to 0 that is not sent in response to a TWT Setup frame with a TWT Request field equal to 1, the Dialog Token field is set to 0.(11ax)

(11ax)A TWT Setup frame contains only one TWT element, except if used for the establishment of a TWT agreement with a range of TWT parameter values (see 10.47.9 (TWT parameter ranges)). In this case, an additional TWT element is present.

### 9.6.24.9 TWT Teardown frame format

The TWT Teardown frame is sent by a STA to request the teardown of a TWT agreement and is transmitted by either STA of an existing TWT agreement. The Action field of the TWT Teardown frame contains the information shown in Table 9-618 (TWT Teardown frame Action field format).

The Category field is defined in 9.4.1.11 (Action field).

The Unprotected S1G Action field is defined in 9.6.24.1 (Unprotected S1G Action field).

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**Table 9-618—TWT Teardown frame Action field format**

| Order | Information |
|---|---|
| 1 | Category |
| 2 | Unprotected S1G Action |
| 3 | TWT Flow |

(11ax)The format of the TWT Flow field if the Negotiation Type subfield is 0 or 1 is defined in Figure 9-1314 (TWT Flow field format if the Negotiation Type subfield is 0 or 1(11ax)). The format of the TWT Flow field if the Negotiation Type field is 2 is defined in Figure 9-1315 (TWT Flow field format if the Negotiation Type subfield is 2(11ax)). The format of the TWT Flow field if the Negotiation Type subfield is 3 is defined in Figure 9-1316 (TWT Flow field format if the Negotiation Type subfield is 3(11ax)).

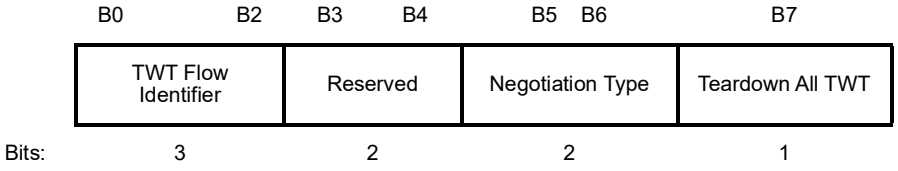


**Figure 9-1314—TWT Flow field format if the Negotiation Type subfield is 0 or 1(11ax)**

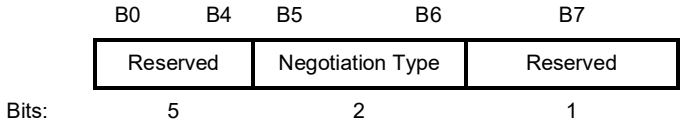


**Figure 9-1315—TWT Flow field format if the Negotiation Type subfield is 2(11ax)**

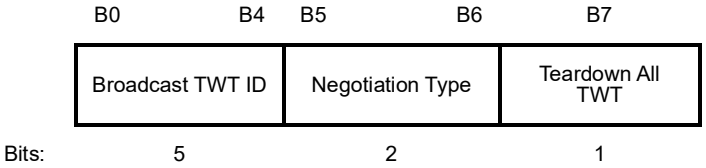


**Figure 9-1316—TWT Flow field format if the Negotiation Type subfield is 3(11ax)**

(11ax)The TWT Flow Identifier/Broadcast TWT ID field contains the TWT Flow Identifier when the Negotiation Type subfield is 0 or 1 and contains the Broadcast TWT ID field when the Negotiation Type subfield is 3. The TWT Flow Identifier field and the Broadcast TWT ID field are ~~is~~ defined in 9.4.2.198 (TWT element) and are reserved if the Teardown All TWT field is 1.

(11ax)The TWT Flow Identifier field in a TWT Teardown frame is set to the value of the TWT Flow Identifier field of the TWT element in the frame that successfully concluded the setup of the TWT that is the subject of the teardown request. The Broadcast TWT ID field of a TWT Teardown frame is set to the value of the Broadcast TWT identifier of the broadcast TWT schedule that is subject of the teardown request.

(11ax)The Negotiation Type subfield indicates the type of negotiation that is subject to the teardown request and is set as defined in Table 9-346 (Interpretation of Negotiation Type subfield and of Target Wake Time, TWT Wake Interval Mantissa, and TWT Wake Interval Exponent subfields(11ax)). An S1G STA sets the


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Negotiation Type subfield to 0. The Negotiation Type subfield is reserved if the Teardown All TWT field is 1.

(11ax)The Teardown All TWT field is set to 1 by an HE STA to indicate that the TWT Teardown frame tears down all TWTs as defined in 26.8 (TWT operation). Otherwise, it is set to 0.

### 9.6.24.10 Sectorized Group ID List frame format

The Sectorized Group ID List frame is an Action or Action No Ack frame of category Unprotected S1G Action. The frame is used to allocate/change sectorized group IDs to a STA. The format of its Action field is defined in Table 9-619 (Sectorized Group ID List frame Action field format).

**Table 9-619—Sectorized Group ID List frame Action field format**

| Order | Information |
|---|---|
| 1 | Category |
| 2 | Unprotected S1G Action |
| 3 | Sectorized Group ID List (9.4.2.210 (Sectorized Group ID List element)) |

The Category field is defined in 9.4.1.11 (Action field).

The Unprotected S1G Action field is defined in 9.6.24.1 (Unprotected S1G Action field).

The Sectorized Group ID List field contains a Sectorized Group ID List as specified in 9.4.2.210 (Sectorized Group ID List element).

### 9.6.24.11 Sector ID Feedback frame format

The Sector ID Feedback frame is an Action or Action No Ack frame of category Unprotected S1G. The format of its Action field is defined in Table 9-620 (Sector ID Feedback frame Action field format).

**Table 9-620—Sector ID Feedback frame Action field format**

| Order | Information |
|---|---|
| 1 | Category |
| 2 | Unprotected S1G Action |
| 3 | Sector ID Index |

The Category field is defined in 9.4.1.11 (Action field).

The Unprotected S1G Action field is defined in 9.6.24.1 (Unprotected S1G Action field).

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The Sector ID index field is shown in Figure 9-1317 (Sector ID Index format).

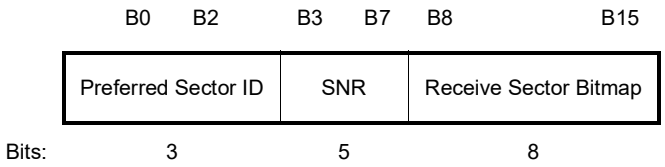


**Figure 9-1317—Sector ID Index format**

The Preferred Sector ID field indicates the sector selected by the STA. The method in which a STA selects the Sector ID is out of the scope of this standard.

The SNR field indicates the received SNR at the preferred Sector, 0 to 30 represents SNR values from –3 to 27 dB, respectively. If the SNR value is less than –3 dB, set to 0. If the SNR value is greater than 27 dB, set to 30. 31 indicates no feedback.

The Receive Sector Bitmap field indicates a bit map. A bit position equal to 0 within the bit map indicates that the STA does not receive the AP signal in the corresponding Sector ID. A bit position equal to 1 within the bit map indicates that the STA does receive the AP signal in the corresponding Sector ID. The position of the bit map (0 to 7) corresponding to the sector ID (see Figure 9-1318 (Receive Sector Bitmap format)).

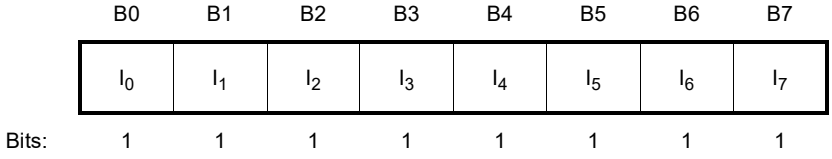


**Figure 9-1318—Receive Sector Bitmap format**

### 9.6.24.12 TWT Information frame format

The TWT Information frame is sent by a STA to request or deliver information about a TWT(11ax) and is transmitted by either STA of an existing TWT agreement (11ax)or is transmitted by a STA to a peer STA that has indicated support of its reception. The Action field of the TWT Information frame contains the information shown in Table 9-621 (TWT Information frame Action field format).

**Table 9-621—TWT Information frame Action field format**

| Order | Information |
|---|---|
| 1 | Category |
| 2 | Unprotected S1G Action |
| 3 | TWT Information (9.4.1.58 (TWT Information field)) |

The Category field is defined in 9.4.1.11 (Action field).

The Unprotected S1G Action field is defined in 9.6.24.1 (Unprotected S1G Action field).


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### 9.6.25 S1G Action frame details

#### 9.6.25.1 S1G Action field

The S1G Action field values are specified in Table 9-622 (S1G Action field values).

**Table 9-622—S1G Action field values**

| S1G Action field value | Description |
|---|---|
| 0 | Reachable Address Update |
| 1 | Relay Activation Request |
| 2 | Relay Activation Response |
| 3 | Header Compression(#1275) |
| 4 | Protected TWT Setup |
| 5 | Protected TWT Teardown |
| 6 | Protected TWT Information |
| 7(#1276) | Protected AID Switch Request |
| 8(#1276) | Protected AID Switch Response |
| 9(#1276) | Protected Sync Control |
| 10(#1276) | Protected STA Information Announcement |
| 11(#1276) | Protected EDCA Parameter Set |
| 12(#1276) | Protected EL Operation |
| 13(#1276) | Protected Sectorized Group ID List |
| 14(#1276) | Protected Sector ID Feedback |
| (#1276)15–255 | Reserved |

#### 9.6.25.2 Reachable Address Update frame format

The Reachable Address Update frame is used to update the addresses that can be reached through a relay STA. The format of the Reachable Address Update frame Action field is shown in Table 9-623 (Reachable Address Update frame Action field format).

**Table 9-623—Reachable Address Update frame Action field format**

| Order | Information |
|---|---|
| 1 | Category |
| 2 | S1G Action |
| 3 | Reachable Address |

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The Category field is defined in 9.4.1.11 (Action field).

The S1G Action field is defined in 9.6.25.1 (S1G Action field).

The Reachable Address element (as specified by 9.4.2.204 (Reachable Address element)) contains the addresses whose reachability through the S1G relay STA is being updated.

### 9.6.25.3 Relay Activation Request frame format

The Relay Activation Request frame is used by the STA or AP to Request start or terminate a relay function. The format of the Relay Activation Request frame Action field is shown in Table 9-624 (Relay Activation Request frame Action field format).

**Table 9-624—Relay Activation Request frame Action field format**

| Order | Information |
|---|---|
| 1 | Category |
| 2 | S1G Action |
| 3 | Relay Activation |

The Category field is defined in 9.4.1.11 (Action field).

The S1G Action field is defined in 9.6.25.1 (S1G Action field).

The Relay Activation Mode subfield of the S1G Relay Activation element (as specified by 9.4.2.205 (S1G Relay Activation element)) included in the Relay Activation Request frame is set to 1.

### 9.6.25.4 Relay Activation Response frame format

The Relay Activation Response frame is used by the STA or AP to confirm or reject the start or the termination of the relay function. The format of the Relay Activation Response frame Action field is shown in Table 9-625 (Relay Activation Response frame Action field format).

**Table 9-625—Relay Activation Response frame Action field format**

| Order | Information |
|---|---|
| 1 | Category |
| 2 | S1G Action |
| 3 | Relay Activation |

The Category field is defined in 9.4.1.11 (Action field).

The S1G Action field is defined in 9.6.25.1 (S1G Action field).

The Relay Activation Mode subfield of the S1G Relay Activation element (as specified by 9.4.2.205 (S1G Relay Activation element)) included in the Relay Activation Response frame is set to 0.


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### 9.6.25.5 Header Compression frame format

The Header Compression frame is used to update information at the recipient STA, as defined in 10.57 (Generation of PV1 MPDUs and header compression procedure). The Header Compression frame Action field contains the information shown in Table 9-626 (Header Compression frame Action field format).

**Table 9-626—Header Compression frame Action field format**

| Order | Information |
|---|---|
| 1 | Category |
| 2 | S1G Action |
| 3 | Dialog Token |
| 4 | Header Compression (see 9.4.2.212 (Header Compression element)) |

The Category field is defined in 9.4.1.11 (Action field).

The S1G Action field is defined in 9.6.25.1 (S1G Action field).

(#417)The Dialog Token field is defined in 9.4.1.12 (Dialog Token field). It is is a value chosen by the STA sending the Header Compression frame to identify the request/response transaction.

The Header Compression field contains a Header Compression element as specified in 9.4.2.212 (Header Compression element).

### 9.6.25.6 Protected TWT Setup frame format

The Protected TWT Setup frame allows robust STA-STA communication of the same information that is conveyed in the TWT Setup frame that is not robust (see 9.6.24.1 (Unprotected S1G Action field)).

The Action field of the Protected TWT Setup frame has the same format as the Action field of the unprotected TWT Setup frame (see 9.6.24.8 (TWT Setup frame format)), except that the Order 2 item is the S1G Action field, which is defined in 9.6.25.1 (S1G Action field), instead of the Unprotected S1G Action field.

### 9.6.25.7 Protected TWT Teardown frame format

The Protected TWT Teardown frame allows robust STA-STA communication of the same information that is conveyed in the TWT Teardown frame that is not robust (see 9.6.24.1 (Unprotected S1G Action field)).

The Action field of the Protected TWT Teardown frame has the same format as the Action field of the unprotected TWT Teardown frame (see 9.6.24.9 (TWT Teardown frame format)), except that the Order 2 item is the S1G Action field, which is defined in 9.6.25.1 (S1G Action field), instead of the Unprotected S1G Action field.

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#### 9.6.25.8 Protected TWT Information frame format

The Protected TWT Information frame allows robust STA-STA communication of the same information that is conveyed in the TWT Information frame that is not robust (see 9.6.24.1 (Unprotected S1G Action field)).

The Action field of the Protected TWT Information frame has the same format as the Action field of the unprotected TWT Information frame (see 9.6.24.12 (TWT Information frame format)), except that the Order 2 item is the S1G Action field, which is defined in 9.6.25.1 (S1G Action field), instead of the Unprotected S1G Action field.

#### 9.6.25.9 Protected AID Switch Request frame format(#1276)

The Protected AID Switch Request frame allows robust STA-STA communication of the same information that is conveyed in the AID Switch Request frame that is not robust (see 9.6.24.1 (Unprotected S1G Action field)).

The Action field of the Protected AID Switch Request frame has the same format as the Action field of the unprotected AID Switch Request frame (see 9.6.24.2 (AID Switch Request frame format)), except that the Order 2 item is the S1G Action field, which is defined in 9.6.25.1 (S1G Action field), instead of the Unprotected S1G Action field.

#### 9.6.25.10 Protected AID Switch Response frame format(#1276)

The Protected AID Switch Response frame is an Action frame of category S1G and is defined to allow robust STA-STA communication of the same information that is conveyed in the AID Switch Response frame that is not robust (see 9.6.24.1 (Unprotected S1G Action field)).

The Action field of the Protected AID Switch Response frame has the same format as the Action field of the unprotected AID Switch Response frame (see 9.6.24.3 (AID Switch Response frame format)), except that the Order 2 item is the S1G Action field, which is defined in 9.6.25.1 (S1G Action field), instead of the Unprotected S1G Action field.

#### 9.6.25.11 Protected Sync Control frame format(#1276)

The Protected Sync Control frame is an Action frame of category S1G and is defined to allow robust STA-STA communication of the same information that is conveyed in the Sync Control frame that is not robust (see 9.6.24.1 (Unprotected S1G Action field)).

The Action field of the Protected Sync Control frame has the same format as the Action field of the unprotected Sync Control frame (see 9.6.24.4 (Sync Control frame format)), except that the Order 2 item is the S1G Action field, which is defined in 9.6.25.1 (S1G Action field), instead of the Unprotected S1G Action field.

#### 9.6.25.12 Protected STA Information Announcement frame format(#1276)

The Protected STA Information Announcement frame is an Action frame of category S1G and is defined to allow robust STA-STA communication of the same information that is conveyed in the STA Information Announcement frame that is not robust (see 9.6.24.1 (Unprotected S1G Action field)).

The Action field of the Protected STA Information Announcement frame has the same format as the Action field of the unprotected STA Information Announcement frame (see 9.6.24.5 (STA Information Announcement frame format)), except that the Order 2 item is the S1G Action field, which is defined in 9.6.25.1 (S1G Action field), instead of the Unprotected S1G Action field.


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#### 9.6.25.13 Protected EDCA Parameter Set frame format(#1276)

The Protected EDCA Parameter Set frame is an Action frame of category S1G and is defined to allow robust STA-STA communication of the same information that is conveyed in the EDCA Parameter Set frame that is not robust (see 9.6.24.1 (Unprotected S1G Action field)).

The Action field of the Protected EDCA Parameter Set frame has the same format as the Action field of the unprotected EDCA Parameter Set frame (see 9.6.24.6 (EDCA Parameter Set frame format)), except that the Order 2 item is the S1G Action field, which is defined in 9.6.25.1 (S1G Action field), instead of the Unprotected S1G Action field.

#### 9.6.25.14 Protected EL Operation frame format(#1276)

The Protected EL Operation frame is an Action frame of category S1G and is defined to allow robust STA-STA communication of the same information that is conveyed in the EL Operation frame that is not robust (see 9.6.24.1 (Unprotected S1G Action field)).

The Action field of the Protected EL Operation frame has the same format as the Action field of the unprotected EL Operation frame (see 9.6.24.7 (EL Operation frame format)), except that the Order 2 item is the S1G Action field, which is defined in 9.6.25.1 (S1G Action field), instead of the Unprotected S1G Action field.

#### 9.6.25.15 Protected Sectorized Group ID List frame format(#1276)

The Protected Sectorized Group ID List frame is an Action frame of category S1G and is defined to allow robust STA-STA communication of the same information that is conveyed in the Sectorized Group ID List frame that is not robust (see 9.6.24.1 (Unprotected S1G Action field)).

The Action field of the Protected Sectorized Group ID List frame has the same format as the Action field of the unprotected Sectorized Group ID List frame (see 9.6.24.10 (Sectorized Group ID List frame format)), except that the Order 2 item is the S1G Action field, which is defined in 9.6.25.1 (S1G Action field), instead of the Unprotected S1G Action field.

#### 9.6.25.16 Protected Sector ID Feedback frame format(#1276)

The Protected Sector ID Feedback frame is an Action frame of category S1G and is defined to allow robust STA-STA communication of the same information that is conveyed in the Sector ID Feedback frame that is not robust (see 9.6.24.1 (Unprotected S1G Action field)).

The Action field of the Protected Sector ID Feedback frame has the same format as the Action field of the unprotected Sector ID Feedback frame (see 9.6.24.11 (Sector ID Feedback frame format)), except that the Order 2 item is the S1G Action field, which is defined in 9.6.25.1 (S1G Action field), instead of the Unprotected S1G Action field.

### 9.6.26 Flow Control Action frame details

#### 9.6.26.1 Flow Control Action field

The Flow Control Action field values are specified in Table 9-627 (Flow Control Action field format).

#### 9.6.26.2 Flow Suspension frame format

The Flow Suspension frame is an Action or an Action No Ack frame of category Flow Control Action used by a STA to suspend incoming transmissions for an amount of time indicated in the Suspend Duration field.

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**Table 9-627—Flow Control Action field format**

| Flow Control Action field value | Description | Time priority |
|---|---|---|
| 0 | Flow suspension | Yes when transmitted as an Action no Ack frame |
| 1 | Flow resumption | Yes when transmitted as an Action no Ack frame |
| 2–255 | Reserved | |

The format of the Flow Suspension frame Action field is shown in Table 9-628 (Flow Suspension frame Action field format).

**Table 9-628—Flow Suspension frame Action field format**

| Order | Information |
|---|---|
| 1 | Category |
| 2 | Flow Control Action |
| 3 | Suspend Duration |

The Category field is defined in 9.4.1.11 (Action field).

The Flow Control Action field is defined in 9.6.26.1 (Flow Control Action field).

The Suspend Duration field is 2 octets and denotes the amount of time, in microseconds, during which the intended recipient STAs are not allowed to transmit Data frames to the STA identified by the TA field of the Flow Suspension frame.

### 9.6.26.3 Flow Resumption frame format

The Flow Resumption frame is an Action or an Action No Ack frame of category Flow Control Action used by the STA identified by the TA field of the frame to cancel any outstanding flow suspension time the STA had previously invoked through the transmission of a Flow Suspension, BAT, TACK, STACK, or NDP Ack frame as described in 10.60 (S1G flow control). The format of the Flow Resumption frame Action field is shown in Table 9-629 (Flow Resumption frame Action field format).

**Table 9-629—Flow Resumption frame Action field format**

| Order | Information |
|---|---|
| 1 | Category |
| 2 | Flow Control Action |


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The Category field is defined in 9.4.1.11 (Action field).

The Flow Control Action field is defined in 9.6.26.1 (Flow Control Action field).

### 9.6.27 Control Response MCS Negotiation Action frame details(#3175)

#### 9.6.27.1 Control Response MCS Negotiation Action field

The Control Response MCS Negotiation Action field values are specified in Table 9-630 (Control Response MCS Negotiation Action field values).

**Table 9-630—Control Response MCS Negotiation Action field values**

| MCS Negotiation Action field value | Description |
|---|---|
| 0 | Control Response MCS Negotiation Request |
| 1 | Control Response MCS Negotiation Response |
| 2–255 | Reserved |

#### 9.6.27.2 Control Response MCS Negotiation Request frame format

The Control Response MCS Negotiation Request frame is used by a STA to negotiate with its peer STA the requested MCS for transmitting control response frame as defined in 10.6.6.5.3 (Control response frame MCS computation). The format of the Action field of the Control Response MCS Negotiation Request frame is shown Table 9-631 (Control Response Negotiation Request frame Action field format).

**Table 9-631—Control Response Negotiation Request frame Action field format**

| Order | Information |
|---|---|
| 1 | Category |
| 2 | Control Response MCS Negotiation Action |
| 3 | MCS Difference |

The Category field is defined in 9.4.1.11 (Action field).

The Control Response MCS Negotiation Action field is defined in 9.6.27.1 (Control Response MCS Negotiation Action field).

The MCS Difference field is 1 octet and is set to an unsigned value that represents the MCS difference between the index of the primary MCS and the index of the MCS that is preferred for use by the STA to transmit control response frame as described in 10.6.6.5.6 (Control response MCS negotiation).

#### 9.6.27.3 Control Response MCS Negotiation Response frame format

The Control Response MCS Negotiation Response frame is used to indicate a response to a Control Response MCS Negotiation Request frame, which is either Accept or Reject, and the MCS Difference

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proposed by the Requesting STA. The format of the Action field of the Control Response MCS Negotiation Response frame is shown in Table 9-632 (Control Response MCS Negotiation Response frame Action field format).

**Table 9-632—Control Response MCS Negotiation Response frame Action field format**

| Order | Information |
|---|---|
| 1 | Category |
| 2 | Control Response MCS Negotiation Action |
| 3 | Command |

The Category field is defined in 9.4.1.11 (Action field).

The Control Response MCS Negotiation Action field is defined in 9.6.27.1 (Control Response MCS Negotiation Action field).

The Command field is 1 octet and is set to a value from the Table 9-633 (Command values) to represent accepting or rejecting the proposed MCS Difference by the Control Response MCS Negotiation Request frame as described in 10.6.6.5.6 (Control response MCS negotiation).

**Table 9-633—Command values**

| Values | Description |
|---|---|
| 0 | Reject |
| 1 | Accept |
| 2–255 | Reserved |

### 9.6.28 CDMG Action frame details

#### 9.6.28.1 CDMG Action field

Several Action frame formats are defined to support CDMG features. A CDMG Action field, in the octet immediately after the Category field, differentiates the CDMG Action frame formats. The CDMG Action field values associated with each frame format within the CDMG category are defined in Table 9-634 (CDMG Action field values).

**Table 9-634—CDMG Action field values**

| CDMG Action field value | Meaning |
|---|---|
| 0 | Notification Period Request frame |
| 1 | Notification Period Response frame |
| 2 | Channel Splitting Request frame |
| 3 | Channel Splitting Response frame |


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**Table 9-634—CDMG Action field values *(continued)***

| CDMG Action field value | Meaning |
|---|---|
| 4 | CDMG Allocation Request frame |
| 5 | CDMG Allocation Response frame |

### 9.6.28.2 Notification Period Request frame format

The format of the Notification Period Request frame Action field is shown in Figure 9-1319 (Notification Period Request frame Action field format).

| | Category | CDMG Action | Dialog Token | NP/BHI Duration |
|---|---|---|---|---|
| Octets: | 1 | 1 | 1 | 2 |

**Figure 9-1319—Notification Period Request frame Action field format**

The Category field is defined in 9.4.1.11 (Action field).

The CDMG Action field is defined in 9.6.28.1 (CDMG Action field).

(#417)The Dialog Token field is defined in 9.4.1.12 (Dialog Token field). It is defined in 9.4.1.12 (Dialog Token field) and set by the requesting STA.

The NP/BHI Duration field is set to the length of the NP/BHI duration requested by the STA intending to establish its BSS on a free 1.08 GHz channel to the peer STA operating on the adjacent 1.08 GHz channel.

### 9.6.28.3 Notification Period Response frame format

The format of the Notification Period Response frame Action field is shown in Table 9-635 (Notification Period Response frame Action field format).

**Table 9-635—Notification Period Response frame Action field format**

| Order | Information |
|---|---|
| 0 | Category |
| 1 | CDMG Action |
| 2 | Dialog Token |
| 3 | Status Code |
| 4 | Dynamic Bandwidth Control |

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The Category field is defined in 9.4.1.11 (Action field).

The CDMG Action field is defined in 9.6.28.1 (CDMG Action field).

(#417)The Dialog Token field is defined in 9.4.1.12 (Dialog Token field). It is copied from the corresponding Notification Period Request frame.

The Status Code field indicates the result of the notification period allocation request and is defined in 9.4.1.9 (Status Code field).

The Dynamic Bandwidth Control element is defined in 9.4.2.219 (Dynamic Bandwidth Control element). This element is present if the Status Code field indicates successful; otherwise, it is not present.

### 9.6.28.4 Channel Splitting Request frame format

The format of the Channel Splitting Request frame Action field is shown in Figure 9-1320 (Channel Splitting Request frame Action field format).

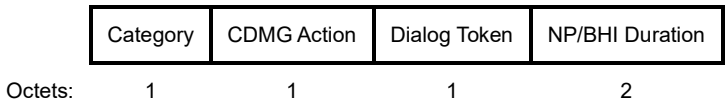


**Figure 9-1320—Channel Splitting Request frame Action field format**

The Category field is defined in 9.4.1.11 (Action field).

The CDMG Action field is defined in 9.6.28.1 (CDMG Action field).

The Dialog Token field is defined in 9.4.1.12 (Dialog Token field) and set by the requesting STA.

The NP/BHI Duration field is set to the length of the NP/BHI duration requested by the STA intending to establish its BSS on a free 1.08 GHz channel to the peer STA operating on the adjacent 1.08 GHz channel.

### 9.6.28.5 Channel Splitting Response frame format

The format of the Channel Splitting Response frame Action field is shown in Table 9-636 (Channel Splitting Response frame Action field format).

**Table 9-636—Channel Splitting Response frame Action field format**

| Order | Information |
|---|---|
| 0 | Category |
| 1 | CDMG Action |
| 2 | Dialog Token |
| 3 | Status Code |
| 4 | Channel Switch Announcement |
| 5 | Beacon Interval |
| 6 | Dynamic Bandwidth Control |


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The Category field is defined in 9.4.1.11 (Action field).

The CDMG Action field is defined in 9.6.28.1 (CDMG Action field).

(#417)The Dialog Token field is defined in 9.4.1.12 (Dialog Token field). It is copied from the corresponding Channel Splitting Request frame.

The Status Code field indicates the result of the channel splitting request and is defined in 9.4.1.11 (Action field).

The Channel Switch Announcement element is defined in 9.4.2.17 (Channel Switch Announcement element). This element is present if the Status Code field indicates successful; otherwise, it is not present.

The Beacon Interval field specifies the beacon interval length on a 2.16 GHz channel set by the STA operating on one of the 1.08 GHz channel after channel splitting and is defined in 9.4.1.3 (Beacon Interval field). This element is present if the Status Code field indicates successful; otherwise, it is not present.

The Dynamic Bandwidth Control element specifies the information of the STA operating on a 1.08 GHz channel after channel splitting and is defined in 9.4.2.219 (Dynamic Bandwidth Control element). This element is present if the Status Code field indicates successful; otherwise, it is not present.

### 9.6.28.6 CDMG Allocation Request frame format

The format of the CDMG Allocation Request frame Action field is shown in Figure 9-1321 (CDMG Allocation Request frame Action field format).

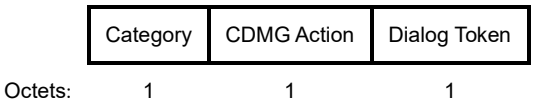


**Figure 9-1321—CDMG Allocation Request frame Action field format**

The Category field is defined in 9.4.1.11 (Action field).

The CDMG Action field is defined in 9.6.28.1 (CDMG Action field).

The Dialog Token field is defined in 9.4.1.12 (Dialog Token field) and set by the requesting STA.

### 9.6.28.7 CDMG Allocation Response frame format

The format of the CDMG Allocation Response frame Action field is shown in Table 9-637 (CDMG Allocation Response frame Action field format).

**Table 9-637—CDMG Allocation Response frame Action field format**

| Order | Information |
|---|---|
| 0 | Category |
| 1 | CDMG Action |
| 2 | Dialog Token |

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**Table 9-637—CDMG Allocation Response frame Action field format *(continued)***

| Order | Information |
|---|---|
| 3 | Status Code |
| 4 | Extended Schedule |

The Category field is defined in 9.4.1.11 (Action field).

The CDMG Action field is defined in 9.6.29.1 (CMMG Action field).

(#417)The Dialog Token field is defined in 9.4.1.12 (Dialog Token field). It is copied from the corresponding CDMG Allocation Request frame.

The Status Code field indicates the result of the Allocation request and is defined in 9.4.1.9 (Status Code field).

The Extended Schedule element indicates all the available time that can be allocated to the DMG STAs on a 2.16 GHz channel by the STA operating on the adjacent 1.08 GHz channel of the STA sending this response and is defined in 9.4.2.130 (Extended Schedule element). This element is present if the Status Code field indicates successful; otherwise, it is not present.

### 9.6.29 CMMG Action frame details

#### 9.6.29.1 CMMG Action field

Several Action frame formats are defined to support CMMG functionality. A CMMG Action field, in the octet immediately after the Category field, differentiates the CMMG Action frame formats. The CMMG Action field values associated with each frame format within the CMMG category are defined in Table 9-638 (CMMG Action field values).

**Table 9-638—CMMG Action field values**

| Value | Meaning | Time priority |
|---|---|---|
| 0 | CMMG CSI | Yes |
| 1 | CMMG Compressed Beamforming | Yes |
| 2 | CMMG Operating Mode Notification | Yes |
| 3–255 | Reserved | |

#### 9.6.29.2 CMMG Compressed Beamforming frame format

The CMMG Compressed Beamforming frame is an Action or an Action No Ack frame of category CMMG. The format of its Action field is defined in Table 9-639 (CMMG Compressed Beamforming frame Action field format).

The Category field is defined in 9.4.1.11 (Action field).

The CMMG Action field is defined in 9.6.29.1 (CMMG Action field).


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**Table 9-639—CMMG Compressed Beamforming frame Action field format**

| Order | Information |
|---|---|
| 1 | Category |
| 2 | CMMG Action |
| 3 | CMMG MIMO Control (see 9.4.1.59 (CMMG MIMO Control field)) |
| 4 | CMMG Compressed Beamforming Report (see 9.4.1.60 (CMMG Compressed Beamforming Report field)) |

The CMMG MIMO Control field (see 9.4.1.59 (CMMG MIMO Control field)) are used as described in Table 9-115 (Subfields of the CMMG MIMO Control field).

The CMMG Compressed Beamforming Report field is defined in 9.4.1.60 (CMMG Compressed Beamforming Report field).

### 9.6.29.3 CMMG Operating Mode Notification frame format

The CMMG Operating Mode Notification frame is used to notify STAs that the transmitting STA is changing its operating channel width, the maximum number of spatial streams it can receive, or both.

In the context of CMMG STAs, references to an Operating Mode Notification frame or element should be understood as referring to a CMMG Operating Mode Notification frame or element, respectively.

The Action field of the CMMG Operating Mode Notification frame contains the information shown in Table 9-640 (CMMG Operating Mode Notification frame Action field format).

**Table 9-640—CMMG Operating Mode Notification frame Action field format**

| Order | Information |
|---|---|
| 1 | Category |
| 2 | CMMG Action |
| 3 | CMMG Operating Mode (see 9.4.1.61 (CMMG Operating Mode field)) |

The Category field is defined in 9.4.1.11 (Action field).

The CMMG Action field is defined in 9.6.29.1 (CMMG Action field).

The CMMG Operating Mode field is defined in 9.4.1.61 (CMMG Operating Mode field).

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### 9.6.30 GLK Action frame details

#### 9.6.30.1 GLK Action field

A GLK Action field, in the octet immediately after the Category field, differentiates the GLK Action frame formats. The GLK Action field values associated with each frame format within the GLK category are defined in Table 9-641 (GLK Action field values(#1707)).

**Table 9-641—GLK Action field values(#1707)**

| Value | Meaning |
|---|---|
| 0 | GLK Groupcast Mode Change Notification |
| 1–255 | Reserved |

#### 9.6.30.2 GLK Groupcast Mode Change Notification

The GLK Groupcast Mode Change Notification frame is used to indicate a change to the GLK groupcast transmission policy. See Table 9-642 (GLK Groupcast Mode Change Notification frame format).

**Table 9-642—GLK Groupcast Mode Change Notification frame format**

| Order | Information |
|---|---|
| 1 | Category |
| 2 | GLK Action |
| 3 | GLK-GCR Parameter Set |

The Category field is defined in 9.4.1.11 (Action field). The GLK Action field is defined in 9.6.30.1 (GLK Action field). The GLK-GCR Parameter Set element is defined in 9.4.2.233 (GLK-GCR Parameter Set element).

### 9.6.31 HE Action frame details(11ax)

#### 9.6.31.1 HE Action field

An HE Action field, in the octet immediately after the Category field, differentiates the HE Action frame formats. The HE Action field values associated with each frame format within the HE category are defined in Table 9-643 (HE Action field values(#3764)(11ax)).

**Table 9-643—HE Action field values(#3764)(11ax)**

| Value | Meaning | Time priority |
|---|---|---|
| 0 | HE Compressed Beamforming/CQI | Yes |


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**Table 9-643—HE Action field values(#3764)(11ax) *(continued)***

| | | |
|---|---|---|
| 1 | Quiet Time Period | No |
| 2 | OPS | No |
| 3–255 | Reserved | |

### 9.6.31.2 HE Compressed Beamforming/CQI frame format

The HE Compressed Beamforming/CQI frame is an Action No Ack frame of category HE. The Action field of an HE Compressed Beamforming/CQI frame contains the information shown in Table 9-644 (HE Compressed Beamforming/CQI frame Action field format(11ax)).

**Table 9-644—HE Compressed Beamforming/CQI frame Action field format(11ax)**

| Order | Information | Notes |
|---|---|---|
| 1 | Category | |
| 2 | HE Action | |
| 3 | HE MIMO Control (see 9.4.1.62 (HE MIMO Control field(11ax))) | |
| 4 | HE Sounding Feedback Segment (see 9.4.1.67 (HE Sounding Feedback Segment field(#6006)))(#6006) | Optional |

The Category field is defined in Table 9-81 (Category values).

The HE Action field is defined in 9.6.31.1 (HE Action field).(#4199)(#6006)

A Vendor Specific element is not present in the HE Compressed Beamforming/CQI frame.

### 9.6.31.3 Quiet Time Period action frame format

The Quiet Time Period action frame is an Action No Ack frame of category HE. The Action field of a Quiet Time Period contains the information shown in Table 9-645 (Quiet Time Period frame body(11ax)).

**Table 9-645—Quiet Time Period frame body(11ax)**

| Order | Information |
|---|---|
| 1 | Category |
| 2 | HE Action |
| 3 | Quiet Time Period element (see 9.4.2.254 (Quiet Time Period element(11ax))) |

The Category field is defined in Table 9-81 (Category values).

The HE Action field is defined in 9.6.31.1 (HE Action field).(#4199)

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The Quiet Time Period element is defined in 9.4.2.254 (Quiet Time Period element(11ax)).

#### 9.6.31.4 OPS frame format

The OPS frame is an Action No Ack frame of category HE. The Action field of an OPS frame contains the information shown in Table 9-646 (OPS frame Action field format(11ax)).

**Table 9-646—OPS frame Action field format(11ax)**

| Order | Information |
|---|---|
| 1 | Category |
| 2 | HE Action |
| 3 | TIM element (see 9.4.2.5 (TIM element)) |
| 4 | OPS element (see 9.4.2.256 (OPS element(11ax))) |

The Category field is defined in Table 9-81 (Category values).

The HE Action field is defined in 9.6.31.1 (HE Action field).(#4199)

### 9.6.32 Protected HE Action frame details(11ax)

#### 9.6.32.1 Protected HE Action field

A Protected HE Action field, in the octet immediately after the Category field, differentiates the Protected HE Action frame formats. The Protected HE Action field values associated with each frame format within the (#2217)Protected HE category are defined in Table 9-647 (Protected HE Action field values(11ax)).

**Table 9-647—Protected HE Action field values(11ax)**

| Value | Meaning |
|---|---|
| 0 | HE BSS Color Change Announcement |
| 1 | MU EDCA Reset |
| 2–255 (#3764) | Reserved |


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### 9.6.32.2 HE BSS Color Change Announcement frame format

The HE BSS Color Change Announcement frame is an Action or Action No Ack frame of category Protected HE. The Action field of an HE BSS Color Change Announcement frame contains the information shown in Table 9-648 (HE BSS Color Change Announcement frame Action field format(11ax)).

**Table 9-648—HE BSS Color Change Announcement frame Action field format(11ax)**

| Order | Information |
|---|---|
| 1 | Category |
| 2 | Protected HE Action |
| 3 | BSS Color Change Announcement element (see 9.4.2.253 (BSS Color Change Announcement element(11ax))) |

NOTE—An HE AP might send an HE BSS Color Change Announcement frame as an Action frame to a STA that appears to have missed a color change announcement and is transmitting with the old color.

The Category field is defined in Table 9-81 (Category values).

The Protected HE Action field is defined in 9.6.32.1 (Protected HE Action field).(#4199)

### 9.6.32.3 MU EDCA Reset frame format

The MU EDCA Reset frame is an Action frame of category Protected HE. The Action field of an MU EDCA Reset frame contains the information shown in Table 9-649 (MU EDCA Reset frame Action field format(11ax)).

**Table 9-649—MU EDCA Reset frame Action field format(11ax)**

| Order | Information |
|---|---|
| 1 | Category |
| 2 | Protected HE Action |
| 3 | MU EDCA Control |

The Category field is defined in Table 9-81 (Category values).

The Protected HE Action field is defined in 9.6.32.1 (Protected HE Action field).(#4199)

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The MU EDCA Control field is defined in Figure 9-1322 (MU EDCA Control field format(11ax)).

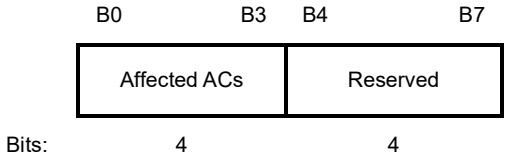


**Figure 9-1322—MU EDCA Control field format(11ax)**

The Affected ACs subfield contains a bitmap that indicates the ACs for which the MUEDCATimer[AC] as defined in 26.2.7 (EDCA operation using MU EDCA parameters) are reset to 0 upon receipt of the MU EDCA Reset frame for affected STAs. Each bit in the bitmap corresponds to one AC with B0 mapped to AC_BK, B1 mapped to AC_BE, B2 mapped to AC_VI and B3 mapped to AC_VO. A value of 1 in the bit position corresponding to a given AC indicates that the MUEDCATimer[AC] for that AC is reset to 0; otherwise, the value of the bit is 0.

### 9.6.33 WUR Action frame details(#3175)(11ba)

#### 9.6.33.1 WUR Action field

Several Action frame formats are defined to support WUR functionalities. A WUR Action field, in the octet field immediately after the Category field, differentiates the formats. The WUR Action field values associated with each frame format are defined in Table 9-650 (WUR Action field values(11ba)).

**Table 9-650—WUR Action field values(11ba)**

| Value | Meaning |
|---|---|
| 0 | WUR Mode Setup |
| 1 | WUR Mode Teardown |
| 2 | WUR Wake-up Indication |
| 3–255 | Reserved |

#### 9.6.33.2 WUR Mode Setup frame format

The WUR Mode Setup frame is an Action frame of category WUR. The Action field of a WUR Mode Setup frame contains the information shown in Table 9-651 (WUR Mode Setup frame Action field format(11ba)).

**Table 9-651—WUR Mode Setup frame Action field format(11ba)**

| Order | Information |
|---|---|
| 1 | Category |
| 2 | WUR Action |


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**Table 9-651—WUR Mode Setup frame Action field format(11ba)**

| Order | Information |
|---|---|
| 3 | Dialog Token |
| 4 | WUR Mode element (see 9.4.2.292 (WUR Mode element(11ba))) |
| 5 | WUR Operation element (optional) (see 9.4.2.291 (WUR Operation element(11ba))) |
| 6 | WUR PN Update (optional) (see 9.4.2.294 (WUR PN Update element(11ba))) |

The Category field is defined in Table 9-81 (Category values).

The WUR Action field is defined in 9.6.33.1 (WUR Action field).(#4199)

The Dialog Token field is defined in 9.4.1.12 (Dialog Token field).

In a WUR Mode Setup frame with the Action Type field of the WUR Mode element equal to "Enter WUR Mode Suspend Request" or "Enter WUR Mode Request", the Dialog Token field is set to a nonzero value chosen by the transmitting STA to identify the request/response transaction.

In a WUR Mode Setup frame with the Action Type field of the WUR Mode element equal to "Enter WUR Mode Suspend Response" or "Enter WUR Mode Response", the Dialog Token field is set to the value copied from the corresponding received WUR Mode Setup frame with the Action Type field of the carrying WUR Mode element equal to "Enter WUR Mode Suspend Request" or "Enter WUR Mode Request"

In a WUR Mode Setup frame with the Action Type field of the WUR Mode element equal to "Enter WUR Mode Suspend" or "Enter WUR Mode", the Dialog Token field is set to 0.

The WUR Mode element field contains a WUR Mode element as defined in 9.4.2.292 (WUR Mode element(11ba)).

The WUR Operation element field contains a WUR Operation element as defined in 9.4.2.291 (WUR Operation element(11ba)).

The WUR PN Update field contains one or more WUR PN Update elements as defined in 9.4.2.294 (WUR PN Update element(11ba)).

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### 9.6.33.3 WUR Mode Teardown frame format

The WUR Mode Teardown frame is an Action frame of category WUR. The Action field of a WUR Mode Teardown frame contains the information shown in Table 9-652 (WUR Mode Teardown frame Action field format(11ba)).

**Table 9-652—WUR Mode Teardown frame Action field format(11ba)**

| Order | Information |
|---|---|
| 1 | Category |
| 2 | WUR Action |

The Category field is defined in Table 9-81 (Category values).

The WUR Action field is defined in 9.6.33.1 (WUR Action field).(#4199)

### 9.6.33.4 WUR Wake-up Indication frame format

The WUR Wake-up Indication frame is an Action frame of category WUR. The Action field of a WUR Wake-up Indication frame contains the information shown in Table 9-653 (WUR Wake-up Indication frame Action field format(11ba)).

**Table 9-653—WUR Wake-up Indication frame Action field format(11ba)**

| Order | Information |
|---|---|
| 1 | Category |
| 2 | WUR Action |
| 3 | WUR Wake-up Indication |

The Category field is defined in Table 9-81 (Category values).

The WUR Action field is defined in 9.6.33.1 (WUR Action field).(#4199)

The WUR Wake-up Indication field is 8 bits in size and contains an unsigned integer.

The WUR Wake-up Indication field is defined in Table 9-654 (WUR Wake-up Indication field values (11ba)).

**Table 9-654—WUR Wake-up Indication field values (11ba)**

| Value | Description |
|---|---|
| 0 | UNSOLICITED_WAKEUP |
| 1–255 | Reserved |


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### 9.6.34 Protected Fine Timing Action frame details(11az)(#8155)

#### 9.6.34.1 Protected Fine Timing Action field

The Protected Fine Timing Action field, in the octet immediately after the Category field(#8217), differentiates between various Protected Fine Timing frames as shown in the Table 9-655 (Protected Fine Timing Action field values(11az)).

**Table 9-655—Protected Fine Timing Action field values(11az)**

| Value | Meaning |
|---|---|
| 0 | Reserved. |
| 1 | Protected FTMR frame. The format of frame after the Action field is identical to the format of the FTM Request frame; see 9.6.7.32 (FTM(11az) Request frame format). It is carried in an Action frame.(#8215) |
| 2 | Protected FTM frame. The format of the frame after the Action field is identical to the format of the FTM frame; see 9.6.7.33 (FTM(11az) frame format). It is carried in an Action frame.(#8215) |
| 3 | Protected LMR frame. The format of the frame after the Action field is identical to the format of the (#8216)LMR frame(#8215); see 9.6.7.49 (LMR frame format(11az)(#8216)). It is carried in an Action No Ack frame.(#8215) |
| 4–255 | Reserved. |

### 9.6.35 EBCS Action frame details(11bc)

#### 9.6.35.1 EBCS Action field

Two Action frame formats are defined to support EBCS functionalities. The EBCS Action field, in the octet field immediately after the Category field, differentiates the formats. The EBCS Action field values associated with each frame format are defined in Table 9-656 (EBCS Action field values(11bc)).

**Table 9-656—EBCS Action field values(11bc)**

| Value | Meaning |
|---|---|
| 0 | EBCS content request |
| 1 | EBCS content response |
| 2–255 | Reserved |

#### 9.6.35.2 EBCS Content Request frame format

The EBCS Content Request frame is an Action frame of category EBCS. The EBCS Content Request frame is transmitted by a STA to its associated EBCS AP to request one or more EBCS traffic streams. The Action field of an EBCS Content Request frame contains the information shown in Table 9-657 (EBCS Content Request frame Action field format(11bc)).

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**Table 9-657—EBCS Content Request frame Action field format(11bc)**

| Order | Information |
|---|---|
| 1 | Category |
| 2 | EBCS Action |
| 3 | Dialog Token |
| 4 | EBCS Content Request |

The Category field is defined in Table 9-81 (Category values).

The EBCS Action field is set to 0 to indicate an EBCS content request as defined in Table 9-656 (EBCS Action field values(11bc)).

The Dialog Token field is defined in 9.4.1.12 (Dialog Token field).

In an EBCS Content Request frame, the Dialog Token field is set to a nonzero value chosen by the transmitting STA to identify the request/response transaction.

The EBCS Content Request field is defined in 9.4.1.68 (EBCS Content Request field(11bc)).

### 9.6.35.3 EBCS Content Response frame format

The EBCS Content Response frame is an Action frame of category EBCS. The EBCS Content Response frame is transmitted by an EBCS AP to an associated EBCS non-AP STA in response to an EBCS Content Request frame received from the EBCS STA. The Action field of an EBCS Content Response frame contains the information shown in Table 9-658 (EBCS Content Response frame Action field format(11bc)).

**Table 9-658—EBCS Content Response frame Action field format(11bc)**

| Field | Information |
|---|---|
| 1 | Category |
| 2 | EBCS Action |
| 3 | Dialog Token |
| 4 | EBCS Content Response |

The Category field is defined in Table 9-81 (Category values).

The EBCS Action field is set to 1 to indicate an EBCS content response as defined in Table 9-656 (EBCS Action field values(11bc)).

The Dialog Token field is defined in 9.4.1.12 (Dialog Token field). The Dialog Token field is set to the value contained in the Dialog Token field in the corresponding received EBCS Content Request frame.


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The EBCS Content Response field is defined in 9.4.1.69 (EBCS Content Response field(11bc)).

## 9.7 Aggregate MPDU (A-MPDU)

### 9.7.1 A-MPDU format

An A-MPDU consists of a sequence of one or more A-MPDU subframes and a variable amount of EOF padding as shown in Figure 9-1323 (A-MPDU format).

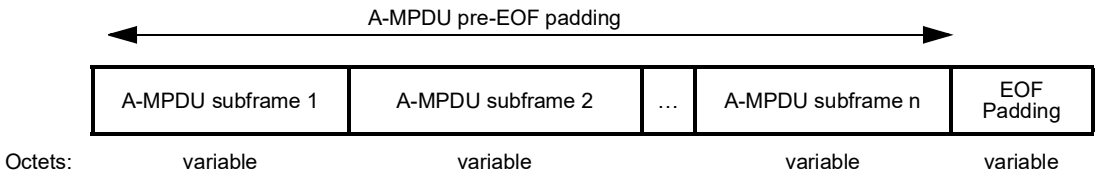


**Figure 9-1323—A-MPDU format**

The structure of the A-MPDU subframe is shown in Figure 9-1325 (A-MPDU subframe format). Each A-MPDU subframe consists of an MPDU delimiter optionally followed by an MPDU. Each nonfinal A-MPDU subframe in an A-MPDU has padding octets appended to make the subframe a multiple of 4 octets in length. The content of these octets is unspecified.

In an HT, DMG or NGV PPDU(11bd), the final A-MPDU subframe is not padded. In a VHT, (11ay)EDMG, or S1G PPDU, padding is added as described below.

The EOF Padding field is shown in Figure 9-1324 (EOF Padding field format). This is present only in a VHT, (11ay)EDMG, S1G, or HE PPDU.(11ax)

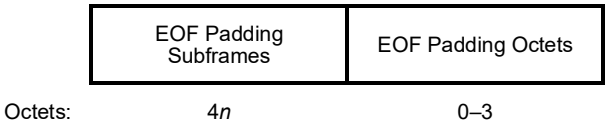


**Figure 9-1324—EOF Padding field format**

The EOF Padding Subframes subfield contains zero or more EOF padding subframes. An EOF padding subframe is an A-MPDU subframe with 0 in the MPDU Length field and 1 in the EOF/Tag(#4367) field.

In a VHT, EDMG,(11ay) S1G, or HE PPDU(11ax), the following padding is present, as determined by the rules in 10.12.6 (A-MPDU padding for VHT, HE(11ax) or S1G PPDU):

— 0–3 octets in the Padding subfield of the final A-MPDU subframe (see Figure 9-1325 (A-MPDU subframe format)) before any EOF padding subframes. The content of these octets is unspecified.
— Zero or more EOF padding subframes in the EOF Padding Subframes subfield.
— 0–3 octets in the EOF Padding Octets subfield. The content of these octets is unspecified.

An A-MPDU pre-EOF padding refers to the contents of the A-MPDU up to, but not including, the EOF Padding field.

NOTE 1—A-MPDU pre-EOF padding includes any A-MPDU subframes with 0 in the MPDU Length field and 0 in the EOF/Tag field inserted in order to meet the minimum MPDU start spacing requirement.(11ax)

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The maximum length of an A-MPDU in an HT PPDU is 65 535 octets. The maximum length of an A-MPDU in a DMG PPDU is 262 143 octets. The maximum length of an A-MPDU pre-EOF padding in a VHT PPDU is 1 048 575 octets. (11ax)The maximum length of an A-MPDU pre-EOF padding in an HE PPDU is 6 500 631 octets. (11ay)(#4367)The maximum length of an A-MPDU in an EDMG PPDU is 4 194 303 octets. The length of an A-MPDU addressed to a particular STA can be further constrained as described in 10.12.2 (A-MPDU length limit rules).

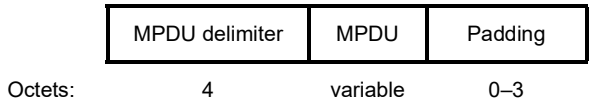


**Figure 9-1325—A-MPDU subframe format**

(11ay)The structure of the MPDU delimiter is defined in Figure 9-1326 (MPDU delimiter(11ay)(#4367)).

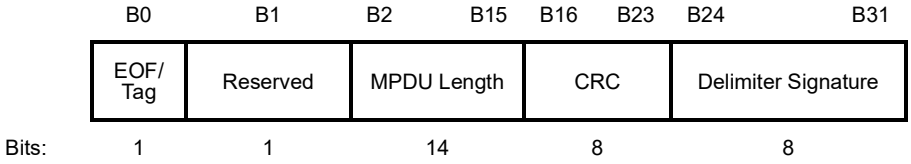


**Figure 9-1326—MPDU delimiter(11ay)(#4367)**

(11ay)The fields of the MPDU delimiter are defined in Table 9-659 (MPDU delimiter fields(11ay)).

**Table 9-659—MPDU delimiter fields(11ay)**

| Field | Size (bits) | Description |
|---|---|---|
| EOF/Tag(11ax) | 1 | End of frame indication if the MPDU Length field is 0. Set to 1 in an A-MPDU subframe that has 0 in the MPDU Length field and that is used to pad the A-MPDU in a VHT or HE PPDU as described in 10.12.6 (A-MPDU padding for VHT, HE(11ax) or S1G PPDU). Set to 1 in the MPDU delimiter of an S-MPDU as described in 10.12.7 (Setting the EOF/Tag(11ax) field of the MPDU delimiter).(11ax)<br><br>(11ax)Tagged/untagged indication if the MPDU Length field is nonzero. Set to 1 in an MPDU delimiter preceding a QoS Data frame or Management frame soliciting an Ack frame or Per AID TID Info field with the Ack Type field set to 1 in a Multi-STA BlockAck frame in a response that is contained in an ack-enabled multi-TID A-MPDU as described in 26.6.3.4 (Ack-enabled multi-TID A-MPDU operation)and ack-enabled single-TID A-MPDU as described in 26.6.3.2 (Ack-enabled single-TID A-MPDU operation). Set to 0 otherwise.<br><br>(11ay)In a DMG PPDU, this field is reserved. In an EDMG PPDU, it is set to 1 in EOF padding subframes and set to 0 otherwise (see 10.12.7 (Setting the EOF/Tag(11ax) field of the MPDU delimiter)). |
| Reserved | 1 | |


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**Table 9-659—MPDU delimiter fields(11ay)**

| | | |
|---|---|---|
| MPDU Length | 14 | Length of the MPDU in octets. Set to 0 if no MPDU is present. An A-MPDU subframe with 0 in the MPDU Length field is used as defined in 10.12.3 (Minimum MPDU start spacing rules) to meet the minimum MPDU start spacing requirement and also to pad the A-MPDU to fill the available octets in a VHT (11ax)or HE PPDU as defined in 10.12.6 (A-MPDU padding for VHT, HE(11ax) or S1G PPDU). |
| CRC | 8 | 8-bit CRC of the preceding 16 bits.(#346) |
| Delimiter Signature | 8 | Pattern that can be used to detect an MPDU delimiter when scanning for an MPDU delimiter.<br>The unique pattern is 0x4E, which is the ASCII value of the character "N".(11ax) |

The format of the MPDU Length field when transmitted by a non-DMG STA is shown in Figure 9-1327 (MPDU Length field format (non-DMG)). The MPDU Length Low subfield contains the 12 low order bits of the MPDU length. In a VHT or HE PPDU(11ax), the MPDU Length High subfield contains the two high order bits of the MPDU length. In an HT PPDU, the MPDU Length High subfield is reserved.

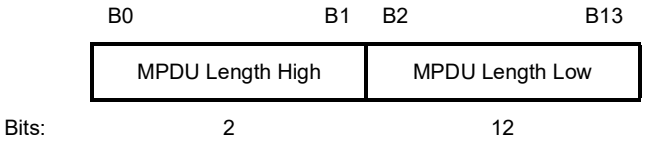


**Figure 9-1327—MPDU Length field format (non-DMG)**

(11ay)The format of the MPDU Length field when transmitted by a DMG STA is shown in Figure 9-1328 (MPDU Length field format (DMG)(11ay)). The MPDU Length Low subfield contains the 13 low order bits of the MPDU length. The MPDU Length High subfield contains one high order bit of the MPDU length.

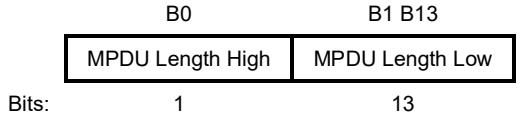


**Figure 9-1328—MPDU Length field format (DMG)(11ay)**

The MPDU length value is derived from the MPDU Length field subfields as follows:(11ax)(11ay)

$$L_{MPDU} = \begin{cases} L_{low} + L_{high} \times 4096, & \text{for a VHT and HE PPDU} \\ L_{low}, & \text{for an HT PPDU} \\ L_{low} + L_{high} \times 8192, & \text{for a DMG and EDMG PPDU} \end{cases} \quad (9\text{-}16)$$

where

$L_{low}$ is the value of the MPDU Length Low subfield

$L_{high}$ is the value of the MPDU Length High subfield

$L$ is the value of the MPDU Length field

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NOTE 2—The format of the MPDU Length field maintains a common encoding structure for HE, VHT, and HT PPDUs(11ax). For HT PPDUs, only the MPDU Length Low subfield is used, while for VHT and HE(11ax) PPDUs, both subfields are used.

### 9.7.2 MPDU delimiter CRC field

The purpose of the MPDU delimiter is to locate the MPDUs within the A-MPDU so that the structure of the A-MPDU can usually be recovered when one or more MPDU delimiters are received with errors. See O.2 (A-MPDU deaggregation) for a description of a deaggregation algorithm.

(#346)The MPDU delimiter CRC field (#4162)is a CRC value used as a check sequence to protect the fields that precede it in the MPDU delimiter. The CRC field is the 1s complement of the remainder generated by the modulo 2 division of the protected bits by the polynomial $x^8 + x^2 + x^1 + 1$, where the shift-register state is preset to all 1s.

NOTE—The order of transmission of bits within the CRC field is defined in 9.2.2 (Conventions).

Figure 9-1329 (MPDU delimiter CRC calculation) illustrates the CRC calculation for the MPDU delimiter.

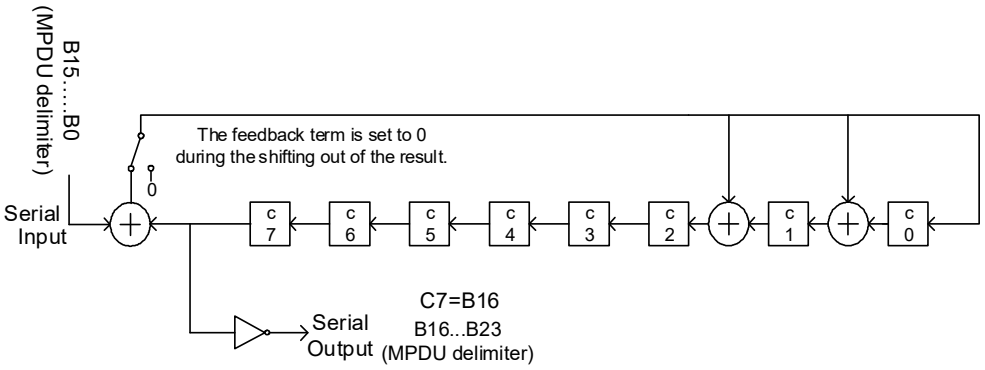


**Figure 9-1329—MPDU delimiter CRC calculation**

### 9.7.3 A-MPDU contents

In a non-DMG PPDU, an A-MPDU is a sequence of A-MPDU subframes carried in a single PPDU with one of the following combinations of RXVECTOR or TXVECTOR parameter values:

- The FORMAT parameter set to VHT
- The FORMAT parameter set to HT_MF or HT_GF and the AGGREGATION parameter set to 1
- The FORMAT parameter set to S1G, S1G_DUP_1M, or S1G_DUP_2M and the AGGREGATION parameter set to 1.
- The FORMAT parameter set to HE_SU, HE_MU, HE_TB, or HE_ER_SU.(11ax)
- The FORMAT parameter set to NGV.(11bd)

(11ax)An A-MPDU carried in an HE SU PPDU, HE ER SU PPDU, HE TB PPDU, or HE MU PPDU can include MPDUs with different values of the TID field as described in 26.6.3 (Multi-TID A-MPDU and ack-enabled single-TID A-MPDU).

In a DMG PPDU, an A-MPDU is a sequence of A-MPDU subframes(#152) carried in a single PPDU with the TXVECTOR/RXVECTOR AGGREGATION parameter set to 1.


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All of the MPDUs within an A-MPDU are addressed to the same RA. (11ax)All of the MPDUs within an A-MPDU have the same TA. All QoS Data frames within an A-MPDU that have a TID for which an HT-immediate block ack agreement exists have the same value for the Ack Policy Indicator subfield of the QoS Control field.

All protected MPDUs within an A-MPDU have the same (#3493)key ID.

The Duration/ID fields in the MAC headers of all MPDUs in an A-MPDU carry the same value. The Duration/ID fields in the MAC headers of the MPDUs in the A-MPDUs carried in a VHT MU PPDU and an HE MU PPDU carry the same value.(11ax)

NOTE 1—The reference point for the Duration/ID field is the end of the PPDU carrying the MPDU. Setting the Duration/ID field to the same value in the case of A-MPDU aggregation means that each MPDU consistently specifies the same NAV setting.

An A-MPDU is transmitted in one of the contexts specified in Table 9-660 (A-MPDU contexts) as defined by the description in the Definition of context column.(11ax)The content of an A-MPDU depends on the context in which it is transmitted as defined in the tables below. Ordering of MPDUs within an A-MPDU is not constrained, except where noted in these tables. See 10.12.1 (A-MPDU contents).

NOTE 2—If the number qualifier for a frame subtype does not exist, zero or more frames of the frame subtype can be aggregated in the A-MPDU.(11ax)

A VHT MU PPDU, S1G MU PPDU, and HE MU PPDU do not carry more than one A-MPDU that contains one or more MPDUs soliciting an immediate response if the immediate response is carried in a PPDU that is not an HE TB PPDU. An HE MU PPDU can carry more than one A-MPDU each of which contains one or more MPDUs soliciting an immediate response if the immediate response is carried in an HE TB PPDU.(11ax)

NOTE 3—The TIDs present in a data enabled A-MPDU context are also constrained by the channel access rules (for a TXOP holder; see 10.23.2 (HCF contention based channel access (EDCA)) and 10.23.3 (HCF controlled channel access (HCCA))), (11ax)the TXOP responder rules (see 26.6 (A-MPDU operation in an HE PPDU), and 26.5.2 (UL MU operation)) and the RD response rules (for an RD responder, see 10.29.4 (Rules for RD responder)). This is not shown in these tables.

NOTE 4—If a STA supports A-MSDUs of 7935 octets (indicated by the Maximum A-MSDU Length field in the HT Capabilities element), A-MSDUs transmitted by that TA within an A-MPDU carried in a PPDU with FORMAT HT_MF or HT_GF or within an MPDU carried in a non-HT PPDU are constrained so that the length of the QoS Data frame carrying the A-MSDU is no more than 4095 octets. The 4095-octet MPDU length limit does not apply to A-MPDUs carried in VHT or DMG PPDUs. The use of A-MSDU within A-MPDU might be further constrained as described in 9.4.1.13 (Block Ack Parameter Set field) through the operation of the A-MSDU Supported field.

NOTE 5—If a STA transmits an A-MPDU in a TDD slot, the contents of the A-MPDU follows the TDD slot category as defined in 10.38.6.2.2 (SP with TDD channel access(11ay)).(11ay)

NOTE 6— Limits on using BRP frames in A-MPDU are defined in 10.41.6.4.1 (General).(11ay)

(11ay)An A-MPDU carried in an EDMG PPDU can include MPDUs with different values for the TID field as described in 10.70 (EDMG A-MPDU with multiple TIDs(11ay)).

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**Table 9-660—A-MPDU contexts**

| Name of Context | Definition of Context | Table defining permitted contents |
|---|---|---|
| (11ax)Non-HE Data Enabled Immediate Response | The A-MPDU is transmitted (#3263)by a TXOP holder or an RD responder including potential immediate responses. | Table 9-661 (A-MPDU contents in the non-HE(11ax) data enabled immediate response context) |
| Data Enabled No Immediate Response | The A-MPDU is transmitted (#3263)by a TXOP holder, (11ax)TXOP responder when transmitted by an HE STA to another HE STA, and the A-MPDU does not include or solicit an immediate response.<br>See NOTE. | Table 9-662 (A-MPDU contents in the data enabled no immediate response context) |
| Control Response | The A-MPDU is transmitted by a STA that is neither a TXOP holder nor an RD responder, (11ax)or the A-MPDU is transmitted by an HE AP in response to an HE TB PPDU, and the transmitter also needs to transmit one of the following immediate response frames:<br>— Ack frame<br>— BlockAck frame with a TID for which an HT-immediate block ack agreement exists<br>— Multi-STA BlockAck frame for acknowledging multi-TID A-MPDU(11ax) | Table 9-663 (A-MPDU contents in the control response context) |
| S-MPDU context | The A-MPDU is transmitted within a VHT PPDU or an HE PPDU(11ax) and contains an S-MPDU. | Table 9-664 (A-MPDU contents in the S-MPDU context(#1762)) |
| (11ax)HE Non-Ack-Enabled Single-TID Immediate Response | The A-MPDU is transmitted by a TXOP holder or TXOP responder in an HE PPDU and solicits block acknowledgment for a single TID. | Table 9-665 (A-MPDU contents in the HE non-ack-enabled single-TID immediate response context(11ax)) |
| (11ax)HE Ack-Enabled Single-TID Immediate Response | The A-MPDU is transmitted by a TXOP holder or TXOP responder in an HE PPDU and solicits single acknowledgment. | Table 9-666 (A-MPDU contents in the HE ack-enabled single-TID immediate response context(11ax)) |


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**Table 9-660—A-MPDU contexts *(continued)***

| Name of Context | Definition of Context | Table defining permitted contents |
|---|---|---|
| (11ax)HE Non-Ack Enabled Multi-TID Immediate Response | The A-MPDU is transmitted by a TXOP holder or TXOP responder in an HE PPDU, and solicits block acknowledgments for multiple TIDs. | Table 9-667 (A-MPDU contents in the HE non-ack-enabled multi-TID immediate response context(11ax)) |
| (11ax)HE Ack-Enabled Multi-TID Immediate Response | The A-MPDU is transmitted by a TXOP holder or TXOP responder in an HE PPDU, and solicits at least one acknowledgment and zero or more block acknowledgments. | Table 9-668 (A-MPDU contents in the HE ack-enabled multi-TID immediate response context(11ax)) |
| NOTE—This context includes cases when no response is generated. | | |

**Table 9-661—A-MPDU contents in the non-HE(11ax) data enabled immediate response context**

| MPDU Description | Conditions | |
|---|---|---|
| Ack | If the preceding PPDU contains an MPDU that requires an Ack frame response, a single Ack frame at the start of the A-MPDU. | Of these, in a non-DMG STA: at most one MPDU is present.<br><br>Of these, in a (11ay)non-EDMG STA: at most one Ack frame is present, and zero or more HT-immediate BlockAck frames are present.<br><br>(11ay)Of these, in an EDMG STA: at most one Ack frame is present. Zero or more HT-immediate BlockAck frames or zero or more EDMG Multi-TID BlockAck frames are present, but not both block ack variants are present in the same A-MPDU. |
| HT-immediate BlockAck | In a non-DMG STA: if the preceding PPDU contains an implicit or explicit block ack request for a TID for which an HT-immediate block ack agreement exists, at most one BlockAck frame for this TID, in which case it occurs at the start of the A-MPDU.<br><br>In a DMG STA: if the preceding PPDU contains an implicit or explicit block ack request for a TID for which an HT-immediate block ack agreement or an unsolicited block ack extension agreement exists, one or more copies of the same BlockAck for this TID.(11ay) | |
| EDMG Multi-TID BlockAck(11ay) | In an EDMG STA: if the preceding PPDU that carried a multi-TID A-MPDU contains implicit or explicit block ack requests for multiple TIDs for which an HT-immediate block ack agreement exists, one or more copies of the same EDMG Multi-TID BlockAck frame.(11ay) | |
| Action No Ack | Action No Ack frames. | |

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**Table 9-661—A-MPDU contents in the non-HE(11ax) data enabled immediate response context *(continued)***

| MPDU Description | Conditions | |
|---|---|---|
| Data frames sent under an HT-immediate block ack agreement | QoS Data frames with the same TID, which corresponds to an HT-immediate block ack agreement. See NOTE 1.(11ay)<br><br>QoS Data frames with different TIDs, which corresponds to multiple HT-immediate block ack agreements. See NOTE 2(11ay) | Of these, at most one of the following is present in a non-DMG BSS:<br>— One or more QoS Data frames with Implicit BAR ack policy<br>— A BlockAckReq frame<br><br>Of these, at most one of the following is present in a DMG BSS:<br>— One or more QoS Data frames with Implicit BAR ack policy<br>— QoS Null frame with the No Ack ack policy<br>— A BlockAckReq frame with an optional QoS Null frame with No Ack ack policy<br>(11ay)Of these, any of the following is present in an EDMG BSS:<br>— One or more QoS Data frames with different TIDs and at the most one Action frame.<br>— One or more QoS Null frames with No Ack ack policy.<br>— One of BlockAckReq or Multi-TID BlockAckReq frame, but not both in the same A-MPDU. |
| QoS Null frames with the No Ack ack policy | In a DMG BSS, QoS Null frames with the No Ack ack policy. | |
| Immediate BlockAckReq | At most one BlockAckReq frame with a TID that corresponds to an HT-immediate block ack agreement or an unsolicited block ack extension agreement. It is not present if any QoS Data frames for that TID are present.(11ay)<br><br>(11ay)Multi-TID BlockAckReq frame with TIDs that correspond to an HT-immediate block ack agreement. It is not present if any QoS Data frames for those TIDs are present.<br><br>This is the last MPDU in the A-MPDU. | |
| Management frame requires Ack or Action Ack frames(11ay) | At most one Action Ack in case of an EDMG STA supporting (#4251)EDMG Multi-TID BlockAck.(11ay) | |
| Block Ack Schedule(11ay) | In an EDMG BSS, one or more copies of the Block Ack Schedule frame is present when transmitted within an EDMG MU PPDU. (11ay) | |
| Data without a block ack agreement(11ay) | QoS Data frames with a TID that does not have an established block ack agreement. These one per TID MPDUs with the Ack Policy field equal to Scheduled Ack are conveyed in an EDMG MU-MIMO PPDU. (11ay) | |
| NOTE 1—These MPDUs all have the same ack policy, which is Implicit BAR, Block Ack, or Scheduled Ack.(11ay)<br>NOTE 2—The agreement can be established using an ADDBA exchange or under an unsolicited block ack extension. (11ay) | | |



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**Table 9-662—A-MPDU contents in the data enabled no immediate response context**

| MPDU Description | Conditions |
|---|---|
| Data without a block ack agreement | QoS Data frames with a TID that does not correspond to a block ack agreement. These have No Ack ack policy and the A-MSDU Present subfield equal to 0. |
| Action No Ack | Action No Ack frames. |
| (11ax)Trigger | If sent by an HE AP, Trigger frames where the Trigger Type field indicates Basic Trigger frame, BSRP Trigger frame, or BQRP Trigger frame.<br><br>The Trigger frames are the first MPDUs of the A-MPDU, unless the A-MPDU also carries an Ack or BlockAck frame in which case the Trigger frames are included immediately after the Ack or BlockAck frame.<br><br>See NOTE 1 and NOTE 2. |
| (11ax)QoS Null frame with No Ack ack policy | If sent to an HE STA, QoS Null frames with No Ack ack policy. |
| NOTE 1—Only an HE AP is allowed to include a Trigger frame in the A-MPDU. The presence of more than one copy of a Trigger frame in an A-MPDU might increase the probability of the successful reception of the Trigger frame. The content of all Trigger frames in the A-MPDU is the same.(11ax)<br><br>NOTE 2—The BSRP and BQRP Trigger frames can be aggregated with other MPDUs in the A-MPDU if the receiver has indicated the support of receiving these trigger types in the BSRP BQRP A-MPDU Aggregation field in the HE Capabilities element.(11ax) | |

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**Table 9-663—A-MPDU contents in the control response context**

| MPDU | Conditions | |
|---|---|---|
| Ack | Ack frame transmitted in response to an MPDU that requires an Ack frame. | (11ax)One of Ack and compressed BlockAck frame is present at the start of the A-MPDU between two STAs that are not both HE STAs; these are not present other than at the start of the A-MPDU.<br><br>(11ax)One of Ack, Compressed BlockAck, and Multi-STA BlockAck frame is present at the start of the A-MPDU between two HE STAs; these are not present other than at the start of the A-MPDU. |
| BlockAck | (11ax)Compressed BlockAck frame with a TID that corresponds to an HT-immediate block ack agreement. See NOTE.(11ay)<br><br>(11ax)Multi-STA BlockAck frame if the preceding PPDU is either an HE TB PPDU that solicits an immediate response (see 26.4.4.5 (Responding to an HE TB PPDU with an SU PPDU)) or an HE PPDU that carries a multi-TID A-MPDU or ack-enabled multi-TID A-MPDU (see26.6.3 (Multi-TID A-MPDU and ack-enabled single-TID A-MPDU)). | |
| EDMG Multi-TID BlockAck(11ay) | If the preceding PPDU that carried a multi-TID A-MPDU contains an implicit or explicit block ack requests for multiple TIDs for which an HT-immediate block ack agreement exists, one or several copies of the same EDMG Multi-TID BlockAck frame.(11ay) | |
| Action No Ack | (11ax)In an A-MPDU between two STAs that are not both HE STAs:<br>BRP +HTC frames.<br>Action No Ack +HTC frames containing an explicit feedback response.<br>Action No Ack frames that are Flow Suspension frames or Flow Resumption frames.<br><br>(11ax)In an A-MPDU between two HE STAs: Action No Ack frames. | |
| (11ax)QoS Null frame with No Ack ack policy | If sent to an HE STA. QoS Null frames with No Ack ack policy. | |
| NOTE—This condition is applicable for BlockAck variants established by block ack agreements and is not applicable for the EDMG Multi-TID BlockAck where the condition depends on a preceding PPDU. (11ay) | | |

**Table 9-664—A-MPDU contents in the S-MPDU context(#1762)**

| MPDU | Conditions |
|---|---|
| An MPDU that would be valid if not transmitted in an A-MPDU(#3517) | An S-MPDU. |



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**Table 9-665—A-MPDU contents in the HE non-ack-enabled single-TID immediate response context(11ax)**

| MPDU | Conditions | |
|---|---|---|
| Ack | If the preceding PPDU contains an MPDU that requires an Ack frame response, a single Ack frame at the start of the A-MPDU. | At most one untagged MPDU that is Ack, Compressed BlockAck, or Multi-STA BlockAck frame is present |
| HT-immediate BlockAck | If the preceding PPDU contains an implicit or explicit block ack request for a TID for which an HT-immediate block ack agreement exists, at most one Compressed BlockAck frame for this TID at the start of the A-MPDU.<br><br>If the preceding PPDU contains explicit block ack requests for multiple TIDs or a multi-TID A-MPDU, at most one Multi-STA BlockAck frame at the start of the A-MPDU. | |
| Action No Ack | Untagged MPDUs that are Action No Ack frames. | |
| QoS Null frame with No Ack ack policy | Untagged MPDUs that are QoS Null frames with No Ack ack policy. | |

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**Table 9-665—A-MPDU contents in the HE non-ack-enabled single-TID immediate response context(11ax)**

| MPDU | Conditions | |
|---|---|---|
| Data frames sent under an HT-immediate block ack agreement | One or more QoS Data frames with the same TID, which corresponds to an HT-immediate block ack agreement<br><br>See NOTE 1. | One of the following is present:<br>— One or more untagged MPDUs, each of which is a QoS Data frame with Implicit BAR, HETP Ack, or Block Ack ack policy and belonging to a block ack agreement, zero or more untagged MPDUs, each of which is a Basic Trigger, BSRP Trigger, or BQRP Trigger frame.<br>— One untagged MPDU that is BlockAckReq frame, zero or more untagged MPDUs each of which is a QoS Null frame with No Ack ack policy.<br>— One or more untagged MPDUs each of which is a Basic Trigger, MU-BAR Trigger, BQRP Trigger, or BSRP Trigger frame. The MU-BAR Trigger frame solicits block acknowledgment for one TID. |
| Compressed BlockAckReq | At most one BlockAckReq frame with a TID that corresponds to an HT-immediate block ack agreement.<br><br>This frame is the last MPDU in the A-MPDU.<br><br>BlockAckReq is not present if any QoS Data frames are present. | |
| Trigger | Trigger frames where the Trigger Type field is Basic Trigger, MU-BAR Trigger, BQRP Trigger or BSRP Trigger.<br><br>MU BAR Trigger frame is not present if any QoS Data frames are present.<br><br>The Trigger frames are the first MPDUs of the A-MPDU, unless the A-MPDU also carries an Ack or BlockAck frame in which case the Trigger frames are included immediately after the Ack or BlockAck frame.<br><br>See NOTE 2 and NOTE 3. | |

NOTE 1—MPDUs from the same TID all have the same ack policy, which is Implicit BAR, HETP Ack or Block Ack.

NOTE 2—Only an HE AP is allowed to include a Trigger frame in the A-MPDU. The presence of more than one copy of a Trigger frame in an A-MPDU might increase the probability of the reception of the Trigger frame. The content of all Trigger frames in the A-MPDU is the same.

NOTE 3–The BSRP and BQRP Trigger frames can be aggregated with other MPDUs in the A-MPDU if the receiver has indicated the support of receiving these trigger types in the BSRP BQRP A-MPDU Aggregation field in the HE Capabilities element.

## 9.8 MAC frame format for PV1 frames

### 9.8.1 Basic components

Each PV1 frame consists of the following basic components:

a) A PV1 MAC header, which comprises frame control, address, optional sequence control information;

b) A variable-length frame body, which contains information specific to the frame type;

c) An FCS, which contains a 32-bit CRC based on ITU-T Recommendation V.42 [B63] (see 9.2.4.9 (FCS field)).


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**Table 9-666—A-MPDU contents in the HE ack-enabled single-TID immediate response context(11ax)**

| MPDU | Conditions | |
|---|---|---|
| Ack | If the preceding PPDU contains an MPDU that requires an Ack frame response, a single Ack frame at the start of the A MPDU. | At most one untagged MPDU that is an Ack, Compressed BlockAck, or Multi-STA BlockAck frame is present |
| HT-immediate BlockAck | If the preceding PPDU contains an implicit or explicit block ack request for a TID for which an HT-immediate block ack agreement exists, at most one Compressed BlockAck frame for this TID at the start of the A-MPDU.<br><br>If the preceding PPDU contains explicit block ack requests for multiple TIDs or a multi-TID A-MPDU, at most one Multi-STA BlockAck frame at the start of the A-MPDU. | |
| Action No Ack | Untagged MPDUs that are Action No Ack frames. | |
| Data frames not sent under an HT-immediate block ack agreement | At most one Data frame with a TID that does not correspond to an HT-immediate block ack agreement and Normal Ack or HETP Ack ack policy. | One of the following:<br>— A tagged MPDU that is a QoS Data frame with Normal Ack or HETP Ack ack policy<br>— A tagged MPDU that is a Management frame that solicits an immediate response<br><br>And at least one untagged MPDU that is a QoS Null frame with No Ack ack policy, Basic Trigger frame, BSRP Trigger frame, or BQRP Trigger frame. |
| Data frames sent under an HT-immediate block ack agreement | At most one QoS Data frame with a TID that corresponds to an HT-immediate block ack agreement | |
| QoS Null frame with No Ack ack policy | QoS Null frames with No Ack ack policy. | |
| Management frame | At most one Management frame that solicits an acknowledgment. | |
| Trigger | Basic Trigger, BQRP Trigger or BSRP Trigger frames.<br><br>The Trigger frames are the first MPDUs of the A-MPDU, unless the A-MPDU also carries an Ack or BlockAck frame in which case the Trigger frames are included immediately after the Ack or BlockAck frame.<br><br>See NOTE 1 and NOTE 2. | |

NOTE 1—Only an HE AP is allowed to include a Trigger frame in the A-MPDU. The presence of more than one copy of a Trigger frame in an A-MPDU might increase the probability of the reception of the Trigger frame. The content of all Trigger frames in the A-MPDU is the same.

NOTE 2—The BSRP Trigger and BQRP Trigger frames can be aggregated with other MPDUs in the A-MPDU if the receiver has indicated the support of receiving these Trigger frame types in the BSRP BQRP A-MPDU Aggregation field in the HE Capabilities element.

NOTE 3—The single Management frame that solicits the acknowledgment in ack-enabled single-TID A-MPDU is treated as single-TID frame, e.g., soliciting Ack of TID 15 in multi-STA BlockAck frame.

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**Table 9-667—A-MPDU contents in the HE non-ack-enabled multi-TID immediate response context(11ax)**

| MPDU | Conditions | |
|---|---|---|
| Ack | If the preceding PPDU contains an MPDU that requires an Ack frame response, a single Ack frame at the start of the A MPDU. | At most one (#3796)untagged MPDU that is an Ack, Compressed BlockAck, or Multi-STA BlockAck frame is present |
| HT-immediate BlockAck | If the preceding PPDU contains an implicit or explicit block ack request for a TID for which an HT-immediate block ack agreement exists, at most one Compressed BlockAck frame for this TID at the start of the A-MPDU.<br><br>If the preceding PPDU contains explicit block ack requests for multiple TIDs or a multi-TID A-MPDU, at most one Multi-STA BlockAck frame at the start of the A-MPDU. | |
| Action No Ack | Untagged MPDUs that are Action No Ack frames. | |
| QoS Null frame with No Ack ack policy | Untagged MPDUs that are QoS Null frames with No Ack ack policy. | |
| Data frames sent under an HT-immediate block ack agreement | QoS Data frames with different TIDs each of which corresponds to an HT-immediate block ack agreement.<br><br>See NOTE 1. | One of the following is present:<br>— Two or more untagged MPDUs that are QoS Data frames that belong to two or more block ack agreements and with Implicit BAR, HETP Ack, or Block Ack ack policy, zero or more untagged MPDUs each of which is a Trigger frame. The Trigger frame is a Basic Trigger, BSRP Trigger, or BQRP Trigger frame<br>— One untagged MPDU that is a Multi-TID BlockAckReq frame.<br>— One or more untagged MPDUs each of which is an MU-BAR Trigger frame that solicits block acknowledgment for more than one TID. |
| Immediate BlockAckReq | At most one multi-TID BlockAckReq frame with TIDs that correspond to HT-immediate block ack agreements<br><br>This frame is the last MPDU in the A-MPDU.<br><br>Multi-TID BlockAckReq frame is not present if any QoS Data frames are present. | |
| Trigger | Basic Trigger, MU-BAR Trigger, BQRP Trigger or BSRP Trigger frames.<br><br>MU-BAR Trigger frame is not present if any QoS Data frames are present.<br><br>The Trigger frames are the first MPDUs of the A-MPDU, unless the A-MPDU also carries an Ack or BlockAck frame in which case the Trigger frames are included immediately after the Ack or BlockAck frame.<br><br>See NOTE 2 and NOTE 3. | |

NOTE 1—MPDUs from the same TID all have the same ack policy, which is Implicit BAR, HETP Ack or Block Ack.

NOTE 2—Only an HE AP is allowed to include a Trigger frame in the A-MPDU. Multiple Trigger frames in one A-MPDU increases the robustness. The content of all Trigger frames in the A-MPDU is the same.

NOTE 3—The BSRP Trigger and BQRP Trigger frames can be aggregated with other MPDUs in the A-MPDU if the receiver has indicated the support of receiving these trigger types in the BSRP BQRP A-MPDU Aggregation field in the HE Capabilities element.


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**Table 9-668—A-MPDU contents in the HE ack-enabled multi-TID immediate response context(11ax)**

| MPDU | Conditions | |
|---|---|---|
| Ack | If the preceding PPDU contains an MPDU that requires an Ack frame response, a single Ack frame at the start of the A MPDU. | At most one untagged MPDU that is an Ack, Compressed BlockAck, or Multi-STA BlockAck frame is present |
| HT-immediate BlockAck | If the preceding PPDU contains an implicit or explicit block ack request for a TID for which an HT-immediate block ack agreement exists, at most one Compressed BlockAck frame for this TID at the start of the A-MPDU.<br><br>If the preceding PPDU contains explicit block ack requests for multiple TIDs or a multi-TID A-MPDU, at most one Multi-STA BlockAck frame at the start of the A-MPDU. | |
| Action No Ack | Untagged MPDUs that are Action No Ack frames. | |
| QoS Null frame with No Ack ack policy | Untagged MPDUs that are QoS Null frames with No Ack ack policy. | |
| Data frames without an HT-immediate block ack agreement | One or more QoS Data frames with each with different TIDs where none of the TID have HT-immediate block ack agreement<br><br>See NOTE 1. | One of the following is present:<br>— Tagged MPDUs each of which is a QoS Data frame with Normal Ack or HETP Ack ack policy and where the TIDs of the QoS Data frames differ if there is more than one, zero or more untagged MPDUs each of which is a Basic Trigger, BSRP Trigger, or BQRP Trigger frame.<br>— Zero or more untagged MPDUs each of which is a QoS Data frame with Implicit BAR, HETP Ack, or Block Ack ack policy and belonging to a block ack agreement, one or more tagged MPDUs each of which is a QoS Data frame with Normal Ack or HETP Ack ack policy and where the TIDs of the QoS Data frames differ if there is more than one, a tagged MPDU that is a Management frame, zero or more untagged MPDUs each of which is a Basic Trigger, BSRP Trigger, or BQRP Trigger frame.<br>— Zero or more untagged MPDUs each of which is a QoS Data frame with Implicit BAR, HETP Ack, or Block Ack ack policy and belonging to a block ack agreement, and two or more tagged MPDUs each of which is a QoS Data frame with Normal Ack or HETP Ack ack policy and where the TIDs of the QoS Data frames differ if there is more than one, zero or more untagged MPDUs each of which is a Basic Trigger, BSRP Trigger, or BQRP Trigger frame. |
| Data frames sent under an HT-immediate block ack agreement | One of the following:<br>— One or more QoS Data frames with a TID that corresponding to an HT-immediate block ack agreement.<br>— QoS Data frames with TIDs that correspond to two or more HT-immediate block ack agreements.<br>See NOTE 1. | |
| Management | At most one Management frame that solicits an acknowledgment | |
| Trigger | One or more Basic Trigger, BQRP Trigger or BSRP Trigger frames.<br><br>The Trigger frames are the first MPDUs of the A-MPDU, unless the A-MPDU also carries an Ack or BlockAck frame in which case the Trigger frames are included immediately after the Ack or BlockAck frame.<br><br>See NOTE 2 and NOTE 3. | |

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**Table 9-668—A-MPDU contents in the HE ack-enabled multi-TID immediate response context(11ax) *(continued)***

| MPDU | Conditions |
|---|---|
| NOTE 1—MPDUs with the same TID all have the same ack policy, which is Implicit BAR, HETP Ack or Block Ack.<br>NOTE 2—Only an HE AP is allowed to include a Trigger frame in the A-MPDU. Multiple Trigger frames in one A-MPDU increases the robustness. The content of all Trigger frames in the A-MPDU is the same.<br>NOTE 3—The BSRP Trigger and BQRP Trigger frames can be aggregated with other MPDUs in the A-MPDU if the receiver has indicated the support of receiving these trigger types in the BSRP BQRP A-MPDU Aggregation field in the HE Capabilities element. | |

### 9.8.2 General PV1 frame format

Figure 9-1330 (PV1 frame format(#1633)) depicts the general PV1 MAC frame format. The first three fields (Frame Control, A1 and A2) and the last field FCS are always present in PV1 frames. The Sequence Control, A3, A4 and Frame body fields are optionally present. Each field is defined in 9.8.3 (PV1 frame fields).

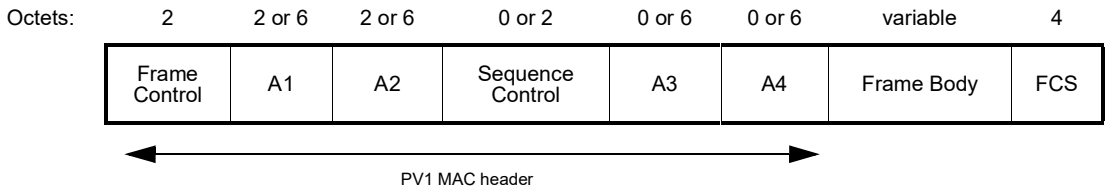


**Figure 9-1330—PV1 frame format(#1633)**

NOTE—In Figure 9-1330 (PV1 frame format(#1633)), the total number of octets in the A1 and A2 fields is either 8 or 12.

The Frame Body field is of variable size, constrained as defined in 9.2.4.8.1 (General).

### 9.8.3 PV1 frame fields

#### 9.8.3.1 Frame Control field

The Frame Control field of the PV1 MAC header for PV1 frames except the PV1 Probe Response(#3384) frame, PV1 Resource Allocation frame, and PV1 Control frames, is defined in Figure 9-1331 (Frame Control field format for some PV1 frames(#1744)).

The Frame Control field of the PV1 MAC header for the PV1 Probe Response frame, PV1 Resource Allocation frame and PV1 Control frames is defined in 9.8.5.3 (PV1 Probe Response frame format), 9.8.5.4 (Resource Allocation frame format), and 9.8.4 (PV1 Control frames), respectively.

The Protocol Version subfield is defined in 9.2.4.1.2 (Protocol Version subfield). For PV1 frames the Protocol Version subfield is 1.

The Type subfield identifies the type of the frame, as defined in Table 9-669 (PV1 frame types).

(#3384)The PTID/Subtype subfield, depending on the type of the PV1 frame, indicates:


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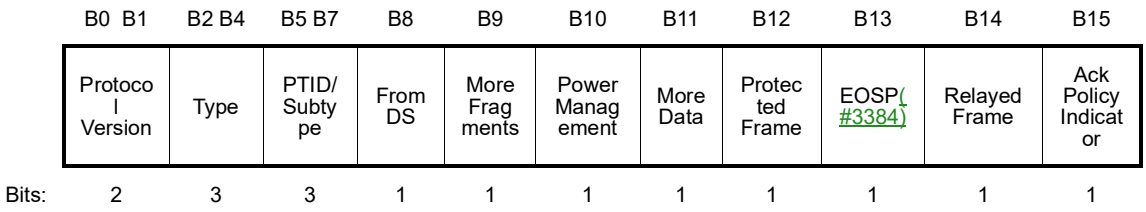


**Figure 9-1331—Frame Control field format for some PV1 frames(#1744)**

**Table 9-669—PV1 frame types**

| Type Value | Type | Description |
|---|---|---|
| 0 | QoS Data | Either the A1 field or the A2 field is (#4169)a SID (defined in 9.8.3.2 (Address fields)), as determined by the From DS subfield in the Frame Control field (see Table 9-670 (From DS subfield values in type 0 or 1 PV1 frames(#278)(#3384))), and the other field contains a MAC address.(#3384) |
| 1 | Management | For PV1 Probe Response frames: both A1 and A2 fields contain MAC addresses.<br>Otherwise: either the A1 field or the A2 field is (#4169)a SID (defined in 9.8.3.2 (Address fields)), as determined by the From DS subfield in the Frame Control field (see Table 9-670 (From DS subfield values in type 0 or 1 PV1 frames(#278)(#3384))), and the other field contains a MAC address.(#3384) |
| 2 | Control | The A1 field is (#4169)a SID(#7172) and the A2 field is either (#4169)a SID(#7172) or contains a MAC address, depending on the PV1 Control frame subtype (see 9.8.4 (PV1 Control frames)).(#6213) |
| 3 | QoS Data | Both A1 and A2 fields contain MAC addresses. |
| 4–6 | Reserved | |
| 7 | Reserved for extension | |

— The 3 LSBs of the TID as defined in 9.2.4.5.2 (TID subfield) for PV1 QoS Data frames (Type (#427)subfield equal to 0 and 3) transmitted by a QoS STA.

— The (#427)subtype for PV1 Control frames (Type subfield equal to 2) as described in 9.8.4 (PV1 Control frames).

— The (#427)subtype for PV1 Management frames (Type subfield equal to 1) as described in 9.8.5 (PV1 Management frames).

The From DS subfield (#3384)defines the addressing of PV1 frames with values of the Type field less than 2, as defined in Table 9-670 (From DS subfield values in type 0 or 1 PV1 frames(#278)(#3384)).

The More Fragments subfield is described in 9.2.4.1.5 (More Fragments subfield).

The Power Management subfield is described in 9.2.4.1.7 (Power Management subfield).

The EOSP subfield is described in 9.2.4.5.3 (EOSP (end of service period) subfield).

The Protected Frame subfield is described in 9.2.4.1.9 (Protected Frame subfield).

The More Data subfield is described in 9.2.4.1.8 (More Data subfield).

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**Table 9-670—From DS subfield values in type 0 or 1 PV1 frames(#278)(#3384)**

| From DS subfield | Meaning | Use |
|---|---|---|
| 0 | A1 contains the MAC address of the receiver<br>A2 is (#4169)a SID, which contains the AID of the transmitter<br>— A2 contains the MAC address of the transmitter for PV1 QoS Data frames with Type subfield equal to 3<br>A3 (if present) contains the MAC address of the destination<br>A4 (if present) contains the MAC address of the source | For frames transmitted by a non-AP STA to an AP<br><br>For frames transmitted from a non-AP STA to non-AP STA (direct link) |
| 1 | A1 is (#4169)a SID, which contains the AID of the receiver<br>— A1 contains the MAC address of the receiver for PV1 QoS Data frames with Type subfield equal to 3<br>A2 is the MAC address of the transmitter<br>A3 (if present) contains the MAC address of the destination<br>A4 (if present) contains the MAC address of the source | AP to non-AP STA |

The Relayed Frame subfield indicates that the current TXOP is shared with the relay STA using the TXOP sharing procedures for relays described in 10.53.5 (Procedures of TXOP sharing for S1G relay operation).

The Ack Policy Indicator subfield identifies the ack policy that is followed upon the delivery of the MPDU, as defined in Table 9-671 (Ack Policy Indicator subfield in the Frame Control field for PV1 frames).

**Table 9-671—Ack Policy Indicator subfield in the Frame Control field for PV1 frames**

| Ack policy | Ack Policy Indicator subfield | Other conditions | Meaning |
|---|---|---|---|
| Normal Ack | 0 | MPDU is a non-A-MPDU frame | Where the frame contains a fragment and both the originator and the addressed recipient support fragment BA:<br>The addressed recipient returns an NDP BlockAck or BAT frame after a SIFS, according to the procedures defined in 10.3.2.12 (Fragment BA procedure) and 10.46.2 (TWT acknowledgment procedure).<br><br>Otherwise:<br>The addressed recipient returns an Ack, TACK or STACK frame after a short interframe space (SIFS)(#320), according to the procedures defined in 10.3.2.11 (Acknowledgment procedure) and 10.46.2 (TWT acknowledgment procedure). |
| Implicit BAR | 0 | MPDU is not a non-A-MPDU frame | The addressed recipient returns a BlockAck or BAT frame, either individually or as part of an A-MPDU starting a SIFS after the PPDU carrying the frame, according to the procedures defined in 10.3.2.11 (Acknowledgment procedure) and 10.46.2 (TWT acknowledgment procedure). |


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**Table 9-671—Ack Policy Indicator subfield in the Frame Control field for PV1 frames**

| | | | |
|---|---|---|---|
| No Ack | 1 | MPDU is a non-A-MPDU frame | The addressed recipient takes no action upon receipt of the frame. More details are provided in 10.26 (No Acknowledgment (No Ack)). This ack policy is used in all individually addressed frames in which the sender does not require acknowledgment. It is also used in all group addressed frames. It is not used for PV1 Data frames with a TID for which a block ack agreement exists. |
| Block Ack | 1 | MPDU is not a non-A-MPDU frame | The addressed recipient takes no action upon the receipt of the frame except for recording the state. The recipient can expect a BlockAckReq frame in the future to which it responds using the procedure described in 10.25 (Block acknowledgment (block ack)). |

### 9.8.3.2 Address fields

There are up to four address fields in the PV1 MAC frame format. These fields are used to indicate the recipient of the frame (A1), the transmitter of the frame (A2), and optionally the MAC address of the source and/or the MAC address of the destination of the frame (A3 and/or A4).

The recipient of the frame (A1) or the transmitter of the frame (A2) can be identified by the AID subfield located in the Short ID (SID) field depending on the value of the From DS subfield of the Frame Control field as described in 9.8.3.1 (Frame Control field). A group of receiving non-AP STAs of the frame can be identified by the AID subfield with a group AID value, as described in 10.54 (Group AID), located in the Short ID (SID) field. The length of the SID field (#8141)is shown in Figure 9-1332 (SID field format).

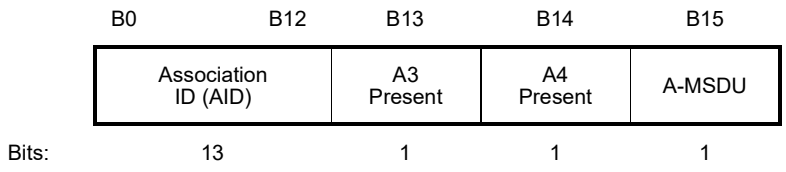


**Figure 9-1332—SID field format**

The AID subfield contains an AID as specified in Table 9-670 (From DS subfield values in type 0 or 1 PV1 frames(#278)(#3384)) in PV1 frames of Type 0, 1, and 2.

The A3 Present subfield is 1 if the A3 is present in the PV1 MAC header, otherwise it is 0.

The A4 Present subfield is 1 if the A4 is present in the PV1 MAC header, otherwise it is 0.

The A-MSDU subfield is 1 if the MPDU contains a Dynamic A-MSDU as described in 9.3.2.2.5 (Dynamic A-MSDU format).

NOTE—PV1 frames without (#4169)a SID field do not contain A3 and A4 fields and do not carry A-MSDUs.

The A3 field is present if A3 is not equal to the address identified by A1 and an A3 is not stored at the receiver, or when A3 is not equal to an A3 stored at the receiver (as described in 10.57 (Generation of PV1 MPDUs and header compression procedure)). When the A3 field is not present, A3 is either stored at the recipient of the frame or, if an A3 is not stored at the recipient of the frame then A3 is equal to the address identified by A1.

The A4 field is present if A4 is not equal to the address identified by A2 and an A4 is not stored at the receiver, or when A4 is not equal to an A4 stored at the receiver (as described in 10.57 (Generation of PV1

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MPDUs and header compression procedure)). When the A4 field is not present, A4 is either stored at the recipient of the frame or, if an A4 is not stored at the recipient of the frame then A4 is equal to the address identified by A2.

#### 9.8.3.3 Sequence Control field

The Sequence Control field is present in all PV1 Data frames and PV1 Management frames other than PV1 Probe Response frames, and is described in 9.2.4.4 (Sequence Control field).(#1892)

#### 9.8.3.4 Frame Body field

The Frame Body field is a variable-length field and is described in 9.2.4.7 (Control subfield variants of an A-Control subfield(11ax)).

#### 9.8.3.5 Overhead for encryption

The overhead for encryption is described in Clause 12 (Security).

#### 9.8.3.6 FCS field

The FCS field is described in 9.2.4.9 (FCS field).

### 9.8.4 PV1 Control frames

#### 9.8.4.1 General

The subfields within the Frame Control field of PV1 Control frames are set as shown in Figure 9-1333 (Frame Control field subfield values within PV1 Control frames(#3463)).

| | B0 B1 | B2 B4 | B5 B7 | B8 B10 | B11 | B12 | B13 | B14 | B15 |
|---|---|---|---|---|---|---|---|---|---|
| | Protocol Version | Type (Control) | PTID/ Subtype | Bandwidth Indication | Dynamic Indication | Power Management | More Data | Flow Control | Next TWT Info Present |
| Bits: | 2 | 3 | 3 | 3 | 1 | 1 | 1 | 1 | 1 |

**Figure 9-1333—Frame Control field subfield values within PV1 Control frames(#3463)**

Table 9-672 (PV1 Control frame subtypes) defines the different PV1 Control frame subtypes.

**Table 9-672—PV1 Control frame subtypes**

| PTID/Subtype value b2 b1 b0(#1743) | Subtype description |
|---|---|
| 000 | STACK |
| 001 | BAT |
| 010–111 | Reserved |

The Bandwidth Indication subfield and the Dynamic Indication subfield are described in 9.2.4.1.11 (Bandwidth Indication and Dynamic Indication subfields).


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The Next TWT Info Present subfield is set to 1 if the Next TWT Info field is present in PV1 Control frames. Otherwise, it is set to 0.

The More Data subfield is described in 9.2.4.1.8 (More Data subfield).

The Flow Control subfield is used for flow suspension signaling as described in 10.60 (S1G flow control).

### 9.8.4.2 STACK frame format

The frame format of the short TWT acknowledgment (STACK) frame is defined in Figure 9-1334 (STACK frame format). The A1 field is (#4169)a SID field that contains the AID of the intended recipient of the frame in the AID subfield when the intended recipient is not an AP and the value 0 when the intended recipient is an AP. A3 Present, A4 Present, and A-MSDU subfields (B13, B14, and B15) of the SID field are reserved.

The A2 field is (#4169)a SID field that contains the bit sequence Scrambler Initialization[0:6] || FCS[23:31] obtained from the scrambler initialization value in the (#3409)SERVICE field (as defined in 23.3.9.2 (SERVICE field)), prior to descrambling, and the FCS field of the PSDU that carries the soliciting frame. The scrambler initialization value is obtained from the RXVECTOR parameter SCRAMBLER_OR_CRC.

| | Frame Control | A1 | A2 | Tetrapartial Timestamp/ Next TWT Info/ Suspend Duration | FCS |
|---|---|---|---|---|---|
| Octets: | 2 | 2 | 2 | 4 | 4 |

**Figure 9-1334—STACK frame format**

If the Next TWT Info Present subfield in the Frame Control field is equal to 0, the Tetrapartial Timestamp/Next TWT Info/Suspend Duration field contains the value of the 4 least significant octets of the STA's TSF timer at the time that the start of the data symbol containing the first bit of the Tetrapartial Timestamp field appears at the transmit antenna connector.

If the Next TWT Info Present subfield in the Frame Control field is equal to 1 and the Flow Control subfield of the Frame Control field is equal to 0, then the Tetrapartial Timestamp/Next TWT Info/Suspend Duration field contains the value of the 4 least significant octets of the TSF timer for the next TWT logically ANDed with the value 0xFFFFFFF8 and then added to the value of the TWT flow identifier that corresponds to that next TWT value.

NOTE—The Next TWT Info/Suspension Duration field carries only a portion of the target TSF time, and changes in the most significant octets of the corresponding target TSF time are not communicated to the receiving STA. Hence, the receiving STA must consider and account for a rollover of the corresponding most significant octets of the target TSF time that might happen at the receiving STA.(#7083)

If the Next TWT Info Present subfield in the Frame Control field is equal to 1 and the Flow Control subfield of the Frame Control field is equal to 0 and the 29 MSBs of the Next TWT Info subfield is equal to all 0s, the transmitter does not currently have a next TWT value available for transmission for the TWT indicated by the TWT flow identifier corresponding to the value of the 3 LSBs of the Next TWT Info field.

If the Next TWT Info Present subfield in the Frame Control field is equal to 1 and the Flow Control subfield of the Frame Control field is equal to 1, then the Tetrapartial Timestamp/Next TWT Info/Suspend Duration field contains a flow suspension duration, in microseconds, during which the intended recipient TWT STAs are not allowed to transmit Data frames to the STA identified by the RA field of the frame that elicited the STACK frame.

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### 9.8.4.3 BAT frame format

The frame format of the Block Acknowledgment TWT (BAT) frame is defined in Figure 9-1335 (BAT frame format):

| | Frame Control | A1 | A2 | Beacon Sequence | Pentapartial Timestamp | Next TWT Info /Suspend Duration | Starting Sequence Control | BAT Bitmap | FCS |
|---|---|---|---|---|---|---|---|---|---|
| Octets: | 2 | 2 | 6 | 1 | 5 | 6 | 2 | 4 | 4 |

**Figure 9-1335—BAT frame format**

The A1 field is (#4169)a SID(#7172) that contains the AID of the intended recipient of the frame in the AID subfield when the intended recipient is not an AP and the value 0 when the intended recipient is an AP. A3 Present, A4 Present, and A-MSDU subfields (B13, B14, and B15) of the SID field are reserved.

The A2 field contains the MAC address of the transmitter sending the frame.

The Beacon Sequence field contains the value of the Change Sequence field from the most recently transmitted Beacon frame.

The Pentapartial Timestamp field contains the value of the 5 least significant octets of the STA's TSF timer at the time that the start of the data symbol containing the first bit of the Pentapartial Timestamp field appears at the transmit antenna connector.

If the Next TWT Info Present subfield in the Frame Control field is equal to 1 and the Flow Control subfield of the Frame Control field is equal to 0, then the Next TWT Info/Suspend Duration field contains a next TWT value for the intended recipient of the frame corresponding to the value of the 6 least significant octets of the TSF timer for the next TWT logically ANDed with the value 0xFFFFFFFFFFF8 and then added to the value of the TWT flow identifier that corresponds to that next TWT value.

If the Next TWT Info Present subfield in the Frame Control field is equal to 1 and the Flow Control subfield of the Frame Control field is equal to 0 and the 45 MSBs of the Next TWT Info/Suspend Duration subfield is equal to all 0s, the transmitter does not currently have a next TWT value available for transmission for the TWT indicated by the TWT flow identifier corresponding to the value of the 3 LSBs of the Next TWT Info/Suspend Duration field.

If the Next TWT Info Present subfield in the Frame Control field is equal to 1 and the Flow Control subfield of the Frame Control field is equal to 1, then the Next TWT Info/Suspend Duration field contains a flow suspension duration, in microseconds, during which the intended recipient TWT STAs are not allowed to transmit Data frames to the STA identified by the A2 field of the BAT frame.

If the Next TWT Info Present subfield in the Frame Control field is equal to 0, then the Next TWT Info/Suspend Duration field is reserved.

The Starting Sequence Control field contains the sequence number of the first MSDU and the TID for which this BAT frame is sent and is defined in Figure 9-1336 (Starting Sequence Control field format):

The BAT Bitmap field is used to indicate the received status of up to 32 MSDUs and A-MSDUs. Each bit that is equal to 1 in the BAT Bitmap field acknowledges the reception of a single MSDU or A-MSDU in sequentially increasing sequence number order, with the first bit of the BAT Bitmap field corresponding to the MSDU or A-MSDU with the sequence number that matches the value of the Starting Sequence Number subfield of the BAT frame.


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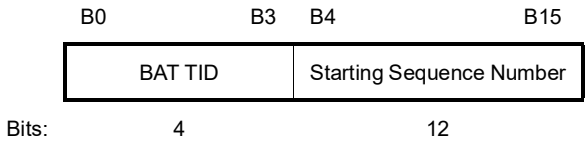


**Figure 9-1336—Starting Sequence Control field format**

### 9.8.5 PV1 Management frames

#### 9.8.5.1 Format of PV1 Management frames

The format of a PV1 Management frame is defined in Figure 9-1337 (PV1 Management frame format).

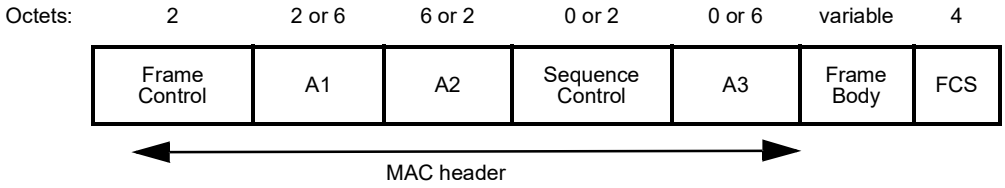


**Figure 9-1337—PV1 Management frame format**

The Frame Control, A1, and A2 fields are present in all PV1 Management frame subtypes.

The address fields A1 and A2 contain the receiver and transmitter addresses either of which can be (#4169)a SID field as described in 9.8.3.2 (Address fields).

The Sequence Control field is described in 9.2.4.4 (Sequence Control field) and is present in PV1 Management frames of subtype Action and Action No Ack.

The address field A3 (if present, as described in 9.8.3.2 (Address fields)) is set to the BSSID.

The frame body consists of the fields followed by the elements defined for each PV1 Management frame subtype. All fields and elements are mandatory unless stated otherwise and appear in the specified, relative order. STAs that encounter an element ID they do not recognize in the frame body of a received PV1 Management frame ignore that element and continue to parse the remainder of the PV1 Management frame body (if any) for additional elements with recognizable element IDs. See 10.28.7 (Vendor specific element parsing).

Table 9-673 (PV1 Management frame subtypes) defines the different PV1 Management frame subtypes.

**Table 9-673—PV1 Management frame subtypes**

| PTID/Subtype value b2 b1 b0(#1743) | Subtype description |
|---|---|
| 000 | Action |
| 001 | Action No Ack |
| 010 | PV1 Probe Response |

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**Table 9-673—PV1 Management frame subtypes**

| | |
|---|---|
| 011 | Resource Allocation |
| 100–111 | Reserved |

PV1 Management frames are Management frames.

### 9.8.5.2 Action and Action No Ack frames

The frame body of a PV1 Management frame of subtype Action is described in 9.3.3.13 (Action frame format) and the format of the Action field formats allowed is described in 9.6 (Action frame format details).(#6292)

The frame body of a PV1 Management frame of subtype Action No Ack is described in 9.3.3.14 (Action No Ack frame format) and the format of the Action field formats allowed is described in 9.6 (Action frame format details).(#6292)

### 9.8.5.3 PV1 Probe Response frame format

The format of the PV1 Probe Response frame is shown in Figure 9-1338 (PV1 Probe Response frame format(#8219)).

| | Frame Control | A1 | A2 | Times tamp | Change Sequence | Next TBTT (optional) | Short SSID (optional) | Access Network Options (optional) | Optional Elements | FCS |
|---|---|---|---|---|---|---|---|---|---|---|
| Octets: | 2 | 6 | 6 | 4 | 1 | 0 or 3 | 0 or 4 | 0 or 1 | variable | 4 |

**Figure 9-1338—PV1 Probe Response frame format(#8219)**

The A1 field contains the MAC address of the intended recipient of the frame.

The A2 field contains the MAC address of the transmitter sending the frame.

The Timestamp field contains the value of the 4 least significant octets of the STA's TSF timer at the time that the start of the data symbol containing the first bit of the Timestamp field appears at the transmit antenna connector.

The Change Sequence field is defined as an unsigned integer, initialized to 0, that increments when a critical update to the Beacon frame has occurred (see 10.45.2 (System information update procedure)).

The Next TBTT field is present if the Next TBTT Present subfield in the Frame Control field is 1 and indicates the most significant 3 octets of the 4 least significant octets of the next TBTT. Otherwise, it is not present.

Either a (#8219)Short SSID field or an SSID element is included in the PV1 Probe Response frame.

(#8219)A Short SSID field is present if the Full SSID Present subfield in the Frame Control field is 0 and it contains a 32-bit CRC calculated over the SSID contained in the Probe Response or S1G Beacon frame (calculation is performed as defined in 9.2.4.9 (FCS field) where the SSID is the calculation fields). An SSID element is not present if the Full SSID Present subfield in the Frame Control field is 0.


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An SSID element as defined in 9.4.2.2 (SSID element) is present in the Optional Elements field of the PV1 Probe Response frame if the Full SSID Present subfield in the Frame Control field is 1. (#8219)A Short SSID field is not present if the Full SSID Present subfield in the Frame Control field is 1.

The Access Network Options field is present if the ANO Present subfield in the Frame Control field is 1 and is defined in 9.4.2.90 (Interworking element). Otherwise, it is not present.

The Optional Elements field contains optional elements requested to be included in the PV1 Probe Response frame such as S1G Beacon Compatibility element. If the S1G Beacon Compatibility element is requested to be included, the PV1 Probe Response frame includes it as the first optional element.

The Frame Control field of the PV1 Probe Response frame is shown in Figure 9-1339 (Frame Control field of PV1 Probe Response frame format).

The Next TBTT present subfield is set to 1 if the Next TBTT field is included in the PV1 Probe Response frame and otherwise set to 0.

The Full SSID Present field indicates whether (#8129)an SSID or a (#8219)short SSID is included in the PV1 Probe Response frame. Setting the field to 1 indicates that an SSID element is included and (#8219)a Short SSID field is not included in the PV1 Probe Response frame. Setting the field to 0 indicates that (#8219)a Short SSID field is included and (#8219)an SSID element is not included in the PV1 Probe Response frame.

| | B0 B1 | B2 B4 | B5 B7 | B8 | B9 | B10 | B11 B13 | B14 | B15 |
|---|---|---|---|---|---|---|---|---|---|
| | Protocol Version | Type | PTID/ Subtype | Next TBTT Present | Full SSID Present | ANO Present | BSS BW | Security | 1 MHz Primary Channel Location |
| Bits: | 2 | 3 | 3 | 1 | 1 | 1 | 3 | 1 | 1 |

**Figure 9-1339—Frame Control field of PV1 Probe Response frame format**

The ANO Present subfield equals 1 if the Access Network Options field is present; otherwise, it equals 0.

The BSS BW subfield indicates the minimum and the maximum operating bandwidths of the BSS and is defined in Table 9-8 (Frame Control field BSS BW setting).

The Security subfield equals 1 if the transmitting STA is an RSNA STA.

The 1 MHz Primary Channel Location subfield indicates the location of the 1 MHz primary channel. If it is equal to 0, it indicates that the 1 MHz primary channel is located at lower side of 2 MHz primary channel. If it is equal to 1, it indicates that the 1 MHz primary channel is located at upper side of 2 MHz primary channel.

### 9.8.5.4 Resource Allocation frame format

The Resource Allocation (RA) frame is broadcasted to all non-AP STAs that belong to the RAW group identified by the RAW Group field of a previously transmitted RPS element with the RAW Type subfield indicating a generic RAW and the RAW Type Options subfield indicating an RA frame (see 9.4.2.190 (RPS element)). The RA frame signals the presence of downlink buffered data for paged STAs and their assigned RAW slots for both uplink and downlink service periods. The Resource Allocation frame has two kinds of format depending on the slot assignment mode indicated in the Frame Control field. The Resource Allocation frame formats are shown in Figure 9-1340 (Resource Allocation frame format when Slot

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Assignment Mode field is 0) and Figure 9-1341 (Resource Allocation frame format when Slot Assignment Mode field is 1).

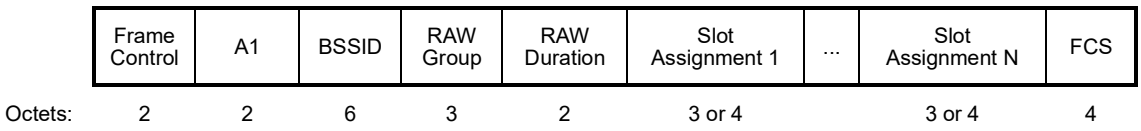


**Figure 9-1340—Resource Allocation frame format when Slot Assignment Mode field is 0**

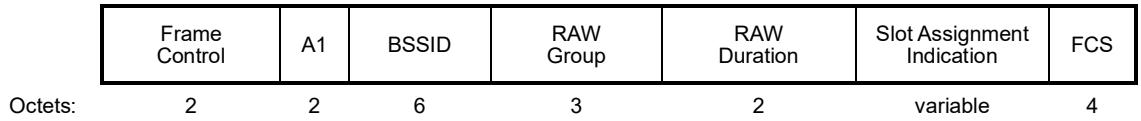


**Figure 9-1341—Resource Allocation frame format when Slot Assignment Mode field is 1**

The Slot Assignment Indication field formats are shown in Figure 9-1342 (Slot Assignment Indication field for MU group when Slot Assignment Mode field is 0 and the Group Indicator field is 1), Figure 9-1343 (Slot Assignment Indication field for a STA when Slot Assignment Mode is 0 and the Group Indicator field is 0), and Figure 9-1344 (Slot Assignment Indication field when Slot Assignment Mode field is 1).

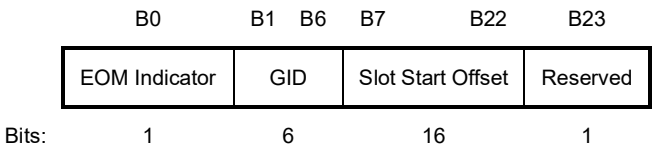


**Figure 9-1342—Slot Assignment Indication field for MU group when Slot Assignment Mode field is 0 and the Group Indicator field is 1**

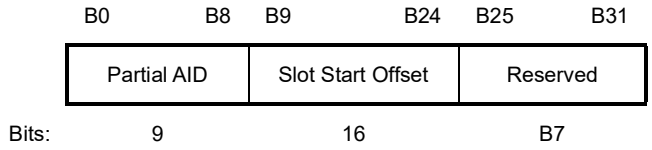


**Figure 9-1343—Slot Assignment Indication field for a STA when Slot Assignment Mode is 0 and the Group Indicator field is 0**

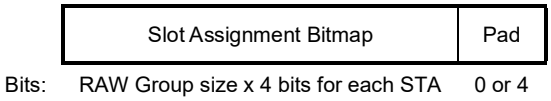


**Figure 9-1344—Slot Assignment Indication field when Slot Assignment Mode field is 1**

The Frame Control field of the Resource Allocation frame is shown in Figure 9-1345 (Frame Control field format for Resource Allocation frame(#3463)).



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| | B0 B1 | B2 B4 | B5 B7 | B8 | B9 | B10 | B11 | B12 | B13 | B14 | B15 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Protocol Version | Type | PTID/ Subtype | Slot Assignment Mode | More Fragments | Power Management | Group Indicator | Protected Frame | End of Service Period | Relayed Frame | Ack Policy Indicator |
| Bits: | 2 | 3 | 3 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

**Figure 9-1345—Frame Control field format for Resource Allocation frame(#3463)**

The subfields of the Frame Control field, except for the Slot Assignment Mode and the Group Indicator subfields, are defined in 9.8.3.1 (Frame Control field). The Slot Assignment Mode and the Group Indicator subfields are defined as follows:

- The Slot Assignment Mode subfield indicates the format of the Resource Allocation frame:
  - If the Slot Assignment Mode subfield is equal to 0, the Resource Allocation frame format is as shown in Figure 9-1340 (Resource Allocation frame format when Slot Assignment Mode field is 0).
  - If the Slot Assignment Mode subfield is equal to 1, the Resource Allocation frame format is as shown in Figure 9-1341 (Resource Allocation frame format when Slot Assignment Mode field is 1).
- The Group Indicator subfield indicates whether any subfield of MU group is included or no subfield of MU group exists in the Slot Assignment field if Slot Assignment mode field is equal to 0. Otherwise, it is reserved.

The A1 field is (#4169)a SID(#7172) that contains the value 0 in the AID subfield. A3 Present, A4 Present, and A-MSDU subfields (B13, B14, and B15) of the SID field are reserved.

The BSSID field indicates the address of the AP transmitting the Resource Allocation frame.

The RAW Group field indicates the STA AIDs that are assigned the RAW as defined in 9.4.2.190 (RPS element). The AIDs in this RAW Group are identical to the AIDs in the RAW Group subfield with the value in the RAW Type subfield set to 0 and the value in the RAW Type Options subfield set to 1 in the RAW Control subfield within the RPS element.(#6038)

The RAW Duration field is an unsigned integer expressed in TUs that indicates the duration of the current RAW where the Resource Allocation frame is broadcasted. The field is either set to the value of the RAW duration deduced from the value in the RAW Slot Definition subfield (9.4.2.190 (RPS element)) or is modified from the value indicated in the RAW Slot Definition subfield of the RPS element (9.4.2.190 (RPS element)).

The Slot Assignment field indicates a partial AID for a STA or a GID for STAs in the corresponding MU Group and their corresponding slot(s) of medium access within the current RAW. Since MU MIMO is used for DL traffic, the first bit, as called end of multi-user (EOM) Indicator, for the MU group block indicates whether the following subfields are used for the last MU group when this bit is 1 or more MU groups exist after subfields for this MU group when the bit is 0. This field is of length 3 octets for each MU Group and 4 octets for each STA and the length is determined based on the value in the EOM subfield.

If Slot Assignment Mode field is 0 and the Group Indicator field is 1, the Slot Assignment field is used for either MU group of STAs or an assigned STA as shown in Figure 9-1342 (Slot Assignment Indication field for MU group when Slot Assignment Mode field is 0 and the Group Indicator field is 1) and Figure 9-1343 (Slot Assignment Indication field for a STA when Slot Assignment Mode is 0 and the Group Indicator field is 0). If Slot Assignment Mode field is 0 and the Group Indicator field is 0, the Slot Assignment field is not

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used for MU group of STAs. The Slot Assignment field for MU group of STAs is located first at the beginning of the Slot Assignment fields, if exists.

The Partial AID subfield indicates a partial AID for an assigned STA.

The Slot Start Offset subfield indicates the start time of a RAW slot, in TU, for a STA's or MU MIMO group of STAs' medium access, relative to the RAW Start Time field as defined in 9.4.2.190 (RPS element) and is of length 2 octets.

The RA frame contains Slot Assignment Indication field to indicate to each of the STAs in the RAW group the number of UL/DL slot allocations within the current RAW.

The Slot Assignment Bitmap subfield indicates the number of RAW slots allocated for all STAs in the RAW group in ascending order with each 4 bits corresponding to one STA. The decimal number represented by the 4 bits indicates the number of allocation units for a STA. For example, setting this subfield to 0 indicates no allocation for a STA. Setting this subfield to 1 indicates one RAW slot for a STA. All RAW slots have equal duration, in TUs, which is calculated by dividing the value of the RAW Duration field with the number of RAW slots allocated to all STAs in the RAW group. The first RAW slot starts at the end of the Resource Allocation frame while the start times of the remaining RAW slots are equal to the end times of their immediately preceding RAW slots as indicated in the Slot Assignment Bitmap subfield.

The Slot Assignment Bitmap subfield has a length in bits, $SAB_{\text{length}}$, which is determined as:

$$SAB_{\text{length}} = (\text{RAW End AID} - \text{RAW Start AID} + 1) \times 4$$

where
RAW End AID and RAW Start AID for the RAW group are defined in 9.4.2.190 (RPS element)

The Pad subfield contains 0 or 4 bits of 0s to make the total number of bits in the Slot Assignment Indication field equal to an integer number of octets.

## 9.9 MAC frame format for WUR frames(11ba)

### 9.9.1 Basic components

Each WUR frame except the WUR Short Wake-up frame consists of the following basic components:

— A *MAC header*, which comprises Frame Control, ID, and Type Dependent Control fields;
— A variable-length *frame body*, which, if present, contains information specific to the frame *type*;
— An *FCS*, which, depending on the Protected subfield in the Frame Control field, contains either a 16-bit CRC or a 16-bit MIC.

The format of a WUR Short Wake-up frame is defined in 9.9.3.5 (WUR Short Wake-up frame format).

### 9.9.2 General WUR frame format

#### 9.9.2.1 General

Figure 9-1346 (WUR frame format(11ba)) depicts the general MAC frame format for WUR frames.

The MAC header of the WUR frame consists of the Frame Control, ID, and Type Dependent Control fields, and is defined in 9.9.2.2 (MAC header).


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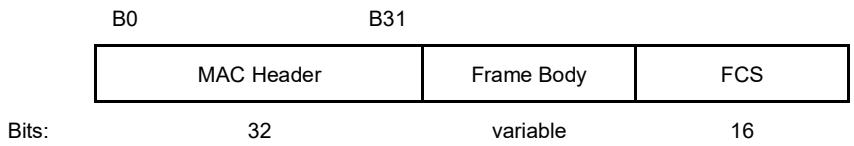


**Figure 9-1346—WUR frame format(11ba)**

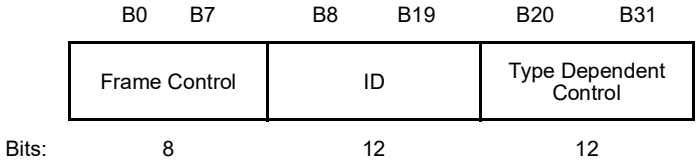


**Figure 9-1347—MAC header field format of the WUR frame(11ba)**

The Frame Body field is optionally present in certain WUR frame types and is defined in 9.9.2.3 (Frame Body field).

A WUR frame (except WUR Short Wake-up frame) that does not have a Frame Body field is referred to as a FL WUR frame. A WUR frame that has a Frame Body field is referred to as a VL WUR frame.

The FCS field is defined in 9.9.2.4 (Frame Check Sequence (FCS) field).

### 9.9.2.2 MAC header

#### 9.9.2.2.1 Frame Control field

The format of the Frame Control field is illustrated in Figure 9-1348 (Frame Control field format of WUR frame(11ba)).

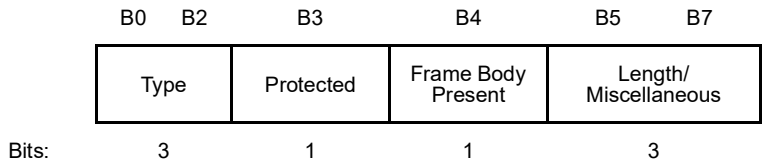


**Figure 9-1348—Frame Control field format of WUR frame(11ba)**

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The Type subfield indicates the type of the WUR frame, as defined in Table 9-674 (WUR frame types(11ba)).

**Table 9-674—WUR frame types(11ba)**

| Type | Type description |
|---|---|
| 0 | WUR Beacon |
| 1 | WUR Wake-up |
| 2 | WUR Vendor Specific |
| 3 | WUR Discovery |
| 4 | WUR Short Wake-up |
| 5–7 | Reserved |

The Protected subfield indicates whether the information carried in the WUR frame has been processed by a message integrity check (MIC) algorithm. The Protected subfield is set to 1 if the WUR frame is protected utilizing the MIC algorithm as defined in 29.10 (WUR frame protection); otherwise it is set to 0 to indicate that the WUR frame contains the 16-bit CRC as defined in 9.9.2.4.2 (Cyclic Redundancy Check (CRC) for WUR frames).

The Frame Body Present subfield indicates whether the Frame Body field is present or not.

The Length/Miscellaneous subfield contains the Length subfield when the Frame Body Present subfield is equal to 1; otherwise it contains the Miscellaneous subfield.

The Length subfield indicates the length in octets of the Frame Body field as defined in 9.9.2.3 (Frame Body field).(#7224)

The Miscellaneous subfield is reserved in all FL WUR frames except for broadcast and group addressed WUR Wake-up frames as defined in 9.9.3.2 (WUR Wake-up frame format).


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#### 9.9.2.2.2 ID field

(#8040)The ID field contains an identifier (or, in the case of WUR Vendor ID, a portion of an identifier) for the WUR frame. The nature of the identifier for various cases is shown in Table 9-675 (Identifiers of WUR frames(11ba)) and depends on the type of WUR frame (see 9.9.3 (Format of individual WUR frame types)).

**Table 9-675—Identifiers of WUR frames(11ba)**

| ID field | Identifier description |
|---|---|
| Transmitter ID | Identifier of the transmitting AP (see 29.5.3 (Transmitter ID)) |
| ID | Identifier of the nontransmitted BSSID (see 29.5.6 (Nontransmitter ID)) |
| WUR Group ID | Identifier of a group of receiving WUR non-AP STAs (see 29.5.4 (WUR Group ID)) |
| WUR ID | Identifier of an individual receiving WUR non-AP STA (see 29.5.5 (WUR ID)) |
| 12 LSB of WUR Vendor ID(#8041)(#6139) | The identifier is a public unique identifier assigned by the IEEE Registration Authority as a 24-bit OUI or a 24-bit CID (see [B15] and [B16]). The 12 LSBs of the identifier are carried in the ID field and the 12 MSBs are carried in the Type Dependent Control field(#6139) |

#### 9.9.2.2.3 Type Dependent Control field

The Type Dependent Control field contains control information that depends on the WUR frame type (see 9.9.3 (Format of individual WUR frame types)).

### 9.9.2.3 Frame Body field

The Frame Body field is a variable-length field that contains information specific to individual WUR frame types (see 9.9.3 (Format of individual WUR frame types)). The Frame Body field is not present when the Frame Body Present subfield of the Frame Control field is 0 (i.e., within FL WUR frames) and is present when the Frame Body Present subfield of the Frame Control field is 1 (i.e., within VL WUR frames).

If present, the length of the Frame Body field is (#7224)$2 \times (L + 1)$ octets, where $L$ is equal to value contained in the Length/Miscellaneous subfield in the Frame Control field.

NOTE—If present, the Frame Body field is between 2 and 16 octets in length.

### 9.9.2.4 Frame Check Sequence (FCS) field

#### 9.9.2.4.1 General

The FCS field contains a 16-bit CRC when the Protected subfield in the Frame Control field is 0 and contains a 16-bit MIC when the Protected subfield in the Frame Control field is 1 except for the WUR Vendor Specific frame (see 9.9.3.4 (WUR Vendor Specific frame format)). The 16-bit CRC is calculated as defined in 9.9.2.4.2 (Cyclic Redundancy Check (CRC) for WUR frames), and the MIC is calculated as defined in 29.10 (WUR frame protection).

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#### 9.9.2.4.2 Cyclic Redundancy Check (CRC) for WUR frames

The CRC is calculated over the *calculation fields*, which are all the fields present in the WUR frame except the CRC field and the Embedded BSSID field (if present in the *calculation fields*).

NOTE 1—The Embedded BSSID field, if present, is part of the *calculation fields* but is not part of the fields of the WUR frame transmitted over the *WM*.

NOTE 2—The Frame Body field is present in the *calculation fields* when the WUR frame is a VL WUR frame (see 9.9.2.3 (Frame Body field)); otherwise, the Frame Body field is not present.

The Embedded BSSID field, if present, is the last field of the *calculation fields*. The Embedded BSSID field contains the 16 MSBs of the compressed BSSID, which is defined in 29.5.2 (Compressed BSSID).

The Embedded BSSID field is present in the *calculation fields* of a WUR Beacon frame and of a WUR (Short) Wake-up frame. The Embedded BSSID field is not present in the *calculation fields* of a WUR Discovery frame. Whether the Embedded BSSID field is present or not in the *calculation fields* of a WUR Vendor Specific frame is vendor specific.

The CRC is the 1s complement of the remainder generated by the modulo 2 division of the *calculation fields* by the polynomial $x^{16}+x^{12}+x^5+1$, where the shift register state is preset to all 1s.

NOTE 3—The order of transmission of bits within the FCS field is defined in 9.2.2 (Conventions).

The *calculation fields* are processed in the order they would have been transmitted.

A schematic of the CRC processing is shown in Figure 9-1349 (CRC-16 implementation for WUR frames(11ba)), where the SERIAL DATA INPUT consists of the *calculation fields* ($B_L$, $B_{L-1}$..., $B_1$, $B_0$), with $B_L$ being the most significant bit of the *calculation fields*. The CRC computation and transmission is the same as the one depicted in Figure 15-2 (CRC-16 implementation(#1879)(#17)(#4029)).

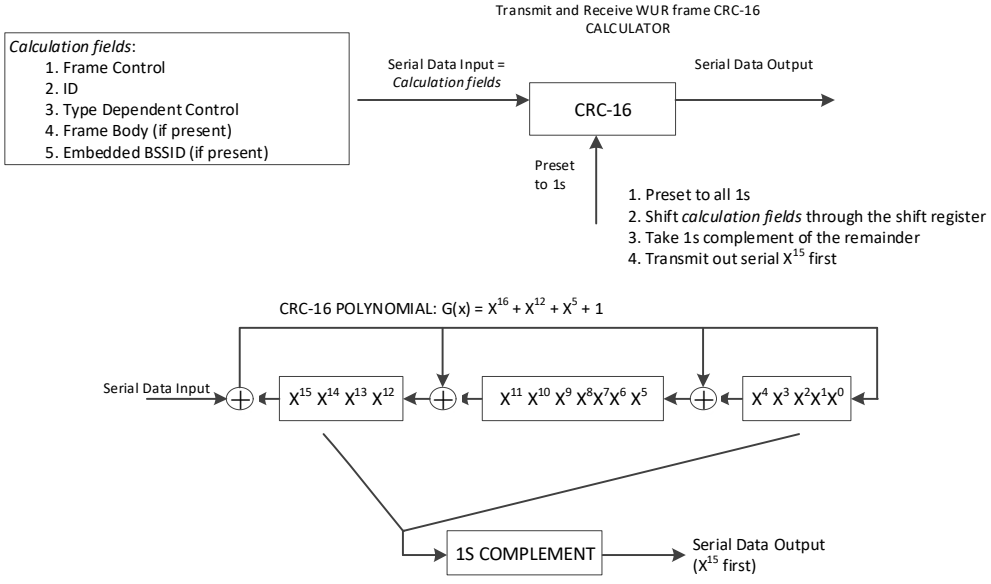


**Figure 9-1349—CRC-16 implementation for WUR frames(11ba)**


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### 9.9.3 Format of individual WUR frame types

#### 9.9.3.1 WUR Beacon frame format

The frame format of the WUR Beacon frame is defined in Figure 9-1346 (WUR frame format(11ba)).

The Frame Control field is defined in 9.9.2.2.1 (Frame Control field).

The Protected subfield of the Frame Control field is set to 0.

The Frame Body Present subfield of the Frame Control field is set to 0.

The Length/Miscellaneous subfield of the Frame Control field is reserved.

The ID field of the WUR Beacon frame is set to the transmitter ID.

The Type Dependent Control field contains the partial TSF that is generated as defined in 29.6.1 (General).

The Frame Body field is not present in the WUR Beacon frame.

The FCS field contains the CRC as defined in 9.9.2.4.2 (Cyclic Redundancy Check (CRC) for WUR frames).

#### 9.9.3.2 WUR Wake-up frame format

The frame format of the WUR Wake-up frame is defined in Figure 9-1346 (WUR frame format(11ba)).

The Frame Control field is defined in 9.9.2.2.1 (Frame Control field).

The ID field of the FL WUR Wake-up frame contains one of the following:

- The WUR ID when the frame is individually addressed to a WUR non-AP STA (see 29.5.5 (WUR ID)).
- The WUR group ID when the frame is group addressed to all WUR non-AP STAs belonging to the group identified by the WUR group ID (see 29.5.4 (WUR Group ID)).
- The transmitter ID when the frame is a broadcast frame transmitted by the WUR AP identified by the transmitter ID (see 29.5.3 (Transmitter ID)).
- The  ID when the frame is a broadcast frame transmitted by the WUR AP identified by the nontransmitted ID when dot11MultiBSSIDImplemented is true (see 29.5.6 (Nontransmitter ID)).

The ID field of the VL WUR Wake-up frame contains a WUR group ID, and the frame is group addressed to one or more WUR non-AP STAs that are identified by the WUR IDs included in the Frame Body field and belong to the group identified by the WUR group ID (see 29.5.4 (WUR Group ID)).

The Type Dependent Control field of a WUR Wake-up frame contains the Sequence Number subfield and the Counter subfield as defined in Figure 9-1350 (Type Dependent Control field format(11ba)(M118)).

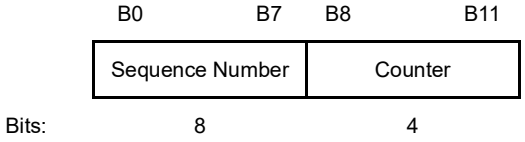


**Figure 9-1350—Type Dependent Control field format(11ba)(M118)**

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The Sequence Number subfield:

- Contains the TSF timer [9: 16] if the Protected subfield in the Frame Control field is 1 and the most recently sent WUR Operation element has the Common PN subfield equal to 1 (see 29.10.4.1 (Generation of the PN by a WUR AP)), or
- Contains PN0 (see 29.10 (WUR frame protection)) if Protected subfield in the Frame Control field is 1, and the most recently sent WUR Operation element has the Common PN subfield equal to 0, or
- Is reserved otherwise.

The Counter subfield:

- Contains the BSS Update Counter field if the WUR Wake-up frame is broadcast. The BSS Update Counter field is defined as an unsigned integer initialized to 0 that increments when a critical update to the BSS parameters has occurred (see 29.9.3 (WUR AP operation)), or
- Contains PN1[0:3] (see 29.10 (WUR frame protection)) if the WUR Wake-up frame is not broadcast, the Protected subfield in the Frame Control field is 1, and the most recently sent WUR Operation element has the Common PN subfield equal to 0, or
- Is reserved otherwise.

The Miscellaneous subfield is present if the Frame Body Present subfield is equal to 0. The format of Miscellaneous subfield is shown in Figure 9-1351 (Miscellaneous subfield format(11ba)) if the frame is broadcast or group addressed FL WUR Wake-up frame. The Miscellaneous subfield is reserved in FL WUR Wake-up frames that are neither broadcast nor group addressed.

NOTE—A broadcast WUR Wake-up frame is always a FL WUR Wake-up frame.

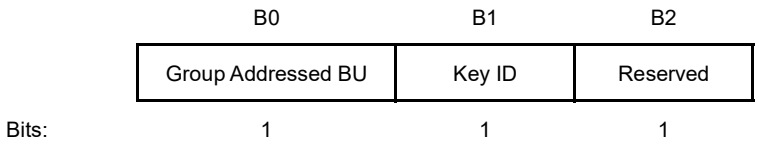


**Figure 9-1351—Miscellaneous subfield format(11ba)**

The Group Addressed BU subfield is set to 1 to indicate that one or more group addressed frames are buffered at the AP corresponding to the BSSID that is identified in the ID field. Otherwise, the Group Addressed BU subfield is set to 0. The Group Addressed BU subfield is reserved in a group addressed FL WUR Wake-up frame.

If the FL WUR Wake-up frame is broadcast or group addressed, and the Protected subfield of the Frame Control field is equal to 1, the Key ID subfield is set to 0 to indicate that the (#3493)WIGTK key ID of the WIGTK used to compute the MIC is 8. If the Protected subfield of the Frame Control field is equal to 1, the Key ID subfield is set to 1 to indicate that the (#3493)WIGTK key ID of the WIGTK used to compute the MIC is 9. Otherwise, the Key ID subfield is reserved.

The Frame Body field is present in a VL WUR Wake-up frame and contains one or more STA Info fields. The Frame Body field is not present otherwise. The format of the STA Info field is defined in Figure 9-1352 (STA Info field format(11ba)).

The WUR ID field is defined in 29.5 (Setting the identifiers of WUR frames).

The FCS field contains a CRC when the Protected field is equal to 0 and a MIC when the Protected field is equal to 1 (see 9.9.2.4 (Frame Check Sequence (FCS) field)).


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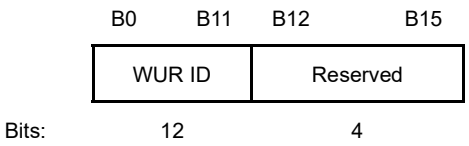


**Figure 9-1352—STA Info field format(11ba)**

### 9.9.3.3 WUR Discovery frame format

The frame format of the WUR Discovery frame is defined in Figure Figure 9-1346 (WUR frame format(11ba)).

The Frame Control field is defined in 9.9.2.2.1 (Frame Control field).

The Protected subfield in the Frame Control field is set to 0.

The Frame Body Present subfield in the Frame Control field is set to 1. The Length/Miscellaneous subfield is set to indicate that the Frame Body field is 4 octets in length.

The ID field is set to the transmitter ID.

The Type Dependent Control field is set to 12 MSBs of the compressed BSSID (see 29.5.2 (Compressed BSSID)).

The format of the Frame Body field is defined in Figure 9-1353 ( Frame Body field format of WUR Discovery frame(11ba)(M118)).

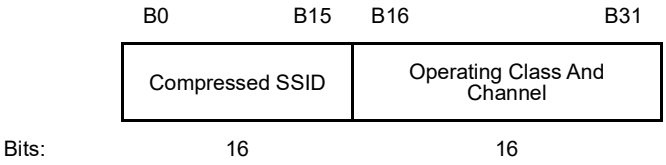


**Figure 9-1353— Frame Body field format of WUR Discovery frame(11ba)(M118)**

The Compressed SSID field contains the 16 LSBs of the short SSID as defined in 9.4.2.169.3 (Calculating the short SSID).

(#8218)NOTE—This is encoded per 9.2.2 (Conventions). For example, if the short SSID has the coefficient of the highest order term set, and the coefficient of the next-to-lowest order term set, and all other coefficients clear, then the Compressed SSID field contains 0x02 followed by 0x00.

The Operating Class And Channel field(#6181) defined in 9.4.1.22 (Operating Class And Channel field(#6181)) indicates the location of the primary channel of the BSS being advertised by the WUR Discovery frame.

The FCS field contains the 16-bit CRC as defined in 9.9.2.4.2 (Cyclic Redundancy Check (CRC) for WUR frames).

### 9.9.3.4 WUR Vendor Specific frame format

The frame format of the WUR Vendor Specific frame is defined in Figure 9-1346 (WUR frame format(11ba)).

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The Frame Control field is defined in 9.9.2.2.1 (Frame Control field).

If the Frame Body Present subfield in the Frame Control field is set to 0, then the Length/Miscellaneous subfield contains vendor specific information that is outside the scope of the standard.

The ID field is set to the 12 LSBs of the (#8042)OUI or CID (see Table 9-675 (Identifiers of WUR frames(11ba))).

The Type Dependent Control field is set to the 12 MSBs of the OUI or CID (see Table 9-675 (Identifiers of WUR frames(11ba))).(#6139)

The Frame Body field, if present, contains vendor specific information that is out of scope of the standard.

The FCS field contains the CRC as defined in 9.9.2.4.2 (Cyclic Redundancy Check (CRC) for WUR frames) when the Protected field is equal to 0 and a MIC when the Protected field is equal to 1, wherein the MIC contains vendor specific control information that is out of scope of the standard.

### 9.9.3.5 WUR Short Wake-up frame format

The frame format of the WUR Short Wake-up frame is defined in Figure 9-1354 (WUR Short Wake-up frame format(11ba)).

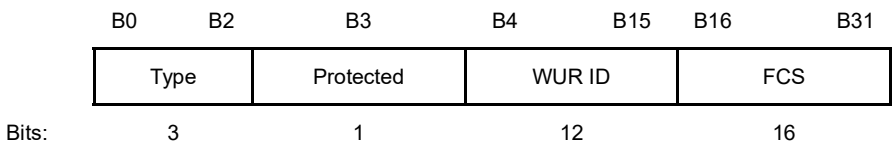


**Figure 9-1354—WUR Short Wake-up frame format(11ba)**

The Type field is defined in Table 9-674 (WUR frame types(11ba)).

The Protected field is set to 0.

The WUR ID field is defined in 29.5 (Setting the identifiers of WUR frames).

The FCS field is defined in 9.9.2.4 (Frame Check Sequence (FCS) field).


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# 10. MAC sublayer functional description

## 10.1 Introduction

The MAC functional description is presented in this clause. The architecture of the MAC sublayer, including the distributed coordination function (DCF), the hybrid coordination function (HCF), the mesh coordination function (MCF), (11ax)the triggered UL access (TUA), and their coexistence in an IEEE 802.11 LAN are introduced in 10.2 (MAC architecture). These functions are expanded on in 10.3 (DCF), 10.23 (HCF), 10.24 (Mesh coordination function (MCF)), and 26.2 (HE channel access).(11ax) Fragmentation and defragmentation are defined in 10.4 (MSDU, (11ax)A-MSDU, and MMPDU fragmentation) and 10.5 (MSDU, (11ax)A-MSDU, and MMPDU defragmentation). Multirate support is addressed in 10.6 (Multirate support). A number of additional restrictions to limit the cases in which MSDUs are reordered or discarded are described in 10.7 (MSDU transmission restrictions). Operation across regulatory dmains is defined in 10.22 (Operation across regulatory domains). The block ack mechanism is described in 10.25 (Block acknowledgment (block ack)). The No Ack mechanism is described in 10.26 (No Acknowledgment (No Ack)). The protection mechanism is described in 10.27 (Protection mechanisms). Rules for processing MAC frames are described in 10.28 (MAC frame processing).

## 10.2 MAC architecture

### 10.2.1 General

The MAC architecture is shown in Figure 10-1 (STA MAC architecture (non-DMG non-CMMG non-S1G)(11ax)(11ba)(#2258)(Ed)), Figure 10-2 (S1G STA MAC architecture), and Figure 10-3 (DMG STA and CMMG STA architecture).

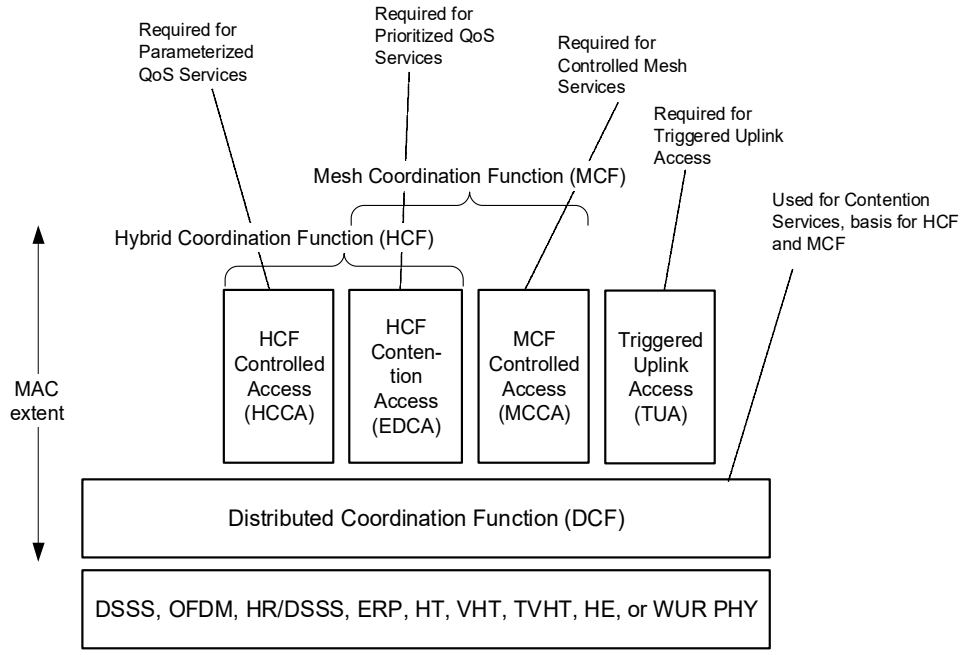


**Figure 10-1—STA MAC architecture (non-DMG non-CMMG non-S1G)(11ax)(11ba)(#2258)(Ed)**

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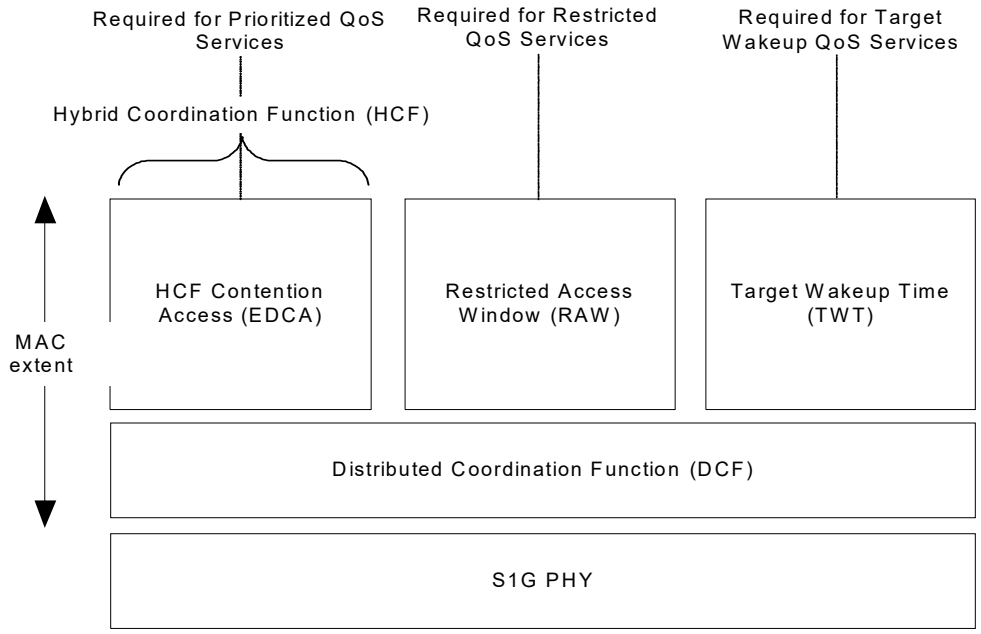


**Figure 10-2—S1G STA MAC architecture**

In a STA that is not a DMG STA, nor a CMMG STA, nor an S1G STA(#2258):

- The MAC provides the HCF, MCF, and TUA(11ax) service using the services of the DCF. The MAC also provides direct access to the DCF service.
- The HCF is present in QoS STAs and absent otherwise.
- The MCF is present in mesh STAs and absent otherwise.
- The TUA is present in non-AP HE STAs and absent otherwise.(11ax)

In an S1G STA:

- The MAC provides EDCA service using the services of the DCF.
- The RAW is optionally present.
- The TWT is optionally present.

In a DMG STA:

- The MAC provides services using the DMG channel access mechanisms.
- PBSS STAs (whether associated with the PCP or not) can receive group addressed frames from the PCP.(#1678)
- PBSS STAs (whether PCP or non-PCP STA) can receive group addressed frames from a non-PCP STA in the BSS.(#1678)

In a CMMG STA:

- The MAC provides services using the CMMG channel access mechanisms.

In either a DMG or CMMG STA:


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— Specific rules apply for access during scheduled periods, which include the association beamforming training (A-BFT) period, announcement transmission interval (ATI), contention based access period (CBAP), and service period (SP).
— The DCF is used during contention based access periods.
— Dynamic allocation (10.38.7 (Dynamic allocation of service period)) is built on service period and contention based access period.

The MAC maintains information in local variables called *MAC variables*. MAC variables that hold state information are also called *state variables*.

NOTE—The MMPDU occupies a position in the management plane similar to that of the MAC service data unit (MSDU) in the data plane. An MSDU, A-MSDU(11ax), or MMPDU is transmitted in one or more MAC protocol data units (MPDUs) (with the Type field set to Data or Management, respectively). (11ax)An A-MSDU is transmitted in one MPDU. An MSDU, A-MSDU, or MMPDU can be carried (in an MPDU) in an aggregate MAC protocol data unit (A-MPDU).(#2019)

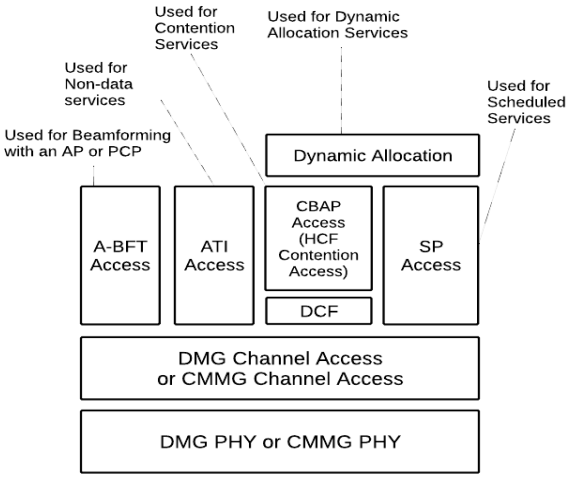


**Figure 10-3—DMG STA and CMMG STA architecture**

### 10.2.2 DCF

The fundamental access method of the MAC used by non-DMG STAs is a DCF known as *carrier sense multiple access with collision avoidance* (CSMA/CA). The DCF shall be implemented in all STAs.

For a STA to transmit, it shall sense the medium to determine if another STA is transmitting. If the medium is not determined to be busy (see 10.3.2.1 (CS mechanism)), the transmission may proceed. The CSMA/CA distributed algorithm mandates that a gap of a minimum specified duration exists between frame exchange sequences. A transmitting STA shall verify that the medium is idle for this required duration before attempting to transmit. If the medium is determined to be busy, a non-DMG STA shall defer until the end of the current transmission, and a DMG STA may defer until the end of the current transmission. After deferral, or prior to attempting to transmit again immediately after a successful transmission, the STA shall initialize a backoff counter to a random backoff count (#4181)(see Equation (10-1)) and shall decrement the backoff counter once per interval of aSlotTime (a backoff slot) while the medium is idle. A refinement of the method may be used under various circumstances to further minimize collisions—here the transmitting and receiving STA exchange short Control frames (RTS and CTS frames for non-DMG STAs, and RTS and DMG CTS frames

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for DMG STAs) after determining that the medium is idle and after any deferrals or backoffs, prior to data transmission. The details of CSMA/CA, deferrals, and backoffs are described in 10.3 (DCF). RTS/CTS and RTS/DMG CTS exchanges are also presented in 10.3 (DCF).

### 10.2.3 Hybrid coordination function (HCF)

#### 10.2.3.1 General

(#1032)The QoS facility includes an additional coordination function called *HCF* that is usable only in QoS network configurations. The HCF shall be implemented in all QoS STAs except mesh STAs. Instead, mesh STAs implement the MCF. The HCF combines functions from the DCF with some enhanced, QoS-specific mechanisms and frame subtypes to allow a uniform set of frame exchange sequences to be used for QoS data transfers . The HCF uses both a contention based channel access method, called the *enhanced distributed channel access (EDCA)* mechanism for contention based transfer and a controlled channel access, referred to as the *HCF controlled channel access (HCCA)* mechanism, for contention free transfer.

A STA may obtain a TXOP using one or both of the channel access mechanisms specified in 10.23 (HCF). If a TXOP is obtained using the contention based channel access, it is defined as *EDCA TXOP*. If a TXOP is obtained using the controlled channel access, it is defined as *HCCA TXOP*. If an HCCA TXOP is obtained due to a QoS (+)CF-Poll frame from the HC, the TXOP is defined as a *polled TXOP*.

(#1707)Time priority Management frames are defined to be those that appear in a table that has a Time priority column and that have a value of Yes in that Time priority column. No other frames are time priority Management frames.

#### 10.2.3.2 HCF contention based channel access (EDCA)

The EDCA mechanism provides differentiated, distributed access to the WM for STAs using eight different UPs. The EDCA mechanism defines four access categories (ACs) that provide support for the delivery of traffic with UPs at the STAs. Six transmit queues are defined when dot11AlternateEDCAActivated is true, and four transmit queues otherwise. The transmit queue and AC are derived from the UPs as shown in Table 10-1 (UP-to-AC mappings(#68)).

NOTE 1—A DMG or S1G STA that implements a single AC (see 10.23.2.1 (Reference model)) has all of its UP values in Table 10-1 (UP-to-AC mappings(#68)) mapped to AC_BE.

For each AC an enhanced variant of the DCF, called an *enhanced distributed channel access function (EDCAF)*, contends for TXOPs using a set of EDCA parameters. When communicating Data frames outside the context of a BSS (dot11OCBActivated is true), the EDCA parameters are the corresponding default values or are as set by the SME in dot11EDCATable (except for TXOP limits, when the TXOP limits are set to 0 for each AC as specified in 10.23.2.9 (TXOP limits)).(#7073) (#7067)For a STA operating OCB the STA's transmit queue for an AC may be cleared by the invocation of the MLME-CANCELTX.request primitive (see 6.5.26 (Cancel transmissions of MSDUs(11bd)((#7067))). For a non-AP STA communicating within a non-mesh QoS BSS, the EDCA parameters used are from the EDCA Parameter Set element or (for a non-AP STA prior to associating with an AP of an infrastructure BSS, a mesh STA, or a STA that operates OCB) from the default values for the parameters. The parameters used by the EDCAF to control its operation are defined by dot11QAPEDCATable at the AP and by dot11EDCATable at the non-AP STA.

The following rules apply for HCF contention based channel access:

a) The minimum specified idle duration is not the constant value (DIFS) defined for DCF, but is a distinct value. This value is specified in table dot11QAPEDCATableAIFSN for an AP and in table dot11EDCATableAIFSN for a non-AP STA; see 10.23.2 (HCF contention based channel access (EDCA)). The minimum idle duration is assigned either by a management entity or by an AP.


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**Table 10-1—UP-to-AC mappings(#68)**

| Priority | UP(#67) | AC | Transmit queue (dot11Alternate-EDCAActivated false or not present) | Transmit queue (dot11Alternate EDCAActivated true) | Designation |
|---|---|---|---|---|---|
| Lowest | 1 | AC_BK | BK | BK | Background |
| | 2 | AC_BK | BK | BK | Background |
| | 0 | AC_BE | BE | BE | Best Effort |
| | 3 | AC_BE | BE | BE | Best Effort |
| | 4 | AC_VI | VI | A_VI | Video (alternate) |
| | 5 | AC_VI | VI | VI | Video (primary) |
| | 6 | AC_VO | VO | VO | Voice (primary) |
| Highest | 7 | AC_VO | VO | A_VO | Voice (alternate) |
| NOTE—The Designation column is an indication of general usage and guidance. Actual uses of each UP are implementation specific. | | | | | |

b) The contention window limits aCWmin and aCWmax, from which the random backoff is computed, are not fixed per PHY, as with DCF, but are variable (contained in tables dot11QAPEDCATableCWmin and dot11QAPEDCATableCWmax for an AP and in tables dot11EDCATableCWmin and dot11EDCATableCWmax for a non-AP STA) and assigned by a management entity or by an AP.

c) Collisions between contending EDCAFs in a STA are resolved within the STA, so that the Data frames from the higher priority AC receive the TXOP and the Data frames from the lower priority colliding AC(s) behave as if there were an external collision on the WM except that the Retry subfield in the MAC headers of MPDUs at the head of the lower priority ACs is not affected.

d) During an EDCA TXOP won by an EDCAF a STA may initiate multiple frame exchange sequences to transmit MMPDUs and/or MSDUs within the same AC. The duration of this EDCA TXOP is bounded, for an AC, by the value dot11QAPEDCATableTXOPLimit for an AP and by dot11EDCATableTXOPLimit for a non-AP STA. A value of 0 for this duration means that the EDCA TXOP is limited as defined by the rule for TXOP limit of 0 found in 10.23.2.9 (TXOP limits).

The QoS AP shall announce the EDCA parameters in selected Beacon frames and in all Probe Response and (Re)Association Response frames by the inclusion of the EDCA Parameter Set element using the information from the MIB entries in dot11EDCATable. If no such element has been received (e.g., prior to association in an infrastructure BSS), a non-AP QoS STA shall use the default values for the parameters. The EDCA Parameter Set element shall be included in all Beacon frames occurring within two delivery traffic indication map (DTIM) periods following a change in announced EDCA parameters, which provides all STAs an opportunity to receive the updated EDCA parameters; it may optionally be included in more Beacon frames. If any associated STAs are in WNM sleep mode or using FMS, these fields should be included by the AP for as many DTIM periods as needed to exceed the longest interval any STA is expected to not receive Beacon frames.

(11ax)An HE AP can additionally provide MU EDCA parameters for non-AP HE STAs as defined in 26.2.7 (EDCA operation using MU EDCA parameters).

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(#307)(#3440)A non-AP non-S1G QoS STA, on receiving an updated EDCA Parameter Set element, should update the dot11EDCATable as soon as practical in the implementation and shall update the dot11EDCATable within an interval of time equal to one beacon interval. The STA shall update the dot11EDCATable and store the EDCA Parameter Set Update Count subfield(#326) in the QoS Info field. A non-AP S1G STA shall update its dot11EDCATable if its STA type is indicated by the STA Type subfield contained in the received EDCA Parameter Set element (see 10.60 (S1G flow control)). An AP may change the EDCA access parameters by changing the EDCA Parameter Set element in the Beacon frame, Probe Response frame, and (Re)Association Response frame. However, the AP should change them only rarely. A non-AP QoS STA shall use the EDCA Parameter Set Update Count subfield(11ax) in the QoS Capability element of Beacon frames, when present, to determine whether the STA is using the current EDCA parameters. If the EDCA Parameter Set Update Count subfield in the QoS Capability element is different from the value that has been stored, it shall query the updated EDCA parameters(#1660) by sending a Probe Request frame to the AP.(#326)

The S1G AP shall set the STA Type subfield of EDCA Parameter Set elements it transmits as follows:

— 1 if it indicates support for sensor STAs but no support for non-sensor STAs
— 2 if it indicates support for non-sensor STAs but no support for sensor STAs

The S1G AP may set the STA Type subfield of EDCA Parameter Set elements to any value that is less than 3 if it indicates support for both sensor STAs and non-sensor STAs as described in 10.60 (S1G flow control).

(#1276)When an S1G AP assigns EDCA Parameters, if management frame protection is negotiated and both STAs set the Extended S1G Action Protection field in the RSNXE that they transmit to 1, the STAs shall:

— use individually addressed Protected EDCA Parameter Set frames instead EDCA Parameter Set frames and
— discard any individually addressed EDCA Parameter Set frame received from the peer STA, with which management frame protection is negotiated.

(#1276)STAs that exchange individually addressed Protected EDCA Parameter Set frames shall follow the rules defined in 12.6.17 (Protection of robust Management frames.).

(#1276)When management frame protection is not negotiated or the Extended S1G Action Protection field in the RSNXE transmitted by either STA is set to 0, the STAs shall not use the Protected EDCA Parameter Set frame.

An S1G AP may assign to an S1G STA EDCA parameters different from the ones in dot11EDCATable, by sending to the STA an EDCA Parameter Set frame with an EDCA Parameter Set element with the Override field equal to 1. An S1G STA receiving an EDCA Parameter Set element with the Override field equal to 1 shall update its MIB values of the EDCA parameters based on the values indicated by the EDCA Parameter Set element.

An S1G STA that receives an EDCA Parameter Set frame with an EDCA Parameter Set element with the Override field equal to 1 shall disregard any EDCA Parameter Set elements with the Override field equal to 0 received afterward during the current association until it receives the EDCA Parameter Set element with the Override field equal to 1 carried in an EDCA Parameter Set frame.

In the Beacon frame the EDCA Parameter Set Update Count subfield is incremented every time any of the announced EDCA parameters change.(#325)

An AP or PCP may use a different set of EDCA parameters(#1660) than it advertises to the STAs in its BSS.

(#1032)(#1670)(#170)A non-QoS STA shall use frames with the QoS subfield of the Subtype subfield set to 0 for data transmissions to other STAs. A STA shall use frames with the QoS subfield of the Subtype


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subfield set to 0 for (#1775)group addressed Data frames that are not GCR frames unless the transmitting STA knows that all STAs in the BSS have QoS capability, in which case the STA shall use QoS Data frames. (#1772)A STA shall use frames with the QoS subfield of the Subtype subfield set to 0 for nonbroadcast (#1775)group addressed Data frames that are not GCR frames unless it is known to the transmitter that all STAs in the BSS that are members of the multicast group have QoS capability, in which case STAs shall use QoS Data frames. An AP with dot11RobustAVStreamingImplemented equal to true or a mesh STA with dot11MeshGCRImplemented equal to true uses frames with the QoS subfield of the Subtype subfield set to 1 for (#1775)GCR frames, as described in 11.21.16.3.5 (Concealment of GCR transmissions).

(#172)A QoS STA shall not transmit to another QoS STA an individually addressed frame with the Type subfield indicating Data and the QoS subfield of the Subtype subfield set to 0, except if the Subtype subfield indicates Null. A QoS STA should not transmit to another QoS STA an individually addressed frame with the Type subfield indicating Data and the Subtype subfield indicating Null.

(#170)A QoS STA that transmits a group addressed frame with the Type subfield indicating Data shall transmit it with the QoS subfield of the Subtype subfield set to 0 if non-QoS STAs are among the intended receivers, should transmit it with the QoS subfield set to 0 if non-QoS STAs might be among the intended receivers, and should transmit it with the QoS subfield set to 1 if no non-QoS STAs are among the intended receivers.

A QoS STA that transmits a Management frame determines access category used for medium access in transmission of the Management frame as follows:

- If dot11QMFActivated is false or not present and
  - If the Management frame is individually addressed to a non-QoS STA, category AC_BE should be selected.

    NOTE 2—AC_VO might be selected prior to completion of the (re)association procedure, to assist timely discovery of and joining a BSS.(#263)
  - If category AC_BE was not selected by the previous step, category AC_VO shall be selected.

    NOTE 3—Selection of AC_VO above is independent of whether the STA is associated with a BSS, or whether there is a QoS facility in the BSS.
- If dot11QMFActivated is true, the STA determines the access category as described in 11.24 (Quality-of-service Management frame (QMF)).

BlockAckReq and BlockAck frames shall be sent using the same access category for medium access as the corresponding QoS Data frames. When a BlockAckReq, Multi-TID BlockAckReq, or Multi-STA BlockAck frame is transmitted by an HE STA, its operation is defined in 26.4 (HE acknowledgment procedure).(11ax)

A non-S1G STA shall send PS-Poll frames using the access category AC_BE. This reduces the likelihood of collisions following a Beacon frame.

If an S1G STA receives an EDCA Parameter Set element from its associated AP and its STA type is indicated in the STA Type subfield in the received EDCA Parameter Set element, an S1G STA shall transmit PS-Poll frames, PS-Poll+BDT frames and NDP PS-Poll frames using the access category indicated in the PS-Poll ACI subfield. Otherwise, an S1G STA shall transmit PS-Poll frames, PS-Poll+BDT frames and NDP PS-Poll frames either using access category AC_VO when the S1G STA is a non-sensor STA or using access category AC_BE when the S1G STA is a sensor STA (see 10.60 (S1G flow control)).

When the first frame in a frame exchange sequence intended to carry a QoS Data, QoS Null or Management frame is an RTS or CTS frame, the RTS or CTS frame shall be transmitted using the access category of the corresponding QoS Data or QoS Null frame or the access category used for medium access of the Management frame.

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Control Wrapper frames shall be sent using the access category that would apply to the carried Control frame.

(#2176)A beamformer may send an HE or VHT NDP Announcement frame or Beamforming Report Poll frame using any access category and without being restricted by admission control procedures.

PS-Poll frames and Management frames are exempted from any and all restrictions on transmissions arising from admission control procedures.

The operation rules of HCF contention based channel access are defined in 10.23.2 (HCF contention based channel access (EDCA)).

The alternate video (A_VI) and alternate voice (A_VO) transmit queues share the same EDCAF as VI and VO transmit queues, respectively, as shown in Figure 10-28 (Reference implementation model when dot11AlternateEDCAActivated is true). When dot11AlternateEDCAActivated is true, a scheduling function above the VO EDCAF selects from the primary or (#476)alternate EDCA transmit queue an MSDU, an A-MSDU, an MMPDU, or set of MSDUs to be the next to be passed to the VO EDCAF (as shown in Figure 10-28 (Reference implementation model when dot11AlternateEDCAActivated is true)) so that the MSDU(s), A-MSDU(s), or MMPDU(s) from the queue with the higher UP are selected with a higher probability than from the queue with the lower UP. When dot11AlternateEDCAActivated is true, a scheduling function above the VI EDCAF selects from the primary or (#476)alternate EDCA transmit queue an MSDU, an A-MSDU, an MMPDU, or set of MSDUs to be the next to be passed to the VI EDCAF so that the MSDU(s), A-MSDU(s), or MMPDU(s) from the queue with the higher UP are selected with a higher probability than from the queue with the lower UP. The default algorithm to select an MSDU, A-MSDU, or MMPDU from either the A_VI or VI queue and to select an MSDU, A-MSDU, or MMPDU from either the A_VO or VO queue is as follows:

— For each EDCAF, an MSDU, A-MSDU, or MMPDU is selected for transmission using the transmission selection procedures defined in 8.6.8 of IEEE Std 802.1Q using two queues, the primary and alternate.

— For a given AC, the order in which frames are selected for transmission shall maintain the requirements specified in 10.7 (MSDU transmission restrictions) of this standard.

Alternative prioritization algorithms that meet the requirements of 10.7 (MSDU transmission restrictions) may be used.(#390)

#### 10.2.3.3 HCF controlled channel access (HCCA)

(#7196)HCCA is deprecated.

The HCCA mechanism uses a QoS-aware centralized coordinator, called a *hybrid coordinator (HC)*. The HC is (#2210)colocated with the AP of the BSS and uses the HC's higher priority of access to the WM to initiate frame exchange sequences and to allocate TXOPs to itself and other STAs in order to provide limited-duration CAPs for contention free transfer of QoS data.

The HC traffic delivery and TXOP allocation may be scheduled to meet the QoS requirements of a particular TC or TS. TXOP allocations and contention free transfers of QoS traffic might be based on the HC's BSS-wide knowledge of the amounts of pending traffic belonging to different TS and/or TCs and are subject to BSS-specific QoS policies.

Implementers are cautioned that QoS STAs are not required to interpret data subtypes that include QoS +CF-Ack in frames not addressed to themselves unless they set the Q-Ack subfield in the QoS Capability element to 1.

The HCF protects the transmissions during each CAP using the virtual CS mechanism.


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A STA may initiate multiple frame exchange sequences during a polled TXOP of sufficient duration to perform more than one such sequence.

The operation rules of the HCCA are defined in 10.23.3 (HCF controlled channel access (HCCA)).

### 10.2.4 Mesh coordination function (MCF)

The mesh facility includes an additional coordination function called *MCF* that is usable only in an MBSS. A mesh STA shall implement the MCF only. MCF has both a contention based channel access and contention free channel access mechanism. The contention based mechanism is EDCA and the contention free mechanism is called the *MCF controlled channel access (MCCA)*. MCF uses the default values for the PTKSA, and GTKSA Replay Counters. The operation rules of the EDCA are defined in 10.23.2 (HCF contention based channel access (EDCA)). The operation rules of the MCCA are defined in 10.24.3 (MCF controlled channel access (MCCA)).

### 10.2.5 Triggered uplink access (TUA)(11ax)

A non-AP HE STA supports trigger-based UL access methods. Triggered UL access (TUA) is used when an HE AP triggers one or more non-AP HE STAs to transmit HE TB PPDUs simultaneously. The optional UL OFDMA-based random access (UORA) additionally allows a non-AP HE STA to access one of a number of resource units (RUs) designated for random access by the HE AP. See 26.5.2 (UL MU operation) and 26.5.4 (UL OFDMA-based random access (UORA))).

### 10.2.6 Combined use of DCF, HCF and TUA(11ax)

The DCF, HCF, and TUA(11ax) are defined so they may operate within the same BSS. The HCF access methods (controlled and contention based) operate sequentially. Sequential operation allows the polled and contention based access methods to alternate, within intervals as short as the time to transmit a frame exchange sequence, under rules defined in 10.23 (HCF). The TUA access methods (see 26.5.2 (UL MU operation) and 26.5.4 (UL OFDMA-based random access (UORA))) allow triggered uplink periods to be interspersed with polled and contention based access methods. In addition, triggered uplink periods support contention based random access.(#1233)

### 10.2.7 Fragmentation/defragmentation overview

The process of partitioning an MSDU, (#2195)A-MSDU, or an MMPDU into smaller MAC-level frames, MPDUs, is called *fragmentation*. Fragmentation creates MPDUs smaller than the original MSDU, (#2195)A-MSDU, or MMPDU length to increase reliability, by increasing the probability of successful transmission as defined in 10.2.2 (DCF) of the MSDU, (#2195)A-MSDU, or MMPDU when channel characteristics limit reception reliability for longer frames. A STA may use fragmentation to use the medium efficiently in consideration of the duration available in granted TXOPs, as long as the rules in 10.4 (MSDU, (11ax)A-MSDU, and MMPDU fragmentation) and 10.11 (A-MSDU operation)(#2195) are followed. Fragmentation is accomplished at each immediate transmitter. The process of recombining MPDUs into a single MSDU, (#2195)A-MSDU, or MMPDU is defined as *defragmentation*. Defragmentation is accomplished at each immediate recipient.

An MSDU transmitted under an HT-immediate block ack agreement shall not be fragmented even if its length exceeds dot11FragmentationThreshold. An MSDU or MMPDU transmitted within an A-MPDU that does not contain an S-MPDU (see 10.12.8 (Transport of S-MPDUs)) shall not be fragmented even if its length exceeds dot11FragmentationThreshold. (#1515)A group addressed MPDU shall not carry a fragment of an MSDU or MMPDU even if the MPDU length exceeds dot11FragmentationThreshold.

NOTE 1—A fragmented MSDU or MMPDU transmitted by an HT STA to another HT STA can be acknowledged only using immediate acknowledgment (i.e., transmission of an Ack frame after a SIFS).

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NOTE 2—As specified in 10.4 (MSDU, (11ax)A-MSDU, and MMPDU fragmentation) and 10.11 (A-MSDU operation), only dynamic fragmentation is supported for A-MSDUs.(#2195)

NOTE 3—A fragmented MSDU or MMPDU transmitted by an S1G STA(#371) can be acknowledged either using immediate acknowledgment (i.e., transmission of an (NDP) Ack frame after a SIFS) or using fragment BA described in 10.3.2.12 (Fragment BA procedure).

Except as described below, when an individually addressed MSDU is received from the LLC or an individually addressed MMPDU is received from the MLME that would result in an MPDU of length greater than dot11FragmentationThreshold, the MSDU or MMPDU shall be fragmented.(#1656) An MSDU or MMPDU may be fragmented even if this is not the case. An exception applies when an MSDU is transmitted using an HT-immediate block ack agreement or when the MSDU or MMPDU is carried in an A-MPDU that does not contain an S-MPDU, in which case the MSDU or MMPDU is transmitted without fragmentation. Each fragment is a frame no longer than dot11FragmentationThreshold, if security encapsulation is not invoked for the MPDU. If security encapsulation is active for the MPDU, then the fragments shall be expanded by the encapsulation overhead and this may result in a fragment larger than dot11FragmentationThreshold.(#1656) An illustration of fragmentation is shown in Figure 10-4 (Fragmentation).

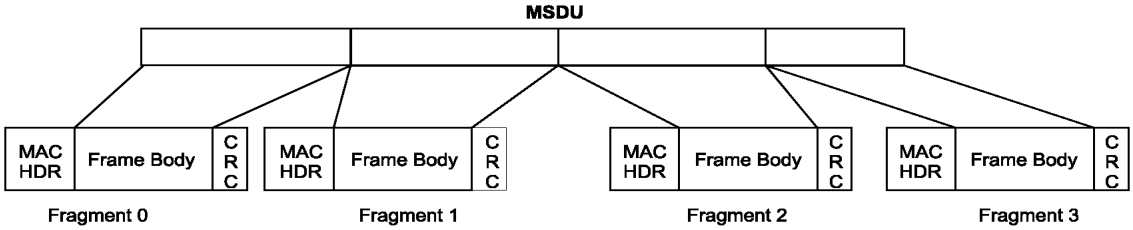


**Figure 10-4—Fragmentation**

The MPDUs resulting from the fragmentation of an MSDU or MMPDU are sent as independent transmissions, each of which is separately acknowledged. This permits transmission retries to occur per fragment, rather than per MSDU or MMPDU. The fragments of a single MSDU or MMPDU are either

— Sent as individual frames using the DCF, or

— Sent as a burst in an EDCA or HCCA TXOP, subject to TXOP limits and medium occupancy limits for the attached PHY.

A QoS Data frame with a TID matching a block ack agreement may be transmitted in a non-A-MPDU with Normal Ack ack policy.

Transmission of fragmented MPDUs by a DMG STA outside of an A-MPDU depends on setting of the No-Fragmentation field in the ADDBA Extension element within the ADDBA Response frame transmitted during the block ack agreement handshake. The MSDU shall not be fragmented if the No-Fragmentation field in the ADDBA Extension element within the ADDBA Response frame transmitted during the block ack agreement handshake is 1. If the No-Fragmentation field in the ADDBA Extension element within the ADDBA Response frame is 0, the originator may fragment an MSDU sent under the block ack agreement, with Normal Ack ack policy for the corresponding MPDUs.

### 10.2.8 MAC data service

The MAC data service provides the transport of MSDUs between MAC peer entities as characterized in 5.1.1 (Data service).

(#114)The transmission process is started by the MAC's receipt of one or more MA-UNITDATA.request primitives, each containing an MSDU and its associated parameters. This might cause one or more Data frames, containing the MSDU(s), to be transmitted.


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(#114)The reception process is started by the MAC's receipt of one or more Data frames containing one or more MSDUs. This might cause one or more MA-UNITDATA.indication primitives, each containing an MSDU and its associated parameters, to be issued.

When dot11SSPNInterfaceActivated is true, an AP shall distribute the group addressed message into the BSS only if dot11NonAPStationAuthSourceMulticast in the dot11InterworkingEntry identified by the source MAC address in the received message is true. When dot11SSPNInterfaceActivated is false, an AP shall distribute the group addressed message into the BSS, except when dot11RelayAPOperationActivated is true and the group addressed message is received from a STA. In that case, the group addressed message shall not be distributed into the BSS, and it shall be forwarded to the S1G relay STA in the same relay. The S1G relay STA shall send the group addressed message to the associated AP as an individually addressed frame using either a four address frame format (PV0 or PV1) or an A-MSDU format as specified in 10.53.4 (Addressing and forwarding of group addressed relay frames).

Unless the MPDU is delivered via DMS, the STA originating the message receives the message as a group addressed message (prior to any filtering). Therefore, a STA shall filter out group addressed messages that contain their address as the source address; the point at which such filtering occurs in the processing of received frames is an implementation choice. When dot11SSPNInterfaceActivated is false, group addressed MSDUs shall be propagated throughout the ESS. When dot11SSPNInterfaceActivated is true, group addressed MSDUs shall be propagated throughout the ESS only if dot11NonAPStationAuthSourceMulticast in the dot11InterworkingEntry identified by the source MAC address in the received message is true.

A STA transmitting on a general link also uses the addressing rules described in 10.64 (Addressing of GLK Data frame transmission).

(#2174)A MAC not contained within an S1G relay shall perform address filtering on the Address 1 field in each MPDU contained in a PPDU and, for non-GLK non-AP STAs, on the DA of each MSDU within an A-MSDU. In the case of a non-GLK STA receiver, when the Address 1 field or DA field contains a group address, address filtering is performed by (#1815)comparing the value in the Address 1 field or DA field to all values in the dot11GroupAddressesTable and the broadcast address value. The STA also validates the BSSID to verify that it either corresponds to the BSS of which the receiving STA is a member, or if dot11OCBActivated is true, that it contains the wildcard BSSID(#3522), indicating a Data frame sent outside the context of a BSS.(#1792) Address 1 filtering is as specified in 10.64 (Addressing of GLK Data frame transmission) when Address 1 is a SYNRA. A GLK AP does not perform any DA filtering for MPDUs received over a non-general link; all MSDUs so received are passed to the DS for further processing. A GLK STA does not perform DA filtering for MPDUs received over a general link; all MSDUs so received are passed to the GLK convergence function and from there to the bridge for further processing.

A mesh STA also uses the address matching rules described in 10.37.3 (Addressing and forwarding of individually addressed mesh Data frames), when it receives an individually addressed frame. When a mesh STA receives a frame with the Address 1 field equal to a group address, the mesh STA also checks the TA to determine whether the group addressed frame originated from one of its peer mesh STAs; if there is no match, the STA shall discard the frame. A mesh STA also uses the address matching rules described in 10.37.4 (Addressing and forwarding of group addressed mesh Data frames).

If the Address 1 field of an MPDU carrying an A-MSDU does not match any address at a receiving STA, then the entire A-MSDU is discarded.

In a QoS STA, the TID parameter of the MA-UNITDATA.request primitive results in a TID being specified for the transmitted MSDU. This TID associates the MSDU with the AC or TS queue for the indicated traffic.

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## 10.3 DCF

### 10.3.1 General

The basic medium access protocol is a DCF that allows for automatic medium sharing between compatible PHYs through the use of CSMA/CA and a random backoff count following a busy medium condition. In addition, all individually addressed traffic uses immediate positive acknowledgment (Ack frame), in which retransmission is scheduled by the sender if no Ack frame is received.

The CSMA/CA protocol is designed to reduce the collision probability between multiple STAs accessing a medium, at the point where collisions would most likely occur. Just after the medium becomes idle following a busy medium (as indicated by the CS function) is when the highest probability of a collision exists. This is because multiple STAs could have been waiting for the medium to become available again. This is the situation that necessitates a random backoff procedure to resolve medium contention conflicts.

The DCF is modified for use by DMG STAs to allow sharing of the medium between compatible DMG PHYs (see 10.3.4 (DCF access procedure)). A DMG STA has no direct knowledge of when it might interfere (collide with the transmission of) another STA.

The CS function of a DMG STA might not indicate the medium busy condition due to the predominant nature of directional transmissions and receptions. The transmission of a STA might interfere (collide) with the transmission of another STA even though the CS function at the first STA does not indicate medium busy. The interference (collision) is identified when the expected response frame is not received. SPSH is achieved by the proper combination of the STA antenna configuration during the media access and data transfer phases.

CS shall be performed both through physical and virtual mechanisms.

The virtual CS mechanism is achieved by distributing reservation information announcing the impending use of the medium. The exchange of RTS and CTS frames prior to the actual Data frame is one means of distribution of this medium reservation information. The RTS and CTS frames contain a Duration field that defines the period of time that the medium is to be reserved to transmit the actual Data frame and the returning Ack frame. A STA receiving either the RTS frame (sent by the originating STA) or the CTS frame (sent by the destination STA) shall process the medium reservation. Thus, a STA might be unable to receive from the originating STA and yet still know about the impending use of the medium to transmit a Data frame. The exchange of an MU-RTS Trigger frame and simultaneous CTS frame (#1926)transmissions by HE STAs prior to the actual Data frames is another means of distribution of this medium reservation information.(11ax)

Another means of distributing the medium reservation information is the Duration/ID field in individually addressed frames. This field gives the time that the medium is reserved, either to the end of the immediately following Ack frame, or in the case of a fragment sequence, to the end of the Ack frame following the next fragment.

The RTS/CTS exchange also performs both a type of fast collision inference and a transmission path check. If the return CTS frame is not detected by the STA originating the RTS, the originating STA may repeat the process (after observing the other medium-use rules) more quickly than if the long Data frame had been transmitted and a return Ack frame had not been detected. An RTS/CTS exchange by VHT STAs also performs fast collision inference on the secondary 20 MHz channel, secondary 40 MHz channel, and secondary 80 MHz channel and helps the VHT STA transmitting the RTS to determine the available bandwidth at the responder.(11ay) Similarly, an RTS/DMG CTS exchange by EDMG STAs performs fast collision inference on the secondary channel, secondary1 channel, and secondary2 channel and helps the EDMG STA transmitting the RTS to determine the available bandwidth at the responder.


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Another advantage of the RTS/CTS mechanism occurs where multiple BSSs utilizing the same channel overlap. The medium reservation mechanism works across the BSS boundaries. The RTS/CTS mechanism might also improve operation in a typical situation in which all STAs are able to receive from the AP, but might not be able to receive from all other STAs in the BSA.

Except for MPDUs transmitted via the GCR service, the RTS/CTS mechanism cannot be used for MPDUs with a group addressed immediate destination because there are multiple recipients for the RTS frame, and thus potentially multiple concurrent senders of the CTS frame in response. For MPDUs transmitted via the GCR service, an RTS frame may be used if it is directed to a STA within the GCR group (see 10.23.2.12.2 (Unsolicited retry procedure) and 10.25.8 (GCR and GLK-GCR block ack)). The RTS/CTS mechanism is not used for every Data frame transmission. Because the additional RTS and CTS frames add overhead inefficiency, the mechanism is not always justified, especially for short Data frames.

The use of the RTS/CTS mechanism under control of dot11RTSThreshold if dot11TXOPDurationRTSThreshold is 1023 or is not present(11ax) is described in 10.3.5 (Individually addressed MPDU transfer procedure).

(11ax)The use of the RTS/CTS mechanism is under the control of dot11TXOPDurationRTSThreshold if dot11TXOPDurationRTSThreshold is present and is not 1023. If this mechanism is enabled, a non-AP HE STA shall initiate a TXOP that is used for individually addressed frames with an RTS/CTS exchange as defined in 26.2.1 (TXOP duration-based RTS/CTS).

All non-DMG STAs that are members of a BSS are able to receive and transmit at all of the data rates in the BSSBasicRateSet parameter of the MLME-START.request primitive or BSSBasicRateSet parameter of the SelectedBSS parameter of the MLME-JOIN.request primitive; see 6.5.4.2.4 (Effect of receipt) and 6.5.11.2.4 (Effect of receipt).

NOTE—The operational rate or MCS set that a STA advertises does not necessarily contain all the mandatory rates or MCSs, respectively. The basic rate or MCS set that a STA starting a BSS advertises does not necessarily contain all the mandatory rates or MCSs, respectively. However, a STA has to be capable of receiving using a mandatory rate or MCS (when required by the rules in 10.6 (Multirate support)) even if it is not present in the operational rate or MCS set, respectively, that the STA advertises, and similarly has to be capable of transmitting using a mandatory rate or MCS (when required by the rules in 10.6 (Multirate support)) even if it is not present in the basic rate or MCS set, respectively. In this context, “mandatory” describes rates or MCSs that are so described, or described using “shall support”, in reference to the STA type, in the PHY clause applicable to the STA.

All HT STAs that are members of a BSS are able to receive and transmit using all of the MCSs in the Basic HT-MCS Set field of the HT Operation parameter of the MLME-START.request primitive or Basic HT-MCS Set field of the HT Operation parameter of the SelectedBSS parameter of the MLME-JOIN.request primitive; see 6.5.4.2.4 (Effect of receipt) and 6.5.11.2.4 (Effect of receipt).

All VHT STAs that are members of a BSS are able to receive and transmit using all of the <VHT-MCS, NSS> tuples in the basic VHT-MCS and NSS set (see 11.38.7 (Basic VHT-MCS and NSS set operation)) except as constrained by the rules of 10.6.13 (Rate selection constraints for VHT STAs).

All DMG STAs that are members of a BSS are able to receive and transmit using all of the MCSs in the OperationalRateSet parameter of the MLME-START.request primitive or OperationalRateSet parameter of the SelectedBSS parameter of the MLME-JOIN.request primitive; see 6.5.4.2.4 (Effect of receipt) and 6.5.11.2.4 (Effect of receipt).

To support the proper operation of the RTS/CTS by non-DMG STAs, RTS/DMG CTS by DMG STAs, and the virtual CS mechanism, (#181)a non-DMG STA shall interpret Control frames with the Subtype subfield equal to RTS or CTS, (#181)and a DMG STA shall interpret Control frames with the Subtype subfield equal to RTS or DMG CTS.

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A Data frame sent under the DCF shall have the Type subfield set to Data and the Subtype subfield set to Data or Null. A STA receiving a frame with the Type subfield equal to Data shall not indicate the frame to the LLC when the Subtype subfield is equal to Null, but shall indicate the frame to the LLC when the Subtype subfield is equal to Data, even if the frame body contains zero octets.

While in the awake state and operating under DCF but not transmitting, a DMG STA can configure its receive antenna to a quasi-omni pattern in order to receive frames transmitted by any STA that is covered by this antenna pattern.

### 10.3.2 Procedures common to the DCF and EDCAF

#### 10.3.2.1 CS mechanism

Physical and virtual CS functions are used to determine the state of the medium. When either function indicates a busy medium, the medium shall be considered busy; otherwise, it shall be considered idle.

A physical CS mechanism shall be provided by the PHY. See Clause 8 (PHY service specification) for how this information is conveyed to the MAC. The details of physical CS are provided in the individual PHY specifications.

A virtual CS mechanism, referred to as the NAV, shall be provided by all MACs. An additional virtual CS mechanism, referred to as response indication deferral (RID), shall be provided by S1G MACs.

The NAV maintains a prediction of future traffic on the medium based on duration information that is announced in RTS/CTS frames by non-DMG STAs, in MU-RTS Trigger/CTS frames by HE STAs as defined in 26.2.6 (MU-RTS Trigger/CTS frame exchange sequence procedure(#109)), and in RTS/DMG CTS frames by DMG STAs prior to the actual exchange of data.(11ax) The duration information is also available in the MAC headers of all frames other than PV1 MAC frames and PS-Poll frames, and during the BTI, the A-BFT, the ATI, the CBAP, and the SP. The duration information in a frame transmitted by an S1G STA is also available in PS-Poll+BDT frames, in NDP CTS frames, in NDP Ack frames whose Idle Indication field value is 0, and in NDP_2M PS-Poll-Ack frames whose Idle Indication field is 0. (11ax) The duration information might also be available in the RXVECTOR parameter TXOP_DURATION when an HE PPDU is received (see 26.11.5 (TXOP_DURATION)).

The mechanism for setting the NAV using RTS/CTS or RTS/DMG CTS in the DCF is described in 10.3.2.4 (Setting and resetting the NAV), and use of the NAV in HCF is described in 10.23.2.2 (EDCA backoff procedure) and 10.23.3.4 (NAV operation of a TXOP under HCCA). Additional details regarding NAV use appear in 10.3.2.6 (RTS/CTS with fragmentation), 10.3.2.15 (NAV distribution), 10.38.10 (Updating multiple NAVs), and 10.27 (Protection mechanisms).

The mechanism for setting the RID is described in 10.3.2.5 (Setting and resetting the RID).

The CS mechanism combines the NAV state, and in S1G STAs also the RID state, and the STA's transmitter status with physical CS to determine the busy/idle state of the medium. The NAV and RID might be thought of as counters that count down to 0 at a uniform rate. In non-S1G STAs, when the NAV counter is 0, the virtual CS indication is that the medium is idle; when the counter is nonzero, the indication is busy. In S1G STAs, when both NAV and RID counters are 0, the virtual CS indication is that the medium is idle; when either the NAV counter or the RID counter is nonzero the indication is that the medium is busy. (11ax)The virtual CS indication of medium for HE STAs with two NAVs is described in 26.2.4 (Updating two NAVs). If a DMG STA supports multiple NAVs as defined in 10.38.10 (Updating multiple NAVs) and all counters are 0, the virtual CS indication is that the medium is idle; when at least one of the counters is nonzero, the indication is busy. The medium shall be determined to be busy when the STA is transmitting.


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(#1058)(#6064)Immediately after aRxTxTurnaroundTime + aAirPropagationTime + 10% × (aSlotTime – aAirPropagationTime) after each MAC slot boundary as defined in 10.3.7 (DCF timing relations) and 10.23.2.4 (Obtaining an EDCA TXOP), the MAC shall issue a PHY-CCARESET.request primitive to the PHY, where aAirPropagationTime determined as described in 10.22.5 (Operation with coverage classes).

#### 10.3.2.2 MAC-level acknowledgments

The reception of some frames, as described in 10.3.2.11 (Acknowledgment procedure), requires the receiving STA to respond with an acknowledgment if the FCS of the received frame is correct. This technique is known as positive acknowledgment.

Lack of reception of an expected frame containing an acknowledgment indicates to the STA initiating the (#109)frame exchange sequence that an error has occurred. Note, however, that the destination STA may have received the frame correctly, and that the error may have occurred in the transfer or reception of the frame containing an acknowledgment. When a frame containing an acknowledgment is lost, the MAC that initiated the (#109)frame exchange sequence does not receive a protocol indication of whether the initial frame was correctly received.

A correctly received frame is one for which the PHY-RXEND.indication primitive does not indicate an error and the FCS indicates the frame is error free.

#### 10.3.2.3 IFS

##### 10.3.2.3.1 General

(#16)The time interval between certain adjacent PPDU[+SigExt]s is called the *IFS*. A STA shall determine that the medium is idle through the use of the CS function for the interval specified. Ten different IFSs are defined to provide priority levels for access to the wireless medium. Figure 10-5 (Some IFS relationships(#16)) shows some of these relationships. All timings are referenced from occurrence of the PHY interface primitives PHY-TXEND.confirm, PHY-TXSTART.confirm, PHY-RXSTART.indication, and PHY-RXEND.indication.

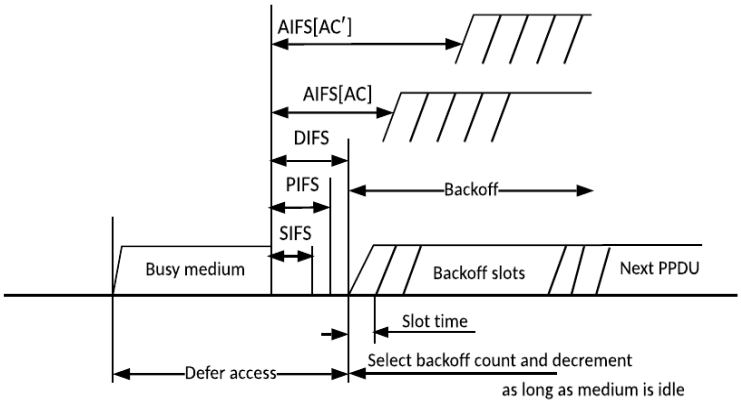


**Figure 10-5—Some IFS relationships(#16)**

The IFSs are as follows:

a) RIFS reduced interframe space
b) SIFS short interframe space
c) PIFS priority interframe space
d) DIFS DCF interframe space
e) AIFS[AC] AIFS arbitration interframe space (for the AC used by the QoS facility)

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f) EIFS extended interframe space
g) SBIFS short beamforming interframe space
h) BRPIFS beam refinement protocol interframe space
i) MBIFS medium beamforming interframe space
j) LBIFS long beamforming interframe space

The different IFSs shall be independent of the STA bit rate. (#16)The IFS timings are defined as the nominal time gaps between primitives at the MAC after accounting for defined delays (see 10.3.7 (DCF timing relations)). The timing of primitives in turn depend on time gaps between PPDU[+SigExt]s on the medium. The IFS timings except AIFS are fixed for each PHY (even in multirate-capable PHYs). The IFSs are determined from attributes specified by the PHY.

(#16)NOTE—The "frame" in "interframe" is due to historical use of "frame" to signify "PHY frame", as a synonym for "PPDU".

#### 10.3.2.3.2 RIFS

The use of RIFS for a non-DMG STA is obsolete, and support for such use might be subject to removal in a future revision of the standard. A VHT or S1G STA shall not transmit frames separated by a RIFS.

RIFS is a means of reducing overhead and thereby increasing network efficiency.

RIFS may be used in place of SIFS to separate multiple transmissions from a single transmitter, when no SIFS-separated response transmission is expected and either of the following is true:

— The transmitter is not a DMG STA.
— The transmitter is a DMG STA, and each transmission occurs with the same transmit antenna configuration.

RIFS shall not be used between frames with different RA field(#3522). The duration of RIFS is defined by the aRIFS PHY characteristic (see Table 19-25 (HT PHY characteristics) and Table 20-30 (DMG PHY characteristics)). (#14)The RIFS is the time from the end of the previous PPDU to the beginning of the preamble of the subsequent PPDU as seen on the WM. A STA shall not allow the space between PPDUs that are defined to be separated by a RIFS, as measured on the medium, to vary from the nominal RIFS (aRIFSTime) by more than ± 10% of aRIFSTime. Two PPDUs separated by a RIFS shall both be HT PPDUs or shall both be DMG PPDUs.

An HT STA shall not transmit PPDUs separated by a RIFS unless the beacon or probe response most recently received from the BSS's AP contains an HT Operation element with RIFS Mode field equal to 1.

There are additional restrictions regarding when RIFS may be employed as defined in 10.29 (Reverse direction protocol)(#3263). See also 10.27.3.3 (RIFS protection).

#### 10.3.2.3.3 SIFS

(#14)The SIFS is the time from the end of the previous PPDU[+SigExt] to the beginning of the preamble of the subsequent PPDU as seen on the WM (#1570)at the STA transmitting the subsequent PPDU.

(#1570)NOTE—The time between these PPDUs as seen on the WM at any other STA in the BSS, including the STA transmitting the previous PPDU, might be anything from SIFS to SIFS + aAirPropagationTime. Because aSlotTime includes aAirPropagationTime, even in the worst case the beginning of the preamble of the subsequent PPDU will arrive before PIFS at any STA in the BSS.


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(#1106)(#3366)SIFS is the shortest of the IFSs between transmissions from different non-DMG STAs. SIFS shall be used when STAs have seized the medium and need to keep it for the duration of the frame exchange sequence to be performed. Using the smallest gap between transmissions within the frame exchange sequence prevents other STAs, which are required to wait for the medium to be idle for a longer gap, from attempting to use the medium, thus giving priority to completion of the frame exchange sequence in progress.

The SIFS shall be used prior to transmission of each of the following frames:

— An (NDP) Ack frame, a TACK frame, a STACK frame, NDP PS-Poll-Ack frame, a (NDP) CTS frame;
— A PPDU containing a BlockAck frame, NDP BlockAck frame, or BAT frame that is an immediate response to either a BlockAckReq frame or an A-MPDU;
— A DMG CTS frame, a DMG DTS frame, a Grant Ack frame;
— A response frame transmitted in the ATI, and the second or subsequent MPDU of a fragment burst;
— A frame within a series of NDP sector training frames transmitted by an S1G AP after a sector training announcement;
— An RTS frame that is sent as an immediate response to a PS-Poll(+BDT) frame.

The SIFS may also be used, and by an S1G STA for an (NDP) (#4258)PS-Poll frame or uplink trigger frame that is a response to an NDP Paging frame (see 10.46.6 (NDP paging setup)).

(#233)(#14)A non-DMG STA shall not allow the space between PPDU[+SigExt]s that are defined to be separated by a SIFS, as measured on the medium (#1570)at the STA, to vary from the nominal SIFS by more than ± 10% × (aSlotTime – aAirPropagationTime) for the PHY in use. (#233)A DMG STA shall not allow the space between PPDUs that are defined to be separated by a SIFS, as measured on the medium (#1570)at the STA, to vary from the nominal SIFS by more than –0% or +10% × (aSlotTime – aAirPropagationTime).(#1106)

When transmitting a response frame immediately following a SIFS, a DMG STA, or CMMG STA(#150) shall set the TXVECTOR parameter LAST_RSSI of the response frame to the power that was measured on the received PPDU, as reported in the RCPI field of the frame that elicited the response frame. The encoding of the value is as follows:

— Power values less than or equal to –68 dBm are represented as the value of 1.
— Power values between –68 dBm and –42 dBm are represented as $\left\lfloor \frac{p-(-71)+0.5}{2} \right\rfloor$, where $p$ is the power in dBm.
— Power values greater than or equal to –42 dBm are represented as the value 15.
— For all other cases, the STA shall set the TXVECTOR parameter LAST_RSSI of the transmitted frame to 0.

A DMG STA that transmits a PPDU containing at least one individually addressed MPDU shall set the TXVECTOR parameter TURNAROUND to 1 if the STA is required to listen for an incoming PPDU immediately following the transmission of the PPDU; otherwise, the STA shall set the TXVECTOR parameter TURNAROUND to 0. The STA shall set the TXVECTOR parameter TURNAROUND to 0 when it transmits an RTS frame.

(#1106)(11ax)An HE STA that transmits an HE TB PPDU a SIFS after the end of a received PPDU follows the procedure in 26.5.2.3 (Non-AP STA behavior for UL MU operation).

#### 10.3.2.3.4 PIFS

The PIFS is used to gain priority access to the medium.

The PIFS may be used as described in the following list and shall not be used otherwise:

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- A STA transmitting a Channel Switch Announcement frame, as described in 11.8 (DFS procedures) or transmitting an Extended Channel Switch Announcement frame, as described in 11.9 (Extended channel switching (ECS))
- A STA transmitting a TIM frame, as described in 11.2.3.14 (TIM Broadcast)
- A STA transmitting a Beacon, DMG Beacon or S1G Beacon frame(#2063)
- An HC starting an HCCA TXOP, as described in 10.23.3.2.2 (CAP generation)
- A non-AP QoS STA that is a polled TXOP holder recovering from the absence of an expected reception in a CAP, as described in 10.23.3.2.3 (Recovery from the absence of an expected reception)
- An HT STA using dual CTS protection before transmission of the CTS2, as described in 10.3.2.10 (Dual CTS protection)
- A TXOP holder continuing to transmit after a transmission failure, as described in 10.23.2.8 (Multiple frame exchange sequences in an EDCA TXOP(#109))
- A TXOP holder transmitting an RTS with a bandwidth signaling TA within multiple frame exchange sequences(#109), as specified in 10.23.2.8 (Multiple frame exchange sequences in an EDCA TXOP(#109))
- An RD initiator continuing to transmit using error recovery, as described in 10.29.3 (Rules for RD initiator)(#3263)
- An HT STA performing clear channel assessment (CCA) in the secondary channel before transmitting a 40 MHz mask PPDU using EDCA channel access, as described in 11.15.9 (STA CCA sensing in a 20/40 MHz BSS)
- An AP continuing to transmit in a GCR block ack TXOP after the failure to receive a BlockAck frame, as described in 10.25.8 (GCR and GLK-GCR block ack)
- A VHT STA performing CCA in the secondary 20 MHz, 40 MHz, and 80 MHz channels before transmitting a 40 MHz, 80 MHz, 160 MHz, or 80+80 MHz mask PPDU using EDCA channel access, as described in 10.23.3 (HCF controlled channel access (HCCA))
- An AP or PCP continuing to transmit in the ATI after a transmission failure during the ATI (10.38.3 (ATI transmission rules))
- A source DMG STA of an SP continuing to transmit after a transmission failure, as described in 10.38.6.2 (Service period (SP) allocation)
- A DMG STA performing EDCA access during an allocated CBAP, as described in 10.38.5 (Contention based access period (CBAP) transmission rules)
- A TVHT STA performing CCA in the secondary TVHT_W and TVHT_2W channels before transmitting a TVHT_2W or TVHT_W+W mask PPDU and TVHT_4W or TVHT_2W+2W mask PPDU, respectively, using EDCA channel access, as defined in 10.23.3 (HCF controlled channel access (HCCA))
- An S1G STA performing clear channel assessment (CCA) in the secondary 2 MHz, 4 MHz, and 8 MHz channels before transmitting a 4 MHz, 8 MHz, or 16 MHz mask PPDU using EDCA channel access, as described in 10.23.2.6 (EDCA channel access in an S1G BSS)
- An S1G AP transmitting sounding NDP(s) within an SST sounding RAW
- (11ay)An EDMG STA performing CCA in the secondary, secondary1, and secondary2 channels before transmitting a 4.32 GHz, 6.48 GHz, 8.64 GHz, 2.16+2.16 GHz, or 4.32+4.32 GHz mask PPDU using EDCA channel access, as described in 10.23.2 (HCF contention based channel access (EDCA)).

With the exception of performing CCA in the secondary channel (where the timing is defined in 11.15.9 (STA CCA sensing in a 20/40 MHz BSS)(11ay) for an HT STA and defined in10.38.12.2 (Channel access over multiple channels) for an EDMG STA), a STA using PIFS starts its transmission after its CS mechanism (see


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10.3.2.1 (CS mechanism)) determines that the medium is idle at the TxPIFS slot boundary, as defined in 10.3.7 (DCF timing relations) and 10.23.2.4 (Obtaining an EDCA TXOP).

#### 10.3.2.3.5 DIFS

The DIFS shall be used by STAs operating under the DCF to transmit Data frames (MPDUs) and Management frames (MMPDUs). A STA using the DCF may transmit if both:

— After it has correctly received a frame, its CS mechanism (see 10.3.2.1 (CS mechanism)) determines that the medium is idle at the TxDIFS slot boundary as defined in 10.3.7 (DCF timing relations).

— The STA's backoff counter has a value of zero.

#### 10.3.2.3.6 AIFS

The AIFS shall be used by QoS STAs that access the medium using the EDCAF to transmit: all Data frames (MPDUs) except during the ATI or an SP, all Management frames (MMPDUs) except during the ATI or an SP, all Extension frames except for the DMG Beacon frame, and the following Control frames:

— PS-Poll(+BDT)

— SSW (if first transmission by an initiator in a CBAP)

— Poll (if first transmission and when in a CBAP)

— Grant (if first transmission and when in a CBAP and not transmitted in response to an SPR frame)

— SPR (when in a CBAP and not transmitted as a response to a Poll)

— RTS (when not transmitted as a response to a PS-Poll(+BDT) frame by an S1G STA)

— CTS (when not transmitted as a response to an RTS frame)

— DMG CTS (when not transmitted as a response to an RTS frame)

— BlockAckReq

— BlockAck (when not transmitted as a response to a BlockAckReq frame)

— NDP PS-Poll

A STA using the EDCAF shall obtain a TXOP for an AC if the STA's CS mechanism (see 10.3.2.1 (CS mechanism)) determines that the medium is idle at the AIFS[AC] slot boundary (see 10.23.2.4 (Obtaining an EDCA TXOP)), after a correctly received frame, and the backoff counter for that AC has a value of zero.

A non-AP and non-PCP QoS STA computes the time periods for each AIFS[AC] from dot11EDCATableAIFSN. In an infrastructure BSS, QoS STAs update their dot11EDCATableAIFSN values using information in the most recent EDCA Parameter Set element of Beacon frames received from the AP of the BSS (see 9.4.2.27 (EDCA Parameter Set element)) if the STA is a non-DMG STA or the most recent EDCA Parameter Set element of DMG Beacon and Announce frames received from the AP or PCP of the BSS if the STA is a DMG STA. A QoS AP or PCP computes the time periods for each AIFS[AC] from dot11QAPEDCATableAIFSN.

#### 10.3.2.3.7 EIFS

(#14)A DCF shall use EIFS before transmission, when it determines that the medium is idle immediately following reception of a PPDU[+SigExt] for which the PHY-RXEND.indication primitive contained an error or a frame for which the FCS value was not correct. Similarly, a STA's EDCA mechanism under HCF shall use the EIFS–DIFS+AIFS[AC] interval. The duration of an EIFS is defined in 10.3.7 (DCF timing relations). The EIFS or EIFS–DIFS+AIFS[AC] interval shall begin following indication by the PHY that the medium is idle after detection of the erroneous PPDU or frame, without regard to the virtual CS mechanism. The STA shall not begin a transmission until the expiration of the later of the NAV and EIFS or EIFS–DIFS+AIFS[AC]. The EIFS and EIFS–DIFS+AIFS[AC] are defined to provide enough time for another STA

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to acknowledge what was, to this STA, an incorrectly received PPDU or frame before this STA commences transmission. Reception of an error-free frame or reception of an HE PPDU with the RXVECTOR parameter TXOP_DURATION that is not set to UNSPECIFIED during the EIFS or EIFS-DIFS+AIFS[AC] resynchronizes the STA to the actual busy/idle state of the medium, so the EIFS or EIFS-DIFS+AIFS[AC] is terminated and medium access (using DIFS or AIFS as appropriate and, if necessary, backoff) continues following reception of the PPDU[+SigExt] containing error-free frame or following an expected end of the received HE PPDU. At the expiration or termination of the EIFS or EIFS-DIFS+AIFS[AC], the STA reverts to the NAV and physical CS to control access to the medium.(11ax)

EIFS shall not be invoked for an A-MPDU if one or more of its frames are received correctly. EIFS shall not be invoked if the RXVECTOR parameter TXOP_DURATION of a received HE PPDU is not set to UNSPECIFIED.(11ax)

#### 10.3.2.3.8 SBIFS

(11ay)The SBIFS shall separate PPDU transmissions in each of the following cases:

a) Back-to-back PPDU transmissions from a single transmitter during a receive sector sweep or TDD beamforming, or

b) Back-to-back PPDU transmissions when each PPDU transmission occurs with a different transmit antenna configuration and no SIFS-separated response transmission is expected, or

c) Back-to-back PPDU transmissions from a single transmitter when each PPDU transmission occurs with a different transmit RF chain and no SIFS-separated response transmission is expected.

(11ay)The duration of SBIFS is determined by the aSBIFSTime PHY characteristic. (#14)The SBIFS is the time from the end of the previous PPDU to the beginning of the preamble of the subsequent PPDU as seen on the WM. A STA shall not allow the space between (11ay)PPDUs that are defined to be separated by a SBIFS, as measured at the DMG antenna, to be less than aSBIFSTime or to be more than aSBIFSTime + aSBIFSAccuracy. (11ay)Two PPDUs separated by a SBIFS shall both be either DMG PPDUs or EDMG PPDUs.

#### 10.3.2.3.9 BRPIFS

The BRPIFS shall be used by STAs between transmissions of BRP frames. (#14)The BRPIFS is the maximum time from the end of the previous PPDU, or training field if present in the PPDU, to the beginning of the preamble of the subsequent PPDU as seen on the WM. The corresponding minimum time is SIFS. BRPIFS is defined to be equal to aBRPIFS+10%.

#### 10.3.2.3.10 MBIFS

The MBIFS shall be used between the BTI and the A-BFT and between the ISS, RSS, SSW-Feedback, and SSW-Ack. (11ay)In a BRP TXSS, MBIFS shall be used in between the first three transmitted BRP PPDUs (see 10.41.10.5 (BRP transmit sector sweep (BRP TXSS))). MBIFS is equal to 3×aSIFSTime. (#233)A DMG STA shall not allow the space between (#14)PPDUs containing frames that are defined to be separated by an MBIFS, as measured on the medium, to vary from the nominal MBIFS by more than –0% or +10% × (aSlotTime – aAirPropagationTime).

#### 10.3.2.3.11 LBIFS

The LBIFS shall be used (11ay)between two consecutive transmissions that use different DMG antennas but with common RF chain, and when the recipient STA is expected to switch DMG antennas. LBIFS is equal to TXTIME(SSW) + 2×SBIFS(11ay), except when used as part of an ISS or an RSS employing Short SSW PPDUs, in which case LBIFS is equal to 2×TXTIME(Short SSW) + 3×SBIFS. (#233)A DMG STA shall not allow the space between (#14)PPDUs containing frames that are defined to be separated by an LBIFS, as


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measured on the medium, to vary from the nominal LBIFS by more than –0% or +10% × (aSlotTime – aAirPropagationTime).

### 10.3.2.4 Setting and resetting the NAV

This subclause describes the setting and resetting of the NAV for non-DMG STAs and DMG STAs that support a single NAV. DMG STAs that support multiple NAVs shall update their NAVs according to the procedures described in 10.38.10 (Updating multiple NAVs). HE STAs with two NAV timers shall update their NAV timers according to the procedures described in 26.2.4 (Updating two NAVs).(11ax)

(#2384)The duration information is indicated by a frame as follows:

— If there is a Duration field in the frame, then the duration information is indicated by the Duration field.

— If the frame is a PS-Poll, then the duration information is equal to the time, in microseconds, required to transmit one Ack frame plus one SIFS under the data rate selection rules. If the calculated duration information includes a fractional microsecond, that duration information is rounded up to the next higher integer.

A STA that receives at least one (#4179)frame in a PSDU can update its NAV with the information from any valid Duration field in the PSDU. When the received frame's RA is equal to the STA's own MAC address, the STA shall not update its NAV. Further, when the received frame is a DMG CTS frame and its TA is equal to the STA's own MAC address, the STA shall not update its NAV. For all other received frames the STA shall update its NAV when the received Duration is greater than the STA's current NAV value. Upon receipt of a PS-Poll frame, a STA, except for an S1G STA for which the RXVECTOR parameter RESPONSE_INDICATION of the received PS-Poll frame is NDP Response, shall update its NAV settings as appropriate under the data rate selection rules using a duration value equal to the time, in microseconds, required to transmit one Ack frame plus one SIFS, but only when the new NAV value is greater than the current NAV value. (#1490)If the value calculated for the Duration/ID field is not an integer, the value inserted in the Duration/ID field is rounded up to the next higher integer. When the NAV is reset, a PHY-CCARESET.request primitive shall be issued. This NAV update operation is performed when the PHY-RXEND.indication primitive is received, except when the PHY-RXEND.indication primitive is received before the end of the PPDU. In this exception, the NAV update is performed at the expected end of the PPDU.(11ax)

NOTE 1—An S1G STA that receives a (#3274)frame that does not include a valid Duration field does not update its NAV. However, it updates its RID as described in 10.3.2.5 (Setting and resetting the RID).

An S1G STA that receives a PS-Poll frame with the RXVECTOR parameter RESPONSE_INDICATION equal to NDP Response shall update its NAV using a duration value equal to NDPTxTime (10.3.2.5.2 (RID update)) plus one SIFS, but only when the new NAV value is greater than the current NAV value. The NDPTxTime is calculated according to additional RXVECTOR parameters as described in 10.3.2.5.2 (RID update).

In addition to the NAV update rules described in this subclause, an S1G STA shall also update its NAV to a new NAV value if it receives information that the NAV is greater than the STA's current NAV value. This information shall be received in the Duration field of the following frames: NDP CTS, NDP Ack, NDP_2M PS-Poll-Ack, and S1G Beacon, except when the received frame is one of the following:

— NDP CTS frame that is either addressed to the S1G STA as a response to an RTS frame, or that is an NDP CTS frame whose value of the Duration field can be disregarded as defined in 10.3.2.9 (CTS and DMG CTS procedure).

— NDP Ack frame that is either addressed to the S1G STA, or that has the Idle Indication field equal to 1 (see 10.3.2.11 (Acknowledgment procedure)).

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- NDP_2M PS-Poll-Ack frame that is either addressed to that S1G STA, or that has the Idle Indication field equal to 1 (see 10.3.2.11 (Acknowledgment procedure)).
- S1G Beacon frame that includes at least one TIM element in which there is an indication of available BUs for the receiving STA in at least one of the TIM elements.
- S1G Beacon frame that includes at least one TIM element and at least one RPS element that indicate both of the following:
  - There is no indication of available BUs for the receiving STA in any of the TIM elements.
  - The receiving S1G STA is allowed to access the first RAW immediately following the S1G Beacon frame as specified in at least one of the RPS elements.

(11ax)An HE AP that is not a TXOP holder shall update the NAV with the duration information indicated by the RXVECTOR parameter TXOP_DURATION for an HE PPDU if all of the following conditions are met and shall not update the NAV with the duration information indicated by the RXVECTOR parameter TXOP_DURATION if one or more of the following conditions are not met:

- The RXVECTOR parameter TXOP_DURATION is not UNSPECIFIED.
- The HE AP does not receive a frame with a Duration field in the PPDU.
- The duration indicated by the RXVECTOR parameter TXOP_DURATION is greater than the current NAV value of the HE AP.

(11ax)An HE AP that is a TXOP holder shall update the NAV with the duration information indicated by the RXVECTOR parameter TXOP_DURATION for an HE PPDU if all of the following conditions are met and shall not update the NAV with the duration information indicated by the RXVECTOR parameter TXOP_DURATION if one or more of the following conditions are not met:

- The RXVECTOR parameter TXOP_DURATION is not UNSPECIFIED.
- The HE AP does not receive a frame with a Duration field in the PPDU.
- The duration indicated by the RXVECTOR parameter TXOP_DURATION is greater than the current NAV value of the HE AP.
- The RXVECTOR parameter BSS_COLOR is not equal to the BSS color of the HE AP.

NOTE 2—A non-AP HE STA maintains two NAVs, but an HE AP might maintain only one NAV (see 26.2.4 (Updating two NAVs)).

NOTE 3—If a STA receives an HE PPDU with the duration information indicated by both a frame with a Duration field and the RXVECTOR parameter TXOP_DURATION, then the duration information indicated by the RXVECTOR parameter TXOP_DURATION is ignored.

Figure 10-6 (RTS/CTS/data/Ack and NAV setting) indicates the NAV for STAs that might receive the RTS frame, while other STAs might receive only the CTS frame, resulting in the lower NAV bar as shown (with the exception of the STA to which the RTS frame was addressed).

A STA that used information from an RTS frame or MU-RTS Trigger frame as the most recent basis to update its NAV setting is permitted to reset its NAV if no (#3038)PHY-RXEARLYSIG.indication or PHY-RXSTART.indication primitive is received from the PHY during a NAVTimeout period starting when the MAC receives a PHY-RXEND.indication primitive corresponding to the detection of the RTS frame or MU-RTS Trigger frame.(11ax)

In (#8178)a non-DMG BSS, NAVTimeout period is equal to (2 × aSIFSTime) + (CTS_Time) + aRxPHYStartDelay + (2 × aSlotTime). In a non-S1G STA, (11ax)if an RTS frame is used for the most recent NAV update, CTS_Time shall be calculated using the length of the CTS frame and the data rate at which the RTS frame used for the most recent NAV update was received. (11ax)If an MU-RTS Trigger frame was used for the most recent NAV update, CTS_Time shall be calculated using the length of the CTS frame and the 6 Mb/s data rate (see 26.2.6 (MU-RTS Trigger/CTS frame exchange sequence procedure(#109))). In an S1G


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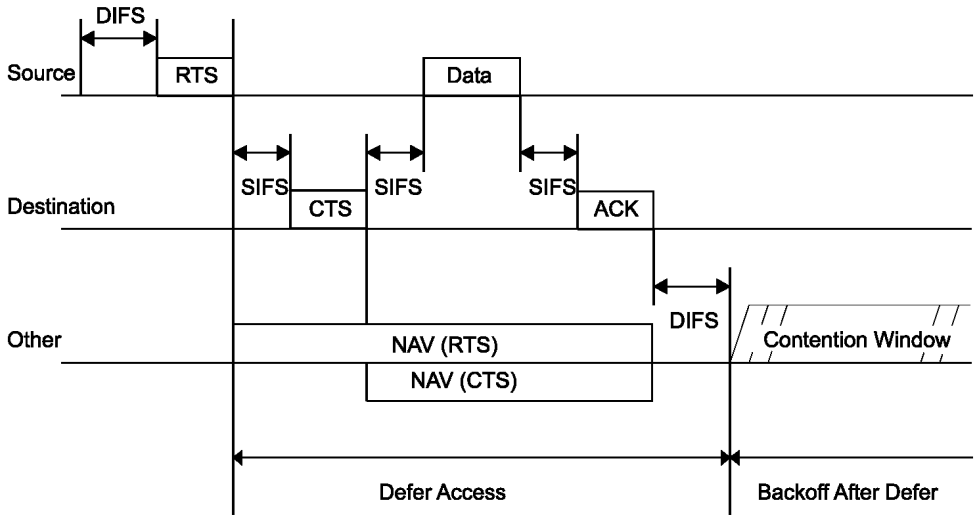


**Figure 10-6—RTS/CTS/data/Ack and NAV setting**

STA, (11ax)CTS_Time shall be calculated using the time required to transmit an NDP CTS frame that is equal to NDPTxTime, which is specified in 10.3.2.5.2 (RID update).

In DMG BSS, NAVTimeout period is equal to (2 × aSIFSTime) + $T_{DMG\text{-}CTS}$ + StartDelayCompensation + (2 × aSlotTime), where $T_{DMG\text{-}CTS}$ is the duration of a DMG CTS frame calculated using the TXVECTOR TRN_LEN parameter equal to the RXVECTOR TRN_LEN parameter of the received RTS frame and StartDelayCompensation is equal to aSlotTime.

NOTE 4—This value of StartDelayCompensation is a compromise over the possible values of aRxPHYStartDelay, which are dependent on both the implementation and the DMG PHY mode.

### 10.3.2.5 Setting and resetting the RID

#### 10.3.2.5.1 General

This subclause describes the setting and resetting of the RID for S1G STAs.

An S1G STA that receives a frame that is not an NDP CMAC PPDU shall update its RID counter based on the values of the received frame's RXVECTOR parameters FORMAT, PREAMBLE_TYPE, RESPONSE_INDICATION, AGGREGATION, MCS, PARTIAL_AID, COLOR, UPLINK_INDICATION, and CH_BANDWITH, as described in this subclause. An S1G STA that receives an NDP CMAC PPDU shall update its RID counter based on the values of the RXVECTOR parameter FORMAT, PREAMBLE_TYPE and the RESPONSE_INDICATION value, which is defined per type of NDP CMAC PPDU in Table 10-2 (RESPONSE_INDICATION value for NDP CMAC PPDUs).

A member PPDU is a PPDU transmitted by a STA that is a member of the same BSS of the receiving STA. A PPDU that is not a member PPDU is a nonmember PPDU.

An S1G STA that receives a member PPDU shall reset and update its RID counter, as defined in 10.3.2.5.2 (RID update), when the PHY-RXSTART.indication primitive corresponding to that PPDU is received. An S1G STA that receives a nonmember PPDU shall not reset the RID counter and shall update the RID counter, i.e., set it to a new value (as defined in 10.3.2.5.2 (RID update)) that is not less than the value that the RID counter will have at the instant of time that corresponds to the end of the received PPDU.

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**Table 10-2—RESPONSE_INDICATION value for NDP CMAC PPDUs**

| NDP CMAC PPDU type | RESPONSE_INDICATION value |
|---|---|
| NDP Ack or NDP PS-Poll-Ack (NDP (PS-Poll-)Ack) | No Response if either Idle Indication field value is 0 or the Duration field value is not 0<br><br>Long Response if Idle Indication field value is 1 and Duration field value is 0 |
| NDP Block Ack | No Response |
| NDP CTS | No Response |
| NDP PS-Poll | NDP Response |
| NDP Beamforming Report Poll | Long Response |
| NDP Paging | No Response |
| NDP Probe Request | No Response |
| NDP CF-End | No Response |

The S1G STA shall classify a received PPDU as a member PPDU if it is an NDP CMAC PPDU, or an S1G_1M PPDU. The S1G STA shall classify a received PPDU as a member PPDU if its PREAMBLE_TYPE is either S1G_LONG_PREAMBLE or S1G_SHORT_PREAMBLE and either of the conditions below is satisfied:

— UPLINK_INDICATION is 1 and the PARTIAL_AID indicates that the PPDU is addressed to the AP with which the non-AP STA is associated.

— UPLINK_INDICATION is 0 and the COLOR indicates that the PPDU is generated by the AP with which the STA is associated.

Because the PARTIAL_AID and COLOR values obtained from received PPDUs are not globally unique, an S1G STA that has classified a PPDU as a member PPDU based on PARTIAL_AID and/or COLOR may additionally use the information contained in a valid MAC header (i.e., neither A1 nor A2 field contain a MAC address that corresponds to a STA that is a member of the same BSS as known at the STA) from an MPDU carried in the received PPDU to change the classification of the PPDU to a nonmember PPDU. If the classification of a PPDU is changed from member to nonmember PPDU, then the STA shall:

— Reload the RID counter to the value that the RID counter had at the time of the receipt of the PHY-RXSTART.indication primitive corresponding to this PPDU minus the difference between the current time and that time; and

— Update the RID counter according to the rules for a nonmember PPDU.

NOTE 1—If the PHY-RXEND.indication primitive for the received S1G PPDU contains an ERROR or FormatViolation then the S1G STA sets the EIFS as described in 10.3.7 (DCF timing relations).

If the RID counter is updated then it shall start counting down the RID counter at the end of the received S1G PPDU, except when the PPDU either contains a valid nonzero Duration field that is used for setting the NAV, as described in 10.3.2.4 (Setting and resetting the NAV), or it is intended to the S1G STA. In both of these cases the RID shall be reset.

The received PPDU has an expected duration, in microseconds, of PSDU_RXTIME, starting from the moment the PHY-RXSTART.indication primitive is received. If the PPDU is an NDP CMAC PPDU, the PSDU_RXTIME is equal to 0. If the PPDU is not an NDP CMAC PPDU, the PSDU_RXTIME is calculated based on multiple RXVECTOR parameters and is equal to


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— The RXTIME defined in Equation (23-69) for S1G_SHORT/S1G_1M formats.

— The RXTIME defined in Equation (23-69) if the PPDU has S1G_LONG format and is an SU PPDU.

— The RXTIME defined in Equation (23-70) minus ($T_{DSTF}$ + $N_{LTF}$ $D_{DLTF}$ + $T_{SIG\text{-}B}$) if the PPDU has S1G_LONG format and is an MU PPDU.

NOTE 2—$T_{DSTF}$, $T_{DLTF}$, and $T_{SIG\text{-}B}$ are defined in Table 23-5 (Timing-related constants) while $N_{LTF}$ is defined in Table 23-11 (Number of LTFs required for different numbers of space-time streams).

Figure 10-7 (Data/Ack with RID setting(#3114)) indicates the RID for STAs that receive the PHY header of the Data frame whose MAC portion does not contain a valid Duration field that updates the NAV. The RID for STAs that receive the PHY header of the Ack frame but not that of the Data frame is 0 (i.e., no response is expected to the Ack frame in this example). The RID is reset for the STA to which the Data was addressed.

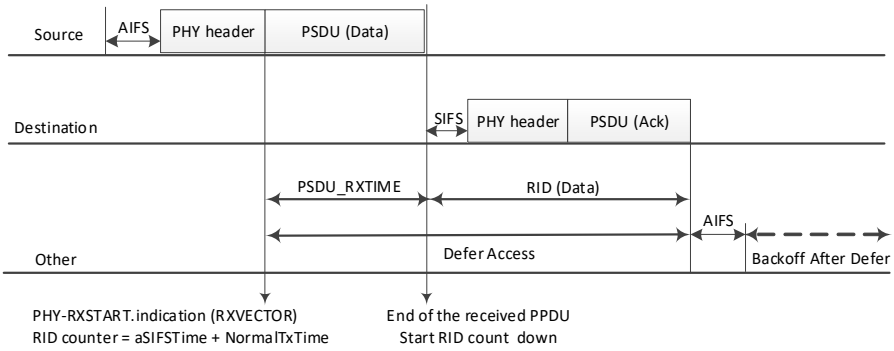


**Figure 10-7—Data/Ack with RID setting(#3114)**

#### 10.3.2.5.2 RID update

An S1G STA updates the value of the RID counter by setting it as described below.

If the value of the RESPONSE_INDICATION parameter is Long Response, the RID counter shall be set to LongTxTime + aSIFSTime, where LongTxTime is obtained as follows:

— If FORMAT is S1G and CH_BANDWIDTH is CBW1 or FORMAT is S1G_DUP_1M, then LongTxTime is equal to the S1G PPDU duration as defined in Table 9-34 (Maximum data unit sizes and durations(#1327)(#4013)).

— If FORMAT is S1G and PREAMBLE_TYPE is S1G_SHORT_PREAMBLE or S1G_LONG_PREAMBLE, then LongTxTime is equal to the largest value in the dot11EDCATableTXOPLimit.

— If FORMAT is S1G_DUP_2M then LongTxTime is equal to the largest value in the dot11EDCATableTXOPLimt(#39)

If the value of the RESPONSE_INDICATION parameter is Normal Response, the RID counter shall be set to NormalTxTime + aSIFSTime. NormalTxTime is calculated based on the RXVECTOR parameters PREAMBLE_TYPE, AGGREGATION, MCS and CH_BANDWIDTH following the rules listed in Table 10-3 (NormalTXTime duration based on RXVECTOR parameters).

If the value of RESPONSE_INDICATION parameter is NDP Response, the RID counter shall be set to NDPTxTime + aSIFSTime. NDPTxTime is calculated based on the RXVECTOR parameter PREAMBLE_TYPE and is equal to the time, in microseconds, required to transmit either an NDP_1M CMAC

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**Table 10-3—NormalTXTime duration based on RXVECTOR parameters**

| PPDU format (see 23.1.4 (PPDU formats)) | AGGREGATION | Expected Response Length (Type) | NormalTxTime |
|---|---|---|---|
| S1G_1M | 0 | 14-octet MPDU (Ack) | The time, in microseconds, required to transmit one Ack frame, where the duration of the frame is calculated according to the rate selection rules described in 10.6.6.5 (Rate selection for control response frames) using its BSSBasicMCSSet parameter and with CH_BANDWIDTH RXVECTOR value equal to CBW1. |
| | 1 | 32-octet MPDU (BlockAck) | The time, in microseconds, required to transmit one BlockAck frame, where the duration of the frame is calculated according to the rate selection rules described in 10.6.6.5 (Rate selection for control response frames) using its BSSBasicMCSSet parameter and with CH_BANDWIDTH RXVECTOR value equal to CBW1 |
| S1G_SHORT or S1G LONG PREAMBLE | 0 | 14-octet MPDU (Ack) | The time, in microseconds, required to transmit one Ack frame, where the duration of the frame is calculated according to the rate selection rules described in 10.6.6.5 (Rate selection for control response frames) using its BSSBasicMCSSet parameter and channel width selection rules for Control frames described in 10.6.6.6 (Channel Width selection for Control frames). |
| | 1 | 32-octet MPDU (BlockAck) | The time, in microseconds, required to transmit one BlockAck frame, where the duration of the frame is calculated according to the rate selection rules described in 10.6.6.5 (Rate selection for control response frames) using its BSSBasicMCSSet parameter and channel width selection rules for Control frames described in 10.6.6.6 (Channel Width selection for Control frames). |

PPDU if the PPDU format is S1G_1M or an NDP_2M CMAC PPDU if the PPDU format is either S1G_SHORT or S1G_LONG (see 23.1.4 (PPDU formats)).

If the value of the RESPONSE_INDICATION parameter is No Response, the RID counter shall be set to 0.

### 10.3.2.6 RTS/CTS with fragmentation

The following is a description of using RTS/CTS for a fragmented MSDU or MMPDU. The RTS/CTS frames define the duration of the following frame and acknowledgment. The Duration/ID field in the Data and Ack frames specifies the total duration of the next fragment and acknowledgment. This is illustrated in Figure 10-8 (RTS/CTS with fragmented MSDU).

Each frame contains information that defines the duration of the next transmission. The duration information from RTS frames shall be used to update the NAV to indicate busy until the end of Ack frame 0. The duration information from the CTS frame shall also be used to update the NAV to indicate busy until the end of Ack frame 0. Both Fragment 0 and Ack frame 0 shall contain duration information to update the NAV to indicate busy until the end of Ack frame 1. This shall be done by using the Duration/ID field in the Data and Ack frames. This shall continue until the last fragment, which shall have a duration of one Ack time plus one SIFS, and its Ack frame, which shall have its Duration/ID field set to 0. Each fragment and Ack frame acts as a virtual RTS frame and CTS frame; therefore no further RTS/CTS frames need to be generated after the RTS/CTS that began the frame exchange sequence.(11ax)


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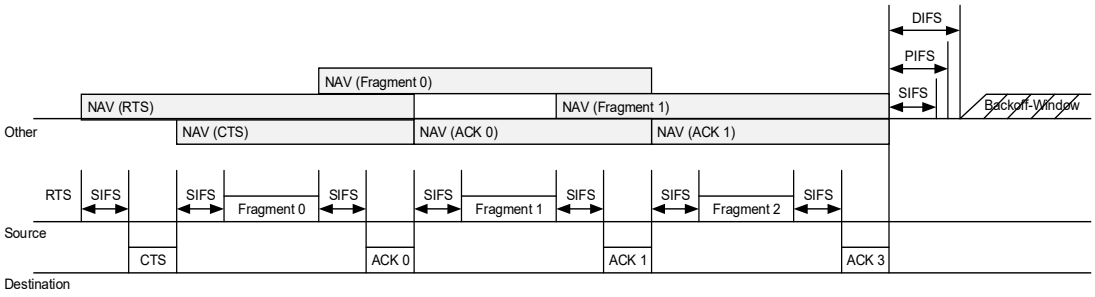


**Figure 10-8—RTS/CTS with fragmented MSDU**

In the case where an acknowledgment is sent but not received by the source STA, STAs that heard the fragment, or Ack frame, mark the channel busy for the next (#109)frame exchange sequence due to the NAV having been updated from these frames. This is the worst-case situation, and it is shown in Figure 10-9 (RTS/CTS with transmitter priority and missed acknowledgment). If an acknowledgment is not sent by the destination STA, STAs that can only hear the destination STA do not update their NAV and may attempt to access the channel when their NAV updated from the previously received frame reaches 0. All STAs that hear the source are free to access the channel after their NAV updated from the transmitted fragment has expired.

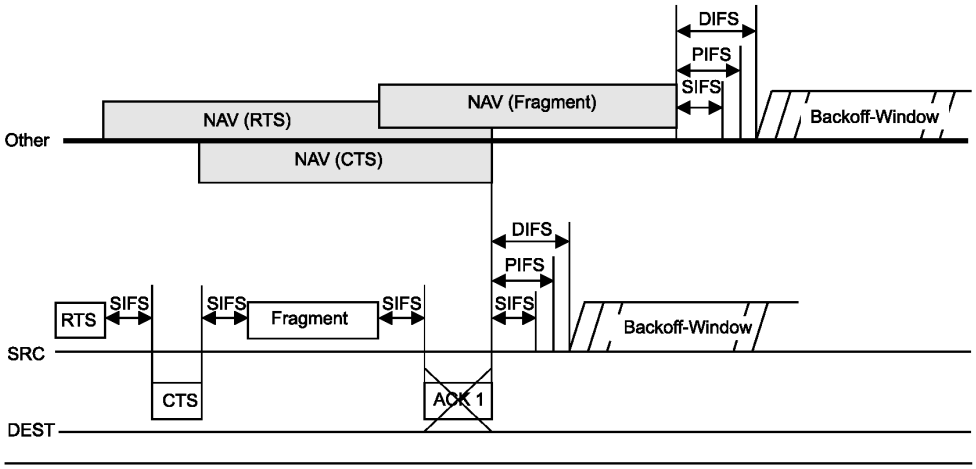


**Figure 10-9—RTS/CTS with transmitter priority and missed acknowledgment**

### 10.3.2.7 VHT and S1G RTS procedure

A VHT STA transmitting an RTS frame carried in non-HT or non-HT duplicate format and addressed to a VHT STA shall set the TA field to a bandwidth signaling TA and shall set the TXVECTOR parameters CH_BANDWIDTH_IN_NON_HT and CH_BANDWIDTH to the same value. (#1782)If the STA sending the RTS frame is capable of dynamic bandwidth operation as the RTS originator (see 10.3.2.9 (CTS and DMG CTS procedure)), the STA shall set the TXVECTOR parameter DYN_BANDWIDTH_IN_NON_HT to Dynamic. Otherwise, the STA shall set the TXVECTOR parameter DYN_BANDWIDTH_IN_NON_HT to Static.

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A VHT STA that initiates a TXOP by transmitting an RTS frame with the TA field set to a bandwidth signaling TA shall not send an RTS frame to a non-VHT STA for the duration of the TXOP.

NOTE—A non-VHT STA considers the bandwidth signaling TA as the address of the TXOP holder. If an RTS frame is sent to a non-VHT STA during a TXOP that is initiated by an RTS frame with a bandwidth signaling TA, the non-VHT STA does not recognize the RTS sender as the TXOP holder.

An S1G STA using dynamic bandwidth operation (see 10.3.2.9 (CTS and DMG CTS procedure)) that transmits an RTS carried in a greater than 2 MHz PPDU with the TXVECTOR parameter FORMAT set to S1G_DUP_2M shall set the Dynamic Indication field in the Frame Control field of the RTS frame to 1. Otherwise, the S1G STA shall set the Dynamic Indication field in the Frame Control field of the RTS carried in any other PPDU to 0 to indicate that it shall not use dynamic bandwidth operation (see 10.3.2.9 (CTS and DMG CTS procedure)).

An S1G STA that transmits an RTS frame to another STA shall set the TXVECTOR parameter RESPONSE_INDICATION to NDP_RESPONSE unless the Link Adaptation Without NDP CMAC PPDU Capable field of the S1G Capabilities element received from that STA contained a value of 1 in which case the S1G STA may set the RESPONSE_INDICATION to NORMAL_RESPONSE as described in 10.31.3 (Link adaptation using the VHT variant HT Control field).

(#371)An S1G STA that initiates a TXOP with a PV1 frame or an NDP CMAC PPDU shall not send an RTS frame for the duration of the TXOP.

### 10.3.2.8 CMMG RTS procedure

A CMMG STA shall transmit an RTS frame carried in CMMG or CMMG duplicate format (see 25.3.10 (CMMG duplication transmission on a 1080 MHz channel)). (#3088)(#1782)If the STA sending the RTS frame is capable of dynamic bandwidth operation as the RTS originator (see 10.3.2.9 (CTS and DMG CTS procedure)), the CMMG STA shall set the TXVECTOR parameter DYN_BANDWIDTH to Dynamic. Otherwise, the STA shall set the TXVECTOR parameter DYN_BANDWIDTH to Static.

### 10.3.2.9 CTS and DMG CTS procedure

A STA that receives an RTS frame addressed to it considers the NAV in determining whether to respond with CTS, unless the NAV was set by a frame originating from the STA sending the RTS frame (see 10.23.2.4 (Obtaining an EDCA TXOP))(#255). In this subclause for a non-S1G STA, “NAV indicates idle” means that the NAV count is 0 or that the NAV count is nonzero but the nonbandwidth signaling TA obtained from the TA field of the RTS frame matches the saved TXOP holder address. In an S1G STA, “NAV indicates idle” means that both NAV and RID counters are 0 or that either NAV or RID counter is nonzero but the TA field of the RTS frame matches the saved TXOP holder address.

A VHT STA that is addressed by an RTS frame in a non-HT or non-HT duplicate PPDU that has a bandwidth signaling TA and that has the RXVECTOR parameter DYN_BANDWIDTH_IN_NON_HT equal to Static behaves as follows:

— If the NAV indicates idle and CCA has been idle for all secondary channels (secondary 20 MHz channel, secondary 40 MHz channel, and secondary 80 MHz channel) in the channel width indicated by the RTS frame’s RXVECTOR parameter CH_BANDWIDTH_IN_NON_HT for a PIFS prior to the start of the RTS frame, then the STA shall respond with a CTS frame carried in a non-HT or non-HT duplicate PPDU after a SIFS. The CTS frame’s TXVECTOR parameters CH_BANDWIDTH and CH_BANDWIDTH_IN_NON_HT shall be set to the same value as the RTS frame’s RXVECTOR parameter CH_BANDWIDTH_IN_NON_HT.

— Otherwise, the STA shall not respond with a CTS frame.


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NOTE 1—A VHT STA that receives a CTS frame in response to an RTS frame the STA has transmitted with the TXVECTOR parameter DYN_BANDWIDTH_IN_NON_HT set to Static might ignore the RXVECTOR parameter CH_BANDWIDTH_IN_NON_HT as it will be the same as the TXVECTOR parameter CH_BANDWIDTH_IN_NON_HT in the RTS frame.(#438)

A VHT STA that is addressed by an RTS frame in a non-HT or non-HT duplicate PPDU that has a bandwidth signaling TA and that has the RXVECTOR parameter DYN_BANDWIDTH_IN_NON_HT equal to Dynamic behaves as follows:

— If the NAV indicates idle, then the STA shall respond with a CTS frame in a non-HT or non-HT duplicate PPDU after a SIFS. The CTS frame's TXVECTOR parameters CH_BANDWIDTH and CH_BANDWIDTH_IN_NON_HT shall be set to any channel width for which CCA on all secondary channels has been idle for a PIFS prior to the start of the RTS frame and that is less than or equal to the channel width indicated in the RTS frame's RXVECTOR parameter CH_BANDWIDTH_IN_NON_HT.

— Otherwise, the STA shall not respond with a CTS frame.

An S1G STA that is addressed by an RTS frame that has the Dynamic Indication field in the Frame Control field equal to 0 (Static) behaves as follows:

— If the NAV indicates idle and the CCA has been idle for all secondary channels within the channel width indicated in the Bandwidth Indication field of the Frame Control field of the RTS frame for a PIFS(#320) prior to the start of the RTS frame, then the STA shall respond with an (NDP) CTS frame after a SIFS. The STA shall set the TXVECTOR parameter CH_BANDWIDTH to a value that is equivalent to the value of the Bandwidth Indication field of the Frame Control field in the received RTS frame. The (NDP_2M) CTS frame shall have the Bandwidth Indication field set to the value of the Bandwidth Indication field of the received RTS frame.

— Otherwise the STA shall not respond with an (NDP) CTS frame.

An S1G STA that is addressed by an RTS carried in a 2 MHz duplicate frame that has the Dynamic Indication field in the Frame Control field equal to 1 (Dynamic) behaves as follows:

— If the NAV indicates idle, then the STA shall respond with an (NDP_2M) CTS frame after a SIFS. The (NDP) CTS frame's TXVECTOR parameter CH_BANDWIDTH may be set to any channel width for which the CCA on all secondary channels has been idle for a PIFS prior to the start of the RTS frame and that is equal to or less than the channel width indicated in the Bandwidth Indication field of the Frame Control field of the RTS frame. The (NDP_2M) CTS frame shall have the Bandwidth Indication field set to a value that is equivalent to the value of the TXVECTOR parameter's CH_BANDWIDTH.

— Otherwise the STA shall not respond with an (NDP) CTS frame.

NOTE 2—The NDP_1M CTS frame is not used for dynamic bandwidth indication.

A non-VHT and non-S1G STA that is addressed by an RTS frame or a VHT STA that is addressed by an RTS frame carried in a non-HT or non-HT duplicate PPDU that has a nonbandwidth signaling TA or a VHT STA that is addressed by an RTS frame in a format other than non-HT or non-HT duplicate behaves as follows:

— If the NAV indicates idle, the STA shall respond with a CTS frame after a SIFS.

— Otherwise, the STA shall not respond with a CTS frame.

The RA field of the CTS frame shall be set to the nonbandwidth signaling TA obtained from the TA field of the RTS frame to which this CTS frame is a response. The Duration field in the CTS frame shall be the duration field from the received RTS frame, adjusted by subtraction of aSIFSTime and the number of microseconds required to transmit the CTS frame at a data rate determined by the rules in 10.6 (Multirate support).

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After transmitting an RTS frame, the STA shall wait for a CTSTimeout interval with a value of aSIFSTime + aSlotTime + aRxPHYStartDelay. This interval begins when the MAC receives a PHY-TXEND.confirm primitive. If a (#3038)PHY-RXEARLYSIG.indication or PHY-RXSTART.indication primitive does not occur during the CTSTimeout interval, the STA shall conclude that the transmission of the RTS frame has failed, and this STA shall invoke its backoff procedure upon expiration of the CTSTimeout interval. If a (#3038)PHY-RXEARLYSIG.indication or PHY-RXSTART.indication primitive does occur during the CTSTimeout interval, the STA shall wait for the corresponding PHY-RXEND.indication primitive to determine whether the RTS frame transmission was successful. (#4179)The reception of a CTS frame addressed to the STA(#6184), corresponding to this PHY-RXEND.indication primitive, shall be interpreted as successful response, permitting the frame exchange sequence to continue(#109). (#4179)Anything else, including the reception of any other frame, shall be interpreted as failure of the RTS frame transmission. In this instance, the STA shall invoke its backoff procedure at the PHY-RXEND.indication primitive and may process the received frame.

A DMG STA follows the procedure defined in this subclause, except that it uses a DMG CTS frame instead of a CTS frame. A non-DMG STA does not transmit DMG CTS frames.

An S1G STA shall transmit NDP CTS frames instead of CTS frames with the following exception: transmission of an CTS frame is required if the link adaptation procedure is negotiated as described in 10.31 (Link adaptation).

The RA/Partial BSSID field of the NDP CTS shall be generated as described in 23.3.12.2.1 (NDP CTS). The Duration field in the NDP CTS frame shall be set to the same value as the Duration field from the received RTS frame, adjusted by subtracting the value of aSIFSTime and the NDPTxTime required to transmit the NDP CTS frame, where NDPTxTime is calculated according to 10.3.2.5.2 (RID update).

An S1G STA that receives an NDP CTS frame should disregard the value of the Duration field of the NDP CTS frame if any of the following conditions are satisfied:

— The Address Indicator field is equal to 1, and the Early Sector Indicator field is equal to 0, and the RA/PBSSID field is equal to the PBSSID of the BSS of which the non-AP STA is a member (see 10.52.4 (TXOP-based sectorization operation)).

— The Address Indicator field is equal to 0, and the RA/PBSSID indicates that the STA is the intended receiver of this frame, and the frame is received during the intervals of time negotiated with the UL-Sync capable AP (see 10.48 (Sync frame operation)).

A CMMG STA that receives an RTS frame in a CMMG or CMMG duplicate PPDU that has the RXVECTOR parameter DYN_BANDWIDTH equal to Static behaves as follows:

— If the NAV indicates idle and CCA has been idle for the secondary channel (secondary 540 MHz channel) in the channel width indicated by the RTS frame's RXVECTOR parameter CH_BANDWIDTH for a PIFS(#320) prior to the start of the RTS frame, then the STA shall respond with a CTS frame carried in a CMMG or CMMG duplicate PPDU after a SIFS. The CTS frame's TXVECTOR parameters CH_BANDWIDTH shall be set to the same value as the RTS frame's RXVECTOR parameter CH_BANDWIDTH.

— Otherwise, the STA shall not respond with a CTS frame.

A CMMG STA that is addressed by an RTS frame in a CMMG or CMMG duplicate PPDU that has the RXVECTOR parameter DYN_BANDWIDTH equal to Dynamic behaves as follows:

— If the NAV indicates idle, then the STA shall respond with a CTS frame in a CMMG or CMMG duplicate PPDU after a SIFS. The CTS frame's TXVECTOR parameters CH_BANDWIDTH may be set to any channel width for which CCA has been idle for a PIFS prior to the start of the RTS frame and that is equal to or less than the channel width indicated in the RTS frame's RXVECTOR parameter indicated in the RTS frame's RXVECTOR parameter CH_BANDWIDTH.

— Otherwise, the STA shall not respond with a CTS frame.


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(11ay)An EDMG STA that is addressed by an RTS frame sent in non-EDMG duplicate PPDU format to establish a TXOP shall behave as follows:

(11ay)If the NAV in the primary channel indicates idle, then

- The STA shall respond with a DMG CTS frame transmitted in non-EDMG or non-EDMG duplicate PPDU format after a SIFS.
- In case the DMG CTS frame is sent in a non-EDMG duplicate PPDU format in response to an RTS sent to establish a TXOP for the transmission of a SISO or an MU PPDU, the TXVECTOR shall be configured as follows:
  - The SCRAMBLER_INIT_SETTING parameter shall be set to indicate Channel_BW if the channel combinations are covered in Table 28-6 (Definition of Scrambler Initialization field when transmitted using the control mode and the Turnaround field is 1(11ay)); otherwise, it shall be set to indicate CONTROL_TRAILER and the parameter CT_TYPE shall be set to CTS_DTS.
  - If the CCA of all the channels that were indicated in the RTS's RXVECTOR parameter CH_BANDWIDTH_SIGNALING were idle for a duration of PIFS prior to the start of the RTS frame, the CH_BANDWIDTH parameter shall be exactly the same as that were indicated in the RTS's RXVECTOR parameter CH_BANDWIDTH_SIGNALING. Otherwise, the CH_BANDWIDTH parameter shall be set to a subset of the channels that were indicated in the RTS's RXVECTOR parameter CH_BANDWIDTH_SIGNALING encoded as defined in Table 28-6 (Definition of Scrambler Initialization field when transmitted using the control mode and the Turnaround field is 1(11ay)) or in the control trailer and where the CCA of such channels were idle for a duration of PIFS prior to the start of the RTS frame.
  - The CH_BANDWIDTH_SIGNALING parameter shall be set to the encoded value of the set of channels indicated by the CH_BANDWIDTH parameter as defined in Table 28-6 (Definition of Scrambler Initialization field when transmitted using the control mode and the Turnaround field is 1(11ay)) or in the control trailer.
- In case the DMG CTS is sent in a non-EDMG duplicate PPDU format in response to an RTS sent to establish a TXOP for the transmission of an SU MIMO PPDU, the TXVECTOR shall be configured as follows:
  - The SCRAMBLER_INIT_SETTING parameter shall be set to indicate CONTROL_TRAILER and the parameter CT_TYPE shall be set to CTS_DTS.
  - If the CCA of all the channels that were indicated in the RTS's RXVECTOR parameter CH_BANDWIDTH_SIGNALING were idle for a duration of PIFS prior to the start of the RTS frame, the CH_BANDWIDTH parameter shall be exactly the same as that were indicated in the RTS's RXVECTOR parameter CH_BANDWIDTH_SIGNALING. Otherwise, the CH_BANDWIDTH parameter shall be set to a subset of the channels that were indicated by the RTS's RXVECTOR parameter CH_BANDWIDTH and for which the CCA of such channels were idle for a duration of PIFS prior to the start of the RTS frame.

Otherwise,

- The STA shall not respond with a DMG CTS frame.
- Except in the case of an RTS frame used for MU-MIMO channel access (see 10.38.12.4.4 (MU-MIMO channel access procedure)), the STA may respond with a DMG DTS frame in a non-EDMG or non-EDMG duplicate PPDU after a SIFS. In case the DMG DTS frame is sent in a non-EDMG duplicate PPDU format, the STA shall set the Duration, NAV-SA and NAV-DA fields of the DMG DTS frame to zero and shall set the TXVECTOR parameters as follows:
  - The SCRAMBLER_INIT_SETTING parameter shall be set to indicate Channel_BW.
  - The CH_BANDWIDTH parameter shall be set to the channels that were indicated in the RTS's RXVECTOR parameter CH_BANDWIDTH_SIGNALING encoded as defined in Table 28-6 (Definition of Scrambler Initialization field when transmitted using the control mode and the Turnaround field is 1(11ay)).

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— The CH_BANDWIDTH_SIGNALING parameter shall be set to the encoded value of the set of channels indicated by the CH_BANDWIDTH parameter as defined in Table 28-6 (Definition of Scrambler Initialization field when transmitted using the control mode and the Turnaround field is 1(11ay)).

An EDMG STA that is addressed by an RTS frame sent to establish TXOP for transmission of at least one MIMO PPDU shall follow the procedure defined in 10.38.12.4 (MIMO channel access).

### 10.3.2.10 Dual CTS protection

#### 10.3.2.10.1 Dual CTS protection procedure

The dual CTS mechanism is obsolete. Support for this mechanism might be removed in a later revision of the standard.

A VHT STA shall not transmit VHT PPDUs in a TXOP protected by dual CTS protection.

A VHT AP shall not transmit an HT Operation element with the Dual CTS Protection field set to 1.

If the Dual CTS Protection field of the HT Operation element has value 1 in the Beacon frames transmitted by its AP, a non-AP HT STA shall start every TXOP with an RTS frame addressed to the AP. The RTS frame shall be an STBC frame if the STBC transmit and receive capabilities of the non-AP HT STA allow it to receive and transmit STBC frames using a single spatial stream; otherwise, the RTS frame shall be a non-STBC frame. The AP shall respond with a dual CTS (CTS1 followed by CTS2) separated by PIFS or SIFS. Table 10-4 (Dual CTS rules) describes the sequence of CTS frame transmissions and the required timing.

**Table 10-4—Dual CTS rules**

| Type of RTS | CTS description | Timing |
|---|---|---|
| RTS (non-STBC frame) | CTS1: Same rate or MCS as the RTS frame (non-STBC frame)<br>CTS2: Basic STBC MCS (STBC frame) | (#6587)A PIFS shall be used as the interval between CTS1 and CTS2.<br><br>If the CS mechanism (see 10.3.2.1 (CS mechanism)) indicates that the medium is busy at the TxPIFS slot boundary (see Figure 10-29 (EDCA mechanism timing relationships(#14)(#1058))) following CTS1, CTS2 shall not be transmitted as part of this frame exchange. |
| RTS (STBC frame) | CTS1: Basic STBC MCS (STBC frame)<br>CTS2: Lowest basic rate (non-STBC frame) | (#6587)A SIFS shall be used as the interval between CTS1 and CTS2.<br>The STA resumes transmission a SIFS+CTS2+SIFS after receiving CTS1, instead of after a SIFS.(#6587) |

The dual CTS response applies only to the AP; a non-AP STA shall respond to an RTS frame with a single CTS frame.

If dual CTS Protection is enabled, the AP shall begin each EDCA TXOP with a CTS frame. This CTS frame uses STBC when the immediately following frame uses non-STBC and vice versa. The RA of this CTS frame shall be identical to the RA of the immediately following frame. The AP may continue a PIFS after the CTS frame, only if the CS mechanism (see 10.3.2.1 (CS mechanism)) indicates that the medium is IDLE at the TxPIFS slot boundary (see Figure 10-29 (EDCA mechanism timing relationships(#14)(#1058))) following the transmission of the CTS frame.


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To avoid the resetting of NAV by STAs that have set their NAV due to the reception of a non-STBC RTS frame that is part of a dual CTS exchange, but then do not hear the CTS2, a non-AP HT STA may create a NAV that is not resettable according to the RTS NAV reset rule defined in 10.3.2.4 (Setting and resetting the NAV) at the receiving STAs by initiating the TXOP with a non-STBC CTS addressed to the AP (known as *CTS-to-AP*).

NOTE 1—Sending a CTS-to-AP allows NAV protection to be established without causing the AP to update its NAV, as opposed to, for example, the sending of a CTS-to-self frame, which would potentially have caused the AP NAV to become set and then prevented it from responding to the subsequent RTS frame. The AP does not set a NAV in the CTS-to-AP case and is able to respond to the following RTS frame. The NAV at receiving STAs is not updated by the RTS frame because its duration does not exceed the duration of the preceding CTS frame, and subsequently, the NAV cannot be reset during CTS2.

An STBC CTS addressed to the AP may be transmitted prior to an STBC RTS frame to set a NAV that is not resettable according to the RTS NAV reset rule defined in 10.3.2.4 (Setting and resetting the NAV) at receiving STAs.

NOTE 2—When an HT STA sends an RTS frame to the AP that is a non-STBC frame, the AP returns a CTS frame that is a non-STBC frame to the STA and then immediately transmits a CTS frame that is an STBC frame. The original non-AP STA is now free to transmit. But a non-HT STA that has set its NAV based on the original RTS frame might reset its NAV and then decrement its backoff counter, given that a SIFS + the duration of CTS2 is longer than a DIFS (i.e., the STA does not detect (#3038)a PHY-RXEARLYSIG.indication or PHY-RXSTART.indication primitive within the period specified in 10.3.2.4 (Setting and resetting the NAV)). Thus, without sending a CTS-to-AP, the NAV reservation might not always work.

If dual CTS protection is enabled and a STA obtains a TXOP and does not have any frames to transmit before the expiration of the TXOP duration, the STA may indicate truncation of the TXOP provided that the remaining duration of the TXOP after the transmission of the last frame can accommodate the CF-End frame, a CF-End frame that is an STBC frame duration at the basic STBC MCS, a CF-End frame that is a non-STBC frame at the lowest basic rate, and three SIFSs. The STA indicates truncation of the TXOP by transmitting a CF-End frame with TXVECTOR parameter restrictions as specified in 10.6.6.3 (Rate selection for CF-End frames).

On receiving a CF-End frame from a STA with a matching BSSID, an AP whose last transmitted HT Operation element contained the Dual CTS Protection field equal to 1 shall respond with dual CF-End frames, one CF-End frame that is an STBC frame at the basic STBC MCS and one CF-End frame that is a non-STBC frame at the lowest basic rate, after a SIFS. Dual CF-End frames eliminate unfairness toward STAs that are not of the same mode as the one that owns the TXOP being truncated.

If the TXOP is owned by the AP and dual CTS protection is enabled in the system, the AP may send dual CF-End frames if it runs out of frames to transmit, provided that the remaining TXOP duration after the transmission of the last frame can accommodate an STBC CF-End frame duration at the lowest STBC basic rate, a CF-End frame that is a non-STBC frame at the lowest basic rate, and two SIFSs.

The spacing between the dual CF-End frames sent by the AP shall be SIFS. The first CF-End frame shall use the same encoding (STBC frame versus non-STBC frame) used for transmissions in the TXOP being truncated, and the second CF-End frame shall use the other encoding.

An STBC-capable STA shall choose between control frame operation using either STBC frames or non-STBC frames. In the non-STBC frame case, it discards Control frames that are STBC frames it receives. In the STBC frame case, it discards Control frames that are non-STBC frames received from its own BSS. This choice is a matter of policy local at the STA.

An S1G STA shall not support the Dual CTS Protection procedure defined in 10.3.2.10 (Dual CTS protection).

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#### 10.3.2.10.2 Dual CTS protection examples

Figure 10-10 (Example of dual CTS mechanism (STBC initiator)) shows an example of the operation of the dual CTS protection mechanism. In this example, the initiating STA is an STBC non-AP STA.

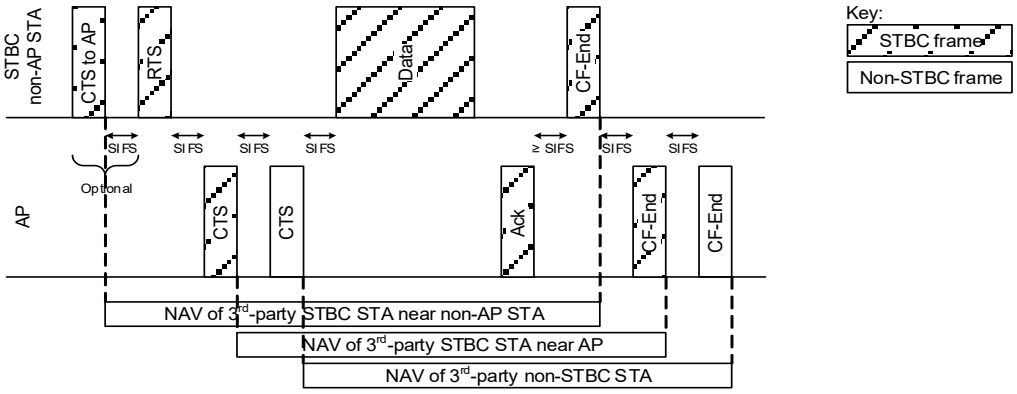


**Figure 10-10—Example of dual CTS mechanism (STBC initiator)**

Figure 10-11 (Example of dual CTS mechanism (non-STBC initiator)) shows an example of the operation of the dual CTS protection mechanism. In this example, the initiating STA is a non-STBC non-AP HT STA.

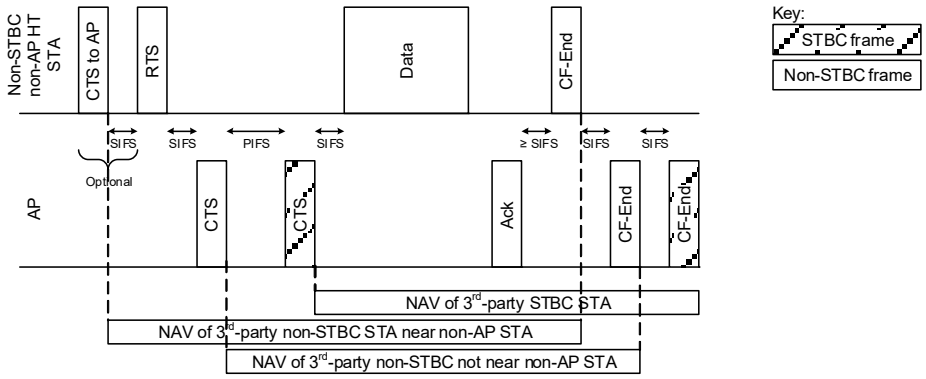


**Figure 10-11—Example of dual CTS mechanism (non-STBC initiator)**

#### 10.3.2.11 Acknowledgment procedure

The following frames require immediate acknowledgment:

- Individually addressed Management frames other than Action No Ack frames
- Individually addressed non-QoS Data frames
- Individually addressed QoS Data frames with Normal Ack or Implicit BAR ack policy
- BlockAck frames not sent in immediate response to A-MPDU
- BlockAckReq frames
- PS-Poll frames, which can be acknowledged by generating a Data frame

During a TWT SP, either the STACK frame or TACK frame can be used in place of the (NDP) Ack frame according to the procedure described in 10.46 (Target wake time (TWT)) and otherwise shall not be used.


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A STA shall not transmit an Ack frame in response to a Management frame of subtype Action No Ack. A STA shall not transmit an Ack or BlockAck frame in response to a group addressed frame. An MPDU that does not require immediate acknowledgment is implicitly considered acknowledged, as if an explicit acknowledgment had been sent.

NOTE 1—Group addressed MSDUs are sent to an AP in individually addressed frames.

Otherwise, upon reception of a frame that requires immediate acknowledgment and, for an AP, with the To DS subfield equal to 1, a STA shall transmit an Ack or BlockAck frame after a SIFS, without regard to the busy/idle state of the medium. (See Figure 10-12 (Individually addressed data/Ack/BlockAck frame).)

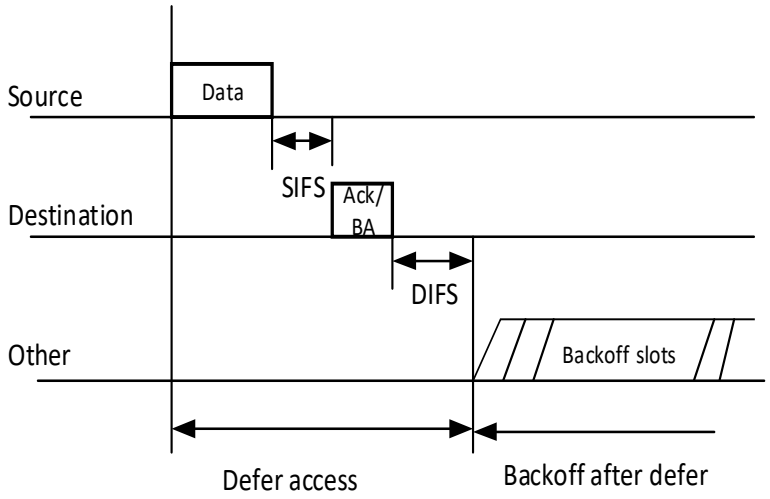


**Figure 10-12—Individually addressed data/Ack/BlockAck frame**

(11ay)A STA operating in an SP with TDD channel access (see 10.38.6.2.2 (SP with TDD channel access(11ay))), upon reception of a frame that requires acknowledgment shall transmit an Ack or BlockAck frame at the start of the earliest occurring TDD slot the STA is assigned to, with the Bitmap and Access Type Schedule field of the TDD slot set to TX, and with slot category of the TDD slot set to Basic TDD slot, as indicated in the TDD Slot Schedule element (see 9.4.2.281 (TDD Slot Schedule element(11ay))).

After transmitting an MPDU that requires an Ack or BlockAck frame as a response(#109), the STA shall wait for an AckTimeout interval, with a value of aSIFSTime + aSlotTime + aRxPHYStartDelay, starting at the PHY-TXEND.confirm primitive. If a (#3038)PHY-RXEARLYSIG.indication or PHY-RXSTART.indication primitive does not occur during the AckTimeout interval, the STA concludes that the transmission of the MPDU has failed, and this STA shall invoke its backoff procedure upon expiration of the AckTimeout interval.

If a (#3038)PHY-RXEARLYSIG.indication or PHY-RXSTART.indication primitive does occur during the AckTimeout interval, the STA shall wait for the corresponding PHY-RXEND.indication primitive to determine whether the MPDU transmission was successful. If the STA (#4179)receives an Ack frame addressed to the STA and corresponding to this PHY-RXEND.indication primitive, this shall be interpreted as successful acknowledgment.

(11ay)A STA operating in an SP with TDD channel access (see 10.38.6.2.2 (SP with TDD channel access(11ay))) has AckTimeout interval value equal to the duration from the PHY-TXEND.confirm primitive of the current frame to the end of the earliest occurring TDD slot the addressed recipient of the MPDU is assigned to, with the Bitmap and Access Type Schedule field of the TDD slot set to RX, and with slot category of the TDD slot set to Basic TDD slot, as indicated in the TDD Slot Schedule element (see 9.4.2.281 (TDD Slot Schedule element(11ay))).

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(11ay)When a STA operating in an SP with TDD channel access transmits, in a TDD slot, an MPDU that has an Ack Policy of Normal Ack, the STA shall not transmit another MPDU that has an Ack Policy of Normal Ack to the same receiver until the corresponding Ack frame is received or the end of the AckTimeout interval, whichever comes first.

If the STA does not (#4179)receive an Ack frame addressed to the STA, this condition shall be interpreted as failure of its MPDU transmission, except as defined below. In this instance, the STA shall invoke its backoff procedure at the PHY-RXEND.indication primitive and may process the received frame. If the STA has transmitted a PS-Poll frame, then the STA's receipt (#4179)of a Data or Management frame transmitted by the recipient of the PS-Poll frame (#6258)and addressed to the STA shall also be accepted as successful acknowledgment of the PS-Poll frame.

NOTE 2—The backoff procedure in the specific case of reception of a corrupted Ack or BlockAck frame results in EIFS rather than DIFS or AIFS being used after the AckTimeout interval and subsequent reception of the corrupted Ack or BlockAck frame (see 10.3.4.3 (Backoff procedure for DCF) and 10.23.2.4 (Obtaining an EDCA TXOP) respectively).

NOTE 3—The receiver STA performs the acknowledgment procedure on all received frames requiring immediate acknowledgment, even if an MSDU or A-MSDU is carried partly or wholly within the frame and is subsequently discarded due to drop eligibility (see DEI subfield in 9.2.4.6.2 (HT variant)).

NOTE 4—The rules that specify the contents of BlockAck frames are defined in 10.25 (Block acknowledgment (block ack)).

Additional exceptions exist for S1G STAs for accepting a (#4179)frame as successful acknowledgment as described in the following three paragraphs:

1) A STA that has enabled the implicit Ack procedure (see 10.53.5.3 (Implicit Ack procedure)) shall consider a received S1G_SHORT/S1G_LONG PPDU as successful acknowledgment of a previously transmitted MPDU that was carried in an S1G_SHORT/S1G_LONG PPDU only in the following two cases:
   a) The STA is a non-AP STA associated to an S1G relay AP and all the conditions below are satisfied:
      — A (#3038)PHY-RXEARLYSIG.indication or PHY-RXSTART.indication primitive that corresponds to the received PPDU is detected within the AckTimeout interval that started as a result of the previously transmitted MPDU.
      — The RXVECTOR parameter PARTIAL_AID is equal to the PARTIAL_AID that corresponds to the BSSID of the parent AP's BSS, or the RXVECTOR parameter PARTIAL_AID is equal to 0 and the PPDU contains an RTS frame with RA equal to the BSSID of the parent AP's BSS.
      — The RXVECTOR parameter UPLINK_INDICATION is equal to 1.
   b) The STA is an AP that has an S1G relay STA associated to it and all the conditions below are satisfied:
      — A (#3038)PHY-RXEARLYSIG.indication or PHY-RXSTART.indication primitive that corresponds to the received PPDU is detected within the AckTimeout interval that started as a result of the previously transmitted MPDU.
      — The RXVECTOR parameter PARTIAL_AID is equal to the 6 LSBs of the PARTIAL_AID that corresponds to the DA of the non-AP STA or the RXVECTOR parameter PARTIAL_AID is equal to 0 and the received PPDU contains an RTS frame with RA equal to the DA of the non-AP STA.
      — The RXVECTOR parameter UPLINK_INDICATION is equal to 0 and the RXVECTOR parameter COLOR is equal to the COLOR value of the S1G relay AP.
2) Under BDT operation as described in 10.49 (Bidirectional TXOP): If a Data frame is sent as an immediate response to an MPDU requiring immediate acknowledgment, the reception of the Data frame shall be accepted as successful acknowledgment of the eliciting MPDU.


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3) The (#4179)reception of an S1G RTS frame(#6298) sent by the recipient of a PS-Poll frame or of a PS-Poll+BDT frame shall be accepted as successful acknowledgment of the PS-Poll or of the PS-Poll+BDT frame.

An S1G STA shall transmit NDP Ack frames for acknowledgment with the following exceptions:

1) Transmission of an Ack frame is required if link adaptation procedure is negotiated as described in 10.31 (Link adaptation).
2) Transmission of a TACK frame or a STACK frame is required if target wake time is negotiated as described in 10.46 (Target wake time (TWT)).
3) Transmission of a TACK frame is required as a response to a PS-Poll frame with the Poll Type subfield equal to 1 as described in 10.47.2 (Rescheduling of awake/doze cycle).
4) Transmission of an NDP PS-Poll-Ack frame is required as a response to an NDP PS-Poll frame.

An S1G STA that satisfies any of the first three exceptions above shall transmit an Ack frame, TACK frame, or STACK frame instead of an NDP Ack frame as a response to an eliciting PPDU for which the RXVECTOR parameter RESPONSE_INDICATION is equal to Normal Response. The control response frame shall have a duration that is equal to NormalTXTime value for a 32-octet MPDU (see Table 10-3 (NormalTXTime duration based on RXVECTOR parameters)) if the eliciting PPDU contains an S-MPDU.

A non-S1G STA shall not transmit NDP Ack and NDP PS-Poll-Ack frames.

An S1G STA that transmits or receives an NDP Ack or NDP PS-Poll-Ack frame shall follow the same rules described above for Ack frames with the following exceptions that apply only to NDP Ack and NDP PS-Poll-Ack frames:

1) An S1G STA that transmits an NDP Ack frame for acknowledgment shall generate the Ack ID field of the NDP Ack frame as described in 23.3.12.2.4 (NDP Ack).
2) An S1G AP that transmits an NDP PS-Poll-Ack frame for acknowledgment of an NDP PS-Poll frame shall generate the Ack ID field of the NDP PS-Poll-Ack frame as described in 23.3.12.2.5 (NDP PS-Poll-Ack). In addition, if the eliciting NDP PS-Poll is an NDP_1M PS-Poll frame the Duration field of the NDP_1M PS-Poll-Ack is set as follows:
    a) If the eliciting NDP_1M PS-Poll frame has a value of the Preferred MCS field equal to “No Preference” the Duration field should indicate an idle period (i.e., the Idle Indication field should be set to 1 as described in 23.3.12.2.5 (NDP PS-Poll-Ack)).
    b) Otherwise, the Duration field should indicate an Ack ID extension (i.e., the Idle Indication field should be set to 0 as described in 23.3.12.2.5 (NDP PS-Poll-Ack)).
3) An S1G STA that expects an NDP Ack frame as a response(#1213) shall consider a received NDP Ack frame as a successful response if the Ack ID field of the NDP Ack frame equals the bit sequence generated from the (#8126)scrambler initialization value and the FCS field of its immediately previously transmitted PSDU as described in 23.3.12.2.4 (NDP Ack).
4) An S1G STA that expects an NDP PS-Poll-Ack frame as a response to an NDP PS-Poll(#1214) shall consider a received NDP PS-Poll-Ack frame as a successful response if the Ack ID field, together with the extension of the Ack ID if present in the Duration field, of the frame equals the bit sequence generated from the RA, TA and CRC fields of its immediately previously transmitted NDP PS-Poll frame as described in 23.3.12.2.5 (NDP PS-Poll-Ack).

Upon reception of a PV1 frame that requires acknowledgment with the (#278)From DS subfield equal to 1, an S1G STA shall generate an acknowledgment frame in response if the AID subfield of A1 field is equal to the AID of the S1G STA and the A2 field is equal to the MAC address of its associated AP. Upon reception of a PV1 frame that requires acknowledgment with the (#278)From DS subfield equal to 0, an S1G STA shall generate an acknowledgment frame in response if A1 field is equal to the MAC address of the S1G STA.

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In an S1G BSS, the AckTimeout interval depends on the TXVECTOR parameter PREAMBLE_TYPE. When the TXVECTOR parameter PREAMBLE_TYPE is equal to S1G_SHORT_PREAMBLE or S1G_LONG PREAMBLE, the AckTimeout interval is calculated with aRxPHYStartDelay value for ≥ 2 MHz short/long preamble except when the receiving STA has indicated use of 1 MHz control responses as described in 10.6.6.6 (Channel Width selection for Control frames) in which case the AckTimeout interval is calculated with aRxPHYStartDelay value for S1G_1M preamble. When the TXVECTOR parameter PREAMBLE_TYPE is equal to S1G_1M preamble, the AckTimeout interval is calculated with aRxPHYStartDelay value for S1G_1M preamble.

During a TWT SP, the BAT frame can be used in place of the (NDP) BlockAck frame, as described in 10.25 (Block acknowledgment (block ack)) and otherwise, is not used.

#### 10.3.2.12 Fragment BA procedure

An S1G STA can partition an MSDU or an MMPDU into multiple fragments as described in 10.4 (MSDU, (11ax)A-MSDU, and MMPDU fragmentation) and send the frames containing the fragments of the MSDU or of the MMPDU as independent transmissions.

An S1G STA indicates support for fragment BA using the Fragment BA Support subfield of the S1G Capabilities Information field in the S1G Capabilities element. An S1G STA shall set the Fragment BA Support subfield to 1 in S1G Capabilities element if dot11FragmentBAOptionImplemented is true. Otherwise, the S1G STA shall set the Fragment BA Support subfield to 0. An S1G STA (known as the originator STA) with dot11FragmentBAOptionImplemented equal to true sending an MSDU or MMPDU (whether fragmented or not) to another S1G STA shall use the fragment BA procedure as described in this subclause if it has received from the STA (known as the recipient STA) a frame that included an S1G Capabilities element with the Fragment BA Support subfield equal to 1. Otherwise an S1G STA shall not use the fragment BA procedure. Non-S1G STAs shall not use the fragment BA procedure.

An originator STA may send fragments with Block Ack ack policy.

The receiving STA that is the intended receiver of either a fragment with Implicit BAR ack policy or a BlockAckReq frame shall send an NDP BlockAck frame after a SIFS, without regard of the idle/busy state of the medium, that is:

— An NDP_1M BlockAck frame if the eliciting fragment is either carried in an S1G_1M PPDU or the receiving STA has indicated use of 1 MHz control response frames as described in 10.6.6.6 (Channel Width selection for Control frames).

— An NDP_2M BlockAck frame if the eliciting fragment is carried in an S1G_SHORT/S1G_LONG PPDU and the receiving STA has not indicated use of 1 MHz control response frames as described in 10.6.6.6 (Channel Width selection for Control frames).

The receiving STA shall generate the BlockAck ID and the Starting Sequence Control field of the NDP BlockAck as described in 23.3.12.2.6 (NDP BlockAck).

The receiving STA shall include the receipt status of a set of the fragments in the BlockAck Bitmap field of the NDP BlockAck frame as follows:

1) If the originator STA elicits an NDP_1M BlockAck frame as a response, the BlockAck Bitmap field of the NDP BlockAck frame indicates the receipt status of a set of fragments which depends on the value of the Fragment Number subfield in the Sequence Control field of the fragment that elicited the response:
    a) If the Fragment Number subfield is not greater than 7 then the BlockAck Bitmap field shall indicate the receipt status of fragments with fragment numbers from 0 to 7.


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b) If the Fragment Number subfield is greater than 7 then the BlockAck Bitmap field shall indicate the receipt status of fragments with fragment numbers from 8 to 15.

2) If the originator STA elicits an NDP_2M BlockAck frame as a response, the BlockAck Bitmap field of the NDP BlockAck frame shall indicate the receipt status of the fragments with fragment numbers from 0 to 15.

NOTE 1—An NDP_1M BlockAck frame can acknowledge only a limited number of consecutive fragments because its BlockAck Bitmap field size is 8. Instead, an NDP_2M BlockAck frame can acknowledge up to the maximum number of fragments because its BlockAck Bitmap field size is 16.

The bitmap of the NDP BlockAck frame is protected using the encoding procedure described in 10.56 (Bitmap protection for NDP BlockAck frames).

An originator STA that elicits an NDP_1M BlockAck frame as a response shall not transmit a fragment that has a Fragment Number subfield greater than 7 if it has not previously received an NDP_1M BlockAck frame that indicates reception of all fragments with fragment numbers from 0 to 7.

The originator STA shall consider an NDP_1M BlockAck frame (or an NDP_2M BlockAck frame) as received if the BlockAck ID field value equals the 2 LSBs (or 6 LSBs) of the (#8126)scrambler initialization value in the (#3409)SERVICE field and the Starting Sequence Control field value equals the Sequence Number of the fragment that elicited the response.

NOTE 2—(#6277)(#8126)The scrambler initialization value is obtained from the PHY-TXEND.confirm parameter SCRAMBLER_OR_CRC. The values of the BlockAck ID and Starting Sequence Number fields(#4200) are obtained after decoding the NDP BlockAck frame as described in 10.56 (Bitmap protection for NDP BlockAck frames).

If the originator STA does not receive an NDP BlockAck frame as an immediate response, it may retransmit the last transmitted fragment to resolicit an immediate NDP BlockAck response.

### 10.3.2.13 MU acknowledgment procedure

#### 10.3.2.13.1 Acknowledgment procedure for DL MU PPDU in SU PPDU(11ax)

The acknowledgment procedure performed by a STA that receives MPDUs that were transmitted within a VHT MU PPDU or an HE MU PPDU is the same as the acknowledgment procedure for MPDUs that were not transmitted within a VHT MU PPDU or an HE MU PPDU sent by an AP, except if the STA is an HE STA that follows the rules defined in 26.3 (Fragmentation and defragmentation) and in 26.4 (HE acknowledgment procedure).(11ax)

NOTE 1—All MPDUs transmitted within a VHT MU PPDU (11ax)or an HE MU PPDU are contained within A-MPDUs, and the rules specified in 9.7.3 (A-MPDU contents) prevent an immediate response (11ax)carried in an SU PPDU to more than one of the A-MPDUs.

Responses to A-MPDUs within a VHT MU PPDU (11ax)or an HE MU PPDU for DL transmission that are not immediate responses to the VHT MU PPDU (11ax)or the HE MU PPDU are transmitted in response to explicit BlockAckReq frames by the AP. Examples of VHT MU PPDU frame exchange sequences are shown in Figure 10-13 (Example of TXOP containing VHT MU PPDU transmission with immediate

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acknowledgment to VHT MU PPDU) and Figure 10-14 (Example of TXOP containing VHT MU PPDU transmission with no immediate acknowledgment to VHT MU PPDU).

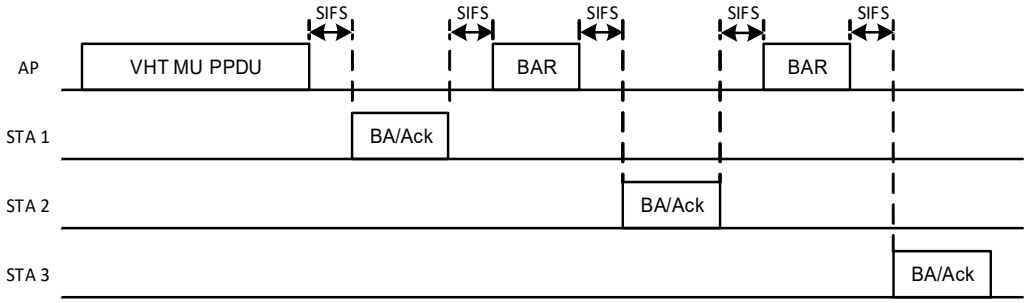


**Figure 10-13—Example of TXOP containing VHT MU PPDU transmission with immediate acknowledgment to VHT MU PPDU**

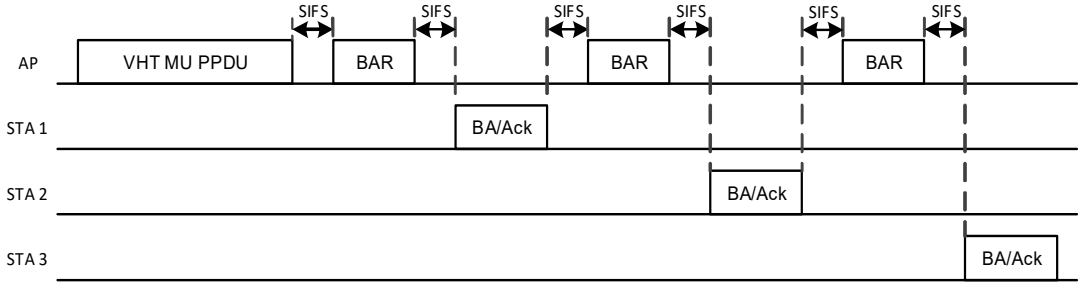


**Figure 10-14—Example of TXOP containing VHT MU PPDU transmission with no immediate acknowledgment to VHT MU PPDU**

Recovery within the TXOP that contains a VHT MU PPDU or an HE MU PPDU can be performed according to the rules of 10.23.2.8 (Multiple frame exchange sequences in an EDCA TXOP(#109)). BlockAckReq frames related to A-MPDUs within a VHT MU PPDU or an HE MU PPDU can be transmitted in a TXOP separate from the one that contained the VHT MU PPDU or the HE MU PPDU.(11ax)

(11ay)An EDMG STA indicates that it is DL MU-MIMO capable by setting the MU-MIMO Supported subfield in the STA's EDMG Capabilities element to 1. An EDMG MU-MIMO initiator shall not transmit an EDMG MU-MIMO PPDU to an EDMG STA that does not have the MU-MIMO Supported subfield equal to 1.

(11ay)An EDMG STA that is DL MU-MIMO capable shall support the (#4251)EDMG Multi-TID BlockAck frame. An MU-MIMO initiator may transmit an MPDU with TID for which a block ack agreement(#3741) does not exist. In this case, the MU-MIMO responder shall respond to the MPDU with (#4251)an EDMG Multi-TID BlockAck frame following the rules defined in 10.70.2 (Acknowledgment context in an EDMG Multi-TID BlockAck frame(#4251)).

(11ay)An EDMG STA that is DL MU-MIMO capable and that has the EDMG Multi-TID Aggregation Support subfield of its EDMG Capabilities element set to a nonzero value


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— May set the EDMG All Ack Support subfield in the STA's EDMG Capabilities element to 1 and
— Shall follow rules defined in 10.70 (EDMG A-MPDU with multiple TIDs(11ay)).

(11ay)The acknowledgment procedure performed by EDMG STAs that receive an MPDU within an EDMG MU PPDU from an MU-MIMO initiator shall follow the schedule defined by the MU-MIMO initiator.

(11ay)An MU-MIMO initiator shall set the ack policy of MPDUs contained in each A-MPDU transmitted within an EDMG MU PPDU to Scheduled Ack and shall include at least one Block Ack Schedule frame in each A-MPDU transmitted within an EDMG MU PPDU. Each Block Ack Schedule frame shall contain the scheduling information for the EDMG STA that is an intended receiver of the A-MPDU. An MU-MIMO initiator shall set the value of the Response Duration subfield of the Block Ack Schedule frame equal to the duration of the expected BlockAck frame or EDMG Multi-TID BlockAck frame (see 10.25.5 (Selection of BlockAck and BlockAckReq variants)) transmission from a STA addressed by an A-MPDU within a transmitted MU PPDU. The value of the expected transmission should be calculated using MCS 0. The values of all subfields of the Block Ack Schedule frame shall not change if transmitted multiple times in the same A-MPDU. An MU-MIMO initiator shall set the value of the Response Offset subfield of the Block Ack Schedule frame to SIFS in an A-MPDU transmitted to a STA that is expected to be the first responder.

(11ay)An EDMG STA shall transmit a BlockAck frame or EDMG Multi-TID BlockAck frame in response to a received EDMG MU PPDU immediately after a period of time equal to the value of the Response Offset subfield from the end of EDMG MU PPDU. The Response Offset subfield is contained in the Block Ack Schedule frame within the MU PPDU.

(11ay)If an MU-MIMO initiator does not intend to elicit a BlockAck frame or EDMG Multi-TID BlockAck frame from a STA addressed by an A-MPDU within a transmitted MU PPDU, it shall set the Ack Policy field equal to No Ack or Block Ack as defined in Table 9-13 (Ack policy) and shall set the values of the Response Offset field and Response Duration field within the frame to 0.

(11ay)If an expected BlockAck frame or EDMG Multi-TID BlockAck frame from a STA was not received by an MU-MIMO initiator, the initiator may transmit a BlockAckReq frame or Multi-TID BlockAckReq frame (see 10.25.5 (Selection of BlockAck and BlockAckReq variants)) to that STA immediately after a period of time equal to the value of the Next PPDU Start Offset subfield starting from the end of EDMG MU PPDU. The Next PPDU Start Offset subfield is contained in the Block Ack Schedule frame within the MU PPDU.

(11ay)The entire MU sequence shall not exceed the established TXOP duration.

(11ay)An example of an A-MPDU transmitted in an EDMG MU PPDU is shown in Figure 10-15 (Example of A-MPDU transmitted in EDMG MU PPDU(11ay)). In this example, an A-MPDU contains three Block Ack Schedule frames: one at the beginning and two at the end of the A-MPDU.

| | | | | | | |
|---|---|---|---|---|---|---|
| **Block Ack Schedule** | QoS Data frame (Ack Policy=01) | QoS Data frame (Ack Policy=01) | … | QoS Data frame (Ack Policy=01) | **Block Ack Schedule** | **Block Ack Schedule** |

**Figure 10-15—Example of A-MPDU transmitted in EDMG MU PPDU(11ay)**

(11ay)An example of the EDMG MU PPDU frame acknowledgment procedure for three EDMG STAs with the illustration of scheduling information delivered to them is shown in Figure 10-16 (Example of TXOP containing EDMG MU PPDU transmission(11ay)). In this example, the value of the Next PPDU Start Offset field is the same for all STAs.

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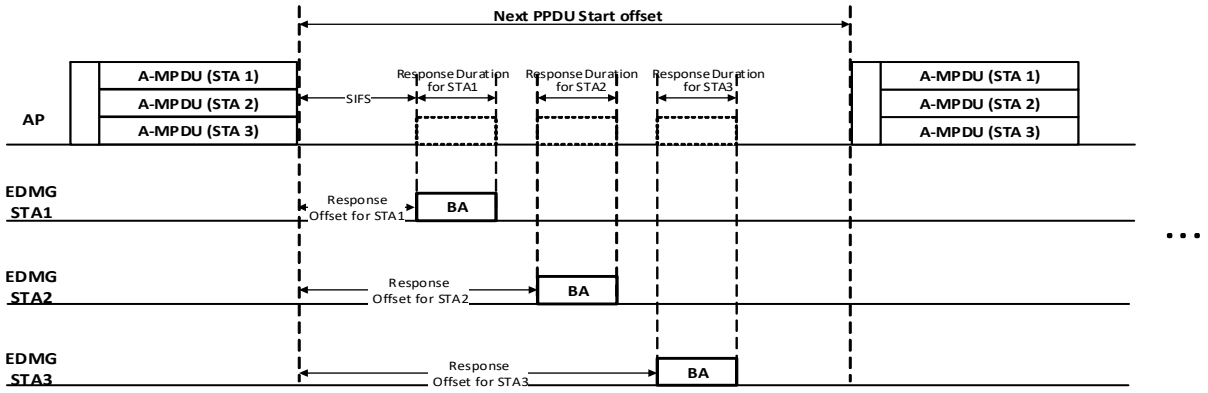


**Figure 10-16—Example of TXOP containing EDMG MU PPDU transmission(11ay)**

NOTE 2—A BlockAck frame is sent in immediate response to the BlockAckReq frame for HT-immediate block ack. An Ack frame might be sent in immediate response carried in an SU PPDU to an S-MPDU in the VHT MU PPDU or the HE MU PPDU. Responses to S-MPDUs for more than one STA contained in an HE MU PPDU are transmitted as specified in 10.3.2.13.2 (Acknowledgment procedure for DL MU PPDU in MU format(11ax)). A Multi-STA BlockAck frame is sent in immediate response to a Multi-TID BlockAckReq frame.(11ax)

NOTE 3—A BlockAckRequest frame would typically not be sent to a STA in the case where the A-MPDU to the STA contained no MPDUs requiring immediate acknowledgment. It could be sent if MPDUs in a previous A-MPDU remain unacknowledged.

### 10.3.2.13.2 Acknowledgment procedure for DL MU PPDU in MU format(11ax)

A non-AP STA shall not set the ack policy to HETP Ack.

A non-AP STA that is the recipient, within an HE MU PPDU, of a QoS Data frame or QoS Null frame with HETP Ack ack policy, of an MU-BAR Trigger frame or a GCR MU-BAR Trigger frame, or of a Management frame that solicits acknowledgment, shall send the immediate response according to the scheduling information that is carried either in the Trigger frame(s) or TRS Control subfield. If a Basic Trigger frame (see 9.3.1.22 (Trigger frame format(11ax))) or frame carrying a TRS Control subfield (see 9.2.4.7.1 (TRS Control)) is not received, then the STA shall not respond.


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An example of UL OFDMA acknowledgment to an HE MU PPDU is shown in Figure 10-17 (Example of HE MU PPDU transmission with immediate UL OFDMA acknowledgment(11ax)).

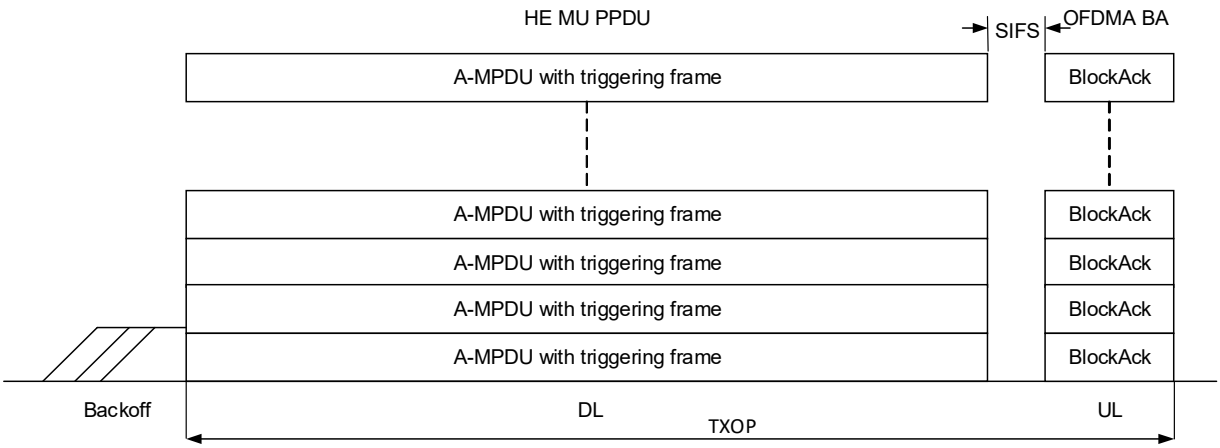


**Figure 10-17—Example of HE MU PPDU transmission with immediate UL OFDMA acknowledgment(11ax)**

An AP may use an MU-BAR Trigger frame or a GCR MU-BAR Trigger frame to solicit acknowledgment frames from multiple HE STAs to which the AP has sent QoS Data frames with Block Ack ack policy or from which the AP has not received immediate acknowledgment frames after sending QoS Data frames with HETP Ack ack policy in an HE MU PPDU.

### 10.3.2.13.3 Acknowledgment procedure for UL MU transmission(11ax)

An AP that receives frames from more than one STA that are part of (#2318)a UL MU transmission (see 9.42.2) and that require an immediate acknowledgment (i.e., a QoS Data frame with Normal Ack or Implicit BAR ack policy or a Management frame other than an Action No Ack frame), shall send an immediate acknowledgment in either an SU PPDU (see 26.4.4.5 (Responding to an HE TB PPDU with an SU PPDU)) or an HE MU PPDU (see 26.4.4.6 (Responding to an HE TB PPDU with an HE MU PPDU)). The Multi-STA BlockAck frame may be transmitted in a non-HT PPDU, non-HT duplicate PPDU, HT PPDU, VHT PPDU, HE SU PPDU, HE ER SU PPDU, or HE MU PPDU. After the reception of (#2318)a UL frame requiring acknowledgment, transmission of the DL acknowledgment shall commence after a SIFS, without regard to the busy/idle state of the medium. When an AP transmits an immediate acknowledgment in an HE MU PPDU in response to an A-MPDU sent in an HE TB PPDU, the AP should send it within the 20 MHz channel(s) where the pre-HE modulated fields of the HE TB PPDU sent by the STA are located. The immediate acknowledgment is an Ack frame, Compressed BlockAck frame, or Multi-STA BlockAck frame.

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An example of multiple BlockAck frames sent in DL MU is shown in Figure 10-18 (Example of UL MU transmission with immediate DL MU transmission containing individually addressed BlockAck frames acknowledging frames received from respective STAs(11ax)).

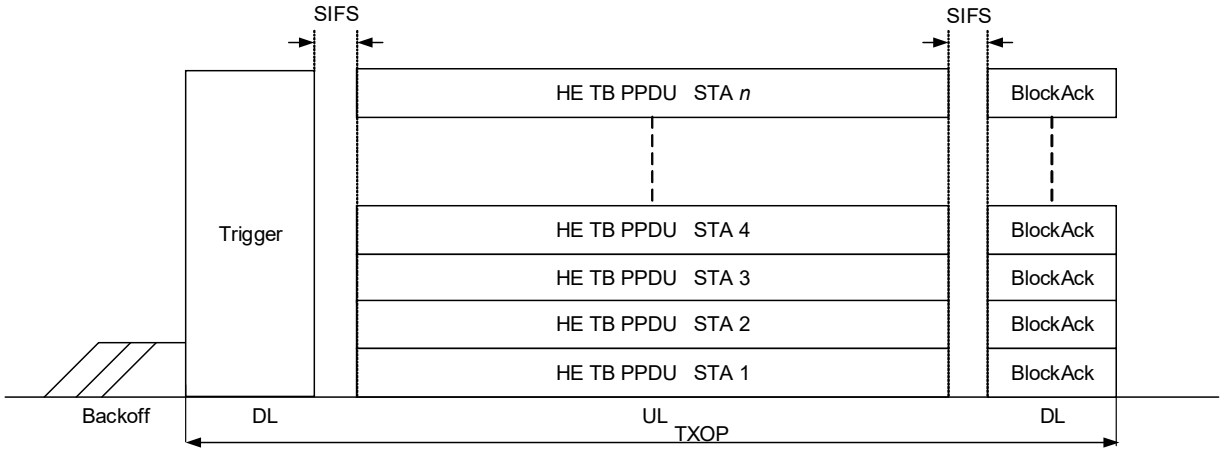


**Figure 10-18—Example of UL MU transmission with immediate DL MU transmission containing individually addressed BlockAck frames acknowledging frames received from respective STAs(11ax)**

An example of a Multi-STA BlockAck frame acknowledgment in a non-HT PPDU, HT PPDU, VHT PPDU, HE SU PPDU, or HE ER SU PPDU is given in Figure 10-19 (Example of UL MU transmissions with immediate Multi-STA BlockAck frame acknowledging MPDUs(11ax)).

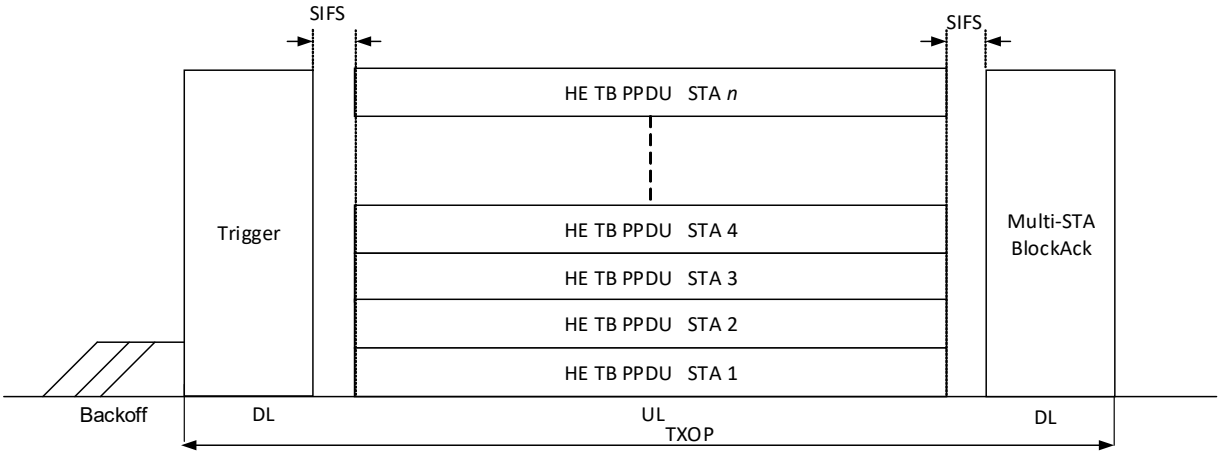


**Figure 10-19—Example of UL MU transmissions with immediate Multi-STA BlockAck frame acknowledging MPDUs(11ax)**

An example of a Multi-STA BlockAck frame acknowledgment in a non-HT duplicate PPDU is given in Figure 10-20 (Example of UL MU transmissions with immediate DL non-HT duplicate PPDU containing Multi-STA BlockAck frame(11ax)).

The Ack Policy Indicator subfield of a QoS Data frame sent in an HE TB PPDU shall not be set to Block Ack.


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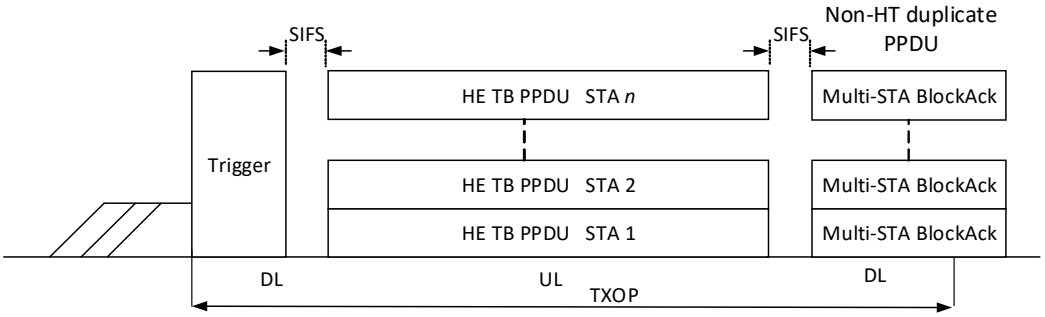


**Figure 10-20—Example of UL MU transmissions with immediate DL non-HT duplicate PPDU containing Multi-STA BlockAck frame(11ax)**

A STA may send a BlockAckReq frame or Multi-TID BlockAckReq frame to solicit the acknowledgment frame(s) from an AP.

### 10.3.2.14 Duplicate detection and recovery

#### 10.3.2.14.1 General

Because MAC-level acknowledgments and retransmissions are incorporated into the protocol, there is the possibility that a frame may be received more than once. The procedures defined in this subclause attempt to filter out these duplicates. Additional duplicate filtering is performed during Receive Buffer Operation for frames that are part of a block ack agreement as described in 10.25.6 (HT-immediate block ack extensions).

Duplicate frame filtering is facilitated through the inclusion of a Sequence Control field (consisting of a sequence number and fragment number) within Data, Management, and Extension frames, a TID subfield in the QoS Control field within QoS Data frames, and an ACI subfield in the Sequence Number field within QMFs, and a PTID/Subtype subfield in the Frame Control field within PV1 Data frames.

NOTE—In 10.3.2.14 (Duplicate detection and recovery), Data frames with a value of 1 in the QoS subfield of the Subtype subfield are collectively referred to as *QoS Data frames*.

#### 10.3.2.14.2 Transmitter requirements

A STA maintains one or more sequence number spaces that are used when transmitting a frame to determine the sequence number for the frame. When multiple sequence number spaces are supported, the appropriate sequence number space is determined by information from the MAC control fields of the frame to be transmitted. Except as noted below, (#270)each sequence number space is represented by a modulo 4096 counter, starting at 0 and incrementing by 1, for each MSDU (if not in an A-MSDU), A-MSDU or MMPDU transmitted using that sequence number space. If dot11MACPrivacyActivated is true, the counter in each sequence number space shall be set to a random number modulo 4096 when the STA's MAC address is changed.

(11ay)NOTE 1—Under a block ack agreement using segmentation and reassembly (see 10.69 (DMG segmentation and reassembly operation(11ay))), the MPDU sequence number is represented by a $2^{\text{MPDU Modulo}}$ counter and the MSDU sequence number is represented by $2^{\text{MSDU Modulo}}$ counter (see 9.2.4.4.2 (Sequence Control field structure when SAR is used(11ay))), where MPDU Modulo and MSDU Modulo are as defined in the SAR Configuration element (see 9.4.2.279 (SAR Configuration element(11ay))).

NOTE 2(11ay)—Group addressed retransmissions of BUs use the same sequence number as the initial group addressed transmission of the BU. Individually addressed retransmissions of a group addressed BU delivered via DMS use the

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same sequence number as the initial individually addressed transmission of the BU. When a BU is delivered both using group addressing and individual addressing (e.g., when DMS is active but there are other associated STAs not using DMS), the sequence number might differ between the group addressed and individually addressed transmissions of the same BU.

MPDUs that are part of the same MSDU or A-MSDU shall have the same sequence number. (#270)Different MSDUs (if not in an A-MSDU), A-MSDUs or MMPDUs have (with a high probability) a different sequence number.

A transmitting STA shall support the applicable sequence number spaces defined in Table 10-5 (Transmitter sequence number spaces). Applicability is defined by the Applies to column. The Status column indicates the level of support that is required if the Applies to column matches the transmission. The Multiplicity column indicates whether the sequence number space contains a single counter, or multiple counters and in the latter case identifies any (#4136)indices. The Transmitter requirements column identifies requirements for the operation of this sequence number space. The referenced requirements are defined at the end of the table.

**Table 10-5—Transmitter sequence number spaces**

| Sequence number space identifier | Sequence number space | Applies to | Status | Multiplicity | Transmitter requirements |
|---|---|---|---|---|---|
| SNS1 | Baseline | A STA transmitting a frame that is not covered by any of the other sequence number spaces. | Mandatory | Single Instance | TR1 |
| SNS2 | Individually addressed QoS Data | A STA transmitting an individually addressed QoS Data frame, excluding SNS5 | Mandatory | Indexed by <Address 1, TID> | |
| SNS3 | Time Priority Management | A QoS STA transmitting a Time Priority Management frame | Optional | Indexed by <Address 1, TID> | |
| SNS4 | QMF | A QMF STA transmitting a QMF that is neither a Protected Fine Timing frame nor a Public Action LMR(11az) | Mandatory | Indexed by <Address 1, AC> | TR2 |
| SNS5 | QoS (+)Null | A STA transmitting a QoS (+)Null frame | Mandatory | None | TR3 |
| SNS6 | Individually addressed PV1 Data frame | A STA operating as an S1G STA transmitting a PV1 Data frame | Mandatory | Indexed by <STA MAC Address identified by Address 1, PTID> | TR4 (#7012) |
| SNS7 | Individually addressed PV1 Management frame | A STA operating as an S1G STA transmitting a PV1 Management frame | Mandatory | Indexed by <STA MAC Address identified by Address 1> | |


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**Table 10-5—Transmitter sequence number spaces *(continued)***

| Sequence number space identifier | Sequence number space | Applies to | Status | Multiplicity | Transmitter requirements |
|---|---|---|---|---|---|
| SNS8(11az) | Protected Fine Timing frame and Public Action LMR frame(#8165) | A STA transmitting Protected Fine Timing frames or Public Action LMR frames(#8165-ED1) | Mandatory | Single Instance | |
| TR1: A transmitting STA should cache the last used sequence number per RA for frames that are assigned sequence numbers from this sequence number space. The STA should check that the successively assigned sequence numbers for frames transmitted to a single RA do not have the same value as is found in the cache for that RA. If the check fails the STA should increment the counter by 2, rather than 1.<br>TR2: The STA shall assign the sequence number from one modulo 1024 counter per <Address 1, AC> tuple starting at 0 and incrementing by 1 for each MMPDU carried in one or more QMFs with Address 1 and ACI fields matching the <Address 1, AC> tuple values corresponding to that counter.<br>TR3: Sequence numbers for transmitted QoS (+)Null frames may be set to any value.<br>(#7012)TR4: The same modulo 4096 counter per <STA MAC Address identified by Address 1, PTID> tuple shall be used for both PV1 Type 0 (QoS Data) and Type 3 (QoS Data) frames. | | | | | |

### 10.3.2.14.3 Receiver requirements

A STA maintains one or more duplicate detection caches. Table 10-6 (Receiver caches) defines the conditions under which a duplication detection cache is supported and the rules followed by the receiver for the cache. When a Data, Management or Extension frame is received, a record of that frame is inserted in an appropriate cache. That record is identified by a sequence number and possibly other information from the MAC control fields of the frame. When a Data, Management or Extension frame is received in which the Retry subfield of the Frame Control field is equal to 1, the appropriate cache, if any, is searched for a matching frame. In DMG, when a group addressed frame is received the appropriate cache is searched for a matching frame. When a PV1 Data frame or PV1 Management frame is received, the appropriate cache, if any,(#303) is searched for a matching frame, (#1945)despite the absence of a Retry subfield in the Frame Control field. If the search is successful, the frame is considered to be a duplicate. Duplicate frames are discarded.

NOTE—The receiver STA performs the Ack and (for an AP) PS procedures on all received frames requiring immediate acknowledgment, even if the frame is discarded due to duplicate filtering.

There is a small possibility that a frame may be improperly rejected due to such a match; however, this occurrence is rare and simply results in a lost frame (similar to an FCS error in other LAN protocols).

A receiving STA shall implement the applicable receiver requirements defined in Table 10-6 (Receiver caches) with Status indicated as Mandatory. A receiving STA should implement the applicable receiver requirements defined in Table 10-6 (Receiver caches) with Status indicated as Recommended. A receiving STA may implement the applicable receiver requirements defined in Table 10-6 (Receiver caches) with Status indicated as Optional. Applicability is defined by the Applies to column. The Status column indicates the level of support that is required if the Applies to column matches the received frame. The Multiplicity/Cache size column indicates the (#4136)indices that identify a cache entry and the number of entries that shall be supported. The Receiver requirements column identifies requirements for the operation of this cache. The referenced requirements are defined at the end of the table. The requirements relate to caching information that identifies a cache entry and discarding duplicate MPDUs.

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**Table 10-6—Receiver caches**

| Receiver cache identifier | Cache name | Applies to | Status | Multiplicity/Cache size | Receiver requirements |
|---|---|---|---|---|---|
| RC1 | Not QoS Data | A STA receiving frames (individually or group addressed) that are not QoS Data, excluding if applicable(#3336):<br>RC4<br>RC5<br>RC6<br>RC7<br>RC8<br>RC10 | Mandatory | Indexed by: <Address 2, sequence number, fragment number>.<br><br>At least the most recent cache entry per <Address 2>. | RR1<br>RR2<br>RR5 |
| RC2 | QoS Data | A STA receiving an (individually or group addressed) QoS Data frame, excluding RC3, and if applicable(#3336): RC7, RC8, RC9, and RC10 | Mandatory | Indexed by: <Address 2, TID, sequence number, fragment number>.<br><br>At least the most recent cache entry per <Address 2, TID> pair in this cache. | RR1<br>RR5 |
| RC3 | QoS (+)Null | A QoS STA receiving a QoS (+)Null frame | Mandatory | None | RR4 |
| RC4 | Non-time priority Management | A STA receiving an individually addressed non-time priority Management frame, excluding RC6 if RC6 is applicable(#4291) | Recommended | Indexed by: <Address 2, sequence number, fragment number><br><br>At least the most recent cache entry per <Address 2> value. | RR1<br>RR2<br>RR5 |
| RC5 | Time priority Management | A STA receiving an individually addressed time priority Management frame | Recommended(#4292) | Indexed by: <Address 2, sequence number, fragment number>.<br><br>At least the most recent cache entry per <Address 2> value. | RR5 |
| RC6 | QMFs | A STA receiving an individually addressed QMF(11az) that is neither a Protected Fine Timing frame nor a Public Action LMR | Mandatory | Indexed by: <Address 2, AC, sequence number, fragment number><br><br>The most recent cache entry per <Address 2, AC, sequence-number, fragment-number>. | RR2<br>RR3<br>RR5 |



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**Table 10-6—Receiver caches *(continued)***

| Receiver cache identifier | Cache name | Applies to | Status | Multiplicity/Cache size | Receiver requirements |
|---|---|---|---|---|---|
| RC7 | Nonmesh GCR | A nonmesh STA receiving a group addressed frame subject to a GCR agreement. | Mandatory | Indexed by: <DA, sequence number><br><br>One cache entry per <DA, sequence-number> tuple for each group address subject to a GCR agreement. | RR5 |
| RC8 | Mesh GCR | A mesh STA receiving a group addressed frame subject to a GCR agreement. | Mandatory | Indexed by: <DA, Address 2, sequence number>.<br><br>One cache entry per <DA, Address 2, sequence-number> tuple for each group address subject to a GCR agreement. | RR5 |
| RC9 | QoS Data under BA | A non-DMG QoS STA receiving a QoS Data frame sent under a block ack agreement | Mandatory(#301) | None | RR4 |
| RC10 | DMG Group Addressed | A DMG STA receiving a group addressed frame. | Mandatory | Indexed by: <Address 1, Address 2, sequence number, fragment number><br><br>The most recent cache entry per <Address 1, Address 2, sequence-number>. | RR6 |
| RC11 | Individually addressed PV1 Data frame | An S1G STA receiving an individually addressed PV1 Data frame | Mandatory | Indexed by <STA MAC Address identified by Address 2, PTID, sequence number, fragment number>.<br>At least the most recent cache entry per <STA MAC Address identified by Address 2, PTID> pair in this cache. | RR1<br>RR6(#304) |
| RC12 | Individually addressed PV1 Management frame | An S1G STA receiving an individually addressed PV1 Management frame | Mandatory | Indexed by <STA MAC Address identified by Address 2, sequence number, fragment number>.<br>At least the most recent cache entry per <STA MAC Address identified by Address 2> pair in this cache. | RR1<br>RR2<br>RR6(#304) |

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**Table 10-6—Receiver caches *(continued)***

| Receiver cache identifier | Cache name | Applies to | Status | Multiplicity/Cache size | Receiver requirements |
|---|---|---|---|---|---|
| RC13(11az) | Protected Fine Timing frame and Public Action LMR frame(#8165) | A STA receiving Protected Fine Timing frames or Public Action LMR frames(#8165-Ed1) | Mandatory | Indexed by: <Address 2, sequence number, fragment number>. At least the most recent cache entry per <Address 2>. | RR1<br>RR2<br>RR5 |

RR1: A receiving non-DMG STA with dot11QMFActivated false or not present and with dot11RobustAVStreamingImplemented false or not present should omit tuples obtained from group addressed frames from this cache.

RR2: A receiving STA should omit tuples obtained from ATIM frames from this cache.

RR3: A receiving QMF STA that is a non-DMG STA with dot11RobustAVStreamingImplemented false or not present shall omit from the cache all tuples obtained from group addressed Data frames.

RR4: For the purposes of duplicate detection using receiver caches, QoS (+)Null frames and, in a non-DMG BSS, QoS Data frames under a block ack agreement, shall be ignored.

RR5: The STA shall discard the frame if the Retry subfield of the Frame Control field is 1 and it matches an entry in the cache.

RR6: The STA shall discard the frame if it matches an entry in the cache.

#### 10.3.2.15 NAV distribution

When a node needs to distribute NAV information, for instance, to reserve the medium for a transmission of a nonbasic rate frame (that might not be heard by other nodes in the BSS), the node may first transmit a CTS frame with the RA field equal to its own MAC address (CTS-to-self) if the node is a non-DMG STA, or it may transmit a DMG CTS frame with the RA field equal to its own MAC address and the TA field equal to the MAC address of the peer STA for which the forthcoming transmission of the node is intended (DMG CTS-to-self) if the node is a DMG STA. A duration value in the frame protects the pending transmission, plus possibly an Ack frame.

The CTS-to-self and DMG CTS-to-self NAV distribution mechanisms are lower in network overhead cost than are the RTS/CTS and RTS/DMG CTS NAV distribution mechanisms, respectively, but CTS-to-self and DMG CTS-to-self are less robust against hidden nodes and collisions than RTS/CTS and RTS/DMG CTS-to-self, respectively. STAs employing a NAV distribution mechanism should choose a mechanism that is appropriate for the given network conditions. If errors occur when employing the CTS-to-self or DMG CTS-to-self mechanism, STAs should switch to a more robust mechanism.

When the NDP CTS frame is a CTS-to-self, the value in the Duration field of the NDP CTS frame shall protect the pending transmission, plus any expected (NDP) Ack frame in response.

#### 10.3.2.16 Operation of aSlotTime

(#2154)An AP with the MAC variable aSlotTime equal to the long slot time shall set the Short Slot Time subfield in transmitted Beacon, Probe Response, Association Response, and Reassociation Response frames to 0. An AP with the MAC variable aSlotTime equal to the short slot time shall set the Short Slot Time


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subfield in transmitted Beacon, Probe Response, Association Response, and Reassociation Response frames to 1.

(#2154)A non-AP STA in which dot11ShortSlotTimeOptionImplemented and dot11ShortSlotTimeOptionActivated are true shall set the MAC variable aSlotTime to the short slot time upon reception of Beacon, Measurement Pilot, Probe Response, Association Response, and Reassociation Response frames with the Short Slot Time subfield value equal to 1 from the AP that the STA is associated or associating to. (#6387)A non-AP STA in which dot11ShortSlotTimeOptionImplemented and dot11ShortSlotTimeOptionActivated are true shall set the MAC variable aSlotTime to the long slot time upon reception of Beacon, Measurement Pilot, Probe Response, Association Response, and Reassociation Response frames with the Short Slot Time subfield value equal to 0 from the AP that the STA is associated or associating to. See also 11.1.3.2 (Beacon generation in non-DMG infrastructure networks).(#1761)

(#6387)A STA in which either dot11ShortSlotTimeOptionImplemented or dot11ShortSlotTimeOptionActivated is false shall set the MAC variable aSlotTime to the long slot (#2154)time at all times. A STA in which dot11ShortSlotTimeOptionImplemented is not present, or whose PHY supports only a single slot time value shall set the MAC variable aSlotTime to the PHY characteristic aSlotTime.

NOTE—The MAC variable aSlotTime is distinct from the PHY characteristic aSlotTime. Outside this subclause, the MAC uses the MAC variable aSlotTime whenever the value of aSlotTime is required.

### 10.3.2.17 Response Indication procedure

An S1G STA distributes RID information in order to protect the response frame expected SIFS after the frame that elicits that response. The TXVECTOR parameter RESPONSE_INDICATION for S1G non-NDPs shall be set based on the expected response type, as described in Table 10-7 (Setting the TXVECTOR parameter RESPONSE_INDICATION). The TXVECTOR parameter RESPONSE_INDICATION for S1G NDPs other than NDP CMAC PPDUs is set as described in 10.35.7 (Transmission of an S1G NDP).

NOTE—The TXVECTOR parameter RESPONSE_INDICATION is not present for NDP CMAC PPDUs.

**Table 10-7—Setting the TXVECTOR parameter RESPONSE_INDICATION**

| RESPONSE_INDICATION | Solicited Immediate Response |
|---|---|
| 0 (No Response) | No immediate response.<br><br>None of the MPDUs in the PPDU solicit an immediate acknowledgment (e.g., a QoS Data frame whose ack policy is neither Normal Ack nor Implicit BAR (see 9.2.4.5.4 (Ack Policy Indicator subfield) and 9.8.3.1 (Frame Control field)), Action No Ack frame). |
| 1 (NDP Response) | The addressed recipient returns an individual NDP CMAC PPDU:<br>— NDP Ack frame, as described in 10.3.2.11 (Acknowledgment procedure),<br>— NDP CTS frame, as described in 10.3.2.9 (CTS and DMG CTS procedure),<br>— NDP BlockAck frame, as described in 10.25.6 (HT-immediate block ack extensions) and 10.3.2.12 (Fragment BA procedure).<br><br>At least one of the MPDUs in the PPDU solicits an immediate acknowledgment, (e.g., a QoS Data frame whose ack policy is either Normal Ack or Implicit BAR, Action frame). |

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**Table 10-7—Setting the TXVECTOR parameter RESPONSE_INDICATION *(continued)***

| RESPONSE_INDICATION | Solicited Immediate Response |
|---|---|
| 2 (Normal Response) | The addressed recipient returns an individual control response frame:<br>— Ack frame, as described in 10.3.2.11 (Acknowledgment procedure),<br>— CTS frame, as described in 10.3.2.9 (CTS and DMG CTS procedure),<br>— BlockAck frame or BAT frame, as described in 10.3.2.11 (Acknowledgment procedure) and 10.46 (Target wake time (TWT)),<br>— TACK frame or STACK frame as described in 10.46 (Target wake time (TWT)).<br><br>At least one of the MPDUs in the PPDU solicits an immediate acknowledgment (e.g., a QoS Data frame whose ack policy is Normal Ack or Implicit BAR; or an Action frame). |
| 3 (Long Response) | The addressed recipient may return a response frame, which is not an individual control response frame. More details are provided in 10.49 (Bidirectional TXOP), 10.29 (Reverse direction protocol), 10.33.3 (Explicit feedback beamforming), and 10.53.5.2 (Explicit Ack procedure). |

An S1G STA shall not cause its intended receiver to generate a control response frame that is not an NDP CMAC PPDU except as specified below:

a) If the intended receiver has indicated that it supports generating +HTC Control frames then the S1G STA can solicit +HTC Control frames of the types described in 10.31 (Link adaptation).

b) If the intended receiver has negotiated with the S1G STA the generation of TACK frame or STACK frames then the S1G STA can solicit TACK frames or STACK frames as described in 10.46 (Target wake time (TWT)).

c) If the intended receiver has indicated that it supports generating TACK frames then the S1G STA can solicit a TACK frame as described in 10.47.2 (Rescheduling of awake/doze cycle).

d) If the intended receiver has negotiated with the S1G STA the use of either BlockAck or BAT frames then the S1G STA can solicit either BlockAck or BAT frames as described in 10.25.5 (Selection of BlockAck and BlockAckReq variants).

e) If the intended receiver has negotiated with the S1G STA the generation of control response frames with different MCSs than the primary MCS as described in 10.6.6.5.6 (Control response MCS negotiation).

An S1G STA transmitting a PPDU that expects an NDP Response shall calculate the Duration/ID field of the transmitted PPDU as described in 9.2.5.2 (Setting for single and multiple protection under enhanced distributed channel access (EDCA)) where the estimated duration of "CTS frame," "Ack frame," or "BlockAck frame" is equal to NDPTxTime. NDPTxTime depends on the TXVECTOR parameter PREAMBLE_TYPE and is equal to the time in microseconds, required to transmit:

— An NDP_1M MAC frame if PREAMBLE_TYPE is an S1G_1M preamble or the intended receiver has indicated the use of 1 MHz control response frames (see 10.6.6.6 (Channel Width selection for Control frames)).

— An NDP_2M MAC frame if PREAMBLE_TYPE is a ≥ 2 MHz short/long preamble and the intended receiver has not indicated the use of 1 MHz control response frames.

An S1G STA that expects a Normal Response that is a BAT frame or TACK frame shall calculate the Duration/ID field of the PPDU as described in 9.2.5.2 (Setting for single and multiple protection under enhanced distributed channel access (EDCA)) using the same estimated duration of a BlockAck frame. An


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S1G STA that expects a Normal Response that is a STACK frame shall use the estimated duration of an Ack frame.

An S1G STA that expects a Long Response shall calculate the Duration/ID field of the PPDU as described in 9.2.5.2 (Setting for single and multiple protection under enhanced distributed channel access (EDCA)) for multiple protection settings.

An S1G STA transmitting an eliciting frame for which it expects a response that is a BAT frame or BlockAck frame as described in 10.25.6 (HT-immediate block ack extensions) or a TACK frame as described in 10.46 (Target wake time (TWT)) and 10.47.2 (Rescheduling of awake/doze cycle) shall carry the eliciting frame in an A-MPDU or in an S-MPDU (i.e., sets the TXVECTOR parameter AGGREGATION to 1). The intended recipient selects the type of control response frame based on the type of the eliciting frame and other information available in the PSDU such as Ack Policy Indicator field, EOF/ Tag(#4367) field, etc.

An S1G STA transmitting an eliciting frame for which it expects a response that is an Ack frame as described in 10.31 (Link adaptation) or a STACK frame as described in 10.46 (Target wake time (TWT)) shall carry the eliciting frame in an MPDU (i.e., sets the TXVECTOR parameter AGGREGATION to 0) except when the intended receiver has set the A-MPDU Supported field in the most recently transmitted S1G Capabilities element to 1, in which case the S1G STA may transmit the eliciting frame as an S-MPDU.

An S1G STA transmitting a CF-End frame shall set the TXVECTOR parameter RESPONSE_INDICATION to No Response.

An S1G AP sending an NDP Ack frame with the More Data field equal to 1 as a response to an eliciting PS-Poll frame may set the Duration field of the NDP Ack frame to the estimated duration of the BU frame that the S1G AP has buffered for the polling STA, plus SIFS, plus the duration of the response from the (#306)non-AP S1G STA, if required.

An S1G AP that sends an NDP_2M PS-Poll-Ack frame with the Idle Indication field equal to 0 and the More Data field equal to 1 as a response to an eliciting NDP PS-Poll frame may set the Duration field of the NDP_2M PS-Poll-Ack frame to the estimated duration of the BU frame that the S1G AP has buffered for the polling STA, plus SIFS, plus the duration of the response from the (#306)non-AP S1G STA, if required. An S1G AP that sends an NDP_2M PS-Poll-Ack frame with the Idle Indication field equal to 0 and the More Data field equal to 0 as a response to an eliciting NDP PS-Poll frame shall set the Duration field of the NDP_2M PS-Poll-Ack frame to 0.

(#111)An S1G STA should protect the sequence of two or more SIFS-separated PV1 frames for which it does not follow the BDT rules defined in 10.49 (Bidirectional TXOP) with a protective mechanism that uses multiple protection as described in 9.2.5.2 (Setting for single and multiple protection under enhanced distributed channel access (EDCA)).

#### 10.3.2.18 EDMG RTS procedure(11ay)

In order to establish a TXOP with a peer EDMG STA, an EDMG STA shall transmit an RTS frame. For channel combinations covered in Table 28-6 (Definition of Scrambler Initialization field when transmitted using the control mode and the Turnaround field is 1(11ay)), the TXVECTOR parameter CH BANDWIDTH shall be set according to rules specified in 10.23.2.14 (EDCA channel access in an EDMG BSS(11ay)). For those combinations that are not covered in Table 28-6 (Definition of Scrambler Initialization field when transmitted using the control mode and the Turnaround field is 1(11ay)), the TXVECTOR parameter SCRAMBLER_INIT_SETTING shall be set to CONTROL_TRAILER.

If a TXOP is established to send at least one SU MIMO or MU MIMO PPDU, and the number of bits set to 1 in the TXVECTOR parameter CH_BANDWIDTH is greater than 1, the RTS frame shall be sent in non-

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EDMG duplicate PPDU format, the TXVECTOR parameter SCRAMBLER_INIT_SETTING shall be set to indicate CONTROL_TRAILER and the parameter CT_TYPE shall be set to GRANT_RTS_CTS2Self.

If a TXOP is established to send at least one SU MIMO or MU MIMO PPDU, and the number of bits set to 1 in the TXVECTOR parameter CH_BANDWIDTH is equal to 1, the RTS frame shall be sent in non-EDMG PPDU format, the TXVECTOR parameter SCRAMBLER_INIT_SETTING shall be set to indicate CONTROL_TRAILER and the parameter CT_TYPE shall be set to GRANT_RTS_CTS2Self.

If a TXOP is established to send PPDUs using a single transmit chain and the number of bits set to 1 in the CH_BANDWIDTH parameter is greater than 1:

— The RTS frame shall be sent in non-EDMG duplicate PPDU format.
— The TXVECTOR parameter SCRAMBLER_INIT_SETTING shall be set to Channel_BW for channel combinations covered in Table 28-6 (Definition of Scrambler Initialization field when transmitted using the control mode and the Turnaround field is 1(11ay)); otherwise, for those combinations that are not covered in Table 28-6 (Definition of Scrambler Initialization field when transmitted using the control mode and the Turnaround field is 1(11ay)) the TXVECTOR parameter SCRAMBLER_INIT_SETTING shall be set to CONTROL_TRAILER.
— The TXVECTOR parameter CH_BANDWIDTH_SIGNALING shall be set to the encoded value of the set of channels indicated by the CH_BANDWIDTH parameter as defined in Table 28-6 (Definition of Scrambler Initialization field when transmitted using the control mode and the Turnaround field is 1(11ay)).

If the number of bits set to 1 in the CH_BANDWIDTH parameter is equal to 1, STA may perform one of the following:

— Follow the procedure defined in the paragraph above, or
— Transmit the RTS in non-EDMG format and follow the procedure defined in 10.3.2.4 (Setting and resetting the NAV).

A CF-End frame sent to truncate a TXOP initiated by RTS frame carried in a non-EDMG duplicate PPDU format shall be sent using a non-EDMG duplicate PPDU format. The TXVECTOR parameters CHANNEL_AGGREGATION and CH_BANDWIDTH_SIGNALING of the CF-End frame shall be set to the same values as indicated by the RXVECTOR parameters of the DMG CTS frame, if received, or to the same values as indicated by the TXVECTOR parameters of the RTS frame otherwise.

An EDMG STA transmitting an RTS frame to establish a TXOP for the transmission of at least one MIMO PPDU or a SISO PPDU using multiple transmit chains with hybrid beamforming follows the procedure defined in 10.38.12.4 (MIMO channel access).

### 10.3.3 Random backoff procedure

A STA desiring to initiate transfer of Data frames and/or Management frames using the DCF shall invoke the CS mechanism (see 10.3.2.1 (CS mechanism)) to determine the busy/idle state of the medium. If the medium is busy, the STA shall defer until the medium is determined to be idle without interruption for a period of time equal to EIFS when the last transition to idle medium was a result of a frame detected on the medium that was not received correctly, or equal to DIFS otherwise. After this DIFS or EIFS medium idle time, the STA shall then generate a random backoff count [defined by Equation (10-1)] for an additional deferral time before transmitting, unless the backoff counter already contains a nonzero value, in which case the selection of a random number is not needed and not performed. This process minimizes collisions during contention between multiple STAs that have been deferring to the same event.

$$\text{Backoff Count} = \text{Random}() \tag{10-1}$$

where


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Random() = Pseudorandom integer drawn from a uniform distribution over the interval [0,CW], where CW is an integer within the range of values of the PHY characteristics aCWmin and aCWmax, aCWmin ≤ CW ≤ aCWmax.

NOTE 1—It is important that designers recognize the need for statistical independence of the random number streams between STAs.

The contention window (CW) parameter shall take an initial value of aCWmin. Every STA shall maintain a STA short retry count (SSRC) as well as a STA long retry count (SLRC), both of which shall take an initial value of 0. The SSRC shall be incremented when any short retry count (SRC) associated with any MPDU with the Type subfield equal to Data or Management is incremented. The SLRC shall be incremented when any long retry count (LRC) associated with any MPDU with the Type subfield equal to Data or Management is incremented. The CW shall take the next value in the series every time an unsuccessful attempt to transmit an MPDU causes either STA retry count to increment, until the CW reaches the value of aCWmax. (#109)(#1325) Once it reaches aCWmax, the CW shall remain at the value of aCWmax until the CW is reset. This improves the stability of the access protocol under high-load conditions. See Figure 10-21 (Example of exponential increase of CW).

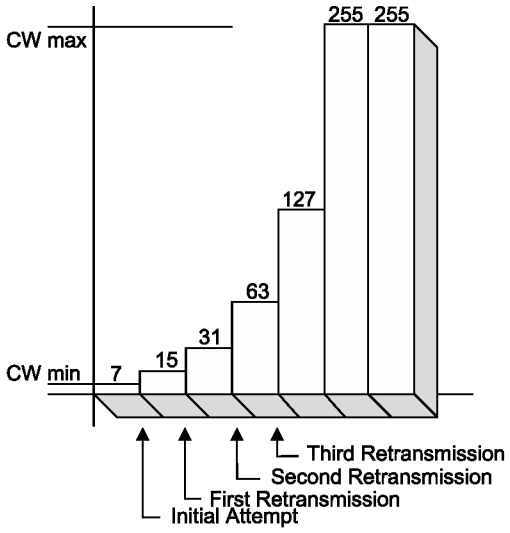


**Figure 10-21—Example of exponential increase of CW**

The CW shall be reset to aCWmin after every successful attempt to transmit a Data or Management frame, or when SSRC reaches dot11ShortRetryLimit.

The SSRC shall be reset to 0 when a CTS frame is received in response to an RTS frame, when a BlockAck frame is received in response to a BlockAckReq frame, when an Ack frame is received in response to the transmission of a frame containing all or part of an MSDU or MMPDU that is contained in a PSDU of length less than or equal to dot11RTSThreshold, or when a frame with a group address in the Address 1 field is transmitted.

The SLRC shall be reset to 0 when an Ack frame is received in response to transmission of a frame containing all or part of an MSDU or MMPDU that is contained in a PSDU of length greater than dot11RTSThreshold, or when a frame with a group address in the Address 1 field is transmitted.

NOTE 2—For non-HE STAs that use DCF for channel access, dot11TXOPDurationRTSThreshold is not present and the use of the RTS/CTS mechanism is under the control of dot11RTSThreshold.(11ax)

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The set of CW values shall be sequentially ascending integer powers of 2, minus 1, beginning with a PHY-specific aCWmin value, and continuing up to a PHY-specific aCWmax value.

### 10.3.4 DCF access procedure

#### 10.3.4.1 Introduction

The CSMA/CA access method is the foundation of the DCF.

#### 10.3.4.2 Basic access

Basic access refers to the core mechanism a STA uses to determine whether it may transmit using the DCF.

A STA may transmit an MPDU when it is operating under the DCF access method, when the STA determines that the medium is idle when a frame is queued for transmission, and remains idle for a period of a DIFS, or an EIFS (10.3.2.3.7 (EIFS)) from the end of the immediately preceding medium-busy event, whichever is the greater, and the backoff counter has a value of zero. Otherwise the random backoff procedure described in 10.3.4.3 (Backoff procedure for DCF) shall be followed.

A DMG STA operating under the DCF access method should transmit frames with its transmit antenna pattern directed toward the intended receiver.

A DMG STA operating under the DCF access method that does not operate in a TXOP exchange may configure its receiving antenna array to a quasi-omni antenna pattern to be ready to receive frames from any DMG STA.

NOTE—The steady state of the antenna configuration might depend on the actual applications in which a DMG STA is involved. For example, a DMG STA that expects transactions with several STAs during a CBAP configures the receiving antenna to a quasi-omni pattern to be ready to receive transmission from any of the STAs. A DMG STA that expects transactions with a single STA (e.g., AP or PCP) might keep its receiving antenna directed to the peer STA.

A DMG STA operating under the DCF access method that is participating in a TXOP exchange should configure its receiving antenna array to be directed toward the other transmitter involved in the TXOP.

The basic access mechanism is illustrated in Figure 10-22 (Basic access method).

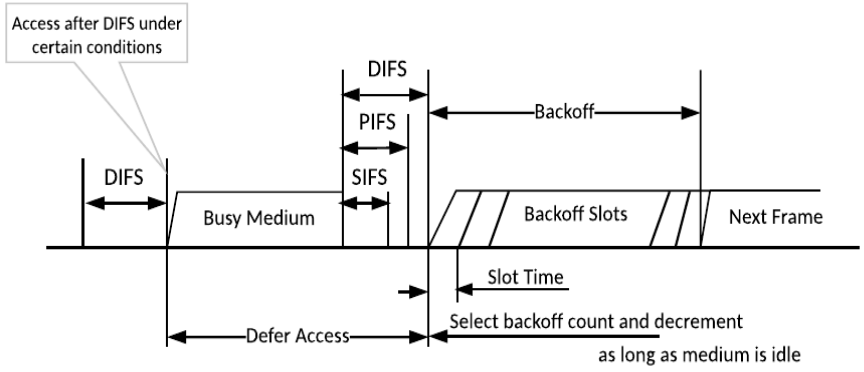


**Figure 10-22—Basic access method**

#### 10.3.4.3 Backoff procedure for DCF

This subclause describes backoff procedure that is to be invoked when DCF is used. For the backoff procedure when EDCA is used, see 10.23.2.2 (EDCA backoff procedure).


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A STA shall invoke the backoff procedure to transfer a frame when finding the medium busy as indicated by either the physical or virtual CS mechanism (see Figure 10-23 (Backoff procedure)). A transmitting STA shall invoke the backoff procedure when the STA infers a failed transmission as defined in 10.3.2.9 (CTS and DMG CTS procedure) or 10.3.2.11 (Acknowledgment procedure).

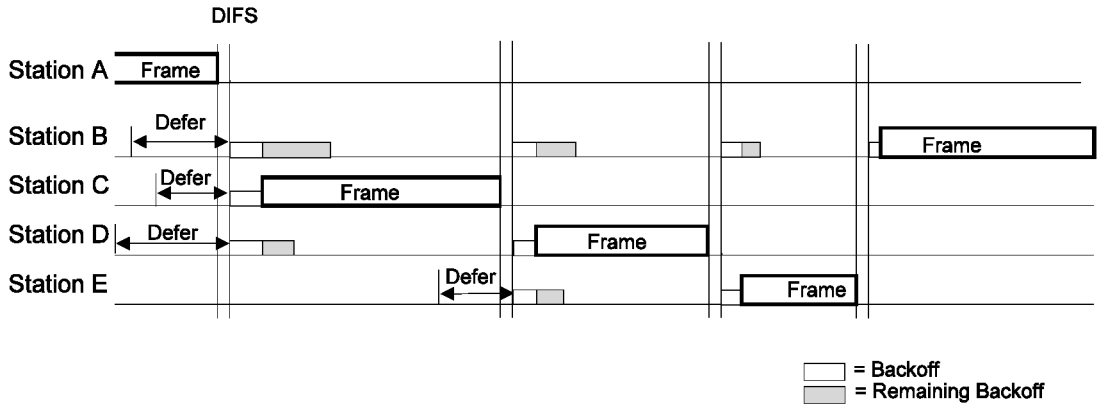


**Figure 10-23—Backoff procedure**

To begin the backoff procedure, the STA shall set its backoff counter to a random value using the equation in 10.3.3 (Random backoff procedure). All backoff slots occur following a DIFS or EIFS as appropriate (see 10.3.3 (Random backoff procedure) and 10.3.2.3.7 (EIFS)) except that no backoff slots for DCF occur during the BTI, the A-BFT, the ATI, and non-CBAP portions of the DTI.

A STA performing the backoff procedure shall use the CS mechanism (see 10.3.2.1 (CS mechanism)) to determine whether there is activity during each backoff slot. If no medium activity is indicated for the duration of a particular backoff slot, then the backoff procedure shall decrement its backoff counter.

If the medium is determined to be busy at any time during a backoff slot, then the backoff counter shall not be decremented for that slot. The backoff counter is next decremented after the medium has been determined to be idle for the duration of a DIFS or EIFS, as appropriate (see 10.3.3 (Random backoff procedure) and 10.3.2.3.7 (EIFS)), plus aSlotTime.

Transmission shall commence when the backoff counter equals 0.

A backoff procedure shall be performed immediately after the end of every transmission with the More Fragments bit equal to 0 of an MPDU with the Type subfield equal to Data, Management, or Control with subtype PS-Poll, even if no additional transmissions are currently queued. In the case of successful acknowledged transmissions, this backoff procedure shall begin at the end of the received Ack frame. In the case of unsuccessful transmissions requiring an immediate response, this backoff procedure shall begin at the end of the AckTimeout interval (as defined in 10.3.2.11 (Acknowledgment procedure)) or CTSTimeout interval (as defined in 10.3.2.9 (CTS and DMG CTS procedure)). An unsuccessful transmission is one where a control response frame is not received from the STA addressed by the RA field of the transmitted frame and the value of the RA field is an individual address. If the transmission is successful, the CW value reverts to aCWmin before the random backoff count is chosen, and the SSRC and/or SLRC are updated as described in 10.3.3 (Random backoff procedure). The result of this procedure is that transmitted frames from a STA are always separated by at least DIFS.

The effect of this procedure is that when multiple STAs are deferring and go into random backoff, then the STA selecting the smallest backoff count using the random function wins the contention (assuming all of the contending STAs detect the same instances of WM activity at their respective receivers, a situation that is not

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always true, due to hidden node effects and interference events). The number of DMG STAs that are able to detect each WM transmission is reduced even further due to SPSH.

In an IBSS the backoff counter for a pending non-Beacon or non-ATIM transmission shall not decrement in the period from the TBTT until the expiration of the ATIM window, and the backoff counter for a pending ATIM frame shall decrement only within the ATIM window. (See Clause 11 (MLME).) Within an IBSS a separate backoff count shall be generated to precede the transmission of a Beacon frame, as described in 11.1.3.5 (Beacon generation in an IBSS).

At the start of an awake window, a DMG STA shall suspend decrementing its backoff counter(s) for any transmission of non-ATIM frames for the duration of the awake window as indicated in the most recently received Awake Window element. At the end of the awake window, the DMG STA shall resume decrementing the backoff counter(s) for non-ATIM frames. A DMG STA shall not decrement the backoff counter for a pending ATIM frame outside the awake window.

(#124)DMG STAs may use different receiving antenna pattern for CCA. Hence, NAV setting behavior might be different depending on the receiving antenna pattern of the STA, even though they are in the same neighborhood. An example of the backoff procedure is described in V.2 (Backoff procedure for DMG STAs(#124)).

#### 10.3.4.4 Recovery procedures and retransmit limits

Under DCF, error recovery is always the responsibility of the STA that initiates a frame exchange sequence(#109). Many circumstances might cause an error to occur that requires recovery. For example, the CTS frame might not be returned after an RTS frame is transmitted. This may happen due to a collision with another transmission, due to interference in the channel during the RTS or CTS frame, or because the STA receiving the RTS frame has an active virtual CS condition (indicating a busy medium time period).

Error recovery shall be attempted by retrying transmissions for frame exchange sequences that the initiating STA infers have failed. Retries shall continue, for each failing frame exchange sequence, until the transmission is successful, or until the relevant retry limit or lifetime is reached, whichever occurs first. A STA shall maintain an SRC and an LRC for each MSDU or MMPDU awaiting transmission. These counts are incremented and reset independently of each other.

After an RTS frame is transmitted, the STA shall perform the CTS procedure, as defined in 10.3.2.9 (CTS and DMG CTS procedure). If the RTS frame transmission fails, the SRC for the MSDU or MMPDU and the SSRC are incremented. This process shall continue until the number of attempts to transmit that MSDU or MMPDU reaches dot11ShortRetryLimit.

After transmitting a frame that requires immediate acknowledgment, the STA shall perform the acknowledgment procedure, as defined in 10.3.2.11 (Acknowledgment procedure). The SRC for an MPDU with the Type subfield equal to Data or Management and of length less than or equal to dot11RTSThreshold and the SSRC shall be incremented every time transmission of that MPDU fails. This SRC and the SSRC shall be reset when transmission of that MPDU succeeds. The LRC for an MPDU with the Type subfield equal to Data or Management and of length greater than dot11RTSThreshold and the SLRC shall be incremented every time transmission of that MPDU fails. This LRC and the SLRC shall be reset when transmission of that MPDU succeeds. All retransmission attempts for an MPDU with the Type subfield equal to Data or Management that has failed the acknowledgment procedure one or more times shall be made with the Retry subfield set to 1.

NOTE 1—These rules do not apply for frames sent under EDCAF by a non-DMG STA under a block ack agreement(#3741) (see 10.23.2.12.1 (General)).(#1468)

NOTE 2—For non-HE STAs that use DCF for channel access, dot11TXOPDurationRTSThreshold is not present, and the use of the RTS/CTS mechanism is under the control of dot11RTSThreshold.(11ax)


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Retries for failed transmission attempts shall continue until the SRC for the MPDU with the Type subfield equal to Data or Management is equal to dot11ShortRetryLimit or until the transmit MSDU timer for the MSDU or any undelivered fragments of that MSDU exceeds dot11MaxTransmitMSDULifetime (see 10.4 (MSDU, (11ax)A-MSDU, and MMPDU fragmentation)). When any of these limits is reached, retry attempts shall cease, and the MPDU with the Type subfield Data (and any MSDU of which it is a part) or Management shall be discarded. A DMG STA, in addition to using random access within a CBAP, may transmit retries in available scheduled SPs.

A STA in PS mode, in an infrastructure BSS, initiates a frame exchange sequence by transmitting a PS-Poll frame to request data from an AP. If no Ack, Data, or Management frame is received from the AP in response to a PS-Poll frame, then the STA shall retry the sequence, by transmitting another PS-Poll frame.

(#1338)If the AP sends a Data or Management frame in response to a PS-Poll frame, but fails to receive the Ack frame acknowledging this Data or Management frame, the next PS-Poll frame from the same STA might cause a retransmission of the last MSDU.(#1338)

NOTE 3—This duplicate MSDU is filtered at the receiving STA using the duplicate frame filtering mechanism.(#1338)

If the AP responds to a PS-Poll frame by transmitting an Ack frame, then responsibility for the Data or Management frame delivery error recovery shifts to the AP because the data are transferred in a subsequent frame exchange sequence, which is initiated by the AP. The AP shall attempt to deliver one buffered BU to the STA that transmitted the PS-Poll frame, using any frame exchange sequence valid for an individually addressed BU. If the PS STA that transmitted the PS-Poll frame returns to doze state after transmitting the Ack frame in response to receipt of this BU, but the AP fails to receive this Ack frame, then the AP retries transmission of this BU until the relevant retry limit is reached. See 11.2.3.7 (Receive operation for STAs in PS mode) for details on filtering of extra PS-Poll frames.

An AP that fails to receive an acknowledgment after the AP transmits a frame with the More Data subfield set to 0 to a non-AP VHT STA that is in TXOP power save mode retransmits the frame within the current TXOP under certain conditions as described in 11.2.3.16 (VHT TXOP power save).

A CMMG AP that fails to receive an acknowledgment after the AP transmits a frame with the More Data field set to 0 to a non-AP CMMG STA in CMMG TXOP power save mode may retransmit the frame within the current TXOP under certain conditions as described in 11.2.3.18 (CMMG TXOP power save).

### 10.3.4.5 Control of the channel

The SIFS is used to provide an efficient MSDU delivery mechanism. Once the STA has contended for the channel, that STA shall continue to send fragments until either all fragments of a single MSDU or MMPDU have been sent or an acknowledgment is not received. Should the sending of the fragments be interrupted due to one of these reasons, when the next opportunity for transmission occurs the STA shall resume transmission. The algorithm by which the STA decides which of the outstanding MSDUs shall next be attempted after an unsuccessful transmission (as defined in 10.3.4.3 (Backoff procedure for DCF)) attempt is beyond the scope of this standard, but any such algorithm shall comply with the restrictions listed in 10.7 (MSDU transmission restrictions).

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Figure 10-24 (Transmission of a fragmented MSDU using SIFS) illustrates the transmission of a fragmented MSDU using the SIFS.

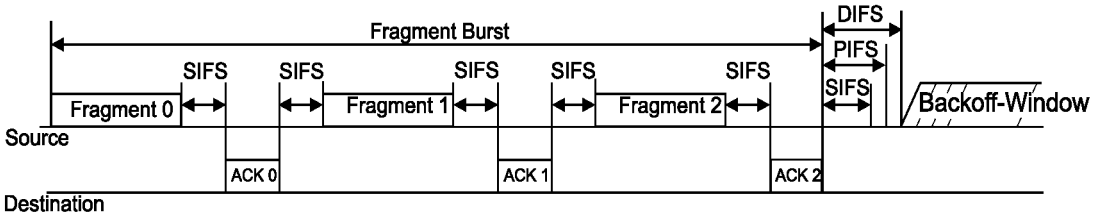


**Figure 10-24—Transmission of a fragmented MSDU using SIFS**

When the source STA transmits a fragment, it shall release the channel, then immediately monitor the channel for an acknowledgment as described in 10.3.2.11 (Acknowledgment procedure).

When the destination STA has finished sending the acknowledgment, the SIFS following the acknowledgment shall be reserved for the source STA to continue (if necessary) with another fragment. The STA sending the acknowledgment shall not transmit on the channel immediately following the acknowledgment.

The process of sending multiple fragments after contending for the channel is defined as a fragment burst.

If the source STA does not receive an acknowledgment frame, it shall attempt to retransmit the failed MPDU or another eligible MPDU, as defined in 10.7 (MSDU transmission restrictions), after performing the backoff procedure and the contention process.

After a STA contends for the channel to retransmit a fragment of an MSDU, it shall start with the last fragment that was not acknowledged. The destination STA shall receive the fragments in order (because the source sends them in order and they are individually acknowledged). It is possible, however, that the destination STA may receive duplicate fragments. It shall be the responsibility of the receiving STA to detect and discard duplicate fragments.

A STA shall transmit after the SIFS only under the following conditions during a fragment burst:

— The STA has just received a fragment that requires immediate acknowledgment.
— The source STA has received an acknowledgment for a previous fragment and has more fragment(s) for the same MSDU to transmit.

The following rules shall also apply:

— When a STA has transmitted a frame other than an initial or intermediate fragment, that STA shall not transmit on the channel following the acknowledgment for that frame, without performing the backoff procedure.
— When an MSDU has been successfully delivered or all retransmission attempts have been exhausted, and the STA has a subsequent MSDU to transmit, then that STA shall perform a backoff procedure.

### 10.3.5 Individually addressed MPDU transfer procedure

(11ax)If dot11TXOPDurationRTSThreshold is 1023 or not present, a STA shall use an RTS/CTS preceding a frame exchange including an individually addressed Data or Management frame when the length of the PSDU is greater than the length threshold indicated by dot11RTSThreshold. (11ax)If dot11TXOPDurationRTSThreshold is present and is not 1023, a non-AP HE STA using EDCA shall use an RTS/CTS exchange as defined in 26.2.1 (TXOP duration-based RTS/CTS). A STA may also use an RTS/CTS


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exchange (11ax)to protect the transmission of individually addressed frames when it is necessary to distribute the NAV, or when it is necessary to establish protection (see 10.27 (Protection mechanisms)), or for other purposes.

NOTE 1—If dot11RTSThreshold is 0, an RTS/CTS exchange precedes all (#109)frame exchange sequences including an individually addressed Data or Management frame, except for a non-AP STA with dot11TXOPDurationRTSThreshold present and not equal to 1023. In this exception, use of an RTS/CTS exchange is controlled by dot11TXOPDurationRTSThreshold (see 26.2.1 (TXOP duration-based RTS/CTS)).(11ax)

NOTE 2—A non-AP STA that transmits an HE TB PPDU outside the context of an RDG is exempt from requirements related to dot11RTSThreshold and dot11TXOPDurationRTSThreshold because the STA is not the TXOP holder.(11ax)

(11ax)If an RTS/CTS exchange is used, the PPDU containing the PSDU shall be transmitted starting one SIFS after the end of the CTS frame.

NOTE 3—No regard is given to the busy or idle status of the medium when transmitting this PSDU.

(11ax)If an RTS/CTS exchange is not used, the PSDU shall be transmitted following the success of the basic access procedure. With or without the use of the RTS/CTS exchange procedure, the STA that is the destination of a Data frame shall follow the acknowledgment procedure.

### 10.3.6 Group addressed MPDU transfer procedure

When a STA transmits group addressed MPDUs in which the To DS subfield is 0, the STA shall use the basic access procedure, unless these MPDUs are delivered using the group addressed transmission service (GATS). When GATS is not used to deliver group addressed MPDUs, the STA shall not use an RTS/(NDP) CTS or RTS/DMG CTS exchange, regardless of the length of the frame. In addition, no recipient of the frame shall transmit an Ack frame. A STA that transmits a group addressed MPDU in which the To DS subfield is 1 shall, in addition to complying with the basic access procedure of CSMA/CA, obey the rules for RTS/CTS exchange and the acknowledgment procedure because the MPDU is directed to the AP. For DMG STAs, the MPDU transmission shall also comply with the access procedures defined in 10.38 (DMG and CMMG channel access).

There is no MAC-level recovery on group addressed frames, except for the following:

— Frames in which the To DS subfield is 1
— Group addressed frames transmitted via the GATS

As a result, the reliability of this traffic is reduced, relative to the reliability of individually addressed traffic, due to the increased probability of lost frames from interference, collisions, or time-varying channel properties.

A DMG STA may transmit a copy of the same group addressed MPDU using different antenna configurations. This might be needed to provide a quasi-omni coverage or to enable transmission by an MCS that is higher than MCS 0. (11bd)A DMG STA with dot11DMGOCBActivated equal to true may transmit copies of the same group addressed MPDU using different antenna configurations to provide sufficient coverage to communicate with peer STAs with which the DMG STA is maintaining beam links and may omit transmissions that use an antenna configuration over which a beamformed link is not maintained. If multiple copies of a group addressed MPDU with a To DS subfield equal to 0 are transmitted, the STA shall not transmit a different frame before the completion of the transmission of all copies of the group addressed MPDU.

NOTE—The following paragraph addresses the Dual CTS protection mechanism. The use of the Dual CTS protection mechanism is obsolete.

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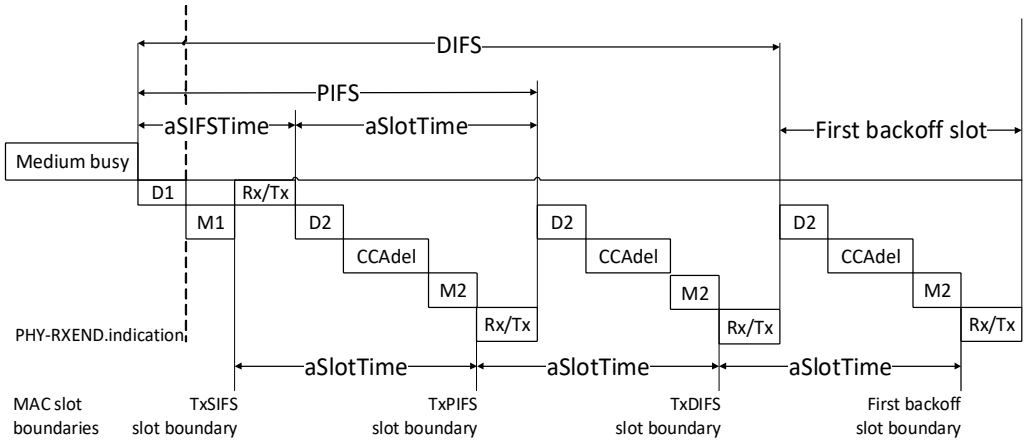
An STBC-capable STA shall discard either all received group addressed Data frames that are STBC frames or all received group addressed Data frames that are non-STBC frames. How it makes this decision is outside the scope of this standard.

A STA that is not an S1G relay STA shall discard an MPDU with a group address in the Address 1 field unless one of the following cases applies: (1) the value in the Address 1 field matches any value in the dot11GroupAddressesTable or is the broadcast address(#3522), or (2) the STA is a GLK STA and the address in the Address 1 field is a SYNRA. A GLK STA shall process an MPDU with a SYNRA in the Address 1 field as described in 10.65 (SYNRA filtering operation). If an MPDU originates from an S1G relay STA's associated AP and if the MPDU has any group address in its Address 1 field, then the STA shall forward that MPDU to the S1G relay AP.

### 10.3.7 DCF timing relations

The IFSs are periods of time on the medium. The attributes of the IFSs are determined by the specific PHY (see Figure 10-25 (DCF timing relationships(#14)(#1058)(#3297))). The IFSs apply to transmission under EDCA,




D1 = aRxPHYDelay (referenced from the end of the last PPDU[+SigExt] on the medium)
D2 = aAirPropagationTime
Rx/Tx = aRxTxTurnaroundTime (begins with a PHY-TXSTART.request)
M1 = M2 = aMACProcessingDelay
CCAdel = aCCATime

**Figure 10-25—DCF timing relationships(#14)(#1058)(#3297)**

too (see Figure 10-29 (EDCA mechanism timing relationships(#14)(#1058))).

All medium timings that are referenced from the end of the transmission are referenced from the end (#14)of the PPDU[+SigExt]. The beginning of transmission refers to the (#14)start of the preamble of the next PPDU. All MAC timings are referenced from the PHY-TXEND.confirm, PHY-TXSTART.confirm, PHY-RXSTART.indication, and PHY-RXEND.indication primitives.

aSIFSTime and aSlotTime are determined per PHY, aSIFSTime is fixed, and aSlotTime can change dynamically as aAirPropagationTime changes (see 10.22.5 (Operation with coverage classes)).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The STA may employ any non-negative value for each of the parameters:

— aRxPHYDelay
— aMACProcessingDelay
— aTxPHYDelay
— aTxRampOnTime
— aCCATime
— aRxTxSwitchTime

provided that the constraints in Equation (10-2), Equation (10-3), and Equation (10-4) are met, and provided that the CCA sensitivity specification for the attached PHY is met (see 15.4.6.5 (CCA), 16.3.8.5 (CCA), 17.3.10.6 (CCA requirements), 18.4.6 (CCA performance), 19.3.19.6 (CCA sensitivity), 20.4.4.2.2 (CCA sensitivity), 20.5.4.2.2 (CCA sensitivity), 21.3.18.5 (CCA sensitivity), and 22.3.18.6 (CCA sensitivity)).

$$aSIFSTime = aRxPHYDelay + aMACProcessingDelay + aRxTxTurnaroundTime \quad (10\text{-}2)$$

$$aSlotTime = aCCATime + aMACProcessingDelay + aRxTxTurnaroundTime + aAirPropagationTime \quad (10\text{-}3)$$

$$aRxTxTurnaroundTime = aTxPHYDelay + aRxTxSwitchTime + aTxRampOnTime \quad (10\text{-}4)$$

where

aAirPropagationTime is determined as described in 10.22.5 (Operation with coverage classes)

aSlotTime, aSIFSTime, and aRxTxTurnaroundTime are the values indicated in the PLME-CHARACTERISTICS.confirm primitive

the other attribute values are the values implemented

The PIFS and DIFS are derived by the Equation (10-5) and Equation (10-6), as illustrated in Figure 10-25 (DCF timing relationships(#14)(#1058)(#3297)).

$$PIFS = aSIFSTime + aSlotTime \quad (10\text{-}5)$$

$$DIFS = aSIFSTime + 2 \times aSlotTime \quad (10\text{-}6)$$

In a non-S1G STA, when dot11DynamicEIFSActivated is false or not defined, the EIFS is derived from the SIFS and the DIFS and the length of time it takes to transmit an Ack frame at the lowest PHY mandatory rate or MCS by Equation (10-7).

$$EIFS = aSIFSTime + AckTxTime + DIFS \quad (10\text{-}7)$$

where AckTxTime is the time expressed in microseconds required to transmit an Ack frame, including preamble, PHY header and any additional PHY dependent information, at the lowest PHY mandatory rate or MCS.

In an S1G STA, the EIFS is equal to DIFS if the PPDU that causes the EIFS does not generate a PHY-RXEND.indication(FormatViolation) primitive. Otherwise, the EIFS for the S1G STA is derived by Equation (10-7), where ACKTxTime is equal to NDPTxTime as defined in 10.3.2.5.2 (RID update).

When dot11DynamicEIFSActivated is true, EIFS is based on an estimated duration of the PPDU that is the possible response to the PPDU that causes the EIFS. The estimation is based on properties of the PHY header of the PPDU that causes the EIFS, such as modulation, rate/MCS, or length.

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NOTE 1—If the L-SIG field is used, as it does not have CRC protection, this information might not always be correct.

In a non-DMG and non-S1G STA, when dot11DynamicEIFSActivated is true, if the PPDU that causes the EIFS does not contain a single MPDU with a length equal to 14 or 32 octets, and the modulation of the PPDU that causes the EIFS is included in Table 10-8 (Determination of the EstimatedAckTxTime based on properties of the PPDU causing the EIFS), then EIFS is determined as shown in Equation (10-8).

$$EIFS = aSIFSTime + EstimatedAckTxTime + DIFS \quad (10\text{-}8)$$

where EstimatedAckTxTime is based on an estimated duration of the PPDU that is the possible response to the PPDU that causes the EIFS, as specified in Table 10-8 (Determination of the EstimatedAckTxTime based on properties of the PPDU causing the EIFS).

**Table 10-8—Determination of the EstimatedAckTxTime based on properties of the PPDU causing the EIFS**

| Modulation of PPDU causing EIFS | Rate/MCS of PPDU causing EIFS | Other properties of PPDU causing EIFS | Presumed response | Presumed response rate | EstimatedAck TxTime (μs) |
|---|---|---|---|---|---|
| (HR-)DSSS | 1 Mb/s | | Ack | 1 Mb/s | 304 |
| (HR-)DSSS | ≥ 2 Mb/s (long preamble) | | Ack | 2 Mb/s | 248 |
| (HR-)DSSS | ≥ 2 Mb/s (short preamble) | | Ack | 2 Mb/s | 152 |
| (ERP-)OFDM | BPSK | | Ack | 6 Mb/s | 44 |
| (ERP-)OFDM | QPSK | | Ack | 12 Mb/s | 32 |
| (ERP-)OFDM | ≥16-QAM | | Ack | 24 Mb/s | 28 |
| HT | BPSK | Aggregation = 0 | Ack | 6 Mb/s | 44 |
| HT | QPSK | Aggregation = 0 | Ack | 12 Mb/s | 32 |
| HT | ≥16-QAM | Aggregation = 0 | Ack | 24 Mb/s | 28 |
| HT | BPSK | Aggregation = 1 | BlockAck | 6 Mb/s | 68 |
| HT | QPSK | Aggregation = 1 | BlockAck | 12 Mb/s | 44 |
| HT | ≥16-QAM | Aggregation = 1 | BlockAck | 24 Mb/s | 32 |
| VHT | BPSK | | BlockAck | | 68 |
| VHT | QPSK | | BlockAck | | 44 |
| VHT | ≥16-QAM | | BlockAck | | 32 |

NOTE 2—This also applies to an HE STA with dot11DynamicEIFSActivated set to true that receives an HE PPDU with the RXVECTOR parameter TXOP_DURATION set to UNSPECIFIED that causes the EIFS.(11ax)

When dot11DynamicEIFSActivated is true and the PPDU that causes the EIFS contains a single MPDU with a length equal to 14 or 32 octets, EIFS is equal to DIFS. This reflects the fact that a 14-octet or 32-octet MPDU is very likely an Ack or a BlockAck frame, which does not cause a response PPDU to be transmitted.


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When dot11DynamicEIFSActivated is true and the modulation of the PPDU that causes the EIFS does not occur in Table 10-8 (Determination of the EstimatedAckTxTime based on properties of the PPDU causing the EIFS), then EIFS is determined as shown in Equation (10-7).

Figure 10-25 (DCF timing relationships(#14)(#1058)(#3297)) illustrates the relation between the SIFS, PIFS, and DIFS as they are measured on the medium and the different MAC slot boundaries TxSIFS, TxPIFS, and TxDIFS. These slot boundaries define when the transmitter shall be turned on by the MAC to meet the different IFS timings on the medium, after subsequent detection of the CCA result of the previous slot time.

Equation (10-9), Equation (10-10), and Equation (10-11) define the MAC slot boundaries using attributes provided by the PHY, which are such that they compensate for implementation timing variations. The starting reference of these slot boundaries is again (#14)the end of the previous PPDU[+SigExt].

$$TxSIFS = SIFS - aRxTxTurnaroundTime \quad (10\text{-}9)$$

$$TxPIFS = TxSIFS + aSlotTime \quad (10\text{-}10)$$

$$TxDIFS = TxSIFS + 2 \times aSlotTime \quad (10\text{-}11)$$

NOTE 3—The tolerance for SIFS is defined in 10.3.2.3.3 (SIFS).

### 10.3.8 Signal extension

Transmissions of PSDUs with the TXVECTOR parameter FORMAT of type NON_HT with NON_HT_MODULATION values of ERP-OFDM and NON_HT_DUP_OFDM and transmissions of frames with the TXVECTOR parameter FORMAT with values of HT_MF, (11ax)HT_GF, HE_SU, HE_MU, HE_ER_SU, or HE_TB (#14)are immediately followed by a period of no transmission of duration aSignalExtension, except for RIFS transmissions. The purpose of this signal extension is to enable the NAV value of Clause 16 (High rate direct sequence spread spectrum (HR/DSSS) PHY specification) STAs to be set correctly.

When an HT STA transmits a PPDU using a RIFS and with the TXVECTOR parameter FORMAT equal to NON_HT with the NON_HT_MODULATION parameter equal to one of ERP-OFDM and NON_HT_DUP_OFDM or a PPDU using a RIFS and with the TXVECTOR parameter FORMAT equal to HT_MF or HT_GF, it shall set the TXVECTOR parameter NO_SIG_EXTN to true. Otherwise, it shall set the TXVECTOR parameter NO_SIG_EXTN to false.

### 10.3.9 Determination of PLME aCWmin characteristics

In the case of the Clause 18 (Extended Rate PHY (ERP) specification) ERP, the aCWmin value is dependent on the requester's characteristic rate set. The characteristic rate set is equal to the IBSS's basic rate set when the STA is an IBSS STA. It is equal to the AP's operational rate set when the STA is associated with an AP. At all other times, it is equal to the STA's mandatory rate set.

If the PHY characteristic aCWmin is a vector, then the MAC variable aCWmin is set to the PHY characteristic aCWmin(0) if the characteristic rate set includes only rates in the set 1, 2, 5.5, 11 and to aCWmin(1) otherwise. If the PHY characteristic aCWmin is a scalar, then the MAC variable aCWmin is set to the PHY characteristic aCWmin.

NOTE—The MAC variable aCWmin is distinct from the PHY characteristic aCWmin. Outside this subclause, the MAC uses the MAC variable aCWmin whenever the value of aCWmin is required.

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## 10.4 MSDU, (11ax)A-MSDU, and MMPDU fragmentation

The MAC may fragment and reassemble MSDUs or MMPDUs that are carried in individually addressed MPDUs. The fragmentation and defragmentation mechanisms allow for fragment retransmission.

(#2198)Dynamic fragmentation allows A-MSDUs to be fragmented. An HE STA may use dynamic fragmentation as defined in 26.3.2 (Dynamic fragmentation) if the conditions in 26.3.2.1 (General) are met. Transmission and retransmission of A-MSDU fragments shall follow the procedures defined in this subclause except where superseded by 26.3 (Fragmentation and defragmentation).

The length of each fragment shall be an equal number of octets for all fragments except the last, which may be smaller. The length of each fragment shall be an even number of octets, except for the last fragment of an MSDU or MMPDU, which may be either an even or an odd number of octets. The length of a fragment shall never be larger than dot11FragmentationThreshold unless security encapsulation is invoked for the MPDU. If security encapsulation is active for the MPDU, then the MPDU shall be expanded by the encapsulation overhead and this may result in a fragment larger than dot11FragmentationThreshold.

A fragment is an MPDU, the Frame Body field of which carries only a portion of an MSDU, (11ax)A-MSDU, or MMPDU. When data are to be transmitted, the number of octets in the fragment (before processing by the security mechanism) shall be limited by dot11FragmentationThreshold and the number of octets in the MPDU that have yet to be assigned to a fragment at the instant the fragment is constructed for the first time. Once a fragment is transmitted for the first time, its frame body content and length shall be fixed until it is successfully delivered to the immediate receiving STA.

(#2128)NOTE 1—Packet numbers for consecutive fragments of an MSDU, A-MSDU or MMPDU in an RSNA are required to increment in steps of 1(#3089) (see 12.5.2.3.2 (PN processing) and 12.5.4.3.2 (PN processing)).

A STA shall support(#546) receiving MPDUs, containing all or part of an MSDU, of arbitrary length that is less than or equal to the maximum MSDU size as(11ax) specified in 9-34 (Maximum data unit sizes and durations(#1327)(#4013)), plus any security encapsulation overhead, plus MAC header and FCS.

A STA shall support(#546) receiving MPDUs, containing all or part of an MMPDU, of arbitrary length that is less than or equal to the minimum of

— The maximum MMPDU size as defined in 9.3.3.1 (Format of (PV0) Management frames), plus any security encapsulation overhead, plus MAC header and FCS
— Any maximum MPDU length advertised by the STA

If a fragment requires retransmission, its frame body content and length shall remain fixed for the lifetime of the MSDU or MMPDU at that STA. Each fragment contains a Sequence Control field, which comprises a sequence number and fragment number. When a STA is transmitting a fragmented MSDU or MMPDU or dynamically fragmented A-MSDU,(#2198) the sequence number shall remain the same for all fragments of that MSDU, A-MSDU,(#2198) or MMPDU. The fragments shall be sent in order of lowest fragment number to highest fragment number, where the fragment number value starts at 0, and increases by 1 for each successive fragment. The Frame Control field also contains a bit, the More Fragments bit, that is equal to 0 to indicate the last fragment of the MSDU, A-MSDU,(#2198) or MMPDU (or that the MSDU, A-MSDU(#2198) or MMPDU was not fragmented, if the Fragment Number subfield is also equal to 0).

The source STA shall maintain a transmit MSDU/MMPDU timer for each MSDU/MMPDU being transmitted. The attribute dot11MaxTransmitMSDULifetime specifies the maximum amount of time allowed to transmit an MSDU/MMPDU. The timer starts on the initial attempt to transmit the MSDU/MMPDU, or first fragment of the MSDU/MMPDU if the MSDU/MMPDU is fragmented. If the timer exceeds dot11MaxTransmitMSDULifetime, then any remaining fragments are discarded by the source STA and no attempt is made to complete transmission of the MSDU/MMPDU.(#2198)


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NOTE 2—A STA might interleave fragments of MSDUs with different TIDs sent to the same receiver, subject to any constraint caused by the number of replay counters.

## 10.5 MSDU, (11ax)A-MSDU, and MMPDU defragmentation

(#4157)(#2200)(#3775)Reception and reassembly of A-MSDU fragments shall follow the procedures defined in this subclause except where superseded by 26.3 (Fragmentation and defragmentation).

The header of each fragment contains the following information that is used by the destination STA to reassemble the MSDU, A-MSDU,(#2200) or MMPDU:

- Frame type
- Address of the sender, obtained from the Address 2 field
- Destination address
- *Sequence Control field:* This field allows the destination STA to check that all incoming fragments belong to the same MSDU, A-MSDU,(#2200) or MMPDU, and the sequence in which the fragments should be reassembled. The sequence number within the Sequence Control field remains the same for all fragments of an MSDU, A-MSDU,(#2200) or MMPDU, while the fragment number within the Sequence Control field increments for each fragment.
- Traffic identifier, for frames with a QoS Control field.
- *More Fragments indicator:* Indicates to the destination STA that this is not the last fragment of a fragmented MSDU, A-MSDU,(#2200) or MMPDU. Only the last fragment of a fragmented MSDU, A-MSDU,(#2200) or MMPDU shall have this bit set to 0. All other fragments of a fragmented MSDU, A-MSDU,(#2200) or MMPDU shall have this bit set to 1.

The destination STA shall reconstruct the MSDU or MMPDU by combining the fragments in order of fragment number subfield of the Sequence Control field. If security encapsulation has been applied to the fragment, it shall be deencapsulated and decrypted before the fragment is used for defragmentation of the MSDU, A-MSDU,(#2200) or MMPDU. If the fragment with the More Fragments bit equal to 0 has not yet been received, then the destination STA knows that the MSDU, A-MSDU,(#2200) or MMPDU is not yet complete. As soon as the STA receives the fragment with the More Fragments bit equal to 0, the STA knows that no more fragments will be received for the MSDU, A-MSDU,(#2200) or MMPDU.

(#2128)An MSDU or MMPDU shall not be reassembled from fragments that were encrypted with different keys, or from a mixture of encrypted and unencrypted fragments.

(#2128)NOTE 1—Packet numbers for consecutive fragments of an MSDU, A-MSDU or MMPDU in an RSNA are required to increment in steps of 1(#3089) (see 12.5.2.4.4 (PN and replay detection) and 12.5.4.4.4 (PN and replay detection) under d)).(#3141)

(#2128)NOTE 2—All the fragments of an MSDU or A-MSDU are required to have the same indication of whether they are fragments of an MSDU or of an A-MSDU (see 26.3.3.1 (General)).

A STA shall support the concurrent reception of fragments of at least three MSDUs or MMPDUs. A STA should support the concurrent reception of fragments of at least one MSDU per access category. An AP should support the concurrent reception of at least one MSDU per access category per associated STA. Note that a STA receiving more than three fragmented MSDUs or MMPDUs concurrently might experience a significant increase in the number of frames discarded.

NOTE 3—The three MSDUs or MMPDUs might be from different peers (e.g., in an IBSS or MBSS).

The destination STA shall maintain a Receive Timer for each MSDU or MMPDU being received, for a minimum of three MSDUs or MMPDUs. The STA may implement additional timers to be able to receive additional concurrent MSDUs or MMPDUs. The receiving STA shall discard all fragments that are part of an

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MSDU or MMPDU for which a timer is not maintained. There is also dot11MaxReceiveLifetime, that specifies the maximum amount of time allowed to receive an MSDU. The receive timer starts on the reception of the first fragment of a fragmented MSDU or MMPDU. If the receive timer exceeds dot11MaxReceiveLifetime, then all received fragments of this MSDU or MMPDU shall be discarded by the destination STA. If additional fragments of this MSDU or MMPDU are subsequently received, those fragments shall be acknowledged and discarded.

To properly reassemble MPDUs into an MSDU, A-MSDU,(#2200) or MMPDU, a destination STA shall discard any duplicated fragments received. A STA shall discard duplicate fragments as described in 10.3.2.14 (Duplicate detection and recovery). However, a duplicate fragment of an individually addressed MSDU, A-MSDU,(#2200) or MMPDU shall be acknowledged.(#2200)

## 10.6 Multirate support

### 10.6.1 Overview

Some PHYs have multiple data transfer rate capabilities that allow implementations to perform dynamic rate switching with the objective of improving performance. The algorithm for performing rate switching is beyond the scope of this standard, but in order to provide coexistence and interoperability on multirate-capable PHYs, this standard defines a set of rules to be followed by all STAs.

Only the data transfer rates of the mandatory rate set of the attached PHY are guaranteed to be supported when a STA for which dot11OCBActivated is true transmits a Management or Data frame. A higher layer protocol entity within a STA in which dot11OCBActivated is true might negotiate a rate outside the mandatory rate set.

A STA that transmits a frame shall select a rate defined by the rules for determining the rates of transmission of protection frames in 10.27 (Protection mechanisms) when the following conditions apply:

- The STA's protection mechanism for non-ERP receivers is enabled.
- The frame is a protection mechanism frame.
- The frame initiates an exchange.

Otherwise, a non-DMG and non-CMMGSTA shall transmit the frame using a rate that is in accordance with rules defined in 10.6.5 (Rate selection for Data and Management frames) and 10.6.6 (Rate selection for Control frames). A DMG STA shall transmit the frame using a rate that is in accordance with rules defined in 10.6.7 (Multirate support for DMG STAs). A CMMG STA shall transmit the frame using a rate that is in accordance with rules defined in 10.6.8 (Multirate support for CMMG STAs).

For specific PHYs, the value of the Duration/ID field is determined using the PLME-TXTIME.request primitive and the PLME-TXTIME.confirm primitive. These specific PHYs are defined in:

- Clause 16 (High rate direct sequence spread spectrum (HR/DSSS) PHY specification) for HR/DSSS
- Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) for OFDM
- Clause 18 (Extended Rate PHY (ERP) specification) for ERP
- Clause 19 (High Throughput (HT) PHY specification(#2297)) for HT
- Clause 20 (Directional multi-gigabit (DMG) PHY specification) for DMG
- Clause 21 (Very high throughput (VHT) PHY specification) for VHT
- Clause 22 (Television very high throughput (TVHT) PHY specification) for TVHT
- Clause 24 (China directional multi-gigabit (CDMG) PHY specification) for CDMG
- Clause 25 (China millimeter-wave multi-gigabit (CMMG) PHY specification) for CMMG
- Clause 27 (High-efficiency (HE) PHY specification(11ax)) for HE(11ax)


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The two PLME-TXTIME primitives are defined in the respective PHY specifications:

- 16.3.4 (HR/DSSS TXTIME calculation) for HR TXTIME calculation
- 17.4.3 (OFDM TXTIME calculation) for OFDM TXTIME calculation
- 18.5.3.2 (ERP-OFDM TXTIME calculations) for ERP-OFDM TXTIME calculation
- 19.4.3 (TXTIME calculation) for HT TXTIME calculation
- 20.11.3 (TXTIME calculation) for DMG PLME TXTIME calculation
- 21.4.3 (TXTIME and PSDU_LENGTH calculation) for VHT PLME TXTIME calculation
- 22.4.3 (TXTIME and PSDU_LENGTH calculation) for TVHT PLME TXTIME calculation
- 25.14.3 (TXTIME calculation) for CMMG PLME TXTIME calculation
- 27.4.3 (TXTIME and PSDU_LENGTH calculation) for HE PLME TXTIME calculation(11ax)

The Duration/ID field in a frame transmitted by a QoS STA may cover multiple frames and might involve using the PLME-TXTIME.request primitive several times.

### 10.6.2 Basic HT-MCS Set field

An AP that transmits a frame containing an HT Operation element with either the Dual Beacon field or the Dual CTS Protection field equal to 1 shall include at least one MCS that has only one spatial stream in the Basic HT-MCS Set field of the HT Operation element of that frame.

### 10.6.3 Basic STBC MCS

The basic STBC MCS has the value null when any of the following conditions is true:

- The Dual Beacon field in the HT Operation element is equal to 0, and the Dual CTS Protection field in the HT Operation element is equal to 0.
- No HT Operation element is present in the Association Response frame received from the current AP.
- The Basic HT-MCS Set field of the HT Operation parameter of the MLME-START.request primitive or Basic HT-MCS Set field of the HT Operation parameter of the SelectedBSS parameter of the MLME-JOIN.request primitive is empty or does not exist.
- The lowest MCS of the Basic HT-MCS Set field of the HT Operation parameter of the MLME-START.request primitive or Basic HT-MCS Set field of the HT Operation parameter of the SelectedBSS parameter of the MLME-JOIN.request primitive has NSS value greater than 1 (the mapping of MCS to NSS is PHY dependent, for the HT PHY see 19.5 (Parameters for HT-MCSs)).

If none of the above conditions is true, then the basic STBC MCS is the lowest MCS index of the Basic HT-MCS Set field of the HT Operation parameter of the MLME-START.request primitive or Basic HT-MCS Set field of the HT Operation parameter of the SelectedBSS parameter of the MLME-JOIN.request primitive.

When an MCS from the basic STBC MCS is required in 10.6.5 (Rate selection for Data and Management frames) and 10.6.6 (Rate selection for Control frames) but the basic STBC MCS has the value null, the STA shall select a mandatory MCS of the attached PHY.

### 10.6.4 Basic rate set, basic HT-MCS set, and basic VHT-MCS and NSS set for mesh STA

A mesh STA shall not establish a mesh peering with a mesh STA using a different BSSBasicRateSet (see 14.3.7 (Candidate peer mesh STA) and 14.3.8 (Establishing or becoming a member of a mesh BSS)).

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The SME of a Mesh STA should use the mandatory PHY rates as the default BSSBasicRateSet in the MLME-START.request primitive to reduce the risk that a candidate peer mesh STA utilizes a different BSSBasicRateSet. If the mesh STA is also an HT STA, it should adopt the mandatory HT-MCSs as the default basic HT-MCS set. If the mesh STA is also a VHT STA, it should adopt <VHT-MCS, NSS> tuples formed from the mandatory VHT-MCSs and NSS = 1 as the default basic VHT-MCS and NSS set (see 11.38.7 (Basic VHT-MCS and NSS set operation)).

### 10.6.5 Rate selection for Data and Management frames

#### 10.6.5.1 Rate selection for non-STBC Beacon (#3263)frames

In an S1G STA, non-STBC S1G Beacon frames shall be transmitted in an S1G 1 MHz PPDU, an S1G 2 MHz PPDU with short preamble, an S1G 1 MHz duplicate PPDU, or an S1G 2 MHz duplicate PPDU with short preamble using one of the mandatory PHY rates.

If the BSSBasicRateSet parameter is not empty, (#3263)a non-STBC Beacon frame that is not an ER beacon or HE beacon shall be transmitted in a non-HT PPDU using one of the rates included in the BSSBasicRateSet parameter. An ER beacon is transmitted as defined in 26.15.5 (Additional rules for ER beacons and group addressed frames), and an HE beacon is transmitted as defined in 26.15.6 (Additional rules for HE beacons and group addressed frames).(11ax)

If the BSSBasicRateSet parameter is empty, the frame shall be transmitted in a non-HT PPDU using one of the mandatory PHY rates.

#### 10.6.5.2 Rate selection for STBC group addressed Data and Management frames

When a STA has dot11TxSTBCOptionActivated true, it shall use the basic STBC MCS when it transmits an STBC Beacon frame or when it transmits a group addressed Data or Management frame that is an STBC frame.

#### 10.6.5.3 Rate selection for EBCS Info, EBCS UL, and EBCS Data frames(11bc)

The transmission rate for EBCS Info frames and EBCS UL frames is determined from dot11EBCSInfoPHYType and dot11EBCSInfoTxRate. When dot11EBCSInfoPHYType is equal to 255, the AP may select a transmission rate following the rules specified in 10.6.5.4 (Rate selection for other group addressed Data and Management frames).

The transmission rate for EBCS Data frames is determined from dot11EBCSTrafficStreamPHYType and dot11EBCSTrafficStreamTxRate. When dot11EBCSTrafficStreamPHYType is equal to 255, the AP may select a transmission rate following the rules specified in 10.6.5.4 (Rate selection for other group addressed Data and Management frames).

#### 10.6.5.4 Rate selection for other group addressed Data and Management frames

This subclause describes the rate selection rules for group addressed Data and Management frames, excluding the following:

- Non-STBC Beacon (#3263)frames
- ER beacon and HE beacon(11ax)
- STBC group addressed Data and Management frames
- Data frames located in an FMS stream (see 11.21.8 (FMS multicast rate processing))
- Group addressed frames transmitted to the GCR concealment address (see 11.21.16.3.5 (Concealment of GCR transmissions))


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- Group addressed Data and Management frames transmitted in an HE ER SU PPDU (see 26.15.5 (Additional rules for ER beacons and group addressed frames))(11ax)
- Group addressed Data and Management frames transmitted in an HE SU PPDU (see 26.15.6 (Additional rules for HE beacons and group addressed frames))(11ax)
- Group addressed Data and Management frames transmitted in an HE MU PPDU (see 26.15.7 (Additional rules for group addressed frames in an HE MU PPDU))(11ax)
- EBCS Info frames, EBCS UL frames and EBCS Data frames(11bc)

If the BSSBasicRateSet parameter is not empty, a Data or Management frame (excluding the frames listed above) with a group address in the Address 1 field shall be transmitted in a non-HT PPDU using one of the rates included in the BSSBasicRateSet parameter or the rate chosen by the AP, described in 11.21.8 (FMS multicast rate processing), if the Data frames are part of an FMS stream.

If the BSSBasicRateSet parameter is empty and the Basic HT-MCS Set field of the HT Operation parameter of the MLME-START.request primitive or Basic HT-MCS Set field of the HT Operation parameter of the SelectedBSS parameter of the MLME-JOIN.request primitive is not empty, the frame shall be transmitted in an HT PPDU using one of the MCSs included in the Basic HT-MCS Set field of the HT Operation parameter of the MLME-START.request primitive or Basic HT-MCS Set field of the HT Operation parameter of the SelectedBSS parameter of the MLME-JOIN.request primitive.

If the BSSBasicRateSet parameter is empty and the Basic HT-MCS Set field of the HT Operation parameter of the MLME-START.request primitive or Basic HT-MCS Set field of the HT Operation parameter of the SelectedBSS parameter of the MLME-JOIN.request primitive is empty and the basic VHT-MCS and NSS set is not empty, the frame shall be transmitted in a VHT PPDU using one of the <VHT-MCS. NSS> tuples included in the basic VHT-MCS and NSS set.

In a non-S1G STA, if the BSSBasicRateSet parameter, the Basic HT-MCS Set field of the HT Operation parameter of the MLME-START.request primitive or Basic HT-MCS Set field of the HT Operation parameter of the SelectedBSS parameter of the MLME-JOIN.request primitive, and the basic VHT-MCS and NSS set are empty (e.g., a scanning STA that is not yet associated with a BSS), the frame shall be transmitted in a non-HT PPDU using one of the mandatory PHY rates.

In an S1G STA, if the BSSBasicS1GMCS_NSSSet parameter is empty (e.g., a scanning STA that is not yet associated with a BSS), the frame shall be transmitted in an S1G PPDU using one of the mandatory PHY rates.

If the BSSBasicS1GMCS_NSSSet is not empty, the frame shall be transmitted in an S1G PPDU using an MCS and NSS from one of the <S1G-MCS, NSS> tuples included in the BSSBasicS1GMCS_NSSSet parameter.

#### 10.6.5.5 Rate selection for polling frames

A Data frame of a subtype that includes CF-Poll that does not also include CF-Ack shall be transmitted at a rate selected as follows:

a) If an initial exchange has already established protection and the Duration/ID field in the frame establishing protection covers the entire TXOP, the rate or MCS is selected according to the rules in 10.6.5.8 (Rate selection for other individually addressed Data and Management frames).

b) Otherwise, the Data frame shall be transmitted at a rate or MCS as defined in 10.6.5.4 (Rate selection for other group addressed Data and Management frames), treating the frame as though it has a group address in the Address 1 field, solely for the purpose of determining the appropriate rate or MCS.

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#### 10.6.5.6 Rate selection for +CF-Ack frames

For a frame of type Data +CF-Ack, Data +CF-Poll+CF-Ack, or CF-Poll +CF-Ack, the rate or MCS and TXVECTOR parameter CH_BANDWIDTH used to transmit the frame shall be chosen from among those supported by both the addressed recipient STA and the STA to which the Ack frame is intended.

#### 10.6.5.7 Rate selection for Data frames sent within an FMS stream

Data frames sent within an FMS stream are sent at a rate negotiated during the establishment of the FMS stream. See 11.21.8 (FMS multicast rate processing).

#### 10.6.5.8 Rate selection for other individually addressed Data and Management frames

A Data or Management frame not identified in 10.6.5.1 (Rate selection for non-STBC Beacon (#3263)frames) to 10.6.5.7 (Rate selection for Data frames sent within an FMS stream) shall be sent using any data rate, MCS, <VHT-MCS, NSS> tuple, or <S1G-MCS, NSS> tuple subject to the following constraints:

- A STA shall not transmit a frame using a rate or MCS that is not supported by the receiver STA, as reported in any Supported Rates and BSS Membership Selectors element, Extended Supported Rates and BSS Membership Selectors element, or Supported MCS Set field in Management frames transmitted by the receiver STA.
- A STA shall not transmit a frame using a <VHT-MCS, NSS> tuple that is not supported by the receiver STA, as reported in any Supported VHT-MCS and NSS Set field in Management frames transmitted by the receiver STA.
- A STA shall not transmit a frame using a <S1G-MCS, NSS> tuple that is not supported by the receiver STA, as reported in any Supported S1G-MCS and NSS Set field in Management frames transmitted by the receiver STA.
- If at least one Operating Mode field with the Rx NSS Type subfield equal to 0 was received from the receiver STA:
  - A STA shall not transmit a frame with the number of spatial streams greater than that indicated in the Rx NSS subfield in the most recently received Operating Mode field with the Rx NSS Type subfield equal to 0 from the receiver STA.
- If at least one Operating Mode field with the Rx NSS Type subfield equal to 1 was received from the receiver STA:
  - A STA shall not transmit an SU PPDU frame using a beamforming steering matrix with the number of spatial streams greater than that indicated in the Rx NSS subfield in the most recently received Operating Mode field with the Rx NSS Type subfield equal to 1 from the receiver STA if the beamforming steering matrix was derived from a VHT Compressed Beamforming report with Feedback Type subfield indicating MU in the VHT Compressed Beamforming frame(s).
- A STA shall not transmit a frame using a value for the CH_BANDWIDTH parameter of the TXVECTOR that is not supported by the receiver STA, as reported in any HT Capabilities element, VHT Capabilities element, or S1G Capabilities element received from the intended receiver.
- An HT STA that is a member of a BSS and that is not a VHT STA shall not transmit a frame using a value for the CH_BANDWIDTH parameter of the TXVECTOR that is not permitted for use in the BSS, as reported in the most recently received HT Operation element, with the exception of transmissions on an off-channel TDLS direct link, which follow the rules described in 11.20.6.2 (General behavior on the off-channel) and 11.20.6.3 (Setting up a 40 MHz TDLS direct link(#2152)).
- A VHT STA that is a member of a BSS shall not transmit a frame using a value for the CH_BANDWIDTH parameter of the TXVECTOR that is not permitted for use in the BSS, as reported in the most recently received VHT Operation element with the following exceptions:


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- Transmissions on an off-channel TDLS direct link follow the rules described in 11.20.6.2 (General behavior on the off-channel) and 11.20.6.3 (Setting up a 40 MHz TDLS direct link(#2152)).
- Transmissions by a VHT STA on a (#2152)TDLS direct link follow the rules described in 11.20.1 (General) and 11.20.6.5 (Setting up a wide bandwidth off-channel TDLS direct link(#2152)).

— An S1G STA that is a member of a BSS shall not transmit a frame using a value for the CH_BANDWIDTH parameter of the TXVECTOR that is not permitted for use in the BSS, as reported in the most recently received S1G Operation element with the following exceptions:

- Transmissions on a TDLS off-channel link follow the rules described in 11.20.6.2 (General behavior on the off-channel) and 11.20.6.3 (Setting up a 40 MHz TDLS direct link(#2152)).
- Transmissions by an S1G STA on a (#2152)TDLS direct link follow the rules described in 11.20.1 (General) and 11.20.6.5 (Setting up a wide bandwidth off-channel TDLS direct link(#2152)).

Additionally, the value of the CH_BANDWIDTH parameter for a transmission by an S1G STA that is operating as an SST STA is limited by the Maximum permitted PPDU bandwidth as indicated in the Maximum Transmission Width field of the most recently received SST element or RPS element (see 10.51 (Subchannel selective transmission (SST)) and 10.23.5 (Restricted access window (RAW) operation).

— If at least one Operating Mode field with the Rx NSS Type subfield equal to 0 was received from the receiver STA:

- A STA shall not transmit a frame using a value for the TXVECTOR parameter CH_BANDWIDTH that is not supported by the receiver STA as reported in the most recently received Operating Mode field with the Rx NSS Type subfield equal to 0 from the receiver STA.

When the operational rate set of the receiving STA or STAs is not known, the transmitting STA shall transmit using a rate in the BSSBasicRateSet parameter, or an MCS in the Basic HT-MCS Set field of the HT Operation parameter of the MLME-START.request primitive or Basic HT-MCS Set field of the HT Operation parameter of the SelectedBSS parameter of the MLME-JOIN.request primitive, or a <VHT-MCS, NSS> tuple in the basic VHT-MCS and NSS set, or an <S1G-MCS, NSS> tuple in the BSSBasicS1GMCS_NSSSet parameter, or a rate from the mandatory rate set of the attached PHY if the BSSBasicRateSet, the Basic HT-MCS Set field of the HT Operation parameter of the MLME-START.request primitive or Basic HT-MCS Set field of the HT Operation parameter of the SelectedBSS parameter of the MLME-JOIN.request primitive, and the basic VHT-MCS and NSS set, and the BSSBasicS1GMCS_NSSSet are empty.

The rules in this subclause also apply to A-MPDUs that aggregate MPDUs with the Type subfield equal to Data or Management with any other types of MPDU.

### 10.6.6 Rate selection for Control frames

#### 10.6.6.1 General rules for rate selection for Control frames

Control frames carried in an A-MPDU that does not contain an S-MPDU shall be sent at a rate selected from the rules defined in 10.6.5.8 (Rate selection for other individually addressed Data and Management frames).

NOTE—The rules defined in 10.6.6.2 (Rate selection for Control frames that initiate a TXOP) to 10.6.6.5 (Rate selection for control response frames) apply only to Control frames not carried in an A-MPDU that does not contain an S-MPDU.

A Control frame shall be carried in an S1G PPDU with NSS equal to 1 without using long preamble, short GI, LDPC coding, STBC format, and traveling pilots when the Control frame is transmitted by an S1G STA.

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The following rules determine whether a Control frame is carried in a non-HT, HT or VHT PPDU:

a) A control response frame shall be carried in an HT PPDU when the Control frame is a response to a frame that meets any of the following conditions:
   1) The frame eliciting the response included an HT variant HT Control field with the TRQ field equal to 1 and the HT NDP Announcement subfield equal to 0, and this responder set the Implicit Transmit Beamforming Receiving Capable field to 1 in its last transmitted HT Capabilities element; or
   2) The frame eliciting the response was an RTS frame carried in an HT PPDU; or
   3) The frame eliciting the response was an STBC frame, and the Dual CTS Protection field was equal to 1 in the last HT Operation element received from its AP or transmitted by the STA (see 10.3.2.10 (Dual CTS protection)).

b) A Control frame may be carried in an HT PPDU when the Control frame meets any of the following conditions:
   1) The Control frame contains an HT variant HT Control field with the MRQ subfield equal to 1, or
   2) The Control frame contains an HT variant HT Control field with the TRQ field equal to 1.

c) A Control frame may be carried in a VHT PPDU when the Control frame contains an HT Control field.

d) A Control frame shall be carried in an HT PPDU or a VHT PPDU when the Control frame is sent using an STBC frame.

e) A control response frame shall be carried in a VHT PPDU if the eliciting frame was an RTS frame carried in a VHT PPDU that contains an HT Control field with MRQ subfield equal to 1.

f) A control response frame may be carried in a VHT PPDU or HT PPDU if the eliciting frame was (#8020)an FTM frame(#7223) carried in a VHT PPDU or HT PPDU, respectively.(11ax)

Otherwise, the Control frame shall be carried in a non-HT PPDU. The requirements specified in 10.30 (Sounding PPDUs), 10.31.2 (Link adaptation using the HT variant HT Control field), and 10.33 (Transmit beamforming) further constrain the choice of non-HT, HT, or VHT PPDU.

If an Operating Mode field has been received from the intended receiver STA, the following constraints also apply:

— If at least one Operating Mode field with the Rx NSS Type subfield equal to 0 was received from the receiver STA:
  — A STA shall not transmit a frame with the number of spatial streams greater than that indicated in the Rx NSS subfield in the most recently received Operating Mode field with the Rx NSS Type subfield equal to 0 from the receiver STA.
— If at least one Operating Mode field with the Rx NSS Type subfield equal to 1 was received from the receiver STA:
  — A STA shall not transmit an SU PPDU frame using a beamforming steering matrix with the number of spatial streams greater than that indicated in the Rx NSS subfield in the most recently received Operating Mode field with the Rx NSS Type subfield equal to 1 from the receiver STA if the beamforming steering matrix was derived from a VHT Compressed Beamforming report with Feedback Type subfield indicating MU in the VHT Compressed Beamforming frame(s).

Selection of channel width is defined in 10.6.6.6 (Channel Width selection for Control frames).

A control response frame is a Control frame that is transmitted as a response to the reception of a frame a SIFS after the PPDU containing the frame that elicited the response, e.g., a CTS frame in response to an RTS frame reception, an Ack frame in response to a Data frame reception, a BlockAck frame in response to a BlockAckReq frame reception. In some situations, the transmission of a Control frame is not a control response transmission, such as when a CTS frame is used to initiate a TXOP.


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(11ax)An HE STA that transmits a Trigger frame, Multi-STA BlockAck frame, or HE/VHT NDP Announcement frame addressed to more than one STA shall use a rate, HT-MCS, <VHT-MCS, NSS> tuple, or <HE-MCS, NSS> tuple that is supported by all recipient STAs.

#### 10.6.6.2 Rate selection for Control frames that initiate a TXOP

This subclause describes the rate selection rules for Control frames that initiate a TXOP and that are either an S-MPDU or not carried in an A-MPDU.

If a Control frame is carried in a non-HT PPDU, the transmitting STA shall transmit the frame using one of the rates in the BSSBasicRateSet parameter or a rate from the mandatory rate set of the attached PHY if the BSSBasicRateSet is empty.

NOTE—Because of their utility in resolving contention and in establishing a NAV, most control subtype frames that initiate a (#109)frame exchange sequence are subject to explicit limitations regarding the choice of transmission rate with the intent of ensuring maximum possible coverage and receivability of the frame.

An HT STA shall select an MCS from the Basic HT-MCS Set field of the HT Operation parameter of the MLME-START.request primitive or Basic HT-MCS Set field of the HT Operation parameter of the SelectedBSS parameter of the MLME-JOIN.request primitive when protection is required (as defined in 10.27 (Protection mechanisms)) and shall select an MCS from the SupportedMCSSet parameter of the intended receiver when protection is not required.

When transmitting a VHT PPDU, a STA shall select a <VHT-MCS, NSS> tuple from the basic VHT-MCS and NSS set when protection is required (as defined in 10.27 (Protection mechanisms)) and shall select a <VHT-MCS, NSS> tuple from the operational VHT-MCS and NSS set parameter of the intended receiver when protection is not required.

#### 10.6.6.3 Rate selection for CF-End frames

A STA that transmits a CF-End frame that is not at the end of a TXOP that was obtained through the use of the dual CTS mechanism shall transmit the frame using a rate in BSSBasicRateSet or from the mandatory rate set of the attached PHY if the BSSBasicRateSet is empty.

A STA that transmits a CF-End frame at the end of a TXOP that was obtained by a non-AP STA through the use of the dual CTS mechanism shall transmit the CF-End frame with the same value for the TXVECTOR parameter STBC, TXVECTOR parameter MCS (if present), and TXVECTOR parameter RATE as was used for the transmission of the matching Control frame at the beginning of the TXOP. The matching Control frame is defined as follows:

- For the first CF-End frame transmitted in the TXOP, the matching Control frame is the first RTS frame transmitted in the TXOP.
- For the second CF-End frame transmitted in the TXOP, the matching Control frame is the first CTS frame that follows the first RTS frame transmitted in the TXOP.
- For the third CF-End frame transmitted in the TXOP, the matching Control frame is the second CTS frame that follows the first RTS frame transmitted in the TXOP.

A STA that transmits a CF-End frame at the end of a TXOP that was obtained by an AP through the use of the dual CTS mechanism shall transmit the CF-End frame with the same value for the TXVECTOR parameter STBC, TXVECTOR parameter MCS (if present), and TXVECTOR parameter RATE as was used for the transmission of the matching Control frame at the beginning of the TXOP. The matching Control frame is defined as follows:

- For the first CF-End frame transmitted in the TXOP, the matching Control frame is the first CTS-to-self frame transmitted in the TXOP.

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— For the second CF-End frame transmitted in the TXOP, the matching Control frame is the first RTS transmitted in the TXOP.

#### 10.6.6.4 Rate selection for Control frames that are not control response frames

This subclause describes the rate selection rules for Control frames that are not control response frames, are not the frame that initiates a TXOP, are not the frame that terminates a TXOP, and are either an S-MPDU or not carried in an A-MPDU.

A frame other than a BlockAckReq or BlockAck that is carried in a non-HT PPDU shall be transmitted by the STA using a rate no higher than the highest rate in the BSSBasicRateSet parameter that is less than or equal to the rate or non-HT reference rate (see 10.6.11 (Non-HT basic rate calculation)) of the previously transmitted frame that was directed to the same receiving STA. If no rate in the BSSBasicRateSet parameter meets these conditions, the Control frame shall be transmitted at a rate no higher than the highest mandatory rate of the attached PHY that is less than or equal to the rate or non-HT reference rate (see 10.6.11 (Non-HT basic rate calculation)) of the previously transmitted frame that was directed to the same receiving STA.

A BlockAckReq or BlockAck frame that is carried in a non-HT PPDU shall be transmitted by the STA using a rate supported by the receiver STA, as reported in the Supported Rates and BSS Membership Selectors element and/or Extended Supported Rates and BSS Membership Selectors element in frames transmitted by that STA. When the operational rate set of the receiving STA or STAs is not known, the transmitting STA shall transmit using a rate from the BSSBasicRateSet parameter or from the mandatory rate set of the attached PHY if the BSSBasicRateSet is empty.

A frame that is carried in an HT PPDU shall be transmitted by the STA using an MCS supported by the receiver STA, as reported in the Supported MCS Set field in the HT Capabilities element received from that STA. When the supported MCS set of the receiving STA or STAs is not known, the transmitting STA shall transmit using an MCS in the Basic HT-MCS Set field of the HT Operation parameter of the MLME-START.request primitive or Basic HT-MCS Set field of the HT Operation parameter of the SelectedBSS parameter of the MLME-JOIN.request primitive.

A frame that is carried in a VHT PPDU shall be transmitted by the STA using a <VHT-MCS, NSS> tuple supported by the receiver STA. A <VHT-MCS, NSS> tuple is supported if reported as such in the Supported VHT-MCS and NSS Set field in the VHT Capabilities element received from that STA. When the Supported VHT-MCS and NSS set of the receiving STA or STAs is not known, the transmitting STA shall transmit using a <VHT-MCS, NSS> tuple in the basic VHT-MCS and NSS set.

A frame that is carried in an S1G PPDU shall be transmitted by the STA using a <S1G-MCS, NSS> tuple supported by the receiver STA, as reported in the Supported S1G-MCS and NSS Set field in the S1G Capabilities element received from that STA. When the Supported S1G-MCS for NSS set of the receiving STA or STAs is not known, the transmitting STA shall transmit using a <S1G-MCS, NSS> tuple in the BSSBasicS1GMCS_NSSSet parameter.

#### 10.6.6.5 Rate selection for control response frames

##### 10.6.6.5.1 Introduction

Subclauses 10.6.6.5.2 (Selection of a rate or MCS) to 10.6.6.5.7 (Control response frame TXVECTOR parameter restrictions) describe the rate selection rules for control response frames that are either an S-MPDU or not carried in an A-MPDU.


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#### 10.6.6.5.2 Selection of a rate or MCS

To allow the transmitting STA to calculate the contents of the Duration/ID field, a STA responding to a received frame transmits its control response frame at a primary rate, or at an alternate rate, or at an MCS, as specified by the following rules:

- If a CTS or Ack frame is carried in a non-HT PPDU, the primary rate is defined to be the highest rate in the BSSBasicRateSet parameter that is less than or equal to the rate (or non-HT reference rate; see 10.6.11 (Non-HT basic rate calculation)) of the previous frame. If no rate in the BSSBasicRateSet parameter meets these conditions, the primary rate is defined to be the highest mandatory rate of the attached PHY that is less than or equal to the rate (or non-HT reference rate; see 10.6.11 (Non-HT basic rate calculation)) of the previous frame. The STA may select an alternate rate according to the rules in 10.6.6.5.4 (Selection of an alternate rate or MCS for a control response frame). The STA shall transmit the non-HT PPDU CTS or Ack frame at either the primary rate or the alternate rate, if one exists.
- If a BlockAck frame is sent as an immediate response to either an Implicit BAR request or to a BlockAckReq frame that was carried in an HT or VHT PPDU and the BlockAck frame is carried in a non-HT PPDU, the primary rate is defined to be the highest rate in the BSSBasicRateSet parameter that is less than or equal to the rate (or non-HT reference rate; see 10.6.11 (Non-HT basic rate calculation)) of the previous frame. If no rate in the BSSBasicRateSet parameter meets these conditions, the primary rate is defined to be the highest mandatory rate of the attached PHY that is less than or equal to the rate (or non-HT reference rate; see 10.6.11 (Non-HT basic rate calculation)) of the previous frame. The STA may select an alternate rate according to the rules in 10.6.6.5.4 (Selection of an alternate rate or MCS for a control response frame). The STA shall transmit the non-HT PPDU BlockAck frame at either the primary rate or the alternate rate, if one exists.
- If a BlockAck frame is sent as an immediate response to either an Implicit BAR request or to a BlockAckReq frame that was carried in an S1G PPDU, the primary rate is defined to be the highest rate in the BSSBasicS1GMCS_NSSSet parameter that is less than or equal to the rate of the previous frame. If no rate in the BSSBasicS1GMCS_NSSSet parameter meets these conditions, the primary rate is defined to be the highest mandatory rate of the attached PHY that is less than or equal to the rate of the previous frame. The STA may select an alternate rate according to the rules in 10.6.6.5.4 (Selection of an alternate rate or MCS for a control response frame). The STA shall transmit the BlockAck control response frame at either the primary rate or the alternate rate, if one exists.
- When in asymmetric BA operation, the S1G STA shall transmit the BlockAck frame at the MCS according to the rules in 10.6.6.5.5 (MCS for asymmetric BA operation).
- When the S1G STA is not following asymmetric BA operation, then
  - If the STA receives an Accept in the Control Response MCS Negotiation Response frame from a responding STA, then it shall transmit the BlockAck frame to the responding STA with the rate described in 10.6.6.5.3 (Control response frame MCS computation).
  - Otherwise, the STA shall transmit the BlockAck frame at either the primary rate or the alternate rate (according to the rules in 10.6.6.5.4 (Selection of an alternate rate or MCS for a control response frame)), if one exists.
- If a Basic BlockAck frame is sent as an immediate response to a BlockAckReq frame that was carried in a non-HT PPDU and the Basic BlockAck frame is carried in a non-HT PPDU, the primary rate is defined to be the same rate and modulation class as the BlockAckReq frame, and the STA shall transmit the Basic BlockAck frame at the primary rate.
- If a Compressed BlockAck frame is sent as an immediate response to a BlockAckReq frame that was carried in a non-HT PPDU and the Compressed BlockAck frame is carried in a non-HT PPDU, the primary rate is defined to be the highest rate in the BSSBasicRateSet parameter that is less than or equal to the rate (or non-HT reference rate; see 10.6.11 (Non-HT basic rate calculation)) of the previous frame. If no rate in the BSSBasicRateSet parameter meets these conditions, the primary rate is defined to be the highest mandatory rate of the attached PHY that is less than or equal to the rate (or non-HT reference rate; see 10.6.11 (Non-HT basic rate calculation)) of the previous frame.

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The STA may select an alternate rate according to the rules in 10.6.6.5.4 (Selection of an alternate rate or MCS for a control response frame). The STA shall transmit the non-HT PPDU Compressed BlockAck frame at either the primary rate or the alternate rate, if one exists.

— If the control response frame is carried in an HT or VHT PPDU, then it is transmitted using an MCS or <VHT-MCS, NSS> tuple as determined by the procedure defined in 10.6.6.5.3 (Control response frame MCS computation).

— If the control response frame is carried in an S1G PPDU, then it is transmitted using an <S1G-MCS, NSS> tuple as determined by the procedure defined in 10.6.6.5.3 (Control response frame MCS computation).

The modulation class of the PSDU containing the control response frame shall be selected according to the following rules:

— If the PSDU containing the received frame is of a modulation class other than HT, VHT, or S1G and the control response frame is carried in a non-HT PPDU, the control response frame shall be transmitted in a PSDU using the same modulation class as the PSDU containing the received frame. In addition, the control response frame shall be sent using the same value for the TXVECTOR parameter PREAMBLE_TYPE as the received frame.

— If the PSDU containing the received frame is of the modulation class HT or VHT and the control response frame is carried in a non-HT PPDU, the control response frame shall be transmitted in a PSDU using one of the ERP-OFDM or OFDM modulation classes.

— If the control response frame is carried in an HT PPDU, the modulation class shall be HT.

— If the control response frame is carried in a VHT PPDU, the modulation class shall be VHT.

— If the control response frame is carried in an S1G PPDU, the modulation class shall be S1G.

The selection of the value for the channel width (CH_BANDWIDTH parameter of the TXVECTOR) of the response transmission is defined in 10.6.6.6 (Channel Width selection for Control frames).

#### 10.6.6.5.3 Control response frame MCS computation

If a control response frame is to be transmitted within an HT or VHT PPDU, the channel width (CH_BANDWIDTH parameter of the TXVECTOR) shall be selected first according to 10.6.6.6 (Channel Width selection for Control frames), and then the MCS or <VHT-MCS, NSS> tuple shall be selected from a set of MCSs and <VHT-MCS, NSS> tuples called the *CandidateMCSSet* as described in this subclause.

If a control response frame is to be transmitted within an S1G PPDU, the channel width (CH_BANDWIDTH parameter of the TXVECTOR) shall be selected first according to 10.6.6.6 (Channel Width selection for Control frames), and then the <S1G-MCS, NSS> tuple shall be selected from a set of <S1G-MCS, NSS> tuples called the *CandidateMCSSet* as described in this subclause.

If the frame eliciting the response was transmitted by an HT STA that is not a VHT STA, the Rx Supported MCS Set is determined from the Supported MCS Set field in the HT Capabilities element received from the STA as follows:

— If a bit in the Rx MCS Bitmask subfield is equal to 0, the corresponding MCS is not supported.

— If a bit in the Rx MCS Bitmask subfield is equal to 1 and the integer part of the data rate (expressed in Mb/s(#4148)) of the corresponding MCS is less than or equal to the rate represented by the Rx Highest Supported Data Rate subfield, then the MCS is supported by the STA on receive. If the Rx Highest Supported Data Rate subfield is equal to 0 and a bit in the Rx MCS Bitmask is equal to 1, then the corresponding MCS is supported by the STA on receive.


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If the frame eliciting the response was transmitted by a VHT STA, the Rx Supported MCS Set is determined for VHT PPDUs as described in 10.6.13 (Rate selection constraints for VHT STAs) and for HT PPDUs from the Supported MCS Set field in the HT Capabilities element received from the STA as follows:

- If a bit in the Rx MCS Bitmask subfield is equal to 0, the corresponding MCS is not supported.
- If a bit in the Rx MCS Bitmask subfield is equal to 1 and the integer part of the data rate (expressed in Mb/s(#4148)) of the corresponding MCS is less than or equal to the rate represented by the Rx Highest Supported Data Rate subfield, then the MCS is supported by the STA on receive. If the Rx Highest Supported Data Rate subfield is equal to 0 and a bit in the Rx MCS Bitmask is equal to 1, then the corresponding MCS is supported by the STA on receive.

The Rx Supported MCS Set is determined for S1G PPDUs as described in 10.6.14 (Rate selection constraints for S1G STAs).

The CandidateMCSSet is determined using the following rules:

- If the frame eliciting the response was an STBC frame and the Dual CTS Protection bit is equal to 1, the CandidateMCSSet shall contain only the basic STBC MCS.
- For S1G STAs, if none of the above conditions is true, the CandidateMCSSet is the BSSBasicS1GMCS_NSSSet parameters. If the frame eliciting the response was an RTS frame, then the CandidateMCSSet may additionally include the <S1G-MCS, NSS> tuple with the same MCS and number of spatial streams as the S1G PPDU. If the combined BSSBasicMCSSet parameter is empty, the CandidateMCSSet shall consist of the set of mandatory <S1G-MCS, NSS> tuples corresponding to the mandatory S1G PHY MCSs with NSS = 1.
- For non-S1G STAs, if none of the above conditions is true, the CandidateMCSSet is the union of the Basic HT-MCS Set field of the HT Operation parameter of the MLME-START.request primitive or Basic HT-MCS Set field of the HT Operation parameter of the SelectedBSS parameter of the MLME-JOIN.request primitive and the basic VHT-MCS and NSS set. If the frame eliciting the response was an RTS frame carried in a VHT PPDU, then the CandidateMCSSet may additionally include the <VHT-MCS, NSS> tuple with the same MCS and number of spatial streams as the VHT PPDU. If the combined Basic HT-MCS Set field of the HT Operation parameter of the MLME-START.request primitive or Basic HT-MCS Set field of the HT Operation parameter of the SelectedBSS parameter of the MLME-JOIN.request primitive is empty, the CandidateMCSSet shall consist of
  - The set of mandatory HT PHY MCSs if the STA eliciting the response is an HT STA that is not a VHT STA
  - The set of mandatory HT-MCSs plus the set of <VHT-MCS, NSS> tuples corresponding to the mandatory VHT PHY MCSs with NSS = 1 if the STA eliciting the response is a VHT STA

MCS values from the CandidateMCSSet that cannot be transmitted with the selected CH_BANDWIDTH parameter value shall be eliminated from the CandidateMCSSet.

The choice of a response MCS is made as follows:

a) If the frame eliciting the response is within a non-HT PPDU,
   1) Eliminate from the CandidateMCSSet all <VHT-MCS, NSS> tuples. Eliminate all MCSs that have a data rate greater than the data rate of the received PPDU (the mapping of MCS to data rate is defined in 19.5 (Parameters for HT-MCSs)).
   2) Find the highest indexed MCS from the CandidateMCSSet. The index of this MCS is the index of the MCS that is the primary MCS for the response transmission.
   3) If the CandidateMCSSet is empty, the primary MCS is the lowest indexed MCS of the mandatory MCSs.
b) If the frame eliciting the response is within an HT PPDU,

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1) Eliminate from the CandidateMCSSet all <VHT-MCS, NSS> tuples. Eliminate all MCSs that have an index that is higher than the index of the MCS of the received frame. Also eliminate all MCSs that have a number of spatial streams greater than that indicated in the Rx NSS subfield in the most recent Operating Mode field with the Rx NSS Type subfield equal to 0 from the intended receiver STA, if at least one Operating Mode field with the Rx NSS Type subfield equal to 0 was received from the intended receiver STA.

2) Determine the highest number of spatial streams ($N_{SS}$) value of the MCSs in the CandidateMCSSet that is less than or equal to the $N_{SS}$ value of the MCS of the received frame. Eliminate all MCSs from the CandidateMCSSet that have an $N_{SS}$ value that is not equal to this $N_{SS}$ value. The mapping from MCS to $N_{SS}$ is dependent on the attached PHY. For the HT PHY, see 19.5 (Parameters for HT-MCSs).

3) Find the highest indexed MCS of the CandidateMCSSet for which the modulation value of each stream is less than or equal to the modulation value of each stream of the MCS of the received frame and for which the coding rate is less than or equal to the coding rate of the MCS from the received frame. This MCS is the primary MCS for the response transmission. The mapping from MCS to modulation and coding rate is dependent on the attached PHY. For the HT PHY, see 19.5 (Parameters for HT-MCSs). For the purpose of comparing modulation values, the following sequence shows increasing modulation values: BPSK, QPSK, 16-QAM, 64-QAM.

4) If no MCS meets the condition in step 3), remove each MCS from the CandidateMCSSet that has the highest value of $N_{SS}$ in the CandidateMCSSet. If the resulting CandidateMCSSet is empty, then set the CandidateMCSSet to the HT PHY mandatory MCSs. Repeat step 3) using the modified CandidateMCSSet.

c) If the frame eliciting the response is within a VHT PPDU,

1) Eliminate from the CandidateMCSSet all MCSs and all <VHT-MCS, NSS> tuples that meet any of the following conditions:

i) Have a data rate that is higher than the data rate of the <VHT-MCS, NSS> tuple of the received frame using the largest possible value of CH_BANDWIDTH that is no larger than the value of CH_BANDWIDTH of the received frame

ii) Have a number of spatial streams greater than that indicated in the Rx NSS subfield in the most recent Operating Mode field with the Rx NSS Type subfield equal to 0 from the intended receiver STA, if at least one Operating Mode field with the Rx NSS Type subfield equal to 0 was received from the intended receiver STA

iii) Have a number of spatial streams greater than that indicated in the Rx NSS subfield in the most recent Operating Mode field with the Rx NSS Type subfield equal to 1 from the intended receiver STA if at least one Operating Mode field with the Rx NSS Type subfield equal to 1 was received from the receiver STA and the control response frame is an SU PPDU frame with a beamforming steering matrix and the beamforming steering matrix was derived from a VHT Compressed Beamforming report with Feedback Type subfield indicating MU in the VHT Compressed Beamforming frame(s)

2) Determine the highest number of spatial streams ($N_{SS}$) value of the MCSs and <VHT-MCS, NSS> tuples in the CandidateMCSSet that is less than or equal to the $N_{SS}$ value of the received frame. Eliminate all MCSs from the CandidateMCSSet that have an $N_{SS}$ value that is not equal to this $N_{SS}$ value. The mapping from MCS to $N_{SS}$ is dependent on the attached PHY. For the HT PHY, see 19.5 (Parameters for HT-MCSs).

3) Find the highest rate MCS or <VHT-MCS, NSS> tuple of the CandidateMCSSet for which the modulation value of each stream is less than or equal to the modulation value of each stream of the MCS of the received frame and for which the coding rate is less than or equal to the coding rate of the MCS from the received frame. This MCS or <VHT-MCS, NSS> tuple is the primary MCS for the response transmission. The mapping from MCS or <VHT-MCS, NSS> tuple to modulation and coding rate is dependent on the attached PHY. For the HT PHY, see 19.5


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(Parameters for HT-MCSs); for the VHT PHY, see 21.5 (Parameters for VHT-MCSs). For the purpose of comparing modulation values, the following sequence shows increasing modulation values: BPSK, QPSK, 16-QAM, 64-QAM, 256-QAM.

4) If no MCS meets the condition in step 3), remove each MCS or <VHT-MCS, NSS> tuple from the CandidateMCSSet that has the highest value of $N_{SS}$ in the CandidateMCSSet. If the resulting CandidateMCSSet is empty, then set the CandidateMCSSet to the VHT PHY mandatory MCSs. Repeat step 3) using the modified CandidateMCSSet.

d) If the frame eliciting the response is within an S1G PPDU,

1) Eliminate from the CandidateMCSSet all MCSs and all <S1G-MCS, NSS> tuples that meet any of the following conditions:

i) Have a data rate that is higher than the data rate of the <S1G-MCS, NSS> tuple of the received frame using the largest possible value of CH_BANDWIDTH that is no larger than the value of CH_BANDWIDTH of the received frame

ii) Have a number of spatial streams greater than one

2) Find the highest rate MCS or <S1G-MCS, NSS> tuple of the CandidateMCSSet for which the modulation value of each stream is less than or equal to the modulation value of each stream of the MCS of the received frame and for which the coding rate is less than or equal to the coding rate of the MCS from the received frame. This MCS or <S1G-MCS, NSS> tuple is the primary MCS for the response transmission. The mapping from MCS or <S1G-MCS, NSS> tuple to modulation and coding rate is dependent on the attached PHY; see 23.5 (Parameters for S1G-MCSs). For the purpose of comparing modulation values, the following sequence shows increasing modulation values: BPSK, QPSK, 16-QAM, 64-QAM, 256-QAM, 1024-QAM.(M102)

3) If no MCS meets the condition in step 2), then set the CandidateMCSSet to the S1G PHY mandatory MCSs. Repeat step 2) using the modified CandidateMCSSet.

Once the primary MCS, <VHT-MCS, NSS> tuple, or <S1G-MCS, NSS> tuple has been selected, the STA may select an alternate MCS according to 10.6.6.5.4 (Selection of an alternate rate or MCS for a control response frame). If the STA has not negotiated the control response MCS negotiation as described in 10.6.6.5.6 (Control response MCS negotiation) or has received a Reject indication in the Control Response MCS Negotiation Response frame, then it shall transmit the control response frame using either the primary MCS or the alternate MCS, if one exists. If the STA has received an Accept indication in the Control Response MCS Negotiation Response frame from a responding STA, then it shall transmit the control response frame to the responding STA using the negotiated MCS or alternative MCS provided that the duration of the frame at the alternate MCS is the same as the duration of the frame at the negotiated MCS, if one exists. Negotiated MCS is computed as the highest MCS less than or equal to the MCS that is MCSDifference lower than the primary MCS if one exists, or the MCS 10 otherwise.

#### 10.6.6.5.4 Selection of an alternate rate or MCS for a control response frame

An alternate rate may be selected provided that all of the following conditions are met:

— The duration of frame at the alternate rate is the same as the duration of the frame at the primary rate determined by 10.6.6.5.2 (Selection of a rate or MCS).

— The alternate rate is in either the BSSBasicRateSet parameter or is a mandatory rate of the attached PHY.

— The modulation class of the frame at the alternate rate is the same class as that of the primary rate selected by 10.6.6.5.2 (Selection of a rate or MCS).

An alternate MCS may be selected provided that both of the following conditions are met:

— The duration of the frame at the alternate MCS is the same as the duration of the frame at the primary MCS.

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— The alternate MCS is in the CandidateMCSSet that was generated according to the procedure of 10.6.6.5.3 (Control response frame MCS computation).

#### 10.6.6.5.5 MCS for asymmetric BA operation

The primary MCS for asymmetric BA operation is defined as the MCS that is MCSDifference (see 10.25.2 (Setup and modification of the block ack parameters)) lower than that of the eliciting A-MPDU. An alternate MCS may be selected provided that the duration of the frame at the alternate MCS is the same as the duration of the frame at the primary MCS.

#### 10.6.6.5.6 Control response MCS negotiation

Control response MCS negotiation allows two STAs with power imbalance to send the control responses with different MCSs than the primary MCS as defined by the rules in 10.6.6.5.3 (Control response frame MCS computation). A STA may initiate the Control Response Negotiation by sending a Control Response MCS Request frame. After reception of a Control Response MCS Response frame that indicates Accept, the STA sends the control response frames with the Negotiated MCS as defined in 10.6.6.5.3 (Control response frame MCS computation).

An S1G STA with dot11MCSNegotiation equal to true shall set the MCS Negotiation Support field of the S1G Capabilities element to 1. An S1G STA with dot11MCSNegotiation equal to false shall set the MCS Negotiation Support field of the S1G Capabilities element to 0.

An S1G STA shall not transmit a Control Response MCS Negotiation Request frame to another S1G STA unless the MCS Negotiation Support field of the S1G Capabilities element received from that STA contained a value of 1 and dot11MCSNegotiation is true.

An S1G STA shall transmit the Control Response MCS Negotiation Response frame to a STA from which it has received a Control Response MCS Negotiation Request frame. The STA shall include a value that indicates either Accept or Reject in the Command field of the Response frame as defined in Table 9-633 (Command values).

#### 10.6.6.5.7 Control response frame TXVECTOR parameter restrictions

A STA shall not transmit a control response frame with the TXVECTOR parameter GI_TYPE set to SHORT_GI unless it is in response to a frame with the RXVECTOR parameter GI_TYPE equal to SHORT_GI.

A STA shall not transmit a control response frame with the TXVECTOR parameter FEC_CODING set to LDPC_CODING unless it is in response to a frame with the RXVECTOR parameter FEC_CODING equal to LDPC_CODING.

A STA shall not transmit a control response frame with the TXVECTOR parameter FORMAT set to HT_GF.

### 10.6.6.6 Channel Width selection for Control frames

The rules in this subclause, combined with the rules in 10.6.6.1 (General rules for rate selection for Control frames), determine the format of control response frames.

(11ax)If a VHT or HE STA transmits to another VHT or HE STA a Control frame that is not an RTS frame or a CF-End frame, if that Control frame is an HE NDP Announcement frame or elicits a control response frame, a VHT Compressed Beamforming frame, or an HE Compressed Beamforming/CQI frame, and


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- If the Control frame is transmitted in a non-HT duplicate PPDU (channel width 40 MHz or wider), the transmitting (11ax)VHT or HE STA shall set the TA field to a bandwidth signaling TA.
- If the Control frame is transmitted in a non-HT PPDU (channel width 20 MHz), the transmitting (11ax)VHT or HE STA may set the TA field to a bandwidth signaling TA.

If the TA is a bandwidth signaling TA, the transmitting VHT STA shall set the TXVECTOR parameters CH_BANDWIDTH_IN_NON_HT and CH_BANDWIDTH to the same value.

NOTE 1—Such Control frames are BlockAckReq frames, PS-Poll frames, VHT NDP Announcement frames, and Beamforming Report Poll frames.

NOTE 2—Control Wrapper frames follow the rules pertaining to the carried Control frame (see 10.9 (Control Wrapper operation)).

Channel width selection rules for RTS frames are described in 10.3.2.7 (VHT and S1G RTS procedure).

A VHT STA that transmits a CF-End frame in a non-HT duplicate PPDU (channel width 40 MHz or wider) addressed to a VHT AP shall set the Individual/Group bit in the BSSID(TA) field to 1.

A VHT STA that transmits a CF-End frame in a non-HT PPDU (channel width 20 MHz) addressed to a VHT AP may set the Individual/Group bit in the BSSID(TA) field to 1.

If the Individual/Group bit in the BSSID(TA) field of the CF-End frame is(M118) 1, the transmitting VHT STA shall set the TXVECTOR parameters CH_BANDWIDTH_IN_NON_HT and CH_BANDWIDTH to the same value.

A STA that sends a Control frame in response to a frame carried in an HT PPDU or a VHT PPDU shall set the TXVECTOR parameter CH_BANDWIDTH to indicate a channel width that is the same as the channel width indicated by the RXVECTOR parameter CH_BANDWIDTH of the frame eliciting the response.

A STA that sends a Control frame in response to a frame carried in a non-HT or non-HT duplicate PPDU with a nonbandwidth signaling TA

- Should set the TXVECTOR parameter CH_BANDWIDTH to the same value as the RXVECTOR parameter CH_BANDWIDTH for the frame eliciting the response.
- Shall not set the TXVECTOR parameter CH_BANDWIDTH to a value greater than the RXVECTOR parameter CH_BANDWIDTH for the frame eliciting the response.

NOTE 3—According to this rule, a STA can respond with a 20 MHz PPDU if it receives a non-HT duplicate frame but is not able to detect the channel width occupied by the frame (whether by design or because the frame was received over a channel that is narrower than the channel on which it was transmitted).

A VHT STA that sends a Control frame that is in response to a non-HT or non-HT duplicate format frame with a bandwidth signaling TA and that is not a CTS shall set the channel width indicated by the TXVECTOR parameter CH_BANDWIDTH to the same value as the channel width indicated by the RXVECTOR parameter CH_BANDWIDTH_IN_NON_HT for the frame eliciting the response. The RA field of a Control frame that is not a CF-End frame and that is sent in response to a Control frame with a bandwidth signaling TA shall be set to a nonbandwidth signaling TA obtained from the TA field of the immediately previous Control frame. For the channel width selection rules for CTS sent in response to an RTS with a bandwidth signaling TA, see 10.3.2.9 (CTS and DMG CTS procedure).

A frame that is intended to provide protection is transmitted using a channel width selected by the rules defined in 10.27 (Protection mechanisms).

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An HT STA that uses a non-HT duplicate frame to establish protection of its TXOP shall send any CF-End frame using a non-HT duplicate frame.

The TXOP holder should set the TXVECTOR parameter CH_BANDWIDTH of a CF-End frame to the maximum bandwidth allowed by the rules in 10.23.2.8 (Multiple frame exchange sequences in an EDCA TXOP(#109)).

NOTE 4—A CF-End frame transmitted by an AP a SIFS duration after receiving a CF-End frame is considered a control response frame.

An S1G STA that has set the 1 MHz Control Response Preamble Support field to 1 in the S1G Capabilities element transmitted to its peer STA shall use S1G_1M preamble transmission as the response of S1G_SHORT_PREAMBLE or S1G_LONG_PREAMBLE as follows:

— An S1G STA that sends a Control frame in response to a frame carried in an S1G PPDU shall set the TXVECTOR parameter CH_BANDWIDTH to indicate a channel width that is the same or lower as the channel width indicated by the RXVECTOR parameter CH_BANDWIDTH of the frame eliciting the response.
— In a TXOP, a STA shall not set the TXVECTOR parameter CH_BANDWIDTH to a value greater than the RXVECTOR parameter CH_BANDWIDTH for the next frame exchange sequence.

Otherwise, in S1G BSS, S1G_1M preamble transmission as the response of S1G_SHORT_PREAMBLE or S1G_LONG_PREAMBLE is not allowed and the S1G STA behaves as follows:

— An S1G STA that sends a Control frame in response to a frame carried in an S1G PPDU shall set the TXVECTOR parameter CH_BANDWIDTH to indicate a channel width that is the same as the channel width indicated by the RXVECTOR parameter CH_BANDWIDTH of the frame eliciting the response, except when the frame eliciting the response is an S1G RTS frame with the Dynamic Indication field in the Frame Control field equal to 1.

When both transmitting STA and receiving STA indicate OBSS mitigation support in the OBSS Mitigation Support subfield of the S1G Capabilities element, the receiving STA operating in a 2/4/8/16 MHz BSS that sends a (duplicate) NDP_2M Ack frame or NDP_2M BlockAck frame in response to a frame carried in an S1G PPDU may set the TXVECTOR parameter CH_BANDWIDTH to indicate a channel width that is less than or equal to the channel width indicated by the RXVECTOR parameter CH_BANDWIDTH of the frame eliciting the response.

An S1G STA transmitting a Control frame or an NDP CMAC PPDU shall set the TXVECTOR parameter FORMAT depending on the value of the TXVECTOR parameter CH_BANDWIDTH:

— If CH_BANDWIDTH is equal to CBW1 then the FORMAT shall be S1G
— If CH_BANDWIDTH is equal to CBW2 then the FORMAT shall be:
  — S1G_DUP_1M if the RXVECTOR parameter CH_BANDWIDTH of the eliciting Control frame is equal to CBW1 and the Bandwidth Indication field in the Frame Control field is 1.
  — S1G_DUP_1M if the S1G STA intends to transmit a duplicate 1 MHz Control frame to an S1G STA that supports duplicate 1 MHz frames as indicated in the duplicate 1 MHz Support field of the S1G Capabilities element received from that S1G STA.
  — S1G otherwise.
— Otherwise, the FORMAT shall be S1G DUP_2M.

#### 10.6.6.7 Control frame TXVECTOR parameter restrictions

A STA shall not transmit a Control frame that initiates a TXOP with the TXVECTOR parameter GI_TYPE set to a value of SHORT_GI.


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A STA shall not transmit a Control frame that initiates a TXOP with the TXVECTOR parameter FEC_CODING set to a value of LDPC_CODING.

### 10.6.7 Multirate support for DMG STAs

#### 10.6.7.1 Usage of DMG Control modulation class

The DMG Control modulation class has only one MCS, which is DMG MCS 0 defined in Clause 20 (Directional multi-gigabit (DMG) PHY specification). The DMG Beacon, SSW-Feedback, SSW-Ack, RTS, DMG CTS, DMG CTS-to-self, DMG DTS, CF-End, Grant, SPR, Poll(11ay), Sector Ack, TDD Beamforming frames (i.e., TDD SSW, TDD SSW Feedback and TDD SSW Ack), and first BRP PPDU in beam refinement shall be transmitted using the DMG Control modulation class. In the case of an RXSS that was specified through the Beamforming Control field with the value of the RXSSTxRate subfield equal to 1 and the RXSSTxRate Supported field in the DMG Capabilities element of the STA performing the RXSS is 1, the first SSW frame of the RXSS shall be transmitted using the DMG Control modulation class, and the remaining frames of the RXSS shall be transmitted using MCS 1 of the DMG SC modulation class. In all other cases, the SSW frames shall be transmitted using the DMG Control modulation class. Other DMG beamforming training frames may be transmitted using the DMG Control modulation class or the DMG SC modulation class.

#### 10.6.7.2 Rate selection rules for Control frames transmitted by DMG STAs

This subclause describes the rate selection rules for Control frames transmitted by DMG STAs. The rate selection rules apply only for MCSs defined in Clause 20 (Directional multi-gigabit (DMG) PHY specification)(11ay) and in Clause 28 (Enhanced directional multi-gigabit (EDMG) PHY specification(11ay)).

A Control frame that does not have an MCS defined in 10.6.7.1 (Usage of DMG Control modulation class) and that is not a control response frame shall be transmitted using an MCS from the mandatory MCS set of the DMG SC modulation class or DMG Control modulation class.

A STA transmitting an Ack or a BlockAck frame that is a response to a frame sent using the DMG low-power SC modulation class shall use an MCS from the DMG low-power SC Supported MCS set of the STA that transmitted the frame that elicited the response as long as (a) the selected MCS has a Data Rate that does not exceed the Data Rate of the frame that elicited the response, and (b) no other MCS satisfying condition (a) results in a shorter frame transmission time.

A STA transmitting a Grant Ack frame shall use the DMG Control modulation class or any MCS from the mandatory MCS set of the DMG SC modulation class.

A STA transmitting an Ack or a BlockAck frame that is a response to a frame sent using the DMG Control modulation class shall use the DMG Control modulation class.

A STA transmitting an Ack frame or a BlockAck frame in response to a frame sent using the DMG SC modulation class shall use an MCS from the mandatory MCS set of the DMG SC modulation class as long as (a) the selected MCS has a Data Rate that does not exceed the Data Rate of the (11ay)last frame that elicited the response, and (b) no other MCS satisfying condition (a) results in a shorter frame transmission time.

(11ay)An EDMG STA transmitting an Ack frame or a BlockAck frame in response to a frame sent using the EDMG SC modulation class or EDMG OFDM modulation class shall

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- Use the rules applicable to an DMG STA rules when the number of bits set to 1 in the CH_BANDWIDTH parameter in the RXVECTOR of the received EDMG PPDU is equal to 1 (i.e., a single 2.16 GHz channel).
- Use MCS1 when the Ack or BlockAck frame is sent within a non-EDMG duplicate PPDU and the number of bits set to 1 in the CH_BANDWIDTH parameter is greater than 1.
- Use one of MCS 1 through MCS 4 from the mandatory MCS set of the EDMG SC modulation class when the ACK or BlockAck frame is sent within an EDMG PPDU as long as (a) the selected MCS has a Data Rate that does not exceed the Data Rate of the frame that elicited the response, and (b) no other MCS satisfying condition (a) results in a shorter frame transmission time.
- In case the PPDU containing the Ack frame or a BlockAck frame carries a control trailer that provides spatial stream feedback, it shall be transmitted using MCS 0 and shall follow the rules defined in 10.42.4 (EDMG spatial stream feedback(11ay)).

(11ay)The rules in this subclause and in 10.6.7.7 (Control frame TXVECTOR parameter restrictions(11ay)) do not apply to Block Ack Schedule frames carried within an A-MPDU. The rate selection rules that apply to a Block Ack Schedule frame are those applying to Data frames (see 10.6.7.4 (Rate selection for individually addressed Data and Management frames transmitted by DMG STAs)).

(11ay)Rules for channel width selection of Control frames for an EDMG STA are specified in 10.6.7.6 (Channel Width selection for Control frames transmitted by EDMG STAs(11ay)).

NOTE—A control response frame is a Control frame that is transmitted within an MPDU as a response to a reception SIFS after the PPDU containing the frame that elicits the response, e.g., a DMG CTS frame in response to an RTS frame reception, an Ack frame in response to a Data frame reception, a BlockAck frame in response to a BlockAckReq frame reception. In some situations, the transmission of some of these Control frames is not a control response transmission, such as when a DMG CTS frame is used to initiate a TXOP.

Except in an A-MPDU consisting of one of the combinations listed below, the rules in this subclause do not apply to Control frames that are contained in A-MPDUs that also include at least one MPDU with the Type subfield equal to Data or Management. In the following cases, the rate selection rules are the same as those for a standalone Ack or BlockAck frame:

- An Ack frame and a QoS Null frame
- A BlockAck frame and a QoS Null frame
- A BlockAckReq frame and a QoS Null frame
- A BlockAck frame, a BlockAckReq frame, and a QoS Null frame

### 10.6.7.3 Rate selection for group addressed Data and Management frames transmitted by DMG STAs

This subclause describes the rate selection rules for group addressed Data and Management frames transmitted by DMG STAs. The rate selection rules apply only for MCSs defined in Clause 20 (Directional multi-gigabit (DMG) PHY specification)(11ay) and in Clause 28 (Enhanced directional multi-gigabit (EDMG) PHY specification(11ay)).

If the transmit antenna pattern of a single transmission of a group addressed frame covers more than one receiver, then the sender shall employ an MCS that is supported by all of the receivers. Furthermore, the sender shall not employ π/2-8-PSK modulation unless all receivers support π/2-8-PSK modulation. If the capability of any receiver is not known, the frame shall be transmitted using an MCS from the mandatory MCS set of the DMG control or SC mode.

If the transmit antenna pattern of a single transmission of a group addressed frame covers only one receiver, the frame shall be transmitted following the rate selection rules of individually addressed frames as


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described in 10.6.7.4 (Rate selection for individually addressed Data and Management frames transmitted by DMG STAs).

(11ay)Group addressed DMG STA Directional Transmit Activity Report frames shall be transmitted using DMG MCS 0.

### 10.6.7.4 Rate selection for individually addressed Data and Management frames transmitted by DMG STAs

This subclause describes the rate selection rules for individually addressed Data and Management frames as transmitted by DMG STAs. The rate selection rules apply only for MCSs defined in Clause 20 (Directional multi-gigabit (DMG) PHY specification)(11ay) and in Clause 28 (Enhanced directional multi-gigabit (EDMG) PHY specification(11ay)).

An individually addressed Data or Management frame(11ay) transmitted to a non-EDMG STA shall be sent using an MCS supported by the receiver STA, as reported in the maximum receive MCS subfields in the Supported MCS Set field(11ay) of the DMG STA Capability Information field and in the Extended SC MCS Capabilities field of the DMG Capabilities element carried in Management frames transmitted by the receiver STA.

(11ay)An individually addressed Data, Management, and Block Ack Schedule frame transmitted to an EDMG STA shall be sent using a combination of MCSs, number of spatial streams and bandwidth supported by the STA, as reported in the

- Maximum receive MCS subfields in the Supported MCS Set subfield within the DMG STA Capability Information field and within the Extended SC MCS Capabilities field of the STA's last transmitted DMG Capabilities element.
- Maximum receive MCS subfields within the Supported MCS field of the STA's last transmitted EDMG Capabilities element.
- Maximum PHY Rate subfield within the Supported MCS field of the STA's last transmitted EDMG Capabilities element.
- If present in the STA's last transmitted EDMG Capabilities element, the maximum number of spatial streams and LDPC codeword supported subfields.

When the Supported MCS set of the receiving STA is not known, the transmitting STA shall transmit using an MCS from the mandatory MCS set of the DMG control or SC mode.

(11ay)When the capabilities of the receiving STA are not known, the transmitting STA shall transmit using an MCS from the mandatory MCS set of the DMG control or SC mode.(11ay) In addition for an EDMG STA, the TXVECTOR parameter LDPC_CW_TYPE shall be set to SHORT.

A DMG STA shall transmit a TPA Request frame and a TPA Response frame using MCS 1.

An individually addressed Data or Management frame with MCS 10 or MCS 11 shall only employ π/2-8-PSK modulation if the receiving STA supports π/2-8-PSK. The receiving STA indicates support by setting the π/2-8-PSK Capable subfield(#402) to 1 in the Supported MCS Set subfield of the DMG STA Capability Information field of the DMG Capabilities element all DMG Capabilities fields that are included in transmitted Management frames.

The rules in this subclause also apply to A-MPDUs that contain at least one MPDU with Type subfield equal to Control and at least one MPDU with Type subfield equal to Data or Management.

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#### 10.6.7.5 Rate selection for BRP PPDUs

The first BRP PPDU transmitted from the initiator to the responder after the SLS phase shall use MCS 0.

The first BRP PPDU transmitted from the responder to the initiator after the SLS phase shall use MCS 0.

A BRP PPDU transmitted during beam refinement at the start of an SP (as defined in 10.38.6.2 (Service period (SP) allocation)) should use MCS 0, otherwise a BRP PPDU transmitted during beam refinement should use MCS 1. A BRP PPDU transmitted during beam refinement shall not use any MCS greater than MCS 12.

BRP PPDUs transmitted during the BRP setup subphase, the MID subphase, and the BC subphase shall use MCS 0.

BRP PPDUs transmitted during a BC subphase, as part of a BC subphase only training, may use MCS 0 to MCS 12.

BRP PPDUs transmitted during beam tracking may use any MCS.

(11ay)If an EDMG BRP PPDU is sent during a BRP transaction to perform beamforming training over a 2.16 GHz, 4.32 GHz, 6.48 GHz, 8.64 GHz, 2.16+2.16 GHz or 4.32+4.32 GHz channel, the EDMG BRP PPDU should be transmitted with MCS 0.

#### 10.6.7.6 Channel Width selection for Control frames transmitted by EDMG STAs(11ay)

The rules in this subclause, combined with the rules in 10.6.7.2 (Rate selection rules for Control frames transmitted by DMG STAs), determine the format of Control frames that are not RTS, DMG CTS, DMG DTS or CF-End frames.

Channel width selection rules for DMG CTS and DMG DTS frames are specified in 10.3.2.9 (CTS and DMG CTS procedure).

Channel width selection rules for RTS and CF-End frames are specified in 10.3.2.18 (EDMG RTS procedure(11ay)).

An EDMG STA that sends a Control frame in response to a frame carried in an EDMG PPDU shall set the TXVECTOR parameters CH_BANDWIDTH and CHANNEL_AGGREGATION to the value indicated by the RXVECTOR parameters CH_BANDWIDTH and CHANNEL_AGGREGATION of the frame eliciting the response.

An EDMG STA that sends a Control frame in response to a frame carried in a non-EDMG duplicate PPDU shall set the TXVECTOR parameters CH_BANDWIDTH and CHANNEL_AGGREGATION as follows:

— If the frame that elicited the response includes the channel bandwidth information in the RXVECTOR parameter CH_BANDWIDTH_SIGNALING or BW_IN_CT, CH_BANDWIDTH and CHANNEL_AGGREGATION shall be set to a value that represents the equivalent channels indicated by the CH_BANDWIDTH_SIGNALING or BW_IN_CT parameter, respectively.

— Otherwise, if the STA received at least one EDMG PPDU as part of the current frame exchange sequence, CH_BANDWIDTH and CHANNEL_AGGREGATION shall be set to respectively, the value of the RXVECTOR parameters CH_BANDWIDTH and CHANNEL_AGGREGATION of the last received EDMG PPDU in the current frame exchange sequence.

— Otherwise, if the STA transmitted at least one EDMG PPDU or non-EDMG duplicate PPDU as part of the current frame exchange sequence, CH_BANDWIDTH and CHANNEL_AGGREGATION shall be set to, respectively, the value of the TXVECTOR parameters CH_BANDWIDTH and


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CHANNEL_AGGREGATION of the last EDMG PPDU or non-EDMG duplicate PPDU, whichever came later, transmitted by the STA in the current frame exchange sequence.

— Otherwise, CH_BANDWIDTH and CHANNEL_AGGREGATION shall be set to, respectively, the estimated value of the RXVECTOR parameters CH_BANDWIDTH and CHANNEL_AGGREGATION of the frame that elicited the response.

#### 10.6.7.7 Control frame TXVECTOR parameter restrictions(11ay)

A STA shall not transmit a Control frame with the TXVECTOR parameter GI_TYPE set to a value that is not equal to NORMAL.

A STA shall not transmit a Control frame with the TXVECTOR parameter EDMG_MODULATION set to EDMG_OFDM_MODE.

A STA shall not transmit a Control frame with the TXVECTOR parameter NUM_STS set to a value greater than one.

A STA shall not transmit a Control frame with the TXVECTOR parameter NUM_USERS set to a value greater than one.

A STA shall not transmit a Control frame with the TXVECTOR parameter LDPC_CW_TYPE set to LONG.

#### 10.6.7.8 Channel Width selection for individually addressed Data and Management frames transmitted by EDMG STAs(11ay)

A TXOP holder that transmits a Data or Management frame during a TXOP that was established using the bandwidth negotiation procedures specified in 10.3.2.9 (CTS and DMG CTS procedure) and 10.3.2.18 (EDMG RTS procedure(11ay)) shall set the TXVECTOR parameters CH_BANDWIDTH and CHANNEL_AGGREGATION according to the following rules:

— The CH_BANDWIDTH and CHANNEL_AGGREGATION parameters shall be set to channels that were indicated in the RXVECTOR parameter CH_BANDWIDTH_SIGNALING, if a control trailer is not present, or parameter BW_IN_CT, if a control trailer is present, of the DMG CTS frame transmitted in a non-EDMG duplicate or non-EDMG PPDU that established the TXOP.

— The CH_BANDWIDTH and CHANNEL_AGGREGATION parameters may indicate a subset of the channels that were indicated as used in an immediately preceding received PPDU in the TXOP, if any, provided the transmitted PPDU is an EDMG PPDU.

— The CH_BANDWIDTH and CHANNEL_AGGREGATION parameters shall not indicate channels that were not used by all previous PPDUs sent in same TXOP.

A TXOP responder that transmits a PPDU as a result of a reverse direction grant shall set the TXVECTOR parameters CH_BANDWIDTH and CHANNEL_AGGREGATION of the PPDU to the value of the RXVECTOR parameters CH_BANDWIDTH and CHANNEL_AGGREGATION of the received EDMG PPDU addressed to the TXOP responder and that granted the reverse direction.

### 10.6.8 Multirate support for CMMG STAs

#### 10.6.8.1 Usage of CMMG Control modulation class

The CMMG Control modulation class has only one MCS, which is CMMG-MCS 0 defined in 25.6.8.14 (CMMG preamble format for sounding PPDU) with the spreading factor set to 13. The DMG Beacon, SSW-Feedback, SSW-Ack, RTS, CTS, and first BRP PPDU in beam refinement shall be transmitted using the CMMG Control modulation class. In the case of an RXSS that was specified through the Beamforming Control field in which the RXSSTxRate subfield is 1 and the RXSSTxRate Supported field in the CMMG Capabilities

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element of the STA performing the RXSS is 1, the first SSW frame of the RXSS shall be transmitted using the CMMG Control modulation class, and the remaining frames of the RXSS shall be transmitted using MCS 0 of the CMMG SC modulation class. In all other cases, the SSW frames shall be transmitted using the CMMG Control modulation class. Other CMMG beamforming training frames may be transmitted using the CMMG Control modulation class or the CMMG SC modulation class.

#### 10.6.8.2 Rate selection rules for Control frames transmitted by CMMG STAs

This subclause describes the rate selection rules for Control frames transmitted by CMMG STAs. The rate selection rules apply only for MCSs defined in Clause 25 (China millimeter-wave multi-gigabit (CMMG) PHY specification).

A Control frame that does not have an MCS defined in 10.6.8.1 (Usage of CMMG Control modulation class) and that is not a control response frame shall be transmitted using an MCS from the mandatory MCS set of the CMMG SC modulation class or CMMG Control modulation class.

A STA transmitting a Grant Ack frame shall use the CMMG Control modulation class or any MCS from the mandatory MCS set of the CMMG SC modulation class.

A STA transmitting an Ack or a BlockAck frame that is a response to a frame sent using the CMMG Control modulation class shall use the CMMG Control modulation class.

A STA transmitting an Ack frame or a BlockAck frame in response to a frame sent using the CMMG SC modulation class or CMMG OFDM modulation class shall use an MCS from the mandatory MCS set of the CMMG SC modulation class as long as

a) The selected MCS has a data rate that does not exceed the data rate of the frame that elicited the response, and
b) No other MCS satisfying condition a) results in a shorter frame transmission time.

NOTE—A control response frame is a Control frame that is transmitted within an MPDU as a response to a reception SIFS after the PPDU containing the frame that elicits the response, e.g., a CTS frame in response to an RTS frame reception, an Ack frame in response to a Data frame reception, a BlockAck frame in response to a BlockAckReq frame reception. In some situations, the transmission of some of these Control frames is not a control response transmission, such as when a DMG CTS frame is used to initiate a TXOP.

Except in an A-MPDU consisting of one of the combinations listed below, the rules in this subclause do not apply to Control frames that are contained in A-MPDUs that also include at least one MPDU with the Type subfield equal to Data or Management. In the following cases, the rate selection rules are the same as those for a standalone Ack or BlockAck frame:

— An Ack frame and a QoS Null frame
— A BlockAck frame and a QoS Null frame
— A BlockAckReq frame and a QoS Null frame
— A BlockAck frame, a BlockAckReq frame, and a QoS Null frame

#### 10.6.8.3 Rate selection for group addressed Data and Management frames transmitted by CMMG STAs

This subclause describes the rate selection rules for group addressed Data and Management frames transmitted by CMMG STAs. The rate selection rules apply only for MCSs defined in Clause 25 (China millimeter-wave multi-gigabit (CMMG) PHY specification).

If the transmit antenna pattern of a single transmission of a group addressed frame covers more than one receiver and the supported set of each of the receivers is known to the sender, then the MCS used for the


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transmission shall be an MCS common to the supported MCS sets of all of the receivers. If such an MCS is not known, the frame shall be transmitted using an MCS from the mandatory MCS set of the CMMG control or SC mode.

If the transmit antenna pattern of a single transmission of a group addressed frame covers only one receiver, the frame shall be transmitted following the rate selection rules of individually addressed frames as described in 10.6.8.4 (Rate selection for individually addressed Data and Management frames transmitted by CMMG STAs).

For SC and OFDM MIMO transmission, if the BSSBasicRateSet parameter is empty, the BSSBasicMCSSet parameter is empty, and the BSS basic CMMG-MCS and NSS set is not empty, then the frame shall be transmitted in a CMMG PPDU using one of the <CMMG-MCS, NSS> tuples included in the BSS basic CMMG-MCS and NSS set.

### 10.6.8.4 Rate selection for individually addressed Data and Management frames transmitted by CMMG STAs

This subclause describes the rate selection rules for individually addressed Data and Management frames as transmitted by CMMG STAs. The rate selection rules apply only for MCSs defined in Clause 25 (China millimeter-wave multi-gigabit (CMMG) PHY specification).

An individually addressed Data or Management frame shall be sent using an MCS supported by the receiver STA, as reported in the maximum receive MCS subfields in the Supported MCS Set field in Management frames transmitted by the receiver STA.

When the supported MCS set of the receiving STA is not known, the transmitting STA shall transmit using an MCS from the mandatory MCS set of the CMMG control or SC mode.

The rules in this subclause also apply to A-MPDUs that contain at least one MPDU with Type subfield equal to Control and at least one MPDU with Type subfield equal to Data or Management.

A Data frame or Management frame for SC and OFDM MIMO transmission shall be sent using any data rate, MCS, or <CMMG-MCS, NSS> tuple subject to the following constraints:

- A STA shall not transmit a frame using a rate or MCS that is not supported by the receiver STA, as reported in any Supported Rates and BSS Membership Selectors element, Extended Supported Rates and BSS Membership Selectors element, or Supported MCS Set field in the Management frames transmitted by the receiver STA.
- A STA shall not transmit a frame using a <CMMG-MCS, NSS> tuple that is not supported by the receiver STA, as reported in any Supported CMMG-MCS and NSS Set field in the Management frames transmitted by the receiver STA.
- If at least one CMMG Operating Mode field with the Rx NSS Type subfield equal to 0 was received from the receiver STA:
  - A STA shall not transmit a frame with the number of spatial streams greater than that indicated in the Rx NSS subfield in the most recently received CMMG Operating Mode field with the Rx NSS Type subfield equal to 0 from the receiver STA.
- A STA shall not transmit a frame using a value for the CH_BANDWIDTH parameter of the TXVECTOR that is not supported by the receiver STA, as reported in any CMMG Capabilities element received from the intended receiver.
- A STA that is a member of a BSS shall not transmit a frame using a value for the CH_BANDWIDTH parameter of the TXVECTOR that is not permitted for use in the BSS, as reported in the most recently received CMMG Operation element with the following exceptions:

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- Transmissions on a TDLS off-channel link follow the rules described in 11.20 (Tunneled direct link setup(#1356)).
- Transmissions by a CMMG STA on a (#2152)TDLS direct link follow the rules described in 11.20 (Tunneled direct link setup(#1356)).

— If at least one CMMG Operating Mode field with the Rx NSS Type subfield equal to 0 was received from the receiver STA:

- A STA shall not transmit a frame using a value for the TXVECTOR parameter CH_BANDWIDTH that is not supported by the receiver STA as reported in the most recently received CMMG Operating Mode field with the Rx NSS Type subfield equal to 0 from the receiver STA.

When the supported rate set of the receiving STA or STAs is not known, the transmitting STA shall transmit using a rate in the BSSBasicRateSet parameter, or an MCS in the BSSBasicMCSSet parameter, or a <CMMG-MCS, NSS> tuple in the BSS basic CMMG-MCS and NSS set, or a rate from the mandatory rate set of the attached PHY if the BSSBasicRateSet, the BSSBasicMCSSet, and the BSS basic CMMG-MCS and NSS set are empty.

The rules in this subclause also apply to A-MPDUs that aggregate MPDUs of type Data or Management with any other types of MPDU.

#### 10.6.8.5 Rate selection for BRP PPDUs for CMMG STAs

The first BRP PPDU transmitted from the initiator to the responder after the SLS phase shall use MCS 0.

The first BRP PPDU transmitted from the responder to the initiator after the SLS phase shall use MCS 0.

BRP PPDUs transmitted during beam refinement should use MCS 0 and shall not use any MCS greater than MCS 8. BRP PPDUs transmitted during beam refinement should use MCS 0 if the BRP PPDU is sent at start of an SP as defined in 10.38.6.2 (Service period (SP) allocation).

BRP PPDUstransmitted during the BRP setup subphase, the MID subphase, and the BC subphase shall use MCS 0.

BRP PPDUs transmitted during a BC subphase, as part of a BC subphase only training, may use MCS 0 to MCS 8. BRP PPDUs transmitted during beam tracking may use any MCS.

### 10.6.9 Multiple BSSID rate selection(#2162)

If the multiple BSSID capability is supported, Beacon frames shall be transmitted using any basic rate valid for all of the BSSs supported. If no such rate exists, then Beacon frames shall be transmitted using any mandatory PHY rate for any PHY type that all BSSs have in common.

### 10.6.10 Modulation classes

Table 10-9 (Modulation classes) defines modulation classes for the rules for response frames in 10.6 (Multirate support).


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**Table 10-9—Modulation classes**

| Description of modulation | Condition that selects this modulation class | | | |
|---|---|---|---|---|
| | **Clause 15 (DSSS PHY specification for the 2.4 GHz band designated for ISM applications) to Clause 18 (Extended Rate PHY (ERP) specification) PHYs or Clause 20 (Directional multi-gigabit (DMG) PHY specification) PHY, or Clause 24 (China directional multi-gigabit (CDMG) PHY specification) PHY, Clause 25 (China millimeter-wave multi-gigabit (CMMG) PHY specification) PHY, or Clause 28 (Enhanced directional multi-gigabit (EDMG) PHY specification(11ay)) PHY(11ay)** | **Clause 19 (High Throughput (HT) PHY specification(#2297)) PHY** | **Clause 21 (Very high throughput (VHT) PHY specification) PHY** | **Clause 27 (High-efficiency (HE) PHY specification(11ax)) PHY(11ax)** |
| DSSS and HR/ DSSS | Clause 15 (DSSS PHY specification for the 2.4 GHz band designated for ISM applications) or Clause 16 (High rate direct sequence spread spectrum (HR/DSSS) PHY specification) transmission | FORMAT is NON_HT. NON_HT_MODULATION is ERP-DSSS or ERP-CCK. | N/A | FORMAT is NON_HT. NON_HT_MODULATION is ERP-DSSS or ERP-CCK. |
| ERP-OFDM | 18.4 (ERP operating specifications (general)) transmission | FORMAT is NON_HT. NON_HT_MODULATION is ERP-OFDM. | N/A | FORMAT is NON_HT. NON_HT_MODULATION is ERP-OFDM. |
| OFDM | Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) transmission | FORMAT is NON_HT. NON_HT_MODULATION is OFDM or NON_HT_DUP_OFDM. | FORMAT is NON_HT. NON_HT_MODULATION is OFDM or NON_HT_DUP_OFDM. | FORMAT is NON_HT. NON_HT_MODULATION is OFDM or NON_HT_DUP_OFDM. |

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**Table 10-9—Modulation classes**

| Description of modulation | Condition that selects this modulation class | | | |
|---|---|---|---|---|
| | **Clause 15 (DSSS PHY specification for the 2.4 GHz band designated for ISM applications) to Clause 18 (Extended Rate PHY (ERP) specification) PHYs or Clause 20 (Directional multi-gigabit (DMG) PHY specification) PHY, or Clause 24 (China directional multi-gigabit (CDMG) PHY specification) PHY, Clause 25 (China millimeter-wave multi-gigabit (CMMG) PHY specification) PHY, or Clause 28 (Enhanced directional multi-gigabit (EDMG) PHY specification(11ay)) PHY(11ay)** | **Clause 19 (High Throughput (HT) PHY specification(#2297)) PHY** | **Clause 21 (Very high throughput (VHT) PHY specification) PHY** | **Clause 27 (High-efficiency (HE) PHY specification(11ax)) PHY(11ax)** |
| HT | N/A | FORMAT is HT_MF or HT_GF. | FORMAT is HT_MF or HT_GF. | FORMAT is HT_MF or HT_GF. |
| DMG Control | Clause 20 (Directional multi-gigabit (DMG) PHY specification) transmission and MCS is 0 | N/A | N/A | N/A |
| DMG SC | Clause 20 (Directional multi-gigabit (DMG) PHY specification) transmission and $1 \leq MCS \leq 12.6$ | N/A | N/A | N/A |
| DMG Low-power SC | Clause 20 (Directional multi-gigabit (DMG) PHY specification) transmission and $25 \leq MCS \leq 31$ | N/A | N/A | N/A |
| VHT | N/A | N/A | FORMAT is VHT. | FORMAT is VHT. |



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**Table 10-9—Modulation classes**

| Description of modulation | Condition that selects this modulation class | | | |
|---|---|---|---|---|
| | **Clause 15 (DSSS PHY specification for the 2.4 GHz band designated for ISM applications) to Clause 18 (Extended Rate PHY (ERP) specification) PHYs or Clause 20 (Directional multi-gigabit (DMG) PHY specification) PHY, or Clause 24 (China directional multi-gigabit (CDMG) PHY specification) PHY, Clause 25 (China millimeter-wave multi-gigabit (CMMG) PHY specification) PHY, or Clause 28 (Enhanced directional multi-gigabit (EDMG) PHY specification(11ay)) PHY(11ay)** | **Clause 19 (High Throughput (HT) PHY specification(#2297) ) PHY** | **Clause 21 (Very high throughput (VHT) PHY specification) PHY** | **Clause 27 (High-efficiency (HE) PHY specification(11ax)) PHY(11ax)** |
| CDMG Control | Clause 24 (China directional multi-gigabit (CDMG) PHY specification) transmission and MCS is 0 | N/A | N/A | N/A |
| CDMG SC | Clause 24 (China directional multi-gigabit (CDMG) PHY specification) transmission and $1 \leq MCS \leq 16$ | N/A | N/A | N/A |
| CDMG Low-power SC | Clause 24 (China directional multi-gigabit (CDMG) PHY specification) transmission and $17 \leq MCS \leq 23$ | N/A | N/A | N/A |
| CMMG Control | Clause 25 (China millimeter-wave multi-gigabit (CMMG) PHY specification) transmission and MCS is 0 | N/A | N/A | N/A |

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**Table 10-9—Modulation classes**

| Description of modulation | Condition that selects this modulation class | | | |
|---|---|---|---|---|
| | **Clause 15 (DSSS PHY specification for the 2.4 GHz band designated for ISM applications) to Clause 18 (Extended Rate PHY (ERP) specification) PHYs or Clause 20 (Directional multi-gigabit (DMG) PHY specification) PHY, or Clause 24 (China directional multi-gigabit (CDMG) PHY specification) PHY, Clause 25 (China millimeter-wave multi-gigabit (CMMG) PHY specification) PHY, or Clause 28 (Enhanced directional multi-gigabit (EDMG) PHY specification(11ay)) PHY(11ay)** | **Clause 19 (High Throughput (HT) PHY specification(#2297)) PHY** | **Clause 21 (Very high throughput (VHT) PHY specification) PHY** | **Clause 27 (High-efficiency (HE) PHY specification(11ax)) PHY(11ax)** |
| CMMG SC | Clause 25 (China millimeter-wave multi-gigabit (CMMG) PHY specification) transmission and $1 \leq MCS \leq 8$ | N/A | N/A | N/A |
| CMMG OFDM | Clause 25 (China millimeter-wave multi-gigabit (CMMG) PHY specification) transmission and $9 \leq MCS \leq 16$ | N/A | N/A | N/A |
| HE(11ax) | N/A | N/A | N/A | FORMAT is HE_SU, HE_ER_SU, HE_MU, or HE_TB. |



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**Table 10-9—Modulation classes**

| Description of modulation | Condition that selects this modulation class | | | |
|---|---|---|---|---|
| | **Clause 15 (DSSS PHY specification for the 2.4 GHz band designated for ISM applications) to Clause 18 (Extended Rate PHY (ERP) specification) PHYs or Clause 20 (Directional multi-gigabit (DMG) PHY specification) PHY, or Clause 24 (China directional multi-gigabit (CDMG) PHY specification) PHY, Clause 25 (China millimeter-wave multi-gigabit (CMMG) PHY specification) PHY, or Clause 28 (Enhanced directional multi-gigabit (EDMG) PHY specification(11ay)) PHY(11ay)** | **Clause 19 (High Throughput (HT) PHY specification(#2297)) PHY** | **Clause 21 (Very high throughput (VHT) PHY specification) PHY** | **Clause 27 (High-efficiency (HE) PHY specification(11ax)) PHY(11ax)** |
| EDMG Control(11ay) | Clause 28 (Enhanced directional multi-gigabit (EDMG) PHY specification(11ay)) transmission<br><br>FORMAT is EDMG and EDMG_MODULATION is EDMG_C_MODE | N/A | N/A | N/A |
| EDMG SC(11ay) | Clause 28 (Enhanced directional multi-gigabit (EDMG) PHY specification(11ay)) transmission<br><br>FORMAT is EDMG, EDMG_MODULATION is EDMG_SC_MODE | N/A | N/A | N/A |

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**Table 10-9—Modulation classes**

| Description of modulation | Condition that selects this modulation class | | | |
|---|---|---|---|---|
| | **Clause 15 (DSSS PHY specification for the 2.4 GHz band designated for ISM applications) to Clause 18 (Extended Rate PHY (ERP) specification) PHYs or Clause 20 (Directional multi-gigabit (DMG) PHY specification) PHY, or Clause 24 (China directional multi-gigabit (CDMG) PHY specification) PHY, Clause 25 (China millimeter-wave multi-gigabit (CMMG) PHY specification) PHY, or Clause 28 (Enhanced directional multi-gigabit (EDMG) PHY specification(11ay)) PHY(11ay)** | **Clause 19 (High Throughput (HT) PHY specification(#2297)) PHY** | **Clause 21 (Very high throughput (VHT) PHY specification) PHY** | **Clause 27 (High-efficiency (HE) PHY specification(11ax)) PHY(11ax)** |
| EDMG OFDM(11ay) | Clause 28 (Enhanced directional multi-gigabit (EDMG) PHY specification(11ay)) transmission<br><br>FORMAT is EDMG, EDMG_MODULATION is EDMG_OFDM_MODE | N/A | N/A | N/A |



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### 10.6.11 Non-HT basic rate calculation

This subclause defines how to convert an HT-MCS, (11ax)a VHT-MCS, or an HE-MCS to a non-HT basic rate for the purpose of determining the rate of the response frame. It consists of two steps as follows:

a) Use the modulation and coding rate determined from the HT-MCS (defined in 19.5 (Parameters for HT-MCSs)), VHT-MCS (defined in 21.5 (Parameters for VHT-MCSs)), or HE-MCS (defined in 27.5 (Parameters for HE-MCSs))(11ax) to locate a non-HT reference rate by lookup into Table 10-10 (Non-HT reference rate).[26] In the case of an MCS with UEQM, the modulation of stream 1 is used.

b) (#4078)The non-HT basic rate is the highest rate in the BSSBasicRateSet that is less than or equal to this non-HT reference rate.

**Table 10-10—Non-HT reference rate**

| Modulation | Coding rate (R) | Non-HT reference rate (Mb/s) |
|---|---|---|
| BPSK | 1/2 | 6 |
| BPSK | 3/4 | 9 |
| QPSK | 1/2 | 12 |
| QPSK | 3/4 | 18 |
| 16-QAM | 1/2 | 24 |
| 16-QAM | 3/4 | 36 |
| 64-QAM | 1/2 | 48 |
| 64-QAM | 2/3 | 48 |
| 64-QAM | 3/4 | 54 |
| 64-QAM | 5/6 | 54 |

[26] For example, if an HT PPDU transmission uses 64-QAM and coding rate of 3/4, the related non-HT reference rate is 54 Mb/s.

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**Table 10-10—Non-HT reference rate *(continued)***

| Modulation | Coding rate (R) | Non-HT reference rate (Mb/s) |
|---|---|---|
| 256-QAM | 3/4 | 54 |
| 256-QAM | 5/6 | 54 |
| 1024-QAM(11ax) | 3/4 | 54 |
| 1024-QAM(11ax) | 5/6 | 54 |

NOTE 1—The selection of a non-HT basic rate for the frame sent in response to an HE PPDU is not influenced by DCM encoding in the HE PPDU.(11ax)

NOTE 2—In a TVWS band, the non-HT reference rate is scaled as described in 22.2.4 (Support for NON_HT and HT formats).

### 10.6.12 Channel Width in non-HT and non-HT duplicate PPDUs

A non-VHT STA shall include neither the CH_BANDWIDTH_IN_NON_HT parameter nor the DYN_BANDWIDTH_IN_NON_HT parameter in either of the TXVECTOR or RXVECTOR for NON_HT PPDUs. A non-VHT STA shall not set the TA field to a bandwidth signaling TA. A VHT STA shall include neither the CH_BANDWIDTH_IN_NON_HT parameter nor the DYN_BANDWIDTH_IN_NON_HT parameter in the TXVECTOR of a non-HT PPDU containing frames addressed to a non-VHT STA. A VHT STA shall not set the TA field to a bandwidth signaling TA in a frame addressed to a non-VHT STA. (11ax)The TA field shall not be set to a bandwidth signaling TA in a frame carried in a DSSS/CCK PPDU. A VHT STA that includes the DYN_BANDWIDTH_IN_NON_HT parameter in the TXVECTOR shall also include the CH_BANDWIDTH_IN_NON_HT parameter in the TXVECTOR. A VHT STA shall not include the DYN_BANDWIDTH_IN_NON_HT parameter in the TXVECTOR for transmitted frames other than RTS frames with bandwidth signaling TA and that are sent in a non-HT PPDU. A STA that transmits an RTS frame with a bandwidth signaling TA shall include the DYN_BANDWIDTH_IN_NON_HT parameter in the TXVECTOR. A VHT STA shall include both the CH_BANDWIDTH_IN_NON_HT and DYN_BANDWIDTH_IN_NON_HT parameters in the RXVECTOR if the PPDU format is NON_HT.

A bandwidth signaling TA may be included in non-HT and non-HT duplicate PPDUs and shall not be included in other PPDUs. If the TXVECTOR parameter CH_BANDWIDTH_IN_NON_HT is present and a Control frame other than a CTS is being transmitted, then the TA field shall be set to a bandwidth signaling TA; otherwise, the TA field shall be set to an individual address.

NOTE—A CTS frame, even though it does not have a TA field, can also be transmitted with the TXVECTOR parameter CH_BANDWIDTH_IN_NON_HT present.

An S1G STA transmitting a Control frame that is not a control response frame shall set the Bandwidth Indication field in the Frame Control field of the frame to a value that is equivalent to the TXVECTOR parameter CH_BANDWIDTH.

An S1G STA shall not transmit a Control frame or an NDP CMAC PPDU with the TXVECTOR parameter S1G_DUP_1M to another S1G STA, unless the Duplicate 1 MHz Support field of the S1G Capabilities element received from that STA contained a value of 1.

An S1G STA transmitting a Control frame that is sent as a response to a Control frame shall set the Bandwidth Indication field in the Frame Control field of the frame to the value of the Bandwidth Indication field in the Frame Control field of the eliciting frame, except for an S1G STA that has indicated the use


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of 1 MHz control response frames (see 10.6.6.6 (Channel Width selection for Control frames)) in which case the Bandwidth Indication field in the Frame Control field of the solicited Control frame shall be set to 0.

An S1G STA shall set the Dynamic Indication field in the Frame Control field of Control frames, other than RTS frame, to 0.

The TXVECTOR parameter CH_BANDWIDTH_IN_NON_HT shall not be present in PPDUs carrying Management or Data frames.

### 10.6.13 Rate selection constraints for VHT STAs

#### 10.6.13.1 Rx Supported VHT-MCS and NSS Set

The Rx Supported VHT-MCS and NSS Set of a first VHT STA is determined by a second VHT STA for each <VHT-MCS, NSS> tuple NSS = 1, …, 8 and bandwidth (20 MHz, 40 MHz, 80 MHz, and 160 MHz or 80+80 MHz) from the Supported VHT-MCS and NSS Set field received from the first STA as follows:

- If support for the VHT-MCS for NSS spatial streams at that bandwidth is mandatory (see 21.5 (Parameters for VHT-MCSs)), then the <VHT-MCS, NSS> tuple at that bandwidth is supported by the first STA on receive.
- Otherwise, if the Max VHT-MCS For *n* SS subfield (*n* = NSS) in the Rx VHT-MCS Map subfield indicates support and the Rx Highest Supported Long GI Data Rate subfield is equal to 0, then
  - the <VHT-MCS, NSS> tuple at that bandwidth is supported by the first STA on receive, except that if dot11VHTExtendedNSSBWCapable of the second STA is true, the supported bandwidth values and NSS values of each <VHT-MCS, NSS> tuple are updated according to Table 9-314 (Setting of the Supported Channel Width Set subfield and Extended NSS BW Support subfield at a STA transmitting the VHT Capabilities Information field) if no Operating Mode Notification frame(#7113) has been received from the first STA, otherwise, according to Table 9-111 (Setting of the Channel Width subfield and 160/80+80 BW subfield at a VHT STA transmitting the Operating Mode field), wherein the VHT Capabilities Information field and the Operating Mode field have been transmitted by the first STA.
- Otherwise, if the Max VHT-MCS For *n* SS subfield (*n* = NSS) in the Rx VHT-MCS Map subfield indicates support and the data rate for long GI of the MCS for NSS spatial streams at that bandwidth (expressed as the largest integer in Mb/s that is less than or equal to the data rate) is less than or equal to the rate represented by the Rx Highest Supported Long GI Data Rate subfield, then
  - the <VHT-MCS, NSS> tuple at that bandwidth is supported by the first STA on receive, except that if dot11VHTExtendedNSSBWCapable of the second STA is true, the supported bandwidth values and NSS values of each <VHT-MCS, NSS> tuple are updated according to Table 9-314 (Setting of the Supported Channel Width Set subfield and Extended NSS BW Support subfield at a STA transmitting the VHT Capabilities Information field) if no Operating Mode Notification frame(#7113) has been received from the first STA, otherwise, according to Table 9-111 (Setting of the Channel Width subfield and 160/80+80 BW subfield at a VHT STA transmitting the Operating Mode field), wherein the VHT Capabilities Information field and the Operating Mode field have been transmitted by the first STA.
- Otherwise, the <VHT-MCS, NSS> tuple at that bandwidth is not supported by the first STA on receive.

The <VHT-MCS, NSS> tuples excluded by 10.6.13.3 (Additional rate selection constraints for VHT PPDUs) are also eliminated from the Rx Supported VHT-MCS and NSS Set.

A VHT STA shall not, unless explicitly stated otherwise, transmit a VHT PPDU unless the <VHT-MCS, NSS> tuple and bandwidth used are in the Rx Supported VHT-MCS and NSS Set of the receiving STA(s).

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NOTE 1—Support for a <VHT-MCS, NSS> tuple at a given bandwidth implies support for both long GI and short GI on receive, if short GI is supported at that bandwidth.

NOTE 2—A STA can determine the expected interpretation of its Supported Channel Width Set and Channel Width and 160/80+80 BW and Extended NSS BW Support fields at a recipient by examining the VHT Extended NSS BW Capable field value in the Supported VHT-MCS and NSS Set field of the recipient.

### 10.6.13.2 Tx Supported VHT-MCS and NSS Set

The Tx Supported VHT-MCS and NSS Set of a first VHT STA is determined by a second STA for each <VHT-MCS, NSS> tuple NSS = 1, …, 8 and bandwidth (20 MHz, 40 MHz, 80 MHz, and 160 MHz or 80+80 MHz) from the Supported VHT-MCS and NSS Set field received from the first STA as follows:

- If support for the <VHT-MCS, NSS> tuple at that bandwidth is mandatory (see 21.5 (Parameters for VHT-MCSs)), then the <VHT-MCS, NSS> tuple at that bandwidth is supported by the first STA on transmit.
- Otherwise, if the Max VHT-MCS for *n* SS subfield (*n* = NSS) in the Tx VHT-MCS Map subfield indicates support and the Tx Highest Supported Long GI Data Rate subfield is equal to 0, then
  - The <VHT-MCS, NSS> tuple at that bandwidth is supported by the first STA on transmit, except that if dot11VHTExtendedNSSBWCapable of the second STA is true, the supported bandwidth values and NSS values of each <VHT-MCS, NSS> tuple are updated according to Table 9-314 (Setting of the Supported Channel Width Set subfield and Extended NSS BW Support subfield at a STA transmitting the VHT Capabilities Information field) if no Operating Mode Notification frame(#7113) has been received from the first STA, otherwise, according to Table 9-111 (Setting of the Channel Width subfield and 160/80+80 BW subfield at a VHT STA transmitting the Operating Mode field), wherein the VHT Capabilities Information field and the Operating Mode field have been transmitted by the first STA.
- Otherwise, if the Max VHT-MCS for *n* SS subfield (*n* = NSS) in the Tx VHT-MCS Map subfield indicates support and the data rate for long GI of the <VHT-MCS, NSS> tuple at that bandwidth (expressed as the largest integer in Mb/s that is less than or equal to the data rate) is less than or equal to the rate represented by the Tx Highest Supported Long GI Data Rate subfield, then
  - The <VHT-MCS, NSS> tuple at that bandwidth is supported by the first STA on transmit, except that if dot11VHTExtendedNSSBWCapable of the second STA is true, the supported bandwidth values and NSS values of each <VHT-MCS, NSS> tuple are updated according to Table 9-314 (Setting of the Supported Channel Width Set subfield and Extended NSS BW Support subfield at a STA transmitting the VHT Capabilities Information field) if no Operating Mode Notification frame(#7113) has been received from the first STA, otherwise, according to Table 9-111 (Setting of the Channel Width subfield and 160/80+80 BW subfield at a VHT STA transmitting the Operating Mode field), wherein the VHT Capabilities Information field and the Operating Mode field have been transmitted by the first STA.
- Otherwise, the <VHT-MCS, NSS> tuple at that bandwidth is not supported by the first STA on transmit.

NOTE 1—In contrast to reception, support for short GI transmissions by a STA cannot be determined by other STAs.

NOTE 2—A STA can determine the expected interpretation of its Supported Channel Width Set and Channel Width and 160/80+80 BW and Extended NSS BW Support fields at a recipient by examining the VHT Extended NSS BW Capable field value in the Supported VHT-MCS and NSS Set field of the recipient.

### 10.6.13.3 Additional rate selection constraints for VHT PPDUs

(11ax)A STA should not transmit a 20 MHz or 40 MHz VHT PPDU with a <VHT-MCS, NSS> tuple that has VHT-MCS 0, 1, 2, or 3 and NSS less than or equal to 4 to a receiver STA that has marked as unsupported the HT-MCS with value VHT-MCS + 8 × (NSS – 1) in the Rx MCS Bitmask subfield in the


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Supported MCS Set field in the HT Capabilities element it transmits. The transmission of a 20 MHz or 40 MHz VHT PPDU with VHT-MCS greater than 3 is not subject to this constraint.

(11ax)A STA should not transmit an 80 MHz, 160 MHz, or 80+80 MHz VHT PPDU with a <VHT-MCS, NSS> tuple that has VHT-MCS 0 or 1 and NSS less than or equal to 4 to a receiver STA that has marked as unsupported the HT-MCS values of both 2 × VHT-MCS + 8 × (NSS – 1) and 2 × VHT-MCS + 1 + 8 × (NSS – 1) in the Rx MCS Bitmask subfield in the Supported MCS Set field in the HT Capabilities element it transmits. The transmission of an 80 MHz, 160 MHz, or 80+80 MHz VHT PPDU with VHT-MCS greater than 1 is not subject to this constraint.

An example tabulation of this behavior is given in Table 10-11 (Example of rate selection for VHT PPDUs).

**Table 10-11—Example of rate selection for VHT PPDUs**

| HT-MCSs that are marked as unsupported | <VHT-MCS, NSS> tuples that are not used for CBW20 and CBW40 | <VHT-MCS, NSS> tuples that are not used for CBW80, CBW160, and CBW80+80 |
|---|---|---|
| 0, 8, 16 | <0, 1>, <0, 2>, <0, 3> | — |
| 1, 9 | <1, 1>, <1, 2> | — |
| 10 | <2, 2> | — |
| 3 | <3, 1> | — |
| 0, 1 | <0, 1>, <1, 1> | <0, 1> |
| 2, 3 | <2, 1>, <3, 1> | <1, 1> |
| 0, 1, 8, 9 | <0, 1>, <1, 1>, <0, 2>, <1, 2> | <0, 1>, <0, 2> |

### 10.6.14 Rate selection constraints for S1G STAs

#### 10.6.14.1 RX Supported S1G-MCS and NSS Set

The Rx Supported S1G-MCS and NSS Set of an S1G STA is determined for each <S1G-MCS, NSS> tuple NSS = 1, …, 4 and bandwidth (1 MHz, 2 MHz, 4 MHz, 8 MHz, and 16 MHz) from its Supported S1G-MCS and NSS Set field and Extended Supported S1G-MCS and NSS Set field(M102) as follows:

— If the Extended Supported S1G-MCS and NSS Set field is present then if the Ext Max S1G-MCS For n SS subfield (n = NSS) in the Ext Rx S1G-MCS Map field indicates support then the <S1G-MCS, NSS> tuple at that bandwidth is supported by the STA on receive.(M102)

— Otherwise(M102), if support for the S1G-MCS for NSS spatial streams at that bandwidth is mandatory (see 23.5 (Parameters for S1G-MCSs)), then the <S1G-MCS, NSS> tuple at that bandwidth is supported by the STA on receive.

— Otherwise, if the Max S1G-MCS For n SS subfield (n = NSS) in the Rx S1G-MCS Map field indicates support and the Rx Highest Supported Long GI Data Rate subfield is equal to 0, then the <S1G-MCS, NSS> tuple at that bandwidth is supported by the STA on receive.

— Otherwise, if the Max S1G-MCS For n SS subfield (n = NSS) in the Rx S1G-MCS Map subfield indicates support and the data rate (expressed in Mb/s(#4148)) for long GI of the MCS for NSS spatial streams at that bandwidth (if the data rate is not an integer, the data rate value is rounded down to the next integer) is less than or equal to the rate represented by the Rx Highest Supported Long GI Data Rate subfield, then the <S1G-MCS, NSS> tuple at that bandwidth is supported by the STA on receive.

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— Otherwise the <S1G-MCS, NSS> tuple at that bandwidth is not supported by the STA on receive.

An S1G STA shall not, unless explicitly stated otherwise, transmit an S1G PPDU unless the <S1G-MCS, NSS> tuple and bandwidth used are in the Rx Supported S1G-MCS and NSS Set of the receiving STA(s) or the Extended Supported S1G-MCS and NSS Set.(M102)

NOTE—Support for a <S1G-MCS, NSS> tuple at a given bandwidth implies support for long GI.

### 10.6.14.2 TX Supported S1G-MCS and NSS Set

The Tx Supported S1G-MCS and NSS Set of an S1G STA is determined for each <S1G-MCS, NSS> tuple NSS = 1, …, 4 and bandwidth (1 MHz, 2 MHz, 4 MHz, 8 MHz, and 16 MHz) from its Supported S1G-MCS and NSS Set field and Extended Supported S1G-MCS and NSS Set field(M102) as follows:

— If the Extended Supported S1G-MCS and NSS Set field is present then if the Ext Max S1G-MCS for n SS subfield (n = NSS) in the Ext Tx S1G-MCS Map subfield indicates support then the <S1G-MCS, NSS> tuple at that bandwidth is supported by the STA on transmit.(M102)

— Otherwise(M102), if support for the <S1G-MCS, NSS> tuple at that bandwidth is mandatory (see 23.5 (Parameters for S1G-MCSs)), then the <S1G-MCS, NSS> tuple at that bandwidth is supported by the STA on transmit.

— Otherwise if the Max S1G-MCS for n SS subfield (n = NSS) in the Tx S1G-MCS Map subfield indicates support and the Tx Highest Supported Long GI Data Rate subfield is equal to 0, then the <S1G-MCS, NSS> tuple at that bandwidth is supported by the STA on transmit.

— Otherwise if the Max S1G-MCS for n SS subfield (n = NSS) in the Tx S1G-MCS Map subfield indicates support and the data rate (expressed in Mb/s(#4148)) for long GI of the <S1G-MCS, NSS> tuple at that bandwidth (if the data rate is not an integer, the data rate value is rounded down to the next integer) is less than or equal to the rate represented by the Tx Highest Supported Long GI Data Rate subfield, then the <S1G-MCS, NSS> tuple at that bandwidth is supported by the STA on transmit.

— Otherwise the <S1G-MCS, NSS> tuple at that bandwidth is not supported by the STA on transmit.

### 10.6.14.3 Additional rate selection constraints for S1G PPDUs

The following apply for a STA that transmits an S1G PPDU:

— If the channel width of the PPDU is equal to CBW1, CBW2, CBW4, CBW8 or CBW16, then the STA should not use a <S1G-MCS, NSS> tuple if the S1G-MCS is equal to 0 and the Min S1G-MCS For n SS subfield in the Basic S1G-MCS and NSS Set field of the S1G Operation element of the receiver STA is equal to 1.

— If the channel width of the PPDU is equal to CBW1, CBW2, CBW4, CBW8 or CBW16, then the STA should not use a <S1G-MCS, NSS> tuple if the S1G-MCS is equal to 0 or 1 and the Min S1G-MCS For n SS subfield in the Basic S1G-MCS and NSS Set field of the S1G Operation element of the receiver STA is equal to 2.

If the channel width of the PPDU is equal to CBW1, then the STA should not use a <S1G-MCS, NSS> tuple if the S1G-MCS is equal to 10 and the B7 of the Channel Width subfield in the S1G Operation Information field of the S1G Operation element of the receiver STA is equal to 0.


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### 10.6.15 Rate selection constraints for CMMG STAs

#### 10.6.15.1 Rx supported CMMG-MCS and NSS set

The Rx supported CMMG-MCS and NSS set of a CMMG STA is determined for each <CMMG-MCS, NSS> tuple NSS = 1,…, 4 and bandwidth (540 MHz and 1080 MHz) from its Supported CMMG-MCS and NSS Set field as follows:

— If support for the CMMG-MCS for NSS spatial streams at that bandwidth is mandatory (see 25.15 (Parameters for CMMG-MCSs)), then the <CMMG-MCS, NSS> tuple at that bandwidth is supported by the STA on receive.

— Otherwise, the <CMMG-MCS, NSS> tuple at that bandwidth is not supported by the STA on receive.

A CMMG STA shall not, unless explicitly stated otherwise, transmit a CMMG PPDU unless the <CMMG-MCS, NSS> tuple and bandwidth used are in the Rx Supported CMMG-MCS and NSS Set of the receiving STA(s).

#### 10.6.15.2 Tx supported CMMG-MCS and NSS set

The Tx supported CMMG-MCS and NSS set of a CMMG STA is determined for each <CMMG-MCS, NSS> tuple NSS = 1,…, 4 and bandwidth (540 MHz and 1080 MHz) from its Supported CMMG-MCS and NSS Set field as follows:

— If support for the <CMMG-MCS, NSS> tuple at that bandwidth is mandatory (see 25.15 (Parameters for CMMG-MCSs)), then the <CMMG-MCS, NSS> tuple at that bandwidth is supported by the STA on transmit.

— Otherwise, the <CMMG-MCS, NSS> tuple at that bandwidth is not supported by the STA on transmit.

## 10.7 MSDU transmission restrictions

To avoid reordering MSDUs between pairs of LLC entities and/or unnecessarily discarding MSDUs, the following restrictions shall be observed by any STA that is able to concurrently process multiple outstanding MSDUs for transmission. The term *outstanding* refers to an MPDU containing all or part of an MSDU or MMPDU for which transmission has been started, and for which delivery of the MSDU or MMPDU has not yet been completed (i.e., an acknowledgment of the final fragment or only corresponding MPDU has not been received and the MSDU or MMPDU has not been discarded due to retries, lifetime, or for some other reason). A STA may have any number (greater than or equal to one) of eligible MSDUs outstanding concurrently, subject to the restrictions below.

A non-QoS STA shall have outstanding at any time:

— No more than one MSDU from any particular SA, and

— No more than one MMPDU

transmitted in one or more MPDUs with a particular individual RA.

NOTE 1—A simpler, more restrictive alternative to the rule in the above paragraph that might be used is that no more than one MSDU transmitted in one or more MPDUs with a particular individual RA be outstanding at any time.

For frames that are not sent within the context of a block ack agreement, a QoS STA shall have outstanding at any time:

— No more than one MSDU or A-MSDU for each TID from any particular SA, and

— No more than one MMPDU

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transmitted in one or more MPDUs with a particular individual RA.

NOTE 2—A simpler, more restrictive alternative to the rule in the above paragraph that might be used is that no more than one MSDU or A-MSDU with any particular TID transmitted in one or more MPDUs with a particular individual RA be outstanding at any time.

A STA should select a value of dot11MaxTransmitMSDULifetime that is sufficiently large that the STA does not discard MSDUs or MMPDUs due to the transmit MSDU/MMPDU timer being exceeded, under normal operating conditions.

An A-MSDU shall contain only MSDUs of a single service class and inherits that service class for the purpose of the following rules. For MSDUs or A-MSDUs belonging to the service class of QoSAck when the receiver is a QoS STA, the QoS Data frames that are used to send these MSDUs or A-MSDUs shall have Normal Ack, Implicit BAR, (#3263)or Block Ack ack policy. For MSDUs or A-MSDUs belonging to the service class of QoSNoAck when the receiver is a QoS STA, the QoS Data frames that are used to send these MSDUs or A-MSDUs shall have No Ack ack policy.

## 10.8 HT Control field operation

If dot11HTControlFieldSupported is true, a STA shall set the +HTC-HT Support subfield of the HT Extended Capabilities field of the HT Capabilities element to 1 in HT Capabilities elements that it transmits. If dot11VHTControlFieldOptionImplemented is true, a STA shall set the +HTC-VHT Support subfield of the VHT Capabilities Information field of the VHT Capabilities element to 1 in VHT Capabilities elements that it transmits. If dot11HEControlFieldOptionImplemented is true, a STA shall set the +HTC-HE Support subfield in the HE MAC Capabilities Information field to 1 in the HE Capabilities elements that it transmits.(11ax)

A STA in which at least one of dot11RDResponderOptionImplemented, dot11MCSFeedbackOptionImplemented, and dot11AlternateEDCAActivated is (11ax)equal to true shall set dot11HTControlFieldSupported or dot11VHTControlFieldOptionImplemented or both equal to true. A STA that has at least one of dot11TRSOptionImplemented, dot11OMIOptionImplemented, dot11HEBSRControlImplemented, dot11HEBQRControlImplemented, dot11RDResponderOptionImplemented, and dot11SRResponderOptionImplemented equal to true or has dot11HEMCSFeedbackOptionImplemented greater than zero shall set dot11HEControlFieldOptionImplemented to true. An HE AP shall set dot11HEControlFieldOptionImplemented to true.(11ax)

An HT variant HT Control field shall not be present in a frame addressed to a STA unless that STA declares support for +HTC-HT in the HT Extended Capabilities field of its HT Capabilities element (see 9.4.2.54 (HT Capabilities element)).

A VHT variant HT Control field shall not be present in a frame addressed to a STA unless that STA declares support for +HTC-VHT in the VHT Capabilities Information field of its VHT Capabilities element or in the S1G Capabilities Information field of S1G Capabilities elements that it transmits.

NOTE—An HT STA that does not support +HTC (HT, VHT or HE(11ax) variant) that receives a +HTC frame addressed to another STA still performs the CRC on the actual length of the MPDU and uses the Duration/ID field to update the NAV, as described in 10.3.2.4 (Setting and resetting the NAV).

(11ax)An HE variant HT Control field shall not be present in a frame addressed to a STA, unless that STA declares support for +HTC-HE in the HE MAC Capabilities Information field in the HE Capabilities element.


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The HE variant HT Control field carried in the frame may contain one or more Control subfields under the conditions listed in Table 10-12 (Conditions for including Control subfield variants(11ax)).

**Table 10-12—Conditions for including Control subfield variants(11ax)**

| Control subfield variant | Condition |
|---|---|
| TRS | The transmitting AP expects an HE TB PPDU that follows the TRS information as described in 26.5.2.2 (Rules for soliciting UL MU frames) and the recipient non-AP STA has set the TRS Support subfield in the HE MAC Capabilities Information field in the HE Capabilities elements it transmits to 1. |
| OM | The transmitting STA changes its operating mode, as described in 26.9 (Operating mode indication) and the recipient STA has set the OM Control Support subfield in the HE MAC Capabilities Information field in the HE Capabilities elements it transmits to 1. |
| HLA | The transmitting STA follows the HE link adaptation procedure, as described in 26.13 (Link adaptation using the HLA Control subfield) and the recipient STA has set the HE Link Adaptation Support subfield in the HE MAC Capabilities Information field in the HE Capabilities elements it transmits to a nonzero value. |
| BSR | The transmitting non-AP STA follows the corresponding buffer status report procedure, as described in 26.5.5 (Buffer status report operation) and the recipient AP has set the BSR Support subfield in the HE MAC Capabilities Information field in the HE Capabilities elements it transmits to 1. |
| UPH | The transmitting non-AP STA follows the UL MU operation procedure, as described in 26.5.2.3 (Non-AP STA behavior for UL MU operation). |
| BQR | The transmitting non-AP STA follows the bandwidth query report procedure, as described in 26.5.2 (UL MU operation) and the recipient AP has set the BQR Support subfield in the HE MAC Capabilities Information field in the HE Capabilities elements it transmits to 1. |
| CAS | The transmitting STA follows either:<br>— The reverse direction protocol procedure described in 10.29 and the recipient STA has set the RD Responder in the HT Extended Capabilities field in the HT Capabilities elements it transmits to 1, or<br>— The PSR procedure described in 26.10.3 (PSR-based spatial reuse operation) and the recipient STA has set the PSR Responder subfield of the HE MAC Capabilities Information field in the HE Capabilities elements it transmits to 1.(#3034) |
| ONES | The transmitting STA may include a ONES Control subfield in an MPDU that is not carried in an HE TB PPDU (see 26.5.2.4 (A-MPDU contents in an HE TB PPDU)). |

If the HT Control field is present in an MPDU aggregated in an A-MPDU, then all MPDUs of the same frame type (i.e., having the same value for the Type subfield of the Frame Control field) aggregated in the same A-MPDU shall contain the same HT Control field. If MSDU(s) received in an MPDU are delivered via an MA-UNITDATA.indication, the drop eligible parameter of the MA-UNITDATA.indication is set to true if the MPDU contains an HT variant HT Control field and the DEI subfield is equal to 1 and set to false otherwise.

(11ax)An HE STA that transmits a frame containing an A-Control subfield shall include at least one Control subfield in the A-Control subfield, and the included Control subfields shall be those that are supported by the receiving STAs, unless the Control ID subfield is 15.

(11ax)An HE STA that receives a Control subfield in an A-Control subfield with a Control ID subfield value that is not recognized or not supported by the HE STA shall ignore the Control subfield and the remainder of

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the A-Control subfield. If more than one Control subfield is present in an A-Control subfield, the Control subfields shall not have the same Control ID value.

(11ax)An HE STA that receives a ONES Control subfield shall ignore the remainder of the A-Control subfield.

If the HT variant HT Control field is present in an MPDU, the DEI subfield provides information on the drop eligibility of the contents of the received MPDU. (#7143)With the information from the DEI subfield, a STA may selectively (#3683)discard frames with the DEI subfield set to 1 in preference to frames with the DEI subfield set to 0, if resources are insufficient. Note that this might not help in the recovery in all conditions, and the STA might still have to fall back to (#7143)an arbitrary discard strategy. The mechanisms for determining whether resources are insufficient or when to discard MSDUs or A-MSDUs are beyond the scope of this standard.

If the value of dot11S1GControlFieldOptionImplemented is true, an S1G STA shall set the +HTC-VHT Capable subfield of the S1G Capabilities Information field of the S1G Capabilities element that it transmits to 1.

An S1G shall not use an HT Control field other than a VHT variant HT Control field. An S1G STA shall not use a VHT variant HT Control field for any purpose other than link adaptation (see 10.31.3 (Link adaptation using the VHT variant HT Control field)).

## 10.9 Control Wrapper operation

A STA supporting the HT Control field that receives a Control Wrapper frame shall process it as though it received a frame of the subtype of the wrapped frame(#6145). An HE STA shall not send a Control Wrapper frame to another HE STA. (11ax)

## 10.10 MSDU processing

A STA can use the U-PID element transmitted in ADDTS Request, DMG ADDTS Request, ADDTS Response and DMG ADDTS Response frames to indicate the upper layer protocol responsible for handling MSDUs corresponding to the TID indicated within the frame carrying the U-PID element (see 11.4.4.4 (TS setup procedures for both AP and non-AP STA initiation)).

A STA that participates in a successful ADDTS exchange that included a U-PID element in the ADDTS Response or DMG ADDTS Response frame with the LLC Header Removed field equal to 1 shall strip the number of octets in the LLC Header Copy field of the U-PID element from the start of an MSDU (received in an MA-UNITDATA.request.primitive) corresponding to the TID indicated in the ADDTS exchange before transmission of the MSDU to the peer STA.

(#6025)NOTE 1—The MSDU in the MA-UNITDATA.request.primitive must start with the octets specified in the LLC Header Copy field.

NOTE 2—The STA does not verify that the MSDU does indeed start with the octets specified in the LLC Header Copy field.

A STA that participates in a successful ADDTS exchange that included a U-PID element in the ADDTS Response or DMG ADDTS Response frame with the LLC Header Removed field equal to 1 and that receives from the peer STA an MSDU corresponding to the TID indicated in the ADDTS exchange shall insert the octets in the LLC Header Copy field of the U-PID element at the start of the MSDU before delivery of the MSDU (in an MA-UNITDATA.indication.primitive).


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NOTE 3—If the LLC Header Removed field is equal to 0, the LLC Header Copy field in the U-PID element is ignored, except for possible implementation-dependent local optimizations.

## 10.11 A-MSDU operation

An A-MSDU contains only MSDUs whose DA parameter values map to a single RA (#462)field value and whose SA parameter values map to a single TA(#3522) (see 9.3.2.2 (Aggregate MSDU (A-MSDU) format)).

(#462)Specifically, for a frame containing an A-MSDU, if the frame is a three-address frame, or a four-address frame in a context defined by this standard:

NOTE 1—This standard defines use of four-address frames in the content of transmissions by a mesh STA (see 10.37 (Mesh forwarding framework)), an S1G relay STA or AP (see 10.53 (S1G relay operation)) or a GLK STA (see 10.64 (Addressing of GLK Data frame transmission)).

— The RA may be a group address if all of the following conditions are met:
  — the frame is from an AP or PCP, or between IBSS, PBSS or mesh STAs
  — the DAs in all A-MSDU subframe headers are group addresses, or the frame is transmitted under GLK and the RA is a SYNRA

  Otherwise, the RA shall be an individual address.

  NOTE 2—STAs conformant with a previous revision of this standard might not accept a group addressed frame containing an A-MSDU, outside the context of a GCR concealment address or a GLK SYNRA, where supported.

— Each DA shall be the RA or, except if the A-MSDU is transmitted on a TDLS direct link, a group address, if none of the following conditions is met:
  — the frame is to an AP or associated PCP
  — the frame is transmitted under DMG relay or S1G relay operation
  — the frame is from a GLK STA
  — the frame is from a mesh STA

  Otherwise, there is no restriction on each DA, except that the first six octets of the first A-MSDU subframe header (the mesh DA, if the frame is from a mesh STA, or the DA in a Basic A-MSDU not from a mesh STA) shall not be AA-AA-03-00-00-00.

  NOTE 3—The address AA-AA-03-00-00-00 is that which results from an attack in which an encrypted QoS Data frame not containing an A-MSDU (whose unencrypted frame body therefore starts with an LLC header followed by a SNAP header constructed per IETF RFC 1042) has the A-MSDU Present subfield changed to 1 by an attacker to cause it to appear to be a payload protected A-MSDU (PP A-MSDU) with multiple MSDUs (each preceded by an A-MSDU subframe header, which starts with the DA or mesh DA).

— Each SA shall be the nonbandwidth signaling TA if none of the following conditions is met:
  — the frame is from an AP or PCP
  — the frame is transmitted under DMG relay or S1G relay operation
  — the frame is from a GLK STA
  — the frame is from a mesh STA

  Otherwise, each SA shall be an individual address.

  NOTE 4—The DA and SA are contained in the DA and SA subfields, respectively, where present, in A-MSDU subframes that are not transmitted in mesh Data frames (Basic A-MSDU subframes transmitted in mesh Data frames contain the mesh DA and mesh SA).

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NOTE 5—Frames not to an AP or associated PCP and frames not from an AP or PCP include frames transmitted between TDLS peer STAs or between IBSS, non-PCP PBSS or mesh STAs.

— In an MBSS,
  — each mesh STA, including the mesh SA in the Address 3 or Address 4 field if present (see Table 9-77 (Address field contents for mesh Data and Multihop Action frames(#462)(#419))), shall be the same individual address
  — in an individually addressed frame, each mesh DA that is an individual address, including the mesh DA in the Address 3 field (see Table 9-77 (Address field contents for mesh Data and Multihop Action frames(#462)(#419))), shall be the same individual address
  — in a group addressed frame, each mesh DA, and the DA in the Address 1 field (see Table 9-77 (Address field contents for mesh Data and Multihop Action frames(#462)(#419))), shall be the same group address.

(#462)A STA that receives a frame containing an A-MSDU that violates these rules should discard it[27].

For the Short A-MSDU case, an A-MSDU contains only MSDUs whose SAs are all the same, and whose DAs are all the same.(#1324) The Short A-MSDU subframe structure is used only between a pair of STAs that communicate directly (see 9.3.2.1 (Format of Data frames)). The Short A-MSDU subframe structure cannot be used for frame forwarding. The constituent MSDUs of an A-MSDU shall all have the same priority parameter value from the corresponding MA-UNITDATA.request primitive.

If the recipient STA has omitted the HE Capabilities element or the recipient STA has transmitted an HE Capabilities element with the A-MSDU Fragmentation Support subfield in the MAC Capabilities Information field set to 0, then an A-MSDU shall be carried, without fragmentation, within a single QoS Data frame. If the recipient STA has transmitted an HE Capabilities element with the A-MSDU Fragmentation Support subfield set to 1, then an A-MSDU may be fragmented, and each fragment is sent to the recipient in a QoS Data frame.(11ax)(#462)(#2195)

The channel access rules for a QoS Data frame carrying an A-MSDU (or fragment thereof)(11ax) are the same as a Data frame carrying an MSDU (or fragment thereof) of the same TID.

The expiration of the A-MSDU lifetime timer occurs only when the lifetime timer of all of the constituent MSDUs of the A-MSDU have expired.

NOTE 6—This rule implicitly allows an MSDU that is a constituent of an A-MSDU to potentially be transmitted after the expiration of its lifetime.

NOTE 7—Selecting any other value for the timeout would result in loss of MSDUs. Selecting the maximum value avoids this loss of MSDUs at the cost of transmitting MSDUs that have exceeded their lifetime.

The following rules in this paragraph apply to the transmission of an A-MSDU:

— A non-DMG and non-S1G STA that has a value of false for dot11HighthroughputOptionImplemented shall not transmit an A-MSDU.
— A non-DMG and non-S1G STA shall not transmit an A-MSDU to a STA from which it has not received a frame containing an HT Capabilities element.

[27]The check on the DA in the first A-MSDU subframe header is important to defend against attacks from malicious outsiders when signaling and payload protected A-MSDUs (SPP A-MSDUs) are not being used. The other checks on the DAs and the checks on the SAs are important to defend against impersonation attacks from malicious insiders (which means there is no protection against malicious APs or PCPs, DMG or S1G relays, GLK STAs, and mesh STAs). The lack of checks on the SA and DA in the case of mesh and relay operation presents an attack surface that is outside the scope of remediation in this standard. In the case of GLK, use of a SYNRA for an individually addressed MSDU with multiple links indicated in the station vector parameter also presents such an attack surface, which can be avoided by transmitting multiple individually addressed MPDUs instead (see 10.64 (Addressing of GLK Data frame transmission)).


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An S1G STA shall not transmit an A-MSDU to an S1G STA from which it received a frame containing an S1G Capabilities element with the A-MSDU Supported subfield equal to 0.

An S1G STA transmitting an A-MSDU shall use only the Dynamic A-MSDU subframe format (see 9.3.2.2.5 (Dynamic A-MSDU format)). The DA Present and SA Present subfields in the Subframe Control field of each Dynamic A-MSDU subframe shall be set to 1 unless the frame carrying the A-MSDU is a PV1 frame (see 9.8 (MAC frame format for PV1 frames)(#1358)).

An A-MSDU carried in a PV1 frame shall include the DA field in a Dynamic A-MSDU subframe if the value of this field

— Is not equal to the value of the A3 stored at the recipient.
— Is not equal to the value of the A3 field of the frame when an A3 is not stored at the recipient.
— Is not equal to the value of the address identified by the A1 field when an A3 field is not present in the frame and an A3 is not stored at the recipient.

Otherwise, the DA field shall not be included in the Dynamic A-MSDU subframe.

An A-MSDU carried in a PV1 frame shall include the SA field in a Dynamic A-MSDU subframe if the value of this field

— Is not equal to the value of the A4 stored at the recipient.
— Is not equal to the value of the A4 field of the frame when an A4 is not stored at the recipient.
— Is not equal to the value of the address identified by the A2 field when an A4 field is not present in the frame and an A4 is not stored at the recipient.

Otherwise, the SA field shall not be included in the Dynamic A-MSDU subframe.

A non-S1G STA transmitting an A-MSDU shall not use the Dynamic A-MSDU format(#1996). A non-DMG STA transmitting an A-MSDU shall not use the Short A-MSDU format.(#1725)(#1996)

The length of an A-MSDU transmitted in an S1G PPDU is limited by the maximum MPDU size supported by the recipient STA (see 10.12.5 (Transport of A-MPDU by the PHY data service)).

A STA shall support the reception of an A-MSDU, where the A-MSDU is carried in a QoS Data frame with Normal Ack ack policy in the following cases:

— By an HT STA (11ax)if the A-MSDU is not aggregated within an A-MPDU
— By a VHT (11ax)or HE STA if the A-MSDU is sent as an S-MPDU
— For a CMMG STA (11ax)if the A-MSDU is not aggregated within an A-MPDU

The use of an A-MSDU carried in a QoS Data frame under a block ack agreement is determined for each block ack agreement. A STA shall not transmit an A-MSDU within a QoS Data frame under a block ack agreement unless the recipient indicates support for A-MSDU by setting the A-MSDU Supported field to 1 in (#4193)the Block Ack Parameter Set field of the ADDBA Response frame.

An HE STA shall not transmit an A-MSDU that is carried in a QoS Data frame for which no block ack agreement exists and that is part of an ack-enabled single-TID A-MPDU, unless the recipient has set the A-MSDU Not Under BA In Ack-Enabled A-MPDU Support subfield in the HE MAC Capabilities Information field in the HE Capabilities element to 1.(11ax)

A STA shall not transmit an A-MSDU in an HT PPDU if the A-MSDU length exceeds the value indicated by the Maximum A-MSDU Length field of the HT Capabilities element received from the recipient STA.(#1439)

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A VHT STA that sets the value of the Maximum MPDU Length subfield in the VHT Capabilities Information field of the VHT Capabilities element to indicate 3895 octets shall set the Maximum A-MSDU Length in the HT Capabilities element to indicate 3839 octets. A VHT STA that sets the Maximum MPDU Length in the VHT Capabilities element to indicate 7991 octets or 11 454 octets shall set the Maximum A-MSDU Length in the HT Capabilities element to indicate 7935 octets.

The length of an A-MSDU transmitted in a VHT PPDU(#4371) is limited by the maximum MPDU size supported by the recipient STA (see 10.12.5 (Transport of A-MPDU by the PHY data service)).

(#4371)The length of an A-MSDU transmitted in an HE PPDU is limited by the maximum MPDU length capability supported by the recipient STA (see 10.12.5 (Transport of A-MPDU by the PHY data service), 26.17.1 (Basic HE BSS operation), and 26.17.2.1 (General)).

NOTE 8—An A-MSDU that meets the A-MSDU length limit for transmission in a VHT PPDU or HE PPDU(11ax) might exceed the A-MSDU length limit for an HT PPDU, in which case it cannot be retransmitted in an HT PPDU.

NOTE 9—Support for A-MSDU aggregation does not affect the maximum size of MSDU transported by the MA-UNITDATA primitives.

A VHT STA shall not transmit an A-MSDU that includes a number of MSDUs greater than the value indicated by the Max Number Of MSDUs In A-MSDU field in any Extended Capabilities element sent by the recipient STA. An HT STA (#4366)that is not a VHT STA should not transmit an A-MSDU that includes a number of MSDUs greater than the value indicated by the Max Number Of MSDUs In A-MSDU field in any Extended Capabilities element sent by the recipient STA. A STA shall not transmit an A-MSDU in a CMMG PPDU to a STA if the A-MSDU length exceeds the value indicated by the Maximum A-MSDU Length field of the CMMG Capabilities element received from the recipient STA.

A DMG STA shall not transmit an A-MSDU that includes a number of Basic A-MSDU subframes greater than the value indicated by the Maximum Number Of Basic A-MSDU Subframes In A-MSDU subfield in any DMG Capabilities element sent by the recipient STA. A DMG STA shall not transmit an A-MSDU that includes a number of Short A-MSDU subframes greater than the value indicated by the Maximum Number Of Short A-MSDU Subframes In A-MSDU subfield in any DMG Capabilities element sent by the recipient STA. A DMG STA that sets the A-MSDU Subframe subfield to 1 in a DMG Attributes field of TSPEC element (9.4.2.28 (TSPEC element)), which indicates Short A-MSDU subframe support, shall support(#546) receiving at least 32 Short A-MSDU subframes in A-MSDU. A CMMG STA that sets the Maximum MPDU Length subfield in the CMMG Capabilities element to indicate 3895 octets shall set the maximum A-MSDU length in the CMMG Capabilities element to indicate 3839 octets. A CMMG STA that sets the Maximum MPDU Length subfield in the CMMG Capabilities element to indicate 7991 octets or 11 454 octets shall set the maximum A-MSDU length in the CMMG Capabilities element to indicate 7935 octets.

The transmitter of frames for a TID established using a PTP TSPEC shall use an A-MSDU subframe format that is the result of the PTP TSPEC negotiation for that TID. The A-MSDU subframe format is negotiated using the PTP TSPEC (9.4.2.28 (TSPEC element)): the Short A-MSDU subframe format shall not be used for frames of the corresponding TID if the A-MSDU subframe field of the PTP TSPEC element is 0 either in the ADDTS Request frame or in the ADDTS Response frame used to set up the TID. Prior to PTP TSPEC negotiation, a STA shall use the Basic A-MSDU subframe format if the STA employs MSDU aggregation.

A non-PCP DMG STA in a PBSS may use the PCP of the PBSS to forward MSDUs to another non-PCP STA in the PBSS if the value of the PCP Forwarding field within the PCP's DMG Capabilities element is 1. A non-PCP DMG STA in a PBSS shall not use the PCP to forward MSDUs if the value of the PCP Forwarding field within the PCP's DMG Capabilities element is 0. To forward an MSDU via the PCP, a non-PCP STA shall encapsulate the MSDU (#2004)within an A-MSDU in an individually addressed MPDU sent to the PCP. The DA field of the A-MSDU shall be set to the destination's individual or group address.


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The length of an A-MSDU transmitted in a CMMG PPDU is limited by the maximum MPDU size supported by the recipient STA (see 10.12.5 (Transport of A-MPDU by the PHY data service)).

A CMMG STA shall not transmit to a recipient CMMG STA an A-MSDU that includes a number of MSDUs greater than the value indicated by the Max Number of MSDUs in A-MSDU field in the Extended Capabilities element received from the recipient STA.

A non-DMG STA indicates support for payload protected A-MSDUs (PP A-MSDUs) or signaling and payload protected A-MSDUs (SPP A-MSDUs), when dot11RSNAActivated is true, in its RSNXE. A non-DMG STA and its peer STA both determine and maintain a record of whether an encrypted A-MSDU sent to its peer is to be a PP A-MSDU or an SPP A-MSDU based on the SPP A-MSDU Capable subfield of the Extended RSN Capabilities field of the RSNXE (see 9.4.2.240 (RSNXE(#1776))). If a STA and its peer STA are DMG STAs or both have their SPP A-MSDU Capable subfields equal to 1, A-MSDUs shall be transmitted as SPP A-MSDUs and shall not be transmitted in PV1 MPDUs.(#1555) Otherwise, A-MSDUs shall be transmitted as PP A-MSDUs.(M57)

NOTE 10—A PV1 MPDU cannot contain an SPP A-MSDU because the signaling of whether an A-MSDU is being carried is not part of the AAD (see Figure 12-19 (AAD construction for PV1 MPDUs)) and so is not protected.(#1555)

Reception and transmission of A-MSDUs using a non-RSNA(#4025) is unaffected by the value of the SPP A-MSDU Capable subfield.(M57)

An AP may transmit an SPP A-MSDU for a GCR group address if it has (#4201)negotiated RSNAs(#4025) with all associated STAs that have an active GCR agreement for this group address.

## 10.12 A-MPDU operation

### 10.12.1 A-MPDU contents

According to its context (defined in Table 9-660 (A-MPDU contexts)), an A-MPDU shall be constrained so that it contains only MPDUs as specified in the relevant table referenced from Table 9-660 (A-MPDU contexts).

The values of the Protocol Version field in the Frame Control field of the MPDUs contained in an A-MPDU shall be the same, except for a Control frame with the Protocol Version field equal to 0 in which case the Control frame can be aggregated with PV1 frame.

If an A-MPDU contains multiple QoS Control fields, then bit 4 of all the QoS Control fields shall have the same value, and bits 8–15 of the QoS Control fields that have the same value in bits 0–3 shall have the same value.(11ax)

When an A-MPDU contains multiple MPDUs whose Protocol Version field value is 1, the values of EOSP and Relayed Frame fields in the Frame Control field, and A3 Present, A4 Present subfields in the SID field shall be identical across MPDUs within the A-MPDU.

A DMG STA that transmits an A-MPDU shall do so only in the Data Enabled Immediate Response context or the Control Response context, with contents as specified in Table 9-661 (A-MPDU contents in the non-HE(11ax) data enabled immediate response context) and Table 9-663 (A-MPDU contents in the control response context), respectively.

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### 10.12.2 A-MPDU length limit rules

A STA indicates in the Maximum A-MPDU Length Exponent field in its HT Capabilities element the maximum A-MPDU length that it can receive in an HT PPDU. A STA indicates in the Maximum A-MPDU Length Exponent field in its VHT Capabilities element the maximum length of the A-MPDU pre-EOF padding that it can receive in a VHT PPDU. A STA indicates in the Maximum A-MPDU Length Exponent field in its S1G Capabilities element the maximum length of the A-MPDU pre-EOF padding that it can receive in an S1G PPDU. A STA indicates in the Maximum A-MPDU Length Exponent field in its DMG Capabilities element the maximum A-MPDU length that it can receive in a DMG PPDU. A STA indicates the maximum length of the A-MPDU pre-EOF padding that it can receive in an HE PPDU in the Maximum A-MPDU Length Exponent field in its HT Capabilities, VHT Capabilities, and HE 6 GHz Band Capabilities elements (if present) and in the Maximum A-MPDU Length Exponent Extension field in its HE Capabilities element.(11ax) A STA indicates in the Maximum A-MPDU Length Exponent field in its EDMG Capabilities element the maximum length of the A-MPDU that it can receive in an EDMG PPDU.(11ay)

A VHT STA that sets the Maximum A-MPDU Length Exponent field in its VHT Capabilities element to a value in the range 0 to 3 shall set the Maximum A-MPDU Length Exponent in its HT Capabilities to the same value. A VHT STA that sets the Maximum A-MPDU Length Exponent field in the VHT Capabilities element to a value larger than 3 shall set the Maximum A-MPDU Length Exponent in its HT Capabilities element to 3.

Using the Maximum A-MPDU Length Exponent fields in the HT Capabilities, (11ax)VHT Capabilities, HE Capabilities, and HE 6 GHz Band Capabilities elements (if present), the STA establishes at association the maximum length of an A-MPDU pre-EOF padding that can be sent to it. An HT STA shall support(#546) receiving A-MPDUs of length up to the value indicated by the Maximum A-MPDU Length Exponent field in its HT Capabilities element. A VHT STA shall support(#546) receiving A-MPDUs where the A-MPDU pre-EOF padding length is up to the value indicated by the Maximum A-MPDU Length Exponent field in its VHT Capabilities element. An S1G STA that sets the A-MPDU Supported subfield in the S1G Capabilities element to 1 shall support(#546) receiving A-MPDUs where the A-MPDU pre-EOF padding length is up to the value indicated by the Maximum A-MPDU Length Exponent field in its S1G Capabilities element.

(11ax)An HE STA shall support(#546) receiving A-MPDUs where the A-MPDU pre-EOF padding length is up to the value indicated by the Maximum A-MPDU Length Exponent field in its HT Capabilities and VHT Capabilities elements and the Maximum A-MPDU Length Exponent Extension field in its HE Capabilities element in the 2.4 GHz or 5 GHz bands. An HE STA shall support(#546) receiving A-MPDUs where the A-MPDU pre-EOF padding length is up to the value indicated by the Maximum A-MPDU Length Exponent Extension field in the HE Capabilities element and the Maximum A-MPDU Length Exponent field in HE 6 GHz Band Capabilities element in the 6 GHz band.

A STA shall not transmit an A-MPDU in an HT PPDU that is longer than the value indicated by the Maximum A-MPDU Length Exponent field in the HT Capabilities element received from the intended receiver. MPDUs in an A-MPDU carried in an HT PPDU shall be limited to a maximum length of 4095 octets. A STA shall not transmit an A-MPDU in a VHT PPDU where the A-MPDU pre-EOF padding length is longer than the value indicated by the Maximum A-MPDU Length Exponent field in the VHT Capabilities element received from the intended receiver. An S1G STA shall not transmit an A-MPDU in an S1G PPDU where the A-MPDU pre-EOF padding length field is longer than the value indicated by the Maximum A-MPDU Length Exponent field in the S1G Capabilities element received from the intended receiver. A STA shall not transmit an A-MPDU in a DMG PPDU that is longer than the value indicated by the Maximum A-MPDU Length Exponent field in the DMG Capabilities element received from the intended receiver. (11ay)A STA shall not transmit an A-MPDU in an EDMG PPDU that is longer than the value indicated by the Maximum A-MPDU Length Exponent field in the EDMG Capabilities element received from the intended receiver.

(11ax)A STA shall not transmit an A-MPDU in an HE PPDU where the A-MPDU pre-EOF padding length is greater than the value indicated by the Maximum A-MPDU Length Exponent field in the HT Capabilities and VHT Capabilities elements and the Maximum A-MPDU Length Exponent Extension field in its HE


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Capabilities elements received from the intended receiver in the 2.4 GHz or 5 GHz bands. A STA shall not transmit an A-MPDU in an HE PPDU where the A-MPDU pre-EOF padding length is greater than the value indicated by the Maximum A-MPDU Length Exponent Extension field in the HE Capabilities element and the Maximum A-MPDU Length Exponent field in the HE 6 GHz Band Capabilities element received from the intended receiver in the 6 GHz band.

An S1G STA shall not transmit an A-MPDU, except for an S-MPDU, to an S1G STA from which it received a frame containing an S1G Capability element with the A-MPDU Supported subfield equal to 0.

(11bd)An NGV STA may transmit an A-MPDU without capability exchange as specified in 31.2.3 (A-MSDU operation, A-MPDU operation, and BA operation). An NGV STA shall support reception of an A-MPDU as specified in 31.2.3 (A-MSDU operation, A-MPDU operation, and BA operation).

NOTE—An NGV STA does not use the HT Capabilities element or the VHT Capabilities element to establish the maximum length of an A-MPDU, as an NGV STA only operates OCB and need not exchange these elements.(11bd)

### 10.12.3 Minimum MPDU start spacing rules

If the intended receiver is a non-HE STA, a STA shall not start the transmission of more than one MPDU within the time limit described in the Minimum MPDU Start Spacing field declared by the intended receiver. If the intended receiver is an HE STA, an HE STA shall not start the transmission of more than one QoS Data frame, QoS Null frame, or Management frame within the time limit described in the Minimum MPDU Start Spacing field declared by the intended receiver. To satisfy this requirement, the number of octets between the start of two consecutive MPDUs in an A-MPDU, *N*, measured at the PHY SAP, shall meet the condition defined by Equation (10-12).(11ax)

$$N \geq \begin{cases} t_{MMSS} \times r/8, \text{ if the A-MPDU is not carried in an HE TB PPDU} \\ t_{MMSS} \times 2^{MMSF} \times r/8, \text{ if the A-MPDU is carried in an HE TB PPDU} \end{cases} \quad (10\text{-}12)$$

where

$t_{MMSS}$ is the time (in microseconds) defined in the Encoding column of Table 9-225 (Subfields of the A-MPDU Parameters field) for an HT STA, of Table 9-351 (Subfields of the S1G Capabilities Information field) for an S1G STA for the value of the Minimum MPDU Start Spacing field, and of Table 9-291 (Subfields of the A-MPDU Parameters subfield) for a DMG STA for the value of the Minimum MPDU Start Spacing field

*MMSF* is the value of the MPDU MU Spacing Factor subfield of the User Info field addressed to the HE STA in the Trigger frame soliciting the HE TB PPDU (see 9.3.1.22 (Trigger frame format(11ax)))(11ax)

*r* is the value of the PHY Data Rate (in Mb/s(#4148)) defined in 19.5 (Parameters for HT-MCSs) for HT PPDUs, in 21.5 (Parameters for VHT-MCSs) for VHT PPDUs, in 23.5 (Parameters for S1G-MCSs) for S1G PPDUs, and in Clause 20 (Directional multi-gigabit (DMG) PHY specification) for a DMG STA

If necessary, in order to satisfy this requirement, a STA shall add padding between MPDUs in an A-MPDU. Any such padding shall be in the form of one or more MPDU delimiters with the MPDU Length field set to 0.

QoS Null frames transmitted by DMG STAs are not subject to this spacing, i.e., no MPDU delimiters with zero length need to be inserted after the MPDU immediately preceding the QoS Null frame in an A-MPDU.

(11az)For FTM procedure measurement exchange with an unassociated STA, the transmitting STA shall use one of the values specified in 9-225 (Subfields of the A-MPDU Parameters field), for the $t_{MMSS}$.

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### 10.12.4 A-MPDU aggregation of group addressed Data frames

A STA that is not one of an AP, a mesh STA, or an NGV STA(11bd) shall not transmit an A-MPDU containing an MPDU with an RA that is a group address.

NOTE 1—An HT AP and an HT mesh STA can transmit an A-MPDU containing MPDUs with an RA that is a group address.

NOTE 2—As a VHT STA and an HE STA are HT STAs, NOTE 1 also applies to VHT APs, VHT mesh STAs, HE APs, and HE mesh STAs.(11ax)

NOTE 3—An AP providing GCR service can transmit an A-MPDU containing MPDUs with an RA that is a group address.

NOTE 4—An S1G AP can transmit an A-MPDU containing MPDUs with an RA that is a group address.

A STA that is an AP or a mesh STA shall not transmit an A-MPDU containing group addressed MPDUs if the HT Protection field is equal to non-HT mixed mode.

A DMG STA may transmit an A-MPDU containing MPDUs with an RA that is a group address.

When a STA transmits a PPDU containing at least one A-MPDU that contains MPDUs with an RA that is a group address, the following shall apply:

— If the PPDU is an HT PPDU(11ax), the maximum A-MPDU length exponent value is the minimum value in the Maximum A-MPDU Length Exponent subfield of the A-MPDU Parameters field of the HT Capabilities element across all HT STAs associated with the transmitting AP or (11ax)across all peer HT mesh STAs.(11ax)

— If the PPDU is a VHT PPDU, the maximum A-MPDU length exponent (11ax)value is the minimum value in the Maximum A-MPDU Length Exponent subfields of the VHT Capabilities elements across all VHT STAs associated with the transmitting AP or across all peer VHT mesh STAs.

— (11ax)If the PPDU is an HE PPDU sent in the 2.4 GHz or 5 GHz band, the maximum A-MPDU length exponent value is the minimum value in the Maximum A-MPDU Length Exponent subfield of the VHT Capabilities elements across all HE STAs associated with the transmitting AP or across all peer HE mesh STAs.

— (11ax)If the PPDU is an HE PPDU sent in the 6 GHz band, the maximum A-MPDU length exponent value is the minimum value in the Maximum A-MPDU Length Exponent subfield of the HE 6 GHz Band Capabilities elements across all HE STAs associated with the transmitting AP or across all peer HE mesh STAs.

— If the PPDU is a VHT PPDU, the minimum MPDU start spacing (11ax)value is the maximum value in the Minimum MPDU Start Spacing subfields of the A-MPDU Parameters field of the HT Capabilities elements across all VHT STAs associated with the transmitting AP or across all peer VHT mesh STAs.

— If the PPDU is an HT PPDU transmitted by an AP(11ax), the minimum MPDU start spacing value (11ax)is the maximum value in the Minimum MPDU Start Spacing subfield of the A-MPDU Parameters field of the HT Capabilities elements across all HT STAs associated with the transmitting AP or across all peer HT mesh STAs.(11ax)

— (11ax)If the PPDU is an HE PPDU sent in the 2.4 GHz or 5 GHz band, the minimum MPDU start spacing value is the maximum value in the Minimum MPDU Start Spacing subfield of the A-MPDU Parameters field of the HT Capabilities elements across all HE STAs associated with the transmitting AP or across all peer HE mesh STAs.

— (11ax)If the PPDU is an HE PPDU sent in the 6 GHz band, the minimum MPDU start spacing value is the maximum value in the Minimum MPDU Start Spacing subfield of the HE 6 GHz Band


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Capabilities elements across all HE STAs associated with the transmitting AP or across all peer HE mesh STAs.

— If the PPDU is a DMG PPDU, the maximum A-MPDU length exponent value (11ax)is the minimum value in the Maximum A-MPDU Length Exponent subfield of the A-MPDU Parameters field of the DMG Capabilities element of all DMG STAs associated with the AP or PCP.

— If the PPDU is a DMG PPDU, the minimum MPDU start spacing value (11ax)is the maximum value in the Minimum MPDU Start Spacing subfield of the A-MPDU Parameters field of the DMG Capabilities element of all DMG STAs associated with the AP or PCP.

— If the PPDU is an S1G PPDU, the maximum A-MPDU length exponent value(11ax) is the minimum value in the Maximum A-MPDU Length Exponent subfields of the S1G Capabilities Information field of the S1G Capabilities elements across all S1G STAs associated with the transmitting AP.

— If the PPDU is an S1G PPDU, the minimum MPDU start spacing value(11ax) is the maximum value in the Minimum MPDU Start Spacing subfields of the S1G Capabilities Information field of the S1G Capabilities elements across all S1G STAs associated with the transmitting AP.

— (11ay)If the PPDU is an EDMG PPDU, the maximum A-MPDU length exponent value that applies is the minimum value in the Maximum A-MPDU Length Exponent subfield of the A-MPDU Parameters field of the EDMG Capabilities element of all EDMG STAs associated with the AP or PCP.

— (11ay)If the PPDU is an EDMG PPDU, the minimum MPDU start spacing value that applies is the maximum value in the Minimum MPDU Start Spacing subfield of the A-MPDU Parameters field of the EDMG Capabilities element of all EDMG STAs associated with the AP or PCP.

### 10.12.5 Transport of A-MPDU by the PHY data service

An A-MPDU shall be transmitted in a PSDU associated with a PHY-TXSTART.request primitive with the TXVECTOR parameter AGGREGATION set to 1 or the TXVECTOR parameter FORMAT set to VHT. A received PSDU is determined to be an A-MPDU when the associated PHY-RXSTART.indication primitive RXVECTOR parameter AGGREGATION is equal to 1 or the RXVECTOR parameter FORMAT is equal to VHT.

A STA shall not transmit an MPDU in an S1G PPDU that exceeds the maximum MPDU length capability indicated in the S1G Capabilities element received from the recipient STA.

An S1G STA shall set the TXVECTOR parameter AGGREGATION to 1 when the length of the PSDU to be carried in the S1G PPDU is greater than aPSDUMaxLengthWithNoAggregation.

### 10.12.6 A-MPDU padding for VHT, HE(11ax) or S1G PPDU

A VHT STA that transmits a VHT PPDU or an S1G STA that transmits an S1G PPDU that contains one or more PSDUs, each of which contains an A-MPDU, shall construct the A-MPDU(s) as described in this subclause.

An A-MPDU pre-EOF padding (see 10.12.2 (A-MPDU length limit rules)) is constructed for each user from any of the following:

— A-MPDU subframes constructed from the MPDUs available for transmission that have a TID value that maps to the primary AC

— A-MPDU subframes with 0 in the MPDU Length field and 0 in the EOF/Tag(#4367) field

provided that each added subframe and the A-MPDU pre-EOF padding meet all of the following:

— A-MPDU content constraints (see 10.12.1 (A-MPDU contents)) for the intended recipient

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- Format and length limit constraints (see 9.7.1 (A-MPDU format) and 10.12.2 (A-MPDU length limit rules)) for the intended recipient
- Minimum MPDU start spacing constraints (see 10.12.3 (Minimum MPDU start spacing rules)) for the intended recipient
- TXOP duration limits (see 10.23.2.9 (TXOP limits)) for the primary AC

The A-MPDU_Length[*n*] for user *n* is initialized as the length of the resulting A-MPDU pre-EOF padding.

This initial value of A-MPDU_Length[*n*] for user *n* is used as the APEP_LENGTH[*n*] parameter value for the PLME-TXTIME.request primitive (see 6.7.5 (PLME-TXTIME.request)). The PLME-TXTIME.request primitive is then invoked once for the VHT PPDU or the S1G PPDU. The PLME-TXTIME.confirm primitive (see 6.7.6 (PLME-TXTIME.confirm)) provides the TXTIME parameter and PSDU_LENGTH[] parameters for all of the users for the transmission.

Subsequently, for each user *n*, as permitted by the rules for EDCA TXOP Sharing (see 10.23.2.7 (Sharing an EDCA TXOP)), a VHT STA or S1G STA may add A-MPDU subframes to the A-MPDU for that user that meets either of the following conditions:

- Have a TID that maps to an AC that is not the primary AC
- Have 0 in the MPDU Length field and 0 in the EOF/Tag(#4367) field

provided that each added subframe and the resulting A-MPDU meet all of the following:

- A-MPDU content constraints (see 10.12.1 (A-MPDU contents)) for the intended recipient
- Length limit constraints (see 9.7.1 (A-MPDU format) and 10.12.2 (A-MPDU length limit rules)) for the intended recipient
- MPDU start spacing constraints (see 10.12.3 (Minimum MPDU start spacing rules)) for the intended recipient

and provided that, after incrementing the A-MPDU_Length[*n*] with the length of each such added A-MPDU subframe, the relationship A-MPDU_Length[*n*] ≤ PSDU_LENGTH[*n*] is true.

Subsequently, for each user n, a VHT STA or S1G STA may add A-MPDU subframes to the A-MPDU for that user that meet the following condition:

- Have 0 in the MPDU Length field

provided that each added subframe and the resulting A-MPDU meet the following condition:

- Length limit constraints (see 9.7.1 (A-MPDU format) and 10.12.2 (A-MPDU length limit rules)) for the intended recipient

and provided that, after incrementing the A-MPDU_Length[n] with the length of each such added A-MPDU subframe, the relationship A-MPDU_Length[*n*] ≤ PSDU_LENGTH[*n*] is true.

An implementation may reduce the A-MPDU_Length[*n*] by the amount of padding for user *n* that was added subsequent to the addition of a subframe for user *n* that contains 1 in the EOF/Tag(#4367) field.

The final value of A-MPDU_Length[] shall be used as APEP_LENGTH[] in the PHY-TXSTART.request primitive for the VHT PPDU or S1G PPDU.

Padding is then added for each user such that the resulting A-MPDU contains exactly PSDU_LENGTH octets for that user as follows:

- First, while A-MPDU_Length[*n*] < PSDU_LENGTH[*n*] and A-MPDU_Length[*n*] mod 4 ≠ 0, add an octet to the final A-MPDU subframe's Padding subfield and increment A-MPDU_Length[*n*] by 1.


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— Then, while A-MPDU_Length[*n*] + 4 ≤ PSDU_LENGTH[*n*], add an EOF padding subframe to the EOF Padding Subframes field and increment A-MPDU_Length[*n*] by 4.
— Finally, while A-MPDU_Length[*n*] < PSDU_LENGTH[*n*], add an octet to the EOF Padding Octets subfield and increment A-MPDU_Length[*n*] by 1.

An A-MPDU subframe with EOF set to 0 shall not be added after any A-MPDU subframe with EOF set to 1, except if the A-MPDU subframe is in an ack-enabled single-TID A-MPDU or ack-enabled multi-TID A-MPDU (see 9.7.3 (A-MPDU contents)).(11ax)

An A-MPDU subframe with EOF set to 1 and with MPDU Length field set to 0 shall not be added before an A-MPDU subframe that contains an S-MPDU (see 10.12.7 (Setting the EOF/Tag(11ax) field of the MPDU delimiter)).

### 10.12.7 Setting the EOF/Tag(11ax) field of the MPDU delimiter

The (11ax)EOF/Tag field may be set to 1 in an A-MPDU subframe carried in a VHT PPDU, HE PPDU, or S1G PPDU if the subframe's MPDU Length field is nonzero and the subframe is the only subframe that has a nonzero MPDU Length field. The (11ax)EOF/Tag field of each A-MPDU subframe with an MPDU Length field with a nonzero value that is not the only A-MPDU subframe with MPDU Length field with a nonzero value in the A-MPDU carried in a VHT PPDU or S1G PPDU shall be set to 0. The (11ax)EOF/Tag field shall be set to 0 in all A-MPDU subframes that are carried in an HT PPDU.

An MPDU that is the only MPDU in an A-MPDU and that is carried in an A-MPDU subframe with 1 in the (11ax)EOF/Tag field is called an S-MPDU.

(11ay)In an EDMG PPDU, the EOF padding can be used to indicate that no more MPDUs are present at end of the A-MPDU in the case the PSDU length exceeds the accumulated size of A-MPDU subframes plus the number of octets(#8150) used for MPDU start spacing.

(11ay)In the sequence of A-MPDU subframes transmitted in an EDMG PPDU, the EOF/Tag(#4367) field is set as follows:

— Shall be set to 0 in all A-MPDU subframes if the subframe's MPDU Length field is nonzero.
— (#2211)May be set to 1 in all A-MPDU subframes if the subframe's MPDU Length field is 0 and no A-MPDU subframe with nonzero value in the subframe's MPDU Length field is set for transmission in the A-MPDU subframes sequence after the subframe with MPDU Length field equal to 0 is transmitted.

(11ax)An MPDU that is carried in an A-MPDU subframe with the EOF/Tag field in the MPDU delimiter set to 1 is called a *tagged* MPDU. An S-MPDU is a tagged MPDU, but a tagged MPDU is not necessarily an S-MPDU.

(11ax)An MPDU that is carried in an A-MPDU subframe with the EOF/Tag field in the MPDU delimiter set to 0 is called an untagged MPDU.

### 10.12.8 Transport of S-MPDUs

The rules for S-MPDU operation are the same as the rules for non-A-MPDU frame operation with other types of non-A-MPDU.

NOTE—This affects the following behavior:
a) The frame could carry a fragment of an MSDU or MMPDU (see 10.2.7 (Fragmentation/defragmentation overview)).
b) Rate selection of control responses (see 10.6 (Multirate support)).

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c) A QoS Data frame cannot have Implicit BAR ack policy, and does not generate a BlockAck frame response (see 9.2.4.5.4 (Ack Policy Indicator subfield)).
d) A QoS Data frame could have Normal Ack ack policy, which solicits an Ack frame immediate response. No block ack agreement is needed in this case (see 9.2.4.5.4 (Ack Policy Indicator subfield)).
e) The frame could be a Management frame that solicits an Ack frame response (see 9.7.3 (A-MPDU contents)).

## 10.13 PPDU duration constraint

A STA shall not transmit an HT PPDU that has a duration (as determined by the (#7074)PLME-TXTIME.confirm primitive defined in 6.7.6 (PLME-TXTIME.confirm)) that is greater than aPPDUMaxTime defined in Table 19-25 (HT PHY characteristics).

A STA shall not transmit a DMG PPDU that has a duration (as determined by the (#7074)PLME-TXTIME.confirm primitive defined in 6.7.6 (PLME-TXTIME.confirm)) that is greater than aPPDUMaxTime defined in Table 20-30 (DMG PHY characteristics).

A CMMG STA shall not transmit a PPDU that has a duration (as determined by the (#7074)PLME-TXTIME.confirm primitive defined in 6.7.6 (PLME-TXTIME.confirm)) that is greater than aPPDUMaxTime.

A STA shall not transmit a VHT PPDU that has a duration (as determined by the (#7074)PLME-TXTIME.confirm primitive defined in 6.7.6 (PLME-TXTIME.confirm)) that is greater than aPPDUMaxTime defined in Table 21-28 (VHT PHY characteristics).

A STA shall not transmit a VHT MU PPDU with the TXVECTOR parameter APEP_LENGTH for any of the users greater than aAPEPMaxLengthVHTMU20, aAPEPMaxLengthVHTMU40 or aAPEPMaxLengthVHTMU80orMore when TXVECTOR parameter CH_BANDWIDTH is CBW20, CBW40, or other values, respectively.

NOTE—In the case of using aPEPMaxLengthVHTMU80orMore, the constraint from Maximum A-MPDU Length Exponent of 7 is smaller and becomes the actual limiting factor (see 10.12.2 (A-MPDU length limit rules)).

A STA shall not transmit a VHT PPDU in TVWS bands that has a duration (as determined by the (#7074)PLME-TXTIME.confirm primitive defined in 6.7.6 (PLME-TXTIME.confirm)) that is greater than aPPDUMaxTime defined in Table 22-25 (TVHT PHY characteristics).

A STA shall not transmit an S1G PPDU that has a duration (as determined by the (#7074)PLME-TXTIME.confirm primitive defined in 6.7.6 (PLME-TXTIME.confirm)) that is greater than aPPDUMaxTime defined in Table 23-41 (S1G PHY characteristics).

An HE STA shall not transmit an HE PPDU that has a duration (as determined by the (#7074)PLME-TXTIME.confirm primitive defined in 6.7.6 (PLME-TXTIME.confirm)) that is greater than *aPPDUMaxTime* defined in Table 27-61 (HE PHY characteristics(11ax)).(11ax)

(11ay)A STA shall not transmit an EDMG PPDU that has a duration (as determined by the PLME-TXTIME.confirm primitive defined in 6.7.6 (PLME-TXTIME.confirm)) that is greater than aPPDUMaxTime defined in Table 20-30 (DMG PHY characteristics).

(11bd)A STA shall not transmit an NGV PPDU that has a duration (as determined by the (#7074)PLME-TXTIME.confirm primitive defined in 6.7.6 (PLME-TXTIME.confirm)(#7074)) that is greater than aPPDUMaxTime defined in Table 32-20 (NGV PHY characteristics).


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## 10.14 DMG A-PPDU and EDMG A-PPDU(11ay) operation

(#3613)A DMG STA is a QoS STA and shall set dot11QosOptionImplemented to true.

A DMG STA is (11ay)DMG aggregate PPDU (A-PPDU) capable if the A-PPDU supported field within the STA's DMG Capabilities element is 1. Otherwise, the STA is not (11ay)DMG A-PPDU capable.

(11ay)An EDMG STA is EDMG A-PPDU capable if the EDMG A-PPDU subfield within the STA's EDMG Capabilities element is 1. Otherwise, the STA is not EDMG A-PPDU capable.

A DMG STA shall not transmit (11ay)a DMG A-PPDU to a STA that is not DMG A-PPDU capable.

(11ay)An EDMG STA shall not transmit an EDMG A-PPDU to a STA that is not EDMG A-PPDU capable.

(11ay)All PPDUs within a DMG A-PPDU shall have the ADD-PPDU parameter of the TXVECTOR set to ADD-PPDU, except for the last PPDU in the DMG A-PPDU that shall have this parameter set to NO-ADD-PPDU. (11ay)An EDMG PPDU shall have the ADD-PPDU parameter of the TXVECTOR set to NO-ADD-PPDU. All PPDUs within an EDMG A-PPDU shall have the EDMG_ADD_PPDU parameter of the TXVECTOR set to ADD-PPDU, except for the last PPDU in the EDMG A-PPDU that shall have this parameter set to NO-ADD-PPDU. A DMG PPDU and an EDMG PPDU shall not be included in the same A-PPDU.

The value of a TXVECTOR parameter of a PPDU belonging to (11ay)a DMG A-PPDU or an EDMG A-PPDU might differ from the value of the same TXVECTOR parameter of another PPDU in the same A-PPDU, including the MCS parameter.

A PPDU within an A-PPDU shall contain an A-MPDU. All MPDUs within A-MPDUs within an A-PPDU shall have the same values for the TA and RA fields. All QoS Data frames within A-MPDUs within an A-PPDU shall have the same ack policy. If a frame that requires an immediate response is present within an A-PPDU, it shall be transmitted in the last A-MPDU of the A-PPDU.

The transmission duration of an A-PPDU shall be no greater than aPPDUMaxTime (see Table 20-30 (DMG PHY characteristics)).

## 10.15 Low-density parity check code (LDPC) operation

An HT STA shall not transmit a frame in a PSDU with the TXVECTOR parameter FORMAT set to HT_MF or HT_GF and TXVECTOR parameter FEC_CODING set to LDPC_CODING unless the RA of the frame corresponds to an HT STA for which the LDPC Coding Capability subfield of the HT Capabilities element received from that STA contained a value of 1 and dot11LDPCCodingOptionActivated is true (if there is more than one intended receiver, then this requirement applies for each intended receiver).

A VHT STA shall not transmit a frame in a PSDU with the TXVECTOR parameter FORMAT set to VHT and TXVECTOR parameter FEC_CODING set to LDPC_CODING unless the RA of the frame corresponds to a VHT STA for which the Rx LDPC subfield of the VHT Capabilities element received from that STA contained a value of 1 and dot11VHTLDPCCodingOptionActivated is true (if there is more than one intended receiver, then this requirement applies for each intended receiver).

An S1G STA shall not transmit a frame in a PSDU with the TXVECTOR parameter FEC_CODING set to LDPC_CODING unless the RA of the frame corresponds to a STA for which the Rx LDPC subfield of the S1G Capabilities element from that STA contained a value of 1 and dot11S1GLDPCCodingOptionActivated is true (if there is more than one intended receiver, then this requirement applies for each intended receiver).

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A STA should not transmit a frame in a PSDU with the TXVECTOR parameter FORMAT set to HT_MF, HT_GF or VHT and TXVECTOR parameter FEC_CODING set to LDPC_CODING if the RA of the frame corresponds to a STA from which it has received a frame containing an Operating Mode field and the most recent Operating Mode field it has received from that STA had the No LDPC subfield equal to 1 (if there is more than one intended receiver, then this requirement applies for each intended receiver).

Further restrictions on TXVECTOR parameter values may apply due to rules found in 10.27 (Protection mechanisms) and 10.6 (Multirate support).

An HE STA shall not transmit a frame in an HE PPDU with the TXVECTOR parameter FEC_CODING set to LDPC_CODING, unless the frame is addressed to an HE STA for which the LDPC Coding In Payload subfield in the HE Capabilities element received from that STA contained a value of 1 and dot11HELDPCCodingInPayloadImplemented is true.(11ax)

## 10.16 STBC operation

A STA that has not set the Tx STBC subfield to 1 in the HT Capabilities element shall not transmit HT PPDUs with a TXVECTOR parameter STBC set to a nonzero value. A STA that has not set the Tx STBC subfield to 1 in the VHT Capabilities element shall not transmit VHT SU PPDUs with a TXVECTOR parameter STBC set to a nonzero value. A STA that has not set the Tx STBC subfield to 1 in the S1G Capabilities element shall not transmit S1G SU PPDUs with the TXVECTOR parameter STBC set to a nonzero value.

A STA shall not send an HT PPDU with the TXVECTOR parameter STBC set to a nonzero value to a recipient STA unless the recipient STA has indicated in the Rx STBC field of its HT Capabilities element that it supports the reception of PPDUs using STBC with a number of spatial streams greater than or equal to the number of spatial streams in the HT PPDU (if there is more than one intended receiver, then this requirement applies for each intended receiver). A STA shall not send a VHT PPDU with the TXVECTOR parameter STBC set to a nonzero value to a recipient STA unless the recipient STA has indicated in the Rx STBC field of its VHT Capabilities element that it supports the reception of PPDUs using STBC with a number of spatial streams greater than or equal to the number of spatial streams in the VHT PPDU (if there is more than one intended receiver, then this requirement applies for each intended receiver). A STA shall not send an S1G PPDU with the TXVECTOR parameter STBC set to a nonzero value to a recipient STA unless the recipient STA has indicated in the Rx STBC field of its S1G Capabilities element that it supports the reception of PPDUs using STBC with a number of spatial streams greater than or equal to the number of spatial streams in the S1G PPDU (if there is more than one intended receiver, then this requirement applies for each intended receiver).

A STA that has not set the Tx STBC subfield to 1 in the CMMG Capabilities element shall not transmit CMMG PPDUs with a TXVECTOR parameter STBC set to a nonzero value.

A STA shall not send a CMMG PPDU with the TXVECTOR parameter STBC set to a nonzero value to a recipient STA unless the recipient STA has indicated in the Rx STBC field of its CMMG Capabilities element that it supports the reception of PPDUs using STBC with a number of spatial streams equal to or greater than the number of spatial streams in the CMMG PPDU (if there is more than one intended receiver, then this requirement applies for each intended receiver).

## 10.17 Short GI operation

A STA may transmit a frame in a PSDU with TXVECTOR parameters CH_BANDWIDTH set to HT_CBW20 and GI_TYPE set to SHORT_GI only if all of the following conditions are met (if there is more than one intended receiver, then this requirement applies for each intended receiver):

— The STA is an HT STA.

— The TXVECTOR parameter FORMAT is equal to HT_MF or HT_GF.


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- The RA of the frame corresponds to a STA for which the Short GI for 20 MHz subfield of the HT Capabilities element contained a value of 1.
- dot11ShortGIOptionInTwentyActivated is present and is true.

A STA may transmit a frame in a PSDU with TXVECTOR parameters CH_BANDWIDTH set to CBW20 and GI_TYPE set to SHORT_GI only if all of the following conditions are met (if there is more than one intended receiver, then this requirement applies for each intended receiver):

- The STA is a VHT STA.
- The TXVECTOR parameter FORMAT is equal to VHT.
- The RA of the frame corresponds to a STA for which the Short GI for 20 MHz subfield of the HT Capabilities element contained a value of 1.
- dot11ShortGIOptionInTwentyActivated is present and is true.

A STA may transmit a frame in a PSDU with TXVECTOR parameters CH_BANDWIDTH set to HT_CBW40 and GI_TYPE set to SHORT_GI only if all of the following conditions are met (if there is more than one intended receiver, then this requirement applies for each intended receiver):

- The STA is an HT STA.
- The TXVECTOR parameter FORMAT is equal to HT_MF or HT_GF.
- The RA of the frame corresponds to a STA for which the Short GI for 40 MHz subfield of the HT Capabilities element contained a value of 1.
- dot11ShortGIOptionInFortyActivated is present and is true.

A STA may transmit a frame in a PSDU with TXVECTOR parameters CH_BANDWIDTH set to CBW40 and GI_TYPE set to SHORT_GI only if all of the following conditions are met (if there is more than one intended receiver, then this requirement applies for each intended receiver):

- The STA is a VHT STA.
- The TXVECTOR parameter FORMAT is equal to VHT.
- The RA of the frame corresponds to a STA for which the Short GI for 40 MHz subfield of the HT Capabilities element contained a value of 1.
- dot11ShortGIOptionInFortyActivated is present and is true.

A STA shall not transmit a frame in a PSDU with TXVECTOR parameters CH_BANDWIDTH set to CBW80 and GI_TYPE set to SHORT_GI unless all of the following conditions are met (if there is more than one intended receiver, then this requirement applies for each intended receiver):

- The STA is a VHT STA.
- The TXVECTOR parameter FORMAT is equal to VHT.
- The RA of the frame corresponds to a STA for which the Short GI for 80 MHz/TVHT_MODE_4C subfield of the VHT Capabilities element contained a value of 1.
- dot11VHTShortGIOptionIn80Activated is present and is true.

A STA may transmit a frame in a PSDU with TXVECTOR parameters CH_BANDWIDTH set to CBW160 or CBW80+80 and GI_TYPE set to SHORT_GI only if all of the following conditions are met (if there is more than one intended receiver, then this requirement applies for each intended receiver):

- The STA is a VHT STA.
- The TXVECTOR parameter FORMAT is equal to VHT.
- The RA of the frame corresponds to a STA for which the Short GI for 160 and 80+80 MHz subfield of the VHT Capabilities element contained a value of 1.
- dot11VHTShortGIOptionIn160and80p80Activated is present and is true.

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A STA may transmit a frame in a PSDU with TXVECTOR parameters FORMAT set to VHT, NUM_USERS set to greater than 1, and GI_TYPE set to SHORT_GI only if all of the following conditions are met:

- The STA is a VHT STA.
- The TXVECTOR parameter FORMAT is equal to VHT.
- The RAs of all MPDUs in the VHT MU PPDU correspond to STAs for which the Short GI subfield of the following conditions are satisfied:
  - If the TXVECTOR parameter CH_BANDWIDTH is(M118) CBW20, the Short GI for 20 MHz subfields of the HT Capabilities element contained a value of 1, and dot11ShortGIOptionInTwentyActivated is present and is true.
  - If the TXVECTOR parameter CH_BANDWIDTH is(M118) CBW40, the Short GI for 40 MHz subfields of the HT Capabilities element contained a value of 1, and dot11ShortGIOptionInFortyActivated is present and is true.
  - If the TXVECTOR parameter CH_BANDWIDTH is(M118) CBW80, the Short GI for 80 MHz/TVHT_MODE_4C subfields of the VHT Capabilities element contained a value of 1, and dot11VHTShortGIOptionIn80Activated is present and is true.
  - If the TXVECTOR parameter CH_BANDWIDTH is(M118) CBW160 or CBW80+80, the Short GI for 160 MHz and 80+80 MHz subfields of the VHT Capabilities element contained a value of 1, and dot11VHTShortGIOptionIn160and80p80Activated is present and is true.

An S1G STA may transmit a frame in a PSDU with TXVECTOR parameters CH_BANDWIDTH set to CBW1 and GI_TYPE set to SHORT_GI only if all of the following conditions are met (if there is more than one intended receiver, then this requirement applies for each intended receiver):

- The RA of the frame corresponds to a STA for which the Short GI for 1 MHz subfield of the S1G Capabilities element is 1.
- dot11ShortGIOptionIn1MActivated is present and is true.

An S1G STA may transmit a frame in a PSDU with TXVECTOR parameters CH_BANDWIDTH set to CBW2 and GI_TYPE set to SHORT_GI only if all of the following conditions are met (if there is more than one intended receiver, then this requirement applies for each intended receiver):

- The RA of the frame corresponds to a STA for which the Short GI for 2 MHz subfield of the S1G Capabilities element is 1.
- dot11ShortGIOptionIn2MActivated is present and is true.

An S1G STA may transmit a frame in a PSDU with TXVECTOR parameters CH_BANDWIDTH set to CBW4 and GI_TYPE set to SHORT_GI only if all of the following conditions are met (if there is more than one intended receiver, then this requirement applies for each intended receiver):

- The RA of the frame corresponds to a STA for which the Short GI for 4 MHz subfield of the S1G Capabilities element is 1.
- dot11ShortGIOptionIn4MActivated is present and is true.

An S1G STA may transmit a frame in a PSDU with TXVECTOR parameters CH_BANDWIDTH set to CBW8 and GI_TYPE set to SHORT_GI only if all of the following conditions are met (if there is more than one intended receiver, then this requirement applies for each intended receiver):

- The RA of the frame corresponds to a STA for which the Short GI for 8 MHz subfield of the S1G Capabilities element is 1.
- dot11ShortGIOptionIn8MActivated is present and is true.

An S1G STA may transmit a frame in a PSDU with TXVECTOR parameters CH_BANDWIDTH set to CBW16 and GI_TYPE set to SHORT_GI only if all of the following conditions are met (if there is more than one intended receiver, then this requirement applies for each intended receiver):


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- The RA of the frame corresponds to a STA for which the Short GI for 16 MHz subfield of the S1G Capabilities element is 1.
- dot11ShortGIOptionIn16MActivated is present and is true.

An S1G STA may transmit a frame in a PSDU with TXVECTOR parameters NUM_USERS set to greater than 1, and GI_TYPE set to SHORT_GI only if all of the following conditions are met:

- The RAs of all MPDUs in the S1G MU PPDU correspond to STAs for which the Short GI subfield of the following conditions are satisfied:
  - If the TXVECTOR parameter CH_BANDWIDTH is (M118)equal to CBW2, the Short GI for 2 MHz subfield of the S1G Capabilities element is equal to 1, and dot11ShortGIOptionIn2MActivated is present and is true.
  - If the TXVECTOR parameter CH_BANDWIDTH is (M118)equal to CBW4, the Short GI for 4 MHz subfield of the S1G Capabilities element is equal to 1, and dot11ShortGIOptionIn4MActivated is present and is true.
  - If the TXVECTOR parameter CH_BANDWIDTH is (M118)equal to CBW8, the Short GI for 8 MHz subfield of the S1G Capabilities element is equal to 1, and dot11ShortGIOptionIn8MActivated is present and is true.
  - If the TXVECTOR parameter CH_BANDWIDTH is (M118)equal to CBW16, the Short GI for 16 MHz subfield of the S1G Capabilities element is equal to 1, and dot11ShortGIOptionIn16MActivated is present and is true.

An HT STA shall not transmit a frame with TXVECTOR parameter FORMAT set to HT_GF and the GI_TYPE parameter set to SHORT_GI when the MCS parameter indicates a single spatial stream.

Further restrictions on TXVECTOR parameter values may apply due to rules found in 10.27 (Protection mechanisms) and 10.6 (Multirate support).

## 10.18 Greenfield operation

An HT STA shall not transmit a frame in a PSDU with the TXVECTOR parameter FORMAT set to HT_GF unless the RA of the frame corresponds to a STA for which the HT-Greenfield subfield of the HT Capabilities element contained a value of 1 and dot11HTGreenfieldOptionActivated is true (if there is more than one intended receiver, then this requirement applies for each intended receiver). Further restrictions may apply due to rules found in 10.27 (Protection mechanisms), 10.6 (Multirate support), and 11.8.8.5 (HT-greenfield transmissions in operating classes that include a behavior limit of DFS_50_100_Behavior).

## 10.19 Group ID and partial AID in VHT and CMMG PPDUs

The partial AID is a nonunique STA identifier defined in Table 10-13 (Settings for the TXVECTOR parameters GROUP_ID and PARTIAL_AID for VHT STAs) and Table 10-14 (Settings for the TXVECTOR parameter PARTIAL_AID for CMMG STAs). The partial AID is carried in the TXVECTOR parameter PARTIAL_AID of a VHT SU PPDU or a CMMG PPDU and is limited to 9 bits.

A STA transmitting a VHT SU PPDU carrying one or more group addressed MPDUs or transmitting a VHT NDP intended for multiple recipients shall set the TXVECTOR parameters GROUP_ID to 63 and PARTIAL_AID to 0. The intended recipient of a VHT NDP is defined in 10.35.6 (Transmission of a VHT NDP).

A STA transmitting a CMMG PPDU carrying one or more group addressed MPDUs shall set the TXVECTOR parameters PARTIAL_AID to 0.

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A STA transmitting a VHT SU PPDU carrying one or more individually addressed MPDUs or a VHT NDP intended for a single recipient shall set the TXVECTOR parameters GROUP_ID and PARTIAL_AID as shown in Table 10-13 (Settings for the TXVECTOR parameters GROUP_ID and PARTIAL_AID for VHT STAs).

**Table 10-13—Settings for the TXVECTOR parameters GROUP_ID and PARTIAL_AID for VHT STAs**

| Condition | GROUP_ID | PARTIAL_AID |
|---|---|---|
| Addressed to AP | 0 | *int(*BSSID[39:47]) |
| Addressed to Mesh STA | 0 | *int(*RA[39:47]) |
| Sent by an AP and addressed to a STA associated with that AP or sent by a TDLS STA in a direct path to a TDLS peer STA | 63 | STA_Partial_AID_VHT (see Equation (10-13)) (#6096) |
| Otherwise (see NOTE) | 63 | 0 |
| NOTE—The last row covers the following cases:<br>a) A PPDU sent to an IBSS STA<br>b) A PPDU sent by an AP to a non associated STA<br>c) Any other condition not explicitly listed elsewhere in the table | | |

A STA transmitting a CMMG PPDU carrying one or more individually addressed MPDUs shall set the TXVECTOR parameter PARTIAL_AID as shown in Table 10-14 (Settings for the TXVECTOR parameter PARTIAL_AID for CMMG STAs).

**Table 10-14—Settings for the TXVECTOR parameter PARTIAL_AID for CMMG STAs**

| Condition | PARTIAL_AID |
|---|---|
| A frame that is not a Control frame that is addressed to an AP. | $(dec(\text{BSSID}[39:47]) \bmod (2^9 - 1)) + 1$ |
| A frame that is not a Control frame that is addressed to an AP. | $(dec(\text{RA}[39:47]) \bmod (2^9 - 1)) + 1$ |
| A frame that is not a Control frame that is sent by an AP and addressed to a STA associated with that AP or sent by a TDLS STA in a direct path to a TDLS peer STA. | STA_Partial_AID_CMMG (see Equation (10-14)) (#6096) |
| Otherwise (see NOTE) | 0 |
| NOTE—The last row covers the following cases:<br>a) A PPDU sent to an IBSS STA<br>b) A PPDU sent by an AP to a non associated STA<br>c) Any other condition not explicitly listed elsewhere in the table | |

A STA shall include the values computed in Table 10-13 (Settings for the TXVECTOR parameters GROUP_ID and PARTIAL_AID for VHT STAs) in the PHYCONFIG_VECTOR parameters PARTIAL_AID_LIST_GID00 and PARTIAL_AID_LIST_GID63.


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A STA that transmits a VHT or CMMG PPDU to a TDLS peer STA obtains the AID for the peer STA from the TDLS Setup Request or TDLS Setup Response frame.

(#6096)An AP should not assign to a STA an AID that results in a 0 value STA_Partial_AID_VHT as computed using Equation (10-13):

$$\text{STA\_Partial\_AID\_VHT} = (\text{AID}[0:8] + int(\text{BSSID}[44:47] \oplus \text{BSSID}[40:43]) \times 2^5) \bmod 2^9 \quad (10\text{-}13)$$

A CMMG AP should not assign to a CMMG STA an AID that results in the STA_Partial_AID_CMMG as computed using Equation (10-14):

$$\text{STA\_Partial\_AID\_CMMG} = (dec(\text{AID}[0:8]) + dec(\text{BSSID}[44:47] \oplus \text{BSSID}[40:43]) \times 2^5) \bmod 2^6 \quad (10\text{-}14)$$

being equal to one of the following:

$$0 \text{ or } (dec(\text{BSSID}[39:47]) \bmod (2^9 - 1)) + 1 \text{ or } (dec(\text{OBSSID}[39:47]) \bmod (2^9 - 1)) + 1$$

where OBSSID is the BSSID of a BSS that is not the BSS of which the AP is a member and for which the AP might be heard by the STA being assigned the AID.

A STA transmitting a VHT MU PPDU sets the TXVECTOR parameter GROUP_ID as described in 21.3.11.4 (Group ID).

As an example of the GROUP_ID and PARTIAL_AID setting, consider the case of a BSS with BSSID 00-21-6A-AC-53-52 that has as a member a non-AP STA assigned AID 5.[28] In VHT PPDUs sent to an AP, the GROUP_ID is set to 0 and the PARTIAL_AID is set to 164. In VHT PPDUs sent by the AP to the non-AP STA associated with that AP, the GROUP_ID is set to 63 and PARTIAL_AID is set to 229.

As an example of the PARTIAL_AID setting, consider the case of a BSS with BSSID 00-21-6A-AC-53-52 that has as a member a non-AP CMMG STA assigned AID 5. In CMMG PPDUs sent to an AP, the PARTIAL_AID is set to 165. In CMMG PPDUs sent by the AP to the non-AP STA associated with that AP, the PARTIAL_AID is set to 37.

A STA transmitting a CMMG PPDU that is addressed to an AP shall set the TXVECTOR parameter UPLINK_INDICATION to 1. The UPLINK_INDICATION parameter shall be set to 0 for all other cases.

The TXVECTOR parameter COLOR is used to assist a receiving STA in identifying the BSS from which a reception originates so that the receiving STA might increase spatial reuse and reduce power consumption by terminating the reception process in the case when the reception is not from the BSS of which the STA is a member. A STA transmitting a CMMG PPDU that is addressed to an AP need not include the TXVECTOR parameter COLOR in the TXVECTOR. A STA transmitting a CMMG PPDU that is not an NDP and that is sent by a TDLS STA in a direct path to a TDLS peer STA shall set the TXVECTOR parameter COLOR to the value of the COLOR parameter, if present, from the RXVECTOR of the most recently received frame from its associated AP or from the DO of the IBSS of which it is a member that contained a COLOR parameter. An AP transmitting a CMMG PPDU shall set the TXVECTOR parameter COLOR to a value of its choosing and shall maintain that value for the duration of the existence of the BSS. The AP which is a member of a Multiple BSSID Set shall set the TXVECTOR parameter COLOR for each different BSSID(*i*) to a same value.

[28] As described in IEEE Std 802, the use of hyphens for the BSSID indicates hexadecimal representation rather than bit-reversed representation.

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An AP shall include the value that it is using for the TXVECTOR parameter COLOR in the COLOR field of the CMMG Capabilities Info field of the CMMG Capabilities element in all frames that contain that element. The COLOR field of the CMMG Capabilities Info field of the CMMG Capabilities element in all frames transmitted from a non-AP STA is reserved.

## 10.20 S1G dynamic AID assignment operation

An S1G STA may support dynamic AID assignment. A STA with dot11DynamicAIDActivated equal to true is defined as a D-AID STA. A D-AID STA shall set the Dynamic AID field of the S1G Capabilities Information field in the S1G Capabilities element to 1. Otherwise it shall set the Dynamic AID field to 0.

(#1276)When performing the S1G dynamic AID operations described in this subclause(Ed1), if management frame protection is negotiated and both STAs set the Extended S1G Action Protection field in the RSNXE that they transmit to 1, the STAs shall:

— use individually addressed Protected AID Switch Request, Protected AID Switch Response and Protected Information Announcement frames instead of AID Switch Request, AID Switch Response and STA Information Announcement frames, respectively and

— discard any individually addressed AID Switch Request, AID Switch Response or STA Information Announcement frame received from the peer STA, with which management frame protection is negotiated.

(#1276)STAs that exchange individually addressed Protected AID Switch Request, Protected AID Switch Response or Protected STA Information Announcement frames shall follow the rules defined in 12.6.17 (Protection of robust Management frames.).

(#1276)When management frame protection is not negotiated or the Extended S1G Action Protection field in the RSNXE transmitted by either STA is set to 0, the STAs shall not use the Protected AID Switch Request, Protected AID Switch Response nor the Protected STA Information Announcement frame.

A D-AID STA may transmit AID Switch Request or AID Switch Response frames to a D-AID STA. A STA shall not transmit an AID Switch Request frame or AID Switch Response frame to a STA from which it has received an S1G Capabilities element with the Dynamic AID field equal to 0.

When the traffic pattern or the service characteristic or the remaining battery life of a D-AID STA is changed, the D-AID STA may change its listen interval. If the listen interval of the STA is changed, the AID of the STA should be updated so that the STA belong to the STA group consisting of the STAs having the same listen interval. A D-AID STA requesting a new listen interval may transmit an AID Switch Request frame containing an AID Request element with the AID Request Interval Present subfield of an AID Request Mode field equal to 1 and the AID Request Interval field equal to the requested new listen interval to the AP. The Service Characteristic field may be included in the AID Request element with the Service Characteristic Present subfield of the AID Request Mode field equal to 1 to inform the AP of the service characteristic of the STA if it has been changed. After receiving the AID Switch Request frame, the AP with dot11DynamicAIDActivated equal to true shall respond with an AID Switch Response frame containing an AID Response element with the AID/Group AID field equal to a new AID and the AID Response Interval field equal to a new listen interval. The AP may assign a particular AID to the D-AID STA taking into account the received service characteristic information from the STA if it is included in the AID Switch Request frame.


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An illustration of the dynamic AID assignment is shown in Figure 10-26 (Illustration of dynamic AID assignment(#220)).

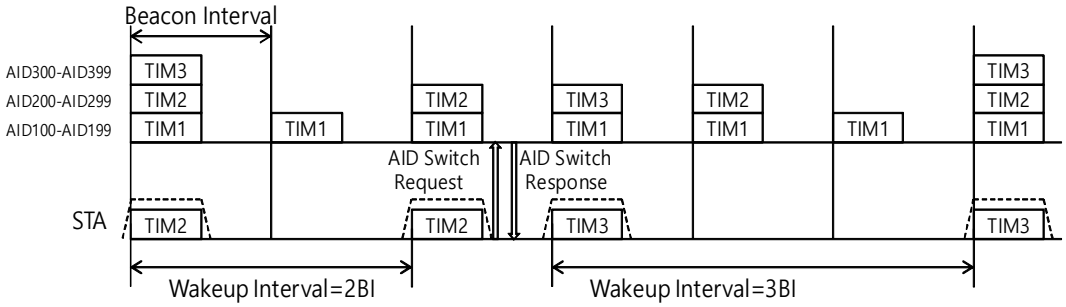


**Figure 10-26—Illustration of dynamic AID assignment(#220)**

A D-AID STA may switch between TIM mode and non-TIM mode during operation.

The mode switching is initiated by a non-AP D-AID STA. When the D-AID STA switches from TIM mode to non-TIM mode, the STA should inform the AP of its switching through the AID Switch Request frame with the Non-TIM Mode Switch subfield of the AID Request element set to 1 and the TIM Mode Switch subfield set to 0, the STA otherwise should inform the AP of its switching through the AID Switch Request frame with the TIM Mode Switch subfield of AID Request element equal to 1 and Non-TIM Mode Switch subfield set to 0 when the STA switches from non-TIM mode to TIM mode. A D-AID STA that switches between TIM mode and non-TIM mode, which also wants to update its listen interval may request a listen interval change by including a listen interval value in the AID Request Interval field in the AID Request element. The Service Characteristic field may be included in the AID Request element if the service characteristic has been changed.

Upon receiving AID Switch Request frame with the Non-TIM Mode Switch subfield or TIM Mode Switch subfield of AID Request element equal to 1, the AP may reassign a new AID to the STA. The new AID is transmitted to the D-AID STA by including it in the AID Response element of the AID Switch Response frame. The AP may reassign a new value for the listen interval and include it in the AID Response Interval field of the AID Response element. The STA shall update its listen interval to the value indicated in the AID Response.

If the AID included in the AID Response element of the AID Switch Response frame is not the same as the STA's current AID, the STA shall use the AID included in the AID Response element as its new AID. The non-AP STA shall switch to the new AID after the duration specified by the AID Switch Count field in the received AID Response element.

An AP can change the group of a STA for load/traffic distribution of each group. An AP with dot11UnsolicitedDynamicAIDActivated equal to true may transmit an unsolicited AID Switch Response frame containing an AID Response element with the AID/Group AID field equal to a new AID and an the AID Response Interval field equal to a new listen interval to the STA that has the Unsolicited Dynamic AID bit equal to 1 in its S1G Capabilities element. The STA for which dot11UnsolicitedDynamicAIDActivated is true shall set the Unsolicited Dynamic AID field of the S1G Capabilities Information field in the S1G Capabilities element to 1.

When a D-AID STA has buffered frames for a peer non-AP STA, it may request to belong to the group of AIDs having the same listen interval with a the peer non-AP STA. A D-AID STA requesting the same listen interval with a the peer non-AP STA may transmit an AID Switch Request frame containing an AID Request element with the Peer STA Address Present subfield of an AID Request Mode field equal to 1 and a the Peer STA Address field equal to the MAC address of the peer non-AP STA to an the AP. After receiving

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the AID Switch Request frame, the AP with dot11DynamicAIDActivated equal to true shall respond with an AID Switch Response frame containing an AID Response element with an the AID/Group AID field equal to a new AID and the AID Response Interval field equal to the same listen interval with the peer non-AP STA.

When the AID of a non-AP D-AID STA has changed and that STA has direct connections with other peer STAs (e.g., TDLS), the AP shall transmit a STA Information Announcement frame (see 9.6.24.5 (STA Information Announcement frame format)) that contains the updated AID of the non-AP STA to each peer STA. A D-AID STA with direct connections with non-AP D-AID STAs that receives a STA Information Announcement frame shall update the AIDs of these STAs with the information contained in the received frame.

If a non-AP STA with direct connections receives a STA Information Announcement frame including an AID Announcement element from a peer STA, the non-AP STA updates the peer STA's AID to the received AID and sends the Ack frame after a SIFS.(#6587)

An S1G STA may indicate to the AP its service characteristic information by including the Service Characteristic field in the AID Request element in (Re)Association Request frames as described in 11.3.5.11 (Service characteristic indication during association) in which case the AID Request Interval field of the element is equal to the value of the Listen Interval field of the (Re)Association Request frame. Otherwise the AID Request element is not present in the (Re)Association Request frame.

## 10.21 Group ID, partial AID, Uplink Indication, and COLOR in S1G PPDUs

The S1G partial AID is a nonunique identifier of an S1G STA as defined in Table 10-15 (Settings for the TXVECTOR parameter PARTIAL_AID for an NDP) and Table 10-16 (Settings for the TXVECTOR parameter PARTIAL_AID for non-1 MHz PPDUs and non-NDPs). The partial AID is carried in the TXVECTOR parameter PARTIAL_AID of an S1G SU PPDU with the TXVECTOR parameter CH_BANDWIDTH set to CBW2, CBW4, CBW8, or CBW16 and is limited to 9 bits.

A STA transmitting an S1G PPDU carrying one or more group addressed MPDUs that share a single, common group AID value shall set the TXVECTOR parameter PARTIAL_AID according to (#4280)Table 10-16 (Settings for the TXVECTOR parameter PARTIAL_AID for non-1 MHz PPDUs and non-NDPs). A STA transmitting an S1G PPDU carrying one or more group addressed MPDUs that do not share a common group AID and a common BSSID or that is transmitting an S1G NDP intended for multiple recipients shall set the TXVECTOR parameter PARTIAL_AID to 0. The intended recipient of an S1G NDP is defined in 10.35.7 (Transmission of an S1G NDP).

A STA transmitting an S1G SU PPDU carrying one or more individually addressed MPDUs or an S1G NDP intended for a single recipient shall select any one of the AIDs assigned to the recipient and then set the TXVECTOR parameter PARTIAL_AID as shown in Table 10-15 (Settings for the TXVECTOR parameter PARTIAL_AID for an NDP) and Table 10-16 (Settings for the TXVECTOR parameter PARTIAL_AID for non-1 MHz PPDUs and non-NDPs).

NOTE—In Table 10-15 (Settings for the TXVECTOR parameter PARTIAL_AID for an NDP) and Table 10-16 (Settings for the TXVECTOR parameter PARTIAL_AID for non-1 MHz PPDUs and non-NDPs), the last row includes the cases of a PPDU carrying MPDUs:

a) Sent by an IBSS STA to one or more IBSS STAs
b) Sent by an AP to a non associated STA
c) Any other condition not explicitly listed elsewhere in the table.

An S1G STA shall include the values computed in Table 10-15 (Settings for the TXVECTOR parameter PARTIAL_AID for an NDP) in the PHYCONFIG_VECTOR parameter PARTIAL_AID_LIST_GID00 and PARTIAL_AID_LIST_GID63.


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**Table 10-15—Settings for the TXVECTOR parameter PARTIAL_AID for an NDP**

| Condition | PARTIAL_AID |
|---|---|
| An NDP that is intended for an AP or sent by an AP and intended for all STAs associated with that AP.(#3454) | (*int*(BSSID[39:47])) mod ($2^9 - 1$) + 1 |
| An NDP that is sent by an AP and intended for a STA associated with that AP or for a group of non-AP STAs with a common group AID and a common BSSID, or sent by a TDLS STA and intended for a TDLS peer STA.(#3454) | STA_Partial_AID_NDP (see Equation (10-15))(#6096) |
| Otherwise | 0 |

**Table 10-16—Settings for the TXVECTOR parameter PARTIAL_AID for non-1 MHz PPDUs and non-NDPs**

| Condition | PARTIAL_AID |
|---|---|
| A PPDU containing one or more frames addressed to an AP; except for a PPDU that just contains a single frame, and that frame is a Control frame.(#3454) | *int*(BSSID[39:47]) mod ($2^9$–1)) + 1 |
| A PPDU containing one or more frames sent by an AP and addressed to a STA associated with that AP or to a group of STAs with a common group AID and a common BSSID, or sent by a TDLS STA in a direct path to a TDLS peer STA; except for a PPDU that just contains a single frame, and that frame is a Control frame.(#3454) | STA_Partial_AID (see Equation (10-16))(#6096) |
| Otherwise | 0 |

An S1G STA that transmits an S1G PPDU to a TDLS peer STA obtains the AID for the peer STA from TDLS Setup Request, or TDLS Setup Response frame.

(#371)(#6096)An S1G AP should not assign an AID that results in the STA_Partial_AID_NDP value as computed using Equation (10-15):

$$\text{STA\_Partial\_AID\_NDP} = (\text{AID}[0{:}8] + int(\text{BSSID}[44{:}47] \oplus \text{BSSID}[40{:}43]) \times 2^5) \bmod 2^9 \quad (10\text{-}15)$$

being equal to one of the following:

$$0 \quad \text{or} \quad (int(\text{BSSID}[39{:}47]) \bmod (2^9 - 1)) + 1 \quad \text{or} \quad (int(\text{OBSSID}[39{:}47]) \bmod (2^9 - 1) + 1$$

where OBSSID is the BSSID of a BSS that is not the BSS of which the AP is a member and for which the AP might be heard by the STA being assigned the AID.

(#6096)An SIG AP should not assign an AID that results in the STA_Partial_AID value as computed using Equation (10-16):

$$\text{STA\_Partial\_AID} = (\text{AID}[0{:}8] + int(\text{BSSID}[44{:}47] \oplus \text{BSSID}[40{:}43]) \times 2^5) \bmod 2^6 \quad (10\text{-}16)$$

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being equal to one of the following:

0 or (*int*(BSSID[39:47]) mod ($2^9$ – 1)) + 1 or (*int*(OBSSID[39:47]) mod ($2^9$ – 1) + 1

where OBSSID is the BSSID of a BSS that is not the BSS of which the AP is a member and for which the AP might be heard by the STA being assigned the AID.

An S1G STA transmitting an S1G MU PPDU sets the TXVECTOR parameter GROUP_ID as described in 23.3.10.4 (Group ID).

As an example of the PARTIAL_AID setting, consider the case of a BSS with BSSID 00-21-6A-AC-53-52 that has as a member a non-AP S1G STA assigned AID 5. In an NDP sent by the non-AP S1G STA to (#371)the AP, the PARTIAL_AID is equal to 165. In an NDP sent by the S1G AP to the non-AP STA, the PARTIAL_AID is equal to 229. In a non-1 MHz S1G PPDU that is not an NDP(#371), that does not contain a Control frame and that is sent by the non-AP S1G STA to the AP, the PARTIAL_AID is set to 165. In a non-1 MHz S1G PPDU that is not an NDP(#371), that does not contain a Control frame and that is sent by the S1G AP to the non-AP STA, the PARTIAL_AID is set to 37.

A STA transmitting a non-1 MHz S1G PPDU that is not an NDP and that is addressed to an AP shall set the TXVECTOR parameter UPLINK_INDICATION to 1. The UPLINK_INDICATION parameter shall be set to 0 for all other cases. The TXVECTOR parameter UPLINK_INDICATION is not present for 1 MHz PPDUs or NDPs.

The TXVECTOR parameter COLOR is used to assist a receiving STA in identifying the BSS from which a received PPDU originates so that the receiving STA reduces intra-BSS collisions by reporting a busy medium regardless of the received power when COLOR indicates that the current PPDU might be intra-BSS and might reduce power consumption by terminating the reception process when the received PPDU could not be from the BSS of which the STA is a member. A STA transmitting a non-1 MHz S1G PPDU that is not an NDP and that is addressed to an AP need not include the TXVECTOR parameter COLOR in the TXVECTOR. A STA transmitting a non-1 MHz S1G PPDU that is not an NDP and that is sent by a TDLS STA in a direct path to a TDLS peer STA shall set the TXVECTOR parameter COLOR to the value of the COLOR parameter, if present, from the RXVECTOR of the most recently received frame from its associated AP or from the STA transmitting a beacon of the IBSS of which it is a member that contained a COLOR parameter. An AP transmitting a non-1 MHz S1G PPDU that is not an NDP shall set the TXVECTOR parameter COLOR to a value of its choosing and shall maintain that value for the duration of the existence of the BSS. The AP which is a member of a Multiple BSSID Set shall set the TXVECTOR parameter COLOR for each different BSSID(*i*) to a same value.

When an S1G AP transmits a non-1 MHz S1G PPDU that is not an NDP, the AP shall set the TXVECTOR parameter COLOR to the value of the COLOR field of the S1G Capabilities Information field of the S1G Capabilities element transmitted by the AP. The COLOR field of the S1G Capabilities Information field of the S1G Capabilities element in all frames transmitted from a non-AP STA is reserved.

The partial BSSID is defined to be the PARTIAL_AID of the address of the STA contained in the AP and is equal to

(*int*(BSSID[39:47]) mod ($2^9$– 1)) + 1


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## 10.22 Operation across regulatory domains

### 10.22.1 General

The PHY of a WLAN is subject to regulations that might vary significantly from one regulatory domain to another. This subclause provides the framework for operation across regulatory domains and describes the mechanism that supports cross-domain mobility and operation in multiple regulatory domains. When this mechanism is active, dot11MultiDomainCapabilityActivated attribute be true.

NOTE—This subclause does not eliminate the need to obtain type acceptance, regulatory approval, equipment authorization, or equipment certification in each of the regulatory domains in which the equipment operates. The mechanisms described in this subclause provide the information to the STA to identify the regulatory domain in which it is located and to cease operation while in those domains for which it does not have type approval. It is incumbent upon the implementer to provide proof of compliance to the requirements of individual regulatory agencies.

The method for configuring individual STAs is outside the scope of this standard. A STA needs to be properly configured for operation in a particular regulatory domain prior to beginning normal operation. Particular care needs to be taken when operating in an IBSS configuration.

### 10.22.2 Operation upon entering a regulatory domain

A STA that is enabled for operation across regulatory domains uses passive scanning when it has lost connectivity with its ESS. Passive scanning is performed using only the receive capabilities of the STA and is, thus, compatible with regulatory requirements. The timeout for determining the loss of connectivity is system dependent and beyond the scope of this standard.

When a STA with dot11MultiDomainCapabilityActivated true enters a regulatory domain, before transmitting, it shall passively scan to learn at least one valid channel, i.e., a channel upon which it detects IEEE 802.11 frames. The Beacon frame transmitted by non-DMG STAs and the DMG Beacon or Announce frame transmitted by DMG STAs contains information on the country code, the maximum allowable transmit power, and the channels that may be used for the regulatory domain. Optionally, these frames may also include in the Country element, on a periodic basis, the regulatory information that would be returned in a Probe Response frame. When DSE dependent STA operation is required in a regulatory domain, a dependent STA may be required to receive a Beacon, DMG Beacon, or an Announce frame signaling dependent enablement (11.11.5 (Dependent STA operation with DSE)), and until one of these frames is received, the STA may continue passive scanning to receive one such frame directly from an enabling STA. Once the STA has acquired the information so that it is able to meet the transmit requirements of the regulatory domain, it shall transmit a Probe Request frame to an AP or PCP to gain the additional necessary regulatory domain information contained in the Probe Response frame, unless the information was previously received in a Beacon, DMG Beacon, or Announce frame. The STA then has sufficient information available to configure its PHY for operation in the regulatory domain.

### 10.22.3 Operation with operating classes

The following, and only the following, are extended spectrum management capable: a VHT STA, (11ax)an HE STA, and a STA that has dot11ExtendedSpectrumManagementImplemented true. A non-VHT STA that has dot11ExtendedSpectrumManagementImplemented true shall indicate that it is extended spectrum management capable using the Extended Spectrum Management Capable field of the Extended Capabilities element.

When communicating with a STA that supports global operating classes, all requests and Action and Action No Ack frames that convey elements containing operating classes shall use global operating class values.

When dot11OperatingClassesImplemented is true, the following statements apply:

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- When dot11OperatingClassesRequired is false, or where operating classes domain information is not present in a STA, that STA is not required to change its operation in response to an element that contains an operating class.
- When dot11OperatingClassesRequired is true, or where operating classes domain information is present in a STA, the STA shall indicate current operating class information in the Country element and Supported Operating Classes element, except for the following cases:(11ax)
  - (11ax)A VHT STA may omit from the Country element any Operating Triplet field for an Operating Class for which the Channel spacing (MHz) column indicates 80 MHz or wider and for which the Behavior limits set column in the applicable table in Annex E contains only a blank entry or either or both of "80+" and "UseEirpForVHTTxPowEnv."
  - (11ax)An HE STA may omit from the Country element any Operating Triplet field for an Operating Class for which the (#4177)Channel starting frequency column in Table E-4 (Global operating classes) is greater than or equal to 5.925 and less than or equal to 7.125.
- When dot11OperatingClassesRequired and dot11ExtendedChannelSwitchActivated are true and a STA is capable of operating as specified in more than one operating class, the STA shall include the Supported Operating Classes element in (Re)Association Request and Response frames.
- When dot11OperatingClassesRequired is true, or where operating classes domain information is present and the STA parsing a Country element finds an invalid First Channel Number field or Operating Class field with a value that is reserved, the STA shall ignore the remainder of the Country element and shall parse any remaining management frame body for additional elements.
- When dot11OperatingClassesRequired is true and the STA supports one or more global operating classes, or where global operating classes domain information is present in a STA, the STA shall indicate current operating class information in the Country element and Supported Operating Classes element using the country string for the global operating classes, except for the following cases:(11ax)
  - (11ax)A VHT STA may omit from the Country element any Operating Triplet field for an Operating Class for which the Channel spacing (MHz) column indicates 80 MHz or wider and for which the Behavior limits set column in the applicable table in Annex E contains only a blank entry or either or both of "80+" and "UseEirpForVHTTxPowEnv."
  - (11ax)An HE STA may omit from the Country element any Operating Triplet field for an Operating Class for which the (#4177)Channel starting frequency column in Table E-4 (Global operating classes) is greater than or equal to 5.925 and less than or equal to 7.125.

### 10.22.4 Operation with the Transmit Power Envelope element

A STA that (11ax)is not operating in the 6 GHz band, is extended spectrum management capable, and(11ax) has dot11SpectrumManagementRequired or dot11RadioMeasurementActivated equal to true shall determine a local maximum transmit power from a Transmit Power Envelope element for which (11ax)the Maximum Transmit Power Interpretation subfield indicates EIRP.

(11ax)A STA that is operating in the 6 GHz band shall determine local and regulatory client maximum transmit powers from Transmit Power Envelope element(s) (#6077)and other sources known to the STA, according to local regulations known at the STA (see 11.7.5 (Specification of regulatory and local maximum transmit power levels) and E.2.7 (6 GHz band(11ax)(#600))). A STA shall ignore Transmit Power Envelope element(s) indicating transmit power category values that the STA is unable to interpret for the current country.

NOTE 1—The Default category value (0) is applicable to, and so can be interpreted for, all countries (see 11.7.5 (Specification of regulatory and local maximum transmit power levels)). An AP in the 6 GHz band has dot11SpectrumManagementRequired equal to true and therefore transmits a Country element in Beacon and Probe Response frames.(11ax)


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A STA that sends two or more Transmit Power Envelope elements in a frame shall order the elements by increasing values of their(11ax) Maximum Transmit Power Interpretation subfields.

(11ax)A STA that is operating in the 6 GHz band that sends two or more Transmit Power Envelope elements in a frame with the same value in the Maximum Transmit Power Interpretation subfield shall order the elements by increasing values of their Maximum Transmit Power Category subfields.

NOTE 2—The Maximum Transmit Power Category subfield is reserved, except in the 6 GHz band.(11ax)

If a STA that is extended spectrum management capable finds an unknown value in the(11ax) Maximum Transmit Power Interpretation subfield in a Transmit Power Envelope element, then the STA shall ignore that and subsequent Transmit Power Envelope elements.

A STA that receives two or more Transmit Power Envelope elements in the same frame with known values in their (11ax)Maximum Transmit Power Interpretation subfields shall process all of the elements according to the local regulations known at the STA.

NOTE 3—If a STA receives two Transmit Power Envelope elements, each with a known value in the(11ax) Maximum Transmit Power Interpretation subfield(11ax), then the expected possibilities are as follows:

a) The STA complies with either element (shared spectrum),
b) The STA complies with both elements (tightened regulations), or
c) The STA complies with the second element (changed regulations).

If a STA receives a Transmit Power Envelope element with the Maximum Transmit Power Interpretation subfield equal to 1 or 3 (EIRP PSD) and the Maximum Transmit Power Count subfield indicating a value of *N* greater than 1, 2, 4, or 8 from an AP that the STA identifies to have BSS bandwidth of 20, 40, 80, or 160/80+80 MHz, respectively, then the STA shall use the Maximum Transmit PSD 1–*M* subfields (*M* equal to 1, 2, 4, or 8 for BSS bandwidth of 20, 40, 80, or 160/80+80 MHz, respectively) to determine the maximum transmit PSD for each 20 MHz channel within the BSS bandwidth. The STA shall ignore the Maximum Transmit PSD *X* subfields with $X > M$.

NOTE 4—This might occur when the AP supports PHY mode(s) unknown to the STA and the actual BSS bandwidth is wider than the BSS bandwidth recognized by the STA.(11ax)

### 10.22.5 Operation with coverage classes

The attribute aSlotTime and other MAC timings are based on the PHY timing parameters, as specified in 10.3.2.3 (IFS), 10.3.7 (DCF timing relations), and 10.23.2.5 (EDCA channel access in a VHT or TVHT BSS), and in particular on aAirPropagationTime. If dot11OperatingClassesRequired is true, it is possible to manage the MAC timings of STAs to increase fairness in contending for the medium. Radio waves propagate at ~300 m/μs in free space, and, for example, 3 μs would be the maximum round-trip delay for a BSS with maximum coverage distance of ~450 m (~900 m round trip). The Coverage Class field of the Country element indicates a value of aAirPropagationTime (see Table 9-133 (Coverage Class field parameters)), and the MAC can use the value to calculate aSlotTime (as specified in the relevant PHY clause) and other timings.

If dot11OperatingClassesRequired is true and a Country element containing a Coverage Class field has been received from the AP of the BSS of which a STA is a member, from the DO of the IBSS of which a STA is a member, or from another mesh STA in the same MBSS, an associated STA, dependent STA, IBSS STA, or member of an MBSS shall, if the relevant PHY clause specifies that aAirPropagationTime is indicated by the coverage class, use MAC timings that correspond to the value of aAirPropagationTime indicated (as specified in the relevant PHY clause).

NOTE 1—Some PHYs do not specify a dependency of aSlotTime on aAirPropagationTime.

NOTE 2—Operation over larger BSS diameters is facilitated by relaxing some PHY timing parameters, while maintaining compatibility with existing implementations in small BSS diameters.

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NOTE 3—An AP using coverage classes that determines that an associating or associated STA does not support coverage classes may deny association to or disassociate that STA. The mechanism by which the AP makes that determination is outside the scope of the standard.

aAirPropagationTime is 0 μs if

- The relevant PHY clause specifies that aAirPropagationTime is indicated by the coverage class, and
- At least one of the following applies:
  - dot11OperatingClassesRequired is false.
  - No Country element containing a Coverage Class field has been received from the AP of the BSS of which a STA is a member, from the DO of the IBSS of which a STA is a member, or from another mesh STA in the same MBSS.

## 10.23 HCF

### 10.23.1 General

Under HCF, the basic unit of allocation of the right to transmit onto the WM is the TXOP. Each TXOP is defined by a starting time and a defined maximum length. In a non-DMG BSS, the TXOP may be obtained by a STA winning an instance of EDCA contention (see 10.23.2 (HCF contention based channel access (EDCA))) or by a STA receiving a QoS (+)CF-Poll frame (see 10.23.3 (HCF controlled channel access (HCCA))). The former is called *EDCA TXOP*, while the latter is called *HCCA TXOP* or *polled TXOP*.

In a DMG BSS, the EDCAF operates only during CBAPs. Operation of the EDCAF is suspended at the end of a CBAP and is resumed at the beginning of the following CBAP. See 10.38.5 (Contention based access period (CBAP) transmission rules) and 10.38.5 (Contention based access period (CBAP) transmission rules) for additional rules regarding contention based access in DMG BSSs.

HCCA is not used by DMG, S1G, and HE STAs.(11ax)

### 10.23.2 HCF contention based channel access (EDCA)

#### 10.23.2.1 Reference model

The EDCA channel access protocol is derived from the DCF procedures described in 10.3 (DCF) by adding four independent enhanced distributed channel access functions (EDCAFs) to provide differentiated priorities to transmitted traffic, through the use of four different access categories (ACs).

For the case in which dot11AlternateEDCAActivated is false or not present, a model of the reference implementation is shown in Figure 10-27 (Reference implementation model when dot11AlternateEDCAActivated is false or not present) and for the case in which dot11AlternateEDCAActivated is true, a model is shown in Figure 10-28 (Reference implementation model when dot11AlternateEDCAActivated is true). These figures illustrate a mapping from frame type or UP to the transmit queues and the four independent EDCAFs. The mapping of UP to the transmit queue and the mapping to AC are described in 10.2.3.2 (HCF contention based channel access (EDCA)) and Table 10-1 (UP-to-AC mappings(#68)). The mapping of frame types to ACs is also described in 10.2.3.2 (HCF contention based channel access (EDCA)).

An S1G STA shall be a QoS STA.

A DMG STA or an S1G STA that is a sensor STA may implement a single AC. If the DMG or S1G STA implements a single AC, all UP and frame types shall be mapped to AC_BE.


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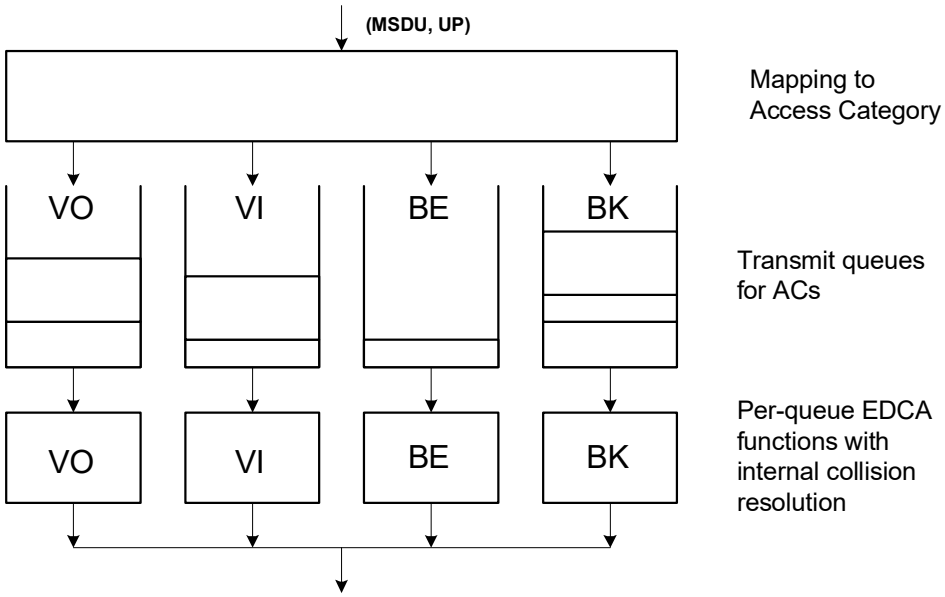


**Figure 10-27—Reference implementation model when dot11AlternateEDCAActivated is false or not present**

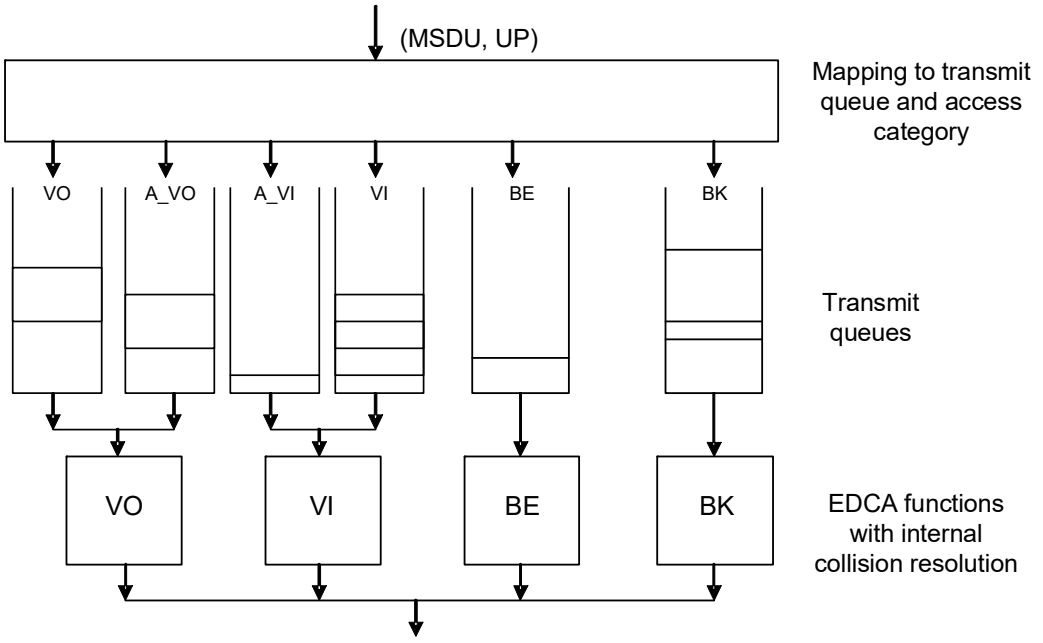


**Figure 10-28—Reference implementation model when dot11AlternateEDCAActivated is true**

NOTE—A DMG or S1G STA that implements a single AC has only one queue in Figure 10-27 (Reference implementation model when dot11AlternateEDCAActivated is false or not present).

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### 10.23.2.2 EDCA backoff procedure

Each EDCAF shall maintain a MAC variable CW[AC], which shall be initialized to the value of the parameter CWmin[AC], for that EDCAF's AC.

For the purposes of this subclause, (#159)transmission success or failure of an MPDU is defined as follows:

- After transmitting an MPDU (even if it is carried in an A-MPDU, (11ax)as part of a VHT or S1G MU PPDU, (11ax)or as part of an HE MU PPDU that is sent using TXVECTOR parameter NUM_USERS > 1) that requires an immediate response:
  - The STA shall wait for a timeout interval of duration aSIFSTime + aSlotTime + aRxPHYStartDelay, starting when the MAC receives a PHY-TXEND.confirm primitive. If a (#3038)PHY-RXEARLYSIG.indication or PHY-RXSTART.indication primitive does not occur during the timeout interval, the transmission of the MPDU has failed.
  - If a (#3038)PHY-RXEARLYSIG.indication or PHY-RXSTART.indication primitive does occur during the timeout interval, the STA shall wait for the corresponding PHY-RXEND.indication primitive to (#4179)receive a response MPDU(#109) that either does not have a TA field or is sent by the recipient of the MPDU requiring a response. (#4179)Anything else, including the reception of any other frame, is defined to be a failure.
- The nonfinal (re)transmission of an MPDU that is delivered using the GCR unsolicited retry retransmission policy (10.23.2.12.2 (Unsolicited retry procedure)) is defined to be a failure.
- In all other cases, the transmission of the MPDU is considered to be a successful transmission.(#159)

The TXNAV timer is a single timer, shared by the EDCAFs within a STA, that is initialized with the duration from the Duration/ID field in the frame most recently successfully transmitted by the TXOP holder, except for PS-Poll frames. The TXNAV timer begins counting down from the end of the transmission of the PPDU containing that frame. The Reservation Allocation Vector (RAV) timer for a mesh STA that has dot11MCCAActivated true is initialized with the MCCAOP Duration in the MCCAOP Reservation field at the start of an MCCAOP reservation. The RAV timer begins counting down from the start of an MCCAOP reservation (see 10.24.3.9.2 (Access during an MCCAOP by mesh STAs that are not the MCCAOP owner)).

The backoff procedure shall be invoked by an EDCAF (11ax)if any of the following events occurs:

a) An MA-UNITDATA.request primitive is received that causes an MPDU corresponding to the EDCAF's AC to be queued for transmission such that all of the following are true:
   1) One of the transmit queues associated with that AC has now become nonempty(#2222)
   2) Any other transmit queues associated with that AC are empty
   3) The backoff counter has a value of 0 for that AC
   4) The medium is busy on the primary channel as indicated by any of the following:
      - Physical CS
      - Virtual CS
      - A nonzero TXNAV timer value
      - For a mesh STA that has dot11MCCAActivated true, a nonzero RAV timer value

b) For the EDCAF that is the TXOP holder, the transmission of the final PPDU transmitted by the TXOP holder during the TXOP has completed, the final PPDU does not solicit an HE TB PPDU, and the TXNAV timer has expired.(11ax)

c) For the EDCAF that is the TXOP holder, the transmission of an MPDU in the initial PPDU of a TXOP fails, as defined in this subclause, and the initial PPDU does not solicit an HE TB PPDU.(11ax)


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d) A transmission attempt by the EDCAF collides internally with another EDCAF of an AC that has higher priority, that is, two or more EDCAFs in the same STA are granted a TXOP at the same time.

e) The transmission of at least one MPDU in the final PPDU transmitted by the TXOP holder during the TXOP for that AC has completed, the PPDU contains an MPDU that solicits an HE TB PPDU and the TXNAV timer has expired.(11ax)

f) The transmission of all MPDUs in the initial PPDU of a TXOP fails, as defined in this subclause, and the PPDU contains an MPDU that solicits an HE TB PPDU.(11ax)

g) If explicitly indicated, such as in 26.17.2.3.3 (Non-AP STA scanning behavior).(11ax)

h) The EDCAF is permitted to initiate a TXOP (see 10.23.2.4 (Obtaining an EDCA TXOP)) but chooses not to.(#3653)

In addition, the backoff procedure may be invoked by an EDCAF if:

i) For the EDCAF that is the TXOP holder, the transmission by the TXOP holder of an MPDU in a non-initial PPDU of a TXOP fails, as defined in this subclause and an MPDU in the non-initial PPDU does not solicit an HE TB PPDU.(11ax)

j) For the EDCAF that is the TXOP holder, the transmission by the TXOP holder of all MPDUs in a non-initial PPDU of a TXOP fails, as defined in this subclause, and the PPDU contains an MPDU that solicits an HE TB PPDU.(11ax)

NOTE 1—If the transmission by the TXOP holder of an MPDU in a non-initial PPDU of a TXOP failed, the STA can perform either a PIFS recovery, as described in 10.23.2.8 (Multiple frame exchange sequences in an EDCA TXOP(#109)), perform a backoff as described in item i) (#1107)above, or wait for the TXNAV timer to expire and invoke the backoff procedure per item b) above. How it chooses among these options is implementation dependent.

A STA that performs a backoff within its existing TXOP per item i) (#1108)above shall not extend the TXNAV timer value (see 10.23.2.8 (Multiple frame exchange sequences in an EDCA TXOP(#109))).

NOTE 2—In other words, the backoff is a continuation of the TXOP, not the start of a new TXOP.

If the backoff procedure is invoked for (M133)reason a), g) or h) above, CW[AC] and QSRC[AC] shall be left unchanged.(#3653)

If the backoff procedure is invoked for (M133)reason b) or e)(11ax) above, CW[AC] shall be set to CWmin[AC], and QSRC[AC] shall be set to 0.(#3653)

If the backoff procedure is invoked for (M133)reason c), d), f), i), or j)(11ax) above, CW[AC] and QSRC[AC] shall be updated as follows:(#3653)

- If QSRC[AC] is less than dot11ShortRetryLimit,
  - QSRC[AC] shall be incremented by 1.
  - CW[AC] shall be set to the lesser of CWmax[AC] and $2^{QSRC[AC]} \times (CWmin[AC] + 1) - 1$.
- Else
  - QSRC[AC] shall be set to 0.
  - CW[AC] shall be set to CWmin[AC].

NOTE 3—An HE STA updates its local MIB variables related to CWmin and CWmax as defined in 26.2.7 (EDCA operation using MU EDCA parameters).(11ax)

(11ax)After transmission of an MPDU in an HE TB PPDU, an HE STA resumes the EDCA backoff procedure without modifying CW or the backoff counter for the associated EDCAF regardless of whether the STA has received the corresponding acknowledgment frame in response to the MPDU sent in the HE TB PPDU.

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### 10.23.2.3 EDCA TXOPs

There are three modes of EDCA TXOP defined: initiation of an EDCA TXOP, sharing an EDCA TXOP, and multiple frame exchange sequence(s)(#109) within an EDCA TXOP. Initiation of the TXOP occurs when the EDCA rules permit access to the medium. Sharing of the EDCA TXOP occurs when an EDCAF within an AP that supports DL MU-MIMO(#3367) has obtained access to the medium, making the corresponding AC the primary AC, and includes traffic from queues associated with (#1109)other ACs, in MU PPDUs transmitted during the TXOP. (#1110)In addition, sharing of the EDCA TXOP also occurs when an EDCAF within an HE STA that intends to transmit a Multi-TID A-MPDU has obtained access to the medium following rules defined in 26.6.3 (Multi-TID A-MPDU and ack-enabled single-TID A-MPDU). Multiple frame exchange sequence(s)(#109) within the TXOP occurs when an EDCAF retains the right to access the medium.

### 10.23.2.4 Obtaining an EDCA TXOP

Each EDCAF shall maintain a backoff counter, which has a value measured in backoff slots as described below.

When the backoff procedure is invoked, the backoff counter is set to an integer value chosen randomly with a uniform distribution taking values in the range 0 to CW[AC].

The duration AIFS[AC] is a duration derived from the value AIFSN[AC] by the relation

AIFS[AC] = AIFSN[AC] × aSlotTime + aSIFSTime.

In an infrastructure BSS, AIFSN[AC] is advertised by an EDCA AP in the EDCA Parameter Set element in Beacon and Probe Response frames transmitted by the AP. The value of AIFSN[AC] shall be greater than or equal to 2 for non-AP STAs. The value of AIFSN[AC] shall be greater than or equal to 1 for APs. An EDCA TXOP is granted to an EDCAF when the EDCAF determines that it shall initiate (#109)a frame exchange sequence according to the following rules:

EDCAF operations shall be performed at slot boundaries, defined as follows on the primary channel, for each EDCAF:

a) Following AIFSN[AC] × aSlotTime – aRxTxTurnaroundTime of idle medium after a SIFS(#6587) (not necessarily idle medium during the SIFS) after the last busy medium on the antenna that was the result of a reception of a frame with a correct FCS or of an S1G frame. Note that upon reception of an S1G frame, an S1G STA updates its RID counter based on information obtained from the RXVECTOR as described in 10.3.2.5 (Setting and resetting the RID) and this update does not depend on the outcome of the FCS check.

b) Following EIFS – DIFS + AIFSN[AC] × aSlotTime + aSIFSTime – aRxTxTurnaroundTime of idle medium after the last indicated busy medium as determined by the physical CS mechanism that was the result of a non-S1G frame reception that has resulted in FCS error, or of a frame reception that has resulted in PHY-RXEND.indication (RXERROR) primitive where the value of RXERROR is not NoError.

c) When any other EDCAF at this STA transmitted a frame requiring immediate acknowledgment, the earlier of

   1) The end of the AckTimeout interval timed from the PHY-TXEND.confirm primitive, followed by AIFSN[AC] × aSlotTime + aSIFSTime – aRxTxTurnaroundTime of idle medium, and

   2) The end of the first AIFSN[AC] × aSlotTime – aRxTxTurnaroundTime of idle medium after a SIFS(#6587) (not necessarily medium idle during the SIFS, the start of the SIFS implied by the length in the PHY header of the previous frame) when a PHY-RXEND.indication primitive occurs as specified in 10.3.2.11 (Acknowledgment procedure).


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d) Following AIFSN[AC] × aSlotTime – aRxTxTurnaroundTime of idle medium after a SIFS(#6587) (not necessarily medium idle during the SIFS) after the last busy medium on the antenna that was the result of a transmission of a frame for any EDCAF and which did not require an acknowledgment and after the expiration of the TXNAV timer if nonzero, and, if dot11MCCAActivated is true, the expiration of the RAV timer if nonzero.

e) Following AIFSN[AC] × aSlotTime + aSIFSTime – aRxTxTurnaroundTime of idle medium after the last indicated busy medium as indicated by the CS mechanism that is not covered by condition a) to condition d).

f) Following aSlotTime of idle medium, which occurs immediately after any of these conditions, a) to f), is met for the EDCAF.

On these specific slot boundaries, each EDCAF shall make a determination to perform one and only one of the following functions:

— Decrement the backoff counter.
— (#109)(#3653)Initiate a TXOP.
— Invoke the backoff procedure due to choosing not to transmit.
— Invoke the backoff procedure due to an internal collision.(#3653)
— Do nothing.

At each of the above-described specific slot boundaries, each EDCAF shall decrement the backoff counter if the backoff counter for that EDCAF has a nonzero value.

At each of the above-described specific slot boundaries, if(#3653)

— There is a frame available for transmission at an EDCAF, and
— The backoff counter for that EDCAF has a value of 0, and
— Initiation of a transmission sequence is not allowed to commence at this time for an EDCAF of higher UP, that EDCAF shall either choose not to transmit (which results in invocation of the backoff procedure as specified in 10.23.2.2 (EDCA backoff procedure)) or initiate a TXOP.

NOTE 1—An EDCAF might choose not to transmit if the available bandwidth (based on the state of the secondary channel(s)) is insufficient for its purposes, or for other reasons.(#3653)

(#3653)At each of the above-described specific slot boundaries, each EDCAF shall report an internal collision (which results in invocation of the backoff procedure as specified in (#1361) 10.23.2.2 (EDCA backoff procedure) (see item d)) if

— There is a frame available for transmission at that EDCAF, and
— The backoff counter for that EDCAF has a value of 0, and
— (#109)Initiation of a frame exchange sequence is allowed to commence at this time for an EDCAF of higher UP.

(#3653)At each of the above-described specific slot boundaries, each EDCAF shall do nothing if

— There is no frame available for transmission at that EDCAF, and
— The backoff counter for that EDCAF has a value of 0.

(#1536)NOTE 2—An EDCAF does nothing at each of the above-described specific slot boundaries if there is not a frame available for transmission at that EDCAF and the backoff counter for that EDCAF has a value of 0.

NOTE 3—If an EDCAF gains access to the channel and transmits MSDUs, A-MSDUs, or MMPDUs from a secondary AC, the EDCAF of the secondary AC is not affected by this operation. If the EDCAF of a secondary AC experiences an internal collision with the EDCAF that gained access to the channel, it performs the backoff procedure regardless of the transmission of any of its MSDUs, A-MSDUs, or MMPDUs (see 10.23.2.7 (Sharing an EDCA TXOP)).

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An example showing the relationship between AIFS, AIFSN, DIFS, and slot times immediately following a medium busy condition (and assuming that medium busy condition was not caused by a frame in error) is shown in Figure 10-29 (EDCA mechanism timing relationships(#14)(#1058)). In this case, with AIFSN = 2, the EDCAF may decrement the backoff counter for the first time at 2 × aSlotTime following the TxSIFS (where TxSIFS is the time at which the MAC responds to the end of the medium busy condition if it is going to respond "after a SIFS")(#6587). If, in this example, the backoff counter contained a value of 1 at the time the medium became idle, transmission would start as a result of an EDCA TXOP on-air at a time

aSIFSTime + 3 × aSlotTime

following the end of the medium busy condition.

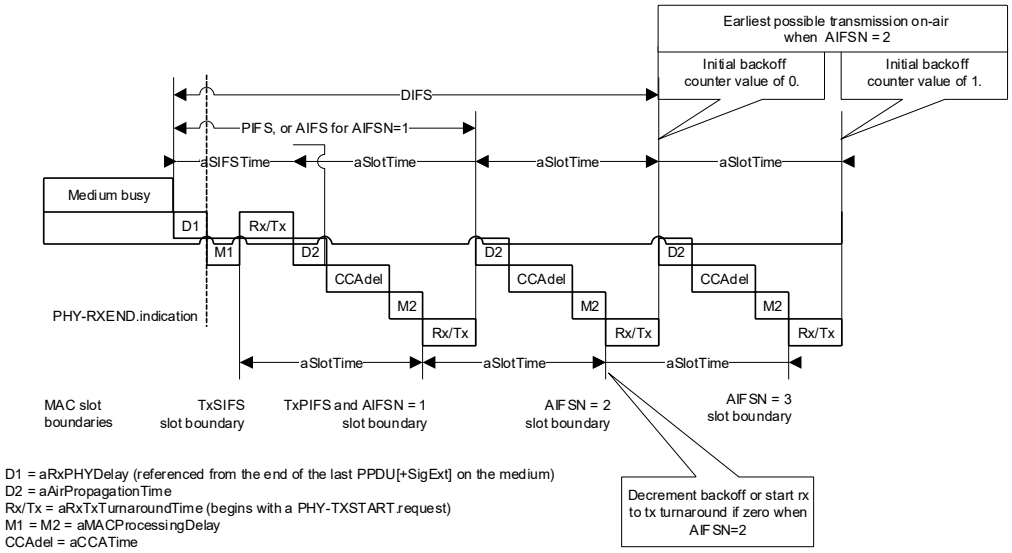


**Figure 10-29—EDCA mechanism timing relationships(#14)(#1058)**

A STA shall save the TXOP holder address for the BSS in which it is associated. (11ax)The TXOP holder address is the MAC address from the Address 2 field of the frame that initiated a frame exchange sequence except (11ax)if this is a CTS frame, in which case the TXOP holder address is the Address 1 field. If the TXOP holder address is obtained from a Control frame, a VHT STA (11ax)or HE STA shall save the nonbandwidth signaling TA(#3522) obtained from the Address 2 field. If a non-VHT non-HE STA(11ax) receives an RTS frame with the RA matching the MAC address of the STA and the MAC address in the TA field in the RTS frame matches the saved TXOP holder address, then the STA shall send the CTS frame after a SIFS(#6587), without regard for, and without resetting, its NAV. If a VHT STA (11ax)or HE STA receives an RTS frame with the RA matching the MAC address of the STA and the nonbandwidth signaling TA(#3522) obtained from the Address 2 field in the RTS frame matches the saved TXOP holder address, then the STA shall send the CTS frame after a SIFS(#6587), without regard for, and without resetting, its NAV. If a CMMG STA receives an RTS frame with the RA matching the MAC address of the STA and the TA value obtained from the Address 2 field in the RTS frame matches the saved TXOP holder address, then the STA shall send the CTS frame after a SIFS(#6587), without regarding for, and without resetting its NAV. When a STA receives a frame addressed to it that requires an immediate response, except for RTS (11ax)and Trigger frames (see 26.5.2.5 (UL MU CS mechanism)), it shall transmit the response independent of its NAV. The saved TXOP holder address shall be cleared when the NAV is reset or when the NAV counts down to 0.


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(11ax)During an EDCA TXOP, the Address 2 field excluding the Individual/Group bit of all Control frames sent by an HE STA that is a TXOP holder and carried in a PPDU that is not an HE MU PPDU shall be set to the same address value.

### 10.23.2.5 EDCA channel access in a VHT or TVHT BSS

If the MAC receives a PHY-CCA.indication primitive with the channel-list parameter present, the channels considered idle are defined in Table 10-17 (Channels indicated idle by the channel-list parameter for VHT or TVHT BSSs).

**Table 10-17—Channels indicated idle by the channel-list parameter for VHT or TVHT BSSs**

| PHY-CCA.indication primitive channel-list parameter entry | Idle channels |
|---|---|
| primary | None |
| secondary | Primary 20 MHz channel |
| secondary40 | Primary 20 MHz channel and secondary 20 MHz channel |
| secondary80 | Primary 20 MHz channel, secondary 20 MHz channel, and secondary 40 MHz channel |

(11ax)If the MAC receives a PHY-CCA.indication primitive with the per20bitmap parameter present, the parameter indicates the busy/idle status of each of the 20 MHz subchannels that comprise the operating channel width.

When a STA and the BSS, of which the STA is a member, both support multiple channel widths, an EDCA TXOP is obtained based solely on activity of the primary channel ((#311)see 10.23.2.4 (Obtaining an EDCA TXOP)). “Idle medium” in this subclause means “idle primary channel.” Likewise “busy medium” means “busy primary channel.” Once an EDCA TXOP has been obtained according to this subclause, further constraints defined in 11.15.9 (STA CCA sensing in a 20/40 MHz BSS) and 10.23.3 (HCF controlled channel access (HCCA)) might limit the width of transmission during the TXOP or deny the channel access, based on the state of CCA on secondary channel, secondary 40 MHz channel, or secondary 80 MHz channel.

In the following description, the CCA is sampled according to the timing relationships defined in 10.3.7 (DCF timing relations). Slot boundaries are determined solely by activity on the primary channel. “Channel idle for an interval of PIFS” means that the STATE parameter of the most recent PHY-CCA.indication primitive was IDLE, and no PHY-CCA.indication(BUSY) occurred during the period of PIFS that ends at the start of transmission, the CCA for that channel was determined to be idle.

(#3653)If one of a STA’s EDCAFs is permitted to initiate a TXOP (as specified in 10.23.2.4 (Obtaining an EDCA TXOP)), the STA shall perform exactly one of the following actions:

a) Transmit a 160 MHz or 80+80 MHz mask PPDU if the secondary channel, the secondary 40 MHz channel, and the secondary 80 MHz channel were idle during an interval of PIFS immediately preceding the start of the TXOP.

b) Transmit an 80 MHz mask PPDU on the primary 80 MHz channel if both the secondary channel and the secondary 40 MHz channel were idle during an interval of PIFS immediately preceding the start of the TXOP.

c) Transmit a 40 MHz mask PPDU on the primary 40 MHz channel if the secondary channel was idle during an interval of (11ax)duration 1) DIFS if the PPDU is transmitted in the 2.4 GHz band or 2) PIFS otherwise, immediately preceding the start of the TXOP.

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d) Transmit a 20 MHz mask PPDU on the primary 20 MHz channel.

e) (#3653)Transmit nothing and invoke the backoff procedure for the EDCAF as specified in 10.23.2.2 (EDCA backoff procedure).

f) Transmit a TVHT_4W or TVHT_2W+2W mask PPDU if the secondary TVHT_W channel and the secondary TVHT_2W channel were idle during an interval of PIFS immediately preceding the start of the TXOP.

g) Transmit a TVHT_2W or TVHT_W+W mask PPDU if the secondary TVHT_W channel was idle during an interval of PIFS immediately preceding the start of the TXOP.

h) Transmit a TVHT_W mask PPDU on the primary TVHT_W channel.

i) Transmit an 80 MHz HE MU PPDU where in the preamble the only punctured subchannel is the secondary 20 MHz channel, if all of the 20 MHz subchannels (other than the primary 20 MHz channel) that are not punctured were idle during an interval of PIFS immediately preceding the start of the TXOP.(11ax)

j) Transmit an 80 MHz HE MU PPDU where in the preamble the only punctured subchannel is one of the two 20 MHz subchannels in the secondary 40 MHz channel, if all of the 20 MHz subchannels that are not punctured were idle during an interval of PIFS immediately preceding the start of the TXOP.(11ax)

k) Transmit a 160 MHz or 80+80 MHz HE MU PPDU where in the preamble the only punctured subchannels are the secondary 20 MHz channel and zero to two of the 20 MHz subchannels in the secondary 80 MHz channel, if all of the 20 MHz subchannels that are not punctured were idle during an interval of PIFS immediately preceding the start of the TXOP. If two of the 20 MHz subchannels in the secondary 80 MHz channel are punctured, these are either the lower two or the higher two. No more than two adjacent 20 MHz subchannels are punctured across the preamble, for a 160 MHz preamble.(11ax)

l) Transmit a 160 MHz or 80+80 MHz HE MU PPDU where in the preamble the only punctured subchannels are zero, one, or both of the 20 MHz subchannels in the secondary 40 MHz channel and zero to two of the 20 MHz subchannels in the secondary 80 MHz channel, if all of the 20 MHz subchannels that are not punctured were idle during an interval of PIFS immediately preceding the start of the TXOP. At least one 20 MHz subchannel is punctured. If two of the 20 MHz subchannels in the secondary 80 MHz channel are punctured, these are either the lower two or the higher two. No more than two adjacent 20 MHz subchannels are punctured across the preamble, for a 160 MHz preamble.(11ax)

NOTE 1—An EDCAF that initiates a TXOP has a frame available for transmission (see 10.23.2.4 (Obtaining an EDCA TXOP)). There might be another EDCAF of lower priority that invokes the backoff procedure due to an internal collision (see 10.23.2.4 (Obtaining an EDCA TXOP).(#3653)

NOTE 2—In the case of rule e), the STA selects a new random number using the current value of CW[AC], and the retry count is(#2188) not updated [as described in 10.23.2.2 (EDCA backoff procedure)(#1478); backoff procedure invoked for event a)].

NOTE 3—An HT, VHT, or HE STA obtains an EDCA TXOP based on activity on the primary channel (see 10.23.2.4 (Obtaining an EDCA TXOP)). The width of transmission is determined by the CCA status of the nonprimary channels during an interval of duration 1) DIFS if transmitting in the 2.4 GHz band or 2) PIFS otherwise, before transmission (see in 10.3.2 (Procedures common to the DCF and EDCAF)).(11ax)

NOTE 4—In the case of rule j), there was(#1477) only one idle 20 MHz subchannel in the secondary 40 MHz channel, and the other 20 MHz subchannel in the secondary 40 MHz channel is preamble punctured.(11ax)


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### 10.23.2.6 EDCA channel access in an S1G BSS

If the MAC receives a PHY-CCA.indication primitive with the channel-list parameter present, the channels considered idle are defined in Table 10-18 (Channels indicated idle by the channel-list parameter for S1G BSSs).

**Table 10-18—Channels indicated idle by the channel-list parameter for S1G BSSs**

| PHY-CCA.indication primitive channel-list parameter entry | Idle channels |
|---|---|
| primary1 | None |
| primary2 | primary 1 MHz channel |
| secondary2 | primary 1 MHz channel, primary 2 MHz channel |
| secondary4 | primary 1 MHz channel, primary 2 MHz channel and secondary 2 MHz channel |
| secondary8 | primary 1 MHz channel, primary 2 MHz channel, secondary 2 MHz channel and secondary 4 MHz channel |

When a STA and the BSS, of which the STA is a member, both support multiple channel widths, an EDCA TXOP is obtained based solely on activity of the primary channel ((#311)see 10.23.2.4 (Obtaining an EDCA TXOP)). "Idle medium" in this subclause means "idle primary channel." Likewise "busy medium" means "busy primary channel."

In the following description, the CCA is sampled according to the timing relationships defined in 10.3.7 (DCF timing relations). Slot boundaries are determined solely by activity on the primary channel. "Channel idle for an interval of PIFS" means that whenever CCA is sampled during the period of PIFS that ends at the start of transmission, the CCA for that channel was determined to be idle.

a) If an S1G STA invokes a backoff procedure at the primary 2 MHz channel for ≥ 2 MHz mask PPDU transmission using the CCA conditions defined in 23.3.18.5.3 (CCA sensitivity for signals occupying the primary 2 MHz and/or primary 1 MHz channel) and one of the STA's EDCAFs is permitted to initiate a TXOP (as specified in 10.23.2.4 (Obtaining an EDCA TXOP)), the STA shall perform exactly one of the following actions:(#3653)
   1) Transmit a 16 MHz mask PPDU if the secondary 2 MHz channel, the secondary 4 MHz channel and the secondary 8 MHz channel were idle during an interval of PIFS immediately preceding the start of the TXOP.
   2) Transmit an 8 MHz mask PPDU on the primary 8 MHz channel if both the secondary 2 MHz channel and the secondary 4 MHz channel were idle during an interval of PIFS immediately preceding the start of the TXOP.
   3) Transmit a 4 MHz mask PPDU on the primary 4 MHz channel if the secondary 2 MHz channel was idle during an interval of PIFS immediately preceding the start of the TXOP.
   4) Transmit a 2 MHz mask PPDU on the primary 2 MHz channel.
   5) Transmit nothing and invoke the backoff procedure for the EDCAF as specified in 10.23.2.3 (EDCA TXOPs).(#3653)

b) (#111)Prior to transmitting an 8 or 16 MHz PPDU, an S1G STA may also invoke a backoff procedure at the primary 2 MHz channel using the CCA conditions defined in 23.3.18.5.3.2 (CCA sensitivity for devices in type 2 channels implementing intended 8 or 16 MHz transmit channel width channel access procedure), if one of the STA's EDCAFs is permitted to initiate a TXOP (as in

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10.23.2.4 (Obtaining an EDCA TXOP)). In this case the S1G STA shall perform exactly one of the following actions:(#3653)

1) Transmit a 16 MHz PPDU if the secondary 2 MHz channel, the secondary 4 MHz channel and the secondary 8 MHz channel were idle during an interval of PIFS immediately preceding the start of the TXOP.
2) Transmit an 8 MHz PPDU on the primary 8 MHz channel if both the secondary 2 MHz channel and the secondary 4 MHz channel were idle during an interval of PIFS immediately preceding the start of the TXOP.
3) Transmit nothing and invoke the backoff procedure for the EDCAF as specified in 10.23.2.2 (EDCA backoff procedure).(#3653)

c) If an S1G STA invokes a backoff procedure at the primary 1 MHz channel for 1 MHz PPDU transmission and one of the STA's EDCAFs is permitted to initiate a TXOP (as specified in 10.23.2.4 (Obtaining an EDCA TXOP)), the S1G STA shall transmit a 1 MHz mask PPDU on the primary 1 MHz channel.(#3653)

NOTE —An EDCAF that initiates a TXOP has a frame available for transmission (see 10.23.2.4 (Obtaining an EDCA TXOP)). There might be another EDCAF of lower priority that invokes the backoff procedure due to an internal collision (see 10.23.2.4 (Obtaining an EDCA TXOP)).(#3653)

### 10.23.2.7 Sharing an EDCA TXOP

The AC associated with the EDCAF that gains an EDCA TXOP is referred to as the primary AC. Frames from ACs other than the primary AC shall not be included in the TXOP, with the following exceptions (TXOP sharing):

— (11ax)For a multi-TID A-MPDU in an HE MU PPDU transmitted by an AP, frames from any AC may be included as defined in 26.6.3 (Multi-TID A-MPDU and ack-enabled single-TID A-MPDU). Otherwise, frames from a higher priority AC may be included when at least one frame from the primary AC has been transmitted and all frames from the primary AC have been transmitted.

NOTE 1—The frames from a higher priority AC might be included in successive PPDUs in the TXOP and/or in one or more MU PPDUs.

— When (11ax)(11ay)VHT AP, EDMG AP, or PCP supports DL MU-MIMO(#3367), frames from a lower priority AC may be included in (11ax)(11ay)VHT or EDMG MU PPDU with the TXVECTOR parameter NUM_USERS > 1 when these frames do not increase the duration of the (11ax)(11ay)VHT or EDMG MU PPDU beyond that required for the transmissions of the frames of the primary AC and any frames from a high priority AC. For a given user, any frames from the primary AC shall be transmitted first and then any frames from a higher priority AC immediately next.

— When an HE AP transmits an HE MU PPDU, frames from higher or lower priority AC may be included in the HE MU PPDU when these frames do not increase the duration of the HE MU PPDU beyond that required for the transmissions of the frames of the primary AC and any frames from a high priority AC. For a given user, any frames from the primary AC shall be transmitted first, and then any frames from a higher priority AC immediately next.(11ax)

NOTE 1—TXOP sharing is an operation performed by a single EDCAF, using frames belonging to another EDCAF's queues.(#2069)

The EDCAF remains bound by the TXOP limit for its AC (i.e., the primary AC), irrespective of the AC(s) of the frames transmitted during the TXOP.


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(#253)With respect to admission control (see 10.23.4.2 (Contention based admission control procedures)), all frames transmitted under TXOP sharing shall be treated as if they were from the primary AC.

NOTE 2—An AP (11ay)or PCP can protect an immediate response by preceding the DL MU-MIMO(#3367) PPDU (which might have TXVECTOR parameter NUM_USERS > 1) with an RTS/CTS, MU-RTS Trigger/CTS (#109)frame exchange sequence or a CTS-to-self transmission.(11ax)

An illustration of TXOP sharing is shown in Figure 10-30 (Illustration of TXOP sharing and PPDU construction (DL MU-MIMO)) and Figure 10-31 (Illustration of TXOP sharing and PPDU construction (non-A-MPDUs)). The AP has frames in queues of three of its ACs. The TXOP was obtained by AC_VI or AC_BE, as shown, and is shared by the other two ACs. The frames target three STAs, STA-1 to STA-3.

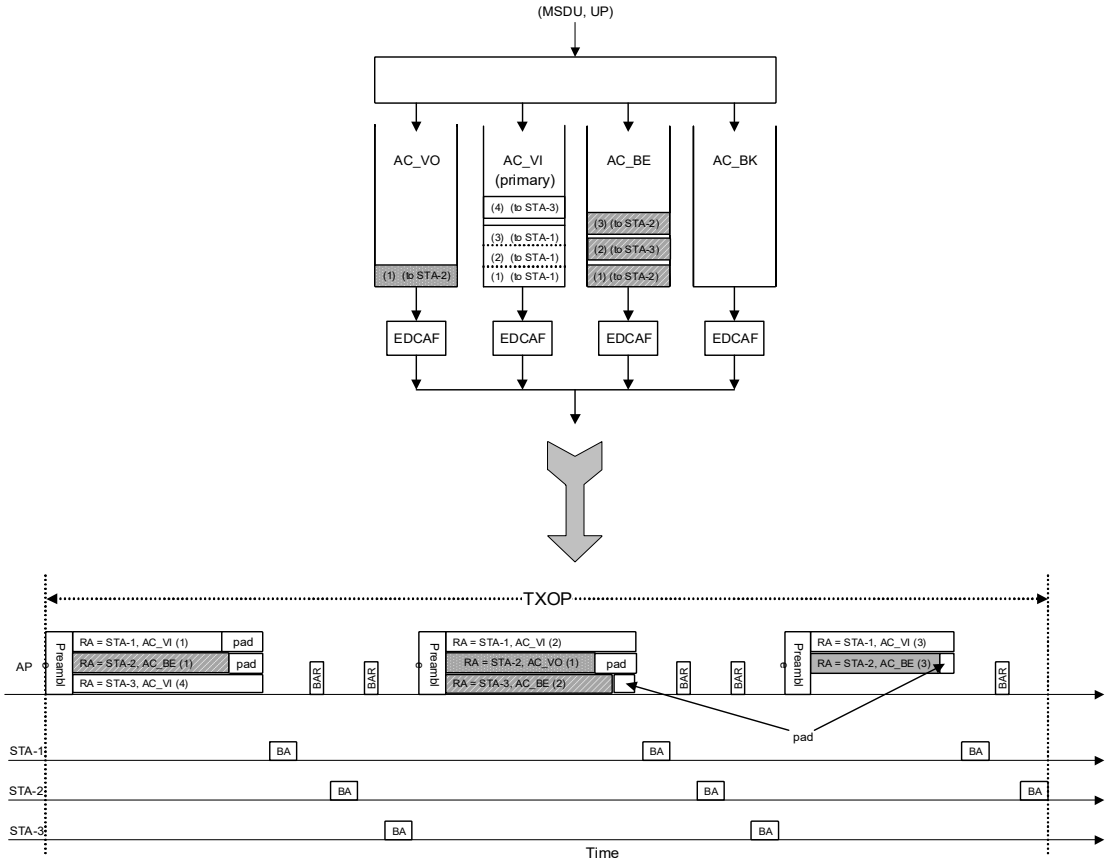


**Figure 10-30—Illustration of TXOP sharing and PPDU construction (DL MU-MIMO)**

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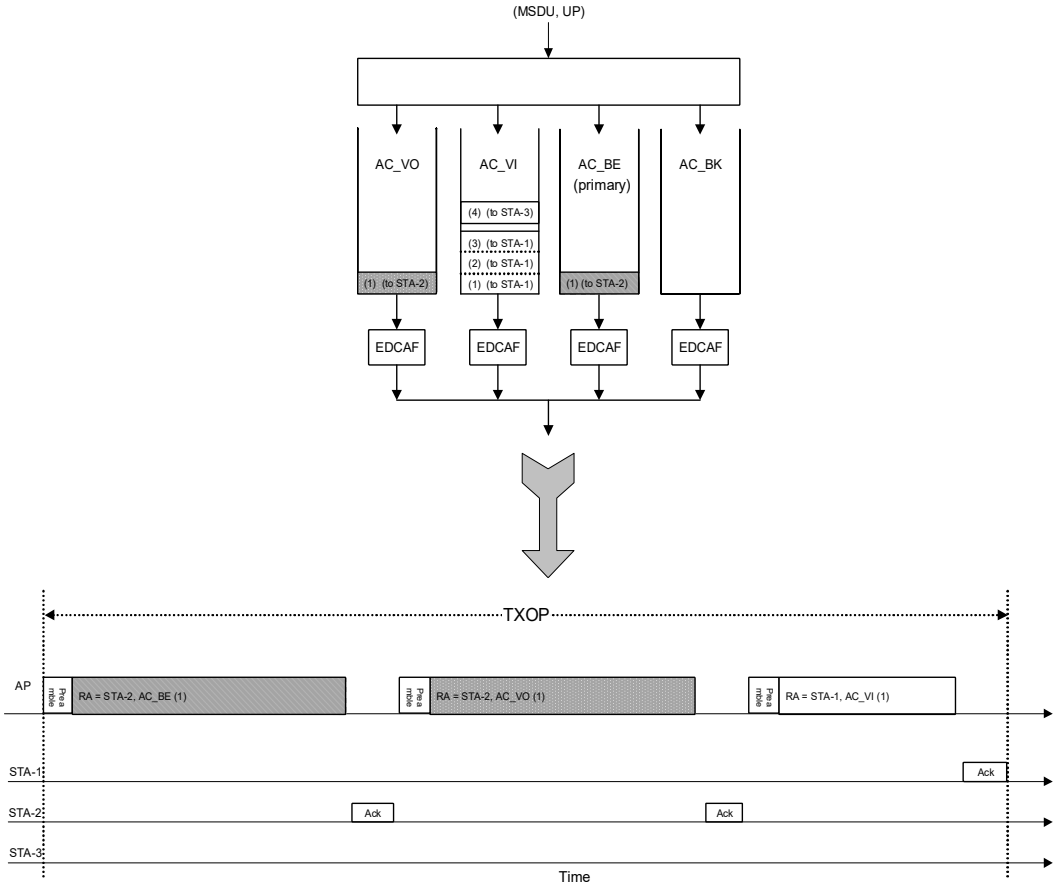


**Figure 10-31—Illustration of TXOP sharing and PPDU construction (non-A-MPDUs)**


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### 10.23.2.8 Multiple frame exchange sequences in an EDCA TXOP(#109)

(#109)Frame exchange sequences of the primary AC may be transmitted in an EDCA TXOP that was acquired following the rules in 10.23.2.4 (Obtaining an EDCA TXOP). Frames that are pending in other ACs shall not be transmitted in this EDCA TXOP except when permitted by the rules in 10.23.2.7 (Sharing an EDCA TXOP). If a TXOP holder has in its transmit queue an additional frame exchange sequence(#109) of the primary AC (or, where permitted, a secondary AC) and the duration of that frame exchange sequence(#109) is less than the remaining TXNAV timer value and, if dot11MCCAActivated is true, the remaining RAV timer value, (#1987)then the TXOP holder may initiate that frame exchange sequence(#109) a SIFS (or RIFS, if the conditions defined in 10.3.2.3.2 (RIFS) are met, or PIFS, if the frame contains a bandwidth signaling TA) after the completion of the immediately preceding frame exchange sequence, subject to the TXOP limit restriction as described in 10.23.2.9 (TXOP limits). A STA shall not commence the transmission of an RTS with a bandwidth signaling TA until at least a PIFS after the immediately preceding frame exchange sequence. A CMMG STA shall not commence the transmission of an RTS frame until at least PIFS time after the immediately preceding frame exchange sequence. An HT STA that is a TXOP holder may transmit multiple MPDUs of the same AC within an A-MPDU as long as the duration of transmission of the A-MPDU plus any expected BlockAck frame response is less than the remaining TXNAV timer value and, if dot11MCCAActivated is true, the remaining RAV timer value. An S1G STA that is a TXOP holder may transmit multiple MPDUs of the same AC within an A-MPDU as long as the duration of transmission of the A-MPDU plus any expected (NDP) BlockAck frame response is less than the remaining TXNAV timer value.

NOTE 1—PIFS is used by a VHT STA to perform CCA in the secondary 20 MHz, 40 MHz, and 80 MHz channels before receiving RTS (see 10.3.2 (Procedures common to the DCF and EDCAF)).

NOTE 2—An RD responder can transmit multiple MPDUs as described in 10.29.4 (Rules for RD responder).

(11ay)NOTE 3—PIFS is used by an EDMG STA to perform CCA in the secondary, secondary1, and secondary2 channels before receiving RTS (see 10.3.2 (Procedures common to the DCF and EDCAF)).

NOTE 4(11ay)—Within a BDT, STAs can transmit multiple MPDUs as described in 10.49 (Bidirectional TXOP).

NOTE 5(11ay)—A PIFS is required to be present preceding an RTS transmission by a CMMG STA in order to allow a recipient of the RTS to perform CCA in the secondary 540 MHz channels to determine the appropriate response to the RTS.

After a valid response(#109) to the initial frame of a TXOP, if the Duration/ID field is set for multiple frame exchange sequences(#109) and there is a subsequent transmission failure, the corresponding channel access function may transmit after the CS mechanism (see 10.3.2.1 (CS mechanism)) indicates that the medium is idle at the TxPIFS slot boundary (see Figure 10-29 (EDCA mechanism timing relationships(#14)(#1058))) provided that the duration of that transmission plus the duration of any expected acknowledgment and applicable IFS is less than the remaining TXNAV timer value and, if dot11MCCAActivated is true, the RAV timer. At the expiration of the TXNAV timer and if dot11MCCAActivated is true, the RAV timer, if the channel access function has not regained access to the medium, then the EDCAF shall invoke the backoff procedure that is described in 10.23.2.4 (Obtaining an EDCA TXOP). Transmission failure is defined in 10.23.2.12 (Retransmit procedures).

All other channel access functions at the STA shall treat the medium as busy until the expiration of the TXNAV timer.

NOTE 6(11ay)—(#109)Frame exchange sequence(s) are granted to an EDCAF, not to a STA, so that multiple frame exchange sequences are permitted only for the transmission of frames of the same AC as the frame that was granted the EDCA TXOP, except as specified in 10.23.2.7 (Sharing an EDCA TXOP).(#3263)

If a TXOP is protected by an RTS or CTS frame carried in a non-HT or a non-HT duplicate PPDU, the TXOP holder shall set the TXVECTOR parameter CH_BANDWIDTH of a PPDU as follows:

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— To be the same or narrower than (11ax)the RXVECTOR parameter CH_BANDWIDTH_IN_NON_HT of the last received CTS frame in the same TXOP, if the RTS frame with a bandwidth signaling TA and TXVECTOR parameter DYN_BANDWIDTH_IN_NON_HT set to Dynamic has been sent by the TXOP holder in the last RTS/CTS exchange.

— Otherwise, to be the same or narrower than the TXVECTOR parameter CH_BANDWIDTH of the RTS frame that has been sent by the TXOP holder in the last RTS/CTS exchange in the same TXOP.

(11ax)If a TXOP is protected by an MU-RTS Trigger frame or CTS frame carried in a non-HT or a non-HT duplicate PPDU, the TXOP holder shall set the TXVECTOR parameter CH_BANDWIDTH of a PPDU as follows:

— To be the same or narrower than the TXVECTOR parameter CH_BANDWIDTH of the MU-RTS Trigger frame that has been sent by the TXOP holder in the last MU-RTS Trigger/CTS (#109)frame exchange sequence in the same TXOP, if the RU Allocation subfields of the MU-RTS Trigger frame for all intended receivers are equal to a value that corresponds to the channel bandwidth that is indicated in the UL BW subfield in the Common Info field of the MU-RTS Trigger frame.

— Otherwise, to be the same or narrower than the TXVECTOR parameter CH_BANDWIDTH of the preceding PPDU that it has transmitted in the same TXOP.

If there is no RTS/CTS (11ax)or MU-RTS Trigger/CTS (#109)frame exchange sequence in non-HT duplicate format in a TXOP, and the TXOP includes at least one non-HT duplicate frame that does not include a PS-Poll, then the TXOP holder shall set the TXVECTOR parameter CH_BANDWIDTH of a PPDU sent after the first non-HT duplicate frame that is not a PS-Poll to be the same or narrower than the TXVECTOR parameter CH_BANDWIDTH of the initial frame in the first non-HT duplicate frame in the same TXOP.

If there is no non-HT duplicate frame in a TXOP, the TXOP holder shall set the TXVECTOR parameter CH_BANDWIDTH of a non-initial PPDU to be the same or narrower than the TXVECTOR parameter CH_BANDWIDTH of the preceding PPDU that it has transmitted in the same TXOP, subject to the following constraints:(11ax)

— If the preceding PPDU is a DL HE MU PPDU with preamble puncture, the TXOP holder shall set the TXVECTOR parameter CH_BANDWIDTH of the non-initial PPDU to a value whose corresponding 20 MHz channels are within a set of 20 MHz channels where pre-HE modulated fields of the preceding PPDU are located.(11ax)

— If the non-initial PPDU is a DL HE MU PPDU with preamble puncture, the TXOP holder shall set the TXVECTOR parameter RU_ALLOCATION of the non-initial PPDU to a value whose corresponding RU is within a set of 20 MHz channels where pre-HE modulated fields of the preceding PPDU are located.(11ax)

If a TXOP is protected by a CTS-to-self frame carried in a non-HT or non-HT duplicate PPDU, the TXOP holder shall set the TXVECTOR parameter CH_BANDWIDTH of a PPDU to be the same or narrower than the TXVECTOR parameter CH_BANDWIDTH of the CTS-to-self frame in the same TXOP.

(#109)Note that multiple frame exchange sequences in a TXOP that use acknowledgment mechanisms other than immediate acknowledgment should use a protective mechanism (such as RTS/CTS or the protection mechanism described in 10.27 (Protection mechanisms)). A QoS AP or a mesh STA may send group addressed frames without using any protection mechanism. In a QoS IBSS, group addressed frames shall be sent one at a time, and backoff shall be performed after the transmission of each of the group addressed frames. In an MBSS, a mesh STA may send multiple group addressed frames in a TXOP, bounded by the TXOP limit, without performing backoff after the TXOP is obtained.

(#111)In the course of transmitting transmit an 8 MHz or 16 MHz PPDU invoking a backoff procedure in the primary 2 MHz channel using the channel busy conditions defined in 23.3.18.5.3.2 (CCA sensitivity for


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devices in type 2 channels implementing intended 8 or 16 MHz transmit channel width channel access procedure) an S1G STA shall not set the Dynamic Indication field to 1 in any RTS frame that is scheduled for transmission at the expiration of this backoff.

### 10.23.2.9 TXOP limits

The duration of a TXOP is the time a STA obtaining a TXOP (the TXOP holder) maintains uninterrupted control of the medium, and it includes the time required to transmit frames sent as an immediate response to TXOP holder transmissions. The TXOP holder shall, subject to the exceptions below, ensure that the duration of a TXOP does not exceed the TXOP limit, when nonzero.

The TXOP limits are advertised by the AP in the EDCA Parameter Set element in Beacon and Probe Response frames transmitted by the AP.

A TXOP limit of 0 indicates that the TXOP holder may transmit or cause to be transmitted (as responses) the following within the current TXOP:

a) One of the following at any rate, subject to the rules in 10.6 (Multirate support)
   1) One or more SU PPDUs carrying fragments of a single MSDU or MMPDU
   2) An SU or MU PPDU, where the PPDU carries a single MSDU, single MMPDU, single A-MSDU, or single A-MPDU(#446)
   3) An MU PPDU carrying A-MPDUs to different users (a single A-MPDU to each user)(#446)
   4) A QoS Null frame or PS-Poll frame that is not an PS-Poll+BDT frame
   5) A Basic Trigger frame, BSRP Trigger frame, or BQRP Trigger frame(11ax)
   6) An HE TB PPDU carrying A-MPDUs from different users (a single A-MPDU from each user)(11ax)
b) Any required acknowledgments
c) Any frames required for protection, including one of the following:
   1) An RTS/CTS or MU-RTS Trigger/CTS frame(11ax) exchange
   2) CTS-to-self
   3) Dual CTS as specified in 10.3.2.10 (Dual CTS protection)
d) Any frames required for beamforming as specified in 10.30 (Sounding PPDUs), 10.35.5 (VHT sounding protocol), (11ax)26.7 (HE sounding operation(#2388)), and 10.41 (DMG beamforming)
e) Any frames required for link adaptation as specified in 10.31 (Link adaptation) and 26.13 (Link adaptation using the HLA Control subfield)(11ax)
f) Any number of BlockAckReq, MU-BAR Trigger, Multi-TID BlockAckReq, or GCR MU-BAR Trigger frames(11ax)

NOTE 1—This is a rule for the TXOP holder. A TXOP responder need not be aware of the TXOP limit nor of when the TXOP was started.

NOTE 2—This rule prevents the use of RD, BDT, and TXOP sharing when the TXOP limit is 0.

When dot11OCBActivated is true, (11bd)dot11NGVOptionImplemented is false or not present, and dot11DMGOCBActivated is false or not present, the TXOP limit shall be 0 for each AC.

The TXOP holder may exceed the TXOP limit only if it does not transmit more than one Data or Management frame in the TXOP, only if it does not transmit a (#3367)DL MU-MIMO PPDU in the TXOP, and only for the following situations:

— Retransmission of an MPDU, not in an A-MPDU consisting of more than one MPDU, where the size of the retransmitted MPDU is the same as the initially transmitted MPDU.(11ax)

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- Transmission of an MSDU or MMPDU less than 600 octets by an S1G non-sensor STA.
- Transmission of a fragment of an MSDU or MMPDU, the fragment being less than 256 octets, by an S1G non-sensor STA.
- Initial transmission of an MSDU under a block ack agreement, where the MSDU is not in an A-MPDU consisting of more than one MPDU and the MSDU is not in an A-MSDU.
- Transmission of a Control frame or a QoS Null frame , not in an A-MPDU consisting of more than one MPDU.
- Initial transmission of a (11ax)(M118)nondynamic fragment of an MSDU or MMPDU (11ax)(see 10.4 (MSDU, (11ax)A-MSDU, and MMPDU fragmentation)), if a previous fragment of that MSDU or MMPDU was retransmitted.
- Transmission of a (11ax)(M118)nondynamic fragment of an MSDU or MMPDU fragmented into 16 fragments.
- Transmission of the 16th dynamic fragment of an MSDU or MMPDU.(11ax)
- Initial transmission of the first dynamic fragment of an MSDU or MMPDU, where the size of the first fragment is equal to the minimum fragment size specified by the receiver STA and the MSDU or MMPDU is not in an A-MPDU consisting of more than one MPDU.(11ax)
- Transmission of an A-MPDU consisting of the initial transmission of a single MPDU not containing an MSDU and that is not an individually addressed Management frame.
- Transmission of a group addressed MPDU, not in an A-MPDU consisting of more than one MPDU.
- Transmission of a null data PPDU (NDP).
- Transmission of a VHT NDP Announcement frame and NDP or transmission of a Beamforming Report Poll frame, where these fit within the TXOP limit and (11ax)only the response and the immediately preceding SIFS (11ax)cause the TXOP limit to be exceeded.
- (11ax)Transmission of one of the following sequences, provided that the sequence fits within the TXOP limit and only the response and the immediately preceding SIFS cause the TXOP limit to be exceeded:
  - An HE NDP Announcement frame and HE sounding NDP
  - An HE NDP Announcement frame and HE sounding NDP and BFRP Trigger frame
  - A BFRP Trigger frame

Except as described above, a STA shall fragment an individually addressed MSDU or MMPDU so that the initial transmission of the first fragment does not cause the TXOP limit to be exceeded.

NOTE 3—The TXOP limit is not exceeded for the following situations:

a) Initial transmission of an MPDU containing an unfragmented though fragmentable (see 10.2.7 (Fragmentation/defragmentation overview) and 26.3 (Fragmentation and defragmentation)) MSDU/MMPDU.(11ax)
b) Initial transmission of the first fragment of a fragmented MSDU/MMPDU, except if the MSDU/MMPDU is fragmented into 16 fragments.
c) Initial transmission of an A-MSDU.
d) Initial transmission of a (M118)nondynamic fragment of a fragmented MSDU/MMPDU, if no previous fragment of that MSDU/MMPDU was retransmitted, except if the MSDU/MMPDU is fragmented into 16 fragments.(11ax)
e) Initial transmission of a dynamic fragment of a fragmented MSDU/MMPDU, except for either the first dynamic fragment of a fragmented MSDU/MMPDU using the minimum fragment size specified by the receiver STA, or the 16th dynamic fragment of a fragmented MSDU/MMPDU.(11ax)
f) Transmission of an A-MPDU consisting of a single MPDU containing an A MSDU or individually addressed Management frame, unless this is a retransmission of that MPDU.
g) Transmission of an A-MPDU consisting of more than one MPDU, even if some or all of the MPDUs are retransmissions.
h) Transmission of a Trigger frame, other than a BFRP Trigger frame, where either the Trigger frame or its response does not fit within the TXOP limit.(11ax)


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If the TXOP holder exceeds the TXOP limit, it should use as high a PHY rate as possible to minimize the duration of the TXOP.

The duration of a TXOP for a mesh STA that has dot11MCCAActivated true shall not exceed the time between the start of the TXOP and the end of the current MCCAOP reservation.

NOTE 4—The rules in this subclause also apply to priority-downgraded MSDUs and A-MSDUs (see 10.23.4.2 (Contention based admission control procedures)).

If the Duration field in a frame carried in an HE TB PPDU is set to 0, the HE TB PPDU shall not include any frames that solicit a control response frame from the AP.(11ax)

### 10.23.2.10 Truncation of TXOP

When a STA gains access to the channel using EDCA and empties its transmission queue, it may transmit a CF-End frame provided that the remaining duration is long enough to transmit this frame. By transmitting the CF-End frame, the STA is explicitly indicating the completion of its TXOP. In a DMG BSS, the STA shall not send a CF-End frame with a nonzero value in the Duration/ID field if the remaining duration is shorter than $2\times T_{CF\text{-}End}$ + 2×SIFS, where $T_{CF\text{-}End}$ is the duration of a CF-End frame. A STA that is an S1G AP may transmit an NDP CF-End frame instead of a CF-End frame. A non-S1G STA shall not transmit an NDP CF-End frame.

An S1G STA that both

— Transmits either a PPDU with its TXVECTOR parameter RESPONSE_INDICATION value Long Response or an NDP (PS-Poll-)Ack frame with its Idle Indication field value 1 and Duration field value 0 and

— Does not receive (after a SIFS) a response with its RXVECTOR parameter RESPONSE_INDICATION value NDP Response or Normal Response

may, after a PIFS(#6587), transmit an NDP CF-End frame to truncate any active RID or NAV.

A TXOP holder that transmits a CF-End frame shall not initiate any further frame exchange sequences within the current TXOP.

An S1G STA that transmits an NDP CF-End frame shall set the frame's Duration field to 0 and shall initiate no other frame exchange sequences in the current TXOP.

A non-AP STA that is not the TXOP holder shall not transmit a CF-End frame.

In a non-DMG BSS, a non-S1G non-HE STA(11ax) shall interpret the reception of a CF-End frame as a NAV reset, i.e., it resets its NAV to 0 at the end of the PPDU containing this frame. After receiving a CF-End frame with a matching BSSID(TA) without comparing Individual/Group bit, an AP may respond by transmitting a CF-End frame after a SIFS(#6587). An HE STA interprets the reception of a CF-End frame as defined in 26.2.5 (Truncation of TXOP).(11ax)

NOTE 1—The transmission of a single CF-End frame by the TXOP holder resets the NAV of STAs hearing the TXOP holder. There may be STAs that could hear the TXOP responder that had set their NAV that do not hear this NAV reset. Those STAs are prevented from contending for the medium until the original NAV reservation expires.

NOTE 2—A CF-End sent by a non-AP VHT STA that is a member of a VHT BSS can include the TXVECTOR parameter CH_BANDWIDTH_IN_NON_HT as defined in 10.6.6.6 (Channel Width selection for Control frames) in case it elicits a CF-End response.

In a DMG BSS, a STA that is not in the listening mode (10.38.6.6 (DMG and CMMG protected period)) shall interpret the reception of a CF-End frame as a NAV reset, i.e., it resets its NAV to 0 at the end of the time

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interval indicated in the value of the Duration/ID field of the received frame. The interval starts at PHY-RXEND.indication primitive of the frame reception. The STA shall not transmit during the interval if the RA field of the frame is not equal to the STA MAC address. The STA may transmit a CF-End frame if the RA field of the received frame is equal to the STA MAC address and the value of the Duration/ID field in the received frame is not equal to 0.

Figure 10-32 (Example of TXOP truncation) shows an example of TXOP truncation. In this example, the STA accesses the medium using EDCA channel access and then transmits a nav-set sequence (e.g., RTS/CTS for non-DMG STAs or RTS/DMG CTS for DMG STAs)(#109). After a SIFS, it then transmits an initiator-sequence, which may involve the exchange of multiple PPDUs between the TXOP holder and TXOP responders. At the end of the second sequence, the TXOP holder has no more data that it can send that fits within the TXOP limit; therefore, it truncates the TXOP by transmitting a CF-End frame.

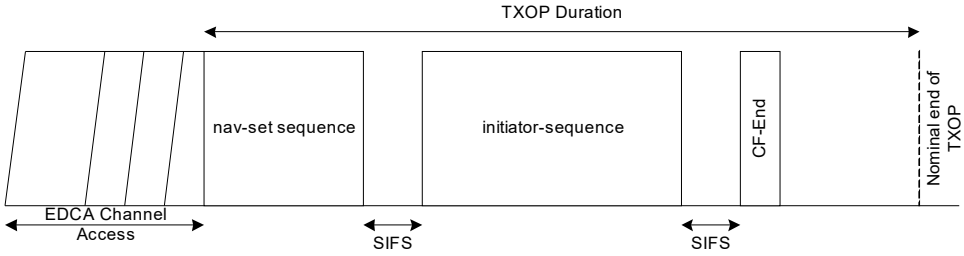


**Figure 10-32—Example of TXOP truncation**

(11ax)Non-DMG non-S1G non-HE STAs that receive a CF-End frame reset their NAV and can start contending for the medium without further delay. An HE STA that receives a CF-End frame may start contending for the medium without further delay as defined in 26.2.5 (Truncation of TXOP). A DMG STA that receives a CF-End frame can start contending for the medium at the end of the time interval equal to the value in the Duration/ID field of the frame if none of its NAVs has a nonzero value (10.38.10 (Updating multiple NAVs).

An S1G STA that receives an NDP CF-End frame should reset its NAV and may start contending for the medium without further delay.

An S1G STA may transmit a CF-End frame containing a value greater or equal to 0 in the Duration/ID field.

An S1G STA shall interpret the reception of a CF-End frame with the Duration/ID field equal to 0 as a NAV reset, i.e., it resets its NAV timer to 0 at the end of the PPDU containing this frame. After receiving a CF-End frame with the Duration/ID field equal to 0 and a matching BSSID, an AP may respond by transmitting a CF-End frame with the Duration/ID field equal to 0 after a SIFS.(#6587)

When an S1G STA receives a CF-End frame with the Duration/ID field not equal to 0 that falls (#6119)in the range [NAV value – 8, NAV value + 8] (microseconds) at the time of the reception of the PHY-RXEND.indication, it shall reset the NAV and may start contending for the medium without further delay. If the received duration value does not fall (#6119)in the range [NAV value – 8, NAV value + 8] microseconds at the time of the reception of the PHY-RXEND.indication, the STA shall discard the CF-End frame.

NOTE 3—A NAV value that varies within ±8 µs(#8087) (#7198)boundaries accommodates almost all inaccuracies (e.g., due to clock drifting) to the NAV counter at the receiving STA.

After receiving a CF-End frame with a matching BSSID, an S1G AP may respond by transmitting a CF-End frame after a SIFS(#6587) in which the value of the Duration field is equal to the value obtained from the


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Duration field of the received CF-End frame adjusted by subtracting the value of aSIFSTime and the time required to transmit the CF-End frame, in units of microseconds. If the adjusted value is a negative value, the Duration field of the CF-End frame is set to 0.

#### 10.23.2.11 Termination of TXOP

A TXOP holder that transmits a PPDU using one of the modulation classes in Table 10-19 (Modulation classes eligible for TXOP termination) should transmit a short Control frame as the final transmission in a TXOP, under the conditions specified in Table 10-20 (Rate and modulation class of a final transmission in a TXOP).

**Table 10-19—Modulation classes eligible for TXOP termination**

| Modulation classes eligible for TXOP termination (see Table 10-9 (Modulation classes)) |
|---|
| DSSS |
| HR/DSSS |
| ERP-OFDM |
| OFDM (20 MHz channel spacing) |
| HT |
| VHT |
| HE(11ax) |

**Table 10-20—Rate and modulation class of a final transmission in a TXOP**

| Modulation class and data rate of immediately preceding frame in TXOP | Rate and modulation class of final transmission |
|---|---|
| DSSS or HR/DSSS with long preamble, data rate > 1 Mb/s | 1 Mb/s DSSS |
| HR/DSSS with short preamble, data rate > 2 Mb/s | 2 Mb/s HR/DSSS short preamble |
| Other eligible modulation classes, except 6 Mb/s OFDM(11ax) | 6 Mb/s OFDM |

The final transmission can be a CF-End, or a CTS-to-self when no NAV needs to be truncated.

NOTE—The final transmission at the lowest data rate within the modulation class is needed because a final transmission at a higher rate can cause spurious EIFSs to occur, because the PHY header of such frames travels farther than the MPDU.

#### 10.23.2.12 Retransmit procedures

#### 10.23.2.12.1 General

A QoS STA shall maintain a frame retry count for each MSDU, A-MSDU, or MMPDU (#451)that requires acknowledgment. The initial value for the frame retry count shall be 0.

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QoS STAs shall also maintain a QoS STA retry count for each AC, QSRC[AC]. The initial value for the QSRC[AC] counters shall be 0.

When dot11RobustAVStreamingImplemented is true, a QoS STA shall maintain a drop-eligible frame retry count for each QoS Data frame with an HT variant HT Control field with the DEI field equal to 1. The initial value for the drop-eligible frame retry count shall be 0.

APs with dot11RobustAVStreamingImplemented equal to true and mesh STAs with dot11MeshGCRImplemented equal to true, shall maintain an unsolicited frame retry count. The initial value for the unsolicited frame retry count shall be 0.

After transmitting a frame that requires an immediate acknowledgment, the STA shall perform either of the acknowledgment procedures, as appropriate, that are defined in 10.3.2.11 (Acknowledgment procedure). The frame retry count for an MSDU or A-MSDU that is not part of a block ack agreement or for an MMPDU shall be incremented every time transmission fails for that MSDU, A-MSDU, or MMPDU, including of an associated RTS.

For APs with dot11RobustAVStreamingImplemented equal to true and mesh STAs with dot11MeshGCRImplemented equal to true, the unsolicited frame retry count shall be incremented after the transmission of every A-MSDU that is transmitted using the GCR unsolicited retry retransmission policy.

All retransmission attempts by a non-DMG STA for an MPDU with the Type subfield equal to Data or Management that is not sent under a block ack agreement and that has failed the acknowledgment procedure one or more times shall be made with the Retry subfield set to 1.

All retransmission attempts by a DMG STA for an MPDU with the Type subfield equal to Data or Management that has failed the acknowledgment procedure one or more times shall be made with the Retry subfield set to 1.

A QoS STA shall maintain a transmit MSDU/MMPDU timer for each MSDU passed to the MAC and for each MMPDU. (#3754)For a non-AP STA, dot11EDCATableMSDULifetime specifies the maximum amount of time allowed to transmit an MSDU/MMPDU for a given AC. (#3754)For an AP, dot11QAPEDCATableMSDULifetime specifies the maximum amount of time allowed to transmit an MSDU/MMPDU for a given AC. The transmit MSDU/MMPDU timer shall be started when the MSDU/MMPDU is passed to the MAC.

NOTE—(#3142)The timer is started at different times for DCF and EDCA.(#2054)

When A-MSDU aggregation is used, the HT STA maintains a single timer for the whole A-MSDU. The timer is restarted each time an MSDU is added to the A-MSDU. The result of this procedure is that no MSDU in the A-MSDU is discarded before a period of dot11EDCATableMSDULifetime (#3754)for a non-AP STA or dot11QAPEDCATableMSDULifetime for an AP has elapsed.

Retries for failed transmission attempts shall continue until one or more of the following conditions occur:

- The frame retry count for the MSDU, A-MSDU, or MMPDU is equal to dot11ShortRetryLimit.
- The drop-eligible frame retry count for the MSDU, A-MSDU, or MMPDU is equal to dot11ShortDEIRetryLimit.
- The unsolicited frame retry count for the A-MSDU is equal to dot11UnsolicitedRetryLimit.
- The transmit MSDU/MMPDU timer for the MSDU/MMPDU or any undelivered fragments of that MSDU/MMPDU exceeds dot11EDCATableMSDULifetime (#3754)for a non-AP STA or dot11QAPEDCATableMSDULifetime for an AP.


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When any of these limits is reached, retry attempts shall cease, and the associated MSDU, A-MSDU, or MMPDU shall be discarded.

For internal collisions, the frame retry counts associated with the MSDUs, A-MSDUs, or MMPDUs involved in the internal collision shall be incremented.

With the exception of a frame belonging to a TID for which block ack agreement is set up, (#1938)a QoS STA shall not initiate the transmission of any Management or Data frame to a specific RA while the transmission of another Management or Data frame with the same RA and having been assigned its sequence number from the same sequence number space has not yet completed to the point of success, retry fail, or other MAC discard (e.g., lifetime expiration).

If an HE STA transmits an HE TB PPDU, the QSRC[AC] for the associated EDCAF is not changed.(11ax)

### 10.23.2.12.2 Unsolicited retry procedure

When using the GCR unsolicited retry retransmission policy for a group address, an AP or mesh STA may retransmit an MPDU to increase the probability of correct reception at the STAs that are listening to this group address (i.e., the group address is in their dot11GroupAddressesTable). The set of MPDUs that may be retransmitted is dependent upon whether block ack agreements are active with the STAs that are listening to this group address and is defined in 11.21.16.3.6 (GCR unsolicited retry). How an AP or a mesh STA chooses which MPDUs to retransmit is an implementation decision and beyond the scope of this standard.

A protective mechanism (such as a mechanism described in 10.27 (Protection mechanisms)) should be used to reduce the probability of other STAs transmitting during the GCR TXOP. When using a protection mechanism that requires a response from another STA, the AP should select a STA that is a member of the GCR group.

The TXOP initiation rules defined in 10.23.2.2 (EDCA backoff procedure) and(#311) 10.23.2.3 (EDCA TXOPs) shall be used for initiating a GCR TXOP. The duration of a GCR TXOP shall be subject to the TXOP limits defined in 10.23.2.9 (TXOP limits).

When transmitting MPDUs using the GCR service with retransmission policy equal to GCR unsolicited retry, the following rules apply:

— Following a MAC protection exchange that includes a response frame, in all GCR unsolicited retry retransmissions, the STA shall either transmit the frames within a GCR TXOP separated by SIFS or invoke its backoff procedure as defined in 10.23.2.2 (EDCA backoff procedure). The STA shall not transmit an MPDU and a retransmission of the same MPDU within the same GCR TXOP. The final frame transmitted within a GCR TXOP shall follow the backoff procedure defined in 10.23.2.2 (EDCA backoff procedure).

— Without MAC protection or with MAC protection that lacks a response frame, in all transmissions, the STA shall invoke the backoff procedure defined in 10.23.2.2 (EDCA backoff procedure), using a value of CWmin[AC] for CW, at the PHY-TXEND.confirm primitive that follows the transmission of each unsolicited retry GCR MPDU.

— All retransmissions of an MPDU shall have the Retry subfield in their Frame Control fields set to 1.

— During a GCR TXOP, frames may be transmitted within the GCR TXOP that do not use the GCR unsolicited retry retransmission policy.

### 10.23.2.13 EDCA channel access in a CMMG BSS

If the MAC receives a PHY-CCA.indication primitive with the channel-list parameter present, the channels considered idle are defined in Table 10-21 (Channels indicated idle by the channel-list parameter for CMMG BSSs).

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**Table 10-21—Channels indicated idle by the channel-list parameter for CMMG BSSs**

| PHY-CCA.indication primitive channel-list parameter entry | Idle channel |
|---|---|
| primary | None |
| secondary | Primary 540 MHz |

In the following description, the CCA is sampled according to the timing relationships defined in 10.3.7 (DCF timing relations). Slot boundaries are determined solely by activity on the primary channel. "Channel idle for an interval of PIFS" means that whenever CCA is sampled during the period of PIFS that ends at the start of transmission, the CCA for that channel was determined to be idle.

If one of a STA's EDCAFs is permitted to initiate a TXOP (as specified in 10.23.2.4 (Obtaining an EDCA TXOP)), the STA shall perform exactly one of the following actions:(#3653)

a) Transmit a 1080 MHz mask PPDU if the secondary 540 MHz channel is idle during an interval of PIFS immediately preceding the start of the TXOP.

b) Transmit a 540 MHz mask PPDU on the primary 540 MHz channel.

c) Transmit nothing and invoke the backoff procedure for the EDCAF as specified in 10.23.2.2 (EDCA backoff procedure).(#3653)

NOTE 1—In the case of rule c), the STA selects a new random number using the current value of CW[AC], and the retry counts are not updated [as described in 10.23.2.2 (EDCA backoff procedure)(#1478); backoff procedure invoked for event a)].

NOTE 2—For CMMG STAs, an EDCA TXOP is obtained based on activity on the primary channel (see 10.23.2.4 (Obtaining an EDCA TXOP)(#311)). The width of transmission is determined by the CCA status of the nonprimary channels during the PIFS before transmission (see 10.23.2.4 (Obtaining an EDCA TXOP)).

NOTE 3—An EDCAF that initiates a TXOP has a frame available for transmission (see 10.23.2.4 (Obtaining an EDCA TXOP)). There might be another EDCAF of lower priority that invokes the backoff procedure due to an internal collision (see 10.23.2.4 (Obtaining an EDCA TXOP)).(#3653)

### 10.23.2.14 EDCA channel access in an EDMG BSS(11ay)

If the MAC receives a PHY-CCA.indication primitive with the channel-list parameter present, the channels considered busy are defined in Table 10-22 (Channels indicated busy by the channel-list parameter(11ay)). Channels not indicated as busy are considered idle.

When a STA and the BSS, of which the STA is a member, both support multiple channel widths, an EDCA TXOP is obtained based solely on activity of the primary channel ((#311)see 10.23.2.4 (Obtaining an EDCA TXOP)). "Idle medium" in this subclause means "idle primary channel." Likewise "busy medium" means "busy primary channel."

Once an EDCA TXOP has been obtained according to this subclause, further constraints defined in 10.38.12.2 (Channel access over multiple channels) and 10.23.2 (HCF contention based channel access


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(EDCA)) might limit the width of transmission during the TXOP or deny the channel access, based on the state of CCA on secondary channels.

**Table 10-22—Channels indicated busy by the channel-list parameter(11ay)**

| PHY-CCA.indication primitive channel-list parameter | Busy channels |
|---|---|
| Primary | Primary |
| secondary | First secondary channel |
| secondary1 | Second secondary channel |
| secondary2 | Third secondary channel |

In the following description, the CCA is sampled according to the timing relationships defined in 10.3.7 (DCF timing relations). Slot boundaries are determined solely by activity on the primary channel. "Channel idle for an interval of PIFS" means that the STATE parameter of the most recent PHY-CCA.indication primitive was IDLE, and no PHY-CCA.indication(BUSY)(#4122) occurred during an interval of PIFS that ends at the start of transmission, the CCA for that channel was determined to be idle.

(#3653)If one of a STA's EDCAFs is permitted to initiate a TXOP (as specified in 10.23.2.4 (Obtaining an EDCA TXOP)), the STA shall perform exactly one of the following actions on the primary, secondary, seconday1, and secondary2 channels defined in Table 8-6 (Definition of EDMG secondary, secondary1, and secondary2 channels(11ay)), which is based on the BSS Operating Channels field and Primary Channel field within the EDMG Operation element transmitted by an EDMG AP or an EDMG PCP:

a) Transmit an 8.64 GHz mask PPDU if the secondary, secondary1 and secondary2 channels are contiguous and secondary, secondary1 and secondary2 were idle during an interval of PIFS immediately preceding the start of the TXOP.

b) Transmit a 4.32+4.32 GHz mask PPDU if the primary and secondary channels are contiguous, secondary1 and secondary2 channels are contiguous and secondary, secondary1 and secondary2 channels were idle during an interval of PIFS immediately preceding the start of the TXOP.

c) Transmit a 6.48 GHz mask PPDU if the primary, secondary and secondary1 channels are contiguous and the secondary and secondary1 channels were idle during an interval of PIFS immediately preceding the start of the TXOP or if the primary, secondary1 and secondary2 channels are contiguous and secondary1 and secondary2 channels were idle during an interval of PIFS immediately preceding the start of the TXOP.

d) Transmit a 4.32 GHz mask PPDU if the primary and secondary channels are contiguous and the secondary channel was idle during an interval of PIFS immediately preceding the start of the TXOP or if the primary and secondary1 channels are contiguous and the secondary1 channel was idle during an interval of PIFS immediately preceding the start of the TXOP.

e) Transmit a 2.16+2.16 GHz mask PPDU if the secondary, secondary1 or secondary2 channels were idle during an interval of PIFS immediately preceding the start of the TXOP.

f) Transmit a 2.16 GHz mask PPDU on the primary channel.

g) Transmit nothing and invoke the backoff procedure for the EDCAF as specified in 10.23.2.2 (EDCA backoff procedure).(#3653)

NOTE 1–In the case of rule g), the STA selects a new random number using the current value of CW[AC], and the retry counters are not updated [as described in 10.23.2.2 (EDCA backoff procedure)(#1478); backoff procedure invoked for event a)].

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NOTE 2–For an EDMG STA, an EDCA TXOP is obtained based on activity on the primary channel (see 10.23.2.4 (Obtaining an EDCA TXOP)). The width of transmission is determined by the CCA status of the nonprimary channels during an interval of PIFS before transmission (see EDMG description in 10.3.2 (Procedures common to the DCF and EDCAF)).

NOTE 3—An EDCAF that initiates a TXOP has a frame available for transmission (see 10.23.2.4 (Obtaining an EDCA TXOP)). There might be another EDCAF of lower priority that invokes the backoff procedure due to an internal collision (see 10.23.2.4 (Obtaining an EDCA TXOP)).(#3653)

An EDMG STA that initiates a PPDU transmission to peer EDMG STA shall set the TXVECTOR parameters CH_BANDWIDTH and CHANNEL_AGGREGATION of the PPDU to a subset of the channels in which the CCA were idle according to Table 8-6 (Definition of EDMG secondary, secondary1, and secondary2 channels(11ay)), and shall set the TXVECTOR parameter SCRAMBLER_INIT_SETTING to a value that provides bandwidth information to the peer STA.

### 10.23.3 HCF controlled channel access (HCCA)

#### 10.23.3.1 General

The HCCA mechanism manages access to the WM using an HC that has higher medium access priority than non-AP STAs. This allows it to transfer MSDUs to STAs and to allocate TXOPs to STAs.

The HC grants a STA a polled TXOP with duration specified in a QoS (+)CF-Poll frame. A STA may transmit multiple frame exchange sequences within given polled TXOPs, subject to the limit on TXOP duration.

All STAs inherently obey the NAV rules of the HCF because each frame transmitted under HCF contains a duration value chosen to cause STAs in the BSS to set their NAVs to protect the expected subsequent frames.

A non-AP QoS STA that is (#181)a non-S1G STA shall respond to QoS (+)CF-Poll frames received from an HC with the Address 1 field matching their own addresses.

The HC shall perform delivery of buffered non-GCR-SP group addressed MSDUs/MMPDUs following DTIM beacons(#3309).

An HC may perform a backoff following an interruption of a frame exchange sequence due to lack of an expected response under the rules described in 10.23.3.2.3 (Recovery from the absence of an expected reception), using the parameters dot11HCCWmin, dot11HCCWmax, and dot11HCCAIFSN and the backoff rules in 10.2 (MAC architecture) and 10.23.2.2 (EDCA backoff procedure). The decision to perform a backoff by the HC is dependent on conditions such as interference from an overlapping BSS. The mechanism to detect the interference from an overlapping BSS and the decision to perform a backoff, DFS (such as in 11.6), or other techniques (such as inter-BSS scheduling) is beyond the scope of this standard.

#### 10.23.3.2 HCCA procedure

##### 10.23.3.2.1 General

To start an HCCA TXOP, the HC gains control of the WM by waiting a shorter time before initiating the first transmission of the TXOP than STAs using the EDCA procedures. The duration values used in QoS frame exchange sequences reserve the medium to permit completion of the current sequence.

##### 10.23.3.2.2 CAP generation

When the HC needs access to the WM to start a CAP, the HC shall sense the WM. When the WM is determined to be idle at the TxPIFS slot boundary as defined in 10.3.7 (DCF timing relations), the HC shall transmit either a QoS (+)CF-Poll with the duration value set to cover the polled TXOP, or the first frame of any


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permitted frame exchange sequence with the duration value set to cover the HCCA TXOP. A CAP shall not extend across a TBTT. The occurrence of a TBTT implies the end of the CAP, after which the regular channel access procedure (EDCA or HCCA) is resumed. It is possible that no Data frame was transmitted during an HCCA TXOP. The shortened termination of the HCCA TXOP does not imply an error condition. CAPs are illustrated in Figure 10-33 (CAP periods).

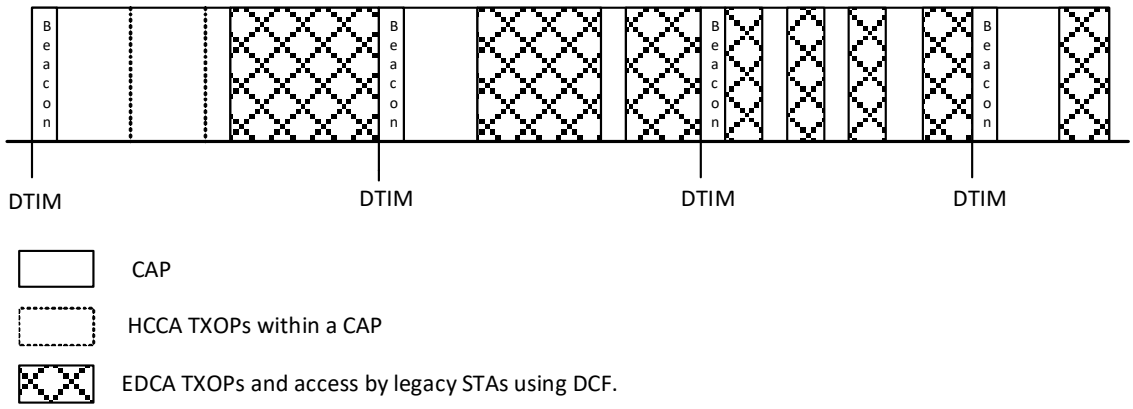


**Figure 10-33—CAP periods**

After the last frame of all other nonfinal frame exchange sequences (e.g., sequences that convey individually addressed QoS Data or Management frames) during an HCCA TXOP, the holder of the current HCCA TXOP shall wait for one SIFS before transmitting the first frame of the next frame exchange sequence. The HC may sense the channel and reclaim the channel if the WM is determined to be idle at the TxPIFS slot boundary after the HCCA TXOP (see Figure 10-29 (EDCA mechanism timing relationships(#14)(#1058))). A CAP ends when the HC does not reclaim the channel at the TxPIFS slot boundary after the end of an HCCA TXOP.

#### 10.23.3.2.3 Recovery from the absence of an expected reception

This subclause describes recovery from the absence of an expected reception in a CAP. Note that the recovery rules from the absence of an expected reception are different from EDCA because in this case the NAVs of all of the STAs in the BSS have already been set up by the transmissions by the HC. The recovery rules for the multiple frame exchange sequences in an EDCA TXOP(#109) are different because a STA may always be hidden and may have not set its NAV due to the transmission by another STA. Finally, since an HC is (#2210)colocated with the AP, the AP may recover using the rules described in this subclause even if the recovery is from the absence of an expected reception.

The beginning of reception of an expected response is detected by the occurrence of PHY-CCA.indication(BUSY,channel-list) primitive at the STA that is expecting the response where the channel-list parameter is absent or, if present, includes “primary.”

If the beginning of such reception does not occur during the first slot time following a SIFS, then:[29]

— If the transmitting STA is the HC, it may initiate recovery by transmitting at the TxPIFS slot boundary after the end of the HC’s last transmission only if the PHY-CCA state indicates IDLE during the CCAdel period preceding the TxPIFS slot boundary as shown in 10-25 (DCF timing relationships(#14)(#1058)(#3297)).

— If the transmitting STA is a non-AP QoS STA, and there is an MPDU for transmission, it shall initiate recovery by transmitting at a PIFS after the end of the last transmission if the PHY-CCA

[29] This restriction is intended to avoid collisions due to inconsistent CCA reports in different STAs, not to optimize the bandwidth usage efficiency.

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state indicates IDLE during the CCAdel period preceding the TxPIFS slot boundary, the polled TXOP limit is nonzero and at least one frame (re)transmissions can be completed within the remaining duration of a nonzero polled TXOP limit.

If the transmitted frame is not of type QoS (+)CF-Poll and the expected response frame is not received correctly, regardless of the occurrence of the PHY-RXSTART.indication primitive, the QoS STA may initiate recovery following the occurrence of PHY-CCA.indication(IDLE) primitive so that a SIFS occurs between the last energy on the WM and the transmission of the recovery frame.

When there is a transmission failure within a polled TXOP, the short retry count (as described in 10.23.2.12 (Retransmit procedures)) corresponding to the failed MSDU or MMPDU shall be incremented.(#4331)

An MPDU belonging to a TC is subject to the respective retry limit as well as the dot11EDCATableMSDULifetime (#3757)for a non-AP STA or dot11QAPEDCATableMSDULifetime for an AP and is discarded when either of them is exceeded.(#4331)

An MPDU belonging to a TS with a specified delay bound is subject to delay bound and is discarded if the MPDU could not be transmitted successfully since it has been delivered to the MAC. An MPDU belonging to a TS with an unspecified delay is subject to dot11MaxTransmitMSDULifetime and is discarded when it is exceeded.

Non-AP STAs that receive a QoS (+)CF-Poll frame shall respond within a SIFS, regardless of the NAV setting. If a response is not received but a PHY-CCA.indication(BUSY) primitive occurs during the slot following a SIFS and is followed by a PHY-RXSTART.indication or PHY-RXEND.indication primitive prior to a PHY-CCA.indication(IDLE) primitive, then the HC assumes that the transmitted QoS (+)CF-Poll frame was received by the polled STA. In the cases of QoS Data +CF-Poll, QoS Data +CF-Ack +CF-Poll, or QoS CF-Ack +CF-Poll, the PHY-CCA.indication(BUSY) primitive is used only to determine whether the transfer of control of the channel has been successful. The PHY-CCA.indication(BUSY) primitive is not used for determining the success or failure of the transmission. If the CF-Poll is piggybacked onto a QoS Data frame, the HC may have to retransmit that QoS Data frame subsequently.

If an HC receives a frame from a STA with a duration/ID covering only the response frame, the HC shall assume that the STA is terminating its TXOP, and the HC may initiate other transmissions, or send a CF-End frame (see 10.23.3.4 (NAV operation of a TXOP under HCCA)).

If a polled QoS STA has no queued traffic to send or if the MPDUs available to send are too long to be transmitted within the specified TXOP limit, the QoS STA shall send a QoS (+)Null frame. In the case of no queued traffic, this QoS (+)Null frame shall have a QoS Control field that reports a queue size of 0 for any TID with the duration/ID set to the time required for the transmission of one Ack frame, plus one SIFS. In the case of insufficient TXOP size, such as when the maximum MSDU size is not specified, this QoS (+)Null frame shall have a QoS Control field that contains the TID and TXOP duration or a nonzero queue size needed to send the MPDU that is ready for transmission. When a queue size is transmitted, the HC shall combine the queue size information with the rate of the received QoS (+)Null frame to determine the required size of the requested TXOP.

Within a polled TXOP, the unused portion of TXOPs shall not be used by the STA and may be reallocated by the HC as follows:

a) The recipient of the final frame, with Normal Ack ack policy, shall be the HC if there will be time remaining in the TXOP after the transmission of the final frame and its expected Ack frame. If there are no frames to be sent to the HC, then the QoS STA shall send to the HC a QoS Null with the Queue Size subfield in the QoS Control field set to 0.
    1) If a PHY-CCA.indication(BUSY) primitive occurs at the STA that is expecting the Ack frame during the first slot following a SIFS after the end of the transmission of the final frame, it shall


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be interpreted as indicating that the channel control has been successfully transferred and no further frames shall be transmitted by the STA in the TXOP, even though the Ack frame from HC may be incorrectly received.[30]

2) If the beginning of the reception of an expected Ack frame to the final frame does not occur, detected as the nonoccurrence of the PHY-CCA.indication(BUSY) primitive at the QoS STA that is expecting the response during the first slot time following a SIFS, the QoS STA shall retransmit the frame or transmit a QoS Null frame, with Normal Ack ack policy and the Queue Size subfield set to 0, after a PIFS(#6587) from the end of last transmission, until such time that it receives an acknowledgment or when there is not enough time remaining in the TXOP for sending such a frame.[31]

b) If there is not enough time within the unused portion of the TXOP to transmit either the QoS Null frame or the frame with the Duration/ID field covering only the response frame, then the STA shall cease control of the channel.[32]

### 10.23.3.3 HCCA TXOP structure and timing

Any QoS Data frame of a subtype that includes CF-Poll contains a TXOP limit in its QoS Control field. The ensuing polled TXOP is protected by the NAV set by the Duration field of the frame that contained the QoS (+)CF-Poll function, as shown in Figure 10-34 (Polled TXOP). Within a polled TXOP, a STA may initiate the transmission of one or more frame exchange sequences, with all such sequences nominally separated by a SIFS. (#136)The STA shall not initiate transmission of a frame unless the transmission and any acknowledgment or other immediate response expected from the peer MAC entity are able to complete within the polled TXOP, and the HC shall account for these when setting the TXOP limit. If the TXOP Limit subfield in the QoS Control field of the QoS Data frame that includes CF-Poll is equal to 0, then the STA to which the frame is directed to shall respond with either one MPDU or one QoS Null frame.

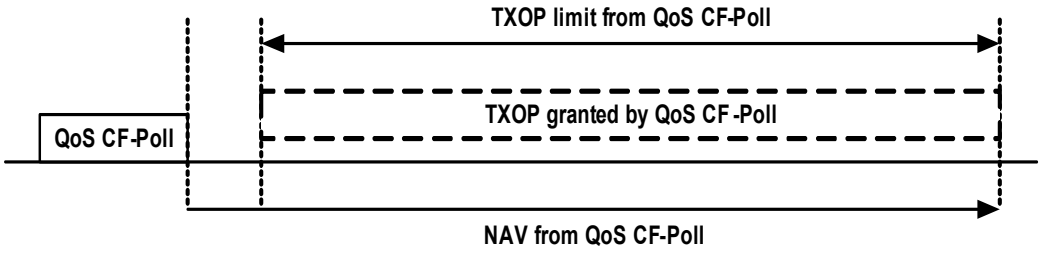


**Figure 10-34—Polled TXOP**

A TXOP or transmission within a TXOP shall not extend across TBTT, or dot11CAPLimit. The HC shall verify that the full duration of any granted TXOP meets these requirements so that a STA may use the time prior to the TXOP limit of a polled TXOP without checking for these constraints. Subject to these limitations, all decisions regarding what MSDUs, A-MSDUs, and/or MMPDUs are transmitted during any given TXOP are made by the STA that holds the TXOP.[33,34]

[30] Note that while the PHY-CCA.indication(BUSY) primitive is used in this instance to determine the control of the channel, it is not used for determining the success or failure of the transmission.

[31] This is to avoid the situation where the HC might not receive the frame and might result in an inefficient use of the channel.

[32] In this case the channel is not accessed until the NAVs expire at all of the STAs.

[33] In certain regulatory domains, channel sensing needs to be done at periodic intervals (for example, in Japan, this period is 4 ms). This means that the duration of a TXOP in these regulatory domains might not be more than this periodic interval. In order to extend the TXOP beyond the limit implied by this periodic interval, the TXOP holder needs to sense the channel at least once in the limit imposed in the regulatory domain, by waiting for at least for the duration of one PIFS during which it senses the channel. If it does not detect any energy, it may continue by sending the next frame. In other words, the total TXOP size assigned should include an extra time allocated (i.e., $n \times$ aSlotTime, where $n$ is the number of times the STA needs to sense the channel) and is given by $\lfloor$TXOP limit/limit imposed in the regulatory domain$\rfloor$.

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#### 10.23.3.4 NAV operation of a TXOP under HCCA

An HC shall set its own NAV to prevent it from transmitting during a TXOP that it has granted to a STA through an HCCA poll. However, the HC may reclaim the TXOP if a STA is not using it or ends the TXOP early (see 10.23.3.2.3 (Recovery from the absence of an expected reception)).

If the HC has no more STAs to poll and it has no more Data, Management, BlockAckReq, or BlockAck frames to send, it may reset the NAVs of all QoS STAs in the BSS by sending a QoS CF-Poll frame with the RA matching (#3403)its MAC address and with the Duration/ID field set to 0.

A STA that receives a QoS (+)CF-Poll frame with a MAC address in the Address 1 field that matches the HC's MAC address and the Duration/ID field value equal to 0 shall reset the NAV value to 0.

When a STA receives a QoS (+)CF-Poll frame containing the BSSID of the BSS of which the STA is a member, that STA shall update the NAV if necessary and shall save the TXOP holder address for that BSS, which is the MAC address from the Address 1 field of the frame containing the QoS (+)CF-Poll. If an RTS frame is received with the RA matching the MAC address of the STA and the MAC address in the TA field in the RTS frame matches the saved TXOP holder address, then the STA shall send the CTS frame after a SIFS(#6587), without regard for, and without resetting, its NAV. The saved TXOP holder address shall be cleared when the NAV is reset or when the NAV counts down to 0.

When a STA receives a frame addressed to it and requires an acknowledgment, it shall respond with an Ack or QoS +CF-Ack frame independent of its NAV. A non-AP STA shall accept a polled TXOP by initiating a frame exchange sequence independent of its NAV.

#### 10.23.3.5 HCCA transfer rules

##### 10.23.3.5.1 General

A TXOP obtained by receiving a QoS (+)CF-Poll frame uses the specified TXOP limit consisting of one or more frame exchange sequences with the sole time-related restriction being that the final sequence shall end not later than the TXOP limit. In QoS CF-Poll and QoS CF-Ack +CF-Poll frames, the TID subfield in the QoS Control field indicates the TS for which the poll is intended. The requirement to respond to that TID is nonbinding, and a STA may respond with any frame. Upon receiving a QoS (+)CF-Poll frame, a STA may send any frames, i.e., QoS Data frames belonging to any TID as well as Management frames in the obtained TXOP. MSDUs may be fragmented in order to fit within TXOPs.

The QoS CF-Poll frames shall be sent only by an HC. Non-AP STAs are not allowed to send QoS (+)CF-Poll frames. A STA shall not send QoS (+)Data frames in response to any Data frame other than the QoS (+)CF-Poll frames.

The TXOP limit is inclusive of the PHY and IFS overhead, and an AP should account for the overhead when granting TXOPs.

If a STA has set up at least one TS for which the Aggregation subfield in the associated TSPEC is equal to 0, the AP shall use only QoS CF-Poll or QoS CF-Ack +CF-Poll frames to poll the STA and shall never use QoS (+)Data +CF-Poll to poll the STA. Note that although QoS (+)CF-Poll is a Data frame, (#151)it should be transmitted at one of the rates in the BSSBasicRateSet parameter in order to set the NAV of all STAs that are not being polled (see 10.6 (Multirate support)). If a CF-Poll is piggybacked with a QoS Data frame, then the

[34] The TID value in the QoS Control field of a QoS Data +CF-Poll frame pertains only to the MSDU or fragment thereof in the Frame Body field of that frame. This TID value does not pertain to the TXOP limit value and does not place any constraints on what frame(s) the addressed STA may send in the granted TXOP.


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frame containing all or part of an MSDU or A-MSDU may be transmitted at a rate that is below the negotiated minimum PHY rate in the TSPEC related to that data.

A QoS STA shall use QoS Data frames for all MSDU transfers to another QoS STA. The TID in the QoS Control fields of these frames shall indicate the TC or TS to which the MPDU belongs. Furthermore, either the Queue Size subfield shall indicate the amount of queued traffic present in the output queue that the STA uses for traffic belonging to this TC or TS, or the TXOP Duration Requested subfield shall indicate the duration that the STA requests for use in the next TXOP for traffic belonging to this TC or TS. The queue size value reflects the amount on the appropriate queue not including the present MPDU. The queue size value may remain constant in all QoS Data frames that carry fragments of the same MSDU even if the amount of queued traffic changes as successive fragments are transmitted. In order to inform the HC of queue status, a STA may use the QoS Null frame indicating the TID and the queue size or TXOP duration request (also see 10.23.3.5.2 (TXOP requests)).

(#181)A QoS STA shall support receiving QoS +CF-Ack frames. The HC may use QoS Data +CF-Ack frames to send frames to the same STA a SIFS after receiving the final transmission of the previous TXOP. The HC may also use QoS Data +CF-Ack frames to send frames to any other STA a SIFS after receiving the final transmission of the previous TXOP, if the STA that sent the final transmission of the previous TXOP has set the Q-Ack subfield in the QoS Capability element in the (Re)Association Request frame to 1. A STA shall respond to QoS Data frames having Normal Ack ack policy with an Ack frame, unless the acknowledgment is piggybacked in which case it shall use a QoS +CF-Ack frame. Piggybacked frames are allowed only within TXOPs initiated by the HC. The HC shall not send a QoS Data frame containing a +CF-Ack with an Address 1 that does not correspond to the address of the STA for which the +CF-Ack is intended, unless the STA to which the +CF-Ack is intended, sets the Q-Ack subfield in the QoS Capability element in the (Re)Association Request frame. STAs are not required to be able to transmit QoS Data frames with subtypes that include +CF-Ack.

An AP that has dot11QAckOptionImplemented true may allow associations with STAs advertising support for the Q-Ack option. Such associations do not require the AP to employ piggyback acknowledgments directed toward that associated STA in frames that are not directed to that associated STA. (#181)A QoS STA shall process received QoS Data frames with subtypes that include +CF-Ack when the STA to which the acknowledgment is directed is the same as the STA addressed by the Address 1 field of that Data frame. A STA that does not set the Q-Ack subfield to 1 in the QoS Capability element in the (Re)Association Request frame is not required to handle the received QoS (+)Data +CF-Ack frames that are addressed to other STAs. The net effect of these restrictions on the use of QoS +CF-Ack frames is that the principal QoS +CF-Ack subtype that is useful is the QoS Data +CF-Ack frame, which can be sent by a STA as the first frame in a polled TXOP when that TXOP was conveyed in a QoS Data +CF-Poll (+CF-Ack) frame and the outgoing frame is directed to the HC's STA address. QoS (Data +)CF-Poll +CF-Ack frames are useful to allow the HC to grant another TXOP to the same STA a SIFS after receiving the final transmission of that STA's previous TXOP. QoS (Data+)CF-Poll +CF-Ack frames are also useful to allow the HC to grant another TXOP to a different STA a SIFS after receiving the final transmission of a STA's previous TXOP, if the STA that sent the final transmission of the previous TXOP has set the Q-Ack subfield in the QoS Capability element in the (Re)Association Request frame to 1.

HCF contention based channel access shall not be used to transmit MSDUs belonging to an established TS (with the HC's acceptance of the associated TSPEC), unless the granted TSPEC indicates it is permitted to do so when the Access Policy subfield of the TS Info field is equal to "HCCA, EDCA mixed mode" (HEMM), the polled STA utilized the full TXOP provided by the HC, and it has more MPDUs to send. When this STA sends frames belonging to a TS using contention based channel access, it shall encode the TID subfield in the QoS Data frame with the TID associated with the TS. When the AP grants a TSPEC with the Access Policy subfield equal to HEMM and if the corresponding AC needs admission control, the AP shall include the medium time that specifies the granted time for EDCA access in the ADDTS Response frame.

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#### 10.23.3.5.2 TXOP requests

STAs may send TXOP requests during polled TXOPs or EDCA TXOPs using the QoS Control field in a QoS Data frame or a QoS Null frame directed to the HC, with the TXOP Duration Requested or Queue Size subfield value and TID subfield value indicated to the HC. APs indicate whether they process TXOP request or queue size in the QoS Info field in the Beacon, Probe Response, and (Re)Association Response frames. An AP shall process requests in at least one format. The AP may reallocate TXOPs if the request belongs to TS or update the EDCA parameter set if the above request belongs to TC. A STA shall use only the request format that the AP indicates it can process.

TXOP Duration Requested subfield values are not cumulative. A TXOP duration requested for a particular TID supersedes any prior TXOP duration requested for that TID. A value of 0 in the TXOP Duration Requested subfield may be used to cancel a pending unsatisfied TXOP request when its MSDU is no longer queued for transmission. The TXOP duration requested is inclusive of the PHY and IFS overhead, and a STA should account for this when attempting to determine whether a given transmission fits within a specified TXOP duration.

The AP may choose to assign a TXOP duration shorter than that requested in the TXOP Duration Requested subfield.

Even if the value of TXOP Duration Requested subfield or Queue Size subfield in a QoS Data frame is 0, the HC shall continue to poll according to the negotiated schedule.

#### 10.23.3.5.3 Use of RTS/CTS

In order to provide improved NAV protection, a STA may send an RTS frame as the first frame of any frame exchange sequence without regard for dot11RTSThreshold or dot11TXOPDurationRTSThreshold.(11ax)

If a QoS STA sends an RTS frame and does not receive an expected CTS frame, then the recovery rules are as specified in 10.23.3.2.3 (Recovery from the absence of an expected reception).

In order to provide NAV protection for a transmission to the AP in response to a QoS Data frame with a subtype that includes CF-Poll, the polled STA may send a CTS frame with the RA containing its own MAC.

NOTE 1—The CTS frame is shorter than a QoS Data frame and has a higher probability that it will be received by other STAs.

NOTE 2—The transmission of the CTS sets the NAV in its own vicinity without the extra time required to send an RTS frame.[35]

#### 10.23.3.5.4 HCCA transfer rules for a VHT STA

A VHT STA that is a member of a BSS that supports multiple channel widths is granted a TXOP for a specified duration and for a channel width that is equal to the channel width of the frame containing the QoS CF-Poll.

### 10.23.4 Admission control at the HC

#### 10.23.4.1 General

An IEEE 802.11 network may use admission control to administer policy or regulate the available bandwidth resources. Admission control is used to attempt to provide a guarantee of the amount of time that a STA has

[35] This is unnecessary because the NAVs in the vicinity of the QoS AP were set by the QoS (+)CF-Poll frame.


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available to access the channel. The HC, which is in the AP, is used to administer admission control in the network. As the QoS facility supports two access mechanisms, there are two distinct admission control mechanisms: one for contention based access and another for controlled access.

Admission control, in general, depends on vendors' implementation of the scheduler, available channel capacity, link conditions, retransmission limits, and the scheduling requirements of a given stream. All of these criteria affect the admissibility of a given stream. If the HC has admitted no streams that require polling, it might not find it necessary to perform the scheduler or related HC functions.

### 10.23.4.2 Contention based admission control procedures

#### 10.23.4.2.1 General

An AP shall support admission control procedures, at least to the minimal extent of advertising that admission is not mandatory on its ACs. The AP uses the ACM (admission control mandatory) subfields advertised in the EDCA Parameter Set element to indicate whether admission control is required for each of the ACs. All ACs with priority higher than that of an AC for which the ACM subfield is set to 1 should have the ACM subfield set to 1. While the CWmin, CWmax, AIFS, and TXOP limit parameters may be adjusted over time by the AP, the ACM subfield shall be static for the duration of the lifetime of the BSS.

A non-AP STA may send frames in an AC where admission control is not mandated.

A non-AP STA may support the admission control procedure in 10.23.4.2.3 (Procedure at non-AP STAs) to send frames in an AC where admission control is mandated. If it does not support that procedure or admission was denied, and both of the following apply:

— dot11RejectUnadmittedTraffic is false or not present
— there is a lower priority AC (see Table 10-1 (UP-to-AC mappings(#68))) that does not require admission control

then it may send such frames using the EDCA parameters of that lower priority AC for channel access; the contents of the frames are unaffected. Otherwise, it shall not send such frames.

A STA shall transmit an ADDTS Request frame to the HC in order to request admission of traffic in any direction (i.e., uplink, downlink, direct, or bidirectional) employing an AC that requires admission control. The ADDTS Request frame shall contain the UP associated with the traffic and shall indicate EDCA as the access policy. The AP shall associate the received UP of the ADDTS Request frame with the appropriate AC per the UP-to-AC mappings described in 10.2.3.2 (HCF contention based channel access (EDCA)).

The HC contained within an AP when dot11SSPNInterfaceActivated is true shall admit a non-AP STA's request based on dot11NonAPStationAuthAccessCategories stored in that non-AP STA's dot11InterworkingEntry, which is part of the dot11InterworkingTable. The dot11InterworkingEntry specifies the EDCA access classes and throughput limitations on each access class for which a non-AP STA is permitted to transmit.

#### 10.23.4.2.2 Procedures at the AP

Regardless of the AC's ACM setting, the AP shall respond to an ADDTS Request frame with an ADDTS Response frame that may be to accept or deny the request. On receipt of an ADDTS Request frame from a non-AP STA, the AP shall make a determination about whether to

a) Accept the request, or
b) Deny the request.

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The algorithm used by the AP to make this determination is implementation dependent. An AP when dot11SSPNInterfaceActivated is true shall use the policies delivered by the SSPN that are stored in the dot11InterworkingEntry, which is part of the dot11InterworkingTable. If the AP decides to accept the request, the AP shall also derive the medium time from the information conveyed in the TSPEC element in the ADDTS Request frame. The AP may use any algorithm in deriving the medium time, but K.2.2 (Deriving medium time) provides a procedure that may be used. Having made such a determination, the AP shall transmit a TSPEC element to the requesting non-AP STA contained in an ADDTS Response frame. If the AP is accepting the request, the Medium Time field shall be specified. If the AP is accepting a request for a downlink TS, the Medium Time field shall be set to 0. If the AP is accepting a request corresponding to an AC for which ACM is 0 (e.g., the TSPEC is to change APSD behavior), the Medium Time field shall be set to 0.

#### 10.23.4.2.3 Procedure at non-AP STAs

Each EDCAF shall maintain two MAC variables: admitted_time and used_time.

The admitted_time and used_time shall be set to 0 at the time of (re)association. The STA may subsequently decide to explicitly request medium time for the AC that is associated with the specified priority.

In order to make such a request, the STA shall transmit a TSPEC element contained in an ADDTS Request frame with the following fields specified (i.e., nonzero): Nominal MSDU Size, Mean Data Rate, Minimum PHY Rate, Inactivity Interval, and Surplus Bandwidth Allowance. The Medium Time field is not used in the request frame and shall be set to 0.

On receipt of a TSPEC element contained in an ADDTS Response frame indicating that the request has been accepted, the STA shall recompute the admitted_time for the specified EDCAF as follows:

admitted_time = admitted_time + dot11EDCAAveragingPeriod × medium time of TSPEC.

The STA may choose to tear down the explicit request at any time. For the teardown of an explicit admission, the STA shall transmit a DELTS frame containing the TSID and direction that specify the TSPEC to the AP.

If the STA sends or receives a DELTS frame, it shall recompute the admitted_time for the specified EDCAF as follows:

admitted_time = admitted_time – dot11EDCAAveragingPeriod × medium time of TSPEC.

The MAC variable used_time is the amount of time used, in units of 32 μs, by the STA in dot11EDCAAveragingPeriod. The MAC variable admitted_time is the medium time allowed by the AP, in units of 32 μs, in dot11EDCAAveragingPeriod. The STA shall update the value of used_time:

a) At dot11EDCAAveragingPeriod second intervals
   used_time = max((used_time – admitted_time), 0)
b) After each successful or unsuccessful frame exchange sequence,
   used_time = used_time + MPDUExchangeTime

The MPDUExchangeTime is the duration of the frame exchange sequence. For the case of an MPDU transmitted with Normal Ack ack policy and without RTS/CTS protection, this equals the time required to transmit the MPDU plus the time required to transmit the expected response frame plus one SIFS. Frame exchange sequences that do not include any Data frames are excluded from the used_time update. Any RD transmission granted by the AP is excluded from the used_time update. If the used_time value reaches or exceeds the admitted_time value, the corresponding EDCAF shall no longer transmit QoS Data frames or QoS Null frames using the EDCA parameters for that AC as specified in the QoS Parameter Set element. However, a STA may choose to temporarily replace the EDCA parameters for that EDCAF with those specified for an AC of lower priority, if no admission control is required for those ACs.


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NOTE—When a frame is transmitted using temporary EDCA parameters, the TID field of that frame is not modified.

If, for example, a STA has made and had accepted an explicit admission for a TS and the channel conditions subsequently worsen, possibly including a change in PHY data rate so that it requires more time to send the same data, the STA may make a request for more admitted_time to the AP and at the same time downgrade the EDCA parameters for that AC for short intervals in order to send some of the traffic at the admitted priority and some at the unadmitted priority, while waiting for a response to the admission request.

### 10.23.4.3 Controlled-access admission control

This subclause describes the schedule management of the admitted HCCA streams by the HC. When the HC provides controlled channel access to STAs, it is responsible for granting or denying polling service to a TS based on the parameters in the associated TSPEC. If the TS is admitted, the HC is responsible for scheduling channel access to this TS based on the negotiated TSPEC fields. The HC should not initiate a modification of TSPEC fields of an admitted TS unless requested by the STA. The HC should not tear down a TS unless explicitly requested by the STA or at the expiration of the inactivity timer. The polling service based on admitted TS provides a "guaranteed channel access" from the scheduler in order to have its QoS requirements met. This is an achievable goal when the WM operates free of external interference (such as operation within the channel by other technologies and co-channel overlapping BSS interference). The nature of wireless communications may preclude absolute guarantees to satisfy QoS requirements.

The following are rules for the operation of the scheduler:

— The scheduler shall be implemented so that, under controlled operating conditions, all STAs with admitted TS are offered TXOPs that satisfy the service schedule.

— Specifically, if a TS is admitted by the HC, then the scheduler shall service the STA during an SP. An SP is a period of time during which a set of one or more downlink individually addressed frames and/or one or more polled TXOPs are granted to the STA. An SP starts at fixed intervals of time specified in Service Interval field. The first SP starts when the lower order 4 octets of the TSF timer equals the value specified in Service Start Time field.[36] Additionally, the minimum TXOP duration shall be at least the time to transmit one maximum MSDU size successfully at the minimum PHY rate specified in the TSPEC. If maximum MSDU size is not specified in the TSPEC, then the minimum TXOP duration shall be at least the time to transmit one nominal MSDU size successfully at the minimum PHY rate. The vendors are free to implement any optimized algorithms, such as reducing the polling overheads, increasing the TXOP duration, etc., within the parameters of the transmitted schedule.

— The HC shall admit its request based on Infrastructure Authorization Information in dot11InterworkingEntry, which is part of the dot11InterworkingTable. The dot11InterworkingEntry specifies whether a non-AP STA is permitted to use HCCA, its throughput limitation and its minimum delay bound.

When the HC aggregates the admitted TS, it shall set the Aggregation field in the granted TSPEC to 1. An AP shall schedule the transmissions in HCCA TXOPs and communicate the service schedule to the STA. The HC shall provide an aggregate service schedule if the STA sets the Aggregation field in its TSPEC request. If the AP establishes an aggregate service schedule for a STA, it shall aggregate all HCCA streams for the STA. The service schedule is communicated to the STA in a Schedule element contained in an ADDTS Response frame. In the ADDTS Response frame, the modified service start time shall not exceed the requested service start time, if specified in ADDTS Request frame, by more than one maximum service interval (SI). The HC uses the maximum SI for the initial scheduling only as there might be situations that HC is not be able to service the TS at the scheduled timing, due to an EDCA or DCF transmission or other interferences interrupting the schedule.

[36] The lower order 4 octets of the TSF timer cover a span of around 71 min. Due to TSF timer wrapover and due to the possibility of receiving the schedule frame after the indicated start time timer, ambiguity may occur. This ambiguity is resolved by using the nearest absolute TSF timer value in past or future when the lower order 4 octets match the Start Time field in the Schedule element.

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The Service Interval field value in the Schedule element shall be greater than the minimum SI. The service schedule could be subsequently updated by an AP as long as it meets TSPEC requirements.

The HC may update the service schedule at any time by sending a Schedule element in a Schedule frame. The updated schedule is in effect when the HC receives the Ack frame for the Schedule frame. The service start time in the Schedule element in the Schedule frame shall not exceed the beginning of the immediately previous SP by more than the maximum SI. The service start time shall not precede the beginning of the immediately previous SP by more than the minimum SI.

A STA may affect the service schedule by modifying or deleting its existing TS as specified in 11.4 (TS operation).

K.3.1 (Guidelines for deriving service schedule parameters) provides guidelines for deriving an aggregate service schedule for a single STA from the STA's admitted TS. The schedule shall meet the QoS requirements specified in the TSPEC.

During any time interval [$t1$, $t2$] including the interval that is greater than the specification interval, the cumulative TXOP duration shall be greater than the time required to transmit all MSDUs (of nominal MSDU size) arriving at the mean data rate for the stream, over the period [$t1$, $t2 - D$]. The parameter $D$ is set to the specified maximum SI in the TSPEC. If maximum SI is not specified, then $D$ is set to the delay bound in the TSPEC.

The HC shall use the minimum PHY rate in calculating TXOPs if the minimum PHY rate is present in the TSPEC field in the ADDTS response. Otherwise, the HC may use an observed PHY rate in calculating TXOPs. A STA may have an operational rate lower than the minimum PHY rate due to varying conditions on the channel for a short time and still may be able to sustain the TS without changing the minimum PHY rate in the TSPEC.

A minimum set of TSPEC fields shall be specified during the TSPEC negotiation. The specification of a minimum set of parameters is required so that the scheduler can determine a schedule for the stream that is to be admitted. These parameters are Mean Data Rate, Nominal MSDU Size, Minimum PHY Rate, Surplus Bandwidth Allowance, and at least one of Maximum Service Interval and Delay Bound in the ADDTS Request frame. In the ADDTS Response frame, these parameters are Mean Data Rate, Nominal MSDU Size, Minimum PHY Rate, Surplus Bandwidth Allowance, and Maximum Service Interval and shall be nonzero when a stream is admitted.

If any of the elements in the minimum set of parameters does not have the required nonzero value, as specified above in this subclause, in the ADDTS Request frame, the HC may replace the unspecified parameters with nonzero values and admit the stream, or it may reject the stream. If the HC admits the stream with the alternative set of TSPEC fields, these parameters are indicated to the STA through the ADDTS Response frame. If both maximum SI and delay bound are specified, the HC may use only the maximum SI. If any other parameter is specified in the TSPEC element, the scheduler may use it when calculating the schedule for the stream. The HC may also use the UP value in the TS Info field for admission control or scheduling purposes; however, this decision is outside the scope of this standard. The mandatory set of parameters might be set by any higher layer entity or may be generated autonomously by the MAC.

If a STA specifies a nonzero minimum SI and if the TS is admitted, the HC shall generate a schedule that conforms to the specified minimum SI.

A reference design for a sample scheduler and admission control unit is provided in Annex K. A sample use of the TSPEC for admission control is also described in Annex K.


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### 10.23.5 Restricted access window (RAW) operation

#### 10.23.5.1 General

Restricting uplink channel access to a small number of STAs and spreading their uplink access attempts over a period of time might improve the medium utilization's efficiency by reducing collisions. When dot11RAWOperationActivated is true, an AP may allocate a medium access interval, called a restricted access window (RAW), for a group of STAs within a (short) beacon interval and broadcast this information using S1G Beacon frame.

An S1G STA with dot11RAWOperationImplemented equal to true shall set the RAW Operation Support field in the S1G Capabilities element it transmits to 1. An S1G STA with dot11RAWOperationImplemented equal to false shall set the RAW Operation Support field in the S1G Capabilities element it transmits to 0.

(#181)A non-AP STA with dot11RAWOperationImplemented equal to true shall follow the RAW procedure, as described in this subclause.

An AP shall not include a non-AP STA in any RAW Group from which it has received an S1G Capabilities element whose RAW Operation Support field value is 0.

An S1G STA in TIM mode with dot11RAWOperationImplemented equal to false that receives an RPS element from the AP it is associated shall not access the WM for the RAW duration indicated in the RPS element.

An S1G STA in TIM mode is in the RAW group indicated by the RAW Group subfield in the RAW Assignment subfield of the RPS element if the AID of the S1G STA in TIM mode ($n$) is greater than or equal to the lowest AID of the STA allocated in the RAW ($N_1$) and the AID of the STA is less than or equal to the highest AID of the S1G STA in TIM mode ($N_2$) allocated in the RAW (i.e., $N_1 \leq n \leq N_2$), where $N_1$ is constructed by (#3487concatenating the Page Index subfield and the RAW Start AID subfield in the RAW Group subfield of the RPS element and $N_2$ is constructed by (#3487)concatenating the Page Index subfield and the RAW End AID subfield in the RAW Group subfield of the RPS element.(#2047)

An S1G STA in TIM mode that receives an RPS element in an S1G Beacon frame transmitted by the AP with which it is associated determines the RAW timing as the RAW duration specified by RAW Slot Definition subfield in the RAW Assignment subfield of the received RPS element and the start time of the RAW specified by the RAW Start Time subfield in the RAW Assignment subfield of the received RPS element.

The RAW is divided into one or more RAW slots. The Slot Duration Count subfield of the RAW Slot Definition subfield in the RAW Assignment subfield of the RPS element defines the duration of a RAW slot in the RAW.

If the S1G STA in TIM mode belongs to the RAW group, it is allowed to contend for medium access at the start of its assigned RAW slot (see 10.23.5.3 (Slot assignment procedure in RAW)) and shall not contend for medium access within a RAW slot not assigned to it during that RAW.

An AP may allocate more than one RAW by including more than one RAW Assignment subfield in the RPS element within a (short) beacon interval with different RAW parameters. The AP may also assign periodic RAWs to a group of S1G STAs in TIM mode where the periodicity information is indicated in the RPS element (see 9.4.2.190 (RPS element)).

An AP may assign to each S1G STA in TIM mode or a group of S1G STAs in TIM mode a RAW slot inside the RAW at which the STA(s) is (are) allowed to contend for medium access. After determining its channel access RAW slot assigned by the AP, the S1G STA in TIM mode starts to access the channel not earlier than

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its assigned RAW slot based on the S1G variant of EDCA (10.23.2.6 (EDCA channel access in an S1G BSS)). An S1G STA in TIM mode that is not a member of the RAW group indicated by the RAW Group subfield in the RAW Assignment subfield of the RPS element or is not allowed to access the RAW implicitly indicated by the values of RAW Type and RAW Type Options subfield for which the RAW Group subfield is not present, shall not access the WM in the indicated channels of the RPS element or in the BSS operating channel if there are no indicated channels for duration of the RAW, except for a non-AP STA that is allowed not to check the Beacon frame (e.g., S1G STA in non-TIM mode). Upon receipt of any frame (e.g., PS-Poll frame or trigger frame) for the RAW duration from an S1G STA in TIM mode not within the RAW group indicated by the RAW Group subfield in the RAW Assignment subfield of the RPS element, the AP shall respond with a Control frame (e.g., NDP PS-Poll ACK frame).

An AP may further indicate on which channel(s) the SST STA(s) that are granted access to the RAW are allowed to transmit for the RAW duration, through the Channel Indication subfield in the RAW Assignment subfield of the RPS element (see 9.4.2.190 (RPS element)). An SST STA is an S1G STA that is associated with an AP and that chooses a subset of the allowed operating channels for the SST on which to operate when SST operation is activated by the AP as indicated (#1776)in the SST element in the Beacon frame. A value of 1 in a bit position in the Channel Activity Bitmap in the Channel Indication subfield of the RPS element indicates that operation is allowed on the BSS operating channel for the RAW duration, with any allowed operating bandwidth that includes that channel, subject to the limitations described in 10.51 (Subchannel selective transmission (SST)). Access to the channel shall be performed according to the signaling of the procedure described in 10.51 (Subchannel selective transmission (SST)) followed by the Channel Indication signaling in RPS element, assuming the primary channel is a channel identified by a value of 1 in one of the Channel Activity bits in the Channel Indication subfield in the RAW Assignment subfield of the RPS element. The channels that are allowed for SST operation in the RPS element can be different from the channels allowed for SST operation in the SST element. An AP shall not include an S1G STA in TIM mode that is not supporting the SST Operation in the RAW Group of an RPS element that has a Channel Indication that does not include the primary BSS operating channel.

An S1G AP may protect the access of sensor STAs in some S1G Beacon frames by allocating the PRAW (10.23.5.8 (Periodic RAW (PRAW) operation)). During the allocated PRAW, only sensor STAs can access the wireless medium. An S1G AP may determine the duration of the PRAW based on the number of sensor STAs in its network, their expected uplink data amount and data rate and any other factors that the S1G AP chooses.

AP may designate a RAW for S1G STAs in non-TIM mode by setting the RAW Type to Simplex RAW and setting the RAW Type Options to Non-TIM RAW in the RPS element. In a non-TIM RAW, only S1G STAs in non-TIM mode that have been previously scheduled within the RAW such as TWT STAs or awake/doze(#6038) rescheduled STAs (as described in 10.47.2 (Rescheduling of awake/doze cycle)) are allowed to access the medium.

### 10.23.5.2 RAW structure and timing

An illustration of the RAW structure and timing diagram is shown in Figure 10-35 (Restricted Access Window (RAW)).

An AP indicates the RAW allocation and RAW slot assignment within the RAW by including the RPS element and the TIM element in an S1G Beacon frame.

An AP allows or prohibits transmission at the end of the assigned RAW slot by using the Cross Slot Boundary subfield in the RAW Slot Definition subfield within the RAW Assignment subfield of the RPS element (9.4.2.190 (RPS element)).


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If the Cross Slot Boundary subfield in the RAW Slot Definition subfield within the RAW Assignment subfield of the RPS element is set to 1, a STA is allowed to cross its assigned RAW slot boundary to complete the ongoing frame exchange sequence.

If the Cross Slot Boundary subfield in the RAW Slot Definition subfield within the RAW Assignment subfield of the RPS element is(M118) 0, a STA shall not transmit or cause to be transmitted a frame exchange sequence that would exceed boundary of its allocated RAW slot.

As shown in Figure 10-35 (Restricted Access Window (RAW)), if the Cross Slot Boundary subfield in RAW Assignment subfield of the RPS element is equal to 0, a STA may initiate frame transmission only if the remaining time to the end of the assigned RAW slot duration is greater than or equal to the transmission time and reception of any immediate response expected from the peer MAC entity prior to the end of the allocated RAW slot boundary. Otherwise, it shall not initiate transmission of a frame even though the remaining RAW slot duration is nonzero.

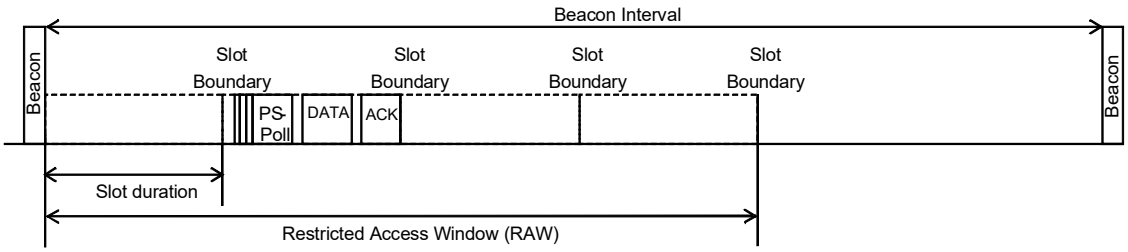


**Figure 10-35—Restricted Access Window (RAW)**

### 10.23.5.3 Slot assignment procedure in RAW

This subclause defines a RAW slot assignment procedure for STAs that are allowed to access the medium within a RAW based on the RPS element and the TIM element in a Beacon frame. Further restrictions apply to a RAW for which the RA Frame Indication field in the RPS element is 1 as described in 10.23.5.7 (RAW Operation with Resource Allocation frame).

A STA shall obtain the number of RAW slots in the RAW ($N_{RAW}$) from the Number of Slots subfield in the RAW Slot Definition subfield of RAW Assignment subfield of the RPS element. The RAW slots in the RAW are indexed from 0 to ($N_{RAW} - 1$) as shown in Figure 10-36 (Illustration of the RAW slot assignment procedure (RAW not restricted to STAs whose AID bits in the TIM element are equal to 1)).

The STA shall determine the index of the RAW slot, $i_{slot}$, in which the STA is allowed to start contending for the medium based on the following mapping function:

$$i_{slot} = (x + N_{offset}) \bmod N_{RAW}$$

where

| | |
|---|---|
| $x$ | is the position index of the AID of the STA or the AID of the STA |
| $N_{offset}$ | represents the offset value in the mapping function |
| $N_{RAW}$ | is the value of the Number of Slots subfield |

The value $x$ is the position index of the AID of the STA if the RAW is restricted to STAs whose AID bits in the TIM element are equal to 1 (the RAW Type field is equal to 0 and the Bit 0 of the RAW Type Options field is equal to 1 or the RAW Type field is equal to 3), and AIDs are arranged in ascending order and each AID is assigned with a position index, which starts from 0 (see Figure 10-37 (Illustration of the RAW slot assignment procedure (RAW restricted to STAs whose AID bits in the TIM element are equal to 1))). Otherwise, if the RAW is not restricted to STAs whose AID bits in the TIM element are equal to 1 (the

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RAW Type field is equal to 0 and the Bit 0 of the Raw Type Options field is equal to 0), $x$ is the AID of the STA (see Figure 10-36 (Illustration of the RAW slot assignment procedure (RAW not restricted to STAs whose AID bits in the TIM element are equal to 1))); $N_{offset}$ represents the offset value in the mapping function, which improves the fairness among the STAs in the RAW, and the STA shall use the 2 least significant octets of the FCS field of the S1G Beacon frame for the $N_{offset}$.

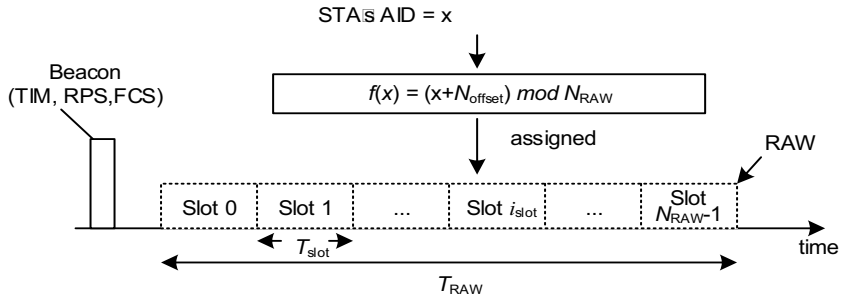


**Figure 10-36—Illustration of the RAW slot assignment procedure (RAW not restricted to STAs whose AID bits in the TIM element are equal to 1)**

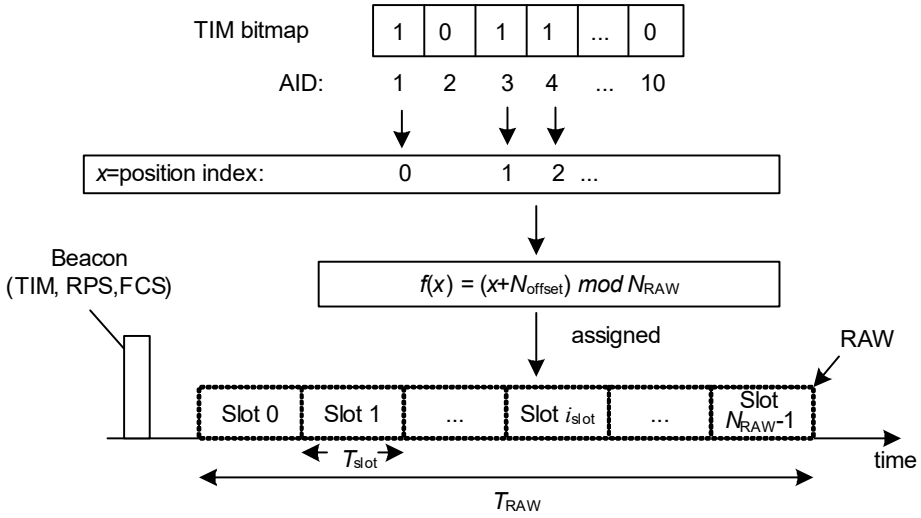


**Figure 10-37—Illustration of the RAW slot assignment procedure (RAW restricted to STAs whose AID bits in the TIM element are equal to 1)**

### 10.23.5.4 Slotted channel access procedure in RAW

When the RAW is not restricted to STAs with DL BU indication in the TIM element (the RAW is a generic RAW and the Paged STA indication is equal to 0), all STAs that belong to a RAW group are allowed to access the medium in the RAW of the RAW group, an AP assigns a RAW slot for each STA that belongs to the RAW group (10.23.5.3 (Slot assignment procedure in RAW)). Each STA that belongs to the RAW group shall start to contend for the WM not earlier than the start of the assigned RAW slot. The channel access is based on EDCA.

When the RAW is restricted to STAs with DL BU indication in the TIM element (the RAW is a generic RAW and the Paged STA indication is equal to 1 or the RAW is a triggering frame RAW), paged STAs only


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are allowed to access the medium in the RAW, after receiving a TIM element, the paged STA starts to contend for the WM not earlier than the allocated RAW slot within the RAW defined as the function of STA position in the TIM element and the RAW group information in the RPS element (10.23.5.3 (Slot assignment procedure in RAW)), and non-paged STAs are not allowed to access the RAW.

An AP may designate a RAW for trigger frames by setting the RAW type to Triggering Frame RAW. When the RAW type is Triggering Frame RAW, each STA in the RAW Group is only allowed to send up to one trigger frame during its assigned RAW slot as described in 10.23.5.3 (Slot assignment procedure in RAW). In the Triggering Frame RAW, a trigger frame is limited to a QoS Null contained in a non-A-MPDU frame or a (NDP) PS-Poll frame. In the Triggering Frame RAW, the STA transmits a trigger frame to the AP not earlier than the start of its assigned RAW slot. The duration of the trigger frame exchange sequence shall not exceed a RAW slot duration calculated by the RAW Slot Definition subfield in the RAW Assignment subfield of the RPS element. And, in the Triggering Frame RAW, crossing RAW slot boundary is not allowed.

After receiving the trigger frame from the paged STA in the Triggering Frame RAW, the AP shall not respond with the downlink buffered BU during the Triggered Frame RAW and may deliver the downlink buffered BU for the corresponding paged STAs after the end of the current Triggering Frame RAW.

An AP may protect transmissions of PS-Poll or trigger frames by setting the NAV for the RAW immediately following the S1G Beacon frame as specified in at least one of the RPS elements (see 10.3.2.4 (Setting and resetting the NAV)). (#221)A STA with dot11RAWOperationImplemented equal to true that is allowed to access the medium during this RAW shall ignore the NAV set by the S1G Beacon frame as described in 10.3.2.4 (Setting and resetting the NAV).

### 10.23.5.5 EDCA backoff procedure in generic RAW or triggering frame RAW

An illustration of EDCA backoff procedure in RAW is shown in Figure 10-38 (Backoff procedure for restricted channel access control).

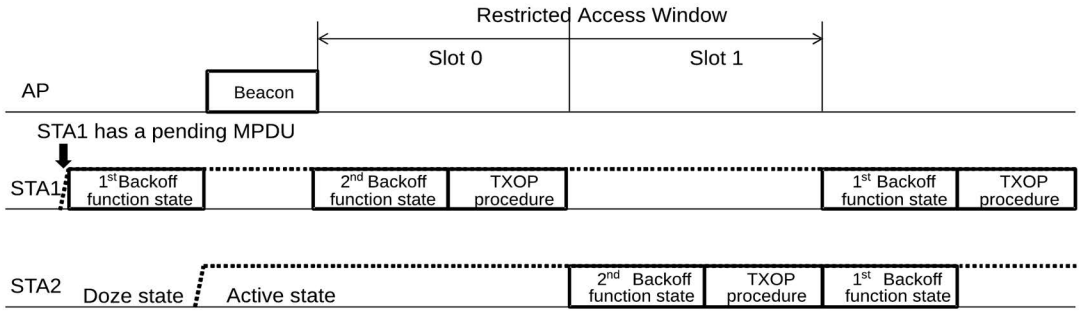


**Figure 10-38—Backoff procedure for restricted channel access control**

For supporting the restricted channel access control based on EDCA, a STA maintains two backoff function states. First backoff function state is used outside RAW and second backoff function state is used inside RAW.

Each STA performing EDCA access suspends an operation of its EDCAF at the start of each RAW and stores the value of the backoff counter, CW[AC], and QSRC[AC] as the first backoff state. At the end of the RAW, the stored first backoff function state is restored and an operation of the EDCAF is resumed. If the previously stored first backoff function state is empty, the EDCAF of a STA shall invoke a backoff procedure, even if no additional transmissions are currently queued.

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If the STA is participating in the RAW and has a pending MPDU, the EDCAF of the STA shall invoke a new backoff procedure for accessing the WM in the RAW using the access category indicated by the (#332)RAW ACI subfield in an EDCA Parameter Set element. At the beginning of the allocated RAW slot, the STA sets the CW[AC] of the secondary backoff procedure to CWmin[AC]. The values of the backoff and CW[AC] used in the RAW is called the second backoff function state.

If the Cross Slot Boundary subfield in RAW Assignment subfield of the RPS element is 0, the STA shall count down backoff only in its assigned RAW slots within the RAW. If the Cross Slot Boundary subfield in RAW Assignment subfield of the RPS element is 1, the STA shall continue to count down backoff after its assigned RAW slots within the RAW.

After the end of the RAW, STAs with the second backoff counter shall reset and disregard the second backoff function state.

#### 10.23.5.6 EDCA backoff procedure in RAWs other than generic or triggering frame RAW

When the S1G STA is performing EDCA in any RAW other than generic or triggering frame RAW, it shall follow the rules defined in 10.23.2 (HCF contention based channel access (EDCA)).

An S1G STA performing EDCA outside a RAW shall suspend an operation of its EDCA at the start of the RAW and may resume it at the end of the RAW if the STA is not included in that RAW.

An S1G STA performing EDCA outside a RAW shall continue its EDCA operation at the start of the RAW if it is included in that RAW.

#### 10.23.5.7 RAW Operation with Resource Allocation frame

An AP transmits a Resource Allocation (RA) frame if Bit 1 of the RAW Type Options subfield is equal to 1 in the RAW Control subfield of the RAW Assignment subfield of the RPS element.

The AP transmits the RA frame to non-AP STAs belonging to the RAW group allocated to access the RAW as specified in the previously transmitted RPS element. A non-AP STA that does not belong to the RAW group may (#3683)discard the RA frame.

An AP shall schedule the Resource Allocation frame as the first frame to be transmitted at the beginning of the RAW following the channel access rules. The beginning of the RAW is further defined in the RAW start time subfield of the RAW assignment subfield of the RPS element.

AP shall defer the transmission of the RA frame till the channel is free but since the preallocated RAW duration information in the RPS frame may be shortened by the delay of the transmission of the RA frame, the AP and STA shall check the transmission time of the allocated RAW slot against the end of RAW period. If the transmission of the RA frame is later than the end of RAW period, the AP and STA shall discard the information indicated in the RPS element and follow the channel access rules defined outside the RAW (10.23.5 (Restricted access window (RAW) operation)).

The AP assigns a RAW slot to either an individual STA indicated by the Partial AID subfield or a group of STAs indicated by the Group ID subfield within the Slot Assignment field of the RA frame when Slot Assignment Mode subfield in the Frame Control field of the RA frame is equal to 0. The AP assigns a RAW slot to an individual STA indicated by the Slot Assignment Indication field of the RA frame when Slot Assignment Mode subfield in the Frame Control field of the RA frame is equal to 1.

An intended STA identified by the RPS element should transition to awake state(#6038) before the RAW start time indicated in the RAW start time subfield of the RAW assignment subfield of the RPS element to receive the RA frame. The STA shall not access the medium during its assigned RAW with the RA


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indication if it fails to receive the RA frame. The STA can resume medium access according to the channel access rule after the RAW.

An intended STA identified by the RPS element of a RAW learns its assigned RAW slots for both uplink and downlink service periods according to the Slot Assignment subfield or the Slot Assignment Bitmap subfield in Slot Assignment Indication field of the RA frame. The STA should be awake before the start of the RAW slot time assigned to it. The AP shall start the delivery of BUs addressed to the STA using the EDCA procedure at the beginning of the RAW slot assignment if the TIM bit for the STA in the TIM element is equal to 1 after receiving an (NDP) PS-Poll or trigger frame from the STA. The STA may transmit uplink data as listed below:

— When the AP explicitly signals permission for the non-AP STA to begin UL transmission using the explicit signaling provided by BDT (10.49 (Bidirectional TXOP)) or RD protocol (10.29 (Reverse direction protocol)).
— Using EDCA procedure when the AP transmits a frame to the STA with more data bit equal to 0.
— Using EDCA procedure at the beginning of its RAW slot assignment if the TIM bit for this STA is 0 and this STA has not negotiated with the AP to use the UL-Sync procedure (10.48 (Sync frame operation)).
— After receiving a frame sequence that contains a sync frame if the STA has negotiated with the AP to use the UL-Sync procedure.

#### 10.23.5.8 Periodic RAW (PRAW) operation

An AP may schedule a RAW in periodic manner by setting Periodic RAW Indication subfield to 1 for the RAW Assignment subfield of an RPS element, and this RAW is called a PRAW.

PRAW allocation may be indicated by an RPS element included in S1G Beacon frames and/or Probe Response frames. Once a PRAW is allocated, the allocation indication is broadcasted by the AP such that every S1G STA in TIM mode can identify the allocation of PRAW. However, it is not necessary for an AP to indicate the PRAW allocation in every S1G Beacon frame transmitted in the beacon interval or short beacon interval, for which PRAW is allocated. The parameters in the RAW Assignment subfield for PRAW shall not be changed until updated PRAW information is broadcasted. A non-AP STA updates the PRAW information and accesses the channel according to the parameters in the RAW Assignment subfield of the PRAW indicated by the Periodic Operation Parameters subfield of the most recently received RPS element.

If an AP allocates more than one PRAW assignments, all active PRAW assignments shall be included in one or more RPS elements in the same S1G Beacon frame.

The S1G Beacon frame after which the first window of the PRAW appears is indicated by the PRAW Start Offset subfield of Periodic Operation Parameters of RPS element, and the starting time of the first window of the PRAW with respect to the S1G Beacon frame is equal to the RAW start time indicated by the same RAW Assignment subfield.

The periodicity of RAW assignment for a group of STAs indicated in the RAW Group subfield of the RAW Assignment subfield of RPS element is valid for a fixed number of periods indicated in the PRAW Validity subfield of the Periodic Operation Parameters subfield in the RAW Assignment subfield of RPS element. An AP may extend current PRAW assignment by indicating the PRAW assignment with the PRAW Validity subfield value extended before it expires.

At each RPS element with one or more PRAW assignments included, an AP indicates next scheduled PRAW indication time at which the AP will send another RPS element with PRAW assignments. The next scheduled PRAW indication time is the closest DTIM beacon(#3309) before any of PRAW Validity subfield value of PRAW assignments included in current RPS element expires.

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An AP may send another RPS element with PRAW assignments before next scheduled PRAW indication time. However, an AP shall not modify currently active PRAW assignment until next scheduled PRAW indication time. If an AP intends to add a new PRAW assignment, the new PRAW assignment shall be indicated from the next scheduled PRAW indication time.

## 10.24 Mesh coordination function (MCF)

### 10.24.1 General

Under MCF, the basic unit of allocation of the right to transmit onto the WM is the TXOP. Each TXOP is defined by a starting time and a defined maximum length.

There are two types of TXOP in MCF: EDCA TXOPs and MCCA TXOPs. The EDCA TXOP is obtained by a mesh STA winning an instance of EDCA contention (see 10.23.2 (HCF contention based channel access (EDCA))). The MCCA TXOP is obtained by a mesh STA gaining control of the WM during an MCCAOP. The MCCAOP is an interval of time for frame transmissions that has been reserved by means of the exchange of MCCA frames (see 10.24.3 (MCF controlled channel access (MCCA))).

EDCA TXOPs of a mesh STA that has dot11MCCAActivated true shall not overlap with the time periods of any of its tracked MCCAOP reservations.

The process of tracking MCCAOP reservations involves the recording of the MCCAOP reservations and the data that structure the MCCAOP advertisements of these reservations, namely the advertisement set sequence number, advertisement elements bitmap, and the advertisement element (#4136)indices, in a local database, and the updating of this database on the basis of received advertisements as described in 10.24.3.7.5 (Receipt of an MCCAOP advertisement).

### 10.24.2 MCF contention based channel access

MCF implements the same EDCA (see 10.23.2 (HCF contention based channel access (EDCA))) as does HCF.

### 10.24.3 MCF controlled channel access (MCCA)

#### 10.24.3.1 General

MCF controlled channel access (MCCA) is an optional access method that allows mesh STAs to access the WM at selected times with lower contention than would otherwise be possible. This standard does not require all mesh STAs to use MCCA. MCCA might be used by a subset of mesh STAs in an MBSS. However, MCCAOP reservations may be set up among mesh STAs that have dot11MCCAActivated true and that operate on the same channel; MCCAOP reservations shall not be set up otherwise. The performance of MCCA might be impacted by STAs that do not respect MCCAOP reservations.

MCCA enabled mesh STAs use Management frames to make reservations for transmissions. The mesh STA transmitting an MCCA Setup Request frame to initiate a reservation becomes the MCCAOP owner of the MCCAOP reservation. The receivers of the MCCA Setup Request frame are the MCCAOP responders. The MCCAOP owner and the MCCAOP responders advertise this MCCAOP reservation to their neighbors via an MCCAOP advertisement. An MCCA enabled neighbor mesh STA shall not transmit during these reserved MCCAOP time periods. During its MCCAOP, the MCCAOP owner obtains a TXOP by winning an instance of EDCA contention. Because of its reservation, the MCCAOP owner experiences no competition from other MCCA enabled neighbor mesh STAs. At the start of an MCCAOP, the EDCAF of the MCCAOP owner replaces the AIFSN, CWmin, and CWmax value of its dot11EDCATable with MCCA access parameters.


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In order to use MCCA, a mesh STA maintains synchronization with its neighboring mesh STAs. Mesh STAs that use MCCA shall use a DTIM interval with a duration of $2^n \times 100$ TU with $n$ being a non-negative integer less than or equal to 17. Additionally, a mesh STA shall track the reservations of its neighboring mesh STAs.

NOTE 1—The DTIM interval of this form was chosen so that the starting times of the reservations do not change relative to each other between consecutive DTIM intervals. The restriction that $n$ be less than or equal to 17 was chosen for compatibility with the maximum DTIM interval as well as the compatibility of the reservation's MCCAOP offset range (see 9.4.2.104.2 (MCCAOP Reservation field)) with the maximal DTIM interval length.

NOTE 2—It is allowed that a different value for the DTIM interval is used for mesh STAs that use MCCA in an MBSS that is centrally controlled and the central authority provides a coordination of the DTIM interval of the mesh STAs that use MCCA in the MBSS.

#### 10.24.3.2 MCCA activation

When it receives an MLME-ACTIVATEMCCA.request primitive from its SME, a mesh STA shall set the MCCA Enabled subfield of the Mesh Capability field in the Mesh Configuration element to 1 in Beacon and Probe Response frames it transmits. It shall not initiate or accept MCCA Setup Request frames for dot11MCCAScanDuration TUs after the receipt of the MLME-ACTIVATEMCCA.request primitive.

During the dot11MCCAScanDuration waiting period, the mesh STA learns its neighborhood MCCAOP periods by receiving Beacon, Probe Response, or MCCA Advertisement frames from neighboring mesh STAs.

After this period, the mesh STA may initiate and accept MCCA Setup Request frames as per 10.24.3.6 (MCCAOP setup procedure).

#### 10.24.3.3 MCCAOP reservations

An MCCAOP reservation specifies a schedule for frame transmissions. The time periods scheduled for frame transmissions in the reservation are called *MCCAOPs*. The schedule is set up between an MCCAOP owner and one (for individually addressed frames) or more (for group addressed frames) MCCAOP responders. MCCAOPs are set up by means of the procedure defined in 10.24.3.6 (MCCAOP setup procedure). Once an MCCAOP reservation is set:

— Access to the channel by MCCA enabled mesh STAs is governed by the procedures in 10.24.3.9 (Access during MCCAOPs).

— The MCCAOP reservation is advertised according to the procedures in 10.24.3.7 (MCCAOP advertisement).

The schedule is defined by means of the MCCAOP Reservation field defined in 9.4.2.104.2 (MCCAOP Reservation field). An MCCAOP reservation schedules a series of MCCAOPs with a common duration given in the MCCAOP Duration subfield of the MCCAOP Reservation field. This series is started after the first DTIM (#1000)beacon following the successful completion of the MCCAOP setup procedure and terminated when the MCCAOP reservation is torn down.

The reservation defines a regular schedule of MCCAOPs in the DTIM interval of the MCCAOP owner. The number of MCCAOPs in the DTIM interval is given by the value of the MCCAOP Periodicity subfield of the MCCAOP Reservation field. The MCCAOP Offset subfield specifies the offset of the first scheduled MCCAOP of the transmission schedule relative to the beginning of the DTIM interval of the MCCAOP owner. The following MCCAOPs are separated by a time interval with a duration equal to the length of the DTIM period divided by the value in the MCCAOP Periodicity subfield.

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An example of an MCCAOP reservation schedule is shown in Figure 10-39 (Example MCCAOP reservation with MCCAOP Periodicity equal to 2). In this example, the MCCAOP Periodicity equals two, so that there are two MCCAOPs in each DTIM interval. As further illustrated in the figure, the MCCAOP Offset value indicates the beginning of the first MCCAOP in each DTIM interval.

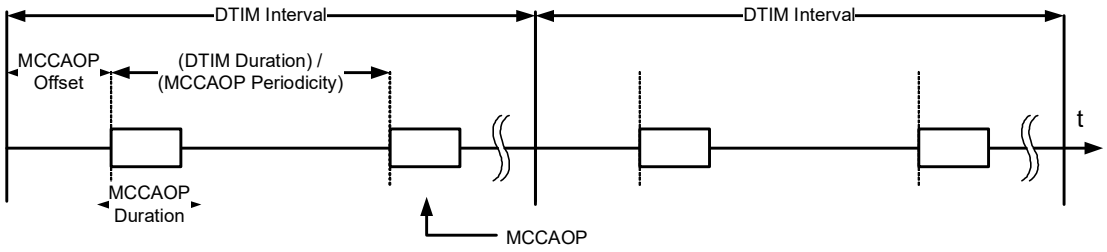


**Figure 10-39—Example MCCAOP reservation with MCCAOP Periodicity equal to 2**

If a mesh STA adjusts its TBTT, e.g., in response to a TBTT adjustment request, it shall adjust the MCCAOP reservations by modifying the MCCAOP Offset of each MCCAOP reservation.

An MCCAOP reservation is identified by an MCCAOP reservation ID. The MCCAOP owner shall select an MCCAOP reservation ID that is unique among all of its MCCAOP reservations. The MCCAOP reservation ID and MAC address of the MCCAOP owner uniquely identify the MCCAOP reservation in the mesh BSS. The MCCAOP reservation ID is an 8-bit unsigned integer and included in the MCCAOP Reservation ID field of an MCCAOP Setup Request element. If this MCCAOP setup request is for an individually addressed transmission, the MCCAOP Reservation ID is between 0 and 127. If this MCCAOP setup request is for a group addressed transmission, the MCCAOP Reservation ID is between 128 and 254. The value 255 is not used to identify a specific MCCAOP reservation but is reserved for usage in the MCCAOP teardown procedure as described in 10.24.3.8 (MCCAOP teardown).

(#181)(#1466)A mesh STA with dot11MCCAActivated equal to true shall support tracking of dot11MCCATrackStatesCapable MCCAOP reservations, including its own reservations. A mesh STA shall record the number of MCCAOP reservations that the mesh STA is currently tracking as dot11MCCATrackStatesActive.

(#181)(#1466)If dot11MCCATrackStatesActive is less than dot11MCCATrackStatesCapable, the mesh STA shall support tracking, setting up, and accepting additional MCCAOP reservations. In this case, the mesh STA shall set the Accept Reservations subfield in the Flags field to 1 in the MCCAOP Advertisement Overview elements it transmits.

(#1466)If dot11MCCATrackStatesActive is equal to dot11MCCATrackStatesCapable, the mesh STA shall not track, set up, or accept additional reservations. In this case, the mesh STA shall set the Accept Reservations subfield in the Flags field to 0 in the MCCAOP Advertisement Overview elements it transmits. Moreover, it shall reply to MCCA Setup Request frames with an MCCA Setup Reply frame with the MCCA Reply Code field in the MCCAOP Setup Reply element equal to 3: Reject: MCCAOP track limit exceeded.

The tracked MCCAOP reservations are advertised as described in 10.24.3.7 (MCCAOP advertisement). How to access the medium during the tracked MCCAOP reservations is specified in 10.24.3.9 (Access during MCCAOPs).


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#### 10.24.3.4 Neighborhood MCCAOP periods at a mesh STA

The set of MCCAOP reservations in which a mesh STA is involved as an MCCAOP owner or an MCCAOP responder and that are used for individually addressed transmissions are referred to as the *TX-RX periods of this mesh STA*.

The set of MCCAOP reservations in which a mesh STA is involved as an MCCAOP owner or an MCCAOP responder and that are used for group addressed transmissions are referred to as the *broadcast periods of this mesh STA*. Optionally, the broadcast periods of a mesh STA includes known target beacon transmission times of Beacon frames for which this mesh STA is either the transmitter or the receiver, and transmission or reception periods of a STA that is (#2210)colocated with the reporting mesh STA, for example, beacon or HCCA times of a (#2210)colocated AP.

The interference periods of a mesh STA comprise the TX-RX periods and the broadcast periods of its neighbor mesh STAs in which the mesh STA is not involved as the owner or as a responder. The TX-RX periods, the broadcast periods, and the interference periods of a mesh STA shall not be used for a new MCCAOP reservation with the mesh STA as transmissions in these periods might experience interference from the transmissions in the new MCCAOPs or might cause interference to them.

The interference periods are directly derived from the TX-RX Periods Report field and Broadcast Periods Report field of the MCCAOP Advertisement elements transmitted by the neighbor mesh STAs. The Interference Periods Report field reflects the latest TX-RX Periods Report and Broadcast Periods Report fields received from the neighbor mesh STAs.

The MCCAOP reservations of a mesh STA and its neighbors define a set of MCCAOPs that are already reserved for frame transmissions in the mesh neighborhood of a mesh STA. This set of MCCAOPs is referred to as the *neighborhood MCCAOP periods for the mesh STA*. Thus, neighborhood MCCAOP periods at a mesh STA include all MCCAOPs for which the mesh STA or one of its neighbors, including neighbors from other MBSSs, is either transmitter or receiver.

#### 10.24.3.5 MCCA access fraction (MAF)

The MCCA access fraction at a mesh STA is the ratio of the time reserved for MCCAOPs in the DTIM interval of this mesh STA to the duration of the DTIM interval. This parameter is reported in the MCCA Access Fraction field of the MCCAOP Advertisement Overview elements. The maximum value for the MAF that is allowed at a mesh STA is specified by dot11MAFlimit. The dot11MAFlimit is copied into the MAF Limit field of the MCCAOP Advertisement Overview element as described in 9.4.2.106 (MCCAOP Advertisement Overview element).

The MAF and the MAF Limit may be used to limit the use of MCCA in the mesh neighborhood of a mesh STA, as specified in 10.24.3.6 (MCCAOP setup procedure). Before attempting to set up an MCCAOP reservation with a neighbor peer mesh STA, a mesh STA shall verify that the new MCCAOP reservation does not cause its MAF to exceed its MAF Limit and that the new MCCAOP reservation does not cause the MAF of any of its neighbor peer mesh STAs to exceed their MAF Limit. An MCCAOP setup request shall be refused by the intended MCCAOP responder if the MAF limit of one of its neighbors is exceeded due to the new setup.

#### 10.24.3.6 MCCAOP setup procedure

The setup of an MCCAOP reservation is initiated by the MCCAOP owner and is accepted or rejected by the MCCAOP responder. The setup procedure for an MCCAOP reservation is as follows:

a) The MCCAOP owner shall build a map of the neighborhood MCCAOP periods in the DTIM interval after hearing advertisements from all of its neighbor mesh STAs with the MCCA Enabled

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subfield of the Mesh Capability field in the Mesh Configuration element equal to 1. It shall request an MCCAOP advertisement, as described in 10.24.3.7.8 (MCCAOP advertisement request procedure), from each neighbor mesh STA from which no advertisement was heard in the last dot11MCCAAdvertPeriodMax DTIM intervals.

b) The MCCAOP owner shall determine the MCCAOP reservation. The MCCAOP parameters shall be chosen in such a way that they satisfy the following conditions:
   1) The reservation shall not overlap with the neighborhood MCCAOP periods of the MCCAOP owner.
   2) The reservation shall not overlap with the interference periods of the intended MCCAOP responder or responders.
   3) The reservation shall not cause the MAF limit to be exceeded for either itself or its neighbor mesh STAs.
   4) The Accept Reservations subfield of the Flags field equals 1 in the most recent MCCAOP Advertisement Overview element received from all intended MCCAOP responders.

c) If the conditions in item b) are satisfied, the MCCAOP owner shall transmit an MCCAOP Setup Request element to the intended MCCAOP responder with the chosen MCCAOP parameters.

d) The MCCAOP responder shall verify the following conditions:
   1) The reservation does not overlap with its neighborhood MCCAOP periods.
   2) The reservation does not cause the MAF limit to be exceeded for itself or its neighbor mesh STAs.
   3) The reservation does not cause dot11MCCATrackStatesActive to exceed dot11MCCATrackStatesCapable.(#1466)

e) If the conditions in item d) are satisfied, the responder shall send an MCCA Setup Reply frame to the MCCAOP owner with the MCCA Reply Code field in the MCCAOP Setup Reply element equal to 0: Accept, as defined in Table 9-285 (MCCA Reply Code field values).

f) If the conditions in item d) are satisfied and the MCCAOP request has been intended for group addressed transmissions, the responder shall include the reservation in its MCCAOP advertisement only after the MCCAOP advertisement from the MCCAOP owner is received.

g) If not all of the conditions in item d) are satisfied and the MCCAOP request is intended for individually addressed transmissions, the responder shall transmit to the MCCAOP owner an MCCA Setup Reply frame that is constructed as follows:
   1) If the condition in item d)1) is not satisfied and both conditions in item d)2) and item d)3) are satisfied, the responder may calculate an alternative MCCAOP reservation and include it in the MCCAOP Reservation field of the MCCAOP Setup Reply element. It shall set the MCCA Reply Code field of the MCCAOP Setup Reply element to 1: Reject: MCCAOP reservation conflict, as defined in Table 9-285 (MCCA Reply Code field values).
   2) If the condition in item d)2) is not satisfied, it shall set the MCCA Reply Code field of the MCCAOP Setup Reply element to 2: Reject: MAF limit exceeded, as defined in Table 9-285 (MCCA Reply Code field values).
   3) If the condition in item d)2) is satisfied and the condition in item d)3) is not satisfied, it shall set the MCCA Reply Code field of the MCCAOP Setup Reply element to 3: Reject: MCCAOP track limit exceeded, as defined in Table 9-285 (MCCA Reply Code field values).

h) If not all of the conditions in item d) are satisfied and the MCCAOP request is intended for group addressed transmissions, the responder shall send an MCCA Setup Reply frame to the MCCAOP owner with the MCCA Reply Code field in the MCCAOP Setup Reply element equal to 1: Reject: MCCAOP reservation conflict.

i) If the MCCAOP owner receives an MCCA Setup Reply frame with MCCA Reply Code equal to Accept, the MCCAOP reservation is established. Otherwise, the mesh STA may repeat the MCCAOP setup procedure using a modified MCCAOP Setup Request. If an alternative MCCAOP


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reservation is included in the MCCAOP Setup Reply element, the mesh STA may consider this alternative in its modified MCCAOP Setup Request.

### 10.24.3.7 MCCAOP advertisement

#### 10.24.3.7.1 General

A mesh STA with dot11MCCAActivated equal to true tracks MCCAOP reservations. The tracked MCCAOP reservations contain the neighborhood MCCAOP periods and optionally other periodic transmission of itself or of neighboring STAs.

The MCCAOP advertisement set contains all MCCAOP reservations tracked by the mesh STA. The MCCAOP advertisement set is represented by an MCCAOP Advertisement Overview element and zero (if the MCCAOP advertisement set is empty) or more (if the MCCAOP advertisement set is nonempty) MCCAOP Advertisement elements. An MCCAOP Advertisement element contains one or more tracked MCCAOP reservations.

The mesh STA advertises its MCCAOP advertisement set to its neighbor mesh STAs.

This subclause describes how the mesh STA constructs the MCCAOP Advertisement Overview element and the MCCAOP Advertisement elements. Further, this subclause describes the procedure to advertise an MCCAOP advertisement set, the procedure to request an MCCAOP advertisement from a neighboring mesh STA, and the procedure to process a received MCCAOP advertisement.

#### 10.24.3.7.2 Construction of an MCCAOP advertisement set

The following terminology is used in this subclause:

- TX-RX report: an MCCAOP Reservation field contained in the TX-RX Periods Report field of an MCCAOP Advertisement element
- Broadcast report: an MCCAOP Reservation field contained in the Broadcast Periods Report field of an MCCAOP Advertisement element
- Interference report: an MCCAOP Reservation field contained in the Interference Periods Report field of an MCCAOP Advertisement element

Each MCCAOP reservation tracked by a mesh STA is one of the following types:

- TX-RX period:
  - An MCCAOP reservation for individually addressed frames for which the mesh STA is the MCCAOP owner or the MCCAOP responder.
- Broadcast period:
  - An MCCAOP reservation for group addressed frames for which the mesh STA is the MCCAOP owner or the MCCAOP responder.
  - Optionally, known target beacon transmission times of Beacon frames for which the mesh STA is either the transmitter or the receiver.
  - Optionally, a transmission or reception period of a STA that is (#2210)colocated with the mesh STA, for example, beacon or HCCA times of a (#2210)colocated AP.
- Interference period:
  - A TX-RX or a broadcast period reported by a neighbor peer mesh STAs of the mesh STA excluding those periods for which this mesh STA is either the MCCAOP owner or the MCCAOP responder.
  - Optionally, a TX-RX or a broadcast period reported by neighbor nonpeer mesh STAs of the mesh STA.

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The MCCAOP reservations are grouped into the following sets:

— MCCAOP TX-RX advertisement set, which includes all TX-RX periods
— MCCAOP broadcast advertisement set, which includes all broadcast periods
— MCCAOP interference advertisement set, which includes all interference periods

These three sets constitute the MCCAOP advertisement set. The mesh STA uses the MCCAOP Overview element and MCCAOP Advertisement elements to advertise its MCCAOP advertisement set to its neighbor mesh STAs.

The mesh STA acts as follows to construct the MCCAOP Overview elements and the MCCAOP Advertisement elements:

a) If the MCCAOP advertisement set is nonempty, the mesh STA constructs one or more MCCAOP reports according to the format described in 9.4.2.107.3 (MCCAOP Reservation Report field) as follows:
    1) If the MCCAOP TX-RX advertisement set is nonempty, the mesh STA constructs one or more TX-RX reports according to the format described in 9.4.2.107.3 (MCCAOP Reservation Report field) such that each reservation in the MCCAOP TX-RX advertisement set occurs exactly in one TX-RX report.
    2) If the MCCAOP broadcast advertisement set is nonempty, the mesh STA constructs one or more broadcast reports according to the format described in 9.4.2.107.3 (MCCAOP Reservation Report field) such that each reservation in the MCCAOP broadcast advertisement set occurs exactly in one broadcast report.
    3) If the MCCAOP interference advertisement set is nonempty, the mesh STA constructs one or more interference reports according to the format described in 9.4.2.107.3 (MCCAOP Reservation Report field) such that each reservation in the MCCAOP interference advertisement set occurs exactly in one interference report.
b) If the MCCAOP advertisement set is nonempty, the mesh STA constructs one or more MCCAOP Advertisement elements as follows:
    1) The MCCAOP Advertisement Set Sequence Number field is set to the MCCAOP advertisement set sequence number as explained in 10.24.3.7.3 (Setting the MCCAOP advertisement set sequence number).
    2) The MCCAOP Advertisement Element Index subfield is set to an identifier that uniquely identifies the MCCAOP Advertisement element in the MCCAOP advertisement set.
    3) Each MCCAOP Advertisement element includes at least one of the TX-RX reports, broadcast reports, or interference reports. Moreover, it includes at most one of the TX-RX reports, at most one of the broadcast reports, and at most one of the interference reports. In case the MCCAOP Advertisement element contains a TX-RX report, the TX-RX Report Present subfield of the MCCAOP Advertisement Element Information field is set to 1; otherwise this subfield is set to 0. In case the MCCAOP Advertisement element contains a broadcast report, the Broadcast Report Present subfield of the MCCAOP Advertisement Element Information field is set to 1; otherwise this subfield is set to 0. In case the MCCAOP Advertisement element contains an interference report, the Interference Report Present subfield of the MCCAOP Advertisement Element Information field is set to 1; otherwise, this subfield is set to 0.
    4) Each report as constructed in step a) is present in exactly one MCCAOP Advertisement element.
c) The mesh STA constructs one MCCAOP Advertisement Overview element such that
    1) The MCCAOP Advertisement Set Sequence Number field is set to the advertisement set sequence number as explained in 10.24.3.7.3 (Setting the MCCAOP advertisement set sequence number).
    2) The Medium Access Fraction field is set to the medium access fraction.


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3) The MAF limit field is set to dot11MAFlimit.
4) The Accept Reservations field is set to 1 if dot11MCCATrackStatesActive is less than dot11MCCATrackStatesCapable, and set to 0 otherwise.(#1466)
5) Bit *i* of the Advertisement Elements Bitmap field is set to 1 if an MCCAOP Advertisement element with the MCCAOP Advertisement Element Index subfield equal to *i* is part of the representation of this MCCAOP advertisement set, and set to 0 otherwise.

#### 10.24.3.7.3 Setting the MCCAOP advertisement set sequence number

The MCCAOP advertisement set sequence number identifies an MCCAOP advertisement set. Mesh STAs with dot11MCCAActivated equal to true assign MCCAOP advertisement set sequence numbers from a single modulo 256 counter. The MCCAOP advertisement set sequence number is initialized to 0. The MCCAOP advertisement set sequence number shall be incremented by 1 if one of the following conditions holds:

a) The mesh STA sets the bit for an MCCAOP Advertisement element in the Advertisement Elements Bitmap from 0 to 1 and this bit has been set to 1 under the same MCCAOP Advertisement Sequence Number before.
b) The bit of the Advertisement Elements Bitmap corresponding to an MCCAOP Advertisement element is equal to 1 and the content of this MCCAOP Advertisement element changes.

However, the MCCAOP advertisement set sequence number may remain unchanged if

— The mesh STA changes a bit in the Advertisement Element Bitmap from 0 to 1 and this bit has not been set to 1 under the same MCCAOP Advertisement Sequence Number before, or
— The mesh STA changes a bit in the Advertisement Elements Bitmap from 1 to 0.

NOTE—The Advertisement Set Sequence Number identifies the current distribution of the MCCAOP advertisement set over the MCCAOP Advertisement elements. Using a new MCCAOP advertisement set sequence number signals a new, (possibly) completely different distribution of the MCCAOP advertisement set over the MCCAOP Advertisement elements, and requires an advertisement of all reservations of the MCCAOP advertisement set. Leaving the MCCAOP advertisement set sequence number unchanged as in the previous MCCAOP Advertisement Overview element indicates MCCAOP Advertisement elements that have previously been advertised are not changed and remain current. This enables a limited advertisement procedure in which only new MCCAOP Advertisement elements are advertised. Additionally, this enables mesh STAs that operate in light or deep sleep mode to request a limited update of the MCCAOP advertisement set of a neighboring mesh STA in which only new MCCAOP Advertisement elements are included.

#### 10.24.3.7.4 Advertisement procedure

To advertise its MCCAOP advertisement set, the mesh STA constructs a representation of the MCCAOP advertisement set as described in 10.24.3.7.2 (Construction of an MCCAOP advertisement set). The MCCAOP advertisement set is advertised by transmitting an MCCAOP Advertisement Overview element and zero or more MCCAOP Advertisement elements (see 10.24.3.7.2 (Construction of an MCCAOP advertisement set)) to neighbor peer mesh STAs. The MCCAOP Advertisement Overview element and the MCCAOP Advertisement elements are transmitted in Beacon frames, Probe Response frames, or MCCA Advertisement frames.

The mesh STA shall advertise its MCCAOP advertisement set according to the following rules:

a) The mesh STA shall advertise at least one MCCAOP Advertisement Overview element in every dot11MCCAAdvertPeriodMax DTIM intervals.
b) The mesh STA shall advertise its MCCAOP Advertisement Overview element and any new MCCAOP Advertisement elements at the latest with the transmission of its next Beacon frame after its MCCAOP advertisement set has changed.

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c) The mesh STA shall advertise the requested MCCAOP Advertisement elements as described in 10.24.3.7.8 (MCCAOP advertisement request procedure) if the mesh STA receives an MCCA Advertisement Request frame.

#### 10.24.3.7.5 Receipt of an MCCAOP advertisement

Upon receipt of an MCCAOP advertisement a mesh STA with dot11MCCAActivated shall compare the Advertisement Set Sequence Number contained in the MCCAOP Advertisement Overview element of the received MCCAOP advertisement with the last advertisement set sequence number that this mesh STA tracked for the sender of the received MCCAOP advertisement.

If the tracked advertisement set sequence number does not equal the Advertisement Set Sequence Number of the received MCCAOP advertisement, the mesh STA shall perform the procedure described in 10.24.3.7.6 (Complete update of the tracked MCCAOP reservations of a neighbor mesh STA).

If the tracked advertisement set sequence number equals the Advertisement Set Sequence Number of the received MCCAOP advertisement, the mesh STA shall compare the Advertisement Elements Bitmap contained in the received MCCAOP Advertisement Overview element with the last Advertisement Elements Bitmap that this mesh STA tracked for the sender of the received MCCAOP advertisement. If the tracked Advertisement Elements Bitmap does not equal the Advertisement Elements Bitmap of the received MCCAOP advertisement, the mesh STA shall perform the procedure described in 10.24.3.7.7 (Partial update of the tracked MCCAOP reservations of a neighbor mesh STA).

NOTE—If both the tracked advertisement set sequence number equals the Advertisement Set Sequence Number of the received MCCAOP advertisement and the tracked Advertisement Elements Bitmap equals the Advertisement Elements Bitmap of the received MCCAOP advertisement, the MCCAOP advertisement set of the sender of the MCCAOP advertisement tracked by the mesh STA is current, and no update of the MCCAOP advertisement set is needed.

#### 10.24.3.7.6 Complete update of the tracked MCCAOP reservations of a neighbor mesh STA

The mesh STA performed the steps in 10.24.3.7.5 (Receipt of an MCCAOP advertisement) and detected that the MCCAOP advertisement set sequence number has been updated. Consequently, the mesh STA shall operate as follows.

The mesh STA shall discard all MCCAOP reservations that it tracked for the sender of the received MCCAOP advertisement. The mesh STA shall record the Advertisement Set Sequence Number and the source address (SA) of the received MCCAOP advertisement. The mesh STA shall record all reservations in the MCCAOP Advertisement elements of the received MCCAOP advertisement.

If the mesh STA does not receive all MCCAOP Advertisement elements of the sender of the MCCAOP advertisement before a frame exchange sequence on the wireless medium causes the mesh STA to set its NAV, the mesh STA shall perform the MCCAOP advertisement request procedure as described in 10.24.3.7.8 (MCCAOP advertisement request procedure).

#### 10.24.3.7.7 Partial update of the tracked MCCAOP reservations of a neighbor mesh STA

The mesh STA performed the steps in 10.24.3.7.5 (Receipt of an MCCAOP advertisement) and detected that part of the MCCAOP advertisement set of the sender of the MCCAOP advertisement has been updated. Consequently, the mesh STA shall operate as follows for each bit in the Advertisement Elements Bitmap contained in the MCCAOP Advertisement Overview element of the received MCCAOP advertisement.

If the bit in position n of the Advertisement Elements Bitmap in the received MCCAOP Advertisement is equal to 0 and if the bit in position n of the Advertisement Elements Bitmap tracked for the sender of the received MCCAOP advertisement is equal to 1, the mesh STA shall delete the reservations with the same


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Advertisement Sequence Number and the same MCCAOP Advertisement Element Index received from the same sender from its tracked reservations.

If the bit in position n of the Advertisement Elements Bitmap in the received MCCAOP Advertisement is equal to 1 and if the bit in position n of the Advertisement Elements Bitmap tracked for the sender of the received MCCAOP advertisement is equal to 0, the mesh STA shall add the reservations of the received MCCAOP Advertisement element with the MCCAOP Advertisement Element Index set to n to its tracked reservations. If the mesh STA does not receive this MCCAOP Advertisement element of the sender of the MCCAOP Advertisement before a frame exchange sequence on the wireless medium causes the mesh STA to set its NAV, the mesh STA shall perform the MCCAOP Advertisement request procedure as described in 10.24.3.7.8 (MCCAOP advertisement request procedure).

NOTE—If the bit in position n of the received Advertisement Elements Bitmap contained in the received MCCAOP Advertisement is equal to the bit in position n of the Advertisement Elements Bitmap tracked for the sender of the received MCCAOP advertisement, then the Advertisement element with the MCCAOP Advertisement Element Index equal to n is current, and no update of this Advertisement element is needed.

#### 10.24.3.7.8 MCCAOP advertisement request procedure

To request all MCCAOP Advertisement elements from a neighbor peer mesh STA, the mesh STA transmits an MCCA Advertisement Request frame without an MCCAOP Advertisement Overview element.

To request a subset of the MCCAOP Advertisement elements of a neighbor peer mesh STA, the mesh STA transmits an MCCA Advertisement Request frame including an MCCAOP Advertisement Overview element. The mesh STA shall set the contents of the MCCAOP Advertisement Overview element as follows. The mesh STA sets

a) The Advertisement Set Sequence Number field to the Advertisement Sequence Number that it tracks for the recipient of this frame
b) In the Advertisement Element Bitmap, the bit to 1 for each MCCAOP Advertisement element that the mesh STA requests from the recipient of this frame
c) The Flags field, the MCCA Access Fraction field, and the MAF Limit field to 0

The mesh STA shall discard the MCCA Advertisement Request frame from its frame queue if it receives all of the MCCAOP Advertisement elements that it requests in the MCCAOP Advertisement Request.

### 10.24.3.8 MCCAOP teardown

#### 10.24.3.8.1 Conditions that trigger an MCCAOP teardown

The MCCAOP owner and the MCCAOP responder may initiate a teardown of an MCCAOP reservation, e.g., when the reservation is no longer needed. A mesh STA shall act as follows to resolve conflicts between MCCAOP reservations in its neighborhood MCCAOP periods. If the conflict is caused by overlapping reservations from its TX-RX periods and broadcast periods, it shall select one of these reservations and initiate a teardown for it. If the conflict is caused by an overlap between a reservation from its TX-RX periods or broadcast periods, and another reservation from its interference periods, it shall act as follows. It creates a first unsigned integer by inverting the bit order of its MAC address and a second unsigned integer by inverting the bit order of the lowest of the known MAC addresses of the owner and responder(s) of the reservation in the interference periods. If the first unsigned integer is smaller than the second unsigned integer, it shall initiate a teardown of the reservation in its TX-RX or broadcast periods. Otherwise, it may initiate a teardown of the reservation in its TX-RX or broadcast periods.

There are also other conditions that trigger the MCCAOP owner and responder to delete a reservation, without an explicit tear down. An MCCAOP owner shall delete a reservation for an individually addressed transmission when it has not received an acknowledgment for any frame transmission in the MCCAOPs

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corresponding to the reservation for greater than dot11MCCAOPtimeout time. An MCCAOP responder shall delete a reservation for individually addressed transmission or group addressed transmissions when it has not received a frame transmission in any of the MCCAOPs corresponding to the reservation for greater than dot11MCCAOPtimeout time.

#### 10.24.3.8.2 MCCAOP teardown procedure

The teardown is initiated by transmitting an MCCA Teardown frame. The MCCAOP Reservation ID field in the MCCAOP Teardown element is set to the MCCAOP Reservation ID of the reservation that is to be torn down. In case the tear down is initiated by an MCCAOP responder, the MCCAOP Owner field of the MCCAOP Teardown element is set to the MAC address of the MCCAOP owner.

The transmitter of the MCCA Teardown frame deletes the reservation after the MCCA Teardown frame has been successfully transmitted. The receiver of the MCCA Teardown frame acts as follows. In case the MCCAOP Reservation ID field corresponds to a reservation for individually addressed transmissions, it deletes the reservation. If the reservation is for group addressed transmissions for which it is the MCCAOP owner, it deletes the reservation if there are no other MCCAOP responders for this reservation.

The MCCAOP owner acts as follows when deleting a reservation:

— It stops executing the access procedure described in 10.24.3.9.1 (Access by MCCAOP owners) at the start of the MCCAOPs corresponding to the reservation that was deleted.
— In case the reservation was for individually addressed frames, it stops advertising the MCCAOP reservation in its TX-RX Periods Report field.
— In case the reservation was for group addressed frames, it stops advertising the MCCAOP reservation in its Broadcast Periods Report field.

The MCCAOP responder acts as follows when deleting a reservation:

— It stops executing the procedure described in 10.24.3.9.2 (Access during an MCCAOP by mesh STAs that are not the MCCAOP owner) during the MCCAOPs corresponding to the reservation that was deleted.
— In case the reservation was for individually addressed frames, it stops advertising the MCCAOP reservation in its TX-RX Periods Report field.
— In case the reservation was for group addressed frames, it stops advertising the MCCAOP reservation in its Broadcast Periods Report field.

### 10.24.3.9 Access during MCCAOPs

#### 10.24.3.9.1 Access by MCCAOP owners

At the start of the MCCAOP, the EDCAF of the MCCAOP owner shall set AIFSN[AC] equal to dot11MCCAAIFSN, CWmax[AC] equal to dot11MCCACWmax, CW[AC] equal to dot11MCCACWmin, and QSRC[AC] to 0 for all ACs. The TXOP limit shall specify a duration value no larger than the MCCAOP Duration.

During the MCCAOP, the EDCAFs of the ACs operates as specified in 10.23.2 (HCF contention based channel access (EDCA)), with the following modifications.

— During the MCCAOP, the EDCAF of each AC shall consider only those frame whose RA matches the MAC address of the MCCAOP responder.
— When the access to the medium is delayed, the TXOP limit shall specify a duration to end no later than the MCCAOP start time plus the MCCAOP Duration.


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— As specified in 10.24.3.9.2 (Access during an MCCAOP by mesh STAs that are not the MCCAOP owner), a neighboring STA shall not access the WM during an MCCAOP, until it receives a frame from either the MCCAOP owner or the MCCAOP responder. With the exception of truncation of an MCCA TXOP by means of a CF-End, standard EDCA TXOP rules apply for the remainder of the MCCAOP. For HT mesh STAs, these include the reverse direction protocol as specified in 10.29 (Reverse direction protocol).

— At the end of the MCCAOP, the parameters used by the EDCAF of the MCCAOP owner shall be set to dot11EDCATable, and QSRC[AC] shall be set to 0 for all ACs.

The MCCAOP owner may adjust the duration of an MCCAOP by setting the Duration/ID field in the frames it transmits. In particular, if an MCCAOP owner has no data to transmit in an MCCAOP corresponding to an MCCAOP reservation that is intended for individually addressed frames, it may transmit an individually addressed QoS Null frame during the MCCAOP to end the MCCAOP.

NOTE—(#161)An MCCAOP owner ought to send a QoS Null frame to end the MCCAOP although there might be situations in which the transmission of a QoS Null is not needed or undesirable.

If an MCCAOP owner has no data to transmit in an MCCAOP reservation that is intended for group addressed frames, it may transmit a group addressed QoS Null frame during the MCCAOP to end the MCCAOP.

### 10.24.3.9.2 Access during an MCCAOP by mesh STAs that are not the MCCAOP owner

The MAC of a mesh STA with dot11MCCAActivated is true shall provide a Reservation Allocation Vector (RAV) mechanism to indicate a busy medium from the start of an MCCAOP corresponding to a reservation in its interference periods until the receipt of a frame transmitted by either the MCCAOP owner or the MCCAOP responder. The RAV mechanism is provided in addition to the PHY and virtual CS mechanisms described in 10.3.2.1 (CS mechanism). It is different from the virtual CS mechanism in two aspects. Firstly, a mesh STA might be neighbor to multiple ongoing MCCAOPs corresponding to different reservations and the regular NAV setting and updating rules do not suffice to prevent interference during these reservations. Secondly, the virtual CS mechanism is set immediately upon receipt of a frame, whereas the RAV mechanism is based on reservation frames received at some earlier time instant. When either the CS function provided by the PHY, the virtual CS function provided by the MAC via the NAV, or the RAV mechanism indicate a busy medium during an MCCAOP for which the mesh STA is neither the MCCAOP owner nor the MCCAOP responder, the medium shall be considered busy; otherwise, it shall be considered idle.

The RAV mechanism maintains an index of future MCCAOPs based on the reservation information that is available in the interference periods of a mesh STA. At the start of each MCCAOP corresponding to a reservation in the interference periods, a RAV is set to indicate a busy medium for the duration of the MCCAOP given in the MCCAOP Duration subfield of the MCCAOP reservation. At the start of each MCCAOP corresponding to a reservation in the TX-RX or broadcast periods for which the mesh STA is an MCCAOP responder, a RAV is set to indicate a busy medium for the duration of the MCCAOP given in the MCCAOP Duration subfield of the MCCAOP reservation. The RAV may be thought of as a counter, corresponding to an MCCAOP corresponding to a reservation in the interference periods. The RAV counts down to zero at a uniform rate. When the counter is zero, the RAV indication is that the medium is idle; when nonzero, the indication is busy.

The mesh STA clears the RAV timer, i.e., sets it to 0, upon receipt of a frame from either the MCCAOP owner or responder. If a mesh STA receives an RTS frame during an MCCAOP for which it is an MCCAOP responder, with the RA matching its MAC address and with the MAC address in the TA field in the RTS frame matching the MAC address of the MCCAOP owner, then the STA shall send the CTS frame after a SIFS(#6587), without regard for the NAV and the RAV, and without resetting its NAV. The RAV for an MCCAOP is not cleared upon receipt of a frame originating from stations that are not the MCCAOP owner or responder. Since the NAV is set upon receipt of frames with a Duration/ID field, the MCCAOP owner

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and responder adjust the reservation period of an MCCAOP to their actual traffic needs by the Duration/ID field in the transmitted frame and obtain protection of the frame transmission via the NAV setting.

The RAV mechanism might be represented by a number of counters, where each counter corresponds to one MCCAOP. The number of counters needed at any instant is equal to the number of MCCAOPs at this instant corresponding to reservations in the interference periods of the mesh STA.

#### 10.24.3.10 Interaction with time synchronization

If a mesh STA adjusts its TBTT, e.g., in response to a TBTT Adjustment Request, it shall adjust the reservations by modifying the MCCAOP Offset of each of the tracked MCCAOP reservations. If a mesh STA adjusts its timing offset value with respect to a neighbor mesh STA, as specified in 14.14.2.2 (Neighbor offset synchronization method), it shall adjust the reservations by modifying the MCCAOP Offset of each of the tracked MCCAOP reservations for which this neighbor mesh STA is the owner. In either case, an MCCAOP advertisement of a mesh STA shall always contain the most recent MCCAOP Offsets.

## 10.25 Block acknowledgment (block ack)

### 10.25.1 Introduction

The block ack mechanism improves channel efficiency by aggregating several acknowledgments into one frame. In this subclause, the STA with data to send using the block ack mechanism is referred to as the *originator*, and the receiver of that data as the *recipient*.

The block ack mechanism is initialized by an exchange of ADDBA Request/Response frames except for GLK-GCR block ack (11bd)and block ack between two NGV STAs, or by using the unsolicited block ack extension mechanism(11ay). After initialization, blocks of QoS Data frames may be transmitted from the originator to the recipient. A block may be started within a polled TXOP, within an SP, or by winning EDCA contention. The number of frames in the block is limited, and the amount of state that is to be kept by the recipient is bounded. The MPDUs within the block of frames are acknowledged by a BlockAck frame, which is requested by a BlockAckReq frame.

For GLK-GCR block ack, the block ack mechanism is initialized when the GLK STA associates with the GLK AP. The MPDUs within a block of SYNRA addressed Data frames are acknowledged by a BlockAck frame, which is requested by a BlockAckReq frame.

The block ack mechanism does not require the setting up of a TS; however, QoS STAs using the TS facility may choose to signal their intention to use block ack mechanism for the scheduler's consideration in assigning TXOPs. The block ack mechanism is also used by the GCR service. Acknowledgments of frames belonging to the same TID, but transmitted during multiple TXOPs/SPs, may also be combined into a single BlockAck frame. This mechanism allows the originator to have flexibility regarding the transmission of Data frames. The originator may split the block of frames across TXOPs/SPs, separate the data transfer and the block ack exchange, and interleave blocks of MPDUs carrying all or part of MSDUs or A-MSDUs for different TIDs or RAs.

(#306)A non-AP S1G STA may negotiate an asymmetric BA with an S1G AP as described in 10.25.2 (Setup and modification of the block ack parameters). A non-S1G STA shall not transmit NDP BlockAck frames and shall not initiate an asymmetric BA. An S1G AP with dot11AsymmetricBlockAckActivated equal to false shall not support asymmetric BA. Under asymmetric BA operation, the responding S1G STA may use a lower MCS for transmitting the immediate BlockAck frame as described in 10.6.6.5.2 (Selection of a rate or MCS). The intended recipient STA maintains a measure of the degree of asymmetry between the AP and the STA and implicitly indicates the value to the originator AP during the block ack setup phase. This degree of asymmetry is represented as the difference in MCS values between AP and STA, and referred to as MCSDifference (see 10.25.2 (Setup and modification of the block ack parameters)). After an asymmetric


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BA agreement is established, the originator AP uses the MCSDifference to calculate the Duration field of PV0 frames carried in the A-MPDU that elicits the BlockAck frame.

An S1G STA that sets the STA Type Support subfield in a transmitted S1G Capabilities element to 0 or 2, as described in 10.62 (S1G BSS type and STA type), shall support the HT-immediate block ack extension. An S1G STA that sets the A-MPDU Supported field in the S1G Capabilities element to 1 shall support the HT-immediate block ack extension.

All arithmetic and equations (including inequalities) in 10.25 (Block acknowledgment (block ack)) are to be understood as being modulo the size of the relevant counter space (typically 4096).

(11ay)Under a block ack agreement using segmentation and reassembly, operations on MSDU Sequence Number and MPDU Sequence Number are performed modulo $2^{\text{MSDU Modulo}}$ and modulo $2^{\text{MPDU Modulo}}$ respectively (see 10.69 (DMG segmentation and reassembly operation(11ay))), where MSDU Modulo and MPDU Modulo correspond to the values of the MSDU Modulo and MPDU Modulo subfields, respectively, defined in the SAR Configuration element. Comparisons between MPDU sequence number and MSDU sequence number are circular modulo $2^{\text{MPDU Modulo}}$ and $2^{\text{MSDU Modulo}}$, respectively, i.e., the sequence number space is considered divided into two parts, one of which is "old" and one of which is "new," by means of a boundary created by adding half the sequence number range to the current start of receive window (modulo $2^{\text{MPDU Modulo}}$ and $2^{\text{MSDU Modulo}}$, respectively). The Block Ack Starting Sequence Control subfield within the BlockAckReq frame represents the MPDU starting sequence number.

(11ay)The EDMG flow control is an amendment to the block ack mechanism to prevent overloading of the recipient's memory space, which may happen in case the link speed is higher than STA's capability to process or consume incoming data. The EDMG flow control adjusts to the recipient's capabilities to optimize network utilization.

### 10.25.2 Setup and modification of the block ack parameters

Where the generic terms ADDBA Request frame, ADDBA Response frame, and DELBA frame are used throughout 10.25 (Block acknowledgment (block ack)) in reference to a block ack agreement between S1G STAs, the appropriate variant according to this subclause (e.g., NDP ADDBA Request, BAT ADDBA Request, and ADDBA Request) is referenced by the generic term.

(#6286)To establish a block ack agreement, an originator sends an ADDBA Request frame indicating the TID for which the block ack agreement is being established. (#6172)The Buffer Size and Block Ack Timeout Value fields in the ADDBA Request frame are advisory. (#6286)A block ack agreement shall not be established between a non-HT non-DMG non-S1G STA and another STA.

If the intended S1G recipient is capable of participating in an HT-immediate block ack agreement, the S1G originator shall send an NDP ADDBA Request to indicate that it expects only NDP BlockAck frames during the block ack agreement with the following exceptions:

a) If the S1G originator has the dot11BATImplemented equal to true and the BAT Support subfield in the S1G Capabilities element received from the S1G recipient is 1 and (#6286)a TWT has been established with the S1G recipient as described in 10.46 (Target wake time (TWT)), then the S1G originator shall send a BAT ADDBA Request to indicate that it expects only BAT frames during the block ack agreement.

b) When any of the conditions below is satisfied then the S1G originator may send an ADDBA Request to indicate that it expects only BlockAck frames during the block ack agreement:

   1) The value of the Buffer Size field in the ADDBA Request, carried in an S1G_LONG or S1G_SHORT PPDU, is greater than 16.

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2) The value of the Buffer Size field of the ADDBA Request, carried in an S1G_1M PPDU, is greater than 8.
3) The dot11AsymmetricBlockAckActivated is true and Asymmetric BA Supported field in the S1G Capabilities element received from the S1G recipient is 1.

The recipient STA shall respond by an ADDBA Response frame. The recipient STA has the option of accepting or rejecting the request. When the recipient STA accepts, then a block ack agreement exists between the originator and recipient.

When the S1G recipient STA rejects the request it may indicate a status code of 109 (REJECTED_NDP_BLOCK_ACK_SUGGESTED) to indicate to the S1G originator that it prefers to generate only NDP BlockAck frames.

When the recipient STA accepts, it indicates the type of block ack agreement, the type of BlockAck frames, and the number of buffers that it shall allocate for the support of this block ack agreement within the ADDBA Response frame and (#6172)the block ack agreement inactivity timeout that is used. Each block ack agreement that is established by a STA may have a different buffer allocation. If the intended recipient STA rejects the request, then the originator shall not use the block ack mechanism.

An S1G recipient STA that accepts an HT-immediate block ack agreement shall respond with the following:

— An NDP ADDBA Response if the value of the Buffer Size field of the NDP ADDBA Response is not greater than the value of the maximum number of MSDUs and A-MSDUs that can be acknowledged with the selected NDP BlockAck frame and (#6286)no TWT has already been established with the S1G originator as described in 10.46 (Target wake time (TWT)).
  — This value is 8 for NDP_1M BlockAck frames and 16 for NDP_2M BlockAck frames as described in 23.3.12.2.6 (NDP BlockAck). The NDP ADDBA Response frame shall be carried in an S1G_1M PPDU to indicate the use of NDP_1M BlockAck frames and shall be carried in an S1G_SHORT or S1G_LONG PPDU to indicate the use of NDP_2M BlockAck frames.
— Otherwise, a BAT ADDBA Response as a response to a BAT ADDBA Request (#6286)if a TWT has already been established with the S1G originator as described in 10.46 (Target wake time (TWT)).
  — The value of the Buffer Size field in the BAT ADDBA Response shall not be greater than 32.
— Otherwise, a ADDBA Response to indicate the use of BlockAck frames.

The MCS subfield in the Originator Preferred MCS field shall be set to 15 unless the dot11AsymmetricBlockAckActivated is true and the Asymmetric BA Supported field in the S1G Capabilities element received from the S1G originator is 1 in which case the MCS subfield may indicate the value of the preferred MCS if asymmetric BA operation is used. The preferred MCS implicitly indicates the MCSDifference value, which is the difference between the preferred MCS and the MCS at which the ADDBA Response is sent.

When the Block Ack Policy subfield value is 1 in an ADDBA Request frame, the responding HT STA shall set the Block Ack Policy subfield to 1 in the ADDBA Response frame accepting the ADDBA Request frame.(M118)

For each accepted block ack agreement, the originator shall set the sequence number of the first frame transmitted under the agreement to the value of the Block Ack Starting Sequence Control field of the ADDBA Request frame of the accepted block ack agreement.

When a block ack agreement is established between two HT STAs, two DMG STAs, or two S1G STAs, the originator may change the size of its transmission window(#1818):(11ax)


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- The transmission window is not greater than the value in the Buffer Size field of the ADDBA Response frame.(11ax)
- The transmission window is not greater than 64 if the sender or receiver of the ADDBA Response frame is a non-HE STA.(11ax)
- The transmission window is not greater than 256 if the sender and receiver of the ADDBA Response frame are HE STAs.(11ax)

If the value in the Buffer Size field of the ADDBA Response frame is smaller than the value in the ADDBA Request frame, the originator shall change the size of its transmission window ($WinSize_O$) so that it meets the following conditions:(11ax)

- Is not greater than the value in the Buffer Size field of the ADDBA Response frame.(11ax)
- Is not greater than 64 if the sender or receiver of the ADDBA Response frame is a non-HE STA or if the STAs that establish the block ack agreement are HT STAs or DMG STAs that are not EDMG STAs.(11ax)(11ay)
- Is not greater than 256 if the sender and receiver of the ADDBA Response frame are HE STAs.(11ax)
- Is not greater than 1024 if the STAs that establish the block ack agreement are EDMG STAs.(11ay)

(11ay)When a block ack agreement is established between two EDMG STAs, the size of the Block Ack bitmap the recipient shall use depends on the established size of the transmission window (#6310)($WinSize_O$). The size of the Block Ack bitmap for an EDMG STA shall be one of 64, 128, 256, 512, or 1024 bits. The size of the Block Ack bitmap shall be the smallest size that is greater than $WinSize_O$ for the established block ack agreement(#1807).

NOTE 1—A block ack associated with a GCR group address does not use an inactivity timer because the GCR originator might switch between the DMS delivery method, the GCR unsolicited retry retransmission policy, and the GCR block ack retransmission policy during the lifetime of a GCR agreement.

NOTE 2—(#6286)A GLK-GCR block ack is established at the time the general link is established and might be used by the general link originator whenever the GCR block ack retransmission policy is active. Therefore, an explicit block ack setup or modification procedure is not defined for GLK-GCR block ack. The GLK-GCR block ack is deleted when the corresponding general link gets reassociated or disassociated.

The A-MSDU Supported field indicates whether an A-MSDU may be sent under the particular block ack agreement. The originator sets this field to 1 to indicate that it might transmit A-MSDUs with this TID. The recipient sets this field to 1 to indicate that it is capable of receiving an A-MSDU with this TID.

NOTE 3—The recipient is free to respond with any setting of the A-MSDU Supported field, irrespective of the originator's setting of the A-MSDU Supported field(#7148). If the value in the ADDBA Response frame is not acceptable to the originator, it can delete the block ack agreement and transmit data using normal acknowledgment.

If the block ack mechanism is being (#6286)established for a TS, bandwidth negotiation (using ADDTS Request and Response frames) should precede the establishment of the block ack mechanism. If the block ack mechanism is being (#6286)established for the GCR service, then the following steps apply:

- One or more GCR request/response frame exchanges(#4173) precede the (#6286)establishment of the block ack mechanism.
- The ADDBA Request and Response frames exchanged to (#6286)establish the block ack agreement(#6171) shall include the GCR Group Address element indicating the group address of the GCR service.

Once the block ack agreement(#6171) has been (#6286)established, QoS Data frames are transferred in A-MPDUs and acknowledged using the procedure described in 10.25.3 (Data and acknowledgment transfer using immediate block ack policy).

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(11ay)An originator may include the SAR Configuration element in the ADDBA Request frame if the recipient supports segmentation and reassembly as indicated by the Segmentation and Reassembly Support subfield within the recipient's DMG Capabilities element. If the SAR Enabled field is(M118) 1 in a SAR Configuration element transmitted within an ADDBA Request frame, the value of the MPDU Modulo subfield shall be more than or equal to 7 and less than or equal to 12, and the sum of the MPDU Modulo and MSDU Modulo subfields shall be equal to 14. If the recipient accepts the SAR configuration within a received ADDBA Request frame, the recipient shall transmit an ADDBA Response frame that includes the SAR Configuration element with the SAR Enabled subfield set to 1, and the MSDU Modulo and MPDU Modulo subfields set to the same value of the MSDU Modulo and MPDU Modulo subfields received in the ADDBA Request frame. A recipient may reject the SAR configuration by setting the SAR Enabled field within the SAR Configuration element in the ADDBA Response to zero or by not including the SAR Configuration element in the ADDBA Response frame. The size of the originator's transmission window shall not be greater than value in the Buffer Size subfield of the Block Ack Parameter Set field of the ADDBA Response frame in the case that the recipient rejects the SAR configuration, but responds with a status code of SUCCESS in the ADDBA Response frame. The originator shall set the Sequence Number field to zero in the first MPDU it transmits under an established block ack agreement in case the recipient rejects the SAR configuration, but responds with a status code of SUCCESS in the ADDBA Response frame.

(11ay)When a block ack agreement with segmentation and reassembly is established, a DMG originator may change the size of its transmission window if the value in the MPDU Buffer Size or MSDU Buffer Size fields within the SAR Configuration element contained in an ADDBA Response frame are larger than the corresponding field values transmitted in the ADDBA Request frame. If the value in the MSDU Buffer Size or the MPDU Buffer Size fields in the ADDBA Response frame is smaller than the corresponding value in the ADDBA Request frame, the originator shall change the size of its transmission window (#6310)($WinSize_O$ or $WinSize_{OI}$) so that it is not larger than the value of the field in the ADDBA Response frame and not larger than 1024. In addition, the MPDU Buffer Size subfield shall not exceed the value of $2^{(\text{MPDU Modulo-2})}$ and shall be equal or larger than the value of the resulting maximum segmented MSDU size as indicated by the Maximum Segmented MSDU Exponent subfield in the recipient's SAR Configuration element divided by the maximum MPDU size as defined in 9.4.2.279 (SAR Configuration element(11ay)). The originator may set the MSDU Buffer Size subfield to a value greater than $2^{\text{MSDU Modulo}-2}$ if the MPDU Modulo subfield is(M118) greater than 9; in this case, the recipient may receive multiple MSDUs or A-MSDUs with identical SNs that are not detected.

(11ay)An EDMG originator STA may insert an EDMG Flow Control Extension Configuration element in an ADDBA Request frame. In this case, no subelements shall be present in the EDMG Flow Control Extension Configuration element.

(11ay)An EDMG recipient STA that responds to an ADDBA Request frame that contains an EDMG Flow Control Extension Configuration element should insert an EDMG Flow Control Extension Configuration element in the ADDBA Response frame sent as response. A Recipient Memory Configuration subelement shall be included in the EDMG Flow Control Extension Configuration element sent by the recipient if at least one subfield, except for the Advanced Recipient Memory Length Capable subfield, in the Recipient Memory Capabilities field of the EDMG Flow Control Extension Configuration element is nonzero.

(11ay)EDMG STAs that established a block ack agreement with or without exchange of an EDMG Flow Control Extension Configuration element shall follow the flow control operation rules defined in 10.25.6.5 (Generation and transmission of BlockAck frames by an HT STA, DMG STA, or S1G STA), 10.25.6.6 (Receive reordering buffer control operation), and 10.25.6.7 (Originator's behavior).

(11ay)The following negotiation rules apply to EDMG STAs (EDMG originator and EDMG recipient) that exchange ADDBA Request and ADDBA Response frames.


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(11ay)An EDMG originator or EDMG recipient support those recipient memory capabilities for which the corresponding subfields in the Recipient Memory Capabilities field of the EDMG originator or EDMG recipient, respectively, are set to 1 in ADDBA Request and ADDBA Response frames of the block ack agreement established between the EDMG originator and EDMG recipient, and do not support otherwise.

(11ay)An EDMG recipient shall not respond with Status Code = SUCCESS in an ADDBA Response frame if the EDMG recipient sets to one at least one of the subfields within the recipient's Recipient Memory Capabilities field and:

— The same subfield is set to 0 in the Recipient Memory Capabilities field in the corresponding ADDBA Request frame received from EDMG originator; or

— No EDMG Flow Control Extension Configuration element is present in the corresponding ADDBA Request frame.

(11ay)NOTE 4—Status Code values (#1780)REFUSED_REASON_UNSPECIFIED, REQUEST_DECLINED, or INVALID_PARAMETERS can be used in the aforementioned case.

(11ay)The recipient memory multiple buffer units capability is supported in a successfully established block ack agreement if both the originator and recipient set the RBUFCAP Quantity Capable and Recipient Memory Multiple Buffer Units Capable subfields to 1 in their respective EDMG Flow Control Extension Configuration elements transmitted in the ADDBA Request and ADDBA Response frames. Otherwise, the recipient memory multiple buffer units capability is not supported.

(11ay)The memory config tag capability is supported in a successfully established block ack agreements if both the originator and recipient set the RBUFCAP Quantity Capable and Two Memory Config Tag Capable subfields to 1 in their respective EDMG Flow Control Extension Configuration elements transmitted in the ADDBA Request and ADDBA Response frames. Otherwise, the memory config tag capability is not supported.

(11ay)The advanced recipient memory length capability is supported in a successfully established block ack agreement if the recipient set the Advanced Recipient Memory Length Capable subfield to 1 in its EDMG Flow Control Extension Configuration element transmitted in the ADDBA Response. Otherwise, the advanced recipient memory length capability is not supported.

(11ay)The TID grouping capability is supported in a successfully established block ack agreements if both the originator and recipient set the TID Grouping Capable and the RBUFCAP Quantity Capable subfields to 1 in their respective EDMG Flow Control Extension Configuration elements transmitted in the ADDBA Request and ADDBA Response frames. The Recipient Memory Capabilities field and fields within the Recipient Memory Configuration subelement for TIDs that were set to 1 in the TID Grouping subfield shall be identical in the ADDBA Response frame.

(11ay)An EDMG STA that has (#4201)negotiated a block ack agreement shall obey the following rules as a recipient in addition to the rules specified in 10.25.6 (HT-immediate block ack extensions). The recipient may transmit an unsolicited ADDBA Response frame that is not a response to an ADDBA Request frame to update the RBUFCAP subfield and Advanced Recipient Memory Length field values. The unsolicited ADDBA Response frame is sent by the recipient that is a TXOP holder or source of an SP. The Dialog Token field of an unsolicited ADDBA Response frame shall be set to 0 and the Status Code field shall be set to SUCCESS. An EDMG Flow Control Extension Configuration element shall be included in the ADDBA Response frame, and the element shall not contain a Recipient Memory Configuration subelement. The RBUFCAP subfield and Advanced Recipient Memory Length Exponent field values shall comply, respectively, with the RBUFCAP quantity and advanced recipient memory length capabilities that established the block ack agreement. After transmitting an unsolicited ADDBA Response frame, the recipient may

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— Transmit a Grant frame to the TXOP responder or SP destination (see 10.38.7.3 (Grant period (GP))) to relinquish the remainder of the TXOP or SP, respectively; or
— Grant a reverse direction (see 10.29 (Reverse direction protocol)) to the TXOP responder or SP destination.

(11ay)An EDMG STA that has (#4201)negotiated a block ack agreement shall obey the following rules as an originator in addition to rules specified in 10.25.6 (HT-immediate block ack extensions). The originator that receives an ADDBA Response frame with the Dialog Token field equal to 0 shall ignore the Block Ack Parameter Set and Block Ack Timeout Value fields of the frame. In addition, the originator shall update the local values of the RBUFCAP and Advanced Recipient Memory Length Exponent field values to the values received in the ADDBA Response frame, provided it is in compliance with RBUFCAP quantity and advanced recipient memory length capabilities.

(11ay)Support for the unsolicited block ack extension is a capability of a recipient. Support for the unsolicited block ack extension by the recipient is advertised by insertion of the Unsolicited Block Ack Extension element in all transmitted Probe Request, Probe Response, Association Request, Association Response, Reassociation Request, Reassociation Response, Information Request and Information Response frames. An originator shall not use the unsolicited block ack extension mechanism with a recipient that does not support the mechanism.

(11ay)An unsolicited block ack extension agreement is established per <TA, RA, TID> tuple. The unsolicited block ack extension agreement is (#6286)established if the following conditions apply:

— The recipient transmits and the originator receives a BlockAck frame in response to an MPDU with the Ack Policy field set to Implicit Block Ack Request sent by the originator; and
— Prior to the reception of the BlockAck frame, the originator does not receive an ADDBA Response frame with Status Code equal to SUCCESS with the same <TA, RA, TID> tuple as the BlockAck frame <TA, RA, TID> tuple.

(11ay)Parameters of the established unsolicited block ack extension agreement are equal to those advertised by the recipient in the recipient's Unsolicited Block Ack Extension element.

(11ay)A pair of EDMG STAs that have an established unsolicited block ack agreement shall follow the RBUFCAP operation rules defined in 10.25.6.5 (Generation and transmission of BlockAck frames by an HT STA, DMG STA, or S1G STA) and 10.25.6.7 (Originator's behavior).

(11ay)An unsolicited block ack extension agreement may be torn down by transmitting a DELBA frame as defined in 10.25.3 (Data and acknowledgment transfer using immediate block ack policy).

(#1807)A block ack agreement may be modified by the originator by sending an ADDBA Request frame ((#3174)(see 11.5.2 (Setup and modification of the block ack parameters), except that MLME-ADDBA primitives are not used by the originator(#4352)). All parameters of the agreement may be modified except for the TID. If the request is not successful, the existing agreement is not modified. (#6171)If the request is successful, the behavior is as if a DELBA frame for the block ack agreement had been transmitted by the originator and received by the recipient immediately prior to the ADDBA Request frame.

(11bd)An NGV STA does not initialize the block ack mechanism as defined in this subclause; a block ack agreement with parameters defined in 31.2.3 (A-MSDU operation, A-MPDU operation, and BA operation) is always in place.

### 10.25.3 Data and acknowledgment transfer using immediate block ack policy

After (#6286)establishing an immediate block ack agreement following the procedure in 10.25.2 (Setup and modification of the block ack parameters), and having gained access to the medium and established protection,


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if necessary, the originator may transmit an A-MPDU. The RA field of the frames that are not delivered using the GCR block ack retransmission policy shall be the recipient's individual address. The RA field in GCR frames delivered using the GCR block ack retransmission policy shall be set to the GCR concealment address. The RA field in Data frames delivered using the GLK-GCR block ack retransmission policy shall be set to a SYNRA. The originator requests acknowledgment of outstanding QoS Data frames by sending a BlockAckReq frame.

### 10.25.4 Teardown of the block ack agreement(#6171)

When the originator has no data to send and the final block ack exchange has completed, it shall signal the end of its use of the block ack mechanism by sending the DELBA frame to its recipient. The DELBA frame sent by the S1G originator shall be a BAT DELBA if a BAT ADDBA Request was sent (#6286)during block ack establishment or NDP DELBA if an NDP ADDBA Request was sent during block ack establishment or DELBA if ADDBA Request was sent during block ack setup. The recipient does not generate a Management frame in response to the DELBA frame.[37] The recipient of the DELBA frame shall release all resources allocated for the block ack transfer.

The block ack agreement shall(#6173) be torn down if there are no BlockAck, BlockAckReq, or (#7155)Data frames received from the peer under the block ack agreement, for the block ack agreement's(#6171) TID, (#6172)within the block ack agreement inactivity timeout (see 11.5.4 (Error recovery upon a peer failure)).

The DELBA frame transmitted to release the block ack (#6286)establishment of a GCR service shall include the GCR Group Address element to indicate the group address of the GCR service. For general links using a GLK-GCR block ack retransmission policy, there is no explicit teardown of the block ack agreement(#6171). The GLK-GCR block ack agreement terminates when the general link is reassociated/ disassociated.

### 10.25.5 Selection of BlockAck and BlockAckReq variants

(#4179)For non-HE STAs, the Multi-TID BlockAckReq variant shall not be used(#3263). The Multi-TID BlockAckReq variant can be used between HE STAs to solicit a Multi-STA BlockAck frame for Multi-TID A-MPDUs. (11ax)

In a DMG BSS, if the Compressed BlockAckReq variant is used related to an HT-immediate agreement, then all of the following BlockAck and BlockAckReq frames transmitted as part of the HT-immediate agreement shall use the Compressed BlockAck and Compressed BlockAckReq variants.(11ax)

In a DMG BSS, if the Extended Compressed BlockAckReq variant is used related to an HT-immediate agreement, then all of the following BlockAck and BlockAckReq frames transmitted as part of the HT-immediate agreement shall use the Extended Compressed BlockAck and Extended Compressed BlockAckReq variants.(11ax)

(11ay)In a DMG BSS, when transmitted between EDMG STAs as part of the HT-immediate agreement, BlockAck frames shall be of EDMG Compressed BlockAck frame variant or of EDMG Multi-TID BlockAck variant, and BlockAckReq frames shall be of Compressed BlockAckReq variant or of Multi-TID BlockAckReq variant.(#4244)

Where the terms BlockAck and BlockAckReq are used (11ax)in 10.25.6 (HT-immediate block ack extensions), the appropriate variant according to this subclause (e.g., Compressed, Multi-TID) is referenced by the generic term. The term BlockAck as used in 10.25.6 (HT-immediate block ack extensions) includes the additional NDP_1M BlockAck, NDP_2M BlockAck, BAT, and BlockAck frame variants.

[37] Normal Ack rules apply.

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(11ax)GCR BlockAck and GCR BlockAckReq variants shall be used in a GCR block ack agreement. GLK-GCR BlockAck and GLK-GCR BlockAckReq variants shall be used in a GLK-GCR block ack agreement.

The S1G recipient of an accepted block ack agreement that was negotiated with NDP ADDBA shall use NDP BlockAck frames instead of BlockAck frames to acknowledge MPDUs within A-MPDUs during an HT-immediate block ack agreement.

The S1G recipient of an accepted block ack agreement that was negotiated with BAT ADDBA shall use BAT frames instead of BlockAck frames to acknowledge MPDUs within A-MPDUs during an HT-immediate block ack agreement. Otherwise, the S1G recipient of an accepted block ack agreement shall not use BAT frames.

The S1G recipient of an accepted block ack agreement that was negotiated with ADDBA shall use BlockAck frames to acknowledge MPDUs within A-MPDUs during an HT-immediate block ack agreement.

The S1G recipient of an accepted block ack agreement that was negotiated with either ADDBA Request/ NDP ADDBA Response or NDP ADDBA Request/ADDBA Response shall use either NDP BlockAck or BlockAck frames depending on the type of response frame elicited by the S1G originator. The type of response shall be:

— An NDP BlockAck frame if the RXVECTOR parameter RESPONSE_INDICATION of the eliciting PPDU that contains a BlockAckReq or an A-MPDU is equal to NDP Response
— A BlockAck frame if the RXVECTOR parameter RESPONSE_INDICATION of the eliciting PPDU that contains a BlockAckReq or an A-MPDU is equal to Normal Response
— A PPDU that contains a BlockAck frame if the RXVECTOR parameter RESPONSE_INDICATION of the eliciting PPDU is equal to Long Response

(11ay)An EDMG STA that has a value of 0 in the EDMG Multi-TID Aggregation Support subfield of the STA's EDMG Capabilities element shall not initiate transmission of Multi-TID BlockAckReq variant frames.

(11ay)An EDMG STA shall not transmit a Multi-TID BlockAckReq variant frame to a peer STA that has a value of 0 in the EDMG Multi-TID Aggregation Support subfield within the peer STA's EDMG Capabilities element.

(11ay)An EDMG STA that indicates a nonzero value in the EDMG Multi-TID Aggregation Support subfield of the STA's EDMG Capabilities element shall respond with an EDMG Multi-TID BlockAck variant frame to a received Multi-TID BlockAckReq variant frame.

(11ay)An EDMG STA that indicates a nonzero value in the EDMG Multi-TID Aggregation Support subfield of the STA's EDMG Capabilities element shall respond with an EDMG Multi-TID BlockAck variant frame to an A-MPDU that contains MPDUs of different TIDs and Ack policy equal to Normal Ack or Scheduled Ack. The STA shall set to 1 the Management Ack subfield in the BA Control field of the EDMG Multi-TID BlockAck variant frame to acknowledge an Action Ack or Management frame received within the multi-TID A-MPDU.

(11ay)An EDMG Multi-TID BlockAck frame shall not include more than one BA Information field for a specific TID.

(11ay)An EDMG STA shall respond with (#4251)an EDMG Multi-TID BlockAck frame to an A-MPDU conveyed in an EDMG MU-MIMO PPDU that contains an MPDU with a TID without a block ack agreement.


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### 10.25.6 HT-immediate block ack extensions

#### 10.25.6.1 Introduction to HT-immediate block ack extensions

An HT extension to the block ack feature (defined in 10.25.1 (Introduction) to 10.25.4 (Teardown of the block ack agreement(#6171))), called *HT-immediate block ack,* is defined in 10.25.6.2 (HT-immediate block ack architecture) to 10.25.6.9 (Originator's support of recipient's partial state).

The HT-immediate extensions simplify immediate block ack use with A-MPDUs and reduce recipient resource requirements.

An HT STA shall support HT-immediate block ack in the role of recipient.

A DMG STA shall support HT-immediate block ack.

(11ax)If the B0 of Fragment Number subfield of a Compressed BlockAck frame or Multi-STA BlockAck frame is equal to 0, then *BitmapLength* represents the maximum length, in bits, of the Block Ack Bitmap subfield in the Compressed BlockAck frame and Multi-STA BlockAck frame for a particular TID; otherwise, *BitmapLength* is derived by dividing by 4 the length represented in the Block Ack Bitmap subfield in the Compressed BlockAck frame and Multi-STA BlockAck frame for a particular TID. For a non-HE STA, *BitmapLength* is 64. For an HE STA, *BitmapLength* is negotiated when the block ack agreement is established as defined in 26.4.3 (Negotiation of block ack bitmap lengths).

(11ay)An EDMG STA shall support HT-immediate block ack with EDMG flow control extension.

(11ay)An HT-immediate block ack agreement in which the SAR Configuration element was included in the both the ADDBA Request and ADDBA Response frames and that had the SAR Enabled subfield set to 1 in both frames is considered as a block ack agreement with segmentation and reassembly.

(11ay)After setting up an immediate block ack (#6286)establishment following the procedure in 10.25.2 (Setup and modification of the block ack parameters), and having gained access to the medium and established protection, if necessary, an originator that is a DMG STA may transmit a block of QoS Data frames separated by SIFS as follows:

— The total number of frames shall not exceed the Buffer Size subfield value in the associated ADDBA Response frame and subject to any additional duration limitations based on the channel access mechanism; and

— If the block ack agreement is between a pair of EDMG STAs, the memory occupied by the frames shall not exceed the values computed in Table 10-24 (FlowControlByteCountLimit computation at the start of a data transfer sequence(11ay)) and in Table 10-25 (FlowControlByteCountLimit computation during a data transfer sequence(11ay)). The actual RBUFCAP value is delivered by the EDMG Compressed BlockAck, EDMG Multi-TID BlockAck, EDMG Flow Control Extension Configuration element in the ADDBA Response frame or the RBUFCAP update of other TIDs as indicated in TID Grouping field of the Recipient Memory Configuration subelement, whichever comes later. If the ADDBA Response frame does not contain an EDMG Flow Control Extension Configuration element, the relevant originator parameters shall be considered as receiving an RBUFCAP with value Receiver Buffer Empty (9.3.1.8.7 (EDMG Compressed BlockAck variant(11ay))).

(11ay)Each of the frames shall have the Ack Policy Indicator subfield in the QoS Control field set to Block Ack. The RA field of the frames shall be the recipient's individual address. The originator requests acknowledgment of outstanding QoS Data frames by sending a BlockAckReq frame. The recipient shall maintain a block ack record for the block. An EDMG recipient shall maintain free memory space for the

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established block ack agreement(s) (10.25.6.5 (Generation and transmission of BlockAck frames by an HT STA, DMG STA, or S1G STA)).

(11ay)An EDMG recipient that is TXOP holder or source of an SP may transmit ADDBA Response frames to the originator as defined in 10.25.2 (Setup and modification of the block ack parameters).

### 10.25.6.2 HT-immediate block ack architecture

The HT-immediate block acknowledgment rules(#553) are explained in terms of the architecture shown in Figure 10-40 (HT-immediate block ack architecture)(11ay) and in Figure 10-41 (HT-immediate block ack architecture with EDMG flow control(#6310)(11ay)) for non-EDMG and EDMG STAs, respectively.

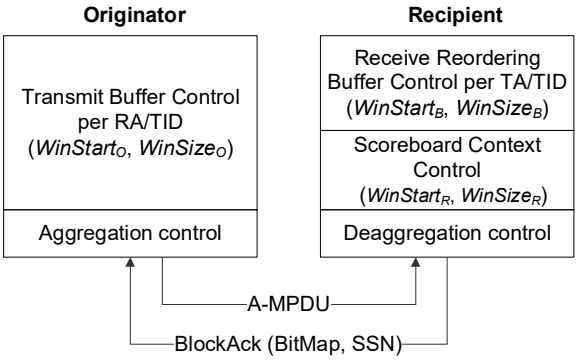


**Figure 10-40—HT-immediate block ack architecture**

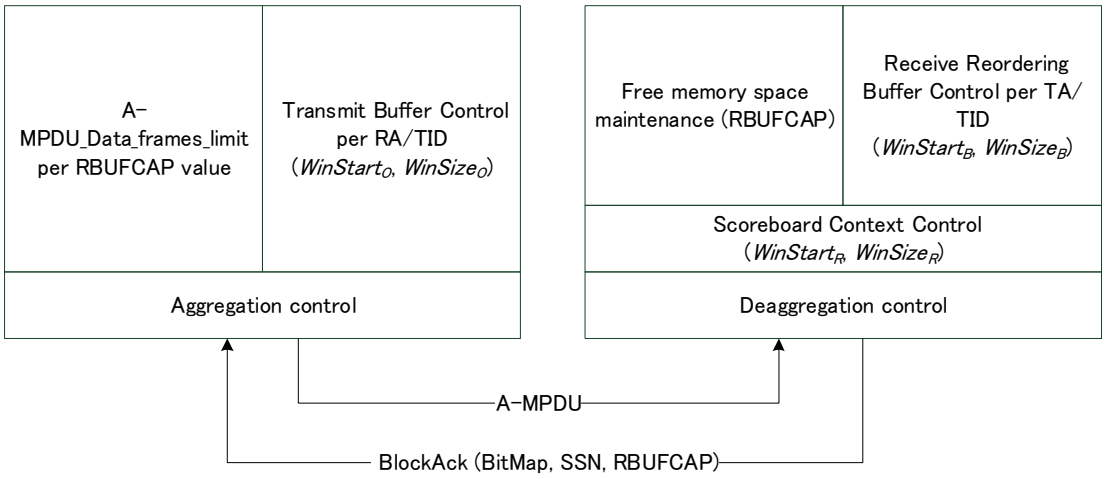


**Figure 10-41—HT-immediate block ack architecture with EDMG flow control(#6310)(11ay)**

The originator contains a transmit buffer control that uses $WinStart_O$ and $WinSize_O$ to submit MPDUs for transmission and releases transmit buffers upon receiving BlockAck frames from the recipient.

$WinStart_O$ is the starting sequence number of the transmit window, and $WinSize_O$ is the number of buffers negotiated in the block ack agreement.


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(11ay)In a block ack agreement with segmentation and reassembly, the originator maintains a transmit buffer control that uses $WinStart_{OJ}$ and $WinSize_{OJ}$ to submit MPDUs for transmission and releases transmit buffers upon reception of BlockAck frames from the recipient. $WinStart_{OJ}$ is the(#4200) starting sequence number of the transmit window and $WinSize_{OJ}$ is the value of the MSDU Buffer Size field in the recipient's SAR Configuration element that established the block ack agreement.

(11ay)An EDMG originator uses RBUFCAP to limit the number of transmitted MPDUs to not exceed the available free memory space at an EDMG recipient.

The Aggregation control creates A-MPDUs. It may adjust the ack policy of transmitted QoS Data frames according to the rules defined in 10.25.6.7 (Originator's behavior) in order to solicit BlockAck frame responses.

The recipient contains a receive reordering buffer control per TA/TID, which contains a related control state. The receive reordering buffer is responsible for reordering MSDUs or A-MSDUs so that MSDUs or A-MSDUs are eventually passed up to the next MAC process in order of received sequence number. It is also responsible for identifying and discarding duplicate frames (i.e., frames that have the same sequence number as a currently buffered frame) that are part of this block ack agreement. It maintains its own state independent of the scoreboard context control to perform this reordering as specified in 10.25.6.6 (Receive reordering buffer control operation).

For each HT-immediate block ack agreement, the recipient chooses either full-state or partial-state operation (this choice is known only to the recipient). A STA may simultaneously use full-state operation for some agreements and partial-state operation for other agreements. The scoreboard context control stores an acknowledgment bitmap containing the current reception status of MSDUs or A-MSDUs for HT-immediate block ack agreements. (11ay)Under a block ack agreement with segmentation and reassembly, the scoreboard context control stores an acknowledgment bitmap containing the current reception status of MPDUs. Under full-state operation, status is maintained in statically assigned memory. Under partial-state operation, status is maintained in a cache memory; therefore, the status information is subject to cache replacement. This entity provides the bitmap and the value for the Starting Sequence Number subfield to be sent in BlockAck frame responses to the originator.

(11ay)An EDMG recipient contains a free memory space maintenance entity. This entity is responsible to compute the RBUFCAP value. This entity provides the RBUFCAP value subfield to be sent in BlockAck and in ADDBA Response frames to an EDMG originator.

The deaggregation control entity separates frames contained in an A-MPDU.

Each received MPDU is analyzed by the scoreboard context control as well as by the receive reordering buffer control.

Each HT-immediate block ack agreement is uniquely identified by a tuple of Address 1, Address 2, and TID from the ADDBA Response frame that successfully established the HT-immediate block ack agreement. The STA that corresponds to Address 1 of the ADDBA Response frame is the originator. The STA that corresponds to Address 2 of the ADDBA Response frame is the recipient. Data frames that contain the same values for Address 1, Address 2, and TID as a successful ADDBA Response frame are (#407)related to the HT-immediate block ack agreement that was established by the receipt of that ADDBA Response frame provided that the HT-immediate block ack agreement is still active.

### 10.25.6.3 Scoreboard context control during full-state operation

For each HT-immediate block ack agreement that uses full-state operation, a recipient shall maintain a block acknowledgment record. This record includes a bitmap, indexed by sequence number; a 12-bit unsigned integer starting sequence number, $WinStart_R$, representing the lowest sequence number position in the bitmap;

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$WinEnd_R$, representing the highest sequence number in the current transmission window; and the maximum transmission window size, $WinSize_R$, which is set to the smaller of *BitmapLength*(11ax) and the value of the Buffer Size field of the associated ADDBA Response frame that established the block ack agreement. A STA implementing full-state operation for an HT-immediate block ack agreement shall maintain the block acknowledgment record for that agreement according to the following rules:

a) At HT-immediate block ack agreement establishment:

   1) (11ay)(#4200)$WinStart_R$ = Starting Sequence Number subfield in the ADDBA Request frame that elicited the ADDBA Response frame that established the HT-immediate block ack agreement or from an MPDU that synchronized an unsolicited block ack agreement.

   2) $WinEnd_R = WinStart_R + WinSize_R - 1$.

b) For each received Data frame that is (#407)related to a specific full-state operation HT-immediate block ack agreement, the block acknowledgment record for that agreement is modified as follows, where *SN* is the value of the Sequence Number subfield of the received Data frame(#6049):

   1) If $WinStart_R \le SN \le WinEnd_R$, set to 1 the bit in position *SN* within the bitmap.(#6049)

   2) If $WinEnd_R < SN < WinStart_R + 2^{11}$,

      i) Set to 0 the bits corresponding to MPDUs with Sequence Number subfield values from $WinEnd_R + 1$ to $SN - 1$.(#6049)

      ii) Set $WinStart_R = SN - WinSize_R + 1$.(#6049)

      iii) Set $WinEnd_R = SN$.(#6049)

      iv) Set to 1 the bit at position *SN* in the bitmap.

   3) If $WinStart_R + 2^{11} \le SN < WinStart_R$, make no changes to the record.

      NOTE —A later-arriving Data frame might validly contain a sequence number that is lower than an earlier-arriving one. This might happen because the transmitter may choose to send Data frames in a nonsequential sequence number order or because a previous Data frame transmission with lower sequence number is not successful and is being retransmitted. (#6049)

c) For each received BlockAckReq frame that is (#407)related to a specific full-state operation HT-immediate block ack agreement that is not a protected block ack agreement, the block acknowledgment record for that agreement is modified as follows, where *SSN* is (#4200)the Starting Sequence Number subfield of the received BlockAckReq frame(#4200):

   1) If $WinStart_R < SSN \le WinEnd_R$,

      i) Set $WinStart_R = SSN$.

      ii) Set to 0 the bits corresponding to MPDUs with Sequence Number subfield values from $WinEnd_R + 1$ to $WinStart_R + WinSize_R - 1$.

      iii) Set $WinEnd_R = WinStart_R + WinSize_R - 1$.

   2) If $WinEnd_R < SSN < WinStart_R + 2^{11}$,

      i) Set $WinStart_R = SSN$.

      ii) Set $WinEnd_R = WinStart_R + WinSize_R - 1$.

      iii) Set to 0 bits the corresponding to MPDU with Sequence Number subfield values from $WinStart_R$ to $WinEnd_R$.

   3) If $WinStart_R + 2^{11} \le SSN \le WinStart_R$, make no changes to the record.

#### 10.25.6.4 Scoreboard context control during partial-state operation

In an HT-immediate block ack agreement that uses partial-state operation, a recipient shall maintain a temporary block acknowledgment record. This temporary record includes a bitmap, indexed by sequence number; a 12-bit unsigned integer $WinStart_R$ (the lowest sequence number represented in the bitmap); a 12-bit unsigned integer $WinEnd_R$ (the highest sequence number in the bitmap); the originator address; TID; and the


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maximum transmission window size, $WinSize_R$, which is set to the smaller of 64 and the value of the Buffer Size field of the associated ADDBA Response frame that established the block ack agreement.

During partial-state operation of scoreboard context control, the recipient retains the current record for an HT-immediate block ack agreement at least as long as it receives data from the same originator. If a frame for an HT-immediate block ack agreement from a different originator is received, the temporary record may be discarded if the resources it uses are needed to store the temporary record corresponding to the newly arriving frame.

A STA implementing partial-state operation for an HT-immediate block ack agreement shall maintain the temporary block acknowledgment record for that agreement according to the following rules:

a) During partial-state operation(#4200), $WinStart_R$ is determined by the Sequence Number subfield value of received Data frames and by the Starting Sequence Number subfield value of received BlockAckReq frames as described below.(#4200)

b) For each received Data frame that is (#407)related to a specific partial-state operation HT-immediate block ack agreement, when no temporary record for the agreement (#407)related to the received Data frame exists at the time of receipt of the Data frame, a temporary block acknowledgment record is created as follows, where *SN* is the value of the Sequence Number subfield of the received Data frame (11ay)if segmentation and reassembly is not used and is the value of the MPDU Sequence Number subfield of the received Data frame when segmentation and reassembly is used(#6049):

   1) $WinEnd_R = SN$.(#6049)
   2) $WinStart_R = WinEnd_R - WinSize_R + 1$.
   3) Create a bitmap of size $WinSize_R$, with the first bit corresponding to sequence number $WinStart_R$ and the last bit corresponding to sequence number $WinEnd_R$, and set all bits in the bitmap to 0.
   4) Set to 1 the bit in the position in the bitmap that corresponds to *SN*.

c) For each received Data frame that is (#407)related to a specific partial-state operation HT-immediate block ack agreement, when a temporary record for the agreement (#407)related to the received Data frame exists at the time of receipt of the Data frame, the temporary block acknowledgment record for that agreement is modified in the same manner as the acknowledgment record for a full-state agreement described in 10.25.6.3 (Scoreboard context control during full-state operation).

d) For each received BlockAckReq frame that is (#407)related to a specific partial-state operation HT-immediate block ack agreement that is not a protected block ack agreement, when no temporary record for the agreement (#407)related to the received frame exists at the time of receipt of the frame, a temporary block acknowledgment record is created as follows, where *SSN* is (#4200)the Starting Sequence Number subfield of the received BlockAckReq frame(#4200):

   1) $WinStart_R = SSN$.
   2) $WinEnd_R = WinStart_R + WinSize_R - 1$.
   3) Create a bitmap of size $WinSize_R$, and set all bits in the bitmap to 0.

e) For each received BlockAckReq frame that is (#407)related to a specific partial-state operation HT-immediate block ack agreement that is not a protected block ack agreement, when a temporary record for the agreement (#407)related to the received frame exists at the time of receipt of the frame, the temporary block acknowledgment record for that agreement is modified in the same manner as the acknowledgment record for a full-state agreement described in 10.25.6.3 (Scoreboard context control during full-state operation).

### 10.25.6.5 Generation and transmission of BlockAck frames by an HT STA, DMG STA, or S1G STA

(#3263)A STA that receives a PPDU that contains a BlockAckReq frame in which the Address 1 field matches its MAC address during either full-state operation or partial-state operation shall transmit a PPDU containing a

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BlockAck frame that is separated on the WM by a SIFS from the PPDU that elicited the BlockAck frame as a response. A STA that receives an A-MPDU that contains one or more QoS Data frames with Implicit BAR ack policy during either full-state operation or partial-state operation shall transmit a PPDU containing a BlockAck frame that is separated on the WM by a SIFS from the PPDU that elicited the BlockAck frame as a response.

(11ay)A STA operating in an SP with TDD channel access (see 10.38.6.2.2 (SP with TDD channel access(11ay))) that receives a PPDU that contains a BlockAckReq frame in which the Address 1 field matches its MAC address during either full-state or partial-state operation shall transmit a PPDU containing a BlockAck frame starting at the earliest occurring TDD slot the STA is assigned to, with the Bitmap and Access Type Schedule field of the TDD slot set to TX, and with slot category of the TDD slot set to Basic TDD slot, as indicated in the TDD Slot Schedule element.

(11ay)A STA operating in an SP with TDD channel access (see 10.38.6.2.2 (SP with TDD channel access(11ay))) that receives an A-MPDU that contains one or more MPDUs in which the Address 1 field matches its MAC address with the Ack Policy field equal to Normal Ack (i.e., implicit block ack request) during either full-state operation or partial-state operation shall transmit a PPDU containing a BlockAck frame starting at the earliest occurring TDD slot the STA is assigned to, with the Bitmap and Access Type Schedule field of the TDD slot set to TX, and with slot category of the TDD slot set to Basic TDD slot, as indicated in the TDD Slot Schedule element.

When responding with a BlockAck frame to either a received BlockAckReq frame or a received QoS Data frame with Implicit BAR ack policy during either full-state operation or partial-state operation, any adjustment to the value of $WinStart_R$ according to the procedures defined within 10.25.6.3 (Scoreboard context control during full-state operation) and 10.25.6.4 (Scoreboard context control during partial-state operation) shall be performed before the generation and transmission of the response BlockAck frame. The Starting Sequence Number subfield of the Block Ack Starting Sequence Control subfield of the BlockAck frame shall be set to any value in the range ($WinEnd_R$ – $BitmapLength$ + 1))(11ax) to $WinStart_R$. The Starting Sequence Number subfield stored in the Starting Sequence Control field of NDP BlockAck and BAT frames shall be set to $WinStart_R$. The values in the recipient's record of status of MPDUs beginning with the MPDU for which the Sequence Number subfield value is equal to $WinStart_R$ and ending with the MPDU for which the Sequence Number subfield value is equal to $WinEnd_R$ shall be included in the bitmap of the BlockAck frame. The bitmap of the NDP BlockAck frame is protected using the encoding procedure described in 10.56 (Bitmap protection for NDP BlockAck frames).

When responding with a BlockAck frame to either a received BlockAckReq frame or a received QoS Data frame with Implicit BAR ack policy during either full-state or partial-state operation, if the adjusted value of $WinStart_R$ is greater than the value of the starting sequence number of the BlockAck frame, within the bitmap of the BlockAck frame, the status of MPDUs with sequence numbers that are less than the adjusted value of $WinStart_R$ may be set to any value.

When responding with a BlockAck frame to either a received BlockAckReq frame or a received QoS Data frame with Implicit BAR ack policy during either full-state or partial-state operation, if the adjusted value of $WinEnd_R$ is less than the value of the starting sequence number of the BlockAck frame plus(11ax) $BitmapLength$ − 1, within the bitmap of the BlockAck frame, the status of MPDUs with sequence numbers that are greater than the adjusted value of $WinEnd_R$ shall be reported as not received (i.e., the corresponding bit in the bitmap shall be set to 0).

If a BlockAckReq frame is received and no matching partial state is available, the recipient shall send a null BlockAck frame in which the bitmap is set to all 0s.

(11ay)If an EDMG STA transmits a BlockAck frame in response to a BlockAckReq frame or an A-MPDU with Ack Policy equal to Normal Ack (i.e., implicit block ack request) during either full-state or partial-state operation, the EDMG STA shall calculate the free memory space value at the generation and transmission of the BlockAck frame. The RBUFCAP subfield value in the transmitted BlockAck frame shall be computed


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as defined in Table 10-23 (RBUFCAP value calculation(11ay)). The free memory space is an estimation of the amount of free memory available at the recipient to collect MPDUs at the time of and during reception of a forthcoming A-MPDU.

(11ay)Within an unsolicited block ack agreement, the RBUFCAP value used by an EDMG STA for the RBUFCAP calculation in (11ay)Table 10-23 (RBUFCAP value calculation(11ay)) shall assume that the RBUFCAP Quantity Capable subfield value is "Not Supported" and shall not use a value between 1 and 254, inclusive.

**Table 10-23—RBUFCAP value calculation(11ay)**

| Free memory space comparison | RBUFCAP Quantity Capable subfield value (10.25.2 (Setup and modification of the block ack parameters)) | RBUFCAP subfield value |
|---|---|---|
| Free memory space ≥ $(2^{(13 + \text{Maximum A-MPDU Length Exponent})} - 1)$ | Supported | Receiver Buffer Empty |
| Free memory space ≥ $(2^{(13 + \text{Maximum A-MPDU Length Exponent})} - 1)$ | Not supported | Receiver Buffer Empty |
| Free memory space < $(2^{(13 + \text{Maximum A-MPDU Length Exponent})} - 1)$ | Supported | Int [Free memory space/ Buffer Unit Size] |
| Free memory space < $(2^{(13 + \text{Maximum A-MPDU Length Exponent})} - 1)$ | Not supported | Receiver Buffer Full |

### 10.25.6.6 Receive reordering buffer control operation

#### 10.25.6.6.1 General

The behavior described in this subclause, 10.25.6.6.2 (Operation for each received Data frame), and 10.25.6.6.3 (Operation for each received BlockAckReq) applies to a STA that uses either partial-state operation or full-state operation for an HT-immediate block ack agreement.

(11ay)For each HT-immediate block ack agreement that does not use segmentation and reassembly, a receive reordering buffer shall be maintained for each HT-immediate block ack agreement. Each receive reordering buffer includes a record comprising the following:

— Buffered MSDUs or A-MSDUs that have been received, but not yet passed up to the next MAC process

— A $WinStart_B$ parameter, indicating the value of the Sequence Number subfield of the first (in order of ascending sequence number) MSDU or A-MSDU that has not yet been received

— A $WinEnd_B$ parameter, indicating the highest sequence number expected to be received in the current reception window

— A $WinSize_B$ parameter, indicating the size of the reception window

(11ay)For each HT-immediate block ack agreement that does not use segmentation and reassembly and is not part of an unsolicited block ack agreement, (#6305)the variables shall be initialized as follows:

— $WinStart_B$ is initialized to the Starting Sequence Number subfield value of the ADDBA Request frame that elicited the ADDBA Response frame that established the HT-immediate block ack agreement.

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— $WinEnd_B$ is initialized to $WinStart_B + WinSize_B - 1$, where $WinSize_B$ is set to the smaller of(11ax) *BitmapLength* and the value of the Buffer Size field of the ADDBA Response frame that established the block ack agreement.

(11ay)For each HT-immediate block ack agreement that does not use segmentation and reassembly, the recipient shall always pass MSDUs or A-MSDUs up to the next MAC process in order of increasing Sequence Number subfield value.

(11ay)For each HT-immediate block ack agreement that uses segmentation and reassembly, a receive reordering buffer shall be maintained. Each receive reordering buffer includes a record comprising the following:

— Buffered MPDUs belonging to MSDUs or A-MSDUs that have been received, but not yet passed up to the next MAC process.

— A $WinStart_B$ parameter, indicating the value of the MPDU Sequence Number subfield of the first (in order of ascending sequence number) MPDU that has not yet been received.

— A $WinEnd_B$ parameter, indicating the highest MPDU sequence number expected to be received in the current reception window.

— A $WinSize_B$ parameter, indicating the size of the reception window.

(11ay)For each HT-immediate block ack agreement that uses segmentation and reassembly, (#4200)$WinStart_B$ and (#4200)$WinEnd_B$ variables shall be initialized as follows:

— $WinStart_B$ is initialized to the (#4200)Starting Sequence Number subfield value of the ADDBA Request frame that elicited the ADDBA Response frame that established the block ack agreement.

— $WinEnd_B$ is initialized to $WinStart_B + WinSize_B - 1$, where $WinSize_B$ is set to the smaller of 1024 and the value of the MPDU Buffer Size field of the ADDBA Response frame that established the block ack agreement.

(11ay)For each HT-immediate block ack agreement that uses segmentation and reassembly, the recipient shall always pass MSDUs or A-MSDUs up to the next MAC process in order of increasing MSDU Sequence Number subfield value.

(11ay)Any MSDU or A-MSDU that has been passed up to the next MAC process shall be deleted from the receive reordering buffer.

#### 10.25.6.6.2 Operation for each received Data frame

##### 10.25.6.6.2.1 Block ack agreements not using segmentation and reassembly(11ay)

For each received Data frame that is related to a specific HT-immediate block ack agreement(11ay) that does not use segmentation and reassembly, the receive reordering buffer record shall be modified as follows, where *SN* is the value of the Sequence Number subfield of the received MPDU:

a) If $WinStart_B \le SN \le WinEnd_B$,

1) Store the received MPDU in the buffer, (#270)if no MSDU or A-MSDU with the same sequence number is already present; otherwise discard the MPDU.

2) Pass MSDUs or A-MSDUs up to the next MAC process if they are stored in the buffer in order of increasing value of the Sequence Number subfield starting with the MSDU or A-MSDU that has $SN=WinStart_B$ or if $SN>WinStart_B$, the STA is a (11ay)non-EDMG STA, and one of the following conditions is met:

i) The MPDU is received as non-first frame in the A-MPDU; the bit at position $SN=WinStart_R - 1$ is set to 1; and all delimiters between the received MPDU and the preceding MPDU ($SN=WinStart_R - 1$) are valid.


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ii) The MPDU is received as first frame in the A-MPDU; the A-MPDU is received in SIFS or RIFS after an A-MPDU or in SIFS after transmission of a BlockAck frame; the bit at position $SN=WinStart_R - 1$ is set to 1; and all delimiters after the MPDU ($SN=WinStart_R - 1$) in the preceding A-MPDU are valid.

iii) The MPDU is received in SIFS or RIFS after an A-MPDU or in SIFS after transmission of a BlockAck frame; the bit at position $SN=WinStart_R - 1$ is set to 1; and all delimiters after the MPDU ($SN=WinStart_R - 1$) in the preceding A-MPDU are valid.

iv) The MPDU is received as first frame in the A-MPDU; the A-MPDU is received in SIFS or RIFS after an MPDU or in SIFS after transmission of an Ack frame; and the bit at position $SN=WinStart_R - 1$ is set to 1.

v) The MPDU is received in SIFS or RIFS after the preceding MPDU or in SIFS after transmission of an Ack frame; and the bit at position $SN=WinStart_R - 1$ is set to 1.

This process is continued sequentially until there is no buffered MSDU or A-MSDU for the next sequential value of the Sequence Number subfield.

3) Set $WinStart_B$ to the value of the Sequence Number subfield of the last MSDU or A-MSDU that was passed up to the next MAC process plus one.

4) Set $WinEnd_B = WinStart_B + WinSize_B - 1$.

b) If $WinEnd_B < SN < WinStart_B + 2^{11}$,

1) Store the received MPDU in the buffer, (#270)if no MSDU or A-MSDU with the same sequence number is already present; otherwise discard the MPDU.

2) Set $WinEnd_B = SN$.

3) Set $WinStart_B = WinEnd_B - WinSize_B + 1$.

4) Pass any complete MSDUs or A-MSDUs stored in the buffer with Sequence Number subfield values that are lower than the new value of $WinStart_B$ up to the next MAC process in order of increasing Sequence Number subfield value. Gaps may exist in the Sequence Number subfield values of the MSDUs or A-MSDUs that are passed up to the next MAC process.

5) In a non-DMG STA, pass MSDUs or A-MSDUs stored in the buffer up to the next MAC process in order of increasing value of the Sequence Number subfield starting with $WinStart_B$ and proceeding sequentially until there is no buffered MSDU or A-MSDU for the next sequential Sequence Number subfield value. For a DMG STA, follow rules defined in item a)2) above.

6) Set $WinStart_B$ to the Sequence Number subfield value of the last MSDU or A-MSDU that was passed up to the next MAC process plus one.

7) Set $WinEnd_B = WinStart_B + WinSize_B - 1$.

c) If $WinStart_B + 2^{11} \leq SN < WinStart_B$, discard the MPDU (do not store the MPDU in the buffer, and do not pass the MSDU or A-MSDU up to the next MAC process).

#### 10.25.6.6.2.2 Block ack agreements using segmentation and reassembly(11ay)

For each received data MPDU that is related to a specific block ack agreement using segmentation and reassembly, the receive reordering buffer record shall be modified as follows, where MPDU_SN is the value of the Sequence Number subfield of the received MPDU:

a) If $WinStart_B \leq MPDU\_SN \leq WinEnd_B$,

1) Store the received MPDU in the buffer if no MPDU with the same sequence number is already present; otherwise, discard the MPDU.

2) Pass to the next MAC process any complete MSDUs or A-MSDUs in the buffer, which includes all MPDUs with the same value of *MSDU_SN* in increasing order of MPDU_SN, from the *MPDU_SN* with Start of MSDU subfield equal to 1 until the MPDU with End of MSDU subfield equal to 1 and which their MPDU_SN starts with $MPDU\_SN = WinStart_B$ and

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proceeds sequentially until there is no buffered MPDUs for the next *MPDU_SN*. An MSDU or A-MSDU is complete if all MPDUs identified with the same MSDU_SN from the *MPDU_SN* with Start of MSDU subfield equal to 1 until the MPDU with End of MSDU subfield equal to 1 are present in the receive reordering buffer.

3) Set $WinStart_B$ to the value of the MPDU_SN subfield of the last MPDU of the MSDU or A-MSDU that was passed up to the next MAC process plus one.

4) Set $WinEnd_B = WinStart_B + WinSize_B - 1$.

b) If $WinEnd_B < MPDU\_SN < WinStart_B + 2^{\text{MPDU Modulo-1}}$,

1) Store the received MPDU in the buffer if no MPDU with the same sequence number is already present; otherwise, discard the MPDU.

2) Set $WinEnd_B = MPDU\_SN$.

3) Set $WinStart_B = WinEnd_B - WinSize_B + 1$.

4) Pass to the next MAC process any complete MSDUs or A-MSDUs in the buffer, which include all MPDUs with the same value of *MSDU_SN* in increasing order of *MPDU_SN*, from the *MPDU_SN* with Start of MSDU subfield equal to 1 until the MPDU with End of MSDU subfield equal to 1 and which their *MPDU_SN* is lower than $WinStart_B$. Gaps may exist in the MPDU_SN subfield, in this case the recipient shall discard the MSDUs or A-MSDUs with missing *MPDU_SN* and may inform the next MAC process of the incomplete or missing *MSDU_SN*.

5) Set $WinStart_B$ to the value of the *MPDU_SN* of the last MSDU or A-MSDU that was passed up to the next MAC process plus one.

6) Set $WinEnd_B = WinStart_B + WinSize_B - 1$.

c) If $WinStart_B + 2^{\text{MPDU Modulo-1}} \leq MPDU\_SN < WinStart_B$, discard the MPDU.

An originator shall not transmit a segmented MSDU if the size of the segmented MSDU is greater than the value defined by the Maximum Segmented MSDU Exponent subfield of the recipient's SAR Configuration element.

#### 10.25.6.6.3 Operation for each received BlockAckReq

##### 10.25.6.6.3.1 Block ack agreements not using segmentation and reassembly(11ay)

For each received BlockAckReq frame that is (#407)related to a specific HT-immediate block ack agreement(11ay) that does not use segmentation and reassembly, the receive reordering buffer record is modified as follows, where *SSN* is the Starting Sequence Number subfield value of the received BlockAckReq frame:

a) If $WinStart_B < SSN < WinStart_B + 2^{11}$,

1) In a block ack agreement that is not a protected block ack agreement, set $WinStart_B = SSN$. See 10.25.7 (Protected block ack agreement) for a protected block ack agreement.

2) Set $WinEnd_B = WinStart_B + WinSize_B - 1$.

3) Pass any complete MSDUs or A-MSDUs stored in the buffer with Sequence Number subfield values that are lower than the new value of $WinStart_B$ up to the next MAC process in order of increasing Sequence Number subfield value. Gaps may exist in the Sequence Number subfield values of the MSDUs or A-MSDUs that are passed up to the next MAC process.

4) Pass MSDUs or A-MSDUs stored in the buffer up to the next MAC process in order of increasing Sequence Number subfield value starting with $SN=WinStart_B$ and proceeding sequentially until there is no buffered MSDU or A-MSDU for the next sequential Sequence Number subfield value.

5) Set $WinStart_B$ to the Sequence Number subfield value of the last MSDU or A-MSDU that was passed up to the next MAC process plus one.


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6) Set $WinEnd_B = WinStart_B + WinSize_B - 1$.

b) If $WinStart_B + 2^{11} \leq SSN \leq WinStart_B$, do not make any changes to the receive reordering buffer record.

#### 10.25.6.6.3.2 Block ack agreements using segmentation and reassembly(11ay)

For each received BlockAckReq frame that is (#407)related to a specific block ack agreement that uses segmentation and reassembly, the receive reordering buffer record is modified as follows, where *MPDU_SSN* is the (#4200)Starting Sequence Number subfield value of the received BlockAckReq frame:

a) If $WinStart_B < MPDU\_SSN < WinStart_B + 2^{\text{MPDU Modulo-1}}$,

1) In a block ack agreement that is not a protected block ack agreement, set $WinStart_B = MPDU\_SSN$. See 10.25.7 (Protected block ack agreement) for a protected block ack agreement.

2) Set $WinEnd_B = WinStart_B + WinSize_B - 1$.

3) Pass to the next MAC process any complete MSDUs or A-MSDUs in the buffer, which include all MPDUs with the same value of *MSDU_SN* in increasing order of MPDU_SN, from the *MPDU_SN* with Start of MSDU subfield equal to 1 until the MPDU with End of MSDU subfield equal to 1 and which their *MPDU_SN* is lower than $WinStart_B$. Gaps may exist in the MPDU_SN subfield, in this case the recipient shall discard the MSDUs or A-MSDUs with missing *MPDU_SN* and may inform the next MAC process of the incomplete or missing MSDUs or A-MSDUs.

4) Pass to the next MAC process any complete MSDUs or A-MSDUs in the buffer, which include all MPDUs with the same value of *MSDU_SN* in increasing order of *MPDU_SN*, from the *MPDU_SN* set with the Start of MSDU subfield equal to 1 until the MPDU with End of MSDU subfield equal to 1 and which their MPDU_SN starts with $MPDU\_SN = WinStart_B$ and proceeds sequentially until there is no buffered MPDUs for the next *MPDU_SN*.

5) Set $WinStart_B$ to the *MPDU_SN* value of the last MSDU or A-MSDU that was passed up to the next MAC process plus one.

6) Set $WinEnd_B = WinStart_B + WinSize_B - 1$.

b) If $WinStart_B + 2^{\text{MPDU Modulo-1}} \leq MPDU\_SSN < WinStart_B$, do not make any changes to the receive reordering buffer record.

### 10.25.6.7 Originator's behavior

#### 10.25.6.7.1 General(11ay)

A STA may send a block of data in a single A-MPDU where each QoS Data frame has Normal Ack ack policy. The originator expects to receive a BlockAck frame response immediately following the A-MPDU if at least one Data frame is received without error.

(11ay)A DMG STA originator operating in an SP with TDD channel access (see 10.38.6.2.2 (SP with TDD channel access(11ay))) expects to receive a BlockAck frame response in the earliest occurring TDD slot with slot category of the TDD slot set to Basic TDD slot as defined in 10.25.6.5 (Generation and transmission of BlockAck frames by an HT STA, DMG STA, or S1G STA) if at least one Data frame is received without error.

(11ay)A DMG STA originator operating in an SP with TDD channel access (see 10.38.6.2.2 (SP with TDD channel access(11ay))) shall not transmit to a peer STA more than one MPDU or A-MPDU that has an Ack Policy of Normal Ack per each occurrence of a TDD slot the peer STA is assigned to, with the Bitmap and Access Type Schedule field of the TDD slot set to TX, and with slot category of the TDD slot set to Basic TDD slot or Data TDD slot, as indicated in the TDD Slot Schedule element.

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If the received BlockAck response is of an expected NDP_1M BlockAck frame (or an NDP_2M BlockAck frame), the S1G originator shall accept it as correctly received if the value obtained from the BlockAck ID field equals the 2 LSBs (or the 6 LSBs) of the (#8126)scrambler initialization value of the immediately previously transmitted A-MPDU that is not an S-MPDU, or BlockAckReq frame,(#4200) and the Starting Sequence Number obtained from the Starting Sequence Control field equals $WinStart_O$. The S1G originator shall otherwise consider the NDP BlockAck frame to be lost.(#6277)

NOTE—(#6277)(#8126)The scrambler initialization value is obtained from the PHY-TXEND.confirm parameter SCRAMBLER_OR_CRC. The values of the BlockAck ID and Starting Sequence Number fields are obtained after decoding the NDP BlockAck frame as described in 10.56 (Bitmap protection for NDP BlockAck frames).

Alternatively, the originator may send an A-MPDU where each QoS Data frame has Block Ack ack policy under an HT-immediate block ack agreement if it does not require a BlockAck frame response immediately following the A-MPDU.

If the BlockAck frame is lost, the originator may transmit a BlockAckReq frame to solicit an immediate BlockAck frame or it may retransmit the Data frames.

During an accepted HT-immediate block ack agreement, the S1G originator shall set the TXVECTOR parameter RESPONSE_INDICATION of a PPDU transmitted to the S1G recipient that elicits a block acknowledgment frame to

— NDP Response if the block ack agreement was negotiated with NDP ADDBA Request/NDP ADDBA Response exchange

— Normal Response if the block ack agreement was negotiated with either BAT ADDBA Request/ BAT ADDBA Response or ADDBA Request/ADDBA Response exchange

During an accepted HT-immediate block ack agreement, the S1G originator is allowed to elicit an NDP BlockAck or a BlockAck frame on a per-PPDU basis only if the block ack agreement was negotiated with either ADDBA Request/NDP ADDBA Response or NDP ADDBA Request/ADDBA Response exchanges. In this case the S1G originator may set the TXVECTOR parameter RESPONSE_INDICATION of a PPDU transmitted to the S1G recipient that elicits a block acknowledgment frame to either NDP Response or Normal Response.

The S1G originator shall not set the TXVECTOR parameter RESPONSE_INDICATION to Long Response for a PPDU transmitted to the S1G recipient that elicits a block acknowledgment frame, if neither BlockAck frame nor BAT frames have been negotiated with the S1G recipient. The S1G originator may set the TXVECTOR parameter RESPONSE_INDICATION to Long Response if either BlockAck frame or BAT frames have been negotiated with the S1G recipient.

The originator may transmit QoS Data frames with a TID matching a block ack agreement in any order provided that their sequence numbers lie within the current transmission window. The originator may transmit an MPDU with a sequence number that is beyond the current transmission window ($SN > WinStart_O + WinSize_O - 1$), in which case the originator's transmission window (and the recipient's window) is moved forward. The originator should not transmit an MPDU with a sequence number that is before the current transmission window (i.e., $SN < WinStart_O$). (11ay)Under a block ack agreement with segmentation and reassembly, the originator may transmit QoS Data frames with a TID matching an established block ack agreement in any order provided that their *MPDU_SN* and MSDU_SN are within the current transmission window. The originator may transmit an MPDU with an *MSDU_SN* that is beyond the current transmission window ($MSDU\_SN > WinStart_{OJ} + WinSize_{OJ} - 1$), in which case the originator's transmission window (and the recipient's window) is moved forward. The originator shall not transmit MSDUs or A-MSDUs that are lower than the current transmission window (i.e., $SN < WinStart_{OJ}$) in case the MSDU Modulo subfield was set to a value smaller than 5.(#6049)

The originator shall not retransmit an MPDU after that MPDU's appropriate lifetime limit.


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When a QoS Data frame that was previously transmitted within an A-MPDU that had Normal Ack ack policy is discarded due to exhausted MSDU lifetime, the originator may send a BlockAckReq frame for a block ack agreement that is not a protected block ack agreement or a PBAC WinStart Update frame for a protected block ack agreement to shift the recipient's $WinStart_B$ and $WinStart_R$ past the hole in the sequence number space that is created by the discarded Data frame and thereby to allow the earliest possible passing of buffered frames up to the next MAC process. (11ay)(#4200)Under a block ack agreement with segmentation and reassembly, the BlockAckReq and PBAC WinStart Update frames shall have a Starting Sequence Number field that corresponds to an MPDU that has the Start of MSDU subfield equal to 1. (#3169)(#3014)

An originator that is a DMG STA shall transmit MPDUs sent under a block ack agreement such that:

- (11ay)If the originator or the recipient are a non-EDMG STA,
  - MPDUs that need to be retransmitted are transmitted first, in sequential order of sequence number, starting from the oldest MPDU that needs to be retransmitted
  - MPDUs that are being transmitted for the first time are sent after any MPDUs that need to be retransmitted, in sequential order of sequence number, starting from the oldest MPDU that has not been transmitted
- QoS Data MPDUs are transmitted with Block Ack ack policy if the A-MPDU that contains them is followed after a SIFS(#6587) or RIFS by another A-MPDU

An originator that is a DMG STA shall not start a new TXOP or SP with a PPDU containing a QoS Data MPDU that has an ack policy other than Normal Ack or Implicit BAR if at least one frame transmitted by the originator to the recipient in the last PPDU did not require an immediate response.

(11ay)At the start of a data transfer sequence that has an established Block Ack agreement, an originator that is an EDMG STA shall not transmit a frame with a PSDU size greater than *FlowControlByteCountLimit*, where *FlowControlByteCountLimit* is defined per the configuration obtained during the Block Ack agreement establishment for the respective TID or group of TIDs described in Table 10-24 (FlowControlByteCountLimit computation at the start of a data transfer sequence(11ay)) and per the computation described in 10.25.6.7.2 (Number of MPDUs per FlowControlByteCountLimit computation(11ay)).

**Table 10-24—FlowControlByteCountLimit computation at the start of a data transfer sequence(11ay)**

| According to Block Ack agreement | | As received via BlockAck or ADDBA Response frame | | FlowControlByteCount Limit |
|---|---|---|---|---|
| Advanced recipient memory length capable | Recipient buffer quantity capable | Updated RBUFCAP | No Memory Kept | |
| 0 | N/A | Receiver Buffer Full | N/A | Zero (see NOTE) |
| N/A | N/A | Receiver Buffer Empty | 0 | $2^{(13 + \text{Maximum A-MPDU Length Exponent})} - 1$ |
| 1 | N/A | N/A | 1 | $2^{(13 + \text{Advanced Recipient Memory Length Exponent})} - 1$ |
| 0 | N/A | Receiver Buffer Empty or Receiver Buffer Available | 1 | Zero (see NOTE) |

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**Table 10-24—FlowControlByteCountLimit computation at the start of a data transfer sequence(11ay) *(continued)***

| According to Block Ack agreement | | As received via BlockAck or ADDBA Response frame | | FlowControlByteCount Limit |
|---|---|---|---|---|
| Advanced recipient memory length capable | Recipient buffer quantity capable | Updated RBUFCAP | No Memory Kept | |
| N/A | 1 | Receiver Buffer Available | 0 | Receiver Buffer Available × Buffer Unit Size |
| NOTE—An originator can poll a responder's RBUFCAP value. | | | | |

(11ay)During a data transfer sequence that has an established Block Ack agreement, an originator that is an EDMG STA shall not transmit a frame with a PSDU size greater than *FlowControlByteCountLimit*, where *FlowControlByteCountLimit* is defined per the configuration obtained during the Block Ack agreement establishment for the respective TID or group of TIDs described in Table 10-25 (FlowControlByteCountLimit computation during a data transfer sequence(11ay)) and per the computation described in 10.25.6.7.2 (Number of MPDUs per FlowControlByteCountLimit computation(11ay)).

**Table 10-25—FlowControlByteCountLimit computation during a data transfer sequence(11ay)**

| According to Block Ack agreement | As received via BlockAck or ADDBA Response frame | FlowControlByteCountLimit |
|---|---|---|
| Recipient buffer quantity capable | Updated RBUFCAP | |
| N/A | Receiver Buffer Full | Zero (see NOTE) |
| N/A | Receiver Buffer Empty | $2^{(13 + \text{Maximum A-MPDU Length Exponent})} - 1$) |
| 1 | Receiver Buffer Available | Receiver Buffer Available × Buffer Unit Size |
| NOTE—An originator can poll a responder's RBUFCAP value. | | |

### 10.25.6.7.2 Number of MPDUs per FlowControlByteCountLimit computation(11ay)

Figure 10-42 (Algorithm for computation of FlowControlByteCountLimit(11ay) (continued on next page)) specifies the algorithm used to compute the number of MPDUs satisfying a given *FlowControlByteCountLimit* based on Table 10-24 (FlowControlByteCountLimit computation at the start of a data transfer sequence(11ay)) and Table 10-25 (FlowControlByteCountLimit computation during a data transfer sequence(11ay)). In this algorithm, the following apply:

— *numOfMpdusForTx* indicates the number of pending MPDUs in the transmit queue that are within the transmission window.

— If the recipient memory multiple buffer units capability is not supported, then the parameters *maxMpduInMem* and *mpduSplitInBuffer* are assigned with values 255 and 1, respectively.


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— Parameters *unitBufferSize*, *rbufcap*, *memoryUnitSize*, *maxMpduInMem*, and *mpduSplitInBuffer* correspond to the last EDMG flow control parameters as received from a TID within a group of TIDs and with the respective memory configuration tag.

— *mpduForTx[k]* contains the size of the MPDU at location *k* in the transmit queue with the padding for minimum A-MPDU spacing and A-MPDU delimiter alignment, if required.

— For a multi-TID A-MPDU containing TIDs not included in a TID group, the algorithm computes the number of MPDUs for each TID using the *FlowControlByteCountLimit* of that TID. For a multi-TID A-MPDU containing TIDs included in a TID group, the algorithm computes the number of MPDUs for all the TIDs using the recent calculated *FlowControlByteCountLimit* for any TID within the TID group.

#### 10.25.6.8 Maintaining block ack state at the originator

If an originator receives a BlockAck frame, the originator updates the status of MPDUs in its transmit buffer that have the same TID as the BlockAck frame, RA equal to the TA of the BlockAck frame and TA equal to the RA of the BlockAck frame. Status update is performed as follows:

— The originator shall not update the status of MPDUs with Sequence Number subfield values between $WinStart_O$ and $SSN - 1$ of the received BlockAck frame, where *SSN* is the Starting Sequence Number subfield in the received BlockAck frame.(#4200)

NOTE 1—It is possible for (#4200)*SSN* to be greater than $WinStart_O$ because of the lack of reception of a nonzero number of MPDUs beginning with the MPDU with Sequence Number subfield value equal to $WinStart_O$ at a recipient that is using partial-state operation.

— For each MPDU for which the status is not acknowledged, and for which the corresponding bit of the received bitmap contains a value of 1, and for which the Sequence Number subfield value is between *SSN* and $WinStart_O + WinSize_O - 1$, the originator shall change its status to acknowledged.(#4200)

NOTE 2—This second rule means that if an originator successfully delivered an MPDU and received the BlockAck frame in one TXOP and then receives a BlockAck frame in a later TXOP in which the MPDU is not indicated as received (i.e., the corresponding bit of the received bitmap is 0 because the partial state has been reset), the originator knows not to retry the MPDU.

(11ay)Under a block ack agreement with segmentation and reassembly, the originator shall update $WinStart_{OJ}$ and $WinEnd_{OJ}$ at the arrival of a BlockAck frame. At each subsequent MPDU sent with End of MSDU subfield set to 1 in the Sequence Control field, $WinStart_{OJ}$ shall be set to *MSDU_SN*+1 and $WinEnd_{OJ}$ shall be set to $WinStart_{OJ} + WinSize_{OJ} - 1$ if following conditions are met:

— The MPDU is indicated as acknowledged in the Block Ack bitmap.

(11ay)All preceding MPDUs starting from MPDU_SN with Start of MSDU subfield set to 1 in the Sequence Control field are indicated as successfully delivered.

#### 10.25.6.9 Originator's support of recipient's partial state

A recipient may choose to employ either full-state operation or partial-state operation for each individual block ack agreement. An originator is unaware of the recipient's choice of full-state or partial-state operation.

NOTE—The originator might solicit a BlockAck frame as the last activity associated with that block ack agreement in the current TXOP to reduce the probability that data are unnecessarily retransmitted due to loss of partial state.

### 10.25.7 Protected block ack agreement

(#1002)A STA indicates support for protected block ack by setting the MFPC subfield in the RSN Capabilities field to 1 (see 9.4.2.23.4 (RSN capabilities)) and the PBAC subfield in the Extended RSN Capabilities field to

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```
int calcAggregationMemory(IN int FlowControlByteCountLimit, IN int memoryUnitSize, IN int
maxMpduInMem, IN int mpduSplitInBuffer, IN int mpduForTx[], IN int numOfMpdusForTx, OUT
int mpduToSend[])
{
       int           memoryToUse = FlowControlByteCountLimit;
       int           freeMemory  = memoryUnitSize;
       int           k = 0;
       int           numOfMpdusInMemoryUnit = 0;
       bool          bIsMpduInserted;

//Adding MPDUs to the queue as long as there are MPDUs in TX Queue and recipient memory
buffer is not full

       while (k < numOfMpdusForTx && (memoryToUse >= mpduForTx[k]))
       {
              bIsMpduInserted = true;

// Handle the case when MPDU[k] has enough memory in one Memory Buffer Unit hence it is
added to the aggregation
              if (freeMemory >= mpduForTx[k])
              {
                     mpduToSend[k] = mpduForTx[k];
                     k++;
                     numOfMpdusInMemoryUnit++;
                     freeMemory -= mpduForTx[k];
                     memoryToUse -= mpduForTx[k];
              }

// Handle the case when MPDU[k] (#6147)does not have enough memory in one Memory Buffer
Unit however it can be spiltted among several buffers hence it is added to the aggregation

              else if (mpduSplitInBuffer == 1)
                                    {
                     mpduToSend[k] = mpduForTx[k];
                     k++;

                     //Calculating the free memory space from the last used Memory Buffer
Unit
                     freeMemory  =  memoryUnitSize  -  ((mpduForTx[k]  -  freeMemory)  %
memoryUnitSize);

                     //The case where MPDU was placed in whole in the previous buffer
                     if (freeMemory == memoryUnitSize)
                     {
                            numOfMpdusInMemoryUnit = 0;
                     }
                     else
                     {
                            numOfMpdusInMemoryUnit = 1;
                     }

                     memoryToUse -= mpduForTx[k];
              }
              else
              {
                     bIsMpduInserted = false;
              }
```

**Figure 10-42—Algorithm for computation of FlowControlByteCountLimit(11ay)**

*(continued on next page)*



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```
//Handle the case where the MPDU cannot be inserted to current Memory Buffer Unit, free
memory is decreased and new Memory Buffer Unit is allocated

                if ((maxMpduInMem != 255 && numOfMpdusInMemoryUnit == maxMpduInMem) ||
                        ((false == bIsMpduInserted) && (mpduSplitInBuffer == 0)))
                {
                        memoryToUse -= freeMemory;
                        freeMemory = memoryUnitSize;
                        numOfMpdusInMemoryUnit = 0;
                }
        }

        return k;
}
```

**Figure 10-36b—Algorithm for computation of FlowControlByteCountLimit**

*(continued from previous page)*

1 (see 9.4.2.240 (RSNXE(#1776))). Such a STA is a PBAC STA; otherwise, the STA is a non-PBAC STA. A block ack agreement that is (#4201)negotiated between two PBAC STAs is a protected block ack agreement. A block ack agreement that is (#4201)negotiated between two STAs when either or both of the STAs is not a PBAC STA is a block ack agreement that is not a protected block ack agreement.

A PBAC STA may choose to negotiate a block ack agreement with a non-PBAC STA if dot11RSNAPBACRequired is false(#1817); otherwise, it shall negotiate a block ack agreement only with other PBAC STAs. If a PBAC STA is communicating with a non-PBAC STA, it shall follow the rules for a nonprotected block ack agreement.

A STA that has (#4201)negotiated a protected block ack agreement shall obey the following rule as a block ack originator in addition to rules specified in 10.25.6.7 (Originator's behavior) and 10.25.6.8 (Maintaining block ack state at the originator):

— To update $WinStart_B$ and $WinStart_R$ at the receiver, the STA shall use a PBAC WinStart Update frame.(#3169)(#3014)

A STA that has successfully negotiated a protected block ack agreement shall obey the following rules for that agreement(#1014) as a block ack recipient in addition to rules specified from(#1014) 10.25.6.3 (Scoreboard context control during full-state operation) to 10.25.6.6 (Receive reordering buffer control operation):

— (#1014)(#1017)The STA shall not use the Starting Sequence Number subfield of the Block Ack Starting Sequence Control field in a BlockAckReq, MU-BAR Trigger or GCR-MU BAR Trigger frame(#3015) to update $WinStart_B$ and $WinStart_R$. If the Starting Sequence Number subfield is greater than $WinEnd_B$ or less than $WinStart_B$, dot11PBACErrors shall be incremented by 1.(#4200)

— Upon receipt of a PBAC WinStart Update frame whose TID and transmitter address are the same as those of the protected block ack agreement, the STA shall update its $WinStart_R$ and $WinStart_B$ values based on the starting sequence number in the PBAC WinStart Update frame according to the procedures outlined for reception of BlockAckReq frames in 10.25.6.3 (Scoreboard context control during full-state operation), 10.25.6.4 (Scoreboard context control during partial-state operation), 10.25.6.6.1 (General), and 10.25.6.6.3 (Operation for each received BlockAckReq), while treating the starting sequence number as though it were the Starting Sequence Number field of a received BlockAckReq frame.(#4200)

### 10.25.8 GCR and GLK-GCR block ack

#### 10.25.8.1 General(11ax)

Subclause 10.25.8 (GCR and GLK-GCR block ack) extends the block ack mechanism to group addressed frames that are transmitted using the GCR block ack and GLK-GCR retransmission policies. Other than the exceptions noted in 10.25.8.2 (Scoreboard context control during GCR block ack) to 10.25.8.4 (GCR block

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ack BlockAckReq and BlockAck frame exchange sequences(#109)), the operation of GCR block ack is the same as is described in 10.25.6 (HT-immediate block ack extensions).

An HE AP shall not send a GCR MU-BAR Trigger frame to a non-AP HE STA if the most recently received Extended Capabilities element from the STA does not indicate support for Robust AV Streaming or Advanced GCR.

### 10.25.8.2 Scoreboard context control during GCR block ack

For each GCR block ack agreement, each recipient shall maintain a block acknowledgment record. This record includes the following information:

— A bitmap, indexed by sequence number
— A 12-bit unsigned integer starting sequence number
— $WinStart_R$, representing the lowest sequence number position in the bitmap
— $WinEnd_R$, representing the highest sequence number in the current transmission window
— The maximum transmission window size, $WinSize_R$

$WinSize_R$ is set to the smaller of 64 and the value of the Buffer Size field of the associated ADDBA Response frame that established the block ack agreement. $WinEnd_R$ is defined as the highest sequence number in the current transmission window. A STA implementing a GCR block ack agreement shall maintain the block acknowledgment record for that agreement according to the following rules:

a) At GCR block ack agreement establishment:
   1) $WinStart_R$ = the Starting Sequence Number subfield value (#4200)in the ADDBA Request frame that elicited the ADDBA Response frame that established the GCR block ack agreement.
   2) $WinEnd_R = WinStart_R + WinSize_R - 1$.
b) For each received Data frame that is (#407)related to a specific GCR block ack agreement, the block acknowledgment record for that agreement is modified as follows, where *SN* is the value of the Sequence Number subfield of the received Data frame:
   1) If $WinStart_R \le SN \le WinEnd_R$, set to 1 the bit in position *SN* within the bitmap.
   2) If $WinEnd_R < SN < WinStart_R + 2^{11}$,
      i) Set to 0 the bits corresponding to MPDUs with Sequence Number subfield values from $WinEnd_R + 1$ to $SN - 1$.
      ii) Set $WinStart_R = SN - WinSize_R + 1$.
      iii) Set $WinEnd_R = SN$.
      iv) Set to 1 the bit at position *SN* in the bitmap.
   3) If $WinStart_R + 2^{11} \le SN \le WinStart_R$, make no changes to the record.
c) For each received BlockAckReq frame that is (#407)related to a specific GCR block ack agreement, the block acknowledgment record for that agreement is modified as follows, where *SSN* is the value from the Starting Sequence Number subfield of the received BlockAckReq frame:
   1) If $WinStart_R < SSN \le WinEnd_R$,
      i) Set $WinStart_R = SSN$.
      ii) Set to 0 the bits corresponding to MPDUs with Sequence Number subfield values from $WinEnd_R + 1$ to $WinStart_R + WinSize_R - 1$.
      iii) Set $WinEnd_R = WinStart_R + WinSize_R - 1$.
   2) If $WinEnd_R < SSN < WinStart_R + 2^{11}$,
      i) Set $WinStart_R = SSN$.
      ii) Set $WinEnd_R = WinStart_R + WinSize_R - 1$.


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iii) Set to 0 bits the corresponding to MPDU with Sequence Number subfield values from $WinStart_R$ to $WinEnd_R$.

3) If $WinStart_R + 2^{11} \leq SSN \leq WinStart_R$, make no changes to the record.

### 10.25.8.3 Scoreboard context control during GLK-GCR block ack

GLK-GCR scoreboarding accounts for all GLK-GCR frames received under the GLK-GCR block ack agreement. The received frame may be discarded after SYNRA filtering (see 10.64 (Addressing of GLK Data frame transmission)) but still accounted for in the scoreboarding.

A GLK AP may (#6286)establish a GLK-GCR block ack agreement with each GLK STA that has indicated support for GLK-GCR in the Association/Reassociation Request frame when the GLK STA associated/ reassociated with the GLK AP. Each of those GLK STAs with GLK-GCR block ack agreement shall maintain a block acknowledgment record for full state operation as defined in 10.25.3 (Data and acknowledgment transfer using immediate block ack policy). This record includes the following information:

— A bitmap, indexed by sequence number
— A 12-bit unsigned integer starting sequence number
— $WinStart_R$, representing the lowest sequence number position in the bitmap
— $WinEnd_R$, representing the highest sequence number in the current transmission window
— The maximum transmission window size, $WinSize_R$

$WinSize_R$ is set to the smaller of 64 and the value of the Buffer Size subfield in the GLK-GCR Parameter Set element in the most recently received Association Response or the Reassociation Response frame that established the GLK-GCR block ack agreement, or the GLK Groupcast Mode Change Notification frame. $WinEnd_R$ is defined as the highest sequence number in the current transmission window. A STA implementing a GLK-GCR block ack agreement shall maintain the block acknowledgment record for that agreement according to the following rules:

a) At GCR block ack agreement establishment (either during general link establishment or when GLK-GCR groupcast mode changes):
   1) $WinStart_R$ = the Starting Sequence Number subfield value (#4200)in the GLK-GCR Parameter Set element included in the Association Response frame, Reassociation Response frame or in the GLK-GCR Groupcast Mode Change Notification frame.
   2) $WinEnd_R = WinStart_R + WinSize_R - 1$.
b) For each Data frame that is received under the GLK-GCR block ack agreement, the block acknowledgment record for that agreement is modified as follows, where SN is the value of the Sequence Number subfield in the received Data frame:
   1) If $WinStart_R \leq SN \leq WinEnd_R$, set to 1 the bit in position SN within the bitmap.
   2) If $WinEnd_R < SN < WinStart_R + 2^{11}$,
      i) Set to 0 the bits corresponding to MPDUs with Sequence Number subfield values from $WinEnd_R + 1$ to SN – 1.
      ii) Set $WinStart_R = SN - WinSize_R + 1$.
      iii) Set $WinEnd_R$ = SN.
      iv) Set to 1 the bit at position SN in the bitmap.
   3) If $WinStart_R + 2^{11} \leq SN \leq WinStart_R$, make no changes to the record.
c) For each BlockAckReq frame received under the GLK-GCR block ack agreement, the block acknowledgment record for that agreement is modified as follows, where SSN is the value from the Starting Sequence Number subfield in the received BlockAckReq frame:
   1) If $WinStart_R < SSN \leq WinEnd_R$,

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i) Set $WinStart_R$ = SSN.

ii) Set to 0 the bits corresponding to MPDUs with Sequence Number subfield values from $WinEnd_R + 1$ to $WinStart_R + WinSize_R - 1$.

iii) Set $WinEnd_R = WinStart_R + WinSize_R - 1$.

2) If $WinEnd_R$ < SSN < $WinStart_R + 2^{11}$,

i) Set $WinStart_R$ = SSN.

ii) Set $WinEnd_R = WinStart_R + WinSize_R - 1$.

iii) Set to 0 bits the corresponding to MPDU with Sequence Number subfield values from $WinStart_R$ to $WinEnd_R$.

3) If $WinStart_R + 2^{11} \leq$ SSN $\leq WinStart_R$, make no changes to the record.

### 10.25.8.4 GCR block ack BlockAckReq and BlockAck frame exchange sequences(#109)

A protective mechanism (such as transmitting an HCCA CAP, MCCA, or RTS/CTS; setting the Duration field in the first frame and response frames to update the NAVs of STAs in the BSS and OBSS(s); or using another mechanism described in 10.27 (Protection mechanisms) and 10.3.2.10 (Dual CTS protection)) should be used to reduce the probability of other STAs transmitting during the GCR TXOP.

If the retransmission policy for a group address is GCR Block Ack, an originator shall not transmit more than the GCR buffer size number of A-MSDUs with the RA field set to the GCR concealment address and the DA field of the A-MSDU subframe set to the GCR group address before sending a BlockAckReq frame to one of the STAs that has a GCR block ack agreement for this group address. The RA field of the BlockAckReq frame shall be set to the MAC address of the destination STA. Upon reception of the BlockAck frame, an originator may send a BlockAckReq frame to another STA that has a block ack agreement for this group address, and this process may be repeated multiple times. If the originator has a GCR block ack agreement with one or more of the HE STAs for this group address, the originator may send a GCR MU-BAR Trigger frame to one or more of the HE STAs that are in the awake state. Upon reception of the BlockAck frame from one or more HE STAs, the originator may send a GCR MU-BAR Trigger frame to one or more other HE STAs that have a GCR block ack agreement, and this process may be repeated multiple times.(11ax)

NOTE 1—If the originator sends a BlockAckReq frame to a STA with a MAC address that matches the SA in any of the A-MSDUs transmitted during the GCR TXOP, the Block Ack Bitmap subfield does not indicate the MSDUs sourced from this STA. This is because the STA will have discarded all group addressed MPDUs transmitted by the AP that have the source address equal to their MAC address (see 10.3.6 (Group addressed MPDU transfer procedure)).

If a recipient receives a BlockAckReq frame with the GCR Group Address subfield equal to a GCR group address, the recipient shall transmit a BlockAck frame at a delay of SIFS after the BlockAckReq frame. The BlockAck frame acknowledges the STA's reception status of the block of group addressed frames requested by the BlockAckReq frame. If an HE STA receives a GCR MU-BAR Trigger frame with the AID12 subfield set to the 12 LSBs of the AID of the HE STA, the HE STA shall include the BlockAck frame in the HE TB PPDU sent in response to the Trigger frame. The BlockAck frame acknowledges the HE STA's reception status of the block of group addressed frames requested by the GCR MU-BAR Trigger frame.(11ax)

Figure 10-43 (Example of frame exchange sequence(#109) with GCR block ack retransmission policy) shows an example of a frame exchange sequence(#109) when the GCR block ack retransmission policy is used. The AP sends several A-MSDUs using the GCR block ack retransmission policy. The AP then sends a BlockAckReq frame to group member 1 of the GCR group, waits for the BlockAck frame, and then sends a BlockAckReq frame to group member 2. After receiving the BlockAck frame from GCR group member 2, the AP determines whether any A-MSDUs need to be retransmitted and sends additional A-MSDUs (some of which might be retransmissions of previous A-MSDUs) using the GCR block ack retransmission policy.


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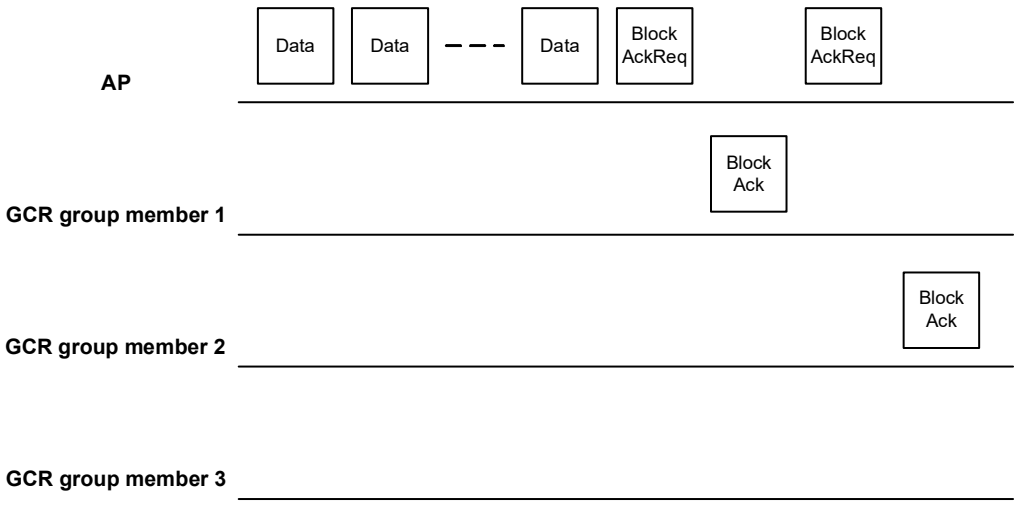


**Figure 10-43—Example of frame exchange sequence(#109) with GCR block ack**

(11ax)Figure 10-43 (Example of frame exchange sequence(#109) with GCR block ack retransmission policy) shows another example of a frame exchange sequence(#109) when the GCR block ack retransmission policy is used. The HE AP sends several A-MSDUs using the GCR block ack retransmission policy. The HE AP then sends a GCR MU-BAR Trigger frame to group members 1 and 2 of the GCR group, waits for the BlockAck frames, then sends a GCR MU-BAR Trigger frame to group members 3 and 4, and waits for the BlockAck frames. The HE AP then sends a BlockAckReq frame to group member 5, which is a non-HE STA, and waits for the BlockAck frame. After receiving the BlockAck frames, the HE AP determines whether any A-MSDUs need to be retransmitted and sends additional A-MSDUs (some of which might be retransmissions of previous A-MSDUs) using the GCR block ack retransmission policy.

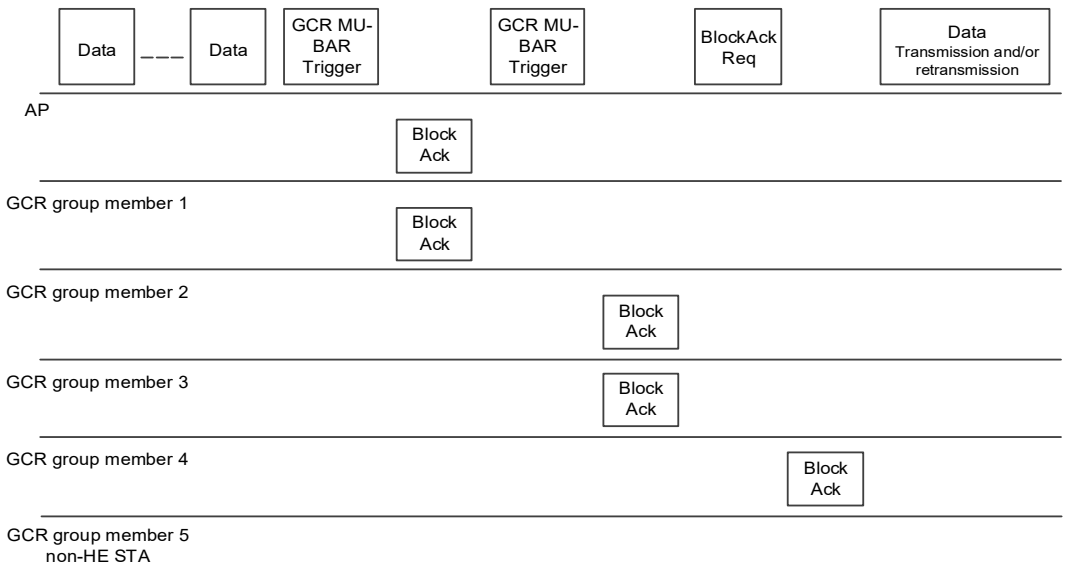


**Figure 10-44—Example of a frame exchange sequence(#109) with GCR MU-BAR**

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After completing the BlockAckReq or GCR MU-BAR Trigger frame and BlockAck (#109)frame exchange sequences, the originator determines, from the information provided in the BlockAck bitmap and from the missing BlockAck frame, the A-MSDUs, if any, that need to be retransmitted.(11ax)

An originator adopting the GCR block ack retransmission policy for a GCR group address chooses a lifetime limit for the group address. The originator may vary the lifetime limit for the group address at any time and may use different lifetime limits for different GCR group addresses. The originator transmits and retries each A-MSDU until the appropriate lifetime limit is reached or until each one has been received by all group members to which a BlockAckReq frame (11ax)or a GCR MU-BAR Trigger frame has been sent, whichever occurs first.

For GCR streams with retransmission policy equal to GCR Block Ack, an originator may regularly send a BlockAckReq frame with the GCR Group Address subfield in the BAR Information field set to the GCR group address and the (#270)Block Ack Starting Sequence Control subfield set to the Sequence Number field in the MPDU containing the earliest A-MSDU that has not been acknowledged by all group members and has not expired due to lifetime limits, in order to minimize buffering latency at receivers in the GCR group. An originator may also send a GCR MU-BAR Trigger frame with the AID12 fields set to the 12 LSBs of the AIDs of HE STAs that transmit the BlockAck frames and the Block Ack Starting Sequence Control subfield set to the Sequence Number field of the earliest A-MSDU of the GCR stream that has not been acknowledged by all group members and has not expired due to lifetime limits, in order to minimize buffering latency at receivers in the GCR group.(11ax)

NOTE 2—This is because an originator might transmit Management frames, QoS Data frames with a group address in the Address 1 field (including different GCR streams), and non-QoS Data frames intermingled. (#1938)Since these are transmitted using a single sequence number space, missing frames or frames sent to group addresses absent from a receiving STA's dot11GroupAddresses table complicate receiver processing for GCR streams with a GCR block ack retransmission policy since the cause of a hole in a receiver's block ack bitmap is ambiguous: it is due either to an MPDU being lost from the GCR stream or to transmissions of MPDUs not related to the GCR service using the same sequence number counter.

For GLK-GCR transmissions with retransmission policy equal to GLK-GCR block ack, an originator may send a BlockAckReq frame with the Block Ack Starting Sequence Control subfield set to the Sequence Number field in the MPDU containing the earliest MSDU that has not been acknowledged and has not expired due to lifetime limits, in order to minimize buffering latency at the receivers of the GLK-GCR transmission.

If an originator accepts two or more GCR agreements with multiple STAs where the GCR agreements have the same Ethernet classifiers, but different additional classifiers, then each STA receives multiple GCR flows from the originator and sends them to upper layers where the MSDUs irrelevant to the STA are discarded, in the same manner that non-GCR MSDUs irrelevant to the STA are discarded. In the Block Ack Bitmap field sent to the originator, each STA sets bits corresponding to MPDUs received from any of the multiple GCR streams. The originator should not retry MPDUs to the STA for the bit positions that are irrelevant to that STA.

The beginning of reception of an expected response to a BlockAckReq frame is detected by the occurrence of a PHY-CCA.indication(BUSY, channel-list) primitive at the STA that is expecting the response where the channel-list parameter is absent or, if present, includes "primary."

If the beginning of such reception does not occur during the first slot time following a SIFS, then the originator may perform error recovery by retransmitting a BlockAckReq frame (11ax)or a GCR MU-BAR Trigger frame PIFS after the previous BlockAckReq frame (11ax)or GCR MU-BAR Trigger frame if both of the following conditions are met:

— The carrier sense mechanism (see 10.3.2.1 (CS mechanism)) indicates that the medium is idle at the TxPIFS slot boundary (see Figure 10-29 (EDCA mechanism timing relationships(#14)(#1058))) after the expected start of a BlockAck frame, and


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— The remaining duration of the GCR TXOP is longer than the total time required to retransmit the GCR BlockAckReq frame (11ax)or GCR MU-BAR Trigger frame plus one slot time.

NOTE 3—If an originator fails to receive a BlockAck frame in response to a BlockAckReq frame and there is insufficient time to transmit a recovery frame, the AP retransmits the BlockAckReq frame in a new TXOP.

### 10.25.9 DMG block ack with flow control

#### 10.25.9.1 General

A DMG STA indicates that it is capable of supporting DMG block ack with flow control by (#6286)establishing the block ack with Flow Control field to 1 within the STA's DMG Capabilities element. A DMG block ack agreement with flow control can be established only when both originator and recipient support this capability.

#### 10.25.9.2 DMG block ack architecture with flow control

The DMG block acknowledgment(#553) rules are explained in terms of the architecture shown in Figure 10-45 (DMG block ack architecture) and explained in this subclause.

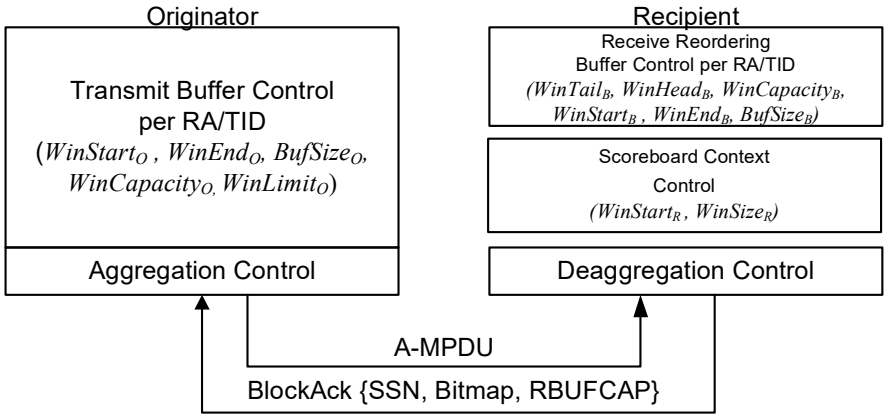


**Figure 10-45—DMG block ack architecture**

The originator contains a transmit buffer control that uses $WinStart_O$, $BufSize_O$, and $WinLimit_O$ to submit MPDUs for transmission, and releases transmit buffers upon receiving BlockAck frames from the recipient or when it advances the transmit control buffer window.

$WinStart_O$ is the starting sequence number of the transmit range, $WinLimit_O$ is the last sequence number expected to exhaust the receiver buffer capacity, and $BufSize_O$ is the number of buffers negotiated in the block ack agreement.

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Figure 10-46 (Flow control and its associated parameters as a function of receiver buffer size) shows the DMG block ack with flow control and its associated parameters from the originator perspective.

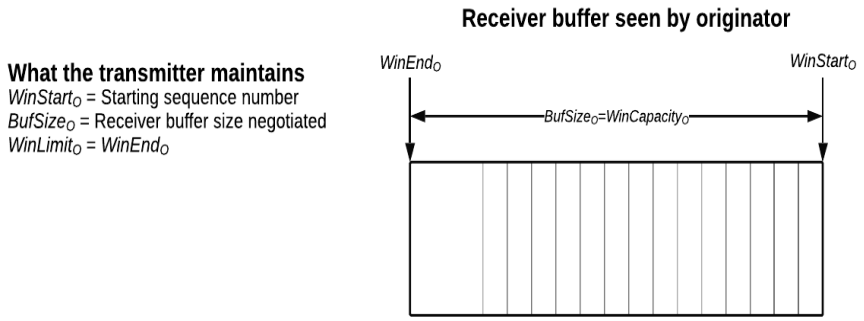


**Figure 10-46—Flow control and its associated parameters as a function of receiver buffer size**

The Aggregation control creates A-MPDUs. It can adjust the ack policy of transmitted QoS Data frames according to the rules defined in 10.25.6.7 (Originator's behavior) in order to solicit block ack responses.

The recipient contains a Receive Reordering Buffer Control per TA/TID, which contains related control state.

The receive reordering buffer is responsible for reordering MSDUs or A-MSDUs so that MSDUs or A-MSDUs are eventually passed up to the next MAC process in order of received sequence number (SN). It maintains its own state independent of the scoreboard context control to perform this reordering as specified in 10.25.6.6 (Receive reordering buffer control operation). The delivery of in order MSDUs or A-MSDUs to the next MAC process is implementation dependent. In some cases, the receiver reordering buffer might be forced to hold on to MSDUs ready for in order delivery due to deferred reception at the next MAC process. This behavior can impose additional buffering requirements on the receiver, causing the actual available buffer capacity to vary dynamically. The reordering buffer is required to manage its lowest and highest (in order) SN, which are marked as $WinTail_B$ and $WinHead_B$, respectively.

The scoreboard context control provides the $WinCapacity_B$, actually controlled by the Reordering buffer in addition to the bitmap field and the Starting Sequence Number field value(#6279)(#4200) to be sent in BlockAck frame responses to the originator.

### 10.25.9.3 Scoreboard context control with flow control

The scoreboard context control with flow control is defined in 10.25.6.3 (Scoreboard context control during full-state operation) and 10.25.6.4 (Scoreboard context control during partial-state operation).

### 10.25.9.4 Receive Reordering Buffer with flow control operation

#### 10.25.9.4.1 General

A recipient shall maintain a receive reordering buffer for each DMG block ack agreement. Each receive reordering buffer includes a record comprising the following:

— Buffered MSDUs or A-MSDUs that have been received, but not yet passed up to the next MAC process

— A $WinStart_B$ parameter, indicating the value of the Sequence Number field (SN) of the first (in order of ascending sequence number) MSDU or A-MSDU that has not yet been received


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- A $WinEnd_B$ parameter, indicating the highest SN expected to be received in the current reception range
- A $BufSize_B$ parameter, indicating the size of the reception window
- A $WinTail_B$ parameter, indicating the value of the Sequence Number field (SN) of the first (in order of ascending sequence number) MSDU or A-MSDU that has not yet been delivered to the next MAC process
- A $WinHead_B$ parameter, indicating the highest SN received in the current reception range

$WinStart_B$ is initialized to the Starting Sequence Number field value(#6279) of the ADDBA Request frame that elicited the ADDBA Response frame that established the DMG block ack agreement.

$WinEnd_B$ is initialized to $WinStart_B + BufSize_B - 1$, where $BufSize_B$ is set to the value of the Buffer Size field of the ADDBA Response frame that established the block ack agreement. (#6279)Both $WinTail_B$ and $WinHead_B$ are initialized to the preceding Starting Sequence Number field value(#6279), to indicate no MPDU was received, within the current reception window.

Any MSDU or A-MSDU that has been passed up to the next MAC process shall be deleted from the receive reordering buffer, advancing the $WinTail_B$.

The recipient shall pass MSDUs or A-MSDUs up to the next MAC process in order of increasing Sequence Number field value.

#### 10.25.9.4.2 Operation for DMG block ack agreement initialization

At DMG block ack agreement establishment:

a) $WinStart_B = SSN$,(#4200) where $SSN$ is the Starting Sequence Number field in the ADDBA Request frame that elicited the ADDBA Response frame that established the DMG block ack agreement
b) $WinEnd_B = WinStart_B + BufSize_B - 1$
c) $WinCapacity_B = BufSize_B$
d) $WinHead_B = SSN - 1$, where SSN is taken from the ADDBA Request, similar to $WinStart_B$
e) $WinTail_B = SSN - 1$

#### 10.25.9.4.3 Operation for each received Data frame

For each received Data frame that is related to a specific DMG block ack agreement, the receive reordering buffer record is modified as follows, where SN is the value of the Sequence Number field of the received MPDU:

a) If $WinStart_B \le SN \le WinEnd_B$
    1) Store the received MPDU in the buffer.
        i) If $SN > WinHead_B$, Set $WinHead_B = SN$.
        ii) If $SN > (WinTail_B + BufSize_B)$,
            1) (#270)All MSDUs and A-MSDUs buffered with sequence numbers from $WinTail_B$ to $SN - BufSize_B$ that were received correctly are passed to the next MAC process.
            2) Set $WinTail_B = SN - BufSize_B$.
        iii) Set $WinCapacity_B = WinTail_B + BufSize_B - WinHead_B$.
    2) Set $WinStart_B$ to the value of the Sequence Number field of the first MSDU or A-MSDU that is missing to allow in-order delivery to the next MAC process.
    3) Set $WinEnd_B = WinStart_B + BufSize_B - 1$.
b) If $WinEnd_B < SN < WinStart_B + 2^{11}$

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1) Store the received MPDU in the buffer.
2) Set $WinEnd_B = SN$.
3) Set $WinStart_B = WinEnd_B - BufSize_B + 1$.
4) (#270)All MSDUs and A-MSDUs buffered with sequence numbers from $WinTail_B$ to $SN - BufSize_B$ that were received correctly are passed to the next MAC process.
5) Set $WinTail_B = SN - BufSize_B$.
6) Set $WinHead_B = SN$.
7) Set $WinCapacity_B = WinTail_B + BufSize_B - WinHead_B$.

c) If $WinStart_B + 2^{11} \leq SN < WinStart_B$, discard the MPDU (do not store the MPDU in the buffer, do not pass the MSDU or A-MSDU up to the next MAC process).

d) For each received BlockAckReq frame the block acknowledgment record for that agreement is modified as follows, where SSN is the value from the Starting Sequence Number field of the received BlockAckReq frame:

1) If $WinStart_B < SSN \leq WinEnd_B$
   i) Set $WinStart_B = SSN$.
   ii) Set $WinEnd_B = WinStart_B + BufSize_B - 1$.
   iii) If $SSN > WinHead_B$, set $WinHead_B = SSN - 1$.
   iv) If $SSN > (WinTail_B + BufSize_B)$,
      1) (#270)All MSDUs and A-MSDUs buffered with sequence numbers from $WinTail_B$ to $SSN - BufSize_B$, are discarded from the buffer.
      2) Set $WinTail_B = SSN - BufSize_B$.
   v) Set $WinCapacity_B = WinTail_B + BufSize_B - WinHead_B$.
2) If $WinEnd_B < SSN < WinStart_B + 2^{11}$
   i) Set $WinStart_B = SSN$.
   ii) Set $WinEnd_B = WinStart_B + BufSize_B - 1$.
   iii) Set $WinHead_B = SSN - 1$.
   iv) If $SSN > (WinTail_B + BufSize_B)$,
      1) (#270)All MSDUs and A-MSDUs buffered with sequence numbers from $WinTail_B$ to $SSN - BufSize_B$, are discarded from the buffer.
      2) Set $WinTail_B = SSN - BufSize_B$.
   v) Set $WinCapacity_B = WinTail_B + BufSize_B - WinHead_B$.
3) If $WinStart_B + 2^{11} \leq SSN \leq WinStart_B$, make no changes to the record.

#### 10.25.9.4.4 Operation for ongoing release of received MPDUs

The reordering buffer shall continue to pass MSDUs or A-MSDUs up to the next MAC process that are stored in the buffer in order of increasing value of the Sequence Number field, starting with the MSDU or A-MSDU that has $SN = WinTail_B$ and proceeding sequentially until there is no ready in-order MSDU or A-MSDU buffered for the next sequential value of the Sequence Number field.

a) Set $WinTail_B$ to the value of the Sequence Number field of the last MSDU or A-MSDU that was passed up to the next MAC process plus one.

### 10.25.9.5 Generation and transmission of BlockAck frame by a STA with flow control

In addition to the behavior specified in 10.25.6.5 (Generation and transmission of BlockAck frames by an HT STA, DMG STA, or S1G STA) when responding with a BlockAck frame, the RBUFCAP field shall be updated with the value of $WinCapacity_B$.


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#### 10.25.9.6 Originator's behavior with flow control support

If the BA with Flow Control field within a recipient's DMG Capabilities element is equal to 1, the originator shall not transmit an MPDU with a SN that is beyond the current recipient's buffer capacity ($WinLimit_O$).

The BlockAck frame indicates the number of free buffer slots available at the recipient for reception of additional MPDUs.

The originator shall update $WinLimit_O$ upon reception of a valid BlockAck:

— Set $WinCapacity_O$ to the received value of the RBUFCAP field in the BlockAck frame.
— Set *MostSuccSN* to the highest *SN* of positively acknowledged MPDUs
— Set $WinLimit_O = MostSuccSN + WinCapacity_O$

NOTE—Updating $WinLimit_O$ limits the transmission of the following MPDUs.

Originator's support of recipient's partial state is defined in 10.25.6.9 (Originator's support of recipient's partial state).

### 10.25.10 Unsolicited block ack extension(11ay)

#### 10.25.10.1 Introduction

The unsolicited block ack is an extension to the HT-Immediate block ack mechanism that allows transmission of A-MPDUs without the need for a prior exchange of ADDBA Request and ADDBA Response frames (#6286)to establish the agreement. The unsolicited block ack extension also enables optimizing the buffering requirements needed at the recipient side with the ability to share the recipient resources among all originators.

A recipient that supports the unsolicited block ack extension is ready to use this mechanism with an originator following the exchange of frames as specified in 10.25.2 (Setup and modification of the block ack parameters).

#### 10.25.10.2 Unsolicited block ack extension agreement architecture

The unsolicited block ack extension to the HT-immediate block ack architecture is identical to the HT-immediate block ack extension architecture described in 10.25.6.2 (HT-immediate block ack architecture) with the following rules:

— (#6310)$WinSize_O$ is the value of the Buffer Size field advertised in the recipient's Unsolicited Block Ack Extension element.
— (#6310)$WinStart_O$ is equal to the sequence number of the first MPDU inside the first A-MPDU sent with a specific tuple <TA, RA, TID>.
— The recipient shall only use full-state operation of the scoreboard context control.

#### 10.25.10.3 Scoreboard context control during full-state operation

The scoreboard context control for the unsolicited block ack extension mechanism shall follow the rules of full-state operation defined in 10.25.6.3 (Scoreboard context control during full-state operation) with the following additional rule. When the recipient flushes buffers in the reordering buffer control, the bits in the bitmap position in the block acknowledgment record for the SNs that are higher than the lowest SN of all unsuccessful MPDUs and lower than the highest SN of all successful MPDUs are set to 0. $WinStart_R$, $WinSize_R$, and $WinEnd_R$ remain unchanged.

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#### 10.25.10.4 Generation and transmission of BlockAck frames

The recipient shall follow the same rules defined in 10.25.6.5 (Generation and transmission of BlockAck frames by an HT STA, DMG STA, or S1G STA).

#### 10.25.10.5 Receive reordering buffer control operation

The receive reordering buffer control behaves the same as in the HT-Immediate block ack agreement defined in 10.25.6.6 (Receive reordering buffer control operation), with the ability of the recipient to flush the buffers when it starts receiving from a different originator or TID.

Under the unsolicited block ack extension mechanism, the parameters are initialized as follows:

- $WinSize_B$ is set to the value of the Buffer Size field advertised in the Unsolicited Block Ack Extension element.
- When the unsolicited block ack extension agreement is established, $WinEnd_B$ is initialized to the sequence number of the first MPDU inside the first A-MPDU sent with a specific tuple <TA, RA, TID>, and (#6310)$WinStart_B$ is set to $WinEnd_B - WinSize_B + 1$.
- The buffered MSDUs in the receive reordering buffer control may be flushed when the STA starts receiving from a different <TA, TID> pair.

The recipient shall pass MSDUs and A-MSDUs up to the next MAC process in order of increasing sequence number.

#### 10.25.10.6 Originator behavior and block ack state maintenance

In addition to the rules defined for the HT-immediate block ack extension specified in 10.25.6.7 (Originator's behavior) and 10.25.6.8 (Maintaining block ack state at the originator), an originator that utilizes the unsolicited block ack extension mechanism:

- Shall not transmit an A-MPDU corresponding to a tuple <TA, RA, TID> before synchronizing at the recipient the *SSN*, $WinStart_R$, and $WinStart_B$ parameters for the specific tuple. The originator may transmit either an MPDU or a BlockAckReq frame to initiate the synchronization. Synchronization is confirmed by reception of an Ack frame from the recipient when an MPDU was used, or by a BlockAck frame when a BlockAckReq was used.
- Shall not release transmitted buffers (MPDUs) with *SN* equal or higher than the first unsuccessful MPDU.
- At the end of a TXOP or SP, shall set to 0 the acknowledgment status of MPDUs with *SN* equal or higher than the first unsuccessful MPDU even if such MPDUs have been already positively acknowledged.
- At the start of the next TXOP or SP, may transmit all the MPDUs with *SN* equal or higher than the first unsuccessful MPDU, or may send a BlockAckReq frame with (#4200)the Starting Sequence Number field equal to the *SN* of the first unsuccessful MPDU to determine the state of the buffers at the recipient and retransmit MPDUs that are not received or flushed by the recipient.

The originator shall not use the multi-TID variant with a recipient if the recipient has not set the Multi-TID Supported subfield in the recipient's Unsolicited Block Ack Extension element to 1.

## 10.26 No Acknowledgment (No Ack)

When a QoS Data frame is transmitted with No Ack ack policy, there is no MAC-level recovery, and the reliability of this traffic is reduced, relative to the reliability of traffic with other ack policy, due to the increased probability of lost frames from interference, collisions, or time-varying channel parameters. A protective


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mechanism (such as transmitting using HCCA, RTS/CTS, or the mechanism described in 10.27 (Protection mechanisms)) should be used to reduce the probability of other STAs transmitting during the TXOP.

## 10.27 Protection mechanisms

### 10.27.1 Introduction

These protection mechanisms cause a STA that is a potential interferer to defer any transmission for a known period of time. When these mechanisms are used, non-ERP STAs do not interfere with frame exchange sequences(#109) using ERP PPDUs between ERP STAs and non-HT STAs do not interfere with frame exchanges using HT PPDUs between HT STAs.

### 10.27.2 Protection mechanism for non-ERP receivers

The intent of a protection mechanism is to cause a STA not to transmit an MPDU with the Type subfield equal to Data or an MMPDU with an ERP-OFDM preamble and header unless it has attempted to update the NAV of receiving non-ERP STAs. The updated NAV period shall be longer than or equal to the total time required to send the Data and any required response frames. An ERP STA shall use protection mechanisms (such as RTS/CTS or CTS-to-self) for ERP-OFDM MPDUs with the Type subfield equal to Data or an MMPDU when the Use_Protection field of the ERP element is equal to 1 (see the requirements of 10.6 (Multirate support)). Protection mechanisms frames shall be sent using one of the mandatory Clause 15 (DSSS PHY specification for the 2.4 GHz band designated for ISM applications) or Clause 16 (High rate direct sequence spread spectrum (HR/DSSS) PHY specification) rates and using one of the mandatory Clause 15 (DSSS PHY specification for the 2.4 GHz band designated for ISM applications) or Clause 16 (High rate direct sequence spread spectrum (HR/DSSS) PHY specification) waveforms, so all STAs in the BSA are able to learn the duration of the exchange even if they cannot detect the ERP-OFDM signals using their CCA function.

In the case of a BSS composed of only ERP STAs, but with knowledge of a neighboring co-channel BSS having non-ERP traffic, the AP might need protection mechanisms to protect the BSS's traffic from interference. This provides propagation of NAV to all attached STAs and all STAs in a neighboring co-channel BSS within range by messages sent using rates contained in the BSSBasicRateSet parameter. The frames that propagate the NAV throughout the BSS include RTS/CTS/Ack frames, all Data frames with the More Fragments field equal to 1, all Data or Management frames sent in response to a(#375) PS-Poll frame that are not preceded(#1212) in the frame exchange sequence by a Data frame with the More Fragments field equal to 1, and CF-End frames.

When RTS/CTS is used as the protection mechanism, cases exist such as NAV resetting (discretionary, as indicated in 10.3.2.4 (Setting and resetting the NAV)), where a hidden STA may reset its NAV and this might cause a collision. The likelihood of occurrence is low, and it is not considered to represent a significant impairment to overall system operation. A mechanism to address this possible situation would be to use alternative protection mechanisms or to revert to alternative modulation methods.

The rules for calculating RTS/CTS NAV fields are unchanged when using RTS/CTS as a protection mechanism.

Additionally, if any of the rates in the BSSBasicRateSet parameter of the protection mechanism frame transmitting STA's BSS are Clause 15 (DSSS PHY specification for the 2.4 GHz band designated for ISM applications) or Clause 16 (High rate direct sequence spread spectrum (HR/DSSS) PHY specification) rates, then the protection mechanism frames shall be sent at one of those Clause 15 (DSSS PHY specification for the 2.4 GHz band designated for ISM applications) or Clause 16 (High rate direct sequence spread spectrum (HR/DSSS) PHY specification) basic rates.

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The NonERP_Present bit shall be set to 1 when a non-ERP STA is associated with the BSS. In an IBSS if an IBSS STA detects one or more non-ERP STAs that are members of the same IBSS the NonERP_Present bit should be set to 1. Examples of when the NonERP_Present bit may additionally be set to 1 include, but are not limited to, when:

a) A non-ERP infrastructure BSS or non-ERP IBSS is overlapping (a non-ERP BSS may be detected by the reception of a Beacon frame where the supported rates contain only Clause 15 (DSSS PHY specification for the 2.4 GHz band designated for ISM applications) or Clause 16 (High rate direct sequence spread spectrum (HR/DSSS) PHY specification) rates).

b) In an IBSS if a Beacon frame is received from one of the IBSS participants where the operational rate set contains no Clause 18 (Extended Rate PHY (ERP) specification) rates and no BSS membership selectors.

c) A Management frame (excluding a Probe Request) is received where the operational rate set contains no Clause 18 (Extended Rate PHY (ERP) specification) rates and no BSS membership selectors.

A non-ERP mesh STA shall set the NonERP_Present and Use_Protection bits to 1, when establishing a mesh peering with a mesh STA.

When a mesh STA establishes a mesh peering with a non-ERP mesh STA, the mesh STA shall set the NonERP_Present bit to 1 and the mesh STA should set the Use_Protection bit to 1. In addition, a mesh STA should set the NonERP_Present bit and the Use_Protection bit to 1 when

— A mesh STA detects the overlapped presence of either a non-ERP BSS, a non-ERP IBSS, or a non-ERP MBSS, or

— A Beacon frame is received from a neighbor STA where the operational rate set contains no Clause 18 (Extended Rate PHY (ERP) specification) rates and no BSS membership selectors, or

— A Management frame (excluding Probe Request) is received where the operational rate set contains no Clause 18 (Extended Rate PHY (ERP) specification) rates and no BSS membership selectors.

A mesh STA may set the NonERP_Present and the Use_Protection bits to 1 based on its internal policies, which is beyond the scope of the standard.

The Use_Protection bit may be set to 1 when the NonERP_Present bit is 1.

If one or more non-ERP STAs are associated in the BSS, the Use_Protection bit shall be set to 1 in transmitted ERP elements.

In an IBSS the setting of the Use_Protection bit is left to the STA. In an IBSS there is no uniform concept of association; therefore, a typical algorithm for setting the Use_Protection bit takes into account the traffic pattern and history on the network. If an IBSS STA detects one or more non-ERP STAs that are members of the same IBSS or receives a Beacon from a member of the same IBSS with the Use_Protection bit equal to 1, then the Use_Protection bit should be set to 1 in the ERP element of transmitted Beacon and Probe Response frames.

An ERP STA shall invoke the use of a protection mechanism after transmission or reception of the Use_Protection bit with a value of 1 in an MMPDU to or from the BSS that the ERP STA has joined or started. An ERP STA may additionally invoke protection mechanism use at other times. An ERP STA may disable protection mechanism use after transmission or reception of the Use_Protection bit with a value of 0 in an MMPDU to or from the BSS that the ERP STA has joined or started.

An ERP mesh STA shall invoke the use of a protection mechanism after the transmission of the Use_Protection bit with a value of 1 in an MMPDU. In addition, an ERP mesh STA may invoke protection


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mechanism at other times. An ERP mesh STA may disable protection mechanism use after transmission of the Use_Protection bit with a value of 0 in an MMPDU.

When there are no non-ERP STAs associated with the BSS and the ERP element sender's dot11ShortPreambleOptionImplemented is true, then the Barker_Preamble_Mode bit may be set to 0. The Barker_Preamble_Mode bit shall be set to 1 by the ERP element sender if one or more associated non-ERP STAs are not short preamble capable as indicated in their Capability Information field, or if the ERP element senders dot11ShortPreambleOptionImplemented is false.

When dot11ShortPreambleOptionImplemented is true and all peer mesh STAs support the short preamble, the mesh STA may set the Barker_Preamble_Mode bit to 0. When dot11ShortPreambleOptionImplemented is false or any of its peer mesh STAs do not support the short preamble, the mesh STA shall set the Barker_Preamble_Mode field to 1.

If an IBSS STA detects one or more nonshort-preamble-capable STAs that are members of the same IBSS, then the Barker_Preamble_Mode bit should be set to 1 in the transmitted ERP element.

An ERP STA shall use long preambles when transmitting Clause 15 (DSSS PHY specification for the 2.4 GHz band designated for ISM applications), Clause 16 (High rate direct sequence spread spectrum (HR/DSSS) PHY specification), and Clause 18 (Extended Rate PHY (ERP) specification) frames after transmission or reception of an ERP element with a Barker_Preamble_Mode value of 1 in an MMPDU to or from the BSS that the ERP STA has joined or started, regardless of (#402)the value of the Short Preamble subfield in the Capability Information field from the same received or transmitted MMPDU that contained the ERP element. An ERP STA may additionally use long preambles when transmitting Clause 15 (DSSS PHY specification for the 2.4 GHz band designated for ISM applications), Clause 16 (High rate direct sequence spread spectrum (HR/DSSS) PHY specification), and Clause 18 (Extended Rate PHY (ERP) specification) frames at other times. An ERP STA may use short preambles when transmitting Clause 15 (DSSS PHY specification for the 2.4 GHz band designated for ISM applications), Clause 16 (High rate direct sequence spread spectrum (HR/DSSS) PHY specification), and Clause 18 (Extended Rate PHY (ERP) specification) frames after transmission or reception of an ERP element with a Barker_Preamble_Mode value of 0 in an MMPDU to or from the BSS that the ERP STA has joined or started, regardless of (#402)the value of the Short Preamble subfield in the Capability Information field from the same received or transmitted MMPDU. A non-ERP STA may also follow the rules given in this paragraph.

An ERP mesh STA shall use long preambles when transmitting Clause 15 (DSSS PHY specification for the 2.4 GHz band designated for ISM applications), Clause 16 (High rate direct sequence spread spectrum (HR/DSSS) PHY specification), and Clause 18 (Extended Rate PHY (ERP) specification) frames after transmission or reception of an ERP element with a Barker_Preamble_Mode value of 1 in an MMPDU to or from the MBSS to which the ERP mesh STA belongs. A Mesh STA may use long preambles when transmitting Clause 15 (DSSS PHY specification for the 2.4 GHz band designated for ISM applications), Clause 16 (High rate direct sequence spread spectrum (HR/DSSS) PHY specification), and Clause 18 (Extended Rate PHY (ERP) specification) frames at other times.

### 10.27.3 Protection mechanisms for transmissions of HT PPDUs

#### 10.27.3.1 General

Transmissions of HT PPDUs, referred to as *HT transmissions*, are protected if there are other STAs present that cannot interpret HT transmissions correctly. The HT Protection and Nongreenfield HT STAs Present fields in the HT Operation element within Beacon and Probe Response frames are used to indicate the protection requirements for HT transmissions.

The HT Protection field may be set to no protection mode only if the following are true:

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- All STAs detected (by any means) in the primary or the secondary channel are HT STAs, and
- All STAs that are known by the transmitting STA to be a member of this BSS are either
  - 20/40 MHz HT STAs in a 20/40 MHz BSS, or
  - 20 MHz HT STAs in a 20 MHz BSS.

The HT Protection field may be set to nonmember protection mode only if the following are true:

- A non-HT STA is detected (by any means) in either the primary or the secondary channel or in both the primary and secondary channels, that is not known by the transmitting STA to be a member of this BSS, and
- All STAs that are known by the transmitting STA to be a member of this BSS are HT STAs.

The HT Protection field may be set to 20 MHz protection mode only if the following are true:

- All STAs detected (by any means) in the primary channel and all STAs detected (by any means) in the secondary channel are HT STAs and all STAs that are members of this BSS are HT STAs, and
- This BSS is a 20/40 MHz BSS, and
- There is at least one 20 MHz HT STA associated with this BSS.

The HT Protection field is set to non-HT mixed mode otherwise.

NOTE 1—The rules stated above allow an HT AP to select non-HT mixed mode at any time.

In an IBSS, the HT Protection field is reserved, but an HT STA shall protect HT transmissions as though the HT Protection field were equal to non-HT mixed mode. An IBSS STA shall protect HT-greenfield format PPDUs and RIFS sequences, adhering to the same requirements as described in the line of Table 10-26 (Protection requirements for HT Protection field values nonmember protection mode and non-HT mixed mode) labeled "Use_Protection = 0 or ERP element is not present (HT Protection field equal to non-HT mixed mode)."

**Table 10-26—Protection requirements for HT Protection field values nonmember protection mode and non-HT mixed mode**

| Condition | Requirements |
|---|---|
| Use_Protection = 0 or ERP element is not present<br>(HT Protection field equal to non-HT mixed mode) | The protection requirements for HT transmissions using HT-greenfield format are specified in 10.27.3.1 (General).<br><br>The protection requirements for HT transmissions using RIFS within the HT transmission burst are specified in 10.27.3.3 (RIFS protection).<br><br>The protection mechanism for other transmissions not already described above is based on one of the sequences defined in Table 10-27 (Applicable HT protection mechanisms). |
| Use_Protection = 1<br>(HT Protection field equal to nonmember protection mode or non-HT mixed mode) | All HT transmissions shall be protected using mechanisms as described in 10.27.2 (Protection mechanism for non-ERP receivers). |

In an MBSS, the HT Protection field and the Nongreenfield HT STAs Present field are determined as described in 10.27.3.5 (Protection rules for an HT mesh STA).


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In an IBSS and an MBSS, the RIFS Mode field of the HT Operation element is reserved, but an HT STA shall operate as though this field were equal to 1.

When the HT Protection field is equal to no protection mode or 20 MHz protection mode and the Nongreenfield HT STAs Present field is equal to 0, no protection is required since all HT STAs in the BSS are capable of decoding HT-mixed format and HT-greenfield format transmissions.

When the HT Protection field is equal to no protection mode or 20 MHz protection mode and the Nongreenfield HT STAs Present field is equal to 1, HT transmissions that use the HT-greenfield format shall be protected. This protection may be established by transmitting a PPDU with the TXVECTOR FORMAT parameter set to HT_MF or any of the methods described in Table 10-27 (Applicable HT protection mechanisms).

**Table 10-27—Applicable HT protection mechanisms**

| HT protection mechanism |
|---|
| Control frames such as RTS/CTS or CTS-to-self prior to the HT transmissions:<br>— 20 MHz transmissions use the rates defined in Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) or Clause 18 (Extended Rate PHY (ERP) specification)<br>— 40 MHz transmissions use non-HT duplicate frames defined in Clause 19 (High Throughput (HT) PHY specification(#2297)) |
| As the first PPDU in the TXOP, send one of:<br>— A non-HT PPDU containing a frame that requires an immediate response<br>— An HT-mixed format PPDU containing a frame that requires an immediate response in a non-HT PPDU<br>PPDUs after the first PPDU exchange may be HT-greenfield format PPDUs and/or be separated by RIFS. |

When the HT Protection field is equal to nonmember protection mode and the Use_Protection field in the ERP element is equal to 0, HT transmissions should be protected. When the HT Protection field is equal to nonmember protection mode, the Use_Protection field in the ERP element is equal to 0, and the Nongreenfield HT STAs Present field is equal to 1, HT transmissions using HT-greenfield format shall be protected. When the HT Protection field is equal to nonmember protection mode and the Use_Protection field in the ERP element is equal to 1, HT transmissions shall be protected according to the requirements described in Table 10-26 (Protection requirements for HT Protection field values nonmember protection mode and non-HT mixed mode).

When the HT Protection field is equal to non-HT mixed mode, HT transmissions shall be protected. The type of protection required depends on the type of transmission as well as the type of the non-HT STAs that are present in the BSS. Protection requirements that apply when the HT Protection field is equal to non-HT mixed mode are described in Table 10-26 (Protection requirements for HT Protection field values nonmember protection mode and non-HT mixed mode).

NOTE 2—Rules for rate selection for the HT protection mechanisms listed in Table 10-27 (Applicable HT protection mechanisms) are described in 10.6 (Multirate support).

If the HT Protection field is equal to no protection mode and the Secondary Channel Offset field is equal to SCA or SCB, a STA may transmit a 40 MHz HT PPDU (TXVECTOR parameter CH_BANDWIDTH set to HT_CBW40) to initiate a TXOP provided that the restrictions specified in 10.6 (Multirate support) are obeyed. When the HT Protection field is not equal to no protection mode or the Secondary Channel Offset field is equal to SCN, a STA shall not transmit a 40 MHz HT PPDU (TXVECTOR parameter CH_BANDWIDTH set to HT_CBW40) to initiate a TXOP.

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### 10.27.3.2 Protection rules for HT STA operating a direct link

An HT STA operating a direct link with another HT STA in a non-HT BSS shall operate according to the rules found in 10.27 (Protection mechanisms) as though the following fields have the settings indicated:

a) The RIFS Mode field of the HT Operation element equal to 1
b) The HT Protection field equal to non-HT mixed mode
c) The Nongreenfield HT STAs Present field equal to 1
d) The OBSS Non-HT STAs Present field equal to 1
e) The Basic HT-MCS Set field equal to all 0s

### 10.27.3.3 RIFS protection

If the HT Protection field is equal to nonmember protection mode or non-HT mixed mode, the AP may set the RIFS Mode field to 0 according to (M118)implementation specific criteria (i.e., such as to protect overlapping non-HT BSSs in the primary or secondary channels).

If the HT Protection field is not equal to nonmember protection mode and it is not equal to non-HT mixed mode, the RIFS Mode field shall be set to 1.

If the RIFS Mode field of an AP's HT Operation element is equal to 1:

a) A STA that is associated with the AP may protect RIFS sequences when the HT Protection field of the HT Operation element transmitted by the AP is equal to nonmember protection mode.
b) A STA that is associated with the AP shall protect RIFS sequences when the HT Protection field of the HT Operation element transmitted by the AP is equal to non-HT mixed mode.

### 10.27.3.4 Use of OBSS Non-HT STAs Present field

The OBSS Non-HT STAs Present field allows HT APs to report the presence of non-HT STAs that are not members of its BSS in the primary channel, the secondary channel, or in both primary and secondary channels.

A second HT AP that detects a first HT AP's Beacon frame with the OBSS Non-HT STAs Present field equal to 1 may cause HT-greenfield format and RIFS sequence transmissions of the second AP's BSS to be protected by setting the HT Protection field of its HT Operation element to non-HT mixed mode. If the NonERP_Present field is equal to 1 in the first AP's Beacon frame, the Use_Protection field may also be set to 1 by the second AP.

An HT STA may also scan for the presence of non-HT devices either autonomously or, for example, after the STA's AP transmits an HT Operation element with the HT Protection field equal to nonmember protection mode. Non-HT devices can be detected as follows:

— Reception of a Management frame that does not carry an HT Capabilities element and the frame is required to carry this element when transmitted by an HT STA, or
— Reception of a Beacon frame containing an HT Operation element with the OBSS Non-HT STAs Present field equal to 1.

When non-HT devices are detected, the STA may enable protection of its HT-greenfield format and RIFS sequence transmissions.

NOTE—If a non-HT device is detected and the STA determines that its HT-greenfield format or RIFS sequence transmissions are affecting the operation of the non-HT device, then the STA might enable protection of its HT-greenfield format and RIFS sequence transmissions.


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See also 11.8.8.5 (HT-greenfield transmissions in operating classes that include a behavior limit of DFS_50_100_Behavior), which defines rules for the OBSS Non-HT STAs Present field related to HT-greenfield transmissions in certain operating classes.

### 10.27.3.5 Protection rules for an HT mesh STA

A mesh STA determines the HT Protection and Nongreenfield HT STAs Present fields in the HT Operation element in the transmitting frame as follows:

The HT Protection field in a mesh STA may be set to no protection mode only if

- All STAs detected in the primary or the secondary channel are HT STAs, and
- All mesh STA members of this MBSS that are one-hop neighbors of the transmitting mesh STA are either:
  - 20/40 MHz HT mesh STAs in a 20/40 MHz MBSS, or
  - 20 MHz HT mesh STAs in a 20 MHz MBSS.

The HT Protection field in a mesh STA may be set to nonmember protection mode only if

- A non-HT STA is detected in either the primary or the secondary channel or in both the primary and secondary channels, that is not known by the transmitting mesh STA to be a member of this MBSS, and
- All mesh STA members of this MBSS that are one-hop neighbors of the transmitting mesh STA are HT mesh STAs.

The HT Protection field in a mesh STA may be set to 20 MHz protection mode only if

- All STAs detected in the primary and all STAs detected in the secondary channel are HT STAs, and
- All mesh STA members of this MBSS that are one-hop neighbors of the transmitting mesh STA are HT mesh STAs, and
- The MBSS is a 20/40 MHz MBSS, and
- There is at least one 20 MHz HT mesh STA that is one-hop neighbor of the transmitting mesh STA.

The HT Protection field in a mesh STA is set to non-HT mixed mode otherwise.

If two peer HT mesh STAs report the same protection mode in HT Protection field, the protection mechanisms of the related mode shall be used to protect the transmission between the peer HT mesh STAs.

If an HT mesh STA and its peer HT mesh STA report different protection modes in HT Protection field, the following rules shall be used:

a) If an HT mesh STA or its peer HT mesh STA reports non-HT mixed mode, the protection mechanisms of non-HT mixed mode shall be used to protect the transmission between the peer HT mesh STAs.

b) If an HT mesh STA or its peer HT mesh STA reports nonmember protection mode and non-HT mixed mode is not reported by any of these HT mesh STAs, the protection mechanisms of nonmember protection mode shall be used to protect the transmission between the peer HT mesh STAs.

c) If an HT mesh STA or its peer HT mesh STA reports 20 MHz protection mode and neither non-HT mixed mode nor nonmember protection mode is reported by any of these HT mesh STAs, the protection mechanisms of 20 MHz protection mode shall be used to protect the transmission between the peer HT mesh STA.

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If at least one HT peer mesh STA in its mesh neighborhood indicates the Nongreenfield HT STAs Present equal to 1, the protection rules related to Nongreenfield HT STAs Present should also be applied to the communication between HT peer mesh STAs.

### 10.27.4 L_LENGTH and L_DATARATE parameter values for HT-mixed format PPDUs

L_LENGTH and L_DATARATE determine the duration that non-HT STAs do not transmit, equal to the remaining duration of the HT PPDU, following the non-HT portion of the preamble of the HT-mixed format PPDU.

The L_DATARATE parameter of the TXVECTOR shall be set to the value 6 Mb/s.

A STA that is transmitting a PPDU with the FORMAT parameter of the TXVECTOR equal to HT_MF shall set the value of the L_LENGTH parameter to the value (in octets) given by Equation (10-17):

$$\text{L\_LENGTH} = \left\lceil \frac{((\text{TXTIME} - \text{Signal Extension}) - \text{NonHTLength})}{\text{aSymbolLength}} \right\rceil \times N_{OPS} - \left\lceil \frac{\text{PHYServiceLength} + \text{PHYConvolutionalTailLength}}{8} \right\rceil \quad (10\text{-}17)$$

where

| | |
|---|---|
| TXTIME | is the duration (in microseconds) of the HT PPDU defined in 6.7.5 (PLME-TXTIME.request) |
| Signal Extension | is 0 μs when TXVECTOR parameter NO_SIG_EXTN is true and is aSignalExtension as defined in Table 19-25 (HT PHY characteristics) of 19.4.4 (HT PHY) when TXVECTOR parameter NO_SIG_EXTN is false |
| aSymbolLength | is the duration of a symbol (in microseconds), defined in 6.7.4 (PLME-CHARACTERISTICS.confirm) |
| NonHTLength | is 20 μs, the duration of the non-HT PHY preamble and L-SIG |
| $N_{OPS}$ | is the number of octets transmitted during a period of aSymbolLength at the rate specified by L_DATARATE |
| PHYServiceLength | is 16 bits, the number of bits in the PHY SERVICE field |
| PHYConvolutionalTailLength | is 6 bits, the number of bits in the convolutional code tail bit sequence |

NOTE 1—The last term of the L_LENGTH definition corrects for the fact that non-HT STAs add the length of the SERVICE field and tail bits (assuming a single convolutional encoder) to the value communicated by the L_LENGTH field.

Equation (10-17) can be simplified to Equation (10-18)

$$\text{L\_LENGTH} = \left\lceil \frac{((\text{TXTIME} - \text{Signal Extension}) - 20)}{4} \right\rceil \times 3 - 3 \quad (10\text{-}18)$$

A STA shall not transmit a PPDU with the FORMAT parameter set to HT_MF in TXVECTOR if the corresponding L_LENGTH value calculated with Equation (10-17) exceeds 4095 octets.

NOTE 2—The transmission of frames with L_LENGTH above 2332 octets (i.e., a Data frame containing an unencrypted 2304-octet MSDU) might be accompanied by a protection mechanism (e.g., RTS/CTS or CTS-to-self protection) if it is determined that the use of L_LENGTH fails to effectively suppress non-HT transmissions. How this is determined is outside the scope of this standard.


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### 10.27.5 Protection rules for VHT STAs

A VHT STA is subject to all of the rules for HT STAs that apply to its operating band, except that a PPDU with the TXVECTOR FORMAT parameter set to VHT may be substituted for a PPDU with the TXVECTOR FORMAT parameter set to HT_MF and that the applicable HT protection mechanisms are extended to include 80, 160 and 80+80 MHz transmissions using non-HT duplicate frames defined in Clause 21 (Very high throughput (VHT) PHY specification).

### 10.27.6 Protection rules for HE STAs(11ax)

An HE STA operating in the 2.4 GHz band is subject to all of the rules for HT STAs that apply to that band, except that a PPDU with the TXVECTOR parameter FORMAT set to HE_SU, HE_ER_SU, HE_MU, or HE_TB may be substituted for a PPDU with the TXVECTOR parameter FORMAT set to HT_MF.

An HE STA operating in the 5 GHz band is subject to all of the rules for VHT STAs that apply to that band, except that a PPDU with the TXVECTOR parameter FORMAT set to HE_SU, HE_ER_SU, HE_MU, or HE_TB may be substituted for a PPDU with the TXVECTOR parameter FORMAT set to VHT.

Additionally, an HE STA can use the MU-RTS/CTS frame exchange sequence(#109) procedure.

### 10.27.7 Protection mechanisms for transmissions of EDMG PPDUs(11ay)

The intent of the protection mechanism is to cause an EDMG STA not to transmit an EDMG PPDU unless it has attempted to update the NAV of receiving non-EDMG STAs. The updated NAV period shall be longer than or equal to the total time required to send the Data and any required response frames. An EDMG STA shall use protection if a TXOP is obtained using the contention based channel access and may use protection at service period access. The protection mechanism does not need to be used if all PPDUs in the obtained TXOP are transmitted by MCS 0.

Frames used to support the protection mechanism shall be transmitted using MCS 0 as defined in Clause 20 or non-EDMG duplicate control mode MCS 0 as defined in Clause 28 (Enhanced directional multi-gigabit (EDMG) PHY specification(11ay)), so STAs in the BSA that receive such frames are able to learn the duration of the exchange even if they cannot detect the EDMG signals using their CCA function.

RTS, DMG CTS, DMG CTS-to-self, DMG DTS and CF-End frames are used as the protection mechanism according to the procedures defined in 10.3.2.4 (Setting and resetting the NAV), 10.3.2.9 (CTS and DMG CTS procedure), and 10.3.2.18 (EDMG RTS procedure(11ay)). The rules for calculating the Duration field value of RTS/DMG CTS frames are unchanged when using RTS/DMG CTS frames as a protection mechanism.

Control frames that are not RTS, DMG CTS, DMG CTS-to-self, DMG DTS and CF-End frames are sent according to the rules defined in 10.6.7.2 (Rate selection rules for Control frames transmitted by DMG STAs) and 10.6.7.6 (Channel Width selection for Control frames transmitted by EDMG STAs(11ay)).

## 10.28 MAC frame processing

### 10.28.1 Introduction

Subclauses 10.28.2 (Revision level field processing) to 10.28.9 (Extensible subelement parsing) describe MAC frame and element processing requirements to provide frame(#2181), element, and subelement extensibility.

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### 10.28.2 Revision level field processing

A MAC entity that receives a frame with a higher revision level than it supports shall discard the frame without indication to the sending STA or to LLC.

### 10.28.3 Duration/ID field processing

When the contents of a received Duration/ID field, treated as an unsigned integer and without regard for address(#3522), type, and subtype (even when type or subtype contain reserved values), are less than 32 768, the duration value is used to update the network allocation vector (NAV) according to the procedures defined in 10.3.2.4 (Setting and resetting the NAV), 10.23.3.4 (NAV operation of a TXOP under HCCA), or 10.38.10 (Updating multiple NAVs), as appropriate.

When the contents of a received Duration/ID field, treated as an unsigned integer, are greater than 32 768, the contents are interpreted as appropriate for the frame type and subtype or ignored if the receiving MAC entity does not have a defined interpretation for that type and subtype(#3128).

### 10.28.4 Response to an invalid Action or Action No Ack frame(#550)

If a STA receives an individually addressed Action or Action No Ack frame(#550) with an unrecognized Category field or some other syntactic error and the MSB of the Category field equal to 0, then the STA shall discard the frame(#3128)(#550).

### 10.28.5 Operation of the Dialog Token field

A dialog token is an integer value that assists a STA in grouping Management frames sent or received at different times as part of the same dialog. The algorithm by which the integer value for the dialog is selected is implementation specific, but should be selected in a manner that minimizes the probability of a frame associated with one dialog being incorrectly associated with another dialog.

### 10.28.6 Element parsing

A STA that encounters an element with an unknown or reserved element ID value, or an element with an element ID extension whose element ID extension value is unknown or reserved, in a Management frame received without error, shall ignore that element and shall parse any remaining management frame body for additional elements with recognizable element ID (and, if present, element ID extension) values.(#1541)(#6098)

### 10.28.7 Vendor specific element parsing

A STA receiving a Vendor Specific element that it does not support shall ignore the Vendor Specific element.

### 10.28.8 Extensible element parsing

Table 9-130 (Element IDs) indicates which elements are considered extensible in future revisions of the standard, by placing a Yes in the Extensible column. Each element that has a Yes in the Extensible column has an Information field with a known length that can be determined from the definition of the Information field in this standard; i.e., the Information field has a fixed structure or has a variable structure whose length is determined by fields within the Information field. A STA that receives an extensible element in which the Length field exceeds the known length of the Information field of that element shall discard any part of the Information field beyond the known length and shall otherwise process the element as though this truncated element had been received.


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### 10.28.9 Extensible subelement parsing

A subelement has the structure defined in 9.4.3 (Subelements) and is contained within an element or subelement.

A STA that encounters an unknown, unsupported, or reserved subelement ID value contained in an element or subelement shall ignore the subelement with that subelement ID value and shall continue to parse any remaining element or subelement body for additional subelements with recognizable subelement ID values.

A STA that receives an element or subelement for which a vendor-specific subelement is defined and that contains a vendor-specific subelement that it does not support shall ignore this vendor-specific subelement and shall continue to parse any remaining element or subelement body for additional subelements with recognizable subelement ID values.

Subelements are defined locally in each subclause that defines a structure containing subelements. Subelement ID numbering is private to that structure. A STA that receives an extensible subelement that is not extensible using subelements and in which the Length field exceeds the length of the structure of the subelement defined in this standard shall discard any part of the subelement beyond that length and shall otherwise process the subelement as though this truncated subelement had been received.

### 10.28.10 Extensible TLV parsing

A TVHT STA that receives a frame containing a TLV tuple with an unknown Type value shall discard the tuple and continue processing the next tuple.

### 10.28.11 Element fragmentation

The general format of elements limits the size of the information to 255 octets in an element without Element ID Extension field (Figure 10-47 (Example of the element fragmentation without Element ID Extension)) or 254 octets in an element with Element ID Extension field (Figure 10-48 (Example of the element fragmentation with Element ID Extension)). A STA may transmit information that is too large to fit in a single element by fragmenting the element into a series of elements consisting of the element that the information does not fit, immediately followed by one or more Fragment elements as illustrated in Figure 10-47 (Example of the element fragmentation without Element ID Extension). Information that fits in a single element shall not be fragmented. (#1018)The rules related to element fragmentation for the case where a fragmentable element is carried as a subelement within an element that is not fragmentable are described in 10.28.13 (Element fragmentation within a subelement of a nonfragmentable element(M118)(#1018)). All the information for a fragmented element shall be in the same MMPDU.

The information to be fragmented is divided into $M + N$ portions, where the following define each variable:

For an element without an Element ID Extension field:

- $L$ is the size of the information in octets.
- $M$ is $\lfloor L/255 \rfloor$ .
- $N$ is equal to 1 if $L$ mod 255 > 0 and equal to 0 otherwise.

For an element with an Element ID Extension field:

- $L$ is the size of the information in octets.
- $M$ is $\lfloor (L + 1)/255 \rfloor$ .(#3752)
- $N$ is equal to 1 if $(L–254)$ mod 255 > 0 and equal to 0 otherwise.

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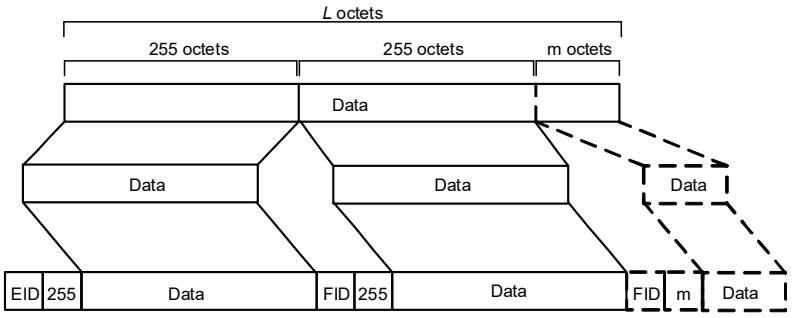
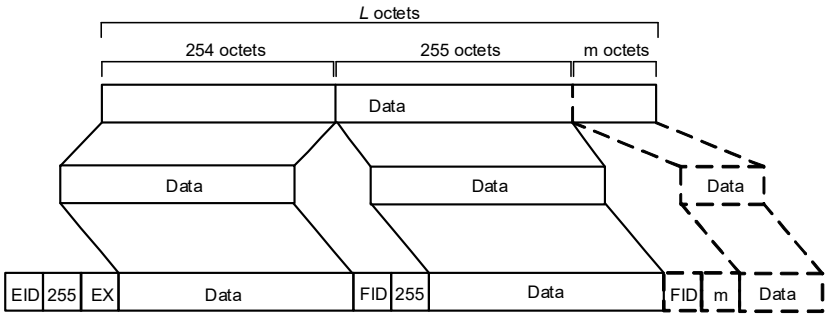



EID: The element ID of the fragmented element
FID: The Fragment element ID
m: *L* mod 255

**Figure 10-47—Example of the element fragmentation without Element ID Extension**




EID: The element ID of the fragmented element
EX: the element ID extension of the fragmented element
FID: The Fragment element ID
m: (*L*–254) mod 255 (The dashed Fragment element is present when (*L*–254) mod 255 is not equal to 0)

**Figure 10-48—Example of the element fragmentation with Element ID Extension**

The element into which the information does not fit is filled with the first portion of information and is termed the leading element. The leading element contains 255 octets of information for the element without Element ID Extension or 254 octets of information for the element with Element ID Extension. This element is immediately followed by $M - 1$ Fragment elements, each containing the next portion of 255 octets of information. If $N = 1$ these elements are immediately followed by the last portion of information.

NOTE—A Fragment element never follows an element with fewer than 255 octets of information without Element ID Extension, and an element with fewer than 254 octets of information with Element ID Extension. A Fragment element is never fragmented.

### 10.28.12 Element defragmentation

Elements that have had their information fragmented shall be followed by one or more Fragment elements. To reconstruct the original information, the portion of information from the leading element shall be concatenated, in order, with the portions of information from the series of Fragment elements that follow it. (#1018)The rules related to element defragmentation for the case where a fragmentable element is carried as a subelement within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an element that is not fragmentable are described in 10.28.14 (Element defragmentation within a subelement of a nonfragmentable element(#1018)(M118)). The defragmentation procedure shall complete when any element other than a Fragment element is encountered, or the end of the MMPDU is reached.

### 10.28.13 Element fragmentation within a subelement of a nonfragmentable element(M118)(#1018)

If a (M118)nonfragmentable element (i.e., has a No in the Fragmentable column in Table 9-130 (Element IDs)) includes a fragmentable element, as a subelement, then the maximum octets of the fragmentable element that can be carried within the subelement are limited by the remaining length in the subelement. In such a case, if the remaining length of the subelement is less than the length of the Information field of the fragmentable element, then the element is fragmented by following procedures described in 10.28.11 (Element fragmentation) where the length considerations are based on the pending octets in the subelement(s) that carries it. In addition, the (M118)nonfragmentable element is followed by at least one element having the same value in the Element ID field and Element ID Extension field (if applicable) as the (M118)nonfragmentable element (e.g., see Figure 11-5 (Example of nontransmitted BSSID profile fragmented across multiple Multiple BSSID elements(11ax)(#1018))). Each subsequent (M118)nonfragmentable element includes, as a first subelement, the same subelement (that carried the fragmented element) and carries a Fragment element (see 9.4.2.187 (Fragment element)) containing the remainder of the contents of the fragmented element. The maximum length of the Fragment element is based on the pending octets in the subelement. The fragmentable element may be fragmented across subelements carried across multiple elements. An example of a fragmentable element carried in a Nontransmitted BSSID Profile subelement of a Multiple BSSID element is shown in Figure 10-49 (Example of a fragmentable element in a nontransmitted BSSID profile carried across Multiple BSSID elements(#1018)).

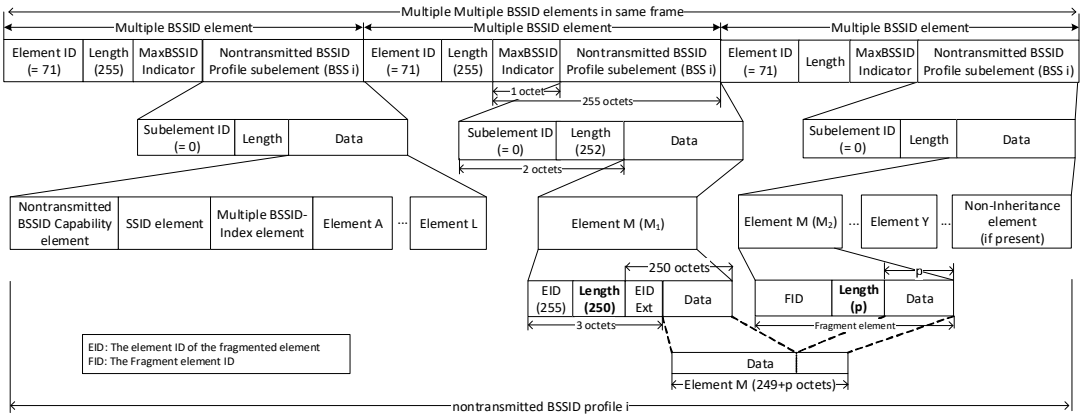


**Figure 10-49—Example of a fragmentable element in a nontransmitted BSSID profile carried across Multiple BSSID elements(#1018)**

### 10.28.14 Element defragmentation within a subelement of a nonfragmentable element(#1018)(M118)

When an element that is fragmentable is carried as a subelement within an element that is not fragmentable, the procedure for defragmentation shall be the same as that described in 10.28.12 (Element defragmentation) with the additional consideration that the fragments of the element are carried across subelements contained in multiple (M118)nonfragmentable elements.

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## 10.29 Reverse direction protocol

### 10.29.1 General

The RD protocol may be supported by an HT STA, by an S1G STA, and by a DMG STA(11ay) that is not an EDMG STA. The RD protocol shall be supported by an EDMG STA if dot11DMGChannelAccessScheme is either dmgChannelAccessOnly or dmgAndTddMixedChannelAccess. A STA receiving an RDG is never required to use the grant.

An HT STA indicates support of the RD feature as an RD responder using the RD Responder subfield of the HT Extended Capabilities field of the HT Capabilities element or the RD Responder subfield of the HE 6 GHz Band Capabilities element. A STA shall set the RD Responder subfield to 1 in frames that it transmits containing the HT Capabilities element in the 2.4 GHz or 5 GHz band and sets the RD Responder subfield to 1 in frames that it transmits containing the HE 6 GHz Band Capabilities element in the 6 GHz band if dot11RDResponderOptionImplemented is true. Otherwise, the STA shall set the RD Responder subfield to 0. In a non-HE HT STA, the RDG/More PPDU subfield and the AC Constraint subfield are present in the HTC field. In an HE STA, the RDG/More PPDU subfield and the AC Constraint subfield are present in the CAS Control subfield.(11ax)

A DMG STA indicates support of the RD feature using the Reverse Direction subfield of the DMG STA Capability Information field of the DMG Capabilities element. A STA shall set the Reverse Direction subfield to 1 in frames that it transmits containing the DMG Capabilities element if dot11RDResponderOptionImplemented is true. Otherwise, the STA shall set the Reverse Direction subfield to 0. In a DMG STA, the RDG/More PPDU subfield and the AC Constraint subfield are present in the QoS Control field.

An S1G STA indicates support of the RD feature as an RD responder using the RD Responder subfield of the S1G Capabilities element. A STA shall set the RD Responder subfield to 1 in frames that it transmits containing the S1G Capabilities element if dot11RDResponderOptionImplemented is true. Otherwise, the STA shall set the RD Responder subfield to 0. (11ay)For an EDMG STA, dot11RDResponderOptionImplemented shall always be set to true if dot11DMGChannelAccessScheme is either dmgChannelAccessOnly or dmgAndTddMixedChannelAccess. For an S1G STA, the RDG/More PPDU subfield and the AC Constraint subfield are present in the HTC field.

### 10.29.2 Reverse direction (RD) frame exchange sequence(#109)

An RD (#109)frame exchange sequence comprises the following:

a) The transmission of a PPDU by a TXOP holder or SP source containing an RD grant (the *RDG PPDU*), which is indicated by the PPDU containing one or more +HTC or DMG MPDUs in which the RDG/More PPDU subfield is equal to 1. The STA that transmits this PPDU is known as the *RD initiator*. The rules for an RD initiator apply only during a single RD (#109)frame exchange sequence, i.e., after the transmission of an RDG PPDU and up to the end of the last PPDU in the RD (#109)frame exchange sequence.

b) The transmission of one or more PPDUs (the *RD response burst*) by the STA addressed in the MPDUs of the RDG PPDU. The first (or only) PPDU of the RD response burst contains at most one immediate BlockAck or Ack frame. The last (or only) PPDU of the RD response burst contains any MPDUs requiring a response that is an immediate BlockAck or Ack frame. The STA that transmits the RD response burst is known as the *RD responder*. The rules for an RD responder apply only during a single RD (#109)frame exchange sequence, i.e., following the reception of an RDG PPDU and up to the transmission of a PPDU by the RD responder in which the RDG/More PPDU subfield is equal to 0.

c) The transmission of a PPDU by the RD initiator containing an immediate BlockAck frame or Ack frame (the *RD initiator final PPDU*), if so required by the last PPDU of the RD response burst.


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NOTE 1—An RD initiator might include multiple RD (#109)frame exchange sequences within a single TXOP or SP. Each RD (#109)frame exchange sequence within a single TXOP or SP might be addressed to a different recipient, and any single recipient might be given more than one RDG within a single TXOP or SP.

NOTE 2—If the RD responder is a VHT AP, the RD response burst can contain VHT MU PPDUs that might have TXVECTOR parameter NUM_USERS > 1. If the RD responder is an HE AP, the RD response burst can contain HE MU PPDUs that might have TXVECTOR parameter NUM_USERS > 1.(11ax)

NOTE 3—If the RD responder is an S1G AP, the RD response burst can contain S1G MU PPDUs that might have TXVECTOR parameter NUM_USERS > 1.

(11ax)If the RD initiator is an HE STA and the RD responder is an HE AP, the RD response burst may contain one or more Basic Trigger frames. The Basic Trigger frames shall trigger the RD initiator and at least one other STA in a full-bandwidth UL MU-MIMO transmission.

An example of an RD (#109)frame exchange sequence is given in O.3 (Example of RD frame exchanges(#109)).

### 10.29.3 Rules for RD initiator

An RDG shall not be present unless the MPDU carrying the grant, or every MPDU carrying the grant in an A-MPDU, matches one of the following conditions:

— (11ay)For a STA that is not an EDMG STA, a QoS Data frame with an ack policy other than (#3263)(11ay)No explicit acknowledgment or Scheduled Ack (i.e., including Implicit BAR), or

— (11ay)For an EDMG STA, a QoS Data frame with the Ack Policy field equal to any value except (#3263)No explicit acknowledgment, or

— (11ay)For a non-DMG STA, a BlockAckReq frame related to an HT-immediate block ack agreement, or

— (11ay)For a non-DMG STA, an MPDU not needing an immediate response (e.g., block ack under an HT-immediate block ack agreement, or Action No Ack).(#3263)

NOTE 1—These rules together with the rules in 9.7.3 (A-MPDU contents) cause an RDG to be delivered in a PPDU that either requires no immediate response or requires an immediate response that is a BlockAck or Ack frame.

NOTE 2—An RD initiator is not required to examine the RD Responder field of a potential responder before deciding whether to send a PPDU to that STA in which the RDG/More PPDU subfield is set to 1.

NOTE 3—An RD initiator is required according to 10.8 (HT Control field operation) to examine the +HTC-HT Support field of a potential responder before deciding whether to send a PPDU to that STA in which the RDG/More PPDU subfield is set to 1.

Transmission of a +HTC or DMG frame by an RD initiator with the RDG/More PPDU subfield equal to 1 (either transmitted as a non-A-MPDU frame,, or within an A-MPDU) indicates that the duration indicated by the Duration/ID field is available for the RD response burst and RD initiator final PPDU (if present).Transmission of an MPDU by an HE RD initiator that contains a CAS Control subfield with the RDG/More PPDU subfield equal to 1 indicates that the duration indicated by the Duration/ID field is available for the RD response burst and RD initiator final PPDU (if present).(11ax)

An RD initiator that sets the RDG/More PPDU field to 1 in a +HTC or DMG frame transmitted during a TXOP shall set the AC Constraint subfield to 1 in that frame if the TXOP was gained through the EDCA channel access mechanism and shall otherwise set it to 0. An RD initiator that sets the RDG/More PPDU field to 1 in a DMG frame transmitted during an SP can set the AC Constraint subfield to 1 to limit the Data frames transmitted by the RD responder.An HE STA RD initiator that sets the RDG/More PPDU field to 1 in a CAS Control subfield in a frame transmitted during a TXOP may set the AC Constraint subfield in the CAS Control subfield to 1.(11ax)

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(11ay)If an RD initiator and an RD responder are EDMG STAs with the Scheduled RD Supported field in their EDMG Capabilities element equal to 1, then the RD initiator may set the ack policy of MPDUs contained in A-MPDU transmitted within an RDG PPDU to Scheduled Ack. In this case, the RD initiator shall include at least one Block Ack Schedule frame with Response Offset and Response Duration fields set to nonzero values in an A-MPDU transmitted within the RDG PPDU. If an A-MPDU is transmitted not as a part of an EDMG MU PPDU, the RD initiator shall set the value of the Response Offset field in the Block Ack Schedule frame equal to SIFS.

An RD initiator shall not transmit a +HTC or DMG frame with the RDG/More PPDU subfield set to 1 that requires a response MPDU that is not one of the following frames:

— Ack
— Compressed BlockAck
— Extended Compressed BlockAck
— Multi-STA BlockAck(11ax)
— EDMG Compressed BlockAck(11ay)
— EDMG Multi-TID BlockAck(11ay)

Subject to TXOP or SP constraints, after transmitting an RDG PPDU, an RD initiator may transmit its next PPDU as follows:

a) *Normal continuation:* The RD initiator may transmit its next PPDU a minimum of a SIFS after receiving a response PPDU that meets one of the following conditions:
   1) Contains one or more received +HTC or DMG frames with the RDG/More PPDU subfield equal to 0
   2) In an HT STA or an S1G STA, contains one or more received frames that are capable of carrying the HT Control field but did not contain an HT Control field
   3) Contains a received frame that requires an immediate response
   4) In a DMG STA, none of the correctly received frames in the PPDU carry the QoS Control field
b) *Error recovery:* For TXOPs and non-DMG SPs, the RD initiator may transmit its next PPDU (11ax)if the CS mechanism (see 10.3.2.1 (CS mechanism)) indicates that the medium is idle at the TxPIFS slot boundary (see Figure 10-29 (EDCA mechanism timing relationships(#14)(#1058))). For DMG SPs, the RD initiator shall not transmit its next PPDU earlier than PIFS following its last PPDU transmission. Transmission is a continuation of the current TXOP or SP.

NOTE 4—Error recovery of the RDG mechanism is the responsibility of the RD initiator.

NOTE 5—Control response frames generated by HE STAs do not carry the HT Control field.(11ax)

A STA that transmits a QoS +CF-Ack Data frame according to the rules in 10.23.3.5 (HCCA transfer rules) may also include an RDG in that frame provided that

— It is a non-A-MPDU frame, and
— The target of the +CF-Ack is equal to the Address 1 field of the frame.

NOTE 6—In a non-DMG BSS, the RD initiator can transmit a CF-End frame according to the rules for TXOP truncation in 10.23.2.10 (Truncation of TXOP) following an RD transmit sequence. An RD responder never transmits a CF-End.

NOTE 7—In a DMG network, the RD initiator can transmit a CF-End frame according to the rules for TXOP truncation in 10.23.2.10 (Truncation of TXOP) or SP truncation in 10.38.8 (Dynamic truncation of service period), as appropriate, following an RD transmit sequence. An RD responder never transmits a CF-End.


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(11ay)The value in the TID Aggregation Limit subfield in a transmitted Block Ack Schedule frame shall be less than or equal to *MT* + 1, where *MT* is the value indicated in the EDMG Multi-TID Aggregation Support subfield within the EDMG Capabilities element transmitted by the EDMG AP or EDMG PCP of the BSS.

### 10.29.4 Rules for RD responder

(11ay)If an RDG was granted by an MPDU contained in an A-MPDU with the ack policy different from Scheduled Ack, an RD responder shall transmit the initial PPDU of the RD response burst a SIFS after the reception of the RDG PPDU. PPDUs in a response burst are separated by SIFS or RIFS. The RIFS rules in the RD are the same as in the forward direction; the use of RIFS is constrained as defined in 10.3.2.3.2 (RIFS) and 10.27.3.3 (RIFS protection).

(11ay)If an RDG was granted by an MPDU contained in an A-MPDU with the ack policy equal to Scheduled Ack, an RD responder shall transmit the initial PPDU of the RD response burst at a time equal to *T_Offset* from the end of RDG PPDU, where *T_Offset* is the value of Response Offset subfield of the Block Ack Schedule frame in the A-MPDU that has the MPDU that granted the RDG. The duration of the RD response burst shall not exceed the value of the Response Duration subfield of the Block Ack Schedule frame in the A-MPDU that has the MPDU that granted the RDG.

NOTE 1—The transmission of a response by the RD responder does not constitute a new channel access but a continuation of the RD initiator's TXOP or SP. An RD responder ignores the NAV when responding to an RDG.

The recipient of an RDG may decline the RDG by

- Not transmitting any frames following the RDG PPDU if(11ax) no response is otherwise required, or
- (11ay)For a non-DMG STA, transmitting a control response frame with the RDG/More PPDU subfield set to 0, or
- (11ay)For a non-DMG STA, transmitting a control response frame that contains no HT Control field, or(11ax)
- Transmitting a control response frame aggregated with other MPDUs with the RDG/More PPDU subfield set to 0.(11ax)

An RD responder that is a non-DMG STA may transmit a +CF-Ack non-A-MPDU frame in response to a QoS Data +HTC non-A-MPDU frame that has the Normal Ack ack policy and the RDG/More PPDU subfield equal to 1.

The RD responder shall ensure that its PPDU transmission(s) and any expected responses fit entirely within the remaining TXOP or SP duration, as indicated in the Duration/ID field of MPDUs within the RDG PPDU.

An RD responder shall not transmit an MPDU (either individually or aggregated within an A-MPDU) that is not one of the following frames:

- Ack
- Compressed BlockAck
- Compressed BlockAckReq
- Extended Compressed BlockAck
- Extended Compressed BlockAckReq
- Multi-STA BlockAck(11ax)
- QoS Data(11ax)
- QoS Null(#4416)
- Management
- Basic Trigger(11ax)

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(11ax)(11ay)For an EDMG Multi-TID A-MPDU or an EDMG MU PPDU, if the AC Constraint subfield is equal to 1, the RD responder shall transmit Data frames following the rules specified in this subclause and in 10.70 (EDMG A-MPDU with multiple TIDs(11ay)). Otherwise, if the AC Constraint subfield is equal to 1, the RD responder shall transmit Data frames of only the same AC as the last frame received from the RD initiator. If the AC Constraint subfield is equal to 1 in the last frame received from an RD initiator,

— A non-HE RD responder shall transmit Data frames of only the same AC as the last frame received from the RD initiator.

— An HE RD responder may transmit an A-MPDU or multi-TID A-MPDU with MPDUs from one or more ACs that have a priority that is equal to or higher than the lowest priority AC of the MPDU(s) carried in the last PPDU received from the RD initiator (see 10.12 (A-MPDU operation)) and if the RD initiator is an HE STA subject to the additional rules defined in 26.6.3 (Multi-TID A-MPDU and ack-enabled single-TID A-MPDU).

(11ax)For a BlockAckReq or BlockAck frame, the AC is determined by examining the TID field. For a Management frame, the AC is AC_VO. The RD initiator shall not transmit a +HTC or DMG MPDU with the RDG/More PPDU subfield set to 1 from which the AC cannot be determined. If the AC Constraint subfield is equal to 0, the RD responder may transmit Data frames of any TID.

NOTE 2—If the RD initiator's last PPDU contained an A-MPDU, the last frame is the last Data frame in the A-MPDU.

During an RD response burst any PPDU transmitted by an RD responder shall contain at least one MPDU with an Address 1 field that matches the MAC address of the RD initiator (11ax)or at least one Trigger frame that addresses the RD initiator, and the inclusion of traffic to STAs other than the RD initiator in a VHT MU PPDU, S1G MU PPDU, or HE MU PPDU(11ax) shall not increase the duration of the(11ax) PPDU beyond that required to transport the traffic to the RD initiator. The RD responder shall not transmit(11ax) a frame that is not a Basic Trigger frame and that causes a response after a SIFS(#6587) with an Address 1 field that does not match the MAC address of the RD initiator. The RD responder shall not transmit any PPDUs with a CH_BANDWIDTH that is wider than the CH_BANDWIDTH of the PPDU containing the frame(s) that delivered the RD grant.

(11ax)An RD responder that transmits a Basic Trigger frame shall set the CS Required subfield to 1 and shall allocate a number of streams for the RD initiator that is not smaller than the number of streams of the RD initiator's last PPDU.

(11ax)If an RD initiator sets the RDG/More PPDU field to 1 in a +HTC frame transmitted during a TXOP and sets the AC Constraint subfield to 1 in that frame, the RD responder shall set the Preferred AC subfield of the Trigger Dependent User Info field in the Trigger frame to the same AC as the last frame received from the RD initiator.

If an RDG PPDU also requires an immediate block ack response, the BlockAck frame shall be included in the first PPDU of the response.

When a PPDU is not the final PPDU of a response burst, an HT Control field carrying the RDG/More PPDU subfield set to 1 shall be present in every MPDU within the PPDU capable of carrying the HT Control field, or if the PPDU is transmitted in a DMG BSS, the RDG/More PPDU subfield within the QoS Control field shall be set to 1 in every MPDU within the PPDU. The last PPDU of a response burst shall have the RDG/More PPDU subfield set to 0 in all +HTC or DMG MPDUs contained in that PPDU.

The RD responder shall not set the RDG/More PPDU subfield to 1 in any MPDU in a PPDU that contains an MPDU that requires an immediate response.

NOTE 3—If the RD responder transmits a PPDU that expects a transmission by the RD initiator after a SIFS(#6587) and no such transmission is detected, the RD responder does not retry the exchange before either another RDG or its own TXOP or SP.


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After transmitting a PPDU containing one or more +HTC or DMG MPDUs in which the RDG/More PPDU subfield is equal to 0, the RD responder shall not transmit any more PPDUs within the current response burst.

NOTE 4—If an RD-capable STA that is not the TXOP holder or SP source receives a PPDU that does not indicate an RDG, there is no difference in its response compared to a STA that is not RD-capable.

(11ay)As part of an RDG, an RD responder that is a DMG STA shall not transmit a PPDU following a BlockAck frame unless the BlockAck frame is transmitted as part of an A-MPDU that includes an MPDU (e.g., QoS Null) that has the RDG/More PPDU subfield set to 1.

(11ay)The following provides additional rules for an RD responder that constructs a multi-TID A-MPDU in response to an MU PPDU.

(11ay)A non-AP and non-PCP EDMG STA with dot11EDMGAMPDUwithMultipleTIDOptionImplemented set to true shall not send a multi-TID A-MPDU to an EDMG AP or EDMG PCP unless all the following conditions are met:

— The EDMG Multi-TID Aggregation Support subfield in the AP's or PCP's EDMG Capabilities element is greater than 0.
— The RDG/More PPDU subfield is set to 1 in the QoS Control field of all MPDU(s) in the EDMG MU PPDU transmitted by the AP or PCP.
— The TID Aggregation Limit field in the Block Ack Schedule frame sent to the STA within the EDMG MU PPDU is nonzero.

(#4245)(11ay)The number of different TID values for QoS Data frames in the multi-TID A-MPDU shall not exceed the value in the TID Aggregation Limit subfield in the Block Ack Schedule frame the EDMG STA received in the MU PPDU. The multi-TID A-MPDU may contain no more than one Management frame, with exception of Action no Ack frames that can occur more than once. Any number of QoS Null frames with the Ack Policy field set to No Ack may be aggregated in the A-MPDU, irrespective of the value of the TID Aggregation Limit subfield and the value of the Preferred AC subfield in the Block Ack Schedule frame.

(11ay)(#4251)An EDMG Multi-TID BlockAck frame is used to acknowledge the MPDUs in a multi-TID A-MPDU. The rules for (#4251)EDMG Multi-TID BlockAck are defined in 10.70 (EDMG A-MPDU with multiple TIDs(11ay)).

(11ay)When a multi-TID A-MPDU is sent in an SP in response to an MPDU with the RD Grant field set to 1 and the AC Constraint field set to 0 as specified in 10.29.3 (Rules for RD initiator), an EDMG STA may aggregate MPDUs from any TID in the multi-TID A-MPDU for transmission in the SP as long as the transmission of the multi-TID A-MPDU does not cause the STA to exceed the current SP duration.

(11ay)An EDMG STA operating as an RD responder that constructs a multi-TID A-MPDU in response to an MU PPDU shall aggregate MPDUs in the A-MPDU in the following order:

— MPDUs with TIDs originating from the same or higher AC as indicated in the Preferred AC subfield of the received Block Ack schedule frame.
— MPDUs with TIDs originating from any other AC in the A-MPDU carried in the MU PPDU, if the responding EDMG STA has no buffered MPDU for TIDs belonging to the same or higher priority AC indicated in the Preferred AC subfield.
— MPDUs with TIDs originating from other ACs within the remaining time of the Response Duration subfield value indicated in the Block Ack Schedule Information field of the received Block Ack Schedule frame.

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### 10.29.5 Reverse direction for EDMG DL MU-MIMO(11ay)

An EDMG STA with dot11EDMGScheduledRDImplemented equal to true shall support the reverse direction for EDMG DL MU-MIMO mechanism described in this subclause.

To start a DL MU PPDU transmission with reverse direction, an AP or PCP shall set the RDG/More PPDU subfield to 1 and the Ack Policy Indicator subfield to Scheduled Ack in the QoS Control field of an MPDU contained in the PPDU and addressed to the intended RD responder. The AP or PCP shall also include at least one Block Ack Schedule frame with nonzero Response Offset, Response Duration and Next PPDU Start Offset fields in an A-MPDU addressed to the intended RD responder.

Upon receiving an RD grant as part of a DL MU-MIMO transmission, an RD responder shall respond according to the rules that are defined in 10.29.4 (Rules for RD responder). The duration of the RD response burst shall be equal to the value of the Response Duration subfield of the last Block Ack Schedule frame received from the RD initiator.

An RD responder that intends to elicit a BlockAck frame from the RD initiator shall set the Ack Policy Indicator subfield of MPDUs addressed to RD initiator to Scheduled Ack.

Upon receiving an RD response burst with the ack policy of MPDUs contained in A-MPDU equal to Scheduled Ack, the RD initiator that granted an RD as part of a DL MU-MIMO transmission shall respond to the RD responder by aggregating a BlockAck frame into the next PPDU transmitted to the RD responder.

Figure 10-50 (Example of reverse direction for DL MU-MIMO(11ay)) illustrates an example of the RD sequence during DL MU-MIMO transmissions. The RD initiator (e.g., an AP) transmits an MU PPDU to STA 1 and STA 2. The RD initiator requests a BlockAck frame and grants an RD to STA 1 by setting RDG/ More PPDU to 1, Ack Policy Indicator subfield set to Scheduled Ack and including a Block Ack Schedule frame with the schedule for the RD response burst. The A-MPDU sent to STA 2 has RDG/More PPDU set to 0, Ack Policy set to Scheduled Ack and includes a Block Ack Schedule frame with the schedule for a BlockAck frame transmission.

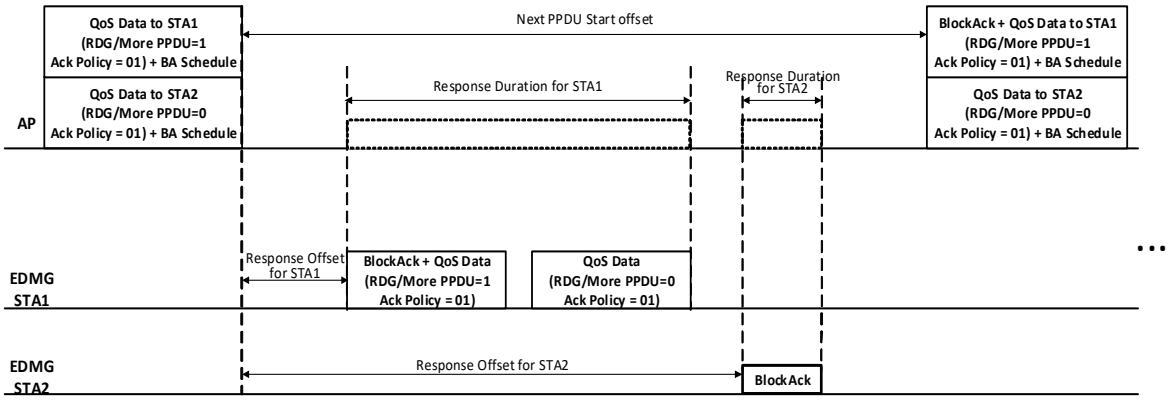


**Figure 10-50—Example of reverse direction for DL MU-MIMO(11ay)**


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Following the reception of the RD grant, STA 1 transmits its RD response burst in multiple PPDUs during the scheduled time slot defined by Response Offset and Response Duration subfields of the received Block Ack Schedule frame. The first PPDU is an A-MPDU, which includes the BlockAck to the RD initiator and QoS Data frames with RDG/More PPDU equal to 1. A PPDU in the RD response burst contains QoS DATA with RDG/More PPDU equal to 1 if it is not the last PPDU, and it contains QoS Data with RDG/More PPDU equal to 0 if it is the last PPDU of the RD response burst. STA 1 requests the acknowledgment for the RD response burst by setting the Ack Policy Indicator subfield to Scheduled Ack. STA 2 did not receive an RD grant, and so it uses the scheduled time slot for the transmission of only a BlockAck frame. After a period of time equal to the value of the Next PPDU Start Offset subfield starting from the end of the EDMG MU PPDU, the AP transmits another MU PPDU to both STA 1 and STA 2. In addition to QoS Data and Block Ack Schedule frames, the A-MPDU sent to STA 1 also includes a BlockAck to the RD response burst.(#3263)

## 10.30 Sounding PPDUs

The behavior described in this subclause is specific to the use of the HT variant HT Control field and CMMG variant HT Control field.

A sounding PPDU is a PPDU for which the SOUNDING parameter of the corresponding RXVECTOR or TXVECTOR has the value SOUNDING. Sounding PPDUs are transmitted by STAs to enable the receiving STAs to estimate the channel between the transmitting STA and the receiving STA.

A STA transmits sounding PPDUs when it operates in the following roles:

- MFB requester (see 10.31.2 (Link adaptation using the HT variant HT Control field) and 10.31.4 (Link adaptation using the CMMG variant HT Control field))
- HT beamformee responding to a training request, calibration initiator, or responder involved in implicit transmit beamforming (see 10.33.2.2 (Unidirectional implicit transmit beamforming), 10.33.2.3 (Bidirectional implicit transmit beamforming), and 10.33.2.4 (Calibration))
- HT beamformer involved in explicit transmit beamforming (see 10.33.3 (Explicit feedback beamforming))
- ASEL transmitter and ASEL sounding-capable transmitter involved in ASEL (see 10.34.2 (ASEL frame exchange procedure))
- CMMG beamformer involved in explicit transmit beamforming (see 10.33.5 (Explicit feedback beamforming for CMMG STAs))

A STA receives sounding PPDUs when it operates in the following roles:

- MFB responder (see 10.31.2 (Link adaptation using the HT variant HT Control field) and 10.31.4 (Link adaptation using the CMMG variant HT Control field))
- HT beamformer sending a training request, calibration initiator, or responder involved in implicit transmit beamforming (see 10.33.2.2 (Unidirectional implicit transmit beamforming), 10.33.2.3 (Bidirectional implicit transmit beamforming), and 10.33.2.4 (Calibration))
- HT beamformee involved in explicit transmit beamforming (see 10.33.3 (Explicit feedback beamforming))
- Transmit ASEL responder and ASEL receiver involved in ASEL (see 10.34.2 (ASEL frame exchange procedure))
- CMMG beamformee involved in explicit transmit beamforming (see 10.33.5 (Explicit feedback beamforming for CMMG STAs))

When transmitting a sounding PPDU, the transmitting STA follows the rules stated below to determine the maximum number of space-time streams for which channel coefficients can be simultaneously estimated:

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- When transmitting a sounding PPDU that
  - Contains a +HTC frame with the MRQ subfield equal to 1, or
  - Is sent as a response to a +HTC frame with the TRQ field equal to 1, or
  - Is sent during a calibration sounding exchange, or
  - Is sent by an HT beamformer involved in explicit transmit beamforming, or
  - Is sent in transmit or receive ASEL exchanges,
  - Is sent by a CMMG beamformer involved in explicit transmit beamforming
- Then:
  - If the sounding PPDU is not an NDP sounding PPDU, the NUM_EXTEN_SS parameter in the TXVECTOR shall not be set to a value greater than the limit indicated by the Channel Estimation Capability subfield in the Transmit Beamforming Capabilities field transmitted by the STA that is the intended receiver of the sounding PPDU.

    NOTE—The maximum number of space-time streams for which channel coefficients can be simultaneously estimated using the HT-LTFs corresponding to the data portion of the PPDU is limited by the Rx MCS Bitmask subfield of the Supported MCS Set field and by the Rx STBC subfield of the HT Capability Information field. Both fields are part of the HT Capabilities element.

  - If the sounding PPDU is an NDP, the number of spatial streams corresponding to the MCS parameter of the TXVECTOR shall not exceed the limit indicated by the Channel Estimation Capability subfield in the Transmit Beamforming Capabilities field transmitted from the STA that is the intended receiver of the NDP (see 10.35.2 (Transmission of an HT NDP) for details on setting the MCS parameter).

(#402)If a STA sets the Receive Staggered Sounding Capable subfield in the Transmit Beamforming Capabilities field to 1, the STA shall set the Channel Estimation Capability subfield in the Transmit Beamforming Capabilities field to indicate a dimension that is greater than or equal to the dimension indicated by the Supported MCS Set field of the HT Capabilities element.

## 10.31 Link adaptation

### 10.31.1 Introduction

To fully exploit MIMO channel variations and transmit beamforming on a MIMO link, a STA can request that another STA provide MIMO channel sounding and MFB.

Link adaptation may be supported by immediate response or delayed response as described below. Unsolicited MFB is also possible.

- *Immediate.* An immediate response occurs when the MFB responder transmits the response in the TXOP obtained by the TXOP holder. This approach allows the MFB requester to obtain the benefit of link adaptation within the same TXOP.
- *Delayed.* A delayed response occurs when the MFB responder transmits the response in the role of a TXOP holder in response to an MRQ in a previous TXOP obtained by the MFB requester.
- *Unsolicited.* An unsolicited response occurs when a STA sends MFB independent of any preceding MRQ.

For an S1G STA, the same link adaptation procedure specified in 10.31.3 (Link adaptation using the VHT variant HT Control field) is applied with the following qualifications:

- “VHT” is replaced by “S1G” when referring to characteristics of an S1G STA or when referring to the contents of an S1G PPDU. More specifically:


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- "VHT Capabilities Info field in the VHT Capabilities element" is replaced by "S1G Capabilities Information field in the S1G Capabilities element"
- "VHT NDP Announcement frame" is replaced by "VHT NDP Announcement frame carried in an S1G PPDU"
- "VHT MU PPDU" is replaced by "S1G MU PPDU"

### 10.31.2 Link adaptation using the HT variant HT Control field

The behavior described in this subclause is specific to the HT variant HT Control field.

A STA that supports link adaptation using the HT Control field shall set the MCS Feedback field of the HT Extended Capabilities field to Unsolicited or Both, depending on its specific MFB capability, in HT Capabilities elements that it transmits. A STA shall not send an MRQ to a STA that has not set the MCS Feedback subfield to Both in the HT Extended Capabilities field of the HT Capabilities element. A STA whose MCS Feedback field of the HT Extended capabilities field of the HT Capabilities element is equal to Unsolicited or Both may transmit unsolicited MFB in any frame that contains a +HTC field.

The MFB requester may set the MRQ subfield to 1 in the MAI subfield of the HT Control field of a +HTC frame to request a STA to provide MFB. In each MRQ, the MFB requester shall set the MSI subfield in the MAI subfield to a value in the range 0 to 6. How the MFB requester chooses the MSI value is implementation dependent.

The appearance of more than one instance of an HT Control field with the MRQ subfield equal to 1 within a single PPDU shall be interpreted by the receiver as a single request for MFB.

An MFB requester shall transmit +HTC frames with the MRQ subfield equal to 1 in one of the following ways:

- Within a sounding PPDU, or
- With the HT NDP Announcement subfield in the +HTC frame set to 1 and following the +HTC frame by an NDP transmission.

The number of HT-LTFs sent in the sounding PPDU or in the NDP is determined by the total number of spatial dimensions to be sounded, including any extra spatial dimensions beyond those used by the data portion of the frame.

An MFB-capable STA (identified by the MCS Feedback field in the Extended HT Capability Information field equal to 3) shall support the following:

- MFB estimate computation and feedback on the receipt of MRQ (MRQ=1 in +HTC) in a sounding PPDU for which the RXVECTOR NUM_EXTEN_SS parameter contains 0 in the PHY-RXSTART.indication primitive.
- MFB estimate computation and feedback on the receipt of MRQ (MRQ=1 in +HTC) in a staggered sounding PPDU if this STA declares support for receive staggered sounding by setting the Receive Staggered Sounding Capable subfield of the Transmit Beamforming Capabilities field to 1.
- MFB estimate computation and feedback on the receipt of NDP (see 10.35 (Null data PPDU (NDP) sounding)) if this STA declares support for receiving NDP sounding by setting the Receive NDP Capable subfield of the Transmit Beamforming Capabilities field to 1. The MFB requester shall set the MRQ subfield to 1 in the frame where the HT NDP Announcement subfield is equal to 1.

On receipt of a +HTC frame with the MRQ subfield equal to 1, an MFB responder initiates computation of the MCS estimate based on the associated sounding PPDU and labels the result of this computation with the MSI value. The MFB responder includes the received MSI value in the MFSI field of the corresponding response frame. In the case of a delayed response, this use of MSI and MFSI fields allows the MFB requester to correlate the MFB with the related MRQ.

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The responder may send a response frame with any of the following combinations of MFB and MFSI:

- MFB = 127, MFSI = 7: no information is provided for the immediately preceding request or for any other pending request. This combination is used when the responder is required to include an HT Control field due to other protocols that use this field (i.e., the reverse direction protocol) and when no MFB is available. It has no effect on the status of any pending MRQ.
- MFB = 127, MFSI in the range 0 to 6: the responder is not providing feedback for the request with he MSI value that matches the MFSI value.(M118)
- MFB in the range 0 to 126, MFSI in the range 0 to 6: the responder is providing feedback for the request that had the MSI value that matches the MFSI value.
- MFB in the range 0 to 126, MFSI = 7: the responder is providing unsolicited feedback.

Hardware and buffer capability may limit the number of MCS estimate computations that an MFB responder is capable of computing simultaneously. When a new MRQ is received either from a different MFB requester or from the same MFB requester with a different MSI value, and the MFB responder is not able to complete the computation for MRQ, the MFB responder may either discard the new request or may abandon an existing request and initiate an MCS estimate computation for the new MRQ.

An MFB responder that discards or abandons the computation for an MRQ should indicate this action to the MFB requester by setting the MFB to the value 127 in the next transmission of a frame addressed to the MFB requester that includes the HT Control field. The value of the MFSI is set to the MSI value of the sounding frame for which the computation was abandoned.

When computing the MCS estimate for an MFB requester whose Tx MCS Set Defined field is equal to 1, the number of spatial streams corresponding to the recommended MCS shall not exceed the limit indicated by the Tx Maximum Number Spatial Streams Supported field. The MFB responder shall not recommend an MCS corresponding to UEQM unless the MFB requester supports such modulation, as indicated by the Tx Unequal Modulation Supported bit in the Supported MCS Set field.

If the MFB is in the same PPDU as a Noncompressed Beamforming frame or a Compressed Beamforming frame, the MFB responder should estimate the recommended MCS under the assumption that the MFB requester uses the steering matrices contained therein.

After the MCS estimate computation is completed, the MFB responder should include the MFB in the MFB field in the next transmission of a frame addressed to the MFB requester that includes an HT Control field. When the MFB requester sets the MRQ subfield to 1 and sets the MSI subfield to a value that matches the MSI subfield value of a previous request for which the responder has not yet provided feedback, the responder shall discard or abandon the computation for the MRQ that corresponds to the previous use of that MSI subfield value.

A STA may respond immediately to a current request for MFB with a frame containing an MFSI field value and MFB field value that correspond to a request that precedes the current request.

Bidirectional request/responses are supported. A STA may act as both the MFB requester for one direction of a duplex link and the MFB responder for the other direction and include both MRQ and MFB in the same HT Data frame.

If an HT beamformer transmits a PPDU with the TXVECTOR EXPANSION_MAT_TYPE set to either COMPRESSED_SV or NON_COMPRESSED_SV, it should use the recommended MCS associated with those matrices reported in a Noncompressed Beamforming frame or a Compressed Beamforming frame.


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### 10.31.3 Link adaptation using the VHT variant HT Control field

This subclause applies to frame exchange sequences that include PPDUs containing an HT variant HT Control field. The VHT variant HT Control field may be used by VHT STAs and S1G STAs.

A STA that supports VHT link adaptation using the VHT variant HT Control field shall set the VHT Link Adaptation Capable subfield in the VHT Capabilities Information field in the VHT Capabilities element to Unsolicited or Both, depending on its specific link adaptation feedback capability. A STA shall not send an MRQ to a STA that has not set the VHT Link Adaptation Capable subfield to Both in the VHT Capabilities Information field of the VHT Capabilities element. A STA whose VHT Link Adaptation Capable subfield of the VHT Capabilities Information field of the VHT Capabilities element is either set to Unsolicited or Both may transmit unsolicited MFB in any frame that contains a VHT variant HT Control field.

The MFB requester or MFB responder that is an S1G STA shall set the S1G subfield in the VHT variant HT Control field to 1. Otherwise the S1G field shall be reserved.

An S1G STA shall not transmit a +HTC Control frame to another S1G STA that does not support VHT link adaptation.

An S1G STA that sets the +HTC VHT Capable to 1 and supports sending control response frames that are not NDP CMAC PPDUs for link adaptation shall set (#402)Link Adaptation Without NDP CMAC PPDU Capable subfield in the S1G Capabilities element to 1. Otherwise it shall set it to 0. An S1G STA shall not elicit a Control frame that is not an NDP CMAC PPDU for link adaptation from another S1G STA when the received Link Adaptation Without NDP CMAC PPDU Capable subfield in the received S1G Capabilities element from the STA is 0.

An S1G STA that is an MFB requester shall set the TXVECTOR parameter RESPONSE_INDICATION to NORMAL_RESPONSE if it intends to elicit link adaptation feedback in the immediate control response frame. Otherwise, it shall not set the TXVECTOR parameter RESPONSE_INDICATION to Normal Response, unless it is permitted to do so as described in 10.25 (Block acknowledgment (block ack)), 10.3.2.11 (Acknowledgment procedure), and 10.46 (Target wake time (TWT)).

An S1G STA that is an MFB responder may transmit a +HTC Control frame as an immediate response to an eliciting frame for which the RXVECTOR parameter RESPONSE_INDICATION is equal to NORMAL_RESPONSE. The +HTC control response frame shall be one of the following:

- +HTC Ack frame if the eliciting frame requires an Ack frame as a response (see 10.3.2.11 (Acknowledgment procedure))
- +HTC BlockAck frame or +HTC BAT frame if the eliciting frame requires a BlockAck frame or BAT frame as a response (see 10.25 (Block acknowledgment (block ack)))
- +HTC TACK frame or +HTC STACK frame if the eliciting frame requires a TACK frame or STACK frame as a response (see 10.46.2 (TWT acknowledgment procedure))
- +HTC CTS frame in the eliciting frame requires an CTS frame as a response (see 10.3.2.9 (CTS and DMG CTS procedure))

Otherwise, the S1G STA shall not transmit a +HTC control response frame.

The MFB requester may set the MRQ field to 1 in the VHT variant HT Control field of a frame to request a STA to provide link adaptation feedback. In each request the MFB requester shall set the MSI/STBC field to a value in the ranges 0 to 6, 0 to 2, or 0 to 3, depending on the settings in the Unsolicited MFB and STBC fields (see 9.2.4.6.3 (VHT variant)). The choice of MSI value is implementation dependent.

The appearance of more than one instance of a VHT variant HT Control field with the MRQ field equal to 1 within a single PPDU shall be interpreted by the receiver as a single request for link adaptation feedback.

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An MFB responder that has set the VHT Link Adaptation Capable subfield to Both in the VHT Capabilities Information field of the VHT Capabilities element shall support both of the following:

— Computation and feedback of the MFB estimate on the receipt of an MFB request (MRQ equal to 1 in the VHT variant HT Control field) in a PPDU that is not a VHT NDP Announcement frame.

— Computation and feedback of the MFB estimate on the receipt of an MFB request (MRQ equal to 1 in VHT variant HT Control field) in a VHT NDP Announcement frame and the receipt of VHT NDPs (see 10.35 (Null data PPDU (NDP) sounding)) if this STA set the SU Beamformee Capable subfield of the VHT Capabilities Information field of the VHT Capabilities element to 1.

On receipt of a VHT variant HT Control field with the MRQ field equal to 1, an MFB responder computes the VHT-MCS, NUM_STS, and SNR estimates based on the PPDU carrying the MRQ or, in the case of a VHT NDP Announcement frame carrying the MRQ, based on the subsequent VHT NDP. The MFB responder labels the result of this computation with the MSI value from the VHT variant HT Control field in the received frame carrying the MRQ. The MFB responder may include the received MSI value in the MFSI field of the corresponding response frame. In the case of a delayed response, this allows the MFB requester to associate the MFB with the soliciting MRQ.

An MFB responder that sends a solicited MFB shall set the Unsolicited MFB subfield in VHT variant HT Control field to 0.

The MFB responder may send a solicited response frame with any of the following combinations of VHT-MCS, NUM_STS, and MFSI:

— VHT-MCS = 15, NUM_STS = 7 in the MFB subfield, MFSI = 7 in a VHT PPDU; and VHT-MCS = 15, NUM_STS = 3, and MFSI = 7 in an S1G PPDU: no information is provided for the immediately preceding request or for any other pending request. This combination is used when the responder is required to include a VHT variant HT Control field due to other protocols that use this field (e.g., the Reverse Direction Protocol) and when no MFB is available. It has no effect on the status of any pending MRQ.

— VHT-MCS = 15, NUM_STS = 7 in the MFB subfield, MFSI in the range 0 to 6 in a VHT PPDU; and VHT-MCS = 15, NUM_STS = 3, and MFSI in the range 0 to 6 in an S1G PPDU: the responder is not providing feedback for the request with the MSI value that matches the MFSI value.(M118)

— VHT-MCS = valid value, NUM_STS = valid value in the MFB subfield, MFSI in the range 0 to 6: the responder is providing feedback for the request that had the MSI value that matches the MFSI value.

An MFB responder that discards or abandons the MFB estimates computed in response to an MRQ may indicate that it has done so by setting the VHT-MCS to 15 and NUM_STS to 7 in the MFB subfield in the next VHT PPDU frame if the frame is carried in a VHT PPDU or by setting the VHT-MCS to 15 and NUM_STS to 3 if the frame is carried in an S1G PPDU containing frames addressed to the MFB requester that includes the VHT variant HT Control field. The value of the MFSI is set to the value of the MSI/STBC subfield of the frame that contains an MRQ for which the computation was abandoned, regardless of whether the MSI/STBC subfield contains an MSI or a Compressed MSI and STBC Indication subfields.

The STA receiving MFB may use the received MFB to compute the appropriate VHT-MCS, SNR, and NUM_STS.

A STA sending unsolicited MFB using the VHT variant HT Control field shall set the Unsolicited MFB subfield to 1.

Unsolicited VHT-MCS, NUM_STS, BW, and SNR estimates reported in the MFB subfield of a VHT variant HT Control field sent by a STA are computed based on the most recent PPDU received by the STA that matches the description indicated by the GID-L, GID-H, Coding Type, STBC Indication, and FB Tx Type fields in the same VHT variant HT Control field.


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In an unsolicited MFB response the GID-L, GID-H, Coding Type, STBC Indication, FB Tx Type, and BW fields are set according to the RXVECTOR parameters of the received PPDU from which the VHT-MCS, SNR, BW, and NUM_STS are estimated, as follows:

- If the VHT-MCS, SNR, BW, and NUM_STS are estimated from a VHT MU PPDU, then the GID-L field is set to the 3 least significant bits and the GID-H field to the 3 most significant bits of the parameter GROUP_ID.
- If the VHT-MCS, SNR, BW, and NUM_STS are estimated from an SU PPDU, then the GID-L field and GID-H field are set to all 1s.
- The Coding Type field is set to 0 if the parameter FEC_CODING is equal to BCC_CODING and set to 1 if equal to LDPC_CODING.
- The STBC Indication field is set to 1 if the parameter STBC is equal to 1 and set to 0 if the STBC parameter is equal to 0.
- The FB TX Type field is set to 1 if the parameter BEAMFORMED is equal to 1 and set to 0 if equal to 0.
- The BW field shall indicate a bandwidth less than or equal to the bandwidth indicated by the parameter CH_BANDWIDTH.

In an MFB response solicited by an MRQ that was not carried in a VHT NDP Announcement frame, the MFB is computed based on RXVECTOR parameters CH_BANDWIDTH, GROUP_ID, NUM_STS, FEC_CODING, BEAMFORMED, and STBC of the received PPDU that carried the MRQ and might additionally be based on other factors that are not part of the RXVECTOR. The NUM_STS subfield of the MFB subfield of VHT variant HT Control field shall be set to an equal or smaller value than the RXVECTOR parameter NUM_STS of the received PPDU that triggered the MRQ.

If the MFB is in the same MPDU as a VHT Compressed Beamforming frame, the MFB responder shall estimate the recommended MFB under the assumption that the beamformer will use the steering matrices contained therein for performing an SU beamformed transmission. In this case the value of the NUM_STS field in the MFB subfield of the VHT variant HT Control field shall be the same as the value of the Nc Index field in the VHT MIMO Control field of the VHT Compressed Beamforming frame and, if the MFB is unsolicited, the Coding Type shall be set to BCC and the FB Tx Type shall be set to 0. Additionally, MFB estimate shall be based on the bandwidth indicated by the Channel Width subfield of the VHT MIMO Control field of the VHT Compressed Beamforming frame. In this case the SNR and BW subfields are reserved and set to 0.

If an unsolicited MFB is not in the same MPDU as a VHT Compressed Beamforming frame, the NUM_STS subfield of the MFB subfield of the VHT variant HT Control field shall be set to an equal or smaller value than the RXVECTOR parameter NUM_STS of the received PPDU from which the MFB parameters are estimated.

If the MFB requester sends the MRQ in a VHT NDP Announcement frame, then the MFB responder shall include the corresponding MFB in (all of) the VHT Compressed Beamforming frame(s) sent in response to the same VHT NDP Announcement frame and NDP sequence.

If the value of the NUM_STS subfield of the MFB field (solicited or unsolicited) is a smaller value than the RXVECTOR parameter NUM_STS of the received PPDU on which the MFB is based, the MFB responder shall estimate the recommended VHT-MCS under the assumption that the MFB requester will transmit the first $N_{STS}$ space-time streams in the corresponding PPDU carrying MRQ. If the MFB is based on an SU PPDU the first $N_{STS}$ space-time streams correspond to columns 1, ..., $N_{STS}$ of the spatial mapping matrix $Q$. If the MFB is based on a VHT MU PPDU, then for the user $u$ the first $N_{STS}$ space-time streams correspond to columns $M_u$+1, ..., $M_u$+$N_{STS,u}$ of the spatial mapping matrix $Q$ ($M_u$ is defined in 21.3.10.11.1 (Transmission in VHT format) and in 23.3.9.11 (OFDM modulation)). The VHT-MCS recommendation shall be a value from the peer's Tx Supported VHT-MCS and NSS Set (see 10.6.13.2 (Tx Supported VHT-MCS and NSS Set)).

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A VHT NDP Announcement frame that contains multiple STA Info fields and that contains a VHT format of HT Control field with the MRQ subfield equal to 1 solicits an MFB response from all of the STAs listed in the STA Info fields.

When the MFB requester sets the MRQ subfield to 1 and sets the MSI/STBC subfield to a value that matches the MSI/STBC subfield value of a previous request for which the responder has not yet provided feedback, the responder shall discard or abandon the computation for the MRQ that corresponds to the previous use of that MSI/STBC subfield value and start a new computation based on the new request.

A STA may respond immediately to a current request for MFB with a frame containing an MFSI field value and an MFB field value that correspond to a request that precedes the current request.

Bidirectional request/responses are supported. A STA may act as both the MFB requester for one direction of a duplex link and the MFB responder for the other direction and include both an MRQ and an MFB in the same VHT variant HT Control field.

### 10.31.4 Link adaptation using the CMMG variant HT Control field

The behavior described in this subclause is specific to the CMMG variant HT Control field.

A STA that supports link adaptation using the CMMG variant HT Control field shall set the CMMG Link Adaptation Capable subfield in the CMMG Capabilities Info field of the CMMG Capabilities element to Unsolicited or Both, depending on its specific link adaptation feedback capability. A STA shall not send an MRQ to STAs that have not set the CMMG Link Adaptation Capable subfield to Both in the CMMG Capabilities Info field of the CMMG Capabilities element. A STA whose most recently transmitted MCS Feedback field of the CMMG Extended capabilities field of the CMMG Capabilities element is equal to Unsolicited or Both may transmit unsolicited MFB in any frame that contains a CMMG variant HT Control field.

The MFB requester may set the MRQ field to 1 in the CMMG variant HT Control field of a frame to request a STA to provide link adaptation feedback. In each request the MFB requester shall set the MSI/STBC field to a value in the ranges 0 to 6, 0 to 2, or 0 to 3, depending on the settings in the Unsolicited MFB and STBC fields (see 9.2.4.6.4 (HE variant(11ax))). The choice of MSI value is implementation dependent.

NOTE 1—The MFB requester might use the MSI subfield as an MRQ sequence number, or it might implement any other encoding of the field.

The appearance of more than one instance of a CMMG variant HT Control field with the MRQ field equal to 1 within a single PPDU shall be interpreted by the receiver as a single request for link adaptation feedback.

In OFDM transmission the number of MCTFs sent in the sounding PPDU or in the NDP is determined by the total number of spatial dimensions to be sounded, including any extra spatial dimensions beyond those used by the data portion of the frame.

On receipt of a CMMG variant HT Control field with the MRQ subfield equal to 1, an MFB responder computes the CMMG-MCS, NUM_STS, and SNR estimates based on the PPDU carrying the MRQ or, in the case of a CMMG with the NDP Announcement subfield set to 1 carrying the MRQ, based on the subsequent CMMG NDP. The MFB responder labels the result of this computation with the MSI value from the CMMG variant HT Control field in the received frame carrying the MRQ. The MFB responder may include the received MSI value in the MFSI field of the corresponding response frame. In the case of a delayed response, this allows the MFB requester to associate the MFB with the soliciting MRQ.

An MFB responder that sends a solicited MFB shall set the Unsolicited MFB subfield in CMMG variant HT Control field to 0.


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The MFB responder may send a solicited response frame with any of the following combinations of CMMG-MCS, NUM_STS, and MFSI:

— CMMG-MCS = 31, NUM_STS = 3 in the MFB subfield, MFSI = 7: no information is provided for the immediately preceding request or for any other pending request. This combination is used when the responder is required to include a CMMG variant HT Control field due to other protocols that use this field (e.g., the reverse direction protocol) and when no MFB is available. It has no effect on the status of any pending MRQ.

— CMMG-MCS = 31, NUM_STS = 3 in the MFB subfield, MFSI in the range 0 to 6: the responder is not providing feedback for the request with the MSI value that matches the MFSI value.(M118)

— CMMG-MCS = valid value, NUM_STS = valid value in the MFB subfield, MFSI in the range 0 to 6: the responder is providing feedback for the request that had the MSI value that matches the MFSI value.

An MFB responder that discards or abandons the MFB estimates computed in response to an MRQ may indicate that it has done so by setting the CMMG-MCS to 31 and NUM_STS to 3 in the MFB subfield in the next frame addressed to the MFB requester that includes the CMMG variant HT Control field. The value of the MFSI is set to the value of the MSI/STBC subfield of the frame that contains an MRQ for which the computation was abandoned, regardless of whether the MSI/STBC subfield contains an MSI or a Compressed MSI and STBC Indication subfields.

The STA receiving MFB may use the received MFB to compute the appropriate CMMG-MCS, SNR, BW, and NUM_STS.

When computing the MCS estimate for an MFB requester whose Tx MCS Set Defined field is equal to 1, the number of spatial streams corresponding to the recommended MCS shall not exceed the limit indicated by the Tx Maximum Number Spatial Streams Supported field.

Hardware and buffer capability may limit the number of MCS estimate computations that a MFB responder is capable of computing simultaneously. When a new MRQ is received either from a different MFB requester or from the same MFB requester with a different MSI value and when the MFB responder is not able to complete the computation for MRQ, then the MFB responder may either discard the new request or abandon an existing request in order to initiate computation for the new MRQ.

A STA sending unsolicited MFB feedback using the CMMG variant HT Control field shall set the Unsolicited MFB subfield to 1.

Unsolicited CMMG-MCS, NUM_STS, BW, and SNR estimates reported in the MFB subfield of a CMMG variant HT Control field sent by a STA are computed based on the most recent PPDU received by the STA that matches the description indicated by the STBC Indication and FB Tx Type fields in the same CMMG variant HT Control field.

In an unsolicited MFB response the STBC Indication, FB Tx Type, and BW fields are set according to the RXVECTOR parameters of the received PPDU from which the CMMG-MCS, SNR, BW, and NUM_STS are estimated, as follows:

— The STBC Indication field is set to 1 if the parameter STBC is equal to 1 and set to 0 if the parameter STBC is equal to 0.

— The FB TX Type field is set to 1 if the parameter BEAMFORMED is equal to 1 and set to 0 if the parameter BEAMFORMED is equal to 0.

— The BW field shall indicate a bandwidth equal to or less than the bandwidth indicated by the parameter CH_BANDWIDTH.

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In an MFB response solicited by an MRQ that was not carried in a CMMG NDP announcement(#1989)(#177), the MFB is computed based on RXVECTOR parameters CH_BANDWIDTH, NUM_STS, BEAMFORMED, and STBC of the received PPDU that carried the MRQ and might additionally be based on other factors that are not part of the RXVECTOR. The NUM_STS subfield of the MFB subfield of the CMMG variant HT Control field shall be set to an equal or smaller value than the RXVECTOR parameter NUM_STS of the received PPDU that triggered the MRQ.

If the MFB is in the same PPDU as a CMMG Compressed Beamforming frame, the MFB responder should estimate the recommended MFB under the assumption that the MFB requester uses the steering matrices contained therein.

If the MFB is in the same MPDU as a CMMG Compressed Beamforming frame, the MFB responder shall estimate the recommended MFB under the assumption that the beamformer uses the steering matrices contained therein. In this case the value of the NUM_STS field in the MFB subfield of the CMMG variant HT Control field shall be the same as the value of the Nc Index field in the CMMG MIMO Control field of the CMMG Compressed Beamforming frame; and, if the MFB is unsolicited, the FB Tx Type shall be set to 0. Additionally, MFB estimate shall be based on the bandwidth indicated by the Channel Width subfield of the CMMG MIMO Control field of the CMMG Compressed Beamforming frame. In this case the SNR and BW subfields are reserved and set to 0.

If an unsolicited MFB is not in the same MPDU as a CMMG Compressed Beamforming frame, the NUM_STS subfield of the MFB subfield of the CMMG variant HT Control field shall be set to an equal or smaller value than the RXVECTOR parameter NUM_STS of the received PPDU from which the MFB parameters are estimated.

After the MFB estimate computation is completed, the MFB responder should include the MFB in the MFB field in the next transmission of a frame addressed to the MFB requester that includes a CMMG variant HT Control field. When the MFB requester sets the MRQ subfield to 1 and sets the MSI subfield to a value that matches the MSI subfield value of a previous request for which the responder has not yet provided feedback, the responder shall discard or abandon the computation for the MRQ that corresponds to the previous use of that MSI subfield value.

A STA may respond immediately to a current request for MFB with a frame containing an MFSI field value and MFB field value that correspond to a request that precedes the current request.

NOTE 2—If a CMMG STA includes the CMMG variant HT Control field in the initial frame of an immediate response exchange and the responding CMMG STA includes the CMMG variant HT Control field in the immediate response frame, the immediate response exchange effectively permits the exchange of the CMMG variant HT Control field elements.

NOTE 3—If an MRQ is included in the last PPDU in a TXOP and there is not enough time for a response, the recipient might transmit the response MFB in a subsequent TXOP.

NOTE 4—Bidirectional request/responses are supported. In this case, a STA acts as the MFB requester for one direction of a duplex link and a MFB responder for the other direction and transmits both MRQ and MFB in the same CMMG Data frames.

## 10.32 CMMG beamforming

A CMMG STA may use beamforming transmission to achieve diversity gain with directional beamforming or the spatial multiplex gain with transmit beamforming.

— Directional beamforming (BF) that does not use an omnidirectional antenna pattern or quasi-omni antenna pattern is a mechanism that is used by a pair of STAs to achieve the necessary link budget for subsequent communication. Directional BF training is a bidirectional sequence of BF frame


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transmissions that uses sector sweep and provides the necessary signaling to allow each STA to determine appropriate antenna system settings for both transmission and reception. CMMG STAs shall follow the same beamforming training rules defined in 10.41 (DMG beamforming). BF frame transmitted by a CMMG STA is contained in CMMG PPDU.

— Transmit beamforming (see 10.33 (Transmit beamforming)) that uses an omnidirectional antenna pattern or quasi-omni antenna pattern.

## 10.33 Transmit beamforming

### 10.33.1 HT steering matrix calculations

In order for an HT beamformer to calculate an appropriate steering matrix for transmit spatial processing when transmitting to a specific HT beamformee, the HT beamformer needs to have an accurate estimate of the channel over which it is transmitting. Two methods of calculation are defined as follows:

— *Implicit feedback*: When using implicit feedback, the beamformer receives long training symbols transmitted by the HT beamformee, which allow the MIMO channel between the HT beamformee and HT beamformer to be estimated. If the channel is reciprocal, the HT beamformer can use the training symbols that it receives from the HT beamformee to make a channel estimate suitable for computing the transmit steering matrix. Generally, calibrated radios in MIMO systems can improve reciprocity. See 10.33.2 (HT transmit beamforming with implicit feedback).

— *Explicit feedback*: When using explicit feedback, the HT beamformee makes a direct estimate of the channel from training symbols sent to the HT beamformee by the HT beamformer. The HT beamformee may prepare CSI or steering feedback based on an observation of these training symbols. The HT beamformee quantizes the feedback and sends it to the HT beamformer. The HT beamformer can use the feedback as the basis for determining transmit steering vectors. See 10.33.3 (Explicit feedback beamforming).

An HT STA shall not transmit a PPDU with the TXVECTOR EXPANSION_MAT parameter present if dot11BeamFormingOptionActivated is false.

In order for a CMMG beamformer to calculate an appropriate steering matrix for transmit spatial processing when transmitting to a specific CMMG beamformee, the CMMG beamformer needs to have an accurate estimate of the channel over which it is transmitting. The method of calculation for CMMG beamformer based on explicit feedback is defined as follows:

— When using explicit feedback, the CMMG beamformee makes a direct estimate of the channel from training symbols sent to the CMMG beamformee by the CMMG beamformer. The CMMG beamformee may prepare CSI or steering feedback based on an observation of these training symbols. The CMMG beamformee quantizes the feedback and sends it to the CMMG beamformer. The CMMG beamformer can use the feedback as the basis for determining transmit steering vectors. See 10.33.5 (Explicit feedback beamforming for CMMG STAs).

A CMMG STA shall not transmit a PPDU with the TXVECTOR EXPANSION_MAT parameter present if dot11BeamFormingOptionActivated is false.

### 10.33.2 HT transmit beamforming with implicit feedback

#### 10.33.2.1 General

The procedures for HT transmit beamforming with implicit feedback use only HT and non-HT PPDUs, and the HT Control field, when present, is the HT variant HT Control field.

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Transmit beamforming with implicit feedback can operate in a unidirectional or bidirectional manner. In unidirectional implicit transmit beamforming, only the HT beamformer sends beamformed transmissions. In bidirectional implicit transmit beamforming, both STAs send beamformed transmissions, i.e., a STA may act as both HT beamformer and HT beamformee.

Calibration of receive/transmit chains should be done to improve performance of transmit beamforming using implicit feedback. Over-the-air calibration is described in 10.33.2.4 (Calibration). For implicit transmit beamforming, only the HT beamformer, which is sending the beamformed transmissions, needs to be calibrated.

A STA that advertises itself as being capable of being an HT beamformer and/or HT beamformee using implicit feedback shall support the requirements in Table 10-28 (STA type requirements for transmit beamforming with implicit feedback).

**Table 10-28—STA type requirements for transmit beamforming with implicit feedback**

| STA capability | Required support |
|---|---|
| Beamformer | Shall set the Implicit Transmit Beamforming Capable subfield to 1 of the Transmit Beamforming Capability field of the HT Capabilities element in HT Capabilities elements that it transmits.<br>Shall set the Implicit Transmit Beamforming Receiving Capable subfield to 1 of the Transmit Beamforming Capability field of the HT Capabilities element.<br>Shall support(#546) receiving a sounding PPDU for which the SOUNDING parameter is SOUNDING and the NUM_EXTEN_SS is equal to 0 in the RXVECTOR in the PHY-RXSTART.indication primitive, independently of the values of the Receive Staggered Sounding Capable and Receive NDP Capable subfields.<br>Shall set the Calibration subfield to 3 of the Transmit Beamforming Capability field of the HT Capabilities element to advertise full calibration support. |
| Beamformee | Shall set the Implicit Transmit Beamforming Receiving Capable subfield to 1 of the Transmit Beamforming Capability field of the HT Capabilities element in HT Capabilities elements that it transmits.<br>Shall support(#546) setting the SOUNDING parameter to SOUNDING and the NUM_EXTEN_SS to 0 in the TXVECTOR in the PHY-TXSTART.request primitive when transmitting a sounding PPDU, as a response to TRQ=1, independently of the values of the Transmit Staggered Sounding Capable and Transmit NDP Capable subfields. |

A STA that performs one of the roles related to transmit beamforming with implicit feedback shall support the associated capabilities shown in Table 10-29 (Transmit beamforming support required with implicit feedback).

**Table 10-29—Transmit beamforming support required with implicit feedback**

| Role | Required support |
|---|---|
| HT beamformee:<br>A receiver of transmit beamformed PPDUs | Shall transmit sounding PPDUs as a response to TRQ=1. |
| Beamformer:<br>A transmitter of beamformed PPDUs | Can receive sounding PPDUs.<br>Can compute steering matrices from MIMO channel estimates obtained from long training symbols in sounding PPDUs received from the HT beamformee. |


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**Table 10-29—Transmit beamforming support required with implicit feedback**

| Role | Required support |
|---|---|
| A responder in a calibration exchange | Can receive and transmit sounding PPDUs.<br>Can respond with a CSI frame that contains channel measurement information obtained during reception of a sounding PPDU. |
| An initiator in a calibration exchange | Can receive and transmit sounding PPDUs.<br>Can receive a CSI frame sent by a calibration responder. |

When an HT beamformee transmits a sounding PPDU, the SOUNDING parameter in the TXVECTOR in the PHY-TXSTART.request primitive shall be set to SOUNDING. If the HT beamformee is capable of implicit transmit beamforming and the HT beamformer is capable of receiving implicit transmit beamforming, the sounding PPDU from the HT beamformee may be steered.

A PPDU containing one or more +HTC MPDUs in which the TRQ field is equal to 1 shall not be sent to a STA that sets the Implicit Transmit Beamforming Receiving Capable subfield of the Transmit Beamforming field of the HT Capabilities element to 0.

If a PPDU containing one or more +HTC MPDUs in which the TRQ field is equal to 1 requires an immediate response, either the response from the HT beamformee shall be included in a sounding PPDU, or the HT NDP Announcement subfield of the HT Control field shall be set to 1 and the PPDU shall be followed by an NDP. If the PPDU in which the TRQ field is equal to 1 does not require an immediate response, either the HT beamformee shall transmit a sounding PPDU in the next TXOP obtained by the HT beamformee, or the HT beamformee shall transmit a PPDU in the next TXOP obtained by the HT beamformee in which the HT NDP Announcement subfield of the HT Control field is set to 1 and that PPDU shall be followed by an NDP. The use of NDP as a sounding PPDU is described in 10.35 (Null data PPDU (NDP) sounding).

NOTE—A STA that acts as an HT beamformer using implicit feedback expects to receive a sounding PPDU in response to a training request. The STA can compute steering matrices from the channel estimates obtained from the received sounding PPDU.

At the end of the TXOP the final PPDU from the HT beamformer shall not have the TRQ field set to 1 in a frame that requests an immediate response if there is not enough time left in the TXOP for the HT beamformee to transmit the longest valid sounding PPDU with its response.

### 10.33.2.2 Unidirectional implicit transmit beamforming

Figure 10-51 (Example PPDU exchange for unidirectional implicit transmit beamforming) shows an example of a PPDU exchange used in unidirectional implicit transmit beamforming using the Clause 19 (High Throughput (HT) PHY specification(#2297)) PHY. In this example, sounding PPDUs are used that carry MPDUs (i.e., an example of implicit beamforming using NDPs is not shown here.) STA A is the beamformer that initiates the PPDU exchange, and STA B is the beamformee.

The PPDU exchange can be summarized as follows:

a) STA A initiates the frame exchange sequence by sending an unsteered PPDU to STA B. The PPDU includes a training request (TRQ= 1) in a +HTC MPDU.

b) STA B sends a sounding PPDU in response to the training request from STA A.

c) On receiving the sounding PPDU, STA A uses the resulting channel estimate to compute steering matrices and uses these matrices to send a steered PPDU back to STA B.

d) The steered PPDU transmitted in step c) and subsequent steered PPDUs transmitted by STA A may include training requests (TRQ=1) in a +HTC MPDU. In response to each training request, STA B

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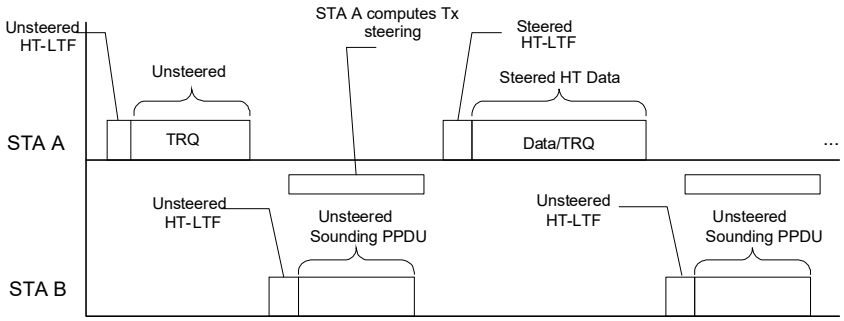


**Figure 10-51—Example PPDU exchange for unidirectional implicit transmit beamforming**

returns a sounding PPDU to STA A, which enables STA A to update its steering vectors. If the steering vectors resulting from step c) or subsequent sounding PPDUs are deemed stale due to delay, the sequence may be restarted by returning to step a).

Step d) in the above PPDU exchange represents steady-state unidirectional transmit beamforming operation.

During the PPDU exchange neither the receiving nor the transmitting STA should switch antennas.

### 10.33.2.3 Bidirectional implicit transmit beamforming

Figure 10-52 (Example PPDU exchange for bidirectional implicit transmit beamforming) shows an example of a PPDU exchange used in bidirectional implicit transmit beamforming, using the Clause 19 (High Throughput (HT) PHY specification(#2297)) PHY. In this example, sounding PPDUs are used that carry MPDUs. STA A initiates the frame exchange sequence(#109), and STA A and STA B alternate in the roles of HT beamformer and HT beamformee.

The PPDU exchange can be summarized as follows:

a) STA A initiates the frame exchange sequence by sending an unsteered PPDU to STA B. The PPDU includes a training request (TRQ= 1) in a +HTC MPDU.

b) STA B sends a sounding PPDU in response to the training request. In addition, this PPDU includes a training request in a +HTC MPDU to enable implicit transmit beamforming in the RD.

c) On receiving the sounding PPDU, STA A uses the resulting channel estimate to compute steering matrices and uses these matrices to send a steered PPDU back to STA B. This steered PPDU is also a sounding PPDU in response to the training request from STA B.

NOTE 1—Steering matrices with nonorthonormal columns should not be used in transmitting sounding PPDUs for implicit feedback. In general, bidirectional implicit beamforming (M118)does not function as described here when the steering matrices have nonorthonormal columns. See 19.3.12.2 (Implicit feedback beamforming).

d) On receiving the sounding PPDU, STA B uses the resulting channel estimate to compute steering matrices and uses these matrices to send a steered PPDU back to STA A. The steered PPDU transmitted in step c) and subsequent steered PPDUs transmitted by STA A may include training requests in HTC. In response to each training request, STA B returns a sounding PPDU to STA A, which enables STA A to update its steering vectors. If the steering vectors resulting from step c) or subsequent sounding PPDUs are deemed stale due to delay, the sequence may be restarted by returning to step a).

e) The steered PPDU transmitted in step d) and subsequent steered PPDUs transmitted by STA B may include training requests in HTC. In response to each training request, STA A returns a sounding PPDU to STA B, which enables STA B to update its steering vectors. If the steering vectors


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resulting from step d) or subsequent sounding PPDUs are deemed stale due to delay, the sequence may be restarted by returning to step a).

Steps d) and e) in the above PPDU exchange represent steady-state bidirectional transmit beamforming operation.

During the PPDU exchange neither the receiving nor the transmitting STA should switch antennas.

NOTE 2—The TRQ protocol used with the beamforming training process is not sufficient to permit STA B to transmit Data frames in the RD. In the example shown in Figure 10-52 (Example PPDU exchange for bidirectional implicit transmit beamforming), STA A would additionally have to follow the rules of the reverse direction protocol (see 10.29 (Reverse direction protocol)).

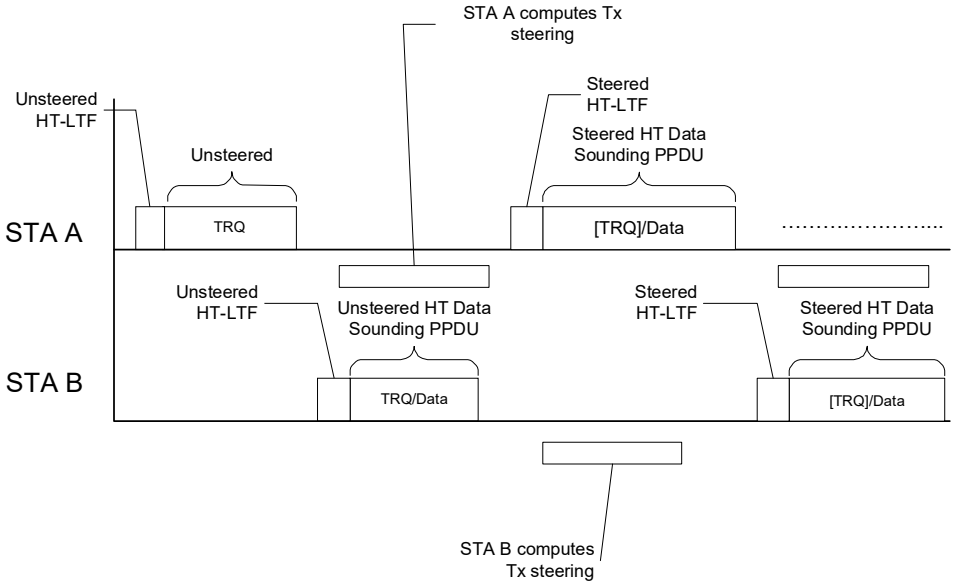


**Figure 10-52—Example PPDU exchange for bidirectional implicit transmit beamforming**

### 10.33.2.4 Calibration

#### 10.33.2.4.1 Introduction

Differences between transmit and receive chains in a STA degrade the inherent reciprocity of the over-the-air time division duplex channel and cause degradation of the performance of implicit beamforming. Calibration acts to remove or reduce differences between transmit and receive chains and enforce reciprocity in the observed baseband-to-baseband channels between two STAs.

A STA acting as an HT beamformer should be calibrated to maximize performance. A STA acting only as an HT beamformee does not need to be calibrated. In order to perform calibration, the STA follows the procedure described below.

The calibration procedure involves the computation of correction matrices that cause the observed channel matrices in the two directions of the link to be transposes of each other and thus renders the resultant channel reciprocal. See 19.3.12.2 (Implicit feedback beamforming) for a more detailed description. If it is able to do so, a STA should calibrate upon association.

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NOTE—STAs with two or more transmit chains should be calibrated in order to engage in implicit transmit beamforming. STAs with any number of RF chains, including those with a single RF chain, can participate in a calibration exchange as a calibration responder.

#### 10.33.2.4.2 Calibration capabilities

A STA that sets the Implicit Transmit Beamforming Capable subfield of the Transmit Beamforming Capabilities field to 1 shall support calibration and shall set the Calibration subfield of the Transmit Beamforming Capabilities field to 3 (indicating full support of calibration) in HT Capabilities elements that it transmits. A STA that does not set the Implicit Transmit Beamforming Capable subfield of the Transmit Beamforming Capabilities field to 1 may support calibration and shall set the Calibration subfield of the Transmit Beamforming Capabilities field to the value that indicates its calibration capability in the Transmit Beamforming Capabilities field in HT Capabilities elements that it transmits (see Table 9-228 (Subfields of the Transmit Beamforming Capabilities field)), when the Transmit Beamforming Capabilities field exists.

A STA that is capable of initiating calibration (the Calibration subfield of the Transmit Beamforming Capabilities field is equal to 3) shall set the CSI Max Number of Rows Beamformer Supported subfield to an appropriate value, even if the STA sets the Explicit Transmit Beamforming CSI Feedback subfield to the value 0.

In order to support calibration, a STA that advertises that it is capable of responding to a calibration request shall support(#546) transmitting a CSI frame in which the value of the Grouping subfield of the MIMO Control field is 0 (no grouping) and the Coefficients Size subfield of the MIMO Control field is 3 ($Nb = 8$ bits) in response to a CSI feedback request indicated by the CSI/Steering subfield of the HT Control field equal to 1 and the Calibration Position subfield of the HT Control field equal to 3, independently of the advertised values of the Explicit Transmit Beamforming CSI Feedback subfield in the Transmit Beamforming Capabilities field in the HT Capabilities element. A STA that advertises that it is capable of initiating a calibration request shall support(#546) receiving a CSI frame in which the value of the Grouping subfield of the MIMO Control field is equal to 0 (no grouping) and the Coefficients Size subfield of the MIMO Control field is equal to 3 ($Nb = 8$ bits) as a response to CSI feedback request indicated by the CSI/Steering subfield of the HT Control field equal to 1 with the Calibration Position subfield equal to 3, independently of the advertised values of the Explicit CSI Transmit Beamforming Capable subfield in the Transmit Beamforming Capabilities field in the HT Capabilities element.

A STA may initiate a calibration training frame exchange sequence with another STA if that STA supports calibration. A STA shall not initiate a calibration training frame exchange sequence(#109) with another STA if that STA does not support calibration.

If the (#402)Receive NDP Capable subfield is equal to 1, the value of the Calibration subfield is equal to 1 or 3, and the device supports transmitting sounding PPDUs for which two or more channel dimensions can be estimated (two or more columns of the MIMO channel matrix), then transmission of NDPs shall be supported (and the (#402)Transmit NDP Capable subfield shall be set to 1).

#### 10.33.2.4.3 Sounding exchange for calibration

Figure 10-53 (Calibration procedure with sounding PPDU containing an MPDU) illustrates the calibration PPDU exchange using sounding PPDUs that contain an MPDU.


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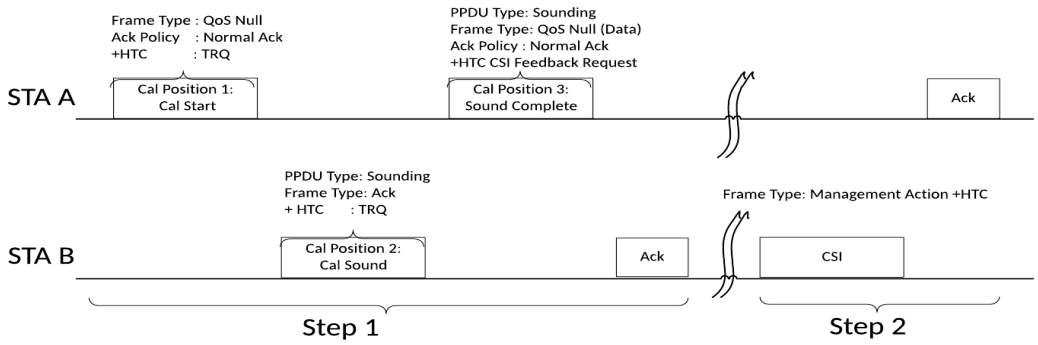


**Figure 10-53—Calibration procedure with sounding PPDU containing an MPDU**

The calibration procedure begins with a calibration (#109)sounding frame exchange sequence shown as Step 1 in Figure 10-53 (Calibration procedure with sounding PPDU containing an MPDU). The Calibration Sequence subfield in the HT Control field shall be incremented each time a new calibration procedure is started.

STA A (the calibration initiator) shall transmit a Calibration Start frame (Calibration Position subfield set to 1) with the TRQ field in the HT Control field set to 1. This frame initiates a calibration procedure. It shall be a QoS Null frame with Normal Ack ack policy.

In response, STA B (the calibration responder) shall transmit a Calibration Sounding Response frame (Calibration Position subfield set to 2), a SIFS after the end of the Calibration Start frame, using a sounding PPDU. This step allows STA A to estimate the MIMO channel from STA B to STA A. In the Calibration Sounding Response frame, the Calibration Sequence subfield in HT Control field shall be set to the same value that is indicated in the Calibration Start frame. The Calibration Sounding Response frame shall have a frame type of Ack+HTC, and the TRQ field in the HT Control field in this frame shall be set to 1.

In response, STA A shall transmit a Calibration Sounding Complete frame (Calibration Position subfield set to 3) that contains the CSI/Steering subfield of the HT Control field set to 1, a SIFS after the end of the Calibration Sounding Response frame, using a sounding PPDU. This step allows STA B to estimate the MIMO channel from STA A to STA B. In this Calibration Sounding Complete frame, the Calibration Sequence subfield in the HT Control field shall be set to the same value that is indicated in the Calibration Sounding Response frame. The Calibration Sounding Complete frame shall be a QoS Null+HTC with Normal Ack ack policy.

A frame in which the Calibration Position subfield is equal to 2 or 3 shall be transmitted in a sounding PPDU (a PPDU for which the SOUNDING parameter is set to SOUNDING). The number of Long Training fields (LTFs) used to obtain MIMO channel estimation that are sent in the sounding PPDU shall be determined by the number of transmit chains ($N_{TX}$) used in sending these LTFs at the STA transmitting the sounding PPDU. The transmit chains used at the calibration initiator are those for which calibration is required.

The calibration responder may train up to maximum available transmit chains to maximize the quality of the resulting calibration, although the number of space-time streams for data symbols shall be determined by the rule described in 10.6 (Multirate support).

When transmitting a sounding PPDU during Step 1 of a calibration procedure, if the Receive Staggered Capability subfield in the Transmit Beamforming Capability field of the HT Capabilities element transmitted by the intended receiver is 0, then,

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— If the sounding PPDU is not an NDP, the number of antennas used by the sender shall be less than or equal to the maximum number of space-time streams indicated by the Rx MCS Bitmask subfield of the Supported MCS Set field and the Rx STBC subfield of the HT Capabilities element transmitted by the intended receiver.

— If the sounding PPDU is an NDP, the number of antennas used by the sender shall be less than or equal to the number indicated by the Channel Estimation Capability subfield in the Transmit Beamforming Capability field of the HT Capabilities element transmitted by the intended receiver.

Sounding PPDUs in which the Calibration Position subfield is equal to 2 or 3 shall use the spatial mapping matrices defined in 19.3.12.3 (Explicit feedback beamforming). The calibration responder shall not remove the spatial mapping from the CSI to be fed back to the initiator of the frame exchange sequence(#109).

NOTE 1—The calibration initiator of this frame exchange sequence(#109) is responsible for accounting for the spatial mapping in both its local channel estimate as well as in the quantized CSI fed back to it.

The row order in the CSI feedback matrix transmitted from STA B shall correspond to the association of the rows of the spatial mapping matrix (#4181)(see Equation (19-75)) to its transmit antennas. For example, the receive antenna at STA B associated with row *i* in the CSI feedback matrix in each subcarrier is the same as its transmit antenna associated with row *i* in the spatial mapping matrix used for transmitting the sounding response with Calibration Position equal to 2.

Figure 10-54 (Calibration procedure with NDP) and Figure 10-55 (Calibration procedure with NDP when STA B supports transmitting sounding PPDUs for which only one channel dimension can be estimated (i.e., a single column of the MIMO channel matrix)) illustrate the calibration PPDU exchange using NDPs.

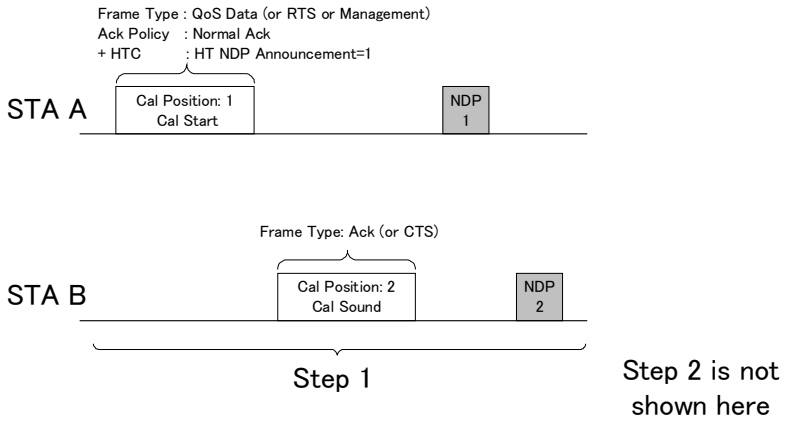


**Figure 10-54—Calibration procedure with NDP**

The calibration procedure begins with a calibration (#109)sounding frame exchange sequence, shown as Step 1 in Figure 10-54 (Calibration procedure with NDP) and Figure 10-55 (Calibration procedure with NDP when STA B supports transmitting sounding PPDUs for which only one channel dimension can be estimated (i.e., a single column of the MIMO channel matrix)), when STA B supports transmitting sounding PPDUs for which only one channel dimension can be estimated (i.e., a single column of the MIMO channel matrix). The Calibration Sequence subfield in the HT Control field shall be incremented each time a new calibration procedure is started.

NDP transmission within a calibration procedure follows the rules defined in 10.35.1 (HT NDP sounding protocol). STA A transmits a Calibration Start frame (i.e., with the Calibration Position subfield set to 1) with the HT NDP Announcement subfield set to 1 and CSI/Steering subfield of the HT Control field set to 1. Only the current TXOP holder may set both the Calibration Position and HT NDP Announcement subfields to 1. This frame initiates a calibration procedure.


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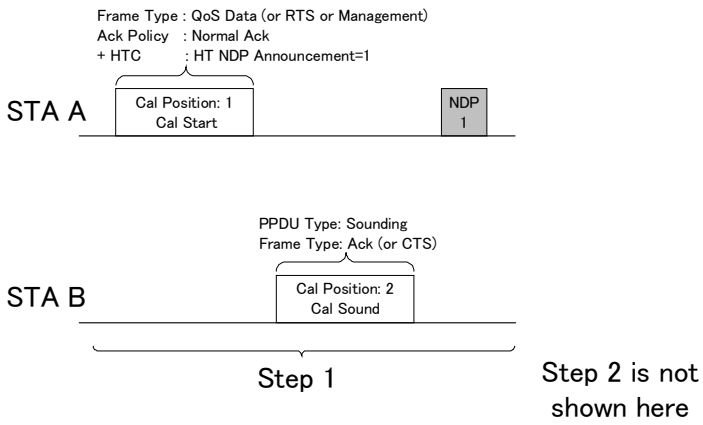


**Figure 10-55—Calibration procedure with NDP when STA B supports transmitting sounding PPDUs for which only one channel dimension can be estimated (i.e., a single column of the MIMO channel matrix)**

STA B shall transmit a Calibration Sounding Response frame (i.e., with the Calibration Position subfield set to 2) after a SIFS after the received Calibration Start frame. If STA B supports transmitting sounding PPDUs for which only one channel dimension can be estimated (i.e., a single column of the MIMO channel matrix), this Calibration Sounding Response frame is sent with the SOUNDING parameter of the TXVECTOR set to SOUNDING (see Figure 10-55 (Calibration procedure with NDP when STA B supports transmitting sounding PPDUs for which only one channel dimension can be estimated (i.e., a single column of the MIMO channel matrix))).

As determined by NDP rules a) or b) in 10.35.1 (HT NDP sounding protocol), STA A sends the first NDP as a sounding PPDU a SIFS after receiving the Calibration Sounding Response frame. This step allows STA B to estimate the MIMO channel from STA A to STA B. In the Calibration Sounding Response frame, the Calibration Sequence subfield in HT Control field shall be set to the same value that is contained in the Calibration Start frame. The Calibration Sounding Response frame shall contain an HT Control field, and the type and subtype of the frame are determined by the Calibration Start frame.

As determined by NDP rule d), STA B might transmit a second NDP as a sounding PPDU a SIFS after receiving the first NDP. This second NDP allows STA A to estimate the channel from STA B to STA A.

NOTE 2—STA B does not transmit an NDP when it supports transmitting sounding PPDUs for which only one channel dimension can be estimated (see Figure 10-55 (Calibration procedure with NDP when STA B supports transmitting sounding PPDUs for which only one channel dimension can be estimated (i.e., a single column of the MIMO channel matrix))).

Otherwise [i.e., if STA B supports transmitting sounding PPDUs for which only one channel dimension can be estimated (single column of the MIMO channel matrix)], the transmission of the sounding PPDU in Calibration Position 2 allows STA A to estimate the channel from STA B to STA A.

NDP sounding PPDUs shall use the spatial mapping matrices defined in 19.3.13.3 (Sounding PPDU for calibration). The calibration responder shall not remove the spatial mapping from the CSI to be fed back to the initiator of the frame exchange sequence(#109).

NOTE 3—The calibration initiator of this frame exchange sequence(#109) is responsible for accounting for the spatial mapping in both its local channel estimate as well as in the quantized CSI fed back to it.

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#### 10.33.2.4.4 CSI reporting for calibration

The remaining message exchange in the calibration procedure is not time critical.

The calibration initiator should not transmit any frames that are part of the calibration sequence shown in Step 1 in Figure 10-53 (Calibration procedure with sounding PPDU containing an MPDU) if either of the response frames from the calibration responder (the frames shown as Calibration Position 2 and Ack in Step 1) is not received correctly within an AckTimeout interval (as defined in 10.3.2.11 (Acknowledgment procedure)) after the PHY-TXEND.confirm primitive. If the calibration initiator aborts the calibration sequence, it may restart the calibration sequence with a value of the Calibration Sequence subfield in the Calibration Control subfield of the HT Control field that is different (i.e., incremented) from the value used in the aborted sequence. Within a non-NDP calibration sequence, the calibration responder should not transmit any further frames that are part of the calibration sequence shown in Step 1 if the frame having Calibration Position 3 is not received correctly within an AckTimeout interval (as defined in 10.3.2.11 (Acknowledgment procedure)) after the PHY-TXEND.confirm primitive.

When the MIMO channel measurements become available at STA B, STA B shall send one or more CSI frames that contain the CSI report (Step 2 in Figure 10-53 (Calibration procedure with sounding PPDU containing an MPDU)). This CSI report shall have full precision, i.e, *Ng*=1 (no grouping) and *Nb*=3 (8 bits). In these CSI frames, the Calibration Sequence subfields in HT Control fields shall be set to the same value that is indicated in the Calibration Sounding Complete frame. These CSI frames shall have a frame type of Management Action +HTC.

STA B should finish transmission of the first CSI frame within aMaxCSIMatricesReportDelay (in milliseconds) after the reception of the frame containing the CSI feedback request or HT NDP announcement.

NOTE—If necessary, the CSI Report field can be split into up to 8 segments as specified in Table 9-85 (Subfields of the MIMO Control field).

A STA that has started but not completed the calibration procedure and that receives some other request that requires the buffering of CSI (such as another calibration initiation frame, MFB request, CSI feedback request for link adaptation, or feedback request for explicit Transmit Beamforming) may ignore the other request.

From the beginning of Step 1 of the calibration procedure and continuing through the end of Step 2 of the calibration procedure, neither the receiving nor the transmitting STA should switch antennas.

### 10.33.3 Explicit feedback beamforming

The procedures in this subclause apply only to HT and non-HT PPDUs for which the HT Control field, if present, is the HT variant HT Control field.

In this subclause, the terms *HT beamformer* and *HT beamformee* refer to STAs that are involved in explicit feedback beamforming.

An HT beamformer uses the feedback response that it receives from the HT beamformee to calculate a beamforming feedback matrix for transmit beamforming. This feedback response may have one of three formats:

- *CSI*: The HT beamformee sends the MIMO channel coefficients to the HT beamformer.
- *Noncompressed beamforming*: The HT beamformee sends calculated beamforming feedback matrices to the HT beamformer.
- *Compressed beamforming*: The HT beamformee sends compressed beamforming feedback matrices to the HT beamformer.


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The supported formats shall be advertised in the HT beamformee's HT Capabilities element.

NOTE 1—An HT beamformer might discard the feedback response if the TSF time when the PHY-CCA.indication(IDLE) primitive corresponding to the feedback response frame's arrival minus the value from the Sounding Timestamp field in the feedback response frame is greater than the coherence time interval of the propagation channel.

An HT beamformee's responding capabilities shall be advertised in HT Capabilities elements that are transmitted by the HT beamformee. Devices that are capable of acting as an HT beamformee shall advertise one of the following response capabilities in the Explicit Transmit Beamforming CSI Feedback subfield of the Transmit Beamforming Capability field:

— *Immediate*: The HT beamformee is capable of sending a feedback response a SIFS after receiving a sounding PPDU and/or is capable of sending a feedback response aggregated in a PPDU that contains a MAC response within the HT beamformer's TXOP.

— *Delayed*: The HT beamformee is not capable of sending the feedback response within the HT beamformer's TXOP, but it is capable of sending the feedback response in a TXOP that it obtains.

— *Immediate and Delayed*: The HT beamformee is capable of sending a feedback response a SIFS after receiving a sounding PPDU, sending a feedback response aggregated in a PPDU that contains a MAC response within the HT beamformer's TXOP, or sending the feedback response in a TXOP that it obtains.

The sounding frame types supported by the HT beamformee, staggered and/or NDP, are advertised in the HT Capabilities element in frames that are transmitted by the HT beamformee.

A STA that sets any of the Explicit Transmit Beamforming CSI Feedback Capable, Explicit Noncompressed Beamforming Feedback Capable, or Explicit Compressed Beamforming Feedback Capable fields to 1 shall transmit explicit feedback based on the receipt of a +HTC sounding PPDU in which the CSI/Steering subfield has a nonzero value and that does not contain Extension HT-LTFs (HT-ELTFs). This requirement is independent of the values of the Receive Staggered Sounding Capable and the Receive NDP Capable fields.

An HT beamformer shall set the SOUNDING parameter of the TXVECTOR to SOUNDING in the PHY-TXSTART.request primitive corresponding to each PPDU that is used for sounding.

An HT beamformer shall set the response type format indicated in the CSI/Steering subfield of the HT Control field of any sounding frame excluding the NDP and of any PPDU with the (#8105)HT NDP Announcement field equal to 1 to one of the nonzero values (CSI, Compressed Beamforming, or Noncompressed Beamforming) that corresponds to a type that is supported by the HT beamformee.

The receipt of a PHY-RXSTART.indication primitive with the RXVECTOR SOUNDING parameter value equal to SOUNDING indicates a sounding PPDU. A non-NDP request for feedback is a sounding PPDU with a +HTC MPDU that contains a nonzero value of the CSI/Steering subfield and that has the HT NDP Announcement subfield equal to 0.

An NDP request for feedback is the combination of a +HTC MPDU that contains a nonzero value of the CSI/Steering subfield and that has the HT NDP Announcement subfield equal to 1 and the NDP that follows.

An HT beamformee that transmits a feedback frame in response to a sounding PPDU sent by an HT beamformer shall transmit a frame of the type (CSI, Compressed Beamforming, or Noncompressed Beamforming) indicated in the CSI/Steering subfield of the HT Control field transmitted by the HT beamformer.

The HT beamformee decides on any subcarrier grouping to be used in the explicit Beamforming feedback. The value selected shall be a value supported by the HT beamformer as indicated in the Minimal Grouping subfield of the HT beamformer's HT Capabilities element.

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An HT beamformee that sets the Explicit Transmit Beamforming CSI Feedback field of its HT Capabilities element to either 2 or 3 shall transmit Explicit CSI feedback after a SIFS(#6587) or later in the HT beamformer's TXOP as a response to a non-NDP request for feedback in a frame that is appropriate for the current frame exchange sequence following Table 10-30 (Rules for HT beamformee immediate feedback transmission responding to non-NDP sounding). An HT beamformee that sets the Explicit Noncompressed Beamforming Feedback Capable field of its HT Capabilities element to either 2 or 3 shall transmit Explicit Noncompressed Beamforming feedback after a SIFS(#6587) or later in the HT beamformer's TXOP as a response to a non-NDP request for feedback in a frame that is appropriate for the current frame exchange sequence following Table 10-30 (Rules for HT beamformee immediate feedback transmission responding to non-NDP sounding).

**Table 10-30—Rules for HT beamformee immediate feedback transmission responding to non-NDP sounding**

| Type of response | Rule |
|---|---|
| CTS response | If the transmission of a CTS is required in response to the non-NDP request for feedback, the transmission of the feedback response frame shall be delayed until the HT beamformee's next transmission within the TXOP. This feedback response frame may be aggregated in an A-MPDU with an Ack or BlockAck frame. |
| Acknowledgment response | If the transmission of an Ack or BlockAck frame is required in response to the non-NDP request for feedback, both the feedback response frame and the control response frame may be aggregated in an A-MPDU. |
| No control response | If the transmission of a control response frame is not required in response to the non-NDP request for feedback, the feedback response frame shall be sent a SIFS after the reception of the sounding PPDU containing the request for feedback. |
| Later aggregation of feedback and acknowledgment | If the immediate-feedback-capable HT beamformee cannot transmit an aggregated or immediate CSI/Steering response in a SIFS after the end of the received sounding PPDU and the HT beamformee is subsequently required to transmit an Ack or BlockAck frame in the same TXOP, it may transmit the feedback response in an A-MPDU with the Ack or BlockAck frame. |

An HT beamformee that sets the Explicit Compressed Beamforming Feedback Capable field of its HT Capabilities element to either 2 or 3 shall transmit Explicit Compressed Beamforming feedback after a SIFS(#6587) or later in the HT beamformer's TXOP as a response to a non-NDP request for feedback in a frame that is appropriate for the current frame exchange sequence following Table 10-30 (Rules for HT beamformee immediate feedback transmission responding to non-NDP sounding).

An HT beamformee that sets the Explicit Transmit Beamforming CSI Feedback field of its HT Capabilities element to either 2 or 3 shall transmit the Explicit CSI feedback after a SIFS(#6587) or later in the HT beamformer's TXOP as a response to an NDP request for feedback in a frame that is appropriate for the current frame exchange sequence following Table 10-31 (Rules for HT beamformee immediate feedback transmission responding to NDP sounding).

An HT beamformee that sets the Explicit Noncompressed Beamforming Feedback Capable field of its HT Capabilities element to either 2 or 3 shall transmit the Explicit Noncompressed Beamforming feedback after a SIFS(#6587) or later in the HT beamformer's TXOP as a response to an NDP request for feedback in a frame that is appropriate for the current frame exchange sequence following Table 10-31 (Rules for HT beamformee immediate feedback transmission responding to NDP sounding).

An HT beamformee that sets the Explicit Compressed Beamforming Feedback Capable field of its HT Capabilities element to either 2 or 3 shall transmit the Explicit Compressed Beamforming feedback after a


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**Table 10-31—Rules for HT beamformee immediate feedback transmission responding to NDP sounding**

| Type of response | Rule |
|---|---|
| Control response | If the transmission of a control response frame is required in response to the NDP request for feedback, the control response frame is transmitted a SIFS after reception of the PPDU that elicited the control response, and the feedback response frame may be transmitted a SIFS after the reception of the NDP.<br>— If the feedback response frame is not transmitted a SIFS after the reception of the NDP and the HT beamformee is subsequently required to transmit an Ack or BlockAck frame in the same TXOP, then the feedback response may be aggregated with the Ack or BlockAck frame.<br>— If the feedback response frame is not transmitted a SIFS after the reception of the NDP and is not transmitted with an aggregated Ack or BlockAck frame in the same TXOP, then the feedback response frame is delayed until the HT beamformee's next transmission within the TXOP. |
| No control response | If the transmission of a control response frame is not required in response to the NDP request for feedback, the feedback response frame may be sent a SIFS after the reception of the NDP.<br>— If the feedback response frame is not transmitted a SIFS after the reception of the NDP and the HT beamformee is subsequently required to transmit an Ack or BlockAck frame in the same TXOP, then the feedback response may be aggregated with the Ack or BlockAck frame.<br>— If the feedback response frame is not transmitted a SIFS after the reception of the NDP and is not transmitted with an aggregated Ack or BlockAck frame in the same TXOP, then the feedback response frame is delayed until the HT beamformee's next transmission within the TXOP. |

SIFS(#6587) or later in the HT beamformer's TXOP as a response to an NDP request for feedback in a frame that is appropriate for the current frame exchange sequence following Table 10-31 (Rules for HT beamformee immediate feedback transmission responding to NDP sounding).

When the HT beamformee sets the Explicit Transmit Beamforming CSI Feedback field of its HT Capabilities element to either 2 or 3 and the HT beamformer has transmitted an NDP or a(#1426) non-NDP Explicit Beamforming CSI feedback request in a frame that does not require immediate control response, the HT beamformer shall not transmit the next PPDU to the HT beamformee until PIFS after transmitting the sounding request.

When the HT beamformee sets the Explicit Noncompressed Beamforming Feedback Capable field of its HT Capabilities element to either 2 or 3 and the HT beamformer has transmitted an NDP or a(#1426) non-NDP Explicit Noncompressed Beamforming feedback request in a frame that does not require immediate control response, the HT beamformer shall not transmit the next PPDU to the HT beamformee until PIFS after the sounding request.

When the HT beamformee sets the Explicit Compressed Beamforming Feedback Capable field of its HT Capabilities element to either 2 or 3 and the HT beamformer has transmitted an NDP or a(#1426) non-NDP Explicit Compressed Beamforming feedback request in a frame that does not require immediate control response, the HT beamformer shall not transmit the next PPDU to the HT beamformee until PIFS after transmitting the sounding request.

An HT beamformee shall not transmit a CSI, Compressed Beamforming, or Noncompressed Beamforming frame except in response to a request for feedback.

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NOTE 2—Error recovery in a TXOP is not affected by sounding. An HT beamformer that is a TXOP holder and that fails to receive an expected response to a sounding PPDU can continue transmission as specified in 10.23.2.8 (Multiple frame exchange sequences in an EDCA TXOP(#109)).

An HT beamformee transmitting a feedback response after a SIFS(#6587) or later in the HT beamformer's TXOP shall use an Action No Ack frame or an Action No Ack +HTC frame (defined in 9.3.3.14 (Action No Ack frame format)).

An HT beamformee transmitting delayed feedback response shall use an Action frame or an Action +HTC frame to send this information within a separate TXOP.

If necessary, the CSI Report field, Noncompressed Beamforming Report field, or Compressed Beamforming Report field may be split into up to 8 frames. The length of each segment shall be equal number of octets for all segments except the last, which may be smaller.

NOTE 3—A STA that has been granted an RDG can act as an HT beamformer during the RDG time period, provided that the RD rules are obeyed.

An HT beamformee that advertises itself as delayed-feedback-capable shall not transmit an immediate feedback response unless it also advertises itself as immediate-feedback-capable.

An HT beamformer may use worst-case parameters to estimate the duration of the expected frame that contains the feedback response, e.g. the lowest rate/MCS in the basic rate/MCS set, HT-mixed format if an HT PPDU is expected, and no grouping.(#280)

An Explicit Feedback Request may be combined with an MRQ. If the response contains a beamforming feedback matrix, the returned MCS shall be derived from the same information that was used to generate this particular beamforming feedback matrix. If the response contains channel coefficients, the returned MCS shall be derived from an analysis of the sounding frame that was used to generate the channel coefficients. The MFB field set to 127 (meaning no feedback) may be used when the HT beamformee is unable to generate the MCS in time for inclusion in the response transmission frame. A CSI-capable STA may be incapable of generating MFB.

Explicit feedback shall be calculated only from a sounding PPDU.

An HT beamformee that transmits a feedback frame of type Compressed Beamforming in response to a sounding PPDU sent by an HT beamformer shall set the *Nr* Index subfield in the MIMO Control field of the feedback frame to indicate the same value as the number of streams in the sounding PPDU.

### 10.33.4 VHT MU beamforming

An MU beamformer may transmit a VHT MU PPDU with a single nonzero TXVECTOR parameter NUM_STS[$p$], where $0 \le p \le 3$ .

An MU beamformer shall not transmit a VHT MU PPDU with a nonzero TXVECTOR parameter NUM_STS[$p$], where $0 \le p \le 3$ , to a STA whose MU Beamformee Capable field is equal to 0.

When transmitting a VHT MU PPDU, an MU beamformer shall order the per-user arrays of TXVECTOR parameters so that the per-user USER_POSITION array is in ascending order.

### 10.33.5 Explicit feedback beamforming for CMMG STAs

In this subclause, the terms *CMMG beamformer* and *CMMG beamformee* refer to STAs that are involved in explicit feedback beamforming.


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A CMMG beamformer uses the feedback response that it receives from the CMMG beamformee to calculate a beamforming feedback matrix for transmit beamforming. This feedback response has the following format:

— *Compressed beamforming*: The CMMG beamformee sends compressed beamforming feedback matrices to the CMMG beamformer.

The supported formats shall be advertised in the beamformee's CMMG Capabilities element.

NOTE 1—An HT and CMMG beamformer might discard the feedback response if the TSF time when the PHY-CCA.indication(IDLE) primitive corresponding to the feedback response frame's arrival minus the value from the Sounding Timestamp field in the feedback response frame is greater than the coherence time interval of the propagation channel.

A CMMG beamformee's responding capabilities shall be advertised in CMMG Capabilities elements contained in DMG Beacon, Probe Request, Probe Response, Association Request, Association Response, Action, and Action No Ack frames that are transmitted by the CMMG beamformee. Devices that are capable of acting as a CMMG beamformee shall advertise one of the following response capabilities in the Explicit Compressed Beamforming Feedback Capable subfield of the Transmit Beamforming Capability field:

— *Immediate:* The CMMG beamformee is capable of sending a feedback response (#319)a SIFS after receiving a sounding PPDU and/or is capable of sending a feedback response aggregated in a PPDU that contains a MAC response within the CMMG beamformer's TXOP.

— *Delayed:* The CMMG beamformee is not capable of sending the feedback response within the CMMG beamformer's TXOP, but it is capable of sending the feedback response in a TXOP that it obtains.

— *Immediate and Delayed:* The CMMG beamformee is capable of sending a feedback response (#319)a SIFS after receiving a sounding PPDU, sending a feedback response aggregated in a PPDU that contains a MAC response within the CMMG beamformer's TXOP, or sending the feedback response in a TXOP that it obtains.

The sounding frame types supported by the CMMG beamformee, staggered and/or NDP, are advertised in the CMMG Capabilities element in frames that are transmitted by the CMMG beamformee.

A STA that sets Explicit Compressed Beamforming Feedback Capable fields to 1 shall transmit explicit feedback based on the receipt of a sounding PPDU in which the CSI/Steering subfield has a nonzero value. This requirement is independent of the values of the Receive Staggered Sounding Capable and the Receive NDP Capable fields.

A CMMG beamformer shall set the SOUNDING parameter of the TXVECTOR to SOUNDING in the PHY-TXSTART.request primitive corresponding to each PPDU that is used for sounding.

A CMMG beamformer shall set the response type format indicated in the CSI/Steering subfield of the CMMG variant HT Control field of any sounding frame excluding the NDP and of any PPDU with the (#8105)CMMG NDP Sounding Announcement field equal to 1 to the value of the type Compressed Beamforming.

The receipt of a PHY-RXSTART.indication primitive with the RXVECTOR SOUNDING parameter value equal to SOUNDING indicates a sounding PPDU. A non-NDP request for feedback is a sounding PPDU that contains a nonzero value of the CSI/Steering subfield and that has the NDP Announcement subfield equal to 0.

An NDP request for feedback is the combination of a CMMG MPDU that contains a nonzero value of the CSI/Steering subfield and that has the NDP Announcement subfield equal to 1 and the NDP that follows.

A CMMG beamformee that transmits a feedback frame in response to a sounding PPDU sent by a beamformer shall transmit a Compressed Beamforming frame.

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The CMMG beamformee decides on any subcarrier grouping to be used in the explicit beamforming feedback. The value selected shall be a value supported by the CMMG beamformer as indicated in the Minimal Grouping subfield of the CMMG beamformer's CMMG Capabilities element.

A CMMG beamformee that sets the Explicit Compressed Feedback Capable field of its CMMG Capabilities element to either 2 or 3 shall transmit explicit compressed beamforming feedback after a SIFS(#6587) or later in the beamformer's TXOP as a response to a non-NDP request for feedback in a frame that is appropriate for the current frame exchange sequence following Table 10-32 (Rules for CMMG beamformee immediate feedback transmission responding to non-NDP sounding).

**Table 10-32—Rules for CMMG beamformee immediate feedback transmission responding to non-NDP sounding**

| Type of response | Rule |
|---|---|
| CTS response | If the transmission of a CTS is required in response to the non-NDP request for feedback, the transmission of the feedback response frame shall be delayed until the CMMG beamformee's next transmission within the TXOP. This feedback response frame may be aggregated in an A-MPDU with an Ack or BlockAck frame. |
| Acknowledgment response | If the transmission of an Ack or BlockAck frame is required in response to the non-NDP request for feedback, both the feedback response frame and the control response frame may be aggregated in an A-MPDU. |
| No control response | If the transmission of a control response frame is not required in response to the non-NDP request for feedback, the feedback response frame shall be sent (#319)a SIFS after the reception of the sounding PPDU containing the request for feedback. |
| Later aggregation of feedback and acknowledgment | If the immediate-feedback-capable CMMG beamformee cannot transmit an aggregated or immediate CSI/Steering response in (#319)a SIFS after the end of the received sounding PPDU and the CMMG beamformee is subsequently required to transmit an Ack or BlockAck frame in the same TXOP, it may transmit the feedback response in an A-MPDU with the Ack or BlockAck frame. |

A CMMG beamformee that sets the Explicit Compressed Beamforming Feedback Capable field of its CMMG Capabilities element to either 2 or 3 shall transmit the explicit compressed beamforming feedback after a SIFS(#6587) or later in the CMMG beamformer's TXOP as a response to an NDP request for feedback in a frame that is appropriate for the current frame exchange sequence following Table 10-33 (Rules for CMMG beamformee immediate feedback transmission responding to NDP sounding).

When the CMMG beamformee sets the Explicit Compressed Beamforming Feedback Capable field of its CMMG Capabilities element to either 2 or 3 and the CMMG beamformer has transmitted an NDP or a(#1426) non-NDP explicit compressed beamforming feedback request in a frame that does not require immediate control response, the CMMG beamformer shall not transmit the next PPDU to the beamformee until PIFS after transmitting the sounding request.

A CMMG beamformee shall not transmit Compressed Beamforming frame except in response to a request for feedback.

NOTE 2—Error recovery in a TXOP is not affected by sounding. A beamformer that is a TXOP holder and that fails to receive an expected response to a sounding PPDU can continue transmission as specified in 10.23.2.4 (Obtaining an EDCA TXOP).

A CMMG beamformee transmitting a feedback response after a SIFS(#6587) or later in the beamformer's TXOP shall use an Action No Ack frame defined in 9.3.3.14 (Action No Ack frame format).


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**Table 10-33—Rules for CMMG beamformee immediate feedback transmission responding to NDP sounding**

| Type of response | Rule |
|---|---|
| Control response | If the transmission of a control response frame is required in response to the NDP request for feedback, the control response frame is transmitted (#319)a SIFS after reception of the PPDU that elicited the control response, and the feedback response frame may be transmitted (#319)a SIFS after the reception of the NDP.<br>— If the feedback response frame is not transmitted (#319)a SIFS after the reception of the NDP and the CMMG beamformee is subsequently required to transmit anAck or BlockAck frame in the same TXOP, then the feedback response may be aggregated with the Ack or BlockAck frame.<br>— If the feedback response frame is not transmitted (#319)a SIFS after the reception of the NDP and is not transmitted with an aggregated Ack or BlockAck frame in the same TXOP, then the feedback response frame is delayed until the CMMG beamformee's next transmission within the TXOP. |
| No control response | If the transmission of a control response frame is not required in response to the NDP request for feedback, the feedback response frame may be sent (#319)a SIFS after the reception of the NDP.<br>— If the feedback response frame is not transmitted (#319)a SIFS after the reception of the NDP and the CMMG beamformee is subsequently required to transmit an Ack or BlockAck frame in the same TXOP, then the feedback response may be aggregated with the Ack or BlockAck frame.<br>— If the feedback response frame is not transmitted (#319)a SIFS after the reception of the NDP and is not transmitted with an aggregated Ack or BlockAck frame in the same TXOP, then the feedback response frame is delayed until the CMMG beamformee's next transmission within the TXOP. |

A CMMG beamformee transmitting delayed feedback response shall use an Action frame to send this information within a separate TXOP.

If necessary, the Compressed Beamforming Report field may be split into up to 8 frames. The length of each segment shall be equal number of octets for all segments except the last, which may be smaller.

NOTE 3—A STA that has been granted an RDG can act as a CMMG beamformer during the RDG time period, provided that the RD rules are obeyed.

A CMMG beamformee that advertises itself as delayed-feedback-capable shall not transmit an immediate feedback response unless it also advertises itself as immediate-feedback-capable.

An explicit feedback request may be combined with an MRQ. If the response contains a beamforming feedback matrix, the returned MCS shall be derived from the same information that was used to generate this particular beamforming feedback matrix. If the response contains channel coefficients, the returned MCS shall be derived from an analysis of the sounding frame that was used to generate the channel coefficients. The MFB field set to 127 (meaning no feedback) may be used when the CMMG beamformee is unable to generate the MCS in time for inclusion in the response transmission frame. A CSI-capable STA may be incapable of generating MFB.

Explicit feedback shall be calculated only from a sounding PPDU.

A CMMG beamformee that transmits a feedback frame of type Compressed Beamforming in response to a sounding PPDU sent by a CMMG beamformer shall set the *Nr* Index subfield in the MIMO Control field of the feedback frame to indicate the same value as the number of streams in the sounding PPDU.

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(#2044)A CMMG beamformer shall set the Number of Sounding Dimensions subfield in the CMMG Capabilities element to a value greater than or equal to 1 (2 STS).

## 10.34 Antenna selection (ASEL)

### 10.34.1 Introduction

The procedures in this subclause apply only to HT and non-HT PPDUs for which the HT Control field, if present, is the HT variant HT Control field.

ASEL is a time-variant mapping of the signals at the RF chains onto a set of antenna elements when the number of RF chains is smaller than the number of antenna elements. The mapping might be chosen based on instantaneous or averaged CSI. ASEL requires the training of the full size channel associated with all antenna elements, which is obtained by transmitting or receiving sounding PPDUs over all antennas. These sounding PPDUs should be sent within a single TXOP. To avoid channel distortions, these sounding PPDUs shall be transmitted consecutively. The training information is exchanged using the HT Control field. When both transmitter and receiver have ASEL capabilities, training of transmit and receive antennas might be done one after another. ASEL supports up to eight antennas and up to four RF chains.

### 10.34.2 ASEL frame exchange procedure

A STA shall not initiate an ASEL training frame exchange(#109) with another STA unless that STA supports ASEL, as determined by the ASEL Capability field (see 9.4.2.54.7 (ASEL Capability field)).

A STA that is capable of supporting ASEL should set each subfield of the ASEL Capability field of the HT Capabilities element to 1 depending on its capabilities in HT Capabilities elements that it transmits (see 9.4.2.54.7 (ASEL Capability field)).

A STA that sets the Explicit CSI Feedback Based Tx ASEL Capable subfield of the ASEL Capability field (see 9.4.2.54.7 (ASEL Capability field)) to 1 shall set the CSI Max Number of Rows Beamformer Supported subfield of the Transmit Beamforming Capabilities field to an appropriate value, even if the STA sets the Explicit Transmit Beamforming CSI Feedback subfield to the value 0.

The frame exchange(#109) for transmit ASEL is shown in Figure 10-56 (Transmit ASEL), where the term *ASEL transmitter* identifies the STA that is conducting transmit ASEL, and the term *transmit ASEL responder* identifies the STA that provides ASEL feedback. The frame exchange comprises the following steps:

a) (Optional) A transmit ASEL responder may initiate the transmit ASEL training by sending a +HTC frame with the ASEL Command subfield set to Transmit Antenna Selection Sounding Request (TXASSR).

b) The ASEL transmitter sends out consecutive sounding PPDUs separated by SIFS in a TXOP of which it is the TXOP holder with no acknowledgment over different antenna sets, each PPDU containing a +HTC frame with the ASEL Command subfield set to Transmit Antenna Selection Sounding Indication (TXASSI or TXASSI-CSI). Each sounding PPDU is transmitted over one antenna set.

   If the ASEL transmitter allows antenna indices feedback (by setting the ASEL Command subfield to TXASSI), the antenna sets from which the sounding PPDUs are transmitted shall be disjoint. If the ASEL transmitter uses NDP sounding PPDUs for the ASEL sounding, the spatial mapping matrix $Q_k$ shall be the identity matrix starting with the first NDP. If the ASEL transmitter uses non-NDP sounding PPDUs for the ASEL sounding, the spatial mapping matrix $Q_k$ shall be an FFT matrix. An


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FFT matrix of size $N$ is defined as a square matrix of dimension $NxN$ with entries $w_{im}$, (#515)$i$=0, ..., $N$–1, $m$=0, ..., $N$–1 where $w_{im} = \frac{1}{\sqrt{N}} \times \exp\left(-j2\pi\frac{im}{N}\right)$.

The ASEL transmitter shall not include TXASSI-CSI in the command field of the sounding frame if the last received value of the Explicit CSI Feedback Capable subfield of the ASEL Capability field (see 9.4.2.54.7 (ASEL Capability field)) from the receiver was 0.

NOTE 1—For example, in the case of sounding over all disjointed antenna sets, the number of consecutive sounding PPDUs equals the smallest integer that is greater than or equal to the number of antennas divided by the number of RF chains. These sounding PPDUs need to be sent within a single TXOP in order to minimize the change in the channel during this procedure.

c) The transmit ASEL responder estimates the subchannel corresponding to each sounding PPDU.

d) If the ASEL Command subfield in the sounding frames is equal to TXASSI-CSI, after receiving all of the sounding PPDUs, the transmit ASEL responder shall respond with the full size CSI in a subsequent TXOP. If the ASEL Command subfield in the sounding frames is equal to TXASSI, after receiving all of the sounding PPDUs, the transmit ASEL responder may either respond with the full size CSI in a subsequent TXOP, or conduct ASEL computation and provide the selected antenna indices in a subsequent TXOP.

   1) CSI is transported using the MIMO CSI Matrices frame defined in 9.6.11.4 (CSI frame format) contained within either an Action No Ack or Action frame. Multiple CSI frames may be required to provide the complete feedback, in which case the value of the Sounding Timestamp field within each of these CSI frames shall correspond to the arrival time of the sounding frame that was used to generate the feedback information contained in the frame.

   2) Antenna indices feedback is carried in the Antenna Selection Indices Feedback frame, defined in 9.6.11.7 (Antenna Selection Indices Feedback frame format). One octet of the Antenna Selection Indices field is used to carry the selected antenna indices feedback.

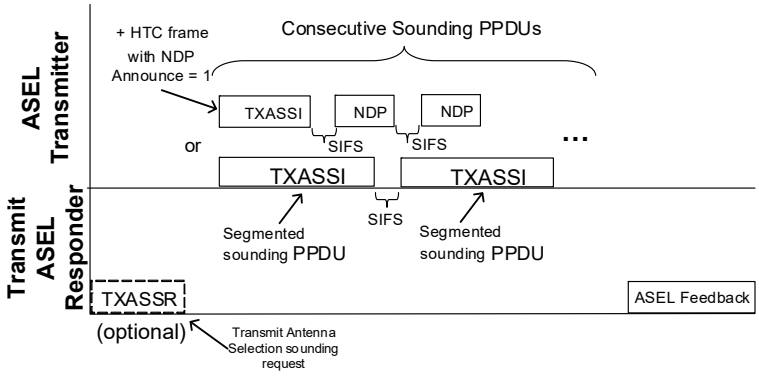


**Figure 10-56—Transmit ASEL**

If the transmit ASEL responder does not correctly receive all of the sounding PPDUs but has correctly received at least one of the preceding sounding PPDUs, it shall send a +HTC frame with the MAI subfield set to the value ASELI (see Table 9-18 (Subfields of Link Adaptation Control subfield)), the ASEL Command subfield set to No Feedback Due to ASEL Training Failure or Stale Feedback to indicate the failure of the ASEL training process, and the ASEL Data subfield set to either of the following:

— The integer value corresponding to the number in sequence of the first sounding PPDU that was not properly received, where 0 corresponds to the first sounding PPDU in the ASEL training sequence or

— The value 0

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A transmit ASEL responder that determines that the ASEL feedback is stale shall notify the ASEL transmitter by transmitting a +HTC MPDU with the MAI subfield set to ASELI, the ASEL Command subfield set to No Feedback Due to ASEL Training Failure or Stale Feedback, and the ASEL Data subfield set to 0.

If, in response to the transmission of a sequence of sounding PPDUs, the ASEL transmitter receives a +HTC MPDU with the MAI subfield equal to ASELI, the ASEL Command subfield equal to No Feedback Due to ASEL Training Failure or Stale Feedback, and the ASEL Data subfield not equal to 0 to indicate a failed ASEL training frame exchange(#109), the ASEL transmitter may perform any of the following actions:

— Do nothing.

— Restart the failed ASEL training frame exchange(#109) from the point of failure by transmitting a +HTC MPDU with the MAI subfield set to ASELI, the ASEL Command subfield set to TXASSR, and the ASEL Data subfield set to a nonzero value to correspond to the command Transmit Antenna Selection Sounding Resumption (a Resumption MPDU), where the ASEL Data subfield value is the order number (from the original training frame sequence) of the first sounding PPDU transmitted in the restarted ASEL training frame sequence and where 0 corresponds to the first sounding PPDU in the original ASEL training sequence.

— Execute a new ASEL training frame sequence by transmitting a +HTC MPDU with the MAI subfield set to ASELI, the ASEL Command subfield set to TXASSI or TXASSI-CSI, and the ASEL Data subfield set to a nonzero value.

If a transmit ASEL responder receives a +HTC MPDU with the MAI subfield equal to ASELI, the ASEL Command subfield equal to TXASSR, and the ASEL Data subfield not equal to 0 to correspond to the command Transmit Antenna Selection Sounding Resumption (a Resumption MPDU), the transmit ASEL responder shall respond to the training sequence according to the original command value (i.e., TXASSI or TXASSI-CSI) and shall assume a total number of sounding PPDUs that corresponds to the number of sounding PPDUs from the original command frame. The number of sounding frames that follow the Resumption MPDU is equal to the number of sounding PPDUs from the original command frame minus the order number transmitted in the ASEL Data subfield of the Resumption MPDU.

The frame exchange(#109) for receive ASEL is shown in Figure 10-57 (Receive ASEL), where the term *ASEL receiver* identifies the STA that is conducting receive ASEL, and the term *ASEL sounding-capable transmitter* identifies the STA sending the consecutive sounding PPDUs used for receive ASEL calculations. The frame exchange comprises the following steps:

— The ASEL receiver transmits a +HTC frame with the MAI subfield set to ASELI, the ASEL Command subfield set to Receive Antenna Selection Sounding Request (RXASSR), and the ASEL Data subfield set to the number of sounding PPDUs required.

NOTE 2—For example, in the case of sounding over all disjointed antenna sets, the number of total consecutive sounding PPDUs or NDPs equals the smallest integer that is greater than or equal to the number of antennas divided by the number of RF chains.

— The ASEL sounding-capable transmitter responds with the corresponding number of sounding PPDUs in its subsequent TXOP. These PPDUs are separated by SIFS. When using non-NDP sounding, each PPDU contains a +HTC frame in which the MAI subfield is set to ASELI, the ASEL Command subfield is set to Receive Antenna Selection Sounding Indication (RXASSI), and the ASEL Data subfield is set to the remaining number of sounding PPDUs to be transmitted. When using NDP sounding, the PPDU that precedes the first NDP contains a +HTC frame in which the NDP Announce field is set to 1, the MAI subfield is set to ASELI, the ASEL Command subfield is set to RXASSI, and the ASEL Data subfield is set to the remaining number of sounding PPDUs to be transmitted.

The ASEL receiver uses different antenna sets to receive these sounding PPDUs, estimates CSI after receiving all these sounding PPDUs, and conducts the ASEL.


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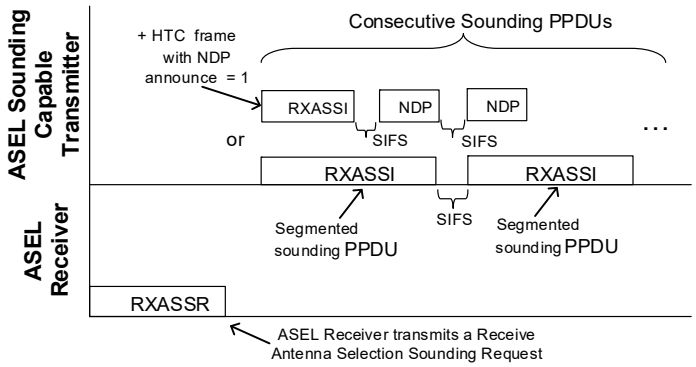


**Figure 10-57—Receive ASEL**

When transmitting the consecutive sounding PPDUs in transmit and receive ASEL exchanges (illustrated in Figure 10-56 (Transmit ASEL) and Figure 10-57 (Receive ASEL)), the transmitter shall not change the TXPWR_LEVEL_INDEX parameter of the TXVECTOR.

When transmitting a sounding PPDU sent in transmit and receive ASEL exchanges (illustrated in Figure 10-56 (Transmit ASEL) and Figure 10-57 (Receive ASEL)), if the Receive Staggered Capability subfield of the Transmit Beamforming Capability field of the HT Capabilities element transmitted by the intended receiver is 0, then,

— If the sounding PPDU is not an NDP, the number of antennas used by the sender, as indicated by the ANTENNA_SET parameter in the TXVECTOR, shall be less than or equal to the maximum number of space-time streams indicated by the Rx MCS Bitmask subfield of the Supported MCS Set field and the Rx STBC subfield of the HT Capabilities element transmitted by the intended receiver.

— If the sounding PPDU is an NDP, the number of antennas used by the sender, as indicated by the ANTENNA_SET parameter in the TXVECTOR, shall be less than or equal to the number indicated by the Channel Estimation Capability subfield of the Transmit Beamforming Capability field of the HT Capabilities element transmitted by the intended receiver.

When both transmitter and receiver have ASEL capabilities, the following constraints apply:

— During a transmit ASEL frame exchange, the transmit ASEL responder shall use a subset of antennas that does not change during the reception of all of the sounding PPDUs of the ASEL sounding sequence.

— During a receive ASEL frame exchange, the ASEL sounding-capable transmitter shall use a subset of antennas that does not change during the transmission of all of the sounding PPDUs of the ASEL sounding sequence.

NOTE 3—When a receiver (either a transmit ASEL responder or an ASEL receiver) conducts ASEL computations (for either transmit or receive ASEL), if there is no transmit beamforming conducted at the same time, to achieve the best performance of ASEL, the receiver assumes that the first $N_{STS}$ columns of the same spatial mapping matrix $Q_k$ used for transmitting ASEL sounding PPDUs, where $N_{STS}$ is the number of space-time streams, are applied for the spatial mapping at the ASEL transmitter after the ASEL exchange as in Figure 10-56 (Transmit ASEL) and Figure 10-57 (Receive ASEL). To achieve the best performance of ASEL, the ASEL transmitter applies the first $N_{STS}$ columns of the same $Q_k$ for spatial mapping after the ASEL exchange as in Figure 10-56 (Transmit ASEL) and Figure 10-57 (Receive ASEL).

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## 10.35 Null data PPDU (NDP) sounding

### 10.35.1 HT NDP sounding protocol

Sounding may be accomplished using either staggered sounding PPDU or HT NDP, as described in 19.3.13 (HT Preamble format for sounding PPDUs). The MAC rules associated with sounding using HT NDP are described in 10.35.1 (HT NDP sounding protocol) to 10.35.4 (Determination of HT NDP source).

An HT STA that has set the Receive NDP Capable field of its HT Capabilities element to 1 during association processes an HT NDP as a sounding PPDU if the destination of the sounding PPDU is determined to match itself as described in 10.35.3 (Determination of HT NDP destination) and if the source of the sounding PPDU can be ascertained as described in 10.35.4 (Determination of HT NDP source).

An RXVECTOR LENGTH parameter equal to 0 indicates that an HT PPDU is an HT NDP.

A STA that is a TXOP holder or an RD responder shall not set both the HT NDP Announcement and RDG/More PPDU subfields to 1 simultaneously. The Calibration Position subfield shall not be set to any value except 0 and 1 in any +HTC frame in a PPDU that is also an HT NDP announcement. The Calibration Position subfield shall be set to 0 in any +HTC frame in a PPDU that is an HT NDP announcement that also contains any +HTC frame with the MAI subfield equal to ASELI. The Calibration Position subfield shall be set to 0 in all +HTC frames in a PPDU that is an HT NDP announcement and that contains any +HTC frame with the MRQ subfield equal to 1. The TRQ field shall be set to 0 in all +HTC frames in a PPDU that is an HT NDP announcement.

An NDP sequence contains at least one HT NDP and at least one PPDU that is not an NDP. Only one PPDU in the NDP sequence may contain an HT NDP announcement. An NDP sequence begins with an HT NDP announcement. The NDP sequence ends at the end of the transmission of the last HT NDP that is announced by the HT NDP announcement. A STA that transmits the first PPDU of an NDP sequence is the NDP sequence owner. In the NDP sequence, only PPDUs that are HT NDPs(#4150) and PPDUs each carrying a Control frame as an S-MPDU(#3202) may follow the NDP sequence's starting PPDU.

A STA shall transmit only one HT NDP per HT NDP announcement, unless the HT NDP announcement includes a value in the ASEL Data subfield of the ASEL Command subfield of the HTC Control field that is greater than one. Each PPDU in an NDP sequence shall start a SIFS after end of the previous PPDU.

A STA shall not transmit a VHT NDP in (#2137)an NDP sequence that contains an HT NDP announcement.

A CTS frame that is a +HTC frame shall not contain the HT NDP Announcement subfield set to 1.

NOTE 1—A CTS frame cannot be used for HT NDP announcement: if the CTS frame is a response to an RTS frame, the optional NAV reset timeout that starts at the end of the RTS frame does not include the additional HT NDP and SIFS (see 10.3.2.4 (Setting and resetting the NAV)). Also, if the CTS were the first frame of an NDP sequence, it would not be possible to determine the destination address of the HT NDP.

A STA shall transmit an HT NDP as follows:

a) A SIFS after sending a PPDU that is an HT NDP announcement and that does not contain an MPDU that requires an immediate response.

b) A SIFS after receiving a correctly formed and addressed immediate response to a PPDU that is an HT NDP announcement and that contains an MPDU that requires an immediate response.

c) A SIFS after transmitting an HT NDP if the HT NDP announcement contains an ASEL Command subfield equal to TXASSI, TXASSI-CSI, or RXASSI and the ASEL Data subfield is equal to a value greater than 0 and if the number of HT NDPs sent before this one is less than the value in the ASEL Data subfield + 1.


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NOTE 2—The total number of sent HT NDPs is equal to the value of in the ASEL Data subfield + 1.

d) A SIFS after receiving an HT NDP from a STA whose HT NDP announcement contained one or more +HTC frames with the Calibration Position subfield equal to 1, when the receiving STA supports transmitting sounding PPDUs for which more than one channel dimension can be estimated (i.e., more than one column of the MIMO channel matrix).

This rule enables the NDP receiver to know that it will receive an HT NDP and can determine the source and destination of the HT NDP. It enables the receiver and transmitter to know when the immediate response and HT NDP will be transmitted relative to the frame containing the HT NDP announcement indication.

A STA that has transmitted an HT NDP announcement in a frame that requires an immediate response and that does not receive the expected response shall terminate the NDP sequence at that point (i.e., the STA does not transmit an HT NDP in the current NDP sequence).

A STA that has received an HT NDP announcement in a +HTC with the Calibration Position equal to 1 or 2, and that does not receive the expected HT NDP shall terminate the NDP sequence at that point (i.e., does not transmit an HT NDP in the current NDP sequence) and not transmit any further frames that are a part of this calibration sequence shown in Step 1 of Figure 10-54 (Calibration procedure with NDP).

Feedback information generated from the reception of an HT NDP is transmitted using any of the feedback rules and signaling as appropriate, e.g., immediate or delayed.

### 10.35.2 Transmission of an HT NDP

A STA that transmits an HT NDP shall set the LENGTH, SOUNDING, STBC, MCS, and NUM_EXTEN_SS parameters of the TXVECTOR as specified in this subclause.

— LENGTH shall be set to 0.
— SOUNDING shall be set to SOUNDING.
— STBC shall be set to 0.
— MCS shall indicate two or more spatial streams.

The number of spatial streams sounded is indicated by the MCS parameter of the TXVECTOR and shall not exceed the limit indicated by the Channel Estimation Capability field in the Transmit Beamforming Capabilities field transmitted by the STA that is the intended receiver of the HT NDP. The MCS parameter may be set to any value, subject to the constraint of the previous sentence, regardless of the value of the Supported MCS Set field of the HT Capabilities field at either the transmitter or recipient of the HT NDP. A STA shall set the NUM_EXTEN_SS parameter of the TXVECTOR to 0 in the PHY-TXSTART.request primitive corresponding to an HT NDP transmission.

A STA shall not transmit an HT NDP announcement with an RA corresponding to another STA unless it has received an HT Capabilities element from the destination STA in which the Receive NDP Capable field is equal to 1.

### 10.35.3 Determination of HT NDP destination

The destination of an HT NDP is determined at the NDP receiver by examining the HT NDP announcement as follows:

— The destination of the first HT NDP in the NDP sequence is equal to the RA of any MPDU within HT NDP announcement.
— If Calibration Position subfield is equal to 1 in the HT NDP announcement at the NDP receiver, the destination of the second HT NDP is equal to the TA of that frame. Otherwise, the destination of the second and any subsequent HT NDPs is equal to the destination of the previous HT NDP.

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See O.4 (Illustration of determination of NDP addresses) for an illustration of these rules.

### 10.35.4 Determination of HT NDP source

The source of an HT NDP is determined at the NDP receiver by examining the NDP sequences's starting PPDU as follows:

— If any MPDU within the HT NDP announcement contains two or more addresses, the source of the first HT NDP is equal to the TA of that frame.

— Otherwise (i.e., the HT NDP announcement contains one address), the source of the first HT NDP is equal to the RA of the MPDU to which the HT NDP announcement is a response.

— If the Calibration Position subfield is equal to 1 in an MPDU in the HT NDP announcement, the source of the second HT NDP is equal to the RA of that MPDU. Otherwise, the source of the second and any subsequent HT NDPs is equal to the source of the previous NDP.

See O.4 (Illustration of determination of NDP addresses) for an illustration of these rules.

### 10.35.5 VHT sounding protocol

#### 10.35.5.1 General

Transmit beamforming and (#3367)DL MU-MIMO require knowledge of the channel state to compute a steering matrix that is applied to the transmitted signal to optimize reception at one or more receivers. The STA transmitting using the steering matrix is called the *VHT beamformer*, and a STA for which reception is optimized is called a *VHT beamformee*. An explicit feedback mechanism is used where the VHT beamformee directly measures the channel from the training symbols transmitted by the VHT beamformer and sends back a transformed estimate of the channel state to the VHT beamformer. The VHT beamformer then uses this estimate, perhaps combining estimates from multiple VHT beamformees, to derive the steering matrix.

If dot11VHTSUBeamformerOptionImplemented is true, a STA shall set the SU Beamformer Capable field in the VHT Capabilities element to 1. If dot11VHTSUBeamformeeOptionImplemented is true, a STA shall set the SU Beamformee Capable field in the VHT Capabilities element to 1.

If dot11VHTMUBeamformerOptionImplemented is true, a STA shall set the MU Beamformer Capable field in the VHT Capabilities element to 1. If dot11VHTMUBeamformeeOptionImplemented is true, a STA shall set the MU Beamformee Capable field in the VHT Capabilities element to 1.

If dot11VHTMUBeamformerOptionImplemented is true, a STA shall set dot11VHTSUBeamformerOptionImplemented to true. If dot11VHTMUBeamformeeOptionImplemented is true, a STA shall set dot11VHTSUBeamformeeOptionImplemented to true.

A STA is a VHT SU-only beamformer if it sets the SU Beamformer Capable field to 1 but sets the MU Beamformer Capable field to 0 in transmitted VHT Capabilities elements. A STA is an SU-only beamformee if it sets the SU Beamformee Capable field to 1 but sets the MU Beamformee Capable field to 0 in transmitted VHT Capabilities elements.

If dot11VHTSUBeamformerOptionImplemented is false, a STA shall not act in the role of a VHT beamformer. If dot11VHTSUBeamformeeOptionImplemented is false, a STA shall not act in the role of a VHT beamformee.

For an S1G STA, the S1G sounding protocol is specified in 10.35.5 (VHT sounding protocol) with "VHT" replaced by "S1G", except in this sentence.


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(#2044)A VHT beamformer shall set the Number Of Sounding Dimensions subfield in the VHT Capabilities element to a value greater than or equal to 1 (2 STS). A VHT beamformee shall set the Beamformee STS Capability subfield in the VHT Capabilities element to a value greater than or equal to 1 (2 STS).

(#4014)VHT compressed beamforming feedback comprises the VHT Compressed Beamforming Report information (see Table 9-105 (VHT Compressed Beamforming Report information)) and the MU Exclusive Beamforming Report information (see Table 9-108 (MU Exclusive Beamforming Report information)). Subclause 9.6.22.2 (VHT Compressed Beamforming frame format) specifies how VHT compressed beamforming feedback is converted into a VHT Compressed Beamforming frame, and it also specifies the rules for the presence or absence of the two fields listed here.

### 10.35.5.2 Rules for VHT sounding protocol sequences

A VHT beamformer shall initiate a sounding feedback sequence by transmitting a VHT NDP Announcement frame followed by a VHT NDP after a SIFS. The VHT beamformer shall include in the VHT NDP Announcement frame one STA Info field for each VHT beamformee that is expected to prepare VHT compressed beamforming feedback and shall identify the VHT beamformee by including the VHT beamformee's AID in the AID12 subfield of the STA Info field. The VHT NDP Announcement frame shall include at least one STA Info field.

NOTE 1—A STA that transmits a VHT NDP Announcement frame to a TDLS peer STA obtains the AID for the peer STA from the TDLS Setup Request or TDLS Setup Response frame.

A VHT beamformer shall not transmit either a VHT NDP Announcement+HTC frame or a Beamforming Report Poll+HTC frame that contains an HT variant HT Control field.

A VHT NDP shall be transmitted only following a SIFS after a VHT NDP Announcement frame. A VHT NDP Announcement frame shall be followed by a VHT NDP after a SIFS(#6587).

A VHT beamformer that has not received a VHT Capabilities element from a STA or where the last VHT Capabilities element received from a STA has the SU Beamformee Capable field set to 0 shall not transmit either of the following:

— A VHT NDP Announcement frame addressed to the STA or that includes the STA's AID in one of the STA Info fields
— A Beamforming Report Poll frame addressed to the STA

A VHT beamformer that transmits a VHT NDP Announcement frame to a VHT SU-only beamformee shall include only one STA Info field in the VHT NDP Announcement frame and set the Feedback Type subfield of the STA Info field to SU.

An S1G beamformee with dot11NDPBeamformingReportPollImplemented equal to true shall set the NDP Beamforming Report Poll Supported field in the S1G Capabilities element to 1. Otherwise it shall set the NDP Beamforming Report Poll Supported field in the S1G Capabilities element to 0.

An S1G beamformer may transmit NDP Beamforming Report Poll frames instead of VHT Beamforming Report Poll frames to an S1G beamformee from which it has received a frame containing an S1G Capabilities element with the NDP Beamforming Report Poll Supported field equal to true; otherwise, the S1G beamformer shall not transmit NDP Beamforming Report Poll frames to the S1G beamformee. A non-S1G beamformer or an S1G beamformer working on 1 MHz channel shall not transmit NDP Beamforming Report Poll frames. (#306)A non-AP S1G beamformer shall not transmit NDP Beamforming Report Poll frames to a non-AP beamformee.

If the VHT NDP Announcement frame includes more than one STA Info field, the RA of the VHT NDP Announcement frame shall be set to the broadcast address. If the VHT NDP Announcement frame includes a

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single STA Info field, the RA of the VHT NDP Announcement frame shall be set to the MAC address of the VHT beamformee.

A VHT NDP Announcement frame shall not include two or more STA Info fields with same value in the AID12 subfield.

A VHT beamformer that transmits a VHT NDP Announcement frame to a VHT beamformee that is an AP, mesh STA or IBSS STA, shall include a single STA Info field in the VHT NDP Announcement frame and shall set the AID12 subfield in the STA Info field to 0.

A VHT NDP Announcement frame with more than one STA Info field shall not carry a VHT variant HT Control field, unless all of the STAs listed in the AID12 subfield of the STA Info fields have set +HTC-VHT Capable to 1 in the VHT Capabilities Information field.

A VHT beamformer that transmits a VHT NDP Announcement frame with more than one STA Info field should transmit any Beamforming Report Poll frames used to retrieve VHT compressed beamforming feedback from the intended VHT beamformees in the same TXOP. If the duration of the TXOP that contained the VHT NDP Announcement frame has insufficient duration to accommodate the transmission of all of the feedback reports, the VHT beamformer may poll for the remaining VHT compressed beamforming feedback in subsequent TXOPs.

A VHT beamformer may use worst-case parameters to estimate the duration of the expected frame(s) that contain(s) the feedback response(s), e.g. the lowest rate/MCS in the basic rate/MCS set, no grouping, and the highest-precision codebook.(#280)

NOTE 2—The transmission of the VHT NDP Announcement, VHT NDP, VHT Compressed Beamforming, and Beamforming Report Poll frames is subject to the rules in 10.23.2.8 (Multiple frame exchange sequences in an EDCA TXOP(#109)).

A VHT beamformer that sets the Feedback Type subfield of a STA Info field to MU shall set the Nc Index subfield of the same STA Info field to a value less than or equal to the minimum of both of the following:

— The maximum number of supported spatial streams for receive operation according to the combination of the corresponding VHT beamformee's Rx VHT-MCS Map subfield in the Supported VHT-MCS and NSS Set field and VHT Capabilities Information field

— The maximum number of supported spatial streams according to the Rx NSS subfield value and, when the value of the VHT Extended NSS BW Capable subfield received from the VHT beamformee is 1 and dot11ExtendedNSSSupported is equal to true, the 160/80+80 BW subfield value in the Operating Mode field of the most recently received Operating Mode Notification frame or Operating Mode Notification element with the Rx NSS Type subfield equal to 0 from the corresponding VHT beamformee, as computed according to 10.6.13.1 (Rx Supported VHT-MCS and NSS Set)

A non-AP VHT beamformee that receives a VHT NDP Announcement frame from a VHT beamformer with which it is associated or has an established TDLS session and that contains the VHT beamformee's AID in the AID12 subfield of the first (or only) STA Info field and also receives a VHT NDP a SIFS after the VHT NDP Announcement frame shall transmit the PPDU containing its VHT compressed beamforming feedback a SIFS after the VHT NDP. A VHT beamformee that is an AP, mesh STA, or IBSS STA, that receives a VHT NDP Announcement frame with the RA matching its MAC address and the AID12 subfield of the only STA Info field set to 0, and that also receives a VHT NDP a SIFS after the VHT NDP Announcement frame shall transmit the PPDU containing its VHT compressed beamforming feedback a SIFS after the VHT NDP. The TXVECTOR parameter CH_BANDWIDTH of the PPDU containing the VHT compressed beamforming feedback shall be set to indicate a bandwidth not wider than that indicated in the RXVECTOR parameter CH_BANDWIDTH of the received VHT NDP. A STA shall (#3683)(#7144)discard received VHT NDP


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Announcement, VHT NDP, and Beamforming Report Poll frames if dot11VHTSUBeamformeeOptionImplemented is false.

A VHT beamformee shall indicate the maximum number of space-time streams it can receive in a VHT NDP in the Beamformee STS Capability subfield of the VHT Capabilities Information field of the VHT Capabilities element. If the beamformee is a non-AP STA, this shall be less than or equal to the maximum total number of space-time streams that the STA can receive in a VHT MU PPDU.

An example of the VHT sounding protocol with a single VHT beamformee is shown in Figure 10-58 (Example of the sounding protocol with a single VHT beamformee).

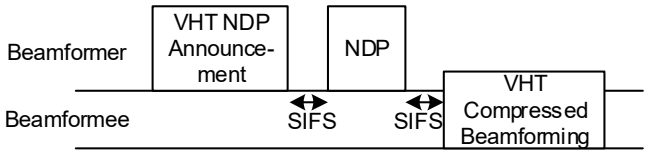


**Figure 10-58—Example of the sounding protocol with a single VHT beamformee**

A non-AP VHT beamformee that receives a VHT NDP Announcement frame from a VHT beamformer with which it is associated or has an established TDLS session and that contains the VHT beamformee's AID in the AID12 subfield of a STA Info field that is not the first STA Info field shall transmit its VHT compressed beamforming feedback a SIFS after receiving a Beamforming Report Poll with RA matching its MAC address and a nonbandwidth signaling TA obtained from the TA field matching the MAC address of the VHT beamformer. If the RXVECTOR parameter CH_BANDWIDTH_IN_NON_HT of the received Beamforming Report Poll frame is valid, the TXVECTOR parameter CH_BANDWIDTH of the PPDU containing the VHT compressed beamforming feedback shall be set to indicate a bandwidth not wider than that indicated by the RXVECTOR parameter CH_BANDWIDTH_IN_NON_HT of the Beamforming Report Poll frame; otherwise, the TXVECTOR parameter CH_BANDWIDTH of the PPDU containing VHT compressed beamforming feedback shall be set to indicate a bandwidth not wider than that indicated by the RXVECTOR parameter CH_BANDWIDTH of the Beamforming Report Poll frame.

An example of the VHT sounding protocol with more than one VHT beamformee is shown in Figure 10-59 (Example of the sounding protocol with more than one VHT beamformee).

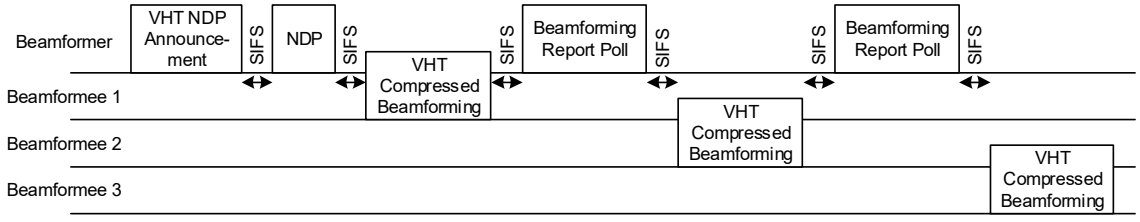


**Figure 10-59—Example of the sounding protocol with more than one VHT beamformee**

The RA field of the VHT Compressed Beamforming frame(s) of the VHT compressed beamforming feedback shall be set to a nonbandwidth signaling TA obtained from the TA field of the VHT NDP Announcement frame or the Beamforming Report Poll frame to which this VHT compressed beamforming feedback is a response.

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If the VHT Beamformee is transmitting VHT Compressed Beamforming frame(s) a SIFS after the VHT NDP, then the VHT Compressed Beamforming frame(s) shall include the VHT Compressed Beamforming Report information and, for the case of MU feedback, the MU Exclusive Beamforming Report information.

A VHT beamformee that transmits a VHT Compressed Beamforming frame shall set the Feedback Type field in the VHT MIMO Control field to the same value as the Feedback Type field in the corresponding STA Info field in the VHT NDP Announcement frame. If the Feedback Type field indicates MU, the STA shall send a VHT Compressed Beamforming frame with the Nc Index field value in the VHT MIMO Control field equal to the minimum of all of the following:

— The Nc Index field value in the corresponding STA Info field in the VHT NDP Announcement Frame
— The maximum number of supported spatial streams for receive operation according to the combination of its Rx VHT-MCS Map subfield in the Supported VHT-MCS and NSS Set field, VHT Capabilities Information field and Operating Mode field (see 10.6.13.1 (Rx Supported VHT-MCS and NSS Set))
— The maximum number of supported spatial streams according to the Rx NSS subfield value and, when the value of the most recently transmitted VHT Extended NSS BW Capable subfield is 1, the 160/80+80 BW subfield value in the Operating Mode field of the most recently transmitted Operating Mode Notification frame or Operating Mode Notification element, as computed according to 10.6.13.1 (Rx Supported VHT-MCS and NSS Set)

If the Feedback Type indicates SU, the Nc Index field value in the VHT MIMO Control field is determined by the VHT beamformee.

The Nr Index field in the VHT MIMO Control field shall be set to the same value as the RXVECTOR parameter NUM_STS of the corresponding VHT NDP. The Nc Index field shall not be set to a value larger than the Nr Index value in the VHT MIMO Control field. A VHT beamformee shall set the value of the Channel Width subfield in the VHT MIMO Control field of a VHT Compressed Beamforming frame to the same value as the RXVECTOR parameter CH_BANDWIDTH of the corresponding VHT NDP.

A VHT beamformee shall not include MU Exclusive Beamforming Report information in VHT compressed beamforming feedback if the Feedback Type subfield in the MIMO Control field of the VHT Compressed Beamforming frame(s) indicates SU. A VHT beamformee shall include both VHT Compressed Beamforming Report information and MU Exclusive Beamforming Report information in VHT compressed beamforming feedback if the Feedback Type subfield in the MIMO Control field of the VHT Compressed Beamforming frame(s) indicates MU.

A VHT beamformee that transmits VHT compressed beamforming feedback shall include neither the VHT Compressed Beamforming Report information nor the MU Exclusive Beamforming Report information, if the transmission duration of the PPDU carrying the VHT Compressed Beamforming Report information and any MU Exclusive Beamforming Report information would exceed the maximum PPDU duration.

The value of the Sounding Dialog Token Number subfield in the VHT MIMO Control field shall be set to the same value as the Sounding Dialog Token Number subfield in the Sounding Dialog Token field in the corresponding VHT NDP Announcement frame.

NOTE 3—The VHT beamformer can use the sounding dialog token in the VHT Compressed Beamforming frame(s) of the VHT compressed beamforming feedback to associate the feedback with a prior VHT NDP Announcement frame and thus compute the delay between sounding and receiving the feedback. The VHT beamformer can use this delay time when making a decision regarding the applicability of the feedback for the link.

NOTE 4—Recovery in the case of a missing response to a VHT NDP Announcement or Beamforming Report Poll frame follows the rules for multiple frame exchange sequence(#109) in an EDCA TXOP (see 10.23.2.8 (Multiple frame exchange sequences in an EDCA TXOP(#109))).


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(#4014)In a frame transmitted by a TVHT STA, the TVHT Compressed Beamforming Report field replaces the VHT Compressed Beamforming Report field.

In a frame transmitted by a TVHT STA, the TVHT MU Exclusive Beamforming Report field replaces the MU Exclusive Beamforming Report field.

### 10.35.5.3 Rules for fragmented feedback in VHT sounding protocol sequences

VHT compressed beamforming feedback shall be transmitted in a single VHT Compressed Beamforming frame unless the result would be a VHT Compressed Beamforming frame that exceeds the VHT beamformer's maximum MPDU length capability.

NOTE 1—The requirement that the VHT compressed beamforming feedback is transmitted in a single VHT Compressed Beamforming frame implies that the VHT beamformee might have to transmit an MPDU that is bigger than its receive capability.

If VHT compressed beamforming feedback would result in a VHT Compressed Beamforming frame that exceeds the VHT beamformer's maximum MPDU length capability, the VHT compressed beamforming feedback shall be split into up to 8 feedback segments, with each feedback segment sent in a different VHT Compressed Beamforming frame and containing successive portions of the VHT compressed beamforming feedback consisting of the VHT Compressed Beamforming Report information followed by any MU Exclusive Beamforming Report information. Each of the feedback segments except the last shall (#4014)be transmitted in a frame that contains the maximum number of octets allowed by the VHT beamformer's maximum MPDU length capability. The last feedback segment may be transmitted in a smaller frame.(#4014) Each feedback segment is identified by the value of the Remaining Feedback Segments subfield and the First Feedback Segment subfield in the VHT MIMO Control field as defined in 9.4.1.46 (VHT MIMO Control field); the other nonreserved subfields of the VHT MIMO Control field shall be the same for all feedback segments. All feedback segments shall be sent in a single A-MPDU and shall be included in the A-MPDU in the descending order of the Remaining Feedback Segments subfield values.

NOTE 2—The feedback segment of VHT compressed beamforming feedback(#4014)(#317) are not MSDU/MMPDU fragments, rather each feedback segment, together with the other fields in the Frame Body field of the VHT Compressed Beamforming frame (see Figure Figure 9-128 (Management frame format) and 9.6.22.2 (VHT Compressed Beamforming frame format)), constitutes a single unfragmented MMPDU.(#4014)

A VHT beamformer, in its first attempt to retrieve VHT compressed beamforming feedback from a VHT beamformee that is not the one indicated by the first STA Info field, shall transmit a Beamforming Report Poll frame to poll all possible feedback segments of the VHT compressed beamforming feedback from the VHT beamformee, by setting all of the bits in the Feedback Segment Retransmission Bitmap field of the Beamforming Report Poll frame to 1.

If a VHT beamformer fails to receive some or all feedback segments of VHT compressed beamforming feedback, the VHT beamformer may, subject to the condition on VHT SU-only beamformees described at the end of this subclause, request a selective retransmission of missing feedback segments by transmitting a Beamforming Report Poll frame with the Feedback Segment Retransmission Bitmap field set as described in 9.3.1.20 (Beamforming Report Poll frame format) to indicate the feedback segments requested for retransmission. If the VHT beamformer fails to receive the feedback segment with the First Feedback Segment field set to 1, the VHT beamformer may request a selective retransmission of missing feedback segments assuming the VHT compressed beamforming feedback is split into 8 feedback segments. The VHT beamformer may also request the retransmission of all feedback segments by setting all of the bits in the Feedback Segment Retransmission Bitmap field of the Beamforming Report Poll frame to 1.

A VHT beamformee that transmits VHT compressed beamforming feedback including the VHT Compressed Beamforming Report information and any MU Exclusive Beamforming Report information in response to a Beamforming Report Poll frame shall either transmit only the feedback segments indicated in the Feedback

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Segment Retransmission Bitmap field in the Beamforming Report Poll frame excluding the indicated feedback segments that do not exist at the VHT beamformee or transmit all of the feedback segments that exist at the VHT beamformee disregarding the Feedback Segment Retransmission Bitmap field in the Beamforming Report Poll frame.

A VHT beamformer shall not transmit a Beamforming Report Poll frame to a VHT SU-only beamformee unless the VHT beamformer has received at least one feedback segment of the VHT compressed beamforming feedback from the VHT beamformee in the current frame exchange sequence.

In a frame transmitted by a TVHT STA, the TVHT Compressed Beamforming Report field replaces the VHT Compressed Beamforming Report field.

In a frame transmitted by a TVHT STA, the TVHT MU Exclusive Beamforming Report field replaces the MU Exclusive Beamforming Report field.

### 10.35.6 Transmission of a VHT NDP

A VHT NDP shall use the SU PPDU format as described in 21.1.4 (PPDU formats). A STA shall transmit a VHT NDP using the following TXVECTOR parameters:

- APEP_LENGTH set to 0
- NUM_USERS set to 1
- NUM_STS indicates two or more space-time streams
- CH_BANDWIDTH set to the same value as the TXVECTOR parameter CH_BANDWIDTH in the preceding VHT NDP Announcement frame
- GROUP_ID and PARTIAL_AID are set as described in 10.19 (Group ID and partial AID in VHT and CMMG PPDUs)

The number of space-time streams sounded and as indicated by the NUM_STS parameter shall not exceed the value indicated in the Beamformee STS Capability field in the VHT Capabilities element of any intended recipient of the VHT NDP. The NUM_STS parameter may be set to any value, subject to the constraint of the previous sentence, regardless of the value of the Supported VHT-MCS and NSS Set field of the VHT Capabilities element at either the transmitter or recipient of the NDP.

(11ax)If an HE STA transmits a VHT NDP where at least one of the intended recipients of the VHT NDP is an HE STA, then the following conditions apply:

- If the bandwidth of an VHT NDP is less than or equal to 80 MHz, the number of space-time streams sounded as indicated by the TXVECTOR parameter NUM_STS shall not exceed the value indicated in the Beamformee STS ≤ 80 MHz subfield in the HE Capabilities element of any intended HE STA recipient of the VHT NDP.
- If the bandwidth of an VHT NDP is greater than 80 MHz, the number of space-time streams sounded as indicated by the TXVECTOR parameter NUM_STS shall not exceed the value indicated in the Beamformee STS > 80 MHz subfield in the HE Capabilities element of any intended HE STA recipient of the VHT NDP.

The intended receiver of a VHT NDP is identified by the RA of the immediately preceding VHT NDP Announcement frame.

The transmitter of a VHT NDP is identified by the TA of the immediately preceding VHT NDP Announcement frame.


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### 10.35.7 Transmission of an S1G NDP

An S1G NDP shall use the 2 MHz short format as described in 23.1.4 (PPDU formats). An S1G STA transmitting an S1G NDP shall use the following TXVECTOR parameters:

- APEP_LENGTH set to 0 if AGGREGATION is equal to(M118) AGGREGATED
- PSDU_LENGTH set to 0 if AGGREGATION is equal to(M118) NOT_AGGREGATED
- NUM_USERS set to 1
- CH_BANDWIDTH set to the same value as the TXVECTOR parameter CH_BANDWIDTH in the preceding VHT NDP Announcement frame carried in an S1G PPDU
- NUM_STS indicates two or more space-time streams
- PARTIAL_AID set as described in 10.21 (Group ID, partial AID, Uplink Indication, and COLOR in S1G PPDUs)
- NDP_INDICATION set to 0
- RESPONSE_INDICATION set to Long Response

The number of space-time streams sounded as indicated by the NUM_STS parameter shall not exceed the value indicated in the Beamformee STS Capability field in the S1G Capabilities element of any intended recipient of the S1G NDP. The NUM_STS parameter may be set to any value, subject to the constraint of the previous sentence, regardless of the value of the Supported S1G-MCS and NSS Set field of the S1G Capabilities element transmitted by either the transmitter or recipient of the S1G NDP.

The intended receiver of an S1G NDP is identified by the RA of the immediately preceding VHT NDP Announcement frame carried in an S1G PPDU.

The transmitter of an S1G NDP is identified by the TA of the immediately preceding VHT NDP Announcement frame carried in an S1G PPDU.

## 10.36 Null data PPDU (NDP) sounding for CMMG STAs

### 10.36.1 NDP rules

Sounding may be accomplished using a CMMG NDP(#1989)(#177), as described in 25.6.8.14 (CMMG preamble format for sounding PPDU). The MAC rules associated with sounding using a CMMG NDP(#1989)(#177) are described in 10.36.1 (NDP rules) and 10.36.2 (Transmission of a CMMG NDP).

A CMMG STA that has set the Receive NDP Capable field of its CMMG Capabilities element to 1 during association processes a CMMG NDP as a sounding PPDU if the destination of the sounding PPDU is determined to match itself and if the source of the sounding PPDU can be ascertained.

An RXVECTOR LENGTH parameter equal to 0 indicates that the PPDU is a CMMG NDP.

(#1989)(#177)A STA that is a TXOP holder or an RD responder shall not set both the CMMG NDP Announcement and RDG/More PPDU subfields to 1 in the same frame.

An NDP sequence contains at least one CMMG NDP and at least one PPDU that is not an NDP. Only one PPDU in the NDP sequence may contain a CMMG NDP announcement. (#1989)(#177)A *CMMG NDP announcement* is a PPDU containing a +HTC frame with the CMMG NDP Announcement subfield set to 1. An NDP sequence begins with a CMMG NDP announcement. The NDP sequence ends at the end of the transmission of the last CMMG NDP that is announced by the CMMG NDP announcement. A STA that transmits the first PPDU of an NDP sequence is the NDP sequence owner. In the NDP sequence, only PPDUs

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that are CMMG NDPs(#4150) and PPDUs each carrying a Control frame as an S-MPDU(#3202) may follow the NDP sequence's starting PPDU.(#177)

A STA shall transmit only one CMMG NDP per NDP announcement. Each PPDU in an NDP sequence shall start a SIFS after end of the previous PPDU.

NOTE—A CTS frame cannot be used for CMMG NDP announcement(#1989)(#177) even if it is in a Control Wrapper frame(#1896); if the CTS frame is a response to an RTS frame, the optional NAV reset timeout that starts at the end of the RTS frame does not include the additional CMMG NDP and SIFS. Also, if the CTS frame were the first frame of an NDP sequence, it would not be possible to determine the destination address of the CMMG NDP.

A STA shall transmit a CMMG NDP as follows:

a) A SIFS after sending (#1989)(#177)a CMMG NDP announcement and that does not contain an MPDU that requires an immediate response.

b) A SIFS after receiving a correctly formed and addressed immediate response to (#1989)(#177)a CMMG NDP announcement and that contains an MPDU that requires an immediate response.

This rule enables the NDP receiver to know that it receives a CMMG NDP and can determine the source and destination of the CMMG NDP. It enables the receiver and transmitter to know when the immediate response and CMMG NDP are transmitted relative to the frame containing the CMMG NDP announcement indication.

(#1989)(#177)A STA that has transmitted a CMMG NDP announcement indication in a frame that requires an immediate response and that does not receive the expected response shall terminate the NDP sequence at that point (i.e., the STA does not transmit a CMMG NDP in the current NDP sequence).

Feedback information generated from the reception of a CMMG NDP is transmitted using any of the feedback rules and signaling as appropriate, e.g., immediate or delayed.

### 10.36.2 Transmission of a CMMG NDP

A STA that transmits a CMMG NDP shall set the LENGTH, SOUNDING, NSS, and STBC parameters of the TXVECTOR as specified in this subclause.

— LENGTH shall be set to 0.
— SOUNDING shall be set to SOUNDING.
— STBC shall be set to 0.
— NSS indicates two or more spatial streams.

The number of spatial streams sounded is indicated by the NSS parameter of the TXVECTOR and shall not exceed the limit indicated by the Channel Estimation Capability field in the Transmit Beamforming Capabilities field transmitted by the STA that is the intended receiver of the CMMG NDP.

### 10.36.3 Determination of CMMG NDP destination

The destination of a CMMG NDP is determined at the NDP receiver by examining the CMMG NDP announcement as follows:

— The destination of the first CMMG NDP in the NDP sequence is equal to the RA of any MPDU within the CMMG NDP announcement.
— (#1989)(#177)If the Calibration Position subfield is equal to 1 in the frame containing the CMMG NDP announcement indication, the destination of the second CMMG NDP is equal to the TA of that frame. Otherwise, the destination of the second and any subsequent CMMG NDPs is equal to the destination of the previous CMMG NDP.


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### 10.36.4 Determination of CMMG NDP source

The source of a CMMG NDP is determined at the NDP receiver by examining the NDP sequences's starting PPDU as follows:

— If any MPDU within the CMMG NDP announcement contains two or more addresses, the source of the first CMMG NDP is equal to the TA of that frame.

— Otherwise (i.e., the CMMG NDP announcement contains one address), the source of the first CMMG NDP is equal to the RA of the MPDU to which the CMMG NDP announcement is a response.

If the Calibration Position subfield is equal to 1 in an MPDU in the CMMG NDP announcement, the source of the second CMMG NDP is equal to the RA of that MPDU. Otherwise, the source of the second and any subsequent CMMG NDPs is equal to the source of the previous NDP.

## 10.37 Mesh forwarding framework

### 10.37.1 General

The term *mesh forwarding* refers to forwarding of MSDUs and MMPDUs on paths determined by the mesh path selection between mesh STAs at the link layer. The mesh paths are contained in the forwarding information. The forwarding information, for instance, the lifetime of a mesh path, may be updated as a consequence of mesh forwarding.

The forwarding of MSDUs and MMPDUs within an MBSS is described in 10.37.3 (Addressing and forwarding of individually addressed mesh Data frames), 10.37.4 (Addressing and forwarding of group addressed mesh Data frames), 10.37.5 (Addressing of Management frames and MMPDU forwarding), and 10.37.8 (MSDU forwarding and unknown destination). The forwarding of MSDUs and MMPDUs between the MBSS and the DS at proxy mesh gates is described in 14.12.3 (Data forwarding at proxy mesh gates).

### 10.37.2 Forwarding information

Forwarding information is created by the active mesh path selection protocol and is utilized for MSDU/MMPDU forwarding as described in 10.37.3 (Addressing and forwarding of individually addressed mesh Data frames) and 10.37.5.2 (MMPDU forwarding using individually addressed Multihop Action frames).

The basic forwarding information to a destination mesh STA consists of the destination mesh STA address, the next-hop address, the precursor list, and the lifetime of this forwarding information.

An entry in the precursor list contains the precursor mesh STA address and the lifetime of this entry. If an existing entry in a precursor list is updated, the lifetime is the maximum of the current and the updated value. If the lifetime of a precursor expires, it will be deleted from the precursor list. Precursors are used to identify legitimate transmitters of individually addressed frames (see 10.37.3.2 (At intermediate and destination mesh STAs (individually addressed))) and for the notification of link failures (in case of HWMP, see 14.11.11 (Path error (PERR) mechanism)).

The forwarding information shall be considered as valid when the active mesh path selection protocol validates it. When a STA performs MSDU/MMPDU forwarding, it shall use valid forwarding information only.

If a STA finds its forwarding information to a particular destination mesh STA is not validated, it shall consider the corresponding next-hop address as unknown and may take necessary actions to forward any

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MSDU/MMPDU appropriately. See 10.37.8 (MSDU forwarding and unknown destination) and 14.11.9.3 (Conditions for generating and sending a PREQ element) for the HWMP case.

The forwarding information shall be considered as invalid if its lifetime has expired. Also, forwarding information is marked as invalid when certain conditions are met in the processing of mesh path selection elements, e.g., path error processing in HWMP (14.11.11.4 (PERR element processing)).

The active path selection protocol may define additional parameters in the forwarding information. Details on the additional parameters of the forwarding information constructed by the hybrid wireless mesh protocol (HWMP) are described in 14.11.8.4 (Forwarding information).

### 10.37.3 Addressing and forwarding of individually addressed mesh Data frames

#### 10.37.3.1 At source mesh STAs (individually addressed)

MSDUs sent by a mesh STA (as a consequence of an MA-UNITDATA.request primitive with an individual destination address) and destined to another mesh STA in the MBSS shall be transmitted using a frame with the four-address MAC header format (with the Address Extension Mode subfield in the Mesh Control field set to "None" (see Table 9-35 (Valid values for the Address Extension Mode subfield))), where the four address fields are set as follows (see row "Mesh Data (individually addressed)" in Table 9-77 (Address field contents for mesh Data and Multihop Action frames(#462)(#419)))(#3212):

— Address 1: The address of the next-hop mesh STA (toward the destination mesh STA according to the forwarding information; see 10.37.2 (Forwarding information)).
— Address 2: The address of the transmitter mesh STA.
— Address 3: The address of the destination mesh STA.
— Address 4: The address of the source mesh STA.

MSDUs that are sent by a mesh STA as a consequence of an MA-UNITDATA.request primitive with an individual destination address and are destined to an address that is different from the mesh STA at the end of a mesh path shall be transmitted using a frame with the four-address MAC header format (with the Address Extension Mode subfield in the Mesh Control field set to "Address5&6" (see Table 9-35 (Valid values for the Address Extension Mode subfield)))(#3212), where the Mesh Address Extension subfield in the Mesh Control field carries the addresses of the end stations, as specified in row "Mesh Data (proxied, individually addressed)" of Table 9-77 (Address field contents for mesh Data and Multihop Action frames(#462)(#419)). The additional addresses 5 and 6 are defined as follows:

— Address 5: The address of the destination end mesh STA (may be the same as Address 3 if the destination is the mesh STA at the end of the mesh path).
— Address 6: The address of the source end mesh STA (may be the same as Address 4 if the source is the mesh STA at the beginning of the mesh path).

NOTE—The destination address is distinct from the mesh STA at the end of the mesh path in two cases: 1) when the destination is an external address and 2) when the destination is a mesh STA distinct from the destination mesh STA at the end of the mesh path. The former case is described in 14.12.3 (Data forwarding at proxy mesh gates). The latter case might occur if a source mesh STA sends the MSDU to another intermediate mesh STA that sends the MSDU on a different mesh path to the destination mesh STA in the MBSS.

The Mesh TTL subfield in the Mesh Control field shall be set to dot11MeshTTL.The MSDUs are forwarded multiple hops, limited by the Mesh TTL value.

The source mesh STA shall set the Mesh Sequence Number subfield in the Mesh Control field to a value from a modulo $2^{32}$ counter that is (#270)incremented by 1 for each new MSDU (not in an A-MSDU)(#1597) or A-MSDU transmitted with a Mesh Control field and for each new MMPDU transmitted using a Multihop Action frame.


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#### 10.37.3.2 At intermediate and destination mesh STAs (individually addressed)

On receipt of an individually addressed mesh Data frame, a mesh STA shall perform the following:

a) The mesh STA shall decipher the frame and check it for authenticity. If it is not from a peer mesh STA, the frame shall be silently discarded.

b) The mesh STA shall check to see whether the MAC address in the Address 3 field is a known destination address; if it is an unknown destination address, the mesh STA may perform any of the following three actions:

   1) Silently discard the frame.

   2) Trigger a path discovery procedure depending on the path selection protocol that is currently active in the mesh BSS. For HWMP, see 14.11.9.3 (Conditions for generating and sending a PREQ element) Case A.

   3) Inform the mesh STA in Address 2 that the destination is unreachable depending on the path selection protocol that is currently active in the mesh BSS. For HWMP, see 14.11.11.3 (Conditions for generating and sending a PERR element) Case B.

c) If Address 2 is not one of the precursors for this destination mesh STA (see 10.37.2 (Forwarding information)), the frame shall be discarded.

If the frame is not discarded and one or more MSDUs are collected from the frame, the mesh STA may detect duplicate MSDUs according to 10.37.6 (Detection of duplicate MSDUs/MMPDUs) and discard them.

If Address 3 does not match the mesh STA's own address, but is a known individual destination MAC address in the forwarding information then the following actions are taken:

— The lifetime of the forwarding information to the destination (Address 3) is set to its initial value.

— The lifetime of the forwarding information to the source (Address 4) is set to its initial value.

— The lifetime of the precursor list entry for the precursor to the destination (Address 2) is set to the maximum of the initial value and the current value.

— The lifetime of the precursor list entry for the precursor to the source (next hop to the destination) is set to the maximum of the initial value and the current value.

— The Mesh TTL in the corresponding Mesh Control field of the collected MSDU is decremented by 1. If zero has been reached, the MSDU shall be discarded.

— If the MSDU has not been discarded, the mesh STA shall forward the MSDU via a frame with the Address 1 field set to the MAC address of the next-hop mesh STA as determined from the forwarding information (see 10.37.2 (Forwarding information)) and the Address 2 field set to its own MAC address and queue the frame for transmission.

If Address 3 matches the mesh STA's own MAC address, the following actions are taken:

— The lifetime of the forwarding information to the source (Address 4) is set to its initial value.

— The lifetime of the precursor list entry for the precursor to the destination (Address 2) is set to the maximum of the initial value and the current value.

— If the Address Extension Mode subfield in the Mesh Control field is "None" (see Table 9-35 (Valid values for the Address Extension Mode subfield)), the MA-UNITDATA.indication primitive is passed from the MAC sublayer entity to the LLC sublayer entity or entities.

— If the Address Extension Mode subfield in the Mesh Control field is "Address5&6" (see Table 9-35 (Valid values for the Address Extension Mode subfield)) and Address 5 is equal to Address 3, the mesh STA is the final destination of the MSDU, and the MA-UNITDATA.indication primitive is passed from the MAC sublayer entity to the LLC sublayer entity or entities.

— If the Address Extension Mode subfield in the Mesh Control field is "Address5&6" (see Table 9-35 (Valid values for the Address Extension Mode subfield)) and Address 5 is a known destination

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MAC address in the forwarding information (mesh STA), the mesh STA shall forward the MSDU via a frame as described in 10.37.3.1 (At source mesh STAs (individually addressed)) with the Address 3 field set to the MAC Address of the Address 5 field.

— If the Address Extension Mode subfield in the Mesh Control field is "Address5&6" (see Table 9-35 (Valid values for the Address Extension Mode subfield)), the MSDU is forwarded according to 14.12.3.2 (Forwarding of MSDUs from the MBSS to the DS) in all other cases.

If Address 3 matches the group address, the mesh STA shall perform the procedures as given in 10.37.4.2 (At recipient mesh STAs (group addressed)).

Note that during the forwarding process at intermediate mesh STAs, the content of the MSDU is not changed.

### 10.37.4 Addressing and forwarding of group addressed mesh Data frames

#### 10.37.4.1 At source mesh STAs (group addressed)

MSDUs sent by a mesh STA (as a consequence of an MA-UNITDATA.request primitive with a group destination address) shall be transmitted using a group addressed mesh Data frame (with the Address Extension Mode subfield in the Mesh Control field set to "None" (see Table 9-35 (Valid values for the Address Extension Mode subfield))) (#4181)(see row "Mesh Data (group addressed)" in Table 9-77 (Address field contents for mesh Data and Multihop Action frames(#462)(#419)))(#3212). An implementation may circumvent the unreliability of group addressed transmissions by using multiple individually addressed mesh Data frames, which are individually acknowledged. In such case, the frame may be converted to individually addressed frames and transmitted as individually addressed mesh Data frames to each peer mesh STA as described in 10.37.3.1 (At source mesh STAs (individually addressed)) with the Address 3 field set to the group address. The circumstances for choosing this method are outside the scope of the standard.

In group addressed mesh Data frames, the address fields are set as follows:

— Address 1: The group address

— Address 2: The address of the transmitter mesh STA

— Address 3: The address of the source mesh STA

The source mesh STA shall set the Mesh TTL subfield in the Mesh Control field to dot11MeshTTL in order to control the hop count. The MSDUs are forwarded multiple hops, limited by the Mesh TTL value. For example, if the Mesh TTL subfield is 1, MSDUs are delivered only to immediate neighbors.

The source mesh STA shall set the Mesh Sequence Number subfield in the Mesh Control field to a value from a modulo $2^{32}$ counter that is (#270)incremented by 1 for each new MSDU (not in an A-MSDU)(#1597) or A-MSDU transmitted with a Mesh Control field and for each new MMPDU transmitted using a Multihop Action frame.

Procedures that enhance the reliability or efficiency of group addressed transmissions are outside the scope of this standard.

#### 10.37.4.2 At recipient mesh STAs (group addressed)

On receipt of a group addressed mesh Data frame with Address 1 (DA) equal to the group address, or on receipt of an individually addressed mesh Data frame with Address 3 (Mesh DA) equal to the group address, a mesh STA shall perform the following:


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a) The mesh STA shall decipher the frame and check it for authenticity. If it is not from a peer mesh STA, the frame shall be silently discarded.

b) If the frame is not discarded and one or more MSDUs are collected from the frame, the mesh STA may detect duplicate MSDUs according to 10.37.6 (Detection of duplicate MSDUs/MMPDUs) and discard them.

c) The mesh STA decrements the Mesh TTL in the Mesh Control field. If the Mesh TTL value has reached zero, the corresponding MSDU shall not be forwarded to other mesh STAs.

d) If the Mesh TTL value has not reached zero and if dot11MeshForwarding is true, the mesh STA shall forward the MSDU via a group address mesh Data frame with the Address 2 field set to its own MAC address.

e) If the Address Extension Mode is "Address4" (see Table 9-35 (Valid values for the Address Extension Mode subfield)) and the recipient mesh STA is a proxy mesh gate and if the Mesh TTL value has not reached zero and if dot11MeshForwarding is true, the MSDU is forwarded according to 14.12.3.2 (Forwarding of MSDUs from the MBSS to the DS).

When the SA and the Mesh SA are not identical (the source address is therefore an external address), the MSDU shall be forwarded by using a frame with the three-address MAC header format (with the Address Extension Mode subfield in the Mesh Control field set to "Address4" (see Table 9-35 (Valid values for the Address Extension Mode subfield)))(#3212) as specified in row "Mesh Data (proxied, group addressed)" of Table 9-77 (Address field contents for mesh Data and Multihop Action frames(#462)(#419)). Otherwise, the MSDU shall be forwarded by using a frame with the three-address MAC header format (with the Address Extension Mode subfield in the Mesh Control field set to "None" (see Table 9-35 (Valid values for the Address Extension Mode subfield)))(#3212) as specified in row "Mesh Data (group addressed)" of Table 9-77 (Address field contents for mesh Data and Multihop Action frames(#462)(#419)).

An implementation may circumvent the unreliability of group addressed transmissions by using multiple individually addressed mesh Data frames, which are individually acknowledged. In such case, the frame may be converted to individually addressed frames and transmitted as an individually addressed mesh Data frame to each peer mesh STAs as described in 10.37.3.2 (At intermediate and destination mesh STAs (individually addressed)) with the Address 3 field set to the group address. If the Address Extension Mode subfield in the Mesh Control field in the group addressed mesh Data frame is equal to "Address4" (see Table 9-35 (Valid values for the Address Extension Mode subfield)), the Address Extension Mode subfield in the Mesh Control field in the individually addressed mesh Data frames is set to "Address5&6" (see Table 9-35 (Valid values for the Address Extension Mode subfield)), the Address 5 field is set to the group address, and the Address 6 field set to the Source Address contained in the Address 4 field of the group addressed mesh Data frame. The circumstances for choosing this method and the ability to determine all of the addresses of the neighbor peer mesh STAs are beyond the scope of the standard.

If one or more MSDUs collected from the frame have not been discarded, the MA-UNITDATA.indication primitive is passed from the MAC sublayer entity to the LLC sublayer entity or entities.

### 10.37.5 Addressing of Management frames and MMPDU forwarding

#### 10.37.5.1 General

All MMPDUs except MMPDUs transmitted using Multihop Action frames are transmitted over only one hop to peer mesh STAs.

NOTE—In several cases, the reception and processing of an Action frame leads to the transmission of a new Action frame of the same type that might include an identical or a modified version of the contents from the elements of the received Action frame. This is called *propagation* in contrast to forwarding.

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A mesh STA may convert a group addressed Management frame to individually addressed Management frames and transmit them as individually addressed frames to each peer mesh STA, if the frame is intended to be delivered only to its peer mesh STAs. The circumstances for choosing this method are outside the scope of the standard.

### 10.37.5.2 MMPDU forwarding using individually addressed Multihop Action frames

MMPDUs sent by a mesh STA and destined to another mesh STA in the MBSS using individually addressed Multihop Action frames (see 9.6.17 (Multihop Action frame details)) shall be transmitted using a Management frame with the three-address MAC header format (with the Address Extension Mode subfield in the Mesh Control field set to "Address4" (see Table 9-35 (Valid values for the Address Extension Mode subfield)))(#3212), where the four address fields are set as follows (see row "Multihop Action (individually addressed)" in Table 9-77 (Address field contents for mesh Data and Multihop Action frames(#462)(#419)))(#3212):

— Address 1: The address of the next-hop mesh STA (toward the destination mesh STA according to the forwarding information; see 10.37.2 (Forwarding information).
— Address 2: The address of the transmitter mesh STA.
— Address 3: The address of the destination mesh STA.
— Address 4: The address of the source mesh STA.

The source mesh STA shall set the Mesh TTL subfield in the Mesh Control field to dot11MeshTTL, and set the Mesh Sequence Number subfield in the Mesh Control field to a value from a modulo $2^{32}$ counter that is (#270)incremented by 1 for each new MSDU (not in an A-MSDU)(#1597) or A-MSDU transmitted with a Mesh Control field and for each new MMPDU transmitted using a Multihop Action frame.

At intermediate and destination mesh STAs, on receipt of an individually addressed Multihop Action frame, the address matching, the reception procedures, the forwarding information update, and the Mesh TTL decrement are performed as described in 10.37.3.2 (At intermediate and destination mesh STAs (individually addressed)), and the MMPDU is forwarded according to the forwarding information and the procedures in 10.37.3.2 (At intermediate and destination mesh STAs (individually addressed)).

At intermediate mesh STAs, frame fields following the Mesh Control field are not required to be examined.

If the Address 3 in the received Multihop Action frame matches the mesh STA's own MAC address or the group address, the mesh STA (destination mesh STA) shall process the content of the MMPDU.

### 10.37.5.3 MMPDU forwarding using group addressed Multihop Action frames

MMPDUs sent by a mesh STA and destined to all other mesh STAs in the MBSS using group addressed Multihop Action frames (see 9.6.17 (Multihop Action frame details)) shall be transmitted using a Management frame with the three-address MAC header format (with the Address Extension Mode subfield in the Mesh Control field set to "None" (see Table 9-35 (Valid values for the Address Extension Mode subfield))], where the three address fields are set as follows (#4181)(see row "Multihop Action (group addressed)" in Table 9-77 (Address field contents for mesh Data and Multihop Action frames(#462)(#419))):

— Address 1: The group address
— Address 2: The address of the transmitter mesh STA
— Address 3: The address of the source mesh STA

An implementation may circumvent the unreliability of group addressed transmissions by using multiple individually addressed Multihop Action frames, which are individually acknowledged. In such case, the frame may be converted to individually addressed frames and transmitted as individually addressed


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Multihop Action frames to each peer mesh STA as described in 10.37.5.2 (MMPDU forwarding using individually addressed Multihop Action frames) with the Address 3 field set to the group address. The circumstances for choosing this method are outside the scope of the standard.

The source mesh STA shall set the Mesh TTL subfield in the Mesh Control field to dot11MeshTTL, and set the Mesh Sequence Number subfield in the Mesh Control field to a value from a modulo $2^{32}$ counter that is (#270)incremented by 1 for each new MSDU (not in an A-MSDU)(#1597) or A-MSDU transmitted with a Mesh Control field and for each new MMPDU transmitted using a Multihop Action frame.

At recipient mesh STAs, on receipt of Multihop Action frame, the address matching, the reception procedures, the forwarding information update, and the Mesh TTL decrement are performed as described in 10.37.4.2 (At recipient mesh STAs (group addressed)), and the MMPDU is forwarded according to the forwarding information and the procedures in 10.37.4.2 (At recipient mesh STAs (group addressed)).

If the Address 1 in the received Multihop Action frame matches the group address, the mesh STA shall process the content of the MMPDU.

Procedures that enhance the reliability or efficiency of group addressed transmissions are outside the scope of this standard.

### 10.37.6 Detection of duplicate MSDUs/MMPDUs

A mesh STA may receive multiple copies of the same MSDU or MMPDU from different neighbor peer mesh STAs.

The filtering of such duplicates is facilitated through the inclusion of a Mesh Sequence Number subfield in the Mesh Control field in mesh Data frames and Multihop Action frames as specified in 9.2.4.8.3 (Mesh Control field).

The receiving mesh STA shall keep a cache of recently received <Mesh SA, Mesh Sequence Number> tuples. The Mesh Source Address (Mesh SA) is contained in Address 4 for individually addressed mesh Data frames and Multihop Action frames. The Mesh Source Address (Mesh SA) is contained in Address 3 for group addressed mesh Data frames.

(#270)A mesh STA shall reject an MSDU, A-MSDU or MMPDU with a Mesh Control field as a duplicate if it matches a <Mesh SA, Mesh Sequence Number> tuple of an entry in the cache.

The rules in 10.3.2.14 (Duplicate detection and recovery) also apply to the filtering of duplicates sent by the same neighbor peer mesh STA.

### 10.37.7 Mesh STAs that do not forward

A mesh STA that has dot11MeshForwarding equal to false does not forward either MSDUs, or Multihop Action frames. The circumstances in which a mesh STA may be allowed to become a non- forwarding entity and the authority to set dot11MeshForwarding to false are beyond the scope of this standard.

A mesh STA that does not forward is a special case of a mesh STA. Such mechanism depends on whether the path selection protocol provides a mechanism to allow mesh STAs not to participate in forwarding. The HWMP path selection protocol provides such a mechanism; see 14.11 (Hybrid wireless mesh protocol (HWMP)).

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### 10.37.8 MSDU forwarding and unknown destination

A source mesh STA in the MBSS might not able to forward an MSDU that it has received as a consequence of an MA-UNITDATA.request primitive with an individual destination address. This is the case if the destination of the MSDU is unknown to the mesh STA. The destination is unknown to a mesh STA if the mesh STA has no valid forwarding information for this destination or if the destination is not in its proxy information as an external STA (see 14.12.4.2 (Proxy information)). Note that the procedure to determine that an address is unknown depends on the active path selection protocol. It might require an attempt to establish a path to the destination (see 14.9 (Mesh path selection and metric framework)).

If the source mesh STA is not able to forward the MSDU because its destination is unknown, the mesh STA shall assume that the destination is outside the MBSS and shall forward the MSDU to known mesh gates in the MBSS as one or more individually addressed frames according to the procedures for frame addressing and data forwarding of individually addressed frames at source mesh STAs in an MBSS (10.37.3.1 (At source mesh STAs (individually addressed))). These frame(s) shall be transmitted using the four-address MAC header format (with the Address Extension Mode subfield in the Mesh Control field set to "Address5&6" (see Table 9-35 (Valid values for the Address Extension Mode subfield)))(#3212), where the Mesh Address Extension subfield in the Mesh Control field carries the address of the destination end station, as specified in row "Mesh Data (proxied, individually addressed)" of Table 9-77 (Address field contents for mesh Data and Multihop Action frames(#462)(#419)). The address fields are set as follows:

— Address 1: The address of the next-hop mesh STA (toward the known mesh gate in the MBSS according to the forwarding information; see 10.37.2 (Forwarding information)).
— Address 2: The address of the source mesh STA.
— Address 3: The address of the known mesh STA in the MBSS.
— Address 4: The address of the source mesh STA.
— Address 5: The address of the destination end mesh STA, which is the unknown destination address of the MSDU.
— Address 6: The address of the source mesh STA, which is the same as Address 4.

If there is no mesh gate available, the mesh STA shall silently discard the MSDU.

Discovery of mesh gates by mesh STAs is performed using propagated elements, such as a GANN (14.12.2 (Gate announcement (GANN))). Other methods specific to the HWMP path selection protocol are also available, such as the proactive PREQ mechanism (14.11.4.2 (Proactive PREQ mechanism)) or the proactive RANN mechanism (14.11.4.3 (Proactive RANN mechanism)), when the Gate Announcement subfield in the Flags field in these HWMP elements is set to 1.


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## 10.38 DMG and CMMG channel access

### 10.38.1 General

Channel access by a DMG STA is related to beacon interval timing and is coordinated using a schedule. A DMG STA operating as an AP or PCP generates the schedule and communicates it to STAs using DMG Beacon and Announce frames. A non-PCP STA that is a non-AP STA and that receives scheduling information accesses the medium during the scheduled periods using the access rules specific to that period. Medium access rules to establish a BSS are defined in 10.39 (DMG and CMMG AP or PCP clustering) and 11.1.4 (Acquiring synchronization, scanning). CMMG STAs follow the same rules of DMG channel access except the specific modification for CMMG STAs as described in 10.38 (DMG and CMMG channel access).

### 10.38.2 Access periods within a beacon interval

Medium time within a DMG or CMMG BSS is divided into beacon intervals. Subdivisions within the beacon interval are called *access periods*. Different access periods within a beacon interval have different access rules. The access periods are described in a schedule that is communicated by the AP or PCP to the non-PCP and non-AP STAs within the BSS. The schedule communicated by the AP or PCP can include the following access periods:

— *BTI:* For DMG STAs, it is an access period during which one or more DMG Beacon frames is transmitted. Not all DMG Beacon frames are detectable by all non-PCP and non-AP STAs (see 10.41.4 (Beamforming in BTI)). Not all beacon intervals contain a BTI. For CMMG STAs, it is an access period during which one or more DMG Beacon frames are transmitted at least in the primary 540 MHz channel. Not all DMG Beacon frames are detectable by all non-PCP and non-AP STAs. A non-PCP STA that is a non-AP STA shall not transmit during the BTI of the BSS of which it is a member.

— *A-BFT:* An access period during which beamforming training is performed with the STA that transmitted a DMG Beacon frame during the preceding BTI (see 10.41.5 (Beamforming in A-BFT)). The presence of the A-BFT is optional and signaled in DMG Beacon frames.

— *ATI:* A request-response based management access period between the AP or PCP and non-AP and non-PCP STAs (see 10.38.3 (ATI transmission rules)). The presence of the ATI is optional and signaled in DMG Beacon frames.

— *CBAP:* An access period during which frame exchange sequences(#109) between STAs that use the channel access rules described in 10.38.5 (Contention based access period (CBAP) transmission rules).

— *SP:* An access period during which frame exchange sequences(#109) between STAs use the channel access rules described in 10.38.6.2 (Service period (SP) allocation).

The BHI comprises the BTI, A-BFT and ATI. The DTI, in turn, comprises contention based access periods (CBAPs) and scheduled service periods (SPs). There is a single BHI and a single DTI per beacon interval.

Figure 10-60 (Example of access periods within a beacon interval) illustrates an example of access periods within a beacon interval comprising a BTI, an A-BFT, an ATI, and two CBAPs and SPs within the DTI. Any combination in the number and order of SPs and CBAPs can be present in the DTI.

(11ay)In an EDMG BSS, the following apply:

— Frames sent during the BTI and ATI shall be transmitted on only the primary channel of the BSS.

— The A-BFT shall be present on the primary channel of the BSS and can also be present on the secondary or secondary1 channel of the BSS (see 10.41.5.1 (Allocation of A-BFT)).

— Transmissions within a CBAP or an SP may span the primary channel and the secondary channel(s).

— The channel width of the primary channel is 2.16 GHz.

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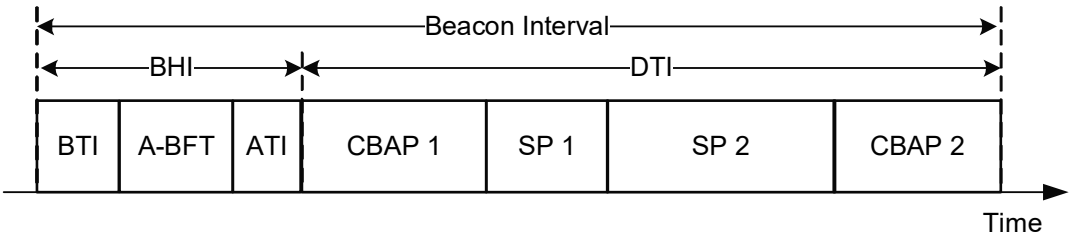


**Figure 10-60—Example of access periods within a beacon interval**

For a 1080 MHz CMMG BSS, the DTI can comprise contention-based access periods (CBAPs) and scheduled service periods (SPs), and the bandwidth of the allocation in the DTI can be 540 MHz and 1080 MHz.

Figure 10-61 (Example of access periods within a beacon interval for CMMG STAs) illustrates an example of access periods within a beacon interval for a 1080 MHz CMMG BSS, comprising a BHI, that may contain BTI, A-BFT, and ATI, and two 540 MHz CBAPs and SPs within the DTI and one 1080 MHz CBAPs and SPs within the DTI. Any combination in the number and order of SPs and CBAPs can be present in the DTI. For a CMMG BSS, the BHI shall be sent on the primary 540 MHz channel and can be sent on the 1080 MHz channel with duplicate format.

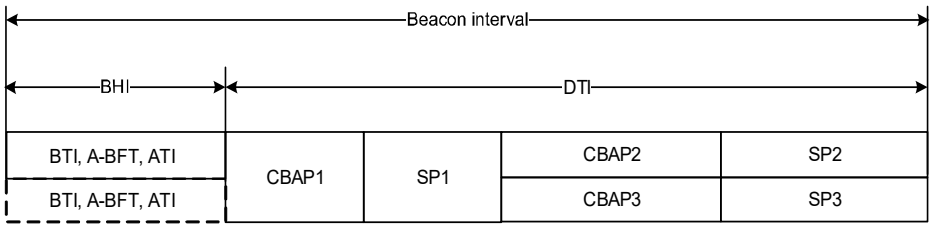


**Figure 10-61—Example of access periods within a beacon interval for CMMG STAs**

The details of the access protocol within each of the access periods are described in the remaining subclauses of 10.38 (DMG and CMMG channel access) and within 10.41 (DMG beamforming).

In the ATI, a non-AP and non-PCP STA shall be ready to receive a transmission from the AP or PCP at least RxAdvanceTime before the expected transmission of a request frame. The destination STA of an SP shall be ready to receive a transmission from the source STA of the SP at least RxAdvanceTime before the start of the SP. A STA that participates in a CBAP shall be ready to receive a transmission within the CBAP at least RxAdvanceTime before the start of the CBAP plus DIFS. In the A-BFT, the AP or PCP should be ready to receive a transmission from a non-AP and non-PCP STA at least RxAdvanceTime before the start of an SSW slot. In all of the preceding rules, RxAdvanceTime is defined as follows:

$$\text{RxAdvanceTime} = \text{Ceil}\left(\left(\frac{C \times T_{DI}}{10^6} + T_P\right),\ T_{TR}\right)$$

where

$C$ is aDMGTSFAccuracy, in ppm

$T_{DI}$ is the time elapsed since a synchronizing reference event, in μs. The synchronizing event is the reception of the Timestamp field from the AP or PCP



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$T_P$ is aAirPropagationTime, in μs

$T_{TR}$ is aTSFResolution, in μs

### 10.38.3 ATI transmission rules

The presence of an ATI in the current beacon interval is signaled by the ATI Present field set to 1 in the current DMG Beacon frame (9.3.4.2 (DMG Beacon)). The Next DMG ATI element (9.4.2.134 (Next DMG ATI element)) transmitted in the Announce frame or in the DMG Beacon frame indicates the earliest start time for the next ATI in a subsequent beacon interval and ATI duration.

An example of an ATI is shown in Figure 10-62 (Example of frame exchanges during the ATI).

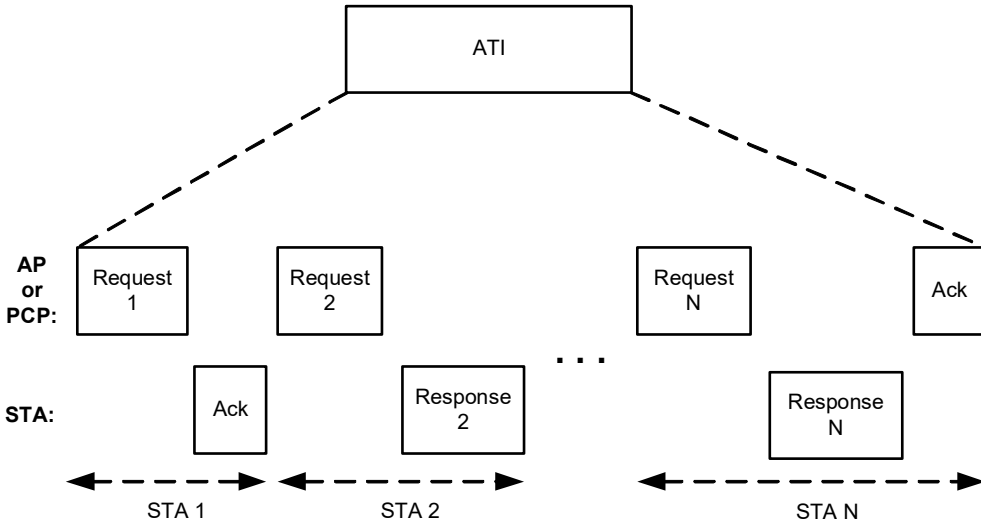


**Figure 10-62—Example of frame exchanges during the ATI**

During an ATI, request and response frames are exchanged between the AP or PCP and any subset of STAs. The AP or PCP initiates all frame exchange sequences that occur during the ATI. The ATI shall not start sooner than Max(guard time, MBIFS), where guard time is defined in 10.38.6.5 (Guard time), following the end of the previous A-BFT when an A-BFT is present in the beacon interval or following the end of the previous BTI when an A-BFT is not present but a BTI is present in the beacon interval. The ATI shall not start before TBTT if the ATI is the first period in the beacon interval(11ay). Once the ATI starts, the AP or PCP may start transmission of a request frame immediately or it may delay the transmission of the request frame if the medium is determined by the CCA mechanism to be busy.

For DMG STAs, during each ATI the AP or PCP shall schedule transmissions to a non-AP and non-PCP STA if the non-AP and non-PCP STA Heartbeat field in the STA's DMG Capabilities element within the Association Request frame of the last successful association attempt is 1. If the non-AP and non-PCP STA does not respond to the frame transmitted by the AP or PCP, the AP or PCP shall use the DMG Control modulation class (10.6.7.1 (Usage of DMG Control modulation class)) at its next transmission attempt to the non-AP and non-PCP STA. The AP or PCP shall use the DMG Control modulation class for all subsequent transmissions to the non-AP and non-PCP STA until it receives a (#3274)frame from the non-AP and non-PCP STA.

For CMMG STAs, during each ATI the AP or PCP shall schedule transmissions to a non-AP and non-PCP STA if the non-AP and non-PCP STA Heartbeat field in the STA's CMMG Capabilities element within the Association Request frame of the last successful association attempt is 1 and the non-AP and non-PCP STA

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is in the awake state. If the non-AP and non-PCP STA does not respond to the frame transmitted by the AP or PCP, the AP or PCP shall use the CMMG Control modulation class ((10.6.8.1 (Usage of CMMG Control modulation class)) at its next transmission attempt to the non-AP and non-PCP STA. The AP or PCP shall use the CMMG Control modulation class for all subsequent transmissions to the non-AP and non-PCP STA until it receives a (#3274)frame from the non-AP and non-PCP STA.

A non-AP and non-PCP STA shall not transmit during the ATI except in response to an individually addressed frame whose TA field contains the AP's or PCP's MAC address and whose RA field contains the STA's MAC address.

During the ATI a STA shall not transmit frames that are not request or response frames. Request and response frames transmitted during the ATI shall be one of the following:

- A Management frame
- An Ack frame
- A Grant, Poll, RTS or DMG CTS frame when transmitted as a request frame
- An SPR or DMG CTS frame when transmitted as a response frame
- A frame with the Type subfield equal to Data only as part of an authentication exchange to reach an RSNA security association

NOTE 1—The Announce frame is designed to be used primarily during the ATI and can perform functions of a DMG Beacon frame.

The transmission of Poll frames during the ATI follows the rules described in 10.38.7 (Dynamic allocation of service period). The Response Offset field within a Poll frame transmitted during the ATI shall be set to 0.

The transmission of Grant frame during the ATI follows the rules described in 10.38.7.3 (Grant period (GP)).

Individually addressed request frames transmitted during the ATI shall not be sent using Action No Ack frames.

During the ATI, after an AP or PCP transmits an individually addressed request frame (such as an Announce frame) to a non-AP and non-PCP STA, and the STA receives that frame, the STA shall transmit a response frame addressed to the AP or PCP. The transmission of the response frame shall commence one SIFS after the reception of the request frame. The AP or PCP shall interpret the receipt of the response frame as an acknowledgment of the request frame. Response frames transmitted by non-AP and non-PCP STAs during the ATI shall be individually addressed to the AP or PCP.

NOTE 2—STAs do not transmit a response frame to the AP or PCP when they receive a request frame from the AP or PCP with the RA equal to a group address (see 10.3.6 (Group addressed MPDU transfer procedure)).

The Duration field of a request frame transmitted during the ATI shall be set to cover the remaining duration of the ATI at the end of the request frame transmission. The Duration field of a response frame transmitted during the ATI shall be set to the value of the Duration field within the previously received request frame minus SIFS and minus the duration of the response frame transmission.

When a transmission by a STA is expected by an AP or PCP and a SIFS elapses without its receipt, the AP or PCP may either repeat its individually addressed transmission to that STA or, as early as one PIFS after the end of its previous transmission, transmit a frame to any other STA.

NOTE 3—If acknowledgment is required, the AP or PCP transmits an Ack frame to acknowledge the reception of a response frame during the ATI (see Figure 10-62 (Example of frame exchanges during the ATI)).


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Multiple request and response frame exchange sequences(#109) between the AP or PCP and a STA might occur during a single ATI.

For CMMG STAs, the bandwidth of a response frame transmitted during the ATI shall be set to the same as previously received request frame.

### 10.38.4 DTI transmission rules

During the DTI, a STA may initiate a frame exchange sequence(#109) (following the DMG channel access rules for DMG STAs and following the CMMG channel access rules for CMMG STAs) if any of the following conditions are met:

a) During a CBAP for which the STA is identified or included as source or destination (10.38.6.3 (Contention based access period (CBAP) allocation), 10.38.7 (Dynamic allocation of service period), and 10.38.8 (Dynamic truncation of service period))

b) During an SP for which the STA is identified as source or destination (10.38.6.2 (Service period (SP) allocation) and 10.38.7 (Dynamic allocation of service period))

and shall not initiate a frame exchange sequence(#109) if none of these conditions are met. A STA initiating data transfer shall check that the transaction, including acknowledgments, completes before the end of the CBAP or SP in which it was initiated. Also, a CMMG STA initiating data transfer shall use a bandwidth no larger than the allocated channel bandwidth of the CBAP or SP in which it was initiated.

When the entire DTI is allocated to CBAP (that is, the CBAP Only field is 1 in the DMG Parameters field for DMG STAs, or the CBAP Only field is 1 in the CMMG Parameters field for CMMG STAs), for DMG STAs, the ATI Present field within the DMG Beacon frame containing the DMG Parameters field shall be set to 0, and for CMMG STAs the ATI Present field within the DMG Beacon frame containing the CMMG Parameters field shall be set to 0.

A DMG or CMMG STA shall support(#546) processing Grant frames. (11ay)An EDMG STA shall support(#546) processing Grant Ack frames and shall set the Grant Ack Supported field to 1 in the STA's DMG Capabilities element. A non-AP and non-PCP DMG or CMMG STA shall support(#546) processing Poll frames and the Extended Schedule element. An AP or PCP shall support(#546) processing SPR frames transmitted by a non-AP and non-PCP STA and responding to an SPR frame with a Grant frame.

The DMG low-power SC mode (20.6 (DMG low-power SC mode)) may be used only within SPs that have the LP SC Used subfield within the Extended Schedule element equal to 1 and shall not be used otherwise. A STA supports the DMG low-power SC mode if the Low-Power SC Mode Supported subfield within its DMG Capabilities element is 1. A STA that supports the DMG low-power SC mode shall not initiate a frame exchange sequence(#109) using the DMG low-power SC mode unless the STAs identified in the RA field of all MPDUs contained within the PPDU support the DMG low-power SC mode. A STA can use the procedure described in 11.28.1 (Information Request and Response) to discover the capabilities of another STA.

A STA that receives a Grant frame and that has the Grant Ack Supported field equal to 1 in the STA's DMG Capabilities element shall respond with a Grant Ack frame SIFS after reception of the Grant frame. In the transmitted Grant Ack frame, the STA shall copy the Source AID, Destination AID, and Beamforming Training fields from the Grant frame that the Grant Ack frame is being sent in response to. A STA that receives a group addressed Grant frame shall not respond with Grant Ack frame. A STA that receives a Grant frame and that does not have the Grant Ack Supported field equal to 1 in the STA's DMG Capabilities element shall not respond with a Grant Ack frame.

(11ay)A STA shall support(#546) receiving MPDUs of arbitrary length that is less than or equal to the MPDU size advertised by the STA (see Table 9-25 (Control ID subfield values(11ax))).

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### 10.38.5 Contention based access period (CBAP) transmission rules

The definition of contention based transmission rules used within a CBAP is provided in 10.3 (DCF) and in 10.23 (HCF). This subclause specifies additional rules applicable to the CBAP.

A STA shall not initiate a frame exchange sequence(#109) within a CBAP unless at least one of the following conditions is met:

- The value of the CBAP Only field is equal to 1 and the value of the CBAP Source field is equal to 0 within the DMG Parameters field of the DMG Beacon frame that allocates the CBAP
- The STA is an AP or PCP and the value of the CBAP Only field is equal to 1 and the value of the CBAP Source field is equal to 1 within the DMG Parameters field of the DMG Beacon frame that allocates the CBAP
- The value of the Source AID field of the CBAP is equal to the broadcast AID
- The STA's AID is equal to the value of the Source AID field of the CBAP
- The STA's AID is equal to the value of the Destination AID field of the CBAP

If a STA's AID is equal to the value of the Source AID field of a CBAP allocation or if a STA performs in the role of AP or PCP and both the CBAP Only and CBAP Source fields are equal to 1 in the DMG Beacon frame that allocates a CBAP, the STA may initiate a frame transmission within the CBAP immediately after the medium is determined to be idle for one PIFS.

A BF initiator (10.41 (DMG beamforming)) should not initiate an SLS phase within a CBAP if there is not enough time within the CBAP to complete the SLS phase.

(#109)A STA shall not extend a frame exchange sequence that started during a CBAP beyond the end of that CBAP. A STA that initiates a sequence shall check that the frame exchange sequence, including any control frame responses, completes before the end of the CBAP.

Operation of the EDCAF is suspended at the end of a CBAP and is resumed at the beginning of the following CBAP. When the EDCAF is being suspended, the values of the backoff and NAVs shall remain unchanged until the start of the following CBAP. A TXOP may be obtained by a DMG STA winning an instance of EDCA contention (see 10.23.2 (HCF contention based channel access (EDCA))).

At the beginning of a TXOP with a TXOP responder that has the Heartbeat field in the TXOP responder's DMG Capabilities element equal to 1 for DMG STAs or has the Heartbeat field in the TXOP responder's CMMG Capabilities element equal to 1 for CMMG STAs, the following rules apply:

- For DMG STAs, the TXOP holder shall transmit a frame to the TXOP responder using the DMG Control modulation class before it uses any other modulation class for transmission if the time elapsed since the last frame received from the TXOP responder is larger than or equal to the Heartbeat Elapsed Time value computed using the Heartbeat Elapsed Indication field within the TXOP responder's DMG Capabilities element.
- For DMG STAs, the TXOP holder may transmit a frame using a modulation class other than the DMG Control modulation class at the start of the TXOP if the time elapsed since the last frame received from the TXOP responder is shorter than the Heartbeat Elapsed Time value computed using the Heartbeat Elapsed Indication field within the TXOP responder's DMG Capabilities element.
- For CMMG STAs, the TXOP holder shall transmit a frame to the TXOP responder using the CMMG Control modulation class before it uses any other modulation class for transmission if the time elapsed since the last frame received from the TXOP responder is larger than or equal to the Heartbeat Elapsed Time value computed using the Heartbeat Elapsed Indication field within the TXOP responder's CMMG Capabilities element.


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— For CMMG STAs, the TXOP holder may transmit a frame using a modulation class other than the CMMG Control modulation class at the start of the TXOP if the time elapsed since the last frame received from the TXOP responder is shorter than the Heartbeat Elapsed Time value computed using the Heartbeat Elapsed Indication field within the TXOP responder's CMMG Capabilities element.

The frame sent by the STA at the beginning of the TXOP may be an RTS frame or a DMG CTS-to-self frame.

Within a CBAP a STA with multiple DMG antennas should use only one DMG antenna in its frame transmission, CCA and frame reception, except if it is the initiator or responder in an SLS (10.41 (DMG beamforming)). The algorithm to select a DMG antenna and switch the active DMG antenna is implementation dependent. Within CBAPs a STA that changed to a different DMG antenna in order to transmit should perform CCA on that DMG antenna until a frame is detected by which it can set its NAV, or until a period of time equal to the dot11DMGNavSync has transpired, whichever is earlier.

### 10.38.6 Channel access in scheduled DTI

#### 10.38.6.1 General

An AP or PCP schedules each allocation with a specified start time from the TSF and with a fixed duration. An allocation can be an SP, where ownership of channel time is granted to a single STA, or a CBAP, where STAs can compete for channel access. The start time of each allocation is based on the TSF of the AP or PCP.

The AP or PCP may schedule SPs or CBAPs only during the DTI of a beacon interval, following the end of an allocated BTI, A-BFT, and ATI when any of these periods are present in the beacon interval.

(11ay)The schedule of the DTI of a beacon interval shall be communicated through the Extended Schedule element and, in an EDMG BSS, also through the EDMG Extended Schedule element. The AP or PCP transmits the Extended Schedule element in either or both an Announce frame or a DMG Beacon frame. If the Extended Schedule element includes at least one TDD SP, it shall be transmitted in a DMG Beacon frame. The Extended Schedule element shall contain the scheduling information of all allocations in the DTI, except if transmitted in an EDMG BSS where the Extended Schedule element may exclude one or more allocations that are included in EDMG Extended Schedule element transmitted through at least one sector. The same Allocation field shall not appear more than once in the Extended Schedule element transmitted in a beacon interval. The content of the Extended Schedule element and the EDMG Extended Schedule element communicated in a beacon interval shall not change if transmitted more than once in the beacon interval, except as follows;

— If the STA transmitting the Extended Schedule element or the EDMG Extended Schedule element is a PCP with multiple DMG antennas, then the value of the PCP Active field of CBAP allocations within the Extended Schedule element or the EDMG Extended Schedule element might change when (#3424)these elements are transmitted through different DMG antennas.

— For the EDMG Extended Schedule element, fields that are related to directional allocation (10.38.12.3 (Directional allocation)) or beamforming training allocation (10.41.10.3.3 (Beamforming training allocation in DTI)) may change during the beacon interval when transmitted through different sectors.

(11ay)The AP or PCP should schedule SPs for a STA such that the scheduled SPs do not overlap in time with the traffic scheduling constraints indicated by this STA in the Traffic Scheduling Constraint Set field of the associated DMG TSPEC element.

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When scheduling a nonpseudo-static allocation or changing the start time of an existing pseudo-static allocation that has a non-AP and non-PCP STA as a source DMG STA or as a destination DMG STA of the allocation, an AP or PCP shall set the start time of the allocation to no less than aMinAllocationDeliveryTime after the last Extended Schedule element containing this allocation is transmitted by the AP or PCP.

NOTE—This rule does not apply to the case when an AP or PCP schedules a new pseudo-static allocation.

When receiving an Extended Schedule element containing a new pseudo-static allocation in which it is expected to participate, a non-AP and non-PCP STA ignores the allocation if the value of the TSF at the time the frame containing the Extended Schedule element is received is greater than the value of the TSF at the start of the pseudo-static allocation; this allocation is called an *obsolete allocation*. The value of the TSF at the start of the pseudo-static allocation is constructed using the value of the Allocation Start Time field within the Allocation field for the pseudo-static allocation.

An SP or CBAP allocation within an Extended Schedule element may comprise one or more individual allocations. The start time of each individual allocation of an SP or CBAP is given by

$$(A_{start} + (i - 1) \times A_{period})$$

where

$A_{start}$ is the value of the Allocation Start field for the SP or CBAP

$A_{period}$ is the value of the Allocation Block Period field for the SP or CBAP

$i$ is an integer greater than 0 and less than or equal to the value of the Number of Blocks field for the SP or CBAP

The end of the $i^{th}$ individual SP or CBAP allocation is computed by adding the start time of the $i^{th}$ individual allocation to the value of the Allocation Block Duration field for the corresponding SP or CBAP allocation.

For CMMG STAs, an SP or CBAP allocation within an Extended Schedule element may be a 540 MHz allocation or a 1080 MHz allocation; the channel and bandwidth of the SP or CBAP allocation are indicated in the Extended Schedule element.

If the PCP Active subfield in the Allocation field for an allocation within an Extended Schedule element is 1, the PCP shall be in the receive state for the duration of that allocation, except when transmitting during that allocation. The AP shall set the PCP Active field to 1 for every allocation within an Extended Schedule element transmitted by the AP.

### 10.38.6.2 Service period (SP) allocation

#### 10.38.6.2.1 General(11ay)

The AP or PCP shall set the AllocationType subfield to 0 in an Allocation field within an Extended Schedule element to indicate an SP allocation.

(11ay)If an SP has the TDD Applicable SP subfield in an Allocation field within an Extended Schedule element equal to 1, it is an SP with TDD channel access (i.e., TDD SP) and the rules specified in 10.38.6.2.2 (SP with TDD channel access(11ay)) for TDD channel access during the SP shall apply. Otherwise, the TDD channel access rules shall not apply and the SP does not use the TDD channel access rules.

(11ay)A DMG STA may transmit in a TDD SP only if the TDD Channel Access Supported subfield in the STA's DMG Capabilities element is 1. Otherwise, the DMG STA shall not transmit in the TDD SP.


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(11ay)A TDD SP comprises a sequence of TDD intervals that, in turn, comprise a sequence of TDD slots (see 10.38.6.2.2 (SP with TDD channel access(11ay))). TDD intervals and TDD slots exist only in a TDD SP. Unless otherwise specified, the rules applicable to an SP shall also be applicable to TDD slots within a TDD SP.

An SP allocation that is not an obsolete allocation is assigned to the source DMG STA identified in the Source AID subfield in an Allocation field within the Extended Schedule element. The source DMG STA shall initiate the frame exchange sequence that takes place during the SP at the start of the SP, except when the source DMG STA intends to establish a DMG protected period in which case the rules described in 10.38.6.6 (DMG and CMMG protected period) shall be followed before the source DMG STA initiates the frame exchange sequence(#109) in the SP. The SP allocation identifies the TC or TS for which the allocation is made; however, the type of traffic transmitted is not restricted to the specified TC or TS (11.4.1 (Introduction)).

An SP (11ay)that is not a TDD SP is assigned to the source CMMG STA identified in the Source AID subfield in an Allocation field that is not an obsolete allocation within the Extended Schedule element. The source CMMG STA shall initiate the frame exchange sequence that takes place during the SP at the start of the SP, except when the source CMMG STA intends to establish a CMMG protected period in which case the rules described in 10.38.6.6 (DMG and CMMG protected period) shall be followed before the source CMMG STA initiates the frame exchange sequence(#109) in the SP. The SP allocation identifies the TC or TS for which the allocation is made; however, the type of traffic transmitted is not restricted to the specified TC or TS (11.4.1 (Introduction)).

Except when transmitting a frame as part of the SP recovery procedure (10.38.6.7 (Service period recovery)) or transmitting a response to the source DMG STA or transmitting a PPDU as part of an RD response burst (10.29 (Reverse direction protocol)) (11ay)or in a TDD slot, the STA identified by the Destination AID field in the Extended Schedule element should be in the receive state for the duration of the SP in order to receive transmissions from the source DMG STA. If the Destination AID field of the scheduled SP is equal to the broadcast AID and if the Source AID field of the scheduled SP is not equal to the broadcast AID, then all STAs on the PBSS/infrastructure BSS should be in the receive state in order to receive transmissions from the source DMG STA for the duration of the SP. Subclause 10.38.7 (Dynamic allocation of service period) describes the rules for when the scheduled SP has both the Source and Destination AID fields equal to the broadcast AID.

Only a STA identified as the source DMG STA or destination DMG STA of an SP may transmit during the SP, except when the rules in 10.38.7 (Dynamic allocation of service period), 10.38.8 (Dynamic truncation of service period), or 10.38.9 (Dynamic extension of service period) are used.

At the beginning of an SP (except when the source DMG STA intends to establish a DMG protected period, see 10.38.6.6 (DMG and CMMG protected period)) before the source DMG STA initiates the frame exchange sequence(#109) in the SP, a source DMG STA shall transmit a frame to the destination DMG STA using the DMG Control modulation class before it uses any other modulation class for transmission if the Heartbeat field in the destination DMG STA's DMG Capabilities element is 1. The frame sent by the source STA may be an RTS frame or a DMG CTS-to-self frame. The frame sent by the source STA may be an SSW frame or a BRP PPDU if the source STA is performing beamforming (10.6.7.5 (Rate selection for BRP PPDUs)).

At the beginning of an SP in a CMMG band, except when the source CMMG STA intends to establish a CMMG protected period (see 10.38.6.6 (DMG and CMMG protected period)) before the source CMMG STA initiates the frame exchange sequence(#109) in the SP, a source CMMG STA shall transmit a frame to the destination CMMG STA using the CMMG Control modulation class before it uses any other modulation class for transmission if the Heartbeat field in the destination CMMG STA's CMMG Capabilities element is 1. The frame sent by the source STA may be an RTS frame or a DMG CTS-to-self frame. The frame sent by the

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source STA may be an SSW frame or a BRP PPDU if the source STA is performing beamforming (10.6.8.5 (Rate selection for BRP PPDUs for CMMG STAs)).

The first frame transmitted by a destination DMG STA to the source DMG STA in an SP shall use the DMG Control modulation class if the Heartbeat field in the source DMG STA's DMG Capabilities element is 1. Subject to the rules specified in 10.6 (Multirate support), subsequent frames transmitted by the destination DMG STA within the SP may use a different modulation class.

At the beginning of an SP, a destination CMMG STA shall transmit a frame to the source CMMG STA using the CMMG Control modulation class before it uses any other modulation for transmission if the Heartbeat field in the source CMMG STA's CMMG Capabilities element is 1 and the frame sent by the destination CMMG STA is the unsolicited DMG DTS as first frame in the SP of the STA performing CMMG protected period.

Any MAC entity coordinated by an MM-SME that belongs to an MMSL cluster identified by the Source AID and Destination AID that are equal to, respectively, the Source AID and Destination AID of the Allocation field that is not an obsolete allocation in the Extended Schedule element that allocates the SP may transmit during the SP, if the STA sent an MMS element to the peer STA and the BeamLink Cluster field within the MMS element is 1.

The AP or PCP may create SPs in its beacon interval with the source and destination AID subfields within an Allocation field set to 255 to prevent transmissions during specific periods in the beacon interval.

The AP or PCP shall set the Beamforming Training subfield to 1 in the Allocation field for an SP within an Extended Schedule element to indicate that the source DMG STA of this SP initiates beamforming training with the destination DMG STA at the start of that SP. The source DMG STA and destination DMG STA of the SP shall perform beamforming training as described in 10.41 (DMG beamforming).

If the PCP Active subfield is 0 in the Allocation field for an SP within an Extended Schedule element, neither the destination DMG STA of the SP nor the source DMG STA of the SP shall transmit to the PCP during the SP if none of the STAs are the PCP.

(11ay)Except for an SP using TDD channel access and under the conditions specified in 10.38.6.2.2 (SP with TDD channel access(11ay)), (#109)in no case shall the source or destination DMG STA extend a frame exchange sequence that started during an SP beyond the end of that SP. A STA that initiates a sequence shall check that the frame exchange sequence, including any control frame responses, completes before the end of the SP.

When scheduling two adjacent SPs (11ay)where at least one of the SPs has the TDD Applicable SP subfield set to 0, the AP or PCP should allocate the SPs separated by at least aDMGPPMinListeningTime if one or more of the source or destination DMG STAs participate in both SPs. (11ay)Otherwise, there is no separation between the SPs (see 10.38.6.2.2 (SP with TDD channel access(11ay))).

Except for frames used for beamforming as described in 10.41 (DMG beamforming), the source of an SP may retransmit a frame PIFS after the end of the frame transmission in case a response frame is expected from the destination DMG STA and a SIFS elapses without receipt of the expected transmission.

The source DMG STA can relinquish the remainder of an SP to the destination DMG STA by sending a Grant frame to the destination DMG STA (10.38.7.3 (Grant period (GP))).

#### 10.38.6.2.2 SP with TDD channel access(11ay)

A DMG AP or DMG PCP shall set the AllocationType subfield to 0 and the TDD Applicable SP subfield to 1 in an Allocation field within an Extended Schedule element to indicate a TDD SP allocation.


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When allocating a TDD SP, the AP or PCP shall set both of the Source AID and Destination AID subfields in the corresponding Allocation field to 0.

If an Extended Schedule element includes at least one TDD SP, a DMG PCP or DMG AP shall include the Extended Schedule element in each transmitted DMG Beacon frame.

The structure of TDD SP is shown in Figure 10-63 (Example of TDD SP(11ay)). A TDD SP consists of one or more consecutive and adjacent TDD intervals specified by the TDD Slot Structure element. A TDD interval comprises one or more TDD slots.

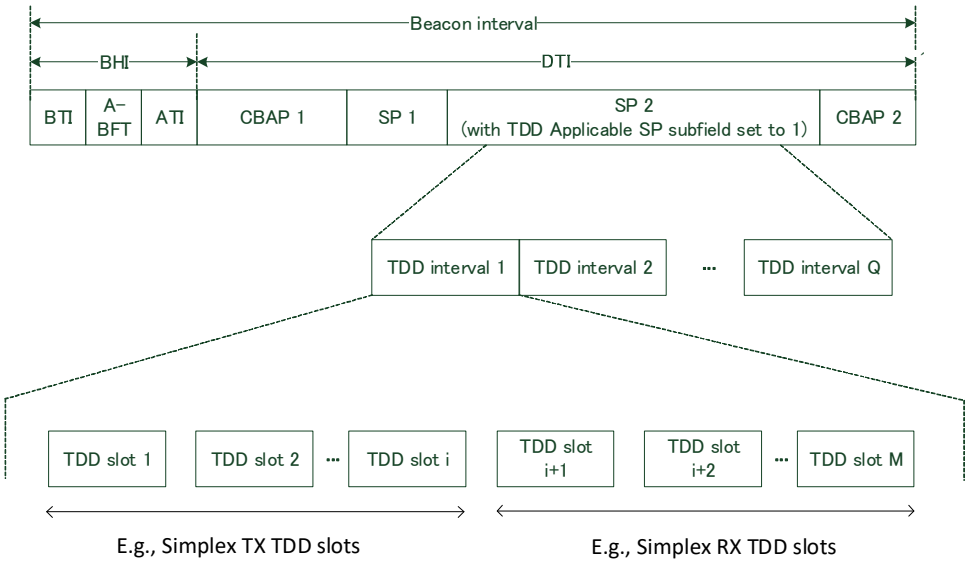


**Figure 10-63—Example of TDD SP(11ay)**

The parameters of the TDD structure within a TDD SP are defined by the TDD Slot Structure element. A non-AP and non-PCP STA shall not transmit a TDD Slot Structure element. A DMG AP or DMG PCP shall transmit a TDD Slot Structure element to each non-AP and non-PCP DMG STA that is expected to transmit or receive during a TDD SP. TDD Slot Structure elements may be included in DMG Beacon or Announce frames transmitted by the DMG AP or DMG PCP. Upon reception of a TDD Slot Structure element corresponding to allocations identified by the Allocation ID subfield value within the element, a DMG STA shall adopt the TDD slot structure within the element for all the TDD SPs identified by the same Allocation ID subfield value at the time indicated by the value of the Slot Structure Start Time field in the element. From the time the DMG STA receives an updated TDD Slot Structure element until the TDD structure is adopted, the current TDD structure shall remain in effect.

The assignment of the TDD slots within a TDD SP is done through the TDD Slot Schedule element. Except for the transmission of a TDD Beamforming frame prior to association, a DMG STA shall not transmit during a TDD SP unless it receives a TDD Slot Schedule element that indicates it is assigned, by the DMG AP or DMG PCP, to at least one TDD slot within the TDD SP that has the Bitmap and Access Type Schedule field for the STA equal to TX. Within a TDD SP, a STA shall not transmit outside the boundaries of a TDD slot it is assigned to with the Bitmap and Access Type Schedule field equal to TX, except between two adjacent TDD slots of the same category and with same destination STA. The DMG AP or DMG PCP shall transmit the TDD Slot Schedule element to each DMG STA that is assigned to access the TDD SP; this transmission shall be done using an Announce frame and Association Response frame before the time indicated by the value of the Slot Schedule Start Time field within the element. Upon reception of a TDD Slot Schedule element corresponding to allocations identified by the Allocation ID subfield value within the

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element, a DMG STA shall adopt the schedule within the element at the time indicated by the value of the Slot Schedule Start Time field within the element.

Figure 10-64 (Example of TDD Slot Structure and TDD Slot Schedule elements relationship(11ay)) depicts an example of the TDD slot timing and access permissions provided by the TDD Slot Structure element and the TDD Slot Schedule element. Starting from the value indicated in the Slot Structure Start Time field, the TDD slot structure repeats each beacon interval. The Slot Structure Start Time field is equal to TBTT2 in this example. In each beacon interval, the TDD intervals indicated by the Number of TDD intervals field, *n*, occupies the entire beacon interval. Each TDD interval has a duration equal to value of the TDD Interval Duration field, *k*, so that $k \times n$ equals the beacon interval duration. Each TDD interval contains *M* TDD slots indicated in the Number of TDD Slots per TDD Interval field (*M* is equal to 3 in this example). Each TDD slot in a TDD Interval is defined by a pair of TDD slot start and TDD slot duration in the Slot Structure field. In the example, starting from value T as indicated in the Slot Schedule Start Time field, a new slot schedule becomes active. The Bitmap and Access Type Schedule field and the Slot Category Schedule field in the TDD Slot Schedule element indicates access type and slot category for each of the $M \times Q$ TDD slots, where *Q* is the value of the Number of TDD Intervals in the Bitmap field (*Q* is equal to 2 in this example). The bitmap that indicates the access type and the slot category for the $M \times Q$ TDD slots is repeated during the time indicated by the value of the TDD Slot Schedule Duration field.

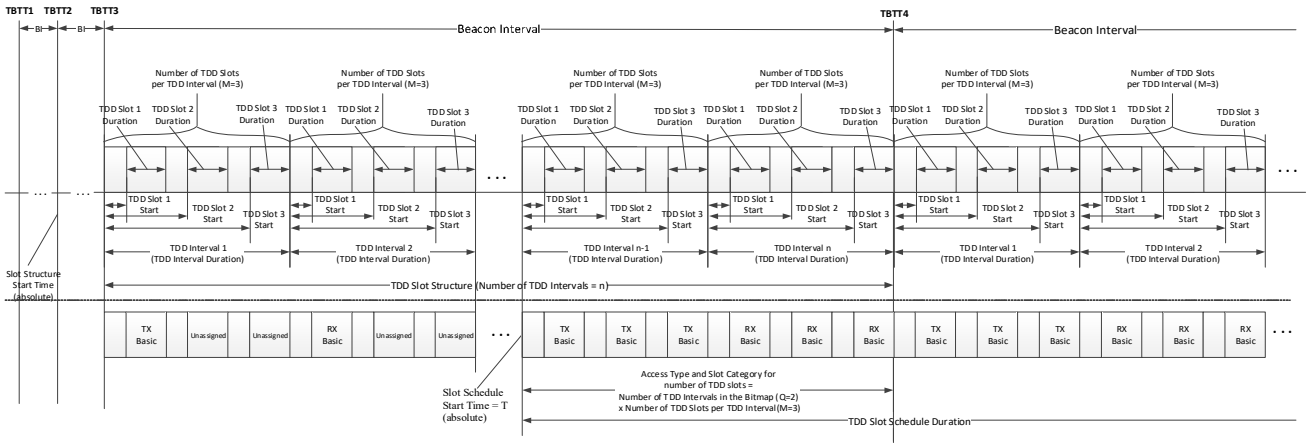


**Figure 10-64—Example of TDD Slot Structure and TDD Slot Schedule elements relationship(11ay)**

A non-AP and non-PCP DMG STA may transmit a TDD Slot Schedule element in an Announce frame or (Re)Association Request frame to a DMG AP or DMG PCP. In this case, the Bitmap and Access Type Schedule field in the element indicates the availability of the STA, which can be used as input to the AP or PCP scheduling.


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TDD slots shall not overlap in time. A TDD slot can be a simplex TDD slot, an unavailable TDD slot, or an unassigned TDD slot. A STA shall not transmit in an unassigned TDD slot or an unavailable TDD slot. RX and TX operations during a simplex TDD slot depend on the STA behavior indicated in the Bitmap and Access Type Schedule field defined in Table 9-398 (Bitmap and Access Type Schedule field encoding(11ay)) as follows:

— A STA shall not transmit in a simplex TDD slot if the Bitmap and Access Type Schedule field indicates a value different from TX for the STA for the TDD slot.

— In a simplex TDD slot that has the Bitmap and Access Type Schedule field for the STA equal to TX, the STA can transmit to the peer STA assigned to the TDD slot.

— In a simplex TDD slot that has the Bitmap and Access Type Schedule field for the STA equal to RX, the STA shall be beamformed towards the peer STA assigned to the TDD slot, shall be ready to receive at least *RxTDDSlotAdvanceTime* before the start of the TDD Slot and shall remain in the receive state for the duration of the TDD slot in order to receive transmissions from the peer STA. *RxTDDSlotAdvanceTime* is computed as follows:

$$RxTDDSlotAdvanceTime = Ceil\ (T_{ME} + T_P, T_{TR})$$

where

$T_{ME}$ is the value of the Maximum Time Synchronization Error subfield in the TDD Slot Structure element describing the TDD SP, in μs

$T_P$ is aTDDAirPropagationTime, in μs

$T_{TR}$ is aTSFResolution, in μs

Provided the STA behavior is the same in adjacent TDD slots, transmissions and receptions in adjacent TDD slots that are assigned to the same pair of STAs may continue in between the adjacent TDD slots.

When an AP or PCP receives a TDD Slot Schedule element from a STA that indicates a TDD slot is an unavailable TDD slot for that STA, the AP or PCP shall not schedule any transmission or reception in this TDD slot for that STA.

Each TDD slot is of one of the following categories: Basic, Data and BF. Table 10-34 (Allowed frames and transmit order for each TDD slot category(11ay)) lists the frames that are allowed to be transmitted during each slot category, together with the transmit order of those frames within the TDD slot.

The reverse direction protocol (see 10.29 (Reverse direction protocol)) shall not be used in a TDD SP.

A DMG STA that has TDD Channel Access Supported subfield in the STA's DMG Capabilities element equal to 1 shall set to 1 at least one of the following subfields in a transmitted DMG Link Margin element: PPDU Statistics Present subfield, LDPC Statistics Present subfield or SC/OFDM Statistics Present subfield.

The Duration field in frames sent in an SP with TDD channel access shall be set as follows: bits 0–13 set to 0, and bits 14–15 set to 1.

#### 10.38.6.3 Contention based access period (CBAP) allocation

The AP or PCP shall set the AllocationType subfield to 1, the Source AID subfield to the broadcast AID or to the AID of the source of the CBAP, and the Destination AID subfield to the broadcast AID or to the AID of the destination of the CBAP in an Allocation field within an Extended Schedule element to indicate a CBAP allocation.

All CBAPs are allocated by the AP or PCP, except when allocated by a non-AP and non-PCP STA with the transmission of a Grant frame following an SP truncation (10.38.8 (Dynamic truncation of service period)). Multiple CBAPs may be present in a beacon interval, with the location and duration of each determined by

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**Table 10-34—Allowed frames and transmit order for each TDD slot category(11ay)**

| TDD slot category | Allowed frames | MPDU transmit order | Conditions | |
|---|---|---|---|---|
| Basic | Control: Ack, BlockAck, DMG CTS-to-self, BlockAckReq<br><br>Extension<br><br>Management<br><br>Data | — Ack (as standalone PPDU, or as part of an A-MPDU; see NOTE 1).<br>— BlockAck (as standalone PPDU, or as part of an A-MPDU; see NOTE 1).<br>— As many Extension and Management frames as available, or fitting in the TDD slot.<br>— Zero or more Data frames, optionally followed by a BlockAckReq frame.<br><br>Optionally, repeat the steps until the end of the TDD slot. See NOTE 3. | — If present, Ack shall be the first frame in the slot.<br>— If present, BlockAck shall be the first frame in the slot, unless preceded by an Ack frame.<br>— Management and Data frames may be aggregated following the rules in 9.7.3 (A-MPDU contents), as long as all buffered Management frames are present in the A-MPDU. | — The following frames may appear only once during the TDD slot: Ack, BlockAck, and BlockAckReq.<br>— PPDUs containing Data or Management frames may be preceded and/or followed by DMG CTS-to-self frames. |
| Data | | — As many Data frames as available, or fitting in the TDD slot, optionally followed by a BlockAckReq frame.<br>— Ack (as standalone PPDU, or as part of an A-MPDU; see NOTE 1 and NOTE 2).<br>— BlockAck (as standalone PPDU, or as part of an A-MPDU; see NOTE 1 and NOTE 2).<br>— Zero or more Extension and Management frames.<br><br>Optionally, repeat the steps until the end of the TDD slot. See NOTE 4. | — Data and Management frames can be aggregated following the rules in 9.7.3 (A-MPDU contents), as long as all buffered Data frames are present in the A-MPDU. | |


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**Table 10-34—Allowed frames and transmit order for each TDD slot category(11ay) *(continued)***

| TDD slot category | Allowed frames | MPDU transmit order | Conditions | |
|---|---|---|---|---|
| BF | TDD Beamforming | — TDD SSW<br>— TDD SSW Feedback<br>— TDD SSW Ack | | |

NOTE 1—Action No Ack frames can also be aggregated with Ack or BlockAck frames and sent as part of an A-MPDU in control response context, as defined in 9.7.3 (A-MPDU contents). Action No Ack frames sent in this fashion are allowed to not follow the MPDU transmit order defined for the slot category.

NOTE 2—Opportunistic transmission of Ack and BlockAck frames in Data TDD slots does not change the timeout rules defined in 10.3.2.11 (Acknowledgment procedure).

NOTE 3—Repeating these steps during the TDD slot means that once STA has transmitted all buffered Management frames, it can transmit zero or more Data frames (optionally followed by a BlockAckReq frame) before it checks for new Management frames to transmit.

NOTE 4—Repeating these steps during the TDD slot means that once STA has transmitted all buffered Data frames, it can transmit Ack, BlockAck, and zero or more Management frames before it checks for new Data frames to transmit.

the AP or PCP and announced in the Extended Schedule element. When only one CBAP is present and no other allocations exist for the DTI, then the AP or PCP shall announce the presence of the CBAP by setting the CBAP Only field to 1 in the DMG Parameters field of the DMG Beacon. If at least one non-CBAP allocation is present, or more than one CBAP is present, or no allocations are present within a DTI, then the AP or PCP shall set the CBAP Only field to 0 in the DMG Parameters field in the DMG Beacon frame transmitted during the BTI. The AP or PCP shall set the CBAP Only field to 0 in the DMG Parameters field within a transmitted DMG Beacon frame if the DMG Beacon frame contains at least one Extended Schedule element.

When the entire DTI is allocated to CBAP through the CBAP Only field in the DMG Parameters field, then that CBAP is pseudo-static and exists for dot11MaxLostBeacons beacon intervals following the most recently transmitted DMG Beacon frame that contained the indication, except if the CBAP is canceled by the transmission by the AP or PCP of a DMG Beacon frame with the CBAP Only field of the DMG Parameters field equal to 0 or an Announce frame with an Extended Schedule element. A guard time (10.38.6.5 (Guard time)) precedes a CBAP that is allocated through the CBAP Only field equal to 1.

Channel access during a CBAP shall follow the rules described in 10.38.5 (Contention based access period (CBAP) transmission rules).

### 10.38.6.4 Pseudo-static allocations

An SP or CBAP allocation is pseudo-static if the Pseudo-static field in the Allocation control field for the SP or CBAP is 1, or when the Extended Schedule element is not used and the CBAP Only field within the DMG Parameters field of the DMG Beacon frame is 1 (10.38.5 (Contention based access period (CBAP) transmission rules)). A pseudo-static SP or CBAP recurs at the same relative offset to TBTT and with the same duration in up to dot11MaxLostBeacons beacon intervals following the last received Extended Schedule element containing the pseudo-static allocation or DMG Beacon frame with the CBAP Only field equal to 1.

A STA might fail to receive up to (dot11MaxLostBeacons–1) Extended Schedule elements or DMG Beacon frame with the CBAP Only field equal to 1 in consecutive beacon intervals and still may access the channel

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during the pseudo-static SP or CBAP. The STA shall cease transmission during a pseudo-static allocation if it fails to receive an Extended Schedule element or DMG Beacon frame with the CBAP Only field equal to 1 for dot11MaxLostBeacons consecutive beacon intervals.

The AP or PCP may change the offset relative to TBTT or the duration of a pseudo-static allocation by transmitting a modified Allocation field in an Extended Schedule element before dot11MaxLostBeacons beacon intervals from the last transmitted Extended Schedule element. The AP or PCP may delete a pseudo-static allocation by transmitting an Extended Schedule element that does not include an allocation field containing that allocation's TID, source AID, and destination AID before the completion of dot11MaxLostBeacons beacon intervals from the last transmitted Extended Schedule element. In either case, the AP or PCP should not schedule a new allocation that overlaps with the previous pseudo-static allocation for a minimum of dot11MaxLostBeacons beacon intervals unless both the new and previous allocation are for a CBAP or the new allocation identifies the same source DMG STA as the original pseudo-static allocation.

If the destination DMG STA of a pseudo-static allocation receives an Extended Schedule element with an Allocation field that indicates a change in the schedule of the pseudo-static allocation, the STA should enter receive state during the new pseudo-static allocation and may enter receive state during the previous allocation to account for the time it can take the source DMG STA of the allocation to receive the updated schedule.

### 10.38.6.5 Guard time

Guard time is the time between the end of one allocation and the start of the following allocation, provided these allocations are not under spatial sharing (11.30 (Spatial sharing and interference mitigation for DMG STAs)). For the purpose of guard time insertion, an allocation is defined as an SP, a CBAP, and a BTI or A-BFT or ATI that is immediately followed by a CBAP allocated through the CBAP Only field (10.38.6.3 (Contention based access period (CBAP) allocation)). Guard times are used to keep transmissions in adjacent allocations from colliding. Figure 10-65 (The guard time) shows an example of the insertion of the guard time such that the allocations are separated by at least the guard time, in case the STAs participating in the adjacent allocations drift toward each other's allocation.

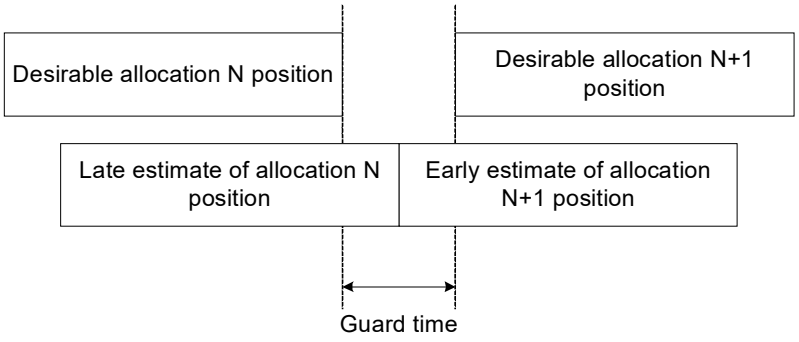


**Figure 10-65—The guard time**

The AP or PCP shall insert a sufficient guard time between adjacent allocations so that transmissions in adjacent allocations do not overlap in time. For each of the adjacent allocations, guard times are calculated based on the worst case drift and the maximum allowed number of lost DMG Beacons. The AP or PCP shall insert a guard time ($T_{guard}$) between adjacent allocations that is not shorter than


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$$T_{guard} = \text{Ceil}\left(\frac{((A_i + 1) \times C \times D_i) + ((A_{i+1} + 1) \times C \times D_{i+1})}{10^6} + SIFS + T_P, T_{TR}\right)$$

where

$A_i$ is the value of MLB allocation $i$, and the value of $A_i$ for each allocation depends on whether the allocation is pseudo-static. $A_i$ is 0 for a nonpseudo-static allocation and is equal to dot11MaxLostBeacons if the allocation is pseudo-static

$C$ is aDMGTSFAccuracy, in ppm

$D_i$ is the time elapsed since a synchronizing reference event, in μs. The synchronizing event is the reception of the Timestamp field from the AP or PCP. For a pseudo-static allocation, $D_i$ is equal to the beacon interval

$SIFS$ in aSIFSTime, in μs

$T_P$ is aAirPropagationTime, in μs, which accounts for the propagation delay between the STAs participating in the adjacent allocations

$T_{TR}$ is aTSFResolution, in μs

### 10.38.6.6 DMG and CMMG protected period

#### 10.38.6.6.1 Introduction

Communicating STA pairs of neighboring PBSS/infrastructure BSS might be granted SPs that potentially create interference for neighbor PBSS/infrastructure BSS STA pairs. SPs within a PBSS/infrastructure BSS can also experience such interference when spatial diversity conditions change. The intent of DMG protected period is to minimize such interference by allowing any pair of STAs to protect their SP and thereby limit the transmission of frames during the DMG protected period to not more than one pair of potentially interfering pairs of communicating stations.

In the CMMG protected period that has 540 MHz or 1080 MHz bandwidth, the STA can use dynamic bandwidth operation to negotiate a bandwidth that can be used in this SP.

A DMG protected period can be created by the source DMG STA during an SP, and shall be created by the source DMG STA if at least one of the following conditions is met:

— The source DMG STA is the AP or PCP of the BSS, the ECAPC Policy Enforced subfield within the DMG Parameters field of the last DMG Beacon frame transmitted by the source DMG STA is equal to 1, and the Protected Period Enforced field within the ECAPC Policy Detail field of the last ECAPC Policy element transmitted by the source DMG STA is equal to 1.

— The source DMG STA is not the AP or PCP of the BSS, the ECAPC Policy Enforced subfield within the DMG Parameters field of the last DMG Beacon frame received by the source DMG STA from the AP or PCP of the BSS is equal to 1, and the Protected Period Enforced field within the ECAPC Policy Detail field of the last ECAPC Policy element received by the source DMG STA from the AP or PCP of the BSS is equal to 1.

Both the source DMG STA and destination DMG STA of an SP are owners of the DMG protected period. During any DMG protected period, both stations can receive frames from the other participant.

A CMMG protected period can use the dynamic bandwidth operation during an SP if the bandwidth of the SP that indicated in the Extended Schedule element is 1080 MHz.

A DMG STA that creates a DMG protected period during an SP in which it is a source DMG STA or a destination DMG STA moves to and stays in listening mode during time interval that starts before the start of the SP and remains in the listening mode until it is allowed to use the SP. The actual duration of the time

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the STA stays in the listening mode is limited by the aDMGPPMinListeningTime parameter. The intent of the listening mode is that the STA listens to other STAs that may have an SP that overlaps with the SP where the STA is a source DMG STA or a destination DMG STA. The NAV mechanism is used to indicate the time occupancy and if the STA is in the listening mode, it updates its NAVs. If the NAVs are not equal to 0, the STA does not use the time of the SP in which it is a source DMG STA or a destination DMG STA. If none of the NAVs has a nonzero value at the start of the SP, the STA is allowed to leave the listening mode and use the SP. If at least one of the NAVs has a nonzero value at the start of the SP, the STA is allowed to leave the listening mode and to use the time remaining in the SP after all NAVs become or already have value zero.

A CMMG STA that creates a CMMG protected period during an SP in which it is a source CMMG STA or a destination CMMG STA moves to and stays in listening mode during time interval that starts before the start of the SP and remains in the listening mode until it is allowed to use the SP. The actual duration of the time the STA stays in the listening mode is limited by the aCMMGPPMinListeningTime parameter. The intent of the listening mode is that the CMMG STA listens to other CMMG STAs that may have an SP that overlaps with the SP where the CMMG STA is a source CMMG STA or a destination CMMG STA. The NAV mechanism is used to indicate the time and frequency occupancy, and the CMMG STA in the listening mode updates NAV timers. If the NAV timers are not equal to 0 for the corresponding channel bandwidth, the CMMG STA does not use the time and the band of the SP in which it is a source CMMG TA or a destination CMMG STA. If none of the NAV timers has a nonzero value at the start of the SP, the DMG STA is allowed to leave the listening mode and use the SP. If at least one of the NAV timers has a nonzero value at the start of the SP, the DMG STA is allowed to leave the listening mode and to use the time remaining in the SP after all NAV timers become or already have value zero.

Listening mode is a mode of operation during which a DMG STA is in receiving state and meets at least one of the following conditions:

a) Its receiving antenna are in the quasi-omni mode.
b) Its receiving antenna are directed to the peer STA for which this DMG STA is either the destination or source DMG STA.

A DMG protected period is established through an RTS/DMG CTS handshake. The DMG CTS can be sent in a CMMG PHY format and can be sent in 540 MHz or 540 MHz duplicated mode. To create a DMG protected period, the source DMG STA of an SP sends an RTS, and the recipient STA responds with a DMG CTS. If the recipient STA responds with a DMG CTS, then a DMG protected period is established; otherwise, no DMG protected period has been established. In all cases of DMG protected period establishment, the same antenna configurations that are used by the STAs that establish the DMG protected period are used for the exchange of frames during the DMG protected period.

#### 10.38.6.6.2 DMG and CMMG protected period establishment and maintenance

A DMG STA that attempts to create a DMG protected period during an SP shall transition to listening mode not less than aDMGPPMinListeningTime before the attempt and shall remain in listening mode for at least aDMGPPMinListeningTime before making the attempt.

A CMMG STA that attempts to create a CMMG protected period shall transition to listening mode on a channel that the bandwidth is indicated in the Extended Schedule element for this SP.

A DMG STA shall not issue an RTS frame to establish a DMG protected period if any of its NAVs is not equal to 0.

A CMMG STA shall not issue an RTS frame to establish a CMMG protected period on a channel if any of its NAV timers corresponding to this channel are not equal to 0. A CMMG STA may issue an RTS frame to


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establish a CMMG protected period on a channel if the bandwidth of the channel is less than the SP allocated channel bandwidth and all of its NAV timers that correspond to this channel are 0.

A DMG STA that transmits an RTS frame to establish a DMG protected period during an SP in which it is a source DMG STA shall not transmit the RTS frame outside of the SP and the value of the Duration field of the RTS frame shall not exceed the duration of the portion of the SP that remains following the RTS frame transmission.

A CMMG STA that transmits an RTS frame to establish a CMMG protected period during an SP in which it is a source CMMG STA shall not transmit the RTS frame outside of the SP, and the value of the Duration field of the RTS frame shall not exceed the duration of the portion of the SP that remains following the RTS transmission. And a CMMG STA that transmits an RTS frame to establish a CMMG protected period during an SP in which it is a source CMMG STA shall not transmit an RTS frame that has a bandwidth that is larger than the allocated bandwidth.

In order to maintain STAs that are not aware of the establishment of the DMG protected period because they have begun listening to the medium after the establishment of a DMG protected period, a STA that established a DMG protected period should transmit additional RTSs. An additional RTS frame should be sent at the end of every (aDMGPPMinListeningTime – aRTSTimeoutTime) interval during the DMG protected period if the duration of the RTS/DMG CTS exchange is less than the time remaining in the SP.

A DMG STA that transmitted an RTS frame that established a DMG protected period shall use the same antenna configuration as was used for the transmission of the RTS frame during transmission of Data frame(s) during the DMG protected period.

A DMG STA should transition to listening mode not less than aDMGPPMinListeningTime before the start of an SP in which it is the destination DMG STA.

During an SP in which it is the destination DMG STA, a DMG STA that receives a valid RTS frame with the RA equal to the recipient DMG STA MAC address and the TA corresponding to the source DMG STA of the SP shall respond with a DMG CTS frame if the recipient DMG STA has been in listening mode for aDMGPPMinListeningTime at the start of the reception of the RTS frame and none of its NAVs has a nonzero value.

During an SP in which it is the destination CMMG STA, a CMMG STA that receives a valid RTS frame addressed to it and the TA corresponding to the source CMMG STA of the SP shall not respond with a DMG CTS frame on the channel if at the start of the reception of the RTS frame the recipient CMMG STA has a nonzero value in at least one of its NAV timers corresponding to this channel.

During an SP in which it is the destination DMG STA, a DMG STA that receives a valid RTS frame with the RA equal to the recipient DMG STA MAC address and the TA corresponding to the source DMG STA of the SP shall not respond with a DMG CTS frame if at the start of the reception of the RTS frame the recipient DMG STA has a nonzero value in at least one of its NAVs or the recipient DMG STA has not been in listening mode for at least aDMGPPMinListeningTime.

During an SP in which it is the destination DMG STA, a DMG STA that receives a valid RTS frame with the RA equal to the recipient DMG STA MAC address and the TA corresponding to the source DMG STA of the SP may respond with a DMG DTS frame if at the start of the reception of the RTS frame the recipient DMG STA has a nonzero value in at least one of its NAVs.

A DMG STA may transmit a DMG DTS frame after the expiration of the aRTSTimeoutTime time following the start of an SP in which it is the destination DMG STA, if any of its NAVs has a nonzero value at that time and no RTS has been received from the source DMG STA of the SP and the STA has been in listening mode for aDMGPPMinListeningTime immediately preceding the start of transmission of the DMG DTS

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frame. The destination DMG STA shall not transmit a DMG DTS frame if any portion of the DMG DTS frame would be transmitted outside of the SP.

The value in the Duration field of a DMG DTS frame shall be calculated by subtracting the DMG DTS frame transmission time from the NAV in the destination DMG STA that has the largest value at the time of the start of the transmission of the DMG DTS frame. The NAV-DA and NAV-SA fields shall be set to the MAC addresses that identify the NAV in the destination DMG STA that was used to determine the Duration field value of the DMG DTS frame.

During an SP in which it is the destination DMG STA, a DMG STA that receives a valid RTS frame with the RA equal to the recipient DMG STA MAC address and the TA corresponding to the source DMG STA of the SP may respond with a DMG DTS frame if at the start of the reception of the RTS frame the recipient DMG STA has not been in listening mode for at least aDMGPPMinListeningTime. The value of the Duration field of the DMG DTS frame sent by the recipient DMG STA shall include the difference of aDMGPPMinListeningTime and the elapsed time since the recipient DMG STA has been in listening mode, and the NAV-SA and the NAV-DA fields of the DMG DTS frame shall contain the recipient DMG STA MAC address.

A destination DMG STA that responds to an RTS frame with a DMG CTS or DMG DTS frame shall transmit the response frame a SIFS after the end of the received RTS frame. A destination DMG STA that transmits either a DMG CTS or a DMG DTS frame shall use the same antenna configuration for the subsequent transmission of Ack frames and Data frames within the SP as is used for the transmission of the DMG CTS or DMG DTS frame.

The source DMG STA of an SP can send a CF-End frame to the destination DMG STA of the SP to truncate a DMG protected period. Regardless of whether this CF-End frame is sent, a CF-End frame is also sent to the AP or PCP (see 10.38.8 (Dynamic truncation of service period)).

#### 10.38.6.6.3 CDMG protected period establishment and maintenance

In addition to establishing a DMG protected period on its current operating channel, a CDMG STA might create another DMG protected period on an overlapping channel to avoid the potential interference from the overlapping channel. This subclause describes rules for establishing and maintaining a CDMG protected period for a pair of CDMG STAs.

A CDMG AP or PCP shall set the Protected Period subfield within the Extended Schedule element sent to the source and destination STAs to indicate whether the protected period is to be created and on which channels the protected period should be created for an SP allocation. The CDMG AP or PCP should determine the time and frequency overlapping status of an SP scheduled by itself with other SPs or CBAPs scheduled by other APs or PCPs according to the schedule information of the neighboring APs or PCPs and itself. The CDMG AP or PCP can obtain the schedule information of the neighboring APs or PCPs by receiving DMG Beacon frames directly if it is within an AP or PCP cluster, or by receiving interference reports included in the Cluster Report elements or DMG TSPEC elements transmitted by STAs within the BSS.

If a CDMG AP or PCP determines that there exists at least one SP or CBAP scheduled by a neighboring AP or PCP that is overlapping in both time and frequency with an SP allocated by the CDMG AP or PCP and cannot determine that the neighboring SP or CBAP does not interfere with its allocated SP based on the received interference report (10.38.6.6.6 (Interference report)) from STAs, the CDMG AP or PCP shall set the Protected Period subfield to a nonzero value for the allocated SP to indicate that the source and destination CDMG STAs are required to establish a protected period for the SP. Otherwise, the CDMG AP or PCP shall set the Protected Period subfield to 0 to indicate that the source and destination CDMG STAs do not have to establish a protected period for the SP.


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If a potentially interfering SP or CBAP is allocated on the current operating channel, the AP or PCP shall set the Protected Period subfield within the Allocation Control field to 1. The source and destination CDMG STAs shall follow the rules defined in 10.38.6.6.1 (Introduction) to establish a DMG protected period on its current operating channel.

If the source CDMG STA and destination CDMG STA are operating on a 1.08 GHz channel and a potentially interfering SP or CBAP is allocated on the overlapping 2.16 GHz channel, the CDMG AP or PCP shall set the Protected Period subfield to 2. The source CDMG STA and destination CDMG STA shall create a CDMG protected period on both the current operating 1.08 GHz channel and the overlapping 2.16 GHz channel.

If the source CDMG STA and destination CDMG STA are operating on a 2.16 GHz channel and a potentially interfering SP or CBAP is allocated on the overlapped low frequency 1.08 GHz channel, the CDMG AP or PCP shall set the Protected Period subfield to 2 to indicate that the source CDMG STA and destination CDMG STA create a DMG protected period on both the current operating 2.16 GHz channel and the low frequency 1.08 GHz channel.

If the source CDMG STA and destination CDMG STA are operating on a 2.16 GHz channel and a potentially interfering SP or CBAP is allocated on the overlapped high frequency 1.08 GHz channel, the CDMG AP or PCP shall set the Protected Period subfield to 3 to indicate that the source CDMG STA and destination CDMG STA create a DMG protected period on both the current operating 2.16 GHz channel and the high frequency 1.08 GHz channel.

If creating a CDMG protected period on two channels is required, the source and destination STAs shall listen to the current channel first and transition to and stay in listening mode following the rules specified in 10.38.6.6.1 (Introduction). If both the results of the PHY layer carrier sensing (CS) and the virtual carrier sensing show that the current channel is idle, the source STA and destination STA shall perform a RTS/DMG CTS handshake on the current channel. Once the first RTS/DMG CTS handshake is completed, the source STA and destination STA shall perform another RTS/DMG CTS handshake on the second channel after a SIFS. After the second RTS/DMG CTS handshake is done, the source STA and destination STA shall switch back to their operating channel and transmit data following a SIFS. An example of creating a CDMG protected period through two RTS/DMG CTS handshakes for CDMG STAs operating on a 1.08 GHz channel is shown in Figure 10-66 (An example of creating a CDMG protected period on two channels for CDMG STAs).

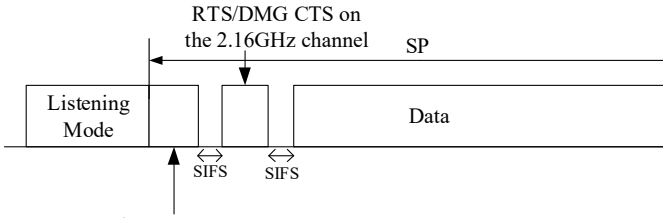


**Figure 10-66—An example of creating a CDMG protected period on two channels for CDMG STAs**

If an RTS/DMG CTS frame exchange sequence(#109) on the 1.08 GHz channel failed, the CDMG STA shall not transmit the subsequent RTS frame on the 2.16 GHz channel after a SIFS(#6587) from the end of the expected CTS frame on the 1.08 GHz channel as shown in Figure 10-66 (An example of creating a CDMG protected period on two channels for CDMG STAs).

In order to maintain protection from STAs that are not aware of the establishment of the CDMG protected period because they have begun listening to the medium after the establishment of a CDMG protected period, a CDMG STA that established a CDMG protected period should transmit additional RTS frames on the channels that are the same as the channels used when establishing the CDMG protected period. The source STA should

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initiate an additional two RTS/DMG CTS handshakes on the two channels at the end of every (aDMGPPMinListeningTime – aRTSTimeoutTime) interval during the CDMG protected period if the duration of the two RTS/DMG CTS handshakes exchange is less than the time remaining in the SP.

A CDMG AP or PCP can merge the time interval of listening mode when creating a CDMG protected period and the channel measurement time during SPSH (see 11.30 (Spatial sharing and interference mitigation for DMG STAs)) by using the Protected Period subfield and the Directional Channel Quality Request element. If the AP or PCP determines two SPs allocated for two pairs of CDMG STAs within the BSS should both be created with protected period, the AP or PCP may transmit a Directional Channel Quality Request element to the two pairs of STAs based on allocation positions of the SPs for the two pairs of STAs. The directional channel measurement time interval indicated by the Directional Channel Quality Request element of one pair of STAs should cover the listening mode that begins at the start of the SP of this pair of STAs. Thus, the two pairs of STAs can direct their received antennae to their peer STAs involved in the same SP to perform channel monitoring required for establishing the protected period and perform the directional channel quality measurement required by the SPSH mechanism simultaneously. The AP or PCP may use the received Directional Channel Quality Report elements after the listening mode for subsequent SPSH with time overlapping SPs for the two pairs of STAs after the beginning of the next beacon interval.

#### 10.38.6.6.4 Dynamic and static bandwidth operation during CMMG protected period

If the CMMG STA that sending the RTS frame to establish a CMMG protected period during an SP in which it is a source CMMG STA is capable of dynamic bandwidth operation (see 10.3.2.8 (CMMG RTS procedure)), the STA shall set the TXVECTOR parameter DYN_BANDWIDTH to Dynamic. Otherwise, the STA shall set the TXVECTOR parameter DYN_BANDWIDTH to Static.

During an SP, a CMMG STA that is the destination CMMG STA in the SP and that is addressed by an RTS frame in a CMMG PPDU that has the RXVECTOR parameter DYN_BANDWIDTH equal to Static behaves as follows:

— If the NAV indicates idle and CCA has been idle for all the channel width indicated by the RTS frame's RXVECTOR parameter CH_BANDWIDTH, then the STA shall respond with a DMG CTS frame carried in a CMMG PPDU after a SIFS. The DMG CTS frame's TXVECTOR parameter CH_BANDWIDTH shall be set to the same value as the RTS frame's RXVECTOR parameter CH_BANDWIDTH.
— Otherwise, the STA shall not respond with a CTS frame.

During an SP, a CMMG STA that is the destination CMMG STA of the SP and that is addressed by an RTS frame in a CMMG PPDU that has the RXVECTOR parameter DYN_BANDWIDTH equal to Dynamic behaves as follows:

— If the NAV indicates idle in the primary 540 MHz channel, then the STA shall respond with a DMG CTS frame carried in a CMMG PPDU after a SIFS. The DMG CTS frame's TXVECTOR parameter CH_BANDWIDTH shall be set to 540 MHz if the CCA on the secondary 540 MHz channel is detected as busy and shall be set to 1080 MHz if the CCA on the secondary 540 MHz channel is detected as idle and the channel width indicated in the RTS frame's RXVECTOR parameter CH_BANDWIDTH is 1080 MHz.
— Otherwise, the STA shall not respond with a CTS frame.

#### 10.38.6.6.5 NAV update in DMG and CMMG protected period

STAs in the listening mode shall update their NAVs according to the procedures described in 10.38.10 (Updating multiple NAVs).

NOTE—Support of multiple NAVs as defined in 10.38.10 (Updating multiple NAVs) is not limited to be used in the listening mode only and is also used in any case a NAV update is performed.


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When an SP terminates, either through time allocation expiration or truncation, then the source DMG STA of that SP may reset any NAV to 0 that has an associated MAC variable NAV_DTSCANCELABLE with a value of true.

#### 10.38.6.6.6 Interference report

A STA that receives an RTS and/or DMG CTS frame that updates the NAV and that overlaps in time with an SP where the STA is destination or source may report the overlap to the AP or PCP by sending a DMG ADDTS Request frame variant (9.6.3.3.2 (DMG ADDTS Response frame variant)) and including in the DMG TSPEC element (9.4.2.132 (DMG TSPEC element)) the indication of interference in the Traffic Scheduling Constraint Set field (Figure 9-657 (Traffic Scheduling Constraint Set field format)). Transmission of the DMG ADDTS Request frame variant shall follow the rules defined in 11.4 (TS operation), with the following exceptions.

The Allocation ID subfield of the DMG TSPEC element shall identify the allocation during which the interference was detected. One ADDTS Request frame is generated and transmitted for each allocation during which interference is detected.

The Traffic Scheduling Constraint Set field of the DMG TSPEC element may contain one or more Constraint subfields. Each Constraint subfield provides information separately for each overlapping NAV event. The following NAV events should be reported:

a) Nonzero NAV at start of SP
b) Extension of NAV during the SP, including extension of an initial nonzero NAV and transitioning of the NAV from zero to nonzero value during the SP
c) Truncation of the NAV during the SP

The TSCONST Start Time field is set to the TSF value at which the NAV event is detected. For event a) above, the TSCONST Start Time field shall be set to the start of the SP. For event b) above, the TSCONST Start Time field shall be set to the time the NAV was updated or initialized to the value reported in the TSCONST Duration field. For event c) above, the TSCONST Start Time field shall be set to the time the NAV was reset.

The TSCONST Duration field shall be set to the NAV value at the TSCONST Start Time, which is the value zero for event c).

The TSCONST Period shall be set to 0 indicating that the field is not applicable.

The Interferer MAC Address shall be set to the NAVDST of the NAV from which the TSCONST Start Time was derived (10.38.10 (Updating multiple NAVs)).

CMMG STAs shall also include the Interferer Channel Bandwidth subfield in the report, and the Interferer Channel Bandwidth subfield shall be set to the CH_BANDWIDTH of the NAV timer.

All values conveyed in the Traffic Scheduling Constraint Set field shall refer to the allocation identified by the value of the Allocation ID subfield of the TSPEC.

The value of other fields within the DMG TSPEC element shall comply with the rules specified in 11.4 (TS operation).

Use of the information conveyed in the Traffic Scheduling Constraint Set field is outside the scope of this standard.

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#### 10.38.6.7 Service period recovery

When a non-AP and non-PCP STA fails to receive the Extended Schedule element for a beacon interval, the non-AP and non-PCP STA has no knowledge of the nonpseudo-static SPs allocated during the beacon interval that indicate it is the source DMG STA; therefore, it fails to transmit during those SPs. If the destination of the nonpseudo-static SP is an AP or PCP and it does not receive any frames from the source non-AP and non-PCP STA for the dot11SPIdleTimeout interval from the start of the SP, the AP or PCP may truncate the SP and use the mechanism described in 10.38.7 (Dynamic allocation of service period) to reallocate the remaining duration of the SP to the source DMG STA of the SP or other STAs provided that it was a truncatable SP. If the SP is not a truncatable SP, the PCP may stay in awake state or may switch to doze state. If the non-AP and non-PCP STA failed to receive the Extended Schedule element from the AP or PCP for that beacon interval, it may switch to doze state or may direct its receive antenna toward the AP or PCP to receive a grant during nonpseudo-static SPs or CBAPs in the current beacon interval.

An AP or PCP may reclaim the entire time allocated in an SP between two non-AP and non-PCP STAs if the following two conditions are met:

— The SP is announced within an Extended Schedule element transmitted during the ATI.
— The AP or PCP does not receive a response frame from at least one of the source and destination non-AP and non-PCP STAs of that SP as part of the ATI exchange (10.38.3 (ATI transmission rules)).

In either case described in this subclause, the AP or PCP may reallocate the reclaimed SP time as a CBAP, SP, or take no further action. Otherwise, if none of these conditions apply, no time may be reclaimed.

### 10.38.7 Dynamic allocation of service period

#### 10.38.7.1 General

Dynamic allocation of service period is employed to allocate channel time during scheduled SPs and CBAPs. The procedure includes an optional Polling Period (PP) phase and a Grant Period (GP) phase. Service periods allocated using this mechanism do not persist beyond a beacon interval. Persistent allocations are created using the allocation mechanisms described in 11.4 (TS operation).

The PP Available field in the STA Availability element (9.8 (MAC frame format for PV1 frames))(#1358) indicates whether a STA participates in the PP phase of the dynamic allocation of service period mechanism. A STA that participates in PP phase of the dynamic allocation of service periods responds to Poll frames during the PP. A STA that participates in dynamic allocation of service periods uses the time allocated through Grant frames during the GP to transmit frames. A STA may set the PP Available field in a transmitted STA Availability element to 0 to indicate that the STA does not respond to Poll frames during the PP and the GP.

NOTE—A STA can receive a Grant frame in periods of the beacon interval other than the GP, in which case the STA uses the time allocated through the Grant frame.

The AP or PCP shall not transmit Poll frames to a STA whose PP Available field in the STA Availability element is 0. The AP or PCP shall not dynamically allocate a service period to a STA that is in a D-BI (11.2.7 (Power management in a PBSS and DMG infrastructure BSS)). An AP or PCP may transmit Poll frames to a STA from which the AP or PCP has not received a STA Availability element with the PP Available field from the STA equal to 0.

An AP or PCP may dynamically allocate Service Periods during a scheduled SP for which both the source and destination AID fields are set to the broadcast AID by setting the Truncatable subfield to 1 within the Allocation field corresponding to the scheduled SP.


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If a non-AP and non-PCP STA is neither source nor an individually addressed destination during a truncatable SP and the non-AP and non-PCP STA participates in dynamic allocation of service periods and the non-AP and non-PCP STA is in an A-BI, then the non-AP and non-PCP STA should be in the awake state for the duration of the truncatable SP.

A non-AP and non-PCP STA that participates in dynamic allocation of service periods shall be in the awake state for dot11MinPPDuration from the start of each truncatable SP for which both the source and the destination AID fields are set to the broadcast AID and that occurs within each A-BI of that STA. Following the expiration of dot11MinPPDuration, the non-AP and non-PCP STA should remain in the awake state until the end of the truncatable SP.

A STA shall be in the awake state for dot11MinPPDuration from the start of each scheduled CBAP that occurs within each A-BI of that STA. A STA that enters the doze state at any time during a CBAP and then returns to the awake state later during that same CBAP shall perform CCA until a frame is detected by which it can set its NAV, or until a period of time equal to the (#2079)NAVSyncDelay has expired before it initiates a transmission.

As described in 10.38.8 (Dynamic truncation of service period), a STA that participates in dynamic allocation of service periods and that is neither source nor destination during a truncatable SP can be in the receive state with its receive antennas configured in a quasi-omni antenna pattern for the duration of the truncatable SP.

A STA that receives a Grant frame with an SP allocation for which it is either source or destination shall not transmit longer than the time granted to it.

Any STA coordinated by an MM-SME that belongs to an MMSL cluster identified by the Source AID and Destination AID that are equal to, respectively, the Source AID and Destination AID of the Dynamic Allocation Info field in the Grant frame may transmit during the allocation, if the STA sent an MMS element to the peer STA and the BeamLink Cluster field within the MMS element is 1.

An example of dynamic allocation of service period is shown in Figure 10-67 (Example of dynamic allocation of service period mechanism).

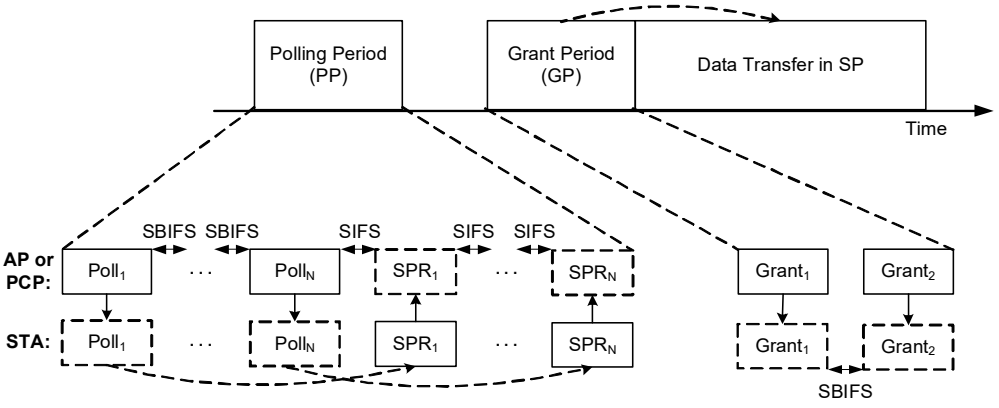


**Figure 10-67—Example of dynamic allocation of service period mechanism**

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### 10.38.7.2 Polling period (PP)

An AP or PCP that uses a PP to dynamically allocate an SP within the DTI shall commence the PP at a time instant indicated by at least one of the following:

— Any time during a scheduled SP for which the source AID and destination AID are equal to the broadcast AID, excluding any time that has been allocated dynamically

— Any time during a TXOP within a scheduled CBAP for which the destination AID is equal to the broadcast AID, excluding any time that has been allocated dynamically

— Any time during the relinquished channel time following an SP truncation, excluding any time that has been allocated dynamically

The AP or PCP shall not transmit a frame during a PP if any portion of that frame would extend beyond the end of the originally scheduled SP or CBAP.

During the PP, the AP or PCP may transmit individually addressed Poll frames to STAs to solicit SPR frames from those STAs. The Duration field within each Poll frame $i$ out of a total of $n$ ($0 < i \le n$) transmitted Poll frames in the PP shall be calculated as defined by Equation (10-19).

$$D_i = D_{i,n} + O_m + \text{Ceil}(\text{TXTIME}(\text{SPR}_m), T_{TR}) \quad (10\text{-}19)$$

where

$D_{i,n}$ is the duration of the remaining poll transmissions, in μs, given by

$$D_{i,n} = \text{Ceil}\left(\sum_{k=i+1}^{n} \text{TXTIME}(\text{Poll}_k) + SBIFS + A_k + S, T_{TR}\right)$$

$O_m$ is the offset of SPR transmission $m$, in μs

$\text{SPR}_m$ is SPR transmission $m$

$T_{TR}$ is aTSFResolution, in μs

The AP or PCP expects an SPR frame in response to each transmitted Poll frame (i.e., $m$=$n$). The position of each SPR frame in the sequence of SPR frames is indicated as $j$. Thus, $j$=1 refers to the first SPR frame transmission in the sequence of SPR frames, and $j$=$m$ refers to the last SPR frame transmission in the sequence of SPR frames. Based on this, the Response Offset field within each Poll frame $i$ transmitted in the PP shall be calculated as follows:

$$\textit{Response Offset}_i = D_{i,n} + O_j$$

where

$D_{i,n}$ is the duration of the remaining poll transmissions, defined in Equation (10-19).

$\text{Poll}_k$ is (M118)poll transmission $k$

$SBIFS$ is aSBIFSTime, in μs

$A_k$ is the antenna switching time, in μs, which is 0 if the AP or PCP uses the same antenna to transmit frame $k$ and frame $k$+1 and is equal to dot11AntennaSwitchingTime otherwise

$S$ is aSBIFSAccuracy, in μs

$T_{TR}$ is aTSFResolution, in μs

$O_j$ is the offset of SPR transmission $j$, given by

$$O_j = \begin{cases} SIFS, & j = 1 \\ O_{j-1} + \text{Ceil}(\text{TXTIME}(\text{SPR}_j) + SIFS, T_{TR}), & 2 < j \le m \end{cases}$$


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*SIFS* is aSIFSTime, in μs, the time interval between the end of the last Poll frame transmitted by the AP or PCP and the expected start time of the first SPR frame by the non-AP and non-PCP STA

$SPR_j$ is an SPR transmission *j*

NOTE—The calculation of $O_j$ guarantees that no less than SIFS or SIFS+dot11AntennaSwitchingTime is provided for the AP or PCP to switch antennas when receiving an SPR from different STAs.

A STA that receives an individually addressed Poll frame shall respond to the AP or PCP with a single directional and individually addressed SPR frame at the time offset from the end of the Poll frame indicated in the Response Offset field within the received Poll frame. The Duration field within the SPR frame shall be set to the value of the Duration field contained in the received Poll frame, minus the value of the Response Offset field contained in the received Poll frame, minus the time taken to transmit the SPR frame. (11ay)If the AP or PCP is an EDMG STA and the AllocationType field within the SPR is equal to SP, the STA may set the TXVECTOR parameter SCRAMBLER_INIT_SETTING to CONTROL_TRAILER and CT_TYPE to SPR to request the PCP or AP to grant the SP allocation on a specific channel or over a specified channel bandwidth.

The PP ends at a time equal to the end of the last Poll frame transmission plus the value of the Response Offset field in that Poll frame plus the expected duration of the SPR transmission that is expected in response to that Poll frame plus SIFS.

### 10.38.7.3 Grant period (GP)

(#111)In order to dynamically allocate an SP within the DTI, an AP or PCP shall commence a GP at a time instant indicated by at least one of the following:

— SIFS following the end of a PP if the PP is present

— Any time during a scheduled SP for which the source AID and destination AID are equal to the broadcast AID if a PP does not precede the GP, excluding any time that has been allocated dynamically

— Any time during a TXOP within a scheduled CBAP for which the destination AID is equal to the broadcast AID, excluding any time that has been allocated dynamically

— Any time during the relinquished channel time following an SP truncation if a PP does not precede the GP, excluding any time that has been allocated dynamically

The AP or PCP shall not transmit a frame during a GP if any portion of that frame would extend beyond the end of the originally scheduled SP or CBAP, or beyond the end of an immediately following SP if that SP has the broadcast AID as both source and destination AID, whichever is later.

A non-AP and non-PCP STA may switch to doze state if it does not receive a Grant frame from the AP or PCP within dot11MinPPDuration from the start of the scheduled SP for which the source AID and destination AID are set to the broadcast AID.

To commence the GP, the AP or PCP shall transmit Grant frames to notify the source DMG STA and destination DMG STA about a dynamically allocated service period, or the AP or PCP shall transmit Grant frames to notify the source CMMG STA and destination CMMG STA about a dynamically allocated service period. The AP or PCP should transmit the last Grant frame within a GP to the source of the dynamically allocated SP if the source of the dynamically allocated SP is not the AP or PCP. In each transmitted Grant frame, the AP or PCP shall set the Duration field within the Grant frame to a time that covers the duration of all remaining Grant frame and Grant Ack frame transmissions, if any, plus all appropriate IFSs (10.3.2.3 (IFS)). In addition, the source AID and destination AID fields shall be set to the source and destination, respectively, of the dynamically allocated SP, the AllocationType field set to indicate the channel access mechanism during the allocation, and the Allocation Duration field set to a value that if added to the value of the Duration field does not overlap in time with another SP that has either the source AID or destination AID

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different from the broadcast AID. An allocation that is indicated in this manner begins at the time that is equal to the PHY-TXEND.indication primitive of the Grant frame plus the value from the Duration field of the Grant frame.

(11ay)If the source DMG STA, destination DMG STA and the STA transmitting the Grant frame are all EDMG STAs, a granted dynamic allocation should meet the bandwidth requirements specified in the received SPR frame.

The Dynamic Allocation Info field within Grant frames transmitted as part of the same GP shall be the same.

NOTE—This means the AP or PCP can create only one allocation per GP.

During an SP between a source DMG STA and a destination DMG STA, the source DMG STA may transmit a Grant frame to the destination DMG STA to relinquish the remainder of the SP to the destination DMG STA. In the Allocation Info field of the transmitted Grant frame, the source DMG STA shall set source AID field to the AID of the destination DMG STA, the destination AID field to the AID of the source DMG STA, the AllocationType field set to indicate SP, and the Allocation Duration field set to a value of 32 768 as defined in 9.5.2 (Dynamic Allocation Info field). The Duration field in the Grant frame shall be set to the time remaining in the SP minus TXTIME (Grant frame) minus aSIFSTime. (11ay)The Beamforming Training subfield within the Beamforming Control field of the Grant frame shall be set to 0. For the remainder of the SP the roles of source DMG STA and destination DMG STA are swapped between the STAs. (11ay)If both the source STA and destination STA are EDMG STAs, and if any bit in the CH_BANDWIDTH parameter in the RXVECTOR of the received Grant frame was 0, the destination STA shall not transmit frames with the corresponding bit in the TXVECTOR parameter CH_BANDWIDTH set to 1, and shall be subject to the channel access rules in 10.38.12.2.1 (Channel access rules).

During an SP between a source CMMG STA and a destination CMMG STA, the source CMMG STA may transmit a Grant frame to the destination CMMG STA to relinquish the remainder of the SP to the destination CMMG STA. In the Allocation Info field of the transmitted Grant frame, the source CMMG STA shall set the Source AID field to the AID of the destination CMMG STA, the Destination AID field to the AID of the source CMMG STA, the AllocationType subfield to indicate SP, the Allocation Duration field to the time remaining in the SP minus the time taken to transmit the Grant frame, and the Allocation Channel Band field to the same channel and bandwidth as the original SP. The Duration field in the Grant frame shall be set to the value of the Allocation Duration field. Upon transmission of the Grant frame, for the remainder of the SP, the roles of source CMMG STA and destination CMMG STA are swapped between the STAs.

During a TXOP between a TXOP holder and a TXOP responder, the TXOP holder may transmit a Grant frame to the TXOP responder to relinquish the remainder of the TXOP to the TXOP responder. In the transmitted Grant frame, the TXOP holder shall set source AID field to the AID of the TXOP responder, the destination AID field to the AID of the TXOP holder, the AllocationType field set to indicate CBAP, and the Allocation Duration field set to a value of 32 768 as defined in 9.5.2 (Dynamic Allocation Info field). For CMMG STAs, the Channel Band field shall be set to the same channel and bandwidth as the original TXOP. The Duration field in the Grant frame shall be set to the time remaining in the TXOP minus TXTIME (Grant frame) minus aSIFSTime. (11ay)The Beamforming Training subfield within the Beamforming Control field of the Grant frame shall be set to 0. For the remainder the TXOP the roles of TXOP holder and TXOP responder are swapped between the STAs. (11ay)If both the TXOP holder and TXOP responder are EDMG STAs, and if any bit in the CH_BANDWIDTH parameter in the RXVECTOR of the received Grant frame was 0, the TXOP responder shall not transmit frames with the corresponding bit in the TXVECTOR parameter CH_BANDWIDTH set to 1, and shall be subject to the channel access rules in 10.38.12.2.1 (Channel access rules).

A STA that receives a Grant frame shall not update its NAV if the value of either the source AID or destination AID fields in the Grant frame are equal to the STA's AID.


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The AP or PCP may grant a dynamic allocation of service period to a STA that does not transmit an SPR frame during the PP.

### 10.38.8 Dynamic truncation of service period

#### 10.38.8.1 DMG dynamic truncation of service period

A STA truncates an SP to release the remaining time in the SP. The STA can use the CF-End frame to truncate the SP at the peer STA, to reset NAV in third party STAs and to return to the AP or PCP the time left in the SP, thus allowing the AP or PCP to grant any portion of the released time as part of an SP to any other STA or to allocate any portion of it as a CBAP. The STA can use the Grant frame to release any part of the time left in the SP as a CBAP.

A STA that is neither source nor destination during a truncatable SP may participate in dynamic allocation of service period by being in the receive state with its receive antenna configured in a quasi-omni antenna pattern for the duration of the truncatable SP. If both the source and destination AID fields of a truncatable SP are set to the broadcast AID, a non-AP and non-PCP STA may direct its receive antenna to its AP or PCP for the duration of the truncatable SP if the non-AP and non-PCP STA does not participate in a frame exchange sequence(#109) and the truncatable SP is not dynamically allocated to the non-AP and non-PCP STA.

Only the source DMG STA of an SP may truncate the SP, except that the destination DMG STA may truncate the SP if it does not receive an expected transmission from the source DMG STA at the start of the SP as defined in 10.38.6.7 (Service period recovery).

Only the source CMMG STA of an SP may truncate the SP, except that the destination CMMG STA may truncate the SP if it does not receive an expected transmission from the source CMMG STA at the start of the SP as defined in 10.38.6.7 (Service period recovery).

In order to advertise the availability of truncatable SP time for reuse through AP or PCP dynamic allocation, a non-AP and non-PCP STA shall transmit (#558)a CF-End frame to the AP or PCP. A STA is not required to truncate an SP if a portion of the SP is unused.

In order to enable CBAP access during the time released through SP truncation, the STA shall broadcast a Grant frame with the Source AID and Destination AID set to broadcast AID, the AllocationType field set to indicate CBAP and the Duration field set to the time needed to transmit the Grant frame(s) (the Duration field in a Grant frame does not include duration of that frame) plus SIFS and plus the time needed to transmit the following CF-End frame and the response CF-End frame, if required and appropriate IFS (10.3.2.3 (IFS)) values. The Allocation Duration field shall be set to a value that is not greater than the result of the subtraction of the value in the Duration field from the time remaining in the SP. The CBAP that is indicated in this manner begins at the time that is equal to the PHY-TXEND.indication primitive of the Grant frame plus the value from the Duration field of the Grant frame and continues for the time indicated in the Allocation Duration field of the Grant frame.

The STA shall not transmit the Grant frame and shall not transmit the CF-End frame to the AP or PCP if the SP is not indicated as truncatable.

After transmission of the CF-End frame to the AP or PCP or after broadcasting a Grant frame, the STA shall transmit a CF-End frame to the peer STA of the SP. The CF-End frame releases any time remaining in the SP at the recipient and resets the NAV in third party STAs. The NAV is reset only if the RA and TA of the CF-End frame match the addresses of the frame that established the NAV (see 10.38.10 (Updating multiple NAVs)). The recipient STA may transmit a CF-End frame SIFS after the reception if the Duration field of the received frame is not equal to 0 and the transmission does not extend beyond the end of the originally scheduled SP.

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A STA shall not initiate SP truncation if there is not enough time left in the SP to complete the frame exchange sequence(#109) required for truncation of the SP.

After the truncation is completed, the AP or PCP may dynamically allocate any portion of the relinquished channel time that has not been allocated to a CBAP through a transmitted Grant frame (10.38.7 (Dynamic allocation of service period)).

#### 10.38.8.2 CDMG dynamic truncation of service period

A CDMG STA truncates an SP to release the remaining time in the SP. The dynamic truncation of SP includes two types of truncation. The first type of truncation is that the STA can return to the AP or PCP the time left in the SP, thus allowing the AP or PCP to grant any portion of the released time as part of an SP to any other STA or to allocate any portion of it as a CBAP. The second type of truncation is that the STA can use the Grant frame to release any part of the time left in the SP as a CBAP.

A CDMG STA supports the DMG dynamic truncation of SP as described in 10.38.8.1 (DMG dynamic truncation of service period). Unlike the DMG dynamic truncation of SP, the SP truncation type shall be determined by the CDMG AP or PCP when allocating an SP.

A CDMG AP or PCP shall determine whether an SP is truncatable and which truncation type is adopted by setting the Truncatable subfield and the Truncation Type subfield within the Allocation Control field when allocating an SP for the source CDMG STA and destination CDMG STA. If the Truncatable subfield of the Extended Schedule element is equal to 1, the CDMG STA may truncate the SP to release any part of the time left in the SP in accordance with the truncation type indicated by the received Truncation Type subfield.

A CDMG AP or PCP should determine the Truncatable subfield and the Truncation Type subfield according to the allocation type requirements of the STAs in its BSS, in order to satisfy the channel access requirements of the STAs using the potential released time of SPs. If the remaining time in the SP released as a CBAP might cause interference to other STAs during SPSH, the CDMG AP or PCP shall set the Truncatable subfield to 1 and the Truncation Type subfield to 0 for the SPs that are under SPSH state to indicate that the CDMG STA returns the time left in the SP to the AP or PCP; otherwise, the CDMG AP or PCP may set the Truncatable subfield to 1 and the Truncation Type subfield to 1. The CDMG AP or PCP may also set the Truncation Type subfield to 0 for an SP in order to mitigate interference to other STAs of a adjacent BSS based on the schedule information of the adjacent BSS.

A CDMG PCP may (#6038)transition to doze state if it is in a truncatable SP that has time left in this SP that is released as a CBAP by the CDMG STA by setting the Truncation Type subfield to 1 and the PCP Active field to 0. If both the Truncatable subfield and the Extendable subfield are set to 0, or if the Truncatable subfield is equal to 1 and the Truncation Type subfield is equal to 1, the CDMG PCP can set the PCP Active subfield to 0.

### 10.38.9 Dynamic extension of service period

A non-AP and non-PCP STA uses dynamic extension of SP to extend the allocated time in the current SP. The additional time can be used to support variable bit rate traffic, for retransmissions or for other purposes. The SPR frame is sent by a non-AP and non-PCP STA to the AP or PCP to request additional SP time in the current beacon interval.

Except in response to a Poll frame from the AP or PCP, a non-AP and non-PCP STA shall not transmit an SPR frame within an SP if the current SP is not extendable (see 9.4.2.130 (Extended Schedule element)).

Only the source DMG STA and destination DMG STA of an SP can transmit an SPR frame during that SP.

If the AP or PCP is not the source of an extendable SP, it should be in the receive state and with its receive antennas configured in a quasi-omni antenna pattern for the duration of the extendable SP.


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To request an extension of the current SP, a non-AP and non-PCP STA shall transmit an SPR frame to the AP or PCP. The non-AP and non-PCP STA shall not request extension of the current SP if there is not enough time left in the SP to complete the frame exchange sequence(#109) required for the SP extension. In the transmitted SPR frame, the STA shall set the RA field to the address of the AP or PCP, the Duration field to the time left in the SP (not including the SPR transmission time), and the Allocation Duration field to the additional amount of time requested by the STA following the end of the current SP.

The AP or PCP may grant the request for an extension of an SP only if the following SP has the broadcast AID as both source and destination AID, and the duration of the following SP is larger than the value of the Allocation Duration field in the received SPR frame. To grant an extension request, the AP or PCP shall transmit a Grant frame with the RA field set to the value of the TA in the received SPR frame, the Duration field set to the value of the Duration field received in the SPR frame minus SIFS and minus the duration of this Grant frame transmission, and the Allocation Duration field set to the amount of additional time granted by the AP or PCP. If a Grant Ack frame is transmitted following reception of the Grant frame, the frame shall be configured as specified in 10.38.4 (DTI transmission rules).

To decline a request for an extension of an SP, the AP or PCP shall transmit a Grant frame with the RA field set to the value of the TA in the received SPR frame, the Duration field set to the value of the Duration field received in the SPR frame minus SIFS and minus the duration of this Grant frame transmission, and the Allocation Duration field set to 0.

The extension request is successful if the non-AP and non-PCP STA receives from the AP or PCP a Grant frame with a nonzero value of the Allocation Duration field SIFS after the SPR. SIFS after the reception of a Grant frame from the AP or PCP with a nonzero value of the Allocation Duration field, the non-AP and non-PCP STA shall transmit a Grant frame to the partner STA of the SP with the Duration field set to the value of the Duration field of the Grant frame received from the AP or PCP minus the duration of this Grant frame transmission minus SIFS, and the Allocation Duration field set to the value of the Allocation Duration field of the Grant frame received from the AP or PCP.

An AP or PCP may extend an SP for which it is the source DMG STA by transmitting a Grant frame to the destination DMG STA of the SP. The Grant frame indicates extension of the SP. The Duration field in the transmitted Grant frame shall be set to the remaining time in the SP. The Allocation Duration field of the Grant frame shall be set to the additional channel time allocated by the AP or PCP following the end of the SP. If a Grant Ack frame is transmitted following reception of the Grant frame the frame shall be configured as specified in 10.38.4 (DTI transmission rules).

### 10.38.10 Updating multiple NAVs

If a DMG STA supports multiple NAVs, the number of available NAVs within the STA shall be not less than aMinNAVTimersNumber. Each NAV is identified by a pair of MAC addresses, NAVSRC and NAVDST, and has associated MAC variables NAV_RTSCANCELABLE, NAV_DTSCANCELABLE and NAV_CHANNEL the last of which is used only by CMMG STAs. The MAC variable NAV_CHANNEL indicates the channel on which the Duration field is received, and it is a channel index that contains channel bandwidth information. Each STA also maintains a MAC variable UPDATE_OPTIONAL. When a STA is enabled for operation, all NAVs shall have NULL values for their NAVSRC and NAVDST identifiers, the value of NAV_RTSCANCELABLE shall be false, the value of NAV_DTSCANCELABLE shall be false, the value of NAV_CHANNEL shall be NULL only for CMMG STAs, and each NAV shall have the value 0. NAV address pairs correspond to the NAV-SA and NAV-DA fields in DMG DTS frames and correspond to the RA and TA fields of all other received frames that are used to update the NAV. Receipt of any frame can cause an update to the NAV whose identifying address pair corresponds to the specified address fields of the received frame according to the rules in this subclause.

DMG STAs receiving any (#4179)frame shall perform the following NAV update operation expressed using the following pseudocode:

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```
NAV_TIMER_UPDATE(received_frame):

        UPDATE_OPTIONAL ← false

        If (received_frame = DMG DTS) {
                UPDATE_OPTIONAL ← true
        }

        If (received_frame(RA) ≠ This STA MAC address || UPDATE_OPTIONAL = true) {
                If (received_frame = DMG DTS) {
                        R_DST ← received_frame(NAV-DA)
                        R_SRC ← received_frame(NAV-SA)
                } else if (received_frame = Ack) {
                        R_DST ← received_frame(RA)
                        R_SRC ← 0
                } else {
                        R_DST ← received_frame(RA)
                        R_SRC ← received_frame(TA)
                }

                R_DUR ← received_frame(DUR)

                N_TIMER ← -1

                // Searching for a matching NAV
                For (x ← 0; x < aMinNAVTimersNumber; x++) {
                        If (received_frame = Ack || NAVSRC(x)=R_DST) {
                                If(NAVDST(x) = R_DST) {
                                        N_TIMER ← x
                                        Break
                                }
                        } else if (NAVSRC(x) = R_SRC && (NAVDST(x) = R_DST
                                                || NAVDST(x) = 0) ||
                                (NAVSRC(x)=0 && NAVDST(x) = R_DST) ||
                                (NAVDST(x)=R_SRC && NAVSRC(x)=R_DST)) {
                                N_TIMER ← x
                                Break
                        }
                }

                // No NAV has been found that matches the addresses
                If (N_TIMER < 0) {
                        For (x ← 0; x < aMinNAVTimersNumber; x++) {
                                If (NAVSRC(x) = NULL && NAVDST(x) = NULL
                                        || NAV(x) = 0) {
                                        NAVSRC(x) ← R_SRC
                                        NAVDST(x) ← R_DST
                                        N_TIMER ← x
                                        Break
```


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```
                                        }
                                }
                        }

                        // Existing NAV found
                        If (N_TIMER ≥ 0) {
                                If (UPDATE_OPTIONAL = false
                                        && R_DUR > NAV(N_TIMER) ) {
                                        NAV(N_TIMER) ← R_DUR
                                        If (received_frame = RTS) {
                                                NAV_RTSCANCELABLE(N_TIMER) ← true
                                        } else {
                                                NAV_RTSCANCELABLE(N_TIMER) ← false
                                        }
                                } else if (UPDATE_OPTIONAL = true && R_DUR > NAV(N_TIMER)) {
                                        If ((implementation decision to update = true) ||
                                        (received_frame(RA) = This STA MAC address &&
                                        This STA MAC address = source DMG STA MAC address for current SP))
                                        ) {
                                                NAV_DTSCANCELABLE(N_TIMER) ← true
                                                NAV(N_TIMER) ← R_DUR
                                        }
                                }
                        }

                } else {
                        No change to NAV
                }

END OF NAV_TIMER_UPDATE
```

CMMG STAs receiving any (#4179)frame shall perform the following NAV update operation expressed using the following pseudocode:

```
NAV_TIMER_UPDATE(received_frame):

        UPDATE_OPTIONAL ← false

        If (received_frame = DMG DTS) {
                UPDATE_OPTIONAL ← true

        }
        If (received_frame(RA) ≠ This STA MAC address || UPDATE_OPTIONAL = true) {
                If (received_frame = DMG DTS) {
                        R_DST ← received_frame(NAV-DA)
                        R_SRC ← received_frame(NAV-SA)
                        R_CHANNEL ← received_frame(CHANNEL BANDWIDTH)
                } else if (received_frame = Ack) {
                        R_DST ← received_frame(RA)
                        R_SRC ← 0
                        NAV_CHANNEL ← received_frame(CHANNEL BANDWIDTH)
```

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```
} else {
        R_DST ← received_frame(RA)
        R_SRC ← received_frame(TA)
}
        R_DUR ← received_frame(DUR)
        N_TIMER ← –1
// Searching for a matching NAV timer
For (x = 0; x < aMinNAVTimersNumber; x++) {
        If (received_frame = Ack || NAVSRC(x)=R_DST) {
                If(NAVDST(x) = R_DST) {
                        N_TIMER ← x
                        Break
                }
                } else if (NAVSRC(x) = R_SRC && (NAVDST(x) = R_DST|| NAVDST(x) = 0)
                ||(NAVSRC(x)=0 && NAVDST(x) = R_DST) ||
                (NAVDST(x)=R_SRC && NAVSRC(x)=R_DST)) {
                        N_TIMER ← x
                        Break
                }
        }
        // No NAV timer has been found that matches the addresses
        If (N_TIMER < 0) {
                For (x = 0; x < aMinNAVTimersNumber; x++) {
                        If (NAVSRC(x) = NULL && NAVDST(x) = NULL
                        || NAV(x) = 0) {
                                NAVSRC(x) ← R_SRC
                                NAVDST(x) ← R_DST
                                NAV_CHNNAL(x) ← R_CHANNEL
                                N_TIMER ← x
                                Break
                        }
                }
        }
        // Existing NAV timer found
        If (N_TIMER  ≥  0) {
                If (UPDATE_OPTIONAL = false) {
                        NAV(N_TIMER) ← R_DUR
                        NAV_CHNNAL(N_TIMER) ← R_CHANNEL
                        If (received_frame = RTS) {
                                NAV_RTSCANCELABLE(N_TIMER) ← true
                        } else {
                                NAV_RTSCANCELABLE(N_TIMER) ← false
                        }
                } else if (UPDATE_OPTIONAL = true) {
                        If ((implementation decision to update = true) ||
                        (received_frame(RA) = This STA MAC address &&
                        This STA MAC address = source DMG STA MAC address for current
                        SP))) {
                                NAV_DTSCANCELABLE(N_TIMER) ← true
```


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```
                                        NAV(N_TIMER) ← R_DUR
                                        NAV_CHNNAL(N_TIMER) ← R_CHANNEL
                                        }
                                }
                        }
                } else {
                        No change to NAV timers
                }
END OF NAV_TIMER_UPDATE
```

A STA that has updated a NAV as a result of the reception of an RTS may reset its NAV(s) as follows. After the NAV update for a duration of NAVTimeout period (10.3.2.4 (Setting and resetting the NAV)), the STA shall monitor the channel to determine if a (#3038)PHY-RXEARLYSIG.indication or PHY-RXSTART.indication primitive is received from the PHY. If such an event has not occurred during this time period, then the STA may reset to 0 any NAV whose NAV_RTSCANCELABLE value is true.

After each NAV is updated, it counts down until it reaches 0 or is reset to 0.

If a STA receives a valid CF-End frame response with RA and TA fields(#3522) that match the NAVSRC and NAVDST values, in any order, for any NAV, then the STA shall set the associated NAV to the value of the Duration field in the received CF-End frame. If one of NAVSRC or NAVDST of a NAV is 0 and the corresponding NAVDST or NAVSRC, respectively, of the NAV matches the RA or the TA field(#3522) of the (#1939)received CF-End frame, then the STA shall set the associated NAV to the value of the Duration field in the received CF-End frame.

If one of NAVSRC or NAVDST of a NAV is 0 and the nonzero NAVDST or NAVSRC of the NAV match either the RA or the TA field(#3522) of a (#1939)received frame, the NAVSRC or NAVDST that is 0 shall be set to the RA or TA that does not match the nonzero NAVSRC or NAVDST.

### 10.38.11 Opportunistic transmission in alternative channel for CDMG STAs

When dot11OpportunisticTransmissionsImplemented is true, an AP or PCP is capable of supporting the scheduling of opportunistic data transmission between two or more non-AP and non-PCP CDMG STAs that support such opportunistic transmission in a channel that is not the BSS's operating channel. The channel for such opportunistic transmission is termed the alternative channel while the BSS's operating channel is termed the dedicated channel as a contrast in this subclause. The spectrum access in the alternative channel is divided into three phases: monitor phase, transmission phase, and suspension phase. Scheduled transmission in the alternative channel shall start with the monitor phase, and then the three phases rotate cyclically until all the scheduled transmissions in the alternative channel are completed as illustrated in Figure 10-68 (Opportunistic transmission in alternative channels for CDMG STAs).

The monitor phase shall last for at least aMaxBIDuration. During the monitor phase, a CDMG STA that is scheduled to operate in the alternative channel shall listen for the transmission of DMG Beacon frames in the alternative channel. If a CDMG STA receives one or more valid DMG Beacon frames with a BSSID different from its own, it shall abandon transmission during the transmission phase.

During the transmission phase, a CDMG STA may transmit frames according to the DTI transmission rules (10.38.4 (DTI transmission rules)). A CDMG STA may continue to listen for the transmission of DMG Beacon frames in the alternative channel during the transmission phase when the CDMG STA is not transmitting. If a CDMG STA is not the source or destination STA in an access period, it may switch to the dedicated channel to receive the DMG Beacon frame or Announce frame send out by the AP or PCP to maintain synchronization with the AP or PCP.

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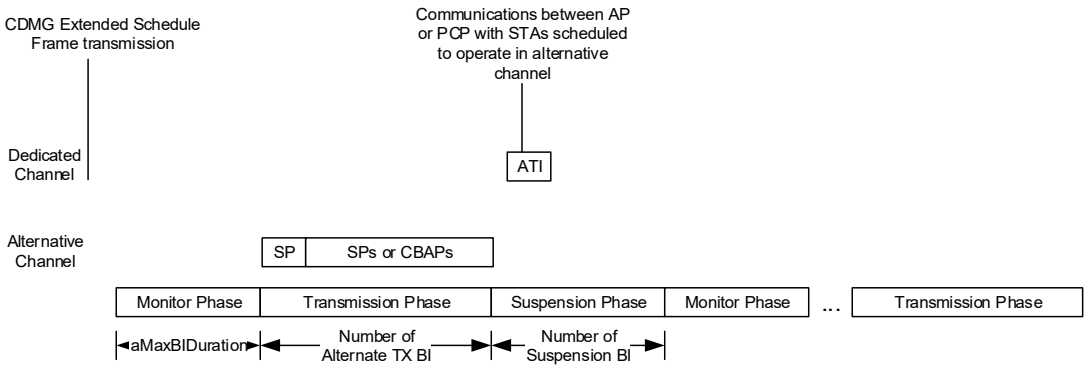


**Figure 10-68—Opportunistic transmission in alternative channels for CDMG STAs**

During the suspension phase, a CDMG STA that is scheduled to operate in the alternative channel shall switch to the dedicated channel and be ready to receive transmission from the AP or PCP in the dedicated channel. The CDMG STA may receive the DMG Beacon frame or Announce frame transmitted by the AP or PCP to maintain synchronization with the AP or PCP during the suspension phase. If a CDMG STA receives a DELTS frame from the AP or PCP during the suspension phase, the CDMG STA should cease opportunistic transmission in the alternative channel.

The schedule of the transmission in the alternative channel is communicated through the CDMG Extended Schedule element (9.4.2.220 (CDMG Extended Schedule element)). The AP or PCP shall transmit the CDMG Extended Schedule element in the Announce frame and/or DMG Beacon frame. The CDMG Extended Schedule element shall contain the scheduling information of all allocations in the alternative channel. The Number of Alternate TX BI field in the CDMG Extended Schedule element indicates the number of beacon intervals that makes up the transmission phase. The Number of Suspension BI field in the CDMG Extended Schedule element indicates the number of beacon intervals that makes up the suspension phase.

The access periods in the alternative channel may be scheduled to be either CBAPs or SPs but the first access period shall be an SP. The CBAPs in the alternative channel may be used by the AP or PCP to send more CDMG STAs to operate in the alternative channel after the initial setup. The source CDMG STA of the first SP in the alternative channel shall transmit a DMG Beacon frame at the start of the first transmission phase in the alternative channel and after every aMaxBIDuration within the transmission phase if the duration of the transmission phase exceeds aMaxBIDuration.

The AP or PCP should send a DMG CTS-to-self frame in the ATIs (10.38.3 (ATI transmission rules)) during the suspension phase to each of the CDMG STAs scheduled to operate in the alternative channel. If a CDMG STA receives one or more DMG Beacon frames with a BSSID different from its own during the monitor phase, the CDMG STA shall respond with a DELTS frame to the AP or PCP with the Reason Code field set to the value defined in 9.4.1.7 (Reason Code field) that indicates the alternative channel is occupied upon reception of a DMG CTS-to-self frame from the AP or PCP during the ATI. If a transmission link in the alternative channel cannot be established during the transmission phase, the CDMG STA shall respond with a DELTS frame to the AP or PCP with the Reason Code field set to 67 to indicate that the transmission link establishment in alternative channel is failed. If the AP or PCP received a DELTS frame with the Reason Code field (9.4.1.7 (Reason Code field)) set to 68 in an ATI, the AP or PCP shall transmit a DELTS frame to each of the CDMG STAs scheduled to operate in the alternative channel in the same ATI.

A CDMG AP or PCP may allocate a pair of STAs to perform SLS on an alternative channel. A CDMG STA may reuse the transmit sector indicated by the Sector Select field obtained from the operating channel, which is the primary channel on an alternative channel with the same channel width, and vice versa. If an SPR frame


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with the Beamforming Training subfield equal to 1 is received from a CDMG initiator STA, the CDMG AP or PCP may configure a channel for the initiator and the responder designated by the initiator to perform BF training according to the AllocationType subfield in the SPR frame. The SPR frame contains channel allocation request in the AllocationType subfield and BF Control field for the initiator and responder that form a BF pair. If the NoPrimaryChannel subfield in the BF Control field is equal to 1 and the Beamforming Training subfield is equal to 1 in the SPR frame, the CDMG AP or PCP can allocate SPs on an alternative channel using the CDMG Extended Schedule element included in a DMG Beacon frame or an Announce frame for the initiator and the responder; otherwise, the CDMG AP or PCP should allocate SPs on the current operating channel. If the CDMG AP or PCP receives SPR frames from multiple pairs of initiators and responders, the CDMG AP or PCP may allocate time overlapping SPs on designated channels with different channel numbers for different pairs of STAs to perform an SLS.

### 10.38.12 EDMG channel access(11ay)

#### 10.38.12.1 General

This subclause specifies channel access rules that are applicable to an EDMG STA. These rules are in addition to the rules specified in 10.3 (DCF), 10.23 (HCF), and 10.29 (Reverse direction protocol), which are applicable to DMG STAs.

An EDMG STA shall set dot11EDMGOptionImplemented to true.

An EDMG STA shall set the EDMG Supported subfield in the DMG Parameters field to 1 in transmitted frames.

#### 10.38.12.2 Channel access over multiple channels

##### 10.38.12.2.1 Channel access rules

The following apply to transmissions performed in an EDMG BSS:

— Transmissions shall not occupy a bandwidth that exceeds the equivalent of four 2.16 GHz channels.

— Transmissions shall be confined to the channel number indicated by the primary channel, the channels indicated in the EDMG Operation element, and the channels indicated in the EDMG Capabilities element.

An EDMG STA shall not transmit an EDMG PPDU to a peer EDMG STA over a channel that is not supported by the peer STA as indicated in the Supported Channels subelement(#3510) in the peer STA's EDMG Capabilities element.

An EDMG STA may transmit a Grant frame to a peer EDMG STA to indicate intent to transmit an EDMG PPDU to the peer STA over a 4.32 GHz, 2.16+2.16 GHz, 6.48 GHz, 4.32+4.32 GHz, or 8.64 GHz channel at the time indicated by the sum of the Allocation Duration field and the Duration field within the Grant frame following the end of the Grant frame transmission as described in 9.5.2 (Dynamic Allocation Info field). When a peer EDMG STA receives the Grant frame, it may

— Limit its receiver bandwidth to 2.16 GHz until the time indicated by the sum of the Allocation Duration field and the Duration field; or

— Configure its receive DMG antenna(s) to a directional antenna pattern only at the time indicated by the sum of the Allocation Duration field and the Duration field, allowing it to employ a quasi-omni antenna pattern beforehand. This would allow the peer EDMG STA to receive from a wider coverage area.

To do this, in the TXVECTOR of the transmitted Grant frame the EDMG STA shall set the TXVECTOR parameter SCRAMBLER_INIT_SETTING to CONTROL_TRAILER, the parameter CT_TYPE to

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GRANT_RTS_CTS2Self, the parameter IS_CHANNEL_NUMBER to ChannelWidth and the parameter BW_IN_CT to indicate the bandwidth with which the EDMG PPDU is going to be transmitted.

An EDMG AP or EDMG PCP may use the EDMG Extended Schedule element to allocate an SP or a CBAP over channels with different bandwidths. For partially or fully overlapping allocations, both the source AID and the destination AID of each allocation shall be different from both the source AID and destination AID of every other overlapping allocation. Channels used for such allocations shall be included in the EDMG Operation element transmitted by the AP or PCP. An allocation and channel access within the allocation follow the following rules:

- If the allocation is an SP, then
  - The allocation does not have to include the primary channel.
  - If the allocation does not include the primary channel, the allocation shall not span more than one 2.16 GHz channel.
- If the allocation is a scheduled CBAP, then channel access during the allocation shall include the primary channel.
- Any transmissions within the allocation shall not exceed the corresponding bandwidth for this allocation.

If the CBAP Only field in a transmitted DMG Beacon frame is 1, then channel access within the CBAP of the DTI specified by the DMG Beacon frame shall include the primary channel.

If an EDMG Extended Schedule element that has at least one Channel Allocation field with the Scheduling Type subfield equal to 0 is present in a transmitted frame, an Extended Schedule element shall also be present in the same frame. The Allocation Key subfield of a Channel Allocation field with the Scheduling Type subfield equal to 0 shall have its contents matched to the tuple <Source AID, Destination AID, Allocation ID> of an Allocation field in the Extended Schedule element for the same allocation. A Channel Allocation field with the Scheduling Type subfield equal to 0 included in the EDMG Extended Schedule element shall be ignored if the contents of its Allocation Key subfield do not match to the tuple <Source AID, Destination AID, Allocation ID> of any Allocation field in the Extended Schedule element.

For an allocation that does not include the primary channel, the allocation information shall be present in the EDMG Extended Schedule element only. This shall be indicated by setting the value of the Scheduling Type subfield for the allocation to 1.

#### 10.38.12.2.2 CCA in secondary channels

An EDMG STA shall maintain physical and virtual CS on a primary channel as specified in 10.3.2 (Procedures common to the DCF and EDCAF).

To perform the procedure specified in 10.23.2.14 (EDCA channel access in an EDMG BSS(11ay)), an EDMG STA shall support(#546) performing energy detection on each of its supported channels that are also supported by the AP or PCP, as indicated in the AP's or PCP's EDMG Operation element.

At the specific slot boundaries (see Figure V-4 (Backoff procedure for DMG STAs(#124))) determined by the STA based on the primary channel CCA, when the transmission begins a TXOP using EDCA (as described in 10.23.2.4 (Obtaining an EDCA TXOP)), the STA may transmit on secondary channels only if the respective secondary channel has also been idle during the times the primary channel CCA is performed (defined in 10.23.2.4 (Obtaining an EDCA TXOP)) for an interval of PIFS immediately preceding the expiration of the backoff counter.


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### 10.38.12.3 Directional allocation

A directional allocation is an allocation during which an EDMG AP or EDMG PCP uses a directional, non quasi-omni DMG antenna pattern to receive frames. Directional allocation can facilitate the frame exchange between an EDMG AP or EDMG PCP and an EDMG STA through the use of a directional link, particularly for those STAs that have asymmetric links (see 10.41.10.3 (Beamforming for asymmetric links)).

To schedule a directional allocation, an EDMG AP or EDMG PCP shall set the IsDirectional subfield in the Receive Direction subfield within the corresponding Channel Allocation field of the EDMG Extended Schedule element to one. The decision to schedule a directional allocation is implementation dependent, but may be as a result of performing the procedure specified in 10.41.10 (EDMG beamforming(11ay)).

Within the Channel Allocation field in the EDMG Extended Schedule element that specifies a directional allocation, the Sector ID and DMG Antenna ID subfields of a directional allocation shall be set to the sector and DMG antenna, respectively, that the PCP or AP uses to receive frames during the entire allocation. A non-PCP and non-AP EDMG STA receiving such allocation shall stay awake during the allocation if the value of the Sector ID and DMG Antenna ID subfields identified in the allocation correspond to a sector and DMG antenna reported by the STA to the PCP or AP in the last beamforming feedback to the PCP or AP, respectively. If the value of the Sector ID and DMG Antenna ID subfields identified in the allocation do not correspond to a sector and DMG antenna reported by the STA to the PCP or AP in the last beamforming feedback, the non-PCP and non-AP EDMG STA shall not access the directional allocation.

Channel access during a directional allocation shall follow the same rules that are applicable to a CBAP (see 10.38.6.3 (Contention based access period (CBAP) allocation)) if the directional allocation is of type CBAP and shall follow the same rules that are applicable to an SP (see 10.38.6.2 (Service period (SP) allocation)) if the directional allocation is of type SP.

### 10.38.12.4 MIMO channel access

#### 10.38.12.4.1 General

This subclause describes the MIMO channel access mechanisms that are applicable to EDMG STAs. General MIMO channel access rules are defined in 10.38.12.4.2 (MIMO channel access rules). The SU-MIMO channel access procedure and the MU-MIMO channel access procedure are specified in 10.38.12.4.3 (SU-MIMO channel access procedure) and 10.38.12.4.4 (MU-MIMO channel access procedure), respectively, and EDMG STAs using these procedures shall also follow the MIMO channel access rules specified in 10.38.12.4.2 (MIMO channel access rules).

In this subclause, the EDMG STA that obtains a TXOP or is the source STA of an allocated SP and that initiates the MIMO channel access procedure is referred to as the initiator, and the EDMG STA(s) that are addressed by the MIMO channel access is referred to as the responder(s).

#### 10.38.12.4.2 MIMO channel access rules

An EDMG STA that has either the MU-MIMO Supported subfield set to 1 or the SU-MIMO Supported subfield set to 1 in the Beamforming Capability subelement of its EDMG Capabilities element shall maintain physical and virtual CS and backoff procedure as specified in 10.23.2 (HCF contention based channel access (EDCA)). This allows the STA to be able to transmit and receive a single space time-stream PPDU (i.e., using SISO transmission) for the establishment of a TXOP when a subsequent transmission of a PPDU with multiple space-time streams is to take place.

When an EDMG STA that has either the MU-MIMO Supported set to 1 or the SU-MIMO Supported set to 1 in the Beamforming Capability subelement of its EDMG Capabilities element attempts to obtain a TXOP for MIMO transmission, CCA shall be maintained such that at least all the MIMO RX DMG antennas

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corresponding to the MIMO TX DMG antennas intended to be used in the TXOP, which have been determined by applying the beamforming protocols defined in 10.41.10.2.2 (SU-MIMO beamforming) or in 10.41.10.2.3 (MU-MIMO beamforming), are observed. The STATE parameter of PHY-CCA.indication can be one of two values: BUSY or IDLE. The parameter value is BUSY if the assessment of the channel by the PHY determines that the channel on at least one of the MIMO TX antennas intended to be used in the TXOP is not idle. The parameter value is IDLE if the assessment by the PHY of the channel on all of the MIMO TX antennas intended to be used in the TXOP determines that the channel is idle.

In the following, "MIMO channel was idle for an interval of PIFS" means that the STATE parameter of the most recent PHY-CCA.indication primitive that sensed at least all the MIMO TX antennas intended to be used in the TXOP was IDLE for an interval of PIFS that ends at the start of the transmission. "MIMO channel was busy" means that the STATE parameter of the most recent PHY-CCA.indication primitive that sensed at least one of the MIMO TX antennas intended to be used in the TXOP was BUSY.

The initiator uses the procedures in 10.3 (DCF) and 10.23.2 (HCF contention based channel access (EDCA)) to obtain a TXOP, or use the procedures in 11.4.12 (DMG allocation formats) to obtain an SP allocation prior to initiating MIMO channel access.

When the channel is clear for SISO transmission (physical and virtual CS are clear) for the corresponding DMG antenna that is used for SISO transmission to establish a TXOP and the backoff timer reaches 0, a STA is permitted to obtain the TXOP. If the initiator has at least one MSDU pending for transmission during the permitted TXOP, the initiator shall perform exactly one of the following actions:

— Transmit a MIMO PPDU or initiate the hybrid beamforming protocol if the MIMO channel was idle for an interval of PIFS immediately preceding the start of the TXOP.
— Transmit a PPDU using a single transmit chain with the same DMG antenna that was used to obtain the TXOP or cancel the hybrid beamforming protocol if any DMG antenna connected to an active receive chain indicates busy during an interval of PIFS immediately preceding the start of the TXOP.
— Restart the channel access attempt by invoking the backoff procedure as specified in 10.23.2 (HCF contention based channel access (EDCA)) as though the medium is busy as indicated by either physical or virtual CS and the backoff timer has a value of 0.

In the case of an SP, if the initiator has at least one MSDU pending for transmission during the SP, the initiator transmits a MIMO PPDU or initiates the hybrid beamforming protocol at the start of the SP.

If the Grant Required field within a responder's EDMG Capabilities element is 1, the initiator shall transmit a Grant frame with a control trailer in a CBAP to this responder before initiating MIMO channel access or the hybrid beamforming protocol, to indicate the intent to transmit a MIMO PPDU to the responder or announce the start of the hybrid beamforming protocol respectively. Otherwise, if the Grant Required field within a responder's EDMG Capabilities is 0, the initiator may optionally transmit a Grant frame to the responder.

In the transmitted Grant frame, the value of the Allocation Duration field plus the Duration field of the Grant frame indicates the estimated time offset from the PHY-TXEND.indication primitive of the Grant frame transmission when the initiator intends to initiate access to the channel to transmit to or start the hybrid beamforming protocol with the responder. For the transmitted Grant frame, the TXVECTOR parameter SCRAMBLER_INIT_SETTING shall be set to CONTROL_TRAILER, the parameter CT_TYPE shall be set to GRANT_RTS_CTS2Self, and the NEXT_TX_SISO parameter shall be set to NextTxMultiAntenna. For hybrid beamforming training, the HBF_TRAINING parameter shall be set NextHBF to indicate that the following transmission from this STA is hybrid beamforming training. The MU_MIMO_NEXT parameter shall be set to NextNotMUMIMO to indicate that the following transmission (see 10.41.10.2.2 (SU-MIMO beamforming)) or hybrid beamforming training (see 10.41.10.2.4 (Hybrid beamforming for SU-MIMO and MU-MIMO)) is performed in SU-MIMO or shall be set to NextMUMIMO to indicate that the following


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transmission (see 10.41.10.2.3 (MU-MIMO beamforming)) or hybrid beamforming training is performed in MU-MIMO. The control trailer shall also indicate the corresponding DMG antenna configuration for the upcoming MIMO transmission or hybrid beamforming training through the TXVECTOR parameters TX_SECTOR_CONFIG_INDEX, MU_MIMO_TX_CONFIG_TYPE and MU_MIMO_TX_CONFIG_INDEX.

If an EDMG STA receives a Grant frame with a control trailer indicating an SU-MIMO or MU-MIMO transmission, or hybrid beamforming training and is able to receive the SU-MIMO or MU-MIMO transmission or perform hybrid beamforming training at the target time indicated by the Grant frame, the EDMG STA shall

— Transmit a Grant Ack frame in response to the received Grant frame.

— In the case when the STA received a Grant frame with a control trailer indicating SU-MIMO transmission or the start of the hybrid beamforming training protocol, for this transmitted Grant Ack frame, the TXVECTOR parameter SCRAMBLER_INIT_SETTING shall be set to CONTROL_TRAILER and the parameter CT_TYPE shall be set to GRANT_RTS_CTS2Self. If it uses SU-MIMO for the transmission in the opposite direction, i.e., from the responder to the initiator, or desires to announce the hybrid beamforming protocol in the opposite direction, the TXVECTOR parameter NEXT_TX_SISO of the Grant Ack shall be set to NextTxMultiAntenna. For hybrid beamforming training, the HBF_TRAINING parameter shall be set NextHBF to indicate that the following transmission from this STA is hybrid beamforming training. The control trailer shall also indicate the corresponding DMG antenna configuration for the upcoming SU-MIMO transmission or hybrid beamforming training in the opposite direction using the TXVECTOR parameter TX_SECTOR_CONFIG_INDEX. If the responder STA intends to use SISO for the transmission in the opposite direction, the TXVECTOR parameter NEXT_TX_SISO of the Grant Ack shall be set to NextTxSingleAntenna.

— Configure its DMG antennas according to the settings included in the control trailer of the received Grant frame within a time period determined by the value of the Allocation Duration field plus the value of the Duration field of the received Grant frame starting from the PHY-TXEND.indication primitive of the Grant frame transmission.

#### 10.38.12.4.3 SU-MIMO channel access procedure

An EDMG STA is SU-MIMO capable if the SU-MIMO Supported field in the STA's EDMG Capabilities element is equal to 1. The SU-MIMO channel access procedure describes how an SU-MIMO capable initiator and an SU-MIMO capable responder shall access the channel to start exchanging one or more EDMG SU PPDUs using SU-MIMO, and also describes how an SU-MIMO capable initiator and responder that are also hybrid beamforming capable start an hybrid beamforming protocol.

Prior to initiating the SU-MIMO channel access with a responder, an initiator shall perform SU-MIMO beamforming with the responder (see 10.41.10.2.2 (SU-MIMO beamforming)).

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An EDMG STA, the SU-MIMO initiator, initiates SU-MIMO channel access by transmitting an RTS frame or a DMG CTS-to-self frame to the intended SU-MIMO responder. The SU-MIMO initiator shall transmit the RTS or DMG CTS-to-self frame with a control trailer to the SU-MIMO responder. The RTS or DMG CTS-to-self frame shall be transmitted using the same set of DMG antennas and antenna configuration planned to be used during the SU-MIMO transmission or hybrid beamforming training, and with a CSD between the transmissions in different antennas as defined in 28.4.7.2 (Non-EDMG PPDU transmission) and 28.4.7.3.3 (EDMG duplicate preamble and Data field transmission over a 4.32 GHz, 6.48 GHz, 8.64 GHz, and 4.32+4.32 GHz channel). For the transmitted RTS or DMG CTS-to-self frame, the TXVECTOR parameter SCRAMBLER_INIT_SETTING shall be set to CONTROL_TRAILER, the parameter CT_TYPE shall be set to GRANT_RTS_CTS2Self, the NEXT_TX_SISO parameter shall be set to NextTxMultiAntenna and the MU_MIMO_NEXT parameter shall be set to NextNotMUMIMO to indicate that the following transmission or hybrid beamforming training is performed in SU-MIMO. For hybrid beamforming training, the HBF_TRAINING parameter shall be set NextHBF to indicate that the following transmission from this STA is hybrid beamforming training. The control trailer shall also indicate the corresponding DMG antenna configuration for the upcoming SU-MIMO transmission or hybrid beamforming training through the TXVECTOR parameter TX_SECTOR_CONFIG_INDEX.

If an SU-MIMO initiator transmits to a responder a DMG CTS-to-self frame that contains a control trailer indicating an SU-MIMO transmission, all the PPDUs transmitted by the initiator to the responder within this TXOP shall use the antenna setting indicated in the TXVECTOR parameter TX_SECTOR_CONFIG_INDEX. For transmissions in the opposite direction, the initiator should configure its receive DMG antennas according to the settings included in the control trailer of the last Grant Ack frame received from the responder and the responder should use the antenna setting indicated in this same transmitted Grant Ack frame. If there was no prior Grant/Grant Ack frame exchange sequence(#109) between the initiator and the responder, the SISO antenna setting should be used instead.

If an SU-MIMO initiator uses a DMG CTS-to-self frame to switch to SU-MIMO transmission in a TDD slot, the initiator and responder shall communicate using SU-MIMO transmissions until one of the following occurs:

— The initiator transmits to the responder a DMG CTS-to-self frame with TXVECTOR parameters CT_TYPE set to GRANT_RTS_CTS-2self and NEXT_TX_SISO set to NextTxSingleAntenna; or

— Beamforming training between the initiator and responder.

If a responder receives an RTS frame with a control trailer indicating an SU-MIMO transmission or a hybrid beamforming announcement addressed to itself and is able to perform the SU-MIMO reception or hybrid beamforming training, the responder shall

— Configure its DMG antennas according to the settings indicated in the RXVECTOR parameter TX_SECTOR_CONFIG_INDEX of the received RTS frame.

— Transmit a DMG CTS frame with a control trailer in response of the received RTS frame. For this transmitted DMG CTS frame, the TXVECTOR parameter SCRAMBLER_INIT_SETTING shall be set to CONTROL_TRAILER and the parameter CT_TYPE shall be set to CTS_DTS.

— If the responder uses SU-MIMO for the transmission in the opposite direction (i.e., from the EDMG STA receiving the RTS frame to the EDMG STA transmitting the RTS frame) or desires to announce the hybrid beamforming protocol in the opposite direction, the TXVECTOR parameter NEXT_TX_SISO of the DMG CTS frame shall be set to NextTxMultiAntenna and the MU_MIMO_NEXT parameter shall be set to NextNotMUMIMO. For hybrid beamforming training, the HBF_TRAINING parameter shall be set NextHBF to indicate that the following transmission from this STA is hybrid beamforming training. The control trailer shall also indicate the corresponding DMG antenna configuration for the upcoming SU-MIMO transmission or hybrid beamforming training in the opposite direction using the TXVECTOR parameter TX_SECTOR_CONFIG_INDEX. The DMG CTS frame shall be transmitted using the same set of DMG antennas and antenna configuration planned to be used during the SU-MIMO transmission or hybrid beamforming training, and with a CSD between the transmissions in different antennas as


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defined in 28.4.7.2 (Non-EDMG PPDU transmission) and 28.4.7.3.3 (EDMG duplicate preamble and Data field transmission over a 4.32 GHz, 6.48 GHz, 8.64 GHz, and 4.32+4.32 GHz channel).

— If the responder uses SISO for the transmission in the opposite direction, the TXVECTOR parameter NEXT_TX_SISO of the DMG CTS frame shall be set to NextTxSingleAntenna and the DMG CTS frame shall be sent using the SISO antenna setting.

Alternatively, if the responder is not able to perform the SU-MIMO reception or hybrid beamforming training, it may transmit a DMG DTS frame with a control trailer to the initiator to provide further information. The DMG DTS frame shall be sent using the SISO antenna setting.

A responder that receives a DMG CTS-to-self frame with a control trailer indicating a SU-MIMO transmission or hybrid beamforming training addressed to itself and is able to perform the SU-MIMO reception or hybrid beamforming training shall

— Configure its DMG antennas according to the settings included in the RXVECTOR parameter TX_SECTOR_CONFIG_INDEX of the received CTS-to-self frame; and

— Begin the SU-MIMO reception or hybrid beamforming training SIFS following the end of the DMG CTS-to-self frame transmission by the initiator.

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Figure 10-69 (SU-MIMO channel access procedure when RTS/DMG CTS is used(11ay)) and Figure 10-70 (SU-MIMO channel access procedure when DMG CTS-to-self is used(11ay)) illustrate examples of frame exchange sequences using the SU-MIMO channel access procedure.

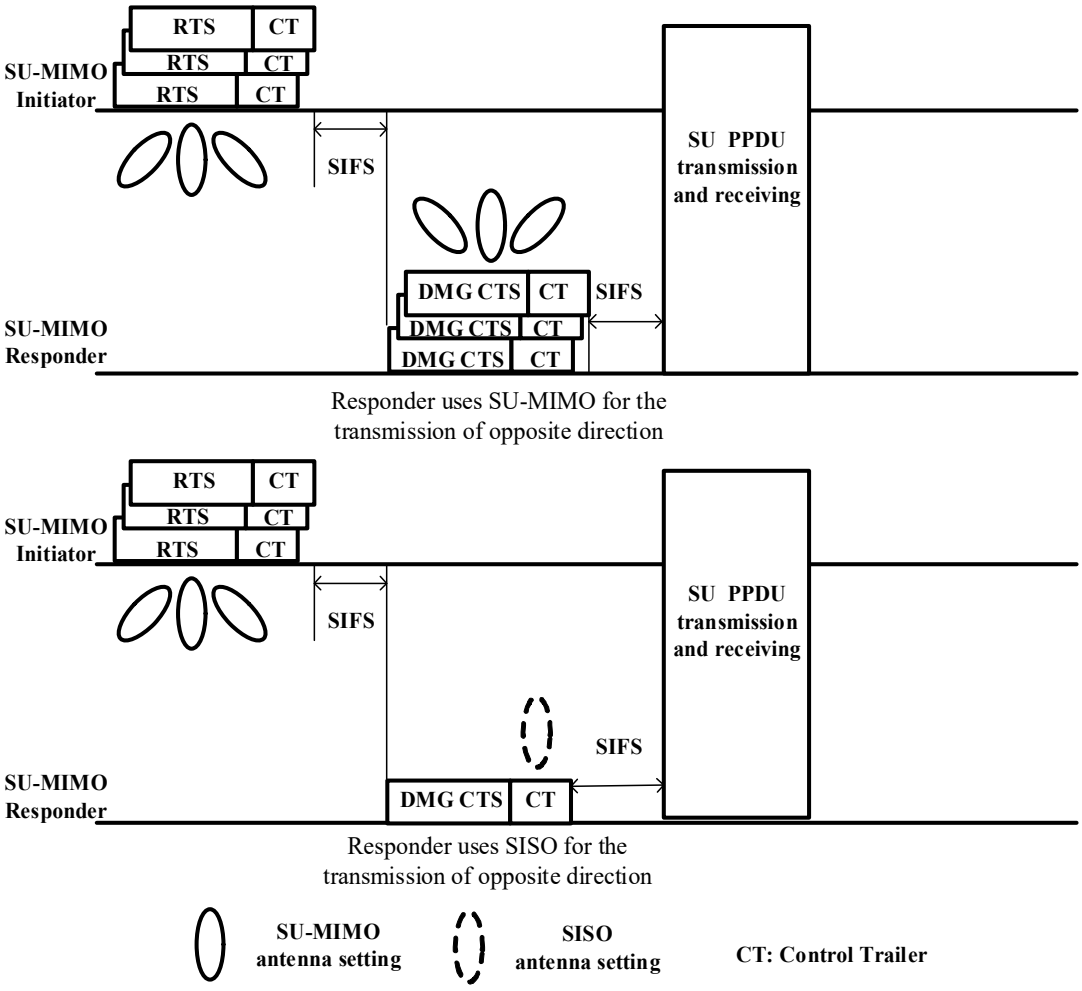


**Figure 10-69—SU-MIMO channel access procedure when RTS/DMG CTS is used(11ay)**

An SU-MIMO initiator may send a CF-End frame to reset the NAV and release the remaining time of the TXOP. If the CF-End is transmitted, it shall be sent using the same set of DMG antennas and antenna configuration during the SU-MIMO transmission or hybrid beamforming training and a CSD between the transmissions in different antennas as defined in 28.4.7.2 (Non-EDMG PPDU transmission).

### 10.38.12.4.4 MU-MIMO channel access procedure

An EDMG STA is MU-MIMO capable if the MU-MIMO Supported subfield of the Beamforming Capability subelement in the STA's EDMG Capabilities element is 1. The MU-MIMO channel access procedure describes how an MU-MIMO capable initiator and multiple MU-MIMO capable responders shall access the channel to start exchanging one or more EDMG MU PPDUs, and also describes how an MU-MIMO capable initiator and multiple MU-MIMO capable responders that are also hybrid beamforming capable (see 10.41.10.2.4 (Hybrid beamforming for SU-MIMO and MU-MIMO)) start the hybrid beamforming protocol.


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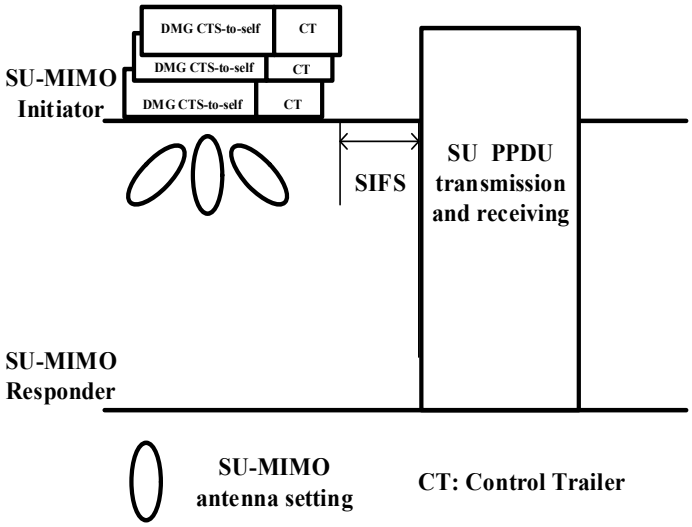


**Figure 10-70—SU-MIMO channel access procedure when DMG CTS-to-self is used(11ay)**

Prior to initiating the MU-MIMO channel access with a set of responder STAs within an MU group, the initiator shall

— Include the MU group within the EDMG Group ID Set element and communicate the resulting element to the STAs in the BSS (see 10.41.10.2.3 (MU-MIMO beamforming)).

— Perform MU-MIMO beamforming with the responders of the MU group (see 10.41.10.2.3 (MU-MIMO beamforming)).

An EDMG STA initiates MU-MIMO channel access by transmitting an RTS frame or a DMG CTS-to-self frame to the intended MU-MIMO group of responders. The EDMG STA shall transmit the RTS frame or DMG CTS-to-self frame with a control trailer to the group of responders. The RTS or DMG CTS-to-self frame shall be transmitted using the same set of DMG antennas and antenna configuration planned to be used during the MU-MIMO transmission or hybrid beamforming training, and a CSD between the transmissions in different antennas as defined in 28.4.7.2 (Non-EDMG PPDU transmission). The TA field of the transmitted DMG CTS-to-self frame shall be set to the broadcast address.

For the transmitted RTS or DMG CTS-to-self frame, the TXVECTOR parameter SCRAMBLER_INIT_SETTING shall be set to CONTROL_TRAILER, the parameter CT_TYPE shall be set to GRANT_RTS_CTS2self, the parameter NEXT_TX_SISO shall be set to NextTxMultiAntenna, and the parameter MU_MIMO_NEXT shall be set to NextMUMIMO to indicate that the following PPDU transmitted by the initiator is an EDMG MU PPDU. In addition to the previous settings, for hybrid beamforming training the HBF_TRAINING parameter shall be set NextHBF to indicate that the following transmission from this STA is hybrid beamforming training. The TXVECTOR parameter EDMG_GROUP_ID shall be set to the value that identifies the corresponding group of responders that are the intended destinations of the EDMG MU PPDU to be transmitted or the intended recipients of the hybrid beamforming training. The TXVECTOR parameters MU_MIMO_TX_CONFIG_TYPE and MU_MIMO_TX_CONFIG_INDEX indicate the corresponding DMG antenna configuration for the upcoming MU-MIMO transmission or hybrid beamforming training. The RA field of the RTS shall be set to the broadcast address. After transmitting the RTS frame, the initiator should configure its receive antenna to a quasi-omni receive pattern to receive the DMG CTS.

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An initiator that transmits an RTS frame or a DMG CTS-to-self frame addressed to an MU group shall set the TXVECTOR parameter IS_CHANNEL_NUMBER to ChannelWidth and shall set the BW_IN_CT to indicate the bandwidth to be used for all EDMG MU PPDU transmissions within the TXOP or SP allocation.

When a responder receives an RTS frame addressed to an MU group and belongs to the corresponding MU-MIMO transmission configuration indicated in the control trailer, if the responder is able to perform the MU-MIMO reception then it shall

— Transmit a DMG CTS frame back to the initiator employing the most recent SISO antenna configuration used between the responder and the initiator. The TA field of the DMG CTS frame shall be set to the broadcast address.

Following the transmission of the DMG CTS frame, the responder shall then configure its antennas according to the settings indicated in the RXVECTOR parameters MU_MIMO_TX_CONFIG_TYPE and MU_MIMO_TX_CONFIG_INDEX of the received RTS frame.

For the successful reception of the DMG CTS frame, the difference in time between all the DMG CTS transmissions as measured at the receiving STA should be no more than $T_{GI\ normal}$ (see 28.5.2.2 (Timing-related parameters)). A STA that transmits the DMG CTS should precompensate for carrier frequency offset error to mitigate the frequency error in the transmitted signal.

The MU-MIMO transmission or hybrid beamforming training shall begin (#7226)between a SIFS and a SIFS + 10% × (aSlotTime – aAirPropagationTime) following the reception or expected reception of the DMG CTS frame by the initiator. This is shown in Figure 10-71 (MU-MIMO channel access flow when RTS/DMG CTS is used(11ay)).

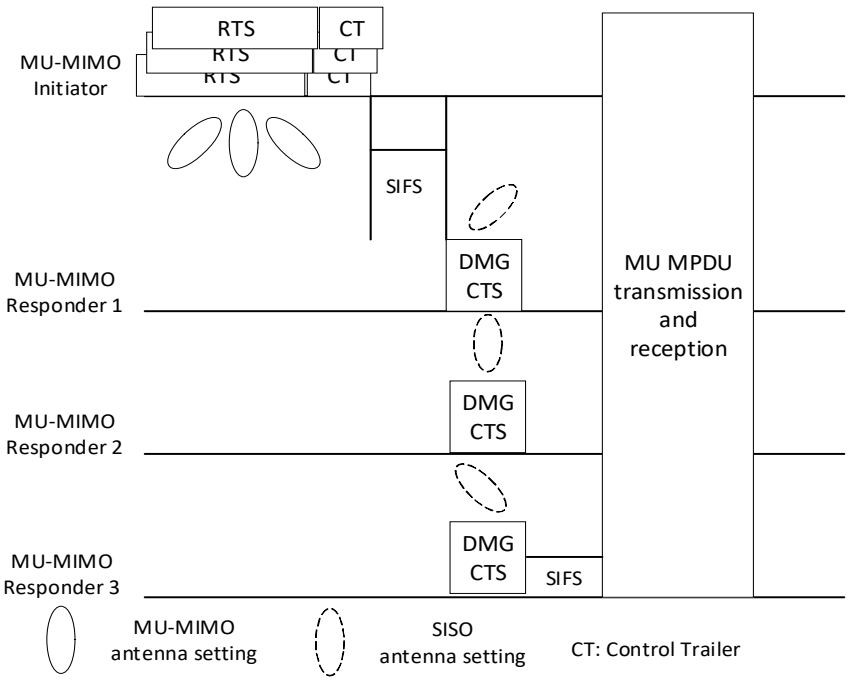


**Figure 10-71—MU-MIMO channel access flow when RTS/DMG CTS is used(11ay)**

NOTE—If an RTS/DMG CTS frame exchange sequence(#109) is used to obtain MU-MIMO channel access, the successful reception of the DMG CTS frame at the initiator is not required to proceed with the MU-MIMO channel access.


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When a responder receives a DMG CTS-to-self frame addressed to an MU group and belongs to the corresponding MU-MIMO transmission configuration indicated in the control trailer, if the responder is able to perform the MU-MIMO reception then it shall configure its antennas according to the settings indicated in the RXVECTOR parameters MU_MIMO_TX_CONFIG_TYPE and MU_MIMO_TX_CONFIG_INDEX of the received CTS-to-self frame. The MU-MIMO transmission or hybrid beamforming shall begin a SIFS following the end of the DMG CTS-to-self frame transmission by the initiator. This is shown in Figure 10-72 (MU-MIMO channel access flow when DMG CTS-to-self is used(11ay)).

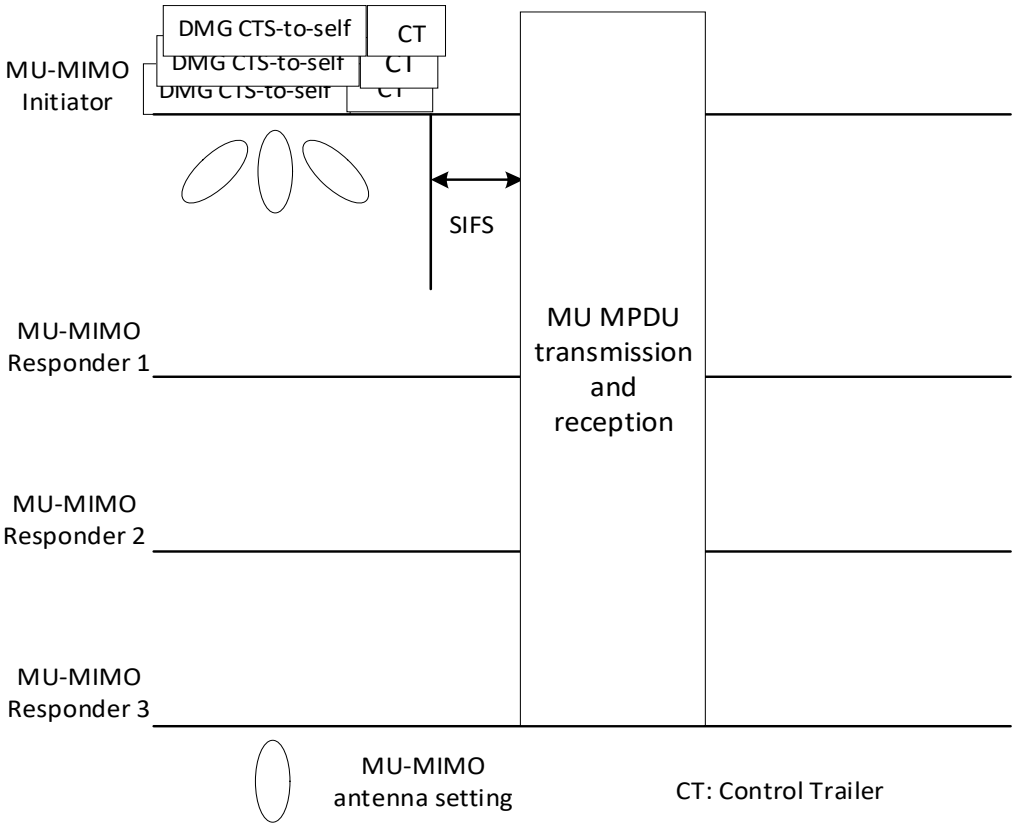


**Figure 10-72—MU-MIMO channel access flow when DMG CTS-to-self is used(11ay)**

Subclause 10.3.2.13 (MU acknowledgment procedure) describes the MU PPDU acknowledgment procedure.

The initiator may send a CF-End frame to one or more responders in an MU-MIMO TXOP to truncate the TXOP.

### 10.38.12.5 Control trailer

To provide additional control signaling, a control trailer may be inserted in a control mode PPDU transmitted to an EDMG STA. An EDMG STA shall set the TXVECTOR parameter SCRAMBLER_INIT_SETTING to CONTROL_TRAILER to indicate the presence of the control trailer in a control mode PPDU and shall set the TXVECTOR parameter CT_TYPE to indicate the type of control trailer to be included in the PPDU. The control trailer is defined in 28.3.7 (Control trailer).

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#### 10.38.12.6 "Near-Far" self classification

A non-PCP and non-AP EDMG STA may estimate whether its signal can be successfully received by an EDMG PCP or EDMG AP that is listening in quasi-omni mode, i.e., to classify itself as a "Near" or a "Far" STA to the PCP or AP. This allows the EDMG STA to decide whether to access the A-BFT (if it is classified as "Near") or to use asymmetric beamforming (if it classified as "Far") as defined in 10.41.10.3 (Beamforming for asymmetric links). To enable this, the PCP or AP informs EDMG STAs about its link budget parameters combined in one value, the PCP/AP Coverage Parameter subfield, which is transmitted in the SSW field of the DMG Beacon frame.

An EDMG STA may classify itself as a "Near" STA if the following inequality is true:

$$P_{APrx} = (EIRP_{STA} - G_{STArx}) + RSSI - C > P_{min\_sensitivity}$$

where

| | |
|---|---|
| $P_{APrx}$ | is an estimation by the STA of the expected power that the STA's transmission is received by the PCP/AP |
| $EIRP_{STA}$ | is set to $P_{STA} + G_{STAtx}$, where $P_{STA}$ and $G_{STAtx}$ are the transmit power and antenna gain for the expected STA transmission |
| $G_{STArx}$ | is the STA's receive antenna gain during DMG Beacon reception |
| $RSSI$ | is the power that was measured by the STA during DMG Beacon reception |
| $C$ | is the value of the PCP/AP Coverage Parameter subfield contained in the SSW field within the received DMG Beacon frame |
| $P_{min\_sensitivity}$ | is the receiver sensitivity for MCS 0 defined in Table 20-3 (Receiver minimum input level sensitivity) |

Otherwise if the above inequality is false, the EDMG STA may classify itself as a "Far" STA.

Figure 10-73 (Example behavior for "Near-Far" self classification(11ay)) illustrates an example behavior used by an EDMG STA to classify itself as "Near" or "Far". After reception of a DMG Beacon frame from an EDMG PCP or EDMG AP that has a valid PCP/AP Coverage Parameter subfield in the SSW field, the EDMG STA checks inequality specified above. In case the inequality is true, EDMG STA classifies itself as a "Near" EDMG STA for this PCP/AP and decides to access the A-BFT or the DTI. In case the inequality is false, the EDMG STA classifies itself as a "Far" EDMG STA for this PCP or AP, and therefore it decides to skip the A-BFT and use asymmetric beamforming, if scheduled by the PCP or AP, to establish communication with the PCP or AP.

## 10.39 DMG and CMMG AP or PCP clustering

### 10.39.1 General

An AP or PCP may use the AP or PCP clustering mechanism to improve spatial sharing and interference mitigation with other co-channel DMG BSSs. An AP or PCP may use the AP or PCP clustering mechanism to improve spatial sharing and interference mitigation with other co-channel CMMG BSSs. There are two types of clustering:

— Decentralized AP or PCP clustering that involves a single S-AP or S-PCP in the BSA of the S-AP or S-PCP

— Centralized AP or PCP clustering where there can be multiple S-APs in the BSA of any one S-AP, and all S-APs are coordinated via a single centralized coordination service set

AP or PCP clustering allows an AP or PCP that is a member of a cluster to schedule transmissions in nonoverlapping time periods with respect to other members of the same cluster since the AP or PCP can


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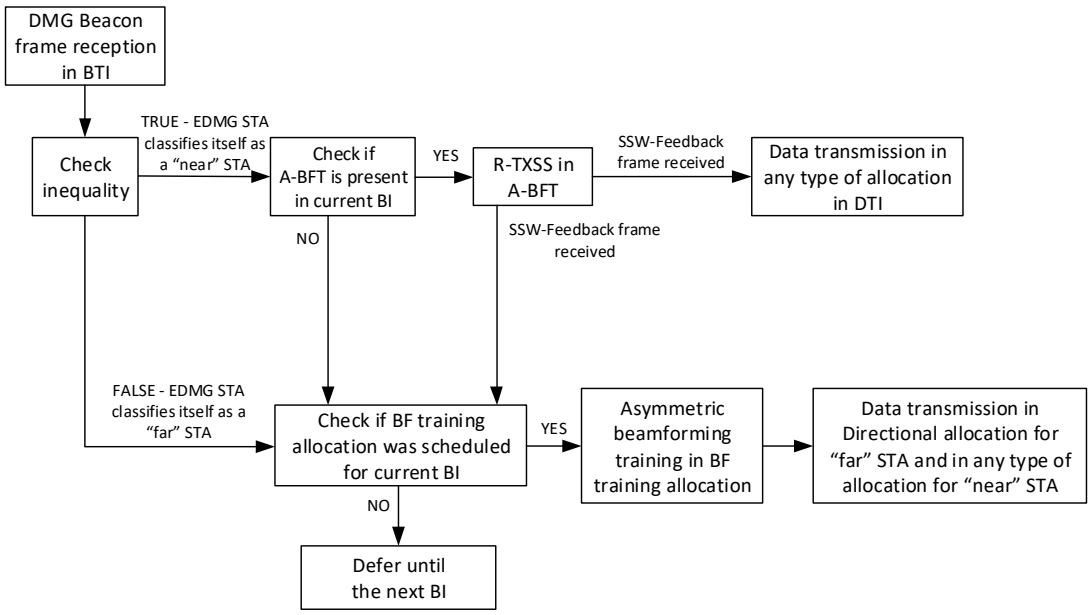


**Figure 10-73—Example behavior for "Near-Far" self classification(11ay)**

receive DMG Beacon and Announce frames containing the Extended Schedule element of other APs and PCPs that are members of the cluster and can also receive the Extended Schedule element from another BSS through associated non-AP and non-PCP STAs (10.39.4 (Cluster report and rescheduling)).

A STA is decentralized AP or PCP clustering capable if it sets the Decentralized AP or PCP Clustering field to 1 within the DMG AP Or PCP Capability Information field in the DMG Capabilities element. A STA is decentralized AP or PCP clustering capable if it sets the Decentralized AP or PCP Clustering field to 1 within the CMMG AP Or PCP Capability Information field in the CMMG Capabilities element. A STA is centralized AP or PCP clustering capable if it sets the Centralized AP or PCP Clustering field to 1 within the DMG AP Or PCP Capability Information field in the DMG Capabilities element. A STA is centralized AP or PCP clustering capable if it sets the Centralized AP or PCP Clustering field to 1 within the CMMG AP Or PCP Capability Information field in the CMMG Capabilities element. The AP or PCP employs the Clustering Control field and ECAPC Policy Enforced field defined in 9.3.4.2 (DMG Beacon) to configure the use of AP or PCP Clustering. A decentralized AP or PCP clustering capable or centralized AP or PCP clustering capable AP or PCP that transmits the Clustering Control field is decentralized clustering enabled or centralized clustering enabled, respectively.

An AP or PCP cluster includes one S-AP or S-PCP and zero or more member APs and PCPs. Decentralized clustering enabled APs and PCPs operating on the same channel may form a decentralized AP or PCP cluster. The Cluster ID of the decentralized AP or PCP cluster shall be set to the MAC address of the S-AP or S-PCP. Centralized clustering enabled APs and PCPs operating on the same channel as a S-AP form a centralized AP or PCP cluster as described in 10.39.2.2 (Centralized AP or PCP cluster formation). The Cluster ID of the centralized AP or PCP cluster shall be set to the MAC address of the S-AP.

A clustering enabled AP or PCP that is not a member of any cluster shall set the Cluster Member Role subfield to 0 in transmitted frames that contain the Clustering Control field.

Each AP or PCP that is a member of an AP or PCP cluster shall include the Clustering Control field in each DMG Beacon frame it transmits.

For each cluster, there exists a set of ClusterMaxMem Beacon SPs. The $n^{th}$ Beacon SP, Beacon $SP_n$, begins at $ClusterTimeOffset_{n-1}$ μs following the TBTT of the S-AP or S-PCP, where

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$ClusterTimeOffset_{n-1} = 1024 \times (dot11BeaconPeriod/ClusterMaxMem) \times (n–1)$

and $n$=2, 3,…, *ClusterMaxMem*

The $ClusterTimeOffset_{n-1}$ and Beacon $SP_n$ where $n$ equals one is reserved for the S-AP or S-PCP.

An AP or PCP that is a member of an AP or PCP cluster shall transmit its DMG Beacon frame during one of the Beacon SPs as specified in 10.39.2 (Cluster formation).

The maximum size of the Beacon SP Duration field transmitted by a S-AP or S-PCP shall be the beacon interval of the S-AP or S-PCP divided by ClusterMaxMem.

### 10.39.2 Cluster formation

#### 10.39.2.1 Decentralized AP or PCP cluster formation

A clustering enabled AP or PCP starts a decentralized AP or PCP cluster by becoming an S-AP or S-PCP, subject to the absence of existing clusters as described below and in 10.39.2.2 (Centralized AP or PCP cluster formation). A decentralized clustering enabled AP or PCP becomes an S-AP or S-PCP of a decentralized AP or PCP cluster by transmitting a DMG Beacon frame at least once every aMinBTIPeriod beacon intervals that has the ECAPC Policy Enforced subfield in the DMG Parameters field set to 0 and that includes a Clustering Control field with the Beacon SP Duration subfield set to dot11BeaconSPDuration, the Cluster ID subfield set to the S-AP or S-PCP MAC address, and the Cluster Member Role subfield set to the value for an S-AP or S-PCP. The value of ClusterMaxMem subfield shall be chosen to keep the result of (beacon interval length/ClusterMaxMem) as an integer number of microseconds.

A decentralized clustering enabled AP or PCP that receives a DMG Beacon frame with the ECAPC Policy Enforced subfield in the DMG Parameters field set to 0 from an S-AP or S-PCP on the channel the AP or PCP selects to establish a BSS shall monitor the channel for DMG Beacon frame transmissions during each Beacon SP for an interval of length at least aMinChannelTime. A Beacon SP is empty if no DMG Beacon frame is received during the Beacon SP over an interval of length aMinChannelTime. The AP or PCP shall not become a member of the cluster if no Beacon SP is determined to be empty during aMinChannelTime, in which case, subject to the requirements described in 10.39.2.2 (Centralized AP or PCP cluster formation), (#1416)the AP or PCP may become the S-AP or S-PCP of a new cluster, or may cease its activity on this channel and may attempt operation on a different channel.

A decentralized clustering enabled AP or PCP that operates its BSS on a channel on which it discovered an S-AP or S-PCP within a decentralized AP or PCP cluster and at least one empty Beacon SP shall transmit its DMG Beacon frame during an empty Beacon SP. By transmitting its DMG Beacon frame during an empty Beacon SP and by setting the clustering control field appropriately as described in 9.3.4.2 (DMG Beacon), the AP or PCP becomes a member AP or member PCP.

The member AP or member PCP shall select a beacon interval length that is equal to the beacon interval length of its S-AP or S-PCP.

The member AP or member PCP shall transmit its DMG Beacon frame with the ECAPC Policy Enforced field set to 0, the Beacon SP Duration subfield set to the value of the Beacon SP Duration subfield contained in the S-AP or S-PCP DMG Beacon frame(#337), the Cluster ID subfield set to the MAC address of the S-AP or S-PCP, the Cluster Member Role subfield set to the member AP or member PCP value, and the ClusterMaxMem subfield set to the value of the ClusterMaxMem field contained in the S-AP or S-PCP DMG Beacon frame(#337).

An AP or PCP with a value of Cluster Member Role that is not zero shall schedule a Beacon SP that is allocated for DMG Beacon frame transmission of other cluster member APs and PCPs within the


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decentralized AP or PCP cluster at each of $ClusterTimeOffset_n$, at any time the AP or PCP transmits its own DMG Beacon frame(#337). The minimum size of the Beacon SP should be equal to the value of the Beacon SP Duration subfield within the S-AP or S-PCP DMG Beacon.

An S-AP or S-PCP and a member AP or member PCP of a decentralized AP or PCP cluster should not transmit or schedule transmissions during a Beacon SP that is not its own Beacon SP.

Figure 10-74 (Decentralized AP or PCP clustering for 3 APs and PCPs) illustrates, for three APs and PCPs, the Beacon SPs of the S-AP or S-PCP and member APs and PCPs of a decentralized AP or PCP cluster.

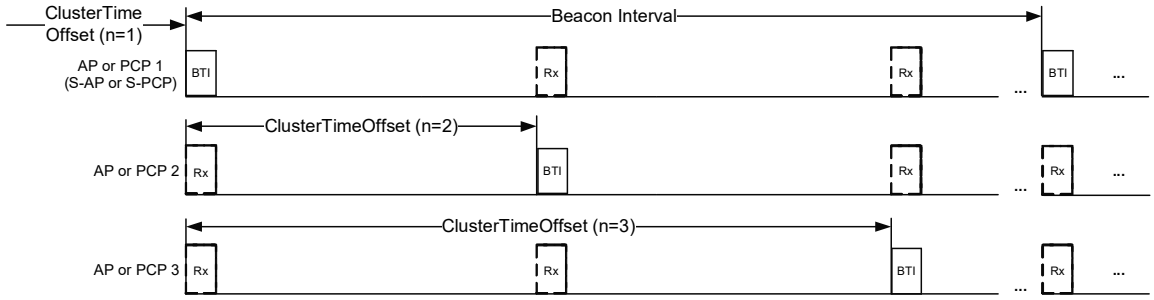


**Figure 10-74—Decentralized AP or PCP clustering for 3 APs and PCPs**

### 10.39.2.2 Centralized AP or PCP cluster formation

In order to become an S-AP, a centralized clustering enabled STA that is stationary with respect to its local environment shall successfully perform both the following steps in order:

- Configuration step
- Verification step

Once these steps have been performed successfully, the STA has become an S-AP.

- *Configuration step*: The configuration step is defined to be successful if the following occur:
  - The STA obtains the MAC address of the CCSR; and
  - The STA obtains an ECAPC Policy Detail field, beacon interval, ClusterMaxMem, Beacon SP Duration, TXSS CBAP Offset, TXSS CBAP Duration, TXSS CBAP MaxMem, TSF synchronization parameters, Cluster Time Offset availability information, and a nonempty list of excluded channels for the intended operating class of the STA from the CCSR; and
  - Either channel 2 is an allowed channel in the current regulatory domain and the list of excluded channels includes channel 2, or channel 2 is not an allowed channel in the current regulatory domain; and
  - The beacon interval/ClusterMaxMem is an integer number of microseconds; and
  - At least one of beacon interval/TXSS CBAP MaxMem or TXSS CBAP MaxMem/beacon interval is an integer.

  Otherwise, the configuration step is defined to be unsuccessful. If the configuration step is unsuccessful, then the STA can attempt to resolve the problem or quit attempting to start a centralized AP or PCP cluster. The method by which the STA obtains the configuration information from the CCSR is not defined in this standard.
- *Verification step*: The verification step is defined to be the following procedure:
  - The centralized clustering enabled STA monitors the channel for DMG Beacon frames over an interval of at least aMinChannelTime.

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— During this monitoring period, for each distinct Cluster ID received in a DMG Beacon frame that has the ECAPC Policy Enforced field set to 1 in the DMG Parameters field and Cluster Member Role set to 1 (S-AP or S-PCP of the cluster) or 2 (a member AP or member PCP of the cluster), the centralized clustering enabled STA determines if an S-AP with a MAC address equal to the Cluster ID belongs to the same CCSS as the centralized clustering enabled STA, via i) attempting to receive an Announce frame from the S-AP that transmitted the DMG Beacon frame according to the channel access rules described in 10.38 (DMG and CMMG channel access) in order to solicit an ECAPC Policy element or ii) any other means. Any such DMG Beacon frame whose transmitter cannot be determined in this way to belong to the same CCSS as the centralized clustering enabled STA is defined to be from another ECAPC.

The verification step is defined to be unsuccessful if, at the end of the monitoring period, there are one or more received DMG Beacon frames that are from another ECAPC. Otherwise, the verification step is defined to be successful.

If a centralized clustering enabled STA receives at least one DMG Beacon frame that has the ECAPC Policy Enforced field set to 1 and from a member AP, S-AP, or member PCP of another ECAPC during the monitoring period and the STA is not an ECAPC policy blind AP or PCP, the STA

— Shall cease its activity on this channel and may attempt operation on a different channel, or

— If one of the received DMG Beacon frames was sent by an S-AP, may elect to unenroll from its current CCSS and join the cluster of the S-AP as a member AP or member PCP.

If a centralized clustering enabled STA receives at least one DMG Beacon frame that has the ECAPC Policy Enforced field set to 1 from an S-AP from the same CCSS during the monitoring period and the STA is not an ECAPC policy blind AP or PCP, the STA may elect either to unenroll from its current CCSS and join the cluster of the S-AP as a member AP or member PCP or to continue and become an S-AP in the CCSS.

In order to become an S-AP in a centralized AP or PCP cluster, a centralized clustering enabled STA shall take the following actions:

— Set dot11ChannelUsageImplemented to true

— Start a BSS as an AP

  — On a channel that is not listed as excluded by the CCSR, and

  — At the start time and with the beacon interval configured by the CCSR

— Include in transmitted DMG Beacon frames

  — The ECAPC Policy Enforced field set to 1 in the DMG Parameters field, and

  — A Clustering Control field with the ClusterMaxMem subfield set to the values configured by the CCSR, the Beacon SP Duration subfield set to the value most recently configured by the CCSR, the Cluster ID subfield set to the S-AP MAC address, and the Cluster Member Role subfield set to 1 (S-AP or S-PCP of the cluster).

An S-AP in a centralized AP or PCP cluster shall set the ECAPC Policy Enforced subfield in the DMG Parameters field to 1 for the lifetime of the BSS.

An S-AP within a centralized AP or PCP cluster shall include the ECAPC Policy element in (Re)Association Response, Announce, and Information Response frames with the ECAPC Policy Detail, TXSS CBAP Offset, and TXSS CBAP Duration fields set to the respective values most recently configured by the CCSR for the S-AP, the TXSS CBAP MaxMem subfield set to the policy configured by the CCSR, the CCSR ID subfield set to the MAC address of the CCSR, and bits in the Available Cluster Time Offset Bitmap subfield set to 0 to indicate the Cluster Time Offsets that are determined to be already in use, excluding the recipient if sent within an individually addressed frame. The means by which a Cluster Time Offset is determined to be in use are unspecified. Bits in the Available Cluster Time Offset Bitmap subfield for other Cluster Time Offsets shall be set to 1.


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An AP or PCP that

— receives a DMG Beacon frame that has the ECAPC Policy Enforced subfield in the DMG Parameters field set to 1 from an S-AP on a channel and

— does not receive at least one DMG Beacon frame that has the ECAPC Policy Enforced subfield in the DMG Parameters field set to 1 from S-AP on every channel supported by the AP or PCP in the Operating Class within the next aMinChannelTime and

— is not an ECAPC policy blind AP or PCP

shall either join the cluster of the S-AP as a member AP or member PCP if centralized clustering enabled or cease its activity on this channel and may attempt operation on a different channel. S-APs within a CCSS report the channels unused by the ECAPC via the (#3311)channel usage procedures (see 11.21.15 (Channel usage procedures)).

An AP or PCP within a decentralized AP or PCP cluster that

— receives a DMG Beacon frame that has the ECAPC Policy Enforced subfield in the DMG Parameters field set to 1 from an S-AP and

— does not receive at least one DMG Beacon frame that has the ECAPC Policy Enforced subfield in the DMG Parameters field set to 1 from an S-AP on every channel supported by the AP or PCP in the Operating Class within the next aMinChannelTime (i.e., does not become a ECAPC policy blind AP ) and

— is not already an ECAPC policy blind AP or PCP

shall quit the decentralized AP or PCP cluster before the next TBTT + beacon interval length, then the AP or PCP shall either join the cluster of the S-AP as a member AP or member PCP if centralized AP or PCP clustering enabled or cease its activity on this channel and may attempt operation on a different channel.

An AP or PCP that receives at least one DMG Beacon frame that has the ECAPC Policy Enforced subfield in the DMG Parameters field set to 1 sent by an S-AP on every channel supported by the AP or PCP in the Operating Class within the most recent aMinChannelTime ignores the ECAPC Policy Enforced subfield (i.e., treats this subfield as though equal to 0) in DMG Beacon frames received from S-APs for 300 × aMinChannelTime. During this period, the AP or PCP is called an *ECAPC policy blind AP or PCP*.

NOTE—An AP or PCP within a decentralized AP or PCP cluster does not cease DMG Beacon frame transmission when quitting a decentralized AP or PCP cluster. Hence, data communication is unaffected while performing these procedures.

A centralized clustering enabled AP or PCP that attempts to join the centralized AP or PCP cluster of an S-AP as a member AP or member PCP shall be a STA coordinated by an MM-SME that also coordinates a second non-AP and non-PCP STA, and shall successfully perform the following steps in order:

— The AP or PCP shall monitor the channel for DMG Beacon frames during each Beacon SP over an interval of length at least aMinChannelTime. A Beacon $SP_n$ is empty if no DMG Beacon frame is received during the Beacon $SP_n$ over an interval of length aMinChannelTime.

— The second non-AP and non-PCP STA shall attempt to associate with the S-AP and thereby receive an Announce frame from the S-AP. The contents of the Announce frame are passed to the AP or PCP.

— Upon receiving an Announce frame that includes the ECAPC Policy element, the AP or PCP shall select a Cluster Time Offset index from the intersection of a) the Cluster Time Offset indices of the empty Beacon SPs with b) the indices indicated by the Available Cluster Offset Bitmap field in the ECAPC Policy element. If the intersection is empty, the AP or PCP shall select a Cluster Time Offset index of an empty Beacon SP. The selected Cluster Time Offset index is passed to the second non-AP and non-PCP STA.

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— The second non-AP and non-PCP STA shall respond to the Announce frame with an Information Response frame that includes the Cluster Time Offset element containing the Cluster Time Offset Index set to the selected index.
— The AP or PCP shall operate its BSS at the selected Cluster Time Offset on the channel of the S-AP and include the AP or PCP clustering control field in transmitted DMG Beacon frames.

The AP or PCP shall not become a member of the centralized AP or PCP cluster if no Beacon SP is determined to be empty during aMinChannelTime or if the second non-AP and non-PCP STA did not associate to the S-AP, in which case the AP or PCP may attempt to join the cluster of another S-AP or cease its activity on this channel and may attempt operation on a different channel.

A member AP or member PCP within a centralized AP or PCP cluster shall select a beacon interval that is equal to the beacon interval of the S-AP of the cluster.

The member AP or member PCP within a centralized AP or PCP cluster shall transmit its DMG Beacon frames with the ECAPC Policy Enforced subfield in the DMG Parameters field set to 1, the Beacon SP Duration subfield in the Clustering Control field set to the value of the Beacon SP Duration subfield contained in the most recently received S-AP DMG Beacon frame(#337), the Cluster ID subfield set to the MAC address of the S-AP, the Cluster Member Role subfield set to 2 (a member AP or member PCP of the cluster), and the ClusterMaxMem subfields set to the value of the ClusterMaxMem field contained in the S-AP DMG Beacon.

A member AP or member PCP within a centralized AP or PCP cluster shall include the ECAPC Policy element in (Re)Association Response, Announce, and Information Response frames with the ECAPC Policy Detail, TXSS CBAP Offset, and TXSS CBAP Duration fields set to the most recently received respective field from the S-AP of the cluster, the TXSS CBAP MaxMem field set to the value of the TXSS CBAP MaxMem field received from the S-AP of the cluster, with the CCSR ID set to the MAC address of the CCSR field received from the S-AP of the cluster, and with the Available Cluster Time Offset Bitmap field reserved.

At any time an AP or PCP within a centralized AP or PCP cluster transmits a DMG Beacon frame, the AP or PCP shall schedule a Beacon SP that reserves time for BHI transmission by other APs and PCPs within the centralized AP or PCP cluster at each in use $\text{ClusterTimeOffset}_{n-1}$ as indicated by the most recently transmitted (if S-AP) or received (if member AP or member PCP) Available Cluster Time Offset Bitmap. The minimum size of the Beacon SP shall be equal to the value of the Beacon SP Duration subfield within the DMG Beacon frame of the S-AP of the centralized AP or PCP cluster. A member AP, S-AP, or member PCP of a centralized AP or PCP cluster shall not transmit or schedule transmissions during a Beacon SP of another member AP, S-AP, or member PCP.

### 10.39.3 Cluster maintenance

#### 10.39.3.1 General cluster maintenance

The TBTT of the S-AP or S-PCP provides a timing reference for the Beacon SPs of the member APs and PCPs. Timing synchronization among the member APs and PCPs facilitates equitable sharing of the common medium among the member APs and PCPs. As long as a member AP or member PCP periodically receives DMG Beacons from the S-AP or S-PCP, the member AP or member PCP is able to maintain synchronization with the S-AP or S-PCP and hence the other member APs and PCPs.

#### 10.39.3.2 Decentralized AP or PCP cluster maintenance

In the case when the S-AP or S-PCP of a decentralized AP or PCP cluster is lost, or appears to a member AP or member PCP to have been lost, another AP or PCP needs to become the S-AP or S-PCP of the


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decentralized AP or PCP cluster in order to allow the remaining member APs and PCPs to maintain synchronization with the cluster. The creation of a new S-AP or S-PCP is called *S-AP or S-PCP handover*. After an S-AP or S-PCP handover, the cluster might continue to function as before, except with altered membership, or the cluster might no longer exist, or there might be one or more new clusters.

A member AP or member PCP of the decentralized AP or PCP cluster shall start an S-AP or S-PCP handover if, within a time period of 4×aMinBTIPeriod beacon intervals, it does not receive a DMG Beacon frame with the ECAPC Policy Enforced field set to 0, with the value of the Cluster ID field equal to the Cluster ID of the cluster of which the AP or PCP is a member and with the Cluster Member Role field set to the S-AP or S-PCP value. This is the first cluster monitoring period. During the next step in the S-AP or S-PCP handover, the member AP or member PCP performs another cluster monitoring period. A cluster monitoring period is a time period of 4×aMinBTIPeriod beacon intervals during which the AP or PCP listens for DMG Beacons while continuing to transmit DMG Beacons using its current Beacon $SP_n$.

NOTE 1—A decentralized clustering enabled AP or PCP does not cease DMG Beacon frame transmission during Cluster Monitoring and S-AP or S-PCP handover. Hence, data communication is unaffected while performing these procedures.

If, during a cluster monitoring period, the member AP or member PCP receives a DMG Beacon frame with the value of Cluster Member Role set to the S-AP or S-PCP value, the member AP or member PCP shall follow the rules in 10.39.2 (Cluster formation) to become a member AP or member PCP of the cluster corresponding to the detected S-AP or S-PCP or cease operation on the channel; in either case, the cluster monitoring period is terminated.

If, during a cluster monitoring period, the AP or PCP receives no DMG Beacons with the value of Cluster Member Role set to the S-AP or S-PCP value and one or more DMG Beacons with the ECAPC Policy Enforced field set to 0 and with Cluster ID equal to the Cluster ID of its last S-AP or S-PCP, then at the end of the cluster monitoring period the AP or PCP compares the MAC addresses of all such received DMG Beacons with its own MAC address. If its MAC address is the lowest, the AP or PCP shall become an S-AP or S-PCP according to the rules in 10.39.2 (Cluster formation). If its MAC address is not the lowest, the AP or PCP shall perform a new cluster monitoring period. If the number of cluster monitoring periods performed by the AP or PCP exceeds dot11MaxNumberOfClusteringMonitoringPeriods, the AP or PCP may cease cluster maintenance and initiate cluster formation as described in 10.39.2 (Cluster formation).

If, during a cluster monitoring period, the AP or PCP does not receive a DMG Beacon frame that contains the value of S-AP or S-PCP in the Cluster Member Role field and does not receive a DMG Beacon frame with the ECAPC Policy Enforced field set to 0 and with Cluster ID equal to the Cluster ID of the cluster of which it is currently a member, then at the end of the cluster monitoring period the AP or PCP may become an S-AP or S-PCP according to the rules of 10.39.2 (Cluster formation), or it may cease its activity on this channel and may attempt operation on a different channel.

NOTE 2—An assumption to allow the establishment of an S-AP or S-PCP in this case is that the APs and PCPs cannot hear each other's DMG Beacons. How a STA decides to switch the channel or to establish an S-AP or S-PCP is implementation dependent.

If, during a cluster monitoring period, the member AP or member PCP of a decentralized AP or PCP cluster receives no DMG Beacons from clustering enabled STAs, then the AP or PCP shall establish itself as an S-AP or S-PCP according to the rules in 10.39.2 (Cluster formation).

If an S-AP or S-PCP of a decentralized AP or PCP cluster detects the presence of a S-AP or S-PCP of another decentralized AP or PCP cluster on the same channel, it should schedule a Beacon SP for the DMG Beacon frame transmission of the other S-AP or S-PCP if the MAC address of the other S-AP or S-PCP is lower than the MAC address of this S-AP or S-PCP. The S-AP or S-PCP with higher MAC address should become a member AP or member PCP of the cluster corresponding to the S-AP or S-PCP with the lower MAC address according to the rules in 10.39.2 (Cluster formation).

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### 10.39.3.3 Centralized AP or PCP cluster maintenance

A STA, while operating as an S-AP, remains stationary with respect to its local environment.

An S-AP within a centralized AP or PCP cluster, upon a change of the Beacon SP Duration field or the ECAPC Policy element configured by the CCSR, shall update the Clustering Control field sent in subsequent frames and shall send individually addressed Announce or Information Response frames to other STAs within the BSS in order notify them of the changes.

When a member AP or member PCP is coordinated by an MM-SME and the member AP or member PCP elects to change its S-AP within a centralized AP or PCP cluster, then a second non-AP and non-PCP STA coordinated by the MM-SME of the member AP or member PCP should disassociate from the previous S-AP, and the member AP or member PCP shall perform the steps described in 10.39.2.2 (Centralized AP or PCP cluster formation) that allow a clustering enabled AP or PCP to join the centralized AP or PCP cluster of an S-AP as a member AP or member PCP.

When a member AP or member PCP is coordinated by an MM-SME and the member AP or member PCP elects to change its Cluster Time Offset within a centralized AP or PCP cluster, then the member AP or member PCP shall pass the updated Cluster Time Offset to a second non-AP and non-PCP STA coordinated by the MM-SME of the member AP or member PCP, and the second non-AP and non-PCP STA shall send an Information Response frame that includes a Cluster Time Offset element containing the Cluster Time Offset Index set to the updated index to the S-AP of the centralized AP or PCP cluster.

A member AP or member PCP within a centralized AP or PCP cluster, upon a change of the Clustering Control field received from its S-AP, shall update the Clustering Control field sent in subsequent frames. Upon a change of the ECAPC Policy Detail field received from its S-AP, a member AP or member PCP within a centralized AP or PCP cluster shall update the ECAPC Policy element sent in subsequent frames and send individually addressed Announce or Information Response frames to other STAs within the BSS in order to notify them of the changes. The member AP or member PCP within the centralized AP or PCP cluster shall attempt to receive a DMG Beacon frame from its S-AP at least once every dot11DMGEcssPolicyDetailUpdateDurationMax TUs.

In the case when a member AP or member PCP of a cluster has not received DMG Beacon frames from its S-AP for a duration exceeding 4×aMinBTIPeriod beacon intervals, and the member AP or member PCP intends to continue to operate a BSS on the channel, the AP or PCP shall either

a) Stop the current BSS then become an S-AP within the CCSS as described in 10.39.2.2 (Centralized AP or PCP cluster formation); or

b) Monitor the channel for DMG Beacon frames for an interval of length at least aMinChannelTime. During this period

   1) If one or more DMG Beacon frames are received with the ECAPC Policy Enforced field set to 1 in the DMG Parameters field and the Cluster Member Role set to 1 (S-AP or S-PCP of cluster) from one or more S-APs and the AP or PCP is not an ECAPC policy blind AP or PCP, then the AP or PCP shall join a selected S-AP as a cluster member as described in 10.39.2.2 (Centralized AP or PCP cluster formation);

   2) Otherwise, if the AP or PCP is an ECAPC policy blind PCP or AP, then it may join a selected S-AP as a cluster member;

   3) Otherwise, if, after the period elapses, no DMG Beacon frames are received with the ECAPC Policy Enforced field in the DMG Parameters field set to 1 and the Cluster Member Role set to 1 (S-AP or S-PCP of cluster) and if the AP or PCP is decentralized AP or PCP clustering capable, then the AP or PCP shall attempt to join a decentralized AP or PCP cluster if present as described in 10.39.2.1 (Decentralized AP or PCP cluster formation). If the AP or PCP is not decentralized AP or PCP clustering capable or a decentralized AP or PCP cluster is not present,


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then the AP or PCP shall set its Cluster Member Role to 0 (not currently participating in a cluster).

c) In all three cases, the AP or PCP

1) Shall set the ECAPC Policy Enforced bit to 0 and shall not include the ECAPC Policy element in (Re)Association Response, Announce, or Information Response frames and

2) Should send individually addressed Announce or Information Response frames to other STAs within the BSS to notify them of the changes.

#### 10.39.3.4 Centralized AP or PCP cluster MAC requirements

If the most recent ECAPC Policy element transmitted by a member AP, S-AP, or member PCP includes the BHI Enforced field set to 1, the member AP, S-AP, or member PCP shall complete the BTI, A-BFT, and ATI for each subsequent beacon interval before TBTT + (8×Beacon SP duration). The most recently transmitted (if an S-AP) or received (if a member AP, member PCP, or non-AP and non-PCP STA) value of Beacon SP Duration is used.

If the most recent ECAPC Policy element transmitted by a member AP, S-AP, or member PCP has the TXSS CBAP Enforced field set to 1, the member AP, S-AP, or member PCP shall complete each of its TXSSs in the DTI within one or more TXSS CBAPs.

If the most recent ECAPC Policy element, received by a non-AP and non-PCP STA in a BSS from the member AP, S-AP, or member PCP of the BSS, has the TXSS CBAP Enforced field set to 1, then the non-AP and non-PCP STA shall perform each of its TXSSs in the DTI within one or more TXSS CBAPs. If the non-AP and non-PCP STA is the source DMG STA of an SP and if the non-AP and non-PCP determines that it needs to perform a TXSS before continuing to transmit to the destination DMG STA of the SP, then the non-AP and non-PCP STA should truncate the SP (see 10.38.8 (Dynamic truncation of service period)). If the non-AP and non-PCP STA is the source CMMG STA of an SP and if the non-AP and non-PCP STA determines that it needs to perform a TXSS before continuing to transmit to the destination CMMG STA of the SP, then the non-AP and non-PCP STA should truncate the SP.

A TXSS CBAP shall last from $T_{Start}$ to $T_{End}$, as defined below, excluding any time that overlaps a BHI or an SP that has source and destination DMG AIDs set to 255 (such as for a Beacon SP). A TXSS CBAP shall last from TStart to TEnd, as defined below, excluding any time that overlaps a BHI or an SP that has source and destination CMMG AIDs set to 255 (such as for a Beacon SP).

$$T_{Start} = T_{TBTT} + 8 \times T_o + \frac{(n-1) \times 1024 \times T_{BI}}{N}, 1 \le n \le N$$

$$T_{End} = T_{TBTT} + 8 \times T_o + \frac{(n-1) \times 1024 \times T_{BI}}{N} + 8 \times T_d, 1 \le n \le N$$

where

$T_{TBTT}$ is the TBTT
$T_o$ is the TXSS CBAP Offset, in microseconds
$T_d$ is the TXSS CBAP Duration, in microseconds
$T_{BI}$ is the beacon interval, in TU
$N$ is TXSS CBAP MaxMem

The most recently transmitted (if an S-AP) or received (if a member AP, member PCP, or non-AP and non-PCP STA) value of TXSS CBAP Offset and TXSS CBAP Duration fields are used.

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The TXSS CBAP is available to all STAs in an ECAPC. A STA may also use the TXSS CBAP for sending frames not related to transmit sector sweeping. Transmission rules during a TXSS CBAP are defined in 10.38.5 (Contention based access period (CBAP) transmission rules).

NOTE—Frames, such as Data frames, sent in a TXSS CBAP when the TXSS CBAP Enforced field is set to 1 might experience erratically higher interference than frames sent at other times due to the TXSSs of other nearby STAs.

Additional centralized AP or PCP cluster requirements are defined in 10.38.6.6 (DMG and CMMG protected period) and 11.1.3.3 (Beacon generation in a DMG infrastructure BSS and in a PBSS).

### 10.39.4 Cluster report and rescheduling

A clustering enabled AP or PCP that receives an Extended Schedule element from another clustering enabled AP or PCP may reschedule SPs and CBAPs in its beacon interval, or move the BTI (11.1.3.3 (Beacon generation in a DMG infrastructure BSS and in a PBSS)), in an attempt to mitigate any interference with the transmissions indicated in the received Extended Schedule element. The AP or PCP can create SPs in its beacon interval with the source and destination AID set to 255 to prevent transmissions during specific periods in the beacon interval (10.38.6.2 (Service period (SP) allocation)).

A non-AP and non-PCP STA that is a member of a BSS and that receives a DMG Beacon frame should send a Cluster Report element to its AP or PCP if the received DMG Beacon frame meets all of the following conditions:

- The DMG Beacon frame is not from the STA's AP or PCP.
- The DMG Beacon frame contains the Clustering Control field.
- Either
  - The value of the Cluster ID field within the Clustering Control field is different from the MAC address of the STA's AP or PCP; or
  - The value of the Cluster ID field within the Clustering Control field is the same as the MAC address of the STA's AP or PCP, the TBTTs of the two BSSs are less than dot11BeaconPeriod/(2×ClusterMemMax) apart in time, and the ECAPC Policy Enforced field in the DMG Beacon frame received most recently from the STA's AP or PCP is equal to 1.

The non-AP and non-PCP STA shall not send a Cluster Report element to its AP or PCP if the received DMG Beacon frame does not meet the preceding conditions.

A Cluster Report element meeting the conditions above shall be transmitted in an Announce or Information Response frame sent to the STA's AP or PCP. Within the transmitted Cluster Report element, the STA shall set the Cluster report subfield to 1. The STA shall set the Clustering Control field within a transmitted Cluster Report element to the corresponding field values within the Clustering Control of the received DMG Beacon frame(#337), shall set the Reported BSSID field to the BSSID field of the received DMG Beacon frame(#337), and shall set the Reference Timestamp field to indicate the DMG Beacon frame reception time. The STA shall set the Schedule present subfield to 1 if the Extended Schedule field is present in the transmitted Cluster Report element; otherwise, it shall set Schedule present subfield to 0. The STA shall set the TSCONST present subfield to 1 if the Traffic Scheduling Constraint Set field is present in the transmitted Cluster Report element; otherwise, it shall set TSCONST present subfield to 0.

The STA shall set the ECAPC Policy Enforced field in the Cluster Report Control field to the value of the ECAPC Policy Enforced field in the received DMG Beacon frame(#337). The STA should attempt to receive an Announce frame from the AP or PCP that transmitted the DMG Beacon frame according to the channel access rules described in 10.38 (DMG and CMMG channel access) in order to solicit an ECAPC Policy element. If the STA obtains an ECAPC Policy element from the AP or PCP that transmitted the DMG Beacon frame(#337), the STA shall set the ECAPC Policy Present subfield to 1 and include the ECAPC Policy element in the transmitted Cluster Report element; otherwise, the STA shall set ECAPC Policy


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Present subfield to 0 and not include the ECAPC Policy element in the transmitted Cluster Report element. If present, the Extended Schedule Element field within the Cluster Report element shall be set to the corresponding field values within the Extended Schedule element of the received DMG Beacon frame(#337). If present, the Traffic Scheduling Constraint Set field shall be set to indicate periods of time with respect to the TBTT of the beacon interval of the BSS the STA participates where the transmitting STA experiences poor channel conditions, such as due to interference.

If the received DMG Beacon frame contains more than one Extended Schedule element entry, the STA shall repeat the aforementioned procedure and transmit a Cluster Report element corresponding to each Extended Schedule element entry.

Upon receiving a Cluster Report element from a non-AP and non-PCP STA with the Cluster report field set to 1, a clustering enabled AP or PCP may reschedule SPs and CBAPs in its beacon interval, move the BTI if the clustering enabled AP or PCP is an S-AP or S-PCP in a decentralized AP or PCP cluster, or change the Cluster Time Offset if the clustering enabled AP or PCP is a member AP or member PCP, or perform other actions, in an attempt to mitigate any interference with the transmissions indicated in the received Cluster Report element. The clustering enabled AP or PCP may also create SPs in its beacon interval with the source and destination AID set to 255 to prevent transmissions during specific periods in the beacon interval.

A member AP or member PCP within a centralized AP or PCP cluster should report new interference information and may report all interference information to the S-AP of the cluster

- When the member AP or member PCP receives one or more of the following:
  - A DMG Beacon frame from another AP or PCP in another centralized AP or PCP cluster within the same CCSS or another CCSS
  - A Cluster Report element with the Cluster Report field set to 1 from a non-AP and non-PCP STA within the same BSS characterizing an AP or PCP in another centralized AP or PCP cluster within the same CCSS or another CCSS; and
- If at least dot11DMGEcssClusterReportDurationMin TUs have elapsed since the last report.

The report should aggregate the information received from all sources and minimize duplication. The member AP or member PCP passes the report to a second non-AP and non-PCP STA coordinated by the MM-SME of the member AP or member PCP, and the second non-AP and non-PCP STA sends the report in an Information Response frame that includes one or more Cluster Report elements to the S-AP of its centralized AP or PCP cluster. If the member AP or member PCP does not elect to change its Cluster Time Offset at this time, the second non-AP and non-PCP STA includes a Cluster Time Offset element with an unchanged Cluster Time Offset Index field.

Via unspecified means, the S-AP might aggregate received DMG Beacon frames and Cluster Report elements and send the aggregate to the CCSR. Upon receiving this information, the CCSR might reconfigure the TSF offsets of an S-AP, reconfigure the ECAPC Policy Detail of an S-AP, update the Cluster Time Offset availability information provided in an individually addressed frame by an S-AP to a member AP or member PCP, or perform other actions.

### 10.39.5 Decentralized AP or PCP cluster request

A non-AP and non-PCP STA that is a member of a BSS may transmit a Cluster Report element to its AP or PCP to request that decentralized AP or PCP clustering be enabled in the BSS. The non-AP and non-PCP STA can make this request if, for example, the device containing the non-AP and non-PCP STA intends to initialize another co-channel BSS (11.1 (Synchronization)) in which it performs the role of AP or PCP and, when performing this role, it wishes to become a member AP or member PCP of the decentralized AP or PCP cluster formed by its current AP or PCP.

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To request AP or PCP clustering to be enabled in the BSS, the STA shall transmit a Cluster Report element with the Cluster request subfield set to 1 to its AP or PCP. Upon receiving a Cluster Report element with the Cluster request subfield set to 1, the AP or PCP should form and maintain decentralized AP or PCP clustering in the BSS according to the procedures described in 10.39.2 (Cluster formation) and 10.39.3 (Cluster maintenance). In doing that, the AP or PCP should set the minimum duration of the Beacon SP to be equal to the Beacon SP duration.

If the non-AP and non-PCP STA does not receive a DMG Beacon frame from its AP or PCP with decentralized AP or PCP clustering enabled after dot11ClusterEnableTime following the transmission to its AP or PCP of a Cluster Report element with the Cluster request subfield set to 1, the non-AP and non-PCP STA may transmit an Announce frame including the last Extended Schedule element transmitted by the AP or PCP. If the Announce frame is transmitted, it shall use MCS 0, and the TA field shall be set to the broadcast address. If a DMG STA receives an Announce frame with the TA field set to the broadcast address and with the BSSID field different from the BSSID of its BSS, the STA may send a Cluster Report element containing the Extended Schedule element within the received Announce frame to its AP or PCP, which might be used by the AP or PCP to reschedule SPs in portions of the beacon interval that are nonoverlapping in time with the SPs contained in the Extended Schedule element reported by the STA. if a CMMG STA receives an Announce frame with the TA field set to the broadcast address and with the BSSID field different from the BSSID of its BSS, the STA may send a Cluster Report element containing the Extended Schedule element within the received Announce frame to its AP or PCP, which might be used by the AP or PCP to reschedule SPs in portions of the beacon interval that are nonoverlapping in time with the SPs contained in the Extended Schedule element reported by the STA.

If a non-AP and non-PCP STA becomes a member AP or member PCP of the clustering enabled by its current AP or PCP, the non-AP and non-PCP STA can synchronize scheduled CBAP allocations, if any, between the BSS in which it performs the role of AP or PCP and the BSS of its current AP or PCP. The non-AP and non-PCP STA can disallow STAs in the BSS in which it plays the role of AP or PCP from transmitting during the Beacon SPs of the cluster it is a part of, and this can be done by allocating an SP time-overlapping with each Beacon SP such that each allocated SP has both the source AID and destination AID fields within the Extended Schedule element set to the AID of the non-AP and non-PCP STA.

## 10.40 CDMG AP or PCP clustering

### 10.40.1 General

A CDMG AP or PCP may use the CDMG AP or PCP clustering mechanism to improve spatial sharing and interference mitigation with other co-channel DMG or CDMG BSSs.

A clustering enabled AP or PCP that is operating on a 2.16 GHz or 1.08 GHz channel and transmitting DMG Beacon frames with the DBC Option subfield of the Dynamic Bandwidth Control element set to 1 (10.63.2.2 (CDMG BSS operating on a 1.08 GHz channel)) is able to start a decentralized AP or PCP cluster or a centralized AP or PCP cluster on a 2.16 GHz channel following the rules as described in 10.39 (DMG and CMMG AP or PCP clustering).

A clustering enabled AP or PCP that is operating on a 1.08 GHz channel and transmitting DMG Beacon frames with the DBC Option subfield of the Dynamic Bandwidth Control element set to 0 (10.63.2.2 (CDMG BSS operating on a 1.08 GHz channel)) is able to start an AP or PCP cluster on a 1.08 GHz channel. Starting an AP or PCP cluster on a 1.08 GHz channel shall follow the rules defined in 10.39 (DMG and CMMG AP or PCP clustering) and in this subclause.

If an AP or PCP cluster starts on a 1.08 GHz channel, the S-AP or S-PCP shall not only transmit its DMG Beacon frame during the first Beacon SP (10.39.1 (General)) on this 1.08 GHz channel but also transmit the DMG Beacon frame during the notification period (NP) of each allocated quiet period (QP) on


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the corresponding 2.16 GHz common channel as described in 10.63 (DBC mechanism for CDMG STAs). Moreover, according to the rules in 10.63 (DBC mechanism for CDMG STAs), the S-AP or S-PCP shall set its beacon interval on the 2.16 GHz common channel as an integer multiple of the beacon interval on the 1.08 GHz channel in terms of TUs, and the maximum length of beacon interval on the 1.08 GHz channel can be given as the same length of the beacon interval on the 2.16 GHz channel.

The member AP or member PCP of a cluster starting on a 1.08 GHz channel shall not allocate QP on the 2.16 GHz common channel to transmit its DMG Beacon frame if there is no legacy non-AP and non-PCP DMG STA within its BSS or it does not involve in a synchronization pair with another AP or PCP operating in the adjacent 1.08 GHz channel. Otherwise, the member AP or member PCP shall transmit its DMG Beacon frame during its NP of the allocated QP on the 2.16 GHz common channel, similar to the S-AP or S-PCP.

### 10.40.2 Cluster formation

#### 10.40.2.1 Decentralized CDMG AP or PCP cluster formation

A decentralized clustering enabled AP or PCP starts a decentralized AP or PCP cluster on a 1.08 GHz channel by becoming an S-AP or S-PCP, subject to the absence of existing clusters on this 1.08 GHz channel as described below and in 10.39.2.1 (Decentralized AP or PCP cluster formation).

The S-AP or S-PCP of an AP or PCP cluster starting on a 1.08 GHz channel shall set the DMG Parameters field and the Clustering Control field following the rules defined in 10.39.2.1 (Decentralized AP or PCP cluster formation) and also set the first bit of the Clustering Status subfield contained in the Dynamic Bandwidth Control element to 1.

A decentralized clustering enabled AP or PCP that receives a DMG Beacon frame from an S-AP or S-PCP on either a 2.16 GHz channel or a 1.08 GHz channel shall know the exact channel on which this S-AP or S-PCP selects to start a cluster through the Channel Splitting subfield, Clustering Status subfield, and the Channel Number field contained in the Dynamic Bandwidth Control element.

If an existing AP or PCP cluster is operating on a 2.16 GHz channel, the decentralized clustering enabled AP or PCP shall monitor the corresponding 2.16 GHz channel and then follow the procedures defined in 10.39.2.1 (Decentralized AP or PCP cluster formation) to become a member AP or member PCP of this cluster.

If the decentralized clustering enabled AP or PCP receives a DMG Beacon frame containing the Clustering Control field from an S-AP or S-PCP on a 1.08 GHz channel, the AP or PCP shall monitor the corresponding 1.08 GHz channel during each Beacon SP according to the received cluster synchronization and control information to listen whether the Beacon SPs are occupied by other member APs or member PCPs. If an empty Beacon SP is discovered, the AP or PCP shall follow the same procedures defined in 10.39.2.1 (Decentralized AP or PCP cluster formation) to become a member AP or member PCP of this cluster.

A decentralized clustering enabled AP or PCP shall not become a member of a cluster starting on a 1.08 GHz channel if no Beacon SP is determined to be empty during aMinChannelTime, in which case, subject to the requirements described in 10.39.2.1 (Decentralized AP or PCP cluster formation), (#1416)the AP or PCP may become the S-AP or S-PCP of a new cluster, or may cease its activity on this 1.08 GHz channel, or may request to operate on the unoccupied adjacent 1.08 GHz channel within the 2.16 GHz common channel (10.63.2.3 (Synchronization of CDMG infrastructure BSS or PBSSs on the adjacent 1.08 GHz channels within a 2.16 GHz channel)), and, if desired, attempt operation on a different 2.16 GHz or 1.08 GHz channel.

The AP or PCP of a decentralized AP or PCP cluster shall not transmit or schedule transmissions during a Beacon SP that is not its own Beacon SP and a QP duration that is not its own QP.

Figure 10-75 (Example of a decentralized AP or PCP cluster on a 1.08 GHz channel) illustrates an example of a decentralized AP or PCP cluster starting on the 1.08 GHz channel 35 while the adjacent 1.08 GHz channel 36

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is unoccupied. The S-AP or S-PCP and member AP 3 or member PCP 3 with a BSS in which there is at least one DMG STA transmit DMG Beacon frames during the NPs of the allocated QPs on the 2.16 GHz channel 2 and their own Beacon SPs on channel 35, respectively. Other member APs or member PCPs transmit DMG Beacon frames only during their own Beacon SPs on channel 35.

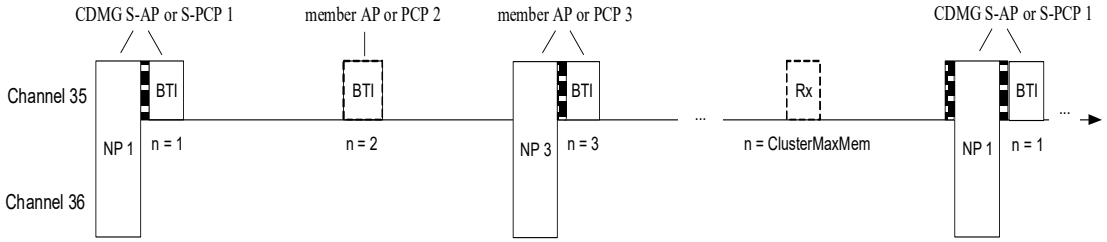


**Figure 10-75—Example of a decentralized AP or PCP cluster on a 1.08 GHz channel**

Figure 10-76 (Example of decentralized clusters for two APs or PCPs of a synchronization pair) illustrates an example of two decentralized AP or PCP clusters starting on the two adjacent 1.08 GHz channel 35 and channel 36, respectively. Two S-APs or S-PCPs form a synchronization pair under the first mode of DBC mechanism(10.43 (Link adaptation using the CMMG link measurement)) and transmit DMG Beacon frames during their own NPs of the allocated QPs on the 2.16 GHz channel 2 and the Beacon SPs on the 1.08 GHz channel 35 and channel 36. Other member APs or member PCPs APs transmit DMG Beacon frames only during their own Beacon SPs on the corresponding 1.08 GHz channels.

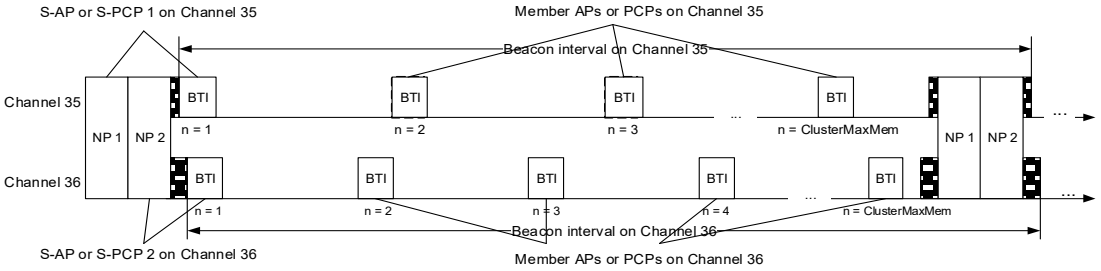


**Figure 10-76—Example of decentralized clusters for two APs or PCPs of a synchronization pair**

The member AP or member PCP operating on a 1.08 GHz channel shall select a beacon interval length on the 1.08 GHz channel that is equal to the beacon interval length of its S-AP or S-PCP on the same channel.

The AP or PCP operating on the 1.08 GHz channel should determine its beacon interval on the 2.16 GHz channel to be equal to the beacon interval of the S-AP or S-PCP on the 2.16 GHz channel according to the cluster synchronization and control information of the S-AP or S-PCP. The AP or PCP operating on the 1.08 GHz channel should continue transmitting the DMG Beacon frames on the 2.16 GHz channel during the beacon SP according to the beacon interval on the 2.16 GHz channel. The AP or PCP operating on the 1.08 GHz channel shall switch back to the 1.08 GHz channel to transmit DMG Beacon frames during the BTI on the 1.08 GHz channel according to the beacon interval on the 2.16 GHz channel.

If a member AP or member PCP does not involve in a synchronization pair with another AP or PCP (10.63.2.3 (Synchronization of CDMG infrastructure BSS or PBSSs on the adjacent 1.08 GHz channels within a 2.16 GHz channel)), it shall set the beacon interval length on the 2.16 GHz channel as an integer multiple of its beacon interval length on the 1.08 GHz channel. Otherwise, if the member AP or member PCP is involved in a


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synchronization pair with another AP or PCP operating in the adjacent 1.08 GHz channel, it shall adjust its beacon interval length on the 2.16 GHz channel as an integer multiple of its beacon interval length on the 1.08 GHz channels and also notify the neighboring AP or PCP that is involved in the synchronization pair to adjust the beacon interval on the 2.16 GHz channel to the same value through a DMG BSS Parameter Change element within the DMG Beacon frame transmitted in its NP of the allocated QP on the 2.16 GHz common channel following the rules in 11.31.4 (FST teardown) In this case, subject to the requirement described in 10.63 (DBC mechanism for CDMG STAs), the neighboring AP or PCP may further adjust its beacon interval on the 1.08 GHz channel as an integer factor of the new beacon interval length on the 2.16 GHz channel in units of TUs. The procedures of the adjusting beacon interval and CDMG SBBI for AP or PCP 1 and AP or PCP 2 that is involved in a synchronization pair should be as follows:

a) If the AP or PCP 1 detected an empty Beacon SP on the 1.08 GHz channel, AP or PCP 1 shall change the current beacon interval length beacon interval 1 to beacon interval 2 on the 2.16 GHz channel to align the beginning of the first BTI on the 1.08 GHz channel after beacon interval 2 duration with the beginning of the empty Beacon SP.

b) Determine whether the ratio of beacon interval 2 divided by CDMG SBBI of the S-AP or S-PCP is an integer. If the ratio of beacon interval 2 divided by CDMG SBBI of the S-AP or S-PCP is an integer, the AP or PCP 1 shall adjust CDMG SBBI 1 to equal the CDMG SBBI of the S-AP or S-PCP. Otherwise, the AP or PCP 1 shall change its beacon interval length beacon interval 2 to beacon interval 3 on 2.16 GHz channel during its next NP 1 and set its CDMG SBBI 1 to the CDMG SBBI of S-AP or S-PCP during the BTI to make the ratio of beacon interval 3 divided by CDMG SBBI of the S-AP or S-PCP an integer. For both cases, the AP or PCP 1 shall notify the AP or PCP 2 of the new beacon interval 2 or beacon interval 3 during the first QP at the end of beacon interval 2 or beacon interval 3, where the QP comprises the NP and a guard interval (GI) used for channel switching, and the AP or PCP 2 should also adjust its SBBI 2 to make the ratio of beacon interval 2 or beacon interval 3 divided by CDMG SBBI 2 an integer.

c) The AP or PCP 1 transmits the DMG Beacon frame including the Clustering Control field during the empty Beacon SP on the 1.08 GHz channel to join the intended 1.08 GHz cluster as a member AP or member PCP.

An example of adjusting beacon interval and CDMG SBBI for step a) and b) is illustrated in Figure 10-77 (Example of joining the CDMG AP or PCP cluster for a CDMG AP or PCP involved in a synchronization pair with another AP or PCP). For step a) and step b), changing beacon interval on the 2.16 GHz channel or changing SBBI on the 1.08 GHz channel is completed by AP or PCP 1 by negotiation with AP or PCP 2 in a notification period (NP) that comprises NP1 and NP2. AP or PCP 1 transmits the DMG Beacon frame to AP or PCP 2 in NP1, and AP or PCP 2 transmits the DMG Beacon frame to AP or PCP 1 in NP2.

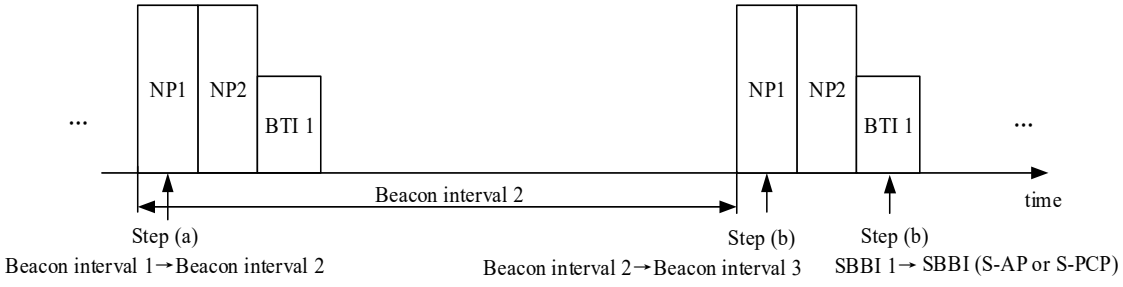


**Figure 10-77—Example of joining the CDMG AP or PCP cluster for a CDMG AP or PCP involved in a synchronization pair with another AP or PCP**

A synchronized AP or PCP is a CDMG AP or PCP that is operating on a 1.08 GHz channel but still transmitting its DMG Beacon frames on the relevant 2.16 GHz channel with the AP or PCP Role subfield of

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the Dynamic Bandwidth Control element (9.4.2.219 (Dynamic Bandwidth Control element)) set to 1 and synchronizing with the synchronizing AP or PCP on the relevant 2.16 GHz channel.

A synchronizing AP or PCP is a CDMG AP or PCP that is operating on a 1.08 GHz channel but still transmitting its DMG Beacon frames on the relevant 2.16 GHz channel with the AP or PCP Role subfield of the Dynamic Bandwidth Control element (9.4.2.219 (Dynamic Bandwidth Control element)) set to 0 and providing synchronization service to a synchronized AP or PCP on the relevant 2.16 GHz channel.

If an AP or PCP involved in a synchronization pair is a synchronized AP or PCP and intends to join to a co-channel AP or PCP cluster, it shall set the AP or PCP Role subfield within the Dynamic Bandwidth Control element to 0 to exchange the role with the synchronizing AP or PCP before joining the co-channel cluster. When the AP or PCP Role subfield is changed, the synchronized AP or PCP shall include the Cluster Switch Announcement element in the DMG Beacon frame to indicate the time that the AP or PCP role exchange occurs.

If an AP or PCP that is involved in a synchronization pair intends to join a discovered cluster or intends to start a cluster on the 2.16 GHz common channel, it should send a Cluster Switch Announcement element included in the DMG Beacon frame during its NP to notify the peer AP or PCP involved in the synchronization pair to monitor the common 2.16 GHz channel and join the cluster on 2.16 GHz channel if an empty Beacon SP can be found. After the Cluster Switch Announcement element is transmitted, the AP or PCP should cease transmission during its NP.

When a decentralized clustering enabled AP or PCP operating on 1.08 GHz channel receives a DMG Beacon frame that contains the Clustering Control field in the Cluster Switch Announcement element from its neighboring AP or PCP of a synchronization pair to indicate the presence of a cluster on the 2.16 GHz common channel, it may monitor this 2.16 GHz channel to become a member AP or member PCP following the procedures described in 10.39.2.1 (Decentralized AP or PCP cluster formation).

When a decentralized clustering enabled AP or PCP operating on a 1.08 GHz channel still experiences poor channel conditions after performing all the actions in an attempt to mitigate any interference, it may broadcast one or more Cluster Probe elements using the DMG Beacon frame or Probe Request frame to detect the presence of a cluster actively on the 2.16 GHz common channel during its NPs, SPs, or CBAPs. In addition to transmitting Cluster Probe elements included in DMG Beacon frames on the 2.16 GHz common channel during NPs, the AP or PCP operating on a 1.08 GHz channel may reserve multiple SPs during DTI and switch to the 2.16 GHz channel during each of the SPs to transmit Cluster Probe elements included in Probe Request frames on the 2.16 GHz common channel.

For an AP or PCP that is operating on a 1.08 GHz channel and is involved in a synchronization pair, the AP or PCP may transmit Cluster Probe elements on the common 2.16 GHz channel, using Probe Request frames during its reserved SPs or using DMG Beacon frames during its NPs. The SPs for receiving a Probe Response frame from S-PCP or S-AP can be scheduled in the NP of the next beacon interval on the 2.16 GHz channel or in a DTI. The peer AP or PCP that is involved in the synchronization pair shall also reserve the same SPs with destination AIDs set to 255 to listen for a Probe Response frame and to avoid interferences to the SPs used for cluster probe.

The S-AP or S-PCP that is operating on the 2.16 GHz common channel and receives a Cluster Probe element shall respond with one or more Probe Response frames including an Extended Cluster Report element in each SP scheduled according to the Cluster Probe element to indicate its presence by including the cluster synchronization and control information of the S-AP or S-PCP in the Extended Cluster Report element. The Cluster Probe element contains timing information for the CDMG S-AP or S-PCP operating on the 2.16 GHz channel to transmit the Probe Response frame for the Cluster Probe element. This element defines a sequence of SPs that are scheduled in a DTI or the next NP by both the cluster probe requesting AP or PCP and responder AP or PCP for receiving and transmitting the response frames. The multiple SPs are reserved corresponding to the SPs during which the Cluster Probe elements are transmitted.


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After receiving a Probe Response frame from an S-AP or S-PCP operating on the 2.16 GHz common channel, during at least one of the reserved SPs in a DTI, the decentralized clustering enabled AP or PCP operating on 1.08 GHz channel may switch to the 2.16 GHz common channel, by using the cluster synchronization and control information in the Extended Cluster Report element in the Probe Response frame of the S-AP or S-PCP operating on the 2.16 GHz channel, and attempt to discover an empty Beacon SP. If an empty Beacon SP exists, then the AP or PCP may transmit DMG Beacon frames during the empty Beacon SP to become a member AP or member PCP of this cluster following the procedures described in 10.39.2.1 (Decentralized AP or PCP cluster formation).

If two APs or PCPs involved in a synchronization pair both receive an Extended Cluster Report element and discover an empty Beacon SP during their reserved SPs at the same time, the AP or PCP that first transmits a Cluster Switch Announcement element during NP should join the empty Beacon SP with priority, and the peer AP or PCP should monitor the 2.16 GHz channel for another aMinChannelTime to find another empty Beacon SP.

If the decentralized clustering enabled AP or PCP on the 1.08 GHz channel does not receive any Probe Response frame from an S-AP or S-PCP during the reserved SPs on the 2.16 GHz channel in the whole DTI, it may reschedule multiple SPs whose positions are adjusted stochastically in the following DTI.

### 10.40.2.2 Centralized CDMG AP or PCP cluster formation

In order to become an S-AP, a centralized clustering enabled CDMG STA that is operating on a 2.16 GHz channel or a 1.08 GHz channel and is stationary with respect to its local environment shall successfully perform both the configuration step and verification step in order and take the actions following the rules as described in 10.39.2.2 (Centralized AP or PCP cluster formation).

If at least one DMG Beacon frame that has the ECAPC Policy Enforced field set to 1 and is sent by an S-AP or member AP or member PCP from another ECAPC is received during the monitoring period, the centralized clustering enabled CDMG STA shall follow the rules as described in 10.39.2.2 (Centralized AP or PCP cluster formation).

The remaining available channels for a centralized CDMG AP or PCP cluster are channels 3, 37, and 38. Channels 2, 35, and 36 are the channels upon which the S-AP is excluded from operating. The channels 3, 37, and 38 that interfere with each other form a channel set. The channel set available for a centralized CDMG AP or PCP cluster is channel {3, 37, 38}.

The functions of a CDMG CCSR shall cover the channel set. The CDMG CCSR shall provide coordination services for all the S-APs operating on the channels of the channel set {3, 37, 38} within the CCSS to mitigate interference. The CDMG CCSR should provide an S-AP with the cluster information of other S-APs. Thus, each S-AP operating on a channel within the channel set can obtain the same cluster information from the CDMG CCSR.

(#111)After receiving a DMG Beacon frame including cluster information transmitted by an S-AP, in order to become a member AP or member PCP, a centralized clustering enabled AP or PCP shall successfully perform the following steps in order:

a) The AP or PCP shall monitor the channel for DMG Beacon frames during each Beacon SP over an interval of length at least aMinChannelTime to find an empty Beacon SP and measure the status of each Beacon SP and the signal quality (RCPI and RSNI) of the received DMG Beacon frames based on the received cluster information of the S-AP. The AP or PCP can determine the timing start point of each Beacon SP over a beacon interval of the S-AP based on the Next BTI Offset field, the Reported BI Duration field, and the Reported Clustering Control field. Thus, the AP or PCP can measure each Beacon SP over a beacon interval of the S-AP based on the timing start point of each

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Beacon SP over a beacon interval and obtain the status of each Beacon SP and signal quality over a beacon interval.

b) If an empty Beacon SP is discovered, the second non-AP and non-PCP STA shall attempt to associate with the S-AP and thereby receive an Announce frame from the S-AP. The contents of the Announce frame are passed to the AP or PCP. All the centralized cluster information of the S-AP(s) operating on the channels in the same channel set except the current S-AP shall be included in the Announce frame. The cluster information of the other S-AP(s) can be conveyed in the Extended Cluster Report elements.

c) The CDMG AP or PCP should determine whether to join the current S-AP's cluster or other S-AP(s)'s cluster based on the signal quality, the states of Beacon SPs during a beacon interval indicated by the Available Cluster Offset Bitmap field in the ECAPC Policy element of the S-AP or the member APs or member PCPs of the current S-AP's cluster, and other S-AP(s)'s cluster information. If the AP or PCP elects to join the current cluster, it proceeds to step d); otherwise, the AP or PCP monitors the channels for DMG Beacon frames during each Beacon SP of all the centralized clusters over an interval of length at least aMinChannelTime using the cluster information from the current S-AP. The CDMG AP or PCP may identify a new intended cluster based on the signal quality of the DMG Beacon frames or the Available Cluster Offset Bitmap field in the ECAPC Policy element of the other clusters, if the intersection of 1) the Cluster Time Offset indices of the empty Beacon SPs with 2) the indices indicated by the Available Cluster Offset Bitmap field shows more common nonempty Beacon SPs. The second non-AP and non-PCP STA shall (#2234)disassociate from the current S-AP and associate with the S-AP of the intended cluster, receive the Announce frame from the S-AP, and pass the contents of the Announce frame to the AP or PCP.

d) Upon receiving an Announce frame that includes the ECAPC Policy element, the AP or PCP shall select a cluster time offset index from the intersection of the cluster time offset indices of the empty Beacon SPs with the indices indicated by the Available Cluster Offset Bitmap field in the ECAPC Policy element. If the intersection is empty, the AP or PCP shall select a cluster time offset index of an empty Beacon SP. The selected cluster time offset index is passed to the second non-AP and non-PCP STA.

e) The second non-AP and non-PCP STA shall respond to the Announce frame with an Information Response frame that includes the Cluster Time Offset element containing the Cluster Time Offset Index field set to the selected index.

f) The AP or PCP shall join the cluster of S-AP at the selected cluster time offset on the channel of the S-AP and transmit DMG Beacon frames with the AP or PCP Clustering Control field.

After joining the centralized AP or PCP cluster, the CDMG member AP or member PCP shall transmit its DMG Beacon frames and include the ECAPC Policy element in (Re)Association Response, Announce, and Information Response frames following the rules as described in 10.39.2.2 (Centralized AP or PCP cluster formation).

### 10.40.3 Cluster maintenance

#### 10.40.3.1 General cluster maintenance

Regardless of whether a cluster starts on a 2.16 GHz channel or a 1.08 GHz channel, the member AP or member PCP is able to maintain synchronization with the S-AP or S-PCP and other member APs or member PCPs through receiving DMG Beacon frames from the S-AP or S-PCP on this channel.

If an AP or PCP cluster starts on a 1.08 GHz channel and the AP or PCP of this cluster involves in a synchronization pair with another AP or PCP operating in the adjacent 1.08 GHz channel at the same time, this pair of APs or PCPs shall also maintain synchronization according to the rules described in 10.63 (DBC mechanism for CDMG STAs) unless one of them ceases its BSS.


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### 10.40.3.2 Decentralized CDMG AP or PCP cluster maintenance

In the case when the S-AP or S-PCP of a decentralized AP or PCP cluster on a 1.08 GHz channel is lost, or appears to a member AP or member PCP to have been lost, the S-AP or S-PCP handover procedures shall follow the rules in 10.39.3.2 (Decentralized AP or PCP cluster maintenance). In addition, the new S-AP or S-PCP shall also transmit the DMG Beacon frame during its NP of the allocated QP on the 2.16 GHz common channel as described in 10.63.5 (Backward compatibility and interoperation), even if there is no legacy non-AP and non-PCP DMG STA within its BSS or it does not involve in a synchronization pair with another AP or PCP operating in the adjacent 1.08 GHz channel.

If the S-AP or S-PCP of a decentralized AP or PCP cluster detects the presence of the S-AP or S-PCP of another decentralized AP or PCP cluster through receiving a DMG Beacon frame on either a 2.16 GHz channel or a 1.08 GHz channel or receiving a Probe Response frame including the Extended Cluster Report element on a 2.16 GHz channel with the DBC Present field set to 1 and the Channel Splitting subfield set to 1, it should become a member AP or member PCP of the other cluster on the corresponding channel according to the procedures described in 10.40.2 (Cluster formation) if the values of its Adjacent Channel Occupancy subfield, Clustering Status subfield, and the Synchronizing AP or PCP MAC Address subfield in the Dynamic Bandwidth Control element are higher than those of the other S-AP or S-PCP.

If the S-AP or S-PCP of a decentralized AP or PCP cluster detects the presence of the S-AP or S-PCP of another decentralized AP or PCP cluster through receiving a DMG Beacon frame on either a 2.16 GHz channel or a 1.08 GHz channel or receiving a Probe Response frame including the Extended Cluster Report element on a 2.16 GHz channel with the DBC Present field set to 1 and the Channel Splitting subfield set to 0, it should become a member AP or member PCP of the other cluster on the corresponding channel according to the procedures described in 10.40.2 (Cluster formation) if its Channel Splitting subfield is 1 or its Channel Splitting subfield is 0, but the MAC Address is higher than that of the other S-AP or S-PCP.

If the S-AP or S-PCP of a decentralized AP or PCP cluster detects the presence of the DMG S-AP or S-PCP of another decentralized AP or PCP cluster through receiving a DMG Beacon frame on a 2.16 GHz channel with the DBC Present field set to 0, it should become a member AP or member PCP of the other cluster on this 2.16 GHz channel according to the procedures described in 10.39.2 (Cluster formation) if its MAC address is higher than that of the other DMG S-AP or S-PCP.

If the S-AP or S-PCP operating on a 1.08 GHz channel detects the presence of the S-AP or S-PCP of another decentralized AP or PCP cluster starting on the 2.16 GHz common channel and intends to become a member AP or member PCP of the other cluster, it may transmit a DMG Beacon frame containing the Cluster Switch Announcement element to its member APs or member PCPs before it switches to the 2.16 GHz common channel. After that, the S-AP or S-PCP may continue transmitting DMG Beacon frames on the 1.08 GHz channel within a time period of (aMinBTIPeriod × BI + aMinChannelTime) to maintain the time reference for the cluster, where BI is the Reported BI Duration field in the Cluster Switch Announcement element. Then it shall monitor the 1.08 GHz channel for DMG Beacon frames within the next time interval of (aMinChannelTime + CDMG SBBI), where CDMG SBBI is its beacon interval on the 1.08 GHz channel.

If no DMG Beacon frames are received over the monitoring period, the S-AP or S-PCP shall cease operation on the 1.08 GHz channel. Otherwise, it may use the cluster coordination mechanism described in 10.40.3.3 (Cluster coordination) to mitigate interference between the cluster operating on the 1.08 GHz channel and the cluster operating on the 2.16 GHz common channel.

Upon receiving a DMG Beacon frame including a Cluster Switch Announcement element on a 1.08 GHz channel, a member AP or member PCP should switch to the corresponding 2.16 GHz common channel to become a member AP or member PCP of the cluster operating on this 2.16 GHz channel following the procedure described in 10.39.2.1 (Decentralized AP or PCP cluster formation). If the AP or PCP cannot detect the presence of the S-AP or S-PCP of another decentralized AP or PCP cluster operating on the 2.16 GHz channel or cannot discover an empty Beacon SP, it should switch back to the former 1.08 GHz channel. After

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that, the decentralized clustering enabled AP or PCP may monitor this 1.08 GHz channel and follow the same procedures defined in 10.39.2.1 (Decentralized AP or PCP cluster formation) to become a member AP or member PCP of the cluster corresponding to the former S-AP or S-PCP or start an S-AP or S-PCP handover process according to 10.39.3.2 (Decentralized AP or PCP cluster maintenance).

#### 10.40.3.3 Cluster coordination

The cluster coordination mechanism allows a CDMG S-AP or S-PCP of a decentralized cluster operating on the 1.08 GHz channel to be a member AP (or member PCP) or S-AP (or S-PCP) of a decentralized cluster operating on the 2.16 GHz channel simultaneously by transmitting and receiving DMG Beacon frames within both clusters. By this means, cluster synchronization and control information can be exchanged to mitigate interference and improve spatial sharing.

In the case when a decentralized clustering enabled CDMG AP or PCP using cluster coordination mechanism, it shall maintain schedule information for both clusters (i.e., beacon intervals, Beacon SPs or SPs) to switch alternatively between the 1.08 GHz channel and 2.16 GHz channel. For example, it should switch to the 2.16 GHz channel prior to a Beacon SP allocated on the 2.16 GHz channel and transmit or receive the DMG Beacon frames.

The decentralized clustering enabled CDMG AP or PCP using cluster coordination mechanism should schedule at least one SP within the cluster operating on the 2.16 GHz channel that has the source and destination DMG AIDs set to 255 and the AllocationType subfield set to 2 indicating the Beacon SP of the synchronization CDMG AP or PCP of the cluster operating on the 1.08 GHz channel. In addition, it may schedule more SPs indicating other nonempty Beacon SPs of the cluster operating on the 1.08 GHz channel.

As being an S-AP or S-PCP of the cluster operating on the 1.08 GHz channel, the AP or PCP using coordination mechanism shall adjust its TBTT to avoid overlapping with any Beacon SP of the cluster operating on the 2.16 GHz channel. In addition, it should schedule multiple SPs within the cluster operating on the 1.08 GHz channel that has the source and destination DMG AIDs set to 255 and the AllocationType subfield set to 0 indicating the schedule information of a nonempty Beacon $SP_n$ of the cluster operating on the 2.16 GHz channel.

If a member AP or member PCP of a cluster operating on the 1.08 GHz channel receives an Extended Schedule element from an S-AP or S-PCP with the same cluster ID that includes at least one Allocation field with the AllocationType subfield set to 0 and the source and destination AIDs set to 255, it may switch to the 2.16 GHz channel according to the schedule information in an attempt to receive a DMG Beacon frame.

#### 10.40.3.4 Centralized CDMG AP or PCP cluster maintenance

In the case when the S-AP or S-PCP of a centralized AP or PCP cluster on a 1.08 GHz channel is lost, or appears to a member AP or member PCP to have been lost, the S-AP handover procedures shall follow the rules in 10.39.3.3 (Centralized AP or PCP cluster maintenance). In addition, the new S-AP or S-PCP shall also transmit a DMG Beacon frame during its NP of the allocated QP on the 2.16 GHz common channel as described in 10.63.5 (Backward compatibility and interoperation), even if there is no legacy non-AP and non-PCP DMG STA within its BSS or it does not involve in a synchronization pair with another AP or PCP operating on the adjacent 1.08 GHz channel.

If a CDMG CCSR detects that a new S-AP that is joining the CCSS is a DMG AP or a CDMG AP operating on the 2.16 GHz channel and there is at least one S-AP operating on a 1.08 GHz channel in its CCSS, the CDMG CCSR shall announce the cluster information (including the cluster ID, cluster synchronization and control information, and the channel number of the new S-AP operating on the 2.16 GHz common channel) to each S-AP operating on 1.08 GHz channel to facilitate the detection of the presence of the new S-AP for the S-APs operating on 1.08 GHz channel.


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If a CDMG S-AP operating on a 1.08 GHz channel receives the cluster information of the new S-AP operating on 2.16 GHz channel from the CCSR, it should measure the state and the signal quality of each Beacon SP and determine whether to join the centralized cluster of the new S-AP based on the state or signal quality of each Beacon SP.

The S-AP shall broadcast the cluster information of the new S-AP to all the member APs or member PCPs in its centralized cluster using the Extended Cluster Report element indicated in the DMG Beacon frame. The member APs or member PCPs on the 1.08 GHz channels should determine whether to join the centralized cluster of the new S-AP based on the cluster information and the monitoring results of the new S-AP operating on the 2.16 GHz channel.

If an S-AP or a member AP or member PCP operating on a 1.08 GHz channel decides to join the centralized cluster of the new S-AP operating on a 2.16 GHz channel, the S-AP or member AP or member PCP shall transmit a Cluster Switch Announcement element to all its cluster members using the DMG Beacon frame to broadcast the cluster information and its cluster switching determination to all the member APs or member PCPs in the centralized cluster. The remaining member APs or member PCPs can update the Available Cluster Offset Bitmap field by using the Cluster Switch Announcement element transmitted by a member AP or member PCP.

#### 10.40.3.5 Centralized CDMG AP or PCP cluster MAC requirements

Centralized CDMG AP or PCP cluster MAC requirements shall follow the rules described in 10.39.3.4 (Centralized AP or PCP cluster MAC requirements).

### 10.40.4 Cluster report and rescheduling

Regardless of whether an AP or PCP cluster starts on a 2.16 GHz channel or a 1.08 GHz channel, a CDMG STA shall follow the rules defined in 10.39.4 (Cluster report and rescheduling) for the cluster report and rescheduling.

When an AP or PCP operating on a 1.08 GHz channel still experiences poor channel conditions after performing all the actions in an attempt to mitigate any interference, it may send an Information Request frame to one of the non-AP and non-PCP STAs within its BSS to monitor the corresponding 2.16 GHz common channel for a cluster monitoring period defined in 10.39.3.2 (Decentralized AP or PCP cluster maintenance). The non-AP and non-PCP STA operating on a 1.08 GHz channel that receives a DMG Beacon frame on the 2.16 GHz common channel shall report the monitoring results through sending a Cluster Report element contained in an Announce frame or Information Response frame to the AP or PCP if the received DMG Beacon frame meets the conditions given in 10.39.4 (Cluster report and rescheduling).

Upon receiving a Cluster Report element included in the Announce frame from a non-AP and non-PCP STA operating on the 1.08 GHz channel with the Cluster Report field equal to 1 and the Cluster Channel Number field equal to 0, a decentralized cluster enabled AP or PCP operating on a 1.08 GHz channel may reserve multiple SPs on the 1.08 GHz channel to identify whether there is an empty Beacon SP. The AP or PCP may reschedule SPs and CBAPs in its beacon interval, or move the BTI if the clustering enabled AP or PCP is an S-AP or S-PCP in a decentralized AP or PCP cluster, or change the cluster time offset if the clustering enabled AP or PCP is a member AP or member PCP, or perform other actions, in an attempt to mitigate any interference from the transmissions as indicated in the received Cluster Report element. The AP or PCP may also create SPs in its beacon interval with the source and destination AIDs set to 255 to eliminate transmissions during specific periods in the beacon interval. In addition, the AP or PCP operating on a 1.08 GHz channel can reserve multiple SPs in a DTI based on the clustering synchronization and control information included in the Cluster Report element, monitoring the Beacon SPs on the 2.16 GHz channel, to identify whether there is an empty Beacon SP of the decentralized cluster operating on the channel indicated by the Cluster Channel Number field.

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Upon receiving a Cluster Report element from a non-AP and non-PCP STA with the Cluster Report field set to 1 and the Cluster Channel Number field set to 0, a clustering enabled AP or PCP that is an S-AP or S-PCP or a member AP or member PCP may switch to the corresponding 2.16 GHz common channel and discover an empty Beacon SP to become a member AP or member PCP of this cluster following the procedures described in 10.40.3.2 (Decentralized CDMG AP or PCP cluster maintenance). The AP or PCP should also broadcast a DMG Beacon frame containing the Cluster Switch Announcement element to other APs or PCPs of the same cluster before it switches to the 2.16 GHz common channel.

### 10.40.5 Decentralized AP or PCP cluster request

Regardless of whether a BSS starts on a 2.16 GHz channel or a 1.08 GHz channel, a CDMG STA shall follow the rules defined in 10.39.4 (Cluster report and rescheduling) for the cluster request.

To request AP or PCP clustering to be enabled in the BSS, the STA shall transmit a Cluster Report element with the Cluster Request subfield set to 1 to its AP or PCP. Upon receiving a Cluster Report element with the Cluster Request subfield set to 1, the AP or PCP should form and maintain decentralized AP or PCP clustering in the BSS according to the procedures described in 10.39.2 (Cluster formation), 10.39.3 (Cluster maintenance), 10.40.2 (Cluster formation), and 10.40.3 (Cluster maintenance).

### 10.40.6 Spatial sharing in a CDMG AP or PCP cluster

This subclause describes mechanisms to enable spatial sharing and interference mitigation among CDMG infrastructure BSSs or PBSSs in a coordinated OBSS environment, i.e., in a CDMG AP or PCP clustering environment. By utilizing the schedule information of SP allocation in other BSSs in an AP or PCP cluster, an AP or PCP acquires and shares channel measurement results of STAs within its BSS by requesting STAs in its BSS to perform directional channel measurement during SPs of other BSSs. Therefore, APs or PCPs in different BSSs can allocate SPs in overlapping time periods in the same channel and achieve spatial sharing among BSSs.

If the SPSH in CDMG Cluster subfield in the CDMG Capabilities element of a CDMG AP or PCP is 1 and one of the Decentralized Cluster field and the Centralized Cluster field is 1, then the CDMG AP or PCP supports spatial sharing mechanism among BSSs in the AP or PCP cluster.

A CDMG STA that supports spatial sharing, as indicated by the SPSH in CDMG Cluster subfield set to 1 in the STA's CDMG Capabilities element, shall support the directional channel quality measurements described in 9.4.2.20.15 (Directional Channel Quality report) and 9.4.2.20.16 (Directional Measurement report).

The SP spatial sharing among BSSs in an AP or PCP cluster contains two phases: SPSH measurement phase and SP spatial sharing phase. The goal of setting an SPSH measurement phase is to allow APs or PCPs to find pairs of links in different BSSs that can coexist. Spatial reuse is not allowed in SPSH measurement phase. Only one pair of STAs participate directional channel quality measurement.

A CDMG S-AP or S-PCP that supports SPSH among BSSs should indicate whether all the member APs or member PCPs in a cluster are in the SPSH measurement phase or in the SP spatial sharing phase by setting the SPSH Measurement Enabled subfield in the Clustering Control field of the DMG Beacon frame to 1 or by setting the Clustering SPSH Enabled field within the Clustering Interference Assessment element to 1. The SPSH Measurement field is set to 1 to indicate that SPSH measurement phase starts. Each member AP or member PCP that supports SPSH among BSSs should request STAs in its BSS to perform directional channel quality measurement during SPs of other BSSs in the same cluster, as described in 11.11 (DSE procedures). The CDMG AP or PCP should send directional channel quality request to STAs in the same BSS and receive directional channel quality report from the STAs. The period of the directional channel quality measurement is indicated by the Channel Quality Measurement Duration subfield within the Clustering Interference Assessment element. The AP or PCP can obtain the interference information that indicates link(s) in its BSS experience interference from at least one link of other BSS within the AP or PCP cluster through channel


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measurement of STAs. The AP or PCP can determine the channel quality across STAs within multiple BSSs and implement spatial sharing based on the results of the measurements performed by the STAs associated with the AP or PCP. The S-AP or S-PCP should periodically set the SPSH Measurement Enabled subfield, generating and sending the indicated information of interference measurement.

In the SPSH measurement phase, each member AP or member PCP that supports SPSH among BSSs in an AP or PCP cluster shall schedule SPs in nonoverlapping period according to the clustering mechanism, as described in 10.39 (DMG and CMMG AP or PCP clustering) and 10.40 (CDMG AP or PCP clustering). If one link in a BSS is transmitting data, link(s) in other BSSs keeps in directional channel measurement state. The determination of the interference from the measured link (existing SP) to the candidate SP is implementation dependent and beyond the scope of this standard.

Each member AP or member PCP in a cluster may record the information that links in other BSSs do not interfere with the link(s) in its BSS through channel measurement of STAs, and include the information in SPSH Report elements that are sent to other AP(s) or PCP(s) through DMG Beacon frames. Each member AP or member PCP can obtain interference information that indicates interference experienced by at least one link of other BSS(s) from link(s) of its BSS, after receiving the SPSH Report element from other APs or PCPs in the same cluster. Each AP or PCP is able to obtain a database of links that may perform SPSH, but the definition of the database is beyond the scope of this standard.

After SPSH measurement, the S-AP or S-PCP shall set the SPSH Measurement Enabled subfield in the Clustering Control field of the DMG Beacon frame to 0, indicating that BSSs in the cluster are allowed to conduct spatial sharing in overlapping SPs in SP spatial sharing phase.

In the SP spatial sharing phase, each AP or PCP in the cluster should schedule SPs to achieve spatial sharing according to the received SP allocation information that indicates scheduled SP allocation for link(s) of other BSS(s) in the same AP or PCP cluster and according to the interference information from link(s) of other BSS(s) to its BSS and the interference information from link(s) of its BSS to link(s) of other BSS(s) obtained in SPSH measurement phase. The SP allocation information is obtained by receiving the Extended Schedule element in the DMG Beacon frame of other AP(s) or PCP(s) in the AP or PCP cluster. The scheduled link(s) of the AP's or PCP's BSS and link(s) of other BSS(s) should not interfere with each other during the same SP.

If an AP or PCP discovers that a link in its BSS and a link in another BSS in the same cluster do not interfere with each other, then the AP or PCP can schedule overlapping SPs for the two links.

Through sending and receiving the SPSH Report element, an AP or PCP should schedule an overlapping candidate SP only after sharing the spatial reuse information including noninterfering links corresponding to the scheduled SPs and candidate SPs with a neighbor AP or PCP. If an AP or PCP cannot know the interference information between links in neighboring BSSs and its BSS, it should not conduct SP spatial sharing.

Figure 10-78 (Example of spatial sharing with interference mitigation among multiple BSSs) illustrates an example of the resulting SP schedule for the spatial sharing among three BSSs in a cluster.

## 10.41 DMG beamforming

### 10.41.1 General

Beamforming (BF) is a mechanism that is used by a pair of STAs to achieve the necessary DMG link budget for subsequent communication. BF training is a bidirectional sequence of BF frame (11ay)or Short SSW PPDU transmissions that uses sector sweep and provides the necessary signaling to allow each STA to determine appropriate antenna system settings for both transmission and reception. After the successful

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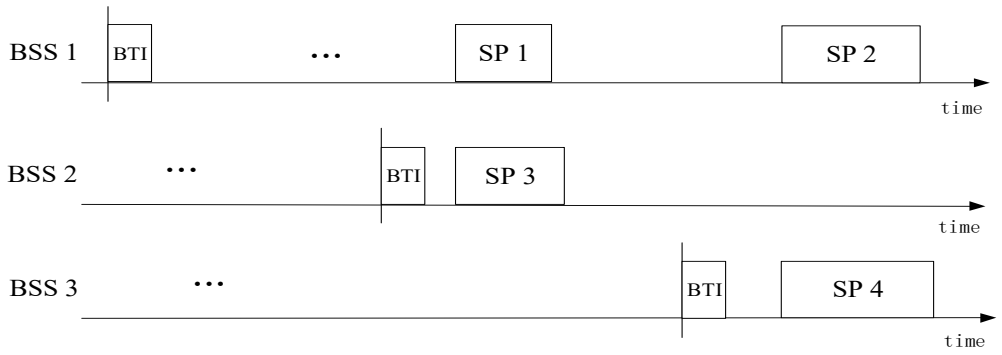


**Figure 10-78—Example of spatial sharing with interference mitigation among multiple BSSs**

completion of BF training, BF is said to be established. A BF frame is an SSW frame, a DMG Beacon frame, an SSW-Feedback frame, an SSW-Ack frame or a BRP frame. Figure 10-79 (An example of beamforming training(#4303)) gives an example of the beamforming training procedure.

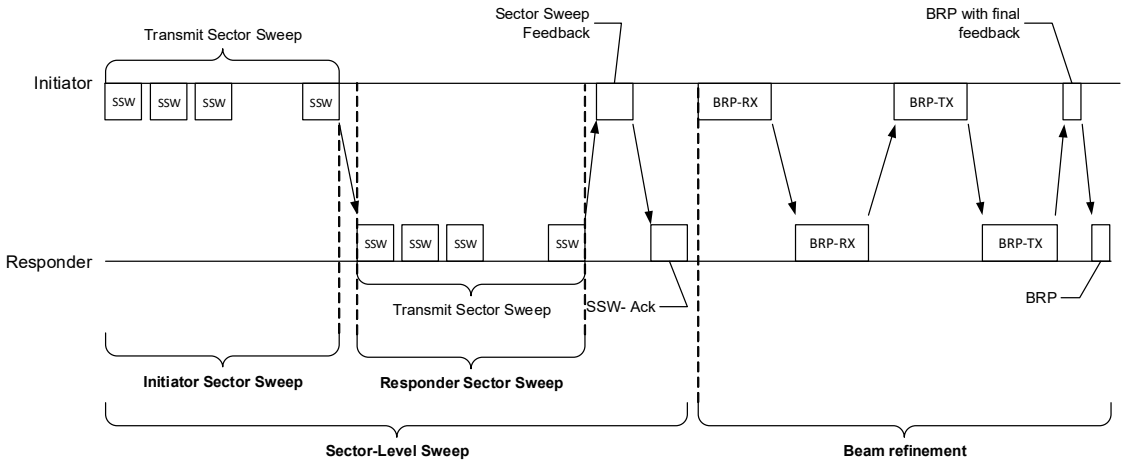


**Figure 10-79—An example of beamforming training(#4303)**

(11ay)Short SSW PPDUs are used between EDMG STAs. Unless otherwise specified, the rules applicable to transmission of SSW frames specified in this subclause are also applicable to transmission of Short SSW PPDUs.

In this subclause, the STA that initiates BF training through the transmission of a BF frame is referred to as the *initiator*, and the recipient STA of the BF frame that participates in BF training with the initiator is referred to as the *responder*. For BF training that occurs within the A-BFT allocation, the AP or PCP is the initiator and a non-AP and non-PCP STA becomes the responder. For BF training that occurs during an SP allocation, the source DMG STA of the SP is the initiator and the destination DMG STA of the SP becomes the responder. For BF training during a CBAP allocation, the TXOP holder is the initiator and the TXOP responder is the responder and the value of the Duration field in the transmitted BF frames does not limit the duration of the BF training procedure. The duration of the BF training procedure is specified in 10.41.6.2 (SLS phase execution) and 10.41.6.4 (BRP phase execution).


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The link from the initiator to the responder is referred to as the *initiator link*, and the link from the responder to the initiator is referred to as the *responder link*.

BF training starts with a SLS from the initiator. A beam refinement protocol (BRP) may follow, if requested by either the initiator or the responder. The purpose of the SLS phase is to enable communications between the two participating STAs at the DMG control mode rate or higher MCS. Normally, the SLS phase provides only transmit BF training. The purpose of the BRP phase is to enable receive training and enable iterative refinement of the AWV of both transmitter and receiver at both participating STAs. If one of the participating STAs chooses to use only one transmit antenna pattern, receive training may be performed as part of the SLS.

Any BF information obtained by an initiator or a responder during a BF training attempt shall be considered invalid if either or both of the following conditions are satisfied:

a) The SLS phase was not completed within dot11MaxBFTime beacon intervals from the start of the SLS phase.
b) The BRP phase, if initiated, was not completed within dot11MaxBFTime beacon intervals from the start of the BRP phase.

A STA shall abort an SLS if the SLS is not completed within dot11MaxBFTime beacon intervals from the start of the SLS, and shall abort a BRP if the BRP is not completed within dot11MaxBFTime beacon intervals from the start of the BRP.

A STA can have one or more DMG antennas. A DMG antenna can be used to create sectors through which a STA can transmit or receive frames. The number of sectors per DMG antenna shall not be greater than 64. The total number of sectors across all DMG antennas in a STA shall not be greater than 128.

Table 10-35 (Mandatory and optional procedures in the Beamforming mechanism) shows the mandatory and optional procedures in the beamforming mechanism described in this subclause.

**Table 10-35—Mandatory and optional procedures in the Beamforming mechanism**

| Beamforming item | Support mandatory | Notes |
|---|---|---|
| SLS phase (10.41.2 (Sector-level sweep (SLS) phase), 10.41.6.2 (SLS phase execution)) | Yes | A DMG STA is capable to participate in an SLS with any other STA as described in 10.41.2 (Sector-level sweep (SLS) phase) and 10.41.6.2 (SLS phase execution). |
| Beamforming in BTI (10.41.4 (Beamforming in BTI)) | Yes | When operating as an AP or PCP, a DMG STA is capable to perform beamforming in the BTI as described in 10.41.4 (Beamforming in BTI). |
| Beamforming in A-BFT (10.41.5 (Beamforming in A-BFT)) | Yes | When operating as an AP or PCP, a DMG STA is capable to perform beamforming in the A-BFT as described in 10.41.5 (Beamforming in A-BFT). |
| BRP setup subphase (10.41.3.2 (BRP setup subphase)) | Yes | A DMG STA is capable to negotiate BRP settings with any other STA as described in 10.41.3.2 (BRP setup subphase). |

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**Table 10-35—Mandatory and optional procedures in the Beamforming mechanism *(contin-***

| Beamforming item | | Support mandatory | Notes |
|---|---|---|---|
| MIDC subphase (10.41.6.3 (Multiple sector ID capture (MIDC) subphase)) | MID subphase | No | A DMG STA does not have to be capable to perform MID as described in 10.41.6.3 (Multiple sector ID capture (MIDC) subphase). |
| | BC subphase | No | A DMG STA does not have to be capable to perform BC as described in 10.41.6.3 (Multiple sector ID capture (MIDC) subphase). |
| BRP phase (10.41.3 (Beam Refinement Protocol (BRP) phase), 10.41.6.4 (BRP phase execution)) | Feedback = BS-FBCK | Yes | A DMG STA is capable to perform the BRP with any other STA as described in 10.41.3 (Beam Refinement Protocol (BRP) phase) and 10.41.6.4 (BRP phase execution) and is capable to return the BS-FBCK. |
| | Feedback = Channel measurement | No | A DMG STA is capable to perform the BRP with any other STA as described in 10.41.3 (Beam Refinement Protocol (BRP) phase) and 10.41.6.4 (BRP phase execution), but does not have to be capable to return channel measurements. |
| Beam tracking (10.41.7 (Beam tracking)) | Feedback = BS-FBCK | Yes | A DMG STA is capable of responding to a receive beam tracking request. A DMG STA is capable of responding to a transmit beam tracking request with the BS-FBCK. |
| | Feedback = Channel measurement | No | A DMG STA is capable of responding to a receive beam tracking request. A DMG STA does not have to be capable of responding to a transmit beam tracking request with channel measurements. |

An SLS between an initiator and a responder is successful for the initiator if, after the completion of the SLS, the initiator receives a response to a frame transmitted to the responder using the sector and antenna selected during the SLS. The SLS is successful for the responder if, after the completion of the SLS, the responder receives a response to a frame transmitted to the initiator using the sector and antenna selected during the SLS.

In this subclause, the last negotiated Total Number of Sectors field, Number of RX DMG Antennas field, and RXSS Length field held by the initiator with respect to the responder refer to the last value of the corresponding field received by the initiator from the responder and that the SLS between the initiator and responder using this value was successful for the initiator. Similarly, the last negotiated Total Number of Sectors field, Number of RX DMG Antennas field, and RXSS Length field held by the responder with respect to the initiator refer to the last value of the corresponding field received by the responder from the initiator and that the SLS between the responder and initiator using this value was successful for the responder.

Until an SLS is successful between an initiator and a responder, the last negotiated Total Number of Sectors field, Number of RX DMG Antennas field, and RXSS Length field used by the initiator with respect to the responder refer to the value of these fields in the responder's DMG Capabilities element, and the last negotiated Total Number of Sectors field, Number of RX DMG Antennas field, and RXSS Length field used by the responder with respect to the initiator refer to the value of these fields in the initiator's DMG Capabilities element.

If an MMSL cluster capable STA has successfully transmitted to a peer STA an MMS element with the BeamLink Cluster field set to 1, then all MAC entities coordinated by the same MM-SME as the MMSL cluster capable STA shall use a single beamformed link for the MMSL cluster. Also, the MAC address used


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by the MMSL cluster capable STA to initiate the beamforming procedure shall remain the same until the completion of the beamforming procedure.

A CMMG STA shall follow the DMG beamforming rules as described in 10.41 (DMG beamforming) where a BF frame transmitted by a CMMG STA is contained in a CMMG PPDU.

A CDMG STA shall follow the DMG beamforming rules as described in 10.41 (DMG beamforming), including the rules of CDMG enhanced beam tracking as described in 10.41.9 (CDMG enhanced beam tracking).

(11ay)A non-AP and non-PCP initiator or a non-AP and non-PCP unsolicited RSS responder may send an SPR frame to request a dynamic allocation of a service period to the AP or PCP to perform beamforming training. If either the initiator or the responder is an AP or a PCP and both initiator and responder are EDMG STAs that have an established control mode link between them, then the AP or PCP shall send a Grant frame to the responder (or the initiator of an unsolicited RSS). The non-AP and non-PCP STA shall respond with a Grant Ack frame to the AP or PCP, as appropriate, to update the last negotiated Total Number of Sectors field and Number of RX DMG Antennas field with respect to each other before starting an SLS procedure in the same CBAP or SP.

(11ay)If both the initiator and the responder are non-AP and non-PCP EDMG STAs, the initiator (or the responder of an unsolicited RSS) may send an SPR frame in a PPDU with the NUM_SECTORS and NUM_ANT parameters of TXVECTOR set to, respectively, the number of sectors of the I-TXSS (or R-TXSS if an unsolicited RSS) and the requested number of repetitions of the R-TXSS in the SLS to be performed. If the AP or PCP did not receive an SPR frame in a PPDU with a control trailer from the initiator (or the responder of an unsolicited RSS) immediately prior to a GP, the AP or PCP shall set the Number of RX DMG Antennas field to 1 and set the Total Number of Sectors field to the value indicated in the Total Number of Sectors field in the last DMG Capabilities element received from the initiator (or the responder of an unsolicited RSS) in a Grant frame transmitted to the responder (or the initiator of an unsolicited RSS) during the GP.

### 10.41.2 Sector-level sweep (SLS) phase

#### 10.41.2.1 General

The SLS phase can include as many as four components: an initiator sector sweep (ISS) to train the initiator link as described in 10.41.2.2 (Initiator sector sweep (ISS)), a responder sector sweep (RSS) to train the responder link as described in 10.41.2.3 (Responder sector sweep (RSS)), an SSW feedback procedure as described in 10.41.2.4 (Sector sweep (SSW) feedback), and an SSW ack procedure as described in 10.41.2.5 (SSW ack).

An initiator shall begin the SLS phase by transmitting the frames of the ISS.

A responder shall not begin transmitting the frames of an RSS before the ISS is successfully completed (as defined in 10.41.1 (General)), except when the ISS occurs in the BTI (10.41.5 (Beamforming in A-BFT)).

An initiator shall not begin an SSW feedback procedure before the RSS phase is successfully completed (as defined in 10.41.1 (General)), except when the RSS occurs in the A-BFT.

A responder shall not begin an SSW ack procedure with an initiator in the A-BFT. A responder shall begin an SSW ack procedure with an initiator immediately following the successful completion (as defined in 10.41.1 (General)) of the SSW feedback procedure with the initiator.

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During the SLS phase the only BF frames an initiator may transmit are the DMG Beacon frame, the SSW frame, and the SSW-Feedback frame. During the SLS phase the only BF frames a responder may transmit are the SSW frame and the SSW-Ack frame.

(11ay)If an initiator uses SSW frames to perform the ISS, the responder shall use SSW frames to perform the RSS. If an initiator uses Short SSW PPDUs to perform the ISS, the responder shall use Short SSW PPDUs to perform the RSS.

(11ay)A STA shall not transmit a Short SSW PPDU to another STA that is not an EDMG STA. A STA performing an ISS or an RSS using Short SSW PPDUs shall increase the value of the CDOWN field within the Short SSW PPDU by two for each LBIFS contained as part of a sector sweep.

(11ay)An EDMG STA that supports reception of Short SSW PPDUs from unassociated STAs during CBAP allocations shall set the RX Unassociated Short SSW subfield in the SSW field(#4303) to 1 within transmitted DMG Beacon frames.

If during the SLS the initiator and responder each execute a TXSS, then at the end of the SLS phase both the initiator and the responder possess their own transmit sector. If either the ISS or the RSS employs a receive sector sweep, then the responder or the initiator, respectively, possesses its own receive sector.

The following rule applies to all channel access in DMG BSSs. A STA shall not transmit a frame as part of a sector sweep comprising at least two sectors if a response is expected within SIFS from the STA identified in the RA field of the transmitted frame.

A STA shall not change its transmit power during a sector sweep.

(11ay)Except when used to implement radar functionality as described in Annex AB, the following rules apply to a PPDU transmitted as part of a sector sweep:

- (11ay)The PPDU transmitted by a non-EDMG STA as part of a sector sweep does not include a TRN field. A (11ay)non-EDMG STA shall set the TRN-LEN parameter of the TXVECTOR to 0 for a frame transmitted as part of a sector sweep.
- (11ay)The PPDU transmitted by an EDMG STA as part of a sector sweep and that does not include a DMG Beacon does not also include a TRN field. An EDMG STA shall set the TRN-LEN parameter of the TXVECTOR to 0 for a frame transmitted as part of a sector sweep and that is not a DMG Beacon.

Two examples of the SLS phases are shown in Figure 10-80 (An example of SLS where receive sector sweep is used in the response sector sweep(#6280)(#4303)) and Figure 10-81 (An example of SLS where transmit sector sweep is used in the response sector sweep(#4303)(#4303)).

In Figure 10-80 (An example of SLS where receive sector sweep is used in the response sector sweep(#6280)(#4303)) the initiator has many sectors, the responder has only one transmit sector, and receive sector sweep is used (#6280)in the responder sector sweep (the responder is transmitting all responder SSW frames through the same transmit sector, and the initiator is switching receive antennas at the same time).


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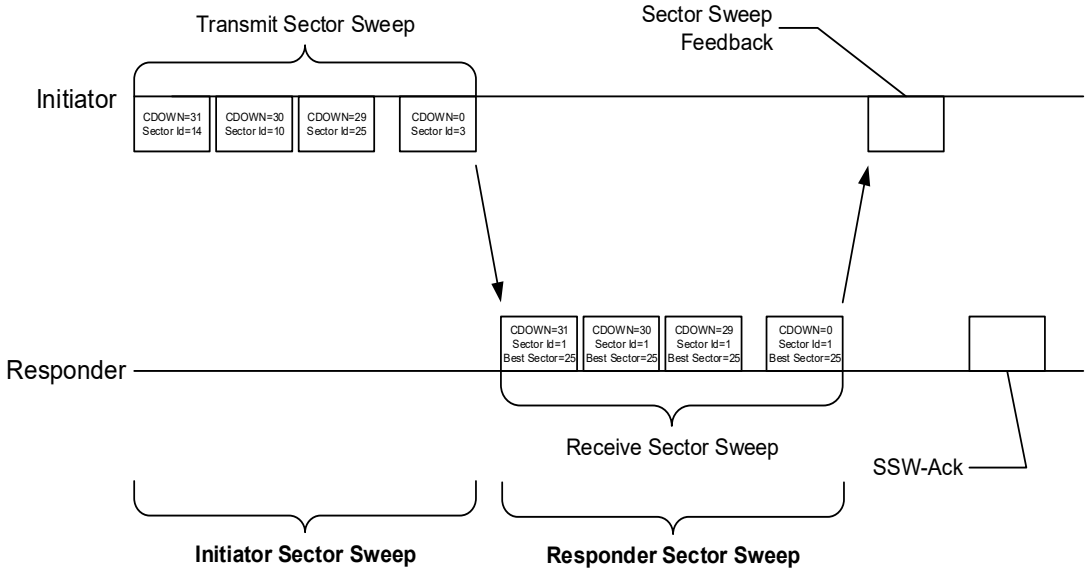


**Figure 10-80—An example of SLS where receive sector sweep is used in the response sector sweep(#6280)(#4303)**

In Figure 10-81 (An example of SLS where transmit sector sweep is used in the response sector sweep(#4303)(#4303)) the initiator has many transmit sectors, and the responder has one transmit sector. In this case, receive training for the initiator is performed in the BRP phase.

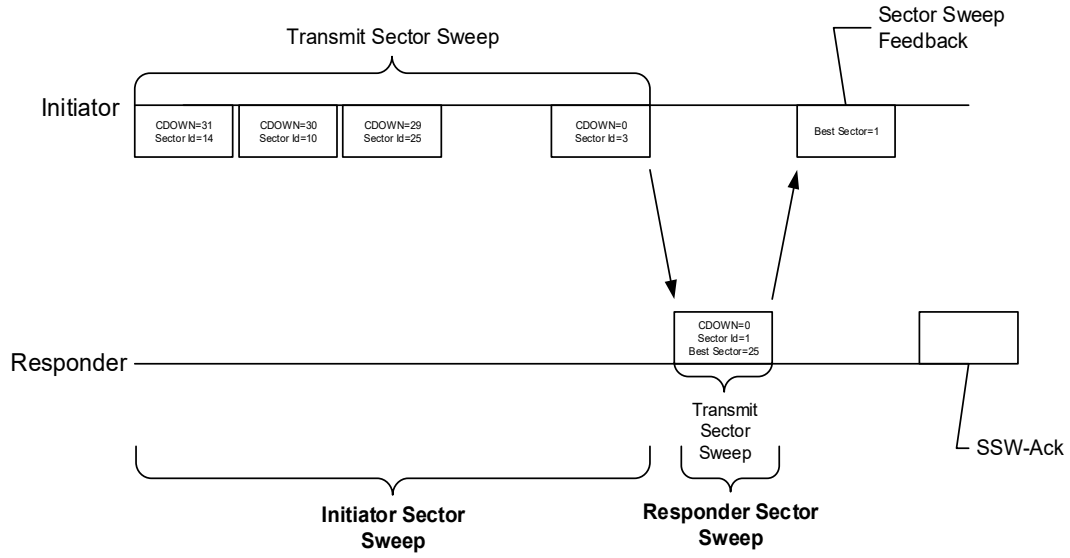


**Figure 10-81—An example of SLS where transmit sector sweep is used in the response sector sweep(#4303)(#4303)**

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### 10.41.2.2 Initiator sector sweep (ISS)

#### 10.41.2.2.1 General

An ISS comprises either an initiator TXSS or an initiator RXSS.

An initiator RXSS may be performed in an ISS when the initiator chooses to use only one transmit antenna pattern across each of its DMG antennas.

An initiator may employ either DMG Beacon frames or SSW frames in the ISS. If the initiator begins an ISS with the transmission of a DMG Beacon frame, it shall use the DMG Beacon frame for all subsequent transmissions during the ISS. Conversely, if the initiator begins an ISS with the transmission of an SSW frame, it shall use the SSW frame for all subsequent transmissions during the ISS. A responder never begins an ISS.

An initiator may employ (11ay)DMG Beacon frames, SSW frames, or Short SSW PPDUs in the ISS. If the initiator begins an ISS with the transmission of a DMG Beacon frame, it shall use the DMG Beacon frame for all subsequent transmissions during the ISS. (11ay)If the initiator begins an ISS with the transmission of an SSW frame, it shall use the SSW frame for all subsequent transmissions during the ISS. (11ay)If the initiator begins an ISS with the transmission of a Short SSW PPDU, it shall use the Short SSW PPDU for all subsequent transmissions during the ISS. A responder never begins an ISS.

The initiator shall set the Direction subfield in the SSW field(#4303) to 0 within each DMG Beacon and SSW frame transmitted during an ISS. (11ay)The initiator shall set the TXVECTOR parameter SSSW_DIR to Initiator within each Short SSW PPDU transmitted during an ISS.

(11ay)During a CBAP, an EDMG STA may obtain a TXOP with an unsolicited RSS by transmitting a Grant frame at the beginning of the TXOP or use an existing TXOP for an unsolicited RSS (see 10.41.6.2 (SLS phase execution)). If a TXOP is obtained through the transmission of a Grant frame and the TXOP holder intends to continue the TXOP with an unsolicited RSS, the TXOP holder shall set the Unsolicited RSS subfield in the Grant frame to 1 to indicate the SLS begins with an unsolicited RSS and is performed without an ISS.

(11ay)If an SP is allocated with the Unsolicited RSS subfield in the BF Control field set to 1, the source STA shall set the Direction subfield in the SSW frame(s) to 1 to indicate the SLS begins with an unsolicited RSS and is performed without an ISS.

The initiator shall set the Total Sectors in ISS subfield within the SSW Feedback field to the total number of sectors that it is using in the ISS. The total is computed as the sum of all sectors employed on all antennas in the ISS multiplied by the number of the responder's receive DMG antennas. For example, if 4 sectors are used on antenna 0, 3 sectors on antenna 1, 5 sectors on antenna 2, and the responder has two receive DMG antennas, then the Total Sectors in ISS subfield is set to 24.

#### 10.41.2.2.2 Initiator TXSS

When the IsInitiatorTXSS field for a specific SP is 1 in a received Extended Schedule element (see 9.4.2.130 (Extended Schedule element)) or Grant frame (see 9.3.1.12 (Grant frame format)) and the Beamforming Training field of the BF Control field for that SP in the same Extended Schedule element or Grant frame is 1, then the SP contains an initiator TXSS, and the initiator shall start an initiator TXSS at the start of the next SP as indicated by the received Extended Schedule element or Grant frame.

During the BTI, the initiator shall start an initiator TXSS (see also 10.41.4 (Beamforming in BTI)).


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During a CBAP, an initiator may obtain a TXOP with an initiator TXSS or use an existing(#2225) TXOP for the initiator TXSS. If transmission of a Grant frame to the responder is used to initiate the TXSS, the Beamforming Training and IsInitiatorTXSS fields of the BF Control field is set to 1. If a Grant Ack frame is transmitted by the responder, it shall comply with 10.38.4 (DTI transmission rules). In the Grant Ack frame, the responder shall set the Beamforming Training field to 1. The initiator starts the initiator TXSS SIFS after transmission of the Grant frame or after the reception of the Grant Ack frame if the Grant Ack Supported field in the responder's DMG Capabilities element is 1 or PIFS interval after the transmission the Grant frame otherwise.

During an initiator TXSS, the Sector ID field in each BF frame shall be set to a value that uniquely identifies the transmit antenna sector employed when the BF frame is transmitted. The CDOWN field in each transmitted frame shall contain the total number of transmissions remaining until the end of the initiator TXSS, including any LBIFS if required, such that the last BF frame transmission of the initiator TXSS has the CDOWN field set to 0. Each transmitted BF frame shall be separated by a time interval equal to SBIFS, unless the allocation ends as described in 10.41.6 (Beamforming in DTI). This is indicated in Figure 10-82 (Initiator TXSS or initiator RXSS).

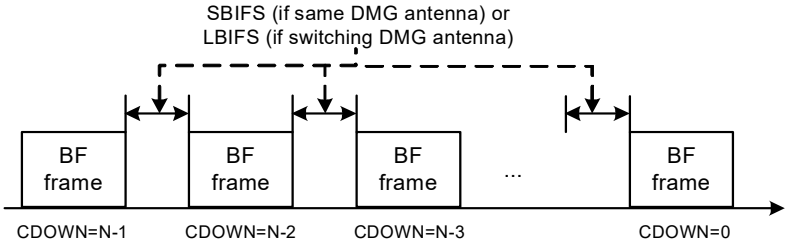


**Figure 10-82—Initiator TXSS or initiator RXSS**

(11ay)An initiator that is not associated to the responder may transmit Short SSW PPDUs during the initiator TXSS if it has received a DMG Beacon frame from the responder with the RX Unassociated Short SSW subfield in the SSW field(#4303) set to 1. In this case, in the Short SSW PPDU the initiator shall set the TXVECTOR parameter SSSW_ADD_MODE to IndividualAddr, SSSW_SOURCE_AID, and SSSW_DESTINATION_AID parameters to random values between $[0, 255]$ and the SSSW_UNASSOCIATED parameter to 1. The values of the SSSW_SOURCE_AID and SSSW_DESTINATION_AID parameters shall not change between Short SSW PPDUs transmitted within the same initiator TXSS.

If the initiator has more than one DMG antenna, the initiator transmits the BF frame through a number of sectors equal to the value of the last negotiated Total Number of Sectors field that was transmitted by the initiator to the responder. In each transmitted BF frame, the initiator shall set the Sector ID and DMG Antenna ID fields to uniquely identify the sector and the DMG antenna ID, respectively, the initiator is using for the frame transmission and shall set the CDOWN field to the total number of transmissions remaining from all of the initiator's DMG antennas.

If an ISS is outside the BTI and if the responder has more than one DMG antenna, the initiator repeats its initiator sector sweep for the number of DMG antennas indicated by the responder in the last negotiated Number of RX DMG Antennas field that was transmitted by the responder. Repetitions of the initiator sector sweep are separated by an interval equal to LBIFS. In this case CDOWN indicates the number of sectors until the end of transmission from all initiator's DMG antennas to all responder's DMG antennas. At the start of an initiator TXSS, the responder should have its first receive DMG antenna configured to a quasi-omni pattern and should not change its receive antenna configuration for a time corresponding to the value of the last negotiated Total Number of Sectors field transmitted by the initiator multiplied by the time to

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transmit a single SSW frame, plus appropriate IFSs (10.3.2.3 (IFS)). After this time, the responder may switch to a quasi-omni pattern in another DMG antenna.

The initiator TXSS ends at the end time of the BF frame from the initiator with the CDOWN field set to 0. If the responder is unable to receive this frame, the responder shall assume that the initiator TXSS has completed at the expected end time of this frame.

#### 10.41.2.2.3 Initiator RXSS

An initiator RXSS may be requested only when an initiator is aware of the capabilities of a responder, which includes the RXSS Length field. An initiator can obtain the capabilities of a responder using the Information Request and Response procedure as described in 11.28.1 (Information Request and Response).

When the IsInitiatorTXSS field for a specific SP in a received Extended Schedule element or Grant frame is 0 and the Beamforming Training field of the BF Control field for that SP in the same Extended Schedule element or Grant frame is 1, then the SP shall contain an initiator RXSS, and the initiator shall start an initiator RXSS at the start of the next SP described by the received Extended Schedule element or Grant frame.

The initiator never performs an initiator RXSS during the BTI.

During a CBAP, an initiator shall not obtain a TXOP with an initiator RXSS. When transmission of a Grant frame to the responder is used to initiate the RXSS the Beamforming Training field set to 1 and the IsInitiatorTXSS field set to 0. If a Grant Ack frame is transmitted by the responder it shall comply with 10.38.4 (DTI transmission rules). In the Grant Ack frame, the responder shall set the Beamforming Training field to 1. The initiator starts the initiator RXSS SIFS after transmission of the Grant frame or after the reception of the Grant Ack frame if the Grant Ack Supported field in the responder's DMG Capabilities element is 1 or PIFS after the transmission the Grant frame otherwise.

If the initiator uses more than one transmit sector or more than one transmit DMG antenna to perform beamforming with the responder, the initiator shall perform an initiator TXSS with the responder before participating in an initiator RXSS with the responder.

During the initiator RXSS the initiator shall transmit from the DMG antenna and sector that were selected during the preceding TXSS with the responder the number of BF frames indicated by the responder in the last negotiated RXSS Length field transmitted by the responder. Each transmitted BF frame shall be transmitted with the same fixed antenna sector or pattern. The initiator shall set the Sector ID and DMG Antenna ID fields in each transmitted BF frame to a value that uniquely identifies the single sector through which the BF frame is transmitted. The initiator shall set the CDOWN field in each transmitted BF frame to contain the total number of transmissions remaining to the end of the initiator RXSS, such that the last BF frame transmission of the initiator RXSS has the CDOWN field set to 0. Each transmitted BF frame shall be separated by a time interval equal to SBIFS, except if the allocation ends as described in 10.41.6 (Beamforming in DTI). This is indicated in Figure 10-82 (Initiator TXSS or initiator RXSS).

During an initiator RXSS, the responder should have its receive antenna array configured to sweep RXSS Length sectors, including any LBIFS if required, while attempting to receive SSW frames from the initiator.

The initiator RXSS ends at the end time of the SSW frame from the initiator with the CDOWN field set to 0. If the responder is unable to receive this frame, the responder shall assume that the initiator RXSS has completed at the expected end time of this frame.


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### 10.41.2.3 Responder sector sweep (RSS)

#### 10.41.2.3.1 General

An RSS comprises either a responder TXSS or a responder RXSS.

A responder RXSS may be performed in an RSS when the responder chooses to use only one transmit antenna pattern across each of its DMG antennas.

The responder initiates an RSS with the transmission of an SSW frame (11ay)if the preceding ISS was performed with at least one SSW frame. The responder initiates an RSS with the transmission of a Short SSW PPDU if the preceding ISS was performed with at least one Short SSW PPDU. If the ISS was performed in the BTI, the responder behavior in the A-BFT is described in 10.41.5.2 (Operation during the A-BFT).

The responder shall set the Direction subfield in the SSW field(#4303) to 1 within each SSW frame transmitted during an RSS. (11ay)The responder shall set the TXVECTOR parameter SSSW_DIR to Responder within each Short SSW PPDU transmitted during an RSS.

#### 10.41.2.3.2 Responder TXSS

If the DMG Beacon frame immediately preceding an A-BFT contained a value of one in the IsResponderTXSS subfield of the Beacon Interval Control field, then the A-BFT is a responder TXSS A-BFT.

When the IsResponderTXSS field for a specific SP in a received Extended Schedule element or Grant frame is 1 and the Beamforming Training field of the BF Control field for that SP in the same Extended Schedule element or Grant frame is 1, then the SP contains a responder TXSS, and the responder shall initiate a TXSS following the completion of the ISS in the SP described by the received Extended Schedule element or Grant frame.

When the RXSS Length field within an SSW frame used to obtain a TXOP during a CBAP is 0, the responder shall initiate a TXSS following the completion of the ISS in the TXOP described by the received SSW frame.

(11ay)A responder that has transmitted a DMG Beacon frame with the RX Unassociated Short SSW subfield in the SSW field(#4303) set to 1 and that receives a Short SSW PPDU as part of an ISS with the Direction field set to 0 and the Unassociated field set to 1 during the CBAP, shall initiate a responder TXSS using Short SSW PPDUs following the completion of the ISS. In this case, the responder shall set the Source AID field and Destination AID field in transmitted Short SSW PPDUs to the values of the Source AID field and Destination AID field, respectively, in the received Short SSW PPDUs during the ISS.

During a responder TXSS, the responder shall set the Sector ID and the DMG Antenna ID fields in each transmitted SSW frame to a value that uniquely identifies the sector through which the SSW frame is transmitted. The initial value of CDOWN is set to the total number of sectors in the responder (covering all DMG antennas) multiplied by the number of DMG antennas at the initiator minus one. The responder shall set the CDOWN field in each transmitted SSW frame to contain the total number of transmissions remaining to the end of the responder TXSS, including any LBIFS if required, such that the last SSW frame transmission of the responder TXSS has the CDOWN field set to 0. The responder shall transmit from its DMG antennas in increasing order of DMG antenna ID. Each transmitted SSW frame shall be separated by an interval of time equal to SBIFS. Transmissions are not separated by SBIFS if the allocation ends as described in 10.41.4 (Beamforming in BTI) and 10.41.6 (Beamforming in DTI) or if the end of an SSW slot is reached as described in 10.41.5 (Beamforming in A-BFT) or when the responder completed a full sweep of all its transmit sectors and is ready to transmit to another DMG antenna of the initiator. In the latter case,

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the next transmission is separated from the previous transmission by LBIFS. This is indicated in Figure 10-83 (Responder TXSS or responder RXSS).

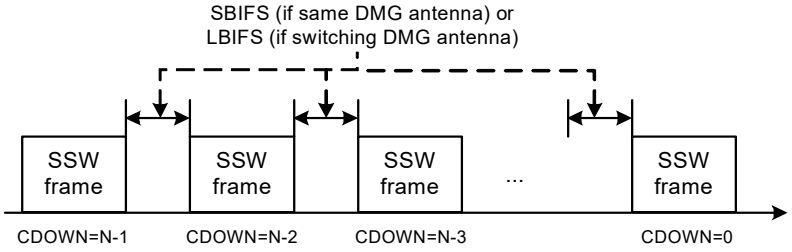


**Figure 10-83—Responder TXSS or responder RXSS**

A responder that has more than one DMG antenna and has set the value of the DMG Antenna Reciprocity field in its DMG Capabilities element to 0 transmits sequentially through all of the sectors of all of its DMG antennas. A responder that has more than one DMG antenna and has set the value of the DMG Antenna Reciprocity field in the responder's DMG Capabilities element to 1 transmits through the DMG antenna from which it had the best reception in the initiator sector sweep. The length of the sector sweep to each of the initiator's DMG antennas is not dependent on the value of the DMG Antenna Reciprocity field.

A responder that has only one DMG antenna should transmits through all its sectors, regardless of the setting of the DMG Antenna Reciprocity field.

The responder shall set the Sector Select field and the DMG Antenna Select field in each transmitted SSW frame to the value of the Sector ID field and DMG Antenna ID field, respectively, of the frame received with the best quality during the ISS. (11ay)The responder shall set the Short SSW Feedback field in each transmitted Short SSW PPDU to the value of the CDOWN field of the Short SSW PPDU that was received with the best quality during the preceding initiator TXSS. The determination of which frame is received with best quality is implementation dependent and beyond the scope of this standard. The responder shall set the SNR Report field (11ay)in transmitted SSW frames to the SNR measured for the frame indicated by the Sector Select field and DMG Antenna Select field.

If the initiator has more than one DMG antenna, the responder repeats its responder sector sweep for the number of DMG antennas indicated by the initiator in the last negotiated Number of RX DMG Antennas field transmitted by the initiator. At the start of a responder TXSS, the initiator should have its receive antenna array configured to a quasi-omni antenna pattern in one of its DMG antennas for a time corresponding to the value of the last negotiated Total Number of Sectors field transmitted by the responder multiplied by the time to transmit a single SSW frame, plus any appropriate IFSs (10.3.2.3 (IFS)). After this time, the initiator may switch to a quasi-omni pattern in another DMG antenna.

(11ay)If the initiator transmitted Short SSW PPDUs with the Unassociated field set to 1 during the ISS, it shall match the transmitted Source AID field and Destination AID field values with the received Source AID field and Destination AID field values, respectively, in the received Short SSW PPDUs during the RSS to determine if it is the intended recipient of the RSS.

The responder TXSS ends at the end time of the SSW frame from the responder with the CDOWN field set to 0. If the initiator is unable to receive this frame, the initiator shall assume that the responder TXSS has completed at the expected end time of this frame.


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#### 10.41.2.3.3 Responder RXSS

If the DMG Beacon frame immediately preceding an A-BFT contained a value of zero in the IsResponderTXSS subfield of the Beacon Interval Control field within the DMG Beacon frame(#337), then the A-BFT is a responder RXSS A-BFT.

When the IsResponderTXSS field for a specific SP in a received Extended Schedule element or Grant frame is 0 and the Beamforming Training field of the BF Control field for that SP in the same Extended Schedule element or Grant frame is 1, then the SP contains a responder RXSS, and the responder shall initiate an RXSS following the completion of the ISS in the SP described by the received Extended Schedule element or Grant frame.

When the RXSS Length field within an SSW frame used to obtain a TXOP during a CBAP is nonzero, the responder shall initiate an RXSS following the completion of the ISS in the TXOP described by the received SSW frame.

If the responder chooses to use more than one transmit sector or more than one transmit DMG antenna to perform beamforming with the initiator, the responder shall perform a responder TXSS with the initiator before participating in a responder RXSS with the initiator.

During the responder RXSS, the responder shall transmit the number of SSW frames indicated by the initiator in the initiator's most recently transmitted RXSS Length field (non-A-BFT) or FSS field (A-BFT) from the DMG antenna and sector that were selected during the preceding TXSS with the initiator. The responder shall set the Sector ID and DMG Antenna ID fields in each transmitted frame to a value that uniquely identifies the sector and DMG antenna, respectively, through which the BF frame is transmitted. The responder shall set the CDOWN field in each transmitted SSW frame to contain the total number of transmissions remaining until the end of the responder RXSS, such that the last SSW frame transmission of the responder RXSS has the CDOWN field equal to 0. Each transmitted SSW frame shall be separated by an interval of time equal to SBIFS, except if the allocation ends as described in 10.41.6 (Beamforming in DTI) or if the end of an SSW slot is reached as described in 10.41.5 (Beamforming in A-BFT). This is indicated in Figure 10-83 (Responder TXSS or responder RXSS).

The responder shall set the Sector Select field and the DMG Antenna Select field in each transmitted SSW frame to the value of the Sector ID field and the DMG Antenna ID field, respectively, of the frame received with the best quality during the ISS. The determination of which frame is received with best quality is implementation dependent and beyond the scope of this standard.

At the start of a responder RXSS, the initiator should have its receive antenna array configured to sweep over RXSS Length sectors, including any LBIFS if required, when it attempts to receive frames from the responder until the completion of the responder RXSS.

The responder RXSS ends at the end time of the SSW frame from the responder with the CDOWN field set to 0. If the initiator is unable to receive this frame, the initiator shall assume that the responder RXSS has completed at the expected end time of this frame.

### 10.41.2.4 Sector sweep (SSW) feedback

An SSW feedback procedure occurs following each RSS.

During an SSW feedback procedure, the initiator shall transmit an SSW-Feedback frame to the responder.

During an SSW feedback procedure, the responder should have its receive antenna array configured to a quasi-omni antenna pattern in the DMG antenna through which it received with the highest quality during the ISS, or to the best antenna configuration it has found during RXSS if RXSS has been performed during

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the ISS, and should not change its receive antenna configuration when it communicates with the initiator until the expected end of the SSW feedback procedure.

(11ay)When a responder TXSS comprising SSW frames was performed during the preceding RSS, the initiator shall set the Sector Select field and the DMG Antenna Select field in the SSW-Feedback frame it transmits to the value of the Sector ID field and DMG Antenna ID field, respectively, of the frame received with the best quality during the responder TXSS. The determination of which frame is received with the best quality is implementation dependent and beyond the scope of this standard. In addition, the initiator shall set the SNR Report field to the SNR measured for the frame received by the sector and DMG antenna indicated by the Sector Select field and DMG Antenna Select field. The SSW-Feedback frame shall be transmitted through the sector identified by the value of the Sector Select field and DMG Antenna Select field received from the responder during the preceding responder TXSS.

(11ay)When a responder TXSS comprising Short SSW PPDUs was performed during the preceding RSS, the initiator shall transmit an SSW-Feedback frame through the sector identified by the value of the Short SSW Feedback field received from the responder during the responder TXSS. In the SSW-Feedback frame, the initiator shall set the EDMG Extension Flag subfield to 1, the Sector Select and Sector Select MSB subfields to represent the value of the CDOWN field within the Short SSW PPDU that was received with the best quality during the responder TXSS, and shall set the DMG Antenna Select and DMG Antenna Select MSB subfields to the value of the RF Chain ID field within the same Short SSW PPDU. The determination of which PPDU is received with the best quality is implementation dependent and beyond the scope of this standard, but should be based on the reception quality measured over the DMG antenna used to transmit the current SSW-Feedback frame. In addition, the initiator shall set the SNR Report field to the SNR measured for the PPDU received by the sector and DMG antenna indicated by the Sector Select, Sector Select MSB, DMG Antenna Select and DMG Antenna Select MSB subfields.

When responder RXSS was performed during the preceding RSS, the Sector Select field and the DMG Antenna select field in the transmitted SSW-Feedback frame are reserved. The initiator shall set the SNR Report field to the SNR measured on the frame on the receive sector designated by the RSS. The SSW-Feedback frame shall be transmitted through the sector identified by the value of the Sector Select field received from the responder during its most recently completed RSS with the initiator.

The initiator may include transmit training as part of the beam refinement phase by setting the TX-TRN-REQ field to 1 in the SSW Feedback frame and setting the L-RX field to indicate the length of the training sequence it requests the responder to use in the beam refinement phase. The initiator may carry out the MIDC subphase as part of the beam refinement by setting the BC-REQ field to 1 (to request a BC subphase) and setting the MID-REQ field to 1 (to request an MID subphase); in this case, the L-RX field shall be set to indicate the number of receive AWVs the initiator uses during the MID subphase.

If the responder receives an SSW-Feedback frame from the initiator before it completes the RSS with the initiator such as described in 10.41.5 (Beamforming in A-BFT), the responder may cease the RSS.

#### 10.41.2.5 SSW ack

When present, the SSW ack procedure occurs following an SSW feedback procedure.

When a responder TXSS is performed during an RSS, the responder shall transmit an SSW-Ack frame to the initiator to perform an SSW ack procedure. The SSW-Ack frame shall be transmitted through the sector identified by the value of the Sector Select field and the DMG Antenna Select field received from the initiator in the last SSW-Feedback frame (11ay)if the RSS comprises SSW frames, and by the value of the Sector Select subfield, Sector Select MSB subfield, DMG Antenna Select subfield, and DMG Antenna Select MSB subfield received from the initiator in the last SSW-Feedback frame if the RSS comprises Short SSW PPDUs. If the RSS comprises Short SSW PPDUs, the Sector Select field and the Sector Select MSB field in the SSW-Ack frame shall be set to values corresponding to a sector from the same initiator DMG


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antenna that was used to transmit the preceding SSW-Feedback frame. The values should be based on the reception quality measured over the same DMG antenna used to transmit the current SSW-Ack frame and may correspond to a sector different from the sector indicated by the Short SSW Feedback field in Short SSW PPDUs transmitted during the RSS.

(11ay)When an initiator TXSS comprising of Short SSW PPDUs with the Unassociated field set to 1 is performed during the ISS, the Sector Select subfield, Sector Select MSB subfield, DMG Antenna Select subfield and DMG Antenna Select MSB subfield in the SSW-Ack frame are ignored.

When an RXSS was performed during an RSS, an SSW-Ack frame shall be sent by the responder to the initiator. The SSW-Ack frame should be sent using the DMG antenna indicated in the DMG Antenna Select field in the last SSW-Feedback frame.

The responder may include transmit training as part of the beam refinement phase by setting the TX-TRN-REQ field to 1 in the SSW-Ack frame and setting the L-RX field to indicate the length of the training sequence it requests the initiator to use in the beam refinement phase, as described in 9.5.4 (BRP Request field). The responder may carry out a MID subphase by setting the MID-REQ bit to 1 in the BRP Request field of the SSW frame. In this case, it shall also set the L-RX field to indicate the number of receive AWVs it uses during the MID subphase. The responder may carry out a BC subphase by setting the BC-REQ bit to 1. If the initiator has set either the MID-REQ or the BC-REQ fields to 1 in the SSW-Feedback frame, the responder may set the MID-Grant or the BC-Grant fields to 1, or both, to grant the requests.

(11ay)If the RSS comprises SSW frames, at the start of an SSW ack procedure, the initiator should have its receive antenna array configured to a quasi-omni antenna pattern using the DMG antenna through which it received with the highest quality during the RSS, or the best receive sector if an RXSS has been performed during the RSS, and should not change its receive antenna configuration while it attempts to receive from the responder until the expected end of the SSW ack procedure. (11ay)If the RSS comprises Short SSW PPDUs, at the start of an SSW ack procedure, the initiator should have its receive antenna array configured to a quasi-omni antenna pattern using the DMG antenna used to transmit the preceding SSW-Feedback frame.

### 10.41.3 Beam Refinement Protocol (BRP) phase

#### 10.41.3.1 General

BRP is a process in which a STA trains its RX and TX antenna array(s) and improves its TX antenna configuration and RX antenna configuration using an iterative procedure. BRP may be used regardless of the antenna configuration a STA supports.

The BRP phase is composed of a BRP setup subphase, a Multiple sector ID Detection (MID) subphase, a Beam Combining (BC) subphase, a subset of the previous subphases, and one or more beam refinement transactions. BRP setup allows STAs to exchange beam refinement capability information and to request the execution of the other BRP subphases. MID and BC (collectively, the MIDC subphase) are optionally used to find better initial AWVs for iterative beam refinement than might have been found by SLS due to imperfect quasi-omni receive antenna patterns. In MID, a quasi-omni transmit pattern is tested against a number of receive AWVs; this reverses the scanning roles from the transmit sector sweep. In BC, a small set of transmit and receive AWVs are tested in pairwise combinations, thus avoiding the use of quasi-omni patterns. Finally, given the starting point from SLS or MIDC, STAs can explore a broader set of transmit and receive AWVs using (#4173)a request/response frame exchange referred to as a *beam refinement transaction*.

The BRP setup subphase may be skipped if the BRP phase does not include a MID or BC subphase. MID and BC subphases can be skipped if either STA indicates that the subphase is not needed by setting the MID-REQ and BC-REQ fields to 0 or by setting the MID-Grant and BC-Grant fields to 0. The beam refinement

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transaction can be skipped if both sides indicate that the transaction is not needed by setting the L-RX and TX-TRN-REQ fields to 0.

The BRP setup subphase is defined in 10.41.3.2 (BRP setup subphase).

The MID subphase is composed of either an R-MID subphase or an I-MID subphase or both, which are composed of one or more transmissions of BRP-RX PPDUs (20.9.2.2 (Beam refinement)), followed by feedback contained in the next BRP frames from the initiator and responder.

The BC subphase is composed of either an R-BC subphase or an I-BC subphase or both, which are composed of transmission of BRP-RX PPDUs to select a beam, followed by feedback.

A beam refinement transaction is a set of BRP frames consisting of beam refinement requests and responses. A beam refinement request can be either a transmit beam refinement request or a receive beam refinement request or both.

A transmit beam refinement request (TX-TRN-REQ field within the BRP Request field set to 1) indicates the need for transmit antenna array training by the transmitting STA. The BRP PPDU that has the TX-TRN-REQ set to 1 (or the next BRP PPDU from this STA) shall include transmit training (TRN-T) subfields appended to it. The STA responding to the BRP PPDU shall include feedback based on measurements it performed during the reception of the BRP PPDU. The feedback type is dictated by the FBCK-TYPE field within the DMG Beam Refinement element contained in the BRP PPDU.

A receive beam refinement request (L-RX field within the BRP Request field greater than zero) indicates the need of the receive antenna array training for the transmitting STA. The responding STA shall respond with a BRP PPDU with receive training (TRN-R) subfields appended to it.

(11ay)An EDMG STA may enable training of both TX and RX on the same PPDU by setting the TXVECTOR parameter EDMG_TRN_LEN to a value greater than 0 and the parameter RX_TRN_PER_TX_TRN to a value greater than one.

(11ay)Prior to transmitting an EDMG PPDU on a 4.32 GHz, 6.48 GHz, 8.64 GHz, 2.16+2.16 GHz, or 4.32+4.32 GHz channel, an EDMG STA may use the BRP phase described in this subclause or the BRP TXSS protocol defined in 10.41.10.5 (BRP transmit sector sweep (BRP TXSS)) to perform beamforming training over the channel.

Requests and responses can be combined in the same frame. As an example, the same frame can be both a transmit beam refinement request and a receive beam refinement request. The same frame can also be used as receive beam refinement response and a receive beam refinement request. See the example in Figure 10-84 (Example of beam refinement transaction outside of TDD SP allocation(11ay)).

A beam refinement response is separated from a preceding beam refinement request by at least a SIFS and at most a BRPIFS provided sufficient time is available for the complete transmission of those frames within the SP allocation (11ay)that is not a TDD SP or TXOP. Similarly, a beam refinement request, if any, is separated from a preceding beam refinement response by at least a SIFS and at most a BRPIFS provided sufficient time is available for the complete transmission of the beam refinement request within the SP allocation (11ay)is not a TDD SP or TXOP.

(11ay)An EDMG STA may send a beam refinement request to a peer EDMG STA with the EDMG-SHORT-BRP subfield within the BRP Request field set to 1. The peer EDMG STA shall send the response to this request separated by at least SIFS and at most MBIFS from the reception of the request. In this case, the response shall also have the EDMG-SHORT-BRP subfield within the BRP Request field set to 1.


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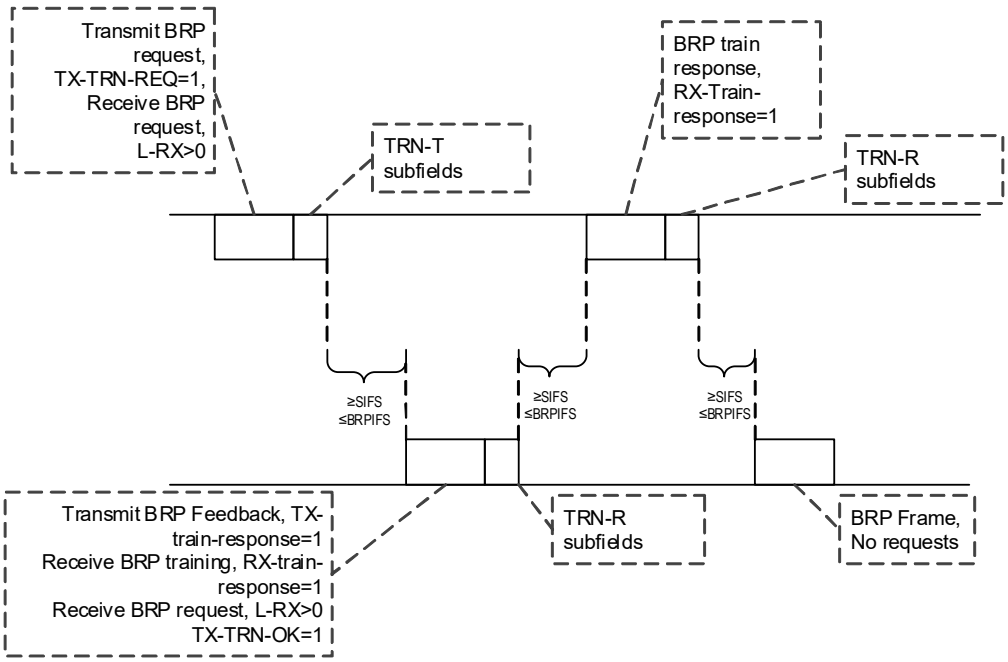


**Figure 10-84—Example of beam refinement transaction outside of TDD SP allocation(11ay)**

(11ay)In a TDD SP, a non-AP and non-PCP STA transmits a beam refinement response to a preceding beam refinement request from an AP or PCP in the earliest occurring TDD slot the non-AP and non-PCP STA is assigned to, with access permission of the TDD slot set to simplex RX TDD slot, and with slot category of the TDD slot set to Basic TDD slot, as indicated in the TDD Slot Schedule element (see 9.4.2.281 (TDD Slot Schedule element(11ay))).

(11ay)In a TDD SP, an AP or PCP transmits a beam refinement response to a preceding beam refinement request from a non-AP and non-PCP STA in the earliest occurring TDD slot the non-AP and non-PCP STA is assigned to, with access permission of the TDD slot set to simplex TX TDD slot, and with slot category of the TDD slot set to Basic TDD slot, as indicated in the TDD Slot Schedule element (see 9.4.2.281 (TDD Slot Schedule element(11ay))).

When performing BRP (11ay)outside a TDD SP allocation, if a responding STA requires longer than SIFS to transmit a BRP frame as a response for beam refinement training request from a requesting STA, the responding STA should keep the IFS not longer than SIFS by transmitting one or more PPDUs to the requesting STA.

When the beam refinement occurs within the same allocation as the SLS, the SLS initiator is the beam refinement initiator. If the beam refinement occurs in a separate allocation, the STA that transmits the first beam refinement request is the beam refinement initiator. The other STA is the beam refinement responder.

A beam refinement transaction is complete when one of the following conditions is met:

a) The initiator determines that it does not need further training and it has received a BRP frame with no training requests from the beam refinement responder.

b) (11ay)When performing BRP outside of a TDD SP allocation, a duration equal to BRPIFS plus aSlotTime has elapsed since the last transmission from the beam refinement initiator to the refinement responder without a response from the beam refinement responder.

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c) (11ay)When performing BRP in a TDD SP allocation, a response from the beam refinement responder is not received in the earliest occurring TDD slot that allows for its transmission.

In Figure 10-84 (Example of beam refinement transaction outside of TDD SP allocation(11ay)), the first PPDU (from the initiator) has TX-TRN-REQ=1, the L-RX field has a value greater than zero and TRN-T subfields are appended to the PPDU. The second PPDU (from the responder) has a value greater than zero in the L-RX field, the TX-train-response field set to 1, the RX-train-response field set to 1, and TRN-R subfields are appended to the PPDU. The last PPDU (from the initiator) has RX-train-response set to 1 and TRN-R subfields are appended to the PPDU.

### 10.41.3.2 BRP setup subphase

The BRP setup subphase is used to exchange the intent and capabilities to conduct some or all of the subphases and beam refinement transactions in a subsequent BRP phase. The BRP setup subphase is used to set up the MIDC subphase, but can also be used to set up beam refinement transactions.

The BRP setup subphase shall be used in the following cases:

— When the RSS part of the SLS phase occurred in an A-BFT, in which case the SSW-Ack frame was not part of the SLS.

— When the initiator set the MID-REQ or BC-REQ fields in the SSW-Feedback frame to 1 or the responder set the MID-REQ or BC-REQ fields in the SSW-Ack frame to 1.

— When the initiator intends to include MID or BC or both subphases, independent of a preceding SLS phase.

The BRP setup subphase starts with the initiator sending a BRP PPDU with the Capability Request subfield set to 1 and with the remaining subfields within the BRP Request field set according to the initiator's need for an MID subphase, a BC subphase, and a beam refinement subphase. The BRP setup subphase can also start when the responder grants a MID-REQ or BC-REQ through the SSW-Ack frame or when the responder requests MID or BC in the SSW-Ack frame. Upon receiving a BRP PPDU with the Capability Request subfield set to 1, the responder shall respond with a BRP PPDU with the subfields within the BRP Request field set to indicate the presence of an MID subphase, a BC subphase and a beam refinement subphase. This process is repeated until the responder transmits to the initiator a BRP PPDU with the Capability Request subfield set to 0 and the initiator sends as a response a BRP PPDU with the Capability Request subfield also set to 0. The BRP PPDU from the initiator that initiates the termination of the BRP setup subphase can be the first BRP PPDU of the BRP phase, either as part of beam refinement or as part of a MID or BC subphase.

A DMG STA (either initiator or responder) requests MID and BC subphases (see 10.41.6.3.2 (MIDC subphase with MID and BC subphases)) by setting both the MID-REQ and BC-REQ subfields to 1 in the BRP Request field of an SSW-Feedback, SSW-Ack or BRP frame. It shall also set the L-RX subfield in the BRP Request field to the number of RX AWV settings it needs in each BRP-RX PPDU during the MID subphase. The peer STA grants the request by setting the MID-Grant and BC-Grant subfields to 1 in the BRP Request field within the next SSW-Ack or BRP frame transmitted to the requesting DMG STA. If either the MID or BC were not granted by the peer STA, the MID and BC subphases shall not occur.

A DMG STA (either initiator or responder) requests an MID only subphase (see 10.41.6.3.3 (MIDC subphase with MID subphase only)) by setting the MID-REQ subfield to 1 in the BRP Request field of an SSW-Feedback, SSW-Ack or BRP frame. The STA shall also set the L-RX subfield in the BRP Request field to the number of RX AWV settings it needs in each BRP-RX PPDU during the MID-subphase. The peer STA grants the request by setting the MID-Grant subfield to 1 in the BRP Request field within the next SSW-Ack or BRP frame transmitted to the requesting DMG STA. The Capability Request subfield and request subfields (TX-TRN-REQ, L-RX, MID-REQ, BC-REQ) within the granting frame shall be set to 0.


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If the MID-REQ was granted, the requesting STA shall transmit a BRP frame with the SNR Present and Sector ID Order Present subfields set to 1 and with the Number of Measurements field in the FBCK-TYPE field indicating the number of SNR measurements from the last SLS phase. In the Channel Measurement Feedback element, the requesting STA sets the SNR subfields to the SNRs corresponding to the TX sectors received during the SLS phase. In the Sector ID Order subfield, the requesting STA lists the sector IDs of the received sectors. The Capability Request field within the BRP frame shall be set to 0. The MID subphase starts with the transmission of a BRP PPDU from the peer STA after the reception of the list of sectors. A STA that has granted a MID only request shall not request MID or BC in the response PPDU. The STA may request MID or BC in the last PPDU it transmits to the requesting STA as part of the MID. The MID only subphase shall not occur if it was not granted by the peer STA.

A DMG STA (either initiator or responder) requests a BC only subphase (see 10.41.6.3.4 (MIDC subphase with BC subphase only)) by setting the BC-REQ subfield to 1 in the BRP Request field of an SSW-Feedback, SSW-Ack, or BRP frame. The peer STA (either a responder or initiator) grants the request by setting the BC-Grant subfield to 1 in the BRP Request field within the next SSW-Ack or BRP frame transmitted to the requesting STA. The BC subphase shall not occur if the peer STA does not grant the request.

A DMG STA indicates that beam refinement transactions (10.41.6.4.2 (Beam refinement transaction)) occur by setting the L-RX field to a value greater than 0 to indicate the need for receive beam refinement or by setting the value of the TX-TRN-REQ field to 1 to indicate the need for transmit beam refinement or by setting both. The beam refinement transactions shall occur if at least one of these conditions is met.

If the initiator has requested an MID subphase by setting the MID-REQ subfield or the BC-REQ subfield to 1 and the responder rejected by setting in the response the MID-Grant subfield or the BC-Grant subfield to 0, respectively, the initiator should send a BRP frame with the MID-REQ field set to 0 and the L-RX field set to indicate the number of TRN-R subfields the initiator requests for use in the BRP transaction.

If the responder has requested an MID subphase by setting the MID-REQ subfield or the BC-REQ subfield to 1 and the initiator rejected by setting in the response the MID-Grant or the BC-Grant subfields to 0, the initiator should send a BRP frame with the Capability Request subfield set to 1. The responder shall respond with a BRP frame with the MID-REQ field set to 0 and the L-RX field set to indicate the number of TRN-R subfields the responder requests for use in the BRP transaction.

Beam refinement transactions shall occur following a MIDC subphase when one or both of the following conditions are met at the last BRP frame transmitted by either the initiator or responder as part of the MID or BC subphases:

a) Either the initiator or the responder set the L-RX field to a value greater than 0.
b) Either the initiator or responder has set the value of the TX-TRN-REQ field to 1.

If within the appropriate IFS the initiator does not receive a response from the responder to a PPDU transmitted to the responder, the initiator may retransmit the PPDU.

After the BRP setup subphase, beamforming training shall immediately continue to the next phase (i.e., either MIDC subphase or the beam refinement transactions). Examples of BRP setup subphase procedures are illustrated in Figure 10-85 (Example of BRP setup subphase procedure (SLS in BTI and A-BFT)) and Figure 10-86 (Example of skipping the BRP setup subphase (SLS in DTI)) as well as in Figure 10-94 (Example of time allocation for the MIDC subphase with the MID subphase only), Figure 10-95 (Example of using BRP setup subphase to set up subsequent MIDC subphase in A-BFT and DTI), and Figure 10-101 (Example of using BRP setup subphase to set up subsequent R-MID subphase(#2259)).

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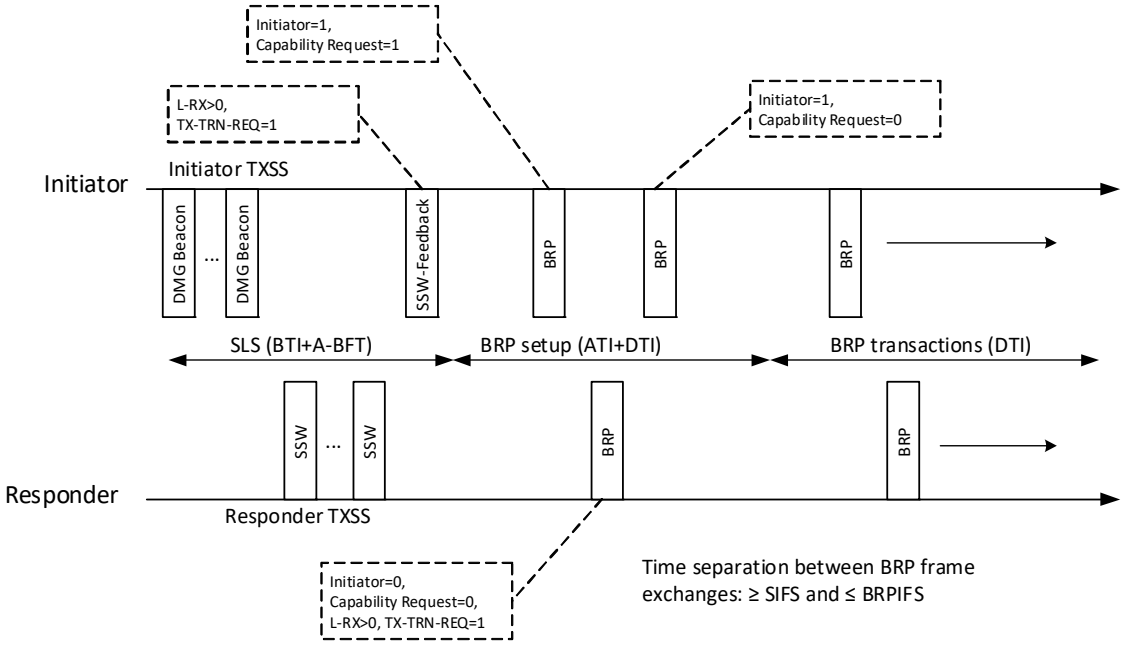


**Figure 10-85—Example of BRP setup subphase procedure (SLS in BTI and A-BFT)**

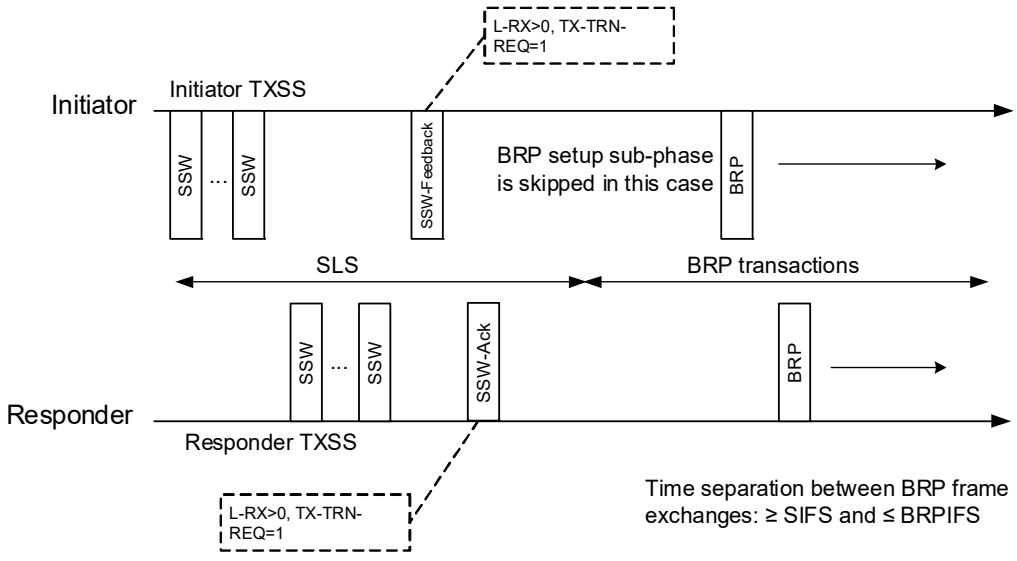


**Figure 10-86—Example of skipping the BRP setup subphase (SLS in DTI)**

### 10.41.4 Beamforming in BTI

In the BTI, the AP or PCP performs an initiator TXSS as the first part of the SLS with the transmission of at least one DMG Beacon frame. The AP or PCP does not transmit SSW frames in the BTI (10.41.2.2.1 (General)).


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The AP or PCP may fragment the initiator TXSS over multiple consecutive BTIs by not transmitting a DMG Beacon frame through all sectors available to the AP or PCP in a single BTI. In a BTI with a fragmented initiator TXSS, the AP or PCP shall transmit DMG Beacon frames with the Fragmented TXSS field set to 1. Otherwise, the AP or PCP shall set the Fragmented TXSS field to 0. The AP or PCP shall not change the duration of the next BTI if at least one of the DMG Beacon frames transmitted in the current BTI have the Fragmented TXSS field set to 1. The CDOWN field shall be set to the total number of transmissions remaining to the end of the initiator TXSS, such that the last DMG Beacon frame transmission of the initiator TXSS has the CDOWN field set to 0 (i.e., in a fragmented TXSS, the value of the CDOWN field covers the total number of transmissions remaining in the fragmented TXSS). The TXSS Span field shall be set to the total number of beacon intervals it takes the AP or PCP to complete the entire TXSS phase.

(11ay)The Duration field within each transmitted DMG Beacon frame shall be set to the time remaining until the end of the current BTI, except in an EDMG BSS if the value of the Next A-BFT subfield is equal to 0 and the value of the A-BFT Multiplier subfield is greater than 0 in the transmitted DMG Beacon frame. In this case, the value of the Duration field shall be set to the time remaining until the end of the transmission of the last DMG Beacon frame in the BTI plus MBIFS plus the duration equivalent to the multiplication of the value of the A-BFT Length subfield and the value of the A-BFT Multiplier subfield. In the latter case, the duration of the BTI covers DMG Beacon transmissions and the additional SSW slots that are present in the A-BFT (see 10.41.5 (Beamforming in A-BFT)).

When an AP or PCP has more than one DMG antenna, the TXSS shall cover all of the sectors in all DMG antennas. The TXSS Span field indicates the total number of beacon intervals it takes the AP or PCP to cover all sectors in all DMG antennas. The value of the TXSS Span field shall be lower than dot11MaximalSectorScan.

(11ay)A non-EDMG AP or non-EDMG PCP, or an EDMG AP or EDMG PCP with a single RF chain, shall not change DMG antennas within a BTI. (11ay)For an EDMG AP or EDMG PCP having multiple RF chains, the EDMG AP or EDMG PCP may switch from one RF chain to another RF chain within a BTI. The set of DMG antennas that are used for DMG Beacon transmission in a BTI form a DMG antenna group. The EDMG AP or EDMG PCP shall not change DMG antennas for the RF chains used within a BTI. Figure 10-87 (Example of use of multiple DMG antennas during BTI and A-BFT(11ay)) shows an example of an EDMG AP or EDMG PCP using a DMG antenna group consisting of DMG antenna 0 and 1 in the BTI and the A-BFT of a first beacon interval, and using another DMG antenna group consisting of DMG antenna 2 and 3 in the BTI and the A-BFT of the following beacon interval.

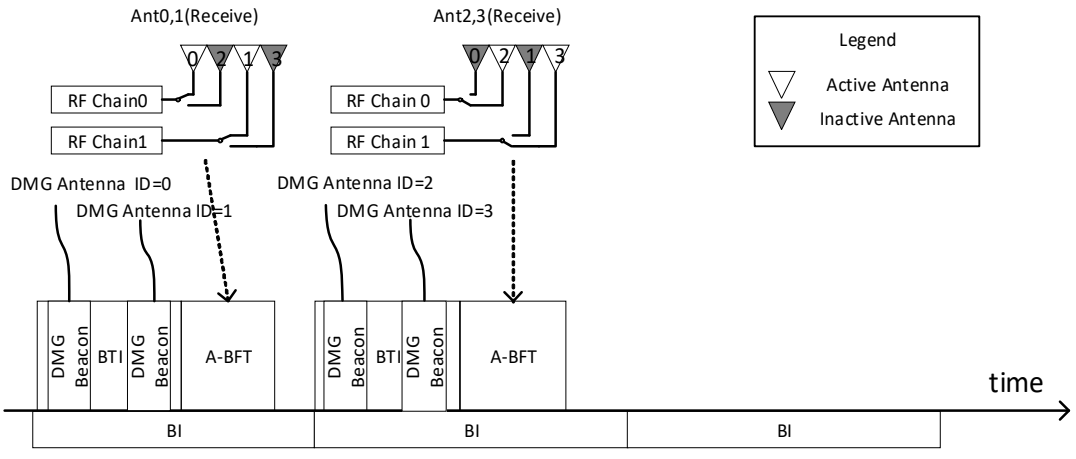


**Figure 10-87—Example of use of multiple DMG antennas during BTI and A-BFT(11ay)**

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The AP or PCP has a regular schedule of transmitting through each DMG antenna (see 10.41.5.4 (Beamforming in A-BFT with multiple DMG antennas)).

NOTE—If an unassociated responder receives a DMG Beacon frame in the BTI with a fragmented initiator TXSS, the responder may start a responder TXSS in the following A-BFT (11ay)or can perform beamforming training for asymmetric links in a subsequent allocation (see 10.41.10.3 (Beamforming for asymmetric links)). (11ay)Alternatively, the responder may scan for the number of beacon intervals indicated in a received TXSS Span field in order to cover a complete initiator TXSS and find a suitable TX sector from the AP or PCP (11ay)to start a responder TXSS or beamforming training for asymmetric links.

Each subfield in the Beacon Interval Control field and DMG Parameters field of each DMG Beacon frame transmitted by the AP or PCP shall retain the same value from start to completion of a TXSS phase.

A PPDU containing a DMG Beacon frame transmitted by an EDMG STA may include TRN-R subfields within the TRN field of the PPDU to enable receive training by an EDMG STA receiving the DMG Beacon. Figure 10-88 (Receive beamforming training during the BTI through the use of TRN-R fields(11ay))depicts an example of how an EDMG STA receiving such a DMG Beacon may use the TRN field appended to a DMG Beacon frame to perform receive beamforming. Although inclusion of TRN-R subfields within a PPDU does not require prior scheduling, the EDMG STA transmitting the DMG Beacon may announce the presence of TRN-R subfields in a subsequent BTI by transmitting an EDMG Training Field Schedule element in DMG Beacon, Announce, Probe Response or Association Response frames.

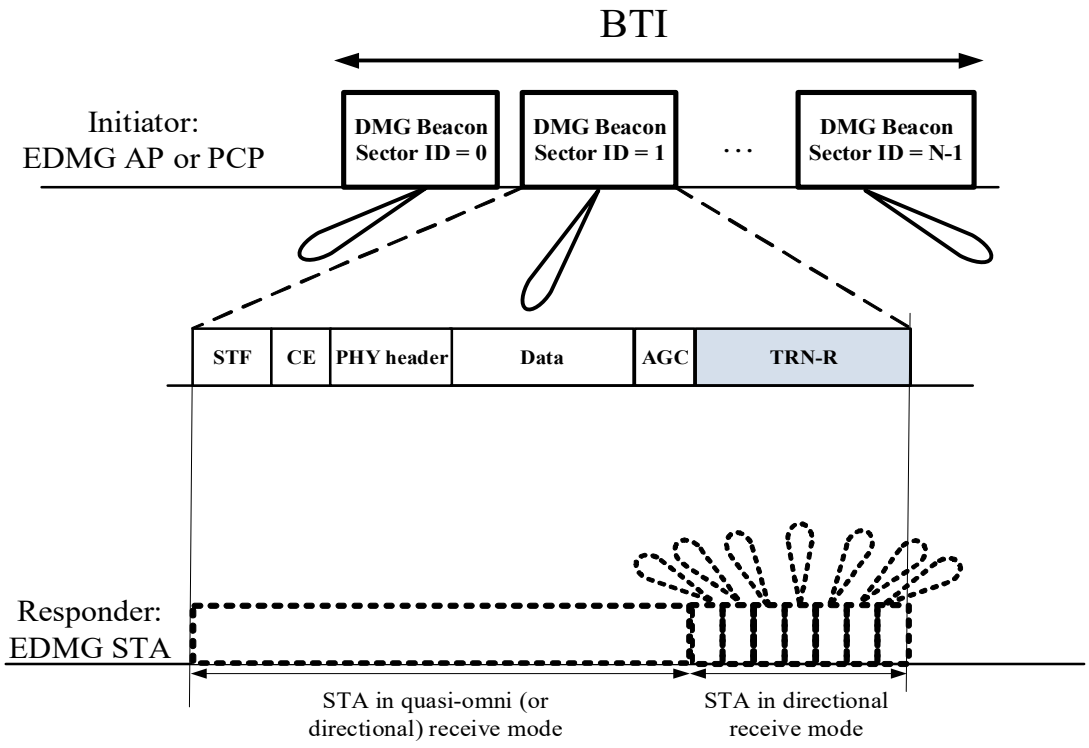


**Figure 10-88—Receive beamforming training during the BTI through the use of TRN-R fields(11ay)**

(11ay)An EDMG STA may set the TRN-LEN parameter of the TXVECTOR of a PPDU containing a DMG Beacon frame to a value greater than or equal to 0 if the PPDU_TYPE parameter of the TXVECTOR is set to TRN-R. The PPDU_TYPE parameter of the TXVECTOR of a PPDU containing a DMG Beacon frame shall not be set to TRN-T.


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(11ay)If a DMG Beacon frame is transmitted by an EDMG STA using a quasi-omni antenna pattern, the Quasi-omni TX subfield in the SSW field(#4303) in the frame shall be set to 1. An EDMG STA may append receive training (TRN-R) subfields to DMG Beacon frames transmitted with the Quasi-omni TX subfield in the SSW field(#4303) set to 1 to enable receive training and, subsequently, selection of a transmit sector by a receiving STA that supports antenna reciprocity or antenna pattern reciprocity. Antenna reciprocity and antenna pattern reciprocity are indicated by setting the DMG Antenna Reciprocity field and Antenna Pattern Reciprocity field in the DMG Capabilities element to 1, respectively.

### 10.41.5 Beamforming in A-BFT

#### 10.41.5.1 Allocation of A-BFT

The AP or PCP shall allocate an A-BFT period MBIFS following the end of a BTI that included a DMG Beacon frame transmission with Next A-BFT equal to 0.

Following the end of a BTI, the AP or PCP shall decrement the value of the Next A-BFT field by 1 provided it is not equal to 0 and shall announce this value in the next BTI. The AP or PCP may increase the Next A-BFT field value following a BTI in which the Next A-BFT field was equal to 0. A STA shall consider that a BTI is completed at the expiration of the value within the Duration field of the last DMG Beacon frame received in that BTI.

All DMG Beacon frames transmitted within the number of beacon intervals specified within the most recently updated TXSS Span field have the same value for each subfield within the Beacon Interval Control field (11.1.3.3 (Beacon generation in a DMG infrastructure BSS and in a PBSS)).

(11ay)When allocating an A-BFT over the primary channel, an EDMG PCP or EDMG AP may also allocate an A-BFT over a secondary channel. This is indicated by the A-BFT in Secondary Channel subfield in the Beacon Interval Control field of a DMG Beacon frame. The A-BFT allocated over the secondary channel has the same start time, length and SSW slot configuration as the A-BFT allocated on the primary channel and signaled through the Beacon Interval Control field of the DMG Beacon frame. An EDMG STA may access the A-BFT allocated over a secondary channel and, in this case, shall use the same access rules specified in this subclause.

(11ay)An EDMG AP or EDMG PCP that transmits a DMG Beacon frame with the value of the A-BFT in Secondary Channel subfield set to a nonzero value shall support(#546) simultaneously receiving SSW frames transmitted by EDMG STAs during the corresponding A-BFT on the primary and adjacent secondary channels and, in response, shall support(#546) simultaneously transmitting SSW-Feedback frames on the primary and adjacent secondary channels using the same sector of the same DMG antenna as indicated in the SSW frame(s) received within the same SSW slot.

(11ay)To accommodate a larger number of STAs attempting access during the A-BFT, the number of SSW slots available to EDMG STAs in an A-BFT can be increased compared to what is available to non-EDMG STAs. The presence of additional SSW slots is indicated through the A-BFT Multiplier subfield in the Beacon Interval Control field in a DMG Beacon frame. When the A-BFT Multiplier field is nonzero and the Next A-BFT field is 0, an EDMG STA subtracts (A-BFT Multiplier × A-BFT Length) from the value of the Duration field of the received DMG Beacon frame to determine the start time of the additional SSW slots available to the EDMG STA. These additional SSW slots are then immediately followed by the SSW slots available to both EDMG and non-EDMG STAs, which is indicated by the value of the A-BFT Length field. Thus, from an EDMG STA's perspective, the A-BFT contains A-BFT Length × (1 + A-BFT Multiplier) SSW slots.

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### 10.41.5.2 Operation during the A-BFT

Beamforming training in the A-BFT consists of the RSS and SSW feedback procedures of the SLS between the AP or PCP and a STA.

In the A-BFT, the AP or PCP is the initiator and the STA is the responder in the RSS part of the SLS (10.41.2.3 (Responder sector sweep (RSS))). The BRP phase shall not be performed within the A-BFT. A STA shall not transmit in the A-BFT of a beacon interval if it does not receive at least one DMG Beacon frame during the BTI of that beacon interval.

(11ay)In all cases, a DMG STA may use SSW frames to perform an RSS during the A-BFT. If the BSS is an EDMG BSS and if the STA is associated with the BSS, an EDMG STA may use Short SSW PPDUs (see 28.9.1 (Short SSW PPDU)) instead of SSW frames to perform an RSS during the A-BFT. When using Short SSW PPDUs, an EDMG STA can transmit more Short SSW PPDUs within an SSW slot compared to when SSW frames are used.

A DMG STA that receives a DMG Beacon frame with the Discovery Mode field equal to 1 may transmit in the A-BFT following the BTI where the DMG Beacon frame is received if at least one of the following conditions is met:

— The CC Present field within the received DMG Beacon frame is equal to 1 and the STA's MAC address is equal to the value of the A-BFT Responder Address subfield within the received DMG Beacon frame.

— The CC Present field within the received DMG Beacon frame is equal to 1, the value of the A-BFT Responder Address subfield within the received DMG Beacon frame is a group address of a group to which the STA belongs, and the responding STA's role matches the role identified by the value of the BSS Type subfield within the received DMG Beacon frame and the (#4177)Responding STA role column of Table 9-99 (The BSS Type subfield when the Discovery mode field is 1).

— The CC Present field within the received DMG Beacon frame is equal to 0.

If none of these conditions is met following the reception of a DMG Beacon frame with the Discovery Mode field equal to 1, the STA shall not transmit in the A-BFT.

The A-BFT is slotted and the length of the A-BFT is an integer multiple of the sector sweep slot time. The structure of the A-BFT (11ay)when SSW frames are used is shown in Figure 10-89 (A-BFT structure when SSW frames are used(11ay)). (11ay)The structure of the A-BFT when Short SSW PPDUs are used is shown in Figure 10-89 (A-BFT structure when SSW frames are used(11ay)). A non-EDMG AP or non-EDMG PCP shall announce the size of the A-BFT in the A-BFT Length subfield of the Beacon Interval Control field (9.3.4.2 (DMG Beacon))(11ay), while an EDMG AP or EDMG PCP shall also use the A-BFT Multiplier subfield of the Beacon Interval Control field. The first SSW slot begins at the start of the A-BFT, and the following SSW slots are adjacent and nonoverlapping. An SSW slot (Figure 10-91 (SSW slot (aSSSlotTime) definition)) is a period of time within the A-BFT that can be used by a responder to transmit at least one SSW frame. An SSW slot has a duration of aSSSlotTime. aSSSlotTime is defined to be

aSSSlotTime = aAirPropagationTime + aSSDuration + MBIFS + aSSFBDuration + MBIFS

where

aAirPropagationTime accounts for the propagation delay between the initiator and the responder

(11ay)aSSDuration provides(11ay), if the STA transmits SSW frames in the A-BFT, time for a responder to transmit up to the number of SSW frames announced in the FSS subfield of the Beacon Interval Control field in the DMG Beacon (see 11.37 (DMG MAC sublayer attributes)); otherwise, if the STA transmits Short SSW PPDUs in the A-BFT, the number of Short SSW PPDUs the STA may transmit is a function of the value of the FSS subfield of the Beacon Interval Control field in


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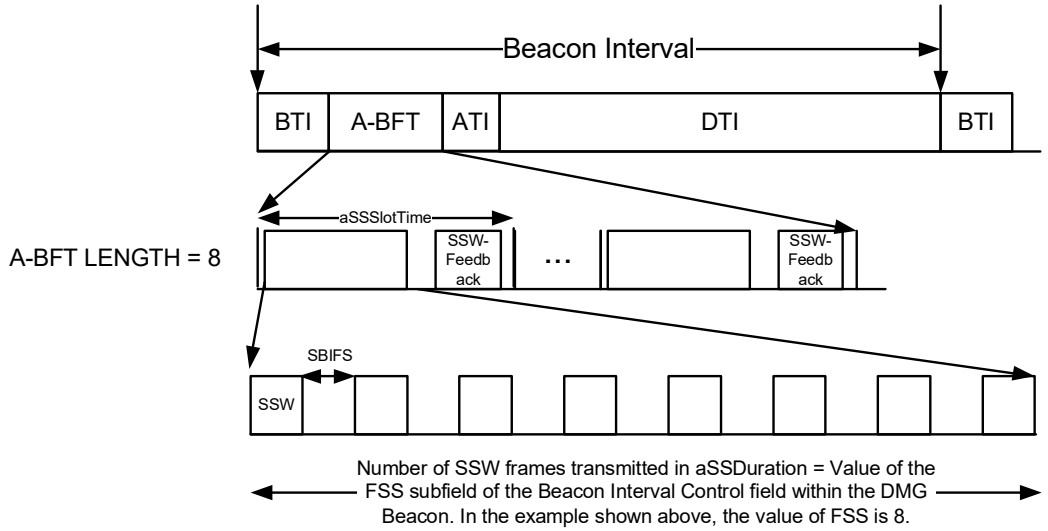
| | |
|---|---|
| | the DMG Beacon as indicated by Table 10-36 (Number of Short SSW PPDUs as a function of the FSS subfield value(11ay)) |
| aSSFBDuration | provides time for the initiator to perform an SSW feedback procedure (see 11.37 (DMG MAC sublayer attributes)) |

**Table 10-36—Number of Short SSW PPDUs as a function of the FSS subfield value(11ay)**

| Value of the FSS subfield | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Number of Short SSW PPDUs | 1 | 3 | 4 | 6 | 8 | 9 | 11 | 12 | 14 | 16 | 17 | 19 | 21 | 22 | 24 | 25 |

The initiator shall set the FSS subfield of the Beacon Interval Control field in the DMG Beacon frame to a value that is no less than aSSFramesPerSlot. See Figure 10-89 (A-BFT structure when SSW frames are used(11ay)).




**Example of A-BFT with length 8 and with each SSW slot accommodating 8 SSW frames. A possible contention between 3 STAs is shown in the figure below:** STAs A, B and C are competing for access. All STAs choose a random value between [0,7]. STA A chooses value = 2, while STAs B and C choose value = 5, which might result in a collision.

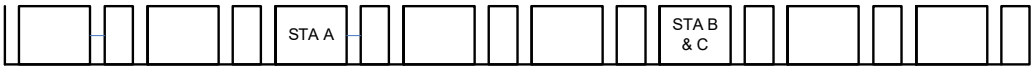



**Figure 10-89—A-BFT structure when SSW frames are used(11ay)**

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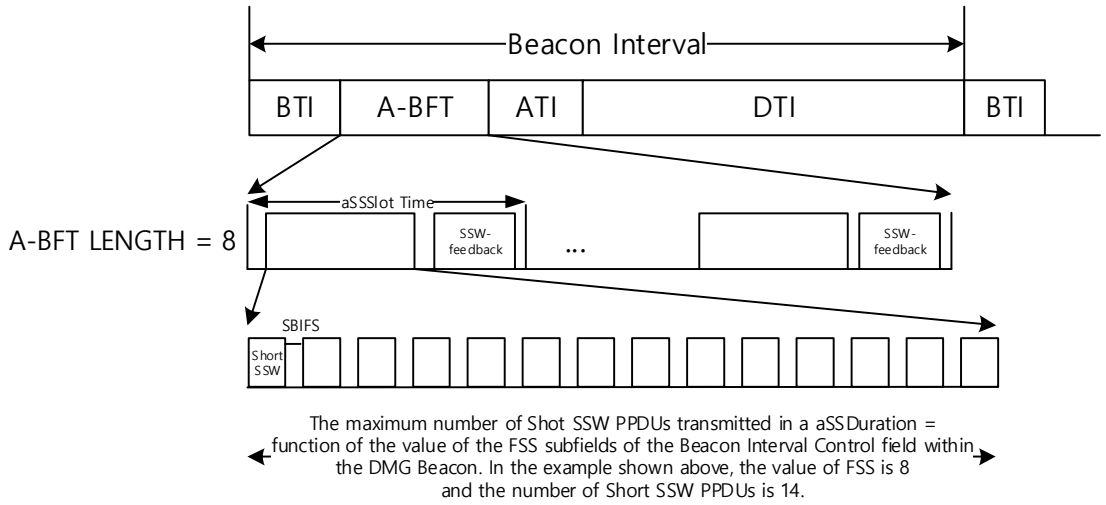


**Figure 10-90—A-BFT structure when Short SSW PPDUs are used(11ay)**

If the IsResponderTXSS subfield of the Beacon Interval Control field is equal to 1, the A-BFT shall be used to perform a responder TXSS. Otherwise, the A-BFT shall be used to perform a responder RXSS. In the case of a responder RXSS, the same slotted structure described above is used and the responder shall transmit the number of SSW frames announced in the FSS field in the DMG Beacon. If the AP or PCP allocates the A-BFT as a responder RXSS, it should set the value of the FSS field within the Beacon Interval Control to the number of receive sectors supported by the AP or PCP. The AP or PCP shall allocate the A-BFT as a responder TXSS at least once every dot11ABFTRTXSSSwitch beacon intervals in which an A-BFT is present.

At the start of each A-BFT, the responder(s) shall invoke a random backoff procedure to initiate or resume an RSS as follows. (11ay)If either the initiator or the responder is a non-EDMG STA, the random backoff procedure begins at the start of the A-BFT with the responder selecting a backoff count as a random integer drawn from a uniform distribution [0, A-BFT Length), i.e., 0 to A-BFT Length – 1, where A-BFT Length is the value of the A-BFT Length field in the last received DMG Beacon. (11ay)If both the initiator and the responder are EDMG STAs, the random backoff procedure begins at the start of the A-BFT with the responder:

— Selecting a single 2.16 GHz channel where the A-BFT is present based on the value of the A-BFT in Secondary Channel subfield in the last received DMG Beacon. Any frame transmission between the initiatior and responder during the A-BFT shall be performed using the selected channel.

— Selecting a backoff count as a random integer drawn from a uniform distribution [0, A-BFT Length + A-BFT Length × A-BFT Multiplier), i.e., 0 to A-BFT Length + A-BFT Length × A-BFT Multiplier – 1, where A-BFT Length and A-BFT Multiplier are the values of the A-BFT Length and A-BFT Multiplier fields, respectively, in the last received DMG Beacon.

The responder shall decrement the backoff count by one at the end of each SSW slot, even if the CS function at the responder indicates the medium busy condition for that SSW slot. The responder may initiate the RSS only at the start of the SSW slot for which the backoff count is 0 at the beginning of the SSW slot. See Figure 10-91 (SSW slot (aSSSlotTime) definition).


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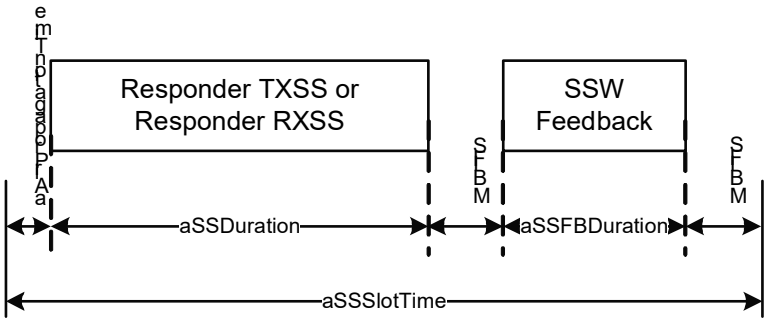


**Figure 10-91—SSW slot (aSSSlotTime) definition**

The responder shall transmit no more SSW frames within an SSW slot than indicated in the value of the FSS subfield in the DMG Beacon. If the responder has more SSW frames to transmit as part of the RSS, but is not allowed to send any more SSW frames in the current SSW slot, then the responder may resume the RSS at the start of the following SSW slot provided that the A-BFT has not ended. If the responder cannot complete the RSS before the end of the A-BFT, it may use the same backoff procedure described above to resume the RSS at the next A-BFT for which the value of the IsResponderTXSS field is the same as the current A-BFT.

(11ay)For a non-EDMG AP or a non-EDMG PCP or if the A-BFT in Secondary Channel subfield is 0, the initiator shall initiate an SSW feedback procedure to a responder (10.41.2.4 (Sector sweep (SSW) feedback)) at a time such that the beginning of the first symbol of the SSW-Feedback frame on the WM occurs at aSSFBDuration + MBIFS before the end of the SSW slot. (11ay)If the A-BFT in Secondary Channel subfield is(M118) a nonzero value and an EDMG AP or EDMG PCP received SSW frames transmitted from different EDMG STAs on the primary channel and/or adjacent secondary channel(s) with the same Sector ID and the DMG Antenna ID subfield values, the initiator shall initiate an SSW feedback procedure to the responder(s) on the corresponding primary channel and/or adjacent channel(s) at a time such that the beginning of the first symbol of the SSW-Feedback frame(s) on the WM occurs at aSSFBDuration + MBIFS before the end of the SSW slot. If the A-BFT in Secondary Channel subfield is set to a nonzero value and an EDMG AP or EDMG PCP received SSW frame(s) transmitted from different EDMG STAs on the primary channel and/or adjacent secondary channel(s) with different Sector ID or DMG Antenna ID subfield values, the initiator shall initiate an SSW feedback procedure to the responder on the primary channel at a time such that the beginning of the first symbol of the SSW- Feedback frame on the WM occurs at aSSFBDuration + MBIFS before the end of the SSW slot, and/or should initiate the SSW feedback procedure to the responder(s) on the adjacent secondary channel(s) at a time such that the beginning of the first symbol of the SSW-Feedback frame on the WM occurs at aSSFBDuration + MBIFS before the end of the next available SSW slot (s).

A responder that transmitted at least one SSW frame (11ay)or Short SSW PPDU within an SSW slot shall be in quasi-omni receive mode for a period of aSSFBDuration ending MBIFS before the end of the SSW slot. The initiator may initiate an SSW feedback procedure to the responder at an SSW slot even if the responder did not complete RSS within that SSW slot. If the initiator transmits an SSW-Feedback under this circumstance, it can transmit an Announce frame to the responder in an ATI. Following the reception of the Announce frame, the responder can respond with an SPR frame requesting time for the responder to continue with the RSS. Alternatively, the responder can transmit an SPR frame to the AP or PCP in accordance with the channel access rules.

The information contained in an SSW-Feedback frame is based on the SSW frames received during the SSW slot in which the SSW-Feedback frame was transmitted. To communicate with each other following an SLS, an initiator and responder should use the information contained within the SSW-Feedback frame that

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had the highest value in its SNR Report field and was transmitted or received, respectively, as part of the most recent SLS between the initiator and responder.

A responder that receives an SSW-Feedback frame from the initiator during an A-BFT that was allocated with a DMG Beacon frame with Discovery Mode equal to 1 should not attempt to access the following aMaxABFTAccessPeriod A-BFT allocations to redo beamforming with the initiator, unless in the BTI preceding the A-BFT the responder receives a DMG Beacon frame that has the Discovery Mode field equal to 1, the CC Present field equal to 1 and the value of the A-BFT Responder Address subfield equal to the responder's MAC address. This allows other STAs the opportunity to successfully contend for A-BFT access and perform beamforming with the initiator.

The responder may attempt to restart the RSS within the same A-BFT if it does not receive an SSW-Feedback frame from the initiator by the end of the SSW slot in which it completes the RSS. To do this, the responder shall invoke the random backoff procedure beginning at the start of the SSW slot following the completion of the RSS. (11ay)If either the initiator or the responder is a non-EDMG STA, the responder shall select a backoff count as a random integer drawn from a uniform distribution [0, A-BFT Length), i.e., 0 to A-BFT Length – 1, where A-BFT Length is the value of the A-BFT Length field in the last received DMG Beacon. (11ay)If both the initiator and the responder are EDMG STAs, the random backoff procedure begins at the start of the A-BFT with the responder:

— Selecting a single 2.16 GHz channel where the A-BFT is present based on the value of the A-BFT in Secondary Channel subfield in the last received DMG Beacon. Any frame exchange between the initiator and responder during the A-BFT shall be performed using the selected channel.
— Selecting a backoff count as a random integer drawn from a uniform distribution [0, A-BFT Length + A-BFT Length × A-BFT Multiplier), i.e., 0 to A-BFT Length + A-BFT Length × A-BFT Multiplier – 1, where A-BFT Length and A-BFT Multiplier are the values of the A-BFT Length and A-BFT Multiplier fields, respectively, in the last received DMG Beacon.

The responder shall decrement the backoff count by one at the end of each SSW slot, even if the CS function at the responder indicates the medium busy condition for that SSW slot. The responder may restart the RSS at the start of the SSW slot for which the backoff count is 0 at the beginning of the SSW slot provided the A-BFT still has SSW slots available.

At the end of an A-BFT the responder shall cancel a backoff procedure that was started during the A-BFT, but has not been completed at the end of the A-BFT. As described above, the responder invokes a random backoff procedure at the start of each A-BFT.

Each STA maintains a counter, FailedRSSAttempts, of the consecutive number of times the STA initiates RSS during A-BFTs but does not receive an SSW-Feedback frame as a response. If FailedRSSAttempts exceeds (11ay)RSSRetryLimit, the STA shall select a backoff count as a random integer drawn from a uniform distribution [0, (11ay)RSSBackoff), i.e., 0 to (11ay)RSSBackoff – 1. (11ay)For a non-EDMG STA the value of RSSRetryLimit is equal to dot11RSSRetryLimit and the value of RSSBackoff is equal to dot11RSSBackoff, and for an EDMG STA the value of RSSRetryLimit is equal to the value of the RSS Retry Limit subfield in the last received EDMG Operation element and the value of RSSBackoff is equal to the value the RSS Backoff subfield in the last received EDMG Operation element. The responder shall decrement the backoff count by one at the end of each A-BFT period in the following beacon intervals. The responder may reinitiate RSS only during an A-BFT when the backoff count becomes zero. The STA shall set FailedRSSAttempts to 0 upon receiving an SSW-Feedback frame during the A-BFT.

In an A-BFT, the responder shall not initiate an SSW ack procedure (10.41.2.5 (SSW ack)) in response to an SSW-Feedback frame from the initiator. The SSW ack procedure occurs within the DTI of a beacon interval (10.41.6.2 (SLS phase execution)); it does not occur otherwise.


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If the AP or PCP receives an SSW frame from the responder during the RSS with the Poll Required field within the SSW frame equal to 1 and the TDDTI field within the AP's or PCP's DMG Capabilities element is 1, the AP or PCP shall allocate time for the responder and the AP or PCP to communicate during the ATI or within an SP of the DTI of at least one of the following aMinBTIPeriod beacon intervals beginning with the beacon interval in which the SSW frame was received. This can be done through the Extended Schedule element or the transmission of a Poll or Grant frame addressed to the responder, and the allocated time can be used for at least one of association, authentication, and service period request.

After transmitting an SSW-Feedback frame to the responder, the initiator shall send a BRP frame with the Capability Request subfield within the BRP Request field set to 1 and addressed to the responder. The BRP frame shall be sent in one of the following aMinBTIPeriod beacon intervals beginning with the beacon interval in which the RSS phase with the responder was last completed. The BRP frame shall be transmitted at MCS 0 using the sector identified by the Sector Select field received from the responder during the RSS.

In an ATI after the completion of the SSW feedback procedure, a responder should have its receive antenna configured to a quasi-omni antenna pattern in the DMG antenna in which it received the best sector from the initiator during the preceding ISS in order to receive an Announce, Grant, or BRP frame (with the Capability Request subfield within the BRP Request field set to 1) from the initiator, while the initiator should configure its transmit DMG antenna to the value of the Sector Select and the DMG Antenna Select fields received from the responder during the preceding RSS. If the responder does not receive an Announce or Grant frame from the initiator with the RA equal to the responder's MAC address until aMinBTIPeriod beacon intervals after the beacon interval in which the SLS phase with the initiator was last attempted, it may retry BF with the initiator in the A-BFT.

NOTE—Due to the multiple access nature of RSS in the A-BFT, the AP or PCP might not receive the best sector for communication with the STA. The AP or PCP might schedule an SP to perform BF again with the STA to find the best sector for communication with the STA.

#### 10.41.5.3 STA Beamforming after A-BFT

The initiator shall either initiate BRP execution with the responder in the next CBAP or shall schedule time in the DTI for BRP execution with the responder if the initiator needs BRP training or the responder indicated a need for training (by setting any of the L-RX, TX-TRN-REQ, MID-REQ, or BC-REQ fields to a nonzero value) as a response to an SSW-Feedback or BRP frame with Capability Request subfield within the BRP Request field set to 1.

The responder may initiate BRP in a CBAP by sending a BRP frame with any of the training request fields (i.e., L-RX, TX-TRN-REQ, MID-REQ, BC-REQ) set to 1.

To schedule time in the DTI for BRP execution with a responder, the initiator may use any of the following methods:

1) Allocate an SP with the Beamforming Training subfield set to 1 in the Allocation field within an Extended Schedule element. The source of the SP shall be the initiator and the destination of the SP shall be the responder. The Extended Schedule element is carried in DMG Beacon or Announce frames, as defined in 10.38.4 (DTI transmission rules). The source AID of the allocation shall be set to the AID of the initiator. The destination AID of the allocation shall be set to the AID of the responder or the broadcast AID.
2) Allocate a CBAP in which the initiator or responder may start beamforming training with each other. The CBAP allocation is announced in an Extended Schedule element carried in a DMG Beacon or an Announce frame, as defined in 10.38.4 (DTI transmission rules). The source AID of the CBAP shall be set to the AID of the initiator or to the broadcast AID. The destination AID of the CBAP may be set to the AID of the responder or to the broadcast AID.

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3) Use a Grant frame to allocate either a CBAP or an SP in which the initiator or responder may start beamforming with each other. In the Grant frame, the initiator shall set the RA field to the MAC address of the responder and the TA field to the MAC address of the initiator. In the Dynamic Allocation Info field of the Grant frame, the AllocationType field shall be set to indicate CBAP or SP, the source AID field shall be set to the AID of the initiator, the destination AID field shall be set to the AID of the responder or the broadcast AID, and the Allocation Duration field shall be set to the expected duration of the BRP phase.
4) Allocate a DTI as CBAP only as defined in 10.38.4 (DTI transmission rules).

At least one of the above allocations shall occur during one of the following aMinBTIPeriod beacon intervals beginning with the beacon interval in which the SLS phase with the responder was last completed.

The duration of the allocation, as specified in the Allocation Block Duration (see 9.4.2.130 (Extended Schedule element)), shall cover at least the expected duration of the BRP phase.

If the initiator receives at least one SSW frame from a responder within an A-BFT but did not transmit an SSW-Feedback frame to the responder within that A-BFT, the initiator may schedule time in the DTI to perform the ISS and RSS. To do that, the initiator may use one of the methods above. The Allocation Block Duration field shall be set to cover at least the ISS and RSS.

The initiator may transmit an Announce frame to the responder during the ATI to announce a CBAP allocation in the beacon interval. If the responder receives the Announce frame with a CBAP allocation, the responder may contend for a TXOP during a CBAP to perform the BRP execution with the initiator or continue the RSS with the initiator.

Any Announce or Grant frame the initiator sends to a responder after initiating beamforming with the responder in the A-BFT but before beamforming with the responder is completed shall be transmitted at MCS 0 using the sector identified by the Sector Select field received from the responder in the RSS.

The execution of the beamforming procedure in an allocation in the DTI is described in 10.41.6 (Beamforming in DTI).

#### 10.41.5.4 Beamforming in A-BFT with multiple DMG antennas

(11ay)A non-EDMG AP or non-EDMG PCP, or an EDMG AP or EDMG PCP that used one RF chain in the last BTI, shall receive through a quasi-omni antenna pattern from a single DMG antenna throughout an A-BFT unless RXSS is used in the A-BFT, in which case it switches through antenna patterns as described in 10.41.5.2 (Operation during the A-BFT). (11ay)An EDMG AP or EDMG PCP that used multiple RF chains to transmit DMG Beacon frames in the last BTI shall simultaneously receive throughout the A-BFT with a quasi-omni antenna pattern from each DMG antenna used in the last BTI.

An AP or PCP shall have an A-BFT every *k* beacon intervals, where *k* is the value indicated by the N BIs A-BFT subfield in the Beacon Interval Control field. In an A-BFT, the (11ay)non-EDMG AP or non-EDMG PCP, or an EDMG AP or EDMG PCP with one or multiple DMG antennas but that used one RF chain in the last BTI, shall receive in a quasi-omni antenna pattern using the DMG antenna indicated by the value of the DMG Antenna ID subfield within the SSW field transmitted in the DMG Beacon. (11ay)A non-EDMG AP or non-EDMG PCP, or an EDMG AP or EDMG PCP having a single RF chain, with multiple DMG antennas has a regular schedule of receiving through each DMG antenna corresponding to the DMG antenna in which a DMG Beacon frame is transmitted through. The AP or PCP shall switch RX DMG antenna every *l* allocations, where *l* is the value of the N A-BFT in Ant subfield within the Beacon Interval Control field.

(11ay)In an A-BFT, an EDMG AP or EDMG PCP that used multiple RF chains and the same number of DMG antennas within one DMG antenna group in the last BTI shall receive in a quasi-omni antenna pattern


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through each DMG antenna indicated by the values of the DMG Antenna ID subfields within the SSW fields(#4303) transmitted in one or multiple DMG Beacon frames during the last BTI. DMG Beacon frames transmitted from different DMG antennas have different values in their DMG Antenna ID subfields. An EDMG AP or EDMG PCP having multiple RF chains and multiple DMG antenna groups has a regular schedule of receiving through each DMG antenna group corresponding to the DMG antennas in which a DMG Beacon frame is transmitted through. The EDMG AP or EDMG PCP with multiple RF chains shall switch RX DMG antenna group every *l* allocations, where *l* is the value of the N A-BFT in Ant subfield within the Beacon Interval Control field.

In each DMG Beacon frame(#337), the A-BFT Count subfield in the Beacon Interval Control field indicates the number of A-BFTs that have passed since the AP or PCP last switched RX DMG antennas.

### 10.41.6 Beamforming in DTI

#### 10.41.6.1 General

An initiator and responder may perform BF training within an SP or CBAP.

An initiator shall determine the capabilities of the responder prior to initiating BF training with the responder if the responder is associated. A STA may obtain the capabilities of other STAs through the Information Request and Information Response frames (11.28.1 (Information Request and Response)) or following a STA's association with the PBSS/infrastructure BSS. The initiator should use its own capabilities and the capabilities of the responder to compute the required allocation size and TXOP duration to perform BF training and BF training related timeouts.

An initiator may request the AP or PCP to schedule an SP to perform BF training with a responder by setting the Beamforming Training subfield in the BF Control field of the DMG TSPEC element or SPR frame to 1. The AP or PCP shall set the Beamforming Training subfield to 1 in the Allocation field of the Extended Schedule element if the Beamforming Training subfield in the BF Control field of the DMG TSPEC element or SPR frame that generated this Allocation field is equal to 1. The AP or PCP should set the Beamforming Training subfield in an Allocation field of the Extended Schedule element to 0 if this subfield was equal to 1 when the allocation was last transmitted by the AP or PCP in an Extended Schedule element and if, since that last transmission, the AP or PCP did not receive a DMG TSPEC element for this allocation with the Beamforming Training subfield equal to 1.

#### 10.41.6.2 SLS phase execution

For BF training in the DTI, both the initiator and responder shall use the SSW frame for the ISS and RSS.

The initiator shall begin an ISS (10.41.2.2 (Initiator sector sweep (ISS))) at the start of an SP allocation or TXOP with an initiator TXSS, except in the case of an SP allocation that has the IsInitiatorTXSS field for this SP is equal to 0 in which case the initiator shall begin an ISS with an initiator RXSS.

If the responder has more than one DMG antenna, the initiator shall repeat its ISS $k$+1 times, where $k$ is the value indicated by the responder in the last negotiated Number of RX DMG Antennas field transmitted by the responder. Repetitions of the ISS are separated by an interval equal to LBIFS. The value of the CDOWN field within SSW frames transmitted in the ISS indicates the number of sectors until the end of transmissions from all of the initiator's DMG antennas to all of the responder's DMG antennas. The ISS phase shall not be fragmented across multiple allocations.

The RSS comprises a responder TXSS unless the allocation is an SP and the IsResponderTXSS field for this SP is equal to 0 or the allocation is a CBAP and the RXSS Length field within the SSW frame received by the responder during the ISS is nonzero. The responder shall begin an RSS (10.41.2.3 (Responder sector sweep (RSS))) MBIFS following the completion of an ISS, provided the responder received an SSW frame

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from the initiator during the ISS and there is sufficient time in the allocation for the responder to transmit all SSW frames necessary to complete the RSS phase. The responder shall not begin or continue the RSS phase in a different allocation from the allocation that contained the ISS phase.

NOTE 1(11ay)—The responder can begin an RSS if there is not sufficient time in the allocation to complete the RSS phase. The RSS phase does not continue in a subsequent allocation in this case.

The initiator shall begin an SSW feedback procedure (10.41.2.4 (Sector sweep (SSW) feedback)) MBIFS following the completion of an RSS, provided the initiator received an SSW frame from the responder during the RSS and there is sufficient time left in the allocation to complete the SSW feedback procedure followed by an SSW ack procedure (10.41.2.5 (SSW ack)) from the responder in an MBIFS. If there is not sufficient time left in the allocation for the completion of the SSW feedback and SSW ack procedures, the initiator may begin the SSW feedback procedure in the following allocation between the initiator and the responder.

The responder shall begin an SSW ack procedure (10.41.2.5 (SSW ack)) to the initiator an MBIFS following the reception of an SSW-Feedback frame from the initiator.

The initiator may restart the SSW feedback procedure up to dot11BFRetryLimit times if it does not receive an SSW-Ack frame from the responder an MBIFS following the completion of the SSW feedback procedure. The initiator shall restart the SSW feedback procedure PIFS following the expected end of the SSW-Ack frame by the responder, provided there is sufficient time left in the allocation for the initiator to begin the SSW feedback procedure followed by an SSW ack procedure from the responder in an MBIFS. If there is not sufficient time left in the allocation for the completion of the SSW feedback and SSW ack procedures, the initiator may restart the SSW feedback procedure in the following allocation between the initiator and the responder.

Once started, the initiator and responder shall complete the SLS phase before any additional frame exchange sequence(#109) takes place between these STAs.

(11ay)An EDMG STA that is a TXOP holder or is an SP source may transmit SSW frame(s) with the Direction subfield set to 1 and the RA field set to the TA field of an SSW frame that the STA received with the Unsolicited RSS Enabled field set to 1.

(11ay)NOTE 2—If a TXOP holder or source STA of an SP transmits SSW frames with the Direction field set to 1 at the beginning of a TXOP or SP, respectively, the STA is considered as the responder for an ISS or RSS that occurred in an earlier BTI, TXOP or SP. The EDMG STA performing the ISS or RSS in the earlier BTI, TXOP or SP is considered as the initiator for the subsequent unsolicited RSS.

(11ay)If an EDMG STA receives a DMG Beacon or SSW frame from an EDMG STA with the Unsolicited RSS Enabled subfield equal to 1, the STA may process the received DMG Beacon or SSW frames as a responder even if the A-BFT is not present for the case of a received DMG Beacon frame, or even if the STA's MAC address does not match the RA field for the case of a received SSW frame. The STA may then perform an RSS with the initiator in response to the received SSW frames in a subsequent TXOP or SP. This is known as an unsolicited RSS.

(11ay)If an EDMG STA receives a DMG Beacon or SSW frame with the Unsolicited RSS Enabled subfield equal to 1 and if, as a result, an unsolicited RSS is performed, the EDMG STA shall complete the unsolicited RSS within the same beacon interval in which the DMG Beacon or SSW frame was received.

(11ay)An EDMG STA shall not perform an unsolicited RSS in response to a DMG Beacon or SSW frame with the Unsolicited RSS Enabled subfield equal to 0.

(11ay)An unsolicited RSS takes place when all of the following conditions are met:


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a) A first EDMG STA transmits a DMG Beacon or SSW frame with the Unsolicited RSS Enabled subfield set to 1; and

b) Following the transmission of a DMG Beacon or SSW frame with the Unsolicited RSS Enabled subfield set to 1, the first EDMG STA receives an SSW frame from a second EDMG STA that is not a response to an immediately preceding ISS or RSS and that has the Direction field equal to 1 and the RA field equal to the first STA's MAC address; and

c) In the case the first STA transmitted an SSW frame in condition a), the second STA that transmitted the SSW frame identified in condition b) is different from the STA addressed by the SSW frame transmitted by the first STA in condition a).

(11ay)An EDMG STA that receives an unsolicited RSS shall perform an SSW Feedback as specified in 10.41.2.4 (Sector sweep (SSW) feedback).

(11ay)An EDMG STA that transmitted an unsolicited RSS shall wait for MBIFSTimeout interval, which has a value of MBIFS + aSlotTime + aRxPHYStartDelay, starting at the PHY-TXEND.confirm primitive of the last SSW frame transmitted as part of the unsolicited RSS. If a (#3038)PHY-RXEARLYSIG.indication or PHY-RXSTART.indication primitive does not occur during the MBIFSTimeout interval, the STA concludes that the unsolicited RSS failed and may initiate an ISS to the STA to which the unsolicited RSS was transmitted.

(11ay)Figure 10-92 (Example of unsolicited RSS(11ay)) shows an example of an unsolicited RSS. STA A that performs an ISS or RSS with STA C sets the Unsolicited RSS Enabled subfield to 1 to indicate it is operating as an initiator corresponding to a potential unsolicited RSS in a subsequent TXOP or SP. STA B (TXOP holder or source STA of the SP) transmitting SSW frames with the Direction subfield set to 1 at the beginning of a TXOP or SP (e.g., TXOP2 or SP2) is considered as the responder of STA A for the ISS or RSS in the earlier BTI, TXOP or SP (e.g., TXOP1 or SP1). In the TXOP2 or SP2, if an SSW frame with the Direction subfield set to 1 is received, STA A operates as the initiator and responds with an SSW-Feedback frame without performing an ISS.

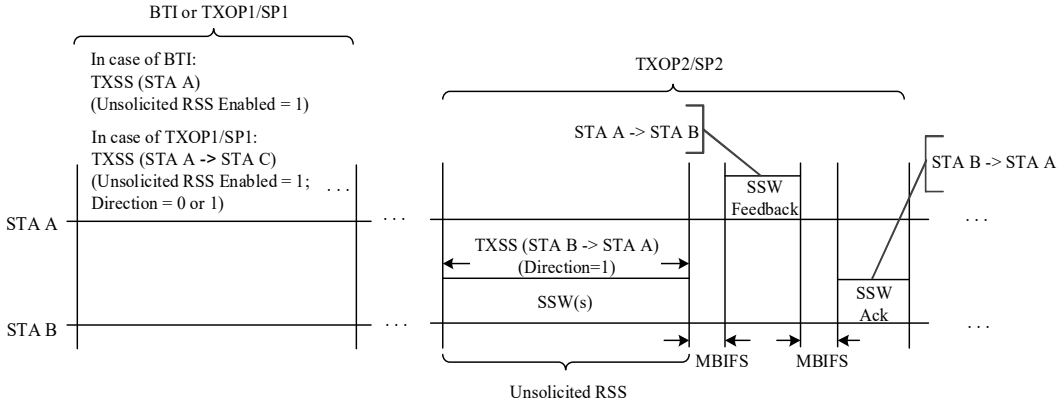


**Figure 10-92—Example of unsolicited RSS(11ay)**

### 10.41.6.3 Multiple sector ID capture (MIDC) subphase

#### 10.41.6.3.1 General

In practice, the quasi-omni RX antenna patterns used in the SLS phase might exhibit imperfections that lead to an incorrect choice of the best TX sector and consequently a sub-optimal starting point for beam refinement in the BRP phase. To remedy this, a multiple sector ID capture (MIDC) subphase may be used. Instead of selecting the starting point for the beam refinement transactions (i.e., the best TX sector) based on

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information obtained with quasi-omni RX antenna patterns from the SLS phase, the MIDC subphase enables the use of additional information based on the trial of multiple transmit and receive sectors.

The MIDC subphase can be implemented in two ways. The first option is to conduct a trial between a small set of transmit and receive AWV settings with wide (e.g., quasi-omni) antenna patterns. The second option is to carry out a trial between a small set of TX sectors and a set of RX AWV settings, chosen by the receiver in an implementation dependent manner, that maximizes the probability of determining the RX AWVs that best match the chosen set of TX sectors. Note that this may involve using a set of RX AWVs that correspond to the "full set" of RX sectors (from the SLS phase). The set of TX sectors are chosen from a TX sector sweep with a quasi-omni RX antenna pattern. With either option, the end result from the MIDC subphase can be the better starting point transmit and receive sector pair for further beam refinement.

For the first option above, the MIDC subphase consists of a MID subphase and a BC subphase. This is further elaborated upon in 10.41.6.3.2 (MIDC subphase with MID and BC subphases), and a sample time allocation is illustrated in Figure 10-93 (Example of time allocation for the MIDC subphase with MID and BC subphases). For the second option, the MIDC subphase consists only of a MID subphase. This is further elaborated upon in 10.41.6.3.3 (MIDC subphase with MID subphase only), and a sample time allocation is illustrated in Figure 10-94 (Example of time allocation for the MIDC subphase with the MID subphase only).

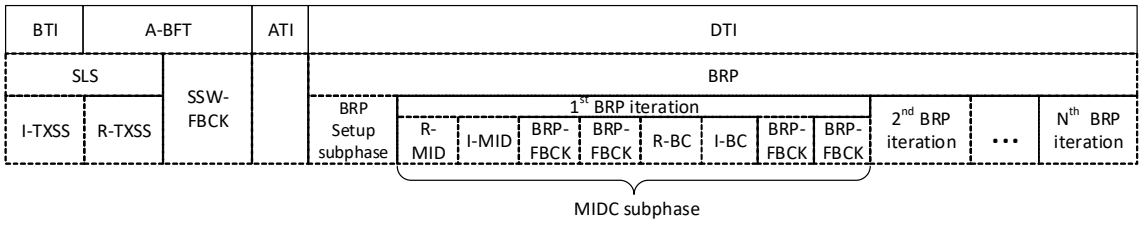


**Figure 10-93—Example of time allocation for the MIDC subphase with MID and BC subphases**

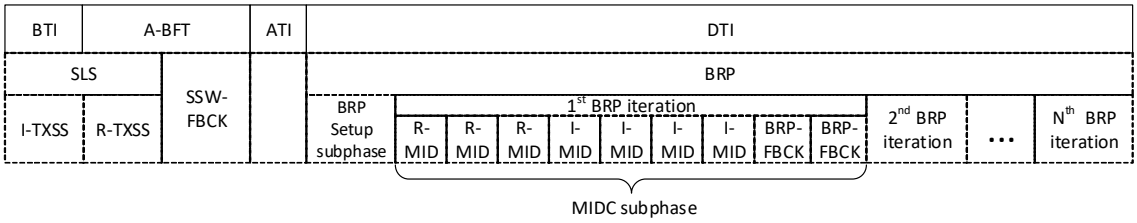


**Figure 10-94—Example of time allocation for the MIDC subphase with the MID subphase only**

Prior to the beginning of the MIDC subphase, a BRP setup subphase is carried out as specified in 10.41.3.2 (BRP setup subphase). This subphase enables the two DMG STAs involved to negotiate whether and how the MIDC subphase is carried out.

In 10.41.6.3 (Multiple sector ID capture (MIDC) subphase) the following terminology is used:

— Nbeam: the value of the Number of Beams subfield of the FBCK-TYPE field.

— Nbeam(Link Type,Antenna Type): represents a combination of Nbeam, Link Type (I for Initiator, R for Responder), and Antenna Type (TX for Transmitter, RX for Receiver).

— Number of Measurements: the value of the Number of Measurements subfield of the FBCK-TYPE field.


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Examples of how the MIDC subphase is set up, depending on whether beamforming is initiated in the BTI and A-BFT or in the DTI, are illustrated in Figure 10-95 (Example of using BRP setup subphase to set up subsequent MIDC subphase in A-BFT and DTI) and Figure 10-96 (Example of using BRP setup subphase to set up subsequent MIDC subphase in DTI), respectively. Note that the MIDC subphase is applicable only when both the initiator and the responder have the ability to switch among their sectors.

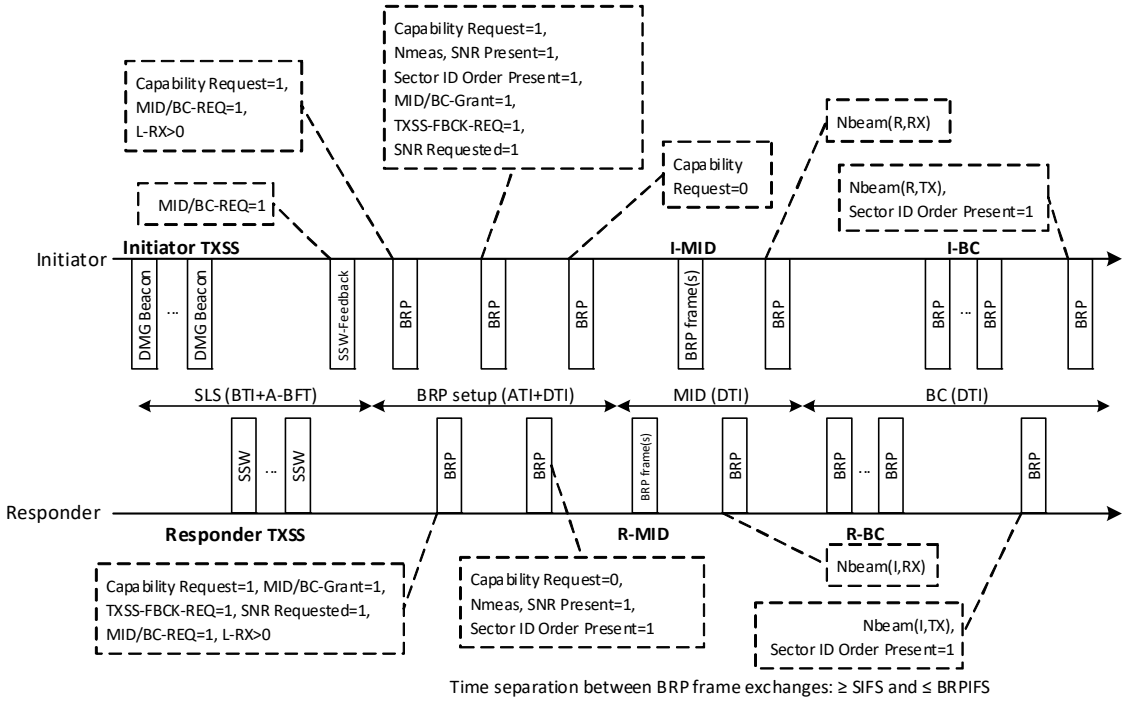


**Figure 10-95—Example of using BRP setup subphase to set up subsequent MIDC subphase in A-BFT and DTI**

### 10.41.6.3.2 MIDC subphase with MID and BC subphases

The MIDC subphase can be implemented such that small subsets of TX sector IDs and RX AWVs are first chosen, followed by trials between these subsets to determine the optimal starting TX sector ID and RX AWV pair. The set of TX sectors is chosen from an a priori TX sector sweep with a quasi-omni RX antenna pattern (in the SLS phase). To enable the selection of the RX sectors, and the subsequent trial between the transmit and receive sectors, the MIDC subphase consists of an MID subphase and a BC (or beam combining) subphase. In the MID subphase, a wide TX beam (e.g., quasi-omni) is used while the receiver sweeps through its choice of AWV settings to determine the set of RX AWVs with the highest link quality. This is followed by the BC subphase, which involves testing the multiple RX AWVs together with multiple TX AWVs.

This is conceptually illustrated in Figure 10-97 (Conceptual flow of sample MIDC subphase execution with MID and BC subphases for initiator link). Note that the consecutive numbering of TX sector IDs (e.g., TX sector ID1, TX sector ID2, …) or RX AWVs is just used for representation purposes. It is used to indicate the subset of TX sector IDs without placing any restrictions on how these sector IDs are selected (i.e., consecutive numbering of TX sector IDs does not mean that the selected TX sector IDs should be those that are consecutively numbered).

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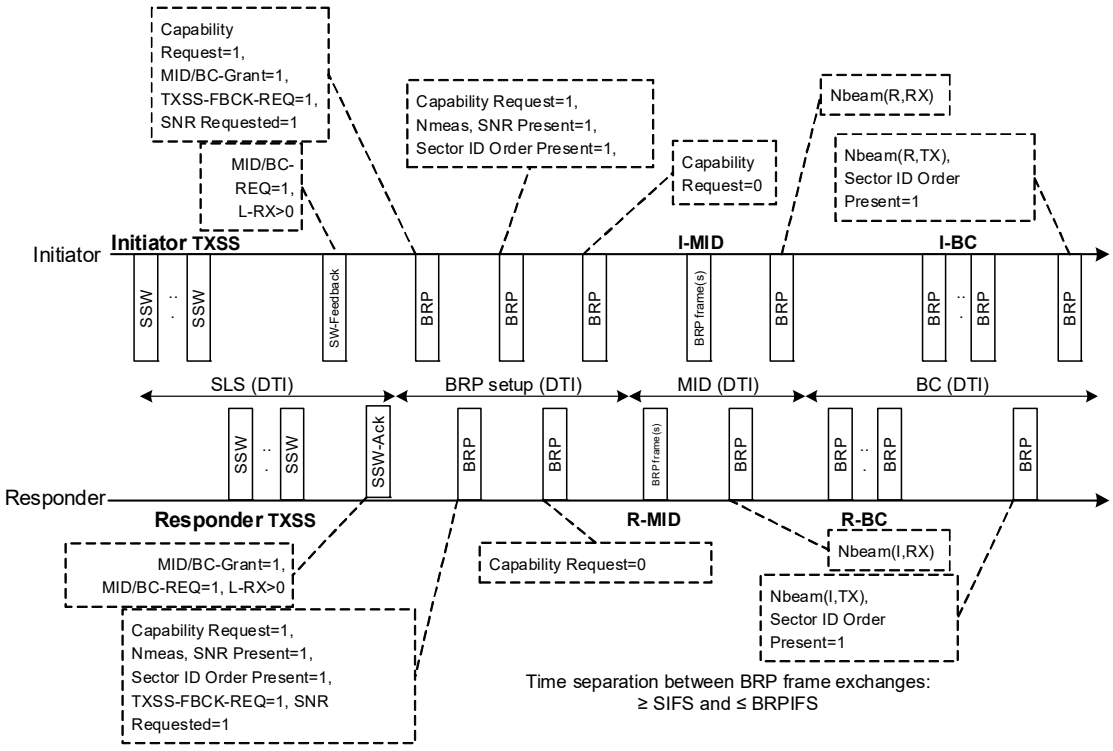


**Figure 10-96—Example of using BRP setup subphase to set up subsequent MIDC subphase in DTI**

a) *Setting up the MID and BC subphases*: To request a MIDC subphase with the MID and the BC subphases, the initiator shall transmit an SSW-Feedback or BRP frame with the MID-REQ and the BC-REQ fields set to 1 in the BRP Request field. The responder may grant this request by setting the MID-Grant and the BC-Grant fields to 1 in the BRP Request field within the next SSW-Ack or BRP frame transmitted to the initiator. The R-MID and R-BC subphases are performed if the request is granted and are not performed otherwise.

The responder shall transmit an SSW-Ack or BRP frame to request a MIDC subphase, with the I-MID and I-BC subphases. It shall do so by setting the MID-REQ and the BC-REQ fields to 1 in the BRP Request field within the transmitted frame. The initiator may grant this request by setting the MID-Grant and the BC-Grant fields to 1 in the BRP Request field within the next BRP frame transmitted to the responder. The I-MID and I-BC subphases are performed if the request is granted and are not performed otherwise.

If all of R-MID, R-BC, I-MID, and I-BC subphases are performed, the MID subphases are performed before the BC subphases. Within the MID subphase, R-MID is performed before I-MID. Within the BC subphase, R-BC is performed before I-BC (see Figure 10-93 (Example of time allocation for the MIDC subphase with MID and BC subphases) and Figure 10-94 (Example of time allocation for the MIDC subphase with the MID subphase only)).

In addition to the MID-REQ, BC-REQ, MID-Grant and BC-Grant fields, the responder (and/or initiator) needs to obtain the number of RX AWV settings to be appended to BRP-RX PPDUs in the R/I-MID subphase. To do this, the initiator (and/or responder) should use the L-RX field in the BRP Request field to convey this information. Similarly, the responder (and/or initiator) needs to obtain the IDs and SNRs of the TX sectors received during the SLS phase for use in the R-BC and I-BC subphases. To do this, the responder (and/or initiator) shall send a BRP PPDU with the TXSS-FBCK-REQ subfield and SNR Requested subfield set to 1 in the FBCK-REQ field of the DMG


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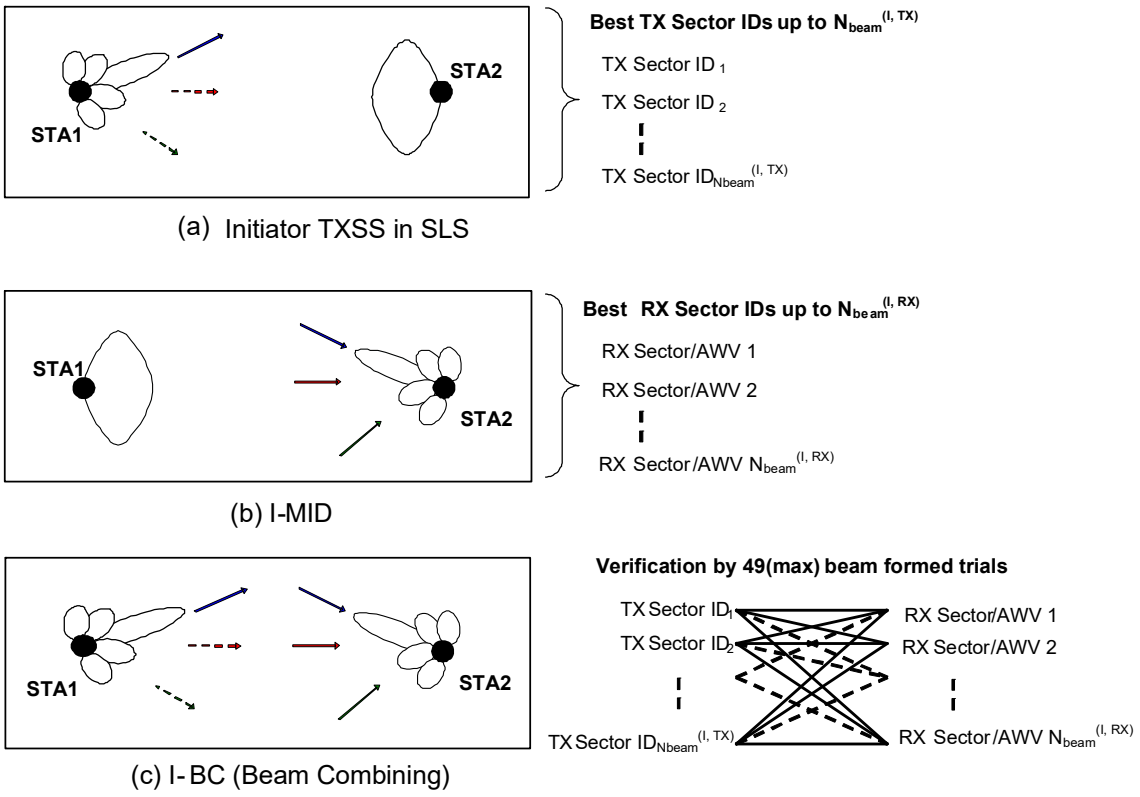


**Figure 10-97—Conceptual flow of sample MIDC subphase execution with MID and BC subphases for initiator link**

Beam Refinement element. In response, the initiator (and/or responder) should send a BRP frame with both the SNR Present subfield and the Sector ID Order Present subfield set to 1. The Number of Measurements subfield in the FBCK-TYPE field is set to indicate the number of sectors received during the last SLS for which an SNR measurement is included. In the Channel Measurement field, the initiator (or responder) should set the SNR subfield to the SNRs corresponding to the TX sectors trialled during the SLS phase. In the Sector ID subfield, it should list the sector IDs of the received sectors. The responder (and/or initiator) should then use the SNR information, and any additional information such as angular separation between sectors, to determine the TX sectors for use in the BC subphase. The responder (or initiator) shall inform the initiator (or responder) of the number of TX sectors using the Number of Beams subfield in the FBCK-TYPE field during the BRP setup subphase. After the R/I-MID subphases, the same field is used to exchange information about the number of RX AWVs to be trialled during the BC subphase.

b) *Executing the MID subphase*: If R-MID was requested and granted during the SLS and/or subsequent BRP setup subphase, then after the BRP setup subphase, the R-MID shall be initiated by the responder sending a BRP frame with TRN-R subfields (as requested in the BRP setup subphase). This PPDU may be transmitted using a wide pattern, approaching an omni transmit pattern, or using a sector antenna pattern. The receiver may use the TRN-R subfields for receive training.

If the MID Extension field in the PPDU is equal to 1, the responder shall transmit another BRP-RX PPDU, which may be transmitted using another transmit pattern. It may continue transmitting BRP-RX PPDUs as long as the MID Extension field in all of them is equal to 1. The last BRP-RX PPDU transmitted by the responder shall have the MID Extension field set to 0.

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If the initiator does not receive a BRP-RX PPDU within BRPIFS after transmitting the last PPDU of the BRP setup subphase, it may retransmit the last PPDU of the BRP setup subphase.

After the initiator receives a BRP-RX PPDU with the MID Extension field set to 0, it shall respond with a BRP frame with the appropriate feedback. This BRP frame should be sent using the best TX sector as determined in the SLS phase, while the responder should use a quasi-omni pattern to receive this frame. The feedback included in this BRP frame is the number of RX AWVs to be tested in the subsequent R-BC subphase using the Number of Beams subfield in the FBCK-TYPE field.

If I-MID was granted in addition to R-MID, the initiator shall send a BRP frame with TRN-R subfields (as requested in the BRP setup subphase). The initiator shall continue to send BRP PPDUs if the MID Extension was set to 1 as in the R-MID.

After the responder receives a BRP-RX PPDU with the MID Extension set to 0, it shall respond by sending a BRP frame with feedback. This BRP frame should be sent using the best TX sector as determined in the SLS phase, while the initiator should use a quasi-omni pattern to receive this frame. The feedback included in this BRP frame is the number of RX AWVs to be tested in the subsequent I-BC subphase using the Number of Beams subfield in the FBCK-TYPE field. The initiator shall respond with a BRP frame with the TX-TRN-OK field set to 1 as an acknowledgment. The R-BC subphase then follows.

If I-MID does not follow R-MID, the BC subphase follows immediately.

c) *Executing the BC subphase*: The execution of an I-BC subphase is used as an example. In an I-BC subphase, the initiator shall transmit Nbeam(I,TX) BRP-RX frames using the number of TX sectors specified during the BRP setup subphase. Each BRP-RX frame shall be appended with Nbeam(I,RX) TRN-R subfields, and shall include the Sector ID subfield of the TX sector used. While receiving these TRN-R subfields, the responder shall switch through the RX AWVs selected during the prior I-MID subphase. To conclude the I-BC subphase, the responder shall feed back to the initiator a BRP frame with (a) the BS-FBCK field set to the TX sector ID of the BRP-RX PPDU received with the highest link quality, and (b) the ordered list of transmit sectors (based on received link quality during the I-BC) using the Sector ID Order subfield in the Channel Measurement Feedback element. This BRP frame should be sent using the best TX sector as determined in the SLS phase, while the initiator should use a quasi-omni pattern to receive this frame. (#4093)Figure 10-98 (Beam combining) depicts the beam combining subphase. The complete procedure is illustrated in Figure 10-99 (Examples of using MID Extension field during execution of MID subphase).

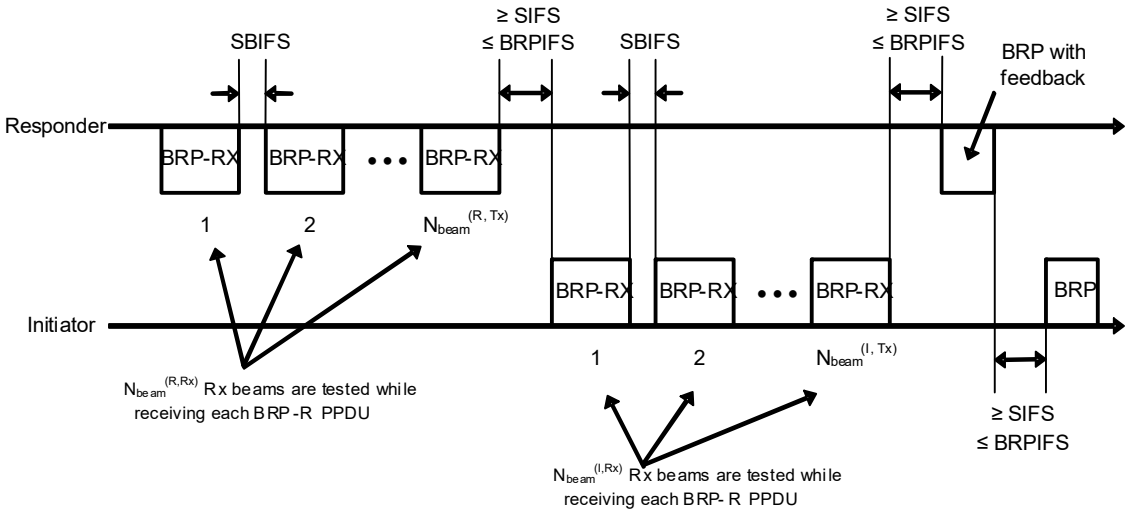


**Figure 10-98—Beam combining**


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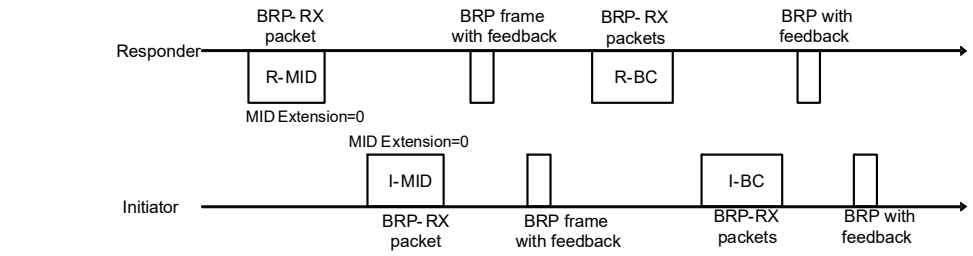
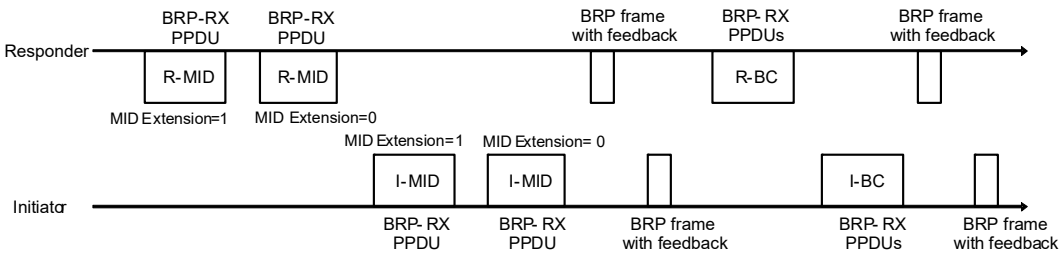
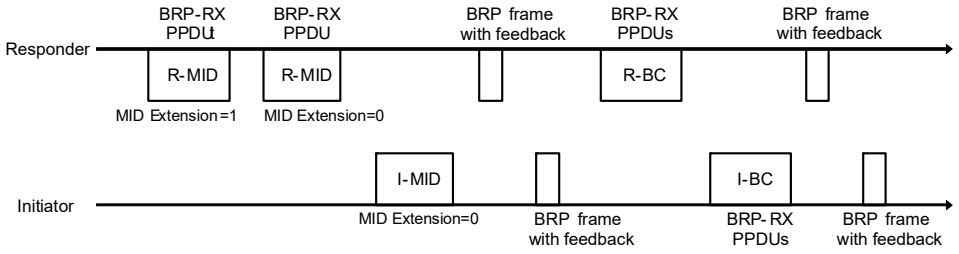



(a) Normal process: one MID and BC for each initiator and responder link
(the initiator and responder use a quasi-omni TX pattern)




(b) The MID for both the initiator and responder are repeated twice:
each TX beam is wider than a TX sector, but narrower than a quasi-omni pattern and covers a different direction




(c) The MID for the initiator is repeated twice:
each TX beam is wider than a TX sector, but narrower than a quasi-omni pattern and covers a different direction

**Figure 10-99—Examples of using MID Extension field during execution of MID subphase**

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#### 10.41.6.3.3 MIDC subphase with MID subphase only

The MIDC subphase may also be implemented such that multiple TX sectors, obtained from the TXSS in the SLS phase, are used instead of wide TX beams. Here, the receiver employs multiple RX AWVs for each TX sector chosen by the transmitter. Based on this joint trial of transmit and receive AWVs, the optimal starting transmit and receive AWV pair is chosen for further refinement in the BRP phase. In this case, the MIDC subphase consists only of the MID subphase. This is conceptually illustrated in Figure 10-100 (Conceptual flow of sample MIDC subphase execution with only MID subphase for initiator link).

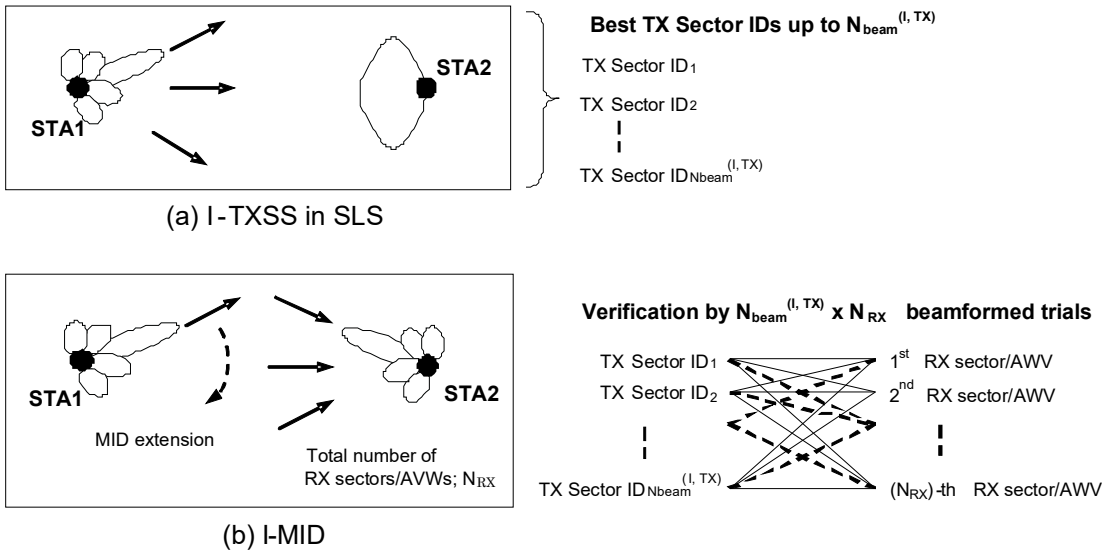


**Figure 10-100—Conceptual flow of sample MIDC subphase execution with only MID subphase for initiator link**

a) *Setting up the MID subphase*: The procedure of setting up the MID-subphase is described in 10.41.3.2 (BRP setup subphase).

In the example of Figure 10-101 (Example of using BRP setup subphase to set up subsequent R-MID subphase(#2259)), the initiator transmits an SSW-Feedback frame with the MID-REQ subfield set to 1 and the BC-REQ subfield set to 0 in the BRP Request field, thus requesting an MIDC with only the R-MID subphase. The responder grants the MID-REQ by setting the MID-Grant subfield to 1 in the SSW-Ack frame. The initiator then sends a frame with the SNR Present and Sector ID Order Present subfields both set to 1, the Number of Measurement subfield in the FBCK-TYPE field indicating the number of SNR measurements from the last SLS phase, and the SNR and Sector ID subfields with the SNRs measured during the SLS phase and the list of received sectors, respectively. The L-RX subfield is set according to the number of training fields the initiator needs


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in each PPDU as part of the R-MID. The responder then starts the R-MID process by transmitting BRP-RX PPDUs.

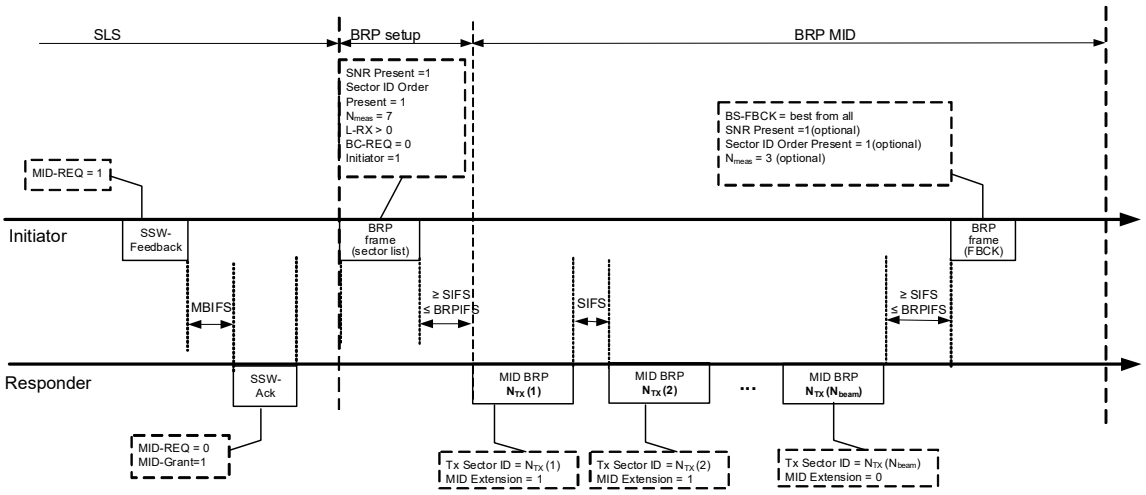


**Figure 10-101—Example of using BRP setup subphase to set up subsequent R-MID subphase(#2259)**

b) *Executing the MID subphase*: The execution of the MID subphase for the responder link (i.e., R-MID) is used as an example. Execution of the MID subphase for the initiator link (i.e., I-MID) is similar, except for a change in the direction of the corresponding frames. In an R-MID subphase, the responder shall transmit one BRP-RX PPDU each from one of the chosen TX sectors. In each PPDU, it shall indicate the sector ID of the TX sector used using the Sector ID field in the BRP Request field. Each transmitted BRP-RX PPDU should be appended with multiple TRN-R subfields such that the initiator can train its receiver antenna during the R-MID subphase. The initiator shall train its receiver antenna by cycling through its choice of RX AWVs while receiving the TRN-R subfields. The initiator shall indicate to the responder the number of TRN-R subfields to be appended using the *L-RX* field in the BRP Request field during the SLS phase or the BRP setup subphase. For all BRP-RX PPDUs except the last one, the responder shall also set the MID Extension field to 1. (11ay)An EDMG responder, responding to an EDMG initiator, may choose to use a single PPDU for training during the MID phase by setting the TXVECTOR parameter EDMG_TRN_LEN to a value greater than 0 and the parameter RX_TRN_PER_TX_TRN to a value equal to the value of the L-RX subfield transmitted during the last SLS phase or last BRP setup subphase, whichever is later. The EDMG responder shall then transmit through a list of chosen sectors during the TRN field of the transmitted PPDU. For each of the responder's TX sector, the initiator shall perform RX AWV training. In the feedback, the initiator shall set the BS-FBCK and BS-FBCK MSB fields to the AWV ID rather than the sector ID, where the first TX sector has AWV ID equal to 0.

In the R-MID subphase, the initiator shall send a BRP frame with feedback. This BRP frame should be sent using the best TX sector as determined in the SLS phase, while the responder should use a quasi-omni pattern to receive this frame. The feedback included in this BRP frame should be (a) the BS-FBCK field set to the TX sector ID (11ay)or the AWV ID (if an EDMG BRP-TX or EDMG BRP-RX/TX PPDU was used) of the (11ay)sector or AWV received with the best quality, and (b) the ordered list of transmit sectors (based on received link quality during the R-MID) using the Sector ID Order subfield. (11ay)An EDMG STA returns the ordered list in the EDMG Sector ID Order field.

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#### 10.41.6.3.4 MIDC subphase with BC subphase only

An MIDC subphase with only the BC subphase is carried out when the MID and BC subphases have been carried out earlier. In this case, the initiator and responder keep track of the transmit and receive sectors, for use in the BC subphase, from earlier iterations. Since the best transmit and receive sectors (in terms of link quality) are kept track of, this information can be used to deal with link blockage events. STAs can utilize only the chosen set of TX sectors in the SLS phase to reduce beamforming training time, and jump to the BC subphase directly without executing the MID subphase. In this manner, fast recovery is possible when some of the backup links are available after partial blockage around the STA.

To carry out the MIDC subphase with the BC subphase only, the MID-REQ field is set to 0 and the BC-REQ field is set to 1 in SSW-Feedback or SSW-Ack or BRP frames, and the BC-Grant field is set to 1 in the following SSW-Ack or BRP frame. The BC subphase can include an I-BC and/or an R-BC (10.41.6.3.2 (MIDC subphase with MID and BC subphases)).

### 10.41.6.4 BRP phase execution

#### 10.41.6.4.1 General

Beam refinement is a request/response based process. A STA requests receive beam refinement training by sending a BRP frame with a nonzero value in the L-RX field. The STA that receives the BRP frame shall respond with a BRP PPDU (20.9.2.2 (Beam refinement)) including as many TRN-R subfields as indicated in the value of the L-RX field within the received BRP frame and with the RX-train-response field in the DMG Beam Refinement element set to 1.

A STA requests transmit beam refinement training by sending a BRP frame as follows. In the BRP Request field, the TX-TRN-REQ field is set to 1, and the FBCK-REQ field indicates the feedback type. The Sector ID Order Requested subfield in the FBCK-REQ field shall be set to 0. In the TXVECTOR, the PPDU_TYPE parameter is set to TRN-T-PACKET, and the TRN_LEN parameter indicates the number of AGC and TRN-T subfields appended to the PPDU.

(#1259)A STA shall reply to a transmit beam refinement training request with a BRP frame containing a DMG Beam Refinement element with the TX-TRN-OK field and TX-train-response field both set to 1 and the BS-FBCK field set to indicate the TRN-T subfield on which the responding STA received the best signal (the determination of best signal is implementation dependent). The FBCK-TYPE field shall be set to according to the format of the Channel Measurement Feedback element, if one is included in the frame. If the SNR Present and Channel Measurement Present subfields of this FBCK-TYPE field are set to 0, the Channel Measurement Feedback element shall not be included. The number of taps indicated in the FBCK-TYPE field shall be less than or equal to the number of taps indicated in the FBCK-REQ field of the request frame.

(11ay)An EDMG STA responding to a transmit beam refinement training request in which the EDMG-SHORT-BRP subfield was 0 may respond within MBIFS with a BRP frame in which the Comeback Delay field in the EDMG BRP Request element is set to a nonzero value. This indicates that the STA is not ready with the feedback within BRPIFS from the request. The value in the Comeback Delay field indicates when the responding STA is ready. The requesting STA may send a BRP frame with a feedback request that contains no training requests and that has the same dialog token as the frame that originally solicited the response after the comeback delay has elapsed; in this case, the responding STA shall respond with feedback within MBIFS. If the TXOP or SP ended before the comeback delay elapsed, the responder may send the feedback in a BRP frame as part of another TXOP or SP. The dialog token within the feedback frame shall be the same as in the BRP frame soliciting the response.

(11ay)An EDMG STA responding to a transmit beam refinement training request in which the EDMG-SHORT-BRP subfield was 1 shall respond within MBIFS with a BRP frame that has the EDMG-SHORT-


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BRP subfield set to 1 and the EDMG-SHORT-FBCK subfield set to 1. The number of valid AWV feedback IDs ($N_{AID}$) in the Short BRP Feedback field shall comply with the following equation:

$$N_{AID} = \begin{cases} 16 & P \geq 16 \\ P & P < 16 \end{cases}$$

where

$$P = \sum_{k=1}^{K} L_k \times \frac{M_k}{N_k} \times T_k$$

$L_K$, $M_K$, $N_K$, and $T_k$ are the values of the EDMG_TRN_LEN, EDMG_TRN_M, EDMG_TRN_N and NUM_TX_CHAINS parameters, respectively, in the RXVECTOR of the $k^{th}$ EDMG BRP PPDU of the TXSS

$K$ is the total number of EDMG BRP PPDU received in the BRP TXSS or BRP-TX

(11ay)If $N_{AID} < 16$, the $(16 - N_{AID})$ Sector Measurement subfields of the Short BRP Feedback field shall be denoted as invalid by setting the SNR subfield to 0xFF as defined in 9.5.8 (Short BRP Feedback field(11ay)).

If a STA requests transmit beam refinement training, but does not send TRN-T subfields, the responding STA shall reply with a BRP frame containing a DMG Beam Refinement element with the TX-TRN-OK field set to 1. In this case (i.e., when the TX-train-response field is equal to 0), the responding STA shall set L-RX field to 0. The requesting STA shall then transmit a BRP PPDU with TRN-T subfields. The responding STA shall then respond with a BRP frame with the TX-train-response field set to 1 and the BS-FBCK and Channel Measurement Feedback element as above.

Beam refinement can be performed following SLS (10.41.6.4.3 (Beam refinement transaction after SLS)). If the responder receives an SSW-Feedback frame from the AP or PCP in an A-BFT, the AP or PCP allocates an SP for the beam refinement if required (see 10.41.5.3 (STA Beamforming after A-BFT)). A STA may transmit a BRP PPDU to another STA whenever the STA transmits a frame to that STA, provided that the transmitting STA knows that the recipient STA's receive antennas are directed to it or are in a quasi-omni antenna pattern.

A STA shall set the Initiator field to 1 within a DMG Beam Refinement element if the previous received frame was not a BRP frame, or the last PPDU the STA transmitted was a BRP frame with the Initiator field set to 1.

A STA that has transmitted a BRP frame with the Initiator field set to 1 and has not received a response BRPIFS after the transmission may retransmit the frame.

(11ay)In a beam refinement transaction outside of a TDD SP allocation, a STA that has transmitted a BRP frame with the Initiator field set to 1 and has not received a response BRPIFS after the transmission may retransmit the frame.

(11ay)In a beam refinement transaction in a TDD SP allocation, a STA that has transmitted a BRP frame with the Initiator field set to 1 and has not received a response in the earliest occurring TDD slot the STA is assigned to, with access permission of the TDD slot set to simplex TX TDD slot, and with slot category of the TDD slot set to Basic TDD slot as indicated in the TDD Slot Schedule element, after the transmission may retransmit the frame, according to the TDD channel access rules (see 10.38.6.2.2 (SP with TDD channel access(11ay))).

A STA may request a TXSS sector list feedback by sending a BRP frame with the TXSS-FBCK-REQ field set to 1, the SNR Requested subfield within the FBCK-REQ field set to 1 and the remaining subfields within

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the FBCK-REQ field set to 0. The responding STA shall respond with a BRP frame with the SNR Present subfield within the FBCK-TYPE field set to 1 and Sector ID Order Present subfield set to 1, with a list of sector IDs indicating the sector IDs of the received SSW frames or DMG Beacon frames, and with the SNR values with which those frames were received in the last TXSS. The Number of Measurements subfield in the FBCK-TYPE field is set to indicate the number of sectors received during the last SLS for which an SNR measurement is included.

(11ay)An EDMG STA may request a TXSS sector list feedback from a peer EDMG STA by sending a BRP frame with the BF Training Type field set to 0, the TXSS-FBCK-REQ field set to 1, the SNR Requested subfield within the FBCK-REQ field set to 1 and the remaining subfields within the FBCK-REQ field set to 0. The responding EDMG STA shall respond with a BRP frame with the BF Training Type field set to 0, the SNR Present and Sector ID Order subfields within the FBCK-TYPE field set to 1, the EDMG Extension Flag field set to 1 and the EDMG Channel Measurement Present field set to 1. In the EDMG Sector ID Order field, the SISO IDs indicate the sector IDs/CDOWN/AWV IDs, TX antennas and RX antennas of sectors that were used for reception in the last TXSS. The SNRs subfield in the Channel Measurement Feedback field indicates the SNRs on the sectors used for reception. The last TXSS may have been performed using DMG Beacon frames, SSW frames, Short SSW PPDUs or BRP-TX PPDUs. If the last TXSS was performed using BRP-TX PPDUs:

— The BRP-CDOWNs associated with each SISO ID indicate the BRP-CDOWN of the received BRP-TX PPDU.

— The Number of Measurements subfield of the FBCK-TYPE field is at least the minimum of $\{16, P\}$, where $P = \sum_{k=1}^{K} L_k \times \frac{M_k}{N_k} \times T_k$, and $L_k$, $M_k$, $N_k$, and $T_k$ are the values of the EDMG_TRN_LEN, EDMG_TRN_M, EDMG_TRN_N, and NUM_TX_CHAINS parameters, respectively, in the RXVECTOR of the received BRP-TX PPDUs and $k$ is the total number of BRP-TX PPDUs received in the TXSS.

(11ay)(#1260)An EDMG STA responding to a TXSS sector list feedback request with the EDMG-SHORT-BRP subfield equal to 0 may respond within MBFIS with a BRP frame with the Comeback Delay field in the EDMG BRP Request element set to a nonzero value. This indicates that the STA is not ready with the feedback within BRPIFS from the request. The value in the Comeback Delay field indicates when the responding STA is ready. The requesting STA may send a BRP frame with a feedback request that contains no training requests and that has the same dialog token as the frame that originally solicited the response after the comeback delay has elapsed; in this case, the responding STA shall respond with feedback within MBIFS. If the TXOP or SP ended before the comeback delay elapsed(#4356), the responder may send the feedback in a BRP frame as part of another TXOP or SP. The dialog token within the feedback frame shall be the same as in the BRP frame soliciting the response.

(11ay)An EDMG STA may request a TXSS sector list feedback from a peer EDMG STA by sending a BRP frame with the EDMG-SHORT-BRP subfield, TXSS-FBCK-REQ subfield and the SNR Requested subfield within the FBCK-REQ set to 1. The responding EDMG STA shall send a BRP frame with the EDMG-SHORT-BRP subfield and the EDMG-SHORT-FBCK subfield set to 1 within MBIFS from the reception of the request.

A STA shall not set the TXSS-FBCK-REQ and the TX-TRN-REQ fields to 1 in the same BRP frame.

Two or more BRP frames shall not be aggregated in the same A-MPDU. A BRP frame (11ay)that contains a beam refinement request may be aggregated with another frame in the same A-MPDU only if the other frame is a single Ack, BA or QoS Null frame. (11ay)A BRP frame that does not contain a beam refinement request may be aggregated with another frame in the same A-MPDU if the other frame is a single Data, Management (except BRP), Ack, Block Ack or QoS Null frame.


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The Duration field within each BRP frame is set to the time remaining until the end of the current allocation, when transmitted within an SP. Otherwise it is set to the time remaining until the end of the TXOP.

(11ay)An initiator EDMG STA may include an EDMG Partial Sector Level Sweep element within a BRP frame transmitted as part of a BRP transaction. The responder EDMG STA shall respond with a BRP frame with an EDMG Partial Sector Level Sweep element representing its preferences for a sector sweep that takes place following the expiration of the beamformed link maintenance timer. If the initiator sets the Agree to Change Initiator/Responder Roles field to 1 and the responder agrees to change beamforming initiator/ responder roles when the beamformed link maintenance timer expires, the responder shall set the Agree to Change Initiator/Responder Roles field to 1. If the initiator sets the Agree to Change Initiator/Responder Roles field to 0, this field is ignored. If the responder sets the Agree to Partial Sector Level Sweep to 1, the exchange is considered successful; otherwise, it is considered as failed.

(11ay)An EDMG STA that supports 6.48 GHz, 8.64 GHz, 2.16+2.16 GHz or 4.32+4.32 GHz PPDU transmission shall not set the DMG TRN RX Only Capable subfield in the STA's EDMG Capabilities element to one. Otherwise, the STA may set the DMG TRN RX Only Capable subfield to one.

(11ay)A 4.32 GHz EDMG PPDU transmission that includes a TRN field shall have the DMG_TRN parameter of the TXVECTOR set to 0.

(11ay)A 2.16 GHz EDMG PPDU transmitted using a single space-time stream that includes the TRN field and is addressed to a STA that has the DMG TRN RX Only Capable subfield set to 1 in the STA's EDMG Capabilities element shall have the DMG_TRN parameter of the TXVECTOR set to 1 and the EDMG_TRN_LEN parameter of the TXVECTOR set to a value greater than 0 and less than 32. Otherwise, the DMG_TRN parameter of the TXVECTOR shall be set to 0. If the EDMG_TRN_LEN parameter of the TXVECTOR of a PPDU sent to a STA that has set the DMG TRN RX Only Capable subfield equal to 1 is greater than 0, the CH_BANDWIDTH parameter shall be set to a value having only 1 bit set to 1.

(11ay)A EDMG STA that receives an EDMG BRP frame with RXVECTOR parameter DMG_TRN equal to 1, with the Channel Measurement Requested subfield of the FBCK-REQ field in the DMG Beam Refinement element within the frame equal to 1 and that has set the Chan-FBCK-CAP subfield to 1 in the last BRP Request field sent to the transmitter of the EDMG BRP frame, shall use the Channel Measurement Feedback element in its response to the received EDMG BRP frame.

#### 10.41.6.4.2 Beam refinement transaction

A beam refinement transaction is a set of BRP frames composed of request and responses.

A beam refinement transaction starts with the beamforming initiator STA sending a BRP frame with the Initiator field set to 1.

A beam refinement responder is a STA that receives a BRP frame (#1261)with the Initiator field set to 1.

A beam refinement transaction participant shall respond to a BRP frame with a BRP frame.

If the beam refinement transaction initiator received a BRP frame from the responder with no training requests, the initiator may terminate the transaction by not transmitting any further BRP PPDUs.

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Figure 10-102 (Example beam refinement transaction (receive training)), Figure 10-103 (Example beam refinement transaction (transmit training)), and Figure 10-104 (Example beam refinement transaction (combination of receive and transmit training)) show examples of beam refinement transactions.

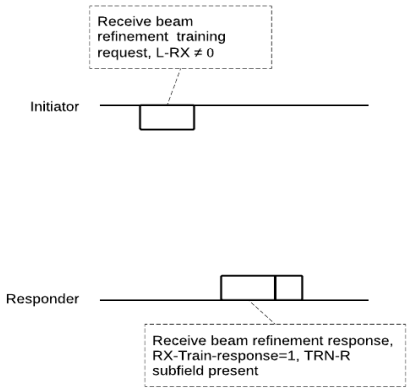


**Figure 10-102—Example beam refinement transaction (receive training)**

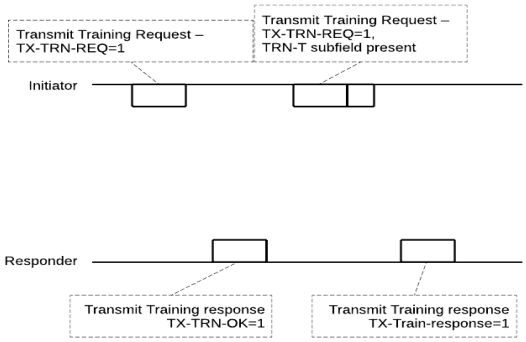


**Figure 10-103—Example beam refinement transaction (transmit training)**

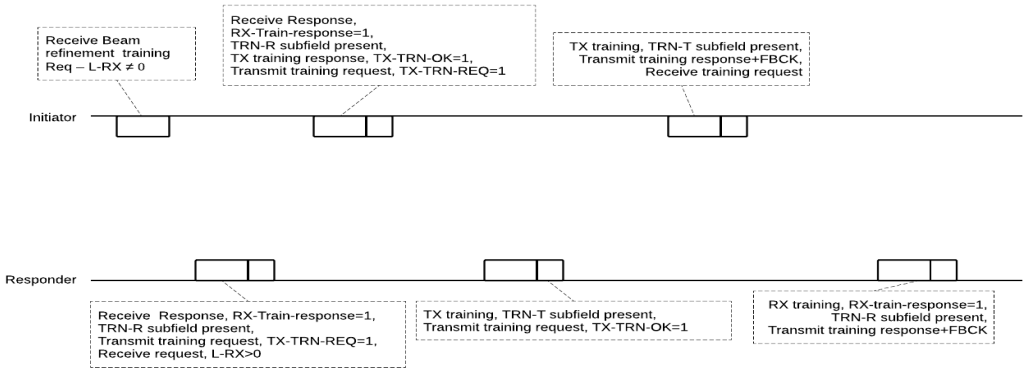


**Figure 10-104—Example beam refinement transaction (combination of receive and transmit training)**

(11ay)All PPDUs in a BRP transaction are transmitted with the same bandwidth and with the same channel aggregation setting. In a BRP transaction, except for the first PPDU of the BRP transaction, an EDMG initiator shall set the values of the TXVECTOR parameters CH_BANDWIDTH and CHANNEL_AGGREGATION of a PPDU to the same corresponding values used in the preceding PPDU transmitted by the initiator in the BRP transaction. In a BRP transaction, an EDMG responder shall transmit a PPDU with TXVECTOR parameter CH_BANDWIDTH equal to the value of the RXVECTOR parameter CH_BANWDITH of the PPDU that elicited the response, and with TXVECTOR parameter CHANNEL_AGGREGATION equal to the value of the RXVECTOR parameter CHANNEL_AGGREGATION of the PPDU that elicited the response.


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#### 10.41.6.4.3 Beam refinement transaction after SLS

If either L-RX or TX-TRN-REQ is nonzero within the BRP Request field in the SSW-Ack frame of the most recent SLS phase execution, no MID or BC was granted during the BRP setup subphase, and no beam refinement transaction has been done since the most recent SLS phase execution, then the initiator shall initiate the beam refinement transaction with the responder by sending a BRP frame to the responder. If the value of the L-RX field is greater than 0 in the SSW-Ack frame, the first BRP frame the initiator transmits to the responder is a BRP-RX frame. If the value of the L-RX field is 0 and the value of the TX-TRN-REQ field is 1, the first BRP frame the initiator transmits to the responder shall have either the TX-TRN-OK field set to 1 or the L-RX field greater than 0.

#### 10.41.6.4.4 Antenna configuration setting during a beam refinement transaction

A STA that has requested beam refinement receive training shall, except when receiving TRN-R subfields, set its receive antenna configuration to the best known receive antenna configuration based on previous beam refinement receive training or RXSS. If the STA has not received a BRP frame since the last SLS and the SLS did not include an RXSS, the STA should set its receive antenna configuration to a quasi-omni antenna pattern in the DMG antenna through which the STA received the best sector during the SLS.

A STA that receives a beam refinement transmit training request shall send the response frame and then set its antenna configuration to the best known receive antenna configuration based on previous beam refinement receive training or RXSS, except if both the initiator STA and responder STA support the Other_AID subfield as indicated through the Supports Other_AID field set to 1 within the STA's DMG Capabilities element and the value of the Other_AID subfield within the BRP Request field is different from 0, in which case the STA sets its antenna configuration to the best known receive antenna configuration for receiving from the STA with AID equal to the value of the Other_AID subfield within the BRP Request field. If the STA has not received a BRP frame since the last SLS and the SLS did not include an RXSS, the STA should set its antennas to a quasi-omni antenna pattern.

In a BRP-RX PPDU, all TRN-R subfields shall be transmitted using the same TX AWV configuration as the preamble and data fields of the PPDU, except if both the transmitting and receiving STAs support the Other_AID subfield as indicated through the Supports Other_AID field set to 1 within the STA's DMG Capabilities element and the value of the Other_AID subfield within the BRP Request field is different from 0, in which case the TRN-R subfields shall be transmitted using the best known TX AWV configuration for transmitting to the STA with AID equal to the value of the Other_AID subfield within the BRP Request field.

A STA that sets to 1 the Antenna Pattern Reciprocity subfield in the DMG STA Capability Information field in the DMG Capabilities element it transmits and that receives a BRP-RX PPDU from a peer STA that also sets to 1 the Antenna Pattern Reciprocity subfield in the DMG STA Capability Information field of the peer's DMG Capabilities element it transmits shall use the same AWV that was configured with the BRP-RX PPDU in subsequent transmissions and receptions with the peer STA during the DTI. This allows STAs that use reciprocity to shorten the beamforming training time.

A STA that sets to 1 the Antenna Pattern Reciprocity subfield in the CMMG Capabilities Info field in the CMMG Capabilities element it transmits and that receives a BRP-RX PPDU from a peer STA that also sets to 1 the Antenna Pattern Reciprocity subfield in the CMMG Capabilities Info field in the CMMG Capabilities element it transmits shall use the same AWV that was configured with the BRP-RX PPDU in subsequent transmissions and receptions with the peer STA during the DTI. This allows STAs that use reciprocity to shorten the beamforming training time.

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### 10.41.7 Beam tracking

(11ay)Beam tracking enables an initiator or responder to track changes in the AWVs of its DMG antennas and/or the spatial mapping matrix $Q$ (defined in Clause 28 (Enhanced directional multi-gigabit (EDMG) PHY specification(11ay))) without the need to perform a complete BRP procedure. Analog beam tracking allows DMG STAs to track changes in the AWVs of its DMG antennas. Baseband beam tracking allows EDMG STAs to track changes in the spatial mapping matrix $Q$ for SU and MU MIMO transmissions that use digital beamforming (see Clause 28 (Enhanced directional multi-gigabit (EDMG) PHY specification(11ay))).

(11ay)Beam tracking may be one of the following:

— Initiator receive beam tracking
— Initiator transmit beam tracking
— Responder receive beam tracking

A STA (beam tracking initiator) may request a peer STA (beam tracking responder) to provide receive beam tracking training signals to the initiator on the next PPDU transmitted by the responder. The initiator does this by setting, in a transmitted PPDU, the TXVECTOR parameter BEAM_TRACKING_REQUEST to BEAM-TRACKING-REQUESTED, TRN_LEN to the number of requested TRN subfields as described in 20.9.2.2.3 (BRP PPDU Header field(#6409)) and PPDU_TYPE to TRN-R. Otherwise, the BEAM_TRACKING_REQUEST parameter shall be set to BEAM-TRACKING-NOT-REQUESTED.

(11ay)An EDMG STA (beam tracking initiator) may request a peer EDMG STA (beam tracking responder) to perform receive beam tracking by setting, in a transmitted PPDU, the TXVECTOR parameter EDMG_BEAM_TRACKING_REQUEST to BEAM-TRACKING-REQUESTED, EDMG_BEAM_TRACKING_TYPE to Analog Beam Tracking or Baseband Beam Tracking, BEAM_TRACKING_REQUEST to BEAM-TRACKING-NOT-REQUESTED, EDMG_TRN_LEN to the number of requested TRN units as described in 28.9.2.2 (EDMG BRP PPDU), and EDMG_PPDU_TYPE to EDMG-TRN-R. Otherwise, the EDMG_BEAM_TRACKING_REQUEST parameter shall be set to BEAM-TRACKING-NOT-REQUESTED.

A beam tracking responder that receives a PPDU (11ay)requesting receive beam tracking with the BEAM_TRACKING_REQUEST (11ay)or EDMG_BEAM_TRACKING_REQUEST parameter in the RXVECTOR set to BEAM-TRACKING-REQUESTED and the PPDU_TYPE parameter(#481) in the RXVECTOR set to TRN-R shall

— (11ay)If BEAM_TRACKING_REQUEST parameter in the RXVECTOR is BEAM-TRACKING-REQUESTED, follow the rules described in 20.9.2.2 (Beam refinement) and shall include a beam refinement AGC field and TRN-R subfields appended to the next PPDU that is transmitted to the initiator in the same allocation and that employs an MCS index greater than 0. The value of the TRN_LEN parameter in the TXVECTOR of that PPDU shall be equal to the value of the TRN_LEN parameter in the RXVECTOR of the PPDU from the initiator.
— (11ay)If BEAM_TRACKING_REQUEST parameter in the RXVECTOR is BEAM-TRACKING-NOT-REQUESTED, EDMG_BEAM_TRACKING_REQUEST parameter in the RXVECTOR is BEAM-TRACKING-REQUESTED, EDMG_BEAM_TRACKING_TYPE parameter in the RXVECTOR is Baseband Beam Tracking, and EDMG_PPDU_TYPE parameter in the RXVECTOR is EDMG-TRN-R, follow the rules described in 28.9.2.2 (EDMG BRP PPDU) and shall include TRN-R subfields to the following PPDU transmitted to the initiator in the same allocation, with an MCS index greater than 0. The following PPDU from the responder to the initiator shall have the value of the TXVECTOR parameter EDMG_PPDU_TYPE equal to EDMG-TRN-R and the value of


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the TXVECTOR parameter EDMG_TRN_LEN equal to the value of the EDMG_TRN_LEN parameter in the RXVECTOR of the PPDU from the initiator.

— (11ay)If BEAM_TRACKING_REQUEST parameter in the RXVECTOR is BEAM-TRACKING-NOT-REQUESTED, EDMG_BEAM_TRACKING_REQUEST parameter in the RXVECTOR is BEAM-TRACKING-REQUESTED, EDMG_BEAM_TRACKING_TYPE parameter in the RXVECTOR is Analog Beam Tracking, and EDMG_PPDU_TYPE parameter in the RXVECTOR is EDMG-TRN-R, follow the rules described in 28.9.2.2 (EDMG BRP PPDU) and the beam tracking responder shall respond with either an EDMG BRP-RX PPDU or an EDMG BRP-RX/TX PPDU to the initiator in the same allocation, with an MCS index greater than 0. If the responder sends an EDMG BRP-RX PPDU, the value of TXVECTOR parameter EDMG_TRN_LEN in the following PPDU from the responder to the initiator shall be equal to the value of the EDMG_TRN_LEN parameter in the RXVECTOR of the PPDU from the initiator. If the responder sends EDMG BRP-RX/TX PPDU, the value of TXVECTOR parameter RX_TRN_PER_TX_TRN in the following PPDU from the responder to the initiator shall be equal to the value of the EDMG_TRN_LEN parameter in the RXVECTOR of the PPDU from the initiator.

(11ay)If a beam tracking responder sends an EDMG BRP-RX/TX PPDU in response to an analog receive beam tracking request, the beam tracking initiator may aggregate in an A-MPDU a BRP frame that contains an EDMG Channel Measurement Feedback element with the feedback (see 10.41.6.4.1 (General)). The feedback type shall be the same as the feedback type in the last BRP frame that was transmitted from the responder to the initiator with TX-TRN-REQ equal to 1. If the initiator has never received a BRP frame from the responder with TX-TRN-REQ equal to 1, the initiator shall respond with all subfields of the FBCK-TYPE field equal to 0 and set the BS-FBCK field to the AWV feedback ID corresponding to the TRN subfields received with the best quality.

(11ay)If the EDMG_BEAM_TRACKING_TYPE parameter in the RXVECTOR is not equal to Baseband Beam Tracking or the received PPDU is not EDMG, a responder may ignore a request for beam tracking within an allocation if it transmits no PPDUs other than PPDUs using MCS 0 (control mode PPDUs) to the initiator within the allocation.(#480)

(11ay)NOTE 1—If the EDMG_BEAM_TRACKING_TYPE parameter in the RXVECTOR is Baseband Beam Tracking, the digital beamformers at the initiator can be set to a predetermined orthogonal matrix (e.g., the identity matrix) during the transmission of the appended TRN-R subfields only and the measurement at the initiator is based on the appended TRN-R subfields.

A beam tracking initiator requesting transmit beam tracking shall (11ay)either

— set the BEAM_TRACKING_REQUEST parameter in the TXVECTOR to BEAM-TRACKING-REQUESTED, PPDU_TYPE to TRN-T, TRN_LEN to the number of TRN Units as described in 20.9.2.2.3 (BRP PPDU Header field(#6409)), and append an AGC field and TRN-T subfields to the PPDU; (11ay)or,

— (11ay)Set the EDMG_BEAM_TRACKING_REQUEST parameter in the TXVECTOR to BEAM-TRACKING-REQUESTED, EDMG_BEAM_TRACKING_TYPE to Analog Beam Tracking or Baseband Beam Tracking, BEAM_TRACKING_REQUEST to BEAM-TRACKING-NOT-REQUESTED, EDMG_PPDU_TYPE to EDMG-TRN-T, and EDMG_TRN_LEN, EDMG_TRN_P, EDMG_TRN_M, and EDMG_TRN_N as described in 28.9.2.2 (EDMG BRP PPDU), and append TRN-T subfields to the PPDU.

(11ay)NOTE 2—If the EDMG_BEAM_TRACKING_TYPE parameter in the TXVECTOR is Baseband Beam Tracking, then EDMG_TRN_LEN TRN units are appended to the PPDU (each with EDMG_TRN_P TRN subfields) and are transmitted using the same AWV as the preamble and Data fields of the PPDU. The digital beamformer for the responder can be set to a predetermined orthogonal matrix (e.g., the identity matrix) during the transmission of the appended TRN-T subfields only and the measurement is based on the appended TRN-T subfields.

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A beam tracking initiator shall not initiate transmit beam tracking if the beam tracking responder has indicated lack of support by setting the DMG STA Beam Tracking Time Limit field to zero.

The beam tracking responder may aggregate (11ay)in an A-MPDU a BRP frame that contains a Channel Measurement Feedback element with the feedback (see 10.41.6.4.1 (General)). The initiator may allocate time for the feedback through a reverse direction grant, provided the reverse direction protocol is supported by both the initiator and responder. The feedback type shall be the same as the feedback type in the last BRP frame that was transmitted from the initiator to the responder with TX-TRN-REQ equal to 1. (11ay)If the NUM_TX_CHAINS parameter in the RXVECTOR of the frame that elicits the feedback is greater than 1, the responder may send the feedback in a MIMO BF Feedback frame. If the responder has never received a BRP frame from the initiator with TX-TRN-REQ equal to 1,

— (11ay)If the BEAM_TRACKING_REQUEST parameter in the RXVECTOR of the PPDU sent by the initiator requesting beam tracking is BEAM-TRACKING-REQUESTED, the responder shall respond with all subfields of the FBCK-TYPE field equal to 0 and set the BS-FBCK field to the index of the TRN-T subfield that was received with the best quality.

— (11ay)If, in the PPDU sent by the initiator requesting beam tracking, BEAM_TRACKING_REQUEST parameter in the RXVECTOR is BEAM-TRACKING-NOT-REQUESTED, EDMG_BEAM_TRACKING_REQUEST parameter in the RXVECTOR is BEAM-TRACKING-REQUESTED and EDMG_BEAM_TRACKING_TYPE in the RXVECTOR is Baseband Beam Tracking, the initiator shall include a FBCK-REQ in a DMG Beam Refinement element to request the needed feedback. The responder shall respond with the requested feedback in a MIMO BF Feedback frame.

— (11ay)If, in the PPDU sent by the initiator requesting beam tracking, BEAM_TRACKING_REQUEST parameter in the RXVECTOR is BEAM-TRACKING-NOT-REQUESTED, EDMG_BEAM_TRACKING_REQUEST parameter in the RXVECTOR is BEAM-TRACKING-REQUESTED, EDMG_BEAM_TRACKING_TYPE in the RXVECTOR is Analog Beam Tracking, and EDMG_PPDU_TYPE is equal to EDMG-TRN-T, the responder shall respond with all subfields of the FBCK-TYPE field equal to 0 and set the BS-FBCK field to the AWV feedback ID corresponding to the TRN subfields received with the best quality.

A beam tracking initiator may also request a beam tracking responder to perform receive beam tracking by setting the TXVECTOR parameter BEAM_TRACKING_REQUEST to BEAM-TRACKING-NOT-REQUESTED, the TRN_LEN parameter to a nonzero value, the PPDU_TYPE parameter to TRN-R, and append an AGC field and TRN-R subfields to the transmitted PPDU.

A beam tracking responder that receives a PPDU with the BEAM_TRACKING_REQUEST parameter in the RXVECTOR equal to BEAM-TRACKING-NOT-REQUESTED, the TRN_LEN parameter in RXVECTOR having a nonzero value and the PPDU_TYPE parameter in the RXVECTOR equal to TRN-R, shall follow the rules described in 20.9.2.2 (Beam refinement) and may use the beam refinement AGC field and TRN-R subfields appended to the received PPDU to perform receive beam training.

(11ay)A beam tracking initiator may request that a beam tracking responder performs receive beam tracking by setting the TXVECTOR parameter EDMG_BEAM_TRACKING_REQUEST to BEAM-TRACKING-NOT-REQUESTED, EDMG_BEAM_TRACKING_TYPE to Analog Beam Tracking, BEAM_TRACKING_REQUEST to BEAM-TRACKING-NOT-REQUESTED, EDMG_PPDU_TYPE to EDMG-TRN-R, EDMG_TRN_LEN to a nonzero value, and appending TRN-R subfields to the PPDU.

(11ay)A beam tracking responder that receives a PPDU with RXVECTOR parameter BEAM_TRACKING_REQUEST equal to BEAM-TRACKING-NOT-REQUESTED, EDMG_BEAM_TRACKING_REQUEST equal to BEAM-TRACKING-NOT-REQUESTED, EDMG_BEAM_TRACKING_TYPE to Analog Beam Tracking, EDMG_PPDU_TYPE equal to EDMG-TRN-R, and EDMG_TRN_LEN to a nonzero value shall follow the rules described in 28.9.2.2 (EDMG BRP PPDU) and may use the TRN-R subfields appended to the received PPDU to perform receive beam


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training. A beam tracking initiator may use the procedures specified above to request a beam tracking responder to perform both transmit and receive beam tracking on the same PPDU. This is done by, on top of the corresponding TXVECTOR parameter configuration specified above, setting the TXVECTOR parameter RX_TRN_PER_TX_TRN to a value greater than 0 and EDMG_PPDU_TYPE to EDMG-TRN-T. In this case, the beam tracking initiator and beam tracking responder shall use the rules described in 28.9.2.2 (EDMG BRP PPDU) to perform both transmit and receive training over the TRN subfields appended to the transmitted PPDU.

(11ay)A beam tracking initiator requesting simultaneous receive and transmit beam tracking shall set the EDMG_BEAM_TRACKING_REQUEST parameter in the TXVECTOR to BEAM-TRACKING-REQUESTED, EDMG_BEAM_TRACKING_TYPE to Analog Beam Tracking, BEAM_TRACKING_REQUEST to BEAM-TRACKING-NOT-REQUESTED, EDMG_PPDU_TYPE to EDMG-TRN-T, the TXVECTOR parameter RX_TRN_PER_TX_TRN to a value greater than 0, and the parameters EDMG_TRN_LEN, EDMG_TRN_P, EDMG_TRN_M, and EDMG_TRN_N as described in 28.9.2.2 (EDMG BRP PPDU), and append a TRN field to the PPDU. The feedback sent by the beam tracking responder shall follow the same specification defined for the transmit beam tracking procedure.

Figure 10-105 (Example of beam tracking procedure with initiator requesting TRN-R) illustrates a beam tracking frame exchange sequence when the beam tracking initiator requests TRN-R subfields, while Figure 10-106 (Example of beam tracking procedure with initiator requesting TRN-T) illustrates a beam tracking frame exchange sequence when the beam tracking initiator requests TRN-T subfields.

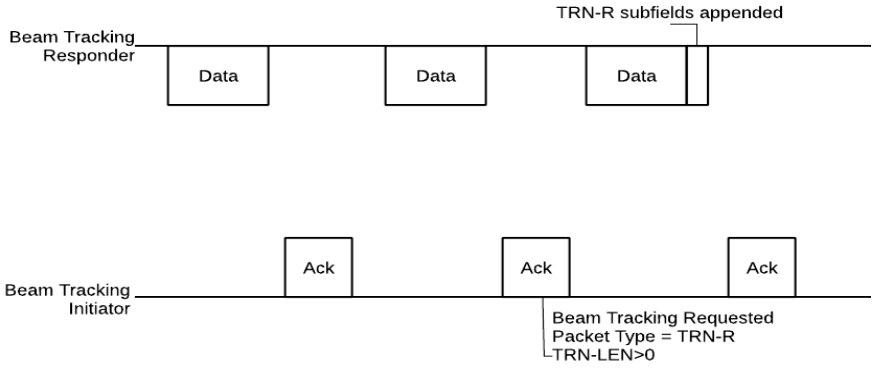


**Figure 10-105—Example of beam tracking procedure with initiator requesting TRN-R**

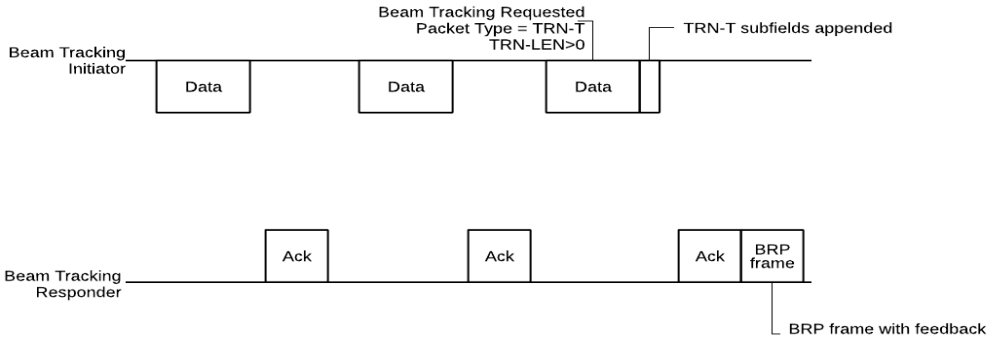


**Figure 10-106—Example of beam tracking procedure with initiator requesting TRN-T**

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A beam tracking initiator may transmit to the beam tracking responder a PPDU requesting transmit beam tracking if at least one of the following conditions is met:

— The time since the last PPDU it transmitted to the beam tracking responder that requested transmit beam tracking is greater than the beam tracking time limit plus BRPIFS.

— A BRP frame with the channel measurement feedback from the beam tracking responder has been received.

(11ay)In addition, a beam tracking initiator or beam tracking responder may request baseband beam tracking if at least one of the following conditions is met:

— The performance of the system is degraded in a hybrid beamforming transmission and the initiator would like to reestimate the spatial mapping matrix $Q$ as part of the link adaptation procedure.

— The initiator did not determine the spatial mapping matrix $Q$ as part of the hybrid beamforming setup procedure, i.e., based on channel measurements reported as feedback to the MIMO training procedure or hybrid beamforming feedback during a hybrid beamforming training procedure as described in item b) in 10.41.10.2.4 (Hybrid beamforming for SU-MIMO and MU-MIMO). In this case, the AWVs of the DMG antennas at the transmitter and receiver have been identified, but a procedure to determine the spatial mapping matrix $Q$ is still needed.

If the beam tracking initiator does not receive the expected feedback from the beam tracking responder within a time period that is less than the beam tracking time limit (11ay)plus BRPIFS of the last request, the beam tracking request has failed.

If the initiator receives the expected feedback from the responder within a time period that is greater than or equal to the beam tracking time limit (11ay)plus BRPIFS of the last request, the initiator should ignore it.

The time of arrival of the beam tracking responder's feedback is indicated by the PHY-RXEND.indication primitive of PPDU that contains the BRP MMPDU.

The time of transmit completion of the beam tracking initiator's PPDU is indicated by the PHY-TXEND.confirm primitive.

The beam tracking responder shall not transmit a BRP frame with feedback to the beam tracking initiator if the time period between PHY-RXEND.indication primitive of the PPDU that contains the beam tracking request and of PHY-TXEND.confirm primitive of the response BRP frame is longer than the beam tracking time limit.

The beam tracking time limit is based on the values of the DMG STA Beam Tracking Time Limit field received from the peer STA in the DMG Capabilities element and the dot11BeamTrackingTimeLimit. The beam tracking time limit is determined according to Table 10-37 (Beam tracking time limit determination).

**Table 10-37—Beam tracking time limit determination**

| DMG STA Beam Tracking Time Limit field from peer STA - denoted A | dot11BeamTrackingTime Limit - denoted B | A vs. B | Beam tracking time limit |
|---|---|---|---|
| 0 | 0 | N/A(#254) | Transmit beam tracking is not supported |
| >0 | 0 | N/A(#254) | |
| 0 | >0 | N/A(#254) | |
| >0 and < 65 535 | >0 and < 65 535 | A ≥ B | A |


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**Table 10-37—Beam tracking time limit determination**

| DMG STA Beam Tracking Time Limit field from peer STA - denoted A | dot11BeamTrackingTime Limit - denoted B | A vs. B | Beam tracking time limit |
|---|---|---|---|
| >0 and < 65 535 | >0 and < 65 535 | A < B | B |
| 65 535 | >0 and < 65 535 | NA | B |
| >0 and < 65 535 | 65 535 | NA | A |
| 65 535 | 65 535 | NA | Default dot11BeamTrackingTimeLimit value |

NOTE 1—If the beam tracking responder has not included the DMG STA Beam Tracking Time Limit field in the DMG Capabilities element, the beam tracking initiator cannot tell whether the procedure failed. Retransmission is therefore implementation dependent.

NOTE 2—The signaling that beam tracking is not supported by setting the DMG STA Beam Tracking Time Limit field to zero is deprecated.

(11ay)If the beam tracking procedure includes the transmission of BRP-TX or EDMG BRP-TX PPDUs, both STAs (initiator and responder) shall not change their antenna settings, except during the transmission of the TRN field in PPDUs used to perform beam tracking, during the procedure. If the beam tracking procedure includes the transmission of EDMG BRP-RX/TX PPDUs, both STAs (initiator and responder) shall not change their antenna settings, except during the transmission and reception of the TRN field in PPDUs used to perform beam tracking, during the procedure. The STAs shall use the beam tracking procedure feedback and then update their antenna settings before their next TXOP or SP.

### 10.41.8 State machines

Figure 10-107 (SLS phase state machine (initiator)) depicts an example state machine of the SLS phase for the initiator, and Figure 10-108 (SLS phase state machine (responder)) illustrates an example state machine of the SLS phase for the responder. These state machines describe the behavior of the initiator and responder during BF and are applicable for any period of the beacon interval where BF is performed.

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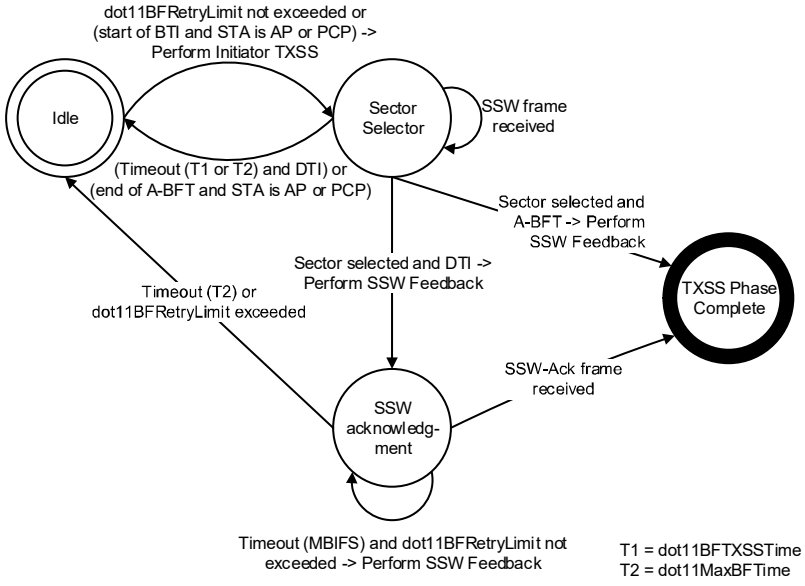


**Figure 10-107—SLS phase state machine (initiator)**

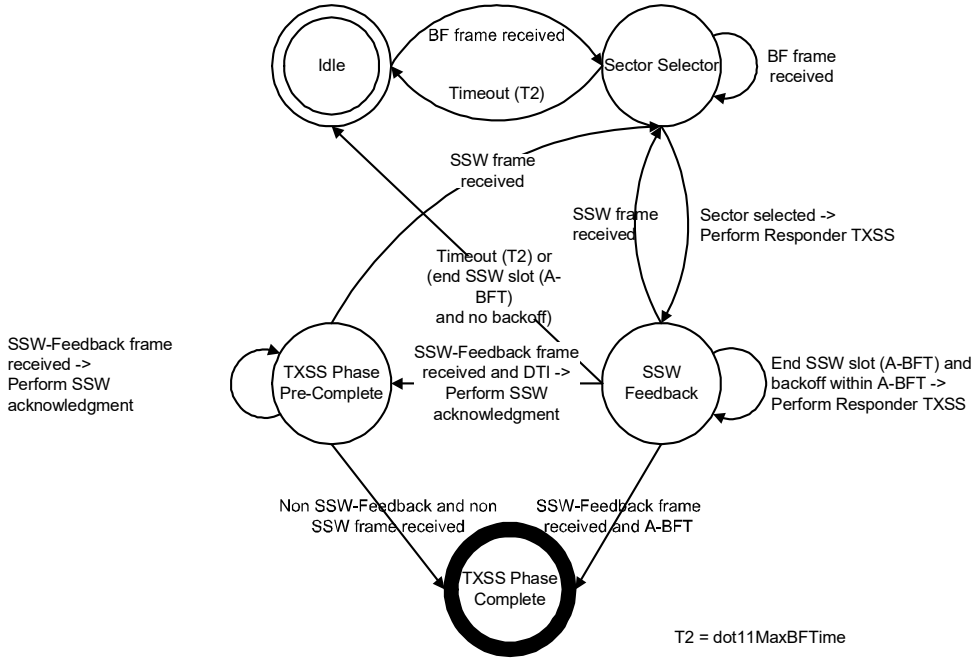


**Figure 10-108—SLS phase state machine (responder)**

### 10.41.9 CDMG enhanced beam tracking

In addition to the beam tracking mechanism in 10.41.7 (Beam tracking), the CDMG enhanced beam tracking mechanism enables CDMG communicating STA pairs to measure and switch to an alternative link to reduce the link outage probability induced by an unexpected blockage or a rapid antenna rotation. The alternative link


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is a suboptimal link configured by a pair of CDMG STAs during the SLS phase or the BRP phase. The enhanced beam tracking mechanism extends the capabilities on the basis of the beam tracking mechanism in 10.41.7 (Beam tracking). A pair of CDMG STAs may perform beam tracking (see 10.41.7 (Beam tracking)) and enhanced beam tracking described in this subclause simultaneously.

The Enhanced Beam Tracking Supported subfield in the CDMG STA Capability Information field of a CDMG STA's CDMG Capabilities element is set to 1 to indicate that the CDMG STA supports enhanced beam tracking.

The initial alternative link of the peer STA under enhanced beam tracking is configured in the BRP phase. Specifically, in the first BRP phase after the SLS, the initiator STA returns the sector and DMG antenna IDs of the alternative link to the responder STA, via transmitting the SSW Report element or the Enhanced Beam Tracking element in the BRP frame(s). The responder STA shall specify the alternative TX AWV according to the received Report Info field in the SSW Report element or the Peer TX Antenna Parameter field in the Enhanced Beam Tracking element. For the BRP phase, the index of the TRN-T subfield that was received with the second best quality in the last received BRP-TX PPDU is included in the Enhanced Beam Tracking element to specify the alternative TX AWV. The alternative link is not used for the current data transmission.

During the enhanced beam tracking phase, if a pair of STAs is operating on the link that is selected with best quality after SLS or BRP phase, switching to alternative link may be required if the signal quality of the current link deteriorates significantly based on the measurement results of e-TRN-R/T. If switching to alternative link is required, the initiator shall set the Switching to Backup AWV Request subfield of the Enhanced Beam Tracking element of the transmitted BRP frame to 1. If the initiator receives an Enhanced Beam Tracking element with the Switching to Backup AWV Enabled subfield set to 1 in the following BRP frame from the responder, the initiator and responder shall switch to the alternative link before transmitting the next frame. After switching to the alternative link, the initiator and responder shall set the last link as the new alternative link.

A CDMG STA (beam tracking initiator) may request a peer CDMG STA (beam tracking responder) to perform enhanced receive beam tracking by setting, in a transmitted PPDU, the TXVECTOR parameter ENHANCED_BEAM_TRACKING_REQUEST to ENHANCED-BEAM-TRACKING-REQUESTED, the TRN_LEN parameter to the number of requested TRN Units as described in 24.9.2.2.3 (BRP PPDU Header field(#6409)), and PPDU_TYPE to TRN-R. Otherwise, the ENHANCED_BEAM_TRACKING_REQUEST parameter shall be set to ENHANCED-BEAM-TRACKING-NOT-REQUESTED.

An enhanced beam tracking responder that receives a PPDU with ENHANCED_BEAM_TRACKING_REQUEST parameter in the RXVECTOR equal to ENHANCED-BEAM-TRACKING-REQUESTED and the PPDU_TYPE parameter in the RXVECTOR equal to TRN-R) shall follow the rules described in 24.9.2.2 (Beam refinement) and shall include a beam refinement AGC field, TRN-R subfields, STF, and CE field appended to the next PPDU transmitted to the initiator. The value of the TRN_LEN parameter in the TXVECTOR of that PPDU shall be set to the value of the TRN_LEN parameter in the RXVECTOR of the PPDU from the initiator.

An enhanced beam tracking initiator requesting enhanced transmit beam tracking shall set the ENHANCED_BEAM_TRACKING_REQUEST parameter in the TXVECTOR to ENHANCED-BEAM-TRACKING-REQUESTED, the PPDU_TYPE to TRN-T, and the TRN_LEN parameter to the number of TRN Units as described in 24.9.2.2.3 (BRP PPDU Header field(#6409)) and append an AGC field, TRN-R subfields, an STF, and a CE field to the PPDU. The enhanced beam tracking responder may aggregate the feedback inside an A-MPDU in a frame sent from the responder to the initiator according to the rules specified in 10.41.6.4.1 (General). The initiator may allocate time for the feedback through a reverse direction grant, provided the reverse direction protocol is supported by both the initiator and responder. The Feedback Type field shall be set to the value of the Feedback Type field in the last BRP frame that was transmitted from the initiator to the responder with the TX-TRN-REQ subfield set to 1. If the responder has never received a BRP frame from the initiator with the TX-TRN-REQ subfield is equal to 1, the responder shall respond with all

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subfields of the FBCK-TYPE field set to 0 and set the BS-FBCK field to the best sector. If switching to the alternative link is required, the initiator shall set the Switching to Backup AWV Request subfield to 1 within the Enhanced Beam Tracking element within the transmitted BRP frame. The responder should respond with an Enhanced Beam Tracking element with the Switching to Backup AWV Enabled subfield set to 1 in the following BRP frame. If the Enhanced Beam Tracking element with the Switching to Backup AWV Enabled subfield set to 1 is transmitted or received, the initiator and responder shall switch to the alternative link before the next frame. After switching to the alternative link, the initiator and responder shall both set the last link as the new alternative link.

An enhanced beam tracking initiator may also request a beam tracking responder to perform receive beam tracking by setting, in a transmitted PPDU, the ENHANCED_BEAM_TRACKING_REQUEST parameter in the TXVECTOR to ENHANCED-BEAM-TRACKING-REQUESTED, the TRN_LEN parameter to a nonzero value, and the PPDU_TYPE parameter to 0 and appending an AGC field, TRN-R subfields, an STF, and a CE field to the transmitted PPDU.

A beam tracking responder that receives a PPDU with the ENHANCED_BEAM_TRACKING_REQUEST parameter in the RXVECTOR equal to ENHANCED-BEAM-TRACKING-REQUESTED, the TRN_LEN parameter not equal to 0, and the PPDU_TYPE parameter equal to 0 shall follow the rules described in 24.9.2.2 (Beam refinement) and may use the beam refinement AGC field, TRN-R subfields, STF, and CE field appended to the received PPDU to perform receive beam tracking. If the switching to the alternative link is required, the responder shall set the Switching to Backup AWV Request subfield within the Enhanced Beam Tracking element within the transmitted BRP frame to 1. The initiator should respond with an Enhanced Beam Tracking element with the Switching to Backup AWV Enabled subfield set to 1 in the following BRP frame. If the Enhanced Beam Tracking element with the Switching to Backup AWV Enabled subfield set to 1 is transmitted or received, the initiator and responder shall switch to the alternative link before the next frame. After switching to the alternative link, the initiator and responder shall both set the last link as the new alternative link.

The CDMG STAs that switched to the alternative link that is a suboptimal link after SLS or BRP phase should measure the quality of the original optimal beam link (the new alternative link) during the subsequent frames exchange. The initiator should transmit a beam tracking request to the responder to switch to the new alternative link if the new alternative link has a better link quality. The decision process of switching to the alternative link is implementation dependent and beyond the scope of this standard.

BRP frames transmitted during enhanced beam tracking may be aggregated within A-MPDUs. Figure 10-109 (Example of an enhanced beam tracking procedure with the initiator requesting TRN-R) illustrates a beam tracking frame exchange sequence when the beam tracking initiator requests TRN-R subfields, while Figure 10-110 (Example of an enhanced beam tracking procedure with the initiator requesting TRN-T) illustrates a beam tracking frame exchange sequence when the beam tracking initiator requests TRN-T subfields.

An example of beam tracking and switching for enhanced beam tracking is shown in Annex W.3.

### 10.41.10 EDMG beamforming(11ay)

#### 10.41.10.1 General

This subclause specifies beamforming mechanisms that are applicable to an EDMG STA. These mechanisms are in addition to the mechanisms specified in the remainder of 10.41 (DMG beamforming), which are applicable to DMG STAs.

If an EDMG STA transmits a BRP frame with the TXVECTOR parameter EDMG_TRN_LEN > 0, the EDMG_PPDU_TYPE parameter equal to either EDMG-TRN-T or EDMG-TRN-R/T, the Channel Measurement Requested subfield in the FBCK-REQ field of the DMG Beam Refinement element equal to 1


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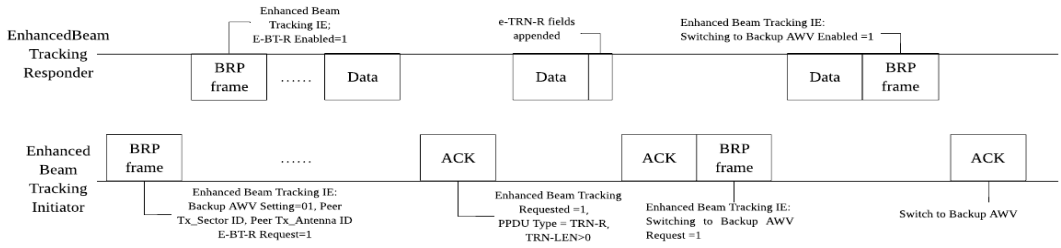


**Figure 10-109—Example of an enhanced beam tracking procedure with the initiator requesting TRN-R**

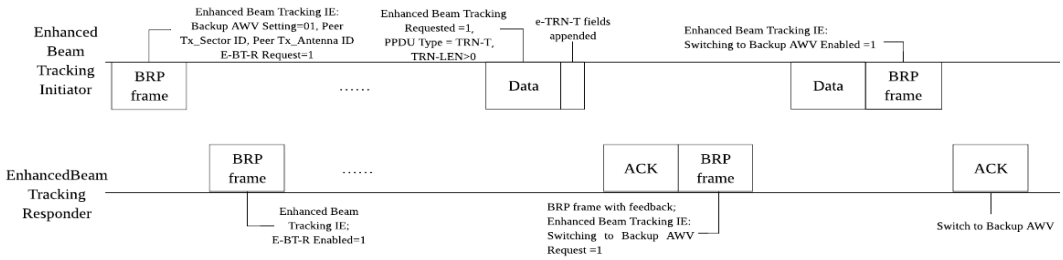


**Figure 10-110—Example of an enhanced beam tracking procedure with the initiator requesting TRN-T**

and the TX-TRN-REQ subfield in the BRP Request field equal to 1, the TXVECTOR parameter EDMG_TRN_P shall not be set to 0.

If an EDMG STA transmits a BRP frame and all the addressed receivers' EDMG Capabilities elements include the Beamforming Capability subelement, the TXVECTOR parameter EDMG_BRP_MIN_SC_BLOCKS shall be set to the largest value of the Requested BRP SC Blocks subfield of all receiver STAs.

If an EDMG STA transmits a BRP frame and at least one of the addressed receivers' EDMG Capabilities element does not include the Beamforming Capability subelement, the TXVECTOR parameter EDMG_BRP_MIN_SC_BLOCKS shall be set to aBRPminSCBlocks that is specified in 20.11.4 (DMG PHY).

A STA can utilize the information from a peer STA's antenna polarization in order to enhance the beamformed link quality with the peer STA. Antenna polarization capability is contained in the Antenna Polarization Capability field in a STA's EDMG Capabilities element. For example, if a STA is synthesizable polarization capable and a peer STA is linear polarization capable, the STA can employ circularly polarized antenna to do initial beamforming training with the peer STA to avoid polarization alignment loss. Once initial beamforming training is completed, the STA can further perform beam refinement by switching to a linear polarized antenna and performing polarization alignment using BRP.

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### 10.41.10.2 MIMO beamforming

#### 10.41.10.2.1 General

This subclause describes the procedures used to perform SU-MIMO and MU-MIMO beamforming training and enable MIMO communication between an initiator and one or more responders. The procedures described in this subclause are performed in the DTI of a beacon interval and shall not be initiated unless the initiator and the intended responder(s) have an established control mode link between them.

The Sector ID Order and Tap Delay fields shall not be present in the Channel Measurement Feedback element included in any MIMO BF Feedback frame transmitted during SU-MIMO or MU-MIMO BF training.

The SNR field shall be present in the Channel Measurement Feedback element included in any MIMO BF Feedback frame transmitted during SU-MIMO or MU-MIMO BF training. The EDMG Sector ID Order field (containing AWV feedback IDs and TX antenna IDs) and the BRP CDOWN field shall be present in the EDMG Channel Measurement Feedback element included in any MIMO BF Feedback frame transmitted during SU-MIMO or MU-MIMO BF training.

#### 10.41.10.2.2 SU-MIMO beamforming

##### 10.41.10.2.2.1 General

An EDMG STA is SU-MIMO capable if the SU-MIMO Supported subfield of the Beamforming Capability subelement in the STA's EDMG Capabilities element is 1. An SU-MIMO capable STA supports both SU-MIMO transmission and reception and the SU-MIMO beamforming protocol described in this subclause.

The SU-MIMO beamforming protocol supports beamforming training for subsequent transmission and reception of multiple spatial streams between an SU-MIMO capable initiator and an SU-MIMO capable responder. The SU-MIMO beamforming protocol enables the determination of transmit antenna settings and the corresponding receive antenna settings for simultaneous transmission of multiple spatial streams from the initiator to the responder or vice versa.

The SU-MIMO beamforming protocol can also be used to enable transmit beamforming and receive beamforming operation between the initiator and the responder in which a single spatial stream is transmitted through multiple DMG antennas using the determined transmit antenna settings and received through multiple DMG antennas using the determined corresponding receive antenna settings.

The SU-MIMO beamforming protocol comprises the following consecutive phases:

— SISO phase
— MIMO phase

##### 10.41.10.2.2.2 SISO phase

This subclause describes the SISO phase performed outside of a TDD SP. When the SISO phase is performed in a TDD SP, the SISO phase comprises TDD BF procedure (see 10.41.11 (TDD beamforming(11ay))).

The objective of the SISO phase is to enable the initiator to collect feedback of the last initiator TXSS from the responder and also enables the responder to collect feedback of the last responder TXSS from the initiator.


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The SISO phase comprises either a MIMO BRP TXSS procedure (see 10.41.10.5 (BRP transmit sector sweep (BRP TXSS))) or a SISO feedback procedure. When the SISO phase comprises a MIMO BRP TXSS procedure, it includes a setup phase, an Initiator BRP TXSS, a Responder BRP TXSS, and a feedback phase as defined in 10.41.10.5 (BRP transmit sector sweep (BRP TXSS)). In particular, the BRP frame sent by the initiator during the setup phase to start the SISO phase shall have the BRP-TXSS, TXSS-INITIATOR and TXSS-MIMO fields within the EDMG BRP Request element all set to 1.

In the BRP frame sent by the initiator during the feedback phase, the EDMG Sector ID Order field in the EDMG Channel Measurement Feedback element indicates AWV feedback IDs, TX antennas and RX antennas of all or a subset of sectors that were received in the Responder BRP TXSS. The BRP CDOWN field in the EDMG Channel Measurement Feedback element indicates BRP CDOWNs of the PPDUs in which these sectors were received. The SNR field in the Channel Measurement Feedback element indicates the SNRs with which these sectors were received. If the number of sectors for a pair of TX and RX DMG antennas that were received in the responder BRP TXSS is larger than aMinTXSSSectorFBCnt, the BRP frame shall contain feedback for at least aMinTXSSSectorFBCnt received sectors for the pair of TX and RX DMG antennas. Otherwise, the BRP frame shall contain feedback for all the received sectors for the pair of TX and RX DMG antennas.

In the BRP frame sent by the responder during the feedback phase, the EDMG Sector ID Order field in the EDMG Channel Measurement Feedback element indicates AWV feedback IDs, TX antennas and RX antennas of all or a subset of sectors that were received in the Initiator BRP TXSS. The BRP CDOWN field in the EDMG Channel Measurement Feedback element indicates BRP CDOWNs of the BRP PPDUs in which these sectors were received. The SNR field in the Channel Measurement Feedback element indicates the SNRs with which these sectors were received. If the number of sectors for a pair of TX and RX DMG antennas that were received in the initiator BRP TXSS is larger than aMinTXSSSectorFBCnt, the BRP frame shall contain feedback for at least aMinTXSSSectorFBCnt received sectors for the pair of TX and RX DMG antennas. Otherwise, the BRP frame shall contain feedback for all the received sectors for the pair of TX and RX DMG antennas.

When the SISO phase comprises a SISO feedback procedure, the initiator shall send a BRP frame to the responder. The DMG Beam Refinement element included in the BRP frame shall have the BF Training Type, TXSS-FBCK-REQ, EDMG Extension Flag and EDMG Channel Measurement Present fields set to 1, the SNR Requested and Sector ID Order Requested subfields within the FBCK-REQ field set to 1, the remaining subfields within the FBCK-REQ field set to 0, and the SNR Present, Sector ID Order Present, Channel Measurement Present, Tap Delay Present and Link Type subfields within the FBCK-TYPE field set to 1, 1, 0, 0, and 1, respectively.

The last responder TXSS may have been performed using SSW frames, Short SSW PPDUs or EDMG BRP-TX PPDUs.

- If the Sector Sweep Frame Type field in the DMG Beam Refinement element is 0, the EDMG Sector ID Order field in the EDMG Channel Measurement Feedback element indicates the sector IDs, TX antennas and RX antennas of all or a subset of sectors that were received in the last responder TXSS.
- If the Sector Sweep Frame Type field in the DMG Beam Refinement element is 1, the EDMG Sector ID Order field in the EDMG Channel Measurement Feedback element indicates the CDOWNs and RX antennas of all or a subset of sectors that were received in the last responder TXSS.
- If the Sector Sweep Frame Type field in the DMG Beam Refinement element is 2, the EDMG Sector ID Order field in the EDMG Channel Measurement Feedback element indicate AWV feedback IDs, TX antennas and RX antennas of all or a subset of sectors that were received in the last responder TXSS.

The BRP CDOWN field in the EDMG Channel Measurement Feedback element indicates the BRP CODWNs of the BRP PPDUs in which these sectors were received. The SNR field in the Channel Measurement Feedback element indicates the SNRs with which these sectors were received. If the number

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of sectors for a pair of TX and RX DMG antennas that were received in the last responder TXSS is larger than aMinTXSSSectorFBCnt, the BRP frame shall contain feedback for at least aMinTXSSSectorFBCnt received sectors for the pair of TX and RX DMG antennas. Otherwise, the BRP frame shall contain feedback for all the received sectors for the pair of TX and RX DMG antennas.

The responder shall send a BRP frame to the initiator within an MBIFS following the reception of the BRP frame from the initiator. The DMG Beam Refinement element included in the BRP frame shall have the BF Training Type, EDMG Extension Flag and EDMG Channel Measurement Present fields set to 1, all the subfields within the FBCK-REQ field set to 0, and the SNR Present, Sector ID Order Present, Channel Measurement Present, Tap Delay Present and Link Type subfields within the FBCK-TYPE field set to 1, 1, 0, 0, and 0, respectively.

The last initiator TXSS may have been performed using DMG Beacon frames, SSW frames, Short SSW PPDUs or EDMG BRP-TX PPDUs.

— If the Sector Sweep Frame Type field in the DMG Beam Refinement element is 0, the EDMG Sector ID Order field in the EDMG Channel Measurement Feedback element indicates the sector IDs, TX antennas and RX antennas of all or a subset of sectors that were received in the last initiator TXSS.

— If the Sector Sweep Frame Type field in the DMG Beam Refinement element is 1, the EDMG Sector ID Order field in the EDMG Channel Measurement Feedback element indicates the CDOWNs and RX antennas of all or a subset of sectors that were received in the last initiator TXSS.

— If the Sector Sweep Frame Type field in the DMG Beam Refinement element is 2, the EDMG Sector ID Order field in the EDMG Channel Measurement Feedback element indicates AWV feedback IDs, TX antennas and RX antennas of all or a subset of sectors that were received in the last initiator TXSS.

The BRP CDOWN field in the EDMG Channel Measurement Feedback element indicates the BRP CODWNs of the BRP PPDUs in which these sectors were received. The SNR field in the Channel Measurement Feedback element indicates the SNRs with which these sectors were received. If the number of sectors for a pair of TX and RX DMG antennas that were received in the last initiator TXSS is larger than aMinTXSSSectorFBCnt, the BRP frame shall contain feedback for at least aMinTXSSSectorFBCnt received sectors for the pair of TX and RX DMG antennas. Otherwise, the BRP frame shall contain feedback for all the received sectors for the pair of TX and RX DMG antennas.

During the SISO feedback procedure, all transmissions should use the DMG control mode.

#### 10.41.10.2.2.3 MIMO phase—general

The MIMO phase enables the training of transmit and receive sectors and DMG antennas to determine best combinations of transmit and receive sectors and DMG antennas for SU-MIMO operation.

When the MIMO phase is performed outside of a TDD SP, the initiator starts the MIMO phase an MBIFS following the end of the SISO phase. When the MIMO phase is performed in a TDD SP, after the end of TDD beamforming, each subphase should start within the earliest occurring TDD slot the initiator is assigned to and with slot category of the TDD slot set to Basic TDD slot, as indicated in the TDD Slot Schedule element.

The MIMO phase consists of a nonreciprocal MIMO phase or a reciprocal MIMO phase (see 10.41.10.2.2 (SU-MIMO beamforming)).

The nonreciprocal MIMO phase shall be supported by all EDMG STAs that are SU-MIMO capable. The reciprocal MIMO phase shall be supported by all EDMG STAs that are SU-MIMO capable and have the Antenna Pattern Reciprocity subfield in the DMG Capabilities element equal to 1.


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The MIMO BF Setup frame, MIMO BF Poll frame and MIMO BF Feedback frame sent in the MIMO phase of an SU-MIMO beamforming shall be transmitted by applying spatial expansion and mapping a single space-time stream to all $N_{TX}$ transmit chains to be trained in the procedure. The MIMO BF Setup frame, MIMO BF Poll frame and MIMO BF Feedback frame should be sent using the EDMG control mode.

BRP frames sent in the MIMO phase of an SU-MIMO beamforming shall be transmitted using EDMG PPDUs by applying spatial expansion and mapping a single space-time stream to all $N_{TX}$ transmit chains to be trained in the procedure. The TRN field of each EDMG BRP-RX/TX PPDU used in SU-MIMO beamforming shall consist of $N_{TX}$ orthogonal waveforms as defined in 28.9.2 (Beam refinement).

At the beginning of the MIMO phase of an SU-MIMO beamforming, if an implementation has not yet determined AWVs to use in some of its transmit chains (for example, if a(#1565) STA has been using a single transmit chain before the MIMO phase), the AWVs used by such chains should be selected in an implementation dependent manner.

The AWVs used in the transmission of a MIMO BF Feedback frame, MIMO BF Poll frame and all fields except for the TRN field of each EDMG BRP-RX/TX PPDU shall be the same as those used in the transmission of MIMO BF Setup frame. Similarly, the AWVs used in the reception of a MIMO BF Feedback frame, MIMO BF Poll frame and all fields except for the TRN field of each EDMG BRP-RX/TX PPDU shall be the same as those used in the reception of MIMO BF Setup frame.

#### 10.41.10.2.2.4 MIMO phase–nonreciprocal

The nonreciprocal MIMO phase is shown in Figure 10-111 (Nonreciprocal MIMO phase of SU-MIMO beamforming(11ay)) and consists of four subphases: an SU-MIMO BF setup subphase, an initiator SU-MIMO BF training (SMBT) subphase, a responder SMBT subphase, and an SU-MIMO BF feedback subphase.

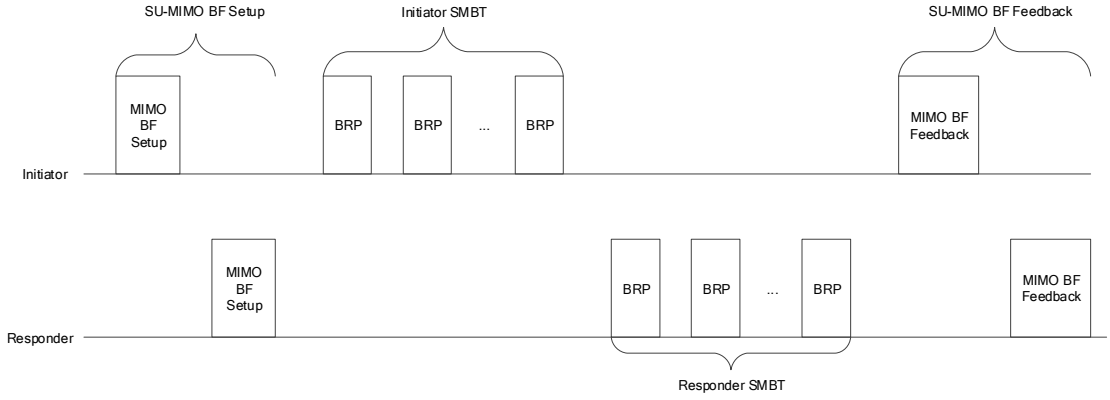


**Figure 10-111—Nonreciprocal MIMO phase of SU-MIMO beamforming(11ay)**

It is mandatory to perform the SU-MIMO BF setup subphase.

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In the SU-MIMO BF setup subphase, the initiator shall send a MIMO BF Setup frame with the TA field and the RA field set to the MAC addresses of the initiator and the responder, respectively. The MIMO BF Setup frame shall indicate a unique dialog token in the Dialog Token field for identifying SU-MIMO BF training. In the MIMO Setup Control element of the MIMO BF Setup frame, the SU/MU and Nonreciprocal/ Reciprocal MIMO Phase fields shall be set to 0 and the Initiator field shall be set to 1. The L-TX-RX field and the Requested EDMG TRN-Unit M field shall indicate the number of TRN subfields requested for receive AWV training in the following responder SMBT subphase. The number of transmit sector combinations requested for the initiator link ($N_{tsc}^{(I)}$) shall be indicated in the Number of TX Sector Combinations Requested subfield of the MIMO FBCK-REQ field. Whether time domain channel response is requested as part of SU-MIMO BF feedback shall be indicated in the Channel Measurement Requested subfield of the MIMO FBCK-REQ field. If the time domain channel response is requested as part of SU-MIMO BF feedback, the Channel Measurement Requested subfield of the MIMO FBCK-REQ field shall be set to 1 and the Number of Taps Requested subfield of the MIMO FBCK-REQ field shall indicate the number of channel taps requested in time domain channel response. For channel aggregation, the Channel Aggregation Requested subfield of the MIMO FBCK-REQ field should be set to 1. Additionally, based on the SNRs of the transmit sectors collected from the responder in the SISO phase, the initiator may select a subset of candidate transmit sectors per DMG antenna to reduce the initiator SMBT training time. Each DMG antenna should have the similar number of candidate transmit sectors in order to avoid biasing a DMG antenna. The L-TX-RX subfield and the Requested EDMG TRN-Unit M subfield of the MIMO BF Setup frame shall indicate the number of TRN subfields requested for receive AWV training in the following responder SMBT subphase.

NOTE 1—If the initiator has antenna pattern reciprocity, the subset of candidate transmit sectors per DMG antenna selected by the initiator for the initiator SMBT subphase can also be used to reduce the number of TRN subfields required for receive AWV training in the following responder SMBT subphase.

In the MIMO phase outside of a TDD SP, the responder shall send a MIMO BF Setup frame a SIFS following the reception of the MIMO BF Setup frame from the initiator. In the MIMO phase in a TDD SP, upon reception of the MIMO BF Setup frame from the initiator, the responder shall send a MIMO BF Setup frame within the earliest occurring TDD slot the responder is assigned to and with slot category of the TDD slot set to Basic TDD slot as indicated in the TDD Slot Schedule element.

The TA field and the RA field of the MIMO BF Setup frame shall be set to the MAC address of the responder and the initiator, respectively. The MIMO BF Setup frame shall indicate the same dialog token value in the Dialog Token field as in the MIMO BF Setup frame received from the initiator. In the MIMO Setup Control element of the MIMO BF Setup frame, the SU/MU, Nonreciprocal/Reciprocal MIMO Phase and Initiator fields shall be set to 0. The L-TX-RX field and the Requested EDMG TRN-Unit M field shall indicate the number of TRN subfields requested for receive AWV training in the following initiator SMBT subphase. The number of transmit sector combinations requested for the responder link ($N_{tsc}^{(R)}$) shall be indicated in the Number of TX Sector Combinations Requested subfield of the MIMO FBCK-REQ field. Whether time domain channel response is requested as part of SU-MIMO BF feedback shall be indicated in the Channel Measurement Requested subfield of the MIMO FBCK-REQ field. If the time domain channel response is requested as part of SU-MIMO BF feedback, the Channel Measurement Requested subfield of the MIMO FBCK-REQ field shall be set to 1 and the Number of Taps Requested subfield of the MIMO FBCK-REQ field shall indicate the number of channel taps requested in time domain channel response. The Channel Aggregation Requested subfield of the MIMO FBCK-REQ field shall be set to the same value as its counterpart in the MIMO BF Setup frame received from the initiator. Additionally, based on the SNRs of the transmit sectors collected from the initiator in the SISO phase, the responder may select a subset of candidate transmit sectors per DMG antenna to reduce the responder SMBT training time. Each DMG antenna should have the similar number of candidate transmit sectors in order to avoid biasing a DMG antenna. The L-TX-RX subfield and the Requested EDMG TRN-Unit M subfield of the MIMO BF Setup frame shall indicate the number of TRN subfields requested for receive AWV training in the following initiator SMBT subphase.


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NOTE 2—If the responder has antenna pattern reciprocity, the subset of candidate transmit sectors per DMG antenna selected by the responder for the responder SMBT subphase can also be used to reduce the number of TRN subfields required for receive AWV training in the following initiator SMBT subphase.

When the MIMO phase is performed outside of a TDD SP, the initiator shall initiate the initiator SMBT subphase an MBIFS following the reception of the MIMO BF Setup frame from the responder. When the MIMO phase is performed in a TDD SP, upon reception of the MIMO BF Setup frame from the responder, the initiator shall initiate the initiator SMBT subphase within the earliest occurring TDD slot the initiator is assigned to and with slot category of the TDD slot set to Basic TDD slot as indicated in the TDD Slot Schedule element.

In the initiator SMBT subphase, the initiator shall transmit EDMG BRP-RX/TX PPDUs to the responder. Each EDMG BRP-RX/TX PPDU shall be separated by SIFS. When performed within a TDD SP and there is not enough time within a TDD slot to transmit all EDMG BRP-RX/TX PPDUs, the remaining EDMG BRP-RX/TX PPDUs are transmitted within the earliest occurring TDD slot the initiator is assigned to and with slot category of the TDD slot set to Basic TDD slot as indicated in the TDD Slot Schedule element. Each transmitted EDMG BRP-RX/TX PPDU is used to train one or more transmit sectors and, for each transmit sector, a number of receive AWVs. In each EDMG BRP-RX/TX PPDU, the initiator shall include, for each selected transmit sector, TRN subfields in the TRN field of the PPDU for the responder to perform receive AWV training. For each EDMG BRP-RX/TX PPDU, the TXVECTOR parameter EDMG_TRN_LEN shall be set to a value greater than 0, and the parameters RX_TRN_PER_TX_TRN and EDMG_TRN_M shall be set to the values of the L-TX-RX and Requested EDMG TRN-Unit M fields in the MIMO BF Setup frame received from the responder, respectively. The TX Antenna Mask field of each EDMG BRP-RX/TX PPDU shall indicate the TX DMG antenna(s) that is being used by the initiator to transmit the EDMG BRP-RX/TX PPDU. The BRP CDOWN field of each EDMG BRP-RX/TX PPDU shall indicate the number of remaining EDMG BRP-RX/TX PPDUs to be transmitted by the initiator in the initiator SMBT subphase.

In the MIMO phase performed outside of a TDD SP, the responder shall initiate the responder SMBT subphase an MBIFS following the reception of an EDMG BRP-RX/TX PPDU with the BRP CDOWN field set to 0 from the initiator. In the MIMO phase performed in a TDD SP, upon reception of an EDMG BRP-RX/TX PPDU with the BRP CDOWN field set to 0 from the initiator, the responder shall initiate the responder SMBT subphase within the earliest occurring TDD slot the responder is assigned to and with slot category of the TDD slot set to Basic TDD slot as indicated in the TDD Slot Schedule element.

In the responder SMBT subphase, the responder shall transmit EDMG BRP-RX/TX PPDUs to the initiator. Each EDMG BRP-RX/TX PPDU shall be separated by SIFS. When performed within a TDD SP and there is not enough time within a TDD slot to transmit all EDMG BRP-RX/TX PPDUs, the remaining EDMG BRP-RX/TX PPDUs are transmitted within the earliest occurring TDD slot the responder is assigned to and with slot category of the TDD slot set to Basic TDD slot as indicated in the TDD Slot Schedule element. For each EDMG BRP-RX/TX PPDU, the TXVECTOR parameter EDMG_TRN_LEN shall be set to a value greater than 0, and the parameters RX_TRN_PER_TX_TRN and EDMG_TRN_M shall be set to the values of the L-TX-RX and Requested EDMG TRN-Unit M fields in the MIMO BF Setup frame received from the initiator, respectively. The TX Antenna Mask field of each EDMG BRP-RX/TX PPDU shall indicate the TX DMG antenna(s) that is being used by the responder to transmit the EDMG BRP-RX/TX PPDU. The BRP CDOWN field of each EDMG BRP-RX/TX PPDU shall indicate the number of remaining EDMG BRP-RX/TX PPDUs to be transmitted by the responder in the responder SMBT subphase.

When the MIMO phase is performed outside of a TDD SP, the initiator shall initiate the SU-MIMO BF feedback subphase an MBIFS following the reception of an EDMG BRP-RX/TX PPDU with the BRP CDOWN field set to 0 from the responder. When the MIMO phase is performed in a TDD SP, upon reception of an EDMG BRP-RX/TX PPDU with the BRP CDOWN field set to 0 from the responder, the initiator shall initiate the SU-MIMO BF feedback subphase within the earliest occurring TDD slot the

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initiator is assigned to and with slot category of the TDD slot set to Basic TDD slot as indicated in the TDD Slot Schedule element.

In the SU-MIMO BF feedback subphase, the initiator shall send to the responder a MIMO BF Feedback frame with the TA field set to the MAC address of the initiator and the RA field set to the MAC address of the responder. The MIMO BF Feedback frame shall carry the dialog token in the Dialog Token field that identifies the SU-MIMO BF training. In the MIMO Feedback Control element of the MIMO BF Feedback frame, the SU/MU field shall be set to 0 and the Link Type field shall be set to 1. If the MIMO BF Feedback frame contains SU-MIMO BF feedback for responder link, the ComeBack Delay field shall be set to 0. Otherwise, the ComeBack Delay field shall be set to a nonzero value that indicates when the initiator is ready with SU-MIMO BF feedback for responder link. If the ComeBack Delay field is(M118) 0 and for a 2.16+2.16 GHz or 4.32+4.32 GHz channel, the Channel Aggregation Present subfield of the MIMO FBCK-TYPE field should be set to 1. If the ComeBack Delay field is(M118) a nonzero value, the Channel Aggregation Present subfield of the MIMO FBCK-TYPE field shall be set to 0. The Number of TX Sector Combinations Present subfield of the MIMO FBCK-TYPE field shall indicate the number of best transmit sector combinations, $N_{tsc}^{(R)}$, recommended by the initiator for responder link.

The EDMG Channel Measurement Feedback element in the MIMO BF Feedback frame shall indicate $N_{tsc}^{(R)}$ best transmit sector combinations in the EDMG Sector ID Order field and the BRP CDOWN field, which are determined based on channel measurement data captured from the responder SMBT subphase. The Channel Measurement Feedback element in the MIMO BF Feedback frame shall contain SNRs corresponding to the $N_{tsc}^{(R)}$ transmit sector combinations in the SNR field. If the Channel Measurement Requested subfield of the MIMO FBCK-REQ field in the MIMO BF Setup frame received from the responder in the preceding SU-MIMO BF setup subphase is 1, the Channel Measurement Present subfield of the MIMO FBCK-TYPE field in the MIMO Feedback Control element shall be set to 1 and the Channel Measurement Feedback element shall contain channel measurements corresponding to the $N_{tsc}^{(R)}$ transmit sector combinations in the Channel Measurement field. If the Tap Delay Requested subfield of the MIMO FBCK-REQ field in the MIMO BF Setup frame received from the responder in the preceding SU-MIMO BF setup subphase is 1, the Tap Delay Present subfield of the MIMO FBCK-TYPE field in the MIMO Feedback Control element shall be set to 1 and the EDMG Channel Measurement Feedback element shall contain relative tap delays for the measurements in the Tap Delay field.

In the MIMO phase outside of a TDD SP, the responder shall send a MIMO BF Feedback frame to the initiator a SIFS following reception of a MIMO BF Feedback frame from the initiator. In the MIMO phase in a TDD SP, upon reception of a MIMO BF Feedback frame from the initiator, the responder shall send a MIMO BF Feedback frame to the initiator within the earliest occurring TDD slot the responder is assigned to and with slot category of the TDD slot set to Basic TDD slot as indicated in the TDD Slot Schedule element.

The TA field of the MIMO BF Feedback shall be set to the MAC address of the responder and the RA field shall be set to the MAC address of the initiator. The MIMO BF Feedback frame shall carry the dialog token in the Dialog Token field that identifies the SU-MIMO BF training. In the MIMO Feedback Control element of the MIMO BF Feedback frame, the SU/MU and Link Type fields shall be set to 0. If the MIMO BF Feedback frame contains SU-MIMO BF feedback for initiator link, the ComeBack Delay field shall be set to 0. Otherwise, the ComeBack Delay field shall be set to a nonzero value that indicates when the responder is ready with SU-MIMO BF feedback for initiator link. If the ComeBack Delay field is(M118) 0 and for 2.16+2.16 or 4.32+4.32 GHz channels, the Channel Aggregation Present subfield of the MIMO FBCK-TYPE field should be set to 1. If the ComeBack Delay field is(M118) a nonzero value, the Channel Aggregation Present subfield of the MIMO FBCK-TYPE field shall be set to 0. The Number of TX Sector Combinations Present subfield of the MIMO FBCK-TYPE field shall indicate the number of best transmit sector combinations, $N_{tsc}^{(I)}$, recommended by the responder for initiator link.

If the ComeBack Delay field of the MIMO BF Feedback frame received from the initiator is nonzero, the responder shall send a MIMO BF Poll frame with the SU/MU and Poll Type fields set to 0 to the initiator


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after the initiator's comeback delay has elapsed subject to the DMG channel access rules in a DTI. The initiator shall send a MIMO BF Feedback frame that contains the SU-MIMO BF feedback for the responder link a SIFS following the reception of the MIMO BF Poll frame. If the ComeBack Delay field of the MIMO BF Feedback frame received from the responder is nonzero, the initiator shall send a MIMO BF Poll frame to the responder with the SU/MU and Poll Type fields set to 0 after the responder's comeback delay has elapsed subject to the DMG channel access rules in a DTI. The responder shall respond with a MIMO BF Feedback frame that contains the SU-MIMO BF feedback for the initiator link a SIFS following the reception of the MIMO BF Poll frame.

The EDMG Channel Measurement Feedback element in the MIMO BF Feedback frame shall indicate $N_{tsc}^{(I)}$ best transmit sector combinations in the EDMG Sector ID Order field and the BRP CDOWN field, which are determined based on channel measurement data captured from the initiator SMBT subphase. The Channel Measurement Feedback element in the MIMO BF Feedback frame shall contain SNRs corresponding to the $N_{tsc}^{(I)}$ transmit sector combinations in the SNR field. If the Channel Measurement Requested subfield of the MIMO FBCK-REQ field in the MIMO BF Setup frame received from the initiator in the preceding SU-MIMO BF setup subphase is 1, the Channel Measurement Present subfield of the MIMO FBCK-TYPE field in the MIMO Feedback Control element shall be set to 1 and the Channel Measurement Feedback element shall contain channel measurements corresponding to the $N_{tsc}^{(I)}$ transmit sector combinations in the Channel Measurement field. If the Tap Delay Requested subfield of the MIMO FBCK-REQ field in the MIMO BF Setup frame received from the initiator in the preceding SU-MIMO BF setup subphase is 1, the Tap Delay Present subfield of the MIMO FBCK-TYPE field in the MIMO Feedback Control element shall be set to 1 and the EDMG Channel Measurement Feedback element shall contain tap delays corresponding to the $N_{tsc}^{(I)}$ transmit sector combinations in the Tap Delay field.

The $N_{tsc}^{(I)}$ best transmit sector combinations (or equivalently $N_{tsc}^{(I)}$ best TX-RX AWV configurations) for the initiator link and the $N_{tsc}^{(R)}$ best transmit sector combinations (or equivalently $N_{tsc}^{(R)}$ best TX-RX AWV configurations) for the responder link shall be determined in such a way that no transmit or receive AWV come from the same DMG antenna (i.e., a transmit sector combination indicated by a specific SISO ID subset in the EDMG Channel Measurement Feedback element comprises a single transmit sector for each of $N_{TX}$ TX DMG antennas and the corresponding receive sector combination comprises a single receive sector for each of $N_{RX}$ RX DMG antennas). The algorithms for determining the $N_{tsc}^{(I)}$ best transmit sector combinations for the initiator link and for determining the $N_{tsc}^{(R)}$ best transmit sector combinations for the responder link are implementation dependent. The transmit sector combinations to be used for the initiator link and the responder link are indicated using either RTS/DMG CTS frames with a control trailer or a DMG CTS-to-self frame with a control trailer at the beginning of a SU-MIMO channel access procedure (see 10.38.12.4.3 (SU-MIMO channel access procedure)).

#### 10.41.10.2.2.5 MIMO phase–reciprocal

The reciprocal MIMO phase might shorten the SU-MIMO BF training time. The initiator may initiate a reciprocal MIMO phase if the following conditions are met:

— The SU-MIMO Supported field in initiator's and responder's EDMG Capabilities element equals one; and

— The Antenna Pattern Reciprocity field in initiator's and responder's DMG Capabilities element equals one

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The reciprocal MIMO phase is shown in Figure 10-112 (Reciprocal MIMO phase of SU-MIMO beamforming(11ay)) and consists of three subphases: an SU-MIMO BF setup subphase, an initiator SMBT subphase and an SU-MIMO BF feedback subphase.

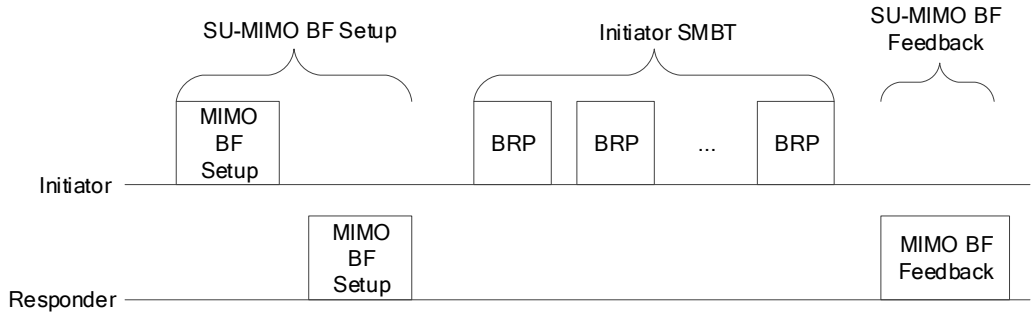


**Figure 10-112—Reciprocal MIMO phase of SU-MIMO beamforming(11ay)**

It is mandatory to perform the SU-MIMO BF setup subphase.

In the SU-MIMO BF setup subphase, the initiator shall send a MIMO BF Setup frame with the TA field and the RA field of the MIMO BF Setup frame set to the MAC addresses of the initiator and the responder, respectively. The MIMO BF Setup frame shall indicate a unique dialog token in the Dialog Token field for identifying SU-MIMO BF training. In the MIMO Setup Control element of the MIMO BF Setup frame, the SU/MU field shall be set to 0, and both the Nonreciprocal/Reciprocal MIMO Phase and Initiator field shall be set to 1. The number of transmit sector combinations requested for the initiator link ($N_{tsc}^{(I)}$) shall be indicated in the Number of TX Sector Combinations Requested subfield of the MIMO FBCK-REQ field. Whether time domain channel response is requested as part of SU-MIMO BF feedback shall be indicated in the Channel Measurement Requested subfield of the MIMO FBCK-REQ field. If the time domain channel response is requested as part of SU-MIMO BF feedback, the Channel Measurement Requested subfield of the MIMO FBCK-REQ field shall be set to 1 and the Number of Taps Requested subfield of the MIMO FBCK-REQ field shall indicate the number of channel taps requested in time domain channel response. For channel aggregation, the Channel Aggregation Requested subfield of the MIMO FBCK-REQ field should be set to 1. Additionally, based on the SNRs of the transmit sectors collected from the responder in the SISO phase, the initiator may select a subset of candidate transmit sectors per DMG antenna to reduce the initiator SMBT training time. Each DMG antenna should have the similar number of candidate transmit sectors in order to avoid biasing a DMG antenna.

In the MIMO phase performed outside of a TDD SP, the responder shall send a MIMO BF Setup frame a SIFS following the reception of the MIMO BF Setup frame from the initiator. In the MIMO phase performed in a TDD SP, upon reception of the MIMO BF Setup frame from the initiator, the responder shall send a MIMO BF Setup frame within the earliest occurring TDD slot the responder is assigned to and with slot category of the TDD slot set to Basic TDD slot as indicated in the TDD Slot Schedule element.

The TA field and the RA field of the MIMO BF Setup frame shall be set to the MAC address of the responder and the initiator, respectively. The MIMO BF Setup frame shall indicate the same dialog token value in the Dialog Token field as in the MIMO BF Setup frame received from the initiator. In the MIMO Setup Control element of the MIMO BF Setup frame, the SU/MU and Initiator fields shall be set to 0, and the Nonreciprocal/Reciprocal MIMO Phase field shall be set to 1. The L-TX-RX field and the Requested EDMG TRN-Unit M field shall indicate the number of TRN subfields requested for receive AWV training in the following initiator SMBT subphase. Based on the SNRs of the transmit sectors collected from the initiator in the SISO phase, the responder may select a subset of candidate receive sectors per DMG antenna to reduce the initiator SMBT training time. Each DMG antenna should have the similar number of candidate receive sectors in order to avoid biasing a DMG antenna.


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When the MIMO phase is performed outside of a TDD SP, the initiator shall initiate the initiator SMBT subphase an MBIFS following the reception of the MIMO BF Setup frame from the responder. When the MIMO phase is performed in a TDD SP, upon reception of the MIMO BF Setup frame from the responder, the initiator shall initiate the initiator SMBT subphase within the earliest occurring TDD slot the initiator is assigned to and with slot category of the TDD slot set to Basic TDD slot as indicated in the TDD Slot Schedule element.

In the initiator SMBT subphase, the initiator shall transmit EDMG BRP-RX/TX PPDUs to the responder. Each EDMG BRP-RX/TX PPDU shall be separated by SIFS. When performed within a TDD SP and there is not enough time within a TDD slot to transmit all EDMG BRP-RX/TX PPDUs, the remaining EDMG BRP-RX/TX PPDUs are transmitted within the earliest occurring TDD slot the initiator is assigned to and with slot category of the TDD slot set to Basic TDD slot as indicated in the TDD Slot Schedule element. Each transmitted EDMG BRP-RX/TX PPDU is used to train one or more transmit sectors and, for each transmit sector, a number of receive AWVs. In each EDMG BRP-RX/TX PPDU, the initiator shall include, for each selected transmit sector, TRN subfields in the TRN field of the PPDU for the responder to perform receive AWV training. For each EDMG BRP-RX/TX PPDU, the TXVECTOR parameter EDMG_TRN_LEN shall be set to a value greater than 0, and the parameters RX_TRN_PER_TX_TRN and EDMG_TRN_M shall be set to the values of the L-TX-RX and Requested EDMG TRN-Unit M fields in the MIMO BF Setup frame received from the responder, respectively. The TX Antenna Mask field of each EDMG BRP-RX/TX PPDU shall indicate the TX DMG antenna(s) that is being used by the initiator to transmit the EDMG BRP-RX/TX PPDU. The BRP CDOWN field of each EDMG BRP-RX/TX PPDU shall indicate the number of remaining EDMG BRP-RX/TX PPDUs to be transmitted by the initiator in the initiator SMBT subphase.

When the MIMO phase is performed outside of a TDD SP, the responder shall initiate the SU-MIMO BF feedback subphase an MBIFS following the reception of an EDMG BRP-RX/TX PPDU with the BRP CDOWN field set to 0 from the initiator. When the MIMO phase is performed in a TDD SP, upon reception of an EDMG BRP-RX/TX PPDU with the BRP CDOWN field set to 0 from the initiator, the responder shall initiate the SU-MIMO BF feedback subphase within the earliest occurring TDD slot the responder is assigned to and with slot category of the TDD slot set to Basic TDD slot as indicated in the TDD Slot Schedule element.

In the SU-MIMO BF feedback subphase, the responder shall send a MIMO BF Feedback frame to the initiator with the TA field set to the MAC address of the responder and the RA field set to the MAC address of the initiator. The MIMO BF Feedback frame shall carry the dialog token in the Dialog Token field that identifies the SU-MIMO BF training. In the MIMO Feedback Control element of the MIMO BF Feedback frame, the SU/MU and Link Type field shall be set to 0. If the MIMO BF Feedback frame contains SU-MIMO BF feedback for the initiator link, the ComeBack Delay field shall be set to 0. Otherwise, the ComeBack Delay field shall be set to a nonzero value that indicates when the responder is ready with SU-MIMO BF feedback for initiator link. If the ComeBack Delay field is(M118) 0 and for 2.16+2.16 GHz or 4.32+4.32 GHz channels, the Channel Aggregation Present subfield of the MIMO FBCK-TYPE field should be set to 1. If the ComeBack Delay field is(M118) a nonzero value, the Channel Aggregation Present subfield of the MIMO FBCK-TYPE field shall be set to 0. The Number of TX Sector Combinations Present subfield of the MIMO FBCK-TYPE field shall indicate the number of best transmit sector combinations, $N_{tsc}^{(I)}$, recommended by the responder for initiator link.

If the ComeBack Delay field of the MIMO BF Feedback frame received from the responder is nonzero, the initiator shall send a MIMO BF Poll frame with the SU/MU and Poll Type fields set to 0 to the responder immediately after the responder's comeback delay has elapsed subject to the DMG channel access rules in a DTI. In this case, the responder shall respond with a MIMO BF Feedback frame that contains SU-MIMO BF feedback for the initiator link a SIFS following the reception of the MIMO BF Poll frame.

The EDMG Channel Measurement Feedback element in the MIMO BF Feedback frame shall indicate $N_{tsc}^{(I)}$ best transmit sector combinations in the EDMG Sector ID Order field and the BRP CDOWN field, which

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are determined based on channel measurement data captured from the initiator SMBT subphase. The Channel Measurement Feedback element in the MIMO BF Feedback frame shall contain SNRs corresponding to the $N_{tsc}^{(I)}$ transmit sector combinations in the SNR field. If the Channel Measurement Requested subfield of the MIMO FBCK-REQ field in the MIMO BF Setup frame received from the initiator in the preceding SU-MIMO BF setup subphase is 1, the Channel Measurement Present subfield of the MIMO FBCK-TYPE field in the MIMO Feedback Control element shall be set to 1 and the Channel Measurement Feedback element shall contain channel measurements corresponding to the $N_{tsc}^{(I)}$ transmit sector combinations in the Channel Measurement field. If the Tap Delay Requested subfield of the MIMO FBCK-REQ field in the MIMO BF Setup frame received from the initiator in the preceding SU-MIMO BF setup subphase is 1, the Tap Delay Present subfield of the MIMO FBCK-TYPE field in the MIMO Feedback Control element shall be set to 1 and the EDMG Channel Measurement Feedback element shall contain tap delays corresponding to the $N_{tsc}^{(I)}$ transmit sector combinations in the Tap Delay field.

The $N_{tsc}^{(I)}$ best transmit sector combinations (or equivalently $N_{tsc}^{(I)}$ best TX-RX AWV configurations) for the initiator link shall be determined in such a way that no transmit or receive AWV come from the same DMG antenna (i.e., a transmit sector combination indicated by a specific SISO ID subset in the EDMG Channel Measurement Feedback element comprises a single transmit sector for each of $N_{TX}$ TX DMG antennas and the corresponding receive sector combination comprises a single receive sector for each of $N_{RX}$ RX DMG antennas). The determined $N_{tsc}^{(I)}$ best transmit and receive sector combinations for the initiator link shall be treated as the $N_{tsc}^{(R)}$ best receive and transmit sector combinations for the responder link, respectively, where $N_{tsc}^{(I)} = N_{tsc}^{(R)}$. The algorithm for determining the $N_{tsc}^{(I)}$ best transmit sector combinations for the initiator link is implementation dependent. The transmit sector combinations to be used for the initiator link and the responder link are indicated using either RTS/DMG CTS frames with a control trailer or a DMG CTS-to-self frame with a control trailer at the beginning of a SU-MIMO channel access procedure (see 10.38.12.4.3 (SU-MIMO channel access procedure)).

### 10.41.10.2.3 MU-MIMO beamforming

#### 10.41.10.2.3.1 General

An EDMG STA is MU-MIMO capable if the MU-MIMO Supported subfield of the Beamforming Capability subelement in the STA's EDMG Capabilities element is 1. The MU-MIMO beamforming protocol enables an MU-MIMO capable initiator and one or more MU-MIMO capable responders in an MU group to establish an antenna configuration that allows the initiator to transmit an EDMG MU PPDU to the responders in the MU group, such that the mutual interference among the streams transmitted in the MU PPDU is minimized. In this context, the method of minimizing interference is implementation dependent.

MU-MIMO beamforming shall not be performed within a TDD SP.

The MU-MIMO beamforming protocol is started and controlled by the initiator, and comprises the following consecutive phases:

— SISO phase
— MIMO phase

The MU-MIMO beamforming protocol uses the EDMG Group ID Set element transmitted by the AP or PCP of the BSS. The AP or PCP shall transmit an EDMG Group ID Set element prior to performing MU-MIMO beamforming protocol. The EDMG Group ID Set element shall include all existing(#2226) groups in a BSS. An MU-MIMO capable EDMG STA shall store the groups in the last received EDMG Group ID Set element transmitted by the AP or PCP. If an AP or PCP needs to change the STAs in an MU group associated with an existing EDMG group ID, it shall send an individually addressed Announce frame including the updated EDMG Group ID Set element to each of the STAs that are affected by the change to notify of the update.


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MIMO BF Setup frames, MIMO BF Poll frames and MIMO BF Selection frames sent by the initiator in the MIMO phase of an MU-MIMO beamforming shall be transmitted by applying spatial expansion and mapping a single space-time stream to all $N_{TX}$ transmit chains to be trained in the procedure. The AWVs used by such chains in the transmission of MIMO BF Setup frames and MIMO BF Selection frames should be selected in an implementation dependent manner. If an implementation has not yet determined AWVs to use in some of its transmit chains for the transmission of MIMO BF Poll frame, the AWVs used by such chains should be selected in an implementation dependent manner. MIMO BF Setup frames, MIMO BF Poll frames and MIMO BF Selection frames should be sent using the EDMG control mode.

In the nonreciprocal MU-MIMO BF feedback subphase, MIMO BF Feedback frame sent by each responder shall be transmitted by applying spatial expansion and mapping a single space-time stream to all $N_{TX}$ transmit chains. If an implementation has not yet determined AWVs to use in some of its transmit chains for the transmission of MIMO BF Feedback frame, the AWVs used by such chains should be selected in an implementation dependent manner. MIMO BF Feedback frame should be sent using the EDMG control mode.

BRP frames sent in the MIMO phase of an MU-MIMO beamforming shall be transmitted using EDMG PPDUs by applying spatial expansion and mapping a single space-time stream to all $N_{TX}$ transmit chains to be trained in the procedure. The TRN field of each EDMG BRP-RX/TX PPDU used in MU-MIMO beamforming shall consist of $N_{TX}$ orthogonal waveforms, as defined in 28.9.2 (Beam refinement). In the nonreciprocal MU-MIMO BF training subphase, the AWVs used by such chains in the transmission of all fields except for the TRN field of each EDMG BRP-RX/TX PPDU should be selected in an implementation dependent manner.

In the reciprocal MU-MIMO BF training subphase, if an implementation has not yet determined AWVs to use in some of its transmit chains for the transmission of all fields except for the TRN field of each EDMG BRP-RX/TX PPDU, the AWVs used by such chains should be selected in an implementation dependent manner.

#### 10.41.10.2.3.2 SISO phase

The goal of the SISO phase is to collect feedback on one or more suitable initiator's TX and responder's RX DMG antennas and sectors between the initiator and each responder in the MU group. This information is then used to perform the following MIMO phase. All transmissions during the SISO phase should use the DMG control mode.

Figure 10-113 (SISO phase of MU-MIMO beamforming(11ay)) depicts the SISO phase, which consists of two subphases, namely, an Initiator TXSS subphase and a SISO Feedback subphase. The initiator may

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perform the Initiator TXSS subphase. The Initiator TXSS subphase enables the initiator to obtain feedback from the responders in the MU group on one or more sectors for each of the initiator's TX DMG antenna.

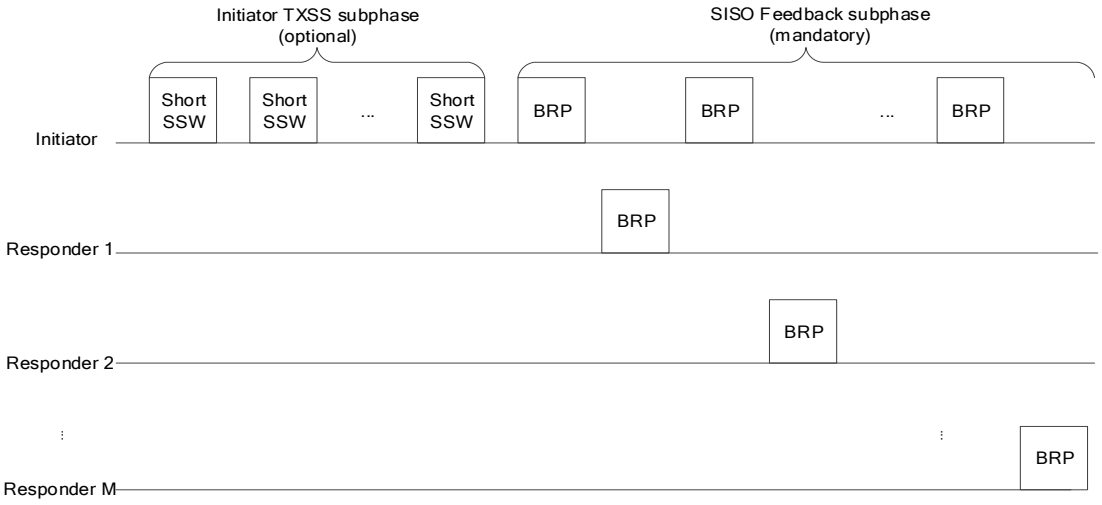


**Figure 10-113—SISO phase of MU-MIMO beamforming(11ay)**

The initiator performs the Initiator TXSS subphase through the use of the Short SSW PPDU (see 28.9.1 (Short SSW PPDU)). In each Short SSW PPDU transmitted as part of the Initiator TXSS, the initiator shall set the TXVECTOR parameter SSSW_DIR to indicate Initiator, shall set the TXVECTOR parameter SSSW_ADD_MODE to indicate GroupAddr and shall set the TXVECTOR parameter SSSW_DESTINATION_AID to contain a group ID announced by the PCP or AP in the last transmitted EDMG Group ID Set element. In addition, the TXVECTOR parameter SSSW_CDOWN shall be set to the number of Short SSW PPDUs remaining until the end of the Initiator TXSS subphase and the TXVECTOR parameter SSSW_SISO_FEEDBACK_DURATION shall be set to the duration of the following SISO Feedback subphase.

An MU-MIMO capable EDMG STA that receives a Short SSW PPDU indicating MU-MIMO transmission determines that it is an intended recipient of the PPDU by matching the value of the RXVECTOR parameter SSSW_DESTINATION_AID in the PPDU with a value of the EDMG Group ID subfield contained in the last received EDMG Group ID Set element. In case a match is found, the EDMG STA is an intended recipient of the PPDU if its AID is included in the EDMG Group ID subfield of the corresponding group. Otherwise, the EDMG STA is not an intended recipient of the PPDU and can ignore the remainder of the Initiator TXSS and SISO Feedback subphase, which can be done through the use of the value of the RXVECTOR parameters SSSW_CDOWN and SSSW_SISO_FEEDBACK_DURATION of the received Short SSW PPDU.

The initiator shall perform the SISO Feedback subphase. If the Initiator TXSS is present, the SISO Feedback subphase shall start MBIFS following the end of the Initiator TXSS subphase. During the SISO Feedback subphase, the initiator transmits a BRP frame to poll each responder in the MU group. The DMG Beam Refinement element of the BRP frame shall have the BF Training Type field set to 2, the TXSS-FBCK-REQ field set to 1, the SNR Requested subfield within the FBCK-REQ field set to 1, the Sector ID Order Requested field within the FBCK-REQ field set to 1, the Channel Measurement Requested subfield within the FBCK-REQ field set to 0, all the subfields within the FBCK-TYPE field set to 0 and the EDMG Channel Measurement Present field set to 0. A responder shall respond with a BRP frame within an MBIFS following the reception of the corresponding BRP frame. The DMG Beam Refinement element of the BRP frame shall have the BF Training Type field set to 2, all the subfields within the FBCK-REQ field set to 0, the SNR Present subfield within the FBCK-TYPE field set to 1, the Sector ID Order Present subfield within the FBCK-TYPE field set to 1, the Channel Measurement Present subfield within the FBCK-TYPE field set


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to 0, the Tap Delay Present subfield within the FBCK-TYPE field set to 0, the Link Type subfield within the FBCK-TYPE field set to 0, the EDMG Extension Flag field set to 1 and the EDMG Channel Measurement Present field set to 1. The BRP frame shall include an EDMG BRP Request element, in which the L-TX-RX and Requested EDMG TRN-Unit M fields indicate the number of TRN subfields requested for receive AWV training in the following nonreciprocal MU-MIMO BF training.

The last initiator TXSS may have been performed using DMG Beacon frames, SSW frames, Short SSW PPDUs or EDMG BRP-TX PPDUs.

— If the Sector Sweep Frame Type field in the DMG Beam Refinement element is 0, the EDMG Sector ID Order field in the EDMG Channel Measurement Feedback element indicates the sector IDs, TX antennas and RX antennas of all or a subset of sectors that were received in the last initiator TXSS.

— If the Sector Sweep Frame Type field in the DMG Beam Refinement element is 1, the EDMG Sector ID Order field in the EDMG Channel Measurement Feedback element indicates the CDOWNs and RX antennas of all or a subset of sectors that were received in the last initiator TXSS.

— If the Sector Sweep Frame Type field in the DMG Beam Refinement element is 2, the EDMG Sector ID Order field in the EDMG Channel Measurement Feedback element indicates AWV feedback IDs, TX antennas and RX antennas of all or a subset of sectors that were received in the last Initiator TXSS.

The BRP CDOWN field in the EDMG Channel Measurement Feedback element indicates the BRP CDOWNs of the PPDUs in which these sectors were received. The SNR field in the Channel Measurement Feedback element indicates the SNRs with which these sectors were received. If the number of sectors for a pair of TX and RX DMG antennas that were received in the last initiator TXSS is larger than aMinTXSSSectorFBCnt, the BRP frame shall contain feedback for at least aMinTXSSSectorFBCnt received sectors for the pair of TX and RX DMG antennas. Otherwise, the BRP frame shall contain feedback for all the received sectors for the pair of TX and RX DMG antennas.

#### 10.41.10.2.3.3 MIMO phase—general

The MIMO phase consists of a nonreciprocal MIMO phase or a reciprocal MIMO phase (see 10.41.10.2.3 (MU-MIMO beamforming)).

The nonreciprocal MIMO phase shall be supported by all EDMG STAs that are MU-MIMO capable. The reciprocal MIMO phase may be supported by EDMG STAs that are MU-MIMO capable.

#### 10.41.10.2.3.4 MIMO phase–nonreciprocal

The initiator shall start the MIMO phase MBIFS following the end of the SISO phase. The nonreciprocal MIMO phase is shown in Figure 10-114 (Nonreciprocal MIMO phase of MU-MIMO beamforming(11ay)) and consists of four subphases, namely, an MU-MIMO BF setup subphase, an MU-MIMO BF training subphase, an MU-MIMO BF feedback subphase, and an MU-MIMO BF selection subphase. Each subphase shall be separated by MBIFS.

Based on the feedback from the SISO phase, in the MU-MIMO BF setup subphase the initiator may exclude some responders from the following MU-MIMO BF training subphase and MU-MIMO BF feedback subphase if the multiuser interference the responders are expected to suffer due to MU-MIMO transmission is negligible. If all of the responders are excluded from the following MU-MIMO BF training subphase and MU-MIMO BF feedback subphase, these two subphases are not present in the MIMO phase.

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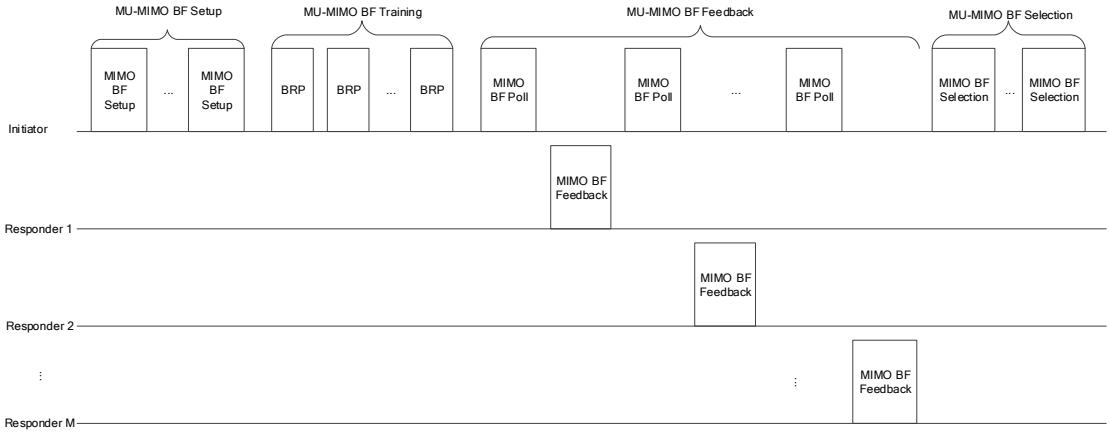


**Figure 10-114—Nonreciprocal MIMO phase of MU-MIMO beamforming(11ay)**

In the MU-MIMO BF setup subphase, the initiator shall transmit one or more MIMO BF Setup frame to each responder in the MU group. The initiator should transmit the minimum number of MIMO BF Setup frames to reach all responders in the MU group. The TA field of each MIMO BF Setup frame shall be set to the BSSID of the initiator and the RA field shall be set to the broadcast address. Each MIMO BF Setup frame shall indicate a unique dialog token in the Dialog Token field for identifying MU-MIMO BF training. In the MIMO Setup Control element of each MIMO BF Setup frame, the SU/MU field shall be set to 1, the Nonreciprocal/Reciprocal MIMO Phase field shall be set to 0, and the Initiator field shall be set to 1. The EDMG group ID of the MU group shall be indicated in the EDMG Group ID field and each remaining responder shall be indicated in the Group User Mask field. Whether time domain channel response is requested as part of MU-MIMO BF feedback shall be indicated in the Channel Measurement Requested subfield of the MIMO FBCK-REQ field. If the time domain channel response is requested as part of MU-MIMO BF feedback, the Channel Measurement Requested subfield of the MIMO FBCK-REQ field shall be set to 1 and the Number of Taps Requested subfield of the MIMO FBCK-REQ field shall indicate the number of channel taps requested in time domain channel response. For channel aggregation, the Channel Aggregation Requested subfield of the MIMO FBCK-REQ field should be set to 1. To reduce the MU-MIMO BF training time, the initiator may select a subset of TX sectors for each DMG antenna. The number of TRN subfields required for receive AWV training is based on the L-TX-RX field and the Requested EDMG TRN-Unit M field of the EDMG BRP Request element included in the BRP frame received from each responder during the SISO feedback subphase. A responder whose corresponding bit in the Group User Mask field of the MIMO Setup Control element included in the received MIMO BF Setup frame is equal to 0 can (#3683)discard frames transmitted in the following MU-MIMO BF training subphase and MU-MIMO BF feedback subphase.

The initiator shall initiate the MU-MIMO BF training subphase an MBIFS following the transmission of the MIMO BF Setup frame. In the MU-MIMO BF training subphase, the initiator shall transmit one or more EDMG BRP-RX/TX PPDUs to the remaining responders in the MU group. Each EDMG BRP-RX/TX PPDU shall be separated by SIFS. Both the TA and RA fields of each transmitted EDMG BRP-RX/TX PPDU shall be set to the MAC address of the initiator. If a responder whose corresponding bit in the Group User Mask field within the last received MIMO BF Setup frame from the initiator was equal to 1 receives an EDMG BRP-RX/TX PPDU with both the TA and RA fields equal to the MAC address of the initiator, the responder should perform receive AWV training. For each EDMG BRP-RX/TX PPDU, the TXVECTOR parameter EDMG_TRN_LEN shall be set to a value greater than 0. The parameters RX_TRN_PER_TX_TRN and EDMG_TRN_M shall be set in such a manner that the number of TRN subfields included in the TRN field used for receive AWV training is the maximum number of receive sectors across all the remaining responders based on the L-TX-RX subfields and the Requested EDMG TRN-Unit M subfields in the feedback from all the remaining responders in the SISO phase. The TX


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Antenna Mask field of each EDMG BRP-RX/TX PPDU shall indicate the TX DMG antenna(s) that is being used by the initiator to transmit the EDMG BRP-RX/TX PPDU. The BRP CDOWN field of each EDMG BRP-RX/TX PPDU shall indicate the number of remaining EDMG BRP-RX/TX PPDUs to be transmitted by the initiator in the MU-MIMO BF training subphase.

The initiator shall initiate the MU-MIMO BF feedback subphase an MBIFS following the transmission of the EDMG BRP-RX/TX PPDU with the BRP CDOWN field set to 0. In the MU-MIMO BF feedback subphase, the initiator shall transmit a MIMO BF Poll frame to poll each remaining responder to collect MU-MIMO BF feedback from the preceding MU-MIMO BF training subphase. The TA field of each MIMO BF Poll frame shall be set to the BSSID of the initiator and the RA field shall be set to the MAC address of the corresponding responder. Each MIMO BF Poll frame carries the dialog token in the Dialog Token field that identifies the MU-MIMO BF training. In the MIMO Poll Control element of each MIMO BF Poll frame, the SU/MU field shall be set to 1 and the Poll Type field shall be set to 0. (#1042)A SIFS after receiving a MIMO BF Poll frame for which a remaining responder is the addressed recipient, the responder shall transmit a MIMO BF Feedback frame to the initiator. The RA field of the MIMO BF Feedback frame shall be set to the BSSID of the initiator and the TA field shall be set to the MAC address of the responder. The MIMO BF Feedback frame carries the dialog token in the Dialog Token field that identifies the MU-MIMO BF training. In the MIMO Feedback Control element of the MIMO BF Feedback frame, the SU/MU field shall be set to 1 and the Link Type field shall be set to 0. If the MIMO BF Feedback frame contains MU-MIMO BF feedback, the ComeBack Delay field shall be set to 0. Otherwise, the ComeBack Delay field shall be set to a nonzero value that indicates when the responder is ready with MU-MIMO BF feedback.

If the ComeBack Delay field is(M118) 0 and for a 2.16+2.16 GHz or 4.32+4.32 GHz channel, the Channel Aggregation Present subfield of the MIMO FBCK-TYPE field should be set to 1. The Number of TX Sector Combinations Present subfield of the MIMO FBCK-TYPE field shall indicate the number of transmit sector combinations, $N_{tsc}$.

The EDMG Channel Measurement Feedback element in the MIMO BF Feedback frame shall indicate $N_{tsc}$ transmit sector combinations in the EDMG Sector ID Order field and the BRP CDOWN field, which are obtained through the channel measurement data captured from the MU-MIMO BF training subphase. The Channel Measurement Feedback element in the MIMO BF Feedback frame shall indicate SNRs corresponding to $N_{tsc}$ transmit sector combinations in the SNR field. If the Channel Measurement Requested subfield of the MIMO FBCK-REQ field in the MIMO BF Setup frame received from the initiator in the preceding MU-MIMO BF setup subphase is 1, the Channel Measurement Present subfield of the MIMO FBCK-TYPE field in the MIMO Feedback Control element shall be set to 1 and the Channel Measurement Feedback element shall contain the channel measurements corresponding to $N_{tsc}$ transmit sector combinations in the Channel Measurement field. If the Tap Delay Requested subfield of the MIMO FBCK-REQ field in the MIMO BF Setup frame received from the initiator in the preceding MU-MIMO BF setup subphase is 1, the Tap Delay Present subfield of the MIMO FBCK-TYPE field in the MIMO Feedback Control element shall be set to 1 and the EDMG Channel Measurement Feedback element shall contain tap delays corresponding to the $N_{tsc}$ transmit sector combinations in the Tap Delay field.

If the ComeBack Delay field of the MIMO BF Feedback frame received from the responder is nonzero, the initiator shall send a MIMO BF Poll frame with the SU/MU field set to 1 and the Poll Type field set to 0 to the responder immediately after the responder's comeback delay has elapsed subject to the DMG channel access rules in a DTI. In this case, the responder shall respond with a MIMO BF Feedback frame that contains the MU-MIMO BF feedback.

Each MIMO BF Poll frame and MIMO BF Feedback frame shall be separated by SIFS, except in the case that a MIMO BF Feedback frame includes a ComeBack Delay field set to a nonzero value.

The initiator shall initiate the MU-MIMO BF selection subphase an MBIFS following reception of the MIMO BF Feedback frame from the last remaining responder. In the MU-MIMO BF selection subphase, the

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initiator shall transmit one or more MIMO BF Selection frames to each responder in the MU group. The initiator should transmit the minimum number of MIMO BF Selection frames to reach all responders in the MU group. The MIMO BF Selection frames should be sent using the DMG control mode. The TA field of the MIMO BF Selection frame shall be set to the BSSID of the initiator and the RA field shall be set to the broadcast address. Each MIMO BF Selection frame contains the dialog token in the Dialog Token field for identifying the MU-MIMO BF training. In the MIMO Selection Control element of each MIMO BF Selection frame, the MU-MIMO Transmission Configuration Type field shall be set to 0 and the Reciprocal MU-MIMO BF Training Based Transmission Configuration field shall not be present. The EDMG group ID corresponding to the MU group, which is the same as that is used in the MU-MIMO BF setup subphase, shall be indicated in the EDMG Group ID field and the number of MU-MIMO transmission configurations, $N_{conf}$, shall be indicated in the Number of MU-MIMO Transmission Configurations field.

Which responder(s) in the MU group is associated with each of $N_{TX}$ TX DMG antennas for each of $N_{conf}$ MU-MIMO transmission configurations shall be indicated in the Configuration $i$ Group User Mask for Antenna $j$ subfield ($i$ = 1, 2, …, $N_{conf}$ and $j$ = 1, 2, …, $N_{TX}$) of the Nonreciprocal MU-MIMO BF Training Based Transmission Configuration field. The TX sector of each of $N_{TX}$ TX DMG antennas and the corresponding RX AWVs or RX DMG antennas of all associated responders used in each of $N_{conf}$ MU-MIMO transmission configurations shall be indicated in the Configuration $i$ User $k$ SISO ID Subset Index/ RX Antenna ID for Antenna $j$ subfields ($k$ = 1, 2, …, $N_{i,j}^{(u)}$, $i$ = 1, 2, …, $N_{conf}$ and $j$ = 1, 2, …, $N_{TX}$) of the Nonreciprocal MU-MIMO BF Training Based Transmission Configuration field. In more details, if User $k$ in Configuration $i$ participated in the nonreciprocal MU-MIMO BF training, the Configuration $i$ User $k$ SISO ID Subset Index/RX Antenna ID for Antenna $j$ subfield indicates the RX AWV of User $k$ corresponding to TX DMG Antenna $j$ in Configuration $i$ from a receiver's perspective. Otherwise, the Configuration $i$ User $k$ SISO ID Subset Index/RX Antenna ID for Antenna $j$ subfield indicates the RX DMG antenna of User $k$ corresponding to TX DMG Antenna $j$ in Configuration $i$.

Each MIMO BF Selection frame may include an EDMG Group ID Set element to update the MU group corresponding to the EDMG group ID indicated in the EDMG Group ID field of the MIMO Selection Control element or other MU groups.

The MU-MIMO transmission configuration to be used for MU-MIMO transmission is indicated using either a RTS frame with a control trailer or a DMG CTS-to-self frame with a control trailer at the beginning of a MU-MIMO channel access procedure (see 10.38.12.4.4 (MU-MIMO channel access procedure)).

#### 10.41.10.2.3.5 MIMO phase—reciprocal

The reciprocal MIMO procedure might shorten the MU-MIMO BF training duration. The initiator may initiate a reciprocal MIMO phase procedure if the following conditions are met:

— The Reciprocal MU-MIMO Supported field in initiator's and intended recipients' EDMG Capabilities element equals one, and

— The Antenna Pattern Reciprocity field in the initiator's DMG Capabilities element equals one.

The reciprocal MIMO phase is shown in Figure 10-115 (Reciprocal MIMO phase of MU-MIMO beamforming(11ay)) and consists of three subphases, namely, an MU-MIMO BF setup subphase, an MU-MIMO BF training subphase and an MU-MIMO selection subphase. Each subphase shall be separated by MBIFS.

Based on the feedback from the SISO phase, in the reciprocal MU-MIMO BF setup subphase the initiator may exclude some responders from the following reciprocal MU-MIMO BF training subphase. This might happen if the multiuser interference the responders are expected to suffer due to MU-MIMO transmission is negligible or if they do not support the reciprocal MU-MIMO BF training subphase. If all of the responders are excluded from the following reciprocal MU-MIMO BF training subphase, this subphase is not present in the reciprocal MIMO phase.


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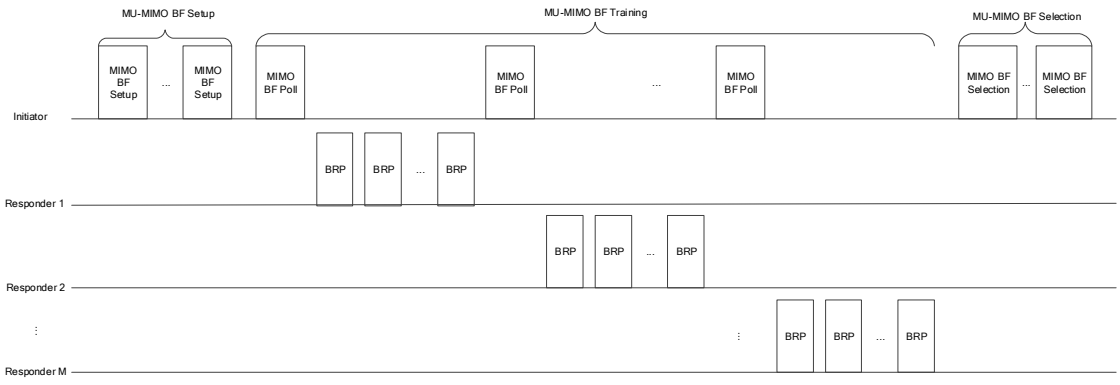


**Figure 10-115—Reciprocal MIMO phase of MU-MIMO beamforming(11ay)**

In the MU-MIMO BF setup subphase, the initiator shall transmit one or more MIMO BF Setup frame to each responder in the MU group. The initiator should transmit the minimum number of MIMO BF Setup frames to reach all responders in the MU group. The TA field of each MIMO BF Setup frame shall be set to the BSSID of the initiator and the RA field shall be set to the broadcast address. Each MIMO BF Setup frame shall indicate a unique dialog token in the Dialog Token field for identifying MU-MIMO BF training. In the MIMO Setup Control element of each MIMO BF Setup frame, all the SU/MU, Nonreciprocal/ Reciprocal MIMO Phase and Initiator fields shall be set to 1. The EDMG group ID of the MU group shall be indicated in the EDMG Group ID field and each remaining responder shall be indicated in the Group User Mask field. For channel aggregation, the Channel Aggregation Requested subfield of the MIMO FBCK-REQ field should be set to 1. A responder whose corresponding bit in the Group User Mask field of the MIMO Setup Control element included in the received MIMO BF Setup frame is equal to 0 can ignore the subsequent MU-MIMO BF training subphase.

The initiator shall initiate an MU-MIMO BF training subphase an MBIFS following the transmission of the MIMO BF Setup frame. In the MU-MIMO BF training subphase, the initiator shall transmit a MIMO BF Poll frame to each remaining responder in the MU group. The TA field of each MIMO BF Poll frame shall be set to the BSSID of the initiator and the RA field shall be set to the MAC address of the corresponding responder. Each MIMO BF Poll frame carries the dialog token in the Dialog Token field that identifies the MU-MIMO BF training. In the MIMO Poll Control element (see 9.4.2.259 (Multiple BSSID Configuration element(11ax))) of each MIMO BF Poll frame, the SU/MU and Poll Type fields shall be set to 1. The Training Duration field shall be set to the maximum duration during which EDMG BRP-RX/TX PPDUs can be transmitted by the polled responder. Additionally, in order to reduce training time, the initiator may reduce the number of TRN subfields used for receive AWV training in the following EDMG BRP-RX/TX PPDUs transmitted by each remaining responder based on the SNRs of transmit sectors collected from each remaining responder in the SISO phase. The L-TX-RX field and the Requested EDMG TRN-Unit M field shall indicate the number of TRN subfields required for receive AWV training in the following EDMG BRP-RX/TX PPDUs to be transmitted by the corresponding responder. The Requested EDMG TRN-Unit P field shall indicate the number of TRN subfields in a TRN-Unit that need to be transmitted with the same AWV as the preamble and Data fields in the following EDMG BRP-RX/TX PPDUs to be transmitted by the corresponding responder.

(#1043)A SIFS after receiving a MIMO BF Poll frame for which a remaining responder is the addressed recipient, the responder shall transmit one or more EDMG BRP-RX/TX PPDU to the initiator, where the TXVECTOR parameter EDMG_TRN_LEN is(M118) larger than zero, and the parameters RX_TRN_PER_TX_TRN, EDMG_TRN_M and EDMG_TRN_P are set to the values of the L-TX-RX field, the Requested EDMG TRN-Unit M field and the Requested EDMG TRN-Unit P field in the corresponding MIMO BF Poll frame received from the initiator, respectively. The TX Antenna Mask field of each EDMG BRP-RX/TX PPDU shall indicate the TX DMG antenna(s) that is being used by the

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responder to transmit the EDMG BRP-RX/TX PPDU. The BRP CDOWN field of each EDMG BRP-RX/TX PPDU shall indicate the number of remaining EDMG BRP-RX/TX PPDUs to be transmitted by the responder.

Each MIMO BF Poll frame and each EDMG BRP-RX/TX PPDU shall be separated by SIFS.

The initiator shall initiate the MU-MIMO BF selection subphase an MBIFS following reception of the EDMG BRP-RX/TX PPDU with the BRP CDOWN field equal to 0 from the last responder in the MU group. In the MU-MIMO BF selection subphase, the initiator shall transmit one or more MIMO BF Selection frame to each responder in the MU group. The initiator should transmit the minimum number of MIMO BF Selection frames to reach all responders in the MU group. The TA field of the MIMO BF Selection frame shall be set to the BSSID of the initiator and the RA field shall be set to the broadcast address. Each MIMO BF Selection frame contains the dialog token in the Dialog Token field for identifying the MU-MIMO training. In the MIMO Selection Control element of each MIMO BF Selection frame, the MU-MIMO Transmission Configuration Type field shall be set to 1 and the Nonreciprocal MU-MIMO BF Training Based Transmission Configuration field shall not be present. The EDMG group ID corresponding to the MU group shall be indicated in the EDMG Group ID field and the number of MU-MIMO transmission configurations, $N_{conf}$, shall be indicated in the Number of MU-MIMO Transmission Configurations field.

Which responder(s) in the MU group is associated with each of $N_{TX}$ TX DMG antennas for each of $N_{conf}$ MU-MIMO transmission configurations shall be indicated in the Configuration *i* Group User Mask for Antenna *j* subfields ($i$ = 1, 2, …, $N_{conf}$ and $j$ = 1, 2, …, $N_{TX}$) of the Reciprocal MU-MIMO BF Training Based Transmission Configuration field. The RX AWVs or RX DMG antennas of all responders associated with each of $N_{TX}$ TX DMG antennas used in each of $N_{conf}$ MU-MIMO transmission configurations shall be indicated in the Configuration *i* User *k* AWV feedback ID for Antenna *j* subfields, the Configuration *i* User *k* BRP CDOWN for Antenna *j* subfield and the Configuration *i* User *k* RX Antenna ID for Antenna *j* subfields ($k$ = 1,2, …, $N_{i,j}^{(u)}$, $i$ = 1, 2, …, $N_{conf}$ and $j$ = 1, 2, …, $N_{TX}$) of the Reciprocal MU-MIMO BF Training Based Transmission Configuration field. In more details, if User *k* in Configuration *i* participated in the reciprocal MU-MIMO BF training, the Configuration *i* User *k* AWV feedback ID for Antenna *j* subfield, the Configuration *i* User *k* BRP CDOWN for Antenna *j* subfield and the Configuration *i* User *k* RX Antenna ID for Antenna *j* subfield indicate the RX AWV of User *k* corresponding to TX DMG Antenna *j* in Configuration *i* from a receiver's perspective. Otherwise, the Configuration *i* User *k* AWV feedback ID for Antenna *j* subfield and the Configuration *i* User *k* BRP CDOWN for Antenna *j* subfield are reserved and the Configuration *i* User *k* RX Antenna ID for Antenna *j* subfield indicates the RX DMG antenna of User *k* corresponding to TX DMG Antenna *j* in Configuration *i*.

#### 10.41.10.2.4 Hybrid beamforming for SU-MIMO and MU-MIMO

##### 10.41.10.2.4.1 General

An EDMG STA is hybrid beamforming capable if either (or both) of the Hybrid Beamforming and SU-MIMO Supported subfield or the Hybrid Beamforming and MU-MIMO Supported subfield in the STA's EDMG Capabilities element is equal to 1. A hybrid beamforming capable STA is hybrid beamforming and SU-MIMO capable if the Hybrid Beamforming and SU-MIMO Supported subfield in the STA's EDMG Capability element is equal to 1. A hybrid beamforming capable STA is hybrid beamforming and MU-MIMO capable if the Hybrid Beamforming and MU-MIMO Supported subfield in the STA's EDMG Capability element is equal to 1. A hybrid beamforming capable STA may be hybrid beamforming and SU-MIMO capable, hybrid beamforming and MU-MIMO capable or both. A hybrid beamforming capable STA supports the hybrid beamforming protocol described in this subclause.

Hybrid beamforming is the transmission and reception of multiple spatial streams using a combination of analog beamforming (by determining appropriate AWVs) and digital beamforming (by determining appropriate spatial mapping matrices) between an SU-MIMO capable initiator and an SU-MIMO capable


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responder or between an MU-MIMO capable initiator and one or more MU-MIMO capable responders. The spatial mapping matrices are determined based on the DMG antenna configuration selected as a result of the SU-MIMO or MU-MIMO beamforming protocol.

The hybrid beamforming protocol supports digital baseband training and hybrid beamforming information feedback for subsequent hybrid beamforming transmission.

The hybrid beamforming protocol can also be used to support the transmission of a single spatial stream using multiple DMG antennas with a combination of analog beamforming and digital beamforming between an SU-MIMO capable initiator and an SU-MIMO capable responder.

The AWVs of the DMG antennas may be selected using the SU-MIMO beamforming protocol (10.41.10.2.2 (SU-MIMO beamforming)) or MU-MIMO beamforming protocol (10.41.10.2.3 (MU-MIMO beamforming)), which enable the determination of the antenna configuration for the simultaneous transmission of single or multiple spatial streams from an initiator to responder(s) (or vice versa in the case of SU-MIMO).

The relationship between a transmitted signal, $\boldsymbol{x}$, and a received signal, $\boldsymbol{Y}$, in a hybrid beamforming transmission (in a flat channel or single frequency bin) can be represented as follows:

$$\boldsymbol{Y}_{i,j} = \boldsymbol{Q}_{Br,i,j}\,\boldsymbol{H}_{BB,i,j}\boldsymbol{Q}_{Bt,i}\boldsymbol{x}_i + \boldsymbol{Q}_{Br,i,j}\boldsymbol{Q}_{Ar,j}\boldsymbol{n}_{i,j} \;;\; \boldsymbol{H}_{BB,i,j} = \boldsymbol{Q}_{Ar,j}\boldsymbol{H}_{i,j}\,\boldsymbol{Q}_{At}$$

where

$\boldsymbol{H_{i,j}}$ is the channel between the transmit DMG antennas and receive DMG antennas of the $j^{th}$ STA in an MU-MIMO transmission

$\boldsymbol{n_{i,j}}$ is additive white noise at the receiver of the $j^{th}$ STA in an MU-MIMO transmission

$\boldsymbol{H_{BB,i,j}}$ is the effective baseband channel at the receiver of the $j^{th}$ STA in an MU-MIMO transmission, i.e., the channel observed by the baseband processor of the receiver when including the effect of their DMG antennas at the transmitter and receiver

$\boldsymbol{Q_{At}}$ is the $N_{TX,A} \times N_{TX}$ response of the DMG antennas of the transmitter

$\boldsymbol{Q_{Ar,j}}$ is the $N_{RX,j} \times N_{RX,j,A}$ response of the DMG antennas at the receiver of the $j^{th}$ STA in an MU-MIMO transmission

$\boldsymbol{Q_{Bt,i}}$ is the $N_{TX} \times N_{STS}$ transmit spatial mapping matrix

$\boldsymbol{Q_{Br,i,j}}$ is the $N_{STS,j} \times N_{RX,j}$ receive equalizer at the receiver of the $j^{th}$ STA in an MU-MIMO transmission

$\boldsymbol{x_i}$ is the transmitted SU-MIMO or MU-MIMO signal

$\boldsymbol{i}$ is the subcarrier index; for an EDMG SC mode PPDU transmission, $i = 0$; for an EDMG OFDM mode PPDU transmission, $-N_{SR} \le i \le N_{SR}$

$\boldsymbol{j}$ is index of $j^{th}$ STA in an MU-MIMO transmission; for an SU-MIMO transmission, $j = 0$

In the hybrid beamforming protocol, the transmitter acquires hybrid beamforming information based on feedback from the receiver derived from the channel in the direction between the transmitter and receiver.

The hybrid beamforming protocol comprises the following phases:

— Announcement phase: optional if the configuration has been previously set
— Sounding phase
— Feedback phase

On completion of the hybrid beamforming protocol, a hybrid beamforming transmission may take place.

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For an EDMG SU PPDU to which hybrid beamforming is applied, $\boldsymbol{Q}_{Bt,i}$ is a transmit spatial mapping matrix and is derived from the TXVECTOR parameter EXPANSION_MAT with enumerated type NON_COMPRESSED_SV or CSI_MATRICES. For an EDMG MU PPDU to which hybrid beamforming is applied, $\boldsymbol{Q}_{Bt,i}$ is a transmit spatial mapping matrix and is derived from the TXVECTOR parameter EXPANSION_MAT with enumerated type COMPRESSED_SV. The transmit spatial mapping matrices are implementation dependent.

#### 10.41.10.2.4.2 Announcement phase—general

The hybrid beamforming protocol announcement phase uses an announcement and optional announcement acknowledgment frame exchange to enable the initiator and responder(s) to set up their DMG antenna configurations to the desired transmit and receive antenna sectors and to indicate the start of the hybrid beamforming protocol.

If the initiator and responder are already in the correct configuration and have previously set up their hybrid beamforming protocol information, the announcement phase is optional.

The parameters governing the hybrid beamforming protocol, such as feedback type and the hybrid beamforming protocol feedback parameters, are signaled during the sounding phase.

For more specifics about the announcement phase, see 10.41.10.2.4 (Hybrid beamforming for SU-MIMO and MU-MIMO) for SU-MIMO and MU-MIMO.

#### 10.41.10.2.4.3 Announcement phase for SU-MIMO

For SU-MIMO, the announcement and announcement acknowledgment for the hybrid beamforming protocol may use

— A Grant frame as the announcement frame and a Grant Ack frame as the announcement acknowledgment frame with a control trailer for signaling the transmission configuration to be used or

— An RTS frame as the announcement and a DMG CTS frame as the announcement acknowledgment frame with a control trailer for signaling the transmission configuration to be used.

The procedure is detailed in 10.38.12.4.3 (SU-MIMO channel access procedure).

#### 10.41.10.2.4.4 Announcement phase for MU-MIMO

Prior to the start of hybrid beamforming training with a set of responder STAs within an MU group, the initiator shall

— Indicate the MU group within the EDMG Group ID Set element and communicate the resulting element to the STAs in the BSS (see 10.41.10.2.3 (MU-MIMO beamforming)) and

— Perform MU-MIMO beamforming with the responders of the MU group (see 10.41.10.2.3 (MU-MIMO beamforming)).

For MU-MIMO, the announcement and announcement acknowledgment for the hybrid beamforming protocol may use

— An RTS as the announcement frame and simultaneous DMG CTS frames as the announcement acknowledgment frame with a control trailer for signaling the transmission configuration or

— A DMG CTS-to-self frame as the announcement frame with a control trailer for signaling the transmission configuration.

The procedure is detailed in 10.38.12.4.4 (MU-MIMO channel access procedure).


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#### 10.41.10.2.4.5 Sounding phase

In the sounding phase of the hybrid beamforming training protocol, the initiator (or responder) may send TRN fields to the responder (initiator) to measure the baseband channel. The TRN fields may be sent during the BRP phase (see 10.41.3 (Beam Refinement Protocol (BRP) phase)) or during the beam tracking phase (see 10.41.7 (Beam tracking)). A transmitter (initiator or responder) that desires to sound the baseband channel shall initiate initiator transmit beam refinement (see 10.41.3 (Beam Refinement Protocol (BRP) phase)) or initiator transmit beam tracking (see 10.41.7 (Beam tracking)). For more information about hybrid beamforming sounding with BRP frames, see 10.41.10.2.4 (Hybrid beamforming for SU-MIMO and MU-MIMO). For more information about hybrid beamforming sounding with tracking, see 10.41.10.2.4 (Hybrid beamforming for SU-MIMO and MU-MIMO).

The spatial mapping matrix, $Q$, for transmission that uses digital beamforming should be computed using the last analog combination decided between a pair of STAs (that is, on the current AWVs used by the STAs).

The transmitter shall use BRP sounding immediately after the hybrid beamforming protocol announcement or when the DMG antenna configuration or the digital beamforming feedback may need to be modified. The transmitter may use BRP or digital baseband beam tracking when DMG antenna configuration and the digital beamforming feedback are unchanged.

NOTE—The transmitter described above is the STA that sends the TRN field and can be the initiator or the responder.

For transmit beam refinement, the BRP frames indicate the TRN configuration and the type of feedback requested, and TRN fields are appended to the BRP frames to enable sounding.

For digital beam tracking, the TRN fields to enable sounding are appended to the initiator frames based on indications in the PHY header. The feedback for the digital beam tracking procedure should be the feedback negotiated in the most recent BRP sounding.

The Digital BF Request field in the EDMG BRP Request element shall be set to 1 to indicate that sounding for digital BF is requested.

For the EDMG SC mode, the DBF FBCK REQ field in the DMG Beam Refinement element shall be set to 0 to indicate MIMO channel measurement feedback, and set to 1 to indicate digital beamforming matrix feedback. For the EDMG OFDM mode, the DBF FBCK REQ field shall always be set to 1 to indicate digital beamforming matrix feedback.

For the EDMG SC mode, the number of taps requested during MIMO channel measurement or digital beamforming matrix feedback shall be set in the Number of Taps Requested field in the DMG Beam Refinement element.

#### 10.41.10.2.4.6 Hybrid beamforming sounding with BRP frame(s)

The hybrid beamforming sounding with BRP frames is performed as follows:

a) **SU-MIMO sounding (for both initiator and responder).** The initiator shall initiate the sounding phase a SIFS following reception of the announcement acknowledgment frame (see 10.41.10.2.4 (Hybrid beamforming for SU-MIMO and MU-MIMO)) from the responder. In the initiator sounding subphase, the initiator shall transmit an EDMG BRP-TX PPDU to the responder. The EDMG BRP-TX PPDU shall include a BRP frame with an EDMG BRP Request element with the Digital BF Request field set to 1 indicating a request for performing digital beamforming, and the Feedback Type field set to 0 for SU transmission. The Nc Index field is reserved. The EDMG BRP-TX PPDU shall use the TX sector combination selected in the announcement phase in the transmission of the TRN subfield. In the EDMG BRP-TX PPDU, the TXVECTOR parameter EDMG_TRN_LEN shall be set to a value greater than 0, the parameter RX_TRN_PER_TX_TRN shall be set to 0, the

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parameter NUM_TX_CHAINS shall be set to the number of TX antennas in the TX sector combination and the parameter EDMG_TRN_M shall be set to values based on the desired configuration. The TX Antenna Mask field within the EDMG BRP-TX PPDU shall indicate the transmit DMG antenna(s) that is being used by the initiator to transmit the EDMG BRP-TX PPDU. The same AWV combination shall be maintained during the transmission of the PPDU, including the TRN field.

If the responder indicates that it is going to use SU-MIMO in the opposite direction (from the responder to the initiator) and requests hybrid beamforming training during the announcement phase, the initiator and responder shall delay sending feedback until after the responder completes the sounding phase. The responder shall initiate the responder sounding subphase a SIFS following the reception of an EDMG BRP-TX PPDU from the initiator. In the responder sounding subphase, the responder shall transmit an EDMG BRP-TX PPDU to the initiator. The EDMG BRP-TX PPDU shall include a BRP frame with an EDMG BRP Request element with the Digital BF Request field set to 1 indicating a request for performing digital beamforming, and the Feedback Type field set to 0 for SU transmission. The Nc Index field is reserved. The EDMG BRP-TX PPDU shall use the TX sector combination selected in the announcement phase in the transmission of the TRN subfield. In the EDMG BRP-TX PPDU, the TXVECTOR parameter EDMG_TRN_LEN shall be set to a value greater than 0, the parameter RX_TRN_PER_TX_TRN shall be set to 0, the parameter NUM_TX_CHAINS shall be set to the number of TX antennas in the TX sector combination and the parameter EDMG_TRN_M shall be set to values based on the desired configuration. The TX Antenna Mask field within the EDMG BRP-TX PPDU shall indicate the transmit DMG antenna(s) that is being used by the responder to transmit the EDMG BRP-TX PPDU. The same AWV combination shall be maintained during the transmission of the PPDU, including the TRN field.

In the case that only the initiator requested sounding, the responder shall not send the EDMG BRP-TX PPDU.

Figure 10-116 (Example of frame exchange sequence(#109) using SU-MIMO hybrid beamforming protocol(11ay))illustrates an example of a frame exchange sequence using the SU-MIMO hybrid beamforming protocol.

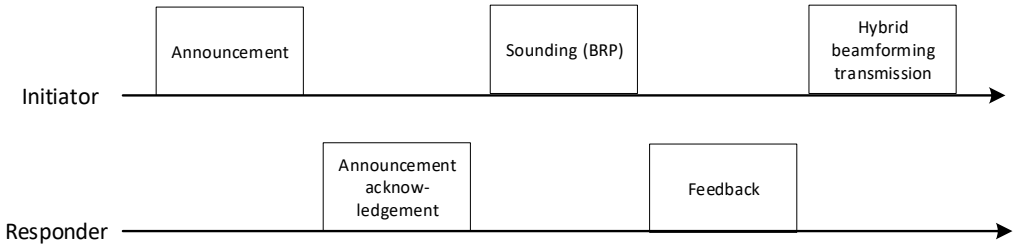


**Figure 10-116—Example of frame exchange sequence(#109) using SU-MIMO hybrid beamforming protocol(11ay)**

b) **MU-MIMO sounding (for initiator).** The initiator shall initiate the hybrid beamforming sounding subphase a SIFS following the reception of the announcement acknowledgment frame(s) from the responder(s), if required, or immediately following the transmission of the DMG CTS-to-self frame from the initiator. In the hybrid beamforming sounding subphase, the initiator shall transmit an EDMG BRP-TX PPDU to the responders in the MU group. The EDMG BRP-TX PPDU shall include a BRP frame with an EDMG BRP Request element with the Digital BF Request field set to 1 indicating a request for performing digital beamforming, and the Feedback Type field set to 1 for MU transmission. For digital beamforming feedback in the EDMG OFDM mode, the Nc Index field is set to the number of columns, *Nc*, in the compressed beamforming feedback matrix minus 1. The RA field in the BRP frame shall be set to the broadcast address. The EDMG BRP-TX PPDU shall use the TX sector combination selected in the announcement phase in the transmission of the whole TRN subfield. In the EDMG BRP-TX PPDU, the TXVECTOR parameter


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EDMG_TRN_LEN shall be set to a value greater than 0. The TXVECTOR parameter RX_TRN_PER_TX_TRN shall be set to 0 and the parameter EDMG_TRN_M shall be set to a value based on the desired configuration. The TX Antenna Mask field within the EDMG BRP-TX PPDU shall indicate the TX DMG antenna(s) that is being used by the initiator to transmit the EDMG BRP-TX PPDU.

#### 10.41.10.2.4.7 Hybrid beamforming sounding with tracking

SU-MIMO tracking may take place after the establishment of a hybrid beamforming link. The combination of an announcement with BRP sounding is used to establish the antenna configuration and feedback parameters to perform tracking.

To perform tracking, the initiator shall transmit an EDMG PPDU setting up an EDMG initiator transmit beam tracking (see 10.41.7 (Beam tracking)) to the responder(s). The antenna configuration and feedback parameters used shall be based on the most recent BRP sounding parameters.

#### 10.41.10.2.4.8 Feedback phase

The feedback phase is used by the hybrid beamforming protocol to feed back the hybrid beamforming information to the transmitter for use in a subsequent hybrid beamforming transmission.

The feedback is carried in the MIMO BF Feedback frame and its contents are as follows:

— For the EDMG SC mode, when the BRP frame used during the sounding phase has the DBF FBCK REQ field equal to 1 within the DMG Refinement element, the MIMO BF Feedback frame contains the Digital BF Feedback element carrying the digital beamforming matrix information. When DBF FBCK REQ field equal to 0, the MIMO BF Feedback frame contains the Channel Measurement Feedback element and the EDMG Channel Measurement Feedback element.

— For the EDMG OFDM mode, the MIMO BF Feedback frame contains the Digital BF Feedback element carrying the digital beamforming matrix information.

The feedback may be based on fixed grouping of the subcarriers with *Ng* = 2, 4 or 8 or the feedback may be based on dynamic grouping of the subcarriers in which the distance between the subcarriers may vary based on the characteristics of the channel fed back. (#2328)In dynamic grouping, the selection of subcarriers that are fed back targets minimization of the reconstruction error at the STA receiving the feedback. These are illustrated in Figure 10-117 (Example of EDMG OFDM mode dynamic feedback(11ay)).

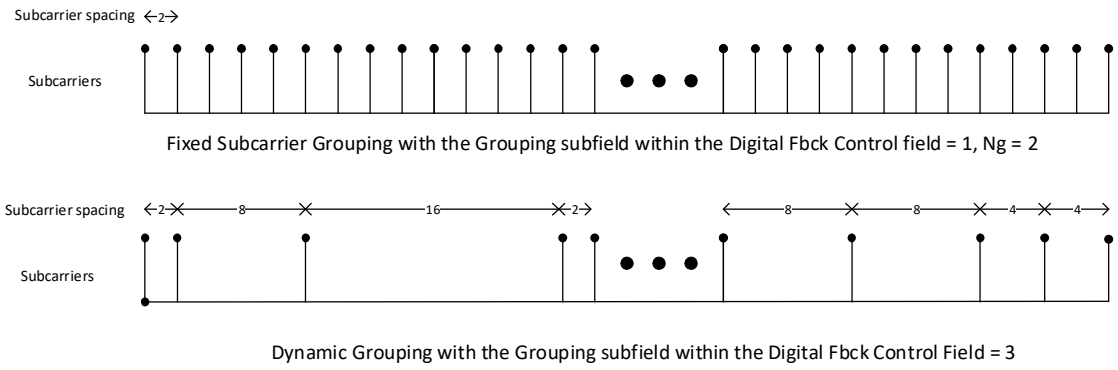


**Figure 10-117—Example of EDMG OFDM mode dynamic feedback(11ay)**

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The capabilities governing the subcarrier grouping of an EDMG STA whose feedback is in the EDMG OFDM mode are contained in the Largest Ng Supported field and the Dynamic Grouping Supported field in the Beamforming Capability subelement of a STA's EDMG Capabilities element.

An EDMG STA shall not transmit digital BF feedback with a subcarrier grouping value larger than that in the Largest Ng Supported field indicated by the STA receiving the feedback. An EDMG STA shall not transmit digital BF feedback using dynamic grouping if the STA receiving the feedback indicates that it does not support dynamic grouping.

The SU-MIMO feedback and MU-MIMO feedback are performed as follows:

a) **SU-MIMO feedback.** If hybrid beamforming training is requested from the initiator to the responder only, the responder shall initiate the feedback phase a SIFS following the reception of an EDMG BRP-TX PPDU from the initiator with the BRP CDOWN field equal to 0.

If hybrid beamforming training is requested from the initiator to the responder and from the responder to the initiator during the announcement phase, the initiator shall commence feedback to the responder a SIFS following the reception of an EDMG BRP-TX PPDU from the initiator with the BRP CDOWN field equal to 0. The responder shall then commence feedback to the initiator a SIFS following the reception of the feedback from the initiator.

An exemplary procedure is shown in Figure 10-118 (Example of frame exchange sequence(#109) using SU-MIMO hybrid beamforming protocol(11ay)).

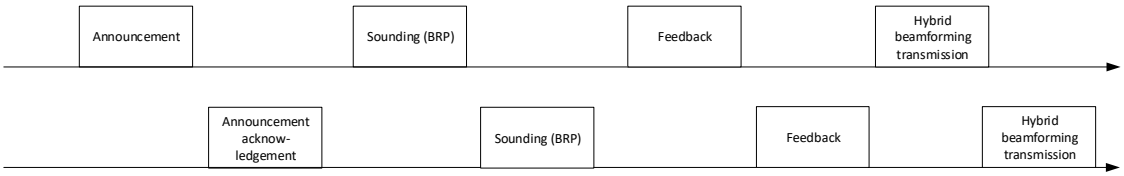


**Figure 10-118—Example of frame exchange sequence(#109) using SU-MIMO hybrid beamforming protocol(11ay)**

b) **MU-MIMO feedback.** The initiator shall initiate the MU-MIMO beamforming feedback subphase an MBIFS following the transmission of an EDMG BRP-TX PPDU with the BRP CDOWN field set to 0. In the MU-MIMO beamforming feedback subphase, the initiator shall transmit a MIMO BF Poll frame to poll each remaining responder to collect hybrid beamforming MU-MIMO feedback from the preceding MU-MIMO sounding subphase. The TA field of each MIMO BF Poll frame shall be set to the MAC address of the initiator and the RA field shall be set to the MAC address of the corresponding responder. Each MIMO BF Poll frame carries the dialog token in the Dialog Token field that identifies the MU-MIMO BF sounding. In the MIMO Poll Control element of each MIMO BF Poll frame, the SU/MU field shall be set to 1 and the Poll Type field shall be set to 0.

(#1044)A SIFS after receiving a MIMO BF Poll frame for which a responder is the addressed recipient, the responder shall transmit a MIMO BF Feedback frame which contains a Digital BF Feedback element to the initiator. The RA field of the MIMO BF Feedback frame shall be set to the MAC address of the initiator and the TA field shall be set to the MAC address of the responder. The MIMO BF Feedback frame carries the dialog token in the Dialog Token field that identifies the MU-MIMO sounding. In the MIMO Feedback Control element of the MIMO BF Feedback frame, the SU/MU field shall be set to 1 and the Link Type field shall be set to 0. If the MIMO BF Feedback frame contains a Digital BF Feedback element, the ComeBack Delay field shall be set to 0. Otherwise, the ComeBack Delay field shall be set to a nonzero value that indicates when the responder is ready with the Digital BF Feedback. If the ComeBack Delay field is(M118) 0 and for a 2.16+2.16 GHz or 4.32+4.32 GHz channel, the Channel Aggregation Present subfield of the MIMO FBCK-TYPE field shall be set to 1. If the ComeBack Delay field is(M118) a nonzero value, the Channel Aggregation Present subfield of the MIMO FBCK-TYPE field shall be set to 0.


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An exemplary procedure is shown in Figure 10-119 (Example of frame exchange sequence(#109) using MU-MIMO hybrid beamforming protocol(11ay)).

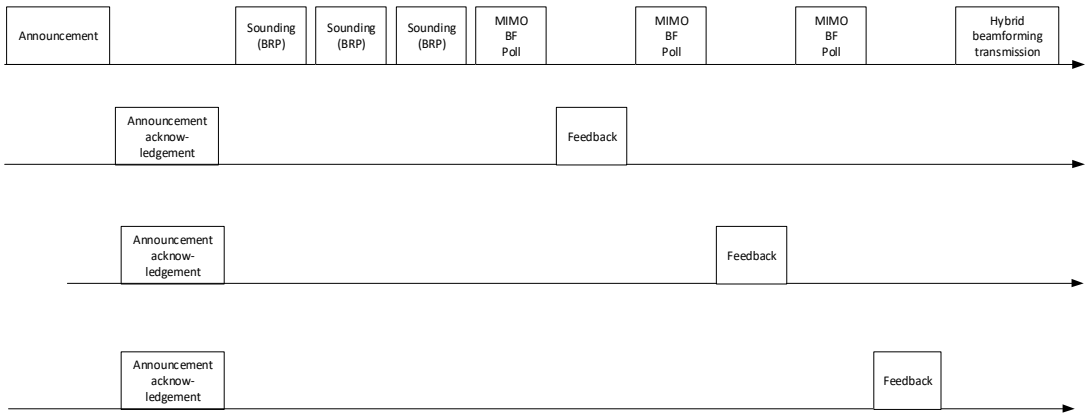


**Figure 10-119—Example of frame exchange sequence(#109) using MU-MIMO hybrid beamforming protocol(11ay)**

### 10.41.10.3 Beamforming for asymmetric links

#### 10.41.10.3.1 General

(#4047)For the purposes of EDMG operation, an asymmetric link is present between a pair of STAs when in one STA the difference between the maximum receive antenna gain and the quasi-omni receive antenna gain is higher than 15 dB, while for the other STA this difference is at most 15 dB.

NOTE—As specified in 20.9.1 (Beamforming concept), 15 dB is the sensitivity difference between the DMG control mode and the DMG SC mode for a PHY data rate greater than 1 Gb/s. When the difference between the full gain receive antenna setting and the quasi-omni receive antenna setting is higher than 15 dB, a STA might be able to receive a PPDU at full gain using the DMG SC mode at a range higher than in a quasi-antenna receive setting using the DMG control mode when the same antenna setting is used by the STA that transmits the PPDU.

The procedure defined in this subclause enables an initiator and a responder that would otherwise have an asymmetric link if a quasi-omni antenna configuration were to be used for communication between them, to perform beamforming according to the procedure described in this subclause. Following the successful establishment of the beamformed link, all frame exchange sequences(#109) between the STAs take place using the established beamformed link. STAs may determine whether to perform asymmetric beamforming according to the "Near-Far" self classification described in 10.38.12.6 ("Near-Far" self classification).

The procedure defined in this subclause requires that the DMG Antenna Reciprocity and Antenna Pattern Reciprocity subfields within the DMG STA Capability Information field of the initiator and responder are both set to 1.

#### 10.41.10.3.2 Scheduling during the BTI

To enable beamforming for asymmetric links, a PCP or AP shall

— In the PPDU containing a DMG Beacon frame transmitted in a BTI through the sector for which the asymmetric beamforming training is considered to be performed, include TRN-R subfields within the TRN field of the PPDU as specified in 10.41.4 (Beamforming in BTI).

— Include an EDMG Extended Schedule element in each DMG Beacon frame that is transmitted in the step above. The EDMG Extended Schedule element shall include at least one allocation that has the Asymmetric Beamforming Training subfield for the allocation set to 1. The duration of this allocation shall be at least

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$N_{STS} \times aSTSTime + MBIFS + aAirPropagationTime + TXTIME(Sector\ Ack)$

where

| | |
|---|---|
| $N_{STS}$ | is the value of the Number of Space-time Slots subfield in the EDMG Extended Schedule element describing this allocation. |
| *aSTSTime* | is the duration a space-time slot defined in 10.41.10.3.3 (Beamforming training allocation in DTI). |
| *TXTIME*(*Sector Ack*) | is the transmission time of a Sector Ack frame, assuming there are $N_{STS}$ Sector Ack subfields in the Sector Ack frame. |

A PCP or AP shall not include in a DMG Beacon frame an EDMG Extended Schedule element including an allocation that has the Asymmetric Beamforming Training subfield for the allocation equal to 1 without inserting TRN-R subfields in the TRN field of the PPDU containing the DMG Beacon.

A non-PCP and non-AP STA receiving a DMG Beacon frame with appended TRN-R fields and that executes the beamforming procedure described in this subclause shall use the TRN-R fields to perform receive beamforming as specified in 10.41.2 (Sector-level sweep (SLS) phase). The STA may then use one or more of the allocations announced in the EDMG Extended Schedule element that have the Asymmetric Beamforming Training subfield equal to 1 (see 9.4.2.266 (EDMG Extended Schedule element(11ay))) to perform the procedure specified in 10.41.10.3.3 (Beamforming training allocation in DTI). The STA should select the asymmetric beamforming allocation which corresponds to the DMG Beacon frame received with the best quality in the BTI. The determination of which DMG Beacon frame was received with the best quality is implementation dependent.

### 10.41.10.3.3 Beamforming training allocation in DTI

A beamforming training allocation in the DTI is scheduled through the EDMG Extended Schedule element. A beamforming training allocation has the Asymmetric Beamforming Training subfield for the allocation equal to 1. Channel access during a beamforming training allocation is as follows:

— The PCP or AP (i.e., the initiator) shall listen on the combination of sector and DMG antenna that was used for transmission of the DMG Beacon frame describing this allocation during the last BTI. The PCP or AP shall listen for $N_{STS}$ space-time slots for any responder's transmission, where $N_{STS}$ is the value of the Number of Space-time Slots subfield describing the allocation. A space-time slot has a duration of aAirPropagationTime + TXTIME(SSW) + aSIFSTime, where aAirPropagationTime accounts for the propagation delay between the initiator and the responder.

— At the start of the allocation, the responder(s) shall invoke a random backoff procedure to transmit an SSW frame. The random backoff procedure begins at the start of the beamforming training allocation with the responder selecting a backoff count as a random integer drawn from a uniform distribution [0, $N_{STS}$), i.e., 0 to $N_{STS} - 1$. The responder shall decrement the backoff count by one at the end of each space-time slot, even if the CS function at the responder indicates the medium busy condition for that space-time slot. The responder may transmit the SSW frame only at the start of the space-time slot for which the backoff count is 0 at the beginning of the space-time slot. The responder's transmission is performed in directional mode using a transmit DMG antenna and sector corresponding to the receive DMG antenna and sector trained by the TRN-R subfields received in the last BTI.

— A responder may transmit more than one consecutive SSW frame within one beamforming training allocation, but shall not exceed the maximum number of space-time slots a responder can occupy as given by $2^{Nmax\ STS}$, where *Nmax STS* is the value of the Nmax STS subfield describing the allocation.

— After transmitting the SSW frame(s), the responder switches to directional receive in the sector trained by TRN-R in the last BTI.


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— MBIFS after the PCP or AP completes listening for $N_{STS}$ space-time slots, the initiator shall transmit a Sector Ack frame on the same combination of sector and DMG antenna that was used for listening. The Sector Ack frame contains the information about the STAs that have been identified during the allocation. In case several SSW frames have been received from a STA, the Sector Ack refers to the SSW frame that was received with the best quality. The determination of which frame was received with the best quality is implementation dependent.

— A responder that transmits an SSW frame during a beamforming training allocation, but that does not receive a Sector Ack frame in response, may repeat the attempt to perform asymmetric beamforming training during the next beamforming training allocation.

An example of beamforming training for asymmetric links of three EDMG STAs and an EDMG PCP or EDMG AP is shown in Figure 10-120 (Example of beamforming training for asymmetric links in beamforming training allocation(11ay)). In the example, the AP or PCP allocates a dedicated SP to perform the asymmetric beamforming training, which consists of sequential listening on each sector, followed by the Sector Ack transmissions by the PCP or AP. STA#1 selects the second (out of four) space-time slot and transmits the SSW frame with a beamforming link determined by the TRN-R appended during the last BTI. STAs #2 and #3 choose the same third space-time slot and transmit SSW frames, which results in a collision. MBIFS after the fourth space-time slot, (#1414)the AP transmits a Sector Ack frame that includes information about all STAs from which SSW frames were received: STA#1 and either one of STAs #2 or #3 or none of them. If after the reception of the Sector Ack frame a STA cannot find itself in the list of identified STAs, it may retry to perform asymmetric beamforming training during the next beamforming training allocation for this sector. A STA can attempt to receive the Sector Ack frame using either a directional or a quasi-omni antenna pattern.

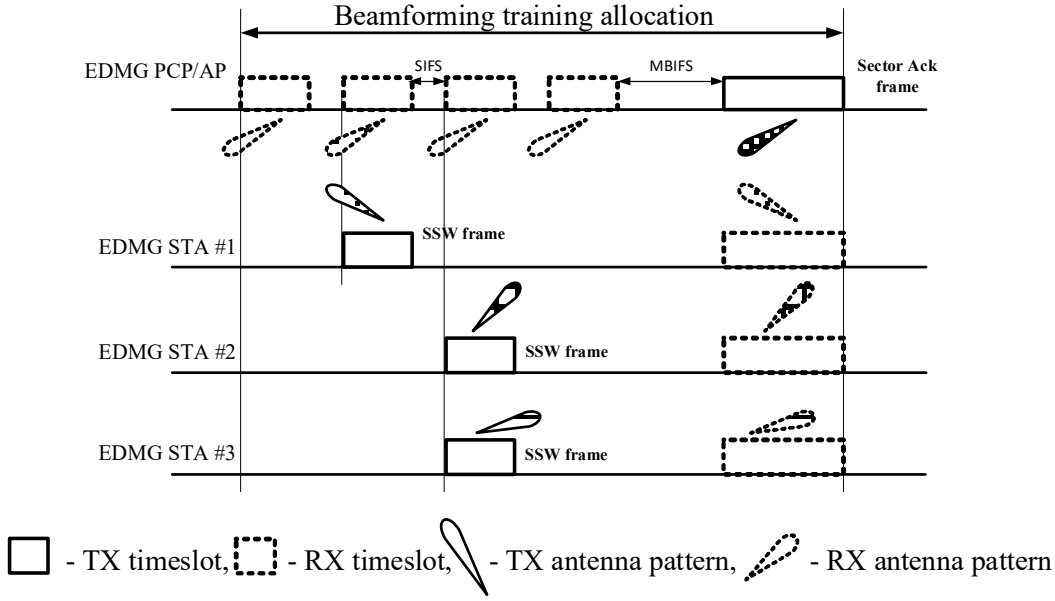


**Figure 10-120—Example of beamforming training for asymmetric links in beamforming training allocation(11ay)**

Following the successful completion of the beamforming training, the AP or PCP can schedule directional allocations for data exchange with the non-PCP and non-AP STA (see 10.38.12.3 (Directional allocation)).

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#### 10.41.10.4 Group beamforming

An initiator that is an AP or PCP may simultaneously train a group of responder STAs that have antenna pattern reciprocity. This is referred to as group beamforming and, if performed, takes place in the BTI of a beacon interval. In group beamforming, the initiator trains its transmit antennas and sectors while a group of responders train their receive antennas and sectors. A DMG STA supports antenna pattern reciprocity if the value of the Antenna Pattern Reciprocity field in the STA's DMG Capabilities element is 1.

To perform group beamforming, an AP or PCP shall, as specified in 10.41.4 (Beamforming in BTI), include TRN-R subfields within the TRN field of each PPDU containing a DMG Beacon frame transmitted in a BTI. This is done by

— Setting the TXVECTOR parameter EDMG_TRN_LEN to a value greater than 0. The value of this parameter should be based on the maximum number of receive sectors and antennas across all intended responders; and
— Setting the TXVECTOR parameter EDMG_PPDU_TYPE to EDMG-TRN-R.

If the number of TRN-R subfield is smaller than a responder(s)' receive sectors and antennas, the responder(s) may train selected receive sectors and antennas with the available TRN-R subfields and may continue to train the other receive sectors and antennas with a subsequent DMG Beacon frame transmitted by the same transmit sector and with TRN-R subfields appended. Through reception of these TRN-R subfields, responders can determine the initiator's transmit antenna(s) and sector(s) that were received with the best quality and, given antenna pattern reciprocity, the responders can also determine their corresponding transmit antenna(s) and sector(s) with the best quality.

If the responder detects a change in the initiator's best TX antenna and sector, the responder may inform the AP or PCP of the change by transmitting an unsolicited Information Response frame to the AP or PCP containing an EDMG Channel Measurement Feedback element with an updated list of antenna and sector pairs.

#### 10.41.10.5 BRP transmit sector sweep (BRP TXSS)

##### 10.41.10.5.1 General

Beam refinement protocol transmit sector sweep (BRP TXSS) is a procedure that allows EDMG STAs to determine improved antenna configurations for transmission and reception. The procedure is performed with the use of BRP frames, and consists of various phases of transmit sector sweep and receive training.

In BRP TXSS, the STA that initiates the procedure through the transmission of a BRP frame is referred to as the initiator, and the recipient STA of the BRP frame that participates in a BRP TXSS with the initiator is referred to as the responder.

In the BRP TXSS procedure, a BRP frame with acknowledgment is defined as a BRP frame that has the TX-TRN-OK field within the DMG Beam refinement element set to 1.

BRP TXSS may include as many as six phases: setup phase, transmit training phase by the initiator with feedback (referred to as Initiator BRP TXSS), receive training phase of the responder, transmit training phase by the responder with feedback (referred to as Responder BRP TXSS), receive training phase of the initiator, and acknowledgment phase. A BRP TXSS shall include a setup phase, an Initiator BRP TXSS, and an acknowledgment phase. As defined in 10.41.10.5.2 (BRP TXSS configuration), receive training for responder, Responder BRP TXSS, and receive training for initiator are included in a BRP TXSS depending on whether the procedure is a SISO BRP TXSS or a MIMO BRP TXSS and, for a SISO BRP TXSS, on reciprocity characteristics of the initiator and the responder.


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An example of BRP TXSS is shown in Figure 10-121 (BRP TXSS when comprising all six phases(11ay)) for the case when the procedure is comprised of all six phases. In Figure 10-121 (BRP TXSS when comprising all six phases(11ay)) and in the remainder of 10.41.10.5 (BRP transmit sector sweep (BRP TXSS)):

— $N_{init}$ is the value of the TXSS-PPDUs subfield within the EDMG BRP Request element in the BRP frame sent by the initiator to start the BRP TXSS.
— $R_{init}$ is the value of the TXSS-REPEAT subfield within the EDMG BRP Request element in the BRP frame sent by the initiator to start the BRP TXSS.
— $N_{resp}$ is the value of the TXSS-PPDUs subfield within the EDMG BRP Request element in the BRP frame sent by the responder to confirm the procedure.
— Rresp is the value of the TXSS-REPEAT subfield within the EDMG BRP Request element in the BRP frame sent by the responder to confirm the procedure.

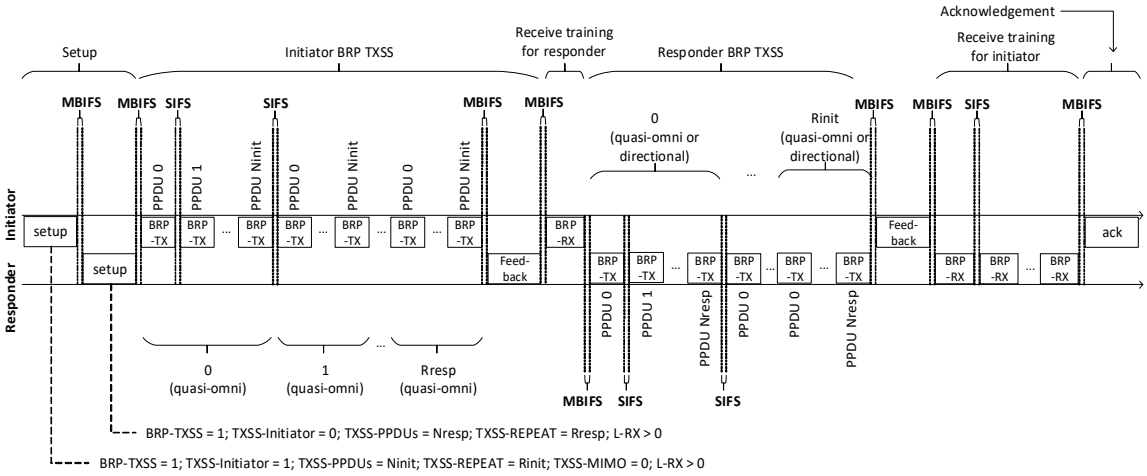


**Figure 10-121—BRP TXSS when comprising all six phases(11ay)**

As shown in Figure 10-121 (BRP TXSS when comprising all six phases(11ay)) and as defined in 10.41.10.5.3 (BRP TXSS execution), the setup phase consists of the transmission of a BRP frame that requests BRP TXSS by the initiator followed by the transmission of a BRP frame that confirms the procedure by the responder. After receiving confirmation of the BRP TXSS request from the responder, the initiator performs an Initiator BRP TXSS. As defined in 10.41.10.5.2 (BRP TXSS configuration), in an Initiator BRP TXSS the initiator transmits $N_{init}$ + 1 EDMG BRP-TX PPDUs consecutively $R_{resp}$ + 1 times, and the same DMG antenna or set of DMG antennas is used by the responder when receiving the TRN field of all $N_{init}$ + 1 EDMG BRP-TX PPDUs within one of the $R_{resp}$ + 1 repetitions. The feedback sent by the responder within the Initiator BRP TXSS consists of a BRP frame with feedback of the measurements it performed during the reception of EDMG BRP-TX PPDUs. If receive training of the responder is included in the procedure, the TRN field of the EDMG BRP-RX PPDU sent immediately after the Initiator BRP TXSS is transmitted by the initiator and received by the responder using antenna configurations determined in the preceding Initiator BRP TXSS. In a Responder BRP TXSS, if present, the responder transmits $N_{resp}$ + 1 EDMG BRP-TX PPDUs consecutively $R_{init}$ + 1 times, and the same DMG antenna or set of DMG antennas is used by the initiator when receiving the TRN field of all $N_{resp}$ +1 EDMG BRP-TX PPDUs within one of the $R_{init}$ +1 repetitions. The feedback sent by the initiator within the Responder BRP TXSS consists of a BRP frame with feedback of the measurements it performed during the reception of EDMG BRP-TX PPDUs transmitted by the responder. If receive training of the initiator is included in the procedure, the TRN field of the one or more EDMG BRP-RX PPDUs sent immediately after the Responder BRP TXSS are transmitted by the responder and received by the initiator using antenna configurations determined in the preceding phases of the procedure. As defined in 10.41.10.5.2 (BRP TXSS configuration), the number of EDMG BRP-RX PPDUs transmitted in the receive training of the initiator depends on

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reciprocity characteristics of the initiator and the responder. The BRP TXSS is concluded with the transmission of a BRP frame with acknowledgment.

The TRN field of EDMG BRP-TX and EDMG BRP-RX PPDUs sent in a BRP TXSS may be transmitted with different DMG antennas than the ones used in the setup phase. Also, the TRN field of EDMG BRP-TX and EDMG BRP-RX PPDUs used in the procedure may be received with DMG antennas that are not the same ones used in the setup phase.

If both initiator and responder of a BRP TXSS are SU-MIMO capable (as defined in 10.41.10.2.2 (SU-MIMO beamforming)), EDMG BRP-TX PPDUs used in a BRP TXSS may be sent using multiple transmit chains simultaneously. As described in 10.41.10.2.2 (SU-MIMO beamforming), the procedure in this case corresponds to the SISO phase of SU-MIMO beamforming training, and the MIMO phase of SU-MIMO beamforming training shall be performed after completion of the BRP TXSS.

As defined in 28.9.2.2.2 (EDMG BRP PPDU structure), the TRN field in EDMG BRP PPDUs sent as part of BRP TXSS is transmitted over the entire channel bandwidth. Therefore, the BRP TXSS allows for transmit sector sweep over the entire channel bandwidth when the initiator and responder operate on a 4.32 GHz, 6.48 GHz, 8.64 GHz, 2.16+2.16 GHz, or 4.32+4.32 GHz channel.

Similar to as specified in 10.41.6.4.2 (Beam refinement transaction), all the PPDUs in a BRP-TXSS are transmitted with the same TXVECTOR parameters CH_BANDWIDTH and CHANNEL_AGGREGATION values as those of the PPDU that initiated the BRP-TXSS.

#### 10.41.10.5.2 BRP TXSS configuration

##### 10.41.10.5.2.1 General

A SISO BRP TXSS is a BRP TXSS in which EDMG BRP PPDUs used in the procedure are transmitted using a single transmit chain. A MIMO BRP TXSS is a BRP TXSS in which EDMG BRP PPDUs used in the procedure are transmitted using multiple transmit chains.

##### 10.41.10.5.2.2 SISO BRP TXSS configuration—general

BRP frames transmitted in a BRP TXSS with feedback within an Initiator BRP TXSS or a Responder BRP TXSS and with acknowledgment at the end of the procedure shall be transmitted and received with the same DMG antennas and AWVs used in the setup phase. Also, these frames shall not include a TRN field.

All fields except for the TRN field of EDMG BRP-TX and EDMG BRP-RX PPDUs used in SISO BRP TXSS shall be transmitted with the same DMG antenna and AWV used in the setup phase. The TRN field of EDMG BRP-TX and EDMG BRP-RX PPDUs used in SISO BRP TXSS may be transmitted with a different DMG antenna than the one used in the transmission of the remaining fields of the same PPDU.

All fields of EDMG BRP-TX and EDMG BRP-RX PPDUs used in SISO BRP TXSS except for the TRN field shall be received with the same DMG antenna and AWV used in the setup phase. The TRN field of EDMG BRP-TX and EDMG BRP-RX PPDUs used in SISO BRP TXSS may be received with a DMG antenna that is not the same one used in the reception of the remaining fields of the same PPDU.

The Initiator BRP TXSS shall consist of the transmission of $N_{init}$ + 1 EDMG BRP-TX PPDUs consecutively repeated $R_{resp}$ + 1 times by the initiator followed by the transmission of a BRP frame with feedback by the responder. The EDMG BRP-TX PPDUs transmitted in an Initiator BRP TXSS shall be configured as follows:

— The TXVECTOR parameter TRN_RX_PATTERN of the PPDU shall be set to QUASI_OMNI.


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- The TXVECTOR of the $i^{th}$ EDMG BRP-TX PPDU within each of the $R_{resp}$ + 1 repetitions, where $1 \leq i \leq N_{init} + 1$, shall have the same value for the parameters EDMG_TRN_LEN, EDMG_TRN_P, EDMG_TRN_M, and EDMG_TRN_N.
- The TRN field of the $i^{th}$ EDMG BRP-TX PPDU within each of the $R_{resp}$ + 1 repetitions, where $1 \leq i \leq N_{init} + 1$, shall be transmitted using the same DMG antenna.
- The $j^{th}$ TRN subfield of the $k^{th}$ TRN-Unit of the $i^{th}$ EDMG BRP-TX PPDU within each of the $R_{resp}$ + 1 repetitions, where $1 \leq j \leq M + 1$, $2 \leq k \leq L + 1$, and $1 \leq i \leq N_{init} + 1$, where $M$ and $L$ are the values of the TXVECTOR parameters EDMG_TRN_M and EDMG_TRN_LEN, shall be transmitted using the same AWV.
- The initiator should transmit the TRN field of each of the $N_{init}$ + 1 EDMG BRP-TX PPDUs within one of the $R_{resp}$ + 1 repetitions in an Initiator BRP TXSS using a different DMG antenna.

Similarly, the Responder BRP TXSS, if present, shall consist of the transmission of $N_{resp}$ +1 EDMG BRP-TX PPDUs consecutively repeated $R_{init}$ + 1 times by the responder followed by the transmission of a BRP frame with feedback by the initiator. The EDMG BRP-TX PPDUs transmitted in a Responder BRP TXSS shall be configured as follows:

- The value of the TXVECTOR parameter TRN_RX_PATTERN shall be set according to the Antenna Pattern Reciprocity and the DMG Antenna Reciprocity subfields within the DMG STA Capability Information field of both initiator and responder, as defined in 10.41.10.5.2 (BRP TXSS configuration).
- The TXVECTOR of the $i^{th}$ EDMG BRP-TX PPDU within each of the $R_{init}$ + 1 repetitions, where $1 \leq i \leq N_{resp} + 1$, shall have the same value for the parameters EDMG_TRN_LEN, EDMG_TRN_P, EDMG_TRN_M, and EDMG_TRN_N.
- The TRN field of the $i^{th}$ EDMG BRP-TX PPDU within each of the $R_{init}$ + 1 repetitions, where $1 \leq i \leq N_{resp} + 1$, shall be transmitted using the same DMG antenna.
- The $j^{th}$ TRN subfield of the $k^{th}$ TRN-Unit of the $i^{th}$ EDMG BRP-TX PPDU within each of the $R_{init}$ + 1 repetitions, where $1 \leq j \leq M + 1$, $2 \leq k \leq L + 1$, and $1 \leq i \leq N_{resp} + 1$, where $M$ and $L$ are the values of the TXVECTOR parameters EDMG_TRN_M and EDMG_TRN_LEN, respectively, shall be transmitted using the same AWV.
- The responder should transmit the TRN field of each of the $N_{resp}$ + 1 EDMG BRP-TX PPDUs within one of the $R_{init}$ + 1 repetitions in a Responder BRP TXSS using a different DMG antenna.

Receive training of the responder after the Initiator BRP TXSS is mandatory in SISO BRP TXSS, and it consists of the transmission of one EDMG BRP-RX PPDU by the initiator that allows for the responder to determine its receive configuration for the transmit configuration determined in the preceding Initiator BRP TXSS. The TRN field of the EDMG BRP-RX PPDU used for receive training of the responder

- Shall be transmitted with the best AWV identified in the preceding Initiator BRP TXSS.
- Shall be received with the DMG antenna corresponding to the best AWV configuration identified in the preceding Initiator BRP TXSS.
- Shall have a length that shall be equal to the value of the L-RX field in the BRP frame sent by the responder to confirm the procedure plus one.

Receive training of the initiator shall be performed if the value of the L-RX field in the BRP frame sent by the initiator to start the BRP TXSS is greater than 0. If the L-RX field in the BRP frame sent to start the BRP TXSS is equal to 0, receive training of the initiator shall not be performed. Receive training of the initiator consists of the transmission of one or more EDMG BRP-RX PPDUs by the responder that allows for the initiator to determine its receive configuration for the transmit configuration determined in the preceding Responder BRP TXSS or in the preceding receive training of the responder. The TRN field of the EDMG BRP-RX PPDUs used for receive training of the initiator

- Shall be transmitted with the best AWV identified in the preceding Responder BRP TXSS or in the receive training of the responder, as defined in 10.41.10.5.2 (BRP TXSS configuration).

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— Shall be received with the DMG antenna corresponding to the best AWV identified in the Responder BRP TXSS or in the Initiator BRP TXSS, or with multiple DMG antennas, as defined in 10.41.10.5.2 (BRP TXSS configuration).

— Shall have a length that shall be equal to the value of the L-RX field in the BRP frame sent by the initiator to start the procedure plus one.

An example of a BRP TXSS is shown in Figure 10-122 (Example of BRP TXSS: responder performs measurements using one DMG antenna(11ay)) for a scenario in which the initiator and the responder have two DMG antennas, and both the initiator and responder use one DMG antenna when performing measurements. It is assumed in this example that the best AWV configuration identified in the Initiator BRP TXSS was obtained when the initiator used DMG antenna 0 and the responder used DMG antenna 1, and that the best AWV configuration identified in the Responder BRP TXSS was obtained when the responder used DMG antenna 0 and the initiator used DMG antenna 0. If the responder in this example was capable of processing all of its antennas simultaneously, the duration of the BRP TXSS could be shortened as shown in Figure 10-123 (Example of BRP TXSS: responder performs measurements using multiple DMG antennas simultaneously(11ay)).

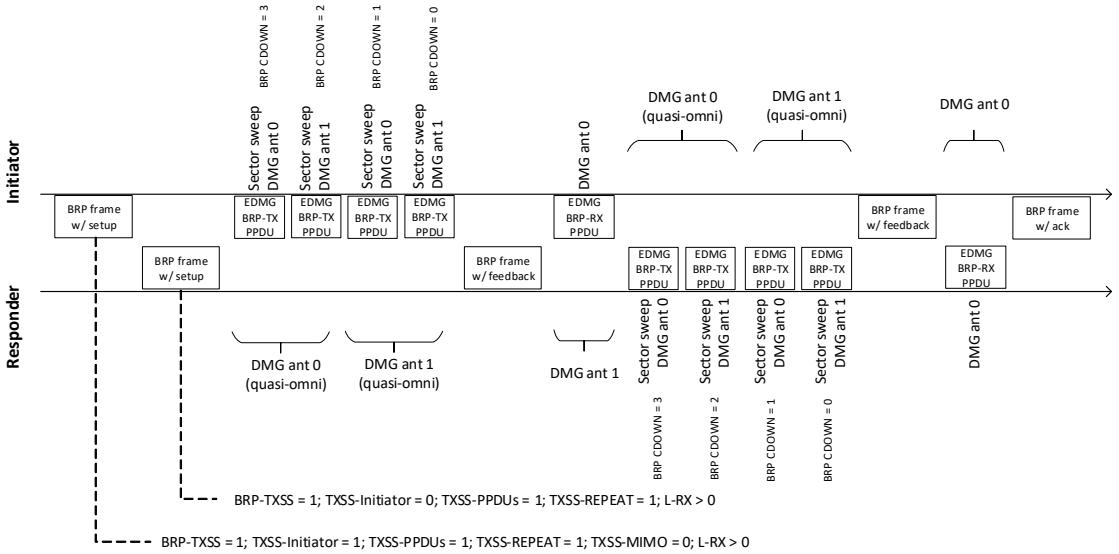


**Figure 10-122—Example of BRP TXSS: responder performs measurements using one DMG antenna(11ay)**

The first TRN-Unit in an EDMG BRP PPDU used in a SISO BRP TXSS may be used for the initiator and responder to switch DMG antennas and shall not be processed by the receiver. Therefore, for EDMG BRP-TX and EDMG BRP-RX PPDUs transmitted during SISO BRP TXSS, the value of the TXVECTOR parameter EDMG_TRN_LEN shall be set to $k + 1$, where

— For the EDMG BRP-RX PPDU sent in the receive training for the responder, $k$ is equal to the value of the L-RX field in the BRP frame sent by the responder to confirm the procedure.

— If present, for the one or more EDMG BRP-RX PPDUs sent in the receive training for the initiator, $k$ is equal to the value of the L-RX field in the BRP frame sent by the initiator to start the BRP TXSS.

The TRN subfields that comprise the first TRN-Unit in EDMG BRP-TX PPDUs used as part of a BRP TXSS shall not be included in the TRN subfield and AWV feedback ID indexing procedures described in 28.9.2.2.5 (TRN field definition).


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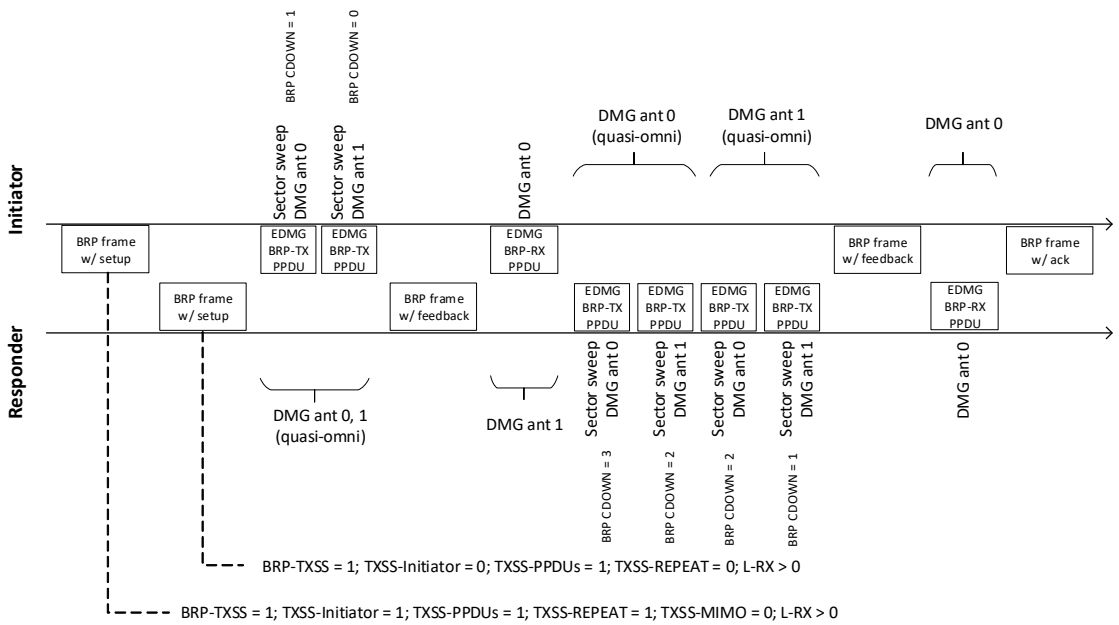


**Figure 10-123—Example of BRP TXSS: responder performs measurements using multiple DMG antennas simultaneously(11ay)**

When transmitting an EDMG BRP-TX or an EDMG BRP-RX PPDU as part of a SISO BRP TXSS, an EDMG STA may change the DMG antenna used in the transmission of its TRN field during the first TRN-Unit and shall not change DMG antenna during the remaining TRN-Units.

When receiving an EDMG BRP-TX or an EDMG BRP-RX PPDU as part of SISO BRP TXSS, an EDMG STA may change the DMG antenna used in the reception of the TRN field during the first TRN-Unit and shall not change DMG antenna during the remaining TRN-Units.

For EDMG BRP-TX PPDUs used in a BRP TXSS, the AWV used in the transmission of the first *P* TRN subfields of each TRN-Unit depends on whether the DMG antenna used in the transmission of an EDMG BRP-TX PPDU changes at the beginning of the TRN field. As defined in 28.9.2.2.5 (TRN field definition), if the TRN field of an EDMG BRP-TX PPDU is transmitted with the same DMG antenna as the remaining fields of the PPDU, the first *P* TRN subfields of each TRN-Unit shall be transmitted using the same AWV as the remaining fields of the PPDU. If the DMG antenna used in the transmission of an EDMG BRP-TX PPDU changes at the beginning of the TRN field, the AWV used in the transmission of the first *P* TRN subfields of each TRN-Unit is selected in an implementation dependent manner and should be the same for all TRN-Units.

### 10.41.10.5.2.3 SISO BRP TXSS configuration—with reciprocity

A STA, responder or initiator, is antenna pattern reciprocal if the Antenna Pattern Reciprocity subfield in the DMG STA Capability Information field of the STA's DMG Capabilities element is 1. Otherwise, the STA is not antenna pattern reciprocal.

A STA, responder or initiator, is DMG antenna reciprocal if the DMG Antenna Reciprocity subfield in the DMG STA Capability Information field of the STA's DMG Capabilities element is 1. Otherwise, the STA is not DMG antenna reciprocal.

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Responder BRP TXSS and receive training for the initiator are included in a SISO BRP TXSS depending on the reciprocity characteristics of the initiator and responder (see 10.41.10.5.2 (BRP TXSS configuration)). Specifically, each of these two phases shall or shall not be included in a SISO BRP TXSS as defined in Table 10-38 (Definition of whether Responder BRP TXSS and receive training for initiator are included in a SISO BRP TXSS(11ay)).

**Table 10-38—Definition of whether Responder BRP TXSS and receive training for initiator are included in a SISO BRP TXSS(11ay)**

("Yes" defines that the phase shall be included, and "No" defines that the phase shall not be included)

| Initiator | Responder | Phase: Responder BRP TXSS | Phase: Receive training for the initiator |
|---|---|---|---|
| Antenna pattern reciprocal | Antenna pattern reciprocal | No | No |
| Antenna pattern reciprocal | DMG antenna reciprocal | Yes | No |
| Antenna pattern reciprocal | Not antenna pattern reciprocal and not DMG antenna reciprocal | Yes | Yes |
| DMG antenna reciprocal | Antenna pattern reciprocal | No | Yes |
| DMG antenna reciprocal | DMG antenna reciprocal | Yes | Yes |
| DMG antenna reciprocal | Not antenna pattern reciprocal and not DMG antenna reciprocal | Yes | Yes |
| Not antenna pattern reciprocal and not DMG antenna reciprocal | Antenna pattern reciprocal | No | Yes |
| Not antenna pattern reciprocal and not DMG antenna reciprocal | DMG antenna reciprocal | Yes | Yes |
| Not antenna pattern reciprocal and not DMG antenna reciprocal | Not antenna pattern reciprocal and not DMG antenna reciprocal | Yes | Yes |

If a SISO BRP TXSS includes receive training for the initiator, the L-RX field in the EDMG BRP Request element or EDMG BRP field within the BRP frame sent by the initiator to start the BRP TXSS shall be set to a value greater than 0. If a SISO BRP TXSS does not include receive training for the initiator, the L-RX field in the EDMG BRP Request element or EDMG BRP field within the BRP frame sent by the initiator to start the BRP TXSS shall be set to 0.

If the initiator is antenna pattern reciprocal and the responder is DMG antenna reciprocal, then

— The TXSS-REPEAT field in the EDMG BRP Request element or EDMG BRP field within the BRP frame sent by the initiator to start the BRP TXSS shall be set to 0.

— The TXVECTOR parameter TRN_RX_PATTERN of EDMG BRP-TX PPDUs used in the Responder BRP TXSS shall be set to DIRECTIONAL.

— The TRN field of the EDMG BRP-TX PPDUs used in the Responder BRP TXSS shall be received with the RX AWV configuration corresponding to the best AWV configuration identified in the Initiator BRP TXSS.

If the initiator is antenna pattern reciprocal and the responder is not antenna pattern reciprocal and is not DMG antenna reciprocal, then

— The TXSS-REPEAT field in the EDMG BRP Request element or EDMG BRP field within the BRP frame sent by the initiator to start the BRP TXSS shall be set to 0.


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- The TXVECTOR parameter TRN_RX_PATTERN of EDMG BRP-TX PPDUs used in the Responder BRP TXSS shall be set to QUASI_OMNI.
- The TRN field of the EDMG BRP-TX PPDUs used in the Responder BRP TXSS shall be received with the DMG antenna corresponding to the best AWV configuration identified in the Initiator BRP TXSS.

If the initiator is DMG antenna reciprocal and the SISO BRP TXSS includes a Responder BRP TXSS, then

- The TXSS-REPEAT field in the EDMG BRP Request element or EDMG BRP field within the BRP frame sent by the initiator to start the BRP TXSS shall be set to 0.
- The TXVECTOR parameter TRN_RX_PATTERN of EDMG BRP-TX PPDUs used in the Responder BRP TXSS shall be set to QUASI_OMNI.
- The TRN field of the EDMG BRP-TX PPDUs used in the Responder BRP TXSS shall be received with the DMG antenna corresponding to the best AWV configuration identified in the Initiator BRP TXSS.

If the initiator is not antenna pattern reciprocal and is not DMG antenna reciprocal and the SISO BRP TXSS includes a Responder BRP TXSS, then

- The TXSS-REPEAT field in the EDMG BRP Request element or EDMG BRP field within the BRP frame sent by the initiator to start the BRP TXSS may be set to a value greater than 0.
- The TXVECTOR parameter TRN_RX_PATTERN of EDMG BRP-TX PPDUs used in the Responder BRP TXSS shall be set to QUASI_OMNI.

If the responder is DMG antenna reciprocal, then

- The TXSS-PPDUs field in the EDMG BRP Request element or EDMG BRP field within the BRP frame sent by the responder to acknowledge the BRP TXSS request shall be set to 0.
- The TRN field of the EDMG BRP-TX PPDUs used in the Responder BRP TXSS shall be transmitted using the DMG antenna corresponding to the best AWV configuration identified in the Initiator BRP TXSS.

If the responder is not antenna pattern reciprocal and is not DMG antenna reciprocal, the TXSS-PPDUs field in the EDMG BRP Request element or EDMG BRP field within the BRP frame sent by the responder to acknowledge the BRP TXSS request may be set to a value greater than 0.

If the initiator is not antenna pattern reciprocal and is not DMG antenna reciprocal, and the responder is antenna pattern reciprocal, the receive training of the initiator consist of the transmission of $R_{init} + 1$ EDMG BRP-RX PPDUs. For all other cases, the receive training of the initiator consists of the transmission of one EDMG BRP-RX PPDU.

If the initiator is DMG antenna reciprocal, the EDMG BRP-RX PPDU sent in the receive training of the initiator is received using the DMG antenna corresponding to the best AWV configuration identified in the Initiator BRP TXSS.

If the initiator is antenna pattern reciprocal and the responder is not antenna pattern reciprocal and is not DMG antenna reciprocal, the EDMG BRP-RX PPDU sent in the receive training of the initiator is received using the DMG antenna corresponding to the best AWV configuration identified in the Initiator BRP TXSS.

If the initiator is not antenna pattern reciprocal and is not DMG antenna reciprocal, and the responder is not antenna pattern reciprocal, the EDMG BRP-RX PPDU sent in the receive training of the initiator is received by the initiator with the DMG antenna corresponding to the best transmit AWV of the responder as identified in the Responder BRP TXSS.

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The AWV configuration used in the transmission of the TRN field of the one or more EDMG BRP-RX PPDUs by the responder corresponds to the best AWV configuration identified in the receive training for the responder for the following cases:

— If the initiator is DMG antenna reciprocal and the responder is antenna pattern reciprocal.

— If the initiator is not antenna pattern reciprocal and is not DMG antenna reciprocal, and the responder is antenna pattern reciprocal.

The AWV configuration used in the transmission of the TRN field of the one or more EDMG BRP-RX PPDUs by the responder corresponds to the best AWV configuration identified in the Responder BRP TXSS for the following cases:

— If the initiator is antenna pattern reciprocal, and the responder is not antenna pattern reciprocal and is not DMG antenna reciprocal.

— If both the initiator and responder are DMG antenna reciprocal.

— If the initiator is DMG antenna reciprocal, and the responder is not antenna pattern reciprocal and is not DMG antenna reciprocal.

— If the initiator is not antenna pattern reciprocal and is not DMG antenna reciprocal, and the responder is DMG antenna reciprocal.

— If both the initiator and the responder are not antenna pattern reciprocal and are not DMG antenna reciprocal.

The examples given in Figure 10-122 (Example of BRP TXSS: responder performs measurements using one DMG antenna(11ay)) and Figure 10-123 (Example of BRP TXSS: responder performs measurements using multiple DMG antennas simultaneously(11ay)) correspond to a scenario in which the initiator and responder are not antenna pattern reciprocal and are not DMG antenna reciprocal.

An example BRP TXSS for the case when the initiator is antenna pattern reciprocal, and the responder is not antenna pattern reciprocal and is not DMG antenna reciprocal is shown in Figure 10-124 (Example of BRP TXSS: initiator is antenna pattern reciprocal, and responder is not antenna pattern reciprocal and is not DMG antenna reciprocal(11ay)).

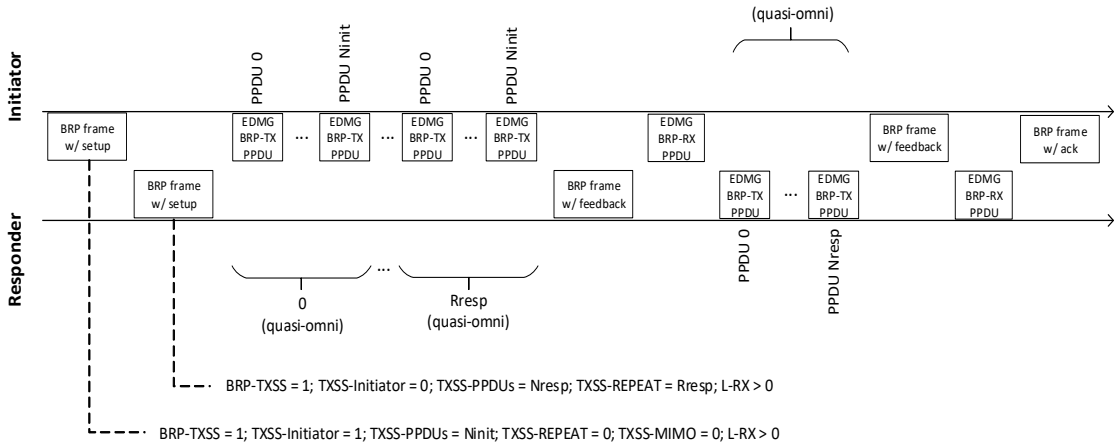


**Figure 10-124—Example of BRP TXSS: initiator is antenna pattern reciprocal, and responder is not antenna pattern reciprocal and is not DMG antenna reciprocal(11ay)**


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An example BRP TXSS for the case when the initiator is DMG antenna reciprocal, and the responder is antenna pattern reciprocal is shown in Figure 10-125 (Example of BRP TXSS: initiator is DMG antenna reciprocal, and responder is antenna pattern reciprocal(11ay)).

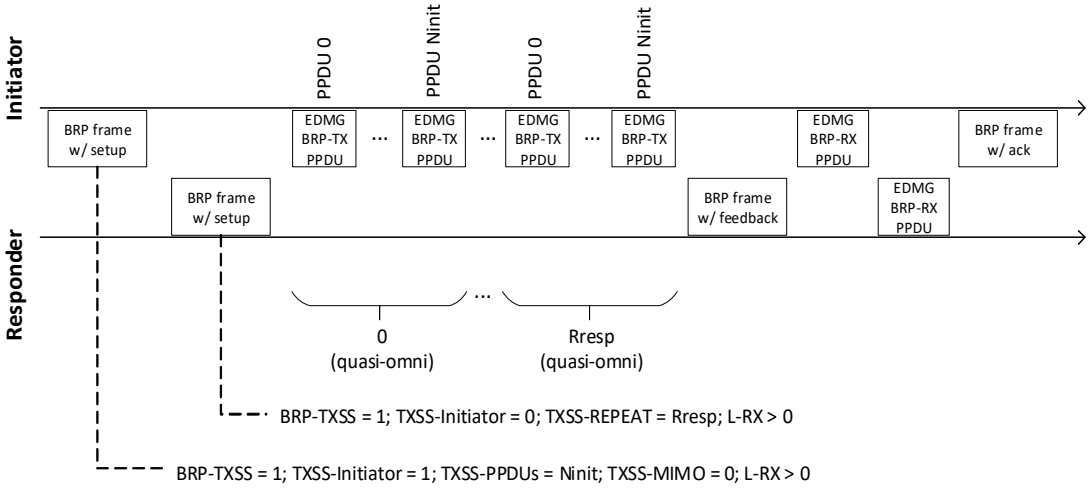


**Figure 10-125—Example of BRP TXSS: initiator is DMG antenna reciprocal, and responder is antenna pattern reciprocal(11ay)**

### 10.41.10.5.2.4 MIMO BRP TXSS configuration

Receive training of the responder and receive training of the initiator shall not be performed in a MIMO BRP TXSS procedure. The L-RX field within the EDMG BRP Request element or EDMG BRP field in the BRP frames transmitted during the setup phase of a MIMO BRP TXSS shall be set to 0.

Responder BRP TXSS is mandatory in MIMO BRP TXSS.

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An example of a MIMO BRP TXSS is shown in Figure 10-126 (Example of MIMO BRP TXSS(11ay)).

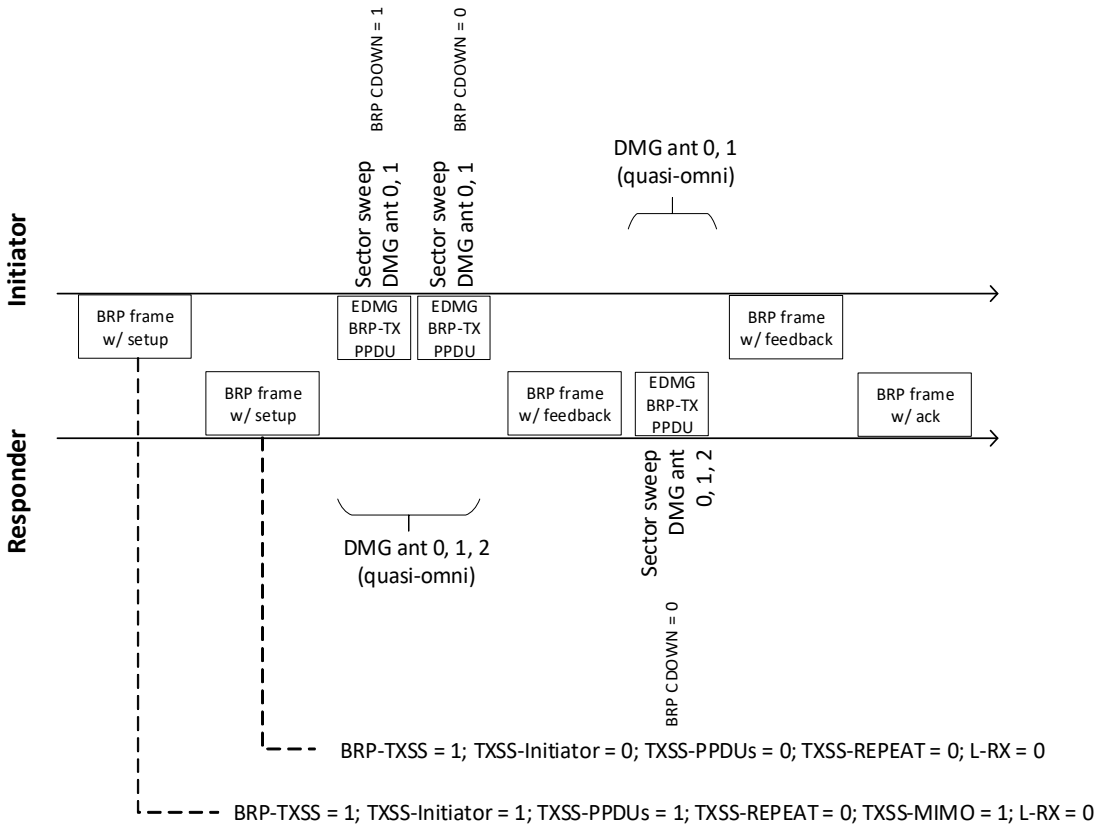


**Figure 10-126—Example of MIMO BRP TXSS(11ay)**

BRP frames sent in a MIMO BRP TXSS shall be transmitted by applying spatial expansion and mapping a single space-time stream to all *N* transmit chains to be trained in the procedure. The TRN field of EDMG BRP-TX PPDUs sent in a MIMO BRP TXSS shall consist of *N* orthogonal waveforms, as defined in 28.9.2 (Beam refinement).

BRP frames transmitted in a MIMO BRP TXSS during the setup phase, with feedback within an Initiator BRP TXSS, with feedback within a Responder BRP TXSS, and with acknowledgment at the end of the procedure shall not include a TRN field.

In the setup phase of a MIMO BRP TXSS, if an implementation has not yet determined AWVs to use in some of its transmit chains (for example, if a station has been using a single transmit chain before the setup phase), the AWVs used by such chains should be selected in an implementation dependent manner.

The DMG antennas and AWVs used in the transmission of all fields, except for the TRN field of EDMG BRP-TX PPDUs sent in the Initiator BRP TXSS, the Responder BRP TXSS, and with acknowledgment, shall be the same ones used in the setup phase. The TRN field of EDMG BRP-TX PPDUs sent in a MIMO BRP TXSS may be transmitted with a different set of DMG antennas than the one used in the transmission of the remaining fields of the same PPDU.

Similarly, the DMG antennas and AWVs used in the reception of all fields, except for the TRN field of BRP frames sent in the Initiator BRP TXSS, the Responder BRP TXSS, and with acknowledgment, shall be the same ones used in the setup phase. The TRN field of EDMG BRP-TX PPDUs sent in a MIMO BRP TXSS


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may be received with a set of DMG antennas that is not the same one used in the reception of the remaining fields of the same PPDU.

The Initiator BRP TXSS shall consist of the transmission of $N_{init}$ + 1 EDMG BRP-TX PPDUs consecutively repeated $R_{resp}$ + 1 times by the initiator followed by the transmission of a BRP frame with feedback by the responder. The EDMG BRP-TX PPDUs transmitted in an Initiator BRP TXSS shall be configured as follows:

— The TXVECTOR parameter TRN_RX_PATTERN of the PPDU shall be set to QUASI_OMNI.

— The TXVECTOR of the $i^{th}$ EDMG BRP-TX PPDU within each of the $R_{resp}$ + 1 repetitions, where $1 \le i \le N_{init}$ + 1, shall have the same value for the parameters EDMG_TRN_LEN, EDMG_TRN_P, EDMG_TRN_M, and EDMG_TRN_N.

— The TRN subfields of the $i^{th}$ EDMG BRP-TX PPDU within each of the $R_{resp}$ + 1 repetitions, where $1 \le i \le N_{init}$+1, shall be transmitted using the same set of DMG antennas and the same AWVs.

— The set of DMG antennas used when transmitting the TRN field of the $N_{init}$ + 1 EDMG BRP-TX PPDUs within one of the $R_{resp}$ + 1 repetitions in an Initiator BRP TXSS should be different.

Similarly, the Responder BRP TXSS shall consist of the transmission of $N_{resp}$ + 1 EDMG BRP-TX PPDUs consecutively repeated $R_{init}$ + 1 times by the responder followed by the transmission of a BRP frame with feedback by the initiator. The EDMG BRP-TX PPDUs transmitted in a Responder BRP TXSS shall be configured as follows:

— The TXVECTOR parameter TRN_RX_PATTERN of the PPDU shall be set to QUASI_OMNI.

— The TXVECTOR of the $i^{th}$ EDMG BRP-TX PPDU within each of the $R_{init}$ + 1 repetitions, where $1 \le i \le N_{resp}$ + 1, shall have the same value for the parameters EDMG_TRN_LEN, EDMG_TRN_P, EDMG_TRN_M, and EDMG_TRN_N.

— The TRN subfields of the $i^{th}$ EDMG BRP-TX PPDU within each of the $R_{init}$ + 1 repetitions, where $1 \le i \le N_{resp}$ + 1, shall be transmitted using the same set of DMG antennas and the same AWVs.

— The set of DMG antennas used when transmitting the TRN field of the $N_{resp}$ + 1 EDMG BRP-TX PPDUs within one of the $R_{init}$ + 1 repetitions in a Responder BRP TXSS should be different.

In both Initiator BRP TXSS and Responder BRP TXSS of a MIMO BRP TXSS, the set of DMG antennas used when receiving the TRN subfields of EDMG BRP-TX PPDUs of different repetitions should be different.

A STA that is part of a MIMO BRP TXSS shall provide feedback for each of the DMG antennas trained in the procedure, as defined in 10.41.10.5.3 (BRP TXSS execution).

The first TRN-Unit in an EDMG BRP PPDU used in a MIMO BRP TXSS may be used for the initiator and responder to switch one or more DMG antennas used and shall not be processed by the receiver. Therefore, for EDMG BRP-TX PPDUs transmitted in a MIMO BRP TXSS, the value of the TXVECTOR parameter EDMG_TRN_LEN shall be set to $k$ + 1, where $k$ is the number of TRN-Units used for transmit training. The TRN subfields that comprise the first TRN-Unit in EDMG BRP-TX PPDUs used as part of a MIMO BRP TXSS shall not be included in the TRN subfield and AWV feedback ID indexing procedures described in 28.9.2.2.5 (TRN field definition).

When transmitting an EDMG BRP-TX PPDU as part of a MIMO BRP TXSS, an EDMG STA may change the set of DMG antennas used in the transmission of its TRN field during the first TRN-Unit and shall not change DMG antennas during the remaining TRN-Units.

When receiving an EDMG BRP-TX PPDU as part of MIMO BRP TXSS, an EDMG STA may change the set of DMG antennas used in the reception of the TRN field during the first TRN-Unit and shall not change DMG antennas during the remaining TRN-Units.

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For EDMG BRP-TX PPDUs used in a MIMO BRP TXSS, the AWVs used in the transmission of the first *P* TRN subfields of each TRN-Unit depends on whether the set of DMG antennas used in the transmission of the EDMG BRP-TX PPDU changes at the beginning of the TRN field. If the TRN field of an EDMG BRP-TX PPDU is transmitted with the same set of DMG antennas as the remaining fields of the PPDU, the first *P* TRN subfields of each TRN-Unit shall be transmitted using the same DMG Antennas and AWVs as the remaining fields of the PPDU. If the set of DMG antennas used in the transmission of an EDMG BRP-TX PPDU changes at the beginning of the TRN field, the AWVs used in the transmission of the first *P* TRN subfields of each TRN-Unit are selected in an implementation dependent manner and should be the same for all TRN-Units.

#### 10.41.10.5.2.5 Configuration of BRP TXSS for 2.16+2.16 GHz and 4.32+4.32 GHz channels

The initiator of a BRP TXSS requests to perform BRP TXSS over a 2.16+2.16 GHz or a 4.32+4.32 GHz channel by sending a BRP frame with setup that has the Channel Aggregation Requested field in the DMG Beam Refinement element set to 1 and with TXVECTOR parameter CHANNEL_AGGREGATION set to (#4167)AGGREGATED. If the responder accepts the request by sending a BRP frame with setup with the Channel Aggregation Requested field set to 1 and the value of the TXVECTOR parameters CH_BANDWIDTH and CHANNEL_AGGREGATION equal to the value of the RXVECTOR parameters CH_BANDWIDTH and CHANNEL_AGGREGATION of the BRP frame sent by the initiator, all BRP frames sent as part of the BRP TXSS shall have the same TXVECTOR parameters CH_BANDWIDTH and CHANNEL_AGGREGATION.

BRP frames sent in a BRP TXSS performed in a 2.16+2.16 GHz or a 4.32+4.32 GHz channel during the setup phase or with the TXVECTOR parameter EDMG_TRN_LEN greater than 0 shall be sent using the EDMG control mode. BRP frames sent in a BRP TXSS with feedback or with acknowledgment shall be transmitted using an EDMG PPDU or a non-EDMG duplicate PPDU. As defined in 28.3.3.3.2.2 (Definition for EDMG control mode PPDU), the total number of transmit chains, $N_{TX}$, is an even number, and the first $N_{TX}/2$ transmit chains are used for transmission on the primary channel and the second $N_{TX}/2$ transmit chains are used for transmission on the secondary channel. In the setup phase, if an implementation has not yet determined AWVs to use in the secondary channel, the AWVs used by the $N_{TX}/2$ transmit chains used for transmission on the secondary channel is selected in an implementation dependent manner. If a BRP frame sent in a BRP TXSS performed in a 2.16+2.16 GHz or a 4.32+4.32 GHz includes a TRN field, the TXVECTOR parameter TRN_AGGREGATION shall be set to AggregationTRN.

If the TXSS-MIMO field within the EDMG BRP Request element or EDMG BRP field in a BRP frame with setup sent by the initiator is equal to 0, the BRP TXSS shall be configured as described in 10.41.10.5.2 (BRP TXSS configuration). If the TXSS-MIMO field is equal to 1, the BRP TXSS shall be configured as described in 10.41.10.5.2 (BRP TXSS configuration). In both cases, the values of the TXSS-PPDUs and TXSS-REPEAT fields exchanged during the setup correspond to the number of PPDUs and of repetitions, respectively, in each of the two aggregated channels.

A STA that is part of a BRP TXSS that is performed over a 2.16+2.16 GHz or a 4.32+4.32 GHz channel shall provide feedback for each of the two aggregated channels. BRP frames with feedback in this case shall have the Channel Aggregation Present field within the DMG Beam Refinement element set to 1.

### 10.41.10.5.3 BRP TXSS execution

A BRP TXSS shall complete within the CBAP or SP in which it was initiated.

The FBCK-REQ subfield in the DMG Beam Refinement element carried within the BRP frame that initiates a BRP TXSS shall be set to 10001 (binary).

To request a BRP TXSS, the initiator sends a BRP frame with both the BRP-TXSS field and the TXSS-INITIATOR field within the EDMG BRP Request element or EDMG BRP field set to 1 and the


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TXSS-PPDUs field set to indicate the number of EDMG BRP-TX PPDUs necessary for the initiator to perform transmit training. To confirm the BRP TXSS execution, the responder shall respond with a BRP frame MBIFS after the reception of the BRP frame sent by the initiator with the BRP-TXSS field within the EDMG BRP Request element or EDMG BRP field set to 1, the TXSS-INITIATOR field set to 0, and the TXSS-REPEAT field set to indicate the number of requested repetitions of the EDMG BRP-TX PPDUs sent by the initiator.

If the procedure includes a Responder BRP TXSS, the TXSS-REPEAT field in the BRP frame sent by the initiator shall be set to indicate the number of requested repetitions of the EDMG BRP-TX PPDUs sent by the responder, and the TXSS-PPDUs field in the BRP frame sent by the responder shall be set to indicate the number of EDMG BRP-TX PPDUs necessary for the responder to perform transmit training. If the procedure does not include a Responder BRP TXSS, the TXSS-REPEAT field in the BRP frame sent by the initiator shall be set to 0 and the TXSS-PPDUs field in the BRP frame sent by the responder shall be set to 0.

The TXSS-MIMO subfield in the EDMG BRP Request element or EDMG BRP field of the BRP frame that initiates the BRP TXSS shall be set to 1 when the procedure is a MIMO BRP TXSS. If the procedure is a SISO BRP TXSS, the TXSS-MIMO subfield shall be set to 0. Both initiator and responder of a BRP TXSS shall be SU-MIMO capable (as defined in 10.41.10.2.2 (SU-MIMO beamforming)) for the TXSS-MIMO subfield to be set to 1.

The initiator shall transmit the first EDMG BRP-TX PPDU MBIFS after the reception of the BRP frame sent by the responder confirming the BRP TXSS execution.

The EDMG BRP-TX PPDUs sent by the initiator in a BRP TXSS procedure shall be separated by SIFS. The responder shall then send a BRP frame to the initiator containing feedback based on measurements it performed during the Initiator BRP TXSS. The BRP frame with feedback transmitted by the responder is separated from the last EDMG BRP-TX PPDU transmitted by the initiator by an MBIFS.

A BRP frame with feedback transmitted in a BRP TXSS may have the EDMG-SHORT-FBCK field set to 0 or 1. If the EDMG-SHORT-FBCK field is 0, the BRP frame shall have the SNR Present subfield within the FBCK-TYPE field set to 1, the Sector ID Order subfield set to 1, the EDMG Extension Flag set to 1 and the EDMG Channel Measurement Present set to 1. The EDMG Sector ID Order field indicates the AWV IDs, TX antennas and RX antennas of sectors that were received in the procedure. If the EDMG-SHORT-FBCK field is 1, the Sector ID/CDOWN/AWV ID subfield indicates the Sector ID of a PPDU received in the sector sweep. For both cases, when the EDMG-SHORT-FBCK field is 0 or 1, the SNR subfields indicate the SNRs with which the BRP PPDUs received through the corresponding sectors were received and the BRP-CDOWN subfields associated with each SISO ID indicate the BRP-CDOWN values within the BRP PPDUs received from the corresponding sector.

In an Initiator BRP TXSS, the BRP CDOWN field within the EDMG BRP Request element or EDMG BRP field in each transmitted EDMG BRP-TX PPDU shall contain the total number of transmissions remaining until the end of the Initiator BRP TXSS, such that the first EDMG BRP-TX PPDU transmitted in the Initiator BRP TXSS has the BRP CDOWN field set to $(N_{init} + 1) \times (R_{resp} + 1) - 1$ and the last PPDU has the BRP CDOWN field set to 0. The use of BRP CDOWN is illustrated in Figure 10-122 (Example of BRP TXSS: responder performs measurements using one DMG antenna(11ay)) and Figure 10-123 (Example of BRP TXSS: responder performs measurements using multiple DMG antennas simultaneously(11ay)).

If the BRP TXSS includes receive training of the responder, the initiator shall transmit one EDMG BRP-RX PPDU MBIFS after the reception of the BRP frame sent by the responder with feedback of the Initiator BRP TXSS.

If the procedure includes a Responder BRP TXSS, the responder shall send the first EDMG BRP-TX PPDU MBIFS after the EDMG BRP-RX PPDU sent by the initiator or, if receive training of the responder is not

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performed, the BRP frame with feedback transmitted by the responder within the Initiator BRP TXSS. The EDMG BRP-TX PPDUs sent by the responder in a BRP TXSS procedure shall be separated by SIFS.

The BRP CDOWN field within the EDMG BRP Request element or EDMG BRP field in each transmitted EDMG BRP-TX PPDU shall contain the total number of transmissions remaining until the end of the Responder BRP TXSS, such that the first EDMG BRP-TX PPDU transmitted in the Responder BRP TXSS has the BRP CDOWN field set to $(N_{resp} + 1) \times (R_{init} + 1) - 1$, and the last PPDU has the BRP CDOWN field set to 0.

If the BRP TXSS includes a Responder BRP TXSS, the initiator shall send a BRP frame to the responder containing feedback based on measurements it performed. The BRP frame with feedback transmitted by the initiator is separated from the last EDMG BRP-TX PPDU transmitted by the responder by an MBIFS.

If the BRP TXSS includes receive training of the initiator, the responder shall transmit the first EDMG BRP-RX PPDU MBIFS after the reception of the BRP frame sent by the initiator with feedback of the Responder BRP TXSS or, if Responder BRP TXSS is not performed, of the EDMG BRP-RX PPDU transmitted by the initiator. The EDMG BRP-RX PPDUs sent by the responder shall be separated by SIFS.

If the BRP TXSS includes receive training of the initiator, the initiator shall transmit a BRP frame with acknowledgment MBIFS after the reception of the last EDMG BRP-RX PPDU transmitted by the responder if it was successfully received. If the BRP TXSS does not include receive training of the initiator, the responder shall transmit a BRP frame with acknowledgment if the last BRP frame sent by the initiator was successfully received.

The responder and initiator of a SISO BRP TXSS shall start using the AWV configurations identified in the procedure immediately after the transmission of the BRP frame with acknowledgment.

If the TXSS-MIMO subfield in the EDMG BRP Request element or EDMG BRP field of the BRP frame that initiated the BRP TXSS was set to 1, the initiator shall start the MIMO phase of SU-MIMO beamforming training an MBIFS following the completion of the BRP TXSS.

### 10.41.10.6 First path beamforming training

(11az)First path beamforming training (FPBT) is a procedure used to determine the best AWV corresponding to the first path. The first path is defined to be the propagation path between TX and RX that is estimated to have the shortest time of flight. In line of sight (LOS) conditions, the first path corresponds to the LOS path. If several AWVs have the same estimated shortest time of flight, the beamforming training shall select among them the first path as the one with best quality. The method a STA uses to determine the first path and the first path with best quality is implementation dependent and beyond the scope of this standard.

(11az)Prior to performing the FPBT, the two EDMG STAs are assumed to know their best transmit AWV and receive AWV for data communication. A FPBT shall be completed within the CBAP or SP in which it was initiated. An EDMG STA that has the First Path Beamforming Training Supported subfield in the STA's RSNXE set to 1 is FPBT capable.

(11az)An EDMG STA shall not initiate FPBT with a peer EDMG STA that is not FPBT capable.

(11az)The FPBT procedure is the same as BRPTXSS procedure (see 10.41.10.5 (BRP transmit sector sweep (BRP TXSS))) except for the following differences:

— FPBT shall be performed in SISO configuration defined in 10.41.10.5.2 (BRP TXSS configuration) with any valid combination of TXVECTOR parameter, CH_BANDWIDTH, and CH_AGGREGATION. FPBT shall not be performed in MIMO configuration. All the phases of the BRP-TXSS procedure shall be supported in FPBT. Selection of which phases are used is dependent


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on the DMG antenna reciprocity and antenna pattern reciprocity properties of the involved EDMG STAs as defined in their DMG STA Capability Information field.

— In the setup phase, the EDMG STA shall transmit a BRP frame with the First Path Beamforming Training subfield set to 1 to request FPBT. An EDMG STA that is FPBT capable, and receives a BRP frame with the First Path Beamforming Training subfield equal to 1, shall set the First Path Beamforming Training subfield to 1 in the BRP frame that it sends in response to the reception of the BRP frame.

— In a BRP transaction (Initiator BRP TXSS, receive training phase of the responder, Responder BRP TXSS, and receive training phase of the initiator) that is part of a first path beamforming training, all transmitted BRP frames shall have the First Path Beamforming Training subfield set to 1 and shall have the FIRST_PATH_TRAINING parameter in the TXVECTOR set to 1. In such a transaction, all TX and RX beamforming training using the TRN field is used to find the AWV of the first path and not the best path. The AWV selected by the FPBT shall not be used for data transmission. It shall be used only in the FTM procedure defined in 11.21.6.4.2.6 (DMG first path AWV for EDCA based ranging measurement exchange(11az)).

(11az)The TRN field of the EDMG BRP-RX PPDU used for the receive training phase of the responder:

— Shall be transmitted with the best first path AWV identified in the preceding Initiator BRP TXSS phase.

— Shall be received with the DMG antenna corresponding to the best first path AWV configuration identified in the preceding Initiator BRP TXSS phase.

— When the receive training phase of the initiator is performed, the TRN field of the EDMG BRP-RX PPDUs used in this phase shall be transmitted with the best first path AWV identified in the preceding Responder BRP TXSS phase or in the receive training of the responder, as defined in 10.41.10.5.2 (BRP TXSS configuration).

### 10.41.10.7 Dual polarization TRN beamforming training

Dual polarization TRN beamforming training may be used to assist a pair of EDMG STAs to determine if a beamformed link between them uses line-of-sight or non-line-of-sight propagation.

An EDMG STA supports dual polarization TRN beamforming training if the Dual Polarization TRN Supported subfield in the STA's EDMG Capabilities element is 1.

An EDMG STA may initiate dual polarization TRN beamforming training with a peer EDMG STA if the peer STA

— Supports dual polarization TRN beamforming training and

— Indicates that it is capable of sending channel measurement feedback by setting the Chan-FBCK-CAP subfield to 1 in the last BRP Request field transmitted by the peer STA to the initiating STA.

Dual polarization TRN beamforming shall include at least a setup phase that consists of BRP frame from the initiator followed by a BRP frame from the responder, which is followed by a TRN training phase and the

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responder's channel measurement feedback as shown in Figure 10-127 (Dual polarization TRN beamforming training procedure(11ay)).

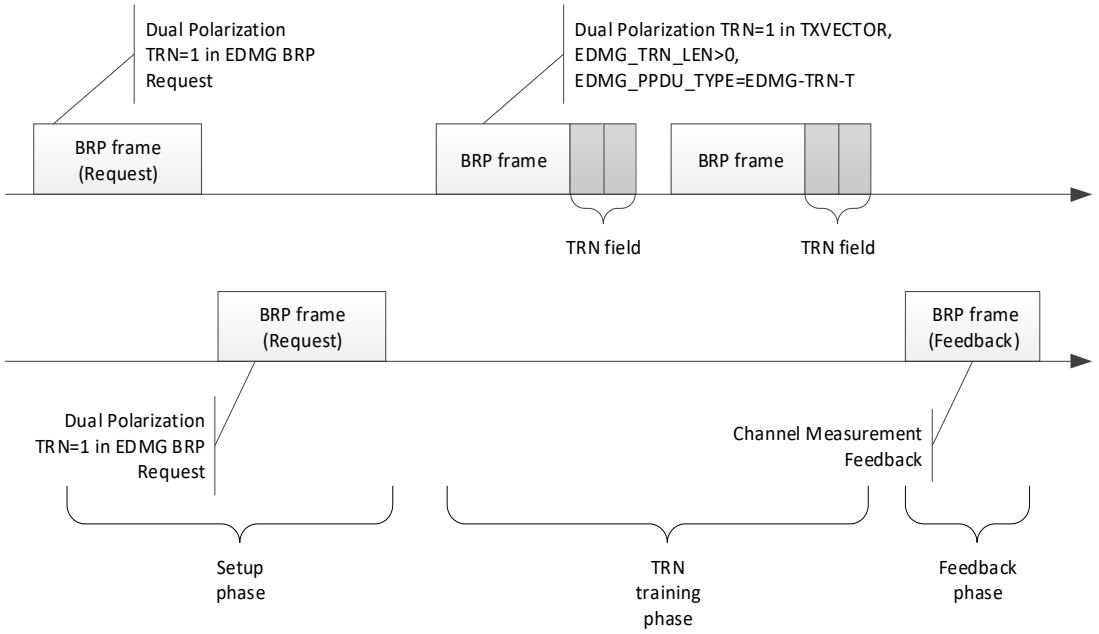


**Figure 10-127—Dual polarization TRN beamforming training procedure(11ay)**

In the setup phase, to request dual polarization TRN beamforming training, an initiating STA shall transmit a BRP frame to a responding STA that includes an EDMG BRP Request element with the following field setting:

- Dual PolarizationTraining set to 1
- TXSS-initiator set to 1
- TXSS-Repeat > 0

To conclude the setup phase, the responder shall respond, in a SIFS following the reception of the BRP frame from the initiator, with a BRP frame that contains an EDMG BRP Request element with the following field setting:

- Dual PolarizationTraining set to 1
- TXSS-initiator set to 0

During the dual polarization transmit training phase, the initiator sends PPDUs with TRN subfields within the TRN field switching polarization as described in 28.9.2.2.5 (TRN field definition), with the following TXVECTOR parameter setting:

- DUAL_POL_TRAINING set to 1.
- EDMG_PPDU_TYPE set to either EDMG-TRN-T or EDMG-TRN-R/T.
- EDMG_TRN_LEN set to a value greater than 0.
- EDMG_TRN_N set to either 1 or 3 (for EDMG_TRN_N=1, two consecutive TRN subfields have alternate polarization, e.g., horizontal vertical (HV) or vertical horizontal (VH); for EDMG_TRN_N=3, the polarization changes after two consecutive TRN subfields, e.g., HHVV or VVHH).

In the TRN training phase, when changing polarizations, the initiator shall change the TRN subfields polarizations with a 90 degrees rotation in a clockwise direction. For example for HV, the polarization


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changes from TRN horizontal polarization direction to vertical polarization direction via a 90 degrees clockwise rotation. As the responder receives the PPDUs in the dual polarization transmit training phase, it measures the signal strength of the dual polarized received TRN subfield as described in 28.9.2.2.5 (TRN field definition). This might require the responder to switch the receive polarization.

In the feedback phase, the responder responds with a BRP frame with the Channel Measurement Feedback element and EDMG Channel Measurement Feedback element that includes the Dual Polarization TRN Measurement field.

The initiator may use the received feedback to estimate if the communication link with the responder is NLOS or LOS.

If, in addition to the TXVECTOR parameters specified above in this subclause, the initiator sets the FIRST_PATH_TRAINING parameter to 1 and the First Path Training field of the EDMG BRP Request element to 1, the responder shall perform the measurement on the first arrival path and respond with a BRP frame with Channel Measurement Feedback element and EDMG Channel Measurement Feedback element with the Dual Polarization TRN field and First Path Training fields in the EDMG BRP Request element set to 1.

### 10.41.11 TDD beamforming(11ay)

#### 10.41.11.1 General

The following TDD beamforming procedures are defined in this subclause:

- TDD individual beamforming: a single STA (initiator) transmits a series of TDD SSW frames through its sectors while a target STA (responder) sweeps the receive sectors specified by MLME-SCAN.request or MLME-TDD-BEAM-MEASUREMENT.request primitives. If the responder receives at least one TDD SSW frame, by exchanging additional frames both initiator and responder are made aware of one or more combinations of transmit beam on the initiator side and receive beam on the responder side that enable communication between the two STAs.
- TDD group beamforming: a single STA (initiator) transmits a series of TDD SSW frames through its sectors while two or more target STAs (responders) sweep the receive sectors specified by MLME-SCAN.request or MLME-TDD-BEAM-MEASUREMENT.request primitives at each target STA. For each responder that receives at least one TDD SSW frame, by exchanging additional frames both initiator and responder are made aware of one or more combinations of transmit beam on the initiator side and receive beam on the responder side.
- TDD beam measurement: a single STA (initiator) transmits a series of TDD SSW frames while a single target STA (responder), or alternatively a group of target STAs (responders), sweep their respective receive sectors. The primary difference between TDD beam measurement and other TDD beamforming procedures is that in TDD beam measurement responders transmit an Announce frame with a TDD Route element to the initiator during the procedure only upon request, and additionally, report the measurement results to the SME.

As specified in 11.54.2 (TDD channel access life cycle), unscheduled TDD beamforming is referred to as the TDD beamforming scheduled via the Transmit Period field within a TDD SSW frames. If TDD beamforming is scheduled via the TDD Slot Schedule element, it is referred to as scheduled TDD beamforming.

After the completion of the TDD beamforming procedure, the responder shall send to the initiator Announce frames containing TDD Route element with the results of the TDD beamforming. For unscheduled TDD beamforming, the initiator and responder may perform the authentication and association procedure described in 11.54.3 (Scheduling for association and secure authentication).

All TDD beamforming procedures shall be performed during a TDD SP.

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The TDD individual and group beamforming procedures assume antenna reciprocity for both the initiator and responder STAs. A TDD Beamforming frame is a TDD SSW frame, a TDD SSW Feedback frame or a TDD SSW Ack frame.

Figure 10-128 (Example of TDD individual beamforming training(11ay)) gives an example of the TDD individual beamforming training procedure.

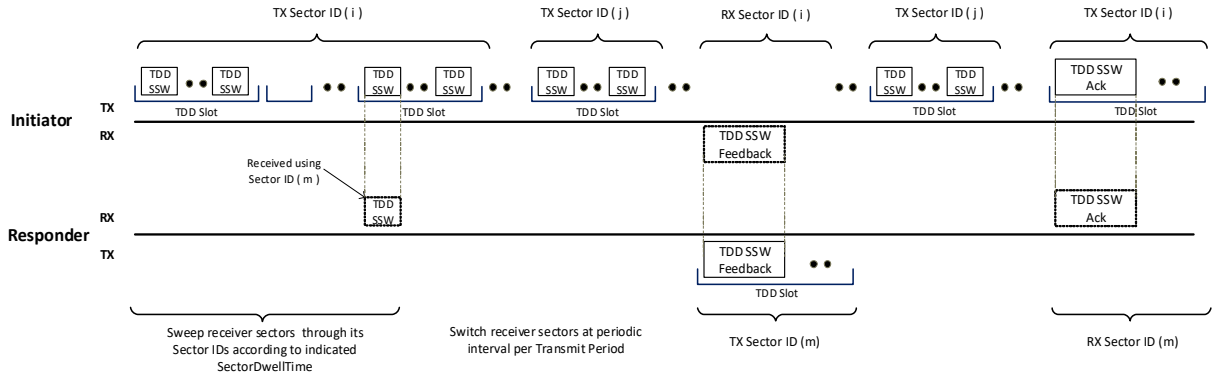


**Figure 10-128—Example of TDD individual beamforming training(11ay)**

During TDD individual beamforming training, a STA that has not established a DMG control mode connection with an intended peer switches its antenna configuration through all its receive sectors. In order to establish a DMG control mode connection, an initiator sends multiple TDD SSW frames during its assigned TDD slots. A TDD SSW frame indicates to the responder the TX Sector ID used by the initiator for the transmission of the TDD SSW frame and, in case of unscheduled TDD beamforming, the frame also includes the time offset for which the responder should send its TDD SSW Feedback frame as response and the time offset the responder shall be ready to receive one or more TDD SSW Ack frames sent to increase robustness. The responder sends its TDD SSW Feedback frame with the same sector it received the TDD SSW frame with the best quality. Following the reception of a TDD SSW Feedback frame, the initiator sends a TDD SSW Ack frame that acknowledges the received configuration.

During TDD individual BF training, the TDD SSW frame is sent periodically and is repeated multiple times for each TX Sector ID. The TDD individual BF training sequence continues until the initiator sets the End of Training subfield in the TDD SSW Ack frame to 1. In unscheduled TDD beamforming, the TDD SSW Ack frame includes also a time offset indication in the Initiator Transmit Offset subfield on when the responder obtains the network configuration parameters and time offset indication in the Responder Transmit Offset subfield on when the responder reports the results of the TDD individual BF procedure.


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Figure 10-129 (Example of TDD group beamforming training(11ay)) gives an example of the TDD group beamforming training procedure.

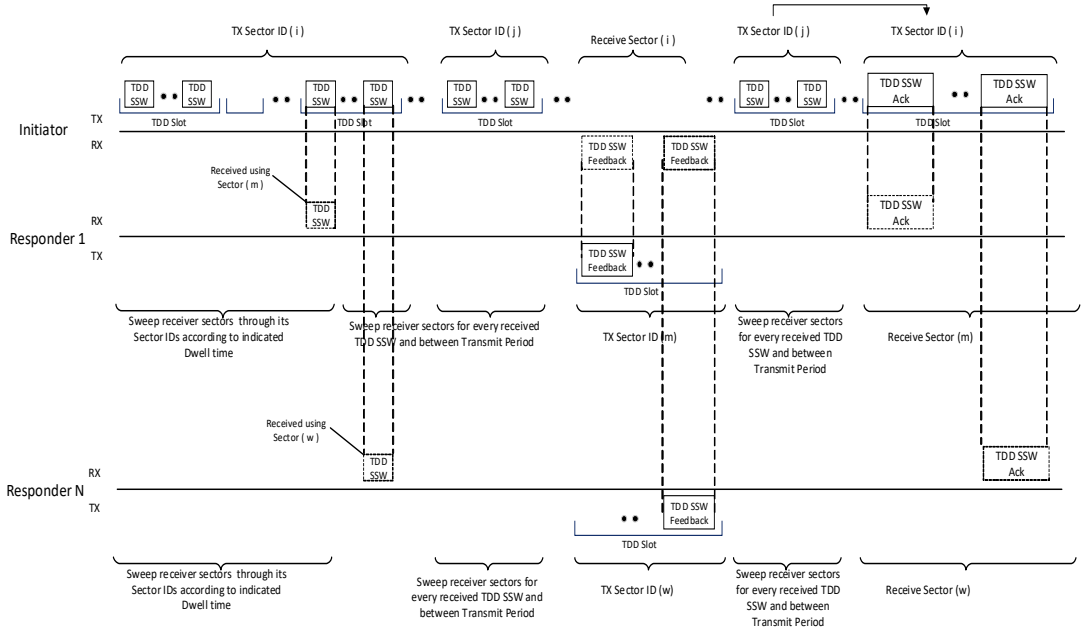


**Figure 10-129—Example of TDD group beamforming training(11ay)**

A STA participating in TDD group beamforming training and that has not established a DMG control mode connection with an intended peer switches its antenna configuration through all its receive sectors. In order to establish a DMG control mode connection, an initiator sends multiple TDD SSW frames during its assigned TDD slots. A TDD SSW frame indicates to the responders the TX Sector ID used by the initiator for the transmission of the TDD SSW frames and, in case of unscheduled TDD beamforming, the frame also includes the time offset for which each responder should send its TDD SSW Feedback frame as response and the time offset each responder shall be ready to receive a TDD SSW Ack frame. Each responder sends its TDD SSW Feedback frame with the same sector it received the TDD SSW frame with the best quality. Following the reception of a TDD SSW Feedback frame, the initiator sends a TDD SSW Ack frame to each responder that acknowledges the received configuration.

During the TDD group BF training, the TDD SSW frame is sent periodically and is repeated multiple times for each TX Sector ID. The TDD group BF training sequence for each responder continues until the initiator sets the End of Training subfield in the TDD SSW Ack frame to 1 for the corresponding responder. For unscheduled TDD beamforming, the initiator also indicates in the Initiator Transmit Offset subfield the time offsets on when the corresponding responder obtains the TDD Slot Schedule element for allocated TDD slots for further TDD link access operation and in the Responder Transmit Offset subfield the time offset on when the corresponding responder reports the results of the TDD group BF procedure. The initiator can end a TDD group BF training with the responders simultaneously or individually. This is implementation dependent and beyond the scope of this standard.

### 10.41.11.2 Initiator operation for TDD individual beamforming

For TDD individual beamforming, the BFType parameter is set to TDD Individual BF in the MLME-TDD-BF-TRAINING.request primitive.

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To initiate TDD individual beamforming with a known responder, the initiator shall send multiple TDD SSW frames with the RA field set to the Responder STA's MAC address as indicated by the PeerSTAAddress parameter of the MLME-TDD-BF-TRAINING.request primitive.

To initiate TDD individual beamforming with an unknown responder, the initiator shall send TDD SSW frames with the RA field set to the broadcast address. The initiator should switch the RA field in a transmitted TDD SSW frame to responder's MAC address after receiving a TDD SSW Feedback frame from the intended responder.

TDD SSW frames that are sent from the same transmit DMG antenna shall have the same TX Antenna ID subfield value. TDD SSW frames that are sent from the same transmit antenna sector shall have the same TX Sector ID, Beamforming Time Unit, Transmit Period, Responder Feedback Offset, Initiator Ack Offset and Number of Requested Feedback subfield values. These frames shall be transmitted with the same transmit power and the PPDUs carrying these frames shall not include TRN fields.

The initiator shall send TDD SSW frames through all the DMG antennas and all the sectors indicated by the TX antenna index and TX sector index values as indicated in the TXAntennaSectorIDList parameter of the MLME-TDD-BF-TRAINING.request primitive. Moreover, for each DMG antenna and for each sector, the initiator shall send TDD SSW frames with the same TX Antenna ID and TX Sector ID subfields values for the number of times indicated in the NumOfTDDSlotPerTXSector parameter multiplied by NumOfSSWPerTDDSlot parameter of the MLME-TDD-BF-TRAINING.request primitive. If the initiator transmits a TDD SSW Ack frame, the initiator shall send as many TDD SSW Ack frames as the number indicated in the NumOfAckPerTDDSlot parameter of the MLME-TDD-BF-TRAINING.request primitive.

The Transmit Period subfield value within TDD SSW frames shall remain the same throughout a TDD beamforming training. If the value of the Transmit Period subfield is nonzero, at the time offset equal to the Transmit Period subfield value the initiator shall transmit a TDD SSW frame of the TDD beamforming training with the same Count Index value.

If the link between the initiator and responder is in the active state (see 11.54 (TDD channel access operation(11ay))), and the initiator has sent the responder at least one frame with a TDD Slot Structure element and a TDD Slot Schedule element, then the initiator should use BF TDD slots to send TDD SSW and TDD SSW Ack frames to the responder. In this case, the Transmit Period, Responder Feedback Offset, Initiator Ack Offset, Initiator Transmit Offset and Responder Transmit Offset subfields shall be set to 0.

TDD SSW and TDD SSW Ack frames transmitted in the same TDD slot shall be separated with SBIFS and shall have a strictly increasing Count Index subfield value. The first TDD SSW frame or TDD SSW Ack frame transmitted in a TDD slot shall have the Count Index subfield set to 0. The Responder Feedback Offset subfield shall be equal in all TDD SSW frames transmitted in the same TDD slot. The Initiator Ack Offset subfield shall be equal in all TDD SSW frames transmitted in the same TDD slot. The Initiator Transmit Offset subfield shall be equal in all TDD SSW Ack frames transmitted in the same TDD slot. The Responder Transmit Offset subfield shall be equal in all TDD SSW Ack frames transmitted in the same TDD slot.

To receive a TDD SSW Feedback frame from the responder, the initiator shall set its receive antenna to the same DMG antenna and sector that were indicated, respectively, in the TX Antenna ID and TX Sector ID subfield of the corresponding TDD SSW frame, at the following offset calculated as a spacing from the end of the transmitted TDD SSW frame to the start of the expected transmission of the TDD SSW Feedback frame by the responder:

$$ResponderFeedbackOffset - [(CountIndex + 1) \times \text{TXTIME(TDD SSW)} + (CountIndex \times \text{SBIFS})] \quad (10\text{-}20)$$


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where

*ResponderFeedbackOffset* is the value of the Responder Feedback Offset subfield in the TDD SSW frame with the same TX Sector ID within the same TDD slot

*CountIndex* is the value of the Count Index subfield in the transmitted TDD SSW frame

Figure 10-130 (TDD SSW Feedback frame transmit time for unscheduled TDD individual BF(11ay)) depicts the timing to transmit the TDD SSW Feedback frame for unscheduled TDD individual BF.

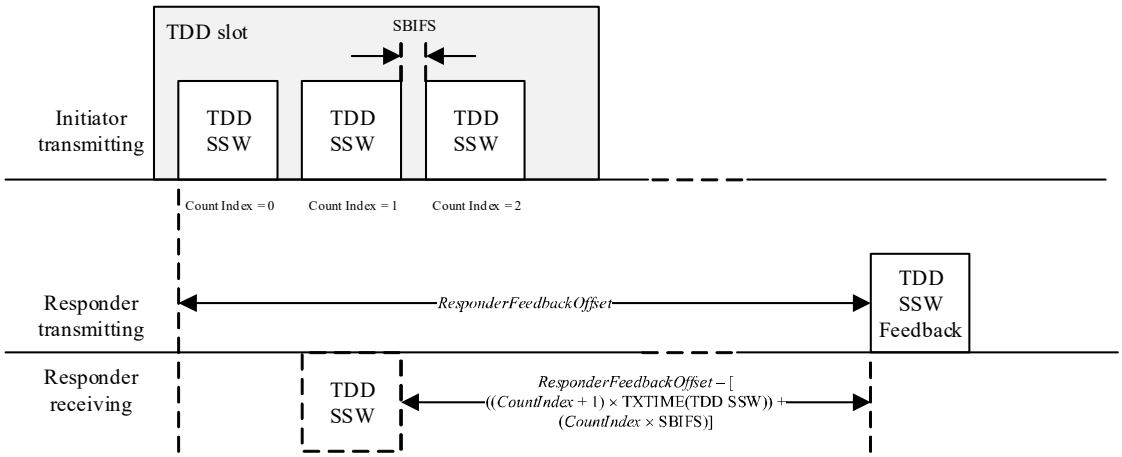


**Figure 10-130—TDD SSW Feedback frame transmit time for unscheduled TDD individual BF(11ay)**

If the initiator received a TDD SSW Feedback frame, it shall transmit one or more TDD SSW Ack frames to the responder. To transmit these frames, the initiator shall set its DMG antenna and sector to the Decoded TX Antenna ID and the Decoded TX Sector ID from the last received TDD SSW Feedback frame. The transmission of the first TDD SSW Ack frame shall start at the following offset calculated as a spacing from the end of the transmitted TDD SSW frame to the start of the transmission of the first TDD SSW Ack frame:

$$InitiatorAckOffset - [(CountIndex + 1) \times \text{TXTIME(TDD SSW)} + (CountIndex \times \text{SBIFS})] \quad (10\text{-}21)$$

where

*InitiatorAckOffset* is the value of the Initiator Ack Offset subfield in the TDD SSW frame with the same TX Sector ID within the same TDD slot

*CountIndex* is the value of the Count Index subfield in the transmitted TDD SSW frame

The TDD SSW Ack frame shall include in the Decoded TX Sector ID subfield the sector indicated by the responder in the TX Sector ID subfield, in the Decoded TX Antenna ID subfield the sector indicated by the responder in the TX Antenna ID subfield of the TDD SSW Feedback frame last received by the initiator, the measured SNR of the decoded TDD SSW Feedback frame in the SNR Report subfield and, when performing unscheduled TDD beamforming, the time offsets to exchange frames containing TDD Route, TDD Slot Structure and TDD Slot Schedule elements.

For TDD individual BF, an initiator may request the responder to stop its receive sector sweeping by setting the End of Training subfield to 1 in transmitted TDD SSW frames. Upon reception of a TDD SSW Feedback frame with the End of Training subfield equal to 1, the initiator shall send one or more TDD SSW Ack frames to the responder with End of Training subfield set to 1 at the time offset indicated by Equation (10-21) or, alternatively, during assigned BF TDD slots. After sending a TDD SSW Ack frame with End of Training subfield equal to 1, the initiator shall configure its receive and transmit DMG antenna and sector index as indicated, respectively, in the Decoded TX Antenna ID and Decoded TX Sector ID subfields of the TDD SSW Feedback frame received from the responder in which its End of Training

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subfield was set to 1. The initiator shall use this DMG antenna and sector for its subsequent transmissions and receptions with the responder, until another sector is negotiated.

After the initiator has sent the TDD SSW Ack frame with the End of Training subfield set to 1 to the responder, it may transmit a single PPDU other than a TDD Beamforming frame to the responder. To transmit the frame, the initiator shall set its antennas to the Decoded TX Sector ID and the Decoded TX Antenna ID from the last received TDD SSW Feedback frame. The transmission of the frame shall start at the following offset calculated as a spacing from the end of the transmitted TDD SSW Ack frame with the End of Training subfield set to 1 to the start of the expected transmission:

$$InitiatorTransmitOffset - [(CountIndex + 1) \times \text{TXTIME(TDD SSW Ack)} + (CountIndex \times \text{SBIFS})] \quad (10\text{-}22)$$

where

*InitiatorTransmitOffset* is the value of the Initiator Transmit Offset subfield in the TDD SSW Ack frame with the End of Training subfield set to 1

*CountIndex* is the value of the Count Index subfield in the transmitted TDD SSW Ack frame with the End of Training subfield set to 1

Subsequent opportunities for the initiator to transmit to the responder are separated by the value of the Transmit Period subfield in the TDD SSW Ack frame with the End of Training subfield set to 1.

After the initiator has sent the last TDD SSW Ack frame with the End of Training subfield set to 1 to the responder, it shall be ready to receive a single PPDU other than a TDD Beamforming frame from the responder by setting its receive DMG antenna and sector to the Decoded TX Antenna ID and the Decoded TX Sector ID from the last received TDD SSW Feedback frame, at the following offset calculated as a spacing from the end of the transmitted TDD SSW Ack frame with the End of Training subfield set to 1 to the start of the expected reception of the frame:

$$ResponderTransmitOffset - [(CountIndex + 1) \times \text{TXTIME(TDD SSW Ack)} + (CountIndex \times \text{SBIFS})] \quad (10\text{-}23)$$

where

*ResponderTransmitOffset* is the value of the Responder Transmit Offset subfield in the TDD SSW Ack frame with the End of Training subfield equal to 1

*CountIndex* is the value of the Count Index subfield in the transmitted TDD SSW Ack frame with the End of Training subfield equal to 1

Subsequent opportunities for the responder to transmit to the initiator are separated by the value of the Transmit Period subfield in the TDD SSW Ack frame with the End of Training subfield set to 1.

For the unscheduled TDD beamforming procedure, Equation (10-20) and Equation (10-21) establish transmit opportunities to exchange TDD Beamforming frames, and Equation (10-22) and Equation (10-23) establish transmit opportunities to exchange frames other than TDD Beamforming frames after TDD beamforming training completion with the responder.

In the unscheduled TDD beamforming procedure, upon transmission of the last TDD SSW Ack frame with End of Training subfield equal to 1, the initiator shall transmit an Announce frame to the responder, at the time offset indicated by Equation (10-22). The Announce frame shall include a TDD Slot Structure element. The initiator shall then, at the time offset indicated by Equation (10-23), be ready to receive a frame from the responder. If necessary, the initiator shall transmit additional frames at the periodic transmit opportunities following the time offset indicated by Equation (10-22), and shall be ready to receive additional frames at the periodic opportunities following the offset indicated by Equation (10-23).


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In the scheduled TDD beamforming procedure, the initiator shall send TDD SSW and TDD SSW Ack frames during BF TDD slots assigned to transmit from the initiator to the responder. The exchange of TDD Route elements takes place during Basic or Data TDD slots available to the initiator and to the responder after completion of the TDD beamforming training with the responder.

### 10.41.11.3 Responder operation for TDD individual beamforming

A responder STA that has is in inactive state (see 11.54 (TDD channel access operation(11ay))), or has not yet received a TDD SSW frame, or has not yet acquired the TDD Slot Structure element used by the BSS shall sweep its receiver antenna through all its receive sectors while dwelling on each sector for a time equal to SectorDwellTime as indicated by the MLME-TDD-BF-SCAN.request primitive.

NOTE 1—To increase the likelihood of detecting the initiator's TDD SSW frame, the responder SME can set SectorDwellTime to at least [2 × TXTIME (TDD SSW) + SBIFS].

Figure 10-131 (Responder's receiver sweeping for unscheduled TDD individual BF(11ay)) gives an example of the responder's receiver sweeping procedure for unscheduled TDD individual BF.

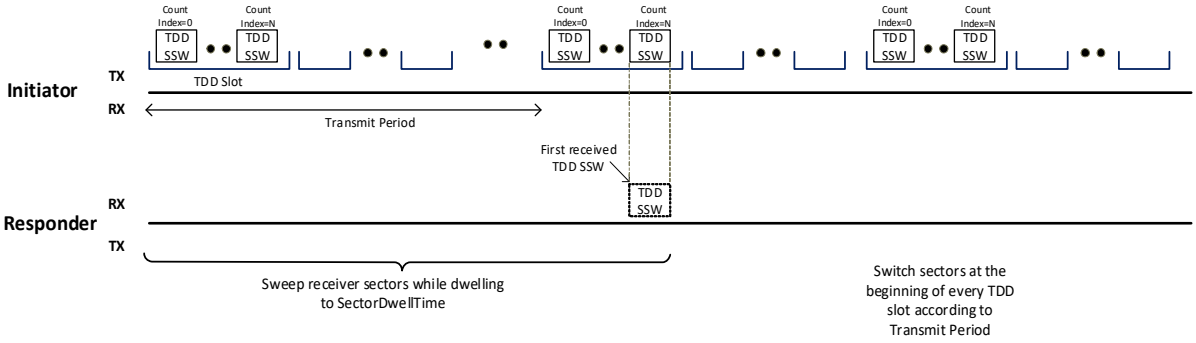


**Figure 10-131—Responder's receiver sweeping for unscheduled TDD individual BF(11ay)**

Once the first TDD SSW frame is received, the responder proceeds with the following operation.

Upon reception on a receive sector of a TDD SSW frame with the RA field set to its MAC address or to the broadcast address, a responder shall switch within the TDD slot to its next receive sector to be ready to receive the next TDD SSW frame transmission within SBIFS. The responder shall switch its receive sector at the beginning of every TDD slot used for BF training at the time specified by a nonzero Transmit Period subfield in the received TDD SSW frame. While sweeping through its receive sectors, the responder shall continue decoding all the received TDD SSW frames.

NOTE 2—Switching the receive sectors after reception of each TDD SSW frame increases the number of trained receive sectors at the expense of receive sector measurement quality.

The responder shall transmit a TDD SSW Feedback frame using the DMG antenna and sector from which the responder received the TDD SSW with the best link quality at the time indicated by Equation (10-20) or, alternatively, during an assigned BF TDD slot. The TDD SSW Feedback frame shall include the DMG antenna index and sector index used by the initiator to transmit the TDD SSW frame in the, respectively, Decoded TX Antenna ID and Decoded TX Sector ID subfields, the DMG antenna index and sector index used by the responder to transmit the TDD SSW Feedback frame in the, respectively, TX Antenna ID and TX Sector ID subfields, and the SNR of the TDD SSW frame received with the best quality in the SNR Report subfield. The number of transmitted TDD SSW Feedback frames shall be equal to the value indicated in the Number of Requested Feedback subfield plus one of the received TDD SSW frame. The Feedback Count Index subfield in each transmitted TDD SSW Feedback frame shall contain the index of the

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TDD SSW Feedback frame transmitted in the same TDD slot, with the first TDD SSW Feedback frame having an index equal to 0. Except for the value of the Feedback Count Index subfield, all subfields of TDD SSW Feedback frames transmitted in a TDD slot shall have the same value of the corresponding field transmitted in the first TDD SSW Feedback frame within the TDD slot.

At the time offset indicated by Equation (10-21) of the decoded TDD SSW frame or, alternatively, during an assigned BF TDD slot, the responder shall set its receiver to the same DMG antenna and to the same sector that was indicated in the, respectively, TX Antenna ID and TX Sector ID subfields of the TDD SSW Feedback frame in order to be ready to receive a TDD SSW Ack frame from the initiator.

The responder shall continue sweeping through its receive sectors until successfully receiving and decoding a TDD SSW Ack frame with End of Training subfield equal to 1. Upon the reception of TDD SSW Ack frame with End of Training subfield equal to 1, the responder shall stop its receive sweeping and shall configure its DMG antenna as indicated in the Decoded TX Antenna ID subfield and its sector as indicated in the Decoded TX Sector ID subfield of the TDD SSW Ack frame received from the initiator that has the End of Training subfield equal to 1. The responder shall use this DMG antenna and sector for its subsequent frame exchange sequences(#109) with the initiator, until another sector is negotiated.

A responder that transmits a TDD SSW Feedback frame in response to a TDD SSW frame sent with End of Training subfield equal to 1 shall set the End of Training subfield in the TDD SSW Feedback frame to 1.

In the unscheduled TDD beamforming procedure, upon reception of a TDD SSW Ack frame with End of Training subfield equal to 1, the responder shall be ready to receive an Announce frame from the initiator at the time offset indicated by Equation (10-22). The responder shall then, at the time offset indicated by Equation (10-23), transmit an Announce or (Re)Association Request frame that includes a TDD Route element listing the ordered pairs of transmit sectors and decoded receive sectors obtained during the TDD beamforming training with the initiator. If necessary, the responder shall transmit additional frames at the periodic transmit opportunities following the time offset indicated by Equation (10-23), and shall be ready to receive additional frames at the periodic opportunities following the offset indicated by Equation (10-22).

In the scheduled TDD beamforming procedure, the responder shall send TDD SSW Feedback frames during BF TDD slots assigned to transmit from the responder to the initiator. The exchange of TDD Route elements takes place during Basic or Data TDD slots available to the initiator and the responder after completion of the TDD beamforming training.

A STA that has started to sweep its receive DMG antenna configuration in response to a TDD SSW frame with RA field set to the broadcast address and, during the same beamforming process, receives a TDD SSW frames with RA field set to an individual address different from the STA's MAC address shall stop its receive sweeping and shall configure its DMG antenna to the sector as indicated in the last successful TDD beamforming or TDD sector switch procedure and shall use this sector for its subsequent frame exchanges with the initiator, until another sector is negotiated.

NOTE 3—Switching from group addressed to individual addressed TDD beamforming can be used as method to discover a new STA in vicinity. In this case, other responders remain connected and revert to previously negotiated sectors.

A non-AP and non-PCP responder that has a link in active state with the initiator and that has received a frame with a TDD Slot Structure element and a TDD Slot Schedule element shall sweep its receiver antenna configuration through its received sectors in BF TDD slots. The responder shall resume the sweep from the previous configuration (used in the preceding BF TDD slot, if any) at the beginning of each BF TDD slot regardless of the value of the Transmit Period subfield within a received TDD SSW frame. In this case, the SectorDwellTime should be set to TXTIME(TDD SSW)+SBIFS. Such a responder shall use a BF TDD slot assigned for transmission from the responder to the initiator to trasnsmit a TDD SSW Feedback frame using the best DMG antenna when receiving TDD SSW frames of the current BF TDD sector training. The


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responder may set the End of Training subfield in the TDD SSW Feedback frame to indicate that it has received enough repetitions from the current transmit sector, so that the initiator may proceed to the next transmit sector. In this case, the initiator shall not set the End of Training subfield in the following TDD SSW Ack frame to 1.

#### 10.41.11.4 Initiator operation for TDD group beamforming

For TDD group beamforming, the BFType parameter is set to TDD group BF in the MLME-TDD-BF-TRAINING.request primitive.

To initiate TDD group beamforming, the initiator shall send multiple TDD SSW frames. For each TDD SSW frame, the RA field shall be set to the broadcast address. The Responder ID subfield of each responder included in a transmitted TDD SSW frame is set to be the value derived from the responder's MAC address following the scheme depicted in Figure 10-132 (Generation of Responder ID subfield(11ay)). The MAC address of each responder is indicated by the PeerSTAAddress parameter of the MLME-TDD-BF-TRAINING-START.request primitive.

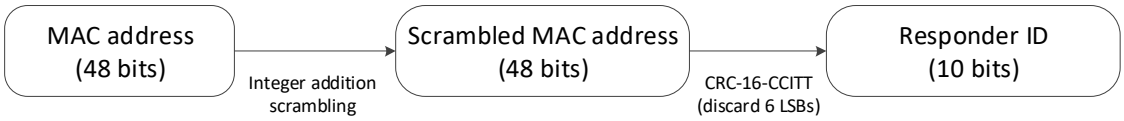


**Figure 10-132—Generation of Responder ID subfield(11ay)**

The process starts by using the MAC address of the responder to generate the scrambled MAC address. The MAC address is divided into three words, $word_i$ ($0 \le i \le 2$), of 16 bits each, where $word_0$ is the 16 MSB of the MAC address and $word_2$ is the 16 LSB of the MAC address. For each $word_i$, a $scrambled\_word_i$ is created as follows:

$$scrambled\_word_i = (word_i + scramble\_pattern) \bmod 2^{16}$$

where

$word_i$ is the corresponding 16 bit word from the MAC address

*scramble_pattern* is $((0x5795 \times seed\_value) \bmod 2^{15})$, where *seed_value* is the value of the Scrambler Initialization field in the L-Header of the PPDU carrying the TDD SSW frame

The scrambled MAC address is generated by the consecutive concatenation of $scrambled\_word_0$, $scrambled\_word_1$, and $scrambled\_word_2$.

Finally, the Responder ID subfield is generated by taking the 10 MSBs of CRC-16-CCITT computed over the scrambled MAC address. The CRC-16 is computed as defined in 20.3.7 (HCS calculation for headers of DMG control mode and DMG SC mode).

TDD SSW frames that are sent from the same transmit DMG antenna shall have the same TX Antenna ID subfield value. TDD SSW frames that are sent from the same transmit sector shall have the same TX Sector ID subfield value. TDD SSW frames shall be transmitted at the same transmit power and shall not include BRP training fields.

An initiator shall send TDD SSW frames through all the DMG antennas and all the sectors indicated by the TX antenna index and TX sector index values contained in the TXAntennaSectorIDList parameter of the MLME-TDD-BF-TRAINING.request primitive. For each DMG antenna and each sector, the initiator shall send TDD SSW frames with the same TX Antenna ID and TX Sector ID subfield values for the number of times indicated in the NumOfTDDSlotPerTXSector parameter multiplied by the NumOfSSWPerTDDSlot

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parameter of the MLME-TDD-BF-TRAINING.request primitive. If the initiator transmits a TDD SSW Ack frame, the initiator shall send as many TDD SSW Ack frames as the number indicated in the NumOfAckPerTDDSlot parameter of the MLME-TDD-BF-TRAINING.request primitive.

The Transmit Period subfield value within TDD SSW frames shall remain the same throughout a TDD beamforming training. If the value of the Transmit Period subfield is nonzero, at the time offset equal to the Transmit Period subfield value the initiator shall transmit a TDD SSW frame or a TDD SSW Ack frame of the TDD beamforming training with the same Count Index value.

TDD SSW and TDD SSW Ack frames transmitted in the same TDD slot shall be be separated with SBIFS and shall have a strictly increasing Count Index subfield value, with the first transmitted TDD SSW frame or TDD SSW Ack frame in a TDD slot having this subfield equal to 0.

To receive a TDD SSW Feedback frame from the responder, the initiator shall set its receive DMG antenna to the same DMG antenna and sector as was indicated, respectively, in the TX Antenna ID and TX Sector ID subfields of the respective TDD SSW frame, at the following offset from the end of the last transmitted TDD SSW frame:

$$ResponderFeedbackOffset_n - [AckCountIndex \times \text{TXTIME(TDD SSW Ack)} + (CountIndex + 1 - AckCountIndex) \times \text{TXTIME(TDD SSW)} + (CountIndex \times \text{SBIFS})] \quad (10\text{-}24)$$

where

$ResponderFeedbackOffset_n$ is the value of the Responder Feedback Offset subfield in the $n^{th}$ responder's Responder Info subfield of the TDD SSW frame with the same TX Sector ID within the same TDD slot

*CountIndex* and *AckCountIndex* are, respectively, the values of the Count Index and Ack Count Index subfields in the transmitted TDD SSW frame

In order to avoid collision of TDD SSW Feedback frames, different Responder Feedback Offset subfield values in the Responder Info subfield of the TDD SSW frame should be used for different responders.

Figure 10-133 (TDD SSW Feedback frame transmit time for unscheduled TDD group BF(11ay)) depicts the calculation of time to transmit a TDD SSW Feedback frame for unscheduled TDD group BF.

If the initiator received a TDD SSW Feedback frame, it shall transmit one or more TDD SSW Ack frames to the responder that sent the TDD SSW Feedback frame. To transmit the frames to this responder the initiator shall set its antennas to the Decoded TX Sector ID and the Decoded TX Antenna ID from the last TDD SSW Feedback frame received from this responder. The transmission of the first TDD SSW Ack frame shall start at the following offset calculated as a spacing from the end of the transmitted TDD SSW frame to the start of the transmission of the first TDD SSW Ack frame to the responder that sent the TDD SSW Feedback frame:

$$InitiatorAckOffset_n - [AckCountIndex \times \text{TXTIME(TDD SSW Ack)} + (CountIndex + 1 - AckCountIndex) \times \text{TXTIME(TDD SSW)} + (Count\ Index \times \text{SBIFS})] \quad (10\text{-}25)$$

where

$InitiatorAckOffset_n$ is the value of the Initiator Ack Offset subfield in the $n^{th}$ responder's Responder Info subfield of the TDD SSW frame with the same TX Sector ID within the same TDD slot

*CountIndex* and *AckCountIndex* are, respectively, the values of the Count Index and Ack Count Index subfields in the transmitted TDD SSW frame


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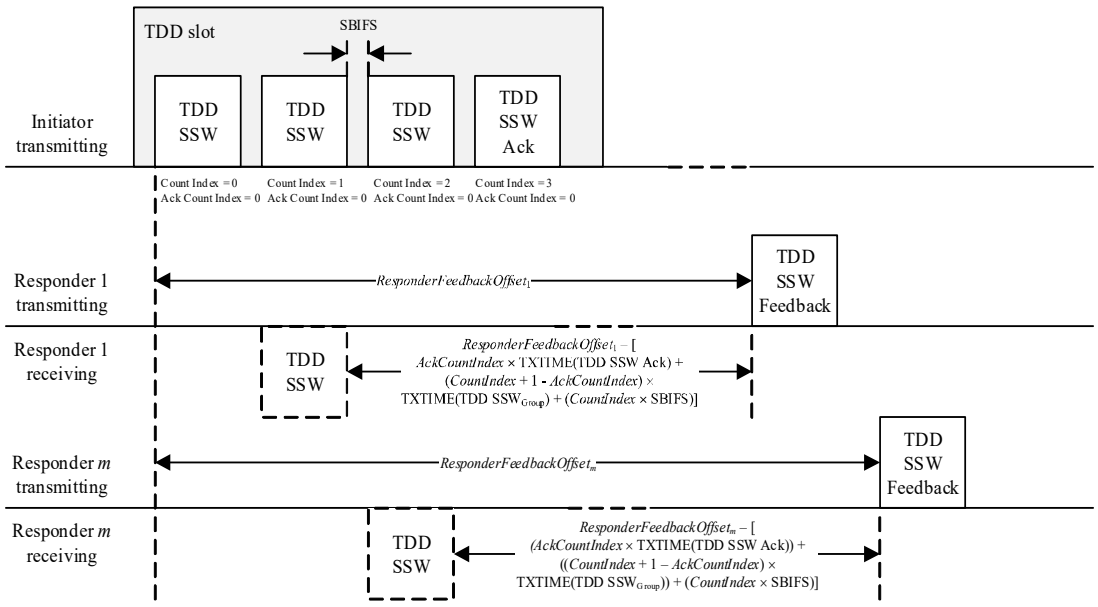


**Figure 10-133—TDD SSW Feedback frame transmit time for unscheduled TDD group BF(11ay)**

The TDD SSW Ack frame shall include the DMG antenna and sector used by the responder to transmit the TDD SSW Feedback frame in, respectively, the Decoded TX Antenna ID and Decoded TX Sector ID subfields, the measured SNR of the decoded TDD SSW Feedback frame in the SNR Report subfield and, when performing unscheduled TDD beamforming, time offsets to exchange frames containing TDD Route, TDD Slot Structure, and TDD Slot Schedule elements.

For TDD group BF, an initiator may request one or more responders to stop their receive sector sweeping by setting the End of Training subfield to 1 in the Responder Info subfield corresponding to each responder in a transmitted TDD SSW frame. Upon reception of a TDD SSW Feedback frame with the End of Training subfield equal to 1 from a responder, the initiator shall send one or more TDD SSW Ack frames to the corresponding responder with the End of Training subfield set to 1 at the time offset indicated by Equation (10-25) or, alternatively, at a TDD slot allocated via the TDD Slot Schedule element. The initiator may also set the End of Training subfield in SSW Ack frames to 1 even if the End of Training subfield in a received TDD SSW Feedback frame was not set to 1. After sending a TDD SSW Ack frame with End of Training subfield equal to 1, the initiator shall configure its receive and transmit DMG antenna and sector index as indicated in the Decoded TX Antenna ID and Decoded TX Sector ID subfields of the TDD SSW Feedback frame received from the corresponding responder in which its End of Training subfield was set to 1. The initiator shall use this DMG antenna and sector for its subsequent transmissions and receptions with the corresponding responder, until another sector is negotiated.

The length of a TDD SSW frame shall remain the same during TDD group beamforming. For each target responder that has completed TDD beamforming training, the corresponding Responder Info Valid subfield shall be set to 0 to indicate an invalid Responder Info subfield.

Once the initiator sends a TDD SSW Ack frame with the End of Training subfield equal to 1 to a target responder, it may transmit a single PPDU other than a TDD Beamforming frame to the target responder. To transmit this frame, the initiator shall set its transmit DMG antenna and sector to the Decoded TX Antenna ID and the Decoded TX Sector ID from the TDD SSW Feedback frame last received from the target responder. The transmission of the frame shall start at the following offset calculated as a spacing from the end of the last transmitted SSW Ack frame with the End of Training subfield set to 1 to the start of the expected transmission:

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*InitiatorTransmitOffset* – [(*AckCountIndex* + 1) × TXTIME(TDD SSW Ack) + (*CountIndex* – *AckCountIndex*) × TXTIME(TDD SSW) + (*Count Index* × SBIFS)] (10-26)

where

*InitiatorTransmitOffset* is the value of the Initiator Transmit Offset subfield in the TDD SSW Ack frame with the End of Training subfield set to 1

*CountIndex* is the value of the Count Index subfield in the received TDD SSW or TDD SSW Ack frame

*AckCountIndex* is the value of the Ack Count Index subfield in the transmitted TDD SSW Ack frame

Subsequent opportunities for the initiator to transmit to the responder are separated by the value of the Transmit Period subfield in the TDD SSW Ack frame with the End of Training subfield set to 1.

After the initiator has sent the last TDD SSW Ack frame with the End of Training subfield equal to 1 to a target responder, it shall be ready to receive a single PPDU other than a TDD Beamforming frame from the responder, by setting its receive DMG antenna and sector to the Decoded TX Antenna ID and the Decoded TX Sector ID and from the TDD SSW Feedback frame last received from the responder, and at the following offset calculated as a spacing from the end of the transmitted TDD SSW Ack frame with the End of Training subfield set to 1 to the start of the expected reception:

*ResponderTransmitOffset* – [(*AckCountIndex* + 1) × TXTIME(TDD SSW Ack) + (*CountIndex* – *AckCountIndex*) × TXTIME(TDD SSW) + (*Count Index* × SBIFS)] (10-27)

where

*ResponderTransmitOffset* is the value of the Responder Transmit Offset subfield in the TDD SSW Ack frame with the End of Training subfield set to 1

*CountIndex* is the value of the Count Index subfield in the respective TDD SSW or TDD SSW Ack frame

*AckCountIndex* is the value of the Ack Count Index subfield in the transmitted TDD SSW Ack frame

Subsequent opportunities for the responder to transmit to the initiator are separated by the value of the Transmit Period subfield in the TDD SSW Ack frame with the End of Training subfield set to 1.

For the unscheduled TDD beamforming procedure, Equation (10-24) and Equation (10-25) establish transmit opportunities to exchange TDD Beamforming frames, and Equation (10-26) and Equation (10-27) establish transmit opportunities to exchange frames other than TDD Beamforming frames after TDD beamforming training completion with the target responder.

In the unscheduled TDD beamforming procedure, upon transmission of the last TDD SSW Ack frame with End of Training subfield equal to 1, the initiator shall follow the same procedure as the initiator in 10.41.11.2 (Initiator operation for TDD individual beamforming) with *InitiatorTransmitOffset* and *ResponderTransmitOffset* parameters given by Equation (10-26) and Equation (10-27) instead of Equation (10-22) and Equation (10-23).

In the scheduled TDD beamforming procedure, the initiator shall send TDD SSW and TDD SSW Ack frames during BF TDD slots assigned to transmit from the initiator to the responder. The exchange of TDD Route elements takes place during (M118)nonbeamforming TDD slots available to the initiator and the target responder after completion of the TDD beamforming training with the target responder.


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### 10.41.11.5 Responder operation for TDD group beamforming

A responder STA that is in inactive state (see 11.54 (TDD channel access operation(11ay))) or has not yet received a TDD SSW frame or has not yet acquired a TDD Slot Structure element used by the BSS shall sweep its receiver antenna through all its receive sectors while dwelling on each sector for a time equal to SectorDwellTime as indicated by the MLME-TDD-BF-SCAN.request primitive.

NOTE—To increase the likelihood of detecting an initiator's TDD SSW frame, the responder SME can set SectorDwellTime to at least [2 × TXTIME (TDD SSW) + SBIFS].

A responder STA that receives a TDD SSW frame with a Responder ID subfield that matches its ID shall sweep its receiver antenna configuration through its receive sectors between TDD beamforming frames received in a TDD slot and shall switch its receive sectors at the beginning of every TDD slot used for BF training according to the time interval indicated by a nonzero Transmit Period subfield value of the received TDD SSW frame.

Figure 10-134 (Responder's receiver sweeping for TDD group BF(11ay)) gives an example of the responder's receiver sweeping procedure for TDD group BF.

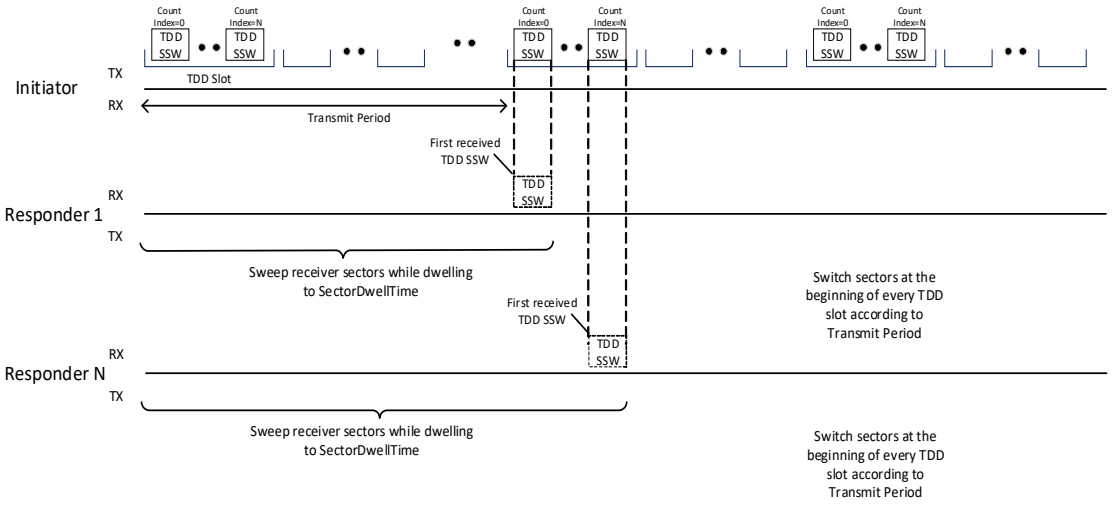


**Figure 10-134—Responder's receiver sweeping for TDD group BF(11ay)**

Once the first TDD SSW frame is received, the responder proceeds with the following operation.

Upon reception of one or more TDD SSW frames on a receive sector, the responder may switch, within the TDD slot, to its next receive sector to be ready to receive the next TDD SSW frame transmission within SBIFS. The responder shall switch its receive sector at the beginning of every TDD slot used for BF training at the time specified by the Transmit Period subfield value in the received TDD SSW frame. While sweeping through its receive sectors, the responder shall continue decoding all the received TDD SSW frames.

The responder shall transmit a TDD SSW Feedback frame using the DMG antenna and sector from which the responder received the TDD SSW with the best link quality at the time indicated by Equation (10-24) in case of unscheduled TDD beamforming or, alternatively, at an assigned BF TDD slot. The TDD SSW Feedback frame shall include the DMG antenna and sector index used by the initiator to transmit the TDD SSW frame in, respectively, the Decoded TX Antenna ID and Decoded TX Sector ID subfields, the antenna

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index and sector index used by the responder to transmit the TDD SSW Feedback frame in, respectively, the TX Antenna ID and TX Sector ID subfields, and the SNR of the TDD SSW frame received with the best quality in the SNR Report subfield.

At the time offset indicated by Equation (10-25) of the decoded TDD SSW frame or, alternatively, at an assigned BF TDD slot, the responder shall set its receiver to the same DMG antenna index and to the same sector that was indicated in, respectively, the TX Antenna ID and TX Sector ID subfields of the TDD SSW Feedback in order to be ready to receive a TDD SSW Ack frame from the initiator.

The responder shall continue sweeping through its receive sectors until successfully receiving and decoding a TDD SSW Ack frame with End of Training subfield equal to 1. Upon the reception of a TDD SSW Ack frame with End of Training subfield equal to 1, the responder shall stop its receive sweeping and shall configure its DMG antenna and sector as indicated in, respectively, the Decoded TX Antenna ID and Decoded TX Sector ID subfields of the TDD SSW Ack frame received from the initiator that has the End of Training subfield equal to 1. The responder shall use this DMG antenna and sector for its subsequent frame exchange sequences(#109) with the initiator, until another sector is negotiated.

A responder that transmits a TDD SSW Feedback frame in response to a TDD SSW frame sent with End of Training subfield equal to 1 shall set the End of Training subfield in the TDD SSW Feedback frame to 1.

In the unscheduled TDD beamforming procedure, upon reception of a TDD SSW Ack frame with End of Training subfield equal to 1, the responder, at the time offset indicated by Equation (10-27), shall follow the same procedure as the responder in 10.41.11.3 (Responder operation for TDD individual beamforming) with *InitiatorTransmitOffset* and *ResponderTransmitOffset* parameters given by Equation (10-26) and Equation (10-27) instead of Equation (10-22) and Equation (10-23).

In the scheduled TDD beamforming procedure, the responder shall send TDD SSW Feedback frames during BF TDD slots assigned to transmit from the responder to the initiator. The exchange of TDD Route elements takes place during Basic or Data TDD slots available to the initiator and the responder after completion of the TDD beamforming training.

### 10.41.11.6 Initiator operation for TDD beam measurement

The initiator operation during a TDD beam measurement is the same as the initiator operation for TDD individual BF, with the following differences:

- TDD beam measurement is started upon receiving an MLME-TDD-BEAM-MEASUREMENT.request primitive with BFRole parameter set to Initiator.
- The Initiator may send an Announce frame to a responder containing a TDD Route element with a TDD Sector Config subelement indicating the RX Sectors ID and RX Antenna ID to be used by the responder in the TDD beam measurement.
- During a TDD beam measurement, the TDD Slot CDOWN field in each transmitted frame shall contain the total number of BF TDD slots remaining until the end of the initiator TDD beam measurement, such that the last TDD SSW frame transmission by the initiator has the TDD Slot CDOWN field equal to 0.
- The initiator may set the Feedback Requested subfield in the TDD Beamforming Information field to 1 to request that the responder(s) send, following the completion of the TDD beam measurement, an Announce frame with a TDD Route element containing the measurement results.
- No TDD SSW Ack frame shall be transmitted.


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#### 10.41.11.7 Responder operation for TDD beam measurement

The responder operation during a TDD beam measurement procedure is the same as the responder operation for TDD individual BF, with the following differences:

- TDD beam measurement is started upon receiving an MLME-TDD-BEAM-MEASUREMENT.request primitive with BFRole parameter set to Responder, or by receiving a TDD SSW frame with the RA field equal to STA's MAC address or the broadcast address, and with the TDD Beam Measurement field set to 1.
- If a TDD Sector Config subelement was received for this TDD beam measurement, the responder shall utilize the RX Sectors ID and RX Antenna ID configurations as indicated in the TDD Sector Config subelement.
- If the Feedback Requested subfield in a TDD SSW frame received by the responder is 0, the responder shall not transmit any frames to the initiator and shall report the measurement results to the SME instead.
- If the Feedback Requested subfield in a TDD SSW frame received by the responder is 1, the responder shall send an Announce frame with a TDD Route element containing the results of the TDD beam measurement on all received sectors. The Announce frame shall be sent in the first TDD slot allocated for transmission from the responder to the initiator.
- TDD beam measurement ends at the end of the TDD slot during which the initiator transmits the last TDD SSW frames with the TDD Slot CDOWN field equal to 0.

## 10.42 DMG link adaptation

### 10.42.1 General

A STA may transmit a Link Measurement Request frame to request a STA indicated in the RA field of the frame to respond with a (11ay)single Link Measurement Report frame or periodic Link Measurement Report frames (9.6.6.5 (Link Measurement Report frame format)). If the Link Measurement Request frame is sent within a PPDU defined in Clause 20 (Directional multi-gigabit (DMG) PHY specification) (11ay)or Clause 28 (Enhanced directional multi-gigabit (EDMG) PHY specification(11ay)), the Link Measurement Report frame shall contain the DMG Link Margin element. (11ay)If the DMG Link Margin element does not include the PPDU Statistics field, nor the LDPC Statistics field and nor the SC/OFDM Statistics field, the requesting STA may use values of the MCS, SNR and Link Margin fields in a received DMG Link Margin element to transmit frames to the STA indicated in the RA field of the Link Measurement Request frame. Otherwise, the requesting STA may use values of the MCS, SNR and Link Margin field(s) in the received PPDU Statistics field to transmit frames to the STA indicated in the RA field of the Link Measurement Request frame.

(11ay)The Number of Space-Time Streams Reported (NSTS) field in a DMG Link Margin element shall be set to the number of space-time streams received.

(11ay)If the Link Measurement Request frame is sent within a PPDU defined in Clause 28 (Enhanced directional multi-gigabit (EDMG) PHY specification(11ay)), the Number of Transmit Chains Reported (NTX) field in the DMG Link Margin element within the Link Measurement Report frame shall be set to the same value indicated in the Extended TPC Configuration subelement within the Link Measurement Request frame. In this case, the requesting STA may use the reported MCS, SNR, and link margin values when transmitting frames to the STA indicated in the RA field of the Link Measurement Request frame using multiple transmit chains.

The requesting STA may aggregate a Link Measurement Request frame in an A-MPDU as defined in Table 9-661 (A-MPDU contents in the non-HE(11ax) data enabled immediate response context) and Table 9-663 (A-MPDU contents in the control response context).

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(11ay)To initiate a periodic link measurement with a peer STA, the requesting STA shall transmit a Link Measurement Request frame to the peer STA that includes the Periodic Report Request subelement. The requesting STA should transmit at least one Management or Data frame (e.g., a QoS Null frame) to the peer STA, preferably requiring acknowledgment, every interval of time indicated by the value of the Report Interval field within the Periodic Report Request subelement to keep the statistics reported in the periodic Link Measurement Report frames transmitted by the peer STA updated.

If the Dialog Token field in the Link Measurement Request frame is nonzero, the responding STA shall perform the measurement on the next frame received from the requesting STA and shall send back a Link Measurement Report frame corresponding to the received frame. (11ay)If the Link Measurement Request frame includes the Periodic Report Request subelement and the responding STA accepts a periodic link measurement request, at the time indicated by the value of the Report Start Time subfield, the responding STA shall send at least one Link Measurement Report frame including the Periodic Report subelement to the requesting STA for each report interval. The transmission of at least one unsolicited Link Measurement Report frame should be as close as possible to the start of each consecutive report interval subject to channel access rules. The total number of report intervals shall be equal or smaller than the value of the Report Count subfield in the Link Measurement Request frame. If the Link Measurement Request frame includes the Periodic Report Request subelement and the responding STA rejects a periodic link measurement request, the responding STA shall transmit a Link Measurement Report frame and set the Accept/Reject Periodic Report subfield within the Periodic Report Control field of the Periodic Report subelement to 0.

The responding STA may aggregate a Link Measurement Report frame in an A-MPDU as defined in Table 9-661 (A-MPDU contents in the non-HE(11ax) data enabled immediate response context) and Table 9-663 (A-MPDU contents in the control response context).

The DMG STA whose MAC address equals the value of the Link Measurement Request frame RA field shall transmit (11ay)one or more Link Measurement Report frame addressed to the requesting STA. The RA field of the Link Measurement Report frame shall be equal to the TA field of the Link Measurement Request frame.

If the Dialog Token field in the Link Measurement Report frame is equal to the nonzero Dialog Token field of the Link Measurement Request frame, then the MCS, SNR, and Link Margin fields of the Link Measurement Report frame shall be computed using the measurements of the PPDU that is the next frame received from the requesting STA(11ay), or the PPDUs received from the requesting STA within the corresponding report interval and subject to the reset condition rules (see 9.4.2.141.6 (LDPC Statistics field(11ay))). The DMG Link Margin element within the Link Measurement Report frame shall include the following:

- (11ay)The RX Chain Statistics field if the Number of RX Chains Reported (NRX) subfield in the Rate Adaptation Control/Extended TPC field is greater than 0.
- (11ay)The PPDU Statistics field if the PPDU Statistics Present subfield in the Rate Adaptation Control/Extended TPC field is 1.
- (11ay)The LDPC Statistics field if the LDPC Statistics Present subfield in the Rate Adaptation Control/Extended TPC field is 1.
- (11ay)The SC/OFDM Statistics field if the SC/OFDM Present subfield in the Rate Adaptation Control/Extended TPC field is 1.

(11ay)The DMG Link Margin element should not include the RX Chain Statistics, PPDU Statistics, LDPC Statistics and SC/OFDM Statistics fields if the Number of PPDUs subfield in the Rate Adaptation Control/ Extended TPC field is 0.

(11ay)NOTE—The MCS, SNR, and link margin values can be carried in either the three similarly named fields in the Link Measurement Report frame, or as part of the PPDU Statistics field in the same frame.


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If the Dialog Token field in the Link Measurement Request frame is equal to 0, the responding STA may set the MCS field in the Link Measurement Report frame to the MCS value computed based on any of the received frames from the requesting STA.

The SNR field and Link Margin field in the Link Measurement Report frame shall indicate the corresponding measurements based on the reception of the PPDU that was used to generate the MCS feedback contained in the same Link Measurement Report frame. (11ay)If the Link Measurement Report frame contains measurements of more than one STS, the SNR subfield in the PPDU Statistics field and the Link Margin subfield in the Extended TPC field in the Link Measurement Report frame shall indicate the corresponding measurements based on the reception of the PPDU that was used to generate the MCS feedback contained in the PPDU Statistics field within the same Link Measurement Report frame, or the corresponding measurements of PPDUs received from the requesting STA within the corresponding report interval and subject to the reset condition rules (see 9.4.2.141.6 (LDPC Statistics field(11ay))).

The Link Measurement Request and Report frames can be used to obtain link margin information, which can be used to determine appropriate action by the requesting STA (e.g., change MCS or control transmit power or initiate FST).

A STA may send an unsolicited Link Measurement Report frame with the Dialog Token field set to 0.

### 10.42.2 DMG TPC

A DMG STA that receives a Link Measurement Report frame containing a DMG Link Margin element that indicates increase or decrease transmit power behaves according to the following rules:

- If the STA implements the recommendation indicated in the Activity field of the Link Measurement Report (11ay)frame that does not include a Rate Adaptation Control/Extended TPC field, it shall send a Link Measurement Report frame containing a DMG Link Adaptation Acknowledgment element. The Activity field of the DMG Link Adaptation Acknowledgment element shall be set to the value of the Activity field in the received DMG Link Margin (11ay)element.
- If the STA does not implement the recommendation indicated in the Activity field of the Link Measurement Report (11ay)frame that does not include a Rate Adaptation Control/Extended TPC field, it may send a Link Measurement report containing a DMG Link Adaptation Acknowledgment element. The Activity field of the DMG Link Adaptation Acknowledgment element shall be set to 0(11ay).
- A STA shall not send a Link Measurement Report later than 2×aPPDUMaxTime after it acknowledged the reception of the Link Measurement report.
- (11ay)If the STA implements the recommendation indicated in the Extended Activity field of a Link Measurement Report frame that includes a Rate Adaptation Control/Extended TPC field for one or more STS, it shall send a Link Measurement Report frame containing a DMG Link Adaptation Acknowledgment element. The value of the Number of STS Reported field within the DMG Link Adaptation Acknowledgment element shall be set to the same value of the Number of STS Reported field in the DMG Link Margin element within the Link Measurement Report frame. If the STA implements the recommendation for an STS, the Extended Activity acknowledgment field of the DMG Link Adaptation Acknowledgment element shall be set to the value of the Extended Activity field in the received DMG Link Margin element of the same STS. If the STA does not implement the recommendation for an STS, the Activity field of the DMG Link Adaptation Acknowledgment element shall be set to 0. In addition, the Extended Activity acknowledgment Parameter value shall be set to the actual transmit power change that the STA implements, using the same encoding as the transmit power change request (see 9.4.2.141.8 (Extended TPC(11ay))).

A DMG STA shall not include the DMG Link Adaptation Acknowledgment element in a Link Measurement Report frame, unless the frame is being transmitted in response to a Link Measurement Report frame whose Activity field is equal to increase or decrease transmit power.

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### 10.42.3 Fast link adaptation

A STA indicates support for fast link adaptation by setting the Fast Link Adaptation field in the STA's DMG Capabilities element to 1. A STA that does not support fast link adaptation sets the Fast Link Adaptation field in the STA's DMG Capabilities element to 0. A STA that supports fast link adaptation shall not initiate fast link adaptation with a peer STA that does not support fast link adaptation.

A STA that supports fast link adaptation shall support the reverse direction protocol (see 10.29 (Reverse direction protocol)). The STA that transmits a Link Measurement Request frame as part of fast link adaptation shall be the RD initiator and the STA that responds with a Link Measurement Report frame shall be the RD responder. Transmission of Link Measurement Request, Link Measurement Report and the frames defined below shall follow the rules of the reverse direction protocol.

A STA initiates fast link adaptation by transmitting a Link Measurement Request frame that is of subtype Action No Ack and has its Dialog Token field set to 0. The PPDU containing the frame shall have the AGGREGATION parameter in the TXVECTOR set to AGGREGATED, shall not contain any other frame that requires immediate response, and shall have a duration (as determined by the (#7074)PLME-TXTIME.confirm primitive defined in 6.7.6 (PLME-TXTIME.confirm)) that is greater than aMinPPDUDurationForDMGMeasurement.

NOTE—The PPDUs have the AGGREGATION parameter in the TXVECTOR set to AGGREGATED to allow padding of the PSDUs with MPDU delimiters of size 0, therefore meeting the transmission duration requirement.

A STA that supports fast link adaptation and receives a Link Measurement Request frame of subtype Action No Ack, with the Dialog Token field equal to 0 and contained in a PPDU with the AGGREGATION parameter in the RXVECTOR equal to AGGREGATED shall respond with a Link Measurement Report frame in no longer than BRPIFS from the reception of the Link Measurement Request frame. The TPC Report element, DMG Link Margin element and other fields transmitted in the Link Measurement Report frame shall reflect measurements on the PPDU that contained the last received Link Measurement Request frame from the initiating STA.

The STA responding with the Link Measurement Report frame shall keep the IFS not longer than SIFS by transmitting PPDUs that do not contain frames requiring immediate response and that have a duration that is greater than aMinPPDUDurationForDMGMeasurement. All transmitted PPDUs should use the same MCS and the same transmit power.

The transmitted Link Measurement Report frame shall be of subtype Action No Ack, shall be sent using MCS 1, and shall be sent within a PPDU with the AGGREGATION parameter in the TXVECTOR set to AGGREGATED. In addition, the PPDU shall not contain any frame that requires immediate response and shall have a duration that is greater than aMinPPDUDurationForDMGMeasurement.

If at least one of the conditions above for the transmission of the Link Measurement Report frame is not met, the STA may follow the rules in 10.42.1 (General) to respond to the received Link Measurement Request frame.

A STA that supports fast link adaptation and that receives a Link Measurement Report frame should respond with an unsolicited Link Measurement Report frame in no longer than BRPIFS from the reception of the Link Measurement Report frame. The TPC Report element, DMG Link Margin element and other fields transmitted in the unsolicited Link Measurement Report frame shall reflect measurements taken on one or more of the PPDUs received by the STA transmitting the unsolicited Link Measurement Report frame, starting with the received Link Measurement Report frame itself. If the unsolicited Link Measurement Report frame is transmitted longer than SIFS from the reception of the Link Measurement Report frame, the STA transmitting the unsolicited Link Measurement Report frame shall keep the IFS not longer than SIFS by transmitting one or more PPDUs before issuing the unsolicited Link Measurement Report frame.


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An example of the fast link adaptation procedure is shown in Figure 10-135 (Example of fast link adaptation procedure).

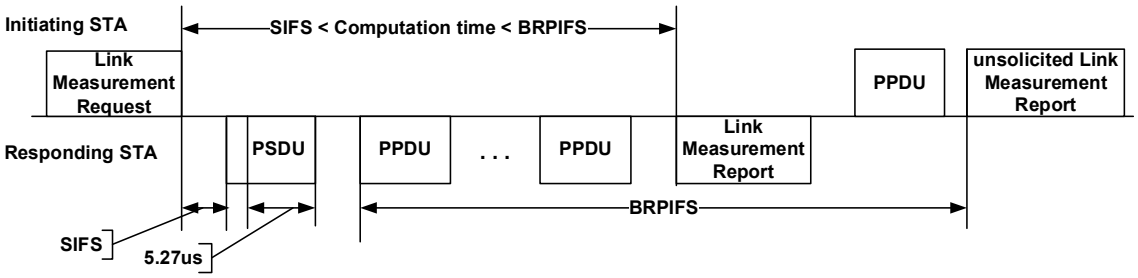


**Figure 10-135—Example of fast link adaptation procedure**

### 10.42.4 EDMG spatial stream feedback(11ay)

An EDMG STA may provide feedback on individual transmitted spatial streams by appending a control trailer (see 10.38.12.5 (Control trailer)) to SSW-Feedback, BlockAck or Ack frames. Spatial stream feedback information may be used for MCS selection or to trigger beamforming between STAs.

To do this, the STA shall set the TXVECTOR parameter SCRAMBLER_INIT_SETTING to CONTROL_TRAILER, shall set the TXVECTOR parameter CT_TYPE to SSW_FEEDBACK in case of transmitting an SSW-Feedback frame, to BLOCK_ACK in case of transmitting a BlockAck frame, or to ACK in case of transmitting an Ack frame. The STA shall set the TXVECTOR parameter STREAM_FBCK to contain the per spatial stream feedback.

The per stream SNR and RSSI information in the control trailer shall be measured by the STA during the reception of the PPDU immediately before the corresponding SSW-Feedback, BlockAck or Ack frame is transmitted.

### 10.42.5 TDD link maintenance(11ay)

A STA indicates support for TDD link maintenance by setting the TDD Link Maintenance Statistics field within the STA's DMG Capabilities element to a nonzero value. A STA that supports TDD link maintenance shall not initiate TDD link maintenance, as specified below, with a peer STA that does not support TDD link maintenance.

The SME of the STA that supports TDD link maintenance shall use the PLME-MINPAYLOADSTAT.request primitive to request the PHY to initiate measurement of signal power of received PPDUs and to compute the receiver statistics as described below. Upon receiving a PLME-MINPAYLOADSTAT.request primitive, the PHY shall use the parameter PSDU_MIN_LENGTH of the primitive to start the measurements and shall respond to the MAC with a PLME-MINPAYLOADSTAT.confirm primitive.

A STA that supports TDD link maintenance and that receives a Link Measurement Request frame shall include a DMG Link Margin element in a transmitted Link Measurement Report frame. The STA shall perform the link statistics measurements and set the DMG Link Margin element according to the following rules:

— In the RX Chain Statistics field, the RCPI shall be measured during the reception of the L-STF or EDMG-STF field of the PPDU. The measurement shall be performed on the same bandwidth as the PSDU.

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- The value of the PPDU Statistics field is computed as follows:
  - For an(#1424) SC mode PPDU, the SNR per stream is found by computing the SNR of the DMG or EDMG preambles. If EDMG preambles are present, it shall be used to compute the SNR. The measurement shall be on the same bandwidth as the PSDU.
  - For an OFDM mode PPDU, the average SNR per stream is found by computing the SNR per subcarrier in decibels for all the pilot and data subcarriers, and then computing the arithmetic mean of those values. Each SNR value per subcarrier and per stream (before being averaged) corresponds to the SNR of one of the pilot or data subcarrier. The SNR value per subcarrier per stream shall be based on measurement of EDMG-STF and/or EDMG-CEF using the same bandwidth as the PSDU.
- To compute the value of the LDPC Statistics field, the PPDUs used for computing the Average Iterations, Max Iteration, Nonzero Syndromes and Number of LDPC Codewords subfields are those PPDUs that have the payload length greater or equal to PSDU_MIN_LENGTH. All reported LDPC statistics shall be measured over the PSDU of a PPDU.
- To compute the value of the SC/OFDM Statistics field, the PPDUs used for computing the EVM and Number of SC Blocks/OFDM Symbols subfields are those PPDUs that have the payload length greater or equal to PSDU_MIN_LENGTH. The EVM is computed by averaging, in power units, the estimated EVM of SC data symbols or OFDM data subcarriers across PSDUs of PPDUs transmitted with an MCS different from MCS 0. The average is performed per space-time stream. The EVM estimation per SC symbol or OFDM carrier should be as close as possible to the value computed when the estimator has full knowledge of the transmitted signal.

When the following reset condition is met, the statistics specified in 9.4.2.141.4 (RX Chain Statistics field(11ay)), 9.4.2.141.5 (PPDU Statistics field(11ay)), 9.4.2.141.6 (LDPC Statistics field(11ay)), and 9.4.2.141.7 (SC/OFDM Statistics field(11ay)) shall be reset:

- Any change of modulation (SC or OFDM), MCS, constellation, LDPC mode, GI/CP length, number of space-time streams, or MIMO type, or
- The number of reports sent reaches the value of the Report Count subfield in the Periodic Report Request subelement (see 9.4.2.288.2 (Periodic Report Request subelement)) associated with this measurement.

To cause the PHY to stop performing measurements over received PPDUs, the SME shall invoke the PLME-MINPAYLOADSTATSTOP.request primitive.

### 10.42.6 Extended TPC(11ay)

A DMG STA supports the extended TPC mechanism specified in this subclause if the Extended TPC Rx Supported subfield in the STA's last transmitted DMG Capabilities element is 1. A STA that supports the extended TPC shall support TDD link maintenance as defined in 10.42.5 (TDD link maintenance(11ay)) and periodic link measurement as defined in 10.42.1 (General).

A STA that has dot11ExtendedTPCActivated set to Rx and that receives a Link Measurement Report frame shall adjust its transmit power according to the values indicated by the Extended TPC field within the DMG Link Margin element carried in the received Link Measurement Report frame. A STA is not required to adjust its transmit power if the value exceeds the STA capabilities.

NOTE 1—A STA that has dot11ExtendedTPCActivated set to Rx sends a Link Measurement Request frame to a peer STA with an Extended Link Measurement element that includes a Periodic Report Request subelement. As such, the STA periodically receives a Link Measurement Report frame that includes the Extended TPC subfield with a transmit power update. The STA uses the received values to update its transmitter power. The peer STA, which responds with a Link Measurement Report frame, continuously evaluates the link based on the information it receives from the STA and computes the transmit power update for the STA.


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A STA that has dot11ExtendedTPCActivated set to Tx and that receives s Link Measurement Report frame shall adjust its transmit power. The algorithm to determine the transmit power adjustment is beyond the scope of this standard. The STA may use any part of received measurements and any additional information available to the STA.

NOTE 2—A STA that has dot11ExtendedTPCActivated set to Tx sends a Link Measurement Request frame to a peer STA with an Extended Link Measurement element that includes a Periodic Report Request subelement. As such, the STA periodically receives a Link Measurement Report frame that includes at least one of the RX Chain Statistics, PPDU Statistics, LDPC Statistics, or SC/OFDM Statistics fields. The STA uses the received values to update its transmitter power. The STA might also receive an Extended TPC subfield, including a transmit power update. When dot11ExtendedTPCActivated is equal to Tx, the STA is not required to adopt the values in Extended TPC subfield; the STA can use these values as additional information to update its transmitter power.

An AP or PCP that has dot11ExtendedTPCActivated set to Tx or Rx shall have Extended TPC Rx Supported subfield in its DMG Capabilities element set to 1, as well as support the computation and report of the Extended TPC field defined in 9.4.2.141.8 (Extended TPC(11ay)).

## 10.43 Link adaptation using the CMMG link measurement

### 10.43.1 General

A STA may transmit a Link Measurement Request frame to request a STA indicated in the RA field of the frame to respond with a Link Measurement Report frame (9.6.6.5 (Link Measurement Report frame format)) in SC transmission. If the Link Measurement Request frame is sent within a PPDU defined in Clause 25 (China millimeter-wave multi-gigabit (CMMG) PHY specification), the Link Measurement Report frame shall contain the CMMG Link Margin element. The requesting STA may use values of the MCS, of the SNR, and of the link margin to transmit frames to the STA indicated in the RA field of the Link Measurement Request frame.

The requesting STA may aggregate a Link Measurement Request frame in an A-MPDU as defined in Table 9-661 (A-MPDU contents in the non-HE(11ax) data enabled immediate response context) and Table 9-663 (A-MPDU contents in the control response context).

If the Dialog Token field in the Link Measurement Request frame is nonzero, the responding STA shall perform the measurement on the next frame received from the requesting STA and shall send back a Link Measurement Report frame corresponding to the received frame.

The responding STA may aggregate a Link Measurement Report frame in an A-MPDU as defined in Table 9-661 (A-MPDU contents in the non-HE(11ax) data enabled immediate response context) and Table 9-663 (A-MPDU contents in the control response context).

A CMMG STA with MAC address that is equal to the value of the Link Measurement Request frame RA field shall transmit a Link Measurement Report frame addressed to the requesting STA. The RA field of the Link Measurement Report frame shall be equal to the TA field of the Link Measurement Request frame.

If the Dialog Token field in the Link Measurement Report frame is equal to the nonzero Dialog Token field of the Link Measurement Request frame, the MCS, SNR, and Link Margin fields of the Link Measurement Report frame shall be computed using the measurements of the PPDU that is the subsequent frame following the Link Measurement Request frame.

If the Dialog Token field in the Link Measurement Request frame is equal to 0, the responding STA may set the MCS field in the Link Measurement Report frame to the MCS value computed based on any of the received frames from the requesting STA.

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The SNR field and Link Margin field in the Link Measurement Report frame shall indicate the corresponding measurements based on the reception of the PPDU that was used to generate the MCS feedback contained in the same Link Measurement Report frame.

The Link Measurement Request and Link Measurement Report frames can be used to obtain link margin information, which can be used to determine appropriate action by the requesting STA (e.g., change MCS or control transmit power or initiate FST).

A STA may send an unsolicited Link Measurement Report frame with the Dialog Token field set to 0.

### 10.43.2 CMMG TPC

A CMMG STA that receives a Link Measurement Report frame containing a CMMG Link Margin element that indicates Increase or Decrease Transmit power behaves according to the following rules:

— If the CMMG STA intends to implement the recommendation indicated in the Activity field of the Link Measurement Report frame, it shall implement the change and send a Link Measurement Report containing a CMMG Link Adaptation Acknowledgment element not later than 2×aPPDUMaxTime after it acknowledged the reception of the Link Measurement Report frame. The Activity field of the CMMG Link Adaptation Acknowledgment element shall be set to the value of the Activity field in the received CMMG Link Margin subelement.

— If the CMMG STA does not implement the recommendation indicated in the Activity field of the Link Measurement Report frame, it may send the Link Measurement report containing a CMMG Link Adaptation Acknowledgment element no later than 2×aPPDUMaxTime after it acknowledges the reception of the Link Measurement Report frame. The Activity field of the CMMG Link Adaptation Acknowledgment element shall be set to 0, indication the STA prefers to not change transmit power.

A CMMG STA shall not include the CMMG Link Adaptation Acknowledgment element in a Link Measurement Report frame unless it is in response to a Link Measurement Report with the Activity field set to increase or decrease transmit power.

### 10.43.3 CMMG fast link adaptation

A CMMG STA supports fast link adaptation if the Fast Link Adaptation field in the STA's CMMG Capabilities Info field is 1. Otherwise, the STA does not support fast link adaptation. A STA that supports fast link adaptation shall not use fast link adaptation with a peer STA that does not support fast link adaptation.

A STA that supports fast link adaptation shall support the reverse direction protocol (see 10.29 (Reverse direction protocol)).

The STA that transmits a Link Measurement Request frame as part of fast link adaptation shall be the RD initiator, and the STA that responds with a Link Measurement Report frame shall be the RD responder. Transmission of Link Measurement Request frame, Link Measurement Report frame, and the frames defined below shall follow the rules of the reverse direction protocol.

A STA initiates fast link adaptation by transmitting a Link Measurement Request frame that is of subtype Action No Ack and that has the Dialog Token field set to 0. The PPDU containing the frame shall have the AGGREGATION parameter in the TXVECTOR set to AGGREGATED, shall not contain any other frame that requires immediate response, and shall have a duration (as determined by the (#7074)PLME-TXTIME.confirm primitive defined in 6.7.6 (PLME-TXTIME.confirm)) that is greater than 5.27 μs.

NOTE—The PPDUs have the AGGREGATION parameter in the TXVECTOR set to AGGREGATED to allow padding of the PSDUs with MPDU delimiters of size 0, therefore meeting the transmission duration requirement.


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A STA that supports fast link adaptation and that receives a Link Measurement Request frame of subtype Action No Ack with the Dialog Token field equal to 0 and contained in a PPDU with the AGGREGATION parameter in the RXVECTOR equal to AGGREGATED shall respond with a Link Measurement Report frame in no longer than BRPIFS from the reception of the Link Measurement Request frame. The TPC Report element, CMMG Link Margin element and other fields transmitted in the Link Measurement Report frame shall reflect measurements on the PPDU that contained the last received Link Measurement Request frame from the initiating STA.

The STA responding with the Link Measurement Report frame shall keep the IFS not longer than a SIFS by transmitting PPDUs that do not contain frames requiring immediate response and that have a duration that is greater than 5.27 μs. All transmitted PPDUs should use the same MCS and the same transmit power.

The transmitted Link Measurement Report frame shall be of subtype Action No Ack, shall be sent using MCS 1, and shall be sent within a PPDU with the AGGREGATION parameter in the TXVECTOR set to AGGREGATED. In addition, the PPDU shall not contain any frame that requires immediate response and shall have a duration that is greater than 5.27 μs.

If at least one of the conditions above for the transmission of the Link Measurement Report frame is not met, the STA may follow the rules in 10.31.1 (Introduction) to respond to the received Link Measurement Request frame.

A STA that supports fast link adaptation and that receives a Link Measurement Report frame should respond with an unsolicited Link Measurement Report frame in no longer than BRPIFS from the reception of the Link Measurement Report frame. The TPC Report element, CMMG Link Margin element, and other fields transmitted in the unsolicited Link Measurement Report frame shall reflect measurements taken on one or more of the PPDUs received by the STA transmitting the unsolicited Link Measurement Report frame, starting with the received Link Measurement Report frame itself. If the unsolicited Link Measurement Report frame is transmitted longer than a SIFS from the reception of the Link Measurement Report frame, the STA transmitting the unsolicited Link Measurement Report frame shall keep the IFS not longer than a SIFS by transmitting one or more PPDUs before issuing the unsolicited Link Measurement Report frame.

## 10.44 DMG relay operation

### 10.44.1 General

The DMG relay procedures are specified in 11.34 (DMG relay procedures). This subclause specifies the supported types of DMG relay.

DMG relay operation is not supported by an IBSS STA. dot11RelayActivated is false in an IBSS STA.

A source REDS, a destination REDS and an RDS can establish two types of relay operation:

— Link switching (10.44.2 (Link switching)): If the direct link between the source REDS and destination REDS is disrupted, the source REDS redirects the transmission of frames addressed to the destination REDS via the RDS. The RDS forwards frames received from the source REDS to the destination REDS and from the destination REDS to the source REDS. Direct communication between the source REDS and destination REDS might resume after the direct link between them is recovered.

— Link cooperation (10.44.3 (Link cooperation)): In this case, the RDS is actively involved in the direct communication between the source REDS and the destination REDS. A frame transmission from the source REDS to the destination REDS is simultaneously repeated by the RDS, which might possibly increase the signal quality received at the destination REDS.

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### 10.44.2 Link switching

#### 10.44.2.1 General

A source REDS that has successfully completed an RLS procedure with a destination REDS for which the value of the Cooperation-Mode subfield within the negotiated Relay Transfer Parameter Set element is 0 may use the selected RDS between the source REDS and destination REDS for the purpose of link switching. This is described in this subclause.

#### 10.44.2.2 SP request and allocation

The source REDS uses the procedures described in 11.4 (TS operation) to request an SP allocation between itself and the destination REDS.

Upon receiving an ADDTS Request frame for which the source AID and the destination AID fields within the DMG TSPEC element are equal to a pair of a source REDS and a destination REDS, respectively, that have successfully completed the RLS procedure defined in 11.34.2.4 (RLS procedure), the AP or PCP schedules an SP with the source DMG STA as the source REDS and the destination DMG STA as the destination REDS.

An RDS shall check the value of the source AID and the destination AID fields of each SP allocation within an Extended Schedule element it receives in a DMG Beacon or Announce frame from the AP or PCP. If the value of the source AID and the destination AID fields of an SP allocation correspond to a source REDS and a destination REDS, respectively, that have successfully completed the RLS setup procedure (11.34.2 (Common relay setup procedures)), the RDS shall operate as an RDS during that SP allocation.

#### 10.44.2.3 Usage of RDS

In link switching, an RDS operates either in FD-AF mode or in HD-DF mode. An RDS capable of FD-AF relaying shall be in one of two frame transmission modes:

— *Normal mode*: A pair of source REDS and destination REDS exchange frames via either the direct link or the relay link until this link is determined to become unavailable due to, for example, blockage or channel degradation.

— *Alternation mode*: A source REDS and a destination REDS exchange frames via two separate links, where the use of each link alternates at each link change interval. The link change interval specifies the time instants at which a source REDS is allowed to change the link used for a frame transmission to the destination REDS as specified in 9.4.2.147 (Relay Transfer Parameter Set element).

An RDS that supports only HD-DF shall operate in the Normal mode.

The frame transmission mode is indicated in the Relay Transfer Parameter Set element exchanged by the source REDS, destination REDS, and RDS during the RLS procedure. A source REDS or destination REDS may change the transmission mode used in a relay link following successful transmission of RLS Request and RLS Response frames as described in 11.34.2.4 (RLS procedure).

An RDS shall start to operate as RDS at the start of an SP for which the value of the source AID and destination AID fields for that SP are equal to the source REDS and destination REDS, respectively, for which the RDS has successfully completed the RLS procedure. The RDS can determine the SPs for which it operates as an RDS upon reception of an Extended Schedule element.


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#### 10.44.2.4 Relay frame exchange rules

##### 10.44.2.4.1 General

Following the completion of the RLS procedure and SP allocation, each of the source REDS, destination REDS, and RDS have a direct link with one another.

The values of link change interval and data sensing time are indicated within the Relay Transfer Parameter Set transmitted by the source REDS to the destination REDS during the RLS procedure. Either the link change interval period or the first period begins at the start of an SP between the source REDS and the destination REDS, and any transmission by the source REDS, destination REDS, and RDS within a link change interval period shall use the same link that is used at the start of the link change interval period. A new link change interval period starts immediately after another link change interval period, but shall not exceed the end of the SP.

In the normal mode, a source REDS shall use the direct link to initiate frame transmission to the destination REDS at the start of the first SP allocated between the source REDS and destination REDS for a particular TID. At the start of the following SP allocations for that same TID, the source REDS uses the last link in which a frame transmission to the destination REDS via this link was successful. In the alternation mode, the source DMG STA shall alternate the frame transmission to the destination REDS between direct frame transmission to the destination REDS and frame transmission through the RDS. The source REDS shall alternate the link used for a frame transmission at the start of each link change interval.

If a source REDS transmits a frame to the destination REDS via the direct link but does not receive an expected Ack frame or BlockAck frame from the destination REDS during a link change interval period, the source REDS should change the link used for frame transmission at the start of the following link change interval period and use the RDS to forward frames to the destination REDS.

If a source REDS transmits a frame to the destination REDS via the RDS but does not receive an expected Ack frame or BlockAck frame from the RDS during a link change interval period or a first period, the source REDS should change the link used for frame transmission at the start of the following link change interval period or the following first period and transmit frames directly to the destination REDS.

##### 10.44.2.4.2 Additional frame exchange rules for FD-AF RDS

If the source REDS decides to change the link at the start of the following link change interval period and the Normal mode is used, the source REDS shall start its frame transmission after data sensing time from the start of the following link change interval period. If the Alternation mode is used, the source REDS alternates the link used for frame transmission at the start of each link change interval period, and the value of data sensing time is ignored.

In the Normal mode, if the destination REDS does not receive a (#3274)frame from the source REDS within data sensing time after the start of a link change interval, the destination REDS shall immediately change the link to attempt to receive frames from the source REDS through the RDS. If the More Data subfield in the last frame received from the source REDS is equal to 0, then the destination REDS shall not switch to the link in the next link change interval period even if it does not receive a frame during the data sensing time.

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An example of frame transfer under Normal mode with FD-AF RDS is illustrated in Figure 10-136 (Example of Normal mode operation with FD-AF relay).

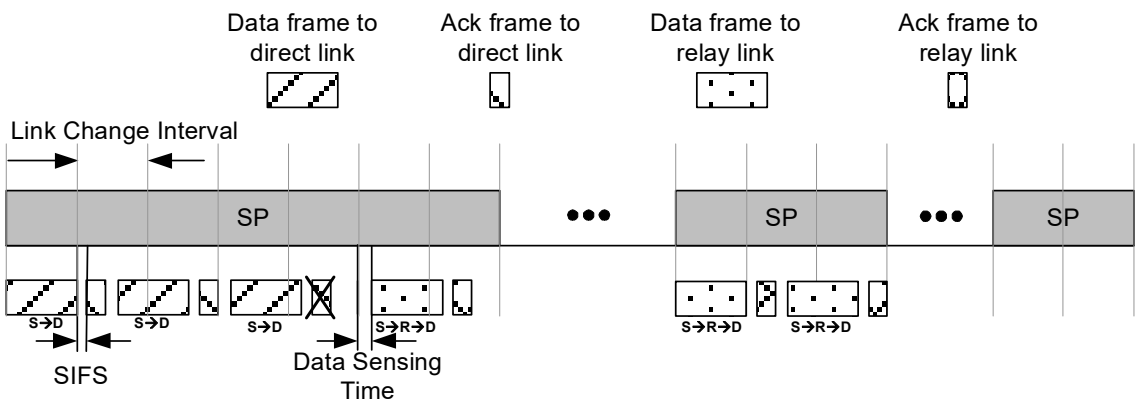


**Figure 10-136—Example of Normal mode operation with FD-AF relay**

In the Alternation mode, if the destination REDS receives an out of order frame, the destination REDS shall remain at the current link. If the More Data subfield in the last frame received from the source REDS is equal to 0, then the destination REDS shall not switch links in the next link change interval period. If the source REDS uses either the direct or the relay link and decides to resume alternate frame transmission, the source REDS should transmit a frame to the other link data sensing time after the next link change interval to inform the destination REDS that operation on the other link has been resumed. Note that this is the only situation when data sensing time is used in the Alternation mode.

#### 10.44.2.4.3 Additional frame exchange rules for HD-DF RDS

When the RDS is operating as a HD-DF RDS and the RDS is used in the frame exchange between the source REDS and the destination REDS, the frame exchange is performed in two periods, which are repeated for as long as the RDS is used. In the first period, the source REDS shall transmit a frame to the RDS and then the RDS responds after a SIFS(#6587) if needed. In the second period, the RDS shall forward the frame received from the source REDS to the destination REDS, and then the destination REDS responds after a SIFS(#6587) if needed. The duration of the first period and the second period are specified in the last Relay Transfer Parameter Set element transmitted from the source REDS.

The first period and second period are valid only when the source REDS and destination REDS exchange frames via the RDS. The link change interval is valid only when the source REDS and destination REDS exchange frames via the direct link. The first period begins at the end of the link change interval when a change to the relay link occurs. The link change interval begins at the end of the second period when a change to the direct link occurs.

The source REDS may transmit a Relay Ack Request frame to the RDS to determine whether all frames forwarded through the RDS were received by the destination REDS. Upon reception of a Relay Ack Request frame, the RDS shall respond with a Relay Ack Response frame with the Block Ack Starting Sequence Control field set to the same value as in the Relay Ack Request frame and the BlockAck Bitmap field set to indicate which frames have been received by the destination REDS.(#7201)

If the source REDS decides to change to the relay link at the start of the following link change interval period, the source REDS shall start its frame transmission at the start of the following link change interval period. If the current link is the direct link and the destination REDS does not receive a (#3274)frame from


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the source REDS within data sensing time after the start of each link change interval, the destination REDS shall change the link and consider the first period to begin at the start of the link change interval.

If a link change to the direct link occurs, the source REDS shall start to transmit a frame using the direct link at the end of the second period when the link change interval begins. The destination REDS shall switch to the direct link at each first period and listen to the medium toward the source REDS. If the destination REDS receives a (#3274)frame from the source REDS, the destination REDS shall remain on the direct link and consider the link change interval to begin at the start of the first period. Otherwise, the destination REDS shall change the link at the start of the next second period and attempt to receive frames from the source REDS through the RDS. If the active link is the relay link and the More Data subfield in the last frame received from the RDS is equal to 0, then the destination REDS shall not switch to the direct link even if it does not receive any frame during the second period.

(#111)In order to use the block ack mechanism through the RDS, the source REDS shall perform the block ack setup procedure with the RDS using the same TID as was used for the direct communication between the source REDS and the destination REDS. Similarly, the RDS shall perform the block ack setup procedure with the destination REDS before transmitting data using the block ack mechanism. Upon reception of an ADDBA Request frame from the source REDS, the RDS shall send an ADDBA Request frame to the destination REDS with the same content for all corresponding fields as the ADDBA Request frame received from the source REDS, except for Buffer Size field, which contains the buffer size of the RDS. Following the reception of the ADDBA Response frame from the destination REDS, the RDS shall send an ADDBA Response frame to the source REDS. The ADDBA Response frame shall have the same content for all corresponding fields as the ADDBA Response frame received from the destination REDS, except for the Buffer Size field, which shall be set to the minimum between the buffer size of the RDS and the destination REDS.

An example of frame transfer with HD-DF RDS is illustrated in Figure 10-137 (Example of operation with HD-DF relay).

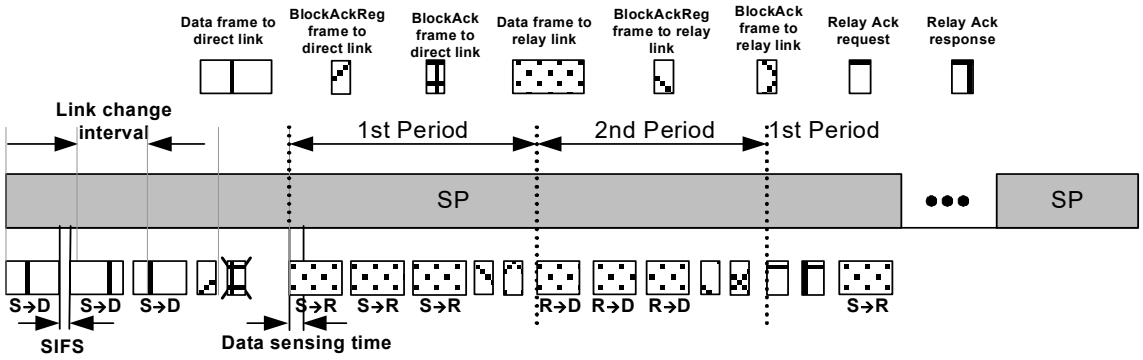


**Figure 10-137—Example of operation with HD-DF relay**

### 10.44.2.4.4 Operation of FD-AF RDS

In an SP allocated for relay operation, a FD-AF RDS operates in an amplify-and-forward manner. This means that for each frame detected at the RF in the receive state within an SP in which it operates as a FD-AF RDS, the RDS amplifies the received signal and simultaneously retransmits it via the RF in transmit state.

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At the start of the SP where it operates as a FD-AF RDS, the RDS shall initiate an RF antenna module in the receive state directed toward the source REDS and another RF antenna module in transmit state directed toward the destination REDS.

For each frame received at the RDS during the SP, the RDS shall follow the same rules for frame exchange sequences (#109)as described in 10.38 (DMG and CMMG channel access). This includes switching the state of each RF available to the RDS from receive to transmit, and vice versa, depending upon the frame type and its ack policy.

### 10.44.2.5 Link monitoring

After a link change, the source REDS might periodically monitor the quality of the previous link. To do that, the source REDS can use the link change mechanism described in 10.44.2.4 (Relay frame exchange rules). If the previous link is the relay link, the source REDS can acquire the channel status by using relay link measurement mechanism as described in 10.44.4 (Relay link adaptation). If the previous link is the direct link, the source REDS can acquire the channel status via the link adaptation mechanism defined in 10.41.9 (CDMG enhanced beam tracking). If the channel quality of the previous link is better than the one on the current link, which is an implementation dependent decision, the source REDS may switch to the previous link.

### 10.44.3 Link cooperation

### 10.44.3.1 TPA procedure

A source REDS, a destination REDS, and an RDS use the common relay setup procedure defined in 11.34.2 (Common relay setup procedures) to set up a link cooperation relay. In addition, to establish a link cooperation relay, the source REDS, destination REDS, and RDS shall perform the TPA procedure described in this subclause and shown in Figure 10-138 (TPA mechanism).

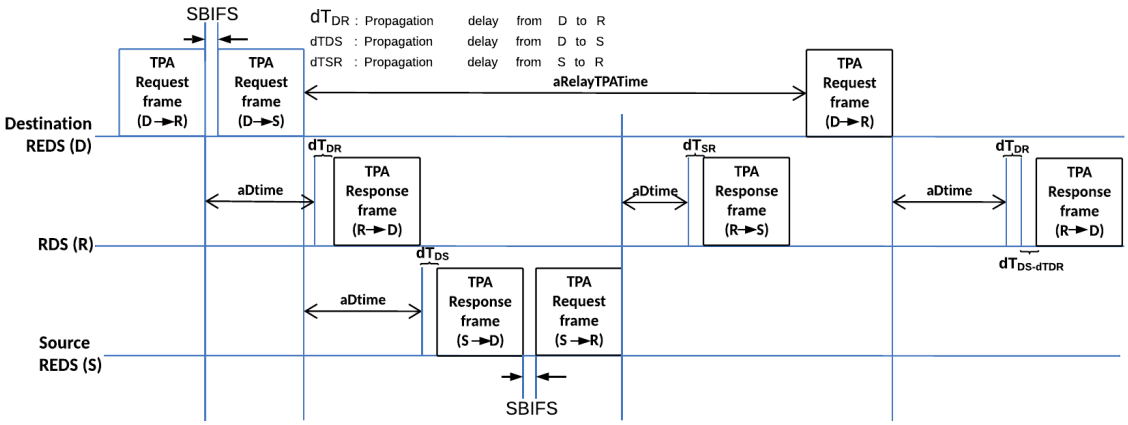


**Figure 10-138—TPA mechanism**

The TPA procedure is triggered by the destination REDS following the common relay setup procedure with the source REDS and RDS. First, the destination REDS uses the procedures described in 11.4 (TS operation) to request the allocation of an SP to perform TPA, wherein the source of the SP is the destination REDS and the destination of the SP is the source REDS. If the value of a source AID and the destination AID fields of an SP allocation correspond to a destination REDS and a source REDS, respectively, that have successfully completed the RLS setup procedure, a STA that performs as an RDS in that SP allocation shall operate during the allocation as a non-RDS-capable DMG STA.


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Within the allocated SP, the destination REDS sends a TPA Request frame to the RDS and sets the Timing Offset field to 0 (see Figure 10-138 (TPA mechanism)). SBIFS following the end of the first TPA Request frame transmission, the destination REDS shall send the second TPA Request frame to the source REDS and set the Timing Offset field to 0. aDtime interval (11.37 (DMG MAC sublayer attributes)) following the reception of the first TPA Request frame, the RDS shall transmit a TPA Response frame back to the destination REDS. Upon receiving the TPA Response frame from the RDS, the destination REDS shall estimate the TPA value of the RDS and the time deviation (i.e., $2 \times dT_{DR}$) between the expected Dtime and the actual arrival time of the TPA Response frame. aDtime interval following the reception of the second TPA Request frame, the source REDS shall transmit a TPA Response frame back to the destination REDS. The destination REDS shall repeat the same procedure upon reception of the TPA Response frame received from the source REDS.

SBIFS following the end of the transmission of the TPA Response frame to the destination REDS, the source REDS shall send a TPA Request frame to the RDS and set the Timing Offset field to 0. aDtime interval following the reception of the TPA Request frame, the RDS shall transmit a TPA Response frame back to the source REDS. Upon reception of the TPA Response frame from the RDS, the source REDS shall estimate the TPA value of the RDS and the time deviation (i.e., $2 \times dT_{SR}$) between aDtime and the actual arrival time of the TPA Response frame.

At aRelayTPATime (11.37 (DMG MAC sublayer attributes)) from the end of the last TPA Request frame transmitted by the destination REDS to the source REDS, the destination REDS shall send a TPA Request frame to the RDS and set the Timing Offset field to $dT_{DS} - dT_{DR}$. Upon reception of the TPA Request frame, the RDS shall transmit a TPA Response frame to the destination REDS at $aDtime + dT_{DR} + (dT_{DS} - dT_{DR})$ from the end of the TPA Request frame. Upon reception of the TPA Response frame, the destination REDS shall estimate the time deviation [i.e., $2 \times dT_{DR} + (dT_{DS} - dT_{DR})$] between aDtime and the actual arrival time of the TPA Response frame. If the destination REDS determines that the estimated deviation is equal to $2 \times dT_{DR} + (dT_{DS} - dT_{DR})$, then the destination REDS considers that the TPA procedure was successful. As the last step of the TPA procedure, the destination REDS shall send a TPA Report frame to the source REDS that includes the information regardless of whether the last TPA procedure succeeded.

If it is not successful, the TPA procedure is repeated until it is successful or upon the decision of the destination REDS to stop performing the TPA procedure. The TPA procedure includes the estimation of the sampling frequency offset (SFO), in order for the source REDS and RDS to adjust their SFOs.

#### 10.44.3.2 Link cooperation data transmission procedure

##### 10.44.3.2.1 General

A source REDS that has successfully completed an RLS procedure with a destination REDS for which the value of the Cooperation-Mode subfield within the negotiated Relay Transfer Parameter Set element is equal to 1 and has successfully completed the TPA procedure shall use the selected RDS between the source REDS and destination REDS for the purpose of link cooperation. This is described in this subclause.

##### 10.44.3.2.2 Cooperative transmission SP request and allocation

If the source REDS receives a TPA Report frame that indicates the successful completion of the TPA procedure with the RDS and the destination REDS, the source REDS uses the procedure in 11.4 (TS operation) to request an SP allocation with the destination REDS. The source REDS might use the SP allocation for communication with the destination REDS with the assistance of the RDS.

##### 10.44.3.2.3 Data transmission rules

As shown in the example of Figure 10-139 (Example of data transmission in SP with link cooperation relay), in the allocated SP the first time interval (T1) and the second time interval (T2) for a cooperative Data frame

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transfer are determined by the PPDU transmission time at each transmission from the source REDS to the destination REDS within the SP.

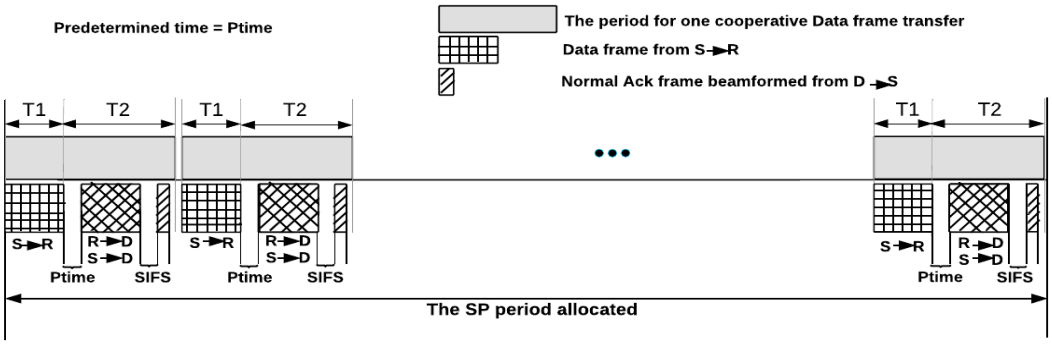


**Figure 10-139—Example of data transmission in SP with link cooperation relay**

The data transmission rules are as follows. At the start of each time T1, the source REDS transmits a frame with its transmit antenna pattern directed toward the RDS and with the TA and the RA fields in the MAC header set to the MAC address of the source REDS and destination REDS, respectively. After $Ptime + dT_{SR}$ from the start of T2, the source REDS retransmits the same frame sent to the RDS during the previous time T1 but now with its transmit antenna pattern directed toward the destination REDS. Similarly, after $Ptime + (dT_{DS} - dT_{DR})$ from the start of T2, the RDS retransmits the same frame it received from the source REDS during the previous time T1. So that the destination REDS might take advantage of the improved received signal level from both of these transmissions, the destination REDS should set its receive antenna pattern during T2 such that it simultaneously covers the links toward both the source REDS and the RDS.

### 10.44.4 Relay link adaptation

When a relay link is used for communication between a source REDS and a destination REDS, the link qualities of the S-R link, the R-D link, and the S-D link might be required.

The source REDS, destination REDS, and RDS use the procedure described in 10.41.9 (CDMG enhanced beam tracking) to request and report the link quality among themselves with the following exception. In the Link Measurement Report frame the RDS transmits to the source REDS, the RDS shall include two Link Margin elements in this order:

— The first Link Margin element shall report the link quality between the source REDS and the RDS.
— The second Link Margin element shall report the link quality between the RDS and the destination REDS.

Upon reception of a Link Measurement Report frame, the source REDS might take several actions including changing the MCS it uses for frame transmission to the RDS and destination REDS.

## 10.45 S1G BSS operation

### 10.45.1 Basic S1G BSS functionality

An S1G STA has dot11S1GOptionImplemented equal to true.


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(#181)An S1G STA that is starting a BSS shall support receiving and transmitting at each of the <S1G-MCS, NSS> tuple values indicated by the Basic S1G-MCS and NSS Set field of the S1G Operation parameter of the MLME-START.request primitive (#181)and shall support receiving at each of the <S1G-MCS, NSS> tuple values indicated by the Supported S1G-MCS and NSS Set field of the S1G Capabilities parameter of the MLME-START.request primitive.

An S1G STA declares its channel width capability in the Supported Channel Width subfield of the S1G Capabilities element S1G Capabilities Information field as described in Table 9-351 (Subfields of the S1G Capabilities Information field).

An S1G STA that is an S1G AP shall set the Channel Width subfield in the S1G Operation Information field of the S1G Operation element to indicate the BSS operating channel width as defined in Table 10-39 (S1G BSS operating channel width), the location of 1 MHz primary channel as defined in Table 9-363 (S1G Operation Information field) and whether MCS 10 is permitted but not recommended as defined in Table 9-363 (S1G Operation Information field). Table 10-39 (S1G BSS operating channel width) is the only combination allowed in an S1G BSS operation. The Channel Width field in the S1G Operation element not listed in Table 10-39 (S1G BSS operating channel width) shall not be declared by an S1G STA that is an S1G AP.

**Table 10-39—S1G BSS operating channel width**

| S1G Operation element Primary Channel Width subfield | S1G Operation element BSS Channel Width subfield | BSS primary channel width (MHz) | BSS operating channel width (MHz) |
|---|---|---|---|
| 0 | 1 | 2 | 2 |
| 0 | 3 | 2 | 4 |
| 0 | 7 | 2 | 8 |
| 0 | 15 | 2 | 16 |
| 1 | 0 | 1 | 1 |
| 1 | 1 | 1 | 2 |
| 1 | 3 | 1 | 4 |
| 1 | 7 | 1 | 8 |
| 1 | 15 | 1 | 16 |

An S1G STA shall determine the channelization based on the Channel Width, Primary Channel Number, and Channel Center Frequency subfields of the S1G Operation Information field (see 23.3.14 (Channelization)).

An S1G STA that is a member of an S1G BSS with a 1 MHz, 2 MHz, 4 MHz, 8 MHz, or 16 MHz operating channel width and 1 MHz primary channel width shall not transmit a 1 MHz S1G PPDU that does not use the primary 1 MHz channel of the BSS, except for a 1 MHz S1G PPDU transmission on an off-channel TDLS direct link as constrained by 11.23.6.4.2 or a 1 MHz S1G PPDU transmission by an SST STA as constrained by 10.51 (Subchannel selective transmission (SST)).

An S1G STA that is a member of an S1G BSS with a 2 MHz, 4 MHz, 8 MHz, or 16 MHz operating channel width and 2 MHz primary channel width shall not transmit a 1 MHz S1G PPDU in a 1 MHz channel that is not the 1 MHz channel indicated by B5 of the Channel Bandwidth subfield in the S1G Operation element as

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defined in Table 9-363 (S1G Operation Information field), except for a 1 MHz S1G PPDU transmission on an off-channel TDLS direct link or a 1 MHz S1G PPDU transmission by an SST STA as constrained by 10.51 (Subchannel selective transmission (SST)).

An S1G STA that is a member of an S1G BSS with a 2 MHz, 4 MHz, 8 MHz, or 16 MHz operating channel width shall not transmit a 2 MHz S1G PPDU that does not use the primary 2 MHz channel of the BSS, except for a 2 MHz S1G PPDU transmission either on an off-channel TDLS direct link or a 2 MHz S1G PPDU transmission by an SST STA as constrained by 10.51 (Subchannel selective transmission (SST)).

An S1G STA that is a member of an S1G BSS with a 4 MHz, 8 MHz, or 16 MHz operating channel width shall not transmit a 4 MHz S1G PPDU that does not use the primary 4 MHz channel of the BSS, except for a 4 MHz S1G PPDU transmission either on an off-channel TDLS direct link or by an SST STA as constrained by 10.51 (Subchannel selective transmission (SST)).

An S1G STA that is a member of an S1G BSS with an 8 MHz or 16 MHz operating channel width shall not transmit an 8 MHz S1G PPDU that does not use the primary 8 MHz channel of the BSS, except for an 8 MHz S1G PPDU transmission either on an off-channel TDLS direct link or by an SST STA as constrained by 10.51 (Subchannel selective transmission (SST)).

An S1G STA that is a member of an S1G BSS with a 16 MHz operating channel width shall not transmit a 16 MHz S1G PPDU that does not use the primary 8 MHz channel and the secondary 8 MHz channel of the BSS, except for a 16 MHz S1G PPDU transmission on an off-channel TDLS direct link.

An S1G STA shall not transmit to a second S1G STA using a bandwidth that is not indicated as supported in the Supported Channel Width subfield in the S1G Capabilities element received from that S1G STA.

An S1G STA shall set the BSS BW field in the Frame Control field of the S1G Beacon frame in line with the values defined in Table 10-39 (S1G BSS operating channel width) that are included in the S1G Operation element transmitted by the STA.

### 10.45.2 System information update procedure

The S1G AP shall increase the value (modulo 256) of the Change Sequence field in the next transmitted S1G Beacon frame(s) when a critical update occurs to any of the elements inside the S1G Beacon frame. The following events shall classify as a critical update:

a) Inclusion of an Extended Channel Switch Announcement
b) Modification of the EDCA parameters
c) Modification of the S1G Operation element

An S1G AP can classify other changes in the S1G Beacon frame as critical updates and among these updates can be included those that are described in 11.2.3.14 (TIM Broadcast).

The S1G STA shall either be awake to receive the next S1G Beacon frame that is transmitted at a TBTT or shall queue for transmission a Probe Request frame when it receives a Change Sequence field that contains a value that is different from the previously received Change Sequence field. When an S1G STA transmits a Probe Request frame to obtain the updated system information, it may include the Change Sequence element in the Probe Request frame to request a compressed Probe Response frame.

When an S1G AP receives a Probe Request frame that contains a Change Sequence element from an S1G STA associated with the S1G AP, it compares the value of the received Change Sequence field with the value of its current Change Sequence field. If the value of the received Change Sequence field is not equal to the value of the current Change Sequence field, the S1G AP should send a compressed Probe Response frame, which is a Probe Response frame that includes the Change Sequence element and only the elements


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that need be updated by the STA. Otherwise, the AP shall send a Probe Response frame as defined in 11.1.4.3.4 (Criteria for sending a response).

### 10.45.3 S1G BSS channel selection methods

Before an S1G STA starts an S1G BSS, the STA shall perform a minimum of dot11S1GOBSSScanCount OBSS scan operations to search for existing BSSs (see 10.45.5 (Scanning requirements for S1G STA)).

If an S1G AP starts an S1G BSS with a 2 MHz primary channel width that occupies some or all channels of any existing BSSs, the S1G AP may select a 2 MHz primary channel of the new S1G BSS that is identical to the 2 MHz primary channel of any one of the existing BSSs.

If an S1G AP selects a 2 MHz primary channel for a new S1G BSS with a 4 MHz, 8 MHz, or 16 MHz operating channel width from among the channels on which no beacons are detected during the OBSS scans, then the selected 2 MHz primary channel meets the following conditions:

— It shall not be identical to the secondary 2 MHz channel of any existing BSSs with a 4 MHz, 8 MHz, or 16 MHz operating channel width.

— It should not overlap with the secondary 4 MHz channel of any existing BSSs with a 16 MHz operating channel width.

An S1G STA that is an S1G AP should not start an S1G BSS with a 2 MHz operating channel width on a channel that is the secondary 2 MHz channel of any existing BSSs with a 4 MHz, 8 MHz, or 16 MHz operating channel width, or is overlapped with the secondary 4 MHz channel of any existing BSSs with a 16 MHz operating channel width.

NOTE—An S1G AP operating an S1G BSS with a 4 MHz, 8 MHz, or 16 MHz operating channel width, on detecting an OBSS whose primary channel is the S1G AP's secondary 2 MHz channel, might switch to 2 MHz BSS operation and/or move to a different channel.

If an S1G AP starts an S1G BSS with a 1 MHz primary channel width that occupies some or all channels of any existing BSSs, the S1G AP may select a 1 MHz primary channel of the new S1G BSS that is identical to the 1 MHz primary channel of any one of the existing BSSs.

If an S1G AP selects a 1 MHz primary channel for a new S1G BSS with a 2 MHz, 4 MHz, 8 MHz, or 16 MHz operating channel width from among the channels on which no beacons are detected during the OBSS scans, then the selected 1 MHz primary channel meets the following conditions:

— It shall not be identical to the secondary 1 MHz channel of any existing BSSs with a 2 MHz, 4 MHz, 8 MHz, or 16 MHz operating channel width.

An S1G STA that is an S1G AP should not start an S1G BSS with a 1 MHz operating channel width on a channel that is the secondary 1 MHz channel of any existing BSSs with a 2 MHz, 4 MHz, 8 MHz, or 16 MHz operating channel width.

When establishing a BSS with a 2 MHz, 4 MHz, 8 MHz, or 16 MHz operating channel width, the S1G AP determines and announces the location of 1 MHz primary channel located at either upper or lower side of the 2 MHz primary channel.

### 10.45.4 S1G BSS channel switching methods

An S1G AP announces a switch of operating channel by using the Extended Channel Switch Announcement element, Extended Channel Switch Announcement frame or both, following the procedure described in 11.9 (Extended channel switching (ECS)).

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An S1G AP may also announce a switch of operating channel width, a new Country String field (possibly including a new Operating Class table number), new operating classes or new TPC parameters for the BSS that come into effect at the same time as the switch of operating channel.

The New Channel Number field in the Extended Channel Switch Announcement element or Extended Channel Switch Announcement frame identifies the primary channel after the switch. The value of the New Channel Number field is set to the value that dot11CurrentPrimaryChannel (see 23.3.14 (Channelization)) will have after the switch.

### 10.45.5 Scanning requirements for S1G STA

An OBSS scan operation is a passive or active scan of a set of channels that are potentially affected by S1G BSS operation (see 11.1.4.1 (General)). Each channel in the set may be scanned more than once during a single OBSS scan operation. OBSS scans are performed by S1G STAs that start an S1G BSS.

During an individual scan within an OBSS scan operation, the minimum per-channel scan duration is dot11OBSSScanPassiveDwell TUs (for a passive scan) or dot11OBSSScanActiveDwell TUs (for an active scan). During an OBSS scan operation, each channel in the set is scanned at least once per dot11BSSWidthTriggerScanInterval seconds, and the minimum total scan time (i.e., the sum of the scan durations) per channel within a single OBSS scan operation is dot11OBSSScanPassiveTotalPerChannel TUs (for a passive scan) or dot11OBSSScanActiveTotalPerChannel TUs (for an active scan).

NOTE—The values provided in the previous paragraph are minimum requirements. For some combinations of parameter values the minimum might be exceeded for some parameters in order to meet the minimum value constraints of other parameters.

### 10.45.6 NAV and RID assertion in an S1G BSS

An S1G STA shall update its NAV as described in 10.3.2.4 (Setting and resetting the NAV) using the Duration/ID field value in any frame that does not have an RA matching the STA's MAC address or the Duration field value in NDP CMAC PPDUs of which it is not the recipient STA and that was received in a 1 MHz PPDU in the primary 1 MHz channel or received in a 2 MHz PPDU in the primary 2 MHz channel or received in a 4 MHz PPDU in the primary 4 MHz channel or received in an 8 MHz PPDU in the primary 8 MHz channel or received in a 16 MHz PPDU.

An S1G STA shall update its RID as described in 10.3.2.5 (Setting and resetting the RID) using the RXVECTOR parameters in any frame that was received in a 1 MHz PPDU in the primary 1 MHz channel or received in a 2 MHz PPDU in the primary 2 MHz channel or received in a 4 MHz PPDU in the primary 4 MHz channel or received in an 8 MHz PPDU in the primary 8 MHz channel or received in a 16 MHz PPDU.

NOTE—The PHY layer might filter out a PPDU as described in 23.3.20 (PHY receive procedure). If so, frames in the PPDU are not received by the MAC and have no effect on the NAV.

### 10.45.7 BSS Basic S1G-MCS and NSS set operation

The BSS basic S1G-MCS and NSS set is the set of <S1G-MCS, NSS> tuples that are supported by all S1G STAs that are members of an S1G BSS, where the S1G-MCS values refer to those obtained from the Max S1G-MCS For n SS subfields of the S1G Operation element as defined in 9.4.2.211 (S1G Operation element). It is established by the STA that starts the S1G BSS, indicated by the Basic S1G-MCS and NSS Set field of the S1G Operation element in the MLME-START.request primitive. Other S1G STAs determine the BSS basic S1G-MCS and NSS set from the Basic S1G-MCS and NSS Set field of the S1G Operation element in the BSSDescription derived through the scan mechanism (see 11.1.4.1 (General)).


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An S1G STA shall not attempt to join (MLME-JOIN.request primitive) a BSS unless it supports (i.e., is able to both transmit and receive using) all the <S1G-MCS, NSS> tuples in the BSS basic S1G-MCS and NSS set.

An S1G STA shall not attempt to (re)associate (MLME-ASSOCIATE.request primitive and MLME-REASSOCIATE.request primitive) with an S1G AP unless the S1G STA supports (i.e., is able to both transmit and receive using) all the <S1G-MCS, NSS> tuples in the Basic S1G-MCS and NSS Set field in the S1G Operation element transmitted by the S1G AP.

The BSS basic S1G-MCS and NSS set is defined by Max S1G-MCS, which indicate the mandatory values and Min S1G-MCS, which indicate the recommended values as defined in 9.4.2.211 (S1G Operation element) and 10.6.14 (Rate selection constraints for S1G STAs).

An S1G AP that indicates support for sensor STAs does not indicate minimum MCS restrictions.

### 10.45.8 S1G coexistence with non-IEEE-802.11 systems

This subclause describes the features available in this standard to improve coexistence with other systems operating in bands below 1 GHz, including IEEE Std 802.15.4 and IEEE Std 802.15.4g.

An S1G STA uses energy detection (ED) based CCA with a threshold of –75 dBm per MHz to improve coexistence with other S1G systems. If an S1G STA detects energy above that threshold on its channel, as described in 23.3.18.5 (CCA sensitivity), then the following mechanisms might be used to mitigate interference:

- Change of operating channel (11.9 (Extended channel switching (ECS)))
- Sectorized beamforming (10.52 (Sectorized beam operation))
- Change the schedule of RAW(s) (10.23.5 (Restricted access window (RAW) operation)), TWT SP(s) (10.46 (Target wake time (TWT))), or SST operating channels (10.51 (Subchannel selective transmission (SST)))
- Defer transmission for a particular interval (10.60 (S1G flow control))

## 10.46 Target wake time (TWT)

### 10.46.1 TWT overview

Target wake times (TWTs) allow STAs to manage activity in the BSS by scheduling STAs to operate at different times in order to minimize contention and to reduce the required amount of time that a STA utilizing a power management mode needs to be awake. TWTs can be individual TWTs, which are described in 10.46 (Target wake time (TWT)) and 26.8.2 (Individual TWT agreements), or broadcast TWTs, which are described in 26.8.3 (Broadcast TWT operation).(11ax)

When performing the TWT operations described in 10.46.1 (TWT overview) to 10.46.8 (TWT teardown), if management frame protection is negotiated and both STAs set the Protected TWT Operations Support field in the RSNXE that they transmit to 1, the STAs shall

- Use individually addressed Protected TWT Setup, Protected TWT Teardown, and Protected TWT Information frames instead of TWT Setup, TWT Teardown, and TWT Information frames, respectively,
- Not transmit BAT, STACK, or TACK frames, and
- Discard any individually addressed TWT Setup, TWT Teardown, TWT Information, BAT, STACK, or TACK frame received from the peer STA, with which management frame protection is negotiated.

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STAs that exchange individually addressed Protected TWT Setup, Protected TWT Teardown, or Protected TWT Information frame shall follow the rules defined in 12.6.17 (Protection of robust Management frames.).

When management frame protection is not negotiated or the Protected TWT Operations Support field in the RSNXE transmitted by either STA is(M118) 0, the STAs shall not use any of the Protected TWT Setup frame, the Protected TWT Teardown frame, and the Protected TWT Information frame.

STAs that request a TWT agreement are called TWT requesting STAs and the STAs that respond to their requests are TWT responding STAs. A TWT requesting STA is assigned specific times to wake and exchange frames with the TWT responding STA. A TWT requesting STA communicates wake scheduling information to its TWT responding STA and the TWT responding STA devises a schedule and delivers TWT values to the TWT requesting STA when a TWT agreement has been established between them. When explicit TWT is employed, a TWT requesting STA wakes and performs a frame exchange and receives the information for the next target wake time for any of the explicit TWT agreements of which the STA is a member,(#6105) in a response from the TWT responding STA as described in 10.46.3 (Explicit TWT operation).(11ax) When implicit TWT is used, the TWT requesting STA calculates the Next TWT by adding a fixed value to the current TWT value as described in 10.46.4 (Implicit TWT operation)(11ax). STAs need not be made aware of the TWT values of other STAs. A TWT requesting STA and a TWT responding STA shall set the Negotiation Type subfield to 0 in the TWT element of transmitted frames containing the TWT element, except when the STAs are HE STAs. Additional TWT setup exchanges between HE STAs for individual TWT operation are defined in 26.8 (TWT operation).(11ax)

The maximum number of active TWT agreements between any pair of STAs cannot exceed 8, since the TWT Flow Identifier field of the TWT element comprises 3 bits. TWT responding STAs may protect TWT times with protection mechanisms including, but not limited to NAV-setting frame exchange sequences(#109). TWT responding STAs that are APs may additionally protect TWT times using RAW scheduling. TWT requesting STAs may wake at times other than TWT. An AP that is a TWT requesting STA shall not be in doze state for a duration that exceeds the value of the dot11MaxAwayDuration during a beacon interval or short beacon interval, as defined in 11.2.3.17 (AP power management).

An (11ax)S1G STA with dot11TWTOptionActivated equal to true and that operates in the role of TWT requesting STA shall set the TWT Requester Support subfield to 1 in all S1G Capabilities elements that it transmits. An (11ax)S1G STA with dot11TWTOptionActivated equal to true and that operates in the role of TWT responding STA shall set the TWT Responder Support subfield to 1 in all S1G Capabilities elements that it transmits.

(11ax)A STA that is not an S1G STA and is not an HE STA and with dot11TWTOptionActivated equal to true and that operates in the role of TWT requesting STA shall set the TWT Requester Support subfield to 1 in all Extended Capabilities elements that it transmits. A STA that is not an S1G STA and is not an HE STA and with dot11TWTOptionActivated equal to true and that operates in the role of TWT responding STA shall set the TWT Responder Support subfield to 1 in all Extended Capabilities elements that it transmits.

If the TWT Responder Support subfield of the S1G Capabilities element, (11ax)HE Capabilities element, or Extended Capabilities element received from its associated AP is equal to 1, a non-AP STA with dot11TWTOptionActivated equal to true may transmit a TWT element to the AP with a value of Request TWT, Suggest TWT, or Demand TWT in the TWT Setup Command field(11ax) and with the TWT Request field equal to 1.

An AP with dot11TWTOptionActivated equal to true shall transmit a TWT element to a STA that is associated to the AP and from which it received a frame containing a TWT element that contained a value of Request TWT, Suggest TWT or Demand TWT in the TWT Setup Command field(11ax) and with the TWT Request field equal to 1, (#4005)except when the received frame is a (Re)Association Request frame sent by


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an HE STA, in which case the AP should transmit a TWT element to the STA. The transmitted TWT element shall be included in the frame that is the appropriate response frame to the received frame. The AP shall include a value of Accept TWT, Alternate TWT, Dictate TWT or Reject TWT in the TWT Setup Command field(11ax) of the response and shall set the TWT Request field to 0. If the AP response's TWT Setup Command field(11ax) includes anything other than Accept TWT or Reject TWT, the STA should send a new request for a TWT value by sending another frame that contains a TWT element, modifying the parameters of the request to indicate, for example, an acceptance of a proposed alternate TWT or dictated TWT value. If the STA receives a TWT response to a TWT request with the TWT Setup Command field(11ax) value of Accept TWT, then the STA has successfully completed a TWT setup with that STA for the TWT Flow Identifier indicated in the TWT response and the STA becomes a TWT requesting STA and the STA may enter the doze state until the TSF matches the next TWT value of the STA, provided that the STA has indicated that it is in a power save mode and no other condition requires the STA to remain awake. The AP becomes a TWT responding STA of the TWT requesting STA.

NOTE 1—A TWT responding STA might choose a TWT Flow Identifier for the TWT response that is different from the TWT Flow Identifier of a received TWT request.(11ax)

NOTE 2—If the frame that contains the TWT element is a (Re)Association Request frame, and the (Re)Association Response frame that is sent in response does not contain a TWT element then the non-AP STA can transmit another TWT request to the associated AP after (re)association.(#4005)

NOTE 3—A TWT requesting STA might renegotiate the TWT parameters of an existing TWT agreement by sending to the TWT responding STA a TWT request with a Flow Identifier that corresponds to that TWT agreement. The TWT response sent by the TWT responding STA containing the TWT Setup Command field of Accept TWT indicates(M118) whether the newly requested TWT parameters are accepted or whether the previously negotiated TWT parameters are still in place.(11ax)

(11ax)The result of an exchange of TWT Setup frames between a TWT requesting STA and a TWT responding STA is defined in Table 10-40 (TWT setup exchange command interpretation(11ax)).

— "Request TWT" indicates that the requesting STA does not provide a set of TWT parameters for a TWT agreement, leaving the choice of parameters to the responding STA.

— "Suggest TWT" indicates that the requesting STA offers a set of preferred TWT parameters for a TWT agreement but might accept alternative TWT parameters that the responding STA indicates.

— "Demand TWT" indicates that the requesting STA currently accepts(M118) only the indicated TWT parameters for a TWT agreement.

(11ax)For transmissions by a responding STA,

— "Accept TWT" indicates that the responding STA has initiated a TWT agreement with the given parameters.

— "Alternate TWT" indicates a counter-offer of TWT parameters (although alternative TWT parameters might be accepted as well) without the creation of a TWT agreement.

— "Dictate TWT" indicates that no TWT agreement is created, but one is likely to be accepted only if the requesting STA transmits a new TWT setup request with the indicated TWT parameters (i.e., no other TWT parameters will be accepted).

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(11ax)For transmissions by a responding STA as part of a negotiation for a new TWT agreement, "Reject TWT" indicates that the negotiation has ended in failure to create a new TWT agreement.

**Table 10-40—TWT setup exchange command interpretation(11ax)**

| TWT Setup Command field in an initiating frame | TWT Setup Command field value in a response frame | TWT condition after the completion of the exchange |
|---|---|---|
| Request TWT, Suggest TWT, or Demand TWT | No frame transmitted | No new individual TWT agreement exists with the TWT flow identifier corresponding to the TWT flow identifier in the initiating frame. No new individual TWT agreement exists. |
| Demand TWT | Accept TWT | An individual TWT agreement exists that uses the TWT parameters identified in the initiating frame. The TWT parameters in the response frame match the TWT parameters of the initiating frame. |
| Suggest TWT or Request TWT | Accept TWT | An individual TWT agreement exists and uses the TWT parameters identified in the response frame. |
| Demand TWT or Suggest TWT | Alternate TWT | No individual TWT agreement exists with the associated TWT flow identifier. The responder is offering an alternative set of parameters to those indicated in the initiating frame. The requesting STA can send a new request with any set of TWT parameters, and the responder might create an individual TWT agreement using those parameters. |
| Demand TWT or Suggest TWT | Dictate TWT | No individual TWT agreement exists with the associated TWT flow identifier. The responder STA offers an alternative set of parameters to those indicated in the initiating frame. The responder STA indicates that it is not willing to accept any other TWT parameters from the requesting STA at this time.<br><br>The requesting STA can send a new request, but will receive an Accept TWT only if it uses the dictated TWT parameters. |
| Request TWT, Suggest TWT, or Demand TWT | Reject TWT | No individual TWT agreement exists with the associated TWT flow identifier. The responding STA will not create any new individual TWT agreement with the requester at this time. |
| NOTE 1—Negotiation Type subfield of the TWT element contained in these frames is equal to 0.<br>NOTE 2—The initiating frame is a TWT request, and the response frame is a TWT response. | | |

The receipt of a TWT command value of Suggest TWT implies that the STA sending the command will consider accepting a proposed TWT that differs from the value found in the TWT field of the element. The receipt of a TWT command value of Demand TWT implies that the STA sending the command will not consider accepting a proposed TWT that differs from the value found in the TWT field of the element. The receipt of a TWT command value of Alternate TWT implies that the STA sending the command will consider accepting a proposed TWT that differs from the value found in the TWT field of the element. The receipt of a TWT command value of Dictate TWT implies that the STA sending the command will not consider accepting a proposed TWT that differs from the value found in the TWT field of the element.


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The MAC addresses of the TWT requesting STA and the TWT responding STA and the TWT Flow Identifier indicated in the TWT Response of a successful TWT setup between those two STAs uniquely identifies a TWT agreement. A MAC variable AdjustedMinimumTWTWakeDuration is defined for each TWT of each TWT agreement and has a value equal to Nominal Minimum TWT Wake Duration minus the elapsed time from the scheduled start of the TWT SP to the actual start of the SP, where the scheduled and actual start times of the TWT SP are determined after any necessary TSF adjustment. Because the value of the AdjustedMinimumTWTWakeDuration depends on the actual TWT SP start time, it is computed for each TWT SP once the TWT SP begins.

The TWT Wake Interval of a TWT agreement is the value calculated as shown in 9.4.2.198 (TWT element) from the TWT Wake Interval Mantissa and TWT Wake Interval Exponent of the TWT response that successfully completed the TWT agreement.

An AP may transmit a TWT element in an individually addressed TWT Setup frame with a value of Request TWT, Suggest TWT or Demand TWT in the TWT Command field and with the TWT Request field equal to 1 to an associated non-AP STA if the TWT Responder Support subfield in the S1G Capabilities element received from the STA is equal to 1. An AP may transmit TWT Setup frames to more than one of its associated non-AP STAs.

A non-AP STA with dot11TWTOptionActivated equal to true shall transmit a frame containing a TWT element to the AP with which it is associated and from which it received an individually addressed frame containing a TWT element that contained a value of Request TWT, Suggest TWT or Demand TWT in the TWT Command field and with the TWT Request field equal to 1. The transmitted TWT element shall be included in the frame that is the appropriate response frame to the received frame. The non-AP STA shall include a value of Accept TWT, Alternate TWT, Dictate TWT or Reject TWT in the TWT Command field of the response and shall set the TWT Request field to 0. If the non-AP STA response's TWT Command field includes anything other than Accept TWT or Reject TWT, the AP should send a new request for a TWT value by sending another frame that contains a TWT element, modifying the parameters of the request to indicate, for example an acceptance of a proposed alternate TWT or dictated TWT value. If the AP receives a TWT response to a TWT request with the TWT Command value of Accept TWT from an associated non-AP STA, then the AP has successfully completed a TWT setup with that STA for the TWT Flow Identifier indicated in the TWT response and the AP becomes a TWT requesting STA with respect to that STA.

A non-AP STA shall not transmit a frame containing a TWT element as a response to a group addressed frame with the TWT Request field equal to 1 that is transmitted by its associated AP.

If the NDP Paging field was not present in the TWT response corresponding to a TWT agreement, the TWT requesting STA shall be in the awake state following each TWT start time associated with each TWT agreement for the AdjustedMinimumTWTWakeDuration associated with that TWT agreement even if no PS-Poll frame, NDP PS-Poll frame, or U-APSD trigger frame has been transmitted by the STA or until it has received an EOSP field equal to 1 from the TWT responding STA, whichever occurs first. If the NDP Paging field was present in the TWT response, the TWT requesting STA shall follow the operational rules defined in 10.46.6 (NDP paging setup).

If the Implicit bit is equal to 1 in the TWT response for a TWT agreement, the TWT associated with that TWT agreement is an implicit TWT and the TWT SP associated with that TWT is an implicit TWT SP. A TWT SP that is not an implicit TWT is an explicit TWT SP.

A TWT requesting STA that is a non-AP STA should transmit frames only within TWT SPs.

A TWT requesting STA that transmits a frame during a TWT SP is not granted any special medium access privileges, nor is there any guarantee that the TWT responding STA assigned the TWT SP to only one TWT requesting STA.

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A single pair of STAs can create multiple TWT agreements. Each unique TWT agreement is identified by a TWT Flow Identifier and the MAC addresses of the TWT requesting STA and TWT responding STA. There are no explicit restrictions on the class of traffic (i.e., EDCA Access Category) that can be transmitted within any specific TWT SP when multiple TWT agreements have been set up by a single TWT requesting STA.

(#262)NOTE 4—The maximum number of TWTs for a single pair of STAs is 8.

A TWT requesting STA that is a non-AP STA may wake to receive Beacons that are transmitted outside of a TWT SP. A TWT requesting STA that is an AP generates S1G Beacon frames as described in 11.1.3 (Maintaining synchronization) and operates in power save mode as described in 11.2.3.17 (AP power management).

A TWT responding STA should include a Pentapartial Timestamp field or a Tetrapartial Timestamp field or a Timestamp field in at least one frame transmitted to a TWT requesting STA during a TWT SP for that STA.

NOTE 5—When dot11TWTOptionActivated is true, a TWT responding STA might use the TWT Wake Interval in determining the lifetime of frames that it buffers for an TWT requesting STA.

The Flow Type field in the TWT response that successfully set up a TWT agreement indicates the type of interaction between the TWT requesting STA and the TWT responding STA within each TWT SP for that TWT agreement. Flow Type field equal to 0 indicates an announced TWT. The TWT responding STA of an announced TWT agreement shall not transmit a frame to the TWT requesting STA within a TWT SP until it has received a PS-Poll frame or APSD trigger frame (see 11.2.3.5 (Power management with APSD)) from the TWT requesting STA. Flow Type field equal to 1 indicates an unannounced TWT. The TWT responding STA of an unannounced TWT agreement may transmit a frame to the TWT requesting STA within a TWT SP before it has received a frame from the TWT requesting STA.

NOTE 6—A TWT requesting STA that is an AP does not send PS-Poll frames, but it can send APSD trigger frames.

A TWT requesting STA that is negotiating SST operation indicates which single channel it desires to use as a temporary primary channel during a TWT SP by setting a single bit to 1 within the TWT Channel field of the TWT element, according to the mapping described for that field. A TWT responding STA that is negotiating SST operation indicates which single channel the TWT requesting STA is permitted to use as a temporary primary channel during a TWT SP by setting a single bit to 1 within the TWT Channel field of the TWT element, according to the mapping described for that field. (11ax)In an S1G BSS, during a TWT SP that was negotiated as part of SST operation, access to a channel that is not the primary channel of the BSS shall be performed according to the procedure described in 10.51 (Subchannel selective transmission (SST)).

(11ax)In an HE BSS, during a trigger-enabled TWT SP, access to a channel that is not the primary channel of the BSS shall be performed according to the procedure described in 26.8.7 (HE subchannel selective transmission).

(11ax)If a STA has received a TWT Constraint Parameters element from another STA, it should not initiate a new TWT agreement or join a broadcast TWT schedule with that STA if the total number of TWT sessions/ schedules between the two STAs would exceed the value of the Max TWT Sessions field in the TWT Constraint Parameters element.

(11ax)If a STA has received a TWT Constraint Parameters element from another STA and includes the Target Wake Time field in a TWT element transmitted to initiate a new TWT agreement with that STA, then it should set the Target Wake Time field to an integer multiple of $n + 1$ TUs [i.e., (Target Wake Time) mod $(n + 1) = 0$] where $n$ is the value from the Starting Target Wake Time Alignment field of the most recent TWT Constraint Parameters element received from that STA.


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### 10.46.2 TWT acknowledgment procedure

STAs need to be able to predict the duration of response transmissions for Duration field calculations and in addition, TWT requesting STAs might need TWT start times delivered in response frames. This subclause contains rules for TWT acknowledgments that allow both objectives to be satisfied at once by requiring specific responses to be transmitted in specific circumstances and by specifying the use of frames that provide both acknowledgment and next TWT information.

A TWT responding STA shall transmit a STACK frame in response to a frame received from a TWT requesting STA (#1414)that has the value NORMAL_RESPONSE in the RXVECTOR parameter RESPONSE_INDICATION and that is not an A-MPDU and not an S-MPDU. A TWT responding STA shall transmit a TACK frame in response to a frame received from a TWT requesting STA (#1414)that has the value NORMAL_RESPONSE in the RXVECTOR parameter RESPONSE_INDICATION and that is an S-MPDU unless the S-MPDU contains a BlockAckReq frame, (#274)in which case the response frame is a BAT frame. A TWT responding STA shall transmit a BAT frame in response to a frame received from a TWT requesting STA (#1414)that has the value NORMAL_RESPONSE in the RXVECTOR parameter RESPONSE_INDICATION and that is an A-MPDU.

A TWT requesting STA with the transmitted TWT Responder Support subfield in the S1G Capabilities element equal to 1 shall transmit a STACK frame in response to a frame received from a TWT responding STA (#1414)that has the value NORMAL_RESPONSE in the RXVECTOR parameter RESPONSE_INDICATION and that is not an A-MPDU and not an S-MPDU. A TWT requesting STA with the transmitted TWT Responder Support subfield in the S1G Capabilities element equal to 1 shall transmit a TACK frame in response to a frame received from a TWT responding STA (#1414)that has the value NORMAL_RESPONSE in the RXVECTOR parameter RESPONSE_INDICATION and that is an S-MPDU unless the S-MPDU contains a BlockAckReq frame, (#274)in which case the response frame is a BAT frame. A TWT requesting STA with the transmitted TWT Responder Support subfield in the S1G Capabilities element equal to 1 shall transmit a BAT frame in response to a frame received from a TWT responding STA (#1414)that has the value NORMAL_RESPONSE in the RXVECTOR parameter RESPONSE_INDICATION and that is an A-MPDU.

A TWT requesting STA that transmits a frame containing a Pentapartial Timestamp field shall set the field to all 0s. A TWT requesting STA that transmits a frame containing a Tetrapartial Timestamp field shall set the field to all 0s. A TWT requesting STA that transmits a frame containing a Next TWT Info field shall set the field to all 0s. A TWT requesting STA that transmits a frame containing a Change Sequence field shall set the field to all 0s.

A TWT requesting STA with the transmitted TWT Responder Support subfield in the S1G Capabilities element equal to 0 that receives a frame that requires an immediate response shall transmit an appropriate response is determined in 10.3.2.17 (Response Indication procedure).

If the intended recipient of a STACK or BAT frame is an AP, then the A1 field of the frame shall be set to 0.

If a TWT responding STA or a TWT requesting STA receives a frame within a TWT SP that has a value other than NORMAL_RESPONSE in the RXVECTOR parameter RESPONSE_INDICATION, the appropriate response is as determined in 10.3.2.17 (Response Indication procedure).

### 10.46.3 Explicit TWT operation

Each TWT SP start value for an explicit TWT is transmitted by the TWT responding STA to the TWT requesting STA in the Next TWT Info/Suspend Duration field of a frame that can contain the field as described in this subclause. The TWT responding STA for an explicit TWT may provide TWT SP start times that are related to one another in a periodic or aperiodic manner.

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During an explicit TWT SP, if a TWT responding STA receives a frame from a TWT requesting STA that permits a BAT frame, TACK frame or STACK frame to be sent in response, then the TWT responding STA shall respond with a frame that includes a Next TWT Info/Suspend Duration field either if it is required to do so according to 10.46.2 (TWT acknowledgment procedure), or if it has not already transmitted a nonzero Next TWT Info/Suspend Duration field to the STA within this TWT SP. If the TWT responding STA has already transmitted a nonzero Next TWT Info/Suspend Duration field to the STA within this TWT SP, and is not otherwise required to respond with a BAT frame, TACK frame or STACK frame, the TWT responding STA may respond to the STA with a frame that contains a Next TWT Info/Suspend Duration field. When present in the response frame, the Next TWT Info/Suspend Duration field may contain the value of the TSF timer corresponding to the next scheduled TWT SP for the STA that is the intended recipient of the frame or may contain the value 0 to indicate that the Next TWT is not currently available for this TWT.

A TWT requesting STA awake for an explicit TWT SP shall not transmit a PS-Poll frame with the Poll Type subfield equal to any value other than 2.

A TWT requesting STA that is awake for an explicit TWT SP shall not enter doze state until it has received a nonzero Next TWT Info/Suspend Duration field from the TWT responding STA and has either been in the awake state for a duration of at least Nominal Minimum TWT Wake Duration from the TWT SP start time as identified by the TWT responding STA or has received an EOSP field equal to 1 from the TWT responding STA. If more than one nonzero Next TWT Info/Suspend Duration field is received from the TWT responding STA during a TWT SP, the receiving STA shall discard all but the most recently received value. If no nonzero Next TWT Info/Suspend Duration field is received from the TWT responding STA during the TWT SP, then following the end of the TWT SP when not otherwise prohibited from transmitting, the TWT requesting STA may transmit a frame that is addressed to the TWT responding STA as a means to solicit a response frame that contains a Next TWT value. Examples of frames that (M118)solicit a Next TWT Info/Suspend Duration field include

— A TWT Information frame with the TWT Flow Identifier subfield equal to the TWT Flow Identifier corresponding to the TWT agreement for which a Next TWT value is requested and with the Next TWT Size subfield equal to 0, soliciting a STACK frame response.

— An A-MPDU containing a TWT Information frame with the TWT Flow Identifier subfield equal to the TWT Flow Identifier corresponding to the TWT agreement for which a Next TWT value is requested and with the Next TWT Size subfield set to 0, soliciting a BAT frame response.

— An S-MPDU containing a TWT Information frame with the TWT Flow Identifier subfield equal to the TWT Flow Identifier corresponding to the TWT agreement for which a Next TWT value is requested and with the Next TWT Size subfield equal to 0, soliciting a TACK frame response.

A TWT requesting STA that transmits a PPDU containing a TWT Information frame receives a response frame that can include a Next TWT field, as indicated above, and therefore, is not required to set the value of the Next TWT Request subfield to 1 to solicit the response of a TWT Information frame that includes a Next TWT field.

During an explicit TWT SP, a TWT responding STA that has transmitted a frame containing a Next TWT subfield equal to 0 shall queue for transmission at least one frame to the same recipient containing the nonzero Next TWT corresponding to the TWT Flow Identifier indicated in the frame with the Next TWT subfield equal to 0.

If a TWT requesting STA has transmitted a frame soliciting a response that contains a Next TWT value and the STA is in a Power Save mode, the STA shall remain in the awake state following the transmission until it receives a response from the TWT responding STA that contains a nonzero Next TWT value. The TWT responding STA shall assume that the TWT requesting STA is in the doze state if the TWT requesting STA is in a Power Save mode, the TWT SP has ended and the TWT responding STA has not received a frame from the TWT requesting STA that solicits a response that contains a nonzero Next TWT value. If a TWT responding STA receives a TWT Information frame from a TWT requesting STA with the Next TWT


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Request subfield equal to 1, then the TWT responding STA shall queue for transmission a TWT Information frame that contains a nonzero Next TWT value corresponding to the TWT Flow Identifier of the received TWT Information frame and shall assume that the TWT requesting STA is in the awake state until the TWT responding STA has transmitted the frame containing the nonzero Next TWT value.

A TWT responding STA may include a nonzero Next TWT value in any TACK frame or STACK frame or BAT frame that is transmitted as a response to a TWT requesting STA.

The TWT responding STA shall include the initial TWT SP start time for an explicit TWT agreement in the Target Wake Time field of the TWT element, which contains a value of Accept TWT in the TWT Setup Command field, a value of 0 in the Implicit bit and the TWT Flow Identifier value corresponding to that TWT agreement in the TWT Flow Identifier subfield.

### 10.46.4 Implicit TWT operation

The TWT values for an implicit TWT are periodic. A TWT requesting STA operating with an implicit TWT agreement shall determine the next TWT SP start time by adding the value of TWT Wake Interval associated with this TWT agreement to the value of the start time of the current TWT SP. A TWT requesting STA operating with an implicit TWT agreement with a TWT flow identifier that matches the TWT flow identifier of a received TWT Information frame from its TWT responding STA shall replace its next TWT SP start time value with the value from the Next TWT subfield of the TWT Information frame.

The TWT responding STA shall include the start time for a series of TWT SPs corresponding to a single TWT Flow Identifier of an Implicit TWT agreement in the Target Wake Time field of the TWT element which contains a value of Accept TWT in the TWT Setup Command field and the TWT Flow Identifier value corresponding to that TWT agreement in the TWT Flow Identifier subfield. The start time of the TWT SP series indicates the beginning time of the first TWT SP in the series. Subsequent TWT SPs start times are determined by adding the value of TWT Wake Interval to the current TWT SP start time.

A TWT requesting STA awake for an implicit TWT SP may transition to the doze state after a duration AdjustedMinimumTWTWakeDuration has elapsed from the TWT SP start time as identified by the TWT requesting STA or after receiving an EOSP field equal to 1 from the TWT responding STA, whichever occurs first.

A TWT responding STA that receives a frame from a TWT requesting STA with which it has established an implicit TWT agreement may respond to the STA with a frame that contains a Next TWT Info/Suspend Duration field (e.g., BAT frame, TACK frame, STACK frame). A TWT requesting STA that is awake for an implicit TWT SP and receives a frame with a Next TWT Info/Suspend Duration field from its TWT responding STA shall use the received Next TWT Info/Suspend Duration field value as the start of the next TWT, instead of the TWT value calculated by adding the value of TWT Wake Interval associated with the TWT SP to the current TWT. Subsequent TWT start times associated with the same TWT agreement are calculated based on the next TWT that was sent by the TWT responding STA.

### 10.46.5 TWT grouping

An AP may include an S1G STA as a member of a TWT group if the STA indicated TWT requester support and indicated support for TWT grouping in the S1G Capabilities Information field in the S1G Capabilities element in its (Re)Association Request frame and may signal TWT times to that STA using the TWT Group Assignment field of the TWT element.

An AP shall not include a non-S1G STA within a TWT group.

When dot11TWTGroupingSupport is true, the AP may assign a TWT group ID to a TWT requesting STA when the TWT Grouping Support subfield is equal to 1 within the S1G Capabilities element received from

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that STA. The AP indicates the TWT value to the TWT requesting STA that supports TWT grouping by transmitting to the STA an individually addressed frame containing a TWT element, which includes

- The value of the assigned group ID in the TWT Group ID subfield.
- The lower 48 bits of a TSF value in the Zero Offset of Group subfield to indicate the TWT value corresponding to the first member of the TWT group that is identified by the TWT group ID.
- A TWT unit value in the TWT Unit subfield (9.4.2.198 (TWT element)).
- A positive offset value indicated in the TWT Offset subfield (9.4.2.198 (TWT element)). The allowed values in the TWT Unit subfield are given in Table 9-349 (TWT Unit subfield encoding).

The intended recipient of the frame containing the TWT element calculates its TWT from the TWT Group Assignment field by multiplying the TWT Unit interpretation value with the value indicated in the TWT Offset subfield and adding the result to the value in the Zero Offset of Group field corresponding to the TWT Group ID subfield in the TWT Group Assignment field of the TWT element.

### 10.46.6 NDP paging setup

This subclause defines a protocol for power saving at a STA by using the TWT protocol to set up scheduled wakeup intervals and by defining efficient signaling for the presence of BUs and synchronization.

A frame including a TWT element with the NDP Paging field present is referred to as NDP paging request or NDP paging response as clarified later. A STA sending an NDP paging request is referred to as NDP paging requester. A STA sending an NDP paging response in a response to an NDP paging request is referred to as NDP paging responder.(#8182)

A STA requests an NDP Paging TWT by sending an NDP paging request. A non-S1G STA shall not transmit NDP Paging frames.(#8182)

The setup procedure follows the protocol described in 10.46.1 (TWT overview), unless otherwise described in this subclause.

A non-AP STA sending an NDP paging request shall set the P-ID field of the NDP paging request to one of the partial AIDs assigned to it by the intended receiver of the NDP paging request (see 10.21 (Group ID, partial AID, Uplink Indication, and COLOR in S1G PPDUs)). (#8182)

An AP sending an NDP paging request to a non-AP STA should set the P-ID field of the NDP paging request to the partial BSSID.(#8182)

(#1045)A SIFS after receiving an NDP paging request, the recipient STA shall respond with an NDP paging response with the NDP Paging fields set as follows:(#8182)

- The P-ID subfield should be set to the same value as the P-ID subfield of the NDP paging request.
- The Max NDP Paging Period subfield shall be set to any value that is less than or equal to the Max NDP Paging Period subfield of the NDP paging request.
- The Action subfield shall be set to one of the values in Table 9-350 (Action field).
- The Partial TSF Offset subfield and Min Sleep Duration subfield are reserved.

The NDP paging setup is successful if the TWT Setup Command subfield of the Request Type field in the NDP paging response is equal to 4 (Accept TWT), otherwise the setup is considered as failed.(#8182)

A STA that has sent an NDP paging response with the TWT Setup Command field equal to 4 (Accept TWT) shall schedule an NDP Paging frame as the first frame for transmission at the TWTs indicated by the NDP paging response, if any of the following conditions is satisfied:(#8182)


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- There are BUs for the requesting STA.
- No NDP Paging frame was sent in the *N* consecutive preceding TWT(s), where *N* is equal to the value of the Max NDP Paging Period subfield in the NDP paging response. (#8182)

Otherwise the STA shall not schedule an NDP Paging frame.(#7220)

The AP shall schedule an NDP Paging frame if there are critical updates to the S1G Beacon frame as defined in 10.45.2 (System information update procedure) and 11.2.3.14 (TIM Broadcast). An AP may additionally send an NDP Paging frame at any of the TWTs indicated by the NDP paging response.(#8182)

If the NDP Paging frame is sent by the AP to the NDP paging requester then this frame shall precede any frame that is sent by the AP to it during its indicated TWT SP and shall have the Direction field equal to 1.(#8182)

If any frame is sent by a non-AP STA to an NDP paging requester during its indicated TWT SP then the first frame sent shall be an NDP Paging frame with the Direction field equal to 0.(#8182)

(#7220)The P-ID field of an NDP Paging frame shall be set to the same value as the P-ID field in the NDP paging response.(#8182) The P-ID field shall be set to 0 to indicate the presence of group addressed BUs.

NOTE—When a group AID is assigned to (#1653)the corresponding group address as described in 10.54 (Group AID), then the P-ID field can be set to the partial AID that corresponds to the group AID as defined in 10.21 (Group ID, partial AID, Uplink Indication, and COLOR in S1G PPDUs).

If the Direction field of the NDP Paging frame is equal to 1, the subfields of the APDI field of the NDP Paging frame shall be set as follows:

- The PTSF subfield is set to TSF[Partial TSF Offset + 4 : Partial TSF Offset + 11], where TSF is the 8-octet value of the TSF timer and Partial TSF Offset is the value of the Partial TSF Offset field in the NDP paging request.(#8182)
- The Check Beacon Flag subfield shall be set to the LSB of the Change Sequence field in the most recently transmitted S1G Beacon frame or of the Check Beacon field in the most recently transmitted TIM frame, if any was sent before the NDP Paging frame.

If the Direction field of the NDP Paging frame is equal to 0, the Partial AID field of NDP Paging frame indicates the partial AID of the STA transmitting the NDP Paging frame.

If no NDP Paging frame is received during the TWT, the TWT requester STA may transition to doze state at the end of the Nominal Minimum TWT Wake Duration for the TWT. If an NDP Paging frame is received, the TWT requester STA may transition to doze state immediately after receiving the NDP Paging frame, unless Min Sleep Duration field was equal to 0 and Action subfield equal to 1 in the NDP paging response that successfully completed the NDP paging setup, in which case the STA shall be in active mode.(#8182)

Upon reception of an NDP Paging frame with the P-ID field matching the value of the P-ID field in the NDP paging response, the NDP paging requester shall behave as follows:(#8182)

- If the Action subfield of the NDP paging response is 0:
  - If the NDP paging requester is a non-AP STA, it shall send a (NDP) PS-Poll frame or uplink trigger frame addressed to the NDP paging responder, after either SIFS or using EDCA within Nominal Minimum TWT Wake Duration.
  - If the NDP paging requester is an AP, it shall send an NDP CTS frame to self with the duration field equal to 0 after either SIFS or using EDCA within Nominal Minimum TWT Wake Duration.
- If the Action subfield of the NDP paging response is 1, the STA shall be in the awake state starting at a time indicated by the Min Sleep Duration field after the end of reception of the NDP Paging frame,

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and it shall remain in the awake state until a frame is received from the NDP paging responder with the EOSP subfield equal to 1.

— If the Action subfield of the NDP paging response is 2, the STA shall be in the awake state at the first TBTT that occurs after a time indicated by the Min Sleep Duration field in the NDP paging response after the end of reception of the NDP Paging frame to receive the S1G Beacon frame.

— If the Action subfield of the NDP paging response is 3, the STA shall be in the awake state at the first DTIM (#8164)beacon that happens after a time indicated by the Min Sleep Duration field in the NDP paging response after the end of reception of the NDP Paging frame to receive the DTIM beacon(#3309).

— If the Action subfield of the NDP paging response is 4, the STA shall be in the awake state starting at a time T after the end of reception of the NDP Paging frame and it shall remain in the awake state until a frame is received from the NDP paging responder with the EOSP subfield equal to 1. The value of T is in units of SIFS and is equal to the value of the Min Sleep Duration field of the NDP paging request plus the value of the ASD subfield in the APDI field of the NDP Paging frame.

If the NDP paging requester is an AP, values 2–7 of the Action subfield are reserved.(#8182)

A non-AP STA that has set up NDP Paging and receives an NDP Paging frame with Direction field equal to 1 and the Check Beacon Flag subfield value different from the LSB of the most recently received Change Sequence value shall either be awake to receive the next S1G Beacon frame that is transmitted at a TBTT or TSBTT or shall queue for transmission a Probe Request frame to obtain the updated system information as described in 10.45.2 (System information update procedure).

### 10.46.7 TWT Sleep setup

A Responder PM Mode bit in the Control field of the TWT response equal to 1 indicates that the Responder STA may be in doze state outside the indicated TWT SP.

### 10.46.8 TWT teardown

Either STA that is a party to an established TWT agreement may delete the TWT agreement by successfully transmitting a TWT Teardown frame. The TWT Flow Identifier field of the TWT Teardown frame shall be set to the value of the TWT Flow Identifier field of the TWT element of the frame that successfully concluded the setup of the TWT agreement that is the subject of the teardown request.

When a TWT Teardown frame is successfully transmitted or received, the TWT agreement corresponding to the TWT Flow Identifier field, TWT requesting STA MAC address and TWT responding STA MAC address of the TWT Teardown frame shall be deleted.

### 10.46.9 TWT parameter ranges(11ax)

A STA that supports receiving two TWT elements in a TWT Setup frame sets the TWT Parameters Range Support field to 1 in the Extended Capabilities elements that it transmits.

A TWT requesting STA may send a TWT request that contains two TWT elements to a TWT responding STA if it has received an Extended Capabilities element from the TWT responding STA with the TWT Parameters Range Support field equal to 1. The TWT requesting STA shall either set the TWT Setup Command fields of the two TWT elements to Suggest TWT or set the TWT Setup Command fields of the two TWT elements to Demand TWT.

A TWT responding STA may send a TWT response that contains two TWT elements to a TWT requesting STA if it has received an Extended Capabilities element from the TWT requesting STA with the TWT Parameters Range Support field equal to 1. The TWT responding STA shall either set the TWT Setup


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Command fields of the two TWT elements to Alternate TWT or set the TWT Setup Command fields of the two TWT elements to Dictate TWT.

If a STA sends a TWT request or a TWT response with two TWT elements:

— It shall set the TWT Flow Identifier field or the Broadcast TWT ID field of the two TWT elements to the same value.

— For a TWT parameter of the proposed TWT agreement that is carried in the Target Wake Time field or Nominal Minimum TWT Wake Duration field, and for the TWT wake interval parameter, the STA may indicate either a single value or a range of values. For other TWT parameters, the STA shall indicate a single value. To indicate a single value for a parameter, the STA sets the value of that parameter to be the same in each TWT element. To indicate a range of values for a parameter, the STA sets the value of that parameter differently in each TWT element. The range indicated for a parameter is the range that starts with the lower value and includes all values up to the higher value, irrespective of their order in the TWT elements, except for the TWT Wake Interval Mantissa and the TWT Wake Interval Exponent fields. The range indicated for the TWT wake interval begins with the lower value of the two TWT wake interval values and ends with the higher value of the two TWT wake interval values, where the TWT wake interval is determined from the TWT Wake Interval Mantissa and TWT Wake Interval Exponent fields as specified in 9.4.2.198 (TWT element).

If a TWT requesting STA sent a TWT request that contains two TWT elements to a TWT responding STA, the TWT responding STA shall set each TWT parameter of the TWT response to a value selected from the range of values provided in the TWT request, if the TWT Setup Command field of the TWT response is Accept TWT and the parameter included a range in the corresponding TWT request.

If a TWT responding STA sent a TWT response that contains two TWT elements to a TWT requesting STA with a TWT Setup Command field value of Dictate TWT, that response implies that a TWT agreement is likely to be accepted only if the requesting STA transmits a new TWT request with the TWT parameters set to a value selected from the range of values provided in the TWT response. If a TWT responding STA sent a TWT response that contains two TWT elements to a TWT requesting STA with a TWT Setup Command field value of Alternate TWT, that response implies a counter-offer of TWT parameters by the TWT responding STA, which can be indicated in the form of a range of values (although alternative TWT parameters might be accepted as well).

## 10.47 Non-TIM operation

### 10.47.1 Resource protection for S1G STAs in non-TIM mode

#### 10.47.1.1 General

Resource protection for S1G STAs in non-TIM mode allows an AP to protect specific times for participating S1G STAs in non-TIM mode from medium access by S1G STAs in TIM mode. The objective of this procedure is to minimize contention between S1G STAs in non-TIM mode and S1G STAs in TIM mode and thus reduce power consumption of S1G STAs in non-TIM mode caused by medium contention with S1G STAs in TIM mode. For this purpose, an AP may set up RAW(s) for S1G STAs in non-TIM mode and then indicate to S1G STAs in TIM mode RAW information during which no S1G STA in TIM mode is allowed to contend. The RAW(s) are used for protecting either TWT(s) scheduled by the AP or specific interval(s) for S1G STAs in non-TIM mode.

When an AP schedules TWT(s) for S1G STAs in non-TIM mode, the AP may set up RAW(s) to protect the TWT(s) for S1G STAs in non-TIM mode. The AP may schedule more than one TWT for S1G STAs in non-TIM mode so that it can set up a RAW which covers the interval summing up the duration indicated by the corresponding Nominal Minimum TWT Wake Duration field assigned to each S1G STA in non-TIM mode in a sequence.

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An AP is a TWT-protection capable AP if it sets both dot11RAWOperationActivated and dot11TWTOptionActivated to true.

An S1G STA in non-TIM mode with dot11TWTOptionActivated equal to true may request for the TWT protection for a TWT-protection capable AP when it sets up a TWT agreement with the AP. In the TWT setup procedure specified in 10.46.1 (TWT overview), an S1G STA in non-TIM mode transmits a TWT element in a (Re)Association Request frame or a TWT Setup frame to the AP, and the S1G STA in non-TIM mode may request for a TWT protection by setting the TWT Protection subfield in the Request Type field of the TWT element (9.4.2.198 (TWT element)) to 1. If the protection is not required by the S1G STA in non-TIM mode, the TWT Protection subfield shall be set to 0.

When a TWT-protection capable AP receives a TWT element from an S1G STA in non-TIM mode with the TWT Protection subfield equal to 1 during the TWT setup procedure, it is recommended that the AP allocates RAW(s) to protect the TWT SPs corresponding to the particular TWT Flow Identifier.

When a TWT-protection capable AP receives a TWT element from an S1G STA in non-TIM mode during the TWT setup procedure and if the AP can guarantee to protect the scheduled TWT(s) for the S1G STA in non-TIM mode by allocating RAW(s), it shall set the TWT Protection subfield in the TWT element included in the (Re)Association Response frame or a TWT Setup frame that is transmitted to the STA during the TWT setup procedure to 1. If the AP cannot guarantee to protect the scheduled TWT(s) by allocating RAW(s), it shall set the TWT Protection subfield in the TWT response to 0.

After a TWT-protection capable AP has successfully completed the TWT setup as described in 10.46.1 (TWT overview) and if the AP has set the TWT Protection subfield in the TWT element to 1 during the TWT setup procedure with the STA, the AP shall set up RAW(s) that covers at least the duration indicated by the Nominal Minimum TWT Wake Duration field (9.4.2.198 (TWT element)) assigned to the S1G STA in non-TIM mode. If the AP has set the TWT Protection subfield to 0, the AP may set up RAW(s) that covers at least the duration indicated by the Nominal Minimum TWT Wake Duration field.

To protect contention for medium access for an S1G STA in non-TIM mode, an AP with dot11RAWOperationActivated equal to true may schedule TWTs within a RAW that is not assigned to any S1G STA in TIM mode. When the AP is polled by TWT STAs that were not scheduled during the RAW duration, the AP may reschedule their awake/doze cycle as described in 10.47.2 (Rescheduling of awake/ doze cycle).

The AP uses either generic RAW(s) or non-TIM RAW(s) for protecting S1G STAs in non-TIM mode:

— In a generic RAW, medium access is only allowed to a group of STAs indicated by the RAW Group field as specified in 10.23.5.4 (Slotted channel access procedure in RAW).

In a non-TIM RAW, the RAW Group field is not present and medium access is only allowed to S1G STAs in non-TIM mode that are scheduled within the duration calculated from the RAW Slot Definition field as specified in 10.23.5.1 (General).

#### 10.47.1.2 Resource protection for S1G STAs in non-TIM mode using periodic RAW (PRAW) operation

In resource protection for S1G STAs in non-TIM mode specified in 10.47.1 (Resource protection for S1G STAs in non-TIM mode), PRAW, which is specified in 10.23.5.8 (Periodic RAW (PRAW) operation) can be used to indicate to S1G STAs in TIM mode information related to periodically scheduled RAWs during which no S1G STAs in TIM mode are allowed to contend.

An example of a basic operation of a PRAW allocation is shown in Figure 10-140 (Example of PRAW operation). In this figure, PRAW is allocated at every short beacon interval, but the allocation of the PRAW


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is indicated at every DTIM beacon(#3309). STA1 is an S1G STA in TIM mode that is not included in the PRAW allocation and STA2 is an S1G STA in non-TIM mode for which the AP has scheduled TWT and is included in the PRAW allocation. When STA1 listens to the Beacon frame, it can identify the allowed user group, start time, duration, and the periodicity of the allocated PRAW. As STA1 is not included in the allowed user group of the PRAW, STA1 will not access the channel during the allocated PRAW, which is indicated in the S1G Beacon frame that is transmitted every short beacon interval. And, STA2 wakes up at its scheduled TWT, which is within the PRAW, and send its uplink data if it has a Data frame to send.

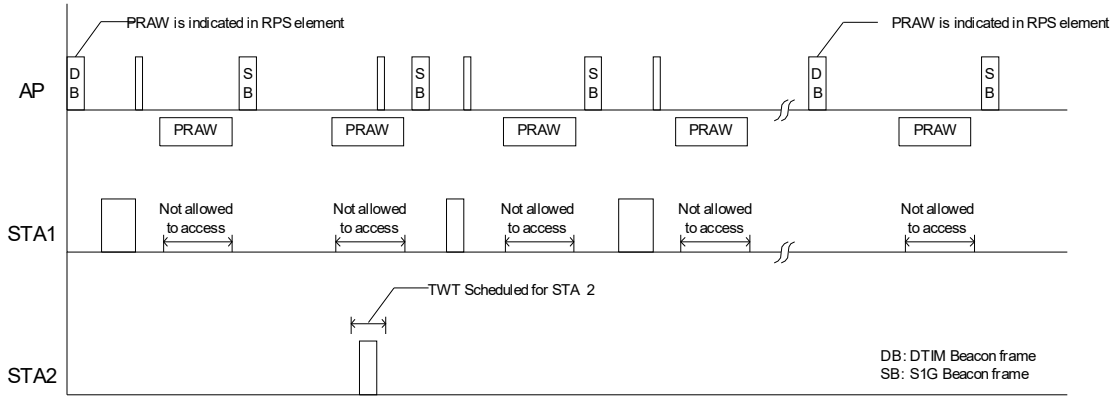


**Figure 10-140—Example of PRAW operation**

### 10.47.2 Rescheduling of awake/doze cycle

This subclause defines a procedure for the S1G AP to reschedule the awake/doze cycle of an S1G STA in Non-TIM Mode.

An S1G STA in non-TIM mode that transmits a PS-Poll frame may set the Poll Type subfield of the Frame Control field to

- 0 if it requests to the AP delivery of DL BUs but without a request for rescheduling of the awake/doze(#6038) cycle.
- 1 if it solicits information regarding the change sequence of the Beacon and the partial timestamp.
- 2 if it is not a TWT STA and requests to the AP delivery of the DL BUs and resynchronizing to the next TBTT.
- 2 if it is a TWT requester STA that transmits the frame to the TWT responder AP within the negotiated TWT SP to request delivery of DL BUs and information for the next TWT.
- 3 if it requests to the AP to reschedule its doze/wake cycle to another service period.

Upon receiving an NDP PS-Poll frame, trigger frame or PS-Poll frame with the Poll Type subfield equal to 0 sent by an S1G STA, the S1G AP responds as described in 11.2.3.6 (AP operation).

NOTE—The S1G STA can be an S1G STA in TIM mode or an S1G STA in non-TIM mode.

Upon receiving a PS-Poll frame with the Poll Type subfield not equal to 0 sent by an S1G STA in non-TIM mode, the AP responds with different frames depending on the value of the Poll Type subfield in the Frame Control field of the PS-Poll frame that elicited the response as follows:

- If the Poll Type subfield is equal to 1 then the AP with dot11PollTACKResponseImplemented equal to true shall respond with a TACK frame that does not contain the Next TWT Info/Suspend Duration field. An S1G STA shall not send a PS-Poll frame with the Poll Type subfield equal to 1 to an AP unless the TACK Support as PS-Poll Response field of the S1G Capabilities element received from that AP is equal to 1.

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- If the Poll Type subfield is equal to 2 and is sent by a TWT requester STA within the negotiated TWT SP then the AP responds with a TACK frame as described in 10.46 (Target wake time (TWT)). A TWT requester STA shall not send a PS-Poll frame with the Poll Type subfield equal to 2 to an AP unless the TWT Responder Support field of the S1G Capabilities element received from that AP is equal to 1.
- If the Poll Type subfield is equal to 2 and is either sent by a STA that is not a TWT requester STA or is sent by a TWT requester STA not within the negotiated TWT SP then the AP shall either respond with the DL BU or with an NDP Ack frame. The NDP Ack frame may include a wakeup timer value (i.e., its Idle Indication field is equal to 1), which expires at the next TBTT.
  - The AP may also respond with a control response frame that includes a Duration field that indicates a wakeup timer (i.e., an NDP Ack or NDP PS-Poll-Ack frame with Idle Indication field equal to 1) if it receives a trigger or NDP PS-Poll frame from an S1G STA in non-TIM mode, which satisfies the criteria above.
  - The S1G STA in non-TIM mode may resynchronize to the S1G Beacon frame with the help of the wakeup timer.
- If the Poll Type subfield is equal to 3, then the AP may respond with an NDP Ack frame that includes a wakeup timer as described in 11.2.3.6 (AP operation):
  - If the STA has requested time slot protection and the AP is UL-Sync capable, then the AP shall protect the TXOP duration following the expiration of the wakeup timer as described in 10.48 (Sync frame operation).
  - A UL-Sync capable AP may also respond with a control response frame that includes a Duration field that indicates a wakeup timer (i.e., an NDP Ack or NDP PS-Poll-Ack frame with Idle Indication field equal to 1) if it receives a trigger or NDP PS-Poll frame from an S1G STA in non-TIM mode that satisfies the criteria above.

The S1G AP shall set More Data field to 1 in the responding control frame if there is a BU buffered for the non-TIM S1G STA. If the non-TIM S1G STA receives a responding control frame in which the Idle Indication field is equal to 1 and the Duration field is a nonzero value, there is no frame transmission for the STA in the indicated duration in which the S1G STA may enter the doze state. After an amount of time that is equal to the value in the Duration field, it shall be in the awake state.

An S1G AP may set the wakeup timer (Duration field) as the duration to a TBTT in the responding control frame (either NDP Ack frame or NDP PS-Poll-Ack frame) and treat the S1G STA in non-TIM mode as an S1G STA in TIM mode starting from the TBTT if the bit corresponding to the S1G STA in non-TIM mode in the traffic indication virtual bitmap is equal to 1 and the STA has indicated support for temporary PS mode switch by setting the Temporary PS Mode Switch subfield to 1 in the S1G Capabilities element it transmitted to the AP. After the amount of time that is equal to the Duration field value in the responding control frame from the S1G AP, the non-TIM S1G STA shall transition to awake state(#6038) to receive a Beacon frame. Upon receiving the Beacon frame, the S1G STA in non-TIM mode infers from the TIM element indicating that there is BU for it that it is treated as an S1G STA in TIM mode and operates as an S1G STA in TIM mode from then on, setting dot11NonTIMModeActivated to false and switching to TIM mode (see 11.2.3.2 (Non-AP STA power management modes)). The S1G STA returns to the S1G STA in non-TIM mode operation mode by setting dot11NonTIMModeActivated to true if the S1G AP indicates that there is no more data buffered for the S1G STA and the S1G STA indicates to the S1G AP that there is no more data to transmit. The S1G AP treats the S1G STA as an S1G STA in non-TIM mode if the STA indicates that there is no more data to transmit and the S1G AP indicates that there is no more data buffered for the STA.

## 10.48 Sync frame operation

This subclause describes a sync frame transmission procedure for uplink traffic, which minimizes the time for medium synchronization for a STA that is changing from doze state to awake state in order to transmit.


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The sync frame is a frame that solicits a Data frame as an immediate response, if any is available, from the receiving STA.

(#1276)When performing the Sync frame operation described in this subclause(Ed1), if management frame protection is negotiated and both STAs set the Extended S1G Action Protection field in the RSNXE that they transmit to 1, the STAs shall:

— use individually addressed Protected Sync Control frames instead of Sync Control frames and
— discard any individually addressed Sync Control frames received from the peer STA, with which management frame protection is negotiated.

(#1276)STAs that exchange individually addressed Protected Sync Control frames shall follow the rules defined in 12.6.17 (Protection of robust Management frames.).

(#1276)When management frame protection is not negotiated or the Extended S1G Action Protection field in the RSNXE transmitted by either STA is(M118) 0, the STAs shall not use the Protected Sync Control frame.

If dot11S1GUplinkSyncOptionImplemented is true, an AP shall set the Uplink Sync Capable field in the S1G Capabilities element to 1. If dot11S1GUplinkSyncOptionImplemented is false, the AP shall set the Uplink Sync Capable field in the S1G Capabilities element to 0.

An AP is (#2318)a UL-Sync (Uplink Sync) capable AP if it sets the Uplink Sync Capable field to 1.

A STA may request (#2318)a UL-Sync capable AP to transmit a sync frame at the slot boundary of the STA in a RAW or at the target wake time of the STA.

A STA may request for a sync frame transmission to the UL-Sync capable AP either during association by sending a (Re)Association Request frame in which the Uplink Sync Capable field in the S1G Capabilities element is equal to 1 or at any time by sending a Sync Control frame (an Action frame of category S1G) in which the Uplink Sync Request field in the Sync Control field is equal to 1.

A STA may request the UL-Sync capable AP to stop the sync frame transmission at any time by sending a Sync Control frame in which the Uplink Sync Request field in the Sync Control field is equal to 0.

When a STA is requesting for a sync frame transmission, a STA may also request an AP to protect a RAW slot in a RAW defined in the Slot Duration field (9.4.2.190 (RPS element)) or a duration at a TWT defined in the Nominal Minimum TWT Wake Duration field (9.4.2.198 (TWT element)), or by setting the Time Slot Protection Request field in the Sync Control field to 1. A STA may also request an AP protection for a TXOP duration after the expiration of a wakeup timer as described in 10.47.2 (Rescheduling of awake/doze cycle). The time slot protection is not requested if the Time Slot Protection Request field is equal to 0. When an AP receives a Sync Control frame from a STA with the Time Slot Protection Request field equal to 1, the AP shall protect a time slot that is assigned for the STA in a RAW, or a duration that is assigned for the STA at a TWT, or a TXOP duration after the expiration of a wakeup timer of the STA with NAV-setting frame exchange sequences(#109). Note that NAV-setting frame exchange sequences(#109) refer to any frame that can set NAV to other third-party stations, and an AP has the flexibility to choose any NAV-setting frame exchange sequences(#109) for protection.

For a STA that requested for a sync frame transmission, the UL-Sync capable AP shall schedule a sync frame at the slot boundary of the STA in the RAW if the Time Slot Protection Request field is equal to 1 or the Cross Slot Boundary field is equal to 1, or at the TWT of the STA, or at the expiration of the wakeup timer, as the next frame for transmission according to the medium access rules specified in Clause 10 (MAC sublayer functional description).

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If the medium is busy at the slot boundary of a STA in the RAW or at the TWT of the STA, or at the expiration of the wakeup timer, or if the UL-Sync capable AP determines that the remaining time in the RAW slot or the TWT SP, or the TXOP duration to be too short to transmit a sync frame, the UL-Sync capable AP shall cancel the scheduled sync frame transmission. When the STA is changing from doze state to awake state in order to transmit, the STA shall follow the rules defined in 11.2.3.2 (Non-AP STA power management modes).

The UL-Sync capable AP should use an NDP CTS frame as a sync frame. The AP may (#468)use any NAV-setting frame as (#468)a sync frame provided that the frame solicits a Data frame as an immediate response from the receiving STA (e.g., a reverse direction grant).

When a STA receives an NDP CTS frame with the RA/Partial BSSID field equal to the S1G partial AID of the STA from the UL-Sync capable AP with which the STA is associated, the STA shall transmit a Data frame to the AP a SIFS after the reception of the NDP CTS frame if the STA has a Data frame to transmit to the AP and has requested the AP for a sync frame transmission. When a STA receives an NDP CTS frame with the RA/Partial BSSID field not equal to the S1G partial AID of the STA, the STA shall follow the NAV setting rules defined in 10.3.2.4 (Setting and resetting the NAV).

(#468)After transmitting the sync frame, the AP shall wait for an AckTimeout interval (as defined in 10.3.2.11 (Acknowledgment procedure)), starting at the PHY-TXEND.confirm primitive. If a (#3038)PHY-RXEARLYSIG.indication or PHY-RXSTART.indication primitive does not occur during the AckTimeout interval, the AP may transmit a CF-End frame or an NDP CF-End frame to reset the NAV provided that the remaining duration is long enough to transmit this frame.

For a STA requesting for a sync frame transmission with the Time Slot Protection Request field set to 0, the AP should not send a sync frame at each slot boundary within a RAW period if the Cross-Slot Boundary field is equal to 0.

Figure 10-141 (Example of uplink sync frame transmission procedure in RAW) illustrates an example of the uplink sync frame transmission procedure in a RAW. STA1 is allocated Slot1 in the RAW and STA2 is allocated Slot3 in the RAW. Both STA1 and STA2 have requested the UL-Sync capable AP to transmit a sync frame at the slot boundary. At the slot boundary of Slot1, the medium is idle and thus the AP transmits a sync frame at the slot boundary. However, at the slot boundary of Slot3, the medium is busy and thus the AP cancels the scheduled sync frame transmission for STA2.

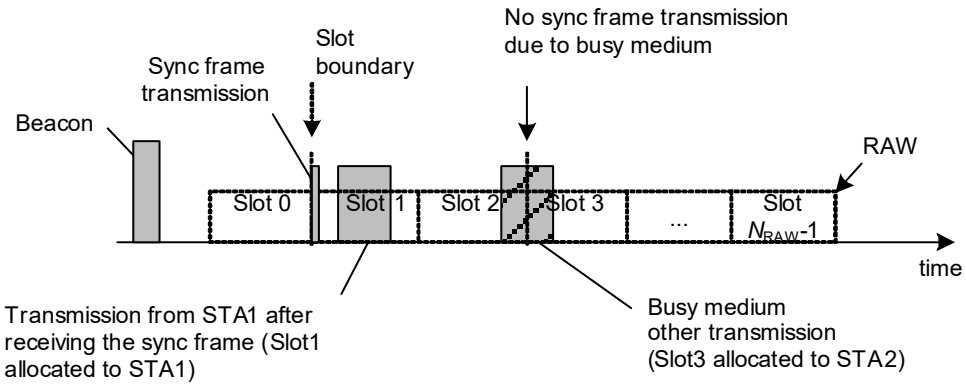


**Figure 10-141—Example of uplink sync frame transmission procedure in RAW**


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## 10.49 Bidirectional TXOP

### 10.49.1 Overview

Bidirectional TXOP (BDT) allows an S1G AP and (#306)a non-AP S1G STA to exchange a sequence of uplink and downlink PPDUs separated by SIFS. This operation combines both uplink and downlink channel access into a continuous frame exchange sequence between a pair of S1G STAs. S1G STAs that participate in BDT use information that is present in the Frame Control field, SIGNAL field and NDP CMAC PPDUs to signal an undergoing BDT as described in 10.49.2 (Rules for BDT). The objective of this operation is to minimize the number of contention-based channel accesses, improve channel efficiency by reducing the number of frame exchange sequences(#109), and reduce S1G STA power consumption by shortening (#435)awake state times.

An S1G STA with dot11BDTImplemented equal to true shall set the BDT Capable field in the S1G Capabilities element to 1. An S1G STA with dot11BDTImplemented equal to false shall set the BDT Capable field in the S1G Capabilities element to 0. An S1G STA shall not use the BDT procedure to transmit frames to another S1G STA whose BDT Capable field is equal to 0.

### 10.49.2 Rules for BDT

Throughout this subclause, an S1G STA signals a Response Indication of Long Response by setting the TXVECTOR parameter RESPONSE_INDICATION to Long Response for non-NDPs and by setting the Idle Indication field to 1 and the Duration field to 0 for NDP (PS-Poll-)Ack frames. The S1G STA signals a Response Indication of No Response by setting the TXVECTOR parameter RESPONSE_INDICATION to No Response for non-NDPs or by setting the Idle Indication field to 0 and the Duration field to 0 for NDP (PS-Poll-)Ack frames. The S1G STA signals a Response Indication of Normal Response by setting the TXVECTOR parameter RESPONSE_INDICATION to Normal Response for non-NDPs.

An S1G AP may initiate a BDT exchange with an NDP PS-Poll-Ack frame that is sent as a response to an NDP PS-Poll frame. (#306)A non-AP S1G STA shall not initiate a BDT exchange with a PS-Poll frame unless it is a PS-Poll+BDT frame with the More Data field equal to 1. A BDT exchange consists of one or more BDT sequences.

A BDT sequence comprises the following:

a) The transmission of one PPDU that is either an NDP PS-Poll-Ack frame or satisfies the following conditions:
   1) Contains a Response Indication of Long Response
   2) Follows the same rule as the initial frame for TXOP as defined in 10.23.2 (HCF contention based channel access (EDCA)) if the PPDU is the first frame sent by the BDT Initiator during this TXOP
   3) Contains a Duration/ID field that sets the NAV
   4) Contains no HT Control field with the RDG/More PPDU subfield equal to 1.

   An S1G STA that transmits this PPDU is known as a BDT Initiator.

b) The transmission of one or more PPDUs (BDT response burst) by the S1G STA addressed in the PPDUs transmitted by the BDT Initiator, separated by SIFS. Only the last (or only) PPDU of the BDT response burst may contain any MPDU requiring an immediate response. All the other PPDUs in the BDT response burst (if there are any) except the last one shall indicate “No Response” in the response indication field. The S1G STA that transmits the BDT response burst is known as the BDT Responder.

c) The transmission of one PPDU by the BDT Initiator containing an immediate response (the BDT Initiator final PPDU), if so required by the last PPDU of the BDT response burst.

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NOTE 1—A BDT Initiator can include multiple BDT sequences, separated by SIFS, within a single TXOP.

NOTE 2—A BDT sequence cannot be started with a PPDU that can not signal a Response Indication, e.g., an NDP PS-Poll frame.

NOTE 3—A BDT sequence can be started with a PS-Poll+BDT frame.

The total duration of the BDT Initiator PPDUs shall not exceed the TXOP limit as described in 10.23.2.9 (TXOP limits).(#3619) The BDT responder PPDU transmission(s) and any expected responses shall fit entirely within the remaining TXOP or SP duration, as indicated in the Duration/ID field of the latest MPDU transmitted by the BDT initiator. The PPDUs may carry Data frames of any TID. A BDT exchange is subject to TXOP duration limits for the current AC.

A BDT Responder sending a BDT response burst containing an immediate response to an eliciting PPDU that had the More Data field equal to 1 shall set the Response Indication to Long Response for the last PPDU in the BDT response burst.

A BDT Responder sending a BDT response burst containing an immediate response to an eliciting PPDU that had the More Data field equal to 0 shall not set the Response Indication of the last PPDU of the BDT response burst to Long Response.

A non-AP STA shall remain in the awake state until the end of the current TXOP when one of the following conditions is met:

— It is the intended receiver of a frame with More Data field equal to 1 that is sent by the AP.
— It is a BDT Initiator of a BDT sequence within a single TXOP.

A non-AP STA may transition to the doze state if it is the intended receiver of a frame with More Data field equal to 0, which is sent by the AP.

Upon receiving a PS-Poll+BDT frame with the More Data field equal to 0, (#111)in order to respond with immediate Data frames an S1G AP may use the RTS/CTS scheme to send buffered data until it transmits a frame with the More Data field equal to 0 or until the duration of the exchange, including the initial PS-Poll+BDT frame reaches the TXOP limit whichever comes first.

Figure 10-142 (Example of BDT frame exchange exchange(#109)) illustrates an example of BDT signaling. STA A initiates the BDT exchange by setting the Response Indication to Long Response in the PS-Poll+BDT frame and in the preamble of two PV0 PPDUs to allow STA B to transmit its BUs. At the end,


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STA B sends a PPDU with the Response Indication 2 (Normal Response) and STA A (M118)terminates the BDT exchange by sending a PPDU with the Response Indication equal to 0 (No response).

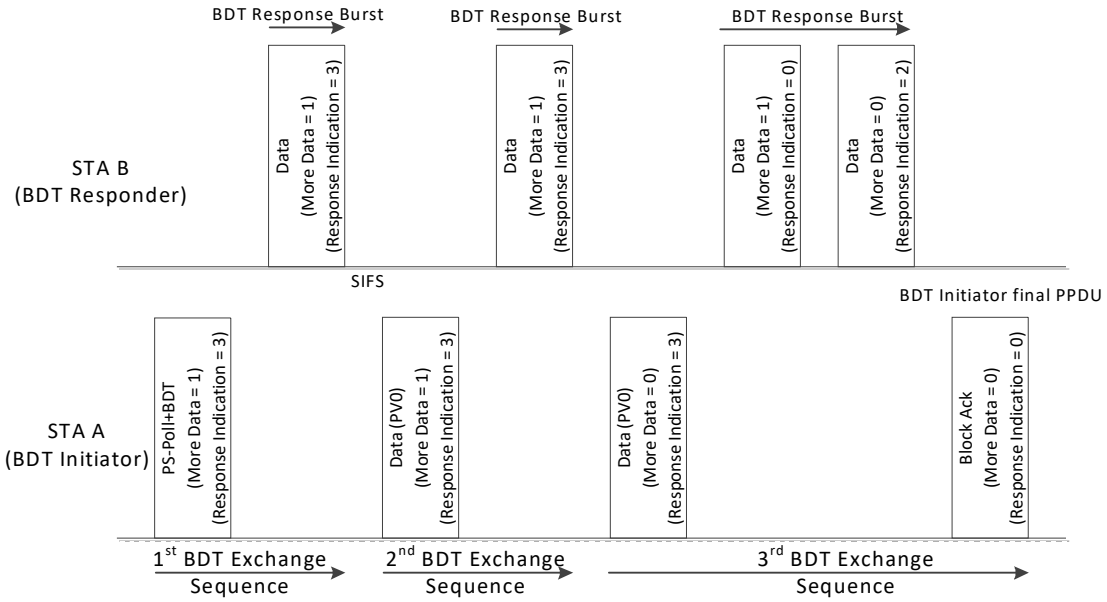


**Figure 10-142—Example of BDT frame exchange exchange(#109)**

NOTE 4—For error recovery, a BDT initiator can transmit the next frame when the CS mechanism (see 10.3.2.1 (CS mechanism)) indicates that medium is idle at TxPIFS slot boundary (defined in 10.3.7 (DCF timing relations)).

## 10.50 Page slicing

An S1G STA with dot11PageSlicingImplemented equal to true shall set the Page Slicing Support field in the S1G Capabilities element to 1. An S1G STA with dot11PageSlicingImplemented equal to false shall set the Page Slicing Support field in the S1G Capabilities element to 0.

If an S1G STA supports the page slicing mechanism as defined in this subclause, then it shall set dot11PageSlicingImplemented to true. Otherwise, an S1G STA that does not support the page slicing mechanism or a non-S1G STA shall set dot11PageSlicingImplemented to false.

The TIM element indicates downlink buffered data for all STAs in the BSS. However, in an S1G BSS with a large number of associated STAs corresponding to a single TIM and page, a single TIM element indicating the downlink buffered data for all STAs in the page can be quite large. To reduce the size of the element needed to communicate buffered data status to power save S1G STAs, an S1G AP may send one portion of a page in the TIM element virtual bitmap of each Beacon frame if dot11PageSlicingActivated is true as described in this subclause.

The traffic-indication virtual bitmap in a TIM includes a subset of the blocks from a single page. This subset of blocks is called a page slice and the size of the subset is indicated in the Page Slice Length subfield of the Page Slice element (9.4.2.191 (Page Slice element)). The case of 4 TIMs and their 4 assigned page slices

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is depicted in Figure 10-143 (Page slicing with Page Slice element with 4 TIMs(#3309)). All page slices corresponding to a single Page Slice element shall have equal size except for the last page slice.

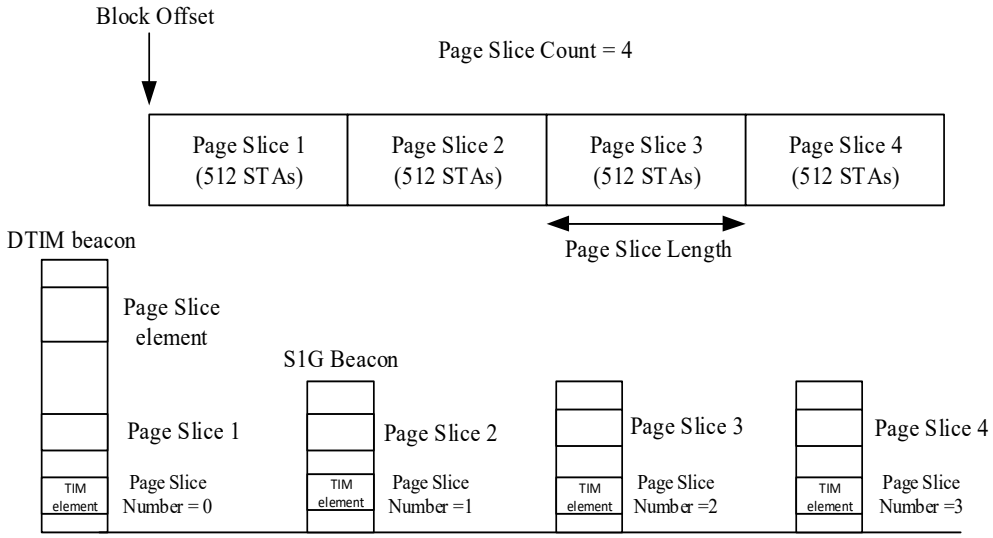


**Figure 10-143—Page slicing with Page Slice element with 4 TIMs(#3309)**

(#6033)If a TIM element contains a Bitmap Control field, an S1G STA shall examine the Traffic Indicator field, irrespective of the Page Slice Number and Page Index fields.

An S1G STA for which dot11PageSlicingImplemented is true shall process all received TIM elements that include a Page Slice Number field that matches its page slice number and a Page Index field that matches its page index,(#4219) and it shall follow the rules of 11.2.3.7 (Receive operation for STAs in PS mode) if the partial virtual bitmap of any of the processed TIM elements included the value of 1 in the position corresponding to any of its AIDs.

An AP that has dot11PageSlicingActivated equal to true shall not include the bit in the partial virtual bitmap that corresponds to the AID of the S1G STA with dot11PageSlicingImplemented equal to false within a TIM element that has a value for the Page Slice Number field that is in the range(#3482) 0 to 30. An AP that has dot11PageSlicingActivated equal to false shall not transmit a TIM element that has a value for the Page Slice Number field that is in the range(#3482) 0 to 30.

If an AP meets the following conditions:

— Its dot11PageSlicingActivated is true.

— Has at least one associated non-AP STA from which it has received an S1G Capabilities element with the Page Slicing Support field equal to 0 within a page.

then the AP shall

— Include in all the S1G Beacons a TIM element with Page Index subfield equal to the corresponding page index and Page Slice Number field equal to 31, if there is buffered traffic for at least one of the STA(s).

— Set the bits in the virtual bitmap of that TIM for those STAs, according to the rules described in 11.2.3.6 (AP operation).

An AP with dot11PageSlicingActivated equal to true and that has at least one associated STA with dot11PageSlicingActivated equal to true and whose AID is contained in


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- The final block (32nd block) of a page, and has indicated a Page Slice Count equal to 0 and a (#6034)Page Slice Length field greater than 1 in the Page Slice Control field of the Page Slice element shall include in the last S1G Beacon frame that precedes the next scheduled DTIM beacon(#3309), a TIM element with Page Index subfield equal to the page index specified in the previously transmitted Page Slice element. The TIM element shall have the Page Slice Number field(#4219) equal to 31 for the indicated page, if there is buffered traffic for at least one of the STA(s) that support page slicing and belong in the final block of the page.
- Any block of a page, and has indicated a Page Slice Count equal to 0 and a (#6034)Page Slice Length field equal to 1 in the Page Slice Control field of the Page Slice element shall include in the only S1G Beacon frame that precedes the next scheduled DTIM beacon(#3309), a TIM element with Page Index subfield equal to the page index specified in the previously transmitted Page Slice element. The TIM element shall have the Page Slice Number field(#4219) equal to 31 for the indicated page, if there is buffered traffic for at least one of the STA(s) that support page slicing and belong in any block of the page.

The setting of the bits in the virtual bitmap of that TIM for STAs that do not support page slicing follows the rules described in 11.2.3.6 (AP operation).

For each page from which an AP with a value of false for dot11PageSlicingActivated has assigned at least one AID corresponding to STA(s) for which there is buffered traffic, the AP shall include in all the S1G Beacons a TIM element for that page with Page Slice Number field(#4219) equal to 31 and shall set the bits in the virtual bitmap of that TIM for all the STAs indicated by the Page Index subfield, according to the rules described in 11.2.3.6 (AP operation).

An AP with dot11PageSlicingActiviated equal to true may include more than one TIM representing different page slices within a Beacon frame. An AP with dot11PageSlicingActiviated equal to true shall not transmit a Page Slice element in any frame other than a Beacon frame that has DTIM count equal to 0. Each page slice corresponding to a TIM, except the last TIM, shall have a size that is equal to the Page Slice Length subfield indicated in the Page Slice element. However, (#7182)the length of the page slice may vary over multiple page periods. (#7180)(#6032)The page period is the number of beacon intervals between successive beacons that carry the Page Slice element for the associated page. Transmission of page slices of a page can span multiple DTIM periods. The AP shall transmit the first page slice in the N-th Beacon frame after the DTIM (#8164)beacon in which the Page Slice element appears, where N is equal to the TIM offset subfield. Subsequent page slices indicated in the Page Slice element appear sequentially in the following (#8164)beacons, e.g., the second slice appears in (N+1)th Beacon frame after the DTIM (#8164)beacon that contained the Page Slice element. A value of zero for TIM offset corresponds to the DTIM beacon(#3309). The TIMs can be flexibly scheduled for page slices of different pages over beacon intervals. Figure 10-143 (Page slicing with Page Slice element with 4 TIMs(#3309)) is an illustration with 4 page slices, which appear in the DTIM beacon(#3309) and the three following Beacons when the TIM Offset subfield of the Page Slice element is equal to 0.

(#6032)The page period is the number of beacon intervals between successive beacons that carry the Page Slice element for the associated page. Transmission of page slices of a page can span multiple DTIM periods.

The Page slice element indicates assignment of STAs in page slices corresponding to their assigned TIMs. STAs within the assigned page slice transition to awake state(#6038) at a corresponding TIM sequentially to receive buffered data from AP. In order to transition to awake state(#6038) at the appropriate TBTT to receive the Page Slice element, a STA may compute the page slice assignment to the TIMs using the length of the Page Bitmap field and the value in the Page Slice Length and Page Slice Count subfields of the Page Slice element. The length of the page slice that appears in each TIM, except for the last TIM identified by a Page Slice element, is indicated in the Page Slice Length subfield. The last TIM includes the blocks indicated by the bits of the Page Bitmap field that have not appeared in previous TIMs.

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An S1G STA with dot11PageSlicingActivated equal to true wakes up to receive a DTIM beacon(#3309) that contains the Page Slice element for its associated page slice from the AP. The STAs check the DTIM beacon(#4221) comprising of the Page Bitmap field and the Block Bitmap fields in (#8164)the Page Slice element and TIM, respectively. The Page Bitmap field in the Page Slice element provides an early indication of buffered data for all blocks in the assigned page slices. If a bit in the Page Bitmap field of the Page Slice element is equal to 0, it indicates that there is no buffered data for STAs with AIDs located in the block corresponding to that bit. These STAs may return to doze state immediately when there is no buffered group addressed data or after receiving buffered broadcast/group data as indicated in the DTIM (#8164)beacon. If the block bit in the Page Bitmap field is equal to 1, then it indicates that there is buffered data at the AP for at least one of the STAs with AIDs in that block.

For STAs that have their AIDs that correspond to a block for which the bit in the Page Bitmap field of the Page Slice element is equal to 1, they compute the length of the page slice and the corresponding TIM to transition to awake state(#6038). If they are not assigned in page slice 1 that is allocated to DTIM slice, then these STAs may return to doze state immediately or after receiving buffered broadcast/group data as indicated in the DTIM (#8164)beacon till their scheduled TIM.

At the assigned page slice, the STAs decode the page slice in order to determine whether there is buffered data available at the AP.

When dot11PageSlicingActivated is true, an S1G AP may use the Listen Interval field and Page Slice element information in determining the lifetime of frames that it buffers for an S1G STA in TIM mode that supports page slicing.

## 10.51 Subchannel selective transmission (SST)

### 10.51.1 SST overview

S1G STAs that are associated with an S1G AP transmit and receive on the channel or channels that are indicated by the AP as the enabled operating channels for the BSS.

An SST BSS is an S1G BSS for which the following conditions are satisfied:

a) The BSS operating channel width indicated in the Channel Width field of the S1G Operation Information element transmitted by the AP is less than or equal to 2 MHz.

b) The SST AP indicates that it enables SST operation by including the SST Operation element in the (Re)Association Response frame sent to the non-AP STA.

In an S1G BSS that is not an SST BSS, the enabled operating channels are indicated in the most recently received S1G Operation element transmitted by the AP. In an S1G SST BSS, the enabled operating channels are indicated in the most recently received SST Operation element transmitted by the AP.

An SST AP is an S1G AP with dot11SelectiveSubchannelTransmissionPermitted equal to true. During aperiodic SST operation, an SST AP indicates the set of enabled SST operating channels in an SST Operation element. During aperiodic SST operation, an SST AP indicates the subset of SST channels that SST STAs are allowed to access during a beacon interval or short beacon interval (see 11.1.3.10.2 (Generation of S1G Beacon frames)) in the SST element that is transmitted in the S1G Beacon frame that initiates that interval and/or in the Channel Indication subfield of RPS elements that include SST STAs in the RAW group. During periodic SST operation, an SST AP indicates the set of enabled SST operating channels in an SST Operation element and indicates the subset of SST channels that SST STAs are allowed to access during a beacon interval or short beacon interval in an RPS element with the Periodic RAW Indication subfield equal to 1.


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An SST STA is an S1G STA that is associated with an SST AP and chooses a subset of the operating channels enabled for SST operation on which to operate in the BSS, when SST operating channels are activated by the AP as indicated in the SST element, the SST operation element, or the RPS element.

SST STAs operating in an SST BSS are allowed to transmit on an SST channel during a beacon interval or short beacon interval only if the channel is permitted for SST use as indicated by the SST AP in an SST element included in the S1G Beacon frame that initiates that interval or as indicated by an RPS element in the case of periodic SST operation.

### 10.51.2 Aperiodic SST operation

An SST AP that sets up an SST BSS shall include the SST Operation element in (Re)Association Response frames sent during association. An S1G AP may include the SST Operation element in S1G Beacon frames. The SST AP indicates the set of enabled SST operating channels, the offset of the primary channel, and the channel width unit in the SST Operation element as described in 9.4.2.213 (SST Operation element). The set of enabled SST operating channels may include channels that are not in use by the BSS as specified by the SST Enabled Channel bitmap of the element. The SST AP that sets up an SST BSS shall choose the subset of allowed SST operating channels from the subset of enabled SST operating channels indicated in the SST Operation element. The set of enabled SST operating channels indicated by the AP is not static. The S1G AP may include the RPS element in S1G Beacon frames to signal additional channels allowed for SST operation within specific RAWs. The channels that are allowed for SST operation in the RPS element can be different from the channels allowed for SST operation in the SST element.

At each TBTT or TSBTT, an SST AP may send S1G Beacon frames on more than one channel from the set of enabled operating channels for the BSS either in parallel or in series or a combination of the two. A STA transmitting parallel S1G Beacons shall use either the value S1G_DUP_1M or the value S1G_DUP_2M for the TXVECTOR parameter FORMAT of the PHY-TXSTART.request primitive for the transmission. An example of Beacons sent in parallel is when one Beacon frame is transmitted with a value of S1G_DUP_2M for the TXVECTOR parameter FORMAT and a value of CBW8 for the TXVECTOR parameter CH_ BANDWIDTH in a BSS with an operating width of 8 MHz. An example of Beacons sent in series is when several different Beacons are transmitted in sequence, each with a value of S1G for the TXVECTOR parameter FORMAT and a value of CBW2 for the TXVECTOR parameter CH_ BANDWIDTH and each transmitted on a different 2 MHz subchannel in a BSS with an 8 MHz operating width. When beacons are transmitted in series, all of the beacons may be queued for transmission at TBTT or TSBTT, but only one Beacon frame is transmitted at a time. SIFS or later after any Beacon frame in the series is transmitted, another Beacon frame may be transmitted in the series, provided that normal medium access rules for the channel of transmission of the Beacon frame have been satisfied.

NOTE—When a series of S1G Beacon frames is transmitted, the AP can use the channel activity schedule of the SST element in those beacons to describe when UL transmissions are permitted by SST STAs in order to protect the beacon sequence and to avoid attempts to communicate with the AP during the beacon transmission sequence. RAW, CTS-to-self and other NAV-setting mechanisms can also be employed for this purpose.

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An SST AP shall include an SST element in the S1G Beacon frame that immediately precedes a beacon interval or short beacon interval when it allows SST operation within that interval (see Figure 10-144 (Selective Subchannel Transmission channel transmission permission allocation for SST element)).

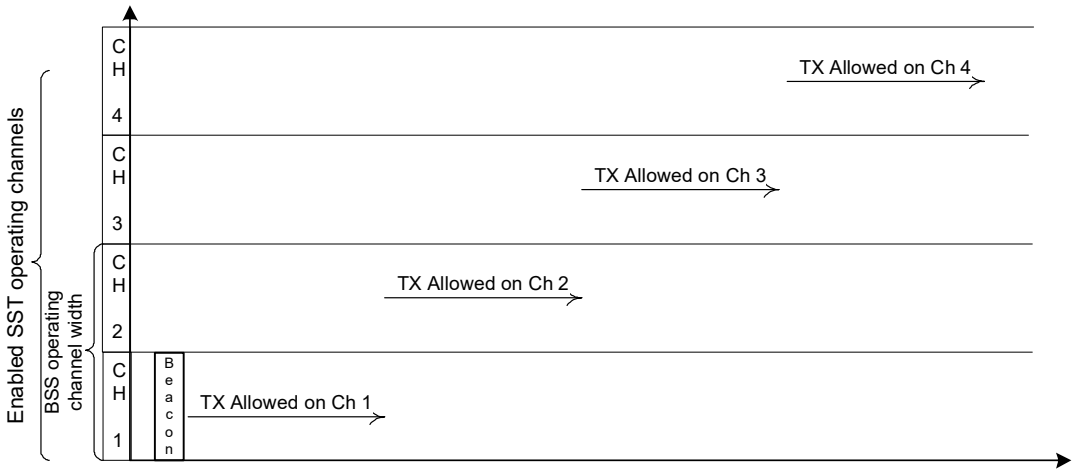


**Figure 10-144—Selective Subchannel Transmission channel transmission permission allocation for SST element**

An SST AP may include an SST element in transmitted S1G Beacon frames. An SST AP includes an SST element with the DL Activity bit in the SST element set to 1 and estimated start times and SST channels for DL transmissions in the Channel Activity Schedule field to indicate the expected times for the transmission of DL frames. These frames can be used by SST STAs to estimate the channel parameters which can be used as input to an algorithm for the selection of an SST channel.

The AP may transmit sounding frames to SST STAs for the purpose of estimating channel parameters. The AP may transmit sounding frames for SST STA channel estimation either in parallel or in series or a combination of the two, where a parallel transmission by an S1G AP shall use either the value S1G_DUP_1M or the value S1G_DUP_2M for the TXVECTOR parameter FORMAT of the PHY-TXSTART.request primitive for the transmission.

An S1G AP may include an SST element (see 9.4.2.200 (SST element(#1776))) in an S1G Beacon frame to indicate on which channels an SST STA is allowed to transmit within the BSS or SST BSS.

An S1G AP may indicate on which SST channels it intends to transmit sounding and nonsounding frames following the transmission of an S1G Beacon frame by including an SST element in the S1G Beacon frame with a nonzero value in at least one bit of the Channel Activity Bitmap subfield and a value of 1 in the corresponding DL Activity subfield. An SST STA may choose an SST channel for transmissions based on its analysis of the sounding signals and received transmissions.

In an SST BSS, an SST STA shall not transmit in a channel that is not the primary channel of the BSS if the corresponding bit of the Channel Activity Bitmap is 0 in the most recently received SST element or RPS element from its associated AP. An SST STA shall not transmit using a channel width that is greater than the value of the SST Channel Unit indicated in the most recently received SST Operation element from its associated AP.

When no SST Operation element has been received by an SST STA from its associated AP, the STA shall not transmit a frame with a BSSID that is equal to the BSSID of the BSS of which the STA is a member, in a channel of operation that is not included in the channels of operation of the BSS.


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If the frames that are transmitted by an S1G AP in response to an announcement of transmission activity within an SST element are sounding frames, the S1G AP shall use the same value for the TXPWR_LEVEL parameter of the TXVECTOR for each of the sounding frame transmissions associated with the SST element announcement. An S1G AP should transmit SST sounding frames at times and on SST channels indicated for downlink activity in the Activity Start Time and Channel Activity Bitmap fields of the SST elements that it transmits.

The AP may signal the presence of a RAW for the purpose of SST sounding for a group of STAs using an SST sounding RAW as indicated within a transmitted RPS element. Such an SST sounding RAW may be scheduled for periodic or nonperiodic operation. Additional RAW(s) may be scheduled as SST report RAW(s) (see 9.4.2.190 (RPS element)) after the SST sounding RAW for the transmission of NDP CMAC PPDUs (e.g., NDP PS-Poll frame) by SST STAs on their selected channel(s) for the purpose of communicating a selected subchannel to the AP. The AP is not required to use a RAW for SST sounding.

In an SST report RAW, the STA transmits a report frame to the AP not earlier than the start of its assigned RAW slot, followed by the AP's response for confirmation after a SIFS(#6587).

When the AP uses a RAW for SST sounding, the RAW Type subfield is equal to sounding RAW, and the RAW Type Options subfield is equal to SST sounding RAW in the RPS element (see 9.4.2.190 (RPS element)) transmitted by the AP. The SST sounding sequence within the SST sounding RAW comprises a series of NDP CMAC PPDUs (e.g., NDP CTS frames), each transmitted on one of the channels among those indicated by the Channel Indication field of the RAW, starting with the lowest frequency channel and continuing in sequence with the next higher frequency channel if more than one channel is indicated. The RPS element for the SST sounding RAW specifies a start time, channel(s) and RAW duration for each RAW assignment. The AP shall not transmit any NDP CMAC PPDU on a channel within an SST sounding RAW before the TxPIFS slot boundary as defined in 10.3.7 (DCF timing relations). If the AP does not observe an idle medium condition within one PIFS after switching to a channel, then the AP shall not transmit an NDP, but shall wait for the duration of an NDP before switching to the next channel. This deterministic channel switching allows listening SST STAs to predict the timing of the sounding transmission for each channel. An AP may schedule multiple SST sounding RAWs to increase the probability that a sounding frame is transmitted on each SST channel. The amount of time allocated in the sounding RAW for the channel switch operations performed by the AP is implementation dependent, and is calculated at the non-AP STA by subtracting the value $N \times$ (PIFS + NDPTxTime) from the total RAW duration and dividing the result by $N$-1, where $N$ is the number of channels to be sounded.

When the AP uses a RAW for SST operation and the RAW is not a sounding RAW, then the RAW Type is generic RAW and the Channel Indication Presence bit is set to 1 and the number of channels indicated in the Channel Indication in the RPS element (see 9.4.2.190 (RPS element)) transmitted by the AP shall be one, unless there is only one STA assigned to each slot in the RAW defined by the RPS element. An AP shall not schedule any non-SST STA within a RAW that has a Channel Indication Presence bit equal to 1.

A local S1G Beacon frame is one that was transmitted by the AP with which a STA is associated.

An SST STA may select one or more SST channels from the enabled SST operating channels as indicated in the SST Operation element transmitted by the SST AP with which it is associated. The SST STA may operate on those SST channels for the beacon interval or short beacon interval following a TBTT or TSBTT if a local S1G Beacon frame with an SST element indicating that a subset of the enabled SST channel(s) are allowed for SST operation has been received by the SST STA during that interval. The STA shall not transmit frames on the indicated allowed SST channels with a bandwidth that is wider than the Maximum Transmission Width specified in the SST element. If no local S1G Beacon frame is received following a TBTT or TSBTT, then no SST STA transmission is allowed during the beacon interval or short beacon interval that begins at that TBTT or TSBTT except on the primary channel of the BSS. If an SST STA receives a local S1G Beacon frame which contains no SST element, the SST STA may transmit on the primary channel of the BSS a PPDU of width up to the BSS bandwidth indicated in the S1G Beacon frame

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during the beacon interval or short beacon interval that immediately follows the reception of the S1G Beacon frame.

An SST STA that has selected an SST operating channel that is not the primary channel for the BSS shall operate on the selected channel as though the channel is the primary channel of the BSS, but only at the times allowed for operation on the selected channel as indicated in this subclause.

An SST STA that selected its best SST operating channel(s) may report its selection to the SST AP by sending an NDP PS-Poll frame on the primary channel of the BSS, including the selected SST channel offset in the UDI field. The transmission of any frame on an allowed subchannel by an SST STA is an implicit indication to the AP as to the subchannel selection made by the SST STA. An SST STA may queue for transmission, a QoS Null(#174) frame addressed to the AP for this purpose. To avoid ambiguity in which subchannel has been selected by the STA as its primary channel, the STA can send the frame using the minimum width channel for the band of operation on the selected primary channel.

An SST STA that has selected a subchannel for operation should operate on that subchannel during times indicated for permitted downlink and uplink operation according to the DL Activity and UL Activity fields and the Activity Start Time field in the SST element. An AP should transmit frames to the SST STA on their selected subchannels.

An SST STA shall not transmit to the AP on an SST operating channel that is not indicated as allowed by the AP in the SST element. The set of allowed SST channels indicated by the AP in the SST element is dynamic and can change every beacon interval or short beacon interval.

An SST AP shall not be away from the primary channel of the BSS for a duration of time that exceeds the value of the dot11MaxAwayDuration during a beacon interval or short beacon interval, as defined in 11.2.3.17 (AP power management).

### 10.51.3 Periodic SST operation

During aperiodic SST operation, an SST AP signals explicit permission of SST STA transmissions during each single beacon interval or short beacon interval in which SST operation is activated by transmitting the SST element. During periodic SST operation, an SST AP signals permission of SST STA transmissions over multiple beacon intervals or short beacon intervals through the transmission of the RPS element with the Channel Indication Presence bit equal to 1 and the Periodic RAW Indication bit equal to 1.

Periodic SST operation shall follow the procedure in 10.51.2 (Aperiodic SST operation) with the additional requirement that the SST AP shall transmit at least one RPS element with the Channel Indication Presence bit set to 1 and the Periodic RAW Indication bit set to 1 preceding the first beacon interval or short beacon interval during which SST operation is permitted and no SST element shall be transmitted. The periodicity, validity, and start offset of the periodic SST operation are indicated in the Periodic Operation Parameters subfield of the RAW Assignment subfield of RPS element. When the RPS element is used to indicate a periodic SST sounding schedule, the RAW Type subfield of the RPS element is set to sounding RAW and the RAW Type Options subfield of the RPS element is set to SST sounding RAW.

## 10.52 Sectorized beam operation

### 10.52.1 Introduction

The partition of the coverage area of a BSS into sectors, each containing a subset of STAs, is called sectorization. This partitioning is generally achieved by the AP transmitting or receiving through a set of antennas or a set of synthesized antenna beams to cover different sectors of the BSS. The goal of the sectorization is to reduce medium contention or interference by the reduced number of STAs within a sector.


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AP shall cover all STAs associated to it with at least one sector or an omnidirectional beam. STAs are allowed to move from one sector to another sector. The entire BSS is assumed to be covered by the omnidirectional beam or the omnidirectional antenna of the AP.

### 10.52.2 Sector Capabilities Exchange

After the sectorized beam-capable non-AP STA is associated with a sectorized beam-capable AP, the AP can transmit through its sectorized beam to the non-AP STA.

If dot11S1GSectorImplemented is true, a non-AP STA shall set the Sectorized Beam-Capable field in the S1G Capabilities element it transmits to 1. The sectorized beam-capable non-AP STA shall support both group sectorization and TXOP-based sectorization operations.

If dot11S1GSectorImplemented is true, an AP shall set the Sectorized Beam-Capable field in the S1G Capabilities element it transmits as follows:

— 1 if the AP supports only TXOP-based sectorization
— 2 if the AP supports only group sectorization
— 3 if the AP supports both TXOP-based sectorization and group sectorization

A STA with dot11S1GSectorImplemented equal to false shall set the Sectorized Beam-Capable field in the S1G Capabilities element to 0.

If dot11S1GSectorTrainingOperationImplemented is true, a STA shall set the Sector Training Operation Support field in the S1G Capabilities element to 1 in the Association Request frame. If dot11S1GSectorTrainingOperationImplemented is false, the STA shall set the Sector Training Operation Support field in the S1G Capabilities element to 0. If dot11S1GSectorTrainingOperationImplemented is true, dot11HTControlFieldSupported is true.

When the AP sets the Sectorized Beam-Capable field to 3 in the S1G Capabilities element it transmits then group sectorization and TXOP-based sectorization may optionally be used at the same time if

— The AP intends to apply TXOP-based sectorization during the omnidirectional beacon interval or the sectorized beacon interval to STAs with the corresponding Sector ID.
— The AP or non-AP STA, intending to apply TXOP-based sectorization during the omnidirectional beacon interval or the sectorized beacon interval, follows the rule according to which a non-AP STA is not allowed to transmit in certain beacon intervals as described in 10.52.3 (Group sectorization operation).

After the exchange of the S1G Capabilities element during the Association, a sectorized beam-capable AP supporting group sectorization operation shall transmit an S1G Sector Operation element with the Sectorization Type field equal to 0 to advertise the period of the current sector, omnidirectional or sectorized beam, the current sector ID, the allowable group IDs, and the duration of the current sector in the Beacon frame to start a beacon interval. A sectorized beam-capable AP supporting TXOP-based sectorization operation may transmit an S1G Sector Operation element with the Sectorization Type field set to 1 to advertise if periodic sector training is on or off, its training period, and the remaining beacon intervals to the next periodic training in the S1G Sector Operation element in a Beacon frame.

A sectorized beam-capable AP may (re)assign a specific Sector ID to a sectorized beam-capable STA after the Association. A sectorized beam-capable STA may optionally send Sector ID feedback to its associated sectorized beam-capable AP. A sectorized beam-capable STA may optionally request sector training from its associated sectorized beam-capable AP. A sectorized beam-capable AP has at least two sectors.

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A STA (#1414)that is not sectorized beam-capable may skip the S1G Sector Operation element in the Beacon frame. In a BSS where the AP does not support group sectorization, a STA, whether it is sectorized beam-capable or not, is allowed to transmit at any beacon interval.

(#1276)When performing the Sectorized beam operation described in 10.52 (Sectorized beam operation), if management frame protection is negotiated and both STAs set the Extended S1G Action Protection field in the RSNXE that they transmit to 1, the STAs shall:

— use individually addressed Protected Sectorized Group ID List and Protected Sector ID Feedback frames instead of Sectorized Group ID List and Sector ID Feedback frames, respectively and

— discard any individually addressed Sectorized Group ID List or Sector ID Feedback frame received from the peer STA, with which management frame protection is negotiated.

(#1276)STAs that exchange individually addressed Protected Sectorized Group ID List or Protected Sector ID Feedback frames shall follow the rules defined in 12.6.17 (Protection of robust Management frames.).

(#1276)When management frame protection is not negotiated or (M118)the Extended S1G Action Protection field is 0 in the RSNXE transmitted by either STA, the STAs shall not use the Protected Sectorized Group ID List nor the Protected Sector ID Feedback frame.

### 10.52.3 Group sectorization operation

Group sectorization operation is based on the AP transmitting a sectorized Beacon frame. A sectorized Beacon frame is a Beacon frame transmitted through a sectorized beam, which covers a specific sector of the BSS.

A BSS that is employing a sectorization operation is called a Sectorized BSS. The sectorization scheme of operation in a BSS is signaled by the presence of an S1G Sector Operation element in Beacon frames, Probe Response frames, and Association Response frames.

In a Sectorized BSS, the AP may alternate the sectorized beacons and the nonsectorized (omnidirectional) beacons, as illustrated by the example in Figure 10-145 (Sectorized BSS operation). More than one sector could be active at the same time, i.e., they can overlap in time. In such case, STAs from different sectors are allowed to transmit while their sectors are active. During the omnidirectional beacon interval all the STAs in the BSS may transmit regardless of their geographical locations. Sectorized beacons are transmitted to selected geographical areas to inform groups of STAs that they are allowed to transmit during the sector intervals specified in the S1G Sector Operation element. The AP with group sectorization operation receives transmissions from all sectors continuously.

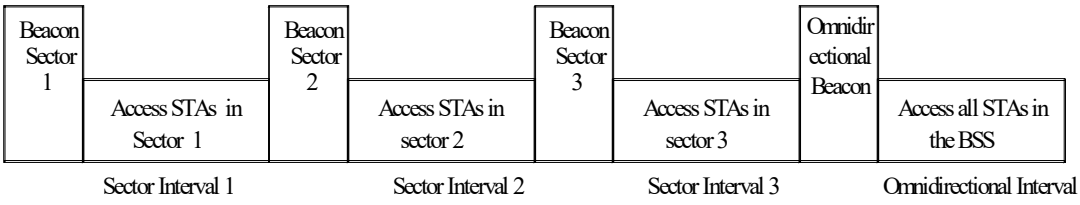


**Figure 10-145—Sectorized BSS operation**

All beacons in a sectorized BSS carry the S1G Sector Operation element. The 1-bit Omni field indicator within the S1G Sector Operation element distinguishes between the sectorized Beacon frame and the omnidirectional Beacon frame transmission. The S1G Sector Operation element further specifies the type of sectorization operation, the type of Beacon frame (sectorized or omnidirectional), the complete rotation period of all (sectorized and omnidirectional) beacons, the subperiod for the current Beacon frame, and the list of groups of STAs that are allowed to transmit during the current beacon interval.


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In a Sectorized BSS with group sectorization operation, each STA is allocated a group ID related to the sectorization operation. STAs that have group ID zero are allowed to transmit in all beacon intervals. A STA that is sectorized beam capable and whose group ID is contained in the list of group IDs carried in the S1G Sector Operation element in a Beacon frame is allowed to transmit until the next TBTT. By default all STAs have group ID 0 unless otherwise specified at the association. Because by default all STAs that support group sectorization belong to group ID 0 before association, all the STAs can transmit at any time before their association. It is expected that during the association, STAs receive a nonzero group ID, which (M118) restricts their activity to a particular sector interval and omnidirectional time interval. The AP may allow some STAs to have the group zero even after association, for instance public safety STAs or some high priority sensors.

A STA that receives a Beacon frame in a Sectorized BSS shall verify if its group ID is contained in the group ID list of the S1G Sector Operation element in the Beacon frame if it intends to transmit before the next TBTT. A STA that has a nonzero group ID, which is not listed in the S1G Sector Operation element of the Beacon frame, is not allowed to transmit during that sector duration.

The STAs that do not support the group sectorization operation are not subject to the rules defined in this subclause.

In a Group Sectorized BSS,

— The S1G AP shall transmit omnidirectional Beacon frames every dot11BeaconPeriod as described in 11.1.2.1 (TSF for an infrastructure BSS or a PBSS).

— The S1G AP may transmit sectorized Beacon frames every sectorized beacon interval. A non-AP STA that is associated to the AP and is group sectorized capable shall transition to awake state(#6038) to read the sectorized Beacon frame if it intends to access the medium during the sectorized beacon interval. A non-AP STA that is not group sectorized capable may (#3683)discard the sectorized Beacon frame and is not subject to the rules described in this subclause.

The purpose of group sectorization operation is to allow the channel access of one or multiple groups of STAs at the time, where the STA group allocation is based on STA sector location and other grouping criteria (e.g., the device type, or traffic type, or the received SNR) in order to reduce the number of hidden nodes that simultaneously access the AP.

Two or more sectors may be active at the same time, i.e., their active time can overlap. In this case the STAs are allowed to transmit in more than one sector. Figure 10-145 (Sectorized BSS operation) presents an example of three nonoverlapping sectors followed by an omnidirectional period. Each sector starts with sectorized Beacon frame that provides the sector ID and the duration of sector activity.

### 10.52.4 TXOP-based sectorization operation

TXOP-based sectorization operation is based on an AP transmitting or receiving through the sectorized beam within a TXOP. At the beginning of a frame exchange sequence(#109), the AP may start with the omnidirectional beam transmission to establish a link with a STA and to set up protection duration within a TXOP before switching to the sectorized beam transmission and reception. In different TXOPs, the AP may use different sectorized beams to communicate with different STAs. (#181)A Sectorized beam capable AP supporting TXOP-based sectorization operation shall support transmitting or receiving through both the omnidirectional beam or the sectorized beams.

In a BSS with TXOP-based sectorization operation, the AP shall signal the operation in Beacon frames, Probe Response frames, Association Response frames, or other frames using the S1G Sector Operation element. The operation of TXOP-based sectorization is defined by the following rules:

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- The switching from an omnidirectional beam transmission to a sectorized beam transmission occurs when the bit position corresponding to the sector is(M118) 1 in the TXVECTOR parameter SECTOR_ID.
- When an AP is aware of the sector in which a STA is in, AP may select the sectorized beam by setting the bit position corresponding to the sector to 1 in the TXVECTOR parameter SECTOR_ID when it transmits to or receives from the STA. Otherwise, the AP transmits or receives through the omnidirectional beam to the STA.
- Once AP transmits to a STA through a sectorized beam by setting the bit in the TXVECTOR parameter SECTOR_ID that corresponds to that sector to 1, it shall use the same sectorized beam to receive from the STA within the same TXOP.
- Once the AP switches to the sectorized beam transmission during an exchange, it shall continue with sectorized beam transmission using the same sectorized beam and the TXOP truncation is not allowed for the remaining duration of the NAV/RID protection.
- An AP shall use the same sectorized beam for transmission after a PIFS(#6587) recovery or backoff recovery in a TXOP.
- TXOP sharing for relaying shall not be used in a TXOP.

Note that a possible realization of an omnidirectional beam is by setting bit positions of all available sectors to 0. Another possible realization of omnidirectional beam is by setting all bit positions to 1 in the TXVECTOR parameter SECTOR_ID and the CSD are inserted to different sectorized beams to avoid unintentional beamforming.

In TXOP-based sectorization operation, during a frame exchange between the AP employing sectorized beamforming and a non-AP STA, spatial reuse by OBSS APs or OBSS non-AP STAs sharing the same wireless medium is allowed under the following rules:

When a protection NAV and RID for a TXOP is set up by an AP's omnidirectional beam transmission and a spatially orthogonal (SO) condition is confirmed by an OBSS non-AP STA or OBSS AP, the OBSS non-AP STA or OBSS AP may initiate an SO exchange after an SO-Backoff. For a non-AP STA the SO-Backoff is initialized with the AC_VO parameters from the most recently received (#327)EDCA Parameter Set element sent by the AP with which the STA is associated. For an AP the SO-Backoff is initialized with the AC_VO parameters of the AP. The SO-Backoff function begins or resumes when the SO condition is confirmed. The SO-Backoff function is independent of all other backoff functions but follows the EDCAF backoff procedure as defined in 10.2.3 (Hybrid coordination function (HCF)). An OBSS non-AP STA or OBSS AP that invokes or resumes an SO-Backoff at the confirmation of an SO condition shall set an SO timer to MAX(NAV, RID) and reset its NAV and RID and suspend EDCAF backoff procedures. At the expiry of the SO timer, the SO-Backoff is suspended and the suspended EDCAF backoff procedures resume. An OBSS non-AP STA or OBSS AP that initiates a new spatially orthogonal frame exchange sequence(#109) after an SO-Backoff procedure shall start the exchange with a nonbeamformed RTS/CTS and shall limit the duration of the exchange such that it ends before the expiry of the SO timer. The new frame exchange sequence(#109) as described is called a spatially orthogonal frame exchange sequence(#109). The new spatially orthogonal frame exchange sequence(#109) initiator may transmit frames from any AC. The STA shall obey the TXOP limit of the AC of the frames transmitted within the SO frame exchange sequence(#109). A STA that transmits an SO frame exchange sequence(#109) may transmit additional SO frame exchange sequences(#109) by continuing to use the SO-Backoff function until the expiry of the SO timer. If the ongoing frame exchange sequence(#109) transmission is between a pair of STAs within its BSS, the STA does not reset its NAV and its RID even though the spatially orthogonal conditions are met. Within the new spatially orthogonal exchange, an OBSS AP shall use an antenna setting which is same as the antenna setting used to detect the SO condition for transmission.


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The SO condition is satisfied if an OBSS non-AP STA or OBSS AP which receives the omnidirectional transmission but not the subsequent sectorized beam transmission from the AP and not the transmission from the STA involving in the frame exchange sequence(#109).

Four types of frame exchange sequences, which can lead to the SO conditions by OBSS non-AP STAs or OBSS APs are described.

a) SO frame exchange sequence 1: As illustrated in Figure 10-146 (SO frame exchange sequence 1), the AP starts a frame exchange sequence(#109) with the omnidirectional beam to establish a link with a STA and set up the protection for the duration of the sectorized beam transmission. The second PPDU has a long format, AP switches to the sectorized beam transmission after the omnidirectional preamble of the long preamble. The AP continues with the sectorized beam transmission for the remaining duration of the NAV/RID protection. An OBSS non-AP STA or OBSS AP receives the omnidirectional beam transmission from the AP may attempt to start an SO frame exchange sequence(#109) by detecting an SO condition. An SO condition is confirmed by an OBSS non-AP STA or OBSS AP, which observes the omnidirectional transmission of the AP but not the beamformed preamble of the AP and not the STA's transmission.

   Note that an OBSS non-AP STA or OBSS AP infers its spatial orthogonality by

   1) Observing the first omnidirectional beam PPDU and the omnidirectional preamble of the long preamble from the AP.
   2) Not observing the subsequent sectorized beam transmission from the AP for the duration of one symbol (D-STF as shown in Figure 23-2 (S1G_LONG format(#7158))) following the omnidirectional portion of the S1G_LONG format.
   3) Observing a gap of no transmission between the first omnidirectional beam PPDU and the omnidirectional preamble of the long preamble by the AP.

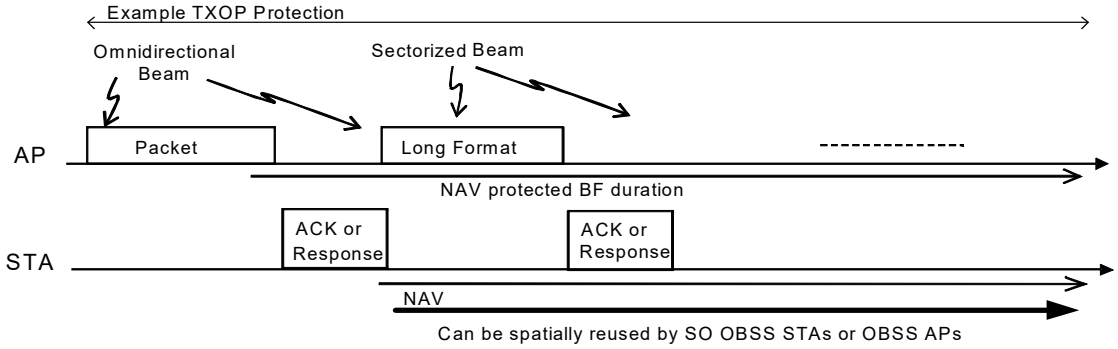


**Figure 10-146—SO frame exchange sequence 1**

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b) SO frame exchange sequence 2: As illustrated in Figure 10-147 (SO frame exchange sequence 2), the AP starts a frame exchange sequence(#109) with the omnidirectional transmission of a PPDU to establish a link with a STA and to set up the protection for the duration of the sectorized beam transmission. Subsequently, the AP switches to a sectorized beam transmission for the remaining duration of the NAV/RID protection. An OBSS non-AP STA or OBSS AP receives the omnidirectional beam transmission from the AP may attempt to start an SO frame exchange sequence(#109) by detecting the SO condition. SO condition is confirmed by an OBSS non-AP STA or OBSS AP, which observes the omnidirectional transmission of the AP but not the beamformed transmission of the AP and not the STA's transmission.

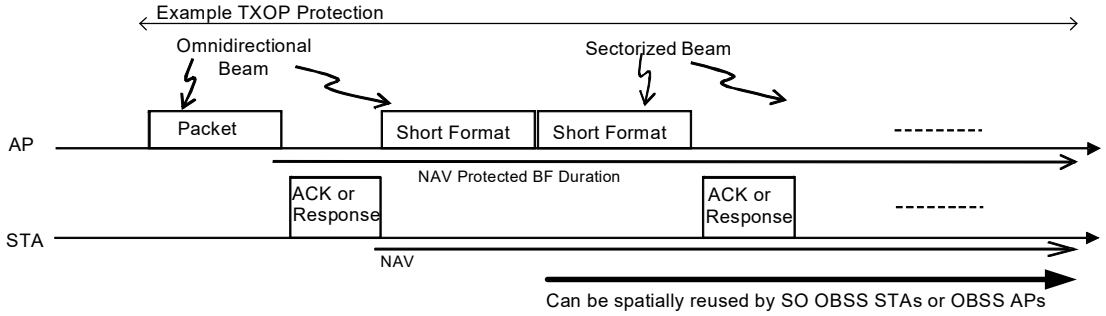


**Figure 10-147—SO frame exchange sequence 2**

Note that an OBSS non-AP STA or OBSS AP infers its spatial orthogonality by

1) Observing the omnidirectional beam transmission by the AP.
2) Not observing the subsequent sectorized beam transmission by the AP for aSIFSTime + aSlotTime + aRxPHYStartDelay duration.
3) Observing a gap of no transmission between the first two omnidirectional beam PPDUs by the AP.

c) SO frame exchange sequence 3: The AP starts a frame exchange sequence(#109) with an omnidirectional RTS frame to solicit a CTS response from a STA and uses the omnidirectional transmission to set up the protection for the duration of the sectorized beam transmission and then switches to the sectorized beam transmission for the remaining duration of the NAV/RID protection. SO condition is confirmed by an OBSS non-AP STA or OBSS AP, which observes the omnidirectional transmission of the AP but not the beamformed transmission of the AP and not the STA's transmission. Note that in the first diagram in Figure 10-148 (SO frame exchange sequence 3), an OBSS non-AP STA or OBSS AP infers its spatial orthogonality with the AP by observing the omnidirectional beam RTS frame and the omnidirectional portion of the long format for the duration of one symbol (D-STF as shown in Figure 23-2 (S1G_LONG format(#7158))) following the omnidirectional portion of the S1G_LONG format but not the subsequent sectorized beam transmission and with the STA by observing a gap of no transmission between the omnidirectional RTS frame and the omnidirectional preamble of the long preamble. Note that in the second diagram in Figure 10-148 (SO frame exchange sequence 3), an OBSS non-AP STA or OBSS AP infers its spatial orthogonality with the AP by observing the transmission of the omnidirectional beam RTS frame and the omnidirectional beam PPDU of the short format but not observing the subsequent sectorized beam transmission for aSIFSTime + aSlotTime + aRxPHYStartDelay duration and with the STA by observing a gap of no transmission between the omnidirectional RTS frame and the omnidirectional beam PPDU of the short format by the AP.


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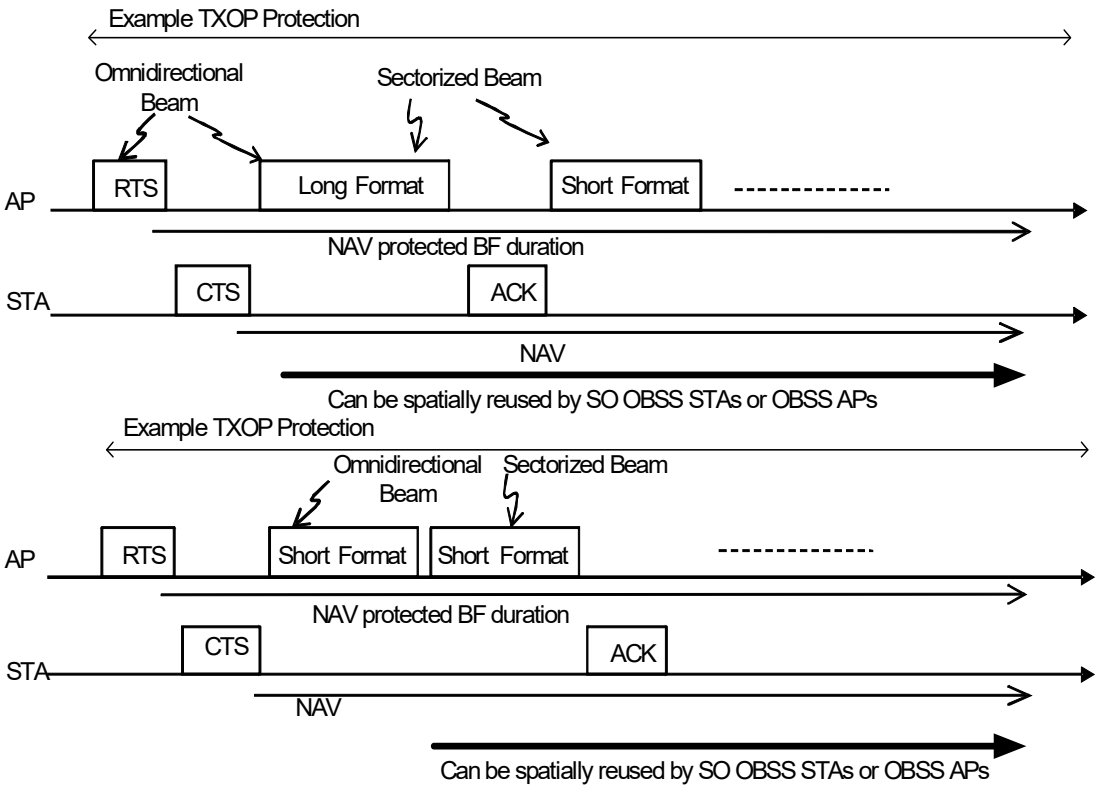


**Figure 10-148—SO frame exchange sequence 3**

d) SO frame exchange sequence 4: A STA starts with the omnidirectional beam to establish a link with the AP. AP uses omnidirectional transmission as the responding and to set up the protection for the duration of the remaining TXOP. Then the AP transmits the sectorized beam transmission (either an omnidirectional preamble of a long preamble or an omnidirectional transmission of a subsequent PPDU) and switches to the sectorized beam transmission. The AP continues with the sectorized beam transmission for the remaining duration of the NAV/RID protection. SO condition is confirmed by an OBSS non-AP STA or OBSS AP, which observes the omnidirectional transmission of the AP but not the beamformed transmission of the AP and not the STA's transmission.

Note that in the first diagram in Figure 10-149 (SO frame exchange sequence 4(#4258)), an OBSS non-AP STA or OBSS AP infers its spatial orthogonality with the AP by observing the omnidirectional beam frame and the omnidirectional portion of the long format for the duration of one symbol (D-STF) following the omnidirectional portion of the S1G_LONG format but not the subsequent sectorized beam transmission and with the STA by observing a gap of no transmission before the AP response to PS-Poll frame or trigger frame from the STA. Note that in the second diagram in Figure 10-149 (SO frame exchange sequence 4(#4258)), an OBSS non-AP STA or OBSS AP infers its spatial orthogonality by

1) Observing the omnidirectional beam PPDU of the short format from the AP.
2) Not observing the subsequent sectorized beam transmission by the AP for aSIFSTime + aSlotTime + aRxPHYStartDelay duration.
3) Observing a gap of no transmission before the first omnidirectional beam PPDU of the short format by the AP.

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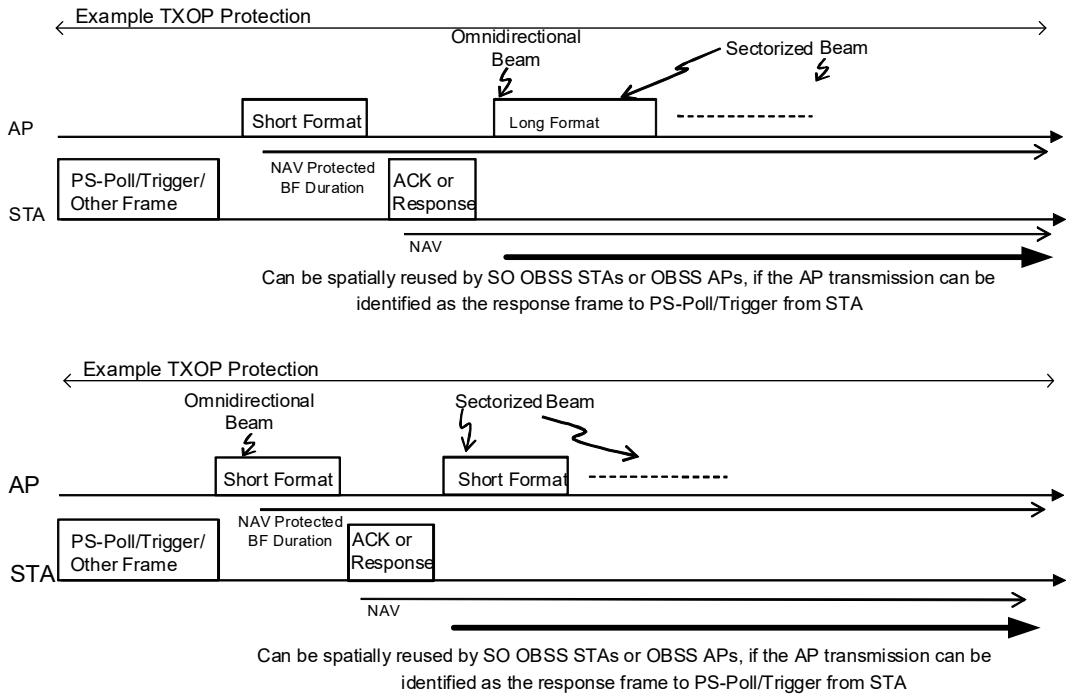


**Figure 10-149—SO frame exchange sequence 4(#4258)**

To facilitate the detection of the spatially orthogonal conditions by OBSS non-AP STAs or OBSS APs, the NDP CTS frame may be transmitted preceding the SO frame exchange sequence(#109). If the Early Sector Indicator in the NDP CTS frame is equal to 1, it indicates that the NDP CTS frame is followed by the sectorized beam frame exchange sequence(#109). Setting the Early Sector Indicator to 1 and Address Indicator to 0 also indicates to the OBSS STAs that it might cancel its NAV and its RID setting if the spatially orthogonal conditions are subsequently met. If the ongoing frame exchange sequence(#109) transmission preceding the NDP CTS frame is between a pair of STAs within its BSS, the STA does not reset its NAV and its RID even though the spatially orthogonal conditions are met. The RXVECTOR parameter COLOR is utilized to detect the SO condition by classifying the received PPDU between a same BSS transmission and an OBSS transmission. Hence, if the Early Sector Indicator is equal to 0, OBSS STA need not check for spatially orthogonal conditions. Figure 10-150 (CTS-to-self preceding SO frame exchange sequence) illustrates the frame exchange sequence(#109) preceded by CTS-to-self using NDP CTS frame.

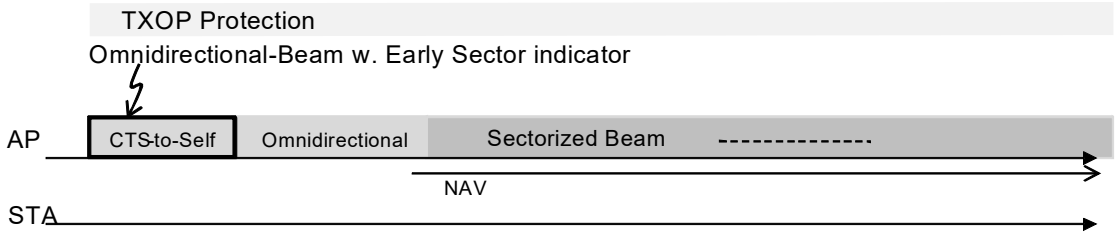


**Figure 10-150—CTS-to-self preceding SO frame exchange sequence**


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### 10.52.5 Sector training operation

#### 10.52.5.1 Introduction

Sector training is one way to help the STAs to determine the best sectors to communicate with the AP. In sector training, an AP with dot11S1GSectorTrainingOperationImplemented equal to true shall transmit training NDP CTSs over all sectors. The best sector might be chosen by a STA based on instantaneous or averaged CSI. The specific method of choosing the sector is beyond the scope of this standard. The results of sector training may be fed-back by the STAs to the AP using Sector ID feedback frame. These training NDP CTSs (with the Address Indication bit set to 1 and the RA/Partial BSSID field set to the partial BSSID of the AP's BSS) shall be transmitted consecutively and should be sent within a single TXOP. Sector training is set up or requested using the HT variant Control field. Sector training supports up to eight sectors. The AP may use other methods to determine the STA's best sector.

#### 10.52.5.2 Procedure

In sector training, the AP sends a sector training announcement followed by a series of NDP CTS sector training frames separated by SIFS.

In TXOP-based sectorization operation, sector training may occur periodically with the training period and the beacon interval in which the training occurs as indicated in S1G Sector Operation element (TXOP-based), in response to a request from a STA, or initiated by the AP. The STAs may perform sector training by receiving the training NDP CTSs from AP. When the AP receives the sector training request from a STA, the AP shall schedule sector training. AP supporting TXOP-based sectorization shall support sector training and sector training request. In the S1G Sector Operation element (TXOP-based) (see 9.4.2.194 (S1G Sector Operation element)), which is transmitted in Beacon frame, Probe Response frame, or Association Response frame, the AP indicates in which beacon interval sector training occurs.

In group sectorization operation, a STA can find its best sector ID by listening to all the sectorized beacons transmitted during dot11BeaconPeriod. The S1G Sector Operation element (group) carried in the sectorized Beacon frame provides the sectorized beacons' rotation period, current sector ID, the subperiod of the current sector and the group IDs of the groups of STAs (#1414)that are allowed to transmit within the current beacon interval. (#333)Sector training may also be used by STAs to reduce time for sector discovery, and to achieve power saving by not having to listen to all the sectorized beacons.

The STA may use the Sector ID feedback frame (see 9.6.24.11 (Sector ID Feedback frame format)) to indicate to the AP which sector is selected.

The STA may request sector training from AP by using the HT variant Control field if it is capable of sector training request. By setting the MAI=14 in the Link Adaptation Control subfield of the HT variant Control field, the STA indicates HT variant control field is used for sector training (or antenna selection) information. Sector training (or sector training resumption) is requested by a STA when the ASELC subfield is equal to 1 and the ASEL Data subfield with values in the range(#3482) 1 to 15, being the number of the first NDP CTS training frames to be transmitted when the command is sector training resumption, where 0 corresponds to the first training frame in the sector training request. When the HT NDP Announcement subfield is also equal to 1, it indicates training NDP CTS frames to follow with consecutive training NDP CTS frames separated by SIFS.

The frame exchange sequence for sector training is shown in Figure 10-151 (Sector training), where the AP transmits training NDP CTS frames, and the STA provides Sector ID feedback. The frame exchange sequence(#109) comprises the following steps:

a) (Optional) A STA may initiate sector training by sending a +HTC frame with the ASELC set to 1 for sector training request.

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b) The AP sends out consecutive training NDP CTSs (with the Address Indication bit set to 1 and the RA/Partial BSSID field set to the partial BSSID of the AP's BSS) separated by SIFS in a TXOP of which it is the TXOP holder with no Ack over different sectorized beams. NDP CTS frames (23.3.12.2.1 (NDP CTS)), with NDP CMAC PPDU Type=0, are used in sector training. Each training NDP CTS frame is transmitted over one sector beam. The first training NDP CTS frame shall be preceded by a +HTC frame with HT NDP Announcement subfield set to 1. The positions of the training NDP CTS frames correspond to the sector IDs of the sectorized beams, in ascending order starting with Sector ID =0.

c) The STA(s) may perform training by selecting the antenna sector based on NDP CTS training frames.

d) The STA(s) engages in the training by receiving the sector training frames may respond with a selected sector ID using the sector ID feedback frame in a subsequent TXOP or during sector report RAW, which may be indicated by Beacon frame for fast sector discovery of multiple STAs (see 10.52.5.4 (Fast Sector Discovery)),

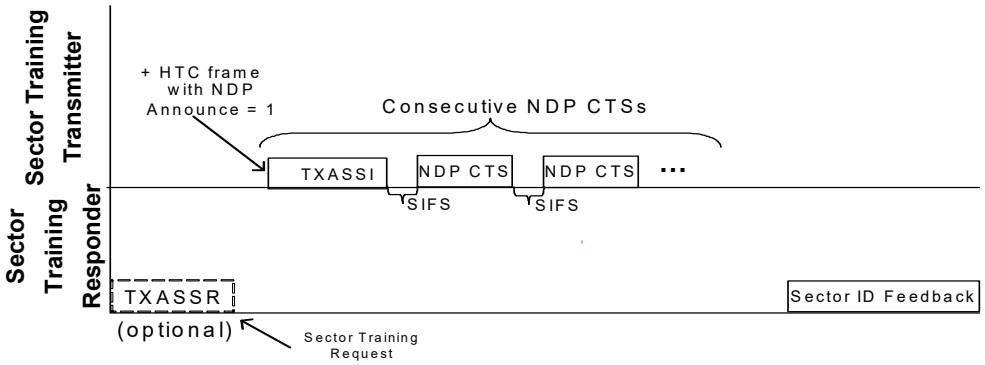


**Figure 10-151—Sector training**

If the AP receives a +HTC MPDU with the MAI subfield equal to 14, the ASEL Command subfield equal to sector training request (i.e., the field value(#560) is 1), and the ASEL Data subfield equal to zero to correspond to the command sector training, the STA shall assume a total number of training NDP CTSs that corresponds to the total number of sectors. If the AP receives a +HTC MPDU with the MAI subfield equal to 14, the ASEL Command subfield equal to sector training request (i.e., the field value(#561) is 1), and the ASEL Data subfield equal nonzero value to correspond to the command sector training resumption (a resumption MPDU), the STA shall assume the number of training frames that follow the resumption MPDU is equal to the number of training NDP CTSs from the total number of sectors minus the order number transmitted in the ASEL Data subfield of the Resumption MPDU.

An AP may schedule sector sounding for multiple STAs by RAW in a beacon interval using the RAW Parameter Set element with the RAW Type field equal to sounding RAW and the RAW Type Options subfield equal to sector sounding RAW (see 9.4.2.190 (RPS element)). During the sounding RAW, non-AP STAs that are associated with the AP are expected not to access the WM during the RAW duration as described in 10.23.5 (Restricted access window (RAW) operation) and can elect to listen to the training NDP CTS frames transmitted by the AP. This sector sounding RAW may be scheduled as periodic or nonperiodic.

Sector training within the sector sounding RAW starts with a frame with HT NDP Announcement subfield equal to 1 in the HT control field and is followed in SIFS by a number of NDP CTS frames, each transmitted through different antenna sector starting with Sector ID equal to 0, and separated by SIFS. If the RAW Type and the RAW Type Options subfield do not indicate that the RAW is a sector sounding RAW, no sector sounding is performed within the RAW.


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Channel bandwidth for sector training shall be a width up to the BSS bandwidth indicated in the S1G Beacon frame during the beacon interval. The AP may transmit NDP CTS frames for sector sounding in parallel (e.g., with a value of S1G_DUP_2M for the TXVECTOR parameter FORMAT and a value of CBW8 for the TXVECTOR parameter CH_BANDWIDTH in a BSS with an operating width of 8 MHz). The Bandwidth Indication field in the sounding frames (in NDP_2M CTS frame) and the Channel Indication field in the sounding RAW shall comply with the TXVECTOR parameter CH_BANDWIDTH.

#### 10.52.5.3 Sector ID feedback

A STA may optionally use an Unprotected S1G Action frame (see 9.6.24.11 (Sector ID Feedback frame format)) for (solicited and unsolicited) Sector ID feedback.

#### 10.52.5.4 Fast Sector Discovery

When multiple STAs report their sector IDs using the Sector ID feedback frames to AP, Sector ID feedback frames may be protected by sector report RAW(s) (see 9.4.2.190 (RPS element)) indicated in the Beacon frame to avoid contentions with others. The sector report RAW(s) may be assigned after the sector sounding RAW for fast sector discovery of multiple STAs.

In the sector report RAW, the STA transmits a report frame to the AP not earlier than the start of its assigned RAW slot, followed by the AP's response for confirmation after a SIFS(#6587).

## 10.53 S1G relay operation

### 10.53.1 General

An S1G relay consists of an S1G relay AP, an S1G relay STA and a relay function.

NOTE—An S1G relay AP is not an S1G relay STA, though it is an S1G STA.(#1615)

An S1G relay consists of an AP with dot11RelayAPImplemented equal to true and a STA with dot11RelaySTAImplemented equal to true.

An example of a relay function is illustrated in Figure 10-152 (S1G relay architecture), where Relay 1, Relay 2, and Relay 3 are S1G relays, each of which consisting of an S1G relay STA, an S1G relay AP and a relay function. The S1G relay STAs of Relay 1 and Relay 2 are associated with an AP that is an S1G root AP. The S1G relay STA of Relay 3 is associated with the S1G relay AP of Relay 1. STA 1 is a non-AP STA associated with the S1G relay AP of Relay 1. STA 2, and STA 3 are non-AP STAs associated with the S1G relay AP of Relay 3. STA 4 and STA 5 are non-AP STAs associated with the S1G relay AP of Relay 2. Frames from STA 1 are forwarded via the relay function of Relay 1 from the S1G relay AP to the S1G relay STA and then to the S1G root AP. Similarly, frames from the S1G root AP are forwarded to STA 1 via the S1G relay STA, the relay function and the S1G relay AP of Relay 1. Similar forwarding is done by Relay 3 and Relay 1 in sequence to handle frames from STA 2 and STA 3 relaying multiple times to or from the root AP.

Relay STA in this context refers to a non-AP STA.

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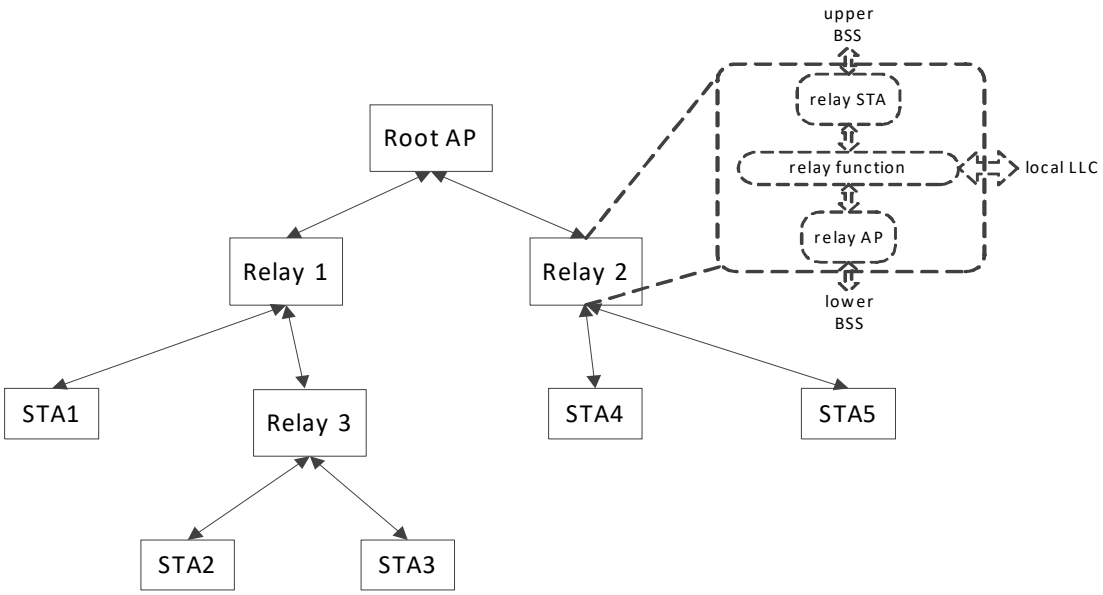


**Figure 10-152—S1G relay architecture**

### 10.53.2 S1G relay operation

A non-AP STA with dot11RelaySTAImplemented equal to true shall include the S1G Relay Activation element in (Re)Association Request frames.

A non-AP STA with dot11RelaySTAImplemented equal to true may include an S1G Relay Activation element with Relay Activation Mode subfield equal to 1 in (Re)Association Request frames, Relay Activation Request frames or Relay Activation Response frames. A non-AP STA with dot11RelaySTAImplemented equal to true may transmit a Relay Activation Request frame to the AP with which it is associated.

A non-AP STA shall not transmit an S1G Relay Activation element that has the Enable Relay Function and the Relay Activation Mode subfields equal to 1 if the most recently received S1G Relay element from the AP to which it is associated had the No More Relay Flag subfield equal to 1.

A non-AP STA with dot11RelaySTAImplemented equal to false shall not include the S1G Relay Activation element in any frames that it transmits.

A non-AP STA transmitting an S1G Relay Activation element shall set the Direction subfield of the element to 0. An AP transmitting S1G Relay Activation element shall set the Direction subfield of the element to 1.

An AP that is the intended receiver of a frame that contains an S1G Relay Activation element with Relay Activation Mode subfield equal to 1 shall respond with the appropriate frame (Probe, (Re)Association, Relay Activation Response) that contains an S1G Relay Activation element with Relay Activation Mode subfield equal to 0.

A non-AP STA with dot11RelaySTAImplemented equal to true shall transmit a Relay Activation Response frame if it receives the corresponding S1G Relay Activation element in a Relay Activation Request frame.


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A non-AP STA with dot11RelaySTAImplemented equal to true that is the intended receiver of a frame that contains an S1G Relay Activation element with Relay Activation Mode subfield equal to 1 and Enable Relay Function subfield equal to 0 shall respond with a frame that contains an S1G Relay Activation element with Relay Activation Mode and Enable Relay Function subfields equal to 0.

An AP may indicate the maximum number of STAs, $N_{max}$, that an S1G relay is allowed to associate by including a Number of STAs field in an S1G Relay Activation element with the Enable Relay Function subfield equal to 1 transmitted to the S1G relay.

A non-AP STA with dot11RelaySTAImplemented equal to true shall set dot11RelaySTAOperationActivated to false unless

a) It receives an S1G Relay Activation element from the AP to which it is associated with Enable Relay Function subfield equal to 1 and Relay Activation Mode subfield equal to 0 as a response of a transmitted S1G Relay Activation element with Enable Relay Function and Relay Activation Mode subfield equal to 1.

b) It transmits an S1G Relay Activation element to the AP to which it is associated with Enable Relay Function subfield equal to 1 and Relay Activation Mode subfield equal to 0 as a response of a received S1G Relay Activation element with Enable Relay Function and Relay Activation Mode subfield equal to 1.

If event a) or b) occurs, then it shall set dot11RelaySTAOperationActivated to true.

A non-AP STA with dot11RelaySTAOperationActivated equal to true is referred to as an S1G relay STA.

An AP with dot11RelayAPImplemented equal to true may include an S1G Relay Activation element with Relay Activation Mode subfield equal to 0 in (Re)Association Response frames, Probe Response frames, Relay Activation Request frames or Relay Activation Response frames.

An AP with dot11RelayAPImplemented equal to true (e.g., the AP in an S1G relay) shall set dot11RelayAPOperationActivated to true only if dot11RelaySTAOperationActivated of the non-AP STA in the relay is true, otherwise it shall set dot11RelayAPOperationActivated to false.

An AP with dot11RelayAPOperationActivated equal to true is referred to as an S1G relay AP.

An S1G relay AP shall include an S1G Relay element in transmitted Beacon frames, PV1 Probe Response frames and Probe Response frames.

An S1G relay AP shall set the No More Relay Flag subfield of an S1G Relay element to 1 if the No More Relay Flag subfield of the latest S1G Relay element received from its parent AP was set to 1. An S1G relay AP may set the No More Relay Flag subfield of the S1G Relay element to 1 in order to limit the number of Relays in its associated STAs.

An S1G Relay AP shall reject association requests when $N_{max}$ has been reached, citing status code 17 (DENIED_NO_MORE_STAS).

An AP with dot11RelayAPImplemented equal to true shall include the S1G Relay element in its Beacon frames and may include the S1G Relay element in its Probe Response frames, PV1 Probe Response frames, and (Re)Association Response frames.

An S1G root AP is defined as an AP with dot11RelayAPImplemented equal to true that sets the Hierarchy Identifier field of transmitted S1G Relay elements to 0.

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An S1G relay AP shall not set the Hierarchy Identifier field of transmitted S1G Relay elements to 0.

An S1G relay AP shall use the same SSID as the AP to which its S1G relay STA is associated.

An S1G relay STA shall send a Reachable Address element that contains the current list of reachable addresses, in the (Re)Association Request frame to the AP to which it is associating. In this frame the relay STA shall set the Initiator MAC address field of the element to its own MAC address, and the Add/Remove subfield to 1.

An S1G relay STA shall send a Reachable Address Update frame to the AP to which it is associated when one of the following conditions occurs:

1) A new non-AP STA associates with the S1G relay AP of the relay.
2) A non-AP STA is disassociated or deauthenticated from the S1G relay AP of the S1G relay.
3) A Reachable Address Update frame is received at the S1G relay AP of the S1G relay.

For conditions 1 and 2 above, the transmitted Reachable Address Update frame shall include Reachable Address subfields for STAs with a changed association or authentication status.

For condition 3 above, the transmitted Reachable Address Update frame shall include all Reachable Address subfields from the received Reachable Address Update frame,

a) Where the received Reachable Address subfield had the Add/Remove subfield equal to 1 (STA joining the relay).
b) Where the received Reachable Address subfield had the Add/Remove subfield equal to 0 (STA leaving the relay), except when the received Reachable Address Update frame came from a Relay STA that is not the next hop for the indicated STA.

The Reachable Address Update frame shall not contain Reachable Address subfields other than those defined for conditions 1) to 3) above. Because the generation of a Reachable Address Update frame might not be immediate, Reachable Address subfields which have different initiator MAC addresses may be combined in a single Reachable Address Update frame under the above conditions.

Reachable Address subfields with the Add/Remove subfield equal to 0 (STA leaving the relay) shall be ignored when received from an S1G relay STA (#1414)that is not the S1G relay STA that transmitted the most recently received Reachable Address Update frame containing a Reachable Address subfield for the indicated STA with the Add/Remove subfield equal to 1 (STA joining the relay).

An S1G relay STA generating a Reachable Address frame [under conditions 1) and 2) above] shall set the Initiator MAC address field of the element to its own MAC address.

An S1G relay STA shall set the Add/Remove subfield of a Reachable Address Update frame to 1 if the STA identified by the MAC Address subfield of Reachable Address subfield is associated to the relay AP of the S1G relay and shall set the Add/Remove subfield to 0 if the STA identified by the MAC Address subfield of Reachable Address subfield disassociated from the S1G relay AP of the S1G relay.

An S1G relay STA shall set the Relay Capable subfield of the Reachable Address subfield of the Reachable Address element to 1 only if the STA identified by the MAC address subfield of the Reachable Address subfield has indicated that it is capable of relay function, otherwise, it shall set it to 0.

An S1G root AP shall update the DS upon receipt of a Reachable Address Update frame.


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### 10.53.3 Addressing and forwarding of individually addressed relay frames

A MAC service tuple (including an MSDU) received via the WM at an S1G relay AP is examined by the relay function, and if the DA matches the address of the STA of the S1G relay the MAC service tuple is delivered via the MAC service to the local higher layer entity. Otherwise, the MAC service tuple is passed to the S1G relay STA and then is forwarded via the WM to the AP to which it is associated, using either a four-address frame format or an A-MSDU format except when the frame carrying the (A-)MSDUs is a PV1 QoS Data frame for which header compression is used as described in 10.57 (Generation of PV1 MPDUs and header compression procedure).

The addressing of the four-address frame shall be as follows in this case:

- Address 1 is the MAC address of the AP (the receiver of the MPDU)
- Address 2 is either the MAC address or the AID of the S1G relay STA (the transmitter of the MPDU)
- Address 3 is the DA of the MSDU (the destination address of the MSDU)
- Address 4 is the SA of the MSDU (the source address of the MSDU)

If the four-address frame is a PV1 QoS Data frame that contains an A-MSDU then the DA and/or SA field(s) shall not be present in any of the A-MSDU subframe headers unless the DA and/or SA for the MSDU contained in the A-MSDU subframe are not equal to the values contained in Address 3 and/or Address 4 of the frame.

Otherwise, the addressing of the frame containing an A-MSDU shall be as follows in this case:

- Address 1 is the MAC address of the AP (the receiver of the MPDU)
- Address 2 is either the MAC address or the AID of the S1G relay STA (the transmitter of the MPDU)
- Address 3 is the MAC address of the AP (the BSSID)
  - If the frame is a PV1 QoS Data frame then Address 3 is not present
- DA in A-MSDU subframe header is the DA of the MSDU (the destination address of the MSDU)
- SA in A-MSDU subframe header is the SA of the MSDU (the source address of the MSDU)

A MAC service tuple passed to a root AP from the DS, or received at an S1G relay STA via the WM, is examined by the relay function, and if the DA matches the address of the AP or an associated non-AP STA, it is delivered using legacy (non-relay) methods. Otherwise, the included MSDU is forwarded via the WM to the associated S1G relay STA (#1414)that most recently included the MSDU's DA in a Reachable Address element, using either a four-address frame format or an A-MSDU format.

The addressing of a four-address frame shall be as follows in this case:

- Address 1 is either the MAC address or the AID of the S1G relay STA (the receiver of the MPDU)
- Address 2 is the MAC address of the AP (the transmitter of the MPDU)
- Address 3 is the DA of the MSDU (the destination address of the MSDU)
- Address 4 is the SA of the MSDU (the source address of the MSDU)

If the four-address frame is a PV1 QoS Data frame that contains an A-MSDU then the DA and/or SA field(s) shall not be present in any of the A-MSDU subframe headers except when DA and/or SA for the MSDU contained in the A-MSDU subframe are different from the values contained in Address 3 and/or Address 4 of the frame.

Otherwise, the addressing of a frame containing an A-MSDU shall be as follows in this case:

- Address 1 is either the MAC address or the AID of the S1G relay STA (the receiver of the MPDU)
- Address 2 is the MAC address of the AP (the transmitter of the MPDU)

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- Address 3 is the MAC address of the AP (the BSSID)
  - If the frame is a PV1 QoS Data frame then Address 3 is not present
- DA in A-MSDU subframe header is the DA of the MSDU (the destination address of the MSDU)
- SA in A-MSDU subframe header is the SA of the MSDU (the source address of the MSDU)

When the frame is a PV1 QoS Data frame and the intended receiver has confirmed storing A3 and/or A4 as described in 10.57 (Generation of PV1 MPDUs and header compression procedure) then the DA and/or SA should not be present in either the A3 and/or A4 fields of the frame or in the DA and/of SA of the A-MSDU subframe header contained in the frame except when the DA and/or SA for the MSDU are different from the stored values.

### 10.53.4 Addressing and forwarding of group addressed relay frames

(#3422)A MAC service tuple with a destination address that is a group address (including an MSDU) received via the WM at an S1G relay AP is passed by the relay function to the S1G relay STA and then is forwarded via the WM to the AP to which the S1G relay STA is associated, using either a four-address frame format or an A-MSDU format except when the frame carrying the (A-)MSDUs is a PV1 QoS Data frame for which header compression is used as described in 10.57 (Generation of PV1 MPDUs and header compression procedure).

The addressing of the four-address frame shall be as follows in this case:

- Address 1 is the MAC address of its associated AP (the receiver of the MPDU)
- Address 2 is either the MAC address or the AID of the S1G relay STA (the transmitter of the MPDU)
- Address 3 is the DA of the MSDU (the group address).
- Address 4 is the SA of the MSDU (the source address of the group addressed MSDU)

If the four-address frame is a PV1 QoS Data frame that contains an A-MSDU then the DA and/or SA field(s) shall not be present in any of the A-MSDU subframe headers unless the DA and/or SA for the MSDU contained in the A-MSDU subframe are not equal to the values contained in Address 3 and/or Address 4 of the frame.

Otherwise, the addressing of the frame containing an A-MSDU shall be as follows in this case:

- Address 1 is the MAC address of its associated AP (the receiver of the MPDU)
- Address 2 is either the MAC address or the AID of the S1G relay STA (the transmitter of the MPDU)
- Address 3 is the MAC address of its associated AP (the BSSID)
  - If the frame is a PV1 QoS Data frame then Address 3 is not present
- DA in A-MSDU subframe header is the DA of the MSDU (the group address)
- SA in A-MSDU subframe header is the SA of the MSDU (the source address of the group addressed MSDU)

When the frame is a PV1 QoS Data frame and the intended receiver has confirmed storing A3 and/or A4 as described in 10.57 (Generation of PV1 MPDUs and header compression procedure) then DA and/or SA should not be present in either the A3 and/or A4 fields of the frame or in the DA and/of SA field(s) of the A-MSDU subframe header contained in the frame except when the DA and/or SA for the MSDU contained in the frame or in the A-MSDU subframe are different from the stored values.

(#3422)A MAC service tuple with a destination address that is a group address passed to a root AP from the DS, or received at an S1G relay STA via the WM, is forwarded via the WM using a 3-address frame format.

The addressing of a 3-address frame shall be as follows in this case:

- Address 1 is the DA of the MSDU (the group address)


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— Address 2 is the MAC address of the AP (the BSSID)
— Address 3 is the SA of the MSDU (the source address of the group addressed MSDU)

Group addressed MSDUs received via the WM at an S1G relay AP are not forwarded to the WM as a broadcast transmission, but are instead forwarded to the S1G relay STA as specified in 10.3.6 (Group addressed MPDU transfer procedure). Therefore, group addressed MSDUs in a relay network first travel to the root AP as an individually addressed transmission, after which they travel down the tree as group transmissions by the S1G root AP and the S1G relay AP(s).

### 10.53.5 Procedures of TXOP sharing for S1G relay operation

#### 10.53.5.1 General

An S1G STA that supports TXOP sharing procedure may set the Relayed Frame field in the Frame Control field of PV1 QoS Data frames (defined in 9.8 (MAC frame format for PV1 frames)(#1358)), the Relayed Frame field in NDP Ack frames, and the Order field in the Frame Control field of an S1G RTS frame to 1. Otherwise, it shall set the Relayed Frame field or Order field in any frame to 0 unless the frame is an NDP Ack frame used for flow control as described in 10.60 (S1G flow control). The S1G STA may use TXOP sharing to transmit to the S1G relay (S1G relay AP or S1G relay STA) either one PV1 QoS Data frame in the TXOP or the last PV1 QoS Data frame of the TXOP where the TXOP is obtained as described in 10.23.2.4 (Obtaining an EDCA TXOP) and the PV1 QoS Data frame has the Ack Policy Indicator subfield equal to 0 and is carried in an MPDU or in an S-MPDU.

Reception of a valid PV1 QoS Data frame with the Relayed Frame field equal to 1 or of an S1G RTS frame with the Order field equal to 1 indicates a relay-shared TXOP.

An S1G STA indicates support of TXOP sharing with implicit Ack using the TXOP Sharing Implicit Ack Support subfield of the S1G Capabilities Information field in the S1G Capabilities element. If dot11TXOPSharingImplicitACKImplemented is true, the S1G STA shall set the TXOP Sharing Implicit Ack Support subfield to 1 in transmitted frames containing the S1G Capabilities element. Otherwise, the S1G STA shall set the TXOP Sharing Implicit Ack Support subfield to 0.

A non-S1G STA shall not perform TXOP sharing.

An S1G relay entity shall not perform TXOP sharing if the S1G relay STA and S1G relay AP are operating in different primary channels for the duration of the TXOP. An S1G relay that performs TXOP sharing shall use a channel width that is the same or narrower than the channel width indicated by the STA that initiated the TXOP.

The sequence of frames exchanged over the first hop and second hop during a relay-shared TXOP depends on the acknowledgment procedure used by the S1G relay.

When an S1G relay (S1G relay STA or S1G relay AP) receives a valid PV1 QoS Data frame with the Relayed Frame field in the Frame Control field equal to 1, the S1G relay may acknowledge the received PV1 QoS Data frame using the implicit or explicit Ack procedure. The S1G relay shall not acknowledge the (#1939)received PV1 QoS Data frame using either implicit or explicit Ack procedure if the Relayed Frame field in the Frame Control field is equal to 0 in the received PV1 QoS Data frame.

NOTE—The frames transmitted over the first hop and second hop can be sent at two different MCSs.

For error recovery purposes, during a relay-shared TXOP, the TXOP owner may transmit its next PPDU when the CS mechanism (see 10.3.2.1 (CS mechanism)) indicates that the medium is idle at the TxPIFS slot boundary (defined in 10.3.7 (DCF timing relations)) (this transmission is a continuation of the current TXOP or SP).

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### 10.53.5.2 Explicit Ack procedure

Throughout this subclause, a Response Indication of Long Response is signaled in an NDP Ack frame by setting the Idle Indication field to 1 and the Duration field to 0 and a Response Indication of No Response is signaled by setting the Idle Indication field to 0 and the Duration field to 0 (see 10.3.2.17 (Response Indication procedure)).

(#111)In order to start a relay-shared TXOP, a non-AP STA (AP) sends a PV1 QoS Data frame addressed to the S1G relay AP (S1G relay STA) with the Relayed Frame field equal to 1. (#111)In order to use the explicit Ack procedure, an S1G relay AP (S1G relay STA) addressed by an RTS frame shall respond with an NDP CTS frame with the Duration field set as described in 10.53.5.4 (Relay-shared TXOP protection mechanisms).

When using the explicit Ack procedure, the S1G relay AP (S1G relay STA) shall signal a Response Indication of Long Response in the NDP Ack frame that is transmitted as an acknowledgment to the non-AP STA (AP). In addition it shall set the Relayed Frame field of the NDP Ack frame to 1. Otherwise, it shall signal a Response Indication of No Response in the NDP Ack frame and shall set the Relayed Frame field to 0.

When using the explicit Ack procedure, the S1G relay STA (S1G relay AP) shall forward the previously received PV1 QoS Data frame to the AP (non-AP STA), SIFS after the S1G relay AP (S1G relay STA) sent the NDP Ack frame to the non-AP STA (AP). In addition, the S1G relay STA (S1G relay AP) may protect the forwarded frame with a protection mechanism such as RTS/CTS exchange. Upon receipt of the relayed PV1 QoS Data frame, the AP (non-AP STA) shall transmit an NDP Ack frame to the S1G relay STA (S1G relay AP), which shall signal a Response Indication of No Response terminating this relay-shared TXOP.

NOTE—The description above applies to both uplink and downlink procedures with the non-AP STA (AP), i.e., either the non-AP STA or the AP is the TXOP owner for the TXOP sharing session.

### 10.53.5.3 Implicit Ack procedure

A STA that supports implicit Ack procedure and intends to transmit a frame to a next hop STA via an S1G relay (S1G relay STA or S1G relay AP) using the implicit Ack procedure needs to enable the implicit Ack procedure (and acquire the required information to operate using implicit Ack) with the S1G relay. The implicit Ack procedure is enabled between the STA and the S1G relay (S1G relay STA or S1G relay AP) if

- The STA is an AP to which the S1G relay STA of the S1G relay is associated and the S1G relay STA has successfully transmitted to the AP a STA Information Announcement frame containing the AID that the S1G relay AP of the S1G relay has assigned to the next hop non-AP STA.
  - The S1G relay STA may transmit a STA Information Announcement frame to its associated AP that supports the implicit Ack procedure when the S1G relay AP either assigns an AID to the next hop non-AP STA during association or changes the AID of the non-AP STA as described in 10.20 (S1G dynamic AID assignment operation).
  - The AP shall determine the PARTIAL_AID of the next hop non-AP STA as described in 10.21 (Group ID, partial AID, Uplink Indication, and COLOR in S1G PPDUs) using the BSSID of the S1G relay AP's BSS and the AID of the next hop non-AP STA to be able to use the implicit Ack procedure.
- The STA is a non-AP STA that is associated to the S1G relay AP and the S1G relay AP has transmitted to the STA an S1G Relay element with the Parent AP BSSID field containing the BSSID of the BSS of the parent AP with which the S1G relay STA of the S1G relay is associated.
  - The non-AP STA shall determine the PARTIAL_AID and the COLOR of the next hop AP as described in 10.21 (Group ID, partial AID, Uplink Indication, and COLOR in S1G PPDUs) using the BSSID and COLOR values used by the next hop AP to be able to use the implicit Ack procedure.


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After the implicit Ack procedure is enabled and all the required information is acquired as described above, the implicit Ack may be used to acknowledge eliciting PV1 QoS Data frames carried in S1G_SHORT/S1G_LONG PPDUs (i.e., that contain a PARTIAL AID, UPLINK_INDICATION, and COLOR in their PHY header).

(#111)In order to share the TXOP with the S1G relay, a STA may start the TXOP by sending to the S1G relay an S1G RTS frame with the Order field set to 1 or a PV1 QoS Data frame that has the Relayed Frame field set to 1. An S1G relay (S1G relay STA or S1G relay AP) that is the intended receiver of the S1G RTS frame which intends to use the implicit Ack procedure shall respond with an NDP CTS frame with the Duration field set as described in 10.53.5.4 (Relay-shared TXOP protection mechanisms).

When an S1G relay receives a PV1 QoS Data frame during a relay-shared TXOP, the S1G relay may directly forward the received frame without sending back an acknowledgment frame to the transmitter of the frame. If the PV1 QoS Data frame was preceded by an RTS frame then the S1G relay should protect the forwarded frame by sending an RTS frame to the intended receiver as described in 10.53.5.4 (Relay-shared TXOP protection mechanisms).

If the MPDU is transmitted by a non-AP STA (#1414)that is associated to an S1G relay AP, to the AP, then the S1G relay AP forwards the received MPDU to the AP to which it is associated, using SIFS. After transmitting the MPDU, the non-AP STA shall wait for an AckTimeout interval to detect a PPDU that would acknowledge the reception of the MPDU as described in 10.3.2.11 (Acknowledgment procedure). An indication of reception allows the frame exchange sequence(#109) to continue, or to end without retries, as appropriate for the particular frame exchange sequence(#109) in progress.

If the MPDU is transmitted by an AP to an S1G relay STA, then the S1G relay STA forwards the received MPDU to the non-AP STA that is associated to the S1G relay AP, using SIFS. After transmitting the MPDU, the AP shall wait for an AckTimeout interval to detect a PPDU that would acknowledge the reception of the MPDU as described in 10.3.2.11 (Acknowledgment procedure). An indication of reception allows the frame exchange sequence(#109) to continue, or to end without retries, as appropriate for the particular frame exchange sequence(#109) in progress. If the RA of the forwarded MPDU is different from the DA of the MPDU transmitted by the AP, then the S1G relay STA shall use the explicit Ack procedure.

### 10.53.5.4 Relay-shared TXOP protection mechanisms

An S1G STA that supports TXOP sharing should initiate a relay-shared TXOP by sending an S1G RTS frame as the first frame in the exchange under EDCA. The S1G STA may set the Order field of the RTS frame to 0 to indicate that the duration of the initiated TXOP is limited as described in 10.23.2.9 (TXOP limits) and that it expects an NDP CTS frame whose Duration field is set as described in 10.3.2.9 (CTS and DMG CTS procedure). Otherwise, it may set the Order field to 1 to indicate that the duration of the initiated TXOP can be extended (i.e., it is not necessarily limited as described in 10.23.2.9 (TXOP limits)) and that it expects an NDP CTS frame whose Duration field is set as described in this subclause.

An S1G relay that is the intended receiver of the S1G RTS frame with the Order field equal to 1 and intends to use the relay-shared TXOP responds with an NDP CTS frame with a value of the Duration field that depends on the acknowledgment procedure it shall use during this relay-shared TXOP:

— If explicit Ack procedure (see 10.53.5.2 (Explicit Ack procedure)) then the Duration field of the NDP CTS frame shall be set to a value $D$:

$$T_{\text{RTS}} + T_{\text{PENDING}} - T_{\text{CTS}} \leq D \leq T_{\text{TXOP\_REMAINING}} - T_{\text{PPDU}}$$

where

$T_{\text{RTS}}$ is the value obtained from the Duration/ID field of the S1G RTS frame that elicited the response

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| | |
|---|---|
| $T_{CTS}$ | is the time, in microseconds, between the end of the PPDU carrying the RTS frame and the end of the NDP CTS frame |
| $T_{PENDING}$ | is the estimated time required for the transmission of the frame to be forwarded, its response if required, protection frame exchange sequences(#109) if required, plus applicable IFS durations |
| $T_{TXOP\_REMAINING}$ | is equal to any $T_{TXOP}$ as defined in 9.2.5.2 (Setting for single and multiple protection under enhanced distributed channel access (EDCA)) minus $T_{RTS}$ |
| $T_{PPDU}$ | is the time required for transmission of the current PPDU |

— If implicit Ack procedure (see 10.53.5.3 (Implicit Ack procedure)), then the Duration/ID field of the NDP CTS frame shall be set according to 9.2.5.6 (Setting for control response frames). When using the implicit Ack procedure, upon reception of a PV1 QoS Data frame that is preceded by the transmission of an NDP CTS frame as described above, the S1G relay (S1G relay STA or S1G relay AP) should protect the PV1 QoS Data frame transmission with an RTS/CTS protection mechanism. The Duration/ID field of the RTS frame shall be less than or equal to $T_{TXOP}$ for that AC, as defined in 9.2.5.2 (Setting for single and multiple protection under enhanced distributed channel access (EDCA)), minus the estimated time since the start of the reception of the RTS frame with the Order field equal to 1 that was sent by the relay-shared TXOP owner.

An S1G relay (S1G relay STA or S1G relay AP) that uses the relay-shared TXOP may transmit an (NDP) CF-End frame after successfully forwarding the PV1 QoS Data frame if the remaining duration is long enough to transmit this frame.

An S1G relay that is the intended receiver of the S1G RTS frame with the Order field equal to 0 responds with an NDP CTS frame as described in 10.3.2.9 (CTS and DMG CTS procedure).

### 10.53.6 S1G relay discovery procedure

A single hop link is an one-hop link between a non-AP STA and the root AP.

A relay link is a multi-hop link between a non-AP STA performing an active scan for S1G relays, and the S1G root AP through the S1G relay.

A non-AP STA that performs active scanning may use the Probe Request frame with an S1G Relay Discovery element when relay discovery procedure is implemented. A non-AP STA with dot11RelayDiscoveryOptionImplemented equal to true may transmit a Probe Request frame including an S1G Relay Discovery element with link budget information for the single hop link and additional QoS requirements for the relay link. This information shall be conveyed using the S1G Relay Discovery element as defined in 9.4.2.206 (S1G Relay Discovery element) if present. The formulas for calculating link budget and QoS requirements are implementation specific.

An S1G relay with dot11RelayDiscoveryOptionImplemented equal to true that receives a Probe Request frame becomes eligible to be an S1G relay for this non-AP STA if the link budget and QoS requirements are met and the SSID and other capability parameters match. If these requirements are met, an S1G relay may respond to the non-AP STA with a Probe Response frame, or a PV1 Probe Response frame as an S1G relay candidate for this non-AP STA. When a non-AP STA uses the S1G Relay Discovery element to indicate the DL/UL maximum/minimum/mean data rates of the direct link or the Delay Bound Requirement of the connection through the S1G relay in the Probe Request frame, the S1G relay may also use those parameters as the criteria of responding to the Probe Request frame. The principle for this operation is to reduce the number of Probe Response, or PV1 Probe Response frames sent from S1G relays.

An S1G relay may optionally include link budget information along with other information in S1G Relay Discovery elements such as DL/UL maximum/minimum/mean data rates, relay STA count or channel


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utilization information in a Probe Response frame, a PV1 Probe Response frame, or a Beacon frame. This information is used for the non-AP STA, when multiple Probe Response, or PV1 Probe Response, frames are received, to select an S1G relay among multiple S1G relay candidates.

An S1G relay with dot11RelayDiscoveryOptionImplemented equal to true that receives a Probe Request frame with the S1G Relay Discovery element from a non-AP STA may respond to the non-AP STA with a probe response frame with the S1G Relay Discovery element carrying the Information Not Available field set to 1 to indicate that for the remaining duration of the current association it will not provide any requested relay discovery information.

## 10.54 Group AID

An S1G STA with dot11GroupAIDActivated equal to true supports the implementation of group addressed traffic delivery using group AID. An S1G STA with dot11GroupAIDActivated equal to true shall set the Group AID Support subfield in the S1G Capabilities element it transmits to 1. Otherwise, it shall set it to 0.

A group AID is an AID that is assigned by an S1G AP to identify a group of S1G STAs. A group AID corresponds to a bit in the traffic-indication virtual bitmap. An S1G AP signals the presence of group addressed BUs that correspond to a group AID using the same signaling as the signaling of individually addressed BUs, i.e., the AP sets the bit corresponding to the group AID in the traffic-indication virtual bitmap to 1 when BUs are present, and sets it to 0 otherwise.

(#334)An S1G AP shall not follow this subclause to transmit a group addressed frame to a STA that has not requested delivery using a group AID for that group address.

An S1G STA with dot11GroupAIDActivated equal to true that has a (#1653)group address may request a group AID from the S1G AP to which it is associated to by sending an AID Switch Request frame. (#1046)A SIFS after receiving the AID Switch Request frame, the S1G AP that supports group AID responds with an AID Switch Response frame that contains the assigned group AID that corresponds to that (#1653)group address and the group listen interval as described in 10.20 (S1G dynamic AID assignment operation). The S1G AP may assign different group AIDs to S1G STAs that have the same (#1653)group address but different group listen intervals. The S1G STA should maintain the link between the assigned group AID to its (#1653)group address and group listen interval.

An S1G AP that has negotiated a group AID shall indicate the presence of group addressed BUs corresponding to the group AID in the TIM included in the S1G Beacon frame that is sent every group listen interval, following the expiration of a counter that corresponds to the AID Switch Count field included in the AID Response element containing the group AID and that started upon transmission of that element.

An S1G STA that has negotiated a group AID and has not negotiated TWTs (see 10.46 (Target wake time (TWT))) shall transition to awake state(#6038) every group listen interval that corresponds to the group AID to receive the S1G Beacon frame, starting from the TBTT or TSBTT that follows the expiration of a counter that corresponds to the AID Switch Count field included in the AID Response element containing the group AID and that started upon receipt of that element. An S1G STA that has negotiated both group AID and TWTs wakes at specific target wake times as defined in 10.46 (Target wake time (TWT)).

For example, when S1G AP with dot11PageSlicingActivated equal to true has data buffered for a group of S1G STAs with dot11PageSlicingActivated equal to true that belong to a group AID, it indicates this condition in the Page Slice element (9.4.2.191 (Page Slice element)) transmitted in a DTIM beacon(#3309). The S1G STAs that detect this indication will transition to awake state(#6038) at the assigned beacon interval to determine the TIM and extract the assigned time slots that carry the buffered group data. The S1G AP transmits the buffered group data within the assigned time slots for the S1G STAs' reception.

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The S1G AP that has indicated the presence of group addressed BUs for a given group AID in an S1G Beacon frame shall deliver these BUs using a (#7012)PV0 frame with the group address that corresponds to the group AID in the A1 field (see 9.8.3.2 (Address fields)) and setting the partial AID as described in 10.21 (Group ID, partial AID, Uplink Indication, and COLOR in S1G PPDUs). These group addressed frames should be delivered during the beacon interval or short beacon interval that follows the S1G Beacon frame or within negotiated TWT SPs if that group AID is assigned to a non-AP STA that follows 10.46 (Target wake time (TWT)).

(#7012)NOTE—An S1G STA that has a group AID assigned for a particular group address may receive duplicate group addressed BUs due to different group delivery procedures.

## 10.55 Traveling pilot operation

An S1G STA with dot11S1GTravelingPilotOptionActivated equal to true shall set the Traveling Pilot Support field in the S1G Capabilities Info field of the S1G Capabilities element, as described in 9.4.2.199 (S1G Capabilities element) to

— 1 if reception of traveling pilots is supported only for one space-time stream
— 3 if reception of traveling pilots is supported for both one and two space-time streams

An S1G STA with dot11S1GTravelingPilotOptionActivated equal to false shall set the Traveling Pilot Support field in the S1G Capabilities element to 0.

An S1G STA shall not transmit a PSDU with the TXVECTOR parameter TRAVELING_PILOTS equal to 1 to an S1G STA unless the Traveling Pilot Support field of the S1G Capabilities element received from that STA contained a value of 1 or 3 and dot11S1GTravelingPilotOptionActivated is true (if there is more than one intended receiver, then this requirement applies for each intended receiver).

## 10.56 Bitmap protection for NDP BlockAck frames

NDP BlockAck frames are protected by the 4 bit CRC of the S1G SIG-A field, which might not be enough to protect the BlockAck Bitmap field contained in the frame. This subclause describes a mechanism that offers increased protection for the BlockAck Bitmap field of NDP BlockAck frames.

The originator of an NDP BlockAck (NDP_1M BlockAck or NDP_2M BlockAck) frame (see 23.3.12.2.6 (NDP BlockAck)) shall protect the BlockAck Bitmap field of the NDP BlockAck frame (shown in Figure 23-22 (NDP CMAC PPDU body field of the NDP_1M CTS frame) and Figure 23-23 (NDP CMAC PPDU body field of the NDP_2M CTS frame)) by using the encoding procedure defined in this subclause.

Initially the bit sequences [B3: B10] for NDP_1M BlockAck and [B3:B18] for NDP_2M BlockAck frames are set as described in 10.25.6.5 (Generation and transmission of BlockAck frames by an HT STA, DMG STA, or S1G STA) or 10.3.2.12 (Fragment BA procedure). Then, prior to transmission, the originator encodes the bit sequences following the procedure below.

Encoding procedure:

For an NDP_1M BlockAck frame:
— [B3: B10] = XOR([B3: B10], [B17: B24]);

For an NDP_2M BlockAck frame
— [B3: B18] = XOR([B3: B18], [B21: B36]);


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The intended recipient shall perform the same procedure to decode the bit sequences [B3: B10] for NDP_1M BlockAck and [B3:B18] for NDP_2M BlockAck frames.

## 10.57 Generation of PV1 MPDUs and header compression procedure

An S1G STA that sets the STA Type Support subfield in a transmitted S1G Capabilities element to 0 or 1, as described in 10.62 (S1G BSS type and STA type), shall set the PV1 Frame Support subfield in the S1G Capabilities element to 1. An S1G STA that sets the STA Type Support subfield in a transmitted S1G Capabilities element to 2 may set the PV1 Frame Support subfield in the S1G Capabilities element to 0.

An S1G STA shall not transmit PV1 MPDUs with the Type subfield equal to 0, 1 or 3 to a peer STA unless the PV1 Frame Support subfield of the S1G Capabilities element received from the peer STA contained a value of 1. An S1G STA with dot11PV1MACHeaderOptionImplemented equal to true shall use the PV1 format instead of the PV0 format to transmit QoS Data, Action, and Action No Ack frames that are individually addressed to a peer STA from which it has received an S1G Capabilities element with PV1 Frame Supported subfield equal to 1.

A non-S1G STA shall not transmit a PV1 frame.(#1632)(#7012)

The header compression procedure enables S1G STAs to store addresses and/or update security parameters at the receiver. An S1G STA with dot11PV1MACHeaderOptionImplemented equal to true shall set dot11RSNAProtectedManagementFramesActivated to true and dot11RSNAUnprotectedManagementFramesAllowed to false.

An S1G STA with dot11PV1MACHeaderOptionImplemented equal to true may include a Header Compression element in Header Compression frames. The STA may include the Header Compression element in (Re)Association Request frames and (Re)Association Response frames when management frame protection is not negotiated for the association. The STA may set the PV1 Data Type 3 Supported subfield in the Header Compression element to 1 to indicate that it supports reception of PV1 frames that have the Type subfield in the Frame Control field equal to 3.

After association, an S1G STA with dot11PV1MACHeaderOptionImplemented equal to true may transmit Header Compression frames and PV1 frames. An S1G STA shall not transmit PV1 frames with Type subfield equal to 3 to a peer STA unless the PV1 Data Type 3 Supported subfield is 1 in the most recently received Header Compression element sent by the peer STA. An S1G STA in an IBSS shall not transmit PV1 frames with a value of the Type subfield equal to 0 or 1.

NOTE—A PV1 frame is an MPDU with Protocol Version field in the Frame Control field equal to 1 (see 9.8 (MAC frame format for PV1 frames)(#1358)).

The header compression procedure uses a Header Compression element, which is referred to as a header compression request or a header compression response, depending on the Request/Response subfield setting of the Header Compression element.

A STA that transmits PV1 frames with Type subfield equal to 0 shall include the A3 field if the value of this field

- Is not equal to the address identified by the A1 field and an A3 is not stored at the receiver.
- Is not equal to the A3 stored at the receiver.

Otherwise, the A3 field shall not be included in the frame.

A STA that transmits PV1 frames with Type subfield equal to 0 shall include the A4 field if the value of this field

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— Is not equal to the address identified by the A2 field and an A4 is not stored at the receiver.
— Is not equal to the A4 stored at the receiver.

Otherwise, the A4 field shall not be included in the frame.

An S1G STA indicates a request to store address fields by sending a header compression request with the Store A3 and/or Store A4 subfields equal to 1. Upon receipt of such a request, the receiving STA shall respond with a header compression response indicating which of the optional fields it stores, by setting the Store A3 and/or Store A4 subfields in the transmitted header compression response to 1. Stored address fields can subsequently be omitted from the MAC header of PV1 frames transmitted by the STA that sent the header compression request. Address A3 and/or A4 fields for which the header compression response indicated 0 are not stored at the receiver and cannot be omitted by the transmitter when the A3 and/or A4 fields contain values that are different from the A1 and/or A2 fields of the same. (#7012)The receiver stores one A3 and one A4 per transmitter. The stored A3 and A4 addresses shall be used at the receiver for all frames from the transmitter that omit the stored addresses.

An S1G STA indicates a request to update security parameters by sending a header compression request with the CCMP Update subfield equal to 1. The receiver STA shall respond with a header compression response acknowledging receipt of the updated security parameters. The receiver STA shall compare the received BPN value to the current locally stored BPN value. If the received BPN value is greater than the locally stored BPN value, the receiver STA shall update the locally stored BPN value. Otherwise, the receiver STA shall not update the locally stored BPN value.

After sending a header compression request, an S1G STA shall postpone the transmission of PV1 frames that do not include the fields that were requested to be stored to the recipient of the header compression request until it receives the corresponding header compression response.

After receiving a header compression request, an S1G STA shall store and activate the included addresses it intends to store and/or the security information included in the header compression request before transmitting the corresponding header compression response.

When no header compression response has been received in response to a header compression request within dot11HeaderCompressionResponseTimeout, an S1G STA shall transmit another header compression request.

A STA that receives a PV1 frame with one or more compressed addresses that it has not stored or which causes a decryption error should transmit an unsolicited header compression response to the transmitter of the PV1 frames, in which the Store A3, and Store A4 fields are all equal to 0. The unsolicited header compression response shall (#7012)specify the SN space of the received PV1 frame using the PTID subfield and Management subfield of the CCMP Update field if the received frame caused a decryption error, where the CCMP Update field shall indicate the stored values for the BPN and (#3493)key ID that correspond to the received PV1 frame.

A STA that has previously transmitted PV1 frames of a given (#7012)SN space to a peer STA and that receives an unsolicited header compression response from the peer STA relative to that (#7012)SN space shall transmit a header compression request to the transmitter of the header compression response. The header compression request shall include all the addresses that the transmitting STA requests to be stored at the receiver and/or the security information that corresponds to the indicated (#7012)SN space.

## 10.58 Transmission of an NDP CMAC PPDU

An S1G STA transmitting an NDP CMAC PPDU shall use the following TXVECTOR parameters:
— NDP_INDICATION set to 1


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- NUM_STS indicates one space-time stream
- APEP_LENGTH set to 0
- NUM_USERS set to 1

An S1G STA in an IBSS shall not transmit an NDP CMAC PPDU, except for an NDP Ack, NDP BlockAck or NDP Probe Request frame.

## 10.59 S1G_Long operation

An S1G STA with dot11S1GLONGOptionActivated equal to true shall set the S1G_LONG Support field in the S1G Capabilities element to 1. An S1G STA with dot11S1GLONGOptionActivated equal to false shall set the S1G_LONG Support field in the S1G Capabilities element to 0.

An S1G STA shall not transmit a PSDU with the TXVECTOR parameter PREAMBLE_TYPE set to S1G_LONG_PREAMBLE to an S1G STA unless the S1G_LONG Support field of the S1G Capabilities element received from that STA contained a value of 1 and dot11S1GLONGOptionActivated is true.

## 10.60 S1G flow control

This subclause describes flow control operation for an S1G STA.

NOTE 1—The S1G relay operation can use the flow control mechanism described in this subclause to prevent from the overflow condition.

A STA that supports flow control shall set the Flow Control Supported subfield to 1 in the S1G Capabilities element it transmits. An S1G AP that implements flow control may refuse (re)association or can disassociate a non-AP STA that sets the Flow Control Supported subfield to 0 in the S1G Capabilities element. The S1G AP that refuses (re)association or disassociates the STA shall set the Status Code field in the (Re)Association Response frame or in the Disassociation frame to FLOW_CONTROL_OPERATION_SUPPORTED.

A STA that sets the Flow Control Supported subfield to 1 in the S1G Capabilities element that it transmits may instruct a second STA that sets the Flow Control Supported subfield to 1 in the S1G Capabilities element that it transmits to stop sending Data frames using a flow-control instruction. The STA sending the flow-control instruction is called the flow-controlling STA. A STA that sets the Flow Control Supported subfield to 0 in the S1G Capabilities element that it transmits shall not instruct a second STA to stop sending Data frames using a flow-control instruction as described in this subclause. A STA that is the intended recipient of a flow-control instruction and that correctly receives that instruction is called a flow-controlled STA. A flow-controlled STA does not transmit any Data frames to the flow-controlling STA that transmitted the flow-control instruction, for the amount of time indicated in the flow-control instruction. A flow-control instruction is any of the following:

- A Flow Suspension frame
- A BAT frame with the Flow Control bit in the Frame Control field equal to 1
- A TACK frame with the Flow Control bit in the Frame Control field equal to 1
- A STACK frame with the Flow Control bit in the Frame Control field equal to 1
- An NDP Ack frame with the Relayed Frame field equal to 1 and the Idle Indication field equal to 1 and the Duration field not equal to 0

NOTE 2—The transmission of BAT frames, STACK frames, TACK frames is only permitted within TWT SP as described in 10.46 (Target wake time (TWT)), 10.25 (Block acknowledgment (block ack)), and 10.3.2.11 (Acknowledgment procedure).

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The Suspend Duration field of the Flow Suspension frame listed above indicates the length of time during which a flow-controlled STA shall not transmit Data frames to the flow-controlling STA identified by the TA field of the Flow Suspension frame.

The Suspend Duration field of the TACK/BAT/STACK frame listed above indicates the length of time during which a flow-controlled TWT STA shall not transmit Data frames to the flow-controlling STA identified by the TA field of the TACK/BAT frame and the RA field of the frame that elicited the STACK frame.

The Duration field of the NDP Ack frame listed above indicates the length of time during which a flow-controlled STA shall not transmit Data frames to the flow-controlling STA identified by the RA field of the frame that elicited the NDP Ack frame.

A flow-controlled STA may resume transmission of Data frames addressed to the flow-controlling STA that had previously suspended transmission after the expiration of the time indicated in the Suspend Duration field of a Flow Suspension frame, TACK frame, BAT frame, or TACK frame or in the Duration field of an NDP Ack frame.

A flow-controlling STA may send a Flow Resumption frame to cancel any outstanding flow suspension time for the flow-controlling STA identified by the TA field of the Flow Resumption frame.

A flow-controlled STA that receives a Flow Resumption frame with a BSSID that matches the BSSID of the BSS of which the flow-controlled STA is a member or with an RA field that matches the address of the flow-controlled STA shall cancel any outstanding flow suspension time, and may resume transmission of Data frames to the flow-controlling STA identified by the TA field of the Flow Resumption frame.

A STA should send a next TWT value in the Next TWT Info/Suspend Duration field of the response frame it transmits to a TWT STA if the More Data bit is equal to 0 in the eliciting frame. A STA may send a suspend time value in the Next TWT Info/Suspend Duration field of a response frame it transmits to a TWT STA if the More Data bit is equal to 1 in the eliciting frame.

## 10.61 Energy limited STAs operation

An S1G STA keeps two timers, ELMaxAwakeTimer and ELRecoveryTimer, for each EL STA; and these timers are initialized upon reception of an EL Operation element from the EL STA:

— The ELMaxAwakeTimer is set to 0.

— The ELRecoveryTimer is set to the value of the Recovery Time field of the EL Operation element.


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These timers uniformly count down to 0 when their values are nonzero. Figure 10-153 (EL STA operation) shows an example of the EL STA frame exchanges with the S1G STA.

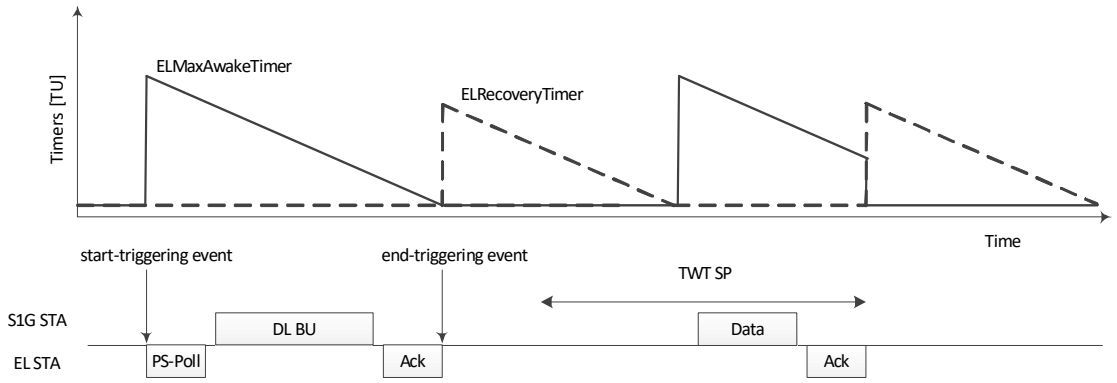


**Figure 10-153—EL STA operation**

The S1G STA shall not transmit to the EL STA, or cause the EL STA to transmit, a PPDU containing individually addressed frames and whose duration would exceed the value of the ELMaxAwakeTimer.

The S1G STA shall set the ELMaxAwakeTimer to the value of the Max Awake Duration field of the most recently received EL Operation element from the EL STA and the ELRecoveryTimer to 0 when a start-triggering event occurs (see Figure 10-153 (EL STA operation) for an example). A start-triggering event occurs when both ELMaxAwakeTimer and ELRecoveryTimer are 0, and one of the following events that identify a transition of the EL STA from doze to awake state occurs:

— An (NDP) PS-Poll or trigger frame sent by the EL STA is received by the S1G STA.
— A TWT starts for the EL STA, where the TWT corresponds to any TWT agreement that the EL STA has set up with the S1G STA.
— A RAW slot allocated for the EL STA starts, where the RAW slot is scheduled in a RAW scheduled for the EL STA by the S1G STA.
— A TBTT or TSBTT at which the EL STA has to be awake is due, where the TBTT or TSBTT is the time the S1G STA sends an S1G Beacon frame that is intended to be received by the EL STA.

NOTE—An EL STA can send a frame that is not a trigger frame to the S1G STA anytime and the reception of this frame from the S1G STA does not qualify as a start-triggering event.

The S1G STA shall not schedule a transmission of a PPDU carrying an individually addressed MPDU intended for the EL STA, or cause the EL STA to transmit an individually addressed frame until the ELRecoveryTimer has reached 0.

The S1G STA shall set the ELRecoveryTimer to the value of the Recovery Time field of the most recently received EL Operation element from the EL STA and the ELMaxAwakeTimer to 0 when an end-triggering event occurs (see Figure 10-153 (EL STA operation) for an example). An EL STA may indicate the recovery duration in the Duration field of an NDP (PS-Poll-)Ack frame with the Idle Indication field set to 1. An end-triggering event occurs when the ELRecoveryTimer is 0 and one of the following events that identify a transition of the EL STA to doze state occurs:

— An acknowledgment is received from the EL STA as a response to the transmission of a BU, where the BU is sent by the S1G STA in response to an (NDP) PS-Poll or trigger frame generated by the EL STA.

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- An acknowledgment is received from the EL STA as a response to of a frame with EOSP field equal to 1, where the frame is sent by the S1G STA.
- An NDP (PS-Poll-)Ack frame is received from the EL STA as a response to a frame generated by the S1G STA, where the NDP (PS-Poll-)Ack frame has an Idle Indication field equal to 1 and a nonzero value of the Duration field.
  - In this case, the ELRecoveryTimer is set to the value of the Duration field of the NDP (PS-Poll-)Ack frame when the Idle Indication field is 1.
- The AdjustedMinimumTWTWakeDuration for a TWT has ended, where the TWT corresponds to any TWT agreement that the EL STA has set up with the S1G STA.
- The RAW slot allocated for the EL STA has ended, where the RAW slot was scheduled in a RAW for the EL STA by the S1G STA.
- The transmission of an S1G Beacon frame has ended, where the S1G Beacon frame is sent at a TBTT or TSBTT at which the EL STA was expected to be awake.
- The transmission of group addressed BU(s) has ended, where the group addressed BU(s) are expected to be received by the EL STA following a DTIM (#1000)beacon.

When the S1G STA cannot complete frames exchanges within ELMaxAwakeTimer, a new backoff procedure is invoked after stopping the current transmission and once the ELRecoveryTimer has expired.

## 10.62 S1G BSS type and STA type

(#306)Non-AP S1G STAs are categorized into two types, sensor STAs and non-sensor STAs.

A non-AP STA that is a sensor STA shall set the STA Type Support subfield in the S1G Capabilities element it transmits to 1. A non-AP STA that is a non-sensor STA shall set the STA Type Support subfield in the S1G Capabilities element it transmits to 2.

There are three types of S1G BSS that an S1G AP can set up: sensor BSS, non-sensor BSS, or mixed BSS. A sensor BSS only supports sensor STAs. A non-sensor BSS supports only non-sensor STAs. A mixed BSS supports both sensor STAs and non-sensor STAs.

An AP may declare a non-sensor BSS by transmitting the S1G Capabilities element in Beacon frames, Probe Response, or PV1 Probe Response frames in which the STA Type Support subfield is 2 (i.e., it indicates that only non-sensor STAs are allowed to associate and operate with that AP).

An AP may declare a sensor BSS by transmitting the S1G Capabilities element in Beacon frames, Probe Response frames, or PV1 Probe Response frames in which the STA Type Support subfield is 1 (i.e., it indicates that only sensor STAs are allowed to associate and operate with that AP).

An AP may declare a mixed BSS by transmitting the S1G Capabilities element in a Beacon, Probe Response or PV1 Probe Response frame, in which the STA Type Support subfield is 0 (i.e., it indicates that any type of STA is allowed to associate and operate with that AP).

An S1G AP that indicates support for sensor STAs shall not indicate minimum MCS restrictions as specified in 10.6.14.3 (Additional rate selection constraints for S1G PPDUs).


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## 10.63 DBC mechanism for CDMG STAs

### 10.63.1 General

A CDMG STA supports the operation of variable bandwidth channels according to the channelization specified in Annex E.1. A CDMG infrastructure BSS or PBSS can operate on a 1.08 GHz or 2.16 GHz bandwidth channel. As specified in Annex E.1, each 2.16 GHz channel encompasses two 1.08 GHz channels. A CDMG infrastructure BSS or PBSS shall use the following DBC mechanism when operating in the country that requires the support of variable bandwidth channels operation to mitigate interference between other CDMG and DMG BSSs.

A CDMG AP or PCP shall follow the procedures in 11.1.4.4.2 (Initializing a DMG BSS) to initialize a CDMG BSS on a 1.08 GHz or a 2.16 GHz bandwidth channel. An AP or PCP operating the BSS on a 1.08 GHz channel shall periodically transmit DMG Beacon frames (10.3.4.2 (Basic access)) on the 2.16 GHz channel that encompasses the 1.08 GHz channel on which the BSS is operating. A CDMG AP or PCP may change the operating bandwidth of its BSS dynamically from 1.08 GHz to 2.16 GHz or vice versa.

A CDMG AP or PCP may request the AP or PCP of an existing CDMG BSS operating on a 2.16 GHz channel (e.g., channel 2) to shift its operating channel to one of the 1.08 GHz channels (e.g., channel 35) within its original 2.16 GHz channel by sending a Channel Splitting Request frame (9.6.28.4 (Channel Splitting Request frame format)) or an Extended Channel Splitting Request frame (9.6.7.43 (Extended Channel Splitting Request frame format)). If the existing CDMG BSS changed its operating channel to one of the 1.08 GHz channels (e.g., channel 35), the CDMG AP or PCP that sends the request frame may then operate a new BSS on the other adjacent 1.08 GHz channel (i.e., channel 36) within the 2.16 GHz channel (i.e., channel 2).

A pair of CDMG APs or PCPs operating on the adjacent 1.08 GHz channels (e.g., channel 35 and channel 6) within a 2.16 GHz channel (i.e., channel 2) should maintain synchronization with each other to mitigate the interference caused by the transmission of the DMG Beacon frame and other frames on the 2.16 GHz channel (i.e., channel 2) according to 10.63.2.3 (Synchronization of CDMG infrastructure BSS or PBSSs on the adjacent 1.08 GHz channels within a 2.16 GHz channel).

### 10.63.2 CDMG channel access

#### 10.63.2.1 CDMG BSS operating on a 2.16 GHz channel

A CDMG AP or PCP operating an infrastructure BSS or PBSS on a 2.16 GHz channel (e.g., channel 2) shall follow the channel access rules as described in 10.38 (DMG and CMMG channel access).

#### 10.63.2.2 CDMG BSS operating on a 1.08 GHz channel

A CDMG AP or PCP operating an infrastructure BSS or PBSS on a 1.08 GHz channel (e.g., channel 35) shall periodically transmit DMG Beacon frames (9.3.4.2 (DMG Beacon)) on the 2.16 GHz channel (i.e., channel 2) that encompasses its operating channel (i.e., channel 35). The time interval between two consecutive DMG Beacon frames transmitted on the 2.16 GHz channel shall be no more than aMaxBIDuration. The generation of the DMG Beacon frames shall follow the rules in (11.1.3.3.3 (Beacon generation in a DMG infrastructure BSS)).

The AP or PCP that starts an infrastructure BSS or PBSS on a 1.08 GHz channel (e.g., channel 35) shall set a TSF timer to track the beacon interval on the encompassing 2.16 GHz channel (i.e., channel 2). At the beginning of a beacon interval on the 2.16 GHz channel, the AP or PCP shall schedule a notification period (NP) or a BHI (10.38.2 (Access periods within a beacon interval)) indicated by the DBC Option subfield of the Dynamic Bandwidth Control element (9.4.2.219 (Dynamic Bandwidth Control element)) contained in each DMG Beacon frame as shown in Figure 10-154 (Example of an AP or PCP that starts its infrastructure BSS or PBSS on channel 35 by transmitting DMG Beacon frames on both channel 2 and channel 35) and Figure 10-

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155 (Example of a CDMG AP or PCP that starts its infrastructure BSS or PBSS on channel 35 by transmitting DMG Beacon frames on channel 2 only), respectively. If a NP is scheduled on the 2.16 GHz channel, at least one BHI shall be scheduled on the 1.08 GHz channel. The NP may include the BTI, A-BFT, and ATI.

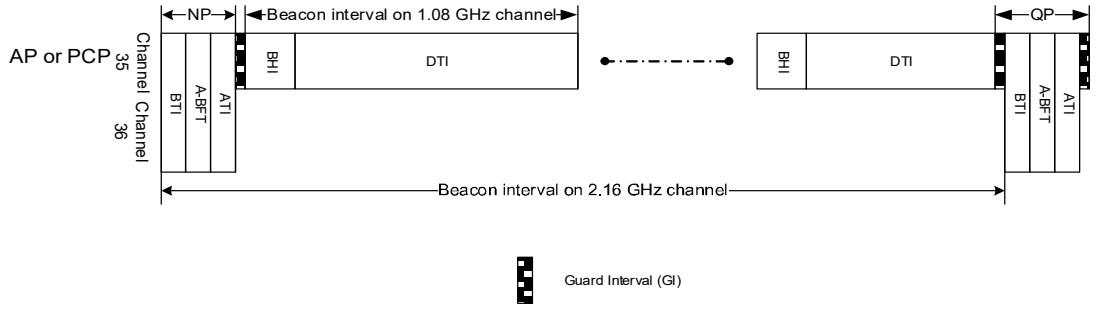


**Figure 10-154—Example of an AP or PCP that starts its infrastructure BSS or PBSS on channel 35 by transmitting DMG Beacon frames on both channel 2 and channel 35**

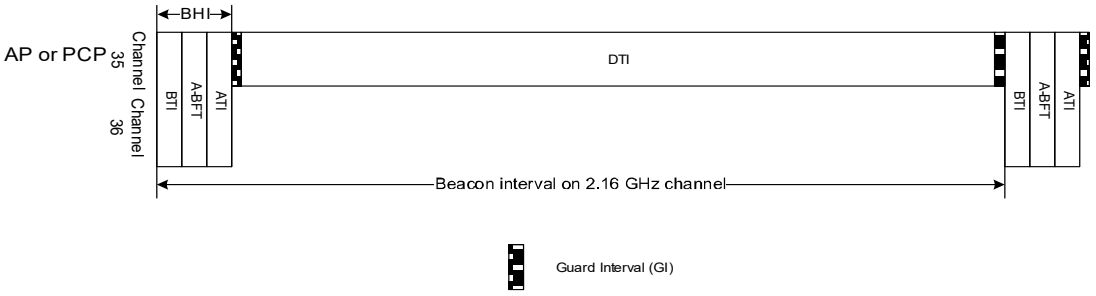


**Figure 10-155—Example of a CDMG AP or PCP that starts its infrastructure BSS or PBSS on channel 35 by transmitting DMG Beacon frames on channel 2 only**

During the BTI on the 2.16 GHz channel, the AP or PCP shall transmit a DMG Beacon frame containing the Dynamic Bandwidth Control element (9.4.2.219 (Dynamic Bandwidth Control element)) that includes information on the operating status of the BSS through the DBC Control field and Channel Number field. The beacon interval length on the 2.16 GHz channel is indicated by the Beacon Interval field (9.4.1.3 (Beacon Interval field)) contained in each DMG Beacon frame.

The AP or PCP may also establish an independent beacon interval on its operating 1.08 GHz channel and set another TSF timer to track it. As illustrated in Figure 10-154 (Example of an AP or PCP that starts its infrastructure BSS or PBSS on channel 35 by transmitting DMG Beacon frames on both channel 2 and channel 35), the beacon interval length on 1.08 GHz channel shall be set as an integer factor of the beacon interval length on 2.16 GHz channel in units of TUs. The maximum length shall be the beacon interval length on the 2.16 GHz channel. The channel access on the 1.08 GHz shall follow the rules described in 10.38 (DMG and CMMG channel access) with a BHI period within each beacon interval. If BHIs are present on the 1.08 GHz channel, the DBC Option subfield of the Dynamic Bandwidth Control element within the DMG Beacon frame is set to 0; otherwise, it is set to 1.

A guard interval (GI) that is an interframe space follows a NP/BHI on the 2.16 GHz channel as shown in Figure 10-154 (Example of an AP or PCP that starts its infrastructure BSS or PBSS on channel 35 by transmitting DMG Beacon frames on both channel 2 and channel 35) and Figure 10-155 (Example of a CDMG AP or PCP that starts its infrastructure BSS or PBSS on channel 35 by transmitting DMG Beacon frames on


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channel 2 only) for CDMG STAs to switch from transmitting and receiving frames on the 2.16 GHz channel to transmitting and receiving frames on the 1.08 GHz channel. The determination of the length of the GI is implementation dependent. At the end of the GI (or the NP/BHI if the GI is not present), the AP or PCP shall be ready to transmit or receive frames on the 1.08 GHz channel indicated by the Channel Number field of the Dynamic Bandwidth Control element.

If a CDMG AP or PCP transmits a DMG Beacon frame with the DBC Option subfield of the Dynamic Bandwidth Control element set to 0, it shall schedule quiet periods (QPs) on a 1.08 GHz channel by scheduling SPs with the AllocationType subfield set to 2 in the Allocation field and the Source AID subfield and Destination AID subfield set to its own AID. The starting times and durations of these QPs shall coincide with the starting times and durations of the NPs on the 2.16 GHz channel. The AP or PCP may also schedule the starting times of the QPs to be earlier than the NPs and the durations of the QPs to be greater than the durations of the NPs to establish a GI before and after each NP as shown in Figure 10-154 (Example of an AP or PCP that starts its infrastructure BSS or PBSS on channel 35 by transmitting DMG Beacon frames on both channel 2 and channel 35).

If a CDMG AP or PCP transmits a DMG Beacon frame with the DBC Option subfield of the Dynamic Bandwidth Control element set to 1, it may schedule QPs before and after the BHIs to serve as GIs as shown in Figure 10-155 (Example of a CDMG AP or PCP that starts its infrastructure BSS or PBSS on channel 35 by transmitting DMG Beacon frames on channel 2 only). The GIs in this case should be longer than the time taken for all the CDMG STAs to switch from transmitting and receiving frames on the 2.16 GHz channel to transmitting and receiving frames on the 1.08 GHz channel. The determination of the length of the GIs is, however, implementation dependent.

If a non-AP and non-PCP CDMG STA receives a DMG Beacon frame from the CDMG AP or PCP with the BSSID equal to the BSSID of the BSS of which the STA is a member and with the DBC Option subfield of the Dynamic Bandwidth Control element set to 0, the STA shall switch to the 1.08 GHz channel indicated by the Channel Number field of the received Dynamic Bandwidth Control element to receive the DMG Beacon frame transmitted on the corresponding 1.08 GHz channel and follow the beamforming rules in 10.41 (DMG beamforming) and the channel access rules in 10.40 (CDMG AP or PCP clustering) on the 1.08 GHz channel. The non-AP and non-PCP STA may use the BI Offset subfield of the Dynamic Bandwidth Control element in the received DMG Beacon frame to predict the starting time of the BTI on the 1.08 GHz channel. In the following medium time, the non-AP and non-PCP STA should be prepared to receive and transmit frames on the 1.08 GHz channel unless it is assigned by the AP or PCP to monitor the 2.16 GHz common channel, or it communicates with other DMG STAs, or it leaves the current infrastructure BSS or PBSS, or the infrastructure BSS or PBSS ceases its services.

Alternatively, if a non-AP and non-PCP CDMG STA receives a DMG Beacon frame from the CDMG AP or PCP with the BSSID equal to the BSSID of the BSS of which the STA is a member and with the DBC Option subfield of the Dynamic Bandwidth Control element set to 1, the STA shall follow the beamforming rules in 10.41 (DMG beamforming) and the channel access rules in 10.38 (DMG and CMMG channel access) within the 2.16 GHz channel during the BHI duration. During the DTI, the STA shall switch to the 1.08 GHz operating channel indicated by the Channel Number field of the received Dynamic Bandwidth Control element to receive and transmit frame following the channel access rules in 10.38 (DMG and CMMG channel access) on the 1.08 GHz channel.

#### 10.63.2.3 Synchronization of CDMG infrastructure BSS or PBSSs on the adjacent 1.08 GHz channels within a 2.16 GHz channel

A CDMG AP or PCP setting up an infrastructure BSS or PBSS on a 1.08 GHz channel (e.g., channel 35) that has a CDMG BSS established on the adjacent 1.08 GHz channel (i.e., channel 36) within the same 2.16 GHz channel (i.e., channel 2) should follow the procedures below to maintain synchronization.

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A CDMG AP or PCP shall scan the 2.16 GHz channel (e.g., channel 2) that encompasses the 1.08 GHz channel (e.g., channel 36) on which the CDMG AP or PCP is going to set up its BSS for DMG Beacon frames. If the CDMG AP or PCP received a DMG Beacon frame containing a Dynamic Bandwidth Control element with the Channel Splitting subfield set to 1, the Channel Number field indicating the existing AP or PCP works on a 1.08 GHz channel, and the Adjacent Channel Occupancy subfield set to 1, the AP or PCP may send an Extended Notification Period Request frame (9.6.7.41 (Extended Notification Period Request frame format)) during the following ATI of the BSS indicated by the BSSID field of the received DMG Beacon frame to request the existing AP or PCP to allocate time for NPs/BHI to transmit DMG Beacon frames on the encompassing 2.16 GHz channel with the NP/BHI Duration field in the Extended Notification Period Request frame indicating the requested duration of NPs/BHIs.

Alternatively, the scanning AP or PCP may attempt to associate with the infrastructure BSS or PBSS indicated by the BSSID field of the received DMG Beacon frame following the rules in 11.3 (STA authentication and association) and subsequently send a Notification Period Request frame (9.6.29.2 (CMMG Compressed Beamforming frame format)). A non-AP and non-PCP CDMG STA within an infrastructure BSS or PBSS operating on a 1.08 GHz channel may send a Notification Period Request frame (9.6.29.2 (CMMG Compressed Beamforming frame format)) during the ATI, SP, or CBAP to request the AP or PCP to allocate time for NPs/BHIs to transmit DMG Beacon frames on the encompassing 2.16 GHz channel with the -NP/BHI Duration field in the Notification Period Request frame indicating the requested duration of NPs/BHIs.

If a CDMG AP or PCP receives a Notification Period Request frame or an Extended Notification Period Request frame, it may allocate QPs on its operating 1.08 GHz channel at the same recurring position in each beacon interval of the 2.16 GHz channel and reply with a Notification Period Response frame (9.6.29.3 (CMMG Operating Mode Notification frame format)) or an Extended Notification Period Response frame (9.6.7.42 (Extended Notification Period Response frame format)) containing a Dynamic Bandwidth Control element with the TBTT Offset field indicating the target starting time of the allocated NPs/BHIs and the NP/BHI Duration field and the Adjacent NP/BHI Duration field indicating the lengths of the NPs/BHIs on the 2.16 GHz channel of itself and the scanning AP or PCP. The CDMG AP or PCP may schedule the starting times of the QPs to be earlier than the NPs and the durations of the QPs to be greater than the durations of the NPs to establish a GI before and after each NP/BHI as shown in Figure 10-156 (Two APs or PCPs with NPs arranged consecutively) and Figure 10-157 (Two APs or PCPs with BHIs arranged apart from each other). The AP or PCP shall scan for DMG Beacon frames in the allocated NPs to determine if a new BSS has been established on the adjacent 1.08 GHz channel.

If a CDMG STA receives a Notification Period Response frame or Extended Notification Period Response frame addressed to it, it may establish an infrastructure BSS or PBSS on the 1.08 GHz channel adjacent to the channel indicated in the Channel Number field of the Dynamic Bandwidth Control element and become the AP or PCP using the following steps. The scanning AP or PCP shall start to transmit DMG Beacon frames at the start of the allocated NP/BHI indicated by the TBTT Offset field of the Dynamic Bandwidth Control element and set a TSF timer to track its beacon interval on the 2.16 GHz channel. The duration of the beacon interval on the 2.16 GHz channel shall be equal to the Beacon Interval field in the received Notification Period Response frame or an Extended Notification Period Response frame. The duration of NP/BHI on the 2.16 GHz channel shall be set to the value of the Adjacent NP/BHI Duration field of the Dynamic Bandwidth Control element in the received Notification Period Response frame or an Extended Notification Period Response frame. The scanning AP or PCP shall continue to receive the DMG Beacon frames from the existing AP or PCP during the NPs/BHIs starting at the time obtained from the Beacon Interval field minus the TBTT Offset field from the beginning of each beacon interval on the 2.16 GHz channel with the length indicated by the NP/BHI Duration field of the Dynamic Bandwidth Control element in the previously received Notification Period Response frame or Extended Notification Period Response frame and maintain synchronization by adjusting its TSF to match the Timestamp field (9.4.1.10 (Timestamp field)) in the received DMG Beacon frames transmitted in these NPs/BHIs. The scanning AP or PCP shall also use the DBC Option subfield of the Dynamic Bandwidth Control element in each DMG Beacon frame to announce whether the beacon interval on its 1.08 GHz operating channel is present or not as described in 10.63.2.2 (CDMG BSS operating on a 1.08 GHz channel).


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A CDMG AP or PCP operating on a 1.08 GHz channel may also actively allocate reserved NPs/BHIs on the 2.16 GHz channel to allow a new CDMG BSS to be established on the adjacent 1.08 GHz channel. The CDMG AP or PCP may allocate QPs on its operating 1.08 GHz channel at the same recurring position in each beacon interval of the 2.16 GHz channel and announce the presence of the reserved NPs/BHIs by transmitting DMG Beacon frames on the 2.16 GHz channel containing a Dynamic Bandwidth Control element with the Channel Splitting subfield equal to 1, the Adjacent Channel Occupancy subfield equal to 1, and the Adjacent NP/BHI Duration field nonzero. The TBTT Offset field and the Adjacent NP/BHI Duration field in the Dynamic Bandwidth Control element indicate the target starting time and the duration of the reserved NPs/BHIs, respectively. The AP or PCP shall scan for DMG Beacon frames in the reserved NPs to determine if a new BSS has been established on the adjacent 1.08 GHz channel.

If a CDMG AP or PCP receives a DMG Beacon frame on the 2.16 GHz channel containing a Dynamic Bandwidth Control element with the Channel Splitting subfield set to 1, the Adjacent Channel Occupancy field set to 1, and the Adjacent NP/BHI Duration field nonzero, it may establish an infrastructure BSS or PBSS on the 1.08 GHz channel adjacent to the channel indicated in the Channel Number field of the Dynamic Bandwidth Control element using the following steps. The AP or PCP shall continue to scan for DMG Beacon frames on the 2.16 GHz channel during the reserved NPs/BHIs indicated by the TBTT Offset field of the Dynamic Bandwidth Control element for an interval of at least aMinChannelTime. If it does not receive any valid DMG Beacon frame, it may start a new BSS by transmitting a DMG Beacon frame at the start of the reversed NP/BHI and set a TSF timer to track its beacon interval on the 2.16 GHz channel. The duration of the beacon interval on the 2.16 GHz channel shall be equal to the Beacon Interval field in the received DMG Beacon frame of the existing AP or PCP. The scanning AP or PCP shall continue to receive the DMG Beacon frames in NPs/BHIs of the existing AP or PCP operating on the adjacent 1.08 GHz channel to maintain synchronization by adjusting its TSF to match the Timestamp field (9.4.1.10 (Timestamp field)) in the received DMG Beacon frames. The scanning AP or PCP shall also use the DBC Option subfield of the Dynamic Bandwidth Control element contained in each DMG Beacon frame to announce whether the beacon interval on its 1.08 GHz operating channel is present or not described in 10.63.2.2 (CDMG BSS operating on a 1.08 GHz channel).

The NPs/BHIs of the two APs or PCPs operating on the adjacent 1.08 GHz channels within a 2.16 GHz channel may be arranged consecutively without interspaces to reduce the number of times they need to switch between transmitting and receiving frames on the 2.16 GHz channel and the 1.08 GHz channels.

Figure 10-156 (Two APs or PCPs with NPs arranged consecutively) shows an example of two APs establishing BSSs on channels 35 and 36, respectively, with two NPs, NP 1 of AP 1 and NP 2 of AP 2, arranged consecutively without interspaces. The same arrangement might apply to PCPs establishing PBSSs. Figure 10-157 (Two APs or PCPs with BHIs arranged apart from each other) shows another example of two APs establishing BSSs on channels 35 and 36, respectively, with two BHIs, BHI 1 of AP 1 and BHI 2 of AP 2, arranged arbitrarily apart from each other. The same arrangement might apply to PCPs establishing PBSSs.

If a CDMG AP or PCP operating on a 1.08 GHz channel with the adjacent 1.08 GHz channel occupied by another CDMG BSS does not receive any DMG Beacon frame transmitted by the CDMG AP or PCP operating on the adjacent 1.08 GHz channel in the assigned NPs/BHIs for a period of 4×aMinBTIPeriod beacon intervals on the 2.16 GHz channel, starting from when the last frame is received from the neighboring AP or PCP, it may proceed to make changes to the assigned NPs/BHIs on the 2.16 GHz channel. The AP or PCP may continue to allocate a NP/BHI on 2.16 GHz channel at the same position to allow another AP or PCP to establish a new BSS on the adjacent 1.08 GHz channel as described above or it may stop allocating QPs on its operating channel that correspond to the NPs/BHIs on 2.16 GHz channel of the BSS operating on the adjacent 1.08 GHz channel. Figure 10-158 (Service cessation for an AP or PCP on channel 35) shows an example that an AP or PCP can cease its service on channel 35, a 1.08 GHz channel.

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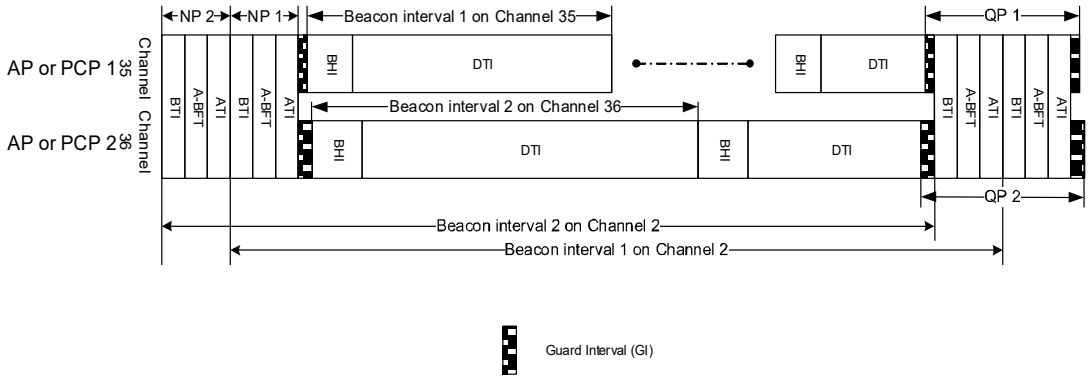


**Figure 10-156—Two APs or PCPs with NPs arranged consecutively**

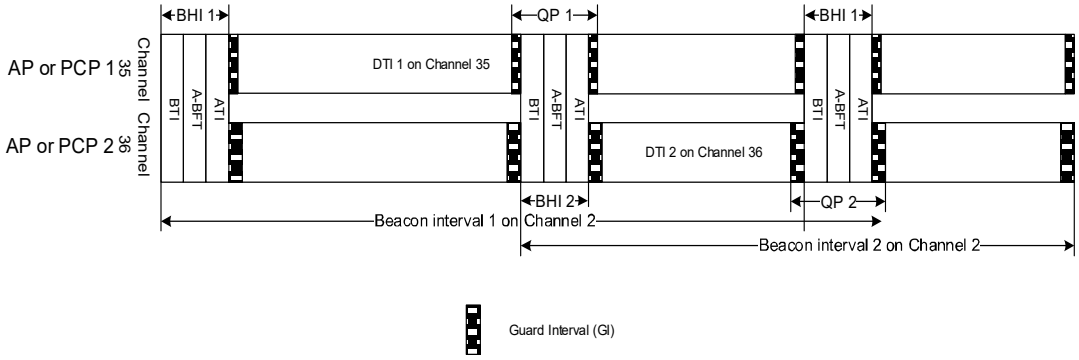


**Figure 10-157—Two APs or PCPs with BHIs arranged apart from each other**

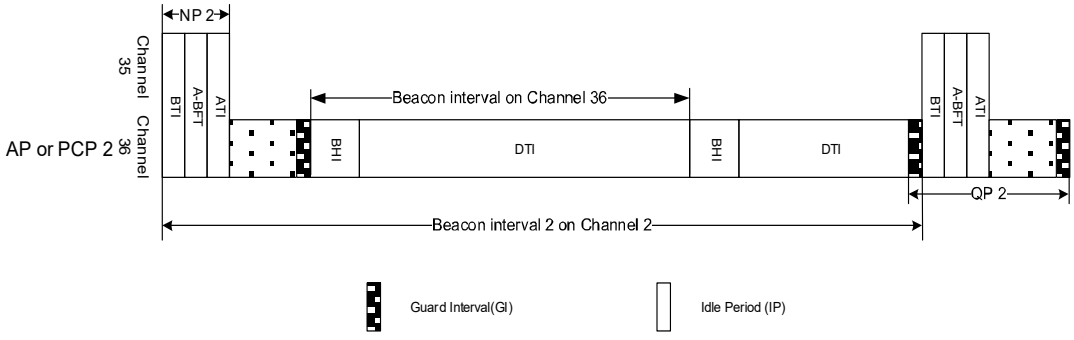


**Figure 10-158—Service cessation for an AP or PCP on channel 35**


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The CDMG AP or PCP may also move its TBTT (11.29.2 (Moving the TBTT)) on the 2.16 GHz channel (e.g., channel 2) backward so that its NPs/BHIs are followed closely by the BHI on its 1.08 GHz operating channel (e.g., channel 36) as illustrated in Figure 10-159 (Moving TBTT by a neighboring AP or PCP on channel 2).

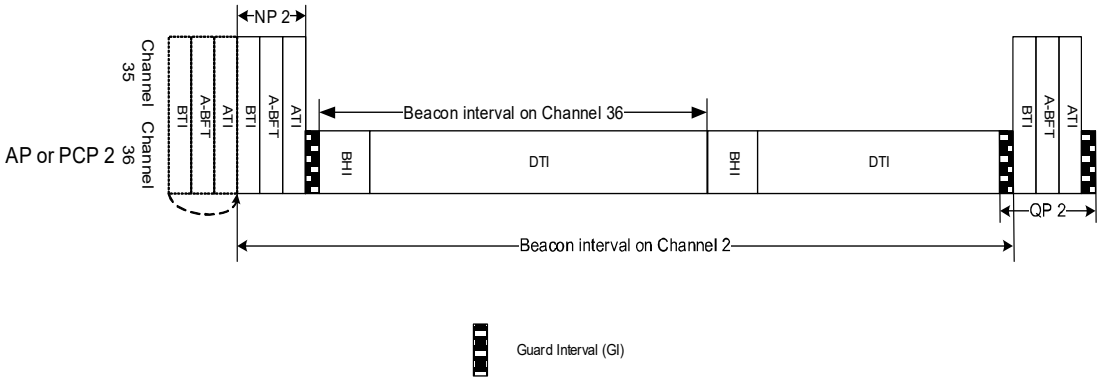


**Figure 10-159—Moving TBTT by a neighboring AP or PCP on channel 2**

### 10.63.3 Channel splitting of a 2.16 GHz channel

If a CDMG STA receives a DMG Beacon frame from a CDMG AP or PCP operating on a 2.16 GHz channel (e.g., channel 2), it may request the AP or PCP to shift its operating channel to one of the 1.08 GHz channels (e.g., channel 35) within its original 2.16 GHz channel by sending an Extended Channel Splitting Request frame (9.6.7.43 (Extended Channel Splitting Request frame format)) during the following ATI or it may associate with the infrastructure BSS or PBSS indicated by the BSSID field of the received DMG Beacon frame following the rules in 11.3 (STA authentication and association) and subsequently send a Channel Splitting Request frame (9.6.28.4 (Channel Splitting Request frame format)).

A non-AP and non-PCP CDMG STA within an infrastructure BSS or PBSS operating on a 2.16 GHz channel (e.g., channel 2) may send a Channel Splitting Request frame (9.6.28.4 (Channel Splitting Request frame format)) during the ATI, SP, or CBAP, to request the AP or PCP to shift its operating channel to one of the 1.08 GHz channels (e.g., channel 35) within its original 2.16 GHz channel. If the existing CDMG BSS changed its operating channel to one of the 1.08 GHz channels (e.g., channel 35), the CDMG STA that sends the Channel Splitting Request frame may then operate a new BSS on the other adjacent 1.08 GHz channel (i.e., channel 36) within the 2.16 GHz channel (i.e., channel 2) as the role of AP or PCP.

The Channel Splitting Request frame or Extended Channel Splitting Request frame shall use the NP/BHI Duration field to indicate the required length of NP/BHI on a 2.16 GHz channel.

If a CDMG AP or PCP receives a Channel Splitting Request frame (9.6.28.4 (Channel Splitting Request frame format)) or Extended Channel Splitting Request frame (9.6.7.43 (Extended Channel Splitting Request frame format)), the AP or PCP may follow the rules in 11.8.8.6 (Selecting and advertising a new channel in a DMG BSS) to switch its operating channel to a 1.08 GHz channel (e.g., channel 35) within its original 2.16 GHz channel (i.e., channel 2). If the AP or PCP switches the operating channel after receiving a Channel Splitting Request frame, it shall inform all its non-AP and non-PCP STAs of the DBC option it selects to operate on the 1.08 GHz channel after channel splitting, the target 1.08 GHz channel number to which it switches, and the starting time of the first beacon interval on 2.16 GHz channel when the channel splitting begins through the DBC Option subfield of the Dynamic Bandwidth Control element and the New Channel Number field and the Channel Switching Count field of the Channel Switch Announce element contained in the DMG Beacon and/or Announce frames. The AP or PCP shall also send a Channel Splitting Response frame (9.6.28.5 (Channel Splitting Response frame format)) or Extended Channel Splitting Response frame (9.6.7.44 (Extended Channel Splitting Response frame format)) to announce the target 1.08 GHz channel number to which it switches and

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the starting time of the first beacon interval on 2.16 GHz channel when the channel splitting begins through the New Channel Number field and the Channel Switching Count field of the Channel Switch Announce element, the length of its beacon interval on 2.16 GHz channel after channel splitting through the Beacon Interval field, and the time offset of the scanning AP's or PCP's beacon interval relative to the existing AP's or PCP's beacon interval on 2.16 GHz channel and the lengths of NP/BHI durations for both APs or PCPs on 2.16 GHz channel through the TBTT Offset field, the NP/BHI Duration field, and the Adjacent NP/BHI Duration field of the Dynamic Bandwidth Control element to the CDMG STA indicated in the Source AID field in the received Channel Splitting Request frame or Extended Channel Splitting Request frame.

If a CDMG AP or PCP receives a Channel Splitting Request frame or Extended Channel Splitting Request frame but is not switching its operating channel, it may reply a Channel Splitting Response frame or an Extended Channel Splitting Response frame to reject the request.

If a CDMG STA sends a Channel Splitting Request frame or Extended Channel Splitting Request frame and then receives Channel Splitting Response frame or an Extended Channel Splitting Response frame with the Channel Splitting subfield set to 1, it shall follow the procedures described in 10.63.2.3 (Synchronization of CDMG infrastructure BSS or PBSSs on the adjacent 1.08 GHz channels within a 2.16 GHz channel) to maintain synchronization with the CDMG AP or PCP that sends the Channel Splitting Response frame or an Extended Channel Splitting Response frame when it starts a new BSS on the adjacent 1.08 GHz channel as the role of AP or PCP.

### 10.63.4 Channel expansion of a 1.08 GHz channel

A CDMG AP or PCP operating an infrastructure BSS or PBSS services on a 1.08 GHz channel (e.g., channel 35) may expand its operating bandwidth by switching to the 2.16 GHz channel (i.e., channel 2) encompassing its original operating channel without interruption to its BSS services.

If a CDMG AP or PCP operating an infrastructure BSS or PBSS on a 1.08 GHz channel (e.g., channel 35) transmits DMG Beacon frames on the 2.16 GHz channel containing a Dynamic Bandwidth Control element with the Channel Splitting subfield set to 1 and the Adjacent Channel Occupancy subfield set to 1, the AP or PCP may follow 11.8.8.6 (Selecting and advertising a new channel in a DMG BSS) to switch its operating channel to the 2.16 GHz channel (e.g., channel 2).

If a CDMG AP or PCP operating an infrastructure BSS or PBSS on a 1.08 GHz channel (e.g., channel 35) transmits DMG Beacon frames on the 2.16 GHz channel containing a Dynamic Bandwidth Control element with the Channel Splitting subfield set to 1 and the Adjacent Channel Occupancy subfield set to 0 but does not receive any DMG Beacon frame during the allocated NPs/BHI from another CDMG AP or PCP for a time period of 4×aMinBTIPeriod beacon intervals on the 2.16 GHz channel, the AP or PCP may follow 11.8.8.6 (Selecting and advertising a new channel in a DMG BSS) to switch its operating channel to the 2.16 GHz channel (e.g., channel 2).

If a CDMG AP or PCP operating an infrastructure BSS or PBSS on a 1.08 GHz channel (e.g., channel 35) transmits DMG Beacon frames on the 2.16 GHz channel containing a Dynamic Bandwidth Control element with the Channel Splitting subfield set to 1 and the Adjacent Channel Occupancy subfield set to 0 and receives a DMG Beacon frame during a NP/BHI from another CDMG AP or PCP operating on the adjacent 1.08 GHz channel (e.g., channel 36) within a 2.16 GHz channel (i.e., channel 2), it shall not expand its operating bandwidth by switching to the 2.16 GHz channel.

If the CDMG AP of PCP is switching the operating channel, it shall transmit DMG Beacon frames during the scheduled NPs on the 2.16 GHz channel containing a Dynamic Bandwidth Control element with the Channel Splitting subfield equal to 1 and the Adjacent Channel Occupancy subfield equal to 0 until the intended channel switch time. The AP or PCP shall inform all the non-AP and non-PCP STAs in the BSS with the target 2.16 GHz channel number to which it switches and the starting time of the first beacon interval on the 2.16 GHz channel after the channel expansion through the New Channel Number field and the Channel


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Switching Count field of the Channel Switch Announce element contained in the DMG Beacon and/or Announce frames. Here, the starting time is set until to the end of a subsequent beacon interval on the 2.16 GHz channel. Note that the beacon interval length after channel expansion might be different with that before channel expansion.

Figure 10-160 (AP or PCP operating on channel 35 with independent beacon interval expanding the operating bandwidth to channel 2) and Figure 10-161 (AP or PCP operating on channel 35 without independent beacon interval expanding the operating bandwidth to channel 2) illustrate the examples that an AP or PCP (e.g., AP or PCP 1) operating on channel 35 switches to channel 2. In Figure 10-160 (AP or PCP operating on channel 35 with independent beacon interval expanding the operating bandwidth to channel 2), the AP or PCP 1 established an independent beacon interval on channel 35 while in Figure 10-161 (AP or PCP operating on channel 35 without independent beacon interval expanding the operating bandwidth to channel 2), the AP or PCP 1 does not.

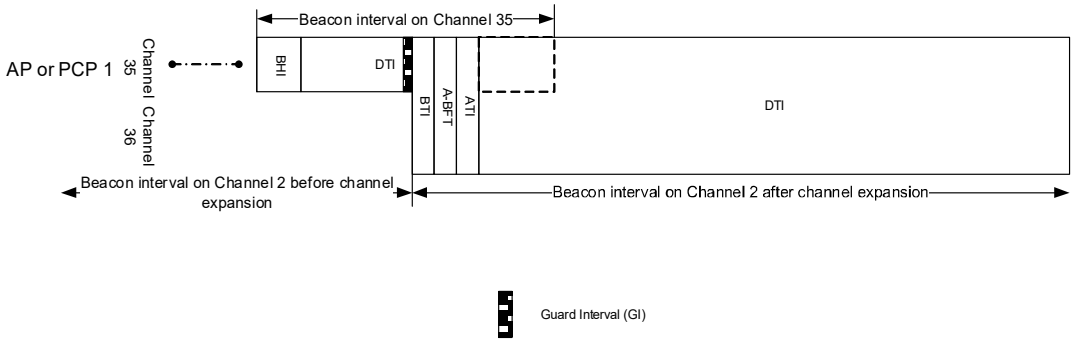


**Figure 10-160—AP or PCP operating on channel 35 with independent beacon interval expanding the operating bandwidth to channel 2**

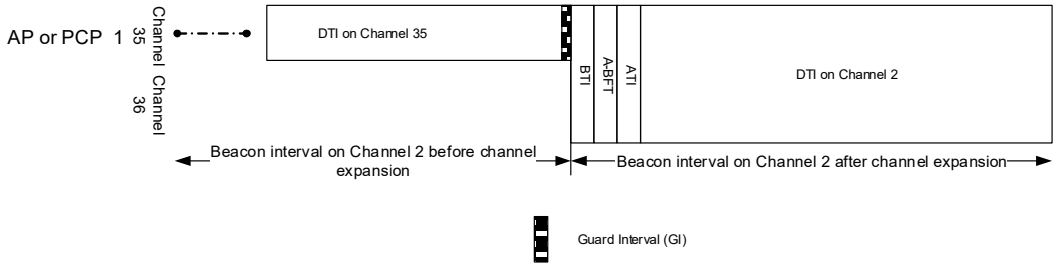


**Figure 10-161—AP or PCP operating on channel 35 without independent beacon interval expanding the operating bandwidth to channel 2**

### 10.63.5 Backward compatibility and interoperation

A CDMG AP or PCP operating an infrastructure BSS or PBSS shall provide interoperability to DMG STAs regardless of the BSS's operating channel. If a CDMG BSS is operating on a 2.16 GHz channel, the CDMG AP or PCP shall follow the channel access rules as described in 10.38 (DMG and CMMG channel access) to provide services to non-AP and non-PCP DMG STAs.

A CDMG STA should not establish a 1.08 GHz BSS within a 2.16 GHz channel on which it received a DMG Beacon frame from a DMG AP or PCP. A CDMG AP or PCP operating on a 1.08 GHz channel shall transmit DMG Beacon frames on both the 1.08 GHz channel and the corresponding 2.16 GHz channel. A DMG STA

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can request to join a CDMG BSS. If the DMG STA successfully joins the CDMG BSS, the CDMG AP or PCP of the BSS shall schedule SPs and/or CBAPs for the DMG STA on the 2.16 GHz channel. The length of the scheduled SPs or CBAPs for DMG STAs on the 2.16 GHz channel is variable and may be up to the entire DTI. In other words, all STAs in the CDMG BSS operate on the 2.16 GHz channel if SPs and/or CBAPs are scheduled only on the 2.16 GHz channel during the DTI. The algorithm to schedule SPs or CBAPs for DMG STAs in a CDMG BSS is implementation dependent and beyond the scope of this standard but should aim to improve the network efficiency.

During an SP or a CBAP, the source and destination CDMG STAs operating on a 1.08 GHz channel in a CDMG BSS shall transmit an RTS frame and a DMG CTS or DMG DTS frame, respectively, on the corresponding 2.16 GHz channel after successfully transmitting and receiving an RTS frame and a DMG CTS or DMG DTS frame, respectively, on the 1.08 GHz channel if the 2.16 GHz channel is idle. Then the DMG STAs can set their NAVs by receiving the RTS or DMG CTS or DMG DTS frames transmitted on the 2.16 GHz channel by the CDMG STAs. After transmitting a CF-End frame to truncate an SP or TXOP on a 1.08 GHz channel within a 2.16 GHz channel, a CDMG STA shall also transmit a corresponding CF-End frame on the 2.16 GHz channel if it is idle.

If a CDMG infrastructure BSS or PBSS is operating on a 1.08 GHz channel, the CDMG AP or PCP shall follow the channel access rules in the BHI as described in 10.38 (DMG and CMMG channel access) during the NPs/BHIs on the 2.16 GHz channel to admit non-AP and non-PCP DMG STAs into the BSS and provide scheduling information to DMG STAs. In the following medium time, the CDMG AP or PCP shall follow the rules in 10.38.6 (Channel access in scheduled DTI) to schedule the SPs or CBAPs for non-AP and non-PCP DMG STAs on the 2.16 GHz channel. If the CDMG AP or PCP establishes an independent beacon interval on its operating 1.08 GHz channel, it shall schedule SPs or CBAPs with non-AP and non-PCP DMG STAs as the source or destination STAs such that the scheduled SPs or CBAPs shall not be overlapped in time with the BHI periods on the 1.08 GHz channel. The CDMG AP or PCP may also schedule SPs or CBAPs on the 2.16 GHz channel for DMG STAs within the BSS to communicate with CDMG STAs within the BSS.

If a CDMG AP or PCP that is operating on a 1.08 GHz channel, with another CDMG BSS operating on the adjacent 1.08 GHz channel within a 2.16 GHz channel, the CDMG AP or PCP shall schedule only SPs or CBAPs with non-AP and non-PCP DMG STAs as the source or destination STAs in time periods that has been reported as unoccupied by the other CDMG AP or PCP through the Extended Schedule element in its DMG Beacon frames. The CDMG AP or PCP shall announce all its allocated SPs and CBAPs for the other CDMG AP or PCP, and the other CDMG AP or PCP can allocate SPs or CBAPs on the common 2.16 GHz channel in the unallocated time. (#111)In order to allocate time on the 2.16 GHz channel, the CMDG AP or PCP may also transmit a CDMG Allocation Request frame (9.6.28.6 (CDMG Allocation Request frame format)) during the ATI of the other AP's or PCP's NP/BHI on the 2.16 GHz channel to request for the available time for allocations on the 2.16 GHz channel. A CDMG AP or PCP that receives a CDMG Allocation Request frame from a CDMG AP or PCP operating on its adjacent 1.08 GHz channel shall reply with a CDMG Allocation Response frame (9.6.28.7 (CDMG Allocation Response frame format)) with an Extended Schedule element to indicate the schedule of all its allocations.

A CDMG AP or PCP that is operating on a 1.08 GHz channel, with another CDMG BSS operating on the adjacent 1.08 GHz channel within a 2.16 GHz channel, should appropriately reserve and schedule the available time for the AP or PCP operating on the adjacent 1.08 GHz channel and itself to allocate SPs or CBAPs on the 2.16 GHz channel, but the method to determine the reservation is implementation dependent. Four cases of backward compatibility and interoperation between DMG STAs and CDMG STAs are illustrated as follows.

A CDMG AP or PCP establishing an infrastructure BSS or PBSS on channel 35, with one or more beacon intervals starting on this channel, allows DMG STAs to join as non-AP and non-PCP STAs and allocates their SPs or CBAPs on channel 2 only, as shown in Figure 10-162 (SPs or CBAPs allocated for DMG STAs on channel 2 with beacon intervals starting on channel 35).


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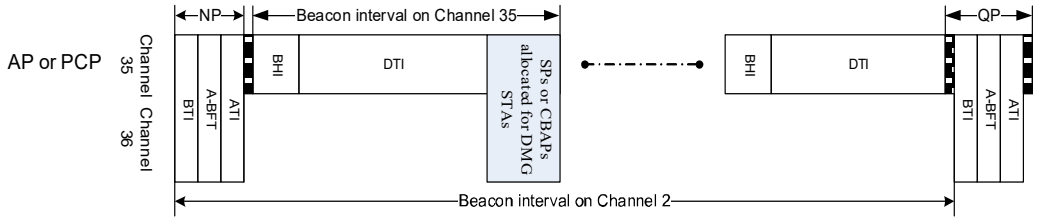


**Figure 10-162—SPs or CBAPs allocated for DMG STAs on channel 2 with beacon intervals starting on channel 35**

A CDMG AP or PCP establishing an infrastructure BSS or PBSS on channel 35, without starting a beacon interval on this channel, allows the DMG STAs to join as non-AP and non-PCP STAs and allocates their SPs or CBAPs on channel 2 only, as shown in Figure 10-163 (SPs or CBAPs allocated for DMG STAs on channel 2 without starting a beacon interval on channel 35).

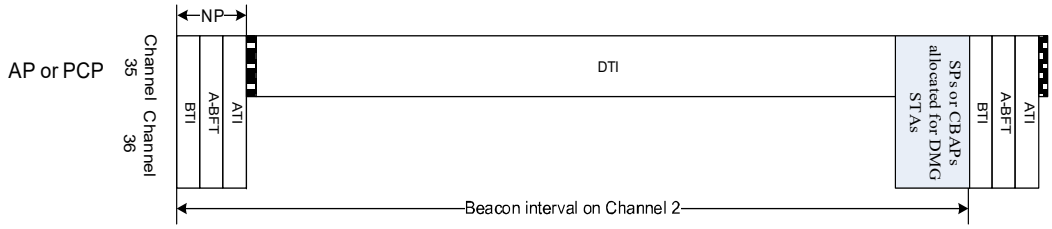


**Figure 10-163—SPs or CBAPs allocated for DMG STAs on channel 2 without starting a beacon interval on channel 35**

CDMG APs or PCPs establishing infrastructure BSSs or PBSSs on channels 35 and 36, respectively, with beacon intervals starting on this channel, allow the DMG STAs to join any of the BSSs or PBSSs as non-AP and non-PCP STAs and allocate their SPs or CBAPs on channel 2 only, as shown in Figure 10-164 (SPs or CBAPs allocated for DMG STAs on channel 2 with beacon intervals starting on channels 35 and 36).

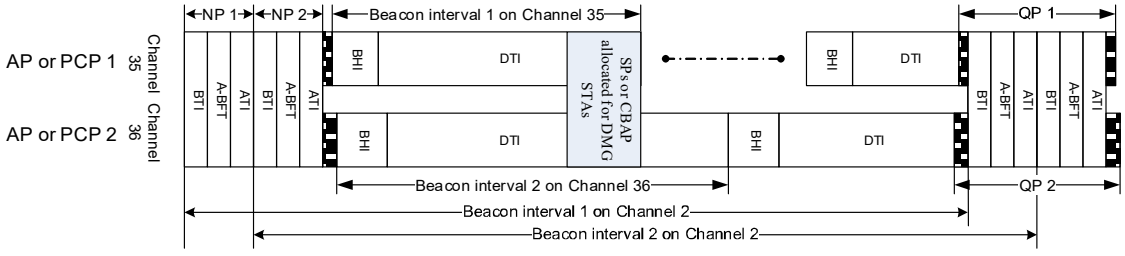


**Figure 10-164—SPs or CBAPs allocated for DMG STAs on channel 2 with beacon intervals starting on channels 35 and 36**

CDMG APs or PCPs establishing infrastructure BSSs or PBSSs on channels 35 and 36, respectively, without starting a beacon interval on this channel, allow the DMG STAs to join any of the BSSs or PBSSs as non-AP

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and non-PCP STAs and allocate their SPs or CBAPs on channel 2 only, as shown in Figure 10-165 (SPs or CBAPs allocated for DMG STAs on channel 2 without starting a beacon interval on channels 35 and 36).

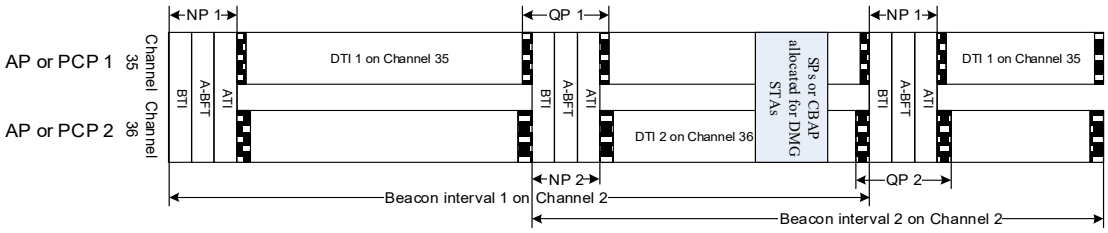


**Figure 10-165—SPs or CBAPs allocated for DMG STAs on channel 2 without starting a beacon interval on channels 35 and 36**

## 10.64 Addressing of GLK Data frame transmission

If a corresponding IEEE 802.1Q Bridge provides a station vector parameter that indicates a single general link, then the GLK STA shall transmit the MSDU using individually addressed MPDU(s) to the peer STA with one of the following methods:

- A frame with a three-address MAC header if the RA and the DA are equal and the transmitter is an AP.
- A frame with a four-address MAC header.
- A frame containing a Basic A-MSDU.

If a corresponding IEEE 802.1Q Bridge provides a station vector parameter that indicates multiple general links, then GLK transmission of the MSDU shall use one of the following methods:

- Transmit multiple individually addressed MPDUs to peer STAs.
- Transmit group addressed MPDU(s) using a SYNRA in a frame with a four-address MAC header with the following restrictions:
  - Shall not be sent by a non-GLK STA or non-AP STA.
  - Shall not address a STA that is in PS mode.
  - Shall not address a STA whose general link might pass through a relay.

A GLK AP may use any combination of these methods, such that each peer STA is addressed once. This also applies for each retry triggered by GLK-GCR, which shall use the same method for all transmission attempts.

The addressing of the frame with a four-address MAC header shall be as follows:

- Address 1 is the MAC address of the immediate destination STA (the receiver of the MPDU) or a SYNRA.
- Address 2 is the MAC address of the transmitter STA (the transmitter of the MPDU).
- Address 3 is the DA of the MSDU (the destination address of the MSDU), or BSSID for a Basic A-MSDU.
- Address 4 is the SA of the MSDU (the source address of the MSDU), or BSSID for a Basic A-MSDU.

The addressing of the frame with the three-address MAC header format containing a (#279)Basic A-MSDU shall be as follows:


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- Address 1 is the MAC address of the immediate destination STA (the receiver of the MPDU).
- Address 2 is the MAC address of the transmitter STA (the transmitter of the MPDU).
- Address 3 is the BSSID.
- DA in A-MSDU subframe header is the DA of the MSDU (the destination address of the MSDU).
- SA in A-MSDU subframe header is the SA of the MSDU (the source address of the MSDU).

## 10.65 SYNRA filtering operation

A GLK infrastructure non-AP STA shall support reception of frames with a SYNRA as RA.

When a GLK non-AP STA receives an RA that is a group address in an MPDU from its associated GLK AP, if the SYNRA Type subfield does not represent a supported SYNRA type, or the From DS and To DS subfields in the Frame Control field are not both 1, then the non-AP STA shall discard the frame, and not use the frame for updating any scoreboard used for GLK-GCR block ack. All other group addressed Data frames received from the associated GLK AP shall be counted as received for the purposes of the scoreboard used for GLK-GCR block ack, even if discarded based on the subsequent SYNRA filtering, as described below.

For Basic SYNRA Control subfield, the frame shall be discarded if any of the following filter rules are satisfied:

- The AID of the STA falls within the range of AID values covered by the AID Bitmap subfield, and the bit representing its AID value is 0.
- The AID of the STA falls outside the range of AID values covered by the AID Bitmap subfield, and the Other AID subfield is 0.

## 10.67 EDMG phase hopping and open loop precoding operation(11ay)

An EDMG STA supports phase hopping modulation defined in 28.6.9.3.8 (Phase hopping modulation) if the Phase Hopping Supported field in the STA's EDMG Capabilities element is 1. A phase hopping cbapable STA may transmit to a peer STA an EDMG OFDM mode SU PPDU with the TXVEXTOR parameter PHASE_HOPPING set to PH_APPLIED only if the peer STA has set the Phase Hopping Supported subfield in the peer STA's EDMG Capabilities element to 1 and the NUM_STS parameter in the TXVECTOR is set to 2.

An EDMG STA supports open loop precoding defined in 28.6.9.3.8 (Phase hopping modulation) if the Open Loop Precoding Supported subfield in the STA's EDMG Capabilities element is 1. An open loop precoding capable STA is also phase hopping capable. An open loop precoding capable STA may transmit to a peer STA an EDMG OFDM mode SU PPDU with the TXVECTOR parameter OPEN_LOOP_PC set to OL_APPLIED only if the peer STA has set the Open Loop Precoding Supported subfield in the peer STA's EDMG Capabilities element to 1, and the NUM_ STS parameter in the TXVECTOR is set to 2 and the PHASE_HOPPING parameter in the TXVECTOR is set to PH_APPLIED.

## 10.68 EDMG AP or EDMG PCP distributed scheduling protocol operation(11ay)

### 10.68.1 General

An EDMG PCP or EDMG AP may use the distributed scheduling protocol to improve spatial sharing and interference mitigation with other BSSs that use one or more of the same channels. An EDMG PCP or EDMG AP with dot11EDMGDistributedSchedulingProtocolActivated equal to true shall enable the distributed scheduling protocol by setting the Distributed Scheduling Enabled subfield to 1 in a transmitted EDMG Extended Schedule element. An EDMG PCP or EDMG AP shall follow the distributed scheduling protocol as described in this subclause during any beacon interval in which the PCP or AP transmits an

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EDMG Extended Schedule element with the Distributed Scheduling Enabled subfield equal to 1. In such cases, the PCP or AP is distributed scheduling enabled for this beacon interval.

### 10.68.2 Distributed scheduling initialization

When an EDMG PCP or EDMG AP first enables the distributed scheduling protocol, it shall listen for the maximum permitted beacon interval duration for DMG Beacons frames from neighboring PCPs or APs to determine the location (in terms of time and channel) and periodicity of their DMG Beacon frame transmissions as well as whether these PCPs or APs have the distributed scheduling protocol enabled.

### 10.68.3 Distributed scheduling protocol

While not engaged in communication within its BSS, a distributed scheduling enabled EDMG PCP or EDMG AP shall listen for DMG Beacon frames from neighboring PCPs or APs to determine their upcoming transmission schedules by parsing the Extended Schedule elements and EDMG Extended Schedule elements contained in received DMG Beacon frames. This may require listening on different channels, since neighbor PCPs or APs may operate in different primary channels.

If an AP or PCP determines that the BTI of a neighbor AP or PCP is overlapping or getting close to overlapping its own BTI in time, the AP or PCP may use the procedure in 11.30.2 (Spatial sharing and interference assessment) to move the TBTT of its BSS to remove or avoid the overlap. The procedure to determine when two BTIs are overlapping or drifting too close to overlapping in time is implementation dependent.

To distribute channel resources among PCPs or APs in the same coverage area, the PCP or AP shall determine how much of each beacon interval it can occupy on any given channel by dividing its beacon interval duration by the number of detected neighboring PCPs or APs that are using that channel. Thus, for each channel $i$ that the PCP or AP is using, the PCP or AP shall not schedule allocations covering more than $1/(N_i + 1)$ of the beacon interval, where $N_i$ is the number of detected neighboring PCPs or APs using channel $i$. Both the BHI and SPs shall count toward a PCP or AP's beacon interval usage, whereas CBAPs shall not count towards this total since CBAPs do not provide guaranteed transmissions.

When creating the Extended Schedule element and EDMG Extended Schedule elements, a distributed scheduling enabled PCP or AP shall do the following on each channel it is using. The PCP or AP shall randomly schedule its SPs over unoccupied time periods first. If after scheduling its SPs over unoccupied time periods the PCP or AP has not yet used its share of the channel, it may randomly schedule remaining SPs over time periods with no neighbor SPs. Finally, if after scheduling its SPs over time periods with no neighbor SPs the PCP or AP has not yet used its share of the channel, it may randomly schedule its remaining SPs over time periods with no SPs of distributed scheduling enabled PCPs or APs (i.e., the PCP or AP is allowed to schedule over SPs of neighbors that have not enabled the distributed scheduling protocol).

A distributed scheduling enabled PCP or AP may schedule CBAPs anywhere in the DTI except during periods when the PCP or AP needs to listen for neighbor beacons. Allocated CBAPs should not traverse the start of SPs belonging to neighboring BSSs.

## 10.69 DMG segmentation and reassembly operation(11ay)

### 10.69.1 General

A STA supports segmentation and reassembly if dot11SAROptionImplemented is true and, as a consequence, the Segmentation and Reassembly Support subfield in the STA's DMG Capabilities element


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is 1. A STA that supports segmentation and reassembly may employ this mechanism with a peer STA if the peer STA also supports segmentation and reassembly.

A DMG STA that supports segmentation and reassembly may segment large MSDUs received at the MAC SAP or A-MSDUs received at the A-MSDU aggregation function into MSDU or A-MSDU segments, respectively, that are transmitted into MPDUs (see 10.69.2 (Segmentation operation)). These MSDU or A-MSDU segments are reassembled at the recipient STA to recreate the original MSDU or A-MSDU (see 10.69.3 (Reassembly operation)). MSDU or A-MSDU segments shall be carried in individually addressed MPDUs.

The segmentation and reassembly mechanism allows a STA to receive at the MAC SAP an MSDU with a size that is optimal for an upper layer, or to aggregate MSDUs into A-MSDU, and that is not limited to the maximum transmission unit. The MSDU is delivered to the MAC SAP and the A-MSDU is delivered to the A-MSDU (#4172)deaggregation function of the recipient STA through, respectively, MSDU or A-MSDU segments carried within MPDUs transmitted over the wireless link using the HT-Immediate BlockAck mechanism (see 10.25.6 (HT-immediate block ack extensions)). The recipient STA is responsible to reassemble the segmented MSDUs or A-MSDUs into their original size MSDU or A-MSDU and forward it to, respectively, the MAC SAP or A-MSDU (#4172)deaggregation function. This mechanism allows sending a large MSDU or A-MSDU over the wireless link without the need for any upper layer fragmentation or segmentation processing. The maximum segmented MSDU or A-MSDU size is negotiated between communicating peers during SAR establishment (see 10.25.2 (Setup and modification of the block ack parameters)).

Segmentation and reassembly is established for a particular TID through the use of an ADDBA Request and ADDBA Response frame exchange that includes the SAR Configuration element. Segmentation and reassembly shall not be used under an unsolicited block ack agreement.

A pair of STAs that use segmentation and reassembly for a particular TID shall not employ MSDU fragmentation, as defined in 10.5 (MSDU, (11ax)A-MSDU, and MMPDU defragmentation), for this TID.

A STA that supports segmentation and reassembly shall support(#546) reception of MPDUs carrying segments of different MSDUs or A-MSDU, plus any security encapsulation overhead, MAC header and FCS and to reassemble it back to the original MSDU or A-MSDU size.

Figure 10-166 (Example of segmentation and reassembly procedure(11ay)(#6268)) depicts an example of the transmission of MSDUs using the segmentation and reassembly procedure. In this example, the upper layer of the originator uses the MA-UNITDATA.request primitive(#6268) to pass MSDUs to the MAC for delivery to the recipient. MAC level acknowledgments are not depicted in the figure. Delivered MPDUs reside in the recipient's reordering buffer. A MA-UNITDATA.indication primitive is used to deliver the complete MSDU to the recipient's upper layer. Moreover, in this example, MSDU $K - 1$ contains one segment delivered in the MPDU with $SN = N - 1$, which is successfully delivered to the recipient's reordering buffer and then released to the recipient's upper layer. MSDU $K$ comprises four MSDU segments that are transmitted to the recipient by MPDUs with $SN = N$, $N + 1$, $N + 2$, and $N + 3$. The first transmission

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attempt of MPDU $SN = N + 2$ fails and is retransmitted. The entire MSDU $K$ is released to the recipient's upper layer upon arrival of all MSDU segments at the recipient's reordering buffer.

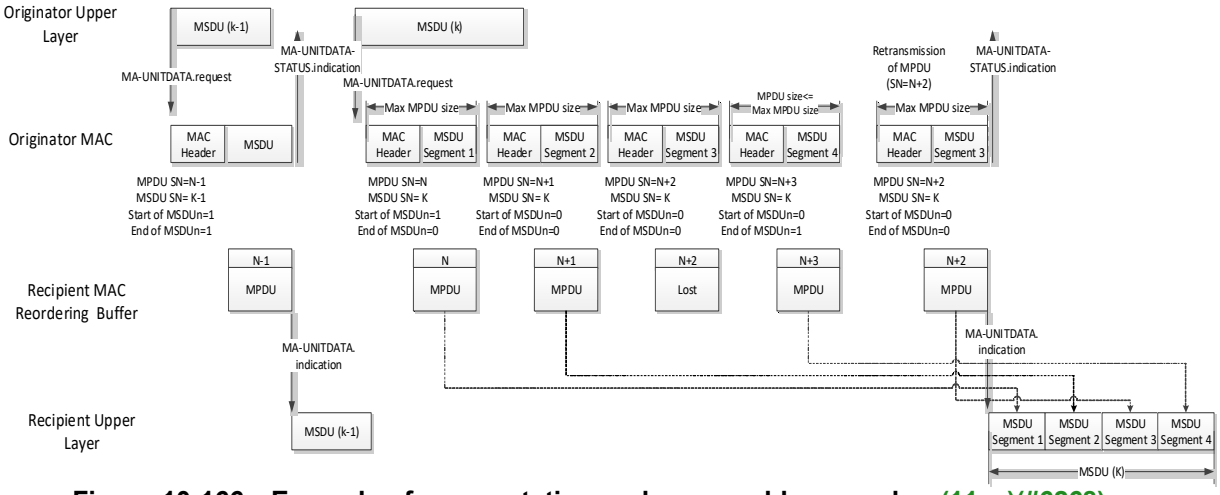


**Figure 10-166—Example of segmentation and reassembly procedure(11ay)(#6268)**

### 10.69.2 Segmentation operation

An MSDU or A-MSDU segment is carried within an MPDU. An MSDU or A-MSDU segment may comprise all or a portion of an MSDU or A-MSDU. Once an MSDU or A-MSDU segment is transmitted for the first time, its frame body content and length shall remain unchanged until it is successfully delivered to the recipient STA or the MSDU or A-MSDU is discarded.

An MPDU that contains the first segment of an MSDU or A-MSDU shall be assigned with a value of the Start of MSDU subfield equal to 1; otherwise, Start of MSDU shall be set to 0. An MPDU that contains the last segment of an MSDU or A-MSDU shall be assigned with a value of the End of MSDU subfield equal to 1; otherwise, the End of MSDU subfield shall be set to 0. An MPDU that has the End of MSDU subfield equal to 1 and the Start of MSDU subfield equal to 1 contains an entire single MSDU or A-MSDU. An MPDU that has the End of MSDU subfield equal to 0 and the Start of MSDU subfield equal to 1 shall have a size given by the maximum MPDU size as defined in 9.4.2.279 (SAR Configuration element(11ay)). All MSDU Sequence Number and MPDU Sequence Number values assigned to an MPDU shall be set with continuously increasing sequential values.

### 10.69.3 Reassembly operation

A recipient STA reassembles an MSDU or A-MSDU comprising, respectively, one or more MSDU or A-MSDU segments according to the Start of MSDU, End of MSDU, MSDU Sequence Number, and MPDU Sequence Number indications of the MPDU of which the MSDU or A-MSDU segment is a part, as described in 10.25.6.6.2 (Operation for each received Data frame). The recipient MAC entity shall reassemble the MSDU or A-MSDU by concatenating, in increasing order of MPDU SN, the MSDU, or A-MSDU segments contained in the decrypted frame body of MPDUs with equal sequence numbers starting from the MPDU with Start of MSDU subfield equal to 1 and ending with the MPDU with End of MSDU subfield equal to 1.

The MA-UNITDATA.indication primitive is used by a recipient MAC to release a reassembled MSDU to its MAC SAP.


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## 10.70 EDMG A-MPDU with multiple TIDs(11ay)

### 10.70.1 General

A multi-TID A-MPDU is an A-MPDU that contains QoS Data frames where at least two of the QoS Data frames have different TID values.

An EDMG STA with dot11EDMGAMPDUwithMultipleTIDOptionImplemented set to true shall set the EDMG Multi-TID Aggregation Support subfield of the EDMG Capabilities element it transmits to a nonzero value. An EDMG STA with dot11EDMGAMPDUwithMultipleTIDOptionImplemented equal to false shall set the Multi-TID Aggregation Support subfield of the EDMG Capabilities element it transmits to zero.

An EDMG STA with dot11EDMGAMPDUwithMultipleTIDOptionImplemented set to true and that supports unsolicited block ack may set the Multi-TID Supported subfield of the Unsolicited Block Ack Extension Parameters field within the Unsolicited Block Ack Extension elements it transmits to 1. Otherwise, the EDMG STA shall set the Multi-TID Supported subfield to 0 to indicate that multi-TID is not supported under an unsolicited block ack agreement.

An EDMG STA may transmit a multi-TID A-MPDU to a peer EDMG STA if the EDMG STA has received from the peer STA an EDMG Capabilities element where the EDMG Multi-TID Aggregation Support subfield is nonzero. Otherwise, the EDMG STA shall not transmit a multi-TID A-MPDU to the peer EDMG STA.

An EDMG STA may transmit a multi-TID A-MPDU to a peer EDMG STA with a number of TIDs that does not exceed $MT + 1$, where $MT$ is the value indicated in the EDMG Multi-TID Aggregation Support subfield within the EDMG Capabilities element transmitted by the peer EDMG STA.

An EDMG STA shall construct a multi-TID A-MPDU as defined in 9.6.35 (EBCS Action frame details(11bc)) and 10.12 (A-MPDU operation).

The sum of all block ack bitmap fields, negotiated as specified in 10.25.2 (Setup and modification of the block ack parameters), of all block ack agreements identified by TIDs included in a Multi-TID A-MPDU shall be less than or equal to 2048.

An EDMG STA may aggregate in a multi-TID A-MPDU QoS Data frames with multiple TIDs as defined in Table 9-662 (A-MPDU contents in the data enabled no immediate response context).(#3263)

An EDMG STA may aggregate MPDUs from any TID in a multi-TID A-MPDU to be transmitted in an SP.

A multi-TID A-MPDU shall not be transmitted in a TXOP, except when the TXOP limit is nonzero for the AC that is used to gain access to the medium. This AC is defined as the primary AC. When the TXOP limit is nonzero, the STA may aggregate QoS Data frames from one or more TIDs in the A-MPDU under the following conditions:

- The A-MPDU is transmitted by the STA within the TXOP.
- The A-MPDU contains MPDUs with TIDs that correspond to the primary AC.
- When no more MPDUs can be aggregated in the A-MPDU from any of the TIDs that correspond to the primary AC, then the A-MPDU may additionally contain one or more MPDUs with TIDs that do not correspond to the primary AC if
  - The TIDs correspond to an AC that has a higher priority with respect to the primary AC.
  - The addition of these MPDUs does not cause the STA to exceed the current TXOP duration.

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(#4251)An EDMG Multi-TID BlockAck frame shall be used to acknowledge MPDUs in a received multi-TID A-MPDU. The rules for (#4251)EDMG Multi-TID BlockAck are defined in 10.25.5 (Selection of BlockAck and BlockAckReq variants).

When a multi-TID A-MPDU is sent in response to an MPDU, received within an SU PPDU, with the RD Grant field set to 1 and the AC Constraint field set to 1 as specified in 10.29.3 (Rules for RD initiator), the lowest priority AC indicated in the MPDU that solicited the A-MPDU is defined as the primary AC. The recipient EDMG STA with dot11EDMGAMPDUwithMultipleTIDOptionImplemented equal to true may transmit a multi-TID A-MPDU and aggregate QoS Data frames from one or more TIDs in the A-MPDU under the following conditions:

- The A-MPDU is transmitted by the STA within the same TXOP or SP where the A-MPDU is solicited.
- The A-MPDU contains one or more MPDUs with any of the TIDs that correspond to the primary AC.
- When no more MPDUs can be aggregated in the A-MPDU from any of the TIDs that correspond to the primary AC, then the A-MPDU may additionally contain one or more MPDUs with TIDs that do not correspond to the primary AC if
  - The TIDs correspond to an AC that has a higher priority with respect to the primary AC.
  - The addition of these MPDUs does not cause the STA to exceed the current TXOP or SP duration.

### 10.70.2 Acknowledgment context in an EDMG Multi-TID BlockAck frame(#4251)

A recipient of a multi-TID A-MPDU or of an EDMG MU-MIMO PPDU sets the Ack Type subfield in the (#4251)EDMG Multi-TID BlockAck frame sent as a response depending on the acknowledgment context. The following acknowledgment contexts are defined as follows:

- **All Ack context:** If the originator has the EDMG All Ack Support subfield in its EDMG Capabilities element equal to 1, the recipient may set the Ack Type field to 2 to indicate the successful reception of all the MPDUs carried in the multi-TID A-MPDU. Otherwise, the recipient shall not set the Ack Type field to 2. The Multi-STA BlockAck frame shall contain only one Per-TID Info subfield field in the (#4251)EDMG Multi-TID BlockAck frame.
- **BlockAck context:** The recipient shall set the Ack Type subfield to 0 and the TID field of each Per-TID Info subfield to a TID value of an MPDU contained in the multi-TID A-MPDU. The Block Ack Starting Sequence Control and Block Ack Bitmap fields shall be set according to 10.25.6 (HT-immediate block ack extensions) for each block ack agreement.
- **Ack context:** The recipient of an EDMG MU-MIMO PPDU shall set the Ack Type subfield to 1 and the TID field of the Per-TID Info subfield to the TID value of the MPDU with no block ack agreement contained in the EDMG MU-MIMO PPDU.

If all MPDUs in the multi-TID A-MPDU are received successfully, the recipient may follow the procedure described in the All Ack context. Otherwise, the recipient shall use the procedure defined in the BlockAck and Ack context.


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# 11. MLME

## 11.1 Synchronization

### 11.1.1 General

STAs in a single infrastructure BSS, PBSS, or IBSS are synchronized to a common clock using the mechanisms defined in 11.1 (Synchronization).

STAs in mesh BSSs use a synchronization method that is part of the extensible synchronization framework. The synchronization in an MBSS is described in 14.14 (Synchronization and beaconing in MBSSs).

A STA for which dot11OCBActivated is true is not a member of a BSS and, therefore, is not required to synchronize to a common clock or to use these mechanisms.

A timing synchronization function (TSF) keeps the timers for all STAs in the same BSS synchronized. All STAs in which dot11OCBActivated is false maintain a local TSF timer. STAs in which dot11OCBActivated is true may maintain a TSF timer for purposes other than synchronization.

A multi-band capable device (11.31 (Multi-band operation)) shall maintain a local TSF timer for each channel in which the STA operates.

(11ay)A DMG STA that operates under TDD channel access (see 10.38.6.2.2 (SP with TDD channel access(11ay))) and that has the TDD Synchronization Mode subfield in the DMG Capabilities element equal to 1 shall maintain a local TSF timer as specified in 11.1.7 (TDD time synchronization(11ay)).

### 11.1.2 Basic approach

#### 11.1.2.1 TSF for an infrastructure BSS or a PBSS

In an infrastructure BSS or in a PBSS, the AP in the infrastructure BSS or the PCP in the PBSS shall be the timing master for the TSF. In a non-DMG and non-S1G BSS, the AP shall periodically transmit frames called *Beacon frames*. Instead of Beacon frames, an S1G AP shall periodically transmit S1G Beacon frames (as described in 11.1.3.10.1 (General S1G synchronization)), which provide a similar function to the Beacon frame in a non-S1G BSS. Within an S1G BSS, the generation and/or reception of a Beacon frame and all references to it refer to that of the S1G Beacon frame. In a DMG BSS, the AP or PCP shall regularly transmit frames called *DMG Beacon frames* and *Announce frames*, which provide a similar function to the Beacon frame in a non-DMG BSS. Beacon, S1G Beacon, DMG Beacon, and Announce frames contain the value of the AP's or PCP's TSF timer in order to synchronize the TSF timers of other STAs in a BSS. A receiving STA shall accept the timing information in Beacon, S1G Beacon, DMG Beacon, and Announce frames sent from the AP or PCP servicing its BSS. An S1G STA that receives an S1G Beacon frame shall update its TSF timer according to the algorithm described in 11.1.3.10.3 (TSF timer accuracy with S1G Beacon frame). If a STA's TSF timer is different from the timestamp in the received Beacon, S1G Beacon, DMG Beacon, or Announce frame, the receiving STA shall set its local TSF timer to the received timestamp value. A STA that receives a frame from its currently associated AP containing a Tetrapartial Timestamp or a Pentapartial Timestamp field may update its local TSF using the received portions of the AP's TSF timer contained in the received field, following the procedure described in 11.1.3.10.3 (TSF timer accuracy with S1G Beacon frame).

In a non-DMG and non-S1G BSS, Beacon frames shall be generated for transmission by the AP once every dot11BeaconPeriod TUs. In an S1G BSS, the S1G AP shall generate S1G Beacon frames every dot11BeaconPeriod TUs; and if dot11ShortBeaconInterval is true, it shall additionally generate S1G Beacon frames every dot11ShortBeaconPeriod TUs as described in 11.1.3.10.1 (General S1G synchronization).

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NOTE 1—The beacon interval, and hence the valid values of dot11BeaconPeriod, is constrained for APs in which dot11PublicHCCATXOPNegotiationActivated is true or dot11ProtectedHCCATXOPNegotiationActivated is true as specified in 11.26.4.1 (General).

In a DMG infrastructure BSS, zero or more DMG Beacon frames shall be generated for transmission by the AP every dot11BeaconPeriod TUs (see 11.1.3.3 (Beacon generation in a DMG infrastructure BSS and in a PBSS)). The AP shall transmit at least one DMG Beacon frame through each sector the AP chooses to use, within a time interval that is not longer than dot11BeaconPeriod × dot11MaxLostBeacons TUs. The determination of the sectors the AP chooses to use is implementation dependent, but should be determined in a way that allows unassociated STAs to discover the AP. The TXSS Span field in the DMG Beacon frame shall be set to a value that is less than or equal to dot11MaxLostBeacons.

NOTE 2—The AP can change the sectors it transmits DMG Beacon frames through, and the value of the TXSS Span field, depending on the number and location of associated STAs, and the AP's intention to be discoverable in various sectors.

In a PBSS, the value of the TSF timer is delivered to the STA by the DMG Beacon frames generated at each BTI and by the Announce frames generated during the ATI. In a PBSS, at TBTTs that do not start with a BTI, the PCP begins a beacon interval with an ATI sequence (see 11.1.3.3.2 (Beacon generation in a PBSS)). The time interval in between two consecutive BTIs shall be an integer multiple of dot11BeaconPeriod TUs. A PCP or DMG AP shall set the Next Beacon subfield of the Beacon Interval Control field in the DMG Beacon frame to a value that indicates the number of beacon intervals following the current beacon interval during which the DMG Beacon frame will not be transmitted. The PCP shall transmit at least one DMG Beacon frame to each associated STA within a time interval that is not longer than dot11BeaconPeriod × dot11MaxLostBeacons TUs. The PCP shall transmit at least one DMG Beacon frame through each possible antenna configuration in a full-coverage set of antenna configurations within the number of beacon intervals specified within the most recently updated TXSS Span field.

#### 11.1.2.2 TSF for an IBSS

The TSF in an IBSS is implemented via a distributed algorithm that is performed by all of the members of the BSS. Each STA in the IBSS shall transmit Beacon or S1G Beacon frames according to the algorithm described in this clause. Each IBSS STA shall adopt the TSF value received from any Beacon or S1G Beacon frame or probe response from the IBSS of which it is a member and which has a TSF value later than its own TSF timer. All Beacon frames transmitted in an S1G IBSS shall be S1G Beacon frames, and all references to the Beacon frame (generation and/or reception) in an S1G BSS refer to that of the S1G Beacon frame.

#### 11.1.2.3 TSF for an MBSS

The TSF in an MBSS is provided by the MBSS's active synchronization method. A mesh STA shall initialize its TSF timer according to the MBSS's active synchronization method. The mesh STA shall periodically transmit Beacon frames that contain the value of its TSF timer to announce its local time reference. Mesh STAs receiving a Beacon frame use the timing information in the Beacon frame as specified by the MBSS's active synchronization method. See 14.14.2 (Extensible synchronization framework) for details.

### 11.1.3 Maintaining synchronization

#### 11.1.3.1 General

Each STA shall maintain a TSF timer with modulus $2^{64}$ counting in increments of microseconds. (#439)Non-AP STAs that are not in a PBSS expect to receive Beacon frames at a nominal rate. In a non-DMG infrastructure BSS, the interval between Beacon frames is defined by dot11BeaconPeriod. In a DMG infrastructure BSS, the STAs expect to receive at least one DMG Beacon frame every dot11BeaconPeriod × dot11MaxLostBeacons TUs. (#439)Non-AP STAs in a PBSS expect to receive at least one DMG Beacon frame or one Announce frame every dot11BeaconPeriod × dot11MaxLostBeacons TUs.


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A non-DMG STA sending a Beacon, Timing Advertisement, or Probe Response frame, or a TIM frame with a TSF timestamp, shall set the frame's Timestamp field so that it equals the value of the STA's TSF timer at the time that the start of the data symbol containing the first bit of the Timestamp field appears at the transmit antenna connector. The Address 1 field of the Beacon or Timing Advertisement frame shall be set to the broadcast address.

A DMG STA sending a DMG Beacon, Announce, Timing Advertisement, or Probe Response frame, or a TIM frame with a TSF timestamp, shall set the frame's Timestamp field so that it equals the value of the STA's TSF timer at the time that the start of the data symbol containing the first bit of the frame appears at the transmit antenna connector. The Address 1 field of the Timing Advertisement frame shall be set to the broadcast address.

NOTE 1—In order that the value of the Timestamp field match the TSF value at the correct time, implementations need to compensate for delays along the transmit path, such as delays through the local PHY from the MAC-PHY interface to the transmit antenna connector.

NOTE 2—Unless otherwise specified, the rules that apply to Beacon frames might, depending on context, apply equivalently to DMG Beacon and S1G Beacon frames.(#3187)

### 11.1.3.2 Beacon generation in non-DMG infrastructure networks

If the AP is a non-S1G AP, it shall define the timing for the entire BSS by transmitting Beacon frames according to dot11BeaconPeriod. If the AP is an S1G AP, it shall define the timing for the entire BSS by transmitting S1G Beacon frames according to dot11BeaconPeriod. This defines a series of TBTTs exactly dot11BeaconPeriod TUs apart. (#133)Time 0 is defined to be the TBTT when the first Beacon frame is expected to be sent and this beacon shall have the DTIM Count field of the TIM element set to 0. At each TBTT, the AP shall schedule a Beacon frame as the next frame for transmission according to the medium access rules specified in Clause 10 (MAC sublayer functional description).

NOTE 1—To achieve this requirement, the AP suspends any pending transmissions until the beacon has been transmitted. In the case of a DTIM (#8164)beacon, the AP also suspends any pending individually addressed transmissions until any pending group addressed transmissions have been performed (see 11.2.3.4 (TIM types)).

NOTE 2—When dot11MultiBSSIDImplemented is true, the DTIM Count field in the TIM element applies to the AP corresponding to the transmitted BSSID.(#133)

The beacon period is included in Beacon and Probe Response frames, and a STA shall adopt that beacon period when joining the BSS, i.e., the STA (#135)shall set dot11BeaconPeriod to that beacon period. A(#1426) non-S1G AP shall not transmit S1G Beacon frames. The operation of an S1G AP is further defined in 11.1.3.10.1 (General S1G synchronization).

NOTE 3—Though the transmission of a Beacon frame might be delayed because of CSMA deferrals, subsequent Beacon frames are scheduled at the undelayed nominal beacon interval. This is shown in Figure 11-1 (Beacon transmission on a busy network).

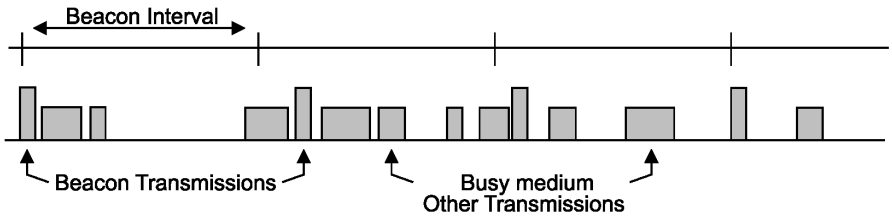


**Figure 11-1—Beacon transmission on a busy network**

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(#2154)The AP shall set the Short Slot Time subfield in the Capability Information field in the transmitted Beacon, Probe Response, Association Response, and Reassociation Response frames to indicate the currently used slot time value within its BSS (see 10.3.2.16 (Operation of aSlotTime)).

(#2154)An AP that supports Clause 18 (Extended Rate PHY (ERP) specification) operation shall use the long slot time unless the BSS consists only of the STAs that support short slot time. STAs indicate support for short slot time by setting the Short Slot Time subfield to 1 when transmitting Association Request and Reassociation Request frames. If the BSS consists of only STAs that support short slot time, short slot time may be used. APs indicate usage of the short slot time by setting the Short Slot Time subfield to 1 in all Beacon, Probe Response, Association Response, and Reassociation Response frame transmissions as described in 9.4.1.4 (Capability Information field).

If a STA that does not support short slot time associates with an AP that supports Clause 18 (Extended Rate PHY (ERP) specification) operation, and the AP is using short slot time, the AP shall use long slot time beginning at the first Beacon frame subsequent to the association of the long slot time STA.

(#2154)NOTE 4—An AP that is using short slot time might reject association from a STA that does not support short slot time. See DENIED_NO_SHORT_SLOT_TIME_SUPPORT in 9.4.1.9 (Status Code field).

An AP whose last transmitted values for the Tx STBC subfield and Rx STBC subfield of the HT Capability Information field of the HT Capabilities element are both nonzero may transmit an STBC Beacon frame and group addressed traffic using the basic STBC MCS, as defined in 10.6.3 (Basic STBC MCS). An AP that transmits an STBC Beacon frame shall set the Dual Beacon field to 1 in transmitted HT Operation elements. A VHT AP shall set the Dual Beacon field to 0 in transmitted HT Operation elements. The STBC Beacon field shall be set to 1 to identify an STBC Beacon frame. The TBTT for the STBC Beacon frame shall be offset by half of a beacon interval from the TBTT of the non-STBC Beacon frame. Except for the setting of the STBC Beacon field, TIM element, and TSF field, all other fields inside the STBC Beacon frame shall be identical to the non-STBC Beacon frame.

The dual beacon mechanism is obsolete. Support for this mechanism might be removed in a later revision of the standard.

#### 11.1.3.3 Beacon generation in a DMG infrastructure BSS and in a PBSS

##### 11.1.3.3.1 General

A DMG STA acting as an AP or PCP follows the DMG channel access procedures (see 10.38 (DMG and CMMG channel access)) and the rules described in this subclause to transmit DMG Beacon frames.

Each DMG Beacon frame transmitted by a PCP and by a DMG AP shall have the Discovery Mode field within the DMG Beacon frame set to 0.

The Duration field of each transmitted DMG Beacon frame shall be set to the time remaining until the end of the current BTI.

A PCP and a DMG AP establish a series of target beacon transmission times (TBTTs) spaced dot11BeaconPeriod TUs apart. The period between two TBTTs is referred to as the *beacon interval*. The beacon interval length shall be no more than aMaxBIDuration. Time value zero of the TSF is defined to be a TBTT.

The length of the beacon interval is included in the DMG Beacon, Announce, and Probe Response frames, and a DMG STA shall adopt that beacon interval when joining the BSS.


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A PCP and a DMG AP that move the TBTT (11.29.2 (Moving the TBTT)) or change the beacon interval duration (11.29.3 (Changing beacon interval duration)) shall reestablish the TBTT by resetting the TSF to 0 at the time the BSS parameter change takes effect in the BSS.

(11ay)A PCP or an AP that schedules a TDD SP that occupies the entire beacon interval shall transmit DMG Beacons frames according to the procedure specified in 11.1.3.3.4 (Beacon generation under TDD channel access(11ay)). In all other cases, the following procedures shall apply.

At each BTI, a PCP and a DMG AP schedule DMG Beacon frames for transmission according to the procedure specified in 10.41.4 (Beamforming in BTI). Subject to this constraint, the AP or PCP may delay the DMG Beacon frame transmission if the medium is determined by the CCA mechanism to be busy. When delaying a DMG Beacon frame transmission, the AP or PCP shall check that the BTI, A-BFT, and ATI do not overlap in time with pseudo-static SPs for which the AP or PCP is not the source DMG STA and, if AP or PCP clustering is in use, that the DMG Beacon frame transmission follows the additional rules described in 10.39 (DMG and CMMG AP or PCP clustering).

An AP or PCP may transmit DMG Beacon frames through different antenna configurations during the BTI, but shall not transmit more than one DMG Beacon frame through the same antenna configuration during the BTI of any beacon interval. For any beacon interval that does not include a DMG Beacon frame transmission in the BTI, the AP shall begin the beacon interval with an ATI, and the PCP may begin the beacon interval with an ATI (11.2.7.3 (PCP power management mode)).

(11ay)An EDMG AP or EDMG PCP can transmit a DMG Beacon frame using a quasi-omni antenna pattern as described in 10.41.4 (Beamforming in BTI).

(11ay)NOTE 1—The reception of a DMG Beacon frame transmitted using a quasi-omni antenna pattern indicates to the receiving STA a possibility of communicating with the AP or PCP (e.g., Probe Request, Probe Response) using a quasi-omni transmit antenna pattern.

When the DMG Beacon frame transmission is performed as multiple directional transmissions, an AP or PCP should change the sequence of directions through which a DMG Beacon frame is transmitted after it has transmitted a DMG Beacon frame through each direction in the current sequence of directions. When the ECAPC Policy Enforced field is equal to 1 in the DMG Beacon frame most recently transmitted by an AP or PCP, then

— When the AP or PCP transmits a DMG Beacon frame as multiple directional transmissions, the AP or PCP shall change the sequence of directions through which a DMG Beacon frame is transmitted after it has transmitted a DMG Beacon frame through each direction in the current sequence of directions.
— When the AP or PCP transmits a DMG Beacon frame as a single transmission, the AP or PCP shall randomly delay the transmission of the DMG Beacon frame by up to min(4×TXTIME(DMG Beacon), 1024×dot11MinBHIDuration) μs after the TBTT.

This is done to randomize and potentially minimize interference to/from the DMG Beacon. One such example is indicated in Figure 11-2 (Example of DMG beacon transmission by an AP or PCP during the BTI). If the sequence of directions is changed, the sequence of directions shall be pseudorandomly chosen from a sequence of directions covering the full set of directions available to an AP or PCP.

(11ay)NOTE 2—An AP or PCP operating in a DMG BSS can transmit Announce frames during the ATI (10.38.3 (ATI transmission rules)). An Announce frame can perform the function of a DMG Beacon frame, can be transmitted as an individually addressed frame directed to a STA, and can provide a much more spectrally efficient access than using a DMG Beacon frame.

A DMG STA that is an AP or a PCP shall include a DMG Operation element within a transmitted DMG Beacon frame if the CBAP Only field within the DMG Beacon frame is equal to 1. A DMG STA that is an AP

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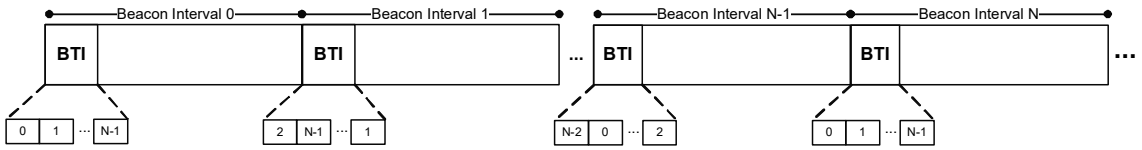


**Figure 11-2—Example of DMG beacon transmission by an AP or PCP during the BTI**

or a PCP shall include a DMG Operation element within a transmitted DMG Beacon frame if the CBAP Only field within the DMG Beacon frame is equal to 0 and the Extended Schedule element is included in the DMG Beacon frame. A DMG STA that is an AP or a PCP shall include a DMG Operation element within a transmitted Announce frame if the Extended Schedule element is included in the Announce frame.

#### 11.1.3.3.2 Beacon generation in a PBSS

In a PBSS, every beacon interval shall start with a BTI or ATI, except in PCP power save (PPS) mode, where a PCP D-BI need not start with a BTI or ATI (see 11.2.7.3.3 (PCP operation with a wakeup schedule)).

A PCP that transmits a DMG Beacon frame with the CBAP Only field equal to 1 within a BTI shall include a BTI in any following beacon intervals until the completion of the TXSS of which the DMG Beacon frame is a part.

#### 11.1.3.3.3 Beacon generation in a DMG infrastructure BSS

A DMG AP shall set dot11MaxLostBeacons to the value of the aMinBTIPeriod parameter.

#### 11.1.3.3.4 Beacon generation under TDD channel access(11ay)

If a TDD SP occupies the entire beacon interval, the DMG Beacon frame fields shall be set as follows:

— Next A-BFT subfield: set to a nonzero value
— Duration field: bits 0–13 set to 0, and bit 14 and bit 15 set to 1

### 11.1.3.4 DMG beacon generation before establishment of a BSS

A DMG STA can transmit DMG Beacon frames before establishment of a BSS to discover and perform beamforming during the A-BFT with another DMG STA so that the following frame exchanges between these STAs do not have to be done as a sector sweep (see 11.1.4.3.3 (Active scanning procedure for a DMG STA)).

A DMG STA that transmits DMG Beacon frames before establishment of a BSS shall set the Discovery Mode field in each transmitted DMG Beacon frame to 1 to indicates that the establishment of a BSS procedure defined in 11.1.4.4 (Initializing a BSS) has not been performed. In addition, the STA shall set the Next A-BFT field to 0.

Before establishment of a BSS, the spacing between TBTTs can change, and the time to the next TBTT is contained in each DMG Beacon frame transmitted at the last BTI. At each TBTT, the STA should generate a random value for the Beacon Interval field within the DMG Beacon frame from a uniform distribution between (10 TUs, 200 TUs), i.e., 10 TUs to 199 TUs. Every DMG Beacon frame transmission in the same BTI shall have the same value in its Beacon Interval field.

The TSF shall be set to 0 at the first TBTT for which the Discovery Mode field within the DMG Beacon frame is equal to 1. After that, the TSF shall be set to 0 at the TBTT of the beacon interval in which the STA changes the Beacon Interval field.


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A STA shall transmit the first DMG Beacon frame of the next BTI at the time indicated by the start of the transmission of the first DMG Beacon frame within the last BTI and the Beacon Interval field contained in the DMG Beacon frame transmitted within the last BTI, unless the medium is determined by the CCA mechanism to be busy in which case the STA may delay the transmission of the first DMG Beacon frame transmission.

A STA that transmits a DMG Beacon frame with the Discovery Mode field equal to 1 may indicate the STA(s) that is allowed to respond in the A-BFT following the BTI where the DMG Beacon frame is transmitted. To do that, in the DMG Beacon frame the STA shall set the CC Present field to 1 and shall set the A-BFT Responder Address subfield to an individual address or to a group address of a group that includes the STA(s) that is allowed to respond in the A-BFT.

(11ay)An EDMG STA can transmit a DMG Beacon using a quasi-omni antenna pattern as described in 10.41.4 (Beamforming in BTI).

(11ay)NOTE—The reception of a DMG Beacon frame transmitted using a quasi-omni antenna pattern indicates to the receiving STA a possibility of communicating with the transmitting STA (e.g. Probe Request, Probe Response) using a quasi-omni transmit antenna pattern.

A DMG STA that is transmitting DMG Beacon frames with the Discovery Mode field equal to 1 should configure its receive antenna to a quasi-omni antenna pattern and stay in receiving state during portions of the DTI defined by the DMG Beacon frame transmissions. This enables the STA to receive frames transmitted by any STA that is covered by this antenna pattern.

A STA (11bd)with dot11DMGOCBActivated equal to false that is transmitting DMG Beacon frames with the Discovery Mode field equal to 1 should cease transmitting these beacons when it has received a DMG Beacon frame from another STA, or when it has received acknowledgment of a transmitted Probe Response frame. If a BSS is not initialized as a result of the channel scanning, the STA can resume transmitting DMG Beacon frames with the Discovery Mode field equal to 1.

(11bd)A STA with dot11DMGOCBActivated equal to true that is transmitting DMG Beacon frames with the Discovery Mode field equal to 1 may continue transmitting these beacons for discovery as described in 11.1.4.7 (DMG discovery outside the context of a BSS(11bd)) even if it has received a DMG Beacon frame from another STA.

The procedure of TBTT change described in the preceding paragraph is applicable for DMG Beacon frame generation before establishment of a BSS, whereas the procedures defined in 11.29.2 (Moving the TBTT) and 11.29.3 (Changing beacon interval duration) are used to change the DMG BSS parameters after an infrastructure BSS or PBSS has been established.

A STA shall set the Duration field of each transmitted DMG Beacon frame to the time remaining until the end of the current BTI.

### 11.1.3.5 Beacon generation in an IBSS

Beacon generation in an IBSS is distributed. The beacon period is included in Beacon, Announce, and Probe Response frames, and a STA shall adopt that beacon period when joining the IBSS. All members of the IBSS participate in beacon generation. Each STA shall maintain its own TSF timer that is used for dot11BeaconPeriod timing. The beacon interval within an IBSS is established by the STA at which the MLME-START.request primitive is performed to create the IBSS. An S1G STA in an IBSS has dot11ShortBeaconInterval set to false. This defines a series of TBTTs exactly dot11BeaconPeriod TUs apart. Time zero is defined to be a TBTT. At each TBTT the STA shall

a) Suspend the decrementing of the backoff counter for any pending transmission that is not a Beacon or DMG Beacon frame,

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b) Calculate a random delay uniformly distributed in the range between zero and twice aCWmin × aSlotTime when the STA is a non-DMG STA, and between zero and the result of two multiplied by aCWminDMGIBSS multiplied by the duration of the STA's following BTI when the STA is a DMG STA,

c) Wait for the period of the random delay, decrementing the random delay timer using the same algorithm as for backoff, except that SIFS + aSlotTime should be used as the initial medium idle period within the backoff procedure. If the ATIM window in use within the IBSS is greater than 0 and the end of the ATIM window occurs before the random delay timer expires, cancel the remaining random delay and pending Beacon frame transmission and proceed to step f),

d) Cancel the remaining random delay and the pending Beacon frame transmission or BTI (DMG only), if a Beacon frame arrives from the IBSS of which the STA is a member before the random delay timer has expired,

e) Send a Beacon frame in a non-DMG BSS or DMG Beacon frame(s) in a DMG BSS if the random delay has expired and no Beacon frame in a non-DMG BSS or no DMG Beacon frame in a DMG BSS has arrived from the IBSS of which the STA is a member during the delay period,

f) If the ATIM window in use within the IBSS is greater than 0, then

   1) Resume decrementing the backoff counter for any pending transmission allowed inside the ATIM window and

   2) At the end of the ATIM window duration resume the backoff for any pending frames intended for transmission outside the ATIM window,

g) If the ATIM window in use within the IBSS is 0, then resume decrementing the backoff counter for any pending transmissions.

Figure 11-3 (Beacon transmission in an IBSS) illustrates beacon transmission in an IBSS.

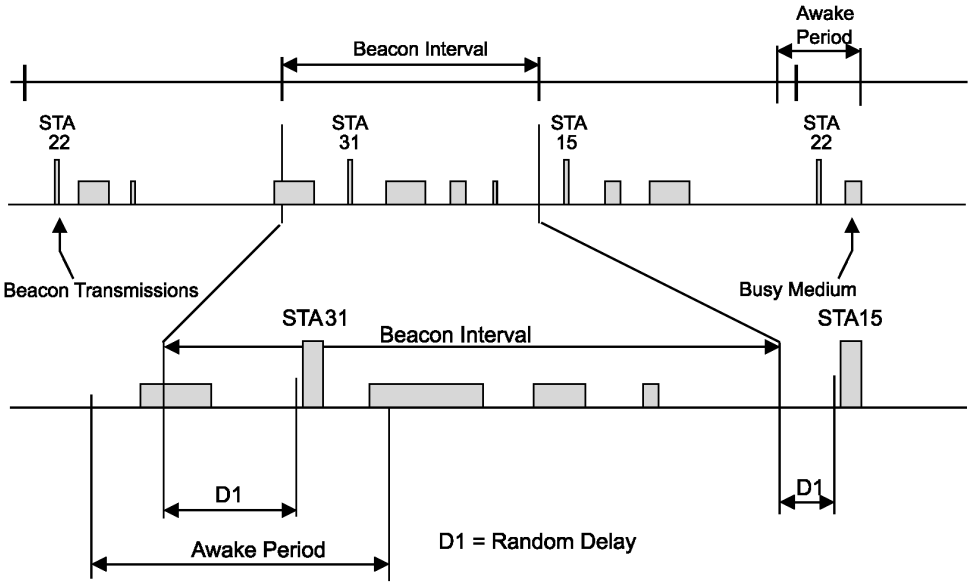


**Figure 11-3—Beacon transmission in an IBSS**

### 11.1.3.6 Beacon generation in an MBSS

Beacon generation in an MBSS is described in 14.14.3.1 (Beacon generation in MBSSs).


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#### 11.1.3.7 Beacon reception

STAs in an infrastructure network or PBSS shall use information in received Beacon frames, DMG Beacon frames, or Announce frames only if the BSSID field is equal to the MAC address currently in use by the STA contained in the AP of the BSS or to the MAC address currently in use by the PCP of the PBSS. A non-AP STA in an infrastructure BSS and a non-PCP STA in a PBSS that supports the Multiple BSSID capability shall use other information in received Beacon or DMG Beacon frames only if the BSSID field of the non-AP or non-PCP STA is equal to the MAC address currently in use by the STA contained in the AP or PCP, respectively, of the BSS corresponding to the transmitted BSSID or if the BSSID field of the non-AP or non-PCP STA is equal to one of the nontransmitted BSSIDs.

STAs in a non-DMG IBSS shall use information in any received Beacon frame for which the IBSS subfield of the Capability field is 1, the content of the SSID element is equal to the SSID of the IBSS, and the TSF value is later than the receiving STA's TSF timer. Use of this information is specified in 11.1.5 (Adjusting STA timers).

STAs in an MBSS shall use information in received Beacon frames as described in 14.14.3.2 (Beacon reception for mesh STA).

A non-AP STA in which dot11MultiBSSIDImplemented is true shall support frame filtering for up to two BSSIDs; one for the transmitted BSSID and one for the nontransmitted BSSID. The STA, when associated with a BSS corresponding to a nontransmitted BSSID, shall discard all Data and Management frames that use the transmitted BSSID as the transmitter address, except for Beacon, FILS Discovery, Probe Response, and TIM frames.

DMG IBSS STAs shall use other information in any received DMG Beacon (excluding those with the Discovery Mode field equal to 1) and Announce frames for which the BSS Type subfield is 1, the content of the SSID element is equal to the SSID of the IBSS, and the TSF value is later than the receiving STA's TSF timer. Use of this information is specified in 11.1.5 (Adjusting STA timers).

A STA shall ignore the BSS Type field contained in a received DMG Beacon frame if the Discovery Mode field within the DMG Beacon frame is 1.

An active DMG STA operating in a BSS shall be ready to receive from its AP or PCP for a period of time of at least dot11MinBHIDuration following the TBTT or expected ATI start time as specified in the last Next DMG ATI element (9.4.2.134 (Next DMG ATI element)) transmitted by the AP or PCP.

An active DMG STA that is receive beamforming trained with the AP or PCP shall direct its receive antenna pattern toward the AP or PCP or use a quasi-omni antenna pattern during this time.

A non-PCP STA that receives a DMG Beacon frame from a PCP in which the PCP Association Ready field is 0 shall not transmit an Association Request frame addressed to the PCP that transmitted the received DMG Beacon frame(#337). A non-PCP STA that receives a DMG Beacon frame from a PCP with the PCP Association Ready field set to 1 may transmit an Association Request frame addressed to the PCP that transmitted the received DMG Beacon frame(#337).

#### 11.1.3.8 Multiple BSSID procedure

##### 11.1.3.8.1 General(11ax)

A STA that supports the Multiple BSSID capability has dot11MultiBSSIDImplemented equal to true and shall set to 1 the Multiple BSSID field of the Extended Capabilities elements that it transmits. Support for the Multiple BSSID capability is mandatory for a FILS STA and non-AP HE STA. An AP that supports enhancements related to the discovery and advertisement of a nontransmitted BSSID shall set the Enhanced Multi-BSSID Advertisement Support bit in the Extended Capabilities element to 1 and is referred to as an

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EMA AP. A 6 GHz AP with dot11MultiBSSIDImplemented equal to true and advertising a partial list of nontransmitted BSSID profiles shall operate as an EMA AP. If an HE AP operating in the 2.4 GHz or 5 GHz bands has dot11MultiBSSIDImplemented equal to true, advertises a partial list of nontransmitted BSSID profiles, and intends a non-AP STA to discover the complete list of nontransmitted BSSID profiles, where a complete list of nontransmitted BSSID profile comprises only BSSIDs that are discoverable, then the HE AP shall operate as an EMA AP.(11ax)

(11ax)A nontransmitted BSSID is discoverable if the AP corresponding to the transmitted BSSID includes information of that BSSID in its Beacon and Probe Response frames (though not necessarily in every frame).(11ax)(#1004)

(11ax)An AP with dot11MultiBSSIDImplemented equal to true shall set the Co-Hosted BSS subfield in HE Operation element that it transmits to 0.

(11ax)The BSSID of the AP belonging to a multiple BSSID set is referred to as the transmitted BSSID if the AP includes the Multiple BSSID element in the Beacon frame that it transmits. In a multiple BSSID set, there shall not be more than one AP corresponding to the transmitted BSSID. The BSSID of an AP belonging to a multiple BSSID set is a nontransmitted BSSID if the (#4222)AP's BSS's BSSID is derived according to 9.4.2.44 (Multiple BSSID element) and 9.4.2.72 (Multiple BSSID-Index element). Among all AP STAs in a multiple BSSID set, only the AP corresponding to the transmitted BSSID shall transmit a Beacon frame.

See 11.1.4.3.4 (Criteria for sending a response) for the rules governing transmission of Probe Response frames in a multiple BSSID set.

#### 11.1.3.8.2 Nontransmitted BSSID profile(11ax)

A nontransmitted BSSID profile represents information about a particular nontransmitted BSSID. It consists of a set of elements that are carried in a single Nontransmitted BSSID Profile subelement, unless the subelement cannot fit in a single Multiple BSSID element. In this case, the nontransmitted BSSID profile is fragmented and is carried in more than one Nontransmitted BSSID Profile subelements across more than one Multiple BSSID element in the same frame. Each nontransmitted BSSID profile, at a minimum, shall include the elements that are mandatory for that BSS (i.e., Nontransmitted BSSID Capability element, SSID element, Multiple BSSID-Index element as described in 9.4.2.44 (Multiple BSSID element)). An example of Multiple BSSID element carrying one or more Nontransmitted BSSID Profile subelements is shown in Figure 11-4 (Example of Multiple BSSID element carrying Nontransmitted BSSID Profile subelements(11ax)(#1018)). The figure also shows the order in which the elements are present within each Nontransmitted BSSID Profile subelement.


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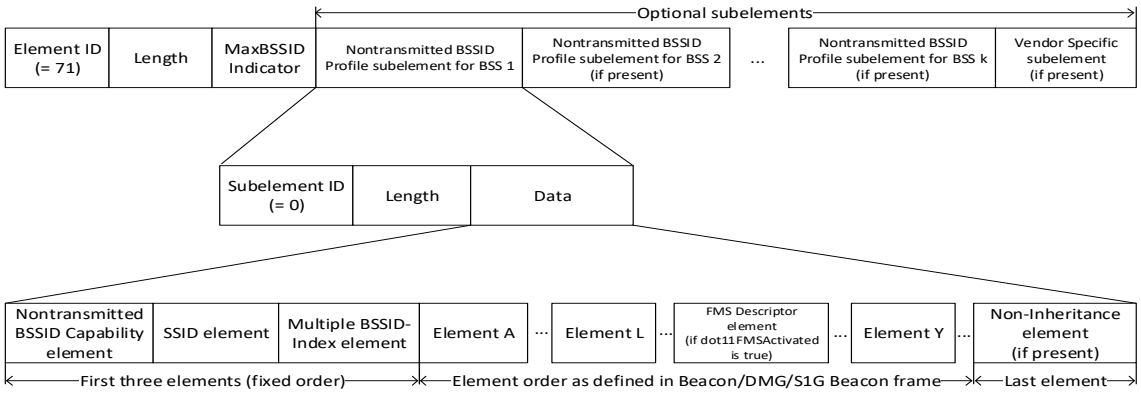


**Figure 11-4—Example of Multiple BSSID element carrying Nontransmitted BSSID Profile subelements(11ax)(#1018)**

(#4)A non-AP and non-PCP STA derives its nontransmitted BSSID(#3522) according to 9.4.2.44 (Multiple BSSID element) and 9.4.2.72 (Multiple BSSID-Index element).

An AP shall not carry a nontransmitted BSSID profile across multiple Multiple BSSID elements in a frame, unless the nontransmitted BSSID profile cannot fit in one multiple BSSID element due to the size limit of the multiple BSSID element.

If there is a need to fragment a nontransmitted BSSID profile across more than one Multiple BSSID element in a frame, an AP shall not fragment a (#6004)nonfragmentable element in the profile across multiple Multiple BSSID elements, and it shall place the next element in that profile as the first element in the first Nontransmitted BSSID Profile subelement of the immediately following Multiple BSSID element. An AP shall not fragment a nontransmitted BSSID profile across two frames. If a frame carries multiple Multiple BSSID elements, the MaxBSSID Indicator field in all the Multiple BSSID elements shall carry the same value. (#1018)In addition, an AP corresponding to the transmitted BSSID shall follow the procedures described in 10.28.13 (Element fragmentation within a subelement of a nonfragmentable element(M118)(#1018)) if a nontransmitted BSSID profile carries a fragmentable element whose Information field cannot fit the remaining length of the subelement.

(#1018)A non-AP STA shall determine that a nontransmitted BSSID profile is fragmented if the next element in the frame is a Multiple BSSID element in which the first Nontransmitted BSSID Profile subelement does not contain the Nontransmitted BSSID Capability element as the first element. In addition, the non-AP STA shall follow the procedures described in 10.28.14 (Element defragmentation within a subelement of a nonfragmentable element(#1018)(M118)) if the first element in the first Nontransmitted BSSID Profile subelement of the subsequent Multiple BSSID element is a Fragment element.

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An example of a nontransmitted BSSID profile fragmented across two Multiple BSSID elements in a frame is shown in Figure 11-5 (Example of nontransmitted BSSID profile fragmented across multiple Multiple BSSID elements(11ax)(#1018)).

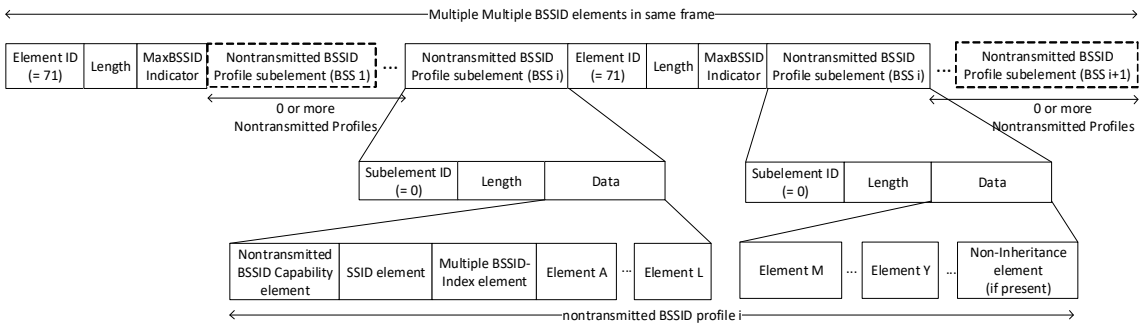


**Figure 11-5—Example of nontransmitted BSSID profile fragmented across multiple Multiple BSSID elements(11ax)(#1018)**

NOTE—As described in 9.4.3 (Subelements), the Length field of the Nontransmitted BSSID Profile subelement indicates the number of octets only in the Data field of the subelement.

### 11.1.3.8.3 Discovery of a nontransmitted BSSID profile(11ax)

An AP or PCP may choose to include only a partial list of nontransmitted BSSID profiles in the Beacon frame, S1G Beacon frame, or DMG Beacon frame or to include different sets of nontransmitted BSSID profiles in different Beacon frames, S1G Beacon frames, or DMG Beacon frames. An AP corresponding to the transmitted BSSID may choose to include only a partial list of nontransmitted BSSID profiles in an unsolicited broadcast Probe Response frame or a Probe Response frame sent in response to a Probe Request frame with Address 3 field set to wildcard BSSID and SSID set to wildcard. An AP advertising a complete list of nontransmitted BSSID profiles shall set the Complete List Of NonTxBSSID Profiles field of Extended Capabilities element to 1.

(#3)If the most recent Beacon or Probe Response frame transmitted by the AP corresponding to the transmitted BSSID has the Complete List Of NonTxBSSID Profiles field equal to 0, then a non-AP STA with dot11MultiBSSIDImplemented equal to true should listen for additional Beacon frames from the AP or may send a Probe Request frame to the AP to gather information about one or more nontransmitted BSSIDs in the multiple BSSID set whose profile is not carried in the frame and that are of interest to the non-AP STA.

An EMA AP operating in the 2.4 GHz or 5 GHz band that transmits a Beacon or Probe Response frame carrying a partial list of nontransmitted BSSID profiles should include in the frame a Reduced Neighbor Report element carrying information for at least the nontransmitted BSSIDs that are not present in the Multiple BSSID element carried in that frame.

A 6 GHz-only EMA AP that transmits a Beacon or broadcast Probe Response frame carrying a partial list of nontransmitted BSSID profiles shall include a Reduced Neighbor Report element carrying information for at least the nontransmitted BSSIDs that are discoverable and not present in the Multiple BSSID element carried in that frame.

A 6 GHz-only EMA AP that transmits a FILS Discovery frame shall include a Reduced Neighbor Report element carrying information on all nontransmitted BSSIDs in the multiple BSSID set that are discoverable.


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The EMA AP does this to aid the fast discovery of all nontransmitted BSSIDs in the multiple BSSID set that are discoverable.

NOTE 1—A FILS Discovery frame received from a 6 GHz AP with the Multiple BSSIDs Presence Indicator subfield equal to 1 and not carrying a Reduced Neighbor Report element implies that the AP's Beacon frame carries a complete list of nontransmitted BSSID profiles or that the information of the nontransmitted BSSID(s) is advertised in the 2.4 GHz or 5 GHz band by a (#2210)colocated AP (see 11.53 (Out-of-band discovery of a 6 GHz BSS(11ax))).

An EMA AP advertising a partial list of BSSID profiles, shall include the Multiple BSSID Configuration element (see 9.4.2.259 (Multiple BSSID Configuration element(11ax))) in its Beacon frame, S1G Beacon frame, or DMG Beacon frame and in any Probe Response frame it sends to indicate the configuration of the multiple BSSID set.

An AP shall set the BSSID Count field of the Multiple BSSID Configuration element to indicate the number of active BSSIDs in the multiple BSSID set, and shall set the Full Set Rx Periodicity field to indicate the number of beacons a scanning STA is required to receive in order to discover all the active nontransmitted BSSIDs in the set. An AP corresponding to the transmitted BSSID shall respond with a Probe Response frame carrying one or more Multiple BSSID elements that include, at a minimum, the profiles for the nontransmitted BSSIDs requested by the soliciting Probe Request frame.

NOTE 2—A nontransmitted BSSID profile is requested if, in the soliciting Probe Request frame, the SSID or BSSID matches the SSID or the BSSID, respectively, of the BSS corresponding to the nontransmitted BSSID.

An unassociated non-AP STA may transmit a Probe Request frame containing a Known BSSID element (see 9.4.2.260 (Known BSSID element)) and addressed to an EMA AP corresponding to the transmitted BSSID to gather information on nontransmitted BSSIDs that it has not discovered.

An EMA AP that transmits a Probe Response frame in response to a Probe Request frame containing a Known BSSID element shall, at a minimum, include the nontransmitted BSSID profiles not known to the requesting STA, unless the AP is unable to fit all of them in the response frame.

An EMA AP that includes a partial list of nontransmitted BSSID profiles in its Beacon frame, S1G Beacon frame, or DMG Beacon frame, shall advertise a particular nontransmitted BSSID profile in a repeating pattern such that the profile is present in at least one beacon in a sequence of beacons indicated by the Full Set Rx Periodicity field of the Multiple BSSID Configuration element, unless the membership of the multiple BSSID set changes. An EMA AP shall include a nontransmitted BSSID profile in the DTIM beacon of that BSS so that STAs associated to that AP can receive the profile (and any updates to the BSS configuration) without having to transition to awake state(#6038) to receive additional beacons. An EMA AP shall select the DTIM interval for a nontransmitted BSSID as a multiple of the value carried in the Full Set Rx Periodicity field of the Multiple BSSID Configuration element. Annex AA provides several example configurations.

NOTE 3—An AP corresponding to a nontransmitted BSSID can transmit a group addressed frame to advertise any changes to its BSS operational parameters or termination of the BSS (i.e., transmission of a broadcast Disassociation frame) during the beacon interval that follows the profile's DTIM beacon.(#1019)

NOTE 4—In order to aid fast discovery of nontransmitted BSSIDs via passive scanning, it is recommended that an AP select a small value for the Full Set Rx Periodicity field.

#### 11.1.3.8.4 Inheritance of element values(11ax)

(#4)(11ax)When a nontransmitted BSSID profile is present in one or more Multiple BSSID elements carried in a Probe Response frame, Beacon frame, DMG Beacon frame, or S1G Beacon frame, the profile shall include all elements that are specific to the corresponding nontransmitted BSS. An element, identified by (#3195)Element ID and Element ID Extension fields (if applicable), is considered to be specific to a BSS if any of the following conditions are satisfied:

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- At least one element with the same (#3195)Element ID and Extended Element ID fields (if applicable) is included in the frame that carries the Multiple BSSID element but the contents of the Information field are not the same for the nontransmitted BSSID.
- The nontransmitted BSSID satisfies the condition as specified in(#4000) Table 9-69 (Probe Response frame body) for a Probe Response frame, Table 9-62 (Beacon frame body) for a non-DMG non-S1G AP, Table 9-75 (DMG Beacon frame body) for a DMG AP, or Table 9-76 (Minimum and full set of optional elements) for a S1G AP for that element to be present while the transmitted BSSID does not satisfy the corresponding condition.

(#7035)NOTE—For example, when there exists one or more Vendor Specific elements carried in a frame that includes the Multiple BSSID element containing a nontransmitted BSSID profile, and the contents of the Information field for at least one of the Vendor Specific elements are not the same as that of at least one Vendor Specific element that applies to the nontransmitted BSSID profile then, each Vendor Specific element that applies to the nontransmitted BSSID profile is included in the Nontransmitted BSSID Profile subelement.(#4)

(#4000)When present in a nontransmitted BSSID profile, the elements appear in the same order as that in Table 9-69 (Probe Response frame body) for a Probe Response frame, Table 9-62 (Beacon frame body) for a non-DMG non-S1G AP, Table 9-75 (DMG Beacon frame body) for a DMG AP, or Table 9-76 (Minimum and full set of optional elements) for a S1G AP.

(#4)If an element, identified by (#3195)Element ID and Element ID Extension fields (if applicable), is carried in a Probe Response frame, Beacon frame, DMG Beacon frame, or S1G Beacon frame transmitted by an AP corresponding to the transmitted BSSID and there is no element having the same Element ID and Element ID Extension (if applicable) present in a nontransmitted BSSID profile, and the element is not listed in the Non-Inheritance element (if included) in the nontransmitted BSSID profile for that BSS, then a non-AP STA receiving the frame shall consider the element to be part of that nontransmitted BSSID's profile and the contents of the Information field shall apply to the nontransmitted BSSID. Otherwise, a non-AP STA receiving the frame shall not consider the element to be part of the nontransmitted BSSID profile.

(#4)Figure 11-6 (Example of inheritance in a nontransmitted BSSID profile(#4)) illustrates the inheritance of elements in a nontransmitted BSSID profile. The example shows a Management frame (such as a Probe Response frame, Beacon frame, DMG Beacon frame, or S1G Beacon frame) transmitted by an AP corresponding to a transmitted BSSID. The frame includes several elements identified by their corresponding (M118)element ID (extension) values shown in parenthesis. The Multiple BSSID element (Element ID = 71) contains profiles for nontransmitted BSSID N and BSSID M. In this example, the Nontransmitted BSSID Profile subelement for BSSID N is expanded to show details of its contents and to illustrate the inheritance operation. Similar considerations (M118)apply for the Nontransmitted BSSID Profile subelement for BSSID M (not shown in the figure). In this example, the contents of the Information fields for Element ID's (Extension) B, C, and E are the same for BSSID N and as a result, these elements are not carried in the nontransmitted BSSID profile for BSSID N. In other words, BSSID N inherits these elements from the transmitted BSSID. BSSID N does not inherit element identified by (M118)element ID (extension) A and is listed in the Non-Inheritance element, which is the last element in the nontransmitted BSSID profile. Since the content of the Information field for the element identified by (M118)element ID (extension) F is not the same for BSSID N and the transmitted BSSID, the element is carried in the nontransmitted BSSID profile for BSSID N. Elements identified by (M118)element ID (extension) D and Y, are specific to the BSSID N and are carried in its profile. Since there is a difference between the Vendor Specific elements that apply to the transmitted BSSID and BSSID N, each Vendor Specific element that applies to BSSID N is carried in its nontransmitted BSSID profile, including Vendor Specific element carrying "Content (1)" which (#6025)needs to be replicated in order to still apply to BSSID N.


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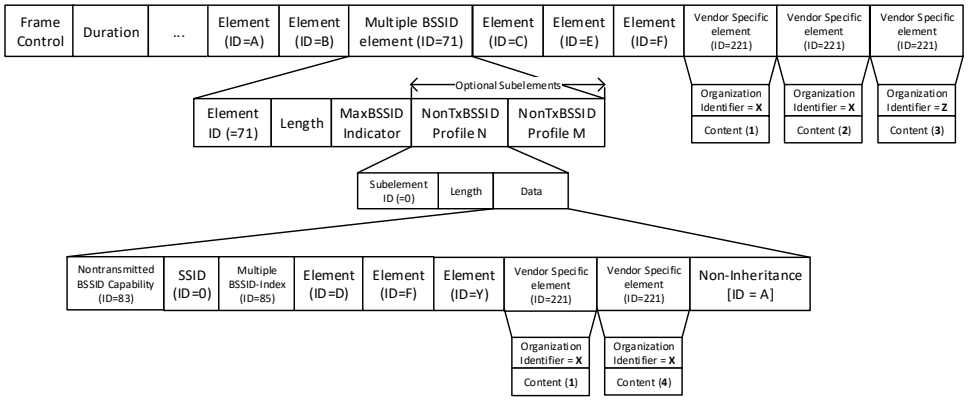


**Figure 11-6—Example of inheritance in a nontransmitted BSSID profile(#4)**

### 11.1.3.8.5 Traffic advertisement in a multiple BSSID set(11ax)

The Partial Virtual Bitmap field of the TIM element carried in the Beacon, S1G Beacon, or TIM frame shall indicate the presence or absence of traffic to be delivered to all stations associated (11ax)with an AP corresponding to a transmitted or nontransmitted BSSID. The first $2^n$ bits of the bitmap are reserved for the indication of group addressed frame for the transmitted and all nontransmitted BSSIDs (see 9.4.2.5.1 (General)). (M165)The Traffic Indicator field of the Bitmap Control field shall be set to 1 to indicate that one or more non-GCR-SP non-SYNRA group addressed frames, that are not to be delivered using group AID, are buffered at the AP corresponding to the transmitted BSSID. The field corresponding to a (#8132)BSSID index (i.e., a bit position between 1 and $2^n - 1$ of the Partial Virtual Bitmap field matching the BSSID index of a nontransmitted BSSID) shall be set to 1 to indicate that one or more non-GCR-SP non-SYNRA group addressed frames, that are not to be delivered using group AID, are buffered at the AP corresponding to that nontransmitted BSSID. (#133)See Annex L for examples of traffic indication (including that for group addressed frames) in a multiple BSSID set. The AID space is shared by all BSSs and the lowest AID value that shall be assigned to a non-S1G STA is $2^n$ (see 9.4.2.5 (TIM element)). The value of the 11 LSBs of the AID assigned to an S1G STA shall be greater than $2^n$. The Encoded Blocks that contain these first $2^n$ AIDs (if any) shall precede the Encoded Blocks that contain AIDs for the S1G STAs in the S1G Partial Virtual Bitmap field of each page. (11ax)Each BSS of the Multiple BSSID set may have a different DTIM interval, which is signaled in the DTIM Period and DTIM Count fields that are present in the Multiple BSSID-Index element carried in the nontransmitted BSSID profile for that BSS.

NOTE 1—The DTIM Count and DTIM Period fields of the TIM element carried in the Beacon frame transmitted by an AP corresponding to the transmitted BSSID indicates the DTIM interval for the transmitted BSSID.(#133)

(#1019)An AP (which can correspond to either the transmitted BSSID or a nontransmitted BSSID) should advertise any change to the operational parameters that are specific to its BSS (such as, but not limited to, UORA parameter set or broadcast TWT parameter set) during the DTIM beacon(#3309) for its BSS so that STAs associated to that AP can receive the changes in the DTIM beacon without having to transition to awake state(#6038) for additional Beacon frames or S1G Beacon frames between the DTIM beacons(#3309).

(#1020)For operational parameters that apply to all the BSSs in the multiple BSSID set and those that involve a countdown (such as, but not limited to, channel switch announcement or BSS color change announcement), the AP corresponding to the transmitted BSSID should select a countdown value such that the pertinent element(s) appears in at least one DTIM beacon(#3309) of each AP in the set. This (M118)allows a STA associated with

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an AP in the set to receive the announcement during the DTIM beacon(#3309) corresponding to its associated BSS.

(11ax)Based upon its knowledge of the capability of associated non-AP STAs to support the multiple BSSID capability, as indicated by the corresponding field in the Extended Capabilities element and the content of the traffic indication virtual bitmap, an AP shall encode the Partial Virtual Bitmap and the Bitmap Control fields of the TIM element using one of the three methods (Method A, Method B, or Method C) defined in 9.4.2.5.1 (General). Specifically, a non-S1G AP shall use Method B if it determines that the bit for each associated non-AP STA in the traffic indication virtual bitmap that is reconstructed by each non-AP STA from the received TIM element encoded using Method B is set correctly. Otherwise, a non-S1G AP shall use Method A, and an S1G AP shall use Method C.

NOTE 2—If all the recipients of the TIM element are STAs that support the multiple BSSID capability (e.g., when the TIM element is carried in HE beacon, ER beacon, FILS Discovery frame, or OPS frame where all the addressees are non-AP HE STAs), the transmitting AP uses Method B to encode the Partial Virtual Bitmap and the Bitmap Control fields of the TIM element.(11ax)

Multiple BSSID rate selection is defined in 10.6.9 (Multiple BSSID rate selection(#2162)).

#### 11.1.3.8.6 Multiple BSSID Index Adjustment Procedure(#3018)

This subclause describes the procedure to adjust multiple BSSID index (see 9.4.2.72 (Multiple BSSID-Index element)) values for each BSSID in a multiple BSSID set, which (M118)results in a different BSSID in the set taking over the role of the transmitted BSSID. The procedure (#4394)helps to ensure that the multiple BSSID set continues to operate even if the AP corresponding to the transmitted BSSID no longer operates its BSS or intends to relinquish the role of being the transmitted BSSID.

An AP that supports the procedure described in this subclause sets the Multiple BSSID Role Switch Support subfield in the Extended Capabilities element to 1. A non-AP STA that supports computing the new BSSID index upon receiving the Index Adjustment Factor field sets the Multiple BSSID Role Switch Support subfield in the Extended Capabilities element to 1. When the multiple BSSID index adjustment procedure is being performed, the AP should transmit a Disassociation frame to each non-AP STA that does not support this procedure.(#4372)

NOTE 1—If a non-AP STA that does not support this feature has indicated in its Extended Capabilities element that it supports BSS transition management, then the AP is recommended to indicate to that non-AP STA that disassociation is imminent and recommend other AP(s) for the non-AP STA to transition to (see 11.21.7.3 (BSS transition management request)).(#4372)

(#4002)When the multiple BSSID index adjustment procedure is being performed (#6005)the AP corresponding to a transmitted BSSID in a multiple BSSID set shall(#6005) include the Multiple BSSID Configuration element (#4002)containing the Index Adjustment Factor field set to a nonzero value(#6005) in the Beacon, DMG Beacon, S1G Beacon, and Probe Response frames (#6005)that it transmits until the time when the adjustment occurs to inform non-AP STAs associated with all the APs in the multiple BSSID set that a BSSID index adjustment is imminent. The time advertised in the Index Adjustment TBTT Count field should be long enough that all non-AP STAs associated with the APs in the multiple BSSID set, including non-AP STAs in power save mode, have an opportunity to receive at least one Multiple BSSID Configuration element carrying the Index Adjustment Factor field before the adjustment takes effect.

(#4002)At the TBTT indicated by the Index Adjustment TBTT Count field of the Multiple BSSID Configuration element, the AP transmitting the element and a non-AP STA receiving the element shall compute the updated index for each BSSID belonging to the multiple BSSID set as follows:

$$\text{New Index} = (\text{Old Index} + iaf) \bmod 2^n$$


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where *n* is the MaxBSSID Indicator field in the Multiple BSSID element and *iaf* is the Index Adjustment Factor field in the Multiple BSSID Configuration element.

(#4003)Following the index adjustment, the AP performs the following actions:

— The BSSID whose new index value is 0 shall take on the role of the transmitted BSSID, and subsequent Beacon, DMG Beacon, S1G Beacon and Probe Response frames shall be transmitted by the AP corresponding to this BSSID.

— The BSSID Index field in a Multiple BSSID-Index element carried in a nontransmitted BSSID profile (#4004)shall advertise the new index value for that nontransmitted BSSID.

— The elements included in a nontransmitted BSSID profile shall be based on inheritance with respect to the contents of the Management frame that carries the nontransmitted BSSID profile and that is transmitted by the new transmitted BSSID (also see 11.1.3.8.4 (Inheritance of element values(11ax))).

— The indication of buffered group addressed frames via the bits in the TIM element shall be based on the new index value for each BSSID in the set (also see 11.1.3.8.5 (Traffic advertisement in a multiple BSSID set(11ax))).

(#4003)Following the index adjustment, a non-AP STA performs the following actions:

— The BSSID whose new index value is 0 shall be identified as the new transmitted BSSID.

— The BSSID index for the non-AP STA's associated AP shall be updated to the new index value and subsequently this value shall be used to determine buffered group address frames for its associated AP (also see 11.1.3.8.5 (Traffic advertisement in a multiple BSSID set(11ax))).

— The inheritance as described in 11.1.3.8.4 (Inheritance of element values(11ax)) shall be applied with respect to the new transmitted BSSID.

The value carried in the Index Adjustment Factor field shall be selected such that an index belonging to an active nontransmitted BSSID is updated to the value 0.

NOTE 2—The procedure makes no change to the BSSIDs (i.e., the MAC addresses) of the corresponding APs. Only the index within the multiple BSSID set is rotated such that a former nontransmitted BSSID with an updated index value of 0 takes on the role of the transmitted BSSID.

(#4003)NOTE 3—For example, if we start with $n = 3$, transmitted BSSID = 8c-fd-0f-7f-1e-f5, and two nontransmitted BSSIDs BSSID(2) = 8c-fd-0f-7f-1e-f7 and BSSID(5) = 8c-fd-0f-7f-1e-f2, then an *iaf* of 6 converts(M118) the BSSID 8c-fd-0f-7f-1e-f7 to index $(2+6) \bmod 2^3=0$ as the transmitted BSSID, and the other BSSID index values are updated as BSSID$((5+6) \bmod 2^3=3)$ = 8c-fd-0f-7f-1e-f2 and BSSID$((0+6) \bmod 2^3=6)$ = 8c-fd-0f-7f-1e-f5 where the latter BSSID is converted into a nontransmitted BSSID.

### 11.1.3.9 TSF timer accuracy

A non-DMG STA's TSF timer shall be accurate to within ± 100 ppm. A DMG STA's TSF timer shall be accurate to within ± 20 ppm.

NOTE—The worst-case drift between two non-DMG STAs is, therefore, ± 200 ppm, and between two DMG STAs, ± 40 ppm.

Upon receiving a Beacon, a DMG Beacon, or an Announce frame for the BSS, as described in 11.1.3.7 (Beacon reception), a STA shall update its TSF timer according to the following algorithm

— Non-DMG STA: The received timestamp value shall be adjusted by adding an amount equal to the receiving STA's delay through its local PHY components plus the time since the first bit of the timestamp was received at the MAC/PHY interface.

— DMG STA: The received timestamp value shall be adjusted by adding an amount equal to the receiving STA's delay through its local PHY components plus the time since the last data symbol of

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the PHY header, excluding any guard interval, was received as indicated by the PHY-RXSTART.indication primitive.

In the case of an infrastructure BSS or a PBSS, the STA's TSF timer shall then be set to the adjusted value of the timestamp. In the case of an IBSS, the STA's TSF timer shall be set to the adjusted value of the received timestamp, if the adjusted value of the timestamp is later than the value of the STA's TSF timer.

When a STA is a member of a BSS with a nontransmitted BSSID, it shall use the TSF from the Beacon, S1G Beacon or DMG Beacon frame transmitted by the transmitted BSSID.(#3019)

#### 11.1.3.10 Maintaining synchronization using S1G Beacon frames

##### 11.1.3.10.1 General S1G synchronization

An S1G AP schedules an S1G Beacon frame at intervals given by the dot11BeaconPeriod or dot11ShortBeaconPeriod as described in 11.1.2.1 (TSF for an infrastructure BSS or a PBSS).

An S1G Beacon frame scheduled at TSBTT that is not a TBTT may include the elements from the minimum set of elements shown in Table 9-76 (Minimum and full set of optional elements). An S1G Beacon frame scheduled at TBTT shall include the S1G Beacon Compatibility element as the first optional element and may include all the other elements from the full set of elements shown in Table 9-76 (Minimum and full set of optional elements). Note that the S1G Beacon Compatibility element replaces the following fields of the Beacon frame body: Timestamp, Beacon Interval and Capability Information which are not included in an S1G Beacon frame. The S1G Beacon Compatibility element shall be generated no later than the Timestamp field of the S1G Beacon frame that carries the element and not earlier than $2^{31}$– 1 μs(#8087)(#7198). A STA can reconstruct the (#2047)TSF timer at the AP by concatenating the (#2047)TSF Completion field in the S1G Beacon Compatibility element with the Timestamp field in the S1G Beacon frame as described in 11.1.3.10.3 (TSF timer accuracy with S1G Beacon frame).

##### 11.1.3.10.2 Generation of S1G Beacon frames

In an infrastructure BSS, S1G Beacon frames shall be transmitted by an S1G AP. Each S1G STA in an IBSS shall transmit S1G Beacon frames. An AP with dot11ShortBeaconInterval equal to true shall further define the timing for the BSS by sending S1G Beacon frames according to the dot11ShortBeaconPeriod. The value for the dot11ShortBeaconPeriod shall be such that dot11BeaconPeriod = $n$×dot11ShortBeaconPeriod, where $n$ is a positive integer. This defines a series of TSBTTs exactly dot11ShortBeaconPeriod TUs apart. If $n$ is greater than 1, the Next TBTT field shall be present in S1G Beacon frames transmitted at TSBTT that is not a TBTT; otherwise, it shall not be present in S1G Beacon frames.

(#133)Time 0 is defined to be the TBTT or TSBTT when the first S1G Beacon frame is expected to be sent and this beacon shall have the DTIM Count field of the TIM element set to 0. At each TBTT or TSBTT, the AP shall schedule an S1G Beacon frame as the next frame for transmission. At each TBTT or TSBTT the AP should suspend the decrementing of the backoff counter for any pending non-beacon transmission and transmit the S1G Beacon frame according to the medium access rules specified in Clause 10 (MAC sublayer functional description).

NOTE—When dot11MultiBSSIDImplemented is true, the DTIM Count field in the TIM element applies to the AP corresponding to the transmitted BSSID.(#133)

The beacon period is included in S1G Beacon, Probe Response, and PV1 Probe Response frames, and a STA shall adopt that beacon period when joining the S1G BSS and S1G IBSS, i.e., the STA shall set its dot11BeaconPeriod to that beacon period. If dot11ShortBeaconInterval is equal to true, short beacon period included in the Short Beacon Interval element shall be carried in an S1G Beacon, Probe Response, and PV1 Probe Response frames. An S1G STA shall adopt that short beacon period when joining the S1G BSS or S1G


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IBSS, i.e., the STA shall set its dot11ShortBeaconInterval to true and its dot11ShortBeaconPeriod to that short beacon period.

#### 11.1.3.10.3 TSF timer accuracy with S1G Beacon frame

Upon receiving an S1G Beacon frame with a valid FCS and BSSID, an S1G STA shall update its TSF timer according to the algorithm described below.

The received Timestamp value shall be adjusted by adding an amount equal to the receiving STA's delay through its local PHY components plus the time since the first bit of the Timestamp field was received at the MAC/PHY interface.

If the received S1G Beacon frame does not include an S1G Beacon Compatibility element:

— If the most significant bit (MSB) of the adjusted value of the received Timestamp is not equal to the MSB of the 4 least significant octets of the local TSF timer then the value of the 4 most significant octets of the TSF timer shall be adjusted to account for roll over as follows:
  — The value shall be increased by one unit (modulo $2^{32}$) if LT > AT and LT > AT + $2^{31}$
  — The value shall be decreased by one unit (modulo $2^{32}$) if LT < AT and LT < AT – $2^{31}$

  where AT is the adjusted value of the received Timestamp and LT is the value of the 4 least significant octets of the local TSF timer
— The 4 least significant octets of the STA's local TSF timer shall be set to the adjusted value of the Timestamp.

If the received S1G Beacon frame includes an S1G Beacon Compatibility element:

— The 4 least significant octets of the STA's TSF timer shall then be set to the adjusted value of the Timestamp.
— If the most significant bit of the adjusted value of the Timestamp is 0 and the TSF Rollover Flag field in the S1G Beacon Compatibility element is 1, then the 4 most significant octets of the TSF timer shall be adjusted to account for roll over (i.e., the value obtained from the TSF Completion field shall be increased by one unit (modulo $2^{32}$). Otherwise, the 4 most significant octets of the TSF timer shall be set to the TSF Completion field in the S1G Beacon Compatibility element.

### 11.1.4 Acquiring synchronization, scanning

#### 11.1.4.1 General

A STA shall operate in either a Passive Scanning mode or an Active Scanning mode depending on the current value of the ScanMode parameter of the MLME-SCAN.request primitive.

NOTE 1—Active scanning is restricted in some frequency bands and regulatory domains.

Upon receipt of the MLME-SCAN.request primitive, a STA shall perform scanning procedures according to the parameters given in the primitive. The SSID parameter indicates the SSID for which to scan. The SSID List parameter indicates one or more SSIDs for which to scan.

To become a member of a particular ESS using passive scanning, a STA shall scan for Beacon and DMG Beacon frames containing that ESS's SSID, returning all Beacon and DMG Beacon frames matching the desired SSID in the BSSDescriptionSet parameter of the corresponding MLME-SCAN.confirm primitive with the appropriate bits in the Capability Information field or DMG Capabilities field indicating whether the Beacon frame or DMG Beacon frame came from an infrastructure BSS, PBSS, or IBSS. If dot11RMMeasurementPilotActivated is greater than 1, the STA shall additionally scan for Measurement Pilot frames, returning in the BSSDescriptionFromMeasurementPilotSet parameter all Measurement Pilot frames

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that equal the requested BSSID of the corresponding MLME-SCAN.request primitive and are not already members of the BSSDescriptionSet. A FILS STA shall additionally scan for FILS Discovery frames, returning in the BSSDescriptionFromFDSet parameter all FILS Discovery frames of the scanned ESSs. The STA is not required to return a BSSDescriptionFromFDSet parameter for any BSS that is already a member of the BSSDescriptionSet.

To actively scan, the STA shall transmit Probe Request frames containing a wildcard SSID (see 9.4.2.2 (SSID element)), the desired SSID or one or more SSID List elements, but a DMG STA might also have to transmit DMG Beacon frames or perform beamforming training prior to the transmission of Probe Request frames. When the SSID List element is present in the Probe Request frame, one or more of the SSID elements may include a wildcard SSID (see 9.4.2.2 (SSID element)). The exact procedure for determining the SSID or SSID List values in the MLME-SCAN.request primitive is not specified in this standard. When a STA scans for a BSS whose AP does not support the SSID List element, or for a BSS for which AP support of the SSID List element is unknown, the SSID element with an SSID or wildcard SSID shall be included in the MLME-SCAN.request primitive. During FILS scanning, the scanning STA may optimize the scanning process by using intermediate results, including the Reduced Neighbor Report element. Details of how to optimize scanning is out of scope of this standard. An MLME-SCAN.confirm primitive is issued each time that a BSS matching the selection criteria in the MLME-SCAN.request primitive is discovered when the ReportingOption parameter in the MLME-SCAN.request primitive is present and is equal to IMMEDIATE. An MLME-SCAN.confirm primitive is issued each time that the scanning STA has completed the scanning of a channel when the value of the ReportingOption parameter in the MLME-SCAN.request primitive is present and is equal to CHANNEL_SPECIFIC.

NOTE 2—MLME-SCAN.request primitives and resulting Probe Request frames might include a Request element or Extended Request element(s) that can be used to request radio measurement information from the scanned BSSs. Requested radio measurement information from the scanned BSSs is included in the Probe Response frames and in the MLME-SCAN.confirm primitive.

Upon completion of scanning, an MLME-SCAN.confirm primitive is issued by the MLME indicating all of the BSS information received.

In DMG BSSs, the Active Scan procedure (11.1.4.3 (Active scanning and probing procedures)) can be used for device discovery prior to initializing or joining a BSS.

Upon receipt of an MLME-JOIN.request primitive, the nonmesh STA shall use the synchronization procedure described in 11.1.4.5 (Synchronizing with a BSS). The MLME-JOIN.request primitive is not used to start synchronization in an MBSS. The synchronization in an MBSS is described in 14.14 (Synchronization and beaconing in MBSSs).

Upon receipt of an MLME-SCAN.request primitive with the SSID parameter equal to the wildcard SSID, the STA shall passively scan for any Beacon, DMG Beacon, FILS Discovery, Measurement Pilot frames, or Probe Response frames containing Address 1 field equal to the broadcast address, or (#1662)transmit Probe Request or DMG Beacon frames containing the wildcard SSID, as appropriate depending upon the value of ScanMode.

If a STA's scanning does not result in finding a BSS with the target SSID and of the target type, or does not result in finding any BSS, the STA may start an IBSS upon receipt of the MLME-START.request primitive.

NOTE 3—Starting an IBSS is restricted in some frequency bands and regulatory domains.

When scanning MBSSs, the STA shall process the procedures described in 14.3 (Mesh discovery).

When a STA starts a BSS, that STA shall determine the BSSID of the BSS. If the BSSType indicates an infrastructure BSS, then the STA shall start an infrastructure BSS and the BSSID shall be equal to the STA's dot11StationID. If the BSSType indicates a PBSS, then the STA shall start a PBSS. For both the infrastructure BSS and the PBSS, the value of the BSSID shall remain unchanged, even if dot11StationID is changed after


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the completion of the MLME-START.request primitive. If the BSSType indicates an IBSS, the STA shall start an IBSS, and the BSSID shall be an individual locally administered (#1893)MAC address as defined in Clause 8 of IEEE Std 802-2014. The remaining 46 bits of that MAC address shall be a number selected in a manner that minimizes the probability of STAs generating the same number, even when those STAs are subjected to the same initial conditions. The value of the SSID parameter shall be used as the SSID of the new BSS.

NOTE 4—It is important that designers recognize the need for statistical independence of the random number streams between STAs.

(11bd)Upon receipt of the MLME-DMG-OCB-START.request primitive, a DMG STA with dot11DMGOCBActivated equal to true shall start a discovery procedure outside the context of a BSS as described in 11.1.4.7 (DMG discovery outside the context of a BSS(11bd)) and start operation outside the context of a BSS as described in 31.3 (Operation in the 60 GHz band).

#### 11.1.4.2 Passive scanning

##### 11.1.4.2.1 Passive scanning for non-DMG STAs

If the ScanType parameter indicates a passive scan, the STA shall listen to each channel scanned for no longer than a maximum duration defined by the MaxChannelTime parameter.

##### 11.1.4.2.2 Passive scanning for DMG STAs

Upon receipt of the MLME-SCAN.request primitive with the ScanType parameter set to Passive, a DMG STA shall passively scan for transmissions on each channel specified within the ChannelList parameter of the MLME-SCAN.request primitive. The channel traversal order during passive scanning is implementation specific.

That is, the STA shall be in the receive state scanning for a period of time in a channel no less than MinChannelTime and return information on all DMG Beacon frames received matching a particular BSSID or SSID parameters specified in the MLME-SCAN.request primitive. If no DMG beacon scan parameters are specified in the request, then the STA shall return information on all received DMG Beacon frames.

If at any time during the scan the STA detects a frame that is not a DMG Beacon frame, the STA shall continue to scan the current channel until the scanning timer expires. After scanning one channel, the STA shall initiate scanning in another channel if at least one channel within the ChannelList parameter has not yet been scanned.

When the STA has completed scanning all indicated channels, it returns the scan results via the MLME-SCAN.confirm primitive.

NOTE—Unlike a DMG STA that is actively scanning and that is not a member of PBSS (see 11.1.4.3.3 (Active scanning procedure for a DMG STA)), a DMG STA that is passively scanning does not respond to (#3751)Probe Request frames (see 11.1.4.3.4 (Criteria for sending a response)).

#### 11.1.4.3 Active scanning and probing procedures

##### 11.1.4.3.1 Introduction

Active scanning involves the generation of Probe Request frames and the subsequent processing of received (#3751)Probe Response frames. The details of the active scanning procedures are as specified in the following subclauses.

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#### 11.1.4.3.2 Active scanning procedure for a non-DMG STA

Upon receipt of the MLME-SCAN.request primitive with ScanType parameter indicating an active scan, a STA shall use the following procedure.

For each channel to be scanned:

a) Wait until the ProbeDelay time has expired or a PHY-RXSTART.indication primitive has been received.

b) If the STA is a FILS STA (11ax)or a 6 GHz HE STA, set the FILSProbeTimer to 0 and starts the FILSProbeTimer. While the FILSProbeTimer is less than dot11FILSProbeDelay,(11ax) the STA may skip a (#3751)Probe Request frame transmission and proceed to step g) after setting the ActiveScanningTimer to 0 and starting the ActiveScanningTimer, if one of the following conditions matches:

   1) The STA receives a broadcast Probe Request frame that the SME considers to be suitable to discover a candidate AP for association.

   2) The STA receives one or more of Probe Response, Beacon, Measurement Pilot, or FILS Discovery frame that identify an AP that the SME considers a suitable candidate for association.

   3) The STA successfully sent a Probe Request frame by following the UORA procedure as defined in 26.5.4 (UL OFDMA-based random access (UORA))).(11ax)

NOTE—How an SME considers a (#3751)Probe Request frame or AP suitable is outside the scope of this standard.

c) Perform the basic access procedure as defined in 10.3.4.2 (Basic access). (11ax)While waiting for access to WM, the STA may send one or more Probe Request frames by following the UORA procedure and proceed to step g). Send a (#3751)Probe Request frame to the broadcast address(#1313). The (#3751)Probe Request frame is sent with the SSID and BSSID from the received MLME-SCAN.request primitive. If dot11SSIDListActivated is true and the SSID List parameter is present in the MLME-SCAN.request primitive, then one or more SSID List elements should be present in the (#3751)Probe Request frame, indicating all SSIDs in the SSID List parameter if possible.

d) (11ax)When dot11SSIDListActivated is true and either or both of the SSID List and Short SSID List parameters are present in the MLME-SCAN. request primitive, send zero or more (#3751)Probe Request frames to the broadcast address(#1313), each with one or more SSIDs indicated in the SSID List and/or Short SSID List parameters and the BSSID from the MLME-SCAN.request primitive. A Probe Request frame that contains a Short SSID List element shall have the SSID field of the SSID element set to the SSID of a known AP or set to the one-octet value 128 if the STA does not know any SSID. These additional (#3751)Probe Request frames [following step c)] should only carry SSIDs not indicated in the step c) (#3751)Probe Request frame. The basic access procedure (10.3.4.2 (Basic access)) is performed prior to each (#3751)Probe Request frame transmission.

e) Initialize the ActiveScanningTimer to 0 and start the ActiveScanningTimer.

f) If a PHY-CCA.indication(BUSY)(#4122) primitive is not received before the ActiveScanningTimer reaches MinChannelTime, then proceed to step k).(#132)

g) If the STA is a non-FILS STA, receive all Probe Response and Beacon frames while the ActiveScanningTimer is less than MaxChannelTime.

h) If the STA is a FILS STA and while the ActiveScanningTimer is less than MaxChannelTime:

   1) Receive Probe Response, FILS Discovery, and Beacon frames regardless of the receiver address. Process any received FILS Discovery, Probe Response, and Beacon frames.

   2) If the ReportingOption parameter of the MLME-SCAN.request primitive is IMMEDIATE, and the scanning FILS STA detects a BSS whose MLME-SCAN.confirm primitive has not been issued during the ongoing scan, then an MLME-SCAN.confirm primitive with the ResultCode


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equal to INTERMEDIATE_SCAN_RESULT and one or more of BSSDescriptionSet, BSSDescriptionFromFDSet, or BSSDescriptionFromMeasurementPilotSet containing information of the detected BSS is immediately issued.

i) If the ReportingOption parameter of the MLME-SCAN.request primitive is CHANNEL_SPECIFIC, do the following:

   1) If the ActiveScanningTimer has not reached MaxChannelTime, wait until the ActiveScanningTimer reaches the MaxChannelTime and then proceed to item 2); otherwise, proceed directly to item 2).

   2) Issue an MLME-SCAN.confirm primitive, with the ResultCode equal to INTERMEDIATE_SCAN_RESULT and one BSSDescriptionSet, BSSDescriptionFromFDSet, or BSSDescriptionFromMeasurementPilotSet containing information of all BSSs that have been discovered from the scanned channel.

j) Process all (#3751)Probe Response frames received until the timer reaches MaxChannelTime, constructing BSSDescriptions corresponding to the (#3751)(#4121)probe responses that match the criteria specified in the MLME-SCAN.request primitive.

k) Set the NAV to 0 and scan the next channel.

l) When all channels in the ChannelList have been scanned, and the ReportingOption parameter of the MLME-SCAN.request primitive is AT_END or not present, the MLME shall issue an MLME-SCAN.confirm primitive with one or more of the BSSDescriptionSet, BSSDescriptionFromFDSet, or BSSDescriptionFromMeasurementPilotSet containing all of the information gathered during the scan.

See Figure 11-7 (Active scanning by a non-DMG STA with a Probe Request frame addressed to a specific BSSID(#3751)) and Figure 11-8 (Active scanning by a non-DMG STA with a Probe Request frame addressed to wildcard BSSID(#3751)).

If the MLME receives an MLME-SCAN-STOP.request primitive, the STA shall stop scanning. The STA should discard any Probe Request frame queued for transmission. If the STA is transmitting a Probe Request frame, the STA shall complete the transmission of the Probe Request frame. The STA shall not continue the active scanning process on unscanned channels listed in the ChannelList parameter of the MLME-SCAN.request primitive. If the ReportingOption parameter of the MLME-SCAN.request primitive is AT_END or not present, then the MLME shall issue an MLME-SCAN.confirm primitive with the ResultCode set to SUCCESS and with one or more of BSSDescriptionSet, BSSDescriptionFromFDSet, or BSSDescriptionFromMeasurementPilotSet containing all of the information gathered during the scan.

A FILS STA shall indicate its MaxChannelTime in the Max Channel Time field of the FILS Request Parameters element of the Probe Request frame to prevent the responding STA from transmitting the Probe Response frame after the time indicated by the MaxChannelTime has elapsed.

The Max Channel Time field shall be set to the MaxChannelTime of the MLME-SCAN.request primitive as defined in 9.4.2.176 (FILS Request Parameters element(#2193)).

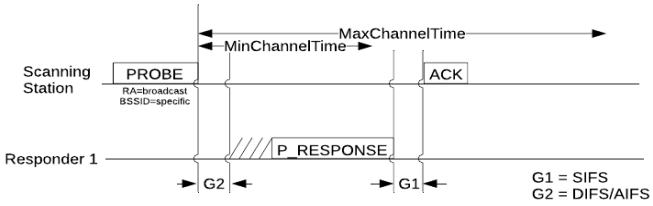


**Figure 11-7—Active scanning by a non-DMG STA with a Probe Request frame addressed to a specific BSSID(#3751)**

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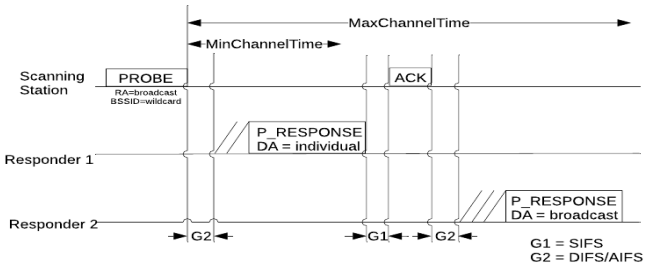


**Figure 11-8—Active scanning by a non-DMG STA with a Probe Request frame addressed to wildcard BSSID(#3751)**

#### 11.1.4.3.3 Active scanning procedure for a DMG STA

Upon receipt of the MLME-SCAN.request primitive with ScanType parameter indicating an active scan, a DMG STA shall use the following procedure.

For each channel to be scanned:

a) Wait until the ProbeDelay time has expired or a PHY-RXSTART.indication primitive has been received.

b) Initialize a timer to 0 and start it running.

c) If the DiscoveryMode parameter of the MLME-SCAN.request primitive is equal to 1, generate DMG Beacon frames as (described in 11.1.3.4 (DMG beacon generation before establishment of a BSS)) for a period no longer than MaxChannelTime.

d) If a DMG Beacon frame is received before the timer reaches MaxChannelTime and beamforming training is required (see 10.41 (DMG beamforming)), perform beamforming training defined in 10.41.5 (Beamforming in A-BFT).

e) Perform the basic access procedure defined in 10.3.4.2 (Basic access).

f) If an SSW-Feedback frame is transmitted or received in step d), then:

   1) Send a (#3751)Probe Request frame to the broadcast address(#1313) or

      — Following the transmission of an SSW-Feedback frame, send a (#3751)Probe Request frame to the MAC address of the STA addressed by the SSW-Feedback frame.

      — Optionally, following the reception of an SSW-Feedback frame, send a (#3751)Probe Request frame to the MAC address of the STA that transmitted the SSW-Feedback frame.

      In all (#3751)Probe Request frames sent under step f) 1), the Probe Request frame is sent with the SSID and BSSID from the received MLME-SCAN.request primitive and includes the DMG Capabilities element. The basic access procedure (10.3.4.2 (Basic access)) is performed prior to the (#3751)Probe Request frame transmission.

   2) When the SSID List parameter is present in the MLME-SCAN.request primitive, send zero or more (#3751)Probe Request frames to the broadcast address(#1313). Each (#3751)Probe Request frame is sent with an SSID indicated in the SSID List parameter and the BSSID from the received MLME-SCAN.request primitive and includes the DMG Capabilities element. The basic access procedure (10.3.4.2 (Basic access)) is performed prior to each (#3751)Probe Request frame transmission.

g) If an SSW-Feedback frame is neither transmitted nor received in step d), then:

   1) Optionally send a (#3751)Probe Request frame to the broadcast address(#1313). The (#3751)Probe Request frame is sent with the SSID and BSSID from the received MLME-SCAN.request primitive and includes the DMG Capabilities element. (11ay)An EDMG STA may transmit the (#3751)Probe Request frame using a quasi-omni antenna pattern and, in this


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case, may send the (#3751)Probe Request frame using an EDMG BRP-RX PPDU. The basic access procedure (10.3.4.2 (Basic access)) is performed prior to the (#3751)Probe Request frame transmission.

2) When the SSID List is present in the MLME-SCAN.request primitive, send zero or more (#3751)Probe Request frames to the broadcast address(#1313). Each (#3751)Probe Request frame is sent with an SSID indicated in the SSID List and the BSSID from the MLME-SCAN.request primitive and includes the DMG Capabilities element. (11ay)An EDMG STA may transmit the (#3751)Probe Request frame using a quasi-omni antenna pattern and, in this case, may send the (#3751)Probe Request frame using an EDMG BRP-RX PPDU. The basic access procedure (10.3.4.2 (Basic access)) is performed prior to each (#3751)Probe Request frame transmission.

h) Respond with a (#3751)Probe Response frame to any (#3751)Probe Request frame received, subject to the conditions in 11.1.4.3.4 (Criteria for sending a response).

NOTE—The requirement to respond with a (#3751)Probe Response frame also applies to a non-AP non-PCP DMG STA that is not a member of a PBSS.

i) Process all (#3751)Probe Response frames received until the timer reaches MaxChannelTime, constructing BSSDescriptions corresponding to the (#3751)Probe Response frames that match the criteria specified in the MLME-SCAN.request primitive.

j) Set the NAV to 0 and scan the next channel.

When all channels in the ChannelList have been scanned, the MLME shall issue an MLME-SCAN.confirm primitive with the BSSDescriptionSet containing all the BSSDescriptions constructed during the scan.

See Figure 11-9 (Active scanning for DMG STAs) for DMG STAs that generate DMG Beacon frames with the Discovery Mode field set to 1, where STA A and STA B are actively scanning at the same time and STA B is not a member of a PBSS. STA A may (M118)be a member of a PBSS.

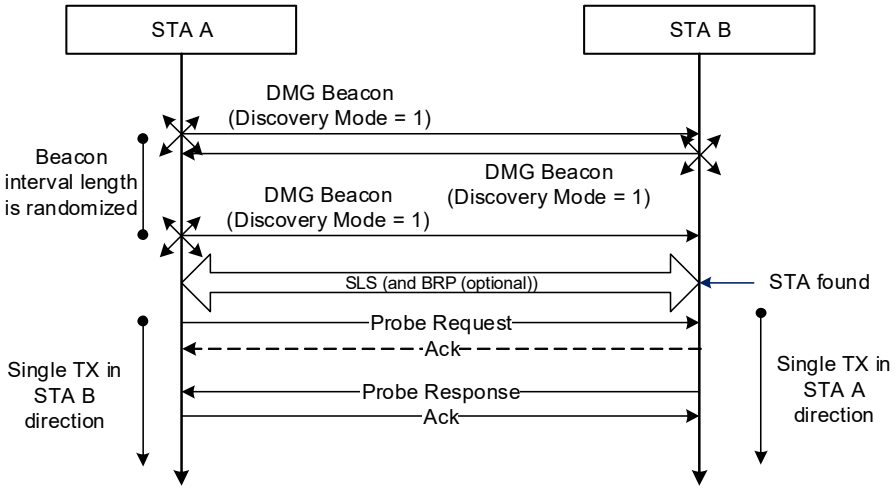


**Figure 11-9—Active scanning for DMG STAs**

### 11.1.4.3.4 Criteria for sending a response

If a STA that receives a Probe Request frame is not in a multiple BSSID set, that STA shall send the Probe Response frame(s), subject to the criteria below. If a STA that receives a Probe Request frame is in a multiple BSSID set, the STA corresponding to the transmitted BSSID shall send the Probe Response frame(s), subject to the criteria below; other STAs in the multiple BSSID set shall not send a Probe Response frame.

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(11ay)An EDMG STA that receives a (#3751)Probe Request frame before performing transmit antenna training may use a quasi-omni antenna pattern for transmission of the Probe Response. An EDMG STA that receives a (#3751)Probe Request frame transmitted using an EDMG BRP-RX PPDU may perform receive training and select a transmit sector if the STA supports antenna reciprocity or antenna pattern reciprocity as indicated by setting the DMG Antenna Reciprocity field or Antenna Pattern Reciprocity field in the DMG Capabilities element to 1 respectively, for transmission to the transmitter of the (#3751)Probe Request frame based on the result of the receive training.

A STA that receives a Probe Request frame shall not respond if any of the following apply:

a) The STA does not match any of the following criteria:
   1) The STA is an AP.
   2) The STA is an IBSS STA.
   3) The STA is a mesh STA.
   4) The STA is a DMG STA that is not a member of a PBSS and that is performing active scan as defined in 11.1.4.3.3 (Active scanning procedure for a DMG STA).
   5) The STA is a PCP.

b) The Address 1 field of the Probe Request frame contains an individual address and one of the following criteria is met:
   1) The STA is not a member of a multiple BSSID set, and the individual address is not the MAC address of the STA.
   2) The STA is a member of a multiple BSSID set, and the individual address does not match the BSSID of any of the BSSs in the multiple BSSID set.

c) The STA is a non-AP STA in a DMG infrastructure BSS and the Address 1 field of the Probe Request frame contains the broadcast address.

d) The STA is a non-PCP STA in a PBSS and the Address 1 field of the Probe Request frame contains the broadcast address.

e) The STA is in an IBSS and did not transmit a Beacon or DMG Beacon frame since the last TBTT, and the Address 1 field of the Probe Request frame contains the broadcast address.

f) The STA is a mesh STA and either of the following criteria are met:
   1) The Probe Request frame does not contain a Mesh ID element.
   2) The Mesh ID element in the Probe Request frame is present but does not contain the wildcard mesh ID(#1755) and does not match the mesh ID(#1755) of the MBSS with which the STA is peered.

g) The STA is not a mesh STA and none of the following criteria are met:
   1) The SSID in the Probe Request frame is the wildcard SSID.
   2) The SSID in the Probe Request frame matches the SSID of the STA's BSS.
   3) The STA is an AP that is in the same (#2210)colocated AP set as a 6 GHz AP, the SSID in the Probe Request frame matches the SSID of the 6 GHz AP, and the STA reports the (#2210)colocated 6 GHz AP in Beacon and Probe Response frames (see 11.53 (Out-of-band discovery of a 6 GHz BSS(11ax))).(11ax)
   4) The STA is a member of a multiple BSSID set and the SSID in the Probe Request frame matches any of the SSIDs of the members of that multiple BSSID set.
   5) (11ax)dot11SSIDListImplemented is true, and the SSID List element is present in the Probe Request frame and includes the SSID of the STA's BSS.
   6) dot11SSIDListImplemented is true, the STA is an AP that is in the same (#2210)colocated AP set as a 6 GHz AP, the SSID List element is present in the Probe Request frame and includes the SSID corresponding to the (#2210)colocated 6 GHz AP, and the AP reports the


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(#2210)colocated 6 GHz AP in Beacon and Probe Response frames (see 11.53 (Out-of-band discovery of a 6 GHz BSS(11ax))).(11ax)

7) dot11ShortSSIDListImplemented is true, and the Short SSID List element is present in the Probe Request frame and includes the (#7151)short SSID corresponding to the SSID of the STA's BSS.(11ax)

8) dot11ShortSSIDListImplemented is true, the STA is an AP that is in the same (#2210)colocated AP set as a 6 GHz AP, the Short SSID List element is present in the Probe Request frame and includes the (#7151)short SSID corresponding to the SSID of the 6 GHz AP, and the AP reports this 6 GHz AP in its Beacon and Probe Response frames (see 11.53 (Out-of-band discovery of a 6 GHz BSS(11ax))).(11ax)

h) The STA is not a mesh STA and the Address 3 field of the Probe Request frame does not contain a wildcard BSSID and one of the following criteria is met:

1) The STA is not a member of a multiple BSSID set and the Address 3 field of the Probe Request frame does not match the BSSID of the STA's BSS.

2) The STA is a member of a multiple BSSID set and the Address 3 field of the Probe Request frame does not match the BSSID of any of the BSSs in the multiple BSSID set.

i) The STA has dot11InterworkingServiceActivated equal to true and the Probe Request frame contains an Interworking element and an Extended Capabilities element whose Interworking field contains the value 1, and at least one of the following criteria is not met:

1) The HESSID field of the Interworking element is absent, or is present and contains the wildcard HESSID or matches the HESSID field of the InterworkingInfo parameter of the last MLME-START.request or MLME-JOIN.request primitive.

2) The Access Network Type field of the Interworking element contains the wildcard access network type or matches the access network type of the STA.

j) The Probe Request frame contains a DSSS Parameter Set element in which the Current Channel field contains a value that is not the same as dot11CurrentChannel.

k) (11ay)The STA is a DMG STA, the transmit antenna of the DMG STA is not trained to transmit to the STA from which the Probe Request frame was received, and the STA is not an EDMG STA that intends to transmit the response using a quasi-omni antenna pattern.

A FILS STA shall not respond to a Probe Request frame if any of the following criteria is met for a FILS Request Parameters element contained in the Probe Request frame:

1) If the FILS Criteria field is present in the FILS Requests Parameters element and the Max Delay Limit field of the FILS Request Parameters indicates a delay shorter than the selected average access delay of the responding STA. The BSS Delay Criterion field of the FILS Criteria field of the FILS Request Parameters element indicates the selected average access delay for the comparison as defined in Table 9-336 (BSS Delay Criterion subfield). The Max Delay Limit field contains the maximum selected average access delay. If the compared Average Access Delay indicates Measurement not available, the STA shall respond and the response shall include a BSS AC Access Delay element as described in 9.4.2.42 (BSS AC Access Delay element) and Average Access Delay as described in 9.4.2.37 (BSS Average Access Delay element) or Average Access Delay as described in 9.4.2.37 (BSS Average Access Delay element) that was requested in the Probe Request frame. If the compared Average Access Delay indicates Service unable to access channel, the response shall not be transmitted.

2) If the FILS Criteria field is present in the FILS Requests Parameters element and the PHY Support Criterion of the FILS Criteria field of the FILS Request Parameters element is 1 and the responding STA is not HT capable.

3) If the FILS Criteria field is present in the FILS Requests Parameters element and the PHY Support Criterion of the FILS Criteria field of the FILS Request Parameters element is 2 and the responding STA is not VHT capable.

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4) If the FILS Criteria field is present in the FILS Requests Parameters element and the PHY Support Criterion of the FILS Criteria field of the FILS Request Parameters element is 3 and the responding STA is not HE capable.(11ax)
5) If the Minimum Data Rate is present in the FILS Request Parameters element and the Minimum Data Rate field of the FILS Request Parameters element indicates a data rate higher than the one that is provided over the MAC SAP.
6) If the RCPI Limit field is present in the FILS Request Parameters element and either of the following conditions is true:
   — The RCPI of the Probe Request frame > –90 dBm + the RCPI Limit field of the FILS Request Parameters element.
   — The RCPI Limit field of the FILS Request Parameters element contains value 255.
7) If the OUI Response Criteria field is present in the FILS Request Parameters element and if any of the OUIs specified by the OUI Response Criteria field are not in the list of known OUIs configured in the AP (see Known OUIs, 6.5.11.2.2 (Semantics of the service primitive)).

If the FILS Request Parameters element is present in the Probe Request frame, the responding FILS STA should discard any Probe Response frame that has not been transmitted as a response to the Probe Request frame when the elapsed time measured from the end of the reception of the Probe Request frame by the MAC entity of the responding STA exceeds the time indicated by the Max Channel Time field of the FILS Request Parameters element of the Probe Request frame. If the FILS Request Parameter element is not present in the Probe Request frame, transmission time of the Probe Response frame to the Probe Request frame by the responding STA is only limited by the retransmission procedure in 10.23.2.12 (Retransmit procedures).

NOTE 1—It is possible for the STA to leave the channel on which it sent the Probe Request frame prior to MaxChannelTime. Should this occur the STA might not receive some of the Probe Response frames transmitted.

An individually addressed Probe Response frame, subject to the criteria above, shall be transmitted to all non-FILS STAs from which a Probe Request frame is received.

If a FILS STA has dot11FILSOmitReplicateProbeResponses equal to false, an individually addressed Probe Response frame, subject to the criteria above, shall be transmitted to all STAs from which a Probe Request frame is received.

If a FILS STA receives one or more Probe Request frame(s) and the STA has dot11FILSOmitReplicateProbeResponses equal to true, then the responding STA shall respond, subject to the criteria above, via the next Beacon frame, a broadcast Probe Response frame, or one or more individually addressed Probe Response frames.

The FILS STA shall respond with the next Beacon frame, as described in 11.1.3 (Maintaining synchronization), to Probe Request frames addressed to individual or broadcast address if all of the following conditions are met:

— The STA is queuing a Beacon frame for transmission;
— The next TBTT of the responding STA is within dot11FILSBeaconResponseWindow;
— The next TBTT is no later than any deadline of Max Channel Time indicated in the FILS Request Parameter element of the Probe Request frame(s), if present; and
— The Beacon frame contains all elements requested by the Request element.

If the next Beacon frame is not used as a response, a Probe Response frame is transmitted. The Probe Response frame shall be addressed to the broadcast or the address of the transmitter of the Probe Request frame. The Probe Response frame may be transmitted to all or some of the Probe Request frames received from FILS STAs. A first FILS STA may choose not to respond to Probe Request frames from a second FILS STA addressed to the broadcast address if the first STA receives an acknowledged (#3751)Probe Response frame


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addressed to the second STA containing the SSID of the first STA's BSS. A non-S1G AP shall remain in the awake state, and shall respond to (#3751)Probe Request frames, subject to the criteria above.

An S1G AP that is awake shall respond to (#3751)NDP Probe Request frames or Probe Request frames, subject to the criteria above. The response to the (#3751)NDP Probe Request frames or Probe Request frames shall have the same CH_BANDWIDTH as the preceding (#3751)NDP Probe Request frame or Probe Request frame. The S1G AP may send a PV1 Probe Response frame instead of a Probe Response frame as specified in 11.1.4.3.7 (Active scanning using PV1 Probe Response).

NOTE 2—This rule does not allow an S1G AP to respond with a (#3751)PV1 Probe Response frame or Probe Response frame in 1 MHz channel width after receiving a (#3751)NDP Probe Request frame or Probe Request frame in 2 MHz channel width.

An IBSS STA that sent a Beacon or DMG Beacon frame shall remain in the awake state, and shall respond to (#3751)Probe Request frames, subject to the criteria above, until a Beacon or DMG Beacon frame with the BSSID of the STA's IBSS is received.

A mesh STA or PCP that is awake shall respond to (#3751)Probe Request frames, subject to the criteria above.

NOTE 3—Results of the procedures defined in this subclause are as follows:

a) Infrastructure BSS: The AP is always awake to respond to (#3751)Probe Request frames.
b) IBSS: At least one STA is(M118) awake to respond to (#3751)Probe Request frames. More than one STA might respond to any given (#3751)Probe Request frame, particularly when more than one STA transmitted a Beacon or DMG Beacon frame following the most recent TBTT, either due to not receiving a previous Beacon or DMG Beacon frame or due to collisions between beacon transmissions.
c) MBSS or PBSS: At any given time it might be the case that no STA is awake to respond to (#3751)Probe Request frames.

#### 11.1.4.3.5 Active scanning for relay discovery

An S1G STA that is performing an active scan to discover operating APs, or S1G relay APs may include the S1G Relay Discovery element (see 9.4.2.206 (S1G Relay Discovery element)) in the Probe Request frame. This element provides information on the QoS criteria on the relay path.

The active scanning procedure for relay AP is similar to the active scanning procedure outlined in 11.1.4.3 (Active scanning and probing procedures).

An S1G relay AP receiving Probe Request frames may respond with a Probe Response or a PV1 Probe Response frame, if the criteria outlined in 11.1.4.3.2 (Active scanning procedure for a non-DMG STA) are met. An S1G relay AP shall not respond with a Probe Response, or a PV1 Probe Response, frame if the QoS criteria on the relay path specified in the S1G Relay Discovery element (see 9.4.2.206 (S1G Relay Discovery element)) cannot be satisfied.

An S1G relay AP sending Probe Response, or PV1 Probe Response frames may include the S1G Relay Discovery element (see 9.4.2.206 (S1G Relay Discovery element)) to carry link budget information between the S1G relay AP and S1G root AP.

An S1G STA may use the information received from different S1G relay APs to determine a suitable S1G relay AP for association. The S1G relay AP selection is made by the S1G STA, and the specific selection procedure is up to the implementation.

#### 11.1.4.3.6 NDP Probing

An NDP probing procedure is used to reduce the energy consumption during the scanning procedure. Upon receipt of the MLME-SCAN.request primitive with ActiveScanType parameter indicating an NDP, a STA for

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which dot11NDPProbingActivated is true shall transmit an NDP Probe Request frame, instead of a Probe Request frame, that has either a (#8219)short SSID or an access network option. The NDP probing procedure is allowed when an S1G STA knows the operating frequency bands and regulatory domains. A non-S1G STA shall not transmit an NDP Probe Request frame.

APs receiving an NDP Probe Request frame shall transmit a broadcast Probe Response only if

a) The compressed SSID in the NDP Probe Request frame is the specific (#8219)short SSID of the AP's BSS.

b) The access network option in the NDP Probe Request frame is the access network option of the AP.

The response to the NDP Probe Request frame shall be a PV1 Probe Response frame if all the criteria below are satisfied:

— dot11PV1ProbeResponseOptionImplemented is true at the responding STA.

— The Requested Probe Response Type field in the NDP Probe Request frame is set to 0.

If any of the criteria above is not satisfied, then the response to the NDP Probe Request frame shall be a Probe Response frame. The AP shall follow the channel access procedure defined in 9.3.4.3 (S1G Beacon frame format) to transmit the probe response.

If PHY-CCA.indication(BUSY)(#4122) primitive has not been detected before the ActiveScanningTimer reaches MinChannelTime, then set NAV to 0 and scan the next channel.

NOTE—If the STA receives a PV1 Probe Response frame, it might transmit a Probe Request frame or wait for a Beacon frame to obtain more information.(#318)(#472)(#473)

An illustration of the NDP probing procedure is shown in Figure 11-10 (NDP probing procedure).

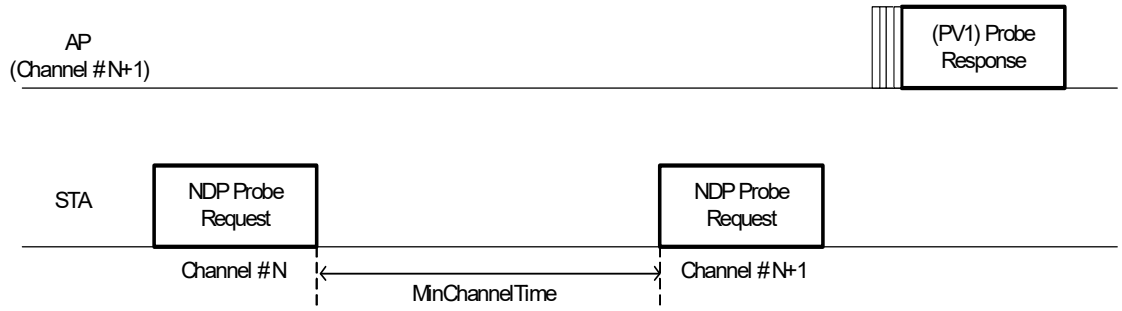


**Figure 11-10—NDP probing procedure**

### 11.1.4.3.7 Active scanning using PV1 Probe Response

An S1G STA may use PV1 Probe Response frames as defined in 9.8.5.3 (PV1 Probe Response frame format) instead of Probe Response frames as defined in 9.3.3.10 (Probe Response frame format). PV1 Probe Response frame is used for reducing overhead of using long Probe Response frame in active scanning by optimizing the frame format and by allowing STA to request minimum information that is required for association with the responding STA to be included in the PV1 Probe Response frame.

An S1G STA may solicit PV1 Probe Response frames by including the PV1 Probe Response Option element defined in 9.4.2.208 (PV1 Probe Response Option element) in the Probe Request frames it transmits or by setting the Requested Probe Response Type field in the NDP Probe Request frame it transmits to 0.


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A STA may include the PV1ProbeResponseOption parameter in the MLME-SCAN.request primitive to include the PV1 Probe Response Option element in the Probe Request frames. The requesting STA indicates which optional information is requested to be included in the PV1 Probe Response frame to the responding STA by setting one or more bits in the Probe Response Option bitmaps in the PV1 Probe Response Option element.

An S1G STA responds to the probe request subject to the criteria defined in 11.1.4.3.4 (Criteria for sending a response). The response to the probe request shall be a PV1 Probe Response frame if all the criteria below are satisfied:

- dot11PV1ProbeResponseOptionImplemented is true at the responding STA.
- A PV1 Probe Response Option element is included in the received Probe Request frame.

If any of the criteria above is not satisfied, then the response to the probe request shall be a Probe Response frame.

When an NDP Probe request frame is used instead of a Probe Request frame, the response shall be either a PV1 Probe Response frame or a Probe Response frame as described in 11.1.4.3.6 (NDP Probing).

If any of the criteria above is not satisfied, then the response to the NDP Probe Request frame shall be a Probe Response frame.

An S1G STA that responds with a PV1 Probe Response frame shall include the following information in the frame:

- The elements that are requested by the requesting STA as indicated in the PV1 Probe Response Option element contained in the received Probe Request frame.
  - If a bit in a Probe Response Option bitmap in the PV1 Probe Response Option element is equal to 1, then the corresponding element is requested and it shall be included in the PV1 Probe Response frame (see 9.4.2.208 (PV1 Probe Response Option element)).
  - If the S1G Beacon Compatibility element is included in the PV1 Probe Response frame, then it shall be included as the first optional element and shall be generated no later than the Timestamp field of the frame and not earlier than $2^{31} - 1$ μs(#8087)(#7198).
- Either the SSID element or the (#8219)Short SSID field.
  - If the Request Full SSID field(#8219) in the PV1 Probe Response Option element is equal to 1, then the SSID element shall be present in the PV1 Probe Response frame and the Short SSID field(#8219) shall not be present. If it is equal to 0 or is not present in the PV1 Probe Response Option element, then the Short SSID field(#8219) shall be present and the SSID element shall not be present.
- The 1 MHz Channel Primary Location field in the Frame Control field shall indicate the location of the 1 MHz primary channel within the 2 MHz primary channel.

PV1 Probe Response frames shall be sent as (#1649)individually addressed frames to the address of the STA that generated the Probe Request frame.

Upon reception of a PV1 Probe Response frame that includes an S1G Beacon Compatibility element an S1G STA that included the PV1 Probe Response Option element in a previously transmitted Probe Request frame or that set the Requested Probe Response Type to 0 in a previously transmitted NDP Probe Request frame may update its TSF timer using the same TSF timer update procedure described in 11.1.3.10.3 (TSF timer accuracy with S1G Beacon frame) for S1G Beacon frames.

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### 11.1.4.3.8 Non-scanning probe request transmission

A STA may send an individually addressed or broadcast Probe Request frame to a peer STA that it has determined is within range, in order to solicit information contained within a response frame, see 11.1.4.3.9 (Contents of a probe response). When the Probe Request frame is sent to the broadcast address, the Address 3 (BSSID) field shall be set to the MAC address of the peer STA.

NOTE 1—A STA might determine that a peer STA is within range by, for example, receiving a frame from that peer STA or, if the peer STA is an AP, by receiving a frame from another AP that corresponds to a (#2210)colocated BSS of the AP.

NOTE 2—Transmission of an individually addressed frame can provide more reliable delivery to a peer STA since it is acknowledged and retransmit procedures apply. The responder STA responds in accordance with 11.1.4.3.4 (Criteria for sending a response). See Figure 11-11 (Example of a probe request addressed to an individual address) for an example in which both the probe request and response are individually addressed. When a STA has not determined that a peer STA is in range, Probe Request frames it sends to discover the peer STA are transmitted in accordance with the active scanning procedures in 11.1.4.3.4 (Criteria for sending a response). For a non-DMG STA, such Probe Request frames are always sent to the broadcast address.

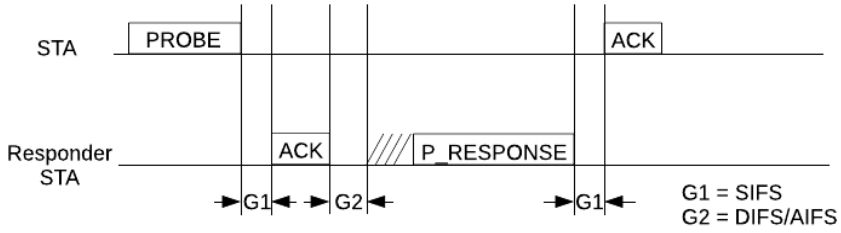


**Figure 11-11—Example of a probe request addressed to an individual address**

### 11.1.4.3.9 Contents of a probe response

A STA that responds to a Probe Request frame according to 11.1.4.3.4 (Criteria for sending a response) shall transmit a Probe Response frame or a Beacon frame to the STA that transmitted the Probe Request frame.

A FILS STA that transmits a Probe Response frame shall either set the Address 1 field to the address of the STA that generated the probe request or to the broadcast address if the STA that generated the probe request indicated FILS Capability. A non-FILS STA that transmits a Probe Response frame shall set the Address 1 field to the address of the STA that generated the probe request.

When a FILS AP responds to a Probe Request frame containing a FILS Capability field in the Extended Capabilities element equal to 1, and when both the FILS AP and the FILS STA that transmitted the Probe Request frame support other than DSSS/CCK rates (see Clause 15 (DSSS PHY specification for the 2.4 GHz band designated for ISM applications) or Clause 16 (High rate direct sequence spread spectrum (HR/DSSS) PHY specification)), the AP shall transmit a Probe Response frame in a PPDU using a rate other than a DSSS/CCK.

(#7114)A STA having dot11InternetworkingServiceActivated true may include in the Probe Response frame a CAG Number element containing one or more current version numbers of the CAG information associated with the AP, where each version number is associated with an advertisement protocol. The current CAG information associated with the AP can be acquired by the GAS query mechanism as described in 11.22.3 (Interworking procedures: generic advertisement service (GAS)) using the associated advertisement protocol.

If there was a Request element, Extended Request element, or Vendor Specific Request element in the Probe Request frame, then:


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— Each element that is listed by a non-FILS STA in the Request element, Extended Request element(s), or Vendor Specific Request element and that is supported by the STA shall be included in the Probe Response frame. An element that is listed in a Request element, Extended Request element, or Vendor Specific Request element and that is not supported by the STA shall not be included. Each element requested by a FILS STA in a Request element shall be included in the Probe Response frame or a Beacon frame if the responding FILS STA supports that element.

— Elements that would not have been included otherwise shall be included after all of the elements that would have been included even in the absence of the Request element, Extended Request element, or Vendor Specific Request element.

— Elements that would have been included even in the absence of the Request element, Extended Request element, or Vendor Specific Request element shall be included in their normal position (see Table 9-69 (Probe Response frame body)), and may be included again after all of the elements that would have been included even in the absence of the Request element.

NOTE—An element that would necessarily be included anyway is not expected to be requested.

— Elements after all of the elements that would have been included even in the absence of the Request element, Extended Request element, or Vendor Specific Request element shall be included in the order that they appear in the (Extended) Request element(s) of the Probe Request frame.

— If dot11RadioMeasurementActivated is true and the RCPI element was requested, an RCPI element containing the RCPI of the Probe Request frame shall be included. If no measurement result is available, the RCPI value shall be set to indicate "Measurement not available" (see Table 9-215 (RCPI values)).

— If dot11RadioMeasurementActivated is true and the RSNI element was requested, an RSNI element containing the RSNI of the Probe Request frame shall be included. If no measurement result is available, the RSNI value shall be set to indicate that a measurement is not available. (see 9.4.2.39 (RSNI element)).

— If a Probe Request frame includes a Request element that contains the element ID of the Reduced Neighbor Report element, a Probe Response frame or a Beacon frame if transmitted may include the Reduced Neighbor Report element if the criteria as defined in 11.1.4.3.4 (Criteria for sending a response) are met for the included BSS. The reported BSSs may have different primary channels to the responding STA.

#### 11.1.4.3.10 PCP selection in a PBSS

The PCP selection procedure is performed by the SME when:

— An MLME-SCAN.confirm primitive is received in response to an MLME-SCAN.request primitive with the value of the ScanType parameter equal to ACTIVE and BSSType parameter equal to PERSONAL

— There is a PCP handover (see 11.27.2 (PCP Handover))

The decision of whether a STA or its peer STA is the PCP depends on a comparison of their respective PCP factors (self_PCP_factor and peer_PCP_factor). The PCP factor, for a DMG STA and a CDMG STA operating on a 2.16 GHz channel, defined in Figure 11-12 (PCP factor for a DMG STA), is the concatenation of the value of some of the fields from the DMG Capabilities element transmitted by the STA (see 9.4.2.126 (DMG Capabilities element)). The PCP factor for a CDMG STA operating on a 1.08 GHz channel is constructed by concatenating the value of select fields present in the STA's DMG Capabilities element and the Supported Channel Width Set field. The PCP factor for a CDMG STA operating on a 1.08 GHz channel is defined in Figure 11-13 (PCP factor for a CDMG STA operating on a 1.08 GHz channel).

NOTE—According to convention, the least significant bit is the leftmost bit (B0).

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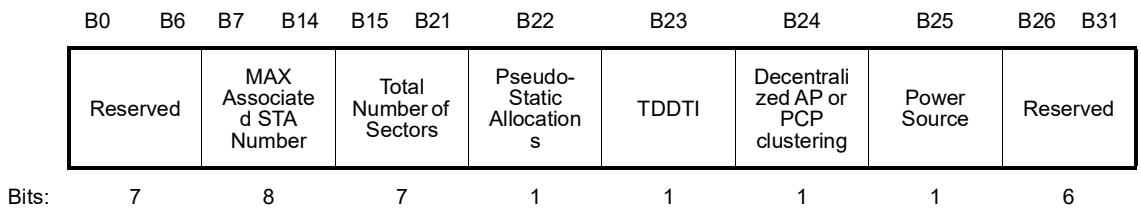


**Figure 11-12—PCP factor for a DMG STA**

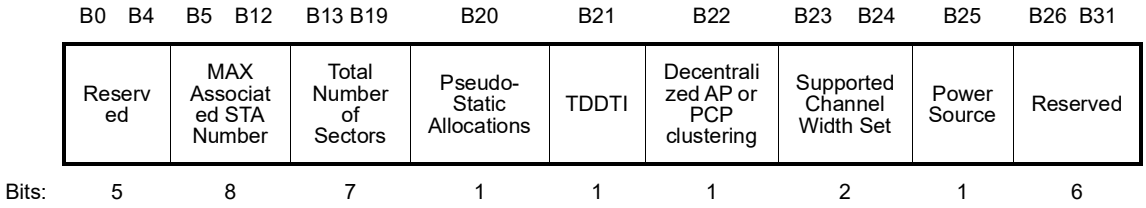


**Figure 11-13—PCP factor for a CDMG STA operating on a 1.08 GHz channel**

The Supported Channel Width Set field in Figure 11-13 (PCP factor for a CDMG STA operating on a 1.08 GHz channel) is obtained via encoding based on the supported channel widths that are indicated by the Operating Classes field of the received Country element or the Supported Operating Classes element of the peer STA. The encoding of the Supported Channel Width Set field is given in Table 11-1 (Encoding of the Supported Channel Width Set field).

**Table 11-1—Encoding of the Supported Channel Width Set field**

| Bit 23 | Bit 24 | Meaning |
|---|---|---|
| 0 | 0 | The CDMG STA supports 1.08 GHz channel width in 60 GHz band. |
| 0 | 1 | The CDMG STA supports both the 1.08 GHz and 2.16 GHz channel widths in 60 GHz band. |
| All other combinations | | Reserved |

For each peer STA reported as part of an MLME-SCAN.confirm primitive or considered as part of a PCP handover, the STA proceeds as follows. If the STA's value of self_PCP_factor is greater than the value of peer_PCP_factor or if the values are equal and the MAC address of the STA is greater than (see 12.7.1 (Key hierarchy) for MAC address comparison) the MAC address of the peer STA contained in the peer STA's DMG Capabilities element, the STA becomes a candidate PCP. Otherwise, the STA does not become a candidate PCP.

Subclause 11.1.4.4.2 (Initializing a DMG BSS) specifies the rules followed by the SME of a candidate PCP to start a PBSS.

### 11.1.4.3.11 Enhanced FILS active scanning to preferred AP

A FILS non-AP STA may maintain one or more BSS configuration parameter sets(#8158). A BSS configuration parameter set(#8158) is obtained from a preferred AP by using a preferred AP determination process that is out of scope of this standard. Each BSS configuration parameter set(#8158) may be different according to the preferred AP's capabilities. A BSS configuration parameter set(#8158) is a set of elements of


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the Beacon frame or the Probe Response frame. The following dynamic elements are excluded from a BSS configuration parameter set(#8158):

- TIM element
- Quiet element
- BSS Load element
- EDCA Parameter element
- BSS Average Access Delay element
- BSS Available Admission Capacity element
- BSS AC Access Delay element
- Time Advertisement element
- Emergency Alert Identifier element
- Beacon Timing element
- QLoad Report element
- Extended BSS Load element
- Quiet Channel element
- Reduced Neighbor Report element (see NOTE 1)
- CAG Number element
- AP-CSN element
- DILS element
- Fragment element (see NOTE 2)
- TWT element(11ax)
- MU EDCA Parameter Set element(11ax)
- NDP Feedback Report Parameter Set element(M118)(11ax)
- UORA Parameter Set element(11ax)
- Spatial Reuse Parameter Set element(11ax)
- HE BSS Load element(11ax)
- Quiet Time Parameter element(11ax)
- Vendor Specific element(11ax)

NOTE 1—The Reduced Neighbor Report element is excluded from the BSS configuration parameter set(#8158) based on the principle that an element is excluded from the BSS configuration parameter set(#8158) if that element has no impact on a FILS STA's ability of using AP-CSN to make a decision of initiating an association procedure with an AP without receiving Beacon or Probe Response frame from the AP.

NOTE 2—Any change in a Fragment element is considered under the context of the element being fragmented by the Fragment element.

If a vendor-specific subelement is included in an element within the BSS configuration parameter set(#8158), the AP-CSN does not provide any indication regarding if that vendor-specific subelement has changed or not, and AP-CSN is not increased if the only change within the BSS configuration parameter set(#8158) is due to the change to a vendor-specific subelement embedded in an element within the BSS configuration parameter set(#8158).

NOTE 3—A vendor-specific subelement can be included in a BSS configuration parameter set(#8158) within one of the permitted elements, even though the Vendor Specific element is excluded.

A FILS AP maintains an AP-CSN list consisting of the current AP-CSN value and an implementation-dependent number of zero of more previous AP-CSN values. The AP initializes the AP-CSN to a random

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integer value in the range(#3482) 0 to 255. For each maintained previous AP-CSN value, the AP also maintains the identifiers of the changed elements.

NOTE 4—The AP maintains the AP-CSN values in the AP-CSN list for a duration whose value is out of the scope of this standard.

An AP maintaining an AP-CSN list shall increase the current AP-CSN value (modulo 256) by one if an update occurs to any of the fields or elements within the BSS configuration parameter set(#8158).

A FILS AP may provide FILS STAs its AP-CSN value by sending a Beacon frame or a Probe Response frame including an AP-CSN element (as defined in 9.4.2.180 (AP Configuration Sequence Number (AP-CSN) element)).

A FILS non-AP STA identifies an BSS configuration parameter set(#8158) by its associated AP-CSN value and the AP's BSS's BSSID.

A FILS non-AP STA may send a Probe Request frame that includes an AP-CSN element (as defined in 9.4.2.180 (AP Configuration Sequence Number (AP-CSN) element)) if the STA has the BSS configuration parameter set(#8158) associated with the AP-CSN of an AP. When sending such a Probe Request frame, the FILS non-AP STA shall send it to the broadcast address(#1313) and set the Address 3 (BSSID) field in the Probe Request frame to the BSSID of the AP's BSS.

When a FILS AP receives a Probe Request frame with an AP-CSN element where the Address 3 (BSSID) field matches the BSSID of this AP's BSS, and the criteria for responding to a Probe Request frame (11.1.4.3.4 (Criteria for sending a response)) are met, the AP sends a Probe Response frame according to comparison result, as follows:

a) If the AP does not maintain an AP-CSN list, the AP sends a Probe Response frame.

b) If the received AP-CSN element matches with the current AP-CSN of the AP, the AP sends an optimized Probe Response frame including mandatory fields (i.e., Timestamp, Capability, and Beacon Interval), the current AP-CSN element, and one or more elements among dynamic elements defined in this subclause.

c) If the received AP-CSN element that matches one of the previous AP-CSN in the AP-CSN list, the AP sends an optimized Probe Response frame including mandatory fields, the current AP-CSN element, the elements that need to be updated at the STA, and one or more elements among dynamic elements defined in this subclause.

If the received AP-CSN value does not match with any of AP-CSN values in the AP-CSN list, the AP shall send a Probe Response frame with its current AP-CSN.(#412)

### 11.1.4.4 Initializing a BSS

#### 11.1.4.4.1 General

Upon receipt of an MLME-START.request primitive, a STA shall determine the BSS's BSSID (as described in 11.1.4 (Acquiring synchronization, scanning)), select channel synchronization information, select a beacon period, initialize and start its TSF timer, and begin transmitting Beacon frames if the STA is a neither a DMG nor an S1G STA, or DMG Beacon frames if the STA is a DMG STA, or S1G Beacon frames if the STA is an S1G STA. See 9.3.3.2 (Beacon frame format) for the description of a Beacon frame, and see 9.3.4.2 (DMG Beacon) for the description of a DMG Beacon frame. Upon receipt of an MLME-START.request primitive, an S1G STA with dot11ShortBeaconInterval equal to true shall select a short beacon period and begin transmitting S1G Beacon frames.


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#### 11.1.4.4.2 Initializing a DMG BSS

Prior to choosing a suitable operating channel and starting a BSS, the SME of a DMG STA should perform a channel scan to ascertain the quality of each channel that the STA supports. The rules for choosing a suitable operating channel are implementation specific and might be subject to regulatory requirements.

When a STA's MAC receives an MLME-START.request primitive, the MAC shall attempt to start a BSS. The STA may listen for a duration of aMinChannelTime, the listening duration, in the channel specified by the SME in the request. If the STA determines the channel is suitable for BSS operation at the end of this listening duration, the STA initializes the BSS by commencing transmission of DMG Beacon frames according to 11.1.3.3 (Beacon generation in a DMG infrastructure BSS and in a PBSS) in the case of a PBSS or an infrastructure BSS and according to 11.1.3.5 (Beacon generation in an IBSS) in the case of an IBSS. If AP or PCP clustering is in use on the selected channel, the DMG Beacon frame transmission by an AP or PCP commences following the additional rules described in 10.39 (DMG and CMMG AP or PCP clustering).

(11ay)For an EDMG BSS, an AP or PCP shall set the Channel BW Configuration subfield within the EDMG Operation element it transmits to a valid value as defined in Table 11-2 (Valid Channel BW Configuration subfield values(11ay)).

**Table 11-2—Valid Channel BW Configuration subfield values(11ay)**

| EDMG Operation element configuration | | | |
|---|---|---|---|
| BSS Operating Channel subfield in EDMG Operation element | | Valid Channel BW Configuration subfield values when primary channel is not adjacent to secondary channel | Valid Channel BW Configuration subfield values when primary channel is adjacent to secondary channel |
| Total number of subfields set to 1 in BSS Operating Channels field | Total number of adjacent channels indicated by BSS Operating Channels field | | |
| 1 | No adjacent channels | 4 | — |
| 2, 3, or 4 | No adjacent channels | 8 | — |
| 2, 3, or 4 | Two adjacent channels | 8 | 5, 8, 9 |
| 4 | Pair of two adjacent channels | — | 8, 9, 12, 13 |
| 3 or 4 | Three adjacent channels | 8 | 6, 8, 9, 10 |
| 4 | Four adjacent channels | — | 7, 11, 12, 13, 14, 15 |

If the STA determines that no channels are suitable or available, it responds with an MLME-START.confirm primitive with a ResultCode of NOT_SUPPORTED. Otherwise, the MLME shall respond with an MLME-START.confirm primitive with a ResultCode of SUCCESS.

The SME should issue an MLME-START.request primitive with BSSType parameter equal to PERSONAL for at least one network in which the STA becomes a candidate PCP as defined in 11.1.4.3.10 (PCP selection in a PBSS). If the STA becomes a candidate PCP of more than one network, the SME may issue an MLME-START.request primitive with BSSType parameter equal to PERSONAL for any of the remaining networks. In either case, the MLME-START.request primitive should be issued no later than 4×aMaxBIDuration after the MAC receives an MLME-SCAN.confirm primitive.

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The SME should not issue an MLME-START.request primitive with BSSType parameter equal to PERSONAL for networks in which the STA does not become a candidate PCP as defined in 11.1.4.3.10 (PCP selection in a PBSS). If the SME issues the MLME-START.request primitive under this circumstance, it shall not be issued if less than 4 × aMaxBIDuration has elapsed since the MAC received the MLME-SCAN.confirm primitive.

### 11.1.4.5 Synchronizing with a BSS

Upon receipt of an MLME-JOIN.request primitive, a STA shall adopt the BSSID in the request. Upon receipt of a Beacon frame from the BSS, a STA shall adopt the TSF timer value of the parameters in the Beacon frame using the algorithm described in 11.1.3.9 (TSF timer accuracy), and the MLME shall issue an MLME-JOIN.confirm primitive indicating the operation was successful.

In addition to these synchronization parameters, a STA joining an infrastructure BSS adopts each of the parameters found in the SelectedBSS parameter of the MLME-JOIN.request primitive except Local time, Capability Information, BSSBasicRateSet parameters, and HT Capabilities element. Local time is not adopted but is used in adopting the TSF as described in 11.1.3.9 (TSF timer accuracy). The Capability Information reflects the capabilities of the sender and is not adopted but may be used to determine local configuration or behavior. The BSSBasicRateSet parameter is not adopted but may determine if the STA can join the BSS.

If the JoinFailureTimeout timer expires prior to the receipt of a Beacon frame from the BSS, the MLME shall issue an MLME-JOIN.confirm primitive indicating the operation was unsuccessful.

If dot11MultiDomainCapabilityActivated is true, a STA that is joining an infrastructure BSS and receives a Beacon or Probe Response frame containing a Country element shall adopt the applicable parameters included in that Country element, and the dot11RegDomainsSupportedEntry shall be set to Other.

In addition to adopting the synchronization parameters as described in the first paragraph of this subclause, a STA joining an IBSS shall adopt each of the parameters found in the SelectedBSS parameter of the MLME-JOIN.request primitive according to the rule found for that parameter in the (#4177)IBSS adoption column of the matching row of the BSSDescription table found in 6.5.3.3.2 (Semantics of the service primitive) when those parameters exist at the STA. Parameters adopted by a STA when joining an IBSS shall not be changed by the STA except when adopting parameters following the reception of a Beacon frame with a later timestamp as described in 11.1.5 (Adjusting STA timers). When an IBSS contains STAs with a mix of STA capabilities, e.g., non-HT and HT, a STA in the IBSS adopts the behavioral parameters of the last beacon with the highest TSF (e.g., a HT STA does not continue use of HT and does not include an HT Operations element in its beacons).

In addition to the table entries in 6.5.3.3.2 (Semantics of the service primitive), if dot11MultiDomainCapabilityActivated is true, a STA that is joining an IBSS and receives a Beacon or Probe Response frame containing a Country element shall adopt the applicable parameters included in that Country element, and the dot11RegDomainsSupportedEntry shall be set to Other.

A DMG STA shall support(#546) transmitting DMG Beacon frames. A DMG STA obtains the operational parameters in use by its AP or PCP through the DMG Operation Information field of the DMG Operation element. A DMG STA shall update the value of its local MIB attributes with the corresponding field value transmitted by its AP or PCP within the DMG BSS Parameter Configuration field of the DMG Operation element (9.4.2.126.7 (TDD Capability Information field(11ay))). Except for the prefix “dot11” used in the MIB attribute naming convention, the name of the field is the same as the name of the corresponding MIB attribute.

### 11.1.4.6 Operation of Supported Rates and BSS Membership Selectors element and Extended Supported Rates and BSS Membership Selectors element

The Supported Rates and BSS Membership Selectors element and Extended Supported Rates and BSS Membership Selectors element in Beacon and Probe Response frames is used by STAs in order to avoid


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joining(#1464) a BSS if they do not support all of the data rates in the BSSBasicRateSet parameter or all of the BSS membership requirements in the BSSMembershipSelectorSet parameter.

A STA shall include the rates from its OperationalRateSet parameter and the rates from the BSSBasicRateSet parameter and the BSS membership selectors from the BSSMembershipSelectorSet parameter in frames it transmits containing Supported Rates and BSS Membership Selectors elements and Extended Supported Rates and BSS Membership Selectors elements according to the rules described in this subclause with the following exceptions:(#24)

1) A non-AP STA may omit the HT and VHT BSS membership selectors, as the (V)HT capabilities are indicated through the presence of a (V)HT Capabilities element.
2) An S1G or CMMG STA should not include supported rates in frames it transmits since its MCS capabilities are indicated in its Capabilities element. An S1G or CMMG STA should ignore supported rates in frames it receives since the peer's MCS capabilities are indicated in its Capabilities element.

NOTE 1—Rates are expressed in units of 500 kb/s, up to 63.5 Mb/s (see 9.4.2.3 (Supported Rates and BSS Membership Selectors element)). This might result in duplicate values for an S1G STA, and in values that cannot be expressed for a CMMG STA.(#24)

For a STA that supports a combined total of eight or fewer data rates and BSS membership selectors the Extended Supported Rates and BSS Membership Selectors element is optional, and may be included in all of the frame types that include the Supported Rates and BSS Membership Selectors element.

A STA that supports a combined total of the number of rates in the OperationalRateSet parameter and the number of BSS membership selectors that exceeds eight shall include an Extended Supported Rates and BSS Membership Selectors element to specify the supported rates and BSS membership selectors that are not included in the Supported Rates and BSS Membership Selectors element.

If the BSSMembershipSelectorSet parameter contains at least one BSS membership selector, then the STA shall include at least one BSS membership selector value from the BSSMembershipSelectorSet parameter in the Supported Rates and BSS Membership Selectors element.

NOTE 2—Inclusion of at least one BSS membership selector in the Supported Rates and BSS Membership Selectors element causes a receiving STA that was implemented before the existence of the Extended Supported Rates and BSS Membership Selectors element to still receive at least one BSS membership selector, which it will consider to be a basic rate that it does not support, and therefore it will not associate to the BSS.

Upon receipt, the Supported Rates and BSS Membership Selectors element in Beacon and Probe Response frames is delivered to the management entity in a STA via the BSSBasicRateSet parameter in the MLME-SCAN.confirm primitive. The BSS membership selector information in Beacon and Probe Response frames is delivered to the management entity in a STA via the BSSMembershipSelectorSet parameter in the MLME-SCAN.confirm primitive. Together, these parameters are used by the management entity in a STA to avoid joining(#1465) a BSS if the STA cannot receive and transmit all of the data rates in the BSSBasicRateSet parameter or does not support all of the features represented in the BSSMembershipSelectorSet parameter.

A STA that is implemented after the existence of the BSSMembershipSelectorSet parameter includes each octet of the Supported Rates and BSS Membership Selectors element that is encoded with the MSB (bit 7) equal to 1 and that it does not recognize as a rate in its BSSMembershipSelectorSet parameter. The STA then determines if it can support all of the features represented in its BSSMembershipSelectorSet parameter before attempting to join the network. If some BSSMembershipSelectorSet parameter values are not recognized by the STA, the STA does not attempt to join the network.

NOTE 3—STA that was implemented before the existence of the BSSMembershipSelectorSet parameter interprets each BSS membership selector in the Supported Rates and BSS Membership Selectors element as though it were a rate from the BSSBasicRateSet parameter. These values of BSS membership selectors will not match a rate that is known to the

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STA and, therefore, the management entity in the STA will not associate with the BSS, because it will determine that the STA cannot receive or transmit at what appears to be a required rate.

#### 11.1.4.7 DMG discovery outside the context of a BSS(11bd)

This subclause applies to a DMG STA when dot11DMGOCBActivated is true.

Upon receipt of the MLME-DMG-OCB-START.request primitive, a DMG STA continuously discovers new peer STAs. If the discovery beacon parameter is equal to true, the STA shall start transmitting DMG Beacon frames with the Discovery Mode field set to 1, the OCB subfield in the Clustering Control field set to 1, and the Beacon Interval field set to a random value as described in 11.1.3.4 (DMG beacon generation before establishment of a BSS). If the discovery beacon parameter is equal to false, the DMG STA shall not transmit DMG Beacon frames.

When the STA receives one or more SSW frames with the OCB subfield equal to 1 during an A-BFT or DTI and completes SLS with the peer STA, and the address of the peer STA is an address that is newly discovered, the STA shall issue an MLME-OCB-DMGDISCOVERY.indication with the PeerInfoSet parameter including the PeerInfo vector for the peer STA that transmitted the SSW frame. (#7077)Each PeerInfo vector consists of the parameters shown in Table 11-3 (PeerInfo vectors(#7077)), in which the term peer STA refers to the STA that transmitted the received DMG Beacon frame, SSW frame, SSW Feedback frame, or SSW Ack frame.

**Table 11-3—PeerInfo vectors(#7077)**

| Name | Type | Valid range | Description |
|---|---|---|---|
| PeerSTAAddress | MAC address | Any valid individual MAC address | Specifies the MAC address of the discovered peer STA. |
| Sector sweep | As defined in frame format | As defined in 9.3.4.2 (DMG Beacon) | The values from the Sector Sweep field from the DMG Beacon frame, else null. |
| Sector sweep feedback | As defined in frame format | As defined in 9.5.3 (SSW Feedback field(#4303)) | The values from the Sector Sweep field from the SSW, SSW Feedback, or SSW Ack frame, else null. |
| DMG parameters | As defined in frame format | As defined in 9.3.4.2 (DMG Beacon) | The values from the DMG Parameters field from the DMG Beacon frame, else null. |
| DMG capabilities | As defined in frame format | As defined in 9.4.2.127 (DMG Operation element) | The values from the DMG Capabilities element if such an element was present in the DMG Beacon frame, else null. |
| EDMG capabilities | As defined in frame format | As defined in 9.4.2.265 (EDMG Operation element(11ay)) | Specifies the parameters within the EDMG Capabilities element that are supported by the MAC entity. |

When the STA receives one or more DMG Beacon frames with the OCB subfield equal to 1 from a peer STA, and the address of the peer STA is an address that is newly discovered, the STA shall perform an SLS with the OCB subfield set to 1 in transmitted SSW frames during the A-BFT following the DMG Beacon frames or the DTI. If the SLS is completed, the STA shall issue an MLME-OCB-DMGDISCOVERY.indication with the PeerInfoSet parameter including the PeerInfo for the peer STA that transmitted the DMG Beacon frame.


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When the STA completes SLS with a peer STA that transmitted an SSW frame with the OCB subfield equal to 1 or a DMG Beacon frame with the OCB subfield equal to 1, and the address of the peer STA is not an address that is newly detected, the STA may issue an MLME-OCB-DMGDISCOVERY.indication with the PeerInfoSet parameter including the PeerInfo regarding the peer STA.

Upon receipt of the MLME-DMG-OCB-STOP.request primitive, a DMG STA shall terminate transmission of DMG Beacon frames and cease discovery of peer STAs.

Figure 11-14 (DMG discovery outside the context of a BSS(11bd)) illustrates an example of the DMG discovery outside the context of a BSS, in which the discovery beacon parameter is equal to true in the MLME-DMG-OCB-START.request primitive for both STAs.

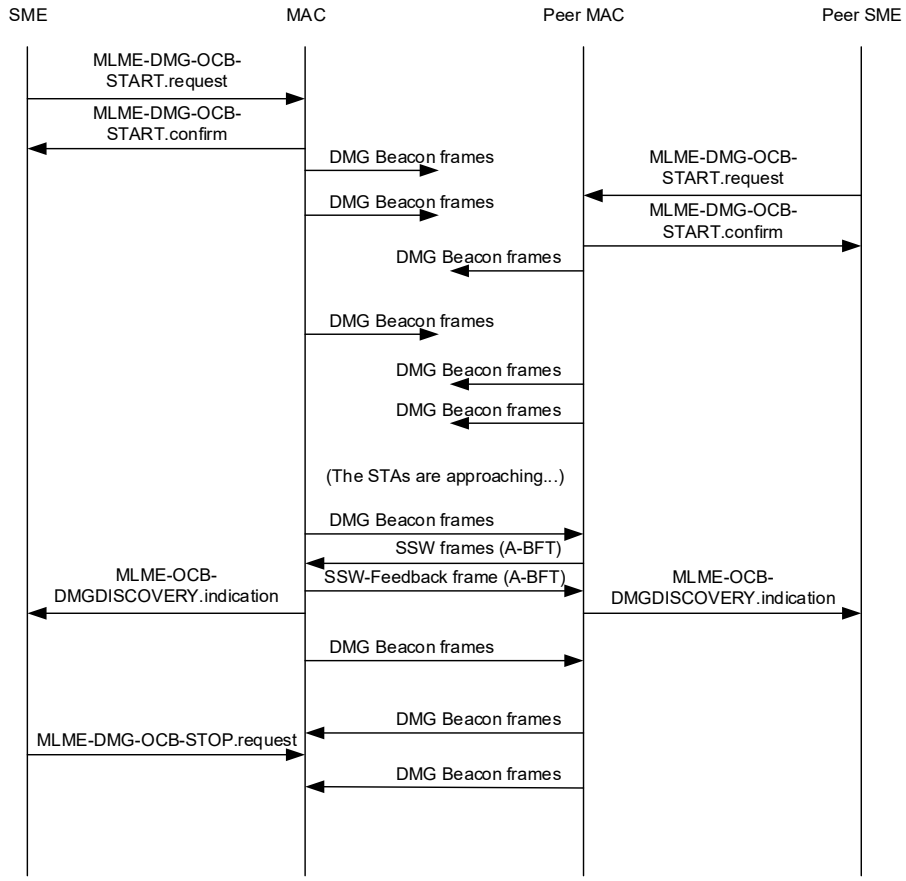


**Figure 11-14—DMG discovery outside the context of a BSS(11bd)**

Figure 11-15 (Beamforming training during the DMG discovery outside the context of a BSS(11bd)) illustrates an example of beamforming training during the DMG discovery outside the context of a BSS, in which the MAC address of the peer STA is informed over a higher layer and included in the MLME-BF-TRAINING.request primitive.

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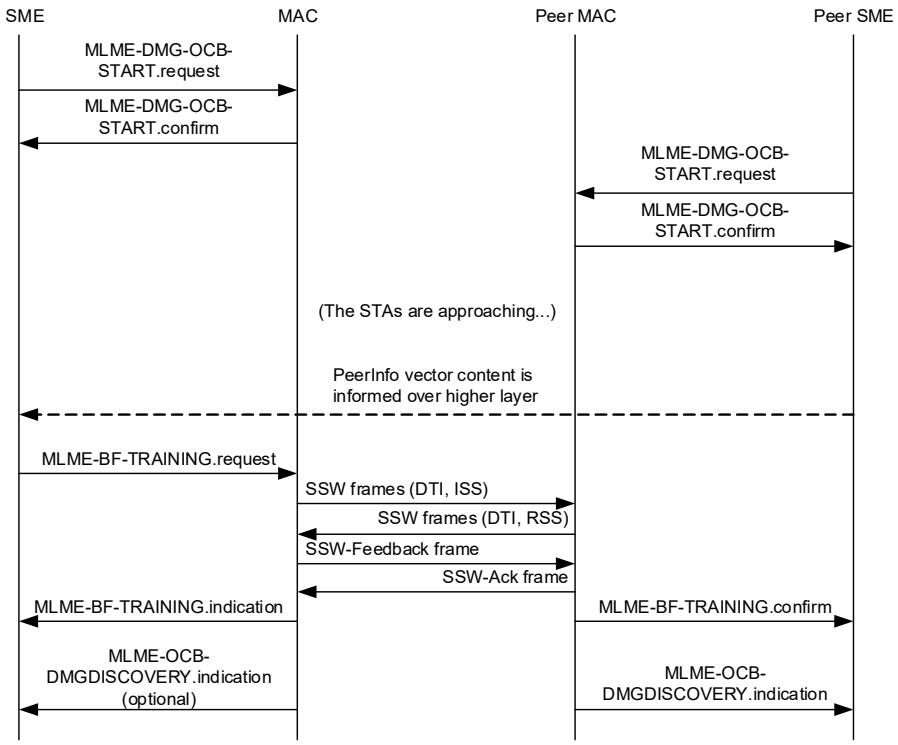


**Figure 11-15—Beamforming training during the DMG discovery outside the context of a BSS(11bd)**

### 11.1.5 Adjusting STA timers

A STA in an infrastructure BSS or PBSS shall adopt the TSF timer value in a Beacon, S1G Beacon, Probe Response, PV1 Probe Response, DMG Beacon, or Announce frame transmitted by the BSS's AP or PCP. The STA shall use the algorithm specified in 11.1.3.9 (TSF timer accuracy).

To response to an MLME-JOIN.request primitive, a STA joining an IBSS shall initialize its TSF timer to 0 and shall not transmit a Beacon, S1G Beacon, Probe Response, PV1 Probe Response, or DMG Beacon frame until it receives from a member of the IBSS a Beacon, S1G Beacon, Probe Response, PV1 Probe Response, or DMG Beacon frame that has a matching SSID. Consequently, the STA joining an IBSS adopts the timer from the next Beacon, S1G Beacon, Probe Response, PV1 Probe Response, or DMG Beacon frame from its IBSS.

A STA receiving a Beacon, S1G Beacon, Probe Response, PV1 Probe Response, DMG Beacon, or Announce frame from another IBSS STA with the same SSID shall compare the Timestamp field with its own TSF time. If the Timestamp field of the received frame is later than its own TSF timer, a STA that is neither a DMG nor an S1G STA in the IBSS shall adopt all parameters contained in the Beacon frame according to the rule for that parameter found in the (#4177)IBSS adoption column of the matching row of the BSSDescription table found in 6.5.3.3.2 (Semantics of the service primitive). An S1G STA shall adopt all parameters contained in the S1G Beacon frame according to the rule for that parameter found in (#4177)IBSS adoption column of the matching row of the BSSDescription table found in 6.5.3.2.2 (Semantics of the service primitive) if the Timestamp field of the received frame is later than its own TSF timer and the TSF Completion field in the S1G Beacon Compatibility element is not less than the value of the 4 most significant octets of its own TSF timer. A DMG IBSS STA shall adopt each parameter contained in the DMG Beacon or Announce frames. Parameters adopted


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by a STA due to the receipt of a later timestamp shall not be changed by the STA except when adopting parameters due to a subsequently received Beacon, S1G Beacon, DMG Beacon, or Announce frame with a later timestamp.

### 11.1.6 Terminating a BSS

At any time an infrastructure BSS or PBSS may be terminated. At any time a STA may cease support for an IBSS that it formed. Upon receipt of an MLME-STOP.request primitive, a STA shall stop transmitting Beacon, S1G Beacon, Probe Response, PV1 Probe Response, DMG Beacon, and Announce frames and deauthenticate all associated STAs.

### 11.1.7 TDD time synchronization(11ay)

This subclause applies to DMG STAs that are operating under TDD channel access (see 10.38.6.2.2 (SP with TDD channel access(11ay))) and that have the TDD Synchronization Mode subfield in their DMG Capabilities element equal to 1.

All STAs shall include a TDD Synchronization element, at least once per beacon interval, in transmitted Announce frames. An AP or PCP may include a TDD Synchronization element in DMG Beacon frames.

NOTE 1—A STA is not required to transmit the TDD Synchronization element during a beacon interval where it does not have transmit opportunity, subject to TDD channel access rules, to transmit an Announce frame.

A STA with dot11DMGTDDLocalClockModeActivated set to true shall not update its TSF timer based on the Timestamp field of a received DMG Beacon or Announce frame.

A STA with dot11DMGTDDLocalClockModeActivated set to false shall update its TSF timer based on the Timestamp field of each received DMG Beacon or Announce frame that includes a TDD Synchronization element with the Sync Mode field set to 0, unless both of the following are true:

— The last frame the STA used to update its TSF timer was a frame received in the same beacon interval as the new frame.

— The Clock Attributes field in the TDD Synchronization element of that last frame scores better than the Clock Attributes field in the TDD Synchronization element of the new frame. The logic to compare two Clock Attributes field values is the same as the logic to compare two IEEE 802.1AS systemIdentity attributes, as defined in 8.6.2 in IEEE Std 802.1AS-Rev/D8.0.

NOTE 2—While the comparison metric and logic are defined the same as IEEE 802.1AS for flexibility, using the IEEE 802.1AS protocol for TDD time synchronization is not required and is beyond the scope of this standard. The logic to compare two Clock Attributes field values is a hierarchical comparison of the Clock Attributes subfields in this order: Priority 1, Clock Class, Clock Accuracy, Offset Scaled Log Variance, and Priority 2, with a lower (#4317)numeric value for each subfield indicating a better clock.

If a STA with dot11DMGTDDLocalClockModeActivated set to false receives an Announce frame that has the Sync Mode field in the TDD Synchronization element equal to 1, then the SME of the STA shall issue an MLME-DISASSOCIATE.request primitive with ReasonCode parameter set to TIME_SYNC_LOST and PeerSTAAddress parameter set to the TA of the received Announce.

## 11.2 Power management

### 11.2.1 General

(#101)A non-AP STA can be in one of two power management modes:

— Active mode: The STA receives and transmits frames at any time if the STA is in awake state. A non-HE STA remains in the awake state. An HE STA remains in the awake state, unless the STA is

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unavailable. A STA that is unavailable is not capable of receiving PPDUs. A STA is permitted to be unavailable as described in 26.14.3 (Opportunistic power save), 26.14.1 (Intra-PPDU power save for non-AP HE STAs), and 26.8.4.4 (TWT Information frame exchange for flexible wake time).(11ax)

— Power save (PS) mode: The STA enters the awake state to receive or transmit frames. The STA remains in the doze state otherwise.

(#101)(Ed1)A STA in PS mode can be in one of two power states:

— Awake: STA is fully powered.

— Doze: STA is not able to transmit or receive (11ba)non-WUR PPDUs and consumes very low power.

The manner in which a STA transitions between power states is determined by its power management mode and reflected in dot11PowerManagementMode.

The power management mode of a STA is selected by the PowerManagementMode parameter of the MLME-POWERMGT.request primitive or MLME-MESHPOWERMGT.request primitive. Once the STA updates its power management mode, the MLME shall issue an MLME-POWERMGT.confirm primitive or MLME-MESHPOWERMGT.confirm primitive respectively indicating the success of the operation.

When MSDUs or A-MSDUs are buffered for power management purposes, the information in the MAC service tuple(s) for the MSDU(s) shall be maintained (and reordered) as a unit.

### 11.2.2 Bufferable MMPDUs

MMPDUs are categorized as bufferable or nonbufferable, as shown in Table 11-4 (Bufferable/nonbufferable classification of MMPDUs). Bufferable MMPDUs are eligible to be queued for delivery using a power-saving mechanism.

Nonbufferable MMPDUs are delivered without reference to a power saving mechanism.

**Table 11-4—Bufferable/nonbufferable classification of MMPDUs**

| Description | Classification |
|---|---|
| An MMPDU that is carried in one or more Action (except for FTM frame(#7223) and FTMR frame(#7223)), Disassociation, or Deauthentication frame | Bufferable |
| An individually addressed MMPDU that is carried in one or more Probe Response frames and that is sent in an IBSS in response to an individually addressed Probe Request frame. | Bufferable |
| All other MMPDUs. | Nonbufferable |

### 11.2.3 Power management in a non-DMG infrastructure network

#### 11.2.3.1 General

A STA that is associated with an AP and that changes power management mode shall inform the AP of this fact using the Power Management subfield within the Frame Control field of transmitted frames. The STA shall remain in its current power management mode until it informs the AP of a power management mode change via a frame exchange sequence(#109) that includes an acknowledgment from the AP. Power management mode shall not change during any single frame exchange sequence(#109).


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NOTE 1—This means the Power Management subfield is the same for all MPDUs in an A-MPDU.

The AP shall buffer individually addressed BUs addressed to STAs operating in a PS mode. These buffered BUs shall be transmitted only at designated times.

If any non-GLK STA in its BSS is in PS mode, the AP shall buffer all non-GCR-SP group addressed BUs that arrive via the DS and deliver them to all non-GLK STAs immediately following the next (#1000)DTIM beacon. If the AP is an S1G AP, the AP may additionally deliver these BUs using group AID as defined in 10.54 (Group AID). If any GLK STA in its BSS is in PS mode, the AP shall not include any such STAs as a SYNRA destination and shall buffer all group addressed BUs that arrive from the attached bridge and are destined to such STAs, delivering them with individually addressed MPDUs using power save delivery methods.

NOTE 2—The group addressed buffered BUs containing one or more MSDUs for GLK type STAs and for non-GLK type STAs are not repeated by the AP to the other type of STA. Network entities external to the AP, such as the bridged network, may repeat these MSDUs to both types of STAs by other means, outside the scope of this standard.

An S1G AP with dot11NDPPSPollSupport equal to true shall set the NDP PS-Poll Supported field in the S1G Capabilities element to 1. Otherwise it shall set the NDP PS-Poll Supported field in the S1G Capabilities element to 0.

The STAs that currently have buffered BUs (excluding those BUs for a STA associated with ACs that are U-APSD delivery-enabled when not all ACs are delivery-enabled by that STA) within the AP are identified in a TIM, which shall be included as an element within all Beacon frames generated by the AP. A STA shall determine that a BU is buffered for it by receiving and interpreting a TIM.

In a non-S1G STA, the traffic-indication virtual bitmap, maintained by the AP, shall be transmitted in a TIM element. In an S1G STA, the traffic-indication virtual bitmap may be divided into more than one page and each page shall be transmitted in a TIM element, hence, more than one TIM element may appear in an S1G Beacon frame. If more than one TIM element is present, then the TIM elements shall be ordered based on the Page Index and Page Slice Number subfields in the Bitmap Control field. TIM elements with Page Slice Number field(#4219) equal to 31 (if any) shall be the first ones and ordered from page 0 to page 3, and may be followed by TIM elements (if any when Page Slicing is supported) with Page Slice Number field(#4219) from 0 to 30 each of which shall also be ordered from page 0 to page 3. In an S1G STA, the traffic virtual bitmap shall be encoded as defined in 9.4.2.5 (TIM element) where the ADE mode may be used by the AP only if the TIM ADE Support field in the S1G Capabilities element received from every STA with AID included in the TIM element, is 1. Otherwise ADE mode shall not be used to encode the TIM element.

A STA operating in PS mode with dot11NonTIMModeActivated equal to false that is not in WNM sleep mode shall periodically listen for Beacon frames, as determined by the ListenInterval parameter of the MLME-ASSOCIATE.request or MLME-REASSOCIATE.request primitive and the ReceiveDTIMBeacons(#4221) parameter of the MLME-POWERMGT.request primitive. STAs operating in PS modes with dot11NonTIMModeActivated equal to true transmit at least one PS-Poll or trigger frame that is individually addressed to the associated AP every ListenInterval parameter used by the MLME primitives starting from the last known transition of the S1G STA in non-TIM mode in doze state unless it follows the TWT or NDP Paging procedure.

WNM sleep mode enables an extended power save mode for non-AP STAs in which a non-AP STA need not listen for every DTIM beacon(#3309), and need not perform GTK/IGTK/BIGTK updates. STAs in WNM sleep mode can transition to awake state(#6038) as infrequently as once every WNM sleep interval to check whether the corresponding TIM bit is set or group addressed traffic is pending.

NOTE 3—A STA might(M118) use both WNM sleep mode and PS mode simultaneously.

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If an S1G AP with dot11NDPPSPollSupport equal to true has a buffered BU for a STA associated with the AP and receives an NDP PS-Poll frame from the STA, it should send the buffered BU with the MCS level that is calculated based on the value indicated in the Preferred MCS subfield in the received NDP PS-Poll frame unless the indicated MCS level violates rate selection rule for Data frames (as defined in 10.6.5 (Rate selection for Data and Management frames)).

The Power Management subfield of the Frame Control field may be set to 0 or 1 within a frame sent by a STA in WNM sleep mode.

When a STA is in WNM sleep mode and in PS mode, the AP buffers individually addressed frames according to the traffic filtering agreement established between the AP and STA, as specified in 11.21.12.2 (TFS non-AP STA operation). When a STA is in WNM sleep mode but not in PS mode, the traffic filtering agreement between the AP and STA and the timer for the WNM sleep interval remain in place, and the AP queues for nonbuffered delivery all matched frames (i.e., matched by the traffic filtering agreement) destined to the STA.

In a BSS operating under the DCF or EDCA, upon determining that a BU is currently buffered in the AP, a STA operating in the normal (non-APSD) PS mode transmits a (NDP) PS-Poll frame to the AP, which responds with the corresponding buffered BU immediately, or acknowledges the (NDP) PS-Poll frame and responds with the corresponding BU at a later time.

An S1G STA may transmit NDP PS-Poll frames instead of PS-Poll frames to an S1G AP from which it has received a frame containing an S1G Capabilities element with the NDP PS-Poll Supported field equal to 1; otherwise, the S1G STA shall not transmit NDP PS-Poll frames. If an S1G STA detects that the partial BSSID of the BSS of which it is a member is equal to the partial BSSID of another BSS from which it receives frames, then the S1G STA shall not transmit NDP PS-Poll frames to its associated AP to avoid ambiguity. A non-S1G STA shall not transmit NDP PS-Poll frames. An S1G STA shall set the Poll Type subfield in the Frame Control field of the transmitted PS-Poll(+BDT) frame to 0 unless it is an S1G STA in non-TIM mode that follows the procedure described in 10.47.2 (Rescheduling of awake/doze cycle). (#371)An S1G STA in TIM mode shall not send a PS-Poll with the Poll Type subfield equal to 1.

A non-AP QoS STA may be in PS mode before the setup of block ack. BUs for a TID without a schedule are sent using Normal Ack following a PS-Poll frame as described in rest of 11.2.3 (Power management in a non-DMG infrastructure network). Uplink block ack agreements, block ack agreements for any TID with a schedule, and any block ack agreements to APSD STAs continue to operate normally.

NOTE 4—When a STA is in normal (non-APSD) PS mode, the rules described in 11.2.3.6 (AP operation) for PS-Poll operation apply to any downlink block ack agreement without an associated schedule. An (A-)MSDU delivered for this block ack agreement in response to the PS-Poll frame might be delivered in an A-MPDU. At most one (A-)MSDU is delivered.(#3191)

An S1G AP may change its Power Management mode as described in 11.2.3.17 (AP power management).

An S1G STA in PS mode shall set the More Data field to 1 in a frame transmitted to its AP when the STA intends to transmit another frame to the AP within this SP. An S1G STA in PS mode shall set the More Data field to 0 in a frame transmitted to its AP when the STA does not intend to transmit another frame to the AP within this SP.

#### 11.2.3.2 Non-AP STA power management modes

(#101)A non-AP STA shall be in active mode upon (re)association, except that if the (re)association is performed using the on-channel tunneling procedure defined in 11.31.5 (On-channel Tunneling (OCT) operation), then the non-AP STA shall be considered to be in power save mode and in doze state upon (re)association on the BSS identified by the BSSID, Band ID, and Channel Number fields contained in the


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Multi-band element transmitted in the On-channel Tunnel Request frame that carries the (Re)Association Request frame.

A STA that has transmitted a frame to an AP with which it is not associated and from which it expects a response shall remain in the awake state until such a response is received or until the procedure has timed out.

To change power management modes a STA shall inform the AP by completing a successful frame exchange(#109) that is initiated by the STA. This frame exchange sequence(#109) shall include a Management frame, Extension frame or Data frame from the STA, and an Ack or a BlockAck frame from the AP. The Power Management subfield(s) in the Frame Control field of the frame(s) sent by the STA in this exchange indicates the power management mode that the STA shall adopt upon successful completion of the (#1673)frame exchange sequence(#109)(#1674), except where the Power Management subfield is reserved (see 9.2.4.1.7 (Power Management subfield)). A non-AP STA shall not change power management mode using a frame exchange sequence(#109) that does not receive an Ack or BlockAck frame from the AP, or using a BlockAckReq frame.

NOTE 1—A PS-Poll frame exchange sequence(#109) does not necessarily result in an Ack frame from the AP, so a non-AP STA cannot change power management mode using a PS-Poll frame.

NOTE 2—The Power Management subfield is ignored in frame exchange sequences(#109) initiated by the AP.

A non-S1G STA that is changing from doze to awake state in order to transmit shall perform CCA until a frame is detected by which it can set its NAV, or until a period of time indicated by the NAVSyncDelay from the MLME-JOIN.request primitive has transpired. An S1G STA that is changing from doze to awake state in order to transmit shall perform CCA until a frame is detected by which it can set its RID or NAV, or until a period of time indicated by the NAVSyncDelay from the MLME-JOIN.request primitive has transpired.

To change power management mode, a STA that is coordinated by an MM-SME shall inform the AP through a successful frame exchange sequence(#109) initiated by the STA. The Power Management subfield in the Frame Control field of the frame sent by the STA in this exchange indicates the power management mode that the STAs coordinated by the MM-SME and advertised in the MMS element sent by the STA shall adopt upon successful completion of the (#1673)frame exchange sequence(#109). To change the power management mode of the coordinated STA, the frame may be sent using any of the MMSLs within the MMSL cluster established with the AP.

An S1G AP that sets the STA Type Support in transmitted S1G Capabilities elements to 0 or 1 shall set dot11NonTIMModeActivated to true and the Non-TIM Support field in the S1G Capabilities element to 1. An S1G AP that sets the STA Type Support in transmitted S1G Capabilities elements to 2 may set dot11NonTIMModeActivated to false and the Non-TIM Support field in the S1G Capabilities element to 0. An S1G AP that sets the STA Type Support in transmitted S1G Capabilities elements to 2 may set dot11NonTIMModeActivated to true and the Non-TIM Support field in the S1G Capabilities element to 1.

An S1G AP shall not set the Non-TIM Support field to 1 in response to a non-TIM Support field equal to 0.

An S1G AP that includes an AID Response element in a (Re)Association Response frame shall set the AID/Group AID field to the AID assigned to the (re)associating STA, the AID Switch Count field to 0, and the AID Response Interval field to the Listen Interval field.

NOTE 3—The S1G AP can specify a listen interval that is different from the listen interval requested by (#306)the non-AP S1G STA in the (Re)Association Request frame if the AP cannot buffer the S1G STA's BUs for the requested listen interval.

(#306)A non-AP S1G STA requests the type of PS mode (TIM mode or non-TIM mode) through the (Re)Association Request frame transmitted to the S1G AP.

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(#306)A non-AP S1G STA requests operation in non-TIM mode by setting the Non-TIM Support field in the S1G Capabilities element in the (Re)Association Request frame to 1.

(#306)A non-AP S1G STA requests operation in TIM mode by setting the Non-TIM Support field in the S1G Capabilities element in the (Re)Association Request frame to 0.

(#306)A non-AP S1G STA determines the type of PS mode (TIM mode or non-TIM mode) from the (Re)Association Response frame received from the S1G AP.

If an S1G AP sets the Non-TIM Support field in the S1G Capabilities element in the (Re)Association Response frame to 1, then (#306)the non-AP S1G STA shall set dot11NonTIMModeActivated to true and operate in non-TIM mode following association, and is referred to as a non-TIM STA.

If an S1G AP sets the Non-TIM Support field in the S1G Capabilities element in the (Re)Association Response frame to 0, then (#306)the non-AP S1G STA shall set dot11NonTIMModeActivated to false and operate in TIM mode following association, and is referred to as a TIM STA.

(#306)A non-AP S1G STA shall operate in the negotiated PS mode during association unless a PS mode switch is negotiated as described in 10.20 (S1G dynamic AID assignment operation) or a temporary PS mode switch has occurred as described in 10.47.2 (Rescheduling of awake/doze cycle). The STA shall update the value of the ListenInterval parameter it uses in invocations of primitives with the AID Response Interval field in the AID Response element of the (Re)Association Response frame.

An S1G STA in TIM mode listens to selected Beacon frames (based upon the ListenInterval parameter of the MLME-ASSOCIATE.request or MLME-REASSOCIATE.request primitive) and sends PS-Poll frames to the AP if the TIM element in the most recent Beacon frame indicates an individually addressed BU is buffered for that STA.

An S1G STA in non-TIM mode shall transmit at least one PS-Poll or trigger frame that is individually addressed to the associated AP every listen interval and might not listen to selected S1G Beacon frames (based upon the ListenInterval parameter of the MLME-ASSOCIATE.request or MLME-REASSOCIATE.request primitive) unless it follows the TWT or NDP Paging procedure. An S1G STA in non-TIM mode may send (NDP) PS-Poll frames to an S1G AP regardless of whether individually addressed buffered BUs have been indicated by the S1G AP.

#### 11.2.3.3 AP TIM transmissions

The TIM shall identify the STAs for which traffic is pending and buffered in the AP. This information is coded in a *partial virtual bitmap*, as described in 9.4.2.5 (TIM element). In addition, the TIM contains an indication whether non-SYNRA group addressed traffic is pending. Every STA is assigned an AID by the AP as part of the association process. AID 0(#7206) is reserved to indicate the presence of buffered non-GCR-SP group addressed BUs (M118)to be delivered using MPDUs with an RA other than a SYNRA but that are not delivered using group AID. The AP shall identify those STAs for which it is prepared to deliver[38] buffered BUs by setting bits in the TIM's partial virtual bitmap that correspond to the appropriate AIDs.

NOTE—AID 0 is signaled in the Traffic Indicator field when the DTIM Count field is zero.(#7217)

For an S1G band, the TIM is coded in an S1G partial virtual bitmap, as described in 9.4.2.5 (TIM element). This information is constructed with one of the four encoding modes: the Block Bitmap mode, the Single AID model, the OLB (offset, length, bitmap) mode, and the ADE (AID with differential encoding) mode. An S1G AP shall not transmit the TIM with the encoding mode in the Block Control subfield set to ADE mode to another S1G STA unless the TIM ADE Support field of the S1G Capabilities element received from that STA contained a value of 1 and dot11TIMADEImplemented is true.

[38] How the AP or mesh STA determines the traffic it is prepared to deliver is outside the scope of this standard.


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### 11.2.3.4 TIM types

Two different TIM types are distinguished: TIM and DTIM. After a DTIM beacon(#6592), the AP shall transmit buffered non-GCR-SP group addressed BUs (M118)to be delivered using MPDUs with an RA other than a SYNRA, before transmitting any individually addressed frames. The AP may additionally deliver these BUs using group AID as defined in 10.54 (Group AID).

The AP shall transmit a TIM with every Beacon frame except when the frame is scheduled for transmission in a TSBTT that is not a TBTT. Every dot11DTIMPeriod, a TIM of type (#8164)DTIM is transmitted within a Beacon frame, rather than an ordinary TIM. An S1G AP with dot11ShortBeaconInterval equal to true may include a TIM in a Beacon frame that is scheduled for transmission in a TSBTT that is not a TBTT. An S1G AP with dot11ShortBeaconInterval equal to true may transmit a TIM of type DTIM in an S1G Beacon frame every dot11ShortBeaconDTIMPeriod.

Figure 11-16 (Infrastructure power management operation) illustrates the AP and STA activity under the (#3250)assumption that a DTIM (#8164)beacon is transmitted once every three TIMs. The top line in Figure 11-16 (Infrastructure power management operation) represents the time axis, with the beacon interval shown together with a DTIM Interval of three beacon intervals. The second line depicts AP activity. The AP schedules Beacon frames for transmission every beacon interval, but the Beacon frames may be delayed if there is traffic at the TBTT. This is indicated as “busy medium” on the second line. For the purposes of this figure, the important fact about Beacon frames is that they contain TIMs, some of which are DTIM beacons(#4221). Note that the second STA with ReceiveDTIMBeacons(#4221) equal to false does not power-on its receiver for all DTIM beacons(#4221).

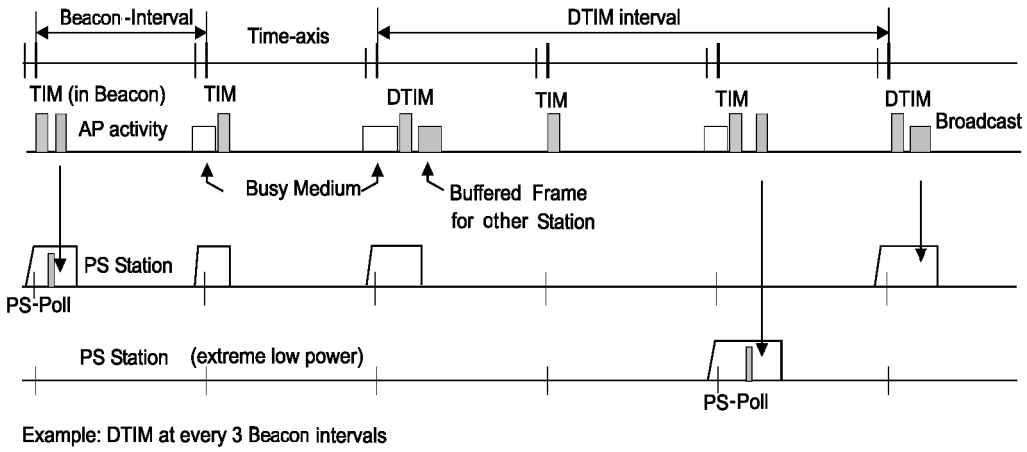


**Figure 11-16—Infrastructure power management operation**

The third and fourth lines in Figure 11-16 (Infrastructure power management operation) depict the activity of two STAs operating with different power management requirements. Both STAs power-on their receivers when they need to listen for a TIM. This is indicated as a rampup of the receiver power prior to the TBTT. The first STA, for example, powers up its receiver and receives a TIM in the first Beacon frame; that TIM indicates the presence of a buffered BU for the receiving STA. The receiving STA then generates a PS-Poll frame, which elicits the transmission of the buffered BU from the AP. Non-GCR-SP group addressed BUs are sent by the AP subsequent to the transmission of a (#1000)DTIM beacon.

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#### 11.2.3.5 Power management with APSD

##### 11.2.3.5.1 Power management with APSD procedures

QoS APs capable of supporting automatic power save delivery (APSD) shall signal this capability through the use of the APSD subfield in the Capability Information field in Beacon, Probe Response, and (Re)Association Response frames.

QoS STAs use the Power Management subfield in the Frame Control field of a frame to indicate whether it is in active or PS mode. As APSD is a mechanism for the delivery of BUs to power saving STAs, the frames transmitted by a STA in PS mode that is using APSD have the Power Management subfield in the Frame Control field set to 1, thereby causing buffering to take place at the AP.

APSD defines two delivery mechanisms, namely *unscheduled APSD* (U-APSD) and *scheduled APSD* (S-APSD). STAs may use U-APSD to have some or all of their BUs delivered during unscheduled SPs. STAs may use S-APSD to schedule delivery of some or all of their BUs during scheduled SPs.

If there is no unscheduled SP in progress, the unscheduled SP begins when the AP receives a trigger frame from a STA, which is a QoS Data or QoS Null frame using an AC the STA has configured to be trigger-enabled. An A-MPDU that contains one or more trigger frames acts as a trigger frame. An unscheduled SP ends after the AP has attempted to transmit at least one BU using a delivery-enabled AC and destined for the STA, but no more than the number indicated in the Max SP Length field of the QoS Capability element of the STA's (Re)Association Request frame if the field has a nonzero value.

NOTE 1—The transmission of one or more fragments of a BU counts as the transmission of one BU for the purposes of the constraint indicated by the Max SP Length field.

The last frame sent during the SP has the EOSP subfield set to 1. An unscheduled SP may be terminated before the maximum number of BUs in the SP has been reached. The times at which an AP may transmit during an unscheduled SP might be constrained by the U-APSD coexistence mechanism (see 11.2.3.5.2 (U-APSD coexistence)).

In order to configure an AP to deliver BUs during an unscheduled SP, a STA designates one or more of its ACs to be delivery-enabled and one or more of its AC to be trigger-enabled. A STA may configure an AP to use U-APSD using two methods. First, the STA may set individual U-APSD Flag bits in the QoS Info subfield of the QoS Capability element carried in (Re)Association Request frames. When a U-APSD Flag bit is 1, it indicates that the corresponding AC is both delivery- and trigger-enabled. When all four U-APSD Flag subfields are equal to 1 in (Re)Association Request frames, all of the ACs associated with the STA are trigger- and delivery-enabled during (re)association. When all four U-APSD Flag subfields are equal to 0 in (Re)Association Request frames, none of the ACs associated with the STA is trigger- or delivery-enabled during (re)association.

Alternatively, the STA may designate one or more AC as trigger-enabled and one or more AC as delivery-enabled by sending an ADDTS Request frame per AC to the AP with the APSD subfield set to 1 and the Schedule subfield set to 0 in the TS Info field in the TSPEC element. APSD settings in a TSPEC request take precedence over the static U-APSD settings carried in the QoS Capability element. In other words, a TSPEC request overwrites any previous U-APSD setting of an AC.

NOTE 2—Such an ADDTS Request frame can be sent regardless of the ACM setting of the AC.

A STA may set an AC to be trigger- or delivery-enabled for its own use by setting up TSPECs with the APSD subfield set to 1 and the Schedule subfield set to 0 in the uplink or downlink direction, respectively. An uplink TSPEC plus a downlink TSPEC, or a bidirectional TSPEC with the APSD subfield equal to 1 and the Schedule subfield equal to 0, makes an AC both trigger- and delivery-enabled. An uplink TSPEC plus a downlink


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TSPEC, or a bidirectional TSPEC with the APSD and the Schedule subfields both equal to 0, makes an AC neither trigger- nor delivery-enabled.

A scheduled SP starts at fixed intervals of time specified in the Service Interval field.The following rules describe scheduled SP operation:

a) If the scheduled Service Interval field equals 0 (for example, with the GCR-A delivery method), the scheduled SP starts from the service start time without a fixed delivery interval.

b) To use a scheduled SP for a TS when the access policy is controlled channel access, a STA shall send an ADDTS Request frame to the AP with the APSD subfield of the TS Info field in the TSPEC element set to 1.

c) To use a scheduled SP for a TS for an AC when the access policy is contention based channel access, a STA shall send an ADDTS Request frame to the AP with the APSD and Schedule subfields of the TS Info field in the TSPEC element both set to 1. If the APSD mechanism is supported by the AP and the AP accepts the corresponding ADDTS Request frame from the STA, the AP shall respond to the ADDTS Request frame with a response containing the Schedule element indicating that the requested service can be accommodated by the AP.

d) When the access policy is contention based channel access for a GCR group addressed stream, a scheduled SP is set up according to 11.21.16.3.3 (GCR setup procedures). The first scheduled SP starts when the lower order 4 octets of the TSF timer equals the value specified in the Service Start Time field.

e) If the SI is nonzero, a STA using scheduled SP shall first transition to awake state(#6038) at the service start time to receive downlink individually addressed and/or GCR-SP group addressed BUs buffered and/or to receive polls from the AP or HC. The STA shall transition to awake state(#6038) subsequently at a fixed time interval equal to the SI.

f) The AP may modify the non-GCR service start time by indicating so in the Schedule element in a successful ADDTS Response frame (which is sent in response to an ADDTS Request frame) and in Schedule frames (which are sent at other times).

g) The AP may modify the GCR service start time by indicating so in the Schedule element in the GCR Response subelements (see 9.4.2.87 (DMS Response element) and 11.21.16.3.4 (GCR operation)).

h) In both non-GCR and GCR cases, the service start time shall be updated (using the previously described service start time modification procedures) whenever the upper 4 octets of the TSF timer change.

A scheduled SP begins at the scheduled wakeup time that corresponds to the SI and the service start time indicated in the Schedule element sent in response to a TSPEC or GCR Request. If the SI is nonzero, the STA shall transition to awake state(#6038) at a subsequent time when the following is true:

$$(TSF - T_{service\text{-}start}) \bmod SI_{min} = 0$$

where

$T_{service\text{-}start}$ is the service start time

$SI_{min}$ is the minimum SI

If the SI is nonzero, a scheduled SP for a GCR group ends after the AP has attempted to transmit at least one BU associated with the GCR group but no more than the number indicated in the Max SP Length field of the QoS Capability element of the STA's (Re)Association Request frame. The last frame of the GCR SP shall have the EOSP subfield set to 1.

NOTE 3—The transmission of one or more fragments of a BU counts as the transmission of one BU for the purposes of the constraint indicated by the Max SP Length field.

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If a scheduled SP overlaps the period during which the AP is required to transmit non-GCR-SP group addressed frames and individually addressed frames to STAs in PS mode that follow a DTIM beacon that has at least 1 bit set to 1 in the partial virtual bitmap of its TIM, the scheduled SP shall be deferred until the AP has transmitted all such buffered frames.

When the GCR-A delivery method is used, the scheduled Service Interval field is 0. If a STA has a GCR agreement with an AP for a group address using the GCR-A delivery method, there is no defined end of the scheduled SP. The STA in PS mode shall enter the awake state and shall remain awake in order to receive the buffered group addressed BUs until the AP changes the delivery method of the stream to a method other than GCR-A or until the GCR agreement is canceled.

If scheduled SPs are supported in a BSS, a STA may use both unscheduled and scheduled APSD on different ACs at the same time. The GCR-SP delivery method may be used on any AC, irrespective of any non-GCR unscheduled or scheduled APSD flows. When a STA establishes scheduled delivery for an AC the AP shall not transmit BUs using that AC during an SP that is initiated by a trigger frame, and it shall not treat BUs using the AC that are received from the STA as trigger frames.(#299)

APSD shall be used only to deliver individually addressed BUs and GCR-SP BUs to a STA. Non-GCR and non-GCR-SP group addressed BU delivery shall follow the frame delivery rules defined for group addressed BUs as defined in 11.2.3.6 (AP operation).

#### 11.2.3.5.2 U-APSD coexistence

A non-AP STA that uses U-APSD might not be able to receive all AP transmitted frames during the service period due to interference observed at the non-AP STA. Although the AP might not observe the same interference, it is able to determine that the frames were not received correctly by the non-AP STA. The U-APSD coexistence capability enables the non-AP STA to indicate a requested transmission duration to the AP for use during U-APSD service periods. Use of the transmission duration enables the AP to transmit frames during the service period and improve the likelihood that the non-AP STA receives the frames when the non-AP STA is experiencing interference. The U-APSD coexistence capability reduces the likelihood that the AP transmits frames during the service period that are not received.

A STA with dot11UAPSDCoexistenceActivated equal to true shall support U-APSD coexistence and shall set to 1 the U-APSD Coexistence field of the Extended Capabilities elements that it transmits. Otherwise it shall set this field to 0.

A non-AP STA that is associated to an AP where both have previously advertised support for the U-APSD coexistence capability may transmit ADDTS Request frames including the U-APSD Coexistence element to the AP.

The content of the ADDTS Request frame excluding the U-APSD Coexistence element is referred to in subsequent text as the base ADDTS request. Upon reception of the ADDTS Request frame, the AP shall process the content of the base ADDTS request as described in 11.2.3.5 (Power management with APSD). If the AP determines that the base ADDTS request cannot be granted it shall respond as described in 11.2.3.5 (Power management with APSD), without processing the U-APSD Coexistence element. If the AP determines the base ADDTS request can be granted, it shall process the U-APSD Coexistence element. If the AP supports transmission of frames during the U-APSD service period for the duration value specified in the U-APSD Coexistence element Interval/Duration field, it shall grant the ADDTS request as described in 11.2.3.5 (Power management with APSD). Otherwise, it shall deny the ADDTS Request.

If the AP has previously granted an ADDTS request with U-APSD coexistence, a non-AP STA that continues using QoS services provided by an ADDTS Request frame without U-APSD coexistence may terminate the use of U-APSD coexistence by transmitting an ADDTS Request frame without the U-APSD Coexistence


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element. A non-AP STA may terminate use of all QoS services (including U-APSD coexistence) resulting from an ADDTS Request frame by transmitting a DELTS Request frame to the AP.

The non-AP STA may transmit multiple ADDTS Request frames to the AP where the last received ADDTS Request frame (M118)overrides any previously received ADDTS Request frame.

An AP that supports U-APSD coexistence and accepts an ADDTS request limits the U-APSD coexistence service period according to the parameters specified in the ADDTS frame U-APSD Coexistence element, and shall transmit frames to the requesting non-AP STA according to the rules in 10.2.3.2 (HCF contention based channel access (EDCA)) and the following rules:

— If the non-AP STA specified a nonzero TSF 0 Offset value in the U-APSD Coexistence element, the AP should not transmit frames to the non-AP STA outside of the U-APSD Coexistence Service Period, which begins when the AP receives the U-APSD trigger frame and ends after the transmission period specified by the result of the following calculation:

*End of transmission period* = $T$ + (*Interval* – (($T$ – *TSF 0 Offset*) mod *Interval*))

where

*T* is the time the U-APSD trigger frame was received at the AP

*Interval* is the UAPSD Coexistence element Duration/Interval field value (see 9.4.2.89 (U-APSD Coexistence element))

or upon the successful transmission of a frame with the EOSP subfield set to 1, whichever is earlier.

— If the non-AP STA specified a TSF 0 Offset value of 0 in the U-APSD Coexistence element, the AP should not transmit frames to the non-AP STA outside of the U-APSD coexistence service period, which begins when the AP receives a U-APSD trigger frame and ends after the transmission period specified by the result of the following calculation:

*End of transmission period* = $T$ + *Duration*

where

*T* is the time the U-APSD trigger frame was received at the AP

*Duration* is the UAPSD Coexistence element Duration/Interval field value (see 9.4.2.89 (U-APSD Coexistence element))

or upon the successful transmission of a frame with the EOSP subfield set to 1, whichever is earlier.

Throughout the U-APSD coexistence service period, the AP shall set the More bit to 1 if it has more frames to be transmitted and it can determine the frame might be received before the service period expires.

The AP should set the EOSP subfield to 1 in the frame that it expects to be the last frame transmitted to the non-AP STA during the U-APSD coexistence duration. If the last frame expected to be transmitted cannot be successfully transmitted to the non-AP STA before the termination of the U-APSD SP, or does not have QoS Control field, the AP should transmit a QoS Null frame with the EOSP subfield set to 1.

The non-AP STA may enter doze state at the end of the U-APSD coexistence service period.

#### 11.2.3.6 AP operation

An AP shall maintain for each currently associated STA a Power Management status that indicates in which power management mode the STA is currently operating. APs that implement and signal their support of APSD shall maintain for each currently associated STA an APSD and an access policy status that indicates whether the STA is presently using APSD and shall maintain the schedule (if any) for the STA. An AP shall, depending on the power management mode of the STA, temporarily buffer BUs destined to the STA. An AP implementing APSD shall, if a STA is using APSD and is in PS mode, temporarily buffer BUs destined to that

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STA. No BUs addressed directly to STAs operating in the active mode shall be buffered for power management reasons. An HE AP should not transmit to an HE STA if the STA might be unavailable, as defined in 26.8.4.4 (TWT Information frame exchange for flexible wake time) and 26.14.3 (Opportunistic power save), unless the transmission is solicited by the STA.(11ax)

The following rules describe the operation:

a) BUs destined for PS STAs shall be temporarily buffered in the AP. The algorithm to manage this buffering is beyond the scope of this standard, with the exception that if the AP is QoS-enabled, it shall preserve the order of arrival of individually addressed frames sent to a given STA on a given TID.(#4297)

b) Nonbufferable MMPDUs and BUs destined for STAs in the active mode shall be directly transmitted to those STAs.

c) At every beacon interval, the AP shall assemble the partial virtual bitmap containing the buffer status per destination for STAs in the PS mode and shall send this out in the TIM element of the Beacon frame. At every beacon interval, the APSD-capable AP shall assemble the partial virtual bitmap containing the buffer status of nondelivery-enabled ACs (if there exists at least one nondelivery-enabled AC) per destination for STAs in PS mode and shall send this out in the TIM element of the Beacon frame. When all ACs are delivery-enabled, the APSD-capable AP shall assemble the partial virtual bitmap containing the buffer status for all ACs per destination. If FMS is enabled, the AP shall include the FMS Descriptor element in every Beacon frame. The FMS Descriptor element shall indicate all FMS group addressed frames that the AP buffers. An S1G AP should set the Duration field in the S1G Beacon frame to the estimated time required for all the S1G STAs that are indicated in the TIM elements and/or are allowed to access the first RAW immediately following the S1G Beacon frame as described in 10.23.5.4 (Slotted channel access procedure in RAW), to send the trigger or (NDP) PS-Poll frame and receive an acknowledgment from the AP. The operation described in this paragraph shall also be performed for every short beacon interval where a TIM is transmitted.

d) If a STA has set up a scheduled SP, (M165)the APSD-capable AP shall transmit frames associated with admitted traffic with the APSD subfield equal to 1 in the TSPECs buffered for the STA during a scheduled SP. If the STA has set up to use unscheduled SPs, the AP shall buffer BUs using delivery-enabled ACs until it has received a trigger frame using a trigger-enabled AC from the non-AP STA, which indicates the start of an unscheduled SP. A trigger frame received by the AP from a STA that already has an unscheduled SP underway shall not trigger the start of a new unscheduled SP. The AP transmits BUs destined for the STA and using delivery-enabled ACs during an unscheduled SP.(M165)

NOTE 1—Transmission of BUs during an unscheduled SP is constrained by the max SP length.

NOTE 2—The AC for delivery of an MMPDU (see 10.2.3.2 (HCF contention based channel access (EDCA))) determines whether it is transmitted using a delivery-enabled AC during an unscheduled SP.

e) For an AP with dot11MultiBSSIDImplemented not true, the Traffic Indicator field in the Bitmap Control field of the TIM element shall be set to 1(#7217) when non-GCR-SP non-SYNRA group addressed traffic that is not to be delivered using group AID is buffered. For an AP with dot11MultiBSSIDImplemented set to true, the indication of group addressed traffic is described in 11.1.3.8.5 (Traffic advertisement in a multiple BSSID set(11ax)).(M165)

f) If any associated non-GLK STAs are in PS mode, the AP shall buffer all non-GCR-SP group addressed BUs that arrive via the DS. If any GLK STA in its BSS is in PS mode, the AP shall not include any such STAs as a SYNRA destination and shall buffer all group addressed BUs destined to such STAs, delivering them with individually addressed MPDUs using power save delivery methods.

g) When dot11FMSActivated is false, the AP shall transmit all buffered non-GCR-SP non-SYNRA group addressed BUs immediately after every DTIM (#8164)beacon or during broadcast TWT SPs within that beacon interval as defined in 26.8.3.2 (Rules for TWT scheduling AP).(11ax)


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When dot11FMSActivated is true and the AP has established an FMS delivery interval for a multicast stream, the AP shall transmit all non-GCR-SP non-SYNRA group addressed BUs belonging to particular FMS stream immediately after the DTIM (#8164)beacon that has the Current Count field of the FMS Counter field set to 0 for that particular FMS stream or during broadcast TWT SPs within that beacon interval as defined in 26.8.3.2 (Rules for TWT scheduling AP).(11ax)

The More Data subfield of each group addressed frame shall be set to indicate the presence of further buffered non-GCR-SP group addressed BUs (M118)to be delivered using MPDUs with an RA other than a SYNRA. If the AP is unable, before the primary or secondary TBTT following the DTIM (#8164)beacon, to transmit all of the buffered non-GCR-SP group addressed BUs (M118)to be delivered using MPDUs with an RA other than a SYNRA, then the AP shall set the Traffic Indicator field(#7217) in the TIM element to 1 for a single BSSID or set the corresponding group address bit to 1 for multiple BSSIDs, as defined in 9.4.2.5 (TIM element), and when dot11FMSActivated is true, shall set the appropriate bits in the FMS Descriptor element as described in 9.4.2.73 (FMS Descriptor element) to indicate for which non-GCR-SP non-SYNRA group addresses there are still buffered BUs, until all buffered non-GCR-SP group addressed BUs (M118)to be delivered using MPDUs with an RA other than a SYNRA have been transmitted.

When the AP transmits an STBC (#8164)Beacon frame, the AP shall retransmit all non-GCR-SP group addressed BUs (M118)to be delivered using MPDUs with an RA other than a SYNRA and that were transmitted following the non-STBC (#8164)Beacon frame except that they are transmitted using the basic STBC MCS. It may be the case that a complete set of buffered non-GCR-SP non-SYNRA group addressed BUs is sent over a period of time during which non-STBC and STBC transmissions are interleaved, but the transition from non-STBC group addressed transmissions to STBC group addressed transmissions shall be preceded by the transmission of an STBC Beacon frame and the transition from STBC group addressed transmissions to non-STBC group addressed transmissions shall be preceded by the transmission of a non-STBC Beacon frame.

h) When the AP receives a PS-Poll frame from a STA that is in PS mode, it shall forward to the STA a buffered BU. The AP shall respond after a SIFS either with a Data or Management frame, or with an Ack frame; in which case the corresponding Data or Management frame is delayed. Until the transmission of this BU either has succeeded or is presumed failed (when maximum retries are exceeded), the AP shall acknowledge (#3683)then discard all PS-Poll frames from the same STA. This prevents a retried PS-Poll frame from being treated as a new request to deliver a buffered BU.

NOTE 3—The BU might be delivered in multiple Data or Management frames.(#3192)

For a STA using U-APSD, the AP transmits one BU destined for the STA from any AC that is not delivery-enabled in response to a(#375) PS-Poll frame from the STA. The AP should transmit the BU from the highest priority AC that is not delivery-enabled and that has a buffered BU. When all ACs associated with the STA are delivery-enabled, the AP transmits one BU from the highest priority AC that has a BU. (#111)Upon receiving a PS-Poll frame, the S1G AP may use the RTS/CTS scheme to protect the transmission of an immediate Data frame.

An S1G AP that sends an acknowledgment frame of type (NDP) Ack or NDP PS-Poll-Ack in response to an (NDP)PS-Poll/trigger frame that is received from an S1G STA shall set the More Data subfield of the acknowledgment frame to 0 when no BU is buffered for the STA; otherwise, it shall set it to 1. The reception of the acknowledgment frame provides the following indications to the S1G STA:

1) If the More Data subfield is equal to 0, it indicates that no service period starts for the STA and that it may enter the doze state,
2) If the More Data subfield is equal to 1, it indicates that a service period starts for the STA after a time T, starting from the end of the acknowledgment frame, after which the S1G STA shall remain in the awake state until a frame is received from the S1G AP that has the EOSP subfield equal to 1. The time T is equal to one of the following:
    i) 0 if the acknowledgment frame is an Ack frame or is an NDP (PS-Poll-)Ack frame with the Idle Indication subfield equal to 0.

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ii) The value indicated in the Duration field of the frame if the frame is an NDP (PS-Poll-)Ack frame with the Idle Indication subfield equal to 1.

For a STA in PS mode and not using U-APSD, the AP shall set the More Data subfield of the response Data or Management frame to 1 to indicate the presence of further buffered BUs (not including the BU currently being transmitted) for the polling STA.

For a STA using U-APSD, the AP shall set the More Data subfield to 1 to indicate the presence of further buffered BUs (not including the BU currently being transmitted) that do not use delivery-enabled ACs. When all ACs associated with the STA are delivery-enabled, the AP shall set the More Data subfield to 1 to indicate the presence of further buffered BUs (not including the BU currently being transmitted) using delivery-enabled ACs.

If there are buffered BUs to transmit to the STA, the AP may set the More Data bit in a QoS +CF-Ack frame to 1 in response to a QoS Data frame to indicate that it has one or more pending BUs buffered for the PS STA identified by the RA in the QoS +CF-Ack frame. An AP may also set the More Data bit in an Ack frame to 1 in response to a QoS Data frame to indicate that it has one or more pending BUs buffered for the PS STA identified by the RA in the Ack frame, if that PS STA has set the More Data Ack subfield in the QoS Info field to 1. An HE AP may also set the More Data bit in a BlockAck or Multi-STA BlockAck frame to 1 to indicate that it has one or more pending BUs buffered for the HE PS STA identified by the RA in the BlockAck or Multi-STA BlockAck frame, if that HE PS STA has set the More Data Ack subfield in the QoS Info field to 1. An HE AP indicates support for sending Ack, BlockAck, or Multi-STA BlockAck frames with a nonzero More Data subfield by setting the More Data Ack subfield to 1 in the QoS Info field of frames it transmits.(11ax)

Unless indicated above, the AP shall set the More Data bit to 0.

i) At each scheduled APSD SP for a STA, the APSD-capable AP (i.e., an AP for which dot11APSDOptionImplemented is true) shall attempt to transmit at least one BU, using admitted TSPECs with the APSD and Schedule subfields both set to 1, that are destined for the STA. At each unscheduled SP for a STA, the AP shall attempt to transmit at least one BU, but no more than the value specified in the Max SP Length field in the QoS Capability element from delivery-enabled ACs, that are destined for the STA.

NOTE 4—The transmission of one or more fragments of a BU counts as the transmission of one BU for the purposes of the constraint indicated by the Max SP Length field.

The AP shall set to 1 the More Data bit of an individually addressed MPDU containing all or part of a BU, using a delivery-enabled AC and destined for that STA, to indicate that more BUs (not including the BU currently being transmitted) are buffered for the delivery-enabled ACs. The AP shall set to 1 the More Data bit of an individually addressed MPDU containing all or part of a BU, using a nondelivery-enabled AC and destined for that STA, to indicate that more BUs (not including the BU currently being transmitted) are buffered for the nondelivery-enabled ACs.

In all frames except for the final frame of the SP, the AP shall set the EOSP subfield, if present, to 0 to indicate the continuation of the SP. An AP may also set the More Data bit to 1 in a QoS +CF-Ack frame in response to a QoS Data frame to indicate that it has one or more pending BUs buffered for the target STA identified by the RA in the QoS +CF-Ack frame. If the QoS Data frame is using a delivery-enabled AC, the AP shall set the More Data bit in the QoS +CF-Ack frame to 1 to indicate more BUs (not including the BU currently being transmitted) are buffered for the delivery-enabled ACs. If the QoS Data frame is not using a delivery-enabled AC, the AP shall set the More Data bit in the QoS +CF-Ack frame to 1 to indicate more BUs (not including the BU currently being transmitted) are buffered for the ACs that are not delivery-enabled.

Unless indicated above, the AP shall set the More Data bit to 0.

The AP considers an APSD STA to be in awake state after it has sent a QoS +CF-Ack frame, with the EOSP subfield equal to 0, to the APSD STA. If necessary, the AP may generate an extra QoS Null frame, with the EOSP subfield set to 1. When the AP has transmitted an individually addressed frame to the STA with the EOSP subfield set to 1 during the SP except for retransmissions of that


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frame, the AP shall not transmit any more frames to that STA using this mechanism until the next SP.

The AP shall set the EOSP subfield to 1 to indicate the end of the SP in APSD.

NOTE 5—Management frames do not have an EOSP subfield and so the end of the SP cannot be indicated in a Management frame. If the SP is to end after a (#6156)Management frame, a QoS Null frame is used to indicate this.

The AP should not set the EOSP field to 1 in a frame that is not an individually addressed Data frame that requires immediate acknowledgment.

j) If the AP does not receive an acknowledgment to an individually addressed MPDU containing all or part of a BU sent to a STA in PS mode following receipt of a PS-Poll frame from that STA, it may retransmit the frame for at most the lesser of the maximum retry limit and dot11QAPMissingAckRetryLimit times before the next Beacon frame, but it shall retransmit that frame at least once before the next Beacon frame, time permitting and subject to its appropriate lifetime limit. If an acknowledgment to the retransmission is not received, it may wait until after the next Beacon frame to further retransmit that frame subject to its appropriate lifetime limit.

k) If the AP does not receive an acknowledgment in response to a non-A-MPDU frame that is an individually addressed Data frame that is sent with the EOSP subfield equal to 1, and that requires immediate acknowledgment, it shall retransmit that frame at least once within the same SP, subject to applicable retry or lifetime limits. If the AP does not receive a BlockAck frame in response to an A-MPDU that contains one or more individually addressed Data frames that are sent with the EOSP subfield equal to 1, and that require immediate acknowledgment, it shall retransmit at least one of those frames at least once within the same SP, subject to applicable retry or lifetime limits. The maximum number of retransmissions within the same SP is the lesser of the maximum retry limit and dot11QAPMissingAckRetryLimit.

If the AP does not receive an acknowledgment to an individually addressed Data or Management frame that requires immediate acknowledgment and that is not the initial attempt in this SP to send a frame with the EOSP subfield equal to 1, it may retransmit that frame in the next SP, subject to applicable retry or lifetime limits.

An AP that transmits an A-MPDU containing Data frames in which the EOSP subfield is equal to 1 and that receives a BlockAck frame that does not acknowledge all of those MPDUs should not transmit any missed Data frames within the current service period because the destination STA might now be asleep.

k) An AP may delete buffered BUs for implementation dependent reasons (subject to 11.2.3.10 (AP aging function)), including the use of an aging function and availability of buffers. The AP may base the aging function on the listen interval indicated by the STA in its (Re)Association Request frame or the WNM sleep interval specified by the non-AP STA in the WNM Sleep Mode Request frame. In addition, the S1G AP may base the aging function on the listen interval indicated by the AP in the (Re)Association Response frame.

NOTE 6—If for example the listen interval is 2, the AP might ensure it does not delete a buffered BU for age reasons until it has twice transmitted a beacon signaling the availability of the buffered BU, and has after this further allowed enough time (which is function of the channel occupancy and link quality) for the STA to request and obtain this buffered BU.(#219)

l) When an AP is informed that a STA has changed to the active mode, then the AP shall send buffered BUs (if any exist) to that STA without waiting for a PS-Poll frame. When an AP is informed that an APSD-capable STA is not using APSD, then the AP shall send buffered BUs (if any exist) to that STA according to the rules corresponding to the current PS mode of the STA.

### 11.2.3.7 Receive operation for STAs in PS mode

(#222)A STA in PS mode shall operate as follows to receive a BU from the AP:

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a) (#221)A STA with dot11NonTIMModeActivated equal to false shall transition to awake state(#6038) early enough to be able to receive the first Beacon frame scheduled for transmission at the time corresponding to the last TBTT or TSBTT for which the STA was awake plus the time interval indicated by the ListenInterval parameter of the MLME-ASSOCIATE.request or MLME REASSOCIATE.request primitive. (#221)A STA with dot11NonTIMModeActivated equal to true is not required to transition to awake state(#6038) to receive a Beacon frame and shall transmit at least one PS-Poll or trigger frame that is individually addressed to the associated AP every listen interval starting from the last known transition of the S1G STA in non-TIM mode in doze state unless it follows the TWT or NDP Paging procedure.

NOTE 1—The STA might wake for a TBTT or TSBTT that is earlier than this deadline. In that case the previous requirement is reset based on a new "last TBTT or TSBTT".

b) When the STA detects that the bit corresponding to its AID is 1 in the TIM, the STA shall issue a PS-Poll frame, or a trigger frame if the STA is using U-APSD and all ACs are delivery-enabled, to retrieve the buffered BU. The PS-Poll or trigger frame shall be transmitted after a random delay uniformly distributed between zero and aCWmin slots following a DIFS.

NOTE 2—The BU might be delivered in multiple Data or Management frames.(#3192)

c) The STA shall remain in the awake state until it receives the BU in response to its poll or it receives another Beacon frame whose TIM indicates that the AP does not have any BUs buffered for this STA. If the bit corresponding to the STA's AID is 1 in the subsequent TIM, the STA shall issue another PS-Poll frame to retrieve the buffered BU. When a STA that is using U-APSD and has all ACs delivery-enabled detects that the bit corresponding to its AID is 1 in the TIM, the STA shall issue a trigger frame or a PS-Poll frame to retrieve the buffered BU.

d) If the More Data subfield in the MPDU(s) containing the BU indicates that more traffic for that STA is buffered, the STA, at its convenience, shall poll until no more BUs are buffered for that STA.

e) When dot11FMSActivated is false and ReceiveDTIMBeacons(#4221) is true, the STA shall transition to awake state(#6038) early enough to be able to receive either every non-STBC DTIM beacon(#7217) or every STBC DTIM beacon(#7217) sent by the AP of the BSS. (M165)The STA shall remain in the awake state to receive the group addressed MPDUs transmitted by the AP as described in 11.2.3.1 (General) and 11.2.3.4 (TIM types) when:

— the STA is associated with either an AP that has not set to 1 the Multiple BSSID field of the Extended Capabilities element it transmits or corresponds to the transmitted BSSID in a multiple BSSID set, and the Traffic Indicator field in the TIM element in the DTIM beacon is equal to 1, or (M165)

— the STA is associated with an AP that corresponds to a nontransmitted BSSID in a multiple BSSID set, and the field corresponding to the (#8132)BSSID index (i.e., a bit position between 1 and $2^n - 1$ of the Partial Virtual Bitmap field matching the BSSID index of a nontransmitted BSSID) in the TIM element is equal to 1 in the DTIM beacon of that nontransmitted BSSID.(M165)

When dot11FMSActivated is true and ReceiveDTIMBeacons(#4221) is true and the STA has been granted by the AP an alternate delivery interval for a multicast stream, the STA shall transition to awake state(#6038) before the (#8164)DTIM beacon having the Current Count field of the FMS Counter field set to 0 for that particular FMS stream.

A STA that stays awake to receive group addressed BUs shall elect to receive all group addressed non-STBC transmissions or all group addressed STBC transmissions and remain awake until the More Data subfield of the appropriate type (non-STBC or STBC) of group addressed BUs indicates there are no further buffered group addressed BUs of that type, or until a TIM is received indicating there are no more buffered group addressed BUs of that type, or until an FMS Descriptor element is received indicating that there are no further buffered group addressed BUs for which the STA has previously received an FMS Response element in a frame that has a value in Address 1 that matches its MAC address or that has an Address 1 value that is a group address corresponding to a group of which it is a member and that was transmitted by the AP with which it is associated and which had


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an Element Status value in the FMS Status subelement of "Accept". If a STA receives a QoS +CF-Ack frame from its AP with the More Data bit equal to 1, then the STA shall operate (11ax)as if it received a TIM with its AID bit equal to 1. (11ax)If a STA has set the More Data Ack subfield in the QoS Info field to 1, then if it receives an Ack frame from its AP with the More Data bit equal to 1, the STA shall operate as if it received a TIM with its AID bit equal to 1. If an HE STA has set the More Data Ack subfield in the QoS Info field to 1, then if it receives a BlockAck or Multi-STA BlockAck frame from its AP with the More Data bit equal to 1, the STA shall operate as if it received a TIM with its AID bit equal to 1. For example, a STA that is using the PS-Poll delivery method shall issue a PS-Poll frame to retrieve a buffered BU. See also 10.3.6 (Group addressed MPDU transfer procedure).

#### 11.2.3.8 Receive operation using APSD

A STA using APSD shall operate as follows to receive a BU from the AP:

a) If a scheduled SP has been set up, the STA transitions from doze to awake state(#6038) at its scheduled start time. (The STA shall transition to awake state(#6038) early enough to receive transmissions at the scheduled SP.)

b) If the STA is initiating an unscheduled SP, the STA wakes up and transmits a trigger frame to the AP. When one or more ACs are not delivery-enabled, the STA may retrieve BUs using those ACs by sending PS-Poll frames to the AP.

c) The STA shall remain awake until it receives a QoS Data frame or QoS Null frame addressed to it, with the EOSP subfield equal to 1.

d) The STA may send additional PS-Poll frames if the More Data subfield is 1 in a downlink individually addressed MPDU containing all or part of a BU that does not use a delivery-enabled AC. The STA may send additional trigger frames if the More Data subfield is 1 in a downlink individually addressed MPDU containing all or part of a BU that uses a delivery-enabled AC.

For receive operation using the U-APSD coexistence mechanism, see additional procedures in 11.2.3.5.2 (U-APSD coexistence).

#### 11.2.3.9 STAs operating in the active mode

A STA operating in this mode shall have its receiver activated continuously, (11ax)unless the STA is allowed to be temporarily unavailable through the opportunistic power save mechanism defined in 26.14.3 (Opportunistic power save) or through the intra-PPDU power save mechanism defined in 26.14.1 (Intra-PPDU power save for non-AP HE STAs) or 26.8.4.4 (TWT Information frame exchange for flexible wake time); such STAs do not need to interpret the TIM elements in Beacon frames.

#### 11.2.3.10 AP aging function

Any AP aging function shall not cause the buffered BU to be discarded after any period that is shorter than that indicated by the STA for which the BUs are buffered, in the Listen Interval field of its (Re)Association Request frame. The exact specification of the aging function is beyond the scope of this standard.

NOTE—This aging function is independent of (i.e., in addition to) other causes of MSDU discard within the MAC, such as due to the operation of a per-TS MSDU lifetime, or related to dot11QAPEDCATableMSDULifetime.(#3263)

#### 11.2.3.11 TDLS peer power save mode

(#3460)TDLS peer power save mode (TDLS peer PSM) is a power save mechanism that can be used between TDLS peer STAs, and which is based on a periodic wakeup schedule. (#4325)A station that signals support for this capability is capable of acting in both the TDLS peer PSM initiator and the TDLS peer PSM responder role.

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(#111)In order to enter TDLS peer PSM (TDLS peer PSM initiator), a STA shall send a TDLS Peer PSM Request frame to the TDLS peer STA (TDLS peer PSM responder), including a proposed periodic wakeup schedule. A TDLS Peer PSM Request frame shall not be transmitted to a STA that did not indicate support for TDLS peer PSM. When the TDLS peer PSM responder accepts the proposed wakeup schedule, it shall respond with a TDLS Peer PSM Response frame indicating status code SUCCESS. Otherwise, the TDLS peer PSM responder shall respond with a TDLS Peer PSM Response frame indicating the appropriate status code for rejecting the schedule. An alternative schedule shall be included in the TDLS Peer PSM Response frame when the status code is equal to TDLS_REJECTED_ALTERNATIVE_PROVIDED. The alternative schedule may be used by the TDLS peer PSM initiator to generate a new TDLS Peer PSM Request frame. After successfully transmitting or receiving a TDLS Peer PSM Response frame indicating status code SUCCESS, the TDLS peer PSM initiator and TDLS peer PSM responder have established a periodic wakeup schedule between them. The wakeup schedule remains valid until one of the following occurs:

— The TDLS direct link is torn down;
— The STAs explicitly update the existing wakeup schedule; or
— No MPDUs containing data have been exchanged for Idle Count consecutive Awake Windows.

A STA transmitting a TDLS Peer PSM Request frame shall remain in the awake state until it received the corresponding TDLS Peer PSM Response frame. A TDLS Peer PSM Request frame may be transmitted via the AP path or via the direct path (which is up to the implementer to decide). A TDLS Peer PSM Response frame shall be transmitted over the direct path.

The timing of the periodic schedule of the TDLS Peer PSM awake windows(#3110)is based on the Offset field, the Interval field, the Awake Window Slots field, and the Maximum Awake Window Duration field of the Wakeup Schedule element that is contained in the TDLS Peer PSM Request frame that established TDLS peer PSM operation on the link.

(#3502)Awake windows begin at TSF values that satisfy Equation (11-1) and that are after the TDLS Peer PSM Request/Response frame exchange has completed, where Interval and Offset are the fields of the Wakeup Schedule element.

$$\text{TSF mod Interval} = \text{Offset}(\#3502) \qquad (11\text{-}1)$$

NOTE —The awake window timings might not be related to the beacon timings (TBTTs).(#3502)

Awake windows(#3110) end when the (#3109)awake window slot counter reaches 0 or when the maximum awake window duration(#3110) has been reached, whichever comes first.

The (#3109)awake window slot counter counts down backoff slots that are determined using AIFS[AC_BE] in the same manner that normal backoff slots are determined according to 10.23.2.4 (Obtaining an EDCA TXOP).

The initial value of the (#3109)awake window slot counter at the start of the awake window(#3110) shall be equal to the value in the Awake Window Slots field of the Wakeup Schedule element that is contained in the TDLS Peer PSM Request frame that established TDLS peer PSM operation on the link.

The (#3109)awake window slot counter begins counting at the beginning of the awake window(#3110) and stops counting when it reaches 0.

A value of 0 in the Maximum Awake Window Duration field of the Wakeup Schedule element that is contained in the TDLS Peer PSM Request frame that established TDLS peer PSM operation on the link means that the end of the awake window(#3110) duration is determined only by the (#3109)awake window slot counter.


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A value of 0 in the Awake Window Slots field of the Wakeup Schedule element that is contained in the TDLS Peer PSM Request frame that established TDLS peer PSM operation on the link means that the duration of the awake window(#3110) is determined only by the maximum awake window(#3110) duration.

The Maximum Awake Window Duration field and the Awake Window Slots field shall not both be set to 0 in a TDLS Peer PSM Request frame.

The Awake Window Slots field in a TDLS Peer PSM Request frame should be set to a value that is larger than CWmin[AC_BE].

A TDLS peer PSM service period is a period of time during which one or more individually addressed frames are transmitted between two TDLS peer STAs when at least one STA employs TDLS peer PSM. A TDLS peer PSM service period may be initiated during an awake window(#3110). A TDLS peer STA in power save mode may enter a doze state when it has successfully transmitted to and received from the corresponding TDLS peer STA in power save mode a QoS frame with the EOSP subfield equal to 1, ending the TDLS peer PSM service period. A TDLS peer STA in power save mode may enter a doze state when it has received from the corresponding TDLS peer STA in active mode a QoS frame with the EOSP subfield equal to 1.

Either STA may update an existing schedule by initiating (#4173)a TDLS peer PSM Request/Response frame exchange. If the TDLS Peer PSM Response frame indicates status code SUCCESS, a new wakeup schedule is established for the TDLS direct link. Otherwise, the existing schedule still applies. The new schedule takes effect after the termination of the current TDLS peer PSM service period.

After the successful PSM setup, a STA informs its TDLS peer STA that it will enter power save mode per (#2152)TDLS direct link by setting the Power Management subfield to 1 in an MPDU requiring immediate acknowledgment. The STA enters power save mode after successful transmission of the MPDU. The power save status on one (#2152)TDLS direct link is independent of the power save status on other links (direct or with the AP) the STA may have.

If a TDLS peer STA enters power save mode when a wakeup schedule is active, it shall be awake at the beginning of each scheduled periodic awake window(#3110), and stay awake for the duration of the awake window(#3110) or until the end of a TDLS peer PSM service period. Otherwise, it may enter a doze state, depending on the current requirements to be awake, imposed by other links. A TDLS peer STA that did not enter power save mode shall remain in the awake state.

When both TDLS peer STAs set the More Data Ack subfield in their QoS Capability element to 1, then the More Data subfield inside an Ack frame set to 0 shall have the same function as the EOSP subfield inside a QoS frame set to 1. Transmission of an Ack frame with the More Data subfield set to 0 under these conditions is equivalent to a successful transmission of a QoS frame with the EOSP subfield set to 1.

When waking up at the beginning of an awake window(#3110), if a STA has no buffered BU to send to a TDLS Peer STA that had the More Data Ack subfield in its QoS Capability element equal to 1 during the TDLS setup exchange, the TDLS STA may send a QoS Null frame with the EOSP subfield of the QoS Control field set to 1, and the More Data subfield of the Frame Control field set to 0. If the TDLS peer STA that is the recipient of this QoS Null frame also has no buffered BU to deliver either, and it had the More Data Ack subfield in its QoS Capability element equal to 1 during the TDLS setup exchange, then the TDLS peer STA shall respond with an Ack frame that has the More Data subfield set to 0. The STA may discard the QoS Null frame if it has not been successfully transmitted at the end of the awake window(#3110). Before the successful transmission of the QoS Null frame, if a QoS Data or QoS Null frame, with an EOSP subfield equal to 1,(#343) is received from the TDLS peer STA the STA may cancel the pending transmission of the QoS Null frame after the transmission of an Ack frame with the More Data subfield set to 0.

To keep track of the connectivity over the (#2152)TDLS direct link and to maintain the wakeup schedule, a TDLS peer STA may start an acknowledged frame exchange sequence(#109) at least once per Idle Count

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consecutive awake windows(#3110), as a keepalive. For instance a QoS Null frame may be used as a keepalive frame. When a TDLS Peer PSM Response frame was successfully transmitted or received and no subsequent TDLS peer PSM service period has started for Idle Count consecutive wakeup periods, a TDLS peer STA shall delete the wakeup schedule for this link, which means that the related periodic wakeup no longer occurs (i.e., the TDLS peer STA no longer has to transition to awake state(#6038) during this period) and that a wakeup schedule no longer exists for this link. When traffic arrives at a TDLS peer STA in TDLS peer PSM mode for a link with no existing wakeup schedule, the STA shall send a TDLS Peer PSM Request frame through the AP path to the TDLS peer STA to activate a new wakeup schedule. When both TDLS peer STAs enter active mode while a wakeup schedule is active, no more TDLS peer PSM service periods will occur, causing the wakeup schedule to be deleted.

If a TDLS peer STA does not receive an acknowledgment to an individually addressed QoS frame sent with the EOSP subfield equal to 1 that terminates a TDLS peer PSM service period, it shall retransmit that frame at least once within the same service period, subject to the applicable retry or lifetime limit. The maximum number of retransmissions within the same service period is the lesser of the maximum retry limit and dot11TDLSPeerSTAMissingAckRetryLimit. If an acknowledgment to the retransmission of this last frame in the same service period is not received, the TDLS peer STA may wait until the next awake window(#3110) to further retransmit that frame, subject to its applicable retry or lifetime limit. When the TDLS peer STA has transmitted an individually addressed frame that terminates a TDLS peer PSM service period then, except for retransmissions of that frame, the TDLS peer STA shall not transmit any more frames to the TDLS peer STA until the next awake window(#3110).

A TDLS peer STA that has an active wakeup schedule shall not decrement a backoff count outside the awake windows(#3110), if that backoff precedes a frame that is destined for transmission on the related TDLS direct link.

At the start of an awake window(#3110), the backoff procedure shall be invoked at an EDCAF if there is a frame available for transmission at that EDCAF, and the backoff counter for that EDCAF has been 0 for at least one backoff slot.

Outside of its awake windows(#3110), and during awake windows(#3110) when on the base channel, a TDLS peer STA can engage in communications with the AP.

#### 11.2.3.12 TDLS peer U-APSD (TPU)

##### 11.2.3.12.1 General

(#3460)A STA supports the TPU buffer STA function if dot11TDLSPeerUAPSDBufferSTAActivated is true. dot11TDLSPeerUAPSDBufferSTAActivated is false in a non-QoS STA. A STA supporting this function shall indicate this by setting the TPU Buffer STA Support subfield in the Extended Capabilities element included in the TDLS Setup Request frame or TDLS Setup Response frame to 1. Support for the TPU buffer STA function means that the STA has the capability to buffer BUs destined to the TPU sleep STA, and to deliver them during unscheduled service periods.

To operate as the TPU sleep STA in TPU, a STA shall configure its TPU capable TDLS peer STA by setting one or more U-APSD Flag subfields inside the QoS Info subfield of the QoS Capability element carried in a TDLS Setup Response frame to 1, or by setting one or more U-APSD Flag subfields inside the QoS Info subfield of the EDCA Parameter Set element carried in a TDLS Setup Confirm frame to 1.

A STA that configured TPU at a TDLS peer STA enters power save mode on a TDLS direct link after the successful transmission to the TDLS peer STA over the (#2152)TDLS direct link of an acknowledged MPDU with the Power Management subfield equal to 1. The STA that transmitted the frame with the Power Management subfield equal to 1 is then referred to as a *TPU sleep STA*. The STA that received the frame with the Power Management subfield equal to 1 is referred to as a *TPU buffer STA*. A TPU sleep STA may be a TPU


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buffer STA at the same time and on the same link, by sending a frame to the TDLS peer STA with the Power Management subfield of the Frame Control field set to 1 (this transmission (M118)is preceded by the transmission of a Peer Traffic Indication frame and the subsequent receipt of a trigger frame that starts a service period). The power save status on one (#2152)TDLS direct link is independent of the power save status on other links (direct or with the AP) the STA may have.

The procedure to trigger and terminate an unscheduled SP between TPU buffer STA and a TPU sleep STA are described in 11.2.3.5 (Power management with APSD) and 11.2.3.6 (AP operation), where the TPU buffer STA shall take the role of the AP and the TPU sleep STA shall take the role of the non-AP STA using U-APSD, except that a frame with the EOSP subfield equal to 1 shall not act as a trigger frame.

#### 11.2.3.12.2 TPU at the TPU buffer STA

BUs at a TPU buffer STA destined for a TPU sleep STA shall be temporarily buffered at the TPU buffer STA. The algorithm to manage this buffering is beyond the scope of this standard, except that the TPU buffer STA shall preserve the order of buffered BUs for a given STA on a given TID.(#4297)

(#7220)A TPU buffer STA shall transmit an individually addressed TDLS Peer Traffic Indication frame to a TPU sleep STA, through the AP, if all of the following conditions are met:

— A BU destined for a TPU sleep STA was placed into a buffer at the TPU buffer STA;
— The buffer into which the BU was placed contained no other frames with the same RA; and
— One or more periods of dot11TDLSPeerUAPSDIndicationWindow beacon intervals have expired after the last service period.

(#7220)Otherwise it shall not transmit this frame.

The TDLS Peer Traffic Indication frame shall be transmitted through the AP path.

The transmitted TDLS Peer Traffic Indication frame shall indicate the nonempty AC(s), by setting the corresponding AC Traffic Available subfield of the TDLS Peer Traffic Indication frame to 1.

A PTI Control element may be included in the TDLS Peer Traffic Indication frame, to allow the TPU sleep STA to not start a service period when the indicated traffic has already been received by the TPU sleep STA.

The TID field contained in the PTI Control element (if included) shall be set to the TID of the latest MPDU that has been transmitted over the TDLS direct link to the TPU sleep STA that is the destination of the TDLS Peer Traffic Indication frame that contains the PTI Control element.

The Sequence Control field contained in the PTI Control element (if included) shall be set to the sequence number of the latest MPDU that has been transmitted over the TDLS direct link to the TPU sleep STA that is the destination of the TDLS Peer Traffic Indication frame that contains the PTI Control element.

After transmitting a TDLS Peer Traffic Indication frame without a PTI Control element, the TPU buffer STA shall stay awake at least until the corresponding or a subsequent TDLS Peer Traffic Response frame is received.

After transmitting a TDLS Peer Traffic Indication frame without a PTI Control element, the TPU buffer STA shall stay awake at least until the MPDU following the MPDU indicated in the Sequence Control field of the PTI Control element is successfully transmitted.

When no corresponding TDLS Peer Traffic Response frame has been received within dot11TDLSResponseTimeout after sending a TDLS Peer Traffic Indication frame, the STA shall tear down the (#2152)TDLS direct link.

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#### 11.2.3.12.3 TPU at the TPU sleep STA

When a TPU sleep STA receives a TDLS Peer Traffic Indication frame without a PTI Control element, the TPU sleep STA shall initiate a service period with the TPU buffer STA during which it shall transmit at least a TDLS Peer Traffic Response frame. The TDLS Peer Traffic Response frame shall echo the values of the Dialog Token and Link Identifier fields from the corresponding TDLS Peer Traffic Indication frame. The TDLS Peer Traffic Response frame shall be sent via the direct path.

When a TPU sleep STA receives a TDLS Peer Traffic Indication frame with a PTI Control element, and the TPU sleep STA has not received from the TPU buffer STA the MPDU following the MPDU that is indicated in the TDLS Peer Traffic Indication frame, the TPU sleep STA shall initiate a service period with the TPU buffer STA to retrieve the buffered traffic for the AC(s) for which no unscheduled SP is currently active.

### 11.2.3.13 FMS power management

#### 11.2.3.13.1 General

Implementation of FMS is optional for a WNM STA. A STA with dot11FMSActivated equal to true shall support FMS and shall set to 1 the FMS field of the Extended Capabilities elements that it transmits.

#### 11.2.3.13.2 FMS general procedures

When dot11FMSActivated is true at the AP, the AP shall include the FMS Descriptor element in every Beacon frame. The FMS Descriptor indicates the FMS group addressed buffered BUs at the AP. If there are no buffered BUs for FMS streams accepted by the AP, the AP shall set the Length field in the FMS Descriptor element to 1. The AP shall include the FMS Descriptor element for a nontransmitted BSSID in the corresponding Nontransmitted BSSID Profile subelement carried in the Multiple BSSID element sent in a Beacon frame.

When dot11FMSActivated is true at the AP, the AP shall support from one to eight different FMS stream delivery intervals for any number of FMS streams. Corresponding to these eight delivery intervals are eight FMS counters. More than one FMSID may have the same delivery interval and therefore (M118)share the same FMS counter. An FMS counter corresponds to each unique delivery interval of one or more FMS streams.

Each FMS counter decrements once per DTIM beacon and when the FMS counter reaches 0, buffered group addressed BUs assigned to that particular interval are scheduled for delivery immediately following the next (#1000)DTIM beacon. After transmission of the buffered group addressed BUs, the AP shall reset the FMS counter to the delivery interval for the FMS streams associated with that FMS counter.

A non-AP STA that does not use FMS wakes every DTIM interval and follows group addressed BU reception rules as defined in 11.2.3.7 (Receive operation for STAs in PS mode).

(#546)A STA that supports FMS shall support a delivery interval of (#3090)1 DTIM interval for any stream.

#### 11.2.3.13.3 FMS Request procedures

A non-AP STA that supports FMS may request use of FMS by sending an FMS Request frame or Reassociation Request frame that includes one or more FMS Request elements to an AP that supports FMS. Each FMS Request element includes one or more FMS subelements. Each FMS subelement identifies an FMS stream, the requested delivery interval and the maximum delivery interval for that stream. The FMS delivery interval shall be an integer multiple of the DTIM period.


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Upon reception of an FMS Request frame or Reassociation Request frame, the AP shall transmit a corresponding single FMS Response frame or Reassociation Response frame that contains a corresponding FMS Response element for each FMS Request element in the same order received. Each FMS Response element shall contain an FMS Status subelement and zero or more other subelements drawn from Table 9-259 (Optional subelement IDs for FMS Response subelements) that corresponds to each FMS subelement in the FMS Request element, in the same order.

For each FMS subelement, the following rules apply:

If the AP accepts the FMS subelement and the requested delivery interval, the Element Status in the corresponding FMS Status subelement shall be set to "Accept" and the FMSID is assigned to a nonzero value. In addition:

- If the FMS stream identified in the FMS subelement matches a delivery interval already in use at the AP, the AP shall assign the FMS stream to use the (#3115)FMS counter ID assigned for that delivery interval.
- When an FMS stream is accepted by the AP, the Current Count value for that FMS stream is decremented by 1 for each DTIM beacon(#3309) in which the Current Count field appears.
- The AP may reschedule transmission of the FMS stream identified by an FMSID to align the transmission time of the FMS stream to the transmission time of other FMS streams that the STA is already receiving at the same delivery interval. The AP has the following two options:
  - Notify the STAs using that FMS stream. The AP shall keep the nonzero Current Count value the same across two consecutive Beacon frames in which the Current Count field appears. The algorithm by which the AP chooses to align or offset the different FMS counters is unspecified.
  - Transmit an unsolicited FMS Response frame to the group address included in the original FMS Response frame for the stream with the updated Delivery Interval field when the Current Count field value reaches 0. Since the AP transmits this FMS Response frame as a group addressed frame, the frame will be scheduled for delivery at the appropriate DTIM interval when all non-AP STAs are awake to receive the frame.
- An AP may terminate the use of FMS and resume default (non-FMS) transmission rules for any FMS stream identified by FMSID for any reason. To terminate the FMS stream, the AP shall send an unsolicited FMS Response frame to the group address included in the original FMS Response frame with Delivery Interval set to 0 and the Element Status in the FMS Status subelement set to one of "Terminate, due to AP policy change", "Terminate, due to lack of resources of AP," and "Terminate, due to other FMS stream with higher priority".
- If the FMS subelement contained a nonzero delivery interval and the non-AP STA specified a maximum delivery interval as part of the FMS request, the AP shall not modify the delivery interval for the stream greater than the maximum delivery interval specified by the non-AP STA.
- An AP shall transmit MSDUs belonging to the same FMSID in the same order that they were received at the MAC Data SAP. MSDUs belonging to the different FMSIDs are transmitted by the AP at the appropriate DTIM (#8164)beacon in the order received at the MAC data SAP based on the interval configured for the FMS stream.

If the AP denies the FMS subelement for any reason, including requested delivery interval, maximum delivery interval and TCLAS, the Element Status in the corresponding FMS Status subelement shall be set to one of "Deny, due to request format error or ambiguous classifier", "Deny, due to lack of resources on AP", "Deny, due to requested classifier(s) matching 2 or more existing streams on different intervals," "Deny, by policy, requested stream or filter is not permitted to participate in the service", and "Deny, reason unspecified".

If the AP selects an alternate delivery interval or alternate maximum delivery interval from the value specified in the FMS Request frame or Reassociation Request frame(#238), the Element Status field in the corresponding FMS Status subelement shall be set to one of "Alternate proposed, due to existing stream with different delivery interval", "Alternate proposed, due to policy limits on AP", "Alternate proposed, because the

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AP changed the delivery interval", and "Alternate proposed, because the AP changed the maximum delivery interval" and the FMS subelement shall indicate the AP selected value(s).

To terminate the use of FMS for an FMS stream identified by FMSID, the non-AP STA shall transmit an FMS Request frame with an FMS Request element and FMS subelement with the FMSID matching the FMS stream and the delivery interval set to 0.

The AP shall respond to a malformed FMS Request frame or Reassociation Request frame with an FMS Response frame or Reassociation Response frame that denies all FMS Request elements by including an FMS status code(#3326) "Deny, due to request format error or ambiguous classifier" in the Element Status field in each FMS Status subelement in the FMS Response element.

#### 11.2.3.13.4 FMS Response procedures

Upon reception of an FMS Response element in a frame that has a value in Address 1 that matches its MAC address or that is a group address corresponding to a group of which it is a member and that was transmitted by the AP with which it is associated, a non-AP STA that supports FMS shall use the following procedures, based on the value of the Element Status value in the FMS Status subelement in the received FMS Response element.

- If the Element Status value in the FMS Status subelement is "Accept":
  - The AP has accepted the FMS subelement contained within the FMS Request element. If the FMS Request element specified a nonzero delivery interval, the AP will deliver the requested streams at the delivery interval as specified by the non-AP STA in the FMS Request element.
  - After receiving the FMS Response element, the non-AP STA shall be awake for the next DTIM beacon so that the non-AP STA can synchronize with the FMS Current Count for the requested FMS stream. Once synchronized with the FMS Current Count, the non-AP STA need not transition to awake state(#6038) at every DTIM interval to receive group addressed BUs.
- If the Element Status value in the FMS Status subelement is one of "Deny, due to request format error or ambiguous classifier", "Deny, due to lack of resources on AP", "Deny, due to requested classifier(s) matching 2 or more existing streams on different intervals", "Deny, by policy, requested stream or filter is not permitted to participate in the service", and "Deny, reason unspecified":
  - The AP does not deliver the requested streams at the delivery interval as specified by the non-AP STA in the FMS Request element. The AP delivers the requested stream at every DTIM interval.
- If the Element Status value in the FMS Status subelement is one of "Alternate proposed, due to existing stream with different delivery interval", "Alternate proposed, due to policy limits on AP", "Alternate proposed, because the AP changed the delivery interval", and "Alternate proposed, because the AP changed the maximum delivery interval":
  - The AP does not deliver the requested streams at the delivery interval and maximum delivery interval as specified by the non-AP STA in the FMS Request element. The FMS Status subelement specifies a delivery interval and a maximum delivery interval that the AP is willing to accept for the specified streams if the non-AP STA sends another FMS Request frame or Reassociation Request frame(#238) with that delivery interval and maximum delivery interval specified.
  - The non-AP STA may submit a new FMS Request frame or Reassociation Request frame(#238) that includes the delivery interval value received from the AP. If the AP accepts this new FMS Request frame or Reassociation Request frame(#238), it shall respond as described in 11.2.3.13.2 (FMS general procedures).
- If the Element Status value in the FMS Status subelement is "Alternate proposed, because the AP is unable to provide requested TCLAS-based classifiers":


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- The AP does not deliver the requested streams at the delivery interval as specified by the non-AP STA in the FMS Request element. The TCLAS element(s) or TCLAS Processing element in the TCLAS Status subelement contains one or more fields or subfields whose values have been modified by the AP. The AP may include fewer TCLAS elements in the FMS Response element than were present in the request; when the AP's response includes a single TCLAS element, it does not include a TCLAS Processing element. If the AP changes a TCLAS element's Classifier Type field in the FMS Response element but is unable to suggest a value for the Classifier Mask field, it shall set that field to 0. If the AP changes a TCLAS element's Classifier Type field or Classifier Mask field in the FMS Response element but is unable to suggest values for one or more Classifier Parameter subfields, it shall set those fields to 0.
- A non-AP STA receiving a modified TCLAS element having a Classifier Mask field equal to 0 or Classifier Parameter subfields equal to 0 shall interpret these values as meaning that no suggested value has been provided by the AP.

— If the Element Status value in the FMS Status subelement is one of "Terminate, due to AP policy change", "Terminate, due to lack of resources of AP", and "Terminate, due to other FMS stream with higher priority":

- The AP terminates(M118) the use of FMS transmission rules for any FMS stream identified by FMSID. If the AP terminates the usage of FMS for a particular stream, the stream is transmitted at DTIM interval.
- The non-AP STA shall transition to awake state(#6038) at every DTIM interval to receive group addressed BUs after receiving the FMS Response element.

#### 11.2.3.14 TIM Broadcast

Implementation of TIM Broadcast is optional for a WNM STA. A STA that implements TIM Broadcast has dot11TIMBroadcastImplemented equal to true. When dot11TIMBroadcastImplemented is true, dot11WirelessManagementImplemented shall be true. A STA with dot11TIMBroadcastActivated equal to true shall support TIM Broadcast and shall set to 1 the TIM Broadcast field of the Extended Capabilities elements that it transmits. This subclause describes TIM broadcast procedures for STAs with dot11TIMBroadcastActivated equal to true.

TIM frames have shorter duration than Beacon frames and are potentially transmitted at a higher data rate. TIM Broadcast allows a non-AP STA to receive a TIM element without receiving a Beacon frame that may reduce the required wake time in a power save mode. The shorter receive time reduces the power consumption for non-AP STAs in a power save mode. The shorter receive time may reduce the power consumption for stations in a standby mode.

A non-AP STA may activate the TIM broadcast service by including a TIM Broadcast Request element in a TIM Broadcast Request frame, Association Request frame or Reassociation Request frame that is transmitted to the AP, which specifies the requested interval between TIM frame transmissions (the TIM broadcast interval). On receipt of a properly formatted TIM Broadcast Request element in a TIM Broadcast Request frame, Association Request frame or Reassociation Request frame, the AP shall include a TIM Broadcast Response element in the corresponding TIM Broadcast Response frame, Association Response frame or Reassociation Response frame, when dot11TIMBroadcastActivated is true. (11ax)A non-AP STA shall transmit a TIM Broadcast Request only if the associated AP has indicated support for TIM Broadcast by setting the TIM Broadcast field of the Extended Capabilities elements that it transmits to 1.

NOTE 1—An OPS AP that transmits TIM frames as described in 26.14.3 (Opportunistic power save) is expected to encode the TIM bits such that an associated non-AP STA that does not support OPS operation can use the information received in the TIM frame as it would do when receiving a TIM frame transmitted following the TIM Broadcast procedure.(11ax)

(11ax)When the requested TIM broadcast interval is acceptable, the AP shall include a TIM Broadcast Response element specifying the requested TIM broadcast interval and a Status field indicating "Accept" when

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noTSF timestamp is present in the TIM frames, or "Accept, timestamp present in TIM frames" when a TSF timestamp is present in the TIM frames. When the AP overrides the requested TIM broadcast interval, it shall include a TIM Broadcast Response element specifying a different TIM broadcast interval and a Status field indicating "Overridden" when no TSF timestamp is present in the TIM frames, or "Overridden, timestamp present in TIM frames" when a TSF timestamp is present in the TIM frames, and include in the TIM Broadcast Response element the smallest TIM broadcast interval that is currently active. Otherwise, the AP shall include a TIM Broadcast Response element with a Status field indicating "Denied." The Status field in a TIM Broadcast Response element that is included in an Association Response frame or Reassociation Response frame has implications only for the TIM Broadcast negotiation.

NOTE 1—The STA might ignore the TIM Broadcast Interval field in the TIM Broadcast Response element if the Status field indicates "Accept" or "Accept, timestamp present in TIM frames", because the TIM broadcast interval is the requested one.

If the AP accepted at least one TIM Broadcast Request with a nonzero TIM Broadcast Interval field, and at least one non-AP STA in PS mode still associated with the AP received in its latest TIM Broadcast Response a status field value equal to 0 (Accepted) in response to a TIM Broadcast Request with a nonzero TIM Broadcast Interval field, the AP shall transmit one or two TIM frames per TIM Broadcast Interval. The AP shall not transmit TIM frames otherwise. When TIM broadcast intervals overlap, a transmitted TIM frame serves both intervals and does not need to be duplicated.

If the AP transmits two TIM frames per TIM Broadcast Interval, the AP shall transmit the high data rate TIM frame first, followed by the low data rate TIM frame.

The AP shall transmit the low data rate TIM frame at the same data rate or MCS as the Beacon frame. The AP shall transmit the high data rate TIM frame at a higher data rate or using an MCS that corresponds to a higher data rate. For Clause 18 (Extended Rate PHY (ERP) specification) and Clause 19 (High Throughput (HT) PHY specification(#2297)) PHYs, if the Beacon frame is transmitted using ERP-DSSS/CCK, the AP shall transmit the high data rate TIM frame and shall transmit it using ERP-OFDM. Otherwise, transmitting the high data rate TIM frame is optional. If the high data rate TIM is not transmitted, the AP shall set the High Rate TIM Rate field to 0 in the TIM Broadcast Response element.

The TIM Broadcast Interval field from the latest received TIM Broadcast Response element (N_TBI) together with dot11BeaconPeriod define a series of target TIM transmission times (TTTTs) N_TBI × dot11BeaconPeriod TUs apart. Time 0 is a TTTT. A non-AP STA may use the information in the High Rate TIM Rate and Low Rate TIM Rate fields to determine which of the two TIM frames they will be receiving. The first TIM frame per TIM broadcast interval is scheduled to be transmitted at the TTTT plus the indicated TIM broadcast offset. The offset may have a negative value that allows the TIM frame(s) to be transmitted before the TBTT. The value of the offset shall not be changed as long as an associated non-AP STA is using the TIM broadcast service.

The AP should accept new TIM broadcast interval requests if this implies transmitting TIM frames more frequently. For instance, if the AP currently transmits TIM frames every fourth beacon period and it receives a new request for every 3 beacon periods, then the AP should accept the new request and transmit TIM frames both every 3 and every 4 beacon periods. The AP may override incongruent requests once available resources (such as counters) have been depleted. An incongruent request is a request that contains an interval that is not an integer divide or a multiple of a currently active TIM Broadcast interval.

The AP shall accept a TIM broadcast interval of 1.

NOTE 2—The DTIM Period subfield in a TIM element in a TIM frame indicates the period for DTIM beacons(#3309) and is unrelated to any TIM Broadcast Interval(s).


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The AP shall increase the value (modulo 256) of the Check Beacon field in the next transmitted TIM frame(s) when a critical update occurs to any of the elements inside the Beacon or DMG Beacon frame.(#4324) The following events shall classify as a critical update:

a) Inclusion of a Channel Switch Announcement element
b) Inclusion of an Extended Channel Switch Announcement element
c) Modification of the EDCA parameters element
d) Inclusion of a Quiet element
e) Modification of the DSSS Parameter Set
f) Modification of the HT Operation element
g) Inclusion of a Wide Bandwidth Channel Switch element
h) Inclusion of a Channel Switch Wrapper element
i) Inclusion of an Operating Mode Notification element
j) Inclusion of a Quiet Channel element
k) Modification of the VHT Operation element
l) Modification of the HE Operation element(11ax)
m) Insertion of a Broadcast TWT element(11ax)
n) Inclusion of the BSS Color Change Announcement element(11ax)
o) Modification of the MU EDCA Parameter Set element(11ax)
p) Modification of the Spatial Reuse Parameter Set element(11ax)
q) Modification of the UORA Parameter Set element(11ax)
r) Insertion of an Index Adjustment Factor field in a Multiple BSSID Configuration element(#3018)

NOTE 4—Modification of an element means that at least (#1031)one field in the element is changed, although not all fields in an element can be changed (e.g., the fields that advertise the basic MCS sets in HT Operation, VHT Operation, and HE Operation elements do not change). Inclusion of an element means that the element is included in a Beacon frame. The insertion of an element means that the element was not present in the previous Beacon frame, is present in the current Beacon frame, and will be carried in the next Beacon frame.(11ax)

An AP may classify other changes in the Beacon frame as critical updates.

The non-AP STA shall attempt to receive the next Beacon frame when it receives a Check Beacon field that contains a value that is different from the previously received Check Beacon field.

The Address 1 field of the TIM frame shall be set to the broadcast address.

In a multiple BSSID set, the APs that do not correspond to the transmitted BSSID shall not transmit a TIM frame.

#### 11.2.3.15 WNM sleep mode

#### 11.2.3.15.1 WNM sleep mode capability

Implementation of the WNM sleep mode capability is optional for a WNM STA. A STA that implements WNM sleep mode has dot11WNMSleepModeImplemented equal to true. When dot11WNMSleepModeImplemented is true, dot11WirelessManagementImplemented shall be true. A STA where dot11WNMSleepModeActivated is true is defined as a STA that supports WNM sleep mode. A STA supporting WNM sleep mode shall set the WNM Sleep Mode field of the Extended Capabilities element to 1. When dot11WNMSleepModeActivated is true, dot11TFSActivated should(#7025) be true.

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A STA in which dot11WNMSleepModeActivated is true may send a WNM Sleep Mode Request or WNM Sleep Mode Response frame to a STA within the same infrastructure BSS whose last received Extended Capabilities element contained a value of 1 for the WNM Sleep Mode field in the Extended Capabilities field. WNM sleep mode is a service that may be provided by an AP to its associated STAs. The WNM sleep mode is not supported in an IBSS.

To prevent key reinstallation attacks, a non-AP STA in which dot11WNMSleepModeActivated is true shall maintain a copy of the most recent GTK, most recent IGTK and most recent BIGTK installed when exiting WNM sleep mode and shall not install a GTK, IGTK or BIGTK when the key to be set upon exiting WNM sleep mode matches any of the(#1708) maintained keys (see 6.5.14 (SetKeys)).

WNM sleep mode enables an extended power save mode for non-AP STAs in which a non-AP STA need not listen for every DTIM beacon(#3309), and need not perform GTK/IGTK/BIGTK updates. A non-AP STA can sleep for extended periods as indicated by the WNM Sleep Interval field of the WNM Sleep Mode element, which is present in WNM Sleep Mode Request frames transmitted by the non-AP STA.

#### 11.2.3.15.2 WNM sleep mode non-AP STA operation

To use the WNM sleep mode service, the non-AP STA's SME shall issue an MLME-SLEEPMODE.request primitive to send a WNM Sleep Mode Request frame. The MLME-SLEEPMODE.request primitive shall include a valid SleepMode parameter with a WNM Sleep Mode element. The Action Type field in the WNM Sleep Mode element shall be set to "Enter WNM sleep mode" and the WNM Sleep Interval field shall be included. The WNM Sleep Interval field shall be less than the BSS max idle period (see 11.21.13 (BSS max idle period management)). The MLME-SLEEPMODE.request primitive (#7025)may also include a valid TFSRequest parameter as defined in the TFS Request element that the AP shall use as triggers to set the STA's TIM bit.

When a traffic filter for group addressed frames is enabled at the AP, the STA may request a notification frame (see 11.21.12.2 (TFS non-AP STA operation)) be sent when requesting the establishment of the traffic filtering agreement.

On receiving a WNM Sleep Mode Response frame with Action Type field in the WNM Sleep Mode element set to "Exit WNM sleep mode", if dot11RSNAOperatingChannelValidationActivated is true and the AP's RSNE indicated OCVC(#3505), the STA shall validate the OCI information by ensuring that all the following are true:

— OCI element is present
— Channel information in the OCI matches current operating channel parameters (see 12.2.10 (Requirements for Operating Channel Validation))

Otherwise, the STA shall discard the frame.

The receipt of an MLME-SLEEPMODE.confirm primitive with a valid SleepMode parameter indicates to the STA's SME that the AP has processed the corresponding WNM Sleep Mode Request frame. The content of the WNM sleep mode parameter in the WNM Sleep Mode Response frame provides the status of WNM Sleep Mode elements processed by the AP. The non-AP STA shall delete the GTKSA if the response indicates success. If RSN is used with management frame protection, the non-AP STA shall delete the IGTKSA if the response indicates success. If RSN is used with (#8133)beacon protection, the non-AP STA shall delete the BIGTKSA if the response indicates success.

While in WNM sleep mode, the non-AP STA need not transition to awake state(#6038) every DTIM interval for group addressed frames.


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The STA wakes up at intervals not longer than the value indicated by the WNM Sleep Interval field to check whether the corresponding TIM bit is set or group addressed traffic is pending. The non-AP STA does not participate in GTK/IGTK/BIGTK updates.

To exit WNM sleep mode, the non-AP STA's SME shall issue an MLME-SLEEPMODE.request primitive to send a WNM Sleep Mode Request frame with an Action Type field in the WNM Sleep Mode element set to "Exit WNM sleep mode". If dot11RSNAOperatingChannelValidationActivated is true and the AP's RSNE indicated OCVC(#3505), the WNM Sleep Mode Request frame shall include an OCI element.

If a STA receives an unsolicited WNM Sleep Mode Response frame with the WNM Sleep Mode Response status value (see Table 9-266 (WNM Sleep Mode Response Status definition)) equal to 1, and the frame is not discarded due to OCI validation, the STA exits WNM sleep mode. If the STA does not receive a WNM Sleep Mode Response frame after sending a WNM Sleep Mode Request frame, it shall issue an MLME-DEAUTHENTICATE.request primitive to deauthenticate from the current AP.

#### 11.2.3.15.3 WNM sleep mode AP operation

On receiving a WNM Sleep Mode Request frame with Action Type field in the WNM Sleep Mode element set to "Exit WNM sleep mode", if dot11RSNAOperatingChannelValidationActivated is true and the non-AP STA's RSNE indicated OCVC(#3505), the AP shall validate the OCI information by ensuring that all the following are true:

— OCI element is present

— Channel information in the OCI fields matches current operating channel parameters (see 12.2.10 (Requirements for Operating Channel Validation))

Otherwise, the AP shall discard the frame.

When an AP's SME receives an MLME-SLEEPMODE.indication primitive with a valid SleepMode parameter and an Action Type in the WNM Sleep Mode element of "Enter WNM sleep mode" it shall issue an MLME-SLEEPMODE.response primitive with SleepMode parameters indicating the status of the request. The Action Type field of the WNM Sleep Mode element in the WNM Sleep Mode Response frame shall be set to "Enter WNM sleep mode".

When WNM sleep mode is enabled for an associated STA, the AP shall stop sending all individually addressed MPDUs to the non-AP STA. The AP may disassociate or deauthenticate the STA at any time for any reason while the non-AP STA is in WNM sleep mode. An AP shall perform the TFS AP operation, as specified in 11.21.12 (TFS procedures) for non-AP STAs for which it has received TFS Request elements. The AP shall set the TIM bit corresponding to the AID of the associated STA for which the AP has queued either a TFS Notify frame or matching frame. An AP shall not perform GTK/IGTK/BIGTK updates for the STAs in WNM sleep mode.

When an AP's SME receives an MLME-SLEEPMODE.indication primitive with a valid SleepMode parameter and an Action Type in the WNM Sleep Mode element of "Exit WNM sleep mode", if the frame is not discarded due to OCI validation, the AP shall disable WNM sleep mode service for the requesting STA, and the AP's SME shall issue an MLME-SLEEPMODE.response primitive with a SleepMode parameter indicating the status of the associated request. When all traffic filter sets established for a STA are deleted upon frame matches, the AP shall also disable the WNM sleep mode service and transmit to the STA an unsolicited WNM Sleep Mode Response frame with the WNM Sleep Mode Response status value (see Table 9-266 (WNM Sleep Mode Response Status definition)) set to 1. When an AP sends a WNM Sleep Mode Response frame with Action Type field in the WNM Sleep Mode element set to "Exit WNM sleep mode", if dot11RSNAOperatingChannelValidationActivated is true and the non-AP STA's RSNE indicated (#6090)OCVC, the WNM Sleep Mode Response frame shall include an OCI element.

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If RSN is used with management frame protection and a valid PTK is configured for the STA, the current GTK, IGTK, and BIGTK shall be included in the WNM Sleep Mode Response frame. If a GTK/IGTK/BIGTK update is in progress, the pending GTK, IGTK, and BIGTK shall be included in the WNM Sleep Mode Response frame.

(#1274)If RSN is used without management frame protection and a valid PTK is configured for the STA, the current GTK shall be sent to the STA using a group key handshake (see 12.7.7 (Group key handshake)) immediately following the WNM Sleep Mode Response frame. (#1274)If a GTK update is in progress, the pending GTK shall be sent to the STA using another group key handshake immediately after the current GTK has been sent.

#### 11.2.3.16 VHT TXOP power save

A VHT AP supports the operation of non-AP VHT STAs in TXOP power save mode in a BSS when dot11VHTTXOPPowerSaveOptionImplemented is true. Non-AP VHT STAs that are in active mode and have dot11VHTTXOPPowerSaveOptionImplemented equal to true operate in TXOP power save mode. A STA that has dot11VHTTXOPPowerSaveOptionImplemented equal to true shall set the TXOP PS field in the VHT Capabilities element to 1; otherwise, the STA shall set the field to 0. A VHT AP may allow non-AP VHT STAs in TXOP power save mode to enter the doze state during a TXOP, which the AP does by transmitting a VHT PPDU with the TXVECTOR parameter TXOP_PS_NOT_ALLOWED set to 0. The value of this parameter in the TXVECTOR of all VHT PPDUs transmitted by the VHT AP may be changed from 1 to 0 during the TXOP to enable TXOP power save mode for the remainder of the TXOP. The value of this parameter in the TXVECTOR of all VHT PPDUs transmitted by VHT AP shall not be changed from 0 to 1 during the TXOP. If dot11VHTTXOPPowerSaveOptionImplemented at VHT AP is false then the VHT AP shall set the TXOP_PS_NOT_ALLOWED to 1 in the TXVECTOR of the frames with FORMAT VHT.

If the AP allows non-AP VHT STAs to enter doze state during a TXOP, then a non-AP VHT STA that is in TXOP power save mode may enter the doze state until the end of that TXOP when one of the following conditions is met:

— On receipt of a VHT MU PPDU, the STA determines that it is not a member of the group indicated by the RXVECTOR parameter GROUP_ID.
— On receipt of an SU PPDU, the STA determines that the RXVECTOR parameter PARTIAL_AID is not equal to 0 nor does it match the STA's partial AID.
— The STA finds that the PARTIAL_AID in the RXVECTOR matches its partial AID but the RA in the MAC header of the corresponding frame that is received correctly does not match the MAC address of the STA.
— The STA receives a frame with an RXVECTOR parameter NUM_STS equal to 0 if it is a member of group indicated by RXVECTOR GROUP_ID.
— In a received VHT NDP Announcement frame, the STA finds that the RXVECTOR parameter PARTIAL_AID is 0 and the AID in the STA Info field is not its AID.
— The STA receives a QoS Data frame intended for it with the More Data subfield equal to 0 and No Ack ack policy or sends an acknowledgment if the ack policy is not No Ack.

The VHT AP shall include a nav-set sequence (e.g., RTS/CTS) (see G.4 (HT, VHT, S1G, and DMG sequences(11ay)) at the beginning of such a TXOP with the Duration/ID value set to the remainder of the TXOP duration. A VHT AP shall not transmit frames to a non-AP VHT STA that has been allowed to enter doze state according to the conditions above for the remainder of the TXOP.

NOTE 1—A VHT AP does not transmit VHT SU PPDUs in the current TXOP if the AP has already transmitted a VHT PPDU with the TXVECTOR parameter TXOP_PS_NOT_ALLOWED set to 0 in the same TXOP and does not want the STAs that are in awake state to enter the doze state.


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If a VHT AP truncates the TXOP in which it allowed STAs to enter doze state, then the VHT AP shall not transmit frames to the STAs that were allowed to enter the doze state until the NAV set at the start of the TXOP has expired.

Under all of the following conditions:

- An AP transmitted a PPDU;
- The PPDU contains individually addressed frame that contains all or part of an MSDU, A-MSDU or MMPDU;
- The frame is addressed to a non-AP VHT STA that is in TXOP power save mode;
- The frame's More Data subfield is 0;
- The transmitted PPDU's TXVECTOR parameter TXOP_PS_NOT_ALLOWED is 0;
- The AP did not receive an acknowledgment to this transmission;

then the AP shall retransmit that frame one or more times within the same TXOP, subject to applicable transmission restrictions. These restrictions include retry and lifetime limits, the TXOP limit and the rules on TXOP sharing (see 10.23.2.7 (Sharing an EDCA TXOP)). If an acknowledgment to the retransmission of this last frame in the same TXOP is not received, it may wait until the next TXOP to further retransmit that frame, subject to its applicable retry or lifetime limit.

NOTE 2—An AP that receives from a VHT STA in TXOP power save mode a BlockAck frame that is a response to an A-MPDU containing MPDUs with the More Data subfield equal to 0 cannot expect to receive a response to subsequent MPDUs retransmitted in the same TXOP because the VHT STA might be in the doze state.

A VHT STA that is in TXOP power save mode and has entered doze state shall continue to operate its NAV during doze state and shall transition into awake state on the expiration of the NAV.

NOTE 3—The STA can contend for access to the medium immediately on the expiration of the NAV.

### 11.2.3.17 AP power management

This subclause describes AP power management procedure for an S1G AP.

An AP with dot11APPMActivated equal to false or not present shall operate in the Active mode. An AP with dot11APPMActivated equal to true may operate in the following Power Management modes:

- Active
- Power save

An AP in active mode shall be in awake state and may receive frames at any time.

An AP with dot11APPMActivated equal to true in Power Save mode may be in any of the following two power states:

- Awake
- Doze

The AP with dot11APPMActivated equal to true may indicate that it is operating in Power Save mode by either:

- Setting the AP PM bit in the Frame Control field of the S1G Beacon frame to 1
- Including one or more RPS elements in the S1G Beacon frame that indicate AP PM RAWs (i.e., with the RAW Assignment Type equal to Simplex RAW and RAW Type Options equal to 0)

The AP shall operate in active mode during a beacon interval or short beacon interval if the AP PM subfield in the S1G Beacon frame transmitted at the TBTT or TSBTT is equal to 0. Similarly, the AP shall operate in

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active mode during one or more RAWs defined by an RPS element with the RAW Assignment type equal to generic RAW, sounding RAW, triggering frame RAW or simplex RAW with RAW Type Options equal to 1 or 2.

An AP that transmits an S1G Beacon frame with AP PM subfield equal to 1 may be in doze state at any time until the next TBTT or TSBTT, except that it shall be in awake state during any of the following intervals of time:

— Any RAW or PRAW intervals that are set up according to 10.23.5 (Restricted access window (RAW) operation), except for RAWs that are defined by any RPS element with RAW Assignment Type equal to simplex RAW and RAW Type Options equal to 0

— Any TWT SPs that are negotiated according to 10.46 (Target wake time (TWT))

An AP that transmits an S1G Beacon frame whose AP PM subfield value is 1 should include an RPS element in the S1G Beacon frame that includes an omni RAW during which all STAs are allowed to access (i.e., the RPS element contains a RAW Assignment subfield with RAW Type field equal to 2 and RAW Type Options subfield equal to 2). The omni RAW may be used for association of new STAs. The AP that does not include the RPS element with the omni RAW, shall be awake for an amount of time not less than *bi – mad* immediately following the S1G Beacon frame, where *bi* is the beacon interval if dot11ShortBeaconInterval is false and is the short beacon interval if dot11ShortBeaconInterval is true, and *mad* is the dot11MaxAwayDuration.

An AP shall not be in doze state for a duration of time that exceeds the value of the dot11MaxAwayDuration. The AP shall set dot11MaxAwayDuration to the lowest value obtained from the Max Away Duration field that is contained in the most recently received MAD elements from any of its associated STAs.

An AP may reject a (re)association of a STA if the Max Away Duration field in the MAD element in the (Re)Association Request frame transmitted by the STA is considered unacceptable. For example, an AP that schedules to be in doze state for 100 ms can reject association of a STA that indicates in the Association Request frame a value of 30 ms in its Max Away Duration field.

An AP may disassociate a STA based on the value indicated by Max Away Duration of the latest MAD element received from that STA.

An AP may include a MAD element in the (Re)Association Response frame or Probe Response frame that indicates the suggested maximum away duration during which the AP can be considered in doze state.

A STA may include a MAD element in the Probe Request or (Re)Association Request frames(#199).

Irrespective of the Power Management mode and Power States, an AP shall maintain the synchronization of the network by generating beacons as described in 11.1.3 (Maintaining synchronization).

A STA that is the intended receiver of a frame transmitted by an AP that has the PM Mode subfield equal to 0 shall consider the AP in active mode.

An AP that has previously sent a frame to one or a group of STAs with PM bit equal to 0, shall send a frame with PM bit equal to 1 to the same set of STAs before changing its operation mode to Power Save mode.

A STA that is the intended receiver of a frame transmitted by an AP that has the PM Mode subfield equal to 1 shall consider the AP in Power Save mode.

#### 11.2.3.18 CMMG TXOP power save

A CMMG AP supports the operation of non-AP CMMG STAs in TXOP power save mode in a BSS when dot11CMMGTXOPPowerSaveOptionImplemented at the AP is true. Non-AP CMMG STAs that are in Active


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mode (see Table 11-5 (Power states for an A-BI)) and have dot11CMMGTXOPPowerSaveOptionImplemented equal to true operate in TXOP power save mode. A STA that has dot11CMMGTXOPPowerSaveOptionImplemented equal to true shall set the CMMG TXOP Power Save field in the CMMG Capabilities element to 1; otherwise, the STA shall set the field to 0. A CMMG AP may allow non-AP CMMG STAs in TXOP power save mode to enter the doze state during a TXOP. A CMMG AP shall indicate this by transmitting a CMMG PPDU with the TXVECTOR parameter TXOP_PS_NOT_ALLOWED set to 0. The value of this parameter in the TXVECTOR of all CMMG PPDUs transmitted by the CMMG AP may be changed from 1 to 0 during the TXOP to enable TXOP PS for the remainder of the TXOP. The value of this parameter in the TXVECTOR of all CMMG PPDUs transmitted by CMMG AP shall not be changed from 0 to 1 during the TXOP. If dot11CMMGTXOPPowerSaveOptionImplemented at CMMG AP is false then the CMMG AP shall set the TXOP_PS_NOT_ALLOWED to 1 in the TXVECTOR of the frames.

If the AP allows non-AP CMMG STAs to enter doze state during a TXOP, then a non-AP CMMG STA that is in CMMG TXOP power save mode may enter the doze state until the end of that TXOP when any of the following conditions is met:

— On receipt of a PPDU, the STA determines that the RXVECTOR parameter UPLINK_INDICATION is equal to 0, but the RXVECTOR parameter COLOR does not match the COLOR indicated by the AP to which the STA is associated.

— The STA finds that the COLOR in the RXVECTOR parameter matches the COLOR indicated by the AP to which the STA is associated but the RXVECTOR parameter PARTIAL_AID is not equal to 0 nor does it match the STA's partial AID.

— The STA finds that the PARTIAL_AID in the RXVECTOR matches its partial AID but the RA in the MAC header of the corresponding frame that is received correctly does not match the MAC address of the STA.(#3263)

— The STA receives a QoS Data frame intended for it with the More Data subfield equal to 0 and No Ack ack policy or sends an acknowledgment if the ack policy is not No Ack.

— On receipt of a PPDU, the non-AP STA determines that the RXVECTOR parameter UPLINK_INDICATION is equal to 1.

The CMMG AP shall include a NAV-set sequence (e.g., RTS/CTS) at the beginning of such a TXOP with the Duration/ID value set to the remainder of the TXOP duration. A CMMG AP shall not transmit frames to a non-AP CMMG STA that has been allowed to enter doze state according to the conditions above for the remainder of the TXOP.

NOTE 1—A CMMG AP does not transmit CMMG PPDUs in the current TXOP if the AP has already transmitted a CMMG PPDU with the TXVECTOR parameter TXOP_PS_NOT_ALLOWED set to 0 in the same TXOP and does not want the STAs that are in awake state to enter the doze state.

If a CMMG AP truncates the TXOP in which it allowed STAs to enter doze state, then the CMMG AP shall not transmit frames to the STAs that were allowed to enter the doze state until the NAV set at the start of the TXOP has expired.

If the AP does not receive an acknowledgment after transmitting an individually addressed frame containing all or part of an MSDU, A-MSDU, or MMPDU sent with the More Data field equal to 0 to a non-AP CMMG STA that is in CMMG TXOP power save mode and the AP had set the TXVECTOR parameter TXOP_PS_NOT_ALLOWED to 0, it shall retransmit that frame at least once within the same TXOP, subject to applicable retry, lifetime limit, or TXOP limit. If an acknowledgment to the retransmission of this last frame in the same TXOP is not received, it may wait until the next TXOP to further retransmit that frame, subject to its applicable retry or lifetime limit.

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NOTE 2—An AP that receives from a CMMG STA in TXOP power save mode a BlockAck frame that is a response to an A-MPDU containing MPDUs with the More Data field equal to 0 cannot expect to receive a response to subsequent MPDUs retransmitted in the same TXOP because the CMMG STA might be in the doze state.

A CMMG STA that is in TXOP power save mode and has entered doze state shall continue to operate its NAV timer during doze state and shall transition into awake state on expiry of the NAV timer.

NOTE 3—The STA can contend for access to the medium immediately on the expiry of the NAV timer.

### 11.2.4 Power management in an IBSS

#### 11.2.4.1 Introduction

Subclause 11.2.4 (Power management in an IBSS) specifies the power management mechanism for use within an IBSS. This mechanism is deprecated.

#### 11.2.4.2 Basic approach

A STA can be in one of two power management modes:

— Active mode: The STA receives and transmits frames at any time. The STA remains in the awake state.

— Power save (PS) mode: The STA enters the awake state to receive or transmit frames. The STA remains in the doze state otherwise.

The basic approach is similar to the infrastructure case in that the STAs are synchronized, and group addressed BUs and the BUs that are to be transmitted to a power-conserving STA are first announced during a period when all STAs are awake. The announcement is done via an ATIM frame sent in an ATIM window. A STA in the PS mode shall listen for these announcements to determine if it needs to remain in the awake state. The presence of the ATIM window in the IBSS indicates if the STA may use PS mode. To maintain correct information on the power save state of other IBSS STAs, a STA needs to remain awake during the ATIM window. At other times the STA may enter the doze state except as indicated in the following procedures.

When a BU is to be transmitted to a destination STA that is in a PS mode, the transmitting STA first transmits an ATIM frame during the ATIM window, in which all of the STAs including those operating in a PS mode are awake. The ATIM window is defined as a specific period of time, defined by the ATIM Window field in the IBSS Parameter Set supplied to the MLME-START.request primitive, following a TBTT, during which only Control frames that are RTS, CTS, or Ack frames; Management frames that are Beacon or ATIM frames; or (QoS) Null frames shall be transmitted. ATIM frame transmission times are randomized, after a Beacon frame is either transmitted or received by the STA, using the backoff procedure with the CW equal to aCWmin. Individually addressed ATIM frames shall be acknowledged. If a STA transmitting an individually addressed ATIM frame does not receive an acknowledgment, the STA shall execute the backoff procedure for retransmission of the ATIM frame. Group addressed ATIM frames shall not be acknowledged.

If a STA receives an individually addressed ATIM frame during the ATIM window, it shall acknowledge the individually addressed ATIM frame and stay awake to receive the announced BUs for the entire beacon interval or until it has completed successful transmission to and reception from the source STA of the received ATIM frame, a frame with the EOSP subfield equal to 1. If a STA does not receive an ATIM frame, it may enter the doze state at the end of the ATIM window. Transmissions of BUs announced by ATIM frames are randomized after the ATIM window, using the backoff procedure described in Clause 10 (MAC sublayer functional description).

It is possible that an ATIM frame may be received from more than one STA, and that a STA that receives an ATIM frame may receive more than one BU from the transmitting STA. ATIM frames are only addressed to the destination STA of the BU.


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An ATIM frame for a BU shall have a destination address identical to that of the BU.

After the ATIM interval, only individually addressed BUs that have been successfully announced with an acknowledged ATIM frame and group addressed BUs that have been announced with an ATIM frame shall be transmitted to STAs in the PS mode. These frames shall be transmitted using the DCF (for non-QoS STAs) or EDCAF (for QoS STAs).

Figure 11-17 (Power management in an IBSS—basic operation) illustrates the basic PS operation.

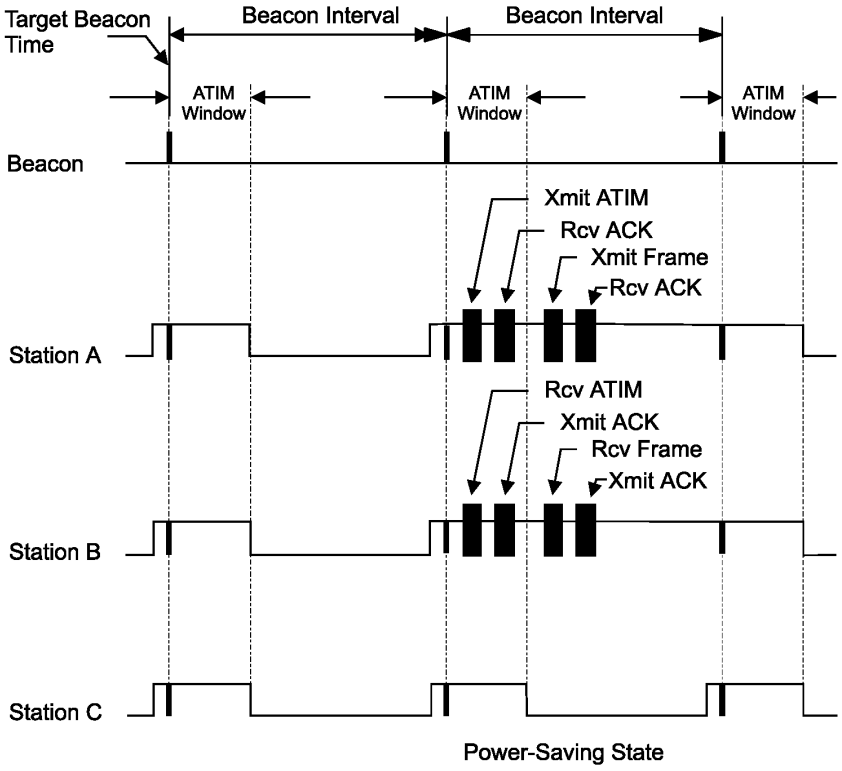


**Figure 11-17—Power management in an IBSS—basic operation**

The estimated power saving state of another STA may be based on the power management information transmitted by that STA and on additional information available locally, such as a history of failed transmission attempts. The use of RTS/CTS in an IBSS may reduce the number of transmissions to a STA that is in PS mode. If an RTS frame is sent and a CTS frame is not received, the transmitting STA may assume that the destination STA is in PS mode. The method of estimating the power management state of other STAs in the IBSS is outside the scope of this standard.

#### 11.2.4.3 Initialization of power management within an IBSS

The following procedure shall be used to initialize power management within a new IBSS, or to learn about the power management being used within an existing IBSS:

a) A STA joining an existing IBSS by the procedure in 11.1.4.4 (Initializing a BSS) shall update its ATIM window with the value contained in the ATIM Window field of the IBSS Parameter Set element within the Beacon or Probe Response frame received during the scan procedure.

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b) A STA starting a new IBSS by the procedure in 11.1.4.4 (Initializing a BSS) shall set the ATIM Window field of the IBSS Parameter Set element within the Beacon frames transmitted to the value of its ATIM window.

c) The start of the ATIM window shall be the TBTT, defined in 11.1.3.5 (Beacon generation in an IBSS). The end of the ATIM window shall be defined as

TSF timer mod dot11BeaconPeriod = ATIMWindow,
where ATIMWindow is the ATIM Window field of the IBSS Parameter Set from the MLME-START.request or MLME-JOIN.request primitives.

d) The ATIM window period shall be static during the lifetime of the IBSS.

e) An ATIM window value of 0 shall indicate that power management is not usable within the IBSS.

#### 11.2.4.4 STA power state transitions

A STA may enter PS mode if the value of the ATIM window in use within the IBSS is greater than 0. A STA shall not enter PS mode if the value of the ATIM window in use within the IBSS is equal to 0.

A STA shall indicate its power management mode in the Power Management subfield of the Frame Control field of frames containing all or part of a BU or individually addressed Probe Request frame, or (QoS) Null frames, that it transmits.

A STA in PS mode shall transition between awake state and doze state according to the following rules:

a) If a STA is operating in PS mode, it shall enter the awake state prior to each TBTT.

b) If a STA receives a group addressed ATIM frame during the ATIM window, the STA shall remain in the awake state until either the STA receives a group addressed frame from the source STA with the EOSP subfield equal to 1 or the end of the next ATIM window, whichever occurs first.

c) If a STA receives at least one individually addressed ATIM frame containing the STA's individual address in the RA field during the ATIM window then the STA shall remain in the awake state at least until the earlier of the completion of the successful transmission to and reception from the source STA of each received ATIM frame, a frame with the EOSP subfield equal to 1, and the end of the next ATIM window.

d) If a STA transmits at least one individually addressed ATIM frame containing a STA's individual address in the RA field during the ATIM window then the STA shall remain in the awake state at least until the earlier of the completion of the successful transmission to and reception from the destination STA of each transmitted ATIM frame, a frame with the EOSP subfield equal to 1, and the end of the next ATIM window.

e) If a STA transmits a Beacon, the STA shall remain in the awake state until the end of the next ATIM window.

f) If the STA has not transmitted an ATIM frame and does not receive either an individually addressed ATIM frame containing the STA's individual address, or a group addressed ATIM frame during the ATIM window, the STA may return to the doze state following the end of the current ATIM window.

### 11.2.5 Power management in an MBSS

Power management in an MBSS is described in 14.15 (Power save in a mesh BSS).

### 11.2.6 SM power save

(11ay)A STA consumes power on all active receive chains, even though they are not necessarily required for the actual frame exchange exchange(#109). The SM power save feature allows a non-AP HT STA or a non-


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AP and non-PCP EDMG STA in an infrastructure BSS or PBSS to operate with only one active receive chain for a significant portion of time.

The STA controls which receive chains are active through the PHY-RXCONFIG.request primitive specifying a PHYCONFIG_VECTOR parameter ACTIVE_RXCHAIN_SET that indicates which of its receive chains should be active.

The basic rules for a STA are defined below. Additional rules for an HE STA in dynamic SM power save mode that sets the HE Dynamic SM Power Save subfield to 1 in the HE MAC Capabilities Information field in the HE Capabilities element it transmits are defined in 26.14.4 (HE dynamic SM power save).

In dynamic SM power save mode, the (11ay)HT STA enables its multiple receive chains when it receives the start of a frame exchange sequence addressed to it(11ay), while the EDMG STA enables its multiple receive chains only when the frame it receives indicates that the following transmission requires the activation of multiple receive chains (see 10.38.12.4 (MIMO channel access))(#231). Such a frame exchange sequence shall start with a single-spatial stream individually addressed frame (11ax)that is not a Trigger frame, that requires an immediate response and that is addressed to the STA in dynamic SM power save mode. (11ay)For an HT STA, an RTS/CTS sequence may be used for this purpose. (11ay)For an EDMG STA in dynamic SM power save mode, a Grant/Grant Ack sequence shall be used for this purpose (see 10.38.12.4.2 (MIMO channel access rules)). The STA shall, subject to its spatial stream capabilities (see 9.4.2.54.4 (Supported MCS Set field) and 9.4.2.156.3 (Supported VHT-MCS and NSS Set field)) and operating mode (see 11.40 (Notification of operating mode changes)), be capable of receiving a PPDU that is sent using more than one spatial stream a SIFS after the end of the PPDU it sends as the immediate response(#380). The STA may switch back to the single receive chain mode immediately after the end of the frame exchange sequence.(#231)

NOTE—(11ay)An HT STA in dynamic SM power save mode cannot distinguish between an RTS/CTS sequence that precedes a MIMO transmission and any other RTS/CTS and, therefore, always enables its multiple receive chains (11ax)if it responds to the RTS addressed to it.

The STA determines(#448) the end of the frame exchange sequence through any of the following:

- It receives an individually addressed frame addressed to another STA.
- It receives a frame with a TA that differs from the TA of the frame that started the TXOP.
- It receives a PPDU and classifies the PPDU as inter-BSS PPDU (see 26.2.2 (Intra-BSS and inter-BSS PPDU classification)).(11ax)
- It receives an HE MU PPDU where the RXVECTOR parameter BSS_COLOR is the BSS color of the BSS in which the STA is associated, the RXVECTOR parameter does not have any STA_ID of an RU that identifies the STA as the recipient or one of the recipients of the RU (see 26.11.1 (STA_ID)), and the BSS Color Disabled subfield in the most recently received HE Operation element from the AP with which the STA is associated is 0.(11ax)
- The CS mechanism (see 10.3.2.1 (CS mechanism)) indicates that the medium is idle at the TxPIFS slot boundary (defined in 10.3.7 (DCF timing relations)).

In static SM power save mode, the STA maintains only a single receive chain active.

The STA may use the SM Power Save frame to communicate its SM power save state. The STA may also use the SM Power Save subfield in the HT Capabilities element (11ay)or EDMG Capabilities element of its (Re)Association Request frame or the SM Power Save subfield in the HE 6 GHz Band Capabilities element of its (Re)Association Request frame to achieve the same purpose. Using the (Re)Association Request frame allows the STA to use only a single receive chain immediately after (re)association.(11ax)

A STA that has one or more (#2152)TDLS direct links shall not operate in SM power save mode.

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Changes to the number of active receive chains are made only after the SM power save mode indication has been successfully delivered (i.e., by acknowledgment of a frame carrying the HT Capabilities element (11ay)or EDMG Capabilities element, (11ax)by acknowledgment of a frame carrying the HE 6 GHz Band Capabilities element, or by acknowledgment of (11ax)an SM Power Save frame). The SM power save mode indication shall be transmitted using an individually addressed frame.

### 11.2.7 Power management in a PBSS and DMG infrastructure BSS

#### 11.2.7.1 General

Power save mechanisms in this subclause enable non-AP STAs to sleep for one or more beacon intervals or for parts of a beacon interval.

The non-AP and non-PCP STA power save mechanisms defined in 11.2.7.2 (Non-AP and non-PCP STA power management mode) enable a non-AP and non-PCP STA to (#6038)transition to doze state after signaling the AP or PCP, or to remain in doze state(#6038) according to a periodic schedule that is negotiated with the AP or PCP. A non-AP and non-PCP STA may use both mechanisms in conjunction to increase its power save opportunity.

Similarly, the PCP power save mechanisms defined in 11.2.7.3 (PCP power management mode) enable a PCP to (#6038)transition to doze state after signaling at least one non-AP and non-PCP STA, or to remain in doze state(#6038) according to a wakeup schedule that is available to all STAs associated with the PCP.

A non-AP STA can be in one of two power management modes:

— Active mode: The STA does not use any of the scheduled or unscheduled power save mechanisms defined in this subclause and operates in the awake state, except during time intervals that it determines it is not the target of any transmission by other STAs, where it may operate in doze state.

— Power save (PS) mode: The STA uses at least one of the scheduled or unscheduled power save mechanisms defined in this subclause and switches between awake and the doze states.

A non-AP STA shall be in active mode upon (re)association.

For scheduled power save, the DMG Wakeup Schedule element (9.4.2.129 (DMG Wakeup Schedule element)) is used to communicate the (#6038)transitions between doze and awake states of a DMG STA, referred to as the STA *wakeup schedule (WS)*. A STA wakeup schedule defines a periodic routine of cycling between a set of contiguous beacon intervals referred to as awake beacon intervals (A-BIs) and a set of contiguous beacon intervals referred to as doze beacon intervals (D-BIs). The rules for alternating between awake and doze power states during A-BIs and D-BIs are defined in 11.2.7.2.3 (Non-AP and non-PCP STA operation with a wakeup schedule) and 11.2.7.3.3 (PCP operation with a wakeup schedule). An overview of these rules is given in Table 11-5 (Power states for an A-BI) and Table 11-6 (Power states for a D-BI).

A STA in PS mode that is following a wakeup schedule and has also exercised unscheduled power save shall follow the D-BI rules in this subclause and shall follow the ATIM rules in 11.2.7.4 (ATIM frame usage for power management of non-AP STAs) for a non-AP STA without wakeup schedule.

An AP or PCP keeps track of the wakeup schedules of all associated non-AP and non-PCP STAs. A non-AP and non-PCP STA keeps track of the wakeup schedule of all associated non-AP and non-PCP STAs that it is communicating with. There is no end time to a wakeup schedule. Once a STA enters PS mode according to its wakeup schedule it stays indefinitely in PS mode until it leaves the PS mode through mechanisms defined in this subclause. Once a STA is made aware of the wakeup schedule of another STA, it is able to keep track of the wakeup schedule on its own. Each STA delivers traffic to a peer STA only when the peer STA is in awake state.


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A STA that has transmitted a frame to an AP or PCP with which it is not associated and from which it expects a response shall remain in the awake state until such a response is received or until the procedure has timed out.

An AP shall buffer BUs addressed to non-AP STAs in doze state. The buffered BUs shall be transmitted only at designated times (11.2.7.2 (Non-AP and non-PCP STA power management mode)). A non-AP STA shall defer delivery of BUs addressed to other non-AP STAs in doze state. The BUs shall be transmitted only at designated times (11.2.7.2 (Non-AP and non-PCP STA power management mode)).

If a PCP sets the BSS Type field within a transmitted DMG Beacon frame to PBSS or the AP or PCP includes a Nontransmitted BSSID Capability element in a transmitted DMG Beacon, Announce, or Probe Response frames and the BSS Type field within the Nontransmitted BSSID Capability element is equal to PBSS, then the AP or PCP shall follow the PCP power management rules described in 11.2.7.3 (PCP power management mode) if the AP or PCP chooses to employ power management.

An AP or PCP may include an Antenna Sector ID Pattern element in Power Save Configuration Response and Probe Response frames transmitted to a non-AP and non-PCP STA. If a non-AP and non-PCP STA uses the information contained in the Antenna Sector ID Pattern element received from its AP or PCP, then during the BTI of an A-BI, the STA might stay awake just to receive DMG Beacon frames transmitted through specific DMG antenna and sector and switch to doze state during other periods in the BTI.

Table 11-5 (Power states for an A-BI) lists the power states for a non-AP and non-PCP STA in PS mode and a PCP in PS mode during an A-BI. Each entry indicates the state, either awake or doze, for the non-AP and non-PCP STA or the PCP in PS mode at various times during the A-BI.

**Table 11-5—Power states for an A-BI**

| Portion of the beacon interval | | PPS PCP | PS non-AP and non-PCP STA |
|---|---|---|---|
| BHI | BTI | Awake | Awake or doze |
| | A-BFT | Awake | Awake or doze |
| | ATI | Awake | Awake |
| DTI | CBAP with the PCP Active field set to 1 in the schedule | Awake or doze | Awake or doze |
| | CBAP with the PCP Active field set to 0 in the schedule | Doze | Awake or doze |
| | SP with Destination AID set to broadcast AID | Awake | Awake |
| | Nontruncatable or nonextensible SP with non-PCP STA as Source AID or Destination AID | Awake or doze | Awake or doze |
| | Truncatable SP or extensible SP with non-AP and non-PCP STA (excluding the PS STA) as Source AID or Destination AID | Awake | Awake or doze |
| | SPs allocated to itself | Awake or doze | Awake or doze |
| | All other SPs | Awake or doze | Awake or doze |
| | Awake window | Awake | Awake |
| | DTI with CBAP Only subfield set to 1 | Awake or doze | Awake or doze |
| | Destination AID field of a CBAP equal to the broadcast AID in the schedule | Awake or doze | Awake or doze |

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**Table 11-5—Power states for an A-BI *(continued)***

| Portion of the beacon interval | | PPS PCP | PS non-AP and non-PCP STA |
|---|---|---|---|
| | (11ay)Unassigned TDD slot | Awake or doze | Doze |
| | (11ay)Assigned simplex RX TDD slot | Awake | Awake |
| | (11ay)Assigned simplex TX TDD slot | Awake | Awake or doze |

Table 11-6 (Power states for a D-BI) lists the power states for a non-AP and non-PCP STA in PS mode and a PCP in PS mode during a D-BI. Each entry indicates the state, either awake or doze, for the non-AP and non-PCP STA or the PCP in PS mode at various times during the D-BI.

**Table 11-6—Power states for a D-BI**

| Portion of the beacon interval | | PPS PCP | PS non-AP and non-PCP STA |
|---|---|---|---|
| BHI | BTI | N/A | Awake or doze |
| | A-BFT | N/A | Awake or doze |
| | ATI | Awake | Awake |
| DTI | CBAP with the PCP Active field set to 1 in the schedule | Doze | Doze |
| | CBAP with the PCP Active field set to 0 in the schedule | Doze | Doze |
| | SP with Destination AID set to broadcast AID | Doze | Doze |
| | SP with a destination AID that is not the broadcast AID | Doze | Awake |
| | Nontruncatable or nonextensible SP with non-PCP STA as Source AID or Destination AID | Doze | Doze |
| | Truncatable SP or extensible SP with non-AP and non-PCP STA (excluding the PS STA) as Source AID or Destination AID | Doze | Doze |
| | SPs allocated to itself | Doze | Doze |
| | All other SPs | Doze | Doze |
| | DTI with CBAP Only subfield set to 1 | Doze | Doze |
| | Destination AID field of a CBAP equal to the broadcast AID in the schedule | Doze | Doze |

The source DMG STA and the destination DMG STA of a nontruncatable SP(11ay), allocated CBAP, or TDD slot with a destination AID that is not the broadcast AID may go to doze state within the SP(11ay), within the CBAP, or within the TDD slot, respectively, after the source DMG STA transmitted a frame to the destination DMG STA of the SP(11ay), the CBAP, or the TDD slot, respectively, with the EOSP subfield set to 1 and received the following response frame from the destination DMG STA of the SP(11ay), the CBAP, or the TDD slot, respectively.


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If the MM-SME Power Mode field within the MMS element sent by an MM-SME coordinated STA is 1, all STAs advertised in the MMS element shall switch to the doze state when the wakeup schedule of any one STA or a successful frame exchange sequence(#109) brings the STA to the doze state.

If the MM-SME Power Mode field within the MMS element sent by an MM-SME coordinated STA is 0, all STAs advertised in the MMS element shall switch to the awake state when the wakeup schedule of any one STA or a successful frame exchange sequence(#109) as described in Annex G brings the STA to the awake state.

### 11.2.7.2 Non-AP and non-PCP STA power management mode

#### 11.2.7.2.1 General

The power management mode of a non-AP and non-PCP STA is selected by the PowerManagementMode parameter of the MLME-POWERMGT.request primitive. Once the STA updates its power management mode, the MLME shall issue an MLME-POWERMGT.confirm primitive indicating the result of the operation. While the STA is in PS mode it may exercise the unscheduled and scheduled power save mechanisms described in this subclause.

Figure 11-18 (State transition diagram of non-AP and non-PCP STA in active and PS modes) illustrates a finite state machine that shows the state transition of a STA in active and PS mode, and also the transition between active and PS modes when the non-AP and non-PCP STA has set up a wakeup schedule.

NOTE—In Figure 11-18 (State transition diagram of non-AP and non-PCP STA in active and PS modes), the notations PSC-REQ(X) and PSC-RSP(Y) indicate that the PSC-REQ and PSC-RSP frames, respectively, are transmitted with the setting as indicated by their corresponding X and Y parameters. The transitions shown “As per T1” are defined in Table 11-5 (Power states for an A-BI). The transitions shown “As per T2” are defined in Table 11-6 (Power states for a D-BI).

#### 11.2.7.2.2 Non-AP and non-PCP STA operation without a wakeup schedule

To change its power state without a wakeup schedule, a non-AP and non-PCP STA shall inform the AP or PCP by completing a successful frame exchange(#109) that is initiated by the STA and that includes a Management frame, Extension frame or Data frame, and also an Ack or a BlockAck frame from the AP or PCP. The Power Management subfield(s) in the Frame Control field of the frame(s) sent by the STA in this exchange (#172)that are acknowledged by the AP or PCP(#1671) indicate the power state that the STA shall adopt upon successful completion of the (#1673)frame exchange sequence(#109)(#1674), except where the Power Management subfield is reserved (see 9.2.4.1.7 (Power Management subfield)). A non-AP and non-PCP STA shall not change its power state using a frame exchange sequence(#109) that does not receive an Ack or BlockAck frame from the AP or PCP, or using a BlockAckReq frame.

A non-AP and non-PCP STA in doze state shall limit the frames it transmits to the following:

- A Management, Extension or Data frame that triggers an Ack or a BlockAck frame from the AP or PCP, with the Power Management subfield in the Frame Control field of the frame set to 0, i.e., a frame to indicate the STA intent to transition out of unscheduled PS mode.
- A Management, Extension or Data frame that triggers an Ack or a BlockAck frame from the AP or PCP, plus Ack and BlockAck frames that respond to the frames sent by the AP or PCP during the reverse direction grant, if the following conditions apply:
  - The Power Management subfield in the Frame Control field of the frame sent by the non-AP and non-PCP STA is set to 1.
  - The AP or PCP has transmitted a Capability Information field in which the Triggered Unscheduled PS subfield is equal to 1.
- An RTS, DMG CTS-to-self, CF-End, Grant, BRP, SSW or SSW-Feedback frame.

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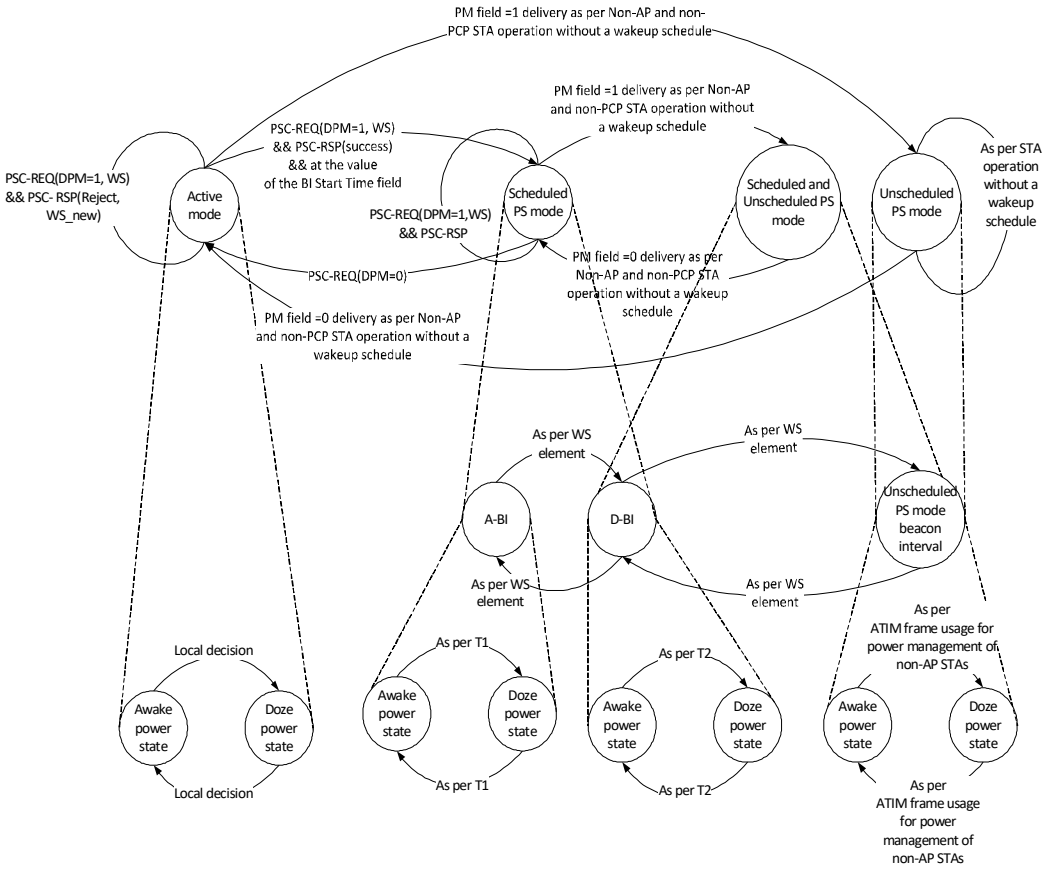


**Figure 11-18—State transition diagram of non-AP and non-PCP STA in active and PS modes**

NOTE 1—A DMG STA in doze state might(M118) need to perform beamforming to restore its links with other DMG STAs.

As long as there is at least one STA that has entered doze state through the unscheduled power save mechanism, the AP or PCP shall establish (11ay)at least one awake window by transmitting an Awake Window element, and shall include a UPSIM element in every DMG Beacon and Announce frame it transmits. The AP or PCP may establish (11ay)awake windows and/or include a UPSIM element in a DMG Beacon or Announce frame it transmits even if no STA is in doze state. The absence of a UPSIM element in a DMG Beacon or Announce frame is equivalent to presence of the UPSIM element in the frame with all bits of the Power Save Indication Bitmap field in the UPSIM element set to 0. The UPSIM element in every DMG Beacon or Announce frame transmitted by the AP or PCP shall indicate the power state of all STAs at the time of frame transmission.

NOTE 2—Transmitting a DMG Beacon frame with the Discovery Mode subfield set to 0, or an Announce frame, without including the UPSIM element in the frame, indicates that no STA is in unscheduled PS mode at the time of the frame transmission.

A non-AP and non-PCP STA may also indicate its power state to another non-AP and non-PCP STA through the Power Management subfield in the Frame Control field of any frame that contains all or part of a BU. The non-AP and non-PCP STA shall indicate its correct power state in the Frame Control field of any frame it transmits that contains all or part of a BU.


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When a non-AP and non-PCP STA that has not set up a wakeup schedule with the AP or PCP enters PS mode, every beacon interval shall be an A-BI for that STA. A non-AP and non-PCP STA that has not set up a wakeup schedule with the AP or PCP and that is in PS mode shall be awake during any allocated SP for which the STA is either the source DMG STA or destination DMG STA during an A-BI. During an A-BI, a non-AP and non-PCP STA that has not set up a wakeup schedule with the AP or PCP and that is in PS mode shall be awake during any allocated CBAP for which the STA is the source DMG STA or destination DMG STA, or the source AID of the CBAP is equal to the broadcast AID or the destination AID of the CBAP is equal to the broadcast AID.

A non-PCP and non-AP STA that is in the doze state may offer an RDG to its AP or PCP if the following conditions apply:

— The AP or PCP has transmitted a Capability Information field in which the Triggered Unscheduled PS field is equal to 1.

— The non-AP and non-PCP has transmitted a Capability Information field in which the Reverse Direction subfield is equal to 1.

The AP or the PCP may use the offered RDG to transmit one or more BUs to the non-PCP and non-AP STA using the reverse direction protocol defined in 10.29 (Reverse direction protocol).

The non-PCP and non-AP STA should continue to offer an RDG to the AP or to the PCP within the current TXOP while the Buffered AC subfield of the QoS Control field in frames transmitted by the AP or by the PCP indicates that one or more BUs are buffered for the AC for which the TXOP was gained.

(11ay)An EDMG AP shall set the Triggered Unscheduled PS subfield to one in any transmitted Capability Information field. A non-AP EDMG STA may set the Triggered Unscheduled PS subfield to one in any transmitted Capability Information field. An EDMG STA is QoS triggered enabled if it transmits a Triggered Unscheduled PS subfield equal to 1.

(11ay)An EDMG STA may include the QoS Triggered Unscheduled element in a PSC-REQ or Association Request frame transmitted to an QoS triggered enabled EDMG AP or EDMG PCP to indicate an explicit request for a QoS triggered unscheduled power save on specific ACs. A QoS triggered enabled EDMG AP or EDMG PCP shall include a QoS Triggered Unscheduled element in the PSC-RSP or Association Response frame, respectively, sent as response with the same QoS-TU AC flag fields set to 1 as those that were set to 1 in the received PSC-REQ or Association Request frame. An EDMG STA may clear the QoS triggered unscheduled power save on a specific AC by sending a successful PSC-REQ frame with the relevant QoS-TU AC flag field set to 0.

(11ay)When QoS triggered unscheduled power save is enabled on a specific AC, an EDMG PCP and an EDMG AP shall deliver the available buffered BU on the AC immediately following a trigger frame that grants the RDG to the EDMG PCP or EDMG AP. The EDMG PCP or EDMG AP shall not deliver to the triggering STA an A-MPDU with a size greater than indicated by the QoS-TU Max A-MPDU Length Exponent field and the A-MPDU shall not contain more MPDUs than the number of MPDUs indicated by the QoS-TU Max MPDU Size field, where both of these fields are indicated in the last QoS Triggered Unscheduled element sent in the PSC-REQ frame or Association Request frame, whichever came later, that established the QoS triggered unscheduled power save.

#### 11.2.7.2.3 Non-AP and non-PCP STA operation with a wakeup schedule

To transition from active mode to PS mode, a non-AP and non-PCP STA that is associated with an AP or PCP shall establish a wakeup schedule (WS) with the AP or PCP. A WS is established with the AP or PCP following the successful transmission of a PSC-REQ frame to the AP or PCP with the DPM field set to 1 and an acknowledged receipt of the corresponding PSC-RSP frame from the AP or PCP provided that the PSC-RSP frame contained a status code indicating success. After receiving a PSC-RSP frame from the AP or PCP

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with a status code indicating success and responding with an acknowledgment, the STA switches to the PS mode at the instant specified by the BI Start Time field of the DMG Wakeup Schedule element transmitted to the AP or PCP. In PS mode, the STA shall cycle between A-BIsand D-BIs following the WS that the STA has established with the AP or PCP.

As long as there is at least one STA that is in PS mode, the AP or PCP shall establish an awake window. The AP or PCP may include an Awake Window element in a DMG Beacon or Announce frame it transmits even if no STA in the BSS has entered PS mode.

A DMG Wakeup Schedule element shall be included in any PSC-REQ frame that the STA transmits to the AP or PCP as an explicit request for a WS. An Awake Window element may also be included in the same PSC-REQ frame to indicate a requested duration for the awake window. If the AP or PCP accepts the proposed WS and the optionally present awake window duration in the PSC-REQ frame, it shall reply with a PSC-RSP frame indicating a status code of SUCCESS. Otherwise, it shall respond with a PSC-RSP frame with a status code indicating the reason for rejecting the request. The AP or PCP may suggest an alternative WS and optionally an awake window duration in the PSC-RSP frame and set the status code to REJECT_WITH_SCHEDULE. If the STA accepts the alternative WS, it shall include this WS in a subsequently transmitted PSC-REQ frame. If the non-AP and non-PCP STA does not accept the alternative WS, it shall not send a PSC-REQ frame for dot11PSRequestSuspensionInterval beacon intervals following the receipt of the PSC-RSP frame from the AP or PCP.

NOTE 1—The AP or PCP can recommend an alternative WS, for example, to align the A-BIs of some or all non-AP and non-PCP STAs.

NOTE 2—The awake window duration sent by the AP or PCP in a PSC-RSP frame is to assist the STA for awake window planning. The awake window duration is always set by the Awake Window element in the most recent DMG Beacon or Announce frame received from the AP or PCP.

If a non-AP and non-PCP STA has established a WS with the AP or PCP and the non-AP and non-PCP STA is in PS mode, the non-AP and non-PCP STA shall have *m* successive A-BIs repeating every *n* beacon interval, where *n* is the Sleep Cycle field of the DMG Wakeup Schedule element contained in the PSC-RSP frame received from the AP or PCP during the frame exchange sequence(#109) that established the WS, and *m* is the Number of Awake BIs field in the DMG Wakeup Schedule element contained in that PSC-RSP frame. During each of its A-BIs, the non-AP and non-PCP STA shall be awake during the awake (11ay)windows that are present, and during all allocated SPs in which it is either the source or destination DMG STA.

An AP or PCP may send an unsolicited PSC-RSP frame without a WS and indicating a status code of success to a non-AP and non-PCP STA in PS mode. Upon receiving the unsolicited PSC-RSP frame meeting these conditions, the non-AP and non-PCP STA shall switch to active mode.

#### 11.2.7.2.4 Non-AP and non-PCP STA operation with or without a wakeup schedule

A non-AP and non-PCP STA in PS mode shall stay awake for dot11MinBHIDuration starting from the beginning of each A-BI and may switch to the doze state after the expiration of this time. The only exception is when the Power Save Configuration Response or Probe Response frame received from the AP or PCP includes an Antenna Sector ID Pattern element, in which case the non-AP and non-PCP STA may use the Antenna Sector ID Pattern element to receive DMG Beacon frames transmitted through a specific DMG antenna and sector, and may switch to doze state during other periods in the BTI.

An AP or PCP shall transmit SP allocation announcements for STAs in PS mode during each of the STAs' A-BIs and may transmit those SP allocation announcements in other beacon intervals. New SPs shall be allocated to begin either within or after the later A-BI of the source DMG STA and destination DMG STA of the SP.

To transition from PS mode to active mode, a non-AP and non-PCP STA that has an established WS with the AP or PCP shall send a PSC-REQ frame with the DPM field set to 0 to the AP or PCP and enter active mode


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following the reception of the Ack frame response. The AP or PCP shall not send a PSC-RSP frame if the DPM field is 0 in the PSC-REQ frame.

In order for a STA to learn the WS of another STA within the BSS, the STA may send an Information Request frame to the other STA or to the AP or PCP as defined in 11.28.1 (Information Request and Response). The AP or PCP maintains a WS distribution table for the lifetime of the BSS, and upon receiving an Information Request frame that contains a request for the WS of a STA identified by the Subject Address field within the frame, shall add an entry to the WS distribution table made up of the STA that transmitted the Information Request frame (the requesting STA) and the STA identified by the Subject Address field within the Information Request frame (the target STA). If the AP or PCP moves the TBTT, changes the duration of the beacon interval, or resets the TSF, the AP or PCP shall transmit an unsolicited Information Response frame with the updated DMG Wakeup Schedule element. When transmitting the DMG Wakeup Schedule element for a STA that is in PS mode, the transmitting STA shall use a value for the BI Start Time field that points to a TBTT that is earlier, but not more than $2^{31}$ μs minus aDMGDWSValidPeriod earlier, than the TBTT of the beacon interval during which the BI Start Time field is transmitted, so that the receiving STA can correctly identify the power management mode of the STA to which the WS belongs.

If the Information Request frame is transmitted to the AP or PCP and the STA indicated in the Information Request's Subject Address field does not have an established WS with the AP or PCP, the AP or PCP shall set the length of the DMG Wakeup Schedule element to 0 in the Information Response frame.

#### 11.2.7.3 PCP power management mode

##### 11.2.7.3.1 General

The power management mode of a PCP is selected by the PowerManagementMode parameter of the MLME-POWERMGT.request primitive. Once the PCP updates its power management mode, the MLME shall issue an MLME-POWERMGT.confirm primitive indicating the result of the operation. While the PCP is in PS mode it may exercise the unscheduled and scheduled power save mechanisms described in this subclause.

##### 11.2.7.3.2 PCP operation without a wakeup schedule

To change its power state without a wakeup schedule, the PCP shall include a UPSIM element in or remove the UPSIM element from every DMG Beacon frame with the Discovery Mode subfield set to 0 and Announce frame that it transmits, and shall indicate its new power state in the UPSIM element if it is included in the frame

NOTE 1—The UPSIM element in a DMG Beacon frame with the Discovery Mode subfield set to 0, or in an Announce frame, includes the power state of the PCP at the time of the frame transmission. Transmitting a DMG Beacon frame with the Discovery Mode subfield set to 0 or an Announce frame, without including the UPSIM element in the frame, indicates that no STA (including the PCP) is in unscheduled PS mode at the time of the frame transmission.

Alternatively, to change its power state without a wakeup schedule, the PCP shall inform all associated STAs by completing a successful frame exchange sequence(#109) that is initiated by the PCP and that includes a Management frame, Extension frame or Data frame, and also an Ack or a BlockAck frame from the associated STA. The Power Management subfield(s) in the Frame Control field of the frame(s) sent by the PCP in this exchange (#172)that are acknowledged by the PCP(#1672) indicate the power state that the PCP shall adopt upon successful completion of the (#1673)frame exchange sequence(#109)(#1674), except where the Power Management subfield is reserved (see 9.2.4.1.7 (Power Management subfield)) The PCP shall not change its power state using a frame exchange sequence(#109) that does not receive an Ack or BlockAck frame from the associated STA, or using a BlockAckReq frame.

The PCP shall not enter doze state unless it has received an Ack or BlockAck from each associated STA. The PCP shall enter awake state as soon as it receives an Ack or BlockAck from one associated STA.

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A PCP in doze state shall limit the frames it transmits to the following:

- A Management, Extension or Data frame that triggers an Ack or a BlockAck frame from a non-AP and non-PCP STA, with the Power Management subfield in the Frame Control field of the frame set to 0, i.e., a frame to indicate the PCP intent to transition out of unscheduled PS mode.
- A Management, Extension or Data frame that triggers an Ack or a BlockAck frame from a non-AP and non-PCP STA, plus Ack and BlockAck frames that respond to the frames sent by the non-AP and non-PCP STA during the reverse direction grant, if the following conditions apply:
  - The Power Management subfield in the Frame Control field of the frame sent by the PCP is set to 1.
  - The non-AP and non-PCP STA has transmitted a Capability Information field in which the Triggered Unscheduled PS subfield is equal to 1.
- An RTS, DMG CTS-to-self, CF-End, Grant, BRP, SSW or SSW-Feedback frame.

NOTE 2—A DMG STA in doze state might(M118) need to perform beamforming to restore its links with other DMG STAs.

The PCP shall indicate the correct power state in the Frame Control field of any frame it transmits to an associated STA that contains all or part of a BU.

#### 11.2.7.3.3 PCP operation with a wakeup schedule

A PCP in PPS mode (PPS PCP) may enter the doze state for one or more consecutive beacon intervals in order to minimize its energy consumption. Figure 11-19 (State transition diagram of PCP power management mode) illustrates a finite state machine that shows the state transition of the PCP power management mode.

NOTE 1—Figure 11-19 (State transition diagram of PCP power management mode) uses the following terminology: "As per T1" means that the transitions are specified in Table 11-5 (Power states for an A-BI), "As per T2" means that the transitions are specified in Table 11-6 (Power states for a D-BI).

To enter PPS mode, or to modify an established WS, the PCP announces a WS through a DMG Wakeup Schedule element (9.4.2.129 (DMG Wakeup Schedule element)) included in a DMG Beacon, Announce, or any Action frame.

The PCP can assume that all associated STAs have received a WS and the Awake Window element that can optionally be transmitted with the WS at the earlier of the following events:

- The PCP has transmitted the DMG Wakeup Schedule element in DMG Beacon or Announce frames for at least dot11MaxLostBeacons successive beacon intervals.
- The PCP has confirmed that each associated STA has received the DMG Wakeup Schedule element by receiving an ACK or a response frame from each associated STA in response to a request frame that includes the DMG Wakeup Schedule element.

The first PCP A-BI of a sleep cycle in a WS starts at the instant specified by the BI Start Time field of the announced DMG Wakeup Schedule element, and the number of successive PCP A-BIs is specified by the Number of Awake BIs field of the DMG Wakeup Schedule element.Once in PPS mode, the PCP transitions between A-BI and D-BI according to the WS it has established.

NOTE 2—The PCP might(M118) need to behave as if it is in active mode or in an A-BI to some associated STAs for a number of planned successive PCP D-BIs if it has not been able to confirm the reception of its WS by each associated STA, and it has not transmitted its WS through DMG Beacon or Announce frames over dot11MaxLostBeacons successive beacon intervals.

In order to transition from PPS mode to active mode, the PCP stops including the DMG Wakeup Schedule element in DMG Beacon and Announce frames. A DMG STA that receives a PCP WS shall assume the PCP


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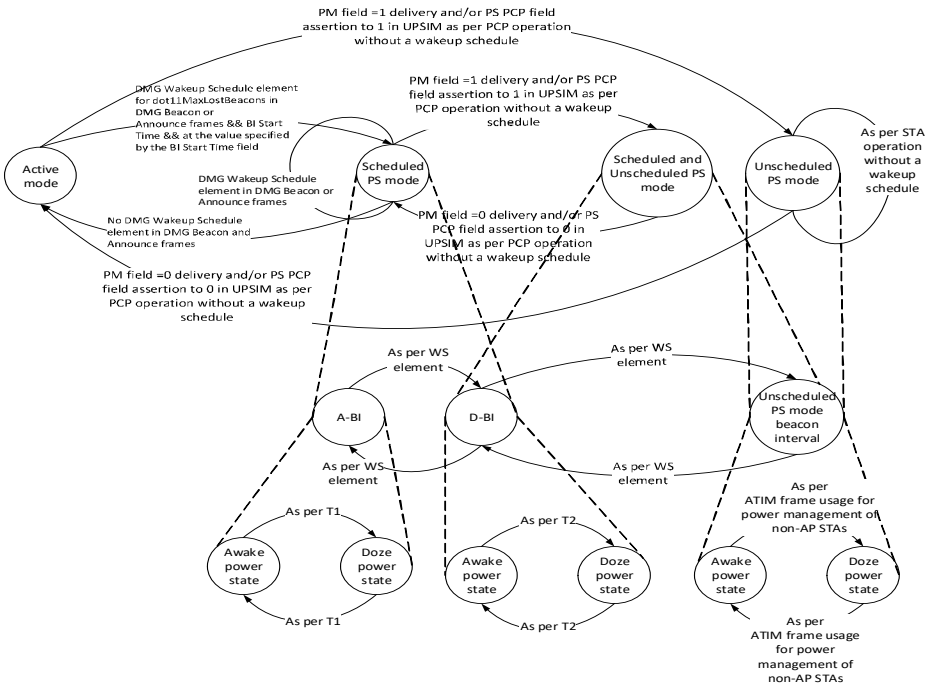


**Figure 11-19—State transition diagram of PCP power management mode**

WS is in effect until it either receives a DMG Beacon or Announce frame that does not include a DMG Wakeup Schedule element or receives a different PCP WS.

In a PCP D-BI, the PCP should schedule a BTI or ATI. If scheduling an ATI, the PCP should transmit an Announce frame during the ATI to associated STAs.

NOTE 3—The PCP provides the PBSS timing synchronization function (TSF). Transmitting frequent TSF information through DMG Beacon or Announce frames is important when there are non-PCP STAs in the PBSS that rely on TSF information to communicate directly with each other.

The PCP may include in the Extended Schedule element the schedule for the beacon intervals during the PCP D-BIs. The PCP may schedule an SP or CBAP within a D-BI by setting the Allocation Start field of the new SP or CBAP in the Extended Schedule element to a value within a D-BI. If the Extended Schedule element is transmitted, the PCP shall transmit it at least dot11MaxLostBeacons times before the PPS PCP enters the doze state.

The PCP shall check that the schedule of pseudo-static allocations transmitted in the last Extended Schedule element before the PCP entered PPS mode is valid during the PCP D-BIs. Thus, a STA participating in such a pseudo-static allocation assumes that the allocation is present during the following consecutive PCP D-BIs.

The PCP may enter and remain in the doze state for any portion of an SP if it is not a source or a destination of the SP. The PCP shall remain in the awake state for any portion of a truncatable or extendable SP (9.4.2.130 (Extended Schedule element)). The CDMG PCP shall remain in the awake state for any portion of an extendable SP or a truncatable SP whose Truncation Type subfield is 0 (9.4.2.130 (Extended Schedule element)). The availability of the PCP during a CBAP in the A-BI shall be announced by setting the PCP Active subfield within the Allocation Control field to 1 for a CBAP allocation made through the Extended Schedule element.

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NOTE 4—A PCP that indicates availability during a CBAP that includes an awake window can exchange ATIM frames with non-AP and non-PCP STAs during the awake window and possibly enter the doze state for the remainder of the CBAP outside the awake window (see 11.2.7.4 (ATIM frame usage for power management of non-AP STAs)).

Figure 11-20 (Example operation of PPS mode) shows an example of the basic operation of a PCP in PPS mode when the PCP sleep interval equals one beacon interval (i.e., PCP (#6038)is in doze state every other beacon interval) and the PCP sleep interval starts right after the first beacon interval. In this example, the first beacon interval and the second beacon interval have the same schedule, but the third beacon interval and the fourth beacon interval have different schedules. The first beacon interval is the A-BI in which the PPS PCP is in the awake state to serve non-PCP STAs. In the first beacon interval, the PCP transmits the Extended Schedule element for the current beacon interval with the pseudo-static subfield set to 1 for all allocations within the Extended Schedule element to indicate that the schedule of the first beacon interval also applies to the second beacon interval. In addition, the PCP transmits the DMG Wakeup Schedule element with the information of the start time and the length of the PCP sleep interval, and the STA Availability element to indicate the availability of the PCP for the CBAP of the A-BI. Following the CBAP of the first beacon interval, the PCP enters the doze state and sleeps for more than one beacon interval. (#6038)The PCP remains in doze state through the remainder of the first beacon interval and through the entire second beacon interval, and transitions to awake state at the start of the third beacon interval in Figure 11-20 (Example operation of PPS mode). Since in this example the schedule of the third beacon interval and the fourth beacon interval are different, the PCP transmits the Extended Schedule element containing the individual allocations for the third beacon interval and fourth beacon interval. The PCP enters the doze state after it completes all exchanges in the third beacon interval and wakes up at the start of the fifth beacon interval.

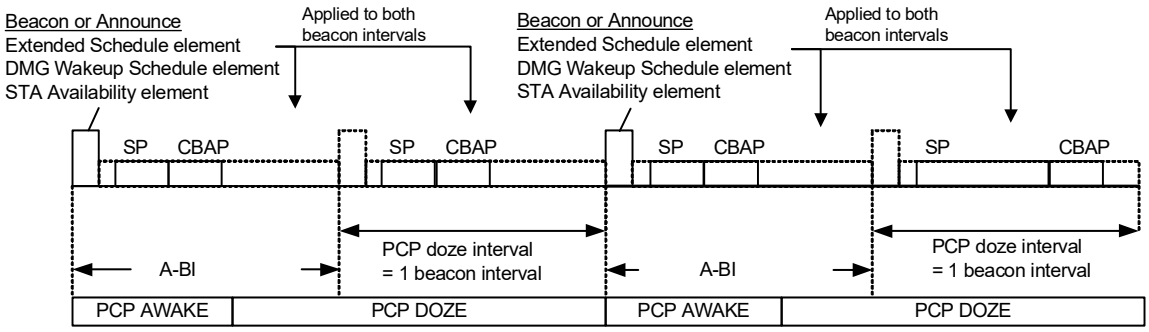


**Figure 11-20—Example operation of PPS mode**

### 11.2.7.4 ATIM frame usage for power management of non-AP STAs

An awake window is present within the first CBAP of a beacon interval that is scheduled through the Extended Schedule element and has the Source AID and Destination AID fields in that Extended Schedule element equal to the broadcast AID, or in a CBAP that is scheduled through the CBAP Only field in the DMG Parameters field (9.4.1.44 (DMG Parameters field)) set to 1, for dot11MaxLostBeacons beacon intervals following the most recent transmission of the Awake Window element (9.4.2.136 (Awake Window element)) by the AP or PCP with the Awake Window Duration field set to a nonzero value.(11ay) If present in the first CBAP, the awake window starts from the beginning of a CBAP and has a duration that is defined by the value of the Awake Window Duration field in the Awake Window element or the CBAP duration, whichever is smaller.

(11ay)If the value of the EDMG Awake Window Duration field within the transmitted Awake Window element is nonzero, an awake window is present within a CBAP allocation of a beacon interval if all of the following conditions are met:

— The CBAP allocation is scheduled in the beacon interval through the EDMG Extended Schedule element

— The CBAP allocation has the Source AID field equal to the broadcast AID


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(11ay)If all these conditions are met, the awake window is present in the CBAP allocation for dot11MaxLostBeacons beacon intervals following the most recent transmission of the Awake Window element by the AP or PCP. The awake window starts from the beginning of the CBAP and has a duration equal to the value of the EDMG Awake Window Duration field within the Awake Window element or the CBAP allocation duration, whichever is smaller.

NOTE 1—Transmission rules during the awake window are the same as the transmission rules for the CBAP that the awake window belongs to.

A non-AP and non-PCP STA delivers the Awake Window element to an AP or PCP as defined in 11.2.7.2.3 (Non-AP and non-PCP STA operation with a wakeup schedule). An AP or PCP delivers the Awake Window element to a non-AP and a non-PCP STA as defined 11.2.7.3 (PCP power management mode).

(11ay)During the awake window, a STA shall transmit only ATIM frames and, if the ATIM frame is individually addressed, Ack frames. A DMG STA in PS mode shall be in the awake state during each awake window that lies within each A-BI for that STA.

BUs that are to be transmitted to a STA that is in PS mode are first announced through ATIM frames during the awake window. A STA in PS mode that is awake during an awake window shall listen for these announcements to determine if it needs to change its power state. If during the awake window the STA does not receive or transmit an ATIM frame with BSSID equal to the BSSID of the BSS of which the STA is a member, then it may enter the doze state at the end of the awake window. If a STA receives an ATIM frame during the awake window, it shall acknowledge the ATIM frame. Any two STAs that successfully complete an ATIM frame exchange with each other during the awake window become peer STAs.

A STA that is in PS mode and following a wakeup schedule and is in the awake state and receives an ATIM frame during the awake window shall be awake during allocations within the current beacon interval that have the Source AID equal to broadcast AID or have a Source AID that identifies a STA whose MAC address is equal to the TA field of the received ATIM frame, or during any DTI that is scheduled through the CBAP Only field in the DMG Parameters field (9.4.1.44 (DMG Parameters field)) set to 1. If a STA transmits an ATIM frame during the awake window, it shall attempt to deliver its BUs during allocations within the current beacon interval that have a Destination AID equal to broadcast AID or have a Destination AID that identifies a STA whose MAC address is equal to the RA field of the transmitted ATIM frame, or during any DTI that is scheduled through the CBAP Only field in the DMG Parameters field (9.4.1.44 (DMG Parameters field)) set to 1. (11ay)A STA that receives from, or transmits to, a peer STA that is not an EDMG STA an ATIM frame during the awake window may enter the doze state when it has successfully transmitted to and received from all corresponding peer STAs for this beacon interval a QoS Data frame with the EOSP subfield set to 1; otherwise it shall stay active until the end of the current beacon interval. (11ay)An EDMG STA that receives from, or transmits to, a peer EDMG STA an ATIM frame during an awake window may enter the doze state when it has successfully transmitted to and received from all corresponding peer STAs for this allocation a QoS Data frame with the EOSP subfield set to 1; otherwise, it shall remain active until the end of the allocation. ATIM frame transmissions and MSDU transmissions follow the rules defined in 11.2.8 (ATIM frame and frame transmission in IBSS, DMG infrastructure BSS, and PBSS).

NOTE 2—A STA is in the doze state and receives an ATIM frame during an awake window can leave the doze state following the procedure in 11.2.7.2.2 (Non-AP and non-PCP STA operation without a wakeup schedule)or 11.2.7.3.2 (PCP operation without a wakeup schedule).

Figure 11-21 (Example of ATIM frame response behavior in PS mode) illustrates an example of a DMG STA response to an ATIM frame. For illustration purposes the 5 beacon intervals shown in the figure are numbered from 0 to 4. The PCP is following a wakeup schedule, with 1 A-BI out of every 4 beacon intervals. The non-PCP STA A is also following a wakeup schedule, with 1 A-BI out of every 2 beacon intervals. In addition, STA A performs unscheduled power save during beacon interval 0, and also during beacon interval 2 to beacon interval 4. (11ay)The PCP is required to remain awake during the following CBAP after receiving an ATIM

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frame in beacon interval 2. An ATIM frame received during beacon interval 4, however, serves as a traffic indication and PCP will transmit frames to STA A only after STA A is in the awake state.

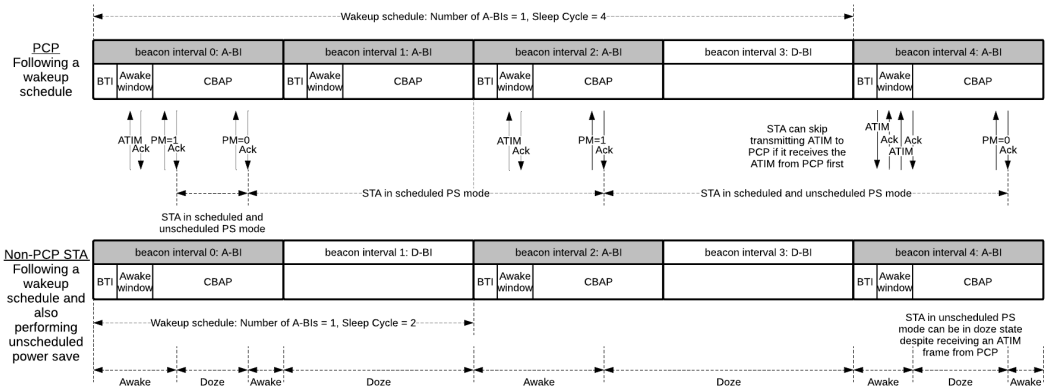


**Figure 11-21—Example of ATIM frame response behavior in PS mode**

The ATIM frame transmission result and EOSP notification result between a MAC address pair can be used for other MAC pairs that are members of the same MMSL cluster.

### 11.2.7.5 MU-MIMO power save(11ay)

The MU-MIMO power save mechanism allows a non-AP and non-PCP EDMG STA in an infrastructure BSS or PBSS to go to PS mode during a TXOP where the STA is involved in an MU-MIMO transmission and acknowledgment procedures.

An EDMG STA that receives A-MPDUs within an EDMG MU PPDU may go to PS mode during the following two periods:

— First period: from the end of its individual A-MPDU within the EDMG MU PPDU to the time it needs to transmit its BA or RD response burst to the initiator (see 10.3.2.13 (MU acknowledgment procedure) and 10.29.5 (Reverse direction for EDMG DL MU-MIMO(11ay))).

— Second period: from the time of sending back the BA or RD response burst to the time indicated in Next PPDU Start Offset subfield in the Block Ack Schedule frame starting from the end of EDMG MU PPDU.

A STA that did not receive a Block Ack Schedule frame within a received MU PPDU shall remain awake in receive mode until it receives a BlockAckReq or Block Ack Schedule frame from the initiator or until the end of the TXOP, whichever comes first.

Once awake at the end of the second period, the EDMG STA shall stay in awake state until it receives the next EDMG MU PPDU from the initiator or until the end of the current TXOP, whichever comes first.

Figure 11-22 (Example of MU-MIMO power save performed in MU group with three EDMG STAs(11ay)) illustrates an example of MU-MIMO power save performed in an MU group with three EDMG STAs.

### 11.2.8 ATIM frame and frame transmission in IBSS, DMG infrastructure BSS, and PBSS

Power management in an IBSS is deprecated. If power management is in use within an IBSS, a STA shall buffer individually addressed BUs for STAs that are known to be in PS mode.


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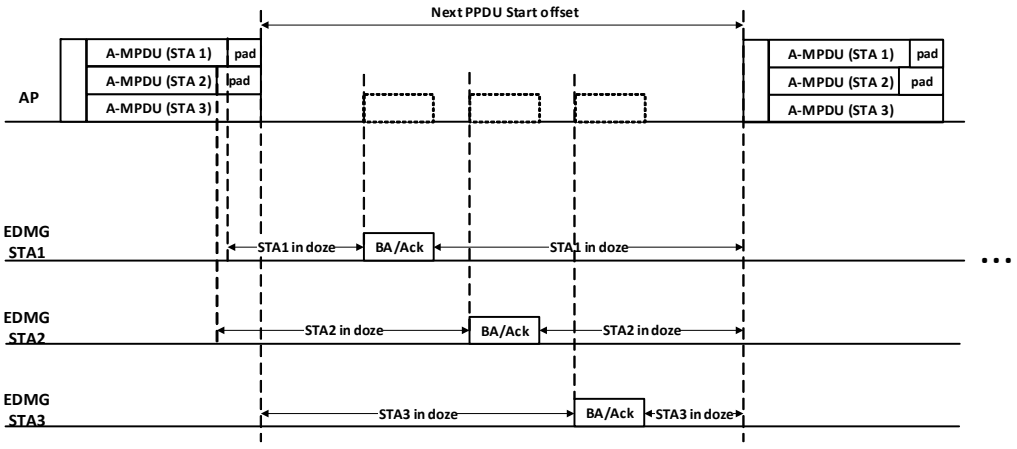


**Figure 11-22—Example of MU-MIMO power save performed in MU group with three EDMG STAs(11ay)**

The following rules describe operation of the ATIM frame and frame transmission to STAs in PS mode in an IBSS, DMG infrastructure BSS and PBSS:

a) Following the reception or transmission of the Beacon frame in a non-DMG IBSS, during the ATIM window, the STA shall queue for transmission an individually addressed ATIM frame to each STA for which it has one or more buffered individually addressed BUs and for which an ATIM frame is not already queued. Following the BTI or ATI in a DMG BSS, during the awake window(#3110), the STA shall queue for transmission an individually addressed ATIM frame to each STA for which it has one or more buffered individually addressed BUs and for which an ATIM frame is not already queued. If the STA has one or more buffered group addressed MSDUs or has one or more buffered group addressed MMPDUs, it shall queue for transmission an appropriately addressed group addressed ATIM frame if such an ATIM frame is not already queued.

b) In a non-DMG IBSS, a STA shall use the backoff procedure defined in 10.3.4.3 (Backoff procedure for DCF) for transmission of the first ATIM frame following the Beacon frame. In a DMG BSS, a STA shall use the backoff procedure defined in 10.3.4.3 (Backoff procedure for DCF) for transmission of the first ATIM frame following the BTI or ATI. All remaining ATIM frames shall be transmitted using the DCF (for non-QoS STAs) or the EDCAF (for QoS STAs).

c) ATIM frames shall be transmitted only during the ATIM window (for an IBSS STA) or awake window(#3110) (for a non-IBSS DMG STA).

d) A non-DMG STA shall transmit no frame types other than RTS, CTS, Ack, Beacon, ATIM and (QoS) Null frames during the ATIM window.

e) Individually addressed ATIM frames shall be acknowledged. If no acknowledgment is received, the ATIM frame shall be retransmitted using either the DCF (for non-QoS STAs) or the EDCAF (for QoS STAs). Group addressed ATIM frames shall not be acknowledged.

f) If a STA is unable to transmit an ATIM frame during the ATIM window (for an IBSS STA) or awake window(#3110) (for a non-IBSS DMG STA), for example due to contention with other STAs, the STA should retain the buffered BUs and either discard the ATIM frame or attempt to transmit the ATIM frame during the next the ATIM window (for an IBSS STA) or awake window(#3110) (for a non-IBSS DMG STA).

g) Immediately following the ATIM window (for an IBSS STA) or awake window(#3110) (for a non-IBSS DMG STA), a STA shall begin transmission of any buffered group addressed frames for which an ATIM frame was previously transmitted. Following the transmission of any group addressed frames, any BUs addressed to STAs for which an acknowledgment for a previously

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transmitted ATIM frame was received shall be transmitted. A STA shall use the backoff procedure defined in 10.3.4.3 (Backoff procedure for DCF) for transmission of the first frame following the (#8140)ATIM window (for an IBSS STA) or awake window(#3110) (for a non-IBSS DMG STA). All remaining frames shall be transmitted using either the DCF (for non-QoS STAs) or the EDCAF (for QoS STAs).

h) If a buffered BU is transmitted using fragmentation and if the BU has been partially transmitted when the next Beacon frame is sent in a non-DMG IBSS or when the next beacon interval begins in a DMG BSS, the STA shall retain the buffered BU and announce the remaining fragments by transmitting an ATIM frame during the next the ATIM window (for an IBSS STA) or awake window(#3110) (for a non-IBSS DMG STA).

i) If a STA is unable to transmit a buffered BU during the beacon interval in which it was announced, for example due to contention with other STAs, the STA shall retain the buffered BU and announce the BU again by transmitting an ATIM frame during the next the ATIM window (for an IBSS STA) or awake window(#3110) (for a non-IBSS DMG STA).

j) Following the transmission of all buffered BUs, a STA may transmit BUs without announcement to STAs that are known to be in the awake state for the current beacon interval.

k) A STA may discard BUs buffered for later transmission to power saving STAs if the STA determines that the BU has been buffered for an excessive amount of time or if other conditions internal to the STA implementation make it desirable to discard buffered BUs (e.g., buffer starvation). A BU should not be discarded that has been buffered for less than dot11BeaconPeriod. The algorithm to manage this buffering is beyond the scope of this standard.

l) In order to indicate its intent to change power management modes, a STA shall transmit individually addressed or group addressed (QoS) Null frames within the ATIM window.

The STA shall not transition into or out of PS mode unless it has received acknowledgments from all recipients to which individually addressed (QoS) Null frames have been transmitted or after it has transmitted a sufficient number of group addressed (QoS) Null frames.

NOTE—The choice between individually addressed and group addressed transmissions, the peer STAs addressed for individually addressed transmissions, and the number of transmissions for group addressed transmissions are implementation choices outside the scope of the standard. A STA might base its choices on factors such as the number of peer STAs it is aware of in the IBSS, the expected traffic from each of these peer STAs, and the reliability of frame exchange sequences(#109) with these peer STAs.

### 11.2.9 Power management with general links

GLK STAs that have established general links (associations) have additional power management behaviors to support Data frames with a SYNRA and GLK GCR. These behaviors are in addition to the GLK STA behaviors listed in the previous subclauses.

NOTE 1—It is suggested that a STA using a general link that carries unknown traffic loads on behalf of other endpoints not use PS mode, due to the increased delay and jitter it would cause. However, GLK STAs that find PS mode useful might(M118) utilize PS mode while performing behaviors in this subclause.

Data frames with a SYNRA are queued for normal (nonbuffered) transmission to associated GLK STAs that are not in PS mode. A SYNRA shall not be used to address GLK STAs in PS mode.

NOTE 2—The net effect of the above is that any GLK non-AP STA in PS mode will, for all traffic for which the PS STA is a recipient, result in MPDUs that are buffered and, if there are multiple receivers, potentially duplicated. The IEEE 802.1Q bridge at the AP should use higher-layer facilities to filter traffic being sent to the STA so as to limit the amount of buffered traffic.

A GLK STA that has enabled GLK-GCR on its general link shall not enter PS mode. GLK STAs shall not use the FMS, TFS nor WNM-Sleep procedures applied to group addressed frames.


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## 11.3 STA authentication and association

### 11.3.1 State variables

A STA (local) for which dot11OCBActivated is false keeps an enumerated state variable for each STA (remote) with which direct communication via the WM is needed. In this context, direct communication refers to the transmission of any Class 2 or Class 3 frame with an Address 1 field that matches the MAC address of the remote STA.

A STA for which dot11MeshActivated is true (i.e., a mesh STA) does not use procedures described in 11.3.5 (Association, reassociation, and disassociation). Instead, a mesh STA uses a mesh peering management protocol (MPM) or a authenticated mesh peering exchange (AMPE) to manage states and state variables for each peer STA. See 14.4 (Mesh peering management (MPM)) and 14.6 (Authenticated mesh peering exchange (AMPE)) for details.

A STA for which dot11OCBActivated is true does not use MAC sublayer authentication or association and does not keep this state variable.

For nonmesh STAs, this state variable expresses the relationship between the local STA and the remote STA. It takes on the following values:

— *State 1*: Initial start state for non-DMG STAs and for DMG STAs that perform IEEE 802.11 authentication. Unauthenticated and unassociated.

— (11az)*State 1a*: Authenticated for non-DMG STAs and for DMG STAs that have performed PASN authentication (12.13 (Preassociation security negotiation(11az))). Unassociated. Association is not possible from this state without non-PASN IEEE 802.11 authentication.

NOTE—This state is used by STAs that wish to exchange robust management frames for example, perform secure ranging, but do not wish to exchange data frames.

— *State 2*: Initial start state for DMG STAs that do not perform IEEE 802.11 authentication. Authenticated (except DMG STAs that do not perform IEEE 802.11 authentication, which are unauthenticated) but unassociated.

— *State 3*: Authenticated (except DMG STAs that did not perform IEEE 802.11 authentication, which are unauthenticated) and associated (pending RSNA authentication(#218)). The IEEE 802.1X Controlled Port is blocked.

— *State 4*: Authenticated (except DMG STAs that did not perform IEEE 802.11 authentication, which are unauthenticated) and associated (RSNA established or not required(#218)). The IEEE 802.1X Controlled Port is unblocked, or not present.

The state variable is kept within the MLME (i.e., is written and read by the MLME). The SME may also read this variable using the MLME-GETAUTHASSOCSTATE.request primitive.

Mesh STAs manage the state variable as described in 14.4.2 (State variable management).

### 11.3.2 State transition diagram for nonmesh STAs

Figure 11-23 (Relationship between state and services between a given pair of nonmesh STAs(11az)(M164)) shows the state transition diagram for nonmesh STA states. Note that only events causing state changes are shown. The state of the sending STA given by Figure 11-23 (Relationship between state and services between a given pair of nonmesh STAs(11az)(M164)) is with respect to the intended receiving STA.

NOTE—A transition to State 1 might occur for other reasons such as no frames having been received from a STA for a period of time.

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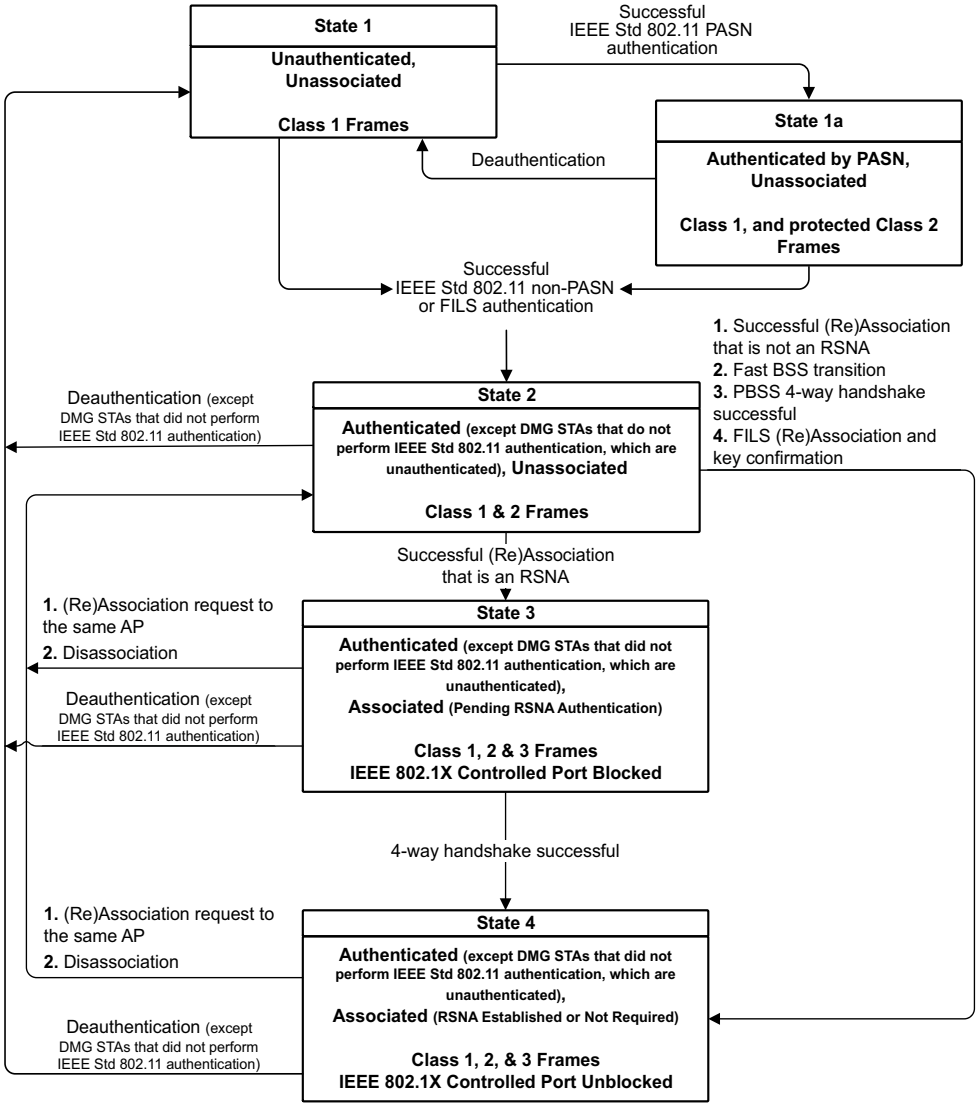


**Figure 11-23—Relationship between state and services between a given pair of nonmesh STAs(11az)(M164)**

### 11.3.3 Frame filtering based on STA state

The current state existing between the transmitter and receiver STAs determines the IEEE 802.11 frame types that may be exchanged between that pair of STAs (see Clause 9 (Frame formats)). A unique state exists for each pair of transmitter and receiver STAs. The allowed frame types are grouped into classes and the classes correspond to the STA state. In State 1, only Class 1 frames are allowed. In State 2, only Class 1 or Class 2 frames are allowed. In State 3 and State 4, all frames are allowed (Classes 1, 2, and 3). In the definition of frame classes, the following terms are used:

— Within an infrastructure BSS: both the transmitting STA and the recipient STA participate in the same infrastructure BSS

— Within a PBSS: both the transmitting STA and the recipient STA participate in the same PBSS


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— Within an IBSS: both the transmitting STA and the recipient STA participate in the same IBSS

— dot11RSNAActivated: reference to the setting of dot11RSNAActivated at the STA that needs to determine whether a transmission or reception is permitted.

NOTE—The phrase "within a BSS" comprises "within a PBSS," "within an IBSS," "within an MBSS," or "within an infrastructure BSS."

STA A participates in the same infrastructure BSS as STA B if at least one of the following conditions is met:

— STA A is associated with STA B, and either STA A or STA B is an AP.

— STA A receives a frame with the value of its TA field equal to the MAC address of STA B and with the value of its BSSID field equal to the BSSID of the BSS of which STA A is a member.

— STA A receives an Information Response frame from the AP with which it is associated containing an explicit indication that STA B is a member of the same BSS as STA A.

STA A participates in the same PBSS as STA B if at least one of the following conditions is met:

— STA A is associated with STA B, and either STA A or STA B is a PCP.

— STA A receives a frame with the value of its TA field equal to the MAC address of STA B and with the value of its BSSID field equal to the BSSID of the PBSS that STA A has joined or started.

— STA A receives a frame, i.e., an Information Response frame, from its PCP containing an explicit indication that STA B is a member of the PBSS that STA A has joined.

STA A participates in the same IBSS as STA B if STA A receives a frame with the value of its TA field equal to the MAC address of STA B and with the value of its BSSID field equal to the BSSID of the IBSS that STA A has joined or started.

The frame classes are defined as follows:

a) Class 1 frames
   1) Control frames
      i) RTS
      ii) CTS
      iii) DMG Clear to send (DMG CTS)
      iv) Ack
      v) Grant
      vi) SSW
      vii) SSW-Feedback
      viii) SSW-Ack
      ix) Grant Ack
      x) CF-End
      xi) In an IBSS and in a PBSS when dot11RSNAActivated is false, Block Ack (BlockAck)
      xii) In an IBSS and in a PBSS when dot11RSNAActivated is false, Block Ack Request (BlockAckReq)
      xiii) In an HE BSS Basic Trigger frame and Multi-STA BlockAck frame(11ax)
   2) Management frames
      i) Probe Request/Response
      ii) Beacon
      iii) Authentication
      iv) Deauthentication

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v) ATIM
vi) Public Action
vii) Self-protected Action
viii) In an IBSS, all Action frames and all Action No Ack frames
ix) Unprotected DMG Action frames
x) In a PBSS when dot11RSNAActivated is false, all Action and Action No Ack frames except the following frames:
1) ADDTS Request
2) ADDTS Response
3) DELTS

3) Data frames
i) Data frames between IBSS STAs
ii) Data frames within a PBSS
iii) (11bc)EBCS Data frames

4) Extension frames
i) DMG Beacon

5) (11ba)WUR frames
i) WUR Beacon
ii) WUR Discovery

b) (11az)Class 1a frames
In an infrastructure BSS when PTKSA from PASN authentication exists
1) Protected Fine Timing frames (9.6.34 (Protected Fine Timing Action frame details(11az)(#8155)))
2) SA Query Request and SA Query Response frames sent to an individual address (11.13 (SA Query procedures))(#6026)

c) Class 2 frames
1) Management frames
i) Association Request/Response
ii) Reassociation Request/Response
iii) Disassociation

d) Class 3 frames
1) Data frames
i) Data frames between STAs in an infrastructure BSS or in an MBSS
2) Management frames
i) In an infrastructure BSS, an MBSS, or a PBSS, all Action and Action No Ack frames except those that are declared to be Class 1 or Class 2 frames
3) Control frames
i) PS-Poll
ii) Poll
iii) SPR
iv) DMG DTS
v) Block Ack (BlockAck), except those that are declared to be Class 1
vi) Block Ack Request (BlockAckReq), except those that are declared to be Class 1 (above)
4) (11ba)WUR frames


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i) WUR Wake-up
ii) WUR Short Wake-up

Class 2 and Class 3 frames are not allowed in an IBSS. If an IBSS STA receives a Class 2 or Class 3 frame, it shall (#3683)discard the frame.

A STA shall not transmit Class 2 frames unless in State 2 or State 3 or State 4. (11az)In State 1a, a STA shall not transmit frames other than Class 1 and Class 1a frames.

A STA shall not transmit Class 3 frames unless in State 3 or State 4.

A multi-band capable device that uses OCT to move from State 2 to either State 3 or State 4 shall not transmit frames before the transmitting STA becomes over-the-WM enabled (see 11.31.5 (On-channel Tunneling (OCT) operation)).

The use of the word “receive” in 11.3 (STA authentication and association) refers to a frame that meets all of the filtering criteria specified in Clause 12 (Security) and Clause 10 (MAC sublayer functional description).

### 11.3.4 Authentication and deauthentication

#### 11.3.4.1 General

This subclause describes the procedures used for IEEE 802.11 authentication and deauthentication. The states used in this description are defined in 11.3.1 (State variables).

Successful authentication (11az)other than PASN authentication sets a STA’s state to State 2, if it (#1983)was State 1 or State 1a. Successful PASN authentication sets the STA’s state to State 1a, if it was in State 1. PASN authentication is disallowed in states other than State 1. Unsuccessful authentication leaves the STA’s state unchanged.

Deauthentication notification sets the state for a STA to State 1. Deauthentication notification when in State 3 or 4 implies disassociation as well. A STA may deauthenticate a peer STA at any time, for any reason.

If STA A in an infrastructure BSS receives (11az)an unprotected Class 2 frame or a Class 3 frame from STA B when the state for STA B is State 1a, STA A shall discard the frame. If the frame has an individual address in the Address 1 field, the MLME of STA A should(#3509) send a Deauthentication frame to STA B.

NOTE—STA A might choose not to send a frame if a denial-of-service attack is suspected.(#3509)

(11az)If STA A in an infrastructure BSS receives any frame other than Class 1 and Class 1a frames (see 11.3.3 (Frame filtering based on STA state)) from STA B when in State 1a, STA A shall discard the frame.

Authentication is optional in an IBSS. In a non-DMG infrastructure BSS, authentication is required. In a DMG infrastructure BSS and PBSS, the Open System authentication algorithm is not used (see 12.3.3.1 (Overview)). APs and PCPs do not initiate authentication.

#### 11.3.4.2 Authentication—originating STA

Upon receipt of an MLME-AUTHENTICATE.request primitive that is part of an on-channel tunneling (see 11.31.5 (On-channel Tunneling (OCT) operation)), the originating STA shall follow the rules in 11.31.5 (On-channel Tunneling (OCT) operation) in addition to the authentication procedure described below.

Upon receipt of an MLME-AUTHENTICATE.request primitive, the originating STA shall authenticate with the indicated STA using the following procedure:

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a) If the STA is in an IBSS, the SME shall delete any PTKSA, GTKSA, IGTKSA, (#3344)WIGTKSA, WTKSA, and BIGTKSA (including temporal keys)(#205) held for communication with the indicated STA by using the MLME-DELETEKEYS.request primitive (see 12.6.16 (RSNA security association termination)).

b) The STA shall execute one of the following:

   1) For the Open System (#3056)authentication algorithm, the authentication mechanism described in 12.3.3.2 (Open System authentication).

   2) For the fast BSS transition (FT) authentication algorithm in an ESS, the authentication mechanism described in 13.5 (FT protocol), or, if resource requests are included, 13.6 (FT resource request protocol).

   3) For SAE authentication in an infrastructure BSS, IBSS, or MBSS, the authentication mechanism described in 12.4 (Authentication using a password).

   4) For FILS authentication, the authentication mechanism described in 12.11 (Authentication for FILS). An AP or PCP may provide estimated association response latency to a non-AP and non-PCP STA using the Association Delay Info field in the Association Delay Info element (9.4.2.173 (Future Channel Guidance element)). The value of the Association Delay Info field shall be larger than dot11HLPWaitTime.

   5) (11az)For PASN authentication, the authentication mechanism described in 12.13 (Preassociation security negotiation(11az)).

c) (11az)For any authentication protocol that is not PASN, if the authentication was successful within the AuthenticateFailureTimeout, the state for the indicated STA shall be set to State 2 if it was in State 1 or State 1a; the state shall remain unchanged if it was other than State 1 or State 1a.

d) (11az)For PASN authentication, if the authentication was successful within the AuthenticateFailureTimeout, the state for the indicated STA shall be set to State 1a if it was State 1; PASN authentication is disallowed in states other than State 1.

e) The MLME shall issue an MLME-AUTHENTICATE.confirm primitive to inform the SME of the result of the authentication.

#### 11.3.4.3 Authentication—destination STA

Upon receipt of an Authentication frame with authentication transaction sequence number equal to 1, the destination STA shall authenticate with the originating STA using the following procedure:

a) If Open System (#3056)authentication algorithm is being used, the STA shall execute the procedure described in 12.3.3.2 (Open System authentication). These result in the generation of an MLME-AUTHENTICATE.indication primitive to inform the SME of the authentication request.

b) If FT authentication is being used, the MLME shall issue an MLME-AUTHENTICATE.indication primitive to inform the SME of the authentication request, including the FT Authentication Elements, and the SME shall execute the procedure as described in 13.5 (FT protocol) or 13.6 (FT resource request protocol).

c) If SAE authentication is being used in an infrastructure BSS, IBSS, or MBSS, the MLME shall issue an MLME-AUTHENTICATE.indication primitive to inform the SME of the authentication request, including the SAE authentication elements, and the SME shall execute the procedure as described in 12.4 (Authentication using a password).

d) If FILS authentication is being used, the MLME shall issue an MLME-AUTHENTICATE.indication primitive to inform the SME of the authentication request, and the SME shall execute the procedure described in 12.11 (Authentication for FILS).

e) (11az)If PASN authentication is being used, the MLME shall issue an MLME-AUTHENTICATE.indication primitive to inform the SME of the authentication request, and the SME shall execute the procedure described in 12.13 (Preassociation security negotiation(11az)).


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f) If the STA is in an IBSS and management frame protection was not negotiated when the PTKSA(s) were created, the SME shall delete any PTKSA, GTKSA, IGTKSA, (#3344)WIGTKSA, WTKSA, and BIGTKSA (including temporal keys)(#205) held for communication with the originating STA by using the MLME-DELETEKEYS.request primitive (see 12.6.16 (RSNA security association termination)).

g) Upon receipt of an MLME-AUTHENTICATE.response primitive, if the ResultCode is not SUCCESS, the MLME shall transmit an Authentication frame with the corresponding status code, as defined in 9.4.1.9 (Status Code field), and the state for the originating STA shall be left unchanged. The Authentication frame is constructed using the appropriate procedure in 12.3.3.2 (Open System authentication)(#3056), 13.5 (FT protocol), 13.6 (FT resource request protocol), (11az)or 12.13 (Preassociation security negotiation(11az)).

h) Upon receipt of an MLME-AUTHENTICATE.response primitive, if the ResultCode is SUCCESS, the MLME shall transmit an Authentication frame that is constructed using the appropriate procedure in 12.3.3.2 (Open System authentication)(#3056), 13.5 (FT protocol) 13.6 (FT resource request protocol) (11az)or 12.13 (Preassociation security negotiation(11az)), with a status code of SUCCESS. The state for the originating STA shall be set to State 2 if it (#1983)was State 1 or State 1a when PASN authentication procedure was not used. The state for the originating STA shall be set to State 1a if it was in State 1 and PASN authentication procedure was used. PASN authentication shall be disallowed in states other than State 1.

NOTE—If management frame protection (#2128)is negotiated, the SME does not change the state for the originating STA and does not delete any of the previously created SAs or temporal keys as a part of this authentication procedure.

If the STA is in an IBSS, if the SME decides to initiate an RSNA, and if the SME does not know the security policy of the peer, it may issue an individually addressed Probe Request frame to the peer by invoking an MLME-SCAN.request primitive to discover the peer's security policy.

When a non-AP and non-PCP STA receives an Authentication frame that includes an Association Delay Info element, it (#135)shall set dot11AssociationResponseTimeOut equal to or larger than the Association Delay Info field.

#### 11.3.4.4 Deauthentication—originating STA

The originating STA shall deauthenticate with the indicated STA using the following procedure:

a) The SME shall generate an MLME-DEAUTHENTICATE.request primitive containing the appropriate reason code for the STA deauthentication, as defined in Table 9-79 (Reason codes) of 9.4.1.7 (Reason Code field).

b) On receipt of the MLME-DEAUTHENTICATE.request primitive, if the state for the indicated STA is (11az)State 1a, State 2, State 3, or State 4, the MLME shall generate a Deauthentication frame to be transmitted to the indicated STA.

NOTE—As the Deauthentication frame is a bufferable MMPDU, the transmission of this frame might be delayed by the operation of a power saving protocol. The AID and the PTKSA are maintained (when applicable) until the frame is acknowledged or attempts to transmit the frame are abandoned.

c) The state for the indicated STA shall be set to State 1.

d) Once the Deauthentication frame is acknowledged or attempts to transmit the frame are abandoned, the MLME shall issue an MLME-DEAUTHENTICATE.confirm primitive to inform the SME of the deauthentication.

e) The SME, upon receipt of an MLME-DEAUTHENTICATE.confirm primitive, shall delete any PTKSA, GTKSA, IGTKSA, BIGTKSA(11ba), WIGTKSA, (#3344)WTKSA, and TPKSA (including temporal keys)(#205) held for communication with the indicated STA by using the MLME-DELETEKEYS.request primitive (see 12.6.16 (RSNA security association termination)) and by generating an MLME-SETPROTECTION.request(None) primitive.

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f) If the STA is contained within an AP or PCP, its SME, upon receipt of an MLME-DEAUTHENTICATE.confirm primitive, shall release the AID assigned for the indicated STA, if the state for the indicated STA was State 3 or State 4.

g) If the STA is contained within an AP, its SME shall inform the DS of the disassociation, if the state for the indicated STA was State 3 or State 4.

h) If the STA is a mesh STA, its SME shall inform the mesh peering instance controller (see 14.4.4 (Mesh peering instance controller)) of the deauthentication.

#### 11.3.4.5 Deauthentication—destination STA

A DMG STA in State 2, State 3 or State 4 that receives a Deauthentication frame shall remain in the same state if it did not perform an IEEE 802.11 authentication exchange.

Otherwise, upon receipt of a Deauthentication frame from a STA for which the state is (11az)State 1a, State 2, State 3, or State 4, the destination STA shall deauthenticate with the originating STA using the following procedure:

a) If management frame protection was not negotiated when the PTKSA(s) were created, or if management frame protection was negotiated when the PTKSA(s) were created(#7049) and the frame is not discarded per management frame protection processing, the MLME shall issue an MLME-DEAUTHENTICATE.indication primitive to inform the SME of the deauthentication, and set the state for the originating STA to State 1.

b) Upon receiving an MLME-DEAUTHENTICATE.indication primitive, the SME shall

   1) Delete any PTKSA, GTKSA, IGTKSA, BIGTKSA(11ba), WIGTKSA, (#3344)WTKSA and TPKSA (including temporal keys)(#205) held for communication with the originating STA by using the MLME-DELETEKEYS.request primitive (see 12.6.16 (RSNA security association termination)) and by generating an MLME-SETPROTECTION.request(None) primitive.

   2) If the STA is contained within an AP or PCP, release the AID assigned for the indicated STA.

   3) If the STA is contained within an AP, inform the DS of the disassociation, if the state for the originating STA was State 3 or State 4.

   4) If the STA is a mesh STA, inform the mesh peering instance controller (see 14.4.4 (Mesh peering instance controller)) of the deauthentication.

### 11.3.5 Association, reassociation, and disassociation

#### 11.3.5.1 General

Subclause 11.3.5 (Association, reassociation, and disassociation) describes the procedures used for IEEE 802.11 association, reassociation, and disassociation.

The states used in this description are defined in 11.3.1 (State variables).

Successful association enables a STA to exchange Class 3 frames. Successful association sets the state for a non-FILS STA to State 3 or State 4. Successful association sets the state for FILS STAs to State 4. (11az)Association and reassociation are not allowed in State 1 and State 1a. In order to associate or reassociate, a STA in State 1 or State 1a shall perform an IEEE 802.11 non-PASN authentication or FILS authentication and transition to State 2.

Successful reassociation enables a STA to exchange Class 3 frames. Unsuccessful reassociation (11az)leaves the state for a STA state unchanged (with respect to the AP or PCP that was sent the Reassociation Request (which may be the current STA))(#3212). Successful reassociation sets the state for a non-FILS STA to State 3 or State 4 (with respect to the AP or PCP that was sent the Reassociation Request frame). Successful reassociation sets the state for a STA to State 2 (with respect to the current AP or PCP, if this is not the AP or


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PCP that was sent the Reassociation Request frame). Successful reassociation sets the state for a FILS STA to State 4 (with respect to the AP or PCP that was sent the Reassociation Request frame).(#429) Reassociation shall be performed only if the originating STA is already associated in the same ESS.

Disassociation notification when not in State 1 sets the state for a non-FILS STA to State 2. Disassociation notification when not in State 1 sets the state for a FILS STA to State 1. The STA shall become associated again prior to sending Class 3 frames. A STA may disassociate a peer STA at any time, for any reason. (11az)The state shall remain unchanged upon disassociation notification in State 1a.

If non-DMG STA A in an infrastructure BSS receives a Class 3 frame from STA B that is authenticated but not associated with STA A (i.e., the state for STA B is State 2 (11az)or State 1a), STA A shall discard the frame. If the frame has an individual address in the Address 1 field, the MLME of STA A should(#3509) send a Disassociation frame to STA B.

NOTE—STA A might choose not to send a frame if a denial-of-service attack is suspected.(#3509)

If DMG STA A in an infrastructure BSS receives a Class 3 frame from STA B that is not associated with STA A (i.e., the state for STA B is State 2 (11az)or State 1a), STA A shall discard the frame. If the frame has an individual address in the Address 1 field, the MLME of STA A shall send a Disassociation frame to STA B.

If an MM-SME coordinated STA receives an Association Response frame with a status code(#1780) equal to SUCCESS and with the Single AID field (#1776)within an MMS element equal to 1, then

— For each of its MAC entities advertised within the MMS element and for which dot11RSNAActivated is true, the state is set to State 3. Progress from State 3 to State 4 occurs independently in each such MAC entity.

— For each of its MAC entities advertised within the MMS element and for which dot11RSNAActivated is false, the state is set to State 4.

If the MM-SME coordinated STA in State 3 is assigned an AID for only the MAC entity identified by the RA field of the Association Response frame with status code(#1780) equal to SUCCESS, the MM-SME may repeat the association procedure for any other MAC entity coordinated by the MM-SME.

Association is not applicable in an IBSS. In an infrastructure BSS, association is required (11az)to exchange Class 3 frames. In a PBSS, association is optional. APs and PCPs do not initiate association.

#### 11.3.5.2 Non-AP and non-PCP STA association initiation procedures

The SME shall delete any PTKSA, GTKSA, IGTKSA, BIGTKSA(11ba), WIGTKSA, (#3344)WTKSA, and TPKSA (including temporal keys)(#205) held for communication with the AP or PCP by using MLME-DELETEKEYS.request primitive (see 12.6.16 (RSNA security association termination)) before invoking MLME-ASSOCIATE.request primitive.

If dot11InterworkingServiceActivated is true, the STA is associating with an AP but does not have credentials for the AP, and the STA is initiating an emergency services association procedure, the SME shall submit the MLME-ASSOCIATE.request primitive with EmergencyServices parameter set to true.

The MM-SME of a non-AP and non-PCP STA may include an MMS element in an MLME-ASSOCIATE.request primitive. The MM-SME shall include in the MMS element the MAC address associated with the MLME SAP instance to which the primitive is submitted.

Upon receipt of an MLME-ASSOCIATE.request primitive that is part of an on-channel tunneling (see 11.31.5 (On-channel Tunneling (OCT) operation)), a non-AP and non-PCP STA shall follow the rules in 11.31.5 (On-channel Tunneling (OCT) operation) in addition to the association procedures described below.

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Upon receipt of an MLME-ASSOCIATE.request primitive, a non-AP and non-PCP STA shall associate with an AP or PCP using the following procedure:

a) If the state for the AP or PCP is State 1 (11az)or State 1a, the MLME shall inform the SME of the failure of the association by issuing an MLME-ASSOCIATE.confirm primitive, and this procedure ends.

b) All the states, agreements and allocations listed in both numbered lists in (#4120)11.3.5.4 (Non-AP and non-PCP STA reassociation initiation procedures) item c) are deleted or reset to initial values.

c) The MLME shall transmit an Association Request frame to the AP or PCP. The RSNE contained in the MLME-ASSOCIATE.request primitive shall be included in the Association Request frame. The RSNE shall specify exactly one pairwise cipher suite and exactly one AKM suite. If the MLME-ASSOCIATE.request primitive contained the EmergencyServices parameter equal to true, an Interworking element with the UESA field set to 1 shall be included in the Association Request frame.

d) If an Association Response frame is received with a status code of SUCCESS, a DMG STA shall write to each of the following MIB attributes the corresponding subfield of the DMG BSS Parameter Configuration field of the DMG Operation element received from the AP or PCP to which it requested association:

1) dot11PSRequestSuspensionInterval from the PSRequestSuspensionInterval subfield
2) dot11MinBHIDuration from the MinBHIDuration subfield
3) dot11BroadcastSTAInfoDuration from the BroadcastSTAInfoDuration subfield
4) dot11AssocRespConfirmTime from the AssocRespConfirmTime subfield
5) dot11MinPPDuration from the MinPPDuration subfield
6) dot11SPIdleTimeout from the SPIdleTimeout subfield
7) dot11MaxLostBeacons from the MaxLostBeacons subfield

e) If an Association Response frame is received with a status code of SUCCESS, the state for the AP or PCP shall be set to State 4 or, if dot11RSNAActivated is true, State 3. The state for any other AP or PCP which is State 3 or State 4 prior to the association request shall be set to State 2, and the MLME shall issue an MLME-ASSOCIATE.confirm primitive to inform the SME of the successful completion of the association.

f) If an Association Response frame is received with a status code of SUCCESS at an MM-SME coordinated STA and the Single AID field within the MMS element is equal to 1, then

— For each of its MAC entities advertised within the MMS element and for which dot11RSNAActivated is true, the state is set to State 3. Progress from State 3 to State 4 occurs independently in each such MAC entity.
— For each of its MAC entities advertised within the MMS element and for which dot11RSNAActivated is false, the state is set to State 4.
— For each of its MAC entities advertised within the MMS element the state for any other AP or PCP which is State 3 or State 4 prior to the association request shall be set to State 2.

g) If an Association Response frame is received with a status code other than SUCCESS or the association fails to complete within dot11AssociationResponseTimeout the state for the AP or PCP shall be set to State 2, and the MLME shall issue an MLME-ASSOCIATE.confirm primitive to inform the SME of the failure of the association. The status code returned in the Association Response frame indicates the cause of the failed association attempt. Any misconfiguration or parameter mismatch, e.g., data rates required as basic rates that the STA did not indicate as supported in the STA's Supported Rates and BSS Membership Selectors element, shall be corrected before the SME issues an MLME-ASSOCIATE.request primitive for the same AP or PCP. If the status code indicates the association failed because of a reason that is not related to configuration (e.g., the AP or PCP is unable to support additional associations) and the Association Response frame does not include a (#1776)TIE with Timeout Interval Type equal to 3 the SME shall not issue


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an MLME-ASSOCIATE.request primitive for the same AP or PCP until a period of at least 2 s has elapsed. If the status code indicates the association failed and the Association Response frame contains a (#1776)TIE with Timeout Interval Type equal to 3, the SME shall not issue an MLME-ASSOCIATE.request primitive for the same AP or PCP until the period specified in the (#1776)TIE has elapsed.

h) If an MLME-ASSOCIATE.confirm primitive is received with a ResultCode of SUCCESS, and RSNA is required, and FILS authentication was not used, then the SME shall perform a 4-way handshake to establish an RSNA. As a part of a successful 4-way handshake, the SME shall enable protection by generating an MLME-SETPROTECTION.request(Rx_Tx) primitive. If an MLME-ASSOCIATE.confirm primitive is received with a ResultCode of SUCCESS, and FILS authentication was used, then the SME shall enable protection by generating an MLME-SETPROTECTION.request(Rx_Tx) primitive.

i) Upon receipt of the MLME-SETPROTECTION.request(Rx_Tx) primitive, the MLME shall set the state of the STA to State 4.

(#2128)NOTE—Any MSDU fragments from the AP or PCP, and if management frame protection was negotiated for the existing association(#7049), any MMPDU fragments from the AP or PCP, are discarded at this point (see 12.6.12 (RSNA key management in an infrastructure BSS)), since fragments are required to be encrypted with the same key (see 10.5 (MSDU, (11ax)A-MSDU, and MMPDU defragmentation)).

#### 11.3.5.3 AP or PCP association receipt procedures

Upon receipt of an Association Request frame from a STA the AP or PCP shall use the following procedure:

a) The MLME shall issue an MLME-ASSOCIATE.indication primitive to inform the SME of the association request. The SME shall issue an MLME-ASSOCIATE.response primitive addressed to the STA identified by the PeerSTAAddress parameter of the MLME-ASSOCIATE.indication primitive. If the association is not successful, the SME shall indicate a specific reason for the failure to associate in the ResultCode parameter. Upon receipt of the MLME-ASSOCIATE.response primitive, the MLME shall transmit an Association Response frame.

b) (#1983)If the state for the STA is State 1 and the STA is a non-DMG STA, the SME shall refuse the association request by issuing an MLME-ASSOCIATE.response primitive with ResultCode NOT_AUTHENTICATED. (11az)If the state for the STA is State 1a and the STA is a non-DMG STA, the SME shall refuse the association request by issuing an MLME-ASSOCIATE.response primitive with ResultCode PASN_NOT_AUTHORIZED.

c) AP with dot11InterworkingServiceActivated true only: If the MLME-ASSOCIATE.indication primitive has the EmergencyServices parameter set to true and the RSN parameter does not include an RSNE, the SME shall not reject the association request on the basis that dot11RSNAActivated is true, thereby granting access, using unprotected frames (see 9.2.4.1.9 (Protected Frame subfield)), to the network for emergency services purposes.

d) Otherwise, in an RSNA the SME shall check the values received in the RSN parameter to see whether the values received match the security policy. If they do not, the SME shall refuse the association by issuing an MLME-ASSOCIATE.response primitive with a ResultCode indicating the security policy mismatch.

e) Otherwise, (#1983)if the state for the STA is State 4, the STA has a valid security association, the STA has negotiated management frame protection, the STA has not performed a successful SAE authentication after the current association was established, (#4069)the STA did not include a valid Known STA Identification element (see 11.13 (SA Query procedures)), and there has been no earlier, timed out SA Query procedure with the STA (which would have allowed a new association process to be started, without an additional SA Query procedure):

   1) The SME shall refuse the association request by issuing an MLME-ASSOCIATE.response primitive with ResultCode REFUSED_TEMPORARILY and TimeoutInterval containing a (#1776)TIE with the Timeout Interval Type field set to 3 (association comeback time(#3389)).

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If the SME is in an ongoing SA Query with the STA, the Timeout Interval Value field shall be set to the remaining SA Query period, otherwise it shall be set to dot11AssociationSAQuery-MaximumTimeout.

2) The state for the STA shall be left unchanged.

3) Following this, if the SME is not in an ongoing SA Query with the STA, the SME shall issue one MLME-SA-QUERY.request primitive addressed to the STA every dot11AssociationSAQueryRetryTimeout TUs until an MLME-SA-QUERY.confirm primitive for the STA is received or dot11AssociationSAQueryMaximumTimeout TUs from the beginning of the SA Query procedure have passed. The SME shall increment the TransactionIdentifier by 1 for each MLME-SA-QUERY.request primitive, (#1645)rolling it over to 0 after the maximum allowed value is reached.

4) If no MLME-SA-QUERY.confirm primitive for the STA is received within the dot11AssociationSAQueryMaximumTimeout period, the SME shall allow a subsequent association process with the STA to be started without starting an additional SA Query procedure, except that the SME may deny a subsequent association process with the STA if an MSDU was received from the STA within this period.

NOTE 1—Reception of an MSDU implies reception of a valid protected frame, which obviates the need for the SA Query procedure.

f) The SME shall refuse an association request from a STA that does not support all of the rates in the BSSBasicRateSet parameter and all of the membership selectors in the BSSMembershipSelectorSet parameter in the MLME-START.request primitive.

g) The SME shall refuse an association request from an HT STA that does not support all of the MCSs in the Basic HT-MCS Set field of the HT Operation parameter in the MLME-START.request primitive.

h) The SME shall refuse an association request from a VHT STA that does not support all of the <VHT-MCS, NSS> tuples indicated by the Basic VHT-MCS And NSS Set field of the VHT Operation parameter in the MLME-START.request primitive.

i) The SME shall refuse an association request from an HE STA that does not support all of the <HE-MCS, NSS> tuples indicated by the Basic HE-MCS And NSS Set field of the HE Operation parameter in the MLME-START.request primitive.(11ax)

j) An AP or PCP may refuse GLK association based on local policy and, if so, shall return the GLK_NOT_AUTHORIZED ResultCode.

NOTE 2—For example, there might be a list of authorized GLK peers or clients or a limit on the number of GLK peers or clients and the peer or client is not on that list or its acceptance would exceed the limit.

k) The SME shall generate an MLME-ASSOCIATE.response primitive with the PeerSTAAddress parameter set to the MAC address of the STA identified by the PeerSTAAddress parameter of the MLME-ASSOCIATE.indication primitive. If the ResultCode in the MLME-ASSOCIATE.response primitive is SUCCESS, the SME has an existing SA with the STA, and an SA Query procedure with that STA has failed to receive a valid response (i.e., has not received an MLME-SA-QUERY.confirm primitive within the dot11AssociationSAQueryMaximumTimeout period), the SME shall issue an MLME-DISASSOCIATE.request primitive addressed to the STA with ReasonCode INVALID_AUTHENTICATION.

NOTE 3—This MLME-DISASSOCIATE.request primitive generates a protected Disassociation frame. If the association request was genuine, the STA has deleted the PTKSA by this point and so the protected Disassociation frame is (#3683)discarded. The purpose is to inform a STA (#1414)that has for some reason failed to respond to an SA Query procedure triggered by a forged association request.


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l) If the ResultCode in the MLME-ASSOCIATE.response primitive is SUCCESS, all the states, agreements and allocations pertaining to the associating STA and listed in both numbered lists in (#4120)11.3.5.4 (Non-AP and non-PCP STA reassociation initiation procedures) item c) are deleted or reset to initial values.

m) If the ResultCode in the MLME-ASSOCIATE.response primitive is SUCCESS, the SME shall delete any PTKSA, GTKSA, IGTKSA, BIGTKSA(11ba), (#3344)WIGTKSA, WTKSA, and TPKSA (including temporal keys)(#205) held for communication with the STA by using the MLME-DELETEKEYS.request primitive (see 12.6.16 (RSNA security association termination)).

n) If the MLME-ASSOCIATE.indication primitive includes an MMS parameter, the AP or PCP shall generate the MLME-ASSOCIATE.response primitive directed to the MLME of the STA identified by the PeerSTAAddress parameter of the MLME-ASSOCIATE.request primitive and take the following additional action, as appropriate:

1) If the Single AID field in the MMS parameter of the MLME-ASSOCIATE.indication primitive is equal to 1, the AP or PCP may allocate a single AID for all of the STAs included in the MMS element. If the AP or PCP allocates the same AID to each STA whose MAC address was included in the MMS element, it shall include the MMS element received from the MM-SME coordinated STA in the MLME-ASSOCIATE.response primitive.

2) If the Single AID field is 0, the AP or PCP shall allocate a distinct AID for each STA specified in the MMS element.

NOTE 4—When the Single AID field is 0, (#4173)a separate association request/response frame exchange is performed for each STA specified in the MMS element, and this assigns the multiple AIDs for the STAs.

o) If an Association Response frame with a status code of SUCCESS is acknowledged by the STA, the state for the STA shall be set to State 4 or, if dot11RSNAActivated is true, State 3.

p) If the ResultCode in the MLME-ASSOCIATE.response primitive is not SUCCESS and management frame protection was negotiated for the existing association(#7049) the state for the STA shall be left unchanged. If the ResultCode is not SUCCESS and management frame protection (#7049)was not negotiated for the existing association the state for the STA shall be set to State 3 if it was State 4.

(#2128)NOTE 5—Any MSDU fragments from the STA, and if management frame protection was negotiated for the existing association(#7049), any MMPDU fragments from the STA, are discarded at this point (see 12.6.12 (RSNA key management in an infrastructure BSS)), since fragments are required to be encrypted with the same key (see 10.5 (MSDU, (11ax)A-MSDU, and MMPDU defragmentation)).

q) If the ResultCode in the MLME-ASSOCIATE.response primitive is SUCCESS and RSNA establishment is required, and FILS authentication was not used, the SME shall attempt a 4-way handshake. Upon a successful completion of the 4-way handshake, the SME shall enable protection by issuing an MLME-SETPROTECTION.request(Rx_Tx) primitive. If FILS authentication was used, the SME shall enable protection by generating an MLME-SETPROTECTION.request(Rx_Tx) primitive. In either case, upon receipt of the MLME-SETPROTECTION.request(Rx_Tx) primitive, the MLME shall set the state for the STA to State 4.

r) AP only: The SME shall inform the DS of any changes in the state of the STA.

### 11.3.5.4 Non-AP and non-PCP STA reassociation initiation procedures

Except when the association is part of a fast BSS transition, the SME shall delete any PTKSA, GTKSA, IGTKSA, BIGTKSA(11ba), (#3344)WIGTKSA, WTKSA, and TPKSA (including temporal keys)(#205) held for communication with the AP or PCP by using the MLME-DELETEKEYS.request primitive (see 12.6.16 (RSNA security association termination)) before invoking an MLME-REASSOCIATE.request primitive.

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If dot11InterworkingServiceActivated is true and the STA was associated to the ESS for unsecured access to emergency services, the SME shall submit the MLME-REASSOCIATE.request primitive with EmergencyServices parameter set to true.

The MM-SME of a non-AP and non-PCP STA may include an MMS element in an MLME-REASSOCIATE.request primitive. The MM-SME shall include in the MMS element the MAC address associated with the MLME SAP instance to which the primitive is submitted.

Upon receipt of an MLME-REASSOCIATE.request primitive that is part of an on-channel tunneling (see 11.31.5 (On-channel Tunneling (OCT) operation)), a non-AP and non-PCP STA shall follow the rules in 11.31.5 (On-channel Tunneling (OCT) operation) in addition to the reassociation procedures described below.

Upon receipt of an MLME-REASSOCIATE.request primitive, a non-AP and non-PCP STA shall reassociate with an AP or PCP using the following procedure:

a) If the STA is not associated in the same ESS or the state for the new AP or PCP is State 1 (11az)or State 1a, the MLME shall inform the SME of the failure of the reassociation by issuing an MLME-REASSOCIATE.confirm primitive, and this procedure ends.

b) The MLME shall transmit a Reassociation Request frame to the new AP or PCP. The RSNE contained in the MLME-ASSOCIATE.request primitive shall be included in the Reassociation Request frame. The RSNE shall specify exactly one pairwise cipher suite and exactly one AKM suite. If the MLME-REASSOCIATE.request primitive contained the EmergencyServices parameter equal to true, an Interworking element with the UESA field set to 1 shall be included in the Reassociation Request frame.

c) If a Reassociation Response frame is received with a status code of SUCCESS, the state variable for the new AP or PCP shall be set to State 4 or to State 3 if dot11RSNAActivated is true and the FT protocol is not used with respect to the new AP or PCP and, unless the old AP or PCP and new AP or PCP are the same, to State 2 with respect to the old AP or PCP, and the MLME shall issue an MLME-REASSOCIATE.confirm primitive to inform the SME of the successful completion of the reassociation.

   If the MLME-REASSOCIATION.request primitive has the new AP's or PCP's MAC address in the CurrentAPAddress parameter (reassociation to the same AP or PCP), the following states, agreements, and allocations shall be deleted or reset to initial values:

   1) All EDCAF state
   2) Any block ack agreements that are not GCR agreements
   3) Sequence number(#1388)
   4) Duplicate detection caches
   5) Anything queued for transmission
   6) Fragmentation and reassembly buffers
   7) Power management mode
   8) WNM sleep mode
   9) TDLS agreements(#1522)
   10) TPKSAs established with any peers
   11) TSPECs
   12) DMG TSPECs
   13) GLK-GCR agreement
   14) MSCS
   15) SCS

   If the reassociation is to the same AP (as described above), the following states, agreements, and allocations are not affected by the reassociation procedure: (#3263)(#8237)

   1) Enablement/Deenablement


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2) GDD enablement(#1522)
3) MMSLs
4) GCR agreements that are not GLK-GCR agreements
5) DMS agreements
6) TFS agreements
7) FMS agreements
8) Triggered autonomous reporting agreements
9) FTM sessions
10) DMG SP and CBAP allocations
11) PTP TSPECs

In the case of reassociation to a different AP or PCP (the CurrentAPAddress parameter is not the new AP's or PCP's MAC address), all the states, agreements and allocations listed above are deleted or reset to initial values.

d) If a Reassociation Response frame is received with a status code of SUCCESS, a DMG STA shall write to each of the following MIB attributes the corresponding subfield of the DMG BSS Parameter Configuration field of the DMG Operation element received from the AP or PCP to which it requested reassociation:

1) dot11PSRequestSuspensionInterval from the PSRequestSuspensionInterval subfield
2) dot11MinBHIDuration from the MinBHIDuration subfield
3) dot11BroadcastSTAInfoDuration from the BroadcastSTAInfoDuration subfield
4) dot11AssocRespConfirmTime from the AssocRespConfirmTime subfield
5) dot11MinPPDuration from the MinPPDuration subfield
6) dot11SPIdleTimeout from the SPIdleTimeout subfield
7) dot11MaxLostBeacons from the MaxLostBeacons subfield

e) If an Association Response frame is received with a status code of SUCCESS at an MM-SME coordinated STA and the Single AID field within the MMS element is equal to 1, then

— For each of its MAC entities advertised within the MMS element and for which dot11RSNAActivated is true, the state is set to State 3. Progress from State 3 to State 4 occurs independently in each such MAC entity.
— For each of its MAC entities advertised within the MMS element and for which dot11RSNAActivated is false, the state is set to State 4.
— For each of its MAC entities advertised within the MMS element the state for any other AP or PCP which is State 3 or State 4 prior to the association request shall be set to State 2.

f) If a Reassociation Response frame is received with a status code other than SUCCESS or the reassociation fails to complete within dot11AssociationResponseTimeout:

1) Except when the association is part of a fast BSS transition, the state for the AP or PCP shall be set to State 2 with respect to the new AP or PCP.

NOTE —This means the STA is disassociated in case of failure of reassociation to the same AP.(#1699)

2) The MLME shall issue an MLME-REASSOCIATE.confirm primitive to inform the SME of the failure of the reassociation. The ResultCode returned in the MLME-REASSOCIATE.confirm primitive indicates the cause of the failed reassociation attempt. Any misconfiguration or parameter mismatch, e.g., data rates required as basic rates that the STA did not indicate as supported in the STA's Supported Rates and BSS Membership Selectors element, shall be corrected before the SME issues an MLME-REASSOCIATE.request primitive for the same AP or PCP. If the status code indicates the reassociation failed because of a reason that is not related to configuration (e.g., the AP or PCP is unable to support additional associations) and the Reassociation Response frame does not include a (#1776)TIE with Timeout Interval Type equal to 3 the SME shall not issue an MLME-

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REASSOCIATE.request primitive for the same AP or PCP until a period of at least 2 s has elapsed. If the status code indicates the reassociation failed and the Reassociation Response frame contains a (#1776)TIE with Timeout Interval Type equal to 3, the SME shall not issue an MLME-REASSOCIATE.request primitive for the same AP or PCP until the period specified in the (#1776)TIE has elapsed.

g) If an MLME-REASSOCIATE.confirm primitive is received with a ResultCode of SUCCESS, and RSNA is required, and FILS authentication was not used, and the STA is in State 3, then the SME shall perform a 4-way handshake to establish an RSNA. As a part of a successful 4-way handshake, the SME shall enable protection by generating an MLME-SETPROTECTION.request(Rx_Tx) primitive. If an MLME-REASSOCIATE.confirm primitive is received with a ResultCode of SUCCESS, and FILS authentication was used, and the STA is in State 3, then the SME shall enable protection by generating an MLME-SETPROTECTION.request(Rx_Tx) primitive.

h) Upon receipt of the MLME-SETPROTECTION.request(Rx_Tx) primitive, the MLME shall set the state of the STA to State 4.

(#2128)NOTE—Per item 6) in the first list under c) any MSDU fragments in the reassembly buffers, and if management frame protection was negotiated for the existing association(#7049), any MMPDU fragments, have been discarded. This is important since fragments are required to be encrypted with the same key (see 10.5 (MSDU, (11ax)A-MSDU, and MMPDU defragmentation)).

#### 11.3.5.5 AP or PCP reassociation receipt procedures

Upon receipt of a Reassociation Request frame from a STA the AP or PCP shall use the following procedure:

a) The MLME shall issue an MLME-REASSOCIATE.indication primitive to inform the SME of the reassociation request. The SME shall issue an MLME-REASSOCIATE.response primitive addressed to the STA identified by the PeerSTAAddress parameter of the MLME-REASSOCIATE.indication primitive. If the reassociation is not successful, the SME shall indicate a specific reason for the failure to reassociate in the ResultCode parameter. Upon receipt of the MLME-REASSOCIATE.response primitive, the MLME shall transmit a Reassociation Response frame.

b) (#1983)If the state for the STA is State 1 (11az)or State 1a and the STA is a non-DMG STA, the SME shall refuse the reassociation request by issuing an MLME REASSOCIATE.response primitive with ResultCode NOT_AUTHENTICATED. If the state for the STA is State 1a and the STA is a non-DMG STA, the SME shall refuse the reassociation request by issuing an MLME REASSOCIATE.response primitive with ResultCode PASN_NOT_AUTHORIZED.

c) AP with dot11InterworkingServiceActivated true only: If the MLME-REASSOCIATE.indication primitive has the EmergencyServices parameter set to true and the RSN parameter does not include an RSNE, the SME shall not reject the reassociation request on the basis that dot11RSNAActivated is true (#3056)thereby granting access, using unprotected frames (see 9.2.4.1.9 (Protected Frame subfield)), to the network for emergency services purposes.

d) Otherwise, in an RSNA the SME shall check the values received in the RSN parameter to see whether the values received match the security policy. If they do not, SME shall refuse the reassociation by issuing an MLME-REASSOCIATE.response primitive with a ResultCode indicating the security policy mismatch.

e) Otherwise, (#1983)if the state for the STA is State 4, the STA has a valid security association, the STA has negotiated management frame protection, the reassociation is not a part of a fast BSS transition, the STA has not performed a successful SAE authentication after the current association was established, (#4069)the STA did not include a valid Known STA Identification element (see 11.13 (SA Query procedures)), and there has been no earlier, timed out SA Query procedure with the STA (which would have allowed a new reassociation process to be started, without an additional SA Query procedure):


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1) The SME shall refuse the reassociation request by issuing an MLME-REASSOCIATE.response primitive with ResultCode REFUSED_TEMPORARILY and TimeoutInterval containing a (#1776)TIE with the Timeout Interval Type field set to 3 (association comeback time(#3389)). If the SME is in an ongoing SA Query with the STA, the Timeout Interval Value field shall be set to the remaining SA Query period, otherwise it shall be set to dot11AssociationSAQueryMaximumTimeout.

2) The state for the STA shall be left unchanged.

3) Following this, if the SME is not in an ongoing SA Query with the STA, the SME shall issue one MLME-SA-QUERY.request primitive addressed to the STA every dot11AssociationSAQueryRetryTimeout TUs until an MLME-SA-QUERY.confirm primitive for the STA is received or dot11AssociationSAQueryMaximumTimeout TUs from the beginning of the SA Query procedure have passed. The SME shall increment the TransactionIdentifier by 1 for each MLME-SA-QUERY.request primitive, rolling it over to 0 after the maximum allowed value is reached.

4) If no MLME-SA-QUERY.confirm primitive for (#1644)the STA is received within the dot11AssociationSAQueryMaximumTimeout period, the SME shall allow a subsequent reassociation process to be started without starting an additional SA Query procedure, except that the SME may deny a subsequent reassociation process with the STA if an MSDU was received from the STA within this period.

NOTE 1—Reception of an MSDU implies reception of a valid protected frame, which obviates the need for the SA Query procedure.

f) The SME shall refuse a reassociation request from a STA that does not support all the rates in the BSSBasicRateSet parameter and all of the membership selectors in the BSSMembershipSelectorSet parameter in the MLME-START.request primitive.

g) The SME shall refuse a reassociation request from an HT STA that does not support all of the MCSs in the Basic HT-MCS Set field of the HT Operation parameter in the MLME-START.request primitive.

h) The SME shall refuse a reassociation request from a VHT STA that does not support all of the <VHT-MCS, NSS> tuples indicated by the Basic VHT-MCS And NSS Set field of the VHT Operation parameter in the MLME-START.request primitive.

i) The SME shall refuse a reassociation request from an HE STA that does not support all of the <HE-MCS, NSS> tuples indicated by the Basic HE-MCS And NSS Set field of the HE Operation parameter in the MLME-START.request primitive.(11ax)

j) If the ResultCode in the MLME-REASSOCIATE.response primitive is SUCCESS, the SME has an existing SA with the STA, and an SA Query procedure with that STA has failed to receive a valid response (i.e., has not received an MLME-SA-QUERY.confirm primitive within the dot11AssociationSAQueryMaximumTimeout period), the SME shall issue an MLME-DISASSOCIATE.request primitive addressed to the STA with ReasonCode INVALID_AUTHENTICATION.

NOTE 2—This MLME-DISASSOCIATE.request primitive generates a protected Disassociation frame. If the reassociation request was genuine, the STA has deleted the PTKSA by this point and so the protected Disassociation frame is discarded. The purpose is to inform a STA (#1414)that has for some reason failed to respond to an SA Query procedure triggered by a forged reassociation request.

k) If (#1699)management frame protection was not negotiated for the existing association(#7049), or the ResultCode in the MLME-REASSOCIATE.response primitive is SUCCESS and the reassociation is not part of a fast BSS transition, the SME shall delete any PTKSA, GTKSA, IGTKSA, BIGTKSA(11ba), (#3344)WIGTKSA, WTKSA, and TPKSA (including temporal keys)(#205) held for communication with the STA by using the MLME-DELETEKEYS.request primitive (see 12.6.16 (RSNA security association termination)).

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l) If the MLME-REASSOCIATE.indication primitive includes an MMS parameter, the AP or PCP shall take the following additional action, as appropriate:

1) If the Single AID field in the MMS parameter of the MLME-REASSOCIATE.indication primitive is equal to 1, the AP or PCP may allocate a single AID for all of the STAs included in the MMS element. If the AP or PCP allocates the same AID to all STAs whose MAC address was included in the MMS element, it shall include the MMS element received from the MM-SME coordinated STA in the MLME-REASSOCIATE.response primitive.

2) If the Single AID field is 0, the AP or PCP shall allocate a distinct AID for each STA specified in the MMS element.

NOTE 3—When the Single AID field is 0, (#4173)a separate reassociation request/response frame exchange is performed for each STA specified in the MMS element, and this assigns the multiple AIDs for the STAs.

m) If a Reassociation Response frame with a status code of SUCCESS is acknowledged by the STA, the state for the STA shall be set to State 4, or to State 3 if dot11RSNAActivated is true and the reassociation is not part of a fast BSS transition.

n) If the ResultCode in the MLME-REASSOCIATE.response primitive is not SUCCESS and management frame protection was negotiated for the existing association(#7049) the state for the STA shall be left unchanged. If the ResultCode is not SUCCESS, management frame protection was not negotiated for the existing association(#7049), and the reassociation is part of a fast BSS transition, the state for the STA shall be left unchanged. If the ResultCode is not SUCCESS, management frame protection was not negotiated for the existing association(#7049), the reassociation is not part of a fast BSS transition, and the state for the STA was State 3 or State 4, the state for the STA shall be set to State 2 if the reassociation is for the same AP, or to State 3 otherwise.(#1699)

o) If the ResultCode in the MLME-REASSOCIATE.response primitive is SUCCESS, RSNA establishment is required, and the reassociation is not part of a fast BSS transition, and FILS is not in use, the SME shall attempt a 4-way handshake. Upon a successful completion of a 4-way handshake, the SME shall enable protection by issuing an MLME-SETPROTECTION.request(Rx_Tx) primitive. If FILS authentication was used, the SME shall enable protection by generating an MLME-SETPROTECTION.request(Rx_Tx) primitive. In either case, upon receipt of the MLME-SETPROTECTION.request(Rx_Tx) primitive, the MLME shall set the state for the STA to State 4.

p) AP only: The SME shall inform the DS of any changes in the state of the STA.

q) If the ResultCode in the MLME-REASSOCIATE.response primitive is SUCCESS and the CurrentAPAddress parameter in the MLME-REASSOCIATION.indication primitive is this AP's or PCP's MAC address (reassociation to the same AP or PCP), the AP or PCP shall match the non-AP STA's treatment of the listed agreements and allocations as described in 11.3.5.4 (Non-AP and non-PCP STA reassociation initiation procedures) item c). The AP or PCP deletes or resets to initial values those items that the non-AP STA is required in 11.3.5.4 (Non-AP and non-PCP STA reassociation initiation procedures) item c) to delete or reset to initial values, and the AP or PCP does not modify the states, agreements and allocations that are listed as not affected by the reassociation procedure.

r) If the ResultCode in the MLME-REASSOCIATE.response primitive is SUCCESS and the CurrentAPAddress parameter in the MLME-REASSOCIATION.indication primitive is not this AP's or PCP's MAC address (reassociation to a different AP or PCP), all the states, agreements and allocations pertaining to the associating STA and listed in both numbered lists in 11.3.5.4 (Non-AP and non-PCP STA reassociation initiation procedures) item c) are deleted or reset to initial values.

(#2128)NOTE 4—Per 11.3.5.4 (Non-AP and non-PCP STA reassociation initiation procedures) item 6) in the first list under c) any MSDU fragments in the reassembly buffers, and if management frame protection was negotiated for the existing association(#7049), any MMPDU fragments, have been discarded. This is important since fragments are required to be encrypted with the same key (see 10.5 (MSDU, (11ax)A-MSDU, and MMPDU defragmentation)).


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#### 11.3.5.6 Non-AP and non-PCP STA disassociation initiation procedures

The SME shall issue an MLME-DISASSOCIATE.request primitive that includes an appropriate Reason Code as defined in Table 9-79 (Reason codes) of 9.4.1.7 (Reason Code field).

Upon receipt of an MLME-DISASSOCIATE.request primitive, a non-AP and non-PCP STA's MLME shall disassociate from an AP or PCP using the following procedure:

a) If the state for the AP or PCP is State 3 or State 4, the MLME shall transmit a Disassociation frame to the AP or PCP.

b) The state for the AP or PCP shall be set to State 2 if it was not State 1 (11az)or State 1a. In the case of an MM-SME coordinated STA, the MLME shall perform this for each STA whose address was included in the MMS parameter of the MLME-ASSOCIATE.request or MLME-REASSOCIATE.request primitive that established the association.

c) The MLME shall issue an MLME-DISASSOCIATE.confirm primitive to inform the SME of the successful completion of the disassociation.

d) Upon receiving an MLME-DISASSOCIATE.confirm primitive, the SME shall delete any PTKSA, GTKSA, IGTKSA, BIGTKSA(11ba), (#3344)WIGTKSA, WTKSA, and TPKSA (including temporal keys)(#205) held for communication with the AP or PCP by using the MLME-DELETEKEYS.request primitive (see 12.6.16 (RSNA security association termination)) and by invoking an MLME-SETPROTECTION.request(None) primitive. In the case of an MM-SME coordinated STA, the MLME shall perform this for each STA whose address was included in the MMS parameter of the MLME-ASSOCIATE.request or MLME-REASSOCIATE.request primitive that established the association.

#### 11.3.5.7 Non-AP and non-PCP STA disassociation receipt procedure

Upon receipt of a Disassociation frame from an AP or PCP for which the state is State 3 or State 4, if management frame protection was not negotiated when the PTKSA(s) were created, or if management frame protection was negotiated when the PTKSA(s) were created(#7049) and the frame is not discarded per management frame protection processing, a non-AP and non-PCP STA shall disassociate from the AP or PCP using the following procedure:

a) The state for the AP or PCP shall be set to State 2.

b) The MLME shall issue an MLME-DISASSOCIATE.indication primitive to inform the SME of the disassociation.

c) Upon receiving the MLME-DISASSOCIATE.indication primitive, the SME shall delete any PTKSA, GTKSA, IGTKSA, BIGTKSA(11ba), (#3344)WIGTKSA, WTKSA, and TPKSA (including temporal keys)(#205) held for communication with the AP or PCP by using the MLME-DELETEKEYS.request primitive (see 12.6.16 (RSNA security association termination)) and by invoking an MLME-SETPROTECTION.request(None) primitive. The MM-SME shall perform this process for each STA whose address was included in the MMS parameter of the MLME-ASSOCIATE.request or MLME-REASSOCIATE.request primitive that established the association.

d) If the reason code indicates a configuration or parameter mismatch as the cause of the disassociation, the SME shall not attempt to associate or reassociate with the AP or PCP until the configuration or parameter mismatch has been corrected.

e) If the reason code indicates the STA was disassociated for a reason other than configuration or parameter mismatch, the SME shall not attempt to associate or reassociate with the AP or PCP until a period of 2 s has elapsed.

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#### 11.3.5.8 AP or PCP disassociation initiation procedure

The SME shall issue an MLME-DISASSOCIATE.request primitive that includes an appropriate Reason Code as defined Table 9-79 (Reason codes) of 9.4.1.7 (Reason Code field).

Upon receipt of an MLME-DISASSOCIATE.request primitive, an AP or PCP shall disassociate a STA using the following procedure:

a) If the state for the STA is State 3 or State 4, the AP or PCP shall generate a Disassociation frame to be transmitted to the indicated STA.

   NOTE—As the Disassociation frame is a bufferable MMPDU, the transmission of this frame might be delayed by the operation of a power saving protocol. The AID and the PTKSA are maintained (when applicable) until the frame is acknowledged or attempts to transmit the frame are abandoned.

b) The state for the STA shall be set to State 2, if it was not State 1 (11az)or State 1a. The MM-SME shall perform this process for each STA whose address was included in the MMS parameter of the MLME-ASSOCIATE.request or MLME-REASSOCIATE.request primitive that established the association.

c) Once the Disassociation frame is acknowledged or attempts to transmit the frame are abandoned, the MLME shall issue an MLME-DISASSOCIATE.confirm primitive to inform the SME of the disassociation.

d) Upon receiving an MLME-DISASSOCIATE.confirm primitive, the SME shall delete any PTKSA, GTKSA, IGTKSA, BIGTKSA(11ba), (#3344)WIGTKSA, WTKSA, and TPKSA (including temporal keys)(#205) held for communication with the STA by using the MLME-DELETEKEYS.request primitive (see 12.6.16 (RSNA security association termination)) and by invoking an MLME-SETPROTECTION.request(None) primitive. The MM-SME shall perform this process for each STA whose address was included in the MMS parameter of the MLME-ASSOCIATE.request or MLME-REASSOCIATE.request primitive that established the association.

e) Upon receiving an MLME-DISASSOCIATE.confirm primitive, the SME shall release the AID assigned for the indicated STA, if the state for the indicated STA was State 3 or State 4.

f) AP only: The SME shall inform the DS of the disassociation.

#### 11.3.5.9 AP or PCP disassociation receipt procedure

Upon receipt of a Disassociation frame from a STA for which the state is State 3 or State 4, if management frame protection was not negotiated when the PTKSA(s) were created, or if management frame protection was negotiated when the PTKSA(s) were created(#7049) and the frame is not discarded per management frame protection processing, the AP or PCP shall disassociate the STA using the following procedure:

a) The state for the STA shall be set to State 2. The MM-SME shall perform this process for each STA whose address was included in the MMS parameter of the MLME-ASSOCIATE.request or MLME-REASSOCIATE.request primitive that established the association.

b) The MLME shall issue an MLME-DISASSOCIATE.indication primitive to inform the SME of the disassociation.

c) Upon receiving an MLME-DISASSOCIATE.indication primitive the SME shall delete any PTKSA, GTKSA, IGTKSA, BIGTKSA(11ba), (#3344)WIGTKSA, WTKSA, and TPKSA (including temporal keys)(#205) held for communication with the STA by using the MLME-DELETEKEYS.request primitive (see 12.6.16 (RSNA security association termination)) and by invoking an MLME-SETPROTECTION.request(None) primitive. The MM-SME shall perform this process for each STA whose address was included in the MMS parameter of the MLME-ASSOCIATE.request or MLME-REASSOCIATE.request primitive that established the association.

d) AP only: The SME shall inform the DS of the disassociation.


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e) The SME shall release the AID assigned for the indicated STA.

#### 11.3.5.10 PBSS procedures for nonassociated STAs

In a PBSS, there are four types of relationships between a PCP and the members of a PBSS:

— Nonassociated, (#3056)pre-RSNA (when dot11RSNAActivated is false)
— Associated, (#3056)pre-RSNA (when dot11RSNAActivated is false)
— Associated, RSNA (when dot11RSNAActivated is true)
— Nonassociated, RSNA (when dot11RSNAActivated is true)

The following rules apply in the last case:

a) In a PBSS, when a STA is in State 2 and dot11RSNAActivated is true, successful RSNA establishment changes the STA to State 4. Unsuccessful RSNA establishment leaves the state unchanged.
b) In a PBSS, when a STA is in State 4, the STA's receipt of a disassociation notification changes the state to State 2.

#### 11.3.5.11 Service characteristic indication during association

A sensor service is the service that a sensor STA is capable of provisioning that is usually delivered using small payload Data frames. Non-sensor services include offloading and critical services. Different service characteristics may have different requirements on QoS, frame length, duty cycle, etc. An AP can optimize the system operating parameters with the knowledge of the service characteristic of each associated STA or place a high priority on association/reassociation for a STA that provides critical services such as health care, home, industrial, alarm monitoring or emergency service.

A non-AP STA may indicate to the AP its service characteristic information during association by including the Service Characteristic field in the AID Request element in the (Re)Association Request frame. The AP may assign a particular AID to the STA taking into account the received service characteristic information from the STA.

### 11.3.6 Additional mechanisms for an AP (#2210)colocated with a mesh STA

If a STA to AP mapping is added to the DS with the STA being a non-AP STA in an infrastructure BSS and the AP being an access point that interconnects through a DS with a mesh gate (that is, AP and mesh gate are (#2210)colocated; see Figure 4-10 (Example device consisting of mesh STA and AP STA to connect an MBSS and an infrastructure BSS)), this mesh gate shall verify that the MAC address of the STA does not belong to a mesh STA in the MBSS. See 4.5.3.3 (Association) and Clause 7 (DS SAP specification) for association and STA to AP mapping in the DS. If the mesh gate determines that the authenticated STA has a MAC address that is a MAC address of a mesh STA in the MBSS, then the (#2210)colocated access point shall deauthenticate the STA with Reason Code UNSPECIFIED_REASON or MACADDRESS-ALREADY-EXISTS-IN-MBSS.

The mechanism for verifying the MAC address of the authenticated STA depends on the active path selection protocol and might be vendor specific. See 14.11.13 (Considerations for support of STAs without mesh functionality) when HWMP is the active path selection protocol.

### 11.3.7 Communicating PBSS information

Following the association or security association of a STA with a PCP, the PCP shall send an unsolicited Information Response frame (9.6.19.5 (Information Response frame format) to all STAs associated with the PCP. The PCP shall send a broadcast Information Response frame and/or shall send individually addressed Information Response frames to each STA associated with the PCP. The PCP shall set the Subject Address

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field of the Information Response frame to the broadcast address and shall include in the Information Response frame the DMG Capabilities element for the PCP and each STA associated with the PCP. This process is referred to as *PBSS information distribution*.

The PCP shall perform a PBSS information distribution at least once every dot11BroadcastSTAInfoDuration beacon intervals.

### 11.3.8 Neighbor report information upon rejection with suggested BSS transition

An AP may provide neighbor report information to a STA that requests authentication or association by responding with an Authentication or (Re)Association Response frame that has the Status Code field set to REJECTED_WITH_SUGGESTED_BSS_TRANSITION and that includes one or more Neighbor Report elements.

An HE STA that has received from an HE AP an Authentication or (Re)Association Response frame that has the Status Code field set to REJECTED_WITH_SUGGESTED_BSS_TRANSITION and that includes one or more Neighbor Report elements for BSSs that are part of the ESS of the HE AP shall, if it re-attempts to associate with the ESS, select an AP from (one of) the Neighbor Report element(s).(11ax)

### 11.3.9 Authentication control

#### 11.3.9.1 General

In infrastructure mode, an S1G AP can use the Authentication Control element to alleviate WM contention when a large number of STAs are trying to or are expected to send Authentication-Request frames(#8189) to the AP at about the same time.

#### 11.3.9.2 Centralized authentication control

When dot11S1GCentralizedAuthenticationControlActivated is true, an S1G STA shall set the Centralized Authentication Control subfield to 1 in the S1G Capabilities Information field of the S1G Capabilities element. Otherwise, the STA shall set it to 0. A STA that transmits the Centralized Authentication Control subfield of the S1G Capabilities Information field set to 0 is not constrained by the requirements specified in this subclause.

A centralized authentication controller access point (CAC AP) shall set the Control subfield to 0 in the Authentication Control element in all transmitted Beacons and Probe Responses frames. A non-CAC AP shall not include an Authentication Control element with the Control field equal to 0 in a Beacon or Probe Response frame.

A CAC AP may include an Authentication Control element with the Control subfield equal to 0 and the Deferral subfield equal to 0 in a Beacon or a Probe Response frame to attempt to limit the number of STAs that can transmit an Authentication-Request frame(#8189) to it. The AP may transmit a different value in the Authentication Control Threshold subfield in the Authentication Control element included in each of Beacon and Probe Response frames that it transmits.

A CAC AP may include, within an individually addressed Probe Response frame that is transmitted in response to a Probe Request frame from a STA, an Authentication Control element that has the Control subfield equal to 0, the Deferral subfield equal to 1 and the Authentication Control Threshold subfield equal to a deferred channel access time. During the deferred channel access time that begins immediately following the reception of the Probe Response, a centralized authentication controlled station (CAC STA) shall not transmit an Authentication-Request frame(#8189) to the AP that transmitted the Probe Response frame.


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A non-CAC STA is not constrained by the Authentication Control rules specified in this subclause when it transmits an Authentication-Request frame(#8189) to the AP. A CAC STA sets the MAC variable AuthenticationRequestTransmission to true when it is initialized.

A CAC STA shall generate a random number *v* when it is initialized. The generated random number *v* shall be uniformly distributed between 0 and 1022. The STA may generate a new random value for *v* after receiving an Authentication-Response frame(#8189) from an AP.

A CAC STA shall compare *v* with the Authentication Control Threshold subfield value in the most recently received Authentication Control element from the AP to which it intends to send an Authentication-Request frame(#8189) if the Control and the Deferral subfields are equal to 0. If *v* is less than the Authentication Control Threshold subfield, the STA may transmit an Authentication-Request frame(#8189) to the AP and shall set the MAC variable AuthenticationRequestTransmission to true. Otherwise, the STA shall set the MAC variable AuthenticationRequestTransmission to false and the STA shall not transmit an Authentication-Request frame(#8189) to the AP. A CAC STA shall update its MIB values of the CAC parameters based on the values received in the Authentication Control element.

A CAC STA shall set the MAC variable AuthenticationRequestTransmission to false and shall defer the transmission of an Authentication-Request frame(#8189) to an AP from which it has received an individually addressed probe response if the Probe Response frame contains an Authentication Control element with the Control subfield equal to 0 and the Deferral subfield equal to 1. The deferral begins at the end of the reception of the Probe Response frame and extends for a period of time equal to the value contained in the Authentication Control Threshold subfield value in the Probe Response frame. At the end of the deferral time period, the STA shall set the MAC variable AuthenticationRequestTransmission to true and may transmit an Authentication-Request frame(#8189) to the AP.

A CAC STA shall set the MAC variable AuthenticationRequestTransmission to true when it receives a Beacon or Probe Response frame that does not include an Authentication Control element from the AP that it intends to join.

An S1G AP shall not set the Deferral subfield in the Authentication Control element of the Beacon frames or the broadcast Probe Response frames to 1.

An S1G STA does not follow the Authentication Control rules defined in this subclause if it receives a Beacon or Probe Response frame that includes an Authentication Control element from the AP that it does not intend to join, or is not intended to the STA.

#### 11.3.9.3 Distributed authentication control

When dot11S1GDistributedAuthenticationControlActivated is true, an S1G AP shall set the Distributed Authentication Control subfield to 1 in the S1G Capabilities Information field of the S1G Capabilities element. Otherwise, the subfield is set to 0.

When an S1G STA receives an S1G Capabilities element with the Distributed Authentication Control field equal to 1, the STA shall determine when it is permitted to access the medium to transmit an Authentication-Request frame(#8189) to the AP from which it received the S1G Capabilities element based on the following procedure:

a) The STA maintains the following distributed authentication control (DAC) parameters:
   1) Authentication control slot duration ($T_{ac}$) in TUs. The default value is(M118) 10 TUs.
   2) Minimum transmission interval ($TI_{min}$) in units of a beacon interval. The default value is(M118) 8 beacon intervals.
   3) Maximum transmission interval ($TI_{max}$) in units of a beacon interval. The default value is(M118) 256 beacon intervals.

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b) The STA maintains a transmission interval (TI) in units of a beacon interval.

c) The TI is initialized to $TI_{min}$.

d) The STA chooses a random number *m* from [0, TI].

e) The STA chooses a random number *l* from [0, L], where $L = \lfloor (bi)/T_{ac} \rfloor$, *l*=0 is the first authentication control slot, and *bi* is the beacon interval.

f) The STA may initiate normal EDCA access procedures for the transmission of the Authentication-Request frame(#8189) beginning at the authentication control slot *l* in the beacon interval *m*, where *m*=0 is the current beacon interval.

g) If the transmission of the Authentication-Request frame(#8189) fails, the TI is increased as follows: $TI = \min\{2 \times TI, TI_{max}\}$.

An S1G AP may assign DAC parameters different from the default values by sending to the STA an Authentication Control element with the Control subfield equal to 1. An S1G STA receiving such an Authentication Control element shall update its MIB values of the DAC parameters based on the values received in the Authentication Control element.

## 11.4 TS operation

### 11.4.1 Introduction

There are three types of traffic specifications: the TSPEC, the DMG TSPEC, and the PTP TSPEC.

A TSPEC describes the traffic characteristics and the QoS requirements of a TS. The main purpose of the TSPEC is to reserve resources within the HC and, in the case of HCCA and HEMM access policies, to modify the HC's scheduling behavior. It also allows other parameters to be specified that are associated with the TS, such as a traffic classifier and ack policy.

The DMG TSPEC (9.4.2.132 (DMG TSPEC element)) describes an allocation (also known as DMG allocation) within either a PBSS or a DMG infrastructure BSS. The purpose of the DMG TSPEC is to create or modify an allocation for the transmission of frames between DMG STAs that are members of a PBSS or that are members of an infrastructure BSS (10.38.6 (Channel access in scheduled DTI)).

To communicate between STAs in a PBSS or between non-AP DMG STAs in an infrastructure BSS, a TSPEC (as defined in 9.4.2.28 (TSPEC element)) is used to create or modify a TS between those STAs. This TSPEC is referred to as a *PTP TSPEC*.

In a DMG BSS, a TSPEC includes parameters that are associated with the TS such as maximum MSDU size, delay bound, and optionally the allocation carrying the TS. A single allocation can carry multiple TSs. Each TS is carried in one allocation, except when

— The TS has an access policy of EDCA, where it can use all CBAP allocations with Source AID equal to the broadcast AID, all CBAP allocations with Source AID matching the source STA of the TS, and all CBAP allocations with Destination AID matching the destination STA of the TS; or

— The TS has an access policy of SEMM, where it can use exactly one SP allocation as well as all CBAP allocations with Source AID equal to the broadcast AID, all CBAP allocations with Source AID matching the source STA of the TS, and all CBAP allocations with Destination AID matching the destination STA of the TS.

A TS may have one or more TCLAS (within the discretion of the STA that sets up the stream) associated with it. A DMG STA or AP uses the parameters in the TCLAS elements to filter the MSDUs belonging to this TS for delivery as part of the TS. An Intra-Access Category Priority element may be associated with a TS by the inclusion of an Intra-Access Category Priority element in an ADDTS Request frame. The User Priority


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subfield of the Intra-Access Category Priority element shall be set to the same UP as specified in the User Priority subfield of the TS Info field. If dot11AlternateEDCAActivated is true, the Alternate Queue subfield is used to select the appropriate EDCA transmit queue when the Access Policy subfield of the TS Info field in the TSPEC is EDCA or HEMM. When an Intra-Access Category Priority element is associated with a TS, the Drop Eligibility subfield is used to indicate the drop eligibility of the MSDUs of this TS.

(#1776)TS may have zero or one Expedited Bandwidth Request elements associated with it. An AP uses the parameters in the Expedited Bandwidth Request element, if present, to understand the precedence level requested by a non-AP STA (see R.5.4 (Description of the Expedited Bandwidth Request element)). For example, the precedence level may be used to convey to the AP that the requested TS is for the purposes of placing an emergency call. Support for precedence levels greater than 18 is optional for STAs.

TSPEC, PTP TSPEC, optional TCLAS, optional EBR, and optional Intra-Access Category Priority elements are transported over the WM by the ADDTS Request frame and the ADDTS Response frame, and across the MLME SAP by the MLME-ADDTS primitives. In addition, a TS could be created if a STA sends a resource request to an AP or PCP prior to initiating a transition to that AP or PCP, as part of performing FST (11.31 (Multi-band operation)), or in the Reassociation Request frame to that AP or PCP.

The DMG TSPEC is transported over the air within DMG ADDTS Request and DMG ADDTS Response frames and across the MLME SAP by the MLME-ADDTS primitives.

Following a successful negotiation, a TS is created, identified within the non-AP STA by its TSID and direction, and identified within the HC by a combination of TSID, direction, and STA address.

Following a successful negotiation of a DMG TSPEC in a PBSS or in a DMG infrastructure BSS, a new allocation is created, or an existing allocation is modified. Within a PBSS or infrastructure BSS, each allocation is uniquely identified by a combination of allocation ID, source AID, and destination AID.

Following a successful negotiation of a PTP TSPEC or a TSPEC in a DMG BSS, the frames corresponding to the PTP TSPEC or TSPEC are identified within the STA by the combination of TSID, requesting non-AP DMG STA address, and responding non-AP DMG STA address and direction.

It is always the responsibility of the non-AP STA to initiate the creation of a TS regardless of its direction. A STA that is not a DMG STA shall not transmit a PTP TSPEC or a DMG TSPEC. A non-AP DMG STA that is not the source DMG STA of a specific TS shall not initiate the exchange of a TSPEC to the AP DMG STA or PCP DMG STA to create that TS. Any non-AP DMG STA can issue a PTP TSPEC to any other non-AP DMG STA to create a TS.

In the TDLS direct link(#1356) case, it is the responsibility of the STA that is going to send the data to create the TS. In this case, the STA negotiates with the HC to gain TXOPs that it uses to send the data. There is no negotiation between the originator and recipient STAs concerning the TS: the originator can discover the capabilities of the recipient (rates, Block Ack) using the TDLS.

In the case of traffic relayed by an AP or PCP, the sending and receiving non-AP and non-PCP STAs may both create individual TS for the traffic. In an infrastructure BSS, any traffic classifier created for the downlink TS applies equally regardless of whether the source is in the same BSS or reached through the DS.

In a non-DMG infrastructure BSS, a non-AP STA may simultaneously support up to eight TSs from the HC to itself and up to eight TSs from itself to other STAs, including the HC. The actual number it supports may be less due to implementation restrictions.

In a non-DMG infrastructure BSS, an HC may simultaneously support up to eight downlink TSs and up to eight uplink TSs per associated STA. The actual number it supports may be less due to implementation restrictions.

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In a DMG BSS there may be up to 16 TSs from a source DMG STA to a destination DMG STA. An additional 16 TSs may be created between the two DMG STAs by reversing the roles of source and destination. The actual number supported in any direction may be less due to implementation restrictions in either the source or destination DMG STA.

In a non-DMG BSS, the traffic admitted in the context of a TSPEC can be sent using EDCA, HCCA, or HEMM. This depends on the access policy set in the TS Info field in the TSPEC. A TSPEC request may be set so that both HCCA and EDCA mechanisms (i.e., HEMM) are used.

In a DMG BSS, the traffic admitted in the context of a PTP TSPEC or TSPEC is sent according to the access policy set in the TS Info field of the PTP TSPEC or TSPEC, respectively. Specifically, the traffic is sent during one or more CBAP allocations if the access policy is EDCA, during an SP allocation if the access policy is SPCA, and during one SP allocation as well as zero or more CBAP allocations if the access policy is SEMM.

A DMG STA transmitting a DMG TSPEC shall set the LP SC Used subfield within the DMG TSPEC to 1 to indicate that the low-power SC mode described in 21.7 is used during the allocation. All frames sent during such an allocation shall use the low-power SC mode. The STA shall set the LP SC Used subfield to 1 only if the STA identified in the Destination AID field within the DMG TSPEC supports the low-power SC mode (9.4.2.126.2 (DMG STA Capability Information field)). In all other cases, the LP SC Used subfield shall be set to 0.

When dot11SSPNInterfaceActivated is true, TSPEC processing by the HC may be subject to limitations received from the SSPN interface. The SSPN may limit access to certain QoS priorities, and further restrict the data rate and delay used with any priority.

### 11.4.2 TSPEC construction

TSPECs and DMG TSPECs are constructed at the SME, from application requirements supplied via the SME, and with information specific to the MAC(#6268).

The value of the Minimum PHY Rate in a TSPEC shall satisfy the following constraints:

a) For an uplink TS, it
   - Is included in dot11SupportedDataRatesTxTable and in the AP's operational rate set, or
   - Corresponds to an HT-MCS included in dot11SupportedHTMCSTxTable, if present, and in the AP's operational HT-MCS set, if defined, at a bandwidth and guard interval supported by the non-AP STA on transmission and permitted in the BSS, or
   - Corresponds to a VHT-MCS and NSS for which support is indicated by the combination of
     - The Tx VHT-MCS Map subfield in the VHT Operation parameter of the MLME-(RE)ASSOCIATE.request primitive, if present, and
     - The AP's operational VHT-MCS and NSS set, if defined, and
     - The VHT Capabilities Information field

     at a bandwidth and guard interval supported by the non-AP STA on transmission and permitted in the BSS.

b) For a downlink TS, it
   - Is included in the OperationalRateSet parameter of the MLME-JOIN.request primitive and supported by the AP on transmission,[39] or
   - Corresponds to an HT-MCS included in dot11SupportedHTMCSRxTable, if present, and supported by the AP on transmission, at a bandwidth and guard interval supported by the non-AP STA on reception and permitted in the BSS,[40] or

[39] How a non-AP STA determines an AP's non-HT rate transmission support is implementation dependent. The non-AP STA might conservatively use the basic rate set, or it might use knowledge of past transmissions by the AP, or it might use other means.


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— Corresponds to a VHT-MCS and NSS for which support is indicated by the combination of
  — The Rx VHT-MCS Map subfield in the VHT Operation parameter of the MLME-(RE)ASSOCIATE.request primitive, if present, and
  — The Tx VHT-MCS Map subfield of the VHT Operation element advertised by the AP, if present, and
  — The VHT Capabilities Information field

  at a bandwidth and guard interval supported by the non-AP STA on reception and permitted in the BSS.

c) For a bidirectional TS, it satisfies both a) and b) above.

See K.4 (TSPEC construction) for a description of the parameter choice for the TSPEC.

NOTE—This standard states no requirements on how a DMG TSPEC is to be generated.

### 11.4.3 TS life cycle

Figure 11-24 (TS life cycle) summarizes the TS life cycle (using the HMSC syntax defined in ITU-T Recommendation Z.120 (2004).

Initially a TS is inactive. A STA shall not transmit any QoS Data frames in which the TID subfield of the QoS Control field matches an inactive TS.

A TS may be established by a Resource Request appearing in a message as part of a fast BSS transition from a STA. Such a TS is created in the accepted state. If the STA subsequently reassociates with this AP, then the TS becomes active. If the STA does not reassociate prior to the expiration of the reassociation timeout, then the TS becomes inactive.

Unless stated otherwise, in a DMG BSS, the owner of an SP is the source DMG STA for that SP, and the owner of a TXOP is the TXOP holder. A STA that owns an SP or a TXOP is said to have the ownership of the SP or the TXOP, respectively. The rules applicable to an SP or TXOP owner are defined in 10.38 (DMG and CMMG channel access) and 11.4 (TS operation).

Following a successful TS setup initiated by a non-AP STA, the TS becomes active, and either the non-AP STA or the HC may transmit QoS Data frames whose TID contains this TSID (according to the Direction field). In the case of EDCA, the TID contains the UP value.

While the TS is active, the non-AP STA can attempt to renegotiate the parameters of the TSPEC characterizing the TS or the parameters of the DMG TSPEC characterizing the allocation carrying the TS.

An active TS becomes inactive following a TS deletion process initiated at either non-AP STA or HC. It also becomes inactive following a TS timeout detected at the HC, or if the HC within an AP when dot11SSPNInterfaceActivated is true determines as defined in 11.22.5 (Interworking procedures: interactions with SSPN) that the non-AP STA's TS has exceeded the transmitted MSDU limit for the access category in which the TS was admitted. In a DMG BSS, a TS timeout is detected at a non-AP STA and causes the TS deletion process to be initiated at the non-AP STA. When an active TS becomes inactive, all of the resources allocated for the TS are released.

[40] How a non-AP STA determines an AP's HT-MCS transmission support, if the Tx MCS Set subfield in the HT Capabilities element advertised by the AP is equal to 0 or if the Tx Rx MCS Set Not Equal subfield in that element is equal to 1, is implementation dependent. The non-AP STA might conservatively use the basic HT-MCS set, or it might use knowledge of past transmissions by the AP, or it might use other means.

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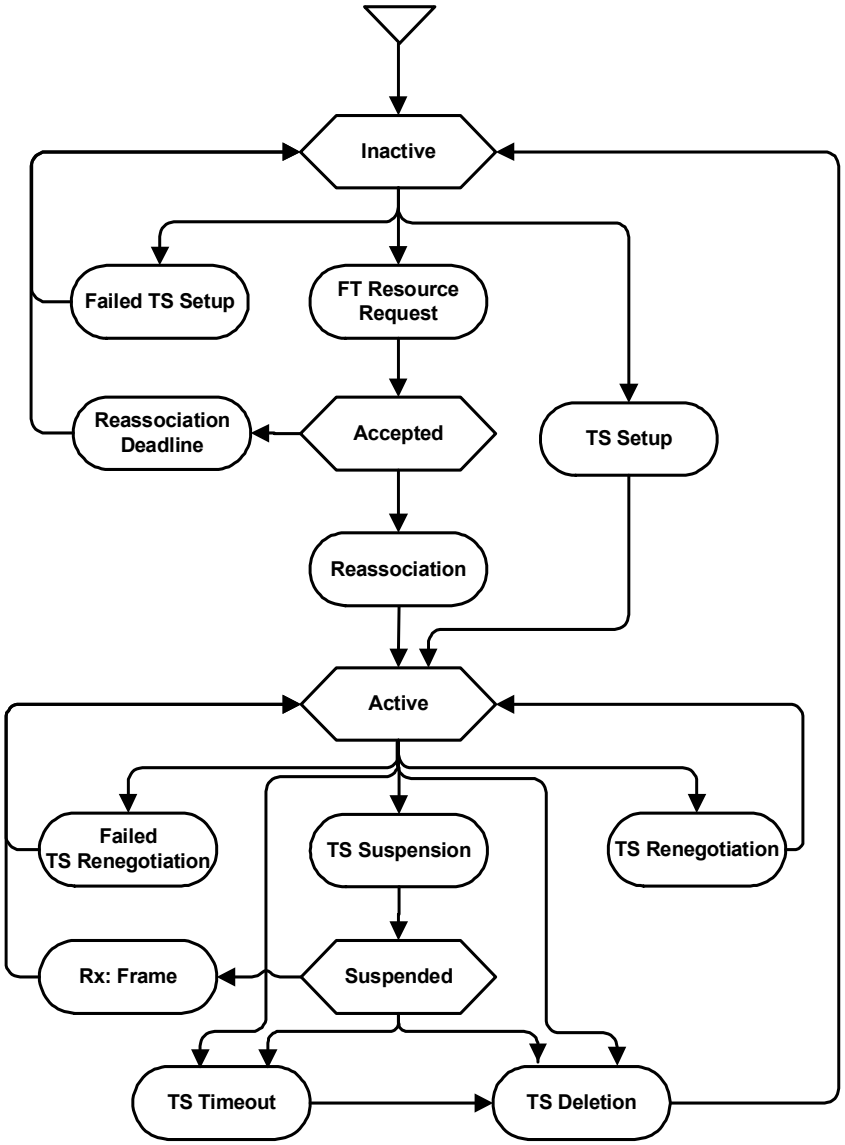


**Figure 11-24—TS life cycle**

An active TS may become suspended if no activity is detected for a duration of a suspension interval. Upon detection of activity, the TS may be reinstated. While the TS is in the suspended state, the HC shall not reclaim the resources assigned to the TS. In a DMG BSS, a TS in which both the source and destination are non-AP and non-PCP STAs shall not be suspended.

### 11.4.4 TS setup

#### 11.4.4.1 General

A TS setup may be initiated by a non-AP STA or an AP.


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#### 11.4.4.2 Non-AP-STA-initiated TS setup

Figure 11-25 (TS setup) shows the sequence of messages occurring at a TS setup initiated by a non-AP STA. This message sequence in this figure and in the subsequent figures does not show the acknowledgment.

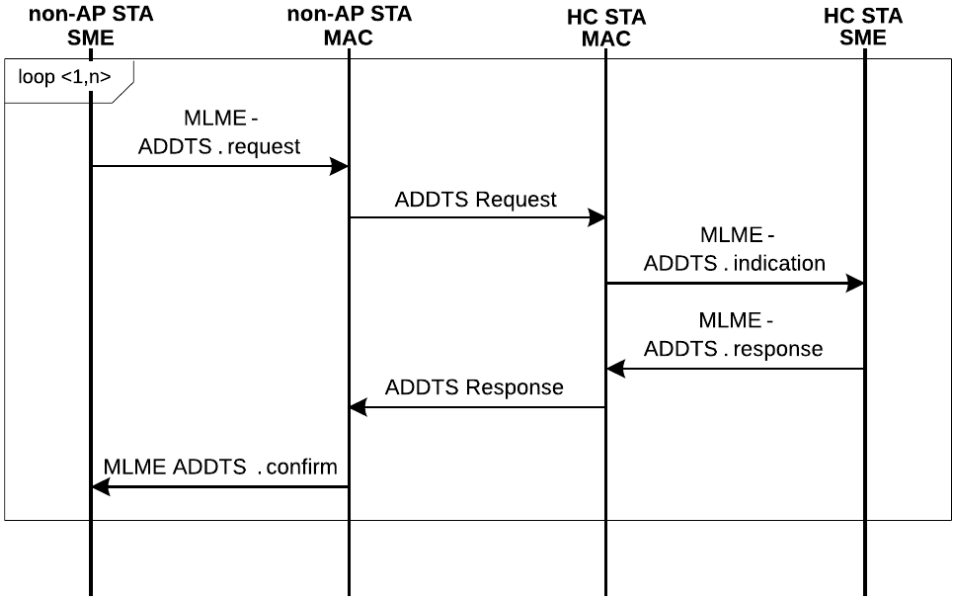


**Figure 11-25—TS setup**

#### 11.4.4.3 AP-initiated TS setup

Figure 11-26 (TS setup when initiated by the AP) shows the sequence of messages occurring at a TS setup initiated by the AP. This message sequence in this figure and in the subsequent figures does not show the acknowledgments.

TS setup may be initiated by an AP in response to a request originating from higher layer protocols. An AP in which dot11RobustAVStreamingImplemented is true shall not send ADDTS Reserve Request frames to an associated STA that has set the RobustAVStreaming bit in the Extended Capabilities element in its (Re)Association Request frame to 0.

The higher layer stream ID is defined by the higher layer protocol. The Higher Layer Stream ID element shall be included in the ADDTS Reserve Request frame sent by the AP to the non-AP STA. This element is used in the TS setup procedure between the AP and the non-AP STA.

The AP initiates the TS setup by sending an ADDTS Reserve Request frame that includes the Higher Layer Stream ID element to the non-AP STA. On receipt of the ADDTS Reserve Request frame from the AP, the non-AP STA shall perform one of the following:

a) Complete the AP-initiated TS setup procedure by sending an ADDTS Reserve Response frame that includes the Higher Layer Stream ID element corresponding to the AP-initiated TS setup procedure and with the status code set to SUCCESS.

b) Send an ADDTS Reserve Response frame with a status code not equal to SUCCESS and abort the AP-initiated TS setup. The Higher Layer Stream ID element in this ADDTS Reserve Response frame shall be set to the higher layer stream ID corresponding to the AP-initiated TS setup procedure.

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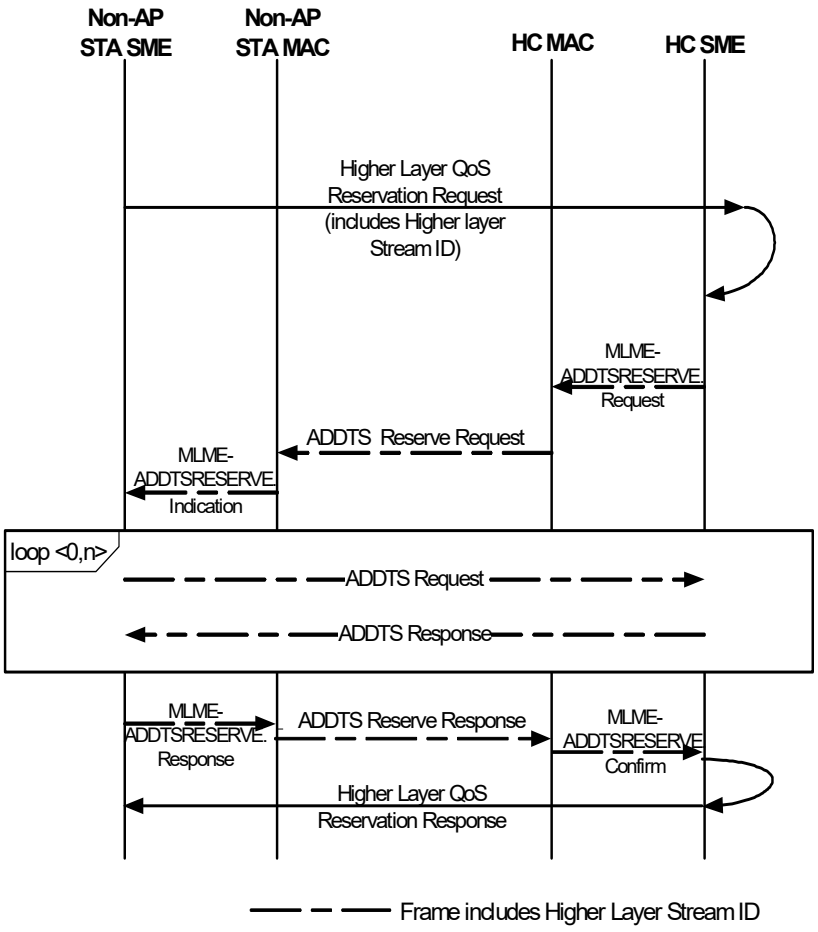


**Figure 11-26—TS setup when initiated by the AP**

c) Send an ADDTS Request frame to the AP. There might be multiple ADDTS Request/ADDTS Response exchanges between the non-AP STA and the AP, as described in 11.4.4.4 (TS setup procedures for both AP and non-AP STA initiation), to negotiate the TSPEC parameters. The Higher Layer Stream ID element shall be included in all frames corresponding to the AP-initiated TS setup procedure that are exchanged between the non-AP STA and the AP. The AP-initiated TS setup procedure is completed by sending an ADDTS Reserve Response frame that includes the Higher Layer Stream ID element corresponding to the AP-initiated TS setup procedure and with the status code set to indicate the result of the TSPEC negotiation.

NOTE 1—Stream Reservation Protocol (SRP) as described in IEEE Std 802.1Q is an example of a higher layer protocol. The IEEE 802.11 subsystem at a non-AP STA does not interpret the SRP reservation request but simply sends it to the AP with which it is associated. A higher layer agent called *Designated Multiple Stream Registration Protocol (MSRP) Node (DMN)* is (#2210)colocated with the AP in the device that supports SRP. All incoming SRP reservation requests are forwarded to the MSRP DMN. The MSRP DMN interprets the SRP reservation request and invokes appropriate IEEE 802.11 primitives in order for the AP to invoke the MLME-ADDTSRESERVE.request primitive. The MSRP DMN responds to the originator of the SRP Reservation request with the outcome of the AP-initiated TS setup procedure. The procedures performed by the MSRP DMN are described in IEEE Std 802.1Q.

NOTE 2—If the higher layer SRP Reservation Request message is lost within the IEEE 802.11 subsystem, the corresponding retry/recovery procedure is the responsibility of the SRP protocol. These procedures are described in IEEE Std 802.1Q.


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#### 11.4.4.4 TS setup procedures for both AP and non-AP STA initiation

The non-AP STA's SME decides that a TS needs to be created or non-AP HE STA traffic characteristics and QoS requirements need to be provided. The mechanism to provide traffic characteristics and QoS requirements is described in 26.5.8 (Use of TSPEC by HE STAs).(11ax) How it does this, and how it selects the TSPEC or DMG TSPEC parameters, is beyond the scope of this standard. The SME generates an MLME-ADDTS.request primitive containing a TSPEC or DMG TSPEC. A TSPEC or DMG TSPEC may also be generated autonomously by the MAC without any initiation by the SME.

NOTE—Such a (#3320)TSPEC or DMG TSPEC might be overridden as a result of a subsequent MLME-ADDTS.request primitive from the SME (see 11.4.4.5 (TS renegotiation))

The STA's MLME transmits the TSPEC or DMG TSPEC in an ADDTS Request frame to the HC STA. If the non-AP STA's MLME is in power save mode, the STA shall include its DMG Wakeup Schedule element in the ADDTS Request frame variant and in the DMG ADDTS Request frame variant.

The HC STA's MLME receives this Management frame and generates an MLME-ADDTS.indication primitive to its SME containing the TSPEC or DMG TSPEC.

The SME in the HC STA decides whether to admit the TSPEC or DMG TSPEC with its associated TCLAS element(s) (if present) and TCLAS Processing element (if present), as specified, refuse the TSPEC or DMG TSPEC, or not admit but suggest an alternative TSPEC, DMG TSPEC, or TCLAS element(s), or TCLAS Processing element.

A DMG STA that responds with an ADDTS Response frame and an HC may change the value of parameters that have been set unspecified by the STA to any value that it deems appropriate, including leaving them unspecified.

If the TSPEC or DMG TSPEC is received from a non-AP STA by an AP when dot11SSPNInterfaceActivated is true, the HC shall use the permissions stored in dot11InterworkingEntry for that STA in the decision to admit or deny the request (see 11.22.5.3 (Reporting and session control with SSPN)). The SME then generates an MLME-ADDTS.response primitive containing the TSPEC or DMG TSPEC, zero or more TCLAS element(s) (only if present in the request) and TCLAS Processing element (only if present in the request) and a ResultCode value. The Result Code field of the MLMEADDTS.response frame shall be set to one of the values in Table 11-7 (Status Code for MLMEADDTS.response(#1114)).(#1114) The SME may include fewer TCLAS elements in the MLME-ADDTS.response primitive than were present in the request; when the SME's response includes a single TCLAS element, it shall not include a TCLAS Processing element. If the SME changes a TCLAS element's Classifier Type field in the MLME-ADDTS.response primitive but is unable to suggest a value for the Classifier Mask field, it shall set that field to 0. If the SME changes a TCLAS element's Classifier Type field or Classifier Mask field in the MLME-ADDTS.response primitive but is unable to suggest values for one or more Classifier Parameter subfields, it shall set those subfields to 0.

**Table 11-7—Status Code for MLMEADDTS.response(#1114)**

| Valid Range | Description |
|---|---|
| REJECTED_FOR_DELAY_PERIOD,<br>REJECTED_WITH_SUGGESTED_BSS_TRANSITION,<br>REQUESTED_TCLAS_NOT_SUPPORTED,<br>TCLAS_RESOURCES_EXHAUSTED,<br>REJECTED_HOME_WITH_SUGGESTED_CHANGES,<br>REJECTED_FOR_SSP_PERMISSIONS,<br>SUCCESS_STA_IN_PS_MODE,<br>REJECT_U-PID_SETTING | Indicates the results of the corresponding MLMEADDTS.indication primitive |

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When the HC in an AP that has dot11SSPNInterfaceActivated equal to true receives a TSPEC, the AP shall inspect it to determine the requested access policy, user priority, and mean data rate as follows:

a) The access category shall be determined from the user priority according to Table 10-1 (UP-to-AC mappings(#68)). For a TS to be admitted when the requested access policy is EDCA, both of the following shall be true:
   1) The field corresponding to this access category in dot11NonAPStationAuthAccessCategories from the non-AP STA's dot11InterworkingEntry is equal to 1.
   2) The sum of the mean data rate of all of the requesting STA's active TSs in this access category plus the mean data rate in the TSPEC is less than or equal to the non-AP STA's dot11InterworkingEntry for dot11NonAPStationAuthMaxVoiceRate, dot11NonAPStation-AuthMaxVideoRate, dot11NonAPStationAuthMaxBestEffortRate, or dot11NonAPStation-AuthMaxBackgroundRate depending on whether the derived access category is AC_VO, AC_VI, AC_BE or AC_BK, respectively.
b) For a TS to be admitted when the requested access policy is HCCA, all of the following shall be true:
   1) The dot11NonAPStationAuthHCCAHEMM value is true.
   2) The sum of the mean data rate of all of the requesting STA's active TSs having access policy set to HCCA plus the mean data rate in the TSPEC is less than or equal to dot11NonAPStationAuthMaxHCCAHEMMRate in the non-AP STA's dot11InterworkingEntry.
   3) The delay bound (M118)provided by the HC in the TSPEC response is less than or equal to dot11NonAPStationAuthHCCAHEMMDelay in the non-AP STA's dot11InterworkingEntry.

If the DMG TSPEC is admitted, the AP or PCP shall set the ResultCode to SUCCESS_STA_IN_PS_MODE if the STA identified by destination AID is in power save mode and shall include in the ADDTS Response frame the DMG Wakeup Schedule element of the destination DMG STA if one is established. In this case, the AP or PCP should defer including the TS schedule in the Extended Schedule element until both source DMG STA and destination DMG STA are in active mode.

The HC STA's MLME transmits an ADDTS Response frame containing this TSPEC or DMG TSPEC and status. The encoding of the ResultCode values to Status Code field values is defined in Table 9-80 (Status codes). The AP or PCP shall transmit the ADDTS Response frame to the STAs identified as source and destination AID of the DMG TSPEC contained in the ADDTS Request frame if the ADDTS request is sent by a non-AP and non-PCP STA. If the ResultCode is SUCCESS, the AP or PCP shall announce the creation of the allocation by setting the Allocation ID subfield in the TSPEC element sent in the ADDTS Response frame to a nonzero value and also by delivering the Extended Schedule element as defined in 10.38.6 (Channel access in scheduled DTI). In an AP when dot11SSPNInterfaceActivated is true, the HC shall set dot11NonAPStationAddtsResultCode in the non-AP STA's dot11InterworkingEntry equal to the ResultCode.

The STA's MLME receives this Management frame. It generates an MLME-ADDTS.confirm primitive to its SME containing the TSPEC or DMG TSPEC and status.

The SME decides whether the response meets its needs. How it does this is beyond the scope of this standard. An SME receiving a modified TCLAS element having a Classifier Mask field equal to 0 or Classifier Parameter subfields equal to 0 should regard these values as meaning that no suggested value has been provided by the HC.

— If the result code is SUCCESS, the TS enters into an active state.
— (#161)If the result code is REJECTED_WITH_SUGGESTED_BSS_TRANSITION, the non-AP STA should try to transition to one of the suggested BSSs according to the process defined in 11.21.7 (BSS transition management(#556)). Once the transition is completed, it should proceed with a TS setup process with the new HC.


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— Otherwise, the whole process can be repeated using the same TSID and direction, a modified TSPEC or DMG TSPEC, optional TCLAS element(s), and an optional TCLAS Processing element until the SME decides that the granted medium time is adequate or inadequate and cannot be improved.

The above rules also apply to the negotiation of the PTP TSPEC and to the negotiation of the DMG TSPEC.

The parameters that are set for a TS may be renegotiated in a similar manner (see 11.4.4.5 (TS renegotiation)).

If the HC or PCP grants medium time for an ADDTS Request frame with the TS Info Ack Policy subfield equal to Block Ack and the Direction field equal to either downlink or bidirectional, then it shall initiate a block ack negotiation by sending an ADDBA Request frame to the STA that originated the ADDTS Request frame. If a non-DMG STA is granted medium time for an ADDTS Request frame with the TS Info Ack Policy subfield equal to Block Ack and the Direction field equal to other than downlink, then it shall initiate a block ack negotiation by sending an ADDBA Request frame to the recipient of the TS.

In a non-DMG BSS, the combination of the TSID and Direction subfields identify the TS, in the context of the STA, to which the TSPEC applies. A bidirectional link request is equivalent to a downlink TS and an uplink TS, each with the same TSID and parameters. In a DMG BSS, the combination of the TSID, source DMG STA AID, destination DMG STA AID, and Direction subfields identifies the TS, in the context of the non-AP STA, to which the TSPEC applies.

The same TSID may be used for multiple TSs at different STAs. A STA can use the same TSID subfield value for a downlink TSPEC and either an uplink or a direct link(#1356) TSPEC at the same time. In a non-DMG BSS, a non-AP STA shall not use the same TSID for both uplink and direct link(#1356) TS. In a DMG BSS, a non-AP STA as a source DMG STA can use the TSID subfield value for an uplink PTP TSPEC, and at the same time the non-AP STA as a destination DMG STA can use the same TSID subfield value for a downlink PTP TSPEC.

If the TS Info Ack Policy subfield of a TSPEC or DMG TSPEC element is Block Ack and the type of Block Ack policy is unknown to the HC, the HC assumes, for TXOP scheduling, that the immediate block ack policy is being used (see 10.25 (Block acknowledgment (block ack))).

An HC shall support(#546) receiving an ADDTS Request frame that contains a TCLAS element and capable of generating an indication that contains this as a parameter.

When a STA requests service at a higher priority than authorized by its dot11InterworkingTableEntry, the HC may provide a suggested TSPEC or DMG TSPEC with a data rate and lower priority that would be authorized. Usage of the TSPEC in an Interworking environment is described in Annex K.

A STA may include a U-PID element in ADDTS Request, DMG ADDTS Request, ADDTS Response and DMG ADDTS Response frames it transmits. The U-PID element is used to indicate the upper layer protocol responsible for handling MSDUs corresponding to the TID indicated within the frame carrying the U-PID element. If a U-PID element is not included in an ADDTS Request, DMG ADDTS Request, ADDTS Response or DMG ADDTS Response frame, MSDUs corresponding to the TID contain an LLC header that is used for upper layer protocol identification.

A U-PID element shall not be included in an ADDTS Response or DMG ADDTS Response frame if a U-PID element was not included in the corresponding ADDTS Request or DMG ADDTS Request frame. If a U-PID element was included in an ADDTS Request or DMG ADDTS Request frame, the same U-PID element shall be included in the corresponding ADDTS Response or DMG ADDTS Response frame if that frame has a Status Code of SUCCESS. The Status Code field shall be set to REJECT_U-PID_SETTING in the ADDTS Response or DMG ADDTS Response frame if the request is rejected frame due to the setting of the U-PID

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element received; this frame may contain an alternative U-PID element that is acceptable to the STA sending the ADDTS Response or DMG ADDTS Response frame.

#### 11.4.4.5 TS renegotiation

A non-AP STA may attempt to modify the parameters of a TSPEC or DMG TSPEC by transmitting an ADDTS Request or DMG ADDTS Request frame. If the (#7190)status code in the corresponding ADDTS Response or DMG ADDTS Response frame is SUCCESS, then any TSPEC with the same TSID or DMG TSPEC with the same allocation ID is overridden with the TSPEC or DMG TSPEC in that frame, the HC and non-AP STA shall reset the inactivity interval timer, and the HC shall reset the suspension interval timer.

### 11.4.5 TS setup by resource request during a fast BSS transition

A QoS STA may transmit a TSPEC as part of a RIC-Request in a resource request message. The SME in the hybrid coordinator (HC) decides whether to accept the TSPEC as specified, or refuse the TSPEC, or not accept but suggest an alternative TSPEC. It then generates a RIC-Response, according to the procedures given in 13.11 (Resource request procedures).

Each TS established by this resource request is placed in the accepted state. This state is an intermediate state between inactive and active. In the accepted state, the inactivity and suspension timers shall not be started for the TS. For a TS based on hybrid coordination function (HCF) controlled channel access (HCCA), the HC shall not generate CF-Poll for the TS.

The SME may take the resource/timing requirements of the TS in the accepted state into consideration before assigning any further resources to any other admitted or accepted TS, and in calculating the available admission capacity for the BSS Load element.

The TS is moved to the active state once the STA performs a reassociation to the AP (see 13.11.3 (Creation and handling of a resource request)). Once the TS becomes active, the inactivity and suspension timers are started. In an AP when dot11SSPNInterfaceActivated is true, the HC shall set dot11NonAPStationAddtsResultCode in the non-AP STA's dot11InterworkingEntry equal to the (#7190)status code in the corresponding RDE.

If the reassociation timer times out and the TS is not yet in the active state, the TS goes back to the inactive state.(#3263)

### 11.4.6 Failed TS setup

There are three possible types of failed TS setup:

a) The transmission of ADDTS Request frame failed.

b) No ADDTS Response frame is received from the HC STA (e.g., because of delay due to congestion or because the response frame cannot be transmitted).

c) An ADDTS Response frame is received that contains the Status Code field equal to REJECTED_FOR_DELAY_PERIOD. In this case, if the Delay field of the TS Delay element of the ADDTS Response frame is nonzero, the STA that transmitted the ADDTS Request frame shall not transmit another ADDTS Request frame to the same AP until the time indicated by the Delay field has elapsed.

Figure 11-27 (Failed TS setup detected within non-AP STA's MLME) summarizes the two cases. In either case in a non-DMG BSS, if the request is not for an existing TS, the SME shall issue a DELTS.request primitive to the HC specifying the TSID and direction of the failed request just in case the HC had received the request and it was the response that was lost. In either case in a DMG BSS, if the request is not for an existing allocation or TS, the SME shall issue a DELTS.request primitive to the non-AP STA specifying the allocation


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ID or TSID and destination DMG STA of the failed request just in case the AP or PCP had received the request and it was the response that was lost.

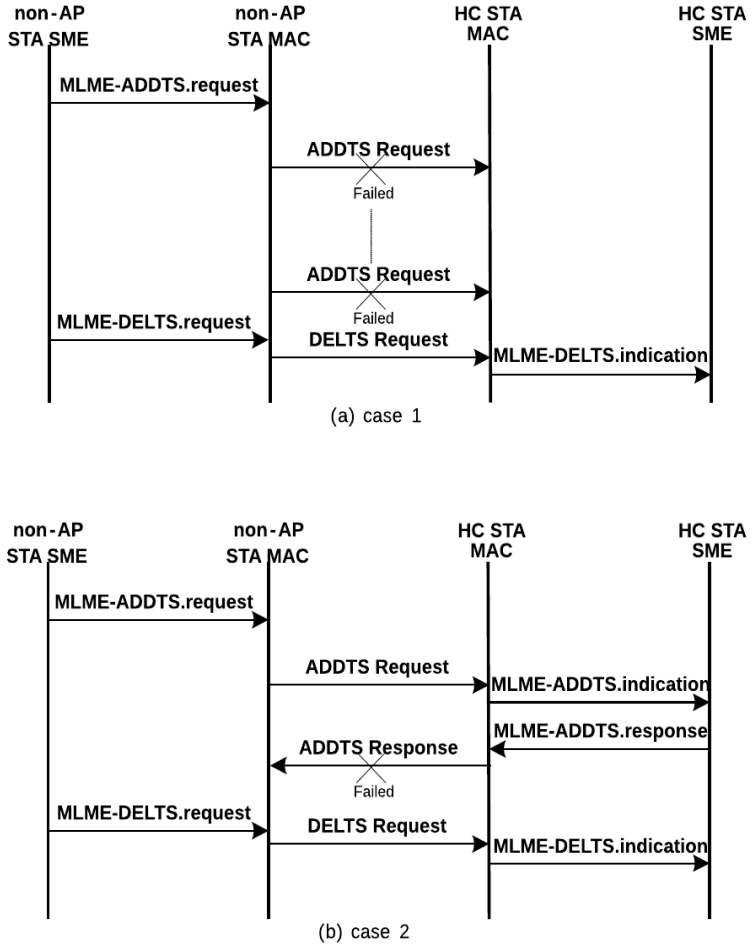


**Figure 11-27—Failed TS setup detected within non-AP STA's MLME**

### 11.4.7 Data transfer

After the setup of a TSPEC or PTP TSPEC, MSDUs are classified above the MAC and are sent to the MAC through the MAC SAP using the MA-UNITDATA.request primitive with the priority parameter encoded to the TID.

In a DMG BSS, MSDUs are transmitted using QoS Data frames. During each CBAP allocation, the MAC delivers MSDUs based on the priority of the transmitted QoS Data frames. The MAC can transmit all MSDUs having a TSID with an associated TSPEC with an access policy of EDCA or SEMM, provided that the source AID of the CBAP allocation is equal to the source AID of the TS, or the source AID of the CBAP allocation is equal to broadcast AID, or the destination AID of the CBAP matches the destination AID of the TS.

During each SP allocation, the MAC delivers MSDUs whose TSIDs identify TSPECs that have been set up to use the SP allocation. Relative prioritization of multiple TSPECs mapped to the same SP allocation is implementation dependent and outside the scope of this standard.

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When an MSDU arrives from the MAC SAP with a TSID for which there is no associated TSPEC, the MSDUs shall be sent using EDCA with the access category AC_BE.

The generation of the associated TID is done by a classifier above the MAC, and it may use the associated TCLAS elements if any are present. When there are multiple TCLAS elements and if the (#2180)Processing field of TCLAS Processing element is 0, the priority parameter in the associated MA-UNITDATA.request primitive is set to TID if the classifier matches the parameters in all of the TCLAS elements associated with the TS. When there are multiple TCLAS elements and if the (#2180)Processing field of the TCLAS Processing element is 1, the priority parameter in the associated MA-UNITDATA.request primitive is set to TID if the classifier matches the parameters in at least one of the TCLAS elements associated with the TS. When there is no TCLAS element and if the (#2180)Processing field of the TCLAS Processing element is 2, the priority parameter in the associated MA-UNITDATA.request primitive is set to TID if the classifier cannot match the parameters to any of the TCLAS elements. An incoming MSDU that is not classified to a particular TS may be classified to another active TS based on the frame classifier for that TS. If, however, all of the frame classifiers for the active TS have been exhausted, the MSDU does not belong to any active TS and is classified to be a best-effort MSDU. See 5.1.1.3 (Interpretation of priority parameter in MAC service primitives) for the treatment of an MSDU with a TSID for which there is no associated TSPEC.

When an MSDU is classified using a TCLAS element, the original UP cannot be recovered by the receiver.

If dot11AlternateEDCAActivated is true, if an Intra-Access Category Priority element was provided when the TS was created, and if the Access Policy subfield of the TS Info field in the TSPEC is EDCA or HEMM, the value from the Alternate Queue subfield is used to select the appropriate EDCA transmit queue.

If an Intra-Access Priority element was provided when the TS was created, the Drop Eligibility subfield is used to determine the drop eligibility of the MSDU.

### 11.4.8 TS deletion

#### 11.4.8.1 Deletion of a TS established between an HC, DMG AP, or PCP and a non-AP and non-PCP STA

The STA may delete a TS in either of two ways: using non-PCP and non-AP STA initiation or using HC, DMG AP or PCP initiation. In both methods, the SME(#1473) generates an MLME-DELTS.request primitive specifying the TS to be deleted and the reason for deleting the TS. This causes the MAC to send a DELTS frame. The encoding of ReasonCode values to Reason Code field values is defined in Table 9-79 (Reason codes).

Having transmitted a DELTS frame, the initiating MAC deletes the TS identified in the DELTS frame when it receives an Ack frame that responds to this DELTS frame. There is no Management frame response.

Figure 11-28 (TS deletion) shows the case of TS deletion initiated by a non-PCP and non-AP STA and the case of TS deletion initiated by an HC, DMG AP, or PCP.

An HC should not delete a TSPEC without a request from the SME, except for inactivity (see 11.4.9 (TS timeout)) or an HC service change that precludes the HC from continuing to meet the requirements of the TSPEC.

All TSPECs that have been set up shall be deleted upon disassociation and reassociation. Reassociation causes the non-PCP and non-AP STA and HC, DMG AP, or PCP to clear their states, and the non-PCP and non-AP STA may then reinitiate the setup.


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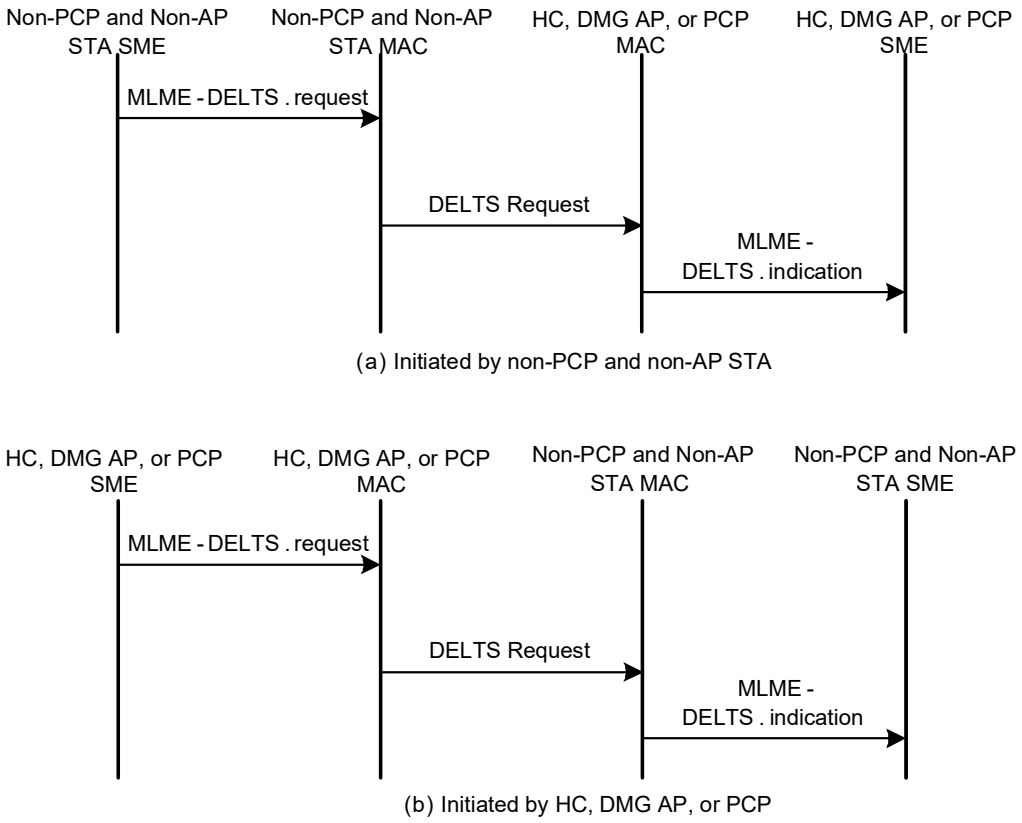


**Figure 11-28—TS deletion**

### 11.4.8.2 Peer-to-peer TS deletion and deletion of an allocation

This subclause describes deletion of a TS established between non-AP and non-PCP DMG STAs (i.e., established using a PTP TSPEC) and deletion of an allocation (i.e., established using a DMG TSPEC).

In this subclause the following procedures for deletion of an allocation or TS are described:

— Deletion of a TS established using a PTP TSPEC by either source or destination STAs
— Deletion of an allocation by either source or destination STAs of that allocation, which might result in the deletion of one or more associated TSs
— Deletion of an allocation (either SP or CBAP) by the AP or PCP

The SME(#1473) generates an MLME-DELTS.request primitive specifying either the TS or the allocation to be deleted and the reason for deleting the TS or allocation, respectively. If generated within a non-AP and non-PCP STA, this primitive causes the MAC to send a single DELTS frame. If generated within an AP or PCP, this primitive causes the MAC to send one or two DELTS frames, as described below. The encoding of ReasonCode values to Reason Code field (see 9.4.1.7 (Reason Code field)) values is defined in Table 9-79 (Reason codes).

A STA that receives an MLME-DELTS.request primitive for a TS that was established using a PTP TSPEC causes the MAC to send a DELTS frame to the peer STA of the TS. This is shown in Figure 11-29 (Deletion of a TS established using a PTP TSPEC).

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NOTE 1—The AP or PCP is unaware of the deletion of the TS.

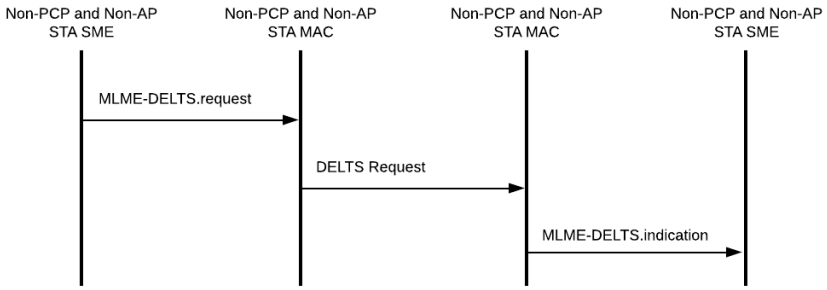


**Figure 11-29—Deletion of a TS established using a PTP TSPEC**

A non-AP and non-PCP STA that receives an MLME-DELTS.request primitive for an allocation causes the MAC to send a DELTS frame to the AP or PCP. If it is transmitted by the STA identified by the Source AID of the allocation and if the Destination AID of the allocation is different from the broadcast AID, the AP or PCP shall send a DELTS frame to the STA identified by the Destination AID of the allocation. If it is transmitted by the STA identified by the Destination AID of the allocation and if the Source AID of the allocation is different from the broadcast AID, the AP or PCP shall send a DELTS frame to the STA identified by the Source AID of the allocation. The AP or PCP shall also delete the scheduling information corresponding to the allocation, identified by the DMG Allocation Info field of the DELTS frame.

Figure 11-30 (Deletion of an allocation in which both Source AID and Destination AID are not the broadcast AID) shows the deletion of an allocation in which both Source AID and Destination AID are not the broadcast AID.

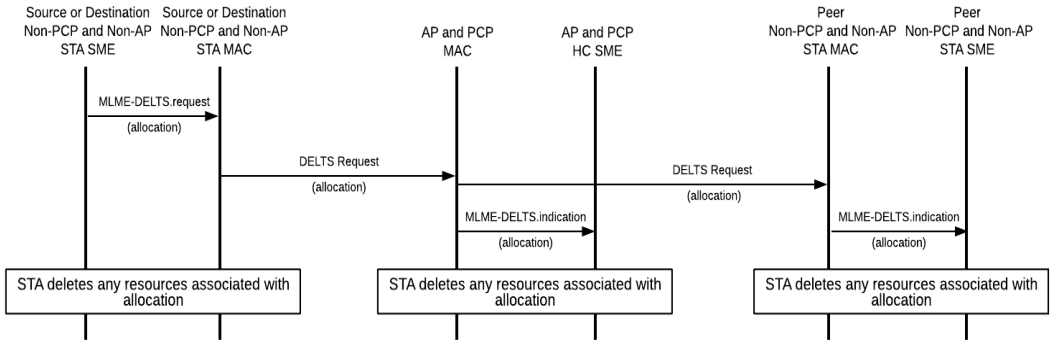


**Figure 11-30—Deletion of an allocation in which both Source AID and Destination AID are not the broadcast AID**

An AP or PCP that receives an MLME-DELTS.request primitive for an allocation causes the MAC to send one or two DELTS frames. If the Destination AID of the allocation is different from the broadcast AID, the AP or PCP shall send a DELTS frame to the STA identified by the Destination AID of the allocation. If the Source AID of the allocation is different from the broadcast AID, the AP or PCP shall send a DELTS frame to the STA identified by the Source AID of the allocation. The AP or PCP shall also delete the scheduling information corresponding to the allocation, identified by the DMG Allocation Info field of the DELTS frame.

An SME that deletes an allocation (using an MLME-DELTS.request primitive) or is notified that an allocation has been deleted (by receiving an MLME-DELTS.indication primitive) also locally deletes (i.e., updates it own


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resources, but does not cause any MAC frames to be transmitted) any TS that is dependent on that allocation as follows:

- Deleting an SP allocation shall also locally delete any TS with access policy SPCA or SEMM using the allocation.
- Deleting a CBAP allocation with Source AID different from the broadcast AID shall also locally delete any TS with access policy EDCA using the allocation.
- Deleting a CBAP allocation with Source AID equal to the broadcast AID shall also locally delete any TS with access policy EDCA using the allocation, unless there is another CBAP allocation the TS could use.

A non-AP and non-PCP STA that associates, disassociates or reassociates (except for reassociation to the same AP) shall locally delete all existing allocations and all TSs that have been established using a PTP TSPEC.

An AP or PCP that receives an MLME-ASSOCIATE.indication, MLME-REASSOCIATE.indication (except when the MLME-REASSOCIATE.indication primitive has this AP's MAC address in the CurrentAPAddress parameter) or MLME-DISASSOCIATE.indication primitive from a STA (the "resetting" STA) with which it has an existing association shall locally delete all allocations that have been established by the resetting STA using a PTP TSPEC. When deleting an allocation in which the Source AID or Destination AID correspond to the resetting STA and the peer STA is not identified by the broadcast AID, the AP or PCP shall send a DELTS to the peer STA to delete that allocation.

NOTE 2—If both Source AID and Destination AID are equal to the broadcast AID, the AP or PCP transmits no DELTS frames. It deletes scheduling information corresponding to the allocation, which is reflected in its subsequent transmission of frames containing an Extended Schedule element.

A STA that generates an MLME-ASSOCIATE.request, MLME-REASSOCIATE.request (except when the MLME-REASSOCIATE.request primitive has the target AP's MAC address in the CurrentAPAddress parameter) or MLME-DISASSOCIATE.request primitive shall locally delete all allocations and all TSs that have been established using a PTP TSPEC.

NOTE 3—Reassociation causes a STA to clear any state related to allocations and TSs that have been established using a PTP TSPEC. A non-PCP and non-AP STA might need to repeat the establishment of any allocations or TSs after reassociation needed to support applications active before the reassociation.

In all of the cases listed above, the TS or allocation is deleted within the initiating MAC when the Ack frame to the Action frame is received. No Action frame response is generated.

### 11.4.9 TS timeout

TS timeout is detected within the HC STA's MAC when no traffic is detected on the TS within the inactivity timeout specified when the TS was created.

For an uplink TS in a non-DMG BSS or for a TS that has the AP or PCP as the destination DMG STA in a DMG BSS, the timeout is based on the arrival of received MSDUs that belong to the TS, after any decryption and reassembly.

For a downlink TS in a non-DMG BSS or for a TS that has the AP or PCP as the source DMG STA in a DMG BSS, the timeout is based on the following:

- Arrival of valid MA-UNITDATA.request primitives using this TS at the MAC SAP when the QoS Data frames are sent with No Ack ack policy
- Confirmation of correctly sent MSDUs that belong to the TS within the MAC when the QoS Data frames are sent with ack policy other than No Ack

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In a DMG BSS and in the case of a TS that is established between non-AP STAs (PTP TSPEC), the timeout of the recipient is based on the arrival of MSDUs that belong to the TS within the MAC after any decryption, A-MSDU unpacking, and reassembly.

In a TS established between non-AP STAs (PTP TSPEC), the timeout of the originator is based on the following:

— Arrival of valid MA-UNITDATA.request primitives using this TS at the MAC SAP when the QoS Data frames are sent with No Ack ack policy

— Confirmation of correctly sent MSDUs that belong to the TS within the MAC when the QoS Data frames are sent with ack policy other than No Ack

In a direct link(#1356) TS in a non-DMG BSS, inactivity is considered to have happened if one of the two following events occurs:

— The HC transmits a QoS CF-Poll frame and the polled STA returns a QoS Null immediately after a SIFS that contains a QoS Control field in which the Queue Size subfield contains 0.

— The HC transmits a QoS CF-Poll frame, and no QoS Null frame is received within the granted TXOP duration that indicates the queue size for the related TSID. This is to confirm that the STA is actually using the assigned TXOP for the given TSID.

In a non-DMG BSS, any other use of a polled TXOP delivered to the STA is considered to be activity on all direct link(#1356) TS associated with that STA. Detection of inactivity of this type is optional.

In response to an inactivity timeout, an HC shall send a DELTS frame to the STA with the reason code(#3205) set to TIMEOUT and inform its SME using the MLME-DELTS.indication primitive. In response to an inactivity timeout, a DMG AP shall send a DELTS frame to the non-AP DMG STA with the reason code(#1780) set to TIMEOUT and inform its SME using the MLME-DELTS.indication primitive. In response to an inactivity timeout, a PCP shall send a DELTS frame to the non-PCP DMG STA with the reason code(#1780) set to TIMEOUT and inform its SME using the MLME-DELTS.indication primitive.

In a DMG BSS when a TS is established between non-AP STAs (PTP TSPEC), then in response to a TS timeout detected within the originator non-AP STA the non-AP STA shall send a DELTS frame to the recipient non-AP STA with the reason code(#1780) set to TIMEOUT and inform its SME using the MLME-DELTS.indication primitive. If the TS timeout is detected within the recipient non-AP STA, the STA shall send a DELTS frame to the originator non-AP STA with the reason code(#1780) set to TIMEOUT and inform its SME using the MLME-DELTS.indication primitive.

The case of uplink TS timeout is shown in Figure 11-31 (TS timeout).

### 11.4.10 TS suspension

TS suspension occurs within the HC's MAC when no traffic is detected on the TS within the suspension interval specified when the TS was created. In the suspended state, the generation of QoS (+)CF-Poll frames is stopped for the related TS.

### 11.4.11 TS reinstatement

A suspended TS may be reinstated following activity for that TS.

For uplink and direct link, a suspended TS may be reinstated by a STA by sending a QoS Data or QoS Null frame. This frame may be sent at the highest priority using EDCA. The generation of successive QoS (+)CF-Poll frames shall then be resumed by the HC.

For downlink, a suspended TS is reinstated by the HC when the AP receives an MSDU from a higher layer.


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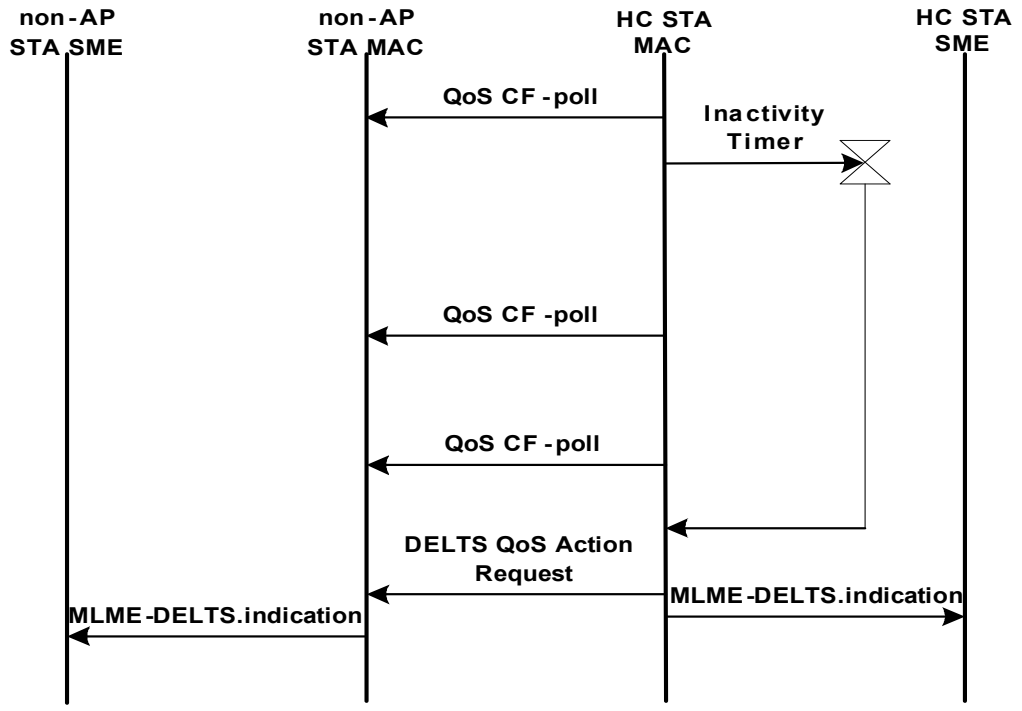
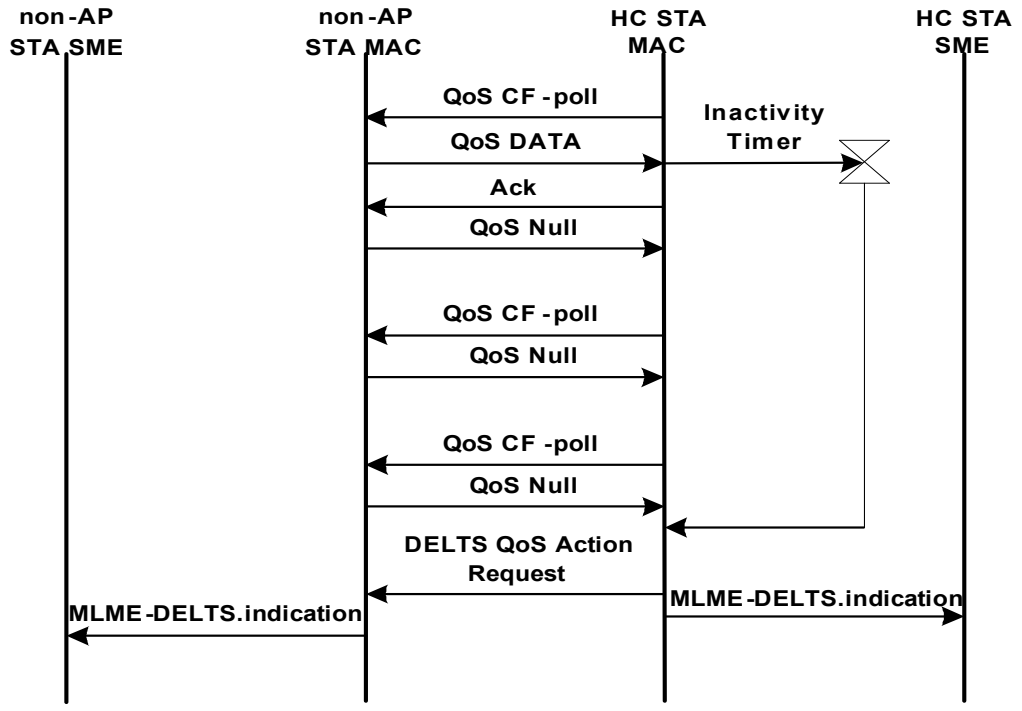



(a) No response from STA




(b) No Data frames from STA

**Figure 11-31—TS timeout**

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### 11.4.12 DMG allocation formats

#### 11.4.12.1 General

A DMG STA manages allocations and TSs as described in 11.4.1 (Introduction) to 11.4.13 (PTP TSPEC operation(#424)). Using the DMG TSPEC element(11ay), a DMG STA can indicate two types of allocation scheduling: isochronous and asynchronous. It should establish an isochronous allocation if it needs periodic access to the channel and does not expect to change the amount of time allocated frequently. It should establish an asynchronous allocation if it expects to make requests for channel time and wishes to reserve a minimum amount of channel time to satisfy for those requests when they occur.

#### 11.4.12.2 Isochronous allocations

In order to request the setup of an isochronous allocation, a DMG STA shall set the Allocation Format field in the DMG TSPEC element to 1.

(11ay)An EDMG STA may request an SP allocation by using the BW, Channel Aggregation and Is Channel Number subfields in the DMG TSPEC element. To request a specific channel, the STA shall set the Is Channel Number subfield to 1 and set the BW subfield to the value of the requested channel; otherwise, the STA shall set the Is Channel Number subfield to 0 and set the BW subfield to the value of requested channel width. Upon reception of a DMG ADDTS Request frame that is admitted, an EDMG AP or EDMG PCP sets the Channel Aggregation subfield in the DMG ADDTS Response frame to the value of the Channel Aggregation subfield in the received DMG TSPEC element for the allocated channel, and sets the value of the BW field in the DMG TSPEC element of the DMG ADDTS Response frame sent in response to the ADDTS Request frame such that it meets the following requirements:

— If the Is Channel Number subfield in the received ADDTS Request frame is equal to 0, the AP or PCP may allocate a channel with channel width less than or equal to the value of the BW subfield in the received ADDTS Request frame.

— If the Is Channel Number subfield in the received ADDTS Request frame is equal to 1, the AP or PCP should allocate the channel as indicated by the BW subfield in the received ADDTS Request frame.

Following the successful admittance of a DMG TSPEC with an isochronous allocation, the AP or PCP should allocate time in the beacon interval to meet the periodicity and minimum allocation requirements specified in the DMG TSPEC element.(11ay) If the PCP or AP is an EDMG STA and both the source and destination STAs of the DMG TSPEC are also EDMG STAs, the allocation time created by the AP or PCP should meet the bandwidth requirements specified in the DMG TSPEC element.

Referring to fields in the DMG TSPEC element, the AP or PCP should check that over each Allocation Period the sum of the time allocations is at least the Minimum Allocation. In addition, the AP or PCP should check that each individual allocation has a minimum duration of at least Minimum SP Duration. See 9.4.2.132 (DMG TSPEC element), 10.38.6 (Channel access in scheduled DTI), and 10.38.6.4 (Pseudo-static allocations).

With an isochronous DMG TSPEC, the allocation period defines the period over which the channel time allocation repeats. The scheduler should check that at least the minimum allocation is made within each allocation period. The allocation may be composed of multiple SPs. The scheduler also checks that each SP making up the allocation is no shorter than the minimum SP duration. The scheduler is free to position the SPs that make up the allocation anywhere in the allocation period. The scheduler may allocate up to the maximum allocation each allocation period if resources permit.

#### 11.4.12.3 Asynchronous allocations

A DMG STA uses the SPR frame to request channel time for asynchronous traffic.


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For each TID, source DMG STA, and destination DMG STA tuple, the AP or PCP can maintain the amount of outstanding channel time that needs to be allocated. Each time it receives an SPR frame, the amount of outstanding channel time is set to the value received in the SPR frame from the source DMG STA for the identified TID and destination DMG STA. The amount of outstanding channel time is decreased by the amount allocated when channel time is scheduled for that TID, source DMG STA, and destination DMG STA tuple.

A DMG STA may also use a DMG TSPEC to reserve resources for asynchronous traffic. In this case, the STA shall set the Allocation Format field in the DMG TSPEC element to 0. The AP or PCP should admit an asynchronous DMG TSPEC only if it is able to meet the minimum allocation requirements specified in the DMG TSPEC element.

With an asynchronous DMG TSPEC, a DMG STA registers the minimum allocation it expects within the allocation period while an SP request is in effect that is greater than the minimum allocation specified. In addition, the STA expects that each allocation is at least of duration specified by the Minimum Duration field of the DMG TSPEC, provided the outstanding SP request is at least that long. In admitting a DMG TSPEC, the AP or PCP should check that there are sufficient resources available to meet the TSPEC requirements.

(11ay)An EDMG STA may request an SP allocation by transmitting an SPR frame with the CONTROL_TRAILER parameter in the TXVECTOR set to Present, CT_TYPE parameter in the TXVECTOR set to SPR, and then using the BW, Channel Aggregation and Is Channel Number subfields in the control trailer. To request a specific channel, the STA shall set the Is Channel Number subfield to 1 and set the BW subfield to the value of the requested channel; otherwise, the STA shall set the Is Channel Number subfield to 0 and set the BW subfield to the value of requested channel width. Upon reception of the SPR frame, an EDMG AP or EDMG PCP responds with a Grant frame that has the CONTROL_TRAILER parameter in the TXVECTOR set to Present and CT_TYPE parameter in the TXVECTOR set to GRANT_RTS_CTS2self. The EDMG AP or EDMG PCP sets the Channel Aggregation subfield in the Grant frame to the value of the Channel Aggregation subfield in the received SPR frame for the allocated channel, and sets the value of the BW field in the control trailer of the Grant frame such that the following requirements are met:

— If the Is Channel Number subfield in the control trailer of the received SPR frame is equal to 0, the AP or PCP may allocate a channel with channel width less than or equal to the value of the BW subfield in the received ADDTS Request frame.

— If the Is Channel Number subfield in the control trailer of the received SPR frame is equal to 1, the AP or PCP should allocate the channel as indicated by the BW subfield in the received ADDTS Request frame.

(11ay)If the source DMG STA, destination DMG STA and the PCP or AP are all EDMG STAs, the allocation time created by the AP or PCP should meet the bandwidth requirements specified in the DMG TSPEC element or SPR frame, as appropriate, received by the AP or PCP.

### 11.4.13 PTP TSPEC operation(#424)

The ADDTS Request frame containing the PTP TSPEC may be sent to the peer non-AP DMG STA directly or through a DMG AP or PCP.

A non-AP DMG STA may add TSs to an existing allocation with a peer non-AP DMG STA. To do this, the non-AP DMG STA transmits an ADDTS Request frame to the peer STA to include the additional TS. The ADDTS Request frame shall contain a PTP TSPEC with the Allocation ID subfield set to indicate the allocation for the additional TS. A TS with EDCA access policy does not need to be added to any CBAP allocation and can use any CBAP allocation as long as the source AID of the CBAP allocation matches the source AID of the TS, or the source AID of the CBAP allocation is equal to the broadcast AID, or the destination AID of the CBAP matches the destination AID of the TS.

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A non-AP DMG STA transmits an ADDTS Request frame to a peer non-AP DMG STA to add a TS to an existing allocation and to possibly communicate traffic-specific parameters such as A-MSDU subframe and Maximum MSDU Size with the peer non-AP DMG STA. The non-AP DMG STA may transmit the ADDTS Request frame directly to the peer STA or to the AP or PCP. In the latter case, the ADDTS Request frame shall contain a TCLAS element with the classifier type set to Ethernet parameters; the Source Address field shall contain the address of the STA that sends the ADDTS Request frame; and the Destination Address field shall contain the address of the peer STA, which is used by the AP or PCP to forward to the peer STA.

The AP or PCP STA shall forward the received ADDTS Request frame to the STA with Address equal to the Destination Address field of the Classifier. If an ADDTS Response frame is received by the AP or PCP STA in response to the forwarded ADDTS Request frame, then the AP or PCP STA shall forward the ADDTS Response frame to the STA with Address equal to the Source Address field of the Classifier. The AP DMG STA and the PCP DMG STA shall not change the content of the elements included in the ADDTS Request and ADDTS Response frames.

If a STA sets the Direction field to a value equal to downlink in the PTP TSPEC included in the ADDTS Request frame, the parameters apply to the STA as the destination DMG STA of that TS. For example, in this case, the Maximum MSDU Size field indicates that the STA is not able to receive MSDUs longer than the value presented in the MSDU Size field. Similarly, if the Direction field indicates uplink, the parameters apply to the STA as the source DMG STA of that TS. In this case, the STA that issued the ADDTS Request frame does not send MSDUs longer than the value of the Maximum MSDU Size field.

## 11.5 Block ack operation

### 11.5.1 Introduction

(#3174)Block ack agreements may be set up, modified by the originator, or deleted from the MAC (see 10.25.2 (Setup and modification of the block ack parameters) (#4353)and 10.25.4 (Teardown of the block ack agreement(#6171))) or from the SME. The setup, modification by the originator and deletion of block ack agreements from the SME is described in this subclause. All parameters of an agreement may be modified except for the TID. If the request is not successful, the existing agreement is not modified. If the request is successful, the behavior is as if a DELBA frame for the block ack agreement had been transmitted by the originator and received by the recipient immediately prior to the ADDBA Request frame.(#6171)

### 11.5.2 Setup and modification of the block ack parameters

#### 11.5.2.1 General

The procedures for setting up and modifying the block ack parameters are described in 11.5.2.2 (Procedure at the originator) and 11.5.2.3 (Procedure at the recipient), respectively, and illustrated in Figure 11-32 (Block ack setup).

#### 11.5.2.2 Procedure at the originator

(#111)Upon receipt of an MLME-ADDBA.request primitive, in order to send QoS Data frames under the block ack mechanism, an initiating STA shall set up (#3174)or modify a block ack agreement using the following procedure:

a) If the initiating STA is an HT STA, is an IBSS STA, and has no block ack agreement with the recipient STA, then the initiating STA shall transmit a Probe Request frame to the recipient STA and shall not transmit an ADDBA Request frame unless it receives a Probe Response frame from the recipient.


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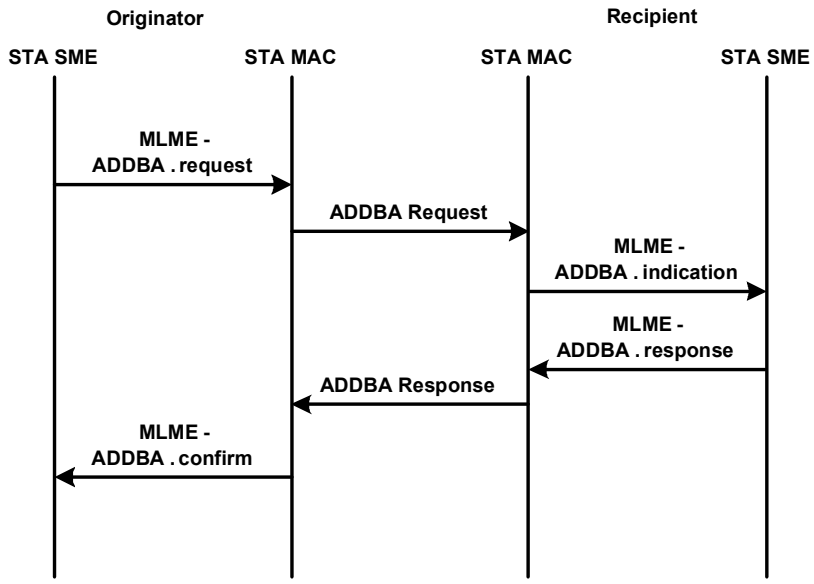


**Figure 11-32—Block ack setup**

NOTE—When the block ack agreement is being established between a non-AP STA and its AP, then the originator and the recipient have exchanged capability information during the association exchange that allows them to determine whether the other STA is an HT STA.

b) If the peer STA is an S1G STA, the S1G originator shall send an NDP ADDBA Request to indicate that it expects only NDP BlockAck frames during the block ack agreement with the following exceptions:

   1) If the S1G originator's dot11BATImplemented is true and the BAT Support subfield in the most recently received S1G Capabilities element from the S1G recipient is 1 and a TWT has been set up with the S1G recipient as described in 10.46 (Target wake time (TWT)), then the S1G originator shall send a BAT ADDBA Request to indicate that it expects only BAT frames during the block ack agreement.

   2) When any of the conditions below is satisfied then the S1G originator may send an ADDBA request to indicate that it expects only BlockAck frames during the block ack agreement:

      i) The value of the Buffer Size field in the ADDBA Request, carried in an S1G_LONG or S1G_SHORT PPDU, is greater than 16.

      ii) The value of the Buffer Size field of the ADDBA Request, carried in an S1G_1M PPDU, is greater than 8.

      iii) The dot11AsymmetricBlockAckActivated is true and Asymmetric BA Supported field in the most recently received S1G Capabilities element from the S1G recipient is 1.

c) If the recipient is capable of participating, the originator sends an ADDBA Request frame indicating the TID and the buffer size. If the recipient is capable of participating and the GCRGroupAddress parameter of the MLME-ADDBA.request primitive is present, the originator sends an ADDBA Request frame that includes a GCR Group Address element. All DMG STAs are capable of participating in the block ack mechanism.

d) If an ADDBA Response frame is received with the matching dialog token and the TID and with a status code equal to SUCCESS, the STA has established (#3174)or modified (#4354)the block ack agreement(#6171) with the recipient STA; and the MLME shall issue an MLME-ADDBA.confirm primitive indicating the successful completion of the setup (#3174)or modification of the block ack agreement.

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e) If an ADDBA Response frame is received with the matching dialog token and the TID and with a status code not equal to SUCCESS, the STA has not established (#3174)or modified the block ack agreement(#6171) with the recipient STA; and the MLME shall issue an MLME-ADDBA.confirm primitive indicating the failure of the setup (#3174)or modification of the block ack agreement.

#### 11.5.2.3 Procedure at the recipient

A recipient shall operate as follows in order to support block ack agreement set up and modification:

a) When an ADDBA Request frame is received from another STA, the MLME shall issue an MLME-ADDBA.indication primitive.

b) Upon receipt of the MLME-ADDBA.response primitive, the STA shall respond by an ADDBA Response frame with a status code(#1780) as defined in 9.6.4.3 (ADDBA Response frame format).

   1) If the status code(#1780) is SUCCESS, the block ack agreement (#3174)has been established or modified. Contained in the frame are the type of Block Ack agreement, the type of BlockAck frames, and the number of buffers that have been allocated for the support of this block. If the recipient STA is (#306)a non-AP S1G STA and it has received from the AP a frame containing an S1G Capabilities element with the Asymmetric BA Supported equal to 1, the Originator Preferred MCS field may be contained in the ADDBA Response frame.

   2) If the status code(#1780) is REFUSED_REASON_UNSPECIFIED(#1780), the block ack agreement has not been established or modified.(#3174)

The encoding of ResultCode values to Status Code field values is defined in Table 9-80 (Status codes).

For S1G STA, the ADDBA Response frame refers to

1) An NDP ADDBA Response if the value of the Buffer Size field of the NDP ADDBA Response is not greater than the value of the maximum number of MSDUs and A-MSDUs that can be acknowledged with the selected NDP BlockAck frame and no TWT has already been set up with the S1G originator as described in 10.46 (Target wake time (TWT)). This value is 8 for NDP 1M BlockAck frames and 16 for NDP_2M BlockAck frames as described in 23.3.12.2.6 (NDP BlockAck). The NDP ADDBA Response frame shall be carried in an S1G_1M PPDU to indicate the use of NDP_1M BlockAck frames and shall be carried in an S1G_SHORT or S1G_LONG PPDU to indicate the use of NDP_2M BlockAck frames.

2) Otherwise, a BAT ADDBA Response as a response to a BAT ADDBA Request if a TWT has already been set up with the S1G originator as described in 10.46 (Target wake time (TWT)). The value of the Buffer Size field in the BAT ADDBA Response shall not be greater than 32.

3) Otherwise, an ADDBA Response indicating the use of BlockAck frames. The MCS subfield in the Originator Preferred MCS field shall be set to 15 unless the dot11AsymmetricBlockAckActivated is true and the Asymmetric BA Supported field in the most recently received S1G Capabilities element from the S1G originator is 1, in which case the MCS subfield may indicate the value of the preferred MCS if asymmetric BA operation is used. The preferred MCS implicitly indicates the MCSDifference value, which is the difference between the preferred MCS and the MCS at which the ADDBA Response is sent.(#4206)

#### 11.5.2.4 Procedure common to both originator and recipient

Once a block ack agreement has been successfully established between two STAs, the type of agreement thus established is dependent on the capabilities of the STAs and the contents of the ADDBA Request and ADDBA Response frames used to establish this agreement as defined in Table 11-8 (Types of block ack agreement based on capabilities and ADDBA conditions for non-DMG STAs) for non-DMG STAs and in Table 11-9 (Types of block ack agreement based on capabilities and ADDBA conditions for DMG STAs) for DMG STAs


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(11ay)that are not EDMG STAs, and in Table 11-10 (Types of block ack agreement based on capabilities and ADDBA conditions for EDMG STAs(11ay)) for EDMG STAs.

**Table 11-8—Types of block ack agreement based on capabilities and ADDBA conditions for non-DMG STAs**

| Capabilities condition | ADDBA condition | Type of block ack agreement |
|---|---|---|
| Both STAs are HT STAs. | Block Ack Policy subfield equal to 1 | HT-immediate |
| Both STAs are robust AV streaming STAs, and the agreement was established using ADDBA Request/Response frames that included GCR Group Address elements. | Block Ack Policy subfield equal to 1 | GCR Block Ack |
| Both STAs are S1G STAs | Block Ack Policy subfield equal to 1 | HT-immediate |

**Table 11-9—Types of block ack agreement based on capabilities and ADDBA conditions for DMG STAs**

| Capabilities condition | ADDBA condition | Type of BlockAckReq and BlockAck variant | Type of block ack agreement |
|---|---|---|---|
| Both STAs have the BlockAck with Flow Control field in the DMG Capabilities element (#4194)set to 1. | Block Ack Policy subfield equal(#4204) to 0 | Compressed | HT-immediate |
| At least one of the STAs has the BlockAck with Flow Control field in the DMG Capabilities element (#4194)set to 0. | Block Ack Policy subfield equal(#4204) to 0 | Compressed | HT-immediate |
| At least one of the STAs has the BlockAck with Flow Control field in the DMG Capabilities element (#4194)set to 0. | Block Ack Policy subfield equal(#4204) to 1 | Extended Compressed | HT-immediate |
| Both STAs have the BlockAck with Flow Control field in the DMG Capabilities element (#4194)set to 1. | Block Ack Policy subfield equal(#4204) to 1 | Extended Compressed | HT-immediate + flow control |

NOTE—If the BlockAckReq and BlockAck variant is Extended Compressed and the Type of block ack agreement is HT-immediate, use of the RBUFCAP field is implementation dependent.

### 11.5.3 Teardown of the block ack agreement(#6171)

#### 11.5.3.1 General

The procedure at the two STAs is described in 11.5.3.2 (Procedure at the initiator of the block ack agreement(#6171) teardown) and 11.5.3.3 (Procedure at the recipient of the DELBA frame) and illustrated in Figure 11-33 (Block ack deletion).

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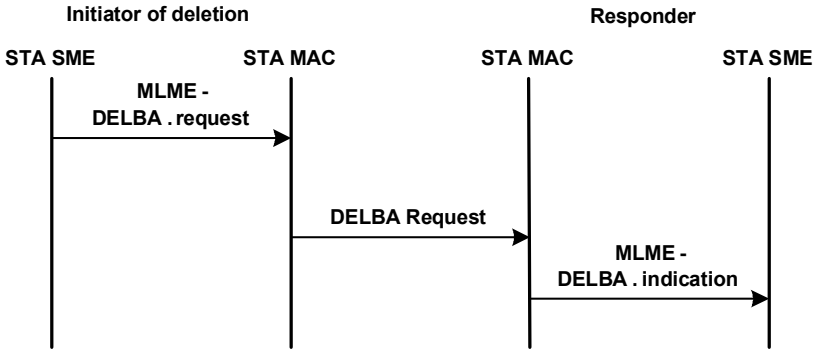


**Figure 11-33—Block ack deletion**

**Table 11-10—Types of block ack agreement based on capabilities and ADDBA conditions for EDMG STAs(11ay)**

| Capabilities conditions | ADDBA condition | Type of BlockAckReq and BlockAck variant | Type of block ack agreement |
|---|---|---|---|
| One of the STAs is a non-EDMG STA | Per Table 11-8 (Types of block ack agreement based on capabilities and ADDBA conditions for non-DMG STAs) | Per Table 11-8 (Types of block ack agreement based on capabilities and ADDBA conditions for non-DMG STAs) | Per Table 11-8 (Types of block ack agreement based on capabilities and ADDBA conditions for non-DMG STAs) |
| Both STAs are EDMG STAs | At least one STA indicates no support for EDMG flow control | Compressed BlockAckReq, EDMG Compressed BlockAck, and EDMG Multi-TID BlockAck | HT-Immediate + EDMG flow control (RBUFCAP with values Receiver Buffer Full, Receiver Buffer Empty, and No Memory Kept) |
| Both STAs are EDMG STAs | Both STAs indicate support for EDMG flow control | Compressed BlockAckReq, EDMG Compressed BlockAck, and EDMG Multi-TID BlockAck | HT-Immediate + EDMG flow control (RBUFCAP with values Receiver Buffer Full, Receiver Buffer Empty, and No Memory Kept) + EDMG flow control per Recipient Memory Capabilities field |

### 11.5.3.2 Procedure at the initiator of the block ack agreement(#6171) teardown

Upon receipt of an MLME-DELBA.request primitive, the MLME shall tear down the block ack agreement by transmitting a DELBA frame.(#6171)

### 11.5.3.3 Procedure at the recipient of the DELBA frame

A STA shall issue an MLME-DELBA.indication primitive with the parameter ReasonCode having a value of REQUESTED when a DELBA frame is received.


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#### 11.5.3.4 Procedure at the block ack originator(#6171)

When a block ack agreement is torn down, the originator shall, for MPDUs under that block ack agreement (i.e., recipient and TID), irrespective of whether it transmitted or received a DELBA frame(#7213), behave as follows.

(#7213)If the last (highest in sequence number space) MPDU transmitted was not acknowledged, and the originator wishes to retry this, the originator shall:

a) Discard all MPDUs that have not been acknowledged, up to and excluding the last (highest in sequence number space) MPDU transmitted, and

b) Retry that last MPDU first, outside the block ack agreement, retaining its sequence number.

(#7213)NOTE—The MPDU cannot be retried in a subsequent new block ack agreement.

(#7213)Otherwise, the originator shall:

a) Discard all MPDUs that have not been acknowledged, up to and including the last (highest in sequence number space) MPDU transmitted, and

b) Set the sequence number of the next MPDU to be transmitted outside the block ack agreement to a sequence number after (in sequence number space) that of the last (highest in sequence number space) MPDU transmitted.(#7230)

#### 11.5.3.5 Procedure at the block ack recipient(#6171)

When a block ack agreement is torn down, the recipient shall, irrespective of whether it transmitted or received a DELBA frame, set the last sequence number received value for MPDUs for the block ack agreement's originator and TID to the sequence number of the last (highest in sequence number space) MPDU received, regardless of the ack policy used in that MPDU.

### 11.5.4 Error recovery upon a peer failure

Every STA shall maintain an inactivity timer for every negotiated block ack setup, unless the block ack agreement is set up for a GCR group address. The inactivity timer at a recipient is reset when MPDUs with the TID for the block ack agreement are received and the ack policy is Block Ack or Implicit BAR. The inactivity timer is not reset when MPDUs corresponding to other TIDs are received. The inactivity timer at the recipient is also reset when a BlockAckReq frame with the TID for the block ack agreement is received. The inactivity timer at the originator is reset when a BlockAck frame with the TID for the block ack agreement is received. (#6172)When a block ack agreement inactivity timeout occurs, the STA shall send a DELBA frame to the peer STA with the Reason Code field set to TIMEOUT and shall issue an MLME-DELBA.indication primitive with the ReasonCode parameter having a value of TIMEOUT. The procedure is illustrated in Figure 11-34 (Error recovery by the receiver upon a peer failure).

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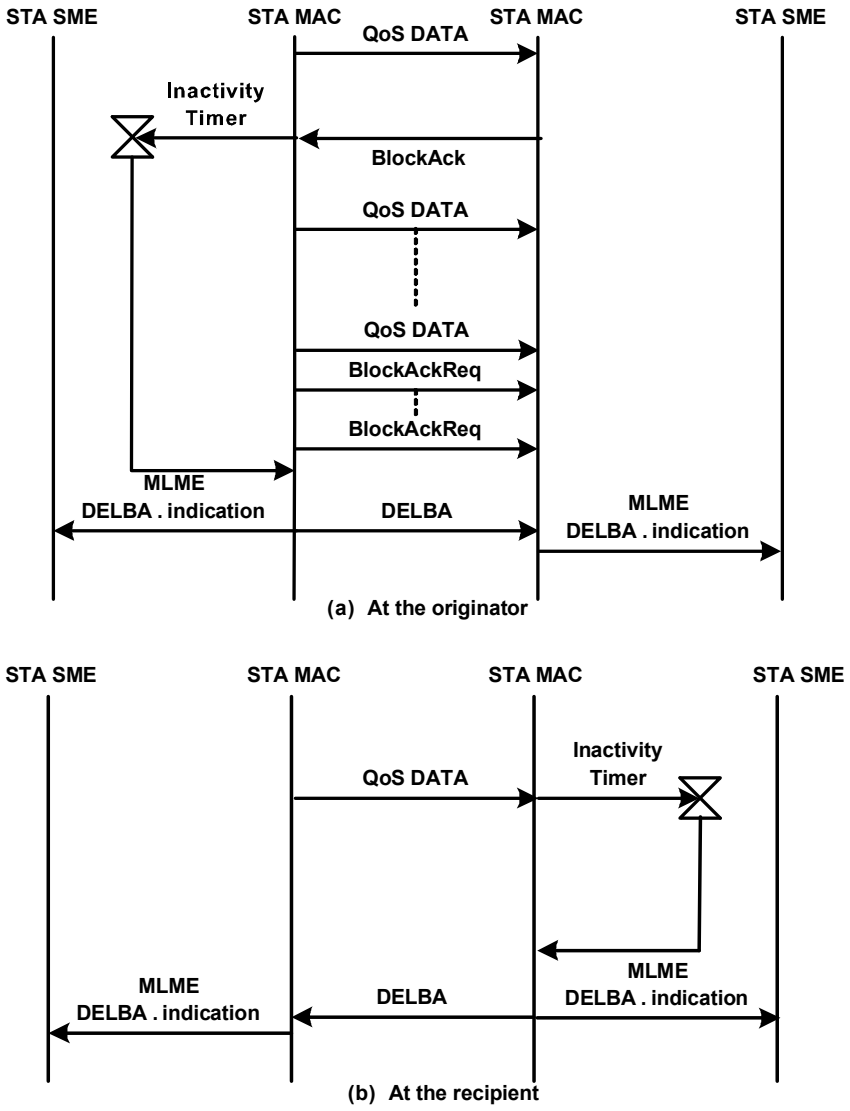


**Figure 11-34—Error recovery by the receiver upon a peer failure**

(#6171)When a recipient does not have an active block ack agreement for a TID, but receives one or more QoS Data frames with Block Ack ack policy, it shall discard them and shall send a DELBA frame. When a recipient does not have an active block ack agreement for a TID, but receives a BlockAckReq frame, it may respond with an Ack frame and shall send a DELBA frame. The originator may attempt to set up a block ack agreement again or may send MPDUs using an alternative acknowledgment mechanism.

## 11.6 Higher layer timer synchronization

### 11.6.1 Introduction

Higher layer timer synchronization is beyond the scope of this standard. However, explanation of how the constructs in this standard might be used to support such capabilities might be useful to the designer.


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One way to accomplish synchronization across a BSS is by multicasting synchronization (sync) packets from the higher layers containing a time stamp and a sequence number. These packets would be opaque to the MAC and would be transported in the same way as any other MSDU (most likely addressed to the group address). Sync packets would be treated as a type of management packet by the higher layers. The time stamp in the sync packet would contain the higher layer clock value at the time when the previous sync packet was transmitted. The sequence number parameter has a value equal to the sequence number of the MSDU in which the time stamp is provided.

The reason the packet would contain the time stamp for the previous sync packet (rather than the current packet) is that hardware and layering constraints would prohibit the ability to provide a time stamp for the exact instant the current packet is transmitted within that packet. However, an MLME-HL-SYNC.indication primitive allows the transmitting STA to know exactly when each sync packet is transmitted. A receiving STA might note the time when each sync packet is received as well as the sequence number for that frame. The receiving STA would save this receive time indication for each packet along with its sequence number and compare the indication of the previously received sync packet to the time stamp in the most currently received packet. This comparison allows the STA to compute an offset, which can be used to adjust its time reference to match that of the synchronization source. A check of the sequence number verifies that the correct packet is being used for time stamp comparison. It is possible a packet is lost; in this case, the received time stamp for the lost packet should be discarded.

(#14)The end of the PPDU[+SigExt] containing the sync packet is indicated by the PHY using the PHY-TXEND.confirm and PHY-RXEND.indication primitives in the transmitter and receiver of the sync packet, respectively. Practical limits on the coincidence of this indication and (#14)the end of the PPDU[+SigExt] containing the sync packet are implementation dependent. The accuracy of this technique also depends on the propagation delay between the source and receiving channel. However, both the time difference (between the PHY indication and (#14)the end of the PPDU[+SigExt] containing the sync packet) and the propagation delay can be considered as fixed-delay components. Therefore, they contribute only to the fixed time difference between the transmitter and receiver STAs' clocks and do not contribute to jitter. An implementation dependent scheme might be used to cancel or minimize this fixed time difference.

The sync packet may also be relayed through the AP. In this case, the STA that generates the time stamps notes the reception of the group addressed sync packet from the AP as the indication to save the higher clock value for the next sync packet. Receiving STAs would also similarly note the time when each sync packet is received from the AP. The sequence number would include a value corresponding to the frame received from the AP.

This is an example implementation using the higher layer timer synchronization feature. Other implementations are possible.

### 11.6.2 Procedure at the STA

In order to determine whether to provide an MLME-HL-SYNC.indication primitive for a particular Data frame, a MAC that supports MLME-HL-SYNC primitives compares the Address 1 field in a Data frame's MAC header to a list of group addresses previously registered by an MLME-HL-SYNC.request primitive.

When the MAC transmits a Data frame with an Address 1 match, the MLME-HL-SYNC.indication shall occur when the (#14)end of the PPDU[+SigExt] carrying the Data frame is transmitted. When the MAC receives a Data frame with an Address 1 match, the MLME-HL-SYNC.indication shall occur when the (#14)end symbol of the PPDU[+SigExt] carrying the matching Data frame is received. In both cases, the MLME-HL-SYNC.indication primitive provided is simultaneous (within implementation dependent delay bounds) with the indication provided to other STAs within the BSS for the same Data frame.

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## 11.7 TPC procedures

### 11.7.1 General

(11ax)Regulations in most regulatory domains require RLANs operating in the 5 GHz band or 6 GHz band to use transmitter power control, involving specification of a regulatory maximum transmit power and a mitigation requirement for each allowed channel. This standard describes such a mechanism, referred to as *transmit power control (TPC)*.

This subclause describes TPC procedures intended to satisfy needs in many regulatory domains and other frequency bands. These procedures might be useful for other purposes (e.g., reduction of interference, range control, reduction of power consumption).

A STA shall use the TPC procedures defined in 11.7 (TPC procedures) if dot11SpectrumManagementRequired is true. dot11SpectrumManagementRequired shall be set to true when regulatory authorities require TPC. It may also be set to true in other circumstances. The TPC procedures provide for the following:

- Association of STAs with an AP or PCP in a BSS based on the STAs' power capability (see 11.7.2 (Association based on transmit power capability))
- Peering of mesh STAs based on the mesh STAs' power capability (see 11.7.3 (Peering based on transmit power capability))
- Specification of regulatory and local maximum transmit power levels for the current channel (see 11.7.5 (Specification of regulatory and local maximum transmit power levels))
- Selection of a transmit power for each transmission in a channel within constraints imposed by regulatory and local requirements (see 11.7.6 (Transmit power selection))
- Adaptation of transmit power based on a range of information, including path loss and link margin estimates (see 11.7.7 (Transmit power adaptation))

If dot11SpectrumManagementRequired is true, a non-DMG STA shall not join an infrastructure BSS, MBSS or IBSS unless the Spectrum Management bit is 1 in the Capability Information field in Beacon frames and Probe Response frames or in the Condensed Capability Information field in Measurement Pilot frames received from other STAs in the BSS, with the following exceptions:

- A STA may operate when the Spectrum Management bit is 0 if the STA determines that it is in a regulatory domain that does not require TPC or determines that it meets regulatory requirements even if TPC is not employed. Potential methods for determining the regulatory domain include receiving a country indication in the Beacon frame, Measurement Pilot frame, user confirmation, or configuration information within the device. Potential methods to meet regulations even if TPC is not employed include using a transmit power that is below the legal maximum (including any mitigation factor).
- A STA shall set dot11SpectrumManagementRequired to true before associating with a BSS in which the Spectrum Management bit is 1 in the Capability Information field in Beacon frames and Probe Response frames or in the Condensed Capability Information field in Measurement Pilot frames received from the BSS.
- An AP may allow association of devices that do not have the Spectrum Management bit equal to 1 in the Capability Information field in Association Request frames and Reassociation Request frames received from the STA to account for the existence of legacy devices that do not support TPC, but do meet regulatory requirements.

A mesh STA shall set dot11SpectrumManagementRequired to true before becoming a member of an MBSS in which the Spectrum Management bit is equal to 1 in the Capability Information field in Beacon frames and Probe Response frames received from the MBSS.


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(11ay)A DMG STA that has dot11ExtendedTPCActivated defined and with a value different from none shall support the Extended TPC as defined in 10.42.6 (Extended TPC(11ay)).

### 11.7.2 Association based on transmit power capability

A STA shall inform an AP or PCP of its minimum and maximum transmit power capability for the current channel when associating or reassociating, using a Power Capability element in (Re)Association Request frames.

An AP or PCP might use the minimum and maximum transmit power capability of associated STAs as an input into an algorithm used to determine the local transmit power constraint for any BSS it maintains. The specification of the algorithm is beyond the scope of this standard.

An AP or PCP may reject a (re)association request from a STA if it considers the STA's minimum or maximum transmit power capability to be unacceptable. For example, a STA's power capability might be unacceptable if it violates local regulatory constraints or increases the probability of hidden STAs by a significant degree. The criteria for accepting or rejecting a (re)association on the basis of transmit power capability are beyond the scope of this standard.

If a STA sends a Country element, a Power Constraint element, and a Transmit Power Envelope element, where the interpretation of the Maximum Transmit Power Level field in the Country element for a 20 MHz or 40 MHz Subband Triplet field is the same as the (11ax)Maximum Transmit Power Interpretation subfield, then at least one of local power constraints indicated by the (11ax)Maximum Transmit Power For 20 MHz and (11ax)Maximum Transmit Power For 40 MHz fields in the Transmit Power Envelope element shall be the same as the indicated local power constraint expressed by the combination of Country element and Power Constraint element.

NOTE—An example of the interpretation of the Maximum Transmit Power Level field in the Country element for a 20 MHz or 40 MHz Subband Triplet field being the same as the (11ax)Maximum Transmit Power Interpretation subfield is when both are EIRP.

### 11.7.3 Peering based on transmit power capability

A mesh STA shall provide a candidate peer mesh STA with its minimum and maximum transmit power capability for the current channel when becoming a member of an MBSS, using a Power Capability element in Mesh Peering Open frames.

A mesh STA may use the minimum and maximum transmit power capability of a neighbor peer mesh STA as an input into the algorithm used to determine the local transmit power constraint. The specification of the algorithm is beyond the scope of this standard.

A mesh STA may reject a Mesh Peering Open request from a candidate mesh STA if it considers the candidate mesh STA's minimum or maximum transmit power capability to be unacceptable. For example, a candidate mesh STA's power capability might be unacceptable if it violates local regulatory constraints. The criteria for establishing or rejecting a Mesh Peering Open request on the basis of transmit power capability are beyond the scope of this standard.

If a STA sends a Country element, a Power Constraint element, and a Transmit Power Envelope element, where the interpretation of the Maximum Transmit Power Level field in the Country element for a 20 MHz or 40 MHz Subband Triplet field is the same as the (11ax)Maximum Transmit Power Interpretation subfield, then at least one of the local power constraints indicated by the (11ax)Maximum Transmit Power For 20 MHz field or (11ax)Maximum Transmit Power For 40 MHz field in the Transmit Power Envelope element shall be the same as the indicated local power constraint expressed by the combination of Country element and Power Constraint element.

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### 11.7.4 Interpretation of transmit power capability

As regards the units of the Minimum Transmit Power Capability and Maximum Transmit Power Capability fields within the Power Capability element sent in a STA's (Re)Association Request frame to an AP, if all of the following apply:

— The STA is extended spectrum management capable.

— The STA has dot11SpectrumManagementRequired or dot11RadioMeasurementActivated equal to true.

— A Beacon or Probe Response frame has been received from the AP by the STA.

— The Beacon or Probe Response frame includes one or more Transmit Power Envelope elements.

then

— The units shall be interpreted according to the Local Maximum Transmit Power Unit Interpretation subfield in the Transmit Power Information field in the (#4022)first or only Transmit Power Envelope element (see 9.4.2.160 (Transmit Power Envelope element)) sent in the most recently received Beacon or Probe Response frame from the AP(#4022).

Otherwise

— The units shall be interpreted as EIRP.

If the Beacon or Probe Response frame most recently received from a neighbor mesh STA by a mesh STA that is extended spectrum management capable and that has dot11SpectrumManagementRequired or dot11RadioMeasurementActivated equal to true includes one or more Transmit Power Envelope elements, then the units of the Minimum Transmit Power Capability and Maximum Transmit Power Capability fields within the Power Capability element sent in the Mesh Peering Open frame to the neighbor mesh STA shall be interpreted according to the Local Maximum Transmit Power Unit Interpretation subfield in the (#4022)first or only Transmit Power Information field in the Transmit Power Envelope element (see 9.4.2.160 (Transmit Power Envelope element)) sent in the most recently received Beacon or Probe Response frame from the AP(#4022). Otherwise, the units of the Minimum Transmit Power Capability and Maximum Transmit Power Capability fields within the Power Capability element sent in the mesh STA's Mesh Peering Open frame to the neighbor mesh STA shall be interpreted as EIRP.

### 11.7.5 Specification of regulatory and local maximum transmit power levels

A STA shall determine a regulatory maximum transmit power for the current channel by selecting the minimum of the following:

— Any regulatory maximum transmit power received in a Country element from the AP in its BSS, PCP in its PBSS, another STA in its IBSS, or a neighbor peer mesh STA in its MBSS

— If the STA is extended spectrum management capable, any regulatory client maximum transmit power (#6077)applicable to the STA (see E.2 (Band-specific operating requirements)) that is received in a Transmit Power Envelope element from the AP in its BSS, another STA in its IBSS, or a neighbor peer mesh STA in its MBSS.(11ax)

— Any regulatory maximum transmit power for the channel in the current regulatory domain known by the STA from other sources

A STA shall determine a local maximum transmit power for the current channel by selecting the minimum of the following:

— Unless the STA is extended spectrum management capable and has received a Transmit Power Envelope element for a channel width of 20 MHz and 40 MHz, any local maximum transmit power received in the combination of a Country element and a Power Constraint element from the AP in its BSS, PCP in its PBSS, another STA in its IBSS, or a neighbor peer mesh STA in its MBSS


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- If the STA is extended spectrum management capable, any local maximum transmit power (#6077)applicable to the STA (see E.2 (Band-specific operating requirements)) that is received in a Transmit Power Envelope element from the AP in its BSS, another STA in its IBSS, or a neighbor peer mesh STA in its MBSS
- Any local maximum transmit power for the channel (11ax)in the current regulatory domain known by the STA from other sources

NOTE 1—A STA might receive a maximum transmit power in a Transmit Power Envelope element from the AP in its BSS, another STA in its IBSS, or a neighbor peer mesh STA in its MBSS in various management frames, including Beacon frames, Probe Response frames, FILS Discovery frames, and (prior to a channel switch) New Transmit Power Envelope elements (in Channel Switch Wrapper elements, Future Channel Guidance elements, Channel Switch Announcement elements/frames, or Extended Channel Switch Announcement elements/frames). Other sources from which a STA might receive a maximum transmit power for a channel include Reduced Neighbor Report elements (20 MHz PSD subfield) sent by a ((#2210)colocated) AP. If this information is received by a STA, any requirements on its usage depend on local regulations known at the STA (see E.2 (Band-specific operating requirements)).(11ax)

NOTE 2—The determination of a maximum transmit power from Transmit Power Envelope element(s) is specified in 10.22.4 (Operation with the Transmit Power Envelope element).(11ax)

The Local Power Constraint field of any transmitted Power Constraint element and each (11ax)Maximum Transmit Power For *X* MHz (11ax)subfield (where *X* = 20, 40, 80, or 160/80+80) in the Transmit Power Envelope element shall each be set to its respective value that allows the mitigation requirements to be satisfied in the current channel.

NOTE 3—The local maximum transmit power for the channel needs to meet the mitigation requirements for the channel in the current regulatory domain. The conservative approach is to set the local maximum transmit power level equal to the regulatory maximum transmit power level minus the mitigation requirement. However, it might be possible to satisfy the mitigation requirement using a higher local maximum transmit power level. A lower local maximum transmit power level might be used for other purposes (e.g., range control, reduction of interference).

The regulatory and local maximum transmit powers may change in a STA during the life of an infrastructure BSS and an MBSS. However, network stability needs to be considered when deciding how often or by how much these maximums are changed. The regulatory and local maximum transmit powers shall not change during the life of an IBSS.

An AP, IBSS STA or mesh STA that is not operating in the 6 GHz band(11ax) shall advertise the regulatory maximum transmit power for that STA's operating channel in Beacon frames and Probe Response frames using a Country element. An AP, IBSS STA or mesh STA shall advertise the local maximum transmit power for that STA's operating channel in Beacon frames and Probe Response frames using the combination of a Country element and a Power Constraint element.

If an AP, IBSS STA, or mesh STA that is not operating in the 6 GHz band(11ax) is extended spectrum management capable, it shall advertise the local maximum transmit power for that STA's operating channel in Beacon frames and Probe Response frames using one Transmit Power Envelope element for each distinct value of the Maximum Transmit Power Interpretation(11ax) subfield that is supported by the BSS, IBSS, or MBSS, respectively. Each Transmit Power Envelope element shall include a local power constraint for all channel widths supported by the BSS.

(11ax)If an AP, IBSS STA, or mesh STA is operating in the 6 GHz band, it shall include Transmit Power Envelope element(s) in Beacon and Probe Response frames as follows:

a) For each distinct combination of values of the Maximum Transmit Power Interpretation subfield and Maximum Transmit Power Category subfield that are supported by the BSS, IBSS, or MBSS, respectively, one Transmit Power Envelope element is included that indicates the regulatory client maximum transmit power for the STA's operating channel.

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b) At a minimum, a regulatory client maximum transmit power is indicated where the Maximum Transmit Power Category subfield is set to 0 (Default)(#6076).

c) If a local maximum transmit power is lower than a regulatory client maximum transmit power for the same combination of values of the Maximum Transmit Power Interpretation subfield and Maximum Transmit Power Category subfield, a Transmit Power Envelope element is included that indicates that local maximum transmit power.

d) Each Transmit Power Envelope element that is included indicates a power constraint for all channel widths supported by the BSS (if an EIRP constraint is advertised) or for all 20 MHz channels within the bandwidth of the BSS (if an EIRP PSD constraint is advertised)(#6076).

NOTE 4—The regulatory client maximum transmit power is the regulatory limit for client devices, such as non-AP STAs, which might be different from the regulatory limit for APs.(11ax)

NOTE 5—STAs operating in the 6 GHz band are extended spectrum management capable (see 10.22.3 (Operation with operating classes)).(11ax)

NOTE 6—If a Transmit Power Envelope element in a Beacon or Probe Response frame in the 6 GHz band indicates EIRP PSD limits, the value of N (see Table 9-320 (Meaning of Maximum Transmit Power Count subfield if Maximum Transmit Power Interpretation subfield is 1, 3 or 5(#6076)(11ax))) is either equal to 0 or equal to the BSS bandwidth, in megahertz, divided by 20 (i.e., 1, 2, 4, or 8 for 20, 40, 80, or 160/80+80 MHz BSS bandwidth, respectively).(11ax)

NOTE 7—An AP, IBSS STA, or mesh STA does not need to send Transmit Power Envelope elements indicating maximum transmit EIRP if it sends Transmit Power Envelope elements indicating maximum transmit PSD and those PSD values are sufficient to ensure regulatory limits on total EIRP are always met for all transmission bandwidths of STAs in the BSS.(11ax)

STAs that are extended spectrum management capable and have dot11RadioMeasurementActivated equal to true should be able to reduce their EIRP to 0 dBm.

NOTE 8(11ax)—When the local maximum transmit power is set by an AP for radio resource management, a typical low value for the local power constraint is 0 dBm. A STA that cannot reduce its transmit power to this level or below will not be able to associate to the AP.

The PCP in a PBSS shall advertise both the regulatory maximum transmit power and the local maximum transmit power for its operating channel in Announce and Probe Response frames (using a Country element for the regulatory maximum and a combination of a Country element and a Power Constraint element for the local maximum). In addition, it should advertise both regulatory and local maximum transmit power in DMG Beacon frames.

When dot11SpectrumManagementRequired is false and dot11RadioMeasurementActivated is true, an AP or a PCP may include a Power Constraint element and a Transmit Power Envelope element in Beacon, DMG Beacon, Announce, and Probe Response frames.

### 11.7.6 Transmit power selection

A STA may select any transmit power for transmissions in a channel within the following constraints:

— A STA shall determine a regulatory maximum transmit power and a local maximum transmit power for a channel in the current regulatory domain before transmitting in the channel.

— An AP shall use a transmit power less than or equal to the regulatory maximum transmit power level for the channel. The AP shall also meet any regulatory mitigation requirement.

— A non-AP STA shall use a transmit power less than or equal to the minimum (#6319)of the local maximum transmit power level and regulatory client maximum transmit power for the channel.(11ax)


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### 11.7.7 Transmit power adaptation

A STA may use any criteria, and in particular any path loss and link margin estimates, to dynamically adapt the transmit power for transmissions of an MPDU to another STA. The adaptation methods or criteria are beyond the scope of this standard.

A STA may use a TPC Request frame to request another STA to respond with a TPC Report frame reporting link margin and transmit power information. A STA that receives a TPC Request frame shall respond with a TPC Report frame that contains a TPC Report element in which the Transmit Power field indicates the power used to transmit the response and the Link Margin field indicates the estimated link margin. A DMG STA may also use the link measurement procedure and the DMG Link Margin element to exchange TPC information.

An AP, PCP, or IBSS STA shall autonomously include a TPC Report element with the Link Margin field set to 0 in Beacon frames, DMG Beacon frames, Announce frames, or Probe Response frames.

## 11.8 DFS procedures

### 11.8.1 General

Regulations that apply to the 5 GHz band in most regulatory domains require RLANs operating in the 5 GHz band to implement a mechanism to avoid co-channel operation with radar systems and to uniformly utilize available channels. This standard describes such a mechanism, referred to as *dynamic frequency selection (DFS)*.

This subclause describes DFS procedures that can be used to satisfy these and similar future regulatory requirements. The procedures might also satisfy comparable needs in other frequency bands and might be useful for other purposes. For example, some of the procedures described in this subclause could be used for channel selection in a DMG BSS.

A STA shall use the DFS procedures defined in 11.8.1 (General) to 11.8.9 (Channel Switch Announcement element operation) if dot11SpectrumManagementRequired is true.

A STA shall use the DFS procedures defined in 11.8.10 (Future Channel Guidance operation) if dot11SpectrumManagementRequired and dot11FutureChannelGuidanceActivated are true.

Attribute dot11SpectrumManagementRequired shall be set to true (#1038)if regulatory authorities require DFS. It may also be set to true in other circumstances. The DFS procedures provide for the following:

- Associating STAs with an AP based on the STAs' supported channels (see 11.8.2 (Association based on supported channels)).
- Quieting the current channel so it can be tested for the presence of radar with less interference from other STAs (see 11.8.3 (Quieting channels for testing)).
- Testing channels for radar before using a channel and while operating in a channel (see 11.8.4 (Testing channels for radar)).
- Discontinuing operations after detecting radar in the current channel to avoid further interference with radar (see 11.8.5 (Discontinuing operations after detecting radar)).
- Detecting radar in the current and other channels, based on regulatory requirements (see 11.8.6 (Detecting radar)).
- Requesting and reporting measurements in the current and other channels (see 11.8.7 (Requesting and reporting of measurements)).
- Selecting and advertising a new channel to assist the migration of a BSS after radar is detected (see 11.8.8 (Selecting and advertising a new channel)).

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— Guiding STAs about the likely future channel should the AP leave this channel (see 11.8.10 (Future Channel Guidance operation)).

In a DMG BSS, the following DFS procedures apply:

— Associating a STA with an AP or a PCP based on the STA's supported channels (see 11.8.2 (Association based on supported channels)).
— Quieting the current channel so it can be tested for interference with less interference from associated STAs (see 11.8.3 (Quieting channels for testing)).
— Requesting and reporting measurements in the current and other channels (see 11.8.7 (Requesting and reporting of measurements)).
— Selecting and advertising a new channel to assist the migration of an infrastructure BSS, IBSS, or PBSS (see 11.8.8 (Selecting and advertising a new channel)).

For the purposes of DFS in a non-DMG BSS, the following statements apply:

— A STA with dot11SpectrumManagementRequired true shall not operate in a BSS unless the Spectrum Management bit is 1 in the Capability Information field in Beacon frames and Probe Response frames received from other STAs in the BSS, with the following exception.
  — A STA may operate when the Spectrum Management bit is 0 if the STA determines that it is in a regulatory domain that does not require DFS or determines that it meets regulatory requirements even if DFS is not employed. Potential methods for determining the regulatory domain include receiving a country indication in the Beacon frame, user confirmation, or configuration information within the device. Potential methods to enable regulations to be met even if DFS is not employed include independently detecting radar and ceasing operation on channels on which radar is detected.
— A STA shall set dot11SpectrumManagementRequired to true before associating with an infrastructure BSS, IBSS, or MBSS in which the Spectrum Management bit is 1 in the Capability Information field in Beacon frames and Probe Response frames received from the infrastructure BSS, IBSS, or MBSS.
— An AP may allow association of devices that do not have the Spectrum Management bit equal to 1 in the Capability Information field in Association Request frames and Reassociation Request frames received from a STA to account for the existence of legacy devices that do not support DFS, but do meet regulatory requirements.

### 11.8.2 Association based on supported channels

#### 11.8.2.1 Association based on supported channels in a non-DMG BSS

A STA shall provide an AP with a list of the channels in which the STA can operate when associating or reassociating by including a Supported Channels element in its (Re)Association Request frames.

An AP may use the supported channels list for associated STAs as an input into an algorithm used to select a new channel for the BSS. The specification of this algorithm is beyond the scope of this standard.

An AP may reject an (re)association request from a STA if it considers the STA's supported channel list to be unacceptable. For example, a STA's supported channel list might be unacceptable if it can operate only in a limited number of channels. The criteria for accepting or rejecting (re)associations are beyond the scope of this standard.

#### 11.8.2.2 Providing supported channels upon association in a DMG BSS

An AP or PCP may advertise the regulatory domain in which it is located via a Country element in the DMG Beacon, Announce, or Information Response frames if dot11MultiDomainCapabilityActivated is true.


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When it (re)associates, the STA shall provide to the AP or PCP a list of channels in which the STA can operate. The STA does this by including a Supported Channels element in the Information Request or (Re)Association Request frames that it transmits. An AP or PCP can use the supported channels list for associated STAs as an input into an algorithm used to select a new channel for the BSS. The specification of this algorithm is beyond the scope of this standard.

The AP or PCP may advertise the supported channels of associated STAs via an Information Response frame with Subject Address field set to the broadcast address and a Supported Channels element that lists the intersection of channels supported by STAs associated with the BSS, as indicated by their Supported Channels elements.

### 11.8.3 Quieting channels for testing

When the AP Quiet Mode field of a Quiet Channel element has the value 1, the Quiet Channel element is called a *mode set Quiet Channel element*.

An AP may schedule quiet intervals by transmitting one or more mode set Quiet Channel elements (VHT AP only) and/or one or more Quiet elements in Beacon frames and Probe Response frames.

A mesh STA may schedule quiet intervals by transmitting one or more Quiet elements in Beacon frames and Probe Response frames. A mesh STA shall not transmit mode set Quiet Channel elements.

A non-VHT AP shall not transmit a Quiet Channel element. An AP shall not transmit a Quiet Channel element with the AP Quiet Mode field value equal to 0 in frames that do not include at least one Quiet element. An AP shall not transmit more than one Quiet Channel element with the AP Quiet Mode field equal to 0. An AP shall not transmit a Quiet Channel element if the BSS bandwidth is 20, 40 or 80 MHz.(#1249)

An AP may stop scheduling quiet intervals, or may transmit Quiet elements with changes in the Quiet Period, Quiet Duration and Quiet Offset fields, or may (VHT AP only) transmit Quiet Channel elements (with changes in the Quiet Period, Quiet Duration and Quiet Offset fields in the case of mode set Quiet Channel elements). A mesh STA may stop scheduling quiet intervals, or may transmit Quiet elements with changes in the Quiet Period, Quiet Duration and Quiet Offset fields, or may transmit (VHT mesh STA only) Quiet Channel elements that are not mode set Quiet Channel elements. Only the most recently received Beacon frame or Probe Response frame defines all future quiet intervals; therefore, all schedules for quiet intervals based on older Beacon frames or Probe Response frames shall be discarded.

An AP or PCP in a DMG BSS may measure one or more channels itself, or the AP or PCP may request associated non-AP and non-PCP STAs in the same BSS to measure one or more channels, either in a dedicated measurement interval or during normal operation. The AP or PCP in a DMG BSS may schedule a service period allocated to itself to quiet the associated STAs and use the self-allocated SP for measurement.

An IBSS STA may schedule quiet intervals only if it is the DFS owner. In order to set a quiet interval schedule, the STA transmits one or more Quiet elements in the first Beacon frame establishing the IBSS. All IBSS STAs shall continue these quiet interval schedules by including appropriate Quiet elements in any transmitted Beacon frames or Probe Response frames. An IBSS STA shall not transmit Quiet Channel elements.

NOTE—This means the quiet interval schedules, if any, are defined by the IBSS STA that starts the IBSS. They cannot subsequently be changed, or initiated, by any STA in the IBSS (including the STA that started the BSS and the DFS owner).

Multiple independent quiet intervals may be scheduled, so that not all quiet intervals have the same timing relationship to TBTT, by including multiple Quiet elements or, in an infrastructure BSS, mode set Quiet Channel elements in Beacon frames or Probe Response frames.

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Control of the channel is lost at the start of a quiet interval, and the following quieting rules apply:

- (#5)The NAV shall be set by a non-VHT STA in the BSS for the length of the quiet interval established by a Quiet element.
- (#5)The NAV shall be set by a VHT STA in the BSS for the duration of the quiet interval established by a Quiet element if a Quiet Channel element was not sent or received with the Quiet element.
- A VHT STA in the BSS shall not transmit PPDUs that occupy the secondary 80 MHz channel or, in an infrastructure BSS, transmit PPDUs to the AP during the quiet interval established by a Quiet element if a Quiet Channel element with the AP Quiet Mode field equal to 0 was sent or received with the Quiet element.
- A VHT STA in an infrastructure BSS shall not transmit PPDUs that occupy the secondary 80 MHz channel during the quiet interval established by a Quiet Channel element with the AP Quiet Mode field in the Quiet Channel element equal to 1.
- Transmission by any non-VHT STA in the BSS of any MPDU and any associated acknowledgment within either the primary channel or the secondary channel (if present) shall complete before the start of the quiet interval.
- Transmission by any VHT STA in the BSS of any MPDU and any associated acknowledgment of the BSS shall complete before the start of the quiet interval established by a Quiet element if a Quiet Channel element was not sent or received with the Quiet element.
- Transmission by any VHT STA in the BSS of any PPDUs that occupy the secondary 80 MHz channel or, in an infrastructure BSS, are directed to the AP, and any associated acknowledgment of the BSS, shall complete before the start of the quiet interval established by a Quiet element if a Quiet Channel element with the AP Quiet Mode field equal to 0 was sent or received with the Quiet element.
- Transmission by any VHT STA in the infrastructure BSS of any PPDUs that occupy the secondary 80 MHz channel and any associated acknowledgment of the BSS shall complete before the start of the quiet interval established by a Quiet Channel element with the AP Quiet Mode field in the Quiet Channel element equal to 1.

Before starting transmission of an MPDU, a STA shall check if there is enough time for the exchange to complete within the time allowed by the quieting rules. If there is not enough time, the STA shall defer the transmission by selecting a random backoff count, using the present CW (without advancing to the next value in the series). The short retry count and long retry count for the MSDU or A-MSDU are not affected.

### 11.8.4 Testing channels for radar

A STA does not transmit in a channel unless the channel has been tested for the presence of radar transmissions according to regulatory requirements.

### 11.8.5 Discontinuing operations after detecting radar

If a STA is operating in a channel and detects radar operating in the channel or accepts that another STA has detected radar operating in the channel, then the STA discontinues transmissions according to regulatory requirements.

### 11.8.6 Detecting radar

The methods that satisfy regulatory requirements to detect radar transmissions are beyond the scope of this standard.


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### 11.8.7 Requesting and reporting of measurements

The response to a Basic request is a Basic report. A STA in an infrastructure BSS or PBSS shall generate a Basic report in response to a Basic request if the request is received from the AP or PCP with which it is associated, except as specified in this subclause.

A STA may measure one or more channels itself or a STA may request other STAs in the same BSS to measure one or more channels on its behalf. These measurements may occur either during a quiet interval or during normal operation.

In order to request other STAs to measure one or more channels, a STA shall use a Spectrum Measurement Request frame containing one or more Measurement Request elements. The measurement request may be sent to an individual or group destination address. Addressing requests to multiple STAs should be used with care to avoid a reply storm.

The measurement requests effectively allowed by these rules are shown in Table 11-11 (Allowed measurement requests).

**Table 11-11—Allowed measurement requests**

| Service set | Source of request | Destination of request | Type of measurement request allowed |
|---|---|---|---|
| BSS | AP | STA | Individual or group |
| | STA | AP | Individual only |
| | STA | STA | None |
| IBSS, MBSS | STA | STA | Individual or group |
| PBSS | PCP | Non-PCP STA | Individual or group |
| | Non-PCP STA | PCP | Individual |
| | Non-PCP STA | Non-PCP STA | None |

A STA that successfully requests another STA to perform a measurement on another channel should not transmit MSDUs, A-MSDUs, or MMPDUs to that STA during the interval defined for the measurement plus any required channel switch intervals. In determining this period, a STA shall assume that any required channel switches take dot11ChannelSwitchTime per switch.

A STA that receives an individually addressed Spectrum Measurement Request frame from a STA in its BSS shall parse the frame's Measurement Request elements in order, with measurements starting at the times specified by the Measurement Request elements.

Any result of a measurement request shall be returned without undue delay to the requesting STA in Measurement Report elements using one or more Spectrum Measurement Report frames. The result may be the completed measurement or an indication that the STA is unable to complete the measurement request.

A STA shall report it is too late to undertake a measurement request if it receives the request after the specified starting time for the measurement.

A STA shall report it is refusing a measurement request if all of the following conditions exist:

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- The STA is capable of undertaking a measurement request.
- The STA does not want to undertake the measurement request at this time.
- The measurement request is not mandatory.

NOTE—Measurements are specified as mandatory or optional in 9.4.2.19 (Measurement Request element).

A STA shall report it is incapable of performing a measurement request if any of the following conditions exists:

- The STA is incapable of undertaking an optional measurement request.
- The STA does not support the channel specified in a mandatory measurement request.
- The STA does not support any requested parallel measurements in the same or different channels.

A Spectrum Measurement Report frame shall contain the same value in its Dialog Token field as the Dialog Token field in the corresponding Spectrum Measurement Request frame, and each Measurement Report element shall contain the same value in its Measurement Token field as the Measurement Token field in the corresponding Measurement Request element.

A STA may autonomously report measurements to another STA in its BSS by transmitting a Spectrum Measurement Report frame that includes a Dialog Token field set to 0 and one or more Measurement Report elements. An IBSS STA may also autonomously report measurements to other STAs in the IBSS using the Channel Map field in the IBSS DFS element in a Beacon frame or Probe Response frame.

A STA may enable or disable measurement requests or autonomous measurement reports from another STA by transmitting Measurement Request elements with the Enable subfield(#291) set to 1 and the Request subfield and Report subfield(#291) set to 0 or 1, as appropriate. These elements do not require a corresponding Measurement Report element in a Spectrum Measurement Report frame. All measurement requests and reports shall be enabled by default. An AP or PCP may ignore a request to disable a mandatory measurement request. All other such requests shall be honored.

The measurement request and report procedures are defined in 11.10 (Radio measurement procedures).

### 11.8.8 Selecting and advertising a new channel

#### 11.8.8.1 General

A channel switch is an attempt to move a BSS to a new operating channel. It is an objective that disruption to the BSS be minimized in this process, although it should be recognized that a channel switch might not successfully move all STAs.

Two procedures are defined for switching channels: the channel switching procedure, which is defined in 11.8.8 (Selecting and advertising a new channel) and 11.8.9 (Channel Switch Announcement element operation), and the extended channel switching procedure, which is defined in 11.9 (Extended channel switching (ECS)).

It should also be stressed that both the channel switching procedure and the extended channel switching procedure are distinct from the regulatory requirement to cease transmission on a particular channel in the presence of radar.

The Address 1 field of a Channel Switch Announcement frame shall be set to the broadcast address.

(#2079)After moving into a new operating channel, a STA shall perform CCA until a frame is detected by which it can set its NAV, or until a period of time indicated by the NAVSyncDelay parameter from the most recent MLME-START.request or MLME-JOIN.request primitive has transpired.


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(#6170)NOTE—Only the extended channel switching procedure allows switching to a different operating class, and hence switching to a different band.

### 11.8.8.2 Selecting and advertising a new channel in a non-DMG infrastructure BSS

This subclause describes operation in an infrastructure BSS that is a non-DMG BSS. For a DMG infrastructure BSS, see 11.8.8.6 (Selecting and advertising a new channel in a DMG BSS).

The decision to switch to a new operating channel in an infrastructure BSS shall be made only by the AP. An AP may make use of the information in Supported Channels(#3510) elements and the results of measurements undertaken by the AP and other STAs in the BSS to assist the selection of the new channel. The algorithm to choose a new channel is beyond the scope of this standard. The AP shall attempt to select a new channel that is supported by all associated STAs.

An AP shall inform associated STAs that the AP is moving to a new channel and shall maintain the association by advertising the switch using Channel Switch Announcement elements in Beacon frames, Probe Response frames, and Channel Switch Announcement frames until the intended channel switch time. The AP may force STAs in the BSS to stop transmissions until the channel switch takes place by setting the Channel Switch Mode field in the Channel Switch Announcement element to 1. The channel switch should be scheduled so that all STAs in the BSS, including STAs in power save mode, have the opportunity to receive at least one Channel Switch Announcement element before the switch. The AP may send the Channel Switch Announcement frame in a BSS without performing a backoff, after determining the WM is idle for one PIFS (see 10.3.2.3 (IFS)).

When an AP transmits (#7160)an Extended Channel Switch Announcement frame or a frame containing a Channel Switch Announcement element or an Extended Channel Switch Announcement element, it should include a Max Channel Switch Time element in the frame if the Channel Switch Count field is nonzero and it may include the element if the field is 0.(#6027) When the AP includes the Max Channel Switch Time element(#6), the AP shall transmit the first Beacon frame in the new channel no later than the time indicated in the Switch Time field of the Max Channel Switch Time element after the last Beacon frame transmitted in the current channel, unless the AP determines that it is unable to operate on the new channel.(#1812)

(#6027)NOTE 1—An Extended Channel Switch Announcement frame does not contain an Extended Channel Switch Announcement element (see 9.6.7.7 (Extended Channel Switch Announcement frame format)).

If a Channel Switch Announcement element in a Beacon or Probe Response frame is used to announce a switch to a 20 MHz BSS bandwidth, then a Wide Bandwidth Channel Switch subelement in a Channel Switch Wrapper element shall not be present in the same frame.

If a Channel Switch Announcement element in a Beacon or Probe Response frame is used to announce a switch to a 40 MHz BSS bandwidth, then a Wide Bandwidth Channel Switch subelement in a Channel Switch Wrapper element shall also be present in the same frame if the STA sending the frame is extended spectrum management capable.

A Channel Switch Wrapper element shall not be included in Beacons and Probe Response frames if the element contains zero subelements.

A STA that receives a Channel Switch Announcement element may choose not to perform the specified switch, but to take alternative action. (#6)A STA that receives a Max Channel Switch Time element from its associated AP should not transmit a frame to the AP on the new channel until it receives a frame on the new channel from the AP.

(#6)NOTE 2—Whether or not a Max Channel Switch Time element is included, regulations might forbid a STA from transmitting on the new channel until it receives an enabling signal (e.g., a Beacon frame).

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(#6)NOTE 3—As an alternative to performing the specified channel switch, a STA might choose to move to a different BSS.

(#1599)(#6)An AP that has indicated OCVC(#3505) shall deauthenticate non-AP STAs that have indicated (#6090)OCVC, are not in WNM Sleep, and have failed to send an SA Query Request frame(#1491) within an implementation specific timeout following a channel switch, and should pause the transmission and reception of Data frames until the SA query procedure has completed successfully for additional protection.

If dot11RSNAOperatingChannelValidationActivated is true and a channel switch is requested while the handshake is in progress, the handshake should be aborted.

A non-AP STA in an infrastructure BSS shall not transmit the Channel Switch Announcement element.

### 11.8.8.3 Selecting and advertising a new channel in an IBSS

DFS in an IBSS is complicated by the following:

- There is no central AP function for collating measurements or coordinating a channel switch. If STAs make independent decisions to switch channel in the presence of radar, there is a danger that all STAs announce switches to different channels if several of them detect the radar.
- There is no association protocol that can be used to
  - Exchange supported channel information
  - Determine membership of the IBSS at a given instant for requesting measurements.
- Beaconing is a shared process; therefore, there is no guarantee that a STA that has something to send (e.g., a channel switch message) will be the next STA to transmit a Beacon frame.
- A 20/40 MHz IBSS cannot be changed to a 20 MHz IBSS, and a 20 MHz IBSS cannot be changed to a 20/40 MHz IBSS.

The DFS owner service, IBSS DFS element, and Channel Switch Announcement frame address these complications:

- The DFS owner service provides a central point of coordination for a channel switch. It attempts to minimize the probability that multiple STAs concurrently decide to switch to different channels. The DFS Owner field and DFS Recovery Interval field in the IBSS DFS element support the DFS owner service.
- Each STA shall include a Channel Map field in the IBSS DFS elements that it transmits. The channel map communicates the STA-supported channel set and basic measurement reports for that STA.
- Each STA shall have the ability to send a Channel Switch Announcement element in a Management frame other than a Beacon frame or Probe Response frame.

The potential for hidden nodes within an IBSS means that an IBSS channel switching procedure might not move all STAs. In some regulatory domains, each STA in an IBSS is required by regulation to detect radar and cease transmission, after a required interval, on any channel on which the presence of radar is detected.

A STA at which an IBSS is started shall be a DFS owner in that IBSS. That STA shall include its MAC address in the DFS Owner field of the IBSS DFS element and DFS Recovery Interval field from the MLME.START.request primitive parameter. The purpose of the DFS owner is to coordinate a channel switch. All STAs in an IBSS shall have the ability to become DFS owner.

Each IBSS STA shall adopt the DFS Owner field and the DFS Recovery Interval field from any valid IBSS DFS element when the received frame contains a matching SSID and the value of the timestamp is later than the STA's TSF timer. The STA shall include the adopted values in the IBSS DFS elements it transmits.


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Because all IBSS STAs participate in sending Beacon frames, this process always, over a number of beacon intervals, results in a unified view of one DFS owner throughout the IBSS.

In order to attempt a channel switch using the DFS owner, a STA that detects radar shall broadcast one or more Spectrum Measurement Report frames indicating the presence of the radar.

A DFS owner receiving a Spectrum Measurement Report frame indicating the presence of radar in the current channel shall select and advertise a new operating channel (including the possibility of no change). The DFS owner may make use of information received in Channel Map fields and from measurements undertaken by other members of the IBSS to assist the selection of the new channel. The algorithm to choose a new channel is beyond the scope of this standard, but shall satisfy any regulatory requirements, including uniform spreading rules and channel testing rules. The DFS owner shall attempt to select a new channel that is supported by all members of the IBSS. Note that this process might be imperfect in that the DFS owner might have incomplete knowledge and there might not be a suitable channel.

The DFS owner shall attempt to make the members of the IBSS aware of the new operating channel by broadcasting at least one Channel Switch Announcement frame. The DFS owner may transmit the Channel Switch Announcement frame in an IBSS without performing a backoff, after determining that the WM is idle for one PIFS (see 10.3.2.3 (IFS)). The DFS owner shall also include the Channel Switch Announcement element in all Beacon frames, Probe Response frames, or Channel Switch Announcement frames until the intended channel switch time. A STA that receives a valid Channel Switch Announcement element that is not a superseded Channel Switch Announcement element (see 11.15.3.3 (Channel management at the AP and in an IBSS)) shall repeat this element in all Beacon frames and Probe Response frames that it transmits. The DFS owner may attempt to silence STAs in the IBSS until the channel switch takes place using the Channel Switch Mode field in the Channel Switch Announcement element. If possible, the channel switch should be scheduled so that all STAs in the IBSS, including STAs in power save mode, have the opportunity to receive at least one Channel Switch Announcement element before the switch.

If a STA does not receive a valid Channel Switch Announcement element from the DFS owner within the DFS recovery time, then it shall enter DFS recovery mode. DFS recovery time is measured from the end of the frame that first announced radar presence, whether that frame was transmitted by the STA or received from another STA. In DFS recovery mode the STA shall assume the role of DFS owner, shall select a new operating channel, and shall advertise the new channel by transmitting a Channel Switch Announcement frame using the contention resolution algorithm defined for beacon transmission at TBTT in 11.1.3.5 (Beacon generation in an IBSS). The STA shall also include the Channel Switch Announcement element in all Beacon frames and Probe Response frames until the intended channel switch time. A STA that is not the DFS owner shall not initiate a channel switch.

If the STA receives a valid Channel Switch Announcement element that is not a superseded Channel Switch Announcement element (see 11.15.3.3 (Channel management at the AP and in an IBSS)) from another member of the IBSS, the STA shall leave DFS owner recovery mode prior to the channel switch and adopt the received channel switch information. If the Channel Switch Announcement element was in a Beacon frame or Probe Response frame, the STA shall also adopt the STA identified by the DFS owner address of the IBSS DFS element as the DFS owner. If the Channel Switch Announcement element was in a Channel Switch Announcement frame, the receiving STA shall adopt the STA that transmitted the frame as the DFS owner.

There are several circumstances when DFS owner recovery is needed (e.g., if the original DFS owner has left the network or if the original measurement report was not received by the initial DFS owner). Note that DFS owner recovery might temporarily give rise to more than one DFS owner in the IBSS. This risk is mitigated by the random nature of the IBSS DFS recovery mechanism. However, because all IBSS STAs participate in sending Beacon frames, over a number of beacon periods, there will be convergence from multiple DFS owners to one DFS owner.

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#### 11.8.8.4 MBSS channel switching

##### 11.8.8.4.1 General

A mesh channel switch might be triggered by the need to avoid interference to a detected radar signal, or to reassign mesh STA channels to maintain MBSS connectivity.

A mesh STA may make use of the information in Supported Channels(#3510) elements, Supported Operating Classes elements, and the results of measurements undertaken by the mesh STAs in the MBSS to assist the selection of the new channel. The algorithm for choosing a new channel is beyond the scope of this standard.

A 20/40 MHz MBSS may be changed to a 20 MHz MBSS and a 20 MHz MBSS may be changed to a 20/40 MHz MBSS.

When an MBSS switches from a 20 MHz MBSS to a 20/40 MHz MBSS or switches from a 20/40 MHz MBSS to a 20 MHz MBSS, a mesh STA might need to do path maintenance to find an optimized path.

##### 11.8.8.4.2 Initiating MBSS channel switch

A mesh STA shall not initiate a new channel switch attempt if there is an ongoing channel switch attempt by this mesh STA.

A mesh STA shall inform each of the peer mesh STAs that the mesh STA is moving to a new channel while maintaining mesh peerings by including Channel Switch Announcement elements together with the Mesh Channel Switch Parameters element in all Beacon frames, Probe Response frames, and Channel Switch Announcement frames that it transmits until the intended channel switch time. The channel switch should be scheduled so that all mesh STAs in the MBSS, including mesh STAs in power save mode, have the opportunity to receive at least one Channel Switch Announcement element before the switch.

The fields in the Channel Switch Announcement element are set as follows:

— The Channel Switch Count field shall be set to the time period until the mesh STA sending the Channel Switch Announcement element switches to the new channel.
— The Channel Switch Mode field is reserved.
— The New Channel Number field shall be set to the number of the channel to which the mesh STA is moving.

The fields in the Mesh Channel Switch Parameters element are set as follows:

— The Precedence Value field shall be set to a random value selected from a uniform distribution in the range 0 to 65 535.
— The mesh STA may force mesh STAs in the MBSS to stop transmissions of frames (except frames containing Channel Switch Announcement element) until the channel switch takes place by setting the Transmit Restrict subfield of the Flags field to 1.
— The Reason subfield in the Flags field shall be set to 1 to indicate that the content of the Reason Code field (as defined in Table 9-79 (Reason codes)) is valid. The Reason Code field shall be set to MESH-CHANNEL-SWITCH-REGULATORY-REQUIREMENTS when the channel switch is initiated to meet regulatory requirement; otherwise, the Reason Code field shall be set to MESH-CHANNEL-SWITCH-UNSPECIFIED.
— The Initiator subfield of the Flag field shall be set to 1.
— The Time To Live field should be set to the maximum number of hops (e.g., dot11MeshHWMPnetDiameter) for which this Channel Switch attempt is intended.


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#### 11.8.8.4.3 Processing channel switch announcement

Upon receipt of a Channel Switch Announcement frame or Extended Channel Switch Announcement frame, a mesh STA shall not accept and shall not process the received Channel Switch Announcement element or Extended Channel Switch Announcement element, if any of the following is true:

— The Mesh Channel Switch Parameters element is not present in the received frame containing the Channel Switch Announcement element or the Extended Channel Switch Announcement element.

— The Time To Live field in the received Mesh Channel Switch Parameters element is 0.

— A mesh channel switch is already running and the mesh STA has not yet moved into the new channel and/or operating class and the current precedence value is greater than or equal to the received Precedence Value field.

A mesh STA that receives a Channel Switch Announcement element may choose not to perform the specified switch, but to take alternative action. For example, it may choose to move to a different MBSS.

If dot11RSNAOperatingChannelValidationActivated is true and a channel switch is requested while the handshake is in progress, the handshake should be aborted.

When a mesh STA accepts a channel switch, it shall adopt the information received in the Channel Switch Announcement element and the Mesh Channel Switch Parameters element. The mesh STA shall schedule the channel switch according to this information. If the Time To Live field value in the received Mesh Channel Switch Parameters element is greater than 1, the mesh STA shall transmit a Channel Switch Announcement frame and shall include a Channel Switch Announcement element together with a Mesh Channel Switch Parameters element in the Beacon and Probe Response frames until the intended channel switch time. The Channel Switch Mode and New Channel Number fields in the transmitted Channel Switch Announcement element(s) are set to the same values as in the received Channel Switch Announcement element. The Channel Switch Count field is set to indicate the time remaining until the channel switch, as specified in 9.4.2.17 (Channel Switch Announcement element). The Reason Code and Precedence Value fields in the transmitted Mesh Channel Switch Parameters element(s) are set to the same values as in the received Mesh Channel Switch Parameters element. The Time to Live and Flags fields are set as specified in 9.4.2.101 (Mesh Channel Switch Parameters element). The Time To Live field shall be set to the received Time To Live field minus 1. The Initiator field shall be set to 0. The Transmit Restrict field shall be set to 1 when the mesh STA requires neighboring mesh STAs not to transmit (until the scheduled channel switch occurs) further frames that do not contain the Channel Switch Announcement element on the current channel. The Transmit Restrict subfield shall be set to 0 otherwise.

It is possible that a channel switch is not successful in moving all of the mesh STAs in MBSS to the new operating channel. Transitioning to a new channel does not tear down mesh peerings and, as long as the mesh peers move to the new operating channel, their peerings are maintained in the new channel.

After moving into a new operating channel, the mesh STA shall perform CCA until a frame is detected by which it can set its NAV, or until a period of time indicated by the NAVSyncDelay parameter from the most recent MLME-START.request primitive has transpired.

#### 11.8.8.4.4 Channel switch across an operating class

When dot11OperatingClassesImplemented is true and the mesh STA is capable of operation in more than one operating class, the mesh STA shall include the Supported Operating Classes element within its Mesh Peering Open frames. The Supported Operating Classes element announces the operating classes that the mesh STA supports.

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When dot11OperatingClassesImplemented is true, a mesh STA may switch from the operating channel to a channel in a different operating class using an Extended Channel Switch Announcement element or frame.(#1663)

NOTE —A mesh STA can switch from the operating channel to a channel in the same operating class using a Channel Switch Announcement or Extended Channel Switch Announcement element or frame (see 11.9.3.4 (Selecting and advertising a new channel in an MBSS)).(#1663)

### 11.8.8.5 HT-greenfield transmissions in operating classes that include a behavior limit of DFS_50_100_Behavior

The requirements described in this subclause apply only when an HT STA is operating in an operating class for which the behavior limits set listed in Annex E includes the value DFS_50_100_Behavior; i.e., the operating class is subject to DFS with 50–100 μs radar pulses.

A non-HT OBSS scan operation is a passive or active scan of the primary channel and of the secondary channel if the STA conducting the scan is in a 20/40 MHz BSS that the STA currently uses or intends to use. During a non-HT OBSS scan operation, the channel scan duration shall be a minimum of dot11OBSSScanPassiveTotalPerChannel TUs when scanning passively and a minimum of dot11OBSSScanActiveTotalPerChannel TUs when scanning actively.

Before an HT STA starts a BSS with the OBSS Non-HT STAs Present field of the HT Operation element equal to 0, the HT STA shall perform a non-HT OBSS scan in order to search for any existing non-HT OBSSs.

When an HT STA detects that there are one or more non-HT OBSSs, and if the HT STA starts a BSS on that channel, then the HT STA shall set to 1 the OBSS Non-HT STAs Present field of the HT Operation element it transmits; otherwise, the HT STA may set to 0 the OBSS Non-HT STAs Present field of the HT Operation element it transmits.

NOTE 1—Detection of a non-HT OBSS can be achieved by the reception of a Beacon or Probe Response frame that does not contain an HT Capabilities element or HT Operation element.

An HT AP shall not transmit a PPDU with the FORMAT parameter of the TXVECTOR set to HT_GF if the OBSS Non-HT STAs Present field of the HT Operation element is equal to 1 in the most recently transmitted Management frame that contained that element.

An HT non-AP STA shall not transmit a PPDU with the FORMAT parameter of the TXVECTOR set to HT_GF if the most recent frame received from its AP containing an HT Operation element has the OBSS Non-HT STAs Present field equal to 1.

NOTE 2—This requirement applies also to PPDUs transmitted on a direct link between two non-AP STAs.

When moving the BSS to a new channel or set of channels and before completing a non-HT OBSS scan of the new channel or set of channels, an HT AP shall set to 1 the OBSS Non-HT STAs Present field of the HT Operation element it transmits. After the HT AP completes one non-HT OBSS scan of the new channel or set of channels and if the HT AP has detected that there are zero non-HT OBSSs, then the HT AP may set to 0 the OBSS Non-HT STAs Present field of the HT Operation element it transmits.

### 11.8.8.6 Selecting and advertising a new channel in a DMG BSS

The decision to switch to a new operating channel in a DMG BSS shall be made only by an AP or PCP. An AP or PCP may make use of the information in received Supported Channels(#3510) elements and the results of measurements undertaken by the AP or PCP and other STAs in the BSS to assist the selection of the new channel. The algorithm to choose a new channel is beyond the scope of this standard.


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An AP or PCP shall inform associated STAs that the AP or PCP is changing to a new channel and shall maintain the association by advertising the switch using the Extended Channel Switch Announcement element in its transmitted DMG Beacon frames, Announce frames, and Information Response frames until the intended channel switch time. The channel switch should be scheduled so that all non-AP and non-PCP STAs in the BSS, including STAs in power save mode, have the opportunity to receive at least one Extended Channel Switch Announcement element before the switch. A STA may ignore the Channel Switch Mode field and either cease transmissions or attempt new transmissions in the operating channel until the channel change occurs.

A STA that receives an Extended Channel Switch Announcement element may choose not to perform the specified switch, but to take alternative action. For example, it may choose to move to a different BSS. A non-AP and non-PCP STA in an infrastructure BSS or PBSS shall not transmit the Extended Channel Switch Announcement element.

#### 11.8.8.7 Selecting and advertising new channels in an EDMG BSS(11ay)

A change in the BSS operating channels or operating channel width as announced by the EDMG Operation element is referred to as a change of operating channels.

The decision to switch to new operating channels in an EDMG BSS shall be made only by an AP or PCP. An AP or PCP may make use of the information it received in EDMG Capabilities elements and the results of measurements undertaken by the AP or PCP and other STAs in the BSS to assist the selection of the new operating channels. The algorithm to choose the new operating channels is beyond the scope of this standard.

An AP or PCP shall inform associated STAs that the AP or PCP is changing operating channels and shall maintain the association by advertising the switch using the Extended Channel Switch Announcement element and EDMG Wide Bandwidth Channel Switch element in its transmitted DMG Beacon frames, Announce frames, or Information Response frames until the intended channel switch time. The channel switch should be scheduled so that all non-AP and non-PCP STAs in the BSS, including STAs in power save mode, have the opportunity to receive at least one Extended Channel Switch Announcement element and EDMG Wide Bandwidth Channel Switch element before the switch. A STA may ignore the Channel Switch Mode field and either cease transmissions or attempt new transmission in the operating channel until the channel change occurs.

A STA that receives an Extended Channel Switch Announcement element and EDMG Wide Bandwidth Channel Switch element chooses whether to perform the specified switch. If a STA that receives an Extended Channel Switch Announcement element and EDMG Wide Bandwidth Channel Switch element chooses to perform the specified switch, it shall operate on the channels indicated in the EDMG Wide Bandwidth Channel Switch element. If a STA that receives an Extended Channel Switch Announcement element and an EDMG Wide Bandwidth Channel Switch element chooses not to perform the specified switch, it may take alternative action. For example, it may choose to move to a different BSS.

A non-AP and non-PCP STA in an infrastructure BSS or PBSS shall not transmit the Extended Channel Switch Announcement element or the EDMG Wide Bandwidth Channel Switch element.

### 11.8.9 Channel Switch Announcement element operation

If a non-DMG STA in a BSS that is not an IBSS receives a Channel Switch Mode field that has the value 1, it shall not transmit any more frames on the channel until the scheduled channel switch occurs. An IBSS STA may treat a Channel Switch Mode field equal to 1 as advisory. A Channel Switch Mode equal to 0 does not impose any requirement on the STA that receives the Channel Switch Announcement frame.

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NOTE —A channel switch announcement cannot be used to switch bands, since the operating class is not communicated.(#3204)

### 11.8.10 Future Channel Guidance operation

This subclause defines a mechanism to create, communicate and act on the Future Channel Guidance element.

When dot11FutureChannelGuidanceActivated is true, a STA shall follow these procedures for future channel guidance operation.

A STA transmitting Beacon frames transmits the Future Channel Guidance element in (Re)Association Response frames and optionally in Beacon frames.

In some bands, the channel clearing time will be much less than one second for all STAs, and future channel guidance permits all STAs (#4110)to know what channels will be used if the current channels are cleared.

In some bands, Beacon frames are an enabling signal, and some STAs are not allowed to transmit in the band before receiving an enabling signal. When Beacon frame reception stops, some STAs are no longer enabled to transmit in the band. In these bands, when Beacon frame reception stops, it is an implicit message to switch from current channels to other channels according to prior future channel guidance.

Future channel guidance indicates future channels that the Beaconing STA switches to while maintaining associations and mesh peering relationships (see 11.8.8.2 (Selecting and advertising a new channel in a non-DMG infrastructure BSS), 11.8.8.3 (Selecting and advertising a new channel in an IBSS), 11.8.8.4.2 (Initiating MBSS channel switch), 11.8.8.6 (Selecting and advertising a new channel in a DMG BSS), 11.9.3.2 (Selecting and advertising a new channel in an infrastructure BSS), 11.9.3.3 (Selecting and advertising a new channel in an IBSS), and 11.9.3.4 (Selecting and advertising a new channel in an MBSS)).

A STA receiving the Future Channel Guidance element shall retain the information until it receives a different Future Channel Guidance element from the same STA, it receives a Channel Switch Announcement element or a Channel Switch Announcement frame from the same STA, or it chooses alternative action. For example, it may choose to move to a different BSS.

## 11.9 Extended channel switching (ECS)

### 11.9.1 General

This subclause describes ECS procedures that change the BSS operating channel frequency and bandwidth. When the STA's dot11ExtendedChannelSwitchActivated value is true, the enabling STAs (see 11.11 (DSE procedures)), APs, DFS owners, and mesh STAs may construct and transmit frames that contain Extended Channel Switch Announcement elements.

A STA shall use the ECS procedures defined in this subclause if dot11ExtendedChannelSwitchActivated is true. To indicate that it can perform ECS procedures, a STA shall set dot11ExtendedChannelSwitchActivated, dot11MultiDomainCapabilityActivated and dot11OperatingClassesRequired to true and shall set to 1 the Extended Channel Switching field in the Extended Capabilities elements it transmits. When dot11ExtendedChannelSwitchActivated is false, the STA shall not use ECS procedures. When an AP is switching to a different channel and one or more of its associated STAs do not support extended channel switching capability, then both the Extended Channel Switch Announcement and the Channel Switch Announcement elements and frames may be used.

If dot11ExtendedChannelSwitchActivated and dot11LCIDSERequired are true, frames containing Channel Switch Announcement elements shall not be transmitted.


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An enabling STA may send frames containing Extended Channel Switch Announcement elements to dependent STAs (see 11.11.5 (Dependent STA operation with DSE)). If dot11DSERequired is true, a STA shall perform ECS procedures to switch at the time indicated by the channel switch count, or the STA shall change its enablement state for the enabling STA to unenabled.

The Address 1 field of an Extended Channel Switch Announcement frame shall be set to the broadcast address.

(#2079)After moving into a new operating channel, a STA shall perform CCA until a frame is detected by which it can set its NAV, or until a period of time indicated by the NAVSyncDelay parameter from the most recent MLME-START.request or MLME-JOIN.request primitive has transpired.(#3176)(#4410)

(#6170)NOTE—The RSN configuration does not change across a channel switch. This means, for example, that a switch from the 2.4 GHz or 5 GHz band to the 6 GHz band is only possible if the RSNE and RSNXE advertised in the 2.4 GHz or 5 GHz band are also valid in the 6 GHz band.

### 11.9.2 Advertising supported operating classes

When dot11ExtendedChannelSwitchActivated or dot11OperatingClassesRequired is true, the Current Operating Class field in the Supported Operating Classes element shall indicate the operating class in use for transmission and reception. The Operating Classes field shall list all operating classes with which the STA is capable of operating for the country that is specified in the Country element (9.4.2.7 (Country element)).

### 11.9.3 Selecting and advertising a new channel and/or operating class

#### 11.9.3.1 General

An attempt may be made to move a BSS to a new operating channel and/or new operating class using extended channel switching. An objective during this process is to minimize disruption to the BSS. It is possible, however, that an extended channel switch is not successful in moving all STAs to the new channel and/or operating class.

#### 11.9.3.2 Selecting and advertising a new channel in an infrastructure BSS

When an AP with dot11DSERequired true receives frames containing Extended Channel Switch Announcement elements from the enabling STA, it shall advertise an extended channel switch with the same channel switch mode, new operating class, new channel number, and channel switch count as received in the Extended Channel Switch Announcement elements.

The decision to switch to a new operating channel and/or operating class in an infrastructure BSS is made by the AP when dot11DSERequired is false. An AP may make use of the information in the Supported Channels element, Supported Operating Classes element, and the results of measurements undertaken by the AP and other STAs in the BSS to assist the selection of the new channel and/or operating class. A method to make the decision and to select a new channel is defined in 11.8.8.2 (Selecting and advertising a new channel in a non-DMG infrastructure BSS).

When an AP is switching to a different operating class and dot11ExtendedChannelSwitchActivated is true, then the AP shall use the Extended Channel Switch Announcement element and frame. In addition, the AP may also send Channel Switch Announcement elements and frames when the requirements signified by the new operating class are met by all associated STAs.

When an AP is switching to a new channel within the same operating class and dot11ExtendedChannelSwitchActivated is true, then the AP shall send the Extended Channel Switch Announcement element and frame, or both the Extended Channel Switch Announcement and the Channel

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Switch Announcement elements and frames. If dot11ExtendedChannelSwitchActivated is false, the AP shall send the Channel Switch Announcement element and frame.

When dot11ExtendedChannelSwitchActivated is true, an AP shall inform associated STAs that the AP is moving to a new channel and/or operating class and maintain the association by advertising the switch using Extended Channel Switch Announcement elements in any transmitted Beacon frames, Probe Response frames, and Extended Channel Switch Announcement frames until the intended channel switch time. The AP may request STAs in the BSS to stop transmissions until the channel switch takes place by setting the Extended Channel Switch Mode field to 1 in the Extended Channel Switch Announcement element. If possible, the channel switch should be scheduled so that all STAs in the BSS, including STAs in power save mode, have the opportunity to receive at least one Extended Channel Switch Announcement element before the switch. The AP may send the Extended Channel Switch Announcement frame without performing a backoff, after determining the WM is idle for one PIFS (see 10.3.2.3 (IFS)). When both the Extended Channel Switch Announcement and the Channel Switch Announcement elements are transmitted in Action frames, they shall be sent in separate frames.

When an AP transmits (#7160)an Extended Channel Switch Announcement frame or a frame containing a Channel Switch Announcement element or an Extended Channel Switch Announcement element, it should include a Max Channel Switch Time element in the frame if the Channel Switch Count field is nonzero and it may include the element if the field is 0.(#6027) When the AP includes the Max Channel Switch Time element(#6), the AP shall transmit the first Beacon frame in the new channel no later than the time indicated in the Switch Time field of the Max Channel Switch Time element after the last Beacon frame transmitted in the current channel, unless the AP determines that it is unable to operate on the new channel(#7160).

If an Extended Channel Switch Announcement element in a Beacon or Probe Response frame is used to announce a switch to a 40 MHz BSS bandwidth, then a Wide Bandwidth Channel Switch subelement in a Channel Switch Wrapper element may be present in the same frame if the STA sending the frame is extended spectrum management capable.

When a STA with dot11DSERequired equal to false receives an Extended Channel Switch Announcement element, it may choose not to perform the specified switch, but to take alternative action. (#6)A STA that receives a Max Channel Switch Time element from its associated AP should not transmit a frame to the AP on the new channel until it receives a frame on the new channel from the AP.

(#6)NOTE 1—Whether or not a Max Channel Switch Time element is included, regulations in certain regulatory domains might(#3091) forbid a STA from transmitting on a new channel until it has received an enabling signal (e.g., a Beacon frame).(#4054)

(#6)NOTE 2—As an alternative to performing the specified channel switch, a STA might choose to move to a different BSS.

If dot11RSNAOperatingChannelValidationActivated is true and a channel switch is requested while a security handshake is in progress, the handshake should be aborted.

If the STA chooses to perform the specified switch and dot11RSNAOperatingChannelValidationActivated is true and the AP has indicated OCVC(#3505), after switching to the new channel the STA shall wait a random delay uniformly-distributed in the range between (Ed1)0 and 5000 μs, and then initiate the SA query procedure once any applicable conditions for transmitting on the new channel are met (e.g., channel access procedures, DFS or enablement procedures). This procedure shall be initiated whether or not the switch was based on a protected Management frame that contained the new operating channel information. The STA may pause Data frame transmission and may (#3683)discard any received Data frames until the SA query procedure has completed successfully for additional protection.

If a STA initiates SA query procedure to validate a channel switch, any existing SA query procedure for channel switch validation shall be abandoned.


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A non-AP STA in an infrastructure BSS shall not transmit the Extended Channel Switch Announcement element.

#### 11.9.3.3 Selecting and advertising a new channel in an IBSS

When a DFS owner with dot11DSERequired true receives frames containing Extended Channel Switch Announcement elements from the enabling STA, it shall advertise an extended channel switch with the same channel switch mode, new operating class, new channel number, and channel switch count as received in the Extended Channel Switch Announcement elements.

The DFS owner that advertises a channel switch shall follow the rules defined in 11.8.8.3 (Selecting and advertising a new channel in an IBSS) with the following extensions:

a) If a DFS owner is switching to a new channel or to the same channel in a different operating class and dot11ExtendedChannelSwitchActivated is true, then the DFS owner shall use the Extended Channel Switch Announcement element and frame.(#3322)

b) If a DFS owner is switching to a new channel within the same operating class and dot11ExtendedChannelSwitchActivated is true, then the DFS owner shall send the Extended Channel Switch Announcement element and frame, or both the Extended Channel Switch Announcement and the Channel Switch Announcement elements and frames. If dot11ExtendedChannelSwitchActivated is false, the DFS owner shall send the Channel Switch Announcement element and frame, or both the Extended Channel Switch Announcement and the Channel Switch Announcement elements and frames.

c) If both the Extended Channel Switch Announcement and the Channel Switch Announcement elements are transmitted in Public Action frames, they shall be sent in separate frames.

The DFS owner may transmit the Extended Channel Switch Announcement frame in an IBSS without performing a backoff, after determining that the WM is idle for one PIFS (see 10.3.2.3 (IFS)).

#### 11.9.3.4 Selecting and advertising a new channel in an MBSS

A mesh STA may make use of the information in the Supported Channels element, Supported Operating Classes element, and the results of measurements undertaken by this mesh STA and other mesh STAs in the MBSS to assist the selection of the new channel and/or operating class.

If dot11ExtendedChannelSwitchActivated is true, the mesh STA that advertises a channel switch shall follow the rules defined in 11.8.8.4 (MBSS channel switching) with the following extensions:

a) If a mesh STA is switching to a different operating class, then the mesh STA shall use the Extended Channel Switch Announcement element and frame.(#3322)

b) If a mesh STA is switching to a new channel within the same operating class, then the mesh STA shall send the Channel Switch Announcement element and frame, or both the Extended Channel Switch Announcement and the Channel Switch Announcement elements and frames.(#3324)

c) The Channel Switch Announcement element and Extended Channel Switch Announcement element, when sent, shall be included in the Beacon and Probe Response frames until the intended channel switch time.(#3325)

## 11.10 Radio measurement procedures

### 11.10.1 General

This subclause describes the radio measurements and the procedures for requesting and reporting radio measurements between STAs. When a STA implements support for one or more of the procedures described in this subclause, it shall set dot11RadioMeasurementActivated to true. When dot11RadioMeasurementActivated

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is true, dot11MultiDomainCapabilityImplemented, dot11MultiDomainCapabilityActivated, dot11OperatingClassesImplemented, and dot11OperatingClassesRequired shall be true.

NOTE—A key issue in radio measurement is network operation and management, considering each STA's service load, power state, and operating conditions. Timely measurement reports might be more important than percentage of wireless capacity or STA capacity used by radio measurements. The measurement requester might consider traffic load and application requirements, regulatory requirements, and specific measurement states from every STA in support of wireless network management. There are no typical scenarios that describe IEEE 802.11 operation in all bands. Off-channel measurements are desirable to gather timely information about the channel to which to switch BSS operation, and the noisier the operating environment, the more urgent the need for radio measurements off the serving channel. In any case, the measuring STA might refuse any measurement request.

### 11.10.2 Measurement on operating and nonoperating channels

Measurements on nonoperating channels might need the measuring STA to interrupt its data services on the operating channel, switch channels, and make measurements. Measurements on the operating channel might not require the STA to interrupt its data services.

All stations are responsible for maintaining data services and an association or membership with the BSS on the operating channel while performing measurements on nonoperating channels.

A STA shall determine the time between successive nonoperating channel measurements. This time may be a fixed length, or it may be determined by the STA using application-specific (or other) knowledge.

### 11.10.3 Measurement start time

A Radio Measurement Request frame may contain a single Measurement Request element or a sequence of Measurement Request elements. A STA that accepts the first or only measurement request within a Radio Measurement Request frame shall start the measurement as soon as practical after receiving the request. Subsequent measurement requests in the Radio Measurement Request frame that are accepted shall start as soon as practical after processing the previous request in the frame. Such measurement start times shall be subject to any specified randomization interval.

The radio measurement category permits a randomization interval to be specified for measurement start times. The intent of this is to avoid traffic storms that could arise with synchronized group addressed measurements. Prior to making each measurement in the requested sequence, the STA shall calculate a random delay distributed uniformly in the range 0 to the randomization interval specified in the measurement request. The STA shall not start the measurement until this delay has expired. Randomization interval is specified in units of TUs. A randomization interval field value of 0 in a measurement request indicates that no random delay is to be used.

NOTE—It is important that designers recognize the need for statistical independence of the random number streams between STAs.

A number of repetitions may be specified in the Radio Measurement Request frame. In this case, the measurements in the frame are repeated as detailed further in 11.10.7 (Repeated Measurement Request frames). Each time a measurement is repeated, the STA shall recalculate the random delay as described above.

When a Measurement Start Time field is present in a measurement report, the measuring STA shall report the value of its TSF timer at the time the measurement started to an accuracy of ± 1 TU.

### 11.10.4 Measurement duration

The values of Request Measurement Duration and Duration Mandatory in the received measurement request and the dot11RMMaxMeasurementDuration setting in the receiving STA determine if the receiving STA


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accepts the measurement request and for how long the measurement is performed. dot11RMMaxMeasurementDuration indicates a measurement duration using the following formula:

$$\text{Maximum Measurement Duration in TUs} = 2^{(\text{dot11RMMaxMeasurementDuration} - 4)} \times \text{BeaconInterval}$$

Table 11-12 (Measurement Duration) describes how a STA responds to a measurement request depending on the values of dot11RMMaxMeasurementDuration, Measurement Duration, and Duration Mandatory.

**Table 11-12—Measurement Duration**

| dot11RMMaxMeasurementDuration | Measurement Duration in the Measurement Request | Duration Mandatory | Notes |
|---|---|---|---|
| 0 | Any value | 1 | The STA shall perform measurements for the requested measurement duration. |
| 0 | Any value | 0 | The STA may perform measurements for a duration shorter than the requested measurement duration. |
| Nonzero | Any value | 0 | The STA shall perform measurements for a maximum duration that is equal to the minimum of the requested measurement duration and the dot11RMMaxMeasurementDuration. |
| Nonzero | Requested measurement duration > Maximum Measurement Duration in TUs | 1 | The STA shall reject the measurement request with the Measurement Report Mode set to “refused.” |
| Nonzero | Requested measurement duration ≤ Maximum Measurement Duration in TUs | 1 | The STA shall perform the measurement for the requested duration. |

Measurement duration on nonoperating channels is defined by dot11RMNonOperatingChannelMaxMeasurementDuration. If this attribute is 0, the STA does not support RM measurements on nonoperating channels; on receipt of a Radio Measurement Request frame requesting a measurement on nonoperating channels, the STA shall reject the measurement request by returning a Measurement Report element in which the Incapable subfield(#291) in the Measurement Report Mode field is 1. The interpretation rules defined in Table 11-12 (Measurement Duration) also apply for all nonzero values of dot11RMNonOperatingChannelMaxMeasurementDuration for measurements on nonoperating channels.

NOTE—Measurement duration on nonoperating channels is subject to further limitations due to maximum (#4308)off-channel time.

If the Duration Mandatory subfield(#291) is 1 in the Measurement Request Mode field(#555) of a measurement request, the requested STA, if it accepts the request, shall perform the measurement over the Measurement Duration specified in the request. If the STA is unable to commit to making the measurement over the requested duration, it shall refuse the request by sending a measurement report in which the Refused subfield(#291) in the Measurement Report Mode field is set to 1. The measurement duration in the measurement report is equal to the requested measurement duration.

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If the Duration Mandatory subfield(#291) is 0 in the Measurement Request Mode field(#555) of a measurement request, the requested STA, if it accepts the request, shall attempt a measurement using the requested duration as a maximum measurement duration, and may report results with an actual measurement duration less than the requested duration. The duration over which the measurement was made (M118)is included in the measurement duration field of the measurement report.

Each separate measurement within the Radio Measurement Request frame shall be performed over a continuous measurement time period. In Radio Measurement Request frames the requested Measurement Duration value shall not be set to 0 except when the request frame is a Beacon request in which the Measurement Mode field value is Beacon Table, or is a STA Statistics request, or is a request for triggered autonomous measurements.

### 11.10.5 Station responsibility for conducting measurements

A radio measurement-capable STA shall decode and interpret each Radio Measurement Request frame that it receives and shall assess the contents against its capabilities and the impact on its own performance. A measurement request may be refused by the receiving STA by sending a Radio Measurement Report frame in which the Refused subfield(#291) in the Measurement Report Mode field is set to 1. The reasons for refusing a measurement request are outside the scope of this standard but may include reduced quality of service, unacceptable power consumption, measurement scheduling conflicts, or other significant factors.

In assessing the performance impact of each Measurement Request element, a STA may use application-specific knowledge or other knowledge to limit the time it spends away from the operating channel. In doing so, the STA may either:

— Reject any Measurement Request element in which the Duration Mandatory subfield(#291) is 1 and that has a mandatory measurement duration exceeding the maximum allowed (#4308)off-channel time, or

— Measure for a reduced duration if the Duration Mandatory subfield(#291) is 0.

A STA shall cancel all in-process radio measurements and shall delete all pending, unprocessed radio measurement requests upon receipt of a Disassociation frame or upon (re)association with a BSSID different from its most recent association.

### 11.10.6 Requesting and reporting of measurements

A STA may perform radio measurements on one or more channels itself or a STA may request STAs in the same BSS to perform measurements on its behalf.

A STA advertises its radio measurement capability using the RM Enabled Capabilities element. If a STA advertises that it is capable of a measurement, it shall not reject a request for the corresponding measurement by sending a Radio Measurement Report frame in which the Incapable subfield(#291) in the Measurement Report Mode field is set to 1, except as specified in 11.10.9.7 (Measurement pause). Measurement requests for radio measurements that the STA has advertised it is not capable of shall be rejected, and the corresponding report shall have the Incapable subfield(#291) in the Measurement Report Mode field set to 1.

When requesting other STAs to measure one or more channels, a STA shall use a Radio Measurement Request frame containing one or more Measurement Request elements. The measurement request may be sent to an individual or group destination address. The permitted measurement requests are shown in Table 11-13 (Allowed measurement requests).

The source and destination of a measurement request shall both be a member of the same infrastructure BSS, a member of the same PBSS, or a member of the same IBSS. Measurement requests with an individual (#300)receiver address shall be sent only to STAs that have indicated radio measurement capability.


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**Table 11-13—Allowed measurement requests**

| Service set | Source of request | Destination of request | Receiver address of Radio Measurement Request frame |
|---|---|---|---|
| Infrastructure BSS | AP | Non-AP STA | Individual or group |
| | Non-AP STA | AP | Individual only |
| | Non-AP STA | Non-AP STA | Individual only for Direct Link within a BSS served by QoS AP, otherwise not allowed |
| IBSS | Non-AP STA | Non-AP STA | Individual or group |
| PBSS | PCP | STA | Individual or group |
| | STA | PCP | Individual only |
| | STA | STA | None |

The set of requested measurements received in the most recently received Radio Measurement Request frame of highest precedence is active. The precedence order for measurement requests shall be as follows (highest precedence first):

— Measurement requests received in individually addressed Radio Measurement Request frames
— Measurement requests received in multicast-group addressed Radio Measurement Request frames
— Measurement requests received in broadcast Radio Measurement Request frames

The Measurement Request elements shall be processed in sequence by default, with certain Measurement Request elements processed in parallel according to the Parallel subfield(#291) setting: see 9.4.2.19 (Measurement Request element). A STA shall accept a measurement request with the Parallel subfield(#291) enabled if dot11RMParallelMeasurementsActivated is true; otherwise, the STA shall reject the Measurement Request by returning a Measurement Report with the Incapable subfield(#291) in the Measurement Report Mode field set to 1.

If dot11RMParallelMeasurementsActivated is true and if measurement resources are available, the STA processes each element by setting up and making the specified measurement. If measurement resources are not available to perform the requested parallel measurements, the STA shall return a Measurement Report with the Refused subfield(#291) in the Measurement Report Mode field set to 1.

The Measurement Request elements within a Radio Measurement Request frame may specify multiple measurement types across multiple channels.

A STA may receive another Radio Measurement Request frame while the measurements requested in a previous Radio Measurement Request frame are pending or in progress. If this request is accepted, the set of measurement requests in the new frame supersedes any previous requests received in a Radio Measurement Request frame of the same or lower precedence. The measuring STA shall report the results of any completed measurements and terminate any pending or in-progress measurements. Results from a terminated in-progress measurement may be valid and reported if Duration Mandatory was not equal to 1 in the corresponding request. It is permissible for the superseding Radio Measurement Request frame to contain no new measurement requests. This has the effect of canceling all pending or in-progress measurements of the same or lower priority. If a station receives a Radio Measurement Request frame with lower precedence than the currently active Radio Measurement Request frame, the station shall discard the measurement requests in the new Radio Measurement Request frame. Measurement Request elements that have the Enable subfield(#291)

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equal to 1 shall be processed in all received Radio Measurement Request frames regardless of these precedence rules.

If a STA receives a Spectrum Measurement Request frame with Measurement Type field equal to 0 (Basic request), this shall take priority over any pending or in-progress radio measurements.

A STA that issues a radio measurement request to another STA to perform a measurement on the operating channel may continue to transmit MPDUs and MMPDUs to that STA while the measurement is being processed.

A STA that issues a radio measurement request to another STA to perform a measurement on a nonoperating channel is not required to take any special action to suspend traffic to that STA. All stations shall maintain state information such that data services and association or membership with the BSS continue when returning from a nonoperating channel measurement.

A single Measurement Request element may generate a large quantity of measurement report data. The measurement report data may be reported using multiple measurement report elements in multiple measurement report frames. The result of each measurement requested in a Measurement Request element shall be reported in one or more Measurement Report elements of type corresponding to the request. Each Measurement Report element returned shall have the same Measurement Token as in the corresponding Measurement Request element, and the same Actual Measurement Start Time field, if present, as in the first returned Measurement Report element. The results of each measurement should be returned without undue delay to the requesting STA.

Measurement Report elements shall be returned to the requesting STA in one or more Radio Measurement Report frames. Each Radio Measurement Report frame shall contain the same Dialog Token field value as the corresponding Radio Measurement Request frame, and the same Actual Measurement Start Time field, if present, as in the first returned Measurement Report element.

When a STA is permanently unable to make a requested measurement, the STA shall respond to such a measurement request received within an individually addressed Radio Measurement Request frame with a measurement report indicating that it is incapable of completing the measurement request. A STA shall not respond to requests received in group addressed frames in this manner. Examples of when a response of incapable is appropriate are

— The requested measurement type is not supported.
— The measuring STA cannot support requested parallel measurements due to the requests relating to different channels.

A STA that receives a response with an incapable indication shall not make the same request to the responding STA during the lifetime of the current association, or IBSS membership. This is logically the same as the responding STA using the Enable and Request subfields(#291) in a measurement request to indicate that it does not accept measurement requests of a certain type. A STA that has indicated an incapable response to a requesting STA may discard further requests of the same type from that STA without responding.

A STA may refuse to make any requested measurement. A STA refusing a measurement request within an individually addressed Radio Measurement Request frame shall respond with a measurement report indicating that it is refusing the measurement request. A STA shall not respond to measurement requests received in group addressed Radio Measurement Request frames in this manner.

By default, a STA may send a radio measurement request of any defined measurement type. A STA that receives a Measurement Request element with the Enable subfield(#291) equal to 1 and the Request subfield(#291) equal to 0 shall not issue a measurement request of the type specified in the request to the STA from which the element was received.


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Since measurements on nonoperating channels interrupt normal operation on the operating channel, the requesting STA should consider each STA's service load, power state, and operating conditions. Since measurements on the operating channel execute concurrently with normal traffic processing, operating channel measurements can be requested more frequently and for longer durations.

### 11.10.7 Repeated Measurement Request frames

Radio Measurement Request frames contain a field specifying the number of repetitions for the Radio Measurement Request frame.

If the Radio Measurement Request frame includes a nonzero value for the Number of Repetitions and dot11RMRepeatedMeasurementsActivated is false, the STA shall reject the measurement request by returning a Measurement Report with the Incapable subfield(#291) in the Measurement Report Mode field set to 1.

If the Radio Measurement Request frame includes a nonzero value for the Number of Repetitions and dot11RMRepeatedMeasurementsActivated is true, the STA shall iterate (repeat) the processing of all of the Measurement Request elements in the frame as specified by the value in the Number of Repetitions field. A value of 0 in the Number of Repetitions field indicates Measurement Request elements are executed once without repetition; a value of 1 in the Number of Repetitions field indicates Measurement Request elements are executed twice, one initial execution and one repetition; and so on. When completing the initial processing of the last Measurement Request element in the frame, the STA shall begin processing of the first Measurement Request element in the frame to repeat the frame until the number of iterations reaches the value in the Number of Repetitions field. Measurement Request elements with the Enable subfield(#291) equal to 1 shall be processed once regardless of the value in the Number of Repetitions in the measurement request.

Each repeated measurement result shall include the same Measurement Token value as in the Measurement Token field of the corresponding (M118)Measurement Request element and the same Dialog Token field as in the Dialog Token field of the corresponding Radio Measurement Request frame.

Measurement results shall be reported for each repetition of a repeated measurement request subject to any conditional reporting requirement.

STAs responding with incapable or refused indications to measurement requests within a Radio Measurement Request frame with a nonzero value for Number of Repetitions shall respond only once.

### 11.10.8 Triggered autonomous reporting

Autonomous reporting is defined for spectrum management measurements supporting DFS; see 11.8.7 (Requesting and reporting of measurements). It allows a STA to report the results of measurements to a peer STA for which there was no explicit measurement request. In this case, the transmission of autonomous reports shall be entirely the decision of the STA at which such reporting has been enabled. An example of this use would be to report a change in conditions at the STA observed as a result of background measurement, e.g., the presence of a radar signal.

In radio measurement, triggered autonomous reporting shall be subject to trigger conditions set by the enabling STA that determine when measurement reports are issued. Triggered autonomous reporting provides a method for conditional reporting during continuous background measurements. An example of the use of triggered autonomous measurement is for reporting problem conditions in continuous, noninvasive statistical monitoring.

Triggered autonomous reporting is defined for the Transmit Stream/Category Measurement measurement type; see 11.10.9.8 (Transmit Stream/Category Measurement report). When dot11MulticastDiagnosticsActivated is true, triggered autonomous reporting is used for Multicast Diagnostics reports (11.10.19 (Multicast diagnostic

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reporting)). When dot11TriggerSTAStatisticsActivated is true, triggered autonomous reporting is used for STA Statistics reports (11.10.9.5 (STA Statistics report)).

If dot11RMTriggeredTransmitStreamCategoryMeasurementActivated is true, a STA indicates that it wishes to accept triggered autonomous reports by sending a Measurement Request element with the Enable and Report subfields(#291) set to 1; see 9.4.2.19 (Measurement Request element). The type of measurement is indicated in the Measurement Type field. Trigger conditions that determine when measurement reports are to be generated shall be specified in the Measurement Request field. A Measurement Request element that is being used to control triggered autonomous reporting shall be sent within a Radio Measurement Request frame. Measurement Request elements being used to request measurements may also appear in the same Radio Measurement Request frame. The Radio Measurement Request frame may be sent to a group receiver address to enable triggered autonomous reports at more than one STA.

A STA shall not send autonomous reports for radio measurement types having triggered autonomous reporting enabled without a requested trigger condition having been met.

If a request to enable triggered autonomous reporting is sent to an individual address and the recipient STA does not support measurements of the type indicated or the recipient STA has dot11RMTriggeredTransmitStreamCategoryMeasurementActivated equal to false, a Measurement Report element shall be returned to the requesting STA with the Incapable Subfield(#291) set to 1. A STA may also refuse to enable triggered autonomous reporting. In this case a Measurement Report element shall be returned to the requesting STA with the Refused subfield(#291) set to 1. Such responses shall not be issued if the request to enable triggered autonomous reporting was sent to a group address.

A STA receiving a request to enable triggered autonomous reporting from another STA may send reports of the appropriate type, addressed to the individual address of the STA that sent the enable request. Autonomous reports shall be sent only to the individual addresses of STAs from which a valid enable request has been received and shall be issued only when a requested trigger condition has been met. The Measurement Token in each Measurement Report element and the Dialog Token field in the Radio Measurement Report frame shall both be set to 0 in a triggered autonomous report.

A STA may update the trigger conditions set for triggered autonomous reports by issuing a new Measurement Request element with the Enable and Report subfields(#291) both set to 1, the Measurement Type field set to the appropriate type and the Measurement Request field indicating the new trigger conditions. A STA disables all triggered autonomous measurement reports by sending a Measurement Request element with the Enable subfield(#291) set to 1 and the Report subfield(#291) set to 0; see 9.4.2.19 (Measurement Request element).

A STA in an infrastructure BSS or PBSS shall cease all triggered autonomous reporting if it disassociates, or reassociates with(#1427) a different BSS (reassociation to the same BSS shall not affect triggered reporting). An IBSS STA shall cease all triggered autonomous reporting if it leaves the BSS.

Triggered autonomous reporting and requested measurements are independent: a STA may request measurements from another STA even if it has enabled triggered autonomous reporting from that STA. All Measurement Request elements received in Radio Measurement Request frames that have the Enable subfield(#291) equal to 1 shall be processed without regard for the measurement precedence rules for requested measurements in 11.10.6 (Requesting and reporting of measurements).

A number of triggered measurements may run concurrently at a non-AP STA. The number of simultaneous triggered measurements supported is outside the scope of the standard. Each triggered measurement is logically separate; reporting conditions such as Trigger Timeout periods apply only to the measurement for which they are established.


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### 11.10.9 Specific measurement usage

#### 11.10.9.1 Beacon report

##### 11.10.9.1.1 General(#1089)

(#3583)A Beacon report is, depending on context, the set of one or more frames responding to a Beacon request, or a single frame providing all or part of the response to a Beacon request.

(#294)If a STA accepts a Beacon request it shall respond with one or more Radio Measurement Report frames containing Beacon reports for all observed BSSs matching the BSSID and SSID in the Beacon request, at the level of detail requested in the Reporting Detail field of the Reporting Detail subelement (or the default shown in Table 9-144 (Reporting Detail field(#1501) values) if not present):

— If the Reporting Detail field equals 0, the Reported Frame Body subelement shall not be included in the Beacon report(s).

— If the Reporting Detail field equals 1, all fields, and any elements identified in a Request element and/or (an) Extended Request element(s)(#1530) if present in the corresponding Beacon request, shall be included, subject to Beacon report truncation (see 11.10.9.1.2 (Truncation and/or fragmentation of reported frame body in Beacon report(#294))), in the Reported Frame Body subelement (or the Reported Frame Body subelements of multiple Beacon reports, in the case of Reported Frame Body subelement fragmentation), in the order that they appeared in the reported frame.

— If the Reporting Detail field equals 2, all fields and elements shall be included, subject to Beacon report truncation (see 11.10.9.1.2 (Truncation and/or fragmentation of reported frame body in Beacon report(#294))), in the order they appeared in the reported frame.

(#294)The RCPI in the Beacon report indicates the power level of the received Beacon, Measurement Pilot, or Probe Response frame. For repeated measurements (when the Radio Measurement Request frame contains a nonzero value for the Number of Repetitions field), the transmission of the Beacon report may be conditional on the measured RCPI or RSNI value. If the Radio Measurement Request frame contains a 0 value for the Number of Repetitions field, the Beacon Reporting subelement shall not be included in the Beacon request. If the Radio Measurement Request frame contains a nonzero value for the Number of Repetitions field, and if both dot11RMBeaconMeasurementReportingConditionsActivated and dot11RMRepeatedMeasurementsActivated are true, and if a Beacon Reporting subelement is included in a Beacon request, the STA shall respond with a Beacon report if the indicated Beacon reporting condition is true. Otherwise, the STA shall not respond with a Beacon report. Table 9-143 (Reporting Condition subfield for Beacon report) lists the reporting conditions that are based on the measured RCPI or RSNI levels.

If the requested Beacon report includes the Supported Operating Classes element, then the channel number, operating class, and/or reported frame information for that measurement may be included in the (#1685)Beacon report; otherwise these fields shall be set to 255 in the (#1685)Beacon report. (#1691)The STA shall use the Reporting Detail field(#1502) specified in the measurement request, or the default if not present, to determine the data to be included in the measurement report. If the STA has no beacon information available then the STA may either refuse the request or send an empty Beacon report.

If dot11RMBeaconPassiveMeasurementActivated is true and the (#6309)measurement mode in the measurement request is Passive, the measuring STA shall perform the following procedure (or an equivalent procedure) on the requested channel:

— Set a measurement duration timer.

— At the end of the measurement duration, process all received Beacons or Probe Response frames with the requested SSID and BSSID to compile the measurement report. (#1691)The STA shall use the Reporting Detail field(#1502) specified in the measurement request, or the default if not presemt,

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to determine the data to be included in the measurement report. If no Beacon or Probe Response frames with the requested SSID and BSSID were received in the measurement duration, then process all Measurement Pilot frames with the requested BSSID to compile the measurement report. Otherwise, compile an empty Beacon report.

If dot11RMBeaconPassiveMeasurementActivated is false and the (#6309)measurement mode in the measurement request is Passive, the measuring STA shall reject the measurement request by returning a Beacon report with the Incapable subfield(#291) in the Measurement Report Mode field set to 1.

If dot11RMBeaconActiveMeasurementActivated is true and the (#6309)measurement mode in the measurement request is Active, the measuring STA shall perform the following procedure (or an equivalent procedure) on the requested channel, if permitted (e.g. the channel is not subject to DFS)(#3402):

— If the channel is not the operating channel, wait for dot11RMMeasurementNavSync, or until a PHY-RXSTART.indication primitive has been received.

— Using the basic access protocol in 10.3.4.2 (Basic access), send a Probe Request frame to the broadcast address(#1313). The BSSID field in the Probe Request frame shall be set to the BSSID field in the measurement request. The SSID element in the Probe Request frame shall be set to the SSID element in the measurement request.

— Set a measurement duration timer.

— At the end of the measurement duration, process all received Probe Response and Beacon frames with the requested SSID and BSSID to compile the measurement report. (#1691)The STA shall use the Reporting Detail field(#1502) specified in the measurement request, or the default if not present, to determine the data to be included in the measurement report. If no Beacons or Probe Response frames were received in the measurement duration and Measurement Pilot frames with the requested BSSID were received in the measurement duration, then process all these Measurement Pilot frames to compile the measurement report. Otherwise, compile an empty Beacon report.

(#4158)If dot11RMBeaconActiveMeasurementActivated is true, the measurement mode in the measurement request is Active, and the measurement on the requested channel is not permitted (e.g., the channel is subject to DFS), the measuring STA shall reject the measurement request by returning a Beacon report with the Refused subfield or the Incapable subfield in the Measurement Report Mode field set to 1.

If dot11RMBeaconActiveMeasurementActivated is false and the (#6309)measurement mode in the measurement request is Active, the measuring STA shall reject the measurement request by returning a Beacon report with the Incapable subfield(#291) set in the Measurement Report Mode field.

When more than one Beacon or Probe Response from a BSS is received in the measurement duration, the contents of the Beacon report shall be based on the latest received. If only Measurement Pilot frames were received in the measurement duration, the contents of the Beacon report shall be based on the latest Measurement Pilot frame received.

If the BSSID field in the Measurement Request contains a wildcard BSSID, all observed BSSs with the requested SSID shall be reported in a separate Beacon report for each BSSID. If the SSID subelement is not included in the Beacon request, all observed BSSs shall be reported in a separate Beacon report for each BSSID. In active mode, Probe Response frames shall be evaluated regardless of whether the Probe Response frame was triggered by the measuring STA's Probe Request.

On accepting an active or passive mode Beacon request, a STA shall conduct measurements as follows:

— If the Channel Number is 0 and the Operating Class identifies the location of the primary channel, then a STA shall conduct iterative measurements on all supported channels in the specified Operating Class where the measurement is permitted on the channel and the channel is valid for the current regulatory domain.


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- If the Channel Number is 0 and if the Operating Class encompasses a primary channel but does not identify the location of the primary channel, then a STA shall conduct iterative measurements on all primary channel positions within all requested and supported channels where the measurement is permitted on the channel and the channel is valid for the current regulatory domain.
- If the Channel Number is 255, the Operating Class identifies the location of the primary channel, and the Beacon request includes AP Channel Report subelements, a STA shall conduct iterative measurements on all supported channels listed in the AP Channel Report subelements that are valid for the current regulatory domain. If there is no AP Channel Report subelement included in the Beacon request, a STA shall conduct iterative measurements on all supported channels listed in the latest AP Channel Report received from the serving AP that are valid for the current regulatory domain. If there are no AP Channel Report subelements included in the Beacon request, and no AP Channel Report included in last received AP Beacon frame, the STA shall reject the Beacon request.
- If the Channel Number is 255, the Operating Class encompasses a primary channel but does not identify the location of the primary channel, and the Beacon request includes AP Channel Report subelements, then a STA shall conduct iterative measurements on all primary channel positions within all requested (in the AP Channel Report) and supported channels that are valid for the current regulatory domain. If there are no AP Channel Report subelements included in the Beacon request, the STA shall reject the Beacon request.
- If the Channel Number is a value other than 0 or 255, a STA shall conduct iterative measurements on the requested channel, where the measurement is permitted on the channel and the channel is valid for the current regulatory domain.

Except when the Measurement Mode field is equal to Beacon Table, measurements shall be made using the specified Measurement Duration with the time between each consecutive measurement as defined in 11.10.2 (Measurement on operating and nonoperating channels). Iterative measurements shall cease when all channels have been measured. While the STA is processing a Beacon request for iterative channel measurements, the STA shall not begin processing the next measurement request in the Radio Measurement Request frame.

If dot11RMBeaconTableMeasurementActivated is true and the (#6309)measurement mode in the measurement request is Beacon Table, the measuring STA shall return a Beacon report containing the current contents of any stored beacon information for any supported channel with the requested SSID and BSSID without performing additional measurements. The receiving STA shall ignore the channel and measurement duration specified in the Beacon request when the Measurement Mode field contains Beacon Table. The beacon information accumulated may be the result of any operation that caused the STA to acquire these results. If the stored beacon information is based on a measurement made by the reporting STA, and if the actual measurement start time, measurement duration, and Parent TSF are available for this measurement, then the (#1685)Beacon report shall include the actual measurement start time, measurement duration, and Parent TSF; otherwise the actual measurement start time, measurement duration, and Parent TSF shall be set to 0. The RCPI and RSNI for that stored beacon measurement may be included in the (#1685)Beacon report; otherwise the (#1685)Beacon report shall indicate that RCPI and RSNI measurements are not available.

If dot11RMBeaconTableMeasurementActivated is false and the (#6309)measurement mode in the measurement request is Beacon Table, the measuring STA shall reject the measurement request by returning a Beacon report with the Incapable subfield(#291) set in the Measurement Report Mode field.

For repeated measurements, the Beacon request may include a Beacon Reporting subelement that determines when the measuring STA is to send a Beacon report for a measured Beacon, Measurement Pilot, or Probe Response frame with the requested SSID and BSSID. When the requested Reporting Condition value is nonzero, and dot11RMBeaconMeasurementReportingConditionsActivated is true, the STA shall create and transmit a Beacon report for that measured frame if the condition indicated in Table 9-143 (Reporting Condition subfield for Beacon report) is true. Otherwise, the STA shall not transmit a Beacon report for that measured frame. If multiple Beacon, Measurement Pilot, or Probe Response frames with the requested specific BSSID are received during the measurement duration, the reporting condition shall be applied only to the latest

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received Beacon, Measurement Pilot, or Probe Response frame. If multiple Beacon, Measurement Pilot, or Probe Response frames are received during the measurement duration when a wildcard BSSID is requested, the STA shall generate one Beacon report for each BSSID occurring in frames that satisfy the reporting condition; the Beacon report shall be based on the latest received Beacon, Measurement Pilot, or Probe Response frame for that specific BSSID. For reporting conditions 5–10, the serving AP's reference RCPI level and the serving AP's reference RSNI level referred to in Table 9-143 (Reporting Condition subfield for Beacon report) are average values of the RCPI or RSNI of the 16 most recent Beacon frames received from the measuring STA's serving AP. The serving AP's reference RCPI level and the serving AP's reference RSNI level are so averaged to provide a more accurate and stable indication of the signal level from the serving AP. For reporting conditions 5–10, the STA shall use the serving AP's reference RCPI level or reference RSNI level (with offset, if any) to test the measured RCPI or RSNI to determine whether to create and send a Beacon report for this measured Beacon, Measurement Pilot, or Probe Response frame.

The STA shall return a Beacon report with the Incapable subfield(#291) set in the Measurement Report Mode field in the following cases:

— Reporting Condition in the Beacon request is nonzero and dot11ReportingConditionsActivated is false,

— Reporting Condition in the Beacon request is nonzero and the Number of Repetitions in the Radio Measurement Request frame is 0.

NOTE 1—Reporting conditions described here for repeated Beacon request measurements are distinct from the conditions defined elsewhere for triggered measurements.

A STA that is not extended spectrum management capable shall not include a Wide Bandwidth Channel Switch subelement in a Beacon request or Beacon report. A STA shall not include a Wide Bandwidth Channel Switch subelement in a Beacon request or Beacon report sent to a STA that is not extended spectrum management capable. If the Wide Bandwidth Channel Switch subelement is included in a Beacon request or Beacon report, then the Operating Class shall indicate a 40 MHz channel spacing.

If $N$ (where $N \geq 1$) AP Channel Report subelements containing an Operating Class with an 80+ behavior limit (the 80+ behavior limit is defined in Table D-2 (Behavior limits), the operating classes that might use this limit are defined in E.1 (Country information and operating classes)) are included contiguously in a Beacon request, then the $N$ subelements shall be followed by one AP Channel Report subelement containing an Operating Class without an 80+ behavior limit (as defined in Annex E). All $N$+1 Channel List fields in each of these subelements shall contain the same number $L$ of channel numbers. This sequence of $N$+1 AP Channel Report subelements indicates a list of $L$ noncontiguous channels comprising $N$+1 frequency segments, where the $l$th channel number in the $n$th Channel List field identifies the channel center frequency of the $n$th frequency segment.

NOTE 2—To identify the BSS bandwidth, the Beacon request might include a Request subelement listing the element IDs of the HT Operation and VHT Operation elements. The Beacon report would then include the requested elements, which contain fields defining the BSS bandwidth.

When a Beacon request includes a Last Beacon Report Indication Request subelement with the Data field equal to 1, the reporting STA shall include a Last Beacon Report Indication subelement in the Beacon report, and set the Data field of the subelement to 1 when that is the last frame of the sequence of frames generated as a response to a Beacon request. Otherwise the Data field is set to 0.

#### 11.10.9.1.2 Truncation and/or fragmentation of reported frame body in Beacon report(#294)

If a Reported Frame Body subelement in a Beacon report would exceed the maximum subelement size or would cause the Measurement Report element in the Beacon report to exceed the maximum element size, and the STA transmitting the Beacon report supports Reported Frame Body subelement fragmentation, the Reported Frame Body subelement shall be fragmented as follows:


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- The payload of the Reported Frame Body subelement is fragmented across two or more Beacon reports
- A Reported Frame Body Fragment ID subelement is present in each Beacon report
- The Beacon Report ID subfield in the Reported Frame Body Fragment ID subelement of each Beacon report is the same, and is different from that of Beacon reports corresponding to a different reported frame
- The Fragment ID Number subfield in the Reported Frame Body Fragment ID subelement of the first Beacon report is set to 0 and is incremented by 1 for each subsequent Beacon report
- The More Frame Body Fragments field in the Reported Frame Body Fragment ID subelement is set to 1 in all except the last Beacon report
- Elements in the Reported Frame Body subelement are not truncated, split across two Beacon reports, or omitted

NOTE 1—This means the last element in the Reported Frame Body subelement of each Beacon report is a complete element.

NOTE 2—The STA requesting a Beacon report (#6025)needs to support Reported Frame Body subelement (de)fragmentation unless it sets the Reporting Detail subelement in the Beacon request to ensure the STA sending the Beacon report does not use fragmentation.

If a Reported Frame Body subelement in a Beacon report would exceed the maximum subelement size or would cause the Measurement Report element in the Beacon report to exceed the maximum element size, and the STA transmitting the Beacon report does not support Reported Frame Body subelement fragmentation, reported elements shall be truncated or omitted as follows to make them fit:

- A TIM element may be truncated such that only the first 4 octets of the element are reported and the element Length field is modified to indicate the truncated length of 4.
- A IBSS DFS element may be truncated so that only the lowest and highest channel number map are reported and the element Length field is modified to indicate the truncated length of 13.
- An RSNE may be truncated so that only the first 4 octets of the element are reported and the element Length field is modified to indicate the truncated length of 4.
- Elements may be omitted from the end of Reported Frame Body subelement.

NOTE 3—Elements are not truncated or omitted if the STA transmitting the Beacon report supports Reported Frame Body subelement fragmentation.

### 11.10.9.2 Frame report

If dot11RMFrameMeasurementActivated is true, and a station accepts a Frame request, it shall respond with a Radio Measurement Report frame containing one or more Measurement Report elements with the Measurement Type field set to Frame. (See 9.4.2.20.8 (Frame report).)

If the MAC Address field included in the Frame request was not set to the broadcast address, the measuring station shall report, in one or more Frame reports, only those Data or Management frames received during the measurement duration with a TA field matching the MAC Address field of the Frame request, if at least one such frame was received. If the MAC address field included in the Frame request was set to the broadcast address, the measuring station shall report all Data or Management frames received during the measurement duration in one or more Frame reports.

If the Frame Request Type of the corresponding Frame request equals 1, then each Frame report contains one Frame Count subelement that contains in turn one or more Frame Report Entries.The measuring station shall count the number of individually addressed Data and Management frames received from one transmitter address during the measurement duration and shall summarize this traffic in a frame report entry.

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The reported Average RCPI shall be an average of the RCPI values of frames received and counted in the Frame Report Entry field. If there are up to 32 frames, then the Average RCPI indicates the mean of the RCPI of each of the frames. If there are more than 32 frames, then the Average RCPI indicates an exponentially weighted average, initialized by the mean RCPI of the first 32 frames and exponentially updated by new RCPI values. The averaging is calculated as depicted as follows.

If the number of frames received is less than or equal to 32:

Average RCPI = Sum of RCPI values / Number of frames

For 33 received frames and above:

Average RCPI = (Last Average RCPI × 31 / 32) + (Current frame RCPI / 32)

The Last RCPI shall be the RCPI value of the most recently received frame counted in the Frame Report Entry field. The Antenna ID field contains the identifying number for the antenna(s) or DMG antenna used to receive the most recently received frame included in this Frame Report Entry field as defined in 9.4.2.38 (Antenna element). If different antennas are used to receive the frame preamble and the frame body, this antenna ID or DMG antenna ID shall contain the identifying number for the antenna(s) used to receive the frame body.

If dot11RMFrameMeasurementActivated is false, a station shall reject the received Frame request by returning a Frame report in which the Incapable subfield(#291) in the Measurement Report Mode field is 1.

A STA that is not extended spectrum management capable shall not include a Wide Bandwidth Channel Switch subelement in a Frame request or Frame report. A STA shall not include a Wide Bandwidth Channel Switch subelement in a Frame request or Frame report sent to a STA that is not extended spectrum management capable. If the Wide Bandwidth Channel Switch subelement is included in a Frame request or Frame report, then the Operating Class shall include a 40 MHz channel spacing.

#### 11.10.9.3 Channel load report

If dot11RMChannelLoadMeasurementActivated is true and a station accepts a Channel Load request, it shall respond with a Radio Measurement Report frame containing one Measurement (Channel Load) Report element. The Channel Load field is defined as the percentage of time, linearly scaled with 255 representing 100%, the STA sensed the medium was busy, as indicated by either the virtual carrier sense mechanism or the physical carrier sense mechanism over the requested channel width (together referred to as the *CS mechanism*). This percentage is computed using the following formula:

$$\text{Channel Load} = \left\lfloor \frac{\text{channel busy time}}{\text{MeasurementDuration} \times 1024} \times 255 \right\rfloor$$

where channel busy time is defined to be the number of microseconds during which the CS mechanism, as defined in 10.3.2.1 (CS mechanism), has indicated a channel busy indication for the requested channel width.

If dot11RMChannelLoadMeasurementActivated is false, a station shall reject the received Channel Load request by returning a Channel Load report with the Incapable subfield(#291) in the Measurement Report Mode field set to 1.

If dot11RMChannelLoadMeasurementActivated is true and if a Channel Load Reporting subelement is included in a Channel Load request, the STA shall respond with a Channel Load report if the indicated channel load reporting condition is true. Otherwise, the STA shall not respond with a Channel Load report.


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A STA that is not extended spectrum management capable shall not include a Wide Bandwidth Channel Switch subelement in a Channel Load request or Channel Load report. A STA shall not include a Wide Bandwidth Channel Switch subelement in a Channel Load request or Channel Load report sent to a STA that is not extended spectrum management capable. If the Wide Bandwidth Channel Switch subelement is included in a Channel Load request or a Channel Load report, then the Operating Class shall indicate a 40 MHz channel spacing.

#### 11.10.9.4 Noise Histogram report

If dot11RMNoiseHistogramMeasurementActivated is true and a station accepts a Noise Histogram request, it shall respond with a Radio Measurement Report frame containing one Measurement (Noise Histogram) Report element. The Noise Histogram report shall contain the IPI densities observed in the channel for the IPI levels defined in Table 9-166 (IPI Definitions for a Noise Histogram report).

To compute the IPI densities, a STA shall measure the amount of time, in microseconds, during which the IPI is in each IPI range specified in Table 9-166 (IPI Definitions for a Noise Histogram report). These IPI measurements shall be taken over the entire associated channel bandwidth, and during the requested measurement duration except for those time intervals during which the NAV is not equal to 0 (when virtual CS mechanism indicates channel busy), or during which frame transmission or reception is occurring. The IPI densities are then computed for each of the nine possible IPI values using:

$$\text{IPI Density} = \text{Integer}\left[\frac{255 \times D_{IPI}}{(1024 \times D_M) - T_{NAV} - T_{TX} - T_{RX}}\right]$$

where

$D_{IPI}$ is the duration receiving at the specified IPI value (μs)
$D_M$ is the measurement duration (TU)
$T_{NAV}$ is the total time that NAV is nonzero during the Measurement Duration (μs)
$T_{TX}$ is the frame transmission time during the Measurement Duration (μs)
$T_{RX}$ is the frame reception time during the Measurement Duration (μs)

The sum of the IPI densities is approximately 255. If either the NAV is nonzero, or if there is frame transmission, or if there is frame reception throughout the entire measurement duration period, no reportable IPI values are measured, and all IPI Densities shall be set to 0 in the Measurement Report element.

A STA shall include in the Noise Histogram report an average noise power indicator (ANPI) value representing the average noise plus interference power on the measured channel at the antenna connector during the measurement duration. The STA may use Noise Histogram IPI density values to calculate ANPI. The IPI densities in the Noise Histogram report may be used to calculate an average noise power for the channel during the measurement duration. This calculated average IPI power value may be reported as the value for ANPI. Any equivalent method to measure ANPI may also be used. ANPI power is defined in dBm using the same accuracy as defined for RCPI.

ANPI may be calculated in any period and at any time by filtering all PHY IPI values in a MAC filter to exclude IPI values received when NAV is nonzero. These filtered IPI values represent idle channel noise and may be stored in a first-in-first-out (FIFO) buffer to facilitate ANPI calculation over a fixed number of IPI samples. ANPI may be so calculated upon receipt of any frame and may be used with RCPI to calculate RSNI for any received frame. Any equivalent method to measure ANPI may also be used to calculate RSNI for any received frame.

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If dot11RMNoiseHistogramMeasurementActivated is false, a station shall reject the received Noise Histogram request by returning a Noise Histogram report with the Incapable subfield(#291) in the Measurement Report Mode field set to 1.

If dot11RMNoiseHistogramMeasurementActivated is true and if a Noise Histogram Reporting subelement is included in a Noise Histogram request, the STA shall respond with a Noise Histogram report if the indicated noise histogram reporting condition is true. Otherwise the STA shall not respond with a Noise Histogram report.

A STA that is not extended spectrum management capable shall not include a Wide Bandwidth Channel Switch subelement in a Noise Histogram request or Noise Histogram report. A STA shall not include a Wide Bandwidth Channel Switch subelement in a Noise Histogram request or Noise Histogram report sent to a STA that is not extended spectrum management capable. If the Wide Bandwidth Channel Switch subelement is included in a Noise Histogram request or a Noise Histogram report, then the Operating Class shall indicate a 40 MHz channel spacing.

#### 11.10.9.5 STA Statistics report

If dot11RMStatisticsMeasurementActivated is true and a station accepts a STA Statistics request, it shall respond with a Radio Measurement Report frame including one STA Statistics report. If the Requested Measurement Duration value is 0, the STA shall report the current values for the requested Statistics Group Data. If the Requested Measurement Duration value is greater than 0, the STA Statistics report reports the change in the requested Statistics Group Data measured within that nonzero Measurement Duration. The reported change in data value shall be the value of the data at the end of the actual Measurement Duration minus the value of the data at the beginning of the actual Measurement Duration. If a STA accepts a STA Statistics request measurement with nonzero, positive Measurement Duration, the STA shall perform the measurement over the requested Measurement Duration without regard to the Duration Mandatory subfield(#291) in the Measurement Request Mode field. If a STA cannot measure over the requested Measurement Duration, the STA shall refuse the Statistics request measurement.

If dot11RMStatisticsMeasurementActivated is false, a station shall reject the received STA Statistics request by returning a Statistics Measurement Report with the Incapable subfield(#291) in the Measurement Report Mode field set to 1.

A STA may request that a STA Statistics report be sent when statistics of interest reach a threshold as defined in the Measurement Request element of the STA Statistics request frame (see 9.4.2.19.9 (STA Statistics request)). This is termed a triggered STA Statistics measurement. Implementation of Triggered STA Statistics Reporting is optional for a WNM STA. A STA that implements Triggered STA Statistics Reporting has dot11TriggerSTAStatisticsImplemented equal to true. When dot11TriggerSTAStatisticsImplemented is true, dot11WirelessManagementImplemented shall be true.

A triggered STA Statistic measurement shall be requested by setting the Enable and Report subfields(#291) to 1 within a Measurement Request element with the Measurement Type field set to STA Statistics. The Measurement Request field shall contain a STA Statistics request with the trigger conditions specified in the Triggered Reporting subelement, as defined in 9.4.2.19.9 (STA Statistics request). One or more trigger conditions shall be set with specified thresholds. See 11.10.8 (Triggered autonomous reporting). To prevent generation of too many triggered reports, the value of the Trigger Timeout field shall be set to greater or equal to dot11MinTriggerTimeout. If the Trigger Timeout field is less than dot11MinTriggerTimeout, the STA shall reject the measurement request by returning a report where the Measurement Report Mode field is “Incapable.”

A STA accepting a triggered STA Statistics measurement shall measure the requested statistics. If a trigger condition occurs, the measuring STA shall send a STA Statistics measurement report to the requesting STA. The measuring STA shall not send further triggered STA Statistics reports for that trigger condition to the requesting STA until the Trigger Timeout period specified in the request frame has expired. The STA Statistics


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measurement report is defined in 9.4.2.19.9 (STA Statistics request). If the number of MPDUs or MSDUs indicated in the Measurement Count field are transmitted or received without any of the counted statistics meeting the corresponding trigger threshold then the measuring STA shall restart measuring for another measurement count window.

If a STA receives a STA Statistics request from the same STA for which a triggered STA Statistics measurement is in progress, the in-progress triggered measurement shall be terminated.

STA Statistics reported in a triggered STA Statistics report shall be the values accumulated over the number of transmitted or received MSDUs or MPDUs before the trigger condition is met. Measurement duration shall not be specified when requesting a triggered STA statistics measurement and the Measurement Duration field in the corresponding Measurement Request shall be set to 0.

All triggered STA Statistics measurements shall be terminated at a measuring STA by receiving a STA Statistics request with the Enable subfield(#291) equal to 1 and the Report subfield(#291) equal to 0. A STA requesting a triggered STA Statistics measurement may update the trigger conditions by sending a STA Statistics request specifying the new trigger conditions.

Once accepted by a measuring STA, a triggered STA Statistics measurement continues to be active until the measurement request is superseded by a STA Statistics request from the requesting STA or the measuring STA disassociates or reassociates.

#### 11.10.9.6 LCI report (Location configuration information report)

If dot11RMLCIMeasurementActivated is true, a STA that receives an LCI request for location information that is not available shall respond with a Radio Measurement Report frame including a Radio Measurement Report element with the Refused subfield(#291) set to 1. If dot11RMLCIMeasurementActivated is true and a STA accepts an LCI request that does not include an azimuth request, it shall respond with a Radio Measurement Report frame including one LCI subelement (LCI report). If both dot11RMLCIMeasurementActivated and dot11RMLCIAzimuthActivated are true, and the STA accepts an LCI request that includes an azimuth request, it shall respond with a Radio Measurement Report frame that includes one LCI subelement (LCI report) and the requested Azimuth Report, if available. If dot11RMLCIAzimuthActivated is false, a STA that receives an LCI request that includes an azimuth request shall respond with a Radio Measurement Report frame including an Radio Measurement Report element with the Incapable subfield(#291) set to 1.

The Datum value shall be 1 (World Geodetic System 1984), unless another datum is required for operation in the regulatory domain.

If the Altitude Type is 2 (Floors of Altitude), the value reported shall be as required for operation in the regulatory domain.

An LCI request shall indicate a location request for the requesting STA, the reporting STA, or a third STA with the MAC address specified in the Target MAC Address subelement, by setting the LCI request Location Subject field to indicate a Local, a Remote, or a third-party request, respectively. Local LCI request is used by the requesting STA to obtain its own location by asking “Where am I?” Remote LCI request is used by requesting STA to obtain location of reporting STA by asking “Where are you?” Third-party location request is used by requesting STA to obtain location of a STA with the MAC address specified in the Target MAC Address subelement.

The Latitude, Longitude, and Altitude fields of the LCI report shall be reported at their best known resolutions unless otherwise configured.

If the STA receiving an LCI request has no location information about the requested LCI subject’s physical location, the STA shall send a LCI subelement indicating an unknown LCI (see 9.4.2.20.10 (LCI report

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(Location configuration information report))). If the STA receiving an LCI request has no location information about the requested Azimuth, the STA shall omit the Azimuth Report subelement. If the STA receiving an LCI request that contains a Maximum Age subelement has already determined the requested LCI within the indicated maximum age, the STA may respond with its already determined LCI; otherwise, the STA shall update its LCI before the STA responds with its LCI. The method by which the physical location and azimuth information in the LCI report is generated is outside the scope of this standard.

A STA that receives an LCI report that contains a Usage Rules/Policy subelement shall process the LCI information in compliance with the retransmission and retention permissions in the Usage-rules subelement.

NOTE 1—A STA that requested an LCI including an Azimuth Request, and received an LCI report in which the Incapable subfield(#291) is 1 might alternatively request the LCI with no Azimuth requested.

If dot11RM3rdPartyMeasurementActivated is false, a STA that receives an LCI request that includes an LCI request with the Location Subject field equal to 2 shall respond with a Radio Measurement Report frame including an Radio Measurement Report element with the Incapable subfield(#291) set to 1.

It is optional for a STA to support an LCI request and an LCI report with the Location Subject field equal to 2. If dot11RM3rdPartyMeasurementActivated is true and a STA supports LCI request and LCI report, the following procedure shall be followed:

— When a non-AP STA requests the geospatial location of a STA with the MAC address specified in the Target MAC Address field, it shall also include its own MAC address in the Originator Requesting STA MAC address field. When an AP receives an LCI request with the Location Subject field value equal to 2, the AP shall generate an LCI request to the STA with the MAC address specified in the Target MAC Address field. If the AP does not have an association with the STA with the MAC address specified in the Target MAC Address field, the AP shall reject the received LCI request by returning an LCI report where the Incapable subfield(#291) is set in the MeasurementReport Mode field. The AP shall copy the Originator Requesting STA MAC address and Target MAC Address fields into the request from the received LCI request.

— When a STA receives an LCI request with the Location Subject field value equal to 2, the STA may generate an LCI report if the MAC address in the Target MAC Address field is its own MAC address; it shall not generate an LCI report otherwise. When an LCI report is generated, the reporting STA shall include its MAC address into the Target MAC Address field and the MAC address present in the Originator Requesting STA MAC address field of the corresponding LCI request into the Originator Requesting STA MAC address field. When an AP receives an LCI report with an Originator Requesting STA MAC address field present, the AP shall generate an LCI report to the associated STA with the MAC address specified in the Originator Requesting STA MAC address field. The AP shall copy the Originator Requesting STA MAC address and Target MAC Address fields into the LCI report being transmitted to the originating requesting STA.

If dot11RMLCIMeasurementActivated is false, a station shall reject the received LCI request by returning an LCI report with the Incapable subfield(#291) in the Measurement Report Mode field set to 1.

If dot11RMLCIMeasurementActivated is true and a STA has its own location configured in LCI format excluding an unknown LCI as defined in 9.4.2.19.10 (LCI request (Location configuration information request)), the STA shall set dot11RMLCIConfigured to true.

NOTE 2—It is recommended that User Applications not send location information to other stations without the express permission of the user. User agents acquire permission through a user interface, unless they have prearranged trust relationships with users. Those permissions that are acquired through the user interface and that are preserved beyond the current browsing session (i.e., beyond the time when the BSS connection is terminated) are revocable and receiving stations should respect revoked permissions. Some user applications might have prearranged trust relationships that do not require such user interfaces. For example, while a social networking application might present a user interface when a friend performs a location request, a VOIP telephone might not present any user interface when using location information to perform an E911 function.


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### 11.10.9.7 Measurement pause

A measurement pause is used within a Radio Measurement Request frame to provide a time delay between the processing of two other Measurement Request elements within the sequence of Measurement Request elements in that frame.

If a STA accepts a Measurement Pause request it shall delay processing of the next measurement request in the Radio Measurement Request frame. If the Measurement Pause request is the last Measurement Request element in a repeated Radio Measurement Request frame, the STA shall delay processing the first Measurement Request element in the Radio Measurement Request frame for the next repeat. In each case the delay shall be no less than the Pause Time value specified in the Measurement Pause request.

NOTE—Measurement pause is always supported by a STA implementing radio measurements.

A measurement pause shall not be sent as the only Measurement Request element in a Radio Measurement Request frame. A measurement pause shall not be included as the last Measurement Request element in a Radio Measurement Request frame that has the Number of Repetitions field equal to 0.

A measurement pause cannot be processed in parallel to other measurements. If the Parallel subfield(#291) is 1 in the Measurement Request element immediately prior to a measurement pause, an incapable response shall be returned even if dot11RMParallelMeasurementsActivated is true.

There is no measurement report associated with a Measurement Pause request.

### 11.10.9.8 Transmit Stream/Category Measurement report

The Transmit Stream/Category Measurement applies to TIDs for Traffic Streams associated with TSPECs and also to TIDs for Traffic Categories for QoS traffic without TSPECs.

If dot11RMTransmitStreamCategoryMeasurementActivated is true and has no resource constraint that prevents it from being able to make the requested measurement, a QoS STA receiving a Transmit Stream/ Category Measurement request shall respond with a Radio Measurement Report frame containing one Measurement (Transmit Stream/Category Measurement) Report element. If the traffic stream (TS) that is corresponding to the Traffic Identifier is deleted, either by a DELTS frame or by disassociation, the STA shall cease sending Radio Measurement Reports.

If dot11RMTransmitStreamCategoryMeasurementActivated is false, a STA shall reject the received Transmit Stream/Category Measurement request by returning a Transmit Stream/Category Measurement report with the Incapable subfield(#291) in the Measurement Report Mode field set to 1.

The transmit stream/category measurement shall be made on traffic that is transmitted from the measuring QoS STA to the peer QoS STA and TID indicated in the request. The Peer STA Address may be the MAC address of the QoS STA from which the Measurement Request was sent, the MAC address of another QoS STA within the BSS, or the broadcast address. A broadcast address shall be used only with a TID corresponding to a TC. In the case of a broadcast address, measurement shall be made on all traffic for the specified TC. Depending on policy, a QoS AP may disallow transmit stream/category measurement requests for traffic to other QoS STAs in the BSS. In this case the QoS AP shall respond with a matching Radio Measurement Report frame with the Incapable subfield of the Measurement Report Mode field set to 1.

If, during the course of a Transmit Stream/Category Measurement, any counter that is included in the Transmit Stream/Category Measurement report increments to a value of $2^{32}$–1, the Transmit Stream/Category Measurement shall terminate, and the Transmit Stream/Category Measurement report shall indicate the shortened, actual measurement duration.

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If the measurement request included multiple transmit stream/category measurement requests for multiple TIDs, the corresponding measurement report shall include a transmit stream/category measurement report for each unique TID in the request that has been admitted. If the measurement request is for a TID that has not been admitted yet, a report is generated only after the TID becomes admitted.

The requesting and reporting STAs are QoS STAs. A non-QoS STA receiving a Transmit Stream/Category Measurement request shall reject the request by returning an indication of incapable.

A QoS STA may request that a measuring QoS STA send a transmit stream/category measurement report when the number of TID-specified MSDUs are discarded or delayed reaches a specified threshold. This is termed a triggered transmit stream/category measurement and shall be requested by setting the Enable and Report subfields(#291) to 1 within a Measurement Request element containing the Transmit Stream/Category Measurement Type. The Measurement Request field shall contain a Transmit Stream/Category Measurement request with the trigger conditions specified in the Triggered Reporting subelement. One or more trigger conditions may be set with specified thresholds. See 9.4.2.19.11 (Transmit Stream/Category Measurement request).

Depending on policy, a QoS AP might not permit the establishment of triggered transmit stream/category measurement. Such a QoS AP receiving a triggered transmit stream/category measurement request shall give an incapable indication. The number of simultaneous triggered transmit stream/category measurements supported at a QoS STA is outside the scope of the standard. A STA shall respond to further requests with a refused indication if the number of simultaneous triggered QoS measurements supported by the STA is reached.

If dot11RMTriggeredTransmitStreamCategoryMeasurementActivated is true, a QoS STA shall accept a triggered Transmit Stream/Category Measurement and shall reject it otherwise. A QoS STA accepting a triggered QoS measurement shall measure the requested TC or TS. If a trigger condition occurs, the measuring QoS STA shall send a Transmit Stream/Category Measurement report to the requesting QoS STA. The measuring QoS STA shall not send further triggered QoS reports until the Trigger Timeout period specified in the request has expired or new trigger conditions have been requested. Measurement of transmit stream/category metrics shall continue during the reporting timeout period. Reporting shall resume following the Trigger Timeout period, or immediately following the acceptance of new trigger conditions.

If a QoS STA receives a Transmit Stream/Category Measurement request for a TC, or TS that is already being measured using a triggered transmit stream/category measurement, the triggered traffic stream measurement shall be suspended for the duration of the requested traffic stream measurement. When triggered measurement resumes, the traffic stream metrics shall be reset.

Traffic stream metrics reported in a triggered transmit stream/category measurement report shall be the values accumulated over the number of successfully and unsuccessfully transmitted MSDUs prior to the trigger event given in the Measurement Count field of the transmit stream/category measurement request that established the trigger condition. It is possible that a consecutive or delay trigger event occurs after acceptance of a triggered transmit stream/category measurement but before the number of MSDUs in Measurement Count has been transmitted. In this case the report shall be the values accumulated since measurement started. The measurement count value appears in the Transmitted MSDU Count field of a triggered transmit stream/category measurement report. Measurement duration shall not be used in triggered QoS measurement, and the Measurement Duration field in both the Measurement Request and any Measurement Report shall be set to 0.

The Measurement Start Time field of a triggered transmit stream/category measurement report shall contain the value of the QoS STA TSF timer at the time the trigger condition occurred to an accuracy of 1 TU.

Once accepted by a measuring QoS STA, a triggered QoS measurement continues to be active until

— The relevant TS is deleted,


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— The measuring QoS STA or QoS STA that requested the measurement disassociates or successfully reassociates, or
— The measurement is terminated by the requesting QoS STA.

All triggered QoS measurements shall be terminated at a measuring QoS STA by receiving a triggered transmit stream/category measurement request with the Enable subfield(#291) equal to 1 and the Report subfield(#291) equal to 0. A triggered QoS measurement request with no trigger conditions specified in the Trigger Conditions field shall terminate a triggered QoS measurement for the TC or TS specified in the request. A QoS STA requesting a triggered QoS measurement may update the trigger conditions by sending a triggered transmit stream/category measurement request specifying the new trigger conditions.

#### 11.10.9.9 Location Civic report

If dot11RMCivicMeasurementActivated is true and civic location information is not available, the STA shall reject a Location Civic request by returning a Radio Measurement Report frame including a Measurement Report element with the Refused subfield(#291) set to 1. If dot11RMCivicMeasurementActivated is true and civic location information is available, the STA shall respond with a Radio Measurement Report frame including one Location Civic report.

A Location Civic request shall indicate a location request for the requesting STA, the reporting STA, or a third STA with the MAC address specified in the Target MAC Address field, by setting the Location Civic request Location Subject field to indicate a Local, a Remote, or a third-party request respectively. Local Location Civic request is used by requesting STA to obtain its own location by asking “Where am I?” Remote Location Civic request is used by requesting STA to obtain location of the reporting STA by asking “Where are you?” Third-party Location request is used by requesting STA to obtain location of a STA with the MAC address specified in the Target MAC Address field.

If dot11RMCivicMeasurementActivated is false, a STA that receives the received Location Civic request shall respond with a Location Civic report where the Incapable subfield(#291) is set in the Measurement Report Mode field.

If dot11RM3rdPartyMeasurementActivated is false, a STA shall reject any LCI request that includes an LCI request with the Location Subject field equal to 2 by returning a Radio Measurement Report frame including an Radio Measurement Report element with the Incapable subfield(#291) set to 1.

It is optional for a STA to support a Location Civic request and a Location Civic report with the Location Subject field equal to 2. If dot11RM3rdPartyMeasurementActivated is true and a STA supports Location Civic request and Location Civic report, the following procedure shall be followed:

— When a non-AP STA requests the civic location of a STA with the MAC address specified in the Target MAC Address field, it shall also include its own MAC address in the Originator Requesting STA MAC address field. When an AP receives a Location Civic request with the Location Subject field value equal to 2, the AP shall generate a Location Civic request to the STA with the MAC address specified in the Target MAC Address field. If the AP does not have an association with the STA with the MAC address specified in the Target MAC Address field, the AP shall reject the received Location Civic request by returning a Location Civic report where the Incapable subfield(#291) is set in the Measurement Report Mode field. The AP shall copy the Originator Requesting STA MAC address and Target MAC Address fields into the request from the received Location Civic request.
— When a STA receives a Location Civic request with the Location Subject field value equal to 2, the STA may generate a Location Civic report if the MAC address in the Target MAC Address field is its own MAC address; it shall not generate a Location Civic report otherwise. When a Location Civic report is generated, the reporting STA shall include its MAC address into the Target MAC Address field and the MAC address present in the Originator Requesting STA MAC address field of

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the corresponding Location Civic request into the Originator Requesting STA MAC address field. When an AP receives a Location Civic report with an Originator Requesting STA MAC address field present, the AP shall generate a Location Civic report to the associated STA with the MAC address specified in the Originator Requesting STA MAC address field. The AP shall copy the Originator Requesting STA MAC address and Target MAC Address fields into the Location Civic report being transmitted to the originating requesting STA.

When a STA receives a Location Civic request with the subject field equal to 2, but does not support third-party location, it shall respond with a Radio Measurement Report frame including a Radio Measurement Report element with the Incapable subfield(#291) set to 1.

If dot11RMCivicMeasurementActivated is true and a STA has its own location configured in civic format, excluding an unknown civic location as defined in 9.4.2.20.13 (Location Civic report), the STA shall set dot11RMCivicConfigured to true.

If dot11RMCivicMeasurementActivated is true and a STA has its own location available in one or more location formats, as defined in Table 9-154 (Civic Location Type field values), and includes Civic Location Type field value 0, indicating "IETF RFC 4776," it shall set the Civic Location field to 1 in the Extended Capabilities element.

NOTE—The Location Civic field's size limit constrains the amount of information that can be carried.

If the Location Civic report contains the Location Reference and Location Shape subelements, the receiving STA may use the information specified in those subelements in combination with the (#4198)Location Civic field value for additional granularity on the position reported in the Location Civic field.

If the Location Civic report contains the Map Image subelement, the receiving STA's SME can retrieve the floor (#4198)map specified by the Map URL field. The method to retrieve the floor map specified by the Map URL field is out of scope of this document. If the URL includes the floor map georegistration parameters s_lat, w_lng, n_lat and e_lng as query parameters then the receiving STA's SME can georeference the floor map.(#6068)

(#4198)For example, if the response to a Location Civic request with Location Subject field equal to Location Subject Local is a Location Civic report containing a Location Reference field equal to "Lobby Entrance", a Location Shape ID field equal to 2-Dimension Point, a Location Shape Value field equal to (0, –1.5), a Map Type field equal to png, a Map URL field equal to "http://www.example.com/maps/exampleBuilding/lobbyLevel.png" (i.e., without floor map georegistration parameters)(#6068) and a Map Registration subelement containing X Min = –50, Y Min = –100, Z Min = 0, X Max = 49.9, Y Max = 0, then a process related to the user interface might retrieve the map image and display it from (–50 m, –100 m) to (49.9 m, 0 m) , place a pin at (0 m, 0 m) labelled "Lobby Entrance", and place a second pin at (0 m, –1.5 m) labelled "You Are Here".(#7198)

### 11.10.9.10 Location Identifier report

The Location Identifier report provides the ability for a STA to receive one or more:

— Indirect URI references and forward a subset of those references to an external agent for the purposes of that agent gathering the STA's location value. The protocol used to query for a location report based on the Public Identifier URI/FQDN provided in the Location Identifier report is indicated by the URI/FQDN Descriptor field.

— FQDNs, one per location server, that can be used to discover the location server and establish communications with it. The protocol used with the location server is indicated by the URI/FQDN Descriptor field.


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If dot11RMIdentifierMeasurementActivated is true and location information is not available, the STA that receives a Location Identifier request shall respond with a Radio Measurement Report frame including a Measurement Report element with the Incapable subfield(#291) set to 1. If dot11RMIdentifierMeasurementActivated is true and location information is available, the STA shall respond with a Radio Measurement Report frame including one Measurement Report element containing a Location Identifier report that carries one or more Public Identifier URI/FQDN subelements.

A Location Identifier request shall indicate a location request for the requesting STA, the reporting STA, or a third-party STA with the MAC address specified in the Target MAC Address field, by setting the Location Identifier request Location Subject field to indicate a Local, a Remote, or a Third-party request respectively. Local Location Identifier request is used by requesting STA to obtain its own location by asking "Where am I?" Remote Location Civic request is used by requesting STA to obtain location of the reporting STA by asking "Where are you?" Third-party Location request is used by requesting STA to obtain location of a STA with the MAC address specified in the Target MAC Address field.

If dot11RM3rdPartyMeasurementActivated is false, a STA that receives an LCI request that includes an LCI request with the Location Subject field equal to 2 shall respond with a Radio Measurement Report frame including an Radio Measurement Report element with the Incapable subfield(#291) set to 1.

It is optional for a STA to support a Location Identifier request and a Location Identifier report with the Location Subject field equal to 2. If dot11RM3rdPartyMeasurementActivated is true and a STA supports Location Identifier request and Location Identifier report, the following procedure shall be followed:

— When a non-AP STA requests the location identifier of a STA with the MAC address specified in the Target MAC Address field, it shall also include its own MAC address in the Originator Requesting STA MAC address field. When an AP receives a Location Identifier request with the Location Subject field value equal to 2, the AP shall generate a Location Identifier request to the STA with the MAC address specified in the Target MAC Address field. If the AP does not have an association with the STA with the MAC address specified in the Target MAC Address field, the AP shall reject the received Location Identifier request by returning a Location Identifier report where the Incapable subfield(#291) is set in the Measurement Report Mode field. The AP shall copy the Originator Requesting STA MAC address and Target MAC Address fields into the request from the received Location Identifier request.

— When a STA receives a Location Identifier request with the Location Subject field value equal to 2, the STA may generate a Location Identifier report if the MAC address in the Target MAC Address field is its own MAC address; it shall not generate a Location Identifier report otherwise. When a Location Identifier report is generated, the reporting STA shall include its MAC address into the Target MAC Address field and the MAC address present in the Originator Requesting STA MAC address field of the corresponding Location Identifier request into the Originator Requesting STA MAC address field. When an AP receives a Location Identifier report with an Originator Requesting STA MAC address field present, the AP shall generate a Location Identifier report to the associated STA with the MAC address specified in the Originator Requesting STA MAC address field. The AP shall copy the Originator Requesting STA MAC address and Target MAC Address fields into the Location Identifier report being transmitted to the originating requesting STA.

When a STA receives an Location Identifier request with the subject field equal to 2, but does not support third-party location, it shall respond with a Radio Measurement Report frame including a Radio Measurement Report element with the Incapable subfield(#291) set to 1.

If dot11RMIdentifierMeasurementActivated is false, a STA shall reject the received Location Identifier request by returning a Location Identifier report where the Incapable subfield(#291) is set in the Measurement Report Mode field.

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If dot11RMIdentifierMeasurementActivated is true and a STA has its own location available in one or more location formats, as defined in Table 9-154 (Civic Location Type field values), and includes Civic Location Type field value 0, indicating "IETF RFC 4776" or geospatial format that can be referenced by a location identifier, it shall set the Identifier Location field to 1 in the Extended Capabilities element.

### 11.10.9.11 FTM Range report(#7065)

The (#7065)FTM Range report provides a means for a requesting STA to request a responding STA that advertises FTM Range Report Capability Enabled equal to true in the RM Enabled Capabilities element to measure and report the ranges between the responding STA and other nearby APs where the ranges are determined using the FTM procedure (see 11.21.6 (FTM procedure(#7065))).

If dot11RMFineTimingMsmtRangeRepActivated is true, dot11FineTimingMsmtInitActivated shall be true also.

If dot11RMFineTimingMsmtRangeRepActivated is false, a STA shall reject any (#7065)FTM Range request by responding with a Radio Measurement Report frame that includes a Measurement Report element with the Incapable subfield(#291) set to 1.

If a responding STA with dot11RMFineTimingMsmtRangeRepActivated equal to true accepts an (#7065)FTM Range request, then:

— If the request includes a maximum age subelement, and the STA has already determined FTM ranges to *C* APs listed in the Neighbor Report subelements in the Measurement Request field within the indicated Maximum Age, then the STA may use these ranges instead of initiating new FTM procedures with the *C* APs. (#570)Define $C_{sub}$ as the subset of APs selected by the STA from the *C* eligible APs.

— Considering the remaining listed APs in the Neighbor Report subelements in the Measurement Request field, if Minimum AP Count exceeds $C_{sub}$, the responding STA shall wait a random delay up to the value of Randomization Interval field in the Measurement Request element (see 11.10.3 (Measurement start time)) then initiate the FTM procedure with at least Minimum AP Count – $C_{sub}$ remaining listed APs. The responding STA should initiate the FTM procedure with the remaining listed APs until either the responding STA has successfully measured the range between the responding STA with at least Minimum AP Count APs or has attempted the FTM procedure with all remaining listed APs. For each FTM procedure that is attempted with a remaining listed AP without success, the responding STA shall record an error entry.

  For procedures related to listed APs that operate on nonoperating channels, see 11.10.2 (Measurement on operating and nonoperating channels).

  The responding STA shall transform the measurements obtained from each FTM procedure with an AP into a range and a maximum error between itself and the AP, while accounting for any clock offsets between the responding STA and the AP.

At the completion of all of the FTM procedures and transformations, the responding STA shall send the all computed range information between itself and other APs, and all error entries, to the requesting STA using a Measurement Report element with Measurement Type field set to (#7065)FTM Range in a Radio Measurement Report frame.

A requesting STA may request a single set of range measurements by setting the Number of Repetitions field to 0 in the Radio Measurement Request frame, or request a regular sequence of range measurements by

— Setting the Number of Repetitions field greater than 0 in the Measurement Request frame, and

— Including a Measurement Request element with Measurement Type field equal to FTM Range and a Measurement Request element with Measurement Type field equal to Measurement Pause (see 11.10.9.7 (Measurement pause)).


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### 11.10.10 Usage of the neighbor report

#### 11.10.10.1 General

A neighbor report is sent by an AP and it contains information on neighboring APs that are members of ESSs requested in the neighbor report request. A neighbor report might not be exhaustive either by choice, or due to the fact that there might be neighbor APs not known to the AP. The neighbor report contents are derived from the NeighborListSet parameter of the MLME-NEIGHBORREPRESP.request primitive. The mechanism by which the contents of this table are determined is outside the scope of this standard, but it may include information from measurement reports received from the STAs within the BSS, information obtained via a management interface, or information from the DS.

NOTE—The purpose of the neighbor report is to enable the STA to optimize aspects of neighbor service set transition and ESS operation. A Neighbor Report element contains information on APs that the STA might use as candidates for a service set transition. Since the information in the neighbor report might be stale, it is advisory; information obtained by the report recipient through a scan or other sources might also be considered, possibly overriding information in the neighbor report. For example, where information contained within a neighbor report is contradicted by information in a Measurement Pilot, Beacon, or Probe Response frame, that response information needs to take precedence.

An AP in which dot11RMNeighborReportActivated is false shall not transmit an (#7065)FTM Range request. An AP in which dot11RMNeighborReportActivated is false should not transmit a Measurement Request with the Measurement Type field equal to LCI and the Location Subject field of the LCI request set to Location Subject Remote.

#### 11.10.10.2 Requesting a neighbor report

A STA requesting a neighbor report from an AP shall send a Neighbor Report Request frame to its associated AP.

A STA can request LCI information of an AP and its neighboring APs, if the AP advertises the FTM responder capability (Extended Capabilities element with the (#7065)FTM Responder field set to 1), the geospatial location capability (Extended Capabilities element with the Geospatial Location field set to 1), and the neighbor report capability (RM Enabled Capabilities element with the Neighbor Report Capability Enabled field set to 1). A STA can request (#7178)civic location information of an AP and its neighboring APs, if the AP advertises the FTM responder capability (Extended Capabilities element with the (#7065)FTM Responder field set to 1), the location civic capability (Extended Capabilities element with the Civic Location field set to 1), and the neighbor report capability (RM Enabled Capabilities element with the Neighbor Report Capability Enabled field set to 1).

To request the LCI of neighboring APs, the STA shall transmit a Neighbor Report Request frame that includes a Measurement Request element with the value of its Measurement Type field equal to LCI. To request the location civic of neighboring APs, the STA shall transmit a Neighbor Report Request frame that includes a Measurement Request element with the value of its Measurement Type field equal to Location Civic.

(11az)To request a list of neighboring APs that support DMG location services, the STA shall transmit a Neighbor Report Request frame that includes a Neighbor DMG request field with a Measurement Request element with the value of its Measurement Type field equal to Neighboring DMG APs. A STA shall not send this type of request to an AP unless it received an Extended Capabilities element from the AP with the DMG Location Supporting APs Information field equal to 1. The Neighbor Report Request frame shall include an SSID element with the SSID set to wildcard SSID.

#### 11.10.10.3 Responding to a neighbor report request

If dot11RMNeighborReportActivated is true, an AP receiving a neighbor report request shall respond with a Neighbor Report Response frame containing zero or more Neighbor Report elements. If an SSID element is

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specified in the corresponding Neighbor Report Request frame, the Neighbor Report element(s) shall contain information only concerning neighbor APs that are members of the ESS identified by the SSID element contained within the neighbor report request. If the SSID element is omitted, the Neighbor Report element(s) shall contain information concerning neighbor APs that belong to the same ESS as the requesting STA. If the wildcard SSID element is specified in the corresponding Neighbor Request frame, the Neighbor Report element(s) shall contain information concerning all neighbor APs. If there are no neighbor APs available, the AP shall send a Neighbor Report Response frame with no Neighbor Report elements.

If dot11RMNeighborReportActivated is true and dot11FineTimingMsmtRespActivated is true, an AP receiving a neighbor report request shall respond with a Neighbor Report Response frame containing one or more Neighbor Report elements.

If dot11RMNeighborReportActivated is false in an AP receiving a neighbor report request, it shall ignore the request.

A serving AP shall include a TSF subelement in the Neighbor Report element if it is able to guarantee an accumulated error of 1.5 TU or better on the TSF Offset subfield. Otherwise, the AP shall not include a TSF subelement in the Neighbor Report element.

When the SSID element is omitted, the SSID element is specified by the wildcard SSID, or the SSID element is present and indicates the AP's own SSID and either of the following is true:

— An AP that has both dot11FineTimingMsmtRespActivated and dot11RMLCIConfigured equal to true receives a Measurement Request element with Measurement Type field equal to LCI

— An AP that has both dot11FineTimingMsmtRespActivated and dot11RMCivicConfigured equal to true receives a Measurement Request element with Measurement Type field equal to Location Civic

within a Neighbor Report Request frame, then the AP shall include a Neighbor Report element for the AP's own BSSID in the Neighbor Report Response frame (i.e., in this case the Neighbor Report Response frame contains one or more Neighbor Report elements). If dot11RMLCIConfigured is equal to true, the Neighbor Report element shall include a Measurement Report subelement with the Measurement Type field equal to LCI. If dot11RMCivicConfigured is equal to true, the Neighbor Report element shall include a Measurement Report sub element with the Measurement Type field equal to Location Civic.

When both of the following are true:

— The SSID element specified in the Neighbor Report Request does not include the AP's own SSID and an AP that has at least one of dot11FineTimingMsmtRespActivated and dot11RMLCIConfigured equal to false receives a Measurement Request element with the Measurement Type field equal to LCI within a Neighbor Report Request frame

— An AP that has at least one of dot11LciCivicInNeighborReport and dot11RMLCIConfigured equal to false receives a Neighbor Report Request frame

then the AP shall not include a Neighbor Report element containing a Measurement Report subelement with the Measurement Type field set to LCI describing the reporting AP in the Neighbor Report Response frame. In this case the Neighbor Report Response frame contains zero or more Neighbor Report elements.

When both of the following are true:

— The SSID element specified in the Neighbor Report request does not include the AP's own SSID and an AP that has at least one of dot11FineTimingMsmtRespActivated and dot11RMCivicConfigured equal to false receives a Measurement Request element with the Measurement Type field equal to Location Civic within a Neighbor Report Request frame

— An AP that has at least one of dot11LciCivicInNeighborReport and dot11RMCivicConfigured equal to false receives a Neighbor Report Request frame


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then the AP shall not include a Neighbor Report element containing a Measurement Report subelement with Measurement Type set to Location Civic describing the reporting AP in the Neighbor Report Response frame (i.e., in this case the Neighbor Report Response frame contains zero or more Neighbor Report elements). In this case the Neighbor Report Response frame contains zero or more Neighbor Report elements.

NOTE—The Neighbor Report Response frame includes a list of Neighbor Report elements one for each neighbor. The criteria for the selection of an AP as a neighbor AP is beyond the scope of this standard(#1560).

The Neighbor Report Response frame shall also include a Neighbor Report element for each neighbor AP.

When either of the following is true in a neighbor AP of the AP (reporting AP) that receives a Measurement Request element with the Measurement Type field equal to LCI within a Neighbor Report Request frame:

— The neighbor AP has both FTM responder capability (Extended Capabilities element with the (#7065)FTM Responder field set to 1) and LCI measurement capability (RM Enabled Capabilities element with the LCI Measurement Capability Enabled field set to 1)

— The reporting AP has dot11LciCivicInNeighborReport equal to true and the neighbor AP has LCI measurement capability (RM Enabled Capabilities element with the LCI Measurement Capability Enabled field set to 1)

then the reporting AP shall include a Neighbor Report element in the Neighbor Report Response frame. In addition if the neighbor AP has (#7177)geospatial location capability (Extended Capabilities element with the Geospatial Location field set to 1), the Neighbor Report element shall include a Measurement Report subelement with Measurement Type equal to LCI. If the maximum horizontal or vertical location error of the neighbor AP relative to a reference AP is known to the AP and this relative error is smaller than the absolute error indicated in the LCI subelement, then the AP may include a Relative Location Error subfield in the Measurement Report field.

When either of the following is true in a neighbor AP of the AP (reporting AP) that receives a Measurement Request element with the Measurement Type equal to Location Civic within a Neighbor Report Request frame:

— The neighbor AP has both FTM responder capability (Extended Capabilities element with the (#7065)FTM Responder field set to 1) and civic location measurement capability (RM Enabled Capabilities element with Civic Location Measurement Capability Enabled set to 1)

— The reporting AP has dot11LciCivicInNeighborReport equal to true and the neighbor AP has civic location measurement capability (RM Enabled Capabilities element with Civic Location Measurement Capability Enabled set to 1)

then the reporting AP shall include a Neighbor Report element in the Neighbor Report Response frame. In addition if the neighbor AP has Civic Location (Extended Capabilities element with the Civic Location field set to 1), the Neighbor Report element shall include a Measurement Report subelement with the Measurement Type field equal to Location Civic.

Each Measurement Report subelement returned shall have the same Measurement Token value as in the Measurement Token field of the corresponding Measurement Request element, or if there is no corresponding Measurement Request then the Measurement Token value shall be set to 0.

If an AP determines that the LCI and/or civic location of a neighboring AP changes, the AP may send an unsolicited Neighbor Report Response frame containing complete neighbor information including the updated neighboring AP location information. The Dialog Token field is set to 0 as defined in 9.6.6.7 (Neighbor Report Response frame format).

A STA that receives an LCI report that contains a Usage Rules/Policy subelement shall process the LCI information in compliance with the retransmission and retention permissions in the Usage-rules subelement.

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The Wide Bandwidth Channel subelement shall not be included in the Neighbor Report element when either the HT Operation subelement or the VHT Operation subelement is included in the Neighbor Report element.

A VHT AP in which dot11FineTimingMsmtRespActivated is true that transmits a Neighbor Report element containing an HT Operation subelement shall include a VHT Operation subelement in the Neighbor Report element.

A non-DMG AP in which dot11FineTimingMsmtRespActivated is true that transmits a Neighbor Report element containing neither an HT Operation subelement nor a VHT Operation subelement shall include a Wide Bandwidth Channel subelement in the Neighbor Report element.

(11az)An AP that has set the DMG/Location Supporting APs In The Area field to 1 in the Extended Capabilities element that receives a Neighbor Report Request frame that includes a Measurement Request element with the value of its Measurement Type field equal to Neighboring DMG APs, shall respond with a Neighbor Report Measurement frame with a list of Neighbor Report elements of neighboring DMG APs supporting location services. Per each DMG AP, the Neighbor Report element shall include a Measurement Report subelement with the Measurement Type field equal to LCI. If available to the sending AP, the Neighbor Report element shall include a TSF subelement. The definition of which APs are neighboring APs is implementation dependent. (#7004)If the AP sending is collocated with a DMG AP that is location capable, the collocated DMG AP should be included in the list.

### 11.10.11 Link measurement

A STA may use a Link Measurement Request frame to request another STA to respond with a Link Measurement Report frame containing a TPC report element. If dot11RMLinkMeasurementActivated is true, a STA receiving a Link Measurement Request frame shall respond with a Link Measurement Report frame containing a TPC Report element indicating the power used to transmit the Link Measurement report. The Link Measurement report also contains antenna ID or DMG antenna ID and signal quality (RCPI and RSNI).

If dot11RMLinkMeasurementActivated is false in an AP or PCP receiving a Link Measurement Request, it shall ignore the request.

### 11.10.12 Measurement of the RPI histogram

To compute RPI densities for an RPI Histogram report (see 9.4.2.20.4 (RPI histogram report)), the STA shall measure the received power level on the specified channel, as detected at the antenna connector, as a function of time over the measurement duration. The tolerance of the received power measurements shall be ± 5 dB. Furthermore, the received signal power measurement should be a monotonic function of the actual power at the antenna connector. The time resolution of the received power measurements is in microseconds. The received power measurements are converted to a sequence of RPI values by quantizing the measurements according to Table 9-164 (RPI definitions for an RPI histogram report). The RPI densities are then computed for each of the eight possible RPI values using

$$\text{RPI Density} = \left\lceil \frac{255 \times D_{RPI}}{1024 \times D_M} \right\rceil$$

where

$D_{RPI}$ is the duration receiving at the specified RPI value (μs)

$D_M$ is the measurement duration (TU)

The sum of the RPI densities is approximately 255, but could be up to 262 because of rounding effects.


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### 11.10.13 Operation of the Max Transmit Power field

The Max Transmit Power field shall be less than or equal to the Max Regulatory Power value for the current channel.

### 11.10.14 Multiple BSSID set

A multiple BSSID set is characterized as follows:

- All members of the set use a common operating class, channel, channel access functions, receive antenna connector, and transmit antenna connector.(11ax)
- The size of the set is $2^n$, for a selected value of $n$:(11ax)
  - $1 \le n \le 8$ if dot11MultiBSSIDImplemented is true.(11ax)
  - $1 \le n \le 46$ if dot11MultiBSSIDImplemented (if present) is false and dot11RMMeasurementPilotActivated is nonzero.(11ax)
- All BSSIDs within the multiple BSSID set are assigned in a way that they are not available as MAC addresses for STAs using a different operating class, channel, receive antenna connector, or transmit antenna connector.(11ax)

NOTE—For example, if the APs within BSSs with BSSIDs 16, 17, and 27 share the same operating class, channel, receive antenna connector, and transmit antenna connector, and the range of MAC addresses from 16 to 31 inclusive is are not assigned to other STAs using a different receive antenna connector or transmit antenna connector, then the BSSIDs 16, 17, and 27 are members of a multiple BSSID set. The set is described by $n = 4$ ($2^n = 16$) with BSSIDs in the range 16–31. The set cannot be described by $n = 8$ for instance since at least one of the BSSIDs in the range 0–255 might be used as a BSSID by an AP that does not share the same operating class, channel, receive antenna connector, and transmit antenna connector.(11ax)

When the multiple BSSID set contains two or more members, the transmission of Measurement Pilot frames is constrained as described in 11.10.15 (Measurement Pilot frame generation and usage).

A Multiple BSSID element, with or without optional subelements, indicates that all APs and PCPs within the indicated range of BSSIDs transmit using a common class, channel, and antenna connector.

A single Beacon frame may contain elements for the multiple BSSID set members; see 11.1.3.8 (Multiple BSSID procedure).

### 11.10.15 Measurement Pilot frame generation and usage

#### 11.10.15.1 General

The Measurement Pilot frame is a compact Action frame transmitted pseudo-periodically by an AP at a small interval relative to a Beacon Interval. The Measurement Pilot frame provides reduced information relative to a Beacon frame to allow for the required small interval. The purpose of the Measurement Pilot frame is to assist a STA with the following functions:

- Rapid discovery of the existence of a BSS via passive scanning
- Rapid collection of neighbor AP signal strength measurements via passive scanning
- Enable transmission of a Probe Request frame

A STA's dot11RMMeasurementPilotActivated determines the level of support for measurement pilot at the STA. Table 11-14 (Measurement pilot activated definition) describes permitted values for dot11RMMeasurementPilotActivated and what they signify.

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**Table 11-14—Measurement pilot activated definition**

| Device function | dot11RM-MeasurementPilot Activated | Notes |
|---|---|---|
| AP and non-AP STA | 0 | If the STA is contained within an AP, it does not generate MPs and if the device is a non-AP STA, it ignores the MPs it receives |
| AP and non-AP STA | 1 | If the STA is contained within an AP, it can transmit MPs, and if the device is a non-AP STA, it can receive the MPs and can use the information contained in MPs. |
| Non-AP STA | 2 | The non-AP STA is making use of the MPs it receives or would receive if they were being transmitted. |
| Non-AP STA | 3–7 | Reserved |
| AP | | The AP is transmitting MPs and using the information contained in them, and the AP is (#1662)transmitting MPs with MP interval set to a value within the range as shown below.<br><br>MP Interval with respect to Beacon Interval: |
| | 2 | > 3% and < 5% of Beacon Interval |
| | 3 | ≥ 5% and < 10% |
| | 4 | ≥ 10% and < 15% |
| | 5 | ≥ 15% and < 20% |
| | 6 | ≥ 20% and < 25% |
| | 7 | ≥ 25% and < 50% |

### 11.10.15.2 Measurement Pilot frame generation by an AP

The AP shall determine if it is a member of a multiple BSSID set with two or more members. If so, at most one AP of the multiple BSSID set shall have dot11RMMeasurementPilotActivated set to a value between 2 and 7. How this occurs is out of scope of this standard.

(#488)If dot11MultiBSSIDImplemented is false and dot11RMMeasurementPilotActivated is between 2 and 7, the following statements apply:

— If the AP is a member of a multiple BSSID set with two or more members, then the BSSIDs of all members of the multiple BSSID set shall be indicated in the Beacon and Probe Response frames by the Multiple BSSID subelement.

— The AP shall maintain a Measurement Pilot frame generation function, which transmits Measurement Pilot frames at a basic rate according to dot11RMMeasurementPilotPeriod.

— The AP defines a series of TMPTTs exactly dot11RMMeasurementPilotPeriod apart. A TMPTT arrives when the AP's local TSF timer (in μs) modulo the measurement pilot interval equals 0.

— At each TMPTT, the AP shall schedule a Measurement Pilot frame as the next frame for transmission ahead of other queued frames using the AC_VO EDCA parameters unless the TMPTT satisfies:

$$\text{TBTT} - \frac{T_{MPP}}{2} \leq \text{TMPTT} < \text{TBTT} + \frac{T_{MPP}}{2}$$


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where $T_{MPP}$ is dot11RMMeasurementPilotPeriod, for any TBTT of members of the multiple BSSID set, in which case the AP shall not generate the Measurement Pilot frame(#297). This is illustrated in Figure 11-35 (Example of Measurement Pilot frame scheduling(#297)). How the AP determines the TBTTs of members of the multiple BSSID set is out of scope of this standard.

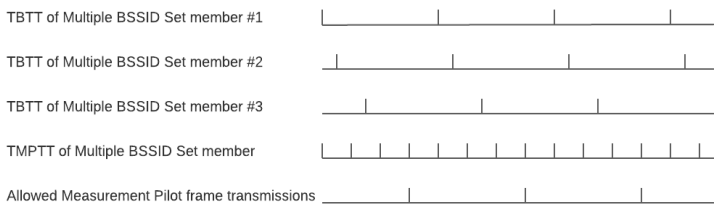


**Figure 11-35—Example of Measurement Pilot frame scheduling(#297)**

In case the medium is determined by the carrier-sense mechanism (see 10.3.2.1 (CS mechanism)) to be unavailable at the TMPTT, the AP shall delay the actual transmission of a Measurement Pilot frame according to the basic medium access rules specified in Clause 10 (MAC sublayer functional description) for a maximum period of one dot11RMMeasurementPilotPeriod and discard the delayed Measurement Pilot frame at the next TMPTT. In this way, a continuously busy medium causes multiple successive Measurement Pilot frames to be delayed, then (#3683)discarded. An AP shall transmit Measurement Pilot frames to the broadcast address. An AP shall not retransmit or buffer Measurement Pilot frames as part of the PSP mechanisms.

— If the AP is a member of a multiple BSSID set with two or more members, then the BSSIDs of all members of the multiple BSSID set shall be indicated in the Measurement Pilot frame using the Multiple BSSID subelement.

NOTE 1—APs are advised to enable Measurement Pilot frames judiciously due to the possibility of excessive medium time being consumed by Measurement Pilot frames from multiple overlapping APs. For instance dot11RMMeasurementPilotTransmissionInformationActivated might be set to false:

a) When enabling Measurement Pilot frames would cause:
   1) More than 10% of the medium time at the AP to be consumed by beacons and Measurement Pilot frames transmitted by any source, or
   2) More than 5% of the medium time at the AP to be consumed by Measurement Pilot frames transmitted by any source.
b) When STAs are not expected to be using Measurement Pilot frames. How this is determined is out of the scope of this standard, but may depend upon many STAs setting the Measurement Pilot Capability field in the RM Enabled Capabilities element to 0 or 1 upon association at any member of the multiple BSSID set recently or at similar times in the past.
c) When all members of the multiple BSSID set are within ESSs that contain one BSS only.
d) When the AP's operating regulatory domain is not subject to DFS regulations.
e) When the AP's operating regulatory domain is subject to DFS regulations but compliance with the regulations is impaired by Measurement Pilot frames.
f) When the number of channels valid for the AP's operating regulatory domain or frequency band is small.
g) When no members of the multiple BSSID set are located at ingress or egress points of an ESS, so are less useful for roaming between an IEEE 802.11 ESS and other networks.

NOTE 2—For efficient use of the medium, it is recommended that Measurement Pilot frames not be sent using a PHY specified in Clause 15 (DSSS PHY specification for the 2.4 GHz band designated for ISM applications) or Clause 16 (High rate direct sequence spread spectrum (HR/DSSS) PHY specification).

An AP that is not extended spectrum management capable shall not include a Wide Bandwidth Channel Switch subelement in a Measurement Pilot frame. If the Wide Bandwidth Channel Switch subelement is included in a Measurement Pilot frame, then the Operating Class shall include a 40 MHz channel spacing.

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### 11.10.15.3 Measurement pilot usage by a STA

Whenever testing a requested BSSID for equality against the BSSID field of a Measurement Pilot frame(#297), the following statements apply:

— If the Measurement Pilot frame does not contain the Multiple BSSID element, then equality shall be true if the requested BSSID equals the BSSID field of the Measurement Pilot frame, and otherwise false.

— If the Measurement Pilot frame contains the Multiple BSSID element, and the requested BSSID is a non-wildcard BSSID, then equality shall be true if the requested BSSID equals any BSSID indicated by the Multiple BSSID element present in the Measurement Pilot frame(#297), and otherwise false.

— If the Measurement Pilot frame contains the Multiple BSSID element, and the requested BSSID is the wildcard BSSID, then equality shall be true.

NOTE—STAs are advised that due to considerations such as those noted in the prior subclause, APs might not transmit Measurement Pilot frames at all times or in all bands.

### 11.10.16 Access delay measurement

Access delay is measured by the AP's or PCP's MAC(#6268) being the average medium access delay for transmitted frames measured from the time the MPDU is ready for transmission (i.e., begins CSMA/CA access or SP access, as appropriate) until the actual frame transmission start time. Access delay measurement results are included in the BSS Average Delay element and in the BSS AC Access Delay element.

For the BSS Average Delay measurement, the AP or PCP shall measure and average the medium access delay for all transmit frames using the DCF or EDCAF over a continuous 30 s measurement window. For the infrastructure BSS AC Access Delay measurement, the QoS AP or PCP shall measure and average the medium access delay for all transmit frames of the indicated AC (see Figure 9-429 (BSS Available Admission Capacity element format)) using EDCA mechanism over a continuous 30 s measurement window. The accuracy for the average medium access delay shall be ± 100 μs or better when averaged over at least 200 frames. Accuracy is not defined for measurements averaged over less than 200 frames.

### 11.10.17 BSS Available Admission Capacity

BSS Available Admission Capacity provides a means for an AP to advertise admission capacity available for explicit admission control in any UP or AC. This information may assist STAs in making service set transition decisions.

The transmitted BSS Available Admission Capacity value represents a proportion of time on the wireless medium scaled linearly in units of 32 μs/s from 0 (0% available time) to 31 250 (100% available time). If an AP transmits a BSS Load element, the values for any transmitted BSS Available Admission Capacity values shall be less than or equal to (#4135)the Available Admission Capacity field of the BSS Load element. If an AP transmits a BSS Available Admission Capacity element, the transmitted values should be current or recently calculated. The AP recalculates Available Admission Capacity values according to local policy. An Available Admission Capacity value of 0 transmitted in the BSS Available Admission Capacity element indicates that no admission capacity is available at the calculation time and that no explicit admissions can be granted by the AP for that UP or AC unless additional capacity becomes available. An AP that receives a TSPEC admission request for total medium time (in both directions, if applicable) that is less than or equal to the current available admission capacity for the requested UP or AC local policy may apply additional local policy before admitting the requested TSPEC.

NOTE 1—Available Admission Capacity values are dynamic in a BSS and the transmitted values cannot always reflect the actual values currently used by the AP for explicit admission control. Thus an AP should recalculate the Available Admission Capacity values regularly or after changes in the environment or the admitted capacity.


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NOTE 2—STAs are advised that requesting admission for any TSPEC at an UP or AC that requires more medium time than is reported as available for the requested UP or AC is possible yet unlikely to be successful.

### 11.10.18 AP Channel Report

The AP Channel Report element contains a list of channels in an operating class where a STA is likely to receive the Beacon or Probe Response frames sent by an AP, excluding the AP transmitting the AP Channel report. An AP Channel Report element only includes channels that are valid for the regulatory domain in which the AP transmitting the element is operating and consistent with the Country element in the frame in which it appears. One AP Channel Report element is included in the Beacon frame for each regulatory domain, which includes channels on which a STA is likely to receive the Beacon or Probe Response frames sent by an AP.

The contents of the AP Channel Report elements may be compiled from the list of unique operating/channel pairs found in the neighbor report. The contents of the AP channel report may be configured or obtained by other means beyond the scope of this standard.

### 11.10.19 Multicast diagnostic reporting

Multicast diagnostic reporting enables an AP to collect statistics on group addressed traffic at associated STAs. The method an AP uses to determine the multicast groups to which an associated STA is a member of is outside the scope of the standard and is typically performed by higher layer protocols. The Multicast Diagnostic request and Multicast Diagnostic report are defined in 9.4.2.19.13 (Multicast Diagnostics request) and 9.4.2.20.12 (Multicast Diagnostics report), respectively.

A STA with dot11MulticastDiagnosticsActivated equal to true shall support multicast diagnostics reporting and shall set to 1 the Multicast Diagnostics field of the Extended Capabilities elements that it transmits. When the Multicast Diagnostics field in the Extended Capabilities field is 1, the Incapable subfield(#291) in the Measurement Report Mode field of a Multicast Diagnostic report shall not be set to 1.

Multicast diagnostic reporting may use the triggered autonomous reporting capability described in 11.10.8 (Triggered autonomous reporting).

The Measurement Start Time field of a triggered diagnostic report shall contain the value of the STA TSF Timer at the time the trigger condition started to occur to an accuracy of ± 1 TU.

An AP may send a Multicast Diagnostic request consisting of one or more Multicast Diagnostic requests in a Radio Measurement Request frame to a non-AP STA that has indicated support of the multicast diagnostic capability or to a (#434)multicast-group address if all associated non-AP STAs support the multicast diagnostic capability. If the STA accepts the request it shall count the number of received MSDUs with the specified group address and the STA shall record the maximum observed PHY data rate of the frames that contained these MSDUs during the requested Measurement Duration. These two values shall be returned in a Multicast Diagnostic report in a Radio Measurement Report frame, as defined in 9.4.2.20.12 (Multicast Diagnostics report). A non-AP STA shall not transmit a Radio Measurement Request frame containing a Multicast Diagnostic request. A STA shall not respond to a Radio Measurement Request frame containing a Multicast Diagnostic request received from a STA other than the AP with which it is associated.

An AP may request that triggered multicast diagnostic reporting be enabled at associated non-AP STAs that have indicated support of the multicast diagnostic capability. To enable multicast diagnostic reporting, the AP shall send a Measurement Request element containing the Request Type field set to Multicast Diagnostics and with the Enable and Report subfields(#291) set to 1 within a Radio Measurement Request frame. See 11.10.8 (Triggered autonomous reporting). For triggered multicast diagnostic reporting, the Multicast MAC Address and trigger conditions for diagnostic reporting shall be specified in the request.

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Multicast diagnostic reporting may be requested for broadcast traffic by setting the Multicast MAC Address field to the broadcast address.

A non-AP STA accepting a request for triggered multicast diagnostic reporting shall send a Multicast Diagnostics report to the requesting STA if the specified trigger condition occurs. The measuring non-AP STA shall not send further triggered Multicast Diagnostics reports until the period specified in the Reactivation Delay field in the Multicast Diagnostic Request has expired, or the non-AP STA receives a revised trigger condition from a Multicast Diagnostic Request. To prevent generation of too many triggered reports, the Reactivation Delay field shall be set to a value greater or equal to A STA's MinTriggerTimeout.

Once accepted, Multicast Diagnostic reporting continues to be active for the specified Multicast MAC address until one of the following occurs:

— The STA receives a Measurement Request element containing a Multicast Diagnostic Request Type and with the Enable subfield(#291) equal to 1 and the Report subfield(#291) equal to 0 within a Radio Measurement Request frame.
— Receipt of a Measurement Request element containing a Multicast Diagnostic Request Type, with the Enable and Report subfields(#291) equal to 1, but with no trigger conditions.
— The STA leaves the multicast group(#433) or disassociates.
— The STA sends a Measurement Report element with the Measurement Result bit set to 1.

The STA shall maintain an inactivity timer for every multicast diagnostic request accepted by the STA in which the Inactivity Timeout Request field is 1. When a timeout of the inactivity timer is detected, the STA shall send a multicast diagnostic report with the inactivity Timeout Trigger field in the Multicast Reporting Reason field set to 1. The inactivity timer at a recipient is reset when MSDUs corresponding to the monitored group address are received.

A STA that declines a request for triggered multicast diagnostic reporting sends a Measurement Report element (as described in 9.4.2.20 (Measurement Report element)) in a Radio Measurement Report frame (as described in 9.6.2.3 (Spectrum Measurement Report frame format)) with the Measurement Report Mode field set appropriately to indicate the reason for a failed or rejected request.

#### 11.10.20 CCA request and report

The response to a CCA request is a CCA report. A STA may support the generation of a CCA report. A STA may generate a CCA report in response to a CCA request.

#### 11.10.21 RPI Histogram request and report

The response to an RPI Histogram request is an RPI histogram report. A STA may support the generation of an RPI histogram. A STA may generate an RPI histogram report in response to an RPI Histogram request.

### 11.11 DSE procedures

#### 11.11.1 General

Regulations that apply to the United States and its territories(#296) 3650 MHz band require enabling STAs to implement a mechanism to enable mobile and portable STA operation. Similar regulations exist in other regulatory domains. This standard describes such a mechanism, referred to as *dependent STA enablement (DSE)*.

Regulations that apply to the United States and its territories(#296) 3650 MHz band require fixed STAs and enabling STAs to have their operating locations registered. Licensees with STAs suffering or causing harmful


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interference are expected to cooperate and resolve problems by mutually satisfactory arrangements. The DSE procedures provide the location of the enabling STA and unique identifiers to assist licensees in the resolution of interference issues. The DSE procedures might also satisfy needs in other frequency bands and be useful for other purposes.

A STA shall use the DSE procedures defined in this subclause if dot11LCIDSERequired is true. dot11DSERequired and dot11ExtendedChannelSwitchActivated shall be true when regulatory authorities require DSE, with the following exceptions: dot11DSERequired shall be set to false to configure STAs to operate as registered STAs, and dot11ExtendedChannelSwitchActivated may be set to false when operating as a fixed STA. A summary of STA attributes and these MIB attributes are shown in Table 11-15 (DSE STA attributes).

**Table 11-15—DSE STA attributes**

| Type of STA | Registered STA | dot11LCIDSERequired and dot11LCIDSEImplemented | dot11ExtendedChannelSwitchActivated | dot11DSERequired |
|---|---|---|---|---|
| Fixed STA | Yes | true | true or false | false |
| Enabling STA | Yes | true | true | false |
| Dependent STA | No | true | true | true |

A fixed STA is a registered STA that broadcasts its registered location and is restricted from enabling other STAs (see 11.11.3 (Registered STA operation)). An enabling STA is a registered STA that broadcasts its registered location, and regulatory authorities permit it to enable operation of unregistered STAs (see 11.11.4 (Enabling STA operation with DSE)). A dependent STA is an unregistered STA that operates under the control of an enabling STA (see 11.11.5 (Dependent STA operation with DSE)). When management frame protection is negotiated, stations shall use Protected Dual of Public Action frames instead of individually addressed Public Action frames for DSE procedures.

The DSE procedures provide for the following:

— Registered STA operation
— Creation of a DSE service area for dependent STA operation
— Dependent STA operation with DSE

### 11.11.2 Enablement and deenablement

#### 11.11.2.1 General

This subclause describes the procedures used for IEEE 802.11 enablement and deenablement. A STA keeps a state variable for each STA with which enablement communication is needed:

— Enablement state with a value of *unenabled* or
— Enablement state with a value of *enabled*

NOTE—Refer to 11.11.5 (Dependent STA operation with DSE) for description of dependent STA operation in either enablement state.

Enablement utilizes a two-frame transaction sequence. The first frame asserts identity and requests enablement. The second frame returns the enablement result. In the description in 11.11.2.2 (Enablement requester STA) and 11.11.2.3 (Enablement responder STA), the STA initiating the enablement is referred to as *enablement requester*, and the STA to which the initial frame in the exchange is addressed is referred to as *enablement*

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*responder*. The specific items in each of the frames described in the following subclauses are defined in 9.6.7.4 (DSE Enablement frame format) and 9.6.7.5 (DSE Deenablement frame format). An enabling STA may decline to enable a requesting STA. If the result is "successful," the requesting STA shall be enabled.

Deenablement utilizes a one-frame transaction sequence. In the description in 11.11.2.4 (Deenablement requester STA) and 11.11.2.5 (Deenablement responder STA), the STA initiating the deenablement is referred to as *deenablement requester*, and the STA to which the frame is addressed is referred to as *deenablement responder*.

### 11.11.2.2 Enablement requester STA

Upon receipt of an MLME-ENABLEMENT.request primitive, the enablement requester STA shall perform the following procedure:

a) Construct and transmit a DSE Enablement frame requesting enablement.
   1) Specific information items in the enablement frame are as follows.
      i) STA identity assertion (in RequesterSTAAddress)
      ii) Enabling STA identity assertion (in ResponderSTAAddress)
      iii) Reason result code = 2
      iv) Enablement identifier = 0
   2) Specific items in the enablement frame sent by the enablement responder STA are described in 11.11.2.3 (Enablement responder STA).

b) On receipt of a matching DSE Enablement frame (i.e., the Requester STA Address and Responder STA Address match the pending request) that acknowledges the DSE Enablement frame, issue an MLME-ENABLEMENT.confirm primitive to inform the SME of the result of the enablement.
   1) The primitive may contain information from an DSE Enablement frame received from the enabling STA (see 11.11.2.3 (Enablement responder STA)), or it may be issued for another reason (see 9.6.7.4 (DSE Enablement frame format)).
   2) The reason result code in the enablement confirmation frame indicates when the enablement is successful.
   3) If the enablement was successful, the enablement state variable for the enablement responder STA shall be set to Enabled.

c) If no matching DSE Enablement frame is received for the DSE Enablement frame within a period of EnablementTimeLimit TUs measured from the receipt of the MLME-ENABLEMENT.request primitive, issue an MLME-ENABLEMENT.confirm primitive with ResultCode set to TIMEOUT.

### 11.11.2.3 Enablement responder STA

Upon receipt of a Public Action DSE Enablement frame with a reason result code of 2, the enablement responder STA may enable the enablement requester STA using the following procedure:

a) Create and transmit a response frame with the enablement status as defined in 9.6.7.4 (DSE Enablement frame format) set in the Reason Result Code field and with a dependent enablement identifier chosen to be unique among all dependent enablement identifiers that have been assigned if enablement was successful. The enablement responder shall transmit the ResultCode parameter from the .confirm primitive mapped as specified in Table 9-474 (Reason Result Code field values) of 9.6.7.4 (DSE Enablement frame format) to indicate the result of the enablement request.
   1) Specific information items in the enablement frame response are as follows:
      i) STA identity assertion (in RequesterSTAAddress)
      ii) Enabling STA identity assertion (in ResponderSTAAddress)


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iii) The result of the requested enablement as defined in 9.6.7.4 (DSE Enablement frame format)

iv) Enablement identifier

b) Issue an MLME-ENABLEMENT.indication primitive to inform the SME of the enablement.

1) If the enablement is successful, the enablement state variable for the enablement requester STA shall be set to Enabled.

#### 11.11.2.4 Deenablement requester STA

Upon receipt of an MLME-DEENABLEMENT.request primitive, the deenablement requester STA shall create and transmit a DSE Deenablement frame to the deenablement responder STA. Specific information items in the deenablement frame are as follows:

a) Enabling STA identity assertion (in RequesterSTAAddress)

b) STA identity assertion (in ResponderSTAAddress)

c) Reason result code = 2

#### 11.11.2.5 Deenablement responder STA

Upon receipt of a DSE Deenablement frame, the deenablement responder STA shall deenable with the deenablement requester STA by issuing an MLME-DEENABLEMENT.indication primitive to inform the SME of the deenablement. The enablement state variable for the deenablement requester STA shall be set to Unenabled.

### 11.11.3 Registered STA operation

A registered STA shall have dot11DSERequired equal to false. They shall transmit the DSE Registered Location element in every Beacon frame and shall set the Dependent STA subfield(#291) in the DSE Registered Location element to 0. If the registered STA is located within a national policy area, such as a Fixed Satellite Service exclusion zone, or within an international agreement area near a national border, the RegLoc Agreement subfield(#291) in the DSE Registered Location element shall be set to 1, signifying to other STAs that additional restrictions on STAs with directional antennas may apply; otherwise, it shall be set to 0.

The Latitude, Longitude, and Altitude fields of the DSE Registered Location element shall be reported at their best known resolutions, which might exceed the resolutions required by regulatory authorities. The Altitude Type field value shall be 3 (i.e., height above ground is in meters(#8192), unless another altitude type is required for operation in the regulatory domain. The Datum field value shall be 1 (World Geodetic System 1984), unless another datum is required for operation in the regulatory domain.

An enabling STA is a registered STA that broadcasts its registered location, and regulatory authorities permit it to enable operation of unregistered STAs (see 11.11.4 (Enabling STA operation with DSE)). A dependent STA is an unregistered STA that operates under the control of an enabling STA (see 11.11.5 (Dependent STA operation with DSE)).

A fixed STA is a registered STA that broadcasts its registered location and is restricted from enabling other STAs. A fixed STA shall have dot11LCIDSERequired set to true, and dot11ExtendedChannelSwitchActivated may be true or false. A fixed STA shall set dot11RegLocDSE to false and the RegLoc DSE subfield(#291) in the DSE Registered Location element to 0, signifying that it is not creating a DSE service area. A fixed STA may operate in an infrastructure BSS or IBSS. A registered STA that is not an enabling STA may operate as an AP and relay Public Action frames (specifically, DSE Enablement, DSE Deenablement, DSE Measurement Request, DSE Measurement Report, DSE Power Constraint) from a dependent STA to its enabling STA. The specification of the algorithm by which Public Action frames are relayed is beyond the scope of this standard.

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Note that the enabling signal is not a Public Action frame and is not relayed (see 11.11.4 (Enabling STA operation with DSE)).

### 11.11.4 Enabling STA operation with DSE

A registered STA may create and manage a DSE service area for dependent STA operation where regulatory requirements permit. A registered STA operating in this manner is referred to as an *enabling STA*. An enabling STA (#135)shall set dot11RegLocDSE to true and shall signify the creation of a DSE service area by setting the RegLoc DSE subfield(#291) in the DSE Registered Location element to 1. Dependent STA transmission of any frames is conditional on receiving directly over the air and decoding a DSE Registered Location element with RegLoc DSE subfield(#291) equal to 1, sent from an enabling STA. Before attempting enablement with any one enabling STA, a dependent STA may have detected several enabling STAs, may attempt enablement with one and fail, and then attempt enablement with another. An enabling STA shall assign dependent enablement identifiers in a way that makes them unique among STAs enabled by this enabling STA to help identify sources of interference.

An enabling STA may issue a DSE measurement request to any of its dependent STAs in order to receive a DSE measurement report that may have reported DSE LCI fields received from nearby STAs. The licensed operator may be able to use these reports to identify interfering STAs or map overlapping coverage in a multiple BSS situation. Because reported DSE LCI fields may refer to any destination address, a single DSE report may contain elements received from STAs that are not yet associated with a BSS.

An enabling STA may issue an ECS announcement to any of its dependent STAs in order to have their radio operation changed in frequency, channel bandwidth, and other operational parameters. A dependent AP or DFS owner with dot11DSERequired true and receiving an ECS announcement from its enabling STA shall perform the extended channel switching procedure as specified in 11.9 (Extended channel switching (ECS)).

An enabling STA may issue a DSE power constraint announcement to any of its dependent STAs in order to have their transmit power reduced from the regulatory limit. A dependent AP or DFS owner with dot11DSERequired true and receiving a DSE power constraint announcement from its enabling STA shall perform the power constraint procedure as specified in 11.11.5 (Dependent STA operation with DSE).

### 11.11.5 Dependent STA operation with DSE

A dependent STA shall set dot11DSERequired to true.

A typical state machine implementation of dependent STA operation with DSE is provided in Figure 11-36 (Dependent STA state machine).

For DSE, the following statements apply:

- A STA with dot11DSERequired true shall not transmit any frames unless it has received a Beacon frame from an enabling STA with the Spectrum Management bit equal to 1 in the Capability Information field and with the RegLoc DSE subfield(#291) equal to 1 in the DSE Registered Location element. A dependent STA that is not enabled shall not transmit, except to attain enablement with an enabling STA, unless such action is mandated to be allowed in the regulatory domain (e.g., emergency services).
- A dependent STA shall not attempt enablement with an enabling STA unless the enabling STA is transmitting Beacon frames with the RegLoc DSE subfield(#291) equal to 1 in the DSE Registered Location element.
- A dependent STA creates a dependent DSE Registered Location element containing the enabling STA's DSE Registered Location element and having the RegLoc DSE subfield(#291) set to 0 and the Dependent STA subfield(#291) set to 1. Before enablement, the Dependent Enablement Identifier field shall be set to 0. Upon attaining enablement, the Dependent Enablement Identifier


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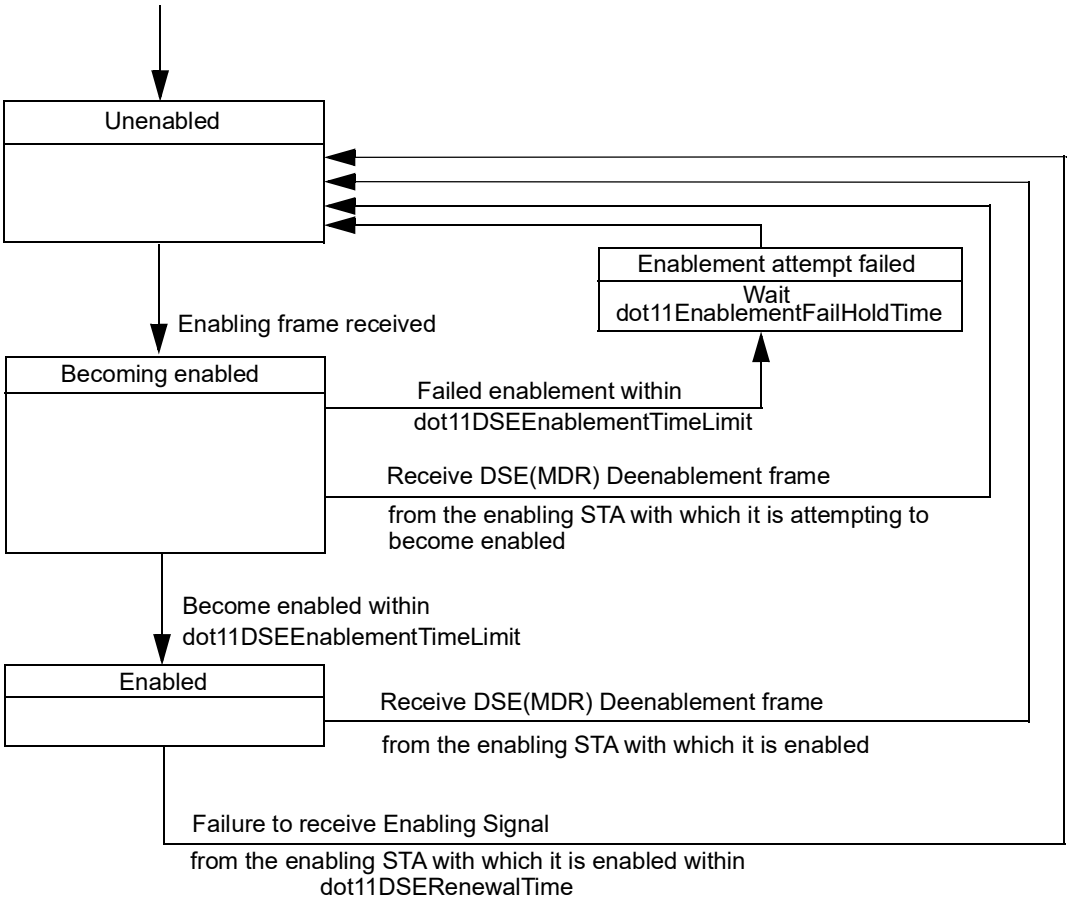


**Figure 11-36—Dependent STA state machine**

field shall be set to the dependent enablement identifier value received by the dependent STA from the enabling STA in the MLME-ENABLEMENT.response primitive.

— The dependent STA shall send a Public Action DSE Registered Location Announcement frame to the broadcast address whenever the sum of dot11TransmittedFragmentCount, dot11GroupTransmittedFrameCount, and dot11ReceivedFragmentCount, modulo dot11DSETransmitDivisor equals 0, possibly delayed by the completion of the sending of the frames of the current MSDU or MMPDU or by the completion of the current transmission opportunity (TXOP).

— A dependent STA that has not attained enablement shall not transmit beyond dot11DSEEnablementTimeLimit (in seconds), measured from the time of the first PHY-TXSTART.request primitive, while attempting to attain enablement. Then if it is not enabled, it shall not transmit for dot11DSEEnablementFailHoldTime (in seconds), before it again attempts to attain enablement.

— A dependent STA receiving a DSE Deenablement frame with the RequesterSTAAddress field matching the enabling STA with which it last attempted enablement and the ResponderSTAAddress field matching its (#3403)(#1893)MAC address shall change its enablement state with the enabling STA to unenabled and set all fields of its DSE Registered Location Information field (see 9.4.2.50 (DSE Registered Location element)) to 0.

— A dependent STA shall return a DSE measurement report in response to a DSE measurement request if the request is received from the AP with which it is associated or the enabling STA with

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which it last attempted enablement and the ResponderSTAAddress field matches its (#3403)(#1893)MAC address. The result may be the completed measurement or an indication that the STA is unable to complete the measurement request. A STA shall report it is too late to undertake a measurement request if it receives the request after the specified starting time for the measurement. The Measurement Report Mode field of a frame that is sent in response to a DSE Measurement Request frame shall not contain a value of 1 for the Incapable subfield and shall not contain a value of 1 for the Refused subfield of the Measurement Report Mode field of the DSE measurement report.

— A dependent STA receiving an ECS frame from the enabling STA with which it last attempted enablement or an ECS element from the AP with which it is associated shall perform the ECS procedure (see 11.9.3 (Selecting and advertising a new channel and/or operating class)).

— A dependent STA receiving a DSE Power Constraint frame with the RequesterSTAAddress field matching the enabling STA with which it last attempted enablement and the ResponderSTAAddress field matching its (#3403)(#1893)MAC address shall constrain its transmit power to be less than or equal to the maximum transmit power level specified for the current channel in the Country element minus the local power constraint specified in the DSE Power Constraint frame.

— An enabled dependent STA shall cease transmission within dot11DSERenewalTime (in seconds) if it has not received either a Beacon frame or a Probe Response frame from its enabling STA with the RegLoc DSE subfield(#291) equal to 1 in the DSE Registered Location element. It shall then change its enablement state with the enabling STA to unenabled and set all fields of its DSE Registered Location Information field (see 9.4.2.50 (DSE Registered Location element)) to 0.

## 11.12 Group addressed management frame protection procedures

When management frame protection is negotiated, the MLME shall provide an encapsulation service for group addressed robust Management frames. All group addressed robust Management frames shall be submitted to this service for encapsulation and transmission.

(#1980)(#162)In an MBSS, for group addressed Action frames of a category specified with Yes in the Group addressed privacy column of Table 9-81 (Category values), the group addressed frame protection service shall take the following actions:

— The frames shall be encapsulated and protected with the MGTK using the (#6020)group data cipher negotiated during the AMPE exchange.

For all other group addressed robust(#1813) Management frames, the group addressed frame protection service shall take the following actions:

— Management frame protection for multicast/broadcast shall be set using the MLME-SETPROTECTION.request primitive with the Protectlist including a Key Type value of IGTK. A non-AP STA shall also set the Protect Type value to Rx. In an IBSS, a STA shall set the ProtectType value to Rx_Tx. An AP shall set the Protect Type value to Tx.

— The IGTK shall be installed using the MLME-SETKEYS.request primitive with the value IGTK for the Key Type parameter of the SetKeyDescriptor.

— The frames shall be encapsulated and protected using BIP (see 12.5.3 (Broadcast/multicast integrity protocol (BIP))).

## 11.13 SA Query procedures

(#4166)If a STA and its peer negotiate management frame protection(#199), then the STA shall support the SA Query procedure.


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To send an SA Query Request or SA Query Response frame to a peer STA, the SME shall issue an MLME-SA-QUERY.request or MLME-SA-QUERY.response primitive respectively. Reception of an SA Query Request or SA Query Response frame is signaled to the SME with an MLME-SA-QUERY.indication or MLME-SA-QUERY.confirm primitive respectively.

A STA that supports the SA Query procedure and receives an SA Query Request frame shall respond with an SA Query Response frame if none of the following are true:

- The STA is not currently associated to the STA that sent the SA Query Request frame (11az)and there is no PTKSA established by PASN authentication.
- The SA Query Request frame was sent to a group address.(#119)
- The STA has sent a (Re)Association Request frame within dot11AssociationResponseTimeOut but has not received a corresponding (Re)Association Response frame.
- dot11RSNAOperatingChannelValidationActivated is true and the sending STA had indicated OCVC(#3505) in its association and either
  - OCI element is not present in the request or
  - Operating channel information indicated does not match the current channel information (see 12.2.10 (Requirements for Operating Channel Validation)).

A STA that responds with an SA Query Response frame to a STA that indicated OCVC(#3505) shall include an OCI element(#426) in the response frame if dot11RSNAOperatingChannelValidationActivated is true.

When a non-AP or non-PCP STA receives the SA Query Response frame from a STA that indicated OCVC(#3505), it shall ensure that OCI element is present in the response and the channel information in the OCI element matches current operating channel parameters (see 12.2.10 (Requirements for Operating Channel Validation)). Otherwise, the receiving STA shall deem the response as invalid and discard it.

(#119)If a STA receives a group addressed SA Query Response frame, it shall deem the response as invalid and discard it.

If a non-AP or non-PCP STA initiated an SA Query procedure following a channel switch and does not receive the SA Query Response frame from a STA that indicated OCVC(#3505) within dot11AssociationSAQueryMaximumTimeout TUs from the beginning of the SA Query procedure, it shall deauthenticate from the BSS.

NOTE 1—A non-AP and non-PCP STA does not respond if it is trying to reassociate with the AP or PCP that sent the SA Query Request frame (since, except in the case of FT to the same AP, it no longer has the PTKSA) or to another AP or PCP (it could maintain the old association and PTKSA until the reassociation is completed). There is no such restriction for an AP or PCP.

If a non-AP and non-PCP STA that has an SA with its AP or PCP for an association that negotiated management frame protection receives an (#2128)individually addressed unprotected Deauthentication or Disassociation frame with reason code INVALID_CLASS2_FRAME or INVALID_CLASS3_FRAME from the AP or PCP, the non-AP and non-PCP STA may use this as an indication that there might be a mismatch in the association state between itself and the AP or PCP. In such a case, the non-AP and non-PCP STA's SME may initiate the SA Query procedure with the AP or PCP to verify the validity of the SA by issuing one MLME-SA-QUERY.request primitive every dot11AssociationSAQueryRetryTimeout TUs until a matching MLME-SA-QUERY.confirm primitive is received or dot11AssociationSAQueryMaximumTimeout TUs from the beginning of the SA Query procedure has passed. If the AP or PCP responds to the SA Query request with a valid SA Query response, the non-AP STA should continue to use the SA. If no valid SA Query response is received, the non-AP and non-PCP STA's SME may delete the SA (and temporal keys)(#205) held for communication with the STA by issuing an MLME-DELETEKEYS.request primitive and the non-AP and non-PCP STA may move into State 1 (or State 2, for a DMG STA) with the AP.

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NOTE 2—The mechanism by which the MAC, MLME and SME coordinate the actions needed to effect these operations is outside the scope of this standard.

When an S1G STA in a power save mode wakes up with an interval longer than dot11AssociationSAQueryMaximumTimeout, an existing SA can be destroyed. So, to maintain its valid SA status, the S1G STA shall wake to listen to SA Query Request frame with the interval specified by dot11AssociationSAQueryMaximumTimeout. When dot11RSNAProtectedManagementFramesActivated is true, an S1G AP shall provide the (#1776)timeout interval (association comeback time(#3389), which is set to dot11AssociationSAQueryMaximumTimeout) in an Association Response frame and Reassociation Response frame with a status code 0 to the S1G STA.

(#4069)A non-AP STA can identify itself securely when (re)associating with the same AP to avoid the need to use the SA Query procedure and association comeback delay when that non-AP STA and the AP share a common PTK-KCK. The non-AP STA includes a Known STA Identification element in its (Re)Association Request frame to do this, and the AP allows the (re)association to proceed without an SA Query procedure if it receives a valid Known STA Identification element.

(#4069)The MIC for the Known STA Identification element shall be calculated using the most recently used PTK-KCK and the integrity algorithm (see Table 12-11 (Integrity and key wrap algorithms(#3244)) for the AKM that was negotiated to be used with that key: MIC(PTK-KCK, Timestamp). The Timestamp value is the most recently received Timestamp field the non-AP STA has received from the AP, e.g., from a Beacon frame. The AP may use this to discard Known STA Identification elements that are based on old information to limit the possibility of replay attacks. The AP should allow timestamp values that it has sent during the last 30 s(#7198), or the BSS max idle period, if it is advertised and larger, to be recognized as valid, but the AP may accept a larger window to accommodate cases where the non-AP STA might use cached information for an association. The AP shall discard the Known STA Identification element if the same timestamp value is used more than once. The Known STA Identification element is valid if it was not discarded, and the received MIC matches the locally calculated value. Otherwise, the Known STA Identification element is invalid and shall not be used to skip an SA Query procedure.

## 11.14 HT BSS Operation

(#181)An HT STA that is starting or joining a BSS shall support receiving and transmitting at each of the MCS values listed in the Basic HT-MCS Set field of the HT Operation parameter of the MLME-START.request primitive or Basic HT-MCS Set field of the HT Operation parameter of the SelectedBSS parameter of the MLME-JOIN.request primitive.

A STA that transmits a frame that contains both an HT Operation element and a DSSS Parameter Set element shall set the Primary Channel field in the HT Operation element to the same value as the Current Channel field in the DSSS Parameter Set element.

## 11.15 20/40 MHz BSS operation

### 11.15.1 Rules for operation in 20/40 MHz BSS

The rules described in 11.15.1 (Rules for operation in 20/40 MHz BSS) to 11.15.12 (Switching between 40 MHz and 20 MHz) are applicable to STAs that are either a STA 5G or a STA 2G4.

A 40-MHz-capable STA (40MC STA) shall support 20/40 BSS coexistence management.

NOTE—A 40MC HT STA that transmits a frame containing an Extended Capabilities element sets the 20/40 BSS Coexistence Management Support field of this element to 1.


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An HT STA 2G4 that is an IBSS STA and that transmits a frame containing an HT Operation element or Secondary Channel Offset element shall set the Secondary Channel Offset field of this element to SCN.

### 11.15.2 Basic 20/40 MHz BSS functionality

An HT AP declares its channel width capability (20 MHz only or 20/40 MHz) in the Supported Channel Width Set subfield of the HT Capabilities element.

An HT AP shall set the STA Channel Width field to 1 in frames in which it has set the Secondary Channel Offset field to SCA or SCB. An HT AP shall set the STA Channel Width field to 0 in frames in which it has set the Secondary Channel Offset field to SCN.

A non-AP HT STA declares its channel width capability (non-40MC HT STA or 40MC HT STA) in the Supported Channel Width Set subfield in the HT Capabilities element.

NOTE 1—A 20/40 MHz BSS might include any mixture of 40MC HT STAs, non-40MC HT STAs, and non-HT STAs. Protection requirements for mixed networks are defined in 10.27 (Protection mechanisms).

NOTE 2—A non-AP HT STA can switch between 40MC HT STA and non-40MC HT STA operation by disassociation followed by association.

An HT STA shall not indicate support for 40 MHz unless it supports reception and transmission of 40 MHz PPDUs using all MCSs within the Basic HT-MCS Set field of the HT Operation parameter of the MLME-START.request primitive or Basic HT-MCS Set field of the HT Operation parameter of the SelectedBSS parameter of the MLME-JOIN.request primitive and all MCSs that are mandatory for the attached PHY.

An HT STA shall not transmit a 20 MHz PPDU containing one or more Data frames using the secondary channel of a 20/40 MHz BSSs. The Notify Channel Width frame may be used by a STA to notify another STA that the STA wishes to receive frames in the indicated channel width.

An HT STA that is an IBSS STA adopts the Secondary Channel Offset field in received frames according to the rules in 11.1.5 (Adjusting STA timers) and shall not transmit either of the following:

— A value in the Secondary Channel Offset field that differs from the most recently adopted value
— An operating class in the Extended Channel Switch Announcement frame or element with a different behavior than the currently adopted PrimaryChannelLowerBehavior or PrimaryChannelUpperBehavior

### 11.15.3 Channel scanning and selection methods for 20/40 MHz operation

#### 11.15.3.1 General

An HT STA shall set the following to true: dot11OperatingClassesImplemented, dot11OperatingClassesRequired, and dot11ExtendedChannelSwitchActivated.

An AP operating a 20/40 MHz BSS, on detecting an OBSS whose primary channel is the AP's secondary channel, switches to 20 MHz BSS operation and may subsequently move to a different channel or pair of channels. A DFS owner (DO) operating a 20/40 MHz IBSS, on detecting an OBSS whose primary channel is the DO's secondary channel, may choose to move to a different pair of channels.

NOTE—The setting up of a 40 MHz off-channel TDLS direct link is specified in 11.20.6.3 (Setting up a 40 MHz TDLS direct link(#2152)).

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### 11.15.3.2 Scanning requirements for a 20/40 MHz BSS

Before an AP or DO starts a 20/40 MHz BSS, it shall perform a minimum of dot11BSSWidthChannelTransitionDelayFactor OBSS scans (see 11.15.5 (Scanning requirements for 40MC HT STA 2G4)) to search for existing BSSs.

If the AP or DO starts a 20/40 MHz BSS in the 5 GHz band and the BSS occupies the same two channels as any existing 20/40 MHz BSSs, then the AP or DO shall select a primary channel of the new BSS that is identical to the primary channel of the existing 20/40 MHz BSSs and a secondary channel of the new 20/40 MHz BSS that is identical to the secondary channel of the existing 20/40 MHz BSSs, unless the AP discovers that on these two channels are existing 20/40 MHz BSSs with different primary and secondary channels.

If an AP or DO starts a 20/40 MHz BSS in the 5 GHz band, the selected secondary channel should correspond to a channel on which no beacons are detected during the dot11BSSWidthChannelTransition-DelayFactor OBSS scan time performed by the AP or DO, unless there are beacons detected on both the selected primary and secondary channels.

NOTE 1—The 20/40 MHz channel sets and their corresponding behavior limits (i.e., choice of primary and secondary channels) permissible in each operating class are defined in Annex E and Annex D, respectively.

An HT AP or a DO that is also an HT STA should not start a 20 MHz BSS in the 5 GHz band on a channel that is the secondary channel of a 20/40 MHz BSS.

The AP or DO may continue to periodically scan after the BSS has been started. Information obtained during such scans is used as described within this subclause and within 11.15.2 (Basic 20/40 MHz BSS functionality).

After starting a 20 MHz BSS, a 40MC HT AP 2G4 shall perform a minimum of dot11BSSWidthChannelTransitionDelayFactor OBSS scans, either by itself or through its associated STAs before making a transition from a 20 MHz BSS to a 20/40 MHz BSS. When the AP performs the scanning and the secondary channel for the 20/40 MHz BSS has been selected, then the scan shall be performed over the set of channels that are allowed operating channels within the current operational regulatory domain and whose center frequency falls within the *affected frequency range* given by Equation (11-1). When the AP performs the scanning without an intended secondary channel for the 20/40 MHz BSS or when the AP's associated STA(s) perform the scanning, then the scan shall be performed on all channels in the frequency band.

NOTE 2—A 40MC HT AP can change from operating a 20 MHz BSS to a 20/40 MHz BSS while maintaining associations by making a change to the transmitted Secondary Channel Offset field.

$$\textit{affected frequency range} = [\frac{f_P + f_S}{2} - 25\ \text{MHz}, \frac{f_P + f_S}{2} + 25\ \text{MHz}] \quad (11\text{-}1)$$

where

$f_P$ is the center frequency of channel $P$

$f_S$ is the center frequency of channel $S$

A 40MC HT AP 2G4 shall maintain a MAC variable *20/40 Operation Permitted* that can have either the value true or false. The initial value of *20/40 Operation Permitted* shall be false. The value of *20/40 Operation Permitted* is recomputed according to Equation (11-2) whenever a BSS channel width trigger event is detected or whenever a period of time has elapsed with no BSS channel width triggers being detected and no overlap being reported, as defined in 11.15.12 (Switching between 40 MHz and 20 MHz).


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*20/40 Operation Permitted* = ($P$ == $OP_i$ for all values of $i$) AND
($P$ == $OT_i$ for all values of $i$) AND
($S$ == $OS_i$ for all values of $i$) (11-2)

where

$P$ is the operating or intended primary channel of the 20/40 MHz BSS

$S$ is the operating or intended secondary channel of the 20/40 MHz BSS

$OP_i$ is member $i$ of the set of channels that are members of the channel set C and that are the primary operating channel of at least one 20/40 MHz BSS that was detected within the AP's BSA during the previous dot11BSSWidthChannelTransitionDelayFactor × dot11BSSWidthTriggerScanInterval seconds

$OS_i$ is member $i$ of the set of channels that are members of the channel set C and that are the secondary operating channel of at least one 20/40 MHz BSS that was detected within the AP's BSA during the previous dot11BSSWidthChannelTransitionDelayFactor × dot11BSSWidthTriggerScanInterval seconds

$OT_i$ is member $i$ of the set that comprises all channels that are members of the channel set C that were listed at least once in the Channel List fields of 20/40 BSS Intolerant Channel Report elements received during the previous dot11BSSWidthChannelTransitionDelayFactor × dot11BSSWidthTriggerScanInterval seconds and all channels that are members of the channel set C and that are the primary operating channel of at least one 20 MHz BSS that was detected within the AP's BSA during the previous dot11BSSWidthChannelTransitionDelayFactor × dot11BSSWidthTriggerScanInterval seconds

C is the set of all channels that are allowed operating channels within the current operational regulatory domain and whose center frequency falls within the *affected frequency range* given by Equation (11-1)

If either side of "==" above is the empty set or has a null value, then the expression is defined to have a Boolean value of true.

A 40MC HT AP 2G4 shall not start a 20/40 MHz BSS in the 2.4 GHz band if the MAC variable *20/40 Operation Permitted* is false (#4181)(see Equation (11-2)).

A 40MC HT AP 2G4 may transmit a frame containing a Secondary Channel Offset field set to a value of SCA or SCB only if *20/40 Operation Permitted* is true.

In addition to information obtained by the 40MC HT AP 2G4 through its own scanning, a 40MC HT AP 2G4 shall use 20/40 BSS Intolerant Channel Report element information from received 20/40 BSS Coexistence Management frames with an Address 1 field that matches the 40MC HT AP 2G4 using either individual or group addressing, but with no qualification of the Address 3 value, when determining if *20/40 Operation Permitted* is true or false. The information from the Channel List fields of received 20/40 BSS Intolerant Channel Report elements is used in generating the *OT* set for Equation (11-2).

After initial establishment of the 20/40 MHz BSS, if the value of *20/40 Operation Permitted* becomes false, the 40MC HT AP 2G4 reverts to 20 MHz BSS operation (see 11.15.12 (Switching between 40 MHz and 20 MHz)). The 40MC HT AP 2G4 might subsequently move the BSS to a pair of channels where the value of *20/40 Operation Permitted* evaluates to true.

### 11.15.3.3 Channel management at the AP and in an IBSS

While operating a 20/40 MHz BSS, a DO or an AP may move its BSS, and an AP may switch the BSS to 20 MHz operation either alone or in combination with a channel move. These channel moving or BSS width switching operations might occur if, for example, another BSS starts to operate in either or both of the primary or secondary channels, or if radar is detected in either or both of the primary or secondary channels, or for other reasons that are beyond the scope of this standard. Specifically, the AP or DO may move its BSS to a different pair of channels, and the AP may separately, or in combination with the channel switch, change from a 20/40 MHz BSS to a 20 MHz BSS using either the primary channel of the previous channel pair or any other

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available 20 MHz channel. While operating a 20 MHz BSS, a DO or an AP may move its BSS, and an AP may switch the BSS to a 20/40 MHz BSS, either alone or in combination with a channel move.

When switching a 20/40 MHz BSS to an operating channel width of 20 MHz, the AP may recalculate the TS bandwidth budget and may delete one or more active TSs by invoking the MLME-DELTS.request primitive with a ReasonCode value of SERVICE_CHANGE_PRECLUDES_TS.

An AP switches between 20/40 MHz BSS and 20 MHz BSS as follows:

— By changing the Secondary Channel Offset field of the HT Operation element in the Beacon frame, and/or

— By changing the Secondary Channel Offset field of the Secondary Channel Offset element, and/or

— Through the New Operating Class field of transmitted Extended Channel Switch Announcement elements.

In order to maintain existing associations and/or minimize disruption to communications with other STAs while making a channel width change or while performing a channel pair relocation, an AP may inform HT STAs within its BSS that it is making the change by including an Extended Channel Switch Announcement element in Beacon, Probe Response, and Extended Channel Switch Announcement frame transmissions until the intended channel switch time. A DO may inform HT STAs within its BSS that it is performing a channel pair relocation by including an Extended Channel Switch Announcement element in Beacon, Probe Response, and Extended Channel Switch Announcement frame transmissions until the intended channel switch time. The New Channel Number field of the Extended Channel Switch Announcement element represents the new channel (when the BSS after relocation/width change is(M118) a 20 MHz BSS) or the primary channel of the new pair of channels (when the BSS after relocation/width change is(M118) a 20/40 MHz BSS). When changing to a new pair of channels, the New Operating Class field specifies the position of the secondary channel relative to the new primary channel, i.e., either above or below.

When transmitting HT Operation elements, Channel Switch Announcement elements, and/or Extended Channel Switch Announcement elements, the AP moving the BSS or changing its channel width selects a combination of operating parameters from any single row of any one of the tables in Annex E that is appropriate for the current operating domain of the AP. Similarly, when transmitting HT Operation elements, Channel Switch Announcement elements, and/or Extended Channel Switch Announcement elements, the DO moving the BSS selects a combination of operating parameters from any single row of any one of the tables in Annex E that is appropriate for the current operating domain of the DO. The AP or DO selects one channel number from the (#4177)Channel set column of the selected row. The AP or DO includes the selected information in subsequently transmitted frames that contain any combination of the following four elements:

— HT Operation element

— Channel Switch Announcement element

— Extended Channel Switch Announcement element

— Secondary Channel Offset element

The AP or DO shall set the Secondary Channel Offset field of transmitted HT Operation elements and transmitted Secondary Channel Offset elements to SCA if the Behavior limits set column of the selected row contains the value PrimaryChannelLowerBehavior. The AP or DO shall set the Secondary Channel Offset field of transmitted HT Operation elements and transmitted Secondary Channel Offset elements to SCB if the Behavior limits set column of the selected row contains the value PrimaryChannelUpperBehavior. The AP or DO shall set the Secondary Channel Offset field of transmitted HT Operation elements and transmitted Secondary Channel Offset elements to SCN if the Behavior limits set column of the selected row contains neither the value PrimaryChannelLowerBehavior nor the value PrimaryChannelUpperBehavior.


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The AP or DO shall set the New Channel Number field of transmitted Channel Switch Announcement elements and Extended Channel Switch Announcement elements to the value of the selected channel from the selected row.

The AP or DO shall set the New Operating Class field of transmitted Extended Channel Switch Announcement elements to the value of the (#4177)Operating class column of the selected row.

Movement of a 20/40 MHz BSS from one channel pair to a different channel pair and changing between 20 MHz and 20/40 MHz operation should be scheduled so that all STAs in the BSS, including STAs in power save mode, have the opportunity to receive at least one Extended Channel Switch Announcement element or Channel Switch Announcement element before the switch.

When the Extended Channel Switch Announcement element and Extended Channel Switch Announcement frame are transmitted in bands where dot11SpectrumManagementRequired is true, the Channel Switch Announcement element and Channel Switch Announcement frame may also be transmitted. A STA that announces a channel switch using both the Extended Channel Switch Announcement element and the Channel Switch Announcement element shall set the New Channel Number field of both elements to the same value. An HT STA that receives a channel switch announcement through both the Extended Channel Switch Announcement element and the Channel Switch Announcement element ignores the received Channel Switch Announcement element; this is called a *superseded* Channel Switch Announcement element.

For 20 MHz operation when the new operating class signifies 40 MHz channel spacing, the 20 MHz channel is the primary channel of the 40 MHz channel.

### 11.15.4 40 MHz PPDU transmission restrictions

#### 11.15.4.1 Fields used to determine 40 MHz PPDU transmission restrictions

Several fields from various frames are used to convey information between STAs regarding the support for 40 MHz PPDU transmission and reception and regarding any current prohibition against the transmission and reception of 40 MHz PPDUs.

The rules defined in 11.15.4.2 (Infrastructure non-AP STA restrictions), 11.15.4.3 (AP restrictions), and 11.15.4.4 (Restrictions on non-AP STAs that are not infrastructure BSS members) describe the behavior that accompanies those fields.

The fields that are used to determine the status of the transmission and reception of 40 MHz PPDUs are as follows:

— The Supported Channel Width Set subfield of the HT Capabilities element
— The Secondary Channel Offset field of the HT Operation element
— The STA Channel Width field of the HT Operation element
— The Channel Width field of the Notify Channel Width frame
— The Extended Channel Switch Announcement element

The Supported Channel Width Set subfield is used to indicate whether the transmitting STA is capable of transmitting and receiving 40 MHz PPDUs.

NOTE—The Supported Channel Width Set subfield transmitted by an AP is constant for the lifetime of its BSS as it is a parameter of the MLME-START.request primitive.

In addition to the restrictions on transmission of 40 MHz mask PPDUs found in 11.15.4.1 (Fields used to determine 40 MHz PPDU transmission restrictions) to 11.15.4.4 (Restrictions on non-AP STAs that are not infrastructure BSS members), if a STA operating in the 2.4 GHz industrial, scientific, and medical (ISM) band

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has no means of determining the presence of non-IEEE-802.11 communication devices operating in the area, then the STA shall not transmit any 40 MHz mask PPDUs.

In addition to the restrictions on transmission of 40 MHz mask PPDUs found in 11.15.4.1 (Fields used to determine 40 MHz PPDU transmission restrictions) to 11.15.4.4 (Restrictions on non-AP STAs that are not infrastructure BSS members), if a STA operating in the 2.4 GHz ISM band has a means of determining the presence of non-IEEE-802.11 communication devices operating in the area and determines either that no non-IEEE-802.11 communication device is operating in the area or that non-IEEE-802.11 communication devices are operating in the area but the STA implements a coexistence mechanism for these non-IEEE-802.11 communication devices, then the STA may transmit 40 MHz mask PPDUs; otherwise, the STA shall not transmit any 40 MHz mask PPDUs.

#### 11.15.4.2 Infrastructure non-AP STA restrictions

A STA that is associated with an AP shall not transmit a value in the Supported Channel Width Set subfield that differs from a previously transmitted value during its current association.

The Secondary Channel Offset field is used to indicate whether the BSS is occupying a 40 MHz wide pair of channels and, when a secondary channel exists, whether it is above or below the primary channel in frequency. The Extended Channel Switch Announcement frame and the Extended Channel Switch Announcement element can each be used to indicate a transition from 20/40 MHz BSS operation to 20 MHz BSS operation and vice versa and to indicate whether a secondary channel, when it exists, is above or below the primary channel in frequency.

A 40MC HT STA shall maintain a MAC variable *40MHzOperatingClass* as described here. The initial value of *40MHzOperatingClass* shall be false. The value of *40MHzOperatingClass* is recomputed according to the rules in this subclause at every TBTT and following the reception of a frame transmitted by the AP associated with the STA when that frame contains either of the following fields:

— Current Operating Class field
— New Operating Class field

The MAC variable *40MHzOperatingClass* becomes true upon reception of a frame transmitted by the associated AP if the frame contained a Current Operating Class field with a value that corresponds to an operating class that corresponds to a channel spacing value of 40 MHz, as specified in Annex E.

The MAC variable *40MHzOperatingClass* becomes false upon reception of a frame transmitted by the associated AP if the frame contained a Current Operating Class field with a value that corresponds to an operating class that does not correspond to a channel spacing value of 40 MHz.

The MAC variable *40MHzOperatingClass* becomes true at the $n^{th}$ TBTT following reception of a frame transmitted by the associated AP that contains an Extended Channel Switch Announcement element with a value of *n* in the Channel Switch Count field and a value in the New Operating Class field that corresponds to an operating class that corresponds to a channel spacing value of 40 MHz provided that the frame is the most recently received frame meeting the above conditions.

The MAC variable *40MHzOperatingClass* becomes false at the $n^{th}$ TBTT following reception of a frame transmitted by the associated AP that contains an Extended Channel Switch Announcement element with a value of *n* in the Channel Switch Count field and a value in the New Operating Class field that corresponds to an operating class that does not correspond to a channel spacing value of 40 MHz provided that the frame is the most recently received frame meeting the above conditions.

A STA can choose to dynamically constrain its operating channel width to 20 MHz while being a member of a 20/40 MHz BSS. Transitions to and from this constrained state are indicated using the transmission of a


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frame that carries the Channel Width field. A Channel Width field value of 0 indicates that the transmitting STA is not currently able to receive 40 MHz PPDUs, beginning at the end of the transmission of the frame that contained the Channel Width field.

A STA shall not transmit a frame containing a STA Channel Width field or a Channel Width field set to 1 if the value of its Supported Channel Width Set subfield is 0.

A STA that is associated with an infrastructure BSS (STA1) shall not transmit a 40 MHz PPDU containing one or more frames addressed to another STA (STA2) unless the following three conditions are true:

— The Supported Channel Width Set subfield of the HT Capabilities element of both STAs is equal to 1.
— The Secondary Channel Offset field of the most recently received HT Operation element sent by the AP of the BSS has a value of SCA or SCB.
— The MAC variable *40MHzOperatingClass* is true.

If the above three conditions are met, STA1 should not transmit a 40 MHz PPDU containing one or more frames addressed to STA2 unless the following two conditions are true:

— Either STA1 has not received a Notify Channel Width frame that was transmitted by STA2, or the Channel Width field of the most recently received Notify Channel Width frame at STA1 that was transmitted by STA2 is nonzero.
— If STA2 is an AP, the STA Channel Width field of the most recently received HT Operation element that was transmitted by STA2 is equal to 1.

#### 11.15.4.3 AP restrictions

An AP shall not transmit a 40 MHz PPDU containing one or more frames addressed to another STA unless the following three conditions are true:

— The Supported Channel Width Set subfield of the HT Capabilities element of the AP and all associated STAs are not equal to 0.
— The Secondary Channel Offset field of the AP's most recently transmitted HT Operation element has a value of SCA or SCB.
— The MAC variable *40MHzOperatingClass* is true.

If the above three conditions are met, the AP should not transmit a 40 MHz PPDU containing frames addressed to another STA unless either the AP has not received a Notify Channel Width frame that was transmitted by the STA or the Channel Width field of the most recently received Notify Channel Width frame at the AP that was transmitted by the STA is nonzero.

An AP shall not transmit a 40 MHz PPDU containing one or more frames with a group address in the Address 1 field unless the following three conditions are true:

— The Supported Channel Width Set subfield of the HT Capabilities element of the AP is equal to 1.
— The Secondary Channel Offset field of the AP's most recently transmitted HT Operation element has a value of SCA or SCB.
— The MAC variable *40MHzOperatingClass* is true.

If the above three conditions are met, the AP should not transmit a 40 MHz PPDU containing one or more frames with a group address in the Address 1 field unless either the AP has not received a Notify Channel Width frame from any STA in the BSS or the Channel Width field of the most recently received Notify Channel Width frame from each STA that transmitted a Notify Channel Width frame is nonzero.

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#### 11.15.4.4 Restrictions on non-AP STAs that are not infrastructure BSS members

An HT STA 2G4 that is not a member of an infrastructure BSS shall not transmit a 40 MHz mask PPDU.

An HT STA 5G that is not associated with an infrastructure BSS (STA1) shall not transmit a 40 MHz PPDU containing frames addressed to another STA (STA2) unless the following three conditions are true:

— The Supported Channel Width Set subfield of the HT Capabilities element of both STAs is equal to 1.

— The Secondary Channel Offset field of the most recently received HT Operation element sent by STA2 has a value of SCA or SCB.

— The Secondary Channel Offset field of the most recently transmitted HT Operation element sent by STA1 has a value of SCA or SCB.

If the above three conditions are met, STA1 should not transmit a 40 MHz PPDU containing one or more frames addressed to STA2 unless STA1 has not received a STA Channel Width field that was transmitted by STA2 or the most recently received STA Channel Width field at STA1 that was transmitted by STA2 is nonzero.

An HT STA 5G that is not associated with an infrastructure BSS (STA1) shall not transmit a 40 MHz PPDU containing one or more frames with a group address in the Address 1 field unless the following two conditions are true:

— The Supported Channel Width Set subfield of the HT Capabilities element transmitted by STA1 is equal to 1.

— The Secondary Channel Offset field of the HT Operation element most recently transmitted by STA1 has a value of SCA or SCB.

If the above two conditions are met, STA1 should not transmit a 40 MHz PPDU containing one or more frames with a group address in the Address 1 field unless the most recently received STA Channel Width field for each other known member of the BSS of which STA1 is a member is equal to 1.

### 11.15.5 Scanning requirements for 40MC HT STA 2G4

An OBSS scan operation is a passive or active scan of a set of channels that are potentially affected by 20/40 MHz BSS operation, i.e., the 20 MHz channels that wholly or partly overlap the 40 MHz signal. Each channel in the set may be scanned more than once during a single OBSS scan operation. OBSS scans are performed by STAs that are 40MC HT STA 2G4. STAs that are 40MC HT STA 5G are not required to perform OBSS scan operations.

NOTE 1—STAs that perform OBSS scans report discovered BSSs and received 20/40 BSS coexistence information to their associated AP (see 11.15.12 (Switching between 40 MHz and 20 MHz)).

During an individual scan within an OBSS scan operation, the minimum per-channel scan duration is dot11OBSSScanPassiveDwell TU (when scanning passively) or dot11OBSSScanActiveDwell TU (when scanning actively). During an OBSS scan operation, each channel in the set is scanned at least once per dot11BSSWidthTriggerScanInterval seconds, and the minimum total scan time (i.e., the sum of the scan durations) per channel within a single OBSS scan operation is dot11OBSSScanPassiveTotalPerChannel TU for a passive scan and dot11OBSSScanActiveTotalPerChannel TU for an active scan.

NOTE 2—The values provided in the previous paragraph indicate the minimum requirements. For some combinations of parameter values, it is necessary to exceed the minimum values of some parameters in order to meet the minimum value constraints of all parameters.


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When an AP transmits an Overlapping BSS Scan Parameters element, the value of each of the fields of the element shall be set to the MIB attribute from the transmitting AP's MIB according to the mapping between the frame fields and MIB attributes as defined in 9.4.2.57 (Overlapping BSS Scan Parameters element).

Upon receipt of a frame containing an Overlapping BSS Scan Parameters element from the AP with which a 40MC HT STA 2G4 is associated, the MLME of the receiving 40MC HT STA 2G4 shall update each of the values of the MIB attributes used during OBSS scanning operations according to the mapping between the frame fields and MIB attributes as defined in 9.4.2.57 (Overlapping BSS Scan Parameters element).

A 40MC HT AP 2G4 may transmit frames containing an Overlapping BSS Scan Parameters element to any or all associated STAs in order to provide OBSS scan parameter values that are different from the default values.

A 40MC HT STA 2G4 that is associated with a 40MC HT AP 2G4 shall perform at least one OBSS scan every dot11BSSWidthTriggerScanInterval seconds, unless the 40MC HT STA 2G4 satisfies the conditions described in 11.15.6 (Exemption from OBSS scanning).

### 11.15.6 Exemption from OBSS scanning

A 40MC HT STA 2G4 shall maintain a MAC variable *ActivityFraction*. The value of *ActivityFraction* is defined by Equation (11-3).

$$ActivityFraction = \frac{T_{ACTIVE}}{T_{MEASURE\text{-}ACTIVE}} \tag{11-3}$$

where

$T_{ACTIVE}$ is the total duration of transmitted MSDUs and received individually addressed MSDUs during the previous $T_{MEASURE\text{-}ACTIVE}$ seconds

$T_{MEASURE\text{-}ACTIVE}$ is dot11BSSWidthChannelTransitionDelayFactor × dot11BSSWidthTriggerScanInterval seconds

A 40MC HT STA 2G4 may transmit to its associated AP a 20/40 BSS Coexistence Management frame with the Scanning Exemption Request field in the 20/40 BSS Coexistence element set to 1.

If the last 20/40 BSS Coexistence Management frame received by a 40MC HT STA 2G4 in an individually addressed frame from its associated AP has the Scanning Exemption Grant field equal to 1, the STA is exempted from scanning whenever the value of its MAC variable *ActivityFraction* is less than dot11OBSSScanActivityThreshold/10 000.

A 40MC HT AP 2G4 shall not transmit a 20/40 BSS Coexistence Management frame with the Scanning Exemption Grant field set to 1 addressed to a 40MC HT STA if the following condition is true:

— The 40MC HT STA has transmitted one or more channel report elements and is the only STA in the BSS that has indicated one or more channels on which a STA has found conditions that disallow the use of a 20/40 MHz BSS.

If there is more than one 40MC HT STA in the BSS that has indicated conditions that disallow the use of 20/40 MHz BSS on a specific channel, then the following apply:

— If all of the 40MC HT STAs that have indicated unavailability of a channel have also requested to be exempt from scanning, the AP shall disallow at least one of the 40MC HT STA to be exempt from scanning.

— If, from the group of 40MC HT STAs that have indicated unavailability of a channel, there is at least one 40MC HT STA that has not requested to be exempt from scanning, the AP may allow all of the STAs that have requested to be exempt from scanning to be exempted from scanning.

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### 11.15.7 Communicating 20/40 BSS coexistence information

In addition to the 20/40 BSS Coexistence Management frame, a STA can include the 20/40 BSS Coexistence element in transmitted Beacon, Probe Request, Probe Response, (Re)Association Request, and (Re)Association Response frames.

### 11.15.8 Support of DSSS/CCK in 40 MHz

Transmission and reception of PPDUs using DSSS/CCK by 40MC HT STAs is managed using the DSSS/CCK Mode in 40 MHz subfield of the HT Capability Information field in the HT Capabilities element (see 9.4.2.54.2 (HT Capability Information field)).

An HT STA declares its capability to use DSSS/CCK rates while it has a 40 MHz operating channel width through the DSSS/CCK Mode in 40 MHz subfield of its (Re)Association Request frames.

If the DSSS/CCK Mode in 40 MHz subfield is equal to 1 in Beacon and Probe Response frames, an associated HT STA in a 20/40 MHz BSS may generate DSSS/CCK transmissions. If the subfield is equal to 0, then the following apply:

— An associated HT STA shall not generate DSSS/CCK transmissions.

— The AP shall not include an ERP element in its Beacon and Probe Response frames.

— The AP shall not include DSSS/CCK rates in the Supported Rates and BSS Membership Selectors element or Extended Supported Rates and BSS Membership Selectors element.

— The AP shall refuse association requests from a STA that includes only DSSS/CCK rates in its Supported Rates and BSS Membership Selectors element and Extended Supported Rates and BSS Membership Selectors element.

— The DSSS/CCK Mode in 40 MHz subfield transmitted by a (re)associating STA is ignored.

A STA not operating in the 2.4 GHz band shall set the DSSS/CCK Mode in 40 MHz subfield to 0.

### 11.15.9 STA CCA sensing in a 20/40 MHz BSS

This subclause defines CCA sensing rules for an HT STA that is not a VHT STA. For rules related to a VHT STA, see 10.3.2.7 (VHT and S1G RTS procedure), 10.23.2.7 (Sharing an EDCA TXOP), and 10.23.3 (HCF controlled channel access (HCCA)).

A STA may transmit a 20 MHz mask PPDU in the primary channel following the rules in 10.23.2 (HCF contention based channel access (EDCA)).

A STA transmitting a 40 MHz mask PPDU that begins a TXOP using EDCA as described in 10.23.2.4 (Obtaining an EDCA TXOP) or that is using a PIFS as permitted in 10.3.2.3.4 (PIFS) shall sense CCA on both the 20 MHz primary channel and the 20 MHz secondary channel before the 40 MHz mask PPDU transmission starts.

Unless explicitly stated otherwise, a STA may treat a PHY-CCA.indication(BUSY) primitive as a PHY-CCA.indication(IDLE) primitive in the following cases:

— If the channel-list parameter is present and equal to {secondary} and the STA is transmitting a 20 MHz mask PPDU on the primary channel, or

— If the channel-list parameter is present and equal to {primary} and the STA is transmitting a 20 MHz mask PPDU on the secondary channel.

NOTE 1—Transmission of PPDUs on the secondary channel is also subject to constraints in 11.15.2 (Basic 20/40 MHz BSS functionality).


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At the specific slot boundaries (see Figure 10-29 (EDCA mechanism timing relationships(#14)(#1058))) determined by the STA based on the 20 MHz primary channel CCA, when the transmission begins a TXOP using EDCA (as described in 10.23.2.4 (Obtaining an EDCA TXOP)), the STA may transmit a pending 40 MHz mask PPDU only if the secondary channel has also been idle during the times the primary channel CCA is performed (defined in 10.23.2.4 (Obtaining an EDCA TXOP)) during an interval of a PIFS for the 5 GHz band and DIFS for the 2.4 GHz band immediately preceding the expiration of the backoff counter. If a STA was unable to transmit a 40 MHz mask PPDU because the secondary channel was occupied during this interval, it may take one of the following steps:

a) Transmit a 20 MHz mask PPDU on the primary channel.

b) Restart the channel access attempt. In this case, the STA shall invoke the backoff procedure as specified in 10.23.2 (HCF contention based channel access (EDCA)) as though the medium is busy as indicated by either physical or virtual CS and the backoff counter has a value of 0.

NOTE 2—As a result of this rule, the STA selects a new random number using the current value of CW[AC], and the retry counts are not updated.

When a TXOP is obtained for a 40 MHz PPDU, the STA may transmit 40 MHz PPDUs and/or 20 MHz PPDUs during the TXOP. When the TXOP is obtained by the exchange of 20 MHz PPDUs only in the primary channel, the STA shall not transmit 40 MHz PPDUs during the TXOP.

### 11.15.10 NAV assertion in 20/40 MHz BSS

An HT STA shall update its NAV using the Duration/ID field value in any frame received in a 20 MHz PPDU in the primary channel or received in a 40 MHz PPDU and that does not have an RA matching the STA's MAC address.

NOTE—A STA need not set its NAV in response to 20 MHz frames received on the secondary channel or any other channel that is not the primary channel, even if it is capable of receiving those frames.

### 11.15.11 Signaling 40 MHz intolerance

An HT STA 2G4 shall set the Forty MHz Intolerant field to 1 in transmitted HT Capabilities elements if dot11FortyMHzIntolerant is true; otherwise, the field shall be set to 0.

A STA 2G4 shall set the Forty MHz Intolerant field to 1 in transmitted 20/40 BSS Coexistence fields if dot11FortyMHzIntolerant is true; otherwise, the field shall be set to 0. A STA 2G4 that is not an HT STA 2G4 shall include a 20/40 BSS Coexistence element in Management frames in which the element may be present if dot11FortyMHzIntolerant is present and dot11FortyMHzIntolerant is true.

A STA 5G shall set the Forty MHz Intolerant field to 0 in transmitted HT Capabilities elements and 20/40 BSS Coexistence fields.

### 11.15.12 Switching between 40 MHz and 20 MHz

A VHT STA is not required to perform any of the behavior described in this subclause associated with Information Request and 20 MHz BSS Width Request.

The following events are defined to be BSS channel width trigger events (TEs):

— **TE-A**: On any of the channels of the channel set defined in Clause 18 (Extended Rate PHY (ERP) specification), reception of a Beacon frame that does not contain an HT Capabilities element.

— **TE-B**: On any of the channels of the channel set defined in Clause 18 (Extended Rate PHY (ERP) specification), reception of a 20/40 BSS Coexistence Management, Beacon, Probe Request, or Probe Response frame that contains a value of 1 in a Forty MHz Intolerant field and that has the

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Address 1 field equal to the receiving STA's address or to a group address(#3522), with no further addressing qualifications.

— **TE-C**: Reception of a 20/40 BSS Coexistence Management frame with the 20 MHz BSS Width Request field equal to 1 and with an Address 1 field that matches the receiving STA using either individual or group addressing and with a TA field that corresponds to the MAC address of a STA with which the receiver is associated.

— **TE-D**: Reception of a 20/40 BSS Coexistence Management frame containing at least one 20/40 BSS Intolerant Channel Report element with a nonzero length and with an Address 1 field equal to the receiving STA's address or to a group address(#3522), but with no qualification of the Address 3 field.

A 40MC HT AP 2G4 shall reevaluate the value of the MAC variable *20/40 Operation Permitted* (see 11.15.3.2 (Scanning requirements for a 20/40 MHz BSS)) when either of the following events occurs:

— A BSS channel width trigger event TE-A is detected.

— A BSS channel width trigger event TE-D is detected.

A 40MC HT AP 2G4 may reevaluate the value of the MAC variable *20/40 Operation Permitted* (see 11.15.3.2 (Scanning requirements for a 20/40 MHz BSS)) when either of the following situations occurs:

— No BSS channel width trigger events TE-A are detected for a period of time equal to dot11BSSWidthChannelTransitionDelayFactor × dot11BSSWidthTriggerScanInterval seconds.

— No BSS channel width trigger events TE-D are detected for a period of time equal to dot11BSSWidthChannelTransitionDelayFactor × dot11BSSWidthTriggerScanInterval seconds.

A 40MC HT AP 2G4 that detects either BSS channel width trigger event TE-B or TE-C or that determines that the value of the MAC variable *20/40 Operation Permitted* has changed from true to false shall set the Secondary Channel Offset field to SCN in transmitted HT Operation elements beginning at the next DTIM (#8164)beacon or next TBTT if no DTIM beacons(#4221) are transmitted to indicate that no secondary channel is present (i.e., that the BSS operating width is 20 MHz).

A 40MC HT AP 2G4 shall not set the Secondary Channel Offset field to a value of SCA or SCB in transmitted HT Operation elements unless the following two conditions have been met:

— A period of dot11BSSWidthChannelTransitionDelayFactor × dot11BSSWidthTriggerScanInterval seconds have elapsed during which no BSS channel width trigger events TE-B or TE-C are detected.

— The value of the MAC variable *20/40 Operation Permitted* (see 11.15.3.2 (Scanning requirements for a 20/40 MHz BSS)) is true.

To request an update of the status of the 20 MHz BSS Width Request field, a 40MC HT AP 2G4 can transmit a 20/40 BSS Coexistence Management frame with a value of 1 in the Information Request field as described in 11.16 (20/40 BSS Coexistence Management frame usage).

A 40MC HT STA 2G4 that is associated with a 40MC HT AP 2G4 shall maintain a record of detected BSS channel width trigger events as follows:

— For each detected BSS channel width trigger event TE-A:

  — If a DSSS Parameter Set field is present in the received Beacon frame, the channel of the BSS channel width trigger event is set to the value of the Current Channel field of the DSSS Parameter Set field; otherwise, the channel of the BSS channel width trigger event is the channel on which the detecting STA received the Beacon frame.

  — If a Supported Operating Classes element is present in the received Beacon frame, the operating class of the BSS channel width trigger event is(#3181) the value of the Current Operating Class field of the Supported Operating Classes element of the received Beacon frame; otherwise, the operating class of the BSS channel width trigger event is "unknown."


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- For each detected BSS channel width trigger event TE-A of a unique combination of operating class and channel, the 40MC HT STA 2G4 shall maintain a record containing two MAC variables:
  - The operating class of the BSS channel width trigger event
  - The channel of the BSS channel width trigger event

NOTE—If a BSS channel width trigger event TE-A is detected for an operating class and channel combination for which no record exists, the STA creates such a record.

If a BSS channel width trigger event TE-A is detected for an operating class and channel combination for which a record already exists, the information in that record shall be updated with the information determined from the new trigger event.

For all BSS channel width trigger events TE-B, the 40MC HT STA 2G4 shall maintain a single record containing an indication of whether one or more trigger events TE-B have been detected.

At the completion of an OBSS scan operation (i.e., at the end of the period of time equal to dot11BSSWidthTriggerScanInterval) or when it receives a 20/40 BSS Coexistence Management frame from its associated AP that contains a value of 1 in the Information Request field, a 40MC HT STA 2G4 that is associated with a 40MC HT AP 2G4 shall create a 20/40 BSS Coexistence Management frame by including a value of 0 for all fields of a 20/40 BSS Coexistence Management frame and then transferring information from the BSS channel width trigger event TE-A and TE-B records to the frame according to the following four steps:

- For each unique operating class that is stored in the set of BSS channel width trigger event TE-A records, the STA shall create a 20/40 BSS Intolerant Channel Report element for inclusion in the frame and include all of the unique channels associated with the operating class in the channel list of that element.
- The STA sets the Forty MHz Intolerant field of the 20/40 BSS Coexistence element per the rules listed in 11.15.11 (Signaling 40 MHz intolerance).
- The STA shall set to 1 the 20 MHz BSS Width Request field of the 20/40 BSS Coexistence element for inclusion in the frame if a record for BSS channel width trigger event TE-B exists and indicates that at least one trigger event TE-B has been detected.
- The STA may set to 1 the Information Request field.

Upon completion of these four steps, the 40MC HT STA 2G4 shall delete all records for trigger events TE-A and TE-B. Subsequently detected trigger events cause the creation of new records as necessary to be used in subsequently generated 20/40 BSS Coexistence Management frames. Following the record deletion, the 40MC HT STA 2G4 shall transmit to its associated 40MC HT AP 2G4 the 20/40 BSS Coexistence Management frame if any of the following conditions is true:

- At least one 20/40 BSS Intolerant Channel Report element with the Length field not equal to 0 is included.
- The Forty MHz Intolerant field is equal to 1.
- The 20 MHz BSS Width Request field is equal to 1.
- The Information Request field is equal to 1.
- The frame was created in response to an Information Request field that was equal to 1.

## 11.16 20/40 BSS Coexistence Management frame usage

A STA that supports the 20/40 BSS Coexistence Management frame type shall set the 20/40 BSS Coexistence Management Support field to 1 in transmitted Extended Capabilities elements.

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A STA that supports the 20/40 BSS Coexistence Management frame type shall include an Extended Capabilities element in transmitted Beacon, (Re)Association Request, (Re)Association Response, Probe Request, and Probe Response frames.

A STA shall not transmit to another STA a 20/40 BSS Coexistence Management frame with an individual address in the Address 1 field if the Extended Capabilities element from the recipient STA contained a value of 0 in the 20/40 BSS Coexistence Management Support field. A STA that transmits a 20/40 BSS Coexistence Management frame may set the Address 1 field to a group address.

NOTE—A 20/40 BSS Coexistence Management frame is a Class 1 frame and, therefore, can be sent to a STA that supports reception of such frames and that is not a member of the same BSS as the transmitting STA. In such a case, the BSSID field of the frame is set to the wildcard BSSID(#3522), regardless of whether the Address 1 field contains an individual or group address value.

A STA may transmit a 20/40 BSS Coexistence Management frame that contains a value of 1 for the Request Information field to another STA that supports the transmission of and reception of the 20/40 BSS Coexistence Management frame, except when the frame is a response to a 20/40 BSS Coexistence Management frame that contains a value of 1 for the Request Information field.

A non-VHT STA that receives a 20/40 BSS Coexistence element with the Information Request field equal to 1, an Address 1 field that matches the receiving STA using an individual address, and a nonwildcard BSSID field that matches the STA's BSS shall immediately queue for transmission a 20/40 BSS Coexistence Management frame with the transmitting STA as the recipient.

## 11.17 Public Action frame addressing

A STA that is a member of a BSS and that transmits an individually addressed Public Action frame to a STA that is not a member of the same BSS shall set the BSSID field of the frame as follows:

— If the recipient STA is known to be a member of another BSS (including being an AP) and that BSS's BSSID is known, the BSSID field shall be set to the BSS's BSSID or the wildcard BSSID(#3522).

— Otherwise, the BSSID field of the frame shall be set to the wildcard BSSID(#3522).

A STA that is a member of a BSS and that transmits a group addressed Public Action frame shall set the BSSID field of the frame to the BSS's BSSID or the wildcard BSSID(#3522).

A STA that is a member of a BSS and that transmits an individually addressed Public Action frame to a STA that is a member of the same BSS shall set the BSSID field of the frame to the BSS's BSSID.

A STA that is not a member of a BSS and that transmits a Public Action frame shall set the BSSID field of the frame as follows:

— If the frame is individually addressed, the recipient STA is known to be a member of a BSS (including being an AP), and that BSS's BSSID is known, the BSSID field shall be set to the BSS's BSSID or the wildcard BSSID(#3522).

— Otherwise, the BSSID field of the frame shall be set to the wildcard BSSID(#3522).

(11bc)If a STA is transmitting an EBCS UL frame, the Address 3 field is set to the EBCS content MAC address (see 34.4 (EBCS UL procedure) and 34.2 (EBCS addressing)). If a STA is transmitting an EBCS Info frame, the Address 3 field is set to the EBCS info MAC address (see 34.3 (EBCS DL procedures) and 34.2 (EBCS addressing)).


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## 11.18 STAs communicating Data frames outside the context of a BSS

When dot11OCBActivated is true in a STA:

a) Synchronization, authentication, association, and frame classes as defined in 11.1 (Synchronization) and 11.3 (STA authentication and association) are not used. Data confidentiality as defined in Clause 12 (Security) is not used. The STA may send Action frames and, if the STA maintains a TSF Timer, Timing Advertisement frames.

b) The STA may send Control frames, except those of subtype PS-Poll and CF-End. (11bd)If the STA is a DMG STA for which dot11DMGOCBActivated is true, in addition to not sending Control frames of subtype PS-Poll and CF-End, the STA shall not send Control frames of subtype Poll, SPR, Grant, Grant Ack, Sector Ack, Block Ack Schedule, and TDD Beamforming.

c) The STA may send Data frames of subtype Data, Null, QoS Data, and QoS Null.

d) The STA shall set the BSSID field in all Management and Data frames to the wildcard BSSID(#3522).

e) If the STA is a DMG STA for which dot11DMGOCBActivated is true, the STA may send DMG Beacon frames. A STA sending DMG Beacon frames shall set the Discovery Mode field to 1, and set the CBAP Only and CBAP Source subfields in the DMG Parameters field to 1 and 0, respectively.(11bd)

A STA with dot11OCBActivated equal to true shall not join or start a BSS.

Whenever MAC sublayer and PHY parameters are changed in a STA in which dot11OCBActivated is true, MAC sublayer and PHY operation shall resume with the appropriate MIB attributes in less than 2 TU.

## 11.19 Timing advertisement

### 11.19.1 Introduction

A STA may advertise a time standard by transmitting a Timing Advertisement element in one of the following frames: Timing Advertisement, Probe Response, Beacon, DMG Beacon or Announce. As defined in 9.4.2.59 (Time Advertisement element) the Time Advertisement element contains two estimates. The Time Value field contains an estimate of the difference between a time standard and the timestamp included in the same frame. (#1114)The SME shall use the (#6099)MLME-GETTSFTIME.request primitive to obtain the current value of the TSF timer. The Time Error field contains an estimate of the standard deviation of the error in the estimate in the Time Value field. The time standard might be derived from an external time source. A STA with an external time source might implement an estimator in a variety of ways, which are beyond the scope of this standard.

### 11.19.2 Timing advertisement frame procedures

The SME provides the Time Advertisement element to the MLME when it requests the MLME to send a Timing Advertisement frame. When a Timing Advertisement frame is received by a STA, its MLME reports the Timestamp, Local Time, Time Advertisement element, and estimates of propagation delay to the SME. For a STA that maintains a TSF Timer and receives a Timing Advertisement frame, Local Time is the value of the STA's TSF timer at the start of reception of the first octet of the Timestamp field of the frame. Otherwise, the Local Time is unspecified. The receiving STA's SME might use the Timestamp, Local Time, and Time Advertisement element to align its estimate of the time standard to the transmitting STA's estimate of the corresponding time standard.

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### 11.19.3 UTC TSF Offset procedures

When dot11UTCTSFOffsetActivated is true, the Time Advertisement and Time Zone elements shall be included in all Probe Response frames, (11ay)the Time Advertisement element shall be included in the Beacon frame every dot11TimeAdvertisementDTIMInterval DTIM intervals(#4221)(11ay), and the Time Advertisement element shall be included in the DMG Beacon frame or in the Announce frame at least every dot11DMGTimeAdvertisementBeaconInterval. When dot11UTCTSFOffsetActivated is false, the Time Advertisement and Time Zone elements shall not be included in Beacon(11ay), Probe Response, and Announce frames.

The AP should periodically synchronize to a UTC reference clock (ITU-R Recommendation TF.460-6 (2002) [B61]) so that the UTC TSF offset can account for drift. The AP shall increment the Time Update Counter field value in the Time Advertisement element each time the synchronization occurs. The method the AP uses to synchronize with a UTC reference clock is out of scope of the standard.

## 11.20 Tunneled direct link setup(#1356)

### 11.20.1 General

Tunneled direct link(#1356) setup (TDLS) is characterized by encapsulating setup frames in Data frames, which allows them to be transmitted through an AP transparently. Therefore, the AP does not need to be (#194)direct link(#1356) capable, nor does it have to support the same set of capabilities that are used on the (#2152)TDLS direct link between the two TDLS peer STAs. TDLS also includes power saving, in the form of TDLS peer PSM (scheduled) and TPU (unscheduled). STAs that set up a TDLS direct link remain associated with their BSS, but have the option of transmitting frames directly to the other TDLS peer STA.

(#237)Transmitting a TDLS frame through the AP means that the frame's RA is set to the BSSID. Transmitting a frame (whether a TDLS frame or another frame) over the direct path means that the frame's RA is set to the MAC address of the TDLS peer STA. An A-MSDU transmitted over the direct path shall not contain an A-MSDU subframe header with a DA field that is a group address.(#250)

NOTE 1—This implies that the RA of frames transmitted over the direct path cannot be a group address.(#195)

To set up and maintain a (#2152)TDLS direct link, both TDLS peer STAs shall be associated with the same infrastructure BSS.

A DMG STA shall not use the TDLS protocol.

A TDLS peer STA may be involved in direct links with multiple TDLS peer STAs at the same time.

The primary channel on which the AP operates is referred to as the base channel and a TDLS STA that operates on this channel is referred to as on the base channel. If the direct link is switched to a channel that is not the base channel, then this channel is referred to as the off-channel, and a TDLS STA that operates on this channel is referred to as off-channel.

Features that are supported by both TDLS peer STAs may be used on a TDLS direct link between those STAs regardless of whether they are supported by the BSS.(11ax) An example is the use of an HT-MCS on a TDLS direct link between HT STAs when these STAs are associated with a non-HT BSS. Features that are supported by the BSS shall follow the BSS rules when they are used on a TDLS direct link on the base channel. The channel width of a TDLS direct link on the base channel shall not exceed the channel width of the BSS of which the TDLS peer STAs are members, except when the TDLS Wider Bandwidth subfield in the Extended Capabilities element of the TDLS Setup Request frame or the TDLS Setup Response frame is 1 for both TDLS peer STAs.


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A VHT STA with a (#2152)TDLS direct link that is not an (#2152)off-channel TDLS direct link shall use as its primary channel the primary channel or the only channel of its BSS. The channel width of a VHT (#2152)TDLS direct link shall not be wider than the maximum channel width supported by either the TDLS initiator STA or the TDLS responder STA.

A 160 MHz bandwidth is defined to be identical to an 80+80 MHz bandwidth (i.e., one bandwidth is not wider than the other).

A STA shall not participate in a TDLS direct link with the same primary 80 MHz channel as the infrastructure BSS or another TDLS direct link of the STA but with a different secondary 80 MHz channel.

(#111)When admission control is required for an AC on the base channel, in order to use this AC for direct link(#1356) transmissions on the base channel, the TDLS peer STA is responsible for setting up a TS with Direction of Direct Link with the AP, as defined in 10.23.4.2 (Contention based admission control procedures).

An S1G STA with a (#2152)TDLS direct link that is not an (#2152)off-channel TDLS direct link shall use as its primary channel the channel indicated by the Primary Channel Number field in the S1G Operation element. The channel width of an S1G (#2152)TDLS direct link shall not be wider than the maximum channel width supported by either the TDLS initiator STA or the TDLS responder STA.

A non-AP STA may act as TDLS initiator STA or TDLS responder STA when dot11TunneledDirectLinkSetupImplemented is true.

(#1399)TDLS payloads (which are transmitted in one or more TDLS frames) shall use the formatting as specified in 11.20.2 (TDLS payload) when they are transmitted through the AP and when they are transmitted over the TDLS direct link. A STA shall not transmit a TDLS Action field in a frame with the Type field of the frame set to Management.(#4255)

(#3201)NOTE 2—The TDLS Discovery Response frame is not a TDLS payload (in one or more TDLS frames) but a Public Action frame.(#1399)

TDLS shall not be used in an IBSS.

TDLS shall not be used in an MBSS.

Security is available on the TDLS direct link only when both TDLS peer STAs have an RSNA with the BSS.

TDLS shall not be used when the TDLS Prohibited subfield included in the Extended Capabilities element of the Association Response frame or Reassociation Response frame that led to the current association is equal to 1.

The HT Operation element shall be present in a TDLS Setup Confirm frame when both STAs are HT capable.

The VHT Operation element shall be present in a TDLS Setup Confirm frame when both STAs are VHT capable and the TDLS direct link is not established in the 2.4 GHz band. When the TDLS Setup Confirm frame includes a VHT Operation element, the Basic VHT-MCS And NSS Set field is reserved.

The HE Operation element shall be present in a TDLS Setup Confirm frame when both STAs are HE capable.(11ax)

The S1G Operation element shall be present in a TDLS Setup Confirm frame for S1G STA.

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(#1114)Figure 11-37 (TDLS direct link establishment(#1356)(#1114)(#3295)(#3584)) depicts the TDLS direct-link establishment process. The figure is an example of only the basic procedure and is not meant to be exhaustive of all possible uses of the protocol.

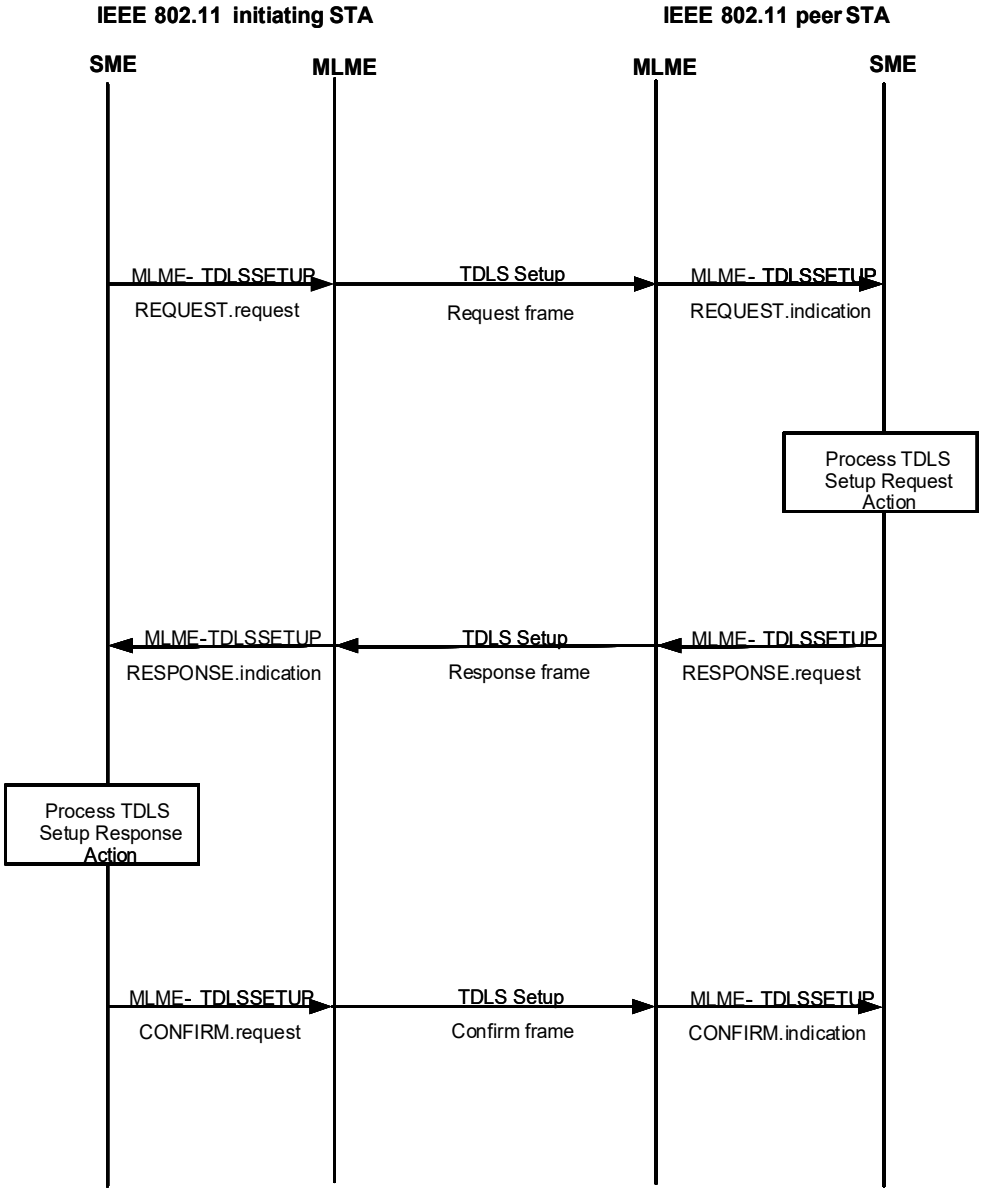


**Figure 11-37—TDLS direct link establishment(#1356)(#1114)(#3295)(#3584)**

### 11.20.2 TDLS payload

(#196)(#3370)TDLS uses MSDUs with (#2186)EtherType 89-0d, as defined in Annex H, for TDLS signaling. The Payload field of the MSDUs contains one of the TDLS Action fields specified in 9.6.12 (TDLS Action field formats) followed by zero or more Vendor Specific elements.(#1680)


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### 11.20.3 TDLS discovery(#197)

To discover TDLS STAs in the same BSS, a TDLS initiator STA may send a TDLS Discovery Request frame to an individual DA, through the AP. The TDLS responder STA Address field contained in the Link Identifier element of the TDLS Discovery Request frame shall be set to the (#1035)DA of the TDLS Discovery Request frame. A TDLS STA that receives a TDLS Discovery Request frame with a matching BSSID in the Link Identifier element shall send a TDLS Discovery Response frame to the requesting STA, via the direct path. The

TDLS responder STA Address field contained in the Link Identifier element of the TDLS Discovery Response frame shall be set to the MAC address of the STA sending the TDLS Discovery Response frame.(#1712)

A TDLS STA may send an individually addressed TDLS Discovery Response frame via the direct path without prior reception of a TDLS Discovery Request frame. A TDLS STA that receives such an unsolicited TDLS Discovery Response frame may respond with an individually addressed TDLS Discovery Response frame. (#1749)The Dialog Token field of the unsolicited TDLS Discovery Response frame may set to any value. (#1750)The Link Identifier field shall be populated as specified for the TDLS Discovery Request frame.

NOTE—The first STA might then proceed with TDLS direct link(#2154) establishment on reception of the TDLS Discovery Response frame from the second STA.(#1748)

A TDLS Discovery Request frame shall not be sent to a group address. A TDLS Discovery Response frame shall not be sent to a group address.

A TDLS STA may also send a TDLS Setup Request frame to a STA in the same BSS to discover whether the peer STA is a TDLS STA. A TDLS Setup Response frame transmitted in response to a(#375) TDLS Setup Request frame indicates that the peer STA sending the TDLS Setup Response frame is a TDLS STA.

(#1751)A TDLS Discovery Response frame that is a response to a TDLS Discovery Request frame or to an unsolicited TDLS Discovery Response frame is transmitted (i.e., not via the AP) to the TDLS peer STA that sent the corresponding TDLS Discovery Request frame or unsolicited TDLS Discovery Response frame.

An alternative mechanism to discover TDLS STAs in the same BSS, is provided by the TDLS Capability ANQP-element, as described in 11.22.3.3.10 (TDLS Capability procedure). This mechanism allows the ANQP request/response frames to use the direct path between the peer STAs.

### 11.20.4 TDLS direct link establishment(#1356)

To establish a TDLS direct link, the TDLS initiator STA shall send a TDLS Setup Request frame to the intended TDLS responder STA.

TDLS Setup Request frames, TDLS Setup Response frames, and TDLS Setup Confirm frames shall be transmitted through the AP and shall not be transmitted to a group address.

Upon receipt of a TDLS Setup Request frame, the following options exist at the TDLS responder STA:

a) The TDLS responder STA accepts the TDLS Setup Request frame, in which case the TDLS responder STA shall respond with a TDLS Setup Response frame with status code SUCCESS.

b) The TDLS responder STA declines the TDLS Setup Request frame, in which case the TDLS responder STA shall respond with a TDLS Setup Response frame with status code REQUEST_DECLINED. A TDLS setup request shall be declined when the BSSID in the received Link Identifier does not match the BSSID of the BSS of which the TDLS responder STA is a member.

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c) The TDLS Setup Request frame is received after sending a TDLS Setup Request frame and before receiving the corresponding TDLS Setup Response frame, and the source address of the received TDLS Setup Request frame is higher than its own MAC address, in which case the TDLS responder STA shall discard the frame and the TDLS responder STA shall send no TDLS Setup Response frame.

d) The TDLS Setup Request frame is received after sending a TDLS Setup Request frame and before receiving the corresponding TDLS Setup Response frame, and the source address of the received TDLS Setup Request frame is lower than its own MAC address. In this case, the TDLS responder STA shall terminate the TDLS setup it initiated. The TDLS responder STA shall send a response according to item a) or item b) above in this case.

e) If a TDLS Setup Request frame is received from a TDLS responder STA with which a currently active TDLS session exists, then the receiving STA shall tear down the existing TDLS direct link as if a TDLS Teardown frame was received, and respond with a TDLS Setup Response frame.

If no TDLS Setup Response frame is received within dot11TDLSResponseTimeout, or if a TDLS Setup Response frame is received with a status code not equal to SUCCESS, the TDLS initiator STA shall terminate the setup procedure and discard the TDLS Setup Response frame. Otherwise, the TDLS initiator STA shall send a TDLS Setup Confirm frame to the TDLS responder STA to confirm the receipt of the TDLS Setup Response frame.

When the BSS does not support EDCA, EDCA may be used on the (#2152)TDLS direct link (on the base channel and on the off-channel), with the default EDCA Parameter Set, per 10.2.3.2 (HCF contention based channel access (EDCA)).

If security is required on the TDLS direct link (see 12.7.8.1 (General)), then the TPK handshake messages are included in the TDLS Setup frames, as follows:

— TPK handshake message 1 shall be included in the TDLS Setup Request frame.
— TPK handshake message 2 shall be included in the TDLS Setup Response frame.
— TPK handshake message 3 shall be included in the TDLS Setup Confirm frame.

When the TDLS setup handshake has been completed, the TDLS initiator STA and the TDLS responder STA are TDLS peer STAs. A TDLS peer STA shall accept Data frames received from the respective TDLS peer STA directly and Data frames destined for the respective TDLS peer STA may be transmitted over the (#2152)TDLS direct link.

(#201)Subsequent to the successful completion of the TPK handshake, all Data frames transmitted on the TDLS direct link, and all Management frames if management frame protection was negotiated(#7049), shall be protected using the TPKSA, per the procedures defined in Clause 12 (Security).

To avoid possible reordering of MSDUs, a TDLS initiator STA shall cease transmitting MSDUs to the TDLS responder STA through the AP after sending a TDLS Setup Request frame, and a TDLS responder STA shall cease transmitting MSDUs to the TDLS initiator STA through the AP after sending a TDLS Setup Response frame indicating status code SUCCESS.

The TDLS Setup Request frame and the TDLS Setup Response frame shall be transmitted using the lowest AC that was used for transmitting MSDUs to the respective TDLS peer STA during the previous dot11TDLSACDeterminationInterval seconds, or at AC_BK. When no MSDUs were transmitted during the previous dot11TDLSACDeterminationInterval seconds, then the TDLS Setup Request frame and the TDLS Setup Response frame may be sent at any AC, subject to applicable Admission Control rules.


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If no TDLS Setup Response frame is received within dot11TDLSResponseTimeout, or if a TDLS Setup Response frame is received with status code other than SUCCESS, the TDLS initiator STA may resume transmitting MSDUs to the TDLS responder STA through the AP.

If a TDLS Setup Confirm frame is transmitted with a status code other than SUCCESS, the TDLS initiator STA may resume transmitting MSDUs to the TDLS responder STA through the AP.

If a TDLS Setup Confirm frame is received with a status code other than SUCCESS, the TDLS responder STA may resume transmitting MSDUs to the TDLS initiator STA through the AP.

A TDLS peer STA shall not transmit MSDUs over the direct link before transmitting or receiving a TDLS Setup Confirm frame with status code SUCCESS.

### 11.20.5 TDLS direct link teardown(#1356)

To tear down a (#2152)TDLS direct link, a TDLS peer STA shall send a TDLS Teardown frame to the respective TDLS peer STA. A TDLS peer STA shall disable the (#2152)TDLS direct link and delete the related security parameters after successfully transmitting TDLS Teardown frame. If security is required on the TDLS direct link (see 12.7.8.1 (General)), then the FTE shall be included in the TDLS Teardown frame.

The TDLS Teardown frame shall be sent over the direct path and the reason code shall be set to(#1692) TDLS_TEARDOWN_UNSPECIFIED_REASON except when the TDLS peer STA is unreachable via the TDLS direct link, (#274)in which case the TDLS Teardown frame shall be sent through the AP and the reason code shall be set to (#1692)TDLS_TEARDOWN_PEER_UNREACHABLE. If the (#2152)TDLS direct link is on an off-channel when this condition occurs, then the TDLS peer STA may switch back to the base channel without initiating a channel switch frame exchange, before transmitting the TDLS Teardown frame.

If present, the contents of the FTE in the TDLS Teardown frame shall be the same as that included in the TPK handshake message 3 with the exception of the MIC field. The MIC shall be calculated on the concatenation, in the following order, of:

— Link Identifier element
— Reason Code
— Dialog token that was used in the MIC calculation for TPK handshake message 3
— Transaction Sequence number (1 octet) which shall be set to the value 4
— FTE, with the MIC field of the FTE set to 0

The MIC shall be calculated using the TPK-KCK and the AES-128-CMAC algorithm. The output of the AES-128-CMAC shall be 128 bits.

If the TPK handshake was successful for this TDLS session, then a receiving STA shall validate the MIC in the TDLS Teardown frame prior to processing the TDLS Teardown frame; a TDLS Teardown frame in which the MIC validation fails is called an *invalid* TDLS Teardown frame. A TDLS peer STA that receives a TDLS Teardown frame that is not an invalid TDLS Teardown frame shall disable the (#2152)TDLS direct link and delete the related security parameters.

When a TDLS direct link gets torn down, any related TSs shall be deleted by the TDLS peer STAs.

A TDLS Teardown frame with Reason Code LEAVING_NETWORK_DEAUTH shall be transmitted to all TDLS peer STAs (via the AP or via the direct path) prior to reassociation with a different AP, deauthentication, disassociation, or association. After receiving a Deauthentication frame or a Disassociation frame from the AP, a Deauthentication frame with Reason Code LEAVING_NETWORK_DEAUTH shall be transmitted via the

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direct path to all TDLS peer STAs that are in the awake state, if management frame protection has not been negotiated on the TDLS direct link.

### 11.20.6 TDLS channel switching

#### 11.20.6.1 General

A STA that supports TDLS channel switching has dot11TDLSChannelSwitchingActivated equal to true and shall set dot11MultiDomainCapabilityActivated and dot11ExtendedChannelSwitchActivated to true. When TDLS channel switching is enabled, the STA may set TDLS Channel Switching subfield to 1. The STA shall include a Supported Channels element and a Supported Operating Classes element in all TDLS Setup Request and TDLS Setup Response frames that have a TDLS Channel Switching subfield equal to 1. (#3510)The Supported Channels element shall indicate the channels supported for the current operating class. The STA shall include only channels in the Supported Channels element for which it can adhere to the local power constraint. A channel switch shall not be initiated by a STA when the TDLS peer STA did not set the TDLS Channel Switching capability field to 1 in the transmitted TDLS Setup Request frame or the TDLS Setup Response frame that caused the TDLS direct link to be set up.

TDLS Channel Switch Request frames and TDLS Channel Switch Response frames shall be transmitted over the TDLS direct link.

TDLS channel switching is different from (I)BSS channel switching as defined in 11.8.8 (Selecting and advertising a new channel).

The target channel is the destination channel of an intended channel switch. The target channel is specified by the STA that initiates a channel switch, from the set of operating classes supported by both TDLS peer STAs. The target channel and operating class are specified in the TDLS Channel Switch Request frame. The Country and Coverage Class settings on the target channel are the same as in the BSS of which both TDLS peer STAs are currently members. Both STAs are entitled to request a channel switch. The events occurring for a channel switch are illustrated in Figure 11-38 (Events occurring for a TDLS direct link channel switch(#1356)(#3461)).

In Figure 11-38 (Events occurring for a TDLS direct link channel switch(#1356)(#3461)), the TDLS peer STAs (STA1 and STA2) are operating on an initial channel. After contending for the medium, STA1 transmits a TDLS Channel Switch Request frame to STA2, via the (#2152)TDLS direct link, indicating a requested switch to a target channel. STA2 transmits an Ack frame (denoted ACK1 in Figure 11-38 (Events occurring for a TDLS direct link channel switch(#1356)(#3461))) after a SIFS(#6587), and processes the TDLS Channel Switch Request frame. After contending for the medium, STA2 transmits a TDLS Channel Switch Response frame to STA1, possibly also after entering power save mode with the AP. STA1 responds with an Ack frame (denoted ACK2 in Figure 11-38 (Events occurring for a TDLS direct link channel switch(#1356)(#3461))) after a SIFS(#6587). If the TDLS Channel Switch Response frame indicated with status code REQUEST_DECLINED, then both STAs continue to operate on the current channel. If the TDLS Channel Switch Response frame indicated with status code SUCCESS, then both STAs shall be listening on the target channel not later than SwitchTime after the end of (#14)the PPDU[+SigExt] containing ACK2, as measured on the WM. After switching channels, each TDLS peer STA shall perform a clear channel assessment (CCA) on the target channel, until a frame is detected by which it can set its NAV, or until a period of time equal to (#3451)dot11TDLSNavSync has transpired (this combined event is indicated as “ProbeTime” in Figure 11-38 (Events occurring for a TDLS direct link channel switch(#1356)(#3461))). The first transmission on the target channel shall be preceded by a random backoff, which shall start at the end of the ProbeTime. The first transmission on the new channel shall not start before the end of SwitchTime. The initiator of the channel switch shall transmit a Data frame on the target channel, unless the SwitchTimeout has expired or the responder to the channel switch transmitted a Data frame on the target channel.


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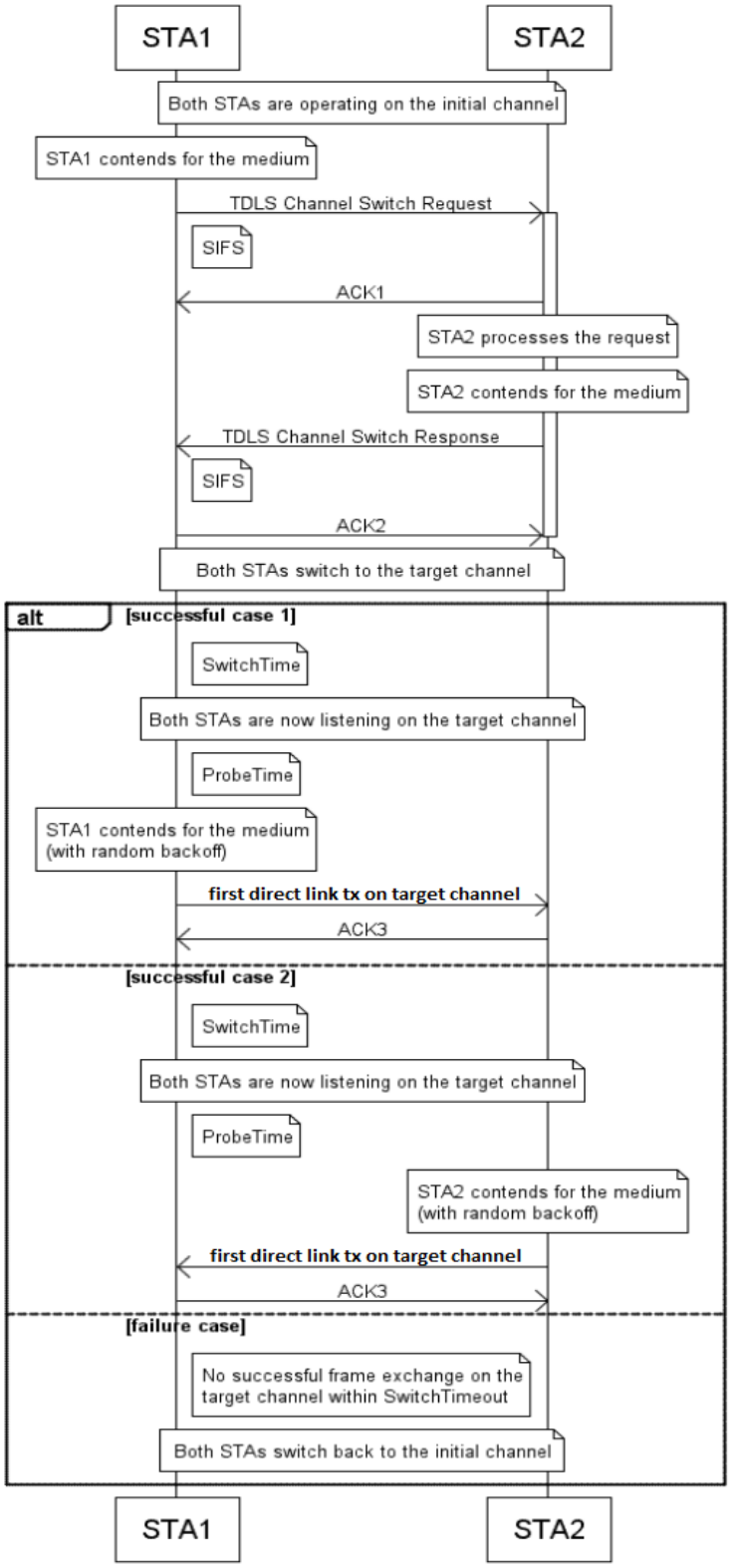


**Figure 11-38—Events occurring for a TDLS direct link channel switch(#1356)(#3461)**

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If no successful frame exchange sequence(#109) has occurred on an off-channel within SwitchTimeout after the end of (#14)the PPDU[+SigExt] containing ACK2, as measured on the WM, a STA shall go back to the base channel, where they shall be listening not later than SwitchTime after the end of the SwitchTimeout. After changing channels (either from the base channel to the off-channel or from the off-channel to the base channel), a TDLS peer STA shall perform CCA until a frame is detected by which it can set its NAV, or until a period of time equal to the ProbeTime has transpired.

Both the TDLS Channel Switch Request frame and the TDLS Channel Switch Response frame shall contain a Channel Switch Timing element. The SwitchTime and SwitchTimeout values in the TDLS Channel Switch Timing element included in the TDLS Channel Switch Request frame shall specify the values required at the STA sending the TDLS Channel Switch Request frame. The SwitchTime and SwitchTimeout values specified in the TDLS Channel Switch Timing element included in the TDLS Channel Switch Response frame shall meet the requirements at the STA sending the TDLS Channel Switch Response frame and shall be equal to or larger than the values specified in the TDLS Channel Switch Request frame. The timing parameters specified in the Channel Switch Timing element included in the TDLS Channel Switch Response frame shall be used for the TDLS channel switching procedure. This procedure causes the larger of the two switch times to become the value that is transmitted in the TDLS Channel Switch Response frame.

The TDLS peer STA shall be in PS mode with the AP and shall not be involved in an active Service Period with the AP before sending a TDLS Channel Switch Request frame or a TDLS Channel Switch Response frame with the Status Code field(#4356) set to SUCCESS. The TDLS peer STA that receives a TDLS Channel Switch Request frame may enter PS mode with the AP prior to sending the TDLS Channel Switch Response frame.

Because there is at least a backoff between the TDLS Channel Switch Request frame and the TDLS Channel Switch Response frame, there is a (small) probability that two STAs issue a TDLS Channel Switch Request frame at more or less the same time. To reduce the probability for this event to occur, a TDLS peer STA should not transmit a TDLS Channel Switch Request frame when a TDLS Channel Switch Request frame is received and no TDLS Channel Switch Response has been transmitted in response. If a TDLS Channel Switch Request frame is received from the TDLS peer STA to which a pending TDLS Channel Switch Request frame was previously sent before receiving TDLS Channel Switch Response, the TDLS initiator STA shall not reply to the TDLS Channel Switch Request frame and the TDLS responder STA shall reply to the TDLS Channel Switch Request frame.

If a TDLS Channel Switch Response frame does not imply a channel switch because the STAs already are on the requested channel, then the SwitchTime and ProbeTime may be skipped and both TDLS peer STAs continue to operate on the requested channel. To cross means that a TDLS Channel Switch Request frame is received from a peer STA after transmitting a TDLS Channel Switch Request frame to the TDLS peer STA, instead of the expected TDLS Channel Switch Response frame.

When a TDLS peer STA does not receive an acknowledgment to a TDLS Channel Switch Response frame, it may retransmit the frame but the number of retransmissions shall be lesser of the maximum retry limit and dot11TDLSPeerSTAMissingAckRetryLimit.

A channel switch from an off-channel to the base channel may be accomplished by sending a TDLS Channel Switch Response frame indicating the base channel as the target channel, without prior TDLS Channel Switch Request frame. The Channel Switch Timing element shall be the same as contained in the Channel Switch Response frame that caused the switch to the off-channel.

TDLS Channel Switching shall not be used when the TDLS Channel Switching Prohibited subfield included in the Extended Capabilities element of the Association Response frame or Reassociation Response frame that led to the current association is equal to 1.


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(#2079)After moving into a new operating channel, a STA shall perform CCA until a frame is detected by which it can set its NAV, or until a period of time indicated by the NAVSyncDelay parameter from the most recent MLME-START.request or MLME-JOIN.request primitive has transpired.

#### 11.20.6.2 General behavior on the off-channel

If dot11SpectrumManagementRequired is true, a TDLS peer STA shall not transmit a TDLS Channel Switch request specifying an off-channel where radar detection is required, unless the STA has tested that channel for the presence of radar, according to regulatory requirements. If a TDLS peer STA that is operating in such a channel detects radar, the TDLS peer STA shall discontinue transmissions according to regulatory requirements, and it shall send a TDLS Channel Switch Request frame indicating a switch to the base channel. The channel switch avoids an interruption on the (#2152)TDLS direct link.

The TDLS peer STA initiating the switch to the channel where radar detection is required by regulation shall be the DFS owner.

A secondary channel of an existing network shall not be selected as an off-channel.(#4309)

On an off-channel, the TDLS peer STAs remain associated with their BSS, so the BSSID remains the same.

It is recommended that in general TDLS STAs propose target channels that have no detectable medium occupancy. If no such channel is available, then it is recommended that the TDLS STA propose a target channel where beacons are detected but with little or no additional medium occupancy. It is further recommended that TDLS STAs do not propose a target channel where the presence of beacons indicate that ACM subfields are set, unless little or no additional medium occupancy is detected.

#### 11.20.6.3 Setting up a 40 MHz TDLS direct link(#2152)

##### 11.20.6.3.1 General

A 40 MHz (#2152)off-channel TDLS direct link may be started if both TDLS peer STAs indicated 40 MHz support in the Supported Channel Width Set field of the HT Capabilities element (which is included in the TDLS Setup Request frame and the TDLS Setup Response frame).

Switching to a 40 MHz (#2152)off-channel TDLS direct link is achieved by including the following information in the TDLS Channel Switch Request frame:

— Operating Class field indicating 40 MHz channel spacing
— Secondary Channel Offset field indicating SCA or SCB

A 40 MHz (#2152)off-channel TDLS direct link shall not be established in the 2.4 GHz band.

The TDLS peer STA initiating the switch to the 40 MHz off-channel shall be the DO.

##### 11.20.6.3.2 Basic 40 MHz functionality

TDLS peer STAs may transmit 40 MHz PPDUs on a (#2152)40 MHz TDLS direct link. A TDLS peer STA shall not transmit a 20 MHz PPDU in the secondary channel of its (#2152)40 MHz TDLS direct link.

##### 11.20.6.3.3 Channel selection for a 40 MHz TDLS direct link(#2152)

If a TDLS peer STA chooses to start a 40 MHz (#2152)TDLS direct link that occupies the same two channels as an existing 40 MHz network (i.e., a 20/40 MHz BSSs or a (#2152)40 MHz TDLS direct link), then it shall select primary and secondary channels of the new direct link that are identical to the primary and secondary

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channels of the existing 40 MHz network, unless the TDLS peer STA discovers that on these two channels there are existing 40 MHz networks with different primary and secondary channels.

If a TDLS peer STA chooses to start a (#2152)40 MHz TDLS direct link, the selected secondary channel should correspond to a channel on which no beacons are detected.

#### 11.20.6.3.4 Switching from a 40 MHz to a 20 MHz TDLS direct link(#2152)

Switching from a 40 MHz (#2152)off-channel TDLS direct link to a 20 MHz (#2152)off-channel TDLS direct link is established through a TDLS channel switch. When on a 40 MHz (#2152)off-channel TDLS direct link, a requested switch to a (#2152)20 MHz TDLS direct link shall always be accepted.

#### 11.20.6.3.5 CCA sensing and NAV assertion in a 40 MHz TDLS direct link(#2152)

When active on a (#2152)40 MHz TDLS direct link, a TDLS peer STA shall follow the CCA rules as defined in 11.15.9 (STA CCA sensing in a 20/40 MHz BSS) and the NAV rules as defined in 11.15.10 (NAV assertion in 20/40 MHz BSS).

### 11.20.6.4 TDLS channel switching and power saving

A TDLS direct link shall not be switched to an off-channel during a TPU service period. While on an off-channel, a TDLS peer STA shall not enter TPU power save mode.

A TDLS direct link may be switched to an off-channel when TDLS peer PSM is active on the link. The wakeup windows occur on the off-channel in the same way they would have occurred had the STAs remained on the base channel. Suspension of the wakeup windows implies a switch back to the base channel.

### 11.20.6.5 Setting up a wide bandwidth off-channel TDLS direct link(#2152)

#### 11.20.6.5.1 General

A wideband TDLS off-channel TDLS direct link is a 40 MHz, 80 MHz, 160 MHz, or 80+80 MHz off-channel TDLS direct link for VHT STAs or 40 MHz off-channel TDLS direct link for HT STAs(#3021) or a 2 MHz, 4 MHz, 8 MHz, or 16 MHz off-channel TDLS direct link for S1G STAs.

A wideband off-channel TDLS direct link may be started if both TDLS peer STAs indicated wideband support in the VHT Capabilities element, (#3021)HT Capabilities element or S1G Capabilities element included in the TDLS Setup Request frame or the TDLS Setup Response frame.

Switching to a (#2152)wideband off-channel TDLS direct link is achieved by including any of the following information in the TDLS Channel Switch Request frame:

— An Operating Class field indicating 40 MHz Channel spacing and a Secondary Channel Offset element indicating SCA or SCB for HT STAs(#3021)
— A Wide Bandwidth Channel Switch element indicating 80 MHz, 160 MHz, or 80+80 MHz channel width for VHT STAs
— A Wide Bandwidth Channel Switch element indicating 4 MHz, 8 MHz, or 16 MHz channel width for S1G STAs

For VHT STAs, the operating class in TDLS Channel Switch Request frame shall have a value representing 5 GHz for the channel starting frequency.

A TDLS peer STA that is extended spectrum management capable and that announces new TPC parameters that come into effect at the same time as the switch to an (#2152)off-channel TDLS direct link, shall include at


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least one Transmit Power Envelope element in the transmitted the TDLS Channel Switch Request frame. The recipient TDLS peer STA that is extended spectrum management capable and that has dot11SpectrumManagementRequired or dot11RadioMeasurementActivated equal to true shall use the parameters in these received element(s) in the recipient STA's TPC calculations for the (#2152)off-channel TDLS direct link.

When announcing new operating classes or both a new operating class table index and new operating classes that come into effect at the same time as the switch to the direct link and that express new regulatory requirements, the TDLS peer VHT or S1G STA initiating the switch shall include a Country element in a transmitted TDLS Channel Switch Request frame. The Country element shall contain all of the Operating Classes for the (#2152)off-channel TDLS direct link in Operating Triplet fields and zero Subband Triplet fields. The Country element shall include one Operating Triplet field that contains the same Operating Class as the Operating Class field in the same frame. The country indicated by the Country string in the TDLS Channel Switch Request frame shall be equal to the country indicated by the Country string of the BSS. The recipient TDLS peer VHT or S1G STA that has dot11MultiDomainCapabilityActivated, dot11SpectrumManagementRequired, or dot11RadioMeasurementActivated equal to true shall use the parameters in the received Country element in the TDLS Channel Switch Request frame in order to maintain regulatory compliance.

The TDLS peer STA initiating the switch to the wideband off-channel shall be the DO on that channel.

#### 11.20.6.5.2 Basic wideband functionality

TDLS peer STAs may transmit up to 40 MHz, 80 MHz, 160 MHz, or 80+80 MHz PPDUs on a 40 MHz, 80 MHz, 160 MHz, or 80+80 MHz (#2152)TDLS direct link, respectively. A TDLS peer STA shall not transmit a 20 MHz PPDU in the nonprimary channel of its 80 MHz, 160 MHz, or 80+80 MHz (#2152)TDLS direct link.

A TDLS peer STA shall not transmit a 40 MHz PPDU that does not use the primary 40 MHz channel of its 80 Hz, 160 MHz, or 80+80 MHz (#2152)TDLS direct link. A TDLS peer STA shall not transmit an 80 MHz PPDU that does not use the primary 80 MHz channel of its 160 MHz or 80+80 MHz (#2152)TDLS direct link.

TDLS peer S1G STAs may transmit up to 4 MHz, 8 MHz, or 16 MHz PPDUs on a 4 MHz, 8 MHz, or 16 MHz off-channel TDLS direct link, respectively. An S1G STA determines the channelization based on the Wide Bandwidth Channel Switch element of the TDLS Channel Switch Request frame.

A TDLS peer S1G STA shall not transmit a 1 MHz PPDU in the nonprimary 1 MHz channel of its 4 MHz, 8 MHz or 16 MHz off-channel TDLS direct link. A TDLS peer S1G STA shall not transmit a 2 MHz PPDU in the nonprimary 2 MHz channel of its 4 MHz, 8 MHz, or 16 MHz off-channel TDLS direct link. A TDLS peer S1G STA shall not transmit a 4 MHz PPDU that does not use the primary 4 MHz channel of its 8 MHz or 16 MHz off-channel TDLS direct link. A TDLS peer S1G STA shall not transmit an 8 MHz PPDU that does not use the primary 8 MHz channel of its 16 MHz off-channel TDLS direct link.

#### 11.20.6.5.3 Channel selection for a wideband off-channel TDLS direct link(#2152)

If a non-S1G TDLS peer STA chooses to start a (#2152)wideband TDLS direct link, the TDLS peer STA shall follow the primary channel selection rules defined in 11.38.2 (Channel selection methods for a VHT BSS) and 11.21.15 (Channel usage procedures) and the secondary 80 MHz channel rule defined in 11.20.1 (General).

If an S1G TDLS peer STA chooses to start a (#2152)wideband TDLS direct link, the TDLS peer STA shall follow the primary channel selection rules defined in 10.45.4 (S1G BSS channel switching methods) and 11.21.15 (Channel usage procedures).

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#### 11.20.6.5.4 Switching from a wideband to a 20 MHz, 1 MHz, or 2 MHz TDLS direct link(#2152)

Switching from a (#2152)wideband off-channel TDLS direct link to a 20 MHz, 1 MHz, or 2 MHz (#2152)off-channel TDLS direct link is established through a TDLS channel switch. A non-S1G STA operating on a (#2152)wideband off-channel TDLS direct link shall accept a requested switch to a (#2152)20 MHz TDLS direct link. An S1G STA operating on a (#2152)wideband off-channel TDLS direct link shall accept a requested switch to 1 MHz or 2 MHz (#2152)TDLS direct link.

#### 11.20.6.5.5 CCA sensing and NAV assertion in a 20 MHz, 40 MHz, 80 MHz, 160 MHz, 80+80 MHz, 1 MHz, 2 MHz, 4 MHz, 8 MHz, or 16 MHz TDLS direct link(#2152)

TDLS peer VHT STAs shall follow the CCA rules defined in 10.3.2.7 (VHT and S1G RTS procedure), 10.23.2.8 (Multiple frame exchange sequences in an EDCA TXOP(#109)), and 10.23.3 (HCF controlled channel access (HCCA)) and the NAV rules defined in 11.38.5 (NAV assertion in a VHT BSS).

TDLS peer S1G STAs shall follow the CCA rules defined in 10.3.2.7 (VHT and S1G RTS procedure) and 10.23.2.8 (Multiple frame exchange sequences in an EDCA TXOP(#109)) and the NAV rules defined in 10.45.6 (NAV and RID assertion in an S1G BSS).

## 11.21 Wireless network management procedures

### 11.21.1 Wireless network management dependencies

When dot11WirelessManagementImplemented is true, the STA is a WNM STA and dot11ExtendedChannelSwitchActivated and dot11RadioMeasurementActivated shall be true. This subclause describes WNM procedures for requesting and reporting WNM capabilities between STAs that support WNM procedures.

When dot11WirelessManagementImplemented is true, and one or more of bit 7 to bit 27 in the Extended Capabilities element have the value 1, the Extended Capabilities element shall be included in Beacon frames, Association Request and Response frames, Reassociation Request and Response frames, and Probe Request and Response frames. When dot11WirelessManagementImplemented is true, for each bit 7 to bit 27 in the received Extended Capabilities element that is 0, a STA shall not request the corresponding feature from the sending STA. A WNM STA receiving a request for a WNM feature from another STA shall reject the request if the receiving WNM STA has not advertised support for the corresponding WNM feature.

### 11.21.2 Event request and report procedures

#### 11.21.2.1 Event request and event report

The Event Request and Event Report frames enable network real-time diagnostics. A STA with dot11EventsActivated equal to true shall support event requests and reports and shall set to 1 the Event field of the Extended Capabilities elements that it transmits. If dot11EventsActivated is true and the Event Type field is neither BSS Color Collision nor BSS Color In Use, a STA shall log all Transition, RSNA, peer-to-peer, and WNM log events, including the corresponding TSF, UTC Offset, and Event Time Error. An HE STA that has dot11EventsActivated equal to true and reports BSS color collisions shall log all BSS color collision events, including the TSF value when the STA finished logging the events that are reported (see Table 11.21.2.7 (BSS color collision event(11ax))).(11ax)

A STA with either dot11AutonomousBSSColorCollisionReportingImplemented equal to true or dot11AutonomousBSSColorInUseReportingImplemented equal to true shall set the Event field of the Extended Capabilities elements that it transmits to 1.(11ax)


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The STA log of events shall not be cleared as a result of BSS transitions. However, if the STA moves to a different ESS or IBSS, the STA shall delete all event log entries.

A STA that supports event reporting may send an Event Request or Event Report frame to a STA within the same infrastructure BSS or the same IBSS whose last received Extended Capabilities element contained a value of 1 for the Event bit in the Extended Capabilities field; it shall not send an Event Request or Event Report frame otherwise. If the STA receives an Event Request frame without error and it supports event reporting, it shall respond with an Event Report frame that includes a Dialog Token field that matches the one in the Event Request frame.

The permitted source and destination STAs for an Event Request frame are shown in Table 11-13 (Allowed measurement requests).

An AP may include zero or more Event Request elements in an Event Request frame. Each Event Request element contains an Event Token that associates this Event Request with any subsequent Event Report elements. When sending Event Report elements, a STA shall use the same Event Token that was included in the original request.

Only a single Event Request frame from a STA is outstanding at a given STA at any time. If a STA that supports event reporting receives a subsequent Event Request frame with a different dialog token before completing the Event Report for the previous request from the requesting STA, the receiving STA may respond to the most recent request frame; it shall not respond to a request frame that is not the most recent one.

Upon a BSS transition, the STA shall cancel any event requests in the latest Event Request frame.

The Event Request elements can contain conditions that specify events to be reported and conditions that establish event reporting when a STA experiences problems or failures. A STA sends an Event Request frame containing one or more Event Request elements, each of which contains zero or more subelements. Subelements are defined for each event type. A STA shall include in the corresponding Event Report element only those events that meet the specified event conditions within the ESS or IBSS of which the transmitting STA is a member.

In each Event Report element, a STA shall include a Status field that indicates the result of the event request/report transaction. If the STA is able to return one or more Event Report elements, then the STA shall return a value of "Successful" in the Event Report element. If the STA has no logged events of the requested type, the STA shall return a value of Successful in the Event Report element without an event included in the Event Report field. If the STA is unable to process the request at that time, the STA shall return a value of "Request failed" in the Event Report element. If a STA refuses an event request, the STA shall return a value of "Request refused" in the Event Report element. The reasons for refusing an event request are outside the scope of this standard but may include reduced quality of service, unacceptable power consumption, measurement scheduling conflicts, or other significant factors. If the STA is incapable of generating an Event Report of the type specified in the Event Request frame, the STA shall return a value of "Request incapable" indicating that the requester should not request again.

If the Event Report elements do not fit into a single MMPDU, the reporting STA shall send the remaining elements in additional Event Report frames until all Event Report elements have been returned to the requesting STA. In any subsequent Event Report frame and for all remaining Event Report elements a reporting STA shall include the same values of the Dialog Token and Event Token fields, respectively, that was sent in the corresponding Event Request frame. When multiple MMPDUs are required, the non-AP STA shall include complete Event Report elements and shall not fragment an element across multiple MMPDUs.

A STA shall transmit both the Event Request frame and the Event Report frame only with a destination address that is an individual address. In an infrastructure BSS, only an AP shall transmit an Event Request frame to a non-AP STA. An AP that supports event reporting shall discard received Event Request frames.

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When a STA transmits an Event Request frame to another STA it shall indicate the types of events requested by setting the Event Type field and shall indicate the maximum number of logged events to report by using the Event Response Limit field in each included Event Request element. If the number of available logged events of the requested type exceeds the Event Response Limit, the STA shall report an Event Response Limit number of the most recent events. If there are no available logged events of the type specified in the Event Request frame, the STA shall send the Event Report frame without any Event Report element. The reporting STA shall send all available Event Report elements for the requested event type when the Event Request field is not present in the Event Request element.

A STA may include a Destination URI element in the Event Request frame. The AP includes the URI in the Destination URI element that the reporting non-AP STA may use to send Event Reports, upon the loss or interruption of connectivity to the BSS.

On receipt of an Event Request frame with an Destination URI element, the reporting non-AP STA SME may send the Event Report to the AP using the Destination URI with another network interface (if available). The non-AP STA SME shall not send the Event Report to the URI contained in the Destination URI element except after detecting loss of BSS connection.

The non-AP STA shall determine loss of connection to the AP that issued the Event Request frame when it has not detected any Beacon frames from the AP for a period no less than the (#3197)ESS detection interval.

If the BSS connection is reestablished to the AP that transmitted the Event Request frame, the non-AP STA shall transmit the corresponding Event Report frame to the AP without using the Destination URI.

When the non-AP STA uses the Destination URI mechanism, it shall transport the Frame Body field of the Event Report frame using the URI given in the Destination URI Element. An example use of the Destination URI is given in Annex Q.

#### 11.21.2.2 Transition event request and report

The Transition Event report provides information on the previous transition events for a given non-AP STA. The Transition Event request and report are only permitted in the infrastructure BSS.

Each STA supporting the Transition Event shall log up to the last five Transition events occurring since the STA associated to the ESS. A STA may log more than five of the most recent Transition events.

Upon receipt of an Event Request frame containing an Event Request element including a Transition Event request, the non-AP STA shall respond with an Event Report frame that includes available Event Report elements within the ESS of which the transmitting STA is a member for the Transition event type.

Transition Event Request subelements are used to specify conditions for reporting of transition events. If any Transition Event Request subelements are present in the Event Request frame, the reporting non-AP STA shall include in the Event Report frame only those available Transition Event Report elements that meet the transition event reporting condition(s) specified in the Event Request frame. If no transition event subelements are present in the Event Request field, the reporting STA shall include all available Transition Event Report elements.

A Frequent Transition subelement in an Event Request frame defines conditions for frequent transition. Frequent transition occurs when the number of BSS transitions exceeds the frequent transition count threshold within the indicated time interval as defined in the Frequent Transition subelement in 9.4.2.65.2 (Transition event request). A STA that receives a Frequent Transition subelement shall, at each BSS transition, apply the conditions for frequent transition to the log of transition events. If the logged transition events meet the conditions for frequent transition, the STA shall send an Event Report frame including a Transition Event


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Report element with Event Report Status set to Detected Frequent Transition and include in that Event Report element the last logged transition event.

For transition logging and reporting purposes, the transition time is defined as the time difference between the starting time and the ending time of a transition between APs, even if the transition results in remaining on the same AP.

The starting time is one of the following items:

— The start of a search for an AP, when the transition reason is 4 (first association to WLAN).
— The latest time that a frame could have been transmitted or received on the source BSS.
— The start of a search for an AP, after determination that a transition has failed.

The ending time is one of the following items:

— The earliest time that a Data frame can be transmitted or received on the target BSS, after completion of RSN, IEEE 802.1X, or other authentication and key management transmissions, when such are required by the target BSS.
— The time that a determination is made that the transition has failed.

#### 11.21.2.3 RSNA event request and report

The RSNA Event Report provides authentication events for a given non-AP STA. The RSNA Event Request and Report are only permitted in an infrastructure BSS.

Each STA supporting the RSNA Event shall log up to the last five RSNA events occurring since the STA associated to the ESS. A STA may log more than five of the most recent RSNA events.

Upon receipt of an Event Request frame containing an Event Request element including an RSNA Event request, the non-AP STA shall respond with an Event Report frame that includes available Event Report elements within the ESS of which the transmitting STA is a member for the RSNA event type.

If an RSNA Event Request subelement is present in the Event Request field, the reporting non-AP STA shall include available Event Report elements that meet the specified condition for the RSNA event type. If no RSNA Event Request subelement is present in the Event Request field, the reporting STA shall include all available RSNA Event Report elements.

#### 11.21.2.4 Peer-to-peer link event request and report

The peer-to-peer link event report provides peer-to-peer connectivity events for a given non-AP STA. A peer-to-peer event occurs when a peer-to-peer link is initiated or terminated.

Each STA supporting the peer-to-peer link event shall log up to the last five peer-to-peer link events occurring since the STA associated to the ESS or IBSS. A STA may log more than five of the most recent peer-to-peer link events. When a link is initiated, a STA shall log and record the TSF time of the peer-to-peer link event without a connection time. When a peer-to-peer link is terminated, a STA shall log the peer-to-peer link event including the connection time for the terminated link and shall delete from the log any initiation event for the same peer-to-peer link.

Upon receipt of an Event Request frame containing an Event Request element including a peer-to-peer link event request, the non-AP STA shall respond with an Event Report frame that includes available Event Report elements within the ESS or IBSS of which the transmitting STA is a member for the Peer-to-peer event type. When a STA includes a Peer-to-Peer Link Event Report element for a link initiation, the STA shall include a

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connection time for the event report element which indicates the time difference from the event timestamp to the current time.

If a Peer-to-Peer Link Event Request subelement is present in the Event Request field, the reporting non-AP STA shall include available Event Report elements that meet the specified condition for the Peer-to-peer event type. If no Peer-to-Peer Link Event Request subelements are present in the Event Request field, the reporting STA shall include all available Peer-to-Peer Link Event Report elements.

#### 11.21.2.5 WNM log event request and report

The WNM log event report is intended to capture PHY and MAC(#6268) events in vendor-specific, human-readable (ASCII text) form. The WNM log is a general reporting mechanism that can apply to configuration or monitoring behavior for PHY and MAC. The WNM log is particularly useful for logging success or failure events across areas such as driver status, IEEE 802.11 or IEEE 802.1X authentication, authorization, status changes while associated or unassociated.

For example:

<0>Oct 03 17:47:00 00:01:02:03:04:05 Adapter DLL Service initialized
<1>Oct 03 17:48:40 00:01:02:03:04:05 Authentication started
<1>Oct 03 17:48:46 00:01:02:03:04:05 IEEE 802.1X Authentication Failed, credential failure
<1>Oct 03 17:49:00 00:01:02:03:04:05 Authentication success

A non-AP STA that supports event reporting may be queried at any time for its current set of WNM log messages. The WNM log messages returned by the non-AP STA may provide insight into the trouble being experienced by non-AP STA.

Upon receipt of an Event Request frame containing an Event Request element including a WNM log event request, the non-AP STA shall respond with an Event Report frame that includes WNM Log Event Report elements.

#### 11.21.2.6 Vendor Specific event request and report

The procedures for use of the Vendor Specific Event Request and Report are vendor specific and are not part of this standard.

#### 11.21.2.7 BSS color collision event(11ax)

The BSS color collision event report enables a non-AP HE STA to inform its associated AP whether a BSS color collision has occurred. The report carries information about the BSS color used by OBSSs that the reporting STA is able to detect (see 26.17.3.5.2 (Autonomous reporting of BSS color collision)).

#### 11.21.2.8 BSS color in use event(11ax)

If a non-AP HE STA communicates with a peer STA with a BSS color that is different from the BSS color used by its associated AP, the non-AP HE STA may send a BSS color in use event report to its associated AP in which the Event Report field has the BSS color used in the communication with the peer STA.

A non-AP HE STA shall send a BSS color in use event report to its associated AP with the Event Report field set to 0 to cancel a previously sent BSS color in use event report.

An AP shall not transmit frames to a non-AP HE STA during a TXOP, if it has received a BSS color in use event report from that non-AP HE STA with a nonzero BSS color in the Event Report field and the AP (#3683)discards an inter-BSS PPDU with the same BSS color value as the one carried in the Event Report field


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to obtain a TXOP by following the procedure in 26.10.2.2 (General operation with non-SRG OBSS PD level) and 26.10.2.3 (General operation with SRG OBSS PD level).

### 11.21.3 Diagnostic request and report procedures

#### 11.21.3.1 Diagnostic request and diagnostic report

The Diagnostic Request and Diagnostic Report protocol provides a tool to diagnose and debug complex network issues. A STA with dot11DiagnosticsActivated equal to true shall support diagnostic reporting and shall set to 1 the Diagnostics field of the Extended Capabilities elements that it transmits.

A STA that supports diagnostics reporting shall send a Diagnostics Request or Diagnostics Report frame to a STA within the same infrastructure BSS or the same IBSS whose last received Extended Capabilities element contained a value of 1 for the Diagnostics bit in the Extended Capabilities field; it shall not send a Diagnostics Request or Diagnostics Report frame otherwise.

The Diagnostic Request frame contains a unique Dialog Token. A value of 0 for the Dialog Token field is a reserved and shall not be used. The source and destination of a Diagnostic Request frame shall both be members of the same BSS. The permitted source and destination STAs for a Diagnostic Request frame are shown in Table 11-13 (Allowed measurement requests). A STA may include one or more Diagnostic Request elements in a Diagnostic Request frame. Each Diagnostic Request element contains a unique Diagnostic Token that identifies the element within the Diagnostic Request frame.

If a STA that supports diagnostic reporting receives a Diagnostic Request frame without error, the STA shall respond with a Diagnostic Report frame that includes a Dialog Token field that matches the one in the Diagnostic Request frame. Each Diagnostic Report element that corresponds to the Diagnostic Request element shall contain the same Diagnostic Token that was included in the original request.

Only a single Diagnostic Request frame from a STA is outstanding at a given STA at any time. If a STA receives a subsequent Diagnostic Request frame with a different dialog token before completing the Diagnostic Report for the previous request from the requesting STA, the STA shall respond to the most recent Diagnostic Request frame; the STA shall not respond to a Diagnostic Request frame that is not the most recent one.

All outstanding diagnostic requests, as indicated by received MLME-DIAGREQUEST.indication primitives, are canceled upon a BSS transition, except when the BSS transition occurs as a result of responding to or initiating a diagnostic request. All outstanding diagnostic requests, as indicated by received MLME-DIAGREQUEST.indication primitives, (#8183)shall be canceled by the SME after the time indicated in the Diagnostic Timeout field, in the Diagnostic Request frame. When a STA that supports diagnostic reporting receives a Diagnostic Request frame with a Diagnostic Request Type of Cancel Diagnostic Request, (#8183)the SME shall cancel all outstanding diagnostic requests, and discard all pending(#7145) diagnostic reports, as indicated by received MLME-DIAGREQUEST.indication primitives.

All Diagnostic Report elements shall include a Status field that indicates the overall result of the transaction. If the STA is able to complete the diagnostic request made in the Diagnostic Request element, then a value of "Successful" shall be returned. If the STA is unable to process the request at that time a value of "Fail" shall be returned. If the STA is incapable of generating a report of the type specified, it shall return a value of "Incapable." If the STA cannot support the request for any other reason, the value of Refused shall be returned.

A STA shall transmit both the Diagnostic Request frame and the Diagnostic Report frame with a destination address that is an individual address.

A STA may include a Destination URI element in the Event Request frame. The AP includes the URI in the Destination URI element that the reporting non-AP STA may use to send Diagnostic Reports, upon the loss or interruption of connectivity to the BSS.

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On receipt of an Diagnostic Request frame with an Destination URI element, the reporting non-AP STA SME may send the Diagnostic Report to the AP using the Destination URI with another network interface (if available).

The non-AP STA shall determine loss of connection to the AP that issued the Diagnostic Request frame when it has not detected any Beacon frames from the AP for a period no less than the (#3197)ESS detection interval.

If the BSS connection is reestablished to the AP that transmitted the Diagnostic Request frame, the non-AP STA shall transmit the corresponding Diagnostic Report frame to the AP without using the Destination URI.

When the non-AP STA uses the Destination URI mechanism, it shall transport the payload of the Diagnostic Report frame using the URI given in the Destination URI Element. An example use of the Destination URI is given in Annex Q.

If a non-AP STA that receives an Destination URI subelement in an Diagnostic Request fails to detect any Beacon frames, belonging to the AP that issued the request for a Diagnostic report, for the period specified by the ESS detection interval, it may use the URI specified in the Destination URI subelement to transport the Diagnostic Report to the AP.

If the Diagnostic Report elements do not fit into a single MMPDU, the reporting STA shall send the remaining elements in additional frames until all Diagnostic Report elements have been returned to the requesting STA. A STA shall include the same values of the Dialog Token and Diagnostic Token fields that were transmitted in the corresponding Diagnostic Request frame in each subsequent Diagnostic Report frame and Diagnostic Report elements. When multiple MMPDUs are required, the STA shall include complete Diagnostic Report elements and shall not fragment an element across multiple MMPDUs.

A STA that supports diagnostic reporting may cancel a previously sent Diagnostic Request frame for which it has not yet received a Diagnostic Report frame by sending a Diagnostic Request frame with the Diagnostic Request Type field value of 0, indicating “Canceled,” to the STA to which it previously sent the Diagnostic Request frame. A STA that supports diagnostic reporting shall inform a STA from which it has previously received a Diagnostic Request frame that the request has been locally canceled by sending a Diagnostic Report frame with the Diagnostic Status field set to a value of 4, indicating “Canceled,” to the requesting STA. In a Diagnostic Request frame with the Diagnostic Request Type field value of 0, and a Diagnostic Report frame with the Diagnostic Status field set to a value of 4, no Diagnostic subelements are included in the Diagnostic Request or Response element.

#### 11.21.3.2 Configuration Profile report

The Configuration Profile report enables an AP to discover the current profile in use for an associated STA, and additional profiles for the ESS of which the STA is a member. A non-AP STA that supports diagnostic reporting and receives a Configuration Profile report request type shall respond with a Diagnostic Report frame that includes all available Diagnostic elements allowed for the type.

STAs that support multiple configuration profiles for an ESS may include multiple Diagnostic Report elements in a single Diagnostic Report frame (or multiple frames if required). Each Diagnostic Report element shall contain a Profile ID element that uniquely identifies the configuration profile(s) for the ESS of which the STA is a member that are available on the device.

#### 11.21.3.3 Manufacturer information STA report

The Manufacturer Information STA Report enables an AP to discover static manufacturer specific data about an associated STA. A non-AP STA that supports diagnostic reporting and receives a Manufacturer Information STA Report request type shall respond with a Diagnostic Report frame that includes all available Diagnostic elements allowed for the type.


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When more than one Antenna Type/Antenna Gain pair is enabled, multiple Antenna Type subelements shall be included in the Manufacturer Information STA Report Diagnostic Report element.

When more than one (#2210)Colocated Radio Type, or Device Type is supported, multiple (#2210)Colocated Radio Type subelements, or Device Type subelements shall be included in the Manufacturer Information STA Report Diagnostic Report element. If the existence or the type of (#2210)colocated radio is unknown, no (#2210)Colocated Radio Type subelements shall be included.

#### 11.21.3.4 Association diagnostic

The purpose of the association diagnostic is to determine that a STA is able to associate with a designated BSS. This test directs an association to be completed with a specific AP.

To initiate the test, an AP that supports diagnostic reporting shall send a Diagnostic Request frame containing a Diagnostic Request Type field set to 3 (i.e., Association Diagnostic) to a STA that supports diagnostic reporting. The AP shall not send an association diagnostic request with a designated BSS that is not part of the ESS and the STA receiving an association diagnostic request shall reject requests to perform diagnostics on a BSS that is not part of the ESS. All parameters required to complete the association are included in the Diagnostic Request element.

Upon receipt of the Diagnostic Request frame containing a Diagnostic Request element specifying an association request, the STA determines whether to accept the request. If the STA declines the request, it shall send a Diagnostic Report frame with the Status field of a Diagnostic Report element set to Refused. If the STA accepts the request, it shall cause an authentication to occur to the AP indicated in the Diagnostic Request element and the STA's SME shall issue an MLME-DIAGREPORT.request primitive, indicating the results of the diagnostic.

One means to cause an authentication to occur is for the STA's SME to issue an MLME-DEAUTHENTICATE.request primitive to deauthenticate from the current AP, and an MLME-AUTHENTICATE.request primitive to authenticate to the AP indicated in the Diagnostic Request element. If successful, the STA shall issue an MLME-(RE)ASSOCIATE.request primitive to associate with the AP indicated in the Diagnostic Request element. If successful, the STA's SME shall then issue an MLME-DEAUTHENTICATE.request primitive to deauthenticate from the AP indicated in the Diagnostic Request element, reassociate with the AP from which it received the Diagnostic Request, and issue an MLME-DIAGREPORT.request primitive, indicating the results of the diagnostic.

#### 11.21.3.5 IEEE 802.1X authentication diagnostic

The purpose of the IEEE 802.1X authentication diagnostic is to determine that the STA is able to complete an IEEE 802.1X authentication with a designated BSS. This test directs an association and IEEE 802.1X authentication to be completed with a specific AP. If a STA that supports diagnostic reporting also supports RSN, the STA shall support the IEEE 802.1X authentication diagnostic.

To initiate the test, an AP that supports diagnostic reporting shall send a Diagnostic Request frame containing a Diagnostic Request Type field set to 4 (i.e., IEEE 802.1X Authentication Diagnostic) to a STA that supports diagnostic reporting. A STA that supports diagnostic reporting in an IBSS or an AP that supports diagnostic reporting shall not send an IEEE 802.1X authentication diagnostic request with a designated BSS that is not part of the ESS, or IBSS and a STA that supports diagnostic reporting which receives a diagnostic request shall reject requests to perform diagnostics on other networks. The AP, EAP method and credential type values included in the AP Descriptor, EAP Method and Credential Type subelements in the Diagnostic Request element shall be used to complete the association and IEEE 802.1X authentication.

Upon receipt of the Diagnostic Request frame containing a Diagnostic Request element specifying an IEEE 802.1X Authentication Diagnostic request, the STA determines whether to accept the request. If the STA

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declines the request, it shall send a Diagnostic Report frame with the Status field of a Diagnostic Report element set to Refused. If the STA accepts the request, it shall cause an IEEE 802.1X authentication to occur to the AP indicated in the Diagnostic Request element and the STA's SME shall issue an MLME-DIAGREPORT.request primitive indicating the results of the diagnostic.

One means to cause an authentication to occur is for the STA's SME to issue an MLME-DEAUTHENTICATE.request primitive to deauthenticate from the current AP, and an MLME-AUTHENTICATE.request primitive to authenticate to the AP indicated in the Diagnostic Request element. If successful, the STA shall issue an MLME-(RE)ASSOCIATE.request primitive to the AP indicated in the Diagnostic Request element. If (re)association succeeds, the STA shall try to complete IEEE 802.1X authentication using parameters specified in the Diagnostic Request element. The STA shall then issue an MLME-DEAUTHENTICATE.request primitive to deauthenticate from the AP indicated in the Diagnostic Request element, reassociate with the AP from which it received a diagnostic request, and issue an MLME-DIAGREPORT.request primitive, indicating the results of the diagnostic.

### 11.21.4 Location track procedures

#### 11.21.4.1 Location track configuration procedures

A STA with dot11LocationTrackingActivated equal to true shall support location tracking and shall set to 1 the Location field of the Extended Capabilities elements that it transmits.

In an infrastructure BSS, a non-AP STA shall not transmit Location Configuration Request frames.

A STA that supports location may configure another STA to transmit Location Track Notification frames for the purpose of tracking the receiving STA's location by sending Location Indication Channels, Location Indication Interval and Location Indication Broadcast Data Rate subelements in a Location Parameters element in a Location Configuration Request frame. The minimum Normal and In-Motion Report Interval in a Location Configuration Request frame is 500 ms.

A STA may transmit the Location Configuration Request frame as a broadcast or individually addressed frame. A STA that supports location and receives a broadcast Location Configuration Request frame shall send a Location Configuration Response frame if the STA does not accept the parameters included in the Location Configuration request; the STA shall not send a Location Configuration Response frame if it accepts the parameters included in the Location Configuration request.

A STA that supports location and receives an individually addressed Location Configuration Request frame shall respond with a Location Configuration Response frame. Upon reception of a new Location Configuration Request frame, the STA shall override any information from a previously received Location Configuration Request frame with the new frame. If all Location Parameter subelements included in the Location Configuration Request frame are successfully configured on the receiving STA, then the STA shall include in the Location Configuration Response frame a single Location Status subelement indicating success. Upon successful configuration, the receiving STA shall start transmitting the Location Track Notification frames based on the Location Configuration Request frame parameters, as described in 11.21.4.2 (Location track notification procedures). If one or more Location Parameter subelements are unsuccessfully configured, then the STA shall include in the Location Configuration Response frame a Location Status subelement for each failed subelement indicating the subelement ID, the status value and the corresponding Location Parameter subelement as described in the paragraphs that follow.

The Location Status subelement has four possible status values: Success, Fail, Refused and Incapable. When the requesting STA receives a Location Configuration Response frame with Location Status indicating anything other than Success, the requesting STA shall assume the original request was not processed and no configuration took effect on the receiving STA and the requesting STA should take appropriate action based on the status value returned.


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For Location Status Fail:

- If the receiving STA has been configured successfully prior to the current Location Configuration Request and continues to transmit Location Track Notification frames based on those parameters, the STA shall respond with its current Location Parameters subelements values.
- If the STA has no previously configured value, the STA shall respond with its minimum Location Parameters subelements that it is capable of supporting.
- The configuring STA may either retry the original request or send an alternate request.

For Location Status Incapable:

- The STA responding to the configuration request may include the minimum Location Parameters subelements that it is capable of supporting.
- The configuring STA shall not send another configuration request matching the previous configuration request while the reporting STA is a member of the same BSS.
- The configuring STA may send an alternate request.

For Location Status Refuse:

- The STA responding to the configuration request may include the minimum Location Parameters subelements that it is capable of supporting.
- The configuring STA may send an alternate request.

The location configuration methods, from highest to lowest precedence, are as follows: 1) an individually addressed Location Configuration Request frame, 2) broadcast Location Configuration Request frame. When a STA receives a new Location Configuration frame at the same or higher precedence than the previous it shall cancel the previous configuration and begin using the newest configuration.

The Location Indication Broadcast Data Rate subelement included in Location Configuration Request frames indicates the target data rate at which the STA shall transmit Location Track Notification frames. The Location Indication Broadcast Data Rate included in the Location Configuration Request frame should be a data rate defined in the basic data rate set.

The Indication Multicast Address field configured in the Location Indication Parameters subelement shall be a multicast locally administered (#1893)MAC address as defined in IEEE Std 802 that is shared across all APs in the same ESS. The STA shall transmit Location Track Notification frames to the Indication Multicast Address with the BSSID field set to the wildcard BSSID. An AP shall discard Location Track Notification frames that are not addressed to the Indication Multicast Address field configured for the ESS.

A non-AP STA shall terminate the transmission of Location Track Notification frames for any of the following reasons:

- The non-AP STA receives a Location Configuration Request frame from the STA to which it is currently associated that includes a Location Parameters element with a Location Indication Parameters subelement specifying an interval of 0.
- The non-AP STA fails to detect any Beacon frames, belonging to the same ESS that originally configured the non-AP STA, for the period specified by (#3198)the ESS detection interval value included in the Location Parameters element transmitted in the Location Configuration Request frame.
- dot11LocationTrackingActivated is false.
- The non-AP STA is disassociated for any reason from the ESS that configured it, including power off, or is configured by a different ESS.
- In an IBSS when the STA detects that it is no longer connected to the other STA that formed the IBSS.

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NOTE—All Public Action frames, including the Location Track Notification frames, are Class 1 frames and the treatment of Public Action frames upon reception by STAs is defined in 11.3 (STA authentication and association).

### 11.21.4.2 Location track notification procedures

Implementation of location track notification is optional for a WNM STA. A STA that implements location track notification has dot11LocationTrackingImplemented equal to true. When dot11LocationTrackingImplemented is true, dot11WirelessManagementImplemented shall be true. A STA in which dot11LocationTrackingActivated is true is defined as a STA that supports location track notification. When location track notification is supported, a STA configured by another STA as described in the previous subclause shall transmit Location Track Notification frames as shown in Figure 11-39 (STA transmission on three channels, three frames per channel with Normal Report Interval).

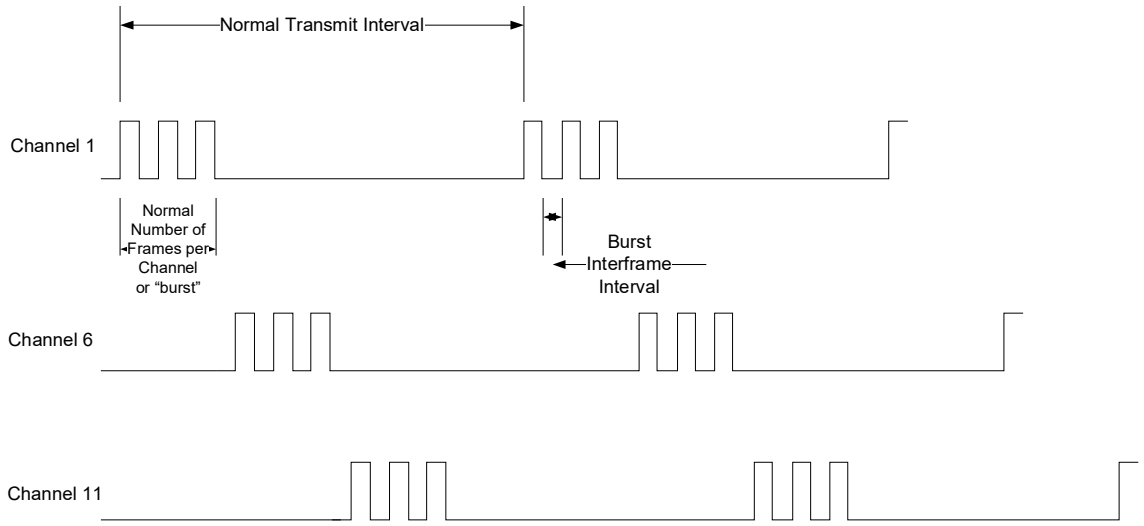


**Figure 11-39—STA transmission on three channels, three frames per channel with Normal Report Interval**

Implementation of Motion Detection or the Time of Departure reporting is optional for a WNM STA. A STA that implements motion detection shall set dot11MotionDetectionImplemented to true. When dot11MotionDetectionImplemented is true, dot11WirelessManagementImplemented shall be true. A STA with dot11MotionDetectionActivated equal to true shall support motion detection. A STA that implements the time of departure capability shall set its dot11TODImplmented to true. When dot11TODImplemented is true, dot11WirelessManagementImplemented shall be true. A STA with dot11TODActivated equal to true shall support time of departure for location tracking.

The STA transmits Location Track Notification frames based on the following parameters and procedures described in 11.21.4.1 (Location track configuration procedures):

a) Location Indication Channels. This subelement indicates the channels on which the STA shall transmit Location Track Notification frames.

b) Indication Multicast Address

   1) A non-IBSS STA shall transmit the Location Track Notification frames to the Indication Multicast Address field in the Location Indication Parameters subelement configured by the Location Configuration Request frame.

   2) An AP shall discard any Location Track Notification frame received from a STA that does not match the Indication Multicast Address field value for the AP's ESS.


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3) An IBSS STA shall transmit the Location Track Notification frames to the destination address of the STA that configured the STA using Location Configuration Request frames.

c) Location Indication Interval

1) When the STA is stationary or dot11MotionDetectionActivated is false, the STA shall transmit a sequence of groups of Location Track Notification frames on each channel. Each group of frames shall contain Normal Number of Frames Per Channel field frames. The first frame in each group of Location Track Notification frames shall be separated from the first frame in the previous group of Location Track Notification frames by a minimum duration indicated by the value of the Normal Report Interval field times the value of the Normal Report Interval Units field.

2) When the STA is in motion and dot11MotionDetectionActivated is true, the STA shall transmit a sequence of groups of Location Track Notification frames on each channel. Each group of frames shall contain In-Motion Number of Frames Per Channel field frames. The first frame in each group of Location Track Notification frames shall be separated from the first frame in the previous group of Location Track Notification frames by a minimum duration indicated by the value of the In-Motion Report Interval field times the value of the In-Motion Report Interval Units field.

NOTE 1—The exact criteria and mechanism to detect motion is out of scope for this standard.(#7142)

3) If a STA is configured to transmit on multiple channels, the STA shall transmit the frames on a single channel before continuing onto the next channel in the configured list of channels.

4) All Location Track Notification frames transmitted on a single channel shall be transmitted with a minimum gap specified by the Burst Interframe Interval field.

5) A STA can never be stationary and in-motion at the same time, and therefore only the Normal Interval field or the In-Motion Interval field apply at any given moment.

d) Tracking Duration

1) The STA shall transmit Location Track Notification frames until the Tracking Duration duration is reached.

2) The duration starts as soon as the STA sends a Configuration Location Response frame with a Location Status value of Success.

3) If the Tracking Duration is a nonzero value the STA shall transmit Location Track Notification frames, based on the Normal and In-Motion Report Interval field values, until the duration ends or is configured to terminate transmission as described in 11.21.4.1 (Location track configuration procedures).

4) If the Tracking Duration is 0 the STA shall continuously transmit Location Track Notification frames as defined by Normal and In-Motion Report Interval field values until configured to terminate transmission as described 11.21.4.1 (Location track configuration procedures).

e) ESS Detection

1) The ESS Detection Interval field is specified in the Location Indication Parameters subelement configured by the Location Configuration Request frame. The (#3197)ESS detection interval defines how often the STA should check for beacons transmitted by one or more APs belonging to the same ESS that configured the STA.

2) If no beacons from the ESS are received during this interval, the STA shall terminate transmission of Location Track Notification frames.

f) Location Indication Options

1) The RM Enabled Capabilities element contained in (Re)Association Request frames indicates the STA's ability to perform radio measurements as described in 9.4.2.43 (RM Enabled Capabilities element). The Location Indication Options subelement Options Used field Beacon Measurement Mode Used bit shall be set to 0 by the AP when the RM Enabled Capabilities

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element bits (defined in Table 9-218 (RM Enabled Capabilities definition)), Beacon Passive Measurement Capability Enabled, Beacon Active Measurement Capability Enabled and Beacon Table Measurement Capability Enabled are all set to 0. If any of RM Enabled Capabilities element bits Beacon Passive Measurement capability enabled, Beacon Active Measurement Capability Enabled or Beacon Table Measurement Capability Enabled are equal to 1 then the Location Indication Options subelement Options Used field Beacon Measurement Mode Used bit may be set to 1.

2) If the Location Indication Options subelement is included and the Options Used field with the Beacon Measurement Mode Used bit equal to 1 in the most recently received Location Configuration Request frame, the STA shall include in the Location Track Notification frames, the result of the most recent successful beacon measurement that was performed using the requested Beacon Measurement Mode contained in the Location Indications Options subelement.

3) If the STA has never performed a successful beacon measurement using the requested Beacon Measurement Mode prior to transmission of the Location Track Notification frame, the STA shall perform the beacon measurement using the requested Beacon Measurement Mode and include the results of that measurement in Location Track Notification frames.

4) After a successful Location Configuration Request frame that included the Location Indication Options subelement and Options Used field with Beacon Measurement Mode Used bit equal to 1, a STA should continue to perform beacon measurement as defined by the Beacon Measurement Mode periodically. How often and under what circumstances the STA performs this measurement is out of scope of this standard.

5) Whenever a STA includes the beacon measurement in the Location Track Notification frames, the STA shall set the Measurement Token field in the Measurement Report element to the same value as the Dialog Token field in the Location Configuration Request frame that initiated the transmission of the location track notification frames by the STA.

6) If the Location Indication Options subelement is not included in the most recently received Location Configuration Request frame or the Location Indication Options subelement is included with the Options Used field with Beacon Measurement Mode Used bit equal to 0, the STA shall not include any beacon measurements in the Location Track Notification frame

g) Location Indication Broadcast Data Rate. The STA shall transmit Location Track Notification frames at the data rate specified in this subelement.

h) Time of Departure

1) If dot11TODActivated is true, the STA shall transmit this subelement in the Location Track Notification frame.

2) In all location tracking frames transmitted by a STA following a successful configuration, the Time of Departure subelement TOD Clock Rate field shall be set to the same value.

3) If the STA has multiple antennas, it shall transmit using an approximation to an omnidirectional pattern.

NOTE 2—The values of the fields in the Time of Departure subelement are measured by the PHY in real time, then passed without real-time requirements to the MAC via the TXSTATUS parameter list in the PHY-TXSTART.confirm primitive.

The diagram in Figure 11-39 (STA transmission on three channels, three frames per channel with Normal Report Interval) shows an example of Location Track Notification frame transmission, for a STA configured to transmit on three channels, with three frames per channel. In this example, a Normal Transmit Interval and Normal number of frames per channel are shown. When a STA is capable of motion detection and is in motion, the In-Motion Report Interval and In-Motion number of frames per channel would apply.


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### 11.21.5 Timing measurement procedure

Implementation of timing measurement is optional for a WNM STA. A STA in which dot11TimingMsmtActivated is true is defined as a STA that supports timing measurement.

A STA in which dot11TimingMsmtActivated is true shall set the Timing Measurement field of the Extended Capabilities element to 1.

A STA in which dot11TimingMsmtActivated is false shall set the Timing Measurement field of the Extended Capabilities element to 0.

A STA that supports the timing measurement procedure may transmit a Timing Measurement Request frame to a peer STA to request it to initiate or to stop an ongoing timing measurement procedure, depending on the Trigger field in the request frame. See Figure 11-40 (Timing measurement procedure(M13)).

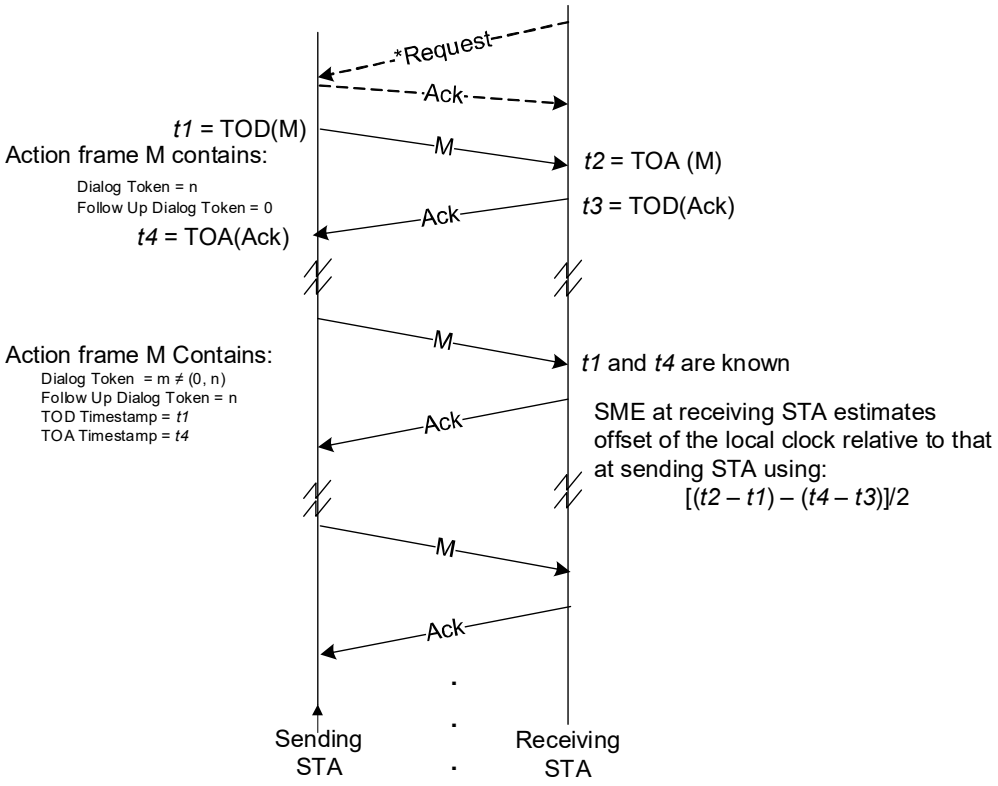


**Figure 11-40—Timing measurement procedure(M13)**

A STA that supports the timing measurement procedure may transmit Timing Measurement frames addressed to a peer STA that also supports the timing measurement procedure. One higher-layer protocol for synchronizing a local clock time between STAs using this feature is specified in IEEE Std 802.1AS.

For non-DMG STAs, both the Timing Measurement frame and the corresponding Ack frame shall be transmitted using a single transmit chain.

A sending STA transmits Timing Measurement frames in overlapping pairs. The first Timing Measurement frame of a pair contains a nonzero value in the Dialog Token field. The follow up Timing Measurement frame contains a Follow Up Dialog Token field set the value of the Dialog Token field in the first frame of the pair.

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With the first Timing Measurement frame, both STAs capture timestamps. The sending STA captures the time at which the Timing Measurement frame is transmitted (t1). The receiving STA captures the time at which the Timing Measurement frame arrives (t2) and the time at which the Ack frame response is transmitted (t3). The sending STA captures the time at which the Ack frame arrives (t4).(#1114) In the follow up Timing Measurement frame, the sending STA transfers the timestamp values it captured (t1 and t4) to the receiving STA.

NOTE 1—A Timing Measurement frame can contain nonzero values in both the Dialog Token and Follow Up Dialog Token fields, meaning that the Action frame contains follow up information from a previous measurement, and new Timestamp values are captured to be sent in a future follow up Timing Measurement frame.

The offset of the clock at the receiving STA with respect to the clock at the sending STA is calculated using Equation (11-4) (assuming a symmetric wireless channel).(#1114)

$$\textit{Clock offset at receiving STA relative to sending STA} = [(t2 - t1) - (t4 - t3)]/2 \quad (11\text{-}4)$$

NOTE 2—An example of state machines and other computations for synchronizing a local clock time between IEEE 802.11 STAs using the values of t1, t2, t3, and t4 provided by the Timing Measurement feature is found in Clause 12 of IEEE Std 802.1AS-2020.

The acknowledgment procedure for Timing Measurement frames is the same as that for other Management frames (see 10.3.2.11 (Acknowledgment procedure)). If the Ack frame for a transmitted Timing Measurement frame is not received, the sending STA may retransmit the frame. The sending STA shall capture a new set of timestamps for the retransmitted frame and its Ack frame.

On receiving a Timing Measurement frame with a Dialog Token for which timestamps have previously been captured, the receiving STA shall discard previously captured timestamps and capture a new set of timestamps.

### 11.21.6 FTM procedure(#7065)

#### 11.21.6.1 General(11az)

The FTM procedure allows a STA to determine its range, relative range, and its direction to or from another STA using time of flight (TOF), time difference of arrival (TDOA), and phase measurement. In order for a STA to obtain its location, the STA may perform this procedure with multiple STAs whose locations are known.

An FTM session is an instance of an FTM procedure between an ISTA and an RSTA along with the associated scheduling and operational parameters (see 9.4.2.166 (FTM Parameters element(11az)) and 9.4.2.300 (Ranging Parameters element(11az))). An FTM session is composed of a negotiation, measurement exchange, and termination.

An RSTA might be required to establish overlapping FTM sessions with a large number of ISTAs (e.g., an AP providing measurements to STAs at a mall or a store). On the other hand, an ISTA might have multiple ongoing FTM sessions on the same or different channels with different RSTAs, while being associated with an AP for the exchange of data or signaling.

Since some of the ISTA's activities may be nondeterministic and might have higher precedence than the FTM session (e.g., data transfer interaction with an associated AP), a conflict might prevent the ISTA from being available at the scheduled time window(s) for executing the ranging measurement exchange(s). The FTM procedure provides mechanisms as described in 11.21.6.1.1 (EDCA based Ranging and TB ranging overview) and 11.21.6.1.2 (Non-TB ranging overview) to ensure that the ISTA is available to execute the ranging measurement exchange as scheduled.


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#### 11.21.6.1.1 EDCA based Ranging and TB ranging overview

To support the constraints of both the initiating and responding STAs, during negotiation the ISTA initially

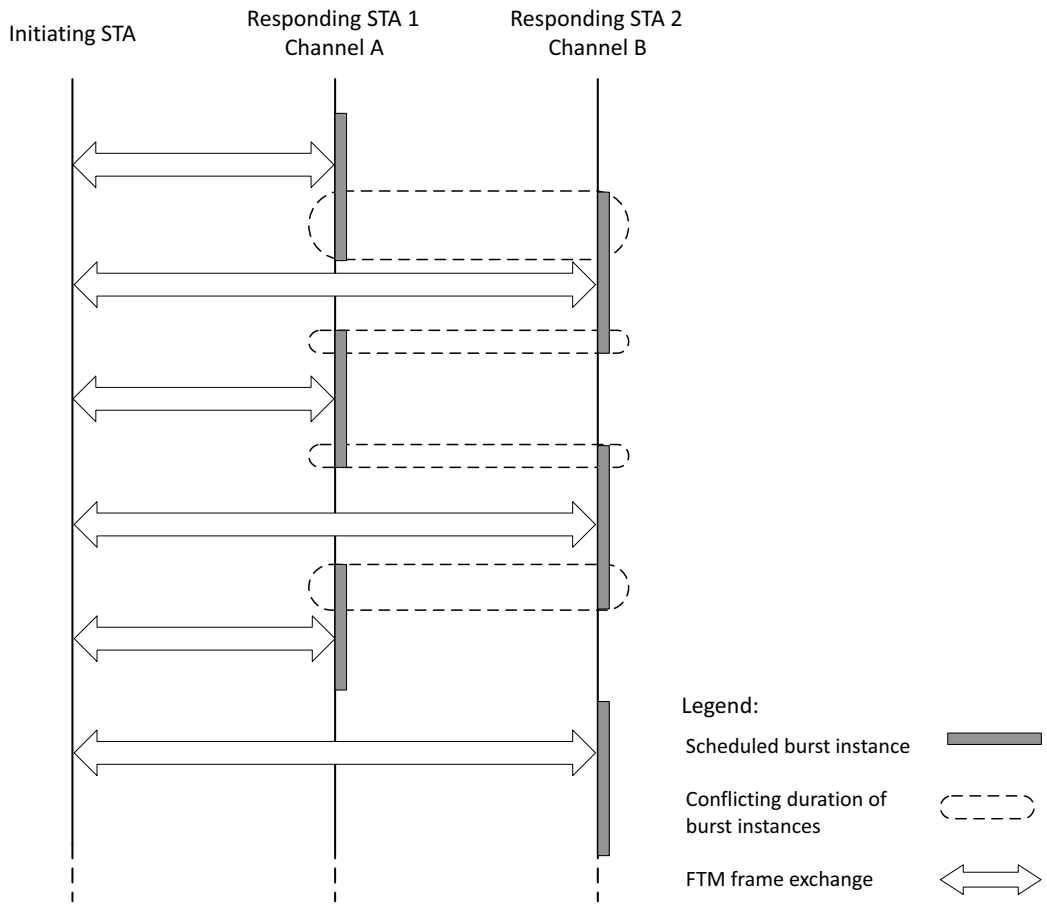


**Figure 11-41—Concurrent FTM sessions(11az)**

requests a preferred periodic time window allocation. The RSTA subsequently responds by accepting or overriding the allocation request based on its resource availability and capability.

The ISTA in Figure 11-41 (Concurrent FTM sessions(11az)) establishes sessions with RSTA 1 and RSTA 2 on different channels. Since the ISTAs may not be able to be on channel (for instance, the ISTA is in the middle of some other activity) at the start of the negotiated time window (i.e., burst instance in the case of EDCA based ranging measurement exchange or availability window in the case of TB ranging measurement exchange (11.21.6.4.3 (TB ranging measurement exchange(11az))) to execute the measurement exchange, within each instance of the negotiated time window, the ISTA indicates whether it is available to start the measurement exchange.

— In EDCA based ranging measurement exchange the ISTA indicates its availability to start the measurement exchange by sending an FTM Request frame with the Trigger field set to 1 during the corresponding burst instance.

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— In TB ranging measurement exchange (11.21.6.4.3 (TB ranging measurement exchange(11az))), the ISTA indicates its availability to start the measurement exchange by responding to the Poll Ranging Trigger from the RSTA.

### 11.21.6.1.2 Non-TB ranging overview

Non-TB ranging measurement exchange is used by the ISTA to determine the measurement timing, based on its scheduling conflicts with other activities and the availability window parameters to identify the availability window instance, which is a time window referenced to the end of the previous measurement instance. During this measurement time window, the ISTA may come to the channel at any time and use contention based access to initiate a new measurement exchange. Because of conflict arising due to other activities, the ISTA does not start measurement at start of availability window while the RSTA waits for the start of measurement exchange. Figure 11-42 (Non-TB ranging concurrent FTM sessions(11az)(#8113)) shows an example of concurrent non-TB ranging sessions. The dotted region indicates that the non-TB ranging measurement exchange does not always start at the beginning of the time window since the ISTA may have been active on another channel.

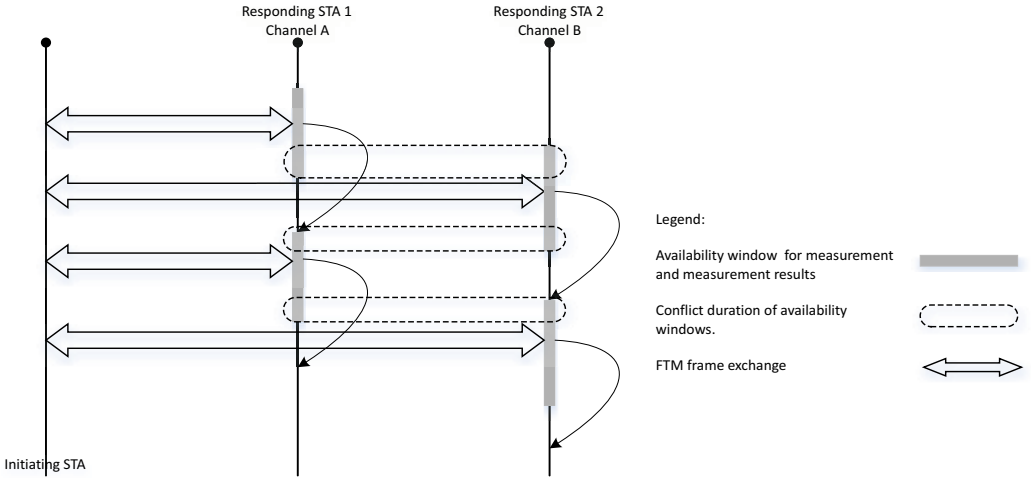


**Figure 11-42—Non-TB ranging concurrent FTM sessions(11az)(#8113)**

The ISTA in Figure 11-42 (Non-TB ranging concurrent FTM sessions(11az)(#8113)), establishes sessions with RSTA 1 and RSTA 2 on different channels. Scheduling of each availability window instance is determined by the timing of the previous measurement instance with the corresponding RSTA. The constraints for an ISTA to initiate the non-TB ranging measurement exchange with each RSTA may be different. The RSTAs shall remain available within the entire availability window instance for the ISTA to initiate the non-TB ranging measurement exchange.

### 11.21.6.1.3 Passive TB ranging overview

Passive TB ranging is a variant of the TB ranging mode referred to in 11.21.6 (FTM procedure(#7065)). In all aspects, except where explicitly stated differently, the passive TB ranging mode, its protocols, procedures, components, and definitions follow the rules for TB ranging.

The rules and procedures related to the use of (#7186)management frame protection and secure HE-LTF in the TB ranging protocol does not apply to passive TB ranging.


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NOTE 1—For example, the text in the following subclauses, and their subclauses, apply also to passive TB ranging:

- Subclause 11.21.6.1.1 (EDCA based Ranging and TB ranging overview)
- Subclause 11.21.6.3.3 (Negotiation for TB and non-TB ranging measurement exchange)
- Subclause 11.21.6.4.3 (TB ranging measurement exchange(11az))
- Subclause 11.21.6.5 (FTM parameter modification(11az))
- Subclause 11.21.6.5.1 (Availability window parameter modification(11az))
- Subclause 11.21.6.6.2 (TB ranging and non-TB ranging session termination(11az))

NOTE 2—Below is a list of example exceptions for passive TB ranging where it does not follow the rules for TB ranging:

- The rules and procedures specific for the secure version of TB ranging does not apply to passive TB ranging.
- The RSTA uses the Ranging Trigger frame of subvariant Passive Sounding for its sounding trigger frames.
- The ISTAs use HE Ranging NDPs for their I2R NDPs.
- The ISTAs do not use the LMR frame for reporting of I2R LMR but instead use the ISTA Passive TB Ranging Measurement Report frame.
- The RSTA sends the Primary and Secondary RSTA Broadcast Passive TB Ranging Measurement Report frames at the end of the measurement exchange.
- The number of spatial streams (NSTS) for passive TB ranging is limited to 4.
- When phase shift feedback is negotiated for passive TB ranging, both the RSTA and the ISTA measure and report PSTOAs, in addition to measuring and reporting TOAs.

The passive TB ranging mode consists of ranging exchanges between an RSTA and a set of ISTAs. These ranging exchanges and associated measurement reporting are set up such that an RSTA or ISTA can listen in to them and use the ranging exchanges and reported ranging measurements to estimate its differential distance to pairs formed by RSTAs and/or ISTAs. The listening STA, a passive STA (PSTA), is not itself an active transmitting participant in the ranging exchanges. That is, the PSTA can passively estimate its differential distances to the pairs of RSTAs and/or ISTAs. For a detailed description of how this differential distance can be calculated; see 11.21.6.4.8.3 (Passive TB ranging measurement sounding phase(11az)). It can then use these differential distances together with knowledge of the RSTA and ISTA locations to estimate its own location.

The RSTA centric scheduling for passive TB ranging operation operates as the RSTA centric scheduling for TB ranging operation referred to in 11.21.6.1.1 (EDCA based Ranging and TB ranging overview). The availability window is here referred to as a passive TB ranging availability window. The passive TB ranging is scheduled by the RSTA in an availability window used for passive location.

In order to announce the scheduling and parameters of the availability window for passive TB ranging, the RSTA includes an RSTA Availability Window element (see 9.4.2.299 (RSTA Availability Window element(11az))) in its Beacon frame (see 9.3.3.2 (Beacon frame format)). Here, the Availability Window Broadcast Format subfield in the Header subfield in the RSTA Availability Information field in the RSTA Availability Window element is set to 1 to indicate that this is an RSTA Availability Window element that is used to signal availability windows for passive TB ranging.

The purpose of the announcement of the availability window for the passive TB ranging is to enable PSTAs to listen to the passive TB ranging exchanges that are occurring during the availability windows.

Consider passive TB ranging between a set of RSTAs and a set of ISTAs as depicted in Figure 11-43 (Example of passive TB ranging used for PSTA location—RSTA1 (AP1) operating passive TB ranging(11az)). Here, three access points, AP1, AP2, and AP3, act as three passive TB ranging responder stations, RSTA1, RSTA2, and RSTA3. RSTA1 operates ranging exchanges in an availability window for passive TB ranging and is performing passive TB ranging exchanges with ISTA1, ISTA2, ISTA3, ISTA4, ISTA5, and ISTA6.

The PSTA is depicted, with the dashed arrows, as listening in to the passive TB ranging exchange between RSTA1 and ISTA4. Generalizing, the PSTA has the opportunity to receive the transmissions of all passive TB

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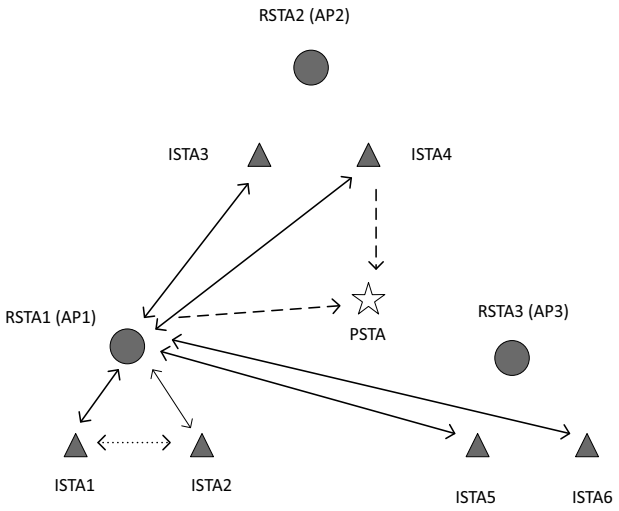


**Figure 11-43—Example of passive TB ranging used for PSTA location—RSTA1 (AP1) operating passive TB ranging(11az)**

ranging exchanges occurring. The reception of each of these ranging exchange transmissions enables the PSTA to estimate its differential distance with respect to the RSTA–ISTA pair and use this information towards its location estimation.

In addition to the ranging exchanges between the ISTAs and RSTA1, the passive TB ranging protocol also allows the same ISTAs to measure time of arrivals of each other's ranging NDPs. An example of one such occurrence is depicted in Figure 11-43 (Example of passive TB ranging used for PSTA location—RSTA1 (AP1) operating passive TB ranging(11az)) in the form of the dotted double arrow between ISTA1 and ISTA2.

Furthermore, if one of the other APs in Figure 11-43 (Example of passive TB ranging used for PSTA location—RSTA1 (AP1) operating passive TB ranging(11az)) temporarily takes on the role of being an ISTA, it may also participate in RSTA1's passive TB ranging operation and perform passive TB ranging exchanges with RSTA1.

At other time intervals, RSTA2 and RSTA3 may operate their own passive TB ranging exchanges in their own availability windows. In each case, the ISTAs may perform passive TB ranging exchanges with RSTA2 or RSTA3.

Each of the access points operating as RSTA1, RSTA2, and RSTA3, announces the timing and bandwidth of its ranging availability window for passive TB ranging in its beacon in an RSTA Availability Window element. By listening to the AP's beacons, the PSTA acquires this information for the different RSTA availability windows for passive TB ranging.

The PSTA listens to all of these ranging exchanges. Considering all ranging exchanges between all RSTAs and all ISTAs, the PSTA has the opportunity to overhear a large set of ranging exchanges between RSTAs and ISTAs in different locations, enabling the use of all of them towards its location estimation and also mitigating non-LOS issues between the ISTA(s)/RSTA involved in the ranging measurements.


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The locations of the RSTA–ISTA or ISTA–ISTA pairs together with their differential distance with respect to the PSTA, generates a set of hyperbolic curves to which the PSTAs location is constrained. The intersection of these hyperbolic curves, or the best approximation to their intersection, is then an estimate of the PSTA's location.

### 11.21.6.2 FTM capabilities

Implementation of FTM is optional for a WNM STA. A STA in which dot11FineTimingMsmtRespActivated is true is defined as a STA that supports FTM as a responder. A STA in which dot11FineTimingMsmtInitActivated is true is defined as a STA that supports FTM as an initiator.

When dot11FineTimingMsmtRespActivated is true, dot11WirelessManagementImplemented shall be true. When dot11FineTimingMsmtInitActivated is true, dot11WirelessManagementImplemented shall be true.

A STA in which dot11FineTimingMsmtRespActivated is true shall set the (#7065)FTM Responder field of the Extended Capabilities element to 1.

A STA in which dot11FineTimingMsmtInitActivated is true shall set the (#7065)FTM Initiator field of the Extended Capabilities element to 1.

A STA in which dot11FineTimingMsmtRespActivated is false shall set the (#7065)FTM Responder field of the Extended Capabilities element (11az)for non-DMG STA or the (#7065)FTM Responder subfield of the DMG Fine Timing and Range Measurement Capability Information field of the DMG Capabilities element for DMG STA to 0.

(11az)A STA in which dot11FineTimingMsmtInitActivated is false shall set the (#7065)FTM Initiator field of the Extended Capabilities element (11az)for non-DMG STA or the (#7065)FTM Initiator subfield of the DMG Capabilities element for DMG STA to 0.

(11az)A STA in which dot11NonTriggerBasedRangingRespImplemented is true shall set the Non-TB Ranging Responder field of the Extended Capabilities element to 1. Otherwise, it shall set the Non-TB Ranging Responder field of the Extended Capabilities element to 0.

(11az)A STA in which dot11TriggerBasedRangingRespImplemented is true shall set the TB Ranging Responder field of the Extended Capabilities element to 1. Otherwise, it shall set the TB Ranging Responder field of the Extended Capabilities element to 0.

(11az)A STA in which dot11SecureLTFImplemented is true shall set the Secure HE-LTF Support field of the RSNXE to 1. Otherwise, it shall set the Secure HE-LTF Support field to 0.

(11az)A STA in which dot11RSTARequiresPMFActivated has the value Required (2) shall set the URNM-MFPR field of the RSNXE to 1. Otherwise, it shall set the URNM-MFPR field to 0.

(11az)A STA in which dot11RSTARequiresPMFActivated has the value Required-X20M (1) shall set the URNM-MFPR-X20 field of the RSNXE to 1. Otherwise, it shall set the URNM-MFPR-X20 field to 0.

(11az)A STA in which dot11DMGOptionImplemented is true and dot11FineTimingMsmtRespActivated is true shall set the (#7065)FTM Responder subfield of the DMG Fine Timing and Range Measurement Capability Information field to 1.

(11az)A STA in which dot11DMGOptionImplemented is true and dot11FineTimingMsmtInitActivated is true shall set the (#7065)FTM Initiator subfield of the DMG Fine Timing and Range Measurement Capability Information field to 1.

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(11az)A STA in which dot11PassiveTBRangingResponderImplemented is true shall set the Passive TB Ranging Responder Measurement Support field of the Extended Capabilities element to 1. Otherwise, it shall set the Passive TB Ranging Responder Measurement Support field of the Extended Capabilities element to 0.

(11az)A STA in which dot11PassiveTBRangingInitiatorImplemented is true shall set the Passive TB Ranging Initiator Measurement Support field of the Extended Capabilities element to 1. Otherwise, it shall set the Passive TB Ranging Initiator Measurement Support field of the Extended Capabilities element to 0.

(11az)A STA shall set the Phase Shift Feedback Support field in the Extended Capabilities element to 1 if dot11PhaseShiftFeedbackImplemented is true and one of the following is true:

— dot11TriggerBasedRangingRespImplemented
— dot11NonTriggerBasedRangingRespImplemented
— dot11PassiveTBRangingInitiatorImplemented
— dot11PassiveTBRangingResponderImplemented

(11az)Otherwise it shall set the Phase Shift Feedback Support field in the Extended Capabilities element to 0.

(11az)A STA in which either dot11NonTriggerBasedRangingRespImplemented is true or dot11TriggerBasedRangingRespImplemented is true shall set the I2R LMR Feedback Policy field of the Extended Capabilities element to 1 if dot11I2RLMRFeedbackPolicy is true. The STA shall set the I2R LMR Feedback Policy field of the Extended Capabilities element to 0 if dot11I2RLMRFeedbackPolicy is false.

(11az)An RSTA in which dot11PhaseShiftFeedbackImplemented is true shall set the Phase Shift TOA Feedback Support field in the Extended Capabilities element to 1 to indicate the RSTA's capability to support phase shift TOA feedback in the R2I LMR.

### 11.21.6.3 FTM procedure negotiation(11az)

#### 11.21.6.3.1 General

In order to initiate an FTM procedure, a STA that supports the FTM procedure as an initiator (referred to as an ISTA) shall transmit an FTM Request frame. This frame is called the IFTMR frame. After transmission of this frame, the ISTA shall be ready to receive an FTM frame.

A STA that supports the FTM procedure as a responder (referred to as an RSTA) shall not transmit FTM frames addressed to a peer STA unless the RSTA has received an IFTMR frame from the peer STA.

The first FTM frame in the FTM session is called the initial FTM (IFTM) frame. The RSTA should transmit an IFTM frame within 10 ms in response to the IFTMR frame. This IFTM frame shall include either an FTM Parameters element or a Ranging Parameters element. The value of the Status Indication field indicates the outcome of the request.

NOTE 1—In an IFTM frame, the RSTA might indicate that the request for an FTM session is successful, even if the IFTM frame includes at least one of the following:

— A Measurement Report element that indicates an unknown LCI.
— A Measurement Report element that indicates an unknown civic location.

NOTE 2—If the ISTA and the RSTA are associated, the channel bandwidth used in the frame exchanges between the ISTA and the RSTA during the ranging measurement exchange is constrained by the rules listed in 10.6.5.8 (Rate selection for other individually addressed Data and Management frames) and in 10.6.6.6 (Channel Width selection for Control frames).


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If the ISTA and the RSTA are associated, a PTKSA is established as defined in 12.6.1.1.6 (PTKSA), 12.7.6 (4-way handshake), 12.11.2 (FILS authentication protocol), and 13.5 (FT protocol). RSN capabilities MFPC and MFPR determine if the PTKSA between RSTA and ISTA is established or not.

If the ISTA and the RSTA are not associated the PTKSA is established using the preassociation security negotiation mechanism as defined in 12.13 (Preassociation security negotiation(11az)), and conditions to establish the context are defined below.

A secure FTM session is established when an ISTA and an RSTA establish a PTKSA and use it to exchange a Protected FTM Request Action frame, serving as the IFTMR frame, and the corresponding Protected FTM Action frame, serving as the IFTM frame, and the negotiation completes successfully; see 9.6.34 (Protected Fine Timing Action frame details(11az)(#8155)). This applies to the following cases:

— A TB ranging measurement exchange.
— A non-TB ranging measurement exchange.
— An EDCA based ranging measurement exchange with a Format And Bandwidth field indicating DMG or EDMG format; see Table 9-325 (Format And Bandwidth subfield).

An ISTA shall not initiate FTM negotiation with a Protected FTM Request Action frame, that is, setup a secure FTM session, unless attempting to negotiate one of the cases listed above. A DMG or EDMG STA may use Protected Fine Timing frames in a DMG or EDMG EDCA based ranging session, respectively.

In the cases listed previously:

— If an RSTA has set the URNM-MFPR field in the RSNXE to 1, regardless of the setting in the URNM-MFPR-X20 field, an ISTA shall establish a PTKSA with that RSTA prior to initiating an FTM procedure negotiation with that RSTA.
— If the RSTA has set the URNM-MFPR-X20 field in the RSNXE to 1, an ISTA shall establish a PTKSA with that RSTA prior to initiating an FTM procedure negotiation with that RSTA unless the Format And Bandwidth subfield of the Ranging Parameters field (see 9.4.2.300 (Ranging Parameters element(11az))) in the IFTMR indicates a 20 MHz Bandwidth.
— An RSTA shall reject an FTM request, if a PTKSA was required, and the ISTA has not successfully set up a PTKSA to allow protection of the FTMR frame, FTM and LMR frames exchanged between the RSTA and the ISTA.

The RSTA may accept the request in the cases not listed above.

#### 11.21.6.3.2 Negotiation for EDCA based ranging measurement exchange

(#8013)The IFTMR frame (see 11.21.6.3 (FTM procedure negotiation(11az)) and its retransmission(s) shall include an FTM Parameters element (see 9.4.2.166 (FTM Parameters element(11az))) with:

— the Trigger field set to 1, and
— a set of scheduling parameters that describe the ISTA's availability for measurement exchange, in the FTM Parameters field.

(#8013)The FTM Parameters field shall not be present in any subsequent FTM Request frames.

In the case when an ISTA requests for a format equal to VHT and/or EDCA based HE and bandwidth equal to 160 MHz (80+80, 160 single RF LO, or 160 two separate RF LOs), the RSTA shall assign the same format and bandwidth as requested by the ISTA for 160 MHz bandwidth, otherwise it shall assign format and bandwidth less than or equal to 80 MHz. An ISTA performing an FTM procedure with an RSTA that is an AP shall support non-ASAP operation. An ISTA performing an FTM procedure with an RSTA that is not an AP shall support ASAP operation.

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The ISTA shall indicate, in the Format And Bandwidth field, a format and bandwidth that it supports, and this may be different from the BSS bandwidth.

NOTE 1—The use of phase relations, per 19.3.11.11.4 (Transmission in 40 MHz HT format) and 21.3.7.5 (Definition of tone rotation), between the 20 MHz parts in non-HT duplicate PPDUs that contain Ack frames transmitted by the ISTA is required to enable the RSTA to accurately determine the TOA of these frames, and is thus required for the ISTA to support FTM using Ack frames transmitted in non-HT duplicate PPDUs. Alternatively, an ISTA that supports transmission of Ack frames in VHT or HT PPDUs in response to FTM frames sent by the RSTA in VHT or HT PPDUs, respectively, is not required to support transmission of Ack frames in non-HT duplicate PPDUs in response to such FTM frames.

The ISTA shall indicate an EDCA based HE format in the Format And Bandwidth field sent to an RSTA if the STAs are operating in the 6 GHz band, at least one of the STAs does not support TB, or does not support non-TB ranging; otherwise the STA shall not indicate an EDCA based HE format in the Format And Bandwidth field.

A STA that supports TB or non-TB ranging is not required to support a Format And Bandwidth value of EDCA based HE.

For EDCA based ranging where the value of the corresponding Format And Bandwidth field value that indicates DMG or EDMG format, see Table 9-325 (Format And Bandwidth subfield), the ISTA shall indicate, in the Ranging Priority subfield of the FTM Parameters field of the FTM Parameters element in the IFTMR frame, its ranging priority as described in Table 9-323 (Definition of the EDMG Ranging Priority subfield when included in the IFTMR frame(11az)). Otherwise, the Ranging Priority subfield of the FTM Parameters field of the FTM Parameters element is reserved.

When the request was successful:

- The RSTA shall indicate, in the Format And Bandwidth field, a format and bandwidth that it supports. The RSTA should indicate the same format and bandwidth in the Format And Bandwidth field as that requested by the ISTA, if the RSTA supports this. The RSTA shall not assign a value that indicates:
  - A bandwidth wider than requested
  - An EDCA based HE format if VHT, DMG, HT mixed, or non-HT format was requested
  - A VHT format if DMG, HT-mixed, or non-HT format was requested
  - An HT format if DMG or non-HT format was requested
  - A DMG format if EDCA based HE, VHT, HT-mixed, or non-HT format was requested
  - An EDCA based HE format only if EDCA based HE was requested, see 26.17.2 (HE BSS operation in the 6 GHz band), and the STA is operating in the 6 GHz band; otherwise the STA shall not indicate EDCA based HE format
  - A VHT (160 with two separate RF LOs) or a VHT (80+80) if a VHT (160 with single RF LO) was requested
  - A VHT (160 with single LO) or a VHT (80+80) if a VHT (160 with two separate RF LOs) was requested
  - A VHT (160 with single LO) or a VHT (160 with two separate RF LOs) if a VHT (80+80) was requested
  - An EDCA based HE (160 with two separate RF LOs) or an EDCA based HE (80+80) if an EDCA based HE (160 with single RF LO) was requested
  - An EDCA based HE (160 with single LO) or an EDCA based HE (80+80) if an EDCA based HE (160 with two separate RF LOs) was requested
  - An EDCA based HE (160 with single LO) or an EDCA based HE (160 with two separate RF LOs) if an EDCA based HE (80+80) was requested


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  - An EDMG format if a DMG format was requested
  - An EDMG OFDM format if an EDMG SC format was requested
- An RSTA that is an AP shall support and select non-ASAP operation when so requested by an ISTA.
- An RSTA that is not an AP shall support and select ASAP operation when so requested by an ISTA.
- If the RSTA is ASAP capable, the RSTA's selection of ASAP should be the same as that requested by the ISTA.
- The RSTA's selection of the Min Delta FTM field value shall be greater than or equal to the value requested by the ISTA.
- The RSTA's selection of the Number of Bursts Exponent field value shall be 0 if the ISTA requested it to be 0.
- The RSTA's selection of the Burst Duration field value should be less than or equal to the one requested by the ISTA if the requested FTMs Per Burst field value is set to a value indicating no preference, subject the recommendations below and the RSTA's policy on the maximum and minimum Burst Duration field values.
- If the Number of Bursts Exponent field is set to 0 and the ASAP field is set to 1, the Burst Duration field value should be set to indicate the value $BD_1$, defined as follows:

$$BD_1 = ((N_{FTMPB} \times (K + 1)) - 1) \times T_{MDFTM} + T_{FTM} + \text{aSIFSTime} + T_{Ack}$$

where

| | |
|---|---|
| $N_{FTMPB}$ | is the value of the FTMs Per Burst field |
| $K$ | is the maximum number of FTM frame retransmissions the RSTA might attempt |
| $T_{MDFTM}$ | is the duration indicated by the Min Delta FTM field of the FTM Parameters field of the IFTM frame (FTM_1) |
| $T_{FTM}$ | is the duration of the IFTM frame if the FTMs Per Burst field of the FTM Parameters field of FTM_1 is set to 1, and the duration of the non IFTM frame otherwise |
| $T_{Ack}$ | is the duration of the Ack frame expected as a response |

- Otherwise, the Burst Duration field value should be set to indicate a value greater than or equal to the following value:

$$BD_1 + T_{FTMR} + \text{aSIFSTime} + T_{Ack} + T_{ACCESS\_FTM}$$

where

| | |
|---|---|
| $T_{FTMR}$ | is the duration of an FTM Request frame without a Measurement Request element and without an FTM Parameters element |
| $T_{ACCESS\_FTM}$ | is the estimated medium access time for the first FTM frame in a burst |

- The RSTA's selection of the value of the FTMs Per Burst field should be the same as the one requested by the ISTA if the requested value of the Burst Duration field is set to a value indicating no preference, see Table 9-322 (Burst Duration subfield encoding), subject to the RSTA's policy on the maximum value of the FTMs Per Burst field.
- The RSTA's selection of Burst Period shall be greater than or equal the RSTA's selection of Burst Duration.
- When the Format And Bandwidth subfield indicates DMG or EDMG format, the RSTA's setting of the Ranging Priority is as defined in Table 9-324 (Definition of the EDMG Ranging Priority subfield when included in the IFTM frame(11az)).

NOTE 2—Apart from the Status Indication, Value, ASAP, Number of Bursts Exponent, Min Delta FTM, and Burst Period fields, the other fields in the FTM Parameters element in the IFTM frame have no constraints.

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When the RSTA cannot support the initiator's Min Delta FTM or Number of Bursts Exponent constraints, the RSTA shall set the Status Indication field to Request incapable and the FTM session ends. When the RSTA is unable to fulfill the request by the ISTA, the RSTA shall set the Status Indication field to Request failed and the FTM session ends.

#### 11.21.6.3.3 Negotiation for TB and non-TB ranging measurement exchange

For TB and non-TB ranging Measurement exchange the IFTMR frame shall have:

— The Trigger field set to 1.

— A set of scheduling parameters in a Ranging Parameters element that describe the ISTA's availability for measurement exchange.

For TB and non-TB ranging measurement exchange, the IFTM frame shall include a Ranging Parameters element containing either the non-TB specific subelement, or the TB specific subelement.

The ISTA shall include one ISTA Availability Window element in the TB specific subelement in the IFTMR frame indicating its availability for TB ranging as well as the requested periodicity. The periodicity of the availability windows requested by the ISTA is expressed in units of 10 TUs in the Count subfield in the ISTA Availability Information field of the ISTA Availability Window element. The value of the Count subfield in the ISTA Availability Information field of the ISTA Availability Window element shall be a multiple of the Beacon Interval of the RSTA in units of 10 TUs.

When the RSTA sets the Status Indication field in an IFTM frame to 1 (#8025)(Success), it shall not include a Non-TB Specific subelement or TB-specific subelement, if the same subelement was not also included in the IFTMR frame by the ISTA.

When the RSTA includes a TB-specific subelement in an IFTM frame and the Status Indication field in the IFTM frame is equal to 1, then the RSTA shall include an RSTA Availability Window element in the IFTM frame. The RSTA Availability Information field in the RSTA Availability Window element shall contain exactly one Availability Window Information field. The Availability Window Information field represents the availability window assigned by the RSTA to the ISTA. The Availability Window Broadcast Format subfield in the Header subfield in the RSTA Availability Information field in this RSTA Availability Window element is set to 0.

When the RSTA includes a TB-specific subelement in an IFTM frame and the Status Indication field in the IFTM frame is equal to 1, the subelement contains an AID/RSID field assignment to the ISTA. The RSID and the AID are derived from the same ID number space and are non-conflicting.

When the RSTA includes a TB-specific subelement in an IFTM frame and the Status Indication field in the IFTM frame is equal to 1, the RSTA shall assign the value of the Max Session Exp field in the TB Ranging Specific subelement in the Ranging Parameters element in the initial FTM frame. The value of this field shall be larger than the assigned periodicity signaled in the Periodicity subfield in the Availability Window Information field in the TB ranging Specific subelement.

When a Ranging Parameters element is included in the IFTMR frame, the ISTA shall indicate the following parameters in the Ranging Parameters field:

— Maximum supported bandwidth in the Format And Bandwidth subfield.

— Maximum number of LTF repetitions it is capable of receiving in the preamble of the R2I NDP, in the Max R2I Repetition subfield.

— Maximum number of LTF repetitions it is capable of transmitting in the preamble of the I2R NDP, in the Max I2R Repetition subfield.


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- Maximum number of space-time streams it is capable of receiving in the R2I NDP for bandwidths less than or equal to 80 MHz, in the Max R2I STS ≤ 80 MHz subfield.
- Maximum number of space-time streams it is capable of receiving in the R2I NDP for bandwidths greater than 80 MHz, in the Max R2I STS > 80 MHz subfield.
- Maximum number of space-time streams it is capable of transmitting in the I2R NDP for bandwidths less than or equal to 80 MHz, in the Max I2R STS ≤ 80 MHz subfield.
- Maximum number of space-time streams it is capable of transmitting in the I2R NDP for bandwidths greater than 80 MHz, in the Max I2R STS > 80 MHz subfield.
- Maximum number of LTFs in total it is capable of receiving, including all repetitions, in the R2I NDP, in the Max R2I LTF Total subfield.
- Maximum number of LTFs in total it is capable of transmitting, including all repetitions, in the I2R NDP, in the Max I2R LTF Total subfield.
- Immediate or delayed feedback capability in the I2R LMR by setting the Immediate I2R Feedback subfield to 1 or 0, respectively.

When based on the policy at the ISTA, the ISTA does not share measurement results with the RSTA, the ISTA shall set the I2R LMR Feedback subfield in the Ranging Parameters field, in the IFTMR frame, to 0. Otherwise the ISTA shall set the I2R LMR Feedback subfield to 1.

When the I2R LMR Feedback subfield in the IFTMR frame is equal to 0, and the I2R LMR Feedback Policy field in the Extended Capabilities element is set to 1 by the RSTA, then the RSTA shall not reject the request because the I2R LMR Feedback subfield in the Ranging Parameters field was set to 0, and shall set the I2R LMR Feedback in the IFTM frame to 0.

When the I2R LMR Feedback subfield in the IFTMR frame is equal to 0, and the I2R LMR Feedback Policy field in the Extended Capabilities element is set to 0 by the RSTA, then the RSTA shall set the I2R LMR Feedback subfield to 1 to indicate it requests the ISTA to transmit the I2R LMR, or to 0 otherwise. In the former case, the ISTA may either proceed with measurement exchange; see 11.21.6.4.3 (TB ranging measurement exchange(11az)) and 11.21.6.4.4 (Non-TB ranging measurement exchange(11az)), or terminate the FTM session (see 11.21.6.6 (FTM session termination(11az))).

When the I2R LMR Feedback subfield in the IFTMR frame is equal to 1, then the RSTA shall set the I2R LMR Feedback subfield to 1 to indicate it requests the ISTA to transmit the I2R LMR, or to 0 otherwise.

NOTE 1—The setting of the I2R LMR Feedback subfield to 1 in the Ranging Parameters field in the Ranging Parameters element contained in the IFTMR frame and IFTM frame is based on higher layer agreements.

NOTE 2—(#8190)An RSTA that accepts a ranging request despite the ISTA having set the I2R LMR Feedback subfield in the Ranging Parameters field in the IFTMR frame to 0 enables use cases where the ISTA might share its location information at a higher layer.

When the ISTA sets the I2R AOA Requested subfield to 1 in the IFTMR frame, the RSTA may set the I2R AOA Requested subfield in the corresponding IFTM frame to 1 to confirm that the ISTA shall deliver the I2R AOA measurement result in any transmitted I2R LMR, and set to 0 otherwise.

When the ISTA sets the R2I AOA Requested subfield to 1 in the IFTMR frame, the RSTA may set R2I AOA Requested subfield in the corresponding IFTM frame to 1 to confirm that the RSTA shall deliver R2I AOA measurement results in the R2I LMR, and set to 0 otherwise.

When the ISTA indicated support to announce the TX power of its I2R NDPs by setting the I2R Tx Power field in the Non-TB specific subelement of the Ranging Parameters element in the IFTMR frame to 1, the RSTA may set the corresponding field in the IFTM frame to 1 to request the ISTA to announce the TX power of its I2R NDs, and 0 otherwise.

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When the ISTA requested the RSTA to announce the TX power of its R2I NDPs by setting the R2I Tx Power field in the Non-TB Specific subelement to 1, the RSTA may set the corresponding field in the IFTM frame to 1. Otherwise, the RSTA shall set the R2I Tx Power field to 0.

For TB ranging and non-TB ranging, the ISTA shall indicate, in the Ranging Priority subfield of the Ranging Parameters field of the Ranging Parameters element in the IFTMR frame, its Ranging Priority according to Table 9-323 (Definition of the EDMG Ranging Priority subfield when included in the IFTMR frame(11az)).

For TB ranging, the RSTA shall indicate, in the Ranging Priority subfield of the Ranging Parameters field of the Ranging Parameters element in the IFTM frame, whether it accommodates the ranging priority request transmitted by the ISTA according to Table 9-324 (Definition of the EDMG Ranging Priority subfield when included in the IFTM frame(11az)).

When the negotiation is successful for TB ranging and non-TB ranging, the corresponding IFTM frame from the RSTA shall include a Ranging Parameters element with the parameters that define the negotiated range measurement session. The RSTA shall indicate the following parameters in the Ranging Parameters field(#8022):

a) In the Format And Bandwidth subfield, it assigns the maximum allowed bandwidth used during measurement exchanges (referred to as RSTA Assigned Max Bandwidth). This value shall not be greater than the value in the corresponding IFTMR frame.

b) In the Max R2I Repetition subfield, it assigns the maximum number of HE-LTF repetitions in the preamble of the R2I NDP for this session (referred to as RSTA Assigned R2I Rep). This value shall not be greater than the value in the corresponding IFTMR frame.

c) In the Max I2R Repetition subfield, it assigns the maximum number of HE-LTF repetitions in the preamble of the I2R NDP for this session (referred to as RSTA Assigned I2R Rep). This value shall not be greater than the value in the corresponding IFTMR frame.

d) In the Max R2I STS ≤ 80 MHz subfield, either the maximum number of space-time streams it is capable of transmitting in the R2I NDP for bandwidths less than or equal to 80 MHz, or the value in the corresponding IFTMR frame, whichever is smaller (referred to as RSTA Assigned R2I STS ≤ 80 MHz).

e) In the Max R2I STS > 80 MHz subfield, either the maximum number of space-time streams it is capable of transmitting in the R2I NDP for bandwidths greater than 80 MHz, or the value in the corresponding IFTMR frame (referred to as RSTA Assigned R2I STS > 80 MHz).

f) In the Max I2R STS ≤ 80 MHz subfield, either the maximum number of space-time streams it is capable of receiving in the I2R NDP for bandwidths less than or equal to 80 MHz, or the value in the corresponding IFTMR frame, whichever is smaller (referred to as RSTA Assigned I2R STS ≤ 80 MHz).

g) In the Max I2R STS > 80 MHz subfield, either the maximum number of space-time streams it is capable of receiving in the I2R NDP for bandwidths greater than 80 MHz, or the value in the corresponding IFTMR frame, whichever is smaller (referred to as RSTA Assigned I2R STS > 80 MHz).

h) In the Max R2I LTF Total subfield, either the maximum number of LTFs in total it is capable of transmitting to this ISTA, including HE-LTF repetitions, in the R2I NDP, or the value in the corresponding IFTMR frame, whichever is smaller (referred to as RSTA Assigned R2I LTF Total).

i) In the Max I2R LTF Total subfield, either the maximum number of LTFs in total it is capable of receiving, including HE-LTF repetitions, in the I2R NDP, or the value in the corresponding IFTMR frame, whichever is smaller (referred to as RSTA Assigned I2R LTF Total).

j) Immediate or delayed feedback in the R2I LMR by setting the Immediate R2I Feedback subfield to 1 or 0, respectively.


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An ISTA and an RSTA may negotiate a phase shift feedback mode of the non-TB ranging and TB ranging measurement exchange (11.21.6.4.3 (TB ranging measurement exchange(11az))), for either the R2I LMR and/or I2R LMR. In this case, instead of the TOA t2 of the I2R NDP, the R2I LMR carries the phase shift tp2 of I2R NDP and instead of the TOA t4 of the R2I NDP, the I2R LMR carries phase shift tp4 of R2I NDP. The ISTA and RSTA can use Equation (11-9) and Equation (11-10) to derive the RTT.

NOTE 3—tp2 and tp4 are reported in the same units of time (not angle) as the TOA; see 9.6.7.49 (LMR frame format(11az)(#8216)).

If an RSTA has set the Phase Shift TOA Feedback Support field to 1 in the Extended Capabilities element, then to request phase shift TOA feedback in the R2I LMR, an ISTA shall set the R2I TOA Type subfield in the Ranging Parameter field in an IFTMR frame to 1. To assign phase shift TOA feedback in the R2I LMR the RSTA shall set the R2I TOA subfield in the Ranging Parameter field in an IFTM frame to 1, otherwise it shall set it to 0. If the RSTA sets the R2I TOA Type subfield in the Ranging Parameter field in an IFTM frame to 1, the RSTA shall report the phase shift TOA feedback (tp2 of the I2R NDP) in the R2I LMR.

An ISTA that has set the I2R LMR feedback subfield in the Ranging Parameters field in an IFTMR frame to 1, shall set the I2R TOA Type subfield to 1 to indicate that it supports phase shift TOA feedback in the I2R LMR, and set it to 0 otherwise. When the ISTA indicates that it does not support phase shift TOA feedback in the I2R LMR, then the RSTA shall set the I2R Type subfield to 0 in the IFTM frame. When the ISTA indicates support for phase shift TOA feedback in the I2R LMR, the RSTA shall set the I2R TOA Type subfield in the Ranging Parameters field of an IFTM frame to 1 to assign phase shift TOA feedback in the I2R LMR, otherwise it shall set it to 0. If the RSTA sets the I2R TOA Type subfield in the Ranging Parameters field of an IFTM frame to 1, the ISTA shall report phase shift TOA feedback (tp4 of the R2I NDP) in the I2R LMR.

An RSTA shall reject a request for TB ranging from an ISTA if the RSTA cannot assign the ISTA to an availability window that overlaps with a 10 TU interval in which the ISTA is available (as signaled by the ISTA Availability Window element in the IFTMR frame).

When an RSTA sets the Status Indication field in an IFTM frame to 1 (Successful), it shall include an FTM Synchronization Information element in this IFTM frame.

When the RSTA includes a TB-specific subelement in an IFTM frame and the Status Indication field in the IFTM frame is equal to 2 (Request incapable) or 3 (Request failed), then the RSTA may include an RSTA Availability Window element in the IFTM frame. The RSTA Availability Information field in the RSTA Availability Window element shall contain one or more Availability Window Information fields. Each Availability Window Information field represents an availability window that the RSTA can assign to that ISTA if requested by the ISTA in future. The passive TB ranging availability window bit in this Availability Window Information subfield is set to 0.

When Management Frame Protection is negotiated for TB and non-TB ranging, a STA shall:

— Use Protected Fine Timing Action frames for FTMR frames, FTM frames, and LMR frames for ranging negotiation and measurement
— Discard unprotected variants of these frames upon reception

An RSTA shall reject a request, unless the request is for passive TB ranging, if it has set the URNM-MFPR field of the RSNXE to 1, and the ISTA has not successfully set up a PTKSA to protect IFTMR, IFTM, and LMR frames exchanged between the RSTA and the ISTA.

Upon reception of an IFTMR frame with the Format And Bandwidth subfield set to a value of 3, 4, or 5 representing the ISTA's support for one of the 160 MHz BW options, the RSTA shall respond with the same requested value in the Format And Bandwidth subfield in the IFTM frame, if it supports the requested 160 MHz BW option, otherwise respond with a value less than 3(#8012).

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#### 11.21.6.3.4 Negotiation for secure HE-LTF in the TB and non-TB ranging measurement exchange

An ISTA and an RSTA may activate a secure HE-LTF measurement exchange for non-TB ranging or TB ranging that uses randomized LTF sequences in the I2R NDPs and R2I NDPs, refer to 11.21.6.4.5 (Secure HE-LTF in the TB and non-TB ranging measurement exchange protocol(11az)).

An RSTA in which dot11SecureLTFImplemented is true shall set the Secure HE-LTF Support field in the RSNXE to 1. An ISTA in which dot11SecureLTFImplemented is true shall include the Secure HE-LTF subelement in the Ranging Parameters element in an IFTMR frame.

When an RSTA has set the Secure HE-LTF Support field to 1 in the RSNXE, then to request a secure HE-LTF measurement exchange mode with the RSTA, an ISTA with dot11SecureLTFImplemented equal to true shall include the Secure HE-LTF subelement in the Ranging Parameters element in the IFTMR frame and set the value of the Secure HE-LTF Required field in the Secure HE-LTF subelement to 1.

When an ISTA has included the Secure HE-LTF subelement in the Ranging Parameters element in its IFTMR frame and set the value of the Secure HE-LTF Required field to 1, then the RSTA that has set the value of the Status Indication field to 1 (i.e., Successful) shall include the Secure HE-LTF subelement in the Ranging Parameter element in its IFTM frame and set the value of the Secure HE-LTF Required field to 1 to assign a secure HE-LTF measurement exchange mode with the ISTA.

When an ISTA has included the Secure HE-LTF subelement in the Ranging Parameters element in an IFTMR frame, then to assign a secure HE-LTF measurement exchange mode with the ISTA, an RSTA with dot11SecureLTFImplemented equal to true shall include a Secure HE-LTF subelement in the Ranging Parameters element in an IFTM and set its Secure HE-LTF Required field to 1.

When an ISTA has included the Secure HE-LTF subelement in the Ranging Parameters element in its IFTMR frame and set the value of the Secure HE-LTF Required field to 1, the ISTA shall set the Max R2I Repetition and Max I2R Repetition subfields to a value greater than 0.

When an RSTA assigns a secure HE-LTF measurement exchange by including a Secure HE-LTF subelement in the Ranging Parameters element in its IFTM frame and setting the Secure HE-LTF Required subfield to 1, the RSTA shall set the *RSTA Assigned R2I Rep* to the Max R2I Repetition subfield value in the IFTMR frame which shall be greater than 0, and the RSTA shall set *RSTA Assigned I2R Rep* to a value greater than 0 and less than or equal to the Max I2R Repetition subfield value in the IFTMR frame, where the *RSTA Assigned R2I Rep* and *RSTA Assigned I2R Rep* specify the number of HE-LTF repetitions in the preamble of the R2I and I2R NDP for this session, respectively.

When an ISTA has included the Secure HE-LTF subelement in the Ranging Parameters element in the IFTMR frame, it shall indicate to the RSTA a request to use the optional frequency domain Tx window in the R2I NDPs by setting the R2I Tx Window field to 1, otherwise shall set it to 0; and indicate its support of the optional frequency domain Tx window in the I2R NDPs by setting the I2R Tx Window field to 1, otherwise shall set it to 0.

When an RSTA has assigned a secure HE-LTF measurement exchange mode, by including a Secure HE-LTF subelement in the Ranging Parameters element in the IFTM frame, and setting its Secure HE-LTF Required field to 1, the RSTA shall also include a Secure HE-LTF Parameters element in the IFTM frame that contains the values of the Validation SAC and (#8016)Secure LTF Counter subfields.

The secure HE-LTF negotiation supports negotiation of the secure HE-LTF protocol version; see Table 9-415 (Secure HE-LTF protocol section identifier(11az)), which allows an RSTA and ISTA to negotiate the highest mutually supported secure HE-LTF protocol version. The secure HE-LTF protocol version is indicated in the Protocol Version field within the Secure HE-LTF subelement. If an RSTA includes a Secure HE-LTF element


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in the IFTM frame, it shall set the Protocol Version subfield to either the same or a lower value than the ISTA's Secure Protocol Version sent in the IFTMR frame with the Status Indication subfield equal to 1 (i.e., Success), or a higher value than the ISTA's Secure Protocol Version with the Status Indication subfield equal to 2 (i.e., 'Request Incapable. Do not send same request again'). Upon receiving an IFTM frame with Status Indication subfield set to 1 (i.e., successful) that includes a Secure HE-LTF subelement, the ISTA shall either proceed with the RSTA's Protocol Version assignment, or if it does not meet its required security level, shall terminate by transmitting an FTMR frame with trigger field set to 0.

NOTE—The secure HE-LTF protocol version negotiation provides user, or system, feedback about the protocol version used, as reported by the MLME. If the negotiation results in termination, user feedback can also be given about the mismatch of versions, helping them understand why it has failed, and what they need to do to address the problem.

When an RSTA has initiated a secure measurement exchange, by including a Secure HE-LTF subelement in the Ranging Parameters element in the IFTM frame, and (#8024)setting the Secure HE-LTF Required field to 1, then it shall indicate to the ISTA whether the I2R and R2I NDPs will use the optional frequency domain Tx window by setting the I2R Tx Window and R2I Tx Window fields in the Secure HE-LTF subelement respectively; see Figure 9-1048 (Secure HE-LTF subelement format(11az)).

— If the ISTA had set the I2R Tx Window field to value 1 in the IFTMR frame and the RSTA sets the corresponding I2R Tx Window field in the IFTM frame to value 1, the ISTA shall use the optional frequency domain Tx Window in the I2R NDPs.

— If the ISTA had set the R2I Tx Window field to value 1 in the IFTMR frame and the RSTA sets the corresponding R2I Tx Window field to value 1 in the IFTM frame, the RSTA shall use the optional frequency domain Tx window in the R2I NDPs.

The Measurement SAC field in the Secure HE-LTF Parameters element is reserved in any IFTM frame.

When dot11SecureLTFImplemented is true, prior to generating the new (#8016)secure LTF counter for a given PTKSA, the RSTA initializes a monotonically increasing 48-bit counter Secure-LTF-Counter to 0. The RSTA also derives a Secure-LTF-Key-Seed as follows:

Secure-LTF-Key-Seed = HMAC-Hash(KDK, "Secure (#8005)LTF key seed")

Where the KDK is derived as part of PTKSA establishment, Hash is the hash determined by the AKM and used to derive the PTK. If the Extended Key ID for Individually Addressed Frames subfield of the RSN Capabilities field is 1 for both the Authenticator and the Supplicant, there may be multiple KDKs each identified by a different Key ID (0 or 1). In such a case, the KDK chosen to derive the Secure-LTF-Key-Seed shall be the most recent.

Similarly, when dot11SecureLTFImplemented is true, an ISTA also derives the same Secure-LTF-Key-Seed prior to initiating a secure FTM negotiation.

For each secure FTM negotiation, prior to transmission of IFTM, and for each measurement within an FTM session, an RSTA shall increment the Secure-LTF-Counter by 1. The Secure-LTF-Counter is included in the Secure HE-LTF Parameters element conveyed to the ISTA. An ISTA determines the Secure-LTF-Counter to use for a measurement using the (#8016)Secure LTF Counter and Validation SAC received from the RSTA in the most recent protected IFTM or LMR frame. The Secure-LTF-Counter shall be reset when a new KDK is derived as part of a new PTK derivation and it shall continue, and not be reset, for each secure FTM negotiation using a given KDK.

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#### 11.21.6.3.5 Capability negotiation for EDCA based ranging with the Format And Bandwidth field set to value in range 31–43

A STA that supports first Path Beamforming Training shall set the First Path Beamforming Training Supported field of the Beamforming Capability subelement in the EDMG Capabilities element to 1. Otherwise it shall set the First Path Beamforming Training Supported field to 0.

A STA that supports secure RTT measurement as described in 11.21.6.4.2.7 (DMG secure measurement exchange for EDMG STAs(11az)) shall set the Secure RTT Support(#7222) field in the RSNXE to 1. Otherwise, it shall set the Secure RTT Support(#7222) field to 0. A STA shall not set the Secure RTT Support(#7222) field in the RSNXE to 1 if it has not also set the First Path Beamforming Training Supported field of the Beamforming Capability subelement in the EDMG Capabilities element to 1.

A STA that supports EDMG SC Ranging shall set the EDMG SC Ranging Supported field of the Beamforming Capability subelement in the EDMG Capabilities element to 1. Otherwise it shall set the EDMG SC Ranging Supported field to 0(#8023).

A STA that supports EDMG OFDM Ranging shall set the EDMG OFDM Ranging Supported field of the Beamforming Capability subelement in the EDMG Capabilities element to 1. Otherwise, it shall set the EDMG OFDM Ranging Supported field to 0; see 11.21.6.3.6 (Negotiation for secure EDMG TRN in EDCA based ranging measurement).

#### 11.21.6.3.6 Negotiation for secure EDMG TRN in EDCA based ranging measurement

An ISTA may request a Secure RTT measurement by setting the Secure RTT Measurement subfield in the Measurement Parameters field in the initial Protected FTM Request frame. An ISTA shall not set the Secure RTT Measurement subfield to 1 in a request to an RSTA if the RSTA has not set the Secure RTT Support(#7222) field in the RXSNE. An ISTA that sets the Secure RTT Measurement subfield to 1 shall generate a 32-octet random Secret Key and include it in the Secure Ranging Operation Parameters field; see Figure 9-1049 (Secure HE-LTF Parameters element format(#8016)(11az)), in the initial Protected FTM Request frame. An RSTA that supports Secure RTT measurement shall acknowledge a request for Secure RTT measurement by setting the Secure RTT Measurement subfield in the Measurement Parameters field in the initial Protected FTM frame.

#### 11.21.6.3.7 Direction measurement negotiation for DMG STAs

A STA that supports inclusion of a TRN field in the transmitted FTM frame and the corresponding acknowledgment to facilitate angle of arrival measurements at the recipient shall set the AOA TX Capability subfield in the DMG Direction Measurement Capabilities field in the DMG Capabilities element to 1. Otherwise it shall set the AOA TX Capability subfield to 0.

A STA that supports angle of arrival estimation using the TRN field included in the received FTM frame or the corresponding acknowledgment shall set the AOA RX Capability subfield in the DMG Direction Measurement Capabilities field in the DMG Capabilities element to 1. Otherwise, it shall set the AOA RX Capability subfield to 0.

A STA that supports inclusion of direction setting specific TRN field(s) in the transmitted FTM frame and the corresponding acknowledgment to facilitate angle of departure estimation(s) at the recipient shall set the AOD TX Capability subfield in the DMG Direction Measurement Capabilities field in the DMG Capabilities element to 1. Otherwise, it shall set the AOD TX Capability subfield to 0.

A STA that supports angle of departure estimation using the TRN field(s) included in the received FTM frame or the corresponding acknowledgment shall set the AOD RX Capability subfield in the DMG Direction


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Measurement Capabilities field in the DMG Capabilities element to 1. Otherwise, it shall set the AOD RX Capability subfield to 0.

A pair of ISTA and RSTA are defined to be mutually direction measurement capable if both the ISTA and the RSTA indicated support for DMG direction measurement by including the DMG Direction Measurement Capabilities field in the DMG Capabilities element, and by the ISTA setting at least one of the first four subfields (AOA TX Capability, AOA RX Capability, AOD TX Capability, AOD RX Capability) of this field to 1 and the RSTA setting one the corresponding subfields (AOA RX Capability, AOA TX Capability, AOD RX Capability, AOD TX Capability) of this field to 1. A DMG ISTA may request that FTM exchanges will include direction measurement if the ISTA and RSTA are mutually direction measurement capable.

A DMG ISTA may request initiator AOA measurement, responder AOA measurement, initiator AOD measurement, and responder AOD measurement, by including a DMG Direction Measurement Parameters subelement in the FTM Parameters element transmitted in the FTMR frame. Valid combinations of AOA and AOD requests and the corresponding required capabilities are shown in Table 11-16 (Valid combinations of direction measurements requests and the required capabilities at the initiator and responder(11az)). The L-RX field in the DMG Direction Measurement Specific Parameters subelement shall be set to the number of TRN units the ISTA needs for AOA estimation in the case where R2I AOA was requested, otherwise it shall be set to 0.

**Table 11-16—Valid combinations of direction measurements requests and the required capabilities at the initiator and responder(11az)**

| Requested parameters | | | | Required initiator capabilities | | | | Required responder capabilities | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| R2I AOA | I2R AOD | I2R AOA | R2I AOD | AOA RX | AOA TX | AOD RX | AOD TX | AOA RX | AOA TX | AOD RX | AOD TX |
| Y | | | | Y | | | | | Y | | |
| | Y | | | | | | Y | | | Y | |
| | | Y | | | Y | | | Y | | | |
| | | | Y | | | Y | | | | | Y |
| Y | Y | | | Y | | | Y | | Y | Y | |
| | | Y | Y | | Y | Y | | Y | | | Y |
| Y | | Y | | Y | Y | | | Y | Y | | |
| | Y | | Y | | | Y | Y | | | Y | Y |

The RSTA should respond within 10 ms from the IFTMR frame with an IFTM frame with an FTM Parameters element with a DMG Direction Measurement Parameters subelement. The requested AOA/AOD I2R/R2I parameters in the IFTM frame shall be set to the same value as those requested in the IFTMR frame. The L-RX field shall be set to the number of TRN units the RSTA needs for AOA estimation in the case where I2R AOA was requested. The RSTA sets the Direction Measurement Density field.

The AOA and AOD parameters requested in the IFTMR frame shall be compatible with the corresponding AOA/AOD TX/RX capabilities as shown in Table 11-16 (Valid combinations of direction measurements requests and the required capabilities at the initiator and responder(11az)).

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#### 11.21.6.3.8 LOS assessment negotiation for EDMG STAs

An EDMG STA that supports LOS assessment by transmitting a LOS Assessment FTM PPDU shall set the dot11LOSAssessmentTXImplemented to true and shall set it to false otherwise.

An EDMG STA that in the role of RSTA supports LOS assessment by switching polarization while receiving a LOS Assessment Ack PPDU and responds with Channel Measurement feedback shall set the dot11LOSAssessmentRXImplemented to true and shall set it to false otherwise.

An EDMG STA for which the dot11LOSAssessmentTXImplemented is true shall set to 1 the LOS Assessment TX Capability subfield in the DMG Direction Measurement Capabilities field.

An EDMG STA for which the dot11LOSAssessmentRXImplemented is true shall set to 1 the LOS Assessment RX capability and the LOS Assessment TX Capability subfields in the DMG Direction Measurement Capabilities field.

An EDMG STA in ISTA role for which the dot11LOSAssessmentTXImplemented is true may establish an FTM session that contains LOS assessment exchanges with another EDMG STA that will take the RSTA role if that STA's LOS Assessment RX capability subfields in the DMG Direction Measurement Capabilities field is set to 1.

The ISTA requests the FTM session by setting the LOS Assessment field to 1 in a DMG Direction Measurement Parameters subelement in the IFTMR frame. The responding RSTA shall set to 1 the LOS Assessment field in the DMG Direction Measurement Parameters element in the IFTM frame.

#### 11.21.6.3.9 Passive TB ranging measurement negotiation

The passive TB ranging measurement negotiation follows the rules and procedures for the TB ranging measurement negotiation detailed in 11.21.6.3.3 (Negotiation for TB and non-TB ranging measurement exchange), unless explicitly stated otherwise.

A STA in which dot11PassiveTBRangingResponderImplemented is true shall set the Passive TB Ranging Responder Measurement Support field in the Extended Capabilities element to 1.

When an RSTA has set the Passive TB Ranging Responder Measurement Support field to 1 in the Extended Capabilities element it transmits, an ISTA with dot11PassiveTBRangingInitiatorImplemented equal to true may set the Passive TB Ranging field in the TB specific subelement in an IFTMR frame to 1 to request a passive TB ranging measurement session between the ISTA and the RSTA.

When requesting, or responding to a request for, passive TB ranging, the I2R LMR Feedback subfield in the Ranging Parameters field of the Ranging Parameters element in the IFTMR and IFTM frames, respectively, is reserved.

NOTE—This is because in passive TB ranging, the transmission of the ISTA Passive TB Ranging Measurement Report frame is mandatory; see 11.21.6.4.8.4 (Passive TB ranging Measurement Reporting phase(11az)).

To assign an ISTA passive TB ranging session, the RSTA shall respond with the Passive TB Ranging subfield in the Ranging Parameters field set to 1 in the corresponding IFTM frame.

When an ISTA sets the Passive TB Ranging field in the TB specific subelement in an IFTMR frame to 1, the ISTA shall not include the Secure HE-LTF subelement in the Ranging Parameters element in an IFTMR frame.

The negotiation of phase shift feedback in passive TB ranging follows the same behavior as for TB ranging.


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If the ISTA sets the Passive TB Ranging field to 1, it shall include an LCI report in the FTM Request frame.

### 11.21.6.4 Measurement exchange

#### 11.21.6.4.1 FTM exchange overview(#8113)(11az)

(#8113)FTM has three basic ranging mechanisms:

— EDCA based ranging described in 11.21.6.4.2 (EDCA based ranging measurement exchange(11az))

— TB ranging described in 11.21.6.4.3 (TB ranging measurement exchange(11az)) and 11.21.6.4.8 (Measurement exchange in passive TB ranging mode(11az))

— Non-TB ranging described in 11.21.6.4.4 (Non-TB ranging measurement exchange(11az))

The frequency of the clock for the FTM timestamps shall be derived from the same reference oscillator as the transmit center frequency and the symbol clock frequency.

NOTE—The transmit center frequency and symbol clock frequency are derived from the same reference oscillator, as per the specifications for the different PHYs.

#### 11.21.6.4.2 EDCA based ranging measurement exchange(11az)

##### 11.21.6.4.2.1 Common behavior for EDCA based ranging measurement exchange(11az)

The time windows during which TOD measurement for the transmission of the (11az)FTM frame and the TOA measurement on the receipt of the acknowledgment corresponding to the transmitted FTM frame are performed are known as burst instances. FTM frames over which TOD and TOA measurements are performed shall not be sent outside burst instances. The timing of the burst instances is defined by the following parameters:

— Partial TSF Timer: The partial TSF timer, as defined in 9.4.2.166 (FTM Parameters element(11az)), at the beginning of the first burst instance.

— Burst Duration: The duration of each burst instance starting at the boundary of a burst period.

— Burst Period: The interval from the beginning of one burst instance to the beginning of the following burst instance.

The (11az)ISTA shall transmit an FTMR frame without a Measurement Request element, without an FTM Parameters element and with the Trigger field set to 1 as soon as it is available on channel during a burst instance. This indicates to the RSTA its availability for the remainder of the burst instance. In response, the RSTA shall transmit an Ack frame and should transmit FTMs Per Burst FTM frames before the end of the burst instance. In addition, the ISTA shall be ready to receive an FTM frame. The first FTM frame and its retransmissions in the burst instance from the RSTA shall include an FTM Synchronization Information element in the FTM Synchronization Information field. The TSF Sync Info field in the FTM Synchronization Information element contained in the FTM frame might be used by the ISTA to synchronize its TSF with the RSTA's in order to determine the start of subsequent burst instances. Subsequent FTM frames within the burst instance shall not include an FTM Parameters element and shall not include an FTM Synchronization Information field (for additional constraints on the FTM frame see 11.21.6.7 (LCI and Location Civic retrieval using FTM procedure)). Consecutive FTM frames to a given peer STA shall be spaced at least Min Delta FTM apart. Within a burst instance the ISTA shall perform FTM on each FTM frame addressed to it, except the last FTM frame. The ISTA may perform FTM on the last FTM frame in a burst instance.

(#8021)NOTE 1—If the (11az)ISTA successfully transmits (#8020)an FTM Request frame with the Trigger field set to 1 late in a burst duration, fewer than the negotiated per burst TOF measurements (i.e., the value of the FTM Per Burst field) might be completed within this burst duration instance.

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(#8021)NOTE 2—If an FTM frame, except for the IFTM frame in the ASAP=0 case, is sent outside a burst instance, it might not be acknowledged.

The first burst instance shall start at the value indicated by the Partial TSF Timer subfield in the (11az)IFTM frame, regardless of the ASAP field's value. When ASAP is(M118) 1 by the RSTA, the Partial TSF Timer subfield value shall be set to a value less than 10 ms from the reception of the most recent IFTMR frame.

The scheduling parameters of an FTM session are illustrated in Figure 11-44 (Example negotiation and measurement frame exchange, ASAP=0, and FTMs Per Burst = 2(#109)(11az)).

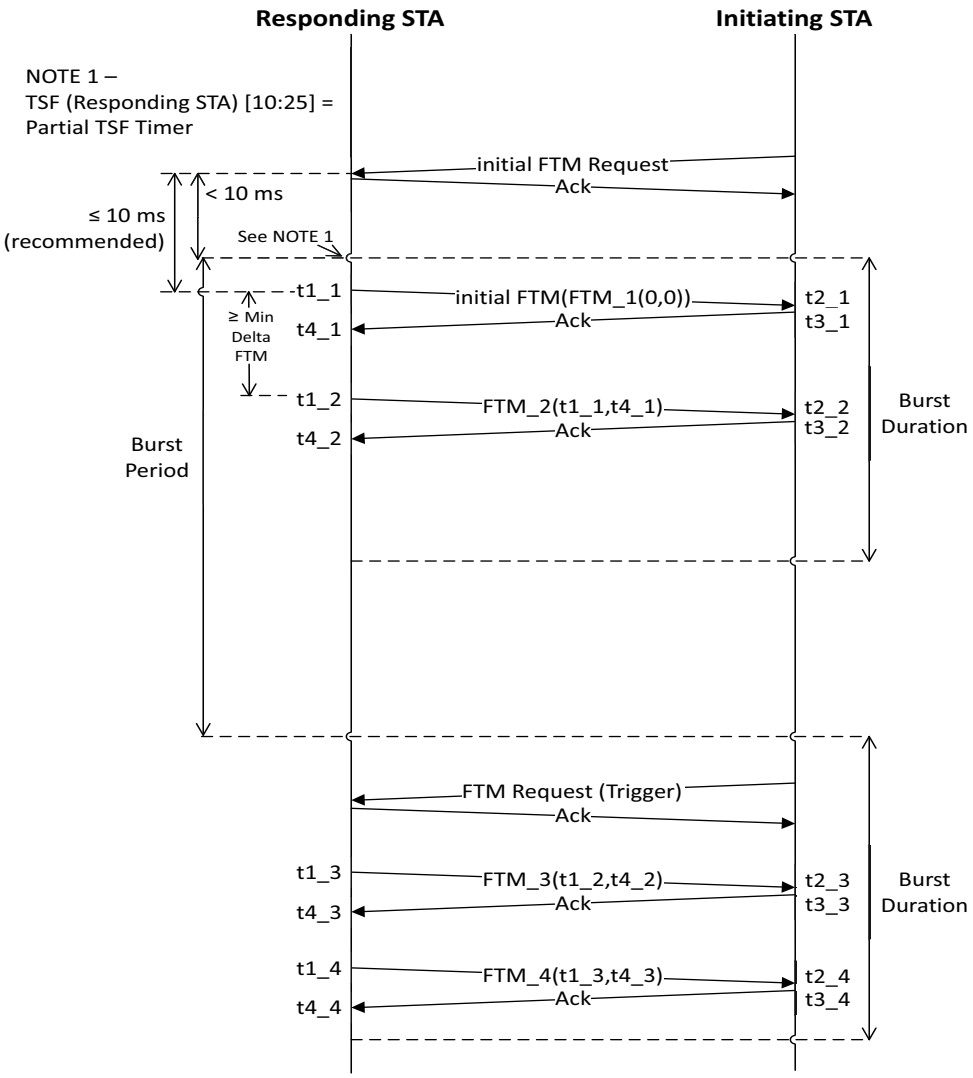


**Figure 11-44—Example negotiation and measurement frame exchange, ASAP=0, and FTMs Per Burst = 2(#109)(11az)**


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The (11az)ISTA can request the RSTA to start the burst instances "as soon as possible" by setting the ASAP subfield to 1. The scheduling in this case is illustrated in Figure 11-45 (Example negotiation and measurement frame exchange, ASAP=1, and FTMs Per Burst = 2(#109)(11az)(#8031)).

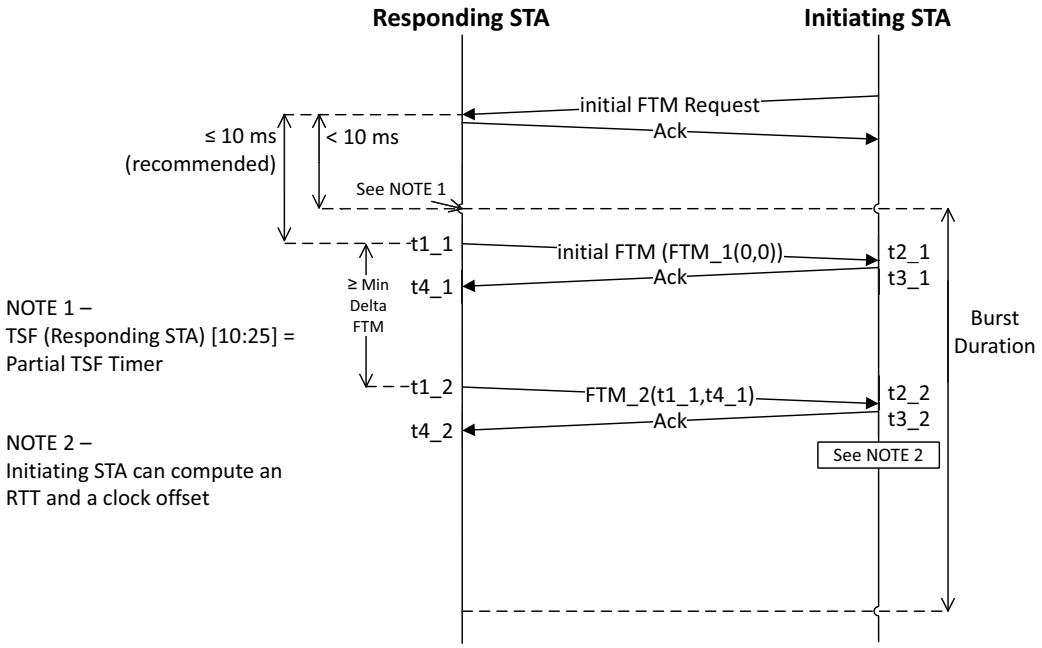


**Figure 11-45—Example negotiation and measurement frame exchange, ASAP=1, and FTMs Per Burst = 2(#109)(11az)(#8031)**

The (11az)ISTA may also request a single burst of FTMs to be taken as soon as possible, in which case it sets the Number of Bursts Exponent subfield to 0 and the ASAP subfield to 1. This is illustrated in Figure 11-46

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(Example negotiation and measurement frame exchange for a single burst instance, ASAP=1, and FTMs Per Burst = 3(#109)).

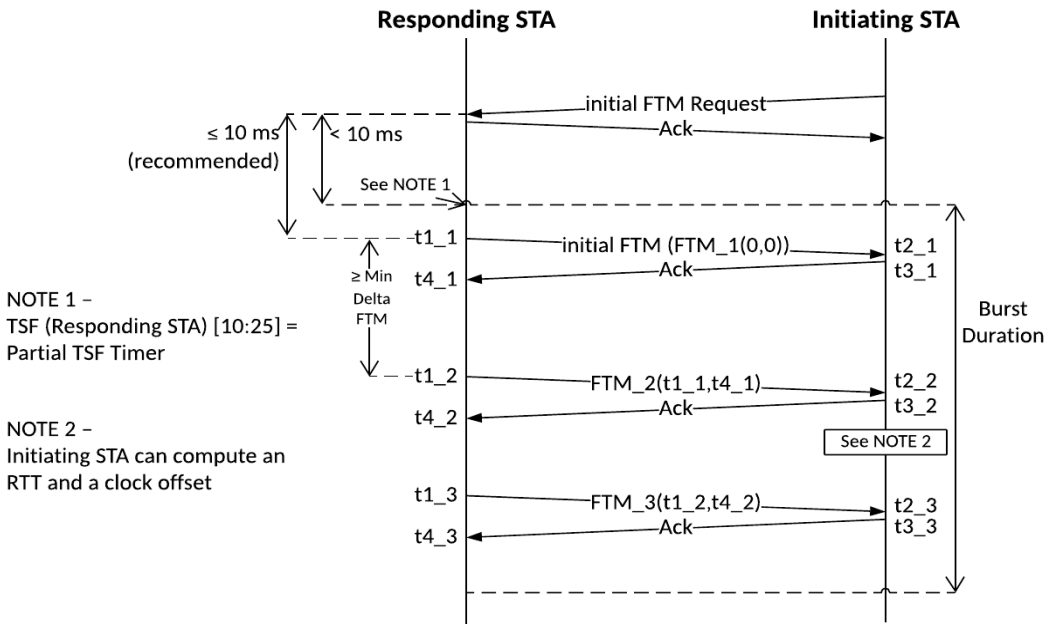


**Figure 11-46—Example negotiation and measurement frame exchange for a single burst instance, ASAP=1, and FTMs Per Burst = 3(#109)**

For non-DMG STAs, both the (11az)FTM frame and the corresponding Ack frame shall be transmitted using a single transmit chain.

The (11az)RSTA shall not transmit FTM frames using Clause 15 (DSSS PHY specification for the 2.4 GHz band designated for ISM applications) or Clause 16 (High rate direct sequence spread spectrum (HR/DSSS) PHY specification) formats, MCS 32 format, or HT-greenfield format.

The (11az)RSTA should transmit FTM frames with the format and bandwidth it indicated in the IFTM frame.

For the (11az)FTM frames transmitted during the FTM session:

- The (11az)RSTA shall not use a bandwidth wider than it indicated in the IFTM frame.
- The (11az)RSTA shall not use an HE format if it indicated VHT, HT-mixed, or non-HT format in the IFTM frame.(11ax)
- The (11az)RSTA shall not use a VHT format if it indicated HT-mixed or non-HT format in the IFTM frame.
- The (11az)RSTA shall not use an HT format if it indicated non-HT format in the IFTM frame.

The ASAP Capable subfield shall be set to 1 in the (11az)IFTM frame if a (11az)RSTA is ASAP-capable; otherwise it shall be set to 0.

A (11az)RSTA transmits FTM frames in overlapping pairs of consecutive frames. For example, in Figure 11-45 (Example negotiation and measurement frame exchange, ASAP=1, and FTMs Per Burst = 2(#109)(11az)(#8031)), FTM_1 and FTM_2, FTM_2 and FTM_3, and FTM_3 and FTM_4 are overlapping pairs of consecutive frames. The first FTM frame of a pair of consecutive FTM frames contains a nonzero value in the Dialog Token field. The follow up FTM frame contains a Follow Up Dialog Token field set to the


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value of the Dialog Token field in the first frame of the consecutive pair. Dialog Token field values of consecutive FTM frames shall increment in steps of 1(#3089), except when the value wraps around to 1 or in the last FTM frame in an FTM session.(#7067)

NOTE 3—(11az)An FTM frame can contain nonzero values in both the Dialog Token and Follow Up Dialog Token fields, meaning that the Action frame contains follow up information from a previous measurement, and new timestamp values are captured to be sent in a future follow up FTM frame.

(#7067)With the first FTM frame, both STAs capture timestamps. The RSTA captures the time at which the FTM frame is transmitted (*t1*). The ISTA captures the time at which the FTM frame arrives (*t2*) and the time at which the Ack response is transmitted (*t3*). The RSTA captures the time at which the Ack frame arrives (*t4*).(#1114-Ed1) In the follow up FTM frame, in the same or the subsequent burst, the RSTA transfers the timestamp values it captured (*t1* and *t4*) to the ISTA. In this follow up FTM frame, the timestamp values (*t1* and *t4*) shall be the measurement according to the RSTA's clock (i.e., without applying any frequency offset correction to the time bases).

(#7067-Ed)For thetimestamp captures, *t1* and *t3* correspond to the point in time at which the start of the preamble for the transmitted FTM frame appears at the antenna connector during transmit (see Figure 11-47 (FTM primitives and timestamps capture for EDCA based ranging measurement exchange(#7067)(#8226))). An implementation may capture a timestamp during the transmit processing earlier or later than the point at which it actually occurs and offset the value to compensate for the time difference.

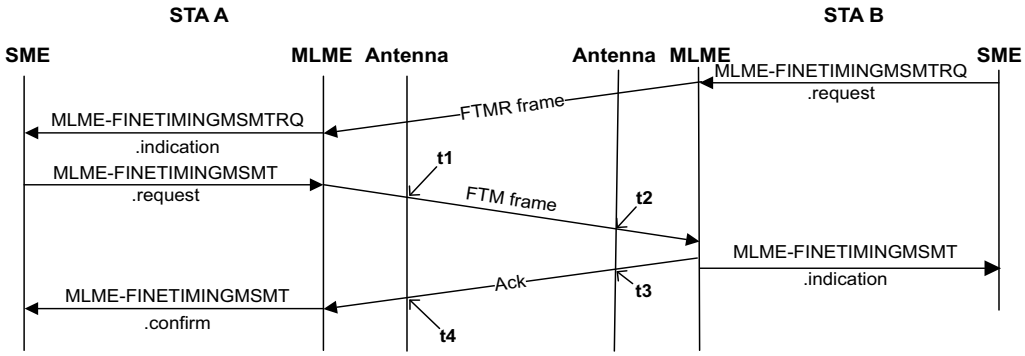


**Figure 11-47—FTM primitives and timestamps capture for EDCA based ranging measurement exchange(#7067)(#8226)**

(#7067)Timestamp captures *t2* and *t4* correspond to the point in time at which the start of the preamble for the incoming FTM frame arrives at the receive antenna connector (see Figure 11-47 (FTM primitives and timestamps capture for EDCA based ranging measurement exchange(#7067)(#8226))). Because time is needed to detect the frame or the relevant LTF in the preamble and synchronize with its logical structure, an implementation determines when the start of the preamble or the relevant LTF in the preamble for the incoming frame arrived at the receive antenna connector by capturing a timestamp some time after it occurred and compensating for the delay by subtracting an offset from the captured value.

When the ASAP subfield is set to 0 by a (11az)RSTA, the Follow Up Dialog Token, TOD, TOA, TOD Error, and TOA Error fields in the FTM frame following the IFTM frame shall be reserved.

When the ASAP subfield is set to 1 by a (11az)RSTA, the timestamps for the IFTM frame shall be captured and sent in the following FTM frame. In the FTM frame following the IFTM frame, the TOD and TOA fields shall be set to the timestamps associated with the IFTM frame.

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The round trip time (RTT) is defined by Equation (11-5).

$$RTT = [(t4' - t1') - (t3 - t2)] \quad (11\text{-}5)$$

where *t1*' and *t4*' are the time at which the (11az)FTM frame was transmitted and the time at which the Ack was received, respectively, as determined by the ISTA.

At the (11az)ISTA, the mechanism by which *t1*' and *t4*' are derived from the TOD and TOA fields is implementation dependent.

The FTM procedure can also be used to synchronize a local clock between STAs. One higher-layer protocol for synchronizing a local clock time between STAs is specified in IEEE Std 802.1AS.

The SME at the (11az)ISTA may estimate the offset of the local clock relative to that at the RSTA using clock offset as defined by Equation (11-6).

$$clock\ offset = [(t2 - t1') - (t4' - t3)]/2 \quad (11\text{-}6)$$

NOTE 4—The (11az)ISTA might track this clock offset over time to derive an estimate of the difference between the ISTA's time base and the RSTA's time base, and thereby improve the accuracy of its derivation of *t1*' and *t4*' from the TOD and TOA fields.

If the Ack frame for a transmitted (11az)FTM frame is not received, the RSTA shall not retry the frame. In order to send the frame again, the RSTA shall send (#8020)an FTM frame with the same Action frame body as the FTM frame for which the Ack was not received, except for updating the Dialog Token if it was nonzero. The Sequence Number in the MAC header is also updated. This is called an *FTM retransmission*.

A (11az)RSTA that transmits (#8020)an FTM frame with the ASAP subfield set to 0 shall set the Partial TSF Timer subfield to an offset value $D_{TSF}$ from the partial value of the RSTA's TSF timer at the time of the transmission of the Ack to the last FTMR frame from the ISTA, subject to

$$D_{TSF} \geq K\_1 \times T_{MDFTM} + T_{FTM\_1} + \text{aSIFSTime} + T_{Ack} + T_{ACCESS\_FTM1}$$

where

| | |
|---|---|
| $K\_1$ | is the maximum number of (11az)IFTM frame (FTM_1) retransmissions the RSTA might attempt |
| $T_{MDFTM}$ | is the value of the Min Delta FTM subfield of the (11az)FTM Parameters field of FTM_1 |
| $T_{FTM\_1}$ | is the duration of the FTM_1 |
| $T_{Ack}$ | is the duration of the Ack frame expected as a response |
| $T_{ACCESS\_FTM1}$ | is the estimated medium access time for FTM_1 |

NOTE 5—This Partial TSF Timer subfield ought to result in the (11az)FTMR frame not being transmitted before a successful transmission of FTM_1.

When neither an Ack to the (11az)IFTM frame nor (#8020)an FTMR frame has been received by the RSTA, the RSTA shall not terminate the FTM session before the time indicated by the Partial TSF timer plus the Burst Duration.

The (11az)RSTA shall set the Follow Up Dialog Token field to 0 in the IFTM frame and its FTM retransmissions.

The (11az)RSTA shall set the Dialog Token field to 0 in the last FTM frame and its FTM retransmissions.


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(11az)When a Secure FTM Session is established as described in 11.21.6.3.1 (General), the FTM frames transmitted during the execution of Measurement Exchange shall be Protected Fine Timing Action frames; see 9.6.34 (Protected Fine Timing Action frame details(11az)(#8155)).

#### 11.21.6.4.2.2 DMG general measurement exchange(11az)

An EDMG ISTA and RSTA that have both indicated support for first path beam forming by setting to 1 the First Path Training Supported field in the Beamforming Capability subelement of the EDMG Capability element shall perform first path beamforming training as defined in 10.41.10.6 (First path beamforming training) prior to any FTM exchange.

A DMG/EDMG ISTA/RSTA performs an FTM exchange that does not require AOA or AOD measurements as defined in 11.21.6.4.2.1 (Common behavior for EDCA based ranging measurement exchange(11az)). To perform an FTM exchange that does require AOD or AOD measurements, it follows the procedure in 11.21.6.4.2.3 (DMG/EDMG AOA/AOD measurement exchange(11az)). In both these cases, when the first path AWV setting is not used in the exchange, the Trigger field shall be set to 1 in the FTM Request frame that initiates the exchange. In both cases the same AWV used for data transfer between the STAs shall be used for transmission and reception of the preamble and data portion of the PPDUs.

An EDMG ISTA initiates an (#8113)FTM exchange using the first path AWV setting by setting the value of the Trigger field of the FTM Request frame that initiates the exchange to 2. An EDMG ISTA may send an FTM Request frame with the trigger set to 2 only if the RSTA has set the First Path Beamforming Training Supported subfield to 1 in the Beamforming field of the EDMG Capabilities element and the ISTA and RSTA have performed beamforming training for first path as defined in 10.41.10.6 (First path beamforming training). When the trigger is equal to 2 in the FTM request frame that initiates the burst, the first path AWV settings shall be used in transmission and reception of FTM and Ack frames sent by the ISTA and RSTA during the FTM burst.

An EDMG ISTA sets a value for the Ranging Priority subfield of the FTM Parameters field of the FTM Parameters element in the IFTMR frame from the values in Table 9-323 (Definition of the EDMG Ranging Priority subfield when included in the IFTMR frame(11az)). The RSTA responds to this request by setting a value for the Ranging Priority subfield of the FTM Parameters field of the FTM Parameters element in the IFTM frame from Table 9-324 (Definition of the EDMG Ranging Priority subfield when included in the IFTM frame(11az)) in response. How an RSTA supports ranging priority is implementation dependent.

#### 11.21.6.4.2.3 DMG/EDMG AOA/AOD measurement exchange(11az)

A DMG ISTA/RSTA pair that has agreed on performing direction measurement by agreeing on either R2I AOA, I2R AOD, I2R AOA, or R2I AOD shall add TRN fields to FTM exchanges in the burst according to the Direction Measurement Density sent by the RSTA in the IFTM frame.

A DMG ISTA/RSTA pair that has agreed on either R2I AOA, I2R AOD, I2R AOA, or R2I AOD using the procedure described in 11.21.6.3.7 (Direction measurement negotiation for DMG STAs) shall be denoted as Direction Measurement FTM pair.

An FTM exchange in which the Trigger field in the FTM Request that initiated the exchange is set to 2 is denoted as a first path AWV FTM exchange.

In a Direction Measurement FTM pair, the first measurement in the burst shall include either R2I AOA, I2R AOD, I2R AOA, or R2I AOD for all values of the Direction Measurement Density.

In a Direction Measurement FTM pair that agreed on R2I AOA, the RSTA shall add a TRN field to the FTM frames in the exchanges specified by the Direction Measurement Density field by setting the TRN_LEN/ EDMG_TRN_LEN to the value of the L_RX field sent by the ISTA and PPDU_TYPE/EDMG_PPDU_TYPE

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to 0. In a first path AWV FTM exchange the RSTA shall also set the TXVECTOR parameter FIRST_PATH_AWV_TRN to FIRST_PATH_AWV_ON_TRN in the FTM frames it sends to the ISTA. The ISTA may receive the TRN field using implementation dependent AWV settings.

In a Direction Measurement FTM pair that agreed on I2R AOA, the ISTA shall add a TRN field to the Ack frames in the exchanges specified by the Direction Measurement Density field by setting the TRN_LEN/ EDMG_TRN_LEN to the value of the L_RX field of the DMG Direction Measurement Parameters received from the RSTA and PPDU_TYPE/EDMG_PPDU_TYPE to 0. In a first path AWV FTM exchange the ISTA shall also set the TXVECTOR parameter FIRST_PATH_AWV_TRN to FIRST_PATH_AWV_ON_TRN in the Ack frames it sends to the RSTA. The RSTA may receive the TRN field using implementation dependent AWV setting. The RSTA shall provide the AOA measurement results in the Direction Measurement Result element included in the next FTM frame sent to the ISTA.

In a Direction Measurement FTM pair that agreed on R2I AOD, the RSTA shall add a TRN field to the FTM frames in the exchanges specified by the Direction Measurement Density field by setting the TRN_LEN/ EDMG_TRN_LEN to a nonzero value and PPDU_TYPE/EDMG_PPDU_TYPE to 1. In a first path AWV FTM exchange the RSTA shall also set the TXVECTOR parameter FIRST_PATH_AWV_TRN to FIRST_PATH_AWV_ON_TRN in the FTM frames it sends to the ISTA. The ISTA shall receive the TRN field using the first path AWV setting. The RSTA may use implementation dependent AWV (such as sectors) in the TRN field.

In a Direction Measurement FTM pair that agreed on I2R AOD, the ISTA shall add a TRN field to the Ack frames in the exchanges specified by the Direction Measurement Density by setting the TRN_LEN/ EDMG_TRN_LEN to a nonzero value and PPDU_TYPE/EDMG_PPDU_TYPE to 1. In a first path AWV FTM exchange the ISTA shall also set the TXVECTOR parameter FIRST_PATH_AWV_TRN to FIRST_PATH_AWV_ON_TRN in the Ack frames it sends to the RSTA. The RSTA shall receive the TRN field using the first path AWV setting. The ISTA may use implementation dependent AWV (such as sectors) in the TRN field. The RSTA shall set the Best AWV ID field in the FTM frames sent to the ISTA following these Ack frames to the AWV ID or the Best Sector Index of the TRN field (if the Ack was an EDMG/DMG PPDU, respectively). If the RSTA has set the AOD Channel Measurement Feedback subfield to 1 in the DMG Direction Measurement Capabilities field, it shall also include a Channel Measurement Feedback Type field and a Channel Measurement Feedback field in the FTM frames sent to the ISTA following the reception of the Ack frames that its RXVECTOR parameter PPDU_TYPE is equal to TRN-T or EDMG_PPDU_TYPE equal to EDMG-TRN-T, and TRN-LEN greater than 0 or EDMG-TRN-LEN greater than 0.

If the Trigger field in the FTMR frame that initiated an FTM exchange in a Direction Measurement FTM pair is equal to 2, all the preamble and PSDU parts of the PPDUs sent during the exchange shall be transmitted and received using the first path AWV setting. The TRN fields of these PPDUs shall also be transmitted and received using the first path AWV setting, except for AOD TRN fields, which may be transmitted with changing AWV setting, and AOA TRN fields, which may be received with changing AWV setting.

#### 11.21.6.4.2.4 DMG AOD feedback exchange after an FTM exchange(11az)

When an ISTA and RSTA agreed on performing an R2I AOD measurement FTM exchange as described in 11.21.6.4.2.3 (DMG/EDMG AOA/AOD measurement exchange(11az)) the ISTA needs to send AOD measurement results to the RSTA, so that the RSTA may use these to generate the AOD estimates and send the results back to the ISTA.

To enable this, the ISTA collects the best sector results throughout the burst.

After the burst the ISTA shall send an FTM frame containing a Multiple AWV ID element with the Trigger field set to 0, to the RSTA. The Number Of Best AWV ID field in the Multiple AWV ID element shall be set to the number of FTM frames in the burst that contained a TRN field enabling AOD estimation. When the RSTA is ready with the AOD results, it should send an FTM frame containing a Multiple AOD Feedback element


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containing the AOD results. The Number Of AOD Feedbacks field in the Multiple AOD Feedback element shall be set to the value of the Number Of Best AWV ID field in the Multiple AWV ID element in the FTM frame from the ISTA that elicited the Multiple AOD feedback.

#### 11.21.6.4.2.5 DMG LOS assessment for EDCA based ranging measurement exchange(11az)

A LOS assessment FTM exchange may provide an ISTA with information about whether the link with the ISTA is over a non-LOS path. A LOS assessment FTM exchange is a DMG FTM burst as defined in 11.21.6.4.2.2 (DMG general measurement exchange(11az)) or 11.21.6.4.2.3 (DMG/EDMG AOA/AOD measurement exchange(11az)) in which one FTM frame from the RSTA to the ISTA is a LOS assessment FTM PPDU. A LOS assessment FTM burst over the non-first path AWV is identified by the RSTA setting the FTM trigger to 3 at the FTMR. A LOS assessment FTM burst over the first path AWV is identified by setting the FTM trigger to 4. An ISTA shall not initiate an FTM burst by an FTMR with the trigger set to 3 or 4 unless the RSTA has indicated it may participate in such exchange by setting to 1 the LOS Assessment TX subfield in the DMG Direction Measurement Capabilities field of the DMG Capabilities element.

A LOS assessment FTM PPDU is defined as a PPDU that contains an FTM frame that is sent with the TXVECTOR parameters set as follows: DUAL_POLARIZATION_TRNS set to 1, EDMG_TRN_LEN set to a value greater than 0, and EDMG_PPDU_TYPE set to EDMG-TRN-R.

The RSTA and the ISTA shall switch polarization while transmitting and receiving the TRN field of the LOS assessment FTM PPDU as described in 28.9.2.2.5 (TRN field definition).

If the RSTA has set the LOS Assessment RX subfield to 1 in the DMG Direction Measurement Capabilities field, the ISTA shall respond to a LOS assessment FTM PPDU with a LOS Assessment Ack PPDU.

A LOS Assessment Ack PPDU is defined to be a PPDU that contains an Ack frame and has the DUAL_POLARIZATION_TRNS field set to 1, the EDMG_TRN_LEN set to a value greater than 0 and the EDMG_PPDU_TYPE set to EDMG-TRN-R. The ISTA and the RSTA shall switch polarization while transmitting and receiving the TRN field of the LOS assessment FTM PPDU and the LOS assessment Ack PPDU as described in 28.9.2.2.5 (TRN field definition). The RSTA shall send a channel measurement element based on the measurements it performed on the Ack PPDU TRN field in the next FTM frame sent to the ISTA.

#### 11.21.6.4.2.6 DMG first path AWV for EDCA based ranging measurement exchange(11az)

A first path AWV FTM burst is started when an ISTA sends the RSTA an FTM Request frame with Trigger field set to 2. An EDMG ISTA may send an FTM Request frame with the trigger set to 2 only if the RSTA has set the First Path Training Supported subfield to 1 in the Beamforming field of the EDMG Capabilities and the ISTA and RSTA have performed beamforming training for first path as defined in 10.41.10.6 (First path beamforming training). All the FTM frames sent from the RSTA to the ISTA during the FTM burst and all the Ack frames sent from the RSTA to the ISTA in response to the FTM frame shall have the setting described in Table 11-17 (TXVECTOR parameter setting for first path AWV FTM exchange(11az)), except when used for AOD and AOA estimation.

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**Table 11-17—TXVECTOR parameter setting for first path AWV FTM exchange(11az)**

| TXVECTOR Parameter | Value |
|---|---|
| EDMG_PPDU_TYPE | EDMG-TRN-T |
| EDMG_TRN_LEN | 1 |
| RX_TRN_PER_TX_TRN | 1 |
| EDMG_TRN_P | 0 |
| EDMG_TRN_M | 3 |
| EDMG_TRN_N | 3 |
| TRN_SEQ_LENGTH | Normal |
| FIRST_PATH_AWV_TRN | FIRST_PATH_AWV_ON_TRN |

The setting of the TXVECTOR parameters when the frames are used for AOA and AOD estimation is described in 11.21.6.4.2.3 (DMG/EDMG AOA/AOD measurement exchange(11az)).

When an FTM frame is sent with the TXVECTOR parameter FIRST_PATH_AWV_TRN set to FIRST_PATH_AWV_ON_TRN, the Ack frame sent in response to this frame shall have the TXVECTOR parameter FIRST_PATH_AWV_TRN set to FIRST_PATH_AWV_ON_TRN. In both these frames the TRN field shall be received by the ISTA and RSTA using the first path AWV receive antenna setting.

#### 11.21.6.4.2.7 DMG secure measurement exchange for EDMG STAs(11az)

Setup of the Secure EDMG Measurement exchange is described in 11.21.6.3.6 (Negotiation for secure EDMG TRN in EDCA based ranging measurement). The Secure EDMG Measurement exchange protocol follows the procedure as described in 11.21.6.4.2 (EDCA based ranging measurement exchange(11az)) with the following changes:

- The Protected FTM Request frame shall be used by the ISTA to initiate the exchange.
- The ISTA shall use the Protected FTM frame during the exchange.
- The PPDUs carrying the Protected FTM frames transmitted by the RSTA and the Acks transmitted by the ISTA shall be based on the format as described in 28.9.3 (EDMG secure ranging PPDU(11az)). In these PPDUs, the TXVECTOR parameter SECURED_TRN shall be set to SECURED_TRN.
- The PPDU carrying the protected FTM frames transmitted by the responder to initiator shall use the first path AWVs obtained during first path beamforming training as described in 10.41.10.6 (First path beamforming training).
- The PPDU carrying the Ack frame transmitted by the initiator to the responder shall use the first path AWVs obtained during first path beamforming training as described in 10.41.10.6 (First path beamforming training).
- If the Ack frame for an FTM frame is not received, the RSTA may retransmit the FTM frame. In this case, the RSTA shall send an FTM frame with the same Action frame body as the FTM frame for which the Ack was not received, except for updating the Dialog Token field if it was nonzero, and a new Secure TRN Sequence (#8033)(see 12.2.12 (EDMG secure ranging sequences(11az))) shall be used. The Sequence Number field in the MAC header is also updated.


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The following rules apply to the FTM retransmission of the secure EDMG measurement exchange:

a) The t2 measured by the RSTA and the t4 measured by the ISTA shall be based on the secure TRN subfields. For verification of security, the RSTA and ISTA should estimate the time separately on each secure TRN subfield and verify that values estimated on different TRN subfields are equal up to a small estimation error.

b) If FTM retransmission is successful, the ISTA may derive the RTT using the received TOA (t4) and TOD (t1) values included in the retransmitted FTM frame, and t2 and t3 values estimated locally in the prior (or preceding) FTM.

c) During the FTM retransmission, the t2 value estimated by the ISTA shall not be used for RTT calculation in the subsequent FTM. This is because the t2 was estimated by correlating two unmatched secure TRNs as a result of FTM retransmission.

d) During the FTM retransmission, the t4 value estimated by the RSTA shall not be included in the subsequent FTM frame. This is because the t4 was estimated by correlating two unmatched secure TRNs as a result of FTM retransmission.

e) Due to rules c) and d), the FTM immediately after the FTM retransmission shall not be used by an ISTA for RTT calculation.

f) A successful FTM retransmission shall only be counted towards to the total number of FTMs Per Burst value.

If an RSTA does not perform FTM retransmission, so that the maximum number of FTM frame retransmissions the RSTA might attempt is zero, the RSTA shall send a new FTM frame (with TOA=0, TOD=0, updated Dialog Token) with new Secure TRN (associated with the updated dialog token) appended when an FTM transmission in a secure EDMG FTM exchange fails.

A STA shall maintain the Dialog Token Counter, and update the Dialog Token Counter to (Dialog Token field value – 1) mod 254 + 1, where the Dialog Token field value corresponds to the value of the Dialog Token field either in the lastly transmitted FTM frame if the STA is an RSTA or in the lastly received FTM frame if the STA is an ISTA.

A STA transmitting an EDMG secure ranging PPDU to a peer STA shall set the TXVECTOR parameters as follows:

— The SECURED TRN parameter is set to SECURED_TRN.

— The SECURE_TRN_SEQUENCE parameter contains the Secure TRN bit sequences associated with the Dialog Token Counter.

After transmitting an EDMG secure ranging PPDU, a STA's MAC sublayer issues a PHY-RXTRNSEQUENCE.request with a TRNVECTOR parameter that provides the TRN sequence associated with the Dialog Token Counter.

When an RSTA transmits an EDMG secure ranging PPDU, it shall include the Protected FTM frame in which the Dialog Token field is set to the Dialog Token Counter.

An ISTA shall transmit an Ack frame to the received Protected FTM frame as an EDMG secure ranging PPDU. An ISTA shall discard the timestamps measured from an EDMG secure ranging PPDU if the Dialog Token field in the Protected FTM frame in the EDMG secure ranging PPDU does not match its Dialog Token Counter.

NOTE—It is recommended that an ISTA or RSTA discards ranging measurements when it detects that the transmit center frequency offset between the ISTA and the RSTA exceeds the allowed tolerance from the values specified in 20.3.3.2.1 (General).

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### 11.21.6.4.3 TB ranging measurement exchange(11az)

#### 11.21.6.4.3.1 General(11az)

TB ranging is the dynamic trigger-based variant of the FTM procedure. The TB ranging measurement exchange consists of one or more scheduled availability windows. The TB ranging measurement exchange is dynamic, as the actual number of ISTAs participating in the measurement exchange can vary across availability windows. Each ISTA that is assigned to the scheduled availability window may participate in or skip the corresponding measurement exchange. The availability windows are scheduled periodic time windows assigned to ISTAs during negotiation (see 11.21.6.3.3 (Negotiation for TB and non-TB ranging measurement exchange)).

Within each availability window the RSTA and ISTAs shall not transmit or trigger transmission of any Data frames; they shall only perform ranging activities related to Polling, Measurement Sounding, and Measurement Reporting phases, as well as signaling of modification of availability window parameters; see 11.21.6.5.1 (Availability window parameter modification(11az)), and TB ranging session termination, see 11.21.6.6.2 (TB ranging and non-TB ranging session termination(11az)). Each availability window by default consists of a single TXOP and may be extended to multiple TXOPs by announcement, if a single TXOP is insufficient to accommodate all ISTAs that responded to the poll; see 11.21.6.4.3.2 (Polling phase of TB ranging(11az)), and 11.21.6.4.3.3 (Measurement Sounding phase of TB ranging(11az)). Each availability window of the TB ranging measurement exchange consists of one or more triplets of sequential phases: Polling phase, Measurement Sounding phase, and Measurement Reporting phase. Figure 11-48 (TB ranging availability windows each with one instance of a polling/sounding/reporting triplet(11az)) shows an example of two availability windows, each composed of a single triplet of Polling, Measurement Sounding, and Measurement Reporting phases. An RSTA and ISTA participating in TB ranging shall perform any Polling, Measurement Sounding, and Measurement Reporting phases only within the availability windows.

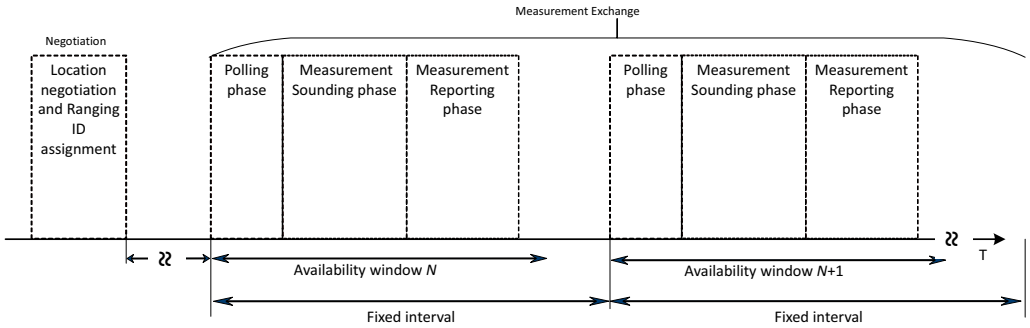


**Figure 11-48—TB ranging availability windows each with one instance of a polling/ sounding/reporting triplet(11az)**

Each availability window typically contains a single poll, where the RSTA should poll all the ISTAs assigned to that availability window. If the available bandwidth is insufficient to allow for the polling of all ISTAs assigned to the availability window with one poll, the RSTA shall indicate that one or more extra polling/ sounding/reporting triplets can be expected within the availability window (see example in Figure 11-49 (TB ranging availability window with two instances of polling/sounding/reporting triplets within a single TXOP(11az)), and Figure 11-50 (TB ranging availability window with two instances of polling/sounding/


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reporting triplets in separate TXOPs(11az)). All instances of polling/sounding/reporting triplets shall be completed before the end of the availability window.

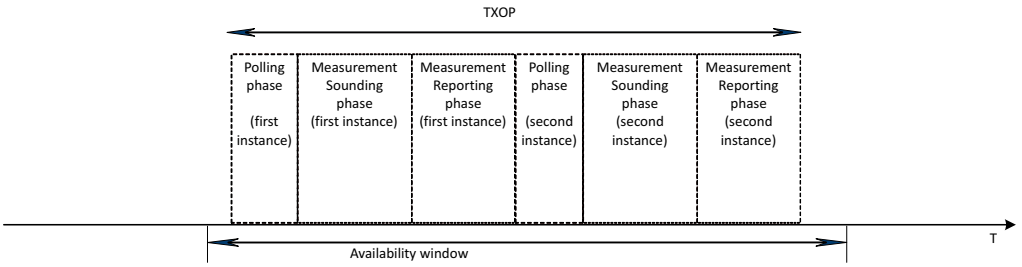


**Figure 11-49—TB ranging availability window with two instances of polling/sounding/ reporting triplets within a single TXOP(11az)**

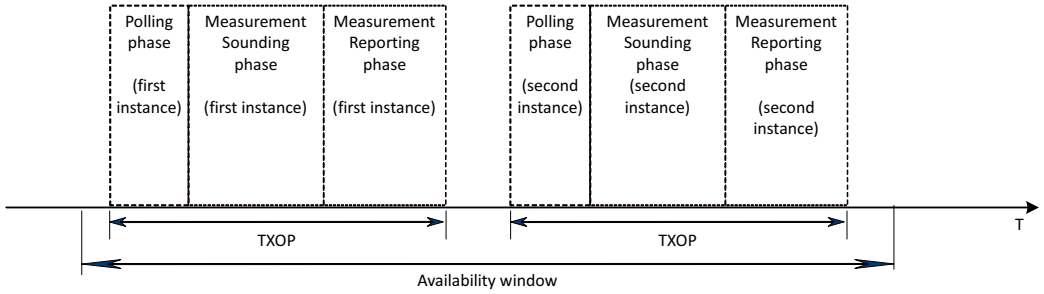


**Figure 11-50—TB ranging availability window with two instances of polling/sounding/ reporting triplets in separate TXOPs(11az)**

During the availability window, measurement resources and results shall be made available to each ISTA whose poll response was received at the RSTA; see 11.21.6.4.3.3 (Measurement Sounding phase of TB ranging(11az)) and 11.21.6.4.3.4 (Reporting phase of TB ranging measurement(11az)). This may also lead to extra instances of polling/sounding/reporting triplets, even if all ISTAs assigned to this availability window were polled in the first Polling phase instance (e.g., if the RSTA is not able to accommodate all ISTAs that responded in a single measurement sounding phase instance; see 11.21.6.4.3.3 (Measurement Sounding phase of TB ranging(11az))).

The timestamps reported within each measurement sounding phase shall be derived from a clock that runs continuously during the measurement sounding phase.

If there is a discontinuity in the clock for the FTM timestamping between two reported TOD timestamps, then the TOD Not Continuous subfield in the TOD Error field of the LMR frame shall be set to 1. Otherwise it shall be set to 0.

NOTE—In some use cases it is of interest to have a clock that runs continuously across subsequent ranging availability windows. For this reason it is desirable for the clock for the FTM timestamping to run continuously.

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Within each availability window, an RSTA shall use an AID or Ranging Session ID (RSID) to identify an associated or unassociated ISTA, respectively. The AID and RSID assignment shall be nonconflicting and shall have the same size and valid address space (as defined in 9.4.1.8 (AID field) and 26.17.4 (AID assignment)). The RSID usage shall follow the same rules as that of AIDs for HE operations. The RSIDs are assigned to unassociated ISTAs during the FTM negotiation; see 11.21.6.3 (FTM procedure negotiation(11az)).

An RSTA shall follow the rules defined in 26.5.2 (UL MU operation) when transmitting any Trigger frames of variant Location for TB ranging with the following rules:

— A Ranging Trigger frame shall be carried in an S-MPDU if the Ranging Trigger frame is carried in a VHT PPDU or HE PPDU.

— An RSTA shall not transmit a Ranging Trigger frame in a VHT MU PPDU or HE MU PPDU.

An RSTA shall not transmit a Sounding Ranging Trigger frame soliciting an HE TB Ranging NDP that uses UL MU-MIMO, that is, where the same RU is allocated to multiple ISTAs, to any ISTA from which it has not received a TB specific subelement in the Ranging Parameters element with the Full Bandwidth UL MU-MIMO field equal to 1.

If required, an ISTA shall transmit any FTM Request frames outside of availability windows allocated to itself. Inside availability windows allocated to itself, an ISTA shall not transmit any frame except when assigned UL resources by a TF transmitted by the RSTA.

An RSTA, in which dot11MultiBSSIDImplemented is true, and that transmits a Ranging Trigger frame or a Ranging NDP Announcement frame to a set of ISTAs, in which at least two ISTAs have a TB ranging measurement exchange with different BSSIDs in the Multiple BSSID set of the RSTA shall set the TA field of these frames to the transmitted BSSID. Any ISTA that negotiates a TB ranging measurement exchange session with a nontransmitted BSSID of an RSTA shall support the reception of a Control frame with TA equal to the transmitted BSSID.

An ISTA shall follow the rules defined in 26.5.2 (UL MU operation) when transmitting any HE TB PPDUs for TB ranging with the exceptions defined in 11.21.6.4.3.2 (Polling phase of TB ranging(11az)), 11.21.6.4.3.3 (Measurement Sounding phase of TB ranging(11az)), and 11.21.6.4.3.4 (Reporting phase of TB ranging measurement(11az)).

(#7067)(#8117)The FTM protocol for a TB ranging measurement exchange and its relationship with the SME and MLME interface is shown in Figure 11-51 (FTM primitives and timestamps reporting capture for TB ranging measurement exchange(#7067)).

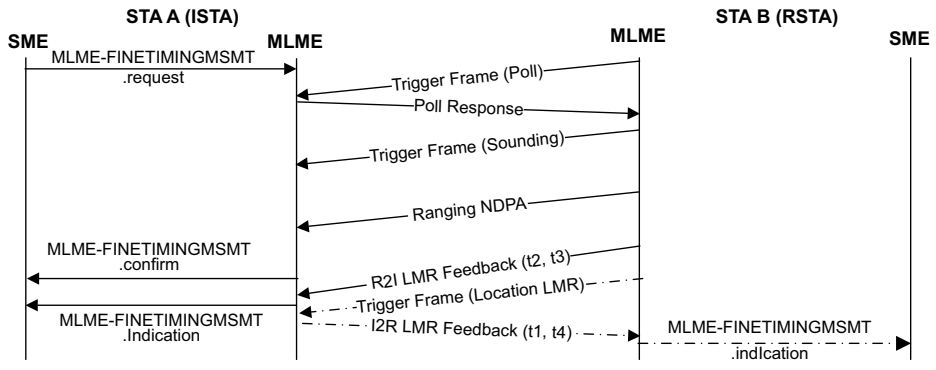


**Figure 11-51—FTM primitives and timestamps reporting capture for TB ranging measurement exchange(#7067)**


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#### 11.21.6.4.3.2 Polling phase of TB ranging(11az)

The Polling phase is the first phase of each polling/sounding/reporting triplet.

In each Polling phase instance, the RSTA shall transmit a Poll Ranging Trigger frame, see 9.3.1.22.10 (Ranging Trigger variant(11az)). Once a response is received, the RSTA shall proceed to the Measurement Sounding phase; otherwise it may transmit additional Poll Ranging Trigger frames, until it receives a response from at least one ISTA. The RSTA shall allocate each RU in the TF Ranging poll to only one ISTA. Any ISTA addressed by a User Info field in a TF Ranging Poll frame that intends to participate in the measurement sequence within this availability window shall send a CTS-to-self in an S-MPDU within an HE TB PPDU in its designated RU allocation as identified in the TF Ranging Poll frame, otherwise shall not send a CTS-to-self to avoid resource allocation in this measurement sequence; see Figure 11-50 (TB ranging availability window with two instances of polling/sounding/reporting triplets in separate TXOPs(11az)).

If the available bandwidth does not allow for the polling of all ISTAs assigned to this availability window using a single TF Ranging Poll frame, the RSTA shall attempt to schedule one or more extra polling/sounding/reporting triplets within the availability window. The RSTA shall indicate the extra polling/sounding/reporting triplets by setting the More TF subfield in the Common Info field to 1 and the RA field to the broadcast address in the TF Ranging Poll frame, and in TFs in subsequent Polling, Measurement Sounding, and Measurement Reporting phases in the same availability window. If the RSTA had set the More TF subfield to 1 in the preceding Ranging Trigger frame, and if there are no additional polling/sounding/reporting triplets in the same availability window, the RSTA shall set the More TF subfield in the Common Info field to 0 and the RA field to the broadcast address in the next Ranging Trigger frame within that availability window. On receipt of such a frame, an ISTA that has not been addressed by a User Info field in the TF, may enter doze state, if no other condition requires this STA to remain awake. Any extra polling/sounding/reporting triplets can either be transmitted in the same TXOP (see example in Figure 11-49 (TB ranging availability window with two instances of polling/sounding/reporting triplets within a single TXOP(11az))) or a new TXOP (see example in Figure 11-50 (TB ranging availability window with two instances of polling/sounding/reporting triplets in separate TXOPs(11az))), depending on the maximum allowed TXOP duration and the predicted length of the extra instances of polling/sounding/reporting triplets.

#### 11.21.6.4.3.3 Measurement Sounding phase of TB ranging(11az)

The measurement-sounding phase commences SIFS time after the Polling phase and is the second phase of each polling/sounding/reporting triplet; see Figure 11-52 (TB ranging availability window with two ISTAs(11az)). The measurement sounding phase consists of one or more Sounding Ranging Trigger frames (see 9.3.1.22.10 (Ranging Trigger variant(11az))) allocating uplink resources to one or more ISTAs; see Figure 11-48 (TB ranging availability windows each with one instance of a polling/sounding/reporting triplet(11az)) and Figure 11-50 (TB ranging availability window with two instances of polling/sounding/reporting triplets in separate TXOPs(11az)). The Ranging variant Trigger frame of Sounding subvariant is called the TF Ranging Sounding frame. Each TF Ranging Sounding frame shall allocate uplink resources for one or more ISTAs' I2R NDP multiplexed in the spatial stream domain covering the full bandwidth. The format of the I2R NDP is an HE TB Ranging NDP; see 27.3.19.2 (HE TB Ranging NDP(11az)). SIFS time after receiving the last I2R NDP, the RSTA shall transmit an NDP Announcement frame followed by an R2I NDP; the Ranging NDP Announcement frame is described in 9.3.1.19 (VHT/HE/Ranging NDP Announcement frame format(11ax)(11az)) and the R2I NDP is an HE Ranging NDP, as described in 27.3.19.1 (HE Ranging NDP(11az)). Figure 11-52 (TB ranging availability window with two ISTAs(11az)) shows an availability window with an RSTA and two ISTAs (ISTA 1 and ISTA 4) responding to the poll. The Ranging

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NDP Announcement frame's STA Info fields specify all the ISTAs that will use the R2I NDP, which shall include the ISTAs that were allocated uplink resources in the measurement sounding phase.

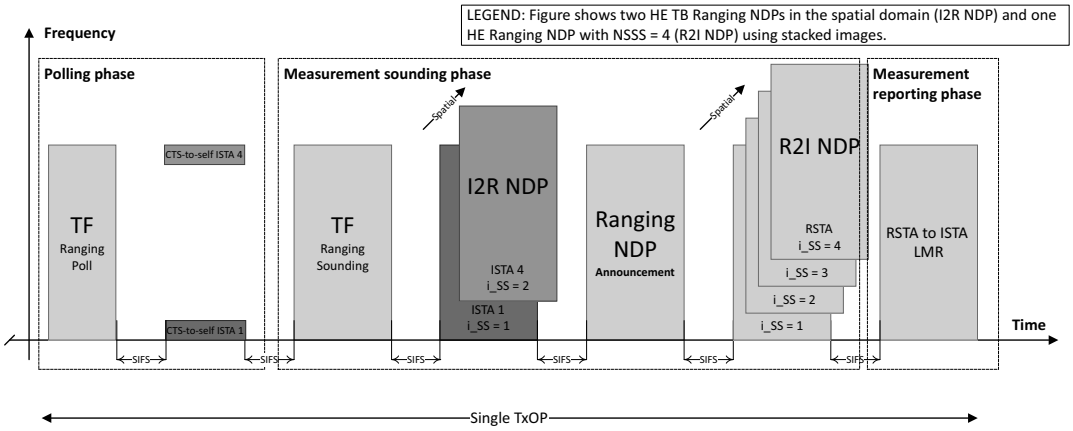


**Figure 11-52—TB ranging availability window with two ISTAs(11az)**

The RSTA shall select a bandwidth value for the measurement sounding phase that is less than or equal to the RSTA Assigned Max Bandwidth of each of the ISTAs that are being allocated resources during this measurement instance. It may be different from the bandwidth used in the Polling phase, but shall adhere to the rules of multiple frame transmission in an EDCA TXOP; see 10.23.2.8 (Multiple frame exchange sequences in an EDCA TXOP(#109)).

The RSTA shall set the TXVECTOR parameter CH_BANDWIDTH of the Trigger frame Ranging Sounding to that same bandwidth and use the same value for the UL BW subfield of the Common Info field of said Trigger frame. When transmitting the Ranging NDP Announcement frame and R2I NDP, the RSTA shall set the TXVECTOR parameter CH_BANDWIDTH to that same bandwidth.

In the TF Ranging Sounding, the RSTA shall set the SS Allocation subfield and the I2R Rep subfield of the User Info fields corresponding to each of the ISTAs triggered by the Trigger frame in the following way:

— The Number of Spatial Streams in each SS Allocation subfield shall not exceed the *RSTA Assigned I2R STS ≤ 80 MHz* for the corresponding ISTA, if the UL BW subfield in the Common Info field indicated a bandwidth less than or equal to 80 MHz, and not exceed the *RSTA Assigned I2R STS > 80 MHz* for the corresponding ISTA otherwise.

— All the I2R Rep subfields in the User Info fields of the TF Ranging Sounding shall be set to the same value. This value indicates the number of LTF repetitions in the I2R NDP preamble and shall not exceed any of the *RSTA Assigned I2R Rep* corresponding to the ISTA triggered by this Trigger frame.

— The product of the number of LTF repetitions, indicated in each of the I2R Rep subfields of the User Info fields, and the number of HE-LTF symbols, indicated in the Number Of HE-LTF Symbols And Midamble Periodicity subfield in the Common Info field, shall not exceed the *RSTA Assigned I2R LTF Total* for any of the ISTA triggered by this Trigger frame.

After transmission of the TF Ranging Sounding, the RSTA's MAC sublayer shall issue a PHY-RXLTFSEQUENCE.request primitive with an LTFVECTOR containing the following parameters:

— The SECURE_LTF_FLAG parameter set to 0.

— The LTF_NSTS and LTF_REP parameter vectors set to the same values as indicated, respectively, by the SS Allocation and I2R Rep subfields of all the User Info fields.


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Similarly, in the Ranging NDP Announcement frame, the RSTA shall set the R2I NSTS subfield and R2I Rep subfield of the STA Info fields corresponding to each of the ISTAs addressed by that frame in the following way:

— The R2I NSTS subfield value shall not exceed the *RSTA Assigned R2I STS ≤ 80 MHz* for the corresponding ISTA, if the TXVECTOR parameter CH_BANDWIDTH for this Ranging NDP Announcement frame is less than or equal to 80 MHz, and not exceed *RSTA Assigned R2I STS > 80 MHz* for the corresponding ISTA otherwise.

— The number of LTF repetitions in the R2I Rep subfield shall be set to a value not to exceed the *RSTA Assigned R2I Rep* for the corresponding ISTA.

— The combination of the values of the R2I NSTS and the R2I Rep shall not lead to a total number of LTF that exceeds the *RSTA Assigned R2I LTF Total* for each corresponding ISTA.

After reception of the Ranging NDP Announcement frame, the ISTAs' MAC sublayer shall issue a PHY-RXLTFSEQUENCE.request primitive with an LTFVECTOR containing the following parameters:

— The SECURE_LTF_FLAG parameter set to 0.

— The LTF_NSTS and LTF_REP parameters set to the same values as indicated, respectively, by the R2I NSTS and R2I Rep subfields of the STA Info field addressed to it.

The RSTA shall set a different value than the previous transmission in the Sounding Dialog Token Number field in its transmitted Ranging NDP Announcement frame as part of each Measurement Sounding phase. Measurement instances are associated with the Sounding Dialog Token Number field value.

The RSTA may schedule some ISTAs that replied during the Polling phase to the first measurement sounding phase instance and other ISTAs to one of possibly multiple extra measurement sounding phase instances; see Figure 11-49 (TB ranging availability window with two instances of polling/sounding/reporting triplets within a single TXOP(11az)) and Figure 11-50 (TB ranging availability window with two instances of polling/sounding/reporting triplets in separate TXOPs(11az)). The RSTA shall only schedule measurement sounding resources to an ISTA in a measurement sounding instance if a valid poll response was received from that ISTA in the corresponding Polling phase instance. This may require an RSTA to poll an ISTA multiple times. This is necessary, for example, if different ISTAs have varying, incompatible, RSTA Assigned Max Bandwidth values or if the RSTA wants to limit the time duration of each range measurement sounding instance.

Both RSTA and ISTA perform RTT measurements by capturing the timestamps of the NDP. The ISTA shall record the time at which the I2R NDP is transmitted (t1). The RSTA shall then capture the time at which the I2R NDP arrives (t2) and shall record the time at which the R2I NDP is transmitted (t3). The ISTA shall finally capture the time at which the R2I NDP arrives (t4); see Figure 11-53 (Timing diagram of a measurement

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sounding phase in TB ranging(11az)). The timestamp values t2 and t3 shall be measured according to the RSTA's clock (i.e., without applying any frequency offset correction to the time basis).

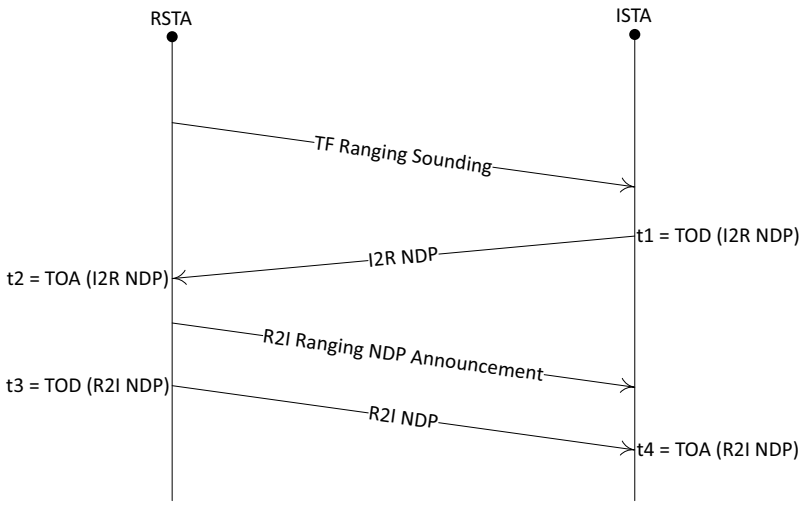


**Figure 11-53—Timing diagram of a measurement sounding phase in TB ranging(11az)**

The Round Trip Time (RTT_ISTA) observed by ISTA is defined as:

$$RTT_{ISTA} = [(t4 - t1) - (t3' - t2')]$$

where t3' and t2' are the time at which the R2I NDP was transmitted and the time at which the I2R NDP was received, respectively, as converted by the ISTA from the RSTA's time basis to its own time basis.

The mechanism by which the ISTA derives t3' and t2' from the TOD and TOA fields of the relevant R2I LMR (see 11.21.6.4.3.4 (Reporting phase of TB ranging measurement(11az))) is implementation dependent.

When the I2R LMR Feedback is negotiated, the RSTA can compute the RTT as:

$$RTT_{RSTA} = [(t4' - t1') - (t3 - t2)]$$

where t1' and t4' are the time at which the I2R NDP was transmitted and the time at which the R2I NDP was received, respectively, as converted by the RSTA from the ISTA's time basis to its own time basis. The mechanism by which the RSTA derives t4' and t1' from the TOD and TOA fields of the relevant I2R LMR is implementation dependent; see 11.21.6.4.3.4 (Reporting phase of TB ranging measurement(11az)).

NOTE 1—When using CFO in the conversion from the ISTA's time basis to the RSTA's, the RSTA uses the CFO reported in the CFO Parameter field of the I2R LMR.

NOTE 2—Refer to 27.3.15.3 (Precorrection accuracy requirements(M118)) for carrier frequency offset (CFO) correction requirements for HE TB PPDU transmission.

In an LMR, the TOA field contains a timestamp that represents the time, with respect to a time base, at which the start of the preamble of the corresponding NDP arrived at the receive antenna connector. The TOD field contains a timestamp that represents the time, with respect to the same time base, at which the start of the preamble of the corresponding NDP appeared at the transmit antenna connector.


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If the measurement sounding phase includes more than a single TF Ranging Sounding frame (see Figure 11-54 (TB ranging availability window with multiple TF Ranging Sounding frames(11az))) each ISTA and RSTA pair shall refer to the t1 and t2 of the I2R NDP transmitted by that ISTA, while t3 and t4 shall be based on the single R2I NDP received by all ISTAs; see Figure 11-55 (Measurement sounding phase with I2R time division multiplexing(11az)).

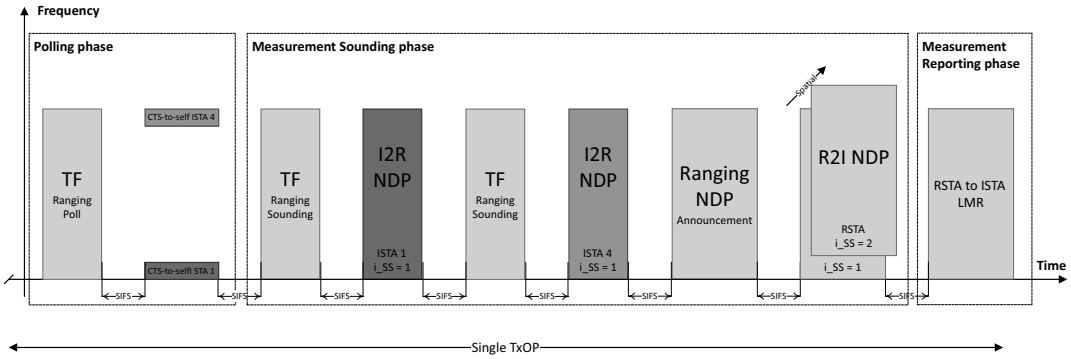


**Figure 11-54—TB ranging availability window with multiple TF Ranging Sounding frames(11az)**

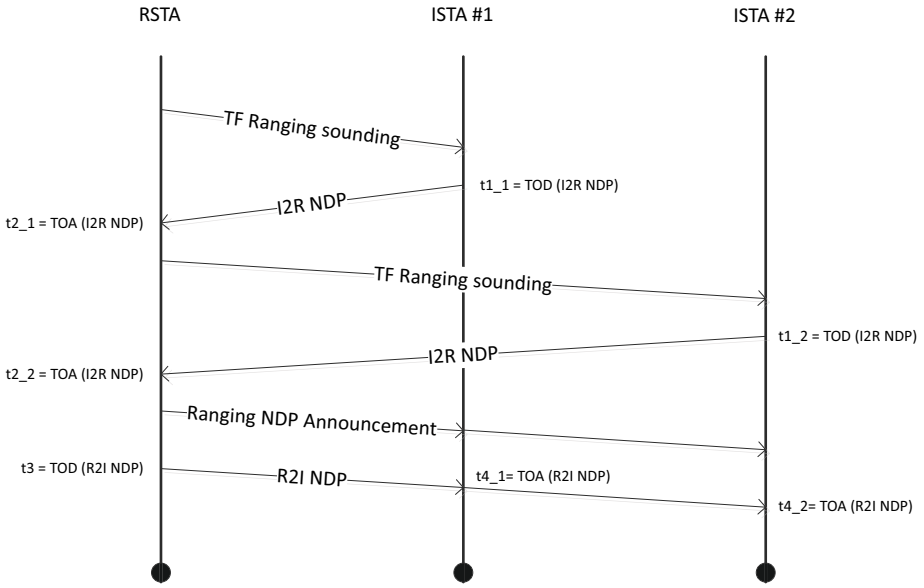


**Figure 11-55—Measurement sounding phase with I2R time division multiplexing(11az)**

If due to retransmission an ISTA receives multiple TF Ranging Sounding frames and transmits multiple I2R NDPs, the ISTA and RSTA shall refer to the t1 and t2 of the I2R NDP last transmitted.

The uplink power control, timing, and frequency synchronization requirements of unassociated STAs performing TB ranging shall follow the same rules as those of associated HE STAs.

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To aid in synchronizing the TSF time at the ISTAs, the RSTA maintains a trigger poll counter. Before transmitting a TF Ranging Poll frame, the RSTA shall increase the trigger poll counter by one (modulo 8) and set the Token subfield of the Trigger Dependent Common Info subfield to the value of the trigger poll counter.

When transmitting a Ranging NDP Announcement frame as part of the TB ranging measurement exchange, an RSTA shall include a value in the Partial TSF subfield in the STA Info field with the AID11 subfield equal to 2044, that is equal to the RSTA's TSF[21:6] at the time of transmission of the preceding TF Ranging Poll frame. Specifically, the time that the first data symbol of the PSDU of said frame was transmitted to the PHY plus the RSTA's delays through its local PHY from the MAC-PHY interface to its interface with the WM.

Additionally, the RSTA shall set the Token subfield in the STA Info field with the AID11 subfield equal to 2044 to the same trigger poll counter value as the Token subfield in the TF Ranging Poll frame whose partial TSF time is carried in the Ranging NDP Announcement frame.

NOTE 3—An ISTA that tries to synchronize to the RSTA's TSF time will need to keep track of the difference between its local TSF[63:22] and the RSTA's TSF[63:22] when updating the TSF[21:6]. When receiving a partial TSF value in a received Ranging NDP Announcement frame from the RSTA, to synchronize its TSF time with the RSTA's TSF time in order to determine the start of a subsequent TB ranging availability window:

— The ISTA should check if its TSF[21:6] at the reception of a TF Ranging Poll frame was larger than the received Partial TSF and the absolute difference is more than $2^{15}$, then the ISTA should increase the RSTA's tracked TSF [63:22] value by 1.

— If the ISTA's TSF [21:6] at the reception of the TF Ranging Poll frame is less than the Partial TSF and the absolute difference is more than $2^{15}$, the ISTA should decrease the RSTA's tracked TSF [63:22] value by 1.

#### 11.21.6.4.3.4 Reporting phase of TB ranging measurement(11az)

The last phase of each polling/sounding/reporting triplet is the measurement reporting phase, which is transmitted a SIFS time after the measurement sounding phase; see Figure 11-50 (TB ranging availability window with two instances of polling/sounding/reporting triplets in separate TXOPs(11az)). The measurement results shall be carried in LMR frames; see 9.6.7.49 (LMR frame format(11az)(#8216)). LMR frames shall carry measurement results from the RSTA to the ISTA, and if negotiated also from the ISTA to the RSTA; see Figure 11-56 (TB ranging measurement reporting phase with bidirectional LMR feedback for n ISTAs(11az)). If the Range Reporting is performed in the context of a Secure FTM Session, see 11.21.6.3 (FTM procedure negotiation(11az)), the corresponding LMR and FTM (see 11.21.6.5.1 (Availability window parameter modification(11az))) frames shall be transmitted using Protected Fine Timing Action frames, and see 9.6.34 (Protected Fine Timing Action frame details(11az)(#8155)).

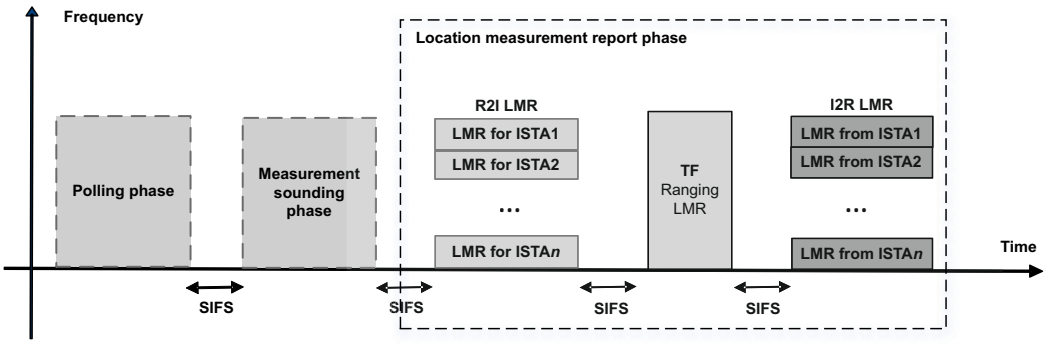


**Figure 11-56—TB ranging measurement reporting phase with bidirectional LMR feedback for *n* ISTAs(11az)**

The feedback type of the I2R and R2I LMRs may be either immediate (i.e., from the current availability window) or delayed (i.e., from the last availability window in which the ISTA responded to the TF Ranging Poll frame and the RSTA allocated resources to that ISTA during the measurement sounding phase). The LMR


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feedback (immediate/delayed) is indicated by the RSTA during the negotiation (see 11.21.6.3.3 (Negotiation for TB and non-TB ranging measurement exchange)).

The Dialog Token field in the LMR frame shall be identical to the Sounding Dialog Token field in the corresponding Ranging NDP Announcement frame in the Measurement Sounding phase from which the reported TOA and TOD values were measured; see 11.21.6.4.3.3 (Measurement Sounding phase of TB ranging(11az)).

NOTE 1—LMR feedback is carried in Action No-Ack frames and is therefore neither acknowledged nor retransmitted; see 9.6.7.49 (LMR frame format(11az)(#8216)).

The RSTA shall transmit an R2I LMR to all ISTAs that were allocated resources in the preceding measurement sounding phase. All the R2I LMR frames shall be carried in one HE MU PPDU, where each RU contains only one user; if there is only one R2I LMR it may be carried in an HE SU PPDU.

If I2R LMR was negotiated, the RSTA shall assign uplink resources to the ISTAs using a Report Ranging Trigger frame; see 9.3.1.22.10 (Ranging Trigger variant(11az)). The Ranging variant Trigger frame of report subvariant is called the TF Ranging LMR.

A TB ranging measurement reporting phase including the optional I2R LMR is illustrated in Figure 11-56 (TB ranging measurement reporting phase with bidirectional LMR feedback for n ISTAs(11az)). If the I2R LMR was negotiated by one or more ISTAs, then SIFS time after transmitting out the R2I LMR, the RSTA transmits a TF Ranging LMR to solicit the I2R LMR frame(s). This TF shall allocate uplink resources to ISTAs that negotiated I2R LMR and were allocated resources in the preceding measurement sounding phase. The RSTA shall allocate each RU in the TF Ranging LMR to only one ISTA. In response to the TF Ranging LMR, each addressed ISTA shall respond by transmitting an I2R LMR frame.

If an ISTA negotiated delayed I2R LMR reporting, and if the TOA measurement for the previous availability window is not ready, then the ISTA shall not respond to the TF Ranging Poll frame in the Polling phase of any availability window until the I2R LMR is ready.

For delayed reporting, the first instance of the R2I LMR and the optional I2R LMR do not have valid TOA/TOD timestamps to include, in this case the RSTA and the ISTA shall set the Invalid Measurement subfield in the TOA Error field of the respective LMR to 1.

In TB ranging, the PHY shall issue the PHY-RXEND.indication primitive with error condition IntegrityCheckError if the PHY detects the integrity check error in the reception of the corresponding HE Ranging NDP or HE TB Ranging NDP. If the PHY of an RSTA issues a PHY-RXEND.indication primitive with error condition IntegrityCheckError, the RSTA shall set the Invalid Measurement field in the R2I LMR frame carrying the TOA measured from the I2R NDP to 1. Correspondingly, if I2R LMR was negotiated between the ISTA and RSTA and the PHY of the ISTA issues a PHY-RXEND.indication primitive with error condition IntegrityCheckError, the ISTA shall set the Invalid Measurement field in the I2R LMR carrying the TOA measured from the R2I NDP to 1.

NOTE 2—When a STA detects that the transmit center frequency offset (CFO) between the ISTA and the RSTA exceeds the allowed tolerance from the values specified in 27.3.21.3 (Transmit center frequency and symbol clock frequency tolerance) and 27.3.15.3 (Precorrection accuracy requirements(M118)), this can be an indication of a security attack.

If I2R LMR reporting was negotiated, then the ISTA shall include a CFO parameter in the I2R LMR; see 9.6.7.49 (LMR frame format(11az)(#8216)). The ISTA shall estimate the CFO parameter based on the PPDU carrying the TF Ranging Sounding frame that solicits the I2R NDP from the ISTA. The RSTA may account for clock rate differences between ISTA and RSTA based on the CFO parameter included in the received I2R LMR. The mechanism by which t4 and t1 are adjusted by the RSTA is implementation specific. The CFO parameter refers to the t1 and t4 indicated in the same I2R LMR.

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If the Invalid Measurement field in an R2I LMR or I2R LMR is equal to 1, the RSTA or ISTA receiving the LMR should discard the TOA carried in the LMR.

In TB ranging measurement reporting phase, if R2I LMR reporting or I2R LMR reporting carries phase shift feedback, then the R2I LMR reporting or the I2R LMR reporting shall be immediate feedback.

In TB ranging measurement reporting phase, if R2I AOA feedback was negotiated, the RSTA shall include the optional AOA feedback subfield in the R2I LMR frame and if I2R LMR reporting was negotiated in addition to I2R AOA Feedback reporting then the ISTA shall include the optional AOA feedback subfield in the I2R LMR frame. The AOA field contains the Direction Measurement Results element described in 9.4.2.302 (Direction Measurement Results element(11az)).

#### 11.21.6.4.4 Non-TB ranging measurement exchange(11az)

##### 11.21.6.4.4.1 General(11az)

In Non-TB ranging, the protocol operates in an ISTA centric scheduling FTM mode; whenever the medium is available, an ISTA may initiate the measurement. The RSTA can only limit the frequency with which the ISTA can initiate measurements, by setting a minimum time interval between subsequent range measurements.

(#7067)(#8117)The FTM protocol for a non-TB ranging measurement exchange and its relationship with the SME and MLME interface is shown in Figure 11-57 (FTM primitives and timestamps reporting capture for non-TB ranging measurement exchange(#7067)).

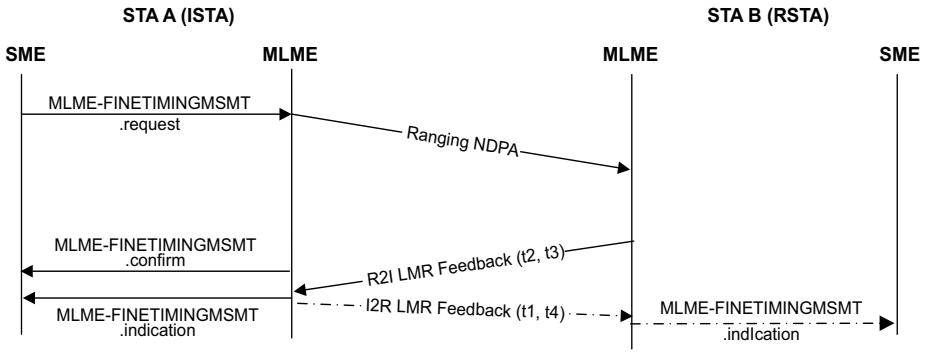


**Figure 11-57—FTM primitives and timestamps reporting capture for non-TB ranging measurement exchange(#7067)**

##### 11.21.6.4.4.2 Measurement sounding phase of non-TB ranging(11az)

An ISTA shall initiate a non-TB ranging measurement instance by transmitting a Ranging NDP Announcement frame addressed to the RSTA, followed by an I2R NDP SIFS after. In response to the correctly received Ranging NDP Announcement frame addressed to itself, the RSTA shall transmit an R2I NDP; see Figure 11-58 (Non-TB ranging measurement exchange sequence(11az)). I2R NDP and R2I NDP refer to NGV Ranging NDPs when dot11NGVOptionImplemented is true and HE ranging NDPs otherwise(11bd). The


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measurement-reporting phase consists of an LMR frame, which is a Location Measurement Report as defined in 9.6.7.49 (LMR frame format(11az)(#8216)).

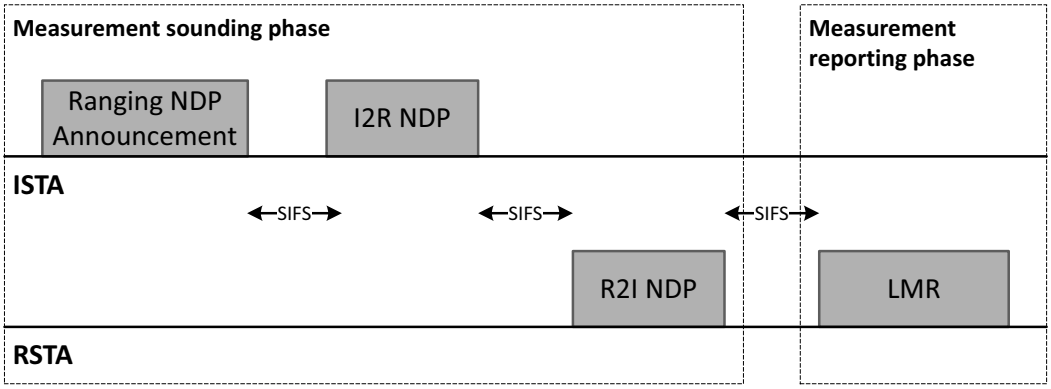


**Figure 11-58—Non-TB ranging measurement exchange sequence(11az)**

For immediate feedback the LMR carries measurement results of the current measurement exchange, while for delayed feedback the LMR carries measurement results of the previous measurement exchange; see 11.21.6.4.4.3 (Non-TB ranging measurement reporting phase(11az)).

An ISTA shall set the Min Time Between Measurements field and the Max Time Between Measurements field in the Non-TB Specific subelement in the Ranging Parameters element in the IFTMR frame, where Max Time Between Measurements shall be larger than Min Time Between Measurements and takes into account the measurement exchange duration. An RSTA shall assign the value of the Min Time Between Measurements and Max Time Between Measurements in the Non-TB Specific subelement in the Ranging Parameters element in the initial FTM frame, where Max Time Between Measurements shall be larger than Min Time Between Measurements and takes into account of the measurement exchange duration.

An ISTA shall not initiate a new measurement exchange sequence until the assigned minimum time interval between subsequent range measurements has elapsed; see Figure 11-60 (Non-TB ranging with immediate reporting(11az)). An ISTA should complete the measurement sequence before the assigned maximum time interval between subsequent range measurements has elapsed.

An ISTA may use any AC to transmit the Ranging NDP Announcement frame.

The ISTA maintains a sounding dialog token counter modulo 64 for each FTM session. When transmitting a Ranging NDP announcement frame to an RSTA, the Sounding Dialog Token Number subfield in the Sounding Dialog field shall be set to the value of the corresponding counter; after which the counter shall be incremented by 1.

After transmitting the Ranging NDP Announcement frame and I2R NDP, the ISTA shall wait for a time interval of aSIFSTime + aSlotTime + aRxPHYStartDelay. This interval begins when the MAC receives a PHY-TXEND.confirm primitive for I2R NDP. If a PHY-RXSTART.indication primitive does not occur during the time interval, the ISTA shall conclude that the transmission of the Ranging NDP Announcement frame + I2R NDP has failed and abort the current measurement exchange. If a PHY-RXSTART.indication primitive occurred during the time interval, the ISTA tries to receive the R2I NDP and the LMR frame from the RSTA addressed by the Ranging NDP Announcement frame. If the LMR is received from the RSTA, the frame exchange initiated by the Ranging NDP Announcement frame is complete, otherwise the ISTA shall conclude that the current measurement exchange has failed.

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The ISTA may invoke the backoff procedure by an EDCAF when the last frame of the measurement exchange initiated by the Ranging NDP Announcement frame has completed and the TXNAV timer has expired.

In the Non-TB ranging measurement exchange sequence, the ISTA shall transmit the Ranging NDP Announcement frame with the same bandwidth as the I2R NDP to reserve the medium. The Ranging NDP Announcement frame shall be individually addressed (#6026)with the RA field set to the address of the RSTA, and contain one STA Info field with the AID11 subfield set to 0. If negotiated, the (#8066)NDP Announcement frame shall contain another STA Info field with AID11 subfield set to 2045, and the I2R Tx Power subfield shall be set to indicate the TX power of the following I2R NDP. If the STA Info field with AID11 subfield set to 2045 is included, the ISTA shall set the R2I NDP Target RSSI subfield to either its preferred receive signal power or a reserved value.

The RSTA shall transmit the R2I NDP with the same bandwidth as the Ranging NDP Announcement frame, while the LMR may be transmitted at a different bandwidth, according to the rules of multiple frame transmission in an EDCA TXOP, see 10.23.2.8 (Multiple frame exchange sequences in an EDCA TXOP(#109)). The allowed bandwidths for the Ranging NDP Announcements, I2R NDP, and R2I NDP, shall be less than or equal to the RSTA Assigned Max Bandwidth.

Accordingly:

— An ISTA transmitting an I2R NDP shall set the TXVECTOR parameter CH_BANDWIDTH to the same value as the TXVECTOR parameter CH_BANDWIDTH in the preceding Ranging NDP Announcement frame.

— An RSTA transmitting an R2I NDP shall set the TXVECTOR parameter CH_BANDWIDTH to the bandwidth of the Ranging NDP Announcement frame and/or the I2R NDP; which are obtained from the RXVECTOR parameter CH_BANDWIDTH of the Ranging NDP Announcement frame or I2R NDP, respectively. For the Ranging NDP Announcement frame, when not received in an HE/VHT/HT/NGV PPDU(11bd): from the RXVECTOR parameter CH_BANDWIDTH_IN_NON_HT when the Ranging NDP Announcement frame is received in a non-HT duplicate PPDU and is 20 MHz when the Ranging NDP Announcement frame is received in a non-HT PPDU.

If the bandwidth is less than or equal to 80 MHz, the ISTA shall set the I2R NSTS subfield and the R2I NSTS subfield in the STA Info field of the Ranging NDP Announcement frame each to a value not to exceed the *RSTA Assigned I2R STS ≤ 80 MHz* and *RSTA Assigned R2I STS ≤ 80 MHz*, respectively. If the bandwidth is greater than 80 MHz, the ISTA shall set these same subfields to values not to exceed the *RSTA Assigned I2R STS > 80 MHz* and *RSTA Assigned R2I STS > 80 MHz*, respectively.

The ISTA shall set the I2R Rep subfield and R2I Rep subfield in the STA Info field of the Ranging NDP Announcement frame each to a value not to exceed the *RSTA Assigned I2R rep* and *RSTA Assigned R2I rep*, respectively. Furthermore, the total number of LTF in the I2R NDP and R2I NDP, based on the number of spatial streams and repetitions, shall not exceed the *RSTA Assigned I2R LTF Total* and *RSTA Assigned R2I LTF Total*, respectively.

After transmission of the Ranging NDP Announcement frame, the ISTA's MAC sublayer shall issue a PHY-RXLTFSEQUENCE.request primitive with a LTFVECTOR containing the following parameters:

— The SECURE_LTF_FLAG parameter set to 0.

— The LTF_NSTS and LTF_REP parameters set to the same values as indicated, respectively, by the R2I NSTS and R2I Rep subfields in the STA Info field with the AID11 subfield less than or equal to 2007.

After reception of the Ranging NDP Announcement frame, the RSTA's MAC sublayer shall issue a PHY-RXLTFSEQUENCE.request primitive with a LTFVECTOR containing the following parameters:

— The SECURE_LTF_FLAG parameter set to 0.


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— The LTF_NSTS and LTF_REP parameters set to the same values as indicated, respectively, by the I2R NSTS and I2R Rep subfields in the STA Info field with the AID11 subfield less than or equal to 2007.

Both RSTA and ISTA perform RTT measurements by capturing the timestamps of the NDP. The ISTA shall record the time at which the I2R NDP is transmitted (t1). The RSTA shall then capture the time at which the I2R NDP arrives (t2) and shall record the time at which the R2I NDP is transmitted (t3). The ISTA shall finally capture the time at which the R2I NDP arrives (t4); see Figure 11-59 (Timing diagram of a measurement sounding phase in non-TB ranging(11az)). The timestamp values t2 and t3 shall be measured according to the RSTA's clock (i.e., without applying any frequency offset correction to the time basis).

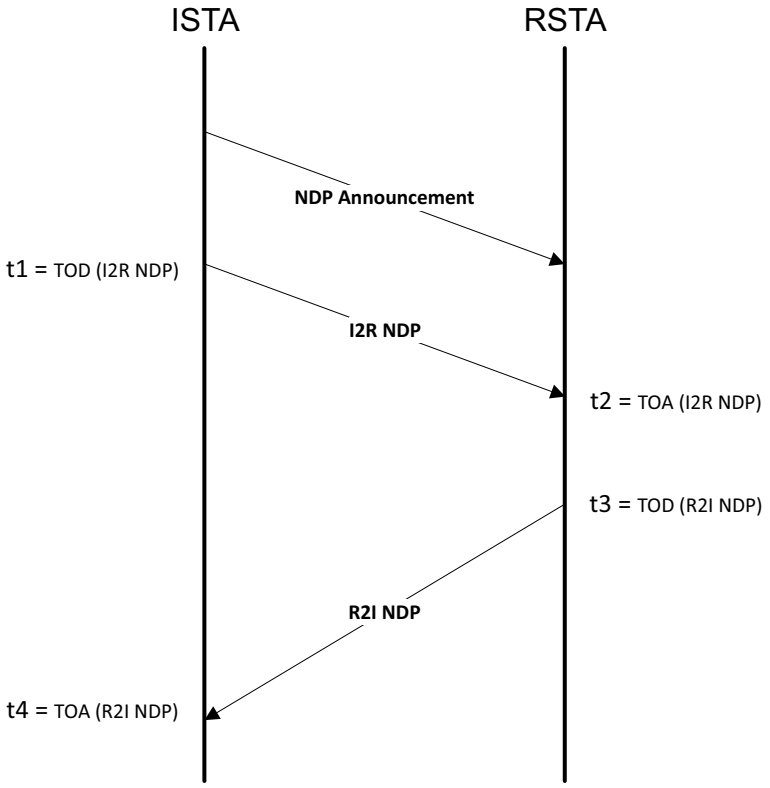


**Figure 11-59—Timing diagram of a measurement sounding phase in non-TB ranging(11az)**

The Round Trip Time ($RTT_{ISTA}$) based on first path reporting is defined as:

$$RTT_{ISTA} = [(t4 - t1) - (t3' - t2')]$$

where t3' and t2' are the time at which the R2I NDP was transmitted and the time at which the I2R NDP was received, respectively, as converted by the ISTA from the RSTA's time basis to its own time basis.

The mechanism by which the ISTA derives t3' and t2' from the TOD and TOA fields of the relevant LMR is implementation dependent.

The Round Trip Time ($RTT_{RSTA}$) based on first path reporting is defined as:

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$$RTT_{RSTA} = [(t4' - t1') - (t3 - t2)]$$

where t1' and t4' are the time at which the I2R NDP was transmitted and the time at which the R2I NDP was received, respectively, as converted by the RSTA from the ISTA's time basis to its own time basis.

The mechanism by which the RSTA derives t1' and t4' from the TOD and TOA fields of the relevant LMR is implementation dependent.

In an LMR, the TOA field contains a timestamp that represents the time, with respect to a time base, at which the start of the preamble of the corresponding NDP arrived at the receive antenna connector. The TOD field contains a timestamp that represents the time, with respect to the same time base, at which the start of the preamble of the corresponding NDP appeared at the transmit antenna connector.

#### 11.21.6.4.4.3 Non-TB ranging measurement reporting phase(11az)

In non-TB ranging, the ranging protocol supports both immediate and delayed reporting.

An RSTA or ISTA indicates immediate reporting by setting the immediate R2I Or I2R Feedback subfield in the Ranging Parameters field of the FTM session frames that enable the measurement exchange, to 1. In immediate reporting, the TOA feedback corresponding to the current measurement exchange sequence shall be reported in the current measurement exchange; see Figure 11-60 (Non-TB ranging with immediate reporting(11az)).

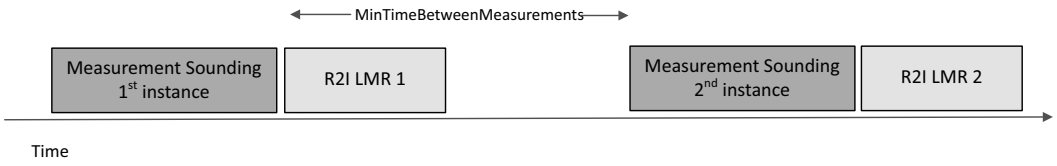


**Figure 11-60—Non-TB ranging with immediate reporting(11az)**

An RSTA or ISTA indicates delayed reporting by setting the Immediate R2I Or I2R Feedback subfield in the Ranging Parameters field to 0. In delayed reporting, the TOA and TOD values in the current LMR shall carry the measurement results of the previous round. In this case, the first instance of the R2I LMR and the optional I2R LMR do not have valid TOA/TOD timestamps to include, and the RSTA and the ISTA shall set the Invalid Measurement subfield in the TOA Error field of the corresponding LMR to 1; see Figure 11-61 (Non-TB ranging with delayed reporting(11az)).

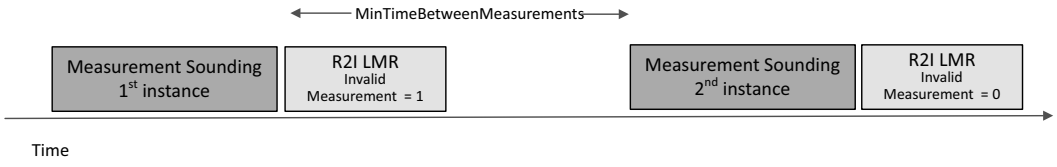


**Figure 11-61—Non-TB ranging with delayed reporting(11az)**

An RSTA that indicated delayed reporting shall provide TOA feedback to the ISTA when the ISTA initiates another measurement sequence after Min Time Between Measurements, but before Max Time Between Measurements; see Figure 11-62 (Illustration of min time between measurements and max time between measurements with delayed reporting(11az)). This TOA feedback is carried in the LMR frame of this new


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measurement sequence and can be either valid or invalid as indicated by the Invalid Measurement field in the LMR frame.

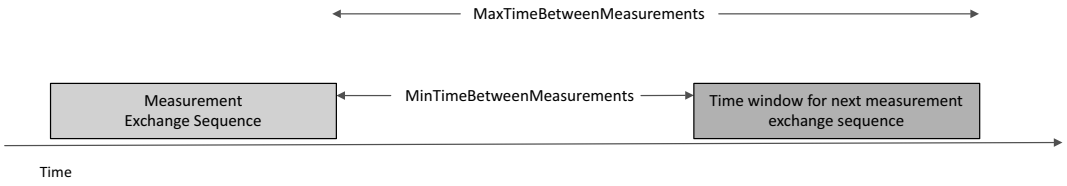


**Figure 11-62—Illustration of min time between measurements and max time between measurements with delayed reporting(11az)**

The Dialog Token field of the LMR frame shall be copied from the Sounding Dialog Token Number subfield in the Ranging NDP Announcement frame that preceded the NDP which is used for the reported measurement.

If negotiated, the RSTA shall set the R2I TX Power field in the R2I LMR to report the TX power of the preceding R2I NDP; otherwise the R2I Tx Power field shall be set to a reserved value. The RSTA shall set the I2R NDP Target RSSI field to its preferred receive signal power or a reserved value.

If I2R LMR feedback is negotiated, the non-TB ranging measurement exchange (11.21.6.4.4 (Non-TB ranging measurement exchange(11az))) sequence shall follow the sequence shown in Figure 11-63 (Non-TB ranging measurement exchange sequence with bidirectional LMR feedback(11az)). After a SIFS(#6587) time of receiving the R2I LMR frame, the ISTA shall transmit the I2R LMR frame to the RSTA. The feedback type of I2R LMR could be either immediate or delayed.

NOTE 1—LMR feedback is carried in an Action No-Ack frame and is therefore neither acknowledged nor retransmitted; see 9.6.7.49 (LMR frame format(11az)(#8216)).

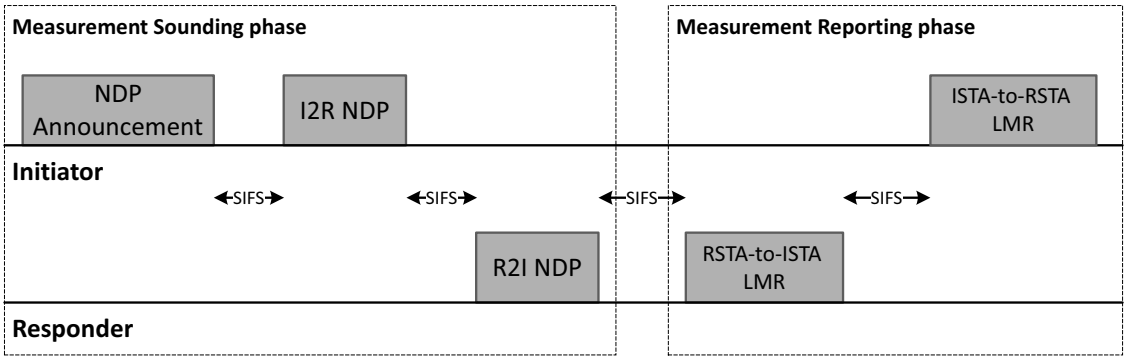


**Figure 11-63—Non-TB ranging measurement exchange sequence with bidirectional LMR feedback(11az)**

The data rate or MCS used for transmitting the R2I and I2R LMR frames is solely decided by the transmitter of each of the frames. The bandwidth used to transmit the R2I LMR frame shall be no greater than that of the soliciting NDP Announcement frame, and the transmit bandwidth of the I2R LMR frame shall be no greater than the bandwidth of the preceding R2I LMR frame.

In non-TB ranging, the PHY shall issue the PHY-RXEND.indication primitive with error condition IntegrityCheckError if the PHY detects the integrity check error in the reception of the corresponding HE Ranging NDP. If the PHY of an RSTA issues a PHY-RXEND.indication primitive with error condition IntegrityCheckError, the RSTA shall set the Invalid Measurement field in the R2I LMR frame carrying the TOA measured from the I2R NDP to 1. Similarly, if I2R LMR was negotiated between the ISTA and RSTA and the PHY of an ISTA issues a PHY-RXEND. Indication primitive with error condition IntegrityCheckError,

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the ISTA shall set the Invalid Measurement field in the I2R LMR carrying the TOA measured from the R2I NDP to 1.

NOTE 2—When a STA detects that the transmit center frequency offset (CFO) between the ISTA and the RSTA exceeds the allowed tolerance from the values specified in 27.3.21.3 (Transmit center frequency and symbol clock frequency tolerance) and 27.3.15.3 (Precorrection accuracy requirements(M118)), this can be an indication of a security attack.

In non-TB ranging, both RSTA and ISTA should measure the CFO value based on reception of I2R NDP and R2I NDP, respectively. Therefore, the CFO parameter field in the I2R LMR, if negotiated, and R2I LMR are reserved. The RSTA and ISTA may account for clock rate differences between ISTA and RSTA, respectively, based on their own measured CFO value. The mechanism by which t4 and t1 are adjusted by the RSTA, and t2 and t3 are adjusted by the ISTA is implementation specific.

If the Invalid Measurement field in R2I LMR or I2R LMR is equal to 1, the RSTA or ISTA receiving the LMR should discard the TOA carried in the LMR.

In the non-TB ranging measurement reporting phase, if R2I LMR reporting or I2R LMR reporting carries phase shift feedback, then the R2I LMR reporting or the I2R LMR reporting shall be immediate feedback.

In the non-TB ranging measurement reporting phase, if R2I AOA feedback was negotiated the RSTA shall include the optional AOA feedback subfield in the R2I LMR frame and if R2I LMR reporting was negotiated in addition to I2R AOA Feedback reporting then the ISTA shall include the optional AOA feedback subfield (see 9.4.2.302 (Direction Measurement Results element(11az))) in the I2R LMR frame. The AOA field contains the Direction Measurement Results element described in 9.4.2.302 (Direction Measurement Results element(11az)).

#### 11.21.6.4.5 Secure HE-LTF in the TB and non-TB ranging measurement exchange protocol(11az)

##### 11.21.6.4.5.1 General(11az)

Both the TB and the non-TB ranging measurement exchanges allow for the use of secure HE-LTF for PHY security if the ISTA and RSTA have established a secure HE-LTF measurement setup as defined in 11.21.6.3.4 (Negotiation for secure HE-LTF in the TB and non-TB ranging measurement exchange). The frame exchange sequences stay nominally the same as described in 11.21.6.4.3 (TB ranging measurement exchange(11az)) and 11.21.6.4.4 (Non-TB ranging measurement exchange(11az)), except that the HE Ranging NDP and HE TB Ranging NDP use secure HE-LTF as described in 27.3.19.1 (HE Ranging NDP(11az)) and 27.3.19.2 (HE TB Ranging NDP(11az)), respectively. To use the secure HE-LTF, the ISTA and RSTA need to share and communicate pseudorandom bit sequences that are used to generate and demodulate the secure HE-LTF, the details and management thereof is described in 11.21.6.4.5.2 (TB ranging measurement exchange with secure HE-LTF(11az)) to 11.21.6.4.5.6 (Secure HE-LTF input octet stream generation on an RSTA(11az)).

##### 11.21.6.4.5.2 TB ranging measurement exchange with secure HE-LTF(11az)

An example of the negotiation and two TB Ranging Measurement Exchanges with secure HE-LTF is shown in Figure 11-64 (Overview of the TB ranging measurement exchange with secure HE-LTF(11az)(#8019)), where the LTF_VALID_SAC and SEC_LTF_CTR refer to the values of the Validation SAC and (#8016)Secure LTF Counter subfields, respectively. The first value of the Validation SAC and its associated (#8016)Secure LTF Counter subfields shall be included in a protected IFTM frame, and thereafter any subsequent value of the Validation SAC and its corresponding (#8016)Secure LTF Counter subfield shall be included in a protected R2I LMR frame. The value of the Validation SAC subfield shall also be the same value of the SAC subfield in the Trigger Dependent User Info field of the Secure Sounding Ranging Trigger frame. The description of how these fields are set in the TB ranging measurement exchange is given next.


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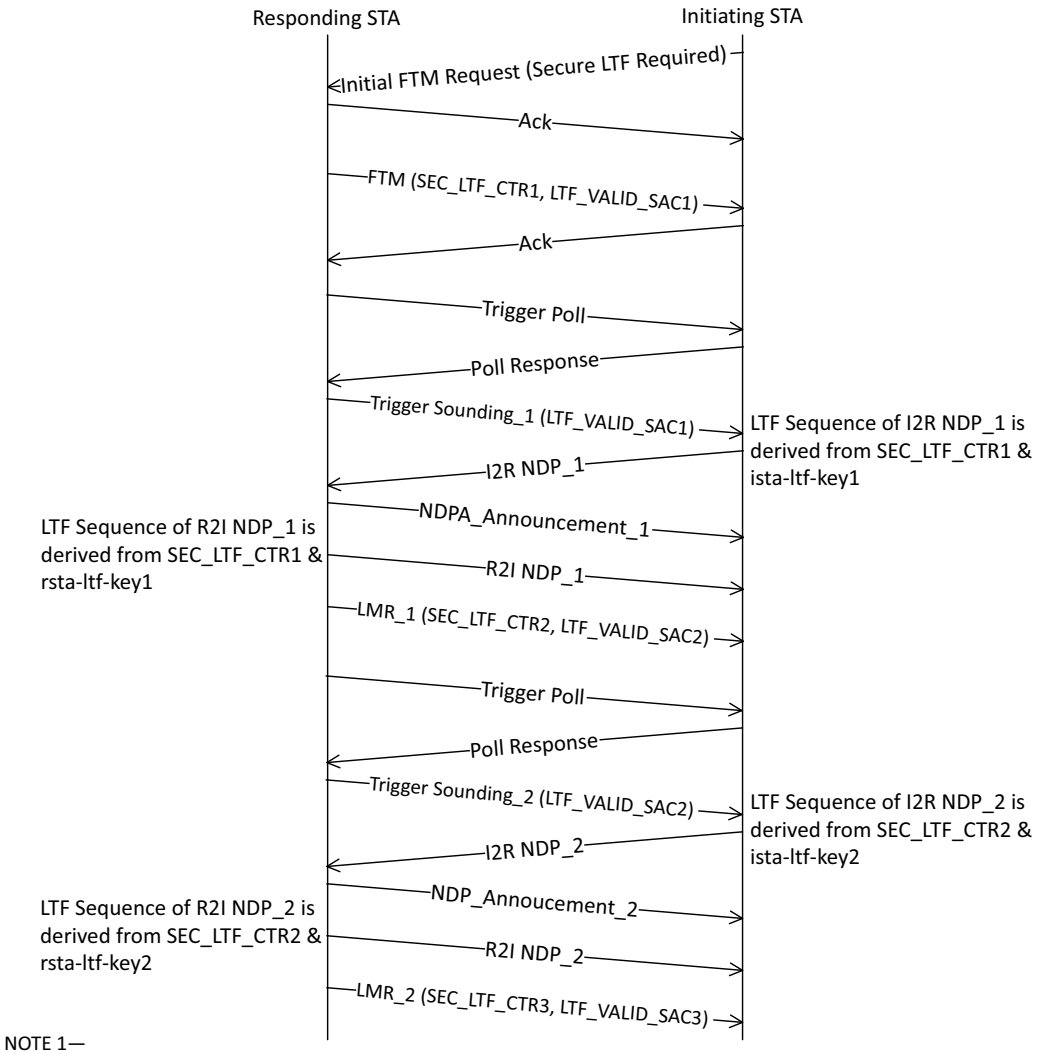


NOTE 1—
When LMR_2 is a delayed feedback type, Range Measurement SAC carried in LMR_2 is set to LTF_VALID_SAC1.
When LMR_2 is an immediate feedback type, Range Measurement SAC carried in LMR_2 is set to LTF_VALID_SAC2.

**Figure 11-64—Overview of the TB ranging measurement exchange with secure HE-LTF(11az)(#8019)**

In a TB ranging measurement exchange with secure HE-LTF where there are multiple ISTAs involved in the measurement sequence, the RSTA shall transmit a Secure Sounding Ranging Trigger frame that includes a single User Info field to trigger a single ISTA at a time.

When an RSTA has established a secure HE-LTF measurement exchange with an ISTA as specified in 11.21.6.3.4 (Negotiation for secure HE-LTF in the TB and non-TB ranging measurement exchange), the RSTA that sends a Secure Sounding Ranging Trigger frame to the STA shall set:

— The SAC subfield in the Trigger Dependent User Info field corresponding to the ISTA in the Secure Sounding Ranging Trigger frame to the same value as in the Validation SAC field in the Secure HE-LTF Parameters element in the last transmitted protected IFTM, or last transmitted protected LMR frame, to the ISTA.

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The RSTA shall set the I2R Rep subfield of the User Info field corresponding to the ISTA in the Secure Sounding Ranging Trigger frame equal to the value of the *RSTA Assigned I2R Rep* corresponding to the ISTA, where the value of the *RSTA Assigned I2R Rep* shall be greater than 0.

After transmission of the Secure Sounding Ranging Trigger frame to the ISTA, the RSTA's MAC sublayer shall issue a PHY-RXLTFSEQUENCE.request primitive with a LTFVECTOR containing the following parameters:

— The SECURE_LTF_FLAG parameter set to 1.

— The LTF_NSTS and LTF_REP parameters set to the same values, respectively, as indicated by the SS Allocation and I2R Rep subfields of the User Info field.

— The LTF_KEY and LTF_IV parameters that are set to *ista-ltf-key* and *ltf-iv*, respectively, for generating the secure HE-LTF based on the value of the (#8016)Secure LTF Counter subfield in the Secure HE-LTF Parameters element in the last transmitted protected IFTM frame or last transmitted protected LMR frame to the ISTA; see 11.21.6.4.5.4 (Overview of secure HE-LTF octet stream generation(11az)).

— The TX_WINDOW_FLAG set to 1 if the RSTA and ISTA have negotiated to use the optional frequency domain Tx window for I2R NDP; it is set to 0 otherwise.

— The LTF_OFFSET set to 0.

When the RSTA receives the HE TB Ranging NDP from the ISTA, the RSTA shall:

a) Send a Ranging NDP Announcement frame.

b) Send an HE Ranging NDP with the TXVECTOR parameters LTF_KEY and LTF_IV set to the *rsta-ltf-key* and *ltf-iv*, respectively, for generating secure HE-LTF based on the value of the Secure HE-LTF Counter subfield in the Secure HE-LTF Parameters element in the last transmitted protected IFTM frame or last transmitted protected LMR frame to the ISTA; see 11.21.6.4.5.4 (Overview of secure HE-LTF octet stream generation(11az)).

c) Send a protected LMR frame that includes the Secure HE-LTF Parameters element to the ISTA.

Otherwise, the RSTA shall follow the rules in 10.23.2.2 (EDCA backoff procedure) as the frame exchange is not successful.

When an RSTA sends a Ranging NDP Announcement frame, it shall set the LTF Offset subfield in the STA Info fields to values that satisfy Equation (11-7) and Equation (11-8).

$$\text{Offset}_i \leq \sum_{k \in \text{MaxOffset}_i} \text{N\_LTF}_k \times \text{Rep}_k \tag{11-7}$$

$$\text{Offset}_i \geq \text{Offset}_j + \text{N\_LTF}_j \times \text{Rep}_j, \quad \forall\, j \in \text{MinOffset}_i \tag{11-8}$$
$$\text{If Offset}_i = 0 \text{ then N\_STS}_i \geq \text{N\_STS}_j, \quad \forall\, j$$

where

$\text{Offset}_n$ represents the LTF Offset subfield value of the *n*th STA Info field in the Ranging NDP Announcement frame.

$\text{N\_STS}_n$ represents the R2I NSTS subfield value plus 1 of the *n*th STA Info field in the Ranging NDP Announcement frame.

$\text{N\_LTF}_n$ represents the number of HE-LTF symbols based on $\text{N\_STS}_n$, see Table 21-13 (Number of VHT-LTFs required for different numbers of space-time streams), for the *n*th STA Info field in the Ranging NDP Announcement frame.


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$Rep_n$ represents the R2I Rep subfield value plus 1 of the *n*th STA Info field in the Ranging NDP Announcement frame.

MinOffset represents the set of indexes of the STA Info fields of which the LTF Offset subfield values are less than the LTF Offset subfield value of the *i*th STA Info field in the Ranging NDP Announcement frame.

MaxOffset represents the set of indexes of all STA Info fields excluding the *i*th STA Info field.

The RSTA shall set the R2I Rep subfield in each of the STA Info fields in the Ranging NDP Announcement frame equal to the *RSTA Assigned R2I Rep* for each of the corresponding ISTAs, where all of the *RSTA Assigned R2I Rep* shall be greater than 0.

When an ISTA receives a Secure Sounding Ranging Trigger frame from an RSTA in which the value of the SAC subfield in the Trigger Dependent User Info field is equal to the value of the Validation SAC subfield in the Secure HE-LTF Parameters element in the last protected IFTM frame, or last protected LMR frame, received from the RSTA, the ISTA shall send an HE TB Ranging NDP with the TXVECTOR parameters LTF_KEY and LTF_IV that are set to *ista-ltf-key* and *ltf-iv*, respectively, for generating the secure HE-LTF based on the value of the (#8016)Secure LTF Counter subfield in the Secure HE-LTF Parameters element in the last protected IFTM frame, or last protected LMR frame, received from the RSTA; see 11.21.6.4.5.4 (Overview of secure HE-LTF octet stream generation(11az)).

When an ISTA receives a Secure Sounding Ranging Trigger frame from an RSTA in which the value of the SAC subfield in the Trigger Dependent User Info field is not equal to the value of the Validation SAC subfield in the Secure HE-LTF Parameters element in the last protected IFTM frame or last protected LMR frame received from the RSTA, the ISTA shall send an HE TB Ranging NDP with the TXVECTOR parameters LTF_KEY and LTF_IV that are set to the *ista-ltf-key* and *ltf-iv*, respectively, for generating any secure HE-LTF.

When an ISTA receives a Ranging NDP Announcement frame from an RSTA in which the AID11 subfield in the STA Info field contains the 11 least significant bits of the AID or RSID of the ISTA, the ISTA shall issue a PHY-RXLTFSEQUENCE.request primitive with the following LTFVECTOR parameters:

— The SECURE_LTF_FLAG parameter set to 1.

— The LTF_NSTS, LTF_REP, and LTF_OFFSET parameters set to the same values, respectively, as indicated by the R2I NSTS, R2I Rep, and LTF Offset subfields of the STA Info field addressed to it.

— The LTF_KEY and LTF_IV parameters that are set to the *rsta-ltf-key* and *ltf-iv* for generating the secure HE-LTF based on the value of the Secure LTF Counter subfield in the Secure LTF Parameters element in the last protected IFTM frame, or last protected LMR frame received from the RSTA; see 11.21.6.4.5.4 (Overview of secure HE-LTF octet stream generation(11az)).

— The TX_WINDOW_FLAG set to 1 if the ISTA and RSTA have negotiated to use the optional frequency domain Tx window for R2I NDP; it is set to 0 otherwise.

When an LMR frame contains range measurement results measured from an I2R NDP or an R2I NDP, an RSTA that transmits an R2I LMR frame, or when negotiated, an ISTA that transmits an I2R LMR frame, shall include the Secure HE-LTF Parameters element in the protected LMR frame:

— The Measurement SAC subfield in the Secure HE-LTF Parameters element in the protected LMR frame shall be set to the same value as in the SAC subfield in the Trigger Dependent User Info field in the Secure Sounding Ranging Trigger destined to the ISTA receiving or transmitting this protected LMR frame.

— The Measurement Result LTF Offset subfield in the Secure HE-LTF Parameters element in the protected LMR frame shall be set to the same value as in the LTF Offset subfield of the STA Info field in the Ranging NDP Announcement frame that preceded the R2I NDP destined to the ISTA for this measurement result.

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When an ISTA or RSTA receives the R2I or I2R protected LMR frame, the ISTA or RSTA shall compare the value of the Measurement Result LTF Offset subfield with the value of the LTF Offset subfield in the corresponding STA Info field of the Ranging NDP Announcement frame, and if these two values don't match, the ISTA or RSTA shall discard the measurement results carried in the protected LMR frame.

When a frame exchange that consists of receiving an HE TB Ranging NDP and transmitting HE Ranging NDP results into a Null-SAC-HE-LTF, the RSTA shall not use the TOA and TOD value of the HE TB Ranging NDP and HE Ranging NDP, respectively, and shall set the Invalid Measurement Indication subfield to 1 in the TOA error field in the protected LMR carrying the TOA value of the I2R HE TB Ranging NDP.

When an ISTA receives a Secure Sounding Ranging Trigger frame from an RSTA in which the value of the SAC subfield in the Trigger Dependent User Info field is not equal to the value of the Validation SAC subfield in the Secure HE-LTF Parameters element in the last protected IFTM frame or last protected LMR frame received from the RSTA, the ISTA shall:

— Not use the TOD value of the I2R HE TB Ranging NDP.

— Not use the TOA value of the R2I HE Ranging NDP, and shall set the Invalid Measurement Indication subfield to 1 in the TOA Error field in the protected LMR carrying the TOA value of the HE Ranging NDP if the I2R LMR transmission from the ISTA was negotiated.

(#8032)The STA shall use a new SAC value and its corresponding ista-ltf-key and rsta-ltf-key in every ranging measurement exchange, even if the current ranging measurement exchange is unsuccessful.

NOTE—In TB ranging measurement exchange with secure HE-LTF, the RSTA never sends the SAC subfield with value 0 in the Trigger Dependent User Info field in the Secure Sounding Ranging Trigger frame.


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When there is a transmission failure within a secure measurement exchange sequence, the recovery procedure of the LTF_VALID_SAC and its associated SEC_LTF_CTR parameters is illustrated in Figure 11-65 (Error recovery of TB ranging measurement exchange using secure HE-LTF(11az)(#8015)).

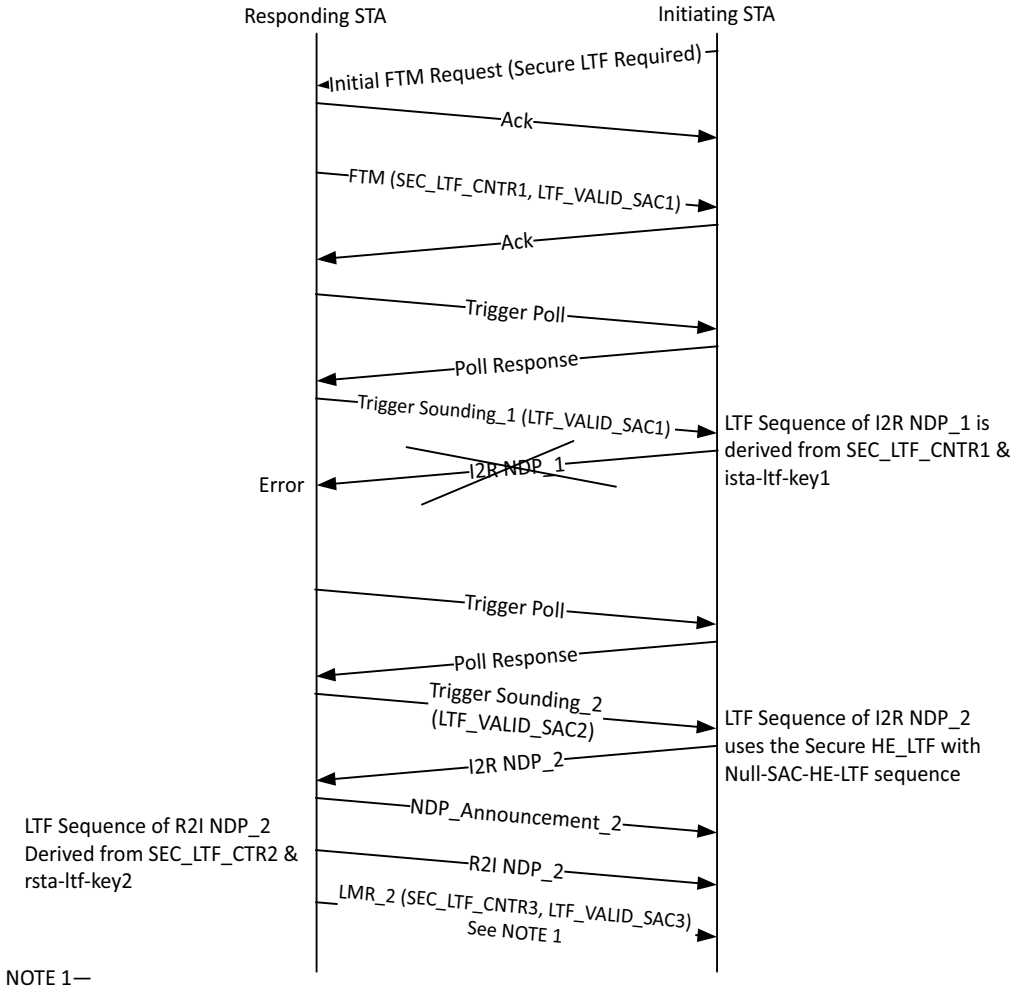


**Figure 11-65—Error recovery of TB ranging measurement exchange using secure HE-LTF(11az)(#8015)**

### 11.21.6.4.5.3 Non-TB ranging measurement exchange with secure HE-LTF(11az)

An overview of the negotiation and two non-TB ranging measurement exchanges are illustrated in Figure 11-66 (Overview of the non-TB ranging measurement exchange with secure HE-LTF(11az)). The LTF_VALID_SAC and its associated SEC_LTF_CTR parameter shall be included in a protected IFTM frame and a protected R2I LMR frame. The LTF_VALID_SAC shall also be included in the SAC subfield in the Ranging NDP Announcement frame. The detailed description of how the fields in these frames are set follows.

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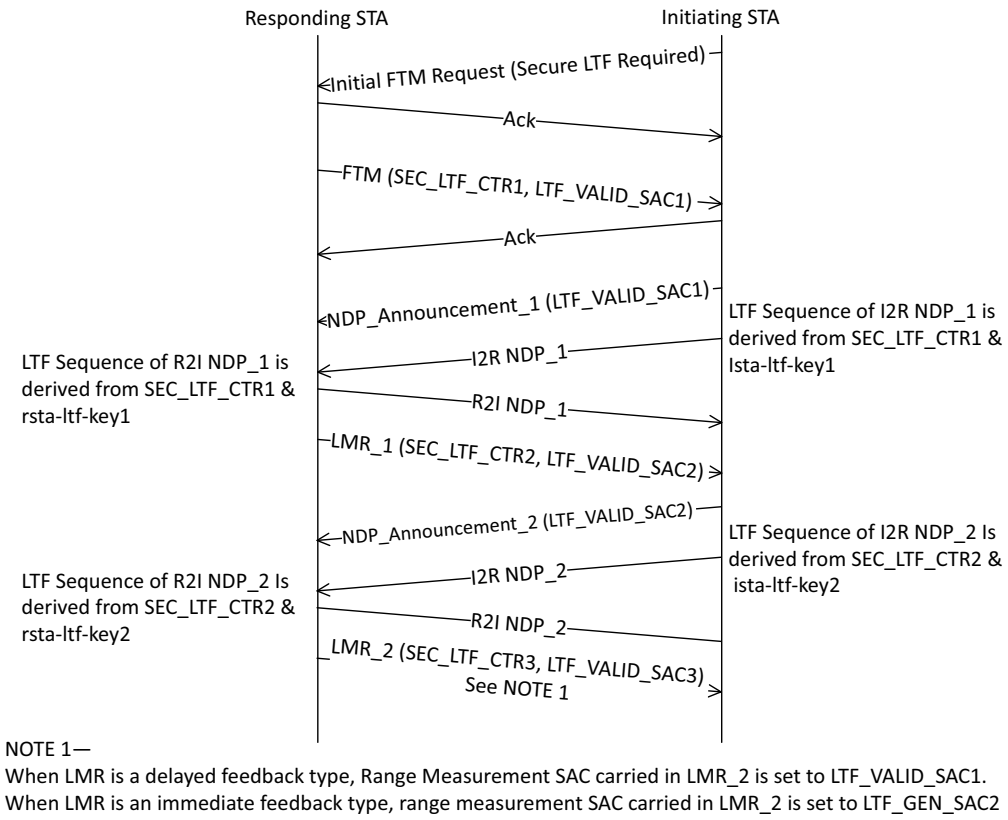


**Figure 11-66—Overview of the non-TB ranging measurement exchange with secure HE-LTF(11az)**

When an ISTA has established a secure HE-LTF measurement exchange with an RSTA as specified in 11.21.6.3.4 (Negotiation for secure HE-LTF in the TB and non-TB ranging measurement exchange), this ISTA shall set the following subfields in any Ranging NDP Announcement frame addressed to that RSTA as follows:

— The SAC subfield in the STA Info field with AID11 equal to 2043 in the Ranging NDP Announcement frame is set to the same value contained in the Validation SAC subfield in the Secure HE-LTF Parameters element in the last protected IFTM frame, or last protected R2I LMR frame, received from the RSTA.

— Otherwise the SAC subfield in the STA Info field with AID11 equal to 2043 in the Ranging NDP Announcement frame is set to a value of 0 to indicate that a new SEC_LTF_CTR and the corresponding LTF_VALID_SAC parameter are needed.

The ISTA shall set the I2R Rep subfield and R2I Rep subfield of the STA Info field in the Ranging NDP Announcement frame to the values of *RSTA Assigned I2R Rep* and the *RSTA Assigned R2I Rep*, respectively, corresponding to the RSTA. Both values of the *RSTA Assigned R2I Rep* and *RSTA Assigned I2R Rep* shall be greater than 0.


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An ISTA that sends an I2R NDP a SIFS after transmission of the Ranging NDP Announcement frame shall set the TXVECTOR parameters LTF_KEY and LTF_IV as follows:

— Either to the value of Null-SAC-HE-LTF if the SAC subfield in the STA Info field with AID11 equal to 2043 in the Ranging NDP Announcement frame, is equal to 0.

— Or the *ista-ltf-key* and *ltf-iv* for generating secure HE-LTF based on the value of the (#8016)Secure LTF Counter subfield in the Secure HE-LTF Parameters element in the last protected IFTM frame or last protected LMR frame, received from the RSTA; see 11.21.6.4.5.4 (Overview of secure HE-LTF octet stream generation(11az)).

After transmission of the Ranging NDP Announcement frame to the RSTA, the ISTA's MAC sublayer shall issue a PHY-RXLTFSEQUENCE.request primitive with an LTFVECTOR containing the following parameters:

— The SECURE_LTF_FLAG parameter set to 1.

— The LTF_NSTS and LTF_REP parameters set to the same values as indicated, respectively, by the R2I NSTS and R2I Rep subfields in the STA Info field with the AID11 subfield less than or equal to 2007.

— The LTF_KEY and LTF_IV parameters that are set to either the value of Null-SAC-HE-LTF, if the SAC subfield in the STA Info field with AID11 equal to 2043 in the Ranging NDP Announcement frame is equal to 0; or the *rsta-ltf-key* and *ltf-iv* for generating a secure HE-LTF based on the values of the (#8016)Secure LTF Counter subfield in the Secure HE-LTF Parameters element in the last protected IFTM frame, or last protected LMR frame received, from the RSTA; see 11.21.6.4.5.4 (Overview of secure HE-LTF octet stream generation(11az)).

— The TX_WINDOW_FLAG set to 1 if the ISTA and RSTA have negotiated to use the optional frequency domain Tx window for R2I NDP; it is set to 0 otherwise.

— The LTF_OFFSET set to 0.

When an RSTA receives a Ranging NDP Announcement frame from an ISTA in which the SAC subfield in the STA Info field with AID11 equal to 2043 is not equal to the value of the Validation SAC subfield in the Secure HE-LTF Parameters element in the last transmitted protected IFTM frame or last transmitted protected LMR frame to the ISTA, the RSTA shall:

— Send an HE Ranging NDP to the ISTA with the TXVECTOR parameters *rsta-ltf-key* and *ltf-iv* for generating any secure HE-LTF to the ISTA, only if the RSTA receives an HE Ranging NDP from the ISTA a SIFS after the ranging NDP Announcement frame.

— Send a protected LMR frame with a Secure HE-LTF Parameters element containing the SEC_LTF_CTR and the corresponding LTF_VALID_SAC parameters to the ISTA, only if the RSTA receives an HE Ranging NDP from the ISTA a SIFS after the ranging NDP Announcement frame.

When an RSTA receives a Ranging NDP Announcement frame from an ISTA in which the value of the SAC subfield in the STA Info field with AID11 equal to 2043 is equal to the value of the Validation SAC subfield in the Secure HE-LTF Parameters element in the last transmitted protected IFTM frame or last transmitted protected LMR frame to the ISTA, the RSTA shall:

— Send an HE Ranging NDP with the TXVECTOR parameters *rsta-ltf-key* and *ltf-iv* for generating a secure HE-LTF based on the values of the (#8016)Secure LTF Counter in the Secure HE-LTF Parameters element in the last transmitted protected IFTM frame, or last transmitted protected LMR frame to the ISTA, only if the RSTA receives an HE Ranging NDP from the ISTA a SIFS after the ranging NDP Announcement frame; see 11.21.6.4.5.4 (Overview of secure HE-LTF octet stream generation(11az)).

— Send a protected LMR frame that includes the Secure HE-LTF Parameters element to the ISTA, only if the RSTA receives an HE Ranging NDP from the ISTA a SIFS after the ranging NDP Announcement frame.

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When an RSTA receives a Ranging NDP Announcement frame from an ISTA, the RSTA shall also issue a PHY-RXLTFSEQUENCE.request primitive with an LTFVECTOR with the following parameters:

— The SECURE_LTF_FLAG parameter set to 1.

— The LTF_NSTS and LTF_REP parameters set to the same values as indicated, respectively, by the I2R NSTS and I2R Rep subfields in the STA Info field with the AID11 subfield less than or equal to 2007.

— The LTF_KEY and LTF_IV parameters that are set to the *ista-ltf-key* and *ltf-iv* for receiving a secure HE-LTF based on the values of the Secure LTF Counter and corresponding Validation SAC subfields in the Secure LTF Parameters element in the last transmitted protected IFTM frame, or last transmitted protected LMR frame to the ISTA; see 11.21.6.4.5.4 (Overview of secure HE-LTF octet stream generation(11az)).

— The TX_WINDOW_FLAG set to 1 if the ISTA and RSTA have negotiated to use the optional frequency domain Tx window for I2R NDP; it is set to 0 otherwise.

— The LTF_OFFSET set to 0.

An RSTA transmitting an R2I LMR frame, or an ISTA when negotiated to transmit LMR frame, containing range measurement results measured from an I2R NDP and an R2I NDP, shall include the Secure HE-LTF Parameters element in the protected LMR frame and set the Measurement SAC subfield in the Secure HE-LTF Parameters element in the protected LMR frame to the same value as in the SAC subfield in the STA Info field with AID11 equal to 2043 in the Ranging NDP Announcement frame that solicited the I2R NDP and the R2I NDP.

When a STA sends a Null-SAC-HE-LTF in a HE Ranging NDP, the STA shall not use the TOD value of the HE Ranging NDP for the secure range measurement exchange.

When a STA receives a Null-SAC-HE-LTF in a HE Ranging NDP, the STA shall not use the TOA value of the HE Ranging NDP, and shall set the Invalid Measurement Indication subfield to 1 in the TOA Error field in the protected LMR carrying the TOA value of the HE Ranging NDP.


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When there is a transmission failure within a secure measurement exchange, the recovery procedure of the LTF_VALID_SAC is illustrated in Figure 11-67 (Error recovery of non-TB ranging measurement exchange using secure HE-LTF(11az)(#8015)).

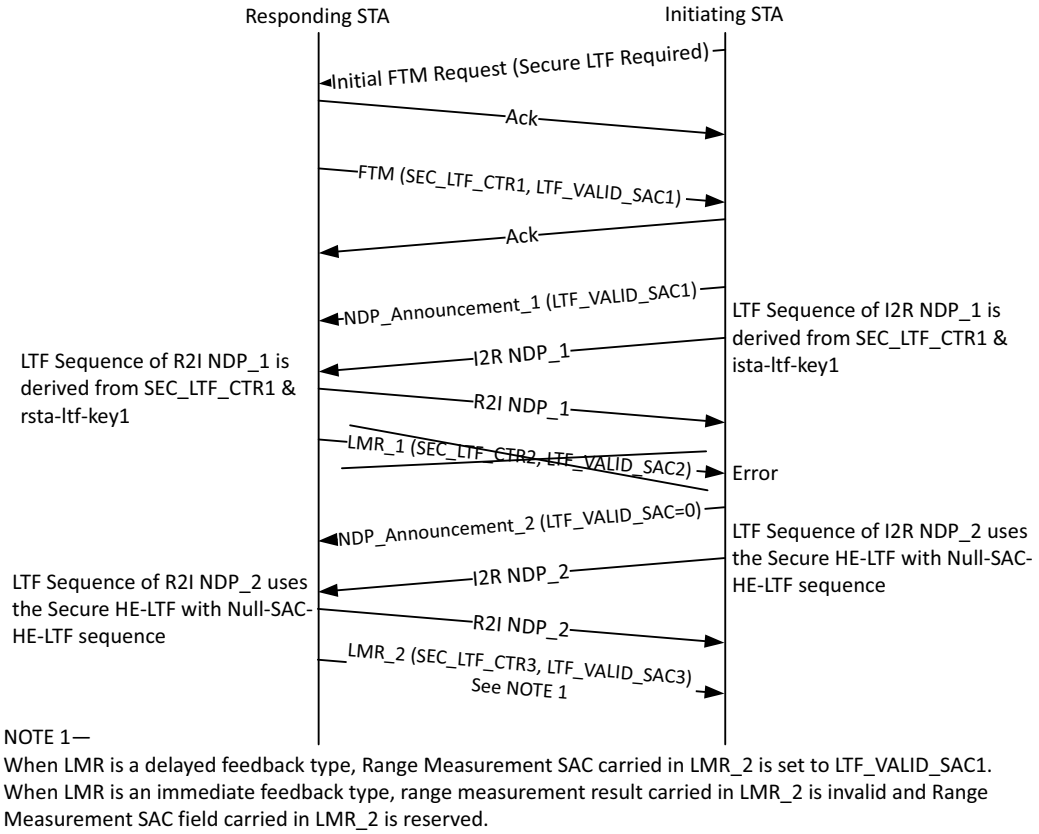


**Figure 11-67—Error recovery of non-TB ranging measurement exchange using secure HE-LTF(11az)(#8015)**

A STA shall discard the LTF_VALID_SAC parameter used in the frame exchange and shall not use the same LTF_VALID_SAC parameter in the current measurement exchange.

### 11.21.6.4.5.4 Overview of secure HE-LTF octet stream generation(11az)

This subclause describes mechanisms for generating the SAC, LTF protection keys, counters, and the pseudorandom octet stream used to randomize the input to the modulation and per stream phase rotation for constructing secure HE-LTFs. The mechanism is illustrated in Figure 11-68 (ISTA secure HE-LTF octet stream generation(11az)(#8003)) and Figure 11-69 (RSTA secure HE-LTF octet stream generation(11az)(#8003)).

For each secure measurement (e.g., NDP exchanges), a SAC and two secret keys *ista-ltf-key* and *rsta-ltf-key* shall be derived by the ISTA and the RSTA independently as follows:

SAC-and-LTF-Keys = KDF-Hash-Length(Secure-LTF-Key-Seed, “Secure (#8005)LTF Expansion”, Secure-LTF-Counter)

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where

| | |
|---|---|
| KDF and Hash | are the key derivation function and hash function determined by the AKM used to derive the PTKSA from which the Secure-LTF-Key-Seed was derived |
| Length | is equal to 272 (bits) |
| SAC | is equal to (#8001)ExtractBits(SAC-and-LTF-Keys, 0, 16) |
| *ista-ltf-key* | is equal to (#8001)ExtractBits(SAC-and-LTF-Keys, 16, 128) |
| *rsta-ltf-key* | is equal to (#8001)ExtractBits(SAC-and-LTF-Keys, 144, 128) |

The *ista-ltf-key* shall be used to generate the pseudorandom octet stream to protect all of the LTFs in PPDUs transmitted by the ISTA. The *rsta-ltf-key* shall be used to generate the pseudorandom octet stream to protect all of the LTFs in PPDUs transmitted by the RSTA. The ISTA and RSTA shall use the same derivation and derive identical keys.

With the SAC constructed as above, an attacker not knowing the Secure-LTF-Key-Seed would not be able to predict the SAC that would be used for a given measurement.

Integer to octet string conversion (MSB first) specified in 12.4.7.2.2 (Integer to octet string conversion) shall be used to encode the value of the (#8016)Secure LTF Counter subfield in the KDF as well as in the transmitted LTF sequence information. The counter shall be padded with leading (MSB) 0s to be exactly 6 octets.

The 16-octet IV input *ltf-iv* to the secure HE-LTF bit generator shall be constructed as follows:

— First 6 octets shall be the transmitter MAC address (A2).

— Next 6 octets shall encode the value of the (#8016)Secure LTF Counter subfield with the encoding convention described above.

— Final 4 octets shall be used as a 32-bit block counter. The block counter shall be initialized to 0 before the NDP with secure HE-LTFs is transmitted or received. The counter shall be incremented by 1 each time an AES block is output by the generator.

Each time pseudorandom bits are required to protect the LTFs in an NDP, the secure HE-LTF bit generator generates the required number of AES blocks using the AES algorithm (see FIPS 197) with the corresponding 128-bit key and 128-bit IV inputs. The output of the AES-128 counter encryption is a 128-bit integer. It shall be converted using the conventions specified in 12.4.7.2.2 (Integer to octet string conversion) to obtain the octet stream used for secure HE-LTF generation.

NOTE 1—A 6-octet parameter representing the value of the (#8016)Secure LTF Counter subfield is sufficient because a (#6026)protected individually addressed Management frame that uses a 6-octet PN is used to convey the LTF sequence information that carries the counter.

NOTE 2—The pseudorandom bit generator is based on AES-128 Counter mode approved by NIST (see NIST SP 800-90A R1 [B66]).

The number of pseudorandom bits that can be generated without violating security guarantees of the scheme is $2^{39}$ without updating the key or reseeding the generator with additional entropy.

Secure HE-LTF measurement requires a variable number of octets from the pseudorandom octet stream depending on the TXVECTOR or RXVECTOR parameters for the LTFs as described in 27.3.20.2 (Generation of a randomized secure HE-LTF sequence(11az)). The initial block counter value used to construct the *ltf-iv* for setting the TXVECTOR and RXVECTOR parameters shall be 0.


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#### 11.21.6.4.5.5 Secure HE-LTF octet stream generation on an ISTA(11az)

Figure 11-68 (ISTA secure HE-LTF octet stream generation(11az)(#8003)) illustrates the scheme for generating the SAC, LTF protection keys, and counter values used to generate a pseudorandom octet stream on an ISTA.

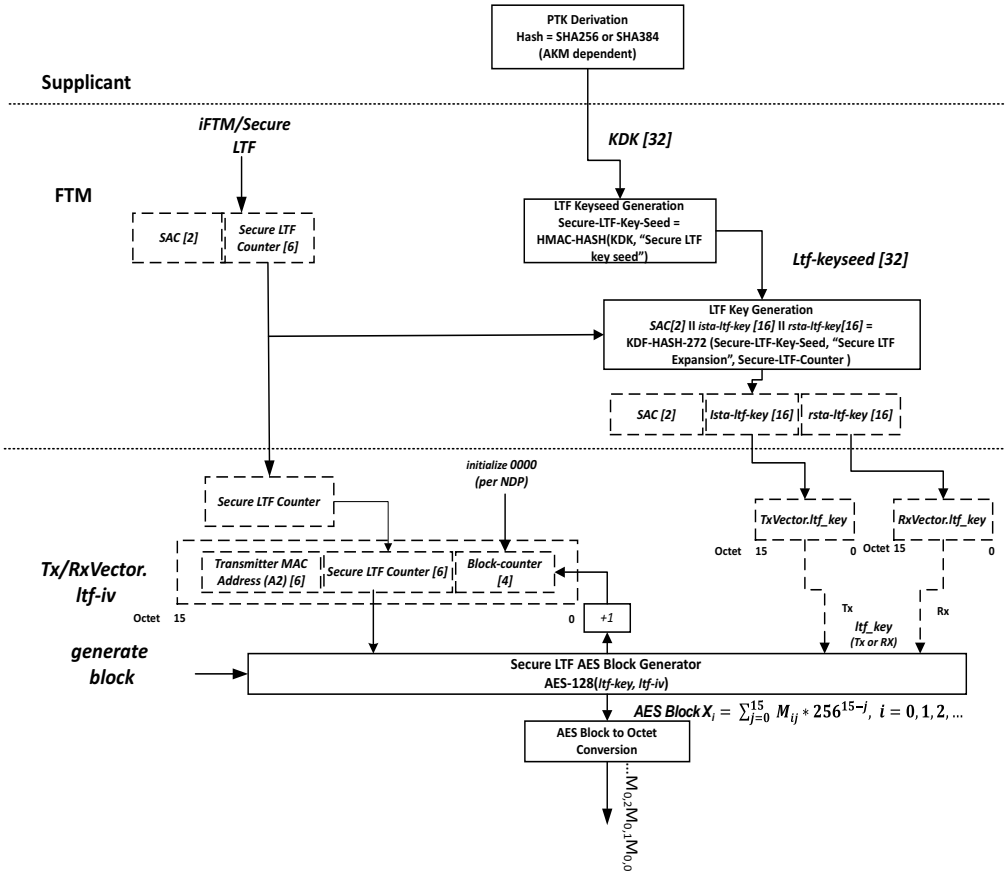


**Figure 11-68—ISTA secure HE-LTF octet stream generation(11az)(#8003)**

For each secure measurement on an ISTA, the following parameters shall be used for generating the pseudorandom octet stream used to construct the LTFs for NDPs:

— The *ista-ltf-key* and *rsta-ltf-key* for transmitted NDP (TXVECTOR parameter LTF_KEY) and received NDP (RXVECTOR parameter LTF_KEY), respectively.

— The *ltf_iv* for transmitted NDP (TXVECTOR parameter LTF-IV) and received NDP (RXVECTOR parameter LTF-IV) with corresponding ISTA MAC address and RSTA MAC address, respectively, together with the value of the (#8016)Secure LTF Counter subfield and the block counter.

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### 11.21.6.4.5.6 Secure HE-LTF input octet stream generation on an RSTA(11az)

Figure 11-69 (RSTA secure HE-LTF octet stream generation(11az)(#8003)) illustrates the scheme for generating the SAC, LTF protection keys, and counter values used to generate a pseudorandom octet stream on an RSTA.

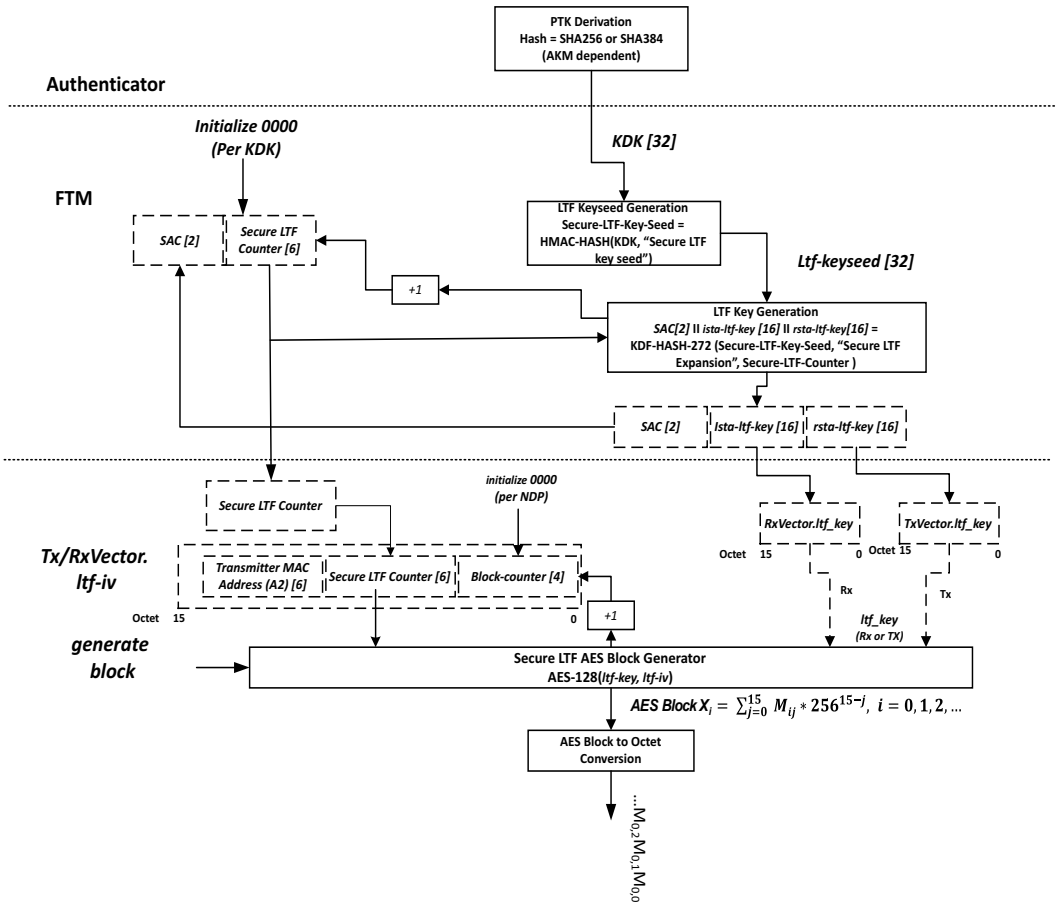


**Figure 11-69—RSTA secure HE-LTF octet stream generation(11az)(#8003)**

For each secure measurement on an RSTA, the following parameters are provided for generating the pseudorandom octet stream to construct the LTFs for NDPs:

— The *ista-ltf-key* and *rsta-ltf-key* for received NDP (RXVECTOR parameter LTF_KEY) and transmitted NDP (TXVECTOR parameter LTF_KEY), respectively.

— The *ltf_iv* for received NDP (RXVECTOR parameter LTF-IV) and for transmitted NDP (TXVECTOR parameter LTF-IV) with corresponding ISTA MAC address and RSTA MAC address, respectively, together with the values of the (#8016)Secure LTF Counter subfield and the block counter.

NOTE—In an R2I NDP used for range measurement, LTFs assigned to each of the recipient STAs would use their corresponding pseudorandom octet stream derived from the key material from the corresponding PTKSA for the recipient.


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The values of the (#8016)Secure LTF Counter subfield shall be maintained for the lifetime of a PTKSA used for secure HE-LTF measurements. It shall not be reset between measurements and shall not be reset for multiple FTM negotiations using the same PTKSA.

The values of the (#8016)Secure LTF Counter subfield used for each measurement protected bits is derived from a given Secure-LTF-Key-Seed (and its KDK and the PTKSA) and shall be unique. When the derived SAC is equal to 0, the RSTA shall increment the (#8016)secure LTF counter parameter by 1 and derive the SAC until a nonzero SAC value is obtained. An RSTA shall also increment the (#8016)secure LTF counter parameter by 1 each time an *ista-ltf-key* and *rsta-ltf-key* are derived.

#### 11.21.6.4.6 Transmission of a ranging NDP(11az)

An RSTA transmitting an HE Ranging NDP to one or more peer ISTAs shall set the TXVECTOR parameters as follows:

- The FORMAT parameter is set to HE_SU.
- The RANGING_FLAG is present.
- The UPLINK_FLAG parameter is set to 0.
- The APEP_LENGTH parameter is set to 0.
- The SECURE_LTF_FLAG is set as follows:
  - Is set to 0 in the TB ranging measurement exchange (11.21.6.4.3 (TB ranging measurement exchange(11az))) and non-TB ranging measurement exchange (11.21.6.4.4 (Non-TB ranging measurement exchange(11az))).
  - Is set to 1 in the TB ranging measurement exchange with secure HE-LTF (11.21.6.4.5.2 (TB ranging measurement exchange with secure HE-LTF(11az))) and the non-TB ranging measurement exchange with secure HE-LTF (11.21.6.4.5.3 (Non-TB ranging measurement exchange with secure HE-LTF(11az))).
- The TX_WINDOW_FLAG is set to 1 if the SECURE_LTF_FLAG is set to 1 and the RSTA and ISTA have negotiated to use the optional frequency domain Tx window for R2I NDPs(#8066); it is set to 0 otherwise.
- In the TB ranging measurement exchange with secure HE-LTF (11.21.6.4.5.2 (TB ranging measurement exchange with secure HE-LTF(11az))), the NUM_USERS parameter is set to the number of ISTAs to which the HE Ranging NDP is transmitted.
- In the Non-TB ranging measurement exchange (11.21.6.4.4 (Non-TB ranging measurement exchange(11az))), the TXPWR_LEVEL_INDEX parameter is set to a value that matches the Tx Power value indicated in the R2I NDP Tx Power field in the following LMR frame, except if the value in the R2I NDP Tx Power field was set to a reserved value.
- The DOPPLER parameter is set to 0.
- The NUM_STS parameter is set as follows:
  - In the TB ranging measurement exchange (11.21.6.4.3 (TB ranging measurement exchange(11az))), set to the same value as the R2I NSTS subfield in the STA Info field in the preceding Ranging NDP Announcement frame plus 1.
  - In the TB ranging measurement exchange with secure HE-LTF (11.21.6.4.5.2 (TB ranging measurement exchange with secure HE-LTF(11az))):
    - When the HE Ranging NDP is transmitted to more than one ISTA, the NUM_STS[$p$] parameter is set to the same value as the R2I NSTS subfield in the STA Info field addressed to the corresponding STA $p$ in the preceding Ranging NDP Announcement frame plus 1.
    - When the HE Ranging NDP is transmitted to one ISTA, the NUM_STS parameter is set to the same value as the R2I NSTS subfield in the STA Info field with AID11 subfield equal or less than 2007 in the preceding Ranging NDP Announcement frame plus 1.

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- In the Non-TB ranging measurement exchange (11.21.6.4.4 (Non-TB ranging measurement exchange(11az))) and the non-TB ranging measurement exchange with secure HE-LTF (11.21.6.4.5.3 (Non-TB ranging measurement exchange with secure HE-LTF(11az))), set to the same value as the R2I NSTS subfield in the STA Info field with AID11 subfield equal or less than 2007 in the preceding Ranging NDP Announcement frame plus 1.

— The LTF_REP parameter is set as follows:

- In the TB ranging measurement exchange (11.21.6.4.3 (TB ranging measurement exchange(11az))), set to the same value as the R2I Rep subfield in the STA Info field in the preceding Ranging NDP Announcement frame plus 1.
- In the TB ranging measurement exchange with secure HE-LTF (11.21.6.4.5.2 (TB ranging measurement exchange with secure HE-LTF(11az))):
  - When the HE Ranging NDP is transmitted to more than one ISTA, the LTF_REP[*p*] parameter is set to the same value as the R2I Rep subfield in the STA Info field addressed to the corresponding STA *p* in the preceding Ranging NDP Announcement frame plus 1.
  - When the HE Ranging NDP is transmitted to one ISTA, the LTF_REP parameter is set to the same value as the R2I Rep subfield in the STA Info field with AID11 subfield equal or less than 2007 in the preceding Ranging NDP Announcement frame plus 1.
- In the non-TB ranging measurement exchange (11.21.6.4.4 (Non-TB ranging measurement exchange(11az))) and the non-TB ranging measurement exchange with secure HE-LTF (11.21.6.4.5.3 (Non-TB ranging measurement exchange with secure HE-LTF(11az))), set to the same value as the R2I Rep subfield in the STA Info field with AID11 subfield less than or equal to 2007 in the preceding Ranging NDP Announcement frame plus 1.

— The CH_BANDWIDTH parameter is set as follows:

- In the TB ranging measurement exchange (11.21.6.4.3 (TB ranging measurement exchange(11az))), and TB ranging measurement exchange with secure HE-LTF (11.21.6.4.5.2 (TB ranging measurement exchange with secure HE-LTF(11az))), set to the same value as the TXVECTOR parameter CH_BANDWIDTH in the preceding Ranging Sounding Trigger frame.
- In the non-TB ranging measurement exchange (11.21.6.4.4 (Non-TB ranging measurement exchange(11az))) and non-TB ranging measurement exchange with secure HE-LTF (11.21.6.4.5.3 (Non-TB ranging measurement exchange with secure HE-LTF(11az))), set to the same value as the TXVECTOR parameter CH_BANDWIDTH in the preceding Ranging NDP Announcement frame.

— In the TB and non-TB ranging measurement exchange with secure HE-LTF (11.21.6.4.5 (Secure HE-LTF in the TB and non-TB ranging measurement exchange protocol(11az))), the LTF_KEY parameter is set as defined in 11.21.6.4.5.2 (TB ranging measurement exchange with secure HE-LTF(11az)) and 11.21.6.4.5.3 (Non-TB ranging measurement exchange with secure HE-LTF(11az)). Otherwise, the LTF_KEY parameter is not present.

— In the TB ranging measurement exchange with secure HE-LTF, the LTF_OFFSET parameter is set as defined in 11.21.6.4.5.2 (TB ranging measurement exchange with secure HE-LTF(11az)). Otherwise, the LTF_OFFSET parameter is not present.

— The HE_LTF_TYPE parameter is set to 2xHE-LTF.

— The GI_TYPE parameter is set to 1u6s_GI.

— The SPATIAL_REUSE parameter is set to (#8035)PRS_AND_NON-SRG_OBSS-PD_PROHIBITED.

— The BSS_COLOR parameter is set to the value indicated in the BSS Color subfield of the HE Operation element transmitted by the RSTA.

— The TXOP_DURATION parameter is set to either 127 or a value defined in Equation (26-3), replacing $D_{\text{HE\_NDPA}}$ by $D_{\text{Ranging\_NDPA}}$, which is the value of the Duration/ID field in the MAC header of the preceding Ranging NDP Announcement frame.


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An ISTA transmitting an HE Ranging NDP shall set the TXVECTOR parameters as follows:

- The FORMAT parameter is set to HE_SU.
- The RANGING_FLAG is present.
- The UPLINK_FLAG parameter is set to 1.
- The APEP_LENGTH parameter is set to 0.
- The SECURE_LTF_FLAG is set as follows:
  - Is set to 0 in the non-TB ranging measurement exchange (11.21.6.4.4 (Non-TB ranging measurement exchange(11az))).
  - Is set to 1 in the non-TB ranging measurement exchange with secure HE-LTF (11.21.6.4.5.3 (Non-TB ranging measurement exchange with secure HE-LTF(11az))).
- The TX_WINDOW_FLAG is set to 1 if the SECURE_LTF_FLAG is set to 1 and the RSTA and ISTA have negotiated to use the optional frequency domain Tx window for I2R NDPs(#8066); it is set to 0 otherwise.
- The DOPPLER parameter is set to 0.
- The NUM_STS parameter is set to the same value as the I2R NSTS subfield in the STA Info field with AID11 subfield equal or less than 2007 in the preceding Ranging NDP Announcement frame plus 1.
- The LTF_REP parameter is set to the same value as the I2R Rep subfield with AID11 subfield equal or less than 2007 in the STA Info field in the preceding Ranging NDP Announcement frame plus 1.
- The TXPWR_LEVEL_INDEX parameter is set to a value that matches the Tx Power value indicated in the I2R NDP Tx Power subfield in the STA Info field with the AID11 subfield set to 2045 in the preceding Ranging (#8066)NDP Announcement frame, except if the value in the I2R NDP Tx Power subfield was set to a reserved value.
- The CH_BANDWIDTH is set to the same value as the TXVECTOR parameter CH_BANDWIDTH in the preceding Ranging NDP Announcement frame.
- In the non-TB ranging measurement exchange with secure HE-LTF, the LTF_KEY parameter is set as defined in 11.21.6.4.5.3 (Non-TB ranging measurement exchange with secure HE-LTF(11az)). Otherwise, the LTF_KEY parameter is not present.
- The HE_LTF_TYPE parameter is set to 2xHE-LTF.
- The GI_TYPE parameter is set to 1u6s_GI .
- The SPATIAL_REUSE parameter is set to (#8035)PRS_AND_NON-SRG_OBSS-PD_PROHIBITED.
- The BSS_COLOR parameter is set to the value indicated in the BSS Color subfield of the HE Operation element received from the RSTA.
- The TXOP_DURATION parameter is set to either 127 or a value defined in Equation (26-3), replacing $D_{\text{HE\_NDPA}}$ by $D_{\text{Ranging\_NDPA}}$, which is the value of the Duration/ID field in the MAC header of the preceding Ranging NDP Announcement frame.

An ISTA transmitting an HE TB Ranging NDP to an RSTA shall set the TXVECTOR parameters as follows:

- The FORMAT parameter is set to HE_TB.
- The RANGING_FLAG is present.
- The APEP_LENGTH parameter is set to 0.
- The SECURE_LTF_FLAG is set as follows:
  - Is set to 0 in the TB ranging measurement exchange (11.21.6.4.3 (TB ranging measurement exchange(11az))).
  - Is set to 1 in the TB ranging measurement exchange with secure HE-LTF (11.21.6.4.5.2 (TB ranging measurement exchange with secure HE-LTF(11az))).

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- The TX_WINDOW_FLAG is set to 1 if the SECURE_LTF_FLAG is set to 1 and the RSTA and ISTA have negotiated to use the optional frequency domain Tx window for I2R NDPs(#8066); it is set to 0 otherwise.
- The DOPPLER parameter is set to 0.
- The NUM_STS parameter is set to the same value as the Number Of Spatial Streams subfield in the SS Allocation field in the User Info field in the preceding Ranging Sounding Trigger frame.
- The LTF_REP parameter is set to the same value as the I2R Rep subfield in the User Info field in the preceding Ranging Sounding Trigger frame plus 1.
- The CH_BANDWIDTH parameter is set to the same value as the TXVECTOR parameter CH_BANDWIDTH in the preceding Ranging Sounding Trigger frame.
- In the TB ranging measurement exchange with secure HE-LTF, the LTF_KEY parameter is set as defined in 11.21.6.4.5.2 (TB ranging measurement exchange with secure HE-LTF(11az)). Otherwise, the LTF_KEY parameter is not present.
- The HE_LTF_TYPE parameter is set to 2xHE-LTF.
- The GI_TYPE parameter is set to 1u6s_GI.
- The SPATIAL_REUSE parameter is set to SRP_AND_NON-SRG_OBSS_PD_PROHIBITED.
- The BSS_COLOR parameter is set to the value indicated in the BSS Color subfield of the HE Operation element received from the RSTA.

The TXOP_DURATION parameter is set as defined in 26.11.5 (TXOP_DURATION).

(11bd)An RSTA transmitting an NGV ranging NDP to an ISTA shall set the TXVECTOR parameters as follows:

- The FORMAT parameter is set to NGV.
- The CH_BANDWIDTH parameter is set to the same value as the RXVECTOR parameter CH_BANDWIDTH in the preceding I2R NDP.
- The NGV-LTF-TYPE parameter is set to 1 to indicate NGV_LTF_2X is used in the NGV ranging NDP.
- The NUM_SS parameter is set to the same value as the R2I N_STS in the STA Info field in the preceding Ranging NDP Announcement frame.
- The APEP_LENGTH parameter is set to 0.
- The LTF_REP parameter is set to the same value as the R2I LTF_REP in the STA Info field in the preceding Ranging NDP Announcement frame.

(11bd)An ISTA transmitting an NGV ranging NDP to an RSTA shall set the TXVECTOR parameters as follows:

- The FORMAT parameter is set to NGV.
- The CH_BANDWIDTH parameter is set to the same value as the TXVECTOR parameter CH_BANDWIDTH in the preceding Ranging NDP Announcement frame.
- The NGV-LTF-TYPE parameter is set to 1 to indicate NGV_LTF_2X is used in the NGV ranging NDP.
- The NUM_SS parameter is set to the same value as the I2R N_STS in the STA Info field in the preceding Ranging NDP Announcement frame.
- The APEP_LENGTH parameter is set to 0.
- The LTF_REP parameter is set to the same value as the I2R LTF_REP in the STA Info field in the preceding Ranging NDP Announcement frame.


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#### 11.21.6.4.7 Time of arrival estimation using phase shift feedback(11az)

Based on Figure 11-70 (Timing diagram of a measurement sounding phase in TB ranging based on phase shift of I2R NDP and R2I NDP PPDUs(11az)), and Equation (11-9), to enable the ISTA to derive the RTT, the RSTA needs to compute TOA t2 and feed t2 and t3 back to the ISTA using R2I LMR. Instead of utilizing TOA t2 for RTT computation, a phase shift feedback can be prepared by the RSTA and fed back to the ISTA for deriving RTT.

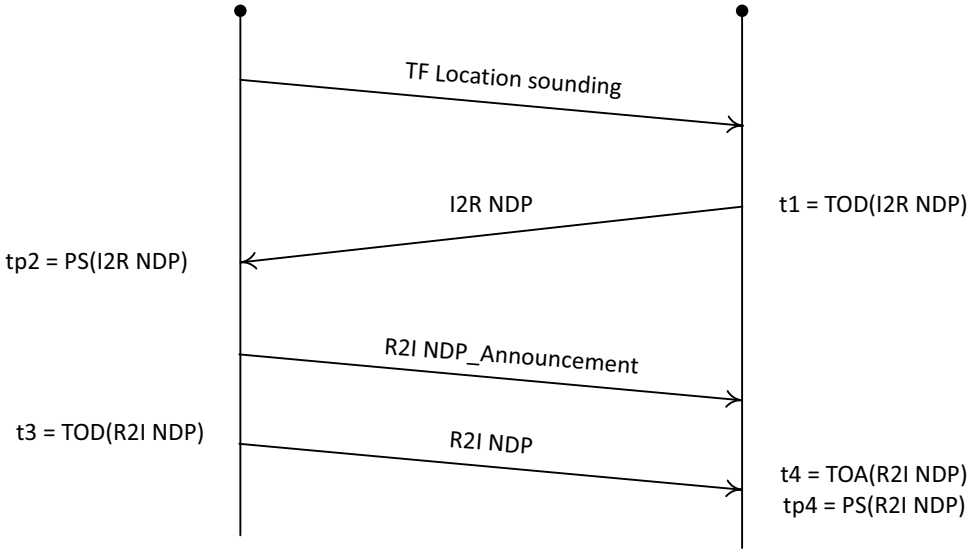


**Figure 11-70—Timing diagram of a measurement sounding phase in TB ranging based on phase shift of I2R NDP and R2I NDP PPDUs(11az)**

As shown in Figure 11-70 (Timing diagram of a measurement sounding phase in TB ranging based on phase shift of I2R NDP and R2I NDP PPDUs(11az)), in the phase shift feedback method, the ISTA transmits an I2R NDP at TOD t1, and the RSTA determines the phase shift tp2 of the I2R NDP. The RSTA transmits an R2I NDP at TOD t3, and the ISTA determines the phase shift tp4 and TOA t4 of the R2I NDP. tp2 and tp4 are determined from the phase slope of the frequency domain channel estimation of the corresponding NDP. An example of calculation of the phase shift is shown in Annex AD.

The RSTA sends the R2I NDP at TOD t3, and after receiving the R2I NDP, the ISTA calculates the phase shift tp4 and TOA t4 of R2I NDP. The value of tp2 and tp4 are calculated utilizing the frequency domain channel estimation of I2R NDP and R2I NDP.

The phase shift is defined as the average linear phase shift between two adjacent tones normalized by the tone spacing. To enable the ISTA to calculate the RTT, the RSTA should feed phase shift tp2 and TOD t3 back to the ISTA using R2I LMR, and the ISTA can calculate the RTT according to Equation (11-9).

$$RTT_{ISTA} = (t4 - t1) - (t3 - t2''), \text{ with } t2'' = tp2 - (tp4 - t4) \quad (11\text{-}9)$$

When the I2R LMR with phase shift feedback is negotiated between ISTA and RSTA, I2R LMR carries phase shift tp4 and TOD t1, and then the RSTA can calculate the RTT according to Equation (11-10).

$$RTT_{RSTA} = (t4'' - t1) - (t3 - t2), \text{ with } t4'' = tp4 - (tp2 - t2) \quad (11\text{-}10)$$

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### 11.21.6.4.8 Measurement exchange in passive TB ranging mode(11az)

#### 11.21.6.4.8.1 General(11az)

As stated in 11.21.6.1.3 (Passive TB ranging overview), the passive TB ranging mode is a variant of the TB ranging mode. In all aspects, except where explicitly stated differently, the passive TB ranging mode, its protocols, procedures, components, and definitions follow the rules for TB ranging mode.

In particular, the measurement exchanges for passive TB ranging follow the rules and procedures described in 11.21.6.4.3 (TB ranging measurement exchange(11az)), with subclauses, unless explicitly stated otherwise.

In passive TB ranging, the RSTA shall transmit the Passive Sounding Ranging Trigger frame instead of the Sounding Ranging Trigger frame. Upon receiving of the Passive Sounding Ranging Trigger frame, the ISTA shall respond with an HE Ranging NDP instead of an HE TB Ranging NDP; see 11.21.6.4.8.3 (Passive TB ranging measurement sounding phase(11az)) for further details.

Furthermore, the RSTA shall broadcast two frames, the Primary and Secondary RSTA Broadcast Passive TB Ranging Measurement Report frames containing measurement data and related information; see 11.21.6.4.8.4 (Passive TB ranging Measurement Reporting phase(11az)) for further details.

The passive TB ranging exchanges shall only occur in an availability window assigned for Passive TB ranging.

For passive TB ranging, the timestamps reported within each availability window shall be derived from a clock that runs continuously during the availability window.

If there is a discontinuity in the clock for the FTM timestamping between two reported TOD timestamps, then the TOD Not Continuous subfield in the Timestamp Error subfield of the Timestamp Measurement Report subfield in the ISTA Passive TB Ranging Measurement Report element shall be set to 1. Otherwise it shall be set to 0.

(#7067)(#8117)The FTM protocol for a passive TB ranging measurement exchange and its relationship with the SME and MLME interface is shown in Figure 0-1 (FTM primitives and timestamps reporting capture for passive TB ranging measurement exchange(#7067)).

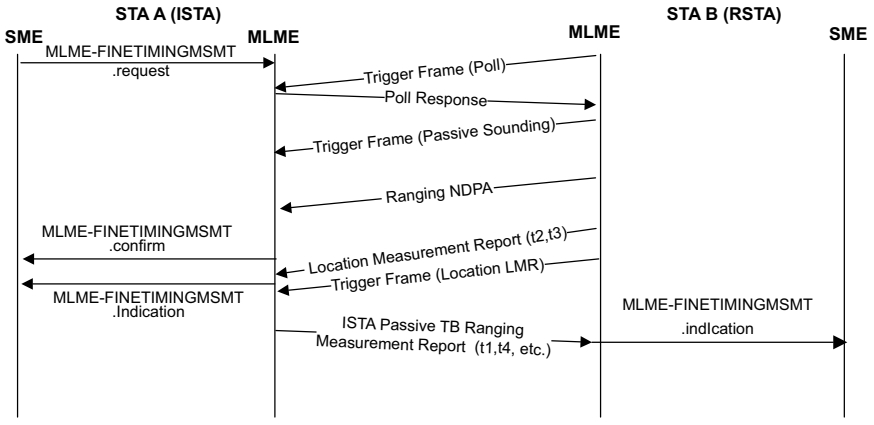


**Figure 0-1—FTM primitives and timestamps reporting capture for passive TB ranging measurement exchange(#7067)**


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#### 11.21.6.4.8.2 Polling phase of passive TB ranging(11az)

The Polling phase of passive TB ranging follows the same rules and procedures for the Polling phase of TB ranging described in 11.21.6.4.3.2 (Polling phase of TB ranging(11az)).

#### 11.21.6.4.8.3 Passive TB ranging measurement sounding phase(11az)

The passive TB ranging measurement sounding follows the same rules and procedures for the measurement sounding for TB ranging described in 11.21.6.4.3.3 (Measurement Sounding phase of TB ranging(11az)), unless explicitly stated otherwise.

The second phase of the passive TB ranging measurement sequence, after the passive TB ranging polling phase, is called the passive TB ranging measurement sounding phase. The passive TB ranging measurement sounding phase may include one or more Passive Sounding Ranging Trigger frames and HE Ranging NDP exchanges, a Ranging NDP Announcement frame, and an HE Ranging NDP transmission; see Figure 11-71 (Passive TB ranging polling, measurement sounding, and measurement reporting phases(11az)).

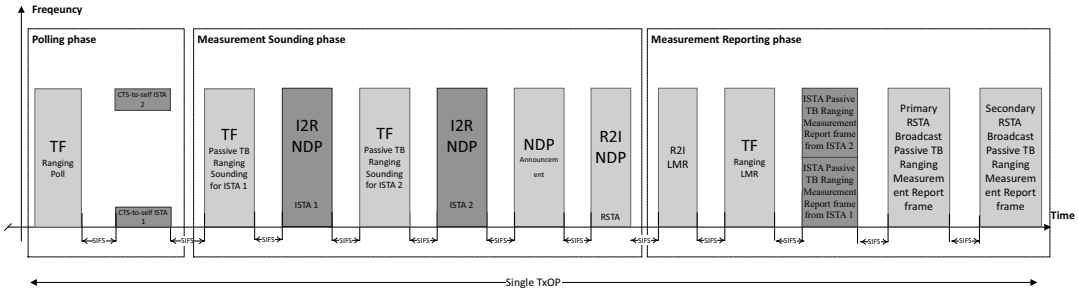


**Figure 11-71—Passive TB ranging polling, measurement sounding, and measurement reporting phases(11az)**

In passive TB ranging, for each ISTA, the RSTA shall transmit a Passive Sounding Ranging Trigger frame, which includes a single User Info field.

An RSTA shall transmit one or more Passive Sounding Ranging Trigger frames, each of which is addressed to a single ISTA, the first one coming a SIFS time after the TB Polling phase.

An ISTA addressed by the AID/RSID in the Passive Sounding Ranging Trigger frame shall transmit an HE Ranging NDP a SIFS time after the reception of the Passive TB Ranging Trigger frame.

An RSTA transmitting a Passive Sounding Ranging Trigger frame shall not use a bandwidth wider than that indicated in the IFTM frame sent to the ISTA, and the RSTA shall set the TXVECTOR parameter CH_BANDWIDTH to be the same value as the UL BW subfield of the Common Info field in the Passive Sounding Ranging Trigger frame.

NOTE—Generally a PSTA benefits from consistent ranging measurement performance when an RSTA initiates a passive TB ranging sequence with the nominal advertised bandwidth in every TXOP.

An RSTA transmitting a Ranging NDP Announcement frame and an HE Ranging NDP after receiving an HE Ranging NDP as a response to a Passive Sounding Ranging Trigger frame shall set the TXVECTOR parameter CH_BANDWIDTH to be the same value as the BW subfield of the Common Info field in the Passive Sounding Ranging Trigger frame.

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An ISTA transmitting an HE Ranging NDP as a response to a Passive Sounding Ranging Trigger frame shall set the TXVECTOR parameter CH_BANDWIDTH to be the same value as the UL BW subfield of the Common Info field in the Passive Sounding Ranging Trigger frame.

As in TB ranging, an ISTA participating in a passive TB ranging exchange shall measure the TOD of its own HE Ranging NDP and either the TOAs, or both the TOAs and the phase shift feedback TOAs (PSTOAs), when it receives the RSTA's HE Ranging NDP. In addition, optionally the ISTA may also measure and report either the TOAs, or both the TOAs and the PSTOAs, when it receives the HE Ranging NDPs transmitted by the other ISTAs participating in the passive TB ranging exchange. By reporting the timestamps for when it received the other ISTAs NDP transmissions, the quality of the location estimate for a PSTA listening in to the passive TB ranging exchanges can be improved.

The value of NSTS used in the passive TB ranging exchanges shall be less than or equal to 4.

When phase shift feedback is negotiated between an ISTA and an RSTA in passive TB ranging, the protocol for the Measurement Sounding phase differs from passive TB ranging with TOA feedback on the following points:

- The RSTA shall measure phase shift feedback TOA (PSTOA), in addition to measuring the TOA, on the I2R NDP(#8066) it receives from the ISTA.
- The ISTA shall measure:
  - The phase shift TOA (PSTOA), in addition to measuring the TOA, for the R2I NDP it receives from the RSTA,
  - And may also measure phase shift TOA(s) (PSTOAs), in addition to measuring the TOA(s), for the I2R NDP(s) it receives from other ISTA(s).

See Figure 11-72 (Example timing diagram of a Measurement Sounding phase in passive TB ranging(11az)) for an example of timestamps measured by the RSTA, ISTA, and a PSTA in a passive TB ranging measurement exchange. The timestamp values t1, t2, t3, and t4 are analogous to the corresponding labeled


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timestamps in 11.21.6.4.3.3 (Measurement Sounding phase of TB ranging(11az)). The timestamps t5 and t6 are the times at which the I2R NDP and R2I NDPs arrive at the PSTA, respectively.

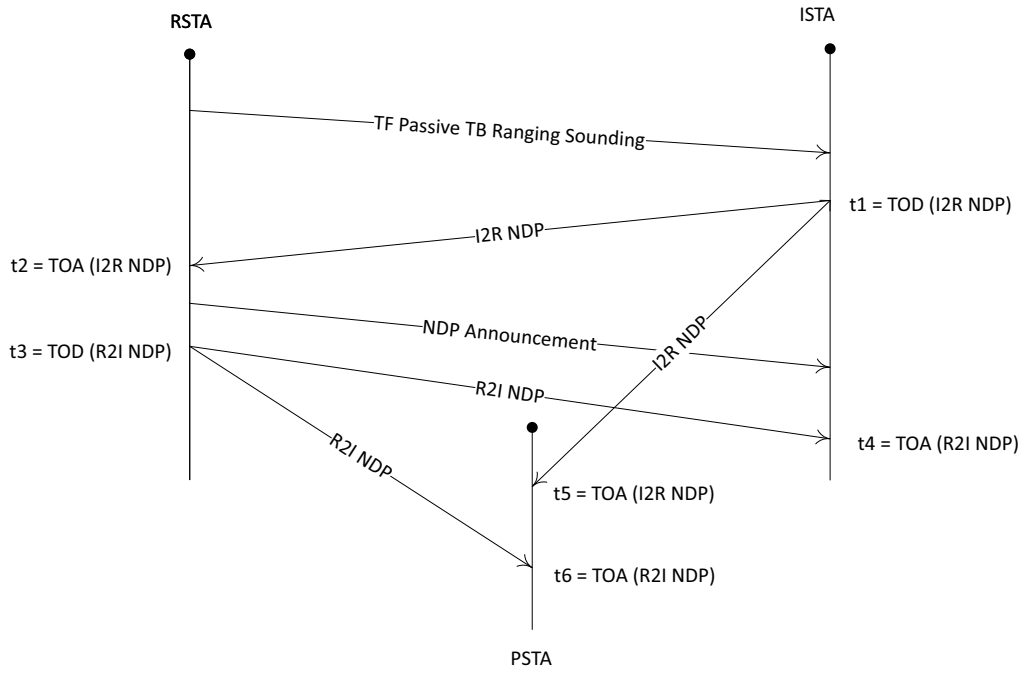


**Figure 11-72—Example timing diagram of a Measurement Sounding phase in passive TB ranging(11az)**

The PSTA may use the ISTA's and RSTA's timestamps, together with its own measured TOAs of the ranging NDPs, t5 and t6, to calculate its differential time of flight to the RSTA and the ISTA.

The differential time-of-flight (DToF) from PSTA to RSTA and ISTA (DToF_PRI) is defined by Equation (11-11).

$$DToF\_PRI = ToF\_PR - ToF\_PI \quad (11\text{-}11)$$

where

ToF_PR is the time of flight between the PSTA and the RSTA
ToF_PI is the time of flight between the PSTA and the ISTA

The differential time of flight DToF_PRI can be computed as per Equation (11-12):

$$DToF\_PRI = t6 - t5 - 0.5 \times t3' + 0.5 \times t2' - 0.5 \times t4' + 0.5 \times t1' \quad (11\text{-}12)$$

where

t1' and t4' are the time at which the I2R NDP was transmitted from the ISTA and the time at which the R2I NDP was received by the ISTA, respectively, converted by the PSTA from the ISTA's time basis to the PSTA's time basis.

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t2' and t3' are the time at which the I2R NDP was received by the RSTA and the time at which the R2I NDP was transmitted by the RSTA, respectively, converted by the PSTA from the RSTA's time basis to the PSTA's time basis.

At the PSTA, the mechanism by which t1' and t4' is derived from t1, t4, the ISTA's reported CFO, and the PSTA's CFO measured with respect to the RSTA, is implementation dependent.

At the PSTA, the mechanism by which t2' and t3' is derived from t2, t3, and the PSTA's CFO measured with respect to the RSTA, is implementation dependent.

By multiplying the differential time of flight, DToF_PRI, with the speed of light, the differential distance from PSTA to RSTA and ISTA can be computed.

See 11.21.6.4.9 (Passive TB ranging differential time-of-flight calculations using phase shift TOA timestamps(11az)) for how the PSTA's differential distance to the RSTA and the ISTA can be computed using PSTOAs measured by the RSTA and the ISTA.

#### 11.21.6.4.8.4 Passive TB ranging Measurement Reporting phase(11az)

The passive TB ranging measurement reporting follows the same rules and procedures for the measurement reporting for TB ranging described in 11.21.6.4.3.4 (Reporting phase of TB ranging measurement(11az)), unless explicitly stated otherwise.

The last phase of the passive TB ranging measurement sequence is the passive TB ranging Measurement Reporting phase and occurs a SIFS time after the passive TB ranging Measurement Sounding phase; see Figure 11-73 (Passive TB ranging Measurement Reporting phase(11az)) for a depiction of the passive TB ranging Measurement Reporting phase.

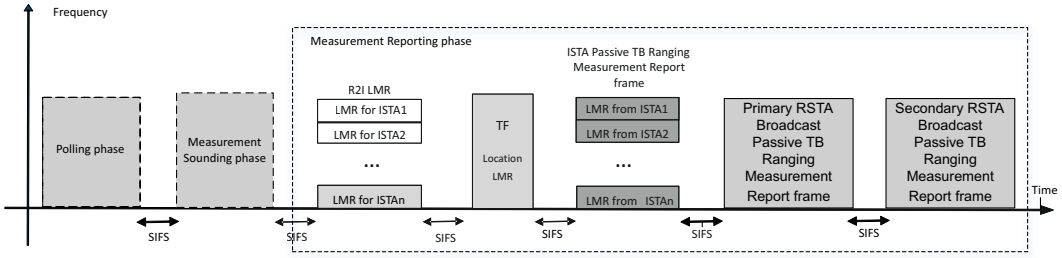


**Figure 11-73—Passive TB ranging Measurement Reporting phase(11az)**

In the passive TB ranging Measurement Reporting phase, an RSTA shall send a Passive TB Ranging Measurement Report frame and the Report Ranging Trigger frame to one or more ISTAs that sent an HE Ranging NDP in the preceding passive TB ranging Measurement Sounding phase. An ISTA addressed by the Report Ranging Trigger frame shall transmit an ISTA Passive TB Ranging Measurement Report frame a SIFS time after the Report Ranging Trigger frame transmission to report its I2R LMR.

In order to facilitate broadcasting of the ISTA's timestamps by the RSTA, the ISTA Passive TB Ranging Measurement Report frame shall be transmitted as a public Action frame.

The ISTA Passive TB Ranging Measurement Report element, see 9.4.2.306 (ISTA Passive TB Ranging Measurement Report element(11az)), in ISTA Passive TB Ranging Measurement Report frames shall contain:

— A Sounding Dialog Token Number identifying the measurement sounding phase in which the reported ISTA's timestamps were measured.


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- The CFO of the ISTA with respect to the RSTA.
- The TOD timestamp for the I2R NDP that the ISTA transmitted—labeled with the AID12/RSID12 of the ISTA.
- The TOA timestamp for the R2I NDP that the ISTA received from the RSTA.
- Optionally, the TOA timestamps for the I2R NDPs received from other ISTAs participating in the passive TB ranging (i.e., polling, sounding, and reporting triplet) identified by the Sounding Dialog Token Number—labeled with their respective AID12/RSID12s.

If phase shift TOA reporting has been negotiated, the ISTA Passive TB Ranging Measurement Report element shall also include:

- The PS-TOA timestamp of the R2I NDP that the ISTA received from the RSTA.
- Optionally, the PS-TOAs for the I2R NDPs received from other ISTAs participating in the passive TB ranging (i.e., polling, sounding, and reporting triplet) identified by the Sounding Dialog Token Number—labeled with their respective AID12/RSID12s.

The ISTA Passive TB Ranging Measurement Report frame shall include an entry for the ISTA's I2R NDP TOD.

The ISTA shall set the More subfield in the More & N Timestamp Measurements Report field in the ISTA Passive TB Ranging Measurement Report element contained in the ISTA Passive TB Ranging Measurement Report frame to 1 if it has more timestamps ready to report but does not have space in its allocated resources by the RSTA for ISTA Passive TB Ranging Measurement Report frame. Else the ISTA shall set the More subfield to 0.

The RSTA shall send the Primary and Secondary RSTA Broadcast Passive TB Ranging Measurement Report frames, the Primary a SIFS time after receiving the ISTA Passive TB Ranging Measurement Report frames from the ISTA and the Secondary a SIFS following the Primary; see Figure 11-73 (Passive TB ranging Measurement Reporting phase(11az)).

The Primary RSTA Broadcast Passive TB Ranging Measurement Report frame shall contain the following:

- Passive TB Ranging LCI Table Counter.
- Passive TB Ranging LCI Table Countdown Info.
- RSTA Passive TB Ranging Measurement Report.
- Passive TB Ranging LCI Table (optionally present).

Each time an RSTA transmits a Primary RSTA Broadcast Passive TB Ranging Measurement Report frame, it shall set the Passive TB Ranging LCI Table Counter value such as to refer to the latest version of the Passive TB Ranging LCI Table element transmitted by the RSTA.

If a Passive TB Ranging LCI Table element is included in the Primary RSTA Broadcast Passive TB Ranging Measurement Report frame, and this element has different content as compared to the last transmitted Passive TB Ranging LCI Table element, then the Passive TB Ranging LCI Table Counter shall be incremented by 1 (modulo 256) from the value associated with the previous Passive TB Ranging LCI Table element content. (The first time the RSTA transmits a Passive TB Ranging LCI Table element the value shall be set to 0). This new value of the Passive TB Ranging LCI Table Counter is now associated with this new version of the Passive TB Ranging LCI Table element.

If a Passive TB Ranging LCI Table element is included in the Primary RSTA Broadcast Passive TB Ranging Measurement Report frame, and this element has the same content as the last transmitted Passive TB Ranging LCI Table element, then the Passive TB Ranging LCI Table Counter value shall be the value associated with this last version of the Passive TB Ranging LCI Table element transmitted by the RSTA.

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If a Passive TB Ranging LCI Table element is not included in the Primary RSTA Broadcast Passive TB Ranging Measurement Report frame, then the Passive TB Ranging LCI Table Counter value shall be the value associated with the last version of the Passive TB Ranging LCI Table element transmitted by the RSTA.

When the Passive TB Ranging LCI Table is present in the Primary Broadcast Passive TB Ranging Measurement Report frame, the RSTA LCI Report field of the Passive TB Ranging LCI Table Report element shall contain the Antenna Placement And Calibration subelement if the RSTA has dot11PassiveTBRangingAODImplemented equal to true, and shall not contain the Antenna Placement And Calibration subelement if the RSTA has dot11PassiveTBRangingAODImplemented equal to false.

When the Passive TB Ranging LCI Table is present in the Primary Broadcast Passive TB Ranging Measurement Report frame, the corresponding entry of the ISTA LCI Reports Entries field of the Passive TB Ranging LCI Table Report element shall contain the Antenna Placement And Calibration subelement if the ISTA has dot11PassiveTBRangingAoDImplemented equal to true, and shall not contain the Antenna Placement And Calibration subelement if the ISTA has dot11PassiveTBRangingAODImplemented equal to false.

The Secondary RSTA Broadcast Passive TB Ranging Measurement Report frame shall contain the following:

— ISTA Passive TB Ranging Measurement Reports.

See 9.6.7.52 (Secondary RSTA Broadcast Passive TB Ranging Measurement Report frame format(11az)).

When phase shift feedback is negotiated between an ISTA and an RSTA in Passive TB ranging, the protocol for the measurement reporting phase differs from Passive TB ranging with TOA feedback on the following points:

— The RSTA shall report its measured PSTOA in the R2I LMR frame.

— The ISTA shall report its measured PSTOA(s), in addition to its measured TOA(s), in the ISTA Passive TB Ranging Measurement Report frame.

  — The PSTOAs are indicated as phase shift TOA timestamps by setting the Measurement Report field of the ISTA Passive TB Ranging Measurement Report element, see 9.4.2.306 (ISTA Passive TB Ranging Measurement Report element(11az)), to the value 10 (PSTOA).

— In the Primary RSTA Broadcast Passive TB Ranging Measurement Report frame, the RSTA shall send a broadcast frame containing its measured PSTOA, in addition to its measured TOA, for the I2R NDPs it has received from the ISTA.

— In the Secondary RSTA Broadcast Passive TB Ranging Measurement Report frame the RSTA shall rebroadcast the timestamps the ISTA has reported to the RSTA. As the ISTA has negotiated phase shift feedback, these would contain PSTOAs in addition to TOAs.

When phase shift feedback is negotiated in Passive TB ranging, the reporting by both the RSTA and the ISTA of phase shift TOAs, the TOD, and CFO shall be immediate feedback. The reported TOAs may be immediate or delayed feedback. When the TOA feedback is delayed, the dialog token shall refer to the previous measurement instance for the RSTA–ISTA pair.

The TODs and PSTOAs measured by the RSTA shall be broadcast in the Primary RSTA Broadcast Passive TB Ranging Measurement Report frame in the reporting phase following the measurement exchange in which they were measured.

The CFO, TOD, and PSTOAs reported by the ISTA shall be rebroadcasted in the Secondary RSTA Broadcast Passive TB Ranging Measurement Report frame in the reporting phase following the measurement exchange in which they were measured.


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### 11.21.6.4.9 Passive TB ranging differential time-of-flight calculations using phase shift TOA timestamps(11az)

In Figure 11-74 (Example of passive TB ranging measurement exchanges with PSTOA measurements(11az)), passive TB ranging measurement exchanges and their reception by a passive station, a PSTA, are depicted for the case when the RSTA and the ISTA are measuring and reporting phase shift TOAs, PSTOAs; see Annex AD for how the phase shift TOAs are calculated.

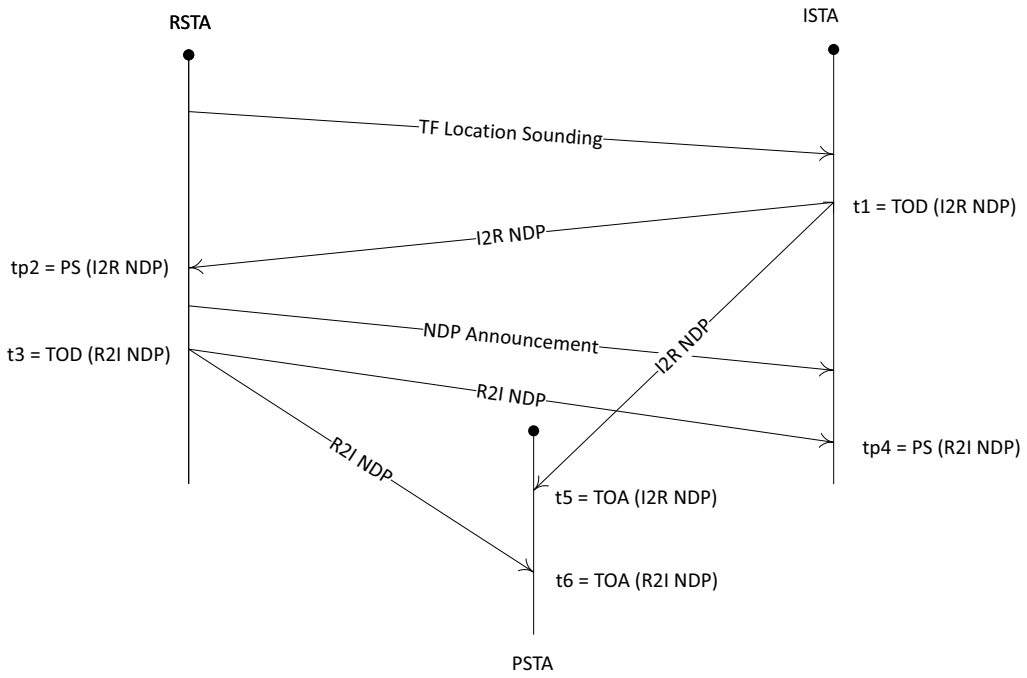


**Figure 11-74—Example of passive TB ranging measurement exchanges with PSTOA measurements(11az)**

The RSTA measures the PSTOA tp2 and the ISTA measures the PSTOA tp4, in addition to measuring their TODs t3 and t1. respectively. The ISTA also measures its CFO with respect to the RSTA. The ISTA reports its CFO and timestamps to the RSTA and the RSTA broadcasts these as well as its own timestamps to the PSTA.

The ISTA also measures and reports the TOA timestamps for the ranging NDPs it receives and the RSTA also measures and broadcasts the TOAs of the ranging NDPs it receives, as well as the ISTAs reported TOAs, though these timestamps are not used in the calculations described here.

The differential time of flight from the PSTA to the RSTA and the ISTA (DToF_PRI) is defined by Equation (11-13):

$$DToF\_PRI = ToF\_PR - ToF\_PI \quad (11\text{-}13)$$

where

ToF_PR is the time of flight between the PSTA and the RSTA
ToF_PI is the time of flight between the PSTA and the ISTA

The differential time of flight (DToF_PRI) can then be computed as per Equation (11-14):

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$$DToF\_PRI = t6 - t5 - 0.5 \times t3' + 0.5 \times tp2' - 0.5 \times tp4' + 0.5 \times t1' \quad (11\text{-}14)$$

where

| | |
|---|---|
| timestamp t1' | is the time at which the I2R NDP was transmitted from the ISTA. |
| timestamp tp4' | is the PSTOA measurement for the time at which the R2I NDP was received by the ISTA, converted from the ISTA's time basis to the PSTA's time basis. |
| timestamp tp2' | is the PSTOA measurement for the time at which the I2R NDP was received by the RSTA. |
| timestamp t3' | is the time at which the R2I NDP was transmitted from the RSTA, converted from the RSTA's time basis to the PSTA's time basis. |

At the PSTA, the mechanism by which t1' and tp4' is derived from t1, tp4, the ISTA's reported CFO, and the PSTA's CFO measured with respect to the RSTA is implementation dependent.

At the PSTA, the mechanism by which t2' and tp3' is derived from t2, tp3, and the PSTA's CFO measured with respect to the RSTA is implementation dependent.

#### 11.21.6.5 FTM parameter modification(11az)

During an FTM session, an (11az)ISTA may terminate the current session and request a new session with modified session parameters by transmitting an FTM Request frame with Trigger field set to 1.

(11az)This FTM Request shall include:

— A new FTM Parameters element if the corresponding FTM session is using an EDCA based measurement exchange; see 11.21.6.4.2 (EDCA based ranging measurement exchange(11az)) or,

— A Ranging Parameters element if the corresponding FTM session is of type non-TB ranging; see 11.21.6.4.4 (Non-TB ranging measurement exchange(11az)), or TB ranging; see 11.21.6.4.3 (TB ranging measurement exchange(11az)).

(11az)NOTE—This allows up to one ranging session between a given ISTA and RSTA at any time.

The existing FTM session is terminated upon reception of such (11az)an FTM Request frame. This FTM Request frame is an initial FTM Request frame for the new FTM session, which follows the behavior described in 11.21.6.3 (FTM procedure negotiation(11az)).

##### 11.21.6.5.1 Availability window parameter modification(11az)

In an FTM session based on TB ranging, the RSTA may modify the availability window parameters corresponding to the FTM session by transmitting an A-MPDU containing an FTM frame and an R2I LMR whenever the RSTA is permitted to transmit such an LMR to that ISTA. The FTM frame is of type Action No Ack and shall contain a Ranging Parameters field containing a TB-Specific subelement. The Availability Window field in the TB-Specific subelement indicates the parameters of the new availability window assigned to the corresponding FTM session. In the FTM frame the Follow Up Dialog Token field is set as 0. The existing ranging session continues based on current availability window parameters until the start of the new availability window signaled in the FTM frame.

#### 11.21.6.6 FTM session termination(11az)

##### 11.21.6.6.1 EDCA based ranging session termination(11az)

An FTM session terminates after the last burst instance, as indicated in the Number of Bursts Exponent, Burst Duration, FTMs Per Burst and Burst Period fields in the (11az)IFTM frame.


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An FTM session may be terminated before then through one of the following:

- At any time during the FTM session when the (11az)RSTA is permitted to transmit an FTM frame (see 11.21.6.4 (Measurement exchange)), the RSTA sends an FTM frame with the Dialog Token field set to 0.
- At any time during the FTM session when the (11az)ISTA is permitted to transmit an FTM Request frame (see 11.21.6.4 (Measurement exchange)), the ISTA sends an FTM Request frame with the Trigger field set to 0. This frame shall not include the following:
  - A Measurement Request element
  - (11az)An FTM Parameters element
- At any time during the FTM session when the initiating STA is permitted to transmit (11az)an FTM Request frame (see 11.21.6.4 (Measurement exchange)), the ISTA terminates the current session and requests a new session with modified FTM parameters (see 11.21.6.5 (FTM parameter modification(11az))).
- After the number of burst instances indicated in the Number of Bursts Exponent field in the (11az)IFTM frame has been reached.

(11az)When the FTM session is a Secure FTM Session, the FTM frames transmitted shall be the Protected Fine Timing Action frames; see 9.6.34 (Protected Fine Timing Action frame details(11az)(#8155)).

#### 11.21.6.6.2 TB ranging and non-TB ranging session termination(11az)

A non-TB ranging FTM session may be terminated if an ISTA does not initiate a non-TB ranging measurement exchange (11.21.6.4.4 (Non-TB ranging measurement exchange(11az))) with an RSTA before the duration signaled in the Max Time Between Measurements field assigned to that ISTA by the RSTA has elapsed from either the end of the successful FTM session negotiation or the beginning of the last successful measurement exchange, whichever is later.

A TB ranging FTM session may be terminated if the ISTA fails to respond to a TF Ranging Poll frame and receive one TF Ranging Sounding frame or TF Ranging Secured Sounding frame containing its AID/RSID at least once within the Max Session Expiry interval. The Max Session Expiry interval starts from either the end of the successful FTM session negotiation or the beginning of the last successful TB ranging measurement exchange (11.21.6.4.3 (TB ranging measurement exchange(11az))), whichever is later. The length of this interval is equal to the duration signaled in the Max Session Exp field, present in the TB Ranging Specific subelement in the Ranging Parameters field in the initial FTM frame.

A TB ranging or a non-TB ranging FTM session may be terminated through one of the following:

- At any time during the session when the RSTA is permitted to transmit an R2I LMR frame, the RSTA transmits an A-MPDU containing an LMR frame and an FTM frame with the Dialog Token field set to 0 and of type Action No ACK. In the FTM frame the Follow Up Dialog Token field is set as 0. The FTM frame shall not include any Ranging Parameters field.
- At any time during the session the ISTA sends an FTM Request frame with the Trigger field set to 0. This frame shall not include the following:
  - Ranging Parameters element.
  - Measurement Request element.
- At any time during the session the ISTA terminates the current session and requests a new session with modified ranging parameters; see 11.21.6.5 (FTM parameter modification(11az)).

When the ranging session is a Secure FTM Session, the corresponding FTM frames transmitted shall be Protected Fine Timing Action frames; see 9.6.34 (Protected Fine Timing Action frame details(11az)(#8155)).

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### 11.21.6.7 LCI and Location Civic retrieval using FTM procedure

Within the FTM procedure, a STA, to request the LCI of (11az)an RSTA that transmits an Extended Capabilities element with the Fine Time Measurement Responder field set to 1, shall include a Measurement Request element with Measurement Type field equal to LCI within the FTM Request frame.

Within the FTM procedure, a STA, to request the Location Civic of (11az)an RSTA that transmits an Extended Capabilities element with the (#7065)FTM Responder field set to 1, shall include a Measurement Request element with Measurement Type field equal to Location Civic within the FTM Request frame.

A Measurement Request element with Measurement Type field equal to LCI shall not be included in (11az)an FTM Request frame unless the FTM Request frame also includes an FTM Parameters element or a Ranging Parameters element. A Measurement Request element with Measurement Type field equal to Location Civic shall not be included in an FTM Request frame unless the FTM Request frame also includes an FTM Parameters element or a Ranging Parameters element.

When (11az)an RSTA that has both dot11FineTimingMsmtRespActivated and dot11RMLCIConfigured equal to true receives a Measurement Request element with Measurement Type field equal to LCI within an IFTMR frame, the RSTA shall include a Measurement Report element with Measurement Type field equal to LCI in the IFTM frame. If the maximum horizontal or vertical location error of the RSTA relative to a reference STA is known and this relative error is smaller than the absolute error indicated in the LCI subelement, then the RSTA may include a Relative Location Error subfield in the Measurement Report field. The RSTA shall not include a Measurement Report element with Measurement Type field equal to LCI in the FTM frame in the current FTM session unless the RSTA's LCI has changed since the last time it was reported to the initiating STA.

When a responding STA that has at least one of dot11FineTimingMsmtRespActivated and dot11RMLCIConfigured equal to false receives a Measurement Request element with Measurement Type field equal to LCI within (#8020)an FTMR frame(#7223), the responding STA shall include a Measurement Report element with the Incapable field set to 1 in the initial FTM frame(#7223).

When a responding STA that has both dot11FineTimingMsmtRespActivated and dot11RMCivicConfigured equal to true receives a Measurement Request element with Measurement Type field equal to Location Civic within an IFTMR frame(#7223)(#7065), the responding STA shall include a Measurement Report element with Measurement Type field equal to Location Civic in the initial FTM frame(#7223). The responding STA shall not include a Measurement Report element with Measurement Type field equal to Location Civic in the FTM frame(#7223) in the current FTM session unless the responding STA's civic location has changed since the last time it was reported to the initiating STA.

When a responding STA that has at least one of dot11FineTimingMsmtRespActivated and dot11RMCivicConfigured equal to false receives a Measurement Request element with Measurement Type equal to Location Civic within (#8020)an FTMR frame(#7223), the responding STA shall include a Measurement Report element with the Incapable field set to 1 in the initial FTM frame(#7223).

Each Measurement Report element returned shall have the same Measurement Token value as in the Measurement Token field of the corresponding Measurement Request element. The FTM frame(#7223) containing the Measurement Report element(s) should be returned without undue delay to the STA.

A STA that receives an LCI report that contains a Usage Rules/Policy subelement shall process the LCI information in compliance with the retransmission and retention permissions in the Usage Rules/Policy subelement.


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### 11.21.7 BSS transition management(#556)

#### 11.21.7.1 BSS transition capability

The BSS transition capability enables improved throughput, effective data rate and/or QoS for the aggregate of STAs in a network by shifting (via transition) individual STA traffic loads to more appropriate points of association within the ESS. In addition, the BSS transition capability provides accounting session control information to a non-AP STA, which might be used to provide an alert to the non-AP STA's user that the STA's session is almost over and the STA will be disassociated from the ESS.

The BSS Transition Management Query, BSS Transition Management Request, BSS Transition Management Response frames provide a means and a protocol to exchange the information needed to enable an AP to inform associated STAs that the BSS will be terminated and to enable a network to manage BSS loads by influencing STA transition decisions. A STA may provide neighbor report information to its associated AP for BSSs that it considers to be transition targets. This information enables the AP to request that the STA transition to a BSS that the STA also prefers.

Implementation of BSS transition management is optional for a WNM STA that is not a non-AP HE STA. If dot11BSSTransitionActivated is true, dot11WirelessManagementImplemented shall be true. A STA with dot11BSSTransitionActivated equal to true shall support BSS transition management and shall set to 1 the BSS Transition field of the Extended Capabilities elements that it transmits. A non-AP HE STA shall have dot11BSSTransitionImplemented and dot11BSSTransitionActivated equal to true.(11ax)

BSS transition management and network load balancing do not apply in an IBSS.(#556)(#1675)

#### 11.21.7.2 BSS transition management query

A non-AP STA supporting BSS transition management may request a BSS Transition Candidate list by sending a BSS Transition Management Query frame to its associated AP if the associated AP indicates that it supports the BSS Transition capability in the Extended Capabilities element. A non-AP STA should include the BSS Transition Candidate List Entries field in the BSS Transition Management Query frame to indicate the non-AP STA's transition preferences. If the non-AP STA transmits a BSS Transition Query frame only to provide transition preferences to the AP, then the BSS Transition Query Reason field of the BSS Transition Management Query frame shall be set to a value of 19, indicating "Preferred BSS Transition Candidate List Included."

The BSS Transition Candidate List Entries field of a BSS Transition Management Query frame contains zero or more Neighbor Report elements describing the non-AP STA's preferences for target BSS candidates. The Preference field value of a Neighbor Report element used in a BSS Transition Management Query frame shall be between 1 and 255. The value of 0 is reserved. The values between 1 and 255 provide the indication of order, with 255 indicating the most preferred BSS within the given candidate list, decreasing numbers representing decreasing preference relative only to entries with lower values of the Preference field, and equal numbers representing equal preference.

#### 11.21.7.3 BSS transition management request

An AP that supports BSS transition management shall respond to a BSS Transition Management Query frame with a BSS Transition Management Request frame. The AP may send an unsolicited BSS Transition Management Request frame to a non-AP STA at any time if the non-AP STA indicates in the Extended Capabilities element that it supports BSS transition management; otherwise the AP shall not send an unsolicited BSS Transition Management Request frame to the STA. (#2220)The AP may transmit a broadcast BSS Transition Management Request frame if at least one associated non-AP STA supports BSS transition management; otherwise the AP shall not transmit a broadcast BSS Transition Management Request frame. When the BSS Transition Management Request frame is transmitted as a broadcast frame, a receiving non-AP

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STA shall not respond with a BSS Transition Management Response frame. A non-AP STA that supports BSS transition management shall respond to an individually addressed BSS Transition Management Request frame with a BSS Transition Management Response frame.

The AP shall include the BSS Transition Candidate List Entries field in the BSS Transition Management Request frame if the AP has information in response to the BSS Transition Management Query frame. The BSS Transition Candidate List Entries field contains zero or more Neighbor Report elements describing the preferences for target BSS candidates. A Preference field value of 0 indicates that the BSS listed is an excluded BSS. The STA should refrain from associating to an AP corresponding to an excluded BSS. The Preference field values are used to establish the relative order of entries within the given list at the given time, and for the given AP.

The values between 1 and 255 provide the indication of order, with 255 indicating the most preferred BSS within the given candidate list, decreasing numbers representing decreasing preference relative only to entries with lower values of the Preference field, and equal numbers representing equal preference. The Preference field value is valid only before the validity interval has expired. The AP may include zero or more subelements in the BSS Transition Candidate List Entries field.

Upon reception of a BSS Transition Management Query frame or BSS Transition Response frame from a non-AP STA that contains a nonempty BSS Transition Candidate List Entries field, the AP should include at least one BSS candidate from that list with a nonzero Preference field value in the BSS Transition Candidate List Entries field of any subsequent BSS Transition Management Request frame with the Preferred Candidate List Included field set to 1 transmitted to the non-AP STA. The AP shall evaluate the BSSs indicated in the BSS Transition Candidate List Entries field in the latest BSS Transition Management Query frame or BSS Transition Management Response frame received from the non-AP STA as BSS transition candidate(s) for the non-AP STA. The means by which the AP evaluates and determines BSS transition candidates is outside the scope of this standard.

A STA that receives a BSS Transition Management Request frame with the Preferred Candidate List Included subfield of the Request Mode field equal to 0 may ignore the BSS Transition Candidate List Entries field of the frame.

A non-AP STA that receives the Abridged bit with a value of 1 shall treat any BSSID in the ESS of which it is a member that does not appear in the BSS Transition Candidate List as if it were present in the BSS Transition Candidate List with a Preference value of 0.

The AP may include one BSS Termination Duration subelement for each BSS in the BSS Transition Candidate List Entry field, including the BSS Termination Duration value and a BSS Termination TSF value. The BSS Termination Duration value may be different for each BSS.

When the AP transmits a BSS Transition Management Request frame with the Disassociation Imminent field set to 1 to a non-AP STA, the Disassociation Timer field in the BSS Transition Management Request frame shall be set to 0 or set to the number of TBTTs that will occur prior to the AP disassociating the non-AP STA. The AP shall start a timer for the non-AP STA with the initial timer value set to the Disassociation Timer field value. The AP shall decrement the timer by one after transmitting each Beacon frame until the timer has value of 0. In subsequent BSS Transition Management Request frames that the AP transmits to the non-AP STA, the Disassociation Timer field shall be set to the value of the timer.

If the most recent BSS Transition Management Request frame that an AP has transmitted to a non-AP STA has the Disassociation Imminent field set to 1, then the AP shall not transmit a Disassociation frame to the non-AP STA unless the timer for the non-AP STA has value of 0.

An AP's SME may have accounting session control information, such as a notice of session expiration. The means by which the AP's SME obtains accounting session control information is out of scope of this standard.


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Accounting session control information might include a duration after which the non-AP STA will be disassociated from the ESS and an optional session information URL at which information may be obtained to extend the accounting session. When an AP's SME has accounting session control information, it shall issue an MLME-BTM.request primitive to the AP's MLME and shall encode the time to session expiration in the Disassociation Timer parameter and shall encode the URL, if available, in the SessionInformationURL parameter. A non-AP STA's SME that receives an MLME-BTM.indication primitive shall forward the MLME-BTM.indication parameters to the appropriate entity within the device (e.g., web browser) to inform the end user; the means and protocol by which the SME accomplishes this is outside the scope of this standard.

A STA's SME receiving an MLME-BTM.indication primitive containing the BSS Transition Candidate List Entries field should use this list of candidates, with individual transition preference values, to make BSS transition decisions. Upon receiving an MLME-BTM.indication primitive, the STA's SME shall disregard any previous MLME-BTM.indication primitive received from the same AP. The STA shall not use the corresponding BSS Transition Candidate List Entries field information after the indicated validity interval. The STA may send a BSS Transition Management Query frame at any time to obtain an updated BSS Transition Candidate List Entries field or to indicate the STA's BSS transition candidates.

A STA's SME receiving an MLME-BTM.indication primitive containing a nonzero value of the Disassociation Timer field should attempt to find a suitable AP with which to reassociate before the indicated disassociation time.

#### 11.21.7.4 BSS transition management response

When the STA's SME receives an MLME-BTM.indication primitive, it may issue an MLME-BTM.response primitive.

The STA's SME may include the result of its BSS transition decision in the Target BSSID field and BTM Status Code field in the MLME-BTM.response primitive. A BTM Status Code field set to a value of 0 (i.e., Accept) indicates the STA will transition from the current BSS. If a non-HE STA's SME receives an MLME-BTM.indication primitive indicating a BSS transition management request with which it is unable to comply, it may issue an MLME-BTM.response primitive with a status code indicating rejection.(11ax)

When a non-AP STA's SME receives an MLME-BTM.indication primitive with the BSS Termination Included field in the Request Mode field equal to 1 it may issue an MLME-BTM.response primitive with the BTM Status Code field set to one of the following values:

- 0 – Accept. Accept the BSS Termination request.
- 4 – Reject, BSS Termination Undesired. Request for deferral of BSS Termination, interval not specified.
- 5 – Reject, BSS Termination Delay. Request for deferral of BSS Termination interval specified in the BSS Termination Delay field in the BSS Transition Management Response frame.

The AP's SME may (#2224)abandon or delay its BSS termination decision based on policies that are out of the scope of this standard. The MLME-RESET.request primitive is invoked to terminate the BSS. The AP shall disassociate all STAs immediately prior to termination of the BSS.

When a non-AP STA's SME receives an MLME-BTM.indication primitive with both the Disassociation Imminent and Preferred Candidate List Included fields equal to 0, the non-AP STA's SME shall issue an MLME-BTM.response primitive with the BTM Status Code field set to one of the following values:

- 0 – Accept.
- 2 – Reject, Insufficient Beacon or Probe Response frames received from all candidates.
- 3 – Reject, Insufficient available capacity from all candidates.
- 6 – Reject, STA BSS Transition Candidate List provided.

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- 7 – Reject, No suitable BSS transition candidates.
- 8 – Reject, Leaving ESS.

When an AP's SME receives an MLME-BTM.confirm primitive with the BTM Status Code field equal to a value of 2, indicating "Reject, Insufficient Beacon or Probe Response frames received from all candidates," the AP's SME should generate an MLME-BTM.request primitive with both the Disassociation Imminent and Preferred Candidate List Included fields set to 0 after providing sufficient time for the non-AP STA to perform its scanning procedures.

If the BTM Status Code field is a value of 6, indicating "Reject, STA BSS Transition Candidate List provided," the non-AP STA shall include a nonempty BSS Transition Candidate List Entries field in the BSS Transition Management Response frame to indicate the non-AP STA's transition preferences. The BTM Status Code field is a value of 8, indicating "Reject, Leaving ESS" if the non-AP STA intends to disassociate from the ESS.

The BSS Transition Candidate List Entries field of a BSS Transition Management Response frame contains zero or more Neighbor Report elements describing the non-AP STA's preferences for target BSS candidates. The Preference field value of a Neighbor Report element used in a BSS Transition Management Response frame shall be between 1 and 255. The value of 0 is reserved. The values between 1 and 255 provide the indication of order, with 255 indicating the most preferred BSS within the given candidate list, decreasing numbers representing decreasing preference relative only to entries with lower values of the Preference field, and equal numbers representing equal preference. The non-AP STA should not list any BSS that is not considered as a target BSS candidate.

When a non-AP STA receives a BSS Transition Management Request frame that has both the Disassociation Imminent and Preferred Candidate List Included fields equal to 1 and a nonempty BSS Transition Candidate List Entries field, if the non-AP STA transmits a BSS Transition Management Response frame to the AP with the BTM Status Code field set to 0 (Accept), then the non-AP STA shall either disassociate from the AP or attempt to (re)associate with an AP corresponding to one of the nonexcluded BSSs in the BSS Transition Candidate List Entries field of the received BSS Transition Management Request frame.

Prior to transitioning to an excluded BSS listed in the BSS Transition Candidate List Entries field of a received BSS Transition Management Request frame, the non-AP STA shall transmit a BSS Transition Management Response frame to the AP indicating the reject reason.

#### 11.21.7.5 Planned ESS(11ax)

The AP may transmit an ESS Report element (see 9.4.2.255 (ESS Report element(11ax))) to indicate whether it is in a planned ESS, to assist associated STAs' BSS transition(#1600). If it indicates that it is in a planned ESS, it indicates whether it is at the physical edge of the ESS and can provide a recommendation on the RSSI level to consider for BSS transition.

If the AP transmits an ESS Report element, it shall set the Planned ESS subfield in the ESS Information field to 1 if it is part of an ESS that is planned with several BSSs in overlapping configuration, whereby an associated STA may adjust its BSS transition algorithms accordingly. Otherwise, it shall set the Planned ESS subfield to 0.

If the Planned ESS subfield is 1, then the AP shall set the Edge Of ESS subfield in the ESS Information field of the ESS Report element to 1 if the AP's BSS is at the edge of an ESS (e.g., exit of a building). Otherwise, it shall set the Edge Of ESS subfield to 0.

NOTE 1—A non-AP STA could then prepare for more aggressive BSS transition(#1600), or the device in which the non-AP STA is located could then prepare for switching to a different system. However, how the non-AP STA uses the edge of ESS information is implementation specific and beyond the scope of this standard.


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If the Planned ESS subfield is 1, then the AP shall set the Recommended BSS Transition RSSI Threshold Within ESS subfield in the ESS Information field of the ESS Report element to indicate the beacon RSSI below which an associated STA should initiate a BSS transition. Otherwise, it shall set the Recommended BSS Transition RSSI Threshold Within ESS subfield to 0.

NOTE 2—A non-AP STA could then use the Recommended BSS Transition RSSI Threshold Within ESS subfield to modify when it starts scanning for a new BSS. However, how the non-AP STA adjusts its BSS transition algorithms is implementation specific and beyond the scope of this standard.

The value of the Edge Of ESS subfield and the Recommended BSS Transition RSSI Threshold Within ESS subfield may be changed by the AP if conditions in the ESS change. An AP shall not change the value of the Planned ESS subfield over the lifetime of the BSS.

### 11.21.8 FMS multicast rate processing

An AP that supports FMS indicates its ability to deliver group addressed frames at alternate delivery intervals by its advertisement of the FMS capability. A STA that supports FMS includes the FMS Request element in FMS Request frames to indicate a request to use the FMS service, including use of a higher multicast rate. The AP selects the TXVECTOR parameters to use with the STA and indicates the rate that these parameters produce and the multicast address in the FMS Response element in the FMS Response frame.

The AP selects TXVECTOR parameters to(M118) be used for transmission to the currently associated STAs requesting FMS service from the AP for the same FMS stream identified by FMSID (the "existing STAs"), and to the requesting STA subject to the following constraints:

- The rate shall not be higher than the lowest rate value provided by the existing STAs and the requesting STA
- The selection of the following TXVECTOR parameters shall be compatible with capabilities declared by the existing STAs and the requesting STA:
  - FORMAT
  - NON_HT_MODULATION
  - PREAMBLE_TYPE
  - MCS
  - CH_BANDWIDTH
  - STBC
  - FEC_CODING
  - GI_TYPE

The STA's SME may request membership in a multicast group or changes in multicast data rate by issuing an MLME-FMS.request primitive. Upon receipt of an FMS Request frame at the AP's SME as indicated by reception of the MLME-FMS.indication primitive the AP's SME shall issue an MLME-FMS.response primitive, indicating the FMS Request element, including the multicast address. The AP may send an FMS Response frame to the STA to change the STA's multicast rate. When the AP sends an FMS Response frame to the STA with an Element Status field, indicating "Multicast rate changes not allowed," the STA shall not send further FMS Request frames to request a change in the multicast rate while the STA is associated to the AP.

### 11.21.9 (#2210)Colocated interference reporting

(#2210)Colocated interference might cause degradation of IEEE 802.11 STA performance either periodically or continuously. (#2210)Colocated interference reporting allows a requesting STA to receive information concerning the (#2210)colocated interference being experienced by another STA that is operating on the same channel as the requesting STA. Such interference might be due to an interaction between radios where a reporting STA is (#2210)colocated with another radio device. (#2210)Colocated interference information

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might be used by the requesting STA to manage communication to the reporting STA such that the effect of the interference might be limited.

Implementation of (#2210)Colocated interference reporting is optional for a WNM STA. A STA that implements (#2210)Colocated Interference reporting has dot11CoLocIntfReportingImplemented equal to true. When dot11CoLocIntfReportingImplemented is true, dot11WirelessManagementImplemented shall be true. A STA with dot11CoLocIntfReportingActivated equal to true shall support (#2210)colocated interference reporting and shall set to 1 the (#2210)Colocated Interference Reporting field of the Extended Capabilities elements that it transmits.

A requesting STA may request that (#2210)colocated interference reporting is enabled at another STA that has indicated support for the interference reporting capability. To enable (#2210)colocated interference reporting, the STA shall send a (#2210)Colocated Interference Request frame with Automatic Response Enabled bit set to the value representing the requested reporting type; see 9.6.13.13 ((#2210)Colocated Interference Request frame format). A STA accepting a request for (#2210)colocated interference reporting shall send the first report when it has knowledge of (#2210)colocated interference.

Subsequently, a STA accepting a request with the Automatic Response Enabled subfield equal to 1 shall send a (#2210)colocated interference report when the temporal characteristics of the interference or the level of the interference caused by (#2210)colocated interferer significantly change to provide updated information, subject to meeting the Report Timeout requirement. A STA accepting a request with the Automatic Response Enabled subfield equal to 2 or 3 shall send the (#2210)colocated interference reports periodically using the period included in the Report Period field in the (#2210)Colocated Interference Reporting element in the report frames. In addition to sending reports periodically, a STA accepting a request with the Automatic Response Enabled field equal to 3 shall send a (#2210)colocated interference report when the temporal characteristics of the interference or the level of the interference caused by (#2210)colocated interferer significantly change, subject to meeting the Report Timeout requirement.

The criteria a reporting STA uses for determining significant changes are internal to the reporting STA and outside the scope of this standard. When the reporting STA sends a (#2210)colocated interference report, it shall restart the Report Period timer for periodic reporting. For either periodic reporting or reporting due to the changes in (#2210)colocated interference, the reporting STA shall not generate (#2210)colocated interference reports more frequently than indicated by the Report Timeout field in Interference Request field in the (#2210)Colocated Interference Request frame.

The requesting STA may disable reporting by sending a (#2210)Colocated Interference Request frame with the Automatic Response Enabled subfield set to 0. The (#2210)colocated interference reporting shall be terminated on receipt of a (#2210)Colocated Interference Request frame with the Automatic Response Enabled subfield equal to 0. All outstanding (#2210)colocated interference requests are canceled upon a BSS transition and/or channel switch. A new (#2210)colocated interference request included in the new (#2210)colocated Interference Request frame supersedes any previously received requests sent by the same STA.

A STA that supports (#2210)colocated interference reporting may send a (#2210)Colocated Interference Request frame to another STA that supports (#2210)colocated interference reporting immediately after they are associated, so that the reporting STA can send a (#2210)colocated interference report as soon as it has knowledge of (#2210)colocated interference. The Dialog Token field is the nonzero value received in the corresponding (#2210)Colocated Interference Request frame which was used to enable reporting.

The reporting STA shall use the Interference Index field in the (#2210)Colocated Interference Report frame to indicate different types of interference. The reporting STA shall select a unique interference index value for each (#2210)colocated interference source. For example if the reporting STA has knowledge of (#2210)colocated interference originating from two interference sources the reporting STA shall report both type of interference using separate (#2210)Colocated Interference Report elements having separate Interference Index field. Both (#2210)Colocated Interference Report elements can be sent in the same


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(#2210)Colocated Interference Report frame and both can have the same report period. A report with the Interference Index field in the (#2210)Colocated Interference Report element equal to 0 indicates that no (#2210)colocated interference is present.

The characteristics of the interference are known a priori without requiring interference detection, measurement, and characterization by the IEEE 802.11 STA. The methods used by a reporting STA to know the periodicity, level of interference, accuracy of the reported interference level, interference center frequency and interference bandwidth are outside the scope of this standard.

### 11.21.10 QoS Traffic capability procedure

Implementation of the QoS Traffic capability is optional for a WNM STA. A STA that implements QoS Traffic capability has dot11QoSTrafficCapabilityImplemented equal to true. When dot11QoSTrafficCapabilityImplemented is true, dot11WirelessManagementImplemented shall be true. A STA with dot11QoSTrafficCapabilityActivated equal to true shall support QoS traffic capability and shall set to 1 the QoS Traffic Capability field of the Extended Capabilities elements that it transmits.

If dot11QoSTrafficCapabilityActivated is true, a QoS AP may use the QoS Traffic Capability field values received from a non-AP QoS STA as one of the factors when determining association, reassociation, and the BSS transition of the STA. A non-AP STA in which dot11QoSTrafficCapabilityActivated is true may send an Association Request, a Reassociation Request or QoS Traffic Capability Update frame to an AP whose last received Extended Capabilities element contained a value of 1 for the (#402)QoS Traffic Capability subfield in the Extended Capabilities field.

If dot11QoSTrafficCapabilityActivated is true, a non-AP QoS shall construct the (#403)QoS traffic capability flags as specified in 9.4.2.76 (QoS Traffic Capability element) and 9.6.13.23 (QoS Traffic Capability Update frame format). (#403)QoS traffic capability flags are constructed at the SME of the non-AP QoS STA, from application requirements supplied to the SME. (#403)The QoS traffic capability flags are constructed from two application requirements: whether generation of traffic is required for applications and whether a specific UP is required for the generated traffic. If such requirements are supplied to the SME, the SME shall set the flag corresponding to the specific UP to 1.

NOTE—The requirements might be known before the traffic is actually generated. For example, a phone application might configured to generate UP 6 traffic upon the initiation of a voice session.

Unless application requirements for a specific UP are supplied to the SME, the SME shall set the flag corresponding to the UP to 0.

If dot11QoSTrafficCapabilityActivated is true, a non-AP QoS STA shall include the QoS Traffic Capability element in an Association Request frame or in a Reassociation Request frame when it is sending such a frame to associate or reassociate with an AP. If there is any change in (#403)QoS traffic capability flags while associated with an AP, the non-AP STA shall send a QoS Traffic Capability Update frame (see 9.6.13.23 (QoS Traffic Capability Update frame format)) including the updated (#403)QoS traffic capability flags to the AP.

### 11.21.11 AC Station Count

Implementation of AC Station Count is optional for a WNM STA. A STA that implements AC (Ed)station count has dot11ACStationCountImplemented equal to true. When dot11ACStationCountImplemented is true, dot11WirelessManagementImplemented and dot11QoSTrafficCapabilityImplemented shall be true. When dot11ACStationCountActivated is true, the STA shall set the AC Station Count field to 1 in the Extended Capabilities element to indicate that the STA supports the AC station count capability. When dot11ACStationCountActivated is false, the STA shall set the AC Station Count field in the Extended Capabilities element to 0 to indicate that the STA does not support this capability.

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If dot11ACStationCountActivated is true, a QoS AP shall construct the (#403)QoS traffic capability bitmask and AC STA count list as specified in 9.4.2.76 (QoS Traffic Capability element). The AP shall construct the STA Count List value based on the UP-to-AC mappings as defined in Table 10-1 (UP-to-AC mappings(#68)), the (#403)QoS traffic capability bitmask/flags of the non-AP STAs that are currently associated with it, and additional information. If dot11ACStationCountActivated is true, a QoS AP shall include the QoS Traffic Capability element in a Probe Response frame and in a Beacon frame.

If dot11ACStationCountActivated is true, a non-AP QoS STA may use the STA Count field values as one of the factors when determining association, reassociation, and the BSS transition. If dot11ACStationCountActivated is false, a non-AP QoS STA shall not use the STA Count field values as one of the factors when determining association, reassociation, and the BSS transition.

### 11.21.12 TFS procedures

#### 11.21.12.1 TFS capability

Implementation of the TFS capability is optional for a WNM STA. A STA that implements TFS shall set dot11TFSImplemented to true. If dot11TFSImplemented value is true, then dot11WirelessManagementImplemented shall be true. A STA with dot11TFSActivated equal to true shall support TFS and shall set to 1 the TFS field in the Extended Capabilities elements that it transmits.

A STA in which dot11TFSActivated is true may send a TFS Request, TFS Response, TFS Notify frame, or TFS Notify Response frame to a STA within the same infrastructure BSS whose last received Extended Capabilities element contained a value of 1 for the TFS bit in the Extended Capabilities field. The traffic filtering service is not supported in an IBSS.

A traffic filtering agreement is established using a TFS Request frame transmitted from a non-AP STA to an AP and a TFS Response frame transmitted from the AP to the non-AP STA. At most one traffic filtering agreement can exist at any one time between a STA and its associated AP.

A traffic filtering agreement comprises one or more traffic filter sets, with a logical OR operation on the match conditions of each traffic filter set.

A traffic filter set contains one or more traffic filters, with a logical AND operation on the match conditions of each traffic filter, and also includes a traffic filter set action. The traffic filter set action defines the actions taken at the AP when a frame match occurs. A frame match occurs when a frame matches to the filtering parameters for a TFS traffic filter set.

NOTE—The frame match can occur when the matched frames are either individually addressed or group addressed.

A TFS Request frame contains one or more TFS Request elements. Each traffic filter set is conveyed by one TFS Request element, within a TFS Request frame.

One TFS Request element contains one or more TFS Request subelements. A TFS Request subelement might be a TFS subelement, in which case it contains the filtering parameters for one traffic filter.

A TFS subelement contains one or more TCLAS elements and an optional TCLAS Processing element that defines the relationship among multiple TCLAS elements within the TFS subelement. The TCLAS Processing element shall be present if more than one TCLAS element is included in the TFS subelement.

A TFS Response frame contains the status of the traffic filters requested in the corresponding TFS Request frame.


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An AP may propose alternative filtering parameters by returning a TFS subelement in the corresponding TFS Response subelement. (See 11.21.12.2 (TFS non-AP STA operation) and 11.21.12.3 (TFS AP operation)). When an AP proposes alternative filtering parameters it shall ensure that the TFS subelements related to the traffic filter set specified by a single TFS Request element all fit within a single TFS Response element.

When an AP transmits a TFS Response frame to a STA in which the Status for all traffic filter requests is "Accept", it shall enable TFS for the STA. The previously established filter parameters, if any, remain in effect when the AP transmits a TFS Response frame with any other Status.

When a traffic filter for group addressed frames is enabled at the AP, the group addressed frames are still delivered, without regard to the frames matching the traffic filter, since other associated STAs may also receive these frames. Because a STA using TFS can be in power save mode for an extended period of time, group addressed frames that match the traffic filter might be delivered before the STA is aware that the traffic filter has been matched. It is likely (but not guaranteed) that the STA does not receive those group addressed frames matching the traffic filter at the scheduled group addressed delivery time. To detect when this might have happened, the STA can request a notification frame be sent when requesting the establishment of the traffic filter. If negotiated with the AP, a frame match is indicated to the non-AP STA via a notification frame.

### 11.21.12.2 TFS non-AP STA operation

To use the TFS, the non-AP STA's SME that supports TFS shall issue an MLME-TFS.request primitive to send a TFS Request frame. The MLME-TFS.request primitive shall include a valid TFSRequest parameter as defined in the TFS Request elements.

The receipt of an MLME-TSF.confirm primitive with a valid TFSResponse parameter indicates to the STA's SME that the AP has processed the corresponding TFS request. The content of the TFSResponse parameter provides the status of each of the TFS Request elements processed by the AP. A TFSResponse parameter optionally contains modified filtering parameters for the corresponding TFS request.

A TFS Response frame in which the Status for all traffic filter requests is "Accept" indicates to the non-AP STA that the filtering operation at the AP has started. Otherwise, the STA might use the information in the TFS Response frame to form a new TFS request.

In order to request the AP to delete a traffic filter set (identified by a unique TFS ID) when a frame matches to the traffic filter set, a non-AP STA shall set the Delete After Match subfield of the TFS Action Code field of the TFS Request element in the TFS Request frame to 1.

In order to request a TFS Notify frame to be sent by the AP upon a frame match, a non-AP STA shall set the Notify subfield of the TFS Action Code field of the TFS Request element in the TFS Request frame to 1.

After receiving a TFS Notify frame, in order to request the AP to resume generation of the TFS Notify frame upon a future frame match, a non-AP STA shall transmit to the AP a TFS Notify Response frame containing one or more TFS IDs.

The non-AP STA may indicate that it is no longer using a particular TFS Request element by transmitting a TFS Request frame without that TFS Request element. The AP shall send a TFS Response frame with the corresponding Status field value set to Accept, upon receipt of the TFS Request frame.

The non-AP STA may choose to terminate use of the TFS service by sending a TFS Request frame with no TFS Request elements in the request thereby canceling all traffic filters at the AP.

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### 11.21.12.3 TFS AP operation

When an AP's SME receives an MLME-TFS.indication primitive with a valid TFSRequest parameter, it shall issue an MLME-TFS.response primitive with a TFSResponse parameter indicating the status of the associated request.

An AP establishes a traffic filtering agreement and starts the filtering operation defined by that traffic filtering agreement when it receives an MLME-TFS.response primitive in which the Status for all traffic filter requests is "Accept".

When the AP establishes a traffic filtering agreement for a requesting STA, the AP shall add to the traffic filtering agreement a traffic filter set that matches individually addressed EAPOL-Key frames addressed to the requesting STA, with bits 0 and 1 of the TFS Action Code field set to 0, without any status indication for this traffic filter set in the TFS Response frame.

When an AP's SME receives an MLME-TFS.indication primitive with a valid TFSRequest parameter having a requested TCLAS-based classifier which it is unable to provide, the SME shall issue an MLME-TFS.response primitive indicating the status of the corresponding request and may include a TFSResponse parameter having a suggested alternative TCLAS-based classifier.

When a traffic filtering agreement is established for a STA, the AP shall discard all individually addressed frames destined for the STA until a frame is found that matches one or more traffic filter sets within the traffic filtering agreement. When a frame is found that matches one or more of the traffic filter sets within the traffic filtering agreement (a matching frame), the AP shall perform the following actions:

— If the traffic filter set action specifies both Delete After Match and Notify, then the AP shall generate a single individually addressed TFS Notify frame for the frames matching to the traffic filter set identified by the corresponding TFS ID. Subsequently, the AP shall delete the traffic filtering agreement.

— If the traffic filter set action specifies Notify but not Delete After Match, then the AP shall generate a single individually address TFS Notify frame for all frames matching to the traffic filter set identified by the corresponding TFS ID. All traffic filter sets established at the AP for the non-AP STA remain to be effective upon a match. If the AP receives a TFS Notify Response frame from the corresponding non-AP STA, the AP resumes generation of a single individually addressed TFS Notify frame for the next frame matching to the traffic filter sets identified by the TFS IDs included in the TFS Notify Response frame. Otherwise, the AP shall not send additional TFS Notify frames upon frame matches.

NOTE—Due to the operation of group addressed frame delivery, a group addressed frame that matches a traffic filter might result in the STA receiving indication of the group addressed frame either before or after the group addressed frame is transmitted by the AP, if the TFS Notify frame is queued in the STA's power save queue. This might result in the STA receiving the group addressed frame in some cases and not receiving it in other cases.

Upon receiving an MLME-TFS.indication primitive, the AP's SME shall disregard any previous MLME-TFS.indication primitive received from the same STA.

The AP shall terminate any TFS operation for a STA when no traffic filters remain for a STA or if the AP's SME receives an MLME-TFS.indication primitive with a null TFSRequest.

### 11.21.13 BSS max idle period management

If dot11BssMaxIdlePeriod is nonzero, an AP shall include the BSS Max Idle Period element in the (Re)Association Response frame. Otherwise, an AP shall not include the BSS Max Idle Period element in the (Re)Association Response frame. A non-S1G STA may send protected or unprotected keepalive frames, as indicated in the Idle Options field.


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Extended (#442)BSS max idle period values are those that had a nonzero unified scaling factor (Table 9-78 (Unified Scaling Factor subfield encoding)) value signaled by an S1G STA. (#306)A non-AP S1G STA may include the BSS Max Idle Period element in transmitted (Re)Association Request frames to indicate a preferred (#442)BSS max idle period value. (#440)The S1G AP chooses a value for (#442)BSS max idle period based on the S1G STA's preferred (#442)BSS max idle period (if any) and the type of the S1G STA. The S1G AP indicates its chosen value to the S1G STA in the (Re)Association Response frame.

If dot11WirelessManagementImplemented is true, dot11BSSMaxIdlePeriod is nonzero and dot11BSSMaxIdlePeriodIndicationByNonAPSTA is true, then (#306)a non-AP non-S1G STA shall include a BSS Max Idle Period element in the (Re)Association Request frame. If the BSS Max Idle Period element is present in the (Re)Association Request frame received by a non-S1G AP that has dot11BSSMaxIdlePeriodIndicationByNonAPSTA equal to true, then the non-S1G AP may choose the non-AP STA's preferred maximum idle period. The non-S1G AP indicates its chosen value to the non-S1G STA in the (Re)Association Response frame.

The value chosen by the AP is the value that the AP will use in making disassociate decisions based on the timeout value equal to (#442)BSS max idle period for the non-AP STA that is the recipient of the (Re)Association Response frame. An AP may provide different values for (#442)BSS max idle period to different STAs.

A STA may send at least one protected or unprotected keepalive frame per (#442)BSS max idle period, as indicated in the Idle Options field. When a STA transmits an unprotected keepalive frame, it shall use a frame that has 48-bit TA and RA fields.

The Max Idle Period field of the BSS Max Idle Period element indicates the time period during which a STA can refrain from transmitting frames to its associated AP without being disassociated due to inactivity(#7006). A non-AP STA is considered inactive if the AP has not received a Data frame, PS-Poll frame, or Management frame (protected or unprotected as specified in this paragraph) of a frame exchange sequence initiated by the STA for a time period greater than or equal to the time specified by the Max Idle Period field. If the Idle Options field requires protected keepalive frames, then the AP may disassociate the STA if no protected frames are received from the STA for a duration of (#442)BSS max idle period. If the Idle Options field allows unprotected or protected keepalive frames, then the AP may disassociate the STA if no protected or unprotected frames with 48-bit TA and RA fields are received from the STA for a duration of (#442)BSS max idle period.

NOTE 1—The AP can disassociate or deauthenticate the STA at any time for other reasons even if the STA satisfies the keep-alive frame transmission requirements. An example of such other reason is group key rekeying. WNM sleep mode (see 11.2.3.15 (WNM sleep mode)) might be used to avoid disconnection due to not replying to group key handshake message 1.(#7006)

(#7007)NOTE 2—A non-AP STA might be in doze state during a group key handshake when the AP advertises a BSS max idld period. The Authenticator might allow such a STA to remain associated even if it missed a new group key. If beacon protection is enabled, such a STA might not have the current BIGTK available when waking up from doze state. This might result in discarding Beacon frames due to MME validation errors. A STA might wait for a new BIGTK to be received through a subsequent group key handshake before disconnecting from the BSS due to beacon loss in cases where it did not wake up to receive buffered frames during a long doze state.

### 11.21.14 Proxy ARP service

Implementation of the proxy ARP service is optional for a WNM STA. A STA that implements the proxy ARP service has dot11ProxyARPImplemented equal to true. When dot11ProxyARPImplemented is true, dot11WirelessManagementImplemented shall be true. When dot11ProxyARPActivated is true, the Proxy ARP Service bit in the Extended Capabilities field shall be set to 1 to indicate that the AP supports the proxy ARP service. When dot11ProxyARPActivated is false, the Proxy ARP Service bit shall be set to 0 to indicate that the AP does not support the proxy ARP service.

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(#1208)When the AP sets the Proxy ARP field to 1 in the Extended Capabilities element, the AP shall maintain a Hardware Address to Internet Address mapping for each associated STA and for each IPv4 and IPv6 address of the STA, and shall update the mapping when one of the addresses of the associated STA changes. A Proxy ARP service receives and processes three types of messages: IPv4 ARP requests, IPv6 ND address lookups, and IPv6 ND duplicate address detection (DAD) messages. These messages are all received as group addressed. If the target address is not known, the Proxy ARP service does not forward the request to the BSS. If the target address is known, the Proxy ARP service can either respond directly on behalf of a STA or forward the request as an (#6026)individually addressed frame to the intended STA. For fixed devices in doze state, a direct response is preferable. Otherwise, forwarding as (#6026)an individually addressed frame is recommended, to avoid responding with misleading information.

(#1208)For IPv4, when the address being resolved in the ARP request (IETF RFC 826) is used by a non-AP STA currently associated to the BSS, the proxy ARP service shall either respond on behalf of the STA to an ARP request or an ARP probe (IETF RFC 5227) or preferably turn the ARP request into an (#6026)individually addressed frame sent to that STA.

(#1208)When an AP receives an IPv4 ARP request from one associated STA or from the DS with a target IPv4 address that corresponds to a second associated STA, the AP that decides to form a proxy ARP response frame shall insert the second STA MAC address as the (#479)sender's MAC address in the ARP response.

(#1208)In contrast to IPv4, Stateless Address Autoconfiguration (SLAAC), which is part of IPv6 Neighbor Discovery (ND), enables a node to form multiple addresses, some of them temporary and with a particular attention paid to privacy. SLAAC addresses may be formed and deprecated asynchronously to the association. Even if the knowledge of IPv6 addresses used by a STA can be obtained by snooping protocols such as IPv6 ND and DHCPv6, or by observing data traffic sourced at the STA, such methods provide only an imperfect knowledge of the state of the STA at the AP, in particular when SLAAC is enabled. Running a Proxy ARP service on an incomplete set of addresses may result in a loss of connectivity, in particular for addresses rarely used and in situations of mobility.

(#1208)This nondeterministic representation of IPv6 address location and binding may also result in undesirable state persistence in the AP when a STA ceases to use an IPv6 address. It follows that protocol snooping is not a recommended technique and that snooping should only be used as last resort. IETF RFC 8505 defines an address registration mechanism that enables the AP to maintain a deterministic knowledge of all the IPv6 addresses of all the associated STAs. IETF RFC 8929 defines a proxy ND service that leverages the address registration to maintain an accurate proxy state that follows the movements of the STAs, while IETF RFC 8928 protects the address ownership against impersonation attacks and address spoofing.

(#1208)The proxy ARP function for IPv4 and IPv6 shall support snooping of DHCPv4, DHCPv6, and IPv6 ND to discover the IPv4 and IPv6 addresses owned by the STA.

(#1208)For IPv6, since the state obtained by snooping SLAAC is unreliable, the proxy ARP function shall support the backbone router function defined in IETF RFC 8929, which creates a binding state based on an IETF RFC 8505 registration by the STA. The proxy ARP function should support IETF RFC 8928 to protect the ownership of the addresses. The non-AP STA shall support the address registration mechanism defined in IETF RFC 8505 and should support the address protection mechanism defined in IETF RFC 8928.

(#1208)IPv6 ND uses IP layer multicast Internet Control Message Protocol version 6 (ICMPv6) Neighbor Solicitation (NS) messages (section 4.3 of IETF RFC 4861) for address resolution (section 7.2 of IETF RFC 4861), which is the equivalent of ARP request, and for duplicate address detection (DAD). The proxy ARP function shall discard those messages if the target IP address does not correspond to an associated STA.(#3683) NS messages are sent as IP layer unicast for neighbor unreachability detection (NUD) (section 7 of IETF RFC 4861). The proxy ARP function shall not operate on IP layer unicast NS messages.


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(#1208)With the IPv6 ND proxy operation defined in IETF RFC 8929, the backbone router function at the AP typically operates as a bridging proxy though operation as a routing proxy is also possible. As a bridging proxy, the NS lookups are replied with the MAC address of the STA, and the packets to the STA are bridged normally; as a routing proxy, the backbone router function replies to lookups from the wired backbone with its own MAC address and then routes to the STA at the IP layer. The routing proxy isolates the layer-2 domains and hides the MAC address of the STA in the wired backbone, for a better stability and scalability of the bridged domain. The Proxy ARP function shall support the bridging proxy and may support the routing proxy operation.

(#1208)When the target IPv6 address of a IP layer multicast NS message corresponds to an associated STA, the Proxy ARP service may respond on behalf of an associated low-power STA with a neighbor advertisement (NA) message (section 4.4 of IETF RFC 4861) with the override flag set to zero, to conserve energy. Preferably, though, the Proxy ARP service should transmit the IP layer multicast NS message as an (#6026)individually addressed frame to the STA and let the STA respond, as recommended in IETF RFC 8929. When MAC address mappings change, the AP may send unsolicited Neighbor Advertisement messages on behalf of a STA if the IPv6 Neighbor Discovery function at the STA failed to do so.

(#1208)The IPv6 ND function at the STA shall register all of the IPv6 addresses on the interface (see section 10 of IETF RFC 8929) to the proxy ARP service at the AP to ensure that the proxy ARP service is aware of all those addresses and will proxy for them. The proxy ND operation may support address mobility (section 6 of IETF RFC 8929) to transfer a role of ND proxy for this STA to the AP with which the STA is associated following a mobility event.

### 11.21.15 Channel usage procedures

The channel usage procedures may be used to

— assist the STA that operates a (#6071)channel-usage-aidable BSS(#3349) or an off-channel TDLS direct link to better coexist with a set of channel-usage-aiding BSSs by exchanging Channel Usage Request and Response frames with an AP of the channel-usage-aiding BSS set, or(#6071)(#3311)(#4009)(#7062)

— (#7062)for a STA to request a channel switch by sending a Channel Usage Request frame to the AP of a channel-usage-aidable BSS, or

— (#7062)for a STA to notify its associated AP of its capability by exchanging Channel Usage Request and Response frames with its associated AP.

Implementation of (#3311)channel usage is optional for a WNM STA. A STA that implements (#3311)channel usage has dot11ChannelUsageImplemented equal to true. When dot11ChannelUsageImplemented is true, dot11WirelessManagementImplemented shall be true, or the STA shall support(#546) acting as an S-AP within a CCSS. A STA with dot11ChannelUsageActivated equal to true shall support channel usage and shall set to 1 the Channel Usage field of the Extended Capabilities elements that it transmits.

(M163)(#8124)A Channel Entry field, in a Channel Usage element with Usage Mode field equal to 0 or 2 shall be interpreted as a recommendation for the indicated channel, and also for all narrower channels fully encompassed by the bandwidth of the indicated channel.

NOTE 1—For example, if such a Channel Usage element indicates global operating class 128 and channel 42 (80 MHz at 5 GHz) is a recommendation for that 80 MHz channel, and also for the two 40 MHz channels (36+40, 44+48) and the four 20 MHz channels (36, 40, 44, 48) within that 80 MHz channel.(M163)

(M163)The operating class(es) included in a Channel Usage element should be selected such that they are expected to be understood by the intended recipient(s) of the element. Operating Class And Channel fields in the Channel Entry field in a Channel Usage element that indicate channels that span a single contiguous bandwidth where the Channel Usage element is sent in a group addressed frame shall be interpreted as a

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recommendation for each of the identified channels and also for any channel that fully encompasses one or more of the identified channels and is within the contiguous bandwidth.

(#1024)(#3145)A TWT agreement that is established between a STA and its associated AP, by exchanging Channel Usage Request and Response frames, is referred to as (#3150)a peer-to-peer TWT agreement and the corresponding TWT schedules are referred to as (#3150) peer-to-peer TWT schedules. (#3145)In this case, the Channel Usage element carried in the Channel Usage Request and Response frames may:

— include a single Channel Entry field with Operating Class And Channel field(s)(#6181) that are different from the associated AP's BSS channel, or

— include a single Channel Entry field with Operating Class And Channel field(s)(#6181) that are the same as the associated AP's BSS channel, or

— include no Channel Entry field.

(#3148)Unless explicitly indicated in this subclause, the rules defined in 10.46 (Target wake time (TWT)) and in 26.8 (TWT operation) shall be ignored when establishing and operating with a peer-to-peer TWT agreement.

NOTE 2—The TWT element is used for a peer-to-peer TWT agreement only to determine the timing parameters of the peer-to-peer TWT schedule.

(#3150)An HE AP that has dot11ChannelUsageActivated equal to true and supports negotiating a peer-to-peer TWT schedule that is requested by a non-AP STA to establish a channel-usage-aidable BSS(#6071)(#3349) or an off-channel TDLS direct link shall set to 1 the (#3022)Peer-to-peer TWT Support field of the Extended Capabilities elements that it transmits.

(#1024)NOTE 3—An HE AP has dot11TWTOptionImplemented equal to true and has the TWT Responder Support subfield set to 1 in the Extended Capabilities element and the HE Capabilities element.

A non-AP STA that supports (#3311)channel usage and is not associated to an AP prior to using a channel-usage-aidable BSS(#6071)(#3349) or an off channel TDLS direct link may transmit a Probe Request frame including both Supported Operating Classes and Channel Usage elements. A non-AP STA supporting (#3311)channel usage may send a Channel Usage Request frame at any time after association to the AP that supports the use of (#3311)channel usage to request the (#3311)channel usage information for supported operating classes. (#1024)A non-AP STA that transmits a Channel Usage Request frame shall set the Usage Mode field of the Channel Usage element to 2 if it requests assistance to setup a channel-usage-aidable BSS(#6071)(#3349) on an off-channel that does not have any infrastructure BSSs operated by any AP that belongs to the ESS of its associated AP. Otherwise, the non-AP STA shall set the Usage Mode field of the Channel Usage element to (#4337)0, 1 or 3.(#3145)

(#1024)A non-AP STA that supports channel usage and has the TWT Requester Support subfield set to 1 (#3391)in the HE Capabilities element that it transmits, may negotiate (#3150)a peer-to-peer TWT schedule with its associated AP, (#3155)to indicate (#8077)the service period, and optionally the channel operation, of a channel-usage-aidable BSS(#6071)(#3349) or an off-channel TDLS direct link, by transmitting a Channel Usage Request frame that includes TWT Elements and Timeout Interval Element fields, if the AP has the (#3022)(#3150)Peer-to-peer TWT Support field set to 1 in the Extended Capabilities element. Each TWT element carried in the TWT Elements field includes a single Individual TWT Parameter Set field whose subfields shall be set as described in 26.8.2 (Individual TWT agreements) (#3155)and 9.4.2.198 (TWT element) except that the TWT Group Assignment subfield shall be set to zero and the Responder PM Mode subfield, the Trigger subfield, the Flow Type subfield, and the TWT Channel subfield shall be reserved. Each TWT element in the TWT Elements field applies to all the Channel Entry subfields of the Channel Usage Elements field. The non-AP STA may indicate the lifetime of the requested peer-to-peer TWT agreement in the Timeout Interval Value field of the TIE that it includes in the Channel Usage Request frame and shall set the Timeout Interval Type field to 5. (#3155)


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(#3148)A non-AP STA may send a Channel Usage Request frame to its associated AP with a TWT element configured as a TWT request. In this case, if the non-AP STA receives a Channel Usage Response frame from the AP that includes a TWT element configured as a TWT response with the TWT Setup Command field indicating Accept TWT, then the non-AP STA has successfully completed the peer-to-peer TWT agreement with the AP for the TWT flow identifier indicated in the TWT element that is carried in the Channel Usage Response frame. Otherwise, that peer-to-peer TWT agreement has not been established. The TWT flow identifier, together with the MAC addresses of the requesting STA and the responding AP, identifies the peer-to-peer TWT agreement.

(#8079)NOTE 4—The AP might choose a value for the TWT Flow Identifier field in a TWT element carried in the Channel Usage Response frame that is different from the value of the TWT Flow Identifier field in the received Channel Usage Request frame.

(#3145)(#6018)To indicate its unavailability, a non-AP STA may transmit a Channel Usage Request frame with the Usage Mode field of the Channel Usage element set to 3 and without a Channel Entry field to inform the AP about its unavailability during the peer-to-peer TWT agreement, also referred to as unavailability notification(#6018). Otherwise, the non-AP STA (#4337)shall set the Usage Mode field to 0, 1 or 2.

(#1024)A non-AP STA that has successfully set up (#3150)a peer-to-peer TWT schedule with its associated AP should use the negotiated (#3150)peer-to-peer TWT SPs for (#3349)(#4311)communication not via the AP.(#3052)

(#3157)A non-AP STA may teardown a peer-to-peer TWT agreement by sending a TWT Teardown frame with the Negotiation Type subfield set to 0 and the TWT Flow Identifier field set to the value of the corresponding TWT flow identifier.

(#8080)An AP shall not send a TWT Teardown frame to a non-AP STA to teardown any peer-to-peer TWT schedule between them.

(#8081)An AP shall not send a TWT Information frame to a non-AP STA to suspend or resume any peer-to-peer TWT schedule between them.

NOTE 5—(#8070)A peer-to-peer TWT agreement is a form of individual TWT agreement, and therefore, the total number of individual TWT agreements including peer-to-peer TWT agreements established between a non-AP STA and its associated AP cannot exceed 8, since the TWT Flow Identifier field of the TWT element comprises 3 bits.(#4010)

(#3157)A non-AP STA may suspend a peer-to-peer TWT agreement by sending a TWT Information frame with the TWT Flow Identifier field set to the value of the TWT Flow Identifier field of the TWT element in the Channel Usage Response frame that concluded the setup of the corresponding peer-to-peer TWT agreement if the AP has set the TWT Information Frame Disabled field to 0 in the TWT element sent during the TWT setup; otherwise, the non-AP STA shall not transmit a TWT Information frame to the AP. If the Next TWT subfield is present in the TWT Information frame, the value of the Next TWT subfield shall be selected from the future target wake times of the corresponding peer-to-peer TWT agreement.(#6196)

NOTE 6—If the Next TWT subfield is present in the TWT Information frame, the peer-to-peer TWT agreement will resume at the time indicated in the Next TWT subfield.(#3157)

Upon receipt of a Channel Usage element in the Probe Request frame, the AP supporting (#3311)channel usage shall send a Probe Response frame including one or more Channel Usage elements. Upon receiving a Channel Usage Request frame (#1024)with the Usage Mode field (#8071)in a Channel Usage element set to 0 or 1, the AP supporting channel usage shall send a Channel Usage Response frame including one or more Channel Usage elements. Channel Usage elements shall include channels that are valid for the regulatory domain in which the AP transmitting the element is operating and consistent with the Country element in the Beacon or Probe Response frame; the Channel Usage elements shall not include any other channels. (#1024)Upon receiving a Channel Usage Request frame with the Usage Mode field set to 2 in a Channel Usage

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element, an AP that supports channel usage shall send a Channel Usage Response frame with the Usage Mode field in the Channel Usage element set to 2 if the AP can determine that none of the APs belonging to the same ESS operate BSSs on the channels indicated by the Channel Entry field in the Channel Usage element of the response. Otherwise, the AP shall set the Usage Mode field of the Channel Usage element to (#4337)0, 1 or 3.(#3145)

NOTE 7—The determination of which APs belonging to the same ESS operate BSSs on a particular channel is implementation dependent and beyond the scope of this standard.(#1024)

(#1024)Upon receiving a Channel Usage Request frame with a TWT element, an AP that supports (#3150)peer-to-peer TWT scheduling shall send a Channel Usage Response frame including (#3145)zero or one Channel Usage element that includes a Channel Entry field with only one Operating Class And Channel field(#6181), a TWT Elements field and may include a Timeout Interval Element field. Each TWT element carried in the TWT Elements field includes a single Individual TWT Parameter Set field whose subfields shall be set as described in 26.8.2 (Individual TWT agreements) except that the TWT Group Assignment subfield shall be set to zero and the Responder PM Mode subfield, the Trigger subfield, the Flow Type subfield, and the TWT Channel subfield shall be reserved. (#3155)The TWT element(s) in the TWT Elements field apply to the Channel Entry subfield of the Channel Usage Elements field, if present. When the lifetime of the peer-to-peer TWT agreement expires, the AP shall send a TWT Teardown frame to terminate that peer-to-peer TWT agreement.

NOTE 8—If the Usage Mode field set to 3, it is possible that the Channel Usage Request frame does not include a Channel Entry field. In such case, the TWT element indicates the unavailability of the requesting non-AP STA for communication with the AP during the peer-to-peer TWT schedule.(#3145)

(#3148)The outcome of the TWT setup when negotiating a peer-to-peer TWT agreement initiated by the exchange of Channel Usage Request and Channel Usage Response frames that carry a TWT element as described in this clause is the same as that defined in Table 10-40 (TWT setup exchange command interpretation(11ax)).

(#3152)The AP shall not send an unsolicited Channel Usage Response frame with a TWT element to a non-AP STA.

(#1024)An AP that successfully sets up (#3150)a peer-to-peer TWT agreement (#3146)after receiving a Channel Usage Request frame with a TWT Elements field from a non-AP STA may indicate the lifetime of the (#3150)peer-to-peer TWT agreement for the corresponding TWT element(s) in the Timeout Interval Value field of the (#3146)TIE that it includes in the Channel Usage Response frame and shall set the corresponding Timeout Interval Type field to 5. An AP that successfully sets up (#3150)a peer-to-peer TWT agreement (#3156)shall consider the non-AP STA to be in power save mode and doze state at the start of the peer-to-peer TWT SP and back to its original power management mode (#8073)(i.e., the power management mode it had before entering the peer-to-peer TWT SP) at the end of the peer-to-peer TWT SP unless the AP receives a frame addressed to it from the non-AP STA within the time that overlaps with the peer-to-peer TWT SP(#8074), in which case, for the remaining portion of that peer-to-peer TWT SP, the AP shall consider the power management mode and power state of the non-AP STA based on the information carried in the frame received from the non-AP STA.

(#3145)Upon receiving a Channel Usage Request frame with a TWT element configured as a TWT request and a Channel Usage element with the Usage Mode field set to 3 (Unavailability indication(#6018)) that does not carry a Channel Entry field, an AP that supports peer-to-peer TWT scheduling shall transmit a Channel Usage Response frame that includes a Channel Usage element without a Channel Entry field and a TWT element configured as a TWT response (i.e., TWT Request field set to 0) with a TWT Setup Command field indicating Accept TWT and all other fields of that TWT element set to the same value as the fields of the TWT element carried in the Channel Usage Request frame. In this case, the Timeout Interval Value field of the TIE, if any, in the Channel Usage Response frame includes the same value as that of the Channel Usage Request frame.


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When the Channel Usage element in a received Probe Request or Channel Usage Request frame includes one or more Operating Class/Channel Pair fields, the Operating Class/Channel Pair field(s) indicate(s) the requested non-AP STA operating class/channels for the usage mode indicated in the frame. (#4006)If the Usage Mode field in the Channel Usage element carries a value that is unknown to the AP, the AP should send in the Probe Response or Channel Usage Response frame a Channel Usage element without a Channel Entry field and with a Usage Mode field value indicating Unknown request, to inform the client that the AP does not support the usage mode indicated in the request. Usage mode Unknown request shall not be used in a Probe Request frame, in a Channel Usage Request frame, or in a Channel Usage Response frame that is sent in response to a Channel Usage Request frame that includes a Channel Usage element with usage modes 0 to 3.

The AP may send an unsolicited group addressed or individually addressed Channel Usage Response frame to the STAs that have requested (#3311)channel usage information if the corresponding (#3311)channel usage information needs to be updated. The Country element shall be included in the unsolicited and/or group addressed Channel Usage Response frame. The AP may include the Power Constraint information and EDCA Parameter in the Channel Usage Response frame. The values of the fields in the Power Constraint and EDCA Parameter Set elements included in the Channel Usage Response frame shall be the same values of the fields in the Power Constraint and EDCA Parameter Set elements that are transmitted by the AP. If a Transmit Power Envelope element is included in the Channel Usage Response frame, the AP sets the Maximum Transmit Power Interpretation field to a value indicating a local power constraint (i.e., 0 or 1) and chooses a single set of values for the Maximum Transmit Power fields for the channel(s) specified in the Channel Usage elements.(#7001)

Upon receipt of a Channel Usage element (#7064)with the Channel Usage field set to 0, 1, or 2 (see Table 9-268 (Usage Mode definitions)) in the Probe Response or Channel Usage Response frame, the receiving STA may use the following:

- The channel usage information as part of channel selection processing
  - (#6075)when starting a (#3349)channel-usage-aidable BSS(#6071) or an off-channel TDLS direct link, or
  - (#6075)when switching the channel of an existing channel-usage-aidable BSS(#6071) or off-channel TDLS direct link
- The Power Constraint element or the Transmit Power Envelope element(#7001), if present, as part of determining its maximum transmit power for transmissions for the (#3349)channel-usage-aidable BSS(#6071) or an off-channel TDLS direct link
- The EDCA Parameter Set element, if present, as part of determining its EDCA parameters for transmissions for the channel-usage-aidable BSS(#3349)(#6071) or an off-channel TDLS direct link
- The QMF Policy element, if present and dot11QMFActivated is true, as part of determining its classification of Management frames for transmissions for the channel-usage-aidable BSS(#6071)(#3349) or an off-channel TDLS direct link

(#4028)A non-AP STA that is operating in a channel-usage-aidable BSS(#6071) may send a Channel Usage Request frame with a Channel Usage element that carries a Usage Mode field with a value equal to 4 to a peer STA to indicate that it prefers to switch the operating channel of the channel-usage-aidable BSS(#6071) to another channel. A non-AP STA may indicate the preferred operating channels by including one or more Operating Class And Channel fields(#6181) in the Channel Entry field of the Channel Usage element carried in the corresponding Channel Usage Request frame. To provide the parameters in the HT Capabilities element, VHT Capabilities element, HE Capabilities element and/or HE 6 GHz Band Capabilities element for the preferred operating channel, the non-AP STA shall include the corresponding capabilities element(s) in the Channel Usage Request frame; otherwise, capabilities element(s) shall not be included. When the Usage Mode field indicates Channel-usage-aidable BSS(#6071) channel switch request and any capabilities elements are included in the Channel Usage Request frame, the Channel Entry field shall include an Operating Class And Channel field that indicates the operating class and channel that the capability notification applies to.(#6016)

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(#4028)Upon receiving a Channel Usage Request frame with a Channel Usage element that carries a Usage Mode field with a value equal to 4, a STA that supports channel-usage-aidable BSS(#6071) channel switch requests and is operating in a channel-usage-aidable BSS(#6071) should consider switching the operating channel of the channel-usage-aidable BSS(#6071) to a new channel that is one of the preferred channels indicated in the received Channel Entry field of the Channel Usage element, if present. The STA shall transmit a Channel Usage Response frame in response to the reception of a Channel Usage Request frame with the Usage Mode field equal to 4 that includes a Channel Usage element with the Usage Mode field set to 4. If the channel switch request is accepted, the STA shall include the target operating class and channel in the Channel Entry field of the Channel Usage element in the Channel Usage Response frame. Otherwise, no Channel Entry field shall be included.(#6016)

(#6016)A STA for which dot11ChannelUsageCapabilityNotificationImplemented is true shall set the Capability Notification Support field to 1 in the Extended Capabilities elements that it transmits. A STA for which dot11ChannelUsageCapabilityNotificationImplemented is not true shall set the Capability Notification Support field to 0 in the Extended Capabilities elements that it transmits.

(#6016)If an AP has the Capability Notification Support field set to 1 in the Extended Capabilities element, an associated non-AP STA for which dot11ChannelUsageCapabilityNotificationImplemented is true may send a Channel Usage Request frame with the Usage Mode field indicating Capability notification in the Channel Usage element to the AP after the non-AP STA receives an Extended Channel Switch Announcement element or an Extended Channel Switch Announcement frame from the AP. When the Usage Mode field indicates Capability notification, the Channel Entry field shall include an Operating Class And Channel field that indicates the operating class and channel that the capability notification applies to.

(#6016)If an AP has the Capability Notification Support field set to 1 in the Extended Capabilities element, an associated non-AP STA for which dot11ChannelUsageCapabilityNotificationImplemented is true shall send a Channel Usage Request frame with the Usage Mode field indicating Capability notification in the Channel Usage element to the AP after the non-AP STA has received an Extended Channel Switch Announcement element or an Extended Channel Switch Announcement frame from the AP if the HT, VHT and/or HE capabilities of the STA are different before and after the channel switch except for the following cases:

— The STA is a STA 5G before the channel switch and a STA 6G after the channel switch, and the only difference in the capabilities before and after the channel switch is that HT and VHT are not supported after the channel switch.

— The STA is a non-HE STA that is a STA 5G before the channel switch and a STA 2G4 after the channel switch, and the only difference in the capabilities before and after the channel switch is that VHT is not supported after the channel switch.

(#6016)When an associated non-AP STA chooses to send a Channel Usage Request frame with the Usage Mode field indicating Capability notification in the Channel Usage element to the AP, the STA shall wait a random delay uniformly distributed in the range between 0 and 5000 μs, and then transmit the Channel Usage Request frame once any applicable conditions for transmitting are met (e.g., channel access procedures, DFS or enablement procedures). The Channel Usage Request frame shall be sent no later than 5 beacon periods after the expected time of the first Beacon frame in the new channel.

NOTE 9—The Channel Usage Request frame indicating Capability notification might be transmitted before or after a channel switch. In either case, the Operating Class And Channel field unambiguously identifies the channel for which the notification applies.(#6016)

NOTE 10—For example, if an AP included the Max Channel Switch Time element in the frame containing the Extended Channel Switch Announcement element, then the non-AP STA cannot send a Channel Usage Request frame with the Usage Mode field indicating Capability notification to the AP if the time elapsed since the last Beacon frame in the channel prior to the channel switch is greater than $T_{MCST} + 5 \times T_{BP}$, where $T_{MCST}$ is the switch time indicated in the Switch Time field in the Max Channel Switch Time element and $T_{BP}$ is the beacon period.(#6016)


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NOTE 11—An AP knows if there are associated non-AP STAs for which dot11ChannelUsageCapabilityNotificationImplemented is false from the Capability Notification Support field in the Extended Capabilities elements transmitted by the associated non-AP STAs. How the AP determines the capabilities of the non-AP STAs for which dot11ChannelUsageCapabilityNotificationImplemented is false after a channel switch is implementation specific. For example, an AP might choose not to perform a channel switch to a different band if there are many associated non-AP STAs for which the Capability Notification Support field is 0 in the Extended Capabilities elements.(#6016)

(#6016)A non-AP STA that is associated to an AP shall not send a Channel Usage Request frame with the Usage Mode field indicating Capability notification in the Channel Usage element to the AP if any of the following conditions are true:

— The non-AP STA has dot11ChannelUsageCapabilityNotificationImplemented equal to false.
— The Capability Notification Support field is equal to 0 in the Extended Capabilities element transmitted by the AP.
— The non-AP STA has received neither an Extended Channel Switch Announcement element nor an Extended Channel Switch Announcement frame from the AP.

NOTE 12—If the STA has not transmitted the Channel Usage Request frame with the Usage Mode field indicating Capability notification in the Channel Usage element within a reasonable time, the AP might ignore the frame or disassociate the STA.(#6016)

(#6016)If a non-AP STA sends a Channel Usage Request frame with the Usage Mode field indicating Capability notification in the Channel Usage element because of channel switch from channel A to channel B, then:

— The STA shall include the HT Capabilities element if the STA supports HT in channel B even if the HT capabilities have not changed between the channels A and B.
— The STA shall include the VHT Capabilities element if the STA supports VHT in channel B even if the VHT capabilities have not changed between channels A and B.
— If channel B is in the 2.4 or 5 GHz band, the STA shall include the HE Capabilities element if the STA supports HE in the channel B even if the HE capabilities have not changed between channels A and B.
— If channel B is in the 6 GHz band, the STA shall include the HE Capabilities element and the HE 6 GHz Band Capabilities element if the STA supports HE in channel B even if the HE capabilities have not changed between the channels A and B.

If a non-AP STA transmits a Channel Usage Request frame with the Usage Mode field indicating Capability notification in the Channel Usage element during channel switch from channel A to channel B, then:

— The STA is indicating that it does not support HT in the channel B if the Channel Usage Request frame does not include the HT Capabilities element.
— The STA is indicating that it does not support VHT in the channel B if the Channel Usage Request frame does not include the VHT Capabilities element.
— The STA is indicating that it does not support HE in the channel B if the Channel Usage Request frame does not include the HE Capabilities element.

NOTE 13—Consider the case, for example, an HE non-AP STA that is a STA 6G receives from its associated AP an Extended Channel Switch Announcement element indicating a channel switch to the 2.4 GHz band. The non-AP STA sends a Channel Usage Request frame with the Usage Mode field indicating Capability notification in the Channel Usage element including only the HT Capabilities element. This means that the non-AP STA is a non-HE HT STA after the channel switch.(#6016)

(#6016)When the Channel Usage element is carried in a Probe Request or Probe Response frame, the Usage Mode field shall not indicate channel-usage-aidable BSS(#6071) channel switch request or Capability notification.

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If either a recommended operating class, or a recommended channel, or both are not supported or understood by the recipient, or if the operating country of the sender is unknown, the recipient shall discard the corresponding channel usage recommendation. A STA that has not requested (#3311)channel usage information shall discard an unsolicited group addressed Channel Usage Response frame.

### 11.21.16 Group addressed transmission service

#### 11.21.16.1 General

The group addressed transmission service provides delivery of group addressed frames and comprises the two services, DMS and GCR. DMG STAs do not use GCR.

#### 11.21.16.2 DMS procedures

In this subclause, the following terms are used:

— *DMS provider*: An AP, PCP, or DMG STA associated with a PCP that provides DMS.

— *DMS recipient*: A non-AP STA that uses DMS.

In an infrastructure BSS, directed multicast service (DMS) is a service that may be provided by an AP to associated STAs that support DMS, where the AP transmits group addressed MSDUs as (#2004)A-MSDUs in individually addressed MPDUs.

In a PBSS, DMS is a service that may be provided by any STA to other STAs in the same PBSS that support DMS, where the STA transmits group addressed MSDUs as (#2004)A-MSDUs in individually addressed MPDUs. If the PCP of the PBSS has the PCP Forwarding field within the PCP's DMG Capabilities element set to 0, a non-PCP STA in the PBSS shall not use the PCP as a DMS provider in the PBSS.

Implementation of DMS is optional for a WNM STA and mandatory for a robust AV streaming STA (as defined in 11.25.1 (Robust AV streaming dependencies)). A STA that implements DMS has dot11DMSImplemented equal to true. When dot11DMSImplemented is true,

— At least one of dot11WirelessManagementImplemented and dot11RobustAVStreamingImplemented shall be true.

— dot11HighThroughputOptionImplemented shall be true for a non-DMG STA that is not a DMG or an S1G STA.

A STA with dot11DMSActivated equal to true shall support the directed multicast service and shall set to 1 the DMS field of the Extended Capabilities element that it transmits.

A DMS recipient may request use of DMS of one or more flows by sending a DMS Request frame or Reassociation Request frame that includes a DMS Request element containing one or more DMS Descriptors with the Request Type field set to "Add" per flow. Each DMS Descriptor field in the DMS Request element identifies group addressed frames that shall be transmitted to the requesting DMS recipient as individually addressed frames in addition to the group address frame transmission. In the TCLAS element, the Classifier Type subfield shall be set to the value 0, 1, or 4, and the Destination Address or Destination IP Address subfield shall be set to the multicast address of the flow that the STA requests to receive as individually addressed frames. In the TSPEC element, the STA may define the characteristics and QoS expectations of the corresponding traffic flow.

Upon receipt of a DMS Request frame or Reassociation Request frame from a DMS recipient, a DMS provider shall respond with a corresponding DMS Response frame or Reassociation Response frame. The response frame shall contain a matching (i.e., as the same DMSID) DMS Status field for each received DMS Descriptor field preserving the order present in the request frame.


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NOTE 1—There is no requirement that the number of DMS Request elements and the number of DMS Response elements match. There is no requirement that the number of DMS Descriptor fields within any DMS Request element matches the number of DMS Status fields within any DMS Response element.

If a DMS provider accepts a DMS request identified by a DMS Descriptor, the Response Type field of the corresponding DMS Status field in the DMS Response element shall be set to "Accept" and a nonzero DMSID shall be assigned. If a DMS provider denies a DMS request identified by a DMS Descriptor, the Response Type field of the corresponding DMS Status field in the DMS Response element shall be set to "Denied" and the DMSID shall be set to 0. If the Response Type field is(M118) "Accept" or "Denied," then the TCLAS Elements, TCLAS Processing Element, TSPEC Element and Optional Subelements fields of a DMS Status field in a DMS Response element shall be copied from the respective TCLAS Elements, TCLAS Processing Element, TSPEC Element and Optional Subelements fields of the corresponding DMS request. When one or more STAs send a DMS request to a DMS provider, containing a DMS descriptor with a set of TCLAS element and TCLAS Processing elements that are identical irrespective of ordering to another received DMS request that is not yet terminated, the DMS provider shall assign the same DMSID as was assigned to the previous DMS request.

If a DMS provider denies the DMS Request, it may suggest an alternative TCLAS-based classifier by including one or more TCLAS elements and an optional TCLAS Processing element. The DMS provider may include fewer TCLAS elements in the DMS Response element than were present in the request; when the DMS provider's response includes a single TCLAS element, it shall not include a TCLAS Processing element. If the DMS provider changes a TCLAS element's Classifier Type field in the DMS Response element but is unable to suggest a value for the Classifier Mask field, it shall set that field to 0. If the DMS provider changes a TCLAS element's Classifier Type field or Classifier Mask field in the DMS Response element but is unable to suggest values for one or more Classifier Parameter subfields, it shall set those subfields to 0.

A DMS recipient receiving a DMS Response frame containing a modified TCLAS element having a Classifier Mask field equal to 0 or having one or more Classifier Parameter subfields equal to 0 shall interpret the values of 0 to mean that no suggested value has been provided by the DMS provider.

If the requested DMS is accepted by the DMS provider, the DMS provider shall send subsequent group addressed MSDUs that match the frame classifier specified in the DMS Descriptors to the DMS recipient as A-MSDU subframes within an individually addressed MPDU that contains an A-MSDU(#1996) (see 9.3.2.2 (Aggregate MSDU (A-MSDU) format) and 10.11 (A-MSDU operation)). The A-MSDU shall be formatted as specified in 9.3.2.2 (Aggregate MSDU (A-MSDU) format) which includes the A-MSDU subframe headers' DA set to the multicast address for the corresponding MSDUs. The DMS provider shall continue to transmit the matching frames as group addressed frames (see 10.3.6 (Group addressed MPDU transfer procedure), and 11.2.3.13 (FMS power management)) if at least one associated STA has not requested DMS for these frames.

A DMS recipient may request modification of the traffic characteristics or attributes of one or more accepted DMS traffic flows by sending a DMS Request frame or Reassociation Request frame that includes a DMS Request element that contains one or more DMS Descriptors each with the Request Type field set to "Change" and the DMSID field set to the DMSID of the accepted DMS traffic flows to be modified. The values of at least one of the TSPEC Element and Optional Subelement fields shall be different from those of the accepted DMS traffic flow.

If a DMS provider accepts a DMS change request identified by a DMS Descriptor, the Response Type field of the corresponding DMS Status field in the DMS Response element shall be set to "Accept" and the DMSID field shall be set to the DMSID carried in the DMS Descriptor. If a DMS provider denies a DMS change request identified by a DMS Descriptor, the Response Type field of the corresponding DMS Status field in the DMS Response element shall be set to "Denied" and the DMSID field shall be set to the DMSID carried in the DMS Descriptor. If a DMS provider denies a DMS change request identified by a DMS Descriptor, the existing DMS traffic flow of the corresponding DMSID shall remain unchanged.

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A DMS recipient may request removal of one or more accepted DMS traffic flows by sending a DMS Request frame or Reassociation Request frame that includes a DMS Request element containing one or more DMS Descriptors each with the Request Type field set to "Remove" and the DMSID field set to the DMSID of the accepted DMS traffic flow to be removed. The DMS Length field shall be set to 1. The TCLAS Elements, TCLAS Processing Element TSPEC Element and Optional Subelements fields shall not be included.

A DMS provider shall terminate one or more accepted DMS traffic flows upon receipt of a DMS Request frame or Reassociation Request frame that includes a DMS Request element containing one or more DMS Descriptors each with the Request Type field equal to "Remove" and the DMSID field set to the DMSID of an accepted DMS traffic flow. The DMS provider shall respond to the termination request by sending a DMS Response frame containing one or more DMS Status fields each including the corresponding DMSID and a value of "Terminate" in the Response Type field. The DMS Length field shall be set to 3. The TCLAS Elements, TCLAS Processing Element, TSPEC Element and Optional Subelement fields shall not be included.

A DMS provider may send an unsolicited DMS Response frame at any time to terminate an accepted DMS traffic flow by including the DMSID and a value of "Terminate" in the Response Type field in the DMS Status field in a DMS Response element. A DMS provider may reject a new DMS traffic flow or terminate a granted DMS traffic flow at any time based on network condition, for example the number of associated STAs and channel load.

A DMS recipient shall keep a list of group addresses for which it has requested DMS and that have been accepted by a DMS provider and shall discard group addressed frames that match a group address in this list until the DMS has been terminated. When the DMS is terminated, and if the sequence number value is provided in the Last Sequence Control field in the DMS Response frame, using the value of the Last Sequence Control field, the DMS recipient shall discard the group addressed frames that are the duplicates of the individually addressed frames.

NOTE 2—When the Last Sequence Control field in the DMS Response frame is not supported at a DMS provider (i.e., the sequence number value is not provided in the field), and a group addressed MSDU has been sent using both individually addressed and group addressed frame transmission, termination of the DMS stream by the DMS provider might result in a DMS recipient receiving undetectable duplicate MSDUs that are not filtered out by the MAC.(#374)

If the length of the DMS Descriptors exceeds 255 octets, then multiple DMS Request elements shall be included, each containing only those DMS Descriptors that are completely contained within 255 octets. If the length of the DMS status fields exceeds 255 octets, then multiple DMS Response elements shall be included, each containing only those DMS Status fields that are completely contained within the first 255 octets.

If a DMS recipient supports both DMS and FMS, it shall not request both services for the same group addressed frames simultaneously, but may request them for different group addressed frames simultaneously.

If a DMS provider supports both DMS and TFS, it shall first apply TFS to the frame and then apply DMS.

### 11.21.16.3 GCR procedures

#### 11.21.16.3.1 Overview

Groupcast with retries (GCR) is a flexible service to improve the delivery of group addressed frames while optimizing for a range of criteria. GCR service may be provided by the AP to associated STAs in an infrastructure BSS or by a mesh STA to its peer mesh STAs in a mesh BSS. GCR uses the setup, modification, and termination procedures defined 11.21.16.2 (DMS procedures). The differences between GCR procedures and DMS procedures are as follows:

a) A GCR agreement applies to a single group address and, if a TCLAS Processing element is present, it has the (#2180)Processing field value set to 0, whereas a DMS flow is not restricted to a single group address.


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b) DMS offers group-to-individually addressed conversion only, whereas GCR includes several retransmission policies and delivery methods.

A non-DMG STA with dot11RobustAVStreamingImplemented true shall implement the GCR procedures defined in 11.21.16.3.2 (GCR group membership procedures) to 11.21.16.3.6 (GCR unsolicited retry). When dot11RobustAVStreamingImplemented is true, dot11DMSImplemented and dot11HighThroughputOptionImplemented shall be true. A STA that implements advanced GCR supports GCR block ack (11.21.16.3.7 (GCR block ack)) and GCR-SP (11.21.16.3.8 (GCR-SP)) and has dot11AdvancedGCRImplemented equal to true. When dot11AdvancedGCRImplemented is true, dot11RobustAVStreamingImplemented shall be true. In a mesh BSS, a STA that implements GCR has dot11MeshGCRImplemented equal to true. When dot11MeshGCRImplemented is true, dot11HighThroughputOptionImplemented shall be true.

DMS allows the transmission of group addressed MSDUs as A-MSDUs in individually addressed MPDUs and is particularly suited to small numbers of group members. It provides a high level of reliability but has low scalability as the efficiency decreases and delay increases proportionally to the number of group members.

GCR employs the DMS Request and DMS Response elements with the addition of GCR Request and Response subelements, respectively, for administering the announcement, setup, modification, and teardown of GCR services between an AP and non-AP STAs or between peer mesh STAs. The DMS procedures and state machine of 11.21.16.2 (DMS procedures) shall apply to GCR with the extensions and constraints specific to GCR described below in 11.21.16.3.3 (GCR setup procedures) to 11.21.16.3.8 (GCR-SP).

Along with the No-Ack/No-Retry or non-GCR (defined in 10.3.6 (Group addressed MPDU transfer procedure)) and the DMS (defined in 11.21.16.2 (DMS procedures)) retransmission mechanisms, GCR defines two additional retransmission policies for group addressed frames:

— GCR unsolicited retry
— GCR block ack

When using the GCR unsolicited retry retransmission policy for a group address, the STA providing GCR service retransmits an MSDU one or more times (subject to applicable retry or lifetime limits) to increase the probability of correct reception at STAs that are listening to this group address. The decision to retransmit these MSDUs is implementation dependent. GCR unsolicited retry is particularly suited to use with large numbers of group members as it has moderate delay, efficiency, and reliability, but high scalability.

The GCR block ack retransmission policy extends the block acknowledgment mechanism to group addressed frames. The STA providing the GCR service initiates block ack agreements with each STA receiving GCR frames that supports GCR block ack for a particular group address. Once this block ack agreement is in place, the STA providing GCR service regularly sends BlockAckReq frames to the STAs receiving the frames to ascertain the reception status of MSDUs related to this group address, as described in 10.25.8 (GCR and GLK-GCR block ack). This allows the STA providing GCR service to discover MSDUs that have not been received and to schedule their retransmission. GCR block ack is particularly suited to use with moderate numbers of group members as it has moderate delay, high efficiency, and moderate scalability and reliability.

The GCR service has two delivery methods for group addressed frames:

— Non-GCR-SP
— GCR-SP (see 11.21.16.3.8 (GCR-SP))

The non-GCR-SP delivery method may be provided using one or more of the following:

— FMS (see 11.2.3.13 (FMS power management))
— Transmit frames in a GCR stream after the DTIM beacon(#3309) if any STA in the GCR group is in PS mode

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- Transmit frames at any time if all STAs in the GCR group are in active mode in an infrastructure BSS
- In accordance with 14.15 (Power save in a mesh BSS) in a mesh BSS

GCR-SP transmits GCR group addressed frames at intervals, where the interval between transmissions might be smaller than the beacon interval. Compared to non-GCR-SP, GCR-SP might provide lower delay and jitter.

GLK-GCR is a variant of GCR where the setup is implicit and is accomplished using a (Re)Association Request and Response frame exchange between the peers and termination is implicit and is accomplished when the corresponding general link is torn down. Modification is explicit and is accomplished using a GLK Groupcast Mode Change Notification frame.

GLK-GCR defines two retransmission policies for group addressed frames:

- GLK-GCR unsolicited retry
- GLK-GCR block ack

When a GLK STA implements the GLK-GCR procedures defined in 11.21.16.4.2 (GLK-GCR operation) or 11.21.16.4.3 (GLK-GCR unsolicited retry), it shall set dot11GLKGCRImplemented to true; otherwise dot11GLKGCRImplemented shall be set to false. When dot11GLKGCRImplemented is true the GLK-GCR subfield(#291) shall be set to 1 in the Extended Capabilities element, to indicate support for GLK-GCR, otherwise the field shall be set to 0.

See 10.25.8 (GCR and GLK-GCR block ack) for the mechanisms by which GCR block ack operates.

### 11.21.16.3.2 GCR group membership procedures

The GCR group membership procedures do not apply to GLK-GCR. GLK-GCR uses SYNRAs.

The procedures described in 11.21.16.3.3 (GCR setup procedures) to 11.21.16.3.8 (GCR-SP) depend upon the AP or mesh STA knowing the membership of the multicast groups of STAs that support GCR.

One method for an AP to discover the multicast groups that its associated STAs are receiving or for a mesh STA to discover the multicast groups that its peer mesh STAs are receiving is to use the Group Membership Request frame (as defined in 9.6.18.4 (Group Membership Request frame format)) to request the contents of the dot11GroupAddressesTable of its associated STAs or peer mesh STAs.

Other methods of group membership detection are also possible, using information that is outside the scope of this standard. For example, group membership detection could be achieved by inspecting the protocol messages of IETF RFC 3376 [B37].

An AP may transmit a Group Membership Request frame as an individually addressed frame to an associated STA that has indicated that it supports robust AV streaming (as indicated by the Robust AV Streaming bit equal to 1 in the Extended Capabilities element) to request the associated STA's dot11GroupAddressesTable. An AP shall not send a Group Membership Request frame to an associated STA that has the Robust AV Streaming bit equal to 0 in its Extended Capabilities element.

A STA for which dot11GCRActivated or dot11MeshGCRActivated is true shall reply to a Group Membership Request frame by sending a Group Membership Response frame with the Dialog Token field set to the value from the Group Membership Request frame, the Address Count field set to the number of entries in the dot11GroupAddressesTable, and the Group Address List field set to the (#1653)group addresses in the dot11GroupAddressesTable. A STA for which dot11GCRActivated or dot11MeshGCRActivated is true shall set dot11GCRGroupMembershipAnnouncementActivated to true upon reception of a Group Membership Request frame.


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A STA for which dot11GCRGroupMembershipAnnouncementActivated and at least one of dot11MeshGCRActivated and dot11GCRActivated are true shall send an unsolicited Group Membership Response frame with the Dialog Token field set to 0, the Address Count field set to the number of entries in the dot11GroupAddressesTable, and the Group Address List field set to (#1653)the group addresses in the dot11GroupAddressesTable, every time the contents of the dot11GroupAddressesTable is modified.

If an unsolicited Group Membership Response frame is sent by an associated STA, the frame shall be transmitted as an individually addressed frame to the AP with which it is associated. If an unsolicited Group Membership Response frame is sent by a mesh station in a mesh BSS, the frame shall be transmitted as a broadcast frame.

#### 11.21.16.3.3 GCR setup procedures

The following setup procedures apply only if the underlying link is a non-general link.

An AP with dot11GCRActivated true may transmit to an associated non-AP STA an unsolicited individually addressed DMS Response frame that contains one DMS Status field with a GCR Response subelement per group address, if it detects that the associated non-AP STA meets all of the following conditions:

— Robust AV Streaming was equal to 1 in the Extended Capabilities element in the most recently received (Re)Association Request frame from the non-AP STA.
— The non-AP STA is receiving one or more group addresses for which there is an active GCR service.
— The non-AP STA does not have a GCR agreement for one or more of these group addresses.

A mesh STA with dot11MeshGCRActivated true may transmit to a peer mesh STA an unsolicited individually addressed DMS Response frame that contains one DMS Status field with a GCR Response subelement per group address, if it detects that the peer mesh STA meets all of the following conditions:

— Mesh GCR was equal to 1 in the Extended Capabilities element in the most recently received (#454)beacon from the peer mesh STA.
— The peer mesh STA is receiving one or more group addresses for which there is an active GCR service.
— The peer mesh STA does not have a GCR agreement for one or more of these group addresses.

Each DMS Status field includes a TCLAS element to identify the GCR group address, the DMSID corresponding to this GCR traffic flow, and other associated parameters. The Status subfield of this DMS Status field shall be set to "GCR Advertise." A STA that receives this DMS Response frame from its AP may initiate a GCR agreement for one or more of the group addresses contained in the frame.

A STA requests use of the GCR service for a group address by sending a DMS Descriptor (as described in 11.21.16.2 (DMS procedures)) with the following modifications:

— The DMS Descriptor shall contain one TCLAS element with the frame classifier type equal to 0 (Ethernet parameters), one TSPEC element, and one GCR Request subelement.
— In addition, the DMS Descriptor may contain other TCLAS elements.
— When there are multiple TCLAS elements, a TCLAS Processing element shall be present, and the (#2180)Processing field in the TCLAS Processing element shall be set to 0. Otherwise, no TCLAS Processing elements shall be present in the DMS Descriptor.
— The TSID subfield within the TS Info field of the TSPEC element shall be reserved. Since the AP might choose a delivery method of GCR-SP, the non-AP STA should set the Minimum Service Interval, Maximum Service Interval, and Service Start Time fields in the TSPEC element to indicate the STA's preferred wakeup schedule. In a mesh BSS, the Delivery Method field shall not be set to "GCR-SP."

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— The GCR Request subelement specifies the retransmission policy and delivery method requested by the non-AP STA for the group addressed stream.

A STA shall not request transmission of a group address via the GCR service while it has an active DMS for this group address. A STA shall not request transmission of a group address via DMS while it has an active GCR service for this group address.

An AP or mesh STA accepts a GCR request by sending a DMS Response frame with a DMS Response element that contains a DMS Status field with the Response Type field set to "Accept" (as described in 11.21.16.2 (DMS procedures)) with the following modifications:

— The DMS Status field shall include a GCR Response subelement indicating the retransmission policy, delivery method, and GCR concealment address for the group addressed stream. The Retransmission Policy field shall not be set to "No Preference." The Delivery Method field shall not be set to "No Preference." The GCR Concealment Address field of the GCR Response subelement shall be set to dot11GCRConcealmentAddress. In a mesh BSS, the Delivery Method field shall not be set to "GCR-SP."

— If the GCR group addressed stream is subject to the GCR-SP delivery method, then the AP shall also include a Schedule element in the DMS Status field indicating the wakeup schedule for the group addressed stream.

— If a TSPEC element is included, the TSID subfield shall be set to 0.

For each GCR Request subelement, the AP or mesh STA may

— Adopt the requested retransmission policy and delivery method, or

— Maintain its existing retransmission policy and delivery method, or

— Select an alternate retransmission policy and delivery method, or

— Deny GCR service for the group addressed stream.

In an infrastructure BSS, the retransmission policy shall not be GCR block ack for a GCR group address while the AP has a GCR agreement for the group address with a non-AP STA that had the Advanced GCR field equal to 0 in the Extended Capabilities element in the (Re)Association Request frame most recently received by the AP.

In a mesh BSS, the retransmission policy shall not be GCR block ack for a GCR group address while the mesh STA has a GCR agreement for the group address with a peer mesh STA that had the Mesh GCR field equal to 0 in the Extended Capabilities element.

An AP or mesh STA denies a GCR request by sending a DMS Response frame with a DMS Response element that contains a DMS Status field with

— The Response Type field set to "Denied" (as described in 11.21.16.2 (DMS procedures)), and

— An empty GCR Response subelement.

If an AP or mesh STA denies a GCR request, it may suggest an alternative TCLAS-based classifier by including one or more TCLAS elements and an optional TCLAS Processing element (as described in 9.4.2.31 (TCLAS Processing element)). One TCLAS element shall be included in the DMS Descriptor with the frame classifier type equal to 0 (Ethernet parameters). Other TCLAS elements may be included in the DMS Descriptor, but, if present, a TCLAS Processing element with the (#2180)Processing field equal to 0 shall also be included.

If a STA requesting GCR service determines that one or more GCR Response subelements are unacceptable, then the STA shall discard any received ADDBA Request frames for the unacceptable GCR streams and shall send a new DMS Request frame containing a DMS Request element with one DMS Descriptor for each


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unacceptable GCR stream. The DMSID fields shall be set to the DMSIDs of the unacceptable streams, and the Request Type field shall be set to "Remove."

In an infrastructure BSS, if the non-AP STA accepts the response to its GCR request, the non-AP STA shall set dot11GCRConcealmentAddress to the value contained in the GCR Concealment Address field of the GCR Response subelement.

In a mesh BSS, if a STA requesting GCR service accepts the response to its GCR request, it shall add to dot11GroupAddressesTable the value contained in the GCR Concealment Address field of the GCR Response subelement.

In a mesh BSS, a GCR agreement instance is identified by a GCR agreement instance identifier. The mesh GCR agreement instance consists of the DMSID, localMAC, peerMAC, and concealment address.

For each group addressed stream requested by the non-AP STA and accepted by the AP, the AP shall immediately initiate a block ack negotiation if both of the following conditions are true:

— The AP advertised an Advanced GCR field equal to 1 in its Extended Capabilities element.
— The non-AP STA advertised an Advanced GCR field equal to 1 in the Extended Capabilities element in the (Re)Association Request frame most recently received by the AP.

For each group addressed stream requested by a mesh STA's peer (STA1), the mesh STA (STA2) receiving the request shall immediately initiate a block ack negotiation if STA2 transmitted a Mesh GCR field equal to 1 in the Extended Capabilities element in its (#454)Beacon frame and STA2 received a (#454)Beacon frame from STA1 in which the Mesh GCR field in the Extended Capabilities element is equal to 1.

If all of the above conditions are true, the AP or mesh STA shall immediately initiate a block ack negotiation by sending an ADDBA Request frame to the STA that originated the GCR request. The Block Ack Policy subfield in the Block Ack Parameter Set field within the ADDBA Request frame shall not be set to 0. The TID subfield in the Block Ack Parameter Set field within the ADDBA Request frame shall be set to 0. The A-MSDU Supported subfield within the ADDBA Request frame shall be set to 1 (A-MSDU permitted). The Starting Sequence Number field within the ADDBA Request frame shall be greater than (modulo 4096) the last sequence number of the last group address frame transmitted before the ADDBA Request frame. A STA shall maintain this block ack agreement for the duration of its GCR agreement, irrespective of whether GCR block ack is the current retransmission policy. While the retransmission policy of the GCR group addressed stream is DMS, the STA receiving GCR frames shall suspend its block ack processing for the group addressed stream.

NOTE—Having a block ack agreement with all members of a GCR group address allows the AP or mesh STA to change the GCR retransmission policy dynamically.

For each GCR agreement, there shall be only one retransmission policy and delivery method active at any time. A GCR agreement between a non-AP STA and an AP or between peer mesh STAs shall begin when the STA providing GCR service successfully transmits an individually addressed DMS Response frame with a DMS Response element containing a DMS Status field that has the Status field set to "Accept" (as described in 11.21.16.2 (DMS procedures)) with the DMS Status field including a GCR Response subelement.

#### 11.21.16.3.4 GCR operation

The GCR operation do not apply to GLK-GCR. See 11.21.16.4.2 (GLK-GCR operation) for GLK-GCR frame exchange procedures.

In an infrastructure BSS, a GCR block ack agreement exists between a non-AP STA and an AP for a group addressed stream from when the non-AP STA successfully transmits an ADDBA Response frame until one of the following situations occurs:

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— The AP or non-AP STA successfully transmits a DELBA frame to the other party.
— The GCR agreement no longer exists.

In a mesh BSS, a GCR block ack agreement exists between a mesh STA and its peer mesh STA for a group addressed stream from the time when the mesh STA successfully transmits an ADDBA Response frame to the peer mesh STA until one of the following situations occurs:

— The mesh STA or the peer mesh STA successfully transmits a DELBA frame to the other party.
— This GCR block ack agreement expires (see 10.25.4 (Teardown of the block ack agreement(#6171))).
— The GCR agreement is terminated.

An AP or a mesh STA may transmit a group addressed stream via the No-Ack/No-Retry (non-GCR; see 10.3.6 (Group addressed MPDU transfer procedure)) service and GCR service simultaneously. Each frame shall be transmitted via the No-Ack/No-Retry retransmission policy before it is transmitted via the GCR service, except when using the GCR-SP delivery method. The AP may transmit each frame via the No-Ack/No-Retry retransmission policy before or after it transmits the frame via the GCR service when using the GCR-SP delivery method. A STA providing GCR service may switch between the DMS, GCR block ack, or GCR unsolicited retry retransmission policies, but only one delivery mode may be active at any given time for each GCR group address.

An AP or mesh STA shall transmit a frame belonging to a group address via the GCR service if any associated STA or peer mesh STA has a GCR agreement for the group address and, otherwise, does not transmit the frame via the GCR service.

In an infrastructure BSS, an AP shall transmit a frame belonging to a group address via the No-Ack/No-Retry service if one or more of the following situations occur:

— The group address is the broadcast address.
— The group address is not the broadcast address, and at least one associated STA has the Robust AV Streaming bit equal to 0 in the Extended Capabilities element of the STA's most recent (Re)Association Request frame and has been determined by the AP to be a member of the group address (how this determination is made is out of the scope of this standard).
— The group address is not the broadcast address, at least one non-AP STA has a block ack agreement for the group address, and the frame precedes the start of the block ack agreement (the sequence number of the frame is less than the starting sequence number of the block ack agreement, as described in 10.25.2 (Setup and modification of the block ack parameters)).

In a mesh BSS, a mesh STA providing GCR service shall transmit a frame belonging to a group address via the No-Ack/No-Retry service if one or more of the following situations occur:

— The group address is the broadcast address.
— The group address is not the broadcast address, and at least one peer mesh STA has the Mesh GCR bit equal to 0 in the Extended Capabilities element of the STA's most recent (#454)Beacon frame and has been determined to be a member of the group address (how this determination is made is out of the scope of this standard).
— The group address is not the broadcast address, at least one peer mesh STA has a block ack agreement for the group address, and the frame precedes the start of the block ack agreement (the sequence number of the frame is less than the starting sequence number of the block ack agreement, as described in 10.25.2 (Setup and modification of the block ack parameters)).

When the AP updates the retransmission policy, the AP shall set the Last Sequence Control field in the GCR Response subelement to the sequence number of the MPDU corresponding to the GCR traffic flow that is being updated that was delivered prior to the change in retransmission policy.


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To avoid undetected retries being passed up at a receiver's MAC SAP, duplicate detection and removal for group addressed frames is required in STAs with dot11RobustAVStreamingImplemented true or dot11MeshGCRImplemented true (see 10.3.2.14 (Duplicate detection and recovery)).

GCR frames shall be QoS Data frames (with QoS subfield of the Subtype subfield set to 1).

If the block ack agreement is successfully established for the group addressed stream and the delivery method for the group addressed stream is GCR-SP, then the non-AP STA is awake for subsequent SPs (see 11.21.16.3.8 (GCR-SP)).

A STA may request a change of GCR service for a group addressed stream by sending a DMS Descriptor with the DMSID identifying the group address and the Request Type field set to "Change" (as described in 11.21.16.2 (DMS procedures)) with the following modifications:

— The DMS Descriptor shall contain zero TCLAS elements, zero TCLAS Processing elements, one TSPEC element, and one GCR Request subelement.

— The TSPEC element and GCR Request subelement of this DMS Descriptor shall together contain at least one field that is different from the original TSPEC element and GCR Request subelement identified by the DMSID.

An AP or mesh STA may update the retransmission policy, delivery method, and schedule for any reason, such as the size of the group changes, the capabilities of the members of the group change, GCR Request subelements for the group are received, or multicast diagnostics are needed. The AP or mesh STA advertises the current settings upon a change and periodically by either of the following methods:

— Transmitting an unsolicited DMS Response frame with the current settings addressed to the GCR concealment address. This DMS Response frame shall be scheduled for delivery at the appropriate DTIM interval or SP in which all STAs within the group are awake to receive the frame. One TCLAS element shall be included with the frame classifier type equal to 0 (Ethernet parameters). Other TCLAS elements may be present, but if present, a TCLAS Processing element with the (#2180)Processing field equal to 0 shall also be included. One TSPEC element and one GCR subelement shall be included per DMS Descriptor in the DMS Response element of the DMS Response frame to identify each GCR stream. The DMSID that identifies the GCR stream shall be included in the DMS Descriptor. Each Status field in the DMS Status fields included in the frame shall be set to "GCR Advertise."

— Transmitting unsolicited DMS Response frames with the current settings individually addressed to each GCR group member. Each GCR stream is identified by the DMSID in a DMS Status field in the DMS Response element of the DMS Response frame. These DMS Status fields shall not include a TCLAS element, TSPEC element, or GCR subelement. Each Status field in the DMS Status fields included in the frame shall be set to "GCR Advertise."

A STA receiving GCR frames shall recover from missing group addressed DMS Response frames containing GCR Response subelements that advertise a changed retransmission policy or delivery method according to Table 11-18 (STA recovery procedures for a changed retransmission policy) or Table 11-19 (Non-AP STA recovery procedures for a changed delivery method), respectively.

A GCR agreement between a non-AP STA and an AP or between peer mesh STAs shall end (as described in 11.21.16.2 (DMS procedures)) when one of the following situations occurs:

— In an infrastructure BSS, the AP deauthenticates or disassociates the non-AP STA, or

— In a mesh BSS, the mesh STA providing GCR service tears down the peer link to the mesh STA receiving GCR frames, or

— The non-AP STA or mesh STA receiving GCR frames successfully transmits a DMS Request frame to the AP or mesh STA providing GCR service containing a DMS Request element that has a DMS

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**Table 11-18—STA recovery procedures for a changed retransmission policy**

| Current retransmission policy state at STA receiving GCR frames | Actual retransmission policy being used by the AP or mesh STA providing GCR service | Recovery procedure |
|---|---|---|
| GCR unsolicited retry or GCR block ack | No-Ack/No-Retry | A STA receiving GCR frames shall cancel the GCR service for the group address by sending a DMS Response frame that contains a DMS Descriptor with the Request Type field set to "Remove" when no frames for the group address are received via the GCR service after a period of dot11GCRPolicyChangeTimeout. |
| DMS | GCR unsolicited retry or GCR block ack | A STA receiving GCR frames shall update its current retransmission policy of the GCR stream to GCR unsolicited retry upon receiving an A-MSDU for the DMS group address concealed via the GCR concealment address. |
| GCR unsolicited retry or GCR block ack | DMS | A STA receiving GCR frames shall update its current retransmission policy of the GCR stream to DMS upon receiving an A-MSDU with the RA field equal to the non-AP STA's individual address and the DA field of the A-MSDU subframe equal to the GCR group address. |
| GCR unsolicited retry | GCR block ack | A STA receiving GCR frames shall update its current retransmission policy of the GCR stream to GCR block ack upon receiving a BlockAckReq frame with a GCR Group Address subfield equal to the GCR group address. |
| GCR block ack | GCR unsolicited retry | A STA receiving GCR frames shall update its current retransmission policy of the GCR stream to GCR unsolicited retry if MSDUs for the GCR group address concealed via the GCR concealment address are being received yet no BlockAckReq frames for the GCR group address are received after a period of dot11GCRPolicyChangeTimeout. |

Descriptor with the DMSID identifying the group addressed stream and the Request Type field set to "Remove," or

— The AP or a mesh STA providing GCR service successfully transmits an individually addressed DMS Response frame with a DMS Response element containing a DMS Status field with the DMSID identifying the group addressed stream that has the Response Type field set to "Terminate."

A GCR agreement between a non-AP STA and an AP or between peer mesh STAs shall end (as described in 11.21.16.2 (DMS procedures)) with the following modifications:

— The DMS Status field shall include a GCR Response subelement.

— The DMS Response frame may be transmitted by an AP to the GCR concealment address or as an individually addressed frame to each STA that has an active GCR agreement for this GCR group address. The DMS Response frame shall be transmitted by a non-AP STA or mesh STA as an individually addressed frame to the STA that it has an active GCR agreement for this GCR group address.


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**Table 11-19—Non-AP STA recovery procedures for a changed delivery method**

| Current delivery method state at non-AP STA | Actual delivery method being used by the AP | Recovery procedure |
|---|---|---|
| Non-GCR-SP | GCR-SP | A non-AP STA shall update the current delivery method state of the GCR stream to GCR-SP if<br>a) No frames with the More Data subfield in the Frame Control field equal to 1 for the GCR stream are received for a period of dot11GCRPolicyChangeTimeout, and<br>b) At least one frame for the GCR stream with the More Data subfield in the Frame Control field equal to 0 is received.<br>Note that upon detecting condition a), the STA should enter the awake state in order to assist with detecting condition b). |
| GCR-SP | Non-GCR-SP | A non-AP STA shall update the current delivery method of the GCR stream to Non-GCR-SP if no frames with the More Data subfield in the Frame Control field equal to 0 for the GCR stream are received for a period of dot11GCRPolicyChangeTimeout and at least one frame for the GCR stream with the More Data subfield in the Frame Control field equal to 1 is received. |

A cancellation of a GCR agreement shall also cause the block ack agreement to be canceled for the GCR stream.

### 11.21.16.3.5 Concealment of GCR transmissions

The concealment of GCR transmissions does not apply to GLK-GCR.

Concealment prevents group addressed frames transmitted via the GCR unsolicited retry or GCR block ack retransmission policies from being passed up through the MAC SAPs of GCR-incapable STAs.

GCR group addressed MSDUs shall be sent in an A-MSDU when

- Retransmitted via the GCR unsolicited retry or GCR block ack retransmission policies, or
- Transmitted via the GCR-SP delivery method.

The MPDU containing this A-MSDU shall have the Address 1 field set to dot11GCRConcealmentAddress and the Retry subfield of the Frame Control field set to 1. The DA field in the A-MSDU subframe shall contain the GCR group address that is being concealed (i.e., the same value as the DA field for non-GCR group addressed delivery). One A-MSDU subframe shall be contained within one frame that contains an A-MSDU(#1996). GCR group addressed MSDUs retransmitted via the GCR unsolicited retry or GCR block ack retransmission policies shall set the Sequence Control field of the MPDU containing this A-MSDU to the same value as the Sequence Control field of the frame that contained the corresponding MSDU that was transmitted with the Retry subfield equal to 0. The first transmission attempt of a GCR group addressed MSDU transmitted via the GCR-SP delivery method shall set the Sequence Control field of the MPDU containing this A-MSDU according to the procedures defined in 10.3.2.14 (Duplicate detection and recovery).

A STA with dot11RobustAVStreamingImplemented true or dot11MeshGCRImplemented true shall not use its GCR concealment address for any purpose other than the transmission of GCR streams.

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A STA with dot11RobustAVStreamingImplemented true or dot11MeshGCRImplemented true and with a GCR agreement shall add the GCR concealment address from the GCR Response subelement to the STA's dot11GroupAddressesTable.

An AP with dot11RobustAVStreamingImplemented true shall not send an MSDU to the DS that has the DA field set to the GCR concealment address.

The Individual/Group Address bit (bit 0) of dot11GCRConcealmentAddress shall be set to 1.

#### 11.21.16.3.6 GCR unsolicited retry

The GCR unsolicited retry procedures do not apply to GLK-GCR. See 11.21.16.4.3 (GLK-GCR unsolicited retry) for GLK-GCR unsolicited retry.

A STA supports the GCR unsolicited retry retransmission policy if dot11RobustAVStreamingImplemented or dot11MeshGCRImplemented is true; otherwise, the STA does not support the GCR service with retransmission policy equal to GCR unsolicited retry.

An AP or a mesh STA adopting the GCR unsolicited retry retransmission policy for a GCR group address chooses a lifetime limit for the group address. The AP or a mesh STA may vary the lifetime limit for the group address at any time and may use different lifetime limits for different GCR group addresses. An AP adopting the GCR unsolicited retry retransmission policy for a GCR group address shall transmit each MSDU according to 11.21.16.3.5 (Concealment of GCR transmissions), subject to the lifetime and retry limits. Transmission uses the backoff procedure described in 10.23.2.12.2 (Unsolicited retry procedure).

If a block ack agreement has successfully been established for a group addressed stream that is delivered using the GCR unsolicited retry retransmission policy, the STA shall follow the duplicate detection procedures defined in 10.3.2.14 (Duplicate detection and recovery).

If a block ack agreement has successfully been established for all STAs receiving a GCR group address, for a group delivered using the GCR unsolicited retry retransmission policy, the AP may retransmit any of the last *m* A-MSDUs that have the DA field in the A-MSDU subfield set to the GCR group address, where *m* is GCR buffer size (as defined in 11.21.16.3.7 (GCR block ack)), subject to the lifetime limits.

If there is a STA with an active GCR agreement for a group address that does not have an active block ack agreement, the AP shall not retransmit a preceding A-MSDU for that group address. A preceding A-MDSU is defined as an A-MSDU with a sequence number value that precedes, using the modulo $2^{12}$ rules defined in 10.25.1 (Introduction), the sequence number value of the last transmitted A-MSDU for the GCR group address.

#### 11.21.16.3.7 GCR block ack

The GCR block ack procedures do not apply to GLK-GCR. See 11.24.16.4.4 for GLK-GCR block ack.

A STA supports the GCR block ack retransmission policy if dot11AdvancedGCRImplemented is true or dot11MeshGCRImplemented is true; otherwise, the STA does not support the GCR service with retransmission policy equal to GCR Block Ack.

The AP shall maintain a set of the most recently received values of the Buffer Size subfield from the Block Ack Parameter Set field in the ADDBA Response frame received from each member of a specific group address. The minimum of that set of values is defined to be the *GCR buffer size* for that group address (see 10.25.8 (GCR and GLK-GCR block ack)).


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#### 11.21.16.3.8 GCR-SP

The GCR-SP delivery method does not apply to GLK-GCR.

The GCR-SP delivery method transmits GCR group addressed frames at intervals that might be smaller than the beacon interval.

A STA supports the GCR-SP delivery method if dot11AdvancedGCRImplemented is true; otherwise, the STA does not support the GCR service with the delivery method equal to GCR-SP.

NOTE—Group addressed traffic transmitted at the end of a DTIM beacon might be an impediment to providing QoS for uplink transmissions and in OBSSs. Therefore, APs in an overlapped environment are advised to make use of GCR-SP for group addressed traffic that consumes appreciable medium time.

Group addressed MSDUs shall not be transmitted via the GCR-SP delivery method policy if a non-GCR-SP delivery method is active for that group address.

All MSDUs transmitted via the GCR-SP delivery method shall be concealed using the procedures described in 11.21.16.3.5 (Concealment of GCR transmissions). A STA receiving group addressed MSDUs transmitted via the GCR-SP delivery method shall discard all nonconcealed MSDUs for this group address.

An AP advertises that a group addressed stream is subject to GCR-SP within a GCR Response subelement. The subelement indicates the start of each SP. See 11.2.3.5 (Power management with APSD). When the Service Interval field in the Schedule element of the DMS Response frame is greater than 0, at every scheduled SP, the AP schedules for transmission buffered GCR-SP group addressed frames assigned to that particular group address.

An AP shall not establish both a GCR-SP and an FMS agreement for a group addressed stream with a single non-AP STA.

An AP may use the GCR-SP delivery method for an accepted GCR service when all of the non-AP STAs that requested the GCR service for the group address have the Robust AV Streaming bit in the Extended Capabilities element equal to 1 and the Advanced GCR bit in the Extended Capabilities element equal to 1. Otherwise, the AP shall not use the GCR-SP delivery method for the accepted GCR service.

When the Service Interval field in the Schedule element of the DMS Response frame is 0, the AP may transmit group addressed frames that are subject to this GCR agreement at any time without regard to the power state of non-AP STAs in the group. This delivery method is called *GCR-A*, where all members of the group need to stay in the awake state to receive these group addressed frames.

### 11.21.16.4 GLK-GCR

#### 11.21.16.4.1 Overview

GLK-GCR functions as GCR does except as described in the subclauses below. The RA field in the MAC header corresponding to the Data frames transmitted under the GLK-GCR agreement shall contain a SYNRA.

#### 11.21.16.4.2 GLK-GCR operation

A GLK AP that supports GLK-GCR and has set up (#1653)GLK-GCR for group transmissions shall transmit group addressed frames only via the GLK-GCR mechanism. The GLK AP shall not transmit (#1653)group addressed frames via the No-Ack/No-Retry (non-GCR; see 10.3.6 (Group addressed MPDU transfer procedure)) service as long as GLK-GCR is active. Data frames using the GLK-GCR mechanism use the non-GCR-SP delivery mode. A GLK AP providing GLK-GCR service may switch between GCR block ack, or

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GCR unsolicited retry retransmission policies only after indicating such a switch using the GLK Groupcast Mode Change Notification frame.

When the GLK AP updates the GLK-GCR retransmission policy, the GLK AP shall set the Last Sequence Control field in the GLK-GCR Parameter Set element to the sequence number of the MPDU corresponding to the GCR traffic flow that is being updated that was delivered prior to the change in retransmission policy.

To avoid undetected retries being passed up at a receiver's MAC SAP, GLK non-AP STAs that support GLK-GCR should detect duplicates of received group addressed frames and discard them (see 10.3.2.14 (Duplicate detection and recovery)).

A GLK AP may update the retransmission policy for any reason, such as a change in the size of the group or the capabilities of the members of the group The GLK AP advertises the current settings using a GLK Groupcast Mode Change Notification frame.

#### 11.21.16.4.3 GLK-GCR unsolicited retry

A STA supports the GLK-GCR unsolicited retry retransmission policy if dot11GLKGCRImplemented is true; otherwise, the STA does not support the GLK-GCR unsolicited retry retransmission policy.

A GLK AP adopting the GLK-GCR unsolicited retry retransmission policy uses the backoff procedure described in 10.23.2.12.2 (Unsolicited retry procedure).

If a block ack agreement has successfully been established for a group addressed stream that is delivered using the GLK-GCR unsolicited retry retransmission policy, the GLK STA shall follow the duplicate detection procedures defined in 10.3.2.14 (Duplicate detection and recovery) and 10.25.3 (Data and acknowledgment transfer using immediate block ack policy).

#### 11.21.16.4.4 GLK-GCR block ack

A STA supports the GLK-GCR block ack retransmission policy if dot11GLKGCRImplemented is true; otherwise, the STA does not support the GLK-GCR block ack retransmission policy.

The Buffer Size subfield in the GLK-GCR Parameters field in the GLK-GCR Parameter Set element sent in the (Re)Association Response frame by the GLK AP is the GCR buffer size (see 10.25.8 (GCR and GLK-GCR block ack)).

### 11.21.17 WNM notification

Implementation of the WNM notification capability is optional for a WNM STA. A STA that implements the WNM notification capability has dot11WNMNotificationImplemented equal to true. When dot11WNMNotificationImplemented is true, dot11WirelessManagementImplemented shall be true. A STA in which dot11WNMNotificationActivated is true is defined as a STA that supports WNM notification. The STA shall set to 1 the WNM Notification field of the Extended Capabilities elements that it transmits.

A STA that supports WNM notification reporting may send a WNM Notification Request or Response frame to a STA within the same infrastructure BSS or the same IBSS whose most recently received Extended Capabilities element contained a value of 1 for the WNM Notification field in the Extended Capabilities field; it shall not send a WNM Notification Request or Response frame otherwise.

A STA shall transmit both the WNM Notification Request frame and the WNM Notification Response frame with a destination address that is an individual address.

The WNM notification capability enables a STA to indicate management information to a peer STA:


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a) Information about its firmware
b) Beacon protection failure

Use of the information provided is outside the scope of this standard. A non-AP STA that supports WNM notification and receives a WNM Notification Request frame with the Type field indicating firmware upgrade notification shall respond with a WNM Notification Response frame with the Response Status field set to 0.

## 11.22 WLAN interworking with external networks procedures

### 11.22.1 General

This subclause describes the actions and the procedures that provide interworking capabilities between IEEE 802.11 infrastructure and external networks.

### 11.22.2 Interworking capabilities and information

STAs indicate their support for interworking service by setting dot11InterworkingServiceActivated to true. When dot11InterworkingServiceActivated is true, STAs include the Interworking element in Beacon and Probe Response frames, and non-AP STAs include the Interworking element in Probe Request frames.

When dot11InterworkingServiceActivated and dot11ExtendedChannelSwitchActivated are both true in an infrastructure BSS, the AP may provide its operating channel and operating class to an Interworked SSPN using the values from dot11OperatingClassesTable.

In an infrastructure BSS, the Interworking element contains signaling for HeSSs(M12). The HESSID is a (#2047)MAC address that identifies the HeSS(M12). The HESSID value shall be the universal MAC address of one of the APs(#1347)(#8228) in the HeSS. (M12)All BSSs in the HeSS use the same value(#6401). Thus, it is a globally unique identifier that, in conjunction with the SSID, may be used to provide network identification for an SSPN.

NOTE 1—The HESSID field in the Interworking element needs to be administered to have the same value across all BSSs in an HeSS(M12)(#6401).

NOTE 2—The concept of an HeSS is orthogonal to an ESS, and any SSIDs can be used by the BSSs that provide access to the HeSS. For more information on HeSS, refer to Wi-Fi Alliance documents [B69] and [B70].(M12)

NOTE 3—If the APs in the HeSS are using locally administered MAC addresses for their BSSIDs, the HESSID might not be any of the BSSIDs in the HeSS.(#1347)

The Interworking element also provides an access network type in Beacon and Probe Response frames to assist the non-AP STA with network discovery and selection.

### 11.22.3 Interworking procedures: generic advertisement service (GAS)

#### 11.22.3.1 Introduction

This subclause describes the actions and procedures that are used to invoke GAS. GAS may be used to enable network selection or service discovery for STAs when dot11InterworkingServiceActivated is true. GAS provides transport mechanisms for advertisement services while STAs are in the unassociated state as well as the associated state. This is accomplished via the use of Public Action frames, which are (#1463)Class 1 frames. GAS information shall be transmitted using Public Action frames. When management frame protection is negotiated, stations shall use individually addressed Protected Dual of Public Action frames instead of Public Action frames.

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A GAS frame exchange may take place between two STAs; one STA transmits a GAS query request and the other STA transmits the GAS query response as described in 11.22.3.2 (GAS Protocol). The advertisement protocol transported by the GAS is one of the query protocols in Table 9-277 (Advertisement protocol ID definitions).(#6058)

A STA may transmit a group addressed GAS query request. Multiple STAs that receive a group addressed GAS query request may send an individually addressed or group addressed GAS query response.(#6058)

A STA that receives multiple, similar GAS query requests from multiple STAs that require the same GAS query response may aggregate the response and transmit a group addressed GAS query response.(#6058)

A STA that receives a group addressed GAS query response may process the GAS query response information without transmitting a GAS query request.(#6058)

GAS shall be supported by a STA when dot11InterworkingServiceActivated is true. ANQP shall be supported by a STA when dot11InterworkingServiceActivated is true. Other advertisement protocols shall be supported when the corresponding dot11GASAdvertisementID is present.

GAS query request fragmentation shall be supported by a STA when dot11GASQueryRequestFragmentationActivated is true.(#6058)

A STA shall not transmit a GAS query request for any advertisement protocol unless that advertisement protocol ID is included in the Advertisement Protocol element in a Beacon or Probe Response frame. The Advertisement Protocol element specifies the advertisement protocols that a STA may use to communicate with advertisement servers(#571), which may be (#2210)colocated with a STA or in an external network. The advertisement protocol identifies the query language used by the advertisement server. The GAS protocol, which is used to transport GAS query requests and GAS query responses, is transparent to the advertisement protocol.(#6058)

### 11.22.3.2 GAS Protocol

#### 11.22.3.2.1 General

The presence of the Interworking element in Beacon or Probe Response frames indicates support for the GAS protocol. The additional presence of the GAS Extension element with the (#1293)Group Addressed GAS subfield in the GAS Extension element set to true in a GAS Initial Request frame or group addressed GAS frames indicates support for the use of group addressed GAS frames. The presence of the Advertisement Protocol element in Beacon or Probe Response frames indicates the advertisement protocol IDs supported in the BSS or IBSS.

(#6058)A STA transmits a GAS query request in either a GAS Initial Request, GAS Comeback Request, GAS Comeback Request Fragment or Group Addressed GAS Request frame and the responding STA provides a GAS query response or information on how to receive the GAS query response in a GAS Initial Response, GAS Comeback Response or Group Addressed GAS Response frame.

(#6058)The GAS query request or GAS query response shall be delivered in a single GAS Initial Request or GAS Initial Response frame, in a Group Addressed GAS Request or Group Addressed GAS Response frame, or in one or more GAS Comeback Request, GAS Comeback Request Fragment or GAS Comeback Response frames. The GAS Initial Request or Response frame shall not include a fragment.


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(#6058)The GAS message sequence diagrams are shown in Figure 11-76 (GAS frame exchange(#109) with dot11GASPauseForServerResponse equal to true(#571)), Figure 11-77 (Group addressed GAS frame exchange with a response discard(#3683)(#109)), Figure 11-78 (GAS frame exchange(#109) with GAS fragmentation and dot11GASPauseForServerResponse equal to true(#571)), Figure 11-79 (GAS frame exchange(#109) with GAS fragmentation and dot11GASPauseForServerResponse equal to false(#571)), Figure 11-80 (Group addressed GAS frame exchange with a timer(#109)), Figure 11-81 (Group addressed GAS frame exchange for a specific fragment(#3683)(#109)(#571)), (#6058)Figure 11-75 (GAS frame exchange with query request fragmentation(#6058)), and Figure 11-82 (GAS frame exchange (#109)using CAG Version(#571)).(Ed)

(#6058)Figure 11-75 (GAS frame exchange with query request fragmentation(#6058)) describes the GAS frame exchange when the GAS query request is too large to fit in one MMPDU and GAS fragmentation is used for delivery. The number of GAS Comeback Request Fragment and GAS Comeback Response frames depends on the number of GAS fragments required for delivery of the GAS query request.

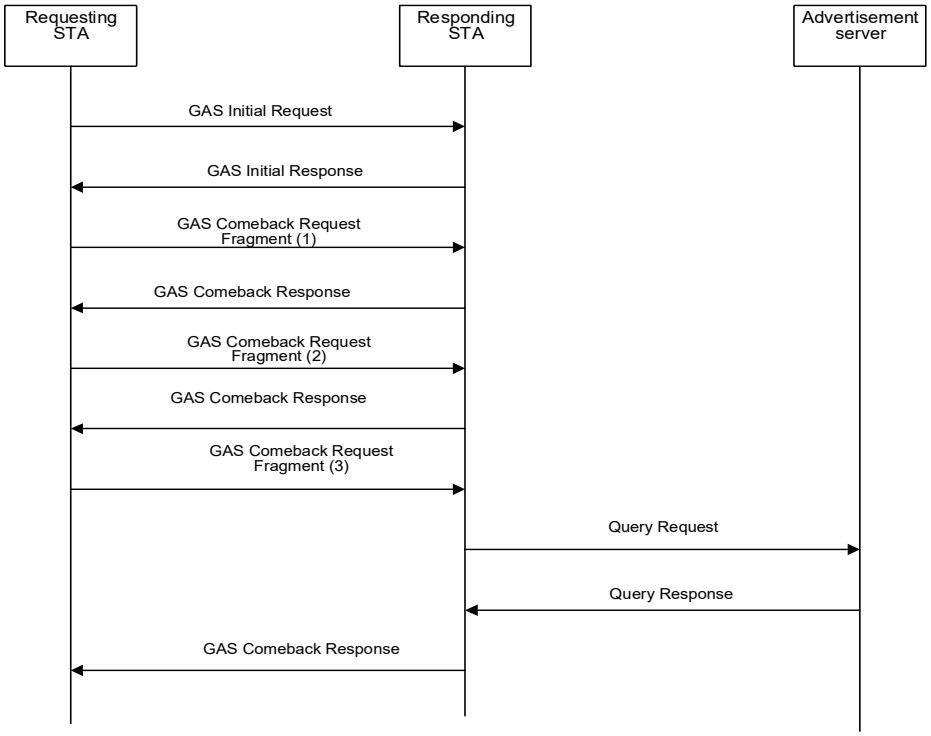


**Figure 11-75—GAS frame exchange with query request fragmentation(#6058)**

If a GAS Initial Request frame or a Group Addressed GAS Request frame contains a Maximum Channel Time field in the GAS Extension Element and if the conditions for replying as described in 11.22.3.2.4 (STA procedures to post a GAS query request to an advertisement server(#571)(#7052)) and 11.22.3.2.5 (STA procedures for transmitting the GAS query response(#7054)) are met, the responding STA shall queue for transmission a GAS Initial Response frame or a Group Addressed GAS Response frame within the indicated Maximum Channel Time.

Figure 11-76 (GAS frame exchange(#109) with dot11GASPauseForServerResponse equal to true(#571)) describes the GAS frame exchange(#109) when dot11GASPauseForServerResponse is true and the result of the GAS query request(#7052) fits within one MMPDU.

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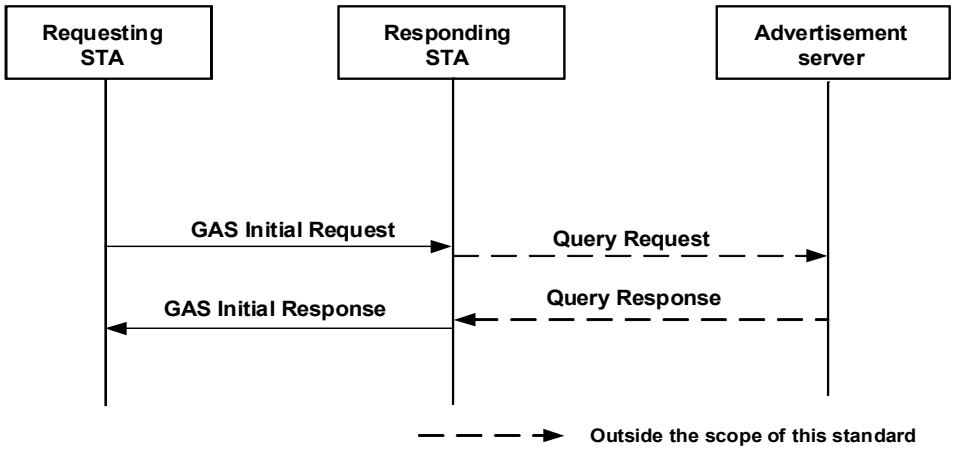


**Figure 11-76—GAS frame exchange(#109) with dot11GASPauseForServerResponse equal to true(#571)**

Figure 11-77 (Group addressed GAS frame exchange with a response discard(#3683)(#109)) describes the GAS frame exchange(#109) when a STA sends a Group Addressed GAS Request frame to a group of STAs. The receiving STA may (M118)respond to the GAS query request(#7052). If the receiving STA responds, it may respond with either a GAS Initial Response frame or a Group Addressed GAS Response frame.

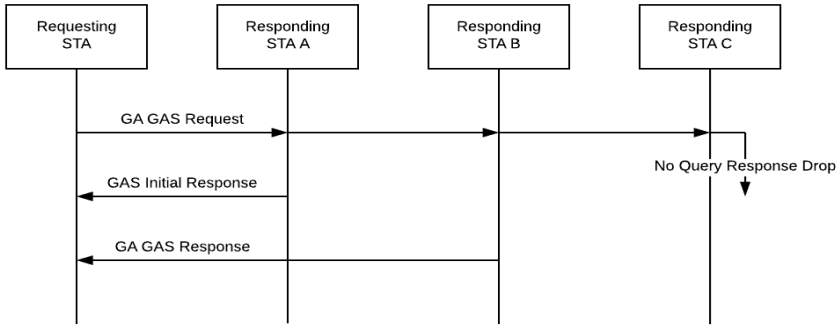


**Figure 11-77—Group addressed GAS frame exchange with a response discard(#3683)(#109)**

Figure 11-78 (GAS frame exchange(#109) with GAS fragmentation and dot11GASPauseForServerResponse equal to true(#571)) (#4094)describes the GAS frame exchange(#109) when dot11GASPauseForServerResponse is true and the result of the GAS query request(#7052) is too large to fit in one MMPDU and GAS fragmentation is used for delivery. The number of GAS Comeback Request and GAS Comeback Response frames depends on the number of GAS fragments required for delivery of the result of the GAS query request(#7052).

Figure 11-79 (GAS frame exchange(#109) with GAS fragmentation and dot11GASPauseForServerResponse equal to false(#571)) describes the GAS frame exchange(#109) when dot11GASPauseForServerResponse is false. The number of GAS Comeback Request and GAS Comeback Response frames depends on the number of GAS fragments required for delivery of the GAS query response(#7054).


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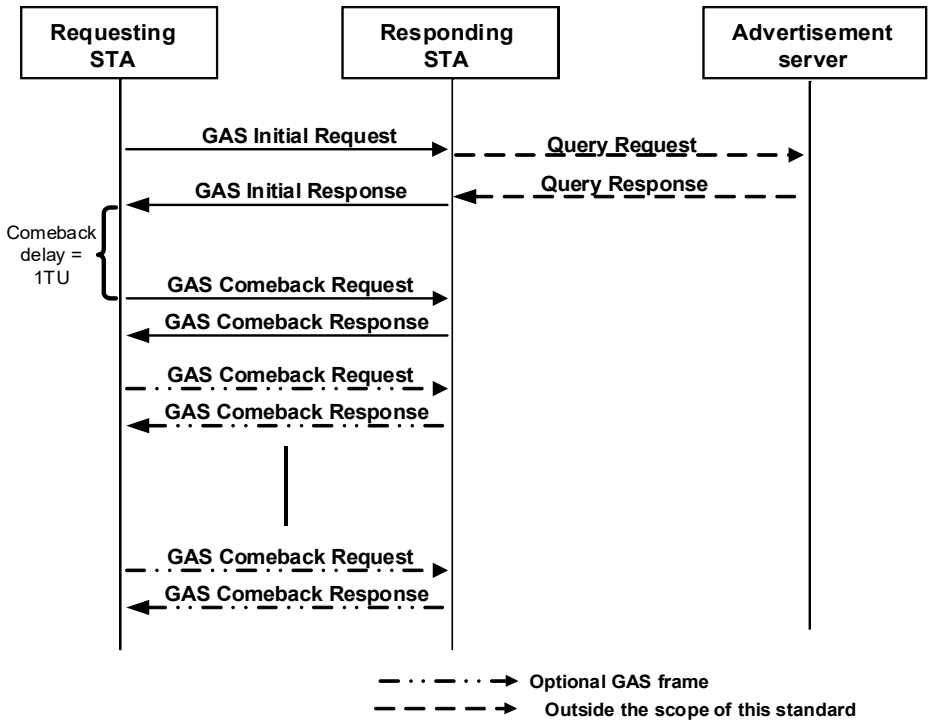


**Figure 11-78—GAS frame exchange(#109) with GAS fragmentation and dot11GASPauseForServerResponse equal to true(#571)**

Figure 11-80 (Group addressed GAS frame exchange with a timer(#109)) describes a GAS frame exchange(#109) when multiple STAs send a GAS Initial Request frame that would result in the same GAS query response(#7054). The receiving STA responds with a Group Addressed GAS Response frame.

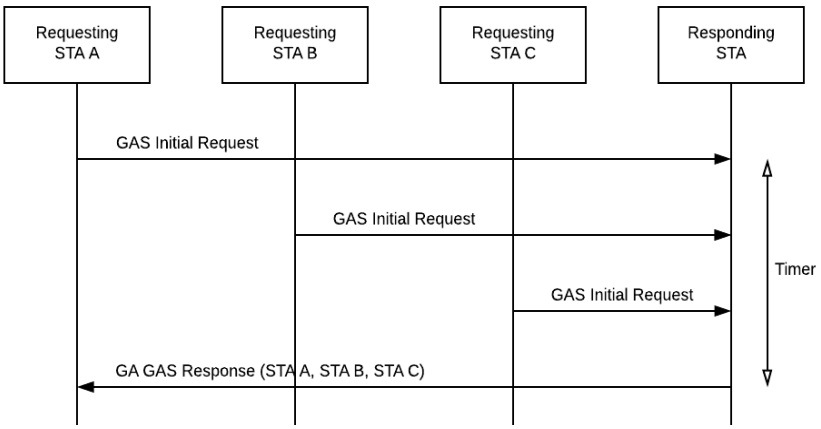


**Figure 11-80—Group addressed GAS frame exchange with a timer(#109)**

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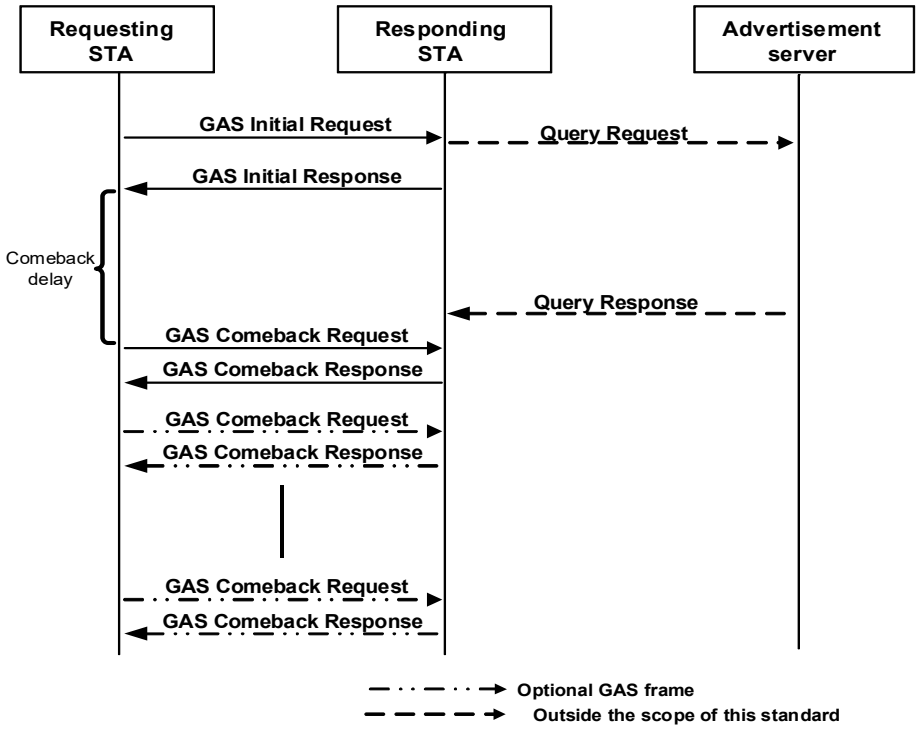


**Figure 11-79—GAS frame exchange(#109) with GAS fragmentation and dot11GASPauseForServerResponse equal to false(#571)**

Figure 11-81 (Group addressed GAS frame exchange for a specific fragment(#3683)(#109)(#571)) describes the GAS frame exchange(#109) when a STA issues a GAS Initial Request frame and, during the course of receiving a fragmented GAS Comeback Response frame, requests a specific fragment for retransmission from the transmitting STA.

Figure 11-82 (GAS frame exchange (#109)using CAG Version(#571)) describes a GAS frame exchange(#109) using CAG Version when a requesting STA requests information that the requesting STA has a cached version of a previous query response and the associated Common Advertisement Group (CAG) Version. The requesting STA provides its cached CAG Version in a GAS Initial Request frame along with the query request. When the responding STA determines that the CAG Version cached by the requesting STA matches a valid CAG Version that the responding STA receives from a relevant advertisement server(#571) as indicated by the CAG Information Type, which is provided by the requesting STA in the same CAG Tuple field that contains the cached CAG Version, then the responding STA provides a GAS response indicating that the information cached by the requesting STA is still valid. When the responding STA determines that the CAG Version cached by the requesting STA does not match any valid CAG Version that the responding STA receives from a relevant advertisement server(#571) as indicated by the CAG Information Type, which is provided by the requesting STA in the same CAG Tuple field that contains the cached CAG Version, then the responding STA posts the query request to the relevant advertisement server(#571) as specified in 11.22.3.2.4 (STA procedures to post a GAS query request to an advertisement server(#571)(#7052)), receives a query response from the advertisement server(#571), and transmits the query response to the requesting STA as specified in 11.22.3.2.5 (STA procedures for transmitting the GAS query response(#7054)).


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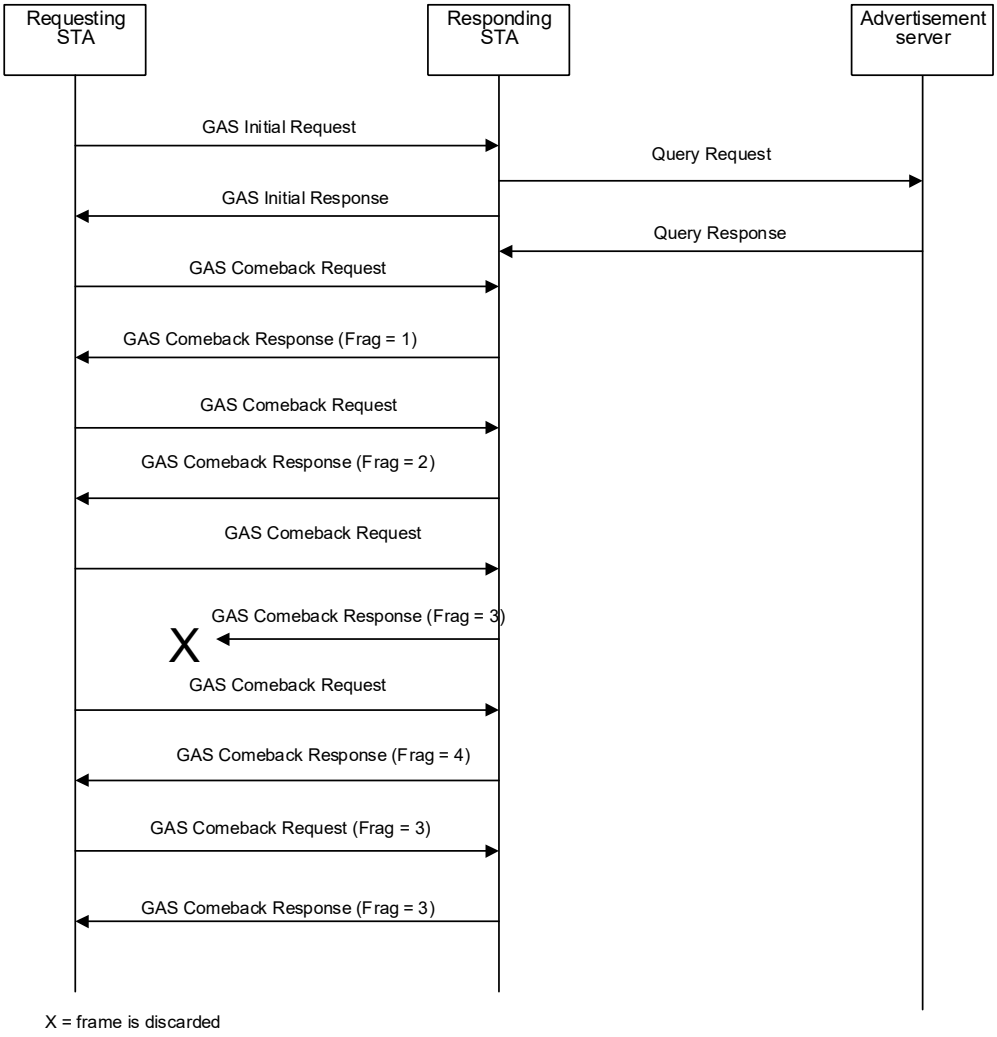


**Figure 11-81—Group addressed GAS frame exchange for a specific fragment(#3683)(#109)(#571)**

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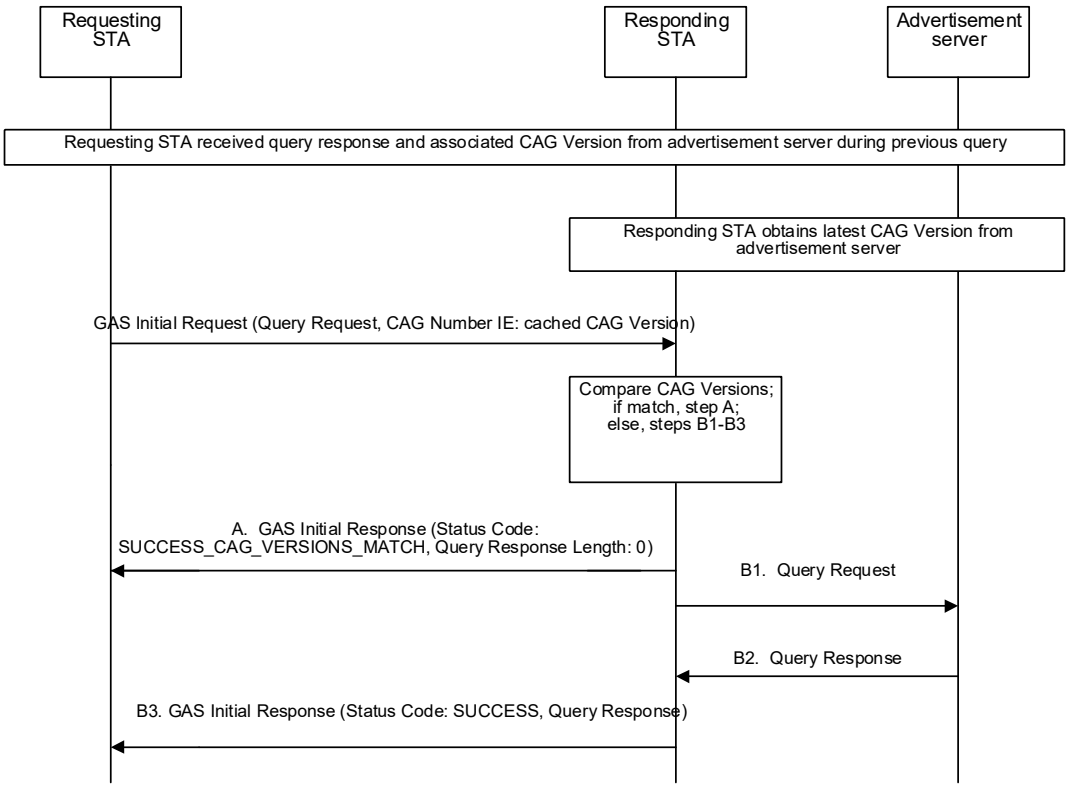


**Figure 11-82—GAS frame exchange (#109)using CAG Version(#571)**



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#### 11.22.3.2.2 STA procedures to transmit a GAS query request(#7052)

Upon receipt of an MLME-GAS.request primitive, the requesting STA shall engage in the following procedure to transmit a query:

a) If GAMode in the primitive is null or set to false, the requesting STA sends a GAS query request by transmitting a GAS Initial Request frame containing a Dialog Token field, an Advertisement Protocol element containing an Advertisement Protocol ID field and GAS query request in the Query Request field. If the GAS Initial Request frame requests information relating to a frequency band different from the frequency band in which the frame is transmitted, the STA shall include a Multi-band element in the GAS Initial Request frame with the Band ID, Operating Class, and Channel Number fields set to indicate to which frequency band the GAS Initial Request frame applies, with other fields in the Multi-band element being reserved. If the frame requests information relating to the frequency band in which the frame is transmitted, a Multi-band element shall not be included in the frame. If the GAS Initial Request frame requests information that the requesting STA has a cached version of a previous query response and the associated CAG Version, the requesting STA may include the cached CAG Version and the associated CAG Information Type in a CAG Number element in the GAS Initial Request frame. If GAMode in the primitive is(M118) true, the requesting STA transmits a Group Addressed GAS Request frame including a GAS Extensions element with the Maximum Channel Time field set to the value of the dot11GASResponseTimeout divided by 10, rounded to the nearest integer, and limited to a value of 255. The GAS protocol supports query requests whose length is greater than the maximum MMPDU size by the STA's use of the GAS Query Fragment ID field in a GAS Comeback Request Fragment frame, subsequent to a GAS Initial Request frame. The GAS Query Fragment ID shall be set to 0 for the initial fragment and incremented by 1 for each subsequent fragment in a multi-fragment query request. The STA shall transmit all fragments that belong to the same query request until all fragments are exhausted. The STA shall set the More GAS Fragments field of the GAS Query Fragment ID to 0 when the transmitted fragment is the final fragment.(#6058)

b) Upon transmission of the GAS Initial Request, Group Addressed GAS Request or GAS Comeback Request Fragment frame, the STA shall set a timer, referred to as the *dot11GASResponseTimer*, equal to dot11GASResponseTimeout or the QueryFailureTimeout parameter provided in the MLME-GAS.request primitive. If both values are present, the timer shall be set to the lesser of the two values.(#6058)

c) If the requesting STA is not in the associated state, it shall remain in active mode until the receipt of a GAS Initial Response, Group Addressed GAS Response or GAS Comeback Response frame with the same value of the Dialog Token field as in the GAS Initial Request frame or until the expiration of the timer, whichever occurs first. If the requesting STA is in the associated state, it may go into power save state until the GAS Initial Response, Group Addressed GAS Response or GAS Comeback Response frame, is available for receipt or the timer expiration, whichever occurs first.(#6058)

d) If the dot11GASResponseTimer expires before a GAS Initial Response, Group Addressed GAS Response or GAS Comeback Response frame is received, the GAS query request was not successful and the MLME shall issue an MLME-GAS.confirm primitive with the ResultCode field set to GAS_QUERY_TIMEOUT and shall set the Query Response Length field to 0.(#6058)

#### 11.22.3.2.3 STA procedures for GAS query request fragmentation(#7053)

The Fragment ID field in the GAS Extension element, when present in a GAS Initial Request frame, indicates that the query request will be transmitted using GAS Comeback Request Fragment and GAS Comeback Response frames that support GAS fragmentation.

If a GAS Query Fragment ID field is present in a GAS Comeback Request Fragment frame the receiving STA shall buffer the query request for a minimum of dot11GASRequestBufferingTime or until the GAS query request is delivered. If the receiving STA does not receive a GAS Comeback Request Fragment frame whose

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source address and dialog token match the source address and value of the Dialog Token field respectively of the corresponding GAS Initial Response frame within this time, it may discard the query request. If the query request received from the requesting STA, is larger than dot11GASQueryRequestLengthLimit for the matching dot11GASAdvertisementID or is larger than the value of the Query Request Length Limit field received from the requesting STA, the responding STA shall discard the request and instead return a status code of GAS_QUERY_REQUEST_TOO_LARGE in the GAS Comeback Response frame. This behavior helps to prevent abuses of the medium that may be caused by an overly large GAS query request.

If the GAS query request received from the requesting STA is greater than the maximum MMPDU size, then the GAS Query Fragment ID shall be set to 0 if this is the first fragment of the query request transmitted; otherwise it shall be incremented by 1; the More GAS Fragments field in the GAS Query Fragment ID shall be set to 1 if there are more fragments of the query request to be transmitted; otherwise it shall be set to 0 (i.e., this fragment is the last fragment of the query request). If a requesting STA receives a GAS Comeback Response that includes the GAS Extension element with the Fragment ID field set to a valid Fragment ID the requesting STA shall transmit a GAS Comeback Request Fragment frame that includes the fragment corresponding to the received Fragment ID.

If the responding STA supports the GAS extension, and the responding STA is unable to receive a GAS query request fragment, then the following procedures apply:

a) If the Fragment Retransmission subfield in the GAS Extension element in the corresponding GAS Initial Request frame is equal to 1, the responding STA may transmit a GAS Comeback Response frame, including the GAS Extension element with the Fragment ID subfield of the GAS Flags field set to the fragment ID of the query request to be retransmitted. Upon receiving the GAS Comeback Response, the requesting STA shall transmit a GAS Comeback Request Fragment frame that includes the query request fragment corresponding to the value received in the Fragment ID field and with the GAS Query Fragment ID subfield in the GAS Comeback Request Fragment frame(#7053) set to the value received in the Fragment ID field. If the Query Request fragment is not available, the requesting STA shall respond with a GAS Comeback Request Fragment frame with a status code set to GAS_FRAGMENT_NOT_AVAILABLE.

b) If the corresponding GAS Initial Request frame does not contain a GAS Extension element or the Fragment Retransmission subfield in the GAS Extension element is equal to 0, the responding STA shall not request the retransmission of a query request fragment using a GAS Comeback Response frame.

If a responding STA receives a GAS Comeback Request Fragment frame with status equal to SUCCESS and the More GAS Fragments field in the GAS Query Fragment ID equal to:

- 1, it shall transmit another GAS Comeback Response frame in order to retrieve the next GAS fragment of a multi-fragment query request.

- 0, the responding STA's MLME shall determine that all fragments have been received by confirming that all fragment IDs from 0 to the value in the GAS Query Fragment ID when the More GAS Fragments field was equal to 0 have been received. Upon receipt of the first GAS Comeback Request Fragment frame and every GAS Comeback Request Fragment frame thereafter, the dot11GASRequestTimer shall be reset.

If all of the query request fragments were received before the expiration of the dot11GASRequestTimer, then the MLME shall issue an MLME-GAS.confirm primitive with result code set to SUCCESS along with the query request.

If not all of the query request fragments were received before the expiration of the dot11GASRequestTimer, then the MLME shall issue an MLME-GAS.confirm primitive with the ResultCode field set to GAS_QUERY_TIMEOUT and shall set the Query Request Length field to 0.


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If a requesting STA receives a GAS Comeback Request frame with a Status Code field equal to either: GAS_QUERY_REQUEST_TOO_ LARGE then the MLME shall issue an MLME-GAS.confirm primitive with the ResultCode field set to the value of the Status Code field and shall set the Query Request Length field to 0.

After a responding STA receives the first GAS fragment of a multi-fragment query request, it shall continue retrieving the query request until all GAS fragments are received or until a transmission failure is detected; the responding STA shall not commence the reception of another query request from the same STA until all GAS fragments are received or until a transmission failure is detected on the first quest request.

#### 11.22.3.2.4 STA procedures to post a GAS query request to an advertisement server(#571)(#7052)

(#6058)Upon receipt of a GAS Initial Request, Group Addressed GAS Request or GAS Comeback Request Fragment frame, an MLME-GAS.indication primitive shall be issued to the STA's SME. Upon receipt of an MLME-GAS.indication primitive indicating the receipt of a GAS Initial Request, Group Addressed GAS Request or GAS Comeback Request Fragment frame, the STA shall transmit a GAS Initial Response, Group Addressed GAS Response or GAS Comeback Response frame to the requesting STA according to the following procedures. If the requesting STA is in the associated state and in the power save mode, the responding STA shall buffer the MMPDU for transmission according to the procedures in 11.2.3 (Power management in a non-DMG infrastructure network); otherwise the STA shall queue the MMPDU for transmission as follows:

a) If the Advertisement Protocol ID field in the Advertisement Protocol element does not equal the value contained in any dot11GASAdvertisementID, then the STA shall not post the query request(#6058) to an advertisement server(#571). The STA shall transmit an individually addressed GAS Initial Response frame to the requesting STA containing a dialog token whose value is identical to the dialog token in the GAS Initial Request frame, a Status Code field(#3326) equal to GAS_ADVERTISEMENT_PROTOCOL_NOT_SUPPORTED (see Table 9-80 (Status codes)), an Advertisement Protocol element containing the Advertisement Protocol ID field used in the GAS Initial Request frame and GAS Comeback Delay and Query Response Length fields both set to 0.(#3326)(#4356)

b) If the query request corresponds to an advertisement protocol whose server is currently unreachable, the responding STA shall transmit an individually addressed GAS Initial Response frame to the requesting STA containing a dialog token whose value is identical to the dialog token in the GAS Initial Request frame, a Status Code equal to SERVER_UNREACHABLE, an Advertisement Protocol element containing an Advertisement Protocol ID field equal to the advertisement protocol ID contained in the GAS Initial Request frame and (#4356)GAS Comeback Delay and Query Response Length fields(#4356) both set to 0. The method used by the AP to determine the server is unreachable is out of scope of this standard. A STA receiving a status code indicating SERVER_UNREACHABLE should wait at least 1 minute before transmitting any further queries using the same advertisement protocol ID to the responding STA.

c) If the GAS Initial Request frame includes a CAG Number element and all the CAG Versions in the CAG Number element match a valid CAG Version that the STA receives from the associated advertisement server(#571), which is identified by the CAG Information Type subfield within the same CAG Tuple field as the CAG Version subfield, then the STA may transmit an individually addressed GAS Initial Response frame to the requesting STA containing a dialog token whose value is identical to the dialog token in the GAS Initial Request frame, a Status Code equal to SUCCESS_CAG_VERSIONS_MATCH, an Advertisement Protocol element containing the Advertisement Protocol ID field used in the GAS Initial Request frame, and GAS Comeback Delay and Query Response Length fields(#4356) both set to 0, without posting the query to an advertisement server(#571). This completes the GAS query request and GAS query response exchange.(#6058)

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d) If the Advertisement Protocol ID field in the Advertisement Protocol element equals the value contained in any dot11GASAdvertisementID, then the STA shall initialize a timer, referred to as the *PostReplyTimer*, to the value of the Maximum Channel Time field times 10, if received in the GAS Initial Request or Group Addressed GAS Request frame, or otherwise, to the value in dot11GASResponseTimeout. The STA posts the query to the advertisement server identified by the advertisement protocol ID.

e) (#6058)If the GAMode associated with the Query Request is true, the STA includes the GAMode parameter, the GAS extension information, the MAC Address, and the Dialog token when it posts the query to the advertisement server(#571) for processing. The methods and protocols the STA uses to post the query are outside the scope of this standard.

   1) If the GAMode associated with the Query Request is true and the advertisement server(#571) has no response to the Query Request, the advertisement server(#571) may (#3683)ignore the request.

   2) If the advertisement server(#571) receives multiple GAS query requests resulting in the same response, the advertisement server(#571) may aggregate these responses into a single GAS query response. The advertisement server(#571) responds to the STA including the aggregated responses as described in 11.22.3.2.6 (Group addressed GAS procedures).(#6058)

f) If dot11GASPauseForServerResponse is false, the responding STA shall transmit an individually addressed GAS Initial Response frame to the requesting STA containing a dialog token whose value is identical to the dialog token in the GAS Initial Request frame, a Status Code field(#3326) set to SUCCESS, an Advertisement Protocol element containing the Advertisement Protocol ID field used in the GAS Initial Request frame, a GAS Comeback Delay field(#3326) set to the value in dot11GASComebackDelay for this advertisement protocol and a Query Response Length field(#3326) set to 0.

g) If dot11GASPauseForServerResponse is true, the GAS query response is delivered as defined in 11.22.3.2.5 (STA procedures for transmitting the GAS query response(#7054)).(#6058)

### 11.22.3.2.5 STA procedures for transmitting the GAS query response(#7054)

After receiving a query response from the advertisement server(#571), the responding STA shall buffer the query response for a minimum of dot11GASResponseBufferingTime after the expiration of the GAS comeback delay timer(#4356) or until the query response is delivered. If the responding STA does not receive a GAS Comeback Request frame whose source MAC address and dialog token match the source MAC address and value of the Dialog Token field respectively of the corresponding GAS Initial Response frame within this time, it may (#3683)discard the query response. If the query response received from the advertisement server(#571) is larger than dot11GASQueryResponseLengthLimit for the matching dot11GASAdvertisementID or is larger than the value of the Query Response Length Limit field received from the requesting STA, the responding STA shall discard the response and instead return a status code of GAS_QUERY_RESPONSE_TOO_ LARGE in the GAS Comeback Response frame. This behavior helps to prevent abuses of the medium that may be caused by overly general queries, which evoke a very large query response.

The GAS protocol supports Query Responses whose length is greater than the IEEE 802.11 maximum MMPDU size by the (#6058)responding STA's use of the GAS Query (#6058)Fragment ID field in the GAS Comeback Response frame; the (#6058)GAS Query Fragment ID shall be set to 0 for the initial fragment and incremented by 1 for each subsequent fragment in a multi-fragment query response. If the (#6058)GAS query response is a multi-fragment response (i.e., contains more than 1 fragment), the STA shall transmit all fragments that belong to the same Query Response until all fragments are exhausted. The STA shall set the More GAS Fragments field of the GAS Query (#6058)Fragment ID to 0 when the transmitted fragment is the final fragment.


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If the GAS Initial Request frame that initiated the GAS transaction contains a Multi-band element, but the GAS Initial Response frame transmitted as a response does not contain a copy of the same Multi-band element, the (#7190)status code in the GAS Initial Response frame shall be set to REQUEST_DECLINED. Otherwise, the requesting and responding STAs shall include a copy of the same Multi-band element in all subsequent GAS Initial Response, GAS Comeback Request, and GAS Comeback Response frames transmitted as part of the GAS transaction. Inclusion of the Multi-band element indicates to which frequency band the GAS transaction applies. If the GAS Initial Request frame that initiated the GAS transaction does not contain a Multi-band element, then none of the subsequent GAS Initial Response, GAS Comeback Request, and GAS Comeback Response frames transmitted as part of the GAS transaction shall include a Multi-band element.

The following procedures shall be used by the responding STA to deliver the query response to the requesting STA:

a) If dot11GASPauseForServerResponse is true:

   1) If the query response is received from the advertisement server(#571) before the PostReplyTimer expires, and if the query response's length is less than or equal to the maximum MMPDU size and the query response is not an aggregated response, the STA shall transmit an individually addressed GAS Initial Response frame to the requesting STA containing a dialog token whose value is identical to the dialog token in the GAS Initial Request frame, the Status Code field(#4356) set to SUCCESS, an Advertisement Protocol element containing the Advertisement Protocol ID field used in the GAS Initial Request frame or the Group Addressed Request frame, a GAS Comeback Delay field set to 0, a Query Response field and a Query Response Length field set to the query response length. This completes the GAS request and response exchange.(#4356)

   2) If the query response is received from the advertisement server(#571) before the PostReplyTimer expires, and if the query response's length is less than or equal to the maximum MMPDU size and the query response is an aggregated response, the STA shall transmit a Group Addressed GAS Response frame containing a dialog token set to 0, the Status Code field(#4356) set to SUCCESS, an Advertisement Protocol element containing the Advertisement Protocol ID field used in the GAS Initial Request frame or the Group Addressed Request frame, a GAS Comeback Delay field set to 0, a Query Response field and a Query Response Length field set to the query response length, and a GAS Extension element containing a list of MAC Address/Dialog Token pairs in the Response Map Duples subfield of the GAS Extension element, identifying the requesting STAs and their Query Requests to which the Group Addressed GAS Response frame responds. This completes the (#4173)(#6058)GAS query request and GAS query response frame exchange.

   3) If the PostReplyTimer expires before the query response is received from the advertisement server(#571) for responding to a GAS Initial Request frame, then the responding STA shall transmit an individually addressed GAS Initial Response frame to the requesting STA containing a dialog token whose value is identical to the dialog token in the GAS Initial Request frame, a Status Code field(#3326) set to GAS_QUERY_TIMEOUT (see Table 9-80 (Status codes)), an Advertisement Protocol element containing the Advertisement Protocol ID field used in the GAS Initial Request frame, (#3326) and GAS Comeback Delay and Query Response Length fields both set to 0. If the query response is subsequently received from the advertisement server(#571), it shall be (#3683)ignored by the responding STA.

   4) If the PostReplyTimer expires before the query response is received from the advertisement server(#571) for responding to a Group Addressed GAS Request frame, then the responding STA shall not transmit an individually addressed GAS Initial Response frame or a Group Addressed GAS Response frame to the requesting STA.

      NOTE—If there is no response to the Query Request, the advertisement server(#571) may (#3683)ignore the request.

   5) If the Query Response received from the advertisement server(#571) is larger than dot11GASQueryResponseLengthLimit or requires more than 128 fragments for transmission

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to the requesting STA, it shall be (#3683)ignored by the responding STA. Then the responding STA shall transmit an individually addressed GAS Initial Response frame to the requesting STA containing a dialog token whose value is identical to the dialog token in the GAS Initial Request frame, a Status Code field(#3326) set to GAS_QUERY_RESPONSE_TOO_ LARGE (see Table 9-80 (Status codes)), an Advertisement Protocol element containing the Advertisement Protocol ID field used in the GAS Initial Request frame, and GAS Comeback Delay and Query Response Length fields both set to 0.(#3326)

6) If the query response's length is larger than the maximum MMPDU size, the responding STA shall transmit an individually addressed GAS Initial Response frame to the requesting STA containing a dialog token whose value is identical to the dialog token in the GAS Initial Request frame, a Status Code field(#3326) set to SUCCESS, an Advertisement Protocol element containing the Advertisement Protocol ID field used in the GAS Initial Request frame, a GAS Comeback Delay field set to 1 (TU), and a Query Response Length field set to 0;(#4356) this indicates the query response will be transmitted using GAS Comeback Request and Response frames that support GAS fragmentation as follows. If the responding STA is capable of retransmitting a Query Response fragment upon request, the responding STA shall include, in the GAS Initial Response frame, a GAS Extension element with the Fragment Retransmission subfield of the GAS Flags field set to 1.

b) If dot11GASPauseForServerResponse is false:

1) If the PostReplyTimer expires before the (#6058)GAS query response is received from the advertisement server(#571) then the responding STA shall buffer for transmission a GAS Comeback Response frame with (#3326)a Status Code field set to GAS_QUERY_TIMEOUT (see Table 9-80 (Status codes)). (#3683)If the query response is subsequently received from the advertisement server(#571), it shall be ignored by the STA.

2) If the Query Response received from the advertisement server(#571) is larger than dot11GASQueryResponseLengthLimit, it shall be (#3683)ignored by the responding STA. Then the STA shall buffer for transmission a GAS Comeback Response frame with status code set to GAS_QUERY_RESPONSE_TOO_ LARGE.

c) If the Query Response is received before the expiration of the PostReplyTimer and its length is less than dot11GASQueryResponseLengthLimit, then the Query Response shall be buffered in one or more GAS Comeback Response frames with status code set to SUCCESS. The responding STA transmits one GAS Comeback Response frame in response to each GAS Comeback Request frame. If the Query Response received from the advertisement server(#571) is less than or equal to the maximum MMPDU size, then the GAS Query (#6058)Fragment ID shall be set to 0 and the More GAS Fragments field in the GAS Query (#6058)Fragment ID shall be set to 0. If the Query Response received from the advertisement server(#571) is greater than the maximum MMPDU size, then the GAS Query (#6058)Fragment ID shall be set to 0 if this is the first fragment of the Query Response transmitted; otherwise it shall be incremented by 1; the More GAS Fragments field in the GAS Query (#6058)Fragment ID shall be set to 1 if there are more fragments of the Query Response to be transmitted; otherwise it shall be set to 0 (i.e., this fragment is the last fragment of the Query Response). If a responding STA receives a GAS Comeback Request that includes the GAS Extension element with the Fragment ID field set to a valid Fragment ID the responding STA shall respond with a GAS Comeback Response frame that includes the fragment corresponding to the received Fragment ID.

d) If a responding STA receives a GAS Comeback Request frame whose source MAC address and dialog token match the destination MAC address and value of the Dialog Token field respectively of an outstanding GAS Initial Response frame and the query response has not been received from the advertisement server(#571) and the PostReplyTimer has not expired, the responding STA shall transmit a GAS Comeback Response frame (#3326)with a Status Code field set to


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GAS_RESPONSE_NOT_RECEIVED_FROM_SERVER (see Table 9-80 (Status codes)) and (#4356)a GAS Comeback Delay field set to the value in dot11GASComebackDelay for this advertisement protocol to indicate when the requesting STA should come back to obtain its Query Response.

e) If a responding STA receives a GAS Comeback Request frame whose source MAC address and Dialog Token do not match the destination MAC address and value of the Dialog Token field respectively of an outstanding GAS Initial Response frame, the STA should transmit a GAS Comeback Response frame with a status code equal to NO_OUTSTANDING_GAS_REQUEST.

A requesting STA shall transmit a GAS Comeback Request frame including the Dialog Token (drawn from the corresponding GAS Initial Response frame) immediately after the expiration of the GAS Comeback Delay. In response, the responding STA provides the Query Response in one or more GAS Comeback Response frames with the corresponding Dialog Token.

If the requesting STA supports (#6058)the GAS extension, and the requesting STA is unable to receive a (#6058)GAS query response fragment, then the following procedures apply:

a) If the Fragment Retransmission subfield in the GAS Extension element in the corresponding GAS Initial Response frame is equal to 1, the requesting STA may transmit a GAS Comeback Request frame, including the GAS Extension element with the Fragment ID subfield of the GAS Flags field set to the fragment ID of the Query Response to be retransmitted. Upon receiving the GAS Comeback Request frame(#6058), the responding STA shall transmit a GAS Comeback Response frame that includes the Query Response fragment corresponding to the value received in the Fragment ID field and with the GAS Query (#6058)Fragment ID subfield in GAS Query (#6058)Fragment field set to the value received in the Fragment ID field. If the Query Response fragment is not available, the (#6155)responding STA shall respond with a GAS Comeback Response frame with a status code set to GAS_FRAGMENT_NOT_AVAILABLE.

b) If the corresponding GAS Initial Response frame does not contain a GAS Extension element or the (#6058)Fragment Retransmission subfield in the GAS Extension element is equal to 0, the requesting STA shall not request the retransmission of a GAS query response(#7054) fragment using a GAS Comeback Request frame.

If a requesting STA receives a GAS Comeback Response frame with status equal to QUERY_RESPONSE_OUTSTANDING, the requesting STA shall wait for the expiration of the GAS comeback delay timer(#4356) from that frame and then, transmit another GAS Comeback Request frame. If the requesting STA's dot11GASResponseTimer (set in 11.22.3.2.2 (STA procedures to transmit a GAS query request(#7052)) step b) expires prior to receiving a GAS Comeback Response frame whose source MAC address and dialog token match those in the corresponding GAS Initial Response frame, the STA shall issue an MLME-GAS.confirm primitive with the ResultCode filed set(#6058) to GAS_QUERY_TIMEOUT and shall set the Query Response Length field(#6058) to 0.

If a requesting STA receives a GAS Comeback Response frame with status equal to SUCCESS and the More GAS Fragments field in the GAS Query Response Fragment ID equal to:(#6058)

— 1, it shall transmit another GAS Comeback Request frame in order to retrieve the next GAS fragment of a multi-fragment query response.

— (#6058)0, the requesting STA's MLME shall determine that all fragments have been received by confirming that all fragment IDs from 0 to the value in the GAS Query (#6058)Fragment ID when the More GAS Fragments field was equal to 0 have been received. Upon receipt of the first GAS Comeback Response frame and every GAS Comeback Response frame thereafter, the dot11GASResponseTimer shall be reset. If all of the query response fragments were received before the expiration of the dot11GASResponseTimer, then the MLME shall issue an MLME-GAS.confirm primitive with result code set to SUCCESS along with the query response. If not all of the query response fragments were received before the expiration of the dot11GASResponseTimer,

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then the MLME shall issue an MLME-GAS.confirm primitive with the ResultCode field set(#6058) to GAS_QUERY_TIMEOUT and shall set the Query Response Length field(#6058) to 0.

After a requesting STA receives the first GAS fragment of a multi-fragment query response, it shall continue retrieving the query response until all GAS fragments are received or until a transmission failure is detected; the requesting STA shall not commence the retrieval of another GAS query response(#7054) from the same STA until all GAS fragments are received or until a transmission failure is detected on the first GAS query response(#7054).

If a requesting STA receives a GAS Comeback Response frame with a Status Code field equal to either: GAS_QUERY_TIMEOUT, GAS_QUERY_RESPONSE_TOO_ LARGE or NO_OUTSTANDING_GAS_REQUEST, then the MLME shall issue an MLME-GAS.confirm primitive with the ResultCode field set to the value of the Status Code field and shall set the Query Response Length field to 0.(#6058)

#### 11.22.3.2.6 Group addressed GAS procedures

Upon receipt of an MLME-GAS.request primitive with the GAMode parameter set to 1 (true), the requesting STA shall follow procedures defined in 11.22.3.2.2 (STA procedures to transmit a GAS query request(#7052)) to transmit a Group Addressed GAS Request frame instead of a GAS Initial Request frame.

Upon receipt of an aggregated Query Response from the advertisement server(#571), the responding STA may transmit the aggregated Query responses using Group Addressed GAS Response frame to the receiving STAs. The length of the Group Addressed GAS Response frame shall not exceed the IEEE 802.11 maximum MMPDU size. The STA shall include a list of MAC Address/Dialog Token pairs in the Response Map Duples subfield of the GAS Extension element included in the Group Addressed GAS Response frame.

#### 11.22.3.2.7 GAS procedures interaction with multiple BSSID set

Non-AP STAs in the unassociated state may use GAS procedures to query advertisement servers(#571) for information. As described in 11.22.3.2 (GAS Protocol), APs indicate their support for a particular GAS advertisement protocol by including an (#4261)Advertisement Protocol element with that advertisement protocol ID in Beacon and Probe Response frames as described in 9.3.3.2 (Beacon frame format) and 9.3.3.10 (Probe Response frame format) respectively. Non-AP STAs receiving Beacon or Probe Response frames from different APs may choose to engage in GAS frame exchange(#109) with one or more of these APs. In some deployment scenarios, these APs may be operating as a multiple BSSID set (as defined in 11.10.14 (Multiple BSSID set)) and may relay the GAS queries to the same advertisement server(#571). Depending on the configuration of the IEEE 802.11 access network, the external network and the advertisement server(#571), a query response from the advertisement server(#571) might or might not be dependent on the BSSID used in the GAS frame exchange(#109) and thus the STA from which the query was relayed. If the GAS query response(#7054) is dependent on the BSSID, a requesting STA may choose to post queries using GAS procedures to more than one STA and expect possibly different Query Responses. If the Query Response is not dependent on the BSSID, then a requesting STA may choose to post queries using GAS procedures to only one STA in the multiple BSSID set (i.e., posting the same query to another member of the multiple BSSID set would yield the same response).

When a Multiple BSSID (as defined in 11.10.14 (Multiple BSSID set)) set contains two or more members and dot11InterworkingServiceActivated is true and dot11GASAdvertisementID is present and a query to the advertisement server(#571) corresponding to dot11GASAdvertisementID is not dependent on the BSSID(#3522) used in the GAS frame exchange(#109) to post the query, then the PAME-BI bit in the Advertisement Protocol tuple of the Advertisement Protocol element corresponding to dot11GASAdvertisementID shall be set to 1; otherwise this bit shall be set to 0.


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### 11.22.3.3 ANQP procedures

#### 11.22.3.3.1 General

A STA may use ANQP to retrieve information as defined in Table 9-426 (ANQP-element definitions) from a peer STA.

A non-AP STA shall not transmit an ANQP request to an AP for any ANQP-element unless the ANQP Advertisement Protocol ID field is included in the Advertisement Protocol element in a Beacon or Probe Response frame from that AP.

A STA shall unless specified otherwise ignore an ANQP request or response that contains non-reserved field/ subfield values that are not known to it.(#1618)

The ANQP request consists of one or more (#1537)ANQP-elements drawn from Table 9-426 (ANQP-element definitions) having an element type of Q in Table 11-20 (ANQP usage) and shall be ordered by nondecreasing Info ID. A Query List ANQP-element included in an ANQP request is formed as described in 11.22.3.2.2 (STA procedures to transmit a GAS query request(#7052)). The ANQP request is transported in the Query Request field of (#7167)Group Addressed GAS Request frames as described in 11.22.3.2.5 (STA procedures for transmitting the GAS query response(#7054)).

The ANQP response is transported in the Query Response field of GAS Response frames. The AP should include in the ANQP response the ANQP-elements requested by the non-AP STA (in the Query List ANQP-element of the ANQP request) that are available at the AP, using the procedure described in 11.22.3.2.5 (STA procedures for transmitting the GAS query response(#7054)). The AP should provide the ANQP-elements requested by the non-AP STA that are not available at the AP at the time of the request but can be obtained by the AP from an advertisement server, using the comeback procedure described in 11.22.3.2 (GAS Protocol). The AP shall not include an ANQP-element in the ANQP response that was not requested by the non-AP STA. ANQP-elements in the ANQP response shall have an ANQP-element type of S in Table 11-20 (ANQP usage) and shall be ordered by nondecreasing Info ID. The non-AP STA may interpret ANQP-elements in any order. The interpretation of ANQP-elements whose semantics overlap is implementation dependent.(#96)

**Table 11-20—ANQP usage**

| ANQP-element name | ANQP-element (subclause) | ANQP-element type | BSS | | IBSS |
|---|---|---|---|---|---|
| | | | AP | Non-AP and non-PCP STA | STA |
| Query List | 9.4.5.2 (Query List ANQP-element) | Q | T, R | T, R | T, R |
| Capability List | 9.4.5.3 (Capability List ANQP-element) | S | T, R | T, R | T, R |
| Venue Name | 9.4.5.4 (Venue Name ANQP-element) | S | T | R | — |
| Emergency Call Number | 9.4.5.5 (Emergency Call Number ANQP-element) | S | T | R | — |

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**Table 11-20—ANQP usage *(continued)***

| ANQP-element name | ANQP-element (subclause) | ANQP-element type | BSS | | IBSS |
|---|---|---|---|---|---|
| | | | AP | Non-AP and non-PCP STA | STA |
| Network Authentication Type | 9.4.5.6 (Network Authentication Type ANQP-element) | S | T | R | — |
| Roaming Consortium | 9.4.5.7 (Roaming Consortium ANQP-element) | S | T | R | — |
| Vendor Specific | 9.4.5.8 (Vendor Specific ANQP-element) | Q, S | T, R | T, R | T, R |
| IP Address Type Availability | 9.4.5.9 (IP Address Type Availability ANQP-element) | S | T, R | T, R | T, R |
| NAI Realm | 9.4.5.10 (NAI Realm ANQP-element) | S | T | R | T, R |
| 3GPP Cellular Network | 9.4.5.11 (3GPP Cellular Network ANQP-element) | S | T | R | — |
| AP Geospatial Location | 9.4.5.12 (AP Geospatial Location ANQP-element) | S | T | R | T, R |
| AP Civic Location | 9.4.5.13 (AP Civic Location ANQP-element) | S | T | R | T, R |
| AP Location Public Identifier URI/FQDN | 9.4.5.14 (AP Location Public Identifier URI/ FQDN ANQP-element) | S | T | R | T, R |
| Domain Name | 9.4.5.15 (Domain Name ANQP-element) | S | T | R | — |
| Emergency Alert Identifier URI | 9.4.5.16 (Emergency Alert URI ANQP-element) | S | T | R | T, R |
| TDLS Capability | 9.4.5.18 (TDLS Capability ANQP-element) | Q, S | T,R | T,R | T, R |


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**Table 11-20—ANQP usage *(continued)***

| ANQP-element name | ANQP-element (subclause) | ANQP-element type | BSS | | IBSS |
|---|---|---|---|---|---|
| | | | AP | Non-AP and non-PCP STA | STA |
| Emergency NAI | 9.4.5.17 (Emergency NAI ANQP-element) | S | T | R | — |
| Neighbor Report | 9.4.5.19 (Neighbor Report ANQP-element) | S | T | R | — |
| Venue URL | 9.4.5.20 (Venue URL ANQP-element) | S | T | R | — |
| Advice of Charge | 9.4.5.21 (Advice of Charge ANQP-element) | S | T | R | — |
| Local Content | 9.4.5.22 (Local Content ANQP-element) | S | T | R | — |
| Network Authentication Type with Timestamp | 9.4.5.23 (Network Authentication Type with Timestamp ANQP-element) | S | T | R | — |
| Query AP List | 9.4.5.24 (Query AP List ANQP-element) | Q | R | T | — |
| AP List Response | 9.4.5.25 (AP List Response ANQP-element) | S | T | R | — |
| Common Advertisement Group | 9.4.5.26 (CAG ANQP-element) | S | T | R | — |
| Service Information Request | 9.4.5.27 (Service Information Request ANQP-element) | Q | R, G | T, G | — |
| Service Information Response | 9.4.5.28 (Service Information Response ANQP-element) | S | T, G | R, G | — |
| Local MAC Address Policy | 9.4.5.29 (Local MAC Address Policy ANQP-element) | S | T | R | — |

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**Table 11-20—ANQP usage *(continued)***

| ANQP-element name | ANQP-element (subclause) | ANQP-element type | BSS | | IBSS |
|---|---|---|---|---|---|
| | | | AP | Non-AP and non-PCP STA | STA |
| Credential Types(#93) | 9.4.5.33 (Credential Types ANQP-element(#93)) | S | T | R | — |
| Service Level Agreement(#93) | 9.4.5.34 (Service Level Agreement ANQP-element(#93)(#1090)) | S | T | R | — |
| Excluded NAI Realm(#93) | 9.4.5.35 (Excluded NAI Realm ANQP-Element(#93)) | S | T | R | — |
| (11bc)EBCS | 9.4.5.30 (EBCS ANQP-element(11bc)) | S | T, R, G | R, G | — |
| (11bc)EBCS Content Request | 9.4.5.31 (EBCS Content Request ANQP-element(11bc)) | Q | T, R | T | — |
| (11bc)EBCS Content Response | 9.4.5.32 (EBCS Content Response ANQP-element(11bc)) | S | T | R | — |

**Symbols**
Q element is an ANQP request
S element is an ANQP response
T ANQP-element may be transmitted by MAC entity
R ANQP-element may be received by MAC entity
G Group addressed ANQP request/response may be transmitted and received by a MAC entity
— ANQP-element is neither transmitted nor received by MAC entity

A STA receiving a CAG ANQP-element in an ANQP response should cache the ANQP-element contents, for later use. The STA caches the ANQP CAG Version and ANQP responses corresponding to each Info ID from the received CAG ANQP-element together with the values of BSSID, or HESSID and the corresponding SSID of the responding AP's BSS. The STA obtains the required ANQP responses either as an ANQP response to a previous ANQP request, or by transmitting an ANQP request for the ANQP response .

The AP obtains the current value of a CAG Version from the associated advertisement server. How the AP obtains the value of the CAG Version from the associated advertisement server is out of the scope of this standard.


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When dot11InterworkingServiceActivated is true, an AP may provide one or more current version numbers of the CAG (CAG Version) associated with the AP, where each version number is associated with a specific advertisement protocol by including the CAG Number element in the Beacon or Probe Response frame.

In order to reduce the network discovery delay at an AP, the BSSID, HESSID, or the corresponding SSID of that AP's BSS are used as a key index in the STA's cache to determine if an ANQP CAG Version received from an AP matches previously cached information.

A STA that makes use of the CAG Version is subject to the following:

— The STA may obtain the CAG Version from the CAG Number element received in Beacon or Probe Response frames.

— The STA searches its cached information using the BSSID, HESSID, or SSID of the AP's BSS as an index to obtain the correct cached ANQP CAG Version entry.

— If the cached ANQP CAG Version does not match the CAG version received in Beacon or Probe Response frames, the STA should transmit an ANQP request for any of the ANQP-elements contained within the CAG. If the CAG Versions do match, the STA should use the cached (#1537)ANQP-elements corresponding to the CAG Version for network discovery.

The mapping of the ANQP CAG Version to the (#1537)ANQP-elements by an advertisement server is outside the scope of this standard.

ANQP usage for infrastructure BSSs and IBSSs shall be in accordance with Table 11-20 (ANQP usage). ANQP usage defines the entities permitted to transmit and receive particular ANQP-elements.

A STA having dot11InterworkingServiceActivated equal to true shall support(#546) using the Query List ANQP-element to request the Capability List ANQP-element; support for all other ANQP-elements is optional.

A STA that encounters an unknown or reserved ANQP Info ID value in a GAS frame (see(#4288) Table 9-426 (ANQP-element definitions)) received without error shall ignore that ANQP Info ID and shall parse any remaining ANQP Info IDs.

A STA that encounters an unknown vendor-specific OI field or subfield in a GAS frame (see 9-471 (Public Action field values)) received without error shall ignore that field or subfield respectively, and shall parse any remaining fields or subfields for additional information with recognizable field or subfield values.

#### 11.22.3.3.2 Query list procedure

The Query List ANQP-element is used by a requesting STA to perform an ANQP request using the procedures defined in 11.22.3.3.1 (General). The requesting STA may include Info IDs in the Query List ANQP-element (#1538)that do not include "Q" in the ANQP-element type as shown in Table 11-20 (ANQP usage); the STA shall not include other Info IDs. The requesting STA should only request the ANQP-elements it needs for its operation.(#92)

A responding STA that encounters an unknown or reserved ANQP Info ID value in an Query List ANQP-element received without error shall ignore that ANQP Info ID and shall parse any remaining ANQP Info IDs.

#### 11.22.3.3.3 Roaming Consortium procedure

The Roaming Consortium ANQP-element, which contains a set of OIs, can be retrieved from an AP by a non-AP STA using the query list procedure defined in 11.22.3.3.2 (Query list procedure). The list of OIs included in the Roaming Consortium ANQP-element shall be those OIs in the dot11RoamingConsortiumTable. An AP may include an OI in the dot11RoamingConsortiumTable, if in conjunction with an AS, it is capable of

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successfully authenticating a non-AP STA having valid security credentials for the SSPN identified by that OI; the AP shall not include an OI otherwise. Methods used by the AP to authenticate the non-AP STA include, but are not limited to, RSNA algorithms and Open System authentication.

Each OI identifies an SSP or group of SSPs (i.e., a roaming consortium). An SSP or group of SSPs can register for and obtain an OI using the procedures described in IEEE SA FAQs—IEEE Registration Authority [B15].

A non-AP STA might have a locally stored binding between an OI and a set of security credentials with which it can authenticate to the network identified by the OI, that is, the SSPN. The method by which this binding is obtained is outside the scope of this standard. A non-AP STA can select from that list of credentials when authenticating to the BSS.

#### 11.22.3.3.4 AP procedure for advertising EAP Method associated with an NAI realm(#3235)

When dot11RSNAActivated is true, NAI realms along with their supported authentication methods may be advertised using the NAI Realm ANQP-element (see 9.4.5.10 (NAI Realm ANQP-element)). Each realm may optionally be associated with a set of EAP methods. Each EAP method may optionally be associated with a set of Authentication Parameters. The NAI realm ANQP-element provides a hint on the methods a STA might use to establish an association in an RSN IEEE 802.1X environment. If the non-AP STA recognizes the NAI realm, it may attempt authentication even if it believes the EAP methods are incorrect.

When dot11RSNAActivated is false and the Network Authentication Type (see 9.4.5.6 (Network Authentication Type ANQP-element)) contains a Network Authentication Type Unit having a Network Authentication Type Indicator field equal to http/https redirection or DNS redirection, NAI realms without supported authentication methods may be advertised using the NAI Realm ANQP-element (see 9.4.5.10 (NAI Realm ANQP-element)).

A non-AP STA having dot11InterworkingServiceActivated equal to true may process the NAI Realm ANQP-element. The selection of the NAI realm the non-AP STA uses for authentication is outside the scope of this standard. A non-AP STA requests the NAI Realm ANQP-element using Query List procedures defined in 11.22.3.3.2 (Query list procedure).

A non-AP STA having dot11InterworkingServiceActivated equal to true may process the EAP Method list as follows:

— The EAP Method list provided by the AP shall be in priority order (the most preferred EAP Method is listed first).
— The credential types help the STA to determine what credentials to use for authentication.
— The STA should confirm the GAS advertisement after an RSNA is established by performing a GAS query request(#7052) for the NAI Realm ANQP-element using Protected Dual of Public Action frames.

NOTE—The advertisements should be confirmed after the RSNA is established to avoid downgrade attacks.

The policy that determines whether a non-AP STA should attempt authentication and/or association with any particular IEEE 802.11 Access Network is outside the scope of this standard.

#### 11.22.3.3.5 3GPP Cellular Network procedure

A STA may retrieve 3GPP Cellular Network information using the Query List procedure in 11.22.3.3.2 (Query list procedure). Realms referenced in the 3GPP Cellular Network ANQP-element should not be included in the NAI Realm ANQP-element (see 9.4.5.10 (NAI Realm ANQP-element)).


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#### 11.22.3.3.6 AP Geospatial Location procedure

A STA may retrieve an AP's geospatial location using the Query List procedure in 11.22.3.3.2 (Query list procedure). A STA in the associated state should retrieve (#7178)geospatial location information from the AP using the procedures in 11.10.9.6 (LCI report (Location configuration information report)).

#### 11.22.3.3.7 AP Civic Location procedure

A STA may retrieve an AP's civic location using the Query List procedure in 11.22.3.3.2 (Query list procedure). A STA in the associated state should retrieve civic location information from the AP using the procedures in 11.10.9.9 (Location Civic report).

#### 11.22.3.3.8 AP Location Public Identifier URI/FQDN procedures

A STA when dot11InterworkingServiceActivated is true may retrieve an AP's Location Public Identifier URI or a location server's FQDN using ANQP procedures in 11.22.3.3 (ANQP procedures). A STA in the associated state should retrieve Location Public Identifier URI/FQDN information from the AP using the procedures in 11.10.9.10 (Location Identifier report).

NOTE—Due to security concerns, there are some URI schemes that ought to be cautiously processed when received by a STA. For example, URIs using the scheme names "data:" and "http:" might direct applications (e.g., a browser) on the STA to Internet pages that contain active scripts. Therefore, URIs received via this ANQP procedure ought not be processed in a general manner, as these scripts might be inadvertently activated.(#351)

#### 11.22.3.3.9 Emergency NAI procedure

A STA that does not have valid credentials to authenticate to a network may use the information in the Emergency NAI ANQP-element as its EAP identity.

The Emergency NAI ANQP-element can be retrieved from the AP using the Query List procedure in 11.22.3.3.2 (Query list procedure).

The STA uses the emergency NAI procedure to indicate its intention to access the network without peer authentication by using the emergency NAI information as its identity in the authentication process, as described in IETF RFC 5216.

#### 11.22.3.3.10 TDLS Capability procedure

A STA may use the TDLS Capability ANQP-element (see 9.4.5.18 (TDLS Capability ANQP-element)) to discover TDLS capabilities of another TDLS STA using the Query List procedure in 11.22.3.3.2 (Query list procedure).

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An example of TDLS capability discovery using ANQP is given in Figure 11-83 (Example TDLS Capability discovery using ANQP(#2152)).

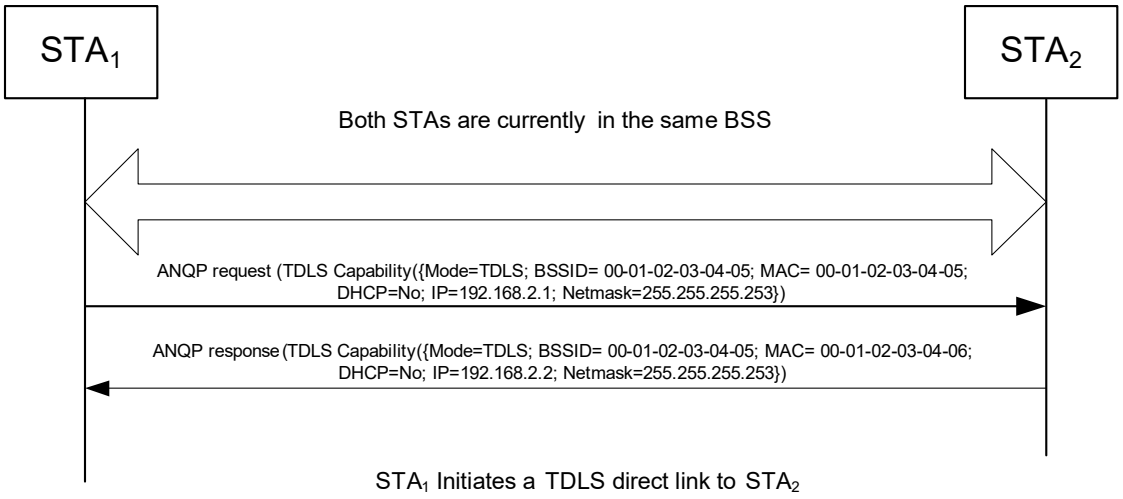


**Figure 11-83—Example TDLS Capability discovery using ANQP(#2152)**

The mechanism shall work as follows:

a) STA1 determines the MAC address of STA2.

b) STA1 sends an ANQP request to STA2. The ANQP request includes a TDLS Capability ANQP-element.

c) STA2 receives the ANQP request and updates the TDLS Capability ANQP-element based on its own capabilities that is returned in the ANQP response to STA1.

#### 11.22.3.3.11 Venue URL procedure

The Venue URL ANQP-element is used to provide web page advertising services or information particular to the venue.

This ANQP-element is to be used in conjunction with the Venue Name ANQP-element, to provide extra information about the venue. Typical operation is to use the Venue Name ANQP-element to determine the list of available venues advertised by a STA, and then the Venue URL ANQP-element is used, if required, to determine a list of Venue URLs, each entry corresponding to the Venue Name entry in the list returned by the Venue Name ANQP-element.

#### 11.22.3.3.12 Advice of Charge procedure

The Advice of Charge ANQP-element is used to provide financial cost advertisements in the form of (#338)advice of charge plan information. The plan information is provided on a per NAI realm basis, so that each authentication realm can advertise the charge associated with obtaining network access. This information might assist with a decision about proceeding with access. Plan information for the special NAI realm "*" is indicated, if none of the explicit NAI realms are currently applicable.

The use and operation of the Plan information schema is outside the scope of this standard.


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As ANQP-elements are transmitted in the clear, prior to STA association, one or more Protected Dual of Public Action frames should be used after association to verify this information.

#### 11.22.3.3.13 Local Content procedure

The Local Content ANQP-element is used to provide local content URLs. Each URL points to local content information that might be relevant, for example by providing information about terms and conditions for BSS access, when automated login procedures are being used.

Several URLs can be provided in the Local Content ANQP-element, each corresponding to a separate state. This allows the STA to display differing local content (e.g., terms and conditions, failure warning information, help page), through the STA association procedure.

For example, the Local Content ANQP-element may return two Local Content Duple fields with values of the State field corresponding to "Not authenticated" and "Failure during authentication." The requesting STA may display the contents of the local web page indicated by the first URL ("Not authenticated") showing terms and conditions of BSS access. If a subsequent association fails, then the requesting STA may display the contents of the local web-page indicated by the second URL ("Failure during authentication") showing a help page.

#### 11.22.3.3.14 Query AP List procedure

The Query AP List ANQP-element is used by a requesting STA to perform a single ANQP request to an AP, using the procedures defined in 11.22.3.3.1 (General) requesting the ANQP information on each AP indicated in the AP list. The requesting STA shall only include Info IDs in the Query List ANQP-element (#1538)that do not include "Q" in the ANQP-element type as shown in Table 11-20 (ANQP usage). Info IDs that have an ANQP-element type of Q shall not be included in the Query AP List ANQP-element (e.g., the Info ID for Vendor Specific ANQP-element shall not be included).

A responding STA that encounters an unknown or reserved ANQP Info ID value in a Query AP List ANQP-element shall ignore that ANQP Info ID and shall parse any remaining ANQP Info IDs.

In the response to a Query AP List, the Query Response field contains an AP List Response ANQP-element. The AP List Response contains multiple query response reports for the APs indicated in the Query AP List. If the responding AP does not provide the requested information for all APs specified in the Query AP List, or for all the requested Info IDs, the STA interprets it as that information not available. How the information obtained from the AP list is used by the STA is left to the implementation and is beyond the scope of this standard(#1560).

#### 11.22.3.3.15 CAG procedure

The CAG ANQP-element is used by a requesting STA to perform an ANQP request to retrieve the Info IDs contained within the CAG associated with ANQP, or ANQP with Service Information Registry, and the current ANQP CAG Version associated with these Info IDs. If the requesting STA to perform an ANQP request to retrieve the Info IDs related both to ANQP and to ANQP with Service Information Registry, the requesting STA shall use separate CAG ANQP-elements. For this purpose, a requesting STA shall use the procedures defined in 11.22.3.3.1 (General) and 11.22.3.3.2 (Query list procedure) and shall include in the ANQP request the Info ID of the CAG ANQP-element as shown in Table 11-20 (ANQP usage). When a responding AP receives a Query List ANQP-element that contains the Info ID of CAG ANQP-element, the responding STA shall include in the GAS query response(#7055) a CAG ANQP-element containing the ANQP CAG Version and the Info IDs of the ANQP-elements that are in the CAG associated with ANQP, or ANQP with Service Information Registry, in the increasing order of the Info ID values. If the responding STA receives Info IDs related both to ANQP and to ANQP with Service Information Registry, the responding STA shall include separate CAG ANQP-elements in the ANQP response. The ANQP response also includes the (other) ANQP-elements that a STA requested in the Query List ANQP-element in the increasing order of the Info ID values.

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The ANQP CAG Version is an unsigned number and it is incremented when there is any change in the CAG associated with ANQP, or ANQP with Service Information Registry, including a change of the Info ID of the ANQP-elements of the CAG or a change in the values of the ANQP-elements included in the CAG. If the ANQP CAG Version exceeds 255, it is reset to 0.

#### 11.22.3.3.16 Local MAC address policy procedure

The Local MAC Address Policy ANQP-element is used by a non-AP STA to discover the MAC address policy for an ESS. The STA should use a MAC address consistent with the local MAC address policy, as determined from the Local MAC Address Policy ANQP-element and the Local MAC Address Policy field in the Extended Capabilities field. An AP may send a DENIED_LOCAL_MAC_ADDRESS_POLICY_VIOLATION status code in an Association Response frame to a STA with a MAC address that is inconsistent with the MAC address policy.

#### 11.22.3.3.17 Enhanced broadcast services procedures(11bc)

EBCS traffic streams may be advertised using the EBCS ANQP-element (see 9.4.5.30 (EBCS ANQP-element(11bc))) transmitted over a GAS query response(#7054) in a GAS Initial Response frame or Group Addressed GAS Response frame. The element describes a set of zero or more EBCS traffic streams that are available from an AP. Each broadcast service advertisement may contain the time and duration of transmission, together with an identifier of the broadcast content (a content ID) and other information relevant to the broadcast service. The information present in each broadcast service advertisement is indicated in a Control field.

NOTE—An EBCS traffic stream signaled in an EBCS ANQP-element might be provided by a malicious user, since the ANQP-element might be unsecured. The origin authentication methods described in 12.15 (Frame authentication for EBCS(11bc)) might be used to authenticate the origin of EBCS traffic streams.

If the content is authenticated in the MAC sublayer(#7173) (nonzero values of the Content Authentication Algorithm field as defined in Table 9-436 (Content Authentication Algorithms(11bc))) or requires negotiation (i.e., one or more of the EBCS Content Request frames, EBCS Content ANQP element, or Out Of Band Request subfields of the Negotiation Method subfield, as defined in 9.4.5.30 (EBCS ANQP-element(11bc)), are set to 1), the information provided by the EBCS ANQP-element needs to be augmented with additional information to receive the traffic stream. The information on the authentication and negotiation method may be obtained in the next EBCS Info frame as indicated by the Content Authentication Algorithm field and in the Negotiation Method field included in the EBCS ANQP-element.

If the content follows the authentication scheme defined in 12.15.4 (No frame authentication with mandatory higher layer source authentication (HLSA)) as indicated by the Content Authentication Algorithm subfield equal to 0 as defined in Table 9-436 (Content Authentication Algorithms(11bc)), the information provided is enough to receive the traffic stream.

The EBCS ANQP-element may be transmitted using a Group Addressed GAS Response frame. In this case, all non-AP STAs and APs may receive the information on the services available at the transmitting AP.

If the EBCS Content Request ANQP-element is one of the permitted negotiation methods, a STA may use it to request registration (or unregistration) from a peer STA. This ANQP-element optionally allows the STA to provide the MAC address of the AP currently serving the EBCS traffic stream, which might not be the same as the one receiving the ANQP request.

#### 11.22.3.3.18 Credentials and Privacy procedure(#93)

Some networks advertise support for multiple SSPs, for example through a roaming consortium However, the venue might only accept credentials from a subset of the roaming consortium members. In other scenarios, the


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venue may have specific constraints on the type of credentials that are acceptable, for example based on the identity verification conducted at the credential creation, or the age of the credentials. The Credential Types ANQP-element is used by a non-AP STA to discover the venue requirements for accepted credentials, which includes the SSP categories that are accepted, and the type of validation and age required for the credentials.

Authentication then occurs(M118) between the non-AP STA and the SSP through a protected tunnel. In some cases, the local venue requires the non-AP STA to also share locally a contactable identity. The Privacy Indicator field in the Credential Types ANQP-element provides an indication on the venue requirements for contactable identity allowing the STA to preserve the user's privacy when identity exposure is not needed.

A Credential Types Tuple subfield shall be ignored if the value in the Validation, Category Group and/or Category Type subfield is reserved.

A First or Second Settlement Indicator subfield and the corresponding First or Second SLA Indicator subfield, respectively, shall be ignored if the value in the First or Second Settlement Indicator subfield, respectively, is reserved.

In some venues, a subset of SSP credentials might not be accepted, for example because they are local competitors. The Excluded NAI Realm ANQP-element provides a list of realms from which credentials are not accepted by the AP.

When multiple credentials are accepted, the local venue may have specific agreements with each SSP based on the roaming profile. The SLA ANQP-element provides the STA with information about the SLA locally available based on the roaming type.

NOTE—How the non-AP STA uses the information indicated by the venue is out of scope of the standard. It is assumed the non-AP STA has a set of local information about credentials that are available, or policies that are acceptable, and proceeds with a connection based on matching this information to the indicated information.

#### 11.22.3.4 Registered location query protocol (RLQP) procedures

When dot11GDDActivated is true, a STA may use RLQP to retrieve information as defined in Table 9-277 (Advertisement protocol ID definitions) from a peer STA that has transmitted an Advertisement Protocol element indicating support for RLQP (see 9.4.2.91 (Advertisement Protocol element)) in a Beacon or Probe Response frame.

If information is not configured for a particular RLQP-element, then a query for that element returns that element with no optional fields.

(#4261)When RLQP is transmitted between a GDD enabling STA and the RLSS, (#3370)MSDUs with (#2186)EtherType 89-0d shall be used, as defined in Annex H. The Payload field of the MSDUs contains RLQP-elements as specified in 9.4.6 (Registered location query protocol (RLQP) elements)(#6207). When an RLQP-element is transmitted between a GDD dependent STA and its GDD enabling STA, protected Action frames shall be used, not MSDUs with (#2186)EtherType 89-0d.

(#4261)NOTE 1—In some regulatory domains, the GDD enabling STA may be required to have a secured connection with the RLSS.(#399)

When security is required by regulation, (#3370)the Payload field of the MSDUs with (#2186)EtherType 89-0d body may employ corresponding security features. Alternatively, various security protocols may also be selected by setting the (#2186)EtherType field to respective values. The IEEE Registration Authority provides a public listing of (#2186)EtherTypes and other identifiers at https://regauth.standards.ieee.org/standards-ra-web/pub/view.html#registries.

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### 11.22.4 Interworking procedures: IEEE 802.21 MIS support

IEEE Std 802.21-2017 enables the optimization of services when performed between heterogeneous IEEE 802 networks. IEEE Std 802.21.1-2017 defines a handover service, which is used in conjunction with IEEE Std 802.21-2017.

STAs with dot11InterworkingServiceActivated equal to true and (#578)dot11GASAdvertisementId equal to MIS Information Service (see Table 9-277 (Advertisement protocol ID definitions)) shall support the transmission and reception of IEEE 802.21 MIIS queries for STAs in all states. STAs with dot11InterworkingServiceActivated equal to true and (#578)dot11GASAdvertisementId equal to MIS Command and Event Services Capability Discovery (see Table 9-277 (Advertisement protocol ID definitions)) shall provide support for IEEE 802.21 MICS/MIES capability discovery for non-AP STAs in all states.

Additionally, support for IEEE 802.21 MIIS query and IEEE 802.21 MICS/MIES capability discovery to non-AP STA's in the associated state is provided by the STA forwarding IP datagrams destined for the MIS point of service to the IEEE 802.21 MIIS server.

A non-AP STA discovers support for these services by receiving Beacon or Probe Response frames with an Advertisement Protocol element having advertisement protocol ID(s) for MIS Information Service and/or IEEE 802.21 MICS/MIES capability discovery.

A non-AP STA forms an IEEE 802.21 information service query by creating its query request according to the procedures defined in IEEE Std 802.21-2017 and formatting that request into an IEEE 802.21 MIS protocol frame as defined in 8.4 of IEEE Std 802.21-2017. The non-AP STA, using the procedures in 11.22.3.2 (GAS Protocol), posts the query to an IEEE 802.21 Information Server by transmitting the MIS formatted frame in the Query Request field of a GAS Initial Request frame. The Advertisement Protocol ID field in the GAS Initial Request frame is set to the value of IEEE 802.21 MIS Information Service (Table 9-277 (Advertisement protocol ID definitions)).

Non-AP STAs in the unauthenticated or unassociated or associated states can use GAS procedures to discover MIS Command and Event Services Capability as specified in Table 9-277 (Advertisement protocol ID definitions).

A non-AP STA forms an IEEE 802.21 MIS Command and Event Service discovery request by encapsulating an MIS_Capability_Discover request into an MIS protocol frame as defined in 8.4 of IEEE Std 802.21-2017. The non-AP STA, using the procedures in 11.22.3.2 (GAS Protocol), posts the discovery request to the network by transmitting the MIS formatted frame in the Query Request field of a GAS Initial Request frame. The Advertisement Protocol ID field in the GAS Initial Request frame is set to the value of MIS Command and Event Services Capability Discovery (Table 9-277 (Advertisement protocol ID definitions)). The method by which the AP relays the discovery request to the network is defined in IEEE Std 802.21-2017 and is outside the scope of this standard.

A non-AP STA retrieves the IEEE 802.21 MIS Command and Event Service discovery response according to the procedures in 11.22.3.2 (GAS Protocol). The discovery response is an MIS protocol frame as defined in 8.4 of IEEE Std 802.21-2017.

### 11.22.5 Interworking procedures: interactions with SSPN

#### 11.22.5.1 General operation

To provide SSPN Interface services, the IEEE 802.11 network interacts with the SSPN corresponding to the user of the non-AP STA either directly or via a roaming relationship. As part of setting up the RSN security association, user policies are communicated to the AP. If dot11SSPNInterfaceActivated is true, these permissions shall be stored in the AP's dot11InterworkingTableEntry for that STA. Thereafter, the AP shall


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use the dot11InterworkingTableEntry for controlling the service provision to that non-AP STA. User policies from the SSPN affect authentication, authorization, and admission control decisions at the AP. In addition, the AP collects statistics about the non-AP STA and reports the statistics to the SSPN when requested. The SSPN may also send service provision instructions to the AP, e.g., to terminate the connection to a non-AP STA. Non-AP STAs do not support the SSPN Interface.

Network deployments typically provide that the AP and the server in the SSPN have a trustworthy channel that can be used to exchange information, without exposure to or influence by any intermediate parties. The establishment of this secure connection between the IEEE 802.11 infrastructure and the SSPN is outside the scope of this standard.

#### 11.22.5.2 Authentication and cipher suites selection with SSPN

When the non-AP STA initiates IEEE 802.1X authentication, the EAP messages are forwarded to the SSPN based on the NAI realm(#545) provided by the non-AP STA. If the IEEE 802.11 infrastructure is unable to forward the EAP message, the AP when dot11SSPNInterfaceActivated is true shall disassociate the non-AP STA with Reason Code NO_SSP_ROAMING_AGREEMENT.

In addition to the EAP messages, the IEEE 802.11 infrastructure also provides extra information regarding the non-AP STA to the SSPN as defined in R.4.2 (SSPN interface parameters), e.g., the Cipher Suite supported by non-AP STA, the location of the AP to which the non-AP STA is associated, etc. Such information may be used by the SSPN to make authentication and service provisioning decisions.

In the SSPN Interface Service, the SSPN uses more information than is carried over EAP to decide on the authentication result. The SSPN might reject a connection request if the cipher suites supported by non-AP STA does not meet its security requirements. In this situation, the SME of the AP when dot11SSPNInterfaceActivated is true shall invoke a disassociation procedure as defined in 11.3.5.8 (AP or PCP disassociation initiation procedure) by issuing the MLME-DISASSOCIATE.request primitive. The AP disassociates the corresponding non-AP STA with Reason Code BAD_CIPHER_OR_AKM.

The SSPN might reject the association request based on the location of the non-AP STA, e.g., if the non-AP STA is requesting association to an AP or associated to an AP located in a forbidden zone. In this situation, the SME of the AP when dot11SSPNInterfaceActivated is true shall invoke a disassociation procedure as defined in 11.3.5.8 (AP or PCP disassociation initiation procedure) by issuing the MLME-DISASSOCIATE.request primitive. The AP disassociates the corresponding non-AP STA with Reason Code NOT_AUTHORIZED_THIS_LOCATION.

#### 11.22.5.3 Reporting and session control with SSPN

An AP with dot11SSPNInterfaceActivated equal to true shall create a dot11InterworkingEntry in its dot11InterworkingTable for each STA that successfully associates. Permissions received from the SSPN for each associated STA shall be populated into the table; if no permissions are received from the SSPN for a particular non-AP STA, then the default permissions or an AP's locally defined policy may be used for that STA's dot11InterworkingEntry. If the AP's local policy is more restrictive than an object's permission value received from the SSPN Interface, then the AP's local policy may be enforced instead.

In an AP when dot11SSPNInterfaceActivated is equal to true, the following procedure occurs:

— The non-AP STA's state contained in the dot11InterworkingEntry shall be transmitted to the new AP after a successful transition. The state definition and the protocol used to transfer the state are beyond the scope of this standard. The new AP shall not forward any frames for that non-AP STA until it receives the dot11InterworkingEntry from the prior AP.

— After the state is successfully transmitted to the new AP, the dot11InterworkingEntry for that non-AP STA shall be deleted from the prior AP's dot11InterworkingTable.

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An AP with dot11SSPNInterfaceActivated equal to true shall delete the dot11InterworkingEntry for a non-AP STA when it disassociates from the BSS.

An AP with dot11SSPNInterfaceActivated equal to true shall enforce the dot11InterworkingEntry limits for a particular non-AP STA by comparing the values of octet counters to authorized access limits:

— dot11NonAPStationVoiceOctetCount is compared to dot11NonAPStationAuthMaxVoiceOctets. When the value of the authorized maximum octet count is exceeded, if the ACM subfield for AC_VO is equal to 1, then the HC shall delete all admitted TSs on this access category and deny all subsequent ADDTS Request frames with TID set to 6 or 7; or if the ACM subfield for AC_VO is equal to 0, then the non-AP STA shall be disassociated using the MLME-DISASSOCIATE.request primitive with a reason code of PEER_INITIATED.

— dot11NonAPStationVideoOctetCount is compared to dot11NonAPStationAuthMaxVideoOctets. When the value of the authorized maximum octet count is exceeded, if the ACM subfield for AC_VI is equal to 1, then the HC shall delete all admitted TSs on this access category and deny all subsequent ADDTS Request frames with TID set to 4 or 5; or if the ACM subfield for AC_VI is equal to 0, then the non-AP STA shall be disassociated using the MLME-DISASSOCIATE.request primitive with a reason code of PEER_INITIATED.

— dot11NonAPStationBestEffortOctetCount is compared to dot11NonAPStationAuthMaxBestEffortOctets. When the value of the authorized maximum octet count is exceeded, if the ACM subfield for AC_BE is equal to 1, then the HC shall delete all admitted TSs on this access category and deny all subsequent ADDTS Request frames with TID set to 0 or 3; or if the ACM subfield for AC_BE is equal to 0, then the non-AP STA shall be disassociated using the MLME-DISASSOCIATE.request primitive with a reason code of PEER_INITIATED.

— dot11NonAPStationBackgroundOctetCount is compared to dot11NonAPStationAuthMaxBackgroundOctets. When the value of the authorized maximum octet count is exceeded, if the ACM subfield for AC_BK is equal to 1, then the HC shall delete all admitted TSs on this access category and deny all subsequent ADDTS Request frames with TID set to 1 or 2; or if the ACM subfield for AC_BK is equal to 0, then the non-AP STA shall be disassociated using the MLME-DISASSOCIATE.request primitive with a reason code of PEER_INITIATED.

— dot11NonAPStationHCCAHEMMOctetCount is compared to dot11NonAPStationAuthMaxHCCAHEMMOctets. When the value of the authorized maximum octet count is exceeded, then the HC shall delete all admitted TSs with access policy of HCCA or HEMM and deny all subsequent ADDTS Request frames with access policy equal to HCCA or HEMM.

— The sum of dot11NonAPStationVoiceOctetCount, dot11NonAPStationVideoOctetCount, dot11NonAPStationBestEffortOctetCount, dot11NonAPStationAuthMaxBackgroundOctets, and dot11NonAPStationHCCAHEMMOctetCount is compared to dot11NonAPStationAuthMaxTotalOctets. When the value of the authorized maximum octet count is exceeded, the non-AP STA shall be disassociated using the MLME-DISASSOCIATE.request primitive with a reason code of PEER_INITIATED.

### 11.22.6 Interworking procedures: emergency services support

Emergency services support provides STAs with the ability to contact authorities in an emergency situation. The following procedures allow the STA to determine whether emergency services are supported by the AP or mesh STA, and whether unauthenticated emergency service access is allowed.

In an AP, when dot11ESNetwork is true, the network is dedicated and limited to accessing emergency services. When dot11ESNetwork is true, the Access Network Type field in the Interworking element shall be set to the value for “Emergency services only network” (see Table 9-276 (Access network type)). When


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dot11ESNetwork is false, the network is not limited to accessing emergency services, and the Access Network Type field in the Interworking element shall be set to a value other than "Emergency services only network." See Table 11-21 (ESR and UESA field settings).

**Table 11-21—ESR and UESA field settings**

| Description | ESR | UESA |
|---|---|---|
| It is unspecified whether emergency services are reachable. | 0 | 0 |
| Emergency services are only reachable for authenticated STAs. | 1 | 0 |
| Reserved | 0 | 1 |
| Emergency services are reachable for STAs. | 1 | 1 |

When an AP is located in a regulatory domain that requires emergency location capabilities, the ESR field shall be set to 1; otherwise the ESR field shall be set to 0. When an AP is located in a regulatory domain that requires emergency location capabilities and location capability is enabled on the AP, the Network Type shall be set to "Emergency services only network" (see Table 9-276 (Access network type)), if location capability is enabled on the AP; otherwise the ESR field shall not be set to 1 and the Network Type shall not be set to "Emergency services only network". In Beacon and Probe Response frames, location capability is advertised when the Civic Location or Geo Location field in the Extended Capabilities element is set to 1.

In an MBSS, if location capability is supported, the mesh STA shall report its location for emergency services.

When dot11ESNetwork is true in a mesh STA, the ESR shall be set to 1. When that mesh STA receives a Mesh Peering Open frame that includes the Interworking element with the ASRA field equal to 1, it allows access to emergency services and forwards MSDUs to an emergency server.

NOTE—The ASRA bit set to 1, informs the mesh STA to prioritize resources for the emergency call, to proactively find a better path before the link conditions deteriorate below a certain threshold, and/or to change some of the mesh STA's behavior (for example, to disable any power save features).

When dot11ESNetwork is false in a mesh STA, the ESR shall be set to 0. When that mesh STA receives a Mesh Peering Open frame that includes the Interworking element with the ASRA field equal to 1, it is unable to support the mesh peering of emergency services and does not forward MDSUs to an emergency server.

### 11.22.7 Interworking procedures: emergency alert system (EAS) support

The EAS provides alerts, typically issued by authorities. The Interworking Procedures EAS support enables the alerts to be transmitted upon request from APs to non-AP STAs. Subsequent to advertisement in Beacon and Probe Response frames, a non-AP STA uses GAS queries to retrieve an EAS message from the network according to the following procedures.

When dot11EASActivated is true, EAS operation shall be supported. When EAS operation is not supported, dot11EASActivated shall be false.

When the IEEE 802.11 infrastructure is informed of the availability of an EAS message (the mechanism by which is outside the scope of this standard), an AP with dot11EASActivated equal true shall advertise the availability of the EAS message by including an Emergency Alert Identifier element (see 9.4.2.95 (Emergency Alert Identifier element)) for that message in its Beacon and Probe Response frames. The AP shall include one instance of an Emergency Alert Identifier element in its Beacon and Probe Response frames for each active EAS Message. The Emergency Alert Identifier element provides an Alert Identifier Hash field value(M118), a

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unique indicator of the EAS Message of the alert to the non-AP STA. The Alert Identifier Hash field value(M118) allows the non-AP STA to determine whether this is a new alert.

NOTE—The same value of hash is(M118) computed by each AP in an ESS and by each AP in different ESSs. Thus a non-AP STA, which can download emergency alert messages when in a preassociated state, can unambiguously determine that it has already downloaded the message, avoiding unnecessary duplicates.

When an EAS Message has expired (the mechanism by which is outside the scope of this standard), an AP with dot11EASActivated equal true shall remove the corresponding instance of an Emergency Alert Identifier element from its Beacon and Probe Response frames.

The Alert Identifier Hash field(M118) in the Emergency Alert Identifier element shall be computed using HMAC-SHA-1-64 hash algorithm as shown in 9.4.2.95 (Emergency Alert Identifier element).

After receiving an Alert Identifier Hash field value(M118) for an EAS Message that has not already been retrieved from the network, a non-AP STA having dot11EASActivated equal true can retrieve the EAS message from the AP as follows:

— The procedures defined in 11.22.3.2 (GAS Protocol), transmit the Alert Identifier Hash field(M118) of the desired message in the Query request field of a GAS Initial Request frame. The Advertisement Protocol ID field in the GAS Initial Request frame is set to the value for EAS (see Table 9-277 (Advertisement protocol ID definitions)).

— The Query response is a message formatted in accordance with OASIS EDXL (see OASIS Standard EDXL-DE).

— A URI is formed by concatenating the Emergency Alert URI with the hexadecimal numerals of the Alert Identifier Hash field(M118) converted to lowercase ASCII encoded characters and the ".xml" file extension. For example, if the Emergency Alert URI is http://eas.server.org and the Alert Identifier Hash is 0x1234567890abcdef, then the URI would be http://eas.server.org/1234567890abcdef.xml (the mechanism by which the URI is retrieved is outside the scope of this standard). The XML file is formatted in accordance with OASIS EDXL. The non-AP STA retrieves the Emergency Alert URI (see 9.4.5.16 (Emergency Alert URI ANQP-element)) using an ANQP request according to the procedures in 11.22.3.3 (ANQP procedures). This method is recommended for non-AP STAs in the associated state.

### 11.22.8 Interworking procedures: support for the advertisement of roaming consortiums

APs can assist non-AP STAs performing network discovery and selection through the advertisement of a Roaming Consortium element. The Roaming Consortium element contains information identifying an SSP or group of SSPs (i.e., a roaming consortium) whose security credentials might be used to authenticate with the AP transmitting this element. An SSP or group of SSPs can register for and obtain an OI using the procedures described in IEEE SA FAQs—IEEE Registration Authority [B15]. Note that a non-AP STA may also use GAS procedures defined in 11.22.3.3.3 (Roaming Consortium procedure) to retrieve a Roaming Consortium ANQP-element, which might contain more OIs than the Roaming Consortium element.

APs having dot11InterworkingServiceActivated equal true and having one or more entries in the dot11RoamingConsortiumTable shall include the Roaming Consortium element in Beacon and Probe Response frames. An AP shall only include an OI in the dot11RoamingConsortiumTable, if, in conjunction with an AS, the AP is capable of successfully authenticating a non-AP STA that holds valid security credentials for the SSPN identified by that OI. Methods used by the AP to authenticate the non-AP STA include, but are not limited to, RSNA algorithms and Open System authentication.

A non-AP STA might have a locally stored binding between an OI and a set of security credentials with which it can authenticate to the network identified by the OI, that is, the SSPN. The method by which this binding is


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obtained is outside the scope of this standard. A non-AP STA might select from that list of credentials when authenticating to the BSS.

### 11.22.9 Interworking procedures: support for QoS mapping from external networks

Maintaining proper end-to-end QoS is an important factor when providing interworking service. This is because the external networks might employ different network-layer (Layer 3) QoS practices. For example, the use of a particular differentiated services code point (DSCP) for a given service might be different between different networks. To provide proper QoS over-the-air in the IEEE 802.11 infrastructure, the mapping from DSCP to UP for the corresponding network needs to be identified and made known to the STAs. If an inconsistent mapping is used then:

— Admission control at the AP may incorrectly reject a service request, because the non-AP STA used the incorrect UP.
— Non-AP STAs might use the incorrect value for User Priority in TSPEC and TCLAS elements.
— The user might be given a different QoS over the IEEE 802.11 network than expected, e.g., a lower QoS might be provided than the STA expected.

Therefore, APs with dot11QosMapActivated equal true shall set the QoS Map field in the Extended Capabilities element to 1; APs with dot11QosMapActivated equal false shall set the QoS Map field in the Extended Capabilities element to 0. The AP's SME causes the QoS mapping to be available to higher layer protocols or applications so they (M118)are able to set the correct priority in an MA-UNITDATA.request primitive.

For frames transmitted by an AP belonging to an admitted TS, the UP obtained from the TS's TCLAS element shall be used instead of the UP derived from the QoS mapping. For frames transmitted by an AP belonging to an admitted TS not having a TCLAS element, the UP shall be derived from the QoS mapping.

Non-AP STAs, when dot11QosMapActivated is equal true, shall set the QoS Map field in the Extended Capabilities element to 1. An AP receiving an Association Request frame or Reassociation Request frame when the QoS Map field in the Extended Capabilities element is equal 1 shall include the QoS Map element in the corresponding Association Response frame or Reassociation Response frame as defined in 9.3.3.6 (Association Response frame format) or 9.3.3.8 (Reassociation Response frame format), respectively. Upon receiving the QoS Map element, the non-AP STA's SME causes the QoS mapping to be available to higher layer protocols or applications so they (M118)are able to set the correct priority in an MA-UNITDATA.request primitive.

When the AP's SME detects a change in the QoS mapping information, it shall update the non-AP STA with the new QoS Map element. It accomplishes this update by invoking the MLME-QOS-MAP.request primitive.

When the MAC entity at the non-AP STA receives a QoS Map Configure frame from the AP, the MLME shall issue an MLME-QOS-MAP.indication primitive to its SME.

When the non-AP STA's SME receives the QoS Map response, it shall make the QoS Map available to higher layers so that in turn, they can invoke the MA-UNITDATA.request primitive with the correct priority.

## 11.23 Preassociation discovery (PAD) procedures

### 11.23.1 General

There are two types of PAD procedures: unsolicited and solicited. The unsolicited PAD procedure is described in 11.23.2 (Unsolicited PAD procedure), and the solicited PAD procedure is described in 11.23.3 (Solicited PAD procedure).

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When dot11UnsolicitedPADActivated or dot11SolicitedPADActivated is true, a non-AP and non-PCP STA may use PAD procedures to allow the SIC to discover the availability of services that the same non-AP and non-PCP STA may access when associated. While the specification of service-specific information is outside the scope of this standard, the service-specific information in the BSS is proxied by a SIR (see 4.5.9.2.4 (Service information registry (SIR))), which might be (#2210)colocated with the AP or PCP.

A non-AP STA with dot11SolicitedPADActivated set to true may set dot11MACPrivacyActivated to true (see 12.2.11 (Requirements for support of MAC privacy enhancements)).

An AP advertises support for PAD by setting the PAD field of the Extended Capabilities element to 1 in its Beacon and Probe Response frames.

A PCP advertises support for PAD by setting the PAD field of the Extended Capabilities element to 1 in its DMG Beacon, Announce, and Probe Response frames.

### 11.23.2 Unsolicited PAD procedure

When dot11UnsolicitedPADActivated is true, an AP shall advertise services from an SIR using a Service Hint element or a Service Hash element, or both, in Beacon and Probe Response frames. Each service may be advertised using either a Service Hint element or a Service Hash element, but not both, in a Beacon or Probe Response frames.The MLME-UPDATE.request primitive shall be used by the SME to indicate the Service Hint and Service Hash elements to the MLME.(#1114)

When dot11UnsolicitedPADActivated is true, a PCP shall advertise services from an SIR using a Service Hint element or a Service Hash element, or both, in DMG Beacon, Announce, or Probe Response frames. Each service may be advertised using either a Service Hint element or a Service Hash element, but not both, in DMG Beacon, Announce, or Probe Response frames.

A Service Hint element is used to advertise the presence of one or more services reachable via a BSS with a probability of matching a wrong service as indicated in the False Positive Probability Range subfield of the Service Hint element. A Service Hash element is used to advertise the presence of one or more services reachable via a BSS with a negligible probability of matching a wrong service. The mechanism for selecting which of a Service Hash or Service Hint element to use to advertise a particular service is beyond the scope of this standard.

When dot11UnsolicitedPADActivated is true, a non-AP and non-PCP STA searching for a service shall perform the following steps for each BSS:

a) From the received Beacon, DMG Beacon, Announce, or Probe Response frames, process the Service Hash elements to generate a list of services reachable via the BSS, and process the Service Hint elements to determine the parameters of the bloom filter.

b) Construct a list comprising service hash values for each service being searched. Then determine the bit positions in the Bloom Filter Array field (M118)to be set to 1 for each service in the list.

c) For each service being searched, determine whether there is a matched service within the list of services, based on either of the following:

   1) The service hash value in the list of services matches the corresponding service hash value constructed in step b).

   2) The values of the bit positions of the Bloom Filter Bit Array field of the Service Hint element, as determined in step b), are all equal to 1.

The non-AP and non-PCP STA may use the resulting information about which services are reachable as input to network discovery and selection procedures. The non-AP and non-PCP STA might proceed with the solicited PAD procedure (see 11.23.3 (Solicited PAD procedure)) or authentication and association procedure


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(see 11.3 (STA authentication and association)) based on the indicated false positive probability and the requirements of the service or the SIC (see the examples in Annex Y).

### 11.23.3 Solicited PAD procedure

When dot11SolicitedPADActivated is true, a non-AP and non-PCP STA may transmit to an AP or PCP a Service Information Request ANQP-element to request information from the SIR about services reachable via the BSS. A non-AP and non-PCP STA may use the Interworking and PAD fields of the Extended Capabilities element received from the AP or PCP to determine whether that AP or PCP supports Solicited PAD.

NOTE—An Interworking field value of 1 implies support for ANQP.

The Service Information Request ANQP-element is used by a non-AP and non-PCP STA to request detailed information about services reachable via the BSS; see examples illustrated in Annex Y.

When dot11SolicitedPADActivated is true, a non-AP and non-PCP STA may send a Service Information Request ANQP-element (see 9.4.5.27 (Service Information Request ANQP-element)) to obtain information about a matching service. The Service Information Request ANQP-element shall include one or more Service Information Request Tuple subfields. Each Service Information Request Tuple subfield shall include a service hash within the Service Hash subfield and a Service Information Request Attribute subfield that is a service-specific request.

When dot11SolicitedPADActivated is true, an SIR shall use the information from the Service Information Request ANQP-element to determine whether the requested service(s) are reachable via the BSS. If matching services are found, corresponding to the Service Hash subfield, the SIR shall respond by requesting the AP or PCP to transmit a Service Information Response ANQP-element that contains a Service Information Response Tuple subfield for each service that satisfies the request. The Service Information Response ANQP-element contains detailed information about the services. When there is no matching service corresponding to the Service Hash subfield in an individually addressed GAS Initial Request frame, the SIR shall respond by requesting the AP or PCP to transmit a Service Information Response ANQP-element containing zero Service Information Response Tuple subfields.

The SIC receives service information from the contents of the Service Information Response ANQP-element. The non-AP and non-PCP STA may use the service information regarding which services are reachable as input to network discovery and selection procedures. The non-AP and non-PCP STA might proceed with the authentication and association procedure (see 11.3 (STA authentication and association)) (see examples illustrated in Annex Y).

### 11.23.4 Service hash procedure

A service hash is generated from a service name after all single octet uppercase alphabetic characters in the service name are converted into corresponding lowercase characters. A service name is defined in IETF RFC 6335.

A service hash contained in the Service Hash subfield of the Service Hash element, or in the Service Information Request ANQP-element, or in the Service Information Response ANQP-element, or a service hash used to map into the Bloom Filter Bit Array is generated as follows:

service hash = (#3506)ExtractBits(SHA-256(service name), 0, 48)

For example, a service hash for the service name of "_ipp._tcp" is created as follows: The service hash contained in the Service Hash subfield of the Service Hash element, the Service Information Request ANQP-element, and the Service Information Response ANQP-element is 0xbfd39037d25c, and the service hash used as input to compute the Bloom Filter Bit Array field is 0xbfd39037d25c.(#7197)

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### 11.23.5 Bloom filter hash function operation

The Bloom filter for a set of service hashes is created as described below.

Let *m* denote the number of bits in the Bloom filter, and let *k*–1 be the setting of the Number Of Hash Functions subfield in the Bloom Filter information field (see 9.4.2.236 (Service Hint element)), i.e., *k* is the number of Bloom filter hash functions (out of a maximum of 16) used by the Bloom filter. For example, when the Number Of Hash Functions subfield is equal to 1, *k* = 2, the first two hash functions are used (*j* =0x00,0x01).

Create the Bloom filter as follows:

a) Set all bits in the Bloom filter to 0.

b) For each service hash in the set of service hashes, compute the *k* bit positions by setting (#515)*j* = 0, …, *k*–1, in the function H(*j*,X,*m*) shown below. Set the bits at the *k* computed bit positions to 1. Note that, in some cases, different values of *j* may return the same bit position.

Let H(*j*,X,*m*) denote the Bloom filter hash function,

where

*j* is the Bloom filter hash function prepend parameter used in the computation; *j* is a single octet and ranges from 0x00 to 0x0F

X is the service hash that is mapped into the Bloom Filter Bit Array field (see 11.23.4 (Service hash procedure) for procedures for generating a service hash used to map into the Bloom Filter Bit Array field)

*m* is the size, in number of bits, of the Bloom filter; how the size of the Bloom filter is determined is out of the scope of this standard

H(*j*,X,*m*) is computed as follows:

Step 1: Compute A(*j*,X) = [*j* || X].

Step 2: Compute B(*j*,X) = CRC32(A(*j*,X)) & 0x0000FFFF. In other words, obtain the least significant 2 octets of the 32-bit CRC of A(*j*,X), where CRC32() is the same 32-bit CRC as defined in 9.2.4.9 (FCS field).

Step 3: H(*j*,X,*m*) = B(*j*,X) mod *m*.

## 11.24 Quality-of-service Management frame (QMF)

### 11.24.1 General

#### 11.24.1.1 Overview

A QMF STA shall set dot11QMFActivated and dot11QosOptionImplemented to true. The QMF STA shall assign an access category to each Management frame according to the access category assignments indicated in the QMF policy that has been configured using the configuration procedures described in 11.24.2 (QMF policy advertisement and configuration procedures).

A QMF STA shall set the QMFActivated subfield in the Extended Capabilities element to 1.

A Management frame shall be transmitted as an IQMF when all five of the following conditions are met:

— The RA of the Management frame corresponds to (#1653)an individual address.

— The frame is transmitted by a QMF STA.

— The transmitting STA has previously received an Extended Capabilities element from the STA corresponding to the RA of the frame being transmitted.


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- The most recently received such Extended Capabilities element indicated that the STA is a QoS STA and has the value of 1 in the QMFActivated subfield.
- The frame is not a time priority Management frame.
- (#3573)The frame is not a PV1 Management frame.

A QMF AP shall transmit a Management frame as a GQMF when all three of the following conditions are met:

- The RA of the Management frame corresponds to (#1653)a group address.
- The transmitting STA has received an Extended Capabilities element that has the QMFActivated subfield equal to 1 from every member of the BSS corresponding to the BSSID field of the Management frame.
- The frame is not a time priority Management frame.
- (#3573)The frame is not a PV1 Management frame.

A non-AP QMF STA shall transmit a Management frame as a GQMF when all three of the following conditions are met:

- The RA of the Management frame corresponds to (#1653)a group address.
- The transmitting STA has received an Extended Capabilities element that has the QMFActivated subfield equal to 1 from its associated AP.
- The frame is not a time priority Management frame.
- (#3573)The frame is not a PV1 Management frame.

A Management frame shall not be transmitted as an IQMF or GQMF, except as defined above.

NOTE—All APs in an ESS need to have the same QMF settings when GQMF has been enabled for use by associated non-AP STAs.(#6401)

When the QMFActivated subfield is zero in the most recently received Extended Capabilities element from a destination STA, or when an Extended Capabilities element has not been received from a destination STA, a transmitting QMF STA shall transmit individually addressed Management frames to that destination STA using access category AC_VO.

If the QMFActivated subfield in the most recently received Extended Capabilities element from a destination QMF STA is equal to 1, but no QMF Policy element has been received from the destination QMF STA, and, if associated, no QMF Policy element has been received from the QMF AP with which the STA is associated, then a QMF STA shall transmit all IQMFs to the destination QMF STA using the default QMF policy access categories defined in Table 11-22 (Default QMF policy). Otherwise, the QMF STA shall transmit individually addressed Management frames as defined in the QMF policy included in the QMF Policy element accepted from the destination QMF STA. In either case, the transmitted Management frames are IQMFs, and the transmitting QMF STA shall indicate the access category used to transmit the frame in the ACI subfield of the sequence number field.

A QMF STA in an unassociated state shall transmit all (#1333)group addressed Management frames as non-QMF. An associated QMF STA shall follow the QMF policy dictated by its associated AP for transmitting GQMFs as described in 11.24.2 (QMF policy advertisement and configuration procedures). The specific access category assignments of different Management frames in a nondefault QMF policy are beyond the scope of this document. The transmitting QMF STA shall indicate the access category used to transmit GQMFs in the ACI subfield of the sequence number field.

Time priority Management frames, when not sent as an immediate response, shall be transmitted using AC_VO.

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A QMF STA shall not modify the access category of an IQMF or GQMF frame after an initial transmission of the frame has been performed, regardless of any subsequent modification to the QMF policy under which the STA is operating.

#### 11.24.1.2 Default QMF policy

The default QMF policy is defined in Table 11-22 (Default QMF policy). It defines the access category of each Management frame based on management subtype value, category value, and action value. QMFs not included in this table shall be assigned an access category AC_BE.

**Table 11-22—Default QMF policy**

| Description | Management Frame Subtype value from Table 9-1 (Valid type and subtype combinations) | Category value from Table 9-81 (Category values) | Action field | QMF access category |
|---|---|---|---|---|
| (Re)Association Request/Response | 0000–0011 | N/A | N/A | AC_VO |
| Probe Request (individually addressed) | 0100 | N/A | N/A | AC_VO |
| Probe Request (group addressed) | 0100 | N/A | N/A | AC_BE |
| Probe Response | 0101 | N/A | N/A | AC_BE |
| Timing Advertisement | 0110 | N/A | N/A | AC_BE |
| Beacon, ATIM, Disassociation, Authentication, Deauthentication | 1000–1100 | N/A | N/A | AC_VO |
| Spectrum management | 1101 | 0 | 0–3 | AC_BE |
| Spectrum management—channel switch announcement | 1101 | 0 | 4 | AC_VO |
| QoS | 1101 | 1 | 0–3 | AC_VO |
| Block Ack | 1101 | 3 | 0–2 | AC_VO |
| Public | 1101 | 4 | 0, 1, 3, 5–6, 8–9 | AC_BE |
| Public—DSE deenablement, extended channel switch announcement | 1101 | 4 | 2, 4 | AC_VO |
| Public—measurement pilot | 1101 | 4 | 7 | AC_VO |
| Public—TDLS Discovery Response | 1101 | 4 | 14 | AC_VO |
| Public—(#7065)FTM Request | 1101 | 4 | 32 | AC_VO |


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**Table 11-22—Default QMF policy *(continued)***

| Description | Management Frame Subtype value from Table 9-1 (Valid type and subtype combinations) | Category value from Table 9-81 (Category values) | Action field | QMF access category |
|---|---|---|---|---|
| Public—(#7065)FTM | 1101 | 4 | 33 | AC_VO |
| Public—FILS | 1101 | 4 | 34 | AC_VO |
| Public—CDMG | 1101 | 4 | 35–42 | AC_BE |
| Public—Interworking | 1101 | 4 | 43, 44 | AC_VI |
| Public—FST | 1101 | 4 | 45 | AC_VO |
| (11az)Public Action—LMR | 1101 | 4 | 47 | AC_VO |
| Radio measurement | 1101 | 5 | 0–5 | AC_BE |
| Fast BSS Transition | 1101 | 6 | 0–4 | AC_VO |
| HT | 1101 | 7 | 0–3 | AC_VO |
| HT | 1101, 1110 | 7 | 4–7 | AC_VO |
| SA Query | 1101 | 8 | 0–1 | AC_VO |
| Protected Dual of Public Action | 1101 | 9 | 1–2, 5–6, 8–9 | AC_BE |
| Protected Dual of Public Action—extended channel switch announcement | 1101 | 9 | 4 | AC_VO |
| WNM | 1101 | 10 | 0–24 | AC_BE |
| Unprotected WNM | 1101 | 11 | 0–1 | AC_BE |
| Mesh Action—HWMP Mesh Path Selection | 1101 | 13 | 1 | AC_VO |
| Mesh Action—Congestion Control | 1011 | 13 | 3 | AC_VO |
| Mesh Action | 1101 | 13 | 0, 2, 4–10 | AC_BE |
| Multihop Action | 1101 | 14 | 0–1 | AC_BE |
| Self-Protected(#1638) | 1101 | 15 | 0–5 | AC_VI |
| DMG | 1101 | 16 | 0–22 | AC_BE |
| (11ay)DMG | 1101 | 16 | 23 | AC_VO |
| (#4220)*Allocated to the Wi-Fi Alliance* [a] | 1101 | 17 | All | AC_BE |
| Fast Session Transfer | 1101 | 18 | 0–5 | AC_VO |
| Robust AV Streaming | 1101 | 19 | 0–3 | AC_BE |
| Unprotected DMG | 1101 | 20 | (11ay)0–5 | AC_VO |
| VHT | 1101, 1110 | 21 | 0–2 | AC_VO |

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**Table 11-22—Default QMF policy *(continued)***

| Description | Management Frame Subtype value from Table 9-1 (Valid type and subtype combinations) | Category value from Table 9-81 (Category values) | Action field | QMF access category |
|---|---|---|---|---|
| Unprotected S1G | 1101 | 22 | 0, 1, 2, 4–9 | AC_BE |
| Unprotected S1G | 1101 | 22 | 3, 11 | AC_VI |
| S1G | 1101 | 23 | 0, 3 | AC_VO |
| S1G | 1101 | 23 | 1, 2 | AC_BE |
| Flow Control | 1101 | 24 | 0, 1 | AC_VO |
| Control Response MCS Negotiation | 1101 | 25 | 0, 1 | AC_BE |
| FILS | 1101 | 26 | 0 | AC_VO |
| CDMG | 1101 | 27 | 0–5 | AC_BE |
| CMMG | 1101 | 28 | 0 | AC_BE |
| CMMG | 1101 | 28 | 1 | AC_VO |
| GLK | 1101 | 29 | 0 | AC_BE |
| (11az)Protected Fine Timing frame | 1101 | 34 | Any | AC_VO for Protected FTM Request and Protected FTM. N/A for Protected LMR. |
| Vendor-specific Protected | 1101 | 126 | N/A | AC_BE |
| Vendor-specific | 1101 | 127 | N/A | AC_BE |

[a] See http://www.wi-fi.org.

### 11.24.2 QMF policy advertisement and configuration procedures

#### 11.24.2.1 Overview

QMF policies are exchanged and implemented between two QMF STAs. A STA's QMF policy is advertised and exchanged using the QMF Policy element described in 9.4.2.118 (Quality-of-Service Management Frame Policy element).

A non-AP QMF STA operating in a BSS shall not transmit a QMF Policy frame to an AP.

The access category for a QMF that is transmitted by a non-AP QMF STA to a peer QMF STA shall be determined from the QMF policy received from the peer if a QMF policy has been received from the peer. Otherwise, the default policy shall be used. The access category for a QMF that is transmitted by a QMF AP is determined from the QMF policy configured at that AP.

In a BSS or MBSS, the access category for any Management frame may be reconfigured.(#1913)


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#### 11.24.2.2 QMF policy change in an infrastructure BSS or in an MBSS

A QMF Policy Change frame is transmitted by a QMF STA to request a change to the QMF policy that the requesting QMF STA uses(M118) for transmitting Management frames to the peer QMF STA in an infrastructure BSS or in an MBSS.

A STA may transmit a QMF Policy Change frame to request a change in the QMF policy for transmitting to a peer STA. A non-AP QMF STA that receives a QMF Policy Change frame may either accept or reject the request. An associated non-AP QMF STA may transmit a QMF Policy Change to the QMF AP in its BSS only if the Extended Capabilities element received from the AP has its QMFReconfigurationActivated subfield equal to 1. If the AP rejects the request, the associated QMF STA shall not request the same policy reconfiguration from the AP during the lifetime of its association.

An AP shall respond to a QMF Policy Change frame received from an associated STA by transmitting a QMF Policy frame. If the QMFReconfigurationActivated subfield is zero in the Extended Capabilities element in the Beacon frame, an AP that receives a QMF Policy Change frame from an associated STA shall respond with a QMF Policy frame, with the Status Code field(#4356) set to REQUEST_DECLINED. If the QMFReconfigurationActivated subfield is 1 in the Extended Capabilities element in the Beacon frame, an AP that receives a QMF Policy Change frame from an associated STA shall evaluate the QMF Policy included in the frame, and shall respond to the request with the resulting QMF Policy element and the Status Code field(#4356) set to SUCCESS if it accepts the policy change, or REQUEST_DECLINED if it rejects the policy change. A QMF AP may transmit a QMF Policy frame with the Status Code field(#4356) set to SUCCESS to an associated QMF STA without having first received a QMF Policy Change frame from that STA.

If an accept status is received in a QMF Policy frame within dot11QMFPolicyChangeTimeout of having transmitted a QMF Policy Change frame with the same dialog token to the STA that transmitted the QMF Policy frame, then the requesting QMF STA shall transmit any subsequently queued Management frames to the peer QMF STA in accordance with the changes to the QMF policy that were indicated in the QMF Policy Change frame.

If a reject status is received in a QMF Policy frame within dot11QMFPolicyChangeTimeout of having transmitted a QMF Policy Change frame with the same dialog token to the STA that transmitted the QMF Policy frame as a response to a QMF Policy Change frame, then the configuration change request is rejected and the requesting QMF STA shall continue to transmit Management frames to the peer QMF STA in accordance with the previously configured QMF policy. The requesting QMF STA shall not transmit a QMF Policy Change frame with a previously rejected QMF policy to a peer QMF STA within dot11QMFPolicyChangeTimeout from the time the requesting STA received the rejection frame.

If the requesting STA does not receive a QMF Policy frame in response to a QMF Policy Change frame within dot11QMFPolicyChangeTimeout, then the requesting STA shall continue to transmit frames according to the previously configured QMF policy.

If a QMF STA has received an Extended Capabilities element with the QMFReconfigurationActivated subfield equal to 0 or has not received an Extended Capabilities element from a destination QMF STA, the QMF STA shall not transmit a QMF Policy Change frame to the destination QMF STA.

A QMF mesh STA or a QMF AP may set dot11QMFReconfigurationActivated to true or false. A non-AP QMF STA in an infrastructure BSS shall set dot11QMFReconfigurationActivated to true and shall set the QMFReconfigurationActivated subfield to 1 in transmitted (re)association requests. A non-AP QMF STA with dot11QMFReconfigurationActivated equal to true shall accept any received QMF Policy frame from its associated AP. A QMF STA with dot11QMFReconfigurationActivated equal to false shall respond with a QMF Policy frame, with the current QMF Policy element and Status Code set to REQUEST_DECLINED.

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The QMFReconfigurationActivated subfield shall be set to one in the Extended Capabilities element when dot11QMFReconfigurationActivated is true. The QMFReconfigurationActivated subfield shall be set to 0 in the Extended Capabilities element when dot11QMFReconfigurationActivated is false.

The SME of a peer QMF STA uses the MLME-QMFPOLICY primitives(#1114) to transmit a QMF Policy frame to a peer STA. The SME of a peer STA uses the MLME-QMFPOLICY.request primitive to transmit a QMF Policy frame to a peer STA. The MLME of a peer QMF STA shall set the dialog token to 0 and set the (#7190)status code to SUCCESS when the QMF Policy frame is transmitted unsolicited to the peer STA.

The SME of a peer QMF STA uses the MLME-QMFPOLICYCHANGE primitives(#1114) to exchange the QMF Policy Change and QMF Policy frames. The SME of a peer STA uses the MLME-QMFPOLICYCHANGE.request primitive to transmit a QMF Policy Change frame to a peer STA. The value of the dialog token in the MLME-QMFPOLICYCHANGE.request primitive shall be set to a value in the range 1 to 255.

The SME of the peer STA evaluates the QMF policy and uses the MLME-QMFPOLICYCHANGE.response primitive to transmit a QMF Policy frame to the STA including the result of the QMF policy change. The value of the dialog token in the MLME-QMFPOLICYCHANGE.response primitive shall be set to the value of the dialog token received in the corresponding MLME-QMFPOLICYCHANGE.indication primitive.

When the QMF STA SME receives an MLME-QMFPOLICYCHANGE.confirm primitive or MLME-QMFPOLICY.indication primitive with Result Code of SUCCESS, it shall set the new QMF policy using the MLME-QMFPOLICYSET.request primitive.

An AP for which dot11AlternateEDCAActivated is true shall not use the alternate video (A_VI) nor alternate voice (A_VO) transmit queues in its QMF policy.

#### 11.24.2.3 QMF policy configuration in an infrastructure BSS

A QMF AP shall include the QMF Policy element in Beacon frames that it transmits. Non-AP QMF STAs acquire QMF policy configuration information from QMF Policy elements received in Beacon, Association Response, Reassociation Response, Probe Response, and QMF Policy frames. The interpretation of the QMF Policy element is described in 11.24.3 (Interpreting QMF access categories).

An associated QMF STA transmitting QMFs shall transmit those frames in accordance with the QMF policy received from its associated AP in the following order of precedence, from highest to lowest:

— QMF policy defined in an unsolicited QMF Policy frame from the associated QMF AP or the QMF Policy Change frame that resulted in a successful response QMF Policy frame from the associated AP, whichever occurred most recently

— QMF policy defined in the QMF Policy element received in the successful (Re)Association Response frame

All unassociated QMF STAs transmitting Management frames to a QMF AP shall transmit those frames to the AP in accordance with the QMF policy in the most recently received Beacon or Probe Response frame from that AP. If no frame containing a QMF Policy element has been received from the AP prior to the transmission of the Management frame(s), then the Management frame(s) shall be transmitted using the access categories of the default QMF policy defined in Table 11-22 (Default QMF policy).

A QMF STA shall transmit all Management frames that are individually addressed to non-QMF STAs using access category AC_VO.

A QMF AP shall set a QMF policy for the transmission of QMFs to its associated STAs. The QMF policy used by the AP for transmission of QMFs to associated STAs is not required to be the same as the QMF policy it advertises.


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If the QMFReconfigurationActivated subfield is equal to 1 in the Extended Capabilities element of the Beacon or Probe Response frame transmitted by the AP, an associated QMF STA may use the QMF Policy Change frame to request a change in its existing QMF policy.

#### 11.24.2.4 QMF policy configuration in an IBSS or OCB

QMF STAs in an IBSS or OCB shall use the default QMF policy for all individually addressed Management frames transmitted to other QMF STAs in the IBSS or OCB.

#### 11.24.2.5 QMF policy configuration in an MBSS

A QMF STA operating in an MBSS shall set the QMFActivated subfield in the Extended Capabilities element to true. (#454)A mesh STA shall not include a QMF Policy element in a Beacon frame. The QMF in an MBSS policy shall be set on a per link basis between two QMF STAs.

The QMF Policy Change and QMF Policy frames are used by QMF STAs in an MBSS to configure QMF policy. See 11.24.2.2 (QMF policy change in an infrastructure BSS or in an MBSS).

A QMF STA shall always accept the QMF policy from the QMF Policy frame transmitted by the peer QMF STA and shall transmit all individually addressed Management frames destined to the peer QMF STA using the received QMF policy.

A QMF STA may request a change in the QMF policy from a peer QMF STA by transmitting a QMF Policy Change to the peer QMF STA. The peer QMF STA may accept or reject this change request. If the peer QMF STA accepts the change, it shall respond with a QMF Policy frame with the Status Code field(#4356) set to SUCCESS and the QMF STA shall transmit IQMFs using the new QMF policy to the peer QMF STA. If the peer QMF STA rejects the change, it shall respond with QMF Policy frame with the Status Code field(#4356) set to REQUEST_DECLINED and the QMF STA shall continue transmitting IQMFs according to the previously configured QMF policy.

If a QMF STA does not receive a QMF Policy frame from a peer QMF STA, it shall transmit Management frames to that peer STA using the default QMF policy.

QMF STAs in an MBSS shall not include policies for group addressed Management frames in the QMF Policy Config Request.

### 11.24.3 Interpreting QMF access categories

The QMF Policy element, as defined in 9.4.2.118 (Quality-of-Service Management Frame Policy element), indicates the transmit access categories of different Management frames. A QMF Policy element with Length field of value 1 means that the access category of all Management frames is defined in the default QMF policy in Table 11-22 (Default QMF policy).

When the Individually Addressed subfield is 1, then the QACM applies to IQMFs. When the Group Addressed subfield is 1, then the QACM applies to GQMFs. A STA shall not transmit a QMF Policy element with both the Individually Addressed and Group Addressed subfields set to 0 in any of the included QACM subfields.

The QMF Policy element contains zero or more QACM fields. When included in the QMF Policy element, each QACM field indicates the access category of a group of Management frames. Using the description from Table 11-23 (QMF policy description for valid combination of optional fields in the QACM field), access categories for all Management frames belonging to either a given subtype or a given action category may be indicated in a single QACM field. When multiple Action frames of the same Category are to be mapped to the same Access Category, this is indicated by setting multiple bits in the Action Value Bitmap. For example, setting Bit 0 and Bit 1 indicates Event Request/Response frames when the Management Frame Subtype

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subfield refers to Management frames of subtype Action and the Category Value subfield refers to the WNM category. The QACM field also may be used to indicate the access category of a single management frame subtype.

**Table 11-23—QMF policy description for valid combination of optional fields in the QACM field**

| QACM field Length subfield | Action frame category | Action Value Bitmap subfield | Description |
|---|---|---|---|
| 0 | Not included | Not included | Policy to be applied to all Management frames of the corresponding subtype |
| 1 | Included | Not included | Policy to be applied to all Action frames of corresponding category value |
| ≥ 2 | Included | Included | Policy to be applied only to Action frames indicated via the action value bitmap for Management frames of the subtype indicated in the Management Frame Subtype subfield and the category value indicated in the Action Frame Category subfield in the corresponding QACM field |

A QMF STA that received a QMF Policy element from its associated QMF AP shall discard any previously received QMF Policy elements. If a Management frame is indicated in multiple QACM fields, the access category of the Management frame is determined by the access category defined in the last QACM field in the QMF Policy that contains the access category assignment of the corresponding Management frame. For example, if an QACM field sets the entire WNM category to access category AC_BE and a later QACM field sets Event Request/Report of WNM category to AC_BK, then all Action frames of WNM category are transmitted using access category AC_BE with the exception of Event Requests/Reports, which are transmitted using access category AC_BK.

## 11.25 Robust AV streaming

### 11.25.1 Robust AV streaming dependencies

When dot11RobustAVStreamingImplemented is true, the STA is a robust AV streaming STA. The attribute dot11QosOptionImplemented shall be true in a robust AV streaming STA.

### 11.25.2 SCS procedures

The stream classification service (SCS) is a service that may be provided by an AP to its associated STAs that support SCS. In SCS, the AP classifies incoming individually addressed MSDUs based upon parameters provided by the non-AP STA.

The classification allows the UP, drop eligibility, and EDCA transmit queue to be selected for all MSDUs matching the classification.

Implementation of SCS is optional for a STA. A STA that implements SCS shall set its dot11SCSImplemented to true. A STA with dot11SCSActivated equal to true shall support stream classification and shall set to 1 the SCS field of the Extended Capabilities elements that it transmits. If dot11SCSActivated is true, dot11SCSImplemented shall be true.

A non-AP STA that supports SCS may request use of SCS by sending an SCS Request frame that includes an SCS Descriptor element with the Request Type field set to “Add” or “Change.” The SCS Descriptor List field


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in the SCS Descriptor element identifies how MSDUs are classified and the priority to assign to MSDUs that match this classification.(#583)(#299)

Each SCS stream is identified by an SCSID. This SCSID is used by a non-AP STA to request creation, modification, or deletion of an SCS stream. The SCSID is used by an AP to identify an SCS stream in SCS responses.

Upon receipt of an SCS Request frame from an associated non-AP STA, the AP shall respond with a corresponding SCS Response frame. A value of SUCCESS shall be set in the corresponding Status field of the SCS Status duple in the SCS Response frame when the AP accepts the SCS request for the requested SCSID. A value of REQUEST_DECLINED, REQUESTED_TCLAS_NOT_SUPPORTED_BY_AP, or INSUFFICIENT_TCLAS_PROCESSING_RESOURCES shall be set in the corresponding SCS Status field of the SCS Status duple in the SCS Response frame when the AP denies the SCS request for the requested SCSID.

If the AP declines a request to change a previously accepted SCSID, the previously accepted classification for this SCSID continues to operate.

If the requested SCS is accepted by the AP, the AP shall process subsequent incoming individually addressed MSDUs from the DS or WM that match the TCLAS elements and optional TCLAS Processing element classifier specified in the SCS Descriptor element.

(#583)If an MSDU matches the classifier specified in the SCS Descriptor elements of multiple SCS streams, the SCS Descriptor element that specifies the greatest number of classifier parameters required for a match (i.e., the most granular classifier) is used. If an MSDU matches the classifier specified in SCS Descriptor elements that specify the same number of classifier parameters, which classifier is used is implementation dependent.

(#583)The number of classifier parameters required for a match in a given TCLAS element is 1 when the Classifier Type is 2, 3 or 10, and is 3 when the Classifier Type is 5. For other classifier types, the Classifier Mask field indicates which classifier parameters are required for a match. For Classifier Types 1 and 4, the (IP) Version classifier parameter is not counted when determining the number of classifier parameters required for a match. Reserved fields are not classifier parameters.

(#583)If multiple TCLAS elements are included in an SCS Descriptor element, the number of classifier parameters required for a match is the sum of the number of classifier parameters required for a match for each TCLAS element if the Processing field in the TCLAS Processing element is 0, or is the minimum of the number of classifier parameters required for a match for each TCLAS element if the Processing field is 1. If a TCLAS Processing element is included where the Processing field is 2, the number of classifier parameters required for a match is 0.

(#583)A STA should not request creation of multiple SCS streams that might match the same MSDU and specify the same number of classifier parameters.

A match of the classifier is defined as follows:

- When the (#2180)Processing field of the TCLAS Processing element is 0, the classifier matches all of the parameters in the TCLAS elements in the SCS Descriptor element.
- When the (#2180)Processing field of the TCLAS Processing element is 1 or the TCLAS Processing element is not present, the classifier matches if the parameters match at least one of the TCLAS elements in the SCS Descriptor element.

The processing of matching MSDUs depends upon the access policy assigned to the MSDU:

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- For matching MSDUs that are not part of a TS (as described in 11.4 (TS operation)), the User Priority subfield of the Intra-Access Category Priority element is used as the UP of these MSDUs.
- For matching MSDUs that are part of a TS (as described in 11.4 (TS operation)), the TID and UP classification of these MSDUs shall follow the rules specified in 11.4.7 (Data transfer).
- If dot11AlternateEDCAActivated is true, for matching MSDUs that are not part of a TS (as described in 11.4 (TS operation)) or for MSDUs that are part of a TS that uses EDCA or HEMM as the access policy, the Alternate Queue subfield of the Intra-Access Category Priority element is used to select whether the primary EDCA transmit queue or alternate EDCA transmit queue is used for these MSDUs.
- All matching MSDUs have their DEI set using the value from the Drop Eligibility subfield of the Intra-Access Category Priority element in the DEI subfield of the HT Control field, as defined in 9.2.4.6 (HT Control field).

A non-AP STA may request the termination of an accepted SCS stream by sending an SCS Request frame with the Request Type field set to "Remove" and the requested SCSIDs in the SCS Descriptor element. (#584)No Intra-Access Priority, TCLAS, or TCLAS Processing elements shall be included in the SCS Descriptor element.

(#586)Upon reception of an SCS Request frame that requests termination of an SCS stream, the AP shall send an SCS Response frame with the Dialog Token and SCSID fields set to the corresponding fields in the SCS Request frame and the Status field set to TCLAS_PROCESSING_TERMINATED.

(#586)The AP may (#1114)use the MLME-SCS-TERM.request primitive to send an unsolicited SCS Response frame at any time to terminate an SCS stream. The AP shall set the Dialog Token field to 0, the SCSID field to identify the SCS stream being terminated, and the Status field to TCLAS_PROCESSING_TERMINATED, TCLAS_PROCESSING_TERMINATED_INSUFFICIENT_QOS, TCLAS_PROCESSING_TERMINATED_POLICY_CONFLICT, or TCLAS_RESOURCES_EXHAUSTED.

When an SCS stream is terminated, the AP shall cease to apply the classifier(s) related to it.

### 11.25.3 MSCS procedures

The mirrored stream classification service (MSCS) is a service that may be provided by an AP to its associated STAs that support MSCS. In MSCS, the AP classifies incoming individually addressed MSDUs from the DS or WM that are destined for a non-AP STA based upon classifier masks provided by that non-AP STA. The AP sets the UP of the MSDUs in the classified streams based on the UP of individually addressed MSDUs in the corresponding mirror (reverse direction) stream from the non-AP STA to the AP.

Implementation of MSCS is optional for a STA. A STA that supports MSCS sets its dot11MSCSActivated to true, and shall set to 1 the Mirrored SCS field of the Extended Capabilities elements that it transmits. When dot11MSCSActivated is true, dot11QosOptionImplemented shall be true.

An MSCS setup is initiated by a non-AP STA's SME. How it does this, and how it selects the MSCS Descriptor parameter, is out of scope of this standard. Setup of an MSCS uses the MLME-MSCS.request, MLME-MSCS.indication, MLME-MSCS.response and MLME-MSCS.confirm primitives (see 6.3.2 (Type 1)).(#3048)

A non-AP STA that supports MSCS may request use of MSCS, or request to update parameters of the currently active MSCS, by sending an MSCS Request frame that includes an MSCS Descriptor element with the Request Type field set to "Add" or "Change", respectively. A non-AP STA that supports MSCS may request use of MSCS by sending a (Re)Association Request frame that includes an MSCS Descriptor element with the


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Request Type field set to “Add”. The MSCS Descriptor element identifies how MSDUs are classified into streams and indicates parameters that determine the priority to assign to the classified MSDUs.

In a TCLAS Mask element in an MSCS Descriptor element, the Classifier Type subfield shall be set to a value that corresponds to a classifier of MSDUs, i.e., less than or equal to 5, or equal to 10.

Upon receipt of an MSCS Request frame from an associated non-AP STA, or receipt from a non-AP STA of a (Re)Association Request frame containing an MSCS Descriptor element, the AP shall respond with a corresponding MSCS Response frame or with a (Re)Association Response frame containing an MSCS Descriptor element, respectively. When the AP accepts the MSCS request in response to an MSCS Request frame, it shall set the Status field in the MSCS Response frame to “SUCCESS” and shall not include an MSCS Descriptor element in the frame. When the AP accepts the MSCS request in response to a (Re)Association Request frame, it shall set the Status field in the MSCS Status subelement of the MSCS Descriptor element of the (Re)Association Response frame to “SUCCESS” and set the Request Type field to “Add”.

A value of REQUEST_DECLINED, REQUESTED_TCLAS_NOT_SUPPORTED_BY_AP(#585), or INSUFFICIENT_TCLAS_PROCESSING_RESOURCES shall be set in the Status field in the MSCS Response frame or in the MSCS Status subelement of the MSCS Descriptor element of the (Re)Association Response frame, when the AP declines the MSCS request; an MSCS Descriptor element is optionally present in the MSCS Response frame for this case. If an MSCS Descriptor element is present in an MSCS Response frame that does not indicate a status of “SUCCESS”, the Request Type field is set to “Change” and the element indicates a suggested set of parameters that could be accepted by the AP in response to a subsequent request by the non-AP STA. In the MSCS Descriptor element of a (Re)Association Response frame with a value in the Status field other than “SUCCESS” the Request Type field is set to “Add” if no suggested set of parameters is indicated, or set to “Change” if the element indicates a suggested set of parameters that could be accepted by the AP in response to a subsequent request by the non-AP.

(#299)When the AP does not accept an MSCS request in response to an MSCS Request frame with a Request Type field value of “Change”, the existing MSCS is unchanged.

An AP has a maximum of one active MSCS per non-AP STA. A non-AP STA shall not (#134)send an MSCS request to an AP with the Request Type field set to “Add” if MSCS is currently active with that AP.(#299)

If MSCS for a non-AP STA is currently active and the AP declines an MSCS request from the non-AP STA with Request Type field set to “Change”, the previously accepted parameters continue to apply.

If the request is accepted by the AP, MSCS for the non-AP STA becomes active. Incoming MSDUs whose DA parameter value maps to an RA equal to the MAC address of the non-AP STA are classified above the AP’s MAC sublayer and are sent to the MAC through the MAC SAP using the MA-UNITDATA.request primitive with the priority parameter equal to the assigned UP, based on the parameters specified in the MSCS Descriptor element. The following procedure is used:

a) The classifier parameters and associated masks of the MSCS are determined according to the TCLAS Mask element(s) in the MSCS Descriptor element as follows:
   - For TCLAS Mask elements indicating a classifier type value less than or equal to 5, but not equal to 3, the classifier parameters specified by that element are indicated by the Classifier Mask subfield; there is no associated mask for these parameters.
   - For TCLAS Mask elements indicating classifier type 3, the classifier parameter specified by that element is equal to the set of octets defined by the Filter Offset subfield and length of the (reserved) Filter Value subfield; the associated mask for the parameter is specified in the Filter Mask subfield.
   - For TCLAS Mask elements indicating classifier type 10, the classifier specified by that element is equal to the set of octets defined by the Protocol Number or Next Header subfield

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and the length of the (reserved) Filter Value subfield; the associated mask for the parameter is specified in the Filter Mask subfield.

— The classifier parameters and associated masks of the MSCS comprise all the classifier parameters and associated masks specified by all the TCLAS Mask elements in the MSCS Descriptor element.

b) The mirror classifier parameters and associated masks are determined as follows:

— If source (Ethernet) address is a classifier parameter, destination (Ethernet) address is a mirror classifier parameter; there is no associated mask for this parameter.

— If destination (Ethernet) address is a classifier parameter, source (Ethernet) address is a mirror classifier parameter; there is no associated mask for this parameter.

— If source IP address is a classifier parameter, destination IP address is a mirror classifier parameter; there is no associated mask for this parameter.

— If destination IP address is a classifier parameter, source IP address is a mirror classifier parameter; there is no associated mask for this parameter.

— If source port is a classifier parameter, destination port is a mirror classifier parameter; there is no associated mask for this parameter.

— If destination port is a classifier parameter, source port is a mirror classifier parameter; there is no associated mask for this parameter.

— If any other parameter is a classifier parameter, the same parameter is a mirror classifier parameter; if the classifier parameter has an associated mask then the mirror classifier parameter has the same associated mask.

c) A logical list is maintained, initially empty, of variables *UP{tuple}*, where each variable represents a user priority associated with a value *tuple* of the masked classifier parameters. Monitoring of incoming individually addressed MSDUs as indicated by the MA-UNITDATA.indication primitive begins. If an MSDU is received that is not part of a TS (as described in 11.4 (TS operation)) and the SA parameter value is equal to the MAC address of the non-AP STA and the priority parameter is equal to an integer value in the range 0 to 7 and the service class parameter is equal to QoSAck, the MSDU's UP is determined per 5.1.1.3 (Interpretation of priority parameter in MAC service primitives) and, if the UP is equal to one of the UPs specified in the User Priority bitmap subfield of the MSCS Descriptor element, the following steps are performed:

1) Determine *m_tuple* of the received MSDU, which is equal to the tuple of all mirror classifier parameters of the MSDU masked by the associated masks (#4181)(see item b) above). If the MSDU has no value for one or more of the mirror classifier parameters, the remaining steps are not performed.

2) Determine *tuple* corresponding to the received MSDU, by mapping all the masked values of parameters in *m_tuple* per the relationships described in item b) above.

3) Add or update the variable *UP{tuple}* in the list, setting the value of the variable to the UP of the received MSDU. When a variable is updated (i.e., when a variable corresponding to the same *tuple* already exists in the list), the previous value of the variable is discarded.

If a period equal to the value of the Stream Timeout subfield of the MSCS Descriptor element has elapsed since a given variable in the list was last updated, that variable may be removed from its maintained list.

d) In parallel, classification begins of incoming MSDUs from the DS or WM whose DA parameter value maps to an RA equal to the MAC address of the non-AP STA. The following steps are performed for each such MSDU:

1) Determine *tuple* of the MSDU, which is equal to the tuple of all the classifier parameters of the MSDU masked by the associated masks (see (a) above). If the MSDU does not have a value for one or more of the classifier parameters, the remaining steps are not performed.


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2) If variable *UP{tuple}* exists in the list for this value of *tuple*, and the MSDU is not part of a TS (as described in 11.4 (TS operation)), and the MSDU is not part of an SCS stream (see 11.25.2 (SCS procedures)), assign the MSDU a UP equal to min(*UP{tuple}, UPLim*), where *UPLim* is the value of the User Priority Limit subfield of the MSCS Descriptor element.

NOTE 1—The maintenance of the logical list of variables *UP{tuple}* described above is a logical description of a required process. The specific implementation of this process is vendor specific and is not required to match the description above.

NOTE 2—When MSCS does not assign a UP to an MSDU that is not part of a TS or an SCS stream, the UP of the MSDU might be set by other mechanisms such as interworking QoS mapping from DSCP values (e.g., see R.3 (QoS mapping guidelines for interworking with external networks)).

NOTE 3—It is recommended that a non-AP STA using MSCS sets the UP of MSDUs it transmits to its associated AP in a way that does not cause the variables *UP{tuple}* maintained by the AP to change excessively often. This helps to minimize management overhead on the AP, and also minimizes the possibility of MSDUs with the same value of *tuple* being delivered to the higher layers out of order during the transition of the UP of those MSDUs. Note that the requirements for ordering of MSDUs with the same TID value in the MAC sublayer (see 5.1.3 (MSDU ordering)) are unaffected by MSCS.

A non-AP STA may request the termination of a currently active MSCS by sending an MSCS Request frame with the Request Type field set to "Remove" in the MSCS Descriptor element. Upon reception of a request to terminate the active MSCS, the AP shall cease to apply the corresponding classifiers and processing related to the active MSCS and delete the maintained list of variables *UP{tuple}*. The AP shall send an MSCS Response frame to confirm the termination of the MSCS, by including a value of "TCLAS_PROCESSING_TERMINATED" in the Status field of an MSCS Response frame and the dialog token in the MSCS Response frame set to the value from the MSCS Request frame that requested termination; an MSCS Descriptor element is not present in the response.

The AP may send an unsolicited MSCS Response frame at any time to cancel an active MSCS, by including a value of "TCLAS_PROCESSING_TERMINATED", "TCLAS_PROCESSING_TERMINATED_INSUFFICIENT_QOS", "TCLAS_PROCESSING_TERMINATED_POLICY_CONFLICT" or "TCLAS_RESOURCES_EXHAUSTED" in the Status field of an MSCS Response frame and the dialog token in the MSCS Response frame set to 0. The MSCS Descriptor element is optionally present; if present the Request Type field is set to "Change" and the element indicates a suggested set of parameters that could be accepted by the AP in response to a subsequent request by the recipient non-AP STA.

## 11.26 Procedures to manage OBSS

### 11.26.1 General

QLoad Report elements, HCCA TXOP Update Count elements, HCCA TXOP Advertisement action frames, and HCCA TXOP Response frames are designed to mitigate the effects of OBSSs and provide the means to

- Advertise QoS load information for channel selection
- Extend the admission control and scheduled mechanisms to a distributed environment
- Enable the coordination of scheduled HCCA TXOPs between HCs operating with OBSSs

OBSS APs are APs that are using the same primary channel and that are able to receive or obtain frames from each other, including Beacon frames. These frames are received directly or via associated STAs that support the Beacon request capability (as indicated by the Beacon Passive Measurement Capability Enabled bit or the Beacon Active Measurement Capability Enabled bit being set in the RM Enabled Capabilities element in the (Re)Association Request frame). An AP might scan other channels as part of its channel selection process or might request associated STAs that support the Beacon request capability to perform an off-channel Beacon

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request measurement, and these procedures might provide QLoad Report elements received from APs operating on other channels. Subclause T.3 (Channel selection using QLoad report) provides an example of using QLoad Reports from adjacent channels.

NOTE 1—These OBSS procedures might use unauthenticated Beacon frames and Public Action frames. Implementations might choose to use additional heuristics (e.g., a history of collaboration and traffic monitoring) to determine the authenticity of this information.

NOTE 2—These OBSS procedures are intended for stationary and portable APs (see 4.2.4 (The impact of handling mobile STAs)).

### 11.26.2 QLoad Report element

#### 11.26.2.1 Introduction

The QLoad Report element is contained in QLoad Report frames or Protected QLoad Report frames that are provided by an AP and, optionally, periodically in the Beacon frame. The QLoad Report frame is transmitted, upon the receipt of a QLoad Request frame by an AP for which dot11QLoadReportActivated is true, to the STA that sent the QLoad Request frame. An AP shall not send a QLoad Request frame or Protected QLoad Request frame to another AP that has QLoad Report field set to 0 in its Extended Capabilities element. The Protected QLoad Report frame is transmitted, upon the receipt of a Protected QLoad Request frame when dot11ProtectedQLoadReportActivated is true, to the STA that sent the Protected QLoad Request frame. An AP for which dot11ProtectedQLoadReportActivated is false shall discard any received Protected QLoad Request or Protected QLoad Report frames.

Whenever there is a change in the contents of the QLoad Report element and there is no pending delay period for an unsolicited QLoad Report frame, an unsolicited QLoad Report frame should be transmitted with the RA field set to the broadcast address, after a randomly selected delay between 1 and dot11QLoadReportDelay seconds. After this delay, the AP shall transmit an unsolicited QLoad Report frame that contains the most recently available QLoad information. When dot11QLoadReportActivated is true, the QLoad Report element shall be included in the Beacon frame every dot11QLoadReportIntervalDTIM DTIM intervals(#4221). When dot11QLoadReportActivated is false, the QLoad Report element shall not be included in Beacon frames.

#### 11.26.2.2 Calculating field values

The value of the Potential Traffic Self field represents the potential QoS traffic of this BSS; therefore, the value in the Mean subfield shall always be greater than or equal to the value of the Mean subfield in the Allocated Traffic Self field.

The AP shall include in the Allocated Traffic Self field all accepted and not deleted TSPECs as they are sent by non-AP STAs. At the deletion of each such TSPEC, the AP shall remove the TSPEC from its Allocated Traffic Self field.

The number of active AC_VI and AC_VO streams shall be provided in the Allocated Traffic Self field. For each admitted admission control TSPEC, the AP calculates a medium time, as described in K.2.2 (Deriving medium time). This medium time, however, does not include the medium access overhead that, in turn, is related to the number of streams. This access overhead is further discussed in T.2.7 (EDCA Overhead Factor), and a recommendation is given for its value.

An example of a method of calculating the values for the Mean and Standard Deviation subfields in the Potential Traffic Self field is given in T.2.3 (Calculation of potential traffic self).

The Sharing Policy field is used to indicate the currently active policy for sharing the medium with OBSSs. Setting the Sharing Policy field to “Static” indicates that the share of the total available medium time of an AP does not change when the value of the Allocated Traffic Shared field changes. Setting the Sharing Policy field


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to "Dynamic" indicates that the share of the total available medium time of an AP might change when the value of the Allocated Traffic Shared field changes. If the Sharing Policy field has the value "Vendor Specific," then the QLoad Report element shall contain a Vendor Specific subelement.

If the value of the Overlap field changes, the share of the total available medium time of an AP might change for both static and dynamic sharing policies.

The value of the Potential Traffic Self field represents the potential QoS traffic of this AP and, therefore, shall always be greater than or equal to the values represented by the Allocated Traffic Self field.

The Allocated Traffic Self field contains the mean and standard deviation values of the total EDCA admission control and HCCA traffic that the AP has allocated at any one time and contains the number of AC_VI and AC_VO EDCA admission control streams. As each stream is added or deleted, the AP shall calculate the new value of the Allocated Traffic Self field. A recommended method for calculating the Allocated Traffic Self field mean and standard deviation values is given in T.2.4 (Calculation of allocated traffic self).

The Allocated Traffic Shared field is calculated from the Allocated Traffic Self fields for all APs that overlap with the AP performing the calculation, including the Allocated Traffic Self field of the AP performing the calculation. A recommended method for summing the Allocated Traffic Self field values is given in T.2.4 (Calculation of allocated traffic self).

The EDCA Access Factor is the total traffic bandwidth requirement for all of the OBSSs expressed as a fraction that may be greater than 1. An implementation might calculate the EDCA Access Factor from the summation of the Potential Traffic Self field values of all of the APs that are overlapping, as follows:

a) Sum all of the Potential Traffic Self field values for all OBSSs, including self, in order to calculate the peak traffic requirement (#1175)in multiples of 32 μs/s. As the Potential Traffic Self field value is expressed in terms of mean and standard deviations, it is possible to sum the Potential Traffic Self field values as a composite stream. A suggested method for this summation is given in T.2.3 (Calculation of potential traffic self).

b) Sum all of the HCCA Peak field values from all OBSSs, including self, in order to calculate the peak HCCA traffic requirement, (#1176)in multiples of 32 μs/s.

c) Subtract the value derived in step b) from the value derived in step a). This value is the EDCA traffic.

d) Sum the AC_VO and AC_VI streams reported in its own QLoad report and all of the QLoad reports of OBSSs. Based upon the number of EDCA streams, an EDCA Overhead Factor can be estimated to account for the medium access time requirements. EDCA Overhead Factor is further discussed in T.2.3 (Calculation of potential traffic self), and a recommendation is given for its value.

e) Multiply together the EDCA traffic from step c) and the EDCA Overhead Factor to obtain a value that represents the total peak bandwidth requirement for the OBSSs. This value is (#1177)in multiples of 32 μs/s.

f) Convert the total peak bandwidth requirement to a fraction that is rounded down to a multiple of 1/64 (8 bits). This value is the EDCA Access Factor. An example for this conversion is given in T.2.6 (Calculation of EDCA Access Factor).

The HCCA Peak field value is the sum of the all of the medium times of active TS that use the HCCA or HEMM access policy over a 1 s period for all of the HCCA TSPECs included in the QLoad field. The TXOP time, scheduled by the HC, multiplied by the reciprocal of its SI, is termed the *HCCA medium time*. The HCCA Peak field value is the summation of the HCCA medium times that the HC has scheduled, in multiples of 32 μs.

The HCCA Access Factor is the total HCCA TXOP medium time requirement for all of the OBSSs expressed as a fraction that may be greater than 1. An implementation might calculate the HCCA Access Factor from the

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summation of the HCCA Peak field values of all of the APs that in an OBSS, by summation of all of the HCCA Peak field values for all APs in OBSSs and converting this summation to a fraction that is rounded down to 1/64 (8 bits). An example for this conversion is given in T.2.8 (Calculation of HCCA Access Factor).

#### 11.26.2.3 Requesting QLoad Reports using radio measurement requests

If an AP has associated STAs that support passive or active beacon measurement (as indicated by the Beacon Passive Measurement Capability Enabled bit or the Beacon Active Measurement Capability Enabled bit being set in the RM Enabled Capabilities element), it may use the neighbor report capability of these associated STAs to attempt to retrieve QLoad Report elements from APs with which the AP is unable to exchange frames directly.

The AP sends a Radio Measurement Request frame that contains a Measurement Request element to an associated STA that supports neighbor reporting and beacon reporting. This Measurement Request element has the Measurement Type field set to "Beacon request" (as defined in Table 9-136 (Measurement type definitions for measurement requests)), and the BSSID field of the Measurement Request field of the Beacon request frame (as defined in Figure 9-250 (Measurement Request field format for Beacon request)) is set to the wildcard BSSID. There shall be a Request subelement in the Measurement Request field of the Beacon request frame that contains the Element ID of the QLoad Report element (as defined in Table 9-130 (Element IDs)) and may contain other element IDs. The SSID subelement shall not be included in the Request subelement of the Measurement Request field of the Beacon request.

Depending upon the signaled enabled radio measurement capabilities of the associated STA, the AP may use either the passive or active measurement mode. The Channel Number field should be set to the primary channel number that is currently being used by the AP, but may be set to other values if off-channel beacon measurement is supported by the STA to which the measurement request is to be sent.

If the measurement request is accepted, the requested STA performs the measurement request (as described in 11.10 (Radio measurement procedures)). The subsequent Radio Measurement Report frame contains (#1685)Beacon reports for successful measurements. These (#1685)Beacon reports might contain QLoad Report elements inside a Reported Frame Body subelement, if the reporting STA received QLoad Report elements from the Beacon or Probe Response frames that it received from neighboring APs. The contents of these QLoad Report elements can then be used in calculating Allocated Traffic Shared, EDCA Access Factor, and HCCA Access Factor field values as described in 11.26.2.2 (Calculating field values).

### 11.26.3 HCCA TXOP negotiation

The procedures described in this subclause allow HCCA APs to cooperatively create new HCCA schedules that do not collide.

When sharing with at least one other HCCA AP, each sharing AP for which dot11RobustAVStreamingImplemented is true shall set its dot11HCCWmax to a value of at least 3.

HCCA APs that are able to directly exchange frames without the use of a third-party STA and signal support for unprotected or protected TXOP negotiation (as indicated by the Unprotected TXOP Negotiation or Protected TXOP Negotiation field equal to 1 in the Extended Capabilities element in Beacon frames) coordinate their TXOP schedules using HCCA TXOP Advertisement and HCCA TXOP Response frames. In this subclause, an HCCA AP in an OBSS that is able to directly exchange frames without the use of a third-party STA is referred to as a *collaboration candidate*.

The HCCA TXOP Update Count element is included in the Beacon frame to indicate that an HCCA TXOP schedule has changed. The Update Count field of the HCCA TXOP Update Count element is incremented (modulo 256) each time a TS with an access policy of HCCA or HEMM is created or deleted. An HCCA AP for which dot11PublicHCCATXOPNegotiationActivated is true or


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dot11ProtectedHCCATXOPNegotiationActivated is true shall advertise the Duration, Service Interval, and Start Time subfields for each HCCA TXOP reservation in a TXOP Reservation field as described in 9.4.1.41 (TXOP Reservation field).

(#181)An HCCA AP for which dot11PublicTXOPNegotiationActivated is true or dot11ProtectedTXOPNegotiationActivated is true shall support maintaining one or more dot11APCEntry(s) for each collaboration candidate in the dot11APCTable. These fields indicate the schedules that the AP should try to avoid using when creating schedules for new TS requests.

Before accepting a TSPEC request that has the Access Policy subfield of the TSPEC element equal to "HCCA" or "HEMM," an HC for which dot11PublicTXOPNegotiationActivated is true or dot11ProtectedTXOPNegotiationActivated is true should examine all dot11APCEntry(s) that are present in the dot11APCTable.

When an AP with dot11PublicHCCATXOPNegotiationActivated true or with dot11ProtectedHCCATXOPNegotiationActivated true receives a TSPEC request that has the Access Policy subfield of the TSPEC element equal to "HCCA" or "HEMM," it shall send an HCCA TXOP advertisement to each collaboration candidate. These HCCA TXOP advertisements shall have the TXOP Reservation field set to the TXOP that the AP is attempting to schedule.

An AP with dot11ProtectedTXOPNegotiationActivated true shall send the HCCA TXOP advertisement using a Protected HCCA TXOP Advertisement frame to each collaboration candidate that indicates support for protected HCCA TXOP negotiation (as indicated by the Protected TXOP Negotiation field equal to 1 in the Extended Capabilities element in Beacon frames from the collaboration candidate).

An AP with dot11PublicTXOPNegotiationActivated true shall send the HCCA TXOP advertisement using an HCCA TXOP Advertisement frame to each collaboration candidate that indicates support for unprotected HCCA TXOP negotiation (as indicated by the Unprotected TXOP Negotiation field equal to 1 in the Extended Capabilities element in Beacon frames from the collaboration candidate) unless the HCCA TXOP advertisement has already been transmitted to this collaboration candidate using a Protected HCCA TXOP Advertisement frame.

NOTE—When peer APs have both unprotected and protected TXOP negotiation activated, protected TXOP negotiation is used.

The AP shall not send an ADDTS Response frame to the requesting STA until one of the following conditions occurs:

a) The AP has received an HCCA TXOP Response frame, with the Status field equal to SUCCESS, from all of the APs to which HCCA TXOP advertisements were sent.
b) At least two Beacon frames have been received from all of the APs to which HCCA TXOP advertisements were sent.
c) A Beacon frame containing the HCCA TXOP Update Count element is received from all of the APs to which HCCA TXOP advertisements were sent.
d) A period of three dot11BeaconPeriod TU has elapsed.

If an AP receives another TSPEC request while waiting for one of the above conditions to occur, it shall delay processing this additional TSPEC request until one of the above conditions occurs.

An AP with dot11PublicTXOPNegotiationActivated false shall discard any received HCCA TXOP Advertisement frames. An AP with dot11ProtectedTXOPNegotiationActivated true shall discard any received unprotected HCCA TXOP Advertisement frames from a peer AP with which it has an active security association.

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Upon reception of an unprotected HCCA TXOP Advertisement frame, an AP with dot11PublicTXOPNegotiationActivated true shall discard all dot11APCEntry(s) from the dot11APCTable that have dot11APCEntryMACAddress equal to the MAC address of the AP that sent the HCCA TXOP Advertisement frame and shall prepare a response using the procedures below.

An AP with dot11ProtectedTXOPNegotiationActivated false shall discard any received Protected HCCA TXOP Advertisement frames.

An AP with dot11ProtectedTXOPNegotiationActivated true that does not have an active security association with a peer AP that indicates support for protected HCCA TXOP negotiation shall use the AP PeerKey protocol (as defined in 12.10.2 (AP PeerKey protocol)) and authenticated mesh peering exchange (AMPE) (as defined in 14.6 (Authenticated mesh peering exchange (AMPE))) to negotiate security parameters and create a new PMKSA and PTKSA to secure the Protected HCCA TXOP Advertisement frames. The use of AMPE proves possession of the PMK (generated using the procedures described in 12.10.2 (AP PeerKey protocol)) and implicitly the private key that corresponds to the peer's public key.

Upon reception of a valid Protected HCCA TXOP Advertisement frame, an AP with dot11ProtectedTXOPNegotiationActivated true shall discard all dot11APCEntry(s) from the dot11APCTable that have dot11APCEntryMACAddress equal to the MAC address of the AP that sent the Protected HCCA TXOP Advertisement frame and shall prepare a response using the procedures below.

If the (Protected) HCCA TXOP Advertisement frame has not been discarded due to the procedures above, the AP shall create a dot11APCEntry in the dot11APCTable for each TXOP reservation in the Active TXOP Reservations field of the (Protected) HCCA TXOP Advertisement frame.

If the (Protected) HCCA TXOP Advertisement frame has not been discarded due to the procedures above, the AP shall inspect its HCCA schedule to check whether the TXOP reservations number given in the Pending TXOP Reservations field of the HCCA TXOP Advertisement frame is in conflict with an existing accepted HCCA TXOP, allocated by itself. If there is no conflict, the AP shall send an HCCA TXOP Response frame with the Status field set to SUCCESS and create a dot11APCEntry for each TXOP reservation in the Pending TXOP Reservations field in the HCCA TXOP Advertisement frame.

If the HCCA advertisement was sent using an unprotected Public Action frame, the HCCA TXOP response shall be sent using an unprotected Public Action frame.

If the HCCA advertisement was sent using a Protected HCCA TXOP Advertisement frame, the HCCA TXOP response shall be sent using a Protected HCCA TXOP Response frame.

If the AP detects that the TXOP given in the (Protected) HCCA TXOP Advertisement frame is in conflict with an existing accepted HCCA TXOP and this AP is not itself currently processing an ADDTS request, it shall send a (Protected) HCCA TXOP Response frame with the Status field set to "TS_SCHEDULE_CONFLICT," the Alternate Schedule field set to a period of time that does not conflict with any currently accepted HCCA TXOPs, and the Avoidance Request field absent. The Duration subfield of the Alternate Schedule field should be greater than or equal to the Duration subfield of the Schedule field in the (Protected) HCCA TXOP Advertisement frame. The Duration subfield of the Alternate Schedule field may be less than the Duration subfield of the Schedule field in the (Protected) HCCA TXOP Advertisement frame when there is an insufficient period of time that does not conflict with currently accepted HCCA TXOPs.

If the AP detects that the TXOP given in the (Protected) HCCA TXOP Advertisement frame is in conflict with an in-progress ADDTS request for an HCCA TXOP for which HCCA TXOP Response frames have not been received, it shall send a (Protected) HCCA TXOP Response frame with the Status field set to "TS_SCHEDULE_CONFLICT" and the Alternate Schedule and Avoidance Request fields set according to the following rules:


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— If MIX($MAC_r$) < MIX($MAC_i$), the Alternate Schedule field is set to a value that does not conflict with any accepted HCCA TXOPs and also does not conflict with the TXOP of the in-progress ADDTS request. The Avoidance Request field is set to the TXOP of the in-progress ADDTS request.

— If MIX($MAC_r$) > MIX($MAC_i$), the Alternate Schedule field is set to the value from the TXOP Reservation field from the HCCA TXOP Advertisement frame. The Avoidance Request field is set to a time period that does not conflict with any accepted HCCA TXOPs nor the TXOP in the Alternate Schedule field and has sufficient duration and service interval to meet the requirements of the in-progress ADDTS request.

where

$MAC_r$ is the MAC address of the AP that received the HCCA TXOP Advertisement frame

$MAC_i$ is the MAC address of the AP that sent the HCCA TXOP Advertisement frame

The MIX function takes the 6 octets of a MAC address and computes a new 6-octet value:

MIX($MAC$) = $MAC$[4] || $MAC$[5] || $MAC$[0] || $MAC$[1] || $MAC$[2] || $MAC$[3]

For the purpose of the comparisons shown above, the resulting 6-octet value is converted to a positive integer treating the first octet as the most significant octet of the integer.

Table 11-24 (Contents of HCCA TXOP Response frame) provides a summary of the values used in an HCCA TXOP Response frame.

**Table 11-24—Contents of HCCA TXOP Response frame**

| Case | Status code | Alternate Schedule field | Avoidance Request field |
|---|---|---|---|
| No conflict with existing or in-progress schedules | SUCCESS | Not present | Not Present |
| Conflicts with existing schedule; no ADDTS request in progress | TS_SCHEDULE_ CONFLICT | Period of time that does not conflict with any currently accepted HCCA TXOPs | Not Present |
| Conflict with in-progress schedules, MIX($MAC_r$) < MIX($MAC_i$) | TS_SCHEDULE_ CONFLICT | Period of time that does not conflict with any currently accepted HCCA TXOPs nor the in-progress ADDTS request | Schedule of in-progress ADDTS request |
| Conflict with in-progress schedules, MIX($MAC_r$) > MIX($MAC_i$) | TS_SCHEDULE_ CONFLICT | Same schedule that was in the HCCA TXOP Advertisement frame | Period of time that does not conflict with any currently accepted HCCA TXOPs nor the period given in the Alternate Schedule field |

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The AP shall keep a record of the TXOP proposed in the Alternate Schedule field in a TXOP avoidance record and should avoid scheduling any new HCCA TXOPs in this proposed period until any of the following conditions occurs:

— A period of dot11HCCATXOPBeaconTimeout multiplied by dot11BeaconPeriod TUs has elapsed.

— The AP with dot11PublicTXOPNegotiationActivated true receives an unprotected HCCA TXOP Advertisement frame from the AP to which the unprotected HCCA TXOP Response frame was sent.

— The AP with dot11ProtectedTXOPNegotiationActivated true receives a Protected HCCA TXOP Advertisement frame from the AP to which the Protected HCCA TXOP Response frame was sent.

If an AP with dot11PublicTXOPNegotiationActivated true receives an unprotected HCCA TXOP Response frame with the Status field equal to "TS_SCHEDULE_CONFLICT," the AP should create a new schedule for the TSPEC request using the suggestion provided in the HCCA TXOP Response frame. If an AP with dot11ProtectedTXOPNegotiationActivated true receives a Protected HCCA TXOP Response frame with the Status field equal to "TS_SCHEDULE_CONFLICT," the AP should create a new schedule for the TSPEC request using the suggestion provided in the Protected HCCA TXOP Response frame.

If an AP creates a new schedule in response to a (Protected) HCCA TXOP Response frame, it shall send a new HCCA TXOP advertisement to each collaboration candidate, using the procedures previously defined in this subclause.

After one or more HCCA TXOP Advertisement frame transmissions that cause the reception of an HCCA TXOP Response frame with the Status field equal to "TS_SCHEDULE_CONFLICT," the AP may terminate the HCCA TXOP advertisement procedure and respond to the ADDTS Request frame with a status code not equal to SUCCESS (decline the ADDTS Request) or a status code equal to SUCCESS (accept the ADDTS request regardless of potential HCCA TXOP conflicts).

### 11.26.4 HCCA AP timing synchronization for HCCA TXOP advertisement

#### 11.26.4.1 General

HCCA APs in OBSSs for which dot11PublicHCCATXOPNegotiationActivated is true or dot11ProtectedHCCATXOPNegotiationActivated is true synchronize their TSF timing so that the HCCA TXOP advertisement scheme does not suffer from time differences between the clocks of the overlapping APs.

In order to use HCCA TXOP advertisement, the AP maintains synchronization with its APs in OBSSs. HCCA APs that use HCCA TXOP advertisement shall use a DTIM interval with a duration of $2^n \times 100$ TU where $n$ a non-negative integer less than or equal to 5.

NOTE—The DTIM interval of the form $2^n \times 100$ TU has been chosen to facilitate the verification that HCCA TXOP reservations do not overlap. The restriction that $n$ be less than or equal to 5 has been chosen so that the range of the HCCA TXOP start time in the reservation (see 9.4.1.41 (TXOP Reservation field)) is compatible with the maximal DTIM interval length.

#### 11.26.4.2 Timing offset

An HCCA AP with dot11PublicHCCATXOPNegotiationActivated true or dot11ProtectedHCCATXOPNegotiationActivated true shall update the timing offset value based on time stamps from the received Beacon frames from HCCA APs that have an entry in the dot11APCTable. The timing offset value is calculated using Equation (11-15).

$$T_{offset} = T_T - T_R \tag{11-15}$$

where


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$T_{offset}$ is the timing offset value
$T_T$ is the value in the Timestamp field in the received Beacon frame from the overlapping HCCA AP
$T_R$ is the Beacon frame reception time measured using the HCCA AP's TSF timer

The offset value is represented as 2s complement. The unit of the offset value is microseconds. The HCCA AP shall keep the $T_{offset}$ value calculated from the latest Beacon frame received from each AP in an OBSS.

#### 11.26.4.3 Clock drift adjustment

When dot11RobustAVStreamingImplemented is true and dot11PublicHCCATXOPNegotiationActivated is true, the HCCA AP shall examine the reception time of the Beacon frames from overlapping HCCA APs with which it maintains synchronization and adjust its TSF timer to compensate the relative timing error among overlapping HCCA APs caused by the clock drift. The HCCA AP adjusts its TSF so that its TSF counting frequency is aligned to the AP with the lowest TSF counting frequency.

The HCCA AP shall operate the following clock drift compensation procedure:

a) If the HCCA AP does not have a valid $T_{offset}$ value obtained from the previous Beacon frame reception from a particular overlapping HCCA AP, it shall not operate the clock drift compensation for that AP.

b) When the HCCA AP receives a Beacon frame from one of the overlapping HCCA APs with which it maintains synchronization, the HCCA AP shall calculate the clock drift amount $T_{ClockDrift}$ by comparing the $T_{offset}$ obtained previously for this overlapping HCCA AP and the $T_{offset}$ obtained from the Beacon frame reception. See Equation (11-16).

$$T_{ClockDrift} = T_{offset,1} - T_{offset,0} \quad (11\text{-}16)$$

where

$T_{ClockDrift}$ is the clock drift amount represented as 2s complement, in microseconds
$T_{offset,1}$ is the $T_{offset}$ obtained from the previous reception
$T_{offset,0}$ is the $T_{offset}$ obtained from the current frame reception

c) The HCCA AP shall calculate the $T_{ClockDrift}$ value for all overlapping HCCA APs with which it maintains synchronization and select the largest $T_{ClockDrift}$ value. If the largest $T_{ClockDrift}$ is greater than zero, it shall suspend its TSF timer for the duration of the largest $T_{ClockDrift}$. The HCCA AP shall suspend its TSF timer frequently enough that the delay during a single beacon period does not exceed 0.08% of its beacon interval.

NOTE—This clock drift compensation procedure is not intended to maintain a strict synchronization. It aims to stop TBTT drifting away among overlapping HCCA APs to allow some jitter of TSF timer.

## 11.27 DMG beamformed link and BSS maintenance

### 11.27.1 Beamformed link maintenance

#### 11.27.1.1 General(11ay)

A pair of DMG STAs that have established a beamformed link can maintain this link. This subclause describes procedures that allow a pair of DMG STAs to maintain a beamformed link that was established between them.

A beamformed link is established as a result of the most recent success of the procedures specified in 10.41.2 (Sector-level sweep (SLS) phase) if the STAs completed the SLS phase or as a result of the most recent success of the procedures specified in 10.41.6.4 (BRP phase execution) if the STAs completed the BRP phase.

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A DMG STA shall negotiate the value of dot11BeamLinkMaintenanceTime using the procedures specified in 10.41.6.2 (SLS phase execution) or may leave it undefined as specified in 9.5.6 (Beamformed Link Maintenance field).

If the dot11BeamLinkMaintenanceTime has been defined as described in 9.5.6 (Beamformed Link Maintenance field), a DMG STA shall implement a beam link maintenance timer to control each beamformed link. The STA shall keep one beam link maintenance timer per beamformed link. After it is set, the beam link maintenance timer shall count down. The timer shall be stopped when it reaches the value zero. The beam link maintenance timer of a beamformed link shall be halted during the following periods of time:

— BTI and A-BFT of a beacon interval
— SPs and CBAPs in which the STA does not participate
— When any of the STAs involved in the beamformed link is in doze state

The beam link maintenance timer shall be set to dot11BeamLinkMaintenanceTime when the source DMG STA and destination DMG STA successfully complete the BRP if the beam refinement phase is performed (10.38.3 (ATI transmission rules)) or the source DMG STA and destination DMG STA successfully complete the SLS (10.41.2 (Sector-level sweep (SLS) phase)) if the beam refinement phase is skipped as defined in 10.38.3 (ATI transmission rules).

A DMG AP or PCP shall set the beam link maintenance timer to dot11BeamLinkMaintenanceTime when it receives a response from the non-AP and non-PCP DMG STA during the ATI or when it receives an SPR frame as a response to a Poll frame, if these frames are received using the beamformed link established with the non-AP and non-PCP DMG STA.

The non-AP and non-PCP DMG STA shall set the beam link maintenance timer to the dot11BeamLinkMaintenanceTime when it receives a request from the DMG AP or PCP during the ATI or when it receives a Poll or a Grant frame, if these frames are received using the beamformed link established with the DMG AP or PCP.

The initiator DMG STA shall set the beam link maintenance timer to the dot11BeamLinkMaintenanceTime when an immediate response or acknowledgment (Ack, BlockAck, DMG CTS, DMG DTS) has been received from the recipient DMG STA of the beamformed link.

The recipient DMG STA shall set the beam link maintenance timer to the dot11BeamLinkMaintenanceTime after the transmission of the immediate response or acknowledgment (Ack, BlockAck, DMG CTS, DMG DTS) has been completed to the initiator DMG STA of the beamformed link.

(11bd)When a DMG STA with dot11DMGOCBActivated equal to true establishes a beamformed link with a peer STA, the STA shall generate an MLME-OCB-LINKSTATUS.indication with the BeamLinkStatus parameter set to ESTABLISHED or an MLME-OCB-DMGDISCOVERY.indication to inform the SME of the establishment of the beamformed link with the peer STA.

NOTE—When the beamformed link was established as a result of the discovery and the STA generated an MLME-OCB-DMGDISCOVERY.indication primitive as specified in 11.1.4.7 (DMG discovery outside the context of a BSS(11bd)), the STA might omit generation of an MLME-OCB-LINKSTATUS.indication.(11bd)


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To prevent expiration of the beam link maintenance timer when a DMG STA does not have MSDUs to send, the STA shall transmit QoS Null frames to maintain a beamformed link.

Following the expiration of the beamlink maintenance time (specified by the current value of dot11BeamLinkMaintenanceTime), the destination DMG STA of the SP shall configure its receive antenna to a quasi-omni antenna pattern for the remainder of the SP and during any SP following the expiration of the beamlink maintenance time.

Any time after dot11BeamLinkMaintenanceTime has elapsed, the source DMG STA of the SP may initiate an ISS to restore the beamformed link with the destination DMG STA of the SP following the rules defined in 10.41.2 (Sector-level sweep (SLS) phase). The source DMG STA may initiate the ISS before expiration of dot11BeamLinkMaintenanceTime.

The responder DMG STA of the beamformed link in the CBAP shall configure its receive antenna to a quasi-omni antenna pattern following the expiration of dot11BeamLinkMaintenanceTime except when it is involved in a frame exchange sequence(#109) with another STA.

Any time after dot11BeamLinkMaintenanceTime has elapsed, the initiator DMG STA of the beamformed link in the CBAP may initiate an ISS to restore the beamformed link with the responder STA following the rules defined in 10.41.2 (Sector-level sweep (SLS) phase). The initiator STA may initiate the ISS before expiration of dot11BeamLinkMaintenanceTime.

(11bd)Upon expiration of dot11BeamLinkMaintenanceTime, a DMG STA for which dot11DMGOCBActivated is true shall generate an MLME-OCB-LINKSTATUS.indication primitive with BeamLinkStatus parameter set to EXPIRED to inform the SME of the expiration of the beam link maintenance timer with the peer STA.

If a DMG STA detects degradation in the link quality between itself and another STA, the STA can use beam tracking or beam refinement to improve the link quality. The STA can request the AP or PCP to schedule an SP to perform BF with the other STA or use a CBAP to perform BF. The STA can use the A-BFT to perform BF if the other STA is its AP or PCP. A DMG AP or PCP can perform BF with a non-AP and non-PCP STA during a CBAP or by scheduling an SP between the AP or PCP and the non-AP and non-PCP STA through an Extended Schedule element transmitted in a DMG Beacon or Announce frame.

If the link quality between a DMG AP or PCP and a non-AP and non-PCP DMG STA degrades, but the STA can still receive DMG Beacon frames with the Next A-BFT field equal to 0, the STA should improve the link quality by performing RSS during the A-BFT period as described in 10.41.5 (Beamforming in A-BFT).

A DMG STA may use the value of the parameter LAST_RSSI in the RXVECTOR of a received frame to decide to initiate beamforming with a peer STA if the value of the LAST_RSSI parameter is different from zero (10.3.2.3.3 (SIFS)).

Figure 11-84 (Example of beamformed link maintenance) illustrates the operation of the beam link maintenance timer for an example involving STA-A and STA-B. In beacon interval *n*, STA-A and STA-B successfully perform beamforming and set up the beam link maintenance timer. In beacon interval *n*+1, the STAs have two SPs established between them. The beam link maintenance timer is halted and released according to the rules described above. Once the timer beam link maintenance timer expires, the STAs redo beamforming.

### 11.27.1.2 EDMG partial SLS(11ay)

An initiator and responder that are EDMG STAs are partial SLS ready if

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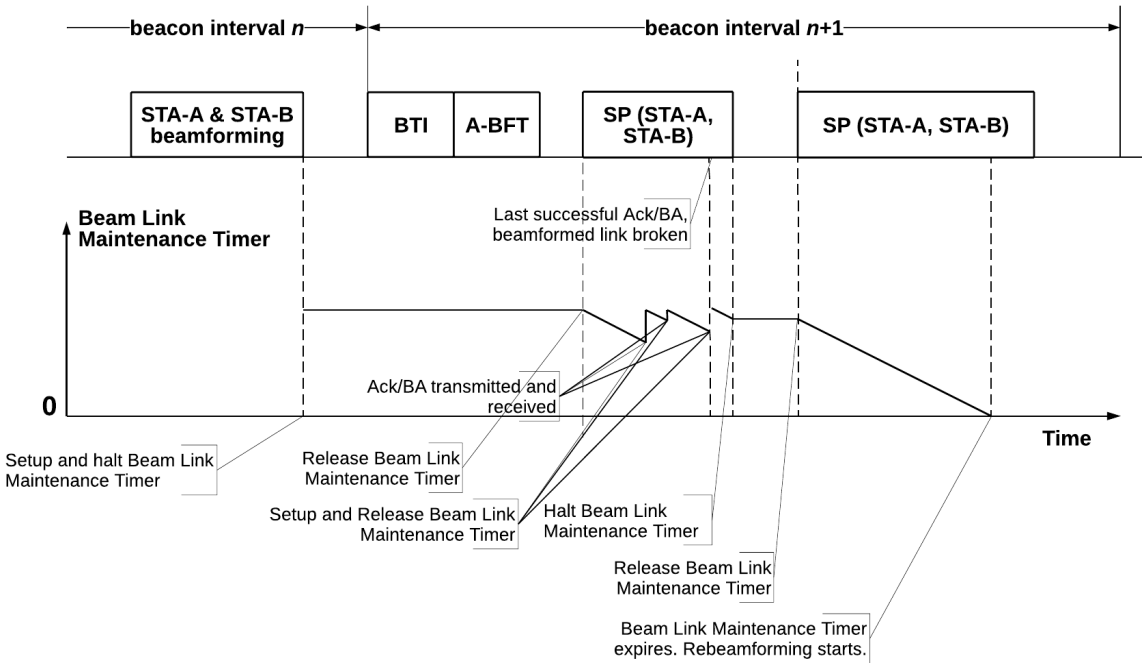


**Figure 11-84—Example of beamformed link maintenance**

— Either the initiator or the responder, or both the initiator and the responder, have more than one DMG antenna, and

— The initiator and responder have successfully exchanged an EDMG Partial Sector Level Sweep element (see 10.41.6.4.1 (General))

When the beam link maintenance timer expires on a link between an initiator and a responder that are partial SLS ready,

1) The responder shall configure its receive DMG antenna to a quasi-omni pattern and switch its receive DMG antennas at a rate of once per a time interval equal to MBIFS plus the number of sectors indicated in the Partial Number of Sectors field of the last EDMG Partial Sector Level Sweep element received from the initiator multiplied by (TXTIME(SSW frame)+SBIFS).

2) The initiator shall initiate an ISS with the number of sectors indicated in the Partial Number of Sectors field of the last EDMG Partial Sector Level Sweep element it sent to the responder. The initiator shall repeat this set of sectors for one plus the number indicated in the Partial Number of RX Antennas field in the last EDMG Partial Sector Level Sweep element received from the responder.

3) When the initiator finishes the ISS, it shall configure its receive antennas to a quasi-omni pattern and switch its receive DMG antennas at a rate of once per a time interval equal to MBIFS plus the number of sectors indicated in the Partial Number of Sectors field of the last EDMG Partial Sector Level Sweep element received from the responder multiplied by (TXTIME(SSW frame)+SBIFS).

4) If the responder received at least one SSW frame from the initiator during step 1, it shall wait for the time indicated in the Duration field of that frame and initiate an RSS with the number of sectors indicated in the Partial Number of Sectors field of the last EDMG Partial Sectors Level Sweep element it has sent to the initiator. The responder shall repeat the RSS to each DMG antenna of the initiator according to the number indicated in the Partial Number of RX Antennas field in the last EDMG Partial Sectors Level Sweep element received from the initiator.


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If the time indicated in the Time to Switch to Full Sector(#4303) Sweep field sent by the initiator to the responder in the last EDMG Partial Sectors Level Sweep element following the expiration of the dot11BeamLinkMaintenanceTime has passed and the initiator and responder have not completed a succsesfull SLS, the initiator and responder shall perform the following steps:

5) The responder shall configure its receive antenna to a quasi-omni pattern and switch its receive DMG antennas at a rate of once per a time interval equal to MBIFS plus the number of sectors indicated in the Total Number of Sectors field of the last EDMG Partial Sector Level Sweep element received from the initiator multiplied by (TXTIME(SSW frame)+SBIFS).
6) The initiator shall initiate an ISS with the number of sectors indicated in the Total Number of Sectors field of the last EDMG Partial Sector Level Sweep element sent to the responder. The initiator shall repeat the ISS for one plus the number indicated in the Total Number of RX Antennas field in the last EDMG Partial Sector Level Sweep element received from the responder.
7) When the initiator finishes the ISS, it shall configure its receive DMG antennas to a quasi-omni patterm and switch its receive DMG antennas at a rate of once per a time interval equal to MBIFS plus the number of sectors indicated in the Total Number of Sectors field of the last EDMG Partial Sector Level Sweep element received from the responder multiplied by (TXTIME(SSW frame)+SBIFS).
8) If the responder received at least one SSW frame from the initiator during step 5, it shall wait until the time indicated in the Duration field of that frame and initiate an RSS with the number of sectors indicated in the Partial Number of Sectors field of the last EDMG Partial Sector Level Sweep element it has sent to the initiator. The responder shall repeat this RSS for each DMG antenna of the initiator according to the number indicated in the Total Number of RX Antennas field in the last EDMG Partial Sector Level Sweep element received from the initiator.

If the initiator and responder agreed to change roles according to the procedure described in 10.41.6.4.1 (General), the initiator and responder in step 1 through step 8 shall become, respectively, the responder and initiator of the EDMG Partial Sector Level Sweep element exchange.

If the procedure in step 1 through step 8 does not complete before the end of the allocation (SP or TXOP) in which the procedure started is reached, the initiator and responder shall resume the procedure at step 5 at the next available allocation.

### 11.27.2 PCP Handover

#### 11.27.2.1 General

A STA is PCP handover capable if the PCP Handover field in the STA's DMG Capabilities element (9.4.2.126 (DMG Capabilities element)) is 1. The STA is PCP handover incapable otherwise.

The PCP handover process allows the information pertinent to the operation of the PBSS to be distributed to suitable PCP handover capable STA(s) and for a PCP handover capable STA to take over the PCP responsibilities from the PCP explicitly or implicitly.

The information pertinent to the operation of a PBSS includes STA information and pseudo-static scheduling information.

The STA information comprises the STA's AID, MAC address, and DMG Capabilities element. The PCP may relay the information to all STAs in the PBSS by using the Information Response frame.

The pseudo-static scheduling information comprises pseudo-static SP and CBAP allocations carried in the Extended Schedule element (9.4.2.130 (Extended Schedule element)).

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A PCP handover capable STA supports two types of PCP Handover, explicit and implicit. In explicit PCP handover, the PCP explicitly selects and schedules the transfer of PCP responsibilities to another PCP handover capable STA as described in 11.27.2.2 (Explicit handover procedure). In implicit PCP handover the PCP distributes the Next PCP List element (9.4.2.139 (Next PCP List element)) in its DMG Beacon or Announce frames and maintains the content of the Next PCP List element to facilitate the implicit handover process described in 11.27.2.3 (Implicit handover procedure). The PCP may determine the priority of next PCPs and update the next PCP list based on information contained within a STA's DMG Capabilities element.

If there is at least one PCP handover capable STA in the PBSS, the NextPCP List element contains an ordered list of one or more PCP handover capable STAs that can take over the role of the PCP during implicit handover. The ordering of STAs in the NextPCP List is specified in decreasing priority order and the criteria for updating the NextPCP List are implementation specific. The PCP shall increment the Token field of the NextPCP List by 1 every time the list is changed. If there are no PCP handover capable STAs in the PBSS, the length of the NextPCP List element is 0, and implicit PCP handover cannot be performed.

When a PCP handover capable STA takes over the PCP responsibilities of a PBSS, the pseudo-static scheduling information shall remain unchanged. Any outstanding request for resource allocation is lost and STAs that have outstanding requests for allocation may request the resource allocation again.

In explicit PCP handover, the PCP shall use the value of the PCP factor when selecting the candidate PCP (see 11.1.4.3.10 (PCP selection in a PBSS)).

Following a PCP handover, a non-PCP STA shall attempt to transmit a frame to the new PCP within dot11MaxLostBeacons beacon intervals. If the new PCP does not receive at least one frame from an associated non-PCP STA for dot11MaxLostBeacons beacon intervals following a PCP handover, it should disassociate the STA from the PBSS.

### 11.27.2.2 Explicit handover procedure

The PCP may transmit a Handover Request frame to a non-PCP STA that is handover capable. Upon receiving a Handover Request, a non-PCP STA becomes the candidate PCP. If the handover request is accepted, the candidate PCP shall transmit a Handover Response frame to the PCP with the Handover Result field set to 0. If the handover request is rejected, the candidate PCP shall transmit a Handover Response frame to the PCP with the Handover Result field set to 1, 2, or 3 and cease to be the candidate PCP.

A non-PCP STA that is handover capable may transmit a Handover Request frame to the PCP of the PBSS if the PCP is handover capable. Upon transmission of the Handover Request frame, the non-PCP STA becomes the candidate PCP. If the handover request is accepted, the PCP shall transmit a Handover Response frame to the candidate PCP with the Handover Result field set to 0. If the handover request is rejected, the PCP shall transmit a Handover Response frame to the candidate PCP with the Handover Result field set to 1, 2, or 3, and the candidate PCP shall cease to be a candidate PCP.

Following the transmission or reception of a successful Handover Response frame, a candidate PCP should request STA information and pseudo-static scheduling information from the PCP using an Information Request frame within the next dot11NbrOfChangeBeacons beacon intervals. The candidate PCP should also request SPs to perform beamforming and, if appropriate, establish a security association with other associated STAs prior to the completion of PCP handover.

Following the reception or transmission of a Handover Response frame, the PCP shall transmit a PCP Handover element within every DMG Beacon or Announce frame for each of the next dot11NbrOfChangeBeacons beacon intervals with the Old BSSID field set to the BSSID of the PBSS, the New PCP Address field set to the MAC address of the candidate PCP, and the Remaining BIs field set to the number of beacon intervals remaining until the candidate PCP takes over the role of PCP for the PBSS. The initial value of the Remaining BIs field shall be equal to the Handover Remaining BI field value last transmitted by


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the PCP in a Handover Request frame to the candidate PCP or equal to the Handover Remaining BI field value last received by the PCP in a Handover Request frame from the candidate PCP, whichever is later. A non-PCP STA receiving a DMG Beacon or Announce frame containing the PCP Handover element shall set the STA's local countdown counter to the value of the Remaining BIs field contained in the PCP Handover element. The STA shall then decrease the local countdown counter by one at each TBTT, and shall use the candidate PCP's address contained in the New PCP Address field within the PCP Handover element as the new beacon filter address once the STA's local countdown reaches zero. When the countdown timer equals zero, the candidate PCP shall assume the role of PCP.

#### 11.27.2.3 Implicit handover procedure

Upon receiving the NextPCP List element, a PCP handover capable STA that finds its AID as the AID entry *i* in the NextPCP List element received from the PCP becomes the implicit candidate PCP *i*. Upon detecting a Token value contained in the NextPCP List element that is different from the value of the last Token received from the PCP, each implicit candidate PCP should request STA information and pseudo-static scheduling information from the PCP by transmitting an Information Request frame addressed to the PCP (11.28.1 (Information Request and Response)).

The implicit handover process is triggered at the implicit candidate PCP *i* when the implicit candidate PCP *i* fails to receive a DMG Beacon or Announce frames from the PCP for (*i* × dot11ImplicitHandoverLostBeacons) beacon intervals. When triggered, the implicit candidate PCP *i* shall send at least one DMG Beacon frame during each of the next dot11MaxLostBeacons BTIs if the following conditions are met:

— No DMG Beacon or Announce frames are received from the PCP.

— No DMG Beacon frame carrying a PCP Handover element with the Old BSSID field equal to the BSSID of the PBSS is received from an implicit candidate PCP with a smaller index on the NextPCP List.

Each DMG Beacon frame sent by the implicit candidate PCP *i* shall contain a PCP Handover element with the Old BSSID field set to the BSSID of the PBSS from which control is being taken, i.e., the previous PBSS, the New PCP Address field set to its MAC address, and the Remaining BIs field initially set to dot11MaxLostBeacons and decremented by 1 at each TBTT. A member non-PCP STA of the PBSS, after failing to receive a DMG Beacon or Announce frame for dot11MaxLostBeacons beacon intervals, should associate with the new PCP sending a DMG Beacon frame containing the PCP Handover element with Old BSSID field equal to the BSSID of the previous PBSS and the smallest Remaining BIs field value. The implicit candidate PCP that successfully transmits a DMG Beacon frame with the Remaining BIs field within the PCP Handover element equal to 0 completes the implicit handover by scheduling, if appropriate, pseudo-static SPs between its member STAs following the pseudo-static scheduling information it obtained from the previous PBSS.

To avoid disruptions to pseudo-static SPs due to implicit handover, the value of dot11ImplicitHandoverLostBeacons should be lower than dot11MaxLostBeacons.

## 11.28 DMG BSS peer and service discovery

### 11.28.1 Information Request and Response

A STA may request information about either a single STA in the BSS or about all of the STAs in the BSS by sending an Information Request frame (9.6.19.4 (Information Request frame format)). If the STA is requesting information about only a single STA in the BSS, it shall set the Subject Address field in the Information Request frame to the MAC address of that STA. If the STA is requesting information about all of the STAs in the Infrastructure BSS and PBSS, it shall set the Subject Address field in the Information Request frame to the broadcast address and shall transmit the Information Request frame to the AP and PCP.

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A STA may transmit an Information Request frame with the Length field of the Request element set to 0 and with no Extended Request element present to another STA in the BSS to determine if the destination DMG STA is still present in the PBSS and is within range of the sending STA.

A STA may transmit an Information Request frame including its STA Capability element and other elements. A non-PCP and non-AP STA shall not include in the Information Request frame the capability information corresponding to another STA.

The STA may transmit an Information Response frame (9.6.19.4 (Information Request frame format)) either unsolicited or as a response to an Information Request frame. If a STA is providing information about a single STA in the BSS, it shall set the Subject Address field in the Information Response frame to the MAC address of that STA. If a STA is providing information about all of the STAs in the PBSS, it shall set the Subject Address field in the Information Response frame to the broadcast address.

A STA processes a received Information Request frame as follows:

— Each element that is listed in a Request element, Extended Request element, or Vendor Specific Request element and that is supported by the STA shall be included in the Information Response frame. An element that is listed in a Request element, Extended Request element, or Vendor Specific Request element and that is not supported by the STA shall not be included.

— If dot11RadioMeasurementActivated is true and the RCPI element was requested, an RCPI element containing the RCPI of the Probe Request frame shall be included. If no measurement result is available, the RCPI value shall be set to indicate “Measurement not available” (see Table 9-215 (RCPI values)).

— If dot11RadioMeasurementActivated is true and the RSNI element was requested, an RSNI element containing the RSNI of the Probe Request frame shall be included. If no measurement result is available, the RSNI value shall be set to indicate that a measurement is not available (see 9.4.2.39 (RSNI element)).

A STA shall send an Information Response frame with no requested or provided elements in response to an Information Request frame that solicits information about a single target STA, as identified by the Subject Address field within the Information Request frame, if

— The target STA is not a member of the PBSS and the STA sending the Information Response frame is the PCP of the PBSS, or AP of the Infrastructure BSS and PBSS, or

— The STA sending the Information Response frame is a non-PCP and non-AP STA and is not the target STA.

In all other cases, the STA shall send the Information Response frame with the information requested by the requesting STA.

### 11.28.2 Peer Service Discovery

An AP or PCP may provide different types of information to a non-AP and non-PCP STA upon request. To query available services in a BSS, a non-AP and non-PCP STA shall send either an Information Request frame or a Probe Request frame to the AP or PCP (11.28.1 (Information Request and Response)). The Information Request and Information Response frames are robust Management frames, while the Probe Request and Probe Response frames are not.

Upon receiving the Information Request frame, the AP or PCP shall respond with an Information Response frame only if all of the following three criteria are true:

a) The SSID in the Information Request frame is the wildcard SSID or the specific SSID of the AP’s or PCP’s BSS.


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b) The BSSID field in the Information Request frame is the wildcard BSSID or the BSSID of the AP or PCP's BSS.

c) The DA field in the Information Request frame is the MAC address of the AP or PCP.

The AP or PCP transmits the Information Response frame to the address of the non-AP and non-PCP STA that generated the Information Request.

## 11.29 Changing DMG BSS parameters

### 11.29.1 General

This subclause describes the methods used by the AP or PCP to change certain key characteristics of the BSS. It also describes a method for a non-AP and non-PCP STA to make a recommendation on those characteristics to the AP or PCP.

The AP or PCP delivers the DMG BSS Parameter Change element to STAs holding pseudo-static SPs and STAs in power save mode before a DMG BSS parameter change.

The AP or PCP shall initiate a DMG BSS parameter change by including a DMG BSS Parameter Change element (9.4.2.125 (DMG BSS Parameter Change element)) in its DMG Beacon or Announce frames. The AP or PCP places the DMG BSS Parameter Change element in every DMG Beacon or Announce frame after the DMG BSS Parameter Change element is first included in the frame, stopping in the DMG Beacon or Announce frame immediately after the DMG BSS parameter change takes effect.

### 11.29.2 Moving the TBTT

The AP or PCP may move the TBTT and hence move the entire beacon interval. Moving the beacon interval means that except for the beacon interval in which the change takes effect, the beacon interval duration is unchanged while the position of the TBTT is moved.

The TBTT shall not be moved by an amount that is larger than the value in the Beacon Interval field present in DMG Beacon and Announce frames in which the DMG BSS Parameter Change element is sent.

To move the TBTT to an intended new TBTT, the AP or PCP shall insert the DMG BSS Parameter Change element in DMG Beacon frames and/or Announce frames with the Move field set to 1 (9.4.2.125 (DMG BSS Parameter Change element)). The DMG Beacon frames and/or the Announce frames containing the DMG BSS Parameter Change element shall be sent at each TBTT dot11NbrOfChangeBeacons times before the TBTT is changed as indicated in the TBTT offset field.

At each transmission of the DMG BSS Parameter Change element, the TBTT Offset field shall be set to a value equal to the lower order 4 octets of the intended new TBTT.

The value of dot11NbrOfChangeBeacons shall be greater than dot11MaxLostBeacons.

NOTE—As defined in 11.1.2.1 (TSF for an infrastructure BSS or a PBSS), the PCP transmits at least one DMG Beacon frame to each associated STA within a time interval that is not longer than dot11BeaconPeriod × dot11MaxLostBeacons TUs.

Announce frames shall be used to deliver the DMG BSS Parameter Change element to all STAs participating in pseudo-static SPs.

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The Beacon Interval field of DMG Beacon frames and the Announce frames sent at the dot11NbrOfChangeBeacons+1 TBTT shall be set to the difference of the intended new TBTT and the TBTT where the DMG Beacon or Announce frames were sent.

STAs associated with an AP or PCP that moves the TBTT shall not transmit during the beacon interval that precedes a new TBTT if the transmission time ends at the TBTT or later, even if the SP or the CBAP were scheduled in the beacon interval.

At the intended new TBTT that is dot11NbrOfChangeBeacons+2 TBTTs after the DMG BSS Parameter Change element is first transmitted, the TSF timer is reset to 0 as defined in 11.1.3.3 (Beacon generation in a DMG infrastructure BSS and in a PBSS).

An AP or PCP member of an AP or PCP cluster that wishes to move its TBTT shall set the TBTT Offset field to an empty Beacon SP allocated by its S-AP or S-PCP as defined in 10.39 (DMG and CMMG AP or PCP clustering).

Figure 11-85 (Moving the TBTT position) illustrates the process in moving the TBTT position.

**Figure 11-85—Moving the TBTT position**

### 11.29.3 Changing beacon interval duration

The AP or PCP may change the duration of its beacon interval during the BSS operation.

To change its beacon interval, the AP or PCP shall insert the DMG BSS Parameter Change element into DMG Beacon frames and/or Announce frames with the Size field set to 1 and the BI Duration field set to the duration of the beacon interval following this DMG BSS parameter change. The TBTT Offset field shall be set to the lower order 4 octets of the TBTT at dot11NbrOfChangeBeacons+1 TBTT position when this DMG BSS parameter change takes effect.

The DMG Beacon frames and/or the Announce frames shall be sent at each TBTT dot11NbrOfChangeBeacons times before the beacon interval is changed as indicated in the BI Duration field of the DMG BSS Parameter Change element.

At each transmission of the DMG BSS Parameter Change element the TBTT Offset field shall be set to a value equal to the lower order 4 octets of the intended TBTT.

The value of dot11NbrOfChangeBeacons shall be greater than dot11MaxLostBeacons.

Announce frames shall be used to deliver the DMG BSS Parameter Change element to all STAs participating in pseudo-static SPs.


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The AP or PCP that shortens the beacon interval shall not schedule SP and CBAP allocations that use more time than allowed in the beacon interval indicated in the BI Duration field of the DMG BSS Parameter Change element.

The beacon interval shall be set to the value of the BI Duration field of the DMG BSS Parameter Change element at the dot11NbrOfChangeBeacons+1 TBTT. At this TBTT, the TSF timer is reset to 0 as defined in 11.1.3.3 (Beacon generation in a DMG infrastructure BSS and in a PBSS).

If the AP or PCP sets the Move and the Size fields to 1 in the same DMG BSS Parameter Change element, it shall set the TBTT Offset field and proceed as defined in 11.29.2 (Moving the TBTT). The beacon interval shall be set to the value of the BI Duration field of the DMG BSS Parameter Change element at the new TBTT as defined in 11.29.2 (Moving the TBTT).

Figure 11-86 (Changing beacon interval duration) illustrates the process in changing the beacon interval duration.

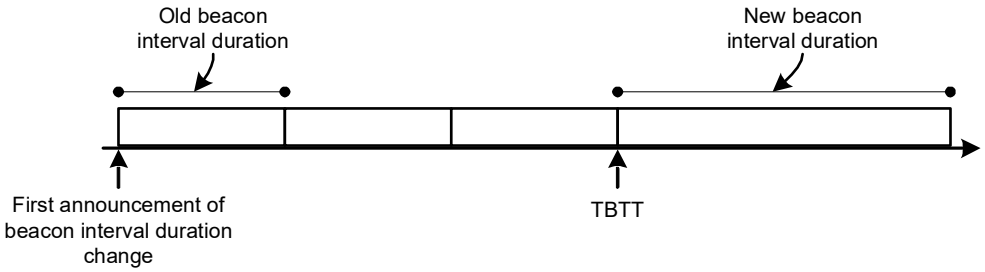


**Figure 11-86—Changing beacon interval duration**

### 11.29.4 Maintaining synchronization in an AP or PCP cluster

A S-AP or S-PCP shall update the Clustering Control field transmitted in the DMG Beacon frame if the DMG BSS parameter change modifies the allocation of the Beacon SPs (10.39 (DMG and CMMG AP or PCP clustering)). If the Clustering Control field is modified as a result of a DMG BSS parameter change, the S-AP or S-PCP shall transmit the updated Clustering Control field in every DMG Beacon frame in which the DMG BSS Parameter Change element is transmitted.

An AP or PCP member of an AP or PCP cluster receiving a S-AP or S-PCP DMG Beacon frame with a DMG BSS Parameter Change element indicating a change in the beacon interval duration or TBTT time shall immediately insert the appropriate DMG BSS Parameter Change element into its DMG Beacons if the S-AP or S-PCP's DMG BSS parameter change causes a modification in the allocation of the Beacon SPs.

If an AP or PCP is required to change the beacon interval or/and TBTT to participate in an AP or PCP cluster or to change the beacon interval or/and TBTT as a result of its S-AP's or S-PCP's parameters change (see 10.39 (DMG and CMMG AP or PCP clustering)), it shall follow the procedures in 11.29.2 (Moving the TBTT) and 11.29.3 (Changing beacon interval duration).

### 11.29.5 Recommending DMG BSS parameters to the AP or PCP

A non-AP and non-PCP STA may make a recommendation for DMG BSS parameters to the AP or PCP by including a DMG BSS Parameter Change element in an Information Request or Information Response frame sent to the AP or PCP.

A non-AP and non-PCP STA may recommend a shift in TBTT by setting the Move subfield in the Change Type Bitmap field of the DMG BSS Parameter Change element to 1 and setting the TBTT Offset field to the

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value of the 4 least significant octets of the non-AP and non-PCP STA's TSF timer at the recommended first changed TBTT. The non-AP and non-PCP should select a value for the TBTT Offset field that gives the AP or PCP enough time to exercise the change. Similarly, a non-AP and non-PCP STA may recommend a beacon interval duration to the AP or PCP by setting the Size subfield in the Change Type Bitmap field of the DMG BSS Parameter Change element to 1 and setting the BI Duration field to the recommended beacon interval duration in TUs.

An AP or PCP that receives an Information Request frame or an unsolicited Information Response frame from a non-AP and non-PCP STA containing a DMG BSS Parameter Change element may use the information within the element to change the DMG BSS parameters. When receiving an Information Request frame that includes the DMG BSS Parameter Change element, AP or PCP responds with an Information Response frame as specified in 11.28.1 (Information Request and Response). If the AP or PCP changes the BSS parameters in the transmitted Information Response frame, the AP or PCP shall include a DMG BSS Parameter Change element reflecting the BSS parameter changes and shall use the procedure defined in 11.29.2 (Moving the TBTT) and 11.29.3 (Changing beacon interval duration), as appropriate, to change the BSS parameters. If the AP or PCP decides not to change the BSS parameters, it shall not include a DMG BSS Parameter Change element in the transmitted Information Response frame.

## 11.30 Spatial sharing and interference mitigation for DMG STAs

### 11.30.1 General

This subclause describes mechanisms to enable spatial sharing and interference mitigation within a PBSS/ infrastructure BSS and in a uncoordinated OBSS environment.(11ay) The mechanisms specified can operate on one or more channels.

Spatial sharing mechanisms allow SPs belonging to different STAs in the same spatial vicinity to be scheduled concurrently (11ay)one or more channels, and for interference mitigation. Alternatively, the AP or PCP can use CBAPs to mitigate interference.

The SPSH and Interference Mitigation field in the DMG Capabilities element indicates whether a STA supports spatial sharing.

A STA that supports spatial sharing, as indicated in the SPSH and Interference Mitigation field equal to 1 in the STA's DMG Capabilities element, shall support the directional channel quality measurements described in 9.4.2.19.16 (Directional Channel Quality request) and 9.4.2.20.15 (Directional Channel Quality report).

An AP or PCP may use the beamforming training information between any pair of STAs within the BSS obtained through the SSW Report element (9.4.2.221 (SSW Report element)) to achieve spatial sharing and interference mitigation. The AP or PCP can transmit an Information Request frame (9.6.19.4 (Information Request frame format)) addressed to a STA for a response with an SSW Report element (9.4.2.221 (SSW Report element)) contained in an Information Response frame (9.6.19.5 (Information Response frame format)). A non-AP and non-PCP STA can also send an unsolicited Information Response frame with an SSW Report element after the STA has completed the beamforming procedure with at least another STA. The SSW Report element may be used to facilitate the selection of candidates for spatial sharing as described in W.1 (Selection of candidate SPs for spatial sharing).

### 11.30.2 Spatial sharing and interference assessment

The AP or PCP should request STAs to perform and report spectrum and radio resource measurements described in 11.10 (Radio measurement procedures) to assess the possibility to perform spatial sharing and for interference mitigation.


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The AP or PCP should use the directional channel quality described in 9.4.2.19.16 (Directional Channel Quality request) and 9.4.2.20.15 (Directional Channel Quality report) to assess the possibility for spatial sharing of SPs over one or more channels(11ay).

An SP to be assessed for spatial sharing with other scheduled (existing) SPs or considered to be reallocated in the beacon interval is hereby termed as a candidate SP. There might be multiple candidate and existing SPs at one time, and an SP may simultaneously assume the role of candidate and existing SP depending upon the context it is used for spatial sharing and interference assessment.

STAs that participate in an SP and that support spatial sharing should perform beamforming training with each other before engaging in any other communication or performing any measurements described in this subclause.

(11ay)For the purpose of spatial sharing with one or more existing SPs allocated on the same channel, the AP or PCP should request the source DMG STA and the destination DMG STA involved in a candidate SP to perform measurements only after the STAs have beamforming trained with each other. (11ay)For the purpose of spatial sharing with one or more existing SPs allocated in different channels, the EDMG AP or EDMG PCP should request each source DMG STA and each destination DMG STA involved in each candidate SP to perform measurements only after the STAs have beamforming trained with each other. The AP or PCP can infer that the STAs in a candidate SP have a beamformed link with each other if the Beamforming Training field within the DMG TSPEC used to set up the candidate SP was set to 1 and at least one beacon interval has elapsed since the candidate SP was first scheduled.

If the AP or PCP transmits a Directional Channel Quality request to a STA involved in a candidate SP to assess the possibility for spatial sharing with (11ay)one or more existing SPs, it shall set the Target STA to the corresponding peer STA's MAC address involved in the candidate SP and shall set the Measurement Method field to indicate ANIPI.(11ay) Additionally, the AP or PCP may include a Measurement Configuration subelement in the Directional Channel Quality request where the Measurement Channel Bitmap subfield indicates one or more 2.16 GHz channels for which the measurement request applies; in this case, it may set the Channel Measurement Report Method subfield to 0 to indicate the results of measurements over all the requested 2.16 GHz channels during each measurement time block are reported per 2.16 GHz channel or may set this subfield to 1 to indicate the averaged results of concurrent measurements over all the requested 2.16 GHz channels during each measurement time block are reported, and may set the Antenna Measurement Report Method subfield to 0 to indicate the results of concurrent measurements over each requested 2.16 GHz channel using multiple RX DMG antennas during a measurement time block are reported per DMG antenna or may set this subfield to 1 to indicate the averaged results of concurrent measurements over each requested 2.16 GHz channel using multiple RX DMG antennas during a measurement time block are reported, and may set the RX Antenna Configuration Type subfield to 0 to indicate the RX antenna configuration for SISO communication is requested to be used for measurements or may set this subfield to 1 to indicate the RX antenna configuration for SU-MIMO communication is requested to be used for measurements. Together with the Measurement Configuration subelement, the AP or PCP may also include an Extended Measurement Configuration subelement in the Directional Channel Quality request, where measurement timing information for the first requested channel is indicated in the Measurement Request field and measurement timing information for the remaining requested channels is indicated in the Extended Measurement Configuration subelement.

If the candidate SP has already been allocated channel time, the AP or PCP should additionally transmit a Directional Channel Quality request to the STAs involved in (11ay)each of the one or more existing SPs to assess the possibility for spatial sharing with the candidate SP. In the Directional Channel Quality request, the AP or PCP shall set the Target STA to the corresponding peer STA involved in the existing SP and shall set the Measurement Method field to indicate ANIPI(11ay). Additionally, the PCP or AP may include a Measurement Configuration subelement in the Directional Channel Quality request where the Measurement Channel Bitmap subfield indicates one or more 2.16 GHz channels for which the measurement request applies; in this case, it may set the Channel Measurement Report Method subfield to 0 to indicate the results

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of measurements over all the requested 2.16 GHz channels during each measurement time block are reported per 2.16 GHz channel or may set this subfield to 1 to indicate the averaged results of concurrent measurements over all the requested 2.16 GHz channels during each measurement time block are reported, and may set the Antenna Measurement Report Method subfield to 0 to indicate the results of concurrent measurements over each requested 2.16 GHz channel using multiple RX DMG antennas during a measurement time block are reported per DMG antenna or may set this subfield to 1 to indicate the averaged results of concurrent measurements over each requested 2.16 GHz channel using multiple RX DMG antennas during a measurement time block are reported, and may set the RX Antenna Configuration Type subfield to 0 to indicate the RX antenna configuration for SISO communication is requested to be used for measurements or may set this subfield to 1 to indicate the RX antenna configuration for SU-MIMO communication is requested to be used for measurements. Together with the Measurement Configuration subelement, the AP or PCP may also include an Extended Measurement Configuration subelement in the Directional Channel Quality request, where measurement timing information for the first requested channel is indicated in the Measurement Request field and measurement timing information for the remaining requested channels is indicated in the Extended Measurement Configuration subelement.

NOTE—When the AP or PCP transmits a Directional Channel Quality request to a STA of an existing SP, it intends to assess the channel quality during transmission by STAs belonging to the candidate SP. Similarly, when the AP or PCP transmits a Directional Channel Quality request to a STA of a candidate SP, it intends to assess the channel quality during transmission by STAs belonging to the existing SP.

If a recipient STA that receives a Directional Channel Quality request frame is already beamformed trained with the target STA specified by the AID field within the frame, then the recipient STA shall carry out the measurement employing the same receive antenna configuration as is used by the recipient STA when receiving frames from the target STA (11ay)using a SISO antenna setting or shall carry out the measurements concurrently employing the same receive antenna configuration as is used by the recipient STA when receiving frames from the target STA using an SU-MIMO antenna setting. If the AID field is(M118) the broadcast AID or an unknown AID, then the recipient STA shall perform the measurements using a quasi-omni antenna pattern.

Figure 11-87 (Example of spatial sharing assessment) illustrates an example of spatial sharing assessment between two SPs. In this example, SP1 is the existing SP and SP2 is the candidate SP. The AP or PCP transmits a Directional Channel Quality request to STAs C and D to measure over SP1's channel allocation, and transmits a Directional Channel Quality request to STAs A and B to measure over SP2's channel allocation. The relation of the Measurement Start Time and Measurement Duration fields in the Directional Channel Quality request message is shown in Figure 11-87 (Example of spatial sharing assessment), while the field Number of Time Blocks is the ratio (Measurement Duration/Measurement Unit).

If a non-AP and non-PCP STA receives a Directional Channel Quality request from its AP or PCP, it should perform the measurements as indicated in the request and shall report back to the AP or PCP using the Directional Channel Quality report. The report shall be formatted and transmitted as per specified in the Directional Channel Quality request. The non-AP and non-PCP STA shall set the Report Mode field (9.4.2.20 (Measurement Report element)) in the report frame to indicate whether it performed the measurement as requested by the AP or PCP.

### 11.30.3 Achieving spatial sharing and interference mitigation

An AP or PCP can estimate the channel quality across STAs participating in the BSS and implement spatial sharing and interference mitigation based on the results of the measurements performed by the STAs associated with the AP or PCP.

An AP or PCP should schedule a candidate SP that overlaps with an existing SP in its beacon interval only after it receives a Directional Channel Quality report from the STAs involved in the candidate SP.(11ay) When an EDMG AP or EDMG PCP schedules a candidate SP that overlaps with an existing SP in its beacon interval,


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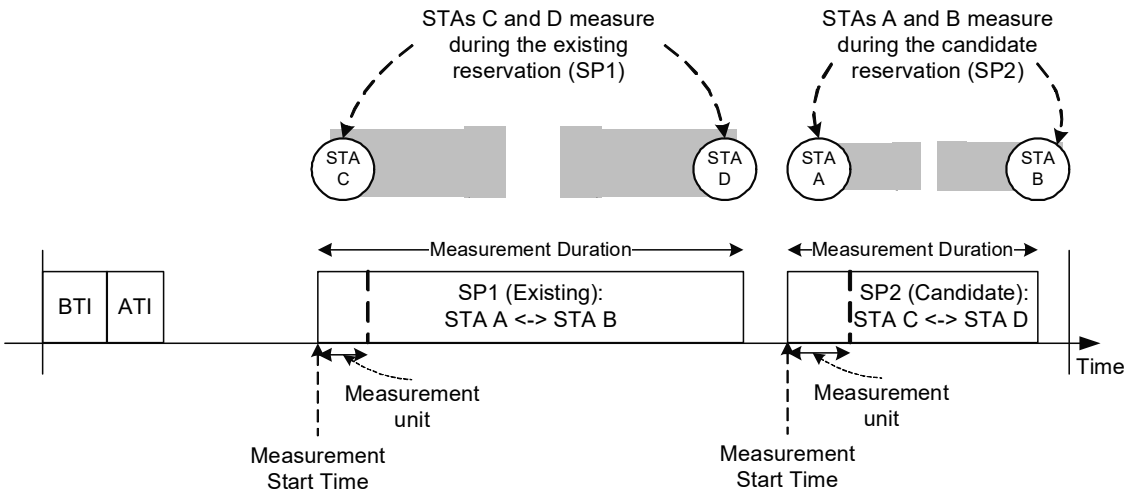


**Figure 11-87—Example of spatial sharing assessment**

it may also recommend whether SISO transmission or SU-MIMO transmission is applied in the candidate SP by using the Recommended Transmission Scheme subfield in the EDMG Extended Schedule element.

If a candidate SP is already scheduled in the beacon interval, the AP or PCP should schedule this candidate SP time-overlapping with an existing SP in its beacon interval only after it receives a Directional Channel Quality report from the STAs involved in the existing SP.(11ay) When an EDMG AP or EDMG PCP schedules this candidate SP time overlapping with an existing SP in its beacon interval, it may also recommend whether SISO transmission or SU-MIMO transmission is applied in this candidate SP by using the Recommended Transmission Scheme subfield in the EDMG Extended Schedule element.

The AP or PCP should schedule a candidate SP during a period of time in the beacon interval where the PBSS/infrastructure BSS performance is expected to be maximized. The determination of performance maximization should be based on measurement reports received by the AP or PCP, but is implementation dependent and beyond the scope of this standard.

The decision process at the AP or PCP to perform spatial sharing of a candidate and an existing SP is implementation dependent and beyond the scope of this standard.

The candidate SP is referred to as a *time-overlapped SP* following the allocation by the AP or PCP of a candidate SP overlapping in time with an existing SP.

Figure 11-88 (Example of spatial sharing between SP1 and SP2) illustrates an example of the resulting SP schedule in the beacon interval for the spatial sharing between the two SPs shown in Figure 11-87 (Example of spatial sharing assessment).

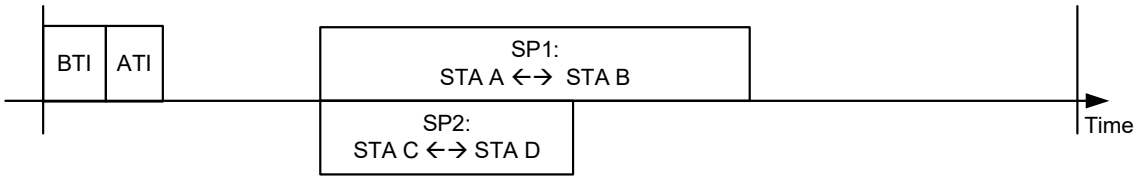


**Figure 11-88—Example of spatial sharing between SP1 and SP2**

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The AP or PCP should periodically transmit a Directional Channel Quality request to each spatial sharing capable STA involved in a time-overlapped and existing SP scheduled under spatial sharing. In the Directional Channel Quality request that the AP or PCP transmits to each STA, the AP or PCP shall set the Target STA to the peer STA involved in the same SP and shall set the Measurement Method field to indicate RSNI.

If a spatial sharing capable non-AP and non-PCP STA receives a Directional Channel Quality request from its AP or PCP, it should perform the measurements as indicated in the request and shall report the results back to the AP or PCP using the Directional Channel Quality report. The report shall be formatted and transmitted as per specified in the corresponding Directional Channel Quality request.

The AP or PCP should stop the spatial sharing of two or more SPs if it determines that the link quality of any of the links involved in the spatial sharing has dropped below acceptable levels. This determination should be based on Directional Channel Quality reports received by the AP or PCP, but is implementation dependent and beyond the scope of this standard.

The STA may include the Traffic Scheduling Constraint Set field with the ADDTS Request frame sent to the AP or PCP for the purpose of interference mitigation. The AP or PCP should consider the information in the Traffic Scheduling Constraint Set field specified by a STA in its SP schedule.

Specific algorithms to realize spatial sharing and interference mitigation among SPs between different STAs is implementation dependent and beyond the scope of this standard.

### 11.30.4 PBSS and infrastructure BSS stability in OBSS scenarios

Except when performing FST (11.31 (Multi-band operation)), the AP or PCP limits the frequency with which it changes the operating PBSS/infrastructure BSS channel to alleviate the instability and ripple effect that might result from frequent channel changes in OBSS scenarios. Upon a channel switch, the AP or PCP of a PBSS/ infrastructure BSS shall select a random number, N, uniformly distributed between [0, SwitchInterval-1] and shall not attempt a new channel switch until N beacon intervals have elapsed since the preceding channel switch. The initial value of SwitchInterval is aMinSwitchInterval and it is doubled upon every new channel switch up to a maximum value of aMaxSwitchInterval. The AP or PCP resets SwitchInterval to aMinSwitchInterval if it remains on the same operating channel for a minimum of aMaxSwitchInterval consecutive beacon intervals.

NOTE—The AP or PCP can keep the SP schedule stable across beacon intervals and minimize schedule changes. This is to allow for STAs to associate with the PBSS/infrastructure BSS or add or modify their SP reservations. Stability in the allocation schedule in a beacon interval allows a PBSS/infrastructure BSS to assess the interference pattern produced by OBSSs and adapt to the environment by scheduling SPs over periods of time in the beacon interval when less interference is expected.

### 11.30.5 Directional transmit activity report(11ay)

DMG STAs for which dot11DMGSTATxActivityReportImplemented is true are capable of transmitting DMG STA Directional Transmit Activity Report frames which, for a given receiving STA (or group of receiving STAs as defined below) and a given 2.16 GHz channel, include information that helps the receiving STAs unintentionally affected by the radiation pattern (more precisely, STAs that receive energy when the transmitting STA uses the given antenna pattern to communicate with its intended targets) to mitigate the interference caused by the transmitting STA, as well as the interference these receiving STAs cause to the transmitting STA.

A STA with both dot11DMGSTATxActivityReportImplemented and dot11DMGSTATxActivityReportActivated equal to true regularly transmits DMG STA Directional Transmit Activity Report frames (activity report frames, for short) as follows.


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For each receiver (or group of receivers always transmitted data through a common transmit antenna pattern and transmit power) and each 2.16 GHz channel that the transmitting STA is using to communicate with the receiver(s), the STA monitors its transmit activity in terms of number of active time units, contiguous or (#3387)noncontiguous, during a sliding window comprising a given number of time units. An active time unit is a period during which the STA has been in transmit mode for a percentage of the time unit greater than or equal to aDMGActiveThresholdPercentage, excluding any time spent towards transmitting a DMG Beacon frame or a PPDU that contains only activity report frames, using the common antenna pattern and the transmit power, and using the 2.16 GHz channels. The time unit duration, in microseconds, is dot11DMGSTATxActivityReportTimeUnit.

As long as the STA has observed at least dot11DMGSTATxActivityReportMinActiveTimeUnits active time units over the last dot11DMGSTATxActivityReportActiveMonitoringTime time units, it shall transmit a PPDU containing one activity report MMPDU, using the common antenna pattern, and on each of the 2.16 GHz channels used for data transmission, at least once during every dot11DMGSTATxActivityReportInterval microseconds, provided that the STA has a transmit opportunity longer than SIFS plus the duration of a PPDU that only includes one activity report frame. The interval between the start of transmission of consecutive Directional Transmit Activity Report frames shall not exceed aDMGSTATxActivityReportingtLimit. If the STA does not have the transmit opportunity to transmit the activity report frame during this time, it shall transmit the frame at the first opportunity.

NOTE 1—For example, the following settings require a capable DMG STA to transmit a DMG STA Directional Transmit Activity Report frame at least once during every second, as long as the STA has had at least 10 active seconds of transmission using a given antenna pattern over the last 60 seconds: dot11DMGSTATxActivityReportActivated = true, dot11DMGSTATxActivityReportTimeUnit = 1000000, dot11DMGSTATxActivityReportMinActiveTimeUnits = 10, dot11DMGSTATxActivityReportActiveMonitoringTime = 60, and dot11DMGSTATxActivityReportInterval = 1000000.

All transmitted activity report frames shall include the Country and DMG STA Directional Transmit Activity Report elements. The DMG STA Directional Transmit Activity Report element shall include the Directional Transmit Activity and Transceiver Parameters subelements.

The PPDUs containing an activity report frame should use the average effective TRP that the transmitting STA expects to apply when it communicates with other STAs using the common antenna pattern and occupying channels that are the same as, or include the channels used for the data transfer.

NOTE 2—For example, when the STA is communicating over a 4.32 GHz channel, it transmits the PPDUs that contain a transmit activity report frame at about half the power on each of the two 2.16 GHz channels in the 4.32 GHz channel.

A DMG STA that has the EDMG Supported subfield equal to 1 in the transmitted DMG Parameters field shall include DMG TRN-R subfields within its TRN field of the PPDU containing an activity report frame to enable receive training. Specifically, the STA transmitting such PPDU shall set the TRN-LEN parameter of the TXVECTOR of the PPDU to a value not less than 2 and shall set the PPDU_TYPE parameter of the TXVECTOR to TRN-R. The PPDU_TYPE parameter of the TXVECTOR of such PPDU shall not be set to TRN-T.

A STA may transmit individually addressed activity report frames to a target STA. When transmitting the activity report frame to a target STA in the same BSS, and when management frame protection is negotiated, the transmitting STA shall use individually addressed Protected Dual of Public Action frames instead of Public Action frames.

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## 11.31 Multi-band operation

### 11.31.1 General

A device is multi-band capable if the value of dot11MultibandImplemented is true. A multi-band capable device is said to be a member of a BSS when one or more of the STAs in the device is a member of the BSS. A STA that is part of a multi-band capable device advertises the capability by including the Multi-band element in Beacon, DMG Beacon, (Re)Association Request, (Re)Association Response, Information Request, Information Response, Probe Request, Probe Response, Announce, FST Setup Request, FST Setup Response, TDLS Discovery Request, TDLS Discovery Response, TDLS Setup Request, and TDLS Setup Response frames.

Except for the FST Setup Request and FST Setup Response frames, which shall not include more than one Multi-band element, a STA may include more than one Multi-band element in any one of these frames if it is part of a device that supports more than two bands or channels. If an AP or PCP includes one or more Multi-band elements within a (Re)Association Response frame with Status Code equal to DENIED_WITH_SUGGESTED_BAND_AND_CHANNEL or a Probe Response frame, the order in which these elements appear in the frame indicate the order, in terms of frequency band and channel number, that the device that includes the STA addressed by the frame should attempt join the BSS following the rules applicable to the respective frequency band and channel (see 11.1 (Synchronization)). For each Multi-band element contained in the frame starting from the first one and proceeding in increasing order, the STA should attempt to join the BSS using the BSSID indicated by the BSSID field, frequency band indicated by the Band ID field and channel number indicated by the Channel Number field provided the Beacon Interval and the Channel Number fields in the Multi-band element are both nonzero.

NOTE—The first Multi-band element in the frame can refer to the current operating frequency band and channel.

A multi-band capable device shall set the Band ID and Operating Class fields within a Multi-band element to specify a frequency band it supports. If the multi-band capable device is or intends to operate in the band indicated within the Multi-band element, it shall set the Channel Number field to indicate the channel of operation within that band. If the multi-band capable device is a member of a BSS both on the channel indicated in the Channel Number field within the Multi-band element and also in the channel on which this element is transmitted, then the multi-band capable device shall set the TSF Offset field within a Multi-band element to the difference between the TSF of the BSS of which the STA is member on the channel indicated in the Channel Number field of this element and the TSF of the BSS corresponding to the BSSID indicated in the Address 3 field of the MPDU in which this element is transmitted. In all other cases, the TSF Offset field shall be set to 0.

In each band/channel, a multi-band capable device may use the same or different MAC addresses. When the STA MAC Address Present field is equal to 1 in a Multi-band element, the STA MAC Address field in the Multi-band element specifies the MAC address that the STA uses in the band and channel that are indicated in the Multi-band element. If the STA MAC Address Present field is 0, the MAC address that the STA uses in the frequency band and channel that are indicated in the Multi-band element is the same as the address the STA uses in the current operating band and channel.

(11ay)The multi-band discovery assistance request is managed by the FST setup protocol and is used in conjunction with a session transfer. State transition of the discovery assistance request is described in 11.31.3 (FST setup protocol) and details of the multi-band discovery assistance procedure are described in 11.31.7 (Multi-band discovery assistance procedure(11ay)). A STA may include a DMG Discovery Assistance element in an FST Setup Request frame only if the recipient STA sets the Discovery Assistance Enabled subfield in the recipient STA's Multi-band element to 1. When a DMG Discovery Assistance element is present in the frame, it indicates a request for a discovery assistance to a recipient STA. A STA that supports the discovery assistance procedure and that receives a discovery assistance request shall include the DMG Discovery Assistance element in the FST Setup Response frame transmitted in response to


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a received FST Setup Response frame containing the multi-band discovery assistance request. If the Discovery Assistance Type subfield in a received DMG Discovery Assistance element is 1, the recipient STA shall include also an Extended Schedule element in the FST Setup Response frame and may include a TDD Slot Structure and TDD Slot Schedule elements.

### 11.31.2 General FST rules

The FST session (see 4.9.4 (Reference model for multi-band operation)) transition is managed by the FST session setup protocol. A multi-band capable device participates as an initiator or as a responder in the FST session setup. Depending on the STA's behavior during the FST session setup, the FST session can be operational in one band, or may be transferred to another band or channel in the same band, or can be operational in multiple bands and/or channels simultaneously and in this case MSDUs can be transmitted in different bands and/or channels any time an MSDU arrives at the MAC SAP. If a multi-band capable device is operational in more than one band/channel simultaneously, the STA may use the FST session setup protocol to change the operation to a single channel.

An FST session between an initiator and a responder is identified by a fast session transfer session identifier. The value of the fast session transfer session identifier is allocated by the initiator of an FST session and shall remain unchanged whether the FST session is operational in one band or more than one band simultaneously. The value of the fast session transfer session identifier shall be unique for an initiator and responder pair, and there shall be no more than one FST session between an initiator and responder pair. An initiator or responder may change the fast session transfer session identifier of its existing FST session by tearing down the existing FST session (11.31.4 (FST teardown)) and setting up a new one with a different fast session transfer session identifier value. The fast session transfer session identifier is signaled in the FSTS ID field. See 9.4.2.144 (Session Transition element), 9.6.20.4 (FST Teardown frame format), 9.6.20.5 (FST Ack Request frame format), and 9.6.20.6 (FST Ack Response frame format).

The FST session addressing mode is transparent if both initiator and responder of the FST session use the same MAC address in the frequency bands/channels involved in the FST. The FST session addressing mode is nontransparent if either the initiator or responder use different MAC addresses in the different frequency bands/channels involved in the FST session. When transparent FST is used, the STA shall present a single MAC SAP to higher layers for all frequency bands/channels in which it uses that MAC address.

When transparent fast session transfer is used, use of Authentication is unnecessary, and use of Association is disallowed, between the initiator and the responder.

An FST is allowed if the FST Setup Request and FST Setup Response frames are permitted to be transmitted as indicated in 11.3.3 (Frame filtering based on STA state).

A multi-band capable device should deliver all fragments, if any, of an MSDU of an FST session before it transfers the FST session.

A multi-band capable device shall include in any transmitted FST Setup Request frame and in any transmitted FST Setup Response frame, all the elements that are applicable to the band, PHY and channel number indicated within its most recently transmitted Multi-band element that was transmitted on the same band and channel number on which it is transmitting the FST Setup Request or FST Setup Response frames. If a Multi-band element is present in the transmitted FST Setup Request or FST Setup Response frames, the Multi-band element is considered as the most recently transmitted Multi-band element.

If a Session Transition element and a Multi-band element are present in the same frame and the values of the Operating Class and Channel Number fields within the Multi-band element are both nonzero, the Band ID field related to the new band within the Session Transition element shall be the same as the Band ID field within the Multi-band element.

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### 11.31.3 FST setup protocol

#### 11.31.3.1 General

A STA supports the FST protocol if the FST Not Supported subfield within the STA's Multi-band element is 0. A STA should not transmit an FST Setup Request frame to a peer STA that does not support the FST protocol. A STA that does not support the FST protocol shall (#3683)discard a received FST Setup Request frame.

The FST setup protocol comprises four states and rules for how to move from one state to the next. The states are Initial, Setup Completed, Transition Done, and Transition Confirmed. In the Initial state, the FST session is operational in one or both bands/channels. In the Setup Completed state, both initiator and responder are ready to change their currently operating band(s)/channel(s). An FST session can be fully or partially transferred to another band/channel. The Transition Done state enables both initiator and responder to operate in the other band/channel if the LLT field was zero. Both initiator and responder have to successfully communicate in the new band/channel to reach the Transition Confirmed state. The state transition diagram of the FST setup protocol is shown in Figure 11-90 (States of the FST setup protocol).

Figure 11-89 (Procedure of the FST setup protocol) depicts the procedure of the FST setup protocol that drives the state machine shown in Figure 11-90 (States of the FST setup protocol). The figure is an example of only the basic procedure and is not meant to be exhaustive of all possible uses of the protocol. In the figure, MLME 1 and MLME 2 represent any two MLMEs of a multi-band capable device according to the reference model described in 4.9.4 (Reference model for multi-band operation). The FST Setup Request and FST Setup Response frame exchange is repeated as necessary until both the FST initiator and FST responder successfully move to the Setup Completed state, as described below. Figure 11-89 (Procedure of the FST setup protocol) illustrates this behavior.

To establish an FST session in the Initial state and transfer it to the Setup Completed state of the FST setup protocol (Figure 11-90 (States of the FST setup protocol)), an initiator and responder shall exchange FST Setup Request and FST Setup Response frames. An FST session exists in Setup Completed state, Transition Done state, or Transition Confirmed state. In the Initial and in the Setup Completed states, the old band/channel represents the frequency band/channel from which the FST session is to be transferred, and the new band/channel represents the frequency band/channel to which the FST session is to be transferred. In the Transition Done state, the new band/channel represents the frequency band/channel on which the FST Ack Request and FST Ack Response frames, if any, are transmitted, and the old band/channel represents the frequency band/channel from which the FST session is being transferred.

The responder shall set the Status Code field to SUCCESS if it accepts the FST Setup Request, shall set the (#7190)status code to REJECTED_WITH_SUGGESTED_CHANGES (see 9.4.1.9 (Status Code field)) to indicate that one or more parameters of the FST Setup Request frame are invalid and shall suggest alternative parameters, shall set the (#7190)status code to PENDING_ADMITTING_FST_SESSION or PENDING_GAP_IN_BA_WINDOW to indicate that an FST setup request is pending, and shall set the Status Code field to REQUEST_DECLINED to reject an FST Setup Request frame.

A responder that is also an enabling STA (see 11.11 (DSE procedures)) may set the (#7190)status code to REJECT_DSE_BAND to indicate that the FST Setup Request frame is rejected because it was initiated by a dependent STA (see 11.11 (DSE procedures)) that is requesting transition to a frequency band subject to DSE procedures. In this case, if the responder is the enabling STA for the dependent STA, the responder may include a (#1776)TIE in the FST Setup Response frame to indicate the period in TUs before which it initiates an FST Setup with the dependent STA. The Timeout Interval Type field within the (#1776)TIE shall be set to 4. The responder can use the parameters in the FST Setup Request frame received from the dependent STA to initiate an FST Setup with the initiator.


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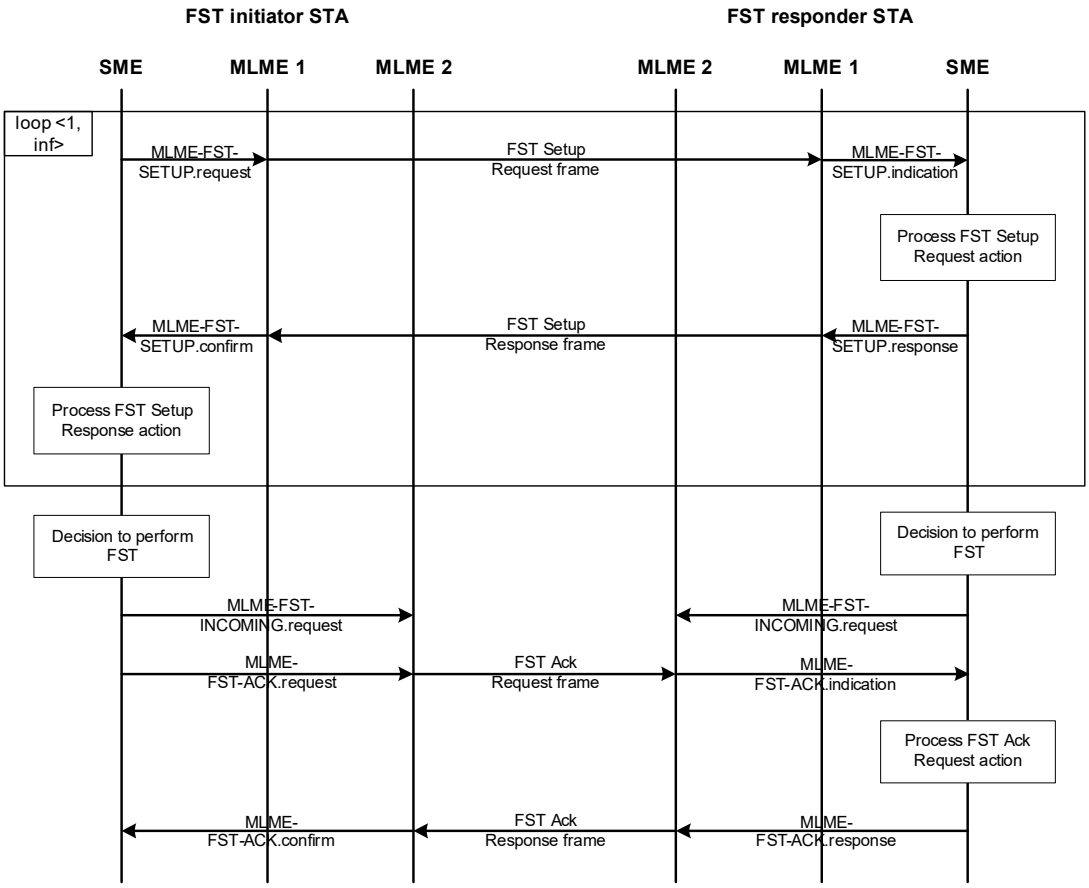


**Figure 11-89—Procedure of the FST setup protocol**

A responder that is also a dependent STA and not enabled shall reject all received FST Setup Request frames for transitioning to a frequency band subject to DSE procedures, except if the transmitter of the FST Setup Request frame is the enabling STA of the dependent STA.

### 11.31.3.2 Transitioning between states

A state transition within the FST setup protocol is controlled by the State Transition Timer (STT). Each STA maintains an STT for each FST session. A STA shall move to the Initial state when the STT moves from 1 to 0 (other than set to 0) or upon reception or transmission of an FST Teardown frame.

The initiator shall set the STT to the value of the FSTSessionTimeout field at successful transmission of an FST Setup Request frame and at each Ack frame sent in response to an FST Setup Response frame with the Status Code field equal to PENDING_ADMITTING_FST_SESSION or PENDING_GAP_IN_BA_WINDOW. The initiator shall set the STT to 0 at the transmission of an Ack frame sent in response to an FST Setup Response frame with the Status Code field equal to SUCCESS.

The responder shall set the STT to the value of the FSTSessionTimeout field at successful transmission of an FST Setup Response frame. The responder shall set the STT to 0 at each transmission of an Ack frame sent in response to an FST Setup Request. The responder should send an FST Setup Response frame no later than FSTSessionTimeout after the transmission of an Ack frame sent in response to an FST Setup Request frame or successful transmission of an FST Setup Response frame with the status code field equal to

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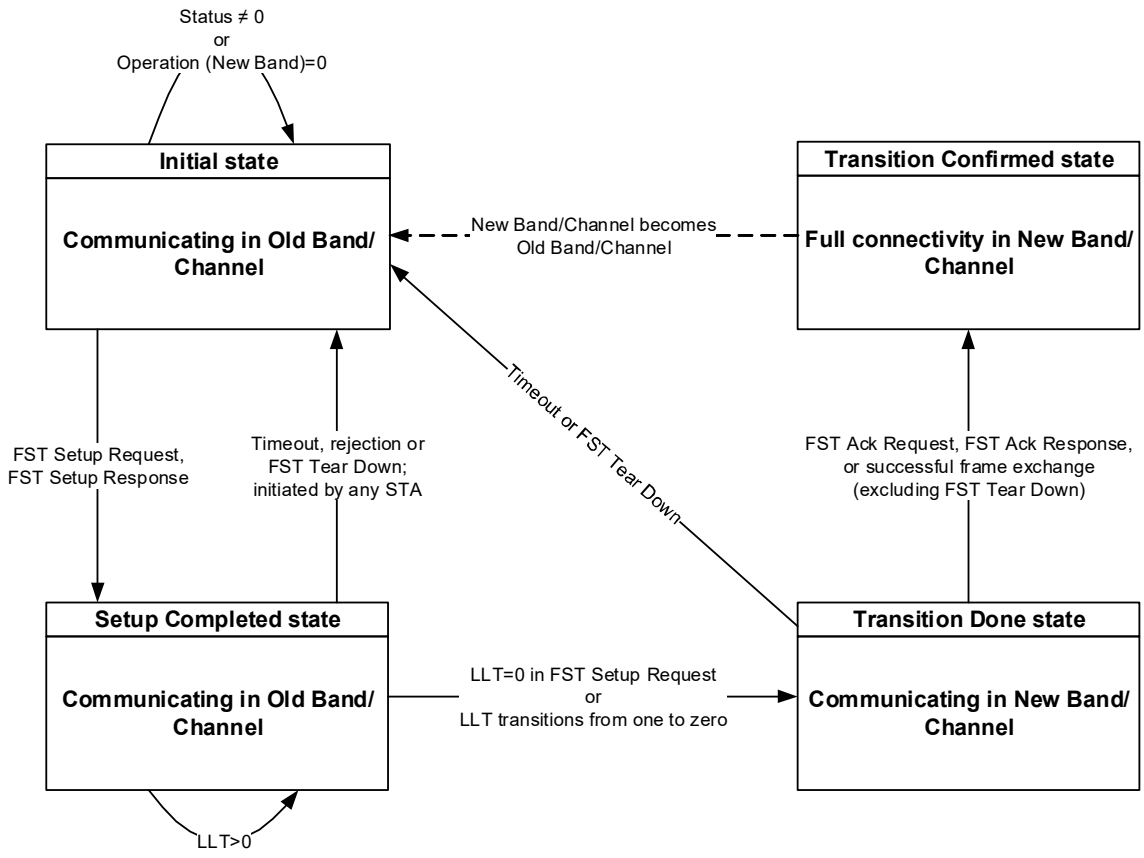


**Figure 11-90—States of the FST setup protocol**

PENDING_ADMITTING_FST_SESSION or PENDING_GAP_IN_BA_WINDOW. In the latter case, the responder shall transmit the unsolicited FST Setup Response frame to the initiator.

There might be multiple FST Setup Request and FST Setup Response frame transmissions by the initiator and the responder, respectively, until the FST session between these STAs becomes established. At each transition, or attempt to transition, from the Initial state to the Setup Completed state, the initiator and responder shall perform the following procedure:

a) The initiator sends an FST Setup Request frame to the responder.

b) Upon receipt of an FST Setup Request frame, the responder shall respond with an FST Setup Response frame unless it has a pending FST Setup Request frame addressed to the initiator and the responder has a numerically larger MAC address (see 12.7.1.1 (General) for comparison of MAC addresses) than the initiator's MAC address, (#274)in which case the responder shall (#3683)discard the received FST Setup Request (#3683)frame.

c) If, after the reception of the acknowledgment to the initiator's FST Setup Request frame, the initiator receives an FST Setup Request frame from the responder, the initiator shall not respond with an FST Setup Response frame if its MAC address is numerically larger (see 12.7.1.1 (General) for comparison of MAC addresses and see 11.1.4.3.10 (PCP selection in a PBSS)) than the responder's MAC address. Otherwise, if its MAC address is numerically smaller than the responder's MAC address, it becomes the responder and shall respond with an FST Setup Response frame and shall not send the FST Setup Request frame during the current FST.

d) The initiator shall not move to the Setup Completed state if at least one of the following conditions is met:


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1) The initiator does not receive an FST Setup Response frame from the responder within the STT.
2) The Status Code field in the received FST Setup Response frame from the responder is different from SUCCESS.
3) A state-specific exception in Table 11-25 (Exceptions for the initiator) takes place.

e) The initiator shall move to the Setup Completed state if none of conditions d(1), d(2), and d(3) is met.

f) The responder shall not move to the Setup Completed state if at least one of the following conditions is met:
1) The responder does not receive the acknowledgment to its transmitted FST Setup Response frame
2) The Status Code field in the FST Setup Response frame it transmitted to the initiator was different from SUCCESS.
3) The value of the Setup and Operation subfields within the Session Transition element in the transmitted FST Setup Response frame results in a status different from any of the rows shown in Figure 11-26 (FST status at state transition), in which case the responder shall set the Status Code field with the transmitted FST Setup Response frame to REQUEST_DECLINED.
4) The resulting status of the Operation subfield in the New Band field is 0.

g) The responder shall move to the Setup Completed state if none of conditions f)1), f)2), f)3), and f)4) is met.

**Table 11-25—Exceptions for the initiator**

| State | Condition | Meaning | Next state |
|---|---|---|---|
| Initial | FST Setup Response frame with Status Code PENDING_ADMITTING_FST_SESSION | Pending, responder in process of admitting FST session. | Initial |
| Initial | FST Setup Response frame with Status Code PENDING_GAP_IN_BA_WINDOW | Pending, block ack window at the responder has gaps. | Initial |
| Initial | FST Setup Response frame with Status Code REJECTED_WITH_SUGGESTED_CHANGES | One or more parameters of the FST Setup Request frame is invalid and the responder suggests alternative parameters. | Initial |
| Initial | FST Setup Response frame with Status Code REQUEST_DECLINED | Responder rejects the request. One particular case is that values of the operating class and channel number fields within the Multi-band element, if any, received in the FST Setup Request frame is different from the corresponding fields within the Multi-band element, if any, transmitted in the following FST Setup Response. | Initial |
| Initial | FST Setup Response frame with Status Code REJECT_DSE_BAND | Responder rejects the request since the initiator is a dependent STA and the request is for transitioning to a frequency band subject to DSE procedures. In the rejection, the responder can include a (#1776)TIE. | Initial |

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**Table 11-25—Exceptions for the initiator *(continued)***

| State | Condition | Meaning | Next state |
|---|---|---|---|
| Initial | Resulting status is different from shown in Table 11-26 (FST status at state transition) | The responder is not able to complete the setup. | Initial |
| Initial | Resulting status of the Operation field in the New Band field is 0 in Table 11-26 (FST status at state transition) | The operation in the new band is disabled. | Initial |
| Setup Completed | FST Setup Response frame with Status Code SUCCESS and LLT field within the FST Setup Request frame is greater than zero | The STA is ready to switch to the new band if the link is lost in the old band. | Setup Completed |
| Setup Completed | Transmission or reception of FST Teardown frame | Termination of FST session. | Initial |

If, upon transition to the Setup Completed state, the LLT field within the last successful FST Setup Request frame received by the responder or transmitted by the initiator was equal to 0, the initiator and responder shall immediately move to the Transition Done state.

If, upon transition to the Setup Completed state, the LLT field within the last successful FST Setup Request frame received by the responder or transmitted by the initiator was greater than 0, the initiator and responder shall proceed as follows:

— If the last FST Setup Request or FST Setup Response frames exchanged between the initiator and responder included a Switching Stream element, then all of the streams within the Switching Stream element that have the LLT Type field set to 1 shall be switched using the Stream-based Link Loss Countdown, and all of the streams within the Switching Stream element that have the LLT Type field set to 0 shall be switched using the STA-based Link Loss Countdown.

— If the neither the FST Setup Request nor the FST Setup Response frames exchanged between the initiator and responder included a Switching Stream element, then the streams shall be switched using the STA-based Link Loss Countdown.

The state transition for the STA, if STA-based, or the stream, if stream-based, from the Setup Completed state to the Transition Done state shall occur immediately after the corresponding Link Loss countdown timer transitions from 1 to 0 within any of the initiator or responder of the FST session.

An initiator and responder shall perform the STA-based and stream-based Link Loss Countdown as follows:

— STA-based Link Loss Countdown: Both initiator and responder shall remain in the Setup Completed state and start a Link Loss countdown timer with an initial value of LLT×32 μs. The Link Loss countdown is reloaded with the value of LLT×32 μs every time that an individually addressed frame is received from the peer STA of the FST session.

— Stream-based Link Loss Countdown: Both the initiator and responder shall start a Link Loss countdown timer with an initial value of LLT×32 μs for each stream identified within the Switching Stream element. The Link Loss countdown for a stream is reloaded with the value of LLT×32 μs every time that an individually addressed frame for that stream is received from the peer STA of the FST session.

Before leaving the Setup Completed state, an initiator and/or responder that is performing a full FST may transmit an FST Setup Response frame in the old band/channel with the Status Code field set to


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PERFORMING_FST_NOW and with the RA field set to the broadcast address to notify other STAs in the BSS of the STA's forthcoming full FST.

Table 11-26 (FST status at state transition) shows the FST session status at each state transition. The Setup and Operation subfields shown in Table 11-26 (FST status at state transition) are present within the Session Transition element. When the value of a subfield in the FST Setup Request frame is different from the value of that same subfield in the following FST Setup Response frame, the resulting status shall be the logical AND of the value of the corresponding subfields in both the FST Setup Request and the FST Setup Response frames.

**Table 11-26—FST status at state transition**

| From State | Old band resulting status | | New band resulting status | | To State | Definition |
|---|---|---|---|---|---|---|
| | Setup | Operation | Setup | Operation | | |
| Initial | 1 | 1 | 0 | 0 | Initial | New band setup and operation are disabled. |
| Initial | 1 | 1 | 1 | 0 | Initial | New band operation is disabled, the setup is kept alive. |
| Initial | 0 | 0 | 1[a] | 1 | Setup Completed | FST session is operational in new band. |
| Initial | 1[a] | 1 | 1[a] | 1 | Setup Completed | FST session is operational in both bands. |
| Initial | 1 | 0 | 1[a] | 1 | Setup Completed | FST session is operational in new band; FST session in old band is kept alive. |
| Setup Completed | Unchanged | Unchanged | Unchanged | Unchanged | Transition Done | No status changes. |
| Transition Done | Unchanged | Unchanged | Unchanged | Unchanged | Transition Confirmed | No status changes. |

[a] The value of this field remains unchanged during the FST.

Upon transition to the Transition Done state and if transparent FST is used, the association state (see 11.3.1 (State variables)) of the STA corresponding to the old band/channel is transferred to the STA corresponding to the new band/channel.

To transition from the Transition Done state to the Transition Confirmed state, the initiator and responder shall perform the following procedure within the channel number of the operating class and band ID specified in the Multi-band element negotiated during the FST session setup:

a) The state transition is controlled by the State Transition Timer (STT). Each STA of the FST session has its own STT. The initiator shall transition to the Initial state when its STT transitions from 1 to 0, but not when the STT is set to 0. The responder shall transition to the Initial state when its STT transitions from 1 to 0, but not when the STT is set to 0.

   The initiator shall set the STT to the value of the FSTSessionTimeout field at successful transmission of an FST Ack Request frame or at transmission of any individually addressed MPDU

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to the responder. The initiator shall set the STT to 0 at the transmission of an Ack frame sent in response to an FST Ack Response frame from the responder or at reception of an Ack frame received in response to a frame sent to the responder.

The responder shall set the STT to FSTSessionTimeout at transmission of an FST Ack Response frame or at transmission of any other individually addressed MPDU to the initiator. The responder shall set the STT to 0 at the reception of an Ack frame received in response to a transmitted FST Ack Response frame or at the reception of any individually addressed frame sent by the initiator. The responder shall transmit an FST Ack Response frame to the initiator no later than FSTSessionTimeout after the transmission of an Ack frame sent in response to an FST Ack Request frame from the initiator.

b) The SME of both the initiator and responder generates an MLME-FST-INCOMING.request primitive that includes the parameters of the FST. This primitive shall be generated to the MLME associated with the channel number, operating class, and band ID specified in the Multi-band element negotiated during the FST session setup. This primitive notifies the MLME of an impending FST.

c) The initiator shall send an FST Ack Request frame or may send any other individually addressed MPDU to the responder.

NOTE 1—Depending on the BSS configuration in the new band/channel, the initiator might have to associate and/or authenticate with the BSS before it is allowed to transmit a frame to the responder.

d) Upon receipt of an FST Ack Request frame, the responder shall respond to the initiator with an FST Ack Response frame.

NOTE 2—Depending on the BSS configuration in the new band/channel, the responder might have to associate and/or authenticate with the BSS before it is allowed to transmit a frame to the initiator.

e) The initiator shall move to the Transition Confirmed state

1) Upon transmission of an Ack frame sent in response to any individually addressed frame, including an FST Ack Response frame, received from the responder; or

2) When the initiator receives an Ack frame from the responder to any non-FST Ack Request frame the initiator transmitted to the responder.

f) The responder shall move to the Transition Confirmed state

1) When the responder receives an Ack frame in response to any individually addressed frame, including an FST Ack Response frame, sent to the initiator; or

2) Upon transmission of an Ack frame sent in response to any individually addressed non-FST Ack Request frame.

Following the transition to the Transition Confirmed state, a STA shall adopt the role indicated in the STA Role field corresponding to the channel number, operating class and band ID that was last transmitted to the peer STA within the Multi-band element. If the STA was operating within a PBSS, was the initiator of the FST session, and the new role of the STA is as an IBSS STA, then the STA shall be a DFS Owner of the IBSS.

In case the transition to the Transition Confirmed state was the result of a Stream-based Link Loss Countdown, the stream shall remain in the Transition Confirmed state until all of the streams included within the corresponding Switching Stream element reach the Transition Confirmed state. Once all streams within the corresponding Switching Stream element reach the Transition Confirmed state or the FST session ceases to exist, the STA moves to the Initial state.

If neither the initiator nor the responder perform in the role of AP or PCP as indicated through the STA Role field within the Multi-band element corresponding to the new band for that STA, one of the STAs can initialize a new BSS (11.1 (Synchronization)) on the new band for communication between the STAs.


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If the Switch Intent field in the last Session Transition element transmitted to a responder is 1, an initiator may switch to the new band and channel indicated in the last transmitted FST Setup Request frame and Multi-band element, respectively, if at least one of the following conditions is satisfied:

- The Status Code field within the FST Setup Response frame received in response to the transmitted FST Setup Request frame is equal to REQUEST_DECLINED.
- The initiator moves to the Initial state due to the STT at the initiator moving from 1 to 0.
- The initiator moves to the Initial state due to the reception of an FST Teardown frame from the responder.

Immediately before an initiator switches to a new band and/or channel, the initiator shall disassociate and delete all TS and block ack agreement(s) it has with a responder for which at least one of the above conditions is met.

Following the successful fast session transfer to a new band, the STA of the FST session shall follow the medium access rules applicable to the new band.

#### 11.31.3.3 FST TS switching

If a STA transmitting an FST Setup Request frame or an FST Setup Response frame does not intend to switch all its streams, then the STA shall include the Switching Stream element in the transmitted frame to indicate which streams are requested to be transferred to the other band/channel. If the FST Setup Request frame includes a Switching Stream element, the FST Setup Response frame should include a Switching Stream element. If the FST Setup Request frame does not include a Switching Stream element, the FST Setup Response frame may include a Switching Stream element. If the STA transmitting the Switching Stream element has not set up a stream in the band indicated in the New Band ID field within this element, it shall set the Stream ID In New Band Valid field to 0. A STA may set up a stream in any band/channel by transmitting ADDBA Request or ADDTS Request frames that include the Multi-band element.

If a STA transmits an ADDTS Request frame to another STA with which it has established an FST session and the ADDTS Request frame is transmitted in a band or channel different from the band or channel to which the ADDTS request is intended to apply, the ADDTS Request frame shall include the Multi-band element with the Band ID, Operating Class, and Channel Number fields set to indicate to which channel the ADDTS Request frame applies. In addition, if these STAs use the nontransparent mode for FST, the STA transmitting the ADDTS Request frame sets the STA MAC Address Present field to 1 and the STA MAC Address field to the MAC address that the STA uses in the band and channel number that are indicated in the Multi-band element contained in the ADDTS Request frame. Similar to the ADDTS Request frame, the Multi-band element shall be included in the ADDBA Request, ADDTS Response, ADDBA Response, DELTS, and DELBA frames when these frames are transmitted in a band or channel different from the band or channel to which they are intended to apply.

When using transparent mode to transfer an FST session corresponding to a TID/TSID, the Direction subfield within the TSPEC element, if any, used to set up the TID/TSID should not be set to indicate a bidirectional link. This enables the SME to use the TID/TSID in conjunction with the source and destination MAC addresses in both the old and new frequency band/channel to uniquely identify the FST session.

If any of the ADDTS variants is used to switch the TS, then the PTP TSPEC or the DMG TSPEC shall be used when the TS is being established to operate in a DMG BSS, and the Basic TSPEC shall be used when the TS is being established to operate in a non-DMG BSS irrespective of the band and channel used to communicate the ADDTS frames and the DMG ADDTS frames.

The rules defined below apply when the ADDTS frames or the DMG ADDTS frames are used to switch TS. When the ADDTS frames and the DMG ADDTS frames are used, then the ADDTS requester and the ADDTS responder provide the functions defined for the ADDBA originator and the ADDBA recipient, respectively.

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If the ADDBA recipient includes the Switching Stream element in any of the FST Setup Request or FST Setup Response frames and if the Stream ID In New Band Valid field within the Switching Stream element is 0, the ADDBA originator should issue the DELBA frame to reject the block ack agreements indicated in the Stream ID In Old Band field. If the originator intends to establish new block ack agreements in the band indicated in the Multi-band element sent by the recipient and with the recipient MAC address indicated in the Multi-band element sent by the recipient, the originator shall transmit an ADDBA Request frame addressed to the recipient.

The originator may include the Multi-band element and the Ethernet type TCLAS element in the ADDBA Request frame. If the MAC Addresses of the originator and recipient to be used in the new band are different from the MAC addresses used in the old band, then the ADDBA Request frame sent in the old band to establish a block ack agreement in the new band shall include the Multi-band and the TCLAS elements. The resulting block ack agreement, if established, applies to the band and channel identified in the Multi-band element included in the ADDBA Request frame. The BlockAck is identified by the TID/TSID and MAC addresses of the originator and the recipient used in the band and channel indicated in the Multi-band element included in ADDBA Request and ADDBA Response frames.

The ADDBA Request frame may be issued in the old band and channel, and the corresponding ADDBA Response frame may be transmitted in the band and channel indicated in the Multi-band element within the ADDBA Request frame.

The following rules for establishment of a multi-band block ack agreement shall apply:

a) If the TA and/or the RA fields of the ADDBA Request frame are different from the originator MAC address and/or the recipient MAC address, respectively, used in the channel and band where the block ack agreement should operate, then the originator shall set the Source Address field and the Destination Address field of the classifier to the originator MAC address and the recipient MAC address, respectively, to be used in the band and channel indicated in the Multi-band element included in the ADDBA Request frame.

b) If the TA and RA are equal to the originator MAC address and the recipient MAC address, respectively, then the Multi-band element, if any, included in the ADDBA Request frame shall indicate the band and channel over which the block ack agreement is to operate. The TCLAS element shall not be included in this ADDBA Request frame.

c) The Multi-band element should not be included in the ADDBA Request frame if in the case b) the ADDBA Request frame is issued in the same band and channel over which the block ack agreement is to operate.

d) If the TA and/or the RA fields of the ADDBA Response frame are different from the recipient MAC address and/or the originator MAC address, respectively, to be used in the channel and band where the block ack agreement should operate, then the recipient shall set the Source Address field and the Destination Address field of the classifier to the recipient MAC Address and the originator MAC address, respectively, to be used in the band and channel indicated in the Multi-band element included in the ADDBA Response frame. The indicated band and channel shall be equal to the band and channel indicated in the Multi-band element of the ADDBA Request frame.

e) If the TA and RA fields are equal to the recipient MAC address and the originator MAC address, respectively, then the Multi-band element, if any, included in the ADDBA Response frame shall indicate the band and channel over which the block ack agreement is to operate. The indicated band and channel shall be equal to the band and channel indicated in the Multi-band element of the ADDBA Request frame. The TCLAS element shall not be included in the ADDBA Response frame.

f) The Multi-band element should not be included in the ADDBA Response frame if in case e) the ADDBA Response frame is issued in the same band and channel over which the block ack agreement is to operate.


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### 11.31.4 FST teardown

At the Setup Completed state or Transition Done state, a STA may transmit an FST Teardown frame to its peer STA of the FST session in order to tear down an FST session that was previously set up using the FST Setup Request/Response frame exchange. Upon transmission or reception of an FST Teardown frame, the initiator and responder move to the Initial state (11.31.3 (FST setup protocol)). When moving to the Initial state and if the Switch Intent field in the last Session Transition element transmitted to a responder is 1, the initiator behaves as described in 11.31.3.2 (Transitioning between states).

### 11.31.5 On-channel Tunneling (OCT) operation

(11ax)OCT allows the following:

— A STA of a multi-band capable device or a STA that is in the same device as another STA to transmit or forward an MMPDU that was constructed by, addressed by, or addressed to a different STA in the same device.

— An AP to transmit or forward an MMPDU that was constructed by, addressed by, or addressed to another AP if either one of the APs sends a Reduced Neighbor Report element with a TBTT Information field describing the other AP or if either one of the APs sends a Neighbor Report element describing the other AP, and where both APs support OCT.

An MMPDU transmitted this way is referred to as an *OCT MMPDU*. The MLME of the nontransmitting STA that constructs or is the destination of an OCT MMPDU is referred to as an *NT-MLME*. The MLME of the STA that transmits or receives an OCT MMPDU over the air is referred to as a *TR-MLME*. An NT-MLME that constructs an OCT MMPDU destined to a peer NT-MLME does so according to the capabilities of the STA that contains the peer NT-MLME.

NOTE 1—OCT can be used in conjunction with or independent from the FST setup protocol.

(11ax)Either of the following conditions indicates that a STA supports OCT and has dot11OCTOptionImplemented equal to true:

— A STA supports OCT if the OCT Not Supported subfield within the STA's Multi-band element is 0.

— A non-AP STA supports OCT if the OCT field is equal to true in the Extended Capabilities elements it transmits.

— If a reporting AP sends a frame with a Reduced Neighbor Report element with a TBTT Information field describing a reported AP that has the OCT Recommended subfield equal to 1, then both the reporting AP and the reported AP support OCT.

— If a reporting AP sends a frame with a Neighbor Report element describing a reported AP that has the OCT Supported With Reporting AP subfield equal to 1, then both the reporting AP and the reported AP support OCT.

A STA should not perform OCT with a peer STA that does not support OCT. A STA that does not support OCT shall ignore a received OCT MMPDU.

Figure 11-91 (On-channel tunneling procedure) depicts the overall OCT procedure. In this figure, <primitive> refers to the name of any of the MLME primitives defined in 6.4 (Table of MLME SAP interfaces(#1114)) that meets all of the following conditions:

— Includes a peer Multi-band element. The peer Multi-band element is used to identify the peer NT-MLME.

— Includes a local Multi-band element. The local Multi-band element is used to identify the local TR-MLME.

An MLME primitive meeting all of the above conditions is referred to as an *OCT MLME primitive*.

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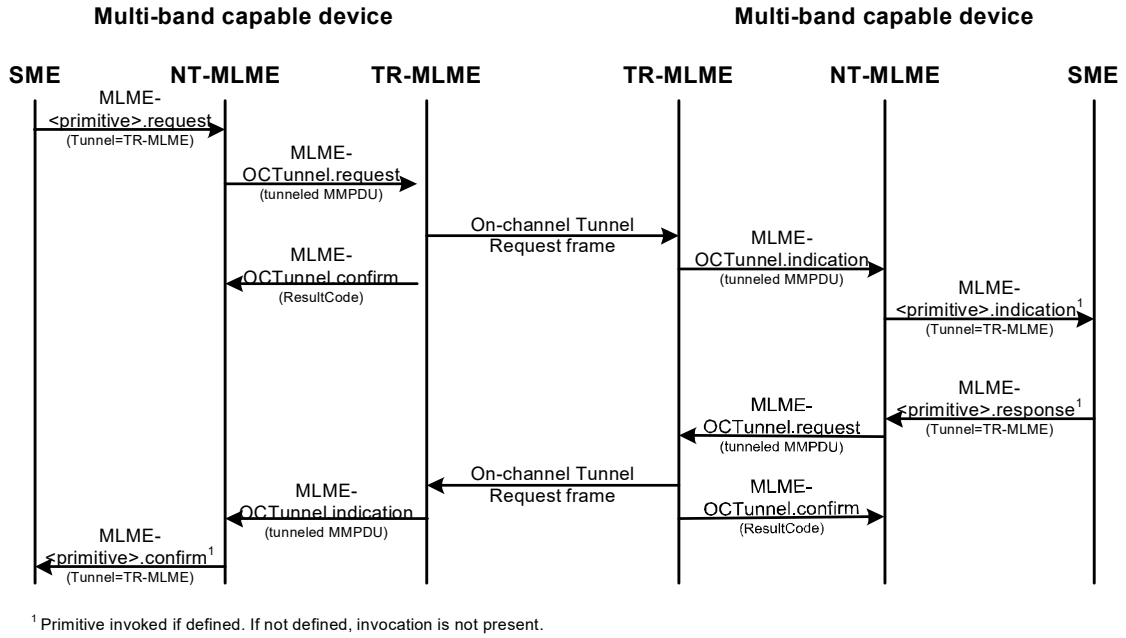


[1] Primitive invoked if defined. If not defined, invocation is not present.

**Figure 11-91—On-channel tunneling procedure**

NOTE 2—MLME-AUTHENTICATE, MLME-ASSOCIATE, and MLME-REASSOCIATE are examples of primitives that are OCT MLME primitives.

The OCT procedure can be used both with the OCT MLME primitives and to transmit a response to an On-channel Tunnel Request frame tunneling a Probe Request frame. The Timestamp field of the Probe Response frame tunneled in an On-channel Tunnel Request frame is reserved.

To perform the OCT procedure, the values of the Band ID, Channel Number and BSSID fields in a Multi-band element or OCT Source element are used to identify an MLME. All other fields in the Multi-band element shall be reserved.

Except for the following cases, the values of the Band ID, Channel Number and BSSID fields in a Multi-band element or OCT Source element are used by an NT-MLME to deliver messages to a TR-MLME through the OCTunnel.request primitive, and are used by a TR-MLME to deliver messages to an NT-MLME through the OCTunnel.indication primitive:

— If the BSSID field is the wildcard BSSID, an MLME (either TR-MLME or NT-MLME) shall not use the BSSID field in selecting the MLME to deliver a message and shall, instead, invoke the corresponding primitive for all MLMEs that match the Band ID and Channel Number fields.

— If the OCT MLME request primitive is the MLME-SCAN.request primitive with ScanType parameter set to ACTIVE and that includes the ChannelList parameter, the NT-MLME shall not use the Channel Number field within the Multi-band local parameter of the MLME-SCAN.request primitive in selecting the TR-MLME to deliver a message and shall, instead, invoke the OCTunnel.request primitive at the TR-MLME(s) that match the Band ID field and BSSID field within Multi-band local parameter, and the channels specified in the ChannelList parameter.

— If the Channel Number field is 0 and the OCT MLME request primitive is not the MLME-SCAN.request primitive with ScanType parameter set to ACTIVE and that includes the ChannelList parameter, an MLME (either TR-MLME or NT-MLME) shall not use the Channel Number field in selecting the MLME to deliver a message and shall, instead, invoke the corresponding primitive for all MLMEs that match the Band ID and BSSID fields.


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— If the Channel Number field is 0 and the OCT MLME request primitive is not the MLME-SCAN.request primitive with ScanType parameter set to ACTIVE and that includes the ChannelList parameter, and the BSSID field is the wildcard BSSID, an MLME (either TR-MLME or NT-MLME) shall use neither the BSSID field nor the Channel Number field in selecting the MLME to deliver a message and shall, instead, invoke the corresponding primitive for all MLMEs that match the Band ID field.

In the following procedure, a "request tunneled MMPDU" is an MMPDU generated in the context of an MLME.request primitive. A "response tunneled MMPDU" is an MMPDU generated in the context of an MLME.response primitive.

To transmit a tunneled MMPDU, the SME of a STA that supports OCT(11ax) generates an OCT MLME request primitive that includes the peer Multi-band element and the local Multi-band element. If the OCT MLME request primitive is the MLME-SCAN.request primitive with (11ax)the ScanType parameter set to ACTIVE, the BSSID field within the peer Multi-band element shall be set to the value of the BSSID parameter in the MLME-SCAN.request primitive and the BSSID field within the local Multi-band element shall be set to (#1653)an individual address.

An NT-MLME receiving an OCT MLME request primitive shall

— As defined in this standard, process the request and construct an OCT MMPDU corresponding to the primitive in question. The NT-MLME shall not transmit any frame as a result of this primitive.

— Generate an MLME-OCTunnel.request primitive with parameters including the OCT MMPDU, the Multi-band peer parameter set to the peer Multi-band element and the OCT source parameter set to the OCT Source element identifying the NT-MLME.

An NT-MLME does not issue an MLME-OCTunnel.request primitive if a selected TR-MLME does not exist. A TR-MLME does not issue an MLME-OCTunnel.indication primitive if a selected NT-MLME does not exist.

A single OCT MLME request primitive received by an NT-MLME may result in the invocation of one or more MLME-OCTunnel.request primitives at TR-MLME(s). Each invocation shall be towards a different TR-MLME.

A TR-MLME receiving an MLME-OCTunnel.request primitive with a request tunneled MMPDU shall transmit an On-channel Tunnel Request frame addressed to the peer TR-MLME and which includes the tunneled MMPDU. The peer TR-MLME(s) is identified by the PeerSTAAddress parameter of the MLME-OCTunnel.request primitive. The On-channel Tunnel Request frame shall not be group addressed. Once the On-channel Tunnel Request frame is transmitted and acknowledged or attempts to transmit the frame are abandoned, the TR-MLME shall issue an MLME-OCTunnel.confirm primitive, with the appropriate result code, to inform the NT-MLME of the outcome of the frame transmission.

A receiving TR-MLME shall discard(#3683) the received On-channel Tunnel Request frame if that frame is not targeting an NT-MLME in the same multi-band capable device as the TR-MLME.

NOTE 3—The mechanism for a TR-MLME to forward an OCT MMPDU received in an On-channel Tunnel Request frame to an NT-MLME not in the same multi-band capable device as the TR-MLME is outside the scope of this standard.

A TR-MLME receiving an On-channel Tunnel Request frame carrying a request tunneled MMPDU shall generate an MLME-OCTunnel.indication primitive with the Multi-band local parameter set to the Multi-band element identifying the TR-MLME, the OCT source parameter set to the value of the OCT Source field contained in the On-channel Tunnel Request frame and the Tunneled RXVECTOR parameter set to the RXVECTOR of the On-channel Tunnel Request frame. The MLME-OCTunnel.indication primitive shall be generated to the NT-MLME identified by the peer Multi-band element contained within the received On-channel Tunnel Request frame.

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An NT-MLME receiving an MLME-OCTunnel.indication primitive carrying a request tunneled MMPDU shall

— As defined in this standard, process the OCT MMPDU parameter of the primitive as if the MMPDU had been received over the air, with the exception that an acknowledgment, if any, shall not be sent as a response to the reception of the MMPDU.

— Generate an OCT MLME indication primitive, if one is defined, corresponding to the frame type of tunneled MMPDU. This primitive is generated to the SME of the STA, which processes the MMPDU as defined in this standard. The Multi-band local parameter of the OCT MLME indication primitive shall be set to the value of the Multi-band local parameter of the MLME-OCTunnel.indication primitive and the Multi-band peer parameter shall be set to a Multi-band element where the value of the Band ID, Channel Number and BSSID fields are set to the value of the corresponding fields in the OCT source parameter of the MLME-OCTunnel.indication primitive.(#2085)

In the case of a .request/.indication primitive, the process stops here. Otherwise, the process continues as described below.

The peer SME responds to the reception of an OCT MLME indication primitive by generating the corresponding OCT MLME response primitive. This response includes the peer Multi-band element and the local Multi-band element.

An NT-MLME receiving an OCT MLME response primitive, if one is defined, or generating a response by itself, if no OCT MLME response primitive is defined (e.g., MLME-SCAN.response is not defined), shall

— As defined in this standard, process the response and construct an OCT MMPDU corresponding to the primitive in question. The NT-MLME shall not transmit any frame as a result of this primitive.

— Generate an MLME-OCTunnel.request primitive with parameters including the OCT MMPDU, the Multi-band peer parameter set to the peer Multi-band element and the OCT source parameter set to the OCT Source element identifying the NT-MLME. If no OCT MLME response primitive is defined, the Multi-band peer parameter shall be set to a Multi-band element where the value of the Band ID, Channel Number and BSSID fields are set to the value of the corresponding fields in the OCT source parameter received in the corresponding MLME-OCTunnel.indication primitive.(#2085) The MLME-OCTunnel.request primitive shall be generated to the TR-MLME identified by the local Multi-band element specified in the OCT MLME response primitive, if one is defined, or to the TR-MLME identified by the Multi-band local parameter of the MLME-OCTunnel.indication primitive that triggered this response, if no OCT MLME response primitive is defined.

A TR-MLME receiving an MLME-OCTunnel.request primitive with a response tunneled MMPDU shall transmit an On-channel Tunnel Request frame addressed to the peer TR-MLME that includes the tunneled MMPDU. The peer TR-MLME(s) is identified by the PeerSTAAddress parameter of the MLME-OCTunnel.request primitive. Once the On-channel Tunnel Request frame is transmitted and acknowledged or attempts to transmit the frame are abandoned, the TR-MLME shall issue an MLME-OCTunnel.confirm primitive, with the appropriate result code, to inform the NT-MLME of the outcome of the frame transmission.

A TR-MLME receiving an On-channel Tunnel Request frame carrying a response tunneled MMPDU shall generate an MLME-OCTunnel.indication primitive with the Multi-band local parameter set to the Multi-band element identifying the TR-MLME, the OCT source parameter set to the value of the OCT Source field contained in the On-channel Tunnel Request frame and the Tunneled RXVECTOR parameter set to the RXVECTOR of the On-channel Tunnel Request frame. The MLME-OCTunnel.indication primitive shall be generated to the NT-MLME identified by the peer Multi-band element contained within the received On-channel Tunnel Request frame.


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An NT-MLME receiving an MLME-OCTunnel.indication primitive carrying a response tunneled MMPDU shall

— Process the OCT MMPDU parameter of the primitive as if the MMPDU had been received over the air.

— Generate an OCT MLME confirm primitive, if one is defined, corresponding to the frame type of the tunneled MMPDU. This primitive is directed at the SME and has the Multi-band local parameter set to the value of the Multi-band local parameter of the MLME-OCTunnel.indication primitive and the Multi-band peer parameter set to a Multi-band element where the value of the Band ID, Channel Number and BSSID fields are set to the value of the corresponding fields in the OCT source parameter of the MLME-OCTunnel.indication primitive.(#2085) If the OCT MLME confirm primitive is the MLME-SCAN.confirm primitive and the NT-MLME did not scan all the channels specified in the corresponding MLME-SCAN.request primitive, the ResultCode parameter in the MLME-SCAN.confirm primitive shall be set to PARTIAL_SCAN and the ScannedChannelList parameter shall list all channels that have been scanned.

An NT-MLME receiving an MLME-OCTunnel.confirm primitive shall:

— As defined in this standard, take action, if there is one, based on the success or otherwise of the OCT MMPDU transmission by the TR-MLME.

Figure 11-92 (Forward path of OCT messages based on OCT parameters(#6313)) and Figure 11-93 (Return path of OCT messages based on OCT parameters(#6313)(#2085)) illustrate the complete forwarding of OCT messages based on the procedure described above in this subclause. Figure 11-92 (Forward path of OCT messages based on OCT parameters(#6313)) depicts the forward path, i.e., from a requesting multi-band device (MBD) that initiates the OCT procedure with a responding MBD. Figure 11-93 (Return path of OCT messages based on OCT parameters(#6313)(#2085)) depicts the return path, i.e., from a responding MBD that generates an OCT MMPDU in response to an OCT MMPDU from a requesting MBD.

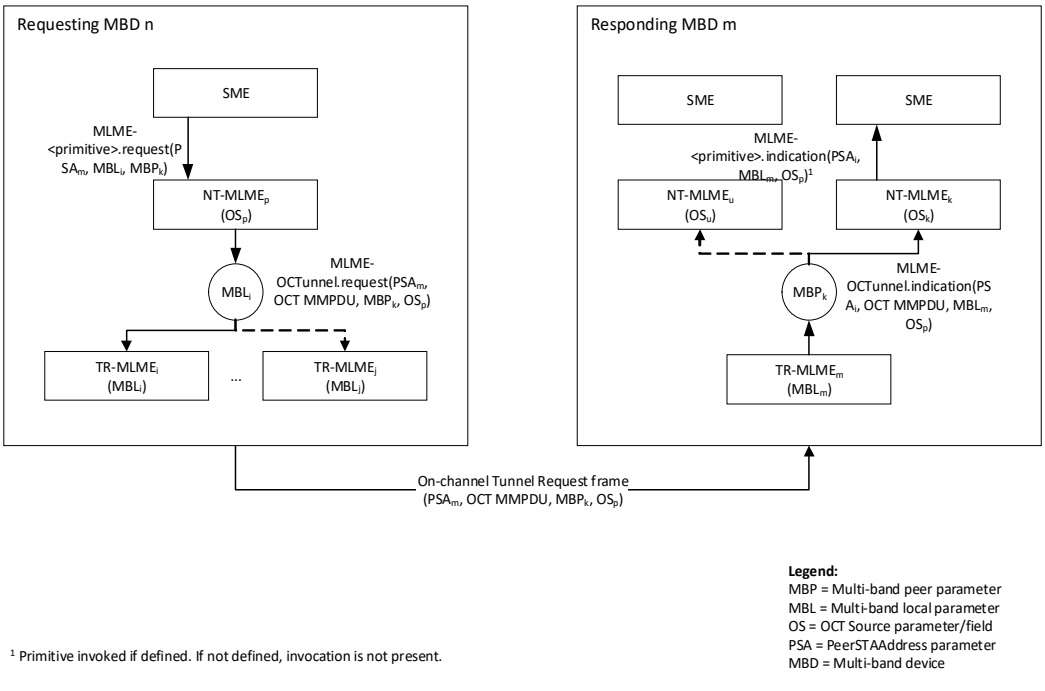


**Figure 11-92—Forward path of OCT messages based on OCT parameters(#6313)**

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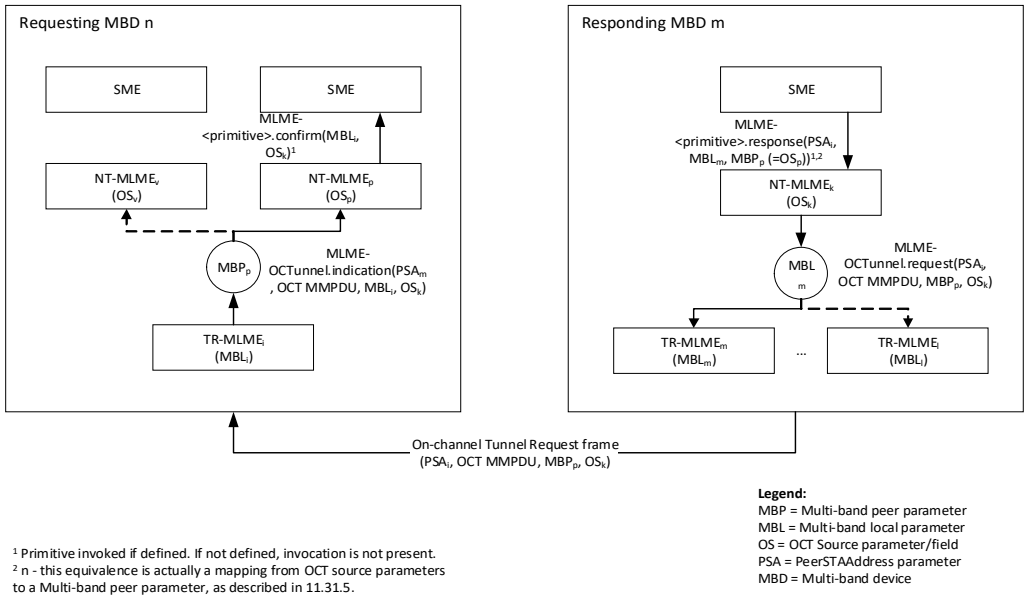


**Figure 11-93—Return path of OCT messages based on OCT parameters(#6313)(#2085)**

### 11.31.6 FST payload

When FST Action frames are forwarded by an AP, FST uses (#3370)MSDUs with (#2186)EtherType 89-0d as defined in Annex H. In this case, the Payload field of the MSDUs contains an FST Action frame body as is specified in 9.6.20 (FST Action frame details).

### 11.31.7 Multi-band discovery assistance procedure(11ay)

#### 11.31.7.1 Multi-band discovery assistance request procedure

The multi-band discovery assistance procedure allows discovery of DMG BSSs using a STA of a multi-band capable device that operates on a band other than its intended band of communication.

A device is multi-band discovery assistance capable if the value of both dot11MultibandImplemented and dot11DiscoveryAssistanceActivated are true for all discovery assistance cooperating STAs in the device. A STA that is part of a multi-band discovery assistance capable device shall advertise the capability of multi-band discovery assistance by setting the Discovery Assistance Enabled subfield in the Multi-band Control field of its Multi-band element to 1.


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Figure 11-94 (Multi-band discovery assistance procedure(11ay)) depicts an example of the overall multi-band discovery assistance procedure.

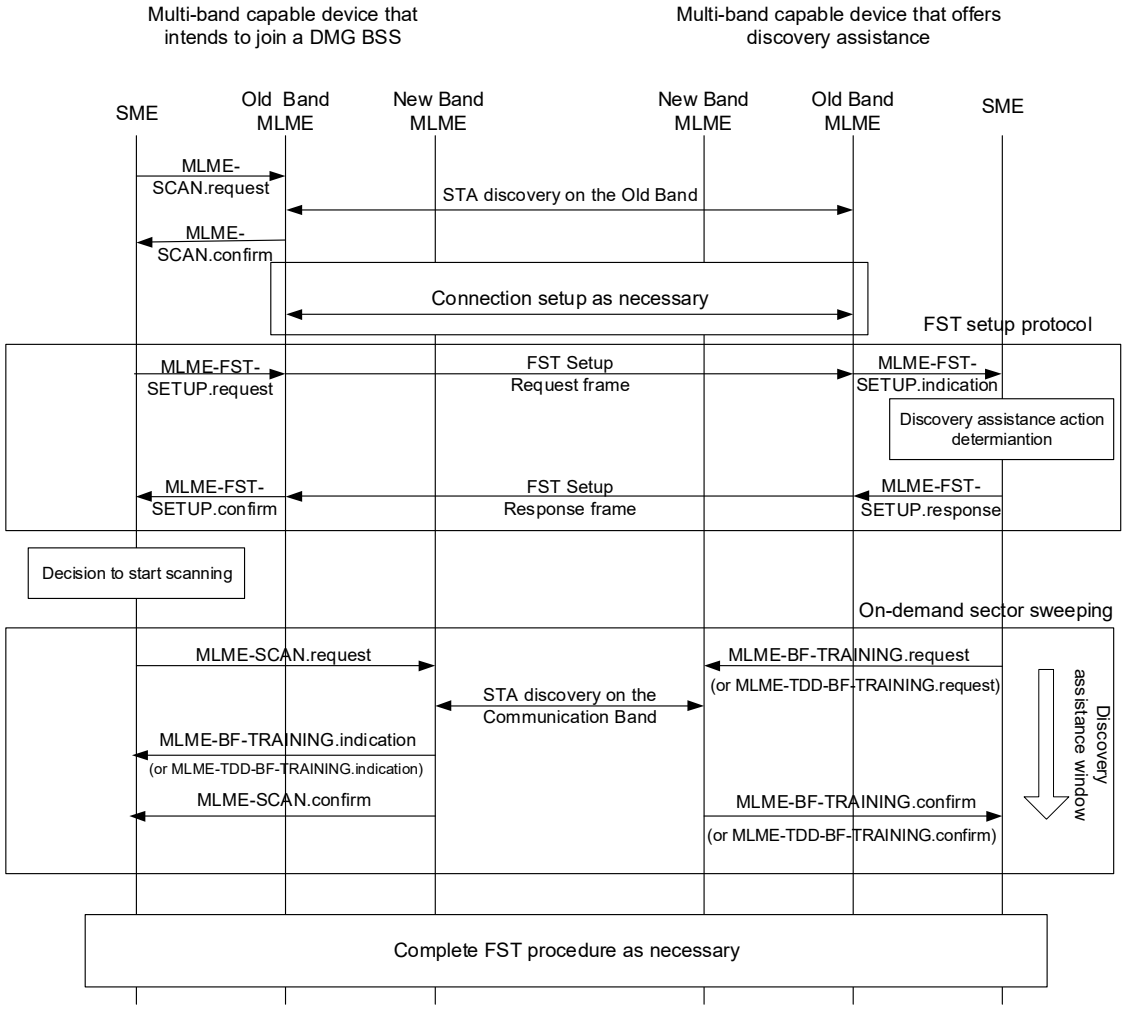


**Figure 11-94—Multi-band discovery assistance procedure(11ay)**

The SME of a STA of a multi-band capable device that intends to join a DMG BSS issues an MLME-SCAN.request primitive to the *Old Band MLME* of the device. After the scanning procedure completes, the *Old Band MLME* issues an MLME-SCAN.confirm primitive to the SME of the STA. The MLME-SCAN.confirm primitive contains information indicating which STAs support multi-band discovery assistance and for which band, i.e., the Discovery Assistance Enabled subfield in the Multi-band Control field of the Multi-band element.

If a multi-band discovery assistance capable device is found and a STA of the device operates a DMG BSS or an EDMG BSS, the SME of the STA that performed scanning may issue MLME-FST-SETUP.request primitive to the *Old Band MLME* of the STA to request the discovered STA to start the discovery assistance procedure with its DMG STA. The *Old Band MLME* receiving the MLME-FST-SETUP.request primitive shall transmit an FST Setup Request frame.

NOTE—If the recipient of an FST Setup Request frame is an AP, the STA transmitting the FST Setup Request frame needs to complete the association and authentication process before transmitting the frame.

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The two multi-band capable devices exchange FST Setup Request frame and FST Setup Response frames, as described in 11.31.3 (FST setup protocol), containing the DMG Discovery Assistance element.

Upon reception of the MLME-FST-SETUP.indication primitive, the SME of the STA that received the discovery assistance request determines if it accepts the requested discovery assistance. The SME shall encode the determination results in the DMG Discovery Assistance element, and issue an MLME-FST-SETUP.response primitive to the *Old Band MLME* to send back discovery assistance response.

The SME that received the MLME-FST-SETUP.confirm primitive including the DMG Discovery Assistance element shall determine if the discovery assistance response indicates that the discovery assistance is accepted. If it has been accepted, the device shall start its DMG STA on the channel specified in the Multi-band element. Further, the SME of the DMG STA shall issue an MLME-SCAN.request primitive to its *New Band MLME* in accordance with the parameters contained in the elements in the received frame.

Upon the successful completion of the on demand sector sweeping, the two multi-band devices may complete the FST procedure as described in 11.31.3 (FST setup protocol).

#### 11.31.7.2 Discovery assistance action determination and on demand sector sweeping

When the SME receiving the discovery assistance request accepts the request, it shall set the Discovery Assistance Request Status Code field of the DMG Discovery Assistance element transmitted in the FST Setup Response frame containing the discovery assistance response to SUCCESS and take one of the following actions with the corresponding DMG STA.

If the DMG STA operates non-TDD channel access, the DMG STA shall provide discovery assistance through one of the following two options:

- Option 1: The DMG STA schedules DMG Beacon frame transmissions sweeping all of its sectors so that the STA requesting discovery assistance can attempt to receive it. The STA sets fields in the DMG Discovery Assistance element as follows and includes it in transmitting response:
  - Sets the Discovery Assistance Type subfield in the Discovery Assistance Control field to 0.
  - Sets the Sector Sweep Start Time field to the TSF value indicating its TBTT when the discovery assistance starts.
  - Sets the Discovery Assistance Window Length to the time duration of the discovery assistance, i.e., DMG Beacon sweeping. The number of transmit antenna sectors in the STA requesting discovery assistance is used to determine the exact number of slots needed in the A-BFT period for the responder TXSS. The DMG STA might use multiple beacon intervals to complete full DMG Beacon sweeping. The Discovery Assistance Window Length might include one or more complete full DMG Beacon Sweep.
- Option 2: The DMG STA schedules a beamforming training period with the discovery assistance requesting DMG STA. The DMG STA adds the beamforming training period allocation to the Extended Schedule element and includes this element in its response. The total duration of the beamforming period shall at least cover the initiator TXSS and the responder TXSS. The DMG STA shall assign a temporary AID to the DMG STA that is requesting discovery assistance, in order to identify the STA in the element. The DMG STA sets fields in the Extended Schedule element sent in its response as follows:
  - Sets the Beamforming Training field, the IsInitiatorTXSS and IsResponderTXSS subfields in the BF Control subfield in the Allocation field to 1 to indicate that beamforming training is initiated at the start of the allocation.
  - If the DMG STA is offering discovery assistance with active scanning, it sets the Source AID subfield in the Allocation field to the temporary AID value that is assigned to the requesting DMG STA. If the DMG STA is offering discovery assistance with passive scanning, it sets the Destination AID subfield in the Allocation field to the temporary AID value that is assigned to the requesting DMG STA.


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The DMG STA sets the fields in the DMG Discovery Assistance element sent in its response as follows:

- Sets the Discovery Assistance Type subfield in the Discovery Assistance Control field to 1.
- Sets the Temporary AID field to the temporary value that is assigned to the requesting DMG STA.
- Sets the Discovery Assistance Window Length to the time duration of the beamforming period, including all time blocks if more than one time block is scheduled.

If the DMG STA operates TDD channel access, the DMG STA shall provide discovery assistance through one of the following two options:

- Option 1: The DMG STA initiates TDD beamforming, as specified in 10.41.11 (TDD beamforming(11ay)), with the STA that requested discovery assistance. The STA sets fields in the DMG Discovery Assistance element sent in the response as follows:
  - Sets the Discovery Assistance Type subfield in the Discovery Assistance Control field to 0.
  - Sets the Sector Sweep Start Time field to the TSF value when the STA starts TDD beamforming procedure.
  - Sets the Dwelling Time field to the recommended time to sweep the receive antenna pattern during the scanning.
  - Sets the Discovery Assistance Window Length to the time duration for the TDD beamforming. The number of DMG STA transmit antenna sectors, the number of receive antenna sectors in the STA requesting discovery assistance and the dwelling time are used to calculate the time required for TDD beamforming as described in 10.41.11 (TDD beamforming(11ay)).
- Option 2: The DMG STA schedules TDD beamforming with the STA that requested discovery assistance. The DMG STA schedules the allocation as part of an Extended Schedule element and includes this element in its response. The TDD Applicable SP subfield in the Allocation Control subfield of the Allocation field in the Extended Schedule field is set to 1 and either the Source AID or the Destination AID subfields in the Allocation field in the Extended schedule element is set to the DMG STA requesting a temporary AID. The DMG STA may include a TDD Slot Structure element and a TDD Slot Schedule element in its response. The DMG STA sets fields in the DMG Discovery Assistance element sent its response as follows:
  - Sets the Discovery Assistance Type subfield in the Discovery Assistance Control field to 1.
  - Sets the Temporary AID field to a temporary value that is assigned to the requesting DMG STA. This temporary AID value is used to identify the requesting DMG STA in the Extended Schedule element.
  - Sets the Dwelling Time field to the recommended time to sweep the receive antenna pattern during the scanning.
  - Sets the Discovery Assistance Window Length to the time duration of the TDD beamforming period, including all time blocks if more than one time block is scheduled.

When a STA that is a part of a multi-band capable device receives an FST Setup Response frame with a Discovery Assistance Response element indicating SUCCESS in the Discovery Assistance Request Status Code field in the received DMG Discovery Assistance element, the STA shall take the following actions with the corresponding peer DMG STA:

- The SME shall issue an MLME-SCAN.request primitive to its New Band MLME, set the BSSID and ChannelList parameters according to the BSSID, Band ID, Operating Class and Channel Number field values captured from the Multi-band element and set the MinChannelTime parameter to the Discovery Assistance Window Length field in the received DMG Discovery Assistance element.

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Depending on the values contained in the Discovery Assistance Control field in the received DMG Discovery Assistance element, the MLME-SCAN.request primitive is issued in one of the following manners:

— If the Dwelling Time Present subfield is 0 and the Discovery Assistance Type subfield is 0, the MLME-SCAN.request primitive is issued before the time specified in the Sector Sweep Start Time field in the received DMG Discovery Assistance element and the ScanType is set to passive scanning.

— If the Dwelling Time Present subfield is 0 and the Discovery Assistance Type subfield is 1, the MLME-SCAN.request primitive is issued before the time of the scheduled beamforming period specified by the Allocation field in the received Extended Schedule element. The ScanType is set to active scanning if the Source AID subfield in the Allocation field in the received Extended Scheduled element is equal to the Temporary AID field in the received DMG Discovery Assistance element. The ScanType is set to passive scanning otherwise. The DMG STA shall perform the initiator TXSS and the responder TXSS within the allocated time specified in the received Extended Schedule element.

— If the Dwelling Time Present subfield is 1 and the Discovery Assistance Type subfield is 0, the MLME-SCAN.request primitive is issued before the time specified in the Sector Sweep Start Time field in the received DMG Discovery Assistance element. The ScanType is set to TDD passive scanning, and SectorDwellTime is set to the value specified in the Dwelling Time field in the received DMG Discovery Assistance element.

— If the Dwelling Time Present subfield is 1 and the Discovery Assistance Type subfield is 1, the MLME-SCAN.request primitive is issued before the time of the scheduled beamforming period specified by the Allocation field in the received Extended Schedule element. The ScanType is set to TDD passive scanning.

The New Band MLME reports the results of the beamforming training procedure by sending an MLME-BF-TRAINING.indication primitive or MLME-TDD-BF-TRAINING.indication primitive to its SME (see 11.36 (DMG beamforming)). After the scanning procedure, the New Band MLME responds back with an MLME-SCAN.confirm primitive to its SME notifying the completion of the scanning on the New Band.

## 11.32 MMSL cluster operation

### 11.32.1 Introduction

A STA is MMSL cluster capable if it includes an MMS element in its most recent transmission of (Re)Association Request, (Re)Association Response, ADDTS Request, ADDTS Response, Probe Request, Probe Response, Information Request, or Information Response frames.

An MM-SME coordinated STA shall be MMSL cluster capable, except for an MM-SME that coordinates two STAs where one STA is a member AP or member PCP in a centralized AP or PCP cluster and the other STA is associated to the S-AP of the centralized AP or PCP cluster.

NOTE—In the centralized clustering case, the two STAs in the MM-SME are communicating with different MAC entities with different SMEs, so there is no individual link for MMSL.

A non-MM-SME coordinated STA may be MMSL cluster capable.

An MMSL cluster capable STA shall include an MMS element in transmitted (Re)Association Request and (Re)Association Response frames.

As described in 4.9.3 (Reference model for supporting multiple MAC sublayers), an MM-SME may coordinate multiple MACs (and their respective STAs).


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Each STA coordinated by the same MM-SME may be used for the MMSL cluster setup and maintenance.

The PCP may deliver an MMS element that includes a MAC address that is equal to the BSSID and other MAC addresses that are not equal to the BSSID. The MAC addresses that are not the BSSID shall not be used to request and respond to association, reassociation, probing, and scheduling services provided by the PCP.

If a non-AP and non-PCP STA has delivered an MMS element to the AP or PCP, the non-AP and non-PCP STA shall not send an ADDTS Request frame to the AP or PCP with the TA field equal to a MAC address that was not included in the delivered MMS element.

If an MM-SME coordinated STA is associated with an AP or PCP that allocates one single AID to all STAs advertised in the MMS element sent by the MM-SME coordinated STA, the AID can be also used to identify the MMSL cluster. If the AID is provided for one of the advertised STAs of the MM-SME coordinated STA, then the same AID applies to all STAs whose addresses are referenced in the delivered MMS element and the Single AID field is set as per Table 9-311 (Single AID subfield definition).

Table 11-27 (Setting of Single AID field) covers the possible cases of the AID use for MMSL cluster identification.

**Table 11-27—Setting of Single AID field**

| MMSL cluster configuration | Is the Single AID allocated to the MM-SME coordinated STA A? | Is the Single AID allocated to the MM-SME coordinated STA B? | AID identification of MMSL cluster |
|---|---|---|---|
| Non-AP and non-PCP MM-SME coordinated STA A is associated to PCP MM-SME coordinated STA B. | Yes | Yes | Yes |
| Non-AP and non-PCP MM-SME coordinated STA A and non-AP and non-PCP MM-SME coordinated STA B are both associated to the same BSS. | Yes | Yes | Yes |
| Non-AP and non-PCP MM-SME coordinated STA A is associated to a BSS and non-AP and non-PCP MM-SME coordinated STA B is not associated to the BSS. | Yes | No | No |
| Non-AP and non-PCP MM-SME coordinated STA A and non-AP and non-PCP STA B are both associated to the same BSS. | Yes | N/A(#254) | Yes |
| Non-AP and non-PCP MM-SME coordinated STA A is associated to a BSS and one MAC entity of non-AP and non-PCP MM-SME coordinated STA B is associated to the same BSS. | Yes | N/A(#254) | Yes |

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### 11.32.2 MMSL cluster setup

#### 11.32.2.1 General

To establish an MMSL cluster, an MMS element of an MM-SME coordinated STA that lists its advertised STAs shall be delivered to the peer STA. The peer STA may be an MM-SME coordinated STA or a non-MM-SME coordinated STA. An MMSL cluster is identified by one of the following:

a) Advertised MAC addresses of the MAC entities of two MM-SME coordinated STAs
b) Advertised MAC addresses of the MAC entities of an MM-SME coordinated STA and of a non-MM-SME coordinated STA

In both cases, the MMS element shall be exchanged between the STAs to set up the MMSL cluster agreement.

If an MMSL cluster capable non-MM-SME coordinated STA receives an ADDTS Request frame that includes an MMS element, the SME of the non-MM-SME coordinated STA shall include the received MMS element in the MLME-ADDTS.response primitive used to send the ADDTS Response frame if the SME accepts the MMSL cluster setup. The SME of the non-MM-SME coordinated STA may set the MMS Element Owner field to "no Owner" in the MMS element included in an MLME-ASSOCIATE.request primitive and MLME-ADDTS.request primitive to establish the MMSL cluster with an MM-SME coordinated STA.

The MMS element shall be exchanged between the STAs of the MMSL cluster only once per MMSL cluster setup.

#### 11.32.2.2 MMSL cluster setup of non-AP and non-PCP MM-SME coordinated STA with AP or PCP

The Association Request and Response frames are used to establish an MMSL cluster between a non-AP and non-PCP MM-SME coordinated STA and an AP or PCP. If the AP or PCP is not an MM-SME coordinated STA, the AP or PCP shall include the MMS element received from the non-AP and non-PCP MM-SME coordinated STA in the Association Response frame sent as response. If the AP or PCP is an MM-SME coordinated STA, the AP or PCP should include its own MMS element that contains its advertised MAC entities in the Association Response frame and shall not include the MMS element received from the non-AP and non-PCP MM-SME coordinated STA in the Association Response frame. The AP or PCP shall not respond with any MMS element if it is not MMSL cluster capable.

The setup of the MMSL cluster fails if the Association Response frame does not contain the MMS element.

#### 11.32.2.3 MMSL cluster setup of non-AP and non-PCP STA with another non-AP and non-PCP STA

If a non-AP and non-PCP MM-SME coordinated STA associated with an AP or PCP has established an AID identified MMSL cluster with the AP or PCP, the non-AP and non-PCP MM-SME coordinated STA shall not use a MAC address that was not included in the MMS element delivered to the AP or PCP to establish an MMSL cluster with another non-AP and non-PCP MM-SME coordinated STA associated with the same AP or PCP.

An ADDTS Request/Response frame exchange with a PTP TSPEC shall be used to establish the MMSL cluster between non-AP and non-PCP MM-SME coordinated STAs and between a non-AP and non-PCP MM-SME coordinated STA and a non-AP and non-PCP non-MM-SME coordinated STA.

A non-AP and non-PCP MM-SME coordinated STA shall include an MMS element that contains its advertised MAC entities in transmitted ADDTS Request frames. If the non-AP and non-PCP STA is not an MM-SME


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coordinated STA, the non-AP and non-PCP STA should include the MMS element with the MMS Element Owner field set to "no Owner" in the ADDTS Request frame.

The non-AP and non-PCP MM-SME coordinated STA shall include its own MMS element that contains its advertised MAC entities in transmitted ADDTS Response frames. The non-MM-SME coordinated STA may include the MMS element of the MM-SME coordinated STA from which it received an ADDTS Request frame in the ADDTS Response frame sent as response. The non-MM-SME coordinated STA shall not respond with any MMS element if it is not MMSL cluster capable.

The setup of the MMSL cluster fails if the ADDTS Response frame does not contain the MMS element.

## 11.33 DMG coexistence with non-IEEE-802.11 systems

This subclause describes the features available in this standard to improve coexistence with other systems(11ay) that operate in the 60 GHz band, including IEEE 802.15 systems.

The same common channelization that is defined in other (11ay)specifications for systems that operate in the 60 GHz band is adopted by the DMG PHY specifications (20.3.1 (Channelization) and 28.3.4 (Channelization)) for 2.16 GHz channels. In regulatory domains where 2 or more channels are defined, a DMG STA should support at least 2 channels.

An AP should not start an infrastructure BSS on a channel where the signal level is at or above aDMGDetectionThres or upon detecting a valid IEEE 802.15.3 CMS preamble at a receive level greater than or equal to –60 dBm.

If a DMG STA is capable of performing directional channel measurements (11.30 (Spatial sharing and interference mitigation for DMG STAs)) to detect non-IEEE-Std-802.11 transmissions on a channel, it can report the results of the measurements to the STA's AP or PCP.

If a DMG STA detects a non-IEEE-802.11 transmission on its channel or if the AP or PCP receives a report (11.10 (Radio measurement procedures)) from a DMG STA on a non-IEEE-802.11 transmission, the following mechanisms might be used to mitigate interference:

- Change operating channel (11.8 (DFS procedures))
- Beamforming (10.41 (DMG beamforming))
- Reduce transmit power (11.7 (TPC procedures))
- Perform FST (11.31 (Multi-band operation))
- Move the TBTT (11.29.2 (Moving the TBTT)), and thus the beacon interval, in the case of an AP or PCP
- Change the schedule of SPs and CBAPs in the beacon interval (9.4.2.130 (Extended Schedule element)) in the case of an AP or PCP
- Defer transmission for a later time
- For periods of time in the beacon interval where the STA experiences poor channel quality, the STA can use the Traffic Scheduling Constraint Set field within the DMG TSPEC element (9.4.2.132 (DMG TSPEC element)) to request its AP or PCP to avoid scheduling an SP for that DMG STA during those periods of time in the beacon interval.
- (11ay)In an EDMG BSS, when operating over multiple channels, the occupied bandwidth of a PPDU transmitted by a TXOP holder may be smaller than the occupied bandwidth of the last PPDU transmitted by the TXOP holder within the same TXOP (10.6.7.6 (Channel Width selection for Control frames transmitted by EDMG STAs(11ay))).

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## 11.34 DMG relay procedures

### 11.34.1 General

Relaying allows a source relay endpoint DMG STA (REDS) to transmit frames to a destination REDS with the assistance of another DMG STA called the *relay DMG STA (RDS)*. Relaying can improve the reliability of communication in a DMG BSS in case the direct link between the source REDS and the destination REDS is disrupted.

A STA is a REDS if both dot11REDSActivated and dot11RelayActivated are true. A REDS shall set the Relay Client field within its Relay Capabilities element to 1. A STA is an RDS if both dot11RDSActivated and dot11RelayActivated are true. An RDS shall set the Relay Supporter field within its Relay Capabilities element to 1. A STA is relay capable if dot11RelayActivated is true and it is either a REDS or an RDS or both, and it is relay incapable otherwise.

A relay capable STA shall advertise its capability by including the Relay Capabilities element in (Re)Association Request, (Re)Association Response, Probe Request, Probe Response, Information Request, and Information Response frames. An AP or relay capable PCP may include the Relay Capabilities element in DMG Beacon frames.

For a STA to operate as a REDS or an RDS in an Infrastructure BSS or PBSS, the following conditions shall be met:

— The STA is a member of the Infrastructure BSS or PBSS.
— The TDDTI field within the DMG STA Capabilities element of the AP or PCP of the BSS is 1.
— The Relay permission field within the Relay Capabilities element of the AP or PCP of the BSS is 1.

A source REDS, a destination REDS, and an RDS can establish the types of relay operation as specified in 10.44.1 (General).

As needed, in the following subclauses, source REDS, RDS, and destination REDS are expressed as S, R, and D, respectively. Also, a direct link between STA S and STA D can be simply referred to as *S-D link*.

### 11.34.2 Common relay setup procedures

#### 11.34.2.1 Introduction

This subclause describes the procedures that a source REDS, a destination REDS, and an RDS employ to set up a relay operation among these STAs. These procedures are used for both link switching and link cooperation relays, and shall be performed in the order shown in this subclause.

#### 11.34.2.2 Relay capabilities and RDS discovery procedures

A source REDS can obtain the capabilities of other STAs in the BSS following the STA's association with the BSS or with the transmission of an Information Request frame as described in 11.28.1 (Information Request and Response).

(#111)In order to set up relay operation with a destination DMG STA, a source DMG STA shall obtain the capabilities of the destination DMG STA prior to initiating the relay setup procedure with the destination DMG STA. The source DMG STA may attempt to set up relay operation with the destination DMG STA only if both the source DMG STA and destination DMG STA are REDS, and there exists at least one RDS in the BSS.

Upon receiving an MLME-RELAY-SEARCH.request primitive, the source DMG STA can discover a list of RDSs in the BSS by transmitting a Relay Search Request frame to the AP or PCP with the destination REDS


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AID field set to the AID of the destination DMG STA. The MLME of the AP or PCP receiving a Relay Search Request frame shall generate an MLME-RELAY-SEARCH.indication primitive. Upon receiving an MLME-RELAY-SEARCH.response primitive, the AP or PCP shall transmit a Relay Search Response frame addressed to the requesting STA and shall include in the transmitted frame a list of RDSs in the BSS. The MLME of the source DMG STA receiving a Relay Search Response frame shall generate an MLME-RELAY-SEARCH.confirm primitive. After the transmission of the Relay Search Response frame to the source DMG STA, the AP or PCP shall transmit an unsolicited Relay Search Response frame to the destination DMG STA with the Relay Capable STA Info field of the source DMG STA and the list of RDSs that the AP or PCP included in the last Relay Search Response frame transmitted to the source DMG STA.

#### 11.34.2.3 RDS selection procedure

Following the transmission of a Relay Search Response frame, the AP or PCP should schedule within its Extended Schedule element two SPs for each RDS included in the transmitted Relay Search Response frame:

— An SP having as source DMG STA the source REDS and as destination DMG STA the RDS, and with the Beamforming Training field set to 1. The duration of the SP should be such that the source REDS and RDS can complete BF as described in 10.41 (DMG beamforming).

— An SP having as source DMG STA the RDS and as destination DMG STA the destination REDS, and with the Beamforming Training field set to 1. The duration of the SP should be such that the RDS and the destination REDS can complete BF as described in 10.41 (DMG beamforming).

After the RDS completes BF with both the source REDS and destination REDS, the source REDS shall send a Multi-Relay Channel Measurement Request frame to the RDS, which shall respond with the transmission of a Multi-Relay Channel Measurement Report frame back to the source REDS. Following the reception of this frame, the source REDS should perform BF with the destination REDS as described in 10.41 (DMG beamforming), and once BF is completed the source REDS shall transmit a Multi-Relay Channel Measurement Request frame to the destination REDS. In response, the destination REDS shall transmit a Multi-Relay Channel Measurement Report frame to the source REDS including the channel measurement information between the destination REDS and all RDSs known to the destination REDS. To shorten the time it takes to complete this procedure, STAs can limit BF to the SLS phase only.

Once this procedure is completed, the source REDS becomes aware of all the channel measurement information between the source REDS and zero or more RDSs and between the destination REDS and zero or more RDSs. The source REDS shall then select a single STA to operate as the RDS between the source REDS and the destination REDS. The selection of the RDS is implementation dependent, and it can be based on information contained within an RDS's Relay Capabilities element and channel measurements.

#### 11.34.2.4 RLS procedure

Following the selection of the RDS to be used between the source REDS and the destination REDS, the source REDS receiving an MLME-RLS.request primitive initiates the RLS procedure by sending an RLS Request frame to the selected RDS. The RLS Request frame includes the capabilities and the AIDs of the source REDS, the destination REDS, and the RDS, and the relay transfer parameter set. Upon receiving the RLS Request frame, the RDS shall transmit an RLS Request frame to the destination REDS containing the same information as received within the frame body of the source REDS's RLS Request frame.

The MLME of the destination REDS receiving a Relay Search Request frame shall generate an MLME-RLS.indication primitive. Upon receiving an MLME-RLS.response primitive, the destination REDS shall transmit an RLS Response frame to the RDS with the destination status code field set to SUCCESS if the destination REDS is willing to participate in the RLS, and set to REQUEST_DECLINED if the destination REDS is not willing to participate in the RLS. Upon receiving the RLS Response frame, the RDS shall transmit an RLS Response frame to the source REDS containing the same information as received within the destination REDS's RLS Response frame, with the exception that the RDS shall set the relay status code field

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to SUCCESS if the RDS is willing to participate in the RLS, and shall set it to REQUEST_DECLINED if the RDS is not willing to participate in the RLS.

The MLME of the source DMG STA receiving an RLS Response frame from the RDS shall generate an MLME-RLS.confirm primitive. Upon receiving an RLS Response frame with the destination status code and relay status code fields set to SUCCESS, the source DMG STA may transmit an RLS Announcement frame to the AP or PCP to indicate that the RLS procedure was successfully completed. If either or both of the destination status code and relay status code fields are nonzero, the RLS procedure is unsuccessful.

Upon the completion of RLS procedure, the source REDS, the destination REDS, and the RDS can redo BF among them.

### 11.34.3 Relay operation-type change procedure

The source REDS may change the relay operation type from link switching to link cooperation, and vice-versa, if either one of S-D, or S-R, or R-D links becomes unavailable or for other reasons. Link unavailability can be determined by the source DMG STA not receiving expected frames from the destination REDS. To assist in this decision, the source REDS can use the link adaptation procedure (10.44.4 (Relay link adaptation)) to obtain the quality of a link.

To change the relay operation type within an SP from link cooperation to link switching in a case that the S-D link becomes unavailable, the source REDS shall transmit a ROC Request frame to the RDS with the Link Cooperation subfield set to 0 and the relay-link subfield set to 1. Upon receiving a ROC Request frame, the RDS shall transmit a ROC Request frame to the destination REDS containing the same information as received within the frame body of the source REDS's ROC Request frame. Following the reception of a ROC Request frame, the destination REDS shall respond with a ROC Response frame to the RDS with the status code field set to SUCCESS if the destination REDS accepts to change the operation into link switching, and set to REQUEST_DECLINED if the destination REDS rejects the request. Upon receiving the ROC Response frame, the RDS shall transmit a ROC Response frame to the source REDS with the status code field set to SUCCESS only if the RDS accepts to change the operation into link switching and the status code field set to SUCCESS in the ROC Response frame received from destination REDS. Otherwise, the RDS shall set the status code field to REQUEST_DECLINED. Upon reception of a ROC Response from the RDS with the status code field set to SUCCESS, the source REDS immediately starts to transmit frames to the destination REDS via the RDS relay link.

To change the relay operation type from link cooperation to link switching in other case that the S-R link becomes unavailable, the source REDS shall a ROC Request frame to the destination REDS with the Link Cooperation subfield set to 0 and the relay-link subfield set to 0. Following the reception of a ROC Request frame, the destination REDS shall respond with a ROC Response frame to the source REDS with the status code field indicating the acceptance or rejection of the request. Upon reception of a ROC Response from the destination REDS with the status code field set to SUCCESS, the source REDS starts to transmit frames to the destination REDS via the direct link in link switching.

To change the relay operation type within an SP from link switching to link cooperation, the source REDS shall transmit a ROC Request frame to the destination REDS via the RDS with the Link Cooperation subfield set to 1. Following the reception of a ROC Request frame from the RDS, the destination REDS shall respond with a ROC Response frame to the source REDS via the RDS with the status code field indicating the acceptance or rejection of the request. Upon reception of a ROC Response frame from the RDS with the status code field set to SUCCESS, the source REDS immediately starts to transmit frames to the destination REDS using the RDS in link cooperation. If a TPA procedure was not performed beforehand since the link switching operation has been continued from the start of relay operation, the STA shall perform the TPA procedure before transmitting using link cooperation.


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NOTE—As described in 10.44.3.2.3 (Data transmission rules), during the SP in link cooperation operation the destination REDS has its receive antenna pattern such that it simultaneously covers the links toward both the source REDS and the RDS.

### 11.34.4 Relay teardown

A source REDS that has successfully completed the RLS procedure with a destination REDS may teardown the relay operation between the source REDS, destination REDS and RDS. To do that, the source REDS shall transmit an RLS Teardown frame to the RDS, destination REDS and AP or PCP of the BSS. Within the RLS Teardown frame, the source REDS shall set the source AID field to the AID of the source REDS, the destination AID field to the AID of the destination REDS and the relay AID field to the AID of the RDS.

A RDS may teardown the relay operation between the source REDS, destination REDS and RDS. To do that, the RDS shall transmit an RLS Teardown frame to the source REDS, destination REDS and AP or PCP of the BSS. Within the RLS Teardown frame, the RDS shall set the source AID field to the AID of the source REDS, the destination AID field to the AID of the destination REDS and the relay AID field to the AID of the RDS.

## 11.35 Quieting adjacent DMG BSSs

### 11.35.1 General

An AP that supports QAB shall set the QAB Capability field within the AP's Extended Capabilities element to 1 and shall set the QAB Capability field to 0 otherwise. In addition, if an AP supports QAB, the AP shall also support scheduling SPs as defined in 10.38.6 (Channel access in scheduled DTI).

### 11.35.2 Procedure at the requester AP

Upon receipt of an MLME-QAB.request primitive, an AP shall perform the following procedure to start the Quiet Adjacent BSS operation (Figure 11-95 (Quieting adjacent BSS operation)):

a) If both the requester and responder APs are QAB capable as indicated by the QAB Capability field within the Extended Capabilities element, the requester AP sends a QAB Request frame indicating the duration, period, offset, and number of the quiet intervals. The requester AP may include multiple Quiet Period Request elements in one frame targeting multiple responder APs.

b) If a QAB Response frame is received with the matching dialog token,(#3206) the AP has confirmed the responder AP has scheduled the requested quiet periods, and the MLME shall issue an MLME-QAB.confirm primitive indicating the success of the procedure.

c) If a QAB Response frame is not received with the matching dialog token, the procedure is considered to have failed, and the MLME shall issue an MLME-QAB.confirm primitive indicating the failure of the procedure.(#3206)

NOTE—The GAS protocol can be used by an AP to verify the capabilities of another AP.

### 11.35.3 Procedure at the responder AP

A responder AP shall operate as follows (Figure 11-95 (Quieting adjacent BSS operation)):

a) When a QAB Request frame matching the BSSID is received from another AP, the MLME shall issue an MLME-QAB.indication primitive.

b) Upon receipt of the MLME-QAB.response primitive, the AP shall respond by transmitting a QAB Response frame if the request is accepted. The AP shall use SPs to schedule the quiet period(s) according to the accepted request. The SPs shall have the AP as both source and destination and the AP shall not transmit during the SP. The QAB procedure shall be terminated if the number of quiet intervals exceeds the value of the Repetition Count field. Contained in the transmitted QAB Response frame is the copy of the request token and the BSSID of the AP's BSS.(#3206)

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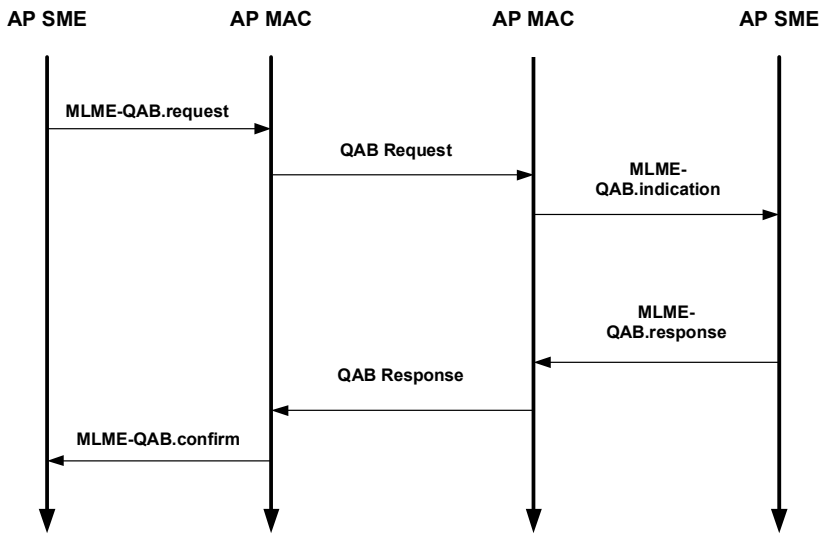


**Figure 11-95—Quieting adjacent BSS operation**

## 11.36 DMG beamforming

### 11.36.1 Non-TDD beamforming(11ay)

Upon receipt of an MLME-BF-TRAINING.request primitive, a STA shall undertake beamforming training with the STA indicated by the PeerSTAAddress parameter according to the procedures defined in 10.41 (DMG beamforming). (11ay)Beamforming training may consist of an SLS not followed by a BRP, an SLS followed by a BRP, or a BRP as defined by the MLME-BF-TRAINING.request primitive. An SLS shall include a BRP if the RequestBRP parameter of the MLME-BF-TRAINING.request primitive is true; otherwise it shall not include a BRP.(#7220)

(11ay)If the MLME-BF-TRAINING.request primitive is used to request a BRP, the parameter BRPRequest parameter shall be included. The information subfields within BRPRequest are used to request and configure DMG beamforming procedures. The indication of whether the requested BRP procedure shall use short BRP frames is also defined in BRPRequest. If the primitive is used to request an EDMG beamforming procedure, the MLME-BF-TRAINING.request primitive shall also include the parameter EDMGBRPRequest. The MLME-BF-TRAINING.request primitive may also include the parameter DMGBeamRefinement that may be used to request and configure both DMG and EDMG beamforming procedures. If the primitive is used to request a partial sector level sweep, it shall also contain the parameter EDMGPartialSLS.

A STA receiving MLME-BF-TRAINING.request primitive may act as either initiator or responder in the beamforming training.

If the STA indicated by the PeerSTAAddress parameter of a received MLME-BF-TRAINING.request primitive is an AP or PCP of a BSS in which a STA is a member, the STA receiving the MLME-BF-TRAINING.request primitive may perform beamforming training during the A-BFT as described in 10.41.5 (Beamforming in A-BFT). Alternatively, the STA receiving the MLME-BF-TRAINING.request primitive may use an SP or a TXOP to perform ISS as described in 10.41.2.2 (Initiator sector sweep (ISS)).


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A STA receiving the MLME-BF-TRAINING.request primitive shall issue an MLME-BF-TRAINING.confirm primitive on completion of the requested beamforming training or on timeout as specified in 10.41 (DMG beamforming).

A STA that performs beamforming training with a peer STA at the request of the peer STA shall issue an MLME-BF-TRAINING.indication primitive on completion of that beamforming training, or on timeout as specified in 10.41 (DMG beamforming).

(11ay)Both MLME-BF-TRAINING.confirm and MLME-BF-TRAINING.indication primitives shall include one or more of the following feedback related parameters if the ResultCode is equal to SUCCESS: DMGBeamRefinement, MeasFeedback, and EDMGMeasFeedback. The presence of these elements in the primitive depends on the specific DMG or EDMG beamforming procedure that was executed.

Figure 11-96 (Beamforming training procedure in the DTI) illustrates an example of the beamforming training procedure in the DTI for a case where the STA receiving the MLME-BF-TRAINING.request primitive acts as initiator.

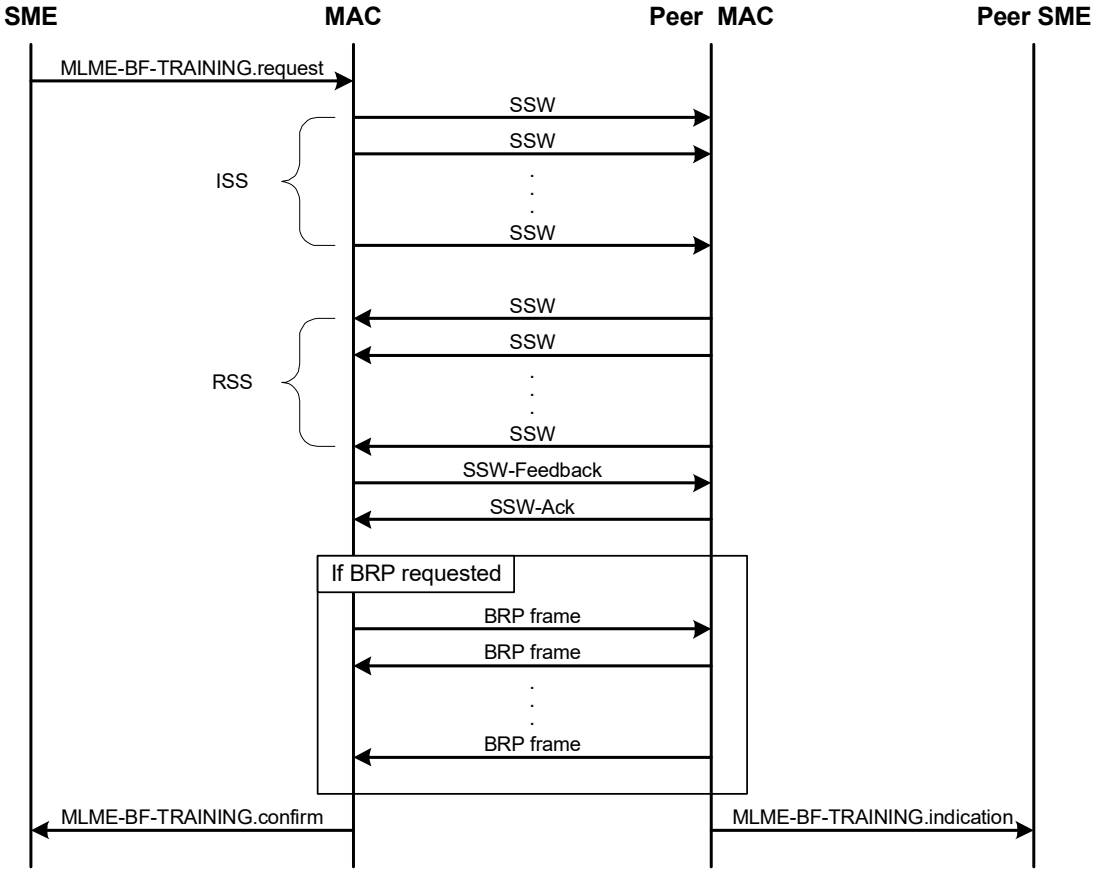


**Figure 11-96—Beamforming training procedure in the DTI**

Figure 11-97 (Beamforming training when joining an infrastructure BSS or PBSS) illustrates an example of the beamforming training procedure in the context of a non-AP and non-PCP STA joining an infrastructure BSS or PBSS. In this scenario, the MLME-BF-TRAINING.request primitive is issued by the STA attempting to associate in order that the link be trained to a degree that allows the over-the-air exchanges necessary for association to succeed.

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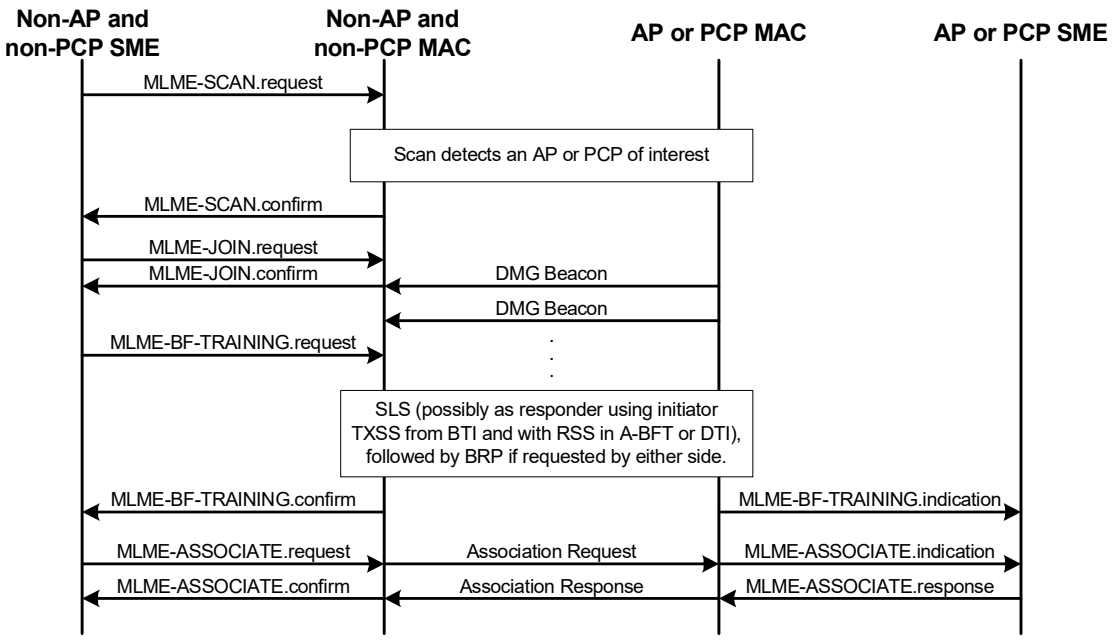


**Figure 11-97—Beamforming training when joining an infrastructure BSS or PBSS**

### 11.36.2 TDD beamforming(11ay)

Upon receipt of an MLME-TDD-BF-TRAINING.request primitive, a DMG STA shall assume the role of TDD beamforming initiator and, based on the BFType parameter, shall perform TDD individual BF or TDD group BF training with the STA indicated by the PeerSTAAddress parameter according to the procedures defined in 10.41.11 (TDD beamforming(11ay)). This beamforming training shall start at the time indicated by the BeamformingStartTimestamp parameter.

Upon receipt of the MLME-SCAN.request primitive with the ScanType parameter equal to TDD passive, a DMG STA shall passively scan for TDD SSW frames by sweeping its receiver antenna through all the receive sectors specified in ScanSectorIDList parameter while dwelling on each sector for a time equal to SectorDwellTime according to procedure described in 10.41.11.3 (Responder operation for TDD individual beamforming). This passive scan shall be performed through all channels specified within the ChannelList parameter.

A STA that successfully performed scan and TDD beamforming training with a peer STA in response to an MLME-SCAN.request primitive shall issue an MLME-SCAN.confirm primitive containing all successfully received DMG Beacon frames that match the desired SSID in the BSSDescriptionSet parameters of the corresponding MLME-SCAN.confirm primitive as described in 11.1.4 (Acquiring synchronization, scanning).

A STA that receives a MLME-TDD-BF-TRAINING.request primitive with BFType parameter set to TDD individual BF or TDD group BF shall assume the initiator role and perform the TDD individual BF or TDD group BF procedure, respectively, defined in 10.41.11 (TDD beamforming(11ay)). The STA shall issue an MLME-TDD-BF-TRAINING.confirm primitive on completion of the requested TDD beamforming procedure after transmitting the last TDD SSW Ack frame with End of Training subfield set to 1. In the primitive, the STA shall set the parameters NumberOfTDDFeedbackPeers and TDDFeedbackResults according to the TDD Route element received from the responder.


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A STA that performs TDD beamforming training with a peer STA at the request of the peer STA shall issue an MLME-TDD-BF-TRAINING.indication primitive on completion of the TDD beamforming training procedure as specified in 10.41.11 (TDD beamforming(11ay)), following the reception of a TDD SSW Ack frame with the RA field set to the STA MAC address and with the End of Training subfield equal to 1.

Figure 11-98 (TDD individual beamforming training procedure(11ay)) illustrates an example of the TDD individual beamforming training procedure.

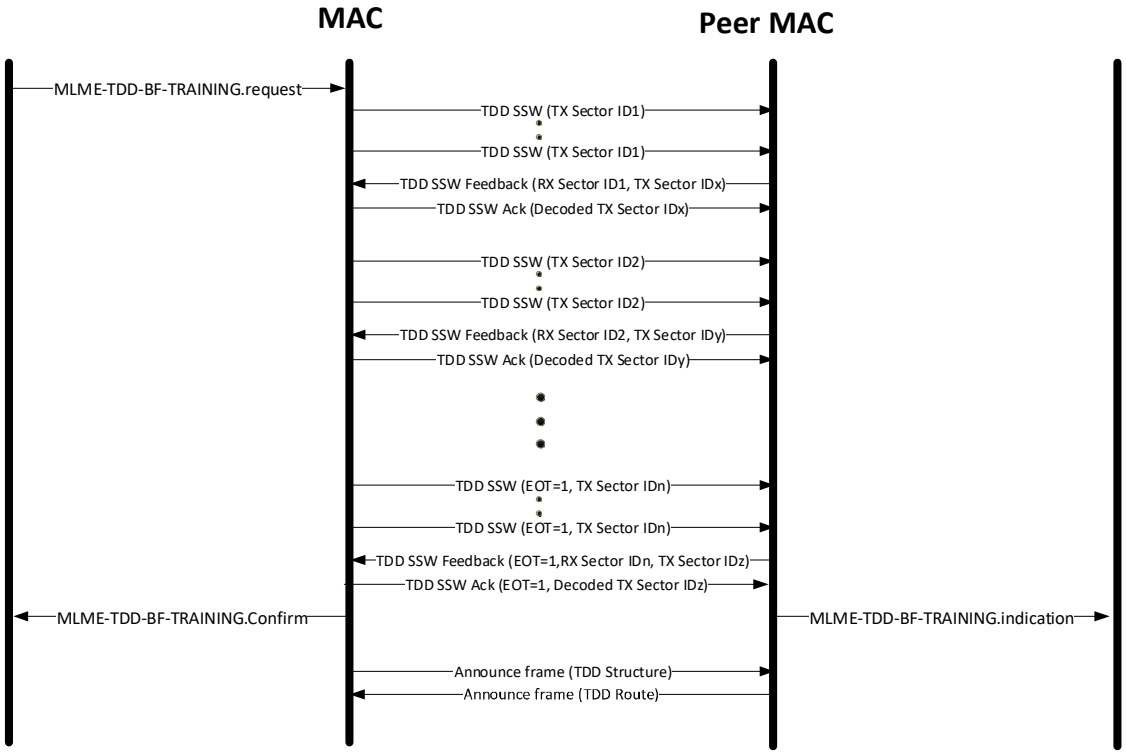


**Figure 11-98—TDD individual beamforming training procedure(11ay)**

Figure 11-99 (TDD group beamforming training procedure(11ay)) illustrates an example of the TDD group beamforming training procedure.

### 11.36.3 TDD sector switch procedure(11ay)

The TDD sector switch procedure allows a pair of DMG STAs operating in an SP with TDD channel access to synchronize the switch of transmit and receive sectors for communication between them. Only a PCP or AP shall initiate the TDD sector switch procedure. An AP or PCP can make use of the information in TDD Sector Feedback subelement and the results of measurements undertaken by STAs in the BSS to determine when to invoke a TDD sector switch procedure.

Upon receipt of an MLME-TDD-SECTOR-SWITCH.request primitive, a DMG STA shall send to the peer STA indicated by the PeerSTAAddress parameter an Announce frame of subtype Action with a TDD Route element that includes a TDD Sector Setting subelement with the Set Sector Request subfield set to 1. This is referred to as a TDD sector switch request message. Messages with Set Sector Response subfield set to 1 and messages with Set Sector Acknowledge subfield set to 1 are referred to as TDD sector switch response and TDD sector switch acknowledge messages, respectively. A STA shall not set to 1 more than one subfield of the TDD Sector Setting Control field in a given transmitted element.

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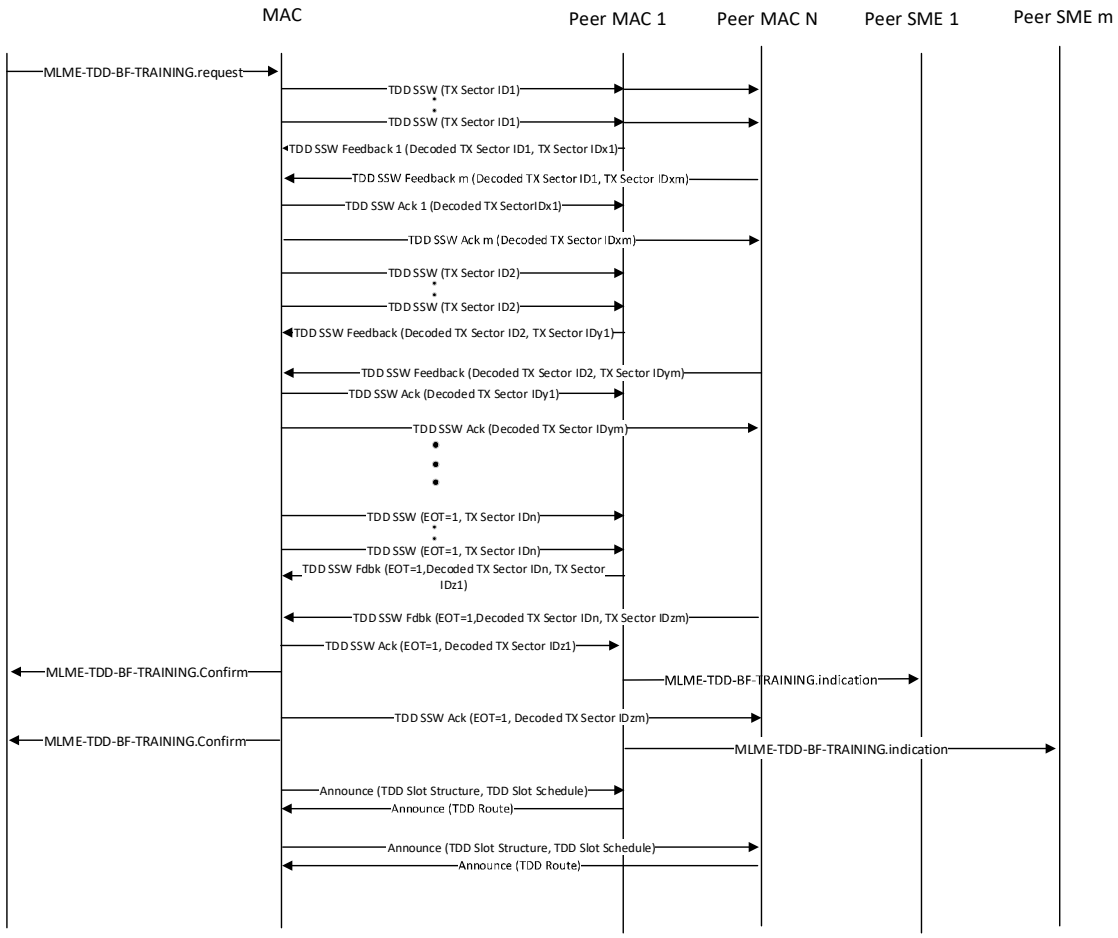


**Figure 11-99—TDD group beamforming training procedure(11ay)**

The Responder TX Antenna ID, Responder RX Antenna ID, Initiator TX Antenna ID and Initiator RX Antenna ID subfields in the TDD Sector Setting subelement shall be set to, respectively, the ResponderTXAntennaID, ResponderRXAntennaID, InitiatorTXAntennaID and InitiatorRXAntennaID parameters of the request primitive. The Responder TX Sector ID, Responder RX Sector ID, Initiator TX Sector ID and Initiator RX Sector ID subfields in the TDD Sector Setting subelement shall be set to, respectively, the ResponderTXSectorID, ResponderRXSectorID, InitiatorTXSectorID and InitiatorRXSectorID parameters of the request primitive. The Set Sector Request subfield in the TDD Sector Setting subelement shall be set to 1.

The Switch Timestamp subfield in the TDD Sector Setting subelement shall be set to the value of the SectorSwitchTimestamp parameter of the request primitive. The Switch Timestamp subfield value shall be set to a time value that allows at least three retransmissions of the Announce frame and the corresponding Ack frame sent in response.

The Revert Timestamp subfield in the TDD Sector Setting subelement shall be set to the value of the SectorRevertTimestamp parameter of the request primitive. The Revert Timestamp subfield value shall be set to a time value that allows the responder at least three retransmissions of a TDD sector switch response message, for the case the responder does not receive the TDD sector switch acknowledge message from the


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initiator, plus time to allow the initiator at least three retransmissions of a TDD sector switch acknowledge message, for the case the initiator does not receive the Ack frame from the responder.

An initiator STA that does not receive an Ack frame in response to a TDD sector switch request message should retransmit the message until the time indicated by the Switch Timestamp subfield.

A MLME-TDD-SECTOR-SWITCH.request primitive incorporating a new SectorSwitchTimestamp value shall not be issued until the SectorRevertTimestamp of the previous request primitive has elapsed.

A responder that receives a TDD sector switch request message shall perform the following:

— Issue an MLME-TDD-SECTOR-SWITCH.indication primitive with the PeerSTAAddress parameter set to the TA of the received message, the ResponderTXAntennaID, ResponderRXAntennaID, InitiatorTXAntennaID, InitiatorRXAntennaID, ResponderTXSectorID, ResponderRXSectorID, InitiatorTXSectorID and InitiatorRXSectorID parameters of the primitive set to, respectively, the Responder TX Antenna ID, Responder RX Antenna ID, Initiator TX Antenna ID, Initiator RX Antenna ID, Responder TX Sector ID, Responder RX Sector ID, Initiator TX Sector ID and Initiator RX Sector ID subfields of the TDD Sector Setting subelement within the received message.

— Respond with an Ack frame to any TDD sector switch request messages that arrive before the time indicated by the Switch Timestamp subfield value within the message.

— Set its receive and transmit antenna configuration corresponding to the Responder RX Antenna ID, Responder RX Sector ID, Responder TX Antenna ID and Responder TX Sector ID subfield values in the TDD sector switch request message, respectively, at the time indicated by the Switch Timestamp subfield.

— Send to the initiator a TDD sector switch response message by transmitting an Announce frame of subtype Action No Ack with the same Sector Setting subelement that was received by the responder, except that the Set Sector Request subfield shall be set to 0 and the Set Sector Response subfield shall be set to 1. The TDD sector switch response message should be sent at the earliest TDD slot occurring after the time indicated by the value of the Switch Timestamp subfield.

An initiator transmitting a TDD sector switch request message shall set its receive and transmit antenna configuration corresponding to the Initiator TX Antenna ID, Initiator TX Sector ID, Initiator RX Antenna ID and Initiator RX Sector ID subfield values, respectively, at the time indicated by the value of the Switch Timestamp subfield.

An initiator receiving a TDD sector switch response message shall send the responder a TDD sector switch acknowledge message by transmitting an Announce frame of subtype Action with the same Sector Setting subelement that was received by the initiator, except that the Set Sector Response subfield shall be set to 0 and the Set Sector Acknowledge subfield shall be set to 1. The TDD sector switch acknowledge message should be sent at the earliest TDD slot occurring after the time indicated by the value of the Switch Timestamp subfield.

A responder receiving a TDD sector switch acknowledge message before the time indicated by the Revert Timestamp value shall issue an MLME-TDD-SECTOR-SWITCH.confirm primitive. The TXAntennaID, RXAntennaID, TXSectorID and RXSectorID parameters of the primitive shall be set to the new transmit DMG antenna and sector index and to the receive DMG antenna and sector (#4136)indices, respectively, and the ResultCode parameter shall be set to SUCCESS.

An initiator transmitting a TDD sector switch acknowledge message before the time indicated by the Revert Timestamp value shall issue MLME-TDD-SECTOR-SWITCH.confirm primitive. The TXAntennaID, RXAntennaID, TXSectorID and RXSectorID parameters of the primitive shall be set to the new transmit DMG antenna and sector index and to the receive DMG antenna and sector (#4136)indices, respectively, and the ResultCode parameter shall be set to SUCCESS.

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A responder that did not receive a TDD sector switch acknowledge message in response to a transmitted TDD sector switch response message should retransmit the TDD sector switch response message before the time indicated by the Revert Timestamp subfield value.

An initiator STA that did not receive an Ack frame in response to a transmitted TDD sector switch acknowledge message should retransmit the TDD sector switch acknowledge message before the time indicated by the Revert Timestamp subfield value.

A responder that did not receive a TDD sector switch acknowledge message by the time indicated by the Revert Timestamp subfield value shall issue an MLME-TDD-SECTOR-SWITCH.confirm primitive with the ResultCode parameter set to FAILURE and shall revert to the antenna configuration used at the start of the TDD sector switch procedure.

An initiator STA that did not receive a TDD sector switch response message by the time indicated by the Revert Timestamp subfield value shall issue an MLME-TDD-SECTOR-SWITCH.confirm primitive with the ResultCode parameter shall be set to FAILURE and shall revert to the antenna configuration used at the start of the TDD sector switch procedure.

An initiator STA that reverted to the previous antenna configuration at the time indicated by the Revert Timestamp subfield value shall send a PPDU that requires Ack frame at the earliest TDD slots occurring after the Revert Timestamp subfield value. An initiator STA receiving a PPDU after the time indicated by the Revert Timestamp subfield shall issue an MLME-TDD-SECTOR-SWITCH.confirm primitive. The TXSectorID and RXSectorID parameters of the primitive shall be set to the sectors used at the start of the TDD sector switch procedure and the ResultCode parameter shall be set to SUCCESS.

A responder receiving a PPDU after the time indicated by the Revert Timestamp subfield value shall issue an MLME-TDD-SECTOR-SWITCH.confirm primitive. The TXSectorID and RXSectorID parameters of the primitive shall be set to the sectors used at the start of the TDD sector switch procedure and the ResultCode parameter shall be set to SUCCESS.

A TDD initiator that did not receive an Ack frame in response to a transmitted PPDU shall initiate the TDD beamforming procedure as described in 10.41.11 (TDD beamforming(11ay)).

A responder that reverted to the antenna configuration at the time indicated by the Revert Timestamp subfield value and that did not receive a PPDU from the initiator at a TDD slot occurring after the Revert Timestamp subfield value shall start the TDD beamforming procedure as a responder as described in 10.41.11 (TDD beamforming(11ay)).


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Figure 11-100 (TDD sector switch procedure(11ay)) illustrates an example of a successful TDD sector switch procedure.

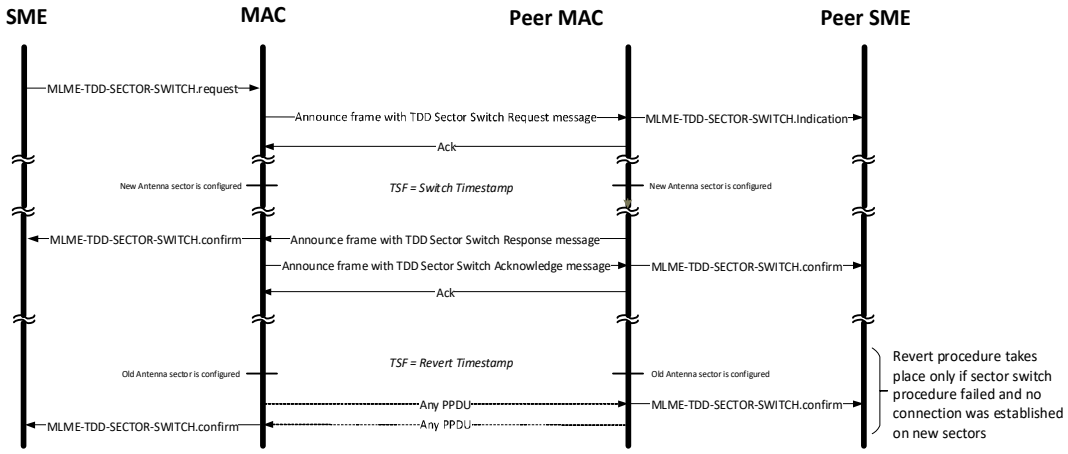


**Figure 11-100—TDD sector switch procedure(11ay)**

### 11.36.4 TDD beam measurement(11ay)

Upon receipt of an MLME-TDD-BEAM-MEASUREMENT.request primitive, a DMG STA shall assume the role of initiator or responder, as specified by the BFRole parameter, and shall perform the beam measurement procedure with the STA(s) indicated by the PeerSTAAddress parameter according to the procedures defined in 10.41.11 (TDD beamforming(11ay)). The beam measurement procedure shall start at the time indicated by the BeamMeasurementStartTimestamp parameter.

A STA that receives an MLME-TDD-BEAM-MEASUREMENT.request primitive with BFRole parameter set to initiator shall issue an MLME-TDD-BEAM-MEASUREMENT.confirm primitive on completion of the beam measurement procedure, as specified in 10.41.11 (TDD beamforming(11ay)).

A STA that performs the TDD beam measurement procedure with a peer STA (the initiator) at the request of the peer STA shall issue an MLME-TDD-BEAM-MEASUREMENT.indication primitive on completion of the TDD beam measurement procedure as specified in 10.41.11 (TDD beamforming(11ay)). The STA shall set the parameters DecodedRXAntennaID, DecodedRXSectorID and SNR Report according to the TDD SSW frames received from the initiator.

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## 11.37 DMG MAC sublayer attributes

A DMG STA has dot11DMGOptionImplemented equal to true.

The attributes that define some of the MAC characteristics are given in Table 11-28 (DMG MAC sublayer attribute values).

**Table 11-28—DMG MAC sublayer attribute values**

| Attribute | Value |
|---|---|
| aMaxBIDuration | 1000 TUs |
| aMinChannelTime | aMaxBIDuration |
| aMinBTIPeriod | 4 |
| aMinSwitchInterval | 2×aMinBTIPeriod |
| aMaxSwitchInterval | 16×aMinSwitchInterval |
| aTSFResolution | 1 μs |
| aDMGPPMinListeningTime | 150 μs |
| aSSFramesPerSlot | 4 |
| aSSDuration | (FSS – 1) × SBIFS + FSS × TXTIME(SSW) |
| aSSFBDuration | TXTIME(SSW-Feedback) |
| aRTSTimeoutTime | TXTIME(RTS) + aAirPropagationTime + aRxPHYDelay + aMACProcessingDelay |
| aDMGTSFAccuracy | 20 ppm |
| aMinNAVTimersNumber | 2 |
| aCWminDMGIBSS | 3 |
| aMinAllocationDeliveryTime | 300 μs |
| aMaxABFTAccessPeriod | 2 |
| aDtime | aSBIFSTime + TXTIME(TPA Request frame) |
| aRelayTPATime | aSBIFSTime + 2 × aAirPropagationTime + 2 × aDtime + TXTIME(TPA Request frame) + 2 × TXTIME(TPA Response frame) |
| aMinPPDUDurationForDMGMeasurement | 5.27 μs |
| aDMGDWSValidPeriod | 60 s(#7198) |
| (11ay)aMinTXSSSectorFBCnt | 16 |
| (11ay)aDMGSTATxActivityReportingtLimit | 2000 ms |


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## 11.38 VHT BSS operation

### 11.38.1 Basic VHT BSS functionality

A VHT STA has dot11VHTOptionImplemented equal to true.

(#181)A STA that is starting a VHT BSS shall support receiving and transmitting at each of the <VHT-MCS, NSS> tuple values indicated by the Basic VHT-MCS And NSS Set field of the VHT Operation parameter of the MLME-START.request primitive and shall support receiving at each of the <VHT-MCS, NSS> tuple values indicated by the Supported VHT-MCS And NSS Set field of the VHT Capabilities parameter of the MLME-START.request primitive.

A STA for which dot11VHTOptionImplemented is true shall set dot11HighThroughputOptionImplemented to true.

A STA that is a VHT AP or a VHT mesh STA declares its channel width capability in the VHT Capabilities element VHT Capabilities Information field as described in Table 9-313 (Subfields of the VHT Capabilities Information field).

A VHT STA shall set the Supported Channel Width Set subfield in its HT Capabilities element HT Capability Information field to 1, indicating that both 20 MHz operation and 40 MHz operation are supported.

At a minimum, a VHT STA sets the Rx MCS Bitmask of the Supported MCS Set field of its HT Capabilities element according to the setting of the Rx VHT-MCS Map subfield of the Supported VHT-MCS And NSS Set field of its VHT Capabilities element as follows: for each subfield Max VHT-MCS For $n$ SS, $1 \le n \le 4$ , of the Rx VHT-MCS Map field with a value other than 3 (no support for that number of spatial streams), the STA shall indicate support for HT-MCSs $8\times(n-1)$ to $8\times(n-1)+7$ in the Rx MCS Bitmask, where $n$ is the number of spatial streams, except for those MCSs marked as unsupported as described in 10.6.13.3 (Additional rate selection constraints for VHT PPDUs).

A STA that is a VHT AP or a VHT mesh STA shall set the STA Channel Width subfield in the HT Operation element HT Operation Information field and the Channel Width, Channel Center Frequency Segment 0 and Channel Center Frequency Segment 1 subfields in the VHT Operation element VHT Operation Information field to indicate the BSS bandwidth as defined in Table 11-29 (VHT BSS bandwidth).

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**Table 11-29—VHT BSS bandwidth**

| HT Operation element STA Channel Width field | VHT Operation element Channel Width field | VHT Operation element Channel Center Frequency Segment 1 subfield | BSS bandwidth |
|---|---|---|---|
| 0 | 0 | 0 | 20 MHz |
| 1 | 0 | 0 | 40 MHz |
| 1 | 1 | 0 | 80 MHz |
| 1 | 1 | CCFS1 > 0 and<br>\| CCFS1 - CCFS0 \| = 8 | 160 MHz |
| 1 | 1 | CCFS1 > 0 and<br>\| CCFS1 - CCFS0 \| > 16 | 80+80 MHz |
| 1 | 2 | 0 | 160 MHz<br>(deprecated) |
| 1 | 3 | CCFS1 > 0 and<br>\| CCFS1 - CCFS0 \| > 16 | 80+80 MHz<br>(deprecated) |

NOTE 1—CCFS0 represents the value of the Channel Center Frequency Segment 0 subfield.

NOTE 2—CCFS1 represents the value of the Channel Center Frequency Segment 1 subfield.



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The setting of the Channel Center Frequency Segment 0 and Channel Center Frequency Segment 1 subfields is shown in Table 11-30 (Setting of Channel Center Frequency Segment 0, Channel Center Frequency Segment 1, and Channel Center Frequency Segment 2 subfields).

**Table 11-30—Setting of Channel Center Frequency Segment 0, Channel Center Frequency Segment 1, and Channel Center Frequency Segment 2 subfields**

| BSS bandwidth | VHT Operation element Channel Width field | Setting of the Channel Center Frequency Segment 0 subfield | Setting of the Channel Center Frequency Segment 1 subfield | Setting of the Channel Center Frequency Segment 2 subfield |
|---|---|---|---|---|
| 20, 40 MHz | 0 | dot11CurrentChannelCenterFrequencyIndex0 | 0 | 0 |
| 80 MHz | 1 | dot11CurrentChannelCenterFrequencyIndex0 | 0 | 0 |
| 160 MHz (At least Max VHT NSS support) | 1 | if dot11CurrentPrimaryChannel is greater than dot11CurrentChannelCenterFrequencyIndex0 then dot11CurrentChannelCenterFrequencyIndex0 + 8, else dot11CurrentChannelCenterFrequencyIndex0 – 8 | dot11CurrentChannelCenterFrequencyIndex0 | 0 |
| 160 MHz (Less than Max VHT NSS support) | 1 | if dot11CurrentPrimaryChannel is greater than dot11CurrentChannelCenterFrequencyIndex0 then dot11CurrentChannelCenterFrequencyIndex0 + 8, else dot11CurrentChannelCenterFrequencyIndex0 – 8 | 0 | dot11CurrentChannelCenterFrequencyIndex0 |
| 80+80 MHz (At least Max VHT NSS support) | 1 | dot11CurrentChannelCenterFrequencyIndex0 | dot11CurrentChannelCenterFrequencyIndex1 | 0 |
| 80+80 MHz (Less than Max VHT NSS support) | 1 | dot11CurrentChannelCenterFrequencyIndex0 | 0 | dot11CurrentChannelCenterFrequencyIndex1 |
| 160 MHz (deprecated) | 2 | dot11CurrentChannelCenterFrequencyIndex0 | 0 | 0 |
| 80+80 MHz (deprecated) | 3 | dot11CurrentChannelCenterFrequencyIndex0 | dot11CurrentChannelCenterFrequencyIndex1 | 0 |

NOTE 1—"At least Max VHT NSS support" means that the NSS support at 160 or 80+80 MHz is at least Max VHT NSS, and therefore the secondary 80 or 160 MHz channel center frequency is signaled through CCFS1.

NOTE 2—"Less than Max VHT NSS support" means that the NSS support at 160 or 80+80 MHz is less than Max VHT NSS, and therefore the secondary 80 or 160 MHz channel center frequency is signaled through CCFS2.

NOTE 3—For NSS support, see Table 9-111 (Setting of the Channel Width subfield and 160/80+80 BW subfield at a VHT STA transmitting the Operating Mode field) and Table 9-314 (Setting of the Supported Channel Width Set subfield and Extended NSS BW Support subfield at a STA transmitting the VHT Capabilities Information field).

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A VHT STA shall determine the channelization using the combination of the information in the HT Operation element Primary Channel field and the VHT Operation element VHT Operation Information field Channel Center Frequency Segment 0 and Channel Center Frequency Segment 1 subfields (see 21.3.14 (Channelization)).

A VHT AP or a VHT mesh STA shall set the HT Operation element HT Operation Information field Secondary Channel Offset subfield to indicate the secondary 20 MHz channel as defined in Table 9-230 (HT Operation element fields and subfields), if the BSS bandwidth is more than 20 MHz.

A VHT STA that is a member of a VHT BSS shall not transmit a 20 MHz VHT PPDU on a channel other than the primary 20 MHz channel, except for a 20 MHz VHT PPDU transmission on an off-channel TDLS direct link as constrained by 11.20.6.5.2 (Basic wideband functionality).

A VHT STA that is a member of a VHT BSS with a 40 MHz, 80 MHz, 160 MHz, or 80+80 MHz BSS bandwidth shall not transmit a 40 MHz VHT PPDU that does not use the primary 40 MHz channel, except for a 40 MHz VHT PPDU transmission on an off-channel TDLS direct link.

A VHT STA that is a member of a VHT BSS with an 80 MHz, 160 MHz, or 80+80 MHz BSS bandwidth shall not transmit an 80 MHz VHT PPDU that does not use the primary 80 MHz channel, except for an 80 MHz VHT PPDU transmission on an off-channel TDLS direct link.

A VHT STA that is a member of a VHT BSS with a 160 MHz or 80+80 MHz BSS bandwidth shall not transmit a 160 MHz or 80+80 MHz VHT PPDU that does not use the primary 80 MHz channel and the secondary 80 MHz channel, except for a 160 MHz or 80+80 MHz VHT PPDU transmission on an off-channel TDLS direct link.

A VHT STA shall not transmit to a second VHT STA using a bandwidth that is not indicated as supported in the Supported Channel Width Set subfield in the HT Capabilities element or in the VHT Capabilities Information field of the VHT Capabilities element received from that VHT STA.

A STA shall not transmit an MPDU in a VHT PPDU that exceeds the maximum MPDU length capability indicated in the VHT Capabilities element received from the recipient STA.

A VHT AP shall set the RIFS Mode field in the HT Operation element to 0.

VHT BSS operation with less than Max VHT NSS support is enabled as defined in Table 11-31 (Extended NSS channel width) and disabled otherwise, in which case the Channel Center Frequency Segment 2 subfield of the HT Operation element shall be 0.

**Table 11-31—Extended NSS channel width**

| HT Operation element STA Channel Width field | VHT Operation element Channel Width field | VHT Operation element CCFS1 field | HT Operation element CCFS2 field | Extended NSS channel width |
|---|---|---|---|---|
| 1 | 1 | 0 | CCFS2 > 0 and \|CCFS2 – CCFS0\| = 8<br>(40 MHz apart) | 160 MHz |
| 1 | 1 | 0 | CCFS2 > 0 and \|CCFS2 - CCFS0\| > 16<br>(> 80 MHz apart) | 80+80 MHz |


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**Table 11-31—Extended NSS channel width *(continued)***

| HT Operation element STA Channel Width field | VHT Operation element Channel Width field | VHT Operation element CCFS1 field | HT Operation element CCFS2 field | Extended NSS channel width |
|---|---|---|---|---|
| 1 | 1 | 0 | CCFS2 > 0 and<br>\|CCFS2 – CCFS0\| < 8<br><br>(< 40 MHz apart) | Reserved |
| 1 | 1 | 0 | CCFS2 > 0 and<br>8 < \|CCFS2 – CCFS0\| ≤ 16<br><br>(> 40 MHz and ≤ 80 MHz apart) | Reserved |

NOTE 1—CCFS0 represents the value of the Channel Center Frequency Segment 0 subfield of the VHT Operation element.

NOTE 2—CCFS2 represents the value of the Channel Center Frequency Segment 2 subfield of the HT Operation element.

When VHT BSS operation with less than Max VHT NSS support is enabled, the NSS support is determined based on the Extended NSS channel width and the VHT Capabilities element per Table 9-314 (Setting of the Supported Channel Width Set subfield and Extended NSS BW Support subfield at a STA transmitting the VHT Capabilities Information field) and Table 9-111 (Setting of the Channel Width subfield and 160/80+80 BW subfield at a VHT STA transmitting the Operating Mode field).

### 11.38.2 Channel selection methods for a VHT BSS

Before a STA starts a VHT BSS, the STA shall perform a minimum of dot11VHTOBSSScanCount OBSS scan operations to search for existing BSSs (see 11.38.3 (Scanning requirements for VHT STA)).

If an AP or a mesh STA starts a VHT BSS that occupies some or all channels of any existing BSSs, the AP or mesh STA may select a primary channel of the new VHT BSS that is identical to the primary channel of any one of the existing BSSs.

If an AP or a mesh STA selects a primary channel for a new VHT BSS with a 40 MHz, 80 MHz, 160 MHz, or 80+80 MHz BSS bandwidth from among the channels on which no beacons are detected during the OBSS scans, then the selected primary channel meets the following conditions:

— It shall not be identical to the secondary 20 MHz channel of any existing BSSs with a 40 MHz, 80 MHz, 160 MHz, or 80+80 MHz BSS bandwidth.

— It should not overlap with the secondary 40 MHz channel of any existing BSSs with a 80 MHz, 160 MHz or 80+80 MHz BSS bandwidth.

A STA that is an AP or mesh STA should not start a VHT BSS with a 20 MHz BSS bandwidth on a channel that is the secondary 20 MHz channel of any existing BSSs with a 40 MHz, 80 MHz, 160 MHz, or 80+80 MHz BSS bandwidth, or is overlapped with the secondary 40 MHz channel of any existing BSSs with a 160 MHz or 80+80 MHz BSS bandwidth.

NOTE—An AP or a mesh STA operating a VHT BSS with a 40 MHz, 80 MHz, 160 MHz, or 80+80 MHz BSS bandwidth, on detecting an OBSS whose primary channel is the AP's or the mesh STA's secondary 20 MHz channel, might switch to 20 MHz BSS operation and/or move to a different channel.

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### 11.38.3 Scanning requirements for VHT STA

An OBSS scan operation is a passive or active scan of a set of channels that are potentially affected by VHT BSS operation (see 11.1.4.1 (General)). Each channel in the set may be scanned more than once during a single OBSS scan operation. OBSS scans are performed by STAs that start a VHT BSS.

During an individual scan within an OBSS scan operation, the minimum per-channel scan duration is dot11OBSSScanPassiveDwell TUs (for a passive scan) or dot11OBSSScanActiveDwell TUs (for an active scan). During an OBSS scan operation, each channel in the set is scanned at least once per dot11BSSWidthTriggerScanInterval seconds, and the minimum total scan time (i.e., the sum of the scan durations) per channel within a single OBSS scan operation is dot11OBSSScanPassiveTotalPerChannel TUs (for a passive scan) or dot11OBSSScanActiveTotalPerChannel TUs (for an active scan).

NOTE—The values provided in the previous paragraph are minimum requirements. For some combinations of parameter values the minimum might be exceeded for some parameters in order to meet the minimum value constraints of other parameters.

### 11.38.4 Channel switching methods for a VHT BSS

A VHT AP announces a switch of operating channel by either of the following:

— Using the Channel Switch Announcement element, Channel Switch Announcement frame, or both, following the procedure described in 11.8.8.2 (Selecting and advertising a new channel in a non-DMG infrastructure BSS)

— Using the Extended Channel Switch Announcement element, Extended Channel Switch Announcement frame, or both, following the procedure described in 11.9 (Extended channel switching (ECS))

A VHT mesh STA announces a switch attempt of operating channel by either of the following:

— Using the Channel Switch Announcement element, Channel Switch Announcement frame, or both, following the procedure described in 11.8.8.4 (MBSS channel switching)

— Using the Extended Channel Switch Announcement element, Extended Channel Switch Announcement frame, or both, following the procedure described in 11.9 (Extended channel switching (ECS))

A VHT AP or a VHT mesh STA may also announce a switch of BSS bandwidth, a new Country String field (possibly including a new Operating Class table number), new operating classes, or new TPC parameters for the BSS that come into effect at the same time as the switch of operating channel.

The New Channel Number field in the Channel Switch Announcement element, Extended Channel Switch Announcement element, Channel Switch Announcement frame, or Extended Channel Switch Announcement frame identifies the primary 20 MHz channel after the switch. The New Channel Number field is set to the value that dot11CurrentPrimaryChannel (see 21.3.14 (Channelization)) will have after the switch.

If a Channel Switch Announcement frame is used to announce a switch to a 20 MHz BSS bandwidth, then neither a Wide Bandwidth Channel Switch element nor a Secondary Channel Offset element shall be present in the frame, except that a Secondary Channel Offset element may be present in a Channel Switch Announcement frame if the Secondary Channel Offset field within the Secondary Channel Offset element is set to SCN.

If a Channel Switch Announcement element is used to announce a switch to a 20 MHz BSS bandwidth, then a Wide Bandwidth Channel Switch subelement in a Channel Switch Wrapper element shall not be present in the same frame.


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If an Extended Channel Switch Announcement element in a Beacon or Probe Response frame or an Extended Channel Switch Announcement frame is used to announce a switch to a 20 MHz BSS bandwidth, then neither a Wide Bandwidth Channel Switch element nor a Wide Bandwidth Channel Switch subelement shall be present in the same frame.

NOTE 1—A Secondary Channel Offset element is never present with the Extended Channel Switch Announcement element or in the Extended Channel Switch Announcement frame. Instead, the indicated operating class within the Extended Channel Switch Announcement element or frame is used to differentiate between a BSS bandwidth of 20 MHz and a BSS bandwidth greater than 20 MHz as well as indicate the location of the secondary 20 MHz channel. For a switch to a 20 MHz BSS bandwidth, the operating class indicated within the Extended Channel Switch Announcement element or frame has a channel spacing of 20 MHz. For a switch to an BSS bandwidth greater than 20 MHz, the operating class indicated within the Extended Channel Switch Announcement element or frame has a channel spacing of 40 MHz.

If a Channel Switch Announcement frame is used to announce a switch to a 40 MHz BSS bandwidth, then the following apply:

— The Secondary Channel Offset element shall be present in the frame.

— The Wide Bandwidth Channel Switch shall not be present in the frame.

If a Channel Switch Announcement element in a Beacon or Probe Response frame is used to announce a switch to a 40 MHz BSS bandwidth, then the Wide Bandwidth Channel Switch subelement in the Channel Switch Wrapper element shall also be present in the same frame.

If an Extended Channel Switch Announcement element in a Beacon or Probe Response frame is used to announce a switch to a 40 MHz BSS bandwidth, then the Wide Bandwidth Channel Switch subelement in the Channel Switch Wrapper element may be present in the same frame.

NOTE 2—The indicated operating class within the Extended Channel Switch Announcement element identifies the bandwidth and the relative position of the primary 20 MHz and secondary 20 MHz channels. Hence a Wide Bandwidth Channel Switch subelement is unnecessary when the Extended Channel Switch Announcement element is used for a channel switch to a 40 MHz bandwidth.

If a Channel Switch Announcement frame is used to announce a switch to an 80 MHz, 80+80 MHz, or 160 MHz BSS bandwidth, then both the Secondary Channel Offset element and the Wide Bandwidth Channel Switch element shall be present in the frame.

If a Channel Switch Announcement element or an Extended Channel Switch Announcement element is used to announce a switch to an 80 MHz, 80+80 MHz, or 160 MHz BSS bandwidth, then a Wide Bandwidth Channel Switch subelement in the Channel Switch Wrapper element shall be present in the same frame.

If an Extended Channel Switch Announcement frame is used to announce a switch to an 80 MHz, 80+80 MHz, or 160 MHz BSS bandwidth, then the Wide Bandwidth Channel Switch element shall be present in the frame.

If an Extended Channel Switch Announcement element or Extended Channel Switch Announcement frame is used to announce a switch to an 80 MHz, 80+80 MHz, or 160 MHz BSS bandwidth, then

— The New Operating Class field identifies the primary 40 MHz channel, and

— The Operating Triplet fields within the New Country subelement or element, respectively, shall indicate all of the operating classes for the switched BSS.

If new BSS TPC parameters are announced that come into effect at the same time as the channel switch, then if an AP, IBSS STA or mesh STA is extended spectrum management capable, it shall include

— At least one New Transmit Power Envelope element in a transmitted Channel Switch Announcement frame or Extended Channel Switch Announcement frame, and

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— At least one New Transmit Power Envelope subelement in a transmitted (#383)Channel Switch Wrapper element in Beacon and Probe Response frames.

A recipient STA in the BSS that is extended spectrum management capable and that has dot11SpectrumManagementRequired or dot11RadioMeasurementActivated equal to true and that maintains association with the BSS after the switch shall use the parameters in these received elements and subelements in the recipient STA's TPC calculations for the new operating channel and BSS bandwidth (see 11.7 (TPC procedures)). If both New Transmit Power Envelope elements and New Transmit Power Envelope subelements are transmitted for the switch, the set of New Transmit Power Envelope elements and set of subelements shall contain the same set of values for the Local Maximum Transmit Power Unit Interpretation subfield, and New Transmit Power Envelope elements and subelements that have the same value of the Local Maximum Transmit Power Unit Interpretation subfield shall also have the same values for their other fields.

If a new country string, new operating classes or both, are coming into effect at the same time as the channel switch, then if an AP, IBSS STA or mesh STA is extended spectrum management capable, it shall include

— A New Country element in a transmitted Extended Channel Switch Announcement frame, and

— A New Country subelement in a transmitted (#383)Channel Switch Wrapper element.

The New Country element or subelement shall contain all of the Operating Classes for the BSS after the switch. The New Country element or subelement, transmitted in an Extended Channel Switch Announcement frame or in the same frame as an Extended Channel Switch Announcement element, respectively, shall include one Operating Triplet field that contains the same Operating Class as the New Operating Class field in the Extended Channel Switch Announcement frame or Extended Channel Switch Announcement element. A recipient STA in the BSS that is extended spectrum management capable and that has dot11MultiDomainCapabilityActivated, dot11SpectrumManagementRequired, or dot11RadioMeasurementActivated equal to true and that maintains association with the BSS after the switch shall use the parameters in these received elements and subelements in order to maintain regulatory compliance. If both New Country elements and New Country subelements are transmitted for the switch, their fields shall be the same.

A Channel Switch Wrapper element shall not be included in Beacon or Probe Response frames if the element contains zero subelements.

NOTE 3—Channel Switch Wrapper is not defined to carry subelements in the case of a switch to 20 MHz and when no change to the country string, operating classes or TPC parameters are announced.

A VHT STA uses only the Transmit Power Envelope element, not the Power Constraint element, for TPC of 80 MHz, 160 MHz, and 80+80 MHz transmissions. In the Country element, a VHT STA shall include zero Subband Triplet fields in an Operating/Subband Sequence field that contains an Operating Class field for which the (#4177)Channel spacing (MHz) column in the applicable table in Annex E equals 80 or 160.

An AP that switches the BSS to a lower BSS bandwidth may recalculate the TS bandwidth budget and may delete one or more active TSs by invoking the MLME-DELTS.request primitive with a ReasonCode value of SERVICE_CHANGE_PRECLUDES_TS.

A VHT STA that is an IBSS STA shall not transmit values in the Wide Bandwidth Channel Switch element that change the frequency ordering of the primary 40 MHz channel and the secondary 40 MHz channel from the ordering of the most recently adopted operating channel, if the operating channel includes a secondary 40 MHz channel. A VHT STA that is a member of an IBSS shall not transmit values in the Wide Bandwidth Channel Switch element that change the frequency ordering of the primary 80 MHz channel and the secondary 80 MHz channel from the ordering of the most recently adopted operating channel, if the operating channel includes a secondary 80 MHz channel.


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### 11.38.5 NAV assertion in a VHT BSS

A VHT STA shall update its NAV as described in 10.3.2.4 (Setting and resetting the NAV) using the Duration/ID field value in any frame that does not have an RA matching the STA's MAC address and that was received in a 20 MHz PPDU in the primary 20 MHz channel or received in a 40 MHz PPDU in the primary 40 MHz channel or received in an 80 MHz PPDU in the primary 80 MHz channel or received in a 160 MHz or 80+80 MHz PPDU.

NOTE—The PHY might filter out a PPDU as described in 21.3.20 (PHY receive procedure) or not receive a PPDU due to VHT TXOP power saving described in 11.2.3.16 (VHT TXOP power save). If so, frames in the PPDU are not received by the MAC and have no effect on the NAV.

### 11.38.6 VHT STA antenna indication

A VHT STA that does not change its Rx antenna pattern after association shall set the Rx Antenna Pattern Consistency subfield in the VHT Capabilities Information field to 1; otherwise, the STA shall set the Rx Antenna Pattern Consistency subfield in the VHT Capabilities Information field to 0.

A VHT STA that does not change its Tx antenna pattern after association shall set the Tx Antenna Pattern Consistency subfield in the VHT Capabilities Information field to 1; otherwise, the STA shall set the Tx Antenna Pattern Consistency subfield in the VHT Capabilities Information field to 0.

### 11.38.7 Basic VHT-MCS and NSS set operation

The basic VHT-MCS and NSS set is the set of <VHT-MCS, NSS> tuples that are supported by all VHT STAs that are members of a VHT BSS. It is established by the STA that starts the VHT BSS, indicated by the Basic VHT-MCS And NSS Set field of the VHT Operation parameter in the MLME-START.request primitive. Other VHT STAs determine the basic VHT-MCS and NSS set from the Basic VHT-MCS And NSS Set field of the VHT Operation element in the BSSDescription derived through the scan mechanism (see 11.1.4.1 (General)).

A VHT STA shall not attempt to join (MLME-JOIN.request primitive) a BSS unless it supports (i.e., is able to both transmit and receive using) all of the <VHT-MCS, NSS> tuples in the basic VHT-MCS and NSS set.

NOTE—A VHT STA does not attempt to (re)associate with a VHT AP unless the STA supports (i.e., is able to both transmit and receive using) all of the <VHT-MCS, NSS> tuples in the Basic VHT-MCS And NSS Set field in the VHT Operation element transmitted by the AP because the MLME-JOIN.request primitive is a necessary precursor to (re)association.

### 11.38.8 Extended NSS BW Support Signaling

If dot11VHTExtendedNSSBWCapable is false, a STA shall set the Extended NSS BW Support subfield of the VHT Capabilities Information field to 0 in VHT Capability elements that it transmits, otherwise, the subfield may be set to 1, 2 or 3 as indicated in 9.4.2.156.2 (VHT Capabilities Information field).

If dot11VHTExtendedNSSBWCapable is false, a STA shall set the VHT Extended NSS BW Capable subfield of the Supported VHT-MCS And NSS Set field to 0 in VHT Capability elements that it transmits, otherwise, the subfield shall be set to 1.

## 11.39 Group ID management operation

An AP determines the possible combinations of STAs that can be addressed by a VHT MU PPDU or an S1G MU PPDU by assigning STAs to groups and to specific user positions within those groups.

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Assignments or changes of user positions corresponding to one or more Group IDs shall be performed using a Group ID Management frame defined in 9.6.22.3 (Group ID Management frame format).

A STA may be assigned to multiple groups by setting multiple subfields of the Membership Status Array field (#6023)(see 9.4.1.52 (Membership Status Array field)) to 1 in the Group ID Management frame addressed to that STA.

A STA's user position in each group of which the STA is a member is indicated by the associated subfield in the User Position Array field (see 9.4.1.53 (User Position Array field)) in the Group ID Management frame addressed to the STA. For each Group ID, an AP may assign the same user position to multiple STAs. A STA shall have only one user position in each group of which the STA is a member.

A non-S1G AP may transmit a Group ID Management frame only if dot11VHTOptionImplemented is true. A Group ID Management frame shall not be sent to a VHT STA that does not have the MU Beamformee Capable field in the VHT Capabilities element equal to 1.

An S1G AP shall not transmit a Group ID Management frame to an S1G STA that does not have the MU Beamformee Capable field in the S1G Capabilities element equal to 1.

A Group ID Management frame shall be sent as an individually addressed frame.

A STA's MLME that receives a Group ID Management frame with an RA matching its MAC address shall issue a PHYCONFIG_VECTOR primitive with the GROUP_ID_MANAGEMENT parameter based on the content of the received Group ID Management frame in order to configure the following lookup tables in the PHY:

a) Group ID to Membership Status, denoted by MembershipStatusInGroupID[$g$] for $1 \le g \le 62$
b) Group ID to User Position, denoted by UserPositionInGroupID[$g$] for $1 \le g \le 62$

Group ID values of 0 and 63 are used for SU PPDU and the PHY filtering of such PPDUs is controlled by the PHYCONFIG_VECTOR primitive LISTEN_TO_GID00 and LISTEN_TO_GID63 parameters. The User Position in Group ID information is interpreted by a STA receiving a VHT MU PPDU or an S1G MU PPDU as explained in 21.3.11.4 (Group ID), or 23.3.10.4 (Group ID), respectively.

Transmission of a Group ID Management frame to a STA and any associated acknowledgment from the STA shall complete before the transmission of a VHT MU PPDU and an S1G MU PPDU to the STA.

A VHT MU PPDU and an S1G MU PPDU shall be transmitted to a STA based on the content of the Group ID Management frame most recently transmitted to the STA and for which an acknowledgment was received.

## 11.40 Notification of operating mode changes

A STA in which dot11OperatingModeNotificationImplemented is true shall set the Operating Mode Notification field in the Extended Capabilities element to 1. A VHT STA shall set dot11OperatingModeNotificationImplemented to true. An S1G STA may set dot11OperatingModeNotificationImplemented to true. A STA in which dot11OperatingModeNotificationImplemented is true is referred to as *operating mode notification capable*.

A STA that is operating mode notification capable and that transmits an Association Request, Reassociation Request, TDLS Setup Response, TDLS Setup Confirm, Mesh Peering Open, or Mesh Peering Confirm frame to a STA that is operating mode notification capable should notify the recipient STA of a change in its operating mode by including the Operating Mode Notification element in the frame.


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A first STA that is operating mode notification capable should notify a second STA that is operating mode notification capable of a change in its operating mode by transmitting an Operating Mode Notification frame to the second STA if the first STA has established any of the following with a second STA:

- An association with an AP
- A (#2152)TDLS direct link
- A Mesh Peer relationship

NOTE 1—A Notify Channel Width frame or the STA Channel Width field in the HT Operation element is used to signal STA operating channel width changes to and from STAs that are not operating mode notification capable.

The Operating Mode field in the Operating Mode Notification frame or the Operating Mode Notification element together with the Supported Channel Width set field and the Extended NSS BW Support field of the VHT Capabilities element indicates the transmitting STA's receive bandwidth and NSS capabilities. See 10.6.13.1 (Rx Supported VHT-MCS and NSS Set).

The notification of a change in supported spatial streams should occur prior to a decrease in the maximum number of spatial streams and following an increase in the maximum number of spatial streams.

The notification of a change in operating bandwidth should occur prior to a decrease in the operating channel width and following an increase in the operating channel width.

A STA shall not transmit an individually addressed frame that contains the Operating Mode field unless the recipient is operating mode notification capable.

A non-S1G AP should notify associated STAs of a change in the maximum number of spatial streams it is able to receive through one or more of the following mechanisms:

- Using individually addressed Operating Mode Notification frames
- Using broadcast Operating Mode Notification frames
- Including the Operating Mode Notification element in Beacon frames for a period of time to allow STAs in PS mode to receive the notification

NOTE 2—A broadcast Operating Mode Notification frame might not be received by a STA in PS mode.

An S1G AP should notify associated STAs of a change in its operating channel width through one or more of the following mechanisms:

- Using the Extended Channel Switch Announcement element, Extended Channel Switch Announcement frame, or both, following the procedure described in 11.9 (Extended channel switching (ECS))
- Using broadcast Operating Mode Notification frames
- Using individually addressed Operating Mode Notification frames
- Using the Channel Width subfield in the S1G Operation element

NOTE 3—A broadcast Operating Mode Notification frame might not be received by a STA in PS mode.

NOTE 4—An AP cannot change the maximum number of spatial streams it is able to receive from HT STAs that are not operating mode notification capable.

The notification should occur prior to a decrease in the maximum number of spatial streams and following an increase in the maximum number of spatial streams.

An AP should notify associated STAs of a change in its operating channel width through one or more of the following mechanisms:

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- Using the Channel Switch Announcement element, Channel Switch Announcement frame or both following the procedure defined in 11.8.8.2 (Selecting and advertising a new channel in a non-DMG infrastructure BSS)
- Using the Extended Channel Switch Announcement element, Extended Channel Switch Announcement frame or both, following the procedure described in 11.9 (Extended channel switching (ECS))
- Using individually addressed Operating Mode Notification frames and/or Notify Channel Width frames
- Using broadcast Operating Mode Notification frames and/or Notify Channel Width frames
- Using the STA Channel Width field in the HT Operation element and/or Channel Width field in the VHT Operation element

NOTE 5—A broadcast Operating Mode Notification or Notify Channel Width frame might not be received by a STA in PS mode.

The notification should occur prior to a decrease in the operating channel width and following an increase in the operating channel width.

A VHT AP that has at least one VHT STA associated and that indicates a channel width change using Action frame(s) shall transmit Operating Mode Notification frame(s) to signal the channel width change. A VHT AP that has at least one non-VHT HT STA associated and that indicates a channel width change using Action frame(s) shall transmit Notify Channel Width frame(s) to signal the channel width change.

A VHT STA shall not transmit an individually addressed Notify Channel Width frame to a VHT STA.

A VHT STA associated with a VHT AP shall (#3683)discard Notify Channel Width frames received from the VHT AP.

An HT AP that is not a VHT AP that changes its operating channel width shall indicate the new operating channel width in the STA Channel Width field in the HT Operation element. A VHT AP that changes its operating channel width shall indicate the new operating channel width in the Channel Width field in the VHT Operation element and STA Channel Width field in the HT Operation element (see Table 11-29 (VHT BSS bandwidth)).

An S1G STA shall not transmit a Notify Channel Width frame.

An S1G AP that changes its operating channel width shall indicate the new operating channel width in the Channel Width field in the S1G Operation element.

An AP shall not include the Operating Mode Notification element in Beacon, Probe Response, Association Response, and Reassociation Response frames when not changing the maximum number of spatial streams the AP is able to receive.

A STA shall not transmit an Operating Mode field with the Rx NSS subfield indicating a number of spatial streams not supported by the recipient STA. The number of spatial streams supported by the recipient STA is reported in the Supported Rates and BSS Membership Selectors element, Extended Supported Rates and BSS Membership Selectors element, Supported MCS Set field, Supported VHT-MCS and NSS Set field, or Supported S1G-MCS and NSS Set field transmitted in Management frames by the recipient STA.

A STA shall not transmit an Operating Mode field with the Channel Width subfield indicating a bandwidth not supported by the STA, as reported in the Supported Channel Width Set subfield in the HT Capability Information field, in the VHT Capabilities Information field, or the S1G Capabilities Information field in Management frames transmitted by the STA.


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A STA that is operating mode notification capable shall not transmit a PPDU to a STA that uses a bandwidth that is greater than the channel width indicated in the most recently received Operating Mode Notification element or Operating Mode Notification frame from that STA. A STA that is operating mode notification capable shall not transmit a PPDU to a STA that uses a greater number of spatial streams than indicated in the most recently received Operating Mode Notification element or Operating Mode Notification frame received from that STA.

NOTE 6—The number of spatial streams might be further restricted if the receiving STA is in SM power save mode (see 11.2.6 (SM power save)).

NOTE 7—To avoid possible frame loss, a VHT or S1G STA that sends an individually addressed Operating Mode Notification frame to a second VHT or S1G STA indicating reduced operating channel width and/or reduced active receive chains can continue with its current operating channel width and active receive chains until it infers that the second STA has processed this notification. The first VHT or S1G STA might make this inference from either of the following:

— By receiving a frame addressed to it from the second VHT or S1G STA in a PPDU with a bandwidth and $N_{SS}$ that are less than or equal to the channel width and $N_{SS}$, respectively, indicated in the Operating Mode Notification frame
— Based on the passage of time in some implementation dependent way, which is outside the scope of this standard

NOTE 8—It might take a long time for a STA to change its operating mode following the transmission of the Operating Mode Notification frame and during that time it might not be able to receive frames resulting in frame loss. If a non-AP STA cannot tolerate frame loss during that period it can set the Power Management subfield of the Frame Control field of the Operating Mode Notification frame to 1 to indicate that it has entered power save. When it has completed its operating mode change, it can send another frame (such as a QoS Null) with the Frame Control Power Management subfield set to 0 to indicate that it has exited power save.

## 11.41 Basic TVHT BSS functionality

(#181)(#1467)A STA that is starting a TVHT BSS shall support receiving and transmitting at each of the <VHT-MCS, NSS> tuple values indicated by the Basic VHT-MCS And NSS Set field of the VHT Operation parameter of the MLME-START.request primitive and shall support receiving at each of the <VHT-MCS, NSS> tuple values indicated by the Supported VHT-MCS and NSS Set field of the VHT Capabilities parameter of the MLME-START.request primitive.

The basic VHT-MCS and NSS set is the set of <VHT-MCS, NSS> tuples that are supported by all TVHT STAs that are members of a TVHT BSS. It is established by the STA that starts the TVHT BSS. Other TVHT STAs determine the basic VHT-MCS and NSS set from the Basic VHT-MCS And NSS Set field of the TVHT Operation element in the BSSDescription derived through the scan mechanism (see 11.1.4.1 (General)).

A TVHT STA shall not attempt to join (MLME-JOIN.request primitive) a BSS unless it supports (i.e., is able to both transmit and receive using) all of the <VHT-MCS, NSS> tuples in the basic VHT-MCS and NSS set.

A STA for which dot11TVHTOptionImplemented is true shall set dot11VHTOptionImplemented to true.

A TVHT AP declares its channel width capability in the VHT Capabilities element VHT Capabilities Information field, as defined in 9.4.2.156 (VHT Capabilities element).

A TVHT AP shall set the Channel Width subfield in the TVHT Operation Information field to indicate the BSS bandwidth and transmitted PPDU type as defined in Table 11-32 (TVHT BSS bandwidth).

A TVHT non-AP STA that receives a frame containing a TVHT Operation element shall determine the channelization based on the Channel Center Frequency Segment 0, Channel Center Frequency Segment 1, and Primary Channel Number subfields of the TVHT Operation Information field (see 22.3.14 (Channelization)).

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**Table 11-32—TVHT BSS bandwidth**

| TVHT Operation element Channel Width field | BSS bandwidth | PPDU type |
|---|---|---|
| 0 | TVHT_W | TVHT_MODE_1 |
| 1 | TVHT_2W | TVHT_MODE_1 |
| | | TVHT_MODE_2C |
| 2 | TVHT_W+W | TVHT_MODE_1 |
| | | TVHT_MODE_2N |
| 3 | TVHT_4W | TVHT_MODE_1 |
| | | TVHT_MODE_2C |
| | | TVHT_MODE_4C |
| 4 | TVHT_2W+2W | TVHT_MODE_1 |
| | | TVHT_MODE_2C |
| | | TVHT_MODE_4N |

A TVHT STA that is a member of a TVHT BSS shall transmit a TVHT_MODE_1 PPDU only on the primary TVHT_W channel, except for a TVHT_MODE_1 PPDU transmission on an off-channel TDLS direct link.

A TVHT STA that is a member of a TVHT BSS with a TVHT_2W, TVHT_4W, or TVHT_W+W BSS bandwidth shall not transmit a TVHT_MODE_2C or TVHT_MODE_2N PPDU that does not use the primary TVHT_W channel and the secondary TVHT_W channel, except for a TVHT_MODE_2C, TVHT_MODE_4C, or TVHT_MODE_2N PPDU transmission on an off-channel TDLS direct link.

A TVHT STA that is a member of a TVHT BSS with a TVHT_4W or TVHT_2W+2W BSS bandwidth shall not transmit a TVHT_MODE_4C or TVHT_MODE_4N PPDU that does not use the primary TVHT_2W channel and the secondary TVHT_2W channel, except for a TVHT_MODE_4C or TVHT_MODE_4N PPDU transmission on an off-channel TDLS direct link.

A TVHT STA shall not transmit to a TVHT STA using a bandwidth that is not indicated as supported in the VHT Capabilities element or Operating Mode Notification frame recently received from that TVHT STA.

In a TVHT BSS, the primary TVHT_W channel is the primary channel.

## 11.42 Operation under the control of a GDB

### 11.42.1 General

When a STA implements support for one or more of the procedures described in this subclause, it shall set dot11TVHTOptionImplemented to true. When dot11TVHTOptionImplemented is true and a STA is initialized for operation in a band that requires GDB control, then dot11GDDActivated shall be true.

In some regulatory domains, STAs shall consult a GDB to determine permissible operating frequencies and parameters before transmitting. Such STAs may operate as geolocation database dependent (GDD) enabling STAs, which are required by regulation to provide their identification, geolocation, and other information to


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the GDB as specified by regulatory authorities. Other STAs are permitted to transmit when enabled by a GDD enabling STA. Such STAs operate as GDD dependent STAs.

Subclause 11.42 (Operation under the control of a GDB) describes procedures for STAs when they are operating under the control of a GDB to satisfy regulatory requirements. For operation under such restrictions, GDD dependent STAs operate according to the control procedures of a GDD enabling STA that enables their operation. The frame exchange sequence between GDD enabling STA and GDD dependent STAs for enabling their operation occurs in State 4 (see 11.3.1 (State variables)).

A GDD enabling STA is a STA that is able to access a GDB and to obtain the information about the permitted frequencies and other information for use in its location. A GDD enabling STA or geolocated non-AP STA populates its dot11STALCITable with location information by a means that has received regulatory approval and is outside the scope of this standard. When location information is set in dot11STALCITable, the STA (#135)shall set dot11GeolocationCapabilityActivated to true(#1889). The current dot11STALCITable allows management access to the location information that is the basis for operation. A GDD enabling STA may transmit a GDD enabling signal and may enable operations of GDD dependent STAs.

A GDD dependent STA is a STA that is under the control of a GDD enabling STA.

The GDD enablement procedure for GDD dependent STAs and the operating rules for GDD enabling and GDD dependent STAs are defined in the following subclauses.

### 11.42.2 GDD enabling STA operation

A GDD enabling STA may transmit a GDD enabling signal in-band on an available frequency to indicate that it offers GDD enablement service.

The GDD enabling signal is a Beacon frame with an Extended Capabilities element that contains a Geodatabase Inband Enabling Signal field with a value of 1. A GDD dependent STA shall not transmit any frames before it receives a GDD enabling signal over the air directly from a GDD enabling STA.

In some regulatory domains the GDD enabling STA may be required to have secure authentication or association with the GDD dependent STA before it sends the GDD Enablement Response frame. If required by regulation, the GDD enabling STA may contact a GDB to verify that the requesting GDD dependent STA is authorized to operate in the frequency band.

Upon receipt of a GDD Enablement Request frame from a GDD dependent STA, the GDD enabling STA sends a GDD Enablement Response frame with either of the following results:

a) The Status Code field set to SUCCESS to indicate the successful enablement of the requesting GDD dependent STA
b) The Status Code field set to ENABLEMENT DENIED or INVALID_PARAMETERS or RESTRICTION FROM AUTHORIZED GDB, in which case the GDD enablement request has been denied

A GDD enabling STA may issue an unsolicited GDD Enablement Response frame with a Status Code AUTHORIZATION DEENABLED to notify a GDD dependent STA to cease its transmissions and change its GDD enablement state to *Unenabled*. When an unsolicited GDD Enablement Response frame with a Status Code AUTHORIZATION DEENABLED is transmitted, the WSM element is not included.

### 11.42.3 GDD dependent STA operation

(#1258)The GDD enablement state variable of a GDD dependent STA is set to one of the following states: *Unenabled*, *AttemptingGDDEnablement*, or *GDDEnabled*. A GDD dependent STA begins operation by

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setting its GDD enablement state variable to *Unenabled* and operates in receive-only mode within the band, passively scanning channels for a GDD enabling signal from a GDD enabling STA.

A typical state machine implementation of GDD dependent STA operation under GDD is provided in Figure 11-101 (GDD dependent STA state transition diagram).

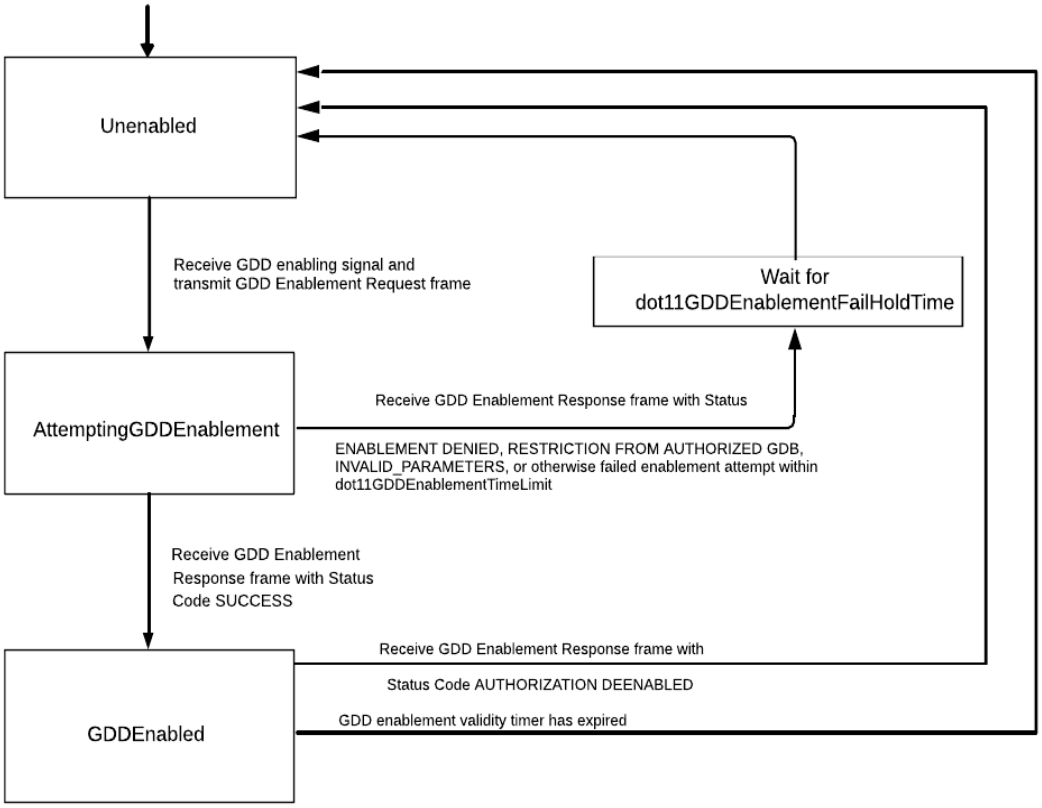


**Figure 11-101—GDD dependent STA state transition diagram**

A GDD dependent STA shall not transmit any frames unless it has received a valid GDD enabling signal from a GDD enabling STA.

A GDD dependent STA that is able to receive a valid GDD enabling signal, but has not been enabled by a GDD enabling STA shall not transmit, except to perform GDD enablement with a GDD enabling STA transmitting the GDD enabling signal.

A GDD dependent STA shall not transmit any frames other than GDD enablement-related frames and authentication and association frames before it performs the following GDD enablement procedure:

a) The GDD dependent STA changes its GDD enablement state variable to *AttemptingGDDEnablement* after receiving a GDD enabling signal.

b) After authentication and association, the GDD dependent STA securely sends a GDD Enablement Request frame to a GDD enabling STA from which it has received a GDD enabling signal. Based on the input received from the GDD dependent STA, the GDD enabling STA responds with a GDD Enablement Response frame indicating the result for the enablement request.

c) When a GDD dependent STA receives a GDD Enablement Response frame with the (#7190)status code SUCCESS within dot11GDDEnablementTimeLimit, the GDD enablement state variable of the


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GDD dependent STA is set to *GDDEnabled*. Once it becomes enabled, the GDD dependent STA maintains a GDD enablement validity timer, which is initialized to dot11ContactVerificationSignalInterval.

A GDD dependent STA that has not attained GDD enablement from a GDD enabling STA shall not transmit beyond dot11GDDEnablementTimeLimit, measured from the time of the first PHY-TXSTART.request primitive, while attempting to attain GDD enablement. Then, when the GDD enablement attempt fails within the allowed maximum time, it shall not transmit for dot11GDDEnablementFailHoldTime, before it may again attempt to attain GDD enablement.

NOTE—A GDD dependent STA might detect several GDD enabling STAs. If the GDD dependent STA is unable to obtain a GDD Enablement Response frame from one GDD enabling STA, it might make further attempts with additional GDD enabling STAs within the maximum time limit of dot11GDDEnablementTimeLimit.

Once in *GDDEnabled* state, the following rules apply to a GDD dependent STA during its operations:

— The GDD dependent STA shall maintain a GDD enablement validity timer. The procedures for maintaining the GDD enablement validity timer are defined in 11.42.8 (White space map (WSM)), 11.42.6 (Contact verification signal (CVS)), and 11.42.4 (Channel availability query (CAQ) procedure).

— A GDD dependent STA shall cease all transmission when the GDD enablement validity timer has expired. It then changes its GDD enablement state to *Unenabled*.

— A GDD dependent STA shall immediately cease all transmission if it receives an unsolicited GDD Enablement Response frame with a Status Code of AUTHORIZATION DEENABLED from the GDD enabling STA that enabled its operation.

### 11.42.4 Channel availability query (CAQ) procedure

#### 11.42.4.1 Introduction

This subclause describes a channel availability query procedure that can be used to obtain the list of available channels for the operation of a GDD STA. A STA shall not use the CAQ procedure specified here unless dot11GDDActivated is true.

A GDD dependent STA sends the channel availability query request to a GDD enabling STA to obtain the list of available channels. The CAQ procedure might be initiated by the GDD dependent STA in order to remain in the *GDDEnabled* state during its normal operational mode, as specified in 11.42.3 (GDD dependent STA operation).

The GDD dependent STA sends the Channel Availability Query frame to obtain the new channel availability information when it receives an indication of change in the available channel list for its use, such as from a recent CVS signal (see 11.42.6 (Contact verification signal (CVS))).

Once the GDD dependent STA receives the response for its Channel Availability Query frame from the GDD enabling STA, it reinitializes the GDD enablement validity timer to dot11ContactVerificationSignalInterval.

A GDD STA that acquires its geolocation position with the accuracy required by the regulatory domain (#135)shall set dot11GeolocationCapabilityActivated to true. Any STA that operates as a GDD enabling STA might have its geolocation position before it initiates the CAQ procedure. Such a STA might transmit a channel availability query request to another GDD enabling STA. The responding STA generates the CAQ response after communicating to the RLSS, if the Channel Availability Query frame was received in a Channel Availability Query RLQP-element.

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NOTE—A GDD enabling STA can send the Channel Availability Query frame to another GDD enabling STA. The responding GDD enabling STA, in such a case, can contact a GDB with the location and identifying parameters sent by the requesting STA.

A GDD enabling STA performs the CAQ procedure to update its channel availability when it determines that its geolocation position has moved beyond the permitted distance or beyond the validity time since its last query, as required by regulation.

STAs might transmit a channel availability query request in the protected dual of a CAQ Public Action frame (see 9.6.7.25 (Channel Availability Query frame format), or in a GAS Initial Request frame containing an Channel Availability Query RLQP-element (see 9.4.6.2 (Channel Availability Query RLQP-element)).

The procedures for channel availability query requesting STA and channel availability query responding STA are specified in 11.42.4.2 (CAQ requesting STA) and 11.42.4.3 (CAQ responding STA).

In some regulatory domains, CAQ procedures may be conducted in other bands with properly implemented security to meet regulatory requirements. In such cases, CAQ RLQP rather than CAQ Protected Dual of Public Action frames shall be used.

### 11.42.4.2 CAQ requesting STA

A GDD dependent STA or a GDD enabling STA may initiate a CAQ procedure as a CAQ requesting STA.

A CAQ requesting STA may use RLQP to transmit a CAQ request when it detects RLQP support by its intended CAQ responder in a Beacon or Probe Response frame and to transmit a CAQ request to a STA with which it is associated when the requesting STA detects RLQP support.

Upon receipt of the MLME-GAS.request primitive with an AdvertisementProtocolID value of RLQP and Query parameters with the values of the fields in the RLQP Channel Availability Query element, the requesting STA performs the procedure specified in 11.22.3.2.2 (STA procedures to transmit a GAS query request(#7052)) to transmit a GAS Initial Request frame that contains the Channel Availability Query RLQP-element. The specific information items in the Query Request field of the GAS Initial Request frame are defined in 9.4.6.2 (Channel Availability Query RLQP-element).

The CAQ requesting STA may send the protected dual of a Channel Availability Query frame where the CAQ responding STA does not support RLQP capability. Upon receipt of the MLME-CHANNELAVAILABILITYQUERY.request primitive with Reason Result Code of 1, the MLME schedules for transmission a Channel Availability Query frame. The specific information items in the protected dual of a CAQ Public Action are defined in 9.6.7.25 (Channel Availability Query frame format).

The CAQ requesting STA sets the Reason Result Code field to 1 and provides the Query Info field, as shown in Figure 9-1158 (Channel Query Info field format), to indicate if the Device Identification or Location Information fields are included in the Channel Availability Query frame.

A GDD enabling STA sending the Channel Availability Query frame should provide its device identification information in a format specified in 9.4.4.2.3 (Device Identification Information).

A GDD enabling STA with dot11GeolocationCapabilityActivated equal to true should provide one or more Location Information fields in its Channel Availability Query frame.

A CAQ requesting STA may request a common channel list applicable to a bounded geographic area by providing more than one Device Location Information field in the Channel Availability Query frame. The bounded geographic area is defined by the area surrounded by the given sets of geographic coordinates in the multiple Device Location Information fields.


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#### 11.42.4.3 CAQ responding STA

A GDD enabling STA that receives the Channel Availability Query frame performs the role of the CAQ responding STA.

When a GDD enabling STA that has dot11RLSSActivated true receives a Channel Availability Query RLQP-element request, it generates and transmits the Channel Availability Query RLQP-element response to the requesting STA. Upon receipt of the MLME-GAS.response primitive with ResponseInfo parameter having a value of the corresponding field in the CAQ element, the responding STA transmits a Channel Availability Query RLQP-element response.

The CAQ responding STA generates the response to the CAQ requesting STA based on the result obtained from the RLSS. The specific information items in the Channel Availability Query RLQP-element response are defined in 9.4.6.2 (Channel Availability Query RLQP-element) and are set as follows:

— Requester STA Address field set to the MAC address of the STA from which the query was received.
— If no security method is enabled on the connection between the CAQ requesting STA and the CAQ responding STA, the Reason Result Code field is set to 4 (REFUSED).
— Reason Result Code field set to 2 or 3 for successful result or to 4 or 5 for failure, as defined in 9.4.6.2 (Channel Availability Query RLQP-element).
— WSM Information field, as defined in 9.4.4.2.6 (WSM information values) when the Reason Result Code is set to 2 or 3.

NOTE—For the CAQ process, the RLSS provides the list of available channels for the location(s) provided by the requesting STA in the Channel Availability Query RLQP-element response. In some regulatory domains, the RLSS can perform access to a GDB to derive its response for the Channel Availability Query RLQP-element request and the associated information it provides in its Channel Availability Query RLQP-element response.

A CAQ responding STA might receive a Channel Availability Query frame or its protected dual. Upon receipt of the MLME-CHANNELAVAILABILITYQUERY.response primitive, the MLME schedules for transmission of the response in a Channel Availability Query frame. The Channel Availability Query frame or its protected dual is generated based on the ResultCode and other parameters received from the SME for the Channel Availability Query frame, as follows:

— Requester STA Address field set to the value of the PeerSTAAddress parameter.
— If no security method is enabled on the connection between the CAQ framing STA and the CAQ responding STA, the Reason Result Code field is set to 4 (REFUSED).
— Reason Result Code field set to 2 or 3 for successful result or to 4 or 5 for failure, as defined in 9.4.6.2 (Channel Availability Query RLQP-element).
— WSM Information field, as defined in 9.4.4.2.6 (WSM information values) when the Reason Result Code is set to 2 or 3.

When a CAQ Responding STA receives the Channel Availability Query frame from a GDD dependent STA, it sets the Reason Result Code field to 2 when the query is successful and provides the WSM information it has obtained for its own location.

When a CAQ Responding STA receives the Channel Availability Query frame from another GDD enabling STA that includes one or more Device Location Information fields in the Channel Availability Query frame, it sets the Reason Result Code field to 2 or 3 when the query is successful and provides the WSM information that is valid for the location of the requesting STA.

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When the Channel Availability Query frame contains multiple Device Location Information fields, the WSM information in the CAQ response is applicable for any location within the bounded area defined by the multiple locations. When the Channel Availability Query frame contains two Device Location Information fields, the WSM information in the CAQ response is applicable for any location within the bounded area determined by the uncertainty values of the coordinates of the second Device Location Information field. If no common channels are available to the bounded geographic area defined by multiple locations, CAQ responding STA responds with Reason Result Code field set to 2 (Success with the available channel list result for Device Location Information field) and WSM information applicable to the first Device Location Information field in the Channel Availability Query frame. If one or more common channels are available to the bounded geographic area defined by multiple locations, the CAQ responding STA responds with Reason Result Code field set to 3 (Success with an available channel list result for a bounded geographic area defined by multiple Device Location Information fields) and a corresponding WSM Information field.

When a CAQ responding STA receives the protected Channel Availability Query frame, the response shall be sent using the protected Channel Availability Query frame.

### 11.42.5 Channel schedule management (CSM) procedures

#### 11.42.5.1 Introduction

This subclause describes a channel schedule management procedure that can be used to obtain the list of available channels for the operation of a GDD STA. STAs can use the CSM procedure specified here when dot11GDDActivated is true.

Upon receipt of MLME-CHANNELSCHEDULEMANAGEMENT.request primitive, the MLME schedules transmission for a CSM request frame. If the parameter Protected of the MLME-CHANNELSCHEDULEMANAGEMENT.request primitive has the value true, then the CSM request frame as defined in 9.6.7.26 (Channel Schedule Management frame format) is transmitted in a Protected Dual of Public Action frame; otherwise the CSM request frame is transmitted in a Public Action frame.

Upon receipt of MLME-GAS.request primitive with an AdvertisementProtocolID parameter value of RLQP and Query parameter for a Channel Schedule Management RLQP-element, the requesting STA performs the procedure specified in 11.22.3.2.2 (STA procedures to transmit a GAS query request(#7052)) to transmit a GAS Initial Request frame that contains the Channel Schedule Management RLQP-element.

A GDD enabling STA transmits a CSM request to a RLSS to query the schedule information on TV channels. By default, a RLSS is able to provide channel schedule information on TV channels. However, the RLSS may reject the request by responding with Reason Result Code field set to the value for “Request declined by RLSS for unspecified reason.”

A GDD enabling STA transmits a CSM request to a RLSS to query the schedule information on WLAN channels. The RLSS maps channel schedule information from TV channels to WLAN channels and provides the schedule information, as defined in 9.4.4.2.5 (Channel Schedule Descriptor), to the GDD enabling STA that sent the query to facilitate WLAN operation. A RLSS that is not capable of providing WLAN channel schedule information responds to a request using the CSM response with the Reason Result Code field set to the value for “Request declined by RLSS because of no capability for providing schedule information on WLAN channels.”

A GDD enabling STA transmits a CSM request to another GDD enabling STA that is capable of database access as indicated in the GDD enabling signal. The GDD enabling STA that is capable of database access is able to access the RLSS and obtain the channel schedule information on TV channels. The GDD enabling STA may respond to a request by sending the CSM response with Reason Result Code field set to the value for “Request Declined by the GDD enabling STA because of no capability for providing schedule information on WLAN channels.”


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A GDD enabling STA may transmit a CSM request to query WLAN channel information from another GDD enabling STA. A GDD enabling STA responds to a CSM request using a CSM response with the Reason Result Code field set to the value for "Success" if it is capable of providing channel schedule information on WLAN channels obtained from a RLSS and responds with the Reason Result Code field set to the value for "Request declined by the GDD enabling STA because of no capability for providing schedule information on WLAN channels," otherwise.

When the information in a CSM response is identical to the information in the most recently transmitted CSM response to the same requesting STA, the responding STA can set the Reason Result Code field value CSM element in a query response to "Successful" with no channel schedule changes from the last query of the RLSS and omit both the Channel Schedule Management Mode and Channel Schedule Descriptor fields.

A GDD enabling STA with dot11ChannelScheduleManagementActivated true may send a CSM frame to update the channel schedule information of another GDD enabling STA that receives an available channel list from it.

The GDD dependent STA shall not transmit a CSM request.

The details of requesting and responding with CSM are provided in 11.42.5.2 (CSM requesting STA) and 11.42.5.3 (CSM responding STA).

### 11.42.5.2 CSM requesting STA

A STA employing RLQP uses the GAS protocol for its CSM procedure with a RLSS. Upon receipt of the MLME-GAS.request primitive with an AdvertisementProtocolID value of RLQP and Query parameter with the value of Channel Schedule Management RLQP-element, the CSM requesting STA transmits an RLQP-element with RLQP ID for CSM in the Query Request field in a GAS Initial Request frame. The specific information items in the Query Request field of the GAS Initial Request frame are generated as follows:

- Reason Result Code field = 0 or 1 as defined in 9.6.7.26 (Channel Schedule Management frame format).
- Channel Schedule Management Mode field = 0 or 1 as defined in 9.6.7.26 (Channel Schedule Management frame format).
- Channel Schedule Descriptor field, as defined in 9.4.4.2.5 (Channel Schedule Descriptor), containing the channel that the STA wants to query.

A STA uses the CSM Public Action frame or its protected dual to query another STA for channel schedule information. Upon receipt of the MLME-CHANNELSCHEDULEMANAGEMENT.request primitive with the CSM parameter of CSM element, the requesting STA transmits a CSM frame. The request frame is generated as follows:

- Reason Result Code field = 0 or 1 as defined in 9.6.7.26 (Channel Schedule Management frame format).
- Channel Schedule Management Mode field = 0 or 1 as defined in 9.6.7.26 (Channel Schedule Management frame format).
- Channel Schedule Descriptor field, as defined in 9.4.4.2.5 (Channel Schedule Descriptor), contains only the channel that the STA wants to query.

### 11.42.5.3 CSM responding STA

A STA employing RLQP uses the GAS protocol for its CSM procedure with a RLSS. Upon receipt of the MLME-GAS.request primitive with an ResponseInfo parameter value of Channel Schedule Management RLQP-element, the CSM responding STA transmits an RLQP-element with RLQP ID for CSM in the Query Response field in a GAS Initial Response frame or one or more GAS Comeback Response frames. The

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responding RLQP CSM shall be transmitted in a Protected Dual of Public Action frame if the received CSM is protected. The specific information items in the Query Response field of the GAS Initial Response frame are generated as follows:

— Reason Result Code field = values 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, or 12 as defined in 9.6.7.26 (Channel Schedule Management frame format).

— Channel Schedule Descriptor field, as defined in 9.4.4.2.5 (Channel Schedule Descriptor), contains the channel and related channel schedule information.

A STA uses CSM Public Action frame or its protected dual to respond to another STA with channel schedule information. Upon receipt of the MLME-CHANNELSCHEDULEMANAGEMENT.request primitive with CSM parameter value of CSM element, the CSM responding STA transmits a CSM frame in response. The responding CSM shall be transmitted in a Protected Dual of Public Action frame if the received CSM is protected. The CSM response frame is generated as follows:

— Reason result code field = values 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, or 12 as defined in 9.6.7.26 (Channel Schedule Management frame format).

— Channel Schedule Descriptor field, as defined in 9.4.4.2.5 (Channel Schedule Descriptor), contains the channel and related channel schedule information.

### 11.42.6 Contact verification signal (CVS)

The Contact Verification Signal frame is transmitted by a GDD enabling STA to establish that its GDD dependent STAs are within the reception range of the GDD enabling STA and to validate the available channel list. A GDD enabling STA with dot11ContactVerificationSignalActivated true shall transmit an individually addressed Protected CVS frame (see 9.6.7.27 (Contact Verification Signal frame format)) to its GDD dependent STAs.

A GDD dependent STA receives a CVS frame transmitted from its GDD enabling STA that provided the WSMs to verify that it is within reception range of that GDD enabling STA. The CVS frame has a Map ID field that indicates whether the WSM has been changed. A GDD dependent STA compares values of the Map ID field in the CVS frame with the Map ID of its existing WSM. If they are the same, then the GDD dependent STA assumes that its WSM is valid, and it sets the GDD enablement validity timer equal to dot11ContactVerificationSignalInterval. If they are different, the WSM is invalid because WSM information has changed. The STA should transmit a Channel Availability Query frame and receive a response in a Channel Availability Query frame that contains an updated WSM. If the GDD dependent STA fails to retrieve the updated WSM, it shall change its GDD enablement state to *unenabled* and stop transmitting over the air after the GDD enablement validity timer has expired.

### 11.42.7 Network channel control (NCC) procedures

#### 11.42.7.1 Introduction

This subclause describes network channel control procedures that can be used to manage channels for operation of a GDD STA. A STA may use the NCC procedures specified here when dot11GDDActivated is true.

Network channel control utilizes a two-message transaction sequence to allow an NCC responding STA to control the frequency usage in TV bands of an NCC requesting STA's WLAN channels. The first MMPDU sent by the NCC requesting STA asserts identity and requests NCC information. The NCC requesting STA may select its preferred frequencies from its WSM and request usage. The MMPDU sent by the NCC responding STA returns the NCC result. The NCC responding STA might grant permission to use the selected frequencies for multiple WLAN channels to the NCC requesting STA by responding with a Network Channel Control frame (see 9.6.7.30 (Network Channel Control frame format)). When responding, the NCC responding STA provides the confirmed WLAN channels and the transmit power constraints as well. The WLAN channels


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that the NCC responding STA confirms might be the same as or a subset of the network channels listed in the Network Channel Control frame received from the NCC requesting STA.

An NCC requesting STA employing RLQP may send an Network Channel Control frame to the RLSS to request its preferred frequencies given by the WSM for WLAN channels. The NCC requesting STA accomplishes this by transmitting an RLQP-element with the RLQP ID for NCC in the Query Request field in a GAS Initial Request frame. After it receives this frame the NCC responding STA forwards the NCC request to the RLSS. After receiving the NCC request, the RLSS responds and sends an NCC response via the NCC responding STA to the NCC requesting STA. When responding, the RLSS also provides the confirmed WLAN channels and the transmit power constraints. The WLAN channels that the RLSS confirms might be the same as or a subset of the network channels listed in the Network Channel Control request frame received from the NCC requesting STA.

Whenever the WSM has changed due to the update of the database information or detection of the primary service signals, an NCC requesting STAs may transmit a new Network Channel Control frame.

#### 11.42.7.2 NCC requesting STA

An NCC requesting STA may be a GDD dependent STA. An NCC requesting STA employing RLQP may use the GAS protocol for its NCC procedure with a RLSS. Upon receipt of the MLME-GAS.request primitive with an AdvertisementProtocolID value of RLQP and Query parameter with the value of Network Channel Control RLQP-element, the NCC requesting STA transmits an RLQP-element with Info ID for NCC in the Query Request field in a GAS Initial Request frame. The specific information items in the Query Request field of the GAS Initial Request frame are generated as follows:

— The Requester STA Address field is set to the MAC address of the NCC requesting STA.
— The Responder STA Address field is set to the MAC address of the NCC responding STA.
— The Reason Result code is REQUEST, as defined in 9.4.6.4 (Network Channel Control RLQP-element).
— The Number of Network Channel Control Triplets field, as defined in 9.4.6.4 (Network Channel Control RLQP-element), gives the number of triplets of Operating Class, Channel Number, and Transmit Power Constraint fields.
— The Operating Class and Channel Number fields, with the values defined in E.1 (Country information and operating classes), together specify the channel frequency and channel bandwidth for WLAN channels selected by the NCC requesting STA.
— The Maximum Transmit Power field, as defined in 9.4.6.4 (Network Channel Control RLQP-element), is set to the intended maximum transmit power in dBm for operation of the requesting STA.

An NCC Requesting STA might use the Network Channel Control frame or its protected dual to query another STA to request frequency usage in TV bands for WLAN channels. Upon receipt of the MLME-NETWORKCHANNELCONTROL.request primitive, the requesting STA transmits a (protected) Network Channel Control frame. The request frame is generated as follows:

— The Requester STA Address field is set to the MAC address of the NCC requesting STA.
— The Responder STA Address field is set to the MAC address of the NCC responding STA.
— The Reason Result Code is REQUEST, as defined in 9.4.6.4 (Network Channel Control RLQP-element).
— The Number of Network Channel Control Triplets field, as defined in 9.4.6.4 (Network Channel Control RLQP-element), gives the number of triplets of Operating Class, Channel Number, and Transmit Power Constraint fields.

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- The Operating Class and Channel Number fields, with the values defined in E.1 (Country information and operating classes), together specify the channel frequency and channel bandwidth for WLAN channels selected by the NCC requesting STA.
- The Maximum Transmit Power field, as defined in 9.4.6.4 (Network Channel Control RLQP-element), is set to the intended maximum transmit power in dBm for operation of the requesting STA.

### 11.42.7.3 NCC responding STA

An NCC responding STA may be a GDD enabling STA. An NCC responding STA employing RLQP may use the GAS protocol for its NCC procedure with a RLSS. Upon receipt of the MLME-GAS.response primitive with a ResponseInfo parameter value of Network Channel Control RLQP-element, the NCC responding STA transmits an RLQP-element with Info ID for NCC in the Query Response field in a GAS Initial Response frame or one or more GAS Comeback Response frames. The specific information items in the Query Response field of the GAS Initial Response frame are generated as follows:

- Requester STA Address field set to the MAC address of the NCC requesting STA.
- Responder STA Address field set to the MAC address of the NCC responding STA.
- Reason Result Code field = values SUCCESS, REFUSED, TOO_MANY_SIMULTANEOUS_REQUESTS, or Continuation frame as defined in 9.4.6.4 (Network Channel Control RLQP-element).
- The Number of Network Channel Control Triplets field, as defined in 9.4.6.4 (Network Channel Control RLQP-element), gives the number of triplets of Operating Class, Channel Number, and Transmit Power Constraint fields.
- The Operating Class and Channel Number fields, with the values defined in E.1 (Country information and operating classes), together specify the channel frequency and channel bandwidth that the NCC responding STA has granted permission to the NCC requesting STA for WLAN operation.
- The Maximum Transmit Power field, as defined in 9.4.6.4 (Network Channel Control RLQP-element), is set to maximum allowable transmit power in dBm of the requesting STA's WLAN operation.

An NCC responding STA may use an Network Channel Control frame or its protected dual to respond to another STA with NCC information. Upon receipt of the MLME-NETWORKCHANNELCONTROL.response primitive with NCC parameter value of NCC element, the NCC responding STA transmits a Network Channel Control frame containing an NCC element. The response frame is generated as follows:

- Requester STA Address field set to the MAC address of the NCC requesting STA.
- Responder STA Address field set to the MAC address of the NCC responding STA.
- Reason Result Code = values SUCCESS, REFUSED, TOO_MANY_SIMULTANEOUS_REQUESTS, or Continuation frame as defined in 9.4.6.4 (Network Channel Control RLQP-element).
- The Number of Network Channel Control Triplets field, as defined in 9.4.6.4 (Network Channel Control RLQP-element), gives the number of triplets of Operating Class, Channel Number, and Transmit Power Constraint fields.
- The Operating Class and Channel Number fields, with the values defined in E.1 (Country information and operating classes), together specify the channel frequency and channel bandwidth that the NCC responding STA has granted permission to the NCC requesting STA for WLAN operation.


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— The Maximum Transmit Power field, as defined in 9.4.6.4 (Network Channel Control RLQP-element), is set to maximum allowable transmit power in dBm of the requesting STA's WLAN operation.

### 11.42.8 White space map (WSM)

This subclause describes WSM procedures that can be used to obtain lists of available channels for operation of a GDD STA. STAs can use the WSM procedure specified here when dot11GDDActivated is true.

When dot11WhiteSpaceMapActivated is true, a GDD STA shall follow the procedures in this subclause.

If dot11WhiteSpaceMapActivated is true, a GDD enabling STA transmits a WSM, and a GDD dependent STA can transmit frames only on the available channels indicated in its valid WSM. GDBs can be different according to each regulatory domain and its regulatory requirements. A WSM Type field value of 1 indicates that the WSM is generated from the GDB and the WSM Information field of the WSM element specifies the available information for TVWS, which is country-specific and defined in 9.4.4.2.6 (WSM information values).

A GDD enabling STA contacts a GDB to obtain the permissible frequencies and operating parameters before it begins its transmissions. After receiving the WSM information from a GDB, a GDD enabling STA operates in TVWS only in the frequencies that the GDB indicates are available. The GDD enabling STA generates WSMs based on the information from the GDB. It may update WSMs when STAs perform a measurement or receive a measurement report in which a primary service signal is measured on a channel, which is indicated as available from the GDB.

A WSM element includes a list of identified available channels and corresponding maximum allowed transmission powers for each available channel.

When a GDD enabling STA retrieves updated available frequency information, it is able to transmit individually addressed Protected WSM Announcement frames with an updated WSM element to its GDD dependent STAs.

A GDD dependent STA receiving a WSM element operates on the channels indicated in the WSM. A GDD dependent STA that receives an updated WSM from its GDD enabling STA shall move its channel of operation if it is operating on a channel that has become unavailable in the updated WSM.

A GDD enabling STA transmits a WSM within a GDD Enablement Response frame, CAQ response frame, and WSM Announcement frame. A Device Class field of a WSM in a GDD Enablement Response frame and CAQ response frame is set to a value of a Device Class field in a GDD Enablement Request frame and Channel Availability Query frame, respectively. A Device Class field of WSM in a WSM Announcement frame is set to a value of the Device Class field of a WSM in a GDD Enablement Request frame.

The value of the Map version bits in the Map ID field is increased by (1 mod 127) whenever the GDD enabling STA transmits the updated WSM. The most recently received WSM is used by the WSM receiving STAs. A WSM with a Map version value of 127 indicates that the WSM is for reference only and it does not affect the GDD enablement states of a GDD dependent STA. If the Type bit in the Map ID field is(M118) 1, the following channel list is a full channel list; and if the Type bit is(M118) 0, the following channel list is a partial channel list. If a STA receives several WSMs with the same Map version and the Type bit is equal to 0, the STA should construct the whole channel list using the multiple WSMs having the same Map version.

GDD dependent STAs receiving a WSM should scan for existing BSSs on the available channels identified within received WSM element. In TVWS a GDD dependent STA receiving a WSM element shall operate on the channels indicated in the WSM. A GDD dependent STA that has previously received a WSM and that

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receives an updated WSM from its AP or GDD enabling STA shall move its channel of operation if it is operating on a channel that has become unavailable in the updated WSM.

If dot11WhiteSpaceMapActivated is true, then the enabled GDD dependent STA may send a Probe Request frame on any channel identified in the received WSM element. An AP that has dot11WhiteSpaceMapActivated true and that receives a Probe Request frame should respond with a Probe Response frame containing a WSM element.

## 11.43 Beacon RSSI

Upon receiving a Beacon frame, a STA measures the received signal strength of the Beacon frame and may store the result in dot11BeaconRssi. If the Beacon frame is received using multiple receive chains, the Beacon RSSI is averaged in linear domain over all active receive chains. The Beacon RSSI is reported in dBm. When operating in frequency bands below 6 GHz, the Beacon RSSI has an accuracy of ± 5 dB (95% confidence interval) within the specified dynamic range of the receiver. Beacon RSSI may be averaged over time using a vendor specific smoothing function.

NOTE —The mechanism by which the MAC obtains a beacon's RSSI is implementation dependent.(#3365)

## 11.44 Estimated throughput

A STA that has a value of true for dot11EstimatedServiceParametersInboundOptionImplemented is an estimated service parameters ESP Inbound STA. A STA that has a value of true for dot11EstimatedServiceParametersOutboundOptionImplemented is an estimated service parameters ESP Outbound STA. The term ESP STA refers to both ESP Inbound STAs and ESP Outbound STAs.

Entities outside the scope of this standard that control the traffic steering decision of a device might benefit by being able to predict the throughput that might be obtained through a link with a STA. Those same entities might also benefit from having the current estimate of throughput for network selection purposes (e.g., to allow comparison of an estimated throughout with existing throughout). The MLME-ESTIMATED-THROUGHPUT.request and MLME-ESTIMATED-THROUGHPUT.confirm primitives together provide an interface to allow such entities, operating through the SME, to obtain estimates of throughput for MSDUs sent between the STA that corresponds to the (#145)PeerSTAAddress indicated in the parameter list of the MLME-ESTIMATED-THROUGHPUT.request primitive and this STA.

When an MLME-ESTIMATED-THROUGHPUT.request primitive is received at the MLME, the MLME can use the parameters provided in the primitive plus the following information to create estimates of throughput per access category to deliver to the SME in the EstimatedThroughputOutbound and EstimatedThroughputInbound parameters of the MLME-ESTIMATED-THROUGHPUT.confirm primitive:

— RSSI measured during reception of Beacon or Probe Response frames transmitted by the STA that corresponds to the MAC entity with the MAC address equal to the (#145)PeerSTAAddress in the MLME-ESTIMATED-THROUGHPUT.request primitive to this STA
— Number of spatial streams that is expected to be supported on the link between this STA and the STA
— Channel bandwidth
— Estimated air time fraction
— Block ack window size

The Estimated Inbound Air Time Fraction subfield value should be determined using the following assumptions:


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- There is sufficient inbound data traffic, destined to the new STA joining the BSS and of the corresponding access category, available to fill the indicated air time
- The new STA joining the BSS does not generate outbound data traffic
- The Data PPDUs transmitted to the new STA joining the BSS are SU PPDUs, even though they might be transmitted as MU PPDUs
- The Data PPDUs transmitted to the new STA joining the BSS are transmitted in EDCA TXOPs of length equal to the duration indicated by dot11QAPEDCATableTXOPLimit for the corresponding access category or, if dot11QAPEDCATableTXOPLimit is 0, equal to the duration indicated by the Data PPDU Duration Target field
- Other than the addition of inbound data traffic destined to the new STA joining the BSS, the characteristics of traffic entering the transmit queues of the STAs accessing the medium do not change if the new STA joins the BSS
- The characteristics of non-EDCA transmissions on the medium (e.g., interferers) do not change if the new STA joins the BSS

The Estimated Outbound Air Time Fraction subfield value should be determined using the following assumptions:

- There is sufficient outbound data traffic, originating from the new STA joining the BSS and of the corresponding access category, available to fill the indicated air time
- No inbound data traffic to the new STA joining the BSS is generated
- The Data PPDUs transmitted by the new STA joining the BSS are SU PPDUs, even though they might be transmitted as MU PPDUs
- The Data PPDUs transmitted by the new STA joining the BSS are transmitted in EDCA TXOPs of length equal to the duration indicated by dot11EDCATableTXOPLimit for the corresponding access category or, if dot11EDCATableTXOPLimit is 0, equal to 5430 μs.
- Other than the addition of outbound data traffic destined to the new STA joining the BSS, the characteristics of traffic entering the transmit queues of the STAs currently accessing the medium do not change if the new STA joins the BSS
- The characteristics of non-EDCA transmissions on the medium (e.g. interferers) do not change if the new STA joins the BSS

If the MLME is incapable of determining a value for the EstimatedThroughputOutbound or EstimatedThroughputInbound parameter for any access category, then the MLME shall return a value of 0 for the value of that parameter for that access category in the MLME-ESTIMATED-THROUGHPUT.confirm primitive.

If the AverageMSDUSizeOutbound parameter for an access category is equal to 0 in the MLME-ESTIMATED-THROUGHPUT.request primitive, the STA shall include a value of 0 in the EstimatedThroughputOutbound parameter for the corresponding access category in the MLME-ESTIMATED-THROUGHPUT.confirm primitive.

If the AverageMSDUSizeOutbound parameter for an access category is equal to –1 in the MLME-ESTIMATED-THROUGHPUT.request primitive, the STA may use any value for the average MSDU size used in calculating the estimated throughput to be included in the corresponding access category in the EstimatedThroughputOutbound parameter of the MLME-ESTIMATED-THROUGHPUT.confirm primitive, but should use a value of 1500 octets.

If the AverageMSDUSizeInbound parameter for an access category is equal to 0 in the MLME-ESTIMATED-THROUGHPUT.request primitive, the STA shall include a value of 0 in the EstimatedThroughputInbound parameter for the corresponding access category in the MLME-ESTIMATED-THROUGHPUT.confirm primitive.

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If the AverageMSDUSizeInbound parameter for an access category is equal to –1 in the MLME-ESTIMATED-THROUGHPUT.request primitive, the STA may use any value for the average MSDU size used in calculating the estimated throughput to be included in the corresponding access category in the EstimatedThroughputInbound parameter of the MLME-ESTIMATED-THROUGHPUT.confirm primitive, but should use a value of 1500 octets.

An ESP Outbound STA should determine a value for EstimatedThroughputOutbound for each AC of a current or potential link with a STA using the equation found in R.7 (Calculating Estimated Throughput).

An ESP Inbound STA that is a non-AP STA may include a Request element that includes the element IDs of the Estimated Service Parameters Inbound element in transmitted Probe Requests. An ESP Outbound STA or a mesh STA may include a Request element that includes the element IDs of the Estimated Service Parameters Outbound element in transmitted Probe Requests.

An ESP Inbound STA that is an AP or an ESP Inbound STA that is a mesh STA shall include the Estimated Service Parameters Inbound element within Probe Response frames transmitted in response to a Probe Request frame that included a Request element that includes the element ID of the Estimated Service Parameters Inbound element. An ESP Inbound STA that is neither an AP nor a mesh STA may include the Estimated Service Parameters Inbound element within Probe Response frames transmitted in response to a Probe Request frame that included a Request element that includes the element ID of the Estimated Service Parameters Inbound element. An ESP Inbound STA may include the Estimated Service Parameters Inbound element within Probe Response frames transmitted in response to a Probe Request frame that did not include a Request element, or included a Request element that did not include the element ID of the Estimated Service Parameters Inbound element.

An ESP Outbound STA that is an AP or an ESP Outbound STA that is a mesh STA shall include the Estimated Service Parameters Outbound element within Probe Response frames transmitted in response to a Probe Request frame that included a Request element that includes the element ID of the Estimated Service Parameters Outbound element. An ESP Outbound STA that is neither an AP nor a mesh STA may include the Estimated Service Parameters Outbound element within Probe Response frames transmitted in response to a Probe Request frame that included a Request element that includes the element ID of the Estimated Service Parameters Outbound element. An ESP Outbound STA may include the Estimated Service Parameters Outbound element within Probe Response frames transmitted in response to a Probe Request frame that did not include a Request element, or included a Request element that did not include the element ID of the Estimated Service Parameters Outbound element.

An ESP Inbound STA that is an AP or an ESP Inbound STA that is a mesh STA shall include the Estimated Service Parameters Inbound element within Beacon frames. An ESP Inbound STA that is not an AP may include the Estimated Service Parameters Inbound element within Beacon frames.

An ESP Outbound STA that is an AP or an ESP Outbound STA that is a mesh STA shall include the Estimated Service Parameters Outbound element within Beacon frames. An ESP Outbound STA that is not an AP may include the Estimated Service Parameters Outbound element within Beacon frames.

An ESP STA that transmits an Estimated Throughput element determines the value of the Data PPDU Duration Target field in a manner that is beyond the scope of this standard, but should use a value of 5430 μs. Because the STA transmitting the element is the STA that would be transmitting the PPDUs, that STA should know what parameters it would be likely to use for those transmissions, although variations in this estimate are possible due to the varying capabilities of the STAs receiving the PPDUs and due to dynamic channel conditions. The transmitting STA can adjust multiple transmission parameters to attempt to maintain the targeted duration despite the variations in the receiving STA and operating condition parameters.


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## 11.45 Fast Initial Link Setup (FILS) procedures

### 11.45.1 General

This subclause describes the Fast Initial Link Setup (FILS) procedures that are used for FILS STAs. FILS is only supported in a non-DMG non-S1G infrastructure BSS.

A FILS STA is a QoS STA and shall set dot11QosOptionImplemented to true.

A FILS non-AP STA shall set the FILS Capability field to 1 in the Extended Capabilities element included in Probe Request and (Re)Association Request frames. A FILS non-AP STA may include FILS Request Parameters or AP-CSN elements in Probe Request frames. A FILS non-AP STA may set the Authentication Algorithm Number field to the value of Fast Initial Link Setup (FILS) authentication in the Authentication frame with the authentication transaction sequence number set to 1 (Authentication Request). A FILS AP advertises its FILS authentication and FILS higher layer setup capabilities by including a FILS Indication element, as specified in 9.4.2.181 (FILS Indication element) and 11.45.4 (FILS authentication and higher layer setup capability indications), in Beacon, Probe Response, and FILS Discovery frames.

A FILS AP shall set the FILS Capability field to 1 in the Extended Capabilities element and shall include the FILS Indication element in Beacon frames, Probe Response frames, and (Re)Association Response frames. A FILS AP may transmit FILS Discovery frames.

### 11.45.2 FILS Discovery frame generation and usage

#### 11.45.2.1 FILS Discovery frame transmission

A FILS AP supporting FILS discovery may generate and transmit FILS Discovery frames. The FILS Discovery frame shall be transmitted at a mandatory PHY rate, and should be transmitted at a basic rate, but shall not be transmitted in a DSSS or HR/DSSS PPDU. The Address 1 field of the FILS Discovery frame shall be set to the broadcast address.

An AP may transmit a FILS Discovery frame as a non-HT duplicate PPDU. When a FILS Discovery frame is transmitted as a non-HT duplicate PPDU, its (#1011)operating class and primary channel shall be indicated by its (#1011)Operating Class and Primary Channel fields, respectively.(#1011)

If an AP transmits a FILS Discovery frame as a non-HT duplicate PPDU in an 80+80 MHz channel bandwidth, the Channel Center Frequency Segment 1 field shall be present in the FILS Discovery frame and shall be set to the channel center frequency of the frequency segment 1 for an 80+80 MHz VHT or HE(11ax) operating channel.

A FILS AP should transmit FILS Discovery frame(s) in every beacon interval. The interval between the transmission of a Beacon frame and a subsequent FILS Discovery frame shall be no less than the interval indicated in dot11FILSFDFrameBeaconMinimumInterval. The transmission interval between subsequent FILS Discovery frames by an AP in a beacon interval shall be no less than the interval indicated in dot11FILSFDFrameBeaconMinimumInterval. If dot11FILSFDFrameBeaconMaximumInteval is (#2005)(#3251)nonzero, and if a Beacon frame, (11ax)broadcast Probe Response frame, or FILS Discovery frame(#252) has not been transmitted by an AP for a period that is equal to dot11FILSFDFrameBeaconMaximumInterval, that AP shall queue for transmission a FILS Discovery frame(#252), (11ax)broadcast Probe Response frame, or a Beacon frame unless the next TBTT is within a duration indicated by the value of dot11FILSFDFrameBeaconMinimumInterval.

An AP may use the FILS Minimum Rate subfield in the FILS Discovery frame to indicate the minimum rate to be used by the AP and FILS STAs in subsequent transmissions between the AP and FILS STAs.

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An AP may include its RSN information in the FD RSN Information subfield of the FILS Discovery frame as described in 12.11.2.2 (Discovery of a FILS AP).(#1011)

(11ax)For the APs in a multiple BSSID set, only the AP corresponding to the transmitted BSSID may transmit a FILS Discovery frame; other APs corresponding to nontransmitted BSSIDs shall not transmit a FILS Discovery frame. If dot11MultiBSSIDImplemented is true, then the following applies to the fields in the FILS Discovery frame:

— The SSID or Short SSID field shall be set to the SSID or short SSID, respectively, of the transmitted BSSID.

— The FILS Capability field shall be present, and the Multiple BSSIDs Presence Indicator subfield shall be set to 1.

(11ax)A 6 GHz AP that is sending FILS Discovery frames shall include at least one Transmit Power Envelope element, where the Maximum Transmit Power Category subfield is set to 0 (Default), including a regulatory client transmit power limit for at least 20 MHz bandwidth (for EIRP) or at least the AP's primary 20 MHz channel (for EIRP PSD).

NOTE 1—The AP is not required to include power constraints for bandwidths greater than 20 MHz in FILS Discovery frames, even if they are supported by the BSS. Therefore, when a Transmit Power Envelope element in a FILS Discovery frame indicates EIRP PSD limits, the value of *N* (see Table 9-320 (Meaning of Maximum Transmit Power Count subfield if Maximum Transmit Power Interpretation subfield is 1, 3 or 5(#6076)(11ax))) can take any valid value equal to or less than the BSS bandwidth, in megahertz, divided by 20.(11ax)

NOTE 2—A Transmit Power Envelope element sent in a FILS Discovery frame by a 6 GHz AP can be used by a STA to determine a transmit power limit for 20 MHz PPDUs corresponding to the 6 GHz AP prior to having received a Beacon or Probe Response frame from that AP. A STA might, for example, determine a transmit power limit based on this information when sending a Probe Request frame with 20 MHz PPDU bandwidth during active scanning on the 6 GHz AP's channel.(11ax)

(11bc)An AP that is not in a multiple BSSID set and has dot11EBCSSupportActivated equal to true and a nonzero dot11EBCSTrafficStreamTable length shall include an EBCS Parameters element in the FILS Discovery frame that it transmits. In a multiple BSSID set, only the AP corresponding to the transmitted BSSID that also has dot11EBCSSupportActivted equal to true and a nonzero dot11EBCSTrafficStreamTable length shall include an EBCS Parameters element in the FILS Discovery frame it transmits.

(11bc)An EBCS AP that provides one or more EBCS traffic streams that require association shall include RSN information in the FD RSN Information subfield in the FILS Discovery Information field.

(11bc)NOTE 3—An EBCS STA that receives a FILS Discovery frame from an AP that contains an EBCS Parameter element can determine the beacon interval during which the next EBCS Info frame is expected to be transmitted by the AP.

(11bc)An EBCS STA that receives a FILS Discovery frame containing an EBCS Parameters element may use RSN information in the FD RSN Information subfield to conduct FILS authentication with the AP that transmitted the FILS discovery frame as described in 12.11.1 (General) if it has determined that the AP provides one or more desired EBCS traffic streams that require association.

(11bc)NOTE 4—An EBCS STA can determine that an AP provides one or more desired EBCS traffic streams that require association based on parameters such as SSID, short SSID, or through other means that are beyond the scope of this standard.

### 11.45.2.2 FILS Discovery frame reception

If a FILS STA has the ReportingOption parameter present in the MLME-SCAN.request primitive and it is not equal to IMMEDIATE or CHANNEL_SPECIFIC, then the STA shall follow the procedures indicated in 11.1.4.1 (General) and not the procedures provided in this clause.


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If an AP has indicated the FILS Minimum Rate in the FILS Minimum Rate subfield of a FILS Discovery frame, a scanning FILS STA that receives such a FILS Discovery frame shall use a data rate that is equal or higher than the indicated FILS Minimum Rate in subsequent transmissions between the AP and the FILS STA.

A scanning FILS STA that receives a FILS Discovery frame compares the received SSID or short SSID in the FILS Discovery frame with the SSID parameter or SSID list provided to the STA previously in an MLME-SCAN.request primitive. If the STA has the ReportingOption parameter present in the MLME-SCAN.request primitive and equal to IMMEDIATE and if the SSID in the FILS Discovery frame matches the SSID parameter or one of the SSIDs in the SSID list, the STA shall issue an MLME-SCAN.confirm primitive with the information obtained from the received FILS Discovery frame immediately after the reception of the FILS Discovery frame, with the ResultCode equal to INTERMEDIATE_SCAN_RESULT. If the STA has the ReportingOption parameter in the MLME-SCAN.request primitive equal to CHANNEL_SPECIFIC and if the SSID in the FILS Discovery frame matches the SSID parameter or one of the SSIDs in the SSID list, the STA shall issue an MLME-SCAN.confirm primitive with the information obtained from the received FILS Discovery frame after the STA has completed the scanning of the current channel, with the ResultCode equal to INTERMEDIATE_SCAN_RESULT.

If the received FILS Discovery frame contains the AP-CSN subfield as defined in 11.1.4.3.11 (Enhanced FILS active scanning to preferred AP) and the non-AP STA maintains previously obtained BSS configuration parameter sets(#8158), the non-AP STA shall use the received AP-CSN information as follows:

- The STA shall check if the BSSID in the received FILS Discovery frame is equal to a BSSID in the previously obtained BSS configuration parameter sets(#8158).
- If an equal BSSID is found, the STA compares the AP-CSN value in the received FILS Discovery frame to the AP-CSN value associated with the BSSID in the BSS configuration parameter sets(#8158).
- If the AP-CSN values are not equal, a FILS non-AP STA may send an individually addressed Probe Request frame including an AP-CSN element, with the value of the AP-CSN associated with the BSSID in the BSS configuration parameter sets (#8158)in the non-AP STA.
- If the AP-CSN values are equal, then the non-AP STA may use the information contained in the BSS configuration parameter set(#8158) to initiate one or more FILS procedures (as defined in 11.45.3 (Higher layer setup during (re)association procedure), 11.45.4 (FILS authentication and higher layer setup capability indications), and 11.45.5 (DILS)), without waiting for next Beacon frame or Probe Response frame.
- If the non-AP STA has not successfully associated with an AP using the above procedures, it shall follow the procedures specified in 11.3.4.2 (Authentication—originating STA) and 11.3.4.3 (Authentication—destination STA).

If a received FILS Discovery frame contains RSN information in the FD RSN Information subfield, a FILS STA may conduct FILS authentication with the AP that transmitted the FILS Discovery frame as described in 12.11.2 (FILS authentication protocol).

A scanning FILS STA that receives a FILS discovery frame can compute the next TBTT based on the Timestamp subfield of the FILS Discovery Information field (see Figure 9-1223 (FILS Discovery Frame Control subfield format) and beacon interval as follows:

$$\text{Next TBTT} = \lceil \text{Timestamp} / (\text{Beacon Interval} \times 1024) \rceil \times (\text{Beacon Interval} \times 1024)$$

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### 11.45.3 Higher layer setup during (re)association procedure

#### 11.45.3.1 General

Higher layer setup, such as IP layer setup, may be performed during a STA's FILS (re)association procedure. Two mechanisms are provided for higher layer setup. One is the higher layer protocol (HLP) encapsulation. The HLP encapsulation, described in 11.45.3.2 (Higher layer protocol encapsulation), shall be supported by all FILS STAs. The other mechanism is the FILS IP address configuration. This is optional for FILS STAs and described in 11.45.3.3 (FILS IP address configuration). FILS IP address configuration is used to reduce the overhead caused by using the DHCP for the IP address assignment. However, (#479)FILS IP address assignment method provides a subset of features supported by the DHCP. In Beacon and Probe Response frames the AP advertises support of the FILS IP address configuration by setting the FILS IP Address Configuration bit to 1 in the FILS Indication element (9.4.2.181 (FILS Indication element)).

NOTE—The non-AP STA can use the following methods to obtain an IP address: 1) FILS IP address configuration, if supported by the AP. 2) Encapsulating higher layer protocols during association.

Higher layer setup information in (Re)Association Request/Response frames shall be protected by the authenticated encryption with associated data (AEAD) scheme (12.11.2.7 (AEAD cipher mode for FILS)).

#### 11.45.3.2 Higher layer protocol encapsulation

The FILS HLP Container element (9.4.2.182 (FILS HLP Container element)) is used for encapsulating higher layer protocol (HLP) packets.

If a non-AP STA uses higher layer protocol encapsulation, the non-AP STA shall construct a FILS HLP Container element for each HLP packet. The non-AP STA may put multiple FILS HLP Container elements into a (Re)Association Request frame as long as they fit in the MMPDU size limit. If the size of the (Re)Association Request frame exceeds the maximum MMPDU size, the non-AP STA shall remove the last FILS HLP Container element from the (Re)Association Request frame until the size of the (Re)Association Request frame does not exceed the maximum MMPDU size. The non-AP STA shall send the HLP packets contained in the removed FILS HLP Container elements as Data frames after association. Then the non-AP STA transmits a (Re)Association Request frame including all of the subjected FILS HLP Container elements. The HLP packet in the FILS HLP Container element can contain any MSDU format defined in 5.1.4 (MSDU format). The FILS HLP Container element may be fragmented as described in 10.28.11 (Element fragmentation) if required. The encapsulation procedure is as follows:

a) The non-AP STA fills FILS HLP Container element(s) with the destination MAC address, the source MAC address of the HLP packet and the HLP packet in MSDU format (see 5.1.4 (MSDU format)). The source MAC address shall be the MAC address of the non-AP STA.

b) The non-AP STA includes the FILS HLP Container element(s) into the (Re)Association Request frame.

If the AP receives a (Re)Association Request frame including FILS HLP Container element(s), the AP decapsulates the HLP packet(s) but shall not transfer the HLP packet(s) until the key confirmation (see 12.11.2.6 (Key confirmation with FILS authentication)) is successfully completed. After successful key confirmation, the AP forwards the HLP packet(s) to the upstream network or BSS according to the destination MAC address of the HLP packet(s). The order of forwarding the HLP packets shall be the same as the order of the FILS HLP Container elements in the (Re)Association Request frame. If the key confirmation fails, the AP (#7146)shall discard the HLP packet(s). The AP may filter HLP packets based on rules that are out of scope for this standard. The packet decapsulation procedure for each FILS HLP Container element is as follows:

1) The AP extracts the destination MAC address, the source MAC address and the HLP packet from the FILS HLP Container element;


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2) The AP verifies that the extracted source MAC address is equal to the source MAC address of the (Re)Association Request frame. If these are different, the AP shall discard the FILS HLP Container element;
3) The AP constructs the frame in appropriate format to deliver the HLP packet to the upstream network or BSS by using the extracted destination MAC address, source MAC address, and HLP packet.

The AP should wait to a transmit (Re)Association Response frame until dot11HLPWaitTime has elapsed after receiving a (Re)Association Request frame. If, before it transmits a (Re)Association Response frame, the AP receives one or more HLP packets from the upstream network or BSS that have the non-AP STA's MAC address or a group address as the destination address, the AP transmits each HLP packet in a different FILS HLP Container element in the (Re)Association Response frame. The order of the FILS HLP Container elements in the (Re)Association Response frame is same as the order of receiving the HLP packets. If the AP receives HLP packets for the non-AP STA after transmitting a (Re)Association Response frame, the AP transmits the HLP packets as Data frames. If, before it transmits a (Re)Association Response frame, the AP does not receive any HLP packets from the upstream network or BSS that have the non-AP STA's MAC address or a group address as the destination address, the AP shall not transmit any FILS HLP Container elements in the (Re)Association Response frame. The status code in the (Re)Association Response frame is not effected by the presence or absence of a FILS HLP Container element. The packet encapsulation procedure for each FILS HLP Container element is as follows:

— The AP sets the fields of the HLP Container element as follows:
  — The Destination MAC Address field is set to the destination MAC address of the received HLP packet, which is the MAC address of the non-AP STA or a group address.
  — The Source MAC Address field is set to the source MAC address of the received HLP packet.
  — The HLP Packet field is set to the HLP packet in MSDU format (see 5.1.4 (MSDU format)).
— The AP includes the FILS HLP Container elements into the (Re)Association Response frame.

If the non-AP STA receives a (Re)Association Response frame with one or more FILS HLP Container elements, the non-AP STA performs key confirmation (12.11.2.6 (Key confirmation with FILS authentication)) first. After successful key confirmation, the non-AP STA shall generate an MA-UNITDATA.indication primitive for each HLP packet. The order of generating MA-UNITDATA.indication primitive of the HLP packets shall be the same as the order of the FILS HLP Container elements in the (Re)Association Response frame. If the key confirmation fails, the non-AP STA shall discard the HLP packet(s). The packet decapsulation procedure for each FILS HLP Container element is as follows:

— The non-AP STA extracts the destination MAC address, source MAC address, and the HLP packet.
— The non-AP STA shall verify that the extracted destination MAC address is equal to the MAC address of the non-AP STA or group addresses. If the destination MAC address is not for the non-AP STA, the non-AP STA shall discard the FILS HLP Container element.
— The non-AP STA shall generate an MA-UNITDATA.indication primitive with the following parameters:
  1) source address: The extracted source MAC address
  2) destination address: The extracted destination MAC address
  3) routing information: all
  4) data: The extracted HLP packet
  5) reception status: success
  6) priority: Contention
  7) service class: QoSAck when the destination address is an individual address. QoSNoAck when the destination address is not an individual address

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For example, the above procedure can be used for IP address configuration. If the network uses DHCPv4/v6 (IETF RFC 2131, IETF RFC 3315), the FILS HLP Container element can carry DHCPv4/v6 packets. If the network uses IPv6 stateless address autoconfiguration (IETF RFC 4862), it can carry Router Solicitation and Router Advertisement packets (IETF RFC 4861).

#### 11.45.3.3 FILS IP address configuration

In order to request an IP address, a STA may include a FILS IP Address Assignment element in the (Re)Association Request frame or FILS Container frame that it sends to the AP.

The AP may send the IP address assigned to the STA in a FILS IP Address Assignment element (9.4.2.183 (FILS IP Address Assignment element)) that is included in a (Re)Association Response frame or a FILS Container frame. Methods for determining the IP address to be assigned to a STA are out of scope in this standard.

When the AP receives a (Re)Association Request frame including a FILS IP Address Assignment element or a FILS Container frame, the AP initiates a procedure to assign an IP address for the STA using a mechanism that is outside the scope of this standard.

If the STA has included a FILS IP Address Assignment element in the (Re)Association Request frame, then the AP may respond to the STA in one of the following ways:

— If the AP is able to assign an IP address in the (Re)Association Response frame, then the AP sets the IP address assignment pending flag in the IP Address Response Control field of the FILS IP Address Assignment element to 0 and includes the IP Address Data field as defined in 9.4.2.183 (FILS IP Address Assignment element) in the (Re)Association Response frame. For IPv6 addresses, an AP performs Duplicate Address Detection (IETF RFC 4862) before assigning an IPv6 address for the STA.

— If the AP is unable to assign an IP address in the (Re)Association Response frame, then the AP sets the IP address assignment pending flag in the IP Address Response Control field of the FILS IP Address Assignment element to 1 and sets the IP address request timeout to 0 in (Re)Association Response frame.

— If the AP needs more time to assign an IP address, the AP sets the IP address assignment pending flag in the IP Address Response Control field of the FILS IP Address Assignment element to 1 and sets the IP address request timeout to the maximum estimated time in the unit of seconds, within which the AP tries to assign an IP address to the requesting STA in the (Re)Association Response frame. When the AP is ready with an IP address within IP address request timeout period, then AP shall send the IP address to the STA using a FILS Container frame. If the STA does not receive the FILS Container frame containing IP assignment within IP address request timeout period, then the STA may initiate IP address assignment procedure using a FILS Container frame or mechanisms that are out of scope of this standard(#1560). If a STA has initiated an IP address assignment procedure using mechanisms that are out of scope of this standard(#1560), due to the expiry of the timeout period, and subsequently receives an FILS container frame containing an IP assignment, it shall discard the IP address assignment received in the FILS container frame.

The STA may use the MLME-FILSContainer.request primitive to request its IP address again to extend its lifetime and include the requested IP address in an IP Address Assignment element in a FILS Container frame. If the STA has included an IP Address Assignment element in the FILS Container frame, then the AP may respond to the STA using the MLME-FILSContainer.response primitive in one of the following ways:

— If the AP is able to assign an IP address immediately, then the AP sets the IP address assignment pending flag in the IP Address Response Control field of the FILS IP Address Assignment element to 0 and includes the IP Address Data field as defined in 9.4.2.183 (FILS IP Address Assignment element) in the FILS Container frame.


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— If the AP is unable to assign an IP address, then the AP sets the IP address assignment pending flag in the IP Address Response Control field of the FILS IP Address Assignment element to 1 and sets the IP address request timeout to 0 in the FILS Container frame.

— If the AP needs more time to assign an IP address, then the AP sets the IP address assignment pending flag in the IP Address Response Control field of the FILS IP Address Assignment element to 1 and sets the IP address request timeout to the maximum estimated time in the unit of seconds within which it (AP) tries to assign an IP address to the requesting STA in FILS Container frame. When the AP is ready to assign an IP address within IP address request timeout period, then the AP shall send the IP address to the STA using a FILS Container frame. If the STA does not receive the FILS Container frame containing an IP assignment within the IP address request timeout period, then the STA may initiate an IP address assignment procedure using mechanisms that are out of scope of this standard(#1560). If a STA has initiated an IP address assignment procedure using mechanisms that are out of scope of this standard(#1560), due to the expiry of the timeout period, and subsequently receives an FILS container frame containing an IP assignment, it shall discard the IP address assignment received in the FILS container frame.

### 11.45.4 FILS authentication and higher layer setup capability indications

A FILS AP shall include a FILS Indication element in Beacon and Probe Response frames, and may include a FILS Indication element in FILS Discovery frames. The FILS Indication element indicates properties of the FILS authentication protocol used and whether the AP performs IP address assignment.

An AP can indicate up to 7 realms that indicate the domain names of the server that the AP is capable of participating in an EAP-RP exchange with (see IETF RFC 6696). The realm of an EAP-RP server is the realm portion of the keyName-NA as defined in IETF RFC 6696. For each of the realms, the FILS Indication element carries a (#2047)hash of the network realm. The hash of the realm (IETF RFC 1035 compliant) is computed as follows:

H = (#3506)ExtractBits(SHA-256(ToLowerCase(D),0,16))(#1982)

where

| | |
|---|---|
| H | is the hashed realm name(#1982) |
| ToLowerCase | is the function that converts upper case characters to lower case |
| D | is the NAI realm of the EAP-RP server used in EAP-RP authentication(#1634) |

NOTE—Internationalized domain names are first converted to an IETF RFC 1035 compliant ASCII form using the operations defined in IETF RFC 3490[B38](#6015).

### 11.45.5 DILS

#### 11.45.5.1 General

To limit the number of STAs that attempt link setup concurrently, the DILS procedure provides a method for an AP to moderate the rate that non-AP STAs transmit Authentication and (Re)Association Request frames to the AP.

(#3179)DILS only applies to FILS STAs.

#### 11.45.5.2 AP procedures for DILS

If dot11DILSImplemented is true, a FILS AP may include the DILS element in Beacon and Probe Response frames, and set the DILS Duration and the optional fields to limit the number of STAs that are allowed to attempt link setup concurrently.

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The AP may set a DILS Duration field reserved for FILS at a high priority, and may set the FILS User Priority field, MAC Address Filter field, and/or Vendor Specific field to specify a subset of STAs that may attempt fast initial link setup during the reserved DILS Duration field specified in the element.

An AP may set (#6307)B0, B1, and B2 of the FILS User Priority field to 1 to indicate FILS without additional delays for the STAs based on the queued type of traffic as specified in 9.4.2.185 (DILS element).

An AP may set the Bit Pattern Length subfield in the MAC Address Filter field to decide the number of bits used for MAC address filtering, and specify the bit pattern in the Bit Pattern subfield to allow STAs with specific MAC addresses to transmit fast initial link setup frames immediately. The more bits used for MAC address filtering, the fewer STAs are allowed to transmit a fast initial link setup frame immediately. How an AP sets the bit pattern in the Bit Pattern subfield is beyond the scope of this standard(#1560).

An AP may set one or more vendor specific criteria in a Vendor Specific field to allow a set of STAs that satisfy the specified criteria to transmit fast initial link setup frames to the AP without additional delays.

#### 11.45.5.3 Non-AP STA procedures for DILS

When a FILS non-AP STA with dot11DILSImplemented value of true receives a Beacon or Probe Response frame that includes a DILS element, the non-AP STA shall check the DILS Flags field to determine if it satisfies the condition specified in each and every optional field that is present. If the non-AP STA satisfies all of the conditions specified in the present optional fields, the non-AP STA shall proceed with a FILS procedure with the AP without additional delays. Otherwise, the non-AP STA shall not associate with the AP until the time specified in the first received DILS Duration field elapses; when it has elapsed the STA may perform link setup with the AP.

When the FILS User Priority field is present, the FILS User Priority condition is satisfied if the non-AP STA has frames with user priority 4–7 in the transmission queue(s) and (#6307)B0 of the FILS User Priority field is 1, or if the non-AP STA has frames with user priority 0–3 in their transmission queue(s) and (#6307)B1 of the FILS User Priority field is 1, or if the non-AP STA has no frame in their transmission queue(s) and (#6307)B2 of the FILS User Priority field is 1. If a STA has frames in multiple queues with different priorities, the STA attempts to associate with the AP based on its highest priority queue.

Any combination of bit values for B0, B1, and B2 is allowed. For instance, B2B1B0=011 indicates that only STAs with traffic are allowed for FILS at a high priority and those STAs with no Data frames in their queues are not allowed. A value of B2B1B0=000 indicates that no FILS station is allowed to join the AP in the next specified time interval.

If a MAC Address Filter field is present, the non-AP STA shall compare its MAC address to the Bit Pattern subfield in the MAC Address Filter field. If the value of the last MAC_ADDR[(47-$n$+1):47] bits of the non-AP STA's MAC address matches the value of the bits used for MAC address filtering in the Bit Pattern subfield, where $n$ is specified in the Bit Pattern Length subfield, the MAC address condition is satisfied.

## 11.46 Support for energy limited STAs

An energy limited (EL) STA is an S1G STA with dot11S1GELOperationActivated equal to true that is powered by a small energy supply and is limited in terms of its ability to transmit or receive in certain intervals of time. (#111)In order to indicate these limitations to an S1G STA, an EL STA uses the signaling described in this subclause. The procedure described below increases the likelihood that frame exchange sequences(#109) between these two STAs are performed successfully.


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An EL STA receiving MLME-ELOPERATION.request primitive shall include an EL Operation element in Probe Request, TDLS Setup Request, TDLS Setup Response, and (Re)Association Request frames and may send EL Operation or Protected EL Operation frames.(#1276)

(#1276)When supporting energy limited STA operation described in this subclause(Ed1), if management frame protection is negotiated and both STAs set the Extended S1G Action Protection field in the RSNXE that they transmit to 1, the STAs shall:

— use individually addressed Protected EL Operation frames instead of EL Operation frames and
— discard any individually addressed EL Operation frames received from the peer STA, with which management frame protection is negotiated.

(#1276)STAs that exchange individually addressed Protected EL Operation frames shall follow the rules defined in 12.6.17 (Protection of robust Management frames.).

(#1276)When management frame protection is not negotiated or the Extended S1G Action Protection field is 0 in the RSNXE transmitted by either STA(M118), the STAs shall not use the Protected EL Operation frame.

An S1G AP that sets the STA Type Support in the S1G Capabilities element to 2 (i.e., supports only non-sensor STAs), as described in 10.62 (S1G BSS type and STA type), may refuse (re)association or can disassociate an EL STA. The S1G AP that refuses (re)association or disassociates an EL STA shall set the Status Code field in the (Re)Association Response frame or in the Disassociation frame to ENERGY_LIMITED_OPERATION_NOT_SUPPORTED.

Upon receipt of an MLME-ELOPERATION.indication primitive, an S1G STA shall maintain two timers, ELMaxAwakeTimer and ELRecoveryTimer according to the procedures defined in 10.61 (Energy limited STAs operation).

## 11.47 DCS procedure for CDMG BSS

### 11.47.1 General

Radio regulations that apply to the 60 GHz band in China allow radio local area networks (RLANs) operating in the Chinese 60 GHz band to operate on a 1.08 GHz or a 2.16 GHz channel, which requires a mechanism to coordinate the allocation of operating channel between two CDMG infrastructure BSSs or CDMG PBSSs. This subclause describes such a mechanism, referred to as dynamic channel selection (DCS). This mechanism is used to improve the flexibility and channel efficiency when RLANs operate in Chinese 60 GHz frequency band, in case that there is no available channel or the bandwidth (e.g., 1.08 GHz) of idle channel(s) cannot satisfy the operating requirements of RLANs. This subclause describes the DCS procedures that can be used to satisfy CDMG regulatory requirements.

Figure 11-102 (Examples of using DCS procedure) illustrates a number of use cases for DCS procedure:

— (#111)In cases 1, 2, and 3, a CDMG AP or PCP can request one of the two BSSs operating on two occupied 1.08 GHz channels to move to one of the two idle channels when starting a new BSS. Case 1 for example, the BSS operating on channel 36 can move to channel 37; or the BSS operating on channel 37 can move to channel 35. Then a 2.16 GHz channel 2 or 3 is idle, and the CDMG AP or PCP can start its BSS on it.
— (#111)In cases 4 and 5, a CDMG AP or PCP can request to start a new BSS operating on a 2.16 GHz channel to move to operate on a 1.08 GHz channel. Case 4 for example, the BSS operating on the channel 2 (2.16 GHz) can move to the channel 38 (1.08 GHz). Then the 2.16 GHz channel 2 is idle, and the CDMG AP or PCP can start its BSS on it.

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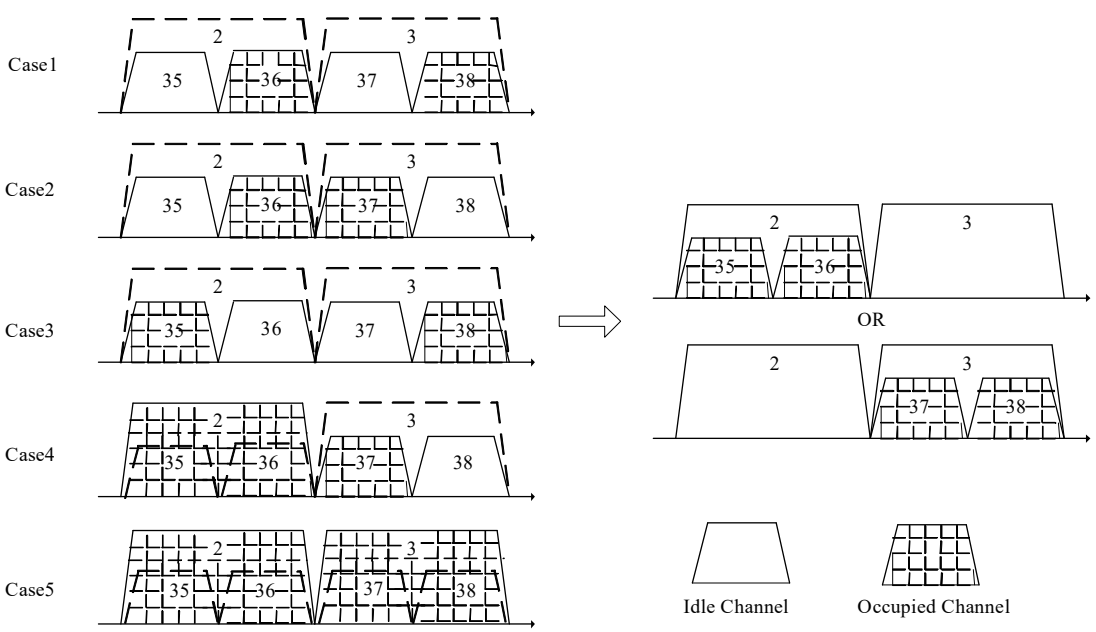


**Figure 11-102—Examples of using DCS procedure**

A CDMG STA is DCS capable if the value of dot11DynamicChannelTransferActivated is true. A CDMG DCS capability STA advertises the capability by including the DCS capability element in DMG Beacon, (Re)Association Request, (Re)Association Response, Information Request, Information Response, Probe Request, Probe Response, Announce, DCS Measurement Request, DCS Measurement Response, DCS Request, and DCS Response frames.

A CDMG AP or PCP shall use the DCS procedures defined in 11.47.1 (General) to 11.47.6 (Networking on the target channel) if the value of dot11DynamicChannelTransferActivated is true. The value of dot11DynamicChannelTransferActivated shall be set to true when a CDMG AP or PCP requires DCS procedures. The DCS procedures provide for the following:

- Assessing current channel condition (see 11.47.2 (Assessing current channel condition))
- Requesting of measurements for new channel for the DCS responder BSS (see 11.47.3 (Requesting measurements for new operating channel))
- Reporting of the result of measurements (see 11.47.4 (Reporting measurements))
- Requesting existing BSS to migrate to a new channel (see 11.47.5 (Requesting existing BSS to migrate to a new channel))
- Operating on the target channel (see 11.47.6 (Networking on the target channel))

Figure 11-103 (Procedure of dynamic channel selection) depicts an example of the procedure of the dynamic channel selection. In the figure, the parameter n corresponds to the number of DCS Measurement Request and DCS Measure Response frame exchanges until the requirement of operating channel or bandwidth for the DCS requester AP or PCP is met. The detailed procedure of dynamic channel selection is described in 11.47.2 (Assessing current channel condition) to 11.47.6 (Networking on the target channel).

Although the DCS procedure is defined for CDMG STAs according to the Chinese regulations, it can be used by other STAs defined in IEEE 802.11 specification to negotiate operating channels between BSSs.


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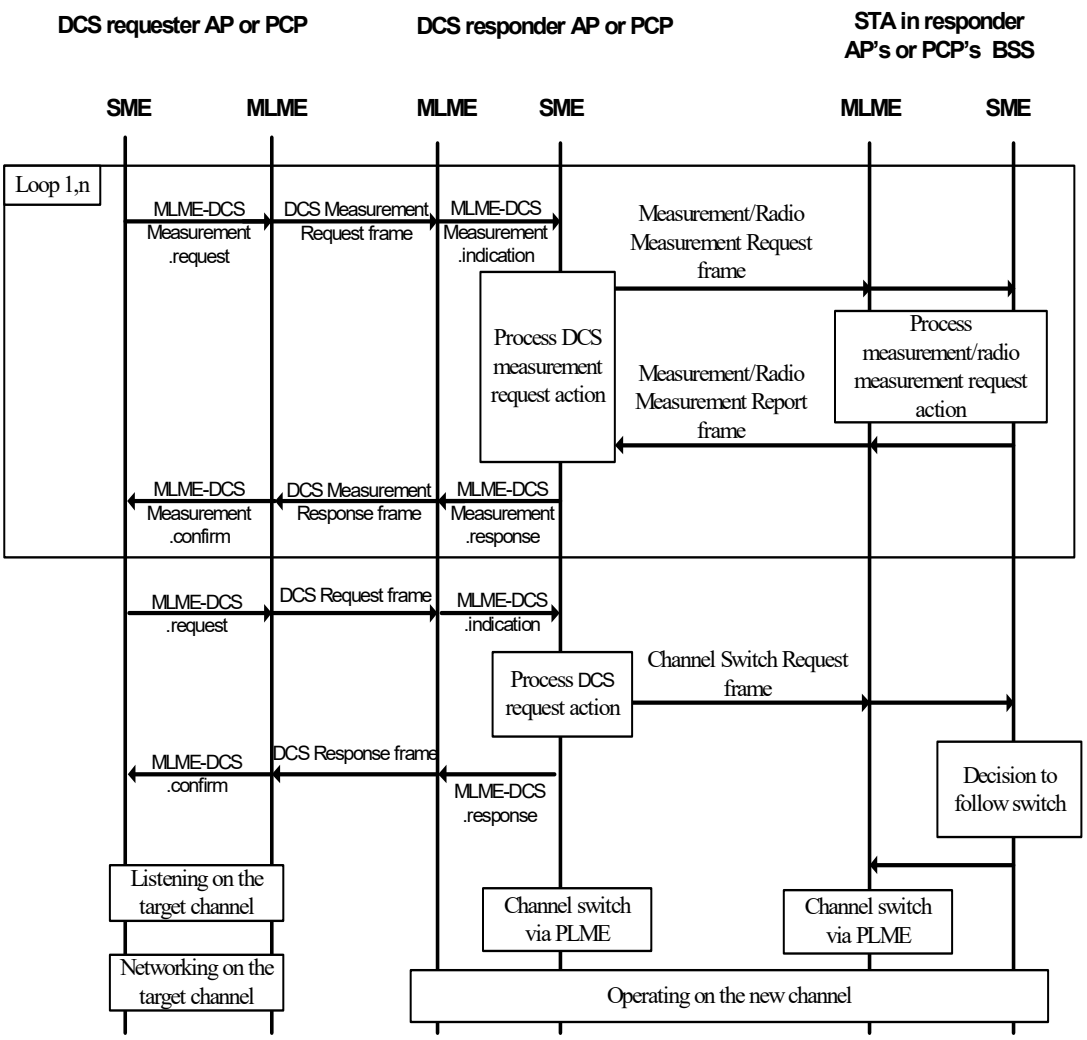


**Figure 11-103—Procedure of dynamic channel selection**

### 11.47.2 Assessing current channel condition

(#111)In order to start a new BSS, a DCS requester AP or PCP assesses an available channel passively by performing a channel scan or clear channel assessment (CCA) or by receiving one or more DMG Beacon frames sent by one or more APs or PCPs within one or more existing infrastructure BSSs or PBSSs. If the available channel bandwidth could not satisfy the operating requirements for RLANs, its AP or PCP can use the DCS procedure to request one or more existing infrastructure BSSs or PBSSs to move to a new operating channel.

### 11.47.3 Requesting measurements for new operating channel

A DCS requester AP or PCP shall send a DCS Measurement Request frame (see 9.6.7.37 (DCS Measurement Request frame format)) to a DCS responder AP or PCP to request one or more STAs in the DCS responder AP's or PCP's BSS to measure all other channels within its supported operating class if the DCS Measurement Request Mode field is equal to 1 or to measure one or more channels indicated by the Optional Subelements

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field if the DCS Measurement Request Mode field is equal to 0. The responder AP or PCP can decide to measure one or more channels requested by the DCS requester AP or PCP after receiving the DCS measurement request. The algorithm to choose the channel to be measured is beyond the scope of this standard.

A DCS responder AP or PCP can use radio measurement procedures (see 11.10 (Radio measurement procedures)) to perform channel measurement.

### 11.47.4 Reporting measurements

After receiving the results of channel measurement from all STAs, the DCS responder AP or PCP shall transmit a DCS Measurement Response frame (see 9.6.7.38 (DCS Measurement Response frame format)) to the DCS requester AP or PCP to report the results for the received DCS Measurement Request frame. The Measurement Report Mode field is set to 0 to indicate that there is no clear channel to which the DCS responder AP's or PCP's BSS to move within the operating class specified in the following Operating Class field, or the DCS responder AP or PCP has declined the DCS measurement request. The Measurement Report Mode field is set to 1 to indicate that all other channels within the operating class specified in the following Operating Class field are available for the DCS responder AP's or PCP's BSS. The Measurement Report Mode field is set to 2 to indicate that the clear channel that is available to the DCS responder AP's or PCP's BSS is indicated in the Optional Subelements field in the DCS Measurement Response frame.

A DCS Measurement Response frame shall contain the same value of the Dialog Token field as in the corresponding DCS Measurement Request frame.

A DCS responder AP or PCP can assess a DCS measurement request against its capabilities and the impact on its BSS's performance. The DCS responder AP or PCP may refuse the DCS measurement request for some reason such as the BSS is busy. The reasons for refusing a DCS measurement request are beyond the scope of this standard but may include reduced quality of service, unacceptable power consumption, measurement scheduling conflicts, or other significant factors.

### 11.47.5 Requesting existing BSS to migrate to a new channel

In order to operate on an occupied channel, a DCS requester AP or PCP should use the information of Supported Operating Class and the results of measurements undertaken by a DCS responder AP or PCP and other STA(s) within the same BSS to assist the selection of a new available channel for the DCS responder AP's or PCP's BSS. The algorithm to choose a new channel is beyond the scope of this standard, but shall satisfy applicable regulatory requirements, including uniform spreading rules and channel testing rules. A DCS requester AP or PCP shall request a DCS responder AP or PCP and other STA(s) in its BSS to migrate to a new available channel indicated in the received DCS Measurement Response frame by transmitting a DCS Request frame (see 9.6.7.39 (DCS Request frame format)) to the DCS responder AP or PCP.

The decision to switch to a new operating channel in a BSS shall be made by a DCS responder AP or PCP. If the DCS responder AP or PCP accepts the DCS request to change the operating channel after receiving a DCS Request frame, the DCS responder AP or PCP shall transmit a DCS Response frame (see 9.6.7.40 (DCS Response frame format)) to the DCS requester AP or PCP to confirm the received DCS request and then shall inform associated STAs that the AP or PCP is moving to a new channel and maintain the association by advertising the switch using Channel Switch Announcement elements or Extended Channel Switch Announcement element in one or more DMG Beacon frames, Probe Response frames, and Channel Switch Announcement frames until the intended channel switch time.

A DCS responder AP or PCP can assess a DCS request against its capabilities and the impact on its BSS's performance. A DCS request may be refused by a DCS responder AP or PCP for some reason such as the BSS is busy. The reasons for refusing a DCS request are beyond the scope of this standard but may include reduced quality of service, unacceptable power consumption, measurement scheduling conflicts, or other significant factors.


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### 11.47.6 Networking on the target channel

A DCS requester AP or PCP shall listen on the target channel after the intended channel switch time indicated by the Channel Switch Count field in a DCS Response frame. Once the PHY-CCA.indication(#4122) primitive indicates that the target channel is idle, the DCS requester AP or PCP can operate on the target channel with other STA(s) in its BSS.

## 11.48 CMMG BSS operation

### 11.48.1 Basic CMMG BSS functionality

A CMMG STA has dot11CMMGOptionImplemented equal to true.

(#181)A STA that is starting a CMMG BSS shall support receiving and transmitting at each of the <CMMG-MCS, NSS> tuple values indicated by the Basic CMMG-MCS and NSS Set field of the CMMG Operation parameter of the MLME-START.request primitive and shall support receiving at each of the <CMMG-MCS, NSS> tuple values indicated by the Supported CMMG-MCS and NSS Set field of the CMMG Capabilities parameter of the MLME-START.request primitive.

A STA that is a CMMG AP or a CMMG mesh STA declares its channel width capability in the Supported Channel Width Set subfield of the CMMG Capabilities element CMMG Capabilities Info field as described in Table 9-365 (Subfields of the CMMG Capabilities Info field).

A STA that is a CMMG AP or a CMMG mesh STA shall set the Channel Width subfield in the CMMG Operation element CMMG Operation Information field to indicate the BSS operating channel width as defined in Table 11-33 (CMMG BSS operating channel width).

**Table 11-33—CMMG BSS operating channel width**

| CMMG Operation element Channel Width field | BSS operating channel width (MHz) |
|---|---|
| 0 | 540 |
| 1 | 1080 |

A CMMG STA that is a member of a CMMG BSS shall not transmit a 540 MHz CMMG PPDU on a channel other than the primary 540 MHz channel of the BSS, except for a 540 MHz CMMG PPDU transmission on an off-channel TDLS direct link as constrained by 11.2 (Power management).

A CMMG STA shall not transmit to a second CMMG STA using a bandwidth that is not indicated as supported in the CMMG Capabilities element received from that CMMG STA.

### 11.48.2 Channel selection methods for a CMMG BSS

Before a STA starts a CMMG BSS, the STA shall perform a minimum of dot11CMMGOBSSScanCount OBSS scan operations to search for existing BSSs (see 11.38.3 (Scanning requirements for VHT STA)).

If an AP or a mesh STA starts a CMMG BSS that occupies some or all channels of any existing BSSs, the AP or mesh STA may select a primary channel of the new CMMG BSS that is identical to the primary channel of any one of the existing BSSs.

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If an AP or a mesh STA selects a primary channel for a new CMMG BSS with a 1080 MHz operating channel width from among the channels on which no beacons are detected during the OBSS scans, then the selected primary channel meets the following conditions:

— It shall not be identical to the secondary 540 MHz channel of any existing BSSs with a 1080 MHz operating channel width.

NOTE—An AP or a mesh STA operating a CMMG BSS with a 1080 MHz operating channel width, on detecting an OBSS whose primary channel is the AP's or the mesh STA's secondary 540 MHz channel, might switch to 540 MHz BSS operation and/or move to a different channel.

### 11.48.3 Scanning requirements for CMMG STAs

An OBSS scan operation is a passive or active scan of a set of channels that are potentially affected by CMMG BSS operation (see 11.1 (Synchronization)). Each channel in the set may be scanned more than once during a single OBSS scan operation. OBSS scans are performed by STAs that start a CMMG BSS.

During an individual scan within an OBSS scan operation, the minimum per-channel scan duration is dot11OBSSScanPassiveDwell TUs (for a passive scan) or dot11OBSSScanActiveDwell TUs (for an active scan). During an OBSS scan operation, each channel in the set is scanned at least once per dot11BSSWidthTriggerScanInterval seconds, and the minimum total scan time (i.e., the sum of the scan durations) per channel within a single OBSS scan operation is dot11OBSSScanPassiveTotalPerChannel TUs (for a passive scan) or dot11OBSSScanActiveTotalPerChannel TUs (for an active scan).

NOTE—The values provided in the previous paragraph are minimum requirements. For some combinations of parameter values, the minimum might be exceeded for some parameters in order to meet the minimum value constraints of other parameter.

### 11.48.4 Channel switching methods for a CMMG BSS

A CMMG AP announces a switch of operating channel by either of the following:

— Using the Channel Switch Announcement element, Channel Switch Announcement frame, or both, following the procedure described in 11.8 (DFS procedures).

— Using the Extended Channel Switch Announcement element, Extended Channel Switch Announcement frame, or both, following the procedure described in 11.9 (Extended channel switching (ECS))).

A CMMG mesh STA announces a switch attempt of operating channel by either of the following:

— Using the Channel Switch Announcement element, Channel Switch Announcement frame, or both, following the procedure described in 11.8.8.4 (MBSS channel switching).

— Using the Extended Channel Switch Announcement element, Extended Channel Switch Announcement frame, or both, following the procedure described in 11.9 (Extended channel switching (ECS)).

A CMMG AP or a CMMG mesh STA may also announce a switch of operating channel width, a new Country String field (possibly including a new Operating Class table number), new operating classes, or new TPC parameters for the BSS that come into effect at the same time as the switch of operating channel.

NOTE 1—Other means to switch the operating channel width are described in 11.40 (Notification of operating mode changes).

The New Channel Number field in the Channel Switch Announcement element, Extended Channel Switch Announcement element, Channel Switch Announcement frame, or Extended Channel Switch Announcement frame identifies the primary 540 MHz channel after the switch. The New Channel Number field is set to the value that dot11CurrentPrimaryChannel (see 25.10 (Channelization)) has after the switch.


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If a Channel Switch Announcement element in a Beacon frame or Probe Response frame is used to announce a switch to a 540 MHz operating channel width, then the Wide Bandwidth Channel Switch subelement in a Channel Switch Wrapper element shall not be present in the same frame.

If an Extended Channel Switch Announcement element in a frame or an Extended Channel Switch Announcement frame is used to announce a switch to a 540 MHz operating channel width, then the Wide Bandwidth Channel Switch subelement shall not be present in the same frame.

NOTE 2—The indicated operating class within the Extended Channel Switch Announcement element or frame is used to differentiate between a BSS operating channel width of 540 MHz and a BSS operating channel width greater than 540 MHz as well as indicate the location of the secondary 540 MHz channel. When switching to a 540 MHz operating channel width, the operating class indicated within the Extended Channel Switch Announcement element or frame has a channel spacing of 540 MHz. When switching to an operating channel width greater than 540 MHz, the operating class indicated within the Extended Channel Switch Announcement element or frame has a channel spacing of 1080 MHz.

If a Channel Switch Announcement element is used in a Beacon or Probe Response frame to announce a switch to a 1080 MHz operating channel width, then the Wide Bandwidth Channel Switch subelement in the Channel Switch Wrapper element shall also be present in the same frame.

If an Extended Channel Switch Announcement element is used in a Beacon or Probe Response frame to announce a switch to a 1080 MHz operating channel width, then the Wide Bandwidth Channel Switch subelement in the Channel Switch Wrapper element may be present in the same frame.

NOTE 3—The indicated operating class within the Extended Channel Switch Announcement element identifies the bandwidth and the relative position of the primary 540 MHz and secondary 540 MHz channels. Hence a Wide Bandwidth Channel Switch subelement is unnecessary when the Extended Channel Switch Announcement element is used for a channel switch to a 1080 MHz bandwidth.

If new BSS TPC parameters are announced that come into effect at the same time as the channel switch, then a STA that is a CMMG AP, a CMMG STA in an IBSS, or a CMMG mesh STA in an MBSS shall include

— At least one New CMMG Transmit Power Envelope element in a transmitted Channel Switch Announcement frame or Extended Channel Switch Announcement frame, and

— At least one New CMMG Transmit Power Envelope subelement in a transmitted (#383)Channel Switch Wrapper element in Beacon and Probe Response frames.

A recipient CMMG STA in the BSS that has dot11SpectrumManagementRequired or dot11RadioMeasurementActivated equal to true and that maintains association with the BSS after the switch shall use the parameters in these received elements and subelements in the recipient STA's TPC calculations for the new operating channel and operating channel width (see 11.7 (TPC procedures)). If both New CMMG Transmit Power Envelope elements and New CMMG Transmit Power Envelope subelements are transmitted for the switch, the set of New CMMG Transmit Power Envelope elements and set of subelements shall contain the same set of values for the Local Maximum Transmit Power Unit Interpretation subfield, and New CMMG Transmit Power Envelope elements and subelements that have the same value for the Local Maximum Transmit Power Unit Interpretation subfield shall also have the same values for their other fields.

If a new country string, new operating classes or both, are coming into effect at the same time as the channel switch, then a STA that is a CMMG AP, a CMMG STA in an IBSS, or a CMMG mesh STA in an MBSS shall include

— A New Country element in a transmitted Extended Channel Switch Announcement frame, and

— A New Country subelement in a transmitted (#383)Channel Switch Wrapper element.

The New Country element or subelement shall contain all the Operating Classes for the BSS after the switch. The New Country element or subelement, transmitted in an Extended Channel Switch Announcement frame or in the same frame as an Extended Channel Switch Announcement element, respectively, shall include

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one Operating Triplet field that contains the same Operating Class as the New Operating Class field in the Extended Channel Switch Announcement frame or Extended Channel Switch Announcement element.

A recipient CMMG STA in the BSS that has dot11MultiDomainCapabilityActivated, dot11SpectrumManagementRequired, or dot11RadioMeasurementActivated equal to true and that maintains association with the BSS after the switch shall use the parameters in these received elements and subelements in order to maintain regulatory compliance. If both New Country elements and New Country subelements are transmitted for the switch, their fields shall be the same.

A Channel Switch Wrapper element shall not be included in Beacon frames or Probe Response frames if the element contains zero subelements.

NOTE 4—Channel Switch Wrapper is not defined to carry subelements in the case of a switch to 540 MHz and when no change to the country string, operating classes, or TPC parameters are announced.

An AP that switches the BSS to a lower operating channel width may recalculate the TS bandwidth budget and may delete one or more active TSs by invoking the MLME-DELTS.request primitive(#314).

### 11.48.5 NAV assertion in a CMMG BSS

A CMMG STA shall update its NAV as described in 10.3.2.4 (Setting and resetting the NAV) using the Duration/ID field value in any frame that does not have an RA matching the STA's MAC address and that was received in a 540 MHz PPDU in the primary 540 MHz channel or received in a 1080 MHz PPDU.

NOTE—The PHY might filter out a PPDU as described in 25.13 (Receive procedure) or not receive a PPDU due to TXOP power saving described in 11.2.3.18 (CMMG TXOP power save). If so, frames in the PPDU are not received by the MAC and have no effect on the NAV.

### 11.48.6 CMMG STAs antenna indication

A CMMG STA that does not change its Rx antenna pattern after association shall set the Rx Antenna Pattern Consistency subfield in the CMMG Capabilities Info field to 1; otherwise, the STA shall set the Rx Antenna Pattern Consistency subfield in the CMMG Capabilities Info field to 0.

A CMMG STA that does not change its Tx antenna pattern after association shall set the Tx Antenna Pattern Consistency subfield in the CMMG Capabilities Info field to 1; otherwise, the STA shall set the Tx Antenna Pattern Consistency subfield in the CMMG Capabilities Info field to 0.

### 11.48.7 BSS basic CMMG-MCS and NSS set operation

The BSS basic CMMG-MCS and NSS set is the set of <CMMG-MCS, NSS> tuples that are supported by all CMMG STAs that are members of a CMMG BSS. It is established by the STA that starts the CMMG BSS, indicated by the Basic CMMG-MCS and NSS Set field of the CMMG Operation element in the MLME-START.request primitive. Other CMMG STAs determine the BSS basic CMMG-MCS and NSS set from the Basic CMMG-MCS and NSS Set field of the CMMG Operation element in the BSSDescription derived through the scan mechanism (see 11.1.4.1 (General)).

A CMMG STA shall not attempt to join (MLME-JOIN.request primitive) a BSS unless it supports (i.e., is able to both transmit and receive using) all the <CMMG-MCS, NSS> tuples in the BSS basic CMMG-MCS and NSS set.

A CMMG STA shall not attempt to (re)associate (MLME-ASSOCIATE.request and MLME-REASSOCIATE. request primitives) with a CMMG AP unless the STA supports (i.e., is able to both transmit and receive using) all the <CMMG-MCS, NSS> tuples in the Basic CMMG-MCS and NSS Set field in the CMMG Operation element transmitted by the AP.


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## 11.49 Reduced neighbor report

A Reduced Neighbor Report element contains information on neighbor APs, (#2210)colocated APs, or a combination of both. An AP that operates in the 2.4 GHz or 5 GHz band and that is in the same (#2210)colocated AP set as one or more 6 GHz APs shall follow the rules in 11.53 (Out-of-band discovery of a 6 GHz BSS(11ax)) for including a Reduced Neighbor Report element in Beacon and Probe Response frames. A Reduced Neighbor Report element might not be exhaustive either by choice or by the fact that there may be neighbor APs not known to the reporting AP. An AP that intends to report neighboring or (#2210)colocated APs may include more than one Reduced Neighbor Report element in a Beacon, Probe Response, or FILS Discovery frame if the reported APs do not all fit in a single Reduced Neighbor Report element; otherwise, it shall not include more than one Reduced Neighbor Report element.(11ax)

(11ax)An AP with dot11MultiBSSIDImplemented equal to true shall not include a Reduced Neighbor Report element in the Nontransmitted BSSID Profile subelement of the Multiple BSSID element.

NOTE 1—The Beacon, Probe Response, or FILS Discovery frame of an AP with dot11MultiBSSIDImplemented equal to true can carry a Reduced Neighbor Report element. In this case, the values of the fields in the Reduced Neighbor Report element apply to all the BSSs in the multiple BSSID set, except for the Same SSID subfield(s), whose value applies only to the BSS corresponding to the transmitted BSSID.

(11ax)If an AP reported in a TBTT Information field in a Reduced Neighbor Report element is not part of a multiple BSSID set, then the BSS Parameters subfield, if included, shall have the Multiple BSSID subfield set to 0. If an AP reported in a TBTT Information field in a Reduced Neighbor Report element is a transmitted BSSID, then the BSS Parameters subfield, if included, shall have the Multiple BSSID subfield set to 1 and the Transmitted BSSID subfield set to 1. If an AP reported in a TBTT Information field in a Reduced Neighbor Report element is a nontransmitted BSSID, then the BSS Parameters subfield, if included, shall have the Multiple BSSID subfield set to 1 and the Transmitted BSSID subfield set to 0.

(11ax)An HE AP with dot11MultiBSSIDImplemented equal to true may advertise one or more nontransmitted BSSIDs in the multiple BSSID set by including the Reduced Neighbor Report element in its Beacon, Probe Response, or FILS Discovery frames with the BSS Parameters subfield of the TBTT Information field containing the (#2210)Colocated subfield set to 1, the Multiple BSSID subfield set to 1, and the Transmitted BSSID subfield set to 0 and with the Operating Class and Channel Number subfields of the Neighbor AP Information field set to the operating class and channel number, respectively, of the transmitting AP (i.e., the transmitted BSSID).

(11ax)A reporting AP should set the OCT Recommended subfield to 1 in the BSS Parameters subfield of a TBTT Information field in a Reduced Neighbor Report element if both the reporting AP and the reported AP have dot11OCTOptionImplemented equal to true and the (#2210)Colocated AP subfield is 1 in the BSS Parameters subfield corresponding to the reported AP. A reporting AP may set the OCT Recommended subfield to 1 in the BSS Parameters subfield of a TBTT Information field in a Reduced Neighbor Report element if both the reporting AP and the reported AP have the same SSID and have dot11OCTOptionImplemented equal to true and the (#2210)Colocated AP subfield is 0 in the BSS Parameters subfield corresponding to the reported AP. If the OCT Recommended subfield is 1 and the (#2210)Colocated AP subfield is 1 in the Neighbor AP Information field describing a reported HE AP in the Reduced Neighbor Report element, then a non-AP STA that has dot11OCTOptionImplemented equal to true should use the OCT procedure described in 11.31.5 (On-channel Tunneling (OCT) operation) to perform active scanning, authentication, and/or association with the reported AP through over-the-air transmissions with the AP that sent the Reduced Neighbor Report element. If the OCT Recommended subfield is 1 and the (#2210)Colocated AP subfield is 0 in the Neighbor AP Information field describing a reported HE AP in the Reduced Neighbor Report element, then a non-AP STA that has dot11OCTOptionImplemented equal to true may use the OCT procedure described in 11.31.5 (On-channel Tunneling (OCT) operation) to perform active scanning, authentication, and/or association with the reported AP through over-the-air transmissions with the AP that sent the Reduced Neighbor Report element.

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The Reduced Neighbor Report element contains a list of operating classes and primary channels along with TBTT information for the reported neighbor APs on each operating class and primary channel. The operating class is selected from values in Table E-4 (Global operating classes) filtered by the requirement that, together with the Channel Number field, the primary channel be identifiable.

NOTE 2—For instance, this excludes operating class 128–130.

When the reporting AP cannot obtain an operating class that, together with the Channel Number field, identifies the primary channel from the neighboring AP, then the reporting AP shall report an operating class that, together with a channel number, identifies the primary channel of the reported BSS. Given a choice of operating classes that preserve the identification of the primary channel, the reporting AP should select an operating class that preserves as many behavior limits as possible are known to the reporting AP.

NOTE 3—An operating class might be unavailable because the neighboring AP does not transmit an operating class or the transmitted operating class does not indicate a primary channel.

A Reduced Neighbor Report element includes only channels that are consistent with the Country element in the frame in which the Reduced Neighbor Report element appears. The Reduced Neighbor Report element contents may be derived from the NeighborListSet parameter of the MLME-NEIGHBORREPRESP.request primitive. The contents of the Reduced Neighbor Report element might also be configured or obtained by other means beyond the scope of this standard.

If the Supported Operating Classes element of the STA is included in the Probe Request frame, the reduced neighbor report contains information on neighbor APs whose current operating class matches the supported operating classes in the Probe Request frame.

If the AP is a TVHT AP that transmits a Probe Response frame, the Filtered Neighbor AP subfield in the Neighbor AP Information field shall be set to 1 if the AP determines that the SSID corresponding to every AP in the Neighbor AP Information field matches the specific SSID in the corresponding Probe Response frame; otherwise it shall be set to 0.

NOTE 4—The Filtered Neighbor AP subfield is reserved when the Reduced Neighbor Report element is transmitted by a non-TVHT AP or by a TVHT AP in a frame other than a Probe Response frame (see 9.4.2.169.2 (Neighbor AP Information field)).

A serving AP shall include a value less than 255 in the Neighbor AP TBTT Offset subfield if it is able to guarantee an accumulated error of 1.5 TU or better.

(11bc)If an EBCS AP has at least one other EBCS AP in the neighborhood or co-located with it that belongs to the same EBCS AP group or EBCS certificate group, then it shall include in the Beacon and Probe Response frames that it transmits a Reduced Neighbor Report element with the TBTT Information Field Type subfield set to 1 and one or more TBTT Information fields, each carrying an EBCS Info Frame Tx Countdown field, which provides information about each of those APs. The Reduced Neighbor Report element may also carry information about non-EBCS APs.

(11bc)When an AP transmits a Reduced Neighbor Report element that includes more than one Neighbor AP Information field and they do not all carry the same value in the TBTT Information Field Type subfield, the AP shall order the Neighbor AP Information fields in increasing order of the values carried in the TBTT Information Field Type subfield.

A STA that receives a Neighbor AP Information field with an unrecognized TBTT Information Field Type subfield shall ignore the remainder of the Reduced Neighbor Report element.


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(11ax)A STA that receives a Neighbor AP Information field with a recognized TBTT Information Field Type subfield but an unrecognized TBTT Information Length subfield has two possible ways of processing the received information:

a) Ignore that Neighbor AP Information field, and continue to process the subsequent Neighbor AP Information fields, or

b) Process the first 13 octets of each TBTT Information field of the Neighbor AP Information field as if the TBTT Information Length subfield had value 13, ignore the remaining TBTT Information Length minus 13 octets of each TBTT Information field of the Neighbor AP Information field, and continue to process the subsequent Neighbor AP Information fields.

(11ax)If the unrecognized TBTT Information Length value is less than or equal to 13, the STA shall follow alternative a). If the unrecognized TBTT Information Length value is greater than 13, an HE STA shall follow alternative b), and a non-HE STA shall follow either alternative a) or b).

(11ax)If an AP that operates in the 2.4 GHz or 5 GHz band advertises in Reduced Neighbor Report elements a 6 GHz AP that is in the same (#2210)colocated AP set as itself, the AP shall include the 20 MHz PSD subfield in the TBTT Information field corresponding to that 6 GHz AP.

(11ax)When a 20 MHz PSD subfield is present in a TBTT Information field that reports a 6 GHz AP, its value shall be set such that the resulting allowed maximum transmit power for the primary 20 MHz channel is equal to the minimum of the regulatory client maximum transmit powers indicated by the Transmit Power Envelope element(s) transmitted by the reported AP in Beacon and Probe Response frames.

NOTE 5—Country-specific operating requirements that relate to use of the Reduced Neighbor Report element are defined in E.2.7 (6 GHz band(11ax)(#600)). (11ax)

NOTE 6—A 20 MHz PSD subfield in a Reduced Neighbor Report element sent in Beacon and Probe Response frames by an AP that is in the same (#2210)colocated AP set as a 6 GHz AP can be used by a STA to determine a local transmit power limit for 20 MHz PPDUs corresponding to a 6 GHz AP, prior to having received a Beacon or Probe Response frame from that AP. The value in the 20 MHz PSD subfield can be used by any STA, although for some categories it may result in determination of a lower transmit power limit than would be determined by (subsequent) reception of a Transmit Power Envelope element. A STA might, for example, determine a transmit power limit based on this information when sending a Probe Request frame with 20 MHz PPDU bandwidth during active scanning on the 6 GHz AP's channel.(11ax)

## 11.50 GLK operation

### 11.50.1 General

GLK STAs are capable of creating general links with other GLK STAs, that can be used as links within an IEEE 802.1Q bridged network. Such links (1) include facilities to send group addressed Data frames to a subset of receiving GLK STAs including use of improved GCR mechanisms, (2) can be mapped to the IEEE 802.1Q Internal Sublayer Service, and (3) provide link metrics appropriate for use by IEEE 802.1Q bridges in making routing decisions.

When dot11GLKImplemented is true, the STA is a GLK STA and dot11QosOptionImplemented shall be true. A STA advertises its GLK capability using the GLK field of the Extended Capabilities element (see 9.4.2.25 (Extended Capabilities element)). dot11GLKImplemented is true if a STA implements the GLK facility, and false or absent otherwise.(#7220)

The Supported Rates and BSS Membership Selectors or Extended Supported Rates and BSS Membership Selectors elements shall include the GLK selector if dot11GLKRequired is true.

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If dot11GLKRequired is true, every association or mesh peering created by the STA shall establish a general link.

In an IBSS, if dot11GLKRequired is not true, general links shall not be established.

A GLK STA shall support SYNRA operations as described in 10.64 (Addressing of GLK Data frame transmission) and 10.65 (SYNRA filtering operation).

### 11.50.2 Reported general link metrics

The bridge management protocols in IEEE Std 802.1Q require link metrics for each general link. GLK STAs shall provide metrics for their general links as follows:

- dot11GLKLinkRawRate, which is the maximum rate at which the GLK STA is capable of transmitting, given its available features and those of the STA with which it is communicating.
- For a windowed set of link rate samples:
  - The minimum
  - The arithmetic mean
  - The geometric mean
  - The standard deviation
  - A composite link rate

NOTE—The passing of link metrics from a GLK STA to the attached IEEE 802.1Q bridge is implementation dependent.

A GLK STA shall maintain an array of sample window data rates for each of its general links. Each such array consists of rate sample windows R[0] to R[N+1] in units of 100 kb/s, where N is the value of dot11GLKLinkRateSamples. Each sample window covers a time period of dot11GLKLinkRateWindowSize×16 TUs. When the association or peering is created, R[0] to R[N+1] are initialized to the lowest data bit rate the STA is configured to use.

Every dot11GLKLinkRateWindowSize×16 TUs, the following steps occur in the order given:

**Step 1:** The data rate sample array is shifted with the value of R[N+1] being discarded, each R[K] is set to the value of R[K-1] for K from N+1 to 1, and R[0] is set as follows:

- Zero if all attempts to transmit data during the window failed.
- The arithmetic mean data rate in units of 100 kb/s of successful transmissions in the window if there were any successful transmissions.
- The data rate that would have been attempted if there were no attempts to transmit data during the window.

**Step 2:** The minimum, arithmetic mean, geometric mean, and standard deviation of the data rates in the sample array entries are calculated as follows:

- The minimum rate is $R_{\text{min}}$, the array entry with the smallest magnitude.
- The arithmetic mean is

$$R_{\text{avg}} = \left\lfloor \left( \sum_{i=0}^{N+1} R[i] \right) / (N+2) \right\rfloor$$


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— The geometric mean is

$$R_{\text{geo}} = \left\lfloor \sqrt[N+2]{\prod_{i=0}^{N+1} (R[i]+1)} \right\rfloor$$

— The standard deviation is

$$R_{\text{std}} = \left\lfloor \sqrt{\left( \sum_{i=0}^{N+1} (R[i] - R_{\text{avg}})^2 \right) / (N+1)} \right\rfloor$$

These are available as dot11GLKLinkMinRate, dot11GLKLinkAvgRate, dot11GLKLinkGeoRate, and dot11GLKLinkSTDRate.

**Step 3:** A composite data rate is then computed using non-negative weights $W$ as follows:

$$R_{\text{composite}} = \left\lfloor \frac{W_{\text{min}} \times R_{\text{min}} + W_{\text{avg}} \times R_{\text{avg}} + W_{\text{geo}} \times R_{\text{geo}}}{1 + W_{\text{min}} + W_{\text{avg}} + W_{\text{geo}}} \right\rfloor$$

where

$W_{\text{min}}$ is dot11GLKLinkRateWmin
$W_{\text{avg}}$ is dot11GLKLinkRateWavg
$W_{\text{geo}}$ is dot11GLKLinkRateWgeo

**Step 4:** A rate is then computed from $R_{\text{composite}}$.

$$R_{\text{current}} = \left\lfloor (R_{\text{composite}} \times 16) / \text{dot11GLKLinkRateScaling} \right\rfloor$$

**Step 5:** The first $R_{\text{reported}}$ for a general link is $R_{\text{current}}$ as determined in step 4. Subsequent values of $R_{\text{reported}}$ are subject to hysteresis based on dot11GLKLinkRateHysteresis. If the previous $R_{\text{reported}}$ is greater than the new $R_{\text{current}} \times$ dot11GLKLinkRateHysteresis/256 and less than the new $R_{\text{current}} \times 256$/dot11GLKLinkRateHysteresis, then the new $R_{\text{reported}}$ is unchanged from the previous $R_{\text{reported}}$. In all other cases, the new $R_{\text{reported}}$ is the new $R_{\text{current}}$. $R_{\text{reported}}$ is available in the per association, direct link, or peering GLK Link dot11GLKLinkRateReported.

In the case of transparent FST, the general link metric is measured relative to the single presented MAC SAP regardless of which PHY is used to exchange MSDUs.

## 11.51 EPD operation

A STA operating in the 5.9 GHz bands is an EPD STA and dot11EPDimplemented shall be set to true or not present. For an EPD STA not operating in the 5.9 GHz bands, dot11EPDImplemented shall be set to true. For a STA that is not EPD, dot11EPDImplemented shall be set to false or not present. When an EPD STA is not operating in the 5.9 GHz bands the EPD subfield is set to 1 in the Capability Information and DMG STA Capability Information fields.

The Supported Rates and BSS Membership Selectors or Extended Supported Rates and BSS Membership Selectors elements shall include the EPD selector if dot11EPDRequired is true.

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See also 5.1.4 (MSDU format).

## 11.52 Beacon protection procedures(#8133)

In an infrastructure BSS, (#1486)when beacon protection is enabled at the non-AP STA, the MLME shall provide an encapsulation service for Beacon frames. All Beacon frames shall be submitted to this service for protection processing.

If dot11BeaconProtectionEnabled is true, the AP shall enable beacon protection and set the Beacon Protection Enabled field of the Extended Capabilities element to 1 to indicate that beacon protection is enabled(#1487). Otherwise, the field shall be set to 0.

If dot11BeaconProtectionEnabled is true and a non-AP STA receives a BIGTK from the AP with which it is associated, the non-AP STA shall enable beacon protection. (#1486)Otherwise, beacon protection is not enabled at the non-AP STA.

NOTE 1—In a multiple BSSID set, a non-AP STA receives BIGTK from its associated AP (which can correspond to either the transmitted BSSID or nontransmitted BSSID) and uses it for validating the contents of the Beacon frame transmitted by the AP corresponding to the transmitted BSSID.(#10)

The beacon protection service shall take the following actions:

— (#8133)Beacon protection shall be set using the MLME-SETPROTECTION.request primitive with the Protectlist including a Key Type value of BIGTK. A non-AP STA shall also set the Protect Type value to Rx. An AP shall set the Protect Type value to Tx.

— The BIGTK shall be installed using the MLME-SETKEYS.request primitive with the value BIGTK for the Key Type parameter.

— The Beacon frames shall be encapsulated and protected using BIP (see 12.5.3 (Broadcast/multicast integrity protocol (BIP))).

— The protected Beacon frames shall be decapsulated and validated using BIP (see 12.5.3 (Broadcast/multicast integrity protocol (BIP))).

If dot11RSNAProtectedManagementFramesActivated is false, dot11BeaconProtectionEnabled shall be set to false.

If OCVC(#3505) is not present in a non-AP STA or if the current AP does not advertise OCVC(#3505), but beacon protection is enabled, the non-AP STA shall verify that the operating channel information in the first received Beacon frame that has been validated using BIP matches the current operating channel parameters. If there is a mismatch, the non-AP STA shall disassociate from the AP.

(#8037)If SSID protection is not supported by a non-AP STA or if the current AP does not advertise support for SSID protection, but beacon protection is enabled, the non-AP STA should verify that the received Beacon frames that have been validated using BIP are consistent with the SSID that was indicated in the (Re)Association Request frame for the current association and if the non-AP STA does not receive consistent information about the SSID in protected Beacon frames, the non-AP STA should disassociate from the AP.

(#8037)NOTE 2—A matching SSID might be indicated in the SSID element or in a Nontransmitted BSSID Profile subelement in a Multiple BSSID element.

Beacon protection is not supported in an IBSS, MBSS or PBSS.(#3304)


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## 11.53 Out-of-band discovery of a 6 GHz BSS(11ax)

An AP that operates in the 2.4 GHz or 5 GHz band and that is in the same (#2210)colocated AP set as one or more 6 GHz APs shall include in Beacon and Probe Response frames that it transmits a Reduced Neighbor Report element with the (#2210)Colocated AP subfield in the BSS Parameters subfield in the TBTT Information field set to 1 to provide at least the operating channels and operating classes of those 6 GHz APs.

NOTE 1—The Reduced Neighbor Report element might contain information on 6 GHz APs that are not in the same co-located AP set as the transmitting AP. In this case the (#2210)Colocated AP subfield is set to 0.

An AP responds to a probe request by following the rules defined in 11.1.4.3.4 (Criteria for sending a response).

If neither of the following conditions is met:

— The AP transmits an individually addressed Probe Response frame to a STA that has signaled that it does not support operating in the 6 GHz band (see 9.4.2.52 (Supported Operating Classes element)), nor

— The AP operating in the 6 GHz band does not intend to be discovered by STAs,

then the following applies:

— If an AP operating in the 2.4 GHz or 5 GHz band is in the same (#2210)colocated AP set as one or more 6 GHz APs and has the same SSID as those 6 GHz APs, then the Beacon and Probe Response frames transmitted by the AP or by the transmitted BSSID of the same Multiple BSSID set as the AP shall include, for each of these 6 GHz APs, a TBTT Information field in a Reduced Neighbor Report element with the BSSID field set to the BSSID of the 6 GHz AP, and with either the Short SSID field set to the short SSID of the 6 GHz AP or the Same SSID subfield in the BSS Parameters subfield set to 1.

— If an AP operating in the 2.4 GHz or 5 GHz band is in the same (#2210)colocated AP set as a 6 GHz AP and has a different SSID, and if no other AP in the same (#2210)colocated AP set and operating in the 2.4 GHz or 5 GHz band is indicating the 6 GHz AP in a Reduced Neighbor Report element of the Beacon and Probe Response frames it transmits, then Beacon and Probe Response frames transmitted by the AP (or by the transmitted BSSID of the same Multiple BSSID set as the AP) shall include a TBTT Information field in a Reduced Neighbor Report element with the BSSID field and the Short SSID field set to the BSSID and short SSID of the 6 GHz AP, respectively.

If the AP reported in the TBTT Information field in the Reduced Neighbor Report element is a 6 GHz AP, the reporting AP shall include the BSS Parameters subfield in the TBTT Information field and shall follow the rules in 11.49 (Reduced neighbor report) to set the Multiple BSSID subfield, the Transmitted BSSID subfield, the (#2210)Colocated AP subfield, and the OCT Recommended subfield.

A STA receiving a frame containing a Reduced Neighbor Report element describing a reported 6 GHz AP with the OCT Recommended subfield set to 1 in the BSS Parameters subfield shall follow the rules in 11.49 (Reduced neighbor report) to perform active scanning, authentication, and/or association with the reported AP.

An AP that operates in the 2.4 GHz or 5 GHz band and that is in the same (#2210)colocated AP set as one or more 6 GHz APs shall include the Advertisement Protocol element in Beacon and Probe Response frames that it transmits and shall support responding with a Neighbor Report ANQP-element (9.4.5.19 (Neighbor Report ANQP-element)) carrying one or more Neighbor Report elements (see 9.4.2.35 (Neighbor Report element)) that include at least the SSID information of all the 6 GHz APs in the same (#2210)colocated AP set, except the 6 GHz APs that do not intend to be discovered.

NOTE 2—The Neighbor Report ANQP-element can also carry Neighbor Report elements containing information on 6 GHz APs that are not in the same (#2210)colocated AP set.

NOTE 3—The AP might respond with a GAS comeback delay of zero.

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NOTE 4—If the Same SSID subfield is(M118) 0 in the BSS Parameters of a reported 6 GHz AP, a non-AP STA that does not know the short SSID of the reported 6 GHz AP and that intends to discover the SSID of the reported 6 GHz AP might:

a) Use the OCT procedure described in 11.31.5 (On-channel Tunneling (OCT) operation) to send a Probe Request frame to the reported AP through over-the-air transmissions with the reporting AP, if the OCT Recommended subfield is 1 in the Neighbor AP Information field describing the reported AP.
b) Use the ANQP procedure described in 11.22.3.3 (ANQP procedures) to send an ANQP request with a Query ID corresponding to Neighbor Report to the reporting AP to retrieve the SSID of the 6 GHz APs, including the reported AP.
c) Send a Probe Request frame to the reported AP including the BSSID of the reported AP.
d) Send a Probe Request frame to the reported AP including the short SSID of the reported AP.
e) Perform passive scanning in the operating channel of the reported AP.

(#2310)An AP may set the Unsolicited Probe Responses Active subfield to 1 for a reported AP in a Reduced Neighbor Report element or Neighbor Report element in a frame it transmits, if all 6 GHz APs, of the same ESS as the reported AP that operate in the same channel as the reported AP, are on the same channel and in range of a STA receiving this frame, have dot11UnsolicitedProbeResponseOptionActivated equal to true and are transmitting unsolicited Probe Response frames every 20 TUs (see 26.17.2.3.2 (AP behavior for fast passive scanning)). Otherwise, the AP shall set the Unsolicited Probe Responses Active subfield to 0.

(#2310)An AP may set the Member Of ESS With 2.4/5 GHz (#2210)Colocated AP subfield to 1 in a Reduced Neighbor Report element in a frame it transmits, if the reported AP is a 6 GHz AP, is part of an ESS where all the APs in the ESS that is operating in the same band as the reported AP and are on the same channel and in range of a STA receiving this frame (irrespective of the operating channel), have dot11MemberOfColocated6GHzESSOptionActivated equal to true and have a corresponding AP operating in the 2.4 GHz or 5 GHz band that is in the same (#2210)colocated AP set as that AP.

NOTE 5—This subfield indicates that the reported AP is part of an ESS that has no 6 GHz-only APs that might be detected by a STA receiving this frame. In other words, all 6 GHz APs that are part of that ESS that might be detected by a STA receiving this frame can be discovered in the 2.4 GHz and/or 5 GHz bands.

## 11.54 TDD channel access operation(11ay)

### 11.54.1 General

In a TDD SP, co-channel interference mitigation requires managing the TDD schedule in each stage of the TDD channel access life cycle. The TDD schedule may change during the TDD channel access life cycle. If a device uses co-channel coordinated management operation (see 4.9.5 (Reference model for co-channel coordinated management operation(11ay))), different STAs in the device may coordinate the configuration of the DMG antennas and the TDD schedule to mitigate the co-channel interference.


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### 11.54.2 TDD channel access life cycle

Figure 11-104 (Example of TDD channel access life cycle(11ay)) summarizes an exemplary TDD channel access life cycle.

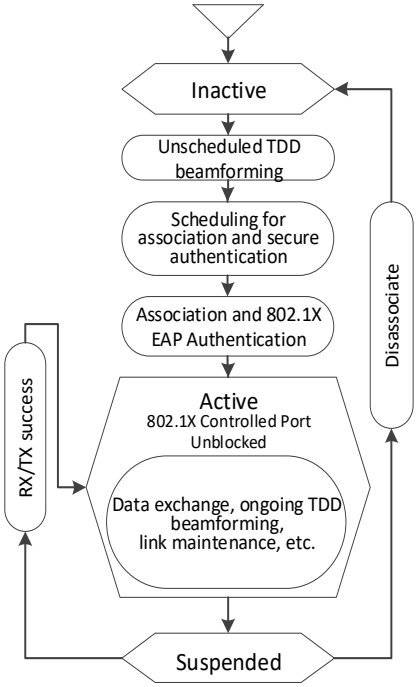


**Figure 11-104—Example of TDD channel access life cycle(11ay)**

Initially, a STA is inactive and not performing any TDD channel access. In this phase, the STA shall not transmit any MPDUs.

The TDD channel access life cycle includes the following phases:

- Unscheduled TDD beamforming
- Scheduling of the TDD channel access for association and secure authentication
- Association and secure authentication
- Scheduling of the TDD channel access for data traffic, ongoing beamforming and link maintenance
- Data exchange accompanied by beamforming and link maintenance

The term *unscheduled TDD beamforming* is used in this subclause to refer to the TDD beamforming scheduled via the Transmit Period field within a TDD SSW frame. TDD beamforming is defined in 11.36.2 (TDD beamforming(11ay)), 11.36.3 (TDD sector switch procedure(11ay)), 11.36.4 (TDD beam measurement(11ay)), and 10.41.10 (EDMG beamforming(11ay)). Scheduling for association, secure authentication, and relevant operations are defined in 11.54.3 (Scheduling for association and secure authentication). TDD channel access becomes active for data transfer (i.e., an MSDU may be transmitted) after successful completion of a secure authentication. Scheduling for data traffic is defined in 11.54.4 (Scheduling for data traffic). Data traffic transfer under TDD channel access is defined in 10.38.6.2.2 (SP with TDD channel access(11ay)) and link maintenance is defined in 10.42.5 (TDD link maintenance(11ay)).

TDD channel access becomes inactive when an implementation dependent number of frames can no longer be successfully delivered.

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An AP (or PCP) shall transmit at least one MPDU with Ack Policy Indicator subfield set to Normal Ack or Implicit BAR in the first TDD slot assigned to each non-AP (or non-PCP) STA following a DMG Beacon transmission. TDD channel access is suspended if an expected MPDU transmission does not succeed within the AckTimeout (see 10.3.2.11 (Acknowledgment procedure)). A beamformed link is considered lost if no successful MPDU transmission takes place during dot11MaxLostBeacons beacon intervals starting at the beacon interval containing the TDD slot where the AP's (or PCP's) MPDU transmission with Ack Policy Indicator subfield set to Normal Ack or Implicit BAR is expected to take place. A STA shall initiate the dissociation procedure at the indication of a link loss. To do that, the AP (or PCP) shall proceed as defined in 11.3.5.8 (AP or PCP disassociation initiation procedure) and 11.3.5.9 (AP or PCP disassociation receipt procedure), and use Reason Code field equal to MISSING_ACKS; the non-AP (or non-PCP) STA shall proceed as defined in 11.3.5.6 (Non-AP and non-PCP STA disassociation initiation procedures) and 11.3.5.7 (Non-AP and non-PCP STA disassociation receipt procedure), and use Reason Code field equal to REASON_INACTIVITY. As part of the disassociation procedure, the STA may optionally transmit the Disassociation frame at the first assigned TDD slot following the link loss indication.

### 11.54.3 Scheduling for association and secure authentication

The schedule for the association and secure authentication is delivered by an AP STA (or PCP STA) via the transmission of an Announce frame at the completion of the unscheduled TDD beamforming as defined in 10.41.11.2 (Initiator operation for TDD individual beamforming), 10.41.11.4 (Initiator operation for TDD group beamforming), and 11.36.2 (TDD beamforming(11ay)). The Announce frame shall use the category Unprotected DMG. The Announce frame conveys the TDD Slot Structure element and the TDD Slot Schedule element (see 10.38.6.2.2 (SP with TDD channel access(11ay))). The message diagram is shown in Figure 11-105 (Scheduling for association and secure authentication(11ay)).

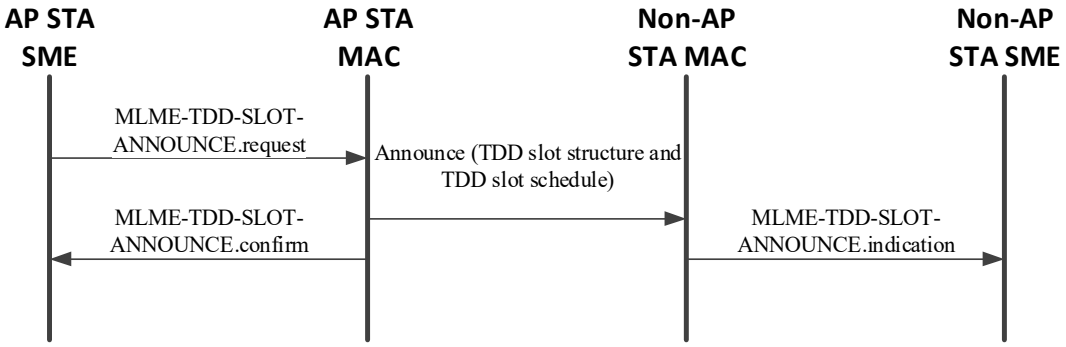


**Figure 11-105—Scheduling for association and secure authentication(11ay)**

Association shall be performed as defined in 11.3.5 (Association, reassociation, and disassociation) according to DMG infrastructure BSS, in case of an AP STA, or PBSS, in case of a PCP STA. Secure authentication shall be performed as defined in 12.5 (RSNA confidentiality and integrity protocols) through 12.9 (Authenticated mesh peering exchange (AMPE)).

Prior to performing association and authentication, the SME of the non-AP may issue an MLME-SCAN.request primitive with ScanType parameter set to ACTIVE to transmit an individually addressed Probe Request frame to the AP STA (or PCP STA) and, as a result, solicit a Probe Response frame from the AP STA (or PCP STA).

Transmission and acknowledgment of Management and Data frames shall follow rules defined in 10.38.6.2.2 (SP with TDD channel access(11ay)).


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The 802.1X (#1909)Controlled Port is unblocked after completion of the 802.1X EAP Authentication, after which time the TDD channel access becomes active for data transmission (see 12.6.7 (RSN management of the IEEE 802.1X Controlled Port)).

### 11.54.4 Scheduling for data traffic

There are a few options to deliver the TDD schedule for data transmission and related functionality. Figure 11-106 (Local delivery of TDD schedule(11ay)) illustrates an option that assumes co-channel coordinated management operation (see 4.9.5 (Reference model for co-channel coordinated management operation(11ay))), where both STAs belong to the same device. In this case, the SME delivers the TDD schedule to a STA and the MLME primitives are local and do not cause a frame to be transmitted.

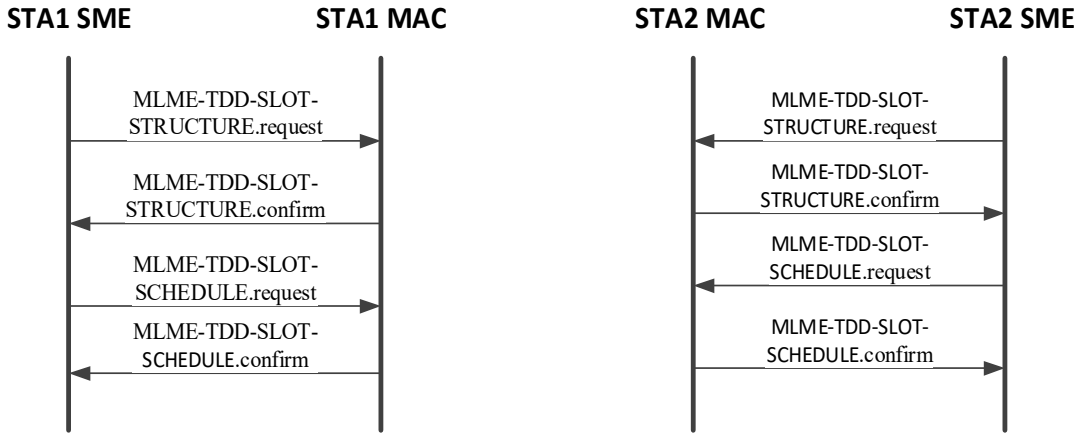


**Figure 11-106—Local delivery of TDD schedule(11ay)**

Figure 11-107 (Delivery of TDD schedule by an AP(11ay)) illustrates an option where an AP (or PCP) delivers the schedule to a non-AP STA (or non-PCP STA). The AP may choose to reserve an amount of time to satisfy the bandwidth request contained in a TDD Bandwidth Request element received from the non-AP STA. The schedule delivered by the AP may be a response to a bandwidth request from the non-AP STA or initiated by the AP without receiving a request from the non-AP STA. Announce frames of a category equal to DMG Action shall be used to deliver the elements for the case defined in 12.6.18 (Robust management frame selection procedure); otherwise, the category equal to Unprotected DMG Action shall be used.

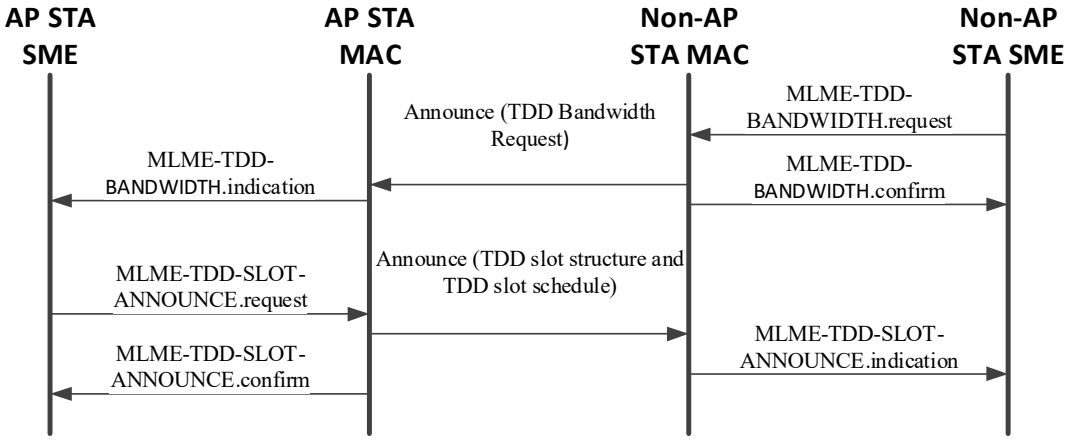


**Figure 11-107—Delivery of TDD schedule by an AP(11ay)**

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An AP (or PCP) and non-AP STA (or non-PCP STA) that belong to different devices may exchange TDD Slot Schedule elements to notify each other of the use of TDD slots. The non-AP STA (or non-PCP STA) may indicate that it is not able to use a TDD slot by specifying the TDD slot as unavailable (see 10.38.6.2.2 (SP with TDD channel access(11ay))). Figure 11-108 (Mutual delivery of TDD schedule(11ay)) illustrates this case. Announce frames of a category equal to DMG Action shall be used to deliver the elements for the case defined in 12.6.18 (Robust management frame selection procedure); otherwise, the category equal to Unprotected DMG Action shall be used.

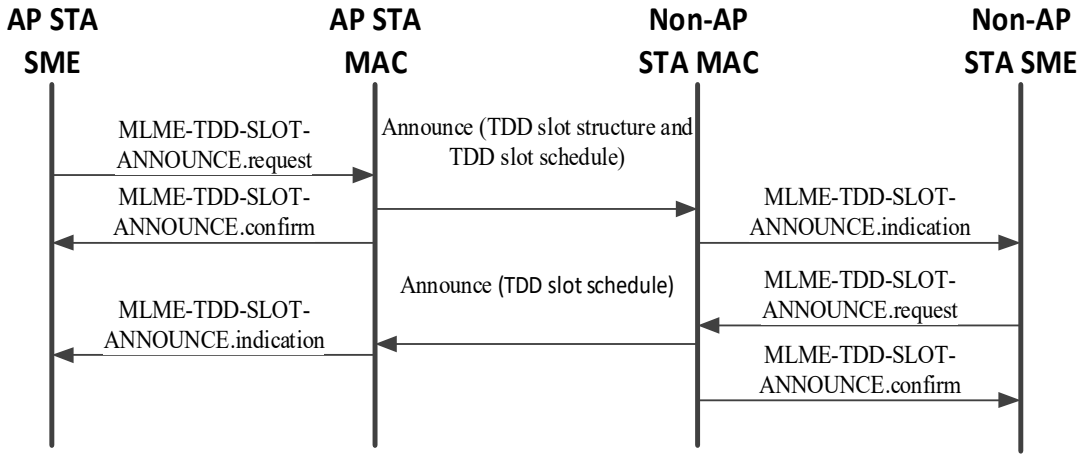


**Figure 11-108—Mutual delivery of TDD schedule(11ay)**


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# 12. Security

## 12.1 Conventions

(#3620)In the context of Clause 12 (Security) and Clause 13 (Fast BSS transition)(#4294), reserved fields and subfields are set to 0 upon transmission and are ignored upon reception.

ASCII and UTF-8 strings are defined in 1.4 (Word usage).

(#1951)*Masking out* refers to forcing certain bits in copies of fields in another structure to 0. The original field itself is not modified.

## 12.2 Framework

### 12.2.1 Classes of security algorithm

This standard defines two classes of security algorithms for IEEE 802.11 networks:

— Algorithms for creating and using an RSNA, called *RSNA algorithms*

— Pre-RSNA algorithms(#3056)

The use of TKIP is (#1643)obsolete. The TKIP algorithm is unsuitable for the purposes of this standard.

### 12.2.2 Security methods

Pre-RSNA security comprises (#3056)IEEE 802.11 entity authentication, described in 12.3.3 (Pre-RSNA authentication)

RSNA security comprises the following algorithms and procedures:

— TKIP, described in (#3127)12.3.4 (Temporal key integrity protocol (TKIP)(#1077))

(#1433)NOTE—TKIP is not however considered a robust security network mechanism.

— CCMP, described in 12.5.2 (CTR with CBC-MAC protocol (CCMP))

— GCMP, described in 12.5.4 (GCM protocol (GCMP))

— BIP, described in 12.5.3 (Broadcast/multicast integrity protocol (BIP))

— RSNA establishment and termination procedures, including use of IEEE 802.1X authentication, described in 12.6 (RSNA security association management), SAE authentication described in 12.4 (Authentication using a password), and OWE described in 12.14 (Opportunistic Wireless Encryption(#6088))(#6088)(#1084).

— Key management procedures, described in 12.7 (Keys and key distribution)

The RSN operations in a CMMG BSS shall be the same as the RSN operations in a DMG BSS.

### 12.2.3 RSNA STA capabilities

(#1852)When dot11RSNAActivated is true, a STA uses the RSNE to advertise support for RSNAs. When dot11RSNAActivated is true, a DMG STA shall set the DMG Privacy subfield to 1 within transmitted DMG Beacon frames. A pre-RSNA STA is not capable of creating RSNAs.

All STAs implementing RSNA shall support the RSNE described in 9.4.2.23 (RSNE).

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### 12.2.4 RSNA establishment

(#1084)An SME establishes an RSNA in one of seven ways:

a) If an RSNA uses authentication negotiated over IEEE Std 802.1X or FILS authentication in an infrastructure BSS, an SME(#3233) establishes an RSNA as follows:

1) It identifies the AP as (#3125)an RSNA AP from the AP's Beacon, DMG Beacon, Announce, Information Response, FILS Discovery, or Probe Response frames.(#3121)

2) It shall invoke Open System or FILS authentication if the STA is a non-DMG STA.

3) It negotiates cipher suites during the association process, as described in 12.6.2 (RSNA selection) and 12.6.3 (RSNA policy selection in an infrastructure BSS).

4) It uses (#3469)IEEE Std 802.1X-2020 to authenticate, as described in 12.6.8 (RSNA establishment in an infrastructure BSS(#1084)) and 12.6.9 (RSNA authentication in an IBSS), FT protocol to authenticate as described in 13.5 (FT protocol) or uses FILS authentication to authenticate as described in 12.11 (Authentication for FILS).(#3122)

5) It establishes one or more temporal keys by executing a key management algorithm, using the protocol defined by 12.7 (Keys and key distribution) or 13 (Fast BSS transition).

6) It protects the data link by programming the negotiated cipher suites and the established temporal key(s)(#3124) into the MAC and then invoking protection. See, for example, 12.5.2 (CTR with CBC-MAC protocol (CCMP)) for a description of the RSNA data protection mechanisms.

7) If the STAs negotiate management frame protection, the SME programs the TK and pairwise cipher suite into the MAC for protection of individually addressed robust Management frames. It also installs the IGTK and IPN for protection of group addressed robust Management frames.

8) If beacon protection is enabled, the SME programs the BIGTK and BIPN into the MAC for the protection of Beacon frames.

9) (11ba)If the STAs negotiate WUR frame protection, the SME programs the WTK and WTPN into the MAC for protection of individually addressed WUR Wake-up frames, and programs the WIGTK and WIPN into the MAC for the protection of broadcast and group addressed WUR Wake-up frames.

b) If an RSNA is based on a PSK or password in an infrastructure BSS, an SME(#3233) establishes an RSNA as follows:

1) It identifies the AP as an RSNA AP from the AP's Beacon, DMG Beacon, Announce, Information Response, or Probe Response frames.

2) If the RSNA AP advertises support for SAE authentication in its Beacon or Probe Response frames, and the STA has a group defined in the dot11RSNAConfigDLCGroupTable and a password for the AP in the dot11RSNAConfigPasswordValueTable, the STA shall invoke SAE authentication to establish a PMK. If the RSNA AP does not advertise support for SAE authentication in its Beacon and Probe Response frames but advertises support for the alternate form of PSK authentication (see 4.10.3.4 (Alternate operations with PSK)), and the STA also supports the alternate form of PSK authentication, the non-DMG STA may invoke Open System authentication and use the PSK as the PMK with the key management algorithm in step 4) below.

3) It negotiates cipher suites during the association process, as described in 12.6.2 (RSNA selection) and 12.6.3 (RSNA policy selection in an infrastructure BSS).

4) It establishes one or more temporal keys by executing a key management algorithm, using the protocol defined by 12.7 (Keys and key distribution) or Clause 13 (Fast BSS transition).(#3123)

5) It protects the data link by programming the negotiated cipher suites and the established temporal key(s)(#3124) into the MAC and then invoking protection.


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6) If the STAs negotiate management frame protection, the SME programs the TK and pairwise cipher suite into the MAC for protection of individually addressed robust Management frames. It also installs the IGTK and IPN for protection of group addressed robust Management frames.

7) If beacon protection is enabled, the SME programs the BIGTK and BIPN into the MAC for the protection of Beacon frames.

8) (11ba)If the STAs negotiate WUR frame protection, the SME programs the WTK and WTPN into the MAC for protection of individually addressed WUR Wake-up frames, and programs the WIGTK and WIPN into the MAC for the protection of broadcast and group addressed WUR Wake-up frames.

c) If an RSNA is based on a PSK or password in an IBSS an SME(#3233) establishes an RSNA as follows:

1) It identifies the peer as an RSNA STA from the peer's Beacon, DMG Beacon, Announce, Information Response, or Probe Response frames.

NOTE 1—STAs might respond to a Data frame from an unrecognized STA by sending a Probe Request frame to find out whether the unrecognized STA is an RSNA STA.

2) If the peer RSNA STA advertises support for SAE authentication in its Beacon and Probe Response frames and the STA has a group defined in the dot11RSNAConfigDLCGroupTable and a password for the peer in the dot11RSNAConfigPasswordValueTable, the STA shall invoke SAE authentication and establish a PMK. If the peer RSNA STA does not advertise support for SAE authentication but advertises support for the alternate form of PSK authentication (see 4.10.3.4 (Alternate operations with PSK)), and the STA also supports the alternate form of PSK authentication the STA may invoke Open System authentication if the STA is a non-DMG STA and use a PSK as the PMK with the alternate form of PSK authentication.

3) Each STA uses the procedures in 12.7 (Keys and key distribution), to establish one or more temporal keys and to negotiate cipher suites. Note that two peer STAs might follow this procedure simultaneously. See 12.6.13 (RSNA key management in an IBSS).

4) It protects the data link by programming the negotiated cipher suites and the established temporal key(s)(#3124) and then invoking protection.

d) If an RSNA uses authentication negotiated over IEEE Std 802.1X in an IBSS, an SME(#3233) establishes an RSNA as follows:

1) It identifies the peer as an RSNA STA from the peer's Beacon, DMG Beacon, Announce, Information Response, or Probe Response frames.

NOTE 2—STAs might respond to a Data frame from an unrecognized STA by sending a Probe Request frame to find out whether the unrecognized STA is an RSNA STA.

2) It may invoke Open System authentication if the STA is a non-DMG STA.

3) Each STA uses (#3469)IEEE Std 802.1X-2020 to authenticate with the AS associated with the other STA's Authenticator, as described in 12.6.8 (RSNA establishment in an infrastructure BSS(#1084)) and 12.6.9 (RSNA authentication in an IBSS).

NOTE 3—Two peer STAs might follow this procedure simultaneously.

4) Each SME establishes one or more temporal keys by executing a key management algorithm, using the protocol defined in 12.7 (Keys and key distribution). Hence two such key management algorithms are happening in parallel between any two STA's Supplicants and Authenticators.

5) Both STAs use the agreed-upon (#8161)TK and pairwise cipher suite from one of the exchanges to protect the link. Each STA uses the GTK established by the exchange it initiated to protect the group addressed frames it transmits.

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e) (#1084)(#3233)If an RSNA allows for confidentiality only (no authentication) in an infrastructure BSS, an SME establishes an RSNA as follows:

1) It identifies the AP as an RSNA AP that supports OWE.
2) Non-DMG STA only: it invokes Open System authentication.
3) It negotiates cipher suites and performs a Diffie-Hellman exchange during the association process as described in 12.6.2 (RSNA selection), 12.6.3 (RSNA policy selection in an infrastructure BSS), and 12.14 (Opportunistic Wireless Encryption(#6088))(#6088).
4) It establishes one or more temporal keys by executing a key management algorithm using the protocol defined in 12.7 (Keys and key distribution).
5) It protects the data link (and, if the STAs negotiate management frame protection, individually addressed robust Management frames) by programming the (#8161)TK and GTK into the MAC and then invoking protection.
6) If the STAs negotiate management frame protection, it programs the IGTK into the MAC for protection of group addressed robust Management frames.
7) If beacon protection is enabled, it programs the BIGTK into the MAC for protection of Beacon frames.
8) If the STAs negotiate WUR frame protection, it programs the WTK into the MAC for protection of individually addressed WUR Wake-up frames, and programs the WIGTK into the MAC for protection of broadcast and group addressed WUR Wake-up frames.

f) In order to associate with a PCP in a PBSS, an SME(#3233) establishes an RSNA with the PCP following the RSNA establishment steps in an infrastructure BSS in accordance with method a) and b) above, as appropriate, with the PCP taking the role of the AP.

g) When an RSNA STA chooses not to associate with a peer in a PBSS, its SME establishes an RSNA with the peer following the RSNA establishment steps in an IBSS in accordance with method c) or d) above, as appropriate, with the caveat that the RSNA authentication and key management algorithm is executed only once between the peers.

h) (11az)If an RSNA uses PASN authentication, an RSNA capable the STA establishes an RSNA as described in 12.13 (Preassociation security negotiation(11az)).

The time a security association takes to set up shall be less than dot11RSNAConfigSATimeout. The security association setup starts when initiated by the SME and completes when the MLME-SETPROTECTION.request primitive is invoked. The action the STA takes on the timeout is a policy decision. Some options include retrying the security association setup or trying another STA. This timeout allows recovery when one of the STAs setting up a security association fails to respond correctly to setting up the security association. It also allows recovery in IBSS when one of the two security associations fails because of a security association timeout.(#3056)

(11az)PASN authentication may be used within an RSNA. However, an RSNA STA shall allow association only if authentication other than PASN was invoked prior to (#8208)association.

### 12.2.5 RSNA assumptions and constraints

An RSNA assumes the following:

a) Each STA can generate cryptographic-quality random numbers. This assumption is fundamental, as cryptographic methods require a source of randomness. See J.5 (Suggestions for random number generation) for suggested hardware and software methods to achieve randomness suitable for this purpose.


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b) When IEEE 802.1X authentication is used, the specific EAP method used performs mutual authentication. This assumption is intrinsic to the design of RSN in IEEE 802.11 LANs and cannot be removed without exposing both the STAs to man-in-the-middle attacks. EAP-MD5 is an example of an EAP method that does not meet this constraint (see IETF RFC 3748). Furthermore, the use of EAP authentication methods where server and client credentials are not differentiated reduces the security of the method to that of a PSK due to the fact that malicious insiders might masquerade as servers and establish a man-in-the-middle attack.

   In particular, the mutual authentication requirement implies an unspecified prior enrollment process (e.g., a long-lived authentication key or establishment of trust through a third party such as a certification authority), as the STA needs to be able to identify the ESS(#3120) as a trustworthy entity and vice versa. (#3120)In an ESS, the STA shares authentication credentials with the AS utilized by the selected AP or, in the case of PSK, the selected AP.

   (#3119)The SSID provides an unprotected indication that the selected AP's authentication entity shares credentials with the STA. Only the successful completion of the IEEE 802.1X EAP or PSK authentication, after association, validates any such indication that the AP is connected to an authorized network or service provider.

c) In an IBSS, the STA shares authentication credentials with the selected STA.(#3120)

d) (#1084)Mutual authentication, when completed, needs to be strong, meaning impersonation attacks are computationally infeasible when based on the information exposed by the authentication.

e) The AP and AS have a trustworthy channel between them that can be used to exchange cryptographic keys without exposure to any intermediate parties.

f) An IEEE 802.1X AS never exposes the common symmetric key to any party except the AP with which the STA is currently communicating. This is a very strong constraint. It implies that the AS itself is never compromised. It also implies that the IEEE 802.1X AS is embedded in the AP or that the AP is physically secure and the AS and the AP lie entirely within the same administrative domain. This assumption follows from the fact that if the AP and the AS are not (#2210)colocated or do not share pairwise key encryption keys directly, then it is impossible to assure the non-AP STA that its key, which is distributed by the AS to the AP, has not been compromised prior to use.

g) A STA never shares with a third party a common symmetric key that it shares with a peer. Doing so destroys the utility of the key for detecting MPDU replay and forgery.

h) The Supplicant and the Authenticator generate a different, fresh PTK for each session between the pair. This assumption is fundamental, as reuse of any PTK would enable compromise of all the data protected by that key.

i) The destination STA chosen by the transmitter is the correct destination. For example, Address Resolution Protocol (ARP) and Internet Control Message Protocol (ICMP) are methods of determining the destination STA's MAC address that are not secure from attacks by other members of the ESS. One of the possible solutions to this problem might be for the STA to send or receive only frames whose final DA or SA are the AP and for the AP to provide a network layer routing function. However, such solutions are outside the scope of this standard.

An HT STA shall not use either of the pairwise cipher suite selectors: "Use group data cipher suite(#6020)" or TKIP to communicate with another HT STA.

NOTE 1—Because a VHT STA is also an HT STA, the elimination of TKIP also applies to VHT STAs.

NOTE 2—Because an HE STA is also an HT STA when operating in the 2.4 GHz band and a VHT STA when operating in the 5 GHz band, and because the security constraints in the 6 GHz band (see 12.12.2 (Security constraints in the 6 GHz band)) disallow use of TKIP, the elimination of TKIP also applies to HE STAs. (#3118)

### 12.2.6 Requirements for the Protected Frame field

The Protected Frame field shall be set to 1 in the following:

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— Data frames that are protected using the mechanisms specified in Clause 12 (Security).
— Individually addressed protected robust Management frames.(#3056)

It shall be set to 0 in all other frames.

### 12.2.7 Requirements for management frame protection

The robust Management frames are Disassociation, Deauthentication, robust Action(#8136), and robust Action No Ack frames.(11az)

(#3129)Action and Action No Ack frames specified with (#4177)No in the Robust column of Table 9-81 (Category values) are not robust Management frames and shall not be protected.

(#1384)When management frame protection is negotiated, individually addressed robust Management frames shall be encapsulated using the pairwise cipher suite (see 12.6.17 (Protection of robust Management frames.)) and group addressed robust Management frames shall be encapsulated using the procedures defined in 11.12 (Group addressed management frame protection procedures).

### 12.2.8 Requirements for beacon protection(#8133)(#7050)

(#1486)When beacon protection is enabled at the AP, protected Beacon frames shall be encapsulated using the procedures defined in 11.52 (Beacon protection procedures(#8133)).

### 12.2.9 Emergency service establishment in an RSN

An AP or mesh STA that supports RSNAs and has the ESR bit set to 1 and the UESA bit set to 1 in the Interworking element in Beacon and Probe Response frames supports both RSNAs and emergency services associations (see 11.3.5.2 (Non-AP and non-PCP STA association initiation procedures)) simultaneously.

In an infrastructure BSS, the STAs with emergency services association should discard all group addressed frames they receive, as they do not possess the group key(#1521) and therefore are not able to decrypt group addressed frames. In an RSNA enabled BSS that has one or more STAs associated with an emergency services association, (#3130)the AP should avoid transmitting unprotected group addressed frames in order not to disturb the operation of STAs that are in possession of group key(#1521). One possible way of achieving this is to support the Proxy ARP service in the AP, as defined in 11.21.14 (Proxy ARP service). In addition, it is recommended that an AP supporting emergency services association should also support DMS to convert group addressed frames to individually addressed frames and transmit them to STAs associated using the emergency services association. STAs using emergency services association might request DMS if needed.

### 12.2.10 Requirements for Operating Channel Validation

When OCVC(#3505) is present, a STA shall advertise this capability in (#6299)the RSNE and shall include operating channel information and validate the Operating Channel Information (OCI) received from an OCVC(#3505) peer in certain protected messages used for key establishment and confirmation.

A STA with OCVC(#3505) validates that the channel information in received OCI matches its current operating channel parameters by:

— Verifying that the maximum bandwidth used by the STA to transmit or receive PPDUs to/from the peer STA from which the OCI was received is no greater than the bandwidth of the operating class specified in the Operating Class field of the received OCI
— Verifying that the primary channel used by the STA to transmit or receive PPDUs to/from the peer STA from which the OCI was received is equal to the Primary Channel Number field (for the corresponding operating class)


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— Verifying that, when 40 MHz bandwidth is used by the STA to transmit or receive PPDUs to/from the peer STA from which the OCI was received, the nonprimary 20 MHz used matches the operating class (i.e., upper/lower behavior) specified in the Operating Class field of the received OCI

— Verifying that, if operating an 80+80 MHz operating class, the frequency segment 1 channel number used by the STA to transmit or receive PPDUs to/from the peer STA from which the OCI was received is equal to the Frequency Segment 1 Channel Number field of the OCI.

If the NT-MLME of a STA with OCVC(#3505) processes an MMPDU containing OCI received in an MLME-OCTunnel.indication primitive (see 11.31.5 (On-channel Tunneling (OCT) operation)):

— The above validation is performed with respect to the expected or current channel used by the STA to transmit or receive PPDUs to/from the peer STA over the WM (i.e., not using the OCT procedure), and

— In addition, the STA verifies that the OCI contains the OCT Operating Class, OCT Primary Channel Number and OCT Frequency Segment 1 Channel Number fields, and uses the OCT information in those fields to perform the above validation with respect to the channel used by the STA corresponding to the TR-MLME from which the MLME-OCTunnel.indication primitive was received to transmit or receive PPDUs containing On-channel Tunnel Request frames to/from the STA corresponding to the TR-MLME used by the peer STA.

(#3334)If a STA with OCVC(#3505) receives a frame from (#1414)a peer STA that is not on the same channel used by the STA to receive PPDUs from the peer STA, or has bandwidth that exceeds the maximum bandwidth used by the STA to receive PPDUs from the peer STA, the frame is discarded.

### 12.2.11 Requirements for support of MAC privacy enhancements

MAC privacy enhancements are enabled on a non-AP STA when dot11MACPrivacyActivated is(M118) true. The STA shall periodically change its MAC address to a random value while not associated to a BSS. The STA shall construct the randomized MAC address from the locally administered address space as defined in IEEE Std 802-2014 and IEEE Std 802c™-2017. However, the non-AP STA shall not change its MAC address during a transactional exchange, for example, transmitting Public Action frames for preassociation discovery, or during the creation of state on an AP using preassociation capabilities, for example, RSN preauthentication or FT over-the-DS. The smaller the period of MAC address change, down to a single transmitted frame per MAC address, the greater the privacy these enhancements afford. The actual period used when changing a MAC address is implementation dependent and outside the scope of this standard.

If such a non-AP STA starts any transaction that establishes state bound to a MAC address and might elect to establish an association or establish transaction state with a discovered BSS, it shall check the value of dot11LocallyAdministeredMACConfig and shall configure its MAC address according to the rules of the local address space prior to the start of the transaction. State created with an AP using a prior MAC address, for instance, RSN preauthentication state or FT state established over-the-DS, is bound to the MAC address used when that state was created. Prior to establishing an association to the AP, the non-AP STA shall change its MAC address to the MAC address used when the state was created.

The SME of the non-AP STA may change the MAC address by generating an MLME-UPDATEMACADDRESS.request primitive containing the new MAC address. On receipt of an MLME-UPDATEMACADDRESS.request primitive, the MLME shall attempt to update the MAC address that is to be used by the MAC entity and shall generate an MLME-UPDATEMACADDRESS.confirm primitive to notify the SME whether the MAC address has been changed to the new value.

Every time a MAC address is changed to a new random value, counters in (#270)all sequence number spaces used to identify each MSDU, A-MSDU or MMPDU shall be reset (see 10.3.2.14.2 (Transmitter requirements)) and the STA shall set the TXVECTOR parameter SCRAMBLER_RESET to RESET_SCRAMBLER on the next transmitted PPDU.

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The non-AP STA connecting to an infrastructure BSS shall retain a single MAC address for the duration of its connection across an ESS. A PMKSA created as part of an RSNA (M118)contains the MAC address used to create the PMKSA. The non-AP STA that supports PMKSA caching shall, if necessary, change its MAC address back to that value when attempting a subsequent association to the ESS using PMKSA caching.

To construct a random MAC address, the STA shall select a randomized MAC address according to IEEE Std 802-2014 and IEEE Std 802c-2017.

To avoid leakage of possibly sensitive network identifying information, STAs should refrain from transmitting Probe Request frames containing preferred SSID values and, instead, use passive scanning or transmit Probe Request frames containing the wildcard SSID.

When dot11MACAddressPolicyActiviated is true, an AP shall set the MAC Address Policy field in the Extended Capabilities field to 1, indicating the existence of a MAC address policy. When dot11MACAddressPolicyActivated is false, an AP STA shall set the MAC Address Policy field in the Extended Capabilities field to 0, indicating that local MAC addresses are not restricted.

A non-AP STA that receives from an AP an Extended Capabilities field with the Local MAC Address Policy subfield set to 1 should, unless it has previously stored the MAC address policy for the ESS, discover that policy, using the MAC Address Policy ANQP-element, before sending any Association Request frame to that AP using a local MAC address as the TA.

### 12.2.12 EDMG secure ranging sequences(11az)

EDMG secure ranging uses Secure TRN subfields, see 28.9.3 (EDMG secure ranging PPDU(11az)), as part of the TRN fields of EDMG PPDUs. Those TRN subfields are based on bit sequences henceforth denoted as secure TRN sequences. These secure TRN bit sequences are generated as follows:

The Secret Key is 32 octets randomly generated by the ISTA and sent in the Secure Ranging Operation Parameters field, see Figure 9-728 (Secure Ranging Operation Parameters field format(11az)), of the EDMG Specific Parameters subelement of the Fine Timing Parameters element sent by the ISTA to the RSTA in the initial Protected FTM request; see 11.21.6.3.6 (Negotiation for secure EDMG TRN in EDCA based ranging measurement). The Secret Key is used as Input Key Material (IKM) to generate pseudorandom secure TRN sequences that are used to construct secure ranging waveforms at the ISTA and RSTA. The Secret Key and Salt shall be discarded after the FTM session is terminated. Each FTM session shall have a different Secret Key.

Pseudorandom secure TRN sequences are generated using HKDF (Hashed Message Authentication Code (HMAC)-based Key Derivation Function) specified in IETF RFC 5869:

The hash function to be employed in HKDF is SHA-256.

The Secret Key is to be used as the IKM in HKDF. See RFC 5869, section 2.2.

The Salt is the PMKID corresponding to the security association between the ISTA and RSTA. See RFC 5869, section 2.2

A pseudorandom key (PRK) is generated using the hash function accepting IKM and Salt as inputs. See RFC 5869 section 2.2. The hash function to be employed to generate the PRK is SHA-256.

The Info field is a fixed string “EDMG Secure RTT”, which is unique to this protocol in order to guard against accidental key reuse in a different subsystem. Key reuse across different subsystems shall be avoided through careful system design, and the Secret Key shall not be visible outside of the subsystem. See RFC 5869, section 2.3.


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Pseudorandom secure TRN sequences are the output of the HKDF-Expand function with the PRK, Info field, and the length of secure TRN sequences required as inputs. See RFC 5869, section 2.3. One time calculation of all pseudorandom secure TRN sequences for multiple timing measurements should be used for minimizing HKDF setup costs in case of multiple ranging attempts. The length of the Secure TRN sequences generated shall be long enough for generating Secure TRN subfields for the number of bursts expected in the session.

Furthermore, if memory is not constrained in an implementation, caching multiple Secret Keys and Salt pairs and pre-generating all secure TRN sequences for multiple timing measurements and multiple FTM sessions is allowed provided that this information is not revealed to third parties.

## 12.3 Pre-RSNA security methods(#3056)(#1077)

### 12.3.1 Overview(#1077)

(#3056)The only pre-RSNA security method is Open System authentication.(#1077)

Open System authentication shall not be used between mesh STAs.(#308)

### 12.3.2 Wired equivalent privacy (WEP)

#### 12.3.2.1 WEP overview

(#3056)WEP is an obsolete cipher that has been removed from the standard as a standalone mechanism. The following subclauses are included for the definition of TKIP.

#### 12.3.2.2 WEP procedures

##### 12.3.2.2.1 WEP ICV algorithm

The WEP ICV shall be computed using the CRC-32, as defined in (#6101)9.2.4.8 (Frame Body field), calculated over the plaintext MPDU Data (PDU) field.

##### 12.3.2.2.2 WEP encryption algorithm

A WEP implementation shall use the ARC4 stream cipher from RSA Security, Inc., as its encryption and decryption algorithm. ARC4 uses a pseudorandom number generator (PRNG) to generate a key stream that it exclusive-ORs (XORs) with a plaintext data stream to produce cipher text or to recover plaintext from a cipher text.

##### 12.3.2.2.3 WEP seed construction

A WEP implementation shall construct a per-MPDU key, called a *seed*, by concatenating an encryption key to an IV.

For WEP-40, bits 0–39 of the WEP key correspond to bits 24–63 of the seed, and bits 0–23 of the IV correspond to bits 0–23 of the seed, respectively. The bit numbering conventions in 9.2.2 (Conventions) apply to the seed. The seed shall be the input to ARC4, in order to encrypt or decrypt the WEP Data and ICV fields.

NOTE—For WEP-104, bits 0–103 of the WEP key correspond to bits 24–127 of the seed, and bit 0–23 of the IV correspond to bits 0–23 of the seed, respectively.

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The WEP implementation encapsulating an MPDU's plaintext data should select a new IV for every MPDU it WEP-protects. The IV selection algorithm is unspecified. The algorithm used to select the encryption key used to construct the seed is also unspecified.

The WEP implementation decapsulating an MPDU shall use the IV from the received MPDU's Init Vector subfield. See 12.3.2.2.5 (WEP MPDU decapsulation) for the specification of how the decapsulator selects the key to use to construct the per-MPDU key.

#### 12.3.2.2.4 WEP MPDU cryptographic encapsulation

WEP shall apply three transformations to the plaintext MPDU to effect the WEP cryptographic encapsulation. WEP computes the ICV over the plaintext data and appends this after the MPDU data. WEP encrypts the MPDU plaintext data and ICV using ARC4 with a seed constructed as specified in 12.3.2.2.3 (WEP seed construction). WEP encodes the IV and key identifier into the IV field, prepended to the encrypted Data field.

Figure 12-1 (WEP encapsulation block diagram) depicts the WEP cryptographic encapsulation process. The ICV shall be computed and appended to the plaintext data prior to encryption, but the IV encoding step may occur in any order convenient for the implementation.

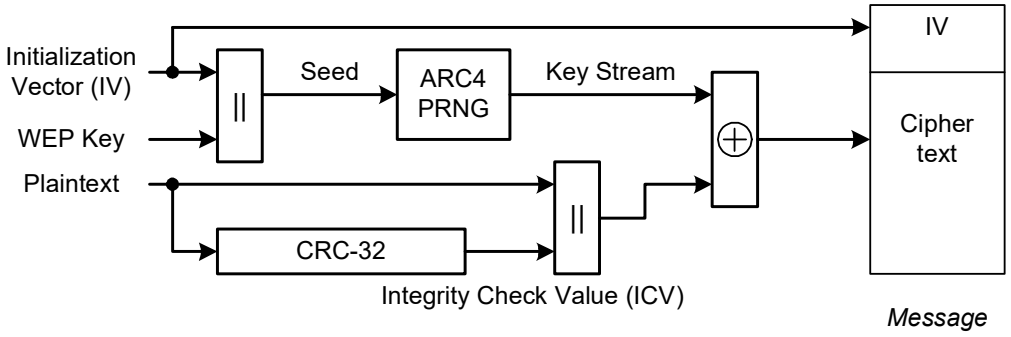


**Figure 12-1—WEP encapsulation block diagram**

#### 12.3.2.2.5 WEP MPDU decapsulation

WEP shall apply three transformations to the WEP MPDU to decapsulate its payload. WEP extracts the IV and key identifier from the received MPDU. If a key-mapping key is present for the <TA,RA> pair, then this shall be used as the WEP key. Otherwise, the key identifier is extracted from the Key ID subfield of the WEP IV field in the received MPDU, identifying the default key to use.

WEP uses the constructed seed to decrypt the Data field of the WEP MPDU; this produces plaintext data and an ICV. Finally WEP recomputes the ICV and bitwise compares it with the decrypted ICV from the MPDU. If the two are bitwise identical, then WEP removes the IV and ICV from the MPDU, which is accepted as valid. If they differ in any bit position, WEP generates an error indication to MAC management. MSDUs with erroneous MPDUs (due to inability to decrypt) shall not be passed to LLC.

Figure 12-2 (WEP decapsulation block diagram) depicts a block diagram for WEP decapsulation. Unlike cryptographic encapsulation, the decapsulation steps shall be in the indicated order.

### 12.3.3 Pre-RSNA authentication

#### 12.3.3.1 Overview

In an infrastructure BSS, a non-DMG STA shall complete an IEEE 802.11 authentication exchange prior to association. A DMG STA not in an IBSS shall complete an IEEE 802.11 authentication exchange prior to


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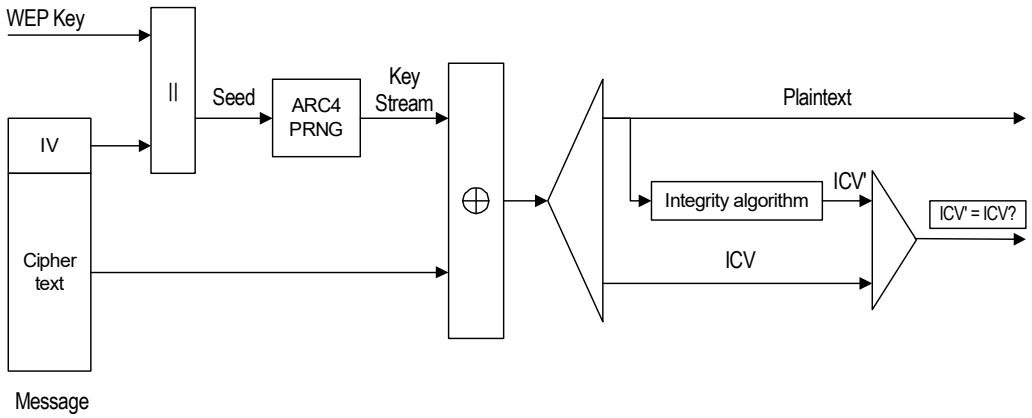


**Figure 12-2—WEP decapsulation block diagram**

association when an authentication algorithm other than the Open System authentication algorithm is requested. A DMG STA shall not perform an IEEE 802.11 authentication exchange using the Open System authentication algorithm. An IEEE 802.11 authentication exchange is optional in an IBSS.

All Authentication frames shall be individually addressed, as IEEE 802.11 authentication is performed between pairs of STAs, i.e., group addressed authentication is not allowed. Deauthentication frames are advisory and may be sent as group addressed frames(#3056).

### 12.3.3.2 Open System authentication

#### 12.3.3.2.1 General

Open System authentication is a null authentication algorithm.

Any non-DMG STA requesting Open System authentication can be authenticated if dot11AuthenticationAlgorithmsTable at the peer STA includes an entry with dot11AuthenticationAlgorithm equal to openSystem and dot11AuthenticationAlgorithmActivated equal to true.

A STA may decline to authenticate with another requesting STA. Open System authentication is the default authentication algorithm for a pre-RSNA STA.

Open System authentication utilizes a two-message authentication transaction sequence. The first message asserts identity and requests authentication. The second message returns the authentication result. If the result is "successful," the STAs shall be declared mutually authenticated.

In the description in 12.3.3.2.2 (Open System authentication (first frame)) and 12.3.3.2.3 (Open System authentication (final frame)), the STA initiating the authentication exchange is referred to as the *requester*, and the STA to which the initial frame in the exchange is addressed is referred to as the *responder*. The specific items in each of the messages described in the following subclauses are defined in 9.3.3.11 (Authentication frame format), Table 9-70 (Authentication frame body), and Table 9-71 (Presence of fields and elements in Authentication frames).

#### 12.3.3.2.2 Open System authentication (first frame)

Upon receipt of an Open System MLME-AUTHENTICATE.request primitive, the requester shall construct an Open System authentication request carried in an Authentication frame and transmit it to the responder.

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#### 12.3.3.2.3 Open System authentication (final frame)

Upon receipt of an Authentication frame requesting Open System authentication, the responder may authenticate the requester using the following procedure:

a) Issue an MLME-AUTHENTICATE.indication primitive to inform the SME of the authentication request.

b) Construct and transmit a response carried in an Authentication frame with the fields as defined in 9.3.3.11 (Authentication frame format) and the (#1780)Status Code field as defined in 9.4.1.9 (Status Code field).

If dot11AuthenticationAlgorithmsTable(#2005) does not include an entry with dot11AuthenticationAlgorithm equal to openSystem and dot11AuthenticationAlgorithmActivated equal to true, the Status Code field shall not be SUCCESS.(#1780)(#3056)

### 12.3.4 Temporal key integrity protocol (TKIP)(#1077)

#### 12.3.4.1 TKIP overview

#### 12.3.4.1.1 General

The TKIP is a cipher suite enhancing WEP on pre-RSNA hardware. TKIP modifies WEP as follows:

a) A transmitter calculates a keyed cryptographic message integrity code (MIC) over the MSDU SA and DA, the MSDU priority (see 12.3.4.3 (TKIP MIC)), and the MSDU plaintext data. TKIP appends the computed MIC to the MSDU data prior to fragmentation into MPDUs. The receiver verifies the MIC after decryption, ICV checking, and defragmentation of the MPDUs into an MSDU and discards any received MSDUs with invalid MICs. TKIP's MIC provides a defense against forgery attacks.

b) Because of the design constraints of the TKIP MIC, it is still possible for an adversary to compromise message integrity; therefore, TKIP also implements countermeasures. The countermeasures bound the probability of a successful forgery and the amount of information an attacker can learn about a key.

c) TKIP uses a per-MPDU TKIP sequence counter (TSC) to sequence the MPDUs it sends. The receiver (#3683)discards MPDUs received out of order, i.e., not received with increasing sequence numbers. This provides replay protection. TKIP encodes the TSC value from the sender to the receiver as a WEP IV and extended IV.

d) TKIP uses a cryptographic mixing function to combine a temporal key, the TA, and the TSC into the WEP seed. The receiver recovers the TSC from a received MPDU and utilizes the mixing function to compute the same WEP seed needed to correctly decrypt the MPDU. The key mixing function is designed to defeat weak-key attacks against the WEP key.

TKIP defines additional MIB attributes; see Annex C.

#### 12.3.4.1.2 TKIP cryptographic encapsulation

TKIP enhances the WEP cryptographic encapsulation with several additional functions, as depicted in Figure 12-3 (TKIP encapsulation block diagram).

a) TKIP MIC computation protects the MSDU Data field and corresponding SA, DA, and Priority fields. The computation of the MIC is performed on the ordered concatenation of the SA, DA, Priority, and MSDU Data fields. The MIC is appended to the MSDU Data field. TKIP discards any MIC padding prior to appending the MIC.


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b) If needed, the MSDU with MIC is fragmented into one or more MPDUs. TKIP assigns a monotonically increasing TSC value to each MPDU, taking care that all of the MPDUs generated from the same MSDU have the same value of extended IV (see 12.3.4.2 (TKIP MPDU formats)).

c) For each MPDU, TKIP uses the key mixing function to compute the WEP seed.

d) TKIP represents the WEP seed as a WEP IV and ARC4 key and passes these with each MPDU to WEP for generation of the ICV (see (#6101)9.2.4.8 (Frame Body field)), and for encryption of the plaintext MPDU, including all or part of the MIC, if present. WEP uses the WEP seed as a WEP default key, identified by a key identifier associated with the temporal key.

NOTE—When the TSC space is exhausted, the choices available to an implementation are to replace the temporal key with a new one or to end communications. Reuse of any TSC value compromises already sent traffic. Note that retransmitted MPDUs reuse the TSC without any compromise of security. The TSC is large enough, however, that TSC space exhaustion is not expected to be an issue.

In Figure 12-3 (TKIP encapsulation block diagram), the TKIP-mixed transmitter address and key (TTAK) denotes the intermediate key produced by Phase 1 of the TKIP mixing function (see 12.3.4.5 (TKIP mixing function)).

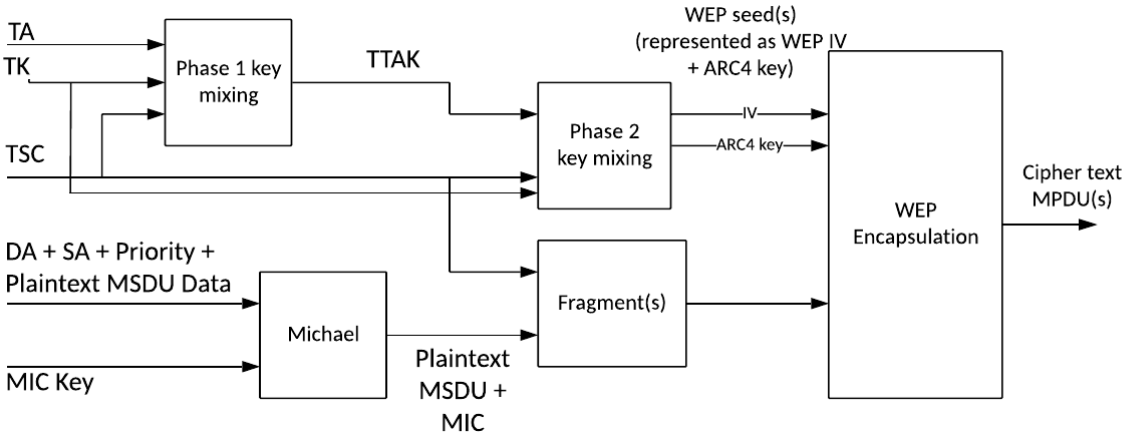


**Figure 12-3—TKIP encapsulation block diagram**

### 12.3.4.1.3 TKIP decapsulation

TKIP enhances the WEP decapsulation process with the following additional steps:

a) Before WEP decapsulates a received MPDU, TKIP extracts the TSC sequence number and key identifier from the WEP IV and the extended IV. TKIP discards a received MPDU that violates the sequencing rules (see 12.3.4.6 (TKIP replay protection procedures)) and otherwise uses the mixing function to construct the WEP seed.

b) TKIP represents the WEP seed as a WEP IV and ARC4 key and passes these with the MPDU to WEP for decapsulation.

c) If WEP indicates the ICV check succeeded, the implementation reassembles the MPDU into an MSDU. If the MSDU defragmentation succeeds, the receiver verifies the TKIP MIC. If MSDU defragmentation fails, then the MSDU is discarded.

d) The MIC verification step recomputes the MIC over the MSDU SA, DA, Priority, and MSDU Data fields (but not the TKIP MIC field). The calculated TKIP MIC result is then compared bitwise to the received MIC.

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e) If the received and the locally computed MIC values are identical, the verification succeeds, and TKIP shall deliver the MSDU to the upper layer. If the two differ, then the verification fails; the receiver shall discard the MSDU and shall engage in appropriate countermeasures.

Figure 12-4 (TKIP decapsulation block diagram) depicts this process.

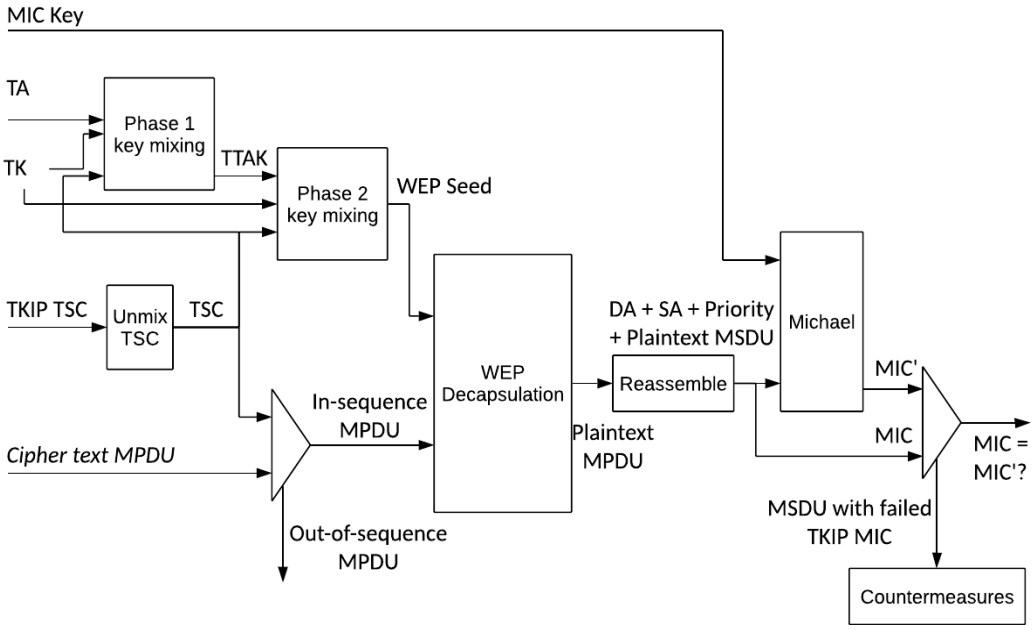


**Figure 12-4—TKIP decapsulation block diagram**

### 12.3.4.2 TKIP MPDU formats

TKIP reuses the pre-RSNA WEP MPDU format. It extends the MPDU by 4 octets to accommodate an extension to the WEP IV, denoted by the Extended IV field, and extends the MSDU format by 8 octets to accommodate the new MIC field. TKIP inserts the Extended IV field immediately after the WEP IV field and before the encrypted data. TKIP appends the MIC to the MSDU Data field; the MIC becomes part of the encrypted data.

Once the MIC is appended to the MSDU data, the added MIC octets are considered part of the MSDU for subsequent fragmentation.

Figure 12-5 (Construction of expanded TKIP MPDU) depicts the layout of the encrypted MPDU when using TKIP. Note that the figure only depicts the case when the MSDU can be encapsulated in a single MPDU.

The ExtIV bit in the Key ID octet indicates the presence or absence of an extended IV. (#3056)For TKIP the ExtIV bit shall be set to 1, and the Extended IV field shall be supplied. (#3056)The Key ID field shall be set to the key index supplied by the MLME-SETKEYS.request primitive for the key used in cryptographic encapsulation of the frame.

TSC5 is the most significant octet of the TSC, and TSC0 is the least significant. Octets TSC0 and TSC1 form the IV sequence number and are used with the TKIP Phase 2 key mixing. Octets TSC2–TSC5 are used in the TKIP Phase 1 key hashing and are in the Extended IV field. When the lower 16-bit sequence number rolls over (0xFFFF → 0x0000), the extended IV value, i.e., the upper 32 bits of the entire 48-bit TSC, shall be incremented by 1.


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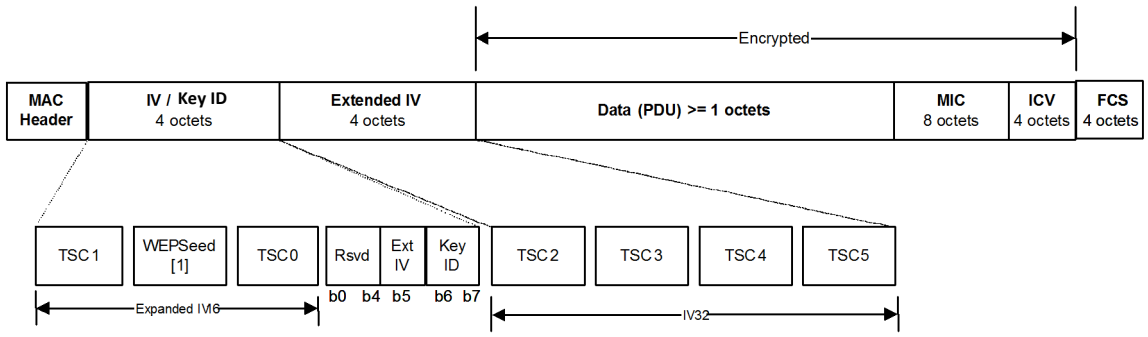


**Figure 12-5—Construction of expanded TKIP MPDU**

NOTE—The rationale for this construction is as follows:

a) Aligning on word boundaries eases implementation on legacy devices.
b) Adding 4 octets of extended IV eliminates TSC exhaustion as a reason to rekey.
c) Key ID octet changes. Bit 5 indicates that an extended IV is present. The receiver/transmitter interprets the 4 octets following the Key ID as the extended IV. The receiving/transmitting STA also uses the value of octets TSC0 and TSC1 to detect that the cached TTAK needs to be updated.

The Extended IV field shall not be encrypted.

WEPSeed[1] is not used to construct the TSC, but is set to (TSC1 | 0x20) & 0x7f.

TKIP shall encrypt all of the MPDUs generated from one MSDU under the same temporal key.

### 12.3.4.3 TKIP MIC

#### 12.3.4.3.1 General

Flaws in the IEEE 802.11 WEP design cause it to fail to meet its goal of protecting data traffic content from casual eavesdroppers. Among the most significant WEP flaws is the lack of a mechanism to defeat message forgeries and other active attacks. To defend against active attacks, TKIP includes a MIC, called *michael*. This MIC offers only weak defenses against message forgeries, but it constitutes the best that can be achieved with the majority of legacy hardware. TKIP uses different MIC keys depending on the direction of the transfer as described in 12.8.1 (Mapping PTK to TKIP keys) and 12.8.2 (Mapping GTK to TKIP keys).

Annex J contains an implementation of the TKIP MIC. It also provides test vectors for the MIC.

#### 12.3.4.3.2 Motivation for the TKIP MIC

Before defining the details of the MIC, it is useful to review the context in which this mechanism operates. Active attacks enabled by the original WEP design include the following:

— Bit-flipping attacks
— Data (payload) truncation, concatenation, and splicing
— Fragmentation attacks
— Iterative guessing attacks against the key
— Redirection by modifying the MPDU DA or RA field
— Impersonation attacks by modifying the MPDU SA or TA field

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The MIC makes it more difficult for any of these attacks to succeed.

All of these attacks remain at the MPDU level with the TKIP MIC. The MIC, however, applies to the MSDU, so it blocks successful MPDU-level attacks. TKIP applies the MIC to the MSDU at the transmitter and verifies it at the MSDU level at the receiver. If a MIC check fails at the MSDU level, the implementation shall discard the MSDU and invoke countermeasures (see 12.3.4.4 (TKIP countermeasures procedures)).

Figure 12-6 (TKIP MIC relation to IEEE 802.11 processing) depicts different peer layers communicating.

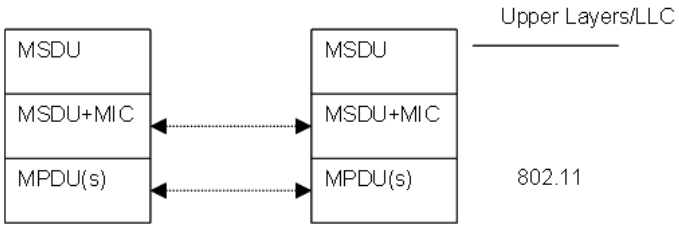


**Figure 12-6—TKIP MIC relation to IEEE 802.11 processing**

This figure depicts an architecture where the MIC is logically appended to the raw MSDU in response to the MA-UNITDATA.request primitive. The TKIP MIC is computed over

— The MSDU DA
— The MSDU SA
— The MSDU Priority
— The entire unencrypted MSDU data (payload)

The DA field, SA field, reserved octets, and (#2047)Priority field are used only for calculating the MIC. The Priority field refers to the priority parameter of the MA-UNITDATA.request primitive. The fields in Figure 12-7 (TKIP MIC processing format) are treated as an octet stream using the conventions described in 9.2.2 (Conventions).

| 6 | 6 | 1 | 3 | M | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | octets |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DA | SA | Priority | 0 | Data | M 0 | M 1 | M 2 | M 3 | M 4 | M 5 | M 6 | M 7 | |

**Figure 12-7—TKIP MIC processing format**

TKIP appends the MIC at the end of the MSDU. The MIC is 8 octets in size for michael. The IEEE 802.11 MAC then applies its normal processing to transmit this MSDU-with-MIC as a sequence of one or more MPDUs. In other words, the MSDU-with-MIC can be partitioned into one or more MPDUs, the WEP ICV is calculated over each MPDU, and the MIC can even be partitioned to lie in two MPDUs after fragmentation. The TKIP MIC augments, but does not replace, the WEP ICV. Because the TKIP MIC is a weak construction, TKIP protects the MIC with encryption, which makes TKIP MIC forgeries more difficult. The WEP ICV helps to prevent false detection of MIC failures that would cause countermeasures to be invoked.

The receiver reverses this procedure to reassemble the MSDU; and, after the MSDU has been logically reassembled, the IEEE 802.11 MAC verifies the MIC prior to delivery of the MSDU to upper layers. If the MIC validation succeeds, the MAC delivers the MSDU. If the MIC validation fails, the MAC shall discard the MSDU and invoke countermeasures (see 12.3.4.4 (TKIP countermeasures procedures)).


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NOTE—TKIP calculates the MIC over the MSDU rather than the MPDU, because doing so increases the implementation flexibility with preexisting WEP hardware.

Note that a MIC alone cannot provide complete forgery protection, as it cannot defend against replay attacks. Therefore, TKIP provides replay detection by TSC sequencing and ICV validation. Furthermore, if TKIP is utilized with a GTK, an insider STA can masquerade as any other STA belonging to the group.

#### 12.3.4.3.3 Definition of the TKIP MIC

Michael generates a 64-bit MIC. The michael key consists of 64 bits, represented as an 8-octet sequence, $k_0...k_7$. This is converted to two 32-bit words, $K_0$ and $K_1$. Throughout this subclause, all conversions between octets and 32-bit words shall use the little endian conventions, given in 9.2.2 (Conventions).

Michael operates on each MSDU including the Priority field, 3 reserved octets, SA field, and DA field. An MSDU consists of octets $m_0...m_{n-1}$ where $n$ is the number of MSDU octets, including SA, DA, Priority, and Data fields. The message is padded at the end with a single octet with value 0x5a, followed by between 4 and 7 zero octets. The number of zero octets is chosen so that the overall length of the padded MSDU is a multiple of four. The padding is not transmitted with the MSDU; it is used to simplify the computation over the final block. The MSDU is then converted to a sequence of 32-bit words $M_0 ...M_{N-1}$, where $N = \lceil (n+5)/4 \rceil$. By construction, $M_{N-1} = 0$ and $M_{N-2} \neq 0$.

The MIC value is computed iteratively starting with the key value ($K_0$ and $K_1$) and applying a block function $b$ for every message word, as shown in Figure 12-8 (Michael message processing). The algorithm loop runs a total of $N$ times ($i$ takes on the values 0 to $N$–1), where $N$ is as above, the number of 32-bit words composing the padded MSDU. The algorithm results in two words ($l$ and $r$), which are converted to a sequence of 8 octets using the least-significant-octet-first convention:

- M0 = $l$ & 0xff
- M1 = ($l$/0x100) & 0xff
- M2 = ($l$/0x10000) & 0xff
- M3 = ($l$/0x1000000) & 0xff
- M4 = $r$ & 0xff
- M5 = ($r$/0x100) & 0xff
- M6 = ($r$/0x10000) & 0xff
- M7 = ($r$/0x1000000) & 0xff

This is the MIC value. The MIC value is appended to the MSDU as data to be sent.

**Input:** Key ($K_0$, $K_1$) and padded MSDU (represented as 32-bit words) $M_0$ ... $M_{N-1}$
**Output:** MIC value ($V_0$, $V_1$)

MICHAEL(($K_0$, $K_1$) , ($M_0$, ... , $M_N$))
($l$,$r$) ← ($K_0$, $K_1$)
**for** $i$ = 0 **to** $N$–1 **do**
    $l \leftarrow l \oplus M_i$
    ($l$,$r$) ← $b$($l$,$r$)
**return** ($l$,$r$)

**Figure 12-8—Michael message processing**

Figure 12-9 (Michael block function) defines the michael block function $b$. It is a Feistel-type construction with alternating additions and XOR operations. It uses <<< to denote the rotate-left operator on 32-bit values, >>>

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for the rotate-right operator, and XSWAP for a function that swaps the position of the 2 least significant octets. It also uses the position of the two most significant octets in a word.

```
Input: (l,r)
Output: (l,r)
b(L,R)
        r ← r ⊕ (l <<< 17)
        l ← (l + r) mod 2^32
        r ← r ⊕ XSWAP(l)
        l ← (l + r) mod 2^32
        r ← r ⊕ (l <<< 3)
        l ← (l + r) mod 2^32
        r ← r ⊕ (l >>> 2)
        l ← (l + r) mod 2^32
        return (l,r)
```

**Figure 12-9—Michael block function**

### 12.3.4.4 TKIP countermeasures procedures

#### 12.3.4.4.1 General

The TKIP MIC trades off security in favor of implementability on pre-RSNA STAs. Michael provides only weak protection against active attacks. A failure of the MIC in a received MSDU indicates a probable active attack. A successful attack against the MIC would mean an attacker could inject forged Data frames and perform further effective attacks against the encryption key itself. If TKIP implementation detects a probable active attack, TKIP shall take countermeasures as specified in this subclause. These countermeasures accomplish the following goals:

— MIC failure events should be logged as a security-relevant matter. A MIC failure is an almost certain indication of an active attack and warrants a followup(#1665) by the system administrator.

— The rate of MIC failures needs to be kept below two per minute. This implies that STAs and APs detecting two MIC failure events within 60 s need to disable all receptions using TKIP for a period of 60 s. The slowdown makes it difficult for an attacker to make a large number of forgery attempts in a short time.

— As an additional security feature, the PTK and, in the case of the Authenticator, the GTK should be changed.

Before verifying the MIC, the receiver shall check the FCS, ICV, and TSC for all related MPDUs. Any MPDU that has an invalid FCS, an incorrect ICV, or a TSC value that is less than or equal to the TSC replay counter shall be discarded before checking the MIC. This avoids unnecessary MIC failure events. Checking the TSC before the MIC makes countermeasure-based denial-of-service attacks harder to perform. While the FCS and ICV mechanisms are sufficient to detect noise, they are insufficient to detect active attacks. The FCS and ICV provide error detection, but not integrity protection.

A single counter or timer shall be used to log MIC failure events. These failure events are defined as follows:

— In an Authenticator:
  — Detection of a MIC failure on a received individually addressed frame.
  — Receipt of Michael MIC Failure Report frame.
— In a Supplicant:
  — Detection of a MIC failure on a received individually addressed or group addressed frame.
  — Attempt to transmit a Michael MIC Failure Report frame.


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The number of MIC failures is accrued independent of the particular key context. Any single MIC failure, whether detected by the Supplicant or the Authenticator and whether resulting from a group MIC key failure or a pairwise MIC key failure, shall be treated as cause for a MIC failure event.

The Supplicant uses a single Michael MIC Failure Report frame to report a MIC failure event to the Authenticator. A Michael MIC Failure Report frame(#1853) is an EAPOL-Key frame with the following Key Information field bits set to 1: MIC bit, Error bit, Request bit, Secure bit. The Supplicant protects this message with the current PTK; the Supplicant uses the KCK portion of the PTK to compute the IEEE 802.1X EAPOL MIC.

The MLME-MICHAELMICFAILURE.indication primitive is used by the IEEE 802.11 MAC to attempt to indicate a MIC failure to the local IEEE 802.1X Supplicant or Authenticator. (#2158)The MLME-EAPOL.request primitive is used by the Supplicant to send the EAPOL-Key frame containing the Michael MIC Failure Report frame(#1853). The MLME-EAPOL.confirm primitive indicates to the Supplicant when the EAPOL-Key frame has been transmitted.

The first MIC failure shall be logged, and a timer initiated to enable enforcement of the countermeasures. If the MIC failure event is detected by the Supplicant, it shall also report the event to the AP by sending a Michael MIC Failure Report frame.

If a subsequent MIC failure occurs within 60 s of the most recent previous failure, then a STA whose IEEE 802.1X entity has acted as a Supplicant shall deauthenticate (as defined in 11.3.4.4 (Deauthentication—originating STA)) itself or deauthenticate all of the STAs with a security association if its IEEE 802.1X entity acted as an Authenticator. In an IBSS STA, both Supplicant and Authenticator actions shall be taken. Furthermore, the device shall not receive or transmit any TKIP-encrypted Data frames, and shall not receive or transmit any unencrypted Data frames other than IEEE 802.1X messages, to or from any peer for a period of at least 60 s after it detects the second failure. If the device is an AP, it shall disallow new associations using TKIP during this 60 s period; at the end of the 60 s period, the AP shall resume normal operations and allow STAs to (re)associate. If the device is an IBSS STA, it shall disallow any new security associations using TKIP during this 60 s period. If the device is a Supplicant, it shall first send a Michael MIC Failure Report frame prior to revoking its PTKSA and deauthenticating itself.

The `aMICFailTime` attribute shall contain the `sysUpTime` value at the time the MIC failure was logged.

#### 12.3.4.4.2 TKIP countermeasures for an Authenticator

The countermeasures used by an Authenticator are depicted in Figure 12-10 (Authenticator MIC countermeasures) and described as follows:

a) In an Authenticator's STA that receives a frame with a MIC error,
   1) Discard the frame.
   2) Increment the MIC failure counter, dot11RSNAStatsTKIPLocalMICFailures.
   3) Generate an MLME-MICHAELMICFAILURE.indication primitive.

b) In an Authenticator that receives an MLME-MICHAELMICFAILURE.indication primitive or a Michael MIC Failure Report frame,
   1) If it is a Michael MIC Failure Report frame, then increment dot11RSNAStatsTKIP-RemoteMICFailures.
   2) If this is the first MIC failure within the past 60 s, initialize the countermeasures timer.
   3) If less than 60 s have passed since the most recent previous MIC failure, the Authenticator shall deauthenticate and delete all PTKSAs for all STAs using TKIP. If the current GTKSA uses TKIP, that GTKSA shall be discarded, and a new GTKSA constructed, but not used for 60 s. The Authenticator shall refuse the construction of new PTKSAs using TKIP as one or more of

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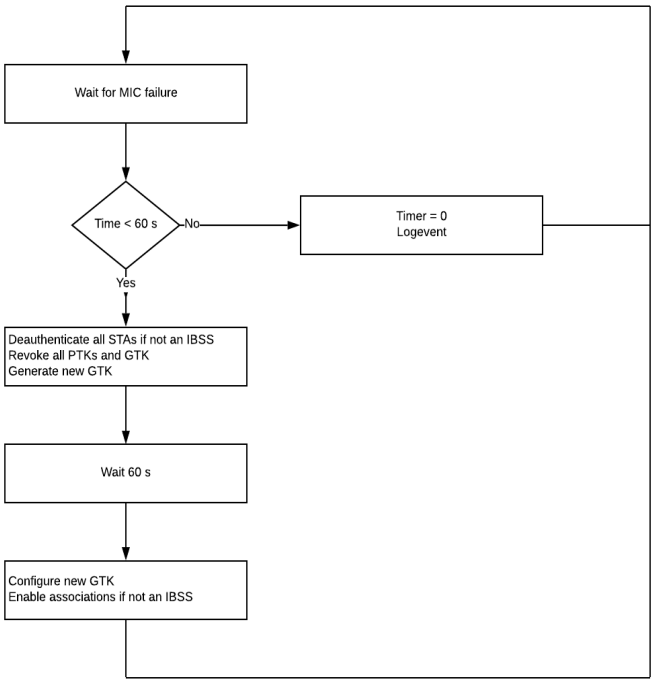


**Figure 12-10—Authenticator MIC countermeasures**

the ciphers for 60 s. At the end of this period, the MIC failure counter and timer shall be reset, and creation of PTKSAs accepted as usual.

4) If the Authenticator is using IEEE 802.1X authentication, the Authenticator shall transition the state of the IEEE 802.1X Authenticator state machine to the INITIALIZE state. This restarts the IEEE 802.1X state machine. If the Authenticator is instead using PSKs, this step is omitted.

Note that a Supplicant's STA may deauthenticate with a reason code of MIC_FAILURE if it is an ESS STA. The Authenticator shall not log the deauthenticate as a MIC failure event to prevent denial-of-service attacks through deauthentications. The Supplicant's STA reports the MIC failure event through the Michael MIC Failure Report frame so that the AP can log the event.

The requirement to deauthenticate all STAs using TKIP includes those using other pairwise ciphers if they are using TKIP as the group data cipher(#6020).

#### 12.3.4.4.3 TKIP countermeasures for a Supplicant

The countermeasures used by a Supplicant are depicted in Figure 12-11 (Supplicant MIC countermeasures) and described as follows:

a) In a Supplicant's STA that receives a frame with a MIC error,
   1) Increment the MIC failure counter, dot11RSNAStatsTKIPLocalMICFailures.
   2) Discard the offending frame.
   3) Generate an MLME-MICHAELMICFAILURE.indication primitive.

b) In a Supplicant that receives an MLME-MICHAELMICFAILURE.indication primitive from its STA,
   1) Send a Michael MIC Failure Report frame to the AP.
   2) If this is the first MIC failure within the past 60 s, initialize the countermeasures timer.


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3) If less than 60 s have passed since the most recent previous MIC failure, delete the PTKSA and GTKSA. Deauthenticate from the AP and wait for 60 s before (re)establishing a TKIP association with the same AP. A TKIP association is any IEEE 802.11 association that uses TKIP for its pairwise or group data cipher suite.(#6020)

c) If a STA receives a Deauthentication frame with the reason code MIC_FAILURE it is unable to verify that the frame has not been forged, since the frame does not contain a MIC. The STA may attempt association with this, or another, AP. If the frame was genuine, then it is probable that attempts to associate with the same AP requesting the use of TKIP will fail because the AP is conducting countermeasures.

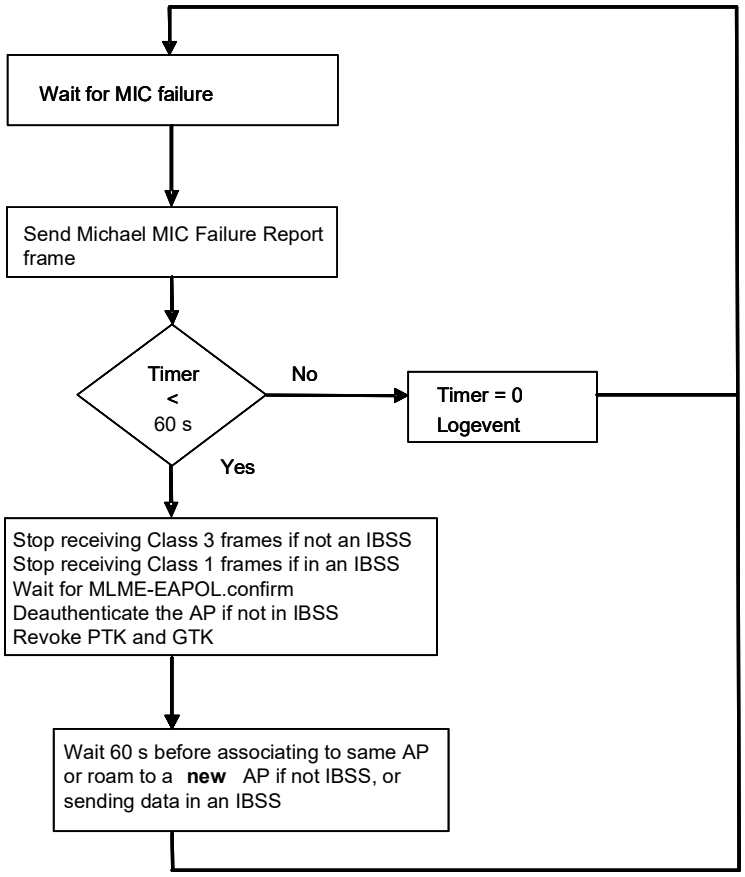


**Figure 12-11—Supplicant MIC countermeasures**

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### 12.3.4.5 TKIP mixing function

#### 12.3.4.5.1 General

Annex J defines a C-language reference implementation of the TKIP mixing function. It also provides test vectors for the mixing function.

The mixing function has two phases. Phase 1 mixes the appropriate temporal key (pairwise or group) with the TA and TSC. A STA may cache the output of this phase to reuse with subsequent MPDUs associated with the same temporal key and TA. Phase 2 mixes the output of Phase 1 with the TSC and temporal key (TK) to produce the WEP seed, also called the *per-frame key*. The WEP seed may be precomputed before it is used. The two-phase process may be summarized as follows:

```
TTAK := Phase1 (TK, TA, TSC)
WEP seed := Phase2 (TTAK, TK, TSC)
```

#### 12.3.4.5.2 S-Box

Both Phase 1 and Phase 2 rely on an S-box, defined in this subclause. The S-box substitutes one 16-bit value with another 16-bit value. This function may be implemented as a table look up.

NOTE—The S-box is a nonlinear substitution. The table look-up is be organized as either a single table with 65 536 entries and a 16-bit index (128K octets of table) or two tables with 256 entries and an 8-bit index (1024 octets for both tables). When the two smaller tables are used, the high order octet is used to obtain a 16-bit value from one table, the low order octet is used to obtain a 16-bit value from the other table, and the S-box output is the XOR of the two 16-bit values. The second S-box table is an octet-swapped replica of the first.

```
#define _S_(v16)     (Sbox[0][Lo8(v16)] ^ Sbox[1][Hi8(v16)])

/* 2-byte by 2-byte subset of the full AES S-box table */
const u16b Sbox[2][256]=       /* Sbox for hash (can be in ROM)     */
{ {
   0xC6A5,0xF884,0xEE99,0xF68D,0xFF0D,0xD6BD,0xDEB1,0x9154,
   0x6050,0x0203,0xCEA9,0x567D,0xE719,0xB562,0x4DE6,0xEC9A,
   0x8F45,0x1F9D,0x8940,0xFA87,0xEF15,0xB2EB,0x8EC9,0xFB0B,
   0x41EC,0xB367,0x5FFD,0x45EA,0x23BF,0x53F7,0xE496,0x9B5B,
   0x75C2,0xE11C,0x3DAE,0x4C6A,0x6C5A,0x7E41,0xF502,0x834F,
   0x685C,0x51F4,0xD134,0xF908,0xE293,0xAB73,0x6253,0x2A3F,
   0x080C,0x9552,0x4665,0x9D5E,0x3028,0x37A1,0x0A0F,0x2FB5,
   0x0E09,0x2436,0x1B9B,0xDF3D,0xCD26,0x4E69,0x7FCD,0xEA9F,
   0x121B,0x1D9E,0x5874,0x342E,0x362D,0xDCB2,0xB4EE,0x5BFB,
   0xA4F6,0x764D,0xB761,0x7DCE,0x527B,0xDD3E,0x5E71,0x1397,
   0xA6F5,0xB968,0x0000,0xC12C,0x4060,0xE31F,0x79C8,0xB6ED,
   0xD4BE,0x8D46,0x67D9,0x724B,0x94DE,0x98D4,0xB0E8,0x854A,
   0xBB6B,0xC52A,0x4FE5,0xED16,0x86C5,0x9AD7,0x6655,0x1194,
   0x8ACF,0xE910,0x0406,0xFE81,0xA0F0,0x7844,0x25BA,0x4BE3,
   0xA2F3,0x5DFE,0x80C0,0x058A,0x3FAD,0x21BC,0x7048,0xF104,
   0x63DF,0x77C1,0xAF75,0x4263,0x2030,0xE51A,0xFD0E,0xBF6D,
   0x814C,0x1814,0x2635,0xC32F,0xBEE1,0x35A2,0x88CC,0x2E39,
   0x9357,0x55F2,0xFC82,0x7A47,0xC8AC,0xBAE7,0x322B,0xE695,
   0xC0A0,0x1998,0x9ED1,0xA37F,0x4466,0x547E,0x3BAB,0x0B83,
   0x8CCA,0xC729,0x6BD3,0x283C,0xA779,0xBCE2,0x161D,0xAD76,
   0xDB3B,0x6456,0x744E,0x141E,0x92DB,0x0C0A,0x486C,0xB8E4,
   0x9F5D,0xBD6E,0x43EF,0xC4A6,0x39A8,0x31A4,0xD337,0xF28B,
   0xD532,0x8B43,0x6E59,0xDAB7,0x018C,0xB164,0x9CD2,0x49E0,
   0xD8B4,0xACFA,0xF307,0xCF25,0xCAAF,0xF48E,0x47E9,0x1018,
   0x6FD5,0xF088,0x4A6F,0x5C72,0x3824,0x57F1,0x73C7,0x9751,
   0xCB23,0xA17C,0xE89C,0x3E21,0x96DD,0x61DC,0x0D86,0x0F85,
```


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```
    0xE090,0x7C42,0x71C4,0xCCAA,0x90D8,0x0605,0xF701,0x1C12,
    0xC2A3,0x6A5F,0xAEF9,0x69D0,0x1791,0x9958,0x3A27,0x27B9,
    0xD938,0xEB13,0x2BB3,0x2233,0xD2BB,0xA970,0x0789,0x33A7,
    0x2DB6,0x3C22,0x1592,0xC920,0x8749,0xAAFF,0x5078,0xA57A,
    0x038F,0x59F8,0x0980,0x1A17,0x65DA,0xD731,0x84C6,0xD0B8,
    0x82C3,0x29B0,0x5A77,0x1E11,0x7BCB,0xA8FC,0x6DD6,0x2C3A,
   },
   {  /* second half of table is byte-reversed version of first! */
    0xA5C6,0x84F8,0x99EE,0x8DF6,0x0DFF,0xBDD6,0xB1DE,0x5491,
    0x5060,0x0302,0xA9CE,0x7D56,0x19E7,0x62B5,0xE64D,0x9AEC,
    0x458F,0x9D1F,0x4089,0x87FA,0x15EF,0xEBB2,0xC98E,0x0BFB,
    0xEC41,0x67B3,0xFD5F,0xEA45,0xBF23,0xF753,0x96E4,0x5B9B,
    0xC275,0x1CE1,0xAE3D,0x6A4C,0x5A6C,0x417E,0x02F5,0x4F83,
    0x5C68,0xF451,0x34D1,0x08F9,0x93E2,0x73AB,0x5362,0x3F2A,
    0x0C08,0x5295,0x6546,0x5E9D,0x2830,0xA137,0x0F0A,0xB52F,
    0x090E,0x3624,0x9B1B,0x3DDF,0x26CD,0x694E,0xCD7F,0x9FEA,
    0x1B12,0x9E1D,0x7458,0x2E34,0x2D36,0xB2DC,0xEEB4,0xFB5B,
    0xF6A4,0x4D76,0x61B7,0xCE7D,0x7B52,0x3EDD,0x715E,0x9713,
    0xF5A6,0x68B9,0x0000,0x2CC1,0x6040,0x1FE3,0xC879,0xEDB6,
    0xBED4,0x468D,0xD967,0x4B72,0xDE94,0xD498,0xE8B0,0x4A85,
    0x6BBB,0x2AC5,0xE54F,0x16ED,0xC586,0xD79A,0x5566,0x9411,
    0xCF8A,0x10E9,0x0604,0x81FE,0xF0A0,0x4478,0xBA25,0xE34B,
    0xF3A2,0xFE5D,0xC080,0x8A05,0xAD3F,0xBC21,0x4870,0x04F1,
    0xDF63,0xC177,0x75AF,0x6342,0x3020,0x1AE5,0x0EFD,0x6DBF,
    0x4C81,0x1418,0x3526,0x2FC3,0xE1BE,0xA235,0xCC88,0x392E,
    0x5793,0xF255,0x82FC,0x477A,0xACC8,0xE7BA,0x2B32,0x95E6,
    0xA0C0,0x9819,0xD19E,0x7FA3,0x6644,0x7E54,0xAB3B,0x830B,
    0xCA8C,0x29C7,0xD36B,0x3C28,0x79A7,0xE2BC,0x1D16,0x76AD,
    0x3BDB,0x5664,0x4E74,0x1E14,0xDB92,0x0A0C,0x6C48,0xE4B8,
    0x5D9F,0x6EBD,0xEF43,0xA6C4,0xA839,0xA431,0x37D3,0x8BF2,
    0x32D5,0x438B,0x596E,0xB7DA,0x8C01,0x64B1,0xD29C,0xE049,
    0xB4D8,0xFAAC,0x07F3,0x25CF,0xAFCA,0x8EF4,0xE947,0x1810,
    0xD56F,0x88F0,0x6F4A,0x725C,0x2438,0xF157,0xC773,0x5197,
    0x23CB,0x7CA1,0x9CE8,0x213E,0xDD96,0xDC61,0x860D,0x850F,
    0x90E0,0x427C,0xC471,0xAACC,0xD890,0x0506,0x01F7,0x121C,
    0xA3C2,0x5F6A,0xF9AE,0xD069,0x9117,0x5899,0x273A,0xB927,
    0x38D9,0x13EB,0xB32B,0x3322,0xBBD2,0x70A9,0x8907,0xA733,
    0xB62D,0x223C,0x9215,0x20C9,0x4987,0xFFAA,0x7850,0x7AA5,
    0x8F03,0xF859,0x8009,0x171A,0xDA65,0x31D7,0xC684,0xB8D0,
    0xC382,0xB029,0x775A,0x111E,0xCB7B,0xFCA8,0xD66D,0x3A2C,
   }
  };
```

#### 12.3.4.5.3 Phase 1 Definition

The inputs to Phase 1 of the temporal key mixing function shall be a temporal key (*TK*), the TA, and the TSC. The temporal key shall be 128 bits in length. Only the 32 MSBs of the TSC and all of the temporal key are used in Phase 1. The output, *TTAK*, shall be 80 bits in length and is represented by an array of 16-bit values: $TTAK_0$ $TTAK_1$ $TTAK_2$ $TTAK_3$ $TTAK_4$.

The description of the Phase 1 algorithm treats all of the following values as arrays of 8-bit values: $TA_0..TA_5$, $TK_0..TK_{15}$. The *TA* octet order is represented according to the conventions from 9.2.2 (Conventions), and the first 3 octets represent the OUI.

The XOR operation, the bitwise-and (&) operation, and the addition (+) operation are used in the Phase 1 specification. A loop counter, *i*, and an array index temporary variable, *j*, are also employed.

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One function, *Mk*16, is used in the definition of Phase 1. The function *Mk*16 constructs a 16-bit value from two 8-bit inputs as $Mk16(X,Y) = (256 \cdot X)+Y$.

Two steps make up the Phase 1 algorithm. The first step initializes *TTAK* from *TSC* and *TA*. The second step uses an S-box to iteratively mix the keying material into the 80-bit *TTAK*. The second step sets the PHASE1_LOOP_COUNT to 8. See Figure 12-12 (Phase 1 key mixing).

```
Input: transmitter address TA0 ... TA5, Temporal Key TK0...TK15, and TSC0...TSC5
Output: intermediate key TTAK0... TTAK4
  PHASE1-KEY- MIXING(TA0 ... TA5, TK0...TK15, TSC0...TSC5)
        PHASE1_STEP1:
        TTAK0 ← MK16(TSC3, TSC2)
        TTAK1 ← MK16(TSC5, TSC4)
        TTAK2 ← Mk16(TA1, TA0)
        TTAK3 ← Mk16(TA3, TA2)
        TTAK4 ← Mk16(TA5, TA4)
        PHASE1_STEP2:
        for i = 0 to PHASE1_LOOP_COUNT
              j ← 2·(i & 1)
              TTAK0 ← TTAK0 + S[TTAK4 ⊕ Mk16(TK1+j, TK0+j)]
              TTAK1 ← TTAK1 + S[TTAK0 ⊕ Mk16(TK5+j, TK4+j)]
              TTAK2 ← TTAK2 + S[TTAK1 ⊕ Mk16(TK9+j, TK8+j)]
              TTAK3 ← TTAK3 + S[TTAK2 ⊕ Mk16(TK13+j, TK12+j)]
              TTAK4 ← TTAK4 + S[TTAK3 ⊕ Mk16(TK1+j, TK0+j )] + i
```

**Figure 12-12—Phase 1 key mixing**

NOTE 1—The TA is mixed into the temporal key in Phase 1 of the hash algorithm. Implementations might achieve a significant performance improvement by caching the output of Phase 1. The Phase 1 output is the same for $2^{16} = 65\,536$ consecutive frames from the same temporal key and TA. Consider the simple case where a STA communicates only with an AP. The STA performs Phase 1 using its own address, and the *TTAK* is used to protect traffic sent to the AP. The STA performs Phase 1 using the AP address, and it is used to unwrap traffic received from the AP.

NOTE 2—The cached *TTAK* from Phase 1 needs to be updated when the lower 16 bits of the TSC wrap and the upper 32 bits need to be updated.

### 12.3.4.5.4 Phase 2 definition

The inputs to Phase 2 of the temporal key mixing function shall be the output of Phase 1 (*TTAK*) together with the temporal key and the TSC. The *TTAK* is 80 bits in length. Only the 16 LSBs of the TSC are used in Phase 2. The temporal key is 128 bits. The output is the WEP seed, which is a per-frame key, and is 128 bits in length. The constructed WEP seed has an internal structure compliant with the WEP specification. In other words, the first 24 bits of the WEP seed shall be transmitted in plaintext as the WEP IV. As such, these 24 bits are used to convey lower 16 bits of the TSC from the sender (encryptor) to the receiver (decryptor). The rest of the TSC shall be conveyed in the Extended IV field. The temporal key and *TTAK* values are represented as in Phase 1. The WEP seed is treated as an array of 8-bit values: $WEPSeed_0 \ldots WEPSeed_{15}$. The TSC shall be treated as an array of 8-bit values: $TSC_0\ TSC_1\ TSC_2\ TSC_3\ TSC_4\ TSC_5$.

The pseudocode specifying the Phase 2 mixing function employs one variable: *PPK*, which is 96 bits long. The *PPK* is represented as an array of 16-bit values: $PPK_0..PPK_5$. The pseudocode also employs a loop counter, *i*. As detailed in this subclause, the mapping from the 16-bit *PPK* values to the 8-bit *WEPseed* values is explicitly little endian to match the endian architecture of the most common processors used for this application.

The XOR (⊕) operation, the addition (+) operation, the AND (&) operation, the OR (|) operation, and the right bit shift (>>) operation are used in the specification of Phase 2. See Figure 12-13 (Phase 2 key mixing).


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```
Input: intermediate key TTAK0…TTAK4, TK, and TKIP sequence counter TSC
Output: WEP Seed WEPSeed0…WEPSeed15
PHASE2-KEY-MIXING(TTAK0…TTAK4, TK0…TK15, TSC0…TSC5)
    PHASE2_STEP1:
        PPK0 ← TTAK0
        PPK1 ← TTAK1
        PPK2 ← TTAK2
        PPK3 ← TTAK3
        PPK4 ← TTAK4
        PPK5 ← TTAK4 + Mk16(TSC1, TSC0)
    PHASE2_STEP2:
        PPK0 ← PPK0 + S[PPK5 ⊕ Mk16(TK1,TK0)]
        PPK1 ← PPK1 + S[PPK0 ⊕ Mk16(TK3,TK2)]
        PPK2 ← PPK2 + S[PPK1 ⊕ Mk16(TK5,TK4)]
        PPK3 ← PPK3 + S[PPK2 ⊕ Mk16(TK7,TK6)]
        PPK4 ← PPK4 + S[PPK3 ⊕ Mk16(TK9,TK8)]
        PPK5 ← PPK5 + S[PPK4 ⊕ Mk16(TK11,TK10)]
        PPK0 ← PPK0 + RotR1(PPK5 ⊕ Mk16(TK13,TK12))
        PPK1 ← PPK1 + RotR1(PPK0 ⊕ Mk16(TK15,TK14))
        PPK2 ← PPK2 + RotR1(PPK1)
        PPK3 ← PPK3 + RotR1(PPK2)
        PPK4 ← PPK4 + RotR1(PPK3)
        PPK5 ← PPK5 + RotR1(PPK4)
    PHASE2_STEP3:
        WEPSeed0 ← TSC1
        WEPSeed1 ← (TSC1 | 0x20) & 0x7F
        WEPSeed2 ← TSC0
        WEPSeed3 ← Lo8((PPK5 ⊕ Mk16(TK1,TK0)) >> 1)
        for i = 0 to 5
            WEPSeed4+(2·i) ← Lo8(PPKi)
            WEPSeed5+(2·i) ← Hi8(PPKi)
        end
    return WEPSeed0…WEPSeed15
```

**Figure 12-13—Phase 2 key mixing**

The algorithm specification relies on four functions:

— The first function, *Lo*8, references the 8 LSBs of the 16-bit input value.

— The second function, *Hi*8, references the 8 MSBs of the 16-bit value.

— The third function, *RotR*1, rotates its 16-bit argument 1 bit to the right.

— The fourth function, *Mk*16, is already used in Phase 1, defined by $Mk16(X,Y) = (256 \cdot X)+Y$, and constructs a 16-bit output from two 8-bit inputs.

NOTE—The rotate and addition operations in STEP2 make Phase 2 particularly sensitive to the endian architecture of the processor, although the performance degradation due to running this algorithm on a big endian processor is expected to be minor.

Phase 2 comprises three steps:

— STEP1 makes a copy of *TTAK* and brings in the TSC.

— STEP2 is a 96-bit bijective mixing, employing an S-box.

— STEP3 brings in the last of the temporal key *TK* bits and assigns the 24-bit WEP IV value.

The WEP IV format carries 3 octets. STEP3 of Phase 2 determines the value of each of these three octets. The construction was selected to preclude the use of known ARC4 weak keys. The recipient can reconstruct the 16 LSBs of the TSC used by the originator by concatenating the third and first octets, ignoring the second octet. The remaining 32 bits of the TSC are obtained from the Extended IV field.

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#### 12.3.4.6 TKIP replay protection procedures

TKIP implementations shall use the TSC field to defend against replay attacks by implementing the following rules:

a) Each MPDU shall have a unique TKIP TSC value.

b) Each transmitter shall maintain a single TSC (48-bit counter) for each PTKSA and GTKSA.

c) The TSC shall be implemented as a 48-bit strictly increasing counter, initialized to 1 when the corresponding TKIP temporal key is initialized or (#1382)refreshed (by rekeying).

d) The WEP IV format carries the 16 LSBs of the 48-bit TSC, as defined by the TKIP mixing function (Phase 2, STEP3). The remainder of the TSC is carried in the Extended IV field.

e) A receiver shall maintain a separate set of TKIP TSC replay counters for each PTKSA and GTKSA.

f) TKIP replay detection takes place after the MIC verification(#163). Thus, a receiver shall delay advancing a TKIP TSC replay counter until an MSDU passes the MIC check, to prevent attackers from injecting MPDUs with valid ICVs and TSCs, but invalid MICs.

NOTE—This works because if an attacker modifies the TSC, then the encryption key is modified and hence both the ICV and MIC decrypt incorrectly, causing the received MPDU to be (#3683)discarded.

g) For each PTKSA and GTKSA, the receiver shall maintain a separate replay counter for each frame priority and shall use the TSC in a received frame to detect replayed frames, subject to the limitations on the number of supported replay counters indicated in the RSN Capabilities field, as described in 9.4.2.23 (RSNE). A replayed frame occurs when the TSC in a received frame is less than or equal to the current replay counter value for the frame's priority. A transmitter shall not reorder TKIP protected frames with different priorities without ensuring that the receiver supports the required number of replay counters. The transmitter shall not reorder TKIP protected frames within a replay counter, but may reorder TKIP protected frames across replay counters. One possible reason for reordering frames is the (#1564)MSDU priority.

h) A receiver shall discard any MPDU that is received out of order and shall increment dot11RSNAStatsTKIPReplays for this key.(#163)

## 12.4 Authentication using a password

### 12.4.1 SAE overview

STAs, both AP STAs and non-AP STAs, may authenticate each other by proving possession of a password. Authentication protocols that employ passwords need to be resistant to off-line dictionary attacks.

Simultaneous authentication of equals (SAE) is a variant of *Dragonfly*, a password-authenticated key exchange based on a zero-knowledge proof. SAE is used by STAs to authenticate with a password; it has the following security properties:

— The successful termination of the protocol results in a PMK shared between the two STAs.

— An attacker is unable to determine either the password or the resulting PMK by passively observing an exchange or by interposing itself into the exchange by faithfully relaying messages between the two STAs.

— An attacker is unable to determine either the password or the resulting shared key by modifying, forging, or replaying frames to an honest, uncorrupted STA.

— An attacker is unable to make more than one guess at the password per attack. This implies that the attacker cannot make one attack and then go offline and make repeated guesses at the password until successful. In other words, SAE is resistant to dictionary attack.

— Compromise of a PMK from a previous run of the protocol does not provide any advantage to an adversary attempting to determine the password or the shared key from any other instance.


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— Compromise of the password does not provide any advantage to an adversary in attempting to determine the PMK from the previous instance.

Unlike other authentication protocols SAE does not (M134)force peers into strict roles where one is an "Initiator" and the other is the "Responder" or one is "Supplicant" and the other "Authenticator." The parties to the exchange are equals, with each side being able to initiate the protocol. Each side may initiate the protocol simultaneously such that each side views itself as the "initiator" for a particular run of the protocol. This is necessary to address the unique nature of MBSSs.

The parties involved are called *STA-A* and *STA-B*. They are identified by their MAC addresses, STA-A-MAC and STA-B-MAC, respectively. STAs begin the protocol when they discover a peer by receiving Beacon or Probe Response frame(s), or when they receive an Authentication frame indicating SAE authentication from a peer.

SAE is an RSNA authentication protocol and is selected according to 12.6.2 (RSNA selection).

SAE shall be implemented on all mesh STAs to facilitate and promote interoperability.

### 12.4.2 Assumptions on SAE

SAE uses two functions, H and CN, that are instantiated with hash functions in HMAC form. H takes a salt and an input key; CN takes a key, a counter, and a sequence of data. Each piece of data passed to CN is converted to an octet string and concatenated before being concatenated to the counter and passed, along with the key, to the hash function.

H(salt, ikm) = HMAC-Hash(salt, ikm)

CN(key, counter, X, Y, Z, …) = HMAC-Hash(key, counter || D2OS(X) || D2OS(Y) || D2OS(Z) || …)

where HMAC-Hash is a specific hash function in HMAC form and D2OS() represents the data to octet string conversion functions in 12.4.7.2 (Data type conversion). Each invocation of CN() specifies the format of the counter.

If used with the looping method(#344) described in 12.4.4.2.2 (Generation of the password element with ECC groups by looping) and 12.4.4.3.2 (Generation of the password element with FFC groups by looping), H and CN are instantiated with SHA-256. If used with the hash-to-element method(#344) described in 12.4.4.2.3 (Hash-to-element(#331) generation of the password element with ECC groups) and 12.4.4.3.3 (Direct generation of the password element with FFC groups), H and CN are instantiated with a hash function from Table 12-1 (Hash algorithm based on length of prime) depending on the size of the prime defining the group being used with SAE.

**Table 12-1—Hash algorithm based on length of prime**

| ECC prime length | FFC prime length | Hash algorithm |
|---|---|---|
| p ≤ 256 | p ≤ 2048 | SHA-256 |
| 256 < p ≤ 384 | 2048 < p ≤ 3072 | SHA-384 |
| 384 < p | 3072 < p | SHA-512 |

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### 12.4.3 Representation of a password

Passwords are used in SAE to deterministically compute a secret element in the negotiated group, called a password element. The input to this process needs to be in the form of a binary string. For the protocol to successfully terminate, it is necessary for each side to produce identical binary strings for a given password, even if that password is in character format. There is no canonical binary representation of a character and ambiguity exists when the password is a character string. To eliminate this ambiguity, a STA shall represent a character-based password as a UTF-8 string that is processed according to the OpaqueString profile of IETF RFC 8265, the output of which is an octet string. The octet string representation of the password, after being processed, is stored in the dot11RSNAConfigPasswordValueTable. When a "password" is called for in the description of SAE that follows the credential from the dot11RSNAConfigPasswordValueTable is used.

Similarly, to address ambiguity when identifying passwords, a STA shall represent a password identifier as a UTF-8 string that is processed according to the UsernameCasePreserved profile of IETF RFC 8265, the output of which is an octet string that is stored in the dot11RSNAConfigPasswordValueTable. When a "password identifier" is called for in the description of SAE that follows, the identifier from the dot11RSNAConfigPasswordValueTable is used. (M162)A mesh STA shall not use a password identifier.

(#8198)In an infrastructure BSS advertising an AKM for which the Authentication type cell in Table 9-190 (AKM suite selectors) identifies SAE, the AP shall set the SAE Password Identifiers In Use subfield of the Extended Capabilities field of the Extended Capabilities element to 1 if any entry in the dot11RSNAConfigPasswordValueTable (#175)has a dot11RSNAConfigPasswordIdentifier that does not have a zero length, and shall set it to 0 otherwise. Similarly, an AP shall set the SAE Password Identifiers Used Exclusively subfield of the Extended Capabilities field of the Extended Capabilities element to 1 if every entry in the dot11RSNAConfigPasswordValueTable (#175)has a dot11RSNAConfigPasswordIdentifier that does not have a zero length and shall set it to 0 otherwise.

### 12.4.4 Finite cyclic groups

#### 12.4.4.1 General

SAE uses discrete logarithm cryptography to achieve authentication and key agreement. Each party to the exchange derives ephemeral public and private keys with respect to a particular set of domain parameters that define a finite cyclic group. Groups may be based on either finite field cryptography (FFC) or on elliptic curve cryptography (ECC). Each component of a group is referred to as an *element*. Groups are negotiated using an identifying number from a repository maintained by IANA as "Group Description" attributes for IETF RFC 2409 (IKE) [B14][B29]. The repository maps an identifying number to a complete set of domain parameters for the particular group. Not all groups defined in this repository are suitable. Only FFC groups whose prime is at least 3072 bits and ECC groups defined over a prime field whose prime is at least 256 bits are suitable for use with SAE. ECC groups defined over a characteristic 2 finite field or ECC groups with a co-factor greater than 1 shall not be used with SAE (see NIST Special Publication 800-57). For the purpose of interoperability, a STA shall implement support for group 19, an ECC group defined over a 256-bit prime order field.

More than one group may be configured on a STA for use with SAE by using the dot11RSNAConfigDLCGroupTable. Configured groups are prioritized in ascending order of preference. If only one group is configured, it is, by definition, the most preferred group.

NOTE—The preference of one group over another is a local policy issue.

SAE uses three arithmetic operators defined for both FFC and ECC groups, an operation that takes two elements to produce a third element (called the *element operation*), an operation that takes an integer (called *scalar*) and an element to produce a second element (called the *scalar operation*), and an operation that takes an element to produce a second element (called the *inverse operation*). The convention used here is to represent


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group elements in uppercase bold italic and scalar values in lowercase italic. The element operation takes two elements, ***X*** and ***Y***, to produce a third element, ***Z***, and is denoted ***Z*** = elem-op(***X***,***Y***); the scalar operation takes a scalar, *x*, and an element, ***Y***, to produce a second element ***Z***(#1409) and is denoted ***Z*** = scalar-op(*x*,***Y***); the inverse operation takes an element, ***X***, to produce a second element, ***Z***, and is denoted ***Z*** = inverse-op(***X***).

scalar-op(*x*,***Y***) is defined as successive iterations of elem-op(***Y***, ***Y***). That is, it is possible to define scalar-op(1, ***Y***) = ***Y*** and for *x* > 1, scalar-op(*x*, ***Y***) = elem-op(scalar-op(*x*-1, ***Y***), ***Y***). The specific definition of elem-op(**X**, ***Y***) depends on the type of group, either ECC or FFC.

#### 12.4.4.2 Elliptic curve cryptography (ECC) groups

##### 12.4.4.2.1 ECC group definition

ECC groups used by SAE are defined by the sextuple (*p*, *a*, *b*, ***G***, *r*, *h*) where *p* is a prime number, *a* and *b* specify the elliptic curve defined by the equation, $y^2 = x^3 + ax + b \bmod p$, ***G*** is a generator (a base point on the elliptic curve), *r* is the prime order of ***G***, and *h* is the co-factor. Elements in ECC groups are the points on the elliptic curve defined by their coordinates—(*x*, *y*)—that satisfy the equation for the curve and the identity element, the so-called "point at infinity."

The element operation in an ECC group is addition of two points on the curve resulting in a third point on the curve. For example, the point ***X*** is added to the point ***Y*** to produce the point ***Z***:

***Z*** = ***X*** + ***Y*** = elem-op(***X***,***Y***)

The scalar operation in an ECC group is multiplication of a point on the curve by a scalar resulting in a second point on the curve. For example, the point ***Y*** is multiplied by the scalar *x* to produce the point ***Z***:

***Z*** = *x****Y*** = scalar-op(*x*,***Y***)

The inverse operation in an ECC group is inversion of a point on a curve resulting in a second point on the curve. A point on an elliptic curve is the inverse of a different point if their sum is the "point at infinity." In other words:

elem-op(***X***, inverse-op(***X***)) = "point at infinity"

ECC groups make use of a mapping function, F, that maps a point (*x*, *y*) that satisfies the curve equation to its x-coordinate—i.e., if ***P*** = (*x*, *y*) then F(***P***) = *x*. Function F is not defined with the identity element as input(#1075).

##### 12.4.4.2.2 Generation of the password element with ECC groups by looping

If the AP does not indicate support for the (#4310)SAE hash-to-element(#3178) method(#355) in its Extended RSN Capabilities field or the SAE initiator does not set the status code to SAE_HASH_TO_ELEMENT in its SAE Commit message, the password element of an ECC group (#3207)(PWE) shall be generated in the following random hunt-and-peck fashion.

NOTE 1—This method cannot be used with a password identifier.

The password and a counter, represented as a single octet and initially set to 1, are used with the peer identities to generate a password seed. The password seed shall then be stretched using the key derivation function (KDF) from 12.7.1.6.2 (Key derivation function (KDF)) to a length equal to the bit length of the prime number, *p*, from the elliptic curve domain parameters with the Label being the string "SAE Hunting and Pecking" and with the Context being the prime number. If the resulting password value is greater than or equal to the prime number, the counter shall be incremented, a new password seed shall be derived and the hunting-and-pecking

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shall continue. Otherwise, it shall be used as the x-coordinate of a candidate point ($x$, $y$) on the curve satisfying the curve equation, if such a point exists. If no solution exists, the counter shall be incremented, a new password-seed shall be derived and the hunting-and-pecking shall continue. Otherwise, there are two possible solutions: ($x$, $y$) and ($x$, $p - y$). The password seed shall be used to determine which one to use: if the least significant bit (LSB) of the password seed is equal to that of $y$, the (#3207)PWE shall be set to ($x$, $y$); otherwise, it shall be set to ($x$, $p - y$).

In order to minimize the possibility of side-channel attacks that attempt to determine the number of interactions of the "hunting-and-pecking" loop required for a given <password, STA-A-MAC, STA-B-MAC> tuple, implementations should perform at least $k$ iterations regardless of whether (#3207)PWE is discovered or not. The value $k$ may be set to any non-negative value and should be set to a sufficiently large number to effectively guarantee the discovery of (#3207)PWE in less than $k$ iterations. If (#3207)PWE is discovered in less than $k$ iterations a random "password" can be used in subsequent iterations to further obfuscate the true cost of discovering (#3207)PWE.

NOTE 2—The probability that one requires more than $n$ iterations of the "hunting and pecking" loop to find (#3207)PWE is roughly $(r/2p)^n$, which rapidly approaches 0 as $n$ increases.

Algorithmically this process is described as follows:

```
found = 0;
counter = 1
Length = len(p)
base = password
do {
        pwd-seed = H(MAX(STA-A-MAC, STA-B-MAC) || MIN(STA-A-MAC, STA-B-MAC),
                base || counter)
        (#478)pwd-value = KDF-Hash-Length(pwd-seed, "SAE Hunting and Pecking", p)
        if (pwd-value < p)
        then
                if (pwd-value^3 + a × pwd-value + b) is a quadratic residue modulo p
                then
                        if (found==0)
                        then
                                x = pwd-value
                                save = pwd-seed
                                found = 1
                                base = a new random number
                        fi
                fi
        fi
        counter = counter + 1
} while ((counter ≤ k) or (found==0))
y = sqrt(x^3 + ax + b) mod p
if (LSB(save) == LSB(y))
then
        (#3207)PWE = (x, y)
else
        (#3207)PWE = (x, p – y)
fi
```

where

(#478)KDF-*Hash-Length*is the key derivation function defined in 12.7.1.6.2 (Key derivation function (KDF)) using the hash algorithm identified by the AKM suite selector (see Table 9-190 (AKM suite selectors)); the context passed to (#478)KDF-*Hash-Length*, $p$, is



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| | |
|---|---|
| | the octet string representation of the prime per 12.4.7.2.2 (Integer to octet string conversion). |
| len() | returns the length of its argument in bits |

Checking whether a value is a quadratic residue modulo a prime can leak information that can be used in launching a side-channel attack. Therefore, a STA should use this blinding technique in determining a quadratic residue to address the possibility of a side-channel attack.

The blinding technique involves multiplication of the value with a random number so the value being checked for quadratic residue modulo a prime can take on all numbers between 1 and $p$–1 with equal probability. The blinded value is multiplied by a quadratic residue or quadratic nonresidue depending on the value of a coin flip and the result is checked whether the result is a quadratic residue or quadratic nonresidue, respectively.

This technique involves creation of a quadratic residue, *qr*, and quadratic nonresidue, *qnr*, prior to beginning of the hunting-and-pecking loop. These values can be chosen at random by checking their legendre symbol:

```
do {
        qr = random() mod p
} while ( LGR(qr | p) is not equal to 1)

do {
        qnr = random() mod p
} while ( LGR(qnr | p) is not equal to -1)
```

The blinding technique of determining whether a value, *v*, is a quadratic residue modulo a prime, *p*, is then:

```
r = (random() mod (p – 1)) + 1
num = (v × r × r) mod p
if (LSB(r) == 1)
then
        num = (num × qr) mod p
        if (LGR(num | p) == 1)
        then
                v is a quadratic residue modulo p
        fi
else
        num = (num × qnr) mod p
        if (LGR(num | p) == –1)
        then
                v is a quadratic residue modulo p
        fi
fi
v is a quadratic nonresidue modulo p
```

The values *qr* and *qnr* may be used for all loops in the hunting-and-pecking process but a new value for *r* shall be generated each time a quadratic residue is checked.

#### 12.4.4.2.3 Hash-to-element(#331) generation of the password element with ECC groups

An SAE peer, e.g. a mesh STA or an AP, indicates support for the hash-to-element method(#344) to obtain an ECC password element by setting the SAE Hash-to-element(#3178) bit to 1 in the Extended RSN Capabilities field in all Beacon and Probe Response frames. A STA that uses a password identifier shall use the hash-to-element(#331) method. An SAE initiator that has identified a peer that supports this method(#344) (through receipt of Beacon or Probe Response frames) shall derive a secret element, PT, according to the following

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method(#344) and indicate this by setting the status code in the SAE Commit message to SAE_HASH_TO_ELEMENT. An SAE initiator shall not indicate support for this form of element derivation unless its peer has already signaled(#3346) support for this method. If an SAE Commit message is received with status code equal to SAE_HASH_TO_ELEMENT the peer shall generate the PWE using the following method(#344) and reply with its own SAE Commit message with status code set to SAE_HASH_TO_ELEMENT.

The hash-to-element method(#344) to derive an element of an ECC group is the Simplified Shallue-Woestijne-Ulas (SSWU) deterministic hash-to-element(#331) method. The SSWU method is called twice with two distinct functions to produce two points on the elliptic curve. The two points are summed to create a secret element PT.

This method works for all Weierstrass elliptic curves whose constants a and b are both not equal to zero. Other curves shall not be used with the hash-to-element(#331) method.

The hash-to-element(#331) method uses HKDF (IETF RFC 5869) with the hash algorithm taken from Table 12-1 (Hash algorithm based on length of prime) based on the length of the prime of the ECC group to perform both functions. First HKDF-Extract is passed a salt in the form of the SSID for which the password is to be used, the password, and optionally a password identifier to produce and intermediary password seed. The resulting seed is passed to HKDF-Expand to produce two distinct strings using different labels. Both values are reduced modulo p, the prime defining the curve, and then passed to SSWU to produce distinct points, *P1* and *P2*, whose sum is *PT*.

This secret *PT* is stored until needed to generate a session specific PWE (see 12.4.5.2 (PWE and secret generation)).

Algorithmically, this process is as follows:

*len* = *olen(p)* + $\lfloor (olen(p))/2 \rfloor$
*pwd-seed* = HKDF-Extract(*ssid*, *password* [|| *identifier*])

*pwd-value* = HKDF-Expand(*pwd-seed*, "*SAE Hash to Element u1 P1*", *len*)
*u1* = *pwd-value* modulo *p*
*P1* = SSWU(*u1*)

*pwd-value* = HKDF-Expand(*pwd-seed*, "*SAE Hash to Element u2 P2*", *len*)
*u2* = *pwd-value* modulo *p*
*P2* = SSWU(*u2*)

*PT* = elem-op(*P1*, *P2*)

where

| | |
|---|---|
| HKDF-Extract() and HKDF-Expand() | are the functions defined in IETF RFC 5869, instantiated with the hash algorithm from Table 12-1 (Hash algorithm based on length of prime) |
| *ssid* | is an octet string that represents the SSID with which the password is to be used |
| *olen*() | returns the length of its argument in octets |
| [|| *identifier*] | indicates the optional inclusion of a password identifier, if present |
| SSWU(*u*) | is a call to the Simple SWU routine passing in parameter *u* |

The SSWU method produces two values, *x1*, and *x2*, at least one of which represents(M118) an abscissa of a point on the curve. If *x1* is the abscissa, then *x1* becomes the x-coordinate otherwise *x2* becomes the x-coordinate. The equation of the curve with the x-coordinate produces the square of the y-coordinate which is


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recovered by taking the square root. The two possible results of the square root are discriminated by checking its least significant bit with the least significant bit of u. The result is a point on the curve.

The SSWU method takes a curve-specific parameter, $z$, which is determined from the following formula, given $p$, $a$, and $b$, from the curve's domain parameter set:

Assign a counter, *ctr*, the value 1. If the following conditions are true for $n = ctr$ then $z = ctr$. Otherwise, if they are true for $n = -ctr$ then $z = -ctr$. Otherwise increment *ctr* and repeat until a value for $z$ is found.

i) $n$ is not a quadratic residue modulo $p$
ii) $n$ is not $-1$
iii) the polynomial $x^3 + a \times x + b - n$ is irreducible
iv) $(b/(n \times a))^3 + a \times (b/(n \times a)) + b$ is a quadratic residue modulo $p$

Values for some defined groups based on their IANA-assigned values are listed in Table 12-2 (Unique curve parameter).

**Table 12-2—Unique curve parameter**

| Curve name | IANA value | z |
|---|---|---|
| NIST p256 | 19 | –10 |
| NIST p384 | 20 | –12 |
| NIST p521 | 21 | –4 |
| NIST p192 | 25 | –5 |
| NIST p224 | 26 | 31 |
| Brainpool p256 | 28 | –2 |
| Brainpool p384 | 29 | –5 |
| Brainpool p512 | 30 | 7 |

Algorithmically, the Simplified SWU method is:

SSWU($u$) {
$m = (z^2 \times u^4 + z \times u^2)$ modulo $p$
$l$ = CEQ($m$, *0*)
$t = inv0(m)$
$x1$ = CSEL($l$, ($b$ / ($z \times a$) modulo $p$), ((– $b/a$) × ($1 + t$)) modulo $p$)
$gx1 = (x1^3 + a \times x1 + b)$ modulo $p$
$x2 = (z \times u^2 \times x1)$ modulo $p$
$gx2 = (x2^3 + a \times x2 + b)$ modulo $p$

$l = gx1$ is a quadratic residue modulo $p$
$v$ = CSEL($l$, $gx1$, $gx2$)
$x$ = CSEL($l$, $x1$, $x2$ )
$y$ = sqrt($v$)

$l$ = CEQ(LSB($u$), LSB($y$))

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```
    P = CSEL(l, (x,y), (x, p – y))
    output P
}
```

where

| | |
|---|---|
| $p$, $a$, and $b$ | are all defined in the domain parameter set for the curve |
| $z$ | is a curve-specific parameter from Table 12-2 (Unique curve parameter) |
| $inv0(x)$ | is calculated as $x^{(p-2)}$ modulo $p$ |
| $x$ | is a quadratic residue if $x^{((p-1)/2)}$ modulo $p$ is zero or one |
| LSB($x$) | returns the least significant bit of $x$ |
| CSEL($x$,$y$,$z$) | operates in constant time and returns $y$ if $x$ is true and $z$ otherwise |
| CEQ($x$,$y$) | operates in constant time and returns true if $x$ equals $y$ and false otherwise |

All operations in the SSWU algorithm shall be done in constant time.

NOTE—For curves based on a prime, $p$, such that $p = 3 \bmod 4$ the square root can be implemented with a single modular exponentiation of $(p+1)/4$, that is sqrt(w) = $w^{(p+1)/4}$ modulo $p$.

#### 12.4.4.3 Finite field cryptography (FFC) groups

##### 12.4.4.3.1 FFC group definition

FFC groups used by SAE are defined by the triple ($p$, $\boldsymbol{G}$, $r$), where $p$ is a prime number, $\boldsymbol{G}$ is a generator, and $r$ is the prime order of $\boldsymbol{G}$ mod $p$. An element, $\boldsymbol{B}$, in an FFC group satisfies $\boldsymbol{B} = \boldsymbol{G}^i \bmod p$ for some integer $i$. This special property differentiates elements from scalars, even though both elements and scalars can be represented as non-negative integers less than the prime modulus p. The notation convention of 12.4.4 (Finite cyclic groups) signifies this difference between an element and a scalar in an FFC group. The identity element for an FFC group is the value 1 mod $p$.

The element operation in an FFC group is modular multiplication of two elements of this group resulting in a third element of this group. For example, the element $\boldsymbol{X}$ is multiplied by the element $\boldsymbol{Y}$ to product the element $\boldsymbol{Z}$:

$$\boldsymbol{Z} = (\boldsymbol{XY}) \bmod p = \text{elem-op}(\boldsymbol{X},\boldsymbol{Y})$$

The scalar operation in an FFC group is modular exponentiation of an element of this group by a scalar resulting in a second element of this group. For example, the point $\boldsymbol{Y}$ is raised to the power $x$ to produce the element $\boldsymbol{Z}$:

$$\boldsymbol{Z} = \boldsymbol{Y}^x \bmod p = \text{scalar-op}(x,\boldsymbol{Y})$$

Some FFC groups in the IANA repository are based on *safe primes*, i.e., a prime, $p$, of the form $p = 2q + 1$, where $q$ is also a prime number. For these FFC groups, the group generated by $\boldsymbol{G}$ always has order $r = (p – 1)/2$ and thus is uniquely derived from context. For other FFC groups, the parameter $r$ shall be explicitly stated as part of the domain parameters.

The inverse operation in an FFC group is modular inversion of an element of this group producing a second element in this group. An element $\boldsymbol{Z}$ is the inverse of a second element $\boldsymbol{X}$ of this group if their modular product is the identity element of the FFC group. In other words:

$$\text{elem-op}(\boldsymbol{X}, \text{inverse-op}(\boldsymbol{X})) = 1 \bmod p$$


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In contrast to ECC groups, FFC groups do not need a mapping function that maps an element of the FFC group to an integer (since those elements are already non-negative integers less than the prime number, *p*). However, for sake of uniform protocol definition, function F with FFC groups is defined as the identity function—i.e., if *x* is an element of the FFC group then F(*x*) = *x*.

#### 12.4.4.3.2 Generation of the password element with FFC groups by looping

If the AP does not indicate support for the SAE hash-to-element method(#355) in its Extended RSN Capabilities field or the SAE initiator does not set the status code to SAE_HASH_TO_ELEMENT in its SAE Commit message, the password element of an FFC group (#4264)(PWE) shall be generated in the following (M134)hunt-and-peck fashion.

NOTE—This method cannot be used with a password identifier.

The password and a counter, represented as a single octet and initially set to 1, are used with the two peer identities to generate a password seed. The password seed shall then be stretched using the key derivation function (KDF) from 12.7.1.6.2 (Key derivation function (KDF)) to a length equal to the bit length of the prime number, *p*, from the group domain parameters with the Label being the string "SAE Hunting and Pecking" and the Content being the prime number. If the resulting password value is greater than or equal to the prime number, the counter shall be incremented, a new password seed shall be derived, and the hunting-and-pecking shall continue. Otherwise, it shall be raised to the power $(p - 1) / r$ (where *p* is the prime number and *r* is the order) modulo the prime number to produce a candidate (#4264)PWE. If the candidate (#4264)PWE is greater than 1, the candidate (#4264)PWE becomes the (#4264)PWE; otherwise, the counter shall be incremented, a new password seed shall be derived, and the hunting-and-pecking shall continue.

Algorithmically this process is described as follows:

```
found = 0;
counter = 1
Length = len(p)
do {
        pwd-seed = H(MAX(STA-A-MAC, STA-B-MAC) || MIN(STA-A-MAC, STA-B-MAC),
                password || counter)
        (#478)pwd-value = KDF-Hash-Length(pwd-seed, "SAE Hunting and Pecking", p)
        if (pwd-value < p)
        then
                (#4264)PWE = pwd-value^((p-1)/r) mod p
                (#4264)if (PWE > 1)
                then
                        found = 1
                fi
        fi
        counter = counter + 1
} while (found==0)
```

where

(#478)KDF-*Hash-Length* is the key derivation function defined in 12.7.1.6.2 (Key derivation function (KDF)) using the hash algorithm identified by the AKM suite selector (see Table 9-190 (AKM suite selectors)); the context passed to (#478)(#3686)KDF-*Hash-Length*, *p*, is the octet string representation of the prime per 12.4.7.2.2 (Integer to octet string conversion)

len() returns the length of its argument in bits

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#### 12.4.4.3.3 Direct generation of the password element with FFC groups

An SAE peer indicates support for the hash-to-element method(#344) to obtain the FFC password element by setting the (#4310)SAE Hash-to-element bit to 1 in the Extended RSN Capabilities field in all Beacon and Probe Response frames. A STA that uses a password identifier shall use the hash-to-element method(#344). An SAE initiator that has identified a peer that supports the following technique (through receipt of Beacon or Probe Response frames) shall derive PT according to the following method(#344) and indicate this by setting the status code in the SAE Commit message to SAE_HASH_TO_ELEMENT. An SAE initiator shall not indicate support for this form of PWE derivation unless its peer has already signaled(#3346) support. If an SAE Commit message is received with status code equal to SAE_HASH_TO_ELEMENT the peer shall generate the PWE using the following method(#344) and reply with its own SAE Commit message with status code set to SAE_HASH_TO_ELEMENT.

The hash-to-element method(#344) uses HKDF (IETF RFC 5869) with the hash algorithm taken from Table 12-1 (Hash algorithm based on length of prime) based on the length of the prime of the FFC group.

To perform the hash-to-element method(#344), HKDF (IETF RFC 5869) is passed a salt in the form of the SSID for which the password is to be used, the password, optionally a password identifier, as an input key, a constant label "SAE Hash to Element", and the length of the prime to produce a password value. The resulting password value shall be reduced into a range such that $1 < pwd\text{-}value < p$. Then, it shall be raised to the power $(p\text{-}1) / q$ and reduced modulo $p$ (where $p$ is the prime number and $q$ is the order). This ensures(M118) PT is a generator of order either 1 (if $PT = 1$) or $q$ (for all other values). The probability of PT taking the value 1 is (M162)negligible but if it happen the label is appended with a constant message and PT is generated again.

This secret PT is stored until needed to generate a session specific PWE.

Algorithmically, this process is as follows:

(M162)*label* = "*SAE Hash to Element*"
*do* {
    $len = olen(p) + \lfloor (olen(p))/2 \rfloor$
    *pwd-seed* = HKDF-Extract(*ssid*, *password* [|| *identifier*])
    *pwd-value* = HKDF-Expand(*pwd-seed*, *label*, *len*)(M162)
    *pwd-value* = (*pwd-value* modulo ($p$ – 2)) + 2
    $PT = pwd\text{-}value^{(p-1)/q}$ modulo $p$
    *label* = *label* || "*PT was one*"(M162)
} *while* (*PT*==1)(M162)

where

| | |
|---|---|
| HKDF-Extract() and HKDF-Expand() | are the functions defined in IETF RFC 5869, instantiated with the hash algorithm from Table 12-1 (Hash algorithm based on length of prime) |
| *ssid* | is an octet string that represents the SSID with which the password is to be used |
| *olen*() | returns the length of its argument in octets |
| [|| *identifier*] | indicates the optional inclusion of a password identifier, if present |
| $p$ and $q$ | are defined in the domain parameter set for the group |

This secret PT is stored until needed to generate a session specific PWE (see 12.4.5.2 (PWE and secret generation)).


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### 12.4.5 SAE protocol

#### 12.4.5.1 Message exchanges

The protocol consists of two message exchanges, a commitment exchange and a confirmation exchange. The commitment exchange is used to force each party to the exchange to commit to a single guess of the password. The confirmation exchange is used to prove that the password guess was correct. Authentication frames are used to perform these exchanges (see 9.3.3.11 (Authentication frame format), 12.4.7.3 (Encoding and decoding of SAE Commit messages) and 12.4.7.4 (Encoding and decoding of SAE Confirm messages))(Ed1). The rules for performing these exchanges are specified by the finite state machine in 12.4.8 (SAE finite state machine).

When a party has sent its message in the commit exchange it is said to have *committed* and when it has sent its message in the confirmation exchange it has *confirmed*. The following rules are ascribed to the protocol:

- A party may *commit* at any time
- A party *confirm*s after it has *committed* and its peer has *committed*
- A party *accept*s authentication after a peer has *confirmed*
- The protocol successfully *terminates* after each peer has *accepted*

#### 12.4.5.2 PWE and secret generation

Prior to beginning the protocol message exchange, the secret element (#3207)PWE and two secret values are generated.

When a STA supports the hash-to-element method(#344) (according to 12.4.4.2.3 (Hash-to-element(#331) generation of the password element with ECC groups) or 12.4.4.3.3 (Direct generation of the password element with FFC groups)) it computes a secret element, PT, offline at provisioning time for all groups it wishes to support with that password. Prior to initiating SAE to a STA that also supports the direct form of hashing to a group element, or upon receipt of an SAE Commit message indicating it was generated using a direct form of hashing to a group element, it shall generate the PWE by hashing the two peer MAC addresses to produce a digest, reducing the digest modulo the order of the particular group, *r*, interpreting the reduced digest as an integer and using it with the secret element to generate the PWE:

$val = H(0^n, MAX(STA\text{-}A\text{-}MAC, STA\text{-}B\text{-}MAC) \,||\, MIN(STA\text{-}A\text{-}MAC, STA\text{-}B\text{-}MAC))$
$val = val$ modulo $(r - 1) + 1$
$PWE = scalar\text{-}op(val, PT)$

where $0^n$ is a salt of all 0s(M118) whose length equals the length of the digest from the hash function used to instantiate H() (see Table 12-1 (Hash algorithm based on length of prime)).

If a STA does not support a direct form of hashing to a group element, it generates the PWE after selecting a group, either the most preferred group if the STA is initiating SAE to a peer, or the group from a received SAE Commit message if the STA is responding to a peer. The (#3207)PWE shall be generated for that group (according to 12.4.4.2.2 (Generation of the password element with ECC groups by looping) or 12.4.4.3.2 (Generation of the password element with FFC groups by looping), depending on whether the group is ECC or FFC, respectively) using the identities of the two STAs and the configured password.

After generation of the (#3207)PWE, each STA shall generate a secret value, *rand*, and a temporary secret value, *mask*, each of which shall be chosen randomly such that $1 < rand < r$ and $1 < mask < r$ and $(rand + mask)$ mod $r$ is greater than 1, where $r$ is the (prime) order of the group. If their sum modulo r is not greater than 1, they shall both be irretrievably deleted and new values shall be randomly generated. The values *rand* and *mask* shall be random numbers produced from a quality random number drawn from a uniform distribution generator. These values shall never be reused on distinct protocol runs.

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#### 12.4.5.3 Construction of an SAE Commit message

The scalar and element in an SAE Commit message shall be produced using (#3207)PWE and secrets generated in 12.4.5.2 (PWE and secret generation), as follows:

*commit-scalar* = (*rand* + *mask*) mod *r*
***COMMIT-ELEMENT*** = inverse-op(scalar-op(*mask*, (#3207)PWE))

This message shall be transmitted to the peer as described in 12.4.7 (Framing of SAE). The temporary secret *mask* may be deleted at this point.

(M67)To derive keys for use with AKM 00-0F-AC:24 or AKM 00-0F-AC:25, an AKM Suite Selector element indicating 00-0F-AC:24 or 00-0F-AC:25 shall be included in an SAE Commit message transmitted to the peer.

(M67)If an SAE Commit message that includes an AKM Suite Selector element has been received, the AKM indicated in the AKM Suite Selector element is supported, and a SAE Commit message is constructed, then the SAE Commit message shall include an AKM Suite Selector element that indicates the same AKM.

#### 12.4.5.4 Processing of a peer's SAE Commit message

If the peer's SAE Commit message contains a (#3132)(#2168)Password Identifier element, the identifier in that element shall be used in construction of the (#2168)PWE for this exchange. If a password identifier is present in the peer's SAE Commit message and there is no password with the given identifier a STA shall fail authentication.

If the peer's SAE Commit message contains a Rejected Groups element, the list of rejected groups shall be checked to ensure that all of the groups in the list are groups that would be rejected. If any groups in the list would not be rejected then processing of the SAE Commit message terminates and the STA shall reject the peer's authentication. While the rejected groups are appended to the Rejected Groups element as they are rejected (see 12.4.7.3 (Encoding and decoding of SAE Commit messages)) there is no inherent order to the groups in the list. The order in which they are sent and received shall be retained when deriving keys.

(M67)If the state of the SAE finite state machine is *Committed* (see 12.4.8.2.2 (Protocol instance states)) and the SAE Commit message that has been sent by the SAE finite state machine to transition into *Committed* state includes an AKM Suite Selector element, the authentication shall fail if either of the following conditions is true:

— the peer's SAE Commit message does not contain an AKM Suite Selector element
— the peer's SAE Commit message contains an AKM Suite Selector element and the AKM Suite Selector element does not indicate the same AKM

Upon receipt of a peer's SAE Commit message both the scalar and element shall be verified.

(M134)If the state of the SAE finite state mechanism is other than *Nothing* (see 12.4.8.2.2 (Protocol instance states)) and the scalar or element from the peer's SAE Commit message are identical to the scalar or element sent by the SAE finite state machine to transition into *Committed* state, processing fails.

If the scalar value is greater than 1 and less than the order, *r*, of the negotiated group, scalar validation succeeds; otherwise, it fails. Element validation depends on the type of group. For FFC groups, the element shall be an integer greater than 1 and less than the prime number *p* minus 1, (*p* – 1), and the scalar operation of the element and the order of the group, *r*, shall equal 1 modulo the prime number *p*. If either of these conditions does not hold, element validation fails; otherwise, it succeeds. For ECC groups, both the x- and y-coordinates of the element shall be non-negative integers less than the prime number *p*, and the two coordinates shall produce a valid point on the curve satisfying the group's curve definition, not being equal to the "point at the


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infinity." If either of those conditions does not hold, element validation fails; otherwise, element validation succeeds.

If either scalar validation or element validation fails, the STA shall reject the peer's authentication. If both the scalar and element from the peer's SAE Commit message are successfully validated, a shared secret element, *K*, shall be derived using the scalar and element (*peer-commit-scalar* and ***PEER-COMMIT-ELEMENT***, respectively) from the peer's SAE Commit message and the STA's secret value.

***K*** = scalar-op(*rand*, (elem-op(scalar-op(*peer-commit-scalar*, (#3207)PWE),
***PEER-COMMIT-ELEMENT***)))

If the shared secret element, ***K***, is the identity element for the negotiated group (the value one for an FFC group or the point-at-infinity for an ECC group) the STA shall reject the peer's authentication. Otherwise, a secret value, *k*, shall be computed as:

$k = F(\boldsymbol{K})$

The entropy of *k* shall then be extracted using H to produce *keyseed*. The key derivation function from 12.7.1.6.2 (Key derivation function (KDF)) shall then be used with the hash algorithm identified for H() (see 12.4.2 (Assumptions on SAE)) to derive a (#3742)SAE key confirmation key, SAE-KCK, and a pairwise master key, PMK, from *keyseed*.

(M67)The intended AKM for the purpose of PMK and (#3742)SAE-KCK size determination (see below) is determined as follows:

- If an AKM Suite Selector element is not included in the SAE Commit message from the peer and the state of the SAE finite state machine is *Nothing* (see 12.4.8.2.2 (Protocol instance states)), then (#3266)AKM 00-0F-AC:8 or 00-0F-AC:9 shall be the intended AKM.
- If the state of the SAE finite state machine is *Committed* (see 12.4.8.2.2 (Protocol instance states)) and the SAE Commit message that has been sent by the SAE finite state machine to transition into *Committed* state does not include an AKM Suite Selector element, then (#3266)AKM 00-0F-AC:8 or 00-0F-AC:9 shall be the intended AKM.
- If an AKM Suite Selector element that indicates AKM 00-0F-AC:24 or AKM 00-0F-AC:25 is included in the SAE Commit message from the peer and the state of the SAE finite state machine is *Nothing* (see 12.4.8.2.2 (Protocol instance states)), then the indicated AKM shall be the intended AKM.
- If the state of the SAE finite state machine is *Committed* (see 12.4.8.2.2 (Protocol instance states)) and the SAE Commit message that has been sent by the SAE finite state machine to transition into *Committed* state includes an AKM Suite Selector element that indicates AKM 00-0F-AC:24 or AKM 00-0F-AC:25, then the indicated AKM shall be the intended AKM.

(M67)If the intended AKM is (M21)00-0F-AC:8 or 00-0F-AC:9 and the looping method of PWE generation (see 12.4.4.2.2 (Generation of the password element with ECC groups by looping) and 12.4.4.3.2 (Generation of the password element with FFC groups by looping)), both the (#3742)SAE-KCK and PMK shall be 256 bits in length. (M67)If the intended AKM is 00-0F-AC:8 or 00-0F-AC:9 and the hash-to-element method(#344) of PWE generation (see 12.4.4.2.3 (Hash-to-element(#331) generation of the password element with ECC groups) and 12.4.4.3.3 (Direct generation of the password element with FFC groups)), the (#3742)SAE-KCK shall have(M67) the length of the digest generated by H() and the PMK shall be 256 bits in length (M21)(see 12.7.1.3 (Pairwise key hierarchy)). (M67)If the intended AKM is 00-0F-AC:24 or 00-0F-AC:25, the hash-to-element method(#344) of PWE generation (see 12.4.4.2.3 (Hash-to-element(#331) generation of the password element with ECC groups) and 12.4.4.3.3 (Direct generation of the password element with FFC groups)) shall be used, the (#3742)SAE-KCK and the PMK shall have the length of the digest generated by H().(M67) Use of other AKMs with the hash-to-element method(#344) requires(M118) definition of the length of the PMK. If both SAE Commit messages indicated a status code of SAE_HASH_TO_ELEMENT, a salt consisting of the

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concatenation of the rejected groups from each peer's Rejected Groups element shall be passed to the KDF; those of the peer with the highest MAC address go first (if only one sent a Rejected Groups element then the salt consists(M118) of that list). If neither peer sent a Rejected Groups element or the status code was not SAE_HASH_TO_ELEMENT, the salt shall consist of a series of octets of the value zero whose length equals the length of the digest of the hash function used to instantiate H().

*keyseed* = H(*salt*, *k*)
*context* = (*commit-scalar* + *peer-commit-scalar*) mod *r*
*Length* = *Q* + *PMK_bits*(M21)
(#478)(#3742)*sae_kck_and_pmk* = KDF-*Hash-Length*(*keyseed*, "SAE KCK and PMK", *context*)
(#3742)*SAE-KCK* = (#3506)ExtractBits(*sae_kck_and_pmk*, 0, *Q*)
*PMK* = (#3506)ExtractBits((#3742)*sae_kck_and_pmk*, *Q*, *PMK_bits*)(M21)

where

| | |
|---|---|
| *salt* | is either a series of 0 octets or a list of rejected groups (see 12.4.7.3 (Encoding and decoding of SAE Commit messages)) |
| (#478)KDF-*Hash-Length* | is the key derivation function defined in 12.7.1.6.2 (Key derivation function (KDF)) using the hash algorithm defined for H() |
| *Q* | is the length of the digest of the H(), the hash function used |
| *context* | is treated as an integer and converted into an octet string of length *m* such that $2^{8m} > r$ according to 12.4.7.2.2 (Integer to octet string conversion) |
| *PMK_bits* | is the length of the PMK in bits, as defined in 12.7.1.3 (Pairwise key hierarchy)(M21) |

The PMK identifier is defined as follows:

PMKID = (#3506)ExtractBits(*context*, 0, 128)

### 12.4.5.5 Construction of an SAE Confirm message

A peer generates a confirmation, *confirm*, and inserts it into an SAE Confirm message by (#4056)passing the SAE-KCK, the current value of the *send-confirm* counter (see 9.4.1.35 (Send-Confirm field)), the scalar and element from the sent SAE Commit message, and the scalar and element from the received SAE Commit message to the confirmation function CN.

*confirm* = CN((#3742)SAE-KCK, *send-confirm, commit-scalar,* ***COMMIT-ELEMENT***, *peer-commit-scalar,* ***PEER-COMMIT-ELEMENT***)

The *send-confirm* counter shall be encoded according to 9.2.2 (Conventions). The elements and scalars shall be in the format they were encoded in when transmitted in an SAE Commit message as described in 12.4.7.3 (Encoding and decoding of SAE Commit messages). The message shall be transmitted to the peer as described in 12.4.7 (Framing of SAE).

### 12.4.5.6 Processing of a peer's SAE Confirm message

Upon receipt of a peer's SAE Confirm message a *verifier* is computed, which is the expected value of the peer's confirmation, *peer-confirm*, extracted from the received an SAE Confirm message. The *verifier* is computed by passing the (#3742)SAE-KCK, the peer's send-confirm counter from the received an SAE Confirm message (see 9.4.1.35 (Send-Confirm field)), the scalar and element from the received SAE Commit message, and scalar and element from the sent SAE Commit message to the confirmation function CN.

*verifier* = CN((#3742)SAE-KCK, *peer-send-confirm, peer-commit-scalar,* ***PEER-COMMIT-ELEMENT***, *commit-scalar,* ***COMMIT-ELEMENT***)


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The *peer-send-confirm* shall be encoded according to 9.2.2 (Conventions). The elements and scalars shall be in the format they were encoded in when transmitted in an SAE Commit message as described in 12.4.7.3 (Encoding and decoding of SAE Commit messages). If the *verifier* differs from the *peer-confirm,* verification of the peer's SAE Confirm message shall fail.

### 12.4.6 Anti-clogging tokens

A STA is required to do a considerable amount of work upon receipt of an SAE Commit message. This opens up the possibility of a distributed denial-of-service attack by flooding a STA with bogus SAE Commit messages from forged MAC addresses. To prevent this from happening, a STA shall maintain an *Open* counter in its SAE state machine indicating the number of open and unfinished protocol instances (see 12.4.5.1 (Message exchanges)). When that counter hits or exceeds dot11RSNASAEAntiCloggingThreshold, the STA shall respond to each SAE Commit message with a rejection that includes an Anti-Clogging Token field statelessly bound to the sender of the SAE Commit message. The sender of the SAE Commit message shall then include the Anti-Clogging Token field in a subsequent SAE Commit message.

The Anti-Clogging Token field is a variable length value that statelessly binds the MAC address of the sender of an SAE Commit message. The length of the Anti-Clogging Token field need not be specified because the generation and processing of the Anti-Clogging Token field is solely up to one peer. To the other peer in the SAE protocol, the Anti-Clogging Token field is merely an opaque blob whose length is insignificant. An Anti-Clogging Token field should not exceed 256 octets.

NOTE—A suggested method for producing Anti-Clogging Token fields is to generate a random secret value each time the state machine variable hits dot11RSNASAEAntiCloggingThreshold and pass that secret and the MAC address of the sender of the SAE Commit message to the random function H to generate the token.

As long as the state machine variable *Open* is greater than or equal to dot11RSNASAEAntiCloggingThreshold all SAE Commit messages that do not include a valid Anti-Clogging Token field shall be rejected with a request to repeat the SAE Commit message and include the token (see 12.4.5.1 (Message exchanges)).

Since the Anti-Clogging Token field is of fixed size and the size of the *peer-commit-scalar* and ***PEER-COMMIT-ELEMENT*** are inferred from the finite cyclic group being used, it is straightforward to determine whether a received SAE Commit message includes an Anti-Clogging Token field or not.

Encoding of the Anti-Clogging Token field and its placement with respect to the *peer-commit-scalar* and ***PEER-COMMIT-ELEMENT*** is described in 12.4.7.3 (Encoding and decoding of SAE Commit messages).

### 12.4.7 Framing of SAE

#### 12.4.7.1 General

SAE Commit messages and SAE Confirm messages are sent and received by an SAE protocol using Authentication frames.

#### 12.4.7.2 Data type conversion

##### 12.4.7.2.1 General

This protocol requires elements in finite cyclic groups to be converted to octet strings prior to transmission and back again upon receipt. To convert an element into an octet string, the first step is to represent the element in integer format and then employ an (#7165)integer to octet string conversion prior to transmission. To convert an octet string into an element requires an octet string to integer conversion and then representing the integer(s) as an element.

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#### 12.4.7.2.2 Integer to octet string conversion

An integer, $x$, shall be converted into an octet string whose length is the smallest integer m such that $2^{8m} > x$ by first representing $x$ in its binary form and then converting the result to an (#1288)octet string.

Given $x$, $m$, represent $x$ as a sequence of $x_{m-i}$ base $2^8$:

$$x = x_{m-1} \times 2^{8(m-1)} + x_{m-2} \times 2^{8(m-2)} + \ldots + x_1 \times 2^8 + x_0$$

then let the octet $M_i$ have the value $x_i$ for $0 \le i \le m-1$, and the octet string shall be $M_{m-1} \| M_{m-2} \| \ldots \| M_1 \| M_0$.

#### 12.4.7.2.3 Octet string to integer conversion

An octet string shall be converted into an integer by viewing the octet string as the base $2^8$ representation of the integer.

$$x = \sum_{i=1}^{m} 2^{8(m-i)} \times M_{m-i}$$

#### 12.4.7.2.4 Element to octet string conversion

For ECC groups, each element, except the "point at infinity," is a point on the elliptic curve satisfying the curve equation and consists of two components: an x-coordinate and a y-coordinate. To convert this point to an octet string, each component shall be treated as an integer and converted into an octet string whose length is the smallest integer $m$ such that $2^{8m} > p$, where $p$ is the prime number specified by the elliptic curve domain parameters, according to 12.4.7.2.2 (Integer to octet string conversion). The point shall be represented as the concatenation of the x-coordinate and the y-coordinate, each represented as an octet string of length $m$ octets, and is $2m$ octets long.

For FFC groups each element is a non-negative integer less than the prime number $p$ specified by the FFC domain parameters. To convert this element into an octet string, it shall be treated directly as an integer and converted into an octet string whose length is the smallest integer $m$ such that $2^{8m} > p$, where $p$ is the prime number specified by the domain parameters, according to 12.4.7.2.2 (Integer to octet string conversion).

#### 12.4.7.2.5 Octet string to element conversion

To convert an octet string into a point on an elliptic curve it is necessary to divide it into two octet strings of equal length $m$. If the length of the octet string does not evenly divide by two, conversion shall fail. Each octet string of length $m$ shall be converted to an integer according to 12.4.7.2.3 (Octet string to integer conversion). The first octet string conversion produces an integer that becomes the x-coordinate of the point and the second octet string conversion produces an integer that becomes the y-coordinate of the point. If either integer equals 0 or is greater than or equal to $p$, the prime from the elliptic curve domain parameters, conversion shall fail. If the resulting $(x, y)$ point does not satisfy the equation of the curve, or produces the "point at infinity," conversion shall fail.

To convert an octet string into an element in a prime modulus group the octet string shall be converted into an integer according to 12.4.7.2.3 (Octet string to integer conversion) and the integer shall be used directly as the group element(#1713).

### 12.4.7.3 Encoding and decoding of SAE Commit messages

An SAE Commit message shall be encoded as an Authentication frame with an Authentication Algorithm Number field set to 3, a Transaction Sequence Number field set to 1 and a Status Code field set to indicate


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SUCCESS or SAE_HASH_TO_ELEMENT.(#3326) Status codes not equal to SUCCESS or SAE_HASH_TO_ELEMENT indicate a rejection of a peer's SAE Commit message and are described in 12.4.7.5 (Status codes).

An SAE Commit message shall (#1592)include a Finite Cyclic Group field (9.4.1.40 (Finite Cyclic Group field)) indicating a group, a Scalar field (9.4.1.37 (Scalar field)) containing the scalar, and an FFE field containing the element (9.4.1.38 (FFE field)).

(#1592)If the SAE Commit message is a request for an Anti-Clogging Token field or in response to such a request (see 12.4.7.5 (Status codes)), an Anti-Clogging Token field shall be included (see 9.4.1.36 (Anti-Clogging Token field)); otherwise it shall not be included. When the PWE is derived using the hash-to-element method, the Anti-Clogging Token field is encapsulated in an Anti-Clogging Token Container element; otherwise, the Anti-Clogging Token field is included in the frame outside of an element as described in Table 9-71 (Presence of fields and elements in Authentication frames).

(#1592)If a password identifier is used in generation of the PWE, a Password Identifier element shall be included and the identifier shall be encoded as a UTF-8 string in the Identifier field (see 9.4.2.215 (Password Identifier element)); otherwise it shall not be included.

(#1592)If the status code of the SAE Commit message is SAE_HASH_TO_ELEMENT and if any groups have been rejected during the current SAE authentication instance, a Rejected Groups element shall be included (see 9.4.2.245 (Rejected Groups element)); otherwise it shall not be included.

If an SAE Commit message with status code set to SAE_HASH_TO_ELEMENT is being sent in response to rejection of (#1592)an SAE Commit message with status code set to UNSUPPORTED_FINITE_CYCLIC_GROUP, (#1809)the group that was rejected shall be appended, after the rejected groups from previous attempts if any, to the ordered list of rejected groups, if not already present there, and a Rejected Groups element (see 9.4.2.245 (Rejected Groups element)) shall be included, containing the ordered list of rejected groups..

(#1592)NOTE—(#1500)Each rejected group is represented using a Finite Cyclic Group field (see 9.4.1.40 (Finite Cyclic Group field)).

When transmitting an SAE Commit message, the scalar and element shall be converted to octet strings and placed in the Scalar field and FFE field, respectively. The scalar shall be treated as an integer and converted into an octet string of length $m$ such that $2^{8m} > r$, where $r$ is the order of the group, according to 12.4.7.2.2 (Integer to octet string conversion), and the element shall be converted into (an) octet string(s) according to 12.4.7.2.4 (Element to octet string conversion). When receiving an SAE Commit message the component octet strings in the Scalar field and FFE field shall be converted into a scalar and element, respectively, according to 12.4.7.2.3 (Octet string to integer conversion) and 12.4.7.2.5 (Octet string to element conversion), respectively.

### 12.4.7.4 Encoding and decoding of SAE Confirm messages

An SAE Confirm message shall be encoded as an Authentication frame with an Authentication Algorithm Number field set to 3, (#3326)a Transaction Sequence Number field set to 2 and a Status Code field set to indicate SUCCESS. Status codes not equal to SUCCESS indicate rejection of a peer's SAE Confirm message and are described in 12.4.7.5 (Status codes).

An SAE Confirm message shall consist of a Send-Confirm field (9.4.1.35 (Send-Confirm field)) and a Confirm field (9.4.1.39 (Confirm field)) containing the output of the random function as described in 12.4.5.5 (Construction of an SAE Confirm message). When transmitting an SAE Confirm message the output of the random function shall be treated as an integer and converted into an octet string of length $m$, where $m$ is the block size of the random function, according to 12.4.7.2.2 (Integer to octet string conversion) and placed in the Confirm field. When receiving an SAE Confirm message, the octet string in the Confirm field shall be

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converted into an integer representing the peer's SAE Confirm message according to 12.4.7.2.3 (Octet string to integer conversion).

#### 12.4.7.5 Status codes

An SAE Commit message with a status code not equal to SUCCESS or SAE_HASH_TO_ELEMENT shall indicate that a peer rejects a previously sent SAE Commit message. An unsupported finite cyclic group is indicated with a status code of UNSUPPORTED_FINITE_CYCLIC_GROUP, "Authentication is rejected because the offered finite cyclic group is not supported." An unknown password identifier is indicated with a status code of UNKNOWN_PASSWORD_IDENTIFER, "Authentication is rejected because the password identifier is unknown." An Anti-Clogging Token field is requested by transmitting an SAE Commit message with a status code of ANTI_CLOGGING_TOKEN_REQUIRED, "Anti-Clogging Token Requested," with the Anti-Clogging Token field occupying the Token field of the Authentication frame.

An SAE Confirm message, with a status code not equal to SUCCESS, shall indicate that a peer rejects a previously sent SAE Confirm message. An SAE Confirm message that was not successfully verified is indicated with a status code of CHALLENGE_FAILURE.

### 12.4.8 SAE finite state machine

#### 12.4.8.1 General

The protocol is instantiated by the finite state machine in Figure 12-14 (SAE finite state machine(#1277)(#3208)(#6089)(M134)). Each instance of the protocol is identified by a tuple consisting of the local MAC address and the peer MAC address. The model in which SAE is defined consists of a parent process, managed by the SME, which receives messages, and dispatches them to the appropriate protocol instance, also managed by the SME. The parent process manages a database of protocol instances indexed by the peer identity. Protocol instances maintain state, receive events from the parent process, send events to itself, and output data.

NOTE—Figure 12-14 (SAE finite state machine(#1277)(#3208)(#6089)(M134)) does not show all state machine transitions. A full description of the SAE finite state machine is in 12.4.8.6.2 (Protocol instance behavior—General) to 12.4.8.6.6 (Protocol instance behavior—Accepted state).

The parent process instantiates protocol instances upon receipt of SAE messages and initiation by SME. The parent process also maintains a counter of the number of protocol instances created.

#### 12.4.8.2 States

##### 12.4.8.2.1 Parent process states

The parent process is in a continuous quiescent state.

##### 12.4.8.2.2 Protocol instance states

Each protocol instance is in one of the following four states:

— *Nothing.* The *Nothing* state represents the initial state of a freshly allocated protocol instance or the terminal state of a soon-to-be deallocated protocol instance. Freshly created protocol instances will immediately transition out of *Nothing* state depending on the reason for their creation. Protocol instances that transition into *Nothing* state shall immediately be irretrievably deleted.

— *Committed.* In the *Committed* state, the finite state machine has sent an SAE Commit message and needs both SAE Commit and SAE Confirm messages from the peer.


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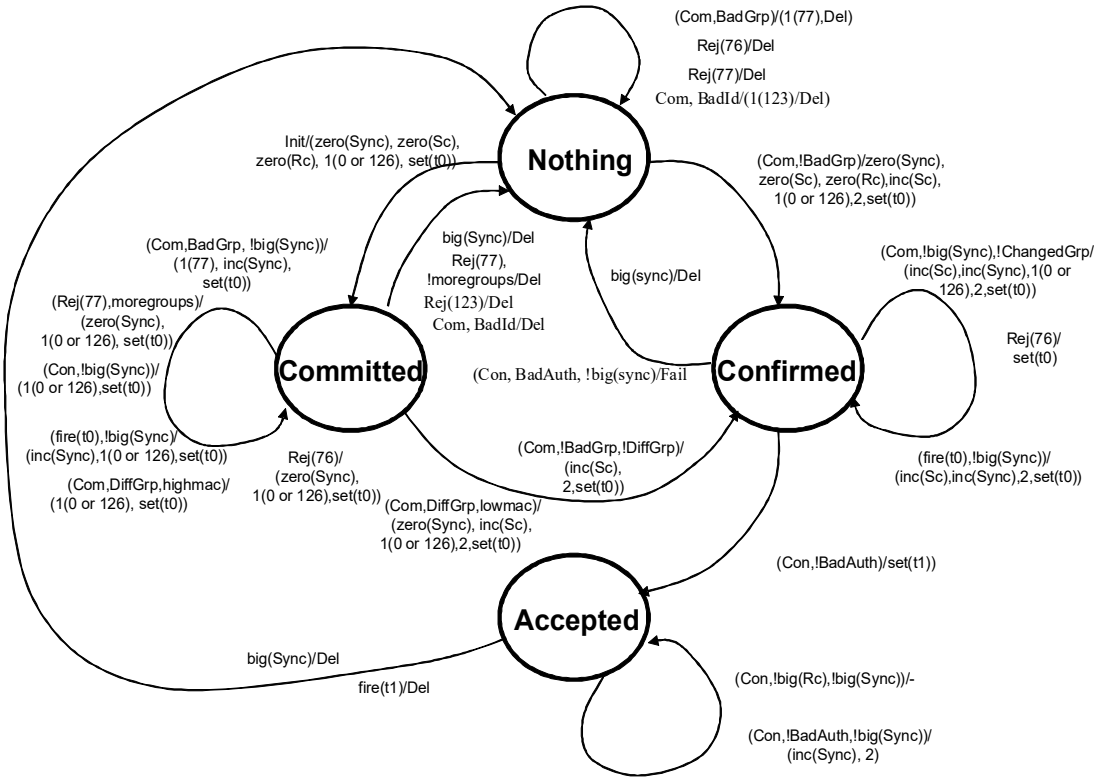


**Figure 12-14—SAE finite state machine(#1277)(#3208)(#6089)(M134)**

— *Confirmed.* In the *Confirmed* state, the finite state machine has sent both an SAE Commit message and an SAE Confirm message and received an SAE Commit message. It awaits an SAE Confirm message.

— *Accepted.* In the *Accepted* state, the protocol instance has both sent and received an SAE Commit message and an SAE Confirm message and the protocol instance has finished.

### 12.4.8.3 Events and output

#### 12.4.8.3.1 Parent process events and output

The parent process receives events from three sources: the SME, protocol instances, and received frames.

The SME signals the following events to the parent SAE process:

— *Initiate.* An *Initiate* event is used to instantiate a protocol instance to begin SAE with a designated peer (M134)identified by its MAC address.

— *Kill.* A *Kill* event is used to remove a protocol instance with a designated peer (M134)identified by its MAC address.

Protocol instances send the following events to the SAE parent process:

— *Fail.* The peer failed to be authenticated.

— *Auth.* The peer was successfully authenticated.

— *Del.* The protocol instance has had a fatal event.

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Receipt of frames containing SAE messages signals the following events to the SAE parent process:

— *Authentication frame with Transaction Sequence number 1.* This event indicates that an SAE Commit message has been received from a peer STA.

— *Authentication frame with Transaction Sequence number 2.* This event indicates that an SAE Confirm message has been received from a peer STA.

The parent process generates Authentication frames with Authentication transaction sequence 1 and a Status of 76 indicating rejection of an Authentication attempt because an Anti-Clogging Token field is required.

#### 12.4.8.3.2 Protocol instance events and output

The protocol instance receives events from the parent SAE process.

— *Com.* Indicates receipt of an SAE Commit message (authentication transaction sequence number 1) with a status of 0(#1277) or 126.

— *Con.* Indicates receipt of an SAE Confirm message (authentication transaction sequence number 2) with a status of 0.

— *Init.* Indicates that the protocol instance should begin negotiation with a specified peer.

— *Rej(N).* Indicates receipt of a rejected SAE Commit message with status *N*.

In addition, protocol instances receive *fire(X)* events indicating the expiration of timer *X*. Upon expiration of a timer and generation of a *fire()* event, the expired timer is not reset.

The protocol instance generates output from the following events:

— *1(N).* Indicates generation of an SAE Commit message (authentication transaction sequence number 1) with status *N*.

— *2.* Indicates generation of an SAE Confirm message (authentication transaction sequence number 2).

### 12.4.8.4 Timers

The parent SAE process does not use timers. Each protocol instance can set timers that result in *fire()* events to be sent to itself. The following timers can be set:

— t0. A retransmission timer.

— t1. A PMK expiration timer.

Timers are set by the protocol instance issuing a *set()* for the particular timer.

### 12.4.8.5 Variables

#### 12.4.8.5.1 Parent process variables

The parent SAE process maintains a counter, *Open*, which indicates the number of protocol instances in either *Committed* or *Confirmed* state. When the parent SAE process starts up, *Open* is set to 0.

The parent process maintains a database of protocol instances.

NOTE—Depending on how Anti-Clogging Token fields (see 12.4.6 (Anti-clogging tokens)) are constructed, the parent SAE process might also maintain a random secret used for token creation.

#### 12.4.8.5.2 Protocol instance variables

Each protocol instance maintains the following three variables:


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- *Sync.* The number of state resynchronizations that have occurred.
- *Sc.* The number of SAE Confirm messages that have been sent. This is the send-confirm counter used in the construction of SAE Confirm messages (see 12.4.5.5 (Construction of an SAE Confirm message)).
- *Rc.* The received value of the *send-confirm* counter in the last received SAE Confirm message. In other words, this is the value of the peer's send-confirm counter.

Function *zero(X)* assigns the value 0 to the variable *X*, *inc(X)* increments the variable *X*, and *big(X)* indicates that the variable *X* has exceeded a maximum value.

In addition, protocol instances maintain the following six indicators that are not maintained as state variables but, instead, indicate the cause of certain behavior. (M134)These indicators can be used to describe the inner workings of the state machine and can be useful for debugging purposes.

- *BadID.* The password identifier in an SAE Commit message is unknown or wrong.
- *BadGrp.* The group specified in an SAE Commit message is not supported.
- *DiffGrp*. The group specified in an SAE Commit message is supported but differs from the one offered.
- *ChangedGrp.* The group specified in an SAE Commit message is supported but differs from the one received in the most recently received valid SAE Commit message.(#6089)
- *BadAuth.* The contents of a confirm frame were incorrect. Authentication rejected due to verifier mismatch while processing SAE confirm message.
- *highmac*. The peer identity is numerically less than the local identity.
- *lowmac*. The peer identity is numerically greater than the local identity.
- *moregroups.* There are finite cyclic groups in the configuration that have not been offered to the peer.

A negative indication is shown with an exclamation point (!)—e.g., "the group specified in an SAE Commit message is supported" would be !BadGrp, which is read as "not BadGrp."

#### 12.4.8.6 Behavior of state machine

##### 12.4.8.6.1 Parent process behavior

For any given peer identity, there shall be only one protocol instance in *Committed* or *Confirmed* state. Similarly, for any given peer identity, there shall be only one protocol instance in *Accepted* state.

The parent process creates protocol instances based upon different actions. Creating a protocol instance entails allocation of state necessary to maintain the protocol instance state machine, putting the protocol instance in *Nothing* state, incrementing the *Open* counter, and inserting the protocol instance into its database indexed by the MAC address of the peer with whom the protocol instance will communicate.

The parent process shall delete protocol instances irretrievably.

Upon receipt of an *Initiate* event, the parent process shall check whether there exists a protocol instance for the peer MAC address (from (M134)the *Initiate* event) in either *Committed* or *Confirmed* state. If there is, the *Initiate* event shall be ignored. Otherwise, a protocol instance shall be created, and an *Init* event shall be sent to the protocol instance.

Upon receipt of a *Kill* event, the parent process shall delete all protocol instances indexed by the peer MAC address (from the *Kill* event) in its database. For each protocol instance in *Committed* or *Confirmed* state, the *Open* counter shall be decremented.

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Upon receipt of a (M134)big(*Sync*), *Del,* or *Fail* event from a protocol instance, the parent process shall decrement the *Open* counter and deletes the protocol instance.

Upon receipt of an *Auth* event from a protocol instance, the parent process shall decrement the *Open* counter. If another protocol instance exists in the database indexed by the same peer identity as the protocol instance that sent the *Auth* event, the other protocol instance shall be deleted.

Upon receipt of an SAE Commit message, the parent process checks whether a protocol instance for the peer MAC address exists in the database. If one does, and it is in either *Committed* state or *Confirmed* state the frame shall be passed to the protocol instance (M134)as a *Com* event. If one does and it is in *Accepted* state, the scalar in the received frame is checked against the *peer-scalar* used in authentication of the existing protocol instance (in *Accepted* state). If it is identical, the frame shall be (#3683)discarded. If not, the parent process checks the value of *Open*. If *Open* is greater than dot11RSNASAEAntiCloggingThreshold, the parent process shall check for the presence of an Anti-Clogging Token field. If an Anti-Clogging Token field exists and is correct, the parent process shall create a protocol instance (M134)and pass the frame to it as a *Com* event. If the Anti-Clogging Token field is incorrect, the frame shall be silently discarded. If Open is greater than or equal to dot11RSNASAEAntiCloggingThreshold and there is no Anti-Clogging Token field in the received frame, the parent process shall construct a response as an Authentication frame with the Authentication Transaction Sequence Number field set to 1, the Status Code field set to ANTI_CLOGGING_TOKEN_REQUIRED, and the body of the frame consisting of an Anti-Clogging Token field (see 12.4.6 (Anti-clogging tokens)). If *Open* is less than dot11RSNASAEAntiCloggingThreshold, the parent process shall create a protocol instance and the frame shall be sent to the protocol instance as a *Com* event.

Upon receipt of an SAE Confirm message, the parent process checks whether a protocol instance for the peer MAC address (as indicated by the SA in the received frame) exists in the database. If there is a single protocol instance, the frame shall be passed to it as a *Con* event. If there are two protocol instances indexed by that peer MAC address, the frame shall be passed, as a *Con* event, to the protocol instance that is not in *Accepted* state. If there are no protocol instances indexed by that peer MAC address, the frame shall be (#3683)discarded.

#### 12.4.8.6.2 Protocol instance behavior—General

State machine behavior is illustrated in Figure 12-14 (SAE finite state machine(#1277)(#3208)(#6089)(M134)). The protocol instance receives events from the parent process and from itself. It generates SAE messages that are transmitted to a peer and sends events to itself and the parent process.

The semantics of the state diagram are “occurrence/behavior” where “occurrence” is a comma-separated list of events and/or indicators, or the special symbol “—” indicating no occurrence; and, “behavior” is a comma-separated list of outputs and/or functions, or the special symbol “—” indicating no behavior.

When the state machine calls for the t0 (retransmission) timer to be set, it shall be set to dot11RSNASAERetransPeriod. When the state machine calls for the t1 (key expiration) timer to be set, it shall be set to dot11RSNAConfigPMKLifetime.

#### 12.4.8.6.3 Protocol instance behavior—Nothing state

In *Nothing* state a protocol instance has just been allocated.

Upon receipt of an *Init* event, the protocol instance shall zero its (#3520)*Sync*, *Rc*, and *Sc* variables, select a group from local configuration and generate the (#3207)PWE and the secret values according to 12.4.5.2 (PWE and secret generation), generate an SAE Commit message (see 12.4.5.3 (Construction of an SAE Commit message)), and set its t0 (retransmission) timer. The protocol instance transitions into *Committed* state.


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(#3520)Upon receipt of a *Com* event, the protocol instance shall check the Status Code field of the (#3328)SAE Authentication frame.

- (#3520)If the Status Code field is not SUCCESS(#1277) or (#3251)SAE_HASH_TO_ELEMENT, the protocol instance shall silently discard the frame and send a *Del* event to the parent process.
- (#3520)Otherwise, the password identifier, if any, shall be checked:
  - (#3520)If a password identifier is present and no password is associated with that identifier, (#4293)the protocol instance shall set *BadID* and construct and transmit an (#3328)SAE Authentication frame with (#3326)status code UNKNOWN_PASSWORD_IDENTIFIER(#3327), (M134)and send a *Del* event to the parent process.
  - (#3520)Otherwise, the Finite Cyclic Group field shall be checked:
    - (#3520)If the group is not supported, the protocol instance shall set *BadGrp*, construct and transmit an (#3328)SAE Authentication frame with (#3326)status code UNSUPPORTED_FINITE_CYCLIC_GROUP and the Finite Cyclic Group field set to the rejected group, and send a *Del* event to the parent process.
    - (#3520)Otherwise, the protocol instance shall zero *Sc* and *Rc* and generate the (#3207)PWE and the secret values according to 12.4.5.2 (PWE and secret generation). It shall then process the received SAE Commit message (see 12.4.5.4 (Processing of a peer's SAE Commit message)):
      - (#3520)If validation of the received SAE Commit message fails, the protocol instance shall (M134)silently discard the frame and send a Del event to the parent process .
      - (#3520)Otherwise, the protocol instance shall construct and transmit an SAE Commit message (see 12.4.5.3 (Construction of an SAE Commit message)), (#595)increment *Sc*, construct and transmit an SAE Confirm message (see 12.4.5.5 (Construction of an SAE Confirm message)), set *Sync* to 0, set the t0 (retransmission) timer, and transitions to *Confirmed* state.

NOTE—A protocol instance in *Nothing* state will never receive an SAE Confirm message due to state machine behavior of the parent process.

#### 12.4.8.6.4 Protocol instance behavior—Committed state

In *Committed* state, a protocol instance has sent its peer an SAE Commit message but has yet to receive (and accept) anything.

Upon receipt of a *Com* event, the t0 (retransmission) timer shall be canceled. Then the following is performed:

- The protocol instance shall check the (#3326)status code of the Authentication frame.
- (#1277)If the (#3326)status code is ANTI_CLOGGING_TOKEN_REQUIRED, a new SAE Commit message shall be constructed with the Anti-Clogging Token field from the received Authentication frame, and the *commit-scalar* and ***COMMIT-ELEMENT*** previously sent. The new SAE Commit message shall be transmitted to the peer, *Sync* shall be zeroed, and the t0 (retransmission) timer shall be set.
- If the (#3326)status code is UNKNOWN_PASSWORD_IDENTIFIER, the protocol instance shall send a Del event to the parent process and transition back to Nothing state.
- If the (#3326)status code is UNSUPPORTED_FINITE_CYCLIC_GROUP, the protocol instance shall (#3520)check the finite cyclic group fbeing rejected. If the rejected group does not match the last offered group the protocol instance shall silently discard the message and set the t0 (retransmission) timer. If the rejected group matches the last offered group, the protocol instance shall choose a different group and generate the (#4264)PWE and the secret values according to 12.4.5.2 (PWE and secret generation); it then generates and transmits a new SAE Commit message

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to the peer, zeros *Sync*, sets the t0 (retransmission) timer, and remains in *Committed* state. If there are no other groups to choose, the protocol instance shall send a *Del* event to the parent process and transitions back to *Nothing* state.

— If the (#1277)status code(#3326) is (M134)a nonzero value other than SAE_HASH_TO_ELEMENT, the frame shall be silently discarded and the t0 (retransmission) timer shall be set.

— If the (#1277)status code(#3326) is (M134)zero or SAE_HASH_TO_ELEMENT, (#3520)the Finite Cyclic Group field is checked. If the group is not supported, *BadGrp* shall be set and the value of *Sync* shall be checked.

  — If *Sync* is greater than dot11RSNASAESync, the protocol instance shall send a *Del* event to the parent process and transitions back to *Nothing* state.

  — If *Sync* is not greater than dot11RSNASAESync, *Sync* shall be incremented, an SAE Commit message (M134)indicating rejection of the offered group with (#3326)status code equal to UNSUPPORTED_FINITE_CYCLIC_GROUP shall be sent to the peer, the t0 (retransmission) timer shall be set and the protocol instance shall remain in *Committed* state.

— If there is a password identifier associated with the password when the protocol instance constructed its SAE Commit message and either there is no password identifier in the received frame or the password identifier in the received frame does not match the password identifier used to construct the protocol instance's SAE Commit message, (#4293)the protocol instance shall set *BadID*, send a Del event to the parent process, and transition back to Nothing state.

— If the group is supported but does not match that used when the protocol instance constructed its SAE Commit message, *DiffGrp* shall be set and the local identity and peer identity shall be checked.

  — (#1650)The mesh STA with the numerically greater of the two MAC addresses shall (#3683)discard the received SAE Commit message, retransmit its last SAE Commit message, set the t0 (retransmission) timer, and remain in *Committed* state.

  — The mesh STA (#1650)with the numerically lesser of the two MAC addresses (#352)shall set *Sync* to zero, increment *Sc*, choose the group from the received SAE Commit message, generate new (#4264)PWE and new secret values according to 12.4.5.2 (PWE and secret generation), (M162)and process the received SAE Commit message according to 12.4.5.4 (Processing of a peer's SAE Commit message). If processing fails, the protocol instance shall generate a Fail event and terminate, otherwise, it shall generate a new SAE Commit message and SAE Confirm message, and transmit the new Commit and Confirm to the peer. It shall then transition to *Confirmed* state.

— If the group is supported and matches that used when the protocol instance constructed its SAE Commit message, the protocol instance checks the *peer-commit-scalar* and ***PEER-COMMIT-ELEMENT*** from the message. If they match those sent as part of the protocol instance's own SAE Commit message, the frame shall be silently discarded (because it is evidence of a reflection attack) and the t0 (retransmission) timer shall be set. If the received element and scalar differ from the element and scalar offered, the received SAE Commit message shall be processed according to 12.4.5.4 (Processing of a peer's SAE Commit message)(M162). If processing fails, the protocol instance shall generate a Fail event and terminate, otherwise (#3520)*Sc* shall be incremented (thereby setting its value to one), the protocol instance shall then construct an SAE Confirm message, transmit it to the peer, and set the t0 (retransmission) timer. It shall then transition to *Confirmed* state.

If the t0 (retransmission) timer fires, the value of (#3520)*Sync* is checked. If *Sync* is greater than dot11RSNASAESync, the protocol instance shall send a *Del* event to the parent process and transition back to *Nothing* state. If *Sync* is not greater than dot11RSNASAESync, (#3520)*Sync* shall be incremented, the last message sent shall be sent again, and the t0 (retransmission) timer shall be set.

Upon receipt of a *Con* event, the protocol instance checks the value of *Sync*. If it is greater than dot11RSNASAESync, the protocol instance shall send a *Del* event to the parent process and transition back to


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*Nothing* state. If *Sync* is not greater than dot11RSNASAESync, the protocol instance shall transmit the last SAE Commit message sent to the peer.

#### 12.4.8.6.5 Protocol instance behavior—Confirmed state

In *Confirmed* state, a protocol instance has sent its peer an SAE Commit message and SAE Confirm message. It has received an SAE Commit message from its peer(M134).

(#116)Upon receipt of a *Com* event, the t0 (retransmission) timer shall be canceled. If the Status is (#1277)(M134)a nonzero value other than SAE_HASH_TO_ELEMENT, the frame shall be silently discarded, the t0 (retransmission) timer set, and the protocol instance shall remain in the *Confirmed* state. Otherwise, if *Sync* is greater than dot11RSNASAESync, the protocol instance shall send the parent process a *Del* event and transitions back to *Nothing* state. Otherwise, if the finite cyclic group differs from the finite cyclic group in the most recently received valid SAE Commit message, the t0 (retransmission) timer shall be set and the frame shall be silently discarded. Otherwise, the protocol instance shall increment *Sync*, increment *Sc*, transmit its SAE Commit message and its SAE Confirm message with the new *Sc* value, and set the t0 (retransmission) timer.

Upon receipt of a *Con* event, the SAE Confirm message shall be processed according to 12.4.5.6 (Processing of a peer's SAE Confirm message). If processing is unsuccessful and the SAE Confirm message is not verified, protocol instance (M134)shall set *BadAuth*, send the parent process a *Fail* event, and transition back to *Nothing* state in Confirmed state. If processing is successful and the SAE Confirm message has been verified, (#3520)*Rc* shall be set to the value of the Send-Confirm field, *Sc* shall be set to the value $2^{16} - 1$, the t1 (key expiration) timer shall be set, the t0 (retransmission) timer shall be canceled, (M134)send the Parent process an *Auth* event, and the protocol instance shall transition to *Accepted* state.

If the t0 (retransmission) timer fires, the value of (#3520)*Sync* shall be checked. If *Sync* is greater than dot11RSNASAESync, the protocol instance shall send a *Del* event to the parent process and transition back to *Nothing* state. If *Sync* is not greater than dot11RSNASAESync, (#3520)*Sync* shall be incremented, *Sc* shall be incremented, and the protocol instance shall create an SAE Confirm message with the new *Sc* value, transmit it to the peer, and set the t0 (retransmission) timer.

#### 12.4.8.6.6 Protocol instance behavior—Accepted state

In *Accepted* state, a protocol instance has sent an SAE Commit message and an SAE Confirm message to its peer and received an SAE Commit message and SAE Confirm message from the peer. Unfortunately, there is no guarantee that the final SAE Confirm message sent by the STA was received by the peer.

Upon receipt of a *Con* event, (#3520)*Sync* shall be checked. If the value is greater than dot11RSNASAESync, the protocol instance shall send a *Del* event to the parent process and shall transition to *Nothing* state. If the value of *Sync* is not greater than dot11RSNASAESync, the Send-Confirm field shall be checked. If its value is not greater than *Rc* or is equal to $2^{16} - 1$, the received frame shall be silently discarded. Otherwise, the Confirm field shall be checked according to 12.4.5.6 (Processing of a peer's SAE Confirm message). If the verification fails, the received frame shall be silently discarded. If the verification succeeds, the *Rc* variable shall be set to the value of the Send-Confirm field, (#3520)*Sync* shall be incremented and a new SAE Confirm message shall be constructed (with *Sc* set to $2^{16} - 1$) and sent to the peer. The protocol instance shall remain in *Accepted* state.

If the t1 (key expiration) timer fires, the protocol instance shall send the parent process a *Del* event and transition to *Nothing* state.

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## 12.5 RSNA confidentiality and integrity protocols

### 12.5.1 Overview

This standard defines the following RSNA data confidentiality and integrity protocols: (#1076)CCMP, and GCMP. This standard defines (11ba)the following integrity protocol for Management frames (11ba)and for WUR Wake-up frames: BIP. (#1076)

BIP is a mechanism that is used only when management frame protection is negotiated. BIP provides integrity protection for group addressed robust Management frames (11ba)and WUR Wake-up frames (see 29.10 (WUR frame protection)).(#354)(#1077)

### 12.5.2 CTR with CBC-MAC protocol (CCMP)

#### 12.5.2.1 General

Subclause 12.5.2 (CTR with CBC-MAC protocol (CCMP)) specifies all variants of CCMP, which provides data confidentiality, authentication, integrity, and replay protection. A non-DMG RSNA STA shall support CCMP-128.

CCMP is based on the CCM of the AES encryption algorithm. CCM combines CTR for data confidentiality and CBC-MAC for authentication and integrity. CCM protects the integrity of both the MPDU Data field and selected portions of the IEEE 802.11 MPDU header.

The AES algorithm is defined in FIPS 197. AES processing used within CCMP uses AES with either a 128-bit key (CCMP-128) or a 256-bit key (CCMP-256).

CCM is defined in IETF RFC 3610. CCM is a generic mode that can be used with any block-oriented encryption algorithm. CCM has two parameters ($M$ and $L$).

CCMP-128 uses the following values for the CCM parameters:

— $M = 8$; indicating that the MIC is 8 octets.
— $L = 2$; indicating that the Length field is 2 octets, which is sufficient to hold the length of the largest possible IEEE 802.11 MPDU, expressed in octets.

CCMP-256 uses the following values for the CCM parameters:

— $M = 16$; indicating that the MIC is 16 octets.
— $L = 2$; indicating that the Length field is 2 octets, which is sufficient to hold the length of the largest possible IEEE 802.11 MPDU, expressed in octets.

CCM requires a fresh temporal key for every session. CCM also requires a unique nonce value for each frame protected by a given temporal key. Reuse of a nonce value with the same temporal key voids all security guarantees.

Annex J provides a test vector for CCM.

When CCMP is selected as the RSN pairwise cipher and management frame protection is negotiated, (#1980)individually addressed robust Management frames, and (#162)(MBSS only) group addressed Action frames of a category specified with Yes in the Group addressed privacy column of Table 9-81 (Category values), shall be protected with CCMP.


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### 12.5.2.2 CCMP MPDU format

Figure 12-15 (Expanded CCMP MPDU(#3525)(11az)) depicts the MPDU when using CCMP.

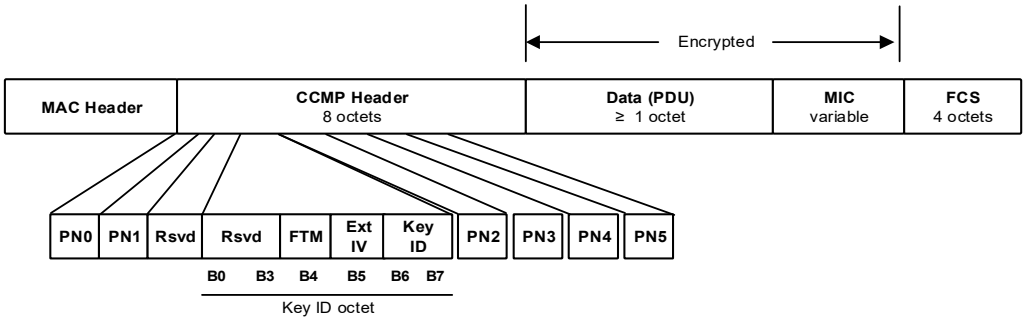


**Figure 12-15—Expanded CCMP MPDU(#3525)(11az)**

For secure PV0 MPDUs, CCMP-128 processing expands the original MPDU size by 16 octets, 8 octets for the CCMP Header field and 8 octets for the MIC field. CCMP-256 processing expands the original MPDU size by 24 octets, 8 octets for the CCMP Header field, and 16 octets for the MIC field. The CCMP Header field is constructed from the PN, ExtIV, and Key ID subfields. PN is a 48-bit PN represented as an array of 6 octets. PN5 is the most significant octet of the PN, and PN0 is the least significant.

The third octet of the CCMP Header field is reserved.(#1386)

The ExtIV subfield (bit 5) of the Key ID octet (#3056)is always set to 1 for CCMP.(#1386)

Bits 6–7 of the Key ID octet are for the Key ID subfield. The remaining bits of the Key ID octet are reserved.(#1386)

(11az)In a protected (#6026)individually addressed (#8153)Action frame, bit 4 of the Key ID octet equals 1 if the frame is a Protected Fine Timing frame—see Table 9-51 (Category values). In other protected (#6026)individually addressed frames, bit 4 is reserved.

(11az)The remaining bits of the Key ID octet are reserved.

The CCMP header is not included in secure PV1 MPDUs, but constructed locally at the STA as defined in 12.5.2.3.6 (Construct CCMP header for transmitted PV1 MPDUs(#7012)) (#7012)and 12.5.2.4.5 (Construct CCMP header for received PV1 MPDUs(#7012)). For secure PV1 MPDUs, CCMP-128 processing expands the original MPDU size by 8 octets for the MIC field. CCMP-256 processing expands the original MPDU size by 16 octets for the MIC field. Figure 12-16 (Expanded PV1 CCMP MPDU) depicts the PV1 MPDU when using CCMP.

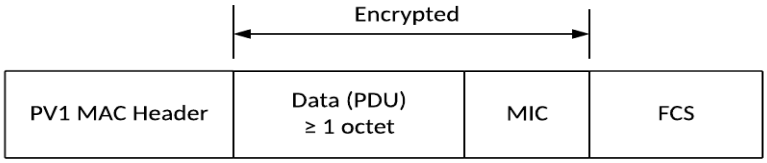


**Figure 12-16—Expanded PV1 CCMP MPDU**

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### 12.5.2.3 CCMP cryptographic encapsulation

#### 12.5.2.3.1 General

The CCMP cryptographic encapsulation process is depicted in Figure 12-17 (CCMP encapsulation block diagram(#1589)) and described as follows:

a) For secure PV0 MPDUs, CCMP encrypts the Frame Body field of a plaintext MPDU and encapsulates the resulting cipher text using the following steps:

1) Increment the PN, to obtain a fresh nonzero(#1505) PN for each MPDU, so that the PN never repeats for the same temporal key.

NOTE 1—The frame body of the retransmitted MPDU is not modified on retransmission.(#3811)

2) Use the fields in the MPDU header to construct the additional authentication data (AAD) for CCM. The CCM algorithm provides integrity protection for the fields included in the AAD. (#1951)MPDU header fields that might change when retransmitted are muted by being (#1951)masked out when calculating the AAD.

3) Construct the (#209)CCM nonce as defined in 12.5.2.3.4 (Construct CCM nonce) (#8168)where MPDU Address 2 is used as A2. If the Type field of the Frame Control field is 10 (Data frame) and there is a QoS Control field present in the MPDU header, the priority value of the MPDU is equal to the value of the TID subfield of the QoS Control field (bits 0 to 3 of the QoS Control field). If the Type field of the Frame Control field is 00 (Management frame) and the frame is a QMF, the priority value of the MPDU is equal to the value in the ACI subfield of the Sequence Number field. Otherwise, the priority value of the MPDU is equal to (#8169)0.

4) Construct the CCMP header as defined in 12.5.2.3.5 (Construct CCMP header for PV0 MPDUs).

5) Use the temporal key, AAD, nonce, and MPDU data to form the cipher text and the encrypted MIC. This step is known as CCM originator processing.

6) Form the encrypted MPDU by combining the original MPDU header, the CCMP header, the encrypted data and the encrypted MIC, as described in 12.5.2.2 (CCMP MPDU format).

b) For secure PV1 MPDUs, CCMP encrypts the Frame Body field of a plaintext MPDU and encapsulates the resulting cipher text using the following steps:

1) When the sequence number of the MPDU is less than the previous sequence number (#7012)for the SN space of the MPDU, increment the base PN (BPN) so that the PN never repeats for the same temporal key and (#37)PTID/ACI.

NOTE 2—The frame body of the retransmitted MPDU is not modified on retransmission.(#3812)

(#3573)NOTE 3—QMF is not supported for PV1 Management frames (see 11.24.1.1 (Overview)).

2) Use the fields in the MPDU header to construct the AAD for CCM. The CCM algorithm provides integrity protection for the fields included in the AAD. MPDU header fields that might change when retransmitted are muted by being (#1951)masked out when calculating the AAD.

3) Construct the (#209)CCM nonce as defined in 12.5.2.3.4 (Construct CCM nonce) from the PN, A2, and the priority value of the MPDU, where A2 is the STA MAC address identified by the A2 field of the MPDU. If the MPDU is a QoS Data MPDU, the priority value of the MPDU is equal to the value of the PTID subfield of the Frame Control field. (#3573)Otherwise, the priority value of the MPDU is equal to (#8169)0.

4) Construct the CCMP header as defined in 12.5.2.3.6 (Construct CCMP header for transmitted PV1 MPDUs(#7012)).

5) Use the temporal key, AAD, nonce, and MPDU data to form the cipher text and the encrypted MIC. This step is known as CCM originator processing.


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6) Form the encrypted MPDU by combining the original MPDU header, the encrypted data, and the encrypted MIC, as described in 12.5.2.2 (CCMP MPDU format).

The CCM reference describes the processing of the key, nonce, AAD, and data to produce the encrypted output. See 12.5.2.3.2 (PN processing) to 12.5.2.3.7 (CCM originator processing) for details of the creation of the AAD and nonce from the MPDU and the associated MPDU-specific processing.

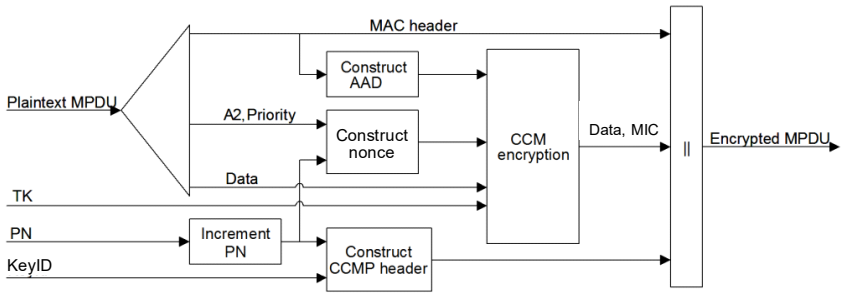


**Figure 12-17—CCMP encapsulation block diagram(#1589)**

### 12.5.2.3.2 PN processing

The PN is incremented by a positive number for each MPDU. The PN shall be incremented in steps of 1 for constituent MPDUs of fragmented MSDUs, (11ax)A-MSDUs, and MMPDUs. For PV0 MPDUs, the PN shall never repeat for a series of encrypted MPDUs using the same temporal key. For PV1 MPDUs, the PN shall never repeat for a series of encrypted MPDUs using the same temporal key and (#7012)SN space.

If the PN exceeds the threshold that is defined in dot11PNExhaustionThresholdLow and dot11PNExhaustionThresholdHigh, an MLME-PN-EXHAUSTION.indication primitive shall be generated.

NOTE 1—When PN space is exhausted, the choices available to an implementation are to replace the corresponding key or to end communications.

NOTE 2—When a group addressed MSDU is retransmitted using GCR, it is concealed from non-GCR capable STAs using the procedures described in 11.21.16.3.5 (Concealment of GCR transmissions). The MPDU containing this concealed A-MSDU has a different PN from the MPDU that contained the original transmission of the group addressed MSDU.

### 12.5.2.3.3 Construct AAD

(#7060)The AAD is constructed as follows:

a) For PV0 MPDUs, the format of the AAD is shown in Figure 12-18 (AAD construction for PV0 MPDUs). The length of the AAD for PV0 varies depending on the presence or absence of the QC and A4 fields and is shown in Table 12-3 (AAD length for PV0 MPDUs).

| | FC | A1 | A2 | A3 | SC | A4 | QC |
|---|---|---|---|---|---|---|---|
| Octets: | 2 | 6 | 6 | 6 | 2 | 6 | 2 |

**Figure 12-18—AAD construction for PV0 MPDUs**

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**Table 12-3—AAD length for PV0 MPDUs**

| QC field | A4 field | AAD length (octets) |
|---|---|---|
| Absent | Absent | 22 |
| Present | Absent | 24 |
| Absent | Present | 28 |
| Present | Present | 30 |

The AAD is constructed from the MPDU header. The AAD includes neither the Duration/ID field nor the HT Control field because the contents of these fields might change during normal operation (e.g., due to a rate change preceding retransmission). The HT Control field might also be inserted or removed during normal operation (e.g., retransmission of an A-MPDU where the original A-MPDU included an MRQ that has already generated a response). For similar reasons, several subfields in the Frame Control field are (#1951)masked out. For PV0 MPDUs, AAD construction is performed as follows:

1) FC – MPDU Frame Control field, with(#4183):
   i) (#486)The 3 LSBs of the Subtype subfield (bits 4 5 6) in a Data frame (#1951)masked out. Bit 7 is not modified
   ii) Retry subfield (bit 11) (#1951)masked out
   iii) Power Management subfield (bit 12) (#1951)masked out
   iv) More Data subfield (bit 13) (#1951)masked out
   v) Protected Frame subfield (bit 14) (#1951)not modified (left as 1)
   vi) +HTC subfield (bit 15) as follows:
      — (#1951)Masked out in all Data frames containing a QoS Control field
      — (#1951)Not modified otherwise
   vii) (#4183)No modification to other subfields
2) A1 – MPDU Address 1 field.
3) A2 – MPDU Address 2 field.
4) A3 – MPDU Address 3 field.
5) SC – MPDU Sequence Control field, (#7028)with bits 0–9 the Sequence Number subfield masked out if the frame is an IQMF and both the STA and its peer set the QMF ACI Subfield Unmask Support subfield to 1 (see 9.4.2.240 (RSNXE(#1776))), and with th entire Sequence Number subfield masked out otherwise.

   (#7028)NOTE—The Fragment Number subfield is not modified. Bits 10–11 of the Sequence Number subfield are not modified if the frame is an IQMF and both the STA and its peer set the QMF ACI Subfield Unmask Support subfield to 1.

6) A4 – MPDU Address field, if present.
7) (#2145)(#217)QC – MDPU QoS Control field contains the MSDU priority, if present. The QC TID is used in the construction of the AAD. When in a non-DMG BSS, if both the STA and its peer have their SPP A-MSDU Capable (M57)subfields (see 9.4.2.240 (RSNXE(#1776))) equal to 1, the A-MSDU Present field is also used in the construction of the AAD. When in a DMG BSS, the A-MSDU Present field and A-MSDU Type field are also used in the construction of the AAD. The remaining QC fields are not used and are (#1951)masked out for the AAD calculation (for a non-DMG BSS, bits 4 to 6, bits 8 to 15, and bit 7 when either the STA or its peer has the SPP A-MSDU Capable field equal to 0; for a DMG BSS, bits 4 to 6 and bits 9 to


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15). When in a DMG BSS, the A-MSDU Present bit 7 and A-MSDU Type bit 8 are used in the construction of the AAD, and the remaining QC fields are (#1951)masked out for the AAD calculation (bits 4 to 6, bits 9 to 15).

b) For PV1 MPDUs, the format of the AAD is shown in Figure 12-19 (AAD construction for PV1 MPDUs).

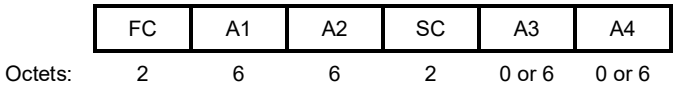


**Figure 12-19—AAD construction for PV1 MPDUs**

For PV1 MPDUs, the length of the AAD varies depending on the presence or absence of the A3 and A4 fields and is shown in Table 12-4 (AAD length for PV1 MPDUs).

**Table 12-4—AAD length for PV1 MPDUs**

| Type subfield in the Frame Control | A3 field in uncompressed header | A4 field in uncompressed header | AAD length (octets) |
|---|---|---|---|
| 0, 1 or 3 | Absent | Absent | 16 |
| 0, 1 or 3 | Present | Absent | 22 |
| 0 or 3 | Absent | Present | 22 |
| 0 or 3 | Present | Present | 28 |

For PV1 MPDUs, AAD construction is performed as follows:

1) FC – MPDU Frame Control field, with(#4183):
   i) Power Management subfield (bit 10) (#1951)masked out
   ii) More Data subfield (bit 11) (#1951)masked out
   iii) Protected Frame subfield (bit 12) (#1951)not modified (left as 1)
   iv) EOSP subfield (bit 13) (#1951)masked out
   v) Relayed Frame subfield (bit 14) (#1951)masked out
   vi) Ack Policy Indicator subfield (bit 15) (#1951)masked out
   vii) (#4183)No modification to other subfields
2) A1 – MPDU A1 field if it contains a MAC address; otherwise, the MAC address that corresponds to the AID value contained in the SID field of the A1 field.
3) A2 – MPDU A2 field if it contains a MAC address; otherwise, the MAC address corresponding to the AID value contained in the SID field of the A2 field.
4) SC – MPDU Sequence Control field, with the Sequence Number subfield (bits 4–15 of the Sequence Control field) (#1951)masked out. The Fragment Number subfield is not modified.
5) A3 – MPDU A3 field if present in the MPDU, the value of A3 stored at the receiver if A3 is stored at the receiver and is not present in the MPDU (see 10.57 (Generation of PV1 MPDUs and header compression procedure)); otherwise, not present.
6) A4 – MPDU A4 field if present in the MPDU, the value of A4 stored at the receiver if A4 is stored at the receiver and is not present in the MPDU (see 10.57 (Generation of PV1 MPDUs and header compression procedure)); otherwise, not present.

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#### 12.5.2.3.4 Construct CCM nonce

(#215)(#209)The CCM nonce is shown in Figure 12-20 (CCM nonce(#215)). The structure of the CCM Nonce Flags field of the CCM nonce is shown in Figure 12-21 (CCM Nonce Flags field(#215)).

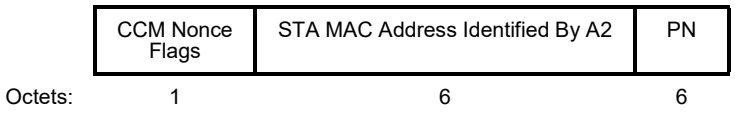


**Figure 12-20—CCM nonce(#215)**

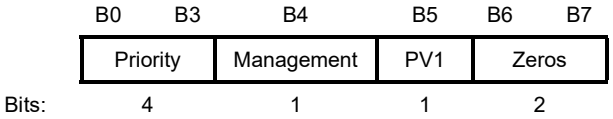


**Figure 12-21—CCM Nonce Flags field(#215)**

The Priority subfield shall be set to the priority value of the MPDU (see 12.5.2.3.1 (General)).(#212)

The Management subfield shall be set to 1 if the MPDU is a Management frame and management frame protection is negotiated; otherwise, it shall be set to 0.

The PV1 subfield shall be set to 1 for a PV1 frame; otherwise, it shall be set to 0.

The Zeros subfield shall be set to 0.

The STA MAC Address Identified By A2 subfield shall contain the Address 2 field from the MAC header for PV0 MPDUs and the MAC address identified by the A2 field in the MAC header for PV1 MPDUs (see 9.8.3.2 (Address fields)).

The PN subfield shall contain the packet number, with PN0 in the last octet of the subfield.

#### 12.5.2.3.5 Construct CCMP header for PV0 MPDUs

The format of the (#2047)CCMP header is given in 12.5.2.2 (CCMP MPDU format). The header encodes the PN, Key ID, and ExtIV field values used to encrypt the MPDU.

#### 12.5.2.3.6 Construct CCMP header for transmitted PV1 MPDUs(#7012)

The CCMP header is not present in secure PV1 MPDUs, but constructed locally at the STA as follows:

- The PN is composed of the Sequence Control field and the base PN (BPN) (#7012)for the SN space of the MPDU, where
  - The Sequence Control field is present in the MPDU header
    - PN0||PN1 = Sequence Control field(#7012)
  - The base PN is retrieved from the local storage at the (#7012)STA
    - PN2||PN3||PN4||PN5 = BPN
  - PN = PN0||PN1|| PN2||PN3||PN4||PN5 (= Sequence Control ||BPN)
- The (#3493)key ID is retrieved from the local storage at the (#7012)STA

The locally stored (#7012)BPNs and (#3493)key ID are initialized to 0 when the PTKSA is established.


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(#7012)At the transmitting STA, the locally stored BPN for the SN space of the MPDU shall be incremented by 1 when the sequence number of the MPDU is less than the previous sequence number for that SN space.

#### 12.5.2.3.7 CCM originator processing

CCM is a generic authenticate-and-encrypt block cipher mode, and in this standard, CCM is used with the AES block cipher.

There are four inputs to CCM originator processing (see Figure 12-17 (CCMP encapsulation block diagram(#1589))):

a) *Key:* the temporal key.
b) *Nonce:* the nonce constructed as described in (#6102)12.5.2.3.4 (Construct CCM nonce).
c) *Plaintext data:* the plaintext frame body of the MPDU to be encrypted and transmitted.
d) *AAD:* the AAD that is the canonical MPDU header as described in 12.5.2.3.3 (Construct AAD).

CCM originator processing provides authentication and integrity of the frame body and the AAD as well as data confidentiality of the frame body. The output from CCM originator processing consists of the encrypted data and an encrypted MIC (see Figure 12-15 (Expanded CCMP MPDU(#3525)(11az))).

The CCM encryption algorithm is described in IETF RFC 3610. The key, nonce, plaintext data and AAD described above are passed to the CCM encryption algorithm as K, N, m and a respectively. The CCM encryption algorithm yields a final result c containing the encrypted message and an encrypted authentication value U; from this the encrypted frame body is taken as the encrypted message and the MIC is taken as U.

The PN values sequentially number each MPDU. (#7012)For each PTKSA and GTKSA, each transmitter shall maintain a single PN (48-bit counter) for PV0 frames. The PN shall be implemented as a 48-bit strictly increasing integer, initialized to 0(#1505) when the corresponding temporal key is initialized or (#1382)refreshed (by rekeying). (#7012)If dot11PV1MACHeaderOptionImplemented is true, the transmitter shall additionally maintain a BPN for each PV1 SN space.

NOTE—(#7012)For secure PV0 frames, the PN is incremented before transmission (see 12.5.2.3.1 (General))(#1505). For secure PV1 frames, the BPN is incremented before transmission if the sequence number of the MPDU is less than the previous sequence number for that SN space (see 12.5.2.3.1 (General)).

A transmitter shall not use an (#1564)MSDU or A-MSDU priority if this would cause the total number of priorities used during the lifetime of the SA to exceed the number of replay counters supported by the receiver (for a pairwise SA) or all the receivers (for a group SA) for that SA. The transmitter shall not reorder CCMP protected frames that are transmitted to the same RA within a replay counter, but may reorder frames across replay counters. One possible reason for reordering frames is the (#1564)MSDU or A-MSDU priority.

The transmitter shall preserve the order of protected robust Management frames that are transmitted to the same DA without the QMF service. When the QMF service is used, the transmitter shall not reorder robust IQMFs within an AC when the frames are transmitted to the same RA.

A CCMP protected individually addressed robust Management frame shall be protected using the same TK as a Data frame.

### 12.5.2.4 CCMP decapsulation

#### 12.5.2.4.1 General

Figure 12-22 (CCMP decapsulation block diagram(#3661)) depicts the CCMP decapsulation process and is described as follows.

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a) For secure PV0 MPDUs, CCMP decrypts the Frame Body field of a cipher text MPDU and decapsulates a plaintext MPDU using the following steps:

1) The encrypted MPDU is parsed to construct the AAD (see 12.5.2.3.3 (Construct AAD)) and nonce (see 12.5.2.3.4 (Construct CCM nonce)) values.
2) The MIC is extracted for use in CCM integrity checking.
3) CCM recipient processing uses the temporal key, AAD, nonce, encrypted MIC, and MPDU cipher text data to recover the MPDU plaintext data as well as to check the integrity of the AAD and MPDU plaintext data.
4) The received MPDU header and the MPDU plaintext data from CCM recipient processing are concatenated to form a plaintext MPDU.
5) The decryption processing prevents replay of MPDUs by validating that the PN in the MPDU is greater than the replay counter maintained for the session(#193), and TID (for Data frames) or ACI (for QMFs).

b) For secure PV1 MPDUs, CCMP decrypts the Frame Body field of a cipher text MPDU and decapsulates a plaintext MPDU using the following steps:

1) The encrypted MPDU is parsed to construct the AAD (see 12.5.2.3.3 (Construct AAD)) and nonce (see 12.5.2.3.4 (Construct CCM nonce)) values.
2) The CCMP header is constructed as defined in (#7012)12.5.2.4.5 (Construct CCMP header for received PV1 MPDUs(#7012)).
3) The MIC is extracted for use in CCM integrity checking.
4) CCM recipient processing uses the temporal key, AAD, nonce, encrypted MIC, and MPDU cipher text data to recover the MPDU plaintext data as well as to check the integrity of the AAD and MPDU plaintext data.
5) The received MPDU header and the MPDU plaintext data from CCM recipient processing are concatenated to form a plaintext MPDU.
6) The decryption processing prevents replay of MPDUs by validating that the PN in the (#193)locally constructed CCMP header (see (#7012)12.5.2.4.5 (Construct CCMP header for received PV1 MPDUs(#7012))) is greater than the replay counter maintained for the session, and (#7012)SN space.

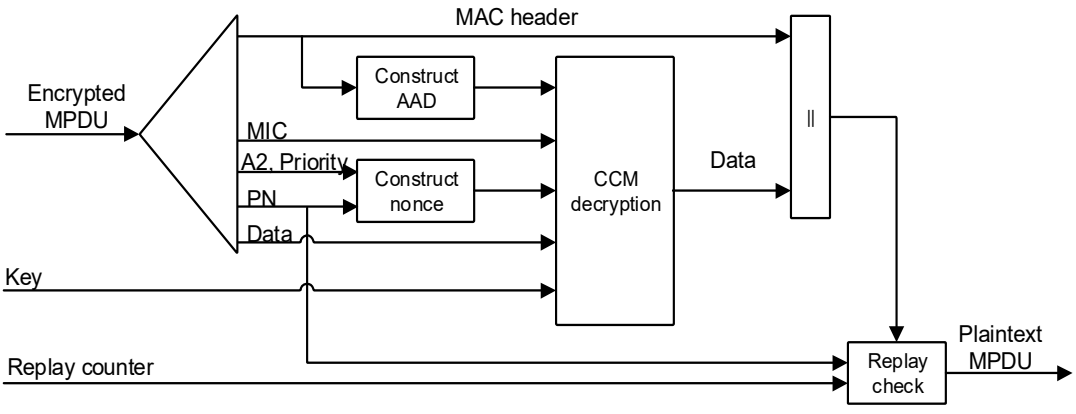


**Figure 12-22—CCMP decapsulation block diagram(#3661)**

See 12.5.2.4.2 (CCM recipient processing) to 12.5.2.4.4 (PN and replay detection) for details of this processing.


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(#3231)When the received frame is a CCMP protected individually addressed robust Management frame, the contents of the MMPDU body after protection is removed shall be delivered to the SME via the MLME primitive designated for that MMPDU rather than through the MA-UNITDATA.indication primitive.

#### 12.5.2.4.2 CCM recipient processing

CCM recipient processing uses the same parameters as CCM originator processing. A CCMP protected individually addressed robust Management frame shall use the same TK as a Data frame.(#1907)

There are five inputs to CCM recipient processing (see Figure 12-22 (CCMP decapsulation block diagram(#3661))):

— *Key:* the temporal key.
— *Nonce:* the nonce constructed as described in 12.5.2.3.3 (Construct AAD).
— *Encrypted data:* the encrypted portion of the frame body from the received MPDU, excluding the MIC (see Figure 12-15 (Expanded CCMP MPDU(#3525)(11az)) and Figure 12-16 (Expanded PV1 CCMP MPDU)).
— *MIC:* the encrypted MIC from the received MPDU.
— *AAD:* the AAD that is the canonical MPDU header as described in 12.5.2.3.3 (Construct AAD).

CCM recipient processing checks the authentication and integrity of the frame body and the AAD as well as decrypting the frame body. A MIC check is performed by comparing the received MIC with a MIC calculated as described in 12.5.2.3 (CCMP cryptographic encapsulation). The plaintext is returned only if the MIC check is successful.

The CCM decryption algorithm is described in IETF RFC 3610. The key, nonce, AAD and encrypted data described above are passed to the CCM decryption algorithm as K, N, a and c respectively. The CCM decryption algorithm yields a decrypted message m and a value T; from this the plaintext frame body described below is taken as m, if the MIC described above matches T.

There is one output from error-free CCM recipient processing:

— *Frame body:* the plaintext frame body, which is 8 octets (CCMP-128) or 16 octets (CCMP-256) smaller than the encrypted portion of the frame body.

#### 12.5.2.4.3 Decrypted CCMP MPDU

The decapsulation process succeeds when the calculated MIC (as described in 12.5.2.3 (CCMP cryptographic encapsulation)) matches the MIC value obtained from decrypting the received encrypted MPDU. The original MPDU header is concatenated with the plaintext data resulting from the successful CCM recipient processing to create the plaintext MPDU.

#### 12.5.2.4.4 PN and replay detection

To effect replay detection, the receiver extracts the PN from the CCMP header.

(#171)NOTE 1—The CCMP header is not present in secure PV1 MPDUs, but constructed locally at the STA as defined in (#7012)12.5.2.4.5 (Construct CCMP header for received PV1 MPDUs(#7012)).

See 12.5.2.2 (CCMP MPDU format) for a description of how the PN is encoded in the CCMP header. The following processing rules are used to detect replay:

a) The receiver shall maintain a separate set of replay counters for each PTKSA, (#166)TPKSA, GTKSA, (#1627)mesh PTKSA, and mesh GTKSA(#239). (#1508)The receiver initializes these replay counters to 0 when it resets the TK, TPK-TK or MTK for a peer, and to the value indicated by

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the peer when it sets the GTK or MGTK. The replay counter is set to the PN value of accepted CCMP MPDUs.

b) For each PTKSA, (#166)TPKSA, GTKSA, (#1627)mesh PTKSA, and mesh GTKSA(#239), the (#4212)receiver shall maintain a separate replay counter for each TID, subject to the limitation of the number of supported replay counters indicated in the RSN Capabilities field (see 9.4.2.23 (RSNE))(#3573). (#6149)In the case of a TPKSA, this shall for both the TDLS initiator STA and the TDLS responder STA be the number indicated by the TDLS initiator STA in the PTKSA Replay Counter field in the TDLS Setup Request frame.

(#6149)NOTE 2—The number indicated by the TDLS responder STA (if a TDLS Discovery Response frame is sent) is ignored, (#7231)as are the GTKSA Replay Counter and Extended Key ID For Individually Addressed Frames fields in the TDLS Setup Request frame and any TDLS Discovery Response frame.

(#171)NOTE 3—For the purpose of replay detection, non-QoS Data frames are treated as having TID 0, and use the (#4300)replay counter corresponding to MSDU priority 0.

c) If (#4166)management frame protection is negotiated, the (#4212)receiver shall set the MFPC bit on a given link to 1, it(#199) shall maintain a single replay counter for received individually addressed robust (#3573)PV0 Management frames (11az)except Protected Fine Timing frames (see 9.6.34 (Protected Fine Timing Action frame details(11az)(#8155)))) that are received with the To DS subfield equal to 0, and (#3573)(S1G STA only) a single replay counter for received individually addressed robust PV1 Management frames (11az)except Protected Fine Timing frames (see 9.6.34 (Protected Fine Timing Action frame details(11az)(#8155)))).

d) (11az)If dot11RSNAProtectedManagementFramesActivated is true and dot11QMFActivated is also true, the (#4212)receiver shall maintain an additional replay counter for each ACI for received individually addressed robust (#3573)PV0 Management frames (11az)except Protected Fine Timing frames (see 9.6.34 (Protected Fine Timing Action frame details(11az)(#8155)))) that are received with the To DS subfield equal to 1.

(#4075)NOTE 4—Separate replay counters for PV0 and PV1 Management frames allow for reordering between the two types. However, S1G STAs are required to use PV1 Management frames for individually addressed Action (and Action No Ack) frames when the peer is known to support them (see 10.57 (Generation of PV1 MPDUs and header compression procedure)), so there is no issue with PV0 Action (and Action No Ack) frames. The other robust Management frames are Deauthentication and Disassociation frames, but reordering of a PV1 Action frame and a Deauthentication/Disassociation frame is not of much concern since the Action frame is not valid after deauthentication/disassociation.

(#3573)NOTE 5—QMF is not supported for PV1 Management frames (see 11.24.1.1 (Overview)).

e) (11az)If dot11RSNAProtectedManagementFramesActivated is true, the recipient shall maintain a separate replay counter for receiving individually addressed Protected Fine Timing frames (see 9.6.34 (Protected Fine Timing Action frame details(11az)(#8155))) and shall use the PN from the received frame to detect replays.

f) The receiver shall discard any Data frame that is received with its PN less than or equal to the value of the replay counter that is associated with the TA(#3573), RA (individual or group address; not if TDLS) and priority value of the received MPDU. The receiver shall discard (#3573)fragmented MSDUs, A-MSDUs(#3089) and MMPDUs whose constituent MPDU PN values are not incrementing in steps of 1. (#4166)(#199)If management frame protection is negotiated, the receiver shall set the MFPC bit on a given link to 1, it shall discard any individually addressed robust Management frame that is received with its PN less than or equal to the value of the replay counter associated with the TA(#3573), (QMF receiver of an individually addressed robust PV0 Management frame with the To DS subfield equal to 1 only) ACI, and (S1G STA only) Protocol Version subfield of that individually addressed Management frame.

g) When discarding a frame, the receiver shall increment by 1 dot11RSNAStatsCCMPReplays for Data frames or dot11RSNAStatsRobustMgmtCCMPReplays for robust Management frames.


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h) For MSDUs or A-MSDUs sent using the block ack feature, reordering of received MSDUs or A-MSDUs according to the block ack receiver operation is performed prior to replay detection.

i) (11az)If the receiver performs replay detection prior to decryption, then the receiver shall check that the replay counter used to detect replays is correct and discard the frame if incorrect. In particular, the separate replay counter for individually addressed Protected Fine Timing frames shall be used if the FTM subfield of the (#8149)(#8151)CCMP of GCMP header (Figure 12-15 (Expanded CCMP MPDU(#3525)(11az)) or Figure 12-28 (Expanded GCMP MPDU(11az))) signals that the (#8154)MPDU is a Protected Fine Timing frame; it shall not be used otherwise.(#7220)

#### 12.5.2.4.5 Construct CCMP header for received PV1 MPDUs(#7012)

The CCMP header is not present in secure PV1 MPDUs, but constructed locally at the STA as follows.

- The PN is composed of the Sequence Control field and the base PN (BPN) for the SN space of the MPDU, where
  - The Sequence Control field is present in the MPDU header
    - PN0||PN1 = Sequence Control field
  - The base PN is retrieved from the local storage at the STA
    - PN2||PN3||PN4||PN5 = BPN
  - PN = PN0||PN1||PN2||PN3||PN4||PN5 (= Sequence Control||BPN)
- The key ID is retrieved from the local storage at the STA

The locally stored BPNs and key ID are initialized to 0 when the PTKSA is established.

The locally stored BPN for the SN space of the MPDU shall be incremented by 1 when the sequence number of the MPDU is less than the previous sequence number for that SN space if any of the following two conditions is satisfied:

- Block Ack is not used
- Block Ack is used but decryption occurs after Block Ack reordering

When Block Ack is used and decryption occurs before Block Ack reordering, the BPN for the SN space of the MPDU may be updated as follows. The receiver maintains a sequence number window of size $w$, (#6171)which is equal to twice the block ack agreement reordering buffer. The sequence number window has a lower edge $a$ and an upper edge $b$. For a received sequence number SN (as part of the received Sequence Control field), the associated packet number (PN) is determined as follows (where $b$ is initialized as $b = 0$):

if ($b \geq w$) then
  $a = b - w$
  if (SN < $a$) then BPN = BPN + 1
  PN = Sequence Control ||BPN
  if not ($a$ < SN < $b$) then $b$ = SN
else (i.e., $b < w$) then
  $a = b - w + 2^{12}$
  if (SN < $a$) then PN = Sequence Control ||BPN
  if (SN ≥ $a$) then PN = Sequence Control ||(BPN − 1)
  if (b < SN < $a$) then $b$ = SN

The BPN can also be updated explicitly through (#4173)a header compression request/response frame exchange, as defined in 10.57 (Generation of PV1 MPDUs and header compression procedure).

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### 12.5.3 Broadcast/multicast integrity protocol (BIP)

#### 12.5.3.1 BIP overview

BIP provides data integrity and replay protection for group addressed robust Management frames after establishment of an IGTKSA (see 12.6.1.1.9 (IGTKSA)). (#6054)For non-S1G STAs, BIP provides data integrity and replay protection for Beacon frames after establishment of a BIGTKSA (see 12.6.1.1.11 (BIGTKSA)). For S1G STAs, BIP provides data integrity and replay protection for S1G Beacon frames after establishment of a BIGTKSA (see 12.6.1.1.11 (BIGTKSA)). (11ba)BIP also provides integrity and replay protection for individually addressed and group addressed WUR frames (see 29.10 (WUR frame protection)).

BIP-CMAC-128 provides data integrity and replay protection, using AES-128 in CMAC Mode with a 128-bit integrity key and a CMAC TLen value of 128 (16 octets). BIP-CMAC-256 provides data integrity and replay protection, using AES-256 in CMAC Mode with a 256-bit integrity key and a CMAC TLen value of 128 (16 octets). NIST Special Publication 800-38B defines the CMAC algorithm, and (#298)NIST Special Publication 800-38D defines the GMAC algorithm. BIP processing uses AES with a 128-bit or 256-bit integrity key and a CMAC TLen value of 128 (16 octets). The CMAC output for BIP-CMAC-256 is not truncated and shall be 128 bits (16 octets). The CMAC output for BIP-CMAC-128 is truncated to 64 bits:

MIC = Truncate-64(CMAC Output).

BIP-GMAC-128 uses AES with a 128-bit integrity key, and BIP-GMAC-256 uses AES with a 256-bit integrity key. The authentication tag for both BIP-GMAC-128 and BIP-GMAC-256 is not truncated and shall be 128 bits (16 octets).

BIP uses the IGTK or BIGTK to compute the MMPDU MIC(11ba), uses the WTK to compute the MIC for protecting individually addressed WUR Wake-up frames, and uses the WIGTK to compute the MIC for protecting broadcast or group addressed WUR Wake-up frames. (#1903)The Authenticator(#1441)(#1380) shall, if management frame protection is negotiated, distribute one new IGTK and IGTK PN (IPN) whenever it distributes a new GTK. The IGTK is identified by the MAC address of the transmitting STA plus an IGTK (#3493)key ID that is encoded in the MME Key ID field. If beacon protection is enabled, the Authenticator(#1441)(#1380) may distribute one new BIGTK and BIPN when it distributes a new GTK. The BIGTK is identified by the MAC address of the transmitting STA plus:(#6054)

— a BIGTK key ID that is encoded in the S1G Beacon Compatibility element, in S1G Beacon frames that use BCE or
— a BIGTK (#3493)key ID that is encoded in the MME Key ID field, in Beacon frames and S1G Beacon frames that do not use BCE.

(#6054)(11ba)If WUR frame protection is negotiated, the Authenticator(#1441)(#1380) may distribute one new WIGTK and WIPN when it distributes a new GTK. The WIGTK is identified by the MAC address of the transmitting STA plus the WIGTK (#3493)key ID that is encoded in the Key ID field (see Figure 12-50 (WIGTK KDE format(#3493)(11ba)), Figure 9-1351 (Miscellaneous subfield format(11ba)), 9.4.2.294 (WUR PN Update element(11ba)) and 9.4.2.46 (FTE(#1776)).

#### 12.5.3.2 BIP encapsulation format(#6054)

The MME(#1517) shall follow all of the other elements in the management frame body but precede the FCS. See 9.4.2.53 (MME(#1517)) for the format of the MME(#1517). The frame format for a protected Management frame is shown in Figure 12-23 (BIP encapsulation(#6054)).

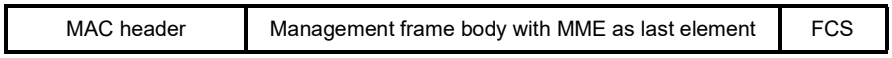


**Figure 12-23—BIP encapsulation(#6054)**


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(#6054)For S1G Beacon frames using BCE, the MIC element shall follow all of the other elements in the frame body but precede the FCS. See 9.4.2.117 (MIC element)for the format of the MIC element. The frame format for an S1G Beacon frame using BCE is shown in Figure 12-24 (BIP compact encapsulation(#6054)).

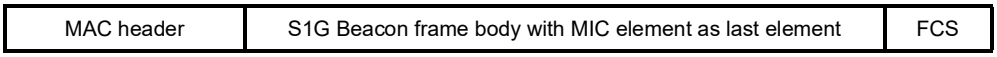


**Figure 12-24—BIP compact encapsulation(#6054)**

### 12.5.3.3 BIP AAD construction

(#6054)For MPDUs that are not S1G Beacon frames, the BIP Additional Authentication Data (AAD) is constructed from the MPDU header. AAD construction is performed as follows:

a) FC—MPDU Frame Control field, with(#4183):
   1) Retry subfield (bit 11) (#1951)masked out
   2) Power Management subfield (bit 12) (#1951)masked out
   3) More Data subfield (bit 13) (#1951)masked out
   4) (#4183)No modifications to other subfields
b) A1—MPDU Address 1 field.
c) A2—MPDU Address 2 field.
d) A3—MPDU Address 3 field.

Figure 12-25 (BIP AAD construction) depicts the format of the AAD(#6293).

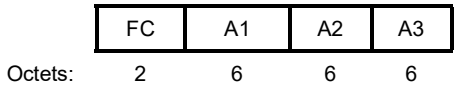


**Figure 12-25—BIP AAD construction**

(#6054)For S1G Beacon frames when BCE is not in use, the BIP Additional Authentication Data (AAD) is constructed from the MPDU header. AAD construction is performed as follows:

a) FC-MPDU Frame Control field.
b) SA-address of the STA transmitting the S1G Beacon frame.
c) Change Sequence.
d) Next TBTT (if present).
e) Short SSID(#8219) (if present).
f) Access Network Options (if present).

NOTE 1—S1G APs with dot11APPMActivated equal to true may enter Power Save mode. To prevent disruption of BSS traffic by an attacker setting the AP PM subfield (bit 15) in modified beacons, the AP PM subfield in S1G Beacon frames is protected by inclusion in the AAD.(#6054)

NOTE 2—The Frame Control field in S1G Beacons does not contain Retry or More Data subfields.(#6054)

(#6054)Figure 12-26 (BIP AAD construction for S1G Beacon frames without BCE(#6054)(#8219)) depicts the format of the AAD. The length of the AAD is 9-17 octets.

(#6054)For S1G Beacon frames when BCE is in use, the BIP Additional Authentication Data (AAD) is constructed from the MPDU header and the BIPN. AAD construction is performed as follows:

a) FC-MPDU Frame Control field.

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| | FC | SA | Change Sequence | Next TBTT | Short SSID | Access Network Options |
|---|---|---|---|---|---|---|
| Octets: | 2 | 6 | 1 | 0 or 3 | 0 or 4 | 0 or 1 |

**Figure 12-26—BIP AAD construction for S1G Beacon frames without BCE(#6054)(#8219)**

b) SA-address of the STA transmitting the S1G Beacon frame.
c) Change Sequence.
d) Next TBTT (if present).
e) Short SSID (#8219)(if present).
f) Access Network Options (if present).
g) BIPN.

(#6054)Figure 12-27 (BIP AAD construction for S1G Beacon frames with BCE(#6054)(#8219)) depicts the format of the AAD. The length of the AAD is 15-23 octets.

| | FC | SA | Change Sequence | Next TBTT | Short SSID | Access Network Options | BIPN |
|---|---|---|---|---|---|---|---|
| Octets: | 2 | 6 | 1 | 0 or 3 | 0 or 4 | 0 or 1 | 6 |

**Figure 12-27—BIP AAD construction for S1G Beacon frames with BCE(#6054)(#8219)**

#### 12.5.3.4 BIP replay counters and packet numbers(#3573)

When management frame protection is negotiated, the receiver shall maintain a 48-bit replay counter for each IGTK. The receiver shall set the (#1504)replay counter to the value of the IPN in the IGTK KDE (see 12.7.2 (EAPOL-Key frames)) provided by the Authenticator in the 4-way handshake, FT 4-way handshake, FT handshake, group key handshake, or FILS authentication. The transmitter shall maintain a single IPN for each IGTK. The IPN shall be implemented as a 48-bit strictly increasing integer, initialized to 1 when the corresponding IGTK is initialized.(#1382)(#1505)

(#1486)When beacon protection is enabled at the non-SP STA, the receiver shall maintain a 48-bit replay counter for each BIGTK. The receiver shall set the (#1504)replay counter to the value of the BIPN in the BIGTK key data encapsulation (KDE) (see 12.7.2 (EAPOL-Key frames)) provided by the Authenticator in the 4-way handshake, FT 4-way handshake, FT handshake, group key handshake, or FILS authentication. The transmitter shall maintain a single BIPN for each BIGTK. When beacon protection is enabled at an S1G AP and BCE is enabled, the BIPN shall be implemented as a 48-bit representation of the number of TSBTTs or TBTTs since TSF time 0. If dot11ShortBeaconInterval is true, the BIPN shall be initialized using Equation (12-1):(#6054)

$$BIPN = \text{Floor}\ (TSF / (1024 \times dot11ShortBeaconPeriod)) \quad (12\text{-}1)$$

(#6054)If dot11ShortBeaconInterval is false, the BIPN shall be initialized using Equation (12-2):

$$BIPN = \text{Floor}\ (TSF / (1024 \times dot11BeaconPeriod) \quad (12\text{-}2)$$

(#6054)When adding protection to, or checking protection on, an S1G Beacon frame, if dot11ShortBeaconInterval is true, the BIPN shall be calculated using Equation (12-3):

$$BIPN = CurrentTSBTT / (1024 \times dot11ShortBeaconPeriod) \quad (12\text{-}3)$$

where


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*CurrentTSBTT* is the TSBTT of the S1G Beacon frame that is being protected, in µs.

(#6054)When adding protection to, or checking protection on, an S1G Beacon frame, if dot11ShortBeaconInterval is false, the BIPN shall be calculated using Equation (12-4):

$$BIPN = CurrentTBTT / (1024 \times dot11BeaconPeriod) \quad (12\text{-}4)$$

where

*CurrentTBTT* is the TBTT of the S1G Beacon frame that is being protected, in µs.

NOTE 1—Calculation of CurrentTBTT or CurrentTSBTT is implementation dependent. One possible implementation is the transmitter could use Ceil(*TSF*/(1024 x *dot11ShortBeaconPeriod*)) and Ceil(*TSF*/(1024 x *dot11BeaconPeriod*)), and the receiver could use Floor(*TSF*/(1024 x *dot11ShortBeaconPeriod*)) and Floor(*TSF*/(1024 x *dot11BeaconPeriod*)).(#6054)

#6054)When beacon protection is enabled at an S1G AP and BCE is disabled, the BIPN shall be implemented as a 48-bit strictly increasing integer, initialized to 1 when the corresponding BIGTK is initialized. For non-S1G STAs, the BIPN shall be implemented as a 48-bit strictly increasing integer, initialized to 1 when the corresponding BIGTK is initialized.(#1382)(#1505)

See 12.5.3.5 (BIP transmission) and 12.5.3.6 (BIP reception) for per frame BIP processing(#3573), including detection of replayed frames.

If the PN is larger than dot11PNExhaustionThreshold, an MLME-PN-EXHAUSTION.indication primitive shall be generated.

NOTE 2—When the IPN space is exhausted, the choices available to an implementation are to replace the corresponding key or to end communications. When the BIPN space is exhausted and BCE is not in use, the choices available to an implementation are to replace the corresponding key or to end communications. When the BIPN space is exhausted and BCE is in use, the choices available to an implementation are to replace the corresponding key and reset the TSF to 0 or to end communications (and the AP may restart the BSS).(#6054)

When dot11QMFActivated is true, the receiver shall maintain an additional replay counter for each ACI for received group addressed robust Management frames that use QMF.

(#3573)NOTE 3—QMF is not supported for PV1 Management frames (see 11.24.1.1 (Overview)).

(#3573)When management frame protection is negotiated, the receiver(#3621) shall maintain a single replay counter for received group addressed robust Management frames that do not use the QMF service. If dot11QMFActivated is also true, the receiver(#3621) shall maintain an additional replay counter for each ACI for received group addressed robust Management frames that use the QMF service. (#3573)When the QMF service is not used, the transmitter shall preserve the order of protected group addressed robust Management frames that are transmitted to the same RA. When the QMF service is used, the transmitter shall (#3573)preserve the order of protected robust GQMFs within an AC that are transmitted to the same RA.

### 12.5.3.5 BIP transmission

When a STA transmits a protected group addressed robust Management frame that is not an S1G Beacon using BCE, it shall

a) Select the IGTK or BIGTK currently active for transmission of frames to the intended group of (#4212)receivers and construct the MME (see 9.4.2.53 (MME(#1517))) with the MIC field (#1951)masked out and the Key ID field set to the corresponding IGTK (#3493)key ID. If the frame is not a GQMF, the transmitting STA shall insert a strictly increasing integer into the MME IPN/ BIPN field. If the frame is a GQMF, then the transmitting STA shall maintain a 48-bit counter for use as the IPN, the counter shall be incremented for each GQMF until the two least significant bits

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of the counter match the ACI of the AC that is used to transmit the frame, and the counter value shall be inserted into the MME IPN/BIPN field of the frame. For BIP-GMAC-128 and BIP-GMAC-256, the initialization vector passed to GMAC shall be:(#6054)

1) For S1G Beacons: a concatenation of the SA field from the MAC header of the MPDU and the non-negative integer inserted into the MME IPN/BIPN field.(#6054)
2) For all other frames: a concatenation of Address 2 from the MAC header of the MPDU and the non-negative integer inserted into the MME IPN/BIPN field.(#6054)

(#3573)NOTE 1—QMF is not supported for PV1 Management frames (see 11.24.1.1 (Overview)).

b) Compute AAD as specified in 12.5.3.3 (BIP AAD construction).
c) Compute an integrity value over the concatenation of AAD and the management frame body including MME with:(#6054)
   1) For protected Beacon frames: the Timestamp field masked out.
   2) For S1G Beacon Frames: the TSF Completion field of the S1G Beacon Compatibility element masked out, if the element is present.

   (#6054)Insert the output into the MME MIC field. For BIP-CMAC-128, the integrity value is 64 bits and is computed using AES-128-CMAC; for BIP-CMAC-256, the integrity value is 128 bits and is computed using AES-256-CMAC; for BIP-GMAC-128, the integrity value is 128 bits and is computed using AES-128-GMAC; and, for BIP-GMAC-256, the integrity value is 128 bits and is computed using AES-256-GMAC.
d) Compose the frame as the (#6054)MAC header, management frame body, including MME, and FCS. The MME shall appear last in the frame body.
e) Transmit the frame.

(#6054)When an S1G STA transmits a protected S1G Beacon frame using BCE, it shall:

a) Select the BIGTK currently active for transmission of frames to the intended group of receivers.
b) Set the BIGTK Key ID Index subfield in the S1G Beacon Compatibility element, if present, to the value that corresponds to the BIGTK key ID (see 9.4.2.195 (S1G Beacon Compatibility element)). If the S1G Beacon Compatibility element is not present, the BIGTK used to protect the frame shall be the same BIGTK used in the most recently transmitted protected S1G Beacon frame that contained an S1G Beacon Compatibility element. If that BIGTK is not available for use, or no previous protected S1G Beacon frame containing an S1G Beacon Compatibility element has been transmitted, then the frame shall be sent without BIP encapsulation.
c) Construct the MIC element (see 9.4.2.117 (MIC element)) with the MIC field masked out.
d) Derive the BIPN using Equation (12-3) if dot11ShortBeaconInterval is true, or Equation (12-4) if dot11ShortBeaconInterval is false. For BIP-GMAC-128 and BIP-GMAC-256, the initialization vector passed to GMAC shall be a concatenation of the SA field from the MAC header of the MPDU and the BIPN.
e) Compute AAD as specified in 12.5.3.3 (BIP AAD construction).
f) Compute an integrity value over the concatenation of AAD and the management frame body including MIC element, with the TSF Completion field of the S1G Beacon Compatibility element masked out if the element is present.
g) Insert the output into the MIC field of the MIC element. For BIP-CMAC-128, the integrity value is 64 bits and is computed using AES-128-CMAC; for BIP-CMAC-256, the integrity value is 128 bits and is computed using AES-256-CMAC; for BIP-GMAC-128, the integrity value is 128 bits and is computed using AES-128-GMAC; and, for BIP-GMAC-256, the integrity value is 128 bits and is computed using AES-256-GMAC.
h) Compose the frame as the MAC header, management frame body, including MIC element, and FCS. The MIC element shall appear last in the frame body.


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i) Transmit the frame.

(#2128)A protected group addressed robust Management frame shall be protected using the group management cipher suite (see 9.4.2.23.2 (Cipher suites)).

(#2128)NOTE 2—BIP does not provide protection against forgery by associated (if in an infrastructure BSS, and optionally in a PBSS) and authenticated STAs. A STA that has left the BSS can successfully forge group addressed robust Management frames until the IGTK is updated.

Once a STA transmits a protected Beacon frame (#6054)or a protected S1G Beacon frame using a new BIGTK, the STA shall not transmit protected Beacon frames (#6054)or protected S1G Beacon frames using the previous(#1847) BIGTK. Once a STA transmits a protected group addressed robust Management frame using a new IGTK, the STA (#4322)shall not transmit protected group addressed robust Management frames using the previously used IGTK.

### 12.5.3.6 BIP reception

When a STA with management frame protection negotiated receives a group addressed robust Management frame, a protected Beacon frame, or a protected S1G Beacon frame that is not using BCE,(#6054) it shall

a) Identify the appropriate IGTK or BIGTK and associated state based on the MME Key ID field. (#4299)If the frame is a robust Management frame (#6054)and no such IGTK exists, silently discard(#187) the frame and terminate BIP processing for this reception. (#6054)If the frame is a protected S1G Beacon frame, and the Encapsulation Mode for the key is BCE, the receiver shall silently discard the frame and optionally transmit to the AP a WNM Notification Re-quest frame to report beacon protection failure. (#4298)If the frame is a protected Beacon frame and no such BIGTK exists, terminate BIP processing for this reception, and
   1) If (#1486)beacon protection is enabled at the non-AP STA, silently discard(#187) the frame and optionally transmit to the AP a WNM Notification Request frame to report beacon protection failure.
   2) Otherwise, process the frame.
b) Perform replay protection on the received frame. The receiver shall interpret the MME IPN/BIPN field as a 48-bit unsigned integer.
   1) If the frame is a robust Management frame but not a GQMF, the receiver shall compare this MME IPN/BIPN(#4295)(#1422) to the value of the (#1504)replay counter for the IGTK identified by the MME Key ID field. If the value from the received MME IPN/BIPN field is less than or equal to the replay counter value for this IGTK, the receiver shall discard the frame and increment the dot11RSNAStatsCMACReplays counter by 1.

      (#3573)NOTE 1—QMF is not supported for PV1 Management frames (see 11.24.1.1 (Overview)).

   2) If the frame is a robust Management frame and also a GQMF, the receiver shall compare this MME IPN/BIPN(#4295)(#1422) to the value of the (#1504)replay counter for the IGTK identified by the MME Key ID field and the AC represented by the value of the ACI subfield of the received frame. If the value from the received MME IPN/BIPN field is less than or equal to the replay counter value for this IGTK and AC, the receiver shall discard the frame and increment the dot11RSNAStatsCMACReplays counter by 1.
   3) If the frame is a protected Beacon frame (#6054)or a protected S1G Beacon frame, the receiver shall compare this MME IPN/BIPN(#1422) to the value of the (#1504)replay counter for the BIGTK identified by the MME Key ID field. If the integer value from the received MME IPN/BIPN field is less than or equal to the replay counter value for this BIGTK, the receiver shall discard the frame and increment the dot11RSNAStatsCMACReplays counter by 1.
c) Compute AAD for this Management frame, as specified in 12.5.3.3 (BIP AAD construction). For BIP-GMAC-128 and BIP-GMAC-256, an initialization vector for GMAC is constructed as:(#6054)

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1) For S1G Beacons: a concatenation of the SA field from the MAC header of the MPDU and the non-negative integer inserted into the MME IPN/BIPN field.

2) For all other frames: a concatenation of Address 2 from the MAC header of the MPDU and the non-negative integer inserted into the MME IPN/BIPN field.

d) Extract and save the received MIC value, and compute a verifier over the concatenation of AAD, the management frame body, with:(#6054)

1) For protected Beacon frames: the Timestamp field masked out

2) For S1G Beacon Frames: the TSF Completion field of the S1G Beacon Compatibility element masked out if the element is present,

and MME, with the MIC field (#1951)masked out in the MME. For BIP-CMAC-128, the integrity value is 64 bits and is computed using AES-128-CMAC; for BIP-CMAC-256, the integrity value is 128 bits and is computed using AES-256-CMAC; for BIP-GMAC-128, the integrity value is 128 bits and is computed using AES-128-GMAC; and, for BIP-GMAC-256, the integrity value is 128 bits and is computed using AES-256-GMAC. If the result does not match the received MIC value, then the receiver shall discard the frame, increment the dot11RSNAStatsBIPMICErrors counter by 1, and terminate BIP processing for this reception.

e) If the frame is a robust Management frame but not a GQMF, update the replay counter for the IGTK identified by the MME Key ID field with the value of the MME IPN/BIPN field.

f) If the frame is a robust Management frame and also a GQMF, update the replay counter for the IGTK identified by the MME Key ID field and the AC represented by the value of the ACI subfield of the received frame with the value of the MME IPN/BIPN field.

g) If the frame is a protected Beacon frame (#6054)or a protected S1G Beacon frame, update the replay counter for the BIGTK identified by the MME Key ID field with the value of the MME IPN/BIPN field.(#3267)

(#6054)When an S1G STA with management frame protection negotiated receives a protected S1G Beacon frame that is using BCE, it shall

a) Identify the appropriate BIGTK and associated state based on the BIGTK Key ID Index subfield in the S1G Beacon Compatibility element, if present (see 9.4.2.195 (S1G Beacon Compatibility element)). If the S1G Beacon Compatibility element is not present, the BIGTK used to check the frame shall be the same BIGTK used in the most recently received protected S1G Beacon frame that contained an S1G Beacon Compatibility element. If the Encapsulation Mode for the key is Normal, the receiver shall silently discard the frame and optionally transmit to the AP a WNM Notification Request frame to report beacon protection failure.

b) If no such BIGTK exists, terminate BIP processing for this reception, and

1) If beacon protection is enabled at the non-AP STA, silently discard the frame and optionally transmit to the AP a WNM Notification Request frame to report beacon protection failure.

2) Otherwise, process the frame.

c) Derive the BIPN using Equation (12-3) if dot11ShortBeaconInterval is true, or Equation (12-4) if dot11ShortBeaconInterval is false. For BIP-GMAC-128 and BIP-GMAC-256, the initialization vector passed to GMAC shall be a concatenation of the SA field from the MAC header of the MPDU and the BIPN.

d) Perform replay protection on the received frame. The receiver shall compare the derived BIPN to the value of the replay counter for the identified BIGTK. If the integer value from the derived BIPN is less than or equal to the replay counter value for this BIGTK, the receiver shall discard the frame and increment the dot11RSNAStatsCMACReplays counter by 1.

NOTE 2—A STA should synchronize to the TSF prior to processing the first protected S1G Beacon frame using BCE.

e) Compute AAD for this Management frame, as specified in 12.5.3.3 (BIP AAD construction).


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f) Extract and save the received MIC value, and compute a verifier over the concatenation of AAD, the management frame body, with the TSF Completion field of the S1G Beacon Compatibility element masked out if the element is present, and MIC element, with the MIC field masked out in the MIC ele-ment. For BIP-CMAC-128, the integrity value is 64 bits and is computed using AES-128-CMAC; for BIP-CMAC-256, the integrity value is 128 bits and is computed using AES-256-CMAC; for BIP-GMAC-128, the integrity value is 128 bits and is computed using AES-128-GMAC; and, for BIP-GMAC-256, the integrity value is 128 bits and is computed using AES-256-GMAC. If the result does not match the received MIC value, then the receiver shall discard the frame, increment the dot11RSNAStatsBIPMICErrors counter by 1, and terminate BIP processing for this reception.

### 12.5.4 GCM protocol (GCMP)

#### 12.5.4.1 GCMP overview

Subclause 12.5.4 (GCM protocol (GCMP)) specifies the GCMP, which provides data confidentiality, authentication, integrity, and replay protection. A DMG (#364)STA shall support GCMP-128.

GCMP is based on the GCM of the AES encryption algorithm. GCM protects the integrity of both the MPDU Data field and selected portions of the MPDU header.

The AES algorithm is defined in FIPS 197. All AES processing used within GCMP uses AES with a 128-bit key (GCMP-128) or a 256-bit key (GCMP-256).

GCM is defined in NIST Special Publication 800-38D. GCM is a generic mode that can be used with any block-oriented encryption algorithm.

GCM requires a fresh temporal key for every session. GCM also requires a unique nonce value for each frame protected by a given temporal key. Reuse of a nonce value with the same temporal key voids all security guarantees. GCMP uses a 128-bit MIC.

Annex J provides test vectors for GCM.

When GCMP is selected as the RSN pairwise cipher and management frame protection is negotiated, (#1980)individually addressed robust Management frames, and (#162)(MBSS only) group addressed Action frames of a category specified with Yes in the Group addressed privacy column of Table 9-81 (Category values), shall be protected with GCMP.

(#1901)An S1G STA shall not use PV1 frames when using GCMP encapsulation.

#### 12.5.4.2 GCMP MPDU format

Figure 12-28 (Expanded GCMP MPDU(11az)) shows the MPDU format when using GCMP.

GCMP processing expands the original MPDU size by 24 octets, 8 octets for the GCMP Header field and 16 octets for the MIC field. The GCMP Header field is constructed from the PN and Key ID subfields. The 48-bit PN is represented as an array of 6 octets. PN5 is the most significant octet of the PN, and PN0 is the least significant.

The ExtIV subfield (bit 5) of the Key ID octet is always set to 1 for GCMP.

The third octet of the GCMP Header field is reserved.(#1385)

Bits 6–7 of the Key ID octet are for the Key ID subfield.

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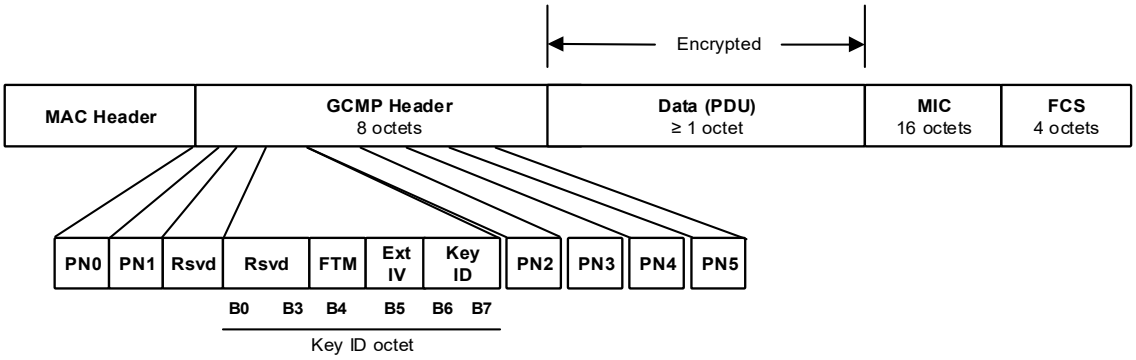


**Figure 12-28—Expanded GCMP MPDU(11az)**

(11az)In a protected (#6026)individually addressed management Action frame, bit 4 of the Key ID octet is set to 1 if the frame is a Protected Fine Timing frame—see Table 9-81 (Category values). In other protected (#6026)individually addressed frames, (#7216)bit 4 is reserved.

### 12.5.4.3 GCMP cryptographic encapsulation

#### 12.5.4.3.1 General

The GCMP cryptographic encapsulation process is depicted in Figure 12-29 (GCMP encapsulation block diagram).

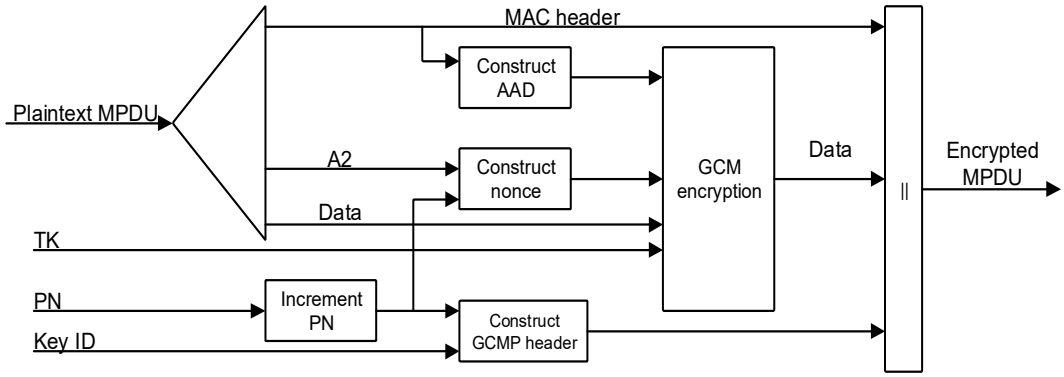


**Figure 12-29—GCMP encapsulation block diagram**

GCMP encrypts the Frame Body field of a plaintext MPDU and encapsulates the resulting cipher text using the following steps:

a) Increment the PN, to obtain a fresh nonzero(#1505) PN for each MPDU, so that the PN never repeats for the same temporal key.

NOTE—Retransmitted MPDUs are not modified on retransmission.

b) Use the fields in the MPDU header to construct the additional authentication data (AAD) for GCM. The GCM algorithm provides integrity protection for the fields included in the AAD. (#1951)MPDU header fields that might change when retransmitted are muted by being masked out when calculating the AAD.

c) Construct the (#209)GCM nonce as defined in (#357)12.5.4.3.4 (Construct GCM nonce)(#8168).

d) Construct the GCMP header as defined in 12.5.4.3.5 (Construct GCMP header).


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e) Use the temporal key, AAD, nonce, and MPDU data to form the cipher text and the MIC. This step is known as GCM originator processing.

f) Form the encrypted MPDU by combining the original MPDU header, the GCMP header, the encrypted data and the MIC, as described in 12.5.4.2 (GCMP MPDU format).

The GCM reference describes the processing of the key, nonce, AAD, and data to produce the encrypted output. See 12.5.4.3.2 (PN processing) to 12.5.4.3.6 (GCM originator processing) for details of the creation of the AAD and nonce from the MPDU and the associated MPDU-specific processing.

#### 12.5.4.3.2 PN processing

The PN is incremented by a positive number for each MPDU. The PN shall be incremented in steps of 1 for constituent MPDUs of fragmented MSDUs, (11ax)A-MSDUs, and MMPDUs. The PN shall never repeat for a series of encrypted MPDUs using the same temporal key.

If the PN exceeds the threshold defined in dot11PNExhaustionThresholdLow and dot11PNExhaustionThresholdHigh, an MLME-PN-EXHAUSTION.indication primitive shall be generated.

NOTE 1—When PN space is exhausted, the choices available to an implementation are to replace the corresponding key or to end communications.

NOTE 2—When a group addressed MSDU is retransmitted using GCR, it is concealed from non-GCR capable STAs using the procedures described in 11.21.16.3.5 (Concealment of GCR transmissions). The MPDU containing this concealed A-MSDU has a different PN from the MPDU that contained the original transmission of the group addressed MSDU.

#### 12.5.4.3.3 Construct AAD

The AAD construction is defined in 12.5.2.3.3 (Construct AAD).

#### 12.5.4.3.4 Construct GCM nonce

(#215)(#209)The GCM nonce is shown in Figure 12-30 (GCM nonce format(#215)).

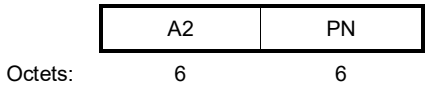


**Figure 12-30—GCM nonce format(#215)**

The A2 subfield shall contain the Address 2 field from the MAC header.

The PN subfield shall contain the packet number, with PN0 in the last octet of the subfield.

#### 12.5.4.3.5 Construct GCMP header

The format of the (#2047)GCMP header is given in 12.5.4.2 (GCMP MPDU format). The header encodes the PN and Key ID field values used to encrypt the MPDU.

#### 12.5.4.3.6 GCM originator processing

GCM is a generic authenticate-and-encrypt block cipher mode, and in this standard, GCM is used with the AES block cipher.

There are four inputs to GCM originator processing (see Figure 12-29 (GCMP encapsulation block diagram)):

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a) *Key:* the temporal key.
b) *Nonce:* the nonce constructed as described in 12.5.4.3.4 (Construct GCM nonce).
c) *Plaintext data:* the plaintext frame body of the MPDU to be encrypted and transmitted.
d) *AAD:* the AAD that is the canonical MPDU header as described in 12.5.4.3.3 (Construct AAD).

GCM originator processing provides authentication and integrity of the frame body and the AAD as well as data confidentiality of the frame body. The output from GCM originator processing consists of the encrypted data and 16 additional octets of MIC (see Figure 12-28 (Expanded GCMP MPDU(11az))).

NOTE—In GCM originator processing, the MIC obtained is not encrypted, unlike in CCM originator processing. Refer to NIST Special Publication 800-38D for details.

The GCM encryption algorithm is described in NIST Special Publication 800-38D. The key, nonce, plaintext data and AAD described above are passed to the GCM encryption algorithm as *K*, *IV*, *P*, and *A*, respectively. The GCM encryption algorithm yields a cipher text *C* and an authentication tag *T*; from this the encrypted frame body is taken as *C* and the MIC is taken as *T*.

The PN values sequentially number each MPDU. Each transmitter shall maintain a single PN (48-bit counter) for each PTKSA and GTKSA. The PN shall be implemented as a 48-bit strictly increasing integer, initialized to 0(#1505) when the corresponding temporal key is initialized or (#1382)refreshed (by rekeying).

NOTE —The PN is incremented before transmission (see 12.5.4.3.1 (General)).(#1505)

(#191)(#193)A transmitter shall not use an (#1564)MSDU or A-MSDU priority if this would cause the total number of priorities used during the lifetime of the SA to exceed the number of replay counters supported by the receiver (for a pairwise SA) or all the receivers (for a group SA) for that SA. The transmitter shall not reorder GCMP protected frames that are transmitted to the same RA within a replay counter, but may reorder frames across replay counters. One possible reason for reordering frames is the (#1564)MSDU or A-MSDU priority.

(#3573)When the QMF service is not used, the transmitter shall preserve the order of protected individually addressed robust Management frames that are transmitted to the same RA. When the QMF service is used, the transmitter shall (#3573)preserve the order of protected robust IQMFs within an AC that are transmitted to the same RA.

A GCMP protected individually addressed robust Management frame shall be protected using the same TK as a Data frame.

### 12.5.4.4 GCMP decapsulation

#### 12.5.4.4.1 General

Figure 12-31 (GCMP decapsulation block diagram(#3661-Ed)) shows the GCMP decapsulation process.

GCMP decrypts the Frame Body field of a cipher text MPDU and decapsulates a plaintext MPDU using the following steps:

a) The encrypted MPDU is parsed to construct the AAD (see 12.5.4.3.3 (Construct AAD)) and nonce (see 12.5.4.3.4 (Construct GCM nonce)) values.
b) The MIC is extracted for use in GCM integrity checking.
c) GCM recipient processing uses the temporal key, AAD, nonce, MIC, and MPDU cipher text data to recover the MPDU plaintext data as well as to check the integrity of the AAD and MPDU plaintext data.


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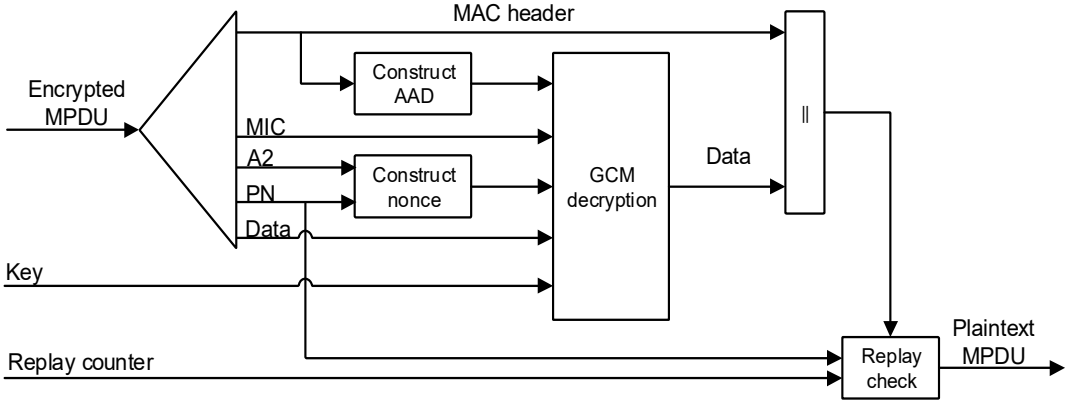


**Figure 12-31—GCMP decapsulation block diagram(#3661-Ed)**

d) The received MPDU header and the MPDU plaintext data from GCM recipient processing are concatenated to form a plaintext MPDU.

e) The decryption processing prevents replay of MPDUs by validating that the PN in the MPDU is greater than the replay counter maintained for the session(#193), and TID (for Data frames) or ACI (for QMFs).

See 12.5.4.4.2 (GCM recipient processing) to 12.5.4.4.4 (PN and replay detection) for details of this processing.

When the received frame is a GCMP protected individually addressed robust Management frame, the contents of the MMPDU body after protection is removed and shall be delivered to the SME via the MLME primitive designated for that MMPDU rather than through the MA-UNITDATA.indication primitive.

#### 12.5.4.4.2 GCM recipient processing

GCM recipient processing uses the same parameters as GCM originator processing. A GCMP protected individually addressed robust Management frame shall use the same TK as a Data frame.

There are five inputs to GCM recipient processing (see Figure 12-31 (GCMP decapsulation block diagram(#3661-Ed))):

— *Key:* the temporal key.
— *Nonce:* the nonce constructed as described in 12.5.4.3.4 (Construct GCM nonce).
— *Encrypted data:* the encrypted portion of the frame body from the received MPDU (see Figure 12-28 (Expanded GCMP MPDU(11az))).
— *MIC:* the MIC from the received MPDU.
— *AAD:* the AAD that is the canonical MPDU header as described in 12.5.4.3.3 (Construct AAD).

GCM recipient processing checks the authentication and integrity of the frame body and the AAD as well as decrypting the frame body. A MIC check is performed by comparing the received MIC with a MIC calculated as described in 12.5.4.3 (GCMP cryptographic encapsulation). The plaintext is returned only if the MIC check is successful.

The GCM decryption algorithm is described in NIST Special Publication 800-38D. The key, nonce, encrypted data, AAD and MIC described above are passed to the GCM decryption algorithm as $K$, $IV$, $C$, $A$

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and *T* respectively. The GCM decryption algorithm yields a plaintext *P* or an indication of inauthenticity *FAIL*; from this the plaintext frame body is taken as *P*, if there was no indication of inauthenticity.

There is one output from error-free GCM recipient processing:

— *Frame body:* the plaintext frame body, which is the same size as the encrypted portion of the frame body.

#### 12.5.4.4.3 Decrypted GCMP MPDU

The decapsulation process succeeds when the calculated MIC (as described in 12.5.4.3 (GCMP cryptographic encapsulation) matches the MIC value obtained from decrypting the received encrypted MPDU. The original MPDU header is concatenated with the plaintext data resulting from the successful GCM recipient processing to create the plaintext MPDU.

#### 12.5.4.4.4 PN and replay detection

To effect replay detection, the receiver extracts the PN from the GCMP header. See 12.5.4.2 (GCMP MPDU format) for a description of how the PN is encoded in the GCMP header. The following processing rules are used to detect replay:

a) The receiver shall maintain a separate set of replay counters for each PTKSA, (#166)TPKSA, GTKSA, mesh PTKSA, and mesh GTKSA(#239). The receiver initializes these replay counters to 0 when it resets the temporal key for a peer. The replay counter is set to the PN value of accepted GCMP MPDUs.

b) For each PTKSA, (#166)TPKSA, GTKSA, mesh PTKSA, and mesh GTKSA(#239), the (#4212)receiver shall maintain a separate replay counter for each TID, subject to the limitation of the number of supported replay counters indicated in the RSN Capabilities field (see 9.4.2.23 (RSNE))(#3573). (#6149)In the case of a TPKSA, this shall for both the TDLS initiator STA and the TDLS responder STA be the number indicated by the TDLS initiator STA in the PTKSA Replay Counter field in the TDLS Setup Request frame.

(#6149)NOTE 1—The number indicated by the TDLS responder STA (if a TDLS Discovery Response frame is sent) is ignored, (#7231)as are the GTKSA Replay Counter and Extended Key ID For Individually Addressed Frames fields in the TDLS Setup Request frame and any TDLS Discovery Response frame.

(#171)NOTE 2—For the purpose of replay detection, non-QoS Data frames are treated as having TID 0, and use the (#4300)replay counter corresponding to MSDU priority 0.

c) (#199)If (#4166)management frame protection is negotiated, the (#4212)receiver shall set the MFPC bit on a given link to 1, it shall maintain a single replay counter for received individually addressed robust Management frames (11az)except Protected Fine Timing frames (see 9.6.34 (Protected Fine Timing Action frame details(11az)(#8155))) that are received with the To DS subfield equal to 0(#3573), and a single replay counter for received individually addressed robust PV1 Management frames except PV1 Protected Fine Timing frames (see 9.6.34 (Protected Fine Timing Action frame details(11az)(#8155)))(11az).

d) (11az)If dot11RSNAProtectedManagementFramesActivated is true and dot11QMFActivated is also true, the (#4212)receiver shall maintain an additional replay counter for each ACI for received individually addressed robust Management frames (11az)except Protected Fine Timing frames (see 9.6.34 (Protected Fine Timing Action frame details(11az)(#8155))) and robust PV1 Management frames except Protected Fine Timing frames (see 9.6.34 (Protected Fine Timing Action frame details(11az)(#8155))) that are received with the To DS subfield equal to 1.

(#3573)NOTE 3—PV1 frames are not supported with GCMP (see 12.5.4.1 (GCMP overview)).


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e) (11az)If dot11RSNAProtectedManagementFramesActivated is true, the recipient shall maintain a separate replay counter for received individually addressed Protected Fine Timing frames (see 9.6.34 (Protected Fine Timing Action frame details(11az)(#8155))) and shall use the PN from the received frame to detect replays.

f) The receiver shall discard any Data frame that is received with its PN less than or equal to the value of the replay counter that is associated with the TA(#3573), RA (individual or group address; not if TDLS) and priority value of the received MPDU. The receiver shall discard (#3573)fragmented MSDUs, A-MSDUs(#3089) and MMPDUs whose constituent MPDU PN values are not incrementing in steps of 1. (#4166)If management frame protection is negotiated, the receiver shall set the MFPC bit on a given link to 1, it(#199) shall discard any individually addressed robust Management frame that is received with its PN less than or equal to the value of the replay counter associated with the TA (#3573)and (QMF receiver of an individually addressed robust Management frame with the To DS subfield equal to 1 only) ACI of that individually addressed Management frame.

g) When discarding a frame, the receiver shall increment by 1 dot11RSNAStatsGCMPReplays for Data frames or dot11RSNAStatsRobustMgmtGCMPReplays for robust Management frames.

h) For MSDUs or A-MSDUs sent using the block ack feature, reordering of received MSDUs or A-MSDUs according to the block ack receiver operation is performed prior to replay detection.

## 12.6 RSNA security association management

### 12.6.1 Security associations

#### 12.6.1.1 Security association definitions

##### 12.6.1.1.1 General

IEEE Std 802.11 uses the notion of a security association to describe secure operation. Secure communications are possible only within the context of a security association, as this is the context providing the state (e.g., cryptographic keys, counters, sequence spaces) needed for correct operation of the IEEE 802.11 cipher suites.

A security association is a set of policy(ies) and key(s) used to protect information. The information in the security association is stored by each party of the security association, needs to be consistent among all parties, and needs to have an identity. The identity is a compact name of the key and other bits of security association information to fit into a table index or an MPDU. The following types of security associations are supported by an RSNA STA:

— PMKSA: A result of a successful IEEE 802.1X exchange, OWE exchange(#1084), SAE authentication, FILS authentication, or preshared PMK information. A PMKSA can be cached.

— PMK-R0 security association: A result of a successful FT initial mobility domain association.

— PMK-R1 security association: A result of a successful FT initial mobility domain association or FT authentication sequence.

— Mesh PMKSA: A result of successful completion of the active authentication protocol.

— PTKSA: A result of a successful 4-way handshake, FT 4-way handshake, FT authentication sequence, FILS authentication, (11az)or PASN authentication.

— Mesh PTKSA(#240): A result of a successful authenticated mesh peering exchange (AMPE).

— (#3685)GTKSA: A result of a successful group key handshake, 4-way handshake, FT 4-way handshake, FT protocol, FT resource request protocol, or FILS authentication.

— IGTKSA: A result of a successful group key handshake, successful 4-way handshake, successful FT 4-way handshake, the Reassociation Response frame of the fast BSS transition protocol, or successful FILS authentication.

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- Mesh GTKSA: A result of a successful AMPE or mesh group key handshake.
- BIGTKSA: A result of a successful group key handshake, successful 4-way handshake, successful FT 4-way handshake, the Reassociation Response frame of the fast BSS transition protocol, or successful FILS authentication.
- TPKSA: A result of a successful TPK handshake.(#165)
- (11ba)WIGTKSA: A result of a successful group key handshake, successful 4-way handshake, successful FT 4-way handshake, the Reassociation Response frame of the fast BSS transition protocol, or successful FILS authentication.

In order to set up a security association to a peer STA, an SME that does not know the security policy of the peer should send a Probe Request frame to the peer STA to find its security policy before setting up a security association to the peer STA.

In order to set up a security association to a peer STA, (#1702)a STA that has received message 1 of a 4-way handshake but does not know the security policy of the peer should send a Probe Request frame to the peer STA to find its security policy before setting up a security association to the peer STA.

#### 12.6.1.1.2 PMKSA

The PMKSA is created by the Authenticator's SME and Supplicant's SME when EAP authentication, SAE authentication, (#1084)FILS authentication, or an OWE exchange completes successfully, or when the PSK is configured.

When the negotiated AKM uses PMKID derivation with (#3744)PTK-KCK as a parameter as defined in 12.7.1.3 (Pairwise key hierarchy), the PMKID derived from the PTK-KCK during the initial 4-way handshake is not changed during the lifetime of this PMKSA.

A PMKSA association is bidirectional. In other words, both parties use the information in the security association for both sending and receiving. The PMKSA is used to create the PTKSA. PMKSAs have a certain lifetime. The PMKSA consists of the following:

- PMKID, as defined in 12.7.1.3 (Pairwise key hierarchy) or 12.7.1.6.3 (PMK-R0). The PMKID identifies the security association.
- Authenticator's or peer's MAC address. For multi-band RSNA, the MAC address is associated with the operating band in use when the PMKSA is established.
- PMK; or if the PMKSA was established with an (#3266)AKMP for which the Authentication type column includes FT authentication (see Table 9-190 (AKM suite selectors)), MPMK (see 12.7.1.6.3 (PMK-R0)).
- Lifetime, as defined in 12.7.1.3 (Pairwise key hierarchy) or 12.7.1.6 (FT key hierarchy).
- AKMP.
- All authorization parameters specified by the AS or local configuration. This might include parameters such as the STA's authorized SSID.
- Cache Identifier, if advertised by the AP in FILS Indication element.

#### 12.6.1.1.3 PMK-R0 security association

The PMK-R0 security association is the result of a successful completion of the IEEE 802.1X authentication, SAE authentication, or use of PSK during the FT initial mobility domain association. This security association is bidirectional. It has a certain lifetime. It consists of the following:

- SSID
- (#1776)MDID


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- PMK-R0
- R0KH-ID
- PMKR0Name
- S0KH-ID
- PMK-R0 lifetime
- Pairwise cipher suite selector
- All authorization parameters specified by the AS or local configuration

#### 12.6.1.1.4 PMK-R1 security association

The PMK-R1 security association is the result of

- A successful completion of the IEEE 802.1X authentication, SAE authentication, or use of PSK during the FT initial mobility domain association or
- A successful completion of the authentication phase in the fast BSS transition to the target AP

This security association is bidirectional. It has a certain lifetime. It consists of the following:

- SSID
- MDID
- PMK-R1
- PMK-R1 lifetime
- PMKR1Name
- R1KH-ID
- R0KH-ID
- PMKR0Name
- S0KH-ID
- S1KH-ID
- Pairwise cipher suite selector
- All authorization parameters specified by the AS or local configuration

#### 12.6.1.1.5 Mesh PMKSA

The mesh PMKSA is the result of successful completion of the active authentication protocol. This security association is bidirectional. The two authenticated parties use the information in the security association for both sending and receiving. The mesh PMKSA is created by the Mesh STA's SME when the active authentication protocol completes successfully with the peer mesh STA. The mesh PMKSA is used to create the mesh PTKSA(#240). Mesh PMKSAs have a certain lifetime. Mesh PMKSAs contain the following, and are identified by their PMKID.

- PMKID, as defined in 12.4.5.4 (Processing of a peer's SAE Commit message)
- (#1544)Mesh STA's or AP's MAC address
- (#1544)Peer mesh STA's or AP's MAC address
- PMK
- AEK, as defined in 14.6.7 (Keys and key derivation algorithm for the authenticated mesh peering exchange (AMPE))
- Lifetime, as defined in 12.7.1.3 (Pairwise key hierarchy)
- Selected (#3266)AKMP (see 9.4.2.23.3 (AKM suites))

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#### 12.6.1.1.6 PTKSA

The PTKSA results from a successful 4-way handshake, FT 4-way handshake, FT protocol, FT resource request protocol, FILS authentication, (11az)or PASN authentication. This security association is also bidirectional. PTKSAs, (11az)except those established using PASN authentication, have the same lifetime as the PMKSA or PMK-R1 security Association, whichever comes first. (11az)PTKSAs for PASN authentication have a minimum of the lifetime of the PMKSA used and the timeout negotiated, if any, during PASN authentication. Because the PTKSA is tied to the PMKSA or to a PMK-R1 security association, it only has the additional information from the 4-way handshake, FT Protocol authentication, FILS authentication (11az)or PASN authentication. (#1381)There shall be only one PTKSA per key ID per band (see (#3269)12.6.20 (Multi-band RSNA)) with the same Supplicant and Authenticator MAC addresses

During the 4-way handshake defined in 12.7.6.5 (4-way handshake message 4) and the FT 4-way handshake defined in 13.4.2 (FT initial mobility domain association in an RSN), there is state created between message 1 and message 3 of the handshake. This does not create a PTKSA until message 3 is validated by the Supplicant and message 4 is validated by the Authenticator.

During the FT authentication sequence defined in 13.8 (FT authentication sequence), the PTKSA is validated when message 3 is validated by the R1KH and message 4 is validated by the S1KH.

During the FILS authentication sequence defined in 12.11.2 (FILS authentication protocol), the PTKSA is validated by key confirmation using (Re)Association Request and (Re)Association Response frames.

The PTKSA consists of the following:

- PTK(11ba), where the PTK includes the KDK when WUR frame protection is negotiated
- Pairwise cipher suite selector(11ba), and when WUR frame protection is negotiated, the cipher suite selector 00-0F-AC:6 (BIP-CMAC-128) for individually addressed WUR Wake-up frames
- (#4109)Supplicant MAC address, depending on the negotiated AKMP(#271)(#3266)
- (#4109)Authenticator MAC address, depending on the negotiated (#3266)AKMP(#271)
- Key ID
- If FT key hierarchy is used,
  - R1KH-ID
  - S1KH-ID
  - PTKName
- (11ba)If WUR frame protection is negotiated,
  - WTK

(#4069)A non-AP STA may retain the PTK-KCK and the negotiated AKM suite selector when deleting a PTKSA to allow Known STA Identification element to be used even when no PTKSA exists, see 11.13 (SA Query procedures).

#### 12.6.1.1.7 Mesh PTKSA(#240)

The mesh PTKSA(#240) is a result of the AMPE. This security association is also bidirectional. It has a certain lifetime. The mesh PTKSA(#240) contains the following:

- MTK, as defined in 14.6.7 (Keys and key derivation algorithm for the authenticated mesh peering exchange (AMPE))
- PMKID
- (#1544)Local mesh STA or AP MAC address
- (#1544)Peer mesh STA or AP MAC address


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- Local Link ID
- Peer Link ID
- Local nonce
- Peer nonce
- Lifetime as defined in 12.6.14 (RSNA key management in an MBSS)
- Pairwise cipher suite selector

#### 12.6.1.1.8 GTKSA

The GTKSA results from a successful 4-way handshake, FT 4-way handshake, FT protocol, FT resource request protocol, group key handshake, or FILS authentication, and is unidirectional. In an infrastructure BSS, there is one GTKSA, used exclusively for encrypting group addressed MPDUs that are transmitted by the AP and for decrypting group addressed transmissions that are received by the STAs. In an IBSS or in a PBSS, each STA defines its own GTKSA, which is used to encrypt its group addressed transmissions, and stores a separate GTKSA for each peer STA so that encrypted group addressed traffic received from other STAs may be decrypted. A GTKSA is created by the Supplicant's SME when message 3 of the 4-way handshake is received, when message 1 of the group key handshake is received, when the Reassociation Response frame of the FT handshake is received, or when the FILS authentication with a status code indicating success is received. The GTKSA is created by the Authenticator's SME when the SME changes the GTK and has sent the GTK to all STAs with which it has a PTKSA. It has the same lifetime as the BSS, unless superseded. A GTKSA consists of the following:

- Direction vector (whether the GTK is used for transmit or receive).
- Group data cipher suite selector.(#6020)
- GTK.
- Authenticator MAC address.
- Key ID.
- All authorization parameters specified by local configuration. This might include parameters such as the STA's authorized SSID.

When the GTK is used to encrypt individually addressed traffic (the selectable cipher suite is "Use group data cipher suite"(#6020)), the GTKSA is bidirectional.

#### 12.6.1.1.9 IGTKSA

When management frame protection is (#7048)negotiated, a non-AP STA's SME creates an IGTKSA when it receives a valid message 3 of the 4-way handshake or FT 4-way handshake, the Reassociation Response frame of the fast BSS transition protocol with a status code indicating success, a Mesh Peering Open Message of the Authenticated Mesh Peering Exchange (AMPE) protocol, a valid message 1 of the group key handshake, or the (Re)Association Response frame of FILS authentication with a status code indicating success. The Authenticator's SME creates an IGTKSA when it establishes or changes the IGTK with all STAs to which it has a valid PTKSA or mesh PTKSA(#240). An IGTKSA has the same lifetime as the BSS, unless superseded.

An IGTKSA consists of the following:

- Direction vector (whether the IGTK is used for transmit or receive)
- Key ID
- IGTK
- Authenticator MAC address

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#### 12.6.1.1.10 Mesh GTKSA

The mesh GTKSA results from a successful AMPE or mesh group key handshake and is unidirectional. In an MBSS, each mesh STA defines its own "transmit mesh GTKSA," which is used to encrypt its group addressed transmissions. Also, each mesh STA stores a separate "receive mesh GTKSA" for each peer mesh STA so that encrypted group addressed traffic received from the peer mesh STAs may be decrypted.

A transmit mesh GTKSA is created by a mesh STA after the SME has changed the mesh GTK (MGTK) and the new MGTK has been sent to all peer mesh STAs. (#384)A receive mesh GTKSA is created by a mesh STA after successfully completing the AMPE in which a MGTK has been received (see 14.6.4 (Distribution of group keys in an MBSS(#1521))), or after receiving a valid message 1 of the mesh group key handshake. The receive mesh GTKSA shall be deleted when the lifetime expires or a new receive mesh GTKSA is created with the same (#3493)key ID for the same MGTK source mesh STA. See 14.7.1 (General).

The MGTK and the GTK shall be independently selected from a uniform distribution. The MGTK source mesh STA MAC address in the mesh GTKSA shall not be the same as the Authenticator MAC address in the GTKSA.

NOTE—The use of a distinct Transmit MGTK and ESS GTK with identical transmit MAC addresses is precluded by limitations on key rollover and reception by STAs in an infrastructure BSS (see 14.12.5 (Mesh STA collocation) for (#2210)colocated mesh STA rules). If the distinct MGTKs were to use different (#3493)key IDs, then rollover would be impossible. (#1280)If the distinct MGTKs were to use the same (#3493)key IDs, then STAs would incorrectly attempt to decrypt mesh broadcast traffic using the ESS GTK, causing error counters (such as dot11RSNAStatsCCMPDecryptErrors) to continuously increment.

The mesh GTKSA contains the following:

— MGTK
— MGTK source mesh STA MAC address (mesh STA that uses this GTK to encrypt transmissions)
— Group data cipher suite selector(#6020)
— Direction vector (whether this is a receive mesh GTKSA or transmit mesh GTKSA)
— Key Index

#### 12.6.1.1.11 BIGTKSA

An Authenticator's SME creates a BIGTKSA when dot11BeaconProtectionEnabled is true. A BIGTKSA has the same lifetime as the BSS, unless superseded.

A Supplicant's SME creates a BIGTKSA when dot11BeaconProtectionEnabled is true, upon receiving a BIGTK from its Authenticator.

A BIGTKSA consists of the following:

— Direction vector (whether the BIGTK is used for transmit or receive)
— Key ID
— BIGTK
— Authenticator MAC address

#### 12.6.1.1.12 WIGTKSA(11ba)

When WUR frame protection is enabled, a WUR non-AP STA's SME creates a WIGTKSA when it receives a WIGTK in a valid message 3 of the 4-way handshake or FT 4-way handshake, the Reassociation Response frame of the fast BSS transition protocol with a status code indicating success, a valid message 1 of the group key handshake, or the (Re)Association Response frame of FILS authentication with a status code


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indicating success. The Authenticator's SME creates a WIGTKSA when it establishes or changes the WIGTK with all WUR non-AP STAs to which it has a valid PTKSA. A WIGTKSA has the same lifetime as the BSS, unless superseded.

A WIGTKSA consists of the following:

— Direction vector (whether the WIGTK is used for transmit or receive)
— The cipher suite selector 00-0F-AC:6 (BIP-CMAC-128) for broadcast and group addressed WUR Wake-up frames
— Key ID
— WIGTK
— Authenticator MAC address

#### 12.6.1.1.13 TPKSA(#1523)

The TPKSA results from a successful completion of the TPK handshake. This security association is bidirectional between the TDLS initiator STA and the TDLS responder STA. The TPKSA is used to create session keys to protect this TDLS session. The TPKSA has the lifetime indicated in the TPK handshake or the lifetime of the TDLS direct link, whichever comes first.

The TPKSA consists of the following:

— MAC addresses of the TDLS initiator STA and the TDLS responder STA
— Pairwise cipher suite selector
— TPK key lifetime(#7162)
— TPK transient key(#6395)
— Link Identifier

### 12.6.1.2 Security association life cycle

#### 12.6.1.2.1 General

A STA can operate in an ESS, an IBSS, an MBSS, or a PBSS, and a security association has a distinct life cycle for each. A STA that operates OCB does not have a security association life cycle.

#### 12.6.1.2.2 Security association in an ESS

In an ESS there are two cases:

— Initial contact between the STA and the ESS
— (#1600)(#7118)Reassociation

(#7119)During initial contact between a STA and ESS an initial security association between the STA and the AP is established via the following steps:

a) The STA selects an authorized ESS by selecting among APs that advertise an appropriate SSID.
b) The STA then performs IEEE 802.11 authentication followed by association to the chosen AP. Confirmation of security parameters takes place during association. (#1084)A non-DMG STA performing IEEE 802.1X authentication uses Open System authentication. A STA performing password-based authentication can use SAE authentication. A STA performing FILS uses FILS authentication. A non-DMG STA executing the OWE exchange (#3229)uses Open System authentication.

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NOTE 1—It is possible for more than one PMKSA to exist. As an example, a second PMKSA might come into existence through PMKSA caching. A STA might leave the ESS and flush its cache. Before its PMKSA expires in the AP's cache, the STA returns to the ESS and establishes a second PMKSA from the AP's perspective.

NOTE 2—An attack altering the security parameters is detected by the key derivation procedure.

NOTE 3—IEEE 802.11 Open System authentication provides no security, but is included to maintain backward compatibility with the IEEE 802.11 state machine (see 11.3 (STA authentication and association)).

c) SAE authentication and FILS authentication provides mutual authentication and derivation of a PMK. If Open System authentication is chosen instead, the Authenticator or the Supplicant initiates IEEE 802.1X authentication. The EAP method used by (#3469)IEEE Std 802.1X-2020 needs to support mutual authentication, as the STA needs assurance that the AP is a legitimate AP.

NOTE 4—Prior to the completion of IEEE 802.1X authentication and the installation of keys, the IEEE 802.1X Controlled Port in the AP blocks all Data frames. The IEEE 802.1X Controlled Port returns to the unauthorized state and blocks all Data frames before invocation of an MLME-DELETEKEYS.request primitive. The IEEE 802.1X Uncontrolled Port allows EAPOL PDUs(#3252) to pass between the Supplicant and Authenticator.

(#1794)Supplicants without a Controlled Port compromise RSN security and shall not be used.

(#1794)NOTE 5—Although (#3469)IEEE Std 802.1X-2020 does not require a Supplicant Controlled Port, this standard relies on the fact that the Supplicant has a Controlled Port in order to provide the needed level of security.

(#1084)NOTE 6—A secure IEEE 802.1X network cannot support promiscuous association, e.g., an unauthenticated operation of IEEE Std 802.11. A trust relationship is needed between the STA and the AS of the targeted SSID prior to association and secure operation, in order for the association to be trustworthy. Without some sort of prior relationship between the ESS and the STA, an attacker could deploy a rogue AP that would not be detected by the STA.

(#1084)NOTE 7—OWE networks are promiscuous and do not require any prior relationship between the ESS and STA. There is a guarantee of confidentiality of the communication between the STA and AP but there is no authentication. OWE networks are therefore not suited to situations where detection of a rouge access point is necessary or where networks require definitive identification of associated STAs.

d) The last step is key management. The authentication process, whether SAE authentication or FILS authentication utilizing Authentication frames or IEEE 802.1X authentication utilizing Data frames post association, (#1084)or the OWE exchange utilizing association frames creates cryptographic keys shared between the cryptographic endpoints—the AP and STA, or the IEEE 802.1X AS and the STA, when using (#1084)SAE/FILS/OWE or IEEE Std 802.1X, respectively. When using IEEE Std 802.1X, the AS transfers these keys to the AP, and the AP and STA uses one of the key confirmation handshakes, e.g., the 4-way handshake or FT 4-way handshake, to complete security association establishment. When using SAE authentication or OWE(#1084) there is no AS and therefore no key transfer; the 4-way handshake is performed directly between the AP and STA. The key confirmation handshake indicates when the link has been secured by the keys and is ready to allow normal data traffic and protected robust Management frames. When FILS authentication is performed, the key confirmation is performed using association frames. Hence, no additional handshake is necessary.

When FT is not enabled, a STA BSS (re)associating(#7117)(#1600) within an ESS establishes a new PMKSA by one of the five schemes:

— In the case of (re)association followed by (#1084)IEEE 802.1X authentication, PSK authentication or the OWE exchange, the STA repeats the same actions as for an initial contact association, (#6114)but its Supplicant also deletes the PTKSA when it transitions from the old AP. The Supplicant also deletes the PTKSA when it disassociates/deauthenticates from all BSSIDs in the ESS (see 11.3.5 (Association, reassociation, and disassociation)).

— In the case of SAE authentication followed by (re)association, the STA repeats the same actions as for initial contact association, but the non-AP STA also deletes the PTKSA when it roams from the old AP. Note that a STA can take advantage of the fact that it can perform SAE authentication to multiple APs while maintaining a single association with one AP, and then use any of the PMKSAs created during authentication to effect a fast BSS transition.


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- A STA (AP) can cache PMKSAs for APs (STAs) in the ESS to which it has previously performed a full IEEE 802.1X authentication, SAE authentication or OWE exchange(#1084). If a STA wishes to roam to an AP for which it has cached one or more PMKSAs, it can include one or more PMKIDs in the RSNE of its (Re)Association Request frame. An AP that has retained the PMK for one or more of the PMKIDs can proceed with the 4-way handshake (see 12.6.8.3 (Cached PMKSAs and RSNA key management)). If the STA fails to send a PMKID when the negotiated AKM uses IEEE 802.1X authentication, the STA and AP need to perform a full IEEE 802.1X authentication.
- A STA already associated with the ESS can request its IEEE 802.1X Supplicant to authenticate with a new AP before associating to that new AP. The normal operation of the DS via the old AP provides the communication between the STA and the new AP. The SME delays reassociation with the new AP until IEEE 802.1X authentication completes via the DS. If IEEE 802.1X authentication completes successfully, then PMKSAs shared between the new AP and the STA are cached, thereby enabling the possible usage of reassociation without requiring a subsequent full IEEE 802.1X authentication procedure.
- In the case of FILS, the STA may repeat the same actions as an initial contact and authentication, The STA may also use a cached PMKSA to authenticate (see 12.6.8.3 (Cached PMKSAs and RSNA key management) and 12.11.2 (FILS authentication protocol)). A STA already associated with the ESS can initiate FILS authentication to multiple other APs while associated.

The MLME-DELETEKEYS.request primitive deletes the temporal key(s) established for the security association so that they cannot be used to protect subsequent IEEE 802.11 traffic. An SME uses this primitive when it deletes a PTKSA, GTKSA, IGTKSA, (11ba)BIGTKSA, WIGTKSA or TPKSA(#205).

#### 12.6.1.2.3 Security association in an IBSS

In an IBSS utilizing IEEE 802.11 Open System authentication and IEEE Std 802.1X, when a STA's SME establishes a security association with a peer STA, it creates both an IEEE 802.1X Supplicant and Authenticator for the peer. A STA in such an IBSS might also receive IEEE 802.1X messages from a previously unknown MAC address.

In an IBSS utilizing IEEE 802.11 SAE authentication, a STA creates a security association for a peer upon successful SAE authentication.

Any IBSS STA may decline to form a security association with a STA joining the IBSS. An attempt to form a security association may also fail because, for example, the peer uses a different PSK or password from what the STA expects.

In an IBSS each STA defines its own GTK(#1521), to secure its group addressed transmissions. Each STA shall use either the 4-way handshake or the group key handshake to distribute its transmit GTK to its new peer STA. When the STA generates a new GTK, it also uses the group key handshake to distribute the new GTK to each established peer.

#### 12.6.1.2.4 Security association in an MBSS

In order to create a secure peering, mesh STAs first authenticate each other and create a mesh PMKSA. This can be done using either SAE or IEEE Std 802.1X. A mesh STA shall support SAE authentication (see 12.4 (Authentication using a password)). A mesh STA may support IEEE 802.1X authentication (see 4.10 (IEEE Std 802.11 and IEEE Std 802.1X-2020(#3469))).

When dot11MeshActiveAuthenticationProtocol is sae (1), the scanning mesh STA shall initiate SAE to the candidate mesh STA. If SAE terminates unsuccessfully, the scanning mesh STA shall terminate the peering establishment procedure. Otherwise, the PMK that results from successful SAE authentication shall be used to create a mesh PMKSA.

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When dot11MeshActiveAuthenticationProtocol is ieee8021x (2), then the scanning mesh STA shall initiate the MPM protocol to establish a peering. If the MPM protocol fails then the scanning mesh STA shall terminate the peering establishment procedure. Otherwise, IEEE 802.1X authentication shall be performed between the two peers according to the following:

a) If only one mesh STA has the Connected to AS field set to 1, that STA shall act as the IEEE 802.1X Authenticator and the other STA shall act as the IEEE 802.1X Supplicant;

b) If both mesh STAs have the Connected to AS field set to 1, then the mesh STA with the higher MAC address shall act as the IEEE 802.1X Authenticator and the other mesh STA shall act as the IEEE 802.1X Supplicant (see 12.7.1 (Key hierarchy) for MAC address comparison).

If IEEE 802.1X authentication fails, the peering establishment procedure shall be terminated and the peering established between the two mesh STAs shall be closed. Otherwise, the peering established between the two mesh STAs shall be closed and a mesh PMKSA shall be created using the PMK that resulted from the successful IEEE 802.1X authentication.

#### 12.6.1.2.5 Security association in a PBSS

A STA and a peer establish an initial security association via the following steps:

a) The STA selects an authorized PBSS by identifying a peer from a DMG Beacon, Announce, Probe Response, or Information Response frames.

b) A STA may associate with a peer if the peer is a PCP.

c) If authentication is required, the STA or the peer initiates IEEE 802.1X authentication. The EAP method used by (#3469)IEEE Std 802.1X-2020 shall support mutual authentication.

d) The last step is key management. The authentication process creates cryptographic keys shared between the IEEE 802.1X AS and the STA. The AS transfers these keys to the peer and the peer and the STA use one of the key confirmation handshakes, e.g., the 4-way handshake or FT 4-way handshake, to complete security association establishment. The key confirmation handshake indicates when the link has been secured by the keys and is ready to allow data traffic and protected robust Management frames.

### 12.6.2 RSNA selection

A STA prepared to establish RSNAs shall advertise its capabilities by including the RSNE in Beacon, Information Response, and Probe Response frames and may also include the RSNE in DMG Beacon and Announce frames. The included RSNE shall specify all of the authentication and cipher suites enabled by the STA's policy. A STA shall not advertise any authentication or cipher suite that is not enabled. (11ba)If WUR frame protection is enabled, a WUR AP shall advertise such capability by setting to 1 the Protected WUR Frame Support subfield in the RSNXE in its Beacon and Probe Response frames.

The SME shall utilize the MLME-SCAN.request primitive to identify neighboring STAs that assert robust security and advertise an SSID identifying an authorized ESS, PBSS, or IBSS. A STA may decline to communicate with STAs that fail to advertise an RSNE in their Beacon, Information Response, and Probe Response frames or that do not advertise an authorized SSID. A STA may also decline to communicate with other STAs that do not advertise authorized authentication and cipher suites within their RSNEs.

A STA shall advertise the same RSNE in its Beacon, DMG Beacon, Announce, Information Response, and Probe Response frames.

NOTE—Whether a STA with robust security enabled attempts to communicate with a STA that does not include the RSNE is a matter of policy.

A STA shall observe the following rules when processing an RSNE:


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- A STA shall advertise the highest version it supports.
- A STA shall request the highest Version field value it supports that is less than or equal to the version advertised by the peer STA.
- Two peer STAs without overlapping supported Version field values shall not use RSNA methods to secure their communication.
- A STA shall ignore suite selectors that it does not recognize.

### 12.6.3 RSNA policy selection in an infrastructure BSS

The requirements in this subclause apply to a STA when dot11RSNAActivated is true.

(#1688)An AP advertises the available RSNA policies in an infrastructure BSS.

RSNA policy selection in an infrastructure BSS utilizes the normal IEEE 802.11 association procedure. RSNA policy selection is performed by the associating STA. The STA does this by including an RSNE (11ba), and if WUR frame protection is enabled, an RSNXE with the Protected WUR Frame Support subfield equal to 1 in its (re)association requests(#199)(#1562).

In an RSN, an AP shall not associate with pre-RSNA STAs, i.e., with STAs that fail to include the RSNE in the (Re)Association Request frame.

An SME initiating an association shall insert an RSNE into its (Re)Association Request via the MLME-ASSOCIATE.request or MLME-REASSOCIATE.request primitive, when the targeted AP indicates RSNA support. The initiating STA's RSNE shall include one authentication and pairwise cipher suite from among those advertised by the targeted AP in its Beacon and Probe Response frames. It shall also specify the (#6020)group data cipher suite and group management cipher suite (if present) specified by the targeted AP. If at least one RSNE field from the AP's RSNE fails to overlap with any value the STA supports, the STA shall decline to associate with that AP. An HT STA shall eliminate TKIP as a choice for the pairwise cipher suite if CCMP-128 or CCMP-256 is advertised by the AP or if the AP included an HT Capabilities element in its Beacon and Probe Response frames. The elimination of TKIP as a choice for the pairwise cipher suite may result in a lack of overlap of the remaining pairwise cipher suite choices, in which case the STA shall decline to create an RSNA(#4025) with that AP.

If an AP receives a (Re)Association Request frame that includes an RSNE and if it chooses to accept the association as a secure association, then it shall use the authentication and pairwise cipher suites in the (Re)Association Request frame, unless the AP includes an optional second RSNE in message 3 of the 4-way handshake. If the second RSNE is supplied in message 3, then the pairwise cipher suite used by the security association, if established, shall be the pairwise cipher from the second RSNE.

In order to accommodate local security policy, a STA may choose not to associate with an AP that does not support any pairwise cipher suites. An AP may indicate that it does not support any pairwise keys by advertising 00-0F-AC:0 (Use group data cipher suite(#6020)) as the pairwise cipher suite selector.

NOTE—When an ESS uses PSKs, STAs negotiate a pairwise cipher. However, any STA in the ESS can derive the pairwise keys of any other that uses the same PSK by capturing the first two messages of the 4-way handshake. This provides malicious insiders with the ability to eavesdrop as well as the ability to establish a man-in-the-middle attack.

An AP and a non-AP STA shall use Table 12-5 (Robust management frame selection in an infrastructure BSS(#587)) and the values of the MFPC and MFPR subfields(#211) advertised in the RSNEs to determine if they may associate, and if so whether management frame protection is enabled.(#587) If either STA does not advertise an RSNE or does not advertise an RSN Capabilities field in an RSNE, this shall be treated as if its MFPC and MFPR bits were 0. A STA in an infrastructure BSS shall, outside the context of TDLS, set the MFPC subfield(#211) to 1 if dot11RSNAProtectedManagementFramesActivated is true and to 0 otherwise,

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and set the MFPR subfield(#211) to 1 if dot11RSNAUnprotectedManagementFramesAllowed is false and to 0 otherwise. dot11RSNAProtectedManagementFramesActivated shall be true if dot11RSNAUnprotectedManagementFramesAllowed is false.(#199)

**Table 12-5—Robust management frame selection in an infrastructure BSS(#587)**

| Non-AP STA MFPC | Non-AP STA MFPR | Non-AP STA action | AP MFPC | AP MFPR | AP action | (#7047) MFP negotiated? |
|---|---|---|---|---|---|---|
| 0 | 0 | The STA may associate with the AP | 0 | 0 | The AP may accept associations from the STA | No |
| 1 | 0 | The STA may associate with the AP | 0 | 0 | The AP may accept associations from the STA | No |
| 0 | 0 | The STA may associate with the AP | 1 | 0 | The AP may accept associations from the STA | No |
| 1 | 0 or 1 | The STA may associate with the AP | 1 | 0 or 1 | The AP may accept associations from the STA | Yes |
| 1 | 1 | The STA shall not associate with the AP | 0 | 0 | N/A | N/A |
| 0 | 0 | The STA shall not associate with the AP (see NOTE) | 1 | 1 | The AP shall reject associations from the STA with the (#7190)status code ROBUST_MANAGEMENT_POLICY_VIOLATION | N/A |
| 0 | 1 | The STA shall not use this combination | | | | N/A |
| | | | 0 | 1 | The AP shall not use this combination | N/A |
| NOTE—STAs conformant with a previous revision of this standard might not ascribe a meaning to the MFPC and MFPR subfields. | | | | | | |

(#199)TDLS STAs shall use Table 12-6 (Robust management frame selection between TDLS STAs(#6149)(#199)) and the (#6149)value of the MFPC bit in the RSNE transmitted by the TDLS initiator STA in the TDLS Setup Request frame to determine if a TDLS direct link is allowed, and if so whether management frame protection is (#7047)negotiated. A TDLS STA should, in the context of TDLS, set the MFPC bit to 1 if dot11RSNAProtectedManagementFramesActivated is true, and shall set it to 0 unless dot11RSNAProtectedManagementFramesActivated is true.

(#6149)NOTE—The MFPR bit from the TDLS initiator STA is ignored by the TDLS responder STA, and (if a TDLS Discovery Response frame is sent) the MFPC and MFPR bits from the TDLS responder STA are


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ignored by the TDLS initiator STA, except that a TDLS initiator STA might set its MFPC bit to 0 if the MFPC bit from the TDLS responder STA is 0.

**Table 12-6—Robust management frame selection between TDLS STAs(#6149)(#199)**

| TDLS initiator STA MFPC | TDLS responder STA MFPC (might not be transmitted) | TDLS initiator STA action | TDLS responder STA action | (#7047) MFP negotiated? |
|---|---|---|---|---|
| 0 | 1 | The TDLS initiator STA may establish a TDLS direct link with the TDLS responder STA | The TDLS responder STA may establish a TDLS direct link with the TDLS initiator STA (see NOTE 1) | No |
| 0 | 0 | | The TDLS responder STA may establish a TDLS direct link with the TDLS initiator STA | |
| 1 | 1 | | | Yes |
| 1 | 0 | See NOTE 2 | The TDLS responder STA should reject attempts by the TDLS initiator STA to establish a TDLS direct link with the (#7190)status code ROBUST_MANAGEMENT_POLICY_VIOLATION (see Note 3) | N/A |

NOTE 1—If the TDLS responder requires MFP, it can cause the TDLS direct link establishment to fail by using the (#7190)status code ROBUST_MANAGEMENT_POLICY_VIOLATION in the TDLS Setup Response frame.

NOTE 2—If a TDLS initiator STA has performed TDLS discovery and determined that the TDLS responder STA is not MFPC, it might, if it trusts the authenticity of the TDLS Discovery Response frame, avoid this situation, i.e., it might set its MFPC bit to 0 and not use MFP.

NOTE 3—Any subsequent attempt to use robust Management frame (e.g., ADDBA Request frames) will fail.

### 12.6.4 RSNA policy selection in an IBSS

In an IBSS all STAs use a single (#6020)group data cipher suite and group management cipher suite (if management frame protection is enabled), and all STAs support a common subset of pairwise cipher suites. However, the SMEs of any pair of non-HT STAs may negotiate to use any common pairwise cipher suite they both support. Each STA shall include the (#6020)group data cipher suite, the group management cipher suite (if management frame protection is enabled) and its list of pairwise cipher suites in its Beacon and Probe Response frames. Two STAs shall not establish a PMKSA unless they have advertised the same group data cipher suite and the group management cipher suite (if management frame protection is enabled)(#6020). Similarly, the two STAs shall not establish a PMKSA if the STAs have advertised disjoint sets of pairwise cipher suites.

An HT STA that is in an IBSS or that is transmitting frames through a (#2152)TDLS direct link shall eliminate TKIP as a choice for the pairwise cipher suite if CCMP-128 or CCMP-256 is advertised by the other STA or if the other STA included an HT Capabilities element in any of its Beacon or Probe Response frames.

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NOTE 1—The elimination of TKIP as a choice for the pairwise cipher suite might result in a lack of overlap of the remaining pairwise cipher suite choices, in which case the STAs do not exchange encrypted frames.

In order to set up a security association with a peer STA, the SME of an IBSS STA that does not know the peer's policy needs first to obtain the peer's security policy using a Probe Request frame. The SME entities of the two STAs select the pairwise cipher suites using one of the 4-way handshakes. The SMEs of each pair of STAs within an IBSS may use the EAPOL-Key 4-way handshake to select a pairwise cipher suite. As specified in 12.7.2 (EAPOL-Key frames), message 2 and message 3 of the 4-way handshake convey an RSNE. The message 2 RSNE includes the selected pairwise cipher suite, and message 3 includes the RSNE that the STA would send in a Probe Response frame.

If the 4-way handshake is successfully completed, then the pair of STAs shall use the pairwise cipher suite specified in message 2 of the 4-way handshake initiated by the Authenticator STA with the higher MAC address (see 12.7.1 (Key hierarchy)).

The SME shall check that the group data cipher suite, the group management cipher suite (if management frame protection is enabled)(#6020) and AKMP match those in the Beacon and Probe Response frames for the IBSS.

NOTE 2—The RSNEs in message 2 and message 3 are not the same as in the Beacon frame. The group data cipher, the group management cipher suite (if management frame protection is enabled)(#6020) and AKMP are the same, but the pairwise ciphers might differ because Beacon frames from different STAs might advertise different pairwise ciphers. Thus, IBSS STAs use the same (#3266)AKMP, group data cipher, and the group management cipher suite (if management frame protection is enabled)(#6020), while different pairwise ciphers might be used between STA pairs.

NOTE 3—When an IBSS uses PSKs, STAs can negotiate a pairwise cipher. However, any STA in the IBSS can derive the PTKs of any other that uses the same PSK by capturing the first two messages of the 4-way handshake. This provides malicious insiders with the ability to eavesdrop as well as the ability to establish a man-in-the-middle attack.

(#199)IBSS STAs shall use Table 12-7 (Robust management frame selection in an IBSS(#199)) and the values of the MFPC and MFPR bits advertised in the RSNEs exchanged in the 4-way handshake to determine if the communication is allowed, and if so whether management frame protection is enabled. If either STA does not advertise an RSNE or does not advertise an RSN Capabilities field in an RSNE, this shall be treated as if its MFPC and MFPR bits were 0. If a 4-way handshake is not performed and a STA has not received an RSNE from a peer STA (e.g., it has not received a Beacon or Probe Response frame from the peer STA), it shall treat this as if the peer's MFPC and MFPR bits were 0. An IBSS STA shall set the MFPC bit to 1 if dot11RSNAProtectedManagementFramesActivated is true and to 0 otherwise, and set the MFPR bit to 1 if dot11RSNAUnprotectedManagementFramesAllowed is false and to 0 otherwise. dot11RSNAProtectedManagementFramesActivated shall be true if dot11RSNAUnprotectedManagementFramesAllowed is false and shall not be true otherwise(#3056).

**Table 12-7—Robust management frame selection in an IBSS(#199)**

| STA MFPC | STA MFPR | STA action | Peer STA MFPC | Peer STA MFPR | Peer STA action | MFP used? |
|---|---|---|---|---|---|---|
| 0 | 0 | The STA may exchange data with the peer STA | 0 | 0 | The peer STA may exchange data with the STA | No |
| 1 | 1 | The STA may exchange data with the peer STA | 1 | 1 | The peer STA may exchange data with the STA | Yes |


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**Table 12-7—Robust management frame selection in an IBSS(#199) *(continued)***

| STA MFPC | STA MFPR | STA action | Peer STA MFPC | Peer STA MFPR | Peer STA action | MFP used? |
|---|---|---|---|---|---|---|
| 1 | 1 | The STA shall not exchange data nor establish a security association with the peer STA | 0 | 0 | N/A | N/A |
| 0 | 0 | The STA should not exchange data nor attempt to establish a security association with the peer STA (see NOTE) | 1 | 1 | The peer STA shall not exchange data with the STA and shall reject security association attempts from the STA with the (#7190)status vode ROBUST_MANAGEMENT_POLICY_VIOLATION | N/A |
| 1 | 0 | The STA shall not use this combination | | | | N/A |
| 0 | 1 | The STA shall not use this combination | | | | N/A |
| | | | 1 | 0 | The peer STA shall not use this combination | N/A |
| | | | 0 | 1 | (#203-Ed1)The peer STA shall not use this combination | N/A |
| NOTE—STAs conformant with a previous revision of this standard might not ascribe a meaning to the MFPC and MFPR subfields. | | | | | | |

### 12.6.5 RSNA policy selection in an MBSS

RSNA policy is advertised in Beacon frames and Probe Response frames. A mesh STA identifies a candidate peer by parsing its neighbor STA's Beacon frames and Probe Response frames (see 14.3 (Mesh discovery)). An HT mesh STA shall eliminate TKIP as a choice for the pairwise cipher suite if CCMP-128 or CCMP-256 is advertised by the peer or if the peer included an HT Capabilities element in any of its Beacon or Probe Response frames.

All mesh STAs in an MBSS use the same group data cipher suite and the group management cipher suite (if management frame protection is enabled)(#6020). Mesh STAs establish authenticated peerings with each other using the AMPE protocol (see 14.6 (Authenticated mesh peering exchange (AMPE))). In AMPE, mesh STAs negotiate a pairwise cipher suite, and establish a mesh PTKSA(#240), to protect individually addressed frames and state a group data cipher suite(#6020) and establish a mesh GTKSA to process incoming group addressed frames from a peer.

The AMPE performs key confirmation of a secret, authenticated, and shared PMK derived by an authenticated key management protocol (see 12.4 (Authentication using a password)) and derives pairwise symmetric keys.

(11az)When establishing an RSNA in an MBSS, PASN authentication shall not be used.

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### 12.6.6 RSNA policy selection in a PBSS

RSNA policy selection in a PBSS utilizes the association procedure (11.3.1 (State variables)) if a non-PCP STA chooses to associate with the PCP(#199). (#1688)A PCP advertises the available RSNA policies in a PBSS. RSNA policy selection is performed by the associating STA. The STA does this by including an RSNE in its (re)association requests(#199).

If a non-PCP STA chooses to associate with the PCP, the STA follows the procedures in 12.6.3 (RSNA policy selection in an infrastructure BSS) to select RSNA policy with the PCP, with the PCP taking the role of the AP. Otherwise, it follows the procedures in 12.6.4 (RSNA policy selection in an IBSS) to select RSNA policy with the peer (including the PCP, if it chose not to associate).(#199)

### 12.6.7 RSN management of the IEEE 802.1X Controlled Port

(#2128)In an RSN, this standard (#1794)relies on the fact that IEEE 802.1X Supplicants and Authenticators exchange protocol information via the IEEE 802.1X (#1909)Uncontrolled Port. The IEEE 802.1X Controlled Port is blocked from passing general data traffic between the STAs until an IEEE 802.1X authentication procedure completes successfully over the IEEE 802.1X Uncontrolled Port. The security of an RSNA depends on this (#1794)being true.

In an infrastructure BSS or PBSS, if the STA associates with the AP or PCP, the STA indicates the IEEE 802.11 link is available by invoking the MLME-ASSOCIATE.confirm or MLME-REASSOCIATE.confirm primitive. This signals the Supplicant that the MAC has transitioned from the disabled to enabled state. At this point, the Supplicant's Controlled Port is blocked, and communication of all non-IEEE-802.1X MSDUs sent or received via the port is not authorized.

In an infrastructure BSS or PBSS, if the AP or PCP associates with a STA, the AP or PCP indicates that the IEEE 802.11 link is available by invoking the MLME-ASSOCIATE.indication or MLME-REASSOCIATE.indication primitive. At this point the Authenticator's Controlled Port corresponding to the STA's association is blocked, and communication of all non-IEEE-802.1X MSDUs sent or received via the Controlled Port is not authorized.

In an IBSS the STA shall block all IEEE 802.1X ports at initialization. Communication of all non-IEEE 802.1X MSDUs sent or received via the Controlled Port is not authorized.

In a PBSS, if a STA chooses not to associate with the PCP, the STA shall block all IEEE 802.1X ports at initialization. Communication of all non-IEEE-802.1X MSDUs sent or received via the Controlled Port is not authorized.

(#1794)NOTE 1—IEEE Std 802.1X maintains each Controlled Port in a blocked state until the IEEE 802.1X state variables portValid and keyDone both become true. (#1794)This means that the IEEE 802.1X Controlled Port discards MSDUs sent across the IEEE 802.11 channel prior to the installation of cryptographic keys into the MAC. This protects (#1795)the upper layers from forged MSDUs written to the channel while it is still being initialized.

(#2128)NOTE 2—(#3397)When using FILS authentication, FT Resource Request protocol, or FT protocol, it means that Data frames other than those containing EAPOL PDUs are discarded when received before the initial 4-way handshake (see 12.7.6 (4-way handshake)) completes, and that unprotected Data frames (other than those containing retransmissions of the third message of the initial 4-way handshake (see 12.7.6.6 (4-way handshake implementation considerations)) are discarded when received after the initial 4-way handshake completes.

The MAC does not distinguish between MSDUs for the Controlled Port, and MSDUs for the Uncontrolled Port. In other words, EAPOL-Start frames and EAPOL-Key frames are encrypted (#2128)and decrypted after invocation of the MLME-SETPROTECTION.request primitive.


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(#2128)NOTE 3—An Authenticator might retransmit the third message of the 4-way handshake (see 12.7.6.6 (4-way handshake implementation considerations)). In the initial 4-way handshake this third message (and the fourth message sent in response) are(M118) unprotected and in a rekeying 4-way handshake the third (and the fourth) message are (M118)protected with the old key. If the ends of the link do not both support extended (#3493)key IDs for individually addressed frames, the mechanism by which a Supplicant might accept and respond to this retransmission of the third message even though the MLME-SETKEYS.request and MLME-SETPROTECTION.request primitives have already been invoked is outside the scope of this standard.

(#1794)NOTE 4—(#3469)IEEE Std 802.1X-2020 does not block the Controlled Port when authentication is triggered through IEEE 802.1X reauthentication. During reauthentication, an existing RSNA can protect all MSDUs exchanged between the STAs. Blocking MSDUs is not required during reauthentication over an RSNA.

(#2128)NOTE 5—EAPOL PDUs are not delivered to the Controlled Port (see IEEE Std 802.1X). This means that an AP does not forward EAPOL PDUs received from a STA to any other STA in the BSS or ESS, to the portal, to the attached bridge port, or to a local higher layer other than the PAE, and that a PCP does not forward EAPOL PDUs received from a STA to any other STA in the BSS or to a local higher layer other than the PAE.

(#2128)EAPOL PDUs shall be carried in individually addressed MSDUs.

If management frame protection is enabled, an Authenticator shall provide the IGTK in the 4-way handshake and the group key handshake unless the group management cipher suite selector for the BSS is 00-0F-AC:7.(#1924)

### 12.6.8 RSNA establishment in an infrastructure BSS(#1084)

#### 12.6.8.1 General

When establishing an RSNA in a non-FT environment or during an FT initial mobility domain association, a STA shall use IEEE 802.11 SAE authentication, FILS authentication, or Open System authentication prior to (re)association. PASN authentication may be used without (re)association.(11az)

NOTE 1—A STA does not open 802.1X port(s) upon successful PASN authentication.(11az)

(#3228)SAE authentication can be initiated when a STA's MLME-SCAN.confirm primitive identifies an AP that advertises support for SAE in its RSNE.

(#3228)FILS authentication can be initiated when a STA's MLME-SCAN.confirm primitive identifies an AP that advertises support for FILS authentication in its RSNE.

(#3228)(#1084)OWE can be initiated when a STA's MLME-SCAN.confirm primitive identifies an AP that advertises support for OWE in its RSNE.

(#3228)IEEE 802.1X authentication can be initiated by any one of the following mechanisms:

— If a STA negotiates to use IEEE 802.1X authentication during (re)association, the STA's management entity may respond to the MLME-ASSOCIATE.confirm (or indication) or MLME-REASSOCIATE.confirm (or indication) primitive by requesting the Supplicant (or Authenticator) to initiate IEEE 802.1X authentication. Thus, in this case, authentication is driven by the STA's decision to associate and the AP's decision to accept the association.

— If a STA's MLME-SCAN.confirm primitive finds another AP within the ESS of which the STA is a member, a STA may signal its Supplicant to use (#3469)IEEE Std 802.1X-2020 to preauthenticate with that AP.

NOTE 2—A (#1600)BSS transitioning STA's IEEE 802.1X Supplicant can initiate preauthentication by (#1836)sending an EAPOL-Start PDU (in one or more EAPOL-Start frames) via its old AP, through the DS, to a new AP.

— If a STA receives an IEEE 802.1X message, it delivers this to its Supplicant or Authenticator, which may initiate a new IEEE 802.1X authentication.

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#### 12.6.8.2 Preauthentication and RSNA key management

Preauthentication allows a STA to perform RSNA authentication with an AP prior to attempting (re)association. (#2182)This might reduce the time until the IEEE 802.1X Controlled Port is unblocked.

(#4071)Preauthentication is deprecated.

A STA shall not use preauthentication except when pairwise keys are employed. A STA shall not use preauthentication within the same mobility domain if an (#3266)AKMP for which the Authentication type column indicates FT authentication (see Table 9-190 (AKM suite selectors)) is used in the current association. Preauthentication shall not be used unless the new AP advertises the preauthentication capability in the RSNE.

(#1084)OWE does not perform authentication and is therefore not supported in preauthentication.

(#4071)Preauthentication shall not be used with AKMPs that use a PMK with length other than 256 bits, e.g., it shall not be used with AKMs 00-0F-AC:12, 00-0F-AC:15, and 00-0F-AC:23.

When preauthentication is used, then:

a) Authentication is independent of BSS transition.(#1600)

b) The Supplicant may authenticate with multiple APs at a time.

NOTE—Preauthentication might be useful as a performance enhancement, as reassociation does not include the protocol overhead of a full reauthentication when it is used.

Preauthentication uses the IEEE 802.1X protocol and state machines with (#2186)EtherType 88-C7, rather than the (#2186)EtherType 88-8E. Only IEEE 802.1X packet types EAPOL-EAP and EAPOL-Start are valid for preauthentication.

A Supplicant may initiate preauthentication when it has completed the 4-way handshake and configured the required temporal key(s). To effect preauthentication, the Supplicant (#1836)sends an EAPOL-Start PDU (in one or more EAPOL-Start frames) with the DA being the BSSID of a targeted AP's BSS and the RA being the BSSID of the BSS of which it is a member. The target AP shall use a BSSID equal to the MAC address of its Authenticator. As preauthentication frames do not use the IEEE 802.1X EAPOL (#2186)EtherType field, the AP with which the STA is currently associated need not apply any special handling. The AP and the MAC in the STA shall handle these frames in the same way as other frames with arbitrary (#2186)EtherType field values that require distribution via the DS.

An AP's Authenticator that (#1836)receives an EAPOL-Start PDU via the DS may initiate IEEE 802.1X authentication to the STA via the DS. The DS forwards this message to the AP with which the STA is associated.

The result of preauthentication may be a PMKSA, if the IEEE 802.1X authentication completes successfully. The (#3266)AKMP shall be (#3266)AKM 00-0F-AC:1 in the PMKSA that results from preauthentication. If preauthentication produces a PMKSA, then, when the Supplicant's STA associates with the preauthenticated AP, the Supplicant may use the PMKSA with the 4-way handshake.

Successful completion of EAP authentication over IEEE Std 802.1X establishes a PMKSA at the Supplicant. The Authenticator has the PMKSA when the AS completes the authentication, passes the keying information (the master session key (MSK), a portion of which is the PMK) to the Authenticator, and the Authenticator creates a PMKSA using the PMK. The PMKSA is inserted into the PMKSA cache. Therefore, if the Supplicant and Authenticator lose synchronization with respect to the PMKSA, the 4-way handshake fails. In such circumstances, dot11RSNA4WayHandshakeFailures shall be incremented.


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A Supplicant may initiate preauthentication with any AP within its present ESS with preauthentication enabled regardless of whether the targeted AP is within radio range.

Even if a STA has preauthenticated, it is still possible that it may have to undergo a full IEEE 802.1X authentication, as the AP's Authenticator may have purged its PMKSA due to, for example, unavailability of resources, delay in the STA associating, etc.

#### 12.6.8.3 Cached PMKSAs and RSNA key management

A STA might cache PMKSAs it establishes as a result of previous authentication. The PMKSA shall not be changed while cached. The PMK in the PMKSA is used with the 4-way handshake or FILS authentication to establish fresh PTKs.

If a STA in an infrastructure BSS has determined it has a valid PMKSA with an AP to which it is about to (re)associate, it performs Open System authentication to the AP, or performs FILS Authentication to the AP, or (only in the case of a DMG STA) does not perform IEEE 802.11 authentication. When Open System authentication is used or IEEE 802.11 authentication is not performed, it includes the PMKID for the PMKSA in the RSNE in the (re)association request. When FILS Authentication is performed, it includes the PMKID for the PMKSA in the FILS Authentication frame (see 12.11.2 (FILS authentication protocol)). When the PMKSA was not created using preauthentication, the AKM indicated in the RSNE by the STA in the (re)association request shall be identical to the AKM used to establish the cached PMKSA in the first place.

A cached PMKSA established using an (#3266)AKMP for which the Authentication type column indicates FT authentication (see Table 9-190 (AKM suite selectors)) may be used in a subsequent FT Initial Mobility Domain Association using an identical (#3266)AKMP. A cached PMKSA is not used in an FT authentication sequence.

If a cached PMKSA is used in FT Initial Mobility Domain Association, the cached MPMK is used to derive the PMK-R0 of a new FT key hierarchy (see 12.7.1.6 (FT key hierarchy)). The PMKID indicated by the STA in the (Re)Association Request frame and message 1 of the FT 4-way handshake (when FILS authentication is not used) or FILS Authentication frame (when FILS authentication is used) is the PMKID of the cached PMKSA as defined in 12.7.1.6.3 (PMK-R0) (i.e., not the PMKR0Name or PMKR1Name of the FT key hierarchy that was derived when the PMKSA was originally established). The PMKR1Name indicated in (#6299)the RSNE in messages 2 and 3 of the FT 4-way handshake (when FILS authentication is not used) or in (Re)Association Request and Response frames (when FILS authentication is used) is the PMKR1Name of the newly derived FT key hierarchy (see 13.4 (FT initial mobility domain association)).

Upon receipt of a (Re)Association Request frame with one or more PMKIDs following Open System authentication or (only in the case of a DMG AP) if IEEE 802.11 authentication was not performed, an AP checks whether its Authenticator has cached a PMKSA for the PMKIDs and whether the AKM in the cached PMKSA matches the AKM in the (Re)Association Request; and if so, it shall assert possession of that PMKSA by beginning the 4-way handshake after association has completed and shall include the PMKID in message 1 (see 12.7.6.2 (4-way handshake message 1)). If the Authenticator does not have a PMKSA for the PMKIDs in the (re)association request or the AKM does not match, its behavior depends on how the PMKSA was established. If SAE authentication was used to establish the PMKSA, then the AP shall reject (re)association by sending a (Re)Association Response frame with status code STATUS_INVALID_PMKID. Note that this allows the non-AP STA to fall back to full SAE authentication to establish another PMKSA. If IEEE 802.1X authentication was used to establish the PMKSA, the AP begins a full IEEE 802.1X authentication after association has completed.

Upon receipt of a FILS Authentication frame with one or more PMKIDs, an AP checks whether its Authenticator has cached a PMKSA for the PMKIDs, whether the AKM in the cached PMKSA matches the AKM in the FILS Authentication frame, and whether the PMK is still valid; and if so, it shall assert possession of that PMK by including the PMKID in the FILS Authentication frame sent in response (see 12.11.2.3.4 (AP

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construction of Authentication frame)). If the Authenticator does not have a PMK for the PMKIDs in the FILS Authentication frame or the AKM does not match, the AP may either reply with (#330)an EAP-Finish/Reauth packet to continue FILS Shared Key authentication option if the non-AP STA included sufficient information for that, or the AP rejects the authentication.

(#6088)A non-AP STA may attempt PMKSA caching in conjunction with the OWE Authentication method by indicating (#8197)AKM 00-0F-AC:18 along with a PMKID in the RSNE and including a Diffie-Hellman parameter in the (Re)Association Request frame. If the AP has a PMKSA with a matching PMKID it shall not include a Diffie-Hellman parameter in its (Re)Association Response frame and not perform a Diffie-Hellman key exchange. If the AP does not have a PMKSA with a matching PMKID it shall perform OWE Authentication as if the PMKID was not present.

If both sides assert possession of a cached PMKSA, but the 4-way handshake or FILS authentication fails, both sides may delete the cached PMKSA for the selected PMKID.

If the lifetime of a cached PMKSA expires, the STA shall delete the expired PMKSA.

If a STA roams to an AP with which it is preauthenticating and the STA does not have a PMKSA for that AP, the STA needs to initiate a full IEEE 802.1X EAP authentication.

### 12.6.9 RSNA authentication in an IBSS

When authentication is used in an IBSS, it is driven by each STA wishing to establish communications. The management entity of this STA chooses a set of STAs with which it might need to authenticate and then may cause the MAC to send an IEEE 802.11 Open System authentication message to each targeted STA. Candidate STAs can be identified from Beacon frames, Probe Response frames, and Data frames from the same BSSID. Before communicating with STAs identified from Data frames, the security policy of the STAs may be obtained, e.g., by sending a Probe Request frame to the STA and obtaining a Probe Response frame. Targeted STAs that wish to respond may return an IEEE 802.11 Open System authentication message to the initiating STA.

When IEEE 802.1X authentication is used, the STA management entity requests its local IEEE 802.1X entity to create a Supplicant PAE for the peer STA. The Supplicant PAE initiates the authentication to the peer STA by (#1836)sending an EAPOL-Start PDU (in one or more EAPOL-Start frames) to the peer. The STA management entity also requests its local IEEE 802.1X entity to create an Authenticator PAE for the peer STA (#1836)on receipt of the EAPOL-Start PDU. The Authenticator initiates authentication to the peer STA by sending an EAP-Request message or, if PSK mode is in effect, message 1 of the 4-way handshake.

Upon initial authentication between any pair of STAs, Data frames, other than IEEE 802.1X messages, are not allowed to flow between the pair of STAs until both STAs in each pair of STAs have successfully completed AKM and have provided the supplied encryption keys.

Upon the initiation of an IEEE 802.1X reauthentication by any STA of a pair of STAs, Data frames continue to flow between the STAs while authentication completes. Upon a timeout or failure in the authentication process, the Authenticator of the STA initiating the reauthentication shall cause a Deauthentication message to be sent to the Supplicant of the STA targeted for reauthentication. The Deauthentication message causes both STAs in the pair of STAs to follow the deauthentication procedure defined in 11.3.4.4 (Deauthentication—originating STA) and 11.3.4.5 (Deauthentication—destination STA).

The IEEE 802.1X reauthentication timers in each STA are independent. If the reauthentication timer of the STA with the higher MAC address (see 12.7.1 (Key hierarchy) for MAC comparison) triggers the reauthentication via its Authenticator, its Supplicant shall (#1836)send an EAPOL-Start PDU to the Authenticator(#1441)(#1380) of the STA with the lower MAC address (see 12.7.1 (Key hierarchy) for MAC


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comparison) to trigger reauthentication on the other STA. This process keeps the pair of STAs in a consistent state with respect to derivation of one or more fresh temporal keys upon an IEEE 802.1X reauthentication.

When it receives an MLME-AUTHENTICATE.indication primitive due to an Open System authentication request, the IEEE 802.11 management entity on a targeted STA shall, if it intends to set up a security association with the peer STA, request its Authenticator to begin IEEE 802.1X authentication, i.e., to send an EAP-Request/Identity message or message 1 of the 4-way handshake to the Supplicant.

(#3490)EAPOL-Key PDUs are used to exchange information between the Supplicant and the Authenticator to negotiate a fresh PTK. The 4-way handshake produces a single PTK from the PMK. The 4-way handshake and group key handshake use the PTK to protect the GTK as it is transferred to the receiving STA.

Password or PSK authentication may also be used in an IBSS. When a single password or PSK is shared among the IBSS STAs, an SAE capable STA wishing to establish communication with a STA that advertises support for SAE in Beacon and Probe Response frames invokes SAE authentication, and upon successful conclusion of SAE, sends 4-way handshake message 1 to the target STA. If the STA does not support SAE authentication or the target STA does not advertise support for SAE in Beacon and Probe Response frames, the STA may use the PSK as a PMK and initiate the 4-way handshake by sending a 4-way handshake message 1 to the target STA. In either case, the targeted STA responds to message 1 with message 2 of the 4-way handshake and begins its 4-way handshake by sending message 1 to the initiating STA. The two 4-way handshakes establish PTKSAs and GTKSAs to be used between the initiating STA and the targeted STA. PSK PMKIDs have security vulnerabilities if used with low-entropy keys and should be used only after taking this into account.

The model for security in an IBSS is not general. In particular, it assumes the following:

a) The sets of use cases for which the authentication procedures described in this subclause are valid are as follows:
   1) Password or (#7207)PSK based authentication using SAE to perform mutual authentication and generation of a shared PMK.
   2) An alternate form of (#7207)PSK based authentication, typically managed by the pass-phrase hash method as described in J.4 (Suggested pass-phrase-to-PSK mapping). This method has security vulnerabilities and should only be used when SAE authentication is not possible.
   3) EAP-based authentication, using credentials that have been issued and preinstalled on the STAs within a common administrative domain, such as a single organization
b) All of the STAs are in direct radio communication. In particular, there is no routing, bridging, or forwarding of traffic by a third STA to effect communication. This assumption is made, because the model makes no provision to protect IBSS topology information from tampering by one of the members.

### 12.6.10 RSNA authentication in an MBSS

When establishing an RSNA in an MBSS, a mesh STA shall use IEEE 802.11 SAE authentication (see 12.4 (Authentication using a password)), or optionally IEEE 802.1X authentication, prior to establishment of an authenticated peering. An RSNA security association, called a *mesh PMKSA*, is created upon successful completion of authentication. The mesh PMKSA is used with the AMPE to create a mesh PTKSA(#240).

A mesh PMKSA may be cached and used with the AMPE to establish a fresh mesh PTKSA(#240). A STA includes the PMKID for the PMKSA in the Mesh Peering Open frame. If the PMKID in a received Mesh Peering Open frame is unknown, the AMPE handshake fails. If both sides assert possession of a cached mesh PMKSA but the AMPE handshake fails, a STA may delete the cached mesh PMKSA for the selected PMKID. A mesh PMKSA shall not be changed while cached.

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Authentication using IEEE 802.11 SAE authentication is based on a password. A password is required to be shared between two mesh STAs in order to successfully complete authentication. This password can be pairwise—each pair of mesh STAs in an MBSS has a unique password—or it can be shared-all mesh STAs in the MBSS share the same password.

Due to the security properties of IEEE 802.11 SAE authentication, an adversary has no greater possibility in determining a shared password than in determining a pairwise password. The potential for misuse, though, is greater if a shared password becomes known to an adversary because an unlimited number of mesh STAs under the control of the adversary can be added to the MBSS.

### 12.6.11 RSNA authentication in a PBSS

IEEE 802.11 Open System authentication is not used in a PBSS.

When establishing an RSNA with a PCP, a STA may associate to the PCP and initiate RSNA authentication with the PCP following the procedures of 12.6.8 (RSNA establishment in an infrastructure BSS(#1084)), with the PCP taking the role of the AP. When a STA chooses not to associate to a peer, it initiates RSNA authentication with the peer following the procedures of 12.6.9 (RSNA authentication in an IBSS) with the following caveat: if both peers simultaneously initiate RSNA authentication, the peer with the lower MAC address shall abandon the authentication it initiated in favor of the authentication initiated by the peer with the higher MAC address.

### 12.6.12 RSNA key management in an infrastructure BSS

When the IEEE 802.1X authentication completes successfully, the STA's IEEE 802.1X Supplicant and the IEEE 802.1X AS share a secret, (#6401)called an MSK and used to generate a *PMK*. In a non-FT environment, the AS transfers the PMK, within the MSK, to the AP, using a technique that is outside the scope of this standard; the derivation of the PMK from the MSK is EAP-method-specific. With the PMK in place, the AP initiates a key confirmation handshake with the STA. The key confirmation handshake sets the IEEE 802.1X state variable portValid (as described in (#3469)IEEE Std 802.1X-2020) to true.

When SAE authentication completes, both STAs share a PMK. With this PMK in place, the AP initiates the key confirmation handshake with the STA.

Key confirmation is part of the FILS authentication exchange and no further handshakes are needed to satisfy key management requirements.

In a non-FT environment or during an FT initial mobility domain association, when FILS authentication is not used, the key confirmation handshake is implemented by the 4-way handshake. The purposes of the 4-way handshake are as follows:

a) Confirm the existence of the PMK at the peer.
b) Ensure that the security association keys are fresh.
c) Synchronize the installation of one or more temporal keys into the MAC.
d) Transfer the GTK from the Authenticator to the Supplicant.
e) Confirm the selection of cipher suites.

NOTE 1—It is possible to forge message 1 of the 4-way handshake. However, the forgery attempt is detected in the failure of the 4-way handshake.

NOTE 2—Neither the AP nor the STA can use the PMK for any purpose but the one specified herein without compromising the key. If the AP uses it for another purpose, then the STA can masquerade as the AP; similarly if the STA reuses the PMK in another context, then the AP can masquerade as the STA.


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The Supplicant and Authenticator signal the completion of key management by utilizing the MLME-SETKEYS.request primitive to configure the agreed-upon temporal pairwise key into the IEEE 802.11 MAC and by calling the MLME-SETPROTECTION.request primitive to enable its use. (#2128)Any MSDU fragments previously received under the corresponding (#3493)key ID shall be discarded at this point. If management frame protection was negotiated for the current association(#7049), any MMPDU fragments previously received under the corresponding (#3493)key ID shall be discarded at this point.

A second key exchange, the group key handshake, is also defined. It distributes a subsequent GTK(11ba), and if WUR frame protection is negotiated, a WIGTK. The AP's Authenticator can use the group key handshake to update the GTK(11ba), and if WUR frame protection is negotiated, the WIGTK at the Supplicant. The group key handshake uses the EAPOL-Key frames for this exchange. When it completes, the Supplicant can use the MLME-SETKEYS.request primitive to configure the GTK(11ba), and if WUR frame protection is negotiated, the WIGTK into the IEEE 802.11 MAC.

### 12.6.13 RSNA key management in an IBSS

To establish a security association between two IBSS STAs, each STA's SME has an accompanying IEEE 802.1X Authenticator and Supplicant. Each SME initiates the 4-way handshake from the Authenticator to the peer STA's Supplicant (see 12.6.9 (RSNA authentication in an IBSS)). Two separate 4-way handshakes are conducted.

The 4-way handshake is used to negotiate the pairwise cipher suites, as described in 12.6.4 (RSNA policy selection in an IBSS). The IEEE 802.11 SME configures the (#8161)TK into the IEEE 802.11 MAC. Each Authenticator uses the (#3744)PTK-KCK and PTK-KEK negotiated by the exchange it initiates to distribute its own GTK and if management frame protection is enabled, its own IGTK. Each Authenticator generates its own GTK and if management frame protection is enabled, its own IGTK, and uses either the 4-way handshake or the group key handshake to transfer the GTK and if management frame protection is negotiated, the IGTK, to other STAs with whom it has completed a 4-way handshake. The pairwise key used between any two STAs shall be the pairwise key from the 4-way handshake initiated by the STA with the highest MAC address.

(#1704)(#3341)A STA joining an IBSS shall adopt the security configuration of the IBSS (see 12.6.4 (RSNA policy selection in an IBSS)). The STA shall not set up a security association with any STA having a different security configuration. The Beacon and Probe Response frames of the various STAs within an IBSS need to reflect a consistent security policy, as the beacon initiation rotates among the STAs.

A STA joining an IBSS shall support and advertise in the Beacon frame the security configuration of the IBSS, which includes the group data cipher suite(#6020), advertised pairwise cipher suite, AKMP, and if management frame protection is enabled, group management cipher suite (see 12.6.4 (RSNA policy selection in an IBSS)). The STA may use the Probe Request frame to discover the security policy of a STA, including additional individual cipher suites the STA supports.(#199)

NOTE—Because of the requirement for a STA joining an IBSS to support the security configuration of the IBSS, all Beacon frames transmitted in an IBSS have the same security policy.

### 12.6.14 RSNA key management in an MBSS

Upon successful completion of the AMPE, a secure mesh peering is established between two mesh STAs. This secure mesh peering includes a mesh PMKSA and a mesh PTKSA(#240). Multiple mesh PTKSAs(#240) may be created using a single mesh PMKSA (a limit to that number is a policy decision outside the scope of this standard).

A mesh PTKSA(#240) is logically a child of the mesh PMKSA. A mesh PTKSA(#240) shall be deleted if the corresponding mesh PMKSA, which was used by the AMPE to create it, is deleted. Mesh PMKSAs are limited by their lifetime (see 12.7.1.3 (Pairwise key hierarchy)).

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### 12.6.15 RSNA key management in a PBSS

Upon successful association and authentication in a PBSS, a STA performs a key confirmation handshake with the PCP, following the procedures in 12.6.12 (RSNA key management in an infrastructure BSS) with the PCP taking the role of the AP. If a STA chooses not to associate to a peer, after successful authentication, it performs a key confirmation handshake with the peer following the procedures in 12.6.13 (RSNA key management in an IBSS) with the following caveat: if both peers simultaneously initiate the key confirmation handshake, the peer with the lower MAC address shall abandon the handshake it initiated in favor of the handshake initiated by the peer with the higher MAC address.

### 12.6.16 RSNA security association termination

When a non-AP STA's SME receives a successful MLME-ASSOCIATE.confirm or MLME-REASSOCIATE.confirm primitive that is not part of a fast BSS transition or receives or invokes an MLME Disassociation or Deauthentication primitive, it deletes some security associations. Similarly, when an AP's SME

— Receives an MLME-ASSOCIATE.indication or MLME-REASSOCIATE.indication primitive from a STA that has not negotiated management frame protection, or

— Receives an MLME-ASSOCIATE.indication or MLME-REASSOCIATE.indication primitive from a STA that has negotiated management frame protection that a) has resulted in an MLME (re)association response that is successful, and b) is not part of a fast BSS transition, or receives an MLME-DEAUTHENTICATE.indication or MLME-DISASSOCIATE.indication primitive or issues an MLME-DEAUTHENTICATE.request or MLME-DISASSOCIATE.request primitive,

it deletes some security associations. (#1851)In the case of an ESS, the non-AP STA's SME shall delete any PTKSA(s), GTKSA(s), IGTKSA(s), BIGTKSA(s)(11ba), (#1562)WIGTKSA(s), (#3344)WTKSA(s) and TPKSA(s), and the AP's SME shall delete the PTKSA. In the case of an IBSS, the SME shall delete the (#3353)PTKSA(s) and the GTKSA(s) and any IGTKSA(s). Once the security associations have been deleted, the SME then (#1423)invokes the MLME-DELETEKEYS.request primitive to delete all temporal keys associated with the deleted security associations.

If a STA loses key state synchronization, it can apply the following rules to recover:

a) Any protected frame(s) received shall be discarded, and an MLME-PROTECTEDFRAMEDROPPED.indication primitive shall be invoked.

b) If the STA is RSNA-enabled and has joined an IBSS, the SME shall execute the authentication procedure as described in 11.3.4.2 (Authentication—originating STA).

c) If the STA is RSNA-enabled and has joined an ESS, the SME shall execute the deauthentication procedures as described in 11.3.4.4 (Deauthentication—originating STA). However, if the STA has initiated the RSN security association, but has not yet invoked the MLME-SETPROTECTION.request primitive, then no additional action is required.

NOTE 1—There is a race condition between when MLME-SETPROTECTION.request primitive is invoked on the Supplicant and when it is invoked on the Authenticator. During this time, the STA might receive an MPDU that it is unable to decrypt; and the MPDU is discarded without a deauthentication occurring.

NOTE 2—Null and QoS (+)Null frames are not protected.

If the selected AKMP fails between a STA and an AP that are associated, then both the STA and the AP shall invoke the MAC deauthentication procedure described in 11.3.4.4 (Deauthentication—originating STA).

When a STA's SME receives an MLME-PN-EXHAUSTION.indication primitive and the PN is associated with a PTKSA, the STA's SME shall invoke an MLME-DISASSOCIATE.request primitive and delete the PTKSA.


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When a STA's SME receives an MLME-PN-EXHAUSTION.indication primitive and the PN is associated with a GTKSA, the STA's SME shall delete the GTKSA.

When a STA's SME receives an MLME-PN-EXHAUSTION.indication primitive and the PN is associated with an IGTKSA, the STA's SME shall delete the IGTKSA.

Once the security associations have been deleted, the SME then (#1423)invokes the MLME-DELETEKEYS.request primitive to delete all temporal keys associated with the deleted security associations.

### 12.6.17 Protection of robust Management frames.

This subclause defines rules that shall be followed by an RSNA STA on a link with a given peer STA. In this subclause "peer STA" refers to the AP a non-AP STA is associated with, a STA that has associated with an AP, a STA in the same IBSS or PBSS, or a TDLS peer STA.(#199)(#210-Ed1)

(#2128)NOTE 1—Management frame protection is negotiated for a link if both STAs set the MFPC bit to 1 (see 12.6.3 (RSNA policy selection in an infrastructure BSS), 12.6.4 (RSNA policy selection in an IBSS), 12.6.5 (RSNA policy selection in an MBSS), and 12.6.6 (RSNA policy selection in a PBSS)).

Protection of group addressed robust Management frames shall be provided by a service in the MLME as described in 11.12 (Group addressed management frame protection procedures). (#1384)Protection of individually addressed robust Management frames shall be provided by a service in the MLME (see 12.2.4 (RSNA establishment)).

(#2128)NOTE 2—Management frame protection cannot be applied until the PTK and (except for a TDLS direct link) IGTK have been set.

(#2128)If management frame protection is not negotiated for the link, a STA shall ignore any protection on a received group addressed robust Management frame.

(#2128)NOTE 3—The STA (M118)is not sent any protected individually addressed robust Management frames. The STA might be sent a protected group addressed robust Management frame by a peer STA that has negotiated management frame protection for links with other STAs.

(#2128)If management frame protection is negotiated for a link, a STA may discard an unprotected individually addressed Deauthentication or Disassociation frame received before the PTKSA has been established.

(#2128)NOTE 4—The STA might start a timer upon receiving the frame, and if the PTKSA establishment progresses or completes before the timer expires, the STA might discard the frame.

(#2128)If management frame protection is negotiated for the link, a STA shall not transmit any of the following, and shall discard all of the following:

— An unprotected individually addressed Deauthentication or Disassociation frame(#1922).

(#2128)NOTE 5—The STA might invoke the SA Query procedures (see 11.13 (SA Query procedures)) if received with a reason code of INVALID_CLASS2_FRAME or INVALID_CLASS3_FRAME.

— An unprotected individually addressed robust Action or robust Action No Ack frame(#7078)

(#2128)NOTE 6—The STA is not(M118) sent any protected individually addressed robust Management frames before the PTKSA has been established.

— An unprotected group addressed robust Management frame.

(#2128)If management frame protection is negotiated for the link, a STA shall discard all of the following:

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- A protected group addressed robust Management frame when the STA has no IGTKSA for the link.
- A protected group addressed robust Management frame that fails the checks described in 12.5.3.6 (BIP reception).

(#2128)NOTE 7—The STA might be sent a protected group addressed robust Management frame when the STA has no IGTKSA for the link by a peer STA that has negotiated management frame protection for links with other STAs.

(#4184)When management frame protection is enabled, an S1G STA shall not transmit group addressed robust PV1 Management frames.

### 12.6.18 Robust management frame selection procedure

(#587)The Protected Dual of Public Action frame is defined to allow robust STA-STA communications of the same information that is conveyed in Action frames that are not robust (see 9.6.10 (Protected Dual of Public Action frame details(#3729))). A Public Action field, in the octet immediately after the Category field, differentiates the Protected Dual of Public Action frame formats. The defined Protected Dual of Public Action frames are listed in Table 9-516 (Public Action field values defined for Protected Dual of Public Action frames). (#1626)When an Action frame is transmitted for which a Protected Dual of Public Action frame is defined (see 9.4.1.11 (Action field)), which variant (i.e., Public Action or Protected Dual of Public Action) is used depends on the setting of the (#6294)Protected parameter of the corresponding MLME.request or MLME.confirm primitive. Where there is no such parameter, the protected variant is used when management frame protection has been negotiated. An individually addressed Protected Dual of Public Action frame shall be protected using the pairwise cipher suite. A group addressed Protected Dual of Public Action frame shall be protected using BIP.(#1631)

(#1766)NOTE—A Protected Dual of Public Action frame is protected by encryption if it is individually addressed and by a MAC if it is group addressed.

(#4266)A STA shall transmit the protected variant when transmitting an individually addressed Public Action frame for which a Protected Dual of Public Action frame is defined if the STA has negotiated management frame protection with the receiver of the frame.

(#1765)When a Public Action frame is received, but a Protected Dual of Public Action frame should have been used, the frame (#4273)shall be discarded.

(11ay)If a Protected Announce Action frame exists to allow robust STA-STA communications of the same information that is conveyed in the corresponding Announce Action frame, the protected variant shall be transmitted between a pair of communicating DMG STAs when dot11ProtectedAnnounceImplemented (#1263)is true for both of these STAs.

(11ay)Otherwise, Protected Announce Action frames of the category DMG Action shall not be used.

(11ay)A DMG STA shall not set dot11ProtectedAnnounceImplemented to true if dot11RSNAProtectedManagementFramesActivated (#1263)is false.

(11ay)A non-EDMG STA shall transmit the RSNXE with the Protected Announce Support field set to 1 when the dot11ProtectedAnnounceImplemented (#1263)is true.

(11ay)An EDMG STA shall set dot11ProtectedAnnounceImplemented to true if dot11RSNAProtectedManagementFramesActivated (#1263)is true. An EDMG STA shall set the Protected Announce Support field in the RSNXE to 0.

(11ay)The Unprotected DMG Action frames are listed in 9.6.21.1 (Unprotected DMG Action field) and the DMG Action frames are listed in 9.6.19 (DMG Action frame details).


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### 12.6.19 RSNA rekeying

When a PTKSA is deleted, a non-AP and non-PCP STA may reassociate with the same AP or PCP and/or establish a new (#1382)PTKSA with the AP or PCP. If the non-AP and non-PCP STA has cached one or more PMKSAs, it may skip the PMKSA establishment and proceed with the creation of a new PTKSA via a 4-way handshake, an FT 4-way handshake, or FILS authentication using the procedures defined in 12.6.8.3 (Cached PMKSAs and RSNA key management). When a GTKSA is deleted, a non-AP and non-PCP STA may create a new GTKSA via (#1664)a 4-way handshake or a group key handshake.

(#1382)Rekeying is the process by which an existing security association is renewed or a new instance of an existing type of security association (e.g., PTKSA, GTKSA) is created.

(#1382)NOTE 1—This includes adding a second PTKSA when extended key IDs for individually addresses frames are supported and changing the GTK when GTK rekeying. In both these cases the key ID differs from the key ID currently in use for that type of security association.

The IEEE 802.11 MAC shall issue an MLME-PN-WARNING.indication primitive when the packet number assignment for a particular PTKSA, IGTKSA, GTKSA, BIGTKSA or TPKSA(#205) reaches or exceeds the threshold that is defined in dot11PNWarningThresholdLow and dot11PNWarningThresholdHigh for the first time. The indication shall be issued only once for a given PTKSA, IGTKSA, GTKSA, BIGTKSA or TPKSA(#205). The SME may use the indication as a trigger to establish a new PTKSA, IGTKSA, GTKSA, BIGTKSA or TPKSA(#205) before the Packet Number space is exhausted.

A PTKSA has a limited lifetime, either in absolute time or due to exhausting the PN space. To maintain an uninterrupted security association, a STA should establish a new PTKSA prior to the expiration of the old PTKSA.

(#1694)Rekeying is not possible for a TDLS direct link. Otherwise, (#1925)an Authenticator may initiate a 4-way handshake for the purpose of (#1382)PTK rekeying (with a PTKSA).

(#1382)An Authenticator may initiate a group key handshake for the purpose of GTK rekeying (with a GTKSA), IGTK keying (with an IGTKSA), BIGTK rekeying (with a BIGTKSA) or WIGTK rekeying (with a WIGTKSA).

(#3551)After performing GTK rekeying, to avoid attacks from STAs that have left the BSS, once an AP transmits a frame encrypted using the new GTK, it shall delete the previous GTK, and once a non-AP STA receives a frame encrypted using the new GTK, it shall delete the previous GTK.

(#1273)A Supplicant(#1441)(#1380) may send (#1440)an EAPOL-Key request frame to the Authenticator(#1380) to request rekeying (see 12.7.2 (EAPOL-Key frames)).

(#1273)NOTE 2—The Authenticator might ignore this request for GTK rekeying.

In addition, if both the Authenticator and the Supplicant support multiple keys for individually addressed traffic, a smooth switchover to the new key is possible using the following procedure.

When both ends of the link support extended (#3493)key IDs for individually addressed frames, it is possible to install the new PTKSA without data loss, provided the new PTKSA uses a different (#3493)key ID from the old PTKSA. Data loss might occur if the same (#3493)key ID is used because it is not possible to precisely coordinate (due to software processing delays) when the new key is used for transmit at one end and when it is applied to receive at the other end. If a different (#3493)key ID is used for the new PTKSA, then provided the new key is installed at the receive side prior to its first use at the transmit side there is no need for precise coordination. During the transition, received MPDUs(#3243) are unambiguously identified using the (#3493)key ID as belonging to either the old or new PTKSA. (#2128)The same (#3493)key ID shall be used

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for all fragments of a given MSDU. If management frame protection was negotiated for the current association(#7049), the same (#3493)key ID shall be used for all fragments of a given MMPDU.

(11ba)When a WIGTKSA is deleted, an originating STA may create a new WIGTKSA by (#1664)using a 4-way handshake or group key handshake.

### 12.6.20 Multi-band RSNA

#### 12.6.20.1 General

A STA is multi-band capable and an RSNA STA if the values of both dot11MultibandImplemented and dot11RSNAActivated are true.

A STA that is multi-band capable and an RSNA STA shall set the Pairwise Cipher Suite Present field of the Multi-band element to 1 and shall include the Pairwise Cipher Suite Count field and the Pairwise Cipher Suite List field in the Multi-band element. The STA may include the RSNE and the Multi-band element in the DMG Beacon and Announce frames and shall include the RSNE and the Multi-band element in Beacon, Probe Response, and Information Response frames. The included RSNE shall specify all of the authentication and cipher suites enabled by the STA's policy for the band where this element is transmitted, and the included Multi-band element shall specify all of the pairwise cipher suites enabled by the STA's policy for the band specified within the Multi-band element. A STA shall not advertise any cipher suite that is not enabled.(#2177)

In order to set up an RSNA with a peer STA for a supported band/channel, a STA that does not know the peer's policy for the band/channel shall first obtain the peer STA's policy for the supported band/channel by using a Probe Request frame or Information Request frame. The STA initiating RSNA establishment for a supported band/channel is called *RSNA initiator*, and the targeted STA of the RSNA establishment is called *RSNA responder*.

A multi-band capable device can create its own group key(s) for one or more supported bands/channels. If the STA uses different MAC addresses in different bands/channels, different GTKSAs shall be created for different bands. If the STA uses a same MAC address in all supported bands/channels, a single GTKSA shall be created for all supported bands/channels.

If the pairwise, group data cipher suite and group management cipher suite(#6020) used by a pair of multi-band capable devices to communicate with each other in the current operating band/channel (#1733)are also supported after the transfer to another band/channel that was performed using transparent FST, the devices shall continue using the same cipher suites to communicate with each other after the transfer. In all other cases, a separate RSNA has to be established for the other band/channel (see 12.6.20.2 (Nontransparent multi-band RSNA) and 12.6.20.4 (Multi-band RSNA with TDLS in a non-DMG BSS)).

#### 12.6.20.2 Nontransparent multi-band RSNA

An RSNA initiator can establish a nontransparent (11.31 (Multi-band operation)) multi-band RSNA with an RSNA responder for a supported band/channel other than the current operating band/channel. The two STAs use the same PMKSA for both the supported band/channel and the current operating band/channel and create different PTKSAs for different bands/channels.

If the RSNA initiator does not have an existing PMKSA with the RSNA responder, the RSNA initiator shall first establish a PMKSA with the RSNA responder in the current operating band/channel and then use the PMKSA to create a PTKSA with the RSNA responder for the supported band/channel. If the RSNA initiator has already established a PMKSA with the RSNA responder, the PMKSA shall be used to create a PTKSA between the two STAs for the supported band/channel.


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With the PMK in place, the RSNA initiator and RSNA responder can proceed in two ways depending on the setting of the Joint Multi-band RSNA subfield within the RSN Capabilities field in the RSNE of both STAs.

If the Joint Multi-band RSNA subfield within the RSN Capabilities field of either the RSNA initiator or RSNA responder is 0, the STA pair uses a 4-way handshake to establish a PTKSA for the current band/channel and may start a separate 4-way handshake in the current operating band/channel to negotiate a pairwise cipher suite for the supported band/channel and establish a PTKSA for the supported band/channel. As specified in 12.7.6 (4-way handshake), message 2 and message 3 of the 4-way handshake convey the Multi-band element associated with the supported band/channel. The Multi-band element in message 2 includes the selected pairwise cipher suite for the supported band/channel. message 3 includes the Multi-band element that the STA would send in a Beacon, DMG Beacon, Announce, Probe Response, or Information Response frame. message 3 may include a second Multi-band element that indicates the STA's pairwise cipher suite assignment for the supported band/channel.

If the Joint Multi-band RSNA subfield within the RSN Capabilities field is 1 for both the RSNA initiator and the RSNA responder and at least one of the STAs uses different MAC addresses for different bands/channels, the STAs shall use a single 4-way handshake to negotiate pairwise cipher suites and establish PTKSAs for both the current operating band/channel and the other supported band(s)/channel(s). As specified in 12.7.6 (4-way handshake), message 2 and message 3 of the 4-way handshake convey the RSNE and the Multi-band element(s). The RSNE in message 2 includes the selected pairwise cipher suite for the current operating band/channel, and the Multi-band element(s) in message 2 includes the selected pairwise cipher suite(s) for the other supported band(s)/channel(s). message 3 includes the RSNE and the Multi-band element(s) that the STA would send in a Beacon, DMG Beacon, Announce, Probe Response, or Information Response frame. message 3 may include a second RSNE and Multi-band element(s) that indicate the STA's pairwise cipher suite assignments for the current operating band/channel and the other supported band(s)/channel(s). (#3744)PTK-KCK and PTK-KEK associated with the current operating band/channel shall be used in the 4-way handshake.

#### 12.6.20.3 Transparent multi-band RSNA

An RSNA initiator can establish a transparent (11.31 (Multi-band operation)) multi-band RSNA with an RSNA responder for both the current operating band/channel and the other supported band(s)/channel(s) if

a) Both STAs use the same MAC address in the current operating band/channel and the other supported band(s)/channel(s); and

b) At least one common pairwise cipher suite is supported by both STAs in the current operating band/channel and the other supported band(s)/channel(s).

Two STAs that establish a transparent multi-band RSNA create one PMKSA and one PTKSA for both the current operating band/channel and other supported band(s)/channel.

A STA shall use a single PN counter (12.5.2.3 (CCMP cryptographic encapsulation) and 12.5.4.3 (GCMP cryptographic encapsulation)) for transmission in both the current operating band and the other supported band(s) when transparent multi-band RSNA is used. (#7012)A STA shall not use PV1 frames when using transparent multi-band RSNA.

If the RSNA initiator does not have an existing PMKSA with the RSNA responder, the RSNA initiator shall first establish a PMKSA with the RSNA responder in the current operating band/channel and then use the PMKSA to create a PTKSA with the RSNA responder for all involved bands/channels. If the RSNA initiator has already established a PMKSA with the RSNA responder, the PMKSA shall be used to create a PTKSA between the two STAs for all involved bands/channels.

With the PMK in place, the STA pair shall use a single 4-way handshake in the current operating band/channel to negotiate a pairwise cipher suite for all involved bands/channels and also establish a single PTKSA for all involved bands/channels. As specified in 12.7.6 (4-way handshake), message 2 and message 3 of the 4-way

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handshake convey the RSNE and the Multi-band element(s). The RSNE and the Multi-band element(s) in message 2 include one selected pairwise cipher suite for all involved bands/channels. message 3 includes the RSNE and the Multi-band element(s) that the STA would send in a Beacon, DMG Beacon, Announce, Probe Response, or Information Response frame. message 3 may include a second RSNE and Multi-band element(s) that indicate the STA's pairwise cipher suite assignment for all involved bands/channels.

#### 12.6.20.4 Multi-band RSNA with TDLS in a non-DMG BSS

When two multi-band capable devices operate in a non-DMG BSS and set up a TDLS direct link in the BSS, the TPK handshake protocol can be used to create a PTKSA for use in another supported band/channel that is supported by both STAs and that was indicated in the Multi-band element in each of the STAs. (#8166)(#7163)The TPK-TK in the TPKSA is used for cryptographic encapsulation of MPDUs in the other supported band/channel.

If at least one of the peer STAs has a different MAC address in the supported band/channel from that of the current operating band/channel, the TPK handshake protocol may be used to establish a PTKSA for the supported band/channel. (#7163)In this case, the TPK transient key derivation shall be used to calculate a different TPKSA in the supported band/channel: the TDLS peer MAC addresses and cipher suite shall be replaced by the MAC addresses and cipher suite indicated within the corresponding Multi-band elements contained in the TDLS Setup Request and TDLS Setup Response frames used to establish the PTKSA for the supported band/channel.

If two TDLS peer STAs use the same MAC addresses and pairwise cipher suites in the operating band/channel and in the supported band/channel, the TPKSA that is acquired by the successful completion of the TPK handshake protocol may be used as the PTKSA for the supported band/channel.

### 12.6.21 Protection of Beacon frames

An AP shall transmit protected Beacon frames if beacon protection is enabled. Protected Beacon frames cannot be validated until a BIGTKSA has been established. If a BIGTKSA exists, the non-AP STA shall validate the MME or MIC element(#6054) in received Beacon frames.

(#2165)For multiple BSSIDs, each Authenticator shall maintain and transmit the BIGTK and BIPN which are common to all of the (#2210)colocated transmitted and nontransmitted BSSs, and the Supplicant uses the received BIGTK and BIPN to maintain a BIGTKSA. If a Supplicant that has a BIGTKSA with an Authenticator that is using a nontransmitted BSSID receives a protected Beacon frame from the AP with the transmitted BSSID, it shall execute the BIP procedures (see 12.5.3 (Broadcast/multicast integrity protocol (BIP))) to validate the Beacon frame.

The group management cipher suite of the AP transmitting a Beacon frame is used to protect Beacon frames.

(#3267)If beacon protection is enabled at a non-AP STA, the STA shall discard Beacon frames without BIP protection received from its associated AP. The STA may use a WNM Notification Request frame to report beacon protection failure. If beacon protection is enabled at a non-AP STA, the STA should discard broadcast Probe Response frames received from its associated AP.

NOTE 1—An EDCA Parameter Set element might need to be retained if the element is not provided in Beacon frames. (#3267)

NOTE 2—A broadcast Probe Response frame might be used as a presence indication.(#3267)

(#1591)Beacon protection is not applicable to IBSS, MBSS or PBSS.


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(#3234)If (#1571)(#1273)the Authenticator receives an EAPOL-Key request frame with a key type of Pairwise and the Authenticator is not currently performing a 4-way handshake with the Supplicant, the Authenticator shall perform PTK rekeying by initiating a 4-way handshake with the Supplicant.

(#3234)(#1273)NOTE 3—The GTK is not changed in response to an EAPOL-Key request frame with a key type of Pairwise.

(#3234)If (#1571)(#1273)the Authenticator receives an EAPOL-Key request frame with a key type of Group and the Authenticator is not currently performing GTK rekeying, the Authenticator should perform GTK rekeying as follows:

— generate a new GTK(#1272) with a new key ID (see 12.7.2 (EAPOL-Key frames))
— initiate a group key handshake with each Supplicant that is not in WNM sleep mode, except a Supplicant with which it is currently performing a 4-way handshake, in which case if it has not yet transmitted message 3 it may deliver the GTK in that message instead, or otherwise it shall initiate the group key handshake after the end of the 4-way handshake.

(#3234)(#1273)NOTE 4—The Authenticator might ignore the request if, for example, it has recently performed GTK rekeying (whether on request from the same Supplicant or otherwise).

## 12.7 Keys and key distribution

### 12.7.1 Key hierarchy

#### 12.7.1.1 General

RSNA defines the following key hierarchies:

a) Pairwise key hierarchy, to protect individually addressed traffic(11ba), where the PTK includes a KDK if WUR frame protection is negotiated and excludes the KDK otherwise
b) GTK, a hierarchy consisting of a single key to protect group addressed traffic

NOTE—(#432)Pairwise key support with RSNA mechanisms allows a receiving STA to detect MAC address spoofing and data forgery. The RSNA architecture binds the transmitter and receiver addresses to the pairwise key. If an attacker creates an MPDU with the spoofed TA, then the decapsulation procedure at the receiver generates an error. GTKs do not have this property.

c) Integrity GTK (IGTK), a hierarchy consisting of a single key to provide integrity protection for group addressed robust Management frames
d) BIGTK, a hierarchy consisting of a single key to provide for integrity protection for Beacon frames
e) FT key hierarchy, to protect individually addressed traffic in an FT environment
f) (11ba)WIGTK, a hierarchy consisting of a single key to provide integrity protection for broadcast and group addressed WUR Wake-up frames

The description of the key hierarchies uses the pseudorandom function producing *n* bits of output, PRF-*n,* defined in 12.7.1.2 (PRF).

In an infrastructure BSS, the IEEE 802.1X Authenticator MAC address (AA) and the AP's MAC address are the same, and the Supplicant's MAC address (SPA) and the STA's MAC address are equal. For the purposes of comparison in this standard, the MAC address is encoded as 6 octets, taken to represent an unsigned integer. The first octet of the MAC address shall be used as the most significant octet. The bit numbering conventions in 9.2.2 (Conventions) shall be used within each octet. This results in a sequence of 48 bits represented such that bit 0 is the first transmitted bit (Individual/Group bit) and bit 47 is the last transmitted bit.

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(#432)An RSNA STA shall support at least one pairwise key for any <TA,RA> pair for use with RSNA mechanisms(#3056).

#### 12.7.1.2 PRF

A PRF is used in a number of places in this standard. Depending on its use, it may need to output 128, 192, 256, 384, 512, or 704 bits. This subclause defines six functions:

- PRF-128, which outputs 128 bits
- PRF-192, which outputs 192 bits
- PRF-256, which outputs 256 bits
- PRF-384, which outputs 384 bits
- PRF-512, which outputs 512 bits
- PRF-704, which outputs 704 bits

In the following, $K$ is a key; $A$ is a unique label for each different purpose of the PRF, treated as an ASCII string; $B$ is a variable length string; $Y$ is a single octet containing 0; $X$ is a single octet containing the loop parameter $i$:

H-SHA-1($K$, $A$, $B$, $X$) ← HMAC-SHA-1($K$, $A$ || $Y$ || $B$ || $X$)

PRF($K$, $A$, $B$, $Len$)
**for** $i \leftarrow 0$ **to** $\left\lceil \frac{Len}{160} \right\rceil$ **do**
$R \leftarrow R$ || H-SHA-1($K$, $A$, $B$, $i$)
**return** (#3506)ExtractBits($R$, 0, $Len$)

PRF-128($K$, $A$, $B$) = PRF($K$, $A$, $B$, 128)
PRF-192($K$, $A$, $B$) = PRF($K$, $A$, $B$, 192)
PRF-256($K$, $A$, $B$) = PRF($K$, $A$, $B$, 256)
PRF-384($K$, $A$, $B$) = PRF($K$, $A$, $B$, 384)
PRF-512($K$, $A$, $B$) = PRF($K$, $A$, $B$, 512)

When the negotiated AKM is 00-0F-AC:5, 00-0F-AC:6, or 00-0F-AC:11, the KDF specified in 12.7.1.6.2 (Key derivation function (KDF)) shall be used instead of the PRF construction defined here. In this case, A is used as the KDF label and B as the KDF context(M20), and the PRF functions are defined as follows:

PRF-128(K, A, B) = KDF-SHA-256-128(K, A, B)
PRF-192(K, A, B) = KDF-SHA-256-192(K, A, B)
PRF-256(K, A, B) = KDF-SHA-256-256(K, A, B)
PRF-384(K, A, B) = KDF-SHA-256-384(K, A, B)
PRF-512(K, A, B) = KDF-SHA-256-512(K, A, B)

When the negotiated AKM is 00-0F-AC:12 or 00-0F-AC:20,(#590) the KDF specified in 12.7.1.6.2 (Key derivation function (KDF)) shall be used instead of the PRF construction defined here. In this case, A is used as the KDF label and B as the KDF context(M20), and the PRF function is defined as follows:

PRF-704(K, A, B) = KDF-SHA-384-704(K, A, B)

When the negotiated AKM is 00-0F-AC:13, the KDF specified in 12.7.1.6.2 (Key derivation function (KDF)) shall be used instead of the PRF construction defined here. In this case, A is used as the KDF label and B as the KDF context(M20), and the PRF functions are defined as follows:


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PRF-384(K, A, B) = KDF-SHA-384-384(K, A, B)
PRF-512(K, A, B) = KDF-SHA-384-512(K, A, B)
PRF-704(K, A, B) = KDF-SHA-384-704(K, A, B)

When the negotiated AKM is 00-0F-AC:14 or 00-0F-AC:16, the KDF specified in 12.7.1.6.2 (Key derivation function (KDF)) shall be used instead of the PRF construction defined here. In this case, A is used as the KDF label and B as the KDF context(M20), and the PRF functions are defined as follows:

PRF-384(K, A, B) = KDF-SHA-256-384(K, A, B)
PRF-512(K, A, B) = KDF-SHA-256-512(K, A, B)
PRF-640(K, A, B) = KDF-SHA-256-640(K, A, B)
PRF-768(K, A, B) = KDF-SHA-256-768(K, A, B)
PRF-896(K, A, B) = KDF-SHA-256-896(K, A, B)
PRF-1024(K, A, B) = KDF-SHA-256-1024(K, A, B)

When the negotiated AKM is 00-0F-AC:15 or 00-0F-AC:17, the KDF specified in 12.7.1.6.2 (Key derivation function (KDF)) shall be used instead of the PRF construction defined here. In this case, A is used as the KDF label and B as the KDF context(M20), and the PRF functions are defined as follows:

PRF-640(K, A, B) = KDF-SHA-384-640(K, A, B)
PRF-768(K, A, B) = KDF-SHA-384-768(K, A, B)
PRF-1024(K, A, B) = KDF-SHA-384-1024(K, A, B)
PRF-1152(K, A, B) = KDF-SHA-384-1152(K, A, B)
PRF-1408(K, A, B) = KDF-SHA-384-1408(K, A, B)
PRF-1536(K, A, B) = KDF-SHA-384-1536(K, A, B)

(M20)When the negotiated AKM is 00-0F-AC:19 or 00-0F-AC:22 or 00-0F-AC:23, the KDF specified in 12.7.1.6.2 (Key derivation function (KDF)) shall be used instead of the PRF construction defined here. In this case, A is used as the KDF label and B as the KDF context, and the PRF functions are defined as follows:

(#3686)PRF-*Length*(K, A, B) = KDF-SHA-384-*Length*(K, A, B)

(M67)When the negotiated AKM is 00-0F-AC:8 or 00-0F-AC:9 or 00-0F-AC:24 or 00-0F-AC:25, the KDF specified in 12.7.1.6.2 (Key derivation function (KDF)) shall be used instead of the PRF construction defined here (see Key derivation type in Table 9-190 (AKM suite selectors)). In this case, A is used as the KDF label and B as the KDF context, and

(#3686)PRF-*Length*(K, A, B) = (#3686)KDF-*Hash-Length*(K, A, B), where Hash is the hash algorithm specified in 12.4.2 (Assumptions on SAE)

### 12.7.1.3 Pairwise key hierarchy

Except when preauthentication or FILS authentication is used, the pairwise key hierarchy utilizes PRF-384, PRF-512, or PRF-704 to derive session specific keys from a PMK, as depicted in Figure 12-32 (Pairwise key hierarchy(11ba)(#4057)(#3744)(#8001)). When using (#3266)AKM 00-0F-AC:12, 00-0F-AC:15, 00-0F-AC:20,(#590) 00-0F-AC:23(M20)(M67), the length of the PMK, PMK_bits, shall be 384 bits. (M67)When using (#3266)AKM 00-0F-AC:24 or 00-0F-AC:25, the length of the PMK, PMK_bits, shall have the length of the digest generated by H() identified in 12.4.2 (Assumptions on SAE). When using AKM suite selectors for which the Authentication type column indicates FT authentication (see Table 9-190 (AKM suite selectors)), the FT key hierarchy is used to derive session specific keys from an MPMK as defined in 12.7.1.6 (FT key hierarchy). With all other AKM suite selectors, the length of the PMK, PMK_bits, shall be 256 bits. The pairwise key hierarchy takes a PMK and generates a PTK.

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The PTK is partitioned into (#3744)PTK-KCK, PTK-KEK, (11ba)a temporal key, and a KDK. (11az)A KDK is derived if any of the following are true:(#7220)

— WUR frame protection is negotiated(11az)

— dot11SecureLTFImplemented is true and the peer STA has advertised secure HE-LTF support capability in its RSNXE (see 9.4.2.240 (RSNXE(#1776))))(11az)

Otherwise, it is not derived. (#7220)

The temporal key is used by the MAC to protect individually addressed communication between the Authenticator's and Supplicant's respective STAs. If WUR frame protection is negotiated, the KDK is used to derive a WTK, which is used by the MAC of the WUR AP to protect and by the MAC of the WUR non-AP STA to validate individually addressed WUR Wake-up frames. PTKs are used between a single Supplicant and a single Authenticator.

(11az)If a KDK is derived to support secure HE-LTF, it is recommended that the KDK is updated periodically for improved ranging security.

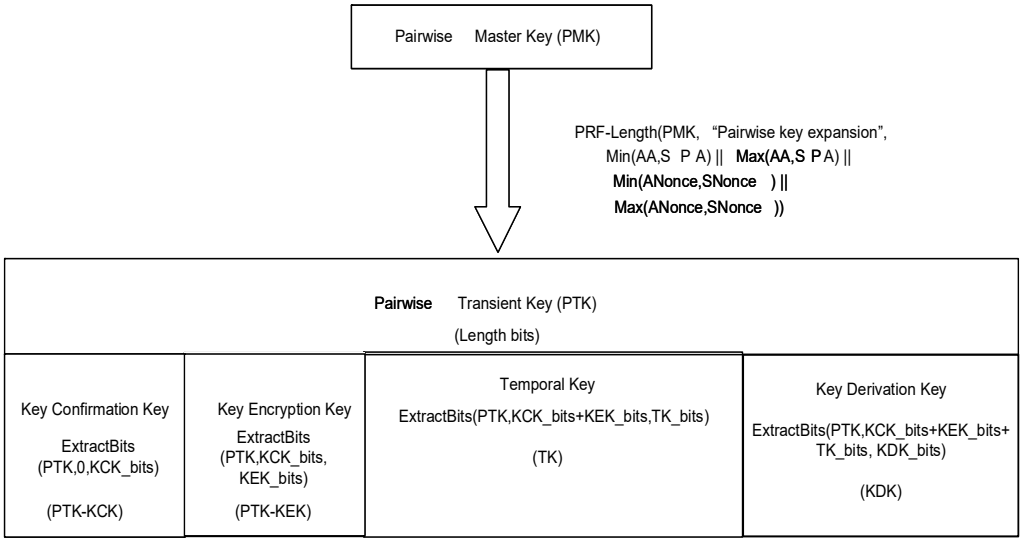


**Figure 12-32—Pairwise key hierarchy(11ba)(#4057)(#3744)(#8001)**

(#7079)When using IEEE 802.1X authentication, the PMK is derived from the MSK. The PMK shall be computed as the first PMK_bits bits (bits 0 to PMK_bits–1) of the MSK: PMK = (#3506)ExtractBits(MSK, 0, PMK_bits). When using SAE or FILS authentication, the PMK is derived per 12.4.5.4 (Processing of a peer's SAE Commit message) or 12.11.2.5.2 (PMKSA key derivation with FILS authentication), respectively.

The PTK shall not be used longer than the PMK lifetime as determined by the minimum of the PMK lifetime indicated by the AS, e.g., Session-Timeout + dot1xAuthTxPeriod or from dot11RSNAConfigPMK-Lifetime. When RADIUS is used and the Session-Timeout attribute is not in the RADIUS Accept message, and if the key lifetime is not otherwise specified, then the PMK lifetime is infinite.

NOTE 1—If the protocol between the Authenticator (or AP) and AS is RADIUS, then the MS-MPPE-Recv-Key attribute (vendor-id = 17; see section 2.4.3 in IETF RFC 2548 [B30]) is available to be used to transport the first 32 octets of the MSK to the AP, and the MS-MPPE-Send-Key attribute (vendor-id = 16; see section 2.4.2 in IETF RFC 2548 [B30]) is available to be used to transport the remaining 32 octets of the MSK.

NOTE 2—When reauthenticating and changing the pairwise key, a race condition might occur when using TKIP. If a frame is received while MLME-SETKEYS.request primitive is being processed, the received frame might be decrypted


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with one key and the MIC checked with a different key. Two possible options to avoid this race condition are as follows: the frame might be checked against the old MIC key, and the received frames might be queued while the keys are changed.

NOTE 3—If the AKMP is RSNA-PSK, then a 256-bit PSK might be configured into the STA and AP or a pass-phrase might be configured into the Supplicant or Authenticator. The method used to configure the PSK is outside this standard, but one method is via user interaction. If a pass-phrase is configured, then a 256-bit key is derived and used as the PSK. In any RSNA-PSK method, the PSK is used directly as the PMK. Implementations might support different PSKs for each pair of communicating STAs.

The following apply when not using FILS authentication:

— SNonce is a random or pseudorandom value contributed by the Supplicant; its value is taken when a PTK is instantiated and is sent to the PTK Authenticator.

— ANonce is a random or pseudorandom value contributed by the Authenticator.

— The PTK shall be derived from the PMK by

PTK = (#3686)PRF-*Length*(PMK, "Pairwise key expansion", Min(AA,SPA) || Max(AA,SPA) || Min(ANonce,SNonce) || Max(ANonce,SNonce))

where (11ba)(#3686)*Length* = KCK_bits + KEK_bits + TK_bits + KDK_bits. The values of KCK_bits and KEK_bits are (#3266)AKMP dependent and are listed in Table 12-11 (Integrity and key wrap algorithms(#3244)). The value of TK_bits is (#3270)cipher suite dependent and is defined in Table 12-8 (Cipher suite key lengths(#1083)(#3532)). (11az)If a KDK is derived, the (11ba)value of KDK_bits is equal to the value of PMK_bits; otherwise the value of KDK_bits shall be 0. The Min and Max operations for IEEE 802 addresses are with the address converted to a positive integer treating the first transmitted octet as the most significant octet of the integer. The nonces are encoded as specified in 9.2.2 (Conventions).

— (11ba)(11az)If a KDK is derived, it shall be computed as the next KDK_bits bits of the PTK:

KDK = (#3506)ExtractBits(PTK, KCK_bits+KEK_bits+TK_bits, KDK_bits)

NOTE 4—The Authenticator and Supplicant normally derive a PTK only once per association. A Supplicant or an Authenticator use the 4-way handshake or FILS authentication to derive a new PTK. Both the Authenticator and Supplicant create a new nonce value for each 4-way handshake or FILS authentication instance.

— The (#3744)PTK-KCK shall be computed as the first KCK_bits bits (bits 0 to KCK_bits–1) of the PTK:

PTK-KCK= (#3506)ExtractBits(PTK, 0, KCK_bits)

The PTK-KCK is used by (#3469)IEEE Std 802.1X-2020 to provided data origin authenticity in the 4-way handshake and group key handshake messages.

— The (#3744)PTK-KEK shall be computed as the next KEK_bits bits of the PTK:

PTK-KEK = (#3506)ExtractBits(PTK, KCK_bits, KEK_bits)

The PTK-KEK is used by the EAPOL-Key frames to provide data confidentiality in the 4-way handshake and group key handshake messages.

— The temporal key (TK) shall be computed as the next TK_bits bits of the PTK:

TK = (#3506)ExtractBits(PTK, KCK_bits+KEK_bits, TK_bits)

When using FILS authentication, the PTK is derived as defined in 12.11.2.5.3 (PTKSA Key derivation with FILS authentication).

(11ba)If WUR frame protection is negotiated, the WTK shall be derived from the KDK using the KDF defined in 12.7.1.6.2:

WTK = (#3686)KDF-*Hash-Length*(KDK, "WUR Temporal Key", Min(AA,SPA) || Max(AA,SPA) || Min(ANonce,SNonce) || Max(ANonce,SNonce)

where

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— (#3686)KDF-*Hash-Length* is the key derivation function as defined in 12.7.1.6.2 (Key derivation function (KDF)) using the hash algorithm identified by the AKM suite selector (see Table 9-190 (AKM suite selectors)).

— (#3686)*Length* is the total number of bits to derive, i.e., number of bits of the WTK, and is equal to 128.

The EAPOL-Key state machines (see 12.7.9 (RSNA Supplicant key management state machine) and 12.7.10 (RSNA Authenticator key management state machine)) use the MLME-SETKEYS.request primitive to configure the temporal key(11ba), and if WUR frame protection is negotiated, the WTK into the STA. The STA uses the temporal key with the pairwise cipher suite; interpretation of this value is (#3270)cipher suite dependent.

When the negotiated AKM is 00-0F-AC:5 or 00-0F-AC:6, the PMK identifier is defined as

PMKID = Truncate-128(HMAC-SHA-256(PMK, “PMK Name” || AA || SPA))

When the negotiated AKM is 00-0F-AC:11, the PMK identifier is defined as

PMKID = Truncate-128(HMAC-SHA-256((#4058)PTK-KCK, “PMK Name” || AA || SPA))

When the negotiated AKM is 00-0F-AC:12, and the PMK identifier is defined as

PMKID = Truncate-128(HMAC-SHA-384((#4058)PTK-KCK, “PMK Name” || AA || SPA))

When the negotiated AKM is 00-0F-AC:14:

— When IEEE 802.1X authentication is used, the PMK identifier is defined as:

PMKID = Truncate-128(HMAC-SHA-256(PMK, “PMK Name” || AA || SPA))

— When FILS authentication is used, the PMK identifier is derived as defined in 12.11.2.5 (Key establishment with FILS authentication).

When the negotiated AKM is 00-0F-AC:15:

— When IEEE 802.1X authentication is used, the PMK identifier is defined as:

PMKID = Truncate-128(HMAC-SHA-384(PMK, “PMK Name” || AA || SPA))

— When FILS authentication is used, the PMK identifier is derived as defined in 12.11.2.5 (Key establishment with FILS authentication).

When the negotiated AKM is 00-0F-AC:20 or 00-0F-AC:23(M20), the PMK identifier is defined as

PMKID = Truncate-128(HMAC-SHA-384(PMK, “PMK Name” || AA || SPA))

When the negotiated AKM is 00-0F-AC:8 or 00-0F-AC:24(M21), the PMK identifier is derived as defined in 12.4.5.4 (Processing of a peer’s SAE Commit message).

When the negotiated AKM is a suite type for which the Authentication type column indicates FT authentication (see Table 9-190 (AKM suite selectors)), the PMKID (used for PMKSA caching in FT Initial Mobility Domain Association, see 12.6.8.3 (Cached PMKSAs and RSNA key management)) and PMKR0Name are derived as defined in 12.7.1.6.3 (PMK-R0) and PMKR1Name is derived as defined in 12.7.1.6.4 (PMK-R1).

Otherwise, the PMK identifier is defined as

PMKID = Truncate-128(HMAC-SHA-1(PMK, “PMK Name” || AA || SPA))


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In all these cases, “PMK Name” is treated as an ASCII string.

When the PMKID is calculated for the PMKSA as part of preauthentication, the AKM has not yet been negotiated. In this case, the HMAC-SHA-1 based derivation is used for the PMKID calculation.

#### 12.7.1.4 Group key hierarchy

The group temporal key (GTK) shall be a random number. The following is an example method for deriving a random GTK. Any other pseudorandom function, such as that specified in 12.7.1.2 (PRF), could also be used.

A group master key (GMK) is an auxiliary key that may be used to derive a GTK at a time interval configured into the AP to reduce the exposure of data if the GMK is ever compromised.

The Authenticator might update the GTK for a number of reasons:

— The Authenticator might change the GTK on disassociation or deauthentication of a STA.
— An event within the SME might trigger a group key handshake.

Figure 12-33 (Group key hierarchy(#3253)) depicts an example of a relationship among the keys of the group key hierarchy. In this model, the group key hierarchy takes a GMK and generates a GTK. The GTK is a temporal key, which is used to protect group addressed communication. GTKs are used between a single Authenticator and all Supplicants authenticated to that Authenticator. The Authenticator derives new GTKs when it needs to update the GTKs.

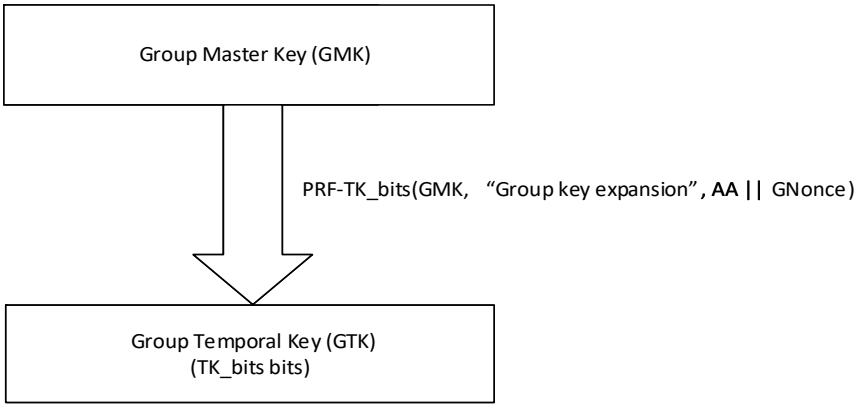


**Figure 12-33—Group key hierarchy(#3253)**

In this example, the following apply:

a) Group nonce (GNonce) is a random or pseudorandom value contributed by the IEEE 802.1X Authenticator.
b) The GTK is derived from the GMK by GTK =(#3253)PRF-TK_bits(GMK, “Group key expansion”, AA || GNonce)
c) (#3253)The value of TK_bits is (#3270)cipher suite dependent and is defined in Table 12-8 (Cipher suite key lengths(#1083)(#3532)). AA is represented as an IEEE 802 address and GNonce as a bit string as defined in 9.2.2 (Conventions).(#3253)
d) The EAPOL-Key state machines (see 12.7.9 (RSNA Supplicant key management state machine) and 12.7.10 (RSNA Authenticator key management state machine)) configure the (#3253)GTK into a STA via the MLME-SETKEYS.request primitive. Its interpretation is (#3270)cipher suite dependent.

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#### 12.7.1.5 Integrity group key hierarchy

The Authenticator shall select the IGTK as a random value each time it is generated.

The Authenticator may update the IGTK for any reason, including:

a) The disassociation or deauthentication of a STA.
b) An event within the SME that triggers a group key handshake.

The IGTK is configured via the MLME-SETKEYS.request primitive; see 6.5.14 (SetKeys). IGTK configuration is described in the EAPOL-Key state machines; see 12.7.9 (RSNA Supplicant key management state machine) and 12.7.10 (RSNA Authenticator key management state machine).

The IPN is used to provide replay protection.

#### 12.7.1.6 FT key hierarchy

##### 12.7.1.6.1 Overview

This subclause describes the FT key hierarchy and its supporting architecture. The FT key hierarchy is designed to allow a STA to make fast BSS transitions between APs without the need to perform an SAE or IEEE 802.1X authentication at every AP within the mobility domain.

The FT key hierarchy can be used with SAE, IEEE 802.1X authentication, PSK authentication, or FILS authentication.

A three-level key hierarchy provides key separation between the key holders. The FT key hierarchy for the Authenticator is shown in Figure 12-34 (FT key hierarchy at an Authenticator). An identical key hierarchy exists for the Supplicant, and identical functions are performed by the corresponding S0KH and S1KH.

The FT key hierarchy shown in Figure 12-34 (FT key hierarchy at an Authenticator) consists of three levels whose keys are derived using the key derivation function (KDF) described in 12.7.1.6.2 (Key derivation function (KDF)) as follows:

a) PMK-R0. The first-level key of the FT key hierarchy. This key is derived as a function of the master session key (MSK), PMK, or PSK. It is stored by the PMK-R0 key holders, R0KH and S0KH.
b) PMK-R1. The second-level key of the FT key hierarchy. This key is mutually derived by the S0KH and R0KH.
c) PTK. The third-level key of the FT key hierarchy that defines the IEEE 802.11 and IEEE 802.1X protection keys. The PTK is mutually derived by the PMK-R1 key holders, R1KH and S1KH.

As shown in Figure 12-34 (FT key hierarchy at an Authenticator), the Master PMK (MPMK) is obtained from the PMK obtained from SAE authentication, from the PSK, or from the MSK resulting (per IETF RFC 3748) from a successful IEEE 802.1X authentication between the AS and the Supplicant, or from the PMK (see 12.11.2.5.2 (PMKSA key derivation with FILS authentication)) resulting from a successful FILS authentication. The R0KH computes the PMK-R0 from the MPMK.

NOTE—The MPMK is a constituent of a PMKSA that may be cached (see 12.6.1.1.2 (PMKSA) and 12.6.8.3 (Cached PMKSAs and RSNA key management)).

Upon a successful authentication, the R0KH shall delete any prior PMK-R0 security association for this mobility domain pertaining to this S0KH. The R0KH shall also delete all PMK-R1 security associations derived from that prior PMK-R0 security association.


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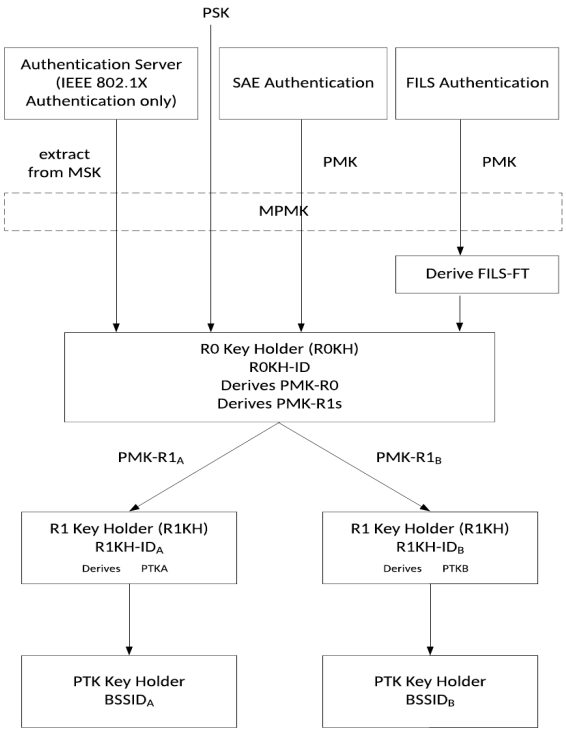


**Figure 12-34—FT key hierarchy at an Authenticator**

(#6401)The R0KH generates the PMK-R1s and delivers them to the R1KHs within the same mobility domain. The PMK-R1s are used for PTK generation. Upon receiving a new PMK-R1 for an S0KH, an R1KH deletes the prior PMK-R1 security association and PTKSAs derived from the prior PMK-R1.(#6401)

The lifetime of the MPMK, PMK-R0, PMK-R1, and PTK are bound to the lifetime of the PMK, PSK, or MSK from which it was derived. For example, the AS may communicate the MSK lifetime with the MSK. If such an attribute is provided, the lifetime of the MPMK shall be not more than the lifetime of the MSK. The lifetime of the PTK, PMK-R1, and PMK-R0 is the same as that of the MPM. When the key lifetime expires, each key holder shall delete its respective MPMK, PMK-R0, PMK-R1 or PTKSA.

The FT key hierarchy derives its keys using the KDF defined in 12.7.1.6.2 (Key derivation function (KDF)) with separate labels to further distinguish derivations.

During a fast BSS transition, a STA shall negotiate the same pairwise cipher suite with target APs as was negotiated in the FT initial mobility domain association. Using the pairwise cipher suite selector value in the PMK-R1 security association received from the R0KH, the target AP shall verify that the same pairwise cipher suite selector is being used.

The distribution of keys from the R0KH to the R1KHs is outside the scope of this standard. (#6401)The PMK-R1s are distributed from the R0KH to the R1KHs following the requirements specified in 13.2.2 (Authenticator key holders).

The PMK-R0 may be deleted by the R0KH after PMK-R1s have been derived. When the PMK-R0 is deleted, the R0KH needs only to maintain the PMK-R1 security associations.

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#### 12.7.1.6.2 Key derivation function (KDF)

The KDF is a variant of the pseudorandom function (PRF) defined in 12.7.1.2 (PRF) and is defined as follows:

(#478)**Output ← KDF-*Hash-Length*(K, Label, Context) where**
Input: *K*, a derivation key whose length equals the block size of the hash algorithm
*Hash*, a cryptographically strong hash algorithm
*Label*, a string identifying the purpose of the keys derived using this KDF, treated as an ASCII string
*Context*, a bit string that provides context to identify the derived key
*Length*, the length of the derived key in bits
Output: a *Length*-bit derived key

*result* ← ""
*iterations* ← $\lceil Length/Hashlen \rceil$
**do** *i* = 1 **to** *iterations*
*result* ← *result* || HMAC-*Hash*(*K*, *i* || *Label* || *Context* || *Length*)
**od**
**return** first *Length* bits of *result,* and irretrievably delete the other bits

where

| | |
|---|---|
| *i* and *Length* | are encoded as 16-bit unsigned integers, represented using the bit ordering conventions of 9.2.2 (Conventions) |
| *K*, *Label*, and *Context* | are bit strings and are represented using the ordering conventions of 9.2.2 (Conventions) |
| *Hashlen* | is the length, in bits, of the digest produced by Hash |

#### 12.7.1.6.3 PMK-R0

The first-level key in the FT key hierarchy, PMK-R0, is derived using the KDF defined in 12.7.1.6.2 (Key derivation function (KDF)). The PMK-R0 is the first level keying material used to derive the next level keys (PMK-R1s).

The PMK-R0 is derived from the MPMK, which is obtained when a PMKSA is established using a negotiated AKM for which the Authentication type column indicates FT authentication (see Table 9-190 (AKM suite selectors)).

If the negotiated AKM is 00-0F-AC:3, then Q = 256 and

— MPMK = (#3506)ExtractBits(MSK, 256, 256), i.e., the second 256 bits of the MSK (which is derived from the IEEE 802.1X authentication)
— PMKID = Truncate-128(HMAC-SHA-256(MPMK, "PMK Name" || AA || SPA))

If the negotiated AKM is 00-0F-AC:4, then Q = 256 and

— MPMK = PSK
— PMKID = Truncate-128(HMAC-SHA-256(MPMK, "PMK Name" || AA || SPA))

If the negotiated AKM is 00-0F-AC:9, then Q = 256 and

— MPMK = PMK generated as the result of SAE authentication per 12.4.5.4 (Processing of a peer's SAE Commit message)
— PMKID is derived as defined in 12.4.5.4 (Processing of a peer's SAE Commit message)

If the negotiated AKM is 00-0F-AC:13, then Q = 384 and


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- MPMK = (#3506)ExtractBits(MSK, 0, 384)(#1667)
- PMKID = Truncate-128(HMAC-SHA-384(MPMK, “PMK Name” || AA || SPA))

If the negotiated AKM is 00-0F-AC:16, then Q = 256 and

- When FILS authentication is used:
  - MPMK = PMK generated as the result of FILS authentication per 12.11.2.5.2 (PMKSA key derivation with FILS authentication)
  - PMKID is defined in 12.11.2.5.2 (PMKSA key derivation with FILS authentication)
- When IEEE 802.1X authentication is used, then
  - MPMK = (#3506)ExtractBits(MSK, 256, 256), i.e., the second 256 bits of the MSK (which is derived from the IEEE 802.1X authentication)
  - PMKID = Truncate-128(HMAC-SHA-256(MPMK, “PMK Name” || AA || SPA))

If the negotiated AKM is 00-0F-AC:17, then Q = 384 and

- When FILS authentication is used,
  - MPMK = PMK generated as the result of FILS authentication per 12.11.2.5.2 (PMKSA key derivation with FILS authentication)
  - PMKID is defined in 12.11.2.5.2 (PMKSA key derivation with FILS authentication)
- When IEEE 802.1X authentication is used, then
  - MPMK = (#3506)ExtractBits(MSK, 0, 384)(#1667)
  - PMKID = Truncate-128(HMAC-SHA-384(MPMK, “PMK Name” || AA || SPA))

If the negotiated AKM is 00-0F-AC:19, then Q = 384 and

- MPMK = PSK
- PMKID = Truncate-128(HMAC-SHA-384(MPMK, “PMK Name” || AA || SPA))

(M20)If the negotiated AKM is 00-0F-AC:22, then Q = 384 and

- MPMK = (#3506)ExtractBits(MSK, 0, 384)(#1667)
- PMKID = Truncate-128(HMAC-SHA-384(MPMK, “PMK Name” || AA || SPA))

(M21)(M67)If the negotiated AKM is 00-0F-AC:25, then Q is equal to the length of the digest generated by H() identified in 12.4.2 (Assumptions on SAE) and

- MPMK = PMK generated as the result of SAE authentication per 12.4.5.4 (Processing of a peer’s SAE Commit message)
- PMKID is derived as defined in 12.4.5.4 (Processing of a peer’s SAE Commit message)

In all these cases, “PMK Name” is treated as an ASCII string.

The PMK-R0 is then derived as follows:

(#478)R0-Key-Data = KDF-*Hash-Length*(XXKey, “FT-R0”, SSIDlength || SSID || MDID || R0KH-length || R0KH-ID || S0KH-ID)

PMK-R0 = (#3506)ExtractBits(R0-Key-Data, 0, Q)

PMK-R0Name-Salt = (#3506)ExtractBits(R0-Key-Data, Q, 128)

(#3686)*Length* = Q + 128

where

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(#478)KDF-*Hash-Length* is the key derivation function as defined in 12.7.1.6.2 (Key derivation function (KDF)) using the hash algorithm identified by the AKM suite selector (see Table 9-190 (AKM suite selectors))

If the negotiated AKM is 00-0F-AC:16 or 00-0F-AC:17 and FILS authentication is used, then XXKey shall be the FILS-FT derived from MPMK as described in 12.11.2.5.3 (PTKSA Key derivation with FILS authentication). Otherwise, XXKey is equal to MPMK.

SSIDlength is a single octet whose value is the number of octets in the SSID

SSID is the service set identifier, a variable length sequence of octets, as it appears in the Beacon and Probe Response frames

MDID is the (#1776)MDID field from the MDE that was used during FT initial mobility domain association

R0KHlength is a single octet whose value is the number of octets in the R0KH-ID

R0KH-ID is the identifier of the holder of PMK-R0 in the Authenticator

S0KH-ID is the Supplicant's MAC address (SPA)

The PMK-R0 is referenced and named as follows:

PMKR0Name = Truncate-128(Hash("FT-R0N" || PMK-R0Name-Salt))

where

Hash is the hash algorithm specific to the negotiated AKM (see Table 9-190 (AKM suite selectors))

"FT-R0N" is treated as an ASCII string

The PMKR0Name is used to identify the PMK-R0.

#### 12.7.1.6.4 PMK-R1

The second-level key in the FT key hierarchy, PMK-R1, is a key used to derive the PTK. The PMK-R1 is derived using the KDF defined in 12.7.1.6.2 (Key derivation function (KDF)):

PMK-R1 = (#478)KDF-*Hash-Length*(PMK-R0, "FT-R1", R1KH-ID || S1KH-ID)

where

(#478)KDF-*Hash-Length* is the key derivation function as defined in 12.7.1.6.2 (Key derivation function (KDF))

*Hash*(#3686) is the hash algorithm specific to the negotiated AKM (see Table 9-190 (AKM suite selectors))

*Length*(#3686) is the length of the hash algorithm's digest

PMK-R0 is the first level key in the FT key hierarchy

R1KH-ID is a MAC address of the holder of the PMK-R1 in the Authenticator of the AP

S1KH-ID is the SPA

The PMK-R1 is referenced and named as follows:

PMKR1Name = Truncate-128(*Hash*("FT-R1N" || PMKR0Name || R1KH-ID || S1KH-ID))

where

*Hash*(#3686) is the hash algorithm specific to the negotiated AKM (see Table 9-190 (AKM suite selectors))

"FT-R1N" is treated as an ASCII string

PMKR1Name is used to identify the PMK-R1.


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#### 12.7.1.6.5 PTK

The third-level key in the FT key hierarchy is the PTK. When FILS authentication is used to establish the FT key hierarchy, PTK for the initial mobility domain association is derived as part of the FILS authentication as defined in 12.11.2.5.3 (PTKSA Key derivation with FILS authentication). Otherwise, this key is mutually derived by the S1KH and the R1KH used by the target AP, with the key length being a function of the negotiated cipher suite as defined by Table 12-8 (Cipher suite key lengths(#1083)(#3532)) in 12.7.2 (EAPOL-Key frames).

Using the KDF defined in 12.7.1.6.2 (Key derivation function (KDF)), the PTK derivation is as follows:

(#478)PTK = KDF-*Hash-Length*(PMK-R1, "FT-PTK", SNonce || ANonce || BSSID || STA-ADDR)

where

(#478)KDF-*Hash-Length* is the key derivation function as defined in 12.7.1.6.2 (Key derivation function (KDF)) using the hash algorithm identified by the AKM suite selector (see Table 9-190 (AKM suite selectors))

PMK-R1 is the key that is shared between the S1KH and the R1KH

SNonce is a 256-bit random bit string contributed by the S1KH

ANonce is a 256-bit random bit string contributed by the R1KH

STA-ADDR is the non-AP STA's MAC address

BSSID is the BSSID of the target AP's BSS

*Length*(#3686) is the total number of bits to derive, i.e., number of bits of the PTK. The length is dependent on the negotiated cipher suites and (#3266)AKMP as defined by Table 12-8 (Cipher suite key lengths(#1083)(#3532)) in 12.7.2 (EAPOL-Key frames) and Table 12-11 (Integrity and key wrap algorithms(#3244)) in 12.7.3 (EAPOL-Key PDU construction and processing)(11ba), and whether a KDK is derived. A KDK shall be derived if any of the following are true:(11az)(#7220)

—WUR frame protection is negotiated(11az)

—dot11SecureLTFImplemented is true and the peer STA has advertised secure HE-LTF support capability in its RSNXE (see 9.4.2.240 (RSNXE(#1776)))(11az)

Otherwise, it shall not be derived.(#7220)

(11ba)Except when a KDK is derived(11az), each PTK has five component keys, (#3744)PTK-KCK, PTK-KEK, a temporal key, KCK2, and KEK2 derived as follows:

The (#3744)PTK-KCK shall be computed as the first KCK_bits bits (bits 0 to KCK_bits–1) of the PTK:

PTK-KCK = (#3506)ExtractBits(PTK, 0, KCK_bits)

The (#3744)PTK-KCK is used to provide data origin authenticity in EAPOL-Key frames, as defined in 12.7.2 (EAPOL-Key frames), and in the FT authentication sequence, as defined in 13.8 (FT authentication sequence).

(11ba)When a KDK is derived(11az), each PTK has six component keys, (#3744)PTK-KCK, PTK-KEK, a temporal key, KCK2, KEK2, and a KDK derived as follows:

(11ba)The (#3744)PTK-KCK, PTK-KEK, temporal key, KCK2, and KEK2 shall be computed in the same way as when a KDK is derived(11az).

(11ba)The KDK shall be computed as the next KDK_bits bits of the PTK:

KDK = (#3506)ExtractBits(PTK, KCK_bits+KEK_bits+TK_bits+KCK2_bits+KEK2_bits, KDK_bits)

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(11ba)The value of KDK_bits is equal to the value of PMK_bits (see 12.7.1.3 (Pairwise key hierarchy)).

(11ba)If WUR frame protection is negotiated, the WTK shall be derived from the KDK using the KDF defined in 12.7.1.6.2 (Key derivation function (KDF))):

WTK = (#3686)KDF-*Hash-Length*(KDK, "WUR Temporal Key", SNonce || ANonce || BSSID || STA-ADDR)

where

— (#3686)KDF-*Hash-Length* is the key derivation function as defined in 12.7.1.6.2 (Key derivation function (KDF)) using the hash algorithm identified by the AKM suite selector (see Table 9-190 (AKM suite selectors)).

— (#3686)*Length* is the total number of bits to derive, i.e., number of bits of the WTK, and is equal to 128.

(11ba)The WTK is used to protect individually addressed WUR Wake-up frames, as defined in 29.10 (WUR frame protection).

The (#3744)PTK-KEK shall be computed as the next KEK_bits of the PTK:

PTK-KEK = (#3506)ExtractBits(PTK, KCK_bits, KEK_bits)

(#4060)The PTK-KEK is used to provide data confidentiality for certain fields (KeyData) in EAPOL-Key frames, as defined in 12.7.2 (EAPOL-Key frames), and in the FT authentication sequence, as defined in 13.8 (FT authentication sequence).

The temporal key (TK) shall be computed as the next TK_bits (see Table 12-8 (Cipher suite key lengths(#1083)(#3532))) bits of the PTK:

TK = (#3506)ExtractBits(PTK, KCK_bits+KEK_bits, TK_bits)

The KCK2 shall be computed as the next KCK2_bits of the PTK:

KCK2 = (#3506)ExtractBits(PTK, KCK_bits+KEK_bits+TK_bits, KCK2_bits)

The KCK2 is used to provide data origin authenticity in the FT authentication sequence, as defined in 13.8 (FT authentication sequence).

The KEK2 shall be computed as the next KEK2_bits of the PTK:

KEK2 = (#3506)ExtractBits(PTK, KCK_bits+KEK_bits+TK_bits+KCK2_bits, KEK2_bits)

The KEK2 is used to provide data confidentiality for certain fields in the FT authentication sequence, as defined in 13.8 (FT authentication sequence).

For vendor-specific cipher suites, the length of the temporal key (and the value of Length) depend on the vendor-specific algorithm.

The temporal key(11ba), and if WUR frame protection is negotiated, the WTK is configured into the STA by the SME through the use of the MLME-SETKEYS.request primitive. The STA uses the temporal key with the pairwise cipher suite; interpretation of this value is specific to the cipher suite.

The PTK is referenced and named as follows:


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PTKName = Truncate-128(SHA-256(PMKR1Name || “FT-PTKN” || SNonce || ANonce || BSSID || STA-ADDR))

where
“FT-PTKN” is treated as an ASCII string

The PTKName is used to identify the PTK.

#### 12.7.1.7 Beacon protection key hierarchy

The Authenticator shall select the BIGTK as a random value each time it is generated.

The Authenticator may update the BIGTK for any reason, including:

a) The disassociation or deauthentication of a STA.
b) An event within the SME that triggers a group key handshake.
c) The reception of a WNM Notification Request frame indicating beacon protection failure.

The BIGTK is configured via the MLME-SETKEYS.request primitive; see 6.5.14 (SetKeys). The BIGTK configuration is described in the EAPOL-Key state machines; see 12.7.9 (RSNA Supplicant key management state machine) and 12.7.10 (RSNA Authenticator key management state machine).

The BIPN is used to provide replay protection.

#### 12.7.1.8 Wake-up radio integrity group temporal key (WIGTK) hierarchy(11ba)

The Authenticator shall select the WIGTK as a random value each time it is generated.

The Authenticator may update the WIGTK for any reason, including:

a) The disassociation or deauthentication of a WUR non-AP STA.
b) An event within the SME that triggers a group key handshake.

The WIGTK is configured via the MLME-SETKEYS.request primitive; see 6.5.14 (SetKeys). The WIGTK configuration is described in the EAPOL-Key state machines; see 12.7.9 (RSNA Supplicant key management state machine) and 12.7.10 (RSNA Authenticator key management state machine).

The WIPN is used to provide replay protection.

### 12.7.2 EAPOL-Key frames

(#1836)IEEE Std 802.11 uses EAPOL-Key PDUs, each carried in one or more EAPOL-Key frames, to exchange information between STAs’ Supplicants and Authenticators. These exchanges result in cryptographic keys and synchronization of security association state. (#1843)EAPOL-Key PDUs are used to implement the:

— 4-way handshake, to confirm that the PMK between associated STAs is the same and live and to transfer the GTK to the STA.
— Group key handshake, to update the GTK at the STA.

When priority processing of Data frames is supported, an SME should send (#1836)EAPOL-Key PDUs at the highest priority.

(#3467)The bit and octet convention for fields in the (#1836)EAPOL-Key PDU are defined in 11.2 of (#3469)IEEE Std 802.1X-2020. (#1836)EAPOL-Key PDUs containing invalid field values shall be silently discarded. Figure 12-35 (EAPOL-Key PDU format(#1836)(#1406)(#4233)) depicts the format of an

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(#1836)EAPOL-Key PDU. (#3394)The Protocol Version, Packet Type, Packet Body Length, and Packet Body fields are specified in 11.3 of IEEE Std 802.1X-2020.

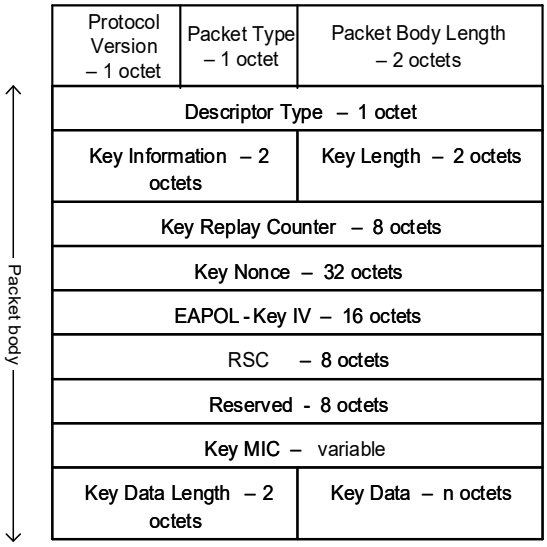


**Figure 12-35—EAPOL-Key PDU format(#1836)(#1406)(#4233)**

(#3394)(#4230)The IEEE 802.11 Key Descriptor consists of the fields from and including the Descriptor Type field to and including the Key Data field in Figure 12-36 (Key Information bit format).

(#3394)There shall be no octets in the Packet Body field of the EAPOL-Key PDU after the Key Data field.

(#3465)NOTE 1—IEEE Std 802.1X-2020 says that for EAPOL-Key frames "The first two fields in the Descriptor Body [i.e., after the Descriptor Type field] comprise a Subtype and a Version, but the IEEE 802.11 EAPOL-Key frames have a key type instead of the subtype."

(#3468)NOTE 2—There might be octets in the MSDU carrying the EAPOL-Key PDU after the Packet Body field (see 11.3 of IEEE Std 802.1X-2020).

The fields of (#1836)an EAPOL-Key PDU are as follows:

a) **Descriptor Type.** This field has a value defined by (#3469)IEEE Std 802.1X-2020, identifying an IEEE 802.11 Key Descriptor.

b) **Key Information**. This field specifies characteristics of the key. See Figure 12-36 (Key Information bit format).

| B0 B2 | B3 | B4 B5 | B6 | B7 | B8 | B9 | B10 | B11 | B12 | B13 B15 |
|---|---|---|---|---|---|---|---|---|---|---|
| Key Descriptor Version | Key Type | Reserved | Install | Key Ack | Key MIC Present(#1829) | Secure | Error | Request | Encrypted Key Data | Reserved |

**Figure 12-36—Key Information bit format**

The bit convention used is as in 11.2 of (#3469)IEEE Std 802.1X-2020. The subfields of the Key Information field are as follows:

1) Key Descriptor Version (bits 0–2) shall be set to 0 on all transmitted (#1836)EAPOL-Key PDUs indicating that the (#1836)EAPOL-Key PDU is constructed and processed according to


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the negotiated AKM as described in Table 12-11 (Integrity and key wrap algorithms(#3244)) except under the following circumstances:

i) The value 1 shall be used for all (#1836)EAPOL-Key PDUs to a STA when the negotiated AKM is 00-0F-AC:1 or 00-0F-AC:2 and the pairwise cipher is TKIP or "Use group data cipher suite"(#6020). In this case, the "Deprecated" row in Table 12-11 (Integrity and key wrap algorithms(#3244)) is used.

ii) (#432)The value 2 shall be used for all (#1836)EAPOL-Key PDUs to a STA when the negotiated AKM is 00-0F-AC:1 or 00-0F-AC:2 and either the pairwise or the group data cipher(#6020) is an RSNA mechanism other than TKIP. In this case, the matching row in Table 12-11 (Integrity and key wrap algorithms(#3244)) is used.

iii) The value 3 shall be used for all (#1836)EAPOL-Key PDUs to a STA when the negotiated AKM is 00-0F-AC:3, 00-0F-AC:4, 00-0F-AC:5, or 00-0F-AC:6. In this case, the matching row in Table 12-11 (Integrity and key wrap algorithms(#3244)) is used.

2) Key Type (bit 3) specifies whether this (#1836)EAPOL-Key PDU is part of a 4-way handshake deriving a PTK.

   i) The value 0 (Group) indicates the message is not part of a PTK derivation.

   ii) The value 1 (Pairwise) indicates the message is part of a PTK derivation.

3) Reserved (bits 4–5).

4) Install (bit 6).

   i) If the value of Key Type (bit 3) is 1, then for the Install bit,

      — The value 1 means the IEEE 802.1X component shall configure the temporal key derived from this message into (#408)the IEEE 802.11 MAC.

      — The value 0 means the IEEE 802.1X component shall not configure the temporal key into the IEEE 802.11 MAC.

   ii) If the value of Key Type (bit 3) is 0, then this bit is reserved.

5) (#1788)Key Ack (bit 7) is set to 1 if sent by the Authenticator, and is set to 0 otherwise. The Supplicant's response to this message shall use the same replay counter as this message.

6) (#1829)Key MIC Present (bit 8) is set to 1 if not using an AEAD cipher and a MIC is in this (#1836)EAPOL-Key PDU and is set to 0 otherwise.

NOTE 3—AEAD cipher mode is described in 12.11.2.7 (AEAD cipher mode for FILS).(#3446)

7) (#1082)Secure (bit 9) indicates whether the Authenticator and the Supplicant share a PTKSA. It is set to 0 in messages 1 and 2 of the 4-way handshake if the Authenticator and the Supplicant do not share a PTKSA. Otherwise, it is set to 1.

(#1082)NOTE 4—Some deployed Authenticator and Supplicant implementations set the Secure bit to 0 in messages 1 and 2 of the 4-way handshake that is used for PTK rekeying even when they already share a previously generated PTKSA. In the interests of interoperability, implementations might ignore the Secure bit in received frames.

(#1786)NOTE 5—The Secure bit is set to 1 in messages 3 and 4 of the 4-way handshake.

8) (#1578)(#1840)Error (bit 10) is set to 1 by a Supplicant to report that a MIC failure occurred in a TKIP MSDU (in which case (#3496)Request (bit 11) is also set to 1); it is set to 0 otherwise.

9) Request (bit 11) is set to 1 by a Supplicant to request that the Authenticator initiate either a 4-way handshake or group key handshake, and is set to 1 by a Supplicant in a Michael MIC Failure Report frame(#1853). The Supplicant shall not set this bit to 1 in on-going 4-way handshakes, i.e., the Key Ack bit (bit 7) shall not be set to 1 in any message in which the Request bit is 1. The Authenticator shall never set this bit to 1.

(#1840)In an EAPOL-Key request frame, the Secure bit is set to 1, the Key MIC Present bit is set to 1 if not using an AEAD cipher and is set to 0 otherwise, and the (#7027)Install bit is set to 0.

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In a Michael MIC Failure Report frame(#1853), setting the bit is not a request to initiate a new handshake. However, the recipient may initiate a new handshake on receiving such a message.

(#1844)An EAPOL-Key request frame shall not be transmitted from a TDLS STA to a TDLS peer STA.

(#1839)NOTE 6—An EAPOL-Key request frame requests initiation of a 4-way handshake or group key handshake. An EAPOL-Start PDU requests initiation of an EAP handshake.

10) Encrypted Key Data (bit 12) is set to 1 if the Key Data field is encrypted and is set to 0 if the Key Data field is not encrypted. This subfield shall be set to 1, and the Key Data field shall be encrypted, if any key material (e.g., GTK) is included in the frame.

11) Reserved (bits 13–15).

c) **Key Length**. This field is represented as an unsigned integer. The value defines the length in octets of the (#1832)temporal key. See Table 12-8 (Cipher suite key lengths(#1083)(#3532)).

**Table 12-8—Cipher suite key lengths(#1083)(#3532)**

| Cipher suite | Key length (octets) | TK_bits (bits) |
|---|---|---|
| BIP-CMAC-128 | 16 | 128 |
| BIP-CMAC-256 | 32 | 256 |
| BIP-GMAC-128 | 16 | 128 |
| BIP-GMAC-256 | 32 | 256 |
| CCMP-128 | 16 | 128 |
| CCMP-256 | 32 | 256 |
| GCMP-128 | 16 | 128 |
| GCMP-256 | 32 | 256 |
| TKIP | 32 | 256 |

d) **Key Replay Counter**. This field is represented as an unsigned integer, and is initialized to 0 when the PMK is established. The Supplicant shall use the key replay counter in the received (#1836)EAPOL-Key PDU when responding to an (#1836)EAPOL-Key PDU. It carries a sequence number that the protocol uses to detect replayed (#1836)EAPOL-Key PDUs.

The Supplicant and Authenticator shall track the key replay counter per security association. The key replay counter shall be initialized to 0 on (re)association. The Authenticator shall increment the key replay counter on each successive (#1836)EAPOL-Key PDU.

When replying to a message from the Authenticator, the Supplicant shall use the Key Replay Counter field value from the last valid (#1836)(#6308)EAPOL-Key PDU received from the Authenticator. (#1822)The Authenticator shall use the key replay counter to identify invalid messages. The Supplicant (#1822)shall also use the key replay counter and ignore (#1836)EAPOL-Key PDUs with a Key Replay Counter field value smaller than or equal to any received in a valid message. The local key replay counter variable (#7194)(#1822)shall not be updated until after the (#1830)(#1836)EAPOL-Key PDU MIC is checked and is found to be valid.

(#6266)NOTE 7—In other words, the Supplicant does not update the key replay counter(#7194) for message 1 in the 4-way handshake, as it includes no MIC. This implies the Supplicant needs to allow for retransmission of message 1 when checking for the key replay counter of message 3.


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The Supplicant shall maintain a separate key replay counter for sending EAPOL-Key request frames to the Authenticator(#6115). The Authenticator shall maintain a separate replay counter to filter received EAPOL-Key request frames.

(#1709)NOTE 8—Since EAPOL-Key request frames are only transmitted by the Supplicant, the Supplicant has two replay counters on transmission and one replay counter on reception, while the Authenticator has one replay counter on transmission and two replay counters on reception.

NOTE 9—The key replay counter does not play any role beyond a performance optimization in the 4-way handshake. In particular, replay protection is provided by selecting a never-before-used nonce value to incorporate into the PTK. It does, however, play a useful role in the group key handshake.

e) **Key Nonce**. This field conveys the ANonce from the Authenticator and the SNonce from the Supplicant. (#3466)It should contain 0 if a nonce is not required to be sent.

(#3466)NOTE 9—Some deployed Supplicant implementations set the Key Nonce field in message 4 of the 4-way handshake to the same value as in message 2.

f) **EAPOL-Key IV**. This field contains the IV used with the (#3744)PTK-KEK. It shall contain 0 when an IV is not required. It should be initialized by taking the current value of the global key counter (see 12.7.10 (RSNA Authenticator key management state machine)) and then incrementing the counter. Note that only the lower 16 octets of the counter value are used.

g) (#1406)**RSC**. This field contains the current receive sequence counter (RSC) for the GTK being installed. It is used in message 3 of the 4-way handshake and message 1 of the group key handshake, where it is used to synchronize the IEEE 802.11 replay state. It may also be used in the Michael MIC Failure Report frame, to report the TSC field value of the frame experiencing a MIC failure. It shall contain 0 in other messages. If the RSC is less than 8 octets in length, it is stored in the first octets and the remaining octets are set to 0. The least significant octet of the RSC is in the first octet of the (#1406)RSC field. The RSC for TKIP is the TKIP sequence number (TSC); for CCMP and GCMP it is the packet number (PN); see Table 12-9 (RSC field(#1406))(#3056).

**Table 12-9—RSC field(#1406)**

| RSC 0 | RSC 1 | RSC 2 | RSC 3 | RSC 4 | RSC 5 | RSC 6 | RSC 7 |
|---|---|---|---|---|---|---|---|
| TSC0 | TSC1 | TSC2 | TSC3 | TSC4 | TSC5 | 0 | 0 |
| PN0 | PN1 | PN2 | PN3 | PN4 | PN5 | 0 | 0 |

h) **Key MIC**. When the (#1823)Key MIC (#1840)Present subfield (of the Key Information field) is equal to 1, the (#1830)Key MIC field is a MIC of the (#1836)EAPOL-Key PDU (see Figure 12-35 (EAPOL-Key PDU format(#1836)(#1406)(#4233))), i.e., from and including the Protocol Version field of the EAPOL PDU (see Figure 12-35 (EAPOL-Key PDU format(#1836)(#1406)(#4233))) to and including the Key Data field, calculated with the Key MIC field set to 0. If the Encrypted Key Data subfield (of the Key Information field) is equal to 1, the Key Data field is encrypted prior to computing the MIC. When using an AEAD cipher, the (#1830)Key MIC (#1840)Present field is not present. When not using an AEAD cipher, when the Key MIC subfield (of the Key Information field) is equal to 0, the Key MIC field is set to 0. The length of this field depends on the negotiated AKM as defined in 12.7.3 (EAPOL-Key PDU construction and processing) (see Table 12-11 (Integrity and key wrap algorithms(#3244))).

i) **Key Data Length**. This field is an unsigned integer. This represents the length of the Key Data field in octets. If the Encrypted Key Data subfield (of the Key Information field) is 1, the length is the length of the Key Data field after encryption, including any padding. The Key Data Length field may be 0 when the Encrypted Key Data subfield is 1.(#190)

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j) **Key Data**. This field is a variable length field that is used to include any additional data required for the key exchange that is not included in the fields of the (#1836)EAPOL-Key PDU. The additional data may be zero or more element(s) (such as the RSNE and RSNXE) and zero or more key data encapsulation(s) (KDEs) (such as GTK KDE or PMKID KDE(s)). KDEs shall be encapsulated using the format shown in Figure 12-37 (KDE format).

**Figure 12-37—KDE format**

The Type field shall be set to 0xdd. The Length field specifies the number of octets in the OUI, Data Type, and Data fields. The OUI field contains either an OUI or CID. The order of the OUI field is described in 9.2.2 (Conventions).

NOTE 10—The KDE format is a subset of the Vendor Specific element format (see 9.4.2.24 (Vendor Specific element)). It is generally not possible to distinguish, from the format, a Vendor Specific element and a vendor specific KDE.

Table 12-10 (KDE selectors) lists the KDE selectors defined by this standard. (#3486)Unless stated otherwise, KDEs defined in this standard are not extensible.

**Table 12-10—KDE selectors**

| OUI | Data type | Meaning |
|---|---|---|
| 00-0F-AC | 0 | Reserved |
| 00-0F-AC | 1 | GTK KDE |
| 00-0F-AC | 2 | Reserved |
| 00-0F-AC | 3 | MAC address KDE |
| 00-0F-AC | 4 | PMKID KDE |
| 00-0F-AC | 5 | Reserved |
| 00-0F-AC | 6 | Nonce KDE |
| 00-0F-AC | 7 | Lifetime KDE |
| 00-0F-AC | 8 | Error KDE |
| 00-0F-AC | 9 | IGTK KDE |
| 00-0F-AC | 10 | Key ID KDE |
| 00-0F-AC | 11 | Multi-band GTK KDE |
| 00-0F-AC | 12 | Multi-band Key ID KDE |
| 00-0F-AC | 13 | OCI KDE |
| 00-0F-AC | 14 | BIGTK KDE |
| (11ba)00-0F-AC | 15 | WIGTK KDE |
| 00-0F-AC | (11ba)16–255 | Reserved |
| Other OUI or CID | Any | Vendor specific |


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A STA shall ignore any elements and KDEs it does not understand.

If the Encrypted Key Data subfield (of the Key Information field) is 1, the entire Key Data field shall be encrypted. If the Key Data field uses the NIST AES key wrap, then the Key Data field shall be padded before encrypting if the length of the key data is nonzero and less than 16 octets, or if it is not a multiple of 8 octets.(#190) The padding consists of appending a single octet 0xdd followed by zero or more 0x00 octets. When processing a received (#1836)EAPOL-Key PDU, the receiver shall ignore this trailing padding. If the Key Data field uses an AEAD cipher, then the Key Data field shall not be padded and the AAD for the encipherment operation shall be the data of the (#1836)EAPOL-Key PDU from the (#3464)Protocol Version field of the EAPOL PDU (see Figure 12-35 (EAPOL-Key PDU format(#1836)(#1406)(#4233))) (inclusive) to the Key Data field (exclusive). Key Data fields that are encrypted, but do not contain the key material (e.g., the GTK)(#1568), shall be accepted.

If the key material (e.g., the GTK)(#1568) is included in the Key Data field, but the Key Data field is not encrypted, the (#1836)EAPOL-Key PDU(#1568) shall be ignored.

The format of the GTK KDE is shown in Figure 12-38 (GTK KDE format(#3492)).

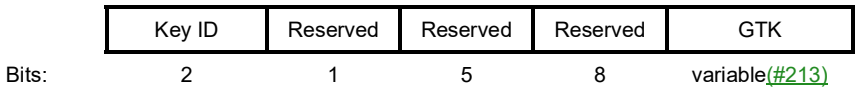


**Figure 12-38—GTK KDE format(#3492)**

(#3493)The Key ID field contains the GTK key ID.

(#3493)The GTK field contains the GTK.

(#3492)The format of the MAC address KDE is shown in Figure 12-39 (MAC address KDE format).

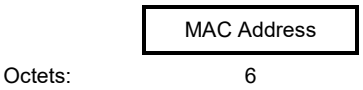


**Figure 12-39—MAC address KDE format**

(#3493)The MAC Address field contains a MAC address.

The format of the PMKID KDE is shown in Figure 12-40 (PMKID KDE format).

**Figure 12-40—PMKID KDE format**

(#3493)The PMKID field contains a PMKID.

The format of the Nonce KDE is shown in Figure 12-41 (Nonce KDE format).

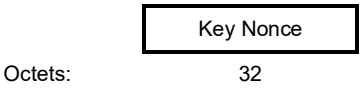


**Figure 12-41—Nonce KDE format**

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(#3493)The Key Nonce field contains a key nonce.

The format of the Lifetime KDE is shown in Figure 12-42 (Lifetime KDE format). (#3493)The Key Lifetime field contains a key lifetime in seconds, in big endian octet order.

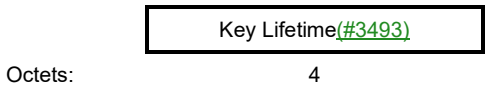


**Figure 12-42—Lifetime KDE format**

The format of the Error KDE is shown in Figure 12-43 (Error KDE format). (#3493)The Error Type field contains an error type, in big endian octet order.

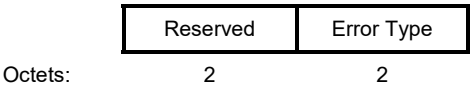


**Figure 12-43—Error KDE format**

(#3493)The format of the IGTK KDE is shown in Figure 12-44 (IGTK KDE format).

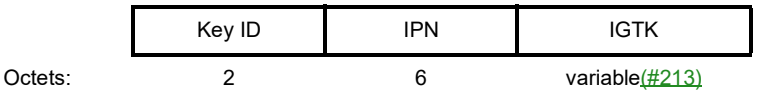


**Figure 12-44—IGTK KDE format**

(#3493)The Key ID field contains the IGTK key ID.

(#3493)The IPN field contains the IPN. The (#3363)IPN field contains the (#6606)last IPN used by the transmitter, and it is used by the receiver as the initial value for the replay counter for the IGTK.

(#3493)The IGTK field contains the IGTK.

The format of the Key ID KDE is shown in Figure 12-45 (Key ID KDE format).

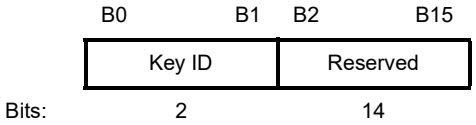


**Figure 12-45—Key ID KDE format**

The Key ID field contains the Authenticator selected (#3493)key ID.

The format of the Multi-band GTK KDE is shown in Figure 12-46 (Multi-band GTK KDE format).

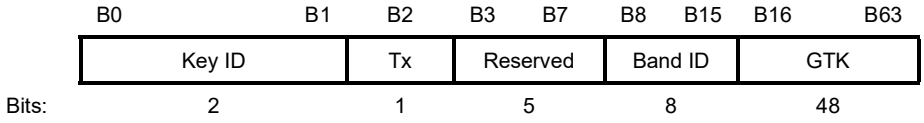


**Figure 12-46—Multi-band GTK KDE format**

The definitions of the Key ID, Tx, and GTK fields are the same as in the GTK KDE described above.


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The Band ID field contains the identification of the frequency band (see 9.4.1.43 (Band ID field)).

The format of the Multi-band Key ID KDE is shown in Figure 12-47 (Multi-band Key ID KDE format).

**Figure 12-47—Multi-band Key ID KDE format**

The definitions of the Key ID and Band ID fields are the same as in the Multi-band GTK KDE described above.

The format of the OCI KDE is shown in Figure 12-48 (OCI KDE format).

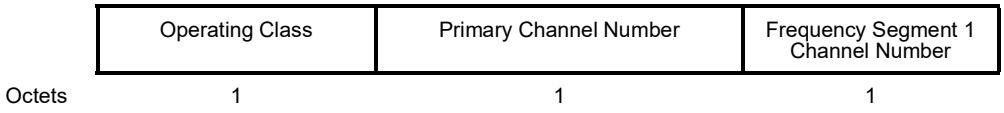


**Figure 12-48—OCI KDE format**

The definitions of Operating Class, Primary Channel Number, and Frequency Segment 1 Channel Number are the same as those described in 9.4.2.235 (OCI element).

The format of the BIGTK KDE is shown in Figure 12-49 (BIGTK KDE format).

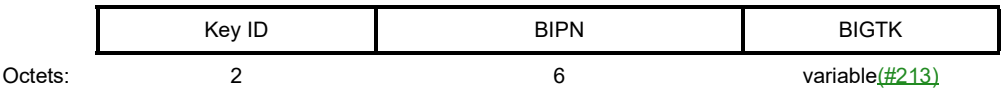


**Figure 12-49—BIGTK KDE format**

(#3493)The Key ID field contains the BIGTK key ID.

The BIPN field contains the BIPN(#1422) that was (#6054)used to protect the last protected Beacon frame(#6606), and it is used by the receiver as the initial value for the replay counter for the BIGTK.

(#3493)The BIGTK field contains the BIGTK.

(11ba)The format of the WIGTK KDE is shown in Figure 12-50 (WIGTK KDE format(#3493)(11ba)).

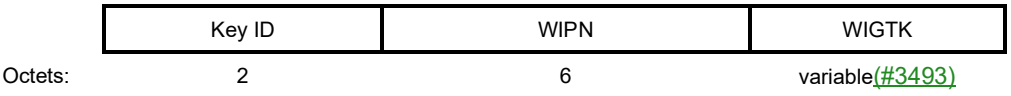


**Figure 12-50—WIGTK KDE format(#3493)(11ba)**

(#3493)The Key ID field contains the WIGTK key ID.

(11ba)The WIPN field contains the WIPN(#1422) that was used for computing the MIC in the last protected broadcast or group addressed WUR Wake-up frame(#6606), and it is used by the receiver as the initial value for the replay counter for the WIGTK.

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(#3493)The WIGTK field contains the WIGTK.

(#7149)(#1843)The following (#1836)EAPOL-Key PDUs are used to implement the (#3416)handshakes:

— **4-way handshake message 1** (#4313)(#1836)EAPOL-Key PDU with the Key Type subfield equal to 1. The fields and their values in the EAPOL-Key PDU are described in 12.7.2 (EAPOL-Key frames). (#3638)Use of the Key Data field to indicate a PMKID when a cached PMKSA is being used in this key derivation is defined in 12.6.8.3 (Cached PMKSAs and RSNA key management).(#589)(#190)

— **4-way handshake message 2** (#4313)(#1836)EAPOL-Key PDU with the Key Type subfield equal to 1. (#589-Ed1)(#190)

An ESS Supplicant's SME shall insert the RSNE it sent in its (Re)Association Request frame, and shall insert the RSNXE it sent in its (Re)Association Request frame if the RSNXE is present in the (Re)Association Request frame it sent. The RSNE and the RSNXE are included as transmitted in the Management frame. On receipt of message 2, the Authenticator's SME shall validate the selected security configuration against the RSNE received in the (Re)Association Request frame, and shall validate the RSNXE included in message 2 against the RSNXE received in the (Re)Association Request frame from the Supplicant.

An IBSS Supplicant's SME shall insert an RSNE containing a selected pairwise cipher suite. The Authenticator's SME shall validate that the pairwise cipher suite selected is one of its configured cipher suites and that the (#6020)group data cipher suite, group management cipher suite (if management frame protection is enabled), and AKM are consistent.

— **4-way handshake message 3** (#4313)(#1836)EAPOL-Key PDU with the Key Type subfield equal to 1.(#190)

An Authenticator's SME shall insert the RSNE it sent in its Beacon or Probe Response frame, and shall insert the RSNXE it sent in its Beacon or Probe Response frame if the RSNXE is present in the Beacon or Probe Response frame it sent. When this message 3 is part of a fast BSS transition initial mobility domain association or an association started through the FT protocol, the PMKR1Name is added in the PMKID List field of the RSNE. The Supplicant's SME shall validate the selected security configuration against the RSNE received in message 3, and shall validate the RSNXE included in message 3 against the RSNXE received in the Beacon or Probe Response frame from the Authenticator. If the second optional RSNE is present, the STA shall either use that cipher suite with its pairwise key or deauthenticate. In any of these cases, if the values do not match, then the receiver shall consider the RSNE or the RSNXE modified and shall use the MLME-DEAUTHENTICATE.request primitive to break the association. A security error should be logged at this time.

It may happen, for example, that a Supplicant selects a pairwise cipher suite which is advertised by an AP, but which policy disallows for this particular STA. An Authenticator may, therefore, insert a second RSNE to overrule the STA's selection. An Authenticator's SME shall insert the second RSNE, after the first RSNE, only for this purpose. (#4263)The Pairwise Cipher Suite Count field in the second RSNE included shall be set to 1 and the Pairwise Cipher Suite List field shall contain one of the ciphers advertised by the Authenticator. All other fields in the second RSNE, disregarding the Length field, shall be identical to those in the first RSNE.(#190)

— **4-way handshake message 4** (#4313)(#1836)EAPOL-Key PDU with the Key Type subfield equal to 1.(#190)

— **Group key handshake message 1** (#4313)(#1836)EAPOL-Key PDU with the Key Type subfield equal to 0.(#190)

— **Group key handshake message 2** (#4313)(#1836)EAPOL-Key PDU with the Key Type subfield equal to 0.(#190)

(#7149)The key wrap algorithm selected depends on the negotiated AKM as defined in 12.7.3 (EAPOL-Key PDU construction and processing).


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### 12.7.3 EAPOL-Key PDU construction and processing

EAPOL-Key frames are constructed and processed according to the negotiated AKM at association time. The negotiated AKM determines what algorithm is used to construct and verify a MIC, the size of the MIC, and the algorithm used to wrap and unwrap the Key Data field.

Table 12-11 (Integrity and key wrap algorithms(#3244)) indicates the particular algorithms to use when constructing and processing EAPOL-Key frames and FT authentication sequence. The AKM of "Deprecated" indicates (#3266)AKM 00-0F-AC:1 or 00-0F-AC:2 when either TKIP or "Use group data cipher suite"(#6020) is the negotiated pairwise cipher. For all other AKMs the negotiated pairwise cipher suite does not influence the algorithms used to process EAPOL-Key frames. For (#3266)AKMs 00-0F-AC:16 and 00-0F-AC:17 (FILS with FT), different keys and algorithms are used in EAPOL-Key frames and FT authentication sequence. These different cases are indicated in (#3753)Table 12-11 (Integrity and key wrap algorithms(#3244)) in <EAPOL-Key> / <FT authentication> format. For AKM 00-0F-AC:18, different keys and algorithms are used as defined in 12.14 (Opportunistic Wireless Encryption(#6088))(#6088) based on the selected hash algorithm. These different cases are indicated in Table 12-11 (Integrity and key wrap algorithms(#3244)) in <value when SHA-256 is used> / <value when SHA-384 is used> / <value when SHA-512 is used> format. For AKMs 00-0F-AC:24 and 00-0F-AC:25, different keys and algorithms are used based on the hash algorithm identified in 12.4.2 (Assumptions on SAE) and Table 12-12 (Hash identified in SAE and integrity algorithm(M67)). These different cases are indicated in Table 12-11 (Integrity and key wrap algorithms(#3244)) in <value when SHA-256 is used> / <value when SHA-384 is used> / <value when SHA-512 is used> format.

HMAC is defined in IETF RFC 2104. MD5 is defined in IETF RFC 1321. SHA-1 is defined by FIPS 180-4. The NIST AES key wrap algorithm is defined in IETF RFC 3394. AES-128-CMAC is defined by NIST Special Publication 800-38B and also found in IETF RFC 4493 [B44].

**Table 12-11—Integrity and key wrap algorithms(#3244)**

| AKM | Integrity algorithm | KCK_bits | Size of MIC (octets) | Key wrap algorithm | KEK_bits | KCK2_bits | KEK2_bits |
|---|---|---|---|---|---|---|---|
| Deprecated | HMAC-MD5 | 128 | 16 | ARC4 | 128 | 0 | 0 |
| 00-0F-AC:1 | HMAC-SHA-1-128 | 128 | 16 | NIST AES Key Wrap | 128 | 0 | 0 |
| 00-0F-AC:2 | HMAC-SHA-1-128 | 128 | 16 | NIST AES Key Wrap | 128 | 0 | 0 |
| 00-0F-AC:3 | AES-128-CMAC | 128 | 16 | NIST AES Key Wrap | 128 | 0 | 0 |
| 00-0F-AC:4 | AES-128-CMAC | 128 | 16 | NIST AES Key Wrap | 128 | 0 | 0 |
| 00-0F-AC:5 | AES-128-CMAC | 128 | 16 | NIST AES Key Wrap | 128 | 0 | 0 |
| 00-0F-AC:6 | AES-128-CMAC | 128 | 16 | NIST AES Key Wrap | 128 | 0 | 0 |
| 00-0F-AC:8 | AES-128-CMAC | 128 | 16 | NIST AES Key Wrap | 128 | 0 | 0 |
| 00-0F-AC:9 | AES-128-CMAC | 128 | 16 | NIST AES Key Wrap | 128 | 0 | 0 |

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**Table 12-11—Integrity and key wrap algorithms(#3244) *(continued)***

| AKM | Integrity algorithm | KCK_bits | Size of MIC (octets) | Key wrap algorithm | KEK_bits | KCK2_bits | KEK2_bits |
|---|---|---|---|---|---|---|---|
| 00-0F-AC:11 | HMAC-SHA-256 | 128 | 16 | NIST AES Key Wrap | 128 | 0 | 0 |
| 00-0F-AC:12 | HMAC-SHA-384 | 192 | 24 | NIST AES Key Wrap | 256 | 0 | 0 |
| 00-0F-AC:13 | HMAC-SHA-384 | 192 | 24 | NIST AES Key Wrap | 256 | 0 | 0 |
| 00-0F-AC:14 | AES-SIV-256 | 0 | 0 | AES-SIV-256 | 256 | 0 | 0 |
| 00-0F-AC:15 | AES-SIV-512 | 0 | 0 | AES-SIV-512 | 512 | 0 | 0 |
| 00-0F-AC:16 | AES-SIV-256/ AES-128-CMAC | 0 | 0/16 | AES-SIV-256/ NIST AES Key Wrap | 256 | 128 | 128 |
| 00-0F-AC:17 | AES-SIV-512/ HMAC-SHA-384 | 0 | 0/24 | AES-SIV-512/ NIST AES Key Wrap | 512 | 192 | 256 |
| 00-0F-AC:18 (#1084) | HMAC-SHA-256/ HMAC-SHA-384/ HMAC-SHA-512 | 128/192/ 256 | 16/24/32 | NIST AES Key Wrap | 128/256/ 256 | 0 | 0 |
| 00-0F-AC:19(M20) | HMAC-SHA-384 | 192 | 24 | NIST AES Key Wrap | 256 | 0 | 0 |
| 00-0F-AC:20(M20) | HMAC-SHA-384 | 192 | 24 | NIST AES Key Wrap | 256 | 0 | 0 |
| 00-0F-AC:21(11az) | See NOTE | N/A | N/A | N/A | N/A | N/A | N/A |
| 00-0F-AC:22(M20) | HMAC-SHA-384 | 192 | 24 | NIST AES Key Wrap | 256 | 0 | 0 |
| 00-0F-AC:23(M20) | HMAC-SHA-384 | 192 | 24 | NIST AES Key Wrap | 256 | 0 | 0 |
| 00-0F-AC:24(M21) | (M67)HMAC-SHA-256/HMAC-SHA-384/HMAC-SHA-512 (see Table 12-12 (Hash identified in SAE and integrity algorithm(M67))) | (M67)128/ 192/256 | (M67)16 /24/32 | NIST AES Key Wrap | (M67)128/ 256/256 | 0 | 0 |
| 00-0F-AC:25(M21) | (M67)HMAC-SHA-256/HMAC-SHA-384/HMAC-SHA-512 (see Table 12-12 (Hash identified in SAE and integrity algorithm(M67))) | (M67)128/ 192/256 | (M67)16 /24/32 | NIST AES Key Wrap | (M67)128/ 256/256 | 0 | 0 |
| NOTE 1—Keys derived using PASN AKM are not used to protect EAPOL frames.(11az) (#8200)NOTE 2—AES-SIV-256 and AES-SIV-512 are AEAD ciphers. | | | | | | | |



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**Table 12-12—Hash identified in SAE and integrity algorithm(M67)**

| Hash identified in 12.4.2 (Assumptions on SAE) | Integrity algorithm |
|---|---|
| SHA-256 | HMAC-SHA-256 |
| SHA-384 | HMAC-SHA-384 |
| SHA-512 | HMAC-SHA-512 |

### 12.7.4 EAPOL-Key PDU notation(#1836)

The following notation is used throughout the remainder of 12.7 (Keys and key distribution) and 13.4 (FT initial mobility domain association) to represent (#1836)EAPOL-Key PDUs:

EAPOL-Key(S, M, A, I, K, Reserved, (#1406)RSC, ANonce/SNonce, MIC, {Key Data})

where

- S — (#1082)is the Secure bit of the Key Information field
- M — means the MIC is available in message. (#216)This should be set in all messages except message 1 of a 4-way handshake. This is the (#1829)Key MIC Present bit of the Key Information field. (#1831)When using an AEAD cipher, this (#1829)Key MIC Present bit is set to 0 regardless of the M parameter value.
- A — means a response is required to this message. This is used when the receiver should respond to this message. This is the Key Ack bit of the Key Information field.
- I — is the Install bit: indicates whether to install (1) or not install (0) for the pairwise key. This is the Install bit of the Key Information field(#216).
- K — is the key type: P (Pairwise), G (Group); this is the Key Type bit of the Key Information field
- Reserved — is reserved
- (#1406)RSC — is the RSC; this is the (#1406)RSC field
- ANonce/SNonce — is the Authenticator or Supplicant nonce, respectively. (#216)This is the Key Nonce field.
- MIC — is the integrity check, which is generated using the (#3744)PTK-KCK. This is the Key MIC field. (#1831)When using an AEAD cipher, (#1825)this parameter is ignored, and no Key MIC field is included in the EAPOL-Key PDU(#216).
- {Key Data} — is a sequence of zero or more elements and KDEs, concatenated and contained in the Key Data field, where
  - RSNE — is (#3493)the RSNE, described in 9.4.2.23 (RSNE)
  - RSNE[KeyName] — is the RSNE, with the PMKID List field set to KeyName
  - GTK[N] — is the GTK KDE, with the (#3493)Key ID field set to N (The key ID specifies which index is used for this GTK. (#3056)Indices 0 and 3 shall not be used for GTKs)
  - FTE — is the (#1776)FTE, described in 9.4.2.46 (FTE(#1776))
  - MDE — is the (#1776)MDE, described in 9.4.2.45 (MDE(#1776))
  - TIE[IntervalType] — is a (#1776)TIE of type IntervalType, as described in 9.4.2.47 (TIE(#1776)), containing e.g., for type KeyLifetime, the lifetime of the FT key hierarchy
  - IGTK[M] — is the (#3493)IGTK KDE, with the Key ID field set to M
  - IPN — (#6605)is the last IPN, as provided by the IGTK KDE
  - BIGTK[Q] — is the (#3493)BIGTK KDE, with the Key ID field set to Q

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| | |
|---|---|
| BIPN | (#6605)is the last BIPN, as provided by the BIGTK KDE |
| (11ba)WIGTK[R] | is the (#3493)WIGTK KDE, with the Key ID field set to R |
| (11ba)WIPN | (#6605)is the last WIPN, as provided by the WIGTK KDE |
| PMKID | is (#3493)the PMKID KDE and is the PMK identifier used during the 4-way handshake for PMK identification |
| OCI(#8238) | is (#3493)the OCI KDE |
| RSNXE | is (#3493)the RSNXE, described in 9.4.2.240 (RSNXE(#1776)) |
| PMKID | (#3493)is the PMK identifier for the PMKSA selected by the Authenticator |
| (M166))SSID | is the SSID element, described in 9.4.2.2 (SSID element) |
| (#6590)[a] | means that a is optionally or conditionally present in {Key Data} |

### 12.7.5 Nonce generation

The following is a description of nonce generation.

All STAs contain a global key counter, which is 256 bits in size. It should be initialized at system boot-up time to a fresh cryptographic-quality random number. Refer to J.5 (Suggestions for random number generation) on random number generation. It is recommended that the counter value is initialized to the following:

PRF-256(Random number, "Init Counter", Local MAC Address || Time)

The local MAC address should be AA on the Authenticator and SPA on the Supplicant.

The random number is 256 bits in size. Time should be the current time from Network Time Protocol (NTP) or another time in NTP format whenever possible. This initialization causes different initial key counter values to occur across system restarts regardless of whether a real-time clock is available. The key counter can be used as additional input data for nonce generation. A STA derives a random nonce for each new use.

### 12.7.6 4-way handshake

#### 12.7.6.1 General

RSNA defines a protocol using (#1836)EAPOL-Key PDUs called the *4-way handshake*. The handshake completes the IEEE 802.1X authentication process. The information flow of the 4-way handshake is as follows:

Message 1: Authenticator → Supplicant: (#8238)OCI((#3596)0 or 1, 0, 1, 0, P, 0, 0, ANonce, 0, {PMKID})(#6590)

Message 2: Supplicant → Authenticator: EAPOL-Key((#3596)0 or 1, 1, 0, 0, P, 0, 0, SNonce, MIC, {RSNE [, RSNXE] [, OCI]})(#6590)(Ed1)

Message 3: Authenticator→Supplicant:
EAPOL-Key(1, 1, 1, 1, P, 0, (#1406)RSC, ANonce, MIC, {RSNE [, RSNXE] [, OCI], GTK(N)(Ed1) [, IGTK(M, IPN)] [, BIGTK(Q, BIPN)] [, WIGTK(R, WIPN)] [, SSID]})(M166-Ed1)(#6590)

Message 4: Supplicant → Authenticator: EAPOL-Key(1, 1, 0, 0, P, 0, 0, 0, MIC, {}).

The FT initial mobility domain association uses the FT 4-way handshake (#1946)to establish an initial set of security associations: PTKSA, GTKSA, IGTKSA if management frame protection is (#7048)negotiated, BIGTKSA(11ba) if beacon protection is enabled, and WIGTKSA if WUR frame protection is negotiated. The FT 4-way handshake protocol is described in 13.4 (FT initial mobility domain association).

(#6590)The receiver of an EAPOL-Key message shall accept elements and KDEs in the Key Data field in any other.


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The following apply:

- EAPOL-Key(·) denotes an (#1836)EAPOL-Key PDU conveying the specified argument list, using the notation introduced in 12.7.4 (EAPOL-Key PDU notation(#1836)).
- ANonce is a nonce that the Authenticator contributes for PTK generation. ANonce has the same value in message 1 and message 3.
- SNonce is a nonce from the Supplicant for PTK generation.
- P means the pairwise bit is set.
- The MIC is computed over the body of the (#1836)EAPOL-Key PDU (with the Key MIC field first zeroed before the computation) using the (#3744)PTK-KCK defined in 12.7.1.3 (Pairwise key hierarchy)(#4144).
- RSNE represents the appropriate RSNEs.
- (#6590)GTK(N) represents the GTK with its (#3493)key ID.
- OCI KDE contains the current operating channel information for the operating channel in which the (#1836)EAPOL-Key PDU is sent. OCI KDE is present when dot11RSNAOperatingChannelValidationActivated is true on the Supplicant in Message 2 and Authenticator in Message 3. Otherwise it is absent.
- RSNXE, when included in message 2, contains the RSNXE that the Supplicant sent in its (Re)Association Request frame, and when included in message 3, contains the RSNXE that the Authenticator sent in its Beacon or Probe Response frame. RSNXE is present in message 2 if this element is present in the (Re)Association Request frame that the Supplicant sent, and is present in message 3 if this element is present in the Beacon or Probe Response frame that the Authenticator sent.
- (#1954)The Key Data descriptions specify what shall or may be included; nothing else shall be included except that one or more vendor specific KDEs and/or Vendor Specific elements may be included.
- (#6590)PMKID identifies the PMKSA selected by the Authenticator
- (#6590)"[, a]" identifies that element "a" is conditionally present in {Key Data}

(#1273)The Supplicant may request a 4-way handshake to obtain a new PTK by sending an EAPOL-Key request frame with a key type of Pairwise (see 12.7.2 (EAPOL-Key frames)).

(#1273)If dot11RSNAOperatingChannelValidationActivated is true and a channel switch is requested while the handshake is in progress, the handshake should be aborted.

#### 12.7.6.2 4-way handshake message 1

Message 1 uses the following values for each of the (#1836)EAPOL-Key PDU fields:

Descriptor Type = N – see 12.7.2 (EAPOL-Key frames)

Key Information:

Key Descriptor Version = 1 (ARC4 encryption with HMAC-MD5) or 2 (NIST AES key wrap with HMAC-SHA-1-128) or 3 (NIST AES key wrap with AES-128-CMAC), in all other cases 0

Key Type = 1 (Pairwise)

Reserved = 0

Install = 0

Key Ack = 1

(#1829)Key MIC Present = 0

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Secure = (#3302)(#3596)0 in initial 4-way handshake, or 1 when PTK rekeying (but see 12.7.2 (EAPOL-Key frames))

Error = 0

Request = 0

Encrypted Key Data = 0

Reserved = 0 – unused by this protocol version

Key Length = (#3270)Cipher suite dependent; see Table 12-8 (Cipher suite key lengths(#1083)(#3532))

Key Replay Counter = *n* – to allow Authenticator or initiator STA to match the right message 2 from Supplicant or peer STA

Key Nonce = ANonce

EAPOL-Key IV = 0

(#1406)RSC = 0

(#1823)Key MIC = 0; not present when using an AEAD cipher(#3633)

Key Data Length = length of Key Data field in octets

Key Data = PMKID for the PMK being used during PTK generation

Processing for PTK generation is as follows:

The Authenticator sends message 1 to the Supplicant at the end of a successful IEEE 802.1X authentication, after (re)association completes for a STA that has authenticated with SAE or for which PSK authentication is negotiated(#3434), when a cached PMKSA is used, or after a STA requests a new key. On reception of message 1, the Supplicant determines whether the Key Replay Counter field value has been used before with the current PMKSA. If the Key Replay Counter field value is less than or equal to the current local value, the Supplicant discards the message. Otherwise, the Supplicant:

a) Generates a new nonce SNonce, if no SNonce has yet been generated for this 4-way handshake. The same SNonce is reused within this 4-way handshake until a valid message 3 has been received.(#6483)

b) Derives PTK(11ba), the derived PTK including the Key derivation key (KDK) if WUR frame protection is being negotiated.

c) Constructs message 2.

#### 12.7.6.3 4-way handshake message 2

Message 2 uses the following values for each of the (#1836)EAPOL-Key PDU fields:

Descriptor Type = N – see 12.7.2 (EAPOL-Key frames)

Key Information:

Key Descriptor Version = 1 (ARC4 encryption with HMAC-MD5) or 2 (NIST AES key wrap with HMAC-SHA-1-128) or 3 (NIST AES key wrap with AES-128-CMAC), in all other cases 0(#4141)

Key Type = 1 (Pairwise)(#4141)

Reserved = 0

Install = 0

Key Ack = 0

(#1829)Key MIC Present = 0 when using an AEAD cipher or 1 otherwise

Secure = (#3302)(#3596)0 in initial 4-way handshake, or 1 when PTK rekeying (but see 12.7.2 (EAPOL-Key frames))



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Error = 0(#4141)

Request = 0(#4141)

Encrypted Key Data = 1 when using an AEAD cipher or 0 otherwise

Reserved = 0 – unused by this protocol version

Key Length = 0

Key Replay Counter = *n* – (#4141)same as message 1, to let the Authenticator or initiator STA know to which message 1 this corresponds

Key Nonce = SNonce

EAPOL-Key IV = 0

(#1406)RSC = 0

Key MIC = MIC((#3744)PTK-KCK, EAPOL); or not present when using an AEAD cipher;(#3633)(#1833)

Key Data Length = length of Key Data field in octets

Key Data =

— included RSNE – the sending STA's RSNE for PTK generation or peer RSNE for the current operating band, and when this message 2 is part of a fast BSS transition initial mobility domain association or an association started through the FT protocol, the PMKR1Name calculated by the S1KH according to the procedures of 12.7.1.6.4 (PMK-R1) is included in the PMKID List field of the RSNE and the FTE and MDE are also included, or

— The sending STA's Multi-band element for PTK generation for a supported band other than the current operating band if dot11MultibandImplemented is true, or

— The sending STA's RSNE and Multi-band element(s) for generating a single PTK for all involved bands, if dot11MultibandImplemented is true and both the Authenticator and the Supplicant use the same MAC address in the current operating band and the other supported band(s); or

— The sending STA's RSNE and Multi-band element(s) for generating a different PTK for each involved band, if dot11MultibandImplemented is true and the Joint Multi-band RSNA subfield of the RSN capabilities field is 1 for both the Authenticator and the Supplicant, and either the Authenticator or the Supplicant uses different MAC addresses for different bands.

— Additionally, contains an OCI KDE when dot11RSNAOperatingChannelValidationActivated is true on the Supplicant.

— The RSNXE that the Supplicant sent in its (Re)Association Request frame, if this element is present in the (Re)Association Request frame that the Supplicant sent.

Processing for PTK generation is as follows:

The Supplicant sends message 2 to the Authenticator.

(#1238)On reception of message 2, the Authenticator checks that the key replay counter corresponds to the outstanding message 1. If not, the Authenticator shall silently discard the message.

If dot11RSNAOperatingChannelValidationActivated is true (#1239)and the Supplicant RSNE indicates OCVC(#3505), the Authenticator shall silently discard message 2 if any of the following are true:

— OCI KDE or (#6386)OCI subelement is missing in the message or FTE, respectively

— Channel information in the OCI does not match current operating channel parameters (see 12.2.10 (Requirements for Operating Channel Validation))

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Otherwise, the Authenticator:

a) Derives PTK.

b) Verifies the message 2 MIC or AEAD decryption operation result.

1) If the calculated MIC does not match the MIC that the Supplicant included in the (#1836)EAPOL-Key PDU or the AEAD decryption operation returns failure, (#1240)the Authenticator shall silently discard message 2.

2) If the MIC or AEAD decryption is valid and this message 2 is part of a fast BSS transition initial mobility domain association or an association started through the FT protocol, the Authenticator checks that all fields of the RSNE other than the (#7029)PMKID Count and PMKID List fields and, if present, the RSNXE bitwise matches the fields from the (Re)Association Request frame and that the FTE and MDE are the same as those provided in the AP's (Re)Association Response frame. If the MIC or AEAD decryption is valid and this message 2 is not part of a fast BSS transition initial mobility domain association and this message 2 is not part of an association started through the FT protocol, the Authenticator checks that the RSNE and, if present, the RSNXE bitwise matches that from the (Re)Association Request frame(#7029), and the Authenticator checks that the PMKR1Name calculated according to the procedures of 12.7.1.6.4 (PMK-R1) is included in the PMKID List field of the RSNE.

(#7029)If all these conditions are met, the Authenticator constructs message 3. Otherwise, the Authenticator uses MLME-DEAUTHENTICATE.request primitive to terminate the association.

c) If management frame protection is being negotiated, the AP initializes the SA Query Transaction Identifier to an (M118)implementation specific non-negative integer value, valid for the current pairwise security association.

#### 12.7.6.4 4-way handshake message 3

Message 3 uses the following values for each of the (#1836)EAPOL-Key PDU fields:

Descriptor Type = N – see 12.7.2 (EAPOL-Key frames)

Key Information:

Key Descriptor Version = 1 (ARC4 encryption with HMAC-MD5) or 2 (NIST AES key wrap with HMAC-SHA-1-128) or 3 (NIST AES key wrap with AES-128-CMAC), in all other cases 0(#4141)

Key Type = 1 (Pairwise)(#4141)

Reserved = 0

Install = (#3056)1

Key Ack = 1

(#1829)Key MIC Present = 0 when using an AEAD cipher or 1 otherwise

Secure = 1 (keys installed)

Error = 0(#4141)

Request = 0(#4141)

Encrypted Key Data = 1

Reserved = 0 – unused by this protocol version

Key Length = (#3270)Cipher suite dependent; see Table 12-8 (Cipher suite key lengths(#1083)(#3532))

Key Replay Counter = *n+1* (#4141)– to allow the Authenticator or initiator STA to match the right message 4 from the Supplicant or peer STA

Key Nonce = ANonce – same as message 1



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EAPOL-Key IV = 0 (Version 2) or random (Version 1)

(#1908)(#1406)RSC = Starting TSC or (#6365)packet number that the Authenticator's STA uses in MPDUs protected by GTK.

Key MIC = MIC((#3744)PTK-KCK, EAPOL); or not present when using an AEAD cipher(#3633)(#1827)(#1833)

Key Data Length = length of Key Data field in octets

Key Data =

— For PTK generation for the current operating band, the AP's Beacon/Probe Response frame's RSNE for the current operating band, and, optionally, a second RSNE that is the Authenticator's pairwise cipher suite assignment for the current operating band, and, if a group data cipher(#6020) has been negotiated, the GTK and the GTK's (#3493)key ID (see 12.7.2 (EAPOL-Key frames)) for the current operating band, and if management frame protection is negotiated, the IGTK KDE, and if beacon protection is enabled, the BIGTK KDE(11ba), and if WUR frame protection is negotiated, the WIGTK KDE, and when this message 3 is part of a fast BSS transition initial mobility domain association or an association started through the FT protocol, the PMKR1Name calculated according to the procedures of 12.7.1.6.4 (PMK-R1) in the PMKID List field of the RSNE and the FTE with the same contents as in the (Re)Association Response frame, the MDE with the same contents as in the (Re)Association Response frame, the reassociation deadline timeout set to the minimum of dot11FTReassociationDeadline and the key lifetime in the TIE[ReassociationDeadline], and the PTK lifetime in the TIE[KeyLifetime]; or

— For PTK generation for a supported band other than the current operating band, the Authenticator's Beacon/DMG Beacon/Announce/Probe Response/Information Response frame's Multi-band element associated with the supported band, and optionally a second Multi-band element that indicates the Authenticator's pairwise cipher suite assignment for the supported band, and, if group data cipher(#6020) for the supported band is negotiated, the Multi-band GTK KDE for the supported band if dot11MultibandImplemented is true, or

— For generating a single PTK for all involved bands, the Authenticator's Beacon/DMG Beacon/Announce/Probe Response/Information Response frame's RSNE and Multi-band element(s), and optionally, additional RSNE and Multi-band element(s) that indicate the Authenticator's assignment of one pairwise cipher suite for all involved bands; if a (#6020)group data cipher for all involved bands is negotiated, the GTK and the GTK's (#3493)key ID for all involved bands, if dot11MultibandImplemented is true and both the Authenticator and the Supplicant use the same MAC address in the current operating band and the other supported band(s), or

— For generating different PTKs for the current operating band and other supported band(s), the Authenticator's Beacon/DMG Beacon/Announce/Probe Response/Information Response frame's RSNE and Multi-band element(s), and optionally, additional RSNE and Multi-band elements that are the Authenticator's pairwise cipher suite assignments for one or more involved bands; if (#6020)group data ciphers for the involved bands are negotiated, the Multi-band GTK KDEs for the involved bands, if dot11MultibandImplemented is true and the Joint Multi-band RSNA subfield is 1 for both the Authenticator and Supplicant, and either the Authenticator or the Supplicant uses different MAC addresses for different bands.

— Additionally, contains an OCI KDE when dot11RSNAOperatingChannelValidationActivated is true on the Authenticator.

— The RSNXE that the Authenticator sent in its Beacon or Probe Response frame, if this element is present in the Beacon or Probe Response frame that the Authenticator sent.

— The SSID element containing the SSID of the BSS when both the Authenticator and the Supplicant have indicated support for SSID protection in the RSNXE.(M166)

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(#1710)NOTE—The GTK is not required to change when PTK rekeying is performed. However, if it does not change, it is ignored (see 6.5.14.1 (MLME-SETKEYS.request)).

Processing for PTK generation is as follows:

If the Extended Key ID for Individually Addressed Frames subfield of the RSN Capabilities field is 1 for both the Authenticator and the Supplicant, then the Authenticator assigns a new (#3493)key ID for the PTKSA in the range(#3482) 0 to 1 that is different from the (#3493)key ID assigned in the previous handshake and uses the MLME-SETKEYS.request primitive to install the new key to receive individually addressed MPDUs protected by the PTK with the assigned (#3493)key ID. Otherwise (#3493)key ID 0 is used and installation of the key is deferred until after message 4 has been received. The Authenticator sends message 3 to the Supplicant.

NOTE—If an existing PTK is still in effect, the Authenticator IEEE 802.11 MAC continues to transmit protected, individually addressed MPDUs (if any) using the existing key. With the installation of the new key for receive, the Authenticator is able to receive protected, individually addressed MPDUs using either the old key (if present) or the new key.

(#1241)On reception of message 3, the Supplicant shall silently discard the message if the Key Replay Counter field value has already been used or if the ANonce value in message 3 differs from the ANonce value in message 1.

If dot11RSNAOperatingChannelValidationActivated is true (#1242)and Authenticator RSNE indicates OCVC (#3505), the Supplicant shall silently discard message 3 if any of the following are true:

— OCI KDE or (#6386)OCI subelement is missing in the message or FTE, respectively

— Channel information in the OCI does not match current operating channel parameters (see 12.2.10 (Requirements for Operating Channel Validation))

The Supplicant (#1243)shall also:

a) (#1243)Verify the RSNE and, if present, the RSNXE. If this message 3 is part of a fast BSS transition initial mobility domain association or an association started through the FT protocol, the Supplicant (#7191)shall verify that the PMKR1Name in the PMKID List field of the RSNE is identical to the value it sent in message 2, that all other fields of the RSNE are identical to the fields in the RSNE present in the Beacon or Probe Response frames and that the FTE and MDE are the same as in the (Re)Association Response frame. Otherwise, the Supplicant shall verify that the RSNE is identical to that the STA received in the Beacon or Probe Response frame. If the RSNXE is present, the Supplicant shall verifiy that the RSNXE is identical to that the STA received in the Beacon or Probe Response frame. If any of these verification steps indicates a mismatch, the STA shall disassociate or deauthenticate. If a second RSNE is provided in the message, the Supplicant shall use the pairwise cipher suite specified in the second RSNE or deauthenticate.

b) (#1243)Verify the message 3 MIC or AEAD decryption operation result. If the calculated MIC does not match the MIC that the Authenticator included in the (#1836)EAPOL-Key PDU or AEAD decryption operation returns failure, (#6110)the Supplicant shall silently discard message 3.

c) (#1243)Update the last-seen value of the Key Replay Counter field.

d) If the Extended Key ID for Individually Addressed Frames subfield of the RSN Capabilities field is 1 for both the Authenticator and Supplicant: (#7191)Use the MLME-SETKEYS.request primitive to configure the IEEE 802.11 MAC to receive individually addressed MPDUs protected by the PTK with the assigned (#3493)key ID.

e) (#1243)Construct message 4.

f) (#1243)Send message 4 to the Authenticator.

g) (#1243)Use the MLME-SETKEYS.request primitive to configure the IEEE 802.11 MAC to send and, if the receive key has not yet been installed, to receive individually addressed MPDUs pro-


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tected by the PTK. The GTK is also configured by using the (#7191)MLME-SETKEYS.request primitive. (11ba)If WUR frame protection is negotiated, the WTK, and if applicable the WIGTK, is also configured by using the MLME-SETKEYS.request primitive.

#### 12.7.6.5 4-way handshake message 4

Message 4 uses the following values for each of the (#1836)EAPOL-Key PDU fields:

Descriptor Type = N – see 12.7.2 (EAPOL-Key frames)

Key Information:

Key Descriptor Version = 1 (ARC4 encryption with HMAC-MD5) or 2 (NIST AES key wrap with HMAC-SHA-1-128) or 3 (NIST AES key wrap with AES-128-CMAC), in all other cases 0(#4141)

Key Type = 1 (Pairwise)(#4141)

Reserved = 0

Install = 0

Key Ack = 0(#1824)

(#1829)Key MIC Present = 0 when using an AEAD cipher or 1 otherwise

Secure = 1

Error = 0

Request = 0

Encrypted Key Data = 1 when using an AEAD cipher or 0 otherwise

Reserved = 0 – unused by this protocol version

Key Length = 0

Key Replay Counter = *n+1* (#4141)– same as message 3, to let the Authenticator or initiator STA know to which message 3 this corresponds

Key Nonce = 0 (#3466)(but see 12.7.2 (EAPOL-Key frames))

EAPOL-Key IV = 0

(#1406)RSC = 0

Key MIC = MIC((#3744)PTK-KCK, EAPOL); or not present when using an AEAD cipher(#3633)(#1833)

Key Data Length = length of Key Data field in octets

Key Data = none required(#3596)(#1954); RSNEs and Multi-band elements shall not be included(#1962)

Processing for PTK generation is as follows:

The Supplicant sends message 4 to the Authenticator. Note that when the 4-way handshake is first used, message 4 is sent in the clear.

On reception of message 4, the Authenticator verifies that the Key Replay Counter field value is one that it used on this 4-way handshake and is strictly larger than that in any other (#1836)EAPOL-Key PDU that has the Request bit in the Key Information field set to 0 and that has been received during this session; if it is not, it silently discards the message. Otherwise:

a) The Authenticator checks the MIC or AEAD decryption operation result. If the calculated MIC does not match the MIC that the Supplicant included in the (#1836)EAPOL-Key PDU or AEAD decryption operation returns failure, (#6108)the Authenticator shall silently discard message 4.

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b) If the MIC is valid, the Authenticator uses the MLME-SETKEYS.request primitive to configure the IEEE 802.11 MAC to send and, if the receive key has not yet been installed, to receive protected, individually addressed MPDUs using for the new PTK. (11ba)If WUR frame protection is negotiated, the WTK is also configured by using the (#7191)MLME-SETKEYS.request primitive.

c) The Authenticator updates the Key Replay Counter field so that it uses a fresh value if a rekey becomes necessary.

#### 12.7.6.6 4-way handshake implementation considerations

If the Authenticator does not receive a reply to its messages, it shall attempt dot11RSNAConfigPairwiseUpdateCount transmits of the message, plus a final timeout. The retransmit timeout value (#6084)should be 100 ms for the first timeout, half the listen interval for the second timeout, and the listen interval for subsequent timeouts. (#6084)If the listen interval is zero, then 100 ms should be used for all timeout values. If it still has not received a response after these retries, then for PTK generation the Authenticator should deauthenticate the STA.

For PTK generation, if the Supplicant does not receive message 1 within the expected time interval (prior to IEEE 802.1X timeout), it should disassociate, deauthenticate, and try another AP or peer STA.

The Authenticator should ignore (#1836)EAPOL-Key PDUs it is not expecting in reply to messages it has sent or (#1836)EAPOL-Key PDUs in which the Ack bit is 1. This stops an attacker from sending the first message to the Supplicant who responds to the Authenticator.

An implementation should save the (#3744)PTK-KCK and PTK-KEK beyond the 4-way handshake, as they are needed for group key handshakes, and recovery from TKIP MIC failures.

The Supplicant uses the MLME-SETKEYS.request primitive to configure the temporal key from 12.7.1 (Key hierarchy)(11ba), and if WUR frame protection is negotiated, the WTK into its STA after sending message 4 to the Authenticator.

If the RSNE check for message 2 or message 3 fails, the SME should log an error and deauthenticate the peer.

(#1273)The Authenticator and Supplicant shall check the Key Ack and Request bits in EAPOL-Key PDUs to stop reflection attacks.

(#1273)The Supplicant shall not use message 1 contents to update state, in particular the keys in use, until validated with message 3.

(M166)If both the Supplicant and the Authenticator indicated support for SSID protection in the RSNXE, the Supplicant shall verify that the Key Data field in message 3 contains the SSID element and that the SSID indicated in that element bitwise matches the SSID indicated in the SSID element in the (Re)Association Request frame. If this verification fails, the Supplicant shall abandon the 4-way handshake and deauthenticate the peer.

#### 12.7.6.7 Sample 4-way handshake

The following is a sample of a 4-way handshake for illustration.

After IEEE 802.1X authentication completes by the AP sending an EAP-Success, the AP initiates the 4-way handshake. See Figure 12-51 (Sample 4-way handshake).


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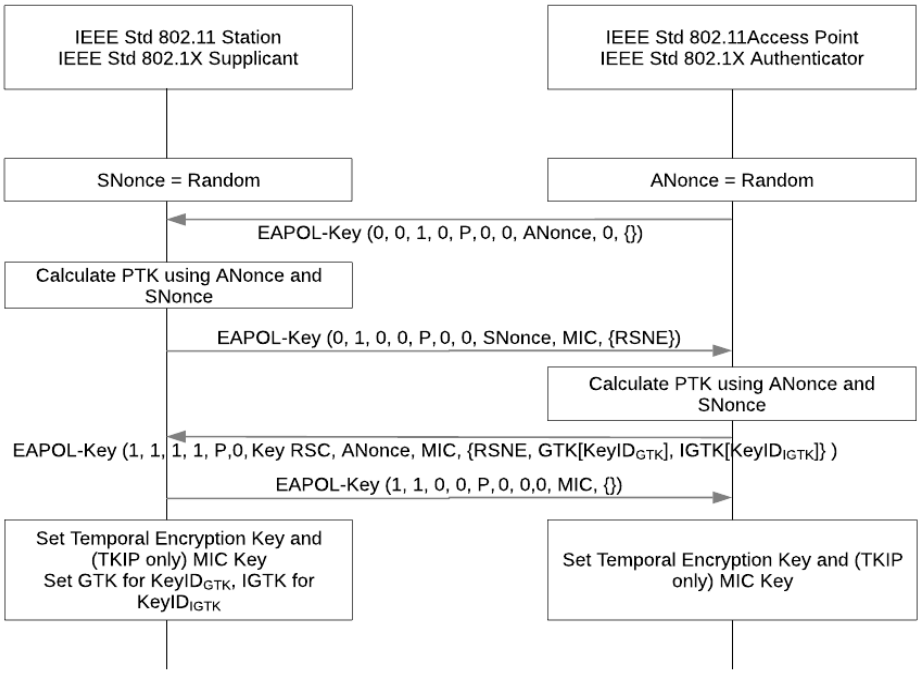


**Figure 12-51—Sample 4-way handshake**

The 4-way handshake consists of the following steps:

a) The Authenticator sends an (#1836)EAPOL-Key PDU containing an ANonce.

b) The Supplicant derives a PTK from ANonce and SNonce.

c) The Supplicant sends an (#1836)EAPOL-Key PDU containing SNonce, the RSNE from the (Re)Association Request frame, and a MIC.

d) The Authenticator derives PTK from ANonce and SNonce and validates the MIC in the (#1836)EAPOL-Key PDU.

e) The Authenticator sends an (#1836)EAPOL-Key PDU containing ANonce, the RSNE from its Beacon or Probe Response frames, the MIC, the GTK, an indication of whether to install the temporal keys, and if management frame protection is negotiated, the IGTK, and if beacon protection is enabled, the BIGTK.

f) The Supplicant sends an (#1836)EAPOL-Key PDU to confirm whether the temporal keys were installed.

#### 12.7.6.8 4-way handshake analysis

The following is an analysis of the 4-way handshake.

This subclause makes the trust assumptions used in this protocol explicit. The protocol assumes the following:

— The PMK is known only by the Supplicant's STA and the Authenticator's STA.

— The Supplicant's STA uses IEEE 802 address SPA.

— The Authenticator's STA uses IEEE 802 address AA.

In many instantiations the RSNA architecture immediately breaks the first assumption because the IEEE 802.1X AS also knows the PMK. Therefore, additional assumptions are required:

— The AS does not expose the PMK to other parties.

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- The AS does not masquerade as the Supplicant to the Authenticator.
- The AS does not masquerade as the Authenticator to the Supplicant.
- The AS does not masquerade as the Supplicant's STA.
- The AS does not masquerade as the Authenticator's STA.

The protocol also assumes this particular Supplicant-Authenticator pair is authorized to know this PMK and to use it in the 4-way handshake. If any of these assumptions are broken, then the protocol fails to provide any security guarantees.

The protocol also assumes that the AS delivers the correct PMK to the AP with IEEE 802 address AA and that the STA with IEEE 802 address SPA hosts the Supplicant that negotiated the PMK with the AS. None of the protocols defined by this standard and (#3469)IEEE Std 802.1X-2020 permit the AS, the Authenticator, the Supplicant, or either STA to verify these assumptions.

The PTK derivation step

PTK =PRF-*Length*(PMK, "Pairwise key expansion", Min(AA,SPA) || Max(AA,SPA) ||
Min(ANonce,SNonce) || Max(ANonce,SNonce))

performs a number of functions:

- Including the AA and SPA in the computation
  - Binds the PTK to the communicating STAs and
  - Prevents undetected man-in-the-middle attacks against 4-way handshake messages between the STAs with these two IEEE 802 addresses.
- If ANonce is randomly selected, including ANonce
  - Guarantees the STA at IEEE 802 address AA that PTK is fresh,
  - Guarantees that message 2 and message 4 are live, and
  - Uniquely identifies PTK as <AA, ANonce>.
- If SNonce is randomly selected, including SNonce
  - Guarantees the STA at IEEE 802 address SPA that PTK is fresh,
  - Guarantees that message 3 is live, and
  - Uniquely identifies PTK as <SPA, SNonce>.

Choosing the nonces randomly helps prevent precomputation attacks. With unpredictable nonces, a man-in-the-middle attack that uses the Supplicant to precompute messages to attack the Authenticator cannot progress beyond message 2, and a similar attack against the Supplicant cannot progress beyond message 3. The protocol might execute further before an error if predictable nonces are used.

Message 1 delivers ANonce to the Supplicant and initiates negotiation for a new PTK. It identifies AA as the peer STA to the Supplicant's STA. If an adversary modifies either of the addresses or ANonce, the Authenticator detects the result when validating the MIC in message 2. Message 1 does not carry a MIC, as it is impossible for the Supplicant to distinguish this message from a replay without maintaining state of all security associations through all time (PMK might be a static key).

Message 2 delivers SNonce to the Authenticator so it can derive the PTK. If the Authenticator selected ANonce randomly, message 2 also demonstrates to the Authenticator that the Supplicant is live, that the PTK is fresh, and that there is no man-in-the-middle attack, as the PTK includes the (#1893)MAC addresses of both. Inclusion of ANonce in the PTK derivation also protects against replay. The MIC prevents undetected modification of message 2 contents.


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Message 3 confirms to the Supplicant that there is no man-in-the-middle attack. If the Supplicant selected SNonce randomly, it also demonstrates that the PTK is fresh and that the Authenticator is live. The MIC again prevents undetected modification of message 3.

While message 4 serves no cryptographic purpose, it serves as an acknowledgment to message 3. It is required to inform the Authenticator that the Supplicant has installed the PTK and GTK and hence can receive encrypted frames.

(#1480)The PTK and GTK are installed using the MLME-SETKEYS.request primitive after message 4 is sent (except at the Authenticator if the Extended Key ID for Individually Addressed Frames subfield of the RSN Capabilities field is 1 for both the Authenticator and the Supplicant (see 12.7.6.4 (4-way handshake message 3))). The PTK is installed before the GTK.

Then the 4-way handshake uses a correct, but unusual, mechanism to guard against replay. As noted earlier in this subclause, ANonce provides replay protection to the Authenticator, and SNonce to the Supplicant. In most session initiation protocols, replay protection is accomplished explicitly by selecting a nonce randomly and requiring the peer to reflect the received nonce in a response message. The 4-way handshake instead mixes ANonce and SNonce into the PTK, and replays are detected implicitly by MIC failures. In particular, the Key Replay Counter field serves no cryptographic purpose in the 4-way handshake. Its presence is not detrimental, however, and it plays a useful role as a minor performance optimization for processing stale instances of message 2. This replay mechanism is correct, but its implicit nature makes the protocol harder to understand than an explicit approach.

It is critical to the correctness of the 4-way handshake that at least one bit differs in each message. Within the 4-way handshake, (#3596)the messages are distinguished by the Key MIC and Encrypted Key Data bits (not both 0 except in message 1), the Key Ack bit (1 in message 1 and message 3 only) and the presence of RSNEs and/or Multi-Band elements (in message 2 but not in message 4).

(#3596)Group key handshake messages are distinct from 4-way handshake messages because they set the Key Type bit differently (0 in group key handshake messages only), and are distinguished from each other by the Key Ack bit (1 in message 1 only). Request messages are distinct from 4-way handshake and group key handshake messages because they set the Request bit differently (1 in request messages only).

### 12.7.7 Group key handshake

#### 12.7.7.1 General

The Authenticator uses the Group key handshake to send a new GTK and, if management frame protection is negotiated, a new IGTK, and if beacon protection is enabled, a new BIGTK(11ba), and if WUR frame protection is negotiated, a new WIGTK to the Supplicant.

(#1721)The Authenticator may initiate the exchange at any time when a Supplicant is disassociated or deauthenticated.

Message 1: Authenticator → Supplicant:

EAPOL-Key((#8238)1, 1, 1, 0, G, 0, (#1406)RSC, 0, MIC, {GTK(N) [, OCI} [, IGTK(M, IPN)] [, BIGTK(Q, BIPN)] [(11ba), WIGTK(R, WIPN)]})(#6590)

Message 2: Supplicant → Authenticator: EAPOL-Key((#8238)1, 1, 0, 0, G, 0, 0, 0, MIC, {[OCI]})(#6590)

(#6590)NOTE 1—Elements and KDEs in the key data field can be included in any order.

The following apply:

— (#1406)RSC denotes the last TSC or (#6365)packet number sent using the GTK.

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- GTK[N] denotes the GTK (#1453)with its (#3493)key ID as encapsulated using the KDE defined in 12.7.2 (EAPOL-Key frames) using the (#3744)PTK-KEK defined in 12.7.1.3 (Pairwise key hierarchy) and associated IV.
- IGTK[M], when present, denotes the IGTK (#1453)with its (#3493)key ID as encapsulated using the KDE defined in 12.7.2 (EAPOL-Key frames) using the (#3744)PTK-KEK defined in 12.7.1.3 (Pairwise key hierarchy) and associated IV.
- BIGTK[Q], when present, denotes the BIGTK with its (#3493)key ID as encapsulated using the KDE as defined in 12.7.2 (EAPOL-Key frames) using the (#3744)PTK-KEK defined in 12.7.1.3 (Pairwise key hierarchy) and associated IV.
- (11ba)WIGTK[R], when present, denotes the WIGTK with its (#3493)key ID as encapsulated using the KDE as defined in 12.7.2 (EAPOL-Key frames) using the (#3744)PTK-KEK defined in 12.7.1.3 (Pairwise key hierarchy) and associated IV.
- The MIC is computed over the body of the (#1836)EAPOL-Key PDU (with the MIC field zeroed for the computation) using the (#3744)PTK-KCK defined in 12.7.1.3 (Pairwise key hierarchy).
- (#8238)The OCI represents the current operating channel information using which the (#1836)EAPOL-Key PDU is sent. OCI is included when dot11RSNAOperatingChannelValidationActivated is true on the STA sending the message.

The Supplicant may (#1273)request a group key handshake to obtain a new GTK by sending an EAPOL-Key request frame with a key type of Group (see 12.7.2 (EAPOL-Key frames)).

(#1273)NOTE 2—The Authenticator might ignore this request.

(#185)An Authenticator shall perform a 4-way handshake before a group key handshake if both are required to be done.

NOTE 3—The Authenticator cannot initiate the group key handshake until the 4-way handshake completes successfully.

If dot11RSNAOperatingChannelValidationActivated is true and a channel switch is requested while the handshake is in progress, the handshake should be aborted.

### 12.7.7.2 Group key handshake message 1

Message 1 uses the following values for each of the (#1836)EAPOL-Key PDU fields:

Descriptor Type = N – see 12.7.2 (EAPOL-Key frames)

Key Information:

Key Descriptor Version = 1 (ARC4 encryption with HMAC-MD5) or 2 (NIST AES key wrap with HMAC-SHA-1-128) or 3 (NIST AES key wrap with AES-128-CMAC), in all other cases 0

Key Type = 0 (Group)

Install = 0

Key Ack = 1

(#1829)Key MIC Present = 0 when using an AEAD cipher or 1 otherwise

Secure = 1

Error = 0

Request = 0

Encrypted Key Data = 1

Reserved = 0

Key Length = 0


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Key Replay Counter = *m*, greater than in the last (#1836)EAPOL-Key PDU transmitted that was not an EAPOL-Key request frame(#1475)

Key Nonce = 0

EAPOL-Key IV = 0 (Version 2) or random (Version 1)

(#1406)RSC = last TSC or PN for the GTK

Key MIC = MIC((#3744)PTK-KCK, EAPOL); not present when using an AEAD cipher(#3633)

Key Data Length = length of Key Data field in octets

Key Data = (#189)

- GTK and the GTK's (#3493)key ID (see 12.7.2 (EAPOL-Key frames))
- When present, IGTK, IGTK's (#3493)key ID, and IPN (see 12.7.2 (EAPOL-Key frames))
- When present, BIGTK, BIGTK's (#3493)key ID, and BIPN (see 12.7.2 (EAPOL-Key frames))
- (11ba)When present, WIGTK, WIGTK's (#3493)key ID, and WIPN (see 12.7.2 (EAPOL-Key frames))
- OCI KDE when dot11RSNAOperatingChannelValidationActivated is true on the Authenticator

The Authenticator sends message 1 to the Supplicant.

On reception of message 1, the Supplicant:

a) Verifies that the Key Replay Counter field value has not yet been seen before, i.e., its value is strictly larger than that in any other (#1836)EAPOL-Key PDU received thus far during this session.

b) If dot11RSNAOperatingChannelValidationActivated is true and Authenticator RSNE indicates OCVC(#3505), (#6111)the Supplicant shall silently discard message 1 if any of the following are true:
   - OCI KDE is missing in the message
   - Channel information in the OCI KDE does not match current operating channel parameters (see 12.2.10 (Requirements for Operating Channel Validation))

c) Verifies that the MIC is valid, i.e., it uses the (#3744)PTK-KCK that is part of the PTK to verify that there is no data integrity error, or that the AEAD decryption steps succeed.

d) Uses the MLME-SETKEYS.request primitive to configure the (#1567)GTK and, the IGTK when present, and the BIGTK if (#1486)beacon protection is enabled at the non-AP STA(11ba), and the WIGTK if WUR frame protection is negotiated, into the MAC.

e) Responds by creating and sending message 2 of the group key handshake to the Authenticator and incrementing the replay counter.

NOTE—The Authenticator increments and uses a new Key Replay Counter field value on every message 1 instance, even retries, because the message 2 responding to an earlier message 1 might have been lost. If the Authenticator did not increment the replay counter, the Supplicant discards the retry, and no responding message 2 ever arrives.

#### 12.7.7.3 Group key handshake message 2

Message 2 uses the following values for each of the (#1836)EAPOL-Key PDU fields:

Descriptor Type = N – see 12.7.2 (EAPOL-Key frames)

Key Information:

Key Descriptor Version = 1 (ARC4 encryption with HMAC-MD5) or 2 (NIST AES key wrap with HMAC-SHA-1-128) or 3 (NIST AES key wrap with AES-128-CMAC), in all other cases 0(#4141)

Key Type = 0 (Group)(#4141)

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Install = 0

Key Ack = 0

(#1829)Key MIC Present = 0 when using an AEAD cipher or 1 otherwise

Secure = 1

Error = 0

Request = 0

Encrypted Key Data = 1 when using an AEAD cipher or 0 otherwise

Reserved = 0

Key Length = 0

Key Replay Counter = *m* (#1475)– same as message 1(#4141), to let the Authenticator or initiator STA know to which message 1 this corresponds

Key Nonce = 0

EAPOL-Key IV = 0

(#1406)RSC = 0

Key MIC = MIC((#3744)PTK-KCK, EAPOL); not present when using an AEAD cipher(#3633)

Key Data Length = length of Key Data field in octets

Key Data = OCI KDE when dot11RSNAOperatingChannelValidationActivated on the Authenticator

On reception of message 2, the Authenticator:

a) Verifies that the Key Replay Counter field value matches one it has used in the group key handshake.

b) If dot11RSNAOperatingChannelValidationActivated is true and Supplicant RSNE indicates OCVC (#3505), (#6109)the Authenticator shall silently discard message 2 if any of the following are true:

— OCI KDE is missing in the message

— Channel information in the OCI KDE does not match current operating channel parameters (see 12.2.10 (Requirements for Operating Channel Validation))

c) Verifies that the MIC is valid, i.e., it uses the (#3744)PTK-KCK that is part of the PTK to verify that there is no data integrity error, or that the AEAD decryption steps succeed.

#### 12.7.7.4 Group key handshake implementation considerations

If the Authenticator does not receive a reply to its messages, its shall attempt dot11RSNAConfigGroupUpdateCount transmits of the message, plus a final timeout. The retransmit timeout value (#6084)should be 100 ms for the first timeout, half the listen interval for the second timeout, and the listen interval for subsequent timeouts. If (#6084)the listen interval is zero, then 100 ms should be used for all timeout values. If it still has not received a response after this, then the Authenticator's STA should use the MLME-DEAUTHENTICATE.request primitive to deauthenticate the STA.

To prevent key reinstallation attacks, the Supplicant shall maintain a copy of the most recent GTK, most recent IGTK, (11ba)most recent BIGTK, and most recent WIGTK, installed as a result of receipt of EAPOL-Key frames. The Supplicant shall not install a GTK, an IGTK(11ba), a BIGTK or a WIGTK when the key to be set matches any of these keys (see 6.5.14 (SetKeys)). (#3194)

#### 12.7.7.5 Sample group key handshake

The following is a sample of a group key handshake for illustration.



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The state machines in 12.7.9 (RSNA Supplicant key management state machine) and 12.7.10 (RSNA Authenticator key management state machine) change the GTK and, when present, IGTK in use by the network. See Figure 12-52 (Sample group key handshake).

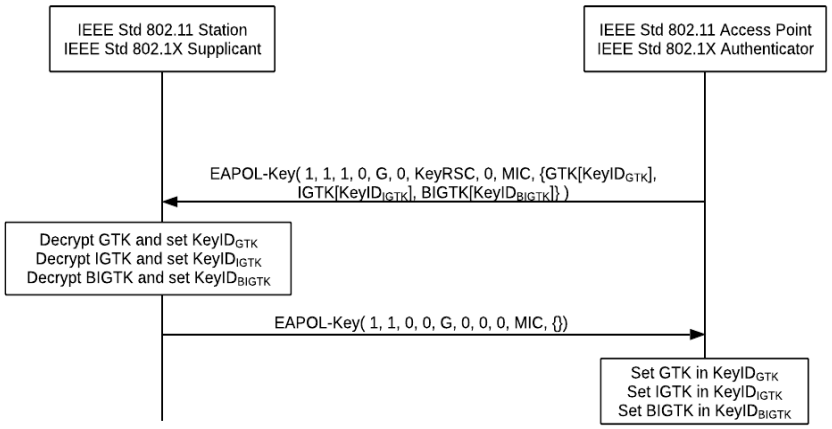


**Figure 12-52—Sample group key handshake**

The following steps occur:

a) The Authenticator generates a new GTK, a new IGTK and when management frame protection has been negotiated, and a new BIGTK when beacon protection is enabled. It encapsulates the GTK, as necessary, the IGTK, and the BIGTK. It sends an (#1836)EAPOL-Key PDU containing the GTK, IGTK and BIGTK (message 1), along with the last TSC or PN used with the GTK (RSC), the last IPN used with the IGTK and the last BIPN used with the BIGTK.

b) On receiving the (#1836)EAPOL-Key PDU, the Supplicant validates the MIC, decapsulates the GTK, the IGTK when present and the BIGTK when present, and uses the MLME-SETKEYS.request primitive to configure the GTK, GTK RSC, IGTK, IGTK RSC, BIGTK and BIGTK RSC in its STA.(#3193)

c) The Supplicant then constructs and sends an (#1836)EAPOL-Key PDU in acknowledgment to the Authenticator.

d) On receiving the (#1836)EAPOL-Key PDU, the Authenticator validates the MIC. If the GTK, the IGTK, if present, and the BIGTK, if present, have not yet been configured using the MLME-SETKEYS.request primitive, after the Authenticator has delivered the GTK, IGTK and BIGTK to all associated STAs, it uses the MLME-SETKEYS.request primitive to configure them.

### 12.7.8 TDLS PeerKey (TPK) security protocol

#### 12.7.8.1 General

The TPK security protocol is executed between the two non-AP STAs that intend to establish an RSNA for (#2152)TDLS direct link(#1356) communication. If any security method(#3056) is enabled on the connection between a STA and the AP, the STA shall require that the TPK security protocol complete successfully before using a (#2152)TDLS direct link. If no security method is enabled on the connection between a STA and the AP, the STA shall not use the TPK security protocol on the (#2152)TDLS direct link.

(#1434)(#1403)NOTE—A STA might refuse to set up a TDLS direct link(#2152) when the STA link to the AP is secured with (#3056)TKIP or is unsecured.

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### 12.7.8.2 TPK handshake

The TPK handshake occurs as part of the TDLS direct link(#1356) setup procedure. The TPKSA is the result of the successful completion of the TPK handshake protocol, which derives keys for providing confidentiality and data origin authentication.

In order to maintain (#6395)TPK transient key confidentiality, both the TDLS initiator STA and the TDLS responder STAs establish an RSNA with their common AP prior to executing the TPK handshake. To meet this criterion, a STA may refuse to initiate the TDLS direct link if:

a) The AP does not include an RSNE in its Beacon and Probe Response frames to advertise the availability of security;

b) The AP's RSNE indicates that (#3056)TKIP (00-0F-AC:2) is enabled as either pairwise or (#6020)group data cipher suites;(#223) or

c) The AP's RSNE indicates that Use group data cipher suite(#6020) (00-0F-AC:0) is used as the pairwise cipher suite.

Violation of any of these cases would cause the TPK handshake to leak the (#6395)TPK transient key.

The TDLS initiator STA and the TDLS responder STA perform the following exchange to set up a (#6395)TPK transient key:

TDLS PMK handshake message 1: TDLS initiator STA → TDLS responder STA:
Link Identifier element, RSNE, (#1776)TIE, FTE

TDLS PMK handshake message 2: TDLS responder STA → TDLS initiator STA:
Link Identifier element, RSNE, (#1776)TIE, FTE

TDLS PMK handshake message 3: TDLS initiator STA → TDLS responder STA:
Link Identifier element, RSNE, (#1776)TIE, FTE

where

| | |
|---|---|
| TDLS initiator STA Address field of the Link Identifier element | is the MAC address of the TDLS initiator STA |
| TDLS responder STA Address field of the Link Identifier element | is the MAC address of the TDLS responder STA |
| (#4165)Timeout Interval Type field of the (#1776)TIE | is the key lifetime |
| (#4165)Pairwise Cipher Suite List field of the RSNE | identifies the cipher suite used to protect the Data frames sent over the (#2152)TDLS direct link |
| (#4165)AKM Suite List field of the RSNE | identifies which Authentication Method was used |
| SNonce field of the FTE | is a 256 bit value randomly generated by the TDLS initiator STA |
| ANonce field of the FTE | is a 256 bit value randomly generated by the TDLS responder STA (set to 0 in message 1) |
| MIC field of the FTE | is 0 for message 1 and computed as described in 12.7.8.4.3 (TPK handshake message 2) and 12.7.8.4.4 (TPK handshake message 3) for messages 2 and 3, respectively |

The TDLS PMK handshake message 1 shall be transmitted in the TDLS Setup Request frame.

TDLS PMK handshake message 2 shall be transmitted in the TDLS Setup Response frame.

TDLS PMK handshake message 3 shall be transmitted in the TDLS Setup Confirm frame.


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The (#6395)TPK transient key shall be derived as follows:

TPK-Key-Input = Hash(min (SNonce, ANonce) || max (SNonce, ANonce))
(#478)TPK = KDF-*Hash-Length*(TPK-Key-Input, "TDLS PMK", min (MAC_I, MAC_R) || max (MAC_I, MAC_R) || BSSID)

where

| | |
|---|---|
| *Hash*(#3686) | is the hash algorithm specific to the negotiated AKM (see Table 9-190 (AKM suite selectors)) |
| (#478)KDF-*Hash-Length* | is the key derivation function defined in 12.7.1.6.2 (Key derivation function (KDF)) |
| *Length*(#3686) | is TK_bits + 128 |
| TK_bits | is (#3270)cipher suite dependent and specified in Table 12-8 (Cipher suite key lengths(#1083)(#3532)) |
| MAC_I and MAC_R | are the MAC addresses of the TDLS initiator STA and the TDLS responder STA, respectively |
| SNonce and ANonce | are the nonces generated by the TDLS initiator STA and TDLS responder STA, respectively, for this instance of the TPK handshake. The BSSID is set to the BSSID of the BSS of which the TDLS initiator STA is a member. |

(#2012)(#6395)A TPK is a transient key, which has two component keys—TPK-KCK and TPK-TK, defined as follows:

The (#3744)TPK key confirmation key (TPK-KCK) shall be computed as the first 128 bits (i.e., bits 0–127) of the TPK.

TPK-KCK = (#3506)ExtractBits(TPK, 0, 128)

The (#3744)TPK-KCK is used to provide data origin authenticity in TDLS Setup Response and TDLS Setup Confirm frames.

The (#3744)(#6395)(#7163)TPK temporal key (TPK-TK) shall be computed as the remaining bits (for CCMP-128, the second 128 bits, i.e., bits 128–255) of the TPK

TPK-TK = (#3506)ExtractBits(TPK, 128, (#3686)*Length* – 128)

The TPK-TK is used to provide confidentiality for direct link(#1356) data.

The temporal key is configured into the STA by the SME through the use of the MLME-SETKEYS.request primitive.

### 12.7.8.3 TPK handshake security assumptions

The security of the TDLS PMK handshake depends on the following:

a) The TDLS initiator STA and the TDLS peer STA each have an RSNA established with the AP that is being used for TDLS Setup.
b) The AP does not expose the nonces exchanged by the TDLS initiator STA and the TDLS responder STA to any external party.
c) The AP does not use these nonces to (#7163)derive the TPK transient key and attack the TDLS direct link(#1356) instance.
d) TDLS message security (encryption and integrity computations) processing at the AP is protected from illegal eavesdropping, alterations, insertions and substitutions.

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e) The TDLS initiator STA and TDLS responder STAs do not expose SNonce, ANonce, or the derived key to a third party.

f) The TDLS initiator STA and the TDLS peer STA are associated to the same AP.

#### 12.7.8.4 TPK Security Protocol handshake messages

##### 12.7.8.4.1 Overview

The TPK handshake consists of three messages. Each message comprises a number of elements and is included (#6302)in the TDLS Setup Request, TDLS Setup Response, and TDLS Setup Confirm frames.

In an RSN, these handshake messages serve to provide a session identifier, are identified by the nonces, and are used as association instance identifiers. These nonces are chosen randomly or pseudorandomly, and are used to (#7163)generate the TPK transient key.

##### 12.7.8.4.2 TPK handshake message 1

If security is required on the TDLS direct link (see 12.7.8.1 (General)), the TDLS initiator STA shall add an RSNE, FTE, and (#1776)TIE to its TDLS Setup Request frame. The elements shall be formatted as follows:

The RSNE, if present, shall be set as follows:

(#3241)The Version field shall be set to 1.

The (#3240)(#3241)(#6167)Pairwise Cipher Suite List field (#1420)shall indicate the pairwise cipher suite to be used with the TPKSA, and the Pairwise Cipher Suite Count field shall be set to 1.

(#3241)The Group Data Cipher Suite field shall be set to 00-0F-AC:7.

The AKM (#3241)Suite Count field shall be set to 1.

The AKM (#3241)Suite List field shall be set to indicate TPK handshake (00-0F-AC:7).

In the RSN Capabilities field, (#3056)the PeerKey Enabled subfield shall be set to 1.

(#3241)The PMKID Count field, if present, shall be set to 0.

(#3241)The PMKID List field shall not be present.

The Group Management Cipher Suite (#3241)field, if present, shall be set to 00-0F-AC:7.

The (#1776)TIE indicates the lifetime of the TPKSA. The Lifetime Interval Type shall be set to 2 (Key Lifetime Interval). The minimum lifetime shall be 300 s(#7198).

The FTE shall be set as follows:

SNonce shall be set to a value chosen randomly by the TDLS initiator STA, see 12.7.5 (Nonce generation) for a recommended procedure.

(#3497)The Optional Parameter(s) field has zero length. All other fields shall be set to 0.

The TDLS initiator STA sends message 1 to the TDLS responder STA.

On reception of message 1, the TDLS responder STA (#6149)proceeds as follows:

If security is not required on the TDLS direct link (see 12.7.8.1 (General)) (#6149)and the request includes an RSNE, (#7237)FTE, or TIE, the TDLS response STA shall reject the request with status code SECURITY_DISABLED.

If security is required on the TDLS direct link (see 12.7.8.1 (General)) (#6149)and the request does not include (#7237)an RSNE, an FTE, and a TIE, the TDLS responder STA shall reject the request with status code INVALID_PARAMETERS.

If the version field of the RSNE is (#7237)not 1, (#6149)the TDLS responder STA shall reject the request with status code UNSUPPORTED_RSNE_VERSION.


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(#6149)If (#3488)the RSNE does not indicate (#4225)the single (#3266)AKM 00-0F-AC:7(TPK handshake), the TDLS responder STA shall reject the request with status code STATUS_INVALID_AKMP.

(#6149)(#7237)If the pairwise cipher suite is not acceptable (including if it is (#3056)TKIP), then the TDLS responder STA shall reject the request with status code STATUS_INVALID_PAIRWISE_CIPHER.

(#6149)(#7237)If the PeerKey Enabled subfield is not equal to 1 in the RSN Capabilities field, the TDLS responder STA shall reject the request with status code INVALID_RSNE_CAPABILITIES.

(#6149)If the number of replay counters indicated by the TDLS initiator STA is not acceptable to the TDLS responder STA at both the TDLS initiator STA and the TDLS responder STA (see 12.5.2.4.4 (PN and replay detection) and 12.5.4.4.4 (PN and replay detection)), the TDLS responder STA shall reject the request with status code INVALID_RSNE_CAPABILITIES.

(#6149)If the suggested lifetime is unacceptable or below the default value, the TDLS responder STA shall reject the request with status code UNACCEPTABLE_LIFETIME.

(#6149)(#7237)If the FTE is not set as described as above, the TDLS responder STA shall reject the request with status code STATUS_INVALID_FTE.

(#6149)The TDLS responder STA shall ignore the remaining fields in the RSNE(#7238).

(#6149)Otherwise, the TDLS responder STA shall respond as specified in 11.20.4 (TDLS direct link establishment(#1356)).

#### 12.7.8.4.3 TPK handshake message 2

If the TDLS responder STA validates the TPK handshake message 1 for this TDLS instance, the TDLS responder STA may respond with TPK handshake message 2. To do so, the TDLS responder STA shall add an RSNE, FTE, and (#1776)TIE to its TDLS Setup Response frame. The elements shall be formatted as follows:

The RSNE shall include the following:

(#3241)The Version field shall be set to the minimum of the maximum version supported by the TDLS responder STA and the version number received in the RSNE of message 1(#6163).

All other RSNE fields shall be same as those received in message 1.

The (#1776)TIE shall be the same as that received in the TPK handshake message 1.

The FTE shall include the following:

ANonce shall be set to a value chosen randomly by the TDLS responder STA, see 12.7.5 (Nonce generation) for a recommended procedure.

SNonce shall be same as that received in message 1 of this sequence

The MIC shall be calculated on the concatenation, in the following order, of:

TDLS initiator STA MAC address (6 octets)

TDLS responder STA MAC address (6 octets)

Transaction Sequence number (1 octet) which shall be set to the value 2

Link Identifier element

RSNE

(#1776)TIE

FTE, with the MIC field of the FTE set to 0.

The MIC shall be calculated using the (#8161)TPK key confirmation key (TPK-KCK) and the AES-128-CMAC algorithm. The output of the AES-128-CMAC shall be 128 bits.

All other fields shall be set to 0.

The TDLS responder STA shall use the MLME-SETKEYS.request primitive to configure the Temporal Key into its STA prior to sending message 2.

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(#6149)The TDLS responder STA sends message 2 to the TDLS initiator STA.

(#6149)On reception of message 2, the TDLS initiator STA proceeds as follows:

If the TDLS initiator STA Address and TDLS responder STA Address of the Link Identifier element do not match those for an outstanding TDLS Setup Request, the TDLS initiator STA shall silently discard (#6149)the response.

If the SNonce field of the FTE does not match that of an outstanding request to the TDLS responder STA, (#6149)the TDLS initiator STA shall silently discard the response.

Otherwise, the TDLS initiator STA shall (#7163)compute the TPK transient key and then validate the MIC in the FTE as specified in MIC calculation procedure for TPK handshake message 2. If invalid, the TDLS initiator STA shall (#7239)silently discard (#6149)the response.

If the version of the RSNE is 0 or is greater than the version of the RSNE sent in message 1, (#6149)the TDLS initiator STA shall reject the response with status code UNSUPPORTED_RSNE_VERSION.

(#8175)(#6149)If the (#3488)Information field of the RSNE is not the same as that sent by the TDLS initiator STA in message 1 of this sequence, except that the version may be lower as long as it is nonzero, then the TDLS initiator STA shall reject the response with status code INVALID_RSNE.

(#6149)If the pairwise cipher suite count is not 1, the TDLS initiator STA shall reject the response with status code STATUS_INVALID_PAIRWISE_CIPHER.

(#6149)If the pairwise cipher suite was not included in the request, the TDLS initiator STA shall reject the response with status code STATUS_INVALID_PAIRWISE_CIPHER.

(#6149)If the (#1776)TIE is not the same as that sent in message 1, the TDLS initiator STA shall reject the response with status code UNACCEPTABLE_LIFETIME.

(#6149)If the BSSID in the Link Identifier element is different from the one sent in message 1, the TDLS initiator STA shall reject the response with status code NOT_IN_SAME_BSS.

If the TDLS initiator STA validates TDLS message 2, the TDLS initiator STA shall create a TPKSA and respond with message 3 as defined in 11.20.4 (TDLS direct link establishment(#1356)). The TDLS initiator STA shall use the MLME-SETKEYS.request primitive to configure the Temporal Key into its STA prior to sending message 3.

#### 12.7.8.4.4 TPK handshake message 3

If the TDLS initiator STA responds to message 2 for this TDLS instance, the TDLS initiator STA shall add an RSNE, FTE, and (#1776)TIE to its TDLS Setup Confirm frame. The elements shall be formatted as follows:

The RSNE shall be the same as the RSNE received in message 2.

The (#1776)TIE shall be the same as that received in the TPK handshake message 2.

With the exception of the MIC field, the contents of the FTE shall be the same as the FTE received in message 2.

The MIC shall be calculated on the concatenation, in the following order, of:

TDLS initiator STA MAC address (6 octets)

TDLS responder STA MAC address (6 octets)

Transaction Sequence number (1 octet), which shall be set to the value 3

Link Identifier element

RSNE

(#1776)TIE

FTE, with the MIC field of the FTE set to 0.

The MIC shall be calculated using the TPK-KCK and the AES-128-CMAC algorithm. The output of the AES-128-CMAC shall be 128 bits.


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All other fields shall be set to 0.

(#6149)The TDLS initiator STA sends message 3 to the TDLS responder STA.

(#6149)On reception of message 3, the TDLS responder STA proceeds as follows:

Confirm that the Source and Destination Address of the Link Identifier element match those for an outstanding TDLS Setup Request;

Confirm that the ANonce and SNonce fields of the FTE match that of an outstanding request to the TDLS initiator STA;

Validate the MIC in the FTE as specified in the MIC calculation procedure for TPK handshake message 3.

If any of the above conditions are not met, the TDLS responder STA shall (#7240)silently discard the (#6149)confirmation. If the above conditions are met, the TDLS responder STA shall:

Validate that (#3488)the RSNE received in message 3 is the same as the RSNE sent by the TDLS responder STA in message 2;

Confirm that the (#1776)TIE is the same as that sent in message 2;

Confirm that the BSSID from the Link Identifier element is the same as that sent in message 2.

If any (#6149)of the above conditions are not met, the TDLS responder STA shall (#7240)silently discard the confirmation and abandon the TPK handshake identified by <ANonce, SNonce> combination, and delete any state resulting from the existing TPK handshake for this sequence.

On successful processing of message 3, the TPK handshake is considered successful.

If the TDLS responder STA does not receive a valid TPK handshake message 3 from the TDLS initiator STA within dot11TDLSResponseTimeout, the TDLS responder STA shall abandon the TPK handshake and delete any state resulting from the TPK handshake.

### 12.7.9 RSNA Supplicant key management state machine

#### 12.7.9.1 General

The Supplicant shall reinitialize the Supplicant state machine whenever its system initializes. A Supplicant enters the AUTHENTICATION state on an event from the MAC that requests another STA to be authenticated. A Supplicant enters the STAKEYSTART state on receiving an (#1836)EAPOL-Key PDU from the Authenticator. If the MIC or any of the (#1836)EAPOL-Key PDUs fails, the Supplicant (#6112)shall silently discard the frame. Figure 12-53 (RSNA Supplicant key management state machine(#4350)(#3257)) depicts the RSNA Supplicant state machine.

Unconditional transfer (UCT) means the event triggers an immediate transition.

This state machine does not use timeouts or retries. The IEEE 802.1X state machine has timeouts that recover from authentication failures, etc.

In order to authenticate an Authenticator, the management entity sends an authentication request event. This might be before or after the STA associates with(#1427) the AP. In an IBSS environment, the event is generated when a Probe Response frame is received.

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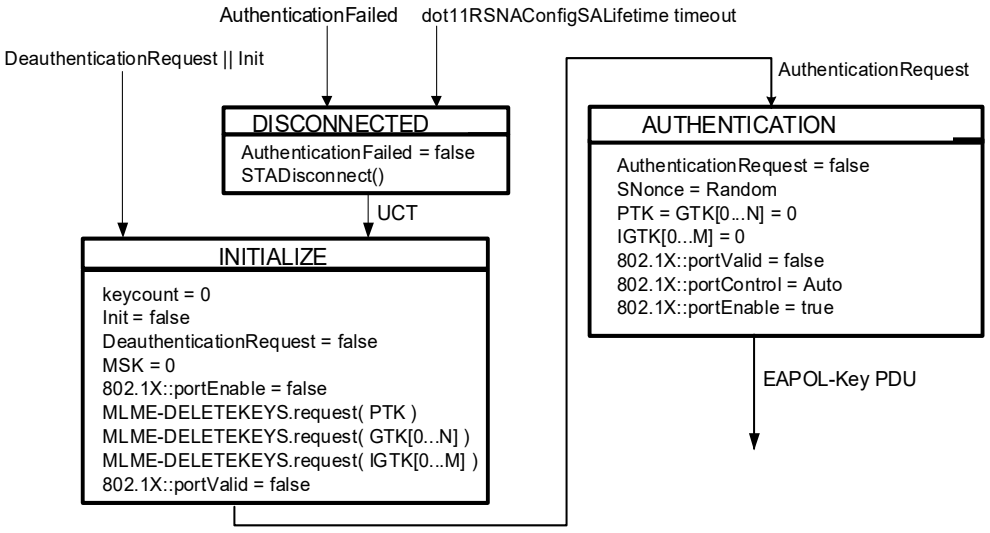


**Figure 12-53—RSNA Supplicant key management state machine(#4350)(#3257)**

### 12.7.9.2 Supplicant state machine states

The following list summarizes the states of the Supplicant state machine:

— **AUTHENTICATION**: A Supplicant enters this state when it sends an IEEE 802.1X AuthenticationRequest to authenticate to an SSID.

— **DISCONNECTED**: A Supplicant enters this state when IEEE 802.1X authentication fails. The Supplicant executes StaDisconnect and enters the INITIALIZE state.

— **INITIALIZE**: A Supplicant enters this state from the DISCONNECTED state, when it receives Disassociation or Deauthentication messages or when the STA initializes, causing the Supplicant to initialize the key state variables.

— **STAKEYSTART:** A Supplicant enters this state when it receives an (#1836)EAPOL-Key PDU. All the information to process the (#1836)EAPOL-Key PDU is in the message and is described in the StaProcessEAPOL-Key procedure.

### 12.7.9.3 Supplicant state machine variables

The following list summarizes the variables used by the Supplicant state machine:

— *DeauthenticationRequest.* The Supplicant sets this variable to true if the Supplicant's STA reports it has received Disassociation or Deauthentication messages.

— *AuthenticationRequest.* The Supplicant sets this variable to true if its STA's IEEE 802.11 management entity reports that an SSID is to be authenticated(#3596).

— *AuthenticationFailed*. The Supplicant sets this variable to true if the IEEE 802.1X authentication failed. The Supplicant uses the MLME-DISASSOCIATE.request primitive to cause its STA to disassociate from the Authenticator's STA.

— *EAPOLKeyReceived.* The Supplicant sets this variable to true when it receives an (#1836)EAPOL-Key PDU.

— *IntegrityFailed.* The Supplicant sets this variable to true when its STA reports that a fatal data integrity error (e.g., michael failure) has occurred.


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NOTE—A michael failure is not the same as MICVerified because IntegrityFailed is generated if the michael integrity check fails; MICVerified is generated from validating the EAPOL-Key integrity check. Note also the STA does not generate this event for ciphers other than TKIP because countermeasures are not required.

— *MICVerified*. The Supplicant sets this variable to true if the MIC on the received (#1836)EAPOL-Key PDU verifies as correct or if the AEAD cipher is used and the AEAD decryption steps succeed. (#6113)The Supplicant shall silently discard any (#1836)EAPOL-Key PDU received with an invalid MIC.

— (#3596)*PTKSAEstablished*. The Supplicant sets this variable to 0 on initialization and to 1 when a PTKSA has been established.

— *SNonce.* This variable represents the Supplicant's nonce.

— *PTK.* This variable represents the current PTK.

— *TPTK.* This variable represents the current PTK until message 3 of the 4-way handshake arrives and is verified.

— *GTK[].* This variable represents the current GTKs for each group key index.

— *IGTK[].* This variable represents the current IGTKs for each group management key index.

— *PMK.* This variable represents the current PMK.

— *keycount*. This variable is used in an IBSS to decide when all of the keys have been delivered and an IBSS link is secure.

— *802.1X::XXX.* This variable denotes another IEEE 802.1X state variable *XXX* not specified in this standard.

#### 12.7.9.4 Supplicant state machine procedures

The following list summarizes the procedures used by the Supplicant state machine:

— **STADisconnect.** The Supplicant invokes this procedure to disassociate and deauthenticate its STA from the AP.

— **MIC**(*x*). The Supplicant invokes this procedure to compute a MIC of the data *x*.

— **CheckMIC**(). (#3245)The Supplicant invokes this procedure to verify a MIC computed by the MIC() function.

— **StaProcessEAPOL-Key.** The Supplicant invokes this procedure to process a received (#1836)EAPOL-Key PDU. The pseudocode for this procedure is as follows:

(#3394)**StaProcessEAPOL-Key** (*S*, *M*, *A*, *I*, *K*, *RSC*, *ANonce*, *MIC*, {RSNE, *GTK*[*N*], *IGTK*[*M*], IPN})

```
(#4143)# Global initialization
PrevANonce ← 0
TPTK ← PTK
TSNonce ← 0
PRSC ← 0
UpdatePTK ← 0
State ← UNKNOWN
(#4143)# Frame specific processing
if M = 1 then
    if Check MIC(PTK, (#1836)EAPOL-Key PDU) fails then
        State ← FAILED
    else
        State ← MICOK
    endif
endif
(#3596)if K = P then
```

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```
if State ≠ FAILED then
    if PSK exists then (#3596)// PSK is a preshared key
        PMK ← PSK
    else
        PMK ← (#3506)ExtractBits(MSK, 0, PMK_bits)
    endif
    TSNonce ← SNonce
    if ANonce ≠ (#4143)PrevANonce then
        TPTK ← Calc PTK(PMK, ANonce, TSNonce)
        (#4143)PrevANonce ← ANonce
    endif
    if State = MICOK then
        PTK ← TPTK
        UpdatePTK ← I
        if UpdatePTK = 1 then
            if no GTK then
                PRSC ← (#3394)RSC
            endif
            if MLME-SETKEYS.request(0, true, PRSC, PTK) fails then
                invoke MLME-
                DEAUTHENTICATE.request
            endif
            MLME-SETPROTECTION.request(TA, Rx)
        endif
        if GTK then
            if (GTK[N] ← Decrypt GTK) succeeds then
                if MLME-SETKEYS.request(N, 0, (#3394)RSC, GTK[N]) fails
                then
                    invoke MLME-DEAUTHENTICATE.request
                endif
            else
                State ← FAILED
            endif
        endif
        if IGTK then
            if (IGTK[M] ← Decrypt IGTK) succeeds then
                if MLME-SETKEYS.request(M, 0, IPN, IGTK[M]) fails then
                    invoke MLME-DEAUTHENTICATE.request
                endif
            else
                State ← FAILED
            endif
        endif
    endif
endif
(#3596)else if K = G then
    if State = MICOK then
        if (GTK[N] ← Decrypt GTK) succeeds then
            if MLME-SETKEYS.request(N, T, RSC, GTK[N]) fails then
                invoke MLME-DEAUTHENTICATE.request
            endif
        else
            State ← FAILED
        endif
```



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```
                    if (IGTK[M] ← Decrypt IGTK) succeeds then
                        if MLME-SETKEYS.request(M, T, IPN, IGTK[M]) fails then
                            invoke MLME-DEAUTHENTICATE request
                        endif
                    else
                        State ← FAILED
                    endif
                else
                    State ← FAILED
                endif
            endif
            (#3596)if State ≠ Failed then
                if K = P && M = 0 && A = 1 then
                    Send EAPOL-Key(PTKSAEstablished, 1, 0, 0, P, 0, 0, TSNonce, MIC(TPTK),
                    {RSNE}) // M2
                else if K = P && M = 1 && A = 1 then
                    Send EAPOL-Key(1, 1, 0, 0, P, 0, 0, 0, MIC(TPTK), {}) // M4
                else if K = G && A = 1 then
                    Send EAPOL-Key(1, 1, 0, 0, G, 0, 0, 0, MIC(TPTK), {}) // G2
                else
                    State ← FAILED
                endif
            endif
            (#3596)if State ≠ Failed && UpdatePTK = 1 then
                    MLME-SETPROTECTION.request(TA, Rx_Tx)
                    PTKSAEstablished ← 1
            endif
            if State = MICOK && S = 1 then
                MLME-SETPROTECTION.request(TA, Rx_Tx)
                if IBSS then
                    keycount++
                    if keycount = 2 then
                        802.1X::portValid← true
                    endif
                else
                    802.1X::portValid← true
                endif
            endif
```

Here UNKNOWN, MICOK, and FAILED are values of the variable State used in the Supplicant pseudocode. State is used to decide how to do the key processing. MICOK is set to 1 when the MIC of the EAPOL-Key has been checked and is valid. FAILED is used when a failure has occurred in processing the (#1836)EAPOL-Key PDU. UNKNOWN is the initial value of the variable State.

When processing 4-way handshake message 3, the GTK, IGTK(11ba), BIGTK if present, and WIGTK if present are decrypted from the (#1836)EAPOL-Key PDU and installed. The PTK shall be installed before the GTK and IGTK.

The Key Replay Counter field used by the Supplicant for (#1836)EAPOL-Key PDUs that are sent in response to an (#1836)EAPOL-Key PDU shall be the received Key Replay Counter field. Invalid (#1836)EAPOL-Key PDUs such as invalid MIC, GTK without a MIC, etc., shall be ignored.

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NOTE 1—TPTK is used to stop attackers changing the PTK on the Supplicant by sending the first message of the 4-way handshake. An attacker can still affect the 4-way handshake while the 4-way handshake is being carried out.

NOTE 2—The PMK is supplied by the authentication method used with (#3469)IEEE Std 802.1X-2020 if preshared mode is not used.

NOTE 3—A PTK is configured into the encryption/integrity engine depending on the Tx/Rx bit, but if configured, is always a transmit key. A GTK is configured into the encryption/integrity engine independent of the state of the Tx/Rx bit, but whether the GTK is used as a transmit key is dependent on the state of the Tx/Rx bit.

— **CalcGTK**(x). Generates the GTK.
— **DecryptGTK**(x). Decrypt the GTK from the (#1836)EAPOL-Key PDU.
— **DecryptIGTK**(x). Decrypt the IGTK from the (#1836)EAPOL-Key PDU.

### 12.7.10 RSNA Authenticator key management state machine

#### 12.7.10.1 General

There is one state diagram for the Authenticator. In an infrastructure BSS, the Authenticator is always on the AP; and in an IBSS environment, the Authenticator is on every STA.

The state diagram shown in parts in Figure 12-54 (Authenticator state machines, part 1(#3596)(#1454)(#8001)) to Figure 12-57 (Authenticator state machines, part 4(#4350)(#1382)) consists of the following states:

a) The AUTHENTICATION, AUTHENTICATION2, INITPMK, INITPSK, PTKSTART, PTKCALCNEGOTIATING, PTKCALCNEGOTIATING2, PTKINITNEGOTIATING, PTKINITDONE, DISCONNECT, DISCONNECTED, and INITIALIZE states. These states handle the initialization, 4-way handshake, teardown, and general clean-up. These states are per associated STA.
b) The IDLE, REKEYNEGOTIATING, KEYERROR, and REKEYESTABLISHED states. These states handle the transfer of the GTK to the associated client. These states are per associated STA.
c) The GTK_INIT, SETKEYS, and SETKEYSDONE states. These states change the GTK when required, trigger all of the PTK group key state machines, and update the IEEE 802.11 MAC in the Authenticator's AP when all STAs have the updated GTK. These states are global to the Authenticator.

Because there are two GTKs, responsibility for updating these keys is given to the group key state machine (see Figure 12-56 (Authenticator state machines, part 3(#3596)(#1455)(#7007))). In other words, this state machine determines which GTK is in use at any time.

(#7007)The Authenticator may skip the "Disconnect = true" step in the KEYERROR state if a BSS max idle period is advertised by the AP and the non-AP STA might have remained in doze state during the group key handshake. When the AP does not disconnect a non-AP STA in such a case, the AP may send the current group keys using group key handshake with this non-AP STA when it transitions to the awake state.

When a second STA associates, the group key state machine is already initialized, and a GTK is already available and in use.

When the GTK is to be updated the variable (#1382)GTKRekey is set to 1. The SETKEYS state updates the GTK and triggers all of the PTK group key state machines that currently exist—one per associated STA. Each PTK group key state machine sends the GTK to its STA. When all of the STAs have received the GTK (or failed to receive the key), the SETKEYSDONE state is executed which updates the APs encryption/integrity engine with the new key.


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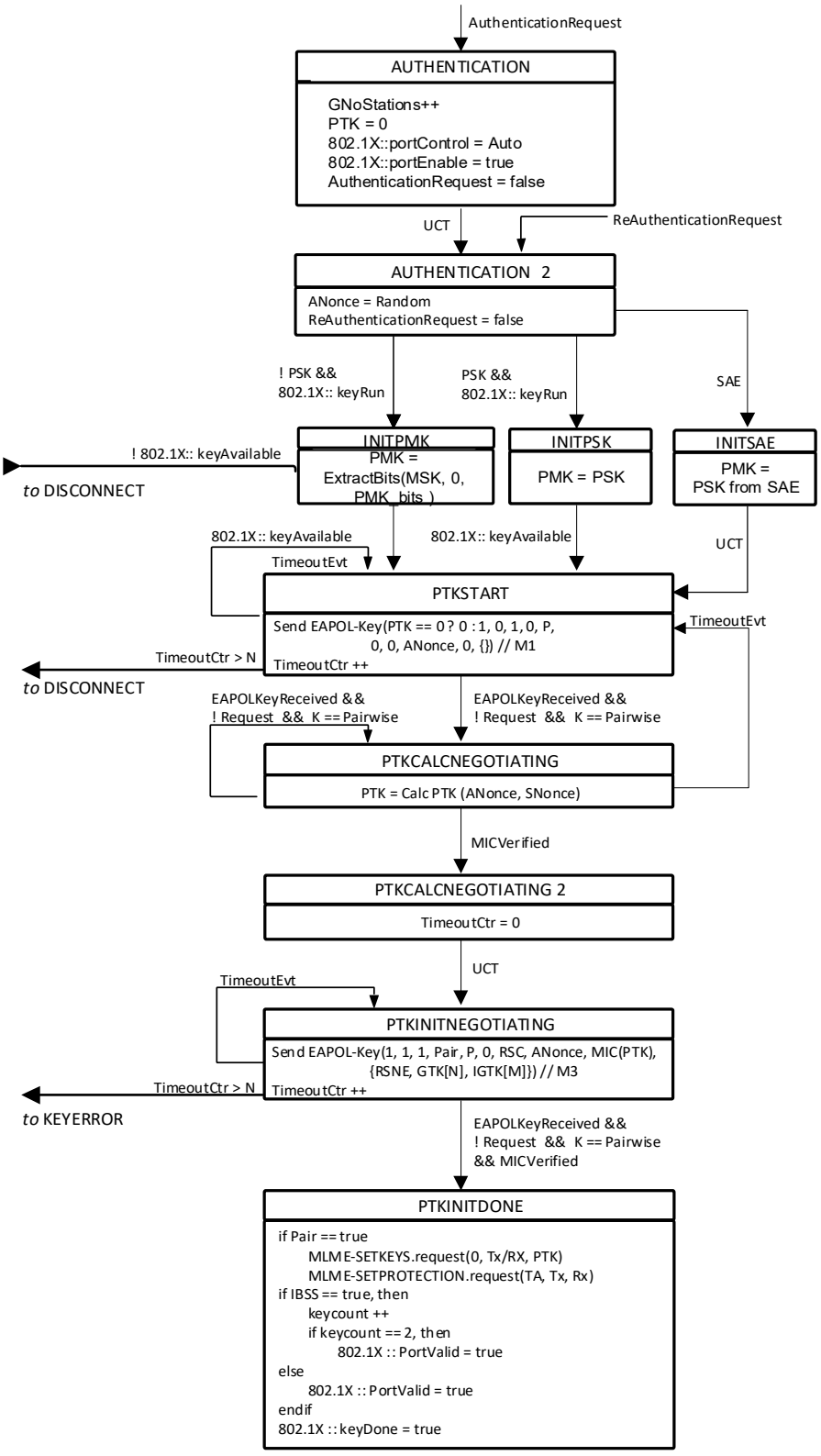


**Figure 12-54—Authenticator state machines, part 1(#3596)(#1454)(#8001)**

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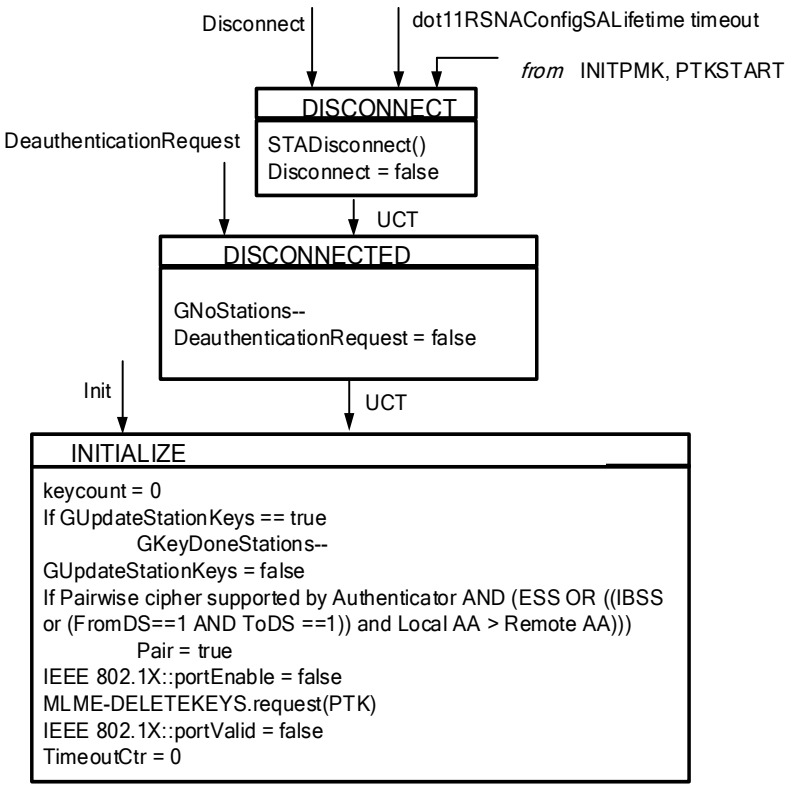


**Figure 12-55—Authenticator state machines, part 2(#4350)**

Both the PTK state machine and the PTK group key state machine use received (#1836)EAPOL-Key PDUs as an event to change states. The PTK state machine only uses (#1836)EAPOL-Key PDUs with the Key Type field equal to Pairwise, and the PTK group key state machine only uses (#1836)EAPOL-Key PDUs with the Key Type field equal to Group.

### 12.7.10.2 Authenticator state machine states

#### 12.7.10.2.1 Authenticator state machine: 4-way handshake (per STA)

The following list summarizes the states the Authenticator state machine uses to support the 4-way handshake:

— **AUTHENTICATION**: This state is entered when an AuthenticationRequest is sent from the management entity to authenticate a BSSID.

— **AUTHENTICATION2**: This state is entered from the AUTHENTICATION state or from the PTKINITDONE state.

— **DISCONNECT**: This state is entered if an (#1836)EAPOL-Key PDU is received and fails its MIC check. It sends a Deauthentication message to the STA and enters the INITIALIZE state.

— **DISCONNECTED**: This state is entered when Disassociation or Deauthentication messages are received.

— **INITIALIZE**: This state is entered from the DISCONNECTED state, when a deauthentication request event occurs, or when the STA initializes. The state initializes the key state variables.

— **INITPMK**: This state is entered when the IEEE 802.1X backend AS completes successfully. If a PMK is supplied, it goes to the PTKSTART state; otherwise, it goes to the DISCONNECTED state.


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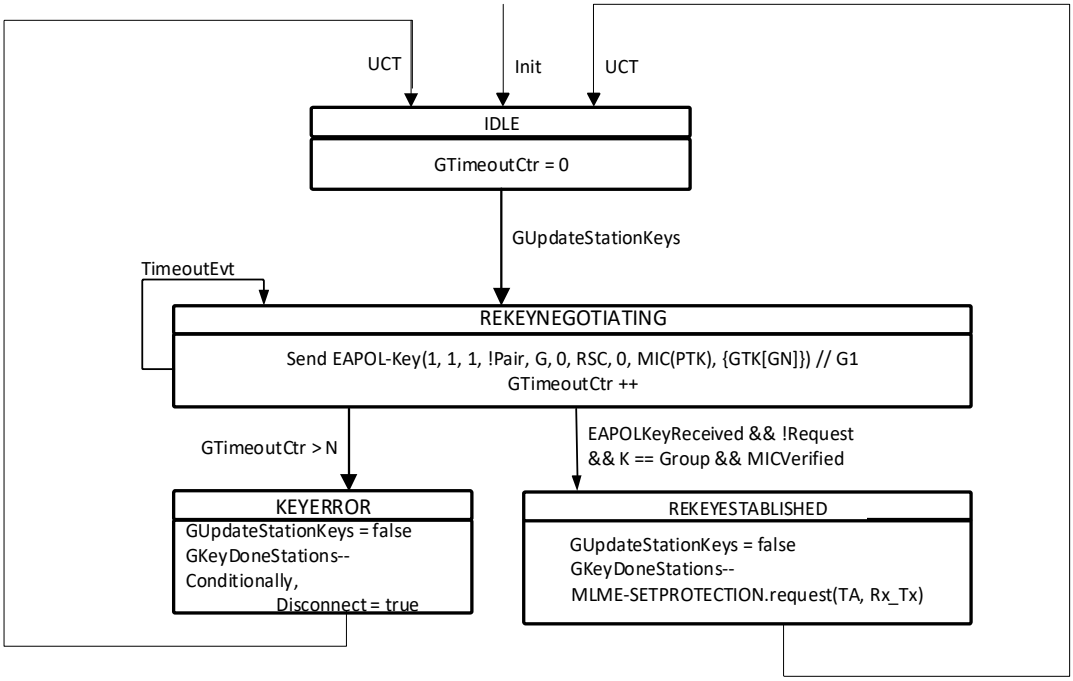


**Figure 12-56—Authenticator state machines, part 3(#3596)(#1455)(#7007)**

— **INITPSK:** This state is entered when a PSK is configured.

— **INITSAE:** This state is entered when SAE authentication is completed successfully.

— **PTKCALCNEGOTIATING:** This state is entered when the second (#1836)EAPOL-Key PDU for the 4-way handshake is received with the key type of Pairwise.

— **PTKCALNEGOTIATING2:** This state is entered when the MIC for the second (#1836)EAPOL-Key PDU of the 4-way handshake is verified.

— **PTKINITNEGOTIATING:** This state is entered when the MIC for the second (#1836)EAPOL-Key PDU for the 4-way handshake is verified. When message 3 of the 4-way handshake is sent in state PTKINITNEGOTIATING, the wrapped GTK shall be sent at the end of the data field, and the GTK length is put in the GTK Length field.

— **PTKINITDONE:** This state is entered when the last (#1836)EAPOL-Key PDU for the 4-way handshake is received with the key type of Pairwise. This state may call SetPTK; if this call fails, the AP should detect and recover from the situation (#2153)for example, by doing a disconnect event for this association.

— **PTKSTART:** This state is entered from INITPMK, INITPSK, or INITSAE to start the 4-way handshake or if no response to the 4-way handshake occurs.

#### 12.7.10.2.2 Authenticator state machine: group key handshake (per STA)

The following list summarizes the states the Authenticator state machine uses to support the group key handshake:

— **IDLE:** This state is entered when no group key handshake is occurring.

— **KEYERROR:** This state is entered if the EAPOL-Key acknowledgment for the group key handshake is not received.

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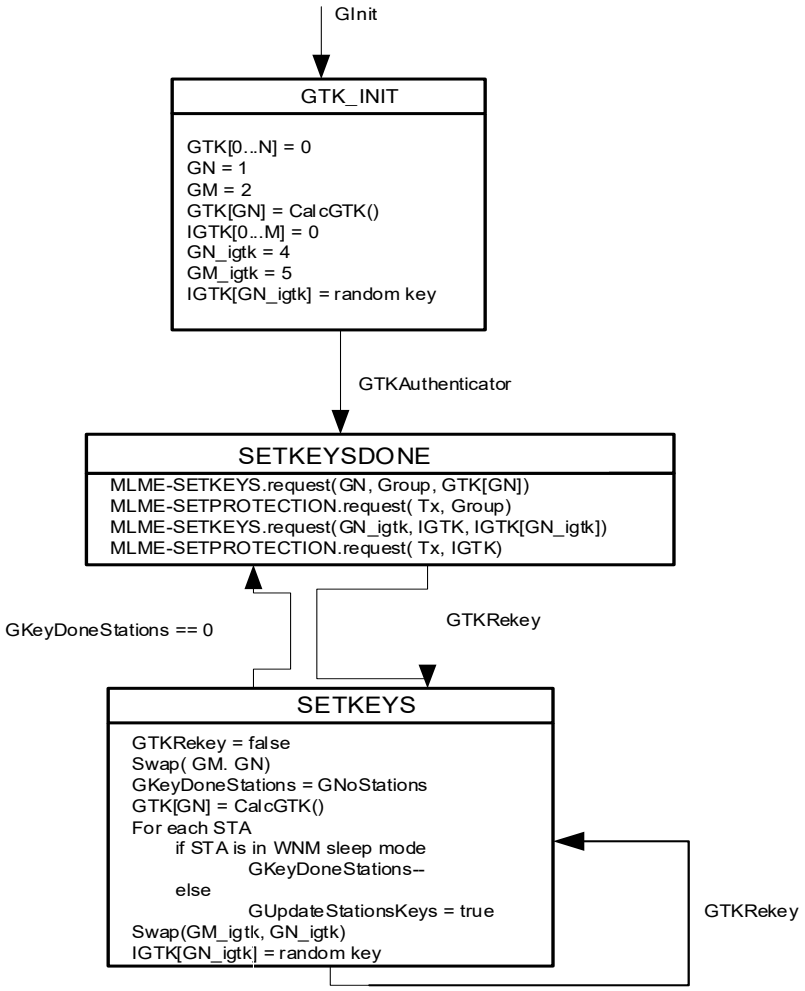


**Figure 12-57—Authenticator state machines, part 4(#4350)(#1382)**

— **REKEYESTABLISHED:** This state is entered when an (#1836)EAPOL-Key PDU is received from the Supplicant with the Key Type subfield equal to Group.

— **REKEYNEGOTIATING:** This state is entered when the GTK is to be sent to the Supplicant.

NOTE—The Rx_Tx flag for sending a GTK is always the opposite of whether the pairwise key is used for data encryption/integrity or not. If a pairwise key is used for encryption/integrity, then the STA never transmits with the GTK; otherwise, the STA uses the GTK for transmit.

### 12.7.10.2.3 Authenticator state machine: group key handshake (global)

The following list summarizes the states the Authenticator state machine uses to coordinate a group key update of all STAs:

— **GTK_INIT:** This state is entered on system initialization.

— **SETKEYS:** This state is entered if the GTK is to be updated on all Supplicants.

— **SETKEYSDONE:** This state is entered if the GTK has been updated on all Supplicants.


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NOTE—SETKEYSDONE calls SetGTK to set the GTK for all associated STAs that are not in WNM sleep mode. If this fails, all communication via this key fails, and the AP needs to detect and recover from this situation. A STA that is in WNM sleep mode will not have the current GTK installed when it wakes up and will need to get new GTK as described in the WNM sleep mode procedures in 11.2.3.15 (WNM sleep mode).

### 12.7.10.3 Authenticator state machine variables

The following list summarizes the variables used by the Authenticator state machine:

— *AuthenticationRequest.* This variable is set to true by the STA's IEEE 802.11 management entity in order to authenticate an association(#3596).

— *ReAuthenticationRequest.* This variable is set to true if the IEEE 802.1X Authenticator received an eapStart or 802.1X::reAuthenticate is 1.

— *DeauthenticationRequest*. This variable is set to true if a Disassociation or Deauthentication message is received.

— *Disconnect***.** This variable is set to true when the STA should initiate a deauthentication.

— *EAPOLKeyReceived.* This variable is set to true when an (#1836)EAPOL-Key PDU is received. (#1836)EAPOL-Key PDUs that are received in response to an (#1836)EAPOL-Key PDU sent by the Authenticator shall contain the same Key Replay Counter field value as the Key Replay Counter field in the transmitted message. (#1836)EAPOL-Key PDUs that contain different Key Replay Counter field values should be discarded. An (#1836)EAPOL-Key PDU that is sent by the Supplicant in response to an (#1836)EAPOL-Key PDU from the Authenticator shall not have the Ack bit set to 1. (#1836)EAPOL-Key PDUs sent by the Supplicant not in response to an EAPOL-Key PDU from the Authenticator shall have the Request bit set to 1.

(#1836)EAPOL-Key PDUs with a key type of Pairwise and a nonzero key index should be ignored.

(#1836)EAPOL-Key PDUs with a key type of Group and an invalid key index should be ignored.

(#6162)NOTE—When an (#1836)EAPOL-Key PDU in which the Ack bit is 0 is received, then it is expected as a reply to a message that the Authenticator sent, and the replay counter is checked against the replay counter used in the sent (#1836)EAPOL-Key PDU. When (#1571)an EAPOL-Key request frame is received, (#3426)a replay counter for these messages is used that is a different replay counter than the replay counter used for sending messages to the Supplicant.

— *GTimeoutCtr*. This variable maintains the count of EAPOL-Key receive timeouts for the group key handshake. It is incremented each time a timeout occurs on EAPOL-Key receive event and is initialized to 0. Annex C details the timeout values. The Key Replay Counter field value for the (#1836)EAPOL-Key PDU shall be incremented on each transmission of the (#1836)EAPOL-Key PDU.

— *GInit*. This variable is used to initialize the group key state machine. This is a group variable.

— *Init*. This variable is used to initialize per-STA state machine

— *TimeoutEvt.* This variable is set to true if the (#1836)EAPOL-Key PDU sent out fails to obtain a response from the Supplicant. The variable may be set to 1 by management action or set to 1 by the operation of a timeout while in the PTKSTART and REKEYNEGOTIATING states.

— *TimeoutCtr.* This variable maintains the count of EAPOL-Key receive timeouts. It is incremented each time a timeout occurs on EAPOL-Key receive event and is initialized to 0. Annex C contains details of the timeout values. The Key Replay Counter field value for the (#1836)EAPOL-Key PDU shall be incremented on each transmission of the (#1836)EAPOL-Key PDU.

— *MICVerified.* This variable is set to true if the MIC on the received (#1836)EAPOL-Key PDU is verified and is correct or if the AEAD cipher is used and the AEAD decryption steps succeed. Any (#1836)EAPOL-Key PDUs with an invalid MIC are (#3683)discarded.

— *GTKAuthenticator.* This variable is set to true if the Authenticator is on an AP or it is the designated Authenticator for an IBSS.

— *GKeyDoneStations.* Count of number of STAs left to have their GTK updated. This is a global variable.

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- *GTKRekey*. This variable is set to true when a group key handshake is required. This is a global variable.
- *GUpdateStationKeys*. This variable is set to true when a new GTK is available to be sent to Supplicants.
- *GNoStations*. This variable counts the number of Authenticators so it is known how many Supplicants need to be sent the GTK. This is a global variable.
- *ANonce*. This variable holds the current nonce to be used if the STA is an Authenticator.
- *GN*, *GM*. These are the current key indices for GTKs. Swap(GM, GN) means that the global key index in GN is swapped with the global key index in GM, so now GM and GN are reversed. (#1456)This is used to change the GTK key ID when rekeying.
- *PTK*. This variable is the current PTK.
- *GTK[]*. This variable is the current GTKs for each GTK index.
- *PMK*. This variable is the buffer holding the current PMK.
- *802.1X::XXX*. This variable is the IEEE 802.1X state variable *XXX*.
- *keycount*. This variable is used in an IBSS to decide when all of the keys have been delivered and an IBSS link is secure.
- *WNM sleep mode*. This variable is true when the non-AP STA is in the WNM sleep mode, as described in 11.2.3.15 (WNM sleep mode). Otherwise, it is false.

#### 12.7.10.4 Authenticator state machine procedures

The following list summarizes the procedures used by the Authenticator state machine:

- **STADisconnect**(). Execution of this procedure deauthenticates the STA.
- **CalcGTK**(x). Generates the GTK.
- **MIC**(x). Computes a MIC over the plaintext data. When an AEAD cipher is used, returns an empty string.

## 12.8 Mapping EAPOL keys to IEEE 802.11 keys

### 12.8.1 Mapping PTK to TKIP keys

See 12.7.1.3 (Pairwise key hierarchy) for the definition of the EAPOL temporal key derived from PTK.

A STA shall use bits 0–127 of the temporal key as its input to the TKIP Phase 1 and Phase 2 mixing functions.

A STA shall use bits 128–191 of the temporal key as the michael key for MSDUs from the Authenticator's STA to the Supplicant's STA.

A STA shall use bits 192–255 of the temporal key as the michael key for MSDUs from the Supplicant's STA to the Authenticator's STA.

### 12.8.2 Mapping GTK to TKIP keys

See 12.7.1.4 (Group key hierarchy) for the definition of the EAPOL temporal key derived from GTK.

A STA shall use bits 0–127 of the temporal key as the input to the TKIP Phase 1 and Phase 2 mixing functions.

A STA shall use bits 128–191 of the temporal key as the michael key for MSDUs from the Authenticator's STA to the Supplicant's STA.


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A STA shall use bits 192–255 of the temporal key as the michael key for MSDUs from the Supplicant's STA to the Authenticator's STA.

### 12.8.3 Mapping PTK to CCMP keys

See 12.7.1.3 (Pairwise key hierarchy) for the definition of the EAPOL temporal key derived from PTK.

A STA shall use the temporal key as the CCMP key for MPDUs between the two communicating STAs.

### 12.8.4 Mapping GTK to CCMP keys

See 12.7.1.4 (Group key hierarchy) for the definition of the EAPOL temporal key derived from GTK.

A STA shall use the temporal key as the CCMP key(#3056).

### 12.8.5 Mapping IGTK to BIP keys

See 12.7.1.5 (Integrity group key hierarchy) for the definition of the IGTK. A STA shall use bits 0-127 of the IGTK as the AES-128-CMAC key, bits 0-127 of the IGTK as the AES-128-GMAC key, bits 0-255 of the IGTK as the AES-256-GMAC key, and bits 0-255 of the IGTK as the AES-256-CMAC key.

### 12.8.6 Mapping PTK to GCMP keys

See 12.7.1.3 (Pairwise key hierarchy) for the definition of the EAPOL temporal key derived from PTK.

A STA shall use the temporal key as the GCMP key for MPDUs between the two communicating STAs.

### 12.8.7 Mapping GTK to GCMP keys

See 12.7.1.4 (Group key hierarchy) for the definition of the EAPOL temporal key derived from GTK.

A STA shall use the temporal key as the GCMP key.

### 12.8.8 Mapping BIGTK to BIP keys

See 12.7.1.7 (Beacon protection key hierarchy) for the definition of the BIGTK. A STA shall use bits 0-127 of the BIGTK as the AES-128-CMAC key, bits 0-127 of the BIGTK as the AES-128-GMAC key, bits 0-255 of the BIGTK as the AES-256-GMAC key, and bits 0-255 of the BIGTK as the AES-256-CMAC key.

### 12.8.9 Mapping WTK to BIP key(11ba)

See 12.7.1.3 (Pairwise key hierarchy) for the definition of the WTK. A STA shall use bits 0–127 of the WTK as the AES-128-CMAC key for protecting individually addressed WUR Wake-up frames.

### 12.8.10 Mapping WIGTK to BIP key(11ba)

See 12.7.1.8 (Wake-up radio integrity group temporal key (WIGTK) hierarchy(11ba)) for the definition of the WIGTK. A STA shall use bits 0–127 of the WIGTK as the AES-128-CMAC key for protecting broadcast and group addressed WUR Wake-up frames.

## 12.9 Authenticated mesh peering exchange (AMPE)

The authenticated mesh peering exchange is defined in 14.6 (Authenticated mesh peering exchange (AMPE)).

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## 12.10 AP PeerKey support

### 12.10.1 AP PeerKey overview

The AP PeerKey protocol provides session identification and creation of an AP PeerKey association to provide for security of OBSS management communication between two APs. The result of a successful run of the AP PeerKey protocol is an AP PeerKey association. An AP PeerKey association is composed of a mesh PMKSA and a mesh PTKSA(#240).

(#1544)NOTE 1—This does not mean that the APs form an MBSS, however.

(#1543)NOTE 2—An AP PeerKey is not used for exchange of Data frames.

Two APs perform the AP PeerKey protocol in order to protect HCCA TXOP Advertisement frames in an OBSS. The AP PeerKey protocol is unauthenticated (neither peer has a verified identity of the other peer) but an AP knows that only the peer AP that completed the AP PeerKey protocol is able to send protected HCCA TXOP Advertisement frames protected by the resulting AP PeerKey association. This allows an AP to determine whether a peer AP honors the HCCA TXOP avoidance schedule that is negotiated. In this manner, an AP is able to honor the negotiated schedule of trusted peer APs and ignore peer APs that are not trustworthy. This allows trustworthy APs to negotiate mutually beneficial schedules while allowing an AP to not disadvantage itself in an OBSS in the presence of untrustworthy APs.

AP PeerKey uses various functions and data to accomplish its task and assumes certain properties about each function as follows:

— H is an “extractor” function (see IETF RFC 5869) that concentrates potentially dispersed entropy from an input to create an output that is a cryptographically strong, pseudorandom key. This function takes as input a nonsecret “salt” and a secret input and produces a fixed-length output.

— A finite cyclic group is negotiated for which solving the discrete logarithm problem is computationally infeasible.

When using (#3266)AKM 00-0F-AC:10 to indicate AP PeerKey, H shall be instantiated as HMAC-SHA-256, taking as input a nonsecret “salt” and a secret input keying material “ikm”:

H(salt, ikm) = HMAC-SHA-256(salt, ikm)

Other instantiations of function H require creation of a new AKM identifier.

### 12.10.2 AP PeerKey protocol

AP PeerKey uses the same discrete logarithm cryptography as SAE (as described in 12.4 (Authentication using a password)) to achieve key agreement. Each party to the exchange has a public and private key with respect to a particular set of domain parameters that define a finite cyclic group. Groups may be based on elliptic curve cryptography (ECC) or finite field cryptography (FFC). Each component of a group is referred to as an *element*. Groups are negotiated using an identifying number from a repository maintained by IANA as “Group Description” attributes for IETF RFC 2409 (IKE) [B14][B29]. The repository maps an identifying number to a complete set of domain parameters for the particular group. For the purpose of interoperability, APs that have dot11ProtectedHCCATXOPNegotiationImplemented true or dot11ProtectedQLoadReportImplemented true shall implement support for group 19, an ECC group defined over a 256-bit prime order field.

AP PeerKey uses one arithmetic operator that takes one element and one scalar value to produce another element (called the *scalar operation*). The convention used here is to represent group elements in uppercase bold italic and scalar values in lowercase italic.


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The private key $d$ shall be chosen randomly so that $1 < d < r$, where $r$ is the order of the group. The public key $\boldsymbol{Q}$ shall be produced using Equation (12-5).

$$\boldsymbol{Q} = \text{scalar-op}(d, \boldsymbol{G}) \quad (12\text{-}5)$$

where

$\boldsymbol{G}$ is the generator (also known as the base point) of the group

An AP for which dot11ProtectedTXOPNegotiationActivated is true or dot11ProtectedQLoadReportActivated is true shall support at least one public key from cyclic group nineteen and may support multiple public keys from multiple cyclic groups. An AP that supports the Multiple BSSID capability and has dot11ProtectedTXOPNegotiationActivated true or dot11ProtectedQLoadReportActivated true may use one public key across multiple BSSIDs, or it may choose to generate a public key for each supported BSSID.

The AP PeerKey protocol consists of an exchange of public keys from an AP and a peer AP. An AP requests the public key of a peer AP by sending a Public Key frame with the Public Key Frame Usage field set to "Request." This frame contains the public key of the initiating AP. The initiating AP awaits a response to its request. The peer AP responds to the "Request" from the initiating AP with a Public Key frame with the Public Key Frame Usage field set to "Response", indicating an acceptable group was sent by the initiating AP, or set to "NAK" indicating that the group sent by the initiating AP was unacceptable.

It is possible for multiple runs of the AP PeerKey protocol to be performed by an AP but there shall be only one instance at a time of the AP PeerKey protocol to a peer AP for a particular group. The state associated with each run of the AP PeerKey protocol is the group and the two public keys of the participating APs.

An AP for which dot11ProtectedTXOPNegotiationActivated is true or dot11ProtectedQLoadReportActivated is true shall reply to a Public Key frame. An AP that has both dot11ProtectedTXOPNegotiationActivated is false and dot11ProtectedQLoadReportActivated is false shall (#3683)discard all received Public Key frames. If the responding AP refuses to perform the AP PeerKey protocol with the initiating AP it shall respond with a Public Key frame, setting the Public Key Frame Usage field to "Refused". Otherwise, if the Finite Cyclic Group field in the public key request is a group that is supported by the responding AP, the AP shall reply with a public key of the same group as the request, generating such a key pair if required, and setting the Public Key Frame Usage field to "Response". The receiving AP shall generate a PMK and a mesh PMKSA, see below, and terminate the AP PeerKey protocol. If the Finite Cyclic Group field in the public key request is not supported by the responding AP, the responding AP shall respond with a Public Key frame, setting the Public Key Frame Usage field to "NAK" and the group set to a group acceptable by the receiving AP.

If the initiating AP does not receive a response to its request after 5 s(#7198), it should retransmit its request. The initiating AP should attempt such retransmission a minimum of five times.

If the initiating AP receives a Public Key frame from a peer AP with the Public Key Frame Usage field set to "NAK", the initiating AP inspects the Finite Cyclic Group field in the received "NAK". If the group is supported, the initiating AP should initiate to the peer AP using the indicated group. If the group is not supported, the AP may choose to initiate to the peer AP using a different group from the dot11RSNAConfigDLCGroupTable. Receipt of a Public Key frame from a peer AP with the Public Key Frame Usage field set to "NAK" terminates the AP PeerKey protocol.

If the initiating AP receives a Public Key frame from a peer AP with the Public Key Frame Usage field set to "Refused", the initiating AP shall terminate the AP PeerKey protocol.

An initiating AP that receives a refusal should delay sending another request for at least 5 s(#7198), and should perform exponential backoff on all subsequent requests by doubling the delay with each subsequent refusal.

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NOTE 1—This standard does not specify a limit on the number of attempts an initiating AP makes to communicate with another AP.

If the initiating AP receives a Public Key frame from a peer AP with the Public Key Frame Usage field set to "Response" and the group set to the value in the initiating AP's "Request", the initiating AP shall generate a PMK and a mesh PMKSA. This terminates the AP PeerKey protocol.

If the initiating AP receives a Public Key frame from a peer AP with the Public Key Frame Usage field set to "Request" prior to receiving a "Response", it checks the Finite Cyclic Group field in the request. If the Group in the received "Request" is the same as the Group the initiating AP sent it its request, the AP shall construct a Public Key frame with the Public Key Frame Usage field set to "Response" containing the public key it sent in its "Request" and transmit it to the peer. The AP shall then generate a PMK and a mesh PMKSA, see below, and terminate the (#3257)AP PeerKey protocol. If the Finite Cyclic Group field differs and the group indicated is supported, the AP shall respond to the peer AP by replying with a public key from that group, generating a key pair if required, and setting the Public Key Frame Usage field to "Response". The AP shall generate a PMK and a mesh PMKSA, see below, and terminate this run of the AP PeerKey protocol.

Once the AP and peer AP have exchanged public keys from the same finite cyclic group they can compute the Diffie-Hellman shared secret using scalar-op() and function F from 12.4.4 (Finite cyclic groups):

$$k = \text{F}(\text{scalor-op}(d, \boldsymbol{Q}_p)) \tag{12-6}$$

where

$d$ is the private key of the AP that is calculating $k$

$\boldsymbol{Q}_p$ is the public key of the peer AP

Entropy of the shared secret shall then be extracted using function H to produce *keyseed* using Equation (12-7).

$$keyseed = \text{H}(<0>32, k) \tag{12-7}$$

where

<0>32 denotes 32 octets of the value zero

The PMK shall be derived according to Equation (12-8), and the PMKID shall be derived according to Equation (12-9).

(#478)PMK = KDF-*Hash*-256(*keyseed*, "AP Peerkey Protocol",
0x00 || Max(LOCAL-MAC, PEER-MAC) || Min(LOCAL-MAC, PEER-MAC) ) (12-8)

PMKID = Truncate-128(SHA-256($Q_1$ || $Q_2$ ||
Max(LOCAL-MAC, PEER-MAC) ||
Min(LOCAL-MAC, PEER-MAC)) (12-9)

where

(#478)KDF-*Hash*-256is the key derivation function defined in 12.7.1.6.2 (Key derivation function (KDF)) using the hash algorithm identified by the AKM suite selector (see Table 9-190 (AKM suite selectors))

0x00 is a single octet with a value of zero

LOCAL-MAC is the AP's MAC address

PEER-MAC is the peer AP's MAC address

$Q_1$ is the public key used by AP1 in the AP PeerKey protocol encoded as an octet stream using the Element to Octet string conversion from 12.4.7.2.3 (Octet string to integer conversion).


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| | |
|---|---|
| $Q_2$ | is the public key used by AP2 in the AP PeerKey protocol encoded as an octet stream using the Element to Octet string conversion from 12.4.7.2.3 (Octet string to integer conversion). |
| AP1 | is the AP whose MAC address equals Max(LOCAL-MAC, PEER-MAC) |
| AP2 | is the AP whose MAC address equals Min(LOCAL-MAC, PEER-MAC) |

The Max and Min operations for IEEE 802 addresses are with the address converted to a positive integer treating the first octet as the most significant octet of the integer.

*keyseed* shall be irretrievably deleted after the PMK is generated.

The lifetime of the mesh PMKSA shall be set to the value dot11RSNAConfigPMKLifetime.

Upon creation of the PMK, an AEK shall be created per 14.6.7 (Keys and key derivation algorithm for the authenticated mesh peering exchange (AMPE)). The mesh PMKSA for this instance of the AP PeerKey protocol shall then be created using the AP's MAC address as the STA's MAC address, the peer AP's MAC address as the peer STA's MAC address, the AEK, the lifetime, and the PMKID. If a mesh PMKSA created by a prior run of the AP PeerKey protocol exists it shall be deleted upon creation of the new PMKSA. All mesh PTKSAs(#240) created by the old mesh PMKSA shall also be deleted.

Upon creation of the mesh PMKSA, the APME protocol (as defined in 14.6 (Authenticated mesh peering exchange (AMPE)) shall be used to prove possession of the PMK (and implicitly the private key that corresponds to the peer's public key) and generate the mesh PTKSA(#240).

Note that it is possible for two APs which simultaneously initiated to each other with different, but acceptable, groups to end up with two mesh PMKSAs. In this unlikely case, the mesh PMKSA from a group with the largest prime in its domain parameter set shall be used with the AMPE protocol. The other mesh PMKSA shall be deleted.

If the AMPE protocol completes successfully, Protected HCCA TXOP Advertisement frames and Protected HCCA TXOP Response frames may be used in the HCCA TXOP negotiation procedures, as defined in 11.26.3 (HCCA TXOP negotiation) using the MTK from the mesh PTKSA(#240). If the AMPE procedure completes successfully, Protected QLoad Request frames and Protected QLoad Report frames may be used in the QLoad report procedures, as defined in 11.26.2 (QLoad Report element) using the MTK from the mesh PTKSA(#240). If the AMPE protocol fails, the peer's public key, PMK, and PMKSA shall be deleted.

NOTE 2—The PMK, as well as any key derived from it, is not authenticated in any way nor is it bound to any identity. This protocol protects an AP that cooperates in scheduling its HCCA TXOPs using Protected HCCA TXOP Advertisement frames because no other entity knows its private key and cannot forge Protected HCCA TXOP Advertisement frames. An AP that receives a Protected HCCA TXOP Advertisement frame is assured it was sent by the holder of a particular private key, and no one else, and can, therefore, establish which APs are cooperating in their HCCA TXOP scheduling. An AP that receives a Protected QLoad Report frame is assured it was sent by the holder of a particular private key, and no other STA, and can, therefore, establish which APs are correctly reporting their QoS load.

## 12.11 Authentication for FILS

### 12.11.1 General

FILS authentication is an RSNA authentication protocol. The FILS authentication protocol authenticates STAs to each other, using either a shared key or a public key. When FILS Shared Key authentication is used, the authentication exchange can optionally be performed with PFS. When FILS Public Key authentication is used, PFS is always used. When the FILS authentication protocol is performed with PFS, the STA and AP derive ephemeral public and private keys with respect to a particular set of domain parameters that define a finite cyclic group and then exchange public keys. The result of the FILS authentication includes a PTKSA.

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The security of FILS authentication depends on the following assumptions:

- When FILS Shared Key authentication is used, each STA shares either a valid rRK as defined in IETF RFC 6696 with a TTP that is capable of being used with EAP-RP, or a PMK cached from a previous authenticated connection.
- When FILS Public Key authentication is used, each STA has a means to trust the public key of the other STA.
- When PFS is used, a finite cyclic group is negotiated where solving the discrete logarithm problem is computationally infeasible.
- When PFS is used, both the STA and AP have in common at least one finite cyclic group from the dot11RSNAConfigDLCGroupTable.

### 12.11.2 FILS authentication protocol

#### 12.11.2.1 General

The STA and AP perform key establishment using Authentication frames and perform key confirmation using (Re)Association Request and (Re)Association Response frames.

After exchanging Authentication frames, the STA and AP derive a shared and secret key (M118)used to derive a set of secret keys (as defined in 12.11.2.5.2 (PMKSA key derivation with FILS authentication)) that are authenticated after exchanging (Re)Association Request and (Re)Association Response frames.

When a shared key is used for FILS authentication, and if the STA shares a valid rRK with the TTP, then EAP-RP as defined in IETF RFC 5295 and IETF RFC 6696 shall be used.

To prevent key reinstallation attacks, the non-AP STA shall maintain a copy of the most recent GTK, most recent IGTK(11ba), most recent BIGTK, and most recent WIGTK installed as part of the FILS authentication protocol as if they were installed as a result of receipt of EAPOL-Key frames (see 12.7.7.4 (Group key handshake implementation considerations)) and shall refuse to update a GTK, IGTK(11ba), BIGTK, or WIGTK when the key to be set matches either one of these two keys (see 6.5.14 (SetKeys)).

#### 12.11.2.2 Discovery of a FILS AP

An AP indicates that it is capable of performing FILS authentication by (#8199)indicating support for an AKM in Table 9-190 (AKM suite selectors) for which the Authentication type cell identifies FILS in an RSNE(#1517) and including it, and the FILS Indication element, in Beacon and Probe Response frames.

(#4117)NOTE—An AP with dot11AuthenticationAlgorithmsTable including an entry with dot11AuthenticationAlgorithm equal to filsSharedKeyWithoutPFS, filsSharedKeyWithPFS, or filsPublicKey is capable of performing FILS authentication.

An AP may indicate that it is capable of performing FILS authentication by indicating support for a FILS AKM in the FD RSN Information subfield in a FILS Discovery frame.

An AP indicates support for FILS Shared Key authentication without PFS by setting the FILS Shared Key authentication without PFS supported bit to 1 in the FILS Information field of the FILS Indication element. An AP indicates support for FILS Shared Key authentication with PFS by setting the FILS Shared Key authentication with PFS Supported bit to 1 in the FILS Information field of the FILS Indication element. An AP may advertise between zero and seven realms using the Realm Identifier subfield(s) of the FILS Indication element that is part of Beacon, Probe Response, and FILS Discovery frames. If the STA believes it shares a valid rRK as defined in IETF RFC 6696 with the AP through, e.g., a hashed domain name that matches an AP-advertised realm, a HESSID, or other ANQP information, the STA may begin FILS Shared Key authentication with the AP using EAP-RP. Domain name hashing is specified in 11.45.4 (FILS authentication and higher


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layer setup capability indications). If a STA discovers a FILS AP and the STA believes it shares a PMKSA with the AP, it may begin the FILS authentication protocol with the AP using PMKSA caching.

An AP indicates support for FILS Public Key authentication by setting the FILS Public Key authentication Supported bit to 1 in the FILS Information field of the FILS Indication element. An AP may advertise up to seven public key indicators in the FILS Indication element that is part of Beacon, Probe Response, and FILS Discovery frames. If the STA discovers that it trusts the issuer of an AP's X.509v3 certificate, or that it trusts its uncertified public key identified by matching its hash, the STA may begin the FILS authentication protocol to the AP and perform mutual authentication using trusted public keys.

#### 12.11.2.3 Key establishment with FILS Shared Key authentication

##### 12.11.2.3.1 Overview

This subclause defines the procedure for establishing a shared key between a FILS STA and AP using FILS Shared Key authentication that uses shared symmetric keys between the STA and the TTP.

A STA may initiate FILS Shared Key authentication either with a FILS AP that is connected to a TTP that shares a valid key, called an rRK, as defined in IETF RFC 6696 with the STA, or with a FILS AP with whom it shares a cached PMKSA. If neither of these cases applies, a full EAP exchange may be performed via IEEE 802.1X authentication to establish rRK as defined in IETF RFC 6696 or another form of FILS authentication may be used to establish a shared PMKSA. When performing a full EAP exchange using RSNA to establish rRK, the Authentication algorithm number 0 (Open System) is used.

(#4117)NOTE—An AP with dot11AuthenticationAlgorithmsTable including an entry with dot11AuthenticationAlgorithm equal to filsSharedKeyWithoutPFS, filsSharedKeyWithPFS, or filsPublicKey is capable of performing FILS authentication.

EAP-RP signaling as defined in IETF RFC 5295 and IETF RFC 6696 is used to validate the mutual possession of rRK between the STA and the TTP. EAP-RP signaling is encapsulated using a (#7044)Wrapped Data element in the Authentication frame. The AP unwraps the encapsulated EAP-RP packet received from the STA in the (#7044)Wrapped Data element and forwards the EAP-RP packet to the TTP using a transport that is out of scope of this standard. When the AP receives an EAP-RP packet from the TTP, the AP forwards the packet to the STA by encapsulating the EAP-RP packet in the (#7044)Wrapped Data element of the Authentication frame.

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The message sequence is depicted in Figure 12-58 (FILS Shared Key authentication(#3596)).

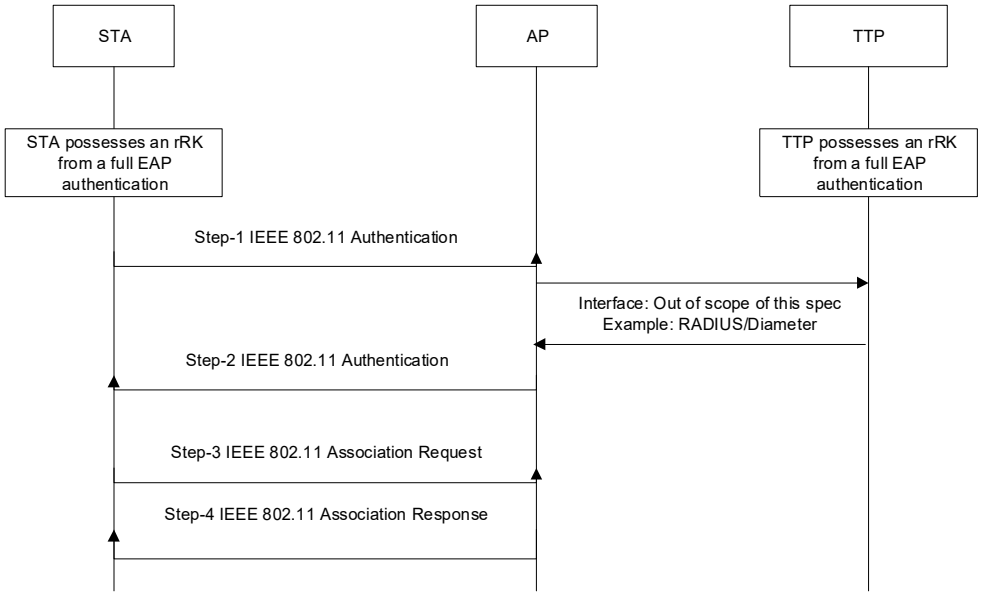


**Figure 12-58—FILS Shared Key authentication(#3596)**

The following subclauses are organized per each step as shown in Figure 12-58 (FILS Shared Key authentication(#3596)).

#### 12.11.2.3.2 Non-AP STA construction of Authentication frame

If the STA chooses to initiate FILS Shared Key authentication, it shall first choose a random 16-octet nonce and then determine whether to attempt PMKSA caching. If PMKSA caching is attempted, it shall generate a list of PMKSA identifiers. If the STA attempts to initiate EAP-RP, it shall construct an EAP-Initiate/Reauth packet per IETF RFC 6696, with the following clarifications:

- Regarding EAP-RP Flags:
  - The B flag shall be set to 0, indicating that this is not an EAP-RP bootstrap message.
  - The L flag shall be set to 1, indicating that the TTP with whom the STA shares the rRK is to provide the lifetimes of rRK and rMSK in (#330)the EAP-Finish/Reauth packet.
  - EAP Identifier is set to 0.
- The Cryptosuite field shall not be set to 1.

If PFS is desired, the STA selects a finite cyclic group from the dot11RSNAConfigDLCGroupTable, which comprises identifying number from a repository maintained by IANA as “Group Description” attributes for IETF RFC 2409 (IKE) [B14][B29]. The STA then generates an ephemeral private key, and performs the group’s scalar-op (see 12.4.4.1 (General)) with its random ephemeral private key and the generator from the selected finite cyclic group to compute an ephemeral public key.

The STA then constructs an Authentication frame with the Authentication algorithm number set to 4 (FILS Shared Key authentication without PFS) or 5 (FILS Shared Key authentication with PFS) (see 9.4.1.1 (Authentication Algorithm Number field)) depending on whether PFS is used, and the Authentication transaction sequence number set to 1. The random nonce shall be encoded in the FILS Nonce element (see 9.4.2.188 (FILS Nonce element)). If a list of PMKSA identifiers was generated, it shall be used to construct the PMKID List field in (#6299)the RSNE. The random FILS Session shall be encoded in the FILS Session


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element (see 9.4.2.178 (FILS Session element)). The EAP-Initiate/Reauth packet, if generated, shall be copied into the (#7044)Wrapped Data field (see 9.4.2.186 ((11az)Wrapped Data element)). If PFS is desired, the chosen finite cyclic group shall be encoded in the Finite Cyclic Group field (see 9.4.1.40 (Finite Cyclic Group field)) and the ephemeral public key shall be encoded in the FFE field (see 9.4.1.38 (FFE field)) according to the element to (#1288)octet string conversion in 12.4.7.2.4 (Element to octet string conversion).

The STA transmits the Authentication frame to the AP.

#### 12.11.2.3.3 AP processing of Authentication frame

Upon reception of the Authentication frame with the Authentication algorithm number equal to 4 or 5, the AP shall perform the following procedure:

a) If Authentication frame includes a Finite Cyclic Group field, then the AP shall first determine whether the indicated finite cyclic group in the received FILS Authentication frame is supported.

b) If the indicated finite cyclic group in the received FILS Authentication frame is not supported, the AP shall respond with an Authentication frame with the Authentication algorithm number set to 5 (FILS Shared Key authentication with PFS) (see 9.4.1.1 (Authentication Algorithm Number field)) and the Status Code field set to 77 (Authentication is rejected because the offered finite cyclic group is not supported) and shall terminate the exchange.

c) If PFS is being used, the STA's public key shall be converted from an octet string to an element according to the conversion in 12.4.7.2.5 (Octet string to element conversion). Then the AP shall validate the STA's public key in a group-specific fashion as described in 5.6.2.3 of (#298)NIST Special Publication 800-56A R2. If validation fails, the AP shall terminate the exchange.

d) The AP shall check whether PMKSA caching is being attempted by the presence of the PMKID List field in (#6299)the RSNE:

   1) If the PMKID List field is present in (#6299)the RSNE, the AP checks whether any PMKSA identifier offered in the PMKID List matches an identifier for a cached PMKSA. If so, the AP selects a PMKID that matches and continues the FILS Shared Key authentication protocol using the PMK from the identified PMKSA.

   2) If a PMKID List field is not present in (#6299)the RSNE or if no PMKSA identifier offered in the PMKID list matches any identifier for a cached PMKSA, the AP checks whether an EAP-Initiate/Reauth packet was included. If not, the AP shall respond with an Authentication frame with the Authentication algorithm number set to 4 or 5 depending on whether PFS is used and the Status Code field set to 53 (invalid PMKID) and shall terminate the exchange.

   3) If an EAP-Initiate/Reauth packet is included and PMKSA caching is not used, the AP shall extract the (#2043)data needed from the (#7044)Wrapped Data field (see 9.4.2.186 ((11az)Wrapped Data element)) and shall forward it to the Authentication Server. When applicable, the AP communicates with the Authentication Server using the same protocols it uses when authenticating with EAP. Suitable protocols include, but are not limited to, remote authentication dial-in user service RADIUS (as specified in IETF RFC 2865 [B33]) and Diameter (as specified in IETF RFC 6942).

If PFS is being used, the AP shall also generate an ephemeral private key and perform the group's scalar-op (see 12.4.4.1 (General)) to produce its own ephemeral public key. The AP may delay the generation of its ephemeral public/private key pair until after receiving a response from the Authentication Server, if applicable. The Authentication Server processes the EAP-Initiate/Reauth packet as specified in IETF RFC 6696 and returns an EAP-Finish/Reauth packet to the AP. In the case of successful authentication by the Authentication Server, the Authentication Server returns the associated EAP-RP rMSK with the EAP-Finish/Reauth packet. If the Authentication Server responds with a failure indication, then the AP shall produce an Authentication frame with the Authentication Algorithm Number field set to 4 (FILS Shared Key authentication without PFS) or 5 (FILS Shared Key authentication with PFS) (see 9.4.1.1 (Authentication Algorithm Number field)), and the Status Code field set to 15 (Authentication rejected because of challenge failure). In the case of successful

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authentication by the Authentication Server, the Authentication Server returns the associated EAP-RP rMSK with the EAP-Finish/Reauth packet and processing terminates.

The AP proceeds by constructing an Authentication frame.

#### 12.11.2.3.4 AP construction of Authentication frame

If PMKSA caching is not used and the AP is not connected to, or does not recognize the Authentication Server identified by the STA using the realm in the key Name-NAI field of the EAP-Initiate/Reauth packet, then the AP shall send Authentication frame with Status Code field set to 113, "Authentication rejected due to unknown Authentication Server" to the non-AP STA.

Otherwise, the AP shall generate its own nonce and construct an Authentication frame for the STA. The AP shall copy the FILS Session element from the Authentication frame sent by the non-AP STA to this response Authentication frame. If PMKSA caching is not used, this frame shall contain the (#7044)wrapped data that encapsulates (#330)the EAP-Finish/Reauth packet received from the Authentication Server. In addition, if PFS is used, the FFE field of the Authentication frame sent by the AP contains the AP's ephemeral public key. In this frame, the AP shall set the Authentication algorithm number to 4 or 5 depending on whether PFS is used, and the Authentication sequence number to 2. If PMKSA caching is used, the AP indicates the selected PMKID in the PMKID List.

If PFS is being used for the exchange, the AP shall perform the group's scalar-op (see 12.4.4.1 (General)) with the STA's ephemeral public key and its own ephemeral private key to produce an ephemeral Diffie-Hellman shared secret, DHss.

The AP transmits the Authentication frame to the STA. Upon transmission of the FILS Authentication frame, the AP proceeds to key establishment per 12.11.2.5 (Key establishment with FILS authentication).

#### 12.11.2.3.5 Non-AP STA processing of Authentication frame

The STA processes the received Authentication frame as follows:

a) The STA shall abandon FILS authentication if any of the following conditions occur:
   1) The received Authentication frame does not include the Authentication Algorithm Number equal to 4 (FILS Shared Key authentication without PFS) or 5 (FILS Shared Key authentication with PFS) (see 9.4.1.1 (Authentication Algorithm Number field)).
   2) PMKSA caching was attempted and the received Authentication frame includes a PMKID that does not match a PMKID in the Authentication frame sent by the STA.
   3) The received Authentication frame does not include either a PMKID or an EAP-Finish/Reauth packet.
   4) The received Authentication frame does not include the FILS Session element.
   5) The received FILS Session value does not match the one in the Authentication frame sent by the STA.

b) If the received Authentication frame includes the Status Code field equal to 15 (Authentication rejected because of challenge failure) or 53 (invalid PMKID), then the STA shall abandon the FILS authentication.

c) The STA verifies that the AP transmitted PFS parameters are consistent with the STA's previous transmissions (indicated by whether or not the STA transmitted an ephemeral public key):
   1) If the STA transmitted an ephemeral public key, and the received Authentication frame does not include an ephemeral public key, then the STA shall abandon the FILS authentication.
   2) If the STA did not transmit an ephemeral public key, and the received Authentication frame includes an ephemeral public key, then the STA shall abandon the FILS authentication.


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d) If applicable, the STA processes the EAP-Finish/Reauth packet as per IETF RFC 6696:
   1) If the R flag = 0, indicating success, then the STA shall derive rMSK.
   2) If the R flag = 1, indicating failure, then the STA shall abandon the FILS authentication.

e) If PFS is being used for the exchange, the AP's public key shall be converted from an octet string to an element according to the conversion in 12.4.7.2.5 (Octet string to element conversion). Then the STA shall validate the AP's public key in a group-specific fashion as described in 5.6.2.3 of (#298)NIST Special Publication 800-56A R2. If validation fails, the STA shall terminate the FILS authentication protocol. Otherwise, the STA shall perform the group's scalar-op (see 12.4.4.1 (General)) with the AP's ephemeral public key and its own ephemeral private key to produce an ephemeral Diffie-Hellman shared secret, DHss.

f) The STA shall perform key derivation per 12.11.2.5 (Key establishment with FILS authentication) and key confirmation per 12.11.2.6 (Key confirmation with FILS authentication).

If the STA was attempting EAP-RP Authentication and did not receive an Authentication frame, then the STA should perform retransmission procedure as defined in IETF RFC 6696, and with (M118)implementation specific timeouts as guided by the AuthenticateFailureTimeout parameter in the MLME-AUTHENTICATE.request. If the retransmission procedure fails, then the STA shall abandon the FILS authentication and should perform full EAP authentication via IEEE 802.1X authentication.

If the STA was attempting PMKSA caching and did not receive an Authentication frame from the AP, the STA may attempt to use an alternate authentication method.

#### 12.11.2.4 Key establishment with FILS Public Key authentication

##### 12.11.2.4.1 General

This subclause defines the procedure for establishing a shared key between a FILS STA and AP using FILS Public Key authentication.

When using FILS Public Key authentication, a STA shall initiate authentication using either a public key or a cached PMKSA.

##### 12.11.2.4.2 Prior to exchange

FILS Public Key authentication performs key establishment with a Diffie-Hellman exchange. Prior to beginning the exchange, the non-AP STA performs the following:

a) Selects a finite cyclic group from the dot11RSNAConfigDLCGroupTable to perform the Diffie-Hellman exchange.

b) Generates a random 16-octet nonce, generates an ephemeral private key, and uses the selected group's scalar-op (see 12.4.4.1 (General)) with its private key to generate its ephemeral public key.

c) Determine whether to attempt PMKSA caching and if so, generates a list of PMKSA identifiers.

d) Constructs an Authentication frame (see 9.3.3.11 (Authentication frame format)) as follows:
   1) The Authentication algorithm number shall be set to 6 (FILS Public Key authentication) (see 9.4.1.1 (Authentication Algorithm Number field)) and the Authentication transaction sequence number shall be set to 1.
   2) The random nonce shall be encoded in the FILS Nonce element (see 9.4.2.188 (FILS Nonce element)).
   3) The chosen finite cyclic group shall be encoded in the Finite Cyclic Group field (see 9.4.1.40 (Finite Cyclic Group field)).

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4) The STA's ephemeral public key shall be encoded into the FFE field (see 9.4.1.38 (FFE field)) according to the element to (#1288)octet string conversion in 12.4.7.2.4 (Element to octet string conversion).
5) The random FILS Session shall be encoded in the FILS Session element (see 9.4.2.178 (FILS Session element)).
6) (#4226)The Pairwise Cipher Suite Count field in the RSNE shall be set to 1.
7) (#4226)The AKM Suite Count field in the RSNE shall be set to 1.
8) If a list of PMKSA identifiers was generated, it shall be used to construct the PMKID List field in (#4226)the RSNE.

The STA then transmits the Authentication frame to the AP.

#### 12.11.2.4.3 Processing after receipt

Upon reception of the Authentication frame with the Authentication algorithm number equal to 6, the AP shall perform the following procedure:

a) If the finite cyclic group indicated by the Finite Cyclic Group field is not acceptable, the AP shall respond with an Authentication frame with the status code of 77 ("Authentication is rejected because the offered finite cyclic group is not supported") and terminate the FILS authentication protocol.
b) If the finite cyclic group is acceptable, the AP shall verify the validity of the STA's ephemeral public key:
   1) The public key is converted from an octet string to an element according to the conversion in 12.4.7.2.5 (Octet string to element conversion).
   2) The public key, as a group element, is verified in a group-specific fashion as described in 5.6.2.3 of (#298)NIST Special Publication 800-56A R2. If verification fails, the AP shall terminate the FILS authentication protocol.
c) The STA's nonce and validated ephemeral public key are extracted from the Authentication frame.
d) The AP shall check whether PMKSA caching is being attempted by the presence of the PMKSA List field in (#6299)the RSNE. If the PMKID List field is present in (#6299)the RSNE, the AP checks whether any PMKSA identifier offered in the PMKID List matches an identifier for a cached PMKSA. If so, the AP selects a PMKID that matches and shall continue the FILS Public Key authentication protocol using PMKSA caching, otherwise the AP shall continue the FILS Public Key authentication protocol using digital signatures.

#### 12.11.2.4.4 Post processing

Next, the AP shall

a) Generate a random 16-octet nonce and a random ephemeral private key, and then uses the agreed-upon group's scalar-op (see 12.4.4.1 (General)) with its private key to generate its ephemeral public key.
b) Construct an Authentication frame (see 9.3.3.11 (Authentication frame format)) as follows:
   1) The Authentication algorithm number is set to 6 (FILS Public Key authentication) (see 9.4.1.1 (Authentication Algorithm Number field)), and the Authentication transaction sequence number is set to 2.
   2) The random nonce is encoded in the FILS Nonce element (see 9.4.2.188 (FILS Nonce element)).
   3) The finite cyclic group is encoded in the Finite Cyclic Group field (see 9.4.1.40 (Finite Cyclic Group field)).


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4) The AP's ephemeral public key is encoded in the FFE field (see 9.4.1.38 (FFE field)) according to the element to (#1288)octet string conversion in 12.4.7.2.4 (Element to octet string conversion).
5) The AP copies the FILS Session element from the Authentication frame received from the STA.
6) If the PMKSA caching is used, the AP indicates the selected PMKID in the PMKID List.

c) Transmit the Authentication frame to the STA.
d) Compute the Diffie-Hellman shared secret, DHss, based on the STA's ephemeral public key and its own ephemeral private key with the chosen group's scalar-op.
e) Perform key derivation (see 12.11.2.5 (Key establishment with FILS authentication)).

#### 12.11.2.4.5 Upon receipt

The STA processes the received Authentication frame as follows:

a) The STA shall abandon FILS authentication if any of the following conditions occur:
1) The received Authentication frame does not include the Authentication Algorithm Number equal to 6 (FILS Public Key authentication) (see 9.4.1.1 (Authentication Algorithm Number field)).
2) PMKSA caching was attempted and the received Authentication frame includes a PMKID that does not match a PMKID in the Authentication frame sent by the STA.
3) The received Authentication frame does not include the FILS Session element.
b) Verifies that the finite cyclic group in the AP's response is equal to the group selected by the STA and that the FILS Session element received from the AP is equal to the FILS Session selected by the STA. If these differ, the STA shall terminate the authentication exchange.
c) Verifies the validity of the AP's ephemeral public key:
1) The public key is converted from an octet string to an element according to the conversion in 12.4.7.2.5 (Octet string to element conversion).
2) The public key, as a group element, is verified in a group-specific fashion according to 5.6.2.3 of (#298)NIST Special Publication 800-56A R2. If public key validation fails the STA shall terminate the authentication exchange.
d) Extracts the AP's nonce and verified ephemeral public key from the Authentication frame.
e) Compute the Diffie-Hellman shared secret, DHss, based on the AP's ephemeral public key and its own ephemeral private key with the chosen group's scalar-op to derive DHss.
f) Performs key derivation (see 12.11.2.5 (Key establishment with FILS authentication)) and begins key confirmation (see 12.11.2.6 (Key confirmation with FILS authentication)).

If the STA was attempting PMKSA caching and did not receive an Authentication frame from the AP, the STA may attempt to use an alternate authentication method.

### 12.11.2.5 Key establishment with FILS authentication

#### 12.11.2.5.1 General

When not using PMKSA caching, a PMK is created according to 12.11.2.5.2 (PMKSA key derivation with FILS authentication). When using PMKSA caching, a new PMKSA is not created. Instead, the PMKSA used for PMKSA caching remains and continues to be identified by the appropriate PMKID. Regardless of whether PMKSA caching is used or not, a PTKSA shall be generated with each FILS authentication exchange.

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PTKSA creation uses the KDF from 12.7.1.6.2 (Key derivation function (KDF)) to derive the following keys from the PMK: an integrity check key (ICK), a (#3744)PTK key encryption key (PTK-KEK), and a temporal key (TK).

PTKSA key establishment shall immediately be followed by key confirmation per 12.11.2.6 (Key confirmation with FILS authentication).

#### 12.11.2.5.2 PMKSA key derivation with FILS authentication

The PMK is derived using the two nonces and the secret(s) from FILS Key establishment. A PMKID used to identify the PMKSA is generated using the hash algorithm from the negotiated AKM on input data specific to the FILS Key Establishment step. The length of the PMK shall be either 256 bits or 384 bits depending on the negotiated AKM, and the length of the PMKID shall be 128 bits. If FILS Shared Key authentication was used to generate input keying material, the PMK and PMKID are derived as follows:

PMK = HMAC-Hash(SNonce || ANonce, rMSK [ || DHss ])

PMKID = Truncate-128(Hash(EAP-Initiate/Reauth))

When FILS Public Key authentication is used to generate input keying material, the PMK and PMKID are derived as follows:

PMK = HMAC-Hash(SNonce || ANonce, DHss)

PMKID = Truncate-128(Hash(gSTA || gAP))

where

| | |
|---|---|
| SNonce | is the STA nonce and ANonce is the AP nonce |
| rMSK | is the shared secret from the EAP-RP exchange |
| DHss | is the shared secret derived from the Diffie-Hellman exchange, when performed; when ECC is used, only the x-coordinate from EDCH is included |
| Brackets | indicate the inclusion of the shared secret when doing a Diffie-Hellman exchange; there is no shared secret to include otherwise |
| EAP-Initiate/Reauth | is the EAP-RP packet sent by the STA during key establishment with FILS Shared Key authentication |
| gSTA | is the STA's Diffie-Hellman value |
| gAP | is the AP's Diffie-Hellman value |
| Hash | is the hash algorithm specific to the negotiated AKM (see Table 9-190 (AKM suite selectors)) |

Upon completion of PMK and PMKID generation the shared secret, DHss, and rMSK, if applicable, shall be irretrievably deleted.

#### 12.11.2.5.3 PTKSA Key derivation with FILS authentication

For PTKSA key generation, the inputs to the PRF are the PMK of the PMKSA, a constant label, and a concatenation of the STA's MAC address, the AP's BSS's BSSID, the STA's nonce, and the AP's nonce. When the negotiated AKM is 00-0F-AC:14 or 00-0F-AC:16, the length of (#3744)PTK-KEK shall be 256 bits, and the length of the ICK shall be 256 bits. When the negotiated AKM is 00-0F-AC:15 or 00-0F-AC:17, the length of the (#3744)PTK-KEK shall be 512 bits, and the length of ICK shall be 384 bits. When the negotiated AKM is 00-0F-AC:16, FILS-FT is 256 bits; when the negotiated AKM is 00-0F-AC:17, FILS-FT is 384 bits; otherwise, FILS-FT is not derived(11ba); when a KDK is derived(11az), the length of KDK is equal to the value of PMK_bits (see 12.7.1.3 (Pairwise key hierarchy)); a KDK shall be derived if any of the following are true:(11az)(#7220)


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— WUR frame protection is negotiated(11az)

— dot11SecureLTFImplemented is true and the peer STA has advertised secure HE-LTF support capability in its RSNXE (see 9.4.2.241 (RSN Extension element (RSNXE)))(11az)

Otherwise, it shall not be derived.(#7220)

The total amount of bits extracted from the KDF shall therefore be (11ba)(#3260)640+TK_bits, 1124+TK_bits, or 1408+TK_bits depending on the negotiated AKM when WUR frame protection is negotiated, otherwise, shall be (#3260)512+TK_bits, 896+TK_bits, or 1280+TK_bits depending on the negotiated AKM, where TK_bits are determined from Table 12-8 (Cipher suite key lengths(#1083)(#3532)):

PTK(#1778) = PRF-X(PMK, "FILS PTK Derivation", SPA || AA || SNonce || ANonce [ || DHss ])
ICK = (#3506)ExtractBits(PTK(#1778), 0, ICK_bits)
(#3744)PTK-KEK = (#3506)ExtractBits(PTK(#1778), ICK_bits, KEK_bits)
TK = (#3506)ExtractBits(PTK(#1778), ICK_bits + KEK_bits, TK_bits)

When doing FT initial mobility domain association using FILS authentication,

FILS-FT = (#3506)ExtractBits(PTK(#1778), ICK_bits + KEK_bits + TK_bits, FILS-FT_bits)

(11ba)When a KDK is derived(11az) while doing FT initial mobility domain association using FILS authentication,

KDK = (#3506)ExtractBits(PTK(#1778), ICK_bits + KEK_bits + TK_bits + FILS-FT_bits, KDK_bits)

(11ba)When a KDK is derived(11az) while not doing FT initial mobility domain association using FILS authentication,

KDK = (#3506)ExtractBits(PTK(#1778), ICK_bits + KEK_bits + TK_bits, KDK_bits)

where

| | |
|---|---|
| ICK_bits | is the length of ICK in bits |
| KEK_bits | (#4061)is the length of PTK-KEK in bits |
| FILS-FT_bits | is the length of FILS-FT in bits when doing FT initial mobility domain association using FILS authentication |
| (11ba)KDK_bits | is the length of KDK in bits and is equal to the value of PMK_bits (see 12.7.1.3 (Pairwise key hierarchy)). |
| X | is 512+TK_bits, (#3260)768+TK_bits, 896+TK_bits, or 1280+TK_bits from Table 12-8 (Cipher suite key lengths(#1083)(#3532)) depending on the negotiated AKM (11ba)when a KDK is derived(11az); otherwise, X s 512+TK_bits, 768+TK bits, 896+TK bits, or 1280+TK bits from Table 12-8 (Cipher suite key lengths(#1083)(#3532)) depending on the negotiated AKM(11az) |
| PMK | is the PMK from the PMKSA, either created from an initial FILS connection or from a cached PMKSA, when PMKSA caching is used; when doing FT initial mobility domain association using FILS authentication, it is equal to MPMK (see 12.7.1.6.3 (PMK-R0)) |
| SPA | is the STA's MAC address and the AA is the AP's BSS's BSSID |
| SNonce | is the STA's nonce |
| ANonce | is the AP's nonce |
| DHss | is the shared secret derived from the Diffie-Hellman exchange, when performed, and PMKSA caching is used |
| Brackets | indicate the inclusion of the shared secret when doing a Diffie-Hellman exchange while using PMKSA caching; there is no shared secret to indicate otherwise |

Upon completion of PTK(#1778) generation the shared secret, DHss, shall be irretrievably deleted if Diffie-Hellman exchange was performed.

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(11ba)If WUR frame protection is negotiated, the WTK shall be derived from the KDK using the KDF defined in 12.7.1.6.2 (Key derivation function (KDF)):

WTK = (#3686)KDF-*Hash-Length*(KDK, "WUR Temporal Key", SPA || AA || SNonce || ANonce [ ||DHss ])

where

— (#3686)KDF-*Hash-Length* is the key derivation function as defined in 12.7.1.6.2 (Key derivation function (KDF)) using the hash algorithm identified by the AKM suite selector (see Table 9-190 (AKM suite selectors)).

— (#3686)*Length* is the total number of bits to derive, i.e., number of bits of the WTK, and is equal to 128.

### 12.11.2.6 Key confirmation with FILS authentication

#### 12.11.2.6.1 General

Key confirmation for FILS authentication is a (Re)Association Request frame followed by a (Re)Association Response frame. Components of the (Re)Association Request and (Re)Association Response frames shall be protected using (#3744)PTK-KEK.

#### 12.11.2.6.2 (Re)Association Request for FILS key confirmation

The STA constructs a (Re)Association Request frame for FILS authentication per 9.3.3.5 (Association Request frame format) and 9.3.3.7 (Reassociation Request frame format). Hash algorithms are used to generate the FILS Key Confirmation element and the specific hash algorithm depends on the negotiated AKM (9.4.2.23.3 (AKM suites)).

If dot11RSNAOperatingChannelValidationActivated is true and AP indicates OCVC(#3505), the STA shall include an OCI element(#426) in the request.

For FILS Shared Key authentication and FILS Public Key authentication when using PMKSA caching, the KeyAuth field of the FILS Key Confirmation element is constructed by using the HMAC mode of the negotiated hash algorithm with a key of ICK on a concatenation of the STA's nonce, the AP's nonce, the STA's MAC address, the AP's BSS's BSSID, and conditionally the STA's public Diffie-Hellman value and the AP's public Diffie-Hellman value, in that order:

Key-Auth = HMAC-Hash(ICK, SNonce || ANonce || STA-MAC || AP-BSSID [ || gSTA || gAP ])

where

| | |
|---|---|
| Hash | is the hash algorithm specific to the negotiated AKM (see Table 9-190 (AKM suite selectors)) |
| SNonce | is the STA's nonce |
| ANonce | is the AP's nonce |
| STA-MAC | is the MAC address of the STA and AP-BSSID is the BSSID of the AP's BSS |
| gSTA | is the STA's Diffie-Hellman public value |
| gAP | is the AP's Diffie-Hellman public value |
| Brackets | indicate the inclusion of the Diffie-Hellman public values when doing PFS with FILS Shared Key authentication or PMKSA caching with FILS Public Key authentication; there are no Diffie-Hellman public values to include otherwise |

For FILS Public Key authentication when PMKSA caching is not used, the KeyAuth field of the FILS Key Confirmation element is a digital signature using the STA's private key, of the negotiated hash algorithm on a


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concatenation of the STA's public Diffie-Hellman value, the AP's public Diffie-Hellman value, the STA's nonce, the AP's nonce, the STA's MAC address, and the AP's BSS's BSSID, in that order:

$$\text{Key-Auth} = \text{Sig-}_{\text{STA}}(\text{gSTA} \parallel \text{gAP} \parallel \text{SNonce} \parallel \text{ANonce} \parallel \text{STA-MAC} \parallel \text{AP-BSSID})$$

where

$\text{Sig-}_{\text{STA}}(\,)$ indicates a digital signature using the STA's private key, analog to the STA's trusted public key

The form of signature depends on the type of public key used by the STA (IETF RFC 3447 for RSA, FIPS 186-4 for DSA, and ISO/IEC 14888-3 for ECDSA). The data to be signed is first hashed and the hash algorithm used with the appropriate digital signature algorithm shall be specific to the negotiated AKM.

The (Re)Association Request frame shall be encrypted using the AEAD algorithm as defined in 12.11.2.7 (AEAD cipher mode for FILS) with the (#3744)PTK-KEK as the key. The AAD used with the AEAD algorithm for the Association Request frame consists of the following data passed as separate components in the following order:

- STA's MAC address
- AP's BSS's BSSID
- STA's nonce
- AP's nonce
- The contents of the (Re)Association Request frame from the Capability Information field (inclusive) to the (#482)FILS Session element (inclusive)

The plaintext passed to the AEAD algorithm is the data that would follow the FILS Session element in an unencrypted frame body. The output of the AEAD algorithm becomes the data that follows the FILS Session element in the encrypted and authenticated (Re)Association Request frame. The output of the algorithm is as specified in IETF RFC 5116. The resulting (Re)Association Request frame shall be transmitted to the AP.

The AP compares FILS session of the received (Re)Association Request frame with the FILS session that was used to identify the FILS session in the Authentication frames. If they differ, authentication exchange fails.

If dot11RSNAOperatingChannelValidationActivated is true and the STA indicates OCVC(#3505) in the RSNE in the request, AP shall validate the OCI element in the request by ensuring that all of the following are true:

- OCI element is present.
- Channel information in the OCI matches current operating channel parameters (see 12.2.10 (Requirements for Operating Channel Validation)).

Otherwise, the AP rejects the request by discarding the frame.

The AP decrypts and verifies the received (Re)Association Request frame with the AEAD algorithm as defined in 12.11.2.7 (AEAD cipher mode for FILS) with the (#3744)PTK-KEK as the key. The AAD is reconstructed as defined above and is passed, along with the cipher text of the received frame, to the AEAD decryption operation.

If the output from the AEAD decryption operation returns a failure, the authentication exchange fails. If the output does not return failure, the output plaintext replaces the cipher text as portion of the frame body that follows the FILS Session element and processing of the received frame continues by checking the value of the FILS Key Confirmation element.

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The AP verifies that the RSNE received in the (Re)Association Request frame has identical AKM suite and cipher suites and RSN capabilities as were included in the RSNE in the Authentication frame from the STA. If these fields differ, the authentication exchange fails.

For FILS Shared Key authentication, the AP constructs a verifier, Key-Auth', in an identical manner as the STA constructed its Key-Auth above.

The AP compares Key-Auth' with the KeyAuth field in the FILS Key Confirmation element of the received frame. If they differ, authentication fails.

For FILS Public Key authentication, the AP uses the STA's (certified) public key from the FILS Public Key element to verify that the signature contained in the KeyAuth field corresponds to the purported signature by the STA over the concatenation of the following:

— STA's public Diffie-Hellman value gSTA
— AP's public Diffie-Hellman value gAP
— STA's nonce SNonce, the AP's nonce ANonce
— STA's MAC address STA-MAC
— AP's BSS's BSSID AP-BSSID

in that order, according to the signature scheme used. Furthermore, the AP checks all certificates in the certificate chain, both cryptographically and from a security policy perspective, according to the procedures for checking certificates and certificate chains in IETF RFC 5280. If any of these verifications fail, authentication fails.

If authentication is deemed a failure, ICK, (#3744)PTK-KEK, TK, and the PTKSA shall be irretrievably deleted and the AP shall return an Authentication frame with a status code set to 112 (Authentication rejected due to FILS authentication failure). If PMKSA caching was not being employed for this failed authentication attempt, the PMKSA shall also be deleted. If PMKSA caching was being employed, the reason for failure might be an impersonation attack. Therefore, when FILS with PMKSA caching fails, the AP may decide to retain the cached PMKSA.

#### 12.11.2.6.3 (Re)Association Response for FILS key confirmation

The AP constructs a (Re)Association Response frame for FILS authentication per 9.3.3.6 (Association Response frame format) and 9.3.3.8 (Reassociation Response frame format). As with the (Re)Association Request frame, hash algorithms are used to generate the FILS Key Confirmation element and the specific hash algorithm depends on the negotiated AKM (see 9.4.2.23.3 (AKM suites)).

The AP constructs a Key Delivery element indicating the current GTK and (#1406)GTK PN, and the current IGTK and IPN if management frame protection is enabled, and the current BIGTK and BIPN if beacon protection is enabled(11ba), and the current WIGTK and WIPN if WUR frame protection is enabled. The GTK is carried in a GTK KDE(#3492). The IGTK and IPN are carried in an IGTK KDE. The BIGTK and BIPN are carried in a BIGTK KDE. (11ba)The WIGTK and WIPN are carried in a WIGTK KDE. The AP puts this element into the (Re)Association Response frame.

If dot11RSNAOperatingChannelValidationActivated is true and STA indicates OCVC(#3505), the AP shall include an OCI element(#426) in the response.

For FILS Shared Key authentication and FILS Public Key authentication when using PMKSA caching, the KeyAuth field of the FILS Key Confirmation element is constructed by using the HMAC mode of the negotiated hash algorithm with a key of ICK on a concatenation of the AP's nonce, the STA's nonce, the AP's


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BSS's BSSID, the STA's MAC address, and conditionally the AP's public Diffie-Hellman value and the STA's public Diffie-Hellman value, in that order:

Key-Auth = HMAC-Hash(ICK, ANonce || SNonce || AP-BSSID || STA-MAC [ || gAP || gSTA ])

where

| | |
|---|---|
| Hash | is the hash algorithm specific to the negotiated AKM (see Table 9-190 (AKM suite selectors)) |
| ANonce | is the AP's nonce |
| SNonce | is the STA's nonce |
| AP-BSSID | is the BSSID of the AP's BSS and STA-MAC is the MAC address of the STA |
| gAP | is the AP's Diffie-Hellman public value |
| gSTA | is the STA's Diffie-Hellman public value |
| Brackets | indicate the inclusion of the Diffie-Hellman public values when doing PFS with FILS Shared Key authentication; there are no Diffie-Hellman public values to include otherwise |

For FILS Public Key authentication when PMKSA caching is not used, the KeyAuth field of the FILS Key Confirmation element is a digital signature using the AP's private key of the output from the negotiated hash algorithm on a concatenation of the AP's public Diffie-Hellman value, the STA's public Diffie-Hellman value, the AP's nonce, the STA's nonce, AP's BSS's BSSID, and the STA's MAC address, in that order. The specific construction of the digital signature depends on the crypto-system of the public/private key pair:

Key-Auth = $Sig\text{-}_{AP}$(gAP || gSTA || ANonce || SNonce || AP-BSSID || STA-MAC)

where

| | |
|---|---|
| $Sig\text{-}_{AP}()$ | indicates a digital signature using the AP's private key analog to the AP's trusted public key |

The form of signature depends on the type of public key used by the AP (IETF RFC 3447 for RSA, FIPS 186-4 for DSA, and ISO/IEC 14888-3 for ECDSA). The data to be signed is first hashed and the hash algorithm used with the appropriate digital signature algorithm shall be specific to the negotiated AKM.

The (Re)Association Response frame shall be encrypted using the AEAD algorithm as defined in 12.11.2.7 (AEAD cipher mode for FILS) with the (#3744)PTK-KEK as the key. The AAD used with the AEAD algorithm for the (Re)Association Response frame consists of the following data passed as separate components in the following order:

— AP's BSS's BSSID
— STA's MAC address
— AP's nonce
— STA's nonce
— The contents of the (Re)Association Response frame from the Capability Information field (inclusive) to the FILS Session element (inclusive)

The plaintext passed to the AEAD algorithm is the data that would follow the FILS Session element in an unencrypted frame body. The output of the AEAD algorithm becomes the data that follows the FILS Session element in the encrypted and authenticated (Re)Association Response frame. The output of the algorithm is as specified in IETF RFC 5116. The resulting (Re)Association Response frame shall be transmitted to the STA.

If dot11RSNAOperatingChannelValidationActivated is true and the AP indicates OCVC(#3505) in its RSNE, the STA shall validate the OCI element in the response by ensuring that all of the following are true:

— OCI element is present
— Channel information in the OCI matches current operating channel parameters (see 12.2.10 (Requirements for Operating Channel Validation))

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Otherwise, the STA shall discard the frame.

The STA decrypts and verifies the received (Re)Association Response frame with the AEAD algorithm as defined in 12.11.2.5 (Key establishment with FILS authentication) with the (#3744)PTK-KEK as the key. The AAD is reconstructed as defined in this subclause above and is passed with the cipher text of the received frame to the AEAD decryption operation.

The STA compares FILS Session of the received frame with the FILS Session it selected to identify the FILS session. If they differ, authentication fails.

If the output from the AEAD decryption operation returns failure, the authentication exchange fails. If the output does not return failure, the output plaintext replaces the cipher text as portion of the frame body that follows the FILS Session element and processing of the received frame continues by checking the value of the FILS Key Confirmation element.

The STA verifies that the RSNE received in the (Re)Association Response frame has identical AKM suites and cipher suites and RSN capabilities as were included in the RSNE in the Beacon, Probe Response, and Authentication frames from the AP. If these fields differ, authentication fails.

For FILS Shared Key authentication, the STA constructs a verifier, Key-Auth', in an identical manner as the AP constructed its Key-Auth above.

The STA compares Key-Auth' with the KeyAuth field in the FILS Key Confirmation element of the received frame. If they differ, authentication fails.

For FILS Public Key authentication, the STA uses the AP's (certified) public key from the FILS Public Key element to verify that the signature contained in the KeyAuth field corresponds to the purported signature by the AP over the concatenation of the following:

— AP's public Diffie-Hellman value gAP
— STA's public Diffie-Hellman value gSTA
— AP's nonce ANonce
— STA's nonce SNonce
— AP's BSS's BSSID AP-BSSID
— STA's MAC address STA-MAC

in that order, according to the signature scheme used. Furthermore, the AP checks all certificates in the certificate chain, both cryptographically and from a security policy perspective, according to the procedures for checking certificates and certificate chains in IETF RFC 5280. If any of these verifications fail, authentication fails.

If authentication is deemed a failure, the ICK, (#3744)PTK-KEK, PMK, and TK shall be irretrievably deleted and the STA shall abandon the exchange. Otherwise authentication succeeds and the STA and AP shall irretrievably delete the nonpersistent secret keying material that is created by executing the key establishment with FILS Shared Key authentication scheme (12.11.2.3 (Key establishment with FILS Shared Key authentication)) or the key establishment with FILS Public Key authentication scheme (12.11.2.4 (Key establishment with FILS Public Key authentication)). The (#4062)PTK-KEK and PMK shall be used for subsequent key management as specified in 12.6 (RSNA security association management). If the lifetime of the rMSK is known, the STA and AP shall set the lifetime of the PMKSA to the lifetime of the rMSK. Otherwise, the STA and AP shall set the lifetime of the PMKSA to the value dot11RSNAConfigPMKLifetime.

Upon successful completion of the FILS authentication procedure, the STA shall process the Key Delivery element in the (Re)Association Response frame. The STA installs the GTK and (#1406)GTK RSC, and IGTK


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and IGTK RSC if management frame protection is enabled, and BIGTK and BIGTK RSC if present in the (#1488)Key Delivery element and dot11BeaconProtectionEnabled is true(11ba), and WIGTK and WIGTK RSC if present in the (#1488)Key Delivery element and dot11RSNAWURFrameProtectionActivated is true.

#### 12.11.2.7 AEAD cipher mode for FILS

FILS authentication uses an AEAD cipher mode to protect (Re)Association Request/Response and EAPOL-Key frames. The AEAD cipher mode is determined by the specific FILS negotiated AKM.

AES-SIV-256 is used when the negotiated AKM is 00-0F-AC:14 or 00-0F-AC:16 and AES-SIV-512 is used when the negotiated AKM is 00-0F-AC:15 or 00-0F-AC:17.

## 12.12 Constraints on allowed security parameters(11ax)

### 12.12.1 Introduction

This standard defines various security mechanisms of which some are deprecated or obsolete and are not considered to meet current requirements for security. Such mechanisms enable interoperability with legacy devices, but are not suitable for new uses where legacy support is not needed. 12.12 (Constraints on allowed security parameters(11ax)) describes constraints on security parameter selection for some use cases.

### 12.12.2 Security constraints in the 6 GHz band

The following apply to a STA operating in the 6 GHz band:

- The STA shall not use the following pre-RSNA security method(#3056):
  - Open System authentication without encryption
- The STA shall not use the following cipher suite selectors:
  - 00-0F-AC:0 (Use group data cipher suite)(#3056)(#6020)
  - 00-0F-AC:2 (TKIP)
- (#1084)The STA shall use Opportunistic Wireless Encryption (12.14 (Opportunistic Wireless Encryption(#6088)))(#6088), when connecting in an infrastructure BSS without authentication (as a replacement for Open System authentication without encryption).
- The STA shall not use the following AKM suite selectors:
  - 00-0F-AC:2 (PSK)
  - 00-0F-AC:4 (FT authentication using PSK)
  - 00-0F-AC:6 (PSK with SHA-256)
  - 00-0F-AC:19 (FT authentication using PSK with SHA-384)
  - 00-0F-AC:20 (PSK with SHA-384)
- (#4397)The STA should use SAE (AKM(#3266) 00-0F-AC:8, 00-0F-AC:9, 00-0F-AC:24, or 00-0F-AC:25) if authenticating using a password where IEEE Std 802.1X is not used (as a replacement for PSK).

(#7152)A STA shall support management frame protection (MFPC = 1) when using RSN. An AP shall require management frame protection (MFPR = 1) when using RSN.

### 12.12.3 Security constraints for HT STAs(#3133)

An HT STA shall not use either of the pairwise cipher suite selectors “Use group data cipher suite”(#6020) or TKIP to communicate with another HT STA.

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### 12.12.4 Security constraints for VHT STAs(#3133)

A VHT STA shall not use either of the pairwise cipher suite selectors: "Use group data cipher suite"(#6020) or TKIP to communicate with another HT STA or VHT STA.

### 12.12.5 Security constraints for HE STAs(#3133)

An HE STA shall not use either of the pairwise cipher suite selectors: "Use group data cipher suite"(#6020) or TKIP to communicate with another HT STA, VHT STA, or HE STA.

### 12.12.6 Security constraints for S1G STAs(#3133)

An S1G STA shall not use the pairwise cipher suite selectors TKIP or "Use group data cipher suite".(#6020)

### 12.12.7 Security constraints for mesh STAs(#3133)

A mesh STA shall not use the pairwise cipher suite selector TKIP.

### 12.12.8 Security constraints for STAs that support management frame protection(#3133)

A STA that has associated with management frame protection enabled shall not use pairwise cipher suite selectors TKIP or "Use group data cipher suite".(#6020)

## 12.13 Preassociation security negotiation(11az)

### 12.13.1 General

(#7185)Preassociation security negotiation (PASN) is an RSNA authentication protocol in all cases where it relies on the existence of a PMKSA for an AKMP, termed base AKMP for PASN. It is a non-RSNA protocol when there is no PMKSA and the corresponding base AKMP used with it. The protocol supports PTKSA establishment with and without mutual authentication and allows for a PMKSA to be established for certain base AKMPs by tunneling the base AKMP protocol messages.

PASN is primarily intended for use in infrastructure networks for a STA and an AP to establish a PTKSA using a three-message authentication frame exchange. (11bd)It may also be used by two STAs each co-located with an NGV STA (see 31.4 (NGV ranging)). Some salient aspects of this protocol are:

- (#7185)Where available, it leverages a cached PMK for a base AKMP or already specified mechanisms for a base AKMP to establish the PMKSA from which the PASN PTKSA is derived. Such a PTKSA provides mutual authentication.
- (#7185)It leverages a cached PMK for a base AKMP or already specified mechanisms for a base AKMP to establish the PMKSA from which the PASN PTKSA is derived.
- It exchanges ephemeral public keys to provide PFS and derive the PTKSA keys, using a PMKSA if one exists. The (M129)PASN AKMP shall not be used in the RSNE of an (re)association request.
- A PTKSA may be derived using ephemeral keys without mutual authentication at the discretion of the protocol peers, that is, it may derive a PTKSA without a PMKSA and is thus a non-RSNA protocol.
- Key establishment and key confirmation is accomplished using authentication frames.
- It allows a PMKSA to be established by tunneling FILS shared key and SAE protocol data as part of PASN Authentication frame contents.
- Authentication is initiated by a non-AP STA.
- PASN authentication does not derive GTKSA or IGTKSA.


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— A provision to allow APs to request the peer to come back later based on resource constraints or other conditions; see 12.13.10 (Comeback cookies).

The security of PASN depends on assumptions similar to those for FILS and SAE authentication. In particular:

— It assumed that both the STAs have in common at least one cyclic group from the dot11RSNAConfigDLCGroupTable that is used to select the ephemeral key exchange parameters.

— Protection is provided against downgrade attacks that may alter security parameters (e.g., RSNE, RSNXE, Group, Hash Function) used in the negotiation.

— Denial of service protection is not guaranteed.

— A cryptographic RNG is available to generate ECC private keys.

— There is no protection for group addressed frames using PASN authentication. Like any PTKSA, the PTKSA established via PASN authentication shall be deleted when the Base PMKSA expires. Similarly, deauthentication (4.5.4.3 (Deauthentication)) results in deletion of PASN PTKSA. For the purpose of interoperability, a STA shall support group 19, an ECC group defined over a 256-bit prime order field.

### 12.13.2 Discovery of a PASN capable AP

An AP indicates it is capable of performing PASN authentication by including the PASN AKMP as part of the RSNE included in Beacon and Probe Response frames. When PASN AKMP is advertised, the AP shall also include at least one additional AKMP in the RSNE unless it allows PTKSA derivation without authentication using the ephemeral keys exchanged during PASN authentication.

### 12.13.3 Key establishment with PASN authentication

#### 12.13.3.1 Overview

This subclause defines the procedure for establishing a PTKSA and the corresponding shared keys between a PASN capable STA and AP or two PASN capable STAs each co-located with an NGV STA (see 31.4 (NGV ranging)).(11bd) The PASN frame sequence used is depicted in Figure 12-59 (PASN authentication(11az)(#7046)(#8201)). It consists of three Authentication frames with the Authentication Algorithm Number field (9.4.1.1 (Authentication Algorithm Number field)) set to 7 (PASN authentication) and the corresponding Authentication Transaction Sequence Number field (9.4.1.2 (Authentication Transaction Sequence Number field)) set to 1, 2, and 3, respectively.

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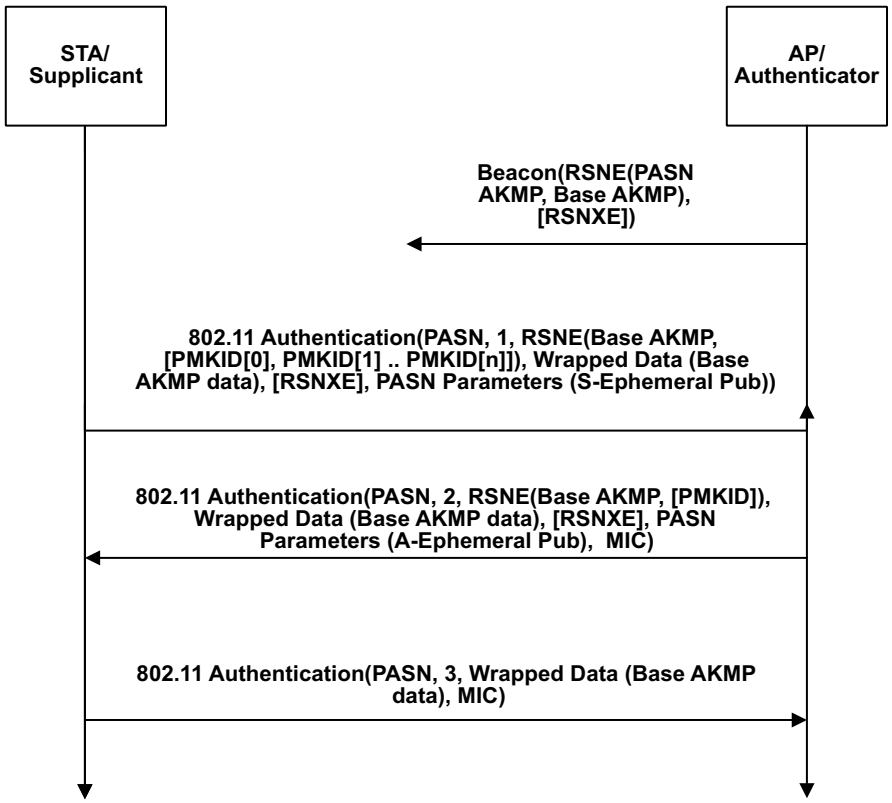


**Figure 12-59—PASN authentication(11az)(#7046)(#8201)**

NOTE—Beacon is only present when the authenticator is an AP and not otherwise. For example when an authenticator is a non-AP STA co-located with an NGV STA, beacons are not present (see 31.4 (NGV ranging)).(11bd)

(#7185)A non-AP STA shall use the first PASN frame to initiate PASN authentication with a PASN capable AP by providing RSNE that contains base AKMP parameters including a list of PMKIDs (possibly empty), STA's ephemeral public key, PASN parameters, and additional base AKMP specific data, if any.

(#7185)The PASN capable AP processes the first PASN frame and responds with a second PASN frame. The processing depends on the base AKMP as specified in 12.13 (Preassociation security negotiation(11az)). If the processing is successful, the AP includes RSNE that contains chosen base AKMP parameters including the chosen PMKID (possibly none), AP's ephemeral public key, PASN parameters, and additional base AKMP specific data, if any. The frame is also integrity protected with a MIC using the Key Confirmation key (KCK) as described in 12.13.9.1 (MIC computation for second PASN frame(#8118)). If the processing fails, the AP may return an appropriate status in the Status Code field (9.4.1.9 (Status Code field)) of the frame without including additional information or silently drop the frame.

The non-AP STA receives and processes the second PASN frame and responds with the third PASN frame. Again, the processing depends on the (#7185)base AKMP as specified later in the document. If the processing is successful, the STA responds with an integrity protected (#8118)third PASN frame; otherwise, it may return an appropriate status in the Status Code field (9.4.1.9 (Status Code field)) of the frame or silently drop the frame. The frame is integrity protected with a MIC using the Key Confirmation key (KCK) as described in 12.13.9.2 (MIC computation for third PASN frame(#8118)).


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(#7185)A successful PASN exchange results in establishment of PTKSA using the ephemeral keys and PMK from the base AKMP (if any). The lifetime of the PTKSA shall be the minimum of PTKSA timeout interval(s) exchanged (if any) but shall not exceed the PMK lifetime for the PMKSA of the base AKMP. The PASN PTKSA will be deleted by the SME of a non-AP STA or an AP when:

— Its lifetime expires.

— Upon initiation of (re)association on a non-AP STA, or successful association by the peer on an AP (see 11.3.5.2 (Non-AP and non-PCP STA association initiation procedures) and 11.3.5.3 (AP or PCP association receipt procedures)).

### 12.13.3.2 PASN frame construction and processing

If non-AP STA chooses to initiate PASN authentication, it first selects the following authentication parameters:

— Base AKMP from among AKMPs advertised by the AP (11bd)or provisioned by a higher layer (applicable for STAs co-located with NGV STAs (see 31.4 (NGV ranging)) if RSNA authentication is desired. Otherwise, if dot11NoAuthPASNActivated is true, (#7185)base AKMP chosen is the PASN AKMP, indicating that PTKSA is to be established without mutual authentication, that is, without a corresponding PMKSA.

— Pairwise cipher suite to use for the PTKSA that is being setup.

— Finite cyclic group from the dot11RSNAConfigDLCGroupTable that is at least of the security strength provided by the (#7185)base AKMP and cipher suites.

With the chosen finite cyclic group, the STA generates an ephemeral (random) private key, and uses the selected group's scalar operation (see 12.4.4.1 (General)) with the private key to generate its ephemeral public key. If PMKSA caching is used, it generates a list of PMKSA identifiers, and then obtains (#7185)base AKMP specific data.

It then composes an RSNE in which:

— Chosen AKMP and pairwise cipher is included.

— MFPC and MFPR (see 9.4.2.23.4 (RSN capabilities) in the RSN Capabilities field are set to 1.

— If dot11RSNAOperatingChannelValidationActivated is true, OCVC (see 9.4.2.23.4 (RSN capabilities)) in the RSN Capabilities field is set to 1.

— No Pairwise bit is set to 0.

— PMKID count and PMKID list set corresponding to PMKSA identifiers.

— Group Data Cipher Suite and Group Management Cipher Suite set to 00-0F-AC:7, indicating that group addressed traffic is not allowed.

— Extended Key ID for Individually Addressed Frames ((#8205)bit 13) shall be 0.

The (#8118)first PASN frame (see 9.3.3.11 (Authentication frame format)) of the exchange is constructed as follows:

— Authentication Algorithm Number field (9.4.1.1 (Authentication Algorithm Number field)) set to 7 (PASN authentication).

— Authentication Transaction Sequence Number field (9.4.1.2 (Authentication Transaction Sequence Number field)) set to 1.

— Including the constructed RSNE.

— Including a PASN Parameters element (9.4.2.305 (PASN Parameters element(11az))) with the wrapped data format, chosen finite cyclic group ID, and the ephemeral public key. Comeback field shall either be absent or set to the cookie length and the cookie received from the AP if the authentication is being retried. Comeback After subfield shall not be present in the Comeback field. The Control field in the element is set appropriately to indicate the presence or absence of fields in the element.

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- Including a Wrapped Data element (9.4.2.186 ((11az)Wrapped Data element)) corresponding to (#7185)base AKMP data, if any. This element may be fragmented using the mechanism specified in 10.28.11 (Element fragmentation) as necessary.
- Optionally including a Timeout Interval element (TIE) (9.4.2.47 (TIE(#1776))) with the Timeout Interval Value set to dot11RSNAConfigPASNPTKSATimeout and Timeout Interval Type set to 2 (key lifetime interval).
- Including RSNXE (9.4.2.240 (RSNXE(#1776))) if any subfield of the Extended RSN Capabilities field in this element, except the Field Length subfield, is nonzero.
- If dot11RSNAOperatingChannelValidationActivated is true including an OCI Element containing an OCI element as defined in 9.4.2.235 (OCI element).

The non-AP STA sends the first PASN frame to the AP.

Upon receiving the first PASN frame, the AP:

- Validates RSNE to ensure it is well formed and the AKMP, Pairwise Cipher, MFPC and MFPR capabilities, No Pairwise bit, and Group Ciphers fields (of length 0) are set as expected. Otherwise processing status is set appropriately, see Table 9-80 (Status codes), to INVALID_RSNE, INVALID_RSNE_CAPABILITIES, INVALID_AKMP, INVALID_GROUP_CIPHER, INVALID_PAIRWISE_CIPHER, UNSUPPORTED_RSNE_VERSION.
- Validates that finite cyclic group indicated in PASN Parameters element is supported (present in dot11RSNAConfigDLCGroupTable). Otherwise processing status is set to UNSUPPORTED_FINITE_CYCLIC_GROUP.
- Validates PASN Parameters element. If resources or other policy does not permit PASN authentication (in general or for the peer) at this time, but will be permitted later, processing status is set to REFUSED_TEMPORARILY. Otherwise if Comeback Info field is present and AP is expecting the field, it shall validate the field. It is outside the scope of this specification as to the validation mechanism used. If the validation fails, unless a processing status of REFUSED_TEMPORARILY is being returned, the processing status is set to INVALID_PARAMETERS.
- (#7185)Verifies the public key as specified in 5.6.2.3 of NIST SP 800-56A R2. If verification fails, the processing status is set to INVALID_PUBLIC_KEY. Verifies that a PMKSA named via a PMKID in the RSNE exists for the specified base AKMP, or the base AKMP is set to PASN AKMP or base AKMP data exists in the frame to allow a PMK to be established. If base AKMP is equal to PASN AKMP, verifies that dot11NoAuthPASNActivated is set to true. Otherwise processing status is set to REFUSED.
- (#7185)Extracts any Base AKMP specific data, including reassembly, 10.28.12 (Element defragmentation) as necessary, and processes it according to the behavior described in a later subclause specific to the AKMP; for example, 12.13.4 (PASN authentication with FILS shared key). This may include waiting for base AKMP related processing to complete before advancing the PASN protocol state. If the base AKMP related processing indicates an error or there is no PMKSA at the end of such processing, processing status is set to PASN_BASE_AKMP_FAILED.
- If dot11RSNAOperatingChannelValidationActivated is true and the peer STA's RSNE indicated (#6090)OCVC, it validates that an OCI element is present and the Channel information in the element matches current operating channel parameters (see 12.2.10 (Requirements for Operating Channel Validation)). Otherwise, if there is a mismatch, processing status is set to OCI_MISMATCH.

The AP begins the construction the second PASN frame as follows:

- Authentication Algorithm Number field (9.4.1.1 (Authentication Algorithm Number field)) set to 7 (PASN authentication)


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- Authentication Transaction Sequence Number field (9.4.1.2 (Authentication Transaction Sequence Number field)) set to 2
- Status code indicating the processing status

If the processing status is REFUSED_TEMPORARILY, the AP constructs and includes in the second PASN frame.

PASN Parameters element (9.4.2.305 (PASN Parameters element(11az))) with Comeback Info field with time for the peer to retry the operation. The Cookie Length subfield is set to nonzero if a cookie is being returned to the non-AP STA, otherwise it is set to 0. The Cookie subfield contains the cookie if the Cookie Length subfield is nonzero. The Control field in the element is set appropriately to indicate the presence or absence of fields in the element. Otherwise, if the validation is successful, the AP with the chosen finite cyclic group, generates an ephemeral (random) private key, and uses the selected group's scalar operation with the private key to generate its ephemeral public key.

- Derives the PTKSA; see 12.13.8 (PTKSA derivation with PASN authentication).
- Perform the group's scalar-op (see 12.4.4.1 (General)) with the non-AP STA's ephemeral public key and its own ephemeral private key to produce an ephemeral Diffie-Hellman shared secret, DHss.
- Constructs and includes in the second PASN frame.
- An RSNE that contains.
- Chosen (#7185)base AKMP and Pairwise cipher.
- MFPC and MFPR (see 9.4.2.23.4 (RSN capabilities)) in the RSN Capabilities field are set to 1.
- If dot11RSNAOperatingChannelValidationActivated is true, OCVC (see 9.4.2.23.4 (RSN capabilities)) in the RSN Capabilities field is set to 1.
- No Pairwise bit is set to 0.
- PMKID count of 1 and PMKID list corresponding to the PMKID from the PMKSA.
- Group Data Cipher Suite and Group Management Cipher Suite set to 00-0F-AC:7, indicating that group addressed traffic is not allowed.
- Extended Key ID for individually addressed frames ((#8205)bit 13) shall be 0.
- PASN Parameters element (9.4.2.305 (PASN Parameters element(11az))) with the wrapped data format, chosen finite cyclic group ID, and the AP's ephemeral public key. The Control field in the element is set appropriately to indicate the presence or absence of fields in the element.
- Wrapped Data element (9.4.2.186 ((11az)Wrapped Data element)) corresponding to (#7185)base AKMP data to be returned to the non-AP STA, if any. This element may be fragmented using mechanism specified in 10.28.11 (Element fragmentation) as necessary.
- Optionally including a Timeout Interval element (TIE) (9.4.2.47 (TIE(#1776))) with Timeout Interval Value set to dot11RSNAConfigPASNPTKSATimeout and Timeout Interval Type set to 2 (key lifetime interval).
- Including RSNXE (9.4.2.240 (RSNXE(#1776))) that is advertised in AP's Beacon and Probe Response frames, if any subfield of the Extended RSN Capabilities field in this element, except the Field Length subfield, is nonzero.
- If dot11RSNAOperatingChannelValidationActivated is true, including an OCI Element containing an OCI element as defined in 9.4.2.235 (OCI element), if dot11RSNAOperatingChannelValidationActivated is true.
- A MIC element (9.4.2.118 (MIC element)) with MIC computed as specified in 12.13.9.1 (MIC computation for second PASN frame(#8118)).

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Once the processing complete, the AP sends the second PASN frame to the non-AP STA. If the processing status returned in the frame was not SUCCESS, the AP shall terminate the PASN authentication protocol. Upon receiving the second PASN frame, the non-AP STA:

- Validates the Status Code field is SUCCESS.
- Validates the PASN Parameters element. If the Status Code field was REFUSED_TEMPORARILY and Comeback Info field in the parameters specifies a comeback time, the STA may retry PASN authentication after the specified time with the specified cookie (if any).
- Validates RSNE to ensure it is well formed and the AKMP, Pairwise Cipher, MFPC and MFPR capabilities, No Pairwise bit, and Group Ciphers fields (of length 0) are set as expected. Validates that finite cyclic group indicated in PASN Parameters element is supported (present in dot11RSNAConfigDLCGroupTable).
- Verifies that the public key as specified in5.6.2.3 of NIST SP 800-56A R2.
- (#7185)Verifies that a PMKSA named via a PMKID in the RSNE exists for the specified base AKMP, or the base AKMP is set to PASN AKMP or base AKMP data exists in the frame to allow a PMK to be established. If base AKMP is equal to PASN AKMP, verifies that dot11NoAuthPASNActivated is set to true.
- Extracts any (#7185)base AKMP specific data and processes it according to the behavior described in a later subclause specific to the AKMP; for example, 12.13.4 (PASN authentication with FILS shared key).
- Locates the PMKSA, which might include waiting for (#7185)base AKMP specific processing to complete.
- Perform the group's scalar-op (see 12.4.4.1 (General)) with the AP's ephemeral public key and its own ephemeral private key to produce an ephemeral Diffie-Hellman shared secret, DHss.
- Derives the PTKSA; see 12.13.8 (PTKSA derivation with PASN authentication).
- If dot11RSNAOperatingChannelValidationActivated is true and the peer STA's RSNE indicated (#6090)OCVC, it validates that an OCI element is present and the Channel information in the element matches current operating channel parameters (see 12.2.10 (Requirements for Operating Channel Validation)). Otherwise, if there is a mismatch, processing status is set to OCI_MISMATCH.
- Computes the MIC as specified in 12.13.9.1 (MIC computation for second PASN frame(#8118)) and verifies it to be the same as the MIC provided in the MIC element.

If validation fails, the non-AP STA shall discard the frame and terminate further protocol processing, but may retry PASN authentication later.

Otherwise the STA begins the construction the third PASN frame as follows:

- Authentication Algorithm Number field (9.4.1.1 (Authentication Algorithm Number field)) set to 7 (PASN authentication).
- Authentication Transaction Sequence Number field (9.4.1.2 (Authentication Transaction Sequence Number field)) set to 3.
- Status code indicating success.
- Constructs and includes in the third PASN frame.
- PASN Parameters element (9.4.2.305 (PASN Parameters element(11az))) with the wrapped data format. Public Key information and Comeback Info fields shall not be present. The Control field in the element is set appropriately to indicate the presence or absence of fields in the element.
- Wrapped Data element (9.4.2.186 ((11az)Wrapped Data element)) corresponding to (#7185)base AKMP data to be returned to the non-AP STA, if any. This element may be fragmented using mechanism specified in 10.28.11 (Element fragmentation) as necessary.


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- If dot11RSNAOperatingChannelValidationActivated is true, including an OCI Element containing an OCI element as defined in 9.4.2.235 (OCI element).
- A MIC element (9.4.2.117 (MIC element)) with MIC computed as specified in 12.13.9.2 (MIC computation for third PASN frame(#8118)).

Once the processing completes, the non-AP STA sends the third PASN frame to the AP. If a success was indicated, it installs the temporal key derived using MLME-SETKEYS.request primitive.

Upon receiving the third PASN frame, the AP:

- Validates that the Status Code field is SUCCESS.
- Validates PASN Parameters element.
- If dot11RSNAOperatingChannelValidationActivated is true and the peer STA's RSNE indicated (#6090)OCVC, it validates that an OCI element is present and the Channel information in the element matches current operating channel parameters (see 12.2.10 (Requirements for Operating Channel Validation)). Otherwise, if there is a mismatch, processing status is set to OCI_MISMATCH.
- Computes the MIC as specified in 12.13.9.2 (MIC computation for third PASN frame(#8118)) and verifies it to be the same as the MIC provided in the MIC element.
- Extracts any (#7185)base AKMP specific data and processes it according to the behavior described in a later subclause specific to the AKMP; for example, 12.13.4 (PASN authentication with FILS shared key). Base AKMP processing may indicate an error.

For the third PASN frame, if the MIC validation fails, the AP shall discard the frame and terminate the processing of the frame with no further effect. If other validation fails, or (#7185)base AKMP processing indicates an error, the AP shall terminate the PASN authentication. If the validation was successful, the AP installs the temporal key derived using MLME-SETKEYS.request primitive to install the new key. If the AP terminated the PASN authentication silently or by sending a failure Status Code to the non-AP STA, other than a temporary refusal, it shall delete all of the PASN authentication state.

If the non-AP STA receives an Authentication frame that does not contain Authentication Algorithm Number field set to 7 (PASN authentication) once it has sent the first PASN frame, it shall abandon the PASN authentication in progress. Likewise, if the AP receives an Authentication frame that does not contain Authentication Algorithm Number field set to 7 (PASN authentication) once it has received the first PASN frame, it shall abandon the PASN authentication in progress.

If the authentication is not successful within the AuthenticateFailureTimeout, the STA shall terminate PASN authentication and delete the PASN authentication state.

NOTE—Because of frame filtering rules (11.3.3 (Frame filtering based on STA state)), the protection using the key installed by PASN authentication is only used to protect management frames, as applicable.

### 12.13.4 PASN authentication with FILS shared key

This subclause specifies aspects of PASN authentication when (#8197)AKM 00-0F-AC:14 or 00-0F-AC:15 is used as a (#7185)base AKMP when PMK Caching is not used with PASN authentication. Otherwise, when PMK Caching is used, the PMKSA identified by the PMKID in the (#8118)first PASN frame is used for the PASN PTKSA derivation.

Where FILS shared key authentication without PFS is desired and there is no cached PMK, the (#7185)base AKMP data is constructed using 9.4.2.186 ((11az)Wrapped Data element).

In the first PASN frame, the Wrapped Data element contains the EAP-Initiate/Re-auth PPDU similar to FILS shared key processing; see 12.11.2.3.2 (Non-AP STA construction of Authentication frame). The EAP-Initiate/

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Re-auth data is forwarded to the AS by the AP and the EAP-Finish/Re-auth PPDU received from the AS is forwarded to the non-AP STA encapsulated in the Wrapped Data element in the second PASN frame. The AS returns the associated EAP-RP rMSK along with the EAP-Finish/Re-auth PPDU to the AP. Wrapped data shall be absent in the third PASN frame.

The resulting rMSK is used in PMKSA derivation (12.11.2.5.2 (PMKSA key derivation with FILS authentication)) where:

— (#7212)SNonce is set to the non-AP STA's ephemeral public key encoded as an octet string (12.4.7.2.4 (Element to octet string conversion))

— (#7212)ANonce is set to AP's ephemeral public key encoded as an octet string (12.4.7.2.4 (Element to octet string conversion))

— DHss is the shared secret derived from the PASN ephemeral key exchange encoded as an octet string (12.4.7.2.2 (Integer to octet string conversion))

The PMKSA is then used in PTKSA derivation for PASN authentication. The PMKID of the PMKSA is derived as defined in 12.11.2.5.2 (PMKSA key derivation with FILS authentication) and the AKMP of the PMKSA is the corresponding (#7185)base AKMP.(M129)

There is only a single FILS session with PASN authentication, and FILS session element is not tunneled.

### 12.13.5 PASN authentication with SAE

This subclause specifies aspects of PASN authentication when (#7032)AKM 00-0F-AC:8 or 00-0F-AC:24 is used as the (#7185)base AKMP when PMK caching is not used. When PMK caching is used PASN authentication relies on the PMKSA already established by SAE protocol. Without PMK caching, wrapped data shall be present in first, second, and third PASN frames and is constructed as follows. When SAE is used with PASN authentication, the direct hashing technique described in 12.4.4.2.3 (Hash-to-element(#331) generation of the password element with ECC groups) or 12.4.4.3.3 (Direct generation of the password element with FFC groups) shall be used. A PASN capable AP shall set SAE hash-to-element bit to 1in the Extended RSN Capabilities field of the RSNXE included in its Beacon, Probe Response, and (#8118)second PASN frames. A non-AP STA initiating PASN authentication shall set SAE hash-to-element bit to 1 in the Extended RSN Capabilities field of the RSNXE in the (#8118)first PASN frame.

The non-AP STA instantiates an SAE protocol instance, 12.4.7 (Framing of SAE), and provides an Initiate event. The PASN authentication process receives an Authentication frame with a Commit message, 12.4.7.3 (Encoding and decoding of SAE Commit messages), from the SAE protocol instance. It then sets the Wrapped Data in the first PASN frame to be the Authentication frame body.

The AP upon receiving the first PASN frame, delivers the frame to SAE for processing via the SAE parent process managed by the SME. If the PASN authentication process receives, from the SAE protocol instance, a failure indication, PASN authentication shall be abandoned. Otherwise PASN authentication process receives Authentication frames with a Commit message, 12.4.7.3 (Encoding and decoding of SAE Commit messages); and a Confirm message, 12.4.7.4 (Encoding and decoding of SAE Confirm messages), in that order, as the SAE protocol instance transitions to the Confirmed state.

The AP sets the Wrapped Data in the second PASN frame, as shown in the Figure 12-60 (PASN Wrapped Data format with SAE(11az)), to be the concatenation of:

— Two octet length of first Authentication frame body in little endian order

— First Authentication frame body with a Commit message

— Two octet length of second Authentication frame body in little endian order

— Second Authentication frame body with a Confirm message


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| | First Authentication Frame Length | First Authentication Frame Body | Second Authentication Frame Length | Second Authentication Frame Body |
|---|---|---|---|---|
| Octets: | 2 | variable | 2 | variable |

**Figure 12-60—PASN Wrapped Data format with SAE(11az)**

The non-AP STA upon receiving the second PASN frame, delivers the Commit and Confirm messages from the AP to the SAE protocol instance. If the PASN authentication process receives, from the SAE protocol instance, a failure indication, PASN authentication shall be abandoned. Otherwise PASN authentication process receives an Authentication frame with a Confirm message (12.4.7.4 (Encoding and decoding of SAE Confirm messages)) as the SAE protocol instance transitions to the Confirmed state followed by a transition to the Accepted state (since it has received both the Commit and Confirm messages from the peer).

The non-AP STA sets the Wrapped Data in the third PASN frame to be the Authentication frame body with a Confirm message. The AP upon receiving the third PASN frame, delivers the Authentication frame from the Wrapped Data to the SAE protocol instance. Either the instance accepts the frame and transitions to the Accepted state or PASN authentication shall be abandoned and the SAE protocol instance destroyed.

Not all aspects of SAE protocol are supported by the above tunneling mechanism. In particular, the tunneled protocol may fail if the SAE state machine desires:

— Anti-Clogging Tokens
— Retries of Commit and Confirm messages

In such cases, SAE authentication may be first used to establish an SAE PMKSA.

The PMKSA is then used in PTKSA derivation for PASN authentication. (M129)The PMKID of the PMKSA is derived as defined in 12.4.5.4 (Processing of a peer's SAE Commit message) and the AKMP of the PMKSA is the corresponding (#7185)base AKMP. If establishment of SAE PMKSA fails, PASN authentication shall be abandoned.

### 12.13.6 PASN authentication with FT

This subclause specifies aspects of PASN authentication when one of (#7033)AKM 00-0F-AC: [3, 4, 13, 19, 22] is used as the (#7185)base AKMP.

(#7096)When used with FT, PASN authentication is an RSNA protocol, and relies on the FT key hierarchy already being established via the FT initial mobility domain association (13.4.2 (FT initial mobility domain association in an RSN)). PASN protocol messages carry the PMKR0Name, and the PASN PTKSA is established like any other (#7185)base AKMP.

(#7096)The Wrapped Data element shall be optionally present in the (#8118)first PASN frame. When the Wrapped Data element is not present, the authentication is non-FT PASN. When present, the authentication is FT PASN. The Wrapped Data element shall contain a set of elements that include RSNE (9.4.2.23 (RSNE)), MDE (9.4.2.45 (MDE(#1776))), and FTE (9.4.2.46 (FTE(#1776))) as specified for the first message of the FT authentication sequence (13.8.2 (FT authentication sequence: contents of first message)). The Wrapped Data element shall be optionally present in the second PASN frames but shall be present if the Wrapped Data element was present in the first PASN frame. When present it shall contain a set of elements that include the RSNE (9.4.2.23 (RSNE)), the MDE (9.4.2.45 (MDE(#1776))), and the FTE (9.4.2.46 (FTE(#1776))) as specified for the second message of the FT authentication sequence (13.8.3 (FT authentication sequence: contents of second message)). The Wrapped Data element shall be absent in the third PASN frame. The elements in the Wrapped Data element are used for additional validation FT security parameters as being used in PASN authentication.

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### 12.13.7 Tunneled PASN(#7096)

Tunneled PASN allows a STA to perform ephemeral key exchanges with a target AP through another AP with which a PASN session is established, and where both APs advertise the same SSID (non-FT case) and the same mobility domain (FT case). The APs advertise this possibility by setting the Tunneled PASN Capability bit in the Extended Capability field. The STA establishes a PASN session with the first AP. The STA then shall send to the first AP a (#8118)first PASN frame that includes the Tunneled PASN element. The Tunneled PASN element shall contain the address that the STA intends to use with the target AP, and the BSSID of the target AP's BSS. The ephemeral key passed in the (#8118)first PASN frame shall be the key that the STA intends to use with the target AP.

The (#8118)second PASN frame shall include the Tunneled PASN element with the STA address and the BSSID of the target AP's BSS. The ephemeral key passed in the (#8118)second PASN frame shall be the key provided by the target AP. The TIE shall be present with Timeout Interval Type field set to 1.

Authentication to the target AP is successful if the target AP receives the (#8118)third PASN frame within the time indicated by the Timeout Interval Value field.

### 12.13.8 PTKSA derivation with PASN authentication

For PTKSA key derivation, the inputs to the PRF are the PMK of the PMKSA, a constant label, and a concatenation of non-AP STA's MAC address, AP's BSSID, and the DH shared secret from the ephemeral exchange.

PTK = KDF-HASH-NNN (PMK, "PASN PTK Derivation", SPA || BSSID || DHss)

where

PMK — (#7185)is the pairwise master key for the base AKMP if the AKMP is other than PASN AKMP; see 9.4.2.23.3 (AKM suites). Otherwise, if the base AKMP is PASN AKMP, that is, the PASN PTKSA is being setup without mutual authentication in a non-RSN, the PMK shall be set to the string "PMKz" padded with 28 0s.

NOTE—The PMK for the derivation can come from a cached PMKSA for the AKMP or from the PMKSA established with PASN by tunneling Wrapped Data or Authentication frames.

DHss — is the shared secret derived from the PASN ephemeral key exchange encoded as an octet string (12.4.7.2.2 (Integer to octet string conversion)).

KDF-HASH-NNN — (#7185)is the key derivation function defined in 12.7.1.6.2 (Key derivation function (KDF)) using the hash algorithm defined for the base AKMP; see Table 9-190 (AKM suite selectors). When there is no base AKMP, the hash algorithm is selected based on the pairwise Cipher Suite provided in the RSNE provided by the AP in the second PASN frame. SHA-256 is used as the hash algorithm, except for the ciphers 00-0F-AC:9 and 00-0F-AC:10 for which SHA-384 is used.

NNN — is the Bits required for KCK, TK, and KDK depending on the pairwise cipher and whether a KDK is derived.

PTK is composed of the Key Confirmation Key (KCK), Temporal Key (TK), and the Key Derivation Key (KDK), which are derived as follows:

KCK = (#8001)ExtractBits(PTK, 0, 256)(#8206)

TK = (#8001)ExtractBits(PTK, 256, TK_Length_Bits)


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TK is the transient key whose length is the same as a key for the pairwise cipher in (#6299)the RSNE provided by the AP in the second PASN frame. (#8207)TK_Length_Bits is the TK_bits in Table 12-8 (Cipher suite key lengths(#1083)(#3532)).

KDK = (#8001)ExtractBits(PTK, 256 + TK_Length_Bits, KDK_bits)

The KDK is of bit length KDK_bits, which has the value 256 if a KDK is derived (see 12.7.1.3 (Pairwise key hierarchy)) or 0 otherwise.

KDK shall be derived if dot11SecureLTFImplemented is true and the peer STA has indicated Secure HE-LTF support capability in its advertised Extended Capabilities.

The Key ID in the PTKSA (see 12.6.1.1.6 (PTKSA)) resulting from PASN authentication shall be (#8236)0.

### 12.13.9 MIC computation with PASN authentication

#### 12.13.9.1 MIC computation for second PASN frame(#8118)

The MIC field of the MIC element in the (#8118)second PASN frame is set by the AP to first MMM octets of:

HMAC-HASH (KCK, BSSID || SPA || Beacon RSNE || Beacon RSNXE || Frame Data)

where

| | |
|---|---|
| HASH | is the hash algorithm used in 12.13.8 (PTKSA derivation with PASN authentication) |
| KCK | is the key confirmation key for the PASN PTKSA |
| BSSID | is the BSSID for the AP's BSS |
| SPA | is the MAC address of the non-AP STA, the transmitter of the first PASN frame |
| Beacon RSNE | is the RSN element sent in the Beacons transmitted by the AP |
| Beacon RSNXE | is the RSNXE sent in the Beacons transmitted by the AP |
| Frame Data | is the body of the (#8118)second PASN frame including the MIC element with the octets in the MIC field of the MIC element set to 0 |
| MMM | is half of the output length in octets for the hash function used, that is, 16 or 24 octets for SHA-256 and SHA-384, respectively |

Beacon RSNE and Beacon RSNXE are included in the MIC computation so that a downgrade attack with forged RSNE Beacons will result in a MIC mismatch and thus PASN authentication failure.

#### 12.13.9.2 MIC computation for third PASN frame(#8118)

The MIC field of the MIC element in the (#8118)third PASN frame is set by the non-AP STA to first MMM octets of:

HMAC-HASH (KCK, SPA || BSSID || F1 Auth || Frame Data)

where

| | |
|---|---|
| HASH | is the hash algorithm used in 12.13.8 (PTKSA derivation with PASN authentication) |
| KCK | is the key confirmation key for the PASN PTKSA |
| SPA | is the MAC address of the non-AP STA, the transmitter of the first PASN frame |
| BSSID | is the BSSID for the AP's BSS |
| F1 Auth | is the HASH of body of the (#8118)first PASN frame |
| Frame Data | is the body of the (#8118)third PASN frame including the MIC element with the octets in the MIC field of the MIC element set to 0 |
| MMM | is half of the output length in octets for the hash function used, that is, 16 or 24 octets for SHA-256 and SHA-384, respectively |

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### 12.13.10 Comeback cookies

An AP is required to do a considerable amount of work upon receiving (#8118)first PASN frame and thus may be subjected to denial of service attacks by an attacker by spraying such frames, each possibly with a different source MAC address. An AP may also have limited resources and may desire to defer authentication for new client STAs. PASN authentication allows an AP to indicate the deferral time (Comeback After field in PASN Parameters element) and optionally a cookie in the Comeback Info field of the PASN Parameters element (9.4.2.305 (PASN Parameters element(11az))) and refuse the authentication temporarily.

The comeback cookie is used similarly to the SAE anti-clogging token (see 12.4.6 (Anti-clogging tokens)) for denial of service protection on an SAE peer. When a client STA receives the Comeback Info field with a deferral time and a cookie, the STA can reinitiate PASN authentication by providing the cookie. The AP would accept or deny authentication based on the received cookie, if one was expected. PASN comeback cookies are an opaque sequence of octets to the client. They are generated and validated by the AP by an implementation dependent scheme. An AP may start requiring clients present the comeback cookie provided based on resource or other constraints outside the scope of this specification.

## 12.14 Opportunistic Wireless Encryption(#6088)

### 12.14.1 General

The Opportunistic Wireless Encryption handshake is executed between a non-AP STA and an AP to establish a PMKSA using a simple Diffie-Hellman key exchange. The handshake does not provide true authentication of the non-AP STA or AP but does enable encryption. This handshake is designed for cases in which access control is either not necessary or can be handled outside of this standard.

### 12.14.2 Opportunistic Wireless Encryption exchange

The Opportunistic Wireless Encryption (OWE) exchange occurs during association of a non-AP STA and an AP that indicate the OWE AKM (9.4.2.23.3 (AKM suites)) by placing a Diffie-Hellman Parameter element in the (Re)Association Request and Response frames, respectively.

First the non-AP STA chooses a group in which to perform the Diffie-Hellman exchange. It then generates a secret private key, $m$, by randomly choosing it such that $1 < m < r$, where $r$ is the (prime) order of the chosen group. It derives a public key, $\boldsymbol{M}$, from the private key and the generator from the chosen group, $\boldsymbol{G}$:

$$\boldsymbol{M} = \text{scalar-op}(m, \boldsymbol{G})$$

where scalar-op() is defined in 12.4.4 (Finite cyclic groups). The non-AP STA then constructs a Diffie-Hellman Parameter element by assigning the appropriate value from the IANA-maintained registry for the chosen group to the Group field and assigning the public key to the Public Key field using the conversion defined in 12.4.7.2.4 (Element to octet string conversion). The non-AP STA inserts the Diffie-Hellman Parameter element into its (Re)Association Request frame per 9.3.3.5 (Association Request frame format) or 9.3.3.7 (Reassociation Request frame format) and transmits the (Re)Association Request frame to the AP. If the non-AP STA chooses to do PMKSA caching it shall include a PMKID in the (Re)Association Request frame.

Upon receipt of the non-AP STA's (Re)Association Request frame indicating OWE, the AP checks whether the STA is also attempting PMKSA caching. If so, and the AP has a PMKSA with a matching PMKID it shall proceed to the 4-way handshake as if it is not doing OWE, the STA's Diffie-Hellman parameter is ignored. If it does not have a PMKSA with a matching PMKID it shall continue with OWE as if the PMKID was not present. The AP then checks the Group field of the Diffie-Hellman Parameter element. If it is not an acceptable value, the AP shall reject association with the reason of UNSUPPORTED_FINITE_CYCLIC_GROUP.


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Otherwise, it shall extract the non-AP STA's public key from the Public Key field using the conversion defined in 12.4.7.2.5 (Octet string to element conversion). The extracted public key, ***M***, shall then be validated using the element validation technique from 12.4.5.4 (Processing of a peer's SAE Commit message). If validation of the public key fails, the AP shall reject association with the reason of REQUEST_DECLINED. If validation of the public key is successful, (Re)Association continues.

The AP shall then generate a private key, *n*, by randomly choosing it such that $1 < n < r$, where *r* is the (prime) order of the group indicated in the Group field of the received Diffie-Hellman Parameter element. It derives a public key, ***N***, from the private key and the generator from the chosen group, ***G***:

$\boldsymbol{N}$ = scalar-op($n$, $\boldsymbol{G}$)

where scalar-op() is defined in 12.4.4 (Finite cyclic groups). It shall then complete the Diffie-Hellman key exchange and generate a shared secret a PMK, and a PMKID:

$\boldsymbol{S}$ = scalar-op($n$, $\boldsymbol{M}$)
$s$ = F($\boldsymbol{S}$)
*prk* = HKDF-Extract($C$ || $A$ || *group*, $s$)
*PMK* = HKDF-Expand (*prk*, "OWE Key Generation", $n$)
*PMKID* = Truncate-128(Hash($C$ || $A$))

where HKDF-Extract() and HKDF-Expand() are the functions defined in IETF RFC 5869, instantiated with the hash algorithm from Table 12-1 (Hash algorithm based on length of prime), *n* is the bit length of the hash algorithm's digest, group is the Group field from the Diffie-Hellman Parameter element, *C* is the non-AP STAs public key from the Public Key field of the Diffie-Hellman Parameter element in the (Re)Association Request frame, *A* is the AP's public key from the Public Key field of the Diffie-Hellman Parameter element in the (Re)Association Response frame, F() is the element-to-scalar mapping function from 12.4.4 (Finite cyclic groups), and Hash() is a hash algorithm from Table 12-1 (Hash algorithm based on length of prime). Intermediate data, ***S*** and *s*, shall be irretrievably deleted upon generation of the PMK. Upon generation of the PMKID the public keys ***M*** and ***N*** (#8116)should be deleted. A PMKSA shall be created containing the PMK and PMKID.

The AP shall then construct an (Re)Association Response frame per 9.3.3.6 (Association Response frame format) or 9.3.3.8 (Reassociation Response frame format) indicating OWE. The AP constructs a Diffie-Hellman Parameter element with the Group field being identical to the Group field of the received (Re)Association Request frame and assigning its public key to the Public Key field using the conversion defined in 12.4.7.2.4 (Element to octet string conversion). The AP inserts the Diffie-Hellman Parameter element into its (Re)Association Response frame per 9.3.3.6 (Association Response frame format) or 9.3.3.8 (Reassociation Response frame format) and transmits the (Re)Association Response frame to the STA.

Upon receipt of the AP's (Re)Association Response frame indicating OWE, the STA checks that the Group field of the Diffie-Hellman Parameter element is identical to the value it inserted in its (Re)Association Request frame. If it is not the STA shall fail (Re)Association. Otherwise, it shall extract the AP's public key from the Public Key field using the conversion defined in 12.4.7.2.5 (Octet string to element conversion). The extracted public key, ***N***, shall then be validated using the element validation technique from 12.4.5.4 (Processing of a peer's SAE Commit message). If validation of the public key fails, the STA shall fail (Re)Association.

Otherwise, the STA shall then complete the Diffie-Hellman key exchange and generate a shared secret a PMK, and a PMKID:

$\boldsymbol{S}$ = scalar-op($m$, $\boldsymbol{N}$)
$s$ = F($\boldsymbol{S}$)
*prk* = HKDF-Extract($C$ || $A$ || *group*, $s$)
*PMK* = HKDF-Expand (*prk*, "OWE Key Generation", $n$)
*PMKID* = Truncate-128(Hash($C$ || $A$))

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where HKDF-Extract() and HKDF-Expand() are the functions defined in IETF RFC 5869, instantiated with the hash algorithm from Table 12-1 (Hash algorithm based on length of prime), *n* is the bit length of the hash algorithm's digest, group is the Group field from the Diffie-Hellman Parameter element, *C* is the non-AP STAs public key from the Public Key field of the Diffie-Hellman Parameter element in the (Re)Association Request frame, *A* is the AP's public key from the Public Key field of the Diffie-Hellman Parameter element in the (Re)Association Response frame, F() is the element-to-scalar mapping function from 12.4.4 (Finite cyclic groups), and Hash() is a hash algorithm from Table 12-1 (Hash algorithm based on length of prime). Intermediate data, ***S*** and *s*, shall be irretrievably deleted upon generation of the PMK. Upon generation of the PMKID the public keys ***M*** and ***N*** can be deleted. A PMKSA shall be created using the PMK and PMKID.

## 12.15 Frame authentication for EBCS(11bc)

### 12.15.1 General

The EBCS procedures provide one-way frame authentication mechanisms that do not require key negotiation between a transmitter and receivers.

The EBCS DL procedure uses one of the following four types of authentication.

— Public key frame authentication (PKFA)
— Hash chain frame authentication (HCFA) with instant authentication
— Hash chain frame authentication (HCFA) without instant authentication
— Higher layer source authentication (HLSA); no frame authentication

The EBCS UL procedure uses PKFA or HLSA.

While PKFA is suitable for occasional small data transfer or time-sensitive data transfer, HCFA is suitable for continuous content distribution such as live streaming or periodic file transfer.

NOTE—PKFA has a higher computational cost than HCFA. HCFA buffering generates latency. The characteristics of HLSA depend on higher layer algorithms.

The following preparations are required for both PKFA and HCFA before starting an EBCS traffic stream:

— The certificate(s) of the CA(s) shall be installed into the EBCS receivers as trusted roots. The installation method is out of scope of this standard.
— The EBCS transmitter generates its own private key and public key pair. The public key shall be signed by one of the CAs for which the EBCS receiver(s) have the certificate.

Preparations for HLSA depend on higher layer algorithms and are out of scope of this standard.

The EBCS procedures does not provide encryption since the purpose of EBCS is to broadcast data that is expected to be received and used by the receivers in the range of the transmitter. If encryption is required, use a higher layer encryption mechanism.

### 12.15.2 EBCS public key frame authentication (PKFA)

#### 12.15.2.1 Signature of an EBCS Info frame

An EBCS transmitter shall use one of the following public key algorithms to sign EBCS Info frames:

— RSASSA-PSS (IETF RFC 8017)
— ECDSA (IETF RFC 6979)


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The hash algorithm for signature generation shall comply with the rule shown in Table 12-1 (Hash algorithm based on length of prime).

The EBCS transmitter generates an EBCS Info frame periodically as described in 34.3.4 (EBCS Info frame generation and usage).

If the length of the EBCS Info frame is larger than the maximum MMPDU length (Table 9-25 (Control ID subfield values(11ax))), the EBCS Info frame shall be fragmented as described in 34.3.5 (EBCS Info frame fragmentation).

If the EBCS Info frame is not fragmented, the EBCS transmitter shall fill all the fields according to 9.6.7.54 (EBCS Info frame format(11bc)) except the signature.

The EBCS transmitter shall generate the signature as follows:

Signature = Sign (transmitter's private key, transmitter's MAC address || EBCS Info frame fields from the beginning of the EBCS Info Sequence Number field to the end of the Content Information List field)

where

Sign (*k, m*) indicates a digital signature for the message *m* using the private key *k*

Otherwise, only the first fragment contains the signature.

Signature = Sign (transmitter's private key, transmitter's MAC address || EBCS Info frame fields from the beginning of the EBCS Info Sequence Number field to the end of the Frame Body field)

And compute the hash value(s) for the following fragment(s):

HashValue = SHA-256 (transmitter's MAC address || EBCS Info frame fields from the beginning of the EBCS Info Sequence Number field to the end of the Frame Body field)

The EBCS transmitter fills the Signature field and the Fragment Hash Values field in EBCS Info frame with the computed signature and hash values respectively as described in 34.3.4 (EBCS Info frame generation and usage).

#### 12.15.2.2 Authentication of an EBCS Info frame

When the EBCS receiver receives an EBCS Info frame with an EBCS Info Authentication algorithm field that indicates neither None nor Prenegotiated, the EBCS receiver shall authenticate the frame.

If the EBCS Info frame is not fragmented, the following procedures shall be applied. If the EBCS Info frame is fragmented, the following procedures shall be applied only to the first fragment.

a) If the difference between the timestamp in the EBCS Info frame and the time of the clock of the EBCS receiver is greater than the allowable time difference in the EBCS Info frame, the EBCS Info frame shall be discarded.

b) Verify the certificate of the AP in the EBCS Info frame with the installed certificate of the CA.The EBCS receiver shall verify the full certificate chain to the certificate of the CA. If the verification fails or the certificate of the CA that signed the certificate of the AP in the EBCS Info frame is not installed, the EBCS Info frame shall be discarded.

c) Verify the signature in the EBCS Info frame with the certificate of the AP in the EBCS Info frame. If the verification fails, the EBCS Info frame shall be discarded.

When the EBCS receiver receives an EBCS Info frame of which EBCS Info Authentication Algorithm field indicates Prenegotiated, the EBCS receiver shall authenticate it.

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If the EBCS Info frame is not fragmented, the following procedures shall be applied. If the EBCS Info frame is fragmented, the following procedures shall be applied only to the first fragment.

1) If the difference between the timestamp in the EBCS Info frame and the time of the clock of the EBCS receiver is greater than the allowable time difference in the EBCS Info frame, the EBCS Info frame shall be discarded.
2) Verify the signature in the EBCS Info frame with the prenegotiated public key. If the verification fails, the EBCS Info frame shall be discarded.

If the EBCS Info frame is fragmented, the EBCS receiver caches the hash value(s) of the fragment(s) and the EBCS receiver shall authenticate the following fragment(s) as follows:

i) Compute the hash value of the fragment as described in 12.15.2.1 (Signature of an EBCS Info frame).
ii) If the computed hash value is equal to the cached hash value, the authentication succeeds. Otherwise, the fragment shall be discarded.
iii) If all the fragments are successfully authenticated, the EBCS receiver shall concatenate them and process the defragmented EBCS Info frame as described in 34.3.4 (EBCS Info frame generation and usage).

If the authentication succeeds:

— The EBCS receiver caches the certificate of the AP, if it exists, and the allowable time difference in the EBCS Info frame.
— If data is present in the Content Information field, the EBCS receiver processes the data in the Content Information field(s) in accordance with 34.3.4 (EBCS Info frame generation and usage).

### 12.15.2.3 PKFA MPDU format

EBCS Data frames sent under PKFA use the PFKA MPDU format. The frame body of a PKFA MPDU is shown in Figure 12-61 (PKFA MPDU format(11bc)).

| | MAC Header | Timestamp | Data Sequence | Data Length | Data (PDU) | Signature | FCS |
|---|---|---|---|---|---|---|---|
| Octets | variable | 8 | 2 | 2 | variable | variable | 4 |

**Figure 12-61—PKFA MPDU format(11bc)**

The MAC Header field and the FCS field are defined in 9.2.1 (Basic components).

The Timestamp field contains the elapsed time from 2020-01-01 00:00 UTC in milliseconds that indicates the time at which the MPDU was generated.

The Data Sequence field indicates the sequence number of the frame that starts from 0 and is incremented by 1 for each MPDU generation. In case of overflow, it is reset to 0.

The Data Length field indicates the length of the Data field in octets.

The Data (PDU) field contains an MSDU.

The Signature field contains the signature for the MPDU. The signature is generated by the following formula.


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Signature = Sign (transmitter's private key, transmitter's MAC address || PKFA MPDU fields from the Timestamp field to the end of the Data (PDU) field)

where

Sign(*k, m*) indicates a digital signature for the message *m* using the private key *k*

#### 12.15.2.4 Authentication of a PKFA MPDU

When an EBCS receiver receives an EBCS Data frame, the EBCS receiver shall authenticate it as follows:

1) If the difference between the timestamp in the PKFA MPDU and the time of the clock is greater than the cached allowable time difference, the PKFA MPDU shall be discarded.
2) Verify the signature in the PKFA MPDU using the cached certificate or the prenegotiated public key. If the verification fails, the PKFA MPDU shall be discarded, otherwise the PDU shall be decapsulated.

#### 12.15.2.5 Signature of the EBCS UL frame

An EBCS non-AP STA generates an EBCS UL frame when it receives data (HLP payload) to be transmitted to a specified destination.

If the Frame Signature Type subfield of the EBCS UL frame is equal to a nonzero value, then one of the following public key algorithms is used to generate the frame signature:

— RSASSA-PSS
— ECDSA

For RSASSA-PSS, the length of the modulus shall be 2048 bits or 4096 bits. SHA-256 for 2048 bits modulus or SHA-512 for 4096 bits modulus shall be used as the mask generation function and as the hash function during signature generation.

For ECDSA, the domain parameters shall be P-256 or P-521. SHA-256 for P-256 or SHA-512 for P-521 shall be used as the hash function during signature generation.

The signature is generated as follows:

Signature = Sign (transmitter's private key, transmitter's MAC address || EBCS UL frame fields from the beginning of the Control field to the last field before the Frame Signature Length field)

where

Sign (*k, m*) indicates a digital signature for the message *m* using the private key *k*

#### 12.15.2.6 Authentication of an EBCS UL frame

An EBCS proxy shall discard an EBCS UL frame if any of the following conditions are met:

1) The STA Certificate subfield is present and any of the following conditions are met:
   a) The certificate of the authority (i.e., specified destination or the CA that signed the STA's certificate) is not installed.
   b) The verification of the STA's certificate using the installed certificate fails.
   c) The Frame Signature Type subfield does not indicate HLSA and the verification of the signature of the frame using the STA's certificate fails.
   d) The Frame Signature Type subfield does not indicate HLSA, the verification of the signature of the frame using the STA's certificate succeeds, and the Frame Count field is present with a value less than or equal to the last seen frame count (if any) from the EBCS non-AP STA.

2. The Frame Tx Time field is present and the difference between the value carried in the field and the

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time when the EBCS UL frame is received is greater than an acceptable value.

NOTE 1—The acceptable time difference at an EBCS proxy can be selected based on local policies or based on the relationship with the specified destination. The selection of an acceptable time difference is out of scope of this standard.

NOTE 2—When the Frame Signature Type subfield indicates HLSA, replay protection is performed by a higher layer and is out of scope of this standard.

An EBCS proxy shall save the value in the most recently received Frame Count field of an EBCS UL frame, as *last seen frame count*, for a certain transmitter only if the EBCS UL frame was not discarded based on the preceding conditions. In addition, an EBCS proxy may have an expiration time after which the *last seen frame count* value for a certain transmitter is discarded.

NOTE 3—A large expiration time reduces the scope for a replay attack.

### 12.15.3 EBCS hash chain frame authentication (HCFA)

#### 12.15.3.1 General

HCFA uses a digital signature and the algorithm of TESLA (Timed Efficient Stream Loss-Tolerant Authentication, IETF RFC 4082).

HCFA provides the following two authentication methods to authenticate each HCFA MPDU:

— HCFA authentication
— Instant authentication (optional)

Each authentication method uses a separate authenticator. HCFA authentication uses the HCFA authenticator, and instant authentication uses the instant authenticator. The instant authenticator is optionally used to avoid buffering malicious HCFA MPDUs on EBCS receivers.

The HCFA method uses both EBCS Info frames (9.6.7.54 (EBCS Info frame format(11bc))) and Data frames. The frame sequence is shown in Figure 12-62 (EBCS HCFA frame sequence(11bc)).

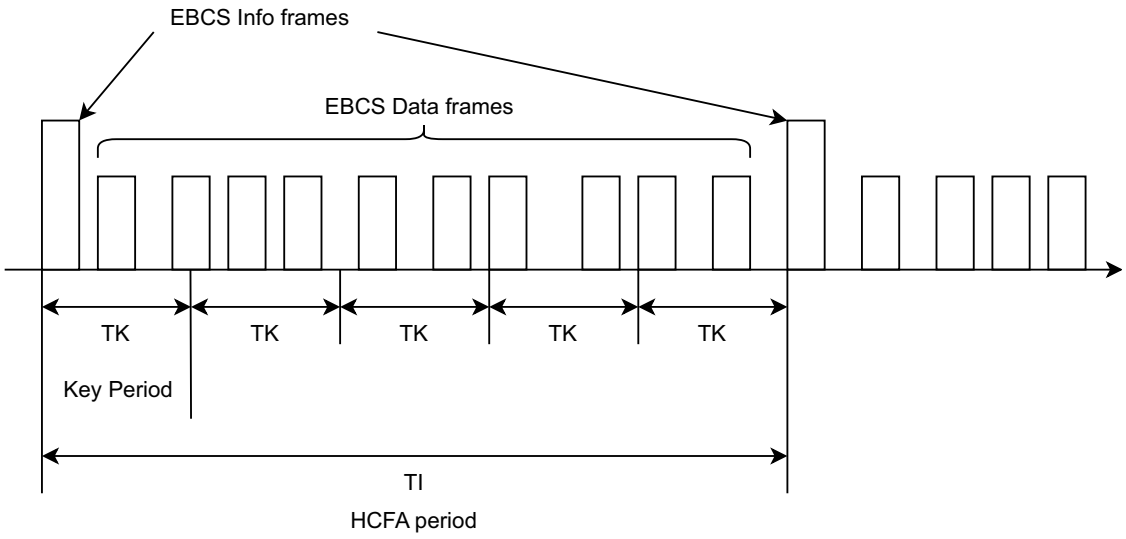


**Figure 12-62—EBCS HCFA frame sequence(11bc)**

EBCS Info frames are transmitted every dot11EBCSInfoInterval ($T_I$). $T_K$ is the HCFA key change interval and is configured as dot11EBCSHCFAKeyChangeInterval. $T_I$ shall be a multiple of $T_K$. The interval


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between one EBCS Info frame and the next EBCS Info frame is called the *HCFA period*. Each HCFA period is identified by the HCFA sequence number that is the lower 3 octets of the EBCS Info Sequence Number field value in the EBCS Info frame that is transmitted at the beginning of the HCFA period.

Each EBCS traffic stream has an ID that is indicated in the Content ID subfield in the Content Information field in the EBCS Info frame.

A period that uses the same HCFA authentication key is called a *key period*. Each key period has a sequence number, a data sequence number, and a key sequence number, each starting with 0 at the beginning of each HCFA period. Note that the key sequence number is different from HCFA key indexes.

Each HCFA MPDU has a sequence number, a data sequence number, and a key sequence number, each starting from 0 at the beginning of each key period. The HCFA MPDU is identified by the following identifiers:

— HCFA sequence number
— Content ID
— Key sequence number
— Data sequence number

The data sequence number is used to identify the correct key for authentication. It is set to 0 at the beginning of a key period to fit in a 2 octet field and to identify the correct authentication key easily. These identifiers can be used for unsolicited retransmission. An EBCS transmission uses group addressed frames only, no Acks are used.

EBCSData($s$, $c$, $k$, $d$) represents the HCFA MPDU in which the HCFA sequence number is $s$, the content ID is $c$, the Key sequence number is $k$, and the Data sequence number is $d$.

IAuth($s$, $c$, $k$, $d$) and HAuth($s$, $c$, $k$, $d$) represent the instant authenticator and the HCFA authenticator for the EBCSData($s$, $c$, $k$, $d$), respectively.

EBCSInfo($s$) represents the EBCS Info frame for which the HCFA sequence number is $s$. For example, in case of two EBCS traffic streams, Stream A and Stream B, the identifiers are shown in Figure 12-63 (Identifiers example(11bc)).

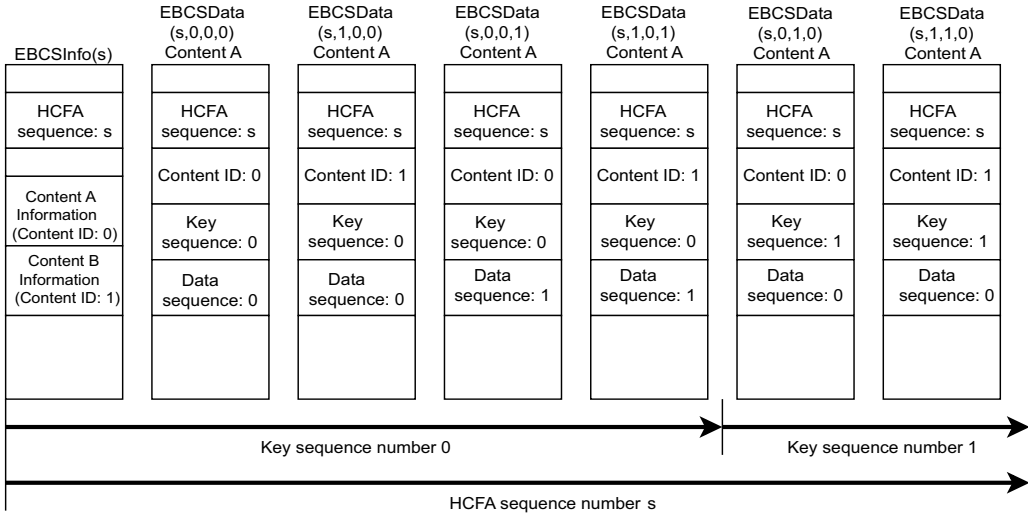


**Figure 12-63—Identifiers example(11bc)**

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The index of the HCFA base key and the HCFA authentication key is defined as $B(s, c, k)$ and $A(s, c, k)$, respectively, where $s$ is the HCFA sequence number, $c$ is the content ID, and $k$ is the key sequence number.

The key sequence number is different from the HCFA base/authentication key index. The HCFA base/authentication keys are used in the reverse sequence of HCFA key generation. The relation between the HCFA base/authentication key index and the HCFA sequence number is shown in Table 12-13 (Relationship between HCFA base/authentication key index and HCFA sequence number(11bc)), where $N$ is the number of HCFA authentication keys generated. An example of the HCFA key delivery is shown in Figure 12-64 (Example HCFA key delivery(11bc))

**Table 12-13—Relationship between HCFA base/authentication key index and HCFA sequence number(11bc)**

| HCFA base/authentication key index | *N*–1 | *N*–2 | *N*–3 | *N*–4 | *N*–5 | *N*–6 | … | 0 |
|---|---|---|---|---|---|---|---|---|
| HCFA sequence number | –3 | –2 | –1 | 0 | 1 | 2 | … | *N*-4 |

NOTE—HCFA sequence number –3, –2 and –1 are used only for key verification.

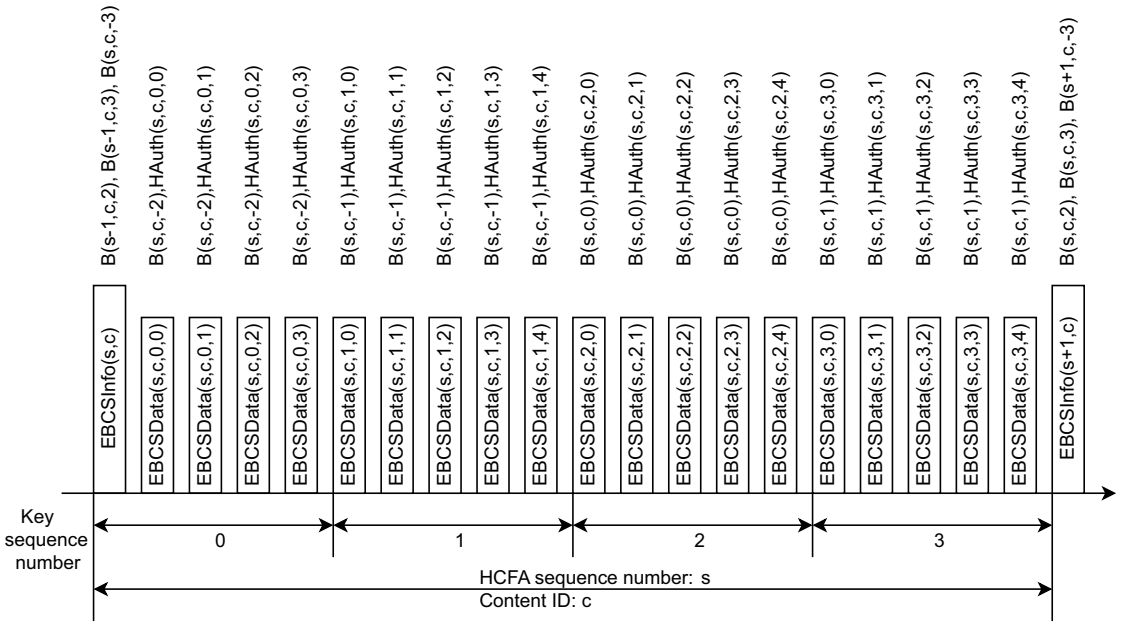


**Figure 12-64—Example HCFA key delivery(11bc)**

An EBCS Info frame and an HCFA MPDU may contain multiple instant authenticators.

For example, EBCSData(*s, c, k, d*) may contain IAuth(*s, c, k, d+1*) and IAuth(*s, c, k, d+3*). In this case, the values 1 and 3 are called *hash distances.* The hash distance is configured in dot11EBCSHCFAHashDistance. Each instant authenticator is delivered with the frame identifier (*s, c, k, d*).


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An example of the instant authenticator delivery is shown in Figure 12-65 (Example Instant authenticator delivery(11bc)).

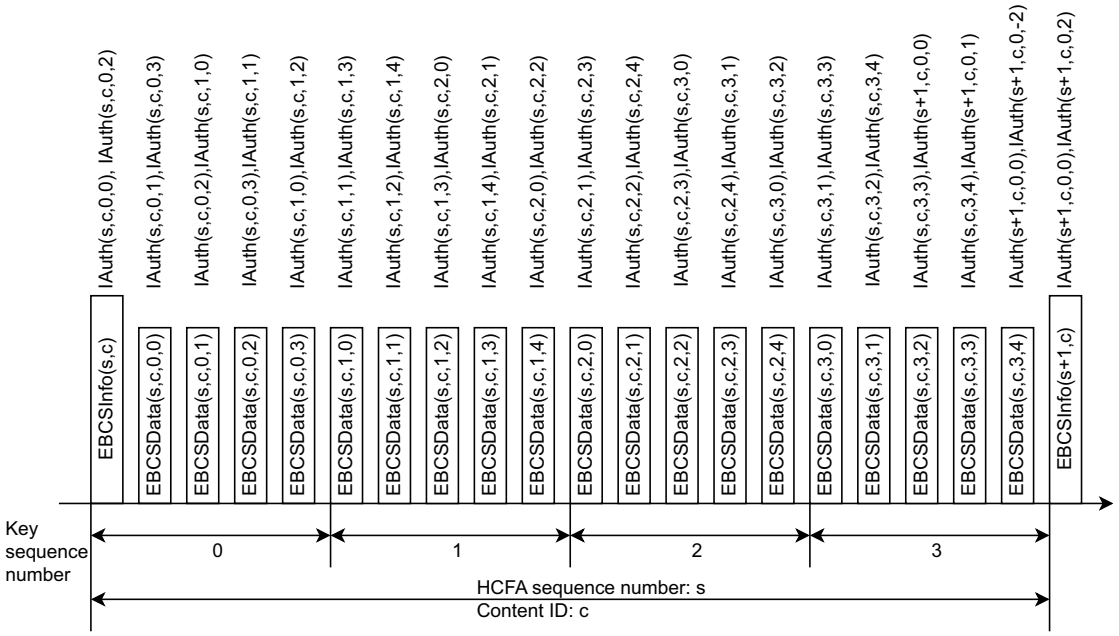


**Figure 12-65—Example Instant authenticator delivery(11bc)**

### 12.15.3.2 Key generation

HCFA is a one-way key chain authentication mechanism. The EBCS transmitter generates HCFA base keys and HCFA authentication keys for each EBCS traffic stream before each EBCS Info frame generation.

SHA-256 hash function is used for HCFA key generation.

The HCFA base keys ($B_{s,n}$) are generated as follows:

$B_{s,0}$ = 256-bit random value

$key\text{-}seed_{s,n}$ = HKDF-Extract(EBCS AP MAC address, $B_{s,n-1}$)

$B_{s,n}$ = HKDF-Expand("EBCS HCFA base key", $key\text{-}seed_{s,n}$) ($n \geq 1$)

where

HKDF-Extract() and HKDF-Expand() are functions defined in IETF RFC 5869, instantiated with SHA-256

$s$ is the HCFA sequence number of the generating EBCS Info frame

EBCS AP MAC address is an octet string that represents the MAC address of an EBCS AP

"EBCS HCFA base key" is an ASCII string

The HCFA authentication keys ($A_{s,n}$) are generated as follows:

$A_{s,n}$ = HKDF-Expand("EBCS HCFA authentication key", $key\text{-}seed_{s,n}$)

where

HKDF-Expand() is a function defined in IETF RFC 5869, instantiated with SHA-256

$s$ is the HCFA sequence number of the generating EBCS Info frame

"EBCS HCFA authentication key" is an ASCII string

The number of keys to be generated ($N$) is following:

$N = T_I / T_K + 3$

where $T_I$ is the EBCS Info frame transmission interval and $T_K$ is the HCFA key change interval.

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The HCFA key generation scheme is shown in Figure 12-66 (HCFA key generation scheme(11bc)).

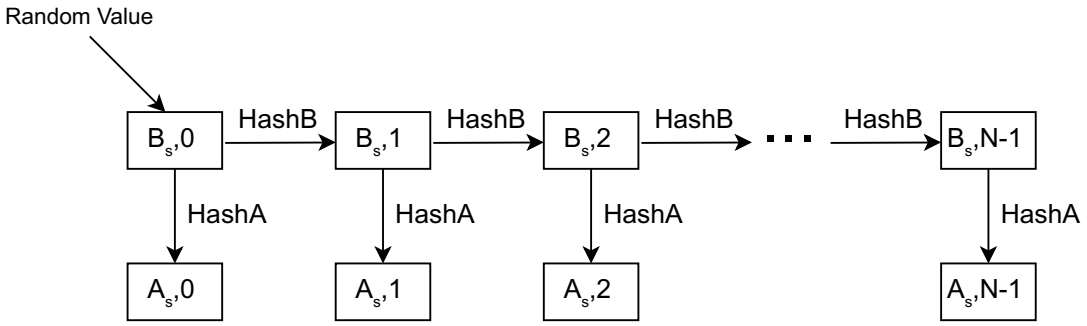


**Figure 12-66—HCFA key generation scheme(11bc)**

In this figure, HashB is the hash function to generate HCFA base keys, and HashA is the hash function to generate HCFA authentication keys.

HCFA keys are generated for each ECBS traffic stream.

### 12.15.3.3 HCFA MPDU

EBCS Data frames sent under HCFA use the HCFA MPDU format. The frame body of an HCFA MPDU is shown in Figure 12-67 (HCFA MPDU format(11bc)).

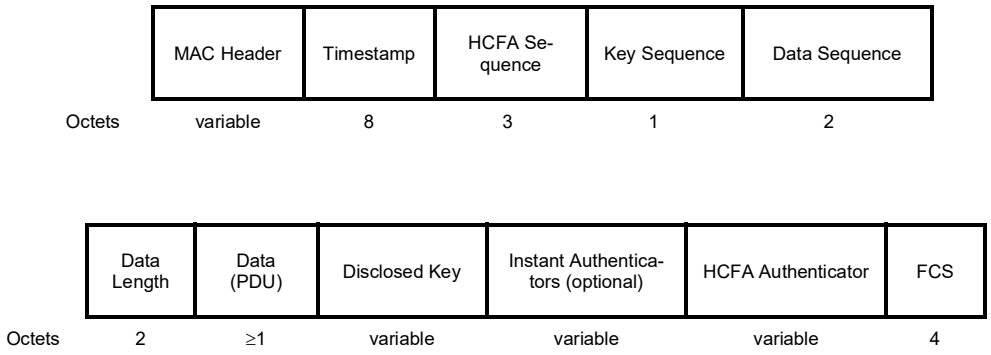


**Figure 12-67—HCFA MPDU format(11bc)**

The MAC Header field and the FCS field are defined in 9.2.1 (Basic components).

The Timestamp field indicates the elapsed time from 2020-01-01 00:00 UTC in milliseconds until the time at which the MPDU was generated.

The HCFA Sequence field indicates the HCFA sequence number of the MPDU.

The Key Sequence field indicates the key sequence number of the MPDU.

The Data Sequence field indicates the data sequence number of the MPDU.

The Data Length field indicates the length of the Data field.

The Data (PDU) field contains an MSDU.

The Disclosed Key field contains the HCFA base key to be disclosed.


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The Instant Authenticator field contains instant authenticator(s) for the MPDU(s) that will be transmitted later.

The HCFA Authenticator field contains the HCFA authenticator of the MPDU.

The HCFA authenticator is the HMAC-SHA-256 value of the MPDU with the HCFA authentication key.

HCFA authenticator = HMAC-SHA-256 (*A(s, c, k)*, transmitter's MAC address || HCFA MPDU fields from the beginning of the Timestamp field to the end of the Instant Authenticator field)

where

*A(s, c, k)* indicates the HCFA authentication key for the HCFA sequence *s*, the content ID *c,* and the key sequence *k*

The instant authenticator is the hash value of the MPDU to be transmitted later that is specified by dot11EBCSHCFAHashDistance, generated as follows:

Instant authenticator = SHA-256 (transmitter's MAC address || HCFA MPDU fields from the beginning of the Timestamp field to the end of the Disclosed Key field)

#### 12.15.3.4 EBCS Info frame reception

A received EBCS Info frame shall be processed as follows:

1) If the EBCS Info frame is fragmented, it shall be defragmented as described in 34.3.6 (EBCS Info frame defragmentation).
2) If the difference between the timestamp in the EBCS Info frame and the time in the EBCS receiver's clock is greater than the HCFA key change interval in the EBCS Info frame, the EBCS Info frame shall be discarded.
3) Verify the certificate of the AP in the EBCS Info frame using the installed certificate of the CA. If the verification fails or the certificate of the CA that signed the certificate of the AP in the EBCS Info frame is not installed, the EBCS Info frame shall be discarded.
4) Verify the signature in the EBCS Info frame using the certificate of the AP in the EBCS Info frame. If the verification fails, the EBCS Info frame shall be discarded.
5) If the HCFA base key(s) of the previous HCFA period, *B(s–1, c, N–4)* and *B(s–1, c, N–5)*, is included and the HCFA MPDUs of the previous HCFA period to be authenticated are present, the HCFA MPDUs shall be authenticated and processed as described in 12.15.3.5 (HCFA MPDU reception).
6) The HCFA sequence number, *s,* and the HCFA base key(s), *B(s, c, 0)*, shall be cached for the HCFA period of the EBCS Info frame.
7) If the instant authenticator(s) are present, the instant authenticators contained in the EBCS Info frame shall be cached.

#### 12.15.3.5 HCFA MPDU reception

HCFA MPDUs shall be discarded until an EBCS Info frame from the BSS is received.

An HCFA MDPU, EBCSData(*s*, *c*, *k*, *d*), is processed as follows:

1) Compute *B(s, c, k-3)* from *B(s, c, k–2)* in the EBCSData(*s*, *c*, *k*, *d*). If the computed *B(s, c, k–3)* is different from the cached *B(s, c , k–3)*, the HCFA MPDU shall be discarded.
2) If instant authentication is used and the instant authenticator of the EBCSData(*s*, *c*, *k*, *d*), IAuth(*s*, *c*, *k*, *d*) (12.15.3.3 (HCFA MPDU)), is cached, compute the hash value of the

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EBCSData(*s*, *c*, *k*, *d*). If the computed hash value is different from the cached instant authenticator, the HCFA MPDU shall be discarded.

3) If instant authentication is used and the instant authenticator of the EBCSData(*s*, *c*, *k*, *d*), IAuth(*s*, *c*, *k*, *d*), is not cached, the HCFA MPDU may be cached until the HCFA base key for the key period is received, or the HCFA MPDU may be discarded.
4) If instant authentication is not used, the HCFA MPDU shall be cached until the HCFA base key for the key period is received.
5) If prior HCFA MPDU(s) using the HCFA authentication key derived from the HCFA base key included in the present HCFA MPDU, EBCSData(*s*,*c*,*k*–2,*), are cached,
   i) Derive the HCFA authentication key, *A(s, c, k–2)*, from the HCFA base key, *B(s, c, k–2)*.
   ii) Compute HCFA authenticator (12.15.3.3 (HCFA MPDU)) for the cached HCFA MPDU(s) by using the HCFA authentication key.
   iii) If the computed HCFA authenticator is different from the HCFA authenticator in the cached HCFA MPDU, the cached HCFA MPDU shall be discarded.

Then forward the MSDU to a higher layer.

Even in case of missing HCFA MPDUs, the EBCS receiver recovers HCFA keys. As described in 12.15.3.2 (Key generation), HCFA base keys are generated using SHA-256 and transmitted in reverse sequence. The EBCS receiver is able to compute the missed HCFA base keys from the last received HCFA base key. For example, if the EBCS receiver missed all HCFA MPDUs containing *B(s, c, k)* but still cached *B(s, c, k–1)* and received *B(s, c, k+1)*, the EBCS receiver computes *B(s, c, k)* and *B(s, c, k–1)* as follows:

*B(s, c, k)* = SHA-256 (“EBCS base key” || *B(s, c, k+1)*)
*B(s, c, k-1)* = SHA-256 (“EBCS base key” || *B(s, c, k)*)

Then the EBCS receiver authenticates the HCFA base keys by comparing the computed *B(s, c, k–1)* and the cached *B(s, c, k–1)*. After successful key authentication, the EBCS receiver authenticates EBCSData(*s*, *c*, *k*, *) and EBCSData(*s*, *c*, *k+1*, *).

### 12.15.4 No frame authentication with mandatory higher layer source authentication (HLSA)

#### 12.15.4.1 General

If neither PKFA nor HCFA is used, a content source authentication mechanism shall be provided by a higher layer. The higher layer source authentication mechanism is out of scope of this standard.

Authentication of EBCS Info frames is optional if the EBCS Info frames include only HLSA content information. The EBCS AP may decide to use EBCS Info frame authentication or not.

If an EBCS Info frame includes the certificate of the AP, the EBCS receiver shall authenticate the EBCS Info frame as described in 12.15.2.2 (Authentication of an EBCS Info frame).


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# 13. Fast BSS transition

## 13.1 Overview

Fast BSS transition seeks to reduce the length of time that connectivity is lost between a STA and the DS during a BSS transition. The FT protocols are part of the reassociation service and only apply to STA transitions between APs within the same mobility domain within the same ESS.

The FT protocols require information to be exchanged during the initial association (or a later reassociation) between a STA [known as the *FT Originator* (FTO)] and AP. The initial exchange is referred to as the *FT initial mobility domain association*. Subsequent reassociations to APs within the same mobility domain may make use of the FT protocols.

Two FT protocols are defined:

— *FT protocol.* This protocol is executed when an FTO makes a transition to a target AP and does not require a resource request prior to its transition.

— *FT resource request protocol.* This protocol is executed when an FTO requires a resource request prior to its transition.

For an FTO to move from its current AP to a target AP utilizing the FT protocols, the message exchanges are performed using one of two methods:

— *Over-the-Air.* The FTO communicates directly with the target AP using IEEE 802.11 authentication with the FT authentication algorithm.

— *Over-the-DS.* The FTO communicates with the target AP via the current AP. The communication between the FTO and the target AP is carried in FT Action frames between the FTO and the current AP. Between the current AP and target AP, communication is via an encapsulation method described in 13.10.3 (Remote Request/Response frame definition). The current AP converts between the two encapsulations.

APs advertise both capabilities and policies for supporting the FT protocols and methods.

Throughout this clause, the notation *Authentication-Request* (#4139)frame refers to an Authentication frame with the Authentication Transaction Sequence Number field equal to 1; *Authentication-Response* (#4139)frame refers to an Authentication frame with the Authentication Transaction Sequence Number field equal to 2; *Authentication-Confirm* (#4139)frame refers to an Authentication frame with the Authentication Transaction Sequence Number field equal to 3; *Authentication-Ack* (#4139)frame refers to an Authentication frame with the Authentication Transaction Sequence Number field equal to 4. The first parameter to the above four messages is the authentication algorithm, such as Open System authentication algorithm (i.e., *Open* in figures in this clause) or FT authentication algorithm (i.e., *FTAA* in figures in this clause).

## 13.2 Key holders

### 13.2.1 Introduction

The FT key holder architecture, shown in Figure 13-1 (FT key holder architecture), describes the FT key management entities and is defined in the context of the IEEE 802.11 basic reference model (see Figure 4-27 (Portion of the ISO/IEC basic reference model covered in this standard(#4114)) in 4.9 (Reference model)).

The R0KH and R1KH are part of AP's SME RSNA key management. The computation of PMK-R0 and PMK-R1, and all of the intermediate results in the computations, shall be restricted to the R0KH. The computation of PTK, and all intermediate results in its computation, shall be restricted to the R1KH.

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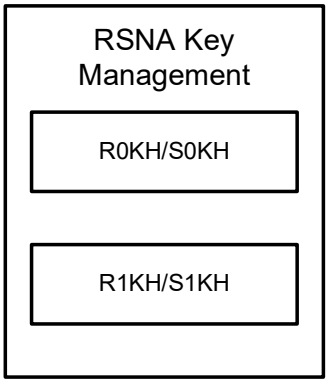


**Figure 13-1—FT key holder architecture**

The S0KH and S1KH are part of the FTO's SME RSNA key management. The computation of PMK-R0 and PMK-R1, and all of the intermediate results in the computations, shall be restricted to the S0KH. The computation of PTK, and all intermediate results in its computation, shall be restricted to the S1KH.

### 13.2.2 Authenticator key holders

The R0KH and R1KH are responsible for the derivation of keys in the FT key hierarchy. For fast BSS transition, the functions of the IEEE 802.1X Authenticator are distributed among the R0KH and R1KHs.

The R0KH interacts with the IEEE 802.1X Authenticator to receive the MSK resulting from an EAP authentication. The R1KH interacts with the IEEE 802.1X Authenticator to open the Controlled Port. Both the R0KH and R1KH interactions with the IEEE 802.1X Authenticator occur within the SME.

The R0KH derives the PMK-R0 for use in the mobility domain utilizing the MSK (when the negotiated AKM is 00-0F-AC:3 or 00-0F-AC:13), the PSK (when the negotiated AKM is 00-0F-AC:4) or the PMK (when the negotiated AKM is 00-0F-AC:9 or 00-0F-AC:25(Ed1)(M21)), or the FILS-FT (when the negotiated AKM is 00-0F-AC:16 or 00-0F-AC:17). The R0KH shall be responsible for deriving a PMK-R1 for each R1KH within the mobility domain.

The R1KH and S1KH each derive the PTK(11ba), the derived PTK including the Key derivation key (KDK) if WUR frame protection is negotiated. If WUR frame protection is negotiated, the R1KH and S1KH each derive a WTK from the KDK.

Each R0KH-ID and R1KH-ID (#6401)needs to be a unique identifier within the mobility domain. This identifier is communicated to the FTO and other key holders. The R0KH-ID is bound into the PMK-R0 derivation and the R1KH-ID is bound into the PMK-R1 derivation.

The R0KH shall meet the following requirements:

— The R0KH shall be (#2210)colocated with the network access server (NAS) Client functionality of the IEEE 802.1X Authenticator.

— The R0KH-ID shall be set to the identity of the co-resident NAS Client (e.g., NAS-Identifier as defined in IETF RFC 2865 [B33] if RADIUS is used as the backend protocol). R0KH-ID shall not be longer than 48 octets to fit in the length limitation of the FTE.

— When the PMK-R0 lifetime expires, the R0KH shall delete the PMK-R0 security association and shall revoke within the R0KH all PMK-R1s derived from the PMK-R0.

— The R0KH shall not expose the PMK-R0 to other parties.


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- The R0KH shall not expose the PMK-R1 to parties other than the authorized R1KH.

The R1KH shall meet the following requirements:

- The R1KH-ID shall be set to a MAC address of the physical entity that stores the PMK-R1 and uses it to generate the PTK. That same MAC address shall be used to advertise the PMK-R1 identity to the STA and the R0KH.
- The R1KH shall derive and distribute the GTK and IGTK to all connected STAs.
- (11ba)If WUR frame protection is enabled, the R1KH shall derive and distribute the WIGTK and WIPN to all WUR non-AP STAs with which the R1KH has negotiated WUR frame protection.
- If beacon protection is enabled, the R1KH shall derive and distribute the BIGTK and BIPN to all connected STAs.
- When the PMK-R1 lifetime expires, the R1KH shall delete the PMK-R1 PMKSA and shall revoke all PTKSAs derived from the PMK-R1 using the MLME-DELETEKEYS primitive.
- The R1KH shall not expose the PMK-R1 to other parties.

dot11FTR0KeyHolderID and dot11FTR1KeyHolderID shall contain the values of R0KH-ID and R1KH-ID as defined in this clause, respectively.

The R0KH and the R1KH (#6401)need to have a secure channel between them that can be used to exchange cryptographic keys without exposure to any intermediate parties. The cryptographic strength of the secure channel between the R0KH and R1KH (#6401)needs to be greater than or equal to the cryptographic strength of the channels for which the keys are used. (#6401)The key transfer includes the PMK-R1, the PMK-R1 PMKSA, the PMK-R1 context, and the associated key authorizations. The protocol for distribution of keying material from the R0KH to the R1KH is outside the scope of this standard.

The PMK-R1 distribution from the R0KH to the R1KHs within the same mobility domain shall satisfy the following(#6401):

- The R0KH authenticates a potential R1KH with the same identity as is included in the PMK-R1 derivation. The cryptographic strength of the authentication is assumed to be greater than or equal to the cryptographic strength of the authentication between the Supplicant and AS.
- The authorization of holding a PMK-R1 is based on the authentication of the R1KH.
- The protected channel provides confidentiality and integrity protection.

### 13.2.3 Supplicant key holders

The S0KH and S1KH are responsible for the derivation of keys in the FT key hierarchy. The S0KH and S1KH (#6401)reside in the Supplicant.

The S0KH interacts with the IEEE 802.1X functional block (see Figure 4-27 (Portion of the ISO/IEC basic reference model covered in this standard(#4114)) in 4.9 (Reference model)) to receive the MSK resulting from an EAP authentication or the FILS-FT resulting from a FILS authentication. The S1KH interacts with the IEEE 802.1X entity to open the Controlled Port. Both the S0KH and S1KH interactions with the IEEE 802.1X entity occur within the SME of a STA.

The S0KH derives the PMK-R0 for use in the mobility domain utilizing the MSK (when the negotiated AKM is 00-0F-AC:3 or 00-0F-AC:13), the PSK (when the negotiated AKM is 00-0F-AC:4) or the PMK (when the negotiated AKM is 00-0F-AC:9 or 00-0F-AC:25(Ed1)(M21)), or the FILS-FT (when the negotiated AKM is 00-0F-AC:16 or 00-0F-AC:17).

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The S1KH shall derive the PTK mutually with the R1KH(11ba), the derived PTK including the Key derivation key (KDK) if WUR frame protection is negotiated. If WUR frame protection is negotiated, the S1KH shall derive a WTK from the KDK.

The S0KH and S1KH shall be identified by the SPA. The S0KH shall not expose the PMK-R0 to other parties and shall not expose the PMK-R1 to parties other than the authorized S1KH. The S1KH shall not expose the PMK-R1 to other parties.

## 13.3 Capability and policy advertisement

The FT capability is advertised in the Beacon and Probe Response frames by including the MDE. The MDE is advertised in the Beacon and Probe Response frames to indicate the MDID, FT capability, and the FT policy.

The MDID field shall be dot11FTMobilityDomainID. The Fast BSS Transition Policy bits in the MDE, i.e., Fast BSS Transition over DS subfield and Resource Request Protocol Capability subfield, shall be set by dot11FTOverDSActivated and dot11FTResourceRequestSupported, respectively.

NOTE—The Fast BSS Transition Policy bits in the MDE need to be the same across the mobility domain.(#6401)

The capability is advertised in the Neighbor Report element. See 11.10 (Radio measurement procedures) and 9.4.2.35 (Neighbor Report element).

If an FTE is included in a Request element in a Probe Request frame, the FTE in the Probe Response frame shall contain the R0KH-ID and R1KH-ID (from dot11FTR0KeyHolderID and dot11FTR1KeyHolderID), and all other fields shall be set to 0.

## 13.4 FT initial mobility domain association

### 13.4.1 Overview

The FT initial mobility domain association is the first (re)association in the mobility domain, where the SME of the STA enables its future use of the FT procedures.

FT initial mobility domain association is typically the first association within the ESS. In addition to Association Request and Response frames, Reassociation Request and Response frames are supported in the initial mobility domain association to enable both FT and non-FT APs to be present in a single ESS.

### 13.4.2 FT initial mobility domain association in an RSN

A STA indicates its support for the FT procedures by including the MDE in the (Re)Association Request frame and indicates its support of security by including the RSNE. The AP responds by including the FTE, MDE, and RSNE in the (Re)Association Response frame. After a successful IEEE 802.1X authentication (if needed) or SAE authentication, the STA and AP perform an FT 4-way handshake. At the end of the sequence, the IEEE 802.1X Controlled Port is opened, and the FT key hierarchy has been established. The message flow is shown in Figure 13-2 (FT initial mobility domain association in an RSN using Open System authentication(#4396)(#6296)).

A non-DMG STA initiates the FT initial mobility domain association procedures by performing an IEEE 802.11 authentication using the Open System authentication algorithm.

STA→AP: Authentication-Request (Open System authentication algorithm)
AP→STA: Authentication-Response (Open System authentication algorithm, Status)


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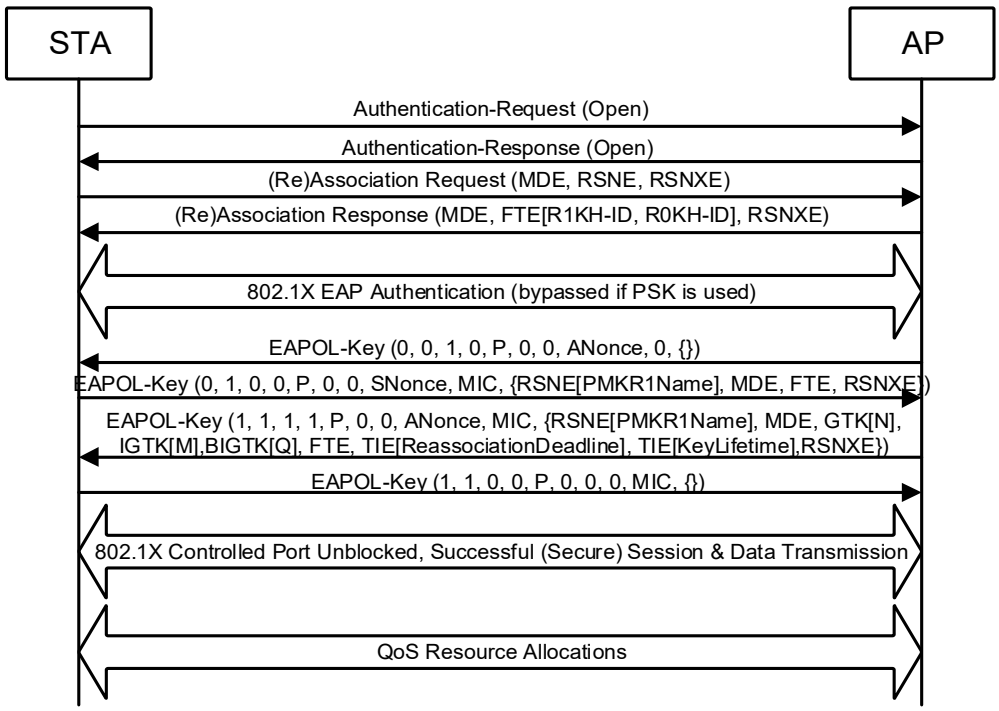


**Figure 13-2—FT initial mobility domain association in an RSN using Open System authentication(#4396)(#6296)**

A DMG STA initiates the FT initial mobility domain association procedures by performing an IEEE 802.11 authentication using the SAE algorithm.

STA→AP: Authentication-Request (SAE algorithm)
AP→STA: Authentication-Response (SAE algorithm, Status)

The SME of the STA initiates the authentication exchange, through the use of the MLME-AUTHENTICATE.request primitive, and the SME of the AP responds with MLME-AUTHENTICATE.response primitive. See 11.3.4 (Authentication and deauthentication).

Upon successful IEEE 802.11 Open System or SAE authentication, if using a suite type for which the Authentication type column indicates FT authentication (see Table 9-190 (AKM suite selectors)), the STA shall send a (Re)Association Request frame to the AP that includes the MDE. The contents of the MDE shall be the values advertised by the AP in its Beacon or Probe Response frames. Additionally, the STA includes its security capabilities in the RSNE.

STA→AP: (Re)Association Request (MDE, RSNE, RSNXE)
AP→STA: (Re)Association Response (MDE, FTE[R1KH-ID, R0KH-ID], RSNXE)

The SME of the STA initiates the (re)association through the use of the MLME-ASSOCIATE.request or MLME-REASSOCIATE.request primitive. The SME of the AP responds to the indication with MLME-ASSOCIATE.response or MLME-REASSOCIATE.response primitive. See 11.3.5 (Association, reassociation, and disassociation).

If the contents of the MDE received by the AP do not match the contents advertised in the Beacon and Probe Response frames, the AP shall reject the (Re)Association Request frame with status code STATUS_INVALID_MDE. If an MDE is present in the (Re)Association Request frame and (#3488)the

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RSNE does not indicate a (#4225)single AKMP, or the Authentication type column for that AKMP does not indicate FT authentication (see Table 9-190 (AKM suite selectors)), the AP shall reject the (Re)Association Request frame with status code STATUS_INVALID_AKMP.

The (Re)Association Response frame from the AP shall contain an MDE, with contents as presented in Beacon and Probe Response frames. The FTE shall include the key holder identities of the AP, the R0KH-ID and R1KH-ID, set to the values of dot11FTR0KeyHolderID and dot11FTR1KeyHolderID, respectively. The FTE shall have a MIC element count of zero (i.e., no MIC present) and have ANonce, SNonce, and MIC fields set to 0. The RSNXE Used subfield of the MIC Control field shall be set to 0. (#3135)When the negotiated AKM is 00-0F-AC:25, the MIC Length subfield of the MIC Control field shall be set to indicate the length of the MIC field.

On successful (re)association, the S0KH on the STA and the R0KH on the AP then proceed with an IEEE 802.1X authentication using EAPOL PDUs carried in IEEE 802.11 Data frames if SAE authentication was not performed (i.e., if AKM(#3266) is not 00-0F-AC:9 or 00-0F-AC:25(Ed1)(M21)). The S0KH shall use the value of R0KH-ID as the endpoint identifier of the NAS Client (NAS-Identifier if RADIUS is used) in the exchange as defined in IETF RFC 3748.

If IEEE 802.1X authentication was performed, then upon successful completion of authentication, the R0KH receives the MSK and authorization attributes. If SAE authentication was performed, the R0KH receives the PMK, resulting in the successful completion of SAE. If a key hierarchy already exists for this STA belonging to the same mobility domain (i.e., having the same MDID), the R0KH shall delete the existing PMK-R0 security association and PMK-R1 security associations. It then calculates the PMK-R0, PMKR0Name, and PMK-R1 and makes the PMK-R1 available to the R1KH of the AP with which the STA is associated.

If the SME of the STA cannot authenticate the AS, then it shall (#2234)disassociate from an MLME-DISASSOCIATE.request primitive. If the AS signals the Authenticator that the STA cannot be authenticated, then the SME of the AP shall (#2234)disassociate from an MLME-DISASSOCIATE.request primitive.

If the MSK lifetime attribute is provided by the AS, the lifetime of the PMK-R0 shall not be more than the lifetime of the MSK. If the MSK lifetime attribute is not provided, the PMK-R0 lifetime shall be dot11FTR0KeyLifetime. For PSK, the PMK-R0 lifetime shall be dot11FTR0KeyLifetime. The lifetime of the PMK-R1s and PTK shall be the same as the lifetime of PMK-R0. When the key lifetime expires, each key holder shall delete its respective PMK-R0, PMK-R1, and PTK SAs.

The R1KH and S1KH then perform an FT 4-way handshake. The (#1836)EAPOL-Key PDU notation is defined in 12.7.4 (EAPOL-Key PDU notation(#1836)).

R1KH→S1KH: EAPOL-Key(0, 0, 1, 0, P, 0, 0, ANonce, 0, {})
S1KH→R1KH: EAPOL-Key(0, 1, 0, 0, P, 0, 0, SNonce, MIC, {RSNE(PMKR1Name) [, RSNXE], MDE, FTE})(#6590)
R1KH→S1KH: EAPOL-Key(1, 1, 1, 1, P, 0, 0, ANonce, MIC, {RSNE(PMKR1Name) [, RSNXE], [, OCI], MDE, FTE, TIE(ReassociationDeadline), TIE(KeyLifetime), GTK(N) [, IGTK(M, IPN)] [, BIGTK(Q, BIPN)] [, (11ba)WIGTK(R, WIPN)]})(#6590)
S1KH→R1KH: EAPOL-Key(1, 1, 0, 0, P, 0, 0, 0, MIC, {})

(#6590)NOTE—Elements and KDEs in the key data field can be included in any order.

The message sequence is described in 12.7.6 (4-way handshake).


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(#3596)The same FT 4-way handshake is performed for PTK rekeying, except that the Secure bit is set in the first two messages (but see 12.7.2 (EAPOL-Key frames)).

It is assumed by this standard that the reassociation deadline is administered consistently across the mobility domain. The mechanism for such consistent administration is outside the scope of this standard.

The PTK shall be calculated by the R1KH and S1KH according to the procedures given in 12.7.1.6.5 (PTK).

Upon completion of a successful FT 4-way handshake, the IEEE 802.1X Controlled Port shall be opened on both the non-AP STA and the AP. Subsequent (#1836)EAPOL-Key PDUs shall use the key replay counter to detect replayed messages.

Upon completion of a successful FT 4-way handshake, the PTK lifetime timer is initiated. The operation of this timer prevents the PTKSA being used for longer than the value provided in the TIE[KeyLifetime] sent in message 3.

Once the PTKSA key lifetime expires, as indicated by the TIE[KeyLifetime], to continue its association in the mobility domain the STA shall perform the FT initial mobility domain association procedures. If the AP sends a Deauthentication or Disassociation frame to the STA with reason code INVALID_AUTHENTICATION, then to continue its association in the mobility domain, the STA shall perform the FT initial mobility domain association procedures with any AP in the mobility domain. If the Supplicant EAPOL state machines are triggered to (#1836)send an EAPOL-Start PDU (in one or more EAPOL-Start frames) after a successful initial mobility domain association, the STA shall perform the FT initial mobility domain association procedures.

### 13.4.3 FT initial mobility domain association in a non-RSN

In this sequence, the STA utilizes the FT procedures by including the MDE in the (Re)Association Request frame. The AP responds by including the MDE in the (Re)Association Response frame. The message flow is shown in Figure 13-3 (FT initial mobility domain association in a non-RSN(#4139)).

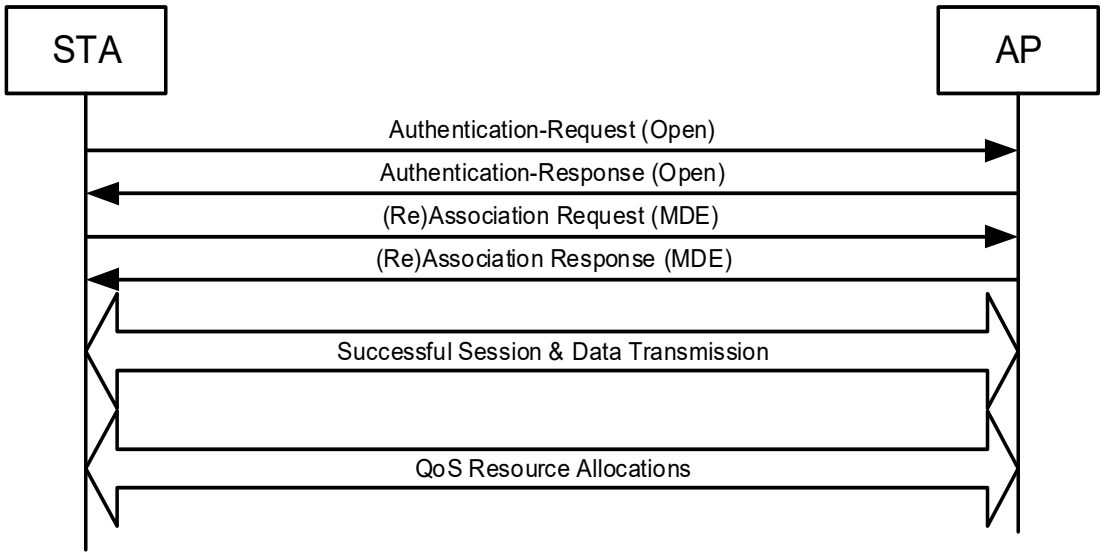


**Figure 13-3—FT initial mobility domain association in a non-RSN(#4139)**

The STA initiates the FT initial mobility domain association procedures by performing an IEEE 802.11 authentication using the Open System authentication algorithm.

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STA→AP: Authentication-Request (Open System authentication algorithm)
AP→STA: Authentication-Response (Open System authentication algorithm, Status)

The SME of the STA initiates the authentication exchange through the use of the primitive MLME-AUTHENTICATE.request primitive, and the SME of the AP responds with MLME-AUTHENTICATE.response primitive. See 11.3.4 (Authentication and deauthentication).

Upon successful IEEE 802.11 Open System authentication, the STA shall send a (Re)Association Request frame to the AP and shall include the MDE. The contents of the MDE shall be the values advertised by the AP in its Beacon or Probe Response frames.

STA→AP: (Re)Association Request (MDE)
AP→STA: (Re)Association Response (MDE)

The SME of the STA initiates the (re)association through the use of the MLME-ASSOCIATE.request or MLME-REASSOCIATE.request primitive. The SME of the AP responds to the indication with MLME-ASSOCIATE.response or MLME-REASSOCIATE.response primitive. See 11.3.5 (Association, reassociation, and disassociation).

If the contents of the MDE received by the AP do not match the contents advertised in the Beacon and Probe Response frames, the AP shall reject the (Re)Association Request frame with status code STATUS_INVALID_MDE.

The (Re)Association Response frame from the AP shall contain an MDE, with contents as presented in Beacon and Probe Response frames.

On successful (re)association, the AP and the non-AP STA shall transition to State 4 (as defined in 11.3 (STA authentication and association)) to enable Data frame transmission.

### 13.4.4 FT initial mobility domain association over FILS in an RSN

A STA may perform FT initial mobility domain association with an AP using FILS Authentication as specified in this clause if it receives an MDE and FILS Indication element in the Beacon or Probe Response frame from the AP.

A STA indicates its support for the FT procedures by including the MDE in the Authentication frame and indicates its support of security in the RSNE. To establish FT key hierarchy, the AP responds by including the FTE, MDE, and RSNE in the Authentication frame. At the end of the sequence, the FT key hierarchy has


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been established. The message flow is shown in Figure 13-4 (FT initial mobility domain association using FILS authentication in an RSN(#7164)).

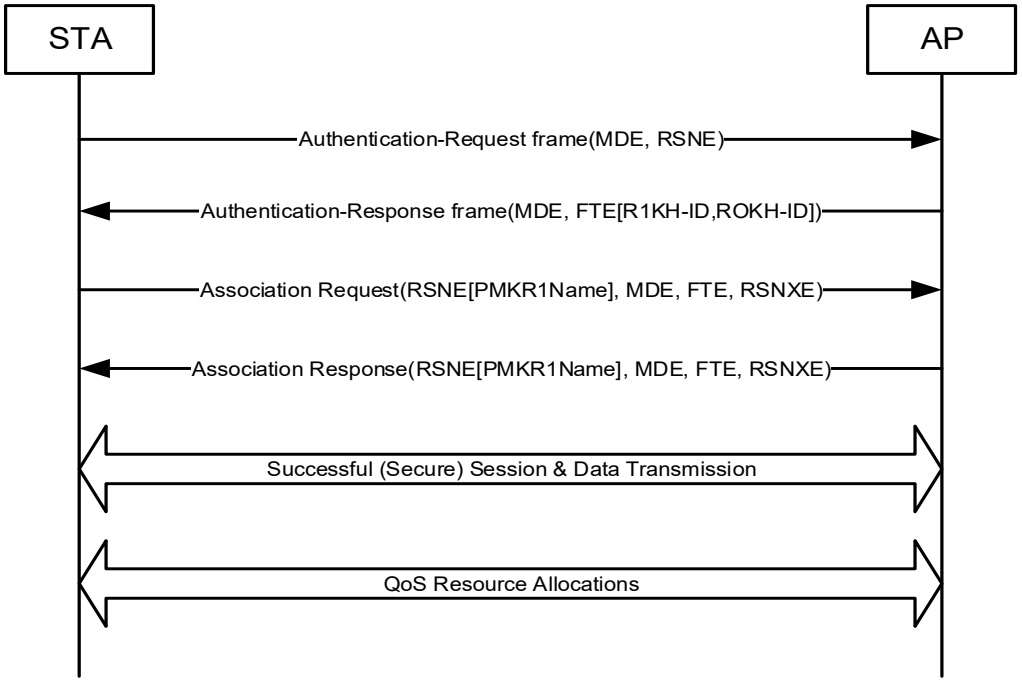


**Figure 13-4—FT initial mobility domain association using FILS authentication in an RSN(#7164)**

To establish the FT key hierarchy, the STA shall send an Authentication frame with the MDE and Authentication algorithm number 4, 5, or 6 to the AP. The contents of the MDE shall be the values advertised by the AP in its Beacon or Probe Response frames. Additionally, the STA includes its security capabilities in the RSNE.

If the contents of the MDE received by the AP do not match the contents advertised in the Beacon and Probe Response frames, the AP shall reject the Authentication frame with status code 54 (“Invalid MDE”). If an MDE is present in the Authentication frame and (#3488)the RSNE does not indicate (#4225)the single AKM(#3266) 00-0F-AC:16 or 00-0F-AC:17 (#4227)(Fast BSS Transition over FILS), the AP shall reject the Authentication frame with status code 43 (“Invalid AKMP”).

Upon successful completion of FILS authentication request processing, the R0KH on the AP uses the FILS-FT (see 12.11.2.5.3 (PTKSA Key derivation with FILS authentication)) to establish key hierarchy. If a key hierarchy already exists for this STA belonging to the same mobility domain (i.e., having the same MDID), the R0KH shall delete the existing PMK-R0 security association and PMK-R1 security associations. It then calculates the PMK-R0, PMKR0Name, and PMK-R1 and makes the PMK-R1 available to the R1KH of the AP to which the STA is associated.

Next, the AP shall construct an Authentication frame. The Authentication frame shall contain an MDE, with contents as presented in Beacon and Probe Response frames. The FTE shall include the key holder identities of the AP, the R0KH-ID and R1KH-ID, set to the values of dot11FTR0KeyHolderID and dot11FTR1KeyHolderID, respectively. The FTE shall have a MIC element count of zero (i.e., no MIC present) and have ANonce, SNonce, and MIC fields set to 0.

(#4263)The S1KH provides the PMKR1Name in the PMKID List field of the RSNE to be included in the (Re)Association Request frame. The PMKR1Name shall be as calculated by the S1KH according to the

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procedures of 12.7.1.6.4 (PMK-R1); all other fields of the RSNE, disregarding the Length field, shall be identical to those in the RSNE present in the STA's Authentication frame. The S1KH shall also provide the FTE and MDE; they shall be the same as those in the AP's Authentication frame. If the S1KH set to 1 any subfield, except the Field Length subfield, of the Extended RSN Capabilities field in the RSNXE, the S1KH shall also provide the RSNXE.

Finally, the R1KH provides the PMKR1Name in the PMKID List field of the RSNE to be included in (#4263)the (Re)Association Response frame. The PMKR1Name shall be as calculated by the R1KH according to the procedures of 12.7.1.6.4 (PMK-R1) and shall be the same as the PMKR1Name in the (Re)Association Request frame; all other fields of the RSNE, disregarding the Length field, shall be identical to those in the RSNE present in the Beacon or Probe Response frames. The R1KH shall also provide the FTE and the MDE; they shall be the same as those in the AP's Authentication frame. If the RSNXE is present in the Beacon or Probe Response frames, the R1KH shall also provide the RSNXE.

When FILS authentication is used to establish the FT key hierarchy, TK and (#3744)PTK-KEK for the initial mobility domain association are derived as part of the FILS authentication as defined in 12.11.2.5.3 (PTKSA Key derivation with FILS authentication).

NOTE—This means that the PTK derivation as described in 12.7.1.6.5 (PTK) is not used in the case of FT initial mobility domain association over FILS.

## 13.5 FT protocol

### 13.5.1 Overview

STAs with dot11FastBSSTransitionActivated equal to true shall support the FT protocol.

The FT protocol supports resource requests as part of the reassociation. The optional FT resource request protocol (see 13.6 (FT resource request protocol)) supports resource requests prior to reassociation.

A STA shall not use any authentication algorithm except the FT authentication algorithm when using the FT protocol.

To prevent key reinstallation attacks, the non-AP STA shall maintain a copy of the most recent GTK, IGTK, and BIGTK when present(11ba), and WIGTK when present, installed as part of the FT protocol as if they were installed as a result of receipt of (#1836)EAPOL-Key PDUs (see 12.7.7.4 (Group key handshake implementation considerations)) and shall refuse to update a GTK, (11ba)an IGTK, a BIGTK or a WIGTK when the key to be set matches either one of these two keys (see 6.5.14 (SetKeys)).

### 13.5.2 Over-the-air FT protocol authentication in an RSN

The over-the-air FT protocol in an RSN is shown in Figure 13-5 (Over-the-air FT protocol in an RSN(#4139)).

The FTO and AP use the FT authentication sequence to specify the PMK-R1 security association and to provide values of SNonce and ANonce that enable a liveness proof, replay protection, and PTK separation. This exchange enables a fresh PTK to be computed in advance of reassociation. The PTKSA is used to protect the subsequent reassociation transaction, including the optional RIC-Request.

To perform an over-the-air fast BSS transition to a target AP, the FTO and target AP shall perform the following exchange:


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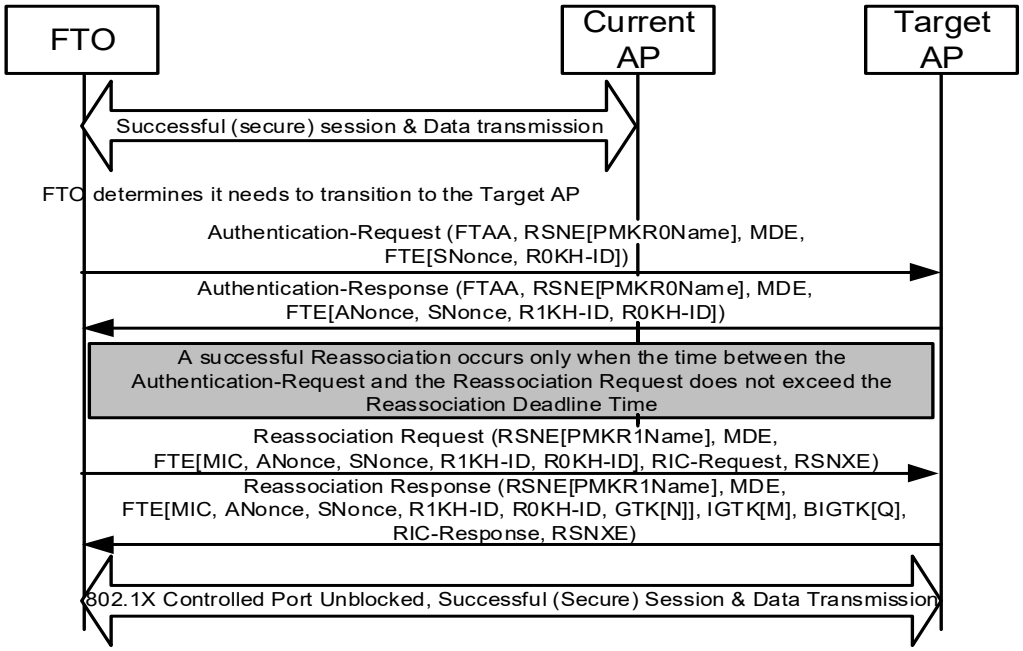


**Figure 13-5—Over-the-air FT protocol in an RSN(#4139)**

FTO→Target AP: Authentication-Request (FTAA, 0, RSNE[PMKR0Name], MDE, FTE[SNonce, R0KH-ID])

Target AP→FTO: Authentication-Response (FTAA, Status, RSNE[PMKR0Name], MDE, FTE[ANonce, SNonce, R1KH-ID, R0KH-ID])

The SME of the FTO initiates the authentication exchange, through the use of the MLME-AUTHENTICATE.request primitive, and the SME of the AP responds with an MLME-AUTHENTICATE.response primitive. See 11.3.4 (Authentication and deauthentication). The MLME primitives for Authentication when the FT authentication algorithm is selected use only authentication transaction sequence number values 1 and 2.

In the Authentication-Request frame, the SA field of the message header shall be set to the MAC address of the FTO, and the DA field of the message header shall be set to the BSSID of the target AP's BSS. The elements in the frame, and their required contents, shall be as given in 13.8.2 (FT authentication sequence: contents of first message).

If the contents of the MDE received by the AP do not match the contents advertised in the Beacon and Probe Response frames, the AP shall reject the authentication request with status code STATUS_INVALID_MDE. If the Authentication-Request frame contains an authentication algorithm equal to FT authentication(#4225), and (#3488)the RSNE does not indicate a single AKMP, or the Authentication type column for that AKMP does not indicate FT authentication (see Table 9-190 (AKM suite selectors)), the AP shall reject the authentication request with status code STATUS_INVALID_AKMP. If the FTE in the Authentication-Request(#3759) frame contains an invalid R0KH-ID, the AP shall reject the Authentication-Request(#3759) frame with status code STATUS_INVALID_FTE. If the RSNE in the Authentication-Request frame contains an invalid PMKR0Name and the AP has determined that it is an invalid PMKR0Name, the AP shall reject the authentication request with status code STATUS_INVALID_PMKID. If the requested R0KH is not reachable, the AP shall respond to the authentication request with status code R0KH_UNREACHABLE. If the FTO selects a pairwise cipher suite in the RSNE that is different from the ones used in the Initial

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mobility domain association, then the AP shall reject the authentication request with status code STATUS_INVALID_PAIRWISE_CIPHER. Subsequent to a rejection of an authentication request, the FTO may retry the authentication request.

In the Authentication-Response frame, the SA field of the message header shall be set to the BSSID of the target AP's BSS, and the DA field of the message header shall be set to the MAC address of the FTO. The Status Code field shall be a value from the options listed in 9.4.1.9 (Status Code field). The elements in the frame, and their required contents, shall be as given in 13.8.3 (FT authentication sequence: contents of second message).

The R1KH of the target AP uses the value of PMKR0Name and other information in the frame to calculate PMKR1Name. If the target AP does not have the key identified by PMKR1Name, it may retrieve that key from the R0KH identified by the FTO. See 13.2 (Key holders). Upon receiving a new PMK-R1 for a STA, the target AP shall delete the prior PMK-R1 security association and PTKSAs derived from the prior PMK-R1.

The FTO and the target AP compute the PTK and PTKName using the PMK-R1, PMKR1Name, ANonce, and SNonce, as specified in 12.7.1.6.5 (PTK). The PTKSA shall be deleted by the target AP if it does not receive a Reassociation Request frame from the FTO within the reassociation deadline timeout value.

If the FTO does not receive a response to the Authentication-Request frame, it may reissue the request following the restrictions given for Authentication frames in 11.3 (STA authentication and association). If the Status Code field value returned by the target AP is SUCCESS, the FTO and target AP transition to State 2 (as defined in 11.3 (STA authentication and association)); the FTO may continue with reassociation (13.7.1 (FT reassociation in an RSN)). Handling of errors returned in the Status Code field shall be as specified in 11.3 (STA authentication and association).

### 13.5.3 Over-the-DS FT protocol in an RSN

A STA shall not initiate an over-the-DS FT authentication to a target AP whose MDE contains the Fast BSS Transition over DS bit equal to 0.

The over-the-DS FT protocol in an RSN is shown in Figure 13-6 (Over-the-DS FT protocol in an RSN).

To perform an over-the-DS fast BSS transition to a target AP, the FTO and the target AP (through the current AP) shall perform the following exchange:

| | |
|---|---|
| FTO→Target AP: | FT Request (FTO address, TargetAP address, RSNE[PMKR0Name], MDE, FTE[SNonce, R0KH-ID]) |
| Target AP→FTO: | FT Response (FTO address, TargetAP address, Status, RSNE[PMKR0Name], MDE, FTE[ANonce, SNonce, R1KH-ID, R0KH-ID]) |

The SME of the FTO initiates the FT Request frame to the target AP by issuing an MLME-REMOTE-REQUEST.request primitive with parameters including the contents of the FT Request frame (FT Action frame with an FT Action field value indicating FT Request) to be sent. The MAC of the FTO transmits this Action frame. For processing at the current AP and target AP, see 13.10 (Remote request broker (RRB) communication). When the MAC of the FTO receives the FT Response frame (FT Action frame with an FT Action field value indicating FT Response), it passes it to the SME by use of MLME-REMOTE-REQUEST.indication primitive, with parameters including the contents of the received Action frame. The MLME interfaces on the FTO, current AP, and the target AP for executing the over-the-DS fast BSS transition are shown in Figure 13-7 (MLME interfaces for over-the-DS FT protocol messages).


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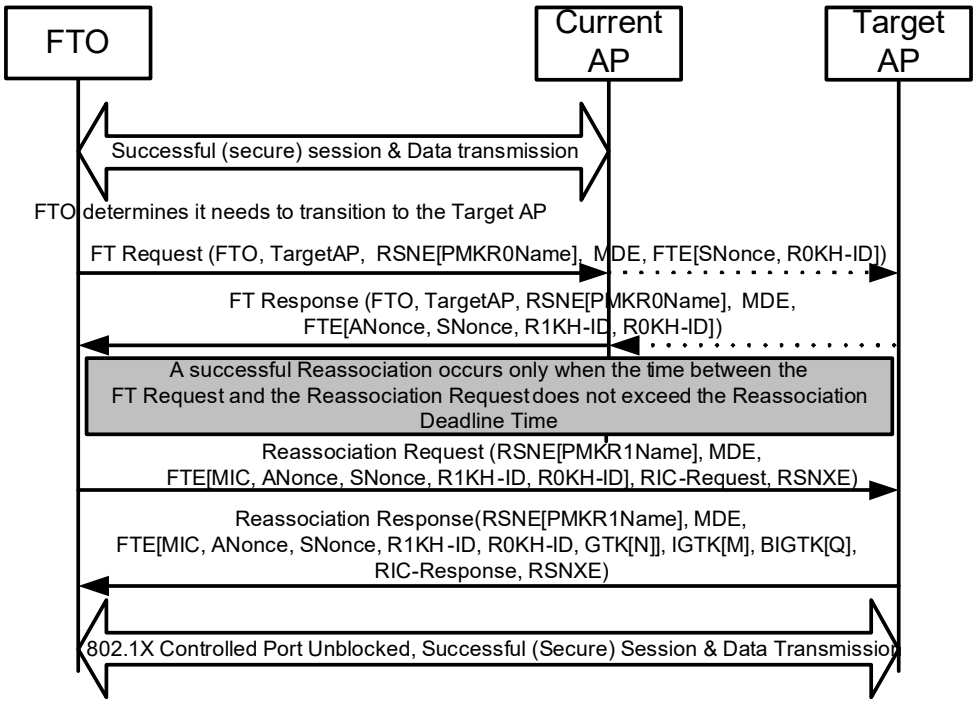


**Figure 13-6—Over-the-DS FT protocol in an RSN**

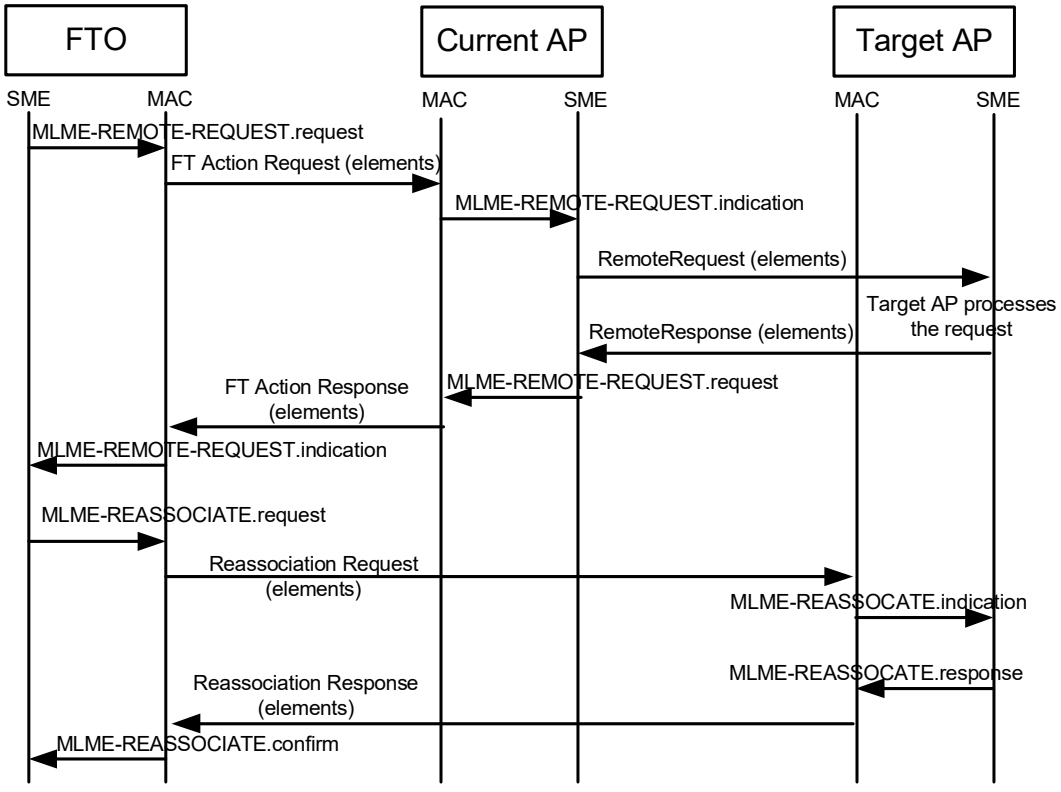


**Figure 13-7—MLME interfaces for over-the-DS FT protocol messages**

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The STA Address field of the FT Request frame shall be set to the MAC address of the FTO, and the Target AP Address field of the FT Request frame shall be set to the BSSID of the target AP's BSS. The elements in the FT Request frame, and their required contents, shall be as given in 13.8.2 (FT authentication sequence: contents of first message).

If the contents of the MDE received by the target AP do not match the contents advertised in the Beacon and Probe Response frames, the target AP shall reject the FT Request frame with status code STATUS_INVALID_MDE. If (#3488)the RSNE does not indicate a (#4225)single AKMP, or the Authentication type column for that AKMP does not indicate FT authentication (see Table 9-190 (AKM suite selectors)), the AP shall reject the FT Request frame with status code STATUS_INVALID_AKMP. If the FTE in the FT Request frame contains an invalid R0KH-ID, the AP shall reject the FT Request frame with status code STATUS_INVALID_FTE. If the RSNE in the FT Request frame contains an invalid PMKR0Name, and the AP has determined that it is an invalid PMKR0Name, the AP shall reject the authentication request with status code STATUS_INVALID_PMKID. If the requested R0KH is not reachable, the AP shall respond to the FT Request frame with status code R0KH_UNREACHABLE. The AP may reject the FT Request frame for limiting the FTO's reassociation to this AP by using the status code REQUEST_DECLINED. If the FTO selects a pairwise cipher suite in the RSNE that is different from the ones used in the initial mobility domain association, then the AP shall reject the FT Request frame with status code STATUS_INVALID_PAIRWISE_CIPHER.

The STA Address field of the FT Response frame shall be set to the MAC address of the FTO, and the Target AP Address field of the FT Response frame shall be set to the BSSID of the target AP's BSS. The elements in the FT Response frame, and their required contents, shall be as given in 13.8.3 (FT authentication sequence: contents of second message). The Status Code field shall be a value from the options listed in 9.4.1.9 (Status Code field).

The R1KH of the target AP uses the value of PMKR0Name and other information from the frame to calculate PMKR1Name. If the target AP does not have the key identified by PMKR1Name, it may retrieve that key from the R0KH identified by the STA. See 13.2 (Key holders). Upon receiving a new PMK-R1 for a STA, the target AP shall delete the prior PMK-R1 security association and PTKSAs derived from the prior PMK-R1.

The FTO and the target AP compute the PTK and PTKName using the PMK-R1, PMKR1Name, ANonce, and SNonce, as specified in 12.7.1.6.5 (PTK). The PTKSA shall be deleted by the target AP if it does not receive a Reassociation Request frame from the FTO within the reassociation deadline timeout value.

If the FTO does not receive a response to the FT Request frame, it may reissue the request following the restrictions given for Authentication frames in 11.3 (STA authentication and association). If the Status Code field value returned by the target AP is SUCCESS, the FTO and target AP transition to State 2 (as defined in 11.3 (STA authentication and association)); the FTO may continue with reassociation (13.7.1 (FT reassociation in an RSN)). Handling of errors returned in the Status Code field shall be as specified for Authentication frames in 11.3 (STA authentication and association).


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### 13.5.4 Over-the-air FT protocol in a non-RSN

The over-the-air FT protocol in a non-RSN is shown in Figure 13-8 (Over-the-air FT protocol in a non-RSN(#4139)).

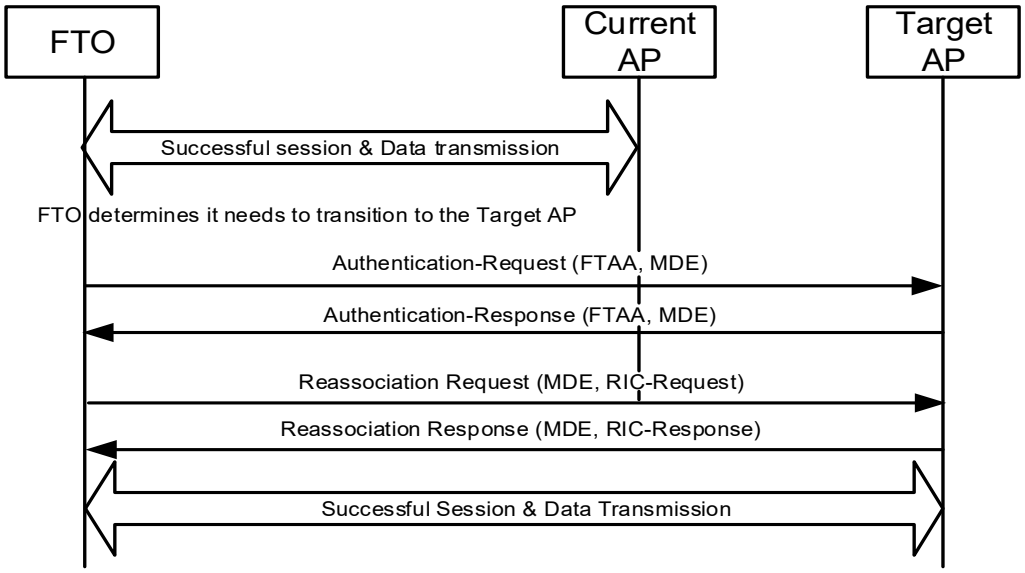


**Figure 13-8—Over-the-air FT protocol in a non-RSN(#4139)**

To perform an over-the-air fast BSS transition to a target AP in a non-RSN, the FTO and target AP shall perform the following exchange:

FTO→Target AP: Authentication-Request (FTAA, 0, MDE)
Target AP→FTO: Authentication-Response (FTAA, Status, MDE)

In the Authentication-Request frame, the SA field of the message header shall be set to the MAC address of the FTO, and the DA field of the message header shall be set to the BSSID of the target AP's BSS. The elements in the frame, and their required contents, shall be as given in 13.8.2 (FT authentication sequence: contents of first message).

If the contents of the MDE received by the target AP do not match the contents advertised in the Beacon and Probe Response frames, the target AP shall reject the authentication request with status code STATUS_INVALID_MDE.

In the Authentication-Response frame, the SA field of the message header shall be set to the BSSID of the target AP's BSS, and the DA field of the message header shall be set to the MAC address of the FTO. The Status Code field shall be a value from the options listed in 9.4.1.9 (Status Code field). The elements in the frame, and their required contents, shall be as given in 13.8.3 (FT authentication sequence: contents of second message).

If the FTO does not receive a response to the Authentication-Request frame, it may reissue the request following the restrictions given for Authentication frames in 11.3 (STA authentication and association). If the Status Code field value returned by the target AP is SUCCESS, the FTO and target AP transition to State 2 (as defined in 11.3 (STA authentication and association)); the FTO may continue with reassociation

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(13.7.2 (FT reassociation in a non-RSN)). Handling of errors returned in the Status Code field shall be as specified in 11.3 (STA authentication and association).

### 13.5.5 Over-the-DS FT protocol in a non-RSN

The over-the-DS FT protocol in a non-RSN is shown in Figure 13-9 (Over-the-DS FT protocol in a non-RSN).

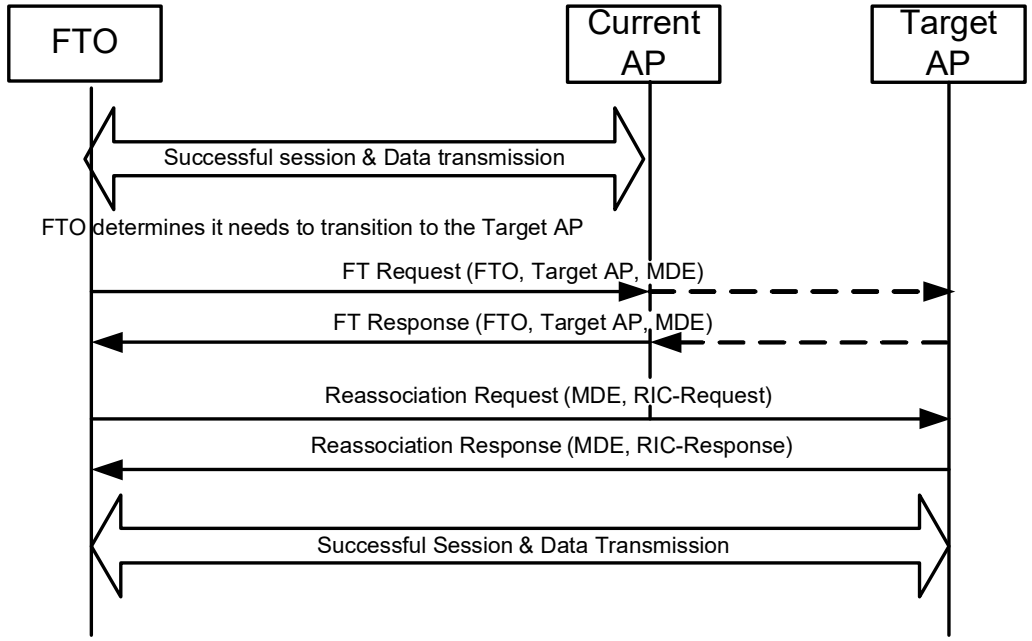


**Figure 13-9—Over-the-DS FT protocol in a non-RSN**

To perform an over-the-DS fast BSS transition to a target AP in a non-RSN, the FTO and the target AP (through the current AP) shall perform the following exchange:

FTO→Target AP: FT Request(FTO, TargetAP, MDE)
Target AP→FTO: FT Response(FTO, TargetAP, Status, MDE)

The STA Address field of the FT Request frame shall be set to the MAC address of the FTO, and the Target AP Address field of the FT Request frame shall be set to the BSSID of the target AP's BSS. The elements in the FT Request frame, and their required contents, shall be as given in 13.8.2 (FT authentication sequence: contents of first message).

If the contents of the MDE received by the target AP do not match the contents advertised in the Beacon and Probe Response frames, the target AP shall reject the FT Request frame with status code STATUS_INVALID_MDE.

The STA Address field of the FT Response frame shall be set to the MAC address of the FTO, and the Target AP Address field of the FT Response frame shall be set to the BSSID of the target AP's BSS. The elements in the FT Response frame, and their required contents, shall be as given in 13.8.3 (FT authentication sequence: contents of second message). The Status Code field shall be a value from the options listed in 9.4.1.9 (Status Code field).


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If the FTO does not receive a response to the FT Request frame, it may reissue the request following the restrictions given for Authentication frames in 11.3 (STA authentication and association). If the Status Code field value returned by the target AP is SUCCESS, the FTO and target AP transition to State 2 (as defined in 11.3 (STA authentication and association)); the FTO may continue with reassociation (13.7.2 (FT reassociation in a non-RSN)). Handling of errors returned in the Status Code field shall be as specified for Authentication frames in 11.3 (STA authentication and association).

## 13.6 FT resource request protocol

### 13.6.1 Overview

The FT resource request protocol involves an additional message exchange after the Authentication-Request/Response frame, or FT Request/Response frame, and prior to reassociation.

APs capable of fast BSS transition may allow FTOs to request resources prior to reassociation. Availability of the FT resource request protocol is advertised by the target AP in the MDE. If the Resource Request Protocol Capability subfield is 0, then the FTO shall not send an Authentication-Confirm nor FT Confirm frame to the AP. An AP that receives an Authentication-Confirm or FT Confirm frame from a STA and does not support the FT resource request protocol shall respond with status code INVALID_PARAMETERS.

The additional message exchange for the FT resource request protocol shall be performed using the same method (over-the-air or over-the-DS) as was used for the Authentication-Request/Response frame or FT Request/Response frame. An AP that receives an FT Confirm frame that did not previously receive an FT Request frame from the same STA shall reject the request with status code STATUS_INVALID_FT_ACTION_FRAME_COUNT. An AP that receives an Authentication-Confirm frame that did not previously receive an Authentication-Request frame from the same STA shall reject the request with status code TRANSACTION_SEQUENCE_ERROR.

### 13.6.2 Over-the-air fast BSS transition with resource request

The over-the-air FT resource request protocol in an RSN is shown in Figure 13-10 (Over-the-air FT resource request protocol in an RSN(#4139)).

The over-the-air FT resource request protocol in a non-RSN is shown in Figure 13-11 (Over-the-air FT resource request protocol in a non-RSN(#4139)).

To perform an over-the-air FT resource request protocol to a target AP, after completing the Authentication-Request/Response frame exchange given in 13.5.2 (Over-the-air FT protocol authentication in an RSN) or 13.5.4 (Over-the-air FT protocol in a non-RSN), the FTO and target AP shall perform the following exchange:

| | |
|---|---|
| FTO→Target AP: | Authentication-Confirm (FTAA, 0, RSNE[PMKR1Name], MDE, FTE[MIC, ANonce, SNonce, R1KH-ID, R0KH-ID], RIC-Request) |
| Target AP→FTO: | Authentication-Ack (FTAA, Status, RSNE[PMKR1Name], MDE, FTE[MIC, ANonce, SNonce, R1KH-ID, R0KH-ID], RIC-Response) |

The SME of the FTO initiates the resource request exchange through the use of the primitive MLME-RESOURCE-REQUEST.request primitive, and the SME of the AP responds with MLME-RESOURCE-REQUEST.response primitive.

In the Authentication-Confirm frame, the SA field of the message header shall be set to the MAC address of the FTO, and the DA field of the message header shall be set to the BSSID of the target AP's BSS. In a non-

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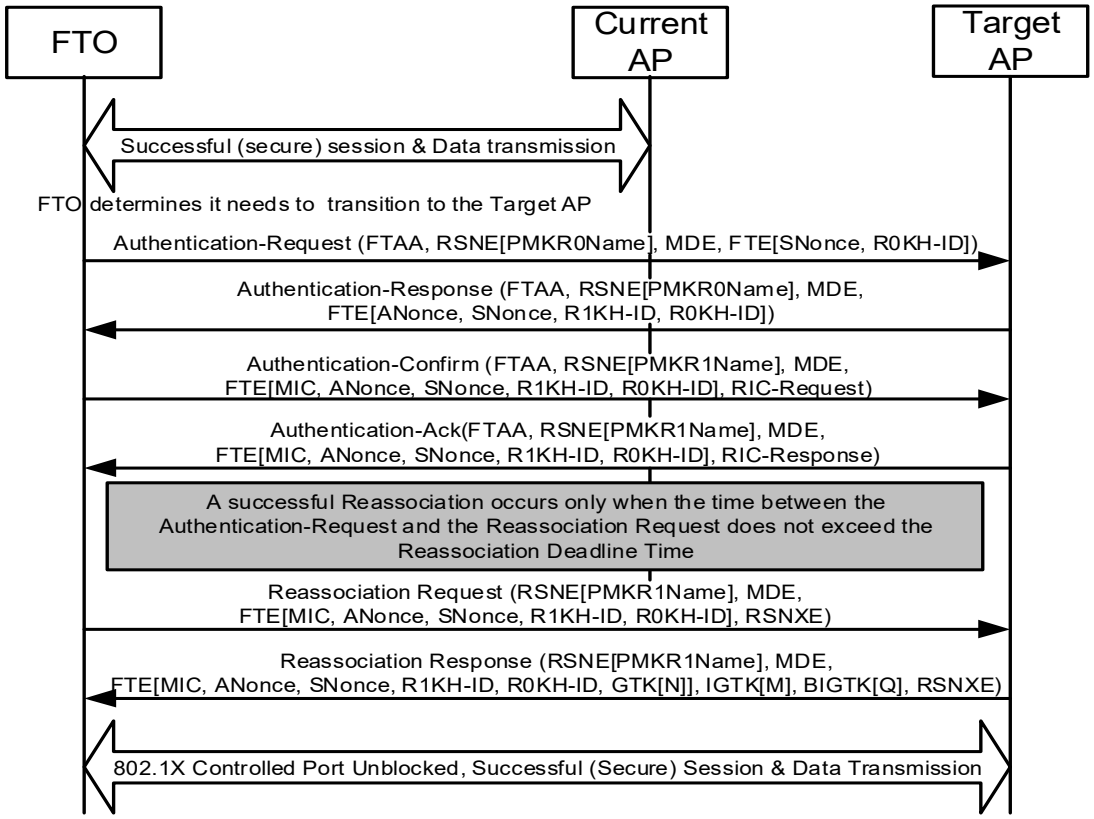


**Figure 13-10—Over-the-air FT resource request protocol in an RSN(#4139)**

RSN, the FTE and RSNE shall not be present. The elements in the frame, the element contents, and MIC calculation shall be as given in 13.8.4 (FT authentication sequence: contents of third message).

If the contents of the MDE received by the target AP do not match the contents advertised in the Beacon and Probe Response frames, the target AP shall reject the Authentication-Confirm frame with status code STATUS_INVALID_MDE.

In an RSN, the R1KH of the target AP verifies the MIC in the FTE in the Authentication-Confirm frame and shall discard the request if it is incorrect. If the FTE in the Authentication-Confirm frame contains a different R0KH-ID, R1KH-ID, ANonce, or SNonce, the AP shall reject the Authentication-Confirm frame with status code STATUS_INVALID_FTE. If the RSNE in the Authentication-Confirm frame contains an invalid PMKR1Name, the AP shall reject the Authentication-Confirm frame with status code STATUS_INVALID_PMKID.

In the Authentication-Ack frame, the SA field of the message header shall be set to the BSSID of the target AP's BSS, and the DA field of the message header shall be set to the MAC address of the FTO. In a non-RSN, the FTE and RSNE shall not be present. The Status Code field shall be a value from the options listed in 9.4.1.9 (Status Code field). The elements in the frame, the element contents, and MIC calculation shall be as given in 13.8.5 (FT authentication sequence: contents of fourth message).

In an RSN, the S1KH of the FTO verifies the MIC in the FTE in the Authentication-Ack frame and shall discard the response if the MIC is incorrect.


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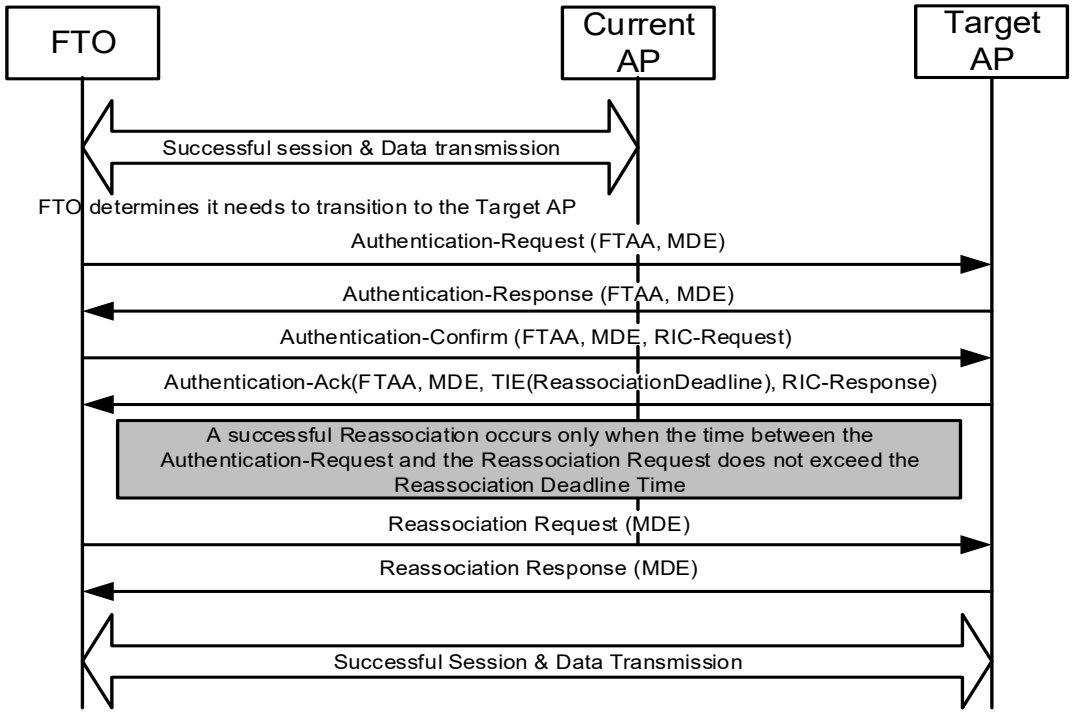


**Figure 13-11—Over-the-air FT resource request protocol in a non-RSN(#4139)**

The FTO may make a request for resources by including a RIC-Request (see 13.11 (Resource request procedures)) in the Authentication-Confirm frame. The RIC-Request is generated by the procedures of 13.11.3.1 (FTO procedures), and the RIC-Response is generated by the procedures of 13.11.3.2 (AP procedures).

If the value of the Status Code field returned by the target AP in the Authentication-Ack frame is not SUCCESS, then the FTO shall abandon this transition attempt.

In an RSN, on successful completion of the FT authentication exchange of the FT resource request protocol, the PTKSA has been established and proven live. The key replay counter shall be initialized to 0, and the subsequent (#1836)EAPOL-Key PDUs (e.g., GTK, IGTK, (11ba)BIGTK, and WIGTK updates) shall use the key replay counter to detect and discard replays. The PTKSA shall be deleted by the target AP if it does not receive a Reassociation Request frame from the FTO within the reassociation deadline timeout value.

In a non-RSN, the Authentication-Ack frame contains a TIE with a reassociation deadline. If the FTO does not send a Reassociation Request frame to the target AP within that interval, the FTO shall abandon this transition attempt.

The exchange between the FTO and the target AP may continue with reassociation (13.7.1 (FT reassociation in an RSN) or 13.7.2 (FT reassociation in a non-RSN)).

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### 13.6.3 Over-the-DS fast BSS transition with resource request

The over-the-DS FT resource request protocol in an RSN is shown in Figure 13-12 (Over-the-DS FT resource request protocol in an RSN).

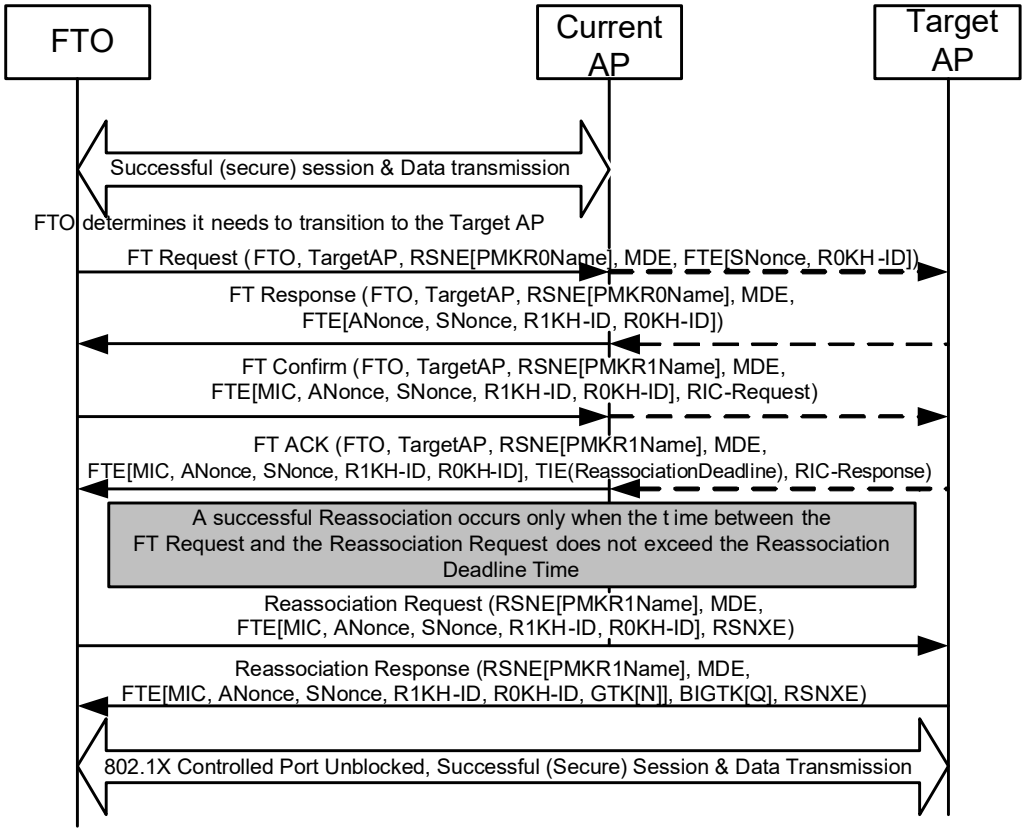


**Figure 13-12—Over-the-DS FT resource request protocol in an RSN**

The over-the-DS FT resource request protocol in a non-RSN is shown in Figure 13-13 (Over-the-DS FT resource request protocol in a non-RSN).

To perform an Over-the-DS FT resource request protocol to a target AP, after completing the FT Request/ Response frame exchange given in 13.5.3 (Over-the-DS FT protocol in an RSN) or 13.5.5 (Over-the-DS FT protocol in a non-RSN), the FTO and target AP (through the current AP) shall perform the following exchange, using the mechanism described in 13.10 (Remote request broker (RRB) communication):

FTO→Target AP: FT Confirm (FTO, TargetAP, RSNE[PMKR1Name], MDE, FTE[MIC, ANonce, SNonce, R1KH-ID, R0KH-ID], RIC-Request)

Target AP→FTO: FT Ack (FTO, TargetAP, Status, RSNE[PMKR1Name], MDE, FTE[MIC, ANonce, SNonce, R1KH-ID, R0KH-ID], TIE[ReassociationDeadline], RIC-Response)


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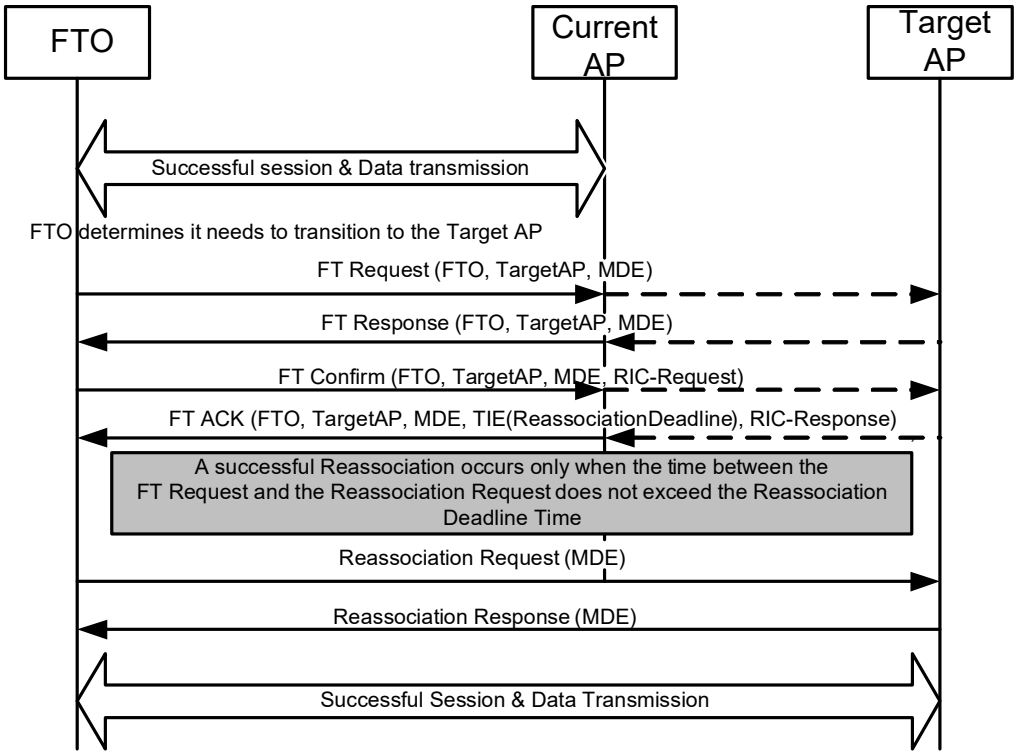


**Figure 13-13—Over-the-DS FT resource request protocol in a non-RSN**

The SME of the FTO initiates the FT Confirm frame to the target AP by issuing an MLME-REMOTE-REQUEST.request primitive with parameters including the contents of the FT Confirm frame (FT Action frame with an FT Action field value indicating FT Confirm) to be sent. The MAC of the FTO transmits this Action frame. For processing at the current AP and target AP, see 13.10 (Remote request broker (RRB) communication). When the MAC of the FTO receives the FT Ack frame (FT Action frame with an FT Action field value indicating FT Ack), it passes it to the SME by use of an MLME-REMOTE-REQUEST.indication primitive, with parameters including the contents of the received Action frame.

The STA Address field of the FT Confirm frame shall be set to the MAC address of the FTO, and the Target AP Address field of the FT Confirm frame shall be set to the BSSID of the target AP's BSS. The elements in the FT Confirm frame, the element contents, and the MIC calculation shall be as given in 13.8.4 (FT authentication sequence: contents of third message). In a non-RSN, the FTE and RSNE shall not be present.

If the contents of the MDE received by the target AP do not match the contents advertised in the Beacon and Probe Response frames, the target AP shall reject the FT Confirm frame with status code STATUS_INVALID_MDE.

In an RSN, the R1KH of the target AP verifies the MIC in the FTE and shall discard the request if it is incorrect. If the FTE in the FT Confirm frame contains a different R0KH-ID, R1KH-ID, ANonce, or SNonce from the values sent in the FT Response frame, the AP shall reject the FT Confirm frame with status code STATUS_INVALID_FTE. If the RSNE in the FT Confirm frame contains an invalid PMKR1Name, the AP shall reject the FT Confirm frame with status code STATUS_INVALID_PMKID.

The STA Address field of the FT Ack frame shall be set to the MAC address of the FTO, and the Target AP Address field of the FT Ack frame shall be set to the BSSID of the target AP's BSS. The elements in the FT Ack frame, the element contents, and the MIC calculation shall be as given in 13.8.5 (FT authentication

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sequence: contents of fourth message). In a non-RSN, the FTE and RSNE shall not be present. The Status Code field value shall be a value from the options listed in 9.4.1.9 (Status Code field), and a TIE may appear.

In an RSN, the S1KH of the FTO verifies the MIC in the FTE in the FT Ack frame and shall discard the response if the MIC is incorrect.

The FTO may make a request for resources by including a RIC-Request (see 13.11 (Resource request procedures)) in the FT Confirm frame. The RIC-Request is generated by the procedures of 13.11.3.1 (FTO procedures), and the RIC-Response is generated by the procedures of 13.11.3.2 (AP procedures).

In order to recover from over-the-DS frame losses, the FTO may retransmit the FT Confirm frame until the reassociation deadline time is reached. If the FTO does not receive a response to the FT Confirm frame or if the value of the Status Code field returned by the target AP in the FT Ack frame is not SUCCESS, then the FTO shall abandon this transition attempt.

In an RSN, on successful completion of the FT Confirm/Acknowledgment frame exchange, the PTKSA has been established and proven live. The key replay counter shall be initialized to 0, and the subsequent EAPOL-Key frames (e.g., GTK, IGTK, (11ba)BIGTK, and WIGTK updates) shall use the key replay counter to detect and discard replays. The PTKSA shall be deleted by the target AP if it does not receive a Reassociation Request frame from the FTO within the reassociation deadline timeout value. Resource request procedures are specified in 13.11 (Resource request procedures).

In a non-RSN, the FT Ack frame contains a TIE with a reassociation deadline. If the FTO does not send a Reassociation Request frame to the target AP within that interval, the FTO shall abandon this transition attempt.

The exchange between the FTO and the target AP may continue with reassociation (13.7.1 (FT reassociation in an RSN) or 13.7.2 (FT reassociation in a non-RSN)).

## 13.7 FT reassociation

### 13.7.1 FT reassociation in an RSN

If the FTO does not send a Reassociation Request frame to the target AP within the reassociation deadline interval received during the FT initial mobility domain association, the target AP may delete the PTKSA, and the FTO shall abandon this transition attempt.

The FTO shall perform a reassociation directly with the target AP via the following exchange:

| | |
|---|---|
| FTO→Target AP: | Reassociation Request(RSNE[PMKR1Name], MDE, FTE[MIC, ANonce, SNonce, R1KH-ID, R0KH-ID], RIC-Request, RSNXE) |
| Target AP→FTO: | Reassociation Response(RSNE[PMKR1Name], MDE, FTE[MIC, ANonce, SNonce, R1KH-ID, R0KH-ID, GTK[N], IGTK[M], BIGTK[Q](11ba), WIGTK[R]], RIC-Response, RSNXE) |

The SME of the FTO initiates the reassociation through the use of the MLME-REASSOCIATE.request primitive. The SME of the AP responds to the indication with MLME-REASSOCIATE.response primitive. See 11.3.5 (Association, reassociation, and disassociation).

In the Reassociation Request frame, the SA field of the message header shall be set to the MAC address of the FTO, and the DA field of the message header shall be set to the BSSID of the target AP's BSS. The elements in the frame, the element contents, and the MIC calculation shall be as given in 13.8.4 (FT authentication sequence: contents of third message).


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The R1KH of the target AP verifies the MIC in the FTE in the Reassociation Request frame and shall discard the request if the MIC is incorrect.

If the target AP includes an RSNXE in its Beacon and Probe Response frames and the RSNXE Used subfield of the MIC Control field of the FTE is(M118) 1, but the Reassociation Request frame does not include an RSNXE, the R1KH of the target AP shall discard the request.

If dot11RSNAOperatingChannelValidationActivated is true and the FTO indicates OCVC(#3505), the target AP shall ensure that OCI subelement of the FTE matches by ensuring that all of the following are true:

— OCI subelement is present

— Channel information in the OCI matches current operating channel parameters (see 12.2.10 (Requirements for Operating Channel Validation))

Otherwise, the AP shall reject the Reassociation Request frame with status code STATUS_INVALID_FTE.

If the contents of the MDE received by the target AP do not match the contents advertised in the Beacon and Probe Response frames, the target AP shall reject the Reassociation Request frame with status code STATUS_INVALID_MDE. If the FTE in the Reassociation Request frame contains a different R0KH-ID, R1KH-ID, ANonce, or SNonce, the AP shall reject the Reassociation Request frame with status code STATUS_INVALID_FTE. If the RSNE in the Reassociation Request frame contains an invalid PMKR1Name, the AP shall reject the Reassociation Request frame with status code STATUS_INVALID_PMKID.

In the Reassociation Response frame, the SA field of the message header shall be set to the BSSID of the target AP's BSS, and the DA field of the message header shall be set to the MAC address of the FTO. The Status Code field shall be a value from the options listed in 9.4.1.9 (Status Code field). The elements in the frame, the element contents, and the MIC calculation shall be as given in 13.8.5 (FT authentication sequence: contents of fourth message).

The S1KH of the FTO verifies the MIC in the FTE in the Reassociation Response frame and shall discard the response if the MIC is incorrect.

If in the Reassociation Response frame the RSNE fields other than the PMKID Count field and the PMKID List field are not identical to the corresponding RSNE fields in the Beacon and Probe Response frames received from the target AP, the S1KH of the FTO shall discard the response. If the PMKID List field does not include the correct PMKR1Name value, the S1KH of the FTO shall discard the response.

If the Beacon and Probe Response frames received from the target AP did not include an RSNXE, but the RSNXE Used subfield of the MIC Control field of the FTE is set to 1, the S1KH of the FTO shall discard the response.

If the Reassociation Response frame includes the RSNXE, the S1KH of the FTO shall verify that this element matches information included in the Beacon and Probe Response frames received from the target AP. If those frames did not include the RSNXE or if (#3488)the RSNXEs are not identical, the S1KH of the FTO shall discard the response.

If dot11RSNAOperatingChannelValidationActivated is true and the target AP indicates OCVC(#3505), FTO shall ensure that OCI subelement of the FTE matches by ensuring that all of the following are true

— OCI subelement is present

— Channel information in the OCI matches current operating channel parameters (see 12.2.10 (Requirements for Operating Channel Validation))

Otherwise, the FTO reject the Reassociation Response frame by discarding the frame.

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If an FTO is performing a reassociation exchange as part of the FT resource request protocol, then the FTO shall not include the RIC-Request in the Reassociation Request frame, and the AP shall not include the RIC-Response in the Reassociation Response frame. If the reassociation exchange is part of the FT resource request protocol and the AP is unable to honor the resources that have been placed in the accepted state for that FTO, then the AP shall reject the Reassociation Request frame and may use status code DENIED_INSUFFICIENT_BANDWIDTH.

If the FTO did not utilize the FT resource request protocol, the FTO may make a request for resources by including a RIC-Request (see 13.11 (Resource request procedures)) in the Reassociation Request frame. The RIC-Request is generated by the procedures of 13.11.3.1 (FTO procedures), and the RIC-Response is generated by the procedures of 13.11.3.2 (AP procedures).

If the Status Code field value returned by the target AP in the response is REFUSED_REASON_UNSPECIFIED, TRANSACTION_SEQUENCE_ERROR, or REJECTED_SEQUENCE_TIMEOUT, then the FTO shall abandon this transition attempt. Handling of other errors returned in the Status Code field shall be as specified in 11.3 (STA authentication and association).

Upon a successful reassociation, the PTKSA has been established and proven live. The SME of the AP shall open the IEEE 802.1X Controlled Port. The FTO shall transition to State 4 (as defined in 11.3 (STA authentication and association)). If the target AP is distinct from the previous AP, the FTO shall enter State 1 with respect to the previous AP.

Upon a successful reassociation, the FTO shall delete any corresponding PTKSA with its previous AP. The SME of the FTO shall issue an MLME-DELETEKEYS.request primitive to delete the pairwise keys with the previous AP, and the FTO and the AP shall issue an MLME-SETKEYS.request primitive and MLME-SETPROTECTION.request primitive to install the pairwise keys. The PTK lifetime timer shall be initialized with the value calculated as the difference between the TIE[KeyLifetime] sent in message 3 of the FT initial mobility domain association and the time since the completion of the FT 4-way handshake during the FT initial mobility domain association.

When the IEEE 802.1X Controlled Port is opened, the (#1836)EAPOL-Key PDU replay counter shall be initialized to 0. The R1KH shall increment the key replay counter on each successive (#1836)EAPOL-Key PDU that it transmits.

### 13.7.2 FT reassociation in a non-RSN

The FTO shall perform a reassociation with the target AP via the following exchange:

FTO→Target AP: Reassociation Request(MDE, RIC-Request)
Target AP→FTO: Reassociation Response(MDE, RIC-Response)

The SME of the FTO initiates the reassociation through the use of the MLME-REASSOCIATE.request primitive. The SME of the AP responds to the indication with MLME-REASSOCIATE.response primitive. See 11.3.5 (Association, reassociation, and disassociation).

In the Reassociation Request frame, the SA field of the message header shall be set to the MAC address of the FTO, and the DA field of the message header shall be set to the BSSID of the target AP's BSS. The elements in Reassociation Request frame, and their required contents, shall be as given in 13.8.4 (FT authentication sequence: contents of third message).


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If the contents of the MDE received by the target AP do not match the contents advertised in the Beacon and Probe Response frames, the target AP shall reject the Reassociation Request frame with status code STATUS_INVALID_MDE.

In the Reassociation Response frame, the SA field of the message header shall be set to the BSSID of the target AP's BSS, and the DA field of the message header shall be set to the MAC address of the FTO. The elements in Reassociation Response frame, and their required contents, shall be as given in 13.8.5 (FT authentication sequence: contents of fourth message). The Status Code field shall be a value from the options listed in 9.4.1.9 (Status Code field).

If the FTO is performing a reassociation exchange as part of the FT resource request protocol, then the FTO shall not include the RIC-Request in the Reassociation Request frame, and the AP shall not include the RIC-Response in the Reassociation Response frame.

If the FTO did not utilize the FT resource request protocol, the FTO may make a request for resources by including a RIC-Request (see 13.11 (Resource request procedures)) in the Reassociation Request frame. The RIC-Request is generated by the procedures of 13.11.3.1 (FTO procedures), and the RIC-Response is generated by the procedures of 13.11.3.2 (AP procedures).

If the Status Code field value returned by the target AP in the response is REFUSED_REASON_UNSPECIFIED, TRANSACTION_SEQUENCE_ERROR, or REJECTED_SEQUENCE_TIMEOUT, then the FTO shall abandon this transition attempt. Handling of other errors returned in the Status Code field shall be as specified in 11.3 (STA authentication and association).

If the AP has dot11RSNAActivated equal to true, upon a successful reassociation, the SME shall open the IEEE 802.1X Controlled Port.

Upon a successful reassociation, the target AP and the FTO shall transition to State 4 (as defined in 11.3 (STA authentication and association)). If the target AP is distinct from the previous AP, then the FTO shall enter State 1 with respect to the previous AP.

## 13.8 FT authentication sequence

### 13.8.1 Overview

The FT authentication sequence comprises four sets of FT elements. Each set of FT elements is referred to in 13.8 (FT authentication sequence) as a *message*. These messages are included in the FT Protocol frames or FT Resource Request Protocol frames to initiate a fast BSS transition. The FT authentication sequence is always initiated by the FTO and responded to by the target AP.

In an RSN, the first two messages in the sequence allow the FTO and target AP to provide association instance identifiers, SNonce and ANonce, respectively. SNonce and ANonce are chosen randomly or pseudorandomly and are used to generate a fresh PTK. The first two messages also enable the target AP to provision the PMK-R1 and the FTO and target AP to compute the PTK. The third and fourth messages demonstrate liveness of the peer, authenticate the elements, and enable an authenticated resource request.

When an FTO invokes the FT protocol, then the first two messages of the sequence are both carried in Authentication frames or both carried in Action frames, and these messages are described in 13.8.2 (FT authentication sequence: contents of first message) and 13.8.3 (FT authentication sequence: contents of second message). The third and fourth messages in the sequence are carried in the Reassociation Request and Reassociation Response frames and are described in 13.8.4 (FT authentication sequence: contents of third message) and 13.8.5 (FT authentication sequence: contents of fourth message).

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When the FTO invokes the FT resource request protocol, then the first four messages of the sequence are all carried in Authentication frames or all carried in Action frames, and these messages are described in 13.8.2 (FT authentication sequence: contents of first message) to 13.8.5 (FT authentication sequence: contents of fourth message). The fifth and sixth frames of the FT resource request protocol are carried in the Reassociation Request frame and Reassociation Response frame and are described in 13.8.4 (FT authentication sequence: contents of third message) and 13.8.5 (FT authentication sequence: contents of fourth message).

Regardless of the transport mechanism, the information contained in the FT authentication sequence consists of the set of elements shown in Table 13-1 (FT authentication elements).

**Table 13-1—FT authentication elements**

| Information | Presence in Authentication Sequence messages | Description |
|---|---|---|
| RSN | The RSNE is present if dot11RSNAActivated is true; otherwise not present.(#3400) | 9.4.2.23 (RSNE) |
| Mobility Domain | The (#1776)MDE is present. | 9.4.2.45 (MDE(#1776)) |
| Fast BSS Transition | The (#1776)FTE is present if dot11RSNAActivated is true. | 9.4.2.46 (FTE(#1776)) |
| Timeout Interval (reassociation deadline) | The (#1776)TIE is optionally present in the fourth message of the sequence if dot11RSNAActivated is not true. | 9.4.2.47 (TIE(#1776)) |
| RIC | The (#1776)RDE is optionally present in the third and fourth messages. | 9.4.2.48 (RDE(#1776)) |
| RSNXE | (#6301)(#4070)The RSNXE is present in the first message if any subfield of the Extended RSN Capabilities field in this element is nonzero, except the Field Length subfield.<br><br>(#6301)(#8214)If the third message is transmitted in a Reassociation Request frame, the RSNXE is present in the third message if an RSNXE is present in a Beacon or Probe Response frame that the FTO has received from the target AP and the FTO set to 1 any subfield, except the Field Length subfield, of the Extended RSN Capabilities field in this element.<br><br>(#6301)(#8214)If the fourth message is transmitted in a Reassociation Response frame, the RSNXE is present in the fourth message if an RSNXE was present in the third message and the target AP set to 1 any subfield, except the Field Length subfield, of the Extended RSN Capabilities field in this element.<br><br>(#6301)Otherwise, the RSNXE is not (#7041)present. | 9.4.2.240 (RSNXE(#1776)) |

The first message is used by the FTO to initiate a fast BSS transition. When RSNA is enabled, the FTO shall include the R0KH-ID and the SNonce in the FTE and the PMKR0Name in the RSNE. The target AP can use the PMKR0Name to derive the PMKR1Name, and if the target AP does not have the PMK-R1 identified by PMKR1Name, it may attempt to retrieve that key from the R0KH identified by R0KH-ID. See 13.2 (Key holders). The FTO includes a fresh SNonce as its contribution to the association instance identifier and to provide key separation of the derived PTK; it is selected randomly to serve as a challenge that demonstrates the liveness of the peer in the fourth message.


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The second message is used by the target AP to respond to the requesting FTO. The target AP provides the key holder identifiers and key names used to generate the PTK. The target AP also includes a fresh ANonce as its contribution to the association instance identifier and to provide key separation of the derived PTK. The response includes a status code.

In an RSN, the third message is used by the FTO to assert to the target AP that it has a valid PTK. If no resources are required, then the FTO omits inclusion of the RIC.

The fourth message is used by the target AP to respond to the requesting FTO. This message serves as final confirmation of the transition, establishes that the AP possesses the PMK-R1 and is participating in this association instance, and protects against downgrade attacks. Note, however, that the RIC is absent if no resources were requested in the third message. This also includes a status code and may include a reassociation deadline.

### 13.8.2 FT authentication sequence: contents of first message

If present, the RSNE shall be set as follows:

- Version field shall be set to 1.
- (#4226)Pairwise Cipher Suite Count field shall be set to 1.
- (#4226)AKM Suite Count field shall be set to 1.
- PMKID Count field shall be set to 1.
- PMKID List field shall contain the PMKR0Name.
- All other fields shall be as specified in 9.4.2.23 (RSNE) and 12.6.3 (RSNA policy selection in an infrastructure BSS).

The MDE shall contain the MDID field and the FT Capability and Policy field settings obtained from the target AP, as advertised by the target AP in Beacon and Probe Response frames. The MDID shall be identical to that obtained during the FT initial mobility domain association exchange.

If present, the FTE shall be set as follows:

- R0KH-ID shall be the value of R0KH-ID obtained by the FTO during its FT initial mobility domain association exchange.
- SNonce shall be set to a value chosen randomly by the FTO, see 12.7.5 (Nonce generation) for a recommended procedure.
- (#3135)When the negotiated AKM is 00-0F-AC:25, the MIC Length subfield of the MIC Control field shall be set to indicate the length of the MIC field.
- All other fields shall be set to 0.

### 13.8.3 FT authentication sequence: contents of second message

If the status code is SUCCESS, then the following rules apply.

If present, the RSNE shall be set as follows:

- Version field shall be set to 1.
- PMKID Count field shall be set to 1.
- PMKID List field shall be set to the value contained in the first message of this sequence.
- All other fields (#3488)of the Information field shall be identical to those in the RSNE advertised by the AP in Beacon and Probe Response frames.

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The MDE shall contain the MDID and FT Capability and Policy fields. This element shall be the same as the MDE advertised by the target AP in Beacon and Probe Response frames.

If present, the FTE shall be set as follows:

- R0KH-ID shall be identical to the R0KH-ID provided by the FTO in the first message.
- R1KH-ID shall be set to the R1KH-ID of the target AP, from dot11FTR1KeyHolderID.
- ANonce shall be set to a value chosen randomly by the target AP, see 12.7.5 (Nonce generation) for a recommended procedure.
- SNonce shall be set to the value contained in the first message of this sequence.
- (#3135)When the negotiated AKM is 00-0F-AC:25, the MIC Length subfield of the MIC Control field shall be set to indicate the length of the MIC field.
- All other fields shall be set to 0.

### 13.8.4 FT authentication sequence: contents of third message

If present, the RSNE shall be set as follows:

- Version field shall be set to 1.
- (#4226)Pairwise Cipher Suite Count field shall be set to 1.
- (#4226)AKM Suite Count field shall be set to 1.
- PMKID Count field shall be set to 1.
- PMKID List field shall contain the PMKR1Name.
- All other fields shall be as specified in 9.4.2.23 (RSNE) and 12.6.3 (RSNA policy selection in an infrastructure BSS).

The MDE shall contain the MDID and FT Capability and Policy fields. This element shall be identical to the MDE contained in the first message of this sequence.

If present, the FTE shall be set as follows:

- ANonce, SNonce, R0KH-ID, and R1KH-ID shall be set to the values contained in the second message of this sequence.
- The Element Count subfield of the MIC Control field shall be set to the number of elements protected in this frame (variable).
- The RSNXE Used subfield of the MIC Control field shall be set to 1 if the FTO set to 1 any subfield, except the Field Length subfield, of the Extended RSN Capabilities field in the RSNXE; otherwise this subfield shall be set to 0.
- (#3135)When the negotiated AKM is 00-0F-AC:25, the MIC Length subfield of the MIC Control field shall be set to indicate the length of the MIC field.
- When the negotiated AKM is 00-0F-AC:3, 00-0F-AC:4, or 00-0F-AC:9, the MIC shall be calculated using the (#4059)PTK-KCK and the AES-128-CMAC algorithm. The output of the AES-128-CMAC shall be 128 bits.
- When the negotiated AKM is 00-0F-AC:13, the MIC shall be calculated using the (#3744)PTK-KCK and the HMAC-SHA-384 algorithm. The output of the HMAC-SHA-384 shall be truncated to 192 bits.
- When the negotiated AKM is 00-0F-AC:16, the MIC shall be calculated using the KCK2 and the AES-128-CMAC algorithm. The output of the AES-128-CMAC shall be 128 bits.
- When the negotiated AKM is 00-0F-AC:17, the MIC shall be calculated using the KCK2 and the HMAC-SHA-384 algorithm. The output of the HMAC-SHA-384 shall be truncated to 192 bits.


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- When the negotiated AKM is 00-0F-AC:25(Ed1), the MIC shall be calculated using the (#3744)PTK-KCK and the HMAC-SHA-256/HMAC-SHA-384/HMAC-SHA-512 algorithm when the length of the (#3744)PTK-KCK in bits is 128/192/256. The output of the HMAC-SHA-256/ HMAC-SHA-384/HMAC-SHA-512 shall be truncated to 128/192/256 bits.(M21)(M67)
- If dot11RSNAOperatingChannelValidationActivated is true and Authenticator indicates OCVC(#3505), the Supplicant(#1441)(#1380) shall include FT OCI subelement in FTE.
- The MIC shall be calculated on the concatenation of the following data, in the order given here:
  - FTO's MAC address (6 octets)
  - Target AP's MAC address (6 octets)
  - Transaction sequence number (1 octet), which shall be set to the value 5 if this is a Reassociation Request frame and, otherwise, set to the value 3
  - RSNE
  - MDE
  - FTE, with the MIC field of the FTE set to 0
  - Contents of the RIC-Request (if present)
  - RSNXE (if present)
- All other fields shall be set to 0.

If resources are being requested by the FTO, then a sequence of elements forming the RIC-Request shall be included.

The RSNXE shall be present if an RSNXE was present in a Beacon or Probe Response frame that the FTO has received from the target AP and the FTO set to 1 any subfield, except the Field Length subfield, of the Extended RSN Capabilities field in this element.

### 13.8.5 FT authentication sequence: contents of fourth message

If the status code is SUCCESS, then the following rules apply.

If present, the RSNE shall be set as follows:

- Version field shall be set to 1.
- PMKID Count field shall be set to 1.
- PMKID List field shall contain the PMKR1Name
- All other fields (#3488)of the Information field shall be identical to those in the RSNE advertised by the target AP in Beacon and Probe Response frames.

The MDE shall contain the MDID and FT Capability and Policy fields. This element shall be identical to the MDE contained in the second message of this sequence.

If present, the FTE shall be set as follows:

- ANonce, SNonce, R0KH-ID, and R1KH-ID shall be set to the values contained in the second message of this sequence.
- The Element Count subfield of the MIC Control field shall be set to the number of elements protected in this frame (variable).
- The RSNXE Used subfield of the MIC Control field shall be set to 1 if the target AP includes an RSNXE in its Beacon and Probe Response frames; otherwise this subfield shall be set to 0.
- (#3135)When the negotiated AKM is 00-0F-AC:25, the MIC Length subfield of the MIC Control field shall be set to indicate the length of the MIC field.

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- If dot11RSNAOperatingChannelValidationActivated is true and Supplicant indicates OCVC(#3505), the Authenticator shall include FT OCI subelement in FTE.
- When this message of the authentication sequence appears in a Reassociation Response frame, the Optional Parameter(s) field in the FTE may include the GTK, IGTK, BIGTK, and WIGTK(11ba) subelements. If a GTK, an IGTK, a BIGTK, or WIGTK(11ba) are included, the Key field of the subelement shall be wrapped using (#3744)PTK-KEK or KEK2 and the appropriate key wrap algorithm, as specified in Table 12-11 (Integrity and key wrap algorithms(#3244)) and 12.7.2 (EAPOL-Key frames). The padding consists of appending a single octet 0xdd followed by zero or more 0x00 octets. When processing a received message, the receiver shall ignore this trailing padding. Addition of padding does not change the value of the Key Length field. Note that the length of the encrypted Key field can be determined from the length of the GTK, IGTK(M21), BIGTK, or WIGTK subelement.
- When the negotiated AKM is 00-0F-AC:3, 00-0F-AC:4, or 00-0F-AC:9, the MIC shall be calculated using the (#3744)PTK-KCK and the AES-128-CMAC algorithm. The output of the AES-128-CMAC algorithm shall be 128 bits.
- When the negotiated AKM is 00-0F-AC:13, the MIC shall be calculated using the (#3744)PTK-KCK and the HMAC-SHA-384 algorithm. The output of the HMAC-SHA-384 shall be truncated to 192 bits.
- When the negotiated AKM is 00-0F-AC:16, the MIC shall be calculated using the KCK2 and the AES-128-CMAC algorithm. The output of the AES-128-CMAC shall be 128 bits.
- When the negotiated AKM is 00-0F-AC:17, the MIC shall be calculated using the KCK2 and the HMAC-SHA-384 algorithm. The output of the HMAC-SHA-384 shall be truncated to 192 bits.
- When the negotiated AKM is 00-0F-AC:25(Ed1), the MIC shall be calculated using the (#3744)PTK-KCK and the HMAC-SHA-256/HMAC-SHA-384/HMAC-SHA-512 algorithm when the length of the (#3744)PTK-KCK in bits is 128/192/256. The output of the HMAC-SHA-256/ HMAC-SHA-384/HMAC-SHA-512 shall be truncated to 128/192/256 bits.(M21)(M67)
- The MIC shall be calculated on the concatenation of the following data, in the order given here:
  - FTO's MAC address (6 octets)
  - Target AP's MAC address (6 octets)
  - Transaction sequence number (1 octet), which shall be set to the value 6 if this is a Reassociation Response frame or, otherwise, set to the value 4
  - RSNE
  - MDE
  - FTE, with the MIC field of the FTE set to 0
  - Contents of the RIC-Response (if present)
  - RSNXE (if present)
- All other fields shall be set to 0.

If this message is other than a Reassociation Response frame and dot11RSNAActivated is false, a TIE may appear. If this message is other than a Reassociation Response frame, includes a RIC-Response, and dot11RSNAActivated is false, then (#1776)a TIE shall appear. If it appears, it shall be set as follows:

- Timeout Interval Type field shall be set to 1 (reassociation deadline).
- Timeout Interval Value field shall be set to the reassociation deadline time.

If resources were requested by the FTO, then a RIC-Response shall be included.

The RSNXE shall be present if an RSNXE was present in the third message and the target AP set to 1 any subfield, except the Field Length subfield, of the Extended RSN Capabilities field in this element.


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## 13.9 FT security architecture state machines

### 13.9.1 Introduction

The FT state machines describe the interaction between the RSNA key management and IEEE 802.11 architectural components.

RSNA key management uses the MA-UNITDATA service primitives to send/receive (#1836)EAPOL-Key PDUs for FT initial association; MLME interfaces described below for FT methods; and MLME-SETKEYS, MLME-DELETEKEYS, and MLME-SETPROTECTION primitives. FT key management uses the following primitives for key management delivery and reception:

- The MLME-REMOTE-REQUEST primitives for FT key management over the DS
- The MLME-AUTHENTICATE primitives for FT key management over the air
- The MLME-RESOURCE-REQUEST primitives for FT resource request over the air
- The MLME-REASSOCIATE primitives for FT key management over the air and over the DS

Some of the state machine design considerations are as follows:

- Details of error handling are not included in the state machines. See 13.4 (FT initial mobility domain association), 13.5 (FT protocol), and 13.6 (FT resource request protocol).
- Retransmission of FT Authentication and (Re)Association Request and Response frames are not included in the state machines; see 13.5 (FT protocol) and 13.6 (FT resource request protocol).

Various signals are used to communicate between the R0KH and the R1KH state machines. Note that these interactions may be between separate entities, rather than within a single SME. These interactions are as follows:

- In the R0KH state machine, FT-PMKR1-SA (PMKR1-SA) sends a PMK-R1 PMKSA to the R1KH.
- In the R1KH state machine, FT-FULL-AUTH (R1KH-ID) requests a key from the R0KH.
- In the R1KH state machine, FT-Transition-Auth (R1KH-ID) requests a key from the R0KH that was used for the initial mobility domain association.

The interactions between the R0KH and IEEE Std 802.1X, between the R1KH and IEEE Std 802.1X, and between the S1KH and IEEE Std 802.1X occur within the SME. At both the target AP and at the FTO, the R1KH and S1KH initialize the IEEE 802.1X EAPOL state machines in the respective SMEs. The Controlled Port is opened without an EAP exchange when the reassociation completes.

### 13.9.2 R0KH state machine

#### 13.9.2.1 General

There is one R0KH state machine, which includes FT key management.

The state diagram in Figure 13-14 (R0KH state machine) consists of a set of states that handle R0KH functions including key hierarchy instantiation, key generation, and cleanup. This state machine interacts with the R1KH state machine.

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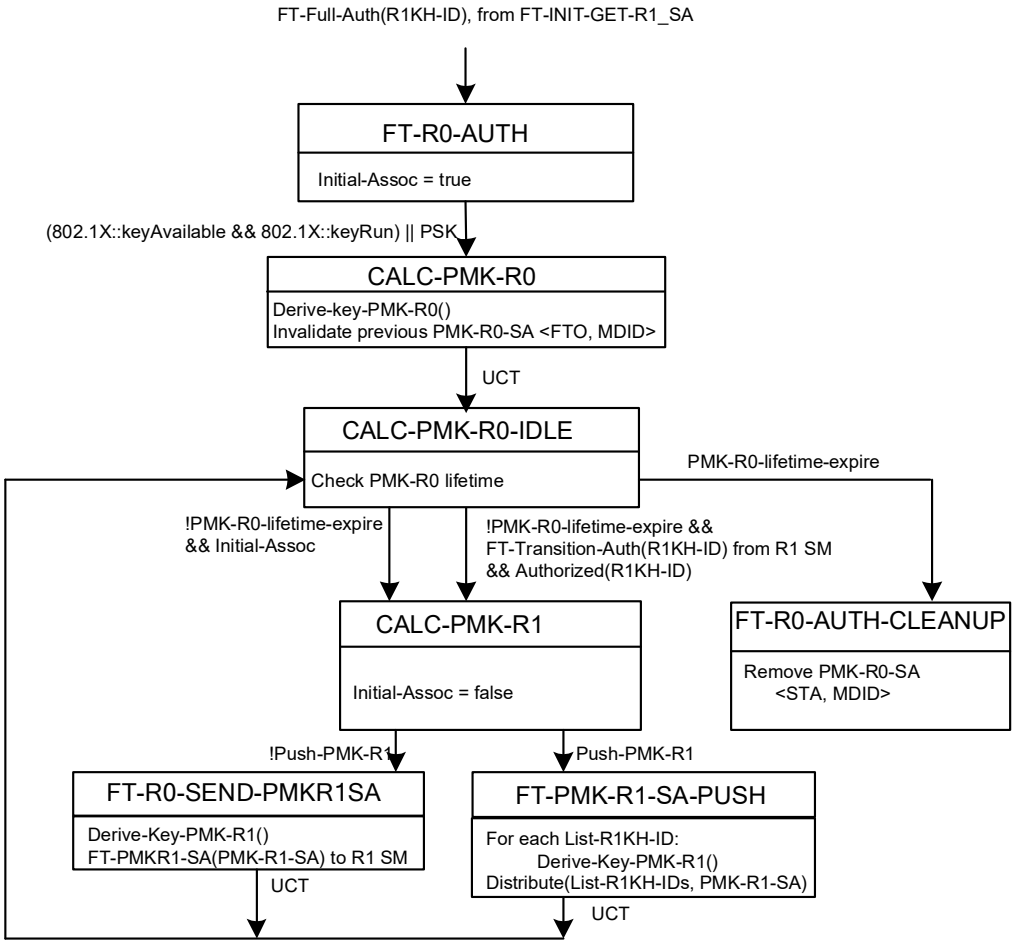


**Figure 13-14—R0KH state machine**

### 13.9.2.2 R0KH state machine states

The following list summarizes the states of the R0KH state machine:

- **CALC-PMK-R0**: This state is entered after the MSK from EAP authentication or PSK is available.
- **CALC-PMK-R0-IDLE**: This state is an intermediate state for the R0KH to wait for new requests from R1KHs.
- **CALC-PMK-R1**: For FT initial association, this state is entered as an unconditional transfer. For FT methods, this state is entered through the event from an R1KH state machine.
- **FT-PMK-R1-SA-PUSH**: This state is entered if Push-PMK-R1 is true. PMK-R1s are derived and distributed to all of the configured R1KHs.
- **FT-R0-AUTH-CLEANUP**: This state is entered when the PMK-R0 lifetime expires.
- **FT-R0-AUTH**: This state is entered through the event from the R1KH state machine. The R1KH state machine sends this event when it determines that a new PMK-R0 is needed.
- **FT-R0-SEND-PMKR1SA**: This state is entered from CALC-PMK-R1 when a request for the PMK-R1 security association is received from an R1KH. PMK-R1 security association is derived and distributed to the requesting R1KH.


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#### 13.9.2.3 R0KH state machine variables

The following list summarizes the variables used by the R0KH state machine:

- *Initial-Assoc.* This variable is used to indicate whether the current authentication is the initial association, in order to trigger the initial derivation of PMK-R1.
- *List-R1KH-IDs*. This variable contains a list of all of the R1KH-IDs in the mobility domain. This list is populated by the key distribution protocol as required in 13.2 (Key holders).
- *PMK-R0-lifetime-expire.* This variable is set to true when PMK-R0 lifetime is deemed expired.
- *PSK.* This variable is set to true when authentication is performed by use of a preshared key.
- *Push-PMK-R1.* This variable is set to true when R0KH can push the PMK-R1 security associations to R1KHs.

#### 13.9.2.4 R0KH state machine procedures

The following list summarizes the procedures used by the R0KH state machine:

- **Authorized(R1KH-ID).** This procedure returns a value of true if the R1KH is a known key holder in the mobility domain.
- **Distribute (List-R1KH-IDs, PMK-R1 PMKSA).** Distributes the PMK-R1-SAs for the current instance of the key hierarchy to the list of R1KH-IDs.
- **Derive-Key-PMK-R0().** This procedure derives the PMK-R0 from the MSK or PSK, derives the PMKR0Name (as described in 12.7.1.6.3 (PMK-R0)), and creates PMK-R0 security association.
- **Derive-Key-PMK-R1 (R1KH-ID).** From the PMK-R0, and the R1KH-ID (as described in 12.7.1.6.4 (PMK-R1)) for the R1KH identified by R1KH-ID, this procedure derives the PMK-R1 and creates a PMK-R1 security association.

### 13.9.3 R1KH state machine

#### 13.9.3.1 General

The R1KH state machine includes functions for FT initial association and FT protocols. The R1KH states performing FT initial association and the R1KH states performing FT protocol exchanges interact differently with the R0KH state machine.

The R1KH state machine and other portions of the SME are defined in Figure 13-15 (R1KH state machine, including portions of the SME (part 1) (#4346)(#3596)(#3727)) and Figure 13-16 (R1KH state machine, including portions of the SME (part 2)) and consist of a set of states that handle FT initial mobility domain association, PMK-R1 reception, PTK handshake and session establishment, FT protocols (including resource requests), and cleanup. This state machine interacts with the R0KH state machine to generate a fresh FT key hierarchy for the initial mobility domain association and to get the PMK-R1 security association (PMK-R1 PMKSA) for the FT protocols. While the figures show the over-the-air message exchanges, the over-the-DS exchanges are handled similarly.

A new instance of the R1KH state machine is created each time initial mobility domain association or fast BSS transition is initiated.

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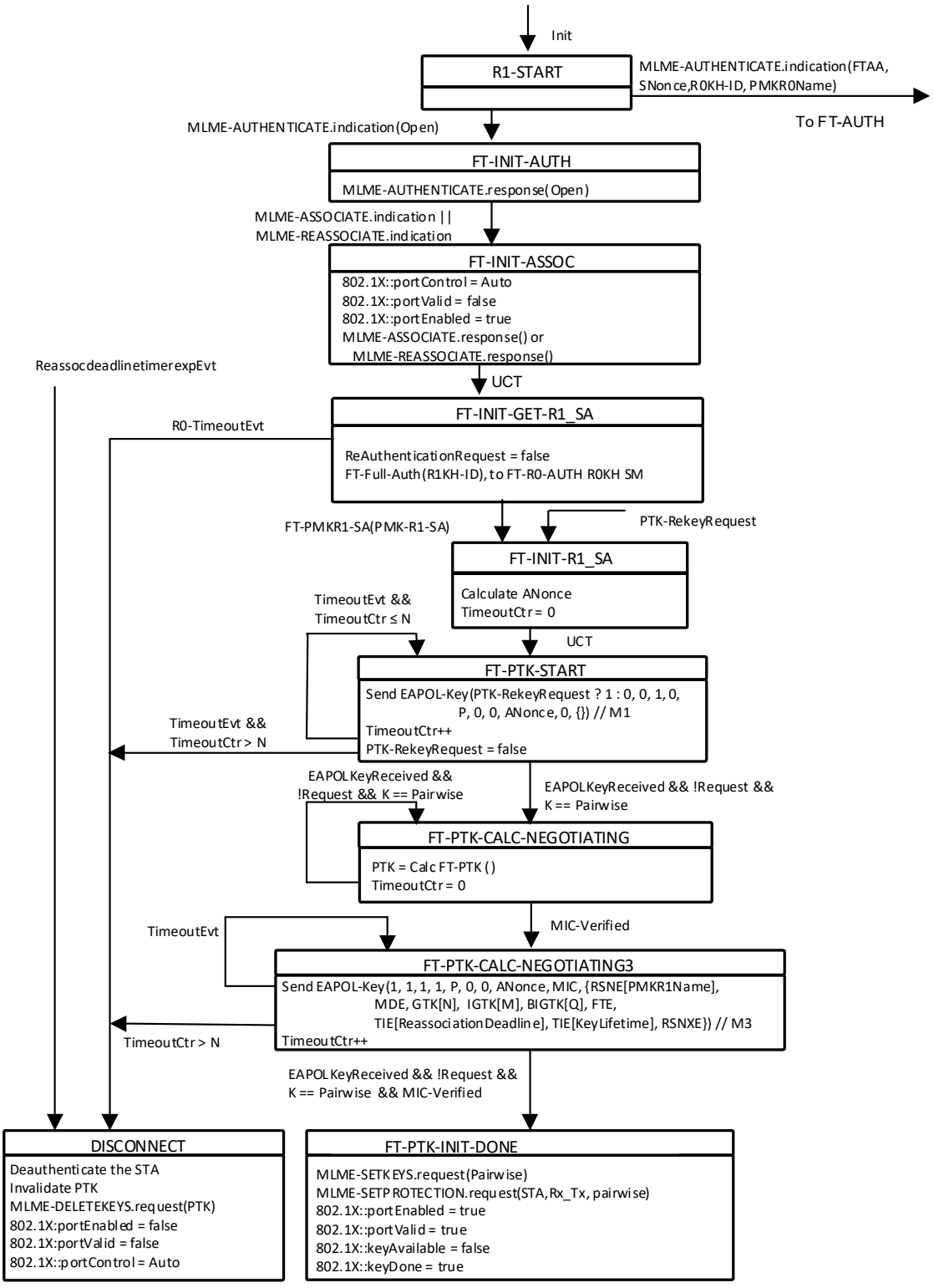


**Figure 13-15—R1KH state machine, including portions of the SME (part 1)**
**(#4346)(#3596)(#3727)**


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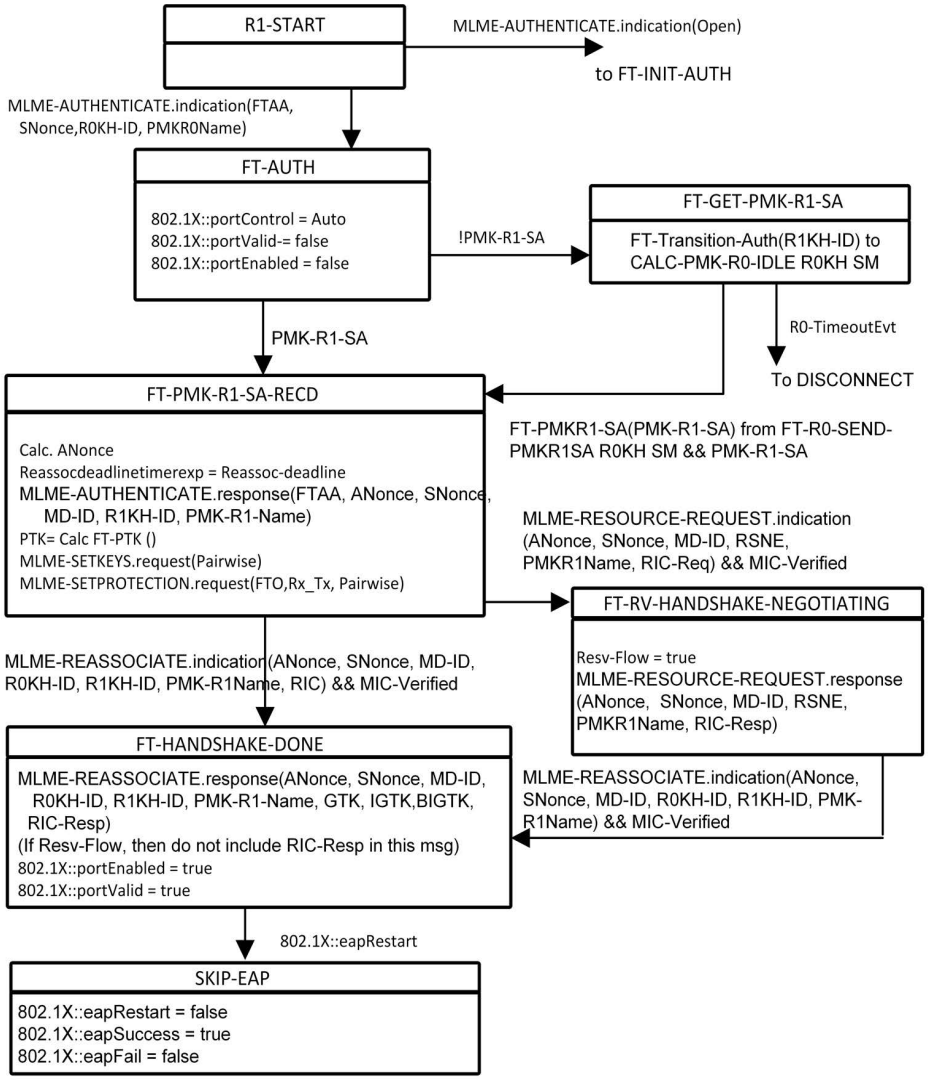


**Figure 13-16—R1KH state machine, including portions of the SME (part 2)**

### 13.9.3.2 R1KH state machine states

The following list summarizes the states of the R1KH state machine:

- **DISCONNECT**: This state is entered when the current session ends or when errors occur.
- **FT-AUTH**: This state is entered upon receipt of an indication that an FT protocol or FT resource request protocol is invoked.
- **FT-GET-PMK-R1-SA**: This state is entered when R1KH sends a message to the R0KH to get the PMK-R1-SA.
- **FT-HANDSHAKE-DONE**: This state is entered when reassociation indication parameters are validated. The Reassociation Response frame is then sent.

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- **FT-INIT-ASSOC**: This state is entered upon receipt of a (Re)Association Request frame during initial mobility domain association.
- **FT-INIT-AUTH**: This state is entered upon receipt of an indication that initial association is invoked.
- **FT-INIT-GET-R1_SA**: This state is entered when the R1KH determines that a new key hierarchy is required.
- **FT-INIT-R1_SA**: This state is entered on receiving the PMK-R1-SA from the R0KH and when rekeying the PTK.
- **FT-PMK-R1-SA-RECD**: This state is entered on receiving the PMK-R1-SA from the R0KH. An FT Authenticate response is sent in this state. This state then calculates the PTK and delivers the key to the MAC.
- **FT-PTK-INIT-DONE**: This state is entered on successful validation of the fourth (#1836)EAPOL-Key PDU. In this state, keys are provided to the MAC.
- **FT-PTK-CALC-NEGOTIATING**: This state is entered when a second (#1836)EAPOL-Key PDU is received.
- **FT-PTK-CALC-NEGOTIATING3**: This state is entered on successful validation of the second (#1836)EAPOL-Key PDU. In this state, the third (#1836)EAPOL-Key PDU is sent.
- **FT-PTK-START**: This state is entered when the PMK-R1-SA is present. This state is the beginning of the 4-way handshake to derive a fresh PTK.
- **FT-RV-HANDSHAKE-NEGOTIATING**: This state is entered when an FT resource request is received. The FT resource response is sent.
- **R1-START**: This is the start of the R1KH state machine.
- **SKIP-EAP**: This state is entered after successful completion of the FT protocol. In this state, the EAPOL state machine is triggered to open the IEEE 802.1X port.

#### 13.9.3.3 R1KH state machine variables

The following list summarizes the variables used by the R1KH state machine:

- *Init.* This variable is set to true to initialize the R1KH the state machine.
- *EAPOLKeyReceived.* This variable is set to true when an (#1836)EAPOL-Key PDU is received.
- *K.* This variable is one of the values of the Key Type bit in the (#1836)EAPOL-Key PDU received and is either Pairwise or Group.
- *MIC-Verified.* This variable is set to true when the message authentication code integrity check passes.
- *Pairwise.* This variable is one of the values of the Key Type bit in the (#1836)EAPOL-Key PDU.
- *PMK-R1-SA.* This variable is set to true when a PMK-R1-SA is present at the R1KH.
- *PTK-RekeyRequest.* This variable is set to true when a PTK rekey request is received.
- *Reassocdeadlinetimerexp.* This variable contains the reassociation deadline timer value.
- *ReassocdeadlinetimerexpEvt.* This variable is set to true when the reassociation deadline timer expires.
- *Request.* This variable is the value of the Request bit in the Key Information field in the EAPOL-Key PDU.
- *Resv-flow.* This variable is set to true when an indication of an FT resource request protocol is received.
- *R0-TimeoutEvt.* This variable is set to true when the timeout for R0KH authentication expires (e.g., when the EAP authentication session timeout expires).


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— *TimeoutCtr.* This variable contains the number of successive timeouts waiting for protocol responses.

— *TimeoutEvt.* This variable is set to true when a timeout for receiving EAPOL-Key response expires.

#### 13.9.3.4 R1KH state machine procedures

The following list summarizes the procedure used by the R1KH state machine:

— **Calc-FT-PTK().** This procedure calculates the PTK.

### 13.9.4 S0KH state machine

#### 13.9.4.1 General

There is one S0KH state machine within the Supplicant, defined in Figure 13-17 (S0KH state machine), which incorporates the FT initial association and key management.

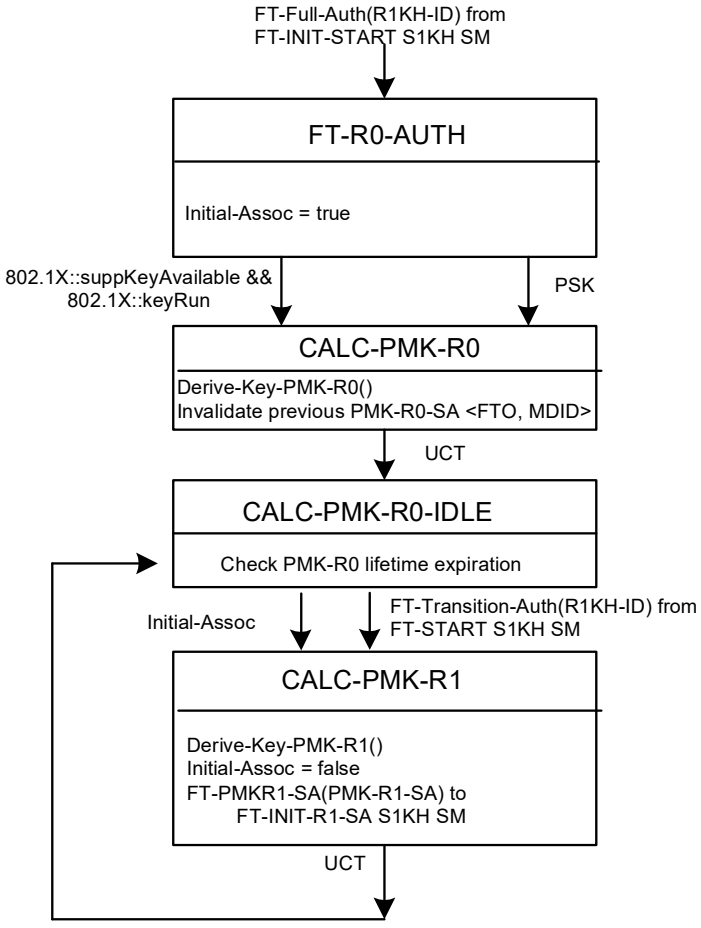


**Figure 13-17—S0KH state machine**

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#### 13.9.4.2 S0KH state machine states

The following list summarizes the states of the S0KH state machine:

— **CALC-PMK-R0**: This state is entered after the key is received, either from the EAP authentication or from the PSK.

— **CALC-PMK-R0-IDLE**: This state is entered after the PMK-R0 has been calculated and either continues with initial association or waits for requests from an S1KH for a PMK-R1.

— **CALC-PMK-R1**: For FT initial association, this state is entered as an unconditional transfer. For FT protocols, this state is entered through the event from the S1KH state machine. In this state, the PMK-R1 is sent to the S1KH.

— **FT-R0-AUTH**: This state is entered when the FT-Full-Auth event occurs during initial association in the S1KH state machine. The S1KH state machine sends this event when it determines that a new PMK-R0 is needed.

#### 13.9.4.3 S0KH state machine variables

The following list summarizes the variables used by the S0KH state machine:

— *Initial-Assoc.* This variable is used to indicate whether the current authentication is the initial association, in order to trigger the initial derivation of PMK-R1.

— *PSK.* This variable is set to true when authentication is performed by use of a preshared key.

#### 13.9.4.4 S0KH state machine procedures

The following list summarizes the procedures used by the S0KH state machine:

— **Derive-Key-PMK-R0().** This procedure derives the PMK-R0 and PMKR0Name and creates PMK-R0 security association.

— **Derive-Key-PMK-R1 (R1KH-ID).** This procedure derives the PMK-R1 and PMKR1Name from PMK-R0 for the indicated R1KH and creates PMK-R1 security association.

### 13.9.5 S1KH state machine

#### 13.9.5.1 General

The S1KH state machine includes functions for fast BSS transitions, including initial association. The S1KH state machine and other portions of the SME are defined in Figure 13-18 (S1KH state machine, including portions of the SME (part 1)(#3596)(#3744)) and Figure 13-19 (S1KH state machine, including portions of the SME (part 2)) and consist of a set of states that handle FT initial association, PTK handshake and session establishment, resource requests, cleanup, and teardown. This state machine interacts with the S0KH state machine to generate a fresh key hierarchy.


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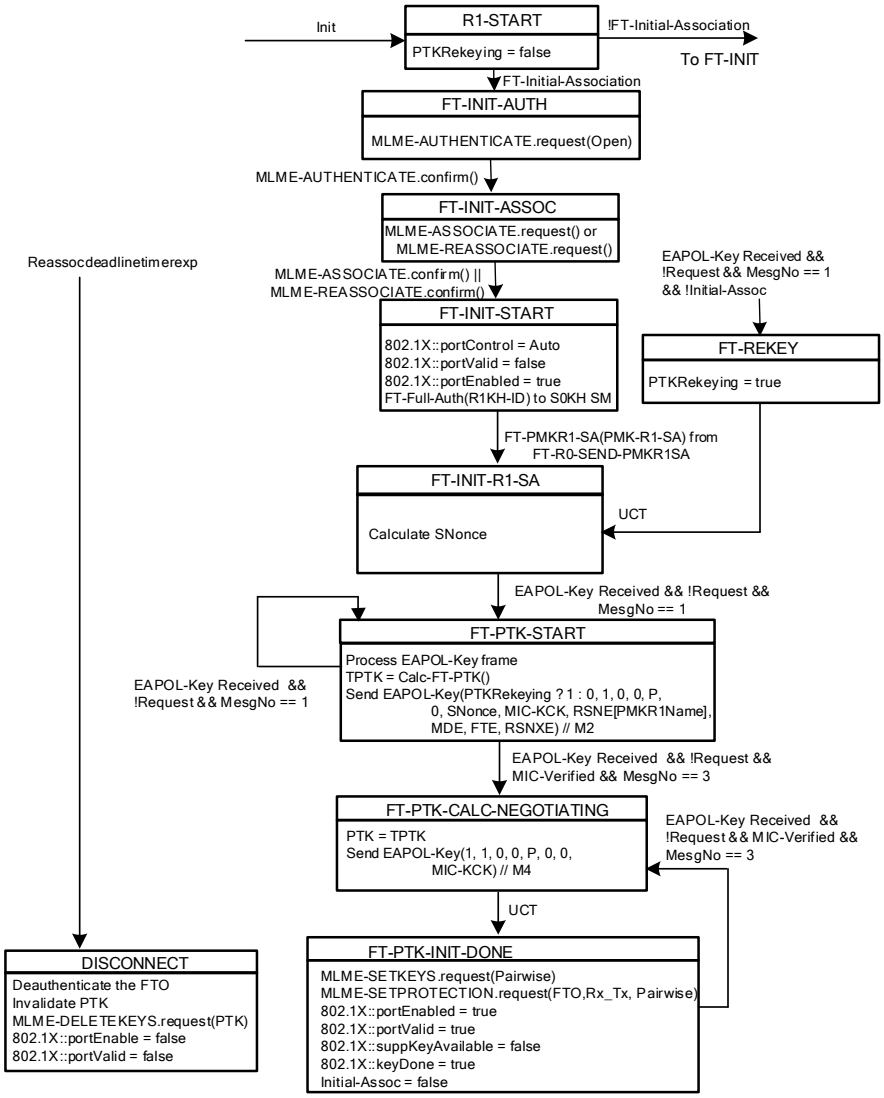


**Figure 13-18—S1KH state machine, including portions of the SME (part 1)(#3596)(#3744)**

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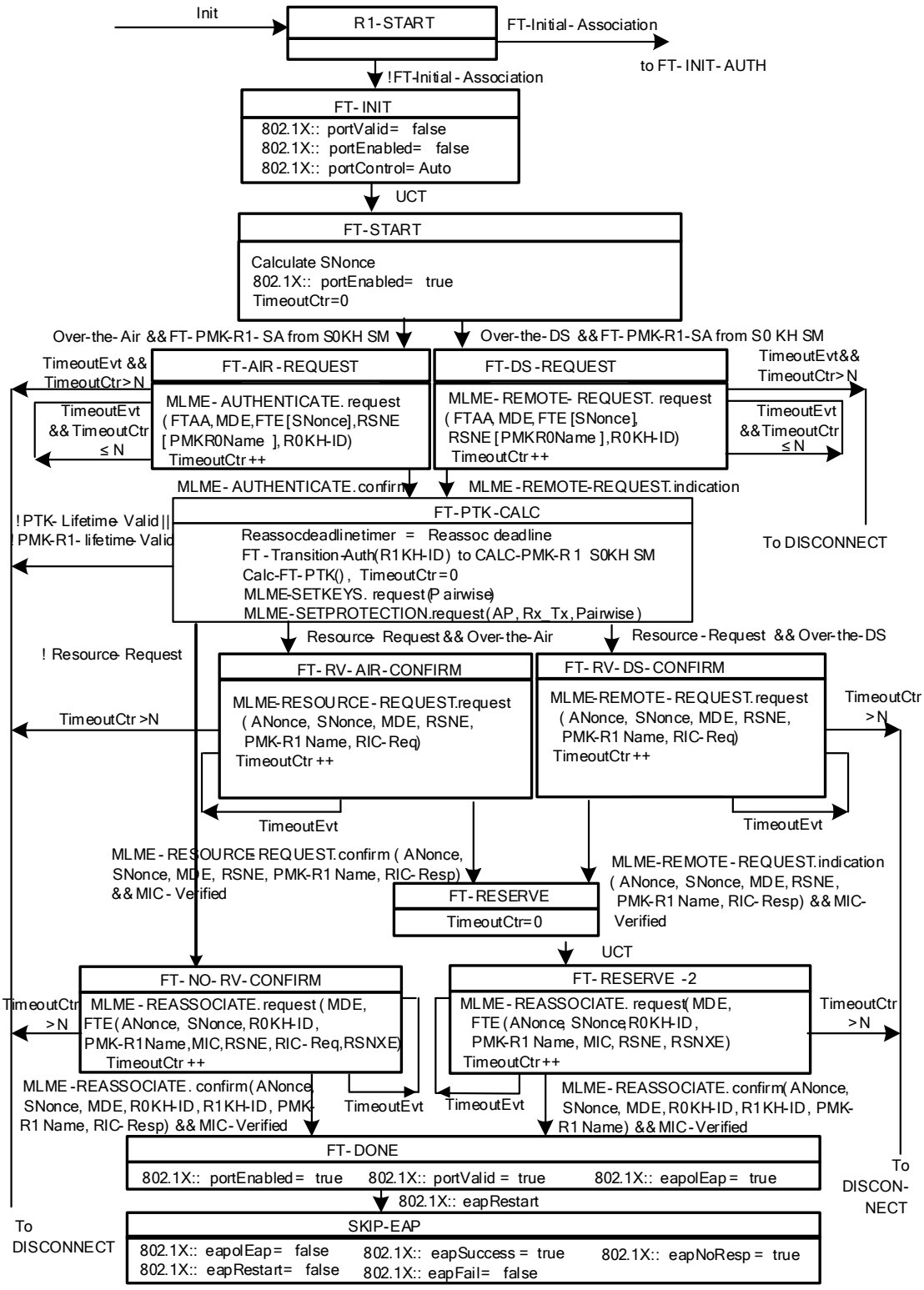


**Figure 13-19—S1KH state machine, including portions of the SME (part 2)**


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#### 13.9.5.2 S1KH state machine states

The following list summarizes the states of the S1KH state machine:

- **DISCONNECT**: This state is entered when the current session expires.
- **FT-AIR-REQUEST**: This state is entered when it is determined that an over-the-air FT method is to be executed. This state sends the Authentication-Request frame over the air.
- **FT-DONE**: This state is entered when a Reassociation Response frame is received.
- **FT-DS-REQUEST**: This state is entered when it is determined that an over-the-DS FT method is to be executed. This state sends the Authentication-Request frame over the DS.
- **FT-INIT**: This state is entered when an FT method is initiated.
- **FT-INIT-ASSOC:** This state is entered when authentication for initial mobility domain association has been completed.
- **FT-INIT-AUTH**: This state is entered when an FT initial association event is initiated.
- **FT-INIT-START:** This state is entered when association for initial mobility domain association has been completed.
- **FT-INIT-R1-SA**: This state is entered on receiving the PMK-R1-SA from the S0KH and when the Authenticator is starting PTK rekeying by sending out (#1836)EAPOL-Key PDU 1.
- **FT-NO-RV-CONFIRM**: This state is entered when performing FT protocol (i.e., not the FT resource request protocol). This state is entered for both over-the-air and over-the-DS processing. This state sends the Reassociation Request frame.
- **FT-PTK-CALC**: This state is entered when the over-the-air Authentication-Response frame is received if an over-the-air Authentication-Request frame was sent or when over-the-DS FT Response frame is received if an over-the-DS FT Request frame was sent. The PTK is calculated and installed in the MAC.
- **FT-PTK-INIT-DONE**: This state is entered after sending the fourth (#1836)EAPOL-Key PDU. This state establishes the PTK into the MAC.
- **FT-PTK-CALC-NEGOTIATING**: This state is entered when a third (#1836)EAPOL-Key PDU is received. This state sends the fourth (#1836)EAPOL-Key PDU.
- **FT-PTK-START**: This state is entered to derive a new PTK when the PMK-R1-SA is present and when the EAPOL-Key 4-way handshake message 1 is received. This state sends the EAPOL-Key 4-way handshake message 2.
- **FT-RESERVE**: This state is entered when the over-the-air Authentication-Ack frame is received if an over-the-air Authentication-Confirm frame was sent or when over-the-DS FT Ack frame is received if an over-the-DS FT Confirm frame was sent.
- **FT-RESERVE-2**: The Reassociation Request frame is sent in this state after completion of FT resource request.
- **FT-RV-AIR-CONFIRM**: This state is entered for over-the-air FT resource request protocol processing. The Authentication-Confirm frame containing the FT resource request is sent.
- **FT-RV-DS-CONFIRM**: This state is entered for over-the-DS FT resource request protocol processing. The Authentication-Confirm frame containing the FT resource request is sent.
- **FT-START**: This state is entered when all FT parameters are validated and FT needs to be initiated.
- **R1-START**: This is the start of the S1KH state machine.
- **SKIP-EAP**: This state is entered after successful completion of the FT protocol. In this state, the EAPOL state machine is triggered to open the IEEE 802.1X port.

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#### 13.9.5.3 S1KH state machine variables

The following list summarizes the variables used by the S1KH state machine:

- *EAPOLKeyReceived.* This variable is set to true when an (#1836)EAPOL-Key PDU is received.
- *FT-Initial-Association.* This variable is set to true when the S1KH is performing an initial association.
- *Init.* This variable is set to true to initialize the S1KH state machine. In addition, this variable is used to restart the state machine when transitioning to a new AP.
- *MesgNo.* In conjunction with *EAPOLKeyReceived*, this variable indicates which message in the 4-way handshake has been received.
- *MIC-Verified.* This variable is set to true when the message authentication integrity check is valid.
- *N.* This variable contains the limit of timeout events before considering the transition a failure.
- *Over-the-Air.* This variable is set to true when the FT protocol is to be exchanged over the air. Note that both *Over-the-Air* and *Over-the-DS* cannot be equal to true at the same time.
- *Over-the-DS.* This variable is set to true when the FT protocol is to be exchanged over the DS. Note that both *Over-the-Air* or *Over-the-DS* cannot be equal to true at the same time.
- *PMK-R1-Lifetime-Valid.* This variable is set to true when the PMK-R1 lifetime is valid.
- *PTK-Lifetime-Valid.* This variable is set to true when the PTK lifetime is valid.
- *Reassocdeadlinetimer.* This variable contains the reassociation deadline timer value.
- *ReassocdeadlinetimerExp.* This variable is set to true when the reassociation deadline timer expires.
- *Resource-request.* This variable is set to true when the FT resource request protocol is to be executed.
- *TimeoutCtr.* This variable contains the number of successive timeouts waiting for protocol responses.
- *TimeoutEvt.* This variable is set to true when a timeout event occurs.
- *TPTK.* This variable contains the newly calculated PTK, which is installed after receipt of message 3 of the 4-way handshake.

#### 13.9.5.4 S1KH state machine procedures

The following list summarizes the procedure used by the S1KH state machine:

- **Calc-FT-PTK().** This procedure calculates the PTK.

## 13.10 Remote request broker (RRB) communication

### 13.10.1 Overview

The RRB mechanism allows the FTO to communicate with a target AP through the FTO's existing association (with the current AP). The FTO transmits an FT Action frame (including the address of the FTO and the BSSID of the target AP's BSS) to the current AP. The current AP includes the contents of the FT Action frame (Request or Confirm) inside a Remote Request frame and transmits it to the target AP over the DS. The target AP processes the remote request and responds to the FTO by sending an FT Action frame (Response or Acknowledgment) through the current AP.

The SME of the FTO initiates an exchange with a target AP by issuing an MLME-REMOTE-REQUEST.request primitive with parameters including the contents of the FT Action frame to be sent. The MAC of the FTO transmits this Action frame. When the MAC of the current AP receives an FT Action frame, it passes it to the RRB by use of an MLME-REMOTE-REQUEST.indication primitive, with parameters including the contents of the received Action frame.


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When the RRB of the current AP has received a response from the target AP, it uses the MLME-REMOTE-REQUEST.request primitive to send the response, as an FT Action frame, to the requesting FTO. The MAC of the current AP transmits this Action frame. When the MAC of the FTO receives an FT Action frame, the MAC passes the Action frame to the SME by use of an MLME-REMOTE-REQUEST.indication primitive, with parameters including the contents of the received Action frame.

### 13.10.2 Remote request broker (RRB)

The RRB resides in the SME on the APs and acts as a forwarding agent (at the current AP) and termination point (at the target AP) for protocol messages over the DS.

The RRB allows APs that are part of the same mobility domain to exchange information over the DS. APs that advertise the same MDID shall be reachable over the DS and support the over-the-DS communication.

As a termination point, when the RRB at the target AP receives a request frame from the current AP, it interacts with the MAC and other parts of the SME to process the request and respond with a Remote Response frame, through the RRB on the current AP, back to the requesting FTO.

As a forwarding agent, when the RRB at the current AP receives a request from an FTO directed to another AP in the same mobility domain, the current AP forwards the request to that target AP. The RRB on the current AP converts Action frames into Remote Request frames and converts Remote Response frames into Action frames.

The target AP and the current AP shall reside in the same mobility domain. The RRB on the current AP shall transmit Remote Request frames to the target AP based on the BSSID of the target AP's BSS (supplied in the FT Action frames) using the same procedures as preauthentication, as described in 12.6.8.2 (Preauthentication and RSNA key management).

The message flow for a resource request over the DS is given in Figure 13-20 (Sample message flow for over-the-DS resource request). The FTO indicates the destination target AP BSSID as part of the FT Action frame. The RRB on the current AP encapsulates the FT Action frame and supplies the current AP BSSID in the Remote Request frame.

### 13.10.3 Remote Request/Response frame definition

This subclause defines a mechanism to transport the remote request and remote response between the current AP and the target AP. Any other mechanism may be used.

The Remote Request frame is transmitted over the DS from the current AP to the target AP. Remote Request/Response frames shall use (#3370)an MSDU with (#2186)EtherType 89-0d, as specified in Annex H. The Payload field of the MSDU for the Remote Request/Response frame is given in Table 13-2 (Remote Request/Response Payload format)(#4068).

**Table 13-2—Remote Request/Response Payload format**

| Size | Information |
|---|---|
| 1 | FT Packet Type |
| 2 | FT Action Length |
| 6 | AP Address |
| Variable | FT Action Frame |

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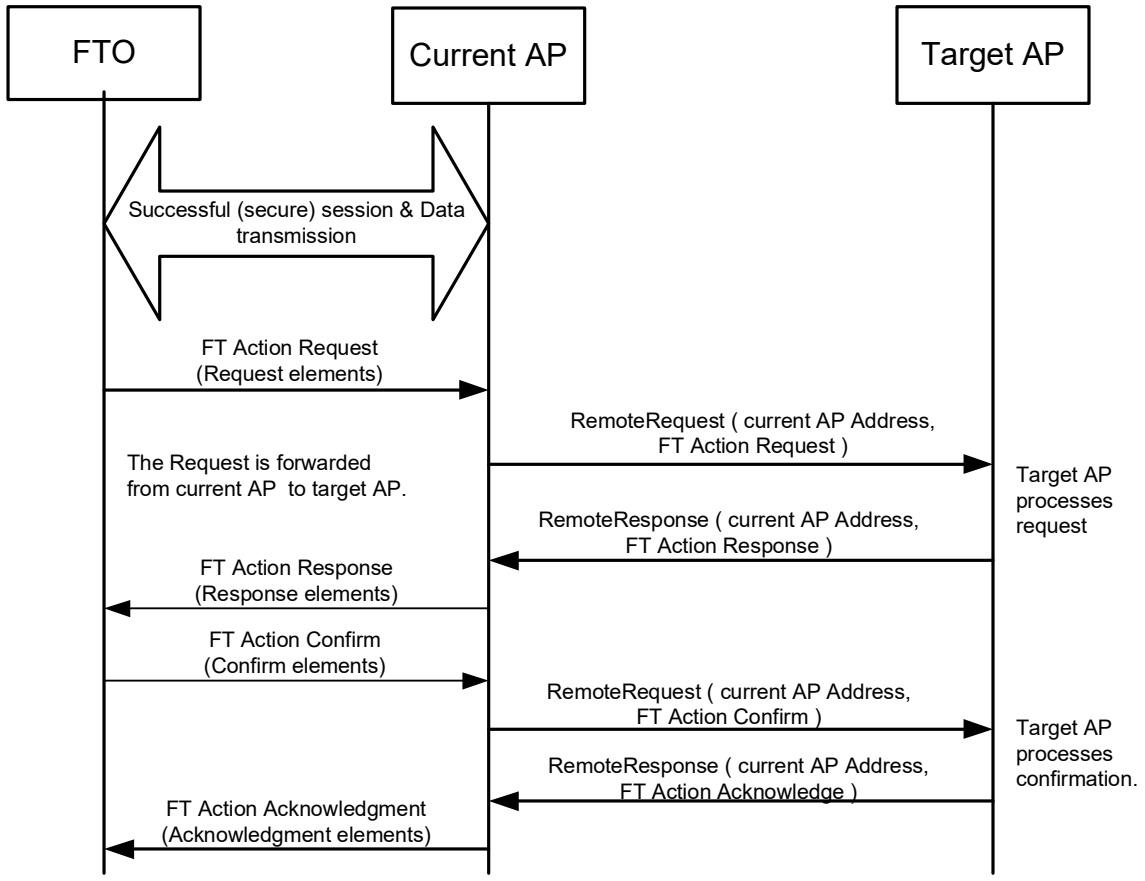


**Figure 13-20—Sample message flow for over-the-DS resource request**

The FT Packet Type field shall be set to 0 for remote request and to 1 for remote response.

The FT Action Length field shall be set to an unsigned number representing the length in octets of the FT Action Frame field, following the bit ordering conventions of 9.2.2 (Conventions).

The AP Address field shall be set to the BSSID of the current AP's BSS. The target AP shall use this address as the destination address when sending the Remote Response frame as a response to the Remote Request.

The FT Action Frame field shall be set to the contents of the FT Action frame, from the Category field to the end of the Action frame body.

## 13.11 Resource request procedures

### 13.11.1 General

When using the resource request procedure, the FTO has the option to request a resource allocation at the target AP. To request resources, the FTO creates a resource information container (RIC) and inserts it in an appropriate request message to the target AP. The request message is sent to the target AP either directly (over the air), or via the current AP (over the DS), according to the FT procedures described in 13.5 (FT protocol) and 13.6 (FT resource request protocol). In an RSNA, resource requests and responses are exchanged only after the establishment of the PTK and are protected by MICs.


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The RIC contains a complete list of resources requested by the FTO. An AP that receives a resource request from an FTO shall discard any previous resource request from that FTO. In an RSN, this resource request shall first be authenticated by the AP through checking of the MIC before the AP discards any previous resource request.

If an FTO is performing a fast BSS transition according to the FT protocol, described in 13.5 (FT protocol), it shall generate a RIC and process the RIC-Response according to the procedures of 13.11.3.1 (FTO procedures), performing the exchange in the Reassociation Request/Response frames.

If an FTO is performing a fast BSS transition according to the FT resource request protocol, described in 13.6 (FT resource request protocol), it shall generate a RIC and process the RIC-Response according to the procedures of 13.11.3.1 (FTO procedures), performing the exchange in the Authentication-Confirm and Authentication-Ack frames (over the air) or FT Confirm and FT Ack frames (over the DS).

### 13.11.2 Resource information container (RIC)

The RIC refers to a collection of elements that are used to express a resource request or response.

When used in making a request, a RIC has one or more Resource Requests, as shown in Figure 13-21 (RIC-Request format).

**Figure 13-21—RIC-Request format**

Each Resource Request consists of an RDE followed by one or more alternative Resource Descriptors. An example of a Resource Request is shown in Figure 13-22 (Resource Request format).

**Figure 13-22—Resource Request format**

Each Resource Descriptor consists of one or more elements. The possible Resource Descriptors that may appear in a RIC, and the elements that they contain, are given in Table 13-3 (Resource types and resource descriptor definitions).

If there are multiple Resource Descriptors, then they are treated as choices by the target AP. The AP attempts to allocate whatever is specified in the first Resource Descriptor; if this fails, the AP attempts to allocate whatever is specified in the next Resource Descriptor instead, and so on until a successful allocation or the AP reaches the end of the Resource Descriptor list. Thus, an OR relationship exists between Resource Descriptors that follow an RDE, with the Resource Descriptors appearing in order of preference.

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**Table 13-3—Resource types and resource descriptor definitions**

| Resource type | Resource Descriptor definition | Notes |
|---|---|---|
| 802.11 QoS | In a request: TSPEC (see 9.4.2.28 (TSPEC element)), followed by zero or more TCLAS (see 9.4.2.29 (TCLAS element)), followed by zero or one TCLAS Processing elements (see 9.4.2.31 (TCLAS Processing element)), followed by zero or one Expedited Bandwidth Request elements (see 9.4.2.92 (Expedited Bandwidth Request element)).<br><br>In a response: a TSPEC element (see 9.4.2.28 (TSPEC element)), followed by zero or one Schedule elements (see 9.4.2.32 (Schedule element)), followed by zero or more Delay elements (see 9.4.2.30 (TS Delay element)), followed by other optional elements as specified in 11.4 (TS operation). | May be sent by a QoS STA that is an FTO to a QoS AP. Definition of TSPEC elements shall be as given in 11.4 (TS operation). Definition of TCLAS, TCLAS Processing, Expedited Bandwidth Request, and Schedule elements, and the rules for including them in requests and responses, shall be as given in 11.4 (TS operation). Resource request procedures shall be as given in 11.4 (TS operation). |
| Block Ack Parameters | In a request: RIC Descriptor (see 9.4.2.49 (RIC Descriptor element)), containing a Resource Type field identifying Block Ack.<br><br>In a response: RIC Descriptor (see 9.4.2.49 (RIC Descriptor element)), containing a Resource Type field identifying Block Ack. | Resource request procedures shall be as given in 11.5 (Block ack operation). |
| Vendor Specific | RDE is followed by any Vendor Specific elements required to specify this resource. | |

An example of a Resource Request consisting of two alternative Resource Descriptors is shown in Figure 13-23 (Resource Request example #1).

**Figure 13-23—Resource Request example #1**

For example, when the resource being requested is QoS for downstream traffic, a TSPEC element may be followed by one or more TCLAS elements and, when multiple TCLAS elements are present, a TCLAS Processing element and (#1776)an Expedited Bandwidth Request element. Such an example Resource Request with two alternative TSPECs, the second of which has an Expedited Bandwidth Request element, is shown in Figure 13-24 (Resource Request example #2).

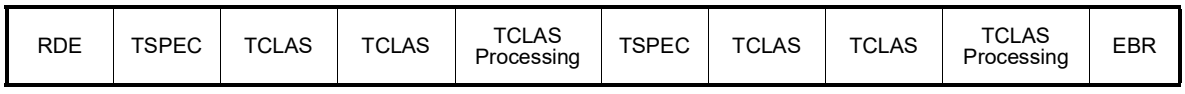


**Figure 13-24—Resource Request example #2**

An example of a RIC with two resource requests, each with a single TSPEC, is given in Figure 13-25 (RIC-Request example #1).


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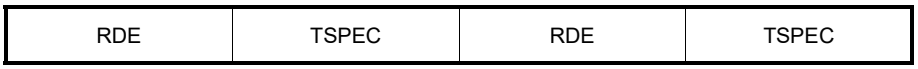


**Figure 13-25—RIC-Request example #1**

An example of a RIC with one resource request, with a choice of two TSPECs, is given in Figure 13-26 (RIC-Request example #2). This indicates that the target AP can select one of the two TSPECs.

**Figure 13-26—RIC-Request example #2**

An example of a RIC with a RIC Descriptor is given in Figure 13-27 (RIC-Request example #3). The target AP can acknowledge if the resource specified in the RIC Descriptor is available.

**Figure 13-27—RIC-Request example #3**

When sent by an AP in response to a RIC-Request, the RIC-Response consists of a list of one or more Resource Responses including one response for each of the Resource Requests that was contained in the RIC-Request. The basic format of a RIC-Response is shown in Figure 13-28 (RIC-Response format).

**Figure 13-28—RIC-Response format**

Each Resource Response consists of an RDE with the RDE identifier matching the RDE identifier in the request, in the same order as the RDEs appeared in the request. The RDE is followed by zero or one Resource Descriptors. If the request was not successful (as indicated in the RDE status), then the AP may include a suggestion that could have been successful. If the resource request was successful, then the particular Resource Descriptor (of the alternatives given by the FTO) is included in the response, as modified by the AP during the processing of the resource request. For example, when the resource being requested is QoS for upstream traffic, the TSPEC element may be followed by a Schedule element.

An example of a RIC-Response with two QoS resource responses, each with a single TSPEC and Schedule element, is given in Figure 13-29 (Example QoS RIC-Response).

**Figure 13-29—Example QoS RIC-Response**

### 13.11.3 Creation and handling of a resource request

#### 13.11.3.1 FTO procedures

The resource request enables an FTO to request resources based on specified Resource Descriptors (e.g., TSPECs) before or at the time the FTO associates with the target AP. In using TSPECs for requesting QoS resources, the TSPECs in the request need not belong to only active TSs; the FTO can send TSPECs for any TS that it intends to use after the transition and request the same resources that would be requested by a later

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ADDTS exchange. For each resource, the FTO may provide the AP with a choice of Resource Descriptors in order of preference, any one of which meets the needs of the application.

The FTO shall construct the RIC with a number of Resource Requests, each delineated by an RDE.

The FTO shall indicate the resources required at the target AP. For QoS resources, each TS shall be requested by a separate RDE and associated TSPEC(s). The RDE Identifier field in the RDE shall be an arbitrary value chosen by the FTO that uniquely identifies the RDE within the RIC. The Status Code field shall be set to SUCCESS, and the Resource Count field shall be set to the number of alternative Resource Descriptors that follow.

Following each RDE, the FTO shall include one or more Resource Descriptors that define the resources required for this TS. When multiple TSPECs follow an RDE as part of a single QoS resource request, a logical "OR" relationship exists between them, and at most one of these TSPECs shall be accepted by the AP. The FTO shall order the Resource Descriptors in decreasing order of preference.

In generating the RDE for QoS resources for a TS, the procedures of 11.4 (TS operation) shall be followed for the generation of TSPECs and inclusion of TCLAS, TCLAS Processing, and Expedited Bandwidth Request elements. If the TS is a downstream flow, then the RDE may also include one or more TCLAS element(s) (defined in 9.4.2.29 (TCLAS element)) and a TCLAS Processing element (defined in 9.4.2.31 (TCLAS Processing element)) if multiple TCLAS elements are included, and (#1776)an optional Expedited Bandwidth Request element, defined in 9.4.2.92 (Expedited Bandwidth Request element). If present, the TCLAS shall appear after the corresponding TSPEC. If present, an Expedited Bandwidth Request element shall appear after the corresponding TSPEC, TCLAS, and TCLAS Processing elements of the TSPEC.

A resource request is considered successful if the status code SUCCESS is returned in each RDE.

If the frame containing the response to the resource request contains a status code other than SUCCESS, the FTO considers that the request has failed and that no resources are being held at the target AP.

The response from the target AP contains a RIC-Response, with the RDEs in the response indicating which resources were considered by the target AP and the setting of the status code indicating which Resource Descriptors were accepted by the AP.

The RDE Identifier field in the RDE enables the FTO to match the response with the RDE in the request. The value of the Status Code field is interpreted as follows:

— Status Code(#3326) = SUCCESS indicates that the request has been accepted. The RDE may be followed by the Resource Descriptor that was accepted.

— Status Code(#3326) = not SUCCESS (one of the values from 9.4.1.9 (Status Code field)) indicates that the resources could not be accepted. The RDE may be followed by a suggested Resource Descriptor that could have been accepted.

A response to a successful resource request (other than in a Reassociation Request frame) may contain a reassociation deadline. If the FTO does not initiate a Reassociation Request frame with the target AP within the reassociation deadline (if appropriate), then the AP releases resources held for that FTO.

### 13.11.3.2 AP procedures

When a RIC appears in a request message, the AP shall check its ability to allocate one resource for each RDE in the RIC in the order appearing in the RIC. In a Reassociation Request frame, the QoS Capability element shall be processed prior to the QoS resource requests in the RIC.


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The behavior of the AP shall be identical to that described in the flowchart in Figure 13-30 (Overview of RIC processing at an AP).

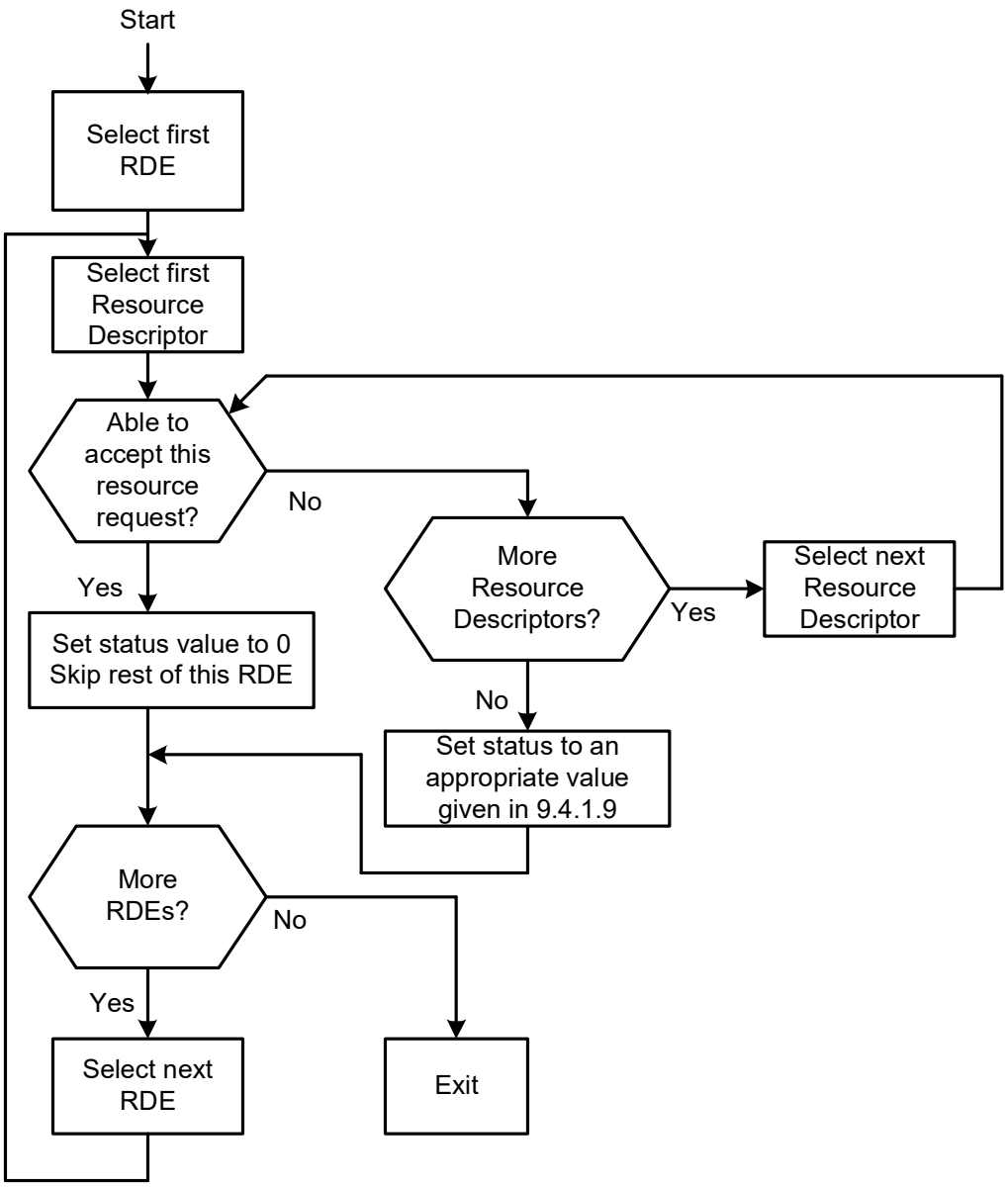


**Figure 13-30—Overview of RIC processing at an AP**

As shown in Figure 13-30 (Overview of RIC processing at an AP), the Resource Descriptors are examined by the AP in the order presented, and the first that could have been allocated is accepted. Thus the preference ordering by the FTO is honored.

The target AP's SME examines the resource requests in the RIC. For requests that require processing by the MAC sublayer, the SME generates an MLME-RESOURCE-REQUEST-LOCAL.request primitive. The MAC shall respond with MLME-RESOURCE-REQUEST-LOCAL.confirm primitive that indicates whether the MAC has accepted the resource request. The SME may also send these resource requests to an external entity such as a backend QoS module for its consideration; these procedures are beyond the scope

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of this standard. The acceptance of a TSPEC by the target AP results in the resource allocation for a TS at the target AP.

In response to a RIC-Request, the AP shall construct a RIC-Response. The RIC-Response shall contain one RDE for each RDE in the RIC-Request. The RDEs shall be in the same order as in the request, and the RDE Identifier field in each RDE shall be the value of the RDE Identifier field in the corresponding RDE in the request. The Status Code field in the RDE shall be set according to the result of the allocation request as follows:

— Status Code(#3326) = SUCCESS indicates that the resource request has been accepted. The RDE shall also be followed by the Resource Descriptor that was accepted.

— Status Code(#3326) = not SUCCESS indicates that the resources could not be accepted. The Status Code field contains a value from 9.4.1.9 (Status Code field) indicating the reason for the failure. In this case, the AP may include a single Resource Descriptor following the RDE indicating a suggested resource that could have been accepted. The Resource Count field shall be set to 0 or 1 depending whether the suggested Resource Descriptor is attached. A not SUCCESS status code in an RDE shall not cause a not SUCCESS status code in the frame containing the RIC.

If the resource request included QoS resources and is successful, then the procedures for handling of TSPEC, TCLAS, TCLAS Processing and Expedited Bandwidth Request elements shall be as specified in 11.4 (TS operation), and the AP shall place the TSs into the accepted state. The RIC-Response shall contain the updated accepted TSPEC. Each RDE may also include a Schedule element (as defined in 9.4.2.32 (Schedule element)) after the accepted TSPEC. Upon reassociation, AP shall move all of the TSs from the accepted state into the active state.

If the FTO does not invoke a reassociation within the reassociation deadline, then the TSs that had been accepted shall become inactive, and the resources shall be released. At the point that the FTO reassociates with the target AP (within the reassociation deadline, if appropriate), the TSs are put into the active state. This may be immediate if the RIC-Request was part of a Reassociation Request frame.


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# 14. MLME mesh procedures

## 14.1 General

Reserved fields and subfields defined in this clause are set to 0 upon transmission and are ignored upon reception.(#3286)

## 14.2 Mesh STA dependencies

When dot11MeshActivated is true, the STA is a mesh STA.

When dot11MeshActivated is true, following shall be true.

— dot11QosOptionImplemented
— dot11ExtendedChannelSwitchActivated (only when dot11SpectrumManagementRequired is true)

When dot11MeshActivated is true, following shall be false.

— dot11OCBActivated
— dot11FastBSSTransitionActivated

A mesh STA does not support functionalities that depend on AP or are only available in an infrastructure BSS, such as HCCA, traffic specifications (TSPECs), traffic stream (TS) management, admission control, automatic power save delivery (APSD), or tunneled direct link(#1356) setup (TDLS).

An HT mesh STA does not support (#3263)STBC.

When dot11DMGOptionImplemented or dot11S1GOptionImplemented is true, dot11MeshActivated shall be false.

A mesh STA with dot11EPDImplemented true shall set dot11EPDRequired to true.

## 14.3 Mesh discovery

### 14.3.1 General

A mesh STA shall perform either active scanning or passive scanning to discover an operating mesh BSS using the MLME-SCAN.request primitive (see 6.5.3 (Scan)). A mesh profile, a set of parameters identifying the mesh BSS configuration, is also obtained through the scanning process, and it is used to determine the scanning mesh STA's active mesh profile. Based on the result of the scan, the mesh STA may establish a new mesh BSS or become a member of the existing mesh BSS, using the START primitive (see 6.5.11 (Start)). The MLME-START.request primitive triggers beaconing that facilitates the discovery of the mesh STA by the neighbor mesh STAs. A mesh STA that becomes a member of a mesh BSS should establish a mesh peering with one or more neighbor mesh STAs that are in the same mesh BSS.

### 14.3.2 Mesh identifier

The mesh ID(#1755) is an identifier of an MBSS. The mesh ID(#1755) may be installed in mesh capable devices by a variety of means that are beyond the scope of this standard. For example, the mesh ID(#1755) might be set by the user, e.g., "Mike's Mesh." A mesh STA shall include the Mesh ID element (see 9.4.2.97 (Mesh ID element)) in its Beacon and Probe Response frames, in order to advertise its identity. The mesh STA shall also include the Mesh ID element in its Mesh Peering Open frames, Mesh Peering Confirm frames, and Mesh Peering Close frames.

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The mesh STA shall set the SSID element (see 9.4.2.2 (SSID element)) in Beacon, Probe Request, and Probe Response frames to the wildcard SSID.

(#391)NOTE 1—The wildcard SSID is used to notify nonmesh STAs that the mesh STA is neither a part of an infrastructure BSS nor an IBSS, so that the nonmesh STAs do not try to join the mesh BSS.

(#391)NOTE 2—In an MBSS, the BSSID field contains the MAC address of the mesh STA transmitting the frame containing the field, not the identifier of the MBSS (see 9.3.3.1 (Format of (PV0) Management frames)).

### 14.3.3 Mesh profile

A mesh profile is a set of parameters that specifies the attributes of a mesh BSS. A mesh profile consists of the following:

a) A mesh ID(#1755)—specified by dot11MeshID
b) A path selection protocol identifier—specified by dot11MeshActivePathSelectionProtocol
c) A path selection metric identifier—specified by dot11MeshActivePathSelectionMetric
d) A congestion control mode identifier—specified by dot11MeshActiveCongestionControlMode
e) A synchronization method identifier—specified by dot11MeshActiveSynchronizationMethod
f) An authentication protocol identifier—specified by dot11MeshActiveAuthenticationProtocol
g) EPD support—specified by dot11EPDImplemented

In a mesh BSS all mesh STAs use the same mesh profile. Two mesh profiles are considered to be the same if all of their parameters match.

An MBSS does not have a BSSID. Any field containing a BSSID contains the MAC address of a particular (originating or target) mesh STA, or the wildcard BSSID where permitted.(#1754)

Before establishing a mesh BSS or becoming a member of a mesh BSS, a mesh STA shall configure one mesh profile. The mesh STA shall not change its mesh profile unless it leaves the mesh BSS of which it is a member. When the mesh STA leaves the mesh BSS of which it is a member, it should explicitly close all of its active mesh peerings using Mesh Peering Close frames (see 14.4.8 (Mesh peering close)) and shall discard all session information obtained while the mesh profile was active, such as local forwarding information, security associations (and related keys), etc. The MLME receives the mesh STA's mesh profile from the SME upon receipt of the MLME-START.request primitive.

The mesh profile is signaled by means of the Mesh ID element and the Mesh Configuration element. The mesh profile is included in the Beacon and Probe Response frames, so that the mesh profile can be obtained by its neighbor mesh STAs through scanning. Mesh Peering Open and Mesh Peering Confirm frames also contain a mesh profile.

### 14.3.4 Mesh STA configuration

The mesh STA configuration is a set of parameters that determines if two mesh STAs can communicate.(#1771) The mesh STA configuration consists of the mesh profile (see 14.3.3 (Mesh profile)), the Supported Rates and BSS Membership Selectors element, the Extended Supported Rates and BSS Membership Selectors element, the HT Operations element (if present), the VHT Operations element (if present), and the HE Operation element (if present).(11ax)

Mesh STA configurations are identical if the following conditions hold:

— The mesh profiles are identical.
— The BSSBasicRateSet parameter of the MLME-START.request primitive is identical to the basic rate set indicated by the Supported Rates and BSS Membership Selectors element and Extended


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Supported Rates and BSS Membership Selectors element, if present, received in the MLME-MESHPEERINGMANAGEMENT.indication primitive.

— For HT mesh STAs, the Basic HT-MCS Set field of the HT Operation parameter of the MLME-START.request primitive is identical to the HT Operation element received in the MLME-MESHPEERINGMANAGEMENT.indication primitive.

— For VHT mesh STAs, the Basic VHT-MCS and NSS Set field in the VHT Operation element of the MLME-START.request primitive is identical to the Basic VHT-MCS and NSS Set field in the VHT Operation element received in the MLME-MESHPEERINGMANAGEMENT.indication primitive.

— For HE mesh STAs, the Basic HE-MCS And NSS Set field in the HE Operation element of the MLME-START.request primitive is identical to the Basic HE-MCS And NSS Set field in the HE Operation element received in the MLME-MESHPEERINGMANAGEMENT.indication primitive.(11ax)

### 14.3.5 Supplemental information for the mesh discovery

A mesh STA shall signal whether it is able to establish additional mesh peerings. A mesh STA signals its ability to establish additional mesh peerings by setting the Accepting Additional Mesh Peerings subfield in the Mesh Capability field in the Mesh Configuration element to 1 (see 9.4.2.96.8 (Mesh Capability)).

The mesh STA sets the Accepting Additional Mesh Peerings subfield in the Mesh Capability field in the Mesh Configuration element to 0 when it is not able to accept new mesh peerings. This parameter is dynamically controlled by the SME and given to the MLME by dot11MeshAcceptingAdditionalPeerings.

NOTE—This control is driven by internal policies. When the Accepting Additional Mesh Peering subfield is 1, the mesh STA is assumed to have sufficient internal resources to accommodate more mesh peerings. The internal policy is outside the scope of this standard. For instance, a mesh STA might be configured to be able to maintain only two mesh peerings.

A mesh STA shall announce its topological information through the Mesh Formation Info field in the Mesh Configuration element. The contents of the Mesh Formation Info field shall be coded to reflect the current configuration.

### 14.3.6 Scanning mesh BSSs

(#391)A mesh STA shall perform active scanning or passive scanning, depending on the value of the ScanType parameter of the MLME-SCAN.request primitive (see 11.1.4 (Acquiring synchronization, scanning)), to discover neighbor mesh STAs. Upon receipt of an MLME-SCAN.request primitive with the Mesh ID parameter, the STA shall passively scan for Beacon frames, or (#1662)transmit Probe Request frames containing the Mesh ID field and wait for Probe Response or Beacon frames, as appropriate, depending on the value of the ScanType parameter. The Mesh ID parameter indicates the mesh ID(#1755) for which to scan.

(#391)To actively scan, the mesh STA shall follow the procedures in 11.1.4.3 (Active scanning and probing procedures), using a wildcard mesh ID(#1755) or the desired mesh ID(#1755) in the Probe Request frame(s).(#1757) A mesh STA that receives a Probe Request frame shall respond to it as specified in 11.1.4.3.4 (Criteria for sending a response).

(#391)To actively scan, the mesh STA shall follow the procedures in 11.1.4.3.4 (Criteria for sending a response), using a wildcard (#1755)mesh ID or the desired (#1755)mesh ID in the Probe Request frame(s).(#1756)

(#391)To passively scan, the mesh STA shall scan for any Beacon frames from MBSSs when the mesh ID(#1755) in the MLME-SCAN.request primitive was the wildcard mesh ID(#1755), and it shall scan for

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Beacon frames containing a specific mesh ID(#1755) given via the mesh ID(#1755) in the MLME-SCAN.request primitive when the mesh ID(#1755) was not the wildcard mesh ID(#1755).

(#391)Upon completion of scanning, an MLME-SCAN.confirm primitive is issued by the MLME indicating all of the discovery information received. Further, a mesh STA shall comply with the passive scan procedure as described in 11.1.4.2 (Passive scanning) and the active scan procedure as described in 11.1.4.3 (Active scanning and probing procedures).

### 14.3.7 Candidate peer mesh STA

When a mesh STA discovers a neighbor mesh STA through the scanning process and the discovered mesh STA is considered a candidate peer mesh STA, it may become a member of the mesh BSS of which the discovered mesh STA is a member and establish a mesh peering with the neighbor mesh STA.

The discovered neighbor mesh STA shall be considered a candidate peer mesh STA if all of the following conditions are met:

a) The discovered neighbor mesh STA has the same mesh STA configuration as the scanning mesh STA (see 14.3.4 (Mesh STA configuration)).(#1771)

   NOTE—If the scanning mesh STA has not become a member of any MBSS yet, it might simply activate the same mesh profile as the discovered neighbor mesh STA's profile to fulfill this condition.

b) The Accepting Additional Mesh Peerings subfield in the Mesh Capability field in the received Beacon or Probe Response frame equals 1.(#1771)

c) If the scanning mesh STA has dot11MeshSecurityActivated equal to true and the dot11MeshActiveAuthenticationProtocol is ieee8021x (2), either the scanning mesh STA has an active connection to an AS or the discovered mesh STA has the Connected to AS subfield in the Mesh Formation field in the Mesh Configuration element equal to 1 in the received Beacon or Probe Response frame.

d) Both mesh STAs have dot11MeshSecurityActivated equal to false or both mesh STAs have dot11MeshSecurityActivated equal to true and the neighbor mesh STA advertises an RSNE that is compatible with that of the scanning mesh STA (see 14.6.2 (Security capabilities selection)).(#1651)

Otherwise it shall not be considered a candidate peer mesh STA.(#7220)

### 14.3.8 Establishing or becoming a member of a mesh BSS

The Mesh Formation Info field in the Mesh Configuration element is available to assist scanning mesh STAs in choosing the mesh BSS of which to become a member. The details of the usage of this information are beyond the scope of this standard.

NOTE 1—Selection of the mesh BSS of which the scanning mesh STA becomes a new member is outside the scope of this standard. That is, the mesh STA might freely select the mesh BSS of a candidate peer mesh STA of which it becomes a new member.

After the determination of the active mesh profile, the mesh STA may establish a new mesh BSS or become a new member to an existing mesh BSS.

When dot11MBCAActivated is true, the mesh STA shall perform the TBTT selection procedure described in 14.14.4.3 (TBTT selection) using TimeStamp, Local Time, Beacon Period, and Beacon Timing in the BSSDescriptionSet parameter given by the MLME-SCAN.confirm primitive, before starting its beaconing.

When dot11MCCAActivated is true, the mesh STA shall choose a DTIM interval with a duration of $2^n \times 100$ TU with $n$ a non-negative integer less than or equal to 17.


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NOTE 2—It is allowed that a different value for the DTIM interval is used for mesh STAs that use MCCA in an MBSS that is centrally controlled and the central authority provides a coordination of the DTIM interval of mesh STAs that use MCCA in the MBSS.

The mesh STA establishes a new mesh BSS by activating a mesh profile that is different from any mesh profile discovered during the scanning of mesh BSSs (see 14.3.6 (Scanning mesh BSSs)).

The mesh STA becomes a new member of an existing mesh BSS by activating the same mesh profile as received from a candidate peer mesh STA of this mesh BSS (see 14.3.6 (Scanning mesh BSSs) and 14.3.7 (Candidate peer mesh STA)).

In either case, the mesh STA shall start beaconing using the START primitive. Upon receipt of the MLME-START.request primitive, the mesh STA shall initialize and start its TSF timer as specified by its active synchronization method as described in 14.14.2 (Extensible synchronization framework), and begin transmitting Beacon frames as described in 14.14.3 (Beaconing).

If the mesh STA has become a new member of an existing mesh BSS, it should establish a mesh peering with one or more candidate peer mesh STAs of this mesh BSS (see 14.3.9 (Establishing mesh peerings)) in order to form the MBSS.

If the mesh STA has become a new member of an existing mesh BSS, it shall adopt the BSSBasicRateSet parameter from a candidate peer mesh STA of this mesh BSS.

After establishing or becoming a member of an MBSS, the mesh STA may continue the discovery procedure described in 14.3.6 (Scanning mesh BSSs) to discover other candidate peer mesh STAs.

### 14.3.9 Establishing mesh peerings

Mesh peerings shall be established only with candidate mesh STAs that are members of the same MBSS.

A mesh peering is established between the mesh STA and the candidate peer mesh STA after the successful completion of the mesh peering management (MPM) protocol (see 14.4 (Mesh peering management (MPM))) or of the authenticated mesh peering exchange (AMPE) (see 14.6 (Authenticated mesh peering exchange (AMPE))). When establishing a secure mesh peering, mesh STAs authenticate each other and create a mesh PMKSA before processing the AMPE (see 14.4.3 (Mesh authentication)).

A candidate peer mesh STA becomes a peer mesh STA when a mesh peering is established between the two mesh STAs.

When dot11MeshActiveSynchronizationMethod is neighborOffsetSynchronization (1), a mesh STA may establish mesh peerings with up to dot11MeshNbrOffsetMaxNeighbor mesh STAs (see 14.14.2.2.1 (General)).

## 14.4 Mesh peering management (MPM)

### 14.4.1 General

The mesh peering management (MPM) protocol is used to establish, maintain, and close mesh peerings between mesh STAs when dot11MeshSecurityActivated is false. When dot11MeshSecurityActivated is true, the peers establish an authenticated mesh peering using the authenticated mesh peering exchange (AMPE) protocol. The AMPE protocol requires an existing mesh PMKSA. If a mesh PMKSA with the candidate peer mesh STA exists, the AMPE shall use that mesh PMKSA. If no mesh PMKSA exists, the peers shall first authenticate to establish a mesh PMKSA; see 14.6 (Authenticated mesh peering exchange (AMPE)).

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Figure 14-1 (Logical flowchart of protocol interaction in the mesh peering management framework) shows the logical flow of protocol interactions in the peering management framework.

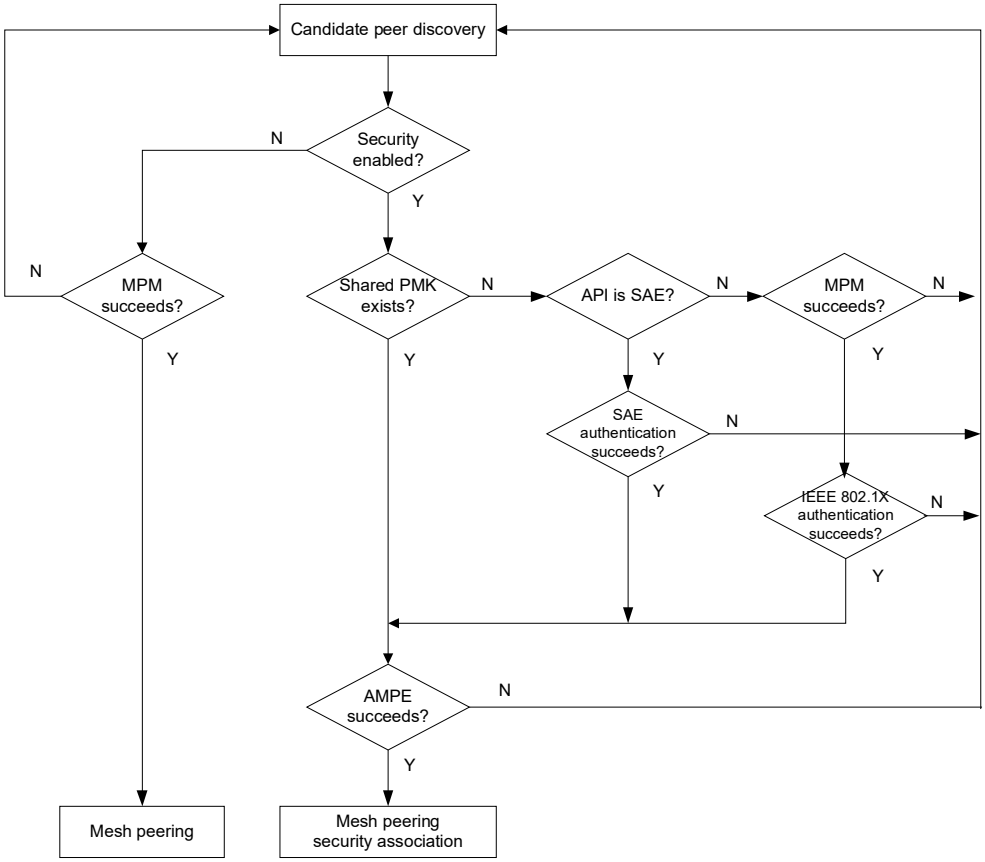


**Figure 14-1—Logical flowchart of protocol interaction in the mesh peering management framework**

The MPM protocol uses Mesh Peering Open frames, Mesh Peering Confirm frames, and Mesh Peering Close frames to establish, manage, and tear down a mesh peering.

The protocol succeeds in establishing a mesh peering when the following requirements are satisfied: 1) both mesh STAs have sent and received (and correctly processed) a Mesh Peering Open frame for this mesh peering; 2) both mesh STAs have sent and received (and correctly processed) a corresponding Mesh Peering Confirm frame for this mesh peering.

A mesh STA that receives and accepts a Mesh Peering Open frame (see 14.4.6.2 (Mesh Peering Open frame processing)) shall assign a unique AID among its neighbor peer mesh STAs to the transmitter of the frame. Since the AID is used in the encoding of the TIM element in the Beacon frame (see 9.4.2.5 (TIM element)), the setting of the AID value is constrained as described in 9.4.1.8 (AID field). AID 0(#7217)(#7206) is reserved to indicate the presence of buffered group addressed MSDUs and MMPDUs (see 14.15.4 (TIM transmissions in an MBSS)).


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### 14.4.2 State variable management

A mesh STA keeps an enumerated state variable (see 11.3.1 (State variables)) for each neighbor STA with which direct communication via the WM is needed. This state variable expresses the relationship between the local STA and a neighbor STA that varies depending on the active authentication protocol. It takes on the values shown in Table 14-1 (State variables for mesh STAs).

**Table 14-1—State variables for mesh STAs**

| State | Active authentication | | |
|---|---|---|---|
| | None | SAE | IEEE Std 802.1X |
| *State 1* | Initial start state, mesh peering not established | Initial start state, unauthenticated, mesh peering not established | Initial start state, unauthenticated, mesh peering not established |
| *State 2* | N/A | Authenticated, mesh peering not established | N/A |
| *State 3* | Mesh peering established | Authenticated, mesh peering established | Unauthenticated, mesh peering established (Pending IEEE 802.1X authentication) |
| *State 4* | N/A | N/A | Authenticated, mesh peering established |

The state transitions in accordance with the protocol interaction shown in Figure 14-1 (Logical flowchart of protocol interaction in the mesh peering management framework).

The current state existing between the neighbor STAs determines the IEEE 802.11 frame types that may be exchanged between that pair of STAs (see Clause 9 (Frame formats)). The allowed frame types are grouped into classes and the classes correspond to the STA state. The allowed frame types and the frame classes in each state are defined in 11.3.3 (Frame filtering based on STA state).

A mesh STA shall not transmit frames other than the ones used for candidate peer mesh STA discovery, MPM, and SAE to a neighboring mesh STA until a mesh peering has been established with the mesh STA.

### 14.4.3 Mesh authentication

See 12.6.1.2.4 (Security association in an MBSS).

### 14.4.4 Mesh peering instance controller

#### 14.4.4.1 Overview

A mesh STA uses a mesh peering instance controller to manage all mesh peering instances.

The mesh peering instance controller performs the following functions:

— Create and delete MPM finite state machines and AMPE finite state machines
— Manage instance identifiers for each mesh peering instance
— Manage mesh PTKSAs(#240) for each mesh peering instance when dot11MeshSecurityActivated is true

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- Preprocess the incoming mesh peering Management frames and pass the frames to the finite state machine with matching instance identifier
- Pass internal commands to the finite state machine with matching instance identifier

A mesh peering instance is identified by a mesh peering instance identifier. The mesh peering instance identifier is the set of localLinkID, localMAC, and peerMAC.

A mesh peering instance consists of its identifier (the localLinkID, localMAC, peerMAC), a peerLinkID (an integer generated by the peer mesh STA or candidate peer mesh STA), and the configuration and capability negotiated and agreed upon by exchanging Mesh Peering Open frames (see 9.6.15.2 (Mesh Peering Open frame format)) and Mesh Peering Confirm frames (see 9.6.15.3 (Mesh Peering Confirm frame format)). If dot11MeshSecurityActivated is true, the mesh peering instance also contains a PMKID identifying the shared PMKSA, a localNonce chosen by the mesh STA and a peerNonce chosen by the peer mesh STA or candidate peer mesh STA.

The localMAC is the MAC address of the mesh STA that is managing this mesh peering instance. The peerMAC is the MAC address of the peer mesh STA or the candidate peer mesh STA. The localLinkID is an integer generated by the mesh STA. The localLinkID shall be unique among all existing link identifiers used by the mesh STA for its MPM finite state machines. The mesh STA selects the localLinkID to provide high assurance that the same number has not been used to identify a recent MPM finite state machine. The peerLinkID is the localLinkID of the peer mesh STA or candidate peer mesh STA and is supplied in the Mesh Peering Management element (see 9.4.2.100 (Mesh Peering Management element)) of the Mesh Peering Open and Mesh Peering Confirm frames.

A mesh peering instance is controlled by an MPM finite state machine (see Table 14-2 (MPM finite state machine) in 14.5.5 (State transitions)) or an AMPE finite state machine (see Table 14-3 (AMPE finite state machine) in 14.6.6.3 (State transitions)).

#### 14.4.4.2 Creating a new mesh peering instance

The mesh peering instance controller creates a new mesh peering instance after either of the following two events:

- The receipt of a Mesh Peering Open frame from a candidate peer mesh STA according to the rules of 14.4.5 (Mesh peering instance selection)
- The receipt of an MLME-MESHPEERINGMANAGEMENT.request primitive with a Mesh Peering Open frame

A unique localLinkID shall be generated for the mesh peering instance. If the mesh peering instance is established by AMPE, a random local nonce shall also be generated.

A mesh STA may create multiple mesh peering instances to establish a peering with the same candidate peer mesh STA.

#### 14.4.4.3 Deleting mesh peering instances

The mesh peering instance controller deletes a mesh peering instance after any of the following events:

- Expiration of a holding timer (see 14.5.4 (Timers))
- Acceptance of a peer's response to an existing request to close the peering (see 14.5.3 (Events and actions))
- Indication from the SME that the peer mesh STA, or candidate peer mesh STA, has deauthenticated

When the deletion occurs, the mesh PTKSA(#240) that is bound to the mesh peering shall be deleted.


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### 14.4.5 Mesh peering instance selection

The content of a mesh peering Management frame received from a candidate peer mesh STA, and the set of mesh peering instances in the mesh peering instance controller determine whether

— A new mesh peering instance is created (see 14.4.4.2 (Creating a new mesh peering instance)), or

— An existing mesh peering instance is updated.

If dot11MeshSecurityActivated is true and the mesh STA shares a PMK with the candidate peer mesh STA but the Mesh Peering Protocol Identifier field in the Mesh Peering Management element of the frame indicates “mesh peering management protocol,” the frame shall be silently discarded.

If dot11MeshSecurityActivated is true and the mesh STA shares a PMK with the candidate peer mesh STA but either the Authenticated Mesh Peering Exchange element(#3425) or the MIC element are not present in the frame, the frame shall be silently discarded.

If dot11MeshSecurityActivated is false but the Mesh Peering Protocol Identifier field in the Mesh Peering Management element of the received frame indicates “authenticated mesh peering exchange,” the frame shall be silently discarded.

If dot11MeshSecurityActivated is false but either the Authenticated Mesh Peering Exchange element(#3425) or the MIC element is present in the frame, the frame shall be silently discarded.

If the frame contains a group address in TA or RA, it shall be silently discarded.

If the incoming mesh peering Management frame is for AMPE and the Chosen PMK from the received frame contains a PMKID that does not identify a valid mesh PMKSA, the frame shall be silently discarded.

If the mesh peering Management frame has not been silently discarded, the mesh peering instance controller attempts to locate a matching mesh peering instance identifier. A match is determined by comparing the contents of the mesh peering Management frame with each peering instance. A match is found if all of the following conditions are true:

— The transmitter’s MAC address (Address 2) is the same as the peerMAC of the mesh peering instance

— The receiver’s MAC address (Address 1) is the same as the localMAC of the mesh peering instance

— The value of the Peer Link ID field is the same as the localLinkID of the mesh peering instance

If the incoming frame is a Mesh Peering Open frame and no matching peering instance was found, a new mesh peering instance is created (and a new Mesh TSKA if dot11MeshSecurityActivated is true). See 14.4.4.2 (Creating a new mesh peering instance).

If the incoming frame is a Mesh Peering Confirm or Mesh Peering Close frame and no matching mesh peering instance is found, it shall be silently discarded.

If the incoming mesh peering Management frame is for AMPE and has not been discarded it shall be further processed as follows:

— If the Peer Nonce field is present in the received frame, and the localNonce in the mesh peering instance is different from the Peer Nonce field of the received frame, the frame shall be (#3683)discarded.

— If the peerNonce in the mesh peering instance exists and is different from the Local Nonce field of the received frame, the frame shall be (#3683)discarded.

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### 14.4.6 Mesh peering open

#### 14.4.6.1 Generating Mesh Peering Open frames

A Mesh Peering Open frame is generated as a result of a sendOpen() action (see 14.5.3 (Events and actions)).

The contents of the frame are described in 9.6.15.2.2 (Mesh Peering Open frame details).

#### 14.4.6.2 Mesh Peering Open frame processing

The mesh STA checks that the Mesh ID element and Mesh Configuration element of the Mesh Peering Open frame is identical to its own mesh STA configuration as specified in 14.3.3 (Mesh profile) and 14.3.4 (Mesh STA configuration). If a mismatch is found the frame shall be rejected with a reason code of MESH-CONFIGURATION-POLICY-VIOLATION and the mesh peering establishment attempt shall be terminated.

When the mesh STA has established a mesh PMKSA with the candidate peer mesh STA, the mesh peering instance controller shall silently discard the Mesh Peering Open frame in the following two conditions:

— The Mesh Peering Open frame supports MPM protocol and the negotiated active authentication is SAE, or

— The Mesh Peering Open frame supports AMPE but the PMKID in the Chosen PMK field in the Authenticated Mesh Peering Exchange element does not identify a mesh PMKSA.

If the Mesh Peering Open frame is not discarded, the mesh peering instance controller actively rejects or accepts the mesh peering open request (see 14.5 (Mesh peering management finite state machine (MPM FSM))). If dot11MeshAcceptingAdditionalPeerings is(M118) 0 the Mesh Peering Open request shall be rejected with reason code MESH-MAX-PEERS.

If the peerLinkID in the mesh peering instance has not been set, the Local Link ID field of the Mesh Peering Open request shall be copied into the peerLinkID in the mesh peering instance. If the incoming Mesh Peering Open frame is for AMPE and the peerNonce in the mesh peering instance has not been set, the Local Nonce field in the incoming Mesh Peering Open frame shall be copied into the peerNonce in the mesh peering instance.

The mesh peering open request may be rejected due to an internal reason with a reason code of MESH-PEERING-CANCELED.

NOTE—Example internal reasons to reject new mesh peering request could be the mesh STA is configured to reject mesh peering request from another specific peer mesh STA.

If the Mesh Peering Open request is rejected, the REQ_RJCT event shall be passed with the specified reason code to the protocol finite state machine to actively reject the mesh peering open request.

### 14.4.7 Mesh peering confirm

#### 14.4.7.1 Generating Mesh Peering Confirm frames

A Mesh Peering Confirm frame is generated as a result of a sendConfirm() action (see 14.5.3 (Events and actions)).

The contents of the frame are described in 9.6.15.3.2 (Mesh Peering Confirm frame details).


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#### 14.4.7.2 Mesh Peering Confirm frame processing

The mesh STA shall check that the Mesh ID element and Mesh Configuration element of the Mesh Peering Confirm frame match its (#3403)mesh STA configuration as specified in 14.3.3 (Mesh profile) and 14.3.4 (Mesh STA configuration). If a mismatch is found, the frame shall be rejected with the reason code of MESH-INCONSISTENT-PARAMETERS.

If the Mesh Peering Confirm frame is rejected, the (#1620)CNF_RJCT event shall be passed with the specified reason code to the protocol finite state machine to actively reject the mesh peering confirm.

Otherwise, the mesh STA accepts the Mesh Peering Confirm frame and performs the actions described in 14.5 (Mesh peering management finite state machine (MPM FSM)).

If the peerLinkID in the mesh peering instance has not been set, the Local Link ID field of the Mesh Peering Confirm request shall be copied into the peerLinkID in the mesh peering instance. If the incoming Mesh Peering Confirm frame is for AMPE and the peerNonce in the mesh peering instance has not been set, the Local Nonce field in the incoming Mesh Peering Confirm frame shall be copied into the peerNonce in the mesh peering instance.

### 14.4.8 Mesh peering close

#### 14.4.8.1 Generating Mesh Peering Close frames

A Mesh Peering Close frame is generated as a result of a sendClose() action (see 14.5.3 (Events and actions)).

The contents of the frame are described in 9.6.15.4.2 (Mesh Peering Close frame details).

When the Mesh Peering Close is generated as a result of a CNCL event, the reason code is MESH-PEERING-CANCELED. When the Mesh Peering Close is generated as a result of a CLS_ACPT event, the reason code is MESH-CLOSE-RCVD.

#### 14.4.8.2 Mesh Peering Close frame processing

The mesh STA shall reject the Mesh Peering Close frame if the value in the Mesh ID element is not the same as the mesh STA's mesh profile. Otherwise, the mesh STA accepts the Mesh Peering Close frame and performs the actions described in 14.5 (Mesh peering management finite state machine (MPM FSM)).

## 14.5 Mesh peering management finite state machine (MPM FSM)

### 14.5.1 General

Each mesh peering instance, including its states and resource, are managed by a mesh peering management finite state machine (MPM FSM). The MPM FSM uses MLME primitives to control the mesh STA to send and receive mesh peering Management frames.

### 14.5.2 States

The MPM FSM uses the following six states:

— IDLE. IDLE state is a terminal state. In the IDLE state, the MPM FSM is ready to start a new mesh peering instance by either passively listening for an incoming Mesh Peering Open frame or actively initiating a mesh peering instance.

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- OPN_SNT. In the OPN_SNT state, the finite state machine has sent a Mesh Peering Open frame and is waiting for a Mesh Peering Open frame and Mesh Peering Confirm frame from the candidate peer mesh STA.
- CNF_RCVD. In the CNF_RCVD state, the finite state machine has received a Mesh Peering Confirm frame, but has not received a Mesh Peering Open frame. The mesh STA has not sent the corresponding Mesh Peering Confirm frame yet.
- OPN_RCVD. In the OPN_RCVD state, the finite state machine has received only the Mesh Peering Open frame but not the Mesh Peering Confirm. The mesh STA has also sent a Mesh Peering Confirm frame upon receiving a Mesh Peering Open frame.
- ESTAB. In the ESTAB state, the finite state machine has received both the Mesh Peering Open and Mesh Peering Confirm frames. The mesh STA has also sent both the Mesh Peering Open frame and Mesh Peering Confirm frame. The mesh peering is established and configured for exchanging frames with the peer mesh STA in the ESTAB state.
- HOLDING. In the HOLDING state, the finite state machine is closing the mesh peering instance with the peer mesh STA or the candidate peer mesh STA.

### 14.5.3 Events and actions

The finite state machine uses three types of events: 1) events for state machine transitions; 2) external events generated by frame processing; and 3) events associated with internal timers.

The events for state machine transitions are as follows:

- CNCL(localLinkID, peerMAC, ReasonCode). Used to instruct the mesh peering instance to cancel the mesh peering with the peer mesh STA. localLinkID identifies the MPM FSM for the corresponding mesh peering instance. peerMAC is the MAC address of the peer mesh entity. ReasonCode is used to inform the reason to cancel the mesh peering instance. See 14.4.8.2 (Mesh Peering Close frame processing).
- ACTOPN(peerMAC, localLinkID). The SME uses this event to create a new mesh peering instance to actively initiate the mesh peering establishment with the candidate peer mesh STA whose MAC address is peerMAC. localLinkID identifies the MPM FSM.

The events generated by frame processing are as follows:

- OPN_ACPT. PeeringOpen_Accept(peerMAC, peerLinkID) event indicates that a Mesh Peering Open frame meeting the correctness criteria of 14.4.6 (Mesh peering open) has been received from peerMAC for the mesh peering instance identified by peerLinkID.
- OPN_RJCT. PeeringOpen_Reject(peerMAC, peerLinkID, meshConfiguration, reasonCode) event indicates that a Mesh Peering Open frame from peerMAC for the mesh peering instance identified by peerLinkID is rejected due to incomplete or erroneous mesh STA configuration (see 14.3.4 (Mesh STA configuration)), as indicated by meshConfiguration, with reasonCode being the specific reason for rejection of the Mesh Peering Open frame. See 14.4.6.2 (Mesh Peering Open frame processing).
- CNF_ACPT. PeeringConfirm_Accept(peerMAC, localLinkID, peerLinkID) event indicates that a Mesh Peering Confirm frame meeting the correctness criteria of 14.4.7 (Mesh peering confirm) has been received from peerMAC for the mesh peering instance identified by localLinkID and peerLinkID.
- CNF_RJCT. PeeringConfirm_Reject(peerMAC, localLinkID, peerLinkID, reasonCode) event indicates that a Mesh Peering Confirm frame from peerMAC for the mesh peering instance identified by localLinkID and peerLinkID is rejected due to incomplete or erroneous configuration, and reasonCode is the specific reason for rejection of the Confirm frame. See 14.4.7.2 (Mesh Peering Confirm frame processing).


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— CLS_ACPT. PeeringClose_Accept(peerMAC, localLinkID, peerLinkID, reasonCode) event indicates that a Mesh Peering Close frame meeting the correctness criteria of 14.4.8 (Mesh peering close) has been received from peerMAC for the mesh peering instance identified by localLinkID and peerLinkID. The reasonCode specifies the reason that caused the generation of the Mesh Peering Close frame. See 14.4.8.2 (Mesh Peering Close frame processing).

— REQ_RJCT. PeeringRequest_Reject(peerMAC, peerLinkID, reasonCode) event indicates a special incidence that the mesh STA rejects the incoming Mesh Peering Open frame requesting to set up a new mesh peering for some specified reason. The incoming request is identified by the peerMAC, peerLinkID is the peerLinkID received from the Mesh Peering Open frame, and reasonCode is the specific reason for rejection of the Mesh Peering Open frame. See 14.4.6.2 (Mesh Peering Open frame processing).

The finite state machine may take an action triggered by an event. It uses two types of actions: sending a mesh peering Management frame and handling a timer.

Actions related to sending a mesh peering Management frame are as follows:

— sndOPN. sendOpen(peerMAC, localLinkID, meshConfiguration) is the action that the mesh STA takes to send its localLinkID and mesh STA Configuration in a Mesh Peering Open frame to the candidate peer mesh STA, whose MAC address is peerMAC. The MLME-MESHPEERINGMANAGEMENT.request primitive shall be invoked to send the frame to the peer mesh entity.

— sndCNF. sendConfirm(peerMAC, localLinkID, peerLinkID, meshConfiguration) is the action that the mesh STA takes to send its localLinkID and meshConfiguration in a Mesh Peering Confirm frame to the candidate peer mesh STA, whose MAC address is peerMAC. peerLinkID is the peerLinkID received from the Mesh Peering Open frame. The MLME-MESHPEERINGMANAGEMENT.request primitive shall be invoked to send the frame to the peer mesh entity.

— sndCLS. sendClose(peerMAC, localLinkID, peerLinkID, reasonCode) is the action that the mesh STA takes to send its localLinkID in a Mesh Peering Close frame to the peer mesh STA or candidate peer mesh STA, whose MAC address is peerMAC. peerLinkID is the peerLinkID received from the Mesh Peering Open frame, and reasonCode is the specific reason for closing the mesh peering. The MLME-MESHPEERINGMANAGEMENT.request primitive shall be invoked to send the frame to the peer mesh entity.

### 14.5.4 Timers

The following three timers are used by the finite state machine:

a) The retryTimer triggers a resend of the Mesh Peering Open frame when a Mesh Peering Confirm frame was not received as a response. The retryTimer is set to the dot11MeshRetryTimeout.

b) The confirmTimer signals that a link establishment attempt should be aborted because a Mesh Peering Confirm frame responding to a Mesh Peering Open frame was never received. The confirmTimer is set to dot11MeshConfirmTimeout.

c) The holdingTimer signals that its mesh peering instance may be completely closed and facilitates graceful shutdown. The holdingTimer is set to dot11MeshHoldingTimeout.

The events associated with internal timers are represented in the state machine table as acronyms that indicate timer expiration. With each timer event there is an associated action.

— TOR1. This event indicates that the retryTimer has expired and the retry counter is less than dot11MeshMaxRetries. The Mesh Peering Open frame shall be resent, an action represented in the state machine table by setR.

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— TOR2. This event indicates that the retryTimer has expired and the retryCounter is equal to dot11MeshMaxRetries. The mesh peering instance shall be closed when TOR2 occurs.

— TOC. This event indicates that the confirmTimer has expired. When TOC event occurs, the mesh peering instance shall be closed, an action represented in the state machine table as setC.

— TOH. This event indicates that the holdingTimer has expired. When TOH occurs, the mesh peering instance shall be closed and the finite state machine shall transition to IDLE state, an action represented in the state machine table as setH.

### 14.5.5 State transitions

Table 14-2 (MPM finite state machine) and Figure 14-2 (Finite state machine of the MPM protocol) summarize the state transitions for the MPM protocol.

In Table 14-2 (MPM finite state machine), each row represents state transitions from the state to all other states. A blank entry indicates an impossible transition.

**Table 14-2—MPM finite state machine**

| From State | To State | | | | | |
|---|---|---|---|---|---|---|
| | **IDLE** | **OPN_SNT** | **CNF_RCVD** | **OPN_RCVD** | **ESTAB** | **HOLDING** |
| **IDLE** | REQ_RJCT / sndCLS | ACTOPN / (sndOPN, setR) | | OPN_ACPT/ (sndOPN, sndCNF, setR) | | |
| **OPN_SNT** | | TOR1 / (sndOPN, setR) | CNF_ACPT / (clR, setC) | OPN_ACPT/ (sndCNF) | | CLS_ACPT, OPN_RJCT, CNF_RJCT, TOR2, CNCL / (sndCLS, clR, setH) |
| **CNF_RCVD** | | | | | OPN_ACPT / (clC, sndCNF) | CLS_ACPT, OPN_RJCT, CNF_RJCT, CNCL / (sndCLS, clC, setH)<br>TOC / (sndCLS, setH) |
| **OPN_RCVD** | | | | OPN_ACPT/ sndCNF<br>TOR1 / (sndOPN, setR) | CNF_ACPT / clR | CLS_ACPT, OPN_RJCT, CNF_RJCT,TOR2, CNCL / (sndCLS, clR, setH) |
| **ESTAB** | | | | | OPN_ACPT / sndCNF | CLS_ACPT, OPN_RJCT, CNF_RJCT, CNCL / (sndCLS, setH) |
| **HOLDING** | TOH / —, CLS_ACPT / clH | | | | | OPN_ACPT, CNF_ACPT, OPN_RJCT, CNF_RJCT / sndCLS |


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In Figure 14-2 (Finite state machine of the MPM protocol), each arrow represents a state transition.

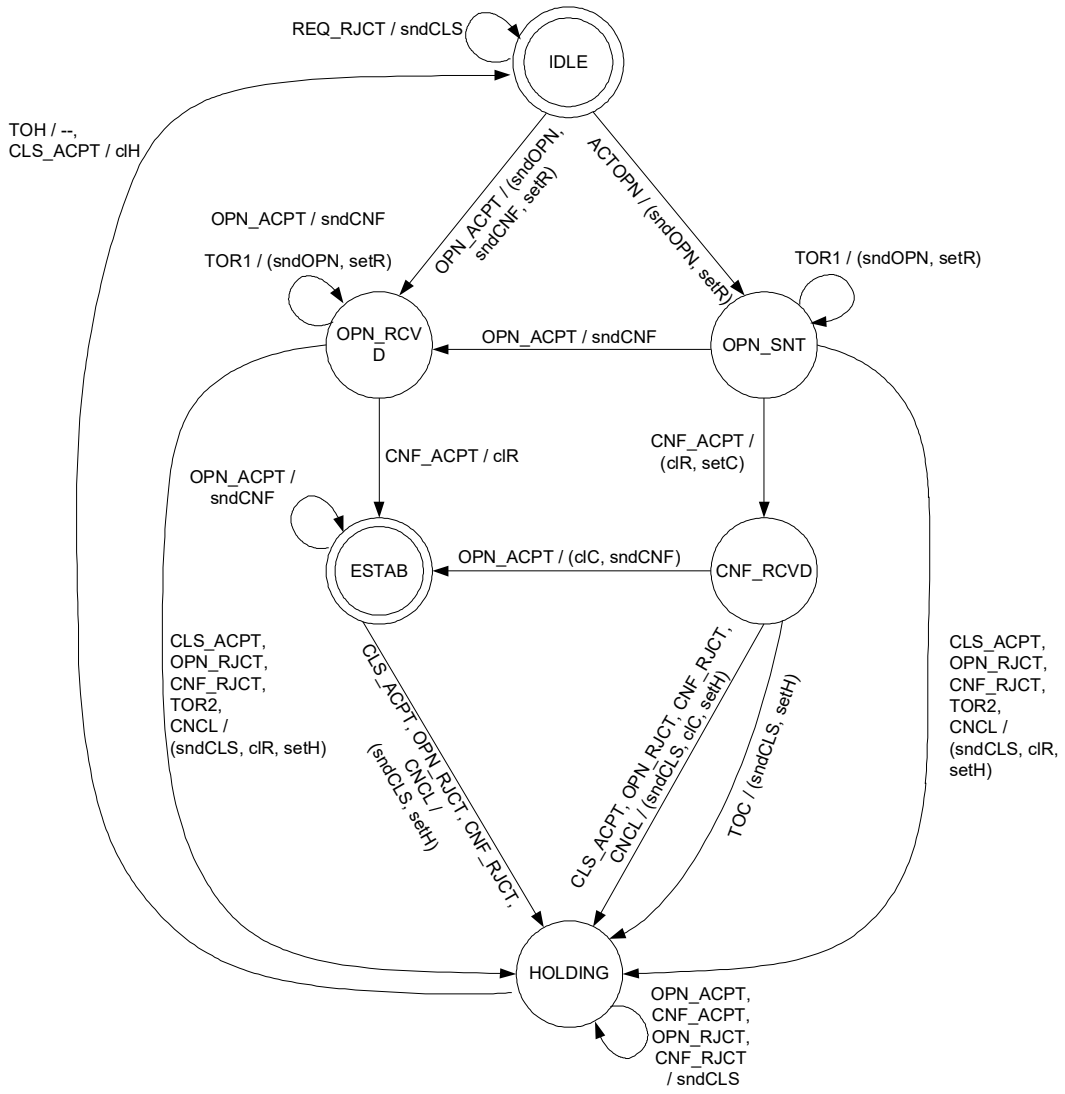


**Figure 14-2—Finite state machine of the MPM protocol**

The event/action representation is defined as the following. “E/A” string represents that the action A is taken given that the event E occurs. “E1, E2/A” string represents that the action A is taken given that the event E1 or event E2 occurs. “E/(A1, A2)” string represents that the action A1 and A2 are taken at a time when event E occurs.

Note that Table 14-2 (MPM finite state machine) and Figure 14-2 (Finite state machine of the MPM protocol) are used for illustration purposes. The protocol behavior is in the following subclauses.

### 14.5.6 IDLE state

IDLE is a quiescent state the finite state machine enters prior to establishing a new mesh peering.

When ACTOPN event occurs, the mesh STA shall set a retryCounter to 0, and perform a sndOPN action. The retryTimer shall be set and the finite state machine shall transition to OPN_SNT state.

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When an OPN_ACPT event occurs, the mesh STA shall perform a sndOPN action and sndCNF action, and set the retryTimer. The finite state machine shall transition to OPN_RCVD state.

When an REQ_RJCT event occurs, a Mesh Peering Close frame shall be sent to reject the mesh peering open request. The reason code in the Mesh Peering Close frame shall be set to the reason code in REQ_RJCT event. The finite state machine shall stay in the IDLE state.

All other events are ignored in this state.

### 14.5.7 OPN_SNT state

In the OPN_SNT state, the mesh STA waits for a Mesh Peering Confirm frame. In this state, the retryTimer is set.

When a CNCL event occurs, the mesh STA shall clear the retryTimer, perform a sndCLS using the reason code specified by the CNCL event, and set the holdingTimer. The finite state machine shall transition to HOLDING state.

When a CLS_ACPT event occurs, the mesh STA shall clear the retryTimer, perform a sndCLS using the reason code specified by the CLS_ACPT event, and set the holdingTimer. The finite state machine shall transition to HOLDING state.

When an OPN_ACPT event occurs, the mesh STA shall send perform a sndCNF action. The finite state machine shall transition to OPN_RCVD state.

NOTE—The retryTimer is still in effect after the state transition.

When an OPN_RJCT event occurs, the mesh STA shall clear the retryTimer, perform a sndCLS using the reason code specified by the OPN_RJCT event, and set the holdingTimer. The finite state machine shall transition to HOLDING state.

When a CNF_ACPT event occurs, the mesh STA shall clear the retryTimer and shall set the confirmTimer and the finite state machine shall transition to CNF_RCVD state.

When a CNF_RJCT event occurs, the mesh STA shall clear the retryTimer, perform a sndCLS action using the reason code specified by the CNF_RJCT event, and set the holdingTimer. The finite state machine shall transition to HOLDING state.

When a TOR1 event occurs, the Mesh STA shall perform a sndOPN action and the retryCounter shall be incremented. The retryTimer shall be and the finite state machine shall stay in the OPN_SNT state.

When a TOR2 event occurs, the mesh STA shall perform a sndCLS action using the reason code MESH-MAX-RETRIES. The holdingTimer shall be set, and the finite state machine shall transition to HOLDING state.

All other events shall be ignored in this state.

### 14.5.8 CNF_RCVD state

In the CNF_RCVD state, the mesh STA has received a Mesh Peering Confirm frame and is waiting for a Mesh Peering Open frame.


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When a CNCL event occurs, the mesh STA shall clear the confirmTimer, perform a sndCLS action using the reason code MESH-PEERING-CANCELED, and set the holdingTimer. The finite state machine shall transition to HOLDING state.

When a CLS_ACPT event occurs, the mesh STA shall clear the confirmTimer, perform a sndCLS using the reason code MESH-CLOSE-RCVD, and set the holdingTimer. The finite state machine shall transition to HOLDING state.

When an OPN_ACPT event occurs, the mesh STA shall clear the confirmTimer and shall perform a sndCNF action. The finite state machine shall transition to ESTAB state.

When an OPN_RJCT event occurs, the mesh STA shall clear the confirmTimer, perform a sndCLS action using the reason code as specified by the OPN_RJCT event, and set the holdingTimer. The finite state machine shall transition to HOLDING state.

When a CNF_RJCT event occurs, the mesh STA shall clear the confirmTimer, perform a sndCLS action using the reason code as specified by the CNF_RJCT event, and set the holdingTimer The finite state machine shall transition to HOLDING state.

When TOC event occurs, the mesh STA shall perform a sndCLS action using the reason code MESH-CONFIRM-TIMEOUT and set the holdingTimer. The finite state machine shall transition to HOLDING state.

All other events shall be ignored in this state.

### 14.5.9 OPN_RCVD state

In the OPN_RCVD state, the mesh STA has received a Mesh Peering Open frame and sent a Mesh Peering Open frame and the corresponding Mesh Peering Confirm frame. An incoming Mesh Peering Confirm is expected.

When a CNCL event occurs, the mesh STA shall clear the retryTimer, perform a sndCLS action using the reason code MESH-PEERING-CANCELED, and set the holdingTimer. The finite state machine shall transition to HOLDING state.

When a CLS_ACPT event occurs, the mesh STA shall clear the retryTimer, perform a sndCLS action, and set the holdingTimer. The finite state machine shall transition to HOLDING state.

When an OPN_ACPT event occurs, the mesh STA shall perform a sndCNF action. The finite state machine shall stay in the OPN_RCVD state.

When an OPN_RJCT event occurs, the mesh STA shall clear the retryTimer, perform a sndCLS action using the reason code as specified by the OPN_RJCT event, and set the holdingTimer. The finite state machine shall transition to HOLDING state.

When a CNF_ACPT event occurs, the retryTimer shall be cleared. The finite state machine shall transition to ESTAB state.

When a CNF_RJCT event occurs, the mesh STA shall clear the retryTimer, perform a sndCLS action using the reason code as specified by the CNF_RJCT event, and set the holdingTimer. The finite state machine shall transition to HOLDING state.

When a TOR1 event occurs, the Mesh STA shall perform a sndOPN action, increment the retryCounter, and set the retryTimer. The finite state machine shall stay in the OPN_RCVD state.

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When a TOR2 event occurs, the mesh STA shall perform a sndCLS action using the reason code MESH-MAX-RETRIES. The holdingTimer shall be set, and the finite state machine shall transition to HOLDING state.

All other events shall be ignored in this state.

#### 14.5.10 ESTAB state

In the ESTAB state, mesh peering has been successfully established with the peer mesh STA.

When a CNCL event occurs, the mesh STA shall perform a sndCLS action using the reason code MESH-PEERING-CANCELED, and set the holdingTimer. The finite state machine shall transition to HOLDING state.

When a CLS_ACPT event occurs, the mesh STA shall perform a sndCLS action using the reason code MESH-CLOSE-RCVD, and set the holdingTimer. The finite state machine shall transition to HOLDING state.

When an OPN_RJCT event occurs, the mesh STA shall perform a sndCLS action using the reason code as specified by the OPN_RJCT event, and set the holdingTimer. The finite state machine shall transition to HOLDING state.

When a CNF_RJCT event occurs, the mesh STA shall perform a sndCLS action using the reason code as specified by the CNF_RJCT event, and set the holdingTimer. The finite state machine shall transition to HOLDING state.

When an OPN_ACPT event occurs, the mesh STA shall respond by performing a sndCNF action. The finite state machine shall stay in the ESTAB state.

All other events shall be ignored in this state.

#### 14.5.11 HOLDING state

In HOLDING state, the mesh STA is closing the mesh peering. The holdingTimer has been set according to the value of dot11MeshHoldingTimeout.

When a CLS_ACPT event occurs, the holdingTimer shall be cleared. The finite state machine shall transition to IDLE state.

When any of the following four events occurs—OPN ACPT, CNF_ACPT, OPN_RJCT, CNF_RJCT—the mesh STA shall send a Mesh Peering Close frame. The finite state machine shall stay in the HOLDING state.

When a TOH event occurs, the finite state machine shall transition to IDLE state.

All other events are ignored in this state.

### 14.6 Authenticated mesh peering exchange (AMPE)

#### 14.6.1 Overview

The authenticated mesh peering exchange (AMPE) establishes an authenticated mesh peering between mesh STAs (#1794)that have established a mesh PMKSA before the initiation of the protocol. An authenticated


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mesh peering includes a mesh peering, corresponding mesh PTKSA(#240), and the two mesh STAs'(#241) mesh GTKSAs.

The AMPE is also used to establish an authenticated peering between two APs that support the AP PeerKey protocol (as defined in 12.10 (AP PeerKey support)) (#1794)and that have established a PMK and PMKID before the initiation of the AMPE exchange.

The AMPE uses mesh peering Management frames. Parameters are exchanged via the RSNE, the Authenticated Mesh Peering Exchange element, and the MIC element.

The major functions provided by AMPE are security capabilities selection, key confirmation, and key management.

— The security capabilities selection function (specified in 14.6.2 (Security capabilities selection)) is performed by agreeing on the security parameters used for the protocol instance.
— Key confirmation using the shared PMK is performed by verifying that the protection on the mesh peering Management frame is correct.
— Key management (specified in 14.6.7 (Keys and key derivation algorithm for the authenticated mesh peering exchange (AMPE))) is performed by the derivation of the temporal key in the mesh PTKSA(#240) and the exchange of each mesh STA's MGTK.

During the AMPE handshake, the mesh STAs generate nonces and transmit them via mesh peering Management frames. The mesh STA shall generate a random value for its localNonce, as specified in 12.7.5 (Nonce generation). The candidate peer mesh STA is expected to generate a random value for the peerNonce, which the mesh STA receives from the candidate peer mesh STA in Confirm and Close Action frames.

Mesh peering Management frames used in the AMPE are protected using the deterministic authenticated encryption mode of AES-SIV (IETF RFC 5297).

### 14.6.2 Security capabilities selection

#### 14.6.2.1 Instance Pairwise Cipher Suite selection

Pairwise cipher suite (#3056)selector TKIP shall not be used as the pairwise cipher suite when dot11MeshSecurityActivated, dot11ProtectedTXOPNegotiationActivated, or dot11ProtectedQLoadReportActivated is true.

If the pairwise cipher suite has not been selected, a STA shall attempt to reach the agreement on the pairwise cipher suite using the following procedure in four steps:

a) The STA shall announce the list of pairwise cipher suites it supports using an ordered list in the RSNE in the Mesh Peering Open frame. The first value in the list is the STA's most preferred cipher suite, and the last value the least preferred.
b) If the STA receives a Mesh Peering Open frame from the candidate peer STA, the STA shall make its decision on the selected pairwise cipher suite based on the intersection of its own ordered list and the received ordered list.
    1) If the intersection is empty, the pairwise cipher suite selection fails and the STA generates the failure reason code MESH-INVALID-SECURITY-CAPABILITY and then takes the corresponding actions specified in 14.6.6 (AMPE finite state machine).
    2) If the intersection contains more than one value, the selected cipher suite shall be the entry in the intersection list most preferred by the STA that has the largest MAC address in the lexicographic ordering.

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c) If the STA receives a Mesh Peering Confirm frame from the candidate peer STA before receiving a Mesh Peering Open frame, the STA shall verify that it supports the pairwise cipher suite chosen by the candidate peer STA. Otherwise, the selection fails and the STA shall generate the failure reason code MESH-INVALID-SECURITY-CAPABILITY.
Furthermore, upon receiving a Mesh Peering Open frame, the STA shall verify that the accepted selected pairwise cipher suite matches the pairwise cipher suite chosen in step b). If they do not match, the selection fails and the STA shall generate the failure reason code MESH-INVALID-SECURITY-CAPABILITY. Otherwise, the pairwise cipher suite selection succeeds, and the STA shall proceed to step d).

d) If the STA is generating a Mesh Peering Confirm frame, it shall set the Selected Pairwise Cipher Suite to the selected pairwise cipher suite upon successful pairwise cipher suite selection.

#### 14.6.2.2 Group data cipher suite and group management cipher suite selection(#6020)

Group data cipher suite(#6020) (#3056)selector TKIP shall not be used as the group data cipher suite(#6020) when dot11MeshSecurityActivated is true.

The mesh STA shall not use a different group data cipher suite or a different group management cipher suite (if management frame protection is enabled)(#6020) than the one used by the peer mesh STA or candidate peer mesh STA in the same MBSS.

A mesh STA shall announce in a Mesh Peering Open frame the group data cipher suite and group management cipher suite (if management frame protection is enabled)(#6020) it uses for broadcast protection. When it receives a Mesh Peering Open frame from a candidate peer, it shall verify that it supports the candidate's announced group data cipher suite and group management cipher suite (if management frame protection is enabled)(#6020). In addition, if the mesh STA receives a Mesh Peering Confirm frame, it shall verify that it supports the group data cipher suite and group management cipher suite (if management frame protection is enabled)(#6020) listed in that frame. If either selection fails, the mesh STA shall issue the appropriate reply frame with the MESH-INVALID-SECURITY-CAPABILITY reason code.

### 14.6.3 Construction and processing AES-SIV-protected mesh peering Management frames

AES-SIV performs deterministic authenticated encryption and takes additional data that is authenticated but not encrypted (AAD). When encrypting and authenticating, AES-SIV takes a key, plaintext data to protect, and multiple distinct components of AAD, to produce a synthetic initialization vector and a cipher text. When verifying encrypted and authenticated data AES-SIV takes a key, a synthetic initialization vector, cipher text data to decrypt and verify, and AAD, to produce either plaintext or the symbol "FAIL," indicating failure to decrypt and verify. Note that the AAD used in the encryption process shall be identical to the AAD used in the decryption process and the synthetic initialization vector produced by the encryption process shall be used in the decryption process.

When the mesh STA constructs a mesh peering Management frame, it shall follow the following procedure:

- The input key shall be the AEK
- The input plaintext shall be the Authenticated Mesh Peering Exchange element(#3425) (see 9.6.15.2 (Mesh Peering Open frame format), 9.6.15.3 (Mesh Peering Confirm frame format), and 9.6.15.4 (Mesh Peering Close frame format))
- The input AAD shall be three distinct components consisting of
  - The localMAC
  - The peerMAC
  - The contents of the mesh peering Management frame from the category (inclusive) to the MIC element (exclusive)


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- The output synthetic initialization vector shall be copied into the MIC field of the MIC element in the mesh peering Management frame
- The output cipher text shall become the remainder of the (M118)mesh peering management frame body (#1767)after the MIC element

When the mesh STA verifies a mesh peering Management frame, it shall follow the following procedure:

- The input key shall be the AEK
- The input synthetic initialization vector shall be the MIC field of the MIC element in the mesh peering Management frame
- The input cipher text shall be the part of the (M118)mesh peering management frame body (#1767) following the MIC element
- The input AAD shall be three distinct components consisting of
  - The peerMAC
  - The localMAC
  - The contents of the mesh peering Management frame from the category (inclusive) to the MIC element (exclusive)
- If AES-SIV returns the symbol "FAIL" processing of the frame shall be deemed a failure with a behavior dependent on the type of mesh peering Management frame
- If AES-SIV returns plaintext it shall be treated as the components of the mesh peering Management frame and processed accordingly

### 14.6.4 Distribution of group keys in an MBSS(#1521)

The MGTK shall be a random or pseudorandom number. The mesh STA shall distribute the MGTK to the peer mesh STA using the Mesh Peering Open frame during the AMPE. Upon successful completion of AMPE, each mesh STA shall establish states for the peer mesh STA's mesh GTKSA. The GTKdata subfield in the Authenticated Mesh Peering Exchange element shall contain the MGTK concatenated with the (#1406)RSC and the GTKExpirationTime (as specified in 9.4.2.116 (Authenticated Mesh Peering Exchange element)).

When dot11RSNAProtectedManagementFramesActivated is true, a mesh STA shall distribute the IGTK to the peer mesh STA using the Mesh Peering Open frame during the AMPE. Upon successful completion of AMPE, each mesh STA shall establish an IGTKSA (see 12.6.1.1.9 (IGTKSA)) with the mesh peer. The IGTKdata subfield in the Authenticated Mesh Peering Exchange element(#3425) shall contain the (#3493)key ID concatenated with the IPN and the IGTK (as specified in 9.4.2.116 (Authenticated Mesh Peering Exchange element)).

### 14.6.5 Mesh peering Management frames for AMPE

#### 14.6.5.1 General

The AMPE is inclusive of the mesh peering management (MPM) protocol. mesh peering Management frames for AMPE have additional processing and construction requirements on top of those for mesh peering Management frames.

The mesh peering Management frames shall be generated with additional information using the RSNE and the Authenticated Mesh Peering Exchange element to support AMPE.

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#### 14.6.5.2 Mesh peering open for AMPE

##### 14.6.5.2.1 Generating Mesh Peering Open frames for AMPE

In addition to contents for establishing a mesh peering as specified in 14.4.6.1 (Generating Mesh Peering Open frames), the Mesh Peering Open frame, if used for the AMPE, shall contain the following:

- In the Mesh Peering Management element, the Mesh Peering Protocol Identifier shall be set to 1 "authenticated mesh peering exchange protocol."
- In the Mesh Peering Management element, the Chosen PMK field shall be set to PMKID that identifies the mesh PMKSA the mesh STA established with the candidate peer mesh STA.
- The RSNE shall be identical to the RSNE in the STA's Beacon and Probe Response frames.
- In the Authenticated Mesh Peering Exchange element:
  - The Selected Pairwise Cipher Suite field shall be set to the first cipher suite selector in the Pairwise Cipher Suite List field in (#6299)the RSNE.
  - The Local Nonce field shall be set to the localNonce value generated by the mesh STA for identifying the current mesh peering instance.
  - The Peer Nonce field shall be set to 0.
  - If dot11MeshSecurityActivated is true, the GTKdata field shall be present and shall contain the data for the mesh STA's MGTK. The GTKdata field shall not be present when AMPE is being used as part of the AP PeerKey protocol (12.10.2 (AP PeerKey protocol)). The components of the GTKdata field are specified in 14.6.4 (Distribution of group keys in an MBSS(#1521)).

The Mesh Peering Open frame shall be protected using AES-SIV as specified in 14.6.3 (Construction and processing AES-SIV-protected mesh peering Management frames).

##### 14.6.5.2.2 Processing Mesh Peering Open frames for AMPE

On receiving a Mesh Peering Open frame, the mesh STA shall verify the received frame. If AES-SIV returns the symbol "FAIL" the OPN_RJCT event shall be invoked to the corresponding AMPE finite state machine and the reason code "MESH-INVALID-GTK" is generated. Otherwise, processing continues.

The received frame shall be rejected if the security capability selection fails (see 14.6.2 (Security capabilities selection)). The OPN_RJCT event shall be invoked to the corresponding AMPE finite state machine.

If dot11RSNAOperatingChannelValidationActivated is true and the received RSNE indicates OCVC(#3505), the mesh STA shall validate the OCI element in the Mesh Peering Open frame by ensuring that all of the following are true:

- OCI element is present
- Channel information in the OCI matches current operating channel parameters (see 12.2.10 (Requirements for Operating Channel Validation))

Otherwise, the mesh STA shall discard the frame.

The peer mesh STA's MGTK extracted from the Mesh Peering Open frame shall be added to the Receive MGTK SA in which the peer's MAC address equals the (#4212)MGTK source mesh STA MAC address.

If all operations succeed, the mesh STA shall proceed to process the Mesh Peering Open frame on basic parameters as specified in 14.4.6.2 (Mesh Peering Open frame processing).


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#### 14.6.5.3 Mesh peering confirm for AMPE

##### 14.6.5.3.1 Generating Mesh Peering Confirm frames for AMPE

In addition to contents for establishing a mesh peering as specified in 14.4.7.1 (Generating Mesh Peering Confirm frames), the Mesh Peering Confirm frame, when used with the AMPE, shall contain the following:

- In the Mesh Peering Management element, the Mesh Peering Protocol Identifier shall be set to 1 "authenticated mesh peering exchange protocol."
- The RSNE shall be the same as sent in the Mesh Peering Open frame.
- In the Authenticated Mesh Peering Exchange element:
  - The Selected Pairwise Cipher Suite field shall be set to the cipher suite selector that indicates the successfully selected pairwise cipher suite (specified in 14.6.2.1 (Instance Pairwise Cipher Suite selection)).
  - The Peer Nonce field shall be set to the nonce value chosen by the peer mesh STA as received in the Local Nonce field in the Mesh Peering Open frame from the candidate peer mesh STA.
  - The GTKdata field shall not be present.
  - The IGTKdata field shall not be present.
  - The rest of fields are set to the same values sent in the Mesh Peering Open frame.

The Mesh Peering Confirm frame shall be protected using AES-SIV as specified in 14.6.3 (Construction and processing AES-SIV-protected mesh peering Management frames).

##### 14.6.5.3.2 Processing Mesh Peering Confirm frames for AMPE

On receiving a Mesh Peering Confirm frame, the mesh STA shall verify the received frame. The received frame shall be discarded if AES-SIV returns the symbol "FAIL."

If AES-SIV returns plaintext, the following operations shall be performed in order:

a) The Selected Pairwise Cipher Suite is checked. If the security capability selection has been done and the received value from Chosen Pairwise Cipher Suite field is not the same as the agreed pairwise cipher suite, the STA shall reject the received frame and the CNF_RJCT event is invoked to the corresponding AMPE finite state machine with the failure reason code MESH-INVALID-SECURITY-CAPABILITY.

b) If dot11MeshSecurityActivated is true the group data cipher suite is checked and group management cipher suite (if management frame protection is enabled)(#6020) is checked. If the received group data cipher suite or received group management cipher suite(#6020) is not supported by the mesh STA, the mesh STA shall reject the received Mesh Peering Confirm frame and the CNF_RJCT event is invoked to the corresponding AMPE finite state machine with the failure reason code MESH-INVALID-SECURITY-CAPABILITY.

c) If dot11RSNAOperatingChannelValidationActivated is true and the received RSNE indicates OCVC(#3505), the mesh STA shall validate the OCI element in the Mesh Peering Confirm frame by ensuring that all of the following are true:
   - OCI element is present
   - Channel information in the OCI matches current operating channel parameters (see 12.2.10 (Requirements for Operating Channel Validation))

   Otherwise, the mesh STA shall discard the frame.

If none of the cases is true, the mesh STA shall proceed to process the Mesh Peering Confirm Action frame on basic parameters as specified in 14.4.7.2 (Mesh Peering Confirm frame processing).

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#### 14.6.5.4 Mesh peering close for AMPE

##### 14.6.5.4.1 Generating Mesh Peering Close frames for AMPE

In addition to contents for closing a mesh peering as specified in 14.4.8.1 (Generating Mesh Peering Close frames), the Mesh Peering Close frame, when used for the AMPE, shall contain the following:

- In the Mesh Peering Management element, the Mesh Peering Protocol Identifier shall be set to 1 "authenticated mesh peering exchange protocol."
- In the Mesh Peering Management element, the Chosen PMK field shall be set to the same value as sent in the Mesh Peering Open frame.
- In the Authenticated Mesh Peering Exchange element:
  - The Selected Pairwise Cipher Suite field shall be set to the same value as sent in the Mesh Peering Open frame.

    NOTE—If the reason for sending the Mesh Peering Close is the pairwise cipher suite selection failure, the information in this field is used to inform the candidate peer mesh STA what was announced by the mesh STA for the mesh peering instance.
  - The Local Nonce field shall be set to the same value as sent in the Mesh Peering Open frame.
  - The Peer Nonce field shall be set to the same value as received in the Local Nonce field of the Authenticated Mesh Peering Exchange element of the incoming mesh peering Management frame from the candidate peer mesh STA.

The Mesh Peering Close frame shall be protected using AES-SIV as specified in 14.6.3 (Construction and processing AES-SIV-protected mesh peering Management frames).

##### 14.6.5.4.2 Processing Mesh Peering Close frames for AMPE

On receiving a Mesh Peering Close frame, the mesh STA shall verify the received frame. The received frame shall be discarded if AES-SIV returns the symbol "FAIL."

If AES-SIV returns plaintext, the mesh STA shall proceed to process the Mesh Peering Close frame on basic parameters as specified in 14.4.8.2 (Mesh Peering Close frame processing).

### 14.6.6 AMPE finite state machine

#### 14.6.6.1 Overview

The finite state machine for AMPE supports all of the states, events, and actions defined for the finite state machine for the MPM protocol. In addition, new events, actions, and state transitions are added to specify the security functions for AMPE.

When a finite state machine is generated and activated for an AMPE instance, the localNonce shall be generated and used together with a new localLinkID to identify the instance.

#### 14.6.6.2 Additional events and actions to MPM FSM

All events for rejecting or ignoring received Action frames shall report the corresponding reason code related to AMPE functions as described in 14.6.5 (Mesh peering Management frames for AMPE).

In addition, there is one new event as follows:

- TOR3—This event indicates that the retryTimer has expired, the dot11MeshMaxRetries has been reached, the AMPE is enabled, but the mesh STA failed to confirm the selection of the shared mesh


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PMKSA. When this event triggers, the protocol instance shall be closed, but no Mesh Peering Close frame shall be sent.

The actions of sending mesh peering Management frames are updated as the following:

— sndOPN—Generate a Mesh Peering Open frame for the current AMPE protocol instance (as specified in 14.6.5.2.1 (Generating Mesh Peering Open frames for AMPE)) and send it to the candidate peer mesh STA.

— sndCNF—Generate a Mesh Peering Confirm frame for the current AMPE protocol instance (as specified in 14.6.5.3.1 (Generating Mesh Peering Confirm frames for AMPE)) and send it to the candidate peer mesh STA.

— sndClose—Generate a Mesh Peering Close frame for the current AMPE protocol instance (as specified in 14.6.5.4.1 (Generating Mesh Peering Close frames for AMPE)) and send it to the candidate peer mesh STA.

#### 14.6.6.3 State transitions

All state transitions specified in MPM FSM shall be used for AMPE finite state machine.

In OPN_SNT state, the following are additional state transitions and actions:

When TOR3 event occurs, the retryTimer shall be cleared and the holdingTimer shall be set. The finite state machine shall transition to HOLDING state.

In OPN_RCVD state, the following are the additional actions:

When CNF_ACPT event occurs, in addition to the actions for MPM protocol, the mesh STA shall signal the completion of key management by utilizing the MLME-SETKEYS.request primitive to configure the agreed-upon mesh temporal pairwise key into the IEEE 802.11 MAC and by calling the MLME-SETPROTECTION.request primitive to enable its use.

In CNF_RCVD state, the following are the additional actions:

When OPN_ACPT event occurs, in addition to the actions for MPM protocol, the mesh STA shall signal the completion of key management by utilizing the MLME-SETKEYS.request primitive to configure the agreed-upon mesh temporal pairwise key into the IEEE 802.11 MAC and received MGTK and by calling the MLME-SETPROTECTION.request primitive to enable the usage.

Table 14-3 (AMPE finite state machine) and Figure 14-3 (Finite state machine of the AMPE protocol) specify the state transitions of the finite state machine for AMPE.

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**Table 14-3—AMPE finite state machine**

| From State | To State | | | | | |
|---|---|---|---|---|---|---|
| | **IDLE** | **OPN_SNT** | **CNF_RCVD** | **OPN_RCVD** | **ESTAB** | **HOLDING** |
| **IDLE** | REQ_RJCT / sndCLS | ACTOPN / (sndOPN, setR) | | OPN_ACPT / (sndOPN, sndCNF, setR) | | |
| **OPN_SNT** | | TOR1 / (sndOPN, setR) | CNF_ACPT / (clR, setC) | OPN_ACPT / (sndCNF) | | CLS_ACPT, OPN_RJCT, CNF_RJCT, TOR2, CNCL / (sndCLS, clR, setH)<br>TOR3 / (clR, setH) |
| **CNF_RCVD** | | | | | OPN_ACPT / (clC, sndCNF) | CLS_ACPT, OPN_RJCT, CNF_RJCT, CNCL / (sndCLS, clC, setH)<br>TOC / (sndCLS, setH) |
| **OPN_RCVD** | | | | TOR1 / (sndOPN, setR)<br>OPN_ACPT / sndCNF | CNF_ACPT / clR | CLS_ACPT, OPN_RJCT, CNF_RJCT,TOR2, CNCL / (sndCLS, clR, setH) |
| **ESTAB** | | | | | OPN_ACPT / sndCNF | CLS_ACPT, OPN_RJCT, CNF_RJCT, CNCL / (sndCLS, setH) |
| **HOLDING** | TOH / —, CLS_ACPT / clH | | | | | OPN_ACPT, CNF_ACPT, OPN_RJCT, CNF_RJCT / sndCLS |


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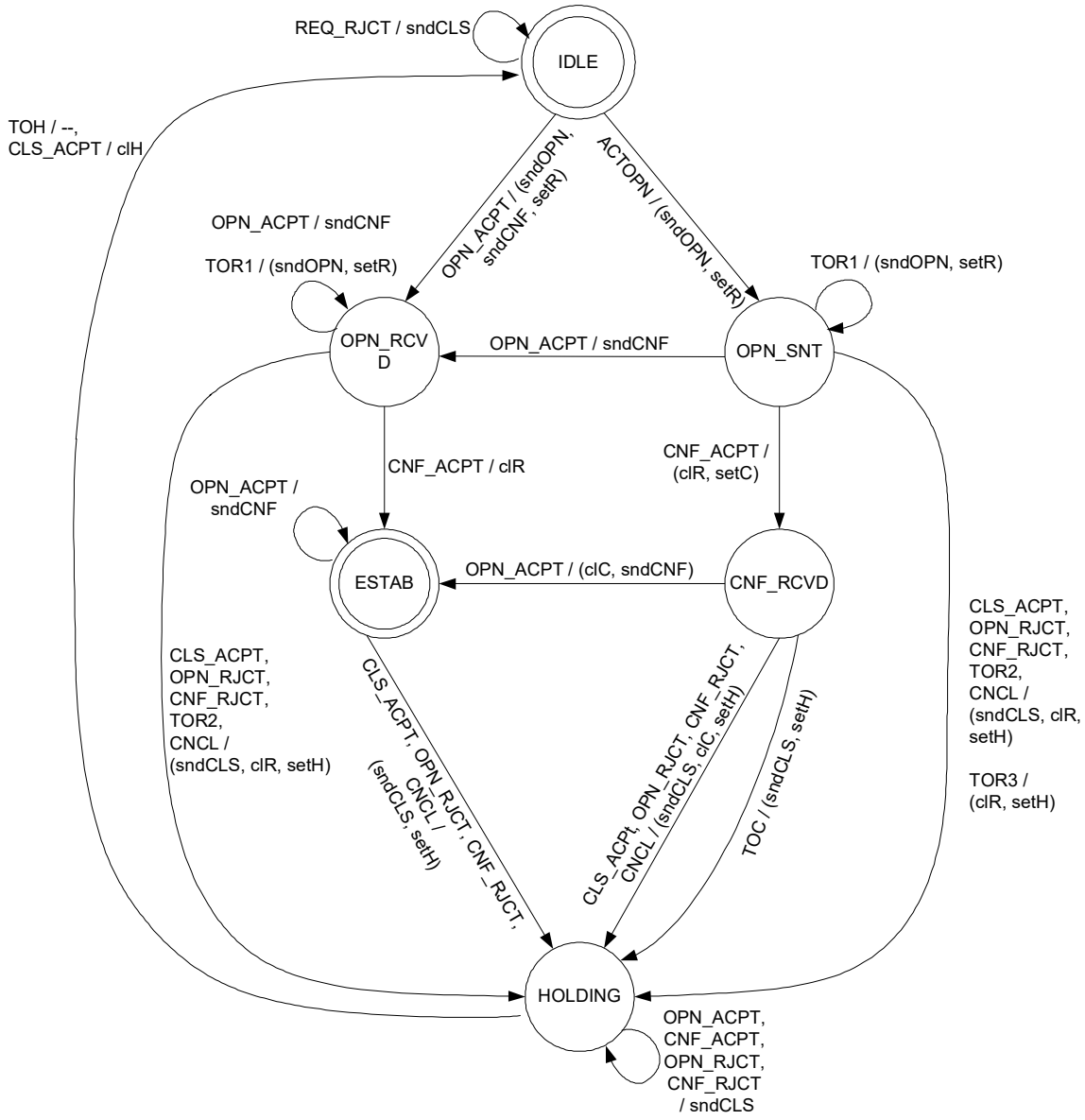


**Figure 14-3—Finite state machine of the AMPE protocol**

### 14.6.7 Keys and key derivation algorithm for the authenticated mesh peering exchange (AMPE)

To execute the AMPE and mesh group key handshake with a candidate peer STA, the local STA shall derive an authenticated encryption key (AEK) and a mesh temporal key (MTK) using the PMK it shares with the candidate peer STA.

The AEK is derived statically from the shared PMK. The MTK is derived from the shared PMK and dynamic information provided by the STA and candidate peer STA.

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The AEK is mutually derived by the local STA and the peer STA once a new PMK has been selected. The AEK shall be derived from the PMK by

(#478)AEK ← KDF-*Hash*-256(PMK, "AEK Derivation", Selected AKM Suite ||
min(localMAC, peerMAC) || max(localMAC, peerMAC))

where

(#478)KDF-*Hash*-256 is the key derivation function defined in 12.7.1.6.2 (Key derivation function (KDF)) using the hash algorithm identified by the AKM suite selector (see Table 9-190 (AKM suite selectors))

Selected AKM Suite is a 4-octet string formed by concatenating the OUI or CID and suite type

The temporal key (MTK) shall be derived from the PMK by

(#478)MTK ← KDF-*Hash-Length*(PMK, "Temporal Key Derivation", min(localNonce, peerNonce) || max(localNonce, peerNonce) || min(localLinkID, peerLinkID) || max(localLinkID, peerLinkID) || Selected AKM Suite || min(localMAC, peerMAC) || max(localMAC, peerMAC))

where

(#478)KDF-*Hash-Length* is the key derivation function defined in 12.7.1.6.2 (Key derivation function (KDF)) using the hash algorithm identified by the AKM suite selector (see Table 9-190 (AKM suite selectors))

Length is (#3270)cipher suite dependent and defined by the TK_bits value in Table 12-8 (Cipher suite key lengths(#1083)(#3532))

Selected AKM Suite is a 4-octet string formed by concatenating the OUI or CID and suite type

"min" and "max" operations for IEEE 802 addresses
are with the address converted to a positive integer, treating the first transmitted octet as the most significant octet of the integer as specified in 12.7.1.3 (Pairwise key hierarchy)

"min" and "max" operations for nonces
are encoded as specified in 9.2.2 (Conventions)

"min" and "max" operations for LinkIDs
select the minimum and maximum, respectively, of the two unsigned integers (In the KDF context, LinkIDs are encoded as 16-bit unsigned integers, represented using the bit ordering conventions of 9.2.2 (Conventions).)

The MTK is used to protect communications between two peer STAs. The local STA and peer STA derive an MTK per peering instance and may rekey the MTK using AMPE.

## 14.7 Mesh group key handshake

### 14.7.1 General

The mesh group key handshake may be used by either mesh STA, after a secure mesh peering has been established, to update the MGTK that it uses to protect group addressed MPDUs that it transmits to its peer mesh STAs.

The mesh STA may update its MGTK when a mesh peering is terminated.

To update the MGTK, the mesh STA shall execute the mesh group key handshake with each of its current peer mesh STAs. The "MGTK source" is the mesh STA that is sending the MGTK to a peer mesh STA using this protocol. (#4212)An "MGTK recipient" is a mesh STA receiving the MGTK being sent by the (#4212)MGTK source.


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The mesh group key handshake shall include the following two messages:

- Message 1: Mesh Group Key Inform frame
- Message 2: Mesh Group Key Acknowledge frame

Mesh Group Key Inform frame and Mesh Group Key Acknowledge frame are conventionally referred to as *mesh group key handshake frames*.

(#185)The mesh STA shall perform an AMPE handshake before a mesh group key handshake if both are required to be done.

NOTE—It is impossible that the MGTK source initiates the mesh group key handshake before the AMPE completes successfully.

### 14.7.2 Protection on mesh group key handshake frames

Mesh group key handshake frames used in mesh group key handshake are protected using the deterministic authenticated encryption mode of AES-SIV (IETF-RFC 5297) when dot11MeshSecurityActivated is true.

When constructing protection on mesh group handshake frames, the following procedure shall be used:

- The key shall be the AEK from the current active security association with the peer mesh STA that receives the mesh group key handshake frame.
- The input plaintext shall be the Authenticated Mesh Peering Exchange element(#3425) (see 9.6.15.5 (Mesh Group Key Inform frame format) and 9.6.15.6 (Mesh Group Key Acknowledge frame format)).
- The plaintext shall be the Authenticated Mesh Peering Exchange element.
- AAD shall be three distinct components as follows:
  - The localMAC
  - The peerMAC
  - The contents of the mesh group key handshake frame from the category (inclusive) to the MIC element (exclusive)
- The synthetic initialization vector produced by AES-SIV shall be copied into the MIC field of the MIC element in the frame.
- The produced cipher text shall become the remainder of the mesh group key handshake frame after the MIC element.

When verifying the protection on the mesh group handshake frames, the following procedure shall be used:

- The key shall be the AEK from the current active security association with the peer mesh STA that receives the mesh group key handshake frame.
- AAD shall be three distinct components as follows:
  - The peerMAC
  - The localMAC
  - The contents of the mesh group key handshake frame from the category (inclusive) to the MIC element (exclusive)
- The synthetic initialization vector shall be the MIC field of the MIC element in the frame.
- The cipher text shall be the content after the MIC element in the frame.
- If AES-SIV validation function takes above input.
  - If the function returns the special symbol “FAIL,” the frame shall be discarded.
  - If the plaintext is returned successfully, the produced plaintext shall be treated as the contents after the MIC element in the frame.

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### 14.7.3 Mesh Group Key Inform frame construction and processing

Mesh Group Key Inform frame shall be constructed as follows:

- The Authenticated Mesh Peering Exchange element shall be set as the following:
  - The Selected Pairwise Cipher Suite field shall be set to 4 octets of zero.
  - The Local Nonce field shall be set to the same value as sent in the Mesh Peering Open frame that established the mesh peering instance.
  - The Peer Nonce field shall be set to the same value as received in the Local Nonce field of the Authenticated Mesh Peering Exchange element of the incoming Mesh Peering Open frame that established the peering instance.
  - The Key Replay Counter field shall be set to the mesh STA's local replay counter value, incremented by 1, for the mesh peering. After setting this field, the local replay counter shall also be incremented by 1.
  - The GTKdata field shall be present and shall contain the data for the MGTK from MGTK source. The components of the GTKdata are specified in 14.6.4 (Distribution of group keys in an MBSS(#1521)).
  - If management frame protection is enabled(#7049), the IGTKdata field shall be present and shall contain the data for the IGTK from IGTK source. The components of the IGTKdata are specified in 14.6.4 (Distribution of group keys in an MBSS(#1521)).
- The MIC element shall be set according to the protection mechanism in 14.7.2 (Protection on mesh group key handshake frames).

The construction of AES-SIV protection on Mesh Group Key Inform frame shall use the construction procedure as in 14.7.2 (Protection on mesh group key handshake frames).

The MGTK source sends the Mesh Group Key Inform frame to the MGTK recipient.

On reception of Mesh Group Key Inform frame, the MGTK recipient shall use the verification procedure in 14.7.2 (Protection on mesh group key handshake frames) to validate the AES-SIV construction.

- If the validation recovers the plaintext successfully, the MGTK recipient shall proceed with the following procedure:
  - Verify that values in the Local Nonce field and the Peer Nonce field in the Authenticated Mesh Peering Exchange element are the same as in the current valid mesh PTKSA(#240) that the MGTK recipient established with the sender of the Mesh Group Key Inform frame. If there is any mismatch, the received Mesh Group Key Inform frame shall be discarded and no further action shall be taken.
  - Verify that the Key Replay Counter (#3111)field has not yet been seen before, i.e., its value is strictly larger than that in any other mesh Group Key Inform frame received thus far during this security association. If this verification fails, the received Mesh Group Key Inform frame shall be discarded and no further action shall be taken.
  - Use the MLME-SETKEYS.request primitive to configure the (#1567)MGTK into the MAC.
  - Respond by constructing and sending mesh group key handshake acknowledge to the MGTK source and incrementing the replay counter.

  NOTE—The MGTK source increments and uses a new Key Replay Counter field value on every Mesh Group Key Inform frame, even retries, because the Mesh Group Key Acknowledge frame responding to an earlier Mesh Group Key Inform frame might have been lost. If the MGTK source did not increment the replay counter, the (#4212)MGTK recipient discards the retry, and no responding Mesh Group Key Acknowledge frame will ever arrive.
- If the AES-SIV validation returns a special symbol "FAIL," the Mesh Group Key Inform frame shall be discarded. No further action shall be taken.


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### 14.7.4 Mesh Group Key Acknowledge frame construction and processing

Mesh Group Key Acknowledge frame shall be constructed as follows:

- The Authenticated Mesh Peering Exchange element shall be set as follows:
  - The Selected Pairwise Cipher Suite field shall be set to 4 octets of zero.
  - The Local Nonce field shall be set to the same value as sent in the Mesh Peering Open frame that established the mesh peering instance.
  - The Peer Nonce field shall be set to the same value as received in the Local Nonce field of the Authenticated Mesh Peering Exchange element of the incoming Mesh Peering Open frame that established the peering instance.
  - The Key Replay Counter (#3111)field shall be set to the same value as received in the Mesh Group Key Inform frame.
  - The GTKdata field shall not be present.
  - The IGTKdata field shall not be present.
- The MIC element shall be set according to the protection mechanism in 14.7.2 (Protection on mesh group key handshake frames).

The construction of AES-SIV protection on Mesh Group Key Acknowledge frame shall use the construction procedure as in 14.7.2 (Protection on mesh group key handshake frames).

The MGTK recipient sends the Mesh Group Key Acknowledge frame to the MGTK source.

On reception of Mesh Group Key Acknowledge frame, the MGTK source shall use the verification procedure in 14.7.2 (Protection on mesh group key handshake frames) to validate the AES-SIV construction.

- If the validation recovers the plaintext successfully, the MGTK source shall set the content of the Authenticated Mesh Peering Exchange element using the recovered plaintext and proceed with the following procedure:
  - Verify that values in the Local Nonce field and the Peer Nonce field in the Authenticated Mesh Peering Exchange element are the same as in the current valid mesh PTKSA(#240) that the MGTK source established with the sender of the Mesh Group Key Acknowledge frame. If there is any mismatch, the received Mesh Group Key Acknowledge frame shall be discarded and no further action shall be taken.
  - Verify that the Key Replay Counter (#3111)field matches the one that it has used for the mesh group key handshake. If this verification fails, the received Mesh Group Key Acknowledge frame shall be discarded and the MGTK source may invoke a retry to send a new Mesh Group Key Inform frame with a new Key Replay Counter (#3111)field.
- If the validation returns a special symbol “FAIL,” the Mesh Group Key Acknowledge frame shall be discarded and the MGTK source may invoke a retry to send a new Mesh Group Key Inform frame with a new Key Replay Counter (#3111)field.

### 14.7.5 Mesh group key implementation considerations

If the MGTK source does not receive a Mesh Group Key Acknowledge frame to its Mesh Group Key Inform frames, it shall attempt dot11MeshConfigGroupUpdateCount additional transmissions of the Mesh Group Key Inform frame. The retransmit timeout value (#6084)should be 100 ms for the first timeout, half the listen interval for the second timeout, and the listen interval for subsequent timeouts. If (#6084)the listen interval is zero, then 100 ms should be used for all timeout values. If it still has not received a response after this, then the MGTK source shall tear down the mesh peering and mesh PTKSA(#240) with this MGTK recipient, by generating a CNCL event for the peering instance, and pass the event to the mesh peering instance controller.

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## 14.8 Mesh security

During the AMPE, the peers negotiate, and agree upon, a pairwise (#3270)cipher suite, a group data cipher suite, and a group management cipher suite (if management frame protection is enabled)(#6020). They also establish a mesh PTKSA(#240) and mesh GTKSA to be used with the pairwise cipher suite and (#6020)group data cipher suite, respectively.

When dot11MeshSecurityActivated is true, (#1980)individually addressed mesh Data frames and individually addressed robust Management frames (see 12.2.7 (Requirements for management frame protection)) shall be protected by the mesh PTKSA(#240), and group addressed Data frames, and group addressed Action frames of a category specified with Yes in the Group addressed privacy column of Table 9-81 (Category values), shall be protected by the MGTK.(#3393)

When dot11RSNAProtectedManagementFramesActivated is true, group addressed robust Management frames that are not protected by the MGTK(#3393) shall be protected using BIP (see 11.12 (Group addressed management frame protection procedures)).

## 14.9 Mesh path selection and metric framework

### 14.9.1 General

The term *mesh path selection* is used to describe selection of multi-hop paths between mesh STAs at the link layer. Mesh path selection creates forwarding information that is utilized for MSDU/MMPDU forwarding as described in 10.37 (Mesh forwarding framework).

### 14.9.2 Extensible path selection framework

This standard allows for alternative and flexible implementations of path selection protocols and metrics.

A mesh STA may include multiple protocol implementations (that is, the default protocol, vendor-specific protocols, etc.) as well as multiple metric implementations, but only one path selection protocol and only one path selection metric shall be used by a mesh STA at a time.

As described in 14.3.3 (Mesh profile) and 14.3.7 (Candidate peer mesh STA), mesh STAs use the Mesh Configuration element (9.4.2.96 (Mesh Configuration element)) to announce the active path selection protocol and active path selection metric of the MBSS. This allows a neighbor mesh STA to identify if it should become a member of the MBSS and how it should establish mesh peerings with its members. This standard does not force an existing MBSS that is using a protocol other than the default protocol to switch to the default protocol when a new mesh STA requests mesh peering establishment. While it is possible, in principle, to implement such behavior, an algorithm to coordinate such reconfiguration is beyond the scope of this standard.

Path selection protocol and path selection metric are identified by a unique identifier as defined in 9.4.2.96.2 (Active Path Selection Protocol Identifier) and 9.4.2.96.3 (Active Path Selection Metric Identifier), respectively. Also, each path selection protocol and each path selection metric specifies the following:

- Data type of metric values
- Length of the metric field
- Operator for aggregation of link metrics to a path metric; the symbol $\oplus$ is used to identify an arbitrary operator for aggregation
- Comparison operator for determining a better or worse path; how this is performed depends on the actual comparison operator
- Initial value of the path metric (path selection metric only)


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The standard defines HWMP as a default path selection protocol (see 14.11 (Hybrid wireless mesh protocol (HWMP))). The standard defines the airtime link metric as a default path selection metric and the high PHY rate airtime link metric as a path selection metric for mesh STAs capable of transmitting frames with a PHY rate higher than 54 Mb/s (see 14.10.2 (Airtime link metric and high PHY rate airtime link metric)). The default path selection protocol and default path selection metric shall be implemented on all mesh STAs.

### 14.9.3 Link metric reporting

A mesh STA may submit a link metric report to or request a link metric report from its neighbor peer mesh STA by transmitting a Mesh Link Metric Report frame. A mesh STA receiving a Mesh Link Metric Report element with the Request subfield of the Flags field equal to 1 shall reply with a Mesh Link Metric Report frame containing the link metric value for the corresponding link.

Upon reception of a Mesh Link Metric Report frame, the mesh STA may update its local link metric information using the link metric information received. The procedure to update the local link metric information with the link metric information received from a neighbor peer mesh STA is outside the scope of the standard.

## 14.10 Path selection link metric

### 14.10.1 General

A path selection link metric is used by the path selection protocol in the assessment of the link quality to identify an efficient radio-aware path. Subclause 14.10.2 (Airtime link metric and high PHY rate airtime link metric) defines two link metrics: a) a default link metric, the airtime link metric; and b) the high PHY rate airtime link metric. A STA should use the high PHY rate airtime link metric when its PHY entity is capable of transmitting frames with PHY rate higher than 54 Mb/s.

The extensibility framework allows the default link metric to be overridden by another path selection metric as specified in the mesh profile.

### 14.10.2 Airtime link metric and high PHY rate airtime link metric

The airtime link metric is used when dot11MeshActivePathSelectionMetric is airtimeLinkMetric (1); the high PHY rate airtime link metric is used when dot11MeshActivePathSelectionMetric is highPHYRateAirtimeLinkMetric (2) (see 14.3.3 (Mesh profile)).

Airtime reflects the amount of channel resources consumed by transmitting the frame over a particular link. This measure is approximate and designed for ease of implementation and interoperability.

The airtime for each link is calculated as follows:

$$c_a = \left[\frac{O}{n} + \frac{B_t}{r}\right]\frac{1}{1-e_f}$$

where

| | |
|---|---|
| $O$, $n$, and $B_t$ | are constants listed in Table 14-4 (Airtime cost constants for airtime link metric and high PHY rate airtime link metric) |
| input parameter $r$ | is the estimated PHY data rate (in Mb/s) at which the mesh STA would transmit a nominal frame containing a frame body of size $B_t$ based on current link conditions; its estimation is dependent on local implementation of rate adaptation |

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input parameter $e_f$ is the estimated frame error rate. It is the probability that when a nominal frame containing a frame body of size $B_t$ is transmitted at the PHY data rate $r$, the frame is corrupted; its estimation is a local implementation choice. Failures due to exceeding Mesh TTL should not be included in this estimate as they are not correlated with link performance

**Table 14-4—Airtime cost constants for airtime link metric and high PHY rate airtime link metric**

| Parameter | Recommended value | Description |
|---|---|---|
| $O$ | Varies depending on PHY | Channel access overhead (in μs), which includes frame headers, training sequences, access protocol frames, etc. |
| $n$ | Varies depending on implementation | 1 for the airtime link metric, i.e., when dot11MeshActivePathSelectionMetric is airtimeLinkMetric (1). Otherwise, number of MSDUs aggregated in a single Data frame. It represents the number of MSDUs that the mesh STA would transmit in a typical Data frame; its estimation is dependent on local implementation of the A-MSDU and A-MPDU construction. |
| $B_t$ | 8192 | Number of bits in the frame body of a nominal frame |

The airtime link metric shall be encoded as an unsigned integer in units of 0.01 TU. An example of the airtime link metric is shown in S.5 (Airtime link metric usage example).

The high PHY rate airtime link metric shall be encoded as an unsigned integer in units of 0.01 μs.

Table 14-5 (Parameters of the airtime link metric and high PHY rate airtime link metric for extensible path selection framework) gives the parameters of the airtime link metric for the extensible path selection framework.

**Table 14-5—Parameters of the airtime link metric and high PHY rate airtime link metric for extensible path selection framework**

| Parameter | Notes |
|---|---|
| Path Selection Metric ID | See Table 9-280 (Active Path Selection Metric Identifier field values) in 9.4.2.96.3 (Active Path Selection Metric Identifier) |
| Data type | Unsigned integer, 0 ≤ metric value < 4 294 967 296 |
| Length of metric field | 4 octets |
| Operator for metric aggregation | addition (+) |
| Comparison operator | *less than, equal to, greater than* as used with integers<br>— metric *a* is *better than* metric *b* if $a < b$<br>— metric *a* is *equal to* metric *b* if $a = b$<br>— metric *a* is *worse than* metric *b* if $a > b$ |
| Initial value of path metric | 0 |


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## 14.11 Hybrid wireless mesh protocol (HWMP)

### 14.11.1 General

The hybrid wireless mesh protocol (HWMP) is a mesh path selection protocol that combines the flexibility of on-demand path selection with proactive topology tree extensions. The combination of reactive and proactive elements of HWMP enables efficient path selection in a wide variety of mesh networks (with or without access to the infrastructure).

HWMP uses a common set of protocol elements, generation and processing rules inspired by Ad Hoc On-Demand Distance Vector (AODV) protocol (IETF RFC 3561 [B39]) adapted for MAC address-based path selection and link metric awareness. HWMP is completely specified herein and does not require reference to AODV specifications or descriptions.

HWMP supports two modes of operation depending on the configuration. These modes provide different levels of functionality as follows:

— On-demand mode: The functionality of this mode is always available, independent of whether a root mesh STA is configured in the MBSS or not. It allows mesh STAs to communicate using peer-to-peer paths.

— Proactive tree building mode: In this mode, additional proactive tree building functionality is added to the on-demand mode. This can be performed by configuring a mesh STA as root mesh STA using either the proactive PREQ mechanism or proactive RANN mechanism. The proactive PREQ mechanism creates paths from the mesh STAs to the root, using only group addressed communication. The RANN mechanism creates paths between the root and each mesh STA using acknowledged communication.

These modes are not exclusive. On-demand and proactive modes are used concurrently, because the proactive modes are extensions of the on-demand mode.

NOTE—One example of concurrent usage of on-demand and proactive mode is for two mesh STAs that are part of the same mesh BSS (or STAs that are proxied by mesh STAs in the same MBSS) to begin communicating using the proactively built tree but subsequently to perform an on-demand discovery for a direct path. This type of concurrent usage of the proactive and on-demand modes allows communication to begin immediately (by forwarding all traffic to the root, which knows all mesh STAs and addresses proxied by mesh STAs in the MBSS) while an on-demand discovery finds a shorter path between two mesh STAs (or STAs that are proxied by mesh STAs in the same MBSS).

All HWMP modes of operation utilize common processing rules and primitives. HWMP elements are the (#1776)PREQ element, PREP element, PERR element, and RANN element. The metric cost of the links determines which paths HWMP builds. In order to propagate the metric information between mesh STAs, a Metric field is used in the PREQ, PREP, and RANN elements.

Path selection in HWMP uses a sequence number mechanism to enable mesh STAs to distinguish current path information from stale path information at all times in order to maintain loop-free connectivity. Each mesh STA maintains its own HWMP SN, which is propagated to other mesh STAs in the HWMP elements. Rules for maintaining HWMP SNs are given in 14.11.8.3 (HWMP sequence numbering).

### 14.11.2 Terminology

This subclause describes terminology for HWMP, especially for the process of path discovery. Terms such as path originator or path target designate very specific entities within the path discovery process. They stay with the same assigned entity for the whole path discovery process and other procedures related to this path discovery. Figure 14-4 (Illustration of definitions) illustrates an example utilizing this terminology.

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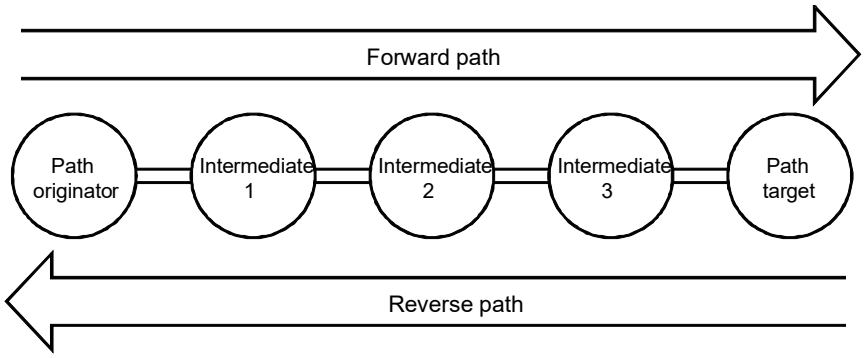


**Figure 14-4—Illustration of definitions**

NOTE 1—Both the path target and path originator are a path destination for the forward path and the reverse path respectively.

The following terms are used within the context of a single PREQ element / PREP element pair, a so-called HWMP path discovery:

- **path originator:** The path originator is the mesh STA that triggers the path discovery.
- **path originator address:** The MAC address of the path originator.
- **path target:** The path target is the entity to which the path originator attempts to establish a path.

  NOTE 2—When an originator mesh STA initially attempts to establish a path to a target, it does not know whether the target is a mesh STA in the mesh BSS or not. Only when the originator receives a PREP element does it learn if the target is a mesh STA in the mesh BSS or not. If the target is in the mesh BSS, it is referred to as a *target mesh STA*. If the target is outside the mesh BSS, the term target proxy mesh gate refers to the mesh gate proxying for the target.
- **path target address:** The MAC address of the path target.
- **intermediate mesh STA:** The intermediate mesh STA is the mesh STA that participates in path selection and is neither path originator nor path target.
- **intermediate mesh STA address:** The MAC address of the intermediate mesh STA.
- **forward path:** The forward path is the mesh path to the path target, set up at the path originator and intermediate mesh STAs.
- **reverse path:** The reverse path is the mesh path to the path originator, set up at the path target and intermediate mesh STAs.
- **HWMP sequence number (HWMP SN):** Each mesh HWMP path selection element contains an HWMP SN that allows recipients to distinguish newer from stale information. An HWMP SN is specific to a mesh STA. See also 14.11.8.3 (HWMP sequence numbering).
- **forwarding information:** The forwarding information maintained by an originator mesh STA, an intermediate mesh STA, or a target mesh STA that allows the mesh STA to perform its path selection and forwarding functions.

  The terminology used when discussing forwarding information is relative to the mesh STA (reference mesh STA, given mesh STA or local mesh STA) and a particular mesh destination of the path. The following terms are specific to a given instance of the forwarding information:
  - **destination mesh STA:** The end station (mesh STA) of a (forward or reverse) path.
  - **destination mesh STA address:** The MAC address of the destination mesh STA.
  - **destination HWMP SN:** The HWMP SN of the destination mesh STA.
  - **next-hop mesh STA:** The next-hop mesh STA is the next peer mesh STA on the mesh path to the destination mesh STA.
  - **next-hop mesh STA address:** The MAC address of the next-hop mesh STA.


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  - **precursor mesh STA:** A precursor mesh STA is a neighbor peer mesh STA on the mesh path that identifies a given mesh STA as the next-hop mesh STA to the destination mesh STA.
  - **precursor mesh STA address:** The MAC address of the precursor mesh STA.
  - **lifetime:** The time during which forwarding information remains active (see 14.11.8.4 (Forwarding information))
- **unreachable destination:** A destination mesh STA is considered unreachable by a source mesh STA or an intermediate mesh STA if the link to the next hop of the mesh path to this destination mesh STA, as derived from its forwarding information, is no longer usable.
- **element time to live (Element TTL)**: An integer number that is used to limit the number of hops an HWMP element may be processed and propagated. Note that this Element TTL is different from the Mesh TTL in the Mesh Control field (see 9.2.4.8.3 (Mesh Control field)).
- **root mesh STA:** A root mesh STA is configured to originate proactive PREQ elements or RANN elements. It is the root of a path selection tree.

Table 14-6 (Precursor and next hop examples (forward path)) and Table 14-7 (Precursor and next hop examples (reverse path)) show the roles of the various mesh STAs in the forward path and reverse path generated as a result of the full PREQ element and PREP element processing as shown in Figure 14-4 (Illustration of definitions). Each row in the table contains the roles of a forward/reverse path from the reference mesh STA's perspective.

**Table 14-6—Precursor and next hop examples (forward path)**

| Forward path (to Path Target) | | | |
|---|---|---|---|
| **Reference mesh STA** | **Precursor mesh STA** | **Next-hop mesh STA** | **Destination mesh STA** |
| Path originator | N/A | Intermediate 1 | Path target |
| Intermediate 2 | Intermediate 1 | Intermediate 3 | Path target |
| Path Target | Intermediate 3 | N/A | Path Target |

**Table 14-7—Precursor and next hop examples (reverse path)**

| Reverse path (to path originator) | | | |
|---|---|---|---|
| **Reference mesh STA** | **Precursor mesh STA** | **Next-hop mesh STA** | **Destination mesh STA** |
| Path originator | Intermediate 1 | N/A | Path originator |
| Intermediate 2 | Intermediate 3 | Intermediate 1 | Path originator |
| Path target | N/A | Intermediate 3 | Path originator |

### 14.11.3 On-demand path selection mode

If a source mesh STA needs to find a path to a destination mesh STA using the on-demand path selection mode, it broadcasts a PREQ element with the path target specified in the list of targets and the metric field initialized to the initial value of the active path selection metric.

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When a mesh STA receives a new PREQ element, it creates or updates its path information to the originator mesh STA and propagates the PREQ element to its neighbor peer mesh STAs if the PREQ element contains a greater HWMP SN, or the HWMP SN is the same as the current path and the PREQ element offers a better metric than the current path. Each mesh STA may receive multiple copies of the same PREQ element that originated at the originator mesh STA, each PREQ element traversing a unique path.

Whenever a mesh STA propagates a PREQ element, the metric field in the PREQ element is updated to reflect the cumulative metric of the path to the originator mesh STA.

If the mesh STA that received a PREQ element is the target mesh STA, it sends a PREP element back to the originator mesh STA after creating or updating a path to the originator mesh STA.

The PREQ element provides the TO (Target Only) subfield that allows path selection to take advantage of existing paths to the target mesh STA by allowing an intermediate mesh STA to return a PREP element to the originator mesh STA. If the TO (Target Only) subfield is 1, only the target mesh STA responds with a PREP element. The effect of setting the TO (Target Only) subfield to 0 is the quick establishment of a path using the PREP element generated by an intermediate mesh STA, allowing the forwarding of MSDUs with a low path selection delay. In order to select (or validate) the best path during the path selection procedure, the intermediate mesh STA that responded with a PREP element propagates the PREQ element with the TO (Target Only) subfield set to 1. This prevents all other intermediate mesh STAs on the way to the target from sending a PREP element.

Intermediate mesh STAs create a path to the target mesh STA on receiving the PREP element, and also forward the PREP element toward the originator. When the originator receives the PREP element, it creates a path to the target mesh STA. If the target mesh STA receives further PREQ elements with a better metric, then the target updates its path to the originator with the new path and also sends a new PREP element to the originator along the updated path. A bidirectional, best metric end-to-end path is established between the originator and target mesh STA.

### 14.11.4 Proactive tree building mode

#### 14.11.4.1 General

There are two mechanisms for proactively disseminating path selection information for reaching the root mesh STA. The first method uses a *proactive* PREQ element and is intended to create paths between all mesh STAs and the root mesh STA in the network proactively. The second method uses a RANN element and is intended to distribute path information for reaching the root mesh STA but there is no forwarding information created.

A mesh STA configured as root mesh STA sends either proactive PREQ elements or proactive RANN elements periodically.

#### 14.11.4.2 Proactive PREQ mechanism

The PREQ tree building process begins with a proactive PREQ element sent by the root mesh STA, with the Target Address set to all 1s and the TO subfield set to 1. The PREQ element contains the path metric (set to the initial value of the active path selection metric by the root mesh STA) and an HWMP SN. The proactive PREQ element is sent periodically by the root mesh STA, with increasing HWMP SNs.

A mesh STA receiving a proactive PREQ element creates or updates its forwarding information to the root mesh STA, updates the metric and hop count of the PREQ element, records the metric and hop count to the root mesh STA, and then transmits the updated PREQ element. Information about the presence of and distance to available root mesh STA(s) is disseminated to all mesh STAs in the network.


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Each mesh STA may receive multiple copies of a proactive PREQ element, each traversing a unique path from the root mesh STA to the mesh STA. A mesh STA updates its current path to the root mesh STA if the PREQ element contains a greater HWMP SN, or the HWMP SN is the same as the current path and the PREQ element offers a better metric than the current path to the root mesh STA; otherwise it does not update its current path.(#7220) The processing of the proactive PREQ element is the same as the processing of the PREQ element in the on-demand mode described in 14.11.3 (On-demand path selection mode).

If the proactive PREQ element is sent with the Proactive PREP subfield set to 0, the recipient mesh STA may send a proactive PREP element. A proactive PREP element is necessary, for example, if the mesh STA has data to send to the root mesh STA, thus requiring the establishment of a forward path from the root mesh STA. During the time the forward path is required, the recipient mesh STA shall send a proactive PREP element even if the Proactive PREP subfield is(M118) 0. Guidance on controlling the generation of proactive PREQ elements in such a case is given in S.7 (Generation of proactive PREP elements in the proactive PREQ mechanism of HWMP).

If the PREQ element is sent with a Proactive PREP subfield set to 1, the recipient mesh STA shall send a proactive PREP element. The proactive PREP element establishes the path from the root mesh STA to the mesh STA.

#### 14.11.4.3 Proactive RANN mechanism

The root mesh STA periodically propagates a RANN element into the network. The information contained in the RANN element is used to disseminate path metrics to the root mesh STA, but reception of a RANN element does not establish a path.

Upon reception of a RANN element, each mesh STA that has to create or refresh a path to the root mesh STA sends an individually addressed frame containing a PREQ element to the root mesh STA via the mesh STA from which it received the RANN element.

The root mesh STA sends a PREP element in response to each PREQ element. The individually addressed frame containing a PREQ element creates the reverse path from the root mesh STA to the originator mesh STA, while the PREP element creates the forward path from the mesh STA to the root mesh STA.

### 14.11.5 (#2210)Colocated STAs

HWMP terminology strictly refers to a STA whose address is used for destination mapping (i.e., the originator address, the intermediate mesh STA address, or the target address). HWMP terminology does not make any assumption about the address used for communication over the WM (i.e., the (#300)transmitter address and the receiver address). For example, there is no requirement that the path originator or the path target of an HWMP path are the same as the address used for transmitting the first and receiving the last (respectively) HWMP Mesh Path Selection frame containing a PREQ element.

The corollary to this is that the first hop of a PREQ element may have a transmitter address that is not the same as the originator address in the PREQ element and that the first hop may have a transmitter address that is not the same as the source address. In order to determine whether a transmission is a first hop or not, mesh STAs should not compare the source and transmitter addresses. Instead, this determination can be made by looking at the hop count field of the PREQ element (which is not used as an acceptance criterion).

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### 14.11.6 Parameters for extensible path selection framework

Table 14-8 (Parameters of HWMP for extensible path selection framework) gives the parameters of HWMP for the extensible path selection framework (see 14.9.2 (Extensible path selection framework)).

**Table 14-8—Parameters of HWMP for extensible path selection framework**

| Parameter | Notes |
|---|---|
| Path Selection Protocol ID | See Table 9-279 (Active Path Selection Protocol Identifier field values) in 9.4.2.96.2 (Active Path Selection Protocol Identifier) |
| Data type of metric field | As defined by active path selection metric |
| Length of metric field | 4 octets |
| Operator for metric aggregation | As defined by active path selection metric |
| Comparison operator | As defined by active path selection metric |
| Initial value of path metric | As defined by active path selection metric |

### 14.11.7 Addressing of HWMP Mesh Path Selection frame

All HWMP elements are sent in an HWMP Mesh Path Selection frame (see 9.6.16.3 (HWMP Mesh Path Selection frame format)). The RANN element may also be sent in a Beacon frame. “Cases” refer to the different conditions that trigger the transmission of an HWMP Mesh Path Selection frame. PREQ element cases are specified in 14.11.9.3 (Conditions for generating and sending a PREQ element). PREP element cases are specified in 14.11.10.3 (Conditions for generating and sending a PREP element). PERR element cases are specified in 14.11.11.3 (Conditions for generating and sending a PERR element). RANN element cases are specified in 14.11.12.3 (Conditions for generating and sending a RANN element).

Note that the PREQ Addressing Mode subfield in the Flags field identifies the propagation mode of the PREQ element; an Addressing Mode subfield equal to 0 indicates that the PREQ element is group addressed, an Addressing Mode subfield equal to 1 indicates that the PREQ element is individually addressed.

The addresses of the HWMP Mesh Path Selection frame shall be as follows:

- PREQ element group addressed—Addressing Mode subfield = 0 [Case A: Path Discovery (Original transmission), Case B: Path Maintenance (Original transmission), Case C: Proactive PREQ element (Original transmission), and Case E: PREQ element Propagation; see 14.11.9.3 (Conditions for generating and sending a PREQ element)]:
  - Address 1: Group address
  - Address 2: Address of the mesh STA sending the PREQ element
  - Address 3: Same as Address 2
- PREQ element individually addressed—Addressing Mode subfield = 1 [Case D: Root Path Confirmation (Original transmission); see 14.11.9.3 (Conditions for generating and sending a PREQ element)]:
  - Address 1: Address 2 of the frame containing the RANN element that triggered the PREQ element
  - Address 2: Address of the mesh STA sending the PREQ element
  - Address 3: Same as Address 2


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- PREQ element individually addressed—Addressing Mode subfield = 1 [Case E: PREQ element Propagation; see 14.11.9.3 (Conditions for generating and sending a PREQ element)]:
  - Address 1: Next-hop MAC address to the mesh STA identified in the Target MAC Address field in the PREQ element
  - Address 2: Address of the mesh STA sending the PREQ element
  - Address 3: Same as Address 2
- PREP element [Case A: Original transmission, Case C: Intermediate reply, Case D: Proactive PREP element in Proactive PREQ element mode; see 14.11.10.3 (Conditions for generating and sending a PREP element)]:
  - Address 1: Address of the next hop to the originator mesh STA address in the PREQ element that triggered the PREP element
  - Address 2: Address of the mesh STA sending the PREP element
  - Address 3: Same as Address 2
- PREP element [Case B: PREP element Propagation; see 14.11.10.3 (Conditions for generating and sending a PREP element)]:
  - Address 1: Address of the next hop to the originator mesh STA address in the PREP element that triggered the PREP element
  - Address 2: Address of the mesh STA sending the PREP element
  - Address 3: Same as Address 2
- PERR element individually addressed [Case A: Original transmission—next hop is unusable; see 14.11.11.3 (Conditions for generating and sending a PERR element)]:
  - Address 1: Address of each one of the precursors for which the active forwarding information has been invalidated
  - Address 2: Address of the mesh STA sending the PERR element
  - Address 3: Same as Address 2
- PERR element individually addressed [Case B: Original transmission—missing forwarding information; see 14.11.11.3 (Conditions for generating and sending a PERR element)]:
  - Address 1: Address of the transmitter of the frame that triggered the PERR element
  - Address 2: Address of the mesh STA sending the PERR element
  - Address 3: Same as Address 2
- PERR element individually addressed [Case C: Original transmission (proxy information is unusable); see 14.11.11.3 (Conditions for generating and sending a PERR element)]:
  - Address 1: Address of each one of the neighbor peer mesh STAs
  - Address 2: Address of the mesh STA sending the PERR element
  - Address 3: Same as Address 2
- PERR element individually addressed [Case D: PERR element propagation; see 14.11.11.3 (Conditions for generating and sending a PERR element)]:
  - Address 1: Address of each one of the precursors for which the active forwarding information has been invalidated
  - Address 2: Address of the mesh STA sending the PERR element
  - Address 3: Same as Address 2
- PERR element group addressed [all cases; see 14.11.11.3 (Conditions for generating and sending a PERR element)]:
  - Address 1: Group address
  - Address 2: Address of the mesh STA sending the PERR element
  - Address 3: Same as Address 2

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- RANN element [all cases; see 14.11.12.3 (Conditions for generating and sending a RANN element)]:
  - Address 1: Group address
  - Address 2: Address of the mesh STA sending the RANN element
  - Address 3: Same as Address 2

Multiple HWMP elements may be sent in the same HWMP Mesh Path Selection frame if they share the same intended Address 1.

### 14.11.8 General rules for processing HWMP elements

#### 14.11.8.1 General

This subclause describes the rules for the processing of the following components of the HWMP elements:

- HWMP SN
- Element TTL
- Metric

#### 14.11.8.2 HWMP propagation

The term *propagate* is used to describe the means by which elements are not transmitted "as is" across the network but are processed and modified along the way. Many HWMP elements are intended to be processed and propagated across an MBSS by mesh STAs. Each propagation is subject to certain rules or limitations as explained in the following subclauses. Certain parameters in the HWMP elements are updated during the propagation. See 14.11.9 (Path request (PREQ) mechanism), 14.11.10 (Path reply (PREP) mechanism), 14.11.11 (Path error (PERR) mechanism), and 14.11.12 (Root announcement (RANN) mechanism).

The originator of an HWMP element sets the initial value of the Element TTL. The mesh STA that receives the HWMP element shall propagate it if the received value of Element TTL is greater than 1. Before propagating the HWMP element, the mesh STA decrements the Element TTL value.

In general, the propagation of an HWMP element is not subject to a delay. Exception exists for the RANN element as described in 14.11.12 (Root announcement (RANN) mechanism).

#### 14.11.8.3 HWMP sequence numbering

HWMP uses sequence numbers to prevent the creation of path loops and to distinguish stale and fresh path information. Each mesh STA keeps its own HWMP SN that it increments, uses in HWMP elements, and processes according to the HWMP rules. HWMP SNs for other mesh STAs are maintained in the forwarding information (see 14.11.8.4 (Forwarding information)).

An HWMP SN is included in the PREQ, PREP, PERR, and RANN elements. The HWMP SN in the forwarding information is updated whenever a mesh STA receives new (i.e., not stale) information about the HWMP SN from a PREQ, PREP, or PERR element that may be received relative to that originator mesh STA, target mesh STA, or destination mesh STA.

HWMP depends on each mesh STA in the network to own and maintain its HWMP SN to guarantee the loop-freedom of all paths toward that mesh STA. A mesh STA increments its own HWMP SN in the following two circumstances:

- If it is an originator mesh STA, it shall increment its own HWMP SN immediately before it starts a path discovery. This prevents conflicts with previously established reverse paths toward the originator mesh STA. However, it might be advantageous not to increment the HWMP SN too


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frequently. An optional mechanism for achieving this is described in 14.11.8.6 (Limiting the rate of HWMP SN increments).

— If it is a target mesh STA, it shall update its own HWMP SN to maximum (current HWMP SN, target HWMP SN in the PREQ element) + 1 immediately before it generates a PREP element in response to a PREQ element. The target HWMP SN of the PREQ element is relevant when a link was broken along the path and the stored sequence number was increased at an intermediate mesh STA.

Comparing HWMP SNs is done using a circular modulo $2^{32}$ comparison.

In general, when a mesh STA receives an element with an HWMP SN that is less than the HWMP SN in the corresponding forwarding information, it discards the received element. If they are the same, the outcome (element processed or not) depends on the type of the element and some additional conditions. These cases are noted in the applicable element descriptions.

The only circumstance in which a mesh STA may change the HWMP SN of another mesh STA in the forwarding information independently of the reception of an HWMP element originated by this mesh STA is in response to a broken or no longer usable link to the next hop toward that destination mesh STA. The mesh STA determines which destinations use a particular next hop by consulting its forwarding information. In this case, for each destination that uses the next hop, the mesh STA increments the HWMP SN in the forwarding information and marks the path as invalid (see also 14.11.11 (Path error (PERR) mechanism)). Whenever any forwarding information containing an HWMP SN greater than the recorded HWMP SN for an affected destination is received by a mesh STA that has marked that recorded forwarding information as invalid, the mesh STA shall update its forwarding information according to the information contained in the update.

#### 14.11.8.4 Forwarding information

In addition to the parameters contained in the basic forwarding information as described in 10.37.2 (Forwarding information), the forwarding information to a destination defined by HWMP also contains at least the destination HWMP SN, the path metric, and the number of hops.

Upon PREQ element and PREP element processing, a mesh STA shall create or update the forwarding information as follows:

— The mesh STA may create or update its forwarding information to the transmitter of the element if the path metric improves.

— The mesh STA shall create or update its forwarding information to the originator mesh STA, if it received a PREQ element, and one of the following conditions is met:
  — The originator HWMP SN > HWMP SN in the forwarding information for this originator mesh STA, or
  — The originator HWMP SN = HWMP SN in the forwarding information for this originator mesh STA AND the updated path metric is better than the path metric in the forwarding information.

— The mesh STA shall create or update its forwarding information to the target mesh STA, if it received a PREP element, and one of the following conditions is met:
  — The Target HWMP SN > HWMP SN in the forwarding information for this target mesh STA, or
  — The Target HWMP SN = HWMP SN in the forwarding information for this target mesh STA AND the updated path metric is better than the path metric in the forwarding information.

Table 14-9 (Data for creation and update of forwarding information due to PREQ element and PREP element) defines the values to be stored in the different fields of the forwarding information after a PREQ

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element or PREP element has been received. Details of PREQ element processing and PREP element processing are described in 14.11.9 (Path request (PREQ) mechanism) and 14.11.10 (Path reply (PREP) mechanism), respectively.

**Table 14-9—Data for creation and update of forwarding information due to PREQ element and PREP element**

| Field of forwarding information | Received PREQ element | | Received PREP element | |
|---|---|---|---|---|
| | Forwarding information for transmitter of PREQ element | Forwarding information for originator mesh STA | Forwarding information for transmitter of PREP element | Forwarding information for target mesh STA |
| HWMP SN | Invalid if created, no change if updated | PREQ element field Originator HWMP Sequence Number | Invalid if created, no change if updated | PREP element field Target HWMP Sequence Number |
| Next hop | Transmitter address of the Management frame containing the PREQ element | Transmitter address of the Management frame containing the PREQ element | Transmitter address of the Management frame containing the PREP element | Transmitter address of the Management frame containing the PREP element |
| Path metric | Accumulation of the initial value of the path metric with the metric of the link to the transmitter of the PREQ element | Accumulation of the value of PREQ element field Metric with the metric of the link to the transmitter of the PREQ element | Accumulation of the initial value of the path metric with the metric of the link to the transmitter of the PREP element | Accumulation of the value of PREP element field Metric with the metric of the link to the transmitter of the PREP element |
| Number of hops | 1 | Value of PREQ element field Hop Count + 1 | 1 | Value of PREP element field Hop Count + 1 |
| Precursor list | No change | No change except in case of an intermediate reply (#4181)(see 14.11.9.4.3 (Effect of receipt) step f)) | No change | See 14.11.10.4.3 (Effect of receipt) step d) |
| Lifetime | The longer one of the lifetime of the stored forwarding information and the value of PREQ element field Lifetime | The longer one of the lifetime of the stored forwarding information and the value of PREQ element field Lifetime | The longer one of the lifetime of the stored forwarding information and the value of PREP element field Lifetime | The longer one of the lifetime of the stored forwarding information and the value of PREP element field Lifetime |

Upon PREP element processing, a mesh STA shall validate the forwarding information as follows:

— When the mesh STA transmits a PREP element, it shall validate its forwarding information to the originator mesh STA of the PREP element.

— When the mesh STA receives a PREP element, it shall validate its forwarding information to the target mesh STA of the PREP element.


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If the mesh STA is unable to forward an MSDU/MMPDU to a next-hop STA as indicated in the forwarding information, it shall invalidate the corresponding forward information (See 14.11.11.3 (Conditions for generating and sending a PERR element)). When a mesh STA receives PERR element, it shall invalidate the forwarding information to the unreachable destination mesh STA indicated in the PERR element. The forwarding information shall be invalidated if its lifetime has expired.

Table 14-10 (Validation and invalidation of the forwarding information) summarizes the timing to validate or invalidate the forwarding information.

**Table 14-10—Validation and invalidation of the forwarding information**

| Event | Action |
|---|---|
| Transmitted PREP element | Validate forwarding information to the originator mesh STA of the PREP element |
| Received PREP element | Validate forwarding information to the target mesh STA of the PREP element |
| Unable to forward MSDU/ MMPDU to a next-hop STA | Invalidate forwarding information that uses the next-hop STA |
| Received PERR element | Invalidate forwarding information to the unreachable destination STA indicated in the Destination Address field in the PERR element |
| Forwarding information lifetime expiration | Invalidate forwarding information that the lifetime is expired |

Details of PREP element processing and PERR element processing are described in 14.11.10 (Path reply (PREP) mechanism) and 14.11.11 (Path error (PERR) mechanism), respectively.

#### 14.11.8.5 Repeated attempts at path discovery

Repeated attempts by a mesh STA at path discovery toward a single target shall be limited to dot11MeshHWMPmaxPREQretries. The minimum waiting time for the repeated attempt at path discovery to a single target is 2 × dot11MeshHWMPnetDiameterTraversalTime. For each attempt, the HWMP SN is incremented and a new Path Discovery ID is chosen.

#### 14.11.8.6 Limiting the rate of HWMP SN increments

In order to improve path stability (and further reduce overhead), a mesh STA may use the same originator HWMP SN for a certain time interval. In this case, the originator HWMP SN shall not be incremented until at least dot11MeshHWMPnetDiameterTraversalTime has elapsed since the previous increment. This mechanism prevents mesh STAs from changing the path frequently to the originator mesh STA every time the originator mesh STA sends a burst of PREQ elements within a very short time. This element of the protocol allows an originator mesh STA to immediately initiate on-demand path discovery to a new target without affecting recently refreshed paths to the originator in other mesh STAs.

### 14.11.9 Path request (PREQ) mechanism

#### 14.11.9.1 General

This subclause describes the function, generation, and processing of the PREQ element.

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#### 14.11.9.2 Function

The PREQ element, described in 9.4.2.111 (PREQ element), is used for the following purposes:

— Discovering a path to one or more target mesh STAs
— Maintaining a path (optional)
— Building a proactive (reverse) path selection tree to the root mesh STA
— Confirming a path to a target mesh STA (optional)

#### 14.11.9.3 Conditions for generating and sending a PREQ element

A mesh STA shall send a PREQ element in an HWMP Mesh Path Selection frame, as defined in 9.6.16.3 (HWMP Mesh Path Selection frame format), in the following cases:

**Case A**: Path Discovery (Original Transmission)

All of the following conditions apply:

— The mesh STA needs to establish an on-demand path to one or more targets for which there is no ongoing path discovery initiated by this mesh STA.
— The mesh STA has not sent a PREQ element for the target mesh STAs less than dot11MeshHWMPpreqMinInterval TUs ago. If this is the case, the transmission of the PREQ element has to be postponed until this condition becomes true.
— The mesh STA has not made more than (dot11MeshHWMPmaxPREQretries – 1) repeated attempts at path discovery toward the target of the PREQ element.

The content of a PREQ element in Case A shall be as shown in Table 14-11 (Contents of a PREQ element in Case A).

**Table 14-11—Contents of a PREQ element in Case A**

| Field | Value |
|---|---|
| Element ID | Value given in Table 9-130 (Element IDs) for the PREQ element |
| Length | 26 + N × 11 (if Bit 6 (AE subfield) in the Flags field = 0)<br>32 + N × 11 (if Bit 6 (AE subfield) in the Flags field = 1) |
| Flags | Bit 0: 0 (gate announcement not applicable)<br>Bit 1: 0 (group addressed)<br>Bit 2: 0 (no proactive PREP element applicable)<br>Bit 3–5: Reserved<br>Bit 6: (1 – if external address present, 0 – otherwise)<br>Bit 7: Reserved |
| Hop Count | 0 |
| Element TTL | Maximum number of hops allowed for this element, e.g., dot11MeshHWMPnetDiameter |
| Path Discovery ID | New unique Path Discovery ID, for instance, previous Path Discovery ID + 1 |
| Originator Mesh STA Address | MAC address of the path originator |
| Originator HWMP Sequence Number | Previous originator HWMP SN + 1; see 14.11.8.6 (Limiting the rate of HWMP SN increments) |


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**Table 14-11—Contents of a PREQ element in Case A *(continued)***

| Field | | Value |
|---|---|---|
| Originator External Address | | Present only if Bit 6 in Flags field = 1; this value is set to the external address, which is the source address of the MSDU (from outside the mesh BSS) that triggered the path discovery at the originator |
| Lifetime | | The time for which mesh STAs receiving the PREQ element consider the forwarding information to be valid, e.g., dot11MeshHWMPactivePathTimeout |
| Metric | | Initial value of active path selection metric |
| Target Count | | N (N ≥ 1) |
| Per Target | Per Target Flags | Bit 0 (TO): dot11MeshHWMPtargetOnly<br>Bit 1: Reserved<br>Bit 2 (USN): 0 if forwarding information for Target Address with valid HWMP SN exists, 1 otherwise<br>Bit 3–7: Reserved |
| | Target Address | MAC address of requested target |
| | Target HWMP Sequence Number | If Per Target Flags Bit 2 (USN) is 0, the latest HWMP SN stored by the originator mesh STA for the target mesh STA from the forwarding information (see 14.11.8.4 (Forwarding information)); otherwise, reserved |

**Case B**: Path Maintenance (Original Transmission) (optional)

All of the following conditions apply:

— The mesh STA has a path to a given target mesh STA that is not a root mesh STA.

— The last PREQ element to this target was sent dot11MeshHWMPmaintenanceInterval TUs (or more) ago.

The content of a PREQ element in Case B shall be as shown in Table 14-12 (Contents of a PREQ element in Case B).

**Table 14-12—Contents of a PREQ element in Case B**

| Field | Value |
|---|---|
| Element ID | Value given in Table 9-130 (Element IDs) for the PREQ element |
| Length | 26 + N × 11 |
| Flags | Bit 0: 0 (gate announcement not applicable)<br>Bit 1: 0 (group addressed)<br>Bit 2: 0 (no proactive PREP element applicable)<br>Bit 3–5: Reserved<br>Bit 6: 0 (no address extension)<br>Bit 7: Reserved |
| Hop Count | 0 |
| Element TTL | Maximum number of hops allowed for this element, e.g., dot11MeshHWMPnetDiameter |
| Path Discovery ID | New unique Path Discovery ID, for instance, previous Path Discovery ID + 1 |

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**Table 14-12—Contents of a PREQ element in Case B *(continued)***

| Field | | Value |
|---|---|---|
| Originator Mesh STA Address | | MAC address of the originator of the PREQ element |
| Originator HWMP Sequence Number | | Originator HWMP SN + 1; see 14.11.8.6 (Limiting the rate of HWMP SN increments) |
| Originator External Address | | Field not present |
| Lifetime | | The time for which mesh STAs receiving the PREQ element consider the forwarding information to be valid, e.g., dot11MeshHWMPactivePathTimeout |
| Metric | | Initial value of active path selection metric |
| Target Count | | N (N ≥ 1) |
| Per Target | Per Target Flags | Bit 0 (TO): 1 (target only)<br>Bit 1: Reserved<br>Bit 2 (USN): 0<br>Bit 3–7: Reserved |
| | Target Address | MAC Address of target mesh STA |
| | Target HWMP Sequence Number | The latest HWMP SN for this target known to the originator mesh STA |

**Case C:** Proactive PREQ element (Original Transmission)

All of the following conditions apply:

— The root mesh STA is configured as root mesh STA using proactive PREQ elements ([dot11MeshHWMProotMode = proactivePREQnoPREP (2)] OR [dot11MeshHWMProotMode = proactivePREQwithPREP (3)]).

— The root mesh STA sent its previous proactive PREQ element dot11MeshHWMProotInterval TUs ago.

The contents of a PREQ element in Case C shall be as shown in Table 14-13 (Contents of a PREQ element in Case C).

**Table 14-13—Contents of a PREQ element in Case C**

| Field | Value |
|---|---|
| Element ID | Value given in Table 9-130 (Element IDs) for the PREQ element |
| Length | 37 |
| Flags | Bit 0: 1 if dot11MeshGateAnnouncements is true (gate announcement), 0 otherwise<br>Bit 1: 0 (group addressed)<br>Bit 2: 0 if dot11MeshHWMProotMode = proactivePREQnoPREP(2), 1 if dot11MeshHWMProotMode = proactivePREQwithPREP(3) (proactive PREP)<br>Bit 3–5: Reserved<br>Bit 6: 0 (no address extension)<br>Bit 7: Reserved |


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**Table 14-13—Contents of a PREQ element in Case C *(continued)***

| Field | | Value |
|---|---|---|
| Hop Count | | 0 |
| Element TTL | | Maximum number of hops allowed for this element, e.g., dot11MeshHWMPnetDiameter |
| Path Discovery ID | | New unique Path Discovery ID, for instance, previous Path Discovery ID + 1 |
| Originator Mesh STA Address | | MAC address of the root mesh STA |
| Originator HWMP Sequence Number | | Originator HWMP SN + 1; see 14.11.8.6 (Limiting the rate of HWMP SN increments) |
| Originator External Address | | Field not present |
| Lifetime | | dot11MeshHWMPactivePathToRootTimeout |
| Metric | | Initial value of active path selection metric |
| Target Count | | 1 |
| Per Target | Per Target Flags | Bit 0 (TO): 1<br>Bit 1: Reserved<br>Bit 2 (USN): 1<br>Bit 3–7: Reserved |
| | Target Address | Broadcast address |
| | Target HWMP Sequence Number | 0 |

**Case D:** Root Path Confirmation (Original Transmission)

One of the following conditions applies:

— The mesh STA has received a RANN element and the metric (RANN metric ⊕ metric to the transmitter of the RANN element) is better than the metric to the root in the current forwarding information.

— The mesh STA has a path to a root mesh STA and the last PREQ element to the root mesh STA was sent dot11MeshHWMPconfirmationInterval TUs (or more) ago.

The content of a PREQ element in Case D shall be as shown in Table 14-14 (Contents of a PREQ element in Case D).

**Table 14-14—Contents of a PREQ element in Case D**

| Field | Value |
|---|---|
| Element ID | Value given in Table 9-130 (Element IDs) for the PREQ element |
| Length | As required |

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**Table 14-14—Contents of a PREQ element in Case D *(continued)***

| Field | | Value |
|---|---|---|
| Flags | | Bit 0: 0 (gate announcement not applicable)<br>Bit 1: 1 (individually addressed)<br>Bit 2: 0 (no proactive PREP element applicable)<br>Bit 3–5: Reserved<br>Bit 6: 0 (no address extension)<br>Bit 7: Reserved |
| Hop Count | | 0 |
| Element TTL | | Maximum number of hops allowed for this element, e.g., dot11MeshHWMPnetDiameter |
| Path Discovery ID | | Not used |
| Originator Mesh STA Address | | MAC address of the originator mesh STA |
| Originator HWMP Sequence Number | | Originator HWMP SN + 1; see 14.11.8.6 (Limiting the rate of HWMP SN increments) |
| Originator External Address | | Field not present |
| Lifetime | | The time for which mesh STAs receiving the PREQ element consider the forwarding information to be valid, e.g., dot11MeshHWMPactivePathToRootTimeout |
| Metric | | Initial value of active path selection metric |
| Target Count | | 1 |
| Per Target | Per Target Flags | Bit 0 (TO): 1<br>Bit 1: Reserved<br>Bit 2 (USN): 0<br>Bit 3–7: Reserved |
| | Target Address | Root mesh STA MAC Address |
| | Target HWMP Sequence Number | The latest HWMP SN for this target known to the originator mesh STA |

**Case E:** PREQ element Propagation

**Case E1 (target count = 1, no PREP element generation as intermediate mesh STA):**

All of the following conditions apply:

- The mesh STA has received and accepted a PREQ element; see 14.11.9.4.2 (Acceptance criteria).
- dot11MeshForwarding is true.
- [The active forwarding information for the originator mesh STA was created or updated according to the rules defined in 14.11.8.4 (Forwarding information)] OR [{the originator HWMP SN of the accepted PREQ element = HWMP SN in the forwarding information for this originator mesh STA} AND {the mesh STA has not previously received a PREQ element with the same originator mesh STA address and the same Path Discovery ID}].
- The Element TTL field is greater than 1; see 14.11.8.2 (HWMP propagation).
- Target Count = 1.


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— [The mesh STA is not the target of the PREQ element)]
OR
[the target of the PREQ element is the MAC broadcast address (all 1s)].

— The mesh STA is not the proxy of the target address.

— [The TO (Target Only) subfield of the target in the PREQ element is set (TO = 1)]
OR
[{the TO (Target Only) subfield of the target in the PREQ element is not set (TO = 0)} AND {mesh STA has no active forwarding information for the requested target}].

The content of a PREQ element in Case E1 shall be as shown in Table 14-15 (Contents of a PREQ element in Case E1).

**Table 14-15—Contents of a PREQ element in Case E1**

| Field | | Value |
|---|---|---|
| Element ID | | Value given in Table 9-130 (Element IDs) for the PREQ element |
| Length | | As received |
| Flags | | As received |
| Hop Count | | As received + 1 |
| Element TTL | | As received – 1 |
| Path Discovery ID | | As received |
| Originator Mesh STA Address | | As received |
| Originator HWMP Sequence Number | | As received |
| Originator External Address | | As received; this field is present if Bit 6 of the Flags field (AE subfield) is 1; it is not present otherwise |
| Lifetime | | As received |
| Metric | | As received ⊕ own metric toward transmitter of received PREQ element |
| Target Count | | 1 |
| Per Target | Per Target Flags | As received |
| | Target MAC Address | As received |
| | Target HWMP Sequence Number | As received |

**Case E2 (target count = 1, PREP element generation as intermediate mesh STA):**

All of the following conditions apply:

— The mesh STA has received and accepted a PREQ element; see 14.11.9.4.2 (Acceptance criteria).

— dot11MeshForwarding is true.

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— [The active forwarding information for the originator mesh STA was created or updated according to the rules defined in 14.11.8.4 (Forwarding information)]
OR
[{the originator HWMP SN of the accepted PREQ element = HWMP SN in the forwarding information for this originator mesh STA} AND {the mesh STA has not previously received a PREQ element with the same originator mesh STA address and the same Path Discovery ID}].

— The Element TTL field is greater than 1; see 14.11.8.2 (HWMP propagation).

— Target Count = 1.

— The mesh STA is not the target of the PREQ element.

— The mesh STA is not the proxy of the target address.

— The mesh STA has active forwarding information for the requested target.

— [The TO (Target Only) subfield of the target in the PREQ element is not set (TO = 0)]
AND
[the mesh STA has active forwarding information for the requested target].

The contents of a PREQ element in Case E2 shall be as shown in Table 14-16 (Contents of a PREQ element in Case E2).

**Table 14-16—Contents of a PREQ element in Case E2**

| Field | | Value |
|---|---|---|
| Element ID | | Value given in Table 9-130 (Element IDs) for the PREQ element |
| Length | | As received |
| Flags | | As received |
| Hop Count | | As received + 1 |
| Element TTL | | As received – 1 |
| Path Discovery ID | | As received |
| Originator Mesh STA Address | | As received |
| Originator HWMP Sequence Number | | As received |
| Originator External Address | | As received; this field is present if Bit 6 of the Flags field (AE subfield) is 1; it is not present otherwise |
| Lifetime | | As received |
| Metric | | As received ⊕ own metric toward transmitter of received PREQ element |
| Target Count | | 1 |
| Per Target | Per Target Flags | Bit 0 (TO): 1 (target only because mesh STA sent a PREP element)<br>Bit 1: Reserved<br>Bit 2 (USN): As received<br>Bit 3–7: Reserved |
| | Target MAC Address | As received |
| | Target HWMP Sequence Number | As received |


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**Case E3 (target count > 1):**

All of the following conditions apply:

- The mesh STA has received and accepted a PREQ element; see 14.11.9.4.2 (Acceptance criteria).
- dot11MeshForwarding is true.
- [The active forwarding information for the originator mesh STA was created or updated according to the rules defined in 14.11.8.4 (Forwarding information)
  OR
  [{the originator HWMP SN of the accepted PREQ element = HWMP SN in the forwarding information for this originator mesh STA} AND {the mesh STA has not previously received a PREQ element with the same originator mesh STA address and the same Path Discovery ID}].
- The Element TTL field is greater than 1; see 14.11.8.2 (HWMP propagation).
- Target Count > 1.
- There is at least one requested target that is neither the recipient MAC address nor an external MAC address proxied by the recipient.

The contents of a PREQ element in Case E3 shall be as shown in Table 14-17 (Contents of a PREQ element in Case E3).

**Table 14-17—Contents of a PREQ element in Case E3**

| Field | Value |
|---|---|
| Element ID | Value given in Table 9-130 (Element IDs) for the PREQ element |
| Length | $26 + N \times 11$ |
| Flags | As received |
| Hop Count | As received + 1 |
| Element TTL | As received – 1 |
| Path Discovery ID | As received |
| Originator Mesh STA Address | As received |
| Originator HWMP Sequence Number | As received |
| Originator External Address | As received; this field is present if Bit 6 of the Flags field (AE subfield) is set to 1; it is not present otherwise |
| Lifetime | As received |
| Metric | As received $\oplus$ own metric toward the transmitter of the received PREQ element |
| Target Count | $1 \leq$ target count $\leq$ received target count<br>received target count less the number of requested destinations, for which the processing mesh STA<br>— Is the target mesh STA or<br>— Is the target proxy mesh gate |

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**Table 14-17—Contents of a PREQ element in Case E3 *(continued)***

| Field | | Value |
|---|---|---|
| Per Target #A | Per Target Flags #A | As received |
| | Target MAC Address #A | As received |
| | Target HWMP Sequence Number #A | As received |
| Per Target #B | Per Target Flags #B | Bit 0 (TO): 1 (target only because mesh STA sent PREP element)<br>Bit 1: As received<br>Bit 2 (USN): As received<br>Bit 3–7: As received |
| | Target MAC Address #B | As received |
| | Target HWMP Sequence Number #B | As received |

(#3251)For the per target fields (Per Target Flags, Target Address, Target HWMP Sequence Number) assume the following:

— Target #A: If target A would have been the only requested target, it would generate a PREQ element for propagation according to case E1.

— Target #B: If target B would have been the only requested target, it would generate a PREQ element for propagation according to case E2.

### 14.11.9.4 PREQ element processing

#### 14.11.9.4.1 General

Received PREQ elements are subject to certain acceptance criteria. Processing and actions taken depend on the contents of the PREQ element and the information available to the receiving mesh STA. See also 14.11.8 (General rules for processing HWMP elements).

#### 14.11.9.4.2 Acceptance criteria

The PREQ element shall not be accepted (and shall not be processed as described in 14.11.9.4.3 (Effect of receipt)) if any of the following is true:

— (The target address of the PREQ element is neither the recipient MAC address, broadcast address, nor an external MAC address proxied by the recipient) AND (dot11MeshForwarding is false)

— (Bit 1 (Addressing Mode subfield) of the Flags field in the PREQ element is equal to 1) AND (there is no valid forwarding information with the destination mesh STA address equal to the Target Address of the PREQ element)

Otherwise, the PREQ element is accepted. See also 14.11.8 (General rules for processing HWMP elements).


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#### 14.11.9.4.3 Effect of receipt

A mesh STA receiving a PREQ element according to the acceptance criteria in 14.11.9.4.2 (Acceptance criteria) shall record the Path Discovery ID and the originator mesh STA address. The receiving mesh STA shall create or update the active forwarding information it maintains for the originator mesh STA of the PREQ element according to the rules defined in 14.11.8.4 (Forwarding information).

If the active forwarding information for the originator mesh STA was created or updated according to the rules defined in 14.11.8.4 (Forwarding information) or if the Target HWMP SN of the PREQ element is the same as the HWMP SN in the forwarding information for the Target Mesh STA and there has been no record of the originator mesh STA and Path Discovery ID, the following applies:

a) If the mesh STA is the target of the PREQ element or is the proxy of the target MAC address it shall initiate the transmission of a PREP element to the originator mesh STA (14.11.10.3 (Conditions for generating and sending a PREP element) Case A). If the PREQ element carries an external address (indicated by the AE subfield in the Flags field), the mesh STA shall update its proxy information with the originator external address as external address, the PREQ element Originator Mesh STA Address as the corresponding proxy, the HWMP Sequence Number as proxy information sequence number, and for the proxy lifetime the longer one of the value of the PREQ element Lifetime field and the proxy lifetime if the proxy information already exists (see also 14.12.4.3 (Proxy update (PXU))).

b) If step a) was not applicable for the mesh STA and the AE subfield in the Flags field in the PREQ element is 1, the mesh STA may update its proxy information with the originator external address as external address, the PREQ element Originator Mesh STA Address as the corresponding proxy, the HWMP Sequence Number as proxy information sequence number, and for the proxy lifetime the longer one of the value of the PREQ element Lifetime field and the proxy lifetime if the proxy information already exists (see also 14.12.4.3 (Proxy update (PXU))).

c) If the mesh STA has valid forwarding information to any of the requested targets and the TO (Target Only) subfield for such a target is not set (TO = 0), it initiates the transmission of a PREP element for each of these targets (see 14.11.10.3 (Conditions for generating and sending a PREP element) Case C).

d) If the mesh STA is initiating a PREP element transmission on behalf of another target according to step c) (intermediate reply), it shall process all of the following:
   - Update the precursor list in its forwarding information for the target mesh STA with the next hop from the forwarding information of the originator mesh STA.
   - Update the lifetime for this precursor that is the longer one of the lifetime of the forwarding information of the target mesh STA.
   - Update the lifetime of the precursor list entry in case it already exists.
   - Update the precursor list in its forwarding information for the originator mesh STA with the next hop toward the target mesh STA.
   - Update the lifetime for this precursor that is the longer one of the lifetime of the forwarding information of the originator mesh STA.
   - Update the lifetime of the precursor list entry in case it already exists.

e) If the received PREQ element is a proactive PREQ element [target address is set to all 1s, TO subfield is set (TO = 1)], the mesh STA generates a proactive PREP element to the root mesh STA (see 14.11.10.3 (Conditions for generating and sending a PREP element) Case D) depending on the setting of the Proactive PREP subfield. If the Proactive PREP subfield is 1, a proactive PREP element is generated, if it is 0, a proactive PREP element is generated only if a bidirectional path to the root mesh STA is required (see S.7 (Generation of proactive PREP elements in the proactive PREQ mechanism of HWMP)).

f) If there are individually addressed targets in the PREQ element that have not been processed in step a) or that have been processed in step c) or in step e), the receiving mesh STA shall propagate

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the PREQ element as defined in 14.11.9.3 (Conditions for generating and sending a PREQ element) Case E.

### 14.11.10 Path reply (PREP) mechanism

#### 14.11.10.1 General

Subclause 14.11.10 (Path reply (PREP) mechanism) describes the function, generation, and processing of the PREP element.

#### 14.11.10.2 Function

The PREP element is transmitted in individually addressed frames and is described in 9.4.2.112 (PREP element). The purpose of the PREP element is as follows:

— To establish the forward path to a target mesh STA or target proxy mesh gate.
— To confirm the reverse path to the originator.

#### 14.11.10.3 Conditions for generating and sending a PREP element

A mesh STA sends out a PREP element in an HWMP Mesh Path Selection frame, as defined in 9.6.16.3 (HWMP Mesh Path Selection frame format), in the following cases:

**Case A**: Path Discovery (Original Transmission)

A PREP element is transmitted if the mesh STA has received and accepted a PREQ element (see 14.11.9.4.2 (Acceptance criteria)) fulfilling any one of the following conditions:

— The Target Address of the PREQ element is the same as MAC address of the receiving mesh STA.
— The Target Address of the PREQ element is an external address currently proxied by the mesh STA.

The content of the generated PREP element in Case A shall be as shown in Table 14-18 (Contents of a PREP element in Case A).

**Case B:** PREP element propagation

A PREP element is propagated if all of the following conditions apply:

— The mesh STA has received and accepted the PREP element; see 14.11.10.4.2 (Acceptance criteria).
— The mesh STA is not the path originator.

The contents of a PREP element in Case B shall be as shown in Table 14-19 (Contents of a PREP element in Case B).

**Case C:** Intermediate reply (Original Transmission)

A PREP element is transmitted if the mesh STA has received a PREQ element fulfilling all of the following conditions:

— The TO (Target Only) subfield in the corresponding Per Target Flags field in the PREQ element is not set (TO = 0)
— The receiving mesh STA has active forwarding information with
  — A destination that is the same as the Target Address of the PREQ element
  — An HWMP SN that is greater than or equal to the Target HWMP SN of the PREQ element
  — A nonzero lifetime


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**Table 14-18—Contents of a PREP element in Case A**

| Field | Value |
|---|---|
| Element ID | Value given in Table 9-130 (Element IDs) for the PREP element |
| Length | As required |
| Flags | Bit 0–5: Reserved<br>Bit 6 (AE): (1 = external address present, 0 = otherwise)<br>Bit 7: Reserved |
| Hop Count | 0 |
| Element TTL | Maximum number of hops allowed for this element |
| Target Mesh STA Address | MAC address of the target mesh STA or target proxy mesh gate |
| Target HWMP Sequence Number | HWMP SN of the target mesh STA or target proxy mesh gate after it has been updated according to 14.11.8.3 (HWMP sequence numbering) |
| Target External Address | External target address on behalf of which the PREP element is sent. Present only if Bit 6 (AE subfield) in the Flags field is 1 |
| Lifetime | As per the PREQ element that triggered the transmission of this PREP element |
| Metric | Initial value of active path selection metric |
| Originator Mesh STA Address | MAC address of the originator mesh STA |
| Originator HWMP Sequence Number | HWMP SN of the originator mesh STA |

**Table 14-19—Contents of a PREP element in Case B**

| Field | Value |
|---|---|
| Element ID | Value given in Table 9-130 (Element IDs) for the PREP element |
| Length | As received |
| Flags | As received |
| Hop Count | As received + 1 |
| Element TTL | As received – 1 |
| Target Mesh STA Address | As received |
| Target HWMP Sequence Number | As received |
| Target External Address | As received |
| Lifetime | As received |
| Metric | As received $\oplus$ own metric toward the transmitting mesh STA |
| Originator Mesh STA Address | As received |
| Originator HWMP Sequence Number | As received |

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The content of the generated PREP element in Case C shall be as shown in Table 14-20 (Contents of a PREP element in Case C).

**Table 14-20—Contents of a PREP element in Case C**

| Field | Value |
|---|---|
| Element ID | Value given in Table 9-130 (Element IDs) for the PREP element |
| Length | 31 |
| Flags | Bit 0–5: Reserved<br>Bit 6 (AE): 0<br>Bit 7: Reserved |
| Hop Count | 0 |
| Element TTL | Maximum number of hops allowed for this element |
| Target Mesh STA Address | Target MAC address from the PREQ element |
| Target HWMP Sequence Number | HWMP SN of the stored forwarding information of the Target of the PREQ element |
| Target External Address | Not present |
| Lifetime | As per the PREQ element that triggered the transmission of this PREP element |
| Metric | Value of path metric taken from the active forwarding information for the target address of the PREQ element |
| Originator Mesh STA Address | MAC address of the originator mesh STA |
| Originator HWMP Sequence Number | HWMP SN of the originator mesh STA |

**Case D:** Proactive PREP element in Proactive PREQ element mode (Original Transmission)

One of the following conditions applies:

— The mesh STA has received a proactive PREQ element with the Proactive PREP subfield set to 0 AND the mesh STA needs to establish or update a bidirectional path to the root mesh STA.

— The mesh STA has received a proactive PREQ element with the Proactive PREP subfield set to 1.

Note that a proactive PREQ element is a PREQ element with a Target Address set to all 1s and its TO subfield set (TO=1).

The content of the generated PREP element in Case D shall be as shown in Table 14-21 (Contents of a PREP element in Case D).

**Table 14-21—Contents of a PREP element in Case D**

| Field | Value |
|---|---|
| Element ID | Value given in Table 9-130 (Element IDs) for the PREP element |
| Length | 31 |


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**Table 14-21—Contents of a PREP element in Case D *(continued)***

| Field | Value |
|---|---|
| Flags | Bit 0–5: Reserved<br>Bit 6 (AE): 0<br>Bit 7: Reserved |
| Hop Count | 0 |
| Element TTL | Maximum number of hops allowed for this element |
| Target Mesh STA Address | MAC address of the mesh STA |
| Target HWMP Sequence Number | HWMP SN of the mesh STA |
| Target External Address | Not present |
| Lifetime | Lifetime of the PREQ element that triggered the transmission of this PREP element |
| Metric | Initial value of active path selection metric |
| Originator Mesh STA Address | MAC address of the root mesh STA (originator mesh STA of the PREQ element) |
| Originator HWMP Sequence Number | HWMP SN of the root mesh STA (originator HWMP SN of the PREQ element) |

When a mesh STA sends out a PREP element in an HWMP Mesh Path Selection frame, it shall validate the forwarding information to the originator mesh STA indicated in the PREP element.

#### 14.11.10.4 PREP element processing

##### 14.11.10.4.1 General

Received PREP elements are subject to certain acceptance criteria. Processing and actions taken depend on the contents of the PREP element and the information available to the receiving mesh STA.

##### 14.11.10.4.2 Acceptance criteria

The PREP element shall not be accepted (and shall not be processed as described in 14.11.10.4.3 (Effect of receipt)) if any of the following is true:

— (The originator mesh STA address of the PREP element is neither the recipient MAC address nor an external MAC address proxied by the recipient) AND (dot11MeshForwarding is false).

Otherwise, the PREP element shall be accepted.

##### 14.11.10.4.3 Effect of receipt

A mesh STA receiving a PREP element according to the acceptance criteria in 14.11.10.4.2 (Acceptance criteria) shall create or update the forwarding information it maintains for the target mesh STA of the PREP element (according to the rules defined in 14.11.8.4 (Forwarding information)). Further, the mesh STA shall validate the forwarding information to the target mesh STA indicated in the PREP element. If the conditions for creating or updating the forwarding information have not been met in those rules, no further steps are applied to the PREP element.

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If the active forwarding information was created or updated according to the rules defined in 14.11.8.4 (Forwarding information), the following apply:

a) If the receiving mesh STA is not the final destination of the PREP element (originator mesh STA) and the Element TTL field > 1, the PREP element is propagated as defined in 14.11.10.3 (Conditions for generating and sending a PREP element) Case B.

b) If the receiving mesh STA is the final destination of the PREP element (originator mesh STA) and its AE subfield in the Flags field is 1, the mesh STA shall store the Target External Address, the Target Mesh STA Address, and the HWMP Sequence Number as proxy information sequence number in its proxy information. The proxy lifetime is the longer one of the value of the PREP element Lifetime field and the proxy lifetime if the proxy information already exists (see also 14.12.4.3 (Proxy update (PXU))).

c) If the receiving mesh STA is not the final destination of the PREP element (originator mesh STA) and its AE subfield in the Flags field is 1, the mesh STA may store the Target External Address, the Target Mesh STA Address, and the HWMP Sequence Number as proxy information sequence number in its proxy information. The proxy lifetime is the longer one of the value of the PREP element Lifetime field and the proxy lifetime if the proxy information already exists (see also 14.12.4.3 (Proxy update (PXU))).

d) If the mesh STA propagates the PREP element, the precursor list for the Target Mesh STA Address is updated by adding the next-hop mesh STA to which the PREP element is propagated. In addition, at the mesh STA the precursor list for the originator mesh STA address is updated by adding the next-hop mesh STA toward the Target Address. The lifetimes of these entries in the precursor lists are the values of the lifetimes of the corresponding forwarding information.

### 14.11.11 Path error (PERR) mechanism

#### 14.11.11.1 General

Subclause 14.11.11 (Path error (PERR) mechanism) describes the function, generation, and processing of the PERR element.

#### 14.11.11.2 Function

The PERR element is used for announcing one or more unreachable destination(s). The announcement is sent to all traffic sources that have a known active path to the destination(s). The active forwarding information associated with the unreachable destination(s) should no longer be used for forwarding.

A PERR element may be either group addressed (if there are many precursors), individually addressed (if there is only one precursor), or individually addressed iteratively to all precursors (see 14.11.7 (Addressing of HWMP Mesh Path Selection frame), item “PERR element individually addressed”). The PERR element is processed as a single element when iteratively individually addressed to several precursors. The PERR element contains the destinations that are unreachable.

A PERR element is propagated by mesh STAs receiving a PERR element if certain conditions are met.

A mesh STA generating or receiving a PERR element may attempt to establish paths to unreachable destinations using any of the available HWMP mechanisms.

#### 14.11.11.3 Conditions for generating and sending a PERR element

A mesh STA shall send out a PERR element in an HWMP Mesh Path Selection frame, as defined in 9.6.16.3 (HWMP Mesh Path Selection frame format), in the following cases:

**Case A**: Original transmission (next hop is unusable)


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The mesh STA has not sent a PERR element less than dot11MeshHWMPperrMinInterval TUs ago, and the following condition applies:

— The mesh STA determines that the link to the next hop of an active path in its forwarding information is no longer usable.

NOTE—The detection might be triggered by the fact that a mesh STA is unable to forward an MSDU/MMPDU to a next-hop mesh STA.

The HWMP SN in the forwarding information of all unreachable destinations announced in this PERR element is incremented by 1. The forwarding information for each unreachable destination announced in this PERR element is invalidated.

The contents of a PERR element in Case A shall be as shown in Table 14-22 (Contents of a PERR element in Case A).

**Table 14-22—Contents of a PERR element in Case A**

| Field | Value |
|---|---|
| Element ID | Value given in Table 9-130 (Element IDs) for the PERR element |
| Length | 2 + N × 13 |
| Element TTL | The maximum number of hops the element is propagated before being discarded |
| Number of Destinations | Number of announced unreachable destinations in the PERR element |
| Flags #1 | Bit 0–5: Reserved<br>Bit 6 (AE): 0<br>Bit 7: Reserved |
| Destination Address #1 | MAC address of unreachable destination #1 |
| HWMP Sequence Number #1 | HWMP SN for Destination Address #1 from the forwarding information after above increment |
| Reason Code #1 | "MESH-PATH-ERROR-DESTINATION-UNREACHABLE"<br>(see 9.4.1.7 (Reason Code field)) |
| ... | ... |

**Case B**: Original transmission (missing forwarding information)

The mesh STA has not sent a PERR element less than dot11MeshHWMPperrMinInterval TUs ago, and one of the following conditions applies:

— The mesh STA receives an individually addressed frame with a destination address not matching its (#3403)MAC address for which it has no forwarding information.

— The mesh STA receives an individually addressed frame with a destination address not matching its (#3403)MAC address and dot11MeshForwarding is false.

The contents of a PERR element in Case B shall be as shown in Table 14-23 (Contents of a PERR element in Case B).

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**Table 14-23—Contents of a PERR element in Case B**

| Field | Value |
|---|---|
| Element ID | Value given in Table 9-130 (Element IDs) for the PERR element |
| Length | 2 + N × 13 |
| Element TTL | The maximum number of hops the element is propagated before being discarded |
| Number of Destinations | Number of announced destinations with missing forwarding information in the PERR element |
| Flags #1 | Bit 0–5: Reserved<br>Bit 6 (AE): 0<br>Bit 7: Reserved |
| Destination Address #1 | MAC address of destination with missing forwarding information #1; this is Address 3 of the received individually addressed frame |
| HWMP Sequence Number #1 | Reserved |
| Reason Code #1 | "MESH-PATH-ERROR-NO-FORWARDING-INFORMATION"<br>(see 9.4.1.7 (Reason Code field)) |
| ... | ... |


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**Case C**: Original transmission (proxy information is unusable)

The mesh STA has not sent a PERR element less than dot11MeshHWMPperrMinInterval TUs ago, and the following condition applies:

— The mesh STA is a proxy mesh gate and determines that an active proxy information where the mesh STA is the proxy mesh gate is no longer usable.

The contents of a PERR element in Case C shall be as shown in Table 14-24 (Contents of a PERR element in Case C).

**Table 14-24—Contents of a PERR element in Case C**

| Field | Value |
|---|---|
| Element ID | Value given in Table 9-130 (Element IDs) for the PERR element |
| Length | 2 + N × 19 |
| Element TTL | The maximum number of hops the element is propagated before being discarded |
| Number of Destinations | Number of announced unreachable external destinations in the PERR element |
| Flags #1 | Bit 0–5: Reserved<br>Bit 6 (AE): 1<br>Bit 7: Reserved |
| Destination Address #1 | MAC address of proxy mesh gate #1 with unusable active proxy information |
| HWMP Sequence Number #1 | Last used HWMP SN for Destination Address #1 |
| Destination External Address #1 | External MAC address of the active proxy information that is not longer usable and for which the mesh STA is the proxy mesh gate |
| Reason Code #1 | "MESH-PATH-ERROR-NO-PROXY-INFORMATION"<br>(see 9.4.1.7 (Reason Code field) |
| ... | ... |

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**Case D:** PERR element propagation

The mesh STA has not sent a PERR element less than dot11MeshHWMPperrMinInterval TUs ago, and all of the following conditions apply:

— The mesh STA received a PERR element from a neighbor peer mesh STA.
— A destination in the PERR element is the same as one of the destinations in the active forwarding information of the mesh STA where the next hop is the transmitter of the received PERR element, and the forwarding information or the proxy information has been invalidated according to conditions in 14.11.11.4.3 (Effect of receipt) case b), case c), or case d).
— dot11MeshForwarding is true.
— The Element TTL field in the received PERR element is greater than 1.

The contents of a PERR element in Case D shall be as shown in Table 14-25 (Contents of a PERR element in Case D).

**Table 14-25—Contents of a PERR element in Case D**

| Field | Value |
|---|---|
| Element ID | Value given in Table 9-130 (Element IDs) for the PERR element |
| Length | if AE subfield = 0: 2 + N × 13<br>if AE subfield = 1: 2 + N × 19 |
| Element TTL | Element TTL in received PERR element – 1 |
| Number of Destinations | 1 ≤ number of destinations in the PERR element ≤ received value<br>Received number of destinations less the number of received destinations for which the transmitter of the PERR element is not the next hop |
| Flags #1 | As received |
| Destination Address #1 | MAC address of unreachable destination #1, as received |
| HWMP Sequence Number #1 | If Reason Code #1 = "MESH-PATH-ERROR-NO-FORWARDING-INFORMATION" and received value = 0, then HWMP SN for Destination Address #1 from the forwarding information after the increment of 14.11.10.4.3 (Effect of receipt) step b)<br>Otherwise, as received |
| Destination External Address #1 | As received; this field is present if Bit 6 (AE subfield) of the Flags field #1 is 1; it is not present otherwise |
| Reason Code #1 | As received |
| ... | ... |

### 14.11.11.4 PERR element processing

#### 14.11.11.4.1 General

Received PERR elements are subject to certain acceptance criteria. Processing and actions taken depend on the contents of the PERR element and the information available to the receiving mesh STA. See also 14.11.8 (General rules for processing HWMP elements).


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#### 14.11.11.4.2 Acceptance criteria

The PERR element shall be accepted (and shall be processed as described in 14.11.11.4.3 (Effect of receipt)) if the following applies:

- The mesh STA that receives the PERR element has forwarding information stored where
  - The destination is contained in the list of unreachable destinations of the PERR element, and
  - The next hop is the transmitter of the received PERR element.

Otherwise, the PERR element shall be discarded.

#### 14.11.11.4.3 Effect of receipt

The following applies only to a PERR element that was accepted according to the acceptance criteria in 14.11.11.4.2 (Acceptance criteria):

a) The mesh STA creates a list of unreachable destinations consisting of those destinations from the received PERR element for which the next hop in the local active forwarding information is the transmitter of the PERR element. Step b) to step e) are applied to the destinations in this list.

b) If the Reason Code is "MESH-PATH-ERROR-NO-FORWARDING-INFORMATION" and the HWMP Sequence Number is 0, the receiving mesh STA increments the HWMP SN in the forwarding information of the listed unreachable destination by 1 and invalidates the forwarding information.

c) If the Reason Code is "MESH-PATH-ERROR-NO-FORWARDING-INFORMATION" and the HWMP Sequence Number is not 0 or the Reason Code is "MESH-PATH-ERROR-DESTINATION-UNREACHABLE" and the received HWMP SN for a listed unreachable destination is higher than the current HWMP SN in the forwarding information for that destination, the receiving mesh STA shall consider that destination unreachable and shall set the HWMP SN in the forwarding information to the HWMP SN received in the PERR element and shall invalidate the forwarding information associated with this unreachable destination.

d) If the Reason Code is "MESH-PATH-ERROR-NO-PROXY-INFORMATION," the receiving mesh STA shall consider the corresponding Destination External Address unreachable and shall invalidate the proxy information associated with this unreachable external destination (proxy mesh gate is the Destination Address of the PERR element, external MAC address is the Destination External Address of the PERR element, proxy information sequence number is the HWMP Sequence Number).

e) A PERR element is propagated according to the conditions defined in 14.11.11.3 (Conditions for generating and sending a PERR element) Case D.

### 14.11.12 Root announcement (RANN) mechanism

#### 14.11.12.1 General

Subclause 14.11.12 (Root announcement (RANN) mechanism) describes the function, generation, and processing of the RANN element.

#### 14.11.12.2 Function

The RANN element, described in 9.4.2.110 (RANN element), is used for announcing the presence of a mesh STA configured as root mesh STA using the proactive RANN mechanism. RANN elements are sent out periodically by the root mesh STA.

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The RANN element propagates path metric information across the network so that each mesh STA can select a best metric path to the announced root mesh STA. This mechanism allows bidirectional trees to be built, using a robust procedure based on individually addressed frames initiated by the mesh STAs. This procedure makes the root mesh STA aware of all mesh STAs.

A receiving mesh STA shall propagate the RANN element as described in 14.11.12.3 (Conditions for generating and sending a RANN element) Case B.

### 14.11.12.3 Conditions for generating and sending a RANN element

A mesh STA sends out a RANN element in an HWMP Mesh Path Selection frame, as defined in 9.6.16.3 (HWMP Mesh Path Selection frame format), in the following cases:

**Case A**: Original transmission

All of the following conditions apply:

- The mesh STA is configured as a root mesh STA using the proactive RANN mechanism [dot11MeshHWMProotMode = rann (4)].
- The root mesh STA sent its previous RANN element dot11MeshHWMPrannInterval TUs ago.

The contents of a RANN element in Case A shall be as shown in Table 14-26 (Contents of a RANN element in Case A).

**Table 14-26—Contents of a RANN element in Case A**

| Field | Value |
|---|---|
| Element ID | Value given in Table 9-130 (Element IDs) for the RANN element |
| Length | 21 |
| Flags | Bit 0: set to 1 if dot11MeshGateAnnouncements is true; set to 0 otherwise<br>Bit 1–7: Reserved |
| Hop Count | 0 |
| Element TTL | Maximum number of hops allowed for this element |
| Root Mesh STA Address | MAC address of the root mesh STA |
| HWMP Sequence Number | Last used HWMP SN of the root mesh STA + 1 |
| Interval | dot11MeshHWMPrannInterval |
| Metric | Initial value of active path selection metric |

**Case B:** Propagation

All of the following conditions apply:

- The mesh STA has valid forwarding information to a root mesh STA using the proactive RANN mechanism [dot11MeshHWMProotMode = rann (4)].
- The mesh STA sent its previous RANN element dot11MeshHWMPrannInterval TUs ago.
- dot11MeshForwarding is true.
- The Element TTL field is greater than 1; see 14.11.8.2 (HWMP propagation).


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The contents of a RANN element in Case B shall be as shown in Table 14-27 (Contents of a RANN element in Case B).

**Table 14-27—Contents of a RANN element in Case B**

| Field | Value |
|---|---|
| Element ID | Value given in Table 9-130 (Element IDs) for the RANN element |
| Length | As received |
| Flags | As received |
| Hop Count | As received + 1 |
| Element TTL | As received – 1 |
| Root Mesh STA Address | As received |
| HWMP Sequence Number | As received |
| Interval | As received |
| Metric | As received ⊕ own link metric toward the transmitting mesh STA |

#### 14.11.12.4 RANN element reception

##### 14.11.12.4.1 General

Received RANN elements are subject to certain acceptance criteria. Processing and actions taken depend on the content of the RANN element and the forwarding information maintained by the receiving mesh STA. See also 14.11.8 (General rules for processing HWMP elements).

##### 14.11.12.4.2 Acceptance criteria

The RANN element shall not be accepted (and shall not be processed as described in 14.11.12.4.3 (Effect of receipt)) if any of the following is true:

— The HWMP Sequence Number < previous HWMP SN from this originating root mesh STA

— (The HWMP Sequence Number = previous HWMP SN) AND (updated path metric is *worse than* previous path metric)

Otherwise, the RANN element shall be accepted.

##### 14.11.12.4.3 Effect of receipt

The following applies only to a RANN element that was accepted according to the acceptance criteria in 14.11.12.4.2 (Acceptance criteria):

a) The receiving mesh STA shall set dot11MeshHWMPrannInterval to the value of the Interval field of the received RANN element.

b) The receiving mesh STA may initiate a PREQ element / PREP element exchange with the root mesh STA to set up or update a path to the root mesh STA. See 14.11.9.3 (Conditions for generating and sending a PREQ element) Case D.

c) The receiving mesh STA may record the Root Mesh STA Address, together with the HWMP Sequence Number, Hop Count, and Metric in order to assist in executing 14.11.9.3 (Conditions for generating and sending a PREQ element) Case D.

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The receiving mesh STA shall transmit a RANN element if the conditions defined in 14.11.12.3 (Conditions for generating and sending a RANN element) Case B are true.

#### 14.11.13 Considerations for support of STAs without mesh functionality

The verification, by the mesh STA (#2210)colocated with the AP, of disjunct MAC addresses between a non-AP STA without mesh functionality and mesh STAs during authentication and association of the non-AP STA without mesh functionality (see 11.3.6 (Additional mechanisms for an AP (#2210)colocated with a mesh STA)) may be done by issuing a PREQ element for the MAC address of the non-AP STA without mesh functionality by the mesh STA (#2210)colocated with the AP. The TO (Target Only) subfield of the Per Target Flags field of the PREQ element shall be set to 1.

The MAC address of the non-AP STA already exists in the MBSS if the AP with mesh functionality receives a PREP element for the MAC address of the non-AP STA and it can be derived from the PREP element that the requested MAC address is originated from a mesh STA. (The AE subfield of the Flags field of the PREP element is set to 0; see 9.4.2.112 (PREP element).)

### 14.12 Interworking with the DS or an attached bridge

#### 14.12.1 Overview of interworking between a mesh BSS and a DS or an attached bridge

A mesh STA that has direct access to a DS is called a *mesh gate*. Other mesh STAs in an MBSS access the DS via the mesh gate. A GLK mesh STA accesses external networks through its attached bridge. An MBSS functions like an IEEE 802 LAN segment that is compatible with IEEE Std 802.1AC(#69). The MBSS appears as a single access domain.

An MBSS may contain two or more mesh gates and/or GLK mesh STAs. When multiple mesh gates and/or GLK mesh STAs in an MBSS have access to the same bridged network or DS, the MBSS has more than one "port" (in the sense of IEEE Std 802.1Q(#70), for example) through which it accesses the DS or bridged network. This situation may lead to broadcast loops. Therefore, mesh gates should cooperate with the DS if present to implement a loop preventing protocol in the DS.

NOTE 1—Bridged networks already have a loop preventing protocol, such as Rapid Spanning Tree Protocol (RSTP) as specified in IEEE Std 802.1Q(#71). With RSTP the resulting active DS or bridged network topology forms a tree. With such cooperation, even if multiple mesh gates and/or GLK mesh STAs connect with the same bridged network or DS, a loop is not formed(M118).

A GLK mesh STA creates a virtual point-to-point LAN to each other GLK mesh STA in the MBSS. Each of these point-to-point LANs is presented by the GLK convergence function as a unique Internal Sublayer Service SAP that is mapped to an IEEE 802.1Q bridge port. Each such SAP is identified by a locally unique service_access_point_identifier, generated by the STA and the GLK convergence function (see 5.2.2 (GLK MAC data service specification)).

When dot11MeshGateAnnouncements is true, the mesh gate announces its presence to other mesh STAs in the MBSS. The mesh gate uses the gate announcement protocol (see 14.12.2 (Gate announcement (GANN))) or alternatively one of the HWMP proactive path selection methods with the Gate Announcement field equal to 1:

— The proactive PREQ mechanism (see 14.11.4.2 (Proactive PREQ mechanism)), with the Gate Announcement field equal to 1 (see 14.11.9.3 (Conditions for generating and sending a PREQ element))
— The proactive RANN mechanism (see 14.11.4.3 (Proactive RANN mechanism)), with the Gate Announcement field equal to 1 (see 14.11.12.3 (Conditions for generating and sending a RANN element))


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When the mesh gate uses one of the HWMP proactive path selection methods, the gate announcement protocol is not used.

A mesh STA discovers the presence of a mesh gate with access to the external network by receiving GANN elements (or PREQ element and RANN element with the Gate Announcement field equal to 1 if using such mechanisms). Mesh STAs propagate these elements to neighbor mesh STAs in order to propagate the information throughout the MBSS.

NOTE 2—The decision to set dot11MeshGateAnnouncements to true is beyond the scope of the standard. In general, the mesh gate announces that it has access to a broader network beyond the MBSS, using gate announcement protocol or HWMP proactive path selection methods with the Gate Announcement field equal to 1. One example of this configuration is that the mesh gate has access to a portal through the DS.

When a mesh gate has access to IEEE 802 STAs outside the mesh BSS (a mesh STA (#2210)colocated with an AP, another mesh STA that belongs to another MBSS, etc.), the mesh gate acts as an intermediary for the IEEE 802 STAs outside the MBSS so that the forwarding information inside the MBSS only contains addresses that belong to the MBSS. The mesh gate acting as an intermediary for external STAs is termed proxy mesh gate. When the end station of an IEEE 802 communication is an external STA, mesh STAs handle addresses of the end-to-end IEEE 802 communication as depicted in Figure 9-136 (Example addressing for a mesh Data frame). Proxy mesh gate operation is described in 14.12.4 (Proxy information and proxy update).

### 14.12.2 Gate announcement (GANN)

#### 14.12.2.1 General

Subclause 14.12.2 (Gate announcement (GANN)) describes the function, generation, and processing of the GANN element.

#### 14.12.2.2 Function

The GANN element, described in 9.4.2.109 (GANN element), is used to announce the presence of a mesh gate with dot11MeshGateAnnouncements equal to true in the mesh BSS. Gate announcements allow mesh STAs to discover such a mesh gate and, if necessary, to build a path toward it.

#### 14.12.2.3 Conditions for generating and sending a GANN element

A mesh STA shall send a GANN element in a Gate Announcement frame, as defined in 9.6.16.4 (Gate Announcement frame format), in the following cases:

**Case A**: Original transmission

The mesh STA is a mesh gate not sending PREQ element or RANN element with the Gate Announcement field equal to 1 and dot11MeshGateAnnouncements is true. The mesh STA shall transmit the Gate Announcement frame at every dot11MeshGateAnnouncementInterval.

The content of a GANN element in Case A shall be as shown in Table 14-28 (Contents of a GANN element in Case A).

The mesh gate shall assign the GANN Sequence Number from a single modulo $2^{32}$ counter, starting at 0 and incrementing by 1 for each GANN element transmission.

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**Table 14-28—Contents of a GANN element in Case A**

| Field | Value |
|---|---|
| Element ID | Value given in Table 9-130 (Element IDs) for the GANN element |
| Length | 15 |
| Flags | Reserved |
| Hop Count | 0 |
| Element TTL | Maximum number of hops allowed for the gate announcement |
| Mesh Gate Address | Mesh STA MAC address |
| GANN Sequence Number | Previous GANN sequence number + 1 |
| Interval | dot11MeshGateAnnouncementInterval |

**Case B:** Propagation

All of the following conditions are met:

— The mesh STA has received and accepted a gate announcement.
— The decremented Element TTL of the gate announcement is greater than or equal to 1.
— dot11MeshForwarding is true.

The content of a GANN element in Case B shall be as shown in Table 14-29 (Contents of a GANN element in Case B).

**Table 14-29—Contents of a GANN element in Case B**

| Field | Value |
|---|---|
| Element ID | Value given in Table 9-130 (Element IDs) for the GANN element |
| Length | 15 |
| Flags | As received |
| Hop Count | As received + 1 |
| Element TTL | As received – 1 |
| Mesh Gate Address | As received |
| GANN Sequence Number | As received |
| Interval | As received |


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#### 14.12.2.4 GANN element processing

##### 14.12.2.4.1 General

A received gate announcement is subject to certain acceptance criteria. Processing depends on the contents of the gate announcement and the information available at the receiving mesh STA.

##### 14.12.2.4.2 Acceptance criteria

The GANN element shall not be accepted (and shall not be processed as described in 14.12.2.4.3 (Effect of receipt)) if the GANN Sequence Number of the gate announcement is equal or lower than the GANN Sequence Number of the most recently accepted gate announcement with the same Mesh Gate Address.

##### 14.12.2.4.3 Effect of receipt

The following applies only to a GANN element that was accepted according to the acceptance criteria in 14.12.2.4.2 (Acceptance criteria). The receiving mesh STA shall transmit a gate announcement as described in 14.12.2.3 (Conditions for generating and sending a GANN element) Case B.

The Mesh Gate Address field of the GANN contains the address of the mesh gate, and may be stored for the purpose of determining paths to the mesh gates. Paths to mesh gates allow mesh STAs to forward MSDUs to addresses for which no path could be determined (see 10.37.8 (MSDU forwarding and unknown destination)).

### 14.12.3 Data forwarding at proxy mesh gates

#### 14.12.3.1 General

Forwarding of MSDUs from the DS into the MBSS by a proxy mesh gate follows the procedures given in 10.37.2 (Forwarding information).

Forwarding of MSDUs from the MBSS into the DS by a proxy mesh gate follows the procedures that apply for the specific (#2210)colocated network.

A proxy mesh gate learns the addresses of the other proxy mesh gates in the MBSS and of external addresses proxied by them through the receipt of path selection messages and messages carrying proxy information (for example, see 9.4.2.114 (PXU element)).

#### 14.12.3.2 Forwarding of MSDUs from the MBSS to the DS

On receipt of an individually addressed mesh Data frame from the MBSS with Address Extension Mode equal to “Address5&6” (see Table 9-35 (Valid values for the Address Extension Mode subfield)), a proxy mesh gate shall perform the following:

— If Address 5 is a known destination MAC address in the proxy information (external address) and proxied by the proxy mesh gate, the proxy mesh gate forwards the MSDU to the external address through the DS.
— If Address 5 is a known destination MAC address in the proxy information (external address) and proxied by a different proxy mesh gate, the MSDU is forwarded through the MBSS to the proxy mesh gate that proxies the external address. The MSDU is sent into the MBSS according to the procedures in 10.37.3.1 (At source mesh STAs (individually addressed)) as an individually addressed mesh Data frame with Address 3 set to the MAC address of the proxy mesh gate of the proxy information proxying Address 5, Address 4 set to the MAC address of this proxy mesh gate, and Address 5 and Address 6 kept unchanged.
— If Address 5 is unknown to the proxy mesh gate, the mesh gate forwards the MSDU to the DS. The mesh gate may send an error notification to the mesh source of the MSDU. In HWMP, this is done

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by sending a PERR element as described in 14.11.11.3 (Conditions for generating and sending a PERR element) Case C.

On receipt of group addressed mesh Data frame from the MBSS with Address Extension Mode equal to "Address4" (see Table 9-35 (Valid values for the Address Extension Mode subfield)), a proxy mesh gate shall forward the MSDU to the DS using a group addressed frame.

#### 14.12.3.3 Forwarding of MSDUs from the DS to the MBSS

On receipt of an individually addressed MSDU from the DS, a proxy mesh gate shall perform the following depending on the possible destination:

a) If the destination of the MSDU is a mesh STA address that the mesh gate knows to be inside the MBSS, the mesh gate forwards the MSDU according to the procedures for frame addressing and data forwarding at source mesh STAs in an MBSS (10.37.3.1 (At source mesh STAs (individually addressed))). The MSDU shall be transmitted using a frame with the four-address MAC header format (with the Address Extension Mode subfield in the Mesh Control field set to "Address5&6" (see Table 9-35 (Valid values for the Address Extension Mode subfield)))(#3212), where the Mesh Address Extension subfield in the Mesh Control field carries the addresses of the end stations, as specified in row "Mesh Data (proxied, individually addressed)" of Table 9-77 (Address field contents for mesh Data and Multihop Action frames(#462)(#419)). The address fields are set as follows:
   - Address 1: The address of the next-hop mesh STA (toward the destination mesh STA according to the forwarding information; see 10.37.2 (Forwarding information)).
   - Address 2: The address of the proxy mesh gate.
   - Address 3: The address of the destination mesh STA.
   - Address 4: The address of the proxy mesh gate.
   - Address 5: The address of the destination end mesh STA that is the same as Address 3.
   - Address 6: The address of the source end mesh STA that is the source address of the MSDU received from the DS.

b) If the destination of the MSDU is an external address that is proxied by another proxy mesh gate in the MBSS, the mesh gate forwards the MSDU according to the procedures for frame addressing and data forwarding at source mesh STAs in an MBSS (10.37.3.1 (At source mesh STAs (individually addressed))). The MSDU shall be transmitted using a frame with the four-address MAC header format (with the Address Extension Mode subfield in the Mesh Control field set to "Address5&6" (see Table 9-35 (Valid values for the Address Extension Mode subfield)))(#3212), where the Mesh Address Extension subfield in the Mesh Control field carries the addresses of the end stations, as specified in row "Mesh Data (proxied, individually addressed)" of Table 9-77 (Address field contents for mesh Data and Multihop Action frames(#462)(#419)). The address fields are set as follows:
   - Address 1: The address of the next-hop mesh STA [toward the proxy mesh gate of the destination of the MSDU as derived from the proxy information (see 14.12.4.2 (Proxy information)) and according to the forwarding information; see 10.37.2 (Forwarding information)].
   - Address 2: The address of this proxy mesh gate.
   - Address 3: The address of the proxy mesh gate of the destination of the MSDU as derived from the proxy information (see 14.12.4.2 (Proxy information)).
   - Address 4: The address of this proxy mesh gate.
   - Address 5: The address of the destination end mesh STA that is the destination address of the MSDU received from the DS.


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— Address 6: The address of the source end mesh STA that is the source address of the MSDU received from the DS.

c) If the MSDU has a destination address that is unknown to the mesh gate, the mesh gate forwards the MSDU to other known mesh gates in the MBSS as an individually addressed frame according to the procedures for frame addressing and data forwarding of individually addressed frames at source mesh STAs in an MBSS (10.37.3.1 (At source mesh STAs (individually addressed))). The MSDU shall be transmitted using a frame with the four-address MAC header format (with the Address Extension Mode subfield in the Mesh Control field set to "Address5&6" (see Table 9-35 (Valid values for the Address Extension Mode subfield)))(#3212), where the Mesh Address Extension subfield in the Mesh Control field carries the addresses of the end stations, as specified in row "Mesh Data (proxied, individually addressed)" of Table 9-77 (Address field contents for mesh Data and Multihop Action frames(#462)(#419)). The address fields are set as follows:

— Address 1: The address of the next-hop mesh STA (toward the other known mesh gate in the MBSS according to the forwarding information; see 10.37.2 (Forwarding information)).

— Address 2: The address of this proxy mesh gate.

— Address 3: The address of the other known mesh gate in the MBSS.

— Address 4: The address of this proxy mesh gate.

— Address 5: The address of the destination end mesh STA that is the unknown destination address of the MSDU received from the DS.

— Address 6: The address of the source end mesh STA that is the source address of the MSDU received from the DS.

Note that the procedure to determine that an address is unknown depends on the active path selection protocol. It might require an attempt to establish a path to the destination (see 14.9 (Mesh path selection and metric framework)).

On receipt of a group addressed MSDU from the DS, the mesh gate forwards the MSDU according to the procedures for frame addressing and data forwarding of group addressed frames at source mesh STAs in an MBSS (10.37.4.1 (At source mesh STAs (group addressed))). The MSDU shall be transmitted using a frame with the three-address MAC header format (with the Address Extension Mode subfield in the Mesh Control field set to "Address4" (see Table 9-35 (Valid values for the Address Extension Mode subfield)))(#3212) where the Mesh Address Extension subfield in the Mesh Control field carries the address of the source end stations, as specified in row "Mesh Data (proxied, group addressed)" of Table 9-77 (Address field contents for mesh Data and Multihop Action frames(#462)(#419)). The address fields are set as follows:

— Address 1: The group address.

— Address 2: The address of the proxy mesh gate.

— Address 3: The address of the proxy mesh gate.

— Address 4: The address of the source external STA.

### 14.12.4 Proxy information and proxy update

#### 14.12.4.1 General

Forwarding information of mesh STAs only contains addresses of mesh STAs that belong to the MBSS. However, the end station of the IEEE 802 communication may be an IEEE 802 station outside the MBSS, and such station is called *external STA*. Examples of external STAs are as follows:

— STAs that are associated with an AP that is (#2210)colocated with a mesh STA

— STAs that are behind a mesh gate

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Mesh STAs forward MSDUs to external STAs by treating MAC addresses of the external STAs as external addresses. The mesh STAs that are the destination mesh STAs of the messages destined to external STAs are called *proxy mesh gates*, and their MAC addresses are called *proxy addresses*.

NOTE—External STAs are reached using mesh services solely, i.e., they are not part of an MBSS. The mechanism by which the proxy mesh gate bridges the MBSS and the external STAs is beyond the scope of the standard. However, the standard describes the method by which mesh STAs use the external addresses that are discovered and bridged by the proxy mesh gate.

#### 14.12.4.2 Proxy information

Proxy mesh gates and source mesh STAs of MSDUs destined to external STAs maintain proxy information. Proxy information contains the external address, the corresponding proxy address, the sequence number of the proxy information, and the corresponding proxy information lifetime.

Mesh STAs can learn the addresses of proxy mesh gates and of the external stations proxied by these proxy mesh gates through the receipt of proxy update messages or path selection messages carrying proxy information. Particularly, proxy information is updated in the following circumstances:

— A mesh STA receives and processes a proxy update (see 14.12.4.3 (Proxy update (PXU))).

— A mesh STA receives and processes an element of the active path selection protocol containing proxy information. In HWMP, these are PREQ elements (see 14.11.9.4.3 (Effect of receipt)), PREP elements (see 14.11.10.4.3 (Effect of receipt)), and PERR elements (see 14.11.11.4.3 (Effect of receipt)).

Additionally, proxy mesh gates may also proactively maintain proxy information on external STAs.

When the proxy information lifetime is specified, a mesh STA shall maintain the proxy information as valid information until the lifetime expires. Details of the lifetime are described in 14.12.4.3.4 (Effect of receipt of a PXU element).

The sequence number of the proxy information and the proxy mesh gate address define a chronological order of the proxy information of an external STA at a specific proxy mesh gate.

When the proxy information is created at the proxy mesh gate, the proxy sequence number is initialized to an arbitrary value. The proxy information sequence number in the proxy information at the proxy mesh gate is incremented by 1 before the transmission of the proxy information to another mesh station. The proxy information sequence number shall be incremented if the proxy information is invalidated.

If proxy information is transmitted in HWMP elements (PREQ, PREP, and PERR), the proxy information sequence number is set to the HWMP SN of the HWMP element containing this proxy information.

Comparison of the proxy information sequence numbers is performed using a circular modulo $2^{32}$ comparison.

Valid proxy information is used to determine and set Address 5 and Address 6 in individually addressed mesh Data frames, or Address 4 in group addressed mesh Data frames.

#### 14.12.4.3 Proxy update (PXU)

##### 14.12.4.3.1 General

Subclause 14.12.4.3 (Proxy update (PXU)) describes the function, generation, and processing of the PXU element.


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#### 14.12.4.3.2 Function

A mesh STA generates a PXU element to inform a destination mesh STA about proxy information of external addresses that are reachable through the proxy mesh gate specified in the PXU element.

NOTE—Typically, a proxy mesh gate generates and sends a PXU element to another proxy mesh gate in the MBSS or a mesh STA that originates traffic to the external stations proxied by the proxy mesh gate. However, the standard also allows other usage of the PXU element.

The PXU element is transmitted in a Proxy Update frame (an individually addressed frame). The Proxy Update frame may contain multiple PXU elements when needed (for instance, the proxy mesh gate has a large number of proxy information).

#### 14.12.4.3.3 Conditions for generating and sending a PXU element

A proxy mesh gate may transmit a PXU when it adds, updates, or deletes an external address to (or from) its proxy information. A proxy mesh gate may also transmit a PXU at periodic intervals.

A mesh STA that holds proxy information of a proxy mesh gate in the MBSS may also transmit a PXU.

A mesh STA may retransmit the same PXU element repeatedly until the mesh STA receives a PXUC element from the destination mesh STA. See 14.12.4.4 (Proxy update confirmation (PXUC)).

The content of a PXU element shall be as shown in Table 14-30 (Contents of a PXU element).

The proxy mesh gate shall assign the PXU ID from a single modulo 256 counter, starting at 0 and incrementing by 1 for each PXU element.

**Table 14-30—Contents of a PXU element**

| Field | Value/description |
|---|---|
| Element ID | Value given in Table 9-130 (Element IDs) for the PXU element |
| Length | 8 + length of N Proxy Information fields |
| PXU ID | Previous PXU ID + 1 |
| PXU Originator MAC Address | MAC address of the originator of the PXU |
| Number of Proxy Information (N) | Number of proxy information reported to the destination mesh STA ($N \geq 1$) |

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**Table 14-30—Contents of a PXU element *(continued)***

| Field | | Value/description |
|---|---|---|
| Per Proxy Information | Flags | Bit 0: 0: add proxy information; 1: delete proxy information<br>Bit 1: 0: Proxy MAC Address field present; 1: Proxy MAC Address = PXU originator MAC address, Proxy MAC Address field not present<br>Bit 2: 0: Proxy Information Lifetime field not present; 1: Proxy Information Lifetime field present; if Bit 0 is 1, Bit 1 shall be set to 0<br>Bit 3–7: Reserved |
| | External MAC Address | MAC address of the STA proxied by the proxy mesh gate |
| | Proxy Information Sequence Number | Proxy information sequence number of the proxy information after being incremented; see 14.12.4.2 (Proxy information) |
| | Proxy MAC Address | MAC address of the proxy mesh gate; this field is present if Bit 1 of the Flags field is 0; it is not present otherwise |
| | Proxy Information Lifetime | The proxy information lifetime of this proxy information as taken from the proxy information of the originator of the PXU |

#### 14.12.4.3.4 Effect of receipt of a PXU element

A mesh STA that receives the PXU element shall update its proxy information with the list of proxy information reported in the PXU under the following conditions:

— Proxy information for the external MAC address and the proxy mesh gate reported in the Proxy Information field of the PXU does not exist at the mesh STA.

— Proxy information for the external MAC address and the proxy mesh gate reported in the Proxy Information field of the PXU does exist at the mesh STA and the value of the Proxy Information Sequence Number subfield in the received PXU is larger than the value of the proxy information sequence number in the proxy information at the mesh STA.

When multiple PXU elements are contained in the received Proxy Update frame, the recipient mesh STA shall process all of the PXU elements in the frame.

The MAC address of the proxy mesh gate is taken from the Proxy MAC Address subfield in the Proxy Information field when bit 1 in the Flags subfield is equal to 0, and from the PXU Originator MAC Address field in the PXU element when bit 1 in the Flags subfield is equal to 1.

The MAC address of the external STA is taken from the External MAC Address subfield of the corresponding Proxy Information field in the received PXU element.

The sequence number of the proxy information is taken from the Proxy Information Sequence Number subfield of the corresponding Proxy Information field in the received PXU element.

If the Proxy Information Lifetime subfield is present (the Lifetime subfield in the Flags subfield is 1) and there is already proxy information stored for the proxy mesh gate and external address reported in the proxy information of the PXU element, the mesh STA shall set the proxy lifetime to the larger one of the proxy lifetime reported by the PXU and the stored proxy information.


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If the Proxy Information Lifetime subfield is present (bit 2 of the Flags subfield is 1) and there is proxy information stored for the proxy mesh gate and external address reported in the proxy information of the PXU element, the mesh STA shall set the proxy information lifetime to the value in the Proxy Information Lifetime subfield.

If the Proxy Information Lifetime subfield is not present, the lifetime of the proxy information is the same as the lifetime of the path to the proxy address. Alternatively, the lifetime of the proxy information may be set to a value representing infinity.

The destination mesh STA that received the PXU shall send a PXUC element to the originator mesh STA of the PXU as described in 14.12.4.4.3 (Conditions for generating and sending a PXUC element).

#### 14.12.4.4 Proxy update confirmation (PXUC)

##### 14.12.4.4.1 General

Subclause 14.12.4.4 (Proxy update confirmation (PXUC)) describes the function, generation, and processing of the PXUC element.

##### 14.12.4.4.2 Function

A PXUC element is generated by the destination mesh STA of a PXU to inform the sender of the PXU that the PXU has been properly received.

The PXUC element is transmitted in a Proxy Update Confirmation frame (an individually addressed frame). The Proxy Update Confirmation frame may contain multiple PXUC elements in order to confirm the reception of multiple PXU elements to the destination of the Proxy Update Confirmation frame.

##### 14.12.4.4.3 Conditions for generating and sending a PXUC element

The destination mesh STA of a Proxy Update frame containing a PXU element shall send a PXUC element to the originator mesh STA of the PXU element.

The content of a PXUC element shall be as shown in Table 14-31 (Contents of a PXUC element).

**Table 14-31—Contents of a PXUC element**

| Field | Value/description |
|---|---|
| Element ID | Value given in Table 9-130 (Element IDs) for the PXUC element |
| Length | 7 |
| PXU ID | PXU ID of the PXU that is being confirmed |
| Destination mesh STA Address | MAC address of the originator of the PXUC |

##### 14.12.4.4.4 Effect of receipt of PXUC element

If a mesh STA receives a PXUC element in a PXUC frame in response to a PXU element it originated, the mesh STA shall no longer send any PXUs with the same PXU ID as given in the received PXUC element.

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### 14.12.5 Mesh STA collocation

A mesh STA (#2210)colocated with another STA shall use a MAC address that is different from the one used by the (#2210)colocated STA. This precludes ambiguities relating to the presence of the Mesh Control field in the Frame Body (see(#6103) 9.2.4.8.3 (Mesh Control field)), GTK use (see 12.6.1.1.10 (Mesh GTKSA)), and proxy information (see 14.12.4.2 (Proxy information)).

Path selection with (#2210)colocated mesh STAs using HWMP is described in 14.11.5 ((#2210)Colocated STAs).

## 14.13 Intra-mesh congestion control

### 14.13.1 General

Intra-mesh congestion control is based on the following three main mechanisms:

a) Local congestion monitoring and congestion detection
b) Congestion control signaling
c) Local rate control

A mesh STA shall activate a congestion control protocol specified by dot11MeshActiveCongestionControlMode. At any given time, there is only one congestion control protocol active in a particular MBSS, signaled in the Congestion Control Mode Identifier field of the Mesh Configuration element. This standard specifies the congestion control signaling protocol that shall be available in any MBSS with an activated congestion control.

NOTE—This standard allows for inclusion of more advanced or alternative congestion control schemes through the Congestion Control Mode Identifier in the Mesh Configuration element.

### 14.13.2 Congestion control signaling protocol

When dot11MeshActiveCongestionControlMode is congestionControlSignaling (1), the mesh STA activates the congestion control signaling protocol. The congestion control signaling protocol specifies the signaling messages used with intra-mesh congestion control. Specific algorithms for local congestion monitoring and congestion detection are beyond the scope of the congestion control signaling protocol.

The congestion control signaling protocol is triggered after congestion is detected at a mesh STA. A mesh STA that detects congestion, and the traffic destination causing this congestion, may transmit a Congestion Control Notification frame to the mesh STAs of the traffic source and other neighboring mesh STAs. The frame contains one or more Congestion Notification elements, each of which specifies the traffic destination causing the congestion and the expected duration of the congestion per AC per mesh destination as estimated by the congested mesh STA.

Upon receipt of a Congestion Notification frame a mesh STA may stop forwarding, or reduce the rate of forwarding, traffic to the destinations listed in the Congestion Notification elements via the mesh STA reporting congestion for the duration specified in the Congestion Notification element. It may also send its own Congestion Control Notification frame to mesh STAs that are the source of the reported congestion, and other neighboring mesh STAs. Any time difference between receipt of the original Congestion Control Notification frame and the transmission of this new Congestion Control Notification frame should be reflected in the duration indicated in the new congestion control notification in such a way that any timers set by mesh STAs in response to the first report of congestion for a given destination all expire at the same time.


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If the Destination MAC Address field in a received Congestion Notification element is the group address, it should be interpreted to mean that communication with the transmitter of this frame should be stopped, or reduced, for the duration specified in the Congestion Notification element. This event should not result in the transmission of a Congestion Notification element with a Destination MAC Address field set to the group address to any neighbor mesh STAs.

When the duration of a traffic congestion report has expired, a mesh STA should resume forwarding traffic to the destinations that were listed in the traffic congestion report via the mesh STA that reported congestion.

NOTE 1—Local policies/mechanisms implemented in a mesh STA might be required to achieve timely transmission of the congestion control signaling messages and to avoid transmission of stale messages that might reduce network efficiency.

NOTE 2—A mesh STA that receives a Congestion Control Notification frame might choose to adjust its frame rate, defined by the number of transmitted frames per a unit of time, to the sender of the Congestion Control Notification frame in the identified congested AC(s) for the duration specified in the Congestion Notification element. The reduction of the frame rate to a congested mesh STA avoids waste of the mesh resources for transmission of frames that with high probability will not be handled/forwarded by the congested mesh STA.

## 14.14 Synchronization and beaconing in MBSSs

### 14.14.1 TSF for MBSSs

A mesh STA shall initialize and update its TSF timer according to the MBSS's active synchronization method. Each mesh STA shall maintain a TSF timer as described in 11.1.3.1 (General), and comply with the TSF timer accuracy as described in 11.1.3.9 (TSF timer accuracy).

### 14.14.2 Extensible synchronization framework

#### 14.14.2.1 General

This standard introduces an extensible framework to enable the implementation of multiple synchronization methods for mesh STAs. Within the extensible synchronization framework, the neighbor offset synchronization method is defined as the default mandatory synchronization method in order to enable minimal synchronization capabilities and interoperability between mesh STAs that use MCCA, MBCA, or operate in light or deep sleep mode. The framework allows the integration of other synchronization methods into MBSSs. A vendor may implement any synchronization method using this framework to meet special application needs. Although a mesh STA may include multiple implementations of synchronization methods, only one synchronization method at a time shall be used by a mesh STA. All mesh STAs in an MBSS use the same synchronization method; see 14.3.7 (Candidate peer mesh STA) item a). The MBSS's active synchronization method is controlled by the SME and given to the MLME by dot11MeshActiveSynchronizationMethod.

A mesh STA shall announce the MBSS's active synchronization method using the Synchronization Method Identifier field in the Mesh Configuration element in their Beacon and Probe Response frames.

#### 14.14.2.2 Neighbor offset synchronization method

##### 14.14.2.2.1 General

When dot11MeshActiveSynchronizationMethod is neighborOffsetSynchronization (1), the mesh STA shall use the neighbor offset synchronization method as its active synchronization method, and maintain the timing offset value between its own TSF timer and the TSF timer of each neighbor STA with which it

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synchronizes. The mesh STA shall set the Synchronization Method Identifier field in the Mesh Configuration element to 1.

The mesh STA shall maintain synchronization with all of its neighbor peer mesh STAs up to dot11MeshNbrOffsetMaxNeighbor mesh STAs. The mesh STA should maintain synchronization with additional neighbor mesh STAs that are in the same MBSS up to a total of dot11MeshNbrOffsetMaxNeighbor mesh STAs and also, additional neighbor mesh STAs that are outside of the MBSS up to a total of dot11MeshNbrOffsetMaxNeighbor mesh STAs.

Upon receipt of an MLME-MESHNEIGHBOROFFSETSYNCSTART.request primitive, the MLME shall start synchronization using the neighbor offset synchronization method with the specified peer STA. Upon receipt of an MLME-MESHNEIGHBOROFFSETSYNCSTOP.request primitive, the MLME shall stop synchronization using the neighbor offset synchronization method with the specified peer STA.

A mesh STA that utilizes the neighbor offset synchronization method may start its TSF timer independently of other mesh STAs. The mesh STA shall calculate the timing offset value with respect to the neighbor STA with which it maintains synchronization, as described in 14.14.2.2.2 (Timing offset calculation). The mesh STA shall adjust its TSF timer based on time stamps received in Beacon or Probe Response frames from neighbor STAs with which it maintains synchronization, as described in 14.14.2.2.3 (Clock drift adjustment).

When the mesh STA alternates awake state and doze state, it might not always listen to the Beacon frames of a neighbor mesh STA with which it maintains synchronization. However, it shall comply with the clock drift compensation procedures and TSF jitter allowance as described in 14.14.2.2.3 (Clock drift adjustment). See S.3.6 (Synchronization maintenance of mesh STAs in deep sleep mode) for more guidelines.

#### 14.14.2.2.2 Timing offset calculation

When dot11MeshActiveSynchronizationMethod is neighborOffsetSynchronization (1), the mesh STA shall calculate the timing offset value with respect to the neighbor STA with which it maintains synchronization. The calculation of the timing offset value is based on time stamps from the received Beacon and Probe Response frames as follows:

$$T_{offset} = T_t - T_r$$

where

$T_{offset}$ is the timing offset value
$T_t$ is the value in the Timestamp field in the received frame
$T_r$ is the frame reception time measured in the TSF timer of the mesh STA

The offset value is represented as a signed integer. The unit of the offset value is μs. The mesh STA shall keep the $T_{offset}$ value calculated from the latest Beacon or Probe Response frame received from each neighbor STA with which it maintains synchronization.

A mesh STA may translate the time measured in the TSF of the neighbor STA into the time base of its own TSF as follows:

$$T_{self} = T_{neighbor} - T_{offset}$$

where

$T_{self}$ is the translated time in its own TSF
$T_{neighbor}$ is the time measured in the TSF timer of the neighbor STA


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Upon receipt of an MLME-MESHNEIGHBOROFFSETCALCULATE.request primitive, the MLME shall receive a Beacon or Probe Response frame from the specified neighbor STA, calculate the $T_{offset}$ from the received frame, and report the calculated $T_{offset}$ to the SME by responding with an MLME-MESHNEIGHBOROFFSETCALCULATE.confirm primitive. $T_{offset}$ is used to provide the timing reference of neighbor STAs.

#### 14.14.2.2.3 Clock drift adjustment

When dot11MeshActiveSynchronizationMethod is neighborOffsetSynchronization (1), the mesh STA shall examine the reception time of the Beacon frames from neighbor STAs with which it maintains synchronization and adjust its TSF timer to compensate the relative timing error among neighbor mesh STAs caused by the clock drift. The mesh STA adjusts its TSF so that its TSF counting is aligned to the most delayed neighbor STA.

When the mesh STA receives a Beacon frame or a Probe Response frame from one of the neighbor STAs with which it maintains synchronization, the mesh STA shall perform the following measurement procedure:

a) The mesh STA checks if the transmitter of the Beacon frame or Probe Response frame is in the process of the TBTT adjustment (see 14.14.4.4.3 (TBTT scanning and adjustment procedures)). If the received frame contains the Mesh Configuration element and the TBTT Adjusting subfield in the Mesh Configuration element(#3438) is 1, the mesh STA shall invalidate the $T_{offset}$ value for this neighbor STA and shall not perform the following steps.

b) The mesh STA checks if it has a valid $T_{offset}$ value obtained from the previous Beacon or Probe Response frame reception from the transmitter of the received frame. If it does not have the valid $T_{offset}$ value, it shall not perform the following steps.

c) The mesh STA calculates the clock drift amount $T_{ClockDrift}$ by comparing the $T_{offset,p}$,the offset value obtained previously for this neighbor STA, and the $T_{offset,c}$, the offset value obtained from the current frame reception.

$$T_{ClockDrift} = T_{offset,\,p} - T_{offset,\,c}$$

where

$T_{ClockDrift}$ is the clock drift amount in μs represented as a signed integer.

d) The mesh STA shall compare the $T_{ClockDrift}$ value with the $T_{MaxClockDrift}$, the largest $T_{ClockDrift}$ value obtained from other neighbor STA within this beacon period. If the $T_{ClockDrift}$ value for this neighbor STA is greater than the $T_{MaxClockDrift}$ value, the mesh STA replaces the $T_{MaxClockDrift}$ value with the $T_{ClockDrift}$ value, in order to determine the largest $T_{ClockDrift}$ value among neighbor STAs.

When the previous $T_{ClockDrift}$ values have been stable for a neighbor mesh STA, the mesh STA may substitute the previous $T_{ClockDrift}$ value for the $T_{ClockDrift}$ value in the measurement procedure and process the step d), at the time of a TBTT of the neighbor STA, without receiving a Beacon frame.

Before the mesh STA transmits a Beacon frame, it shall perform the following adjustment procedure:

— The mesh STA checks if the current $T_{MaxClockDrift}$ value is greater than zero. If the $T_{MaxClockDrift}$ value is greater than zero, it shall continue the following steps. Otherwise, it shall initialize the $T_{MaxClockDrift}$ with zero and shall not perform the following step.

— If the $T_{MaxClockDrift}$ value is smaller than 0.04% of its beacon interval, the mesh STA shall adjust its TSF timer so that the next TBTT is(M118) delayed for the duration of the $T_{MaxClockDrift}$ and initialize the $T_{MaxClockDrift}$ value with zero. Otherwise, it shall adjust its TSF timer so that the next TBTT is(M118) delayed for the duration of 0.04% of its beacon interval and subtract the value of 0.04% of its beacon interval from the $T_{MaxClockDrift}$.

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The mesh STA may adjust its TSF timer only to slow the counting. The mesh STA may adjust its TSF timer within the range of 0.04% in a beacon period.

When the delay amount at each beacon period is not stable, the mesh STA should frequently listen to neighbor STAs' Beacon frames. An implementation might reduce TSF timer jitter caused by the adjustment procedure by making additional adjustments to the $T_{MaxClockDrift}$ , as long as the mesh STA's TSF count is aligned to the most delayed neighbor mesh STA. The means of making these additional adjustments is beyond the scope of this standard.

NOTE—This clock drift compensation procedure does not intend to maintain a strict synchronization. It aims to stop TBTT drifting away among neighbor mesh STAs, allowing some jitter of TSF timer.

### 14.14.3 Beaconing

#### 14.14.3.1 Beacon generation in MBSSs

A mesh STA transmits Beacon frames that are specific to an MBSS. Beacon frames for MBSS, infrastructure BSS, or IBSS are differentiated by the Capability Information field in the Beacon frame as specified in 9.4.1.4 (Capability Information field). A mesh STA that collocates with an AP generates Beacon frames for the MBSS independently of the AP.

The mesh STA shall define a series of TBTTs exactly dot11BeaconPeriod TUs apart. Time zero is defined to be a TBTT with the Beacon frame (#8164)being a DTIM beacon. At each TBTT, the mesh STA shall schedule a Beacon frame as the next frame for transmission according to the medium access rules specified in Clause 10 (MAC sublayer functional description). The Address 1 field of the Beacon frame shall be set to the broadcast address.

NOTE—To achieve this requirement, the mesh STA suspends any pending transmissions until the beacon has been transmitted. In the case of a DTIM (#8164)beacon, the mesh STA also suspends any pending individually addressed transmissions until any pending group addressed transmissions have been performed (see 14.15.5 (TIM types)).

The beacon period is included in Beacon and Probe Response frames.

The mesh STA shall start beaconing upon the receipt of the MLME-START.request primitive.

#### 14.14.3.2 Beacon reception for mesh STA

(#391)A mesh STA shall determine whether a Beacon frame was transmitted by a mesh STA in the same MBSS based on the Mesh ID element, not the Address 3 field (see 14.3.6 (Scanning mesh BSSs)).

A mesh STA shall use information from the Timestamp field without regard to the BSSID or (#1755)mesh ID in order to obtain information necessary for synchronization, if the mesh STA maintains synchronization with the transmitter of the Beacon frame. A mesh STA may use information from the Beacon Interval field and the Beacon Timing element without regard for the mesh ID(#1755) in order to obtain information necessary for MBCA, if the mesh STA maintains synchronization with the transmitter of the Beacon frame and dot11MBCAActivated is true. A mesh STA may use information from the MCCAOP Advertisement Overview element and MCCAOP Advertisement element without regard for the mesh ID(#1755) in order to obtain information necessary for MCCA, if the mesh STA maintains synchronization with the transmitter of the Beacon frame and dot11MCCAActivated is true.

A mesh STA in a mesh BSS shall use information in the Timestamp field, the Beacon Interval field, the Beacon Timing element, the MCCAOP Advertisement Overview element, or the MCCAOP Advertisement element in received Beacon frames only if the mesh STA maintains a mesh peering with the transmitter of the Beacon frame.


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### 14.14.4 Mesh beacon collision avoidance (MBCA)

#### 14.14.4.1 Overview

Mesh STAs use the mesh beacon collision avoidance (MBCA) protocol to detect and mitigate collisions among Beacon frames transmitted by other STAs (including mesh STAs, IBSS APs, and IBSS STAs) on the same channel within the range of 2 hops. MBCA mitigates hidden node problems with respect to Beacon frames.

NOTE—Beacon frames are transmitted without acknowledgment and might collide with other frames. In a mesh BSS, multiple STAs transmit Beacon frames periodically, and mesh STAs might be located out of range of each other. This implies that Beacon frames might suffer from the so-called hidden node problem and might not be received by neighbor STAs. Once Beacon frames from hidden STAs start to collide, Beacon frames keep on colliding if these hidden STAs transmit Beacon frames at the same beacon interval that is a typical operation. MBCA provides a set of rules to mitigate this problem.

When dot11MBCAActivated is true, the mesh STA shall set the MBCA Enabled subfield in the Mesh Capability field of the Mesh Configuration element to 1.

MBCA is composed of beacon timing advertisements, TBTT selection, and TBTT adjustment. When dot11MBCAActivated is true, the mesh STA advertises the TBTT and beacon interval of its neighbor STAs through the Beacon Timing element as described in 14.14.4.2 (Beacon timing advertisement). Upon reception of the Beacon Timing element, the mesh STA obtains the beacon timing information of its neighbor mesh STAs and uses this information for its TBTT selection and TBTT adjustment as described in 14.14.4.3 (TBTT selection) and 14.14.4.4 (TBTT adjustment). The mesh STA may also perform additional procedures described in 14.14.4.5 (Frame transmission across reported TBTT) and 14.14.4.6 (Delayed beacon transmissions).

When dot11MBCAActivated is true, the mesh STA that alternates awake state and doze state should listen to Beacon frames from its neighbor STAs, with which it maintains synchronization, often, in order to advertise and obtain the recent TBTT information.

#### 14.14.4.2 Beacon timing advertisement

##### 14.14.4.2.1 General

When dot11MBCAActivated is true, the mesh STA shall contain Beacon Timing element in Beacon and Probe Response frames in order to advertise its beacon timing information. The mesh STA calculates the TBTT of its neighbor STAs with which it maintains synchronization as described in 14.14.4.2.2 (Calculation of neighbor STA's TBTT), and composes beacon timing information as described in 14.14.4.2.3 (Beacon timing information). The mesh STA collects the beacon timing information from each neighbor STA with which it maintains synchronization. The collection of the beacon timing information is termed "beacon timing information set." The mesh STA contains whole or part of the beacon timing information set in the Beacon Timing element as described in 14.14.4.2.5 (Transmitter's procedure). The mesh STA also maintains the status number of the beacon timing information set and contains the status number in the Beacon Timing element as described in 14.14.4.2.4 (Maintenance of the status number). The receiver of the Beacon Timing element uses the received beacon timing information as described in 14.14.4.2.6 (Receiver's procedure).

##### 14.14.4.2.2 Calculation of neighbor STA's TBTT

When a Beacon frame is received from one of its neighbor STAs with which the mesh STA maintains synchronization, the mesh STA shall calculate the TBTT of the received Beacon frame as follows:

$$T_{TBTT} = T_r - (T_t \bmod (T_{BeaconInterval} \times 1024))$$

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where

| | |
|---|---|
| $T_{TBTT}$ | is the calculated TBTT |
| $T_r$ | is the frame reception time measured in the TSF timer of the receiving mesh STA |
| $T_t$ | is the value in the Timestamp field in the received frame |
| $T_{BeaconInterval}$ | is the value in the Beacon Interval field in the received frame |

The $T_{TBTT}$ is used as described in 14.14.4.2.3 (Beacon timing information).

Further, the mesh STA shall calculate the time difference between the TBTT of the received Beacon frame and the time predicted from the past TBTT as follows:

$$T_{Delta} = | T_{TBTT,\,c} - (T_{TBTT,\,p} + (T_{BeaconInterval} \times N_{Count})) |$$

where

| | |
|---|---|
| $T_{Delta}$ | is the time difference |
| $T_{TBTT,\,c}$ | is the TBTT calculated from the received Beacon frame |
| $T_{TBTT,\,p}$ | is the TBTT calculated for the first time after the latest status number update (see 14.14.4.2.4 (Maintenance of the status number)) |
| $T_{BeaconInterval}$ | is the value in the Beacon Interval field in the received Beacon frame |
| $N_{Count}$ | is the number of TBTTs since $T_{TBTT,\,p}$ has been calculated |

$T_{Delta}$ is used to maintain the status number described in 14.14.4.2.4 (Maintenance of the status number).

#### 14.14.4.2.3 Beacon timing information

The mesh STA shall keep the latest $T_{TBTT}$ together with the beacon interval contained in the received frame and the identifier of the neighbor STA as the beacon timing information with respect to the neighbor STA. When the elapsed time since the latest Beacon frame reception is smaller than 524 288 TU, the beacon timing information is valid.

NOTE—The beacon timing information provides the time reference for a series of the TBTTs of the corresponding STA. Using the beacon timing information, a mesh STA is able to predict future TBTTs by adding the reported beacon interval to the reported TBTT.

The mesh STA shall collect the valid beacon timing information from each neighbor STA with which it maintains synchronization and keep the collection as the beacon timing information set. The beacon timing information set is advertised to its neighbor mesh STAs through the Beacon Timing element as described in 14.14.4.2.5 (Transmitter's procedure).

When the amount of neighbors, for which valid beacon timing information is kept, is large, the beacon timing information set may be divided into multiple tuples of beacon timing information. In such case, a tuple of beacon timing information is included in the Beacon Timing element (see 14.14.4.2.5 (Transmitter's procedure)).

#### 14.14.4.2.4 Maintenance of the status number

The mesh STA shall maintain the status number of the beacon timing information set. The status number is set to a value from a single modulo 16 counter, starting at 0 and incrementing by 1 for each transmission of a frame containing the Beacon Timing element after the mesh STA encountered any of the following events:

a) It starts or stops maintaining synchronization with a neighbor STA.

b) It receives a Beacon frame from a neighbor STA with which it maintains synchronization and the calculated $T_{Delta}$ (see 14.14.4.2.2 (Calculation of neighbor STA's TBTT)) is larger than 255 μs.


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c) It completes the TBTT adjustment procedure described in 14.14.4.4.3 (TBTT scanning and adjustment procedures).

The mesh STA shall set the Status Number subfield in the Report Control field in the Beacon Timing element to the status number. The Status Number subfield in the Report Control field facilitates the detection of the changes in the beacon timing information set.

#### 14.14.4.2.5 Transmitter's procedure

When dot11MBCAActivated is true, the mesh STA shall report the TBTT and beacon interval of its neighbor STAs through the Beacon Timing element as described in this subclause.

The Beacon Timing element reports on timing information of the Beacon frames that are received from the neighbor STAs with which the mesh STA maintains synchronization on the operating channel. The mesh STA shall include the Beacon Timing element in Probe Response frames and in TBTT Adjustment Request frames. The mesh STA shall also include the Beacon Timing element in Beacon frames as specified by dot11MeshBeaconTimingReportInterval and dot11MeshBeaconTimingReportMaxNum. The Beacon Timing element is present in a Beacon frame when the DTIM Count value in the Beacon frame is zero or equal to an integer multiple of dot11MeshBeaconTimingReportInterval.

The maximum number of Beacon Timing Information fields contained in a Beacon Timing element is limited to dot11MeshBeaconTimingReportMaxNum for Beacon frames, or is limited by the maximum element size for other frames. When the number of neighbors, for which valid beacon timing information is kept, is equal or smaller than the limit, the mesh STA shall include all the beacon timing information in a single Beacon Timing element, setting both Beacon Timing Element Number and More Beacon Timing Elements subfield in the Report Control field to 0. When the number of neighbors, for which valid beacon timing information is kept, exceeds the limit, the mesh STA shall divide the beacon timing information set into multiple tuples and assign each tuple with an index number starting from 0. When the beacon timing information set is divided, the mesh STA shall include the successive tuples of beacon timing information in the Beacon Timing elements. In this case, the mesh STA shall set the Beacon Timing Element Number subfield in the Report Control field to the index number of the tuple. The mesh STA shall set the More Beacon Timing Elements subfield in the Report Control field to 1 when it has one or more beacon timing information tuples with a larger index number. The mesh STA shall divide the beacon timing information set into no more than $N_{info}$ tuples, where

$N_{info} = \lceil N_v / N_{max} \rceil$

$N_v$ is the number of valid beacon timing information fields

$N_{max}$ is the maximum number of Beacon Timing Information fields in the Beacon Timing element

The mesh STA may update the combination of the tuples only when the status number described in 14.14.4.2.4 (Maintenance of the status number) is updated. The mesh STA shall include newly updated beacon timing information (i.e., beacon timing information that causes an update of the status number as described in 14.14.4.2.4 (Maintenance of the status number)) in the tuple with a smaller index number. When the status number is updated, the mesh STA shall include the tuple of beacon timing information indexed as 0 in the Beacon Timing element in the subsequent Beacon frame. Successive tuples shall be transmitted in ascending order of the index number in the successive Beacon frames.

NOTE—The standard does not impose mesh STAs to advertise a fragmented beacon timing information set sequentially in its Beacon frames at all times. This implies that the mesh STA might advertise tuples with a smaller index number more frequently, which is useful to notify new beacon timing information efficiently.

When the mesh STA receives a Probe Request frame containing a Beacon Timing element ID in its Request element, it shall respond with a Probe Response frame containing the Beacon Timing element. If all beacon timing information cannot be contained in a Beacon Timing element, the mesh STA shall include multiple

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Beacon Timing elements containing successive tuples of beacon timing information in the order of the Request element (see Table 9-69 (Probe Response frame body)) so that all tuples are transmitted.

#### 14.14.4.2.6 Receiver's procedure

A mesh STA with dot11MBCAActivated equal to true that receives a Beacon Timing element obtains the beacon timing information of its neighbor mesh STA and uses it for its TBTT selection and TBTT adjustment as described in 14.14.4.3 (TBTT selection) and 14.14.4.4 (TBTT adjustment).

When a mesh STA receives a Beacon frame with a Beacon Timing element that contains only a subset of the beacon timing information set, the mesh STA may transmit a Probe Request frame containing a Beacon Timing element ID in its Request element to the transmitter of the Beacon Timing element, in order to request the rest of the beacon timing information.

NOTE 1—The Report Control field in the Beacon Timing element facilitates the detection of the missing beacon timing information.

NOTE 2—Once the entire beacon timing information set with a particular Status Number is obtained, the mesh STA does not need to retrieve beacon timing information as long as the Status Number remains the same.

A mesh STA that receives the Beacon Timing element shall record the reported TBTT and its successive TBTTs as neighbor's essential beacon reception timing if the MSB of the Neighbor STA ID field in the corresponding Beacon Timing Information field is 0. The essential beacon reception timing is used to control the transmission of frames as described in 14.14.4.5 (Frame transmission across reported TBTT).

A mesh STA can also check if its neighbor mesh STAs received its Beacon frame successfully by checking whether the Beacon Timing elements received from its neighbor mesh STAs contain beacon timing information of the mesh STA. When the Beacon Timing element is received from one of the peer mesh STAs, the mesh STA checks if the MSB of the Neighbor STA ID subfield is(M118) 0 and the rest of the field matches with the 7 LSBs of the AID value assigned to the mesh STA through the mesh peering establishment. When the Beacon Timing element is received from a nonpeer mesh STA, the mesh STA checks if the MSB of the Neighbor STA ID subfield is(M118) 1 and the rest of the field matches with MAC_ADDR[42:47] of its own MAC address. If the matching is verified, the corresponding beacon timing information represents the correct beacon reception by the neighbor mesh STA.

If a Beacon frame is received from a neighbor peer mesh STA that is either in active mode or in light sleep mode, the Beacon Timing element is present in the frame, and all beacon timing information is contained in the Beacon Timing element, the mesh STA shall verify whether the neighbor peer mesh STA received its Beacon frame. If the Beacon Timing element does not contain beacon timing information of the mesh STA or the Neighbor TBTT subfield of the corresponding beacon timing information does not reflect the recent TBTT of the mesh STA, the mesh STA considers the previous Beacon frame was not received by the neighbor peer mesh STA.

### 14.14.4.3 TBTT selection

When dot11MBCAActivated is true, the mesh STA performs the TBTT selection described herein before it starts beaconing (see 14.3.8 (Establishing or becoming a member of a mesh BSS)). The mesh STA selects its TBTTs and its beacon interval so that its Beacon frames do not collide with Beacon frames transmitted by other STAs in its 2 hop range.

Before the mesh STA starts beaconing, it performs scanning and discovered neighbor STAs are reported through an MLME-SCAN.confirm primitive (see 14.3.6 (Scanning mesh BSSs)). Using TimeStamp, Local Time, and Beacon Period in the BSSDescriptionSet parameter provided by the MLME-SCAN.confirm primitive, the mesh STA shall obtain the TBTT and beacon interval of its neighbor STAs operating on the


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same channel as the mesh STA starts to operate. The mesh STA shall also collect the beacon timing information contained in the Beacon Timing elements received on the channel through Beacon Timing in the BSSDescriptionSet parameter provided by the MLME-SCAN.confirm primitive, in order to obtain the TBTT and beacon interval of STAs in 2 hop range. After obtaining this information, the mesh STA shall look for a timing of its beacon transmissions so that its Beacon frames are likely not to collide with Beacon frames transmitted by other STAs in its 2 hop range. The mesh STA shall update its TSF timer and select its beacon interval to set its TBTTs to the appropriate timing, and then it shall start beaconing using the MLME-START.request primitive.

#### 14.14.4.4 TBTT adjustment

##### 14.14.4.4.1 Self-determined TBTT adjustment

When dot11MBCAActivated is true, the mesh STA checks if it does not transmit Beacon frames during the beacon transmissions of other STAs within its 2 hop range using the Beacon Timing element received from its neighbor peer mesh STA.

When the mesh STA discovers that its Beacon frames repeatedly collide with the Beacon frames of a neighbor or a neighbor's neighbor and its TBTT comes later than the TBTT of the colliding STA at the time of collision, it shall perform the TBTT scanning procedure described in 14.14.4.4.3 (TBTT scanning and adjustment procedures). If the mesh STA finds an alternative TBTT, it shall start the TBTT adjustment procedure as described in 14.14.4.4.3 (TBTT scanning and adjustment procedures).

##### 14.14.4.4.2 Requested TBTT adjustment

When a mesh STA discovers that Beacon frames from two or more neighbor STAs are colliding repeatedly or a series of TBTTs are close enough to trigger frequent beacon collisions, the mesh STA may transmit a TBTT Adjustment Request frame to the neighbor mesh STA of which the TBTT comes last at a particular collision timing in order to request this neighbor mesh STA to adjust its TBTT. The TBTT Adjustment Request frame may be transmitted only if the following conditions hold:

— The recipient of the TBTT Adjustment Request frame is a peer mesh STA and has set the MBCA Enabled subfield in the Mesh Capability field of the Mesh Configuration element to 1.

— The other colliding STA does not include the Mesh Configuration element in its Beacon frames or the TBTT Adjusting field in the Mesh Configuration element is 0.

When dot11MBCAActivated is true, the mesh STA that receives a TBTT Adjustment Request frame shall perform the TBTT scanning procedure described in 14.14.4.4.3 (TBTT scanning and adjustment procedures), and determine if it can find an appropriate alternative timing for its TBTTs. After the completion of the TBTT scanning procedure, the mesh STA that receives the TBTT Adjustment Request frame shall respond with a TBTT Adjustment Response frame containing the result of the TBTT scanning in the Status Code field. If the mesh STA finds an alternative TBTT, it shall agree with the request. If it agrees with the request, the Status Code field is set to SUCCESS in the TBTT Adjustment Response frame, and it shall complete the TBTT adjustment procedure described in 14.14.4.4.3 (TBTT scanning and adjustment procedures). If it does not agree with the request, it shall indicate the reason in the Status Code field in the TBTT Adjustment Response frame. A mesh STA may set the Status Code field(M118) to either SUCCESS, REFUSED_REASON_UNSPECIFIED, or CANNOT_FIND_ALTERNATIVE_TBTT in the TBTT Adjustment Response frame.

##### 14.14.4.4.3 TBTT scanning and adjustment procedures

When a mesh STA is in need of TBTT adjustment, it tries to find an alternative TBTT first. The mesh STA shall perform the TBTT scanning procedure as follows:

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— The mesh STA checks if its beacon timing information and collected neighbor's beacon timing information are sufficiently new. If the mesh STA did not receive a Beacon frame from a neighbor STA with which it maintains synchronization at the latest TBTT, it shall receive a Beacon or Probe Response frame from the neighbor STA and obtain the TBTT of the neighbor STA and the beacon timing information contained in the Beacon Timing element.

NOTE 1—This is particularly important if the mesh STA is in deep sleep mode for a neighbor peer mesh STA.

— Using the latest TBTT of its neighbor STAs and the latest beacon timing information of neighbor mesh STAs, the mesh STA shall look for an alternative TBTT that does not cause beacon collision among the STAs in its 2 hop range.

If an alternative TBTT is not available, the mesh STA terminates the procedure. If an alternative TBTT is available, the mesh STA shall start the TBTT adjustment procedure as follows:

— The mesh STA shall set the TBTT Adjusting field in the Mesh Configuration element to 1 in order to announce that the TBTT adjustment procedure is ongoing.

— The mesh STA shall suspend its TSF timer for a period of time, no longer than half of the Group Delivery Idle Time (defined in 14.15.5 (TIM types)) within a single beacon period, to slow its TSF.

— The mesh STA shall adjust TBTT information of the neighbor STAs (see 14.14.4.2.3 (Beacon timing information)), that are to be contained in the Beacon Timing element, accordingly by subtracting the delay amount.

— When dot11MCCAActivated is true, the mesh STA shall adjust the MCCAOP reservations accordingly by modifying the MCCAOP Offset of each MCCAOP reservation. See 10.24.3.3 (MCCAOP reservations).

— The mesh STA shall repeat suspending its TSF timer over multiple beacon periods until its TBTT is set to the alternative TBTT.

— Upon completion of the TBTT adjustment, the mesh STA shall update the status number as described in 14.14.4.2.4 (Maintenance of the status number) and shall set the TBTT Adjusting field in the Mesh Configuration element to 0.

NOTE 2—A mesh STA in deep sleep mode might interpret its neighbor mesh STA's TBTT adjustment as a large TSF jitter. When a mesh STA in deep sleep mode observes a large TSF jitter and the Status Number in the Report Control field in the Beacon Timing element of the received Beacon frame (or Probe Response frame) has been updated, the mesh STA in deep sleep mode should not take this jitter as clock drift and listen to the next Beacon frame to verify if the clock drift is large.

#### 14.14.4.5 Frame transmission across reported TBTT

When dot11MBCAActivated is true, the mesh STA should not extend its transmissions across TBTT of its neighbor STAs with which it maintains synchronization. Further, the mesh STA should not extend its transmissions, other than Beacon frames, across all essential beacon reception timing (see 14.14.4.2.6 (Receiver's procedure)) reported from its neighbor mesh STAs with which it maintains synchronization. This operation helps in reducing the hidden STA interference with beacon reception at its neighbor mesh STAs. When both dot11MBCAActivated and dot11MCCAActivated are true, the mesh STA shall not extend its transmissions across TBTT of its neighbor STAs with which it maintains synchronization. Further, the mesh STA shall not extend its transmissions, other than Beacon frames, across all beacon reception timing reported from its neighbor mesh STAs with which it maintains synchronization.

After silencing for dot11MeshAverageBeaconFrameDuration μs from the reported neighbor's TBTT, the mesh STA may start transmitting frames again.


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#### 14.14.4.6 Delayed beacon transmissions

A mesh STA may occasionally delay its Beacon frame transmission from its TBTT for a pseudorandom time. This attribute is specified by dot11MeshDelayedBeaconTxInterval, dot11MeshDelayedBeaconTxMinDelay, and dot11MeshDelayedBeaconTxMaxDelay. When dot11MeshDelayedBeaconTxInterval is(M118) a nonzero value, the mesh STA shall delay its Beacon frame transmission from TBTT, once every dot11MeshDelayedBeaconTxInterval. When the mesh STA transmits a Beacon frame with delay from its TBTT, the delay time shall be randomly selected between dot11MeshDelayedBeaconTxMinDelay and dot11MeshDelayedBeaconTxMaxDelay μs.

NOTE—Delayed beacon transmission allows mesh STAs to discover Beacon frames that are transmitted from multiple mesh STAs with TBTTs close to each other. (#161)A mesh STA ought to set dot11MeshDelayedBeaconTxMaxDelay to a time longer than the typical duration of Beacon frames.

## 14.15 Power save in a mesh BSS

### 14.15.1 General

A mesh STA may use mesh power management modes to reduce its power consumption. A mesh STA manages each of its mesh peerings with a peer-specific mesh power management mode as described in 14.15.2.2 (Peer-specific mesh power management modes). A mesh STA may (#1114)use the MLME-MESHPOWERMGT.request primitive to set the mesh power management mode for a mesh peering independently of the mesh power management modes for its other mesh peerings. A mesh STA also manages a nonpeer mesh power management mode as described in 14.15.2.3 (Nonpeer mesh power management modes). When a mesh STA is in light sleep mode or in deep sleep mode for a mesh peering, the mesh STA shall maintain its mesh awake window as described in 14.15.6 (Mesh awake window).

A mesh STA shall have the capability to buffer frames and to perform mesh power management mode tracking for the peer-specific mesh power management modes of its peer mesh STAs, as described in 14.15.7 (Power save support). A mesh STA shall use mesh peer service periods for individually addressed frame transmissions to neighbor peer mesh STAs that are either in light sleep mode or in deep sleep mode toward this mesh STA, as described in 14.15.9 (Mesh peer service periods). A mesh STA transmits group addressed frames after (#8164)a DTIM beacon when any of its peer mesh STAs is in light sleep mode or deep sleep mode for the mesh peering with the mesh STA (see 14.15.4 (TIM transmissions in an MBSS) and 14.15.5 (TIM types)). These capabilities are referred to as *support for power save*.

### 14.15.2 Mesh power management modes

#### 14.15.2.1 General

The manner in which a mesh STA transitions between power states is determined by its peer-specific mesh power management modes and its nonpeer mesh power management mode. A mesh STA shall be in awake state if any of the conditions specified in 14.15.8.6 (Conditions for doze state) is not fulfilled. A mesh STA maintains peer-specific mesh power management modes for each of its mesh peerings as described in 14.15.2.2 (Peer-specific mesh power management modes). A mesh STA may have a different peer-specific mesh power management mode for each mesh peering. A mesh STA maintains a nonpeer mesh power management mode for nonpeer mesh STAs that is described in 14.15.2.3 (Nonpeer mesh power management modes). An example illustration of the use of peer specific and nonpeer mesh power management modes is shown in Figure 14-5 (Example of mesh power management mode usage).

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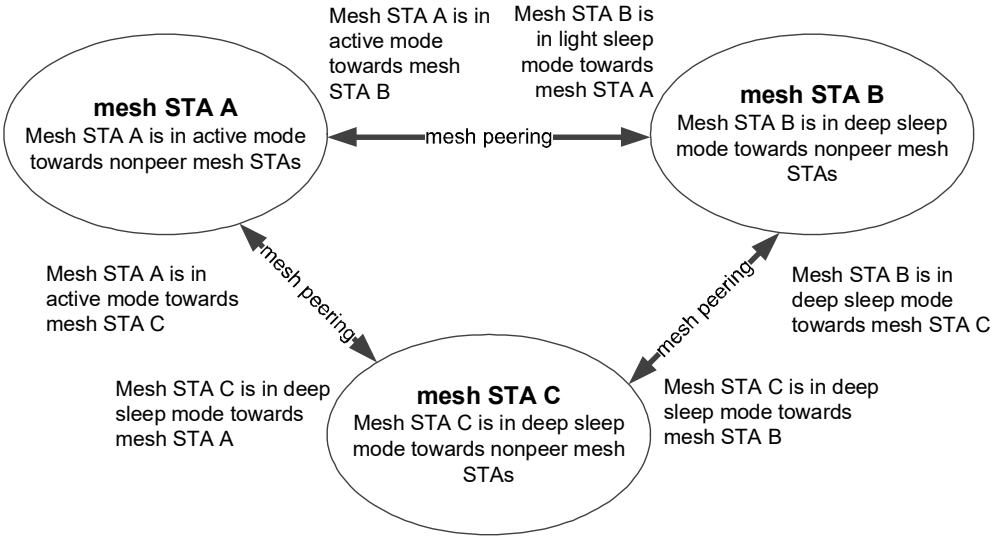


**Figure 14-5—Example of mesh power management mode usage**

### 14.15.2.2 Peer-specific mesh power management modes

The peer-specific mesh power management mode specifies the activity level of the mesh STA for the corresponding mesh peering. Three mesh power management modes are defined: active mode, light sleep mode, and deep sleep mode. The peer-specific mesh power management modes are defined as follows:

— *Active mode:* The mesh STA shall be in awake state all the time.

— *Light sleep mode:* The mesh STA alternates between awake state and doze state, as specified in 14.15.8.4 (Operation in light sleep mode for a mesh peering). The mesh STA shall listen to all of the Beacon frames from the corresponding peer mesh STA.

— *Deep sleep mode:* The mesh STA alternates between awake state and doze state, as specified in 14.15.8.5 (Operation in deep sleep mode for a mesh peering). The mesh STA may choose not to listen to the Beacon frames from the corresponding peer mesh STA.

The combination of the Power Management subfield in the Frame Control field and the Mesh Power Save Level subfield in the QoS Control field contained in mesh Data frames indicates the peer-specific mesh power management mode as shown in (#6291)Table 14-32 (Peer-specific mesh power management mode definition).

**Table 14-32—Peer-specific mesh power management mode definition**

| Activity level | Peer-specific mesh power management mode | Power Management subfield | Mesh Power Save Level subfield |
|---|---|---|---|
| Highest ↑ Lowest | Active mode | 0 | Reserved |
| | Light sleep mode | 1 | 0 |
| | Deep sleep mode | 1 | 1 |


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#### 14.15.2.3 Nonpeer mesh power management modes

The nonpeer mesh power management mode indicates the mesh power management mode of the mesh STA toward the nonpeer mesh STAs. Two nonpeer mesh power management modes are defined: active mode and deep sleep mode. The nonpeer mesh power management mode is indicated by the Power Management subfield in the Frame Control field in group addressed frames, Management frames transmitted to nonpeer neighbor STAs, and in Probe Response frames. When the Power Management subfield in the Frame Control field is(M118) 1, the nonpeer mesh power management mode is deep sleep mode. When the Power Management subfield in the Frame Control field is(M118) 0, the nonpeer mesh power management mode is active mode.

A mesh STA may send Probe Request and Mesh Peering Open Request frames to a nonpeer mesh STA that sets its nonpeer mesh power management mode to deep sleep mode only during the mesh awake window of the mesh STA.

### 14.15.3 Mesh power management mode indications and transitions

#### 14.15.3.1 General

When a mesh STA is in active mode for a mesh peering, it shall set the Power Management subfield in the Frame Control field to 0 in all individually addressed (#419)mesh Data or QoS Null frames transmitted to the corresponding peer mesh STA.

When a mesh STA is in light sleep mode for a mesh peering, it shall set the Power Management subfield in the Frame Control field to 1 and the Mesh Power Save Level subfield in the QoS Control field to 0 in all individually addressed (#419)mesh Data or QoS Null frames transmitted to the corresponding peer mesh STA.

When a mesh STA is in deep sleep mode for a mesh peering, it shall set the Power Management subfield in the Frame Control field to 1 and the Mesh Power Save Level subfield in the QoS Control field to 1 in all individually addressed (#419)mesh Data or QoS Null frames transmitted to the corresponding mesh STA.

When a mesh STA is in deep sleep mode for any of its mesh peerings, the Mesh Power Save Level subfield in the QoS Control field in group addressed mesh Data frames and the Mesh Power Save Level subfield in the Mesh Capability field in the Mesh Configuration element shall be set to 1. When a mesh STA is not in deep sleep mode for any of its mesh peerings, these subfields shall be set to 0.

To change peer-specific mesh power management modes, a mesh STA shall inform its peer mesh STAs through a successful frame exchange initiated by the mesh STA. The Power Management subfield in the Frame Control field and the Mesh Power Save Level subfield in the QoS Control field of the frame sent by the mesh STA in this exchange indicates the peer-specific mesh power management mode that the STA shall adopt upon successful completion of the (#1673)frame exchange sequence(#1674), except where the Power Management subfield is reserved (see 9.2.4.1.7 (Power Management subfield))

The algorithm to trigger the change of a peer-specific mesh power management mode is beyond the scope of this standard.

The nonpeer mesh power management mode is determined by the peer-specific mesh power management modes of the mesh STA. When a mesh STA is in light sleep mode or deep sleep mode for at least one mesh peering, it shall set the nonpeer mesh power management mode to deep sleep mode.

When a mesh STA is in active mode for nonpeer STAs, it shall set the Power Management subfield in the Frame Control field to 0 in group addressed frames, in Management frames transmitted to nonpeer mesh STAs, and in Probe Response frames.

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When a mesh STA is in deep sleep mode for nonpeer STAs, it shall set the Power Management subfield in the Frame Control field to 1 in group addressed frames, in Management frames transmitted to nonpeer mesh STAs, and in Probe Response frames.

#### 14.15.3.2 Transition to a higher activity level

A mesh STA may use group addressed or individually addressed (#419)mesh Data or QoS Null frames to change its mesh power management mode to a higher activity level, for example; from deep sleep to light sleep or to active mode; or from light sleep to active mode.

Individually addressed frames may be used to temporarily raise the activity level of the mesh STA for a mesh peering.

NOTE—This is useful in cases when a link temporarily requires efficient data transmission with the peer mesh STA and the mesh STA is attempting to transit back to lower activity level without performing the mesh power management mode transition signaling with all peer mesh STAs.

#### 14.15.3.3 Transition to a lower activity level

A mesh STA shall use acknowledged individually addressed (#419)mesh Data or QoS Null frames to change its peer-specific mesh power management mode to a lower activity level, for example; from active mode to light or deep sleep mode; or from light sleep to deep sleep mode.

### 14.15.4 TIM transmissions in an MBSS

The TIM element identifies the peer mesh STAs for which traffic is pending and buffered in the reporting mesh STA. This information is coded in a partial virtual bitmap, as described in 9.4.2.5 (TIM element). In addition, the TIM contains an indication whether group addressed traffic is pending, in the Traffic Indicator field, which signals AID 0(#7217). Every neighbor peer mesh STA is assigned an AID by the reporting mesh STA as part of the mesh peering establishment process (see 14.4.1 (General)). The mesh STA shall identify those peer mesh STAs for which it is prepared to deliver[41] buffered MSDUs and MMPDUs by setting bits in the TIM's partial virtual bitmap that correspond to the appropriate AIDs.

### 14.15.5 TIM types

There are two different TIM types: TIM and DTIM. A mesh STA shall transmit a TIM with every Beacon frame. Every DTIMPeriod, a TIM of type DTIM is transmitted with a Beacon frame. (#8164)After transmitting a DTIM beacon, the mesh STA shall send the buffered group addressed MSDUs and MMPDUs, before transmitting any individually addressed frames. The More Data subfield of each group addressed frame shall be set to indicate the presence of further buffered group addressed MSDUs and MMPDUs. The mesh STA sets the More Data subfield to 0 in the last transmitted group addressed frame following the transmission of the DTIM beacon(#3309).

While waiting to receive a group addressed frame that was previously indicated in a TIM element or More Data subfield, a mesh STA that detects CCA is IDLE for the duration of the PHY specific Group Delivery Idle Time may assume that no more frames destined to group addresses will be transmitted and may return to doze state. The Group Delivery Idle Time is identical to the TXOP limit for AC_VI specified by the default EDCA Parameter Set shown in Table 9-194 (Default EDCA Parameter Set element (#1660)parameters if dot11OCBActivated is false and the STA is a non-sensor STA(#251)).

[41] How the AP or mesh STA determines the traffic is prepared to deliver is outside the scope of this standard.


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### 14.15.6 Mesh awake window

A mesh STA shall be in awake state when its mesh awake window is active. A mesh awake window is active after the Beacon and Probe Response frames containing the Mesh Awake Window element. A mesh STA shall include the Mesh Awake Window element in its DTIM beacons(#3309) and may include the Mesh Awake Window element in its TIM Beacon and Probe Response frames. A mesh STA that operates in light sleep mode or deep sleep mode for any of its mesh peerings shall include the Mesh Awake Window element in its Beacon frame if the Beacon frame indicates buffered traffic for at least one peer mesh STA. The start of the mesh awake window is measured from the end of the Beacon or Probe Response frame transmission. The duration of the mesh awake window period is specified by dot11MeshAwakeWindowDuration. A mesh STA shall set the Mesh Awake Window field in the Mesh Awake Window element to dot11MeshAwakeWindowDuration. If the Mesh Awake Window element is not contained in the Beacon frame of a mesh STA, the duration of the mesh awake window period following this beacon is zero.

If the mesh STA that has its mesh awake window active transmits frames destined to group addresses, the duration of the mesh awake window is extended by an additional PostAwakeDuration. The PostAwakeDuration follows the group address frame, and the mesh STA that has its mesh awake window active shall stay in awake state until it has transmitted all of its group addressed frames and the PostAwakeDuration has expired. The PostAwakeDuration is equal to duration of the mesh awake window.

A mesh STA may send a frame to a peer mesh STA that is in light sleep mode or deep sleep mode for the corresponding mesh peering during the mesh awake window of this peer mesh STA. When a peer trigger frame is successfully transmitted it initiates a mesh peer service period as described in 14.15.9 (Mesh peer service periods).

A mesh STA may send Class 1 or Class 2 frames, such as Probe Request or Mesh Peering Open frames, to a nonpeer mesh STA that is in deep sleep mode for nonpeer mesh STAs during the mesh awake window of this nonpeer mesh STA.

### 14.15.7 Power save support

As described in 14.15.2 (Mesh power management modes), a mesh STA indicates its peer-specific mesh power management modes and performs mesh power management mode tracking of the peer-specific mesh power management modes of its peer mesh STAs. A mesh STA shall not arbitrarily transmit frames to mesh STAs operating in a light or deep sleep mode, but shall buffer frames and only transmit them at designated times.

A mesh STA may transmit frames to a mesh STA operating in a light or deep sleep mode if the recipient mesh STA is in the awake state as defined in 14.15.8.4 (Operation in light sleep mode for a mesh peering), 14.15.8.5 (Operation in deep sleep mode for a mesh peering), and 14.15.9 (Mesh peer service periods); otherwise, the mesh STA shall not transmit frames and shall buffer frames.

As described in 14.15.4 (TIM transmissions in an MBSS), a mesh STA indicates the presence of buffered traffic in TIM elements for all peer mesh STAs that operate in light or deep sleep mode toward the mesh STA. The mesh STA sets the Traffic Indicator field(#7217) in the Bitmap Control field of the TIM element to 1 when group addressed traffic is buffered, according to 9.4.2.5 (TIM element). As described in 14.15.5 (TIM types), a mesh STA transmits its group addressed frames after its DTIM beacon if any of its peer mesh STA is in light or deep sleep mode toward the mesh STA.

As described in 14.15.9 (Mesh peer service periods), mesh peer service periods are used for frame transmissions toward a mesh STA that operates in light or deep sleep mode. Mesh peer service periods are not used in frame exchange sequences(#109) toward active mode mesh STAs.

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A mesh STA may initiate a mesh peer service period with a peer mesh STA in deep or light sleep mode by transmitting a peer trigger frame when the mesh awake window of the peer mesh STA is active.

### 14.15.8 Operation in peer-specific and nonpeer mesh power management modes

#### 14.15.8.1 General

Detailed operations of mesh STA in each mesh power management mode are described in the following subclauses. Figure 14-6 (Mesh power management operation) depicts example power state transitions of mesh STAs, when three mesh STAs are in the mesh power management modes shown in (#6291)Figure 14-5 (Example of mesh power management mode usage).

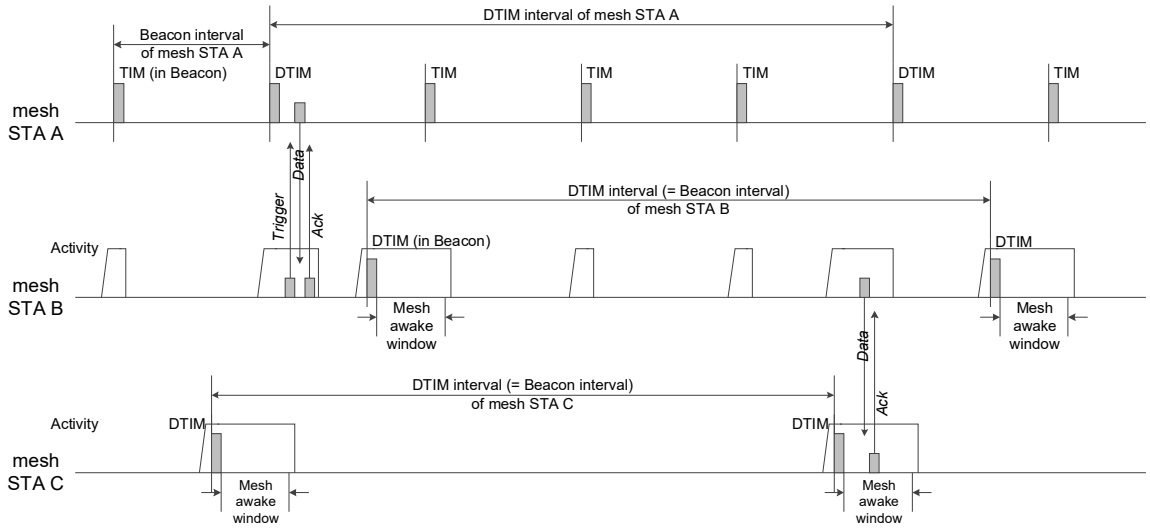


**Figure 14-6—Mesh power management operation**

#### 14.15.8.2 Operation in active mode

When a mesh STA is in active mode for a mesh peering or for nonpeer mesh STAs, it shall be in awake state. Mesh peer service periods are not used in frame exchange sequences(#109) toward mesh STAs that are in active mode.

An active mode mesh STA may receive peer trigger frames from a peer mesh STA in light or deep sleep mode when there is no mesh peer service period ongoing between the peer mesh STAs.

#### 14.15.8.3 Operation in deep sleep mode for nonpeer mesh STAs

If a mesh STA is in deep sleep mode for nonpeer mesh STAs, it shall enter the awake state prior to every TBTT of its own and shall remain in awake state after the beacon transmission for the duration of the mesh awake window and the duration of its group addressed frame transmissions. The mesh STA may receive frames during its mesh awake window as described in 14.15.6 (Mesh awake window).

When receiving a frame initiating a mesh peering management procedure, an authentication procedure, or a passive scanning procedure, a mesh STA in deep sleep mode for nonpeer mesh STAs shall operate in awake state at least until the completion of the mesh peering management procedure (see 14.4 (Mesh peering management (MPM)) and 14.6 (Authenticated mesh peering exchange (AMPE))), until the completion of the authentication procedure (see 14.4.1 (General) and 14.4.3 (Mesh authentication)), or the transmission of the Probe Response frame.


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If a mesh STA receives a peer trigger frame initiating a mesh peer service period from a peer mesh STA, the mesh STA shall remain in awake state until the mesh peer service period is terminated as defined in 14.15.9.4 (Termination of a mesh peer service period).

A mesh STA may return to doze state after its mesh awake window if no frame initiating a response transaction or a mesh peer service period is received during the mesh awake window.

### 14.15.8.4 Operation in light sleep mode for a mesh peering

If a mesh STA is in light sleep mode for a mesh peering, it shall enter the awake state prior to every TBTT of the corresponding peer mesh STA to receive the Beacon frame from the peer mesh STA. The mesh STA may return to the doze state after the beacon reception from this peer mesh STA, if the peer mesh STA did not indicate buffered individually addressed or group addressed frames. If an indication of buffered individually addressed frames is received, the light sleep mode mesh STA shall send a peer trigger frame with the RSPI field set to 1 to initiate a mesh peer service period with the mesh STA that transmitted the Beacon frame (see 14.15.9.2 (Initiation of a mesh peer service period)). If an indication of buffered group addressed frames is received, the light sleep mode mesh STA shall remain in awake state after the DTIM (#1000)beacon reception to receive group addressed frames The mesh STA shall remain awake state until the More Data subfield of a received group addressed frame is(M118) 0 or if no group addressed frame is received within the PHY specific Group Delivery Idle Time. (See 14.15.5 (TIM types).)

NOTE—When a mesh STA is in light sleep mode for a mesh peering, it sets its nonpeer mesh power management mode to deep sleep mode. This implies that a mesh STA operating in light sleep mode a mesh peering is required to comply with the rules described in 14.15.8.3 (Operation in deep sleep mode for nonpeer mesh STAs).

### 14.15.8.5 Operation in deep sleep mode for a mesh peering

A mesh STA operating in deep sleep mode for a mesh peering might not receive Beacon frames from the corresponding peer mesh STA. The logic of how the mesh STA in deep sleep mode maintains synchronization among neighbors is beyond the scope of this standard. Guidance for the synchronization maintenance by the mesh STA in deep sleep mode is given in S.3.6 (Synchronization maintenance of mesh STAs in deep sleep mode).

NOTE—When a mesh STA is in deep sleep mode for a mesh peering, it sets its nonpeer mesh power management mode to deep sleep mode. This implies that a mesh STA operating in deep sleep mode for a mesh peering is required to comply with the rules described in 14.15.8.3 (Operation in deep sleep mode for nonpeer mesh STAs).

### 14.15.8.6 Conditions for doze state

A mesh STA may enter doze state if all of the following conditions are fulfilled:

- The mesh STA operates in light sleep mode or deep sleep mode for all of its mesh peerings, as described in 14.15.8.4 (Operation in light sleep mode for a mesh peering) or 14.15.8.5 (Operation in deep sleep mode for a mesh peering)
- The mesh STA has no mesh peer service period ongoing, as described in 14.15.9 (Mesh peer service periods)
- The mesh STA has no pending transaction of mesh peering management, authentication, nor passive scanning (see 14.15.8.3 (Operation in deep sleep mode for nonpeer mesh STAs))
- The mesh awake window indicated by the mesh STA has expired, as described in 14.15.6 (Mesh awake window)
- The mesh STA has terminated its group addressed frames delivery sequence after its DTIM beacon(#3309), as described in 14.15.5 (TIM types)

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Guidance for using the power save in mesh BSS and default parameter values are given in S.3 (Power save parameters selection).

### 14.15.9 Mesh peer service periods

#### 14.15.9.1 General

Mesh peer service periods are used for individually addressed frame exchange sequences(#109) between neighbor peer mesh STAs in which at least one of the mesh STAs is in light or deep sleep mode for the corresponding mesh peering. A mesh peer service period is a period of time during which one or more individually addressed frames are transmitted between two peer mesh STAs. Within a mesh peer service period, a mesh STA may obtain multiple TXOPs. A mesh peer service period is directional. One mesh STA is the owner of the mesh peer service period. It obtains TXOPs in order to transmit Data frames or Management frames to the recipient in the mesh peer service period. At the end of the frame transmissions, the owner of the mesh peer service period terminates the mesh peer service period. The other mesh STA operates as the recipient of the mesh peer service period and does not obtain TXOPs for transmitting Data frames or Management frames to the owner of the mesh peer service period. A mesh STA may have multiple mesh peer service periods concurrently toward multiple neighbor peer mesh STAs. At most, one mesh peer service period is set up in each direction with each peer mesh STA.

A mesh peer service period is initiated by a peer trigger frame. A peer trigger frame may initiate two mesh peer service periods. This enables both the transmitter and the receiver of the peer trigger frame to become the owner of a mesh peer service period. An example mesh peer service period between two mesh STAs in light or deep sleep mode is shown in Figure 14-7 (Mesh peer service period). The numbering on the left-hand-side describes the phase of the operation: 1 indicates the Initiation phase, 2 indicates the data transmission phase, and 3 indicates the termination phase of the mesh peer service period.

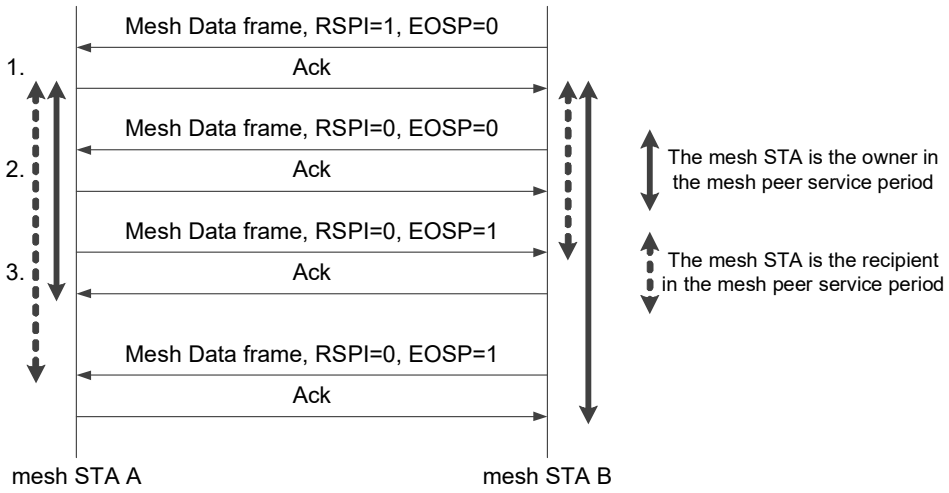


**Figure 14-7—Mesh peer service period**

#### 14.15.9.2 Initiation of a mesh peer service period

A mesh Data frame or a QoS Null frame that requires immediate acknowledgment are used as a peer trigger frame. The RSPI and the EOSP subfields in the QoS Control field control the initiation of a mesh peer service period. Table 14-33 (Mesh peer service period triggering with RSPI and EOSP subfield combinations in peer trigger frame) lists how mesh peer service periods shall be initiated with different combinations of RSPI and EOSP subfield values.


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**Table 14-33—Mesh peer service period triggering with RSPI and EOSP subfield combinations in peer trigger frame**

| RSPI | EOSP | Mesh peer service period triggering |
|---|---|---|
| 0 | 0 | One mesh peer service period is initiated. The transmitter of the trigger frame is the owner in the mesh peer service period. |
| 0 | 1 | No mesh peer service period is initiated. |
| 1 | 0 | Two mesh peer service periods are initiated. Both mesh STAs are owners in a mesh peer service period. |
| 1 | 1 | One mesh peer service period is initiated. The receiver of the trigger frame is the owner in the mesh peer service period. |

Mesh peer service periods are not used in frame transmissions toward active mode mesh STAs.

The mesh peer service period may be initiated in the following cases:

— A mesh STA in light or deep sleep mode receives a peer trigger frame during its mesh awake window as described in 14.15.6 (Mesh awake window)

— A mesh STA in active mode receives a peer trigger frame from the peer mesh STA in light or deep sleep mode as described in 14.15.8.2 (Operation in active mode)

— A mesh STA receives a peer trigger frame from the peer mesh STA in light sleep mode as described in 14.15.8.4 (Operation in light sleep mode for a mesh peering)

In addition, when a mesh STA uses MCCA with a neighbor peer mesh STA while in a light sleep mode for the corresponding mesh peering, a scheduled service period begins at the each MCCAOP start time as described in 14.15.10 (MCCA use by power saving mesh STA). A mesh STA in a light or deep sleep mode shall enter the awake state prior to the start time of scheduled service period.

### 14.15.9.3 Operation during a mesh peer service period

During the mesh peer service period, the owner and the recipient of the mesh peer service period shall operate in awake state. The mesh peer service period may contain one or more TXOPs.

Reverse direction grant (RDG) shall not be used when the receiver of the TXOP operates in light or deep sleep mode for the link and there is no mesh peer service period ongoing toward the TXOP holder.

### 14.15.9.4 Termination of a mesh peer service period

The mesh peer service period is terminated after a successfully acknowledged QoS Null or mesh Data frame with the EOSP subfield set to 1 from the owner of the mesh peer service period.

If the mesh STA does not receive an acknowledgment to a frame that requires an acknowledgment and that is sent with the EOSP subfield set to 1, the mesh STA shall retransmit that frame at least once within the same mesh peer service period, subject to applicable retry or lifetime limits. The maximum number of retransmissions within the same mesh peer service period is the lesser of the Max Retry Limit and dot11MeshSTAMissingAckRetryLimit.

NOTE—If an acknowledgment to the retransmission of this last frame in the same mesh peer service period is not received, the mesh STA might use the next mesh peer service period to further retransmit that frame subject to the applicable retry or lifetime limit.

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### 14.15.10 MCCA use by power saving mesh STA

When dot11MCCAActivated is true and the mesh STA establishes MCCAOPs, the mesh STA shall be in active mode or light sleep mode toward the neighbor peer mesh STAs with which it has established MCCAOPs.

A scheduled mesh peer service period begins at the MCCAOP start time, if the MCCAOP responder operates in light sleep mode for the MCCAOP owner. The MCCAOP owner is the owner of the scheduled mesh peer service period. The MCCAOP responder is the recipient of the scheduled mesh peer service period. Scheduled mesh peer service periods are not used if the MCCAOP responder is in active mode for the MCCAOP owner.

The scheduled mesh peer service period continues until it is successfully terminated by the acknowledged QoS Null or mesh Data frame with the EOSP subfield set to 1 from the owner of the mesh peer service period to the recipient of the mesh peer service period as described in 14.15.9 (Mesh peer service periods).


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# 15. DSSS PHY specification for the 2.4 GHz band designated for ISM applications

## 15.1 Overview

### 15.1.1 General

The PHY for the DSSS system is described in this clause. The RF LAN system is aimed for the 2.4 GHz band designated for ISM applications.

The DSSS system provides a WLAN with both a 1 Mb/s and a 2 Mb/s data payload communication capability. The DSSS system uses baseband modulations of differential binary phase shift keying (DBPSK) and differential quadrature phase shift keying (DQPSK) to provide the 1 Mb/s and 2 Mb/s data rates, respectively.

### 15.1.2 Scope of DSSS PHY services

The PHY services provided to the IEEE 802.11 WLAN MAC by the 2.4 GHz DSSS system are described in this clause. The DSSS PHY consists of the following protocol functions:

a) A function that defines a method of mapping the IEEE 802.11 (#14)PSDUs into a framing format suitable for sending and receiving user data and management information between two or more STAs.

b) A function that defines the characteristics of, and method of transmitting and receiving data through, a WM between two or more STAs each using the DSSS system.

### 15.1.3 DSSS PHY functions

#### 15.1.3.1 General

The 2.4 GHz DSSS PHY architecture is depicted in the reference model shown in Figure 4-27 (Portion of the ISO/IEC basic reference model covered in this standard(#4114)) (in 4.9 (Reference model)). The DSSS PHY contains two functional entities: the PHY function and the layer management function. Each of these functions is described in detail in the following subclauses.

The DSSS PHY service shall be provided to the MAC through the PHY service primitives described in Clause 8 (PHY service specification).

#### 15.1.3.2 PLME

The PLME performs management of the local PHY functions in conjunction with the MLME.

### 15.1.4 Service specification method and notation

The models represented by figures and state diagrams are intended to be illustrations of functions provided. It is important to distinguish between a model and a real implementation. The models are optimized for simplicity and clarity of presentation, but do not necessarily reflect any particular implementation.

The service of a layer or sublayer is a set of capabilities that it offers to a user in the next-higher layer (or sublayer). Abstract services are specified here by describing the service primitives and parameters that characterize each service. This definition is independent of any particular implementation.

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## 15.2 DSSS PHY specific service parameter list

### 15.2.1 Introduction

The architecture of the IEEE 802.11 MAC is intended to be PHY independent. Some PHY implementations require medium management state machines running in the MAC sublayer in order to meet certain PHY requirements. These PHY-dependent MAC state machines reside in a sublayer defined as the MLME. In certain PHY implementations, the MLME may need to interact with the PLME as part of the normal PHY SAP primitives. These interactions are defined by the PLME parameter list currently defined in the PHY service primitives as TXVECTOR and RXVECTOR. The list of these parameters, and the values they may represent, are defined in the specific PHY specifications for each PHY. Subclause 15.2 (DSSS PHY specific service parameter list) addresses the TXVECTOR and RXVECTOR for the DSSS PHY.

### 15.2.2 TXVECTOR parameters(#1369)

The parameters in Table 15-1 (TXVECTOR parameters) are defined as part of the TXVECTOR parameter list in the PHY-TXSTART.request primitive.

**Table 15-1—TXVECTOR parameters**

| Parameter | Value |
|---|---|
| LENGTH | 0 to $2^{12} - 1$ |
| DATARATE | 1, 2 Mb/s |
| SERVICE | Null |
| TXPWR_LEVEL_INDEX | 1 to 8 |
| TIME_OF_DEPARTURE_REQUESTED | false, true. When true, the MAC entity requests that the PHY entity measures and reports time of departure parameters corresponding to the time when the first (#14)PPDU energy is sent by the transmitting port; when false, the MAC entity requests that the PHY entity neither measures nor reports time of departure parameters. |
| TX_ANTENNA | 1 to 255 |

The LENGTH parameter provided in the TXVECTOR is in octets and is converted to microseconds for inclusion in the PHY LENGTH field.

The DATARATE parameter describes the bit rate at which the PHY shall transmit the PSDU. Its value takes any of the rates defined in Table 15-1 (TXVECTOR parameters).

The SERVICE parameter shall be null.

The allowed values for the TXPWR_LEVEL_INDEX parameter are in the range 1 to 8. This parameter is used to indicate which of the available TxPowerLevel attributes defined in the MIB shall be used for the current transmission.

(#1369)The allowed values for the TIME_OF_DEPARTURE_REQUESTED parameter are false or true. A parameter value of true indicates that the MAC sublayer is requesting that the PHY entity provides measurement of when the first (#14)PPDU energy is sent by the transmitting port and reporting within the PHY-TXSTART.confirm primitive. A parameter value of false indicates that the MAC sublayer is


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requesting that the PHY entity not provide time of departure measurement nor reporting in the PHY-TXSTART.confirm primitive.

(#1369)The TX_ANTENNA parameter selects the antenna used by the PHY for transmission (when diversity is disabled), in the range 1 to 255.

### 15.2.3 RXVECTOR parameters(#1369)

The parameters listed in Table 15-2 (RXVECTOR parameters) are defined as part of the RXVECTOR parameter list in the PHY-RXSTART.indication primitive.

**Table 15-2—RXVECTOR parameters**

| Parameter | Value |
|---|---|
| LENGTH | 0 to $2^{12}$ – 1 |
| RSSI | 0–255 |
| SIGNAL | 1, 2 Mb/s |
| SERVICE | 1, 2 Mb/s |
| SQ | 0–255 |
| RX_ANTENNA | 0–255 |
| RX_START_OF_FRAME_OFFSET | (#1373)0 to $2^{32}$ – 1. |
| (#1372)RCPI | See 15.4.6.6 (Received channel power indicator (RCPI) measurement) |

(#1369)The LENGTH parameter is the (#14)PSDU length in octets (calculated from the LENGTH field in microseconds).

(#1369)(#3412)The RSSI parameter is a (#1132)measurement by the PHY of the energy observed at the antenna connector used to receive the current PPDU. RSSI shall be measured during the reception of the PHY preamble. RSSI is intended to be used in a relative manner, and it shall be a monotonically increasing function of the received power.

(#3239)The SIGNAL parameter shall represent the data rate at which the current PPDU was received.

The SERVICE parameter shall be null.

(#3239)The SQ parameter provides to the MAC entity the signal quality of the DSSS PHY PN code correlation. The signal quality shall be sampled when the DSSS PHY achieves code lock and shall be held until the next code lock acquisition. The signal quality may be used in conjunction with RSSI as part of a CCA scheme.

(#3239)The RX_ANTENNA parameter reports the antenna used by the PHY for reception of the most recent PPDU.

(#1373)(#3239)The RX_START_FRAME_OFFSET parameter is an estimate of the offset (in 10 ns units) from the point in time at which the start of the preamble (#14)of the PPDU arrived at the receive antenna connector to the point in time at which this primitive is issued to the MAC.

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### 15.2.4 TXSTATUS parameters(#1369)

The parameters listed in Table 15-3 (TXSTATUS parameters) are defined as part of the TXSTATUS parameter list in the PHY-TXSTART.confirm primitive.

**Table 15-3—TXSTATUS parameters**

| Parameter | Value |
|---|---|
| TIME_OF_DEPARTURE | 0 to $2^{32}$– 1. The locally measured time when the first (#14)PPDU energy is sent by the transmitting port, in units equal to 1/ TIME_OF_DEPARTURE_ClockRate. This parameter is present only if TIME_OF_DEPARTURE_REQUESTED is true in the corresponding request. |
| TIME_OF_DEPARTURE_ClockRate | 0 to $2^{16}$– 1. The clock rate, in units of MHz, is used to generate the TIME_OF_DEPARTURE value. This parameter is present only if TIME_OF_DEPARTURE_REQUESTED is true in the corresponding request. |
| TX_START_OF_FRAME_OFFSET | (#1373)(#1370)0 to $2^{32}$– 1. |

The allowed values for the TIME_OF_DEPARTURE parameter are integers in the range 0 to $2^{32} – 1$. This parameter is used to indicate when the first (#14)PPDU energy is sent by the transmitting port in units equal to 1/TIME_OF_DEPARTURE_ClockRate. TIME_OF_DEPARTURE may be included in the transmitted frame in order for recipients on multiple channels to determine the time differences of air propagation times between transmitter and recipients and hence to compute the location of the transmitter.

TIME_OF_DEPARTURE_ClockRate indicates the clock rate used for TIME_OF_DEPARTURE.

(#1373)(#1370)TX_START_OF_FRAME_OFFSET is an estimate of the offset (in 10 ns units) from the point in time at which the start of the preamble (#14)of the PPDU was transmitted at the transmit antenna connector to the point in time at which this primitive is issued to the MAC.

### 15.2.5 PHYCONFIG_VECTOR parameters(#2115)

The PHYCONFIG_VECTOR carried in a PHY-CONFIG.request primitive for a DSSS PHY contains an OPERATING_CHANNEL parameter, which identifies the operating channel. The PHY shall set dot11CurrentChannel to the value of this parameter.

## 15.3 DSSS PHY

### 15.3.1 Overview

Subclause 15.3 (DSSS PHY) provides a convergence procedure in which (#14)PSDUs are converted to and from PPDUs. During transmission, the (#14)PSDU shall be prepended with a PHY preamble and header to create the PPDU. At the receiver, the PHY preamble and header are processed to aid in demodulation and delivery of the (#14)PSDU.

### 15.3.2 PPDU format

Figure 15-1 (PPDU format(#2260)) shows the format for the PPDU including the DSSS PHY preamble, the DSSS PHY header, and the (#14)PSDU. The PHY preamble contains the following fields: SYNC and SFD.


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The PHY header contains the following fields: Signaling (SIGNAL), Service (SERVICE), length (LENGTH), and CRC-16 (CRC). Each of these fields is described in detail in 15.3.3 (PHY field definitions).

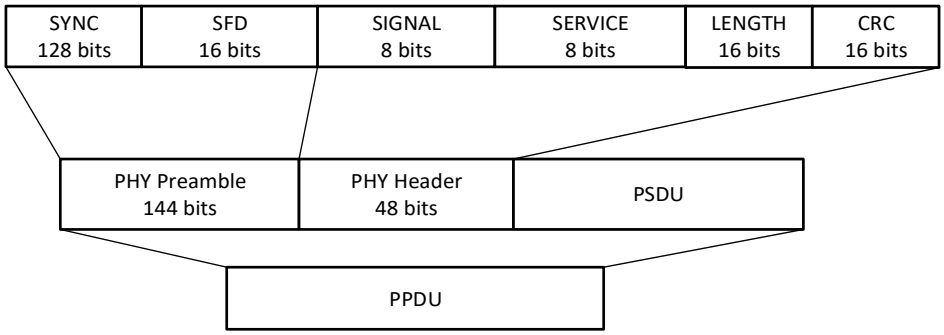


**Figure 15-1—PPDU format(#2260)**

### 15.3.3 PHY field definitions

#### 15.3.3.1 General

The entire PHY preamble and header shall be transmitted using the 1 Mb/s DBPSK modulation described in 15.4.5 (PHY transmit specifications). All transmitted bits shall be scrambled using the feedthrough scrambler described in 15.3.4 (PHY/DSSS PHY data scrambler and descrambler).

#### 15.3.3.2 PHY SYNC field

The SYNC field shall consist of scrambled 1s. This field shall be provided so that the receiver can perform the necessary operations for synchronization.

#### 15.3.3.3 PHY SFD

The SFD shall be provided to indicate the start of PHY-dependent parameters within the PHY preamble. The SFD shall be X'F3A0' (MSB to LSB). The LSB shall be transmitted first in time.

#### 15.3.3.4 PHY SIGNAL field

The SIGNAL field indicates to the PHY the modulation that shall be used for transmission (and reception) of the (#14)PSDU. The data rate shall be equal to the signal field value multiplied by 100 kb/s. The DSSS PHY currently supports two mandatory modulation services given by the following 8-bit words, where the LSB shall be transmitted first in time:

a) X'0A' (MSB to LSB) for 1 Mb/s DBPSK
b) X'14' (MSB to LSB) for 2 Mb/s DQPSK

The DSSS PHY rate change capability is described in 15.3.5 (PHY data modulation and modulation rate change). This field shall be protected by the CRC-16 FCS described in 15.3.3.7 (PHY CRC field).

#### 15.3.3.5 PHY SERVICE field

The SERVICE field is reserved for future use; it shall be set to 0 on transmission and ignored on reception. The LSB shall be transmitted first in time. This field shall be protected by the CRC-16 FCS described in 15.3.3.7 (PHY CRC field).

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### 15.3.3.6 PHY LENGTH field

The PHY LENGTH field shall be an unsigned integer that indicates the number of microseconds required to transmit the (#14)PSDU. The transmitted value shall be determined from the LENGTH parameter in the TXVECTOR issued with the PHY-TXSTART.request primitive described in 8.3.5.5 (PHY-TXSTART.request). The LENGTH field provided in the TXVECTOR is in octets and is converted to microseconds for inclusion in the PHY LENGTH field. The LSB shall be transmitted first in time. This field shall be protected by the CRC-16 FCS described in 15.3.3.7 (PHY CRC field).

### 15.3.3.7 PHY CRC field

The SIGNAL, SERVICE, and LENGTH fields shall be protected with a CRC-16 FCS. The CRC-16 FCS shall be the 1s complement of the remainder generated by the modulo 2 division of the protected PHY fields by the polynomial:

$$x^{16} + x^{12} + x^5 + 1$$

The protected bits shall be processed in transmit order. All FCS calculations shall be made prior to data scrambling. A schematic of the processing is shown in Figure 15-2 (CRC-16 implementation(#1879)(#17)(#4029)).(#17)

As an example, the SIGNAL, SERVICE, and LENGTH fields for a DBPSK signal with an (#14)PSDU length of 192 μs (24 octets) would be given by the following:

0101 0000 0000 0000 0000 0011 0000 0000 (leftmost bit transmitted first in time)

The 1s complement FCS for these protected PHY preamble bits would be the following:

0101 1011 0101 0111 (leftmost bit transmitted first in time)(#17)

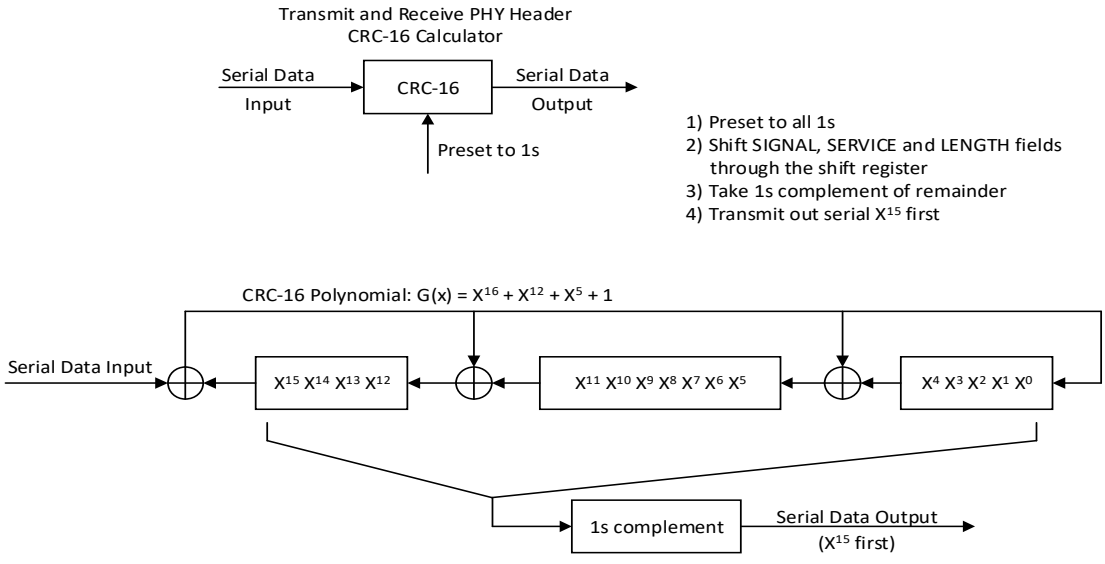


**Figure 15-2—CRC-16 implementation(#1879)(#17)(#4029)**


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An illustrative example of the CRC-16 FCS using the information from Figure 15-2 (CRC-16 implementation(#1879)(#17)(#4029)) is shown(#17) in Figure 15-3 (Example CRC calculation).

| Data | CRC registers MSB LSB | |
|---|---|---|
| | 1111111111111111 | ; initialize preset to 1s |
| 0 | 1110111111011111 | |
| 1 | 1101111110111110 | |
| 0 | 1010111101011101 | |
| 1 | 0101111010111010 | |
| 0 | 1011110101110100 | |
| 0 | 0110101011001001 | |
| 0 | 1101010110010010 | |
| 0 | 1011101100000101 | |
| 0 | 0110011000101011 | |
| 0 | 1100110001010110 | |
| 0 | 1000100010001101 | |
| 0 | 0000000100111011 | |
| 0 | 0000001001110110 | |
| 0 | 0000010011101100 | |
| 0 | 0000100111011000 | |
| 0 | 0001001110110000 | |
| 0 | 0010011101100000 | |
| 0 | 0100111011000000 | |
| 0 | 1001110110000000 | |
| 0 | 0010101100100001 | |
| 0 | 0101011001000010 | |
| 0 | 1010110010000100 | |
| 1 | 0101100100001000 | |
| 1 | 1010001000110001 | |
| 0 | 0101010001000011 | |
| 0 | 1010100010000110 | |
| 0 | 0100000100101101 | |
| 0 | 1000001001011010 | |
| 0 | 0001010010010101 | |
| 0 | 0010100100101010 | |
| 0 | 0101001001010100 | |
| 0 | 1010010010101000 | |
| | 0101101101010111 | ; 1s complement, result = CRC FCS parity |

**Figure 15-3—Example CRC calculation**

### 15.3.4 PHY/DSSS PHY data scrambler and descrambler

The polynomial $G(z) = z^{-7} + z^{-4} + 1$ shall be used to scramble all bits transmitted by the DSSS PHY. The feedthrough configuration of the scrambler and descrambler is self-synchronizing, which requires no prior knowledge of the transmitter initialization of the scrambler for receive processing. Figure 15-4 (Data scrambler) and Figure 15-5 (Data descrambler) show typical implementations of the data scrambler and descrambler, but other implementations are possible.

The scrambler should be initialized to any state except all 1s when transmitting.

### 15.3.5 PHY data modulation and modulation rate change

The PHY preamble shall be transmitted using the 1 Mb/s DBPSK modulation. The SIGNAL field shall indicate the modulation that shall be used to transmit the (#14)PSDU. The transmitter and receiver shall initiate the modulation indicated by the SIGNAL field starting with the first symbol (1 bit for DBPSK or 2 bits for DQPSK) of the (#14)PSDU. The (#14)PSDU transmission rate shall be set by the DATARATE parameter in the TXVECTOR issued with the PHY-TXSTART.request primitive described in 15.2.2 (TXVECTOR parameters(#1369)).

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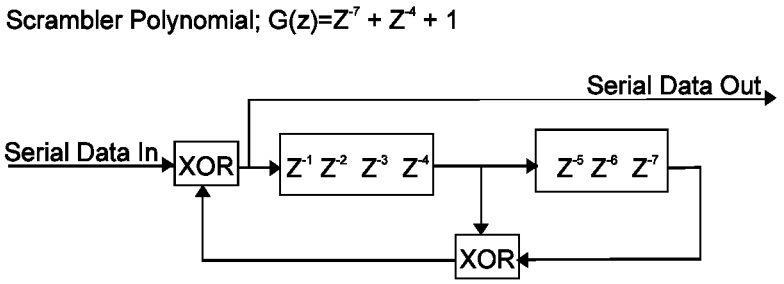


**Figure 15-4—Data scrambler**

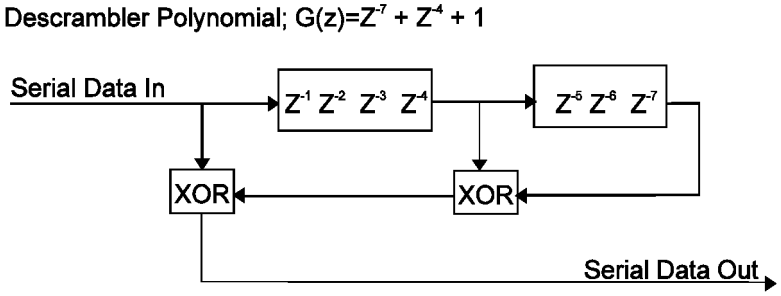


**Figure 15-5—Data descrambler**

### 15.3.6 Transmit PHY

The transmit PHY is shown in Figure 15-6 (Transmit PHY(#1911)(#2260)).

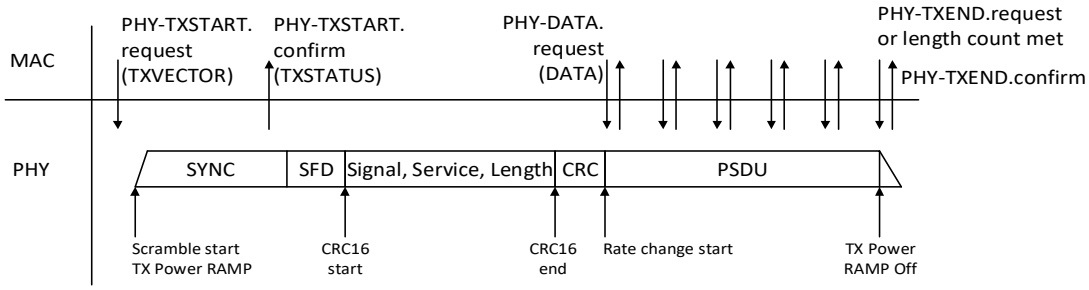


**Figure 15-6—Transmit PHY(#1911)(#2260)**

In order to transmit data, PHY-TXSTART.request primitive shall be issued so that the PHY entity shall be in the transmit state. Further, the PHY shall be set to operate at the appropriate channel through STA management via the PLME. Other transmit parameters such as DATARATE, TX antenna, and TX power are set via the PHY SAP with the PHY-TXSTART.request(TXVECTOR) primitive as described in 15.2.2 (TXVECTOR parameters(#1369)).

Based on the state of CCA indicated by the PHY-CCA.indication primitive, the MAC assesses that the channel is clear. A clear channel shall be indicated by a PHY-CCA.indication(IDLE) primitive. If the channel is clear, transmission of the PPDU shall be initiated by issuing the PHY-TXSTART.request(TXVECTOR) primitive. The TXVECTOR elements for the PHY-TXSTART.request primitive are the PHY header parameters SIGNAL (DATARATE), SERVICE, LENGTH, TX_ANTENNA, TXPWR_LEVEL_INDEX, and


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TIME_OF_DEPARTURE_REQUESTED. The PHY header parameter LENGTH is calculated from the TXVECTOR element by multiplying by 8 for 1 Mb/s and by 4 for 2 Mb/s.

The PHY is configured with the TXVECTOR elements TX_ANTENNA, DATARATE, and TXPWR_LEVEL_INDEX. The PHY entity shall immediately initiate data scrambling and transmission of the PHY preamble based on the parameters passed in the PHY-TXSTART.request primitive. The time required for transmit power-on ramp described in 15.4.5.8 (Transmit power-on and power-down ramp) shall be included in the PHY SYNC field.

Once the PHY preamble transmission is complete, data shall be exchanged between the MAC and the PHY by a series of PHY-DATA.request(DATA) primitives issued by the MAC and PHY-DATA.confirm primitives issued by the PHY. The modulation rate change, if any, shall be initiated with the first data symbol of the (#14)PSDU as described in 15.3.5 (PHY data modulation and modulation rate change). The PHY proceeds with (#14)PSDU transmission through a series of data octet transfers from the MAC. Transmission can be prematurely terminated by the MAC through the PHY-TXEND.request primitive. Normal termination occurs after the transmission of the final bit of the last (#14)PSDU octet according to the number supplied in the TXVECTOR LENGTH field. The PPDU transmission shall be completed and the PHY entity shall enter the receive state. It is recommended that chipping continue during power-down. Each PHY-TXEND.request primitive is acknowledged with a PHY-TXEND.confirm primitive from the PHY.

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A typical state machine implementation of the transmit PHY is provided in Figure 15-7 (PHY transmit state machine(#2260)).

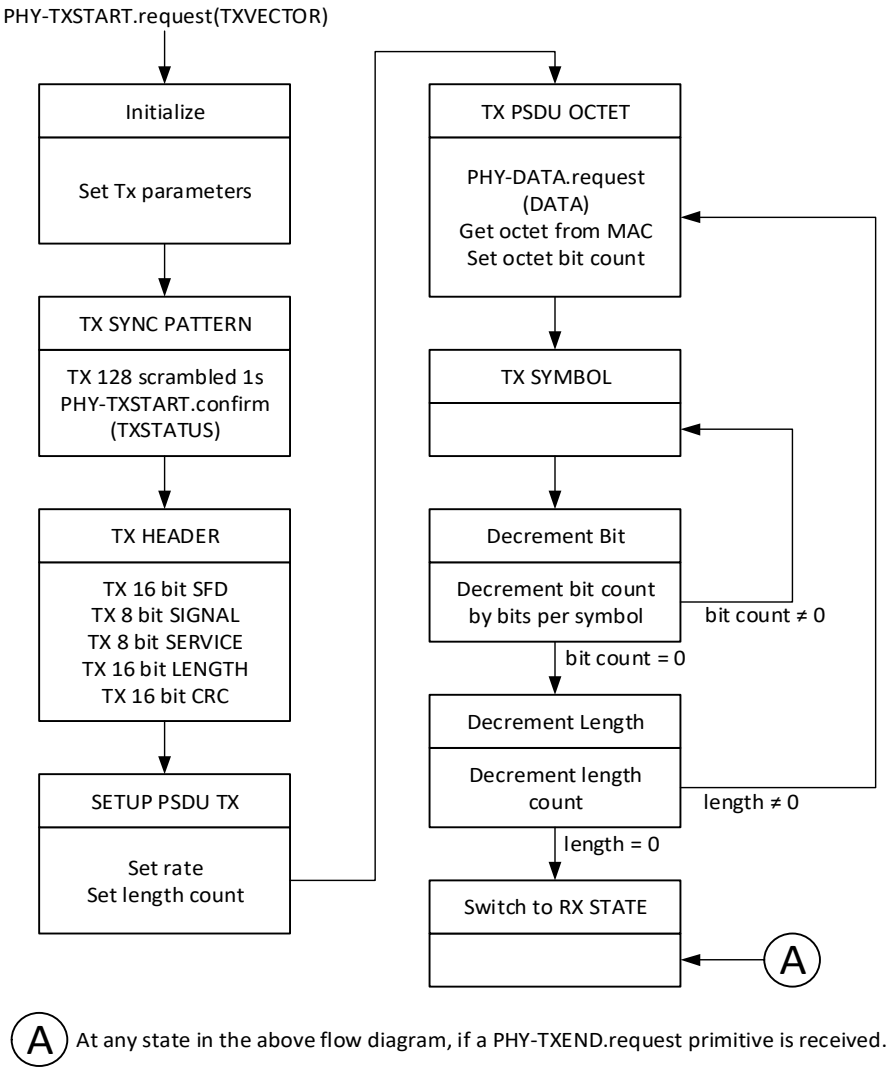


**Figure 15-7—PHY transmit state machine(#2260)**

### 15.3.7 Receive PHY

The receive PHY is shown in Figure 15-8 (Receive PHY(#2260)).

In order to receive data, PHY-TXSTART.request primitive shall be disabled so that the PHY entity is in the receive state. Further, through STA management via the PLME, the PHY is set to the appropriate channel and the CCA method is chosen. Other receive parameters such as RSSI, RCPI, signal quality (SQ), and indicated DATARATE may be accessed via the PHY SAP.

Upon receiving the transmitted energy, according to the selected CCA mode, A PHY-CCA.indication(BUSY) primitive shall be issued for energy detection (ED) and/or code lock prior to correct reception of the PHY header. The PHY measures the RSSI and SQ and the parameters are reported to the MAC in the RXVECTOR.


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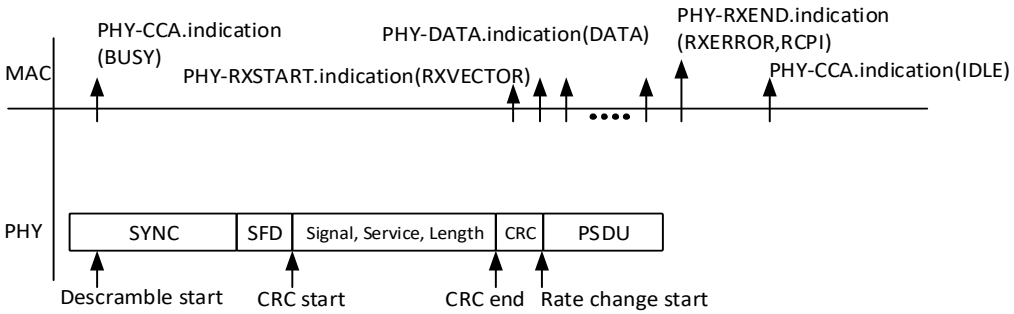


**Figure 15-8—Receive PHY(#2260)**

After a PHY-CCA.indication primitive is issued, the PHY entity shall begin searching for the SFD field. Once the SFD field is detected, CRC-16 processing shall be initiated and the PHY SIGNAL, SERVICE and LENGTH fields are received. The CRC-16 FCS shall be processed. If the CRC-16 FCS check fails, the PHY receiver shall return to the RX IDLE state as depicted in Figure 15-9 (PHY receive state machine(#2260)(#7198)(#8087)). Should the status of CCA return to the IDLE state during reception prior to completion of the full PPDU processing, the PHY receiver shall return to the RX IDLE state.

If the PHY header reception is successful (and the SIGNAL field is completely recognizable and supported), a PHY-RXSTART.indication(RXVECTOR) primitive shall be issued. If dot11TimingMsmtActivated is true, the PHY shall do the following:

— Complete receiving the PHY header and verify the validity of the PHY Header.

— If the PHY header reception is successful (and the SIGNAL field is completely recognizable and supported), a PHY-RXSTART.indication(RXVECTOR) primitive shall be issued and RX_START_OF_FRAME_OFFSET parameter within the RXVECTOR shall be forwarded (see 15.2.3 (RXVECTOR parameters(#1369))).

NOTE—The RX_START_OF_FRAME_OFFSET value is used (#3049)to estimate when the start of the preamble for the incoming (#14)PPDU was detected on the medium at the receive antenna connector.

The RXVECTOR associated with this primitive includes the SIGNAL field, the SERVICE field, the (#14)PSDU length in octets (calculated from the LENGTH field in microseconds), the antenna used for receive (RX_ANTENNA), RSSI, and SQ.

The received (#14)PSDU bits are assembled into octets and presented to the MAC using a series of PHY-DATA.indication(DATA) primitive exchanges. The rate change indicated in the SIGNAL field shall be initiated with the first symbol of the (#14)PSDU as described in 15.3.5 (PHY data modulation and modulation rate change). The PHY proceeds with (#14)PSDU reception. After the reception of the final bit of the last (#14)PSDU octet, as indicated by the PHY preamble LENGTH field, the receiver shall be returned to the RX IDLE state as shown in Figure 15-9 (PHY receive state machine(#2260)(#7198)(#8087)). A PHY-RXEND.indication(NoError) primitive shall be issued. A PHY-CCA.indication(IDLE) primitive shall be issued following a change in PHY carrier sense (PHYCS) and/or PHY energy detection (PHYED) according to the selected CCA method.

In the event that a change in PHYCS or PHYED would cause the status of CCA to return to the IDLE state before the complete reception of the (#14)PSDU, as indicated by the PHY LENGTH field, the error condition shall be reported to the MAC using a PHY-RXEND.indication(CarrierLost) primitive. The CCA of the DSSS PHY shall indicate a busy medium for the intended duration of the transmitted PPDU.

If the PHY header is successful, but the indicated rate in the SIGNAL field is not receivable, a PHY-RXSTART.indication primitive shall not be issued. The PHY shall indicate the error condition by

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issuing a PHY-RXEND.indication(UnsupportedRate) primitive. If the PHY header is successful, but the SERVICE field is out of IEEE 802.11 DSSS specification, a PHY-RXSTART.indication primitive shall not be issued. The PHY shall indicate the error condition by issuing a PHY-RXEND.indication(FormatViolation) primitive. Also, in both cases, the CCA of the DSSS PHY shall indicate a busy medium for the intended duration of the transmitted (#14)PPDU as indicated by the LENGTH field. The intended duration is indicated by the LENGTH field (length $\times 1$ μs).

If dot11RadioMeasurementActiviated is true and RXERROR equals NoError or UnsupportedRate, the PHY-RXEND.indication primitive also includes RCPI as a parameter.

Figure 15-9 (PHY receive state machine(#2260)(#7198)(#8087)) shows the flow of a typical state machine implementation of the receive PHY.


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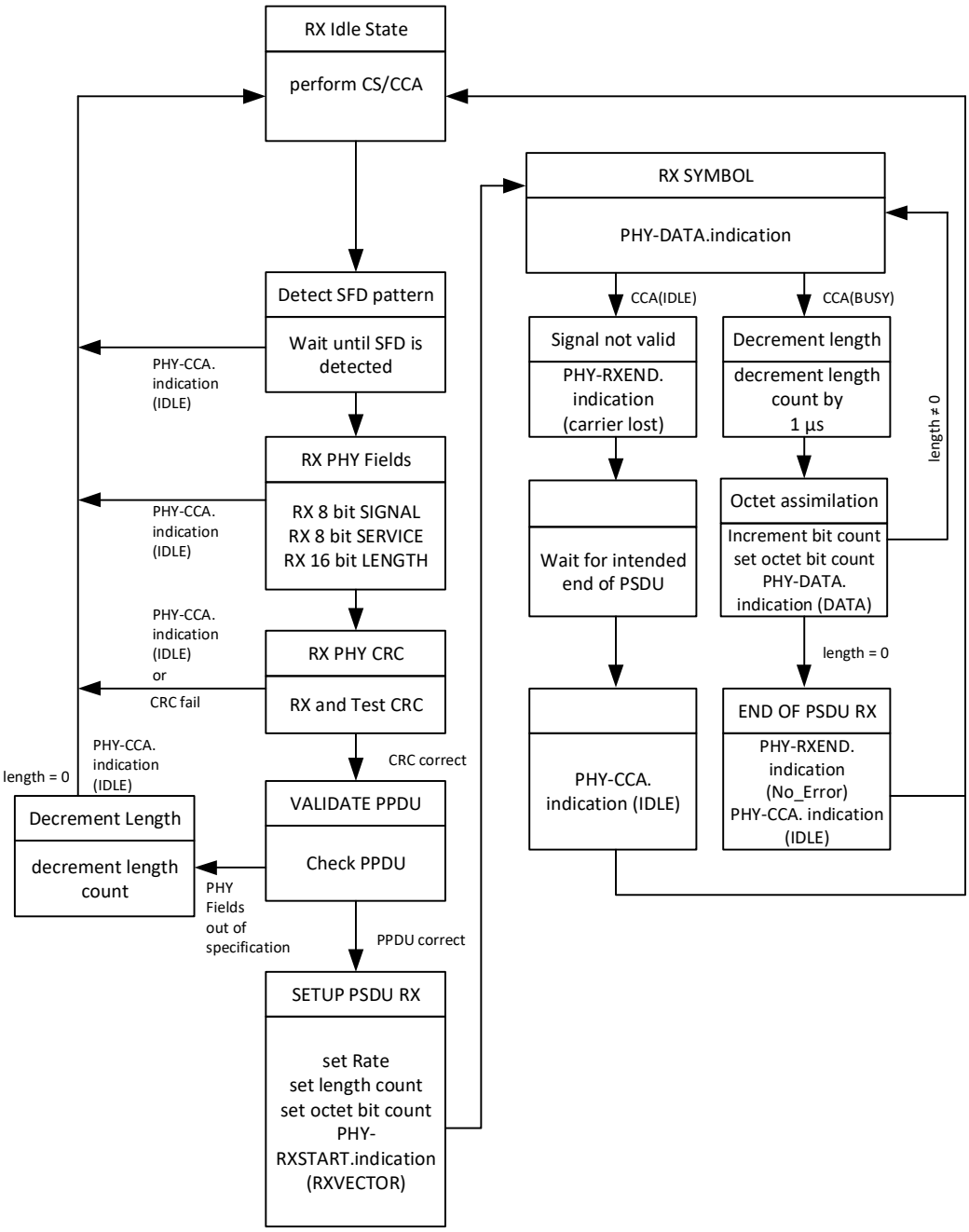


**Figure 15-9—PHY receive state machine(#2260)(#7198)(#8087)**

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## 15.4 DSSS PLME

### 15.4.1 PLME SAP layer management primitives(#6320)

Table 15-4 (MIB attribute default values/ranges) lists the MIB attributes that may be accessed by the PHY entities and intralayer of higher level LMEs. These attributes are accessed via the PLME-GET, PLME-SET, and PLME-RESET primitives defined in Clause 6 (Layer management).

**Table 15-4—MIB attribute default values/ranges**

| Managed object | Default value/range | Operational semantics |
|---|---|---|
| **dot11PhyOperationComplianceGroup** | | |
| dot11PHYType | DSSS–2.4 (02) | Static |
| dot11RegDomainsSupported | Implementation dependent | Static |
| dot11CurrentRegDomain | Implementation dependent | Static |
| **dot11PhyRateGroup** | | |
| dot11SupportedDataRatesTx | X'02', X'04' | Static |
| dot11SupportedDataRatesRx | X'02', X'04' | Static |
| **dot11PhyAntennaComplianceGroup** | | |
| dot11CurrentTxAntenna | Implementation dependent | Dynamic |
| dot11DiversitySupportImplemented | Implementation dependent | Static |
| dot11CurrentRxAntenna | Implementation dependent | Dynamic |
| **dot11PhyTxPowerComplianceGroup** | | |
| dot11NumberSupportedPowerLevelsImplemented | Implementation dependent | Static |
| dot11TxPowerLevel1 | Implementation dependent | Static |
| dot11TxPowerLevel2 | Implementation dependent | Static |
| dot11TxPowerLevel3 | Implementation dependent | Static |
| dot11TxPowerLevel4 | Implementation dependent | Static |
| dot11TxPowerLevel5 | Implementation dependent | Static |
| dot11TxPowerLevel6 | Implementation dependent | Static |
| dot11TxPowerLevel7 | Implementation dependent | Static |
| dot11TxPowerLevel8 | Implementation dependent | Static |
| dot11CurrentTxPowerLevel | Implementation dependent | Dynamic |
| **dot11PhyDSSSComplianceGroup** | | |
| dot11CurrentChannel | Implementation dependent | Dynamic |
| dot11CCAModeSupported | Implementation dependent | Static |
| dot11CurrentCCAMode | Implementation dependent | Dynamic |
| dot11EDThreshold | Implementation dependent | Dynamic |


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**Table 15-4—MIB attribute default values/ranges *(continued)***

| Managed object | Default value/range | Operational semantics |
|---|---|---|
| **dot11AntennasListEntry** | | |
| dot11TxAntennaImplemented | Implementation dependent | Static |
| dot11RxAntennaImplemented | Implementation dependent | Static |
| dot11DiversitySelectionRxImplemented | Implementation dependent | Dynamic |
| NOTE—The column titled "Operational semantics" contains two types: static and dynamic. Static MIB attributes are fixed and cannot be modified for a given PHY implementation. MIB attributes defined as dynamic can be modified by some management entities. | | |

### 15.4.2 DSSS PHY MIB

All DSSS PHY MIB attributes are defined in Clause 8 (PHY service specification), with specific values defined in Table 15-4 (MIB attribute default values/ranges).

When MAX-ACCESS is read-only, the MIB attribute value may be updated by the PLME and read from the MIB attribute by management entities. When MAX-ACCESS is read-write, the MIB attribute may be read and written by management entities but shall not be updated by the PLME.

### 15.4.3 DSSS PHY

(#2123)The DSSS PHY characteristics, provided through the PLME-CHARACTERISTICS service primitive, are shown in Table 15-5 (DSSS PHY characteristics). The definitions for these characteristics are given in 6.7.4 (PLME-CHARACTERISTICS.confirm).

**Table 15-5—DSSS PHY characteristics**

| Characteristic | Value |
|---|---|
| aSlotTime | If dot11OperatingClassesRequired is false, 20 μs<br><br>If dot11OperatingClassesRequired is true, 20 μs plus any coverage-class-dependent aAirPropagationTime (see Table 9-133 (Coverage Class field parameters)) |
| aSIFSTime | 10 μs |
| aCCATime | Implementation dependent, see 10.3.7 (DCF timing relations). |
| aRxPHYStartDelay | 192 μs |
| aRxTxTurnaroundTime | Implementation dependent, see 10.3.7 (DCF timing relations). |
| aTxPHYDelay | Implementation dependent, see 10.3.7 (DCF timing relations). |
| aRxPHYDelay | Implementation dependent, see 10.3.7 (DCF timing relations). |
| aRxTxSwitchTime | Implementation dependent, see 10.3.7 (DCF timing relations). |
| aTxRampOnTime | Implementation dependent, see 10.3.7 (DCF timing relations). |

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**Table 15-5—DSSS PHY characteristics *(continued)***

| Characteristic | Value |
|---|---|
| aAirPropagationTime | As indicated by the coverage class (see 10.22.5 (Operation with coverage classes)). |
| aMACProcessingDelay | Implementation dependent, see 10.3.7 (DCF timing relations). |
| aPSDUMaxLength | $2^{12} - 1$ octets |
| aCWmin | 31 |
| aCWmax | 1023 |

### 15.4.4 PHY operating specifications, general

#### 15.4.4.1 General

Subclause 15.4.4 (PHY operating specifications, general) provides general specifications for the DSSS PHY layer(#4114). These specifications apply to both the Receive and the Transmit functions and general operation of a DSSS PHY.

#### 15.4.4.2 Operating frequency range

(#1603)The DSSS PHY shall operate in the frequency range of 2.4 GHz to 2.5 GHz as allocated by regulatory bodies.

#### 15.4.4.3 Channel Numbering of operating channels

When dot11OperatingClassesRequired is true, channel numbering shall be as specified in 17.3.8.4.2 (Channel numbering) and channelization shall be as specified in 17.3.8.4.3 (Channelization). When dot11OperatingClassesDefined is false or not defined, the channel center frequencies and CHNL_ID numbers shall be as shown in Table 15-6 (DSSS PHY frequency channel plan).

In a multiple cell network topology, overlapping and/or adjacent cells using different channels can operate simultaneously without interference if the distance between the center frequencies is at least 30 MHz.

**Table 15-6—DSSS PHY frequency channel plan**

| CHNL_ID | Frequency (MHz) |
|---|---|
| 1 | 2412 |
| 2 | 2417 |
| 3 | 2422 |
| 4 | 2427 |
| 5 | 2432 |
| 6 | 2437 |
| 7 | 2442 |


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**Table 15-6—DSSS PHY frequency channel plan *(continued)***

| CHNL_ID | Frequency (MHz) |
|---|---|
| 8 | 2447 |
| 9 | 2452 |
| 10 | 2457 |
| 11 | 2462 |
| 12 | 2467 |
| 13 | 2472 |
| 14 | 2484 |

#### 15.4.4.4 Spreading sequence

The following 11-chip Barker sequence shall be used as the PN code sequence:

+1, –1, +1, +1, –1, +1, +1, +1, –1, –1, –1

The leftmost chip shall be output first in time. The first chip shall be aligned at the start of a transmitted symbol. The symbol duration shall be exactly 11 chips long.

#### 15.4.4.5 Modulation and channel data rates

Two modulation formats and data rates are specified for the DSSS PHY: a *basic access rate* and an *enhanced access rate*. The basic access rate shall be based on 1 Mb/s DBPSK modulation. The DBPSK encoder is specified in Table 15-7 (1 Mb/s DBPSK encoding table). The enhanced access rate shall be based on 2 Mb/s DQPSK. The DQPSK encoder is specified in Table 15-8 (2 Mb/s DQPSK encoding table). (In the tables, +jω shall be defined as counterclockwise rotation.)

**Table 15-7—1 Mb/s DBPSK encoding table**

| Bit input | Phase change (+jω) |
|---|---|
| 0 | 0 |
| 1 | π |

**Table 15-8—2 Mb/s DQPSK encoding table**

| Dibit pattern (d0,d1) d0 is first in time | Phase change (+jω) |
|---|---|
| 00 | 0 |
| 01 | π/2 |
| 11 | π |
| 10 | 3π/2 (–π/2) |

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#### 15.4.4.6 Transmit and receive in-band and out-of-band spurious emissions

The DSSS PHY shall comply with in-band and out-of-band spurious emissions as set by the appropriate regulatory bodies.

#### 15.4.4.7 TX-to-RX turnaround time

The TX-to-RX turnaround time shall be less than 10 μs, including the power-down ramp specified in 15.4.5.8 (Transmit power-on and power-down ramp).

The TX-to-RX turnaround time shall be measured on the WM from the trailing edge of the last transmitted symbol to valid CCA detection of the incoming signal.

#### 15.4.4.8 RX-to-TX turnaround time

The RX-to-TX turnaround time shall be measured at the MAC/PHY interface, using the PHY-TXSTART.request primitive and shall be ≤ 5 μs. This includes the transmit power-on ramp described in 15.4.5.8 (Transmit power-on and power-down ramp).

#### 15.4.4.9 Slot time

The value of the slot time is found in Table 15-5 (DSSS PHY characteristics).

#### 15.4.4.10 Transmit and receive antenna connector impedance

The impedance at the transmit antenna connector and receive antenna connector shall be 50 Ω if that connector is exposed.

### 15.4.5 PHY transmit specifications

#### 15.4.5.1 Introduction

The transmit functions and parameters associated with the PHY layer(#4114) are described in 15.4.5.2 (Transmit power levels) to 15.4.5.10 (Transmit modulation accuracy).

#### 15.4.5.2 Transmit power levels

The maximum allowable output power is measured in accordance with practices specified by the appropriate regulatory bodies.

#### 15.4.5.3 Minimum transmitted power level

The minimum transmitted power shall be no less than 1 mW.

#### 15.4.5.4 Transmit power level control

Power control shall be provided for transmitted power greater than 100 mW. A maximum of four power levels may be provided. At a minimum, a radio capable of transmission greater than 100 mW shall support(#546) switching power back to 100 mW or less.


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#### 15.4.5.5 Transmit spectrum mask

(#3816)The overall transmit spectral mask is constructed using two components. First, an interim spectrum mask is constructed whose mask level is determined relative to the SINx/x peak of the signal. The overall transmit spectrum mask is then constructed by taking the higher of the interim transmit spectrum mask and –53 dBm/MHz at each frequency offset.

(#3816)The interim transmit spectrum mask shall be 0 dBr (decibel relative to the SINx/x peak) for $f_c$ – 11 MHz < $f$ < $f_c$ +11 MHz, –30 dBr for $f_c$ – 22 MHz < $f$ < $f_c$ –11 MHz and $f_c$ +11 MHz < $f$ < $f_c$ + 22 MHz, –50 dBr for $f$ < $f_c$ –22 MHz and $f$ > $f_c$ + 22 MHz, where $f_c$ is the channel center frequency. The transmit spectrum mask shall not exceed the maximum of the interim transmit spectrum mask and –53 dBm/MHz at any frequency offset in the 2.4 GHz band. The transmit spectrum mask when the –50 dBr spectrum level is above –53 dBm/MHz is shown in Figure 15-10 (Transmit spectrum mask). The measurements shall be made using 100 kHz resolution bandwidth and a 30 kHz video bandwidth.

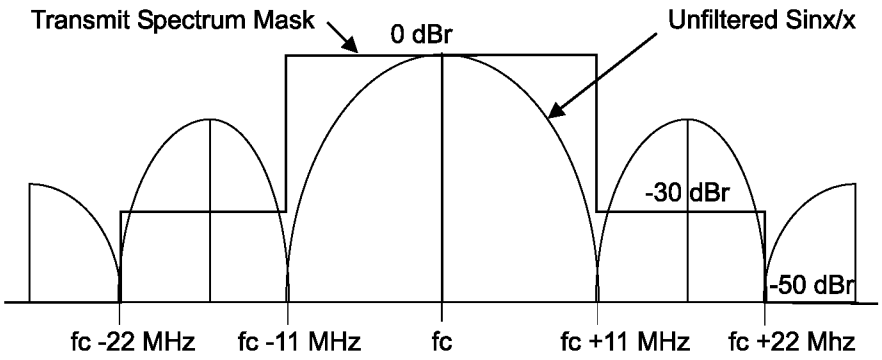


**Figure 15-10—Transmit spectrum mask**

Channel 14 is unique. The Japanese standard ARIB RCR-STD 33 (5.0) [B5] states that B90/2π normalized to the 'transmission speed of modulation signal' shall be > 10, where B90 is the 90% occupied channel bandwidth. Therefore, for channel 14, B90/2π > 13.75 MHz for CCK spreading and >10.0 MHz for Barker spreading.

#### 15.4.5.6 Transmit center frequency tolerance

The transmitted center frequency tolerance shall be ± 25 ppm.

#### 15.4.5.7 Chip clock frequency tolerance

The PN code chip clock frequency tolerance shall be ± 25 ppm.

#### 15.4.5.8 Transmit power-on and power-down ramp

The transmit power-on ramp for 10% to 90% of maximum power shall be no greater than 2 µs. The transmit power-on ramp is shown in Figure 15-11 (Transmit power-on ramp).

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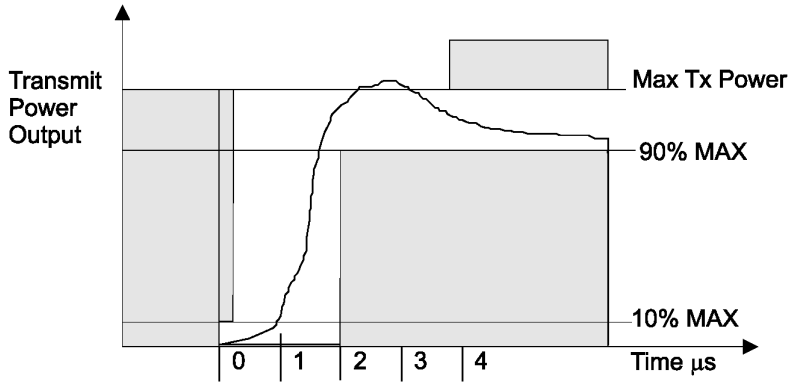


**Figure 15-11—Transmit power-on ramp**

The transmit power-down ramp for 90% to 10% maximum power shall be no greater than 2 μs. The transmit power-down ramp is shown in Figure 15-12 (Transmit power-down ramp).

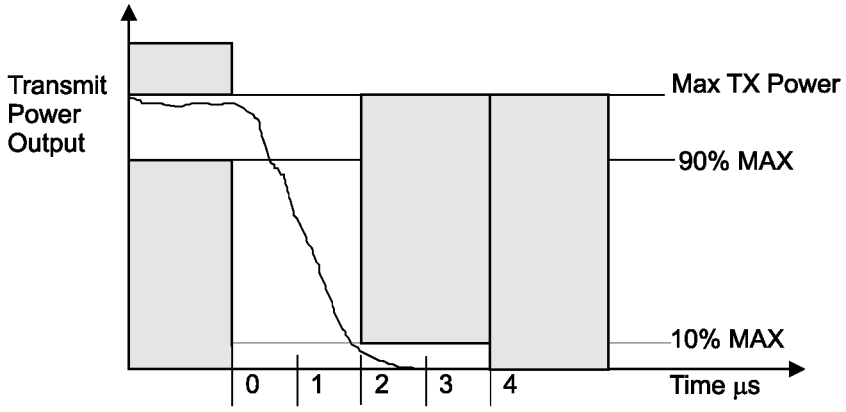


**Figure 15-12—Transmit power-down ramp**

The transmit power ramps shall be constructed such that the DSSS PHY emissions comply with the spurious frequency product specification defined in 15.4.4.6 (Transmit and receive in-band and out-of-band spurious emissions).

### 15.4.5.9 RF carrier suppression

The RF carrier suppression, measured at the channel center frequency, shall be at least 15 dB below the peak sin(x)/x power spectrum. The RF carrier suppression shall be measured while transmitting a repetitive 01 data sequence with the scrambler disabled using DQPSK modulation. A 100 kHz resolution bandwidth shall be used to perform this measurement.


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### 15.4.5.10 Transmit modulation accuracy

The transmit modulation accuracy requirement for the DSSS PHY shall be based on the difference between the actual transmitted waveform and the ideal signal waveform. Modulation accuracy shall be determined by measuring the peak vector error magnitude measured during each chip period. Worst-case vector error magnitude shall not exceed 0.35 for the normalized sampled chip data. The ideal complex I and Q constellation points associated with DQPSK modulation (0.707, 0.707), (0.707, –0.707), (–0.707, 0.707), (–0.707, –0.707) shall be used as the reference. These measurements shall be from baseband I and Q sampled data after recovery through a reference receiver system.

Figure 15-13 (Modulation accuracy measurement example) illustrates the ideal DQPSK constellation points and range of worst-case error specified for modulation accuracy.

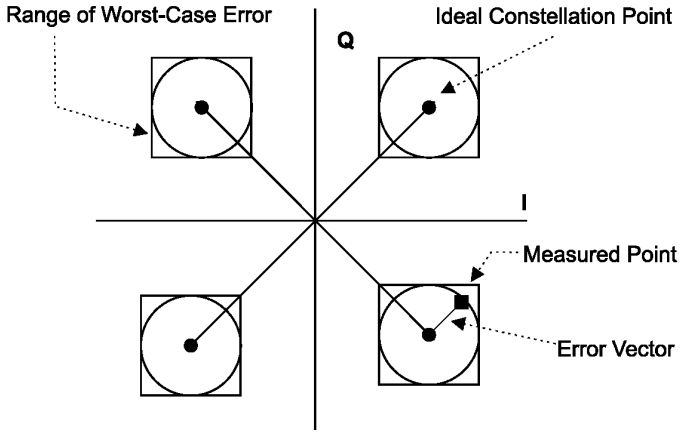


**Figure 15-13—Modulation accuracy measurement example**

Error vector measurement requires a reference receiver capable of carrier lock. All measurements shall be made under carrier lock conditions. The distortion induced in the constellation by the reference receiver shall be calibrated and measured. The test data error vectors described below shall be corrected to compensate for the reference receiver distortion.

The IEEE 802.11 vendor compatible radio shall provide an exposed TX chip clock, which shall be used to sample the I and Q outputs of the reference receiver.

The measurement shall be made under the conditions of continuous DQPSK transmission using scrambled all 1s.

The eye pattern of the I channel shall be used to determine the *I* and *Q* sampling point. The chip clock provided by the vendor radio shall be time delayed such that the samples fall at a 1/2 chip period offset from the mean of the zero crossing positions of the eye (see Figure 15-14 (Chip clock alignment with baseband eye pattern)). This is the ideal center of the eye and might not be the point of maximum eye opening.

Using the aligned chip clock, 1000 samples of the *I* and *Q* baseband outputs from the reference receiver are captured. The vector error magnitudes shall be calculated as follows:

Calculate the dc offsets for *I* and *Q* samples.

$$I_{\text{mean}} = \sum_{n=1}^{1000} I(n) / 1000$$

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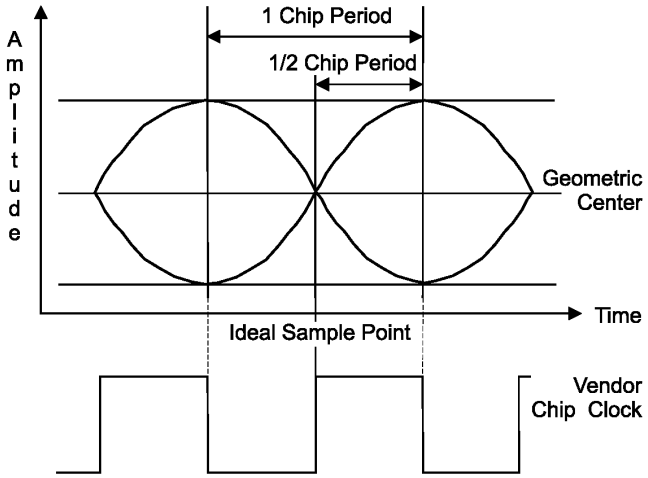


**Figure 15-14—Chip clock alignment with baseband eye pattern**

$$Q_{\text{mean}} = \sum_{n=1}^{1000} Q(n) / 1000$$

Calculate the dc corrected $I$ and $Q$ samples for all $n$ =1000 sample pairs.

$$I_{\text{dc}}(n) = I(n) - I_{\text{mean}}$$

$$Q_{\text{dc}}(n) = Q(n) - Q_{\text{mean}}$$

Calculate the average magnitude of $I$ and $Q$ samples.

$$I_{\text{mag}} = \sum_{n=1}^{1000} \left| I_{\text{dc}}(n) \right| / 1000$$

$$Q_{\text{mag}} = \sum_{n=1}^{1000} \left| Q_{\text{dc}}(n) \right| / 1000$$

Calculate the normalized error vector magnitude for the $I_{\text{dc}}(n)/Q_{\text{dc}}(n)$ pairs.

$$V_{err}(n) = [\{\left| I_{dc}(n) \right| - I_{mag}\}^2 + \{\left| Q_{dc}(n) \right| - Q_{mag}\}^2]^{1/2}$$

where
the average power of the constellation is 1

NOTE—A correction factor might be needed to compensate for the error induced by a test reference receiver system.

For all $n$ =1000 samples, the following condition shall be met:

$$V_{err}(n) < 0.35$$


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#### 15.4.5.11 Time of Departure accuracy

(#8046)The RMS accuracy of the time of departure provided in TIME_OF_DEPARTURE shall be less than or equal to 80 ns.

The Time of Departure accuracy test evaluates TIME_OF_DEPARTURE against aTxPHYTxStartRMS and aTxPHYTxStartRMS against TIME_OF_DEPARTURE_ACCURACY_TEST_THRESH as defined Annex P with the following test parameters:

— MULTICHANNEL_SAMPLING_RATE is $22 \times 10^6\left(1 + \left\lceil \frac{f_H - f_L}{22\ \text{MHz}} \right\rceil\right)$ sample/s

where

$f_H$ is the nominal center frequency in Hz of the highest channel in the channel set

$f_L$ is the nominal center frequency in Hz of the lowest channel in the channel set, the channel set is the set of channels upon which (#14)PPDUs providing measurements are transmitted, the channel set comprises channels uniformly spaced across $f_H - f_L \geq 50$ MHz

— FIRST_TRANSITION_FIELD is the SYNC field.

— SECOND_TRANSITION_FIELD is the SFD field.

— TRAINING_FIELD is the concatenation of the SYNC and SFD fields, using a chip pulse that should approximate a rectangular pulse of duration 1/ 11 MHz convolved with a brick-wall low pass filter of bandwidth 11 MHz.

— TIME_OF_DEPARTURE_ACCURACY_TEST_THRESH is 80 ns.

NOTE—The indicated chip pulse applies to the time of departure accuracy test equipment, and not the transmitter or receiver.

### 15.4.6 PHY receiver specifications

#### 15.4.6.1 Introduction

The receive functions and parameters associated with the PHY layer(#4114) are described in 15.4.6.2 (Receiver minimum input level sensitivity) to 15.4.6.5 (CCA).

#### 15.4.6.2 Receiver minimum input level sensitivity

The (#14)PER shall be less than $8\times10^{-2}$ at an (#14)PSDU length of 1024 octets for an input level of –80 dBm measured at the antenna connector. This (#14)PER shall be specified for 2 Mb/s DQPSK modulation. The test for the minimum input level sensitivity shall be conducted with the ED threshold set ≤ –80 dBm.

#### 15.4.6.3 Receiver maximum input level

If the STA is non-ERP, the receiver shall provide a maximum (#14)PER of $8\times10^{-2}$ at an (#14)PSDU length of 1024 octets for a maximum input level of –4 dBm measured at the antenna connector. This (#14)PER shall be specified for 2 Mb/s DQPSK modulation.

#### 15.4.6.4 Receiver adjacent channel rejection

Adjacent channel rejection is defined between any two channels with ≥ 30 MHz separation in each channel group defined in 15.4.4.3 (Channel Numbering of operating channels).

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The adjacent channel rejection shall be ≥ 35 dB with an (#14)PER of $8\times10^{-2}$ using 2 Mb/s DQPSK modulation described in 15.4.4.5 (Modulation and channel data rates) and an (#14)PSDU length of 1024 octets.

The adjacent channel rejection shall be measured using the following method:

Input a 2 Mb/s DQPSK modulated signal at a level 6 dB greater than specified in 15.4.6.2 (Receiver minimum input level sensitivity). In an adjacent channel (≥ 30 MHz separation as defined by the channel numbering), input a signal modulated in a similar fashion that adheres to the transmit mask specified in 15.4.5.5 (Transmit spectrum mask) to a level 41 dB above the level specified in 15.4.6.2 (Receiver minimum input level sensitivity). The adjacent channel signal shall be derived from a separate signal source. It shall not be a frequency shifted version of the reference channel. Under these conditions, the (#14)PER shall be less than or equal to $8\times10^{-2}$.

### 15.4.6.5 CCA

Requirements in this subclause are applicable to non-ERP DSSS STAs.

The non-ERP DSSS PHY shall provide the capability to perform CCA according to both:

A — at least one of the following options:

- — *CCA Mode 1:* Energy above threshold. CCA shall report a busy medium upon detection of any energy above the ED threshold.
- — *CCA Mode 2:* CS only. CCA shall report a busy medium only upon detection of a DSSS signal. This signal may be above or below the ED threshold.
- — *CCA Mode 3:* CS with energy above threshold. CCA shall report a busy medium upon detection of a DSSS signal with energy above the ED threshold.

and

B — *CCA Mode 6:* CCA shall report a busy medium upon detection of any energy above –62 dBm.

A busy channel shall be indicated by issuing a PHY-CCA.indication(BUSY) primitive.

A clear channel shall be indicated by issuing a PHY-CCA.indication(IDLE) primitive.

For a non-ERP DSSS STA, the value of dot11CCAModeSupported shall indicate the appropriate operation modes. The PHY shall be configured according to dot11CurrentCCAMode.

The CCA parameters are subject to the following criteria:

a) The ED threshold shall be ≤ –80 dBm for TX power > 100 mW, –76 dBm for 50 mW < TX power ≤ 100 mW, and –70 dBm for TX power ≤ 50 mW. The ED threshold is the value contained in dot11EDThreshold.

b) With a valid signal (according to the CCA mode of operation) present at the receiver antenna within 5 μs of the start of a MAC slot boundary, the PHY-CCA.indication(BUSY) primitive shall be generated before the end of the slot time if aSlotTime is 20 μs. Refer to Figure 10-25 (DCF timing relationships(#14)(#1058)(#3297)) (in 10.3.7 (DCF timing relations)) and Figure 10-29 (EDCA mechanism timing relationships(#14)(#1058)) for a definition of slot boundary.

c) In the event that a correct PHY header is received, the DSSS PHY shall not generate a PHY-CCA.indication (IDLE) primitive until the end of the PPDU as determined by TXTIME in 15.4.6.7 (DSSS PHY TXTIME calculation).


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Compliance to DSSS PHY CCA shall be demonstrated by applying a DSSS signal, above the appropriate ED threshold (item a), so that all conditions described in item b and item c are demonstrated.

#### 15.4.6.6 Received channel power indicator (RCPI) measurement

The RCPI is a measure of the received RF power in the selected channel for a received frame. This parameter shall be a (#1132)measurement by the PHY of the received RF power in the channel measured over the (#2011)SYNC field of the received (#14)PPDU or by other equivalent means that meet the specified accuracy.

RCPI shall equal the received RF power (#2011)in dBm within an accuracy of ± 5 dB (95% confidence interval) within the specified dynamic range of the receiver.

#### 15.4.6.7 DSSS PHY TXTIME calculation

The value of the TXTIME parameter returned by the PLME-TXTIME.confirm primitive shall be calculated according to the following equations:

$$\text{TXTIME} = \text{PreambleLength} + \text{PHYHeaderTime} + \left\lceil \frac{\text{LENGTH} \times 8}{\text{DATARATE}} \right\rceil$$

where

| | |
|---|---|
| LENGTH and DATARATE | are values from the TXVECTOR parameter of the corresponding PLME-TXTIME.request primitive |
| LENGTH | is in units of octets |
| DATARATE | is in units of Mb/s |
| The value of PreambleLength | is 144 μs |
| The value of PHYHeaderTime | is 48 μs |

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# 16. High rate direct sequence spread spectrum (HR/DSSS) PHY specification

## 16.1 Overview

### 16.1.1 General

This clause specifies the high rate extension of the PHY for the DSSS system (see Clause 15 (DSSS PHY specification for the 2.4 GHz band designated for ISM applications)), hereinafter known as the HR/DSSS PHY for the 2.4 GHz band designated for ISM applications.

This extension of the DSSS system builds on the data rate capabilities, as described in Clause 15 (DSSS PHY specification for the 2.4 GHz band designated for ISM applications), to provide 5.5 Mb/s and 11 Mb/s payload data rates in addition to the 1 Mb/s and 2 Mb/s rates. To provide the higher rates, 8-chip complementary code keying (CCK) is employed as the modulation scheme. The chipping rate is 11 MHz, which is the same as the DSSS system described in Clause 15 (DSSS PHY specification for the 2.4 GHz band designated for ISM applications), thus providing the same occupied channel bandwidth. The basic new capability described in this clause is called *HR/DSSS*. One mode of the HR/DSSS PHY uses the same PHY preamble and header as the DSSS PHY, so both PHYs can coexist in the same BSS and can use the rate switching mechanism as provided.

In addition to providing higher speed extensions to the DSSS system, a number of optional features allow the performance of the RF LAN system to be improved as technology allows the implementation of these options to become cost effective.

Another optional mode is provided that allows data throughput at the higher rates (2, 5.5, and 11 Mb/s) to be significantly increased by using a shorter PHY preamble. This mode is called *HR/DSSS/short*. This short preamble mode can coexist with DSSS, HR/DSSS under limited circumstances, such as on different channels or with appropriate CCA mechanisms.

### 16.1.2 Scope of HR/DSSS PHY services

This clause specifies the PHY entity for the HR/DSSS extension and explains how this standard accommodates the HR/DSSS PHY.

The HR/DSSS PHY consists of the following two protocol functions:

a) A PHY function that defines a method for mapping the (#14)PSDUs into a PPDU format suitable for sending and receiving data, management, and control information between two or more STAs. The PHY exchanges PPDUs that contain PSDUs. The MAC uses the PHY service, so each MPDU corresponds to a PSDU that is carried in a PPDU.

b) A function that defines the characteristics of, and method of transmitting and receiving data through, a WM between two or more STAs, each using the HR/DSSS PHY system.

### 16.1.3 HR/DSSS PHY functions

#### 16.1.3.1 General

The HR/DSSS PHY contains two functional entities: the PHY function and the layer management function. Each of these functions is described in detail in 16.2 (HR/DSSS PHY) and 16.3 (HR/DSSS PLME).

The HR/DSSS PHY service shall be provided to the MAC through the PHY service primitives described in Clause 8 (PHY service specification).


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#### 16.1.3.2 PLME

The PLME performs management of the local PHY functions in conjunction with the MLME.

### 16.1.4 Service specification method and notation

The models represented by figures and state diagrams are intended to be illustrations of functions provided. It is important to distinguish between a model and a real implementation. The models are optimized for simplicity and clarity of presentation, but do not necessarily reflect any particular implementation.

The service of a layer or sublayer is a set of capabilities that it offers to a user in the next-higher layer (or sublayer). Abstract services are specified here by describing the service primitives and parameters that characterize each service. This definition is independent of any particular implementation.

## 16.2 HR/DSSS PHY

### 16.2.1 Overview

Subclause 16.2 (HR/DSSS PHY) provides a convergence procedure for the 2 Mb/s, 5.5 Mb/s, and 11 Mb/s specification, in which PSDUs are converted to and from PPDUs. During transmission, the PSDU shall be appended to a PHY preamble and header to create the PPDU. Two different preambles and headers are defined: the mandatory supported long preamble and header, which interoperates with the current 1 Mb/s and 2 Mb/s DSSS specification, and an optional short preamble and header. At the receiver, the PHY preamble and header are processed to aid in demodulation and delivery of the PSDU.

The optional short preamble and header provides maximum throughput when interoperability with legacy and nonshort-preamble-capable STAs is not a consideration. That is, it is expected to be used only in networks of STAs that support the optional mode.

### 16.2.2 PPDU format

#### 16.2.2.1 General

Two different preambles and headers are defined: the mandatory supported long preamble and header, which is interoperable with the current 1 Mb/s and 2 Mb/s DSSS specification, and an optional short preamble and header.

#### 16.2.2.2 Long PPDU format

Figure 16-1 (Long PPDU format) shows the format for the interoperable (long) PPDU, including the HR/DSSS PHY preamble, the HR/DSSS PHY header, and the PSDU. The PHY preamble contains the following fields: SYNC and SFD. The PHY header contains the following fields: signaling (SIGNAL), service (SERVICE), length (LENGTH), and CRC-16. Each of these fields is described in detail in 16.2.3 (PPDU field definitions). The format for the PPDU, including the long HR/DSSS PHY preamble, the long HR/DSSS PHY header, and the PSDU, does not differ from the format for 1 Mb/s and 2 Mb/s. The only exceptions are:

a) The encoding of the rate in the SIGNAL field;
b) The use of a bit in the SERVICE field to resolve an ambiguity in PSDU length in octets, when the length is expressed in whole microseconds;
c) The use of a bit in the SERVICE field to indicate that the transit frequency and bit clocks are locked.

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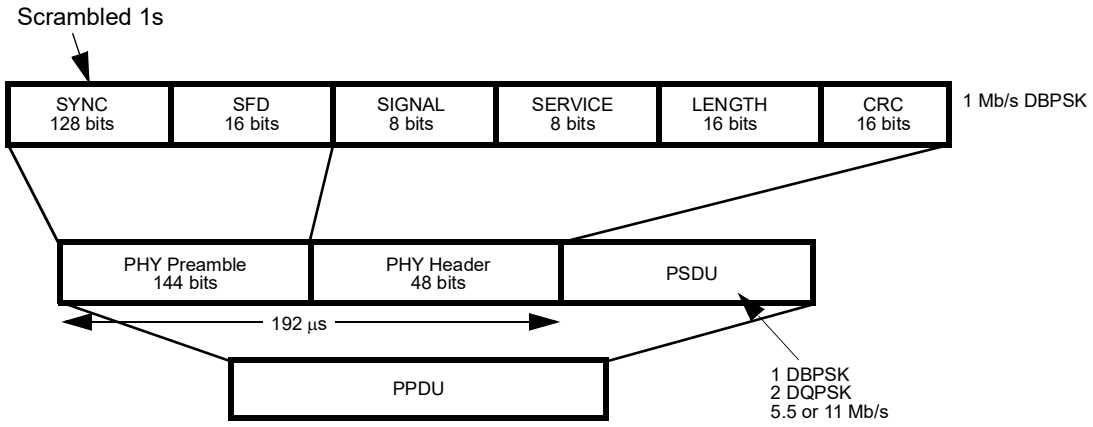


**Figure 16-1—Long PPDU format**

### 16.2.2.3 Short PPDU format

The short PHY preamble and header (HR/DSSS/short) is optional. The short preamble and header may be used to minimize overhead and, thus, maximize the network data throughput. The format of the PPDU, with HR/DSSS/short, is shown in Figure 16-2 (Short PPDU format). A Clause 18 (Extended Rate PHY (ERP) specification) STA shall support the short PPDU format.

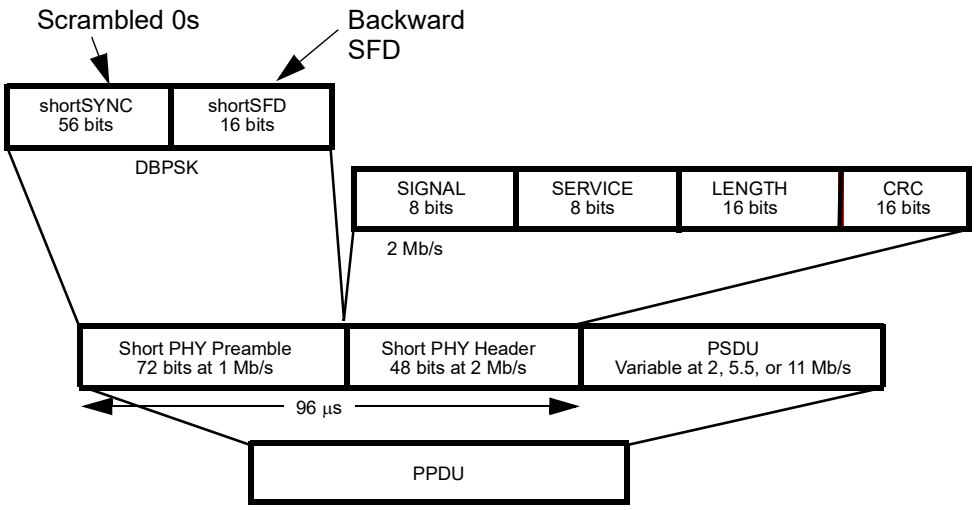


**Figure 16-2—Short PPDU format**

A transmitter using the short PPDU is interoperable with only another receiver that is also capable of receiving this short PPDU. To interoperate with a receiver that is not capable of receiving a short preamble and header, the transmitter shall use the long PHY preamble and header. The short PHY preamble uses the 1 Mb/s Barker code spreading with DBPSK modulation. The short PHY header uses the 2 Mb/s Barker code spreading with DQPSK modulation, and the PSDU is transmitted at 2 Mb/s, 5.5 Mb/s, or 11 Mb/s.


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### 16.2.3 PPDU field definitions

#### 16.2.3.1 General

In the PHY field definition subclauses (16.2.3.2 (Long PHY SYNC field) to 16.2.3.15 (Short PHY data modulation and modulation rate change)), the definitions of the long (Clause 15 (DSSS PHY specification for the 2.4 GHz band designated for ISM applications)) PHY fields are given first, followed by the definitions of the short PHY fields. The names for the short PHY fields are preceded by the term *short*.

#### 16.2.3.2 Long PHY SYNC field

The SYNC field shall consist of scrambled 1 bits. This field is provided so the receiver can perform the necessary synchronization operations. The initial state of the scrambler (seed) shall be [1101100], where the bit specifies the value to put in the first delay element ($Z^1$) in Figure 16-3 (Data scrambler) (in 16.2.4 (PHY/HR/DSSS PHY data scrambler and descrambler)), and the rightmost bit specifies the value to put in the last delay element in the scrambler.

To support the reception of DSSS signals generated with implementations based on Clause 15 (DSSS PHY specification for the 2.4 GHz band designated for ISM applications), the receiver shall also be capable of synchronization on a SYNC field derived from any nonzero scrambler initial state.

#### 16.2.3.3 Long PHY SFD

The SFD shall be provided to indicate the start of PHY-dependent parameters within the PHY preamble. The SFD shall be [1111 0011 1010 0000], where the rightmost bit shall be transmitted first in time.

#### 16.2.3.4 Long PHY SIGNAL field

The SIGNAL field indicates to the PHY the modulation that shall be used for transmission (and reception) of the PSDU. The data rate shall be equal to the SIGNAL field value multiplied by 100 kb/s. The high rate PHY supports four mandatory rates given by the following 8-bit words, which represent the rate in units of 100 kb/s, where the LSB shall be transmitted first in time:

a) X'0A' (MSB to LSB) for 1 Mb/s
b) X'14' (MSB to LSB) for 2 Mb/s
c) X'37' (MSB to LSB) for 5.5 Mb/s
d) X'6E' (MSB to LSB) for 11 Mb/s

The HR/DSSS PHY rate change capability is described in 16.2.3.15 (Short PHY data modulation and modulation rate change). This field shall be protected by the CRC-16 FCS described in 16.2.3.7 (PHY CRC (CRC-16) field).

#### 16.2.3.5 Long PHY SERVICE field

Two bits have been defined in the SERVICE field to support the high rate extension; see Table 16-1 (SERVICE field definitions). The rightmost bit (bit 7) shall be used to supplement the LENGTH field described in 16.2.3.6 (Long PHY LENGTH field). Bit 2 shall be used to indicate that the transmit frequency and symbol clocks are derived from the same oscillator. This locked clocks bit shall be set by the PHY based on its implementation configuration. The SERVICE field shall be transmitted B0 first in time, and shall be protected by the CRC-16 FCS described in 16.2.3.7 (PHY CRC (CRC-16) field). B0, B1, B3, B4, B5, and B6 are reserved and shall be set to 0 on transmission and ignored on reception.

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**Table 16-1—SERVICE field definitions**

| B0 | B1 | B2 | B3 | B4 | B5 | B6 | B7 |
|---|---|---|---|---|---|---|---|
| Reserved | Reserved | Locked clocks bit<br>0 = not locked<br>1 = locked | Reserved | Reserved | Reserved | Reserved | Length extension bit |

### 16.2.3.6 Long PHY LENGTH field

The PHY LENGTH field shall contain an unsigned integer that indicates the number of microseconds required to transmit the PSDU. The transmitted value shall be determined from the LENGTH and DATARATE parameters in the TXVECTOR issued with the PHY-TXSTART.request primitive described in 16.3.5 (Vector descriptions).

The LENGTH field provided in the TXVECTOR is in octets and is converted to microseconds for inclusion in the PHY LENGTH field. The LENGTH field is calculated as follows. Because there is an ambiguity in the number of octets that is described by a length in integer microseconds for any data rate over 8 Mb/s, a length extension bit is present in the SERVICE field to indicate when the smaller potential number of octets is correct as follows:

— 5.5 Mb/s CCK LENGTH = $\left\lceil \text{number of octets} \times \frac{8}{5.5} \right\rceil$.

— 11 Mb/s CCK LENGTH = $\left\lceil \text{number of octets} \times \frac{8}{11} \right\rceil$; the length extension bit shall be set to 0 if (LENGTH – (number of octets × 8/11)) < 8/11 and shall be set to 1 otherwise.

(#455)When the data rate is not 11 Mb/s, the length extension bit is reserved and shall be set to 0 on transmit and ignored on receive.

At the receiver, the number of octets in the (#14)PSDU is calculated as follows:

— 5.5 Mb/s CCK number of octets = $\left\lfloor \text{LENGTH} \times \frac{5.5}{8} \right\rfloor$.

— 11 Mb/s CCK number of octets = $\left\lfloor \text{LENGTH} \times \frac{11}{8} \right\rfloor$, minus 1 if the length extension bit is a 1.

An example for an 11 Mb/s calculation described in pseudocode form is shown below. At the transmitter, the values of the LENGTH field and length extension bit are calculated as follows:

LENGTH' = (number of octets × 8) / R

LENGTH = ⌈LENGTH'⌉

If

(R = 11) and ((LENGTH–LENGTH') ≥ 8/11)

then

length extension = 1



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else

length extension = 0

where
R is the data rate (Mb/s)

At the receiver, the number of octets in the (#14)PSDU is calculated as follows:

$$\text{number of octets} = \left\lfloor \frac{\text{LENGTH} \times R}{8} \right\rfloor - \text{length extension}$$

where
R is the data rate (Mb/s)

Table 16-2 (Example of LENGTH calculations for CCK) shows an example calculation for several LENGTH values of CCK at 11 Mb/s.

**Table 16-2—Example of LENGTH calculations for CCK**

| TX octets | $\frac{\text{Octets} \times 8}{11}$ | LENGTH | Length extension bit | $\frac{\text{LENGTH} \times 11}{8}$ | $\left\lfloor \frac{\text{LENGTH} \times 11}{8} \right\rfloor$ | RX octets |
|---|---|---|---|---|---|---|
| 1023 | 744 | 744 | 0 | 1023 | 1023 | 1023 |
| 1024 | 744.7273 | 745 | 0 | 1024.375 | 1024 | 1024 |
| 1025 | 745.4545 | 746 | 0 | 1025.75 | 1025 | 1025 |
| 1026 | 746.1818 | 747 | 1 | 1027.125 | 1027 | 1026 |

This example illustrates why normal rounding or truncation of the number does produce the right result. The LENGTH field is defined in units of microseconds and corresponds to the actual length, and the number of octets is exact.

The LSB shall be transmitted first in time. This field shall be protected by the CRC-16 FCS described in 16.2.3.7 (PHY CRC (CRC-16) field).

### 16.2.3.7 PHY CRC (CRC-16) field

The SIGNAL, SERVICE, and LENGTH fields shall be protected with a CRC-16 FCS. The CRC-16 FCS is defined in 15.3.3 (PHY field definitions).(#17)

### 16.2.3.8 Long PHY data modulation and modulation rate change

The long PHY preamble and header shall be transmitted using the 1 Mb/s DBPSK modulation. The SIGNAL field indicates the rate that is used to transmit the PSDU. The transmitter and receiver shall initiate the rate indicated by the SIGNAL field, starting with the first octet of the PSDU. The PSDU transmission rate shall be set by the DATARATE parameter in the TXVECTOR, issued with the PHY-TXSTART.request primitive described in 16.3.5 (Vector descriptions).

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#### 16.2.3.9 Short PHY synchronization (shortSYNC)

The shortSYNC field shall consist of scrambled 0 bits. This field is provided so the receiver can perform the necessary synchronization operations. The initial state of the scrambler (seed) shall be [001 1011], where the left end bit specifies the value to place in the first delay element ($Z^1$) in Figure 16-3 (Data scrambler) (in 16.2.4 (PHY/HR/DSSS PHY data scrambler and descrambler)), and the right end bit specifies the value to place in the last delay element ($Z^7$).

#### 16.2.3.10 Short PHY SFD field (shortSFD)

The shortSFD shall be the time reverse of the field of the SFD in the long PHY preamble (16.2.3.3 (Long PHY SFD)). The field is the bit pattern 0000 0101 1100 1111. The right end bit shall be transmitted first in time. A receiver not configured to use the short header option does not detect this SFD.

#### 16.2.3.11 Short PHY SIGNAL field (shortSIGNAL)

The SIGNAL field of the short header indicates to the PHY the data rate that shall be used for transmission (and reception) of the PSDU. A PHY operating with the HR/DSSS/short option supports three mandatory rates given by the following 8-bit words, where the LSB shall be transmitted first in time and the number represents the rate in units of 100 kb/s:

a) X'14' (MSB to LSB) for 2 Mb/s
b) X'37' (MSB to LSB) for 5.5 Mb/s
c) X'6E' (MSB to LSB) for 11 Mb/s

#### 16.2.3.12 Short PHY SERVICE field (shortSERVICE)

The SERVICE field in the short header shall be the same as the SERVICE field described in 16.2.3.5 (Long PHY SERVICE field).

#### 16.2.3.13 Short PHY LENGTH field (shortLENGTH)

The LENGTH field in the short header shall be the same as the LENGTH field described in 16.2.3.6 (Long PHY LENGTH field).

#### 16.2.3.14 Short CRC-16 field (shortCRC)

The CRC in the short header shall be the same as the CRC field defined in 16.2.3.7 (PHY CRC (CRC-16) field). The CRC-16 is calculated over the shortSIGNAL, shortSERVICE, and shortLENGTH fields.

#### 16.2.3.15 Short PHY data modulation and modulation rate change

The short PHY preamble shall be transmitted using the 1 Mb/s DBPSK modulation. The short PHY header shall be transmitted using the 2 Mb/s modulation. The SIGNAL field indicates the rate that is used to transmit the PSDU. The transmitter and receiver shall initiate the rate indicated by the SIGNAL field, starting with the first octet of the PSDU. The PSDU transmission rate shall be set by the DATARATE parameter in the TXVECTOR, issued with the PHY-TXSTART.request primitive described in 16.3.5 (Vector descriptions).

### 16.2.4 PHY/HR/DSSS PHY data scrambler and descrambler

The polynomial (#1407)$G(z) = z^{-7} + z^{-4} + 1$ shall be used to scramble all bits transmitted. The feedthrough configuration of the scrambler and descrambler is self-synchronizing, which requires no prior knowledge of the transmitter initialization of the scrambler for receive processing. Figure 16-3 (Data scrambler) and


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Figure 16-4 (Data descrambler) show typical implementations of the data scrambler and descrambler, but other implementations are possible.

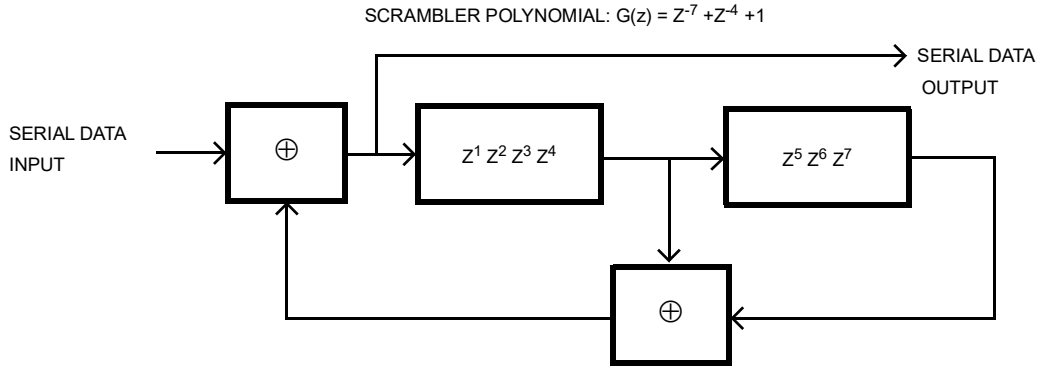


**Figure 16-3—Data scrambler**

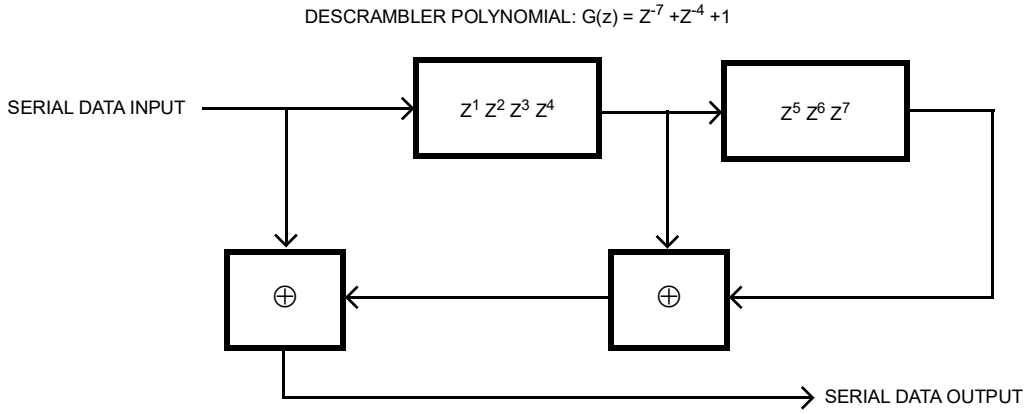


**Figure 16-4—Data descrambler**

The scrambler shall be initialized as specified in 16.2.3.9 (Short PHY synchronization (shortSYNC)) for the short PPDU format and 16.2.3.2 (Long PHY SYNC field) for the long PPDU format. For a long preamble, this shall result in the scrambler registers $Z^1$ to $Z^7$ in Figure 16-3 (Data scrambler) having the data pattern [1101100] (i.e., $Z^1$= 1... $Z^7$= 0) when the scrambler is first started. The scrambler shall be initialized with the reverse pattern [0011011] when transmitting the optional short preamble.

### 16.2.5 Transmit PHY

The transmit procedures for a HR/DSSS PHY using the long PPDU format are the same as the transmit procedures described in 15.3.6 (Transmit PHY) and 15.3.7 (Receive PHY) and do not change apart from the ability to transmit 5.5 Mb/s and 11 Mb/s.

The procedures for a transmitter employing HR/DSSS/short are the same except for length and rate changes. The decision to use the long or short PPDU format is beyond the scope of this standard.

The transmit PHY is shown in Figure 16-5 (Transmit PHY).

A PHY-TXSTART.request(TXVECTOR) primitive is issued by the MAC to start the transmission of a PPDU. In addition to parameters DATARATE and LENGTH, other transmit parameters such as PREAMBLE_TYPE are set via the PHY SAP with the PHY-TXSTART.request(TXVECTOR) primitive, as

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described in 16.3.5 (Vector descriptions). The SIGNAL, SERVICE, and LENGTH fields of the PHY header are calculated as described in 16.2.3 (PPDU field definitions).

The PHY is configured with the TXVECTOR elements TX_ANTENNA, DATARATE, and TXPWR_LEVEL_INDEX. The PHY entity shall immediately initiate data scrambling and transmission of the PHY preamble based on the parameters passed in the PHY-TXSTART.request primitive. The time required for transmit power-on ramp, described in 16.3.7.7 (Transmit power-on and power-down ramp), shall be included in the PHY SYNC field.

Once the PHY preamble transmission is complete, data shall be exchanged between the MAC and the PHY by a series of PHY-DATA.request(DATA) primitives issued by the MAC and PHY-DATA.confirm primitives issued by the PHY. The modulation and rate change, if any, shall be initiated with the first data symbol of the PSDU, as described in 16.2.3.8 (Long PHY data modulation and modulation rate change) and 16.2.3.15 (Short PHY data modulation and modulation rate change). The PHY proceeds with PSDU transmission through a series of data octet transfers from the MAC. Transmission can be prematurely terminated by the MAC through the PHY-TXEND.request primitive. Normal termination occurs after the transmission of the final bit of the last PSDU octet, calculated from the number supplied in the PHY preamble LENGTH and SERVICE fields using the equations specified in 16.2.3.6 (Long PHY LENGTH field). The PPDU transmission shall be completed and the PHY entity shall enter the receive state. It is recommended that modulation continue during power-down to prevent radiating a continuous wave carrier. Each PHY-TXEND.request primitive is acknowledged with a PHY-TXEND.confirm primitive from the PHY.

### 16.2.6 Receive PHY

The receive procedures for receivers configured to receive the mandatory and optional PHYs, rates, and modulations are described in this subclause. A receiver that supports this high rate extension of the standard is capable of receiving 5.5 Mb/s and 11 Mb/s, in addition to 1 Mb/s and 2 Mb/s. If the PHY implements the short preamble option, it shall detect both short and long preamble formats and indicate which type of preamble was received in the RXVECTOR. The receiver shall implement the CCA procedure as defined in 16.3.8.5 (CCA). Upon receiving a PPDU, the receiver shall distinguish between a long and short header format by the value of the SFD, as specified in 16.2.2 (PPDU format). The receiver shall demodulate a long PHY header using BPSK at 1 Mb/s. The receiver shall demodulate a short PHY header using QPSK at 2 Mb/s. The receiver shall use the SIGNAL and SERVICE fields of the PHY header to determine the data rate and modulation of the PSDU.

The receive PHY is shown in Figure 16-6 (Receive PHY(#1058)). In order to receive data, the PHY-TXSTART.request primitive shall be disabled so that the PHY entity is in the receive state. Further, through station management via the PLME, the PHY shall be set to the appropriate channel and the CCA method chosen. Other receive parameters, such as RSSI, RCPI, SQ, and indicated DATARATE, may be accessed via the PHY SAP.

Upon receiving the transmitted energy, according to the selected CCA mode a PHY-CCA.indication(BUSY) primitive shall be issued for ED and/or code lock prior to correct reception of the PHY header. The PHY measures the SQ and RSSI parameters and these are reported to the MAC in the RXVECTOR.

After a PHY-CCA.indication primitive is issued, the PHY entity shall begin searching for the SFD field. Once the SFD field is detected, CRC-16 processing shall be initiated and the PHY SIGNAL, SERVICE, and LENGTH fields shall be received. The CRC-16 FCS shall be processed. If the CRC-16 FCS check fails, the PHY receiver shall return to the RX IDLE state, as depicted in Figure 16-7 (PHY receive state machine(#143)(#2260)). Should the status of CCA return to the IDLE state during reception prior to completion of the full PPDU processing, the PHY receiver shall return to the RX IDLE state.


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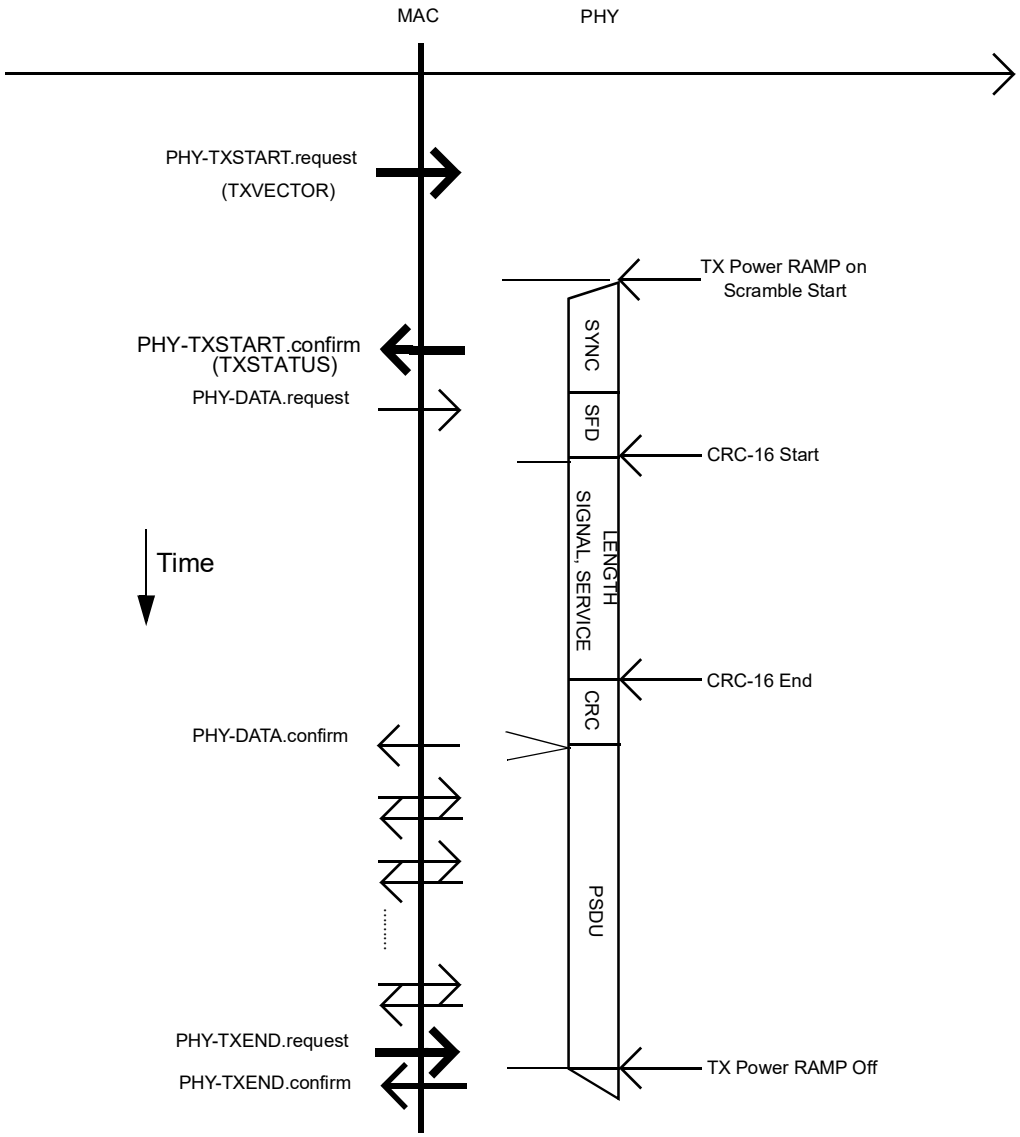


**Figure 16-5—Transmit PHY**

If the PHY header reception is successful (and the SIGNAL field is completely recognizable and supported), a PHY-RXSTART.indication(RXVECTOR) primitive shall be issued. The RXVECTOR associated with this primitive includes:

a) The SIGNAL field

b) The SERVICE field

c) The PSDU length in octets (calculated from the LENGTH field in microseconds and the DATARATE in Mb/s, in accordance with the formula in 16.2.3.6 (Long PHY LENGTH field))

d) RXPREAMBLE_TYPE (which is an enumerated type taking on values SHORTPREAMBLE or LONGPREAMBLE)

e) RX_ANTENNA, RSSI, and SQ

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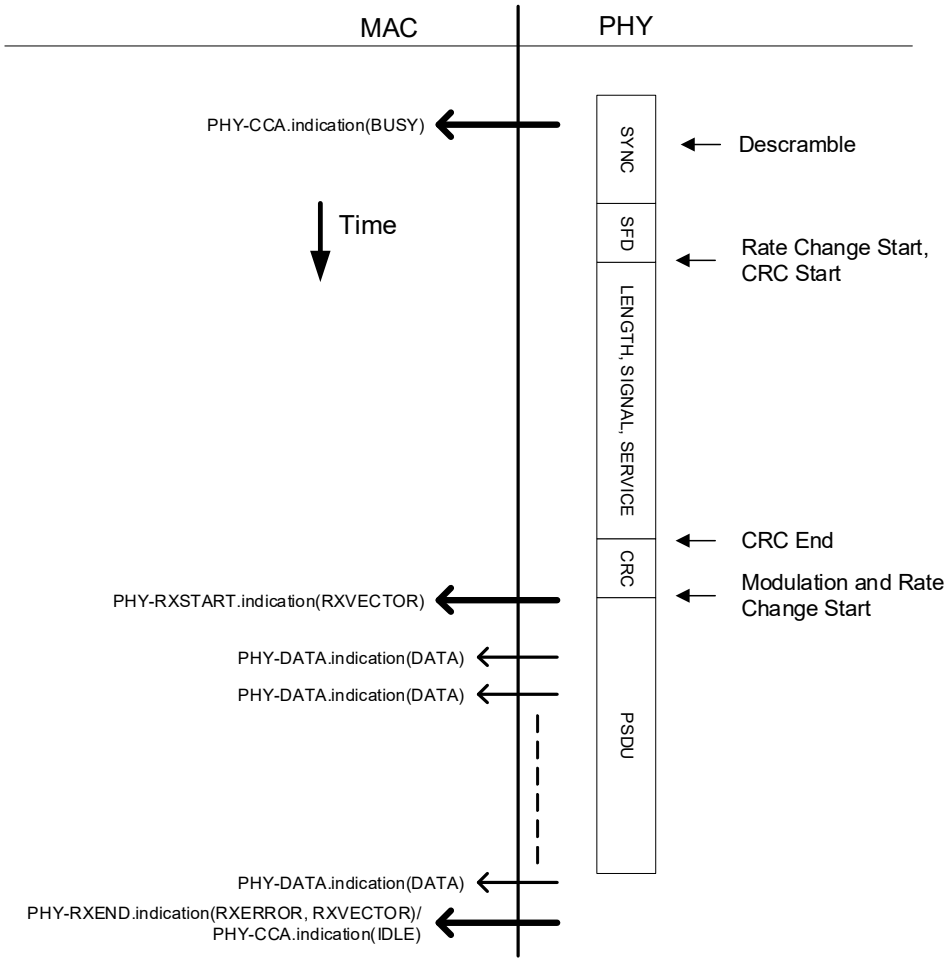


**Figure 16-6—Receive PHY(#1058)**

If dot11TimingMsmtActivated is true, the PHY shall do the following:

— Complete receiving the PHY header and verify the validity of the PHY Header.

— If the PHY header reception is successful (and the SIGNAL field is completely recognizable and supported), a PHY-RXSTART.indication(RXVECTOR) primitive shall be issued and RX_START_OF_FRAME_OFFSET parameter within the RXVECTOR shall be forwarded (see 16.3.5 (Vector descriptions)).

NOTE—The RX_START_OF_FRAME_OFFSET value is used (#3049)to estimate when the start of the preamble for the incoming (#14)PPDU was detected on the medium at the receive antenna connector.

The received PSDU bits are assembled into octets and presented to the MAC using a series of PHY-DATA.indication(DATA) primitive exchanges. The rate and modulation change indicated in the SIGNAL field shall be initiated with the first symbol of the PSDU, as described in 16.2.5 (Transmit PHY). The PHY proceeds with PSDU reception. After reception of the final bit of the last PSDU octet, as indicated by the PHY preamble LENGTH field, the receiver shall be returned to the RX IDLE state shown in Figure 16-7 (PHY receive state machine(#143)(#2260)).


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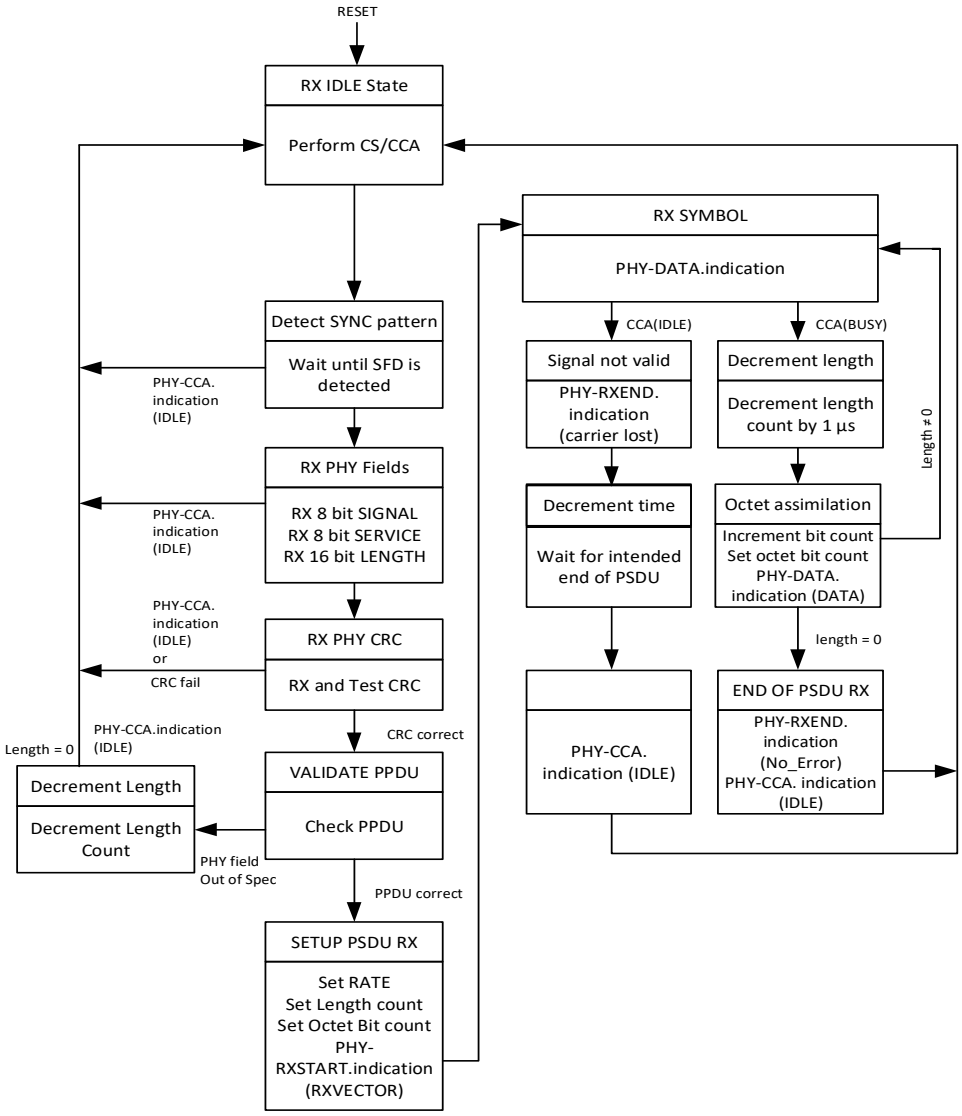


**Figure 16-7—PHY receive state machine(#143)(#2260)**

A PHY-RXEND.indication(NoError) primitive shall be issued. A PHY-CCA.indication(IDLE) primitive shall be issued following a change in PHYCS and/or PHYED according to the selected CCA method.

In the event that a change in PHYCS or PHYED would cause the status of CCA to return to the IDLE state before the complete reception of the PSDU, as indicated by the PHY LENGTH field, the error condition shall be reported to the MAC using a PHY-RXEND.indication(CarrierLost) primitive. The CCA of the HR/DSSS PHY shall indicate a busy medium for the intended duration of the transmitted PPDU.

If the PHY header is successful, but the indicated rate or modulation in the SIGNAL and SERVICE fields is not within the capabilities of the receiver, a PHY-RXSTART.indication primitive shall not be issued. The PHY shall indicate the error condition by issuing a PHY-RXEND.indication(UnsupportedRate) primitive. If the PHY header is invalid, a PHY-RXSTART.indication primitive shall not be issued, and the PHY shall indicate the error condition using a PHY-RXEND.indication(FormatViolation) primitive. Also, in both cases, the CCA of the HR/DSSS PHY shall indicate a busy medium for the intended duration of the

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transmitted PSDU, as indicated by the LENGTH field. The intended duration is indicated by the LENGTH field (LENGTH × 1 μs).

If dot11RadioMeasurementActiviated is true and RXERROR equals NoError or UnsupportedRate, the PHY-RXEND.indication primitive also includes RCPI as a parameter.

A typical state machine implementation of the receive PHY is shown in Figure 16-7 (PHY receive state machine(#143)(#2260)).

## 16.3 HR/DSSS PLME

### 16.3.1 PLME SAP layer management primitives(#6320)

Table 16-3 (MIB attribute default values/ranges) lists the MIB attributes that may be accessed by the PHY entities and intralayer or higher level LMEs. These attributes are accessed via the PLME-GET, PLME-SET, and PLME-RESET primitives defined in Clause 6 (Layer management).

**Table 16-3—MIB attribute default values/ranges**

| Managed object | Default value/range | Operational semantics |
|---|---|---|
| **dot11PhyOperationTable** | | |
| dot11PHYType | High rate–2.4 (X'05') | Static |
| dot11CurrentRegDomain | Implementation dependent | Static |
| **dot11PhyHRDSSSEntryTable** | | |
| dot11ShortPreambleOptionImplemented | Implementation dependent | Static |
| **dot11PhyAntennaTable** | | |
| dot11CurrentTxAntenna | Implementation dependent | Dynamic |
| dot11DiversitySupportImplemented | Implementation dependent | Static |
| dot11CurrentRxAntenna | Implementation dependent | Dynamic |
| **dot11PhyTxPowerTable** | | |
| dot11NumberSupportedPowerLevelsImplemented | Implementation dependent | Static |
| dot11TxPowerLevel1 | Implementation dependent | Static |
| dot11TxPowerLevel2 | Implementation dependent | Static |
| dot11TxPowerLevel3 | Implementation dependent | Static |
| dot11TxPowerLevel4 | Implementation dependent | Static |
| dot11TxPowerLevel5 | Implementation dependent | Static |
| dot11TxPowerLevel6 | Implementation dependent | Static |
| dot11TxPowerLevel7 | Implementation dependent | Static |
| dot11TxPowerLevel8 | Implementation dependent | Static |
| dot11CurrentTxPowerLevel | Implementation dependent | Dynamic |
| **dot11PhyDSSSTable** | | |
| dot11CurrentChannel | Implementation dependent | Dynamic |
| dot11HRCCAModeSupported | Implementation dependent | Static |


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**Table 16-3—MIB attribute default values/ranges *(continued)***

| Managed object | Default value/range | Operational semantics |
|---|---|---|
| dot11CurrentCCAMode | Implementation dependent | Dynamic |
| dot11EDThreshold | Implementation dependent | Dynamic |
| **dot11AntennasListTable** | | |
| dot11SupportedTxAntenna | Implementation dependent | Static |
| dot11SupportedRxAntenna | Implementation dependent | Static |
| dot11DiversitySelectionRxImplemented | Implementation dependent | Dynamic |
| **dot11RegDomainsSupportedTable** | | |
| dot11RegDomainsImplementedValue | Implementation dependent | Static |
| dot11SupportedDataRatesTx | Table Tx X'02', X'04', X'0B', X'16' | Static |
| dot11SupportedDataRatesRx | Table Rx X'02', X'04', X'0B', X'16' | Static |

NOTE—The column titled "Operational semantics" contains two types: static and dynamic. Static MIB attributes are fixed and cannot be modified for a given PHY implementation. Dynamic MIB attributes can be modified by some management entities.

### 16.3.2 HR/DSSS PHY MIB

All HR/DSSS PHY MIB attributes are defined in Annex C, with specific values defined in Table 16-3 (MIB attribute default values/ranges).

When MAX-ACCESS is read-only, the MIB attribute value may be updated by the PLME and read from the MIB attribute by management entities. When MAX-ACCESS is read-write, the MIB attribute may be read and written by management entities but shall not be updated by the PLME.

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### 16.3.3 HR/DSSS PHY

(#2123)The HR/DSSS PHY characteristics, provided through the PLME-CHARACTERISTICS service primitive, are shown in Table 16-4 (HR/DSSS PHY characteristics). The definitions for these characteristics are given in 6.7.4 (PLME-CHARACTERISTICS.confirm).

**Table 16-4—HR/DSSS PHY characteristics**

| Characteristic | Value |
|---|---|
| aSlotTime | If dot11OperatingClassesRequired is false, 20 μs<br><br>If dot11OperatingClassesRequired is true, 20 μs plus any coverage-class-dependent aAirPropagationTime (see Table 9-133 (Coverage Class field parameters)) |
| aSIFSTime | 10 μs |
| aCCATime | Implementation dependent, see 10.3.7 (DCF timing relations). |
| aRxPHYStartDelay | 192 μs for long preamble and 96 μs for short preamble |
| aRxTxTurnaroundTime | Implementation dependent, see 10.3.7 (DCF timing relations). |
| aTxPHYDelay | Implementation dependent, see 10.3.7 (DCF timing relations). |
| aRxPHYDelay | Implementation dependent, see 10.3.7 (DCF timing relations). |
| aRxTxSwitchTime | Implementation dependent, see 10.3.7 (DCF timing relations). |
| aTxRampOnTime | Implementation dependent, see 10.3.7 (DCF timing relations). |
| aAirPropagationTime | As indicated by the coverage class (see 10.22.5 (Operation with coverage classes)). |
| aMACProcessingDelay | Implementation dependent, see 10.3.7 (DCF timing relations). |
| aPSDUMaxLength | $2^{12} - 1$ octets |
| aCWmin | 31 |
| aCWmax | 1023 |

### 16.3.4 HR/DSSS TXTIME calculation

The value of the TXTIME parameter returned by the PLME-TXTIME.confirm primitive shall be calculated according to the following equation:

$$\text{TXTIME} = \text{PreambleLength} + \text{PHYHeaderTime} + \left\lceil \frac{\text{LENGTH} \times 8}{\text{DATARATE}} \right\rceil$$

where

| | |
|---|---|
| LENGTH and DATARATE | are values from the TXVECTOR parameter of the corresponding PLME-TXTIME.request primitive |
| LENGTH | is in units of octets |
| DATARATE | is in units of Mb/s |
| The value of PreambleLength | is 144 μs if the TXPREAMBLE_TYPE value from the TXVECTOR parameter indicates "LONGPREAMBLE," or 72 μs if the |


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| | |
|---|---|
| | TXPREAMBLE_TYPE value from the TXVECTOR parameter indicates “SHORTPREAMBLE” |
| The value of PHYHeaderTime | is 48 μs if the TXPREAMBLE_TYPE value from the TXVECTOR parameter indicates “LONGPREAMBLE,” or 24 μs if the TXPREAMBLE_TYPE value from the TXVECTOR parameter indicates “SHORTPREAMBLE” |

### 16.3.5 Vector descriptions

Several service primitives include a parameter vector. These vectors are a list of parameters as described in Table 16-5 (Parameter vectors). DATARATE and LENGTH are described in 8.3.4.4 (Vector descriptions). The remaining parameters are considered to be management parameters and are specific to this PHY.

**Table 16-5—Parameter vectors**

| Parameter | Associated vector | Value |
|---|---|---|
| DATARATE | RXVECTOR, TXVECTOR | The rate used to transmit the PSDU in Mb/s. |
| LENGTH | RXVECTOR, TXVECTOR | The length of the PSDU in octets. |
| PREAMBLE_TYPE | RXVECTOR, TXVECTOR | The preamble used for the transmission of this PPDU. This is an enumerated type that takes the value SHORTPREAMBLE or LONGPREAMBLE. |
| RX_ANTENNA | RXVECTOR | 1–254 |
| TX_ANTENNA | TXVECTOR | Selects which of the available antennas should be used for transmit, in the range 1 to 255. |
| RSSI | RXVECTOR | (#1758)0–255 |
| SQ | RXVECTOR | 0–8 bits of SQ |
| TIME_OF_DEPARTURE_ REQUESTED | TXVECTOR | false, true. When true, the MAC entity requests that the PHY entity measures and reports time of departure parameters corresponding to the time when the first (#14)PPDU energy is sent by the transmitting port; when false, the MAC entity requests that the PHY entity neither measures nor reports time of departure parameters. |
| TIME_OF_DEPARTURE | TXSTATUS | 0 to $2^{32}$– 1. The time when the first frame energy is sent by the transmitting port, measured by the local PHY entity, in units equal to 1/TIME_OF_DEPARTURE_ClockRate. This parameter is present only if TIME_OF_DEPARTURE_REQUESTED is true in the corresponding request. |
| TIME_OF_DEPARTURE_ ClockRate | TXSTATUS | 0 to $2^{16}$– 1. The clock rate, in units of MHz, is used to generate the TIME_OF_DEPARTURE value. This parameter is present only if TIME_OF_DEPARTURE_REQUESTED is true in the corresponding request. |

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**Table 16-5—Parameter vectors *(continued)***

| Parameter | Associated vector | Value |
|---|---|---|
| TX_START_OF_FRAME_OFFSET | TXSTATUS | 0 to $2^{32}$– 1. An estimate of the offset (in 10 ns units) from the point in time at which the start of the preamble (#14)of the PPDU was transmitted at the transmit antenna connector to the point in time at which this primitive is issued to the MAC. |
| RX_START_OF_FRAME_OFFSET | RXVECTOR | 0 to $2^{32}$– 1. An estimate of the offset (in 10 ns units) from the point in time at which the start of the preamble corresponding to the incoming frame arrived at the receive antenna connector to the point in time at which this primitive is issued to the MAC. |

(#3472)NOTE—The RCPI is not included in the RXVECTOR but is passed in the PHY-RXEND.indication primitive (see 16.2.6 (Receive PHY)).

(#2115)The PHYCONFIG_VECTOR carried in a PHY-CONFIG.request primitive for a HR/DSSS PHY contains an OPERATING_CHANNEL parameter, which identifies the operating channel. The PHY shall set dot11CurrentChannel to the value of this parameter.

### 16.3.6 PHY operating specifications, general

#### 16.3.6.1 General

General specifications for the HR/DSSS PHY layer(#4114) are provided in 16.3.6.2 (Operating frequency range) to 16.3.6.11 (Transmit and receive impedance at the antenna connector). These specifications apply to both the receive and transmit functions and general operation of a HR/DSSS PHY.

WLANs implemented in accordance with this standard are subject to equipment certification and operation requirements established by regional and national regulatory administrations. The PHY specification establishes minimum technical requirements for interoperability, based upon established regulations at the time this standard was issued. These regulations are subject to revision, or may be superseded. Requirements that are subject to local geographic regulations are annotated within the PHY specification. Regulatory requirements that do not affect interoperability are not addressed in this standard. Implementers are referred to the following regulatory sources for further information. Operation in countries within defined regulatory domains may be subject to additional regulations.

#### 16.3.6.2 Operating frequency range

(#1604)The HR/DSSS PHY shall operate in the frequency range of 2.4 GHz to 2.5 GHz as allocated by regulatory bodies.

#### 16.3.6.3 Channel Numbering of operating channels

When dot11OperatingClassesRequired is true, channel numbering shall be as specified in 17.3.8.4.2 (Channel numbering) and channelization shall be as specified in 17.3.8.4.3 (Channelization). When dot11OperatingClassesDefined is false or not defined, the channel center frequencies and CHNL_ID numbers shall be as shown in Table 16-6 (HR/DSSS PHY frequency channel plan).


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**Table 16-6—HR/DSSS PHY frequency channel plan**

| CHNL_ID | Frequency (MHz) |
|---|---|
| 1 | 2412 |
| 2 | 2417 |
| 3 | 2422 |
| 4 | 2427 |
| 5 | 2432 |
| 6 | 2437 |
| 7 | 2442 |
| 8 | 2447 |
| 9 | 2452 |
| 10 | 2457 |
| 11 | 2462 |
| 12 | 2467 |
| 13 | 2472 |
| 14 | 2484 |

In a multiple cell network topology, overlapping and/or adjacent cells using different channels can operate simultaneously without interference if the distance between the center frequencies is at least 25 MHz. Channel 14 shall be designated specifically for operation in Japan.

### 16.3.6.4 Modulation and channel data rates

Four modulation formats and data rates are specified for the HR/DSSS PHY. The basic access rate shall be based on 1 Mb/s DBPSK modulation. The enhanced access rate shall be based on 2 Mb/s DQPSK. The extended direct sequence specification defines two additional data rates. The HR/DSSS access rates shall be based on the CCK modulation scheme for 5.5 Mb/s and 11 Mb/s.

### 16.3.6.5 Spreading sequence and modulation for 1 Mb/s and 2 Mb/s

The following 11-chip Barker sequence shall be used as the PN code sequence for the 1 Mb/s and 2 Mb/s modulation:

+1, –1, +1, +1, –1, +1, +1, +1, –1, –1, –1

The leftmost chip shall be output first in time. The first chip shall be aligned at the start of a transmitted symbol. The symbol duration shall be exactly 11 chips long.

The DBPSK encoder for the basic access rate is specified in Table 16-7 (1 Mb/s DBPSK encoding table). The DQPSK encoder is specified in Table 16-8 (2 Mb/s DQPSK encoding table). (In these tables, $+j\omega$ shall be defined as counterclockwise rotation.)

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**Table 16-7—1 Mb/s DBPSK encoding table**

| Bit input | Phase change (+jω) |
|---|---|
| 0 | 0 |
| 1 | π |

**Table 16-8—2 Mb/s DQPSK encoding table**

| Dibit pattern (d0,d1) (d0 is first in time) | Phase change (+jω) |
|---|---|
| 00 | 0 |
| 01 | π/2 |
| 11 | π |
| 10 | 3π/2 (–π/2) |

### 16.3.6.6 Spreading sequences and modulation for CCK modulation at 5.5 Mb/s and 11 Mb/s

#### 16.3.6.6.1 General

For the CCK modulation modes, the spreading code length is 8 and is based on complementary codes. The chipping rate is 11 Mchip/s. The symbol duration shall be exactly 8 complex chips long.

Equation (16-1) shall be used to derive the CCK codewords that shall be used for spreading both 5.5 Mb/s and 11 Mb/s.

$$c = \{e^{j(\varphi_1+\varphi_2+\varphi_3+\varphi_4)}, e^{j(\varphi_1+\varphi_3+\varphi_4)}, e^{j(\varphi_1+\varphi_2+\varphi_4)}, -e^{j(\varphi_1+\varphi_4)}, e^{j(\varphi_1+\varphi_2+\varphi_3)}, e^{j(\varphi_1+\varphi_3)}, -e^{j(\varphi_1+\varphi_2)}, e^{j\varphi_1}\} \quad (16\text{-}1)$$

where C is the codeword

C = {c0 to c7}

The terms φ1, φ2, φ3, and φ4 are defined in 16.3.6.6.3 (CCK 5.5 Mb/s modulation) for 5.5 Mb/s and 16.3.6.6.4 (CCK 11 Mb/s modulation) for 11 Mb/s.

This formula creates 8 complex chips (c0 to c7), where c0 is transmitted first in time.

This is a form of the generalized Hadamard transform encoding, where φ1 is added to all code chips, φ2 is added to all odd code chips, φ3 is added to all odd pairs of code chips, and φ4 is added to all odd groups of four code chips.

The term φ1 modifies the phase of all code chips of the sequence and shall be DQPSK encoded for 5.5 Mb/s and 11 Mb/s. This shall take the form of rotating the whole symbol by the appropriate amount relative to the phase of the preceding symbol. Note that the chip c7 of the symbol defined above is the chip that indicates the symbol's phase and is transmitted last.


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#### 16.3.6.6.2 Cover code for CCK

The fourth and seventh chips are rotated 180° by a cover sequence to optimize the sequence correlation properties and minimize dc offsets in the codes. This explains the minus sign on the fourth and seventh terms in Equation (16-1).

#### 16.3.6.6.3 CCK 5.5 Mb/s modulation

At 5.5 Mb/s, 4 bits (d0 to d3; d0 first in time) are transmitted per symbol.

The data bits d0 and d1 encode φ1 based on DQPSK. The DQPSK encoder is specified in Table 16-8 (2 Mb/s DQPSK encoding table). (In the table, +jω shall be defined as counterclockwise rotation.) The phase change for φ1 is relative to the phase φ1 of the preceding symbol. For the header to PSDU transition, the phase change for φ1 is relative to the phase of the preceding DQPSK (2 Mb/s) symbol. That is, the phase of the last symbol of the CRC-16 is the reference phase for the first symbol generated from the PSDU octets. (See the definition in 16.3.6.5 (Spreading sequence and modulation for 1 Mb/s and 2 Mb/s) for the reference phase of this Barker coded symbol.) A "+1" chip in the Barker code shall represent the same carrier phase as a "+1" chip in the CCK code.

All odd-numbered symbols generated from the PSDU octets shall be given an extra 180° (π) rotation, in addition to the standard DQPSK modulation as shown in Table 16-9 (DQPSK encoding table). The symbols of the PSDU shall be numbered starting with 0 for the first symbol, for the purposes of determining odd and even symbols. That is, the PSDU transmission starts on an even-numbered symbol.

**Table 16-9—DQPSK encoding table**

| Dibit pattern (d0, d1) (d0 is first in time) | Even symbols phase change (+jω) | Odd symbols phase change (+jω) |
|---|---|---|
| 00 | 0 | π |
| 01 | π/2 | 3π/2 (–π/2) |
| 11 | π | 0 |
| 10 | 3π/2 (–π/2) | π/2 |

The data dibits d2 and d3 CCK encode the basic symbol, as specified in Table 16-10 (5.5 Mb/s CCK encoding table). This table is derived from the formula above by setting φ2 = (d2 × π) + π /2, φ3 = 0, and φ4 = d3 × π. In this table, d2 and d3 are in the order shown, and the complex chips are shown c0 to c7 (left to right), with c0 transmitted first in time.

**Table 16-10—5.5 Mb/s CCK encoding table**

| d2, d3 | c1 | c2 | c3 | c4 | c5 | c6 | c7 | c8 |
|---|---|---|---|---|---|---|---|---|
| 00 | 1j | 1 | 1j | –1 | 1j | 1 | –1j | 1 |
| 01 | –1j | –1 | –1j | 1 | 1j | 1 | –1j | 1 |
| 10 | –1j | 1 | –1j | –1 | –1j | 1 | 1j | 1 |
| 11 | 1j | –1 | 1j | 1 | –1j | 1 | 1j | 1 |

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#### 16.3.6.6.4 CCK 11 Mb/s modulation

At 11 Mb/s, 8 bits (d0 to d7; d0 first in time) are transmitted per symbol.

The first dibit (d0, d1) encodes φ1 based on DQPSK. The DQPSK encoder is specified in Table 16-8 (2 Mb/s DQPSK encoding table). The phase change for φ1 is relative to the phase φ1 of the preceding symbol. In the case of header to PSDU transition, the phase change for φ1 is relative to the phase of the preceding DQPSK symbol. All odd-numbered symbols of the PSDU are given an extra 180° (π) rotation, in accordance with the DQPSK modulation shown in Table 16-8 (2 Mb/s DQPSK encoding table). Symbol numbering starts with 0 for the first symbol of the PSDU.

The data dibits (d2, d3), (d4, d5), and (d6, d7) encode φ2, φ3, and φ4, respectively, based on QPSK as specified in Table 16-11 (QPSK encoding table). Note that this table is binary (not Gray) coded.

**Table 16-11—QPSK encoding table**

| Dibit pattern [di, d(i+1)] (di is first in time) | Phase |
|---|---|
| 00 | 0 |
| 01 | π/2 |
| 10 | π |
| 11 | 3π/2 (–π/2) |

#### 16.3.6.7 Transmit and receive in-band and out-of-band spurious emissions

The HR/DSSS PHY shall comply with in-band and out-of-band spurious emissions as set by the appropriate regulatory bodies.

#### 16.3.6.8 TX-to-RX turnaround time

The TX-to-RX turnaround time shall be less than 10 μs, including the power-down ramp specified in 16.3.7.7 (Transmit power-on and power-down ramp).

The TX-to-RX turnaround time shall be measured on the WM from the trailing edge of the last transmitted symbol to the valid CCA detection of the incoming signal.

#### 16.3.6.9 RX-to-TX turnaround time

The RX-to-TX turnaround time shall be measured at the MAC/PHY interface using the PHY-TXSTART.request primitive, and shall be 5 μs. This includes the transmit power-on ramp described in 16.3.7.7 (Transmit power-on and power-down ramp).

#### 16.3.6.10 Slot time

The value of the slot time is found in Table 16-4 (HR/DSSS PHY characteristics).


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#### 16.3.6.11 Transmit and receive impedance at the antenna connector

The impedance at the transmit antenna connector and receive antenna connector shall be 50 Ω if that connector is exposed.

### 16.3.7 PHY transmit specifications

#### 16.3.7.1 Introduction

The transmit functions and parameters associated with the PHY layer(#4114) are described in 16.3.7.2 (Transmit power levels) to 16.3.7.9 (Transmit modulation accuracy).

#### 16.3.7.2 Transmit power levels

The maximum allowable output power is measured in accordance with practices specified by the appropriate regulatory bodies.

#### 16.3.7.3 Transmit power level control

Power control shall be provided for transmitted power greater than 100 mW. A maximum of four power levels may be provided. As a minimum, a radio capable of transmission greater than 100 mW shall support(#546) switching power back to 100 mW or less.

#### 16.3.7.4 Transmit spectrum mask

(#3816)The overall transmit spectral mask is constructed using two components. First, an interim spectrum mask is constructed whose mask level is determined relative to the SINx/x peak of the signal. The overall transmit spectrum mask is then constructed by taking the higher of the interim transmit spectrum mask and –53 dBm/MHz at each frequency offset.

(#3816)The interim transmit spectrum mask shall be 0 dBr (decibel relative to the SINx/x peak) for $f_c$ – 11 MHz < $f$ < $f_c$ +11 MHz, – 30 dBr for $f_c$ – 22 MHz < $f$ < $f_c$ –11 MHz and $f_c$ + 11 MHz < $f$ < $f_c$ + 22 MHz, and –50 dBr for $f$ < $f_c$ – 22 MHz and $f$ > $f_c$ + 22 MHz, where $f_c$ is the channel center frequency.

(#3816)The transmit spectrum mask shall not exceed the maximum of the interim transmit spectrum mask and –53 dBm/MHz at any frequency offset in the 2.4 GHz band. The transmit spectrum mask when the –50 dBr spectrum level is above –53 dBm/MHz is shown in Figure 16-8 (Transmit spectrum mask). The measurements shall be made using a 100 kHz resolution bandwidth and a 100 kHz video bandwidth.

#### 16.3.7.5 Transmit center frequency tolerance

The transmitted center frequency tolerance shall be ± 25 ppm.

#### 16.3.7.6 Chip clock frequency tolerance

The PN code chip clock frequency tolerance shall be ± 25 ppm. It is highly recommended that the chip clock and the transmit frequency be locked (coupled) for optimum demodulation performance. If these clocks are locked, it is recommended that bit 2 of the SERVICE field be set to 1, as indicated in 16.2.3.5 (Long PHY SERVICE field).

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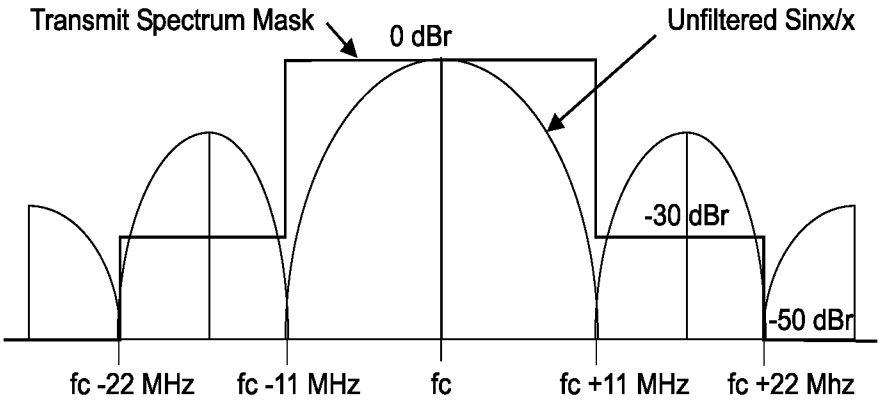


**Figure 16-8—Transmit spectrum mask**

### 16.3.7.7 Transmit power-on and power-down ramp

The transmit power-on ramp for 10% to 90% of maximum power shall be no greater than 2 μs. The transmit power-on ramp is shown in Figure 16-9 (Transmit power-on ramp).

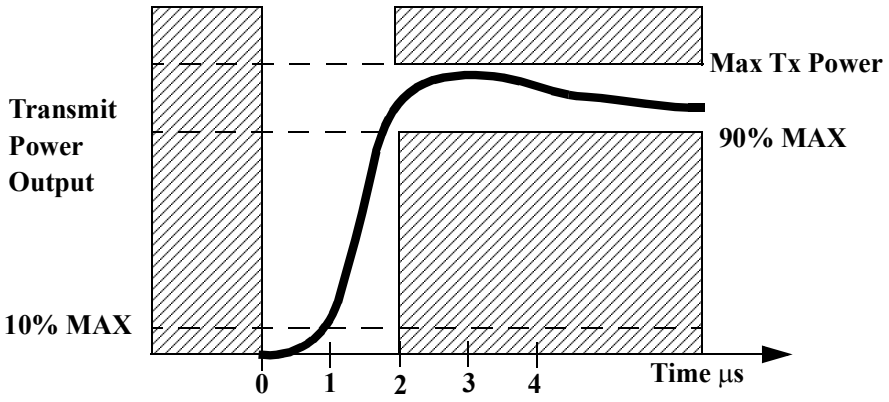


**Figure 16-9—Transmit power-on ramp**


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The transmit power-down ramp for 90% to 10% maximum power shall be no greater than 2 μs. The transmit power-down ramp is shown in Figure 16-10 (Transmit power-down ramp).

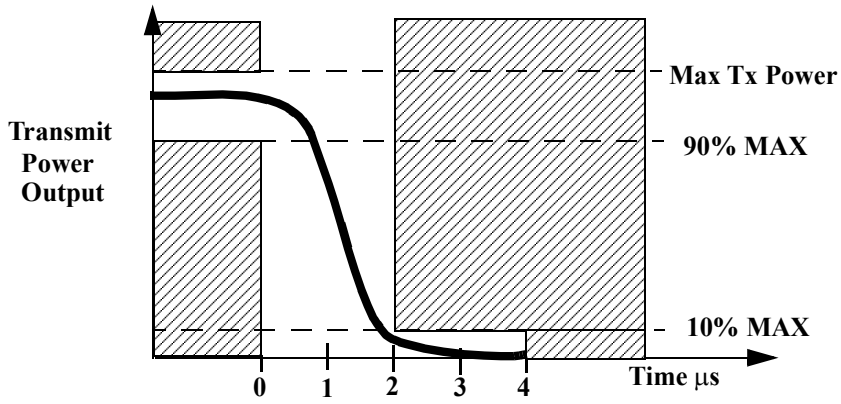


**Figure 16-10—Transmit power-down ramp**

The transmit power ramps shall be constructed such that the HR/DSSS PHY emissions comply with spurious frequency product specification defined in 16.3.6.7 (Transmit and receive in-band and out-of-band spurious emissions).

### 16.3.7.8 RF carrier suppression

The RF carrier suppression, measured at the channel center frequency, shall be at least 15 dB below the peak sin(x)/x power spectrum. The RF carrier suppression shall be measured while transmitting a repetitive 01 data sequence with the scrambler disabled using DQPSK modulation. A 100 kHz resolution bandwidth shall be used to perform this measurement.

### 16.3.7.9 Transmit modulation accuracy

The transmit modulation accuracy requirement for the HR/DSSS PHY shall be based on the difference between the actual transmitted waveform and the ideal signal waveform. Modulation accuracy shall be determined by measuring the peak vector error magnitude during each chip period. Worst-case vector error magnitude shall not exceeded 0.35 for the normalized sampled chip data. The ideal complex I and Q constellation points associated with DQPSK modulation, (0.707, 0.707), (0.707, –0.707), (–0.707, 0.707), (–0.707, –0.707), shall be used as the reference. These measurements shall be from baseband I and Q sampled data after recovery through a reference receiver system.

Figure 16-11 (Modulation accuracy measurement example) illustrates the ideal DQPSK constellation points and range of worst-case error specified for modulation accuracy.

Error vector measurement requires a reference receiver capable of carrier lock. All measurements shall be made under carrier lock conditions. The distortion induced in the constellation by the reference receiver shall be calibrated and measured. The test data error vectors described below shall be corrected to compensate for the reference receiver distortion.

The IEEE Std 802.11-compatible radio shall provide an exposed TX chip clock, which shall be used to sample the I and Q outputs of the reference receiver.

The measurement shall be made under the conditions of continuous DQPSK transmission using scrambled all 1s.

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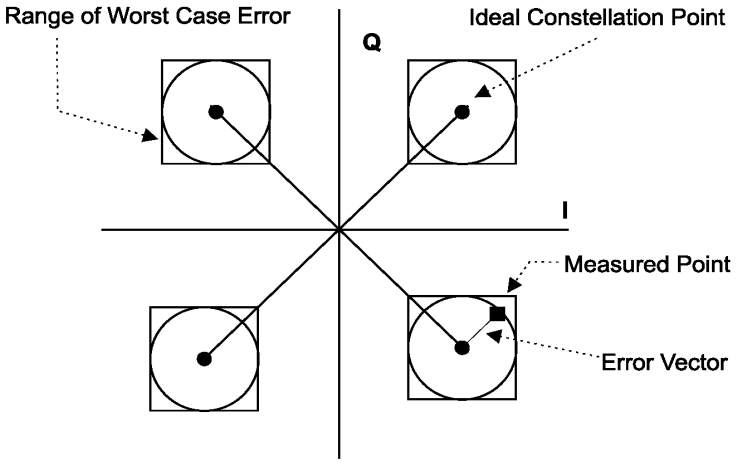


**Figure 16-11—Modulation accuracy measurement example**

The eye pattern of the I channel shall be used to determine the I and Q sampling point. The chip clock provided by the vendor radio shall be time delayed, such that the samples fall at a 1/2 chip period offset from the mean of the zero crossing positions of the eye (see Figure 16-12 (Chip clock alignment with baseband eye pattern)). This is the ideal center of the eye and might not be the point of maximum eye opening.

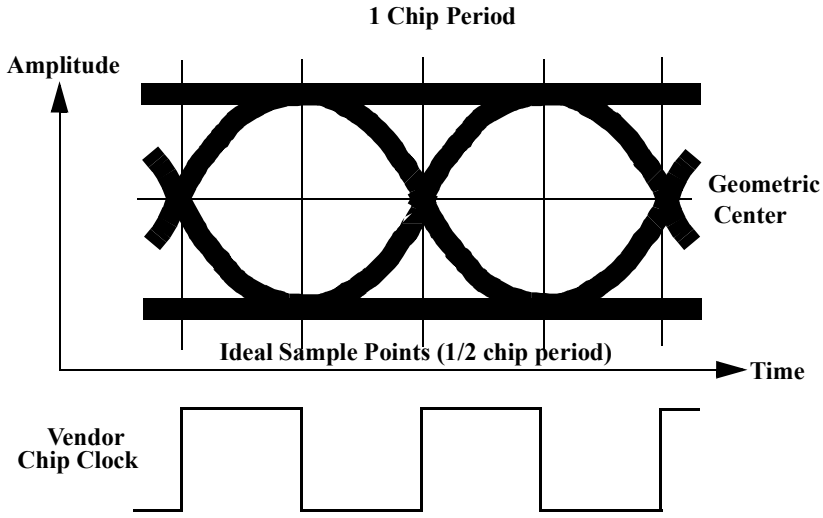


**Figure 16-12—Chip clock alignment with baseband eye pattern**

Using the aligned chip clock, 1000 samples of the I and Q baseband outputs from the reference receiver are captured. The vector error magnitudes shall be calculated as follows:

Calculate the dc offsets for I and Q samples

$$I_{mean} = \sum_{n=0}^{999} I(n)/1000$$


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$$Q_{mean} = \sum_{n=0}^{999} Q(n) / 1000$$

Calculate the dc corrected $I$ and $Q$ samples for all $n$ = 1000 sample pairs

$$I_{dc}(n) = I(n) - I_{mean}$$

$$Q_{dc}(n) = Q(n) - Q_{mean}$$

Calculate the average magnitude of $I$ and $Q$ samples

$$I_{mag} = \sum_{n=0}^{999} |I_{dc}(n)| / 1000$$

$$Q_{mag} = \sum_{n=0}^{999} |Q_{dc}(n)| / 1000$$

Calculate the normalized error vector magnitude for the $I_{dc}(n)/Q_{dc}(n)$ pairs

$$V_{err}(n) = [\{|I_{dc}(n)| - I_{mag}\}^2 + \{|Q_{dc}(n)| - Q_{mag}\}^2]^{\frac{1}{2}} - V_{correction}$$

where

| | |
|---|---|
| the average power of the constellation | is 1 |
| $V_{correction}$ | is the error induced by the reference receiver system |

For all $n$ = 1000 samples, the following condition shall be met:

$$V_{err}(n) < 0.35$$

### 16.3.7.10 Time of Departure accuracy

(#8047)The RMS accuracy of the time of departure provided in TIME_OF_DEPARTURE shall be less than or equal to 80 ns.

The Time of Departure accuracy test evaluates TIME_OF_DEPARTURE against aTxPHYTxStartRMS and aTxPHYTxStartRMS against TIME_OF_DEPARTURE_ACCURACY_TEST_THRESH as defined in Annex P with the following test parameters:

— MULTICHANNEL_SAMPLING_RATE is $22 \times 10^6 \left(1 + \left\lceil \frac{f_H - f_L}{22\ \text{MHz}} \right\rceil\right)$ sample/s

where

$f_H$ is the nominal center frequency in Hz of the highest channel in the channel set

$f_L$ is the nominal center frequency in Hz of the lowest channel in the channel set, the channel set is the set of channels upon which (#14)PPDUs providing measurements are transmitted, the channel set comprises channels uniformly spaced across $f_H - f_L \geq 50$ MHz

— FIRST_TRANSITION_FIELD is the SYNC field.

— SECOND_TRANSITION_FIELD is the SFD field.

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— TRAINING_FIELD is the concatenation of the appropriate short or long SYNC and SFD fields, using a chip pulse which should approximate a rectangular pulse of duration 1/ 11 MHz convolved with a brick-wall low pass filter of bandwidth 11 MHz.
— TIME_OF_DEPARTURE_ACCURACY_TEST_THRESH is 80 ns.

NOTE—The indicated chip pulse applies to the time of departure accuracy test equipment, and not the transmitter or receiver.

### 16.3.8 PHY receiver specifications

#### 16.3.8.1 Introduction

The receive functions and parameters associated with the PHY layer(#4114) are described in 16.3.8.2 (Receiver minimum input level sensitivity) to 16.3.8.5 (CCA).

#### 16.3.8.2 Receiver minimum input level sensitivity

The (#14)PER shall be less than $8\times10^{-2}$ at a PSDU length of 1024 octets for an input level of –76 dBm measured at the antenna connector. This (#14)PER shall be specified for 11 Mb/s CCK modulation. The test for the minimum input level sensitivity shall be conducted with the ED threshold set less than or equal to –76 dBm.

#### 16.3.8.3 Receiver maximum input level

If the STA is non-ERP, the receiver shall provide a maximum (#14)PER of $8\times10^{-2}$ at a PSDU length of 1024 octets for a maximum input level of –10 dBm measured at the antenna connector. This (#14)PER shall be specified for 11 Mb/s CCK modulation.

#### 16.3.8.4 Receiver adjacent channel rejection

Adjacent channel rejection is defined between any two channels with ≥ 25 MHz separation in each channel group, as defined in 16.3.6.3 (Channel Numbering of operating channels).

The adjacent channel rejection shall be greater than or equal to than 35 dB, with an (#14)PER of $8\times10^{-2}$ using 11 Mb/s CCK modulation described in 16.3.6.4 (Modulation and channel data rates) and a PSDU length of 1024 octets.

The adjacent channel rejection shall be measured using the following method.

Input an 11 Mb/s CCK modulated signal at a level 6 dB greater than specified in 16.3.8.2 (Receiver minimum input level sensitivity). In an adjacent channel (≥ 25 MHz separation as defined by the channel numbering), input a signal modulated in a similar fashion, which adheres to the transmit mask specified in 16.3.7.4 (Transmit spectrum mask), to a level 41 dB above the level specified in 16.3.8.2 (Receiver minimum input level sensitivity). The adjacent channel signal shall be derived from a separate signal source. It shall not be a frequency shifted version of the reference channel. Under these conditions, the (#14)PER shall be less than or equal to $8\times10^{-2}$.

#### 16.3.8.5 CCA

Requirements in this subclause are applicable to non-ERP HR/DSSS STAs.

The non-ERP HR/DSSS PHY shall provide the capability to perform CCA according to both:

A — At least one of the following options:


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— *CCA Mode 1*: Energy above threshold. CCA shall report a busy medium upon detecting any energy above the ED threshold.
— *CCA Mode 4*: CS with timer. CCA shall start a timer whose duration is 3.65 ms and report a busy medium only upon the detection of a HR/DSSS PHY signal. CCA shall report an IDLE medium after the timer expires and no HR/DSSS PHY signal is detected. The 3.65 ms timeout is the duration of the longest possible 5.5 Mb/s PSDU.
— *CCA Mode 5*: A combination of CS and energy above threshold. CCA shall report busy at least while a HR/DSSS PPDU is being received with energy above the ED threshold at the antenna connector.

and

B — *CCA Mode 6*: CCA shall report a busy medium upon detection of any energy above –62 dBm.

A busy channel shall be indicated by issuing a PHY-CCA.indication(BUSY) primitive. A clear channel shall be indicated by issuing a PHY-CCA.indication(IDLE) primitive.

For a non-ERP HR/DSSS STA, dot11HRCCAModeSupported shall indicate the appropriate operation modes. The PHY shall be configured through dot11CurrentCCAMode.

The CCA parameters are subject to the following criteria:

a) If a valid HR/DSSS signal is detected during its preamble within the CCA window, the ED threshold shall be less than or equal to –76 dBm for TX power > 100 mW; –73 dBm for 50 mW < TX power ≤ 100 mW; and –70 dBm for TX power ≤ 50 mW. The ED threshold is the value contained in dot11EDThreshold.
b) With a valid signal (according to the CCA mode of operation) present at the receiver antenna within 5 μs of the start of a MAC slot boundary, the PHY-CCA.indication(BUSY) primitive shall be generated before the end of the slot time if aSlotTime is 20 μs. Refer to Figure 10-25 (DCF timing relationships(#14)(#1058)(#3297)) (in 10.3.7 (DCF timing relations)) and Figure 10-29 (EDCA mechanism timing relationships(#14)(#1058)) for a definition of slot boundary.
c) In the event that a correct PHY header is received, the HR/DSSS PHY shall not generate a PHY-CCA.indication(IDLE)(#4122) primitive until the end of the PPDU as determined by TXTIME in 16.3.4 (HR/DSSS TXTIME calculation). Upon reception of a correct PHY header, the timer of CCA Mode 4 shall be overridden by this requirement.

Compliance to the HR/DSSS PHY CCA shall be demonstrated by applying an equivalent HR/DSSS signal above the appropriate ED threshold [item a)] so that all conditions described in item b) and item c) are demonstrated.

#### 16.3.8.6 Received channel power indicator (RCPI) measurement

The RCPI is a measure of the received RF power in the selected channel for a received frame. This parameter shall be a (#1132)measurement by the PHY of the received RF power in the channel measured over the (#2011)SYNC field of the received (#3474)PPDU or by other equivalent means that meet the specified accuracy.

RCPI shall equal the received RF power (#2011)in dBm within an accuracy of ± 5 dB (95% confidence interval) within the specified dynamic range of the receiver.

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# 17. Orthogonal frequency division multiplexing (OFDM) PHY specification

## 17.1 Introduction

### 17.1.1 General

This clause specifies the PHY entity for an orthogonal frequency division multiplexing (OFDM) system. The OFDM system provides a WLAN with data payload communication capabilities of 6, 9, 12, 18, 24, 36, 48, and 54 Mb/s. The support of transmitting and receiving at data rates of 6, 12, and 24 Mb/s is mandatory. The system uses 52 subcarriers that are modulated using binary or quadrature phase shift keying (BPSK or QPSK) or using 16- or 64-quadrature amplitude modulation (16-QAM or 64-QAM). Forward error correction coding (convolutional coding) is used with a coding rate of 1/2, 2/3, or 3/4.

The OFDM system also provides a "half-clocked" operation using 10 MHz channel spacings with data communications capabilities of 3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s. The support of transmitting and receiving at data rates of 3, 6, and 12 Mb/s is mandatory when using 10 MHz channel spacing. The half-clocked operation doubles symbol times and clear channel assessment (CCA) times when using 10 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM PHY are in Annex D and Annex E.

The OFDM system also provides a "quarter-clocked" operation using 5 MHz channel spacing with data communication capabilities of 1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s. The support of transmitting and receiving at data rates of 1.5, 3, and 6 Mb/s is mandatory when using 5 MHz channel spacing. The quarter-clocked operation quadruples symbol times and CCA times when using 5 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM PHY are in Annex D and Annex E.

### 17.1.2 Scope of OFDM services

Subclause 17.1 (Introduction) describes the PHY services provided to the IEEE 802.11 WLAN MAC by the OFDM PHY. The OFDM PHY consists of the following protocol functions:

a) (#14)A function that defines a method of mapping the IEEE 802.11 PSDUs into a PPDU format suitable for sending and receiving data, management, and control information between two or more STAs.

b) A function that defines the characteristics and method of transmitting and receiving data through a WM between two or more STAs, each using the OFDM system.

### 17.1.3 OFDM PHY functions

#### 17.1.3.1 General

The OFDM PHY architecture is depicted in the reference model shown in Figure 4-27 (Portion of the ISO/IEC basic reference model covered in this standard(#4114)) (in 4.9 (Reference model)). The OFDM PHY contains two functional entities: the PHY function and the layer management function. Each of these functions is described in detail in 17.3 (OFDM PHY) and 17.4 (OFDM PLME).

The OFDM PHY service is provided to the MAC through the PHY service primitives described in Clause 8 (PHY service specification).

#### 17.1.3.2 PLME

The PLME performs management of the local PHY functions in conjunction with the MLME.


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#### 17.1.3.3 Service specification method

The models represented by figures and state diagrams are intended to be illustrations of the functions provided. It is important to distinguish between a model and a real implementation. The models are optimized for simplicity and clarity of presentation, but do not necessarily reflect any particular implementation.

The service of a layer or sublayer is the set of capabilities that it offers to a user in the next higher layer (or sublayer). Abstract services are specified here by describing the service primitives and parameters that characterize each service. This definition is independent of any particular implementation.

## 17.2 OFDM PHY specific service parameter list

### 17.2.1 Introduction

The architecture of the IEEE 802.11 MAC is intended to be PHY independent. Some PHY implementations require medium management state machines running in the MAC sublayer in order to meet certain PHY requirements. These PHY-dependent MAC state machines reside in a sublayer defined as the MLME. In certain PHY implementations, the MLME may need to interact with the PLME as part of the normal PHY SAP primitives. These interactions are defined by the PLME parameter list currently defined in the PHY service primitives as TXVECTOR and RXVECTOR. The list of these parameters, and the values they may represent, are defined in the specific PHY specifications for each PHY. Subclause 17.2 (OFDM PHY specific service parameter list) addresses the TXVECTOR and RXVECTOR for the OFDM PHY.

### 17.2.2 TXVECTOR parameters(#1369)

The parameters in Table 17-1 (TXVECTOR parameters) are defined as part of the TXVECTOR parameter list in the PHY-TXSTART.request primitive.

**Table 17-1—TXVECTOR parameters**

| Parameter | Associated primitive | Value |
|---|---|---|
| LENGTH | PHY-TXSTART.request (TXVECTOR) | 1–4095 |
| DATARATE(Ed1) | PHY-TXSTART.request (TXVECTOR) | 6, 9, 12, 18, 24, 36, 48, and 54 Mb/s for 20 MHz channel spacing (Support of 6, 12, and 24 Mb/s data rates is mandatory.)<br><br>3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s for 10 MHz channel spacing (Support of 3, 6, and 12 Mb/s data rates is mandatory.)<br><br>1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s for 5 MHz channel spacing (Support of 1.5, 3, and 6 Mb/s data rates is mandatory.) |
| SERVICE | PHY-TXSTART.request (TXVECTOR) | Null |
| TXPWR_LEVEL_INDEX | PHY-TXSTART.request (TXVECTOR) | 1–8 |

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**Table 17-1—TXVECTOR parameters *(continued)***

| Parameter | Associated primitive | Value |
|---|---|---|
| TIME_OF_ DEPARTURE_ REQUESTED | PHY-TXSTART.request (TXVECTOR) | false, true. When true, the MAC entity requests that the PHY entity measures and reports time of departure parameters corresponding to the time when the first (#14)PPDU energy is sent by the transmitting port; when false, the MAC entity requests that the PHY entity neither measures nor reports time of departure parameters. |
| CH_BANDWIDTH_ IN_NON_HT | PHY-TXSTART.request (TXVECTOR) | If present, CBW20, CBW40, CBW80, CBW160, or CBW80+80 |
| DYN_BANDWIDTH _IN_NON_HT | PHY-TXSTART.request (TXVECTOR) | If present, Static or Dynamic |
| (#602)SCRAMBLER_I NITIAL_VALUE | PHY-TXSTART.request (TXVECTOR) | If present, an integer in the range 1–127 |
| SCRAMBLER_RESET | PHY-TXSTART.request (TXVECTOR) | (#1370)Enumerated Type: RESET_SCRAMBLER: The scrambler is reset NO_SCRAMBLER_RESET: The scrambler is not reset. |
| (11bd)CH_BANDWID TH_ IN_NON_NGV | PHY-TXSTART.request (TXVECTOR) | If present, CBW10 or CBW20 |
| (11bd)DYN_BANDWI DTH_ IN_NON_NGV | PHY-TXSTART.request (TXVECTOR) | If present, Static or Dynamic |

The allowed values for the LENGTH parameter are in the range 1 to 4095. This parameter is used to indicate the number of octets in the (#14)PSDU which the MAC is currently requesting the PHY to transmit. This value is used by the PHY to determine the number of octet transfers that will occur between the MAC and the PHY after receiving a request to start the transmission.

The DATARATE parameter describes the bit rate at which the PHY shall transmit the PSDU. Its value takes any of the rates defined in Table 17-1 (TXVECTOR parameters). Data rates of 6, 12, and 24 Mb/s shall be supported for 20 MHz channel spacing, data rates of 3, 6, and 12 Mb/s shall be supported for 10 MHz channel spacing, and data rates of 1.5, 3, and 6 Mb/s shall be supported for 5 MHz channel spacing; other rates may also be supported.

The SERVICE parameter shall be null.

The allowed values for the TXPWR_LEVEL_INDEX parameter are in the range 1 to 8. This parameter is used to indicate which of the available TxPowerLevel attributes defined in the MIB shall be used for the current transmission.

(#1369)The allowed values for the TIME_OF_DEPARTURE_REQUESTED parameter are false or true. A parameter value of true indicates that the MAC sublayer is requesting that the PHY entity provides measurement of when the first (#14)PPDU energy is sent by the transmitting port and reporting within the PHY-TXSTART.confirm primitive. A parameter value of false indicates that the MAC sublayer is requesting that the PHY entity not provide time of departure measurement nor reporting in the PHY-TXSTART.confirm primitive.


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If present, the allowed values for CH_BANDWIDTH_IN_NON_HT are CBW20, CBW40, CBW80, CBW160, and CBW80+80. If present, this parameter is used to modify the first 7 bits of the scrambling sequence to indicate the bandwidth of the non-HT duplicate PPDU.

(#14)NOTE 1—The CH_BANDWIDTH_IN_NON_HT parameter is not present when the PPDU is transmitted by a non-VHT STA. The CH_BANDWIDTH_IN_NON_HT parameter is not present when the PPDU is transmitted by a VHT STA to a non-VHT STA. See 10.6.12 (Channel Width in non-HT and non-HT duplicate PPDUs).

If present, the allowed values for DYN_BANDWIDTH_IN_NON_HT are Static and Dynamic. If present, this parameter is used to modify the first 7 bits of the scrambling sequence to indicate whether the transmitter is capable of dynamic bandwidth operation as an RTS originator (see 10.3.2.9 (CTS and DMG CTS procedure)).(#1782) If DYN_BANDWIDTH_IN_NON_HT is present, then CH_BANDWIDTH_IN_NON_HT is also present.

(#14)NOTE 2—The DYN_BANDWIDTH_IN_NON_HT parameter is not present when the PPDU is transmitted by a non-VHT STA. The DYN_BANDWIDTH_IN_NON_HT parameter is not present when the PPDU is transmitted by a VHT STA to a non-VHT STA. See 10.6.12 (Channel Width in non-HT and non-HT duplicate PPDUs).

If present, SCRAMBLER_INITIAL_VALUE is an integer in the range 1–127 and is used as the first 7 bits of the scrambling sequence (the first 7 bits transmitted in the SERVICE field after scrambling).

(#1370)SCRAMBLER_RESET indicates whether the scrambler is reset before the start of the PPDU.

(11bd)If present, CH_BANDWIDTH_IN_NON_NGV is used to modify the first 7 bits of the scrambling sequence to indicate the bandwidth of the non-NGV duplicate PPDU.

(11bd)NOTE 3—The CH_BANDWIDTH_IN_NON_NGV parameter is not present when the frame is transmitted by a non-NGV STA. The CH_BANDWIDTH_IN_NON_NGV parameter is not present when the frame is transmitted by an NGV STA and a non-NGV STA is one of the intended recipients (including group addressed transmissions).

(11bd)If present, DYN_BANDWIDTH_IN_NON_NGV is used to modify the first 7 bits of the scrambling sequence to indicate if the transmitter is capable of Static or Dynamic bandwidth operation. If DYN_BANDWIDTH_IN_NON_NGV is present, then CH_BANDWIDTH_IN_NON_NGV is also present.

(11bd)NOTE 4—The DYN_BANDWIDTH_IN_NON_NGV parameter is not present when the frame is transmitted by a non-NGV STA. The DYN_BANDWIDTH_IN_NON_NGV parameter is not present when the frame is transmitted by an NGV STA and a non-NGV STA is one of the intended recipients (including group addressed transmissions).

### 17.2.3 RXVECTOR parameters(#1369)

The parameters listed in Table 17-2 (RXVECTOR parameters) are defined as part of the RXVECTOR parameter list in the PHY-RXSTART.indication primitive.

**Table 17-2—RXVECTOR parameters**

| Parameter | Associated primitive | Value |
|---|---|---|
| LENGTH | PHY-RXSTART.indication | 1–4095 |
| RSSI | PHY-RXSTART.indication (RXVECTOR) | (#1758)0–255 |

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**Table 17-2—RXVECTOR parameters *(continued)***

| Parameter | Associated primitive | Value |
|---|---|---|
| DATARATE | (#2381)PHY-RXSTART.indication (RXVECTOR) | 6, 9, 12, 18, 24, 36, 48, and 54 Mb/s for 20 MHz channel spacing (Support of 6, 12, and 24 Mb/s data rates is mandatory.)<br><br>3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s for 10 MHz channel spacing (Support of 3, 6, and 12 Mb/s data rates is mandatory.)<br><br>1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s for 5 MHz channel spacing (Support of 1.5, 3, and 6 Mb/s data rates is mandatory.) |
| SERVICE | (#2381)PHY-RXSTART.indication (RXVECTOR) | Null |
| RCPI (see NOTE) | PHY-RXEND.indication | (#2011)See 17.3.10.7 (Received channel power indicator (RCPI) measurement) |
| RX_ANTENNA (see NOTE) | PHY-RXSTART.indication (RXVECTOR)<br>PHY-RXEND.indication (RXVECTOR) | 0–255 |
| RX_START_OF_FRAME_OFFSET | PHY-RXSTART.indication (RXVECTOR) | (#1370)0 to $2^{32}$– 1. |
| CH_BANDWIDTH_IN_NON_HT | (#2381)PHY-RXSTART.indication (RXVECTOR) | If present, CBW20, CBW40, CBW80, CBW160, or CBW80+80 |
| DYN_BANDWIDTH_IN_NON_HT | (#2381)PHY-RXSTART.indication (RXVECTOR) | If present, Static or Dynamic |
| (#602)SCRAMBLER_INITIAL_VALUE | (#2381)PHY-RXSTART.indication (RXVECTOR) | If present, an integer in the range 1–127 |
| (11bd)CH_BANDWIDTH_IN_NON_NGV | PHY-RXSTART.request (RXVECTOR) | If present, CBW10 or CBW20 |
| (11bd)DYN_BANDWIDTH_IN_NON_NGV | PHY-RXSTART.request (RXVECTOR) | If present, Static or Dynamic |
| NOTE—Parameter is present only when dot11RadioMeasurementActivated is true. | | |

The allowed values for the LENGTH parameter are in the range 1–4095. This parameter is used to indicate the value contained in the LENGTH field which the PHY has received in the PHY header. (#6320)The MAC and PHY use this value to determine the number of octet transfers that will occur between them during the transfer of the received PSDU.

The allowed values for the RSSI parameter are in the range 0 to 255. This parameter is a (#1132)measurement by the PHY of the energy observed at the antenna connector used to receive the current PPDU. RSSI shall be measured during the reception of the PHY preamble. RSSI is intended to be used in a relative manner, and it shall be a monotonically increasing function of the received power.


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DATARATE shall represent the data rate at which the current PPDU was received. The allowed values of the DATARATE are 6, 9, 12, 18, 24, 36, 48, or 54 Mb/s for 20 MHz channel spacing; 3, 4.5, 6, 9, 12, 18, 24, or 27 Mb/s for 10 MHz channel spacing; and 1.5, 2.25, 3, 4.5, 6, 9, 12, or 13.5 Mb/s for 5 MHz channel spacing.

The SERVICE parameter shall be null.

(#1370)RX_START_FRAME_OFFSET is an estimate of the offset (in 10 ns units) from the point in time at which the start of the preamble (#14)of the PPDU arrived at the receive antenna connector to the point in time at which this primitive is issued to the MAC.

If present, the allowed values for CH_BANDWIDTH_IN_NON_HT are CBW20, CBW40, CBW80, CBW160, and CBW80+80. If present and valid, this parameter indicates the bandwidth of the non-HT duplicate PPDU. This parameter is used by the MAC only when valid (see 10.3.2.9 (CTS and DMG CTS procedure) and 10.6.6.6 (Channel Width selection for Control frames)).

NOTE 1—The CH_BANDWIDTH_IN_NON_HT parameter is not present when the (#14)PPDU is received by a non-VHT STA (see 10.6.12 (Channel Width in non-HT and non-HT duplicate PPDUs)).

If present, the allowed values for DYN_BANDWIDTH_IN_NON_HT are Static and Dynamic. If present and valid, this parameter indicates whether the transmitter is capable of dynamic bandwidth operation as an RTS originator (see 10.3.2.9 (CTS and DMG CTS procedure)).(#1782) This parameter is used by the MAC only when valid (see 10.3.2.9 (CTS and DMG CTS procedure) and 10.6.6.6 (Channel Width selection for Control frames)). If DYN_BANDWIDTH_IN_NON_HT is present, then CH_BANDWIDTH_IN_NON_HT is also present.

NOTE 2—The DYN_BANDWIDTH_IN_NON_HT parameter is not present when the (#14)PPDU is received by a non-VHT STA (see 10.6.12 (Channel Width in non-HT and non-HT duplicate PPDUs)).

SCRAMBLER_INITIAL_VALUE is present in an HE STA, and is the integer representation of the first 7 bits of the scrambling sequence (the first 7 bits received in the SERVICE field prior to descrambling), with the first bit of the scrambling sequence being the LSB of SCRAMBLER_INITIAL_VALUE.

SCRAMBLER_INITIAL_VALUE is not present in a non-HE STA.

(11bd)If present and valid, CH_BANDWIDTH_IN_NON_NGV indicates the bandwidth of the non-NGV duplicate PPDU. This parameter is used by the MAC only when valid (see 10.3.2.9 (CTS and DMG CTS procedure) and 10.6.6.6 (Channel Width selection for Control frames)).

(11bd)NOTE 3—The CH_BANDWIDTH_IN_NON_NGV parameter is not present when the frame is received by a non-NGV STA (see 10.6.12 (Channel Width in non-HT and non-HT duplicate PPDUs)).

If present and valid, DYN_BANDWIDTH_IN_NON_NGV indicates whether the transmitter is capable of Static or Dynamic bandwidth operation. This parameter is used by the MAC only when valid (see 10.3.2.9 (CTS and DMG CTS procedure) and 10.6.6.6 (Channel Width selection for Control frames)). If DYN_BANDWIDTH_IN_NON_NGV is present, then CH_BANDWIDTH_IN_NON_NGV is also present.

NOTE 4—The DYN_BANDWIDTH_IN_NON_NGV parameter is not present when the frame is received by a non-NGV STA (see 10.6.12 (Channel Width in non-HT and non-HT duplicate PPDUs)).

### 17.2.4 TXSTATUS parameters(#1369)

The parameters listed in Table 17-3 (TXSTATUS parameters) are defined as part of the TXSTATUS parameter list in the PHY-TXSTART.confirm primitive.

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**Table 17-3—TXSTATUS parameters**

| Parameter | Associated primitive | Value |
|---|---|---|
| TIME_OF_DEPARTURE | PHY-TXSTART.confirm | 0 to $2^{32}$– 1. The locally measured time when the first (#14)PPDU energy is sent by the transmitting port, in units equal to 1/ TIME_OF_DEPARTURE_ClockRate. This parameter is present only if TIME_OF_DEPARTURE_REQUESTED is true in the corresponding request. |
| TIME_OF_DEPARTURE_ClockRate | PHY-TXSTART.confirm | 0 to $2^{16}$– 1. The clock rate, in units of MHz, is used to generate the TIME_OF_DEPARTURE value. This parameter is present only if TIME_OF_DEPARTURE_REQUESTED is true in the corresponding request. |
| TX_START_OF_FRAME_OFFSET | PHY-TXSTART.confirm | 0 to $2^{32}$– 1. An estimate of the offset (in 10 ns units) from the point in time at which the start of the preamble (#14)of the PPDU was transmitted at the transmit antenna connector to the point in time at which this primitive is issued to the MAC. |

The allowed values for the TIME_OF_DEPARTURE parameter are integers in the range 0 to $2^{32}$– 1. This parameter is used to indicate when the first (#14)PPDU energy is sent by the transmitting port in units equal to 1/TIME_OF_DEPARTURE_ClockRate. TIME_OF_DEPARTURE may be included in the transmitted frame in order for recipients on multiple channels to determine the time differences of air propagation times between transmitter and recipients and hence to compute the location of the transmitter.

TIME_OF_DEPARTURE_ClockRate indicates the clock rate used for TIME_OF_DEPARTURE.

## 17.3 OFDM PHY

### 17.3.1 Introduction

Subclause 17.3 (OFDM PHY) provides a convergence procedure in which PSDUs are converted to and from PPDUs. During transmission, the PSDU shall be provided with a PHY preamble and header to create the PPDU. At the receiver, the PHY preamble and header are processed to aid in demodulation and delivery of the PSDU.

### 17.3.2 PPDU format

#### 17.3.2.1 General

Figure 17-1 (PPDU format) shows the format for the PPDU including the OFDM PHY preamble, OFDM PHY header, PSDU, tail bits, and pad bits. The PHY header contains the following fields: LENGTH, RATE, a reserved bit, an even parity bit, and the SERVICE field. In terms of modulation, the LENGTH, RATE, reserved bit, and parity bit (with 6 zero tail bits appended) constitute a separate single OFDM symbol, denoted SIGNAL, which is transmitted with the most robust combination of BPSK modulation and a coding rate of R = 1/2. The SERVICE field of the PHY header and the PSDU (with 6 zero tail bits and pad bits appended), denoted as DATA, are transmitted at the data rate described in the RATE field and may constitute multiple OFDM symbols. The tail bits in the SIGNAL symbol enable decoding of the RATE and LENGTH fields immediately after the reception of the tail bits. The RATE and LENGTH fields are required


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for decoding the DATA field of the PPDU. In addition, the CCA mechanism is augmented by predicting the duration of the PPDU from the contents of the RATE and LENGTH fields, even if the data rate is not supported by the STA. Each of these fields is described in detail in 17.3.3 (PHY preamble (SYNC)), 17.3.4 (SIGNAL field), and 17.3.5 (DATA field).

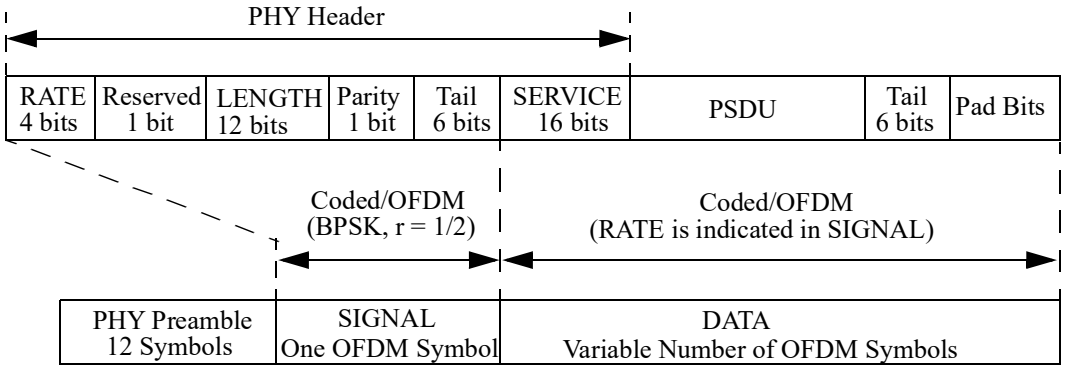


**Figure 17-1—PPDU format**

### 17.3.2.2 Overview of the PPDU encoding process

The encoding process is composed of many detailed steps, which are described fully in later subclauses, as noted below. The following overview intends to facilitate understanding the details of the convergence procedure:

a) Produce the PHY Preamble field, composed of 10 repetitions of a "short training sequence" (used for AGC convergence, diversity selection, timing acquisition, and coarse frequency acquisition in the receiver) and two repetitions of a "long training sequence" (used for channel estimation and fine frequency acquisition in the receiver), preceded by a guard interval (GI). Refer to 17.3.3 (PHY preamble (SYNC)) for details.

b) Produce the PHY header field from the RATE, LENGTH, and SERVICE parameters(#1875) of the TXVECTOR by filling the appropriate fields(#291). The RATE and LENGTH fields of the PHY header are encoded by a convolutional code at a rate of R = 1/2, and are subsequently mapped onto a single BPSK encoded OFDM symbol, denoted as the SIGNAL symbol. In order to facilitate a reliable and timely detection of the RATE and LENGTH fields, 6 zero tail bits are inserted into the PHY header. The encoding of the SIGNAL field into an OFDM symbol follows the same steps for convolutional encoding, interleaving, BPSK modulation, pilot insertion, Fourier transform, and prepending a GI as described subsequently for data transmission with BPSK-OFDM modulated at coding rate 1/2. The contents of the SIGNAL field are not scrambled. Refer to 17.3.4 (SIGNAL field) for details.

c) Calculate from RATE parameter(#1875) of the TXVECTOR the number of data bits per OFDM symbol ($N_{DBPS}$), the coding rate (R), the number of bits in each OFDM subcarrier ($N_{BPSC}$), and the number of coded bits per OFDM symbol ($N_{CBPS}$). Refer to 17.3.2.3 (Modulation-dependent parameters) for details.

d) Append the PSDU to the SERVICE parameter(#1875) of the TXVECTOR. Extend the resulting bit string with zero bits (at least 6 bits) so that the resulting length is a multiple of $N_{DBPS}$. The resulting bit string constitutes the DATA field of the PPDU. Refer to 17.3.5.4 (Pad bits (PAD)) for details.

e) (#602)Generate the scrambling sequence as defined in 17.3.5.5 (PHY DATA scrambler and descrambler) and XOR the scrambling sequence with the extended string of data bits.

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f) Replace the six scrambled zero bits following the data with six nonscrambled zero bits. (Those bits return the convolutional encoder to the zero state and are denoted as tail bits.) Refer to 17.3.5.3 (PPDU TAIL field) for details.

g) Encode the extended, scrambled data string with a convolutional encoder (R = 1/2). Omit (puncture) some of the encoder output string (chosen according to "puncturing pattern") to reach the "coding rate" corresponding to the TXVECTOR parameter RATE. Refer to 17.3.5.6 (Convolutional encoder) for details.

h) Divide the encoded bit string into groups of $N_{CBPS}$ bits. Within each group, perform an "interleaving" (reordering) of the bits according to a rule corresponding to the TXVECTOR parameter RATE. Refer to 17.3.5.7 (Data interleaving) for details.

i) Divide the resulting coded and interleaved data string into groups of $N_{BPSC}$ bits. For each of the bit groups, convert the bit group into a complex number according to the modulation encoding tables. Refer to 17.3.5.8 (Subcarrier modulation mapping) for details.

j) Divide the complex number string into groups of 48 complex numbers. Each such group is associated with one OFDM symbol. In each group, the complex numbers are numbered 0 to 47 and mapped hereafter into OFDM subcarriers numbered –26 to –22, –20 to –8, –6 to –1, 1 to 6, 8 to 20, and 22 to 26. The subcarriers –21, –7, 7, and 21 are skipped and, subsequently, used for inserting pilot subcarriers. The 0 subcarrier, associated with center frequency, is omitted and filled with the value 0. Refer to 17.3.5.10 (OFDM modulation) for details.

k) Four subcarriers are inserted as pilots into positions –21, –7, 7, and 21. The total number of the subcarriers is 52 (48 + 4). Refer to 17.3.5.9 (Pilot subcarriers) for details.

l) For each group of subcarriers –26 to 26, convert the subcarriers to time domain using inverse Fourier transform. Prepend to the Fourier-transformed waveform a circular extension of itself thus forming a GI, and truncate the resulting periodic waveform to a single OFDM symbol length by applying time domain windowing. Refer to 17.3.5.10 (OFDM modulation) for details.

m) Append the OFDM symbols one after another, starting after the SIGNAL symbol describing the RATE and LENGTH fields. Refer to 17.3.5.10 (OFDM modulation) for details.

n) Upconvert the resulting "complex baseband" waveform to an RF according to the center frequency of the operating channel and transmit. Refer to 17.3.2.5 (Mathematical conventions in the signal descriptions) and 17.3.8.2 (Outline description) for details(#1312).

### 17.3.2.3 Modulation-dependent parameters

The modulation parameters dependent on the data rate used shall be set according to Table 17-4 (Modulation-dependent parameters).

**Table 17-4—Modulation-dependent parameters**

| Modulation | Coding rate ($R$) | Coded bits per subcarrier ($N_{BPSC}$) | Coded bits per OFDM symbol ($N_{CBPS}$) | Data bits per OFDM symbol ($N_{DBPS}$) | Data rate (Mb/s) (20 MHz channel spacing) | Data rate (Mb/s) (10 MHz channel spacing) | Data rate (Mb/s) (5 MHz channel spacing) |
|---|---|---|---|---|---|---|---|
| BPSK | 1/2 | 1 | 48 | 24 | 6 | 3 | 1.5 |
| BPSK | 3/4 | 1 | 48 | 36 | 9 | 4.5 | 2.25 |
| QPSK | 1/2 | 2 | 96 | 48 | 12 | 6 | 3 |
| QPSK | 3/4 | 2 | 96 | 72 | 18 | 9 | 4.5 |


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**Table 17-4—Modulation-dependent parameters**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 16-QAM | 1/2 | 4 | 192 | 96 | 24 | 12 | 6 |
| 16-QAM | 3/4 | 4 | 192 | 144 | 36 | 18 | 9 |
| 64-QAM | 2/3 | 6 | 288 | 192 | 48 | 24 | 12 |
| 64-QAM | 3/4 | 6 | 288 | 216 | 54 | 27 | 13.5 |

### 17.3.2.4 Timing-related parameters

Table 17-5 (Timing-related parameters) is the list of timing parameters associated with the OFDM PHY.

**Table 17-5—Timing-related parameters**

| Parameter | Value (20 MHz channel spacing) | Value (10 MHz channel spacing) | Value (5 MHz channel spacing) |
|---|---|---|---|
| $N_{SD}$: Number of data subcarriers | 48 | 48 | 48 |
| $N_{SP}$: Number of pilot subcarriers | 4 | 4 | 4 |
| $N_{ST}$: Number of subcarriers, total | 52 ($N_{SD} + N_{SP}$) | 52 ($N_{SD} + N_{SP}$) | 52 ($N_{SD} + N_{SP}$) |
| $\Delta_F$: Subcarrier frequency spacing | 0.3125 MHz (=20 MHz/64) | 0.156 25 MHz (= 10 MHz/64) | 0.078 125 MHz (= 5 MHz/64) |
| $T_{FFT}$: Inverse Fast Fourier Transform (IFFT) / Fast Fourier Transform (FFT) period | 3.2 µs ($1/\Delta_F$) | 6.4 µs ($1/\Delta_F$) | 12.8 µs ($1/\Delta_F$) |
| $T_{PREAMBLE}$: PHY preamble duration | 16 µs ($T_{SHORT} + T_{LONG}$) | 32 µs ($T_{SHORT} + T_{LONG}$) | 64 µs ($T_{SHORT} + T_{LONG}$) |
| $T_{SIGNAL}$: Duration of the SIGNAL BPSK-OFDM symbol | 4.0 µs ($T_{GI} + T_{FFT}$) | 8.0 µs ($T_{GI} + T_{FFT}$) | 16.0 µs ($T_{GI} + T_{FFT}$) |
| $T_{GI}$: GI duration | 0.8 µs ($T_{FFT}/4$) | 1.6 µs ($T_{FFT}/4$) | 3.2 µs ($T_{FFT}/4$) |
| $T_{GI2}$: Training symbol GI duration | 1.6 µs ($T_{FFT}/2$) | 3.2 µs ($T_{FFT}/2$) | 6.4 µs ($T_{FFT}/2$) |
| $T_{SYM}$: Symbol interval | 4 µs ($T_{GI} + T_{FFT}$) | 8 µs ($T_{GI} + T_{FFT}$) | 16 µs ($T_{GI} + T_{FFT}$) |
| $T_{SHORT}$: Short training sequence duration | 8 µs ($10 \times T_{FFT}/4$) | 16 µs ($10 \times T_{FFT}/4$) | 32 µs ($10 \times T_{FFT}/4$) |
| $T_{LONG}$: Long training sequence duration | 8 µs ($T_{GI2} + 2 \times T_{FFT}$) | 16 µs ($T_{GI2} + 2 \times T_{FFT}$) | 32 µs ($T_{GI2} + 2 \times T_{FFT}$) |

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### 17.3.2.5 Mathematical conventions in the signal descriptions

The transmitted signals are described in a complex baseband signal notation. The actual transmitted signal is related to the complex baseband signal by the following relation:

$$r_{(RF)}\langle t\rangle = Re\{r\langle t\rangle \exp\langle j2\pi f_c t\rangle\} \quad (17\text{-}1)$$

where

$f_c$ denotes the carrier center frequency

The transmitted baseband signal is composed of contributions from several OFDM symbols(#14).

$$r_{PPDU}(t) = r_{PREAMBLE}(t) + r_{SIGNAL}(t - t_{SIGNAL}) + r_{DATA}(t - t_{DATA}) \quad (17\text{-}2)$$

(#14)The fields of which Equation (17-2) are composed are described in 17.3.3 (PHY preamble (SYNC)), 17.3.4 (SIGNAL field), and 17.3.5.10 (OFDM modulation). The time offsets $t_{FIELD}$ determine the starting time of the corresponding field; $t_{SIGNAL}$ is equal to 16 μs for 20 MHz channel spacing, 32 μs for 10 MHz channel spacing, and 64 μs for 5 MHz channel spacing, and $t_{DATA}$ is equal to 20 μs for 20 MHz channel spacing, 40 μs for 10 MHz channel spacing, and 80 μs for 5 MHz channel spacing.

(#14)All of the fields of the signal are constructed as the summation of one or more subfields, where each subfield is defined to be a windowed inverse Fourier transform of a set of coefficients, $C_k$, with $C_k$ defined later as data, pilots, or training symbols in 17.3.3 (PHY preamble (SYNC)) to 17.3.5 (DATA field)(#14).

$$r_{SUBFIELD}(t) = w_{TSUBFIELD}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} C_k \exp(j2\pi k\Delta_f)(t - T_{GUARD}) \quad (17\text{-}3)$$

The parameters $\Delta_F$ and $N_{ST}$ are described in Table 17-5 (Timing-related parameters). The resulting waveform is periodic with a period of $T_{FFT} = 1/\Delta_F$. Shifting the time by $T_{GUARD}$ creates the "circular prefix" used in OFDM to avoid ISI from the previous (#14)subfield. Three kinds of $T_{GUARD}$ are defined: for the short training sequence (= 0 μs), for the long training sequence (= $T_{GI2}$), and for data OFDM symbols (= $T_{GI}$). (Refer to Table 17-5 (Timing-related parameters).) The boundaries of the (#14)subfield are set by a multiplication by a time-windowing function, (#14)$w_{TSUBFIELD}(t)$, which is defined as a rectangular pulse, $w_T(t)$, of duration $T$, accepting the value (#14)$T_{SUBFIELD}$. The time-windowing function, $w_T(t)$, depending on the value of the duration parameter, $T$, may extend over more than one period, $T_{FFT}$. In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble. Figure 17-2 (Illustration of OFDM subfield with cyclic extension and windowing for (a) single reception or (b) two receptions of the FFT period(#14)) illustrates the possibility of extending the windowing function over more than one period, $T_{FFT}$, and additionally shows smoothed transitions by application of a windowing function, as exemplified in Equation (17-4). In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble.

$$w_T(t) = \begin{cases} \sin^2\left(\frac{\pi}{2}(0.5 + t/T_{TR})\right) & (-T_{TR}/2 < t < T_{TR}/2) \\ 1 & (T_{TR}/2 \le t < T - T_{TR}/2) \\ \sin^2\left(\frac{\pi}{2}(0.5 - (t-T)/T_{TR})\right) & (T - T_{TR}/2 \le t < T + T_{TR}/2) \end{cases} \quad (17\text{-}4)$$

In the case of vanishing $T_{TR}$, the windowing function degenerates into a rectangular pulse of duration $T$. This standard describes transmitted waveforms using a rectangular pulse shape. In a typical implementation, a higher $T_{TR}$ is used in order to smooth the transitions between consecutive subsections. This creates a small


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overlap between them, of duration $T_{TR}$, as shown in Figure 17-2 (Illustration of OFDM subfield with cyclic extension and windowing for (a) single reception or (b) two receptions of the FFT period(#14)). The transition time, $T_{TR}$, is about 100 ns. Smoothing the transition is required in order to reduce the spectral sidelobes of the transmitted waveform. However, the binding requirements are the spectral mask and modulation accuracy requirements, as detailed in 17.3.9.3 (Transmit spectrum mask) and 17.3.9.7 (Modulation accuracy). Time domain windowing, as described here, is just one way to achieve those objectives. The implementer may use other methods to achieve the same goal, such as frequency domain filtering.

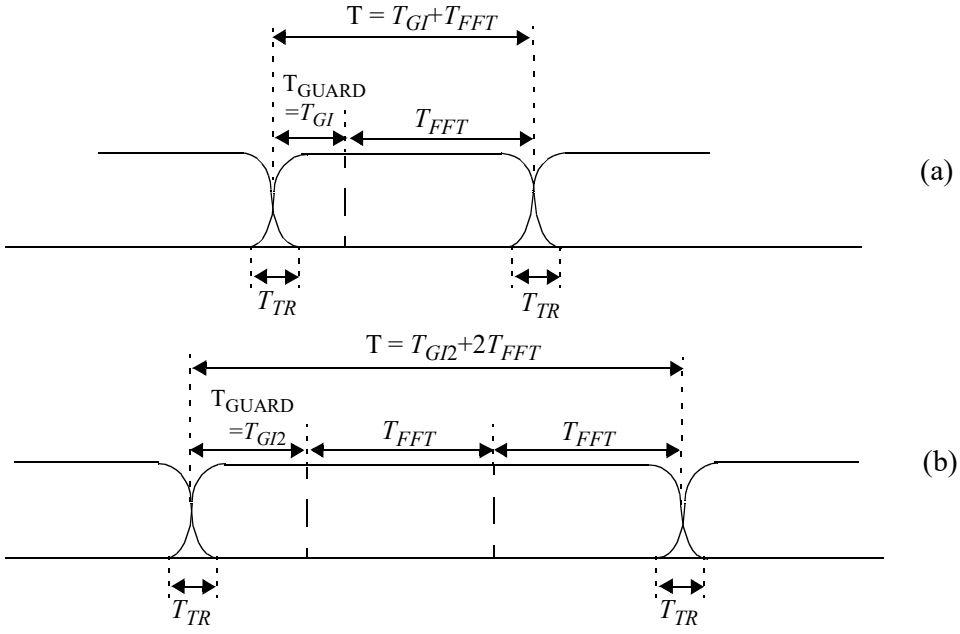


**Figure 17-2—Illustration of OFDM subfield with cyclic extension and windowing for (a) single reception or (b) two receptions of the FFT period(#14)**

### 17.3.2.6 Discrete time implementation considerations

The following descriptions of the discrete time implementation are informational.

In a typical implementation, the windowing function is represented in discrete time. As an example, when a windowing function with parameters T = 4.0 μs and a $T_{TR}$ = 100 ns is applied, and the signal is sampled at 20 Msample/s, it becomes

$$w_T[n] = w_T(nT_S) = \begin{Bmatrix} 1 & 1 \le n \le 79 \\ 0.5 & 0, 80 \\ 0 & otherwise \end{Bmatrix} \quad (17\text{-}5)$$

The common way to implement the inverse Fourier transform, as shown in Equation (17-3), is by an IFFT algorithm. If, for example, a 64-point IFFT is used, the coefficients 1 to 26 are mapped to the same numbered IFFT inputs, while the coefficients –26 to –1 are copied into IFFT inputs 38 to 63. The rest of the inputs, 27 to 37 and the 0 (dc) input, are set to 0. This mapping is illustrated in Figure 17-3 (Inputs and outputs of inverse Fourier transform). After performing an IFFT, the output is cyclically extended and the resulting waveform is windowed to the required OFDM symbol length.

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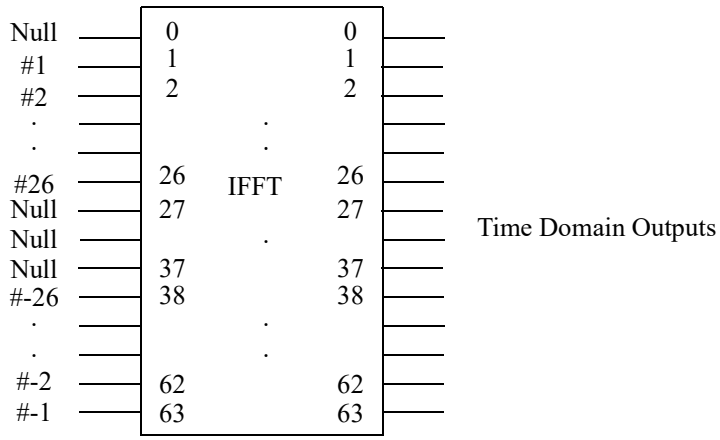


**Figure 17-3—Inputs and outputs of inverse Fourier transform**

### 17.3.3 PHY preamble (SYNC)

The PHY Preamble field is used for synchronization. It consists of 10 short symbols and two long symbols that are shown in Figure 17-4 (OFDM training structure) and described in this subclause. The timings described in this subclause and shown in Figure 17-4 (OFDM training structure) are for 20 MHz channel spacing. They are doubled for half-clocked (i.e., 10 MHz) channel spacing and are quadrupled for quarter-clocked (i.e., 5 MHz) channel spacing.

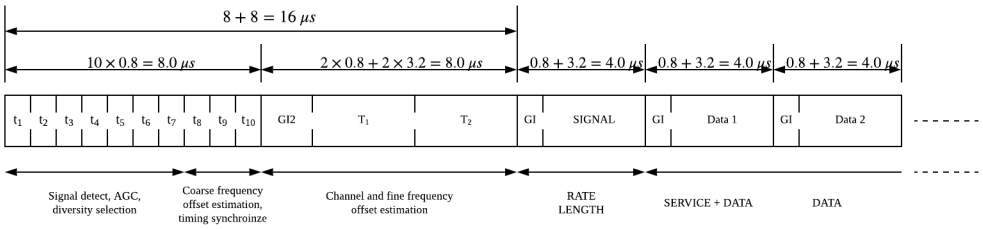


**Figure 17-4—OFDM training structure**

Figure 17-4 (OFDM training structure) shows the OFDM training structure (PHY preamble), where $t_1$ to $t_{10}$ denote short training symbols and $T_1$ and $T_2$ denote long training symbols. The PHY preamble is followed by the SIGNAL field and DATA. The total training length is 16 μs. The dashed boundaries in the figure denote repetitions due to the periodicity of the inverse Fourier transform.

A short OFDM training symbol consists of 12 subcarriers, which are modulated by the elements of the sequence S, given by

$$S_{-26,26} = \sqrt{(13/6)} \times \{0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 0, 0,$$

$$0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0\}$$ (#6297) (17-6)

The multiplication by a factor of $\sqrt{(13/6)}$ is in order to normalize the average power of the resulting OFDM symbol, which utilizes 12 out of 52 subcarriers.


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The signal shall be generated according to the following equation:

$$r_{SHORT}(t) = w_{TSHORT}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} S_k \exp(j2\pi k\Delta_F t) \quad (17\text{-}7)$$

The fact that only spectral lines of $S_{-26:26}$ with indices that are a multiple of 4 have nonzero amplitude results in a periodicity of $T_{FFT}/4 = 0.8$ μs. The interval $T_{SHORT}$ is equal to ten 0.8 μs periods (i.e., 8 μs).

Generation of the short training sequence is illustrated in Table I-2 (Frequency domain representation of the short sequences).

A long OFDM training symbol consists of 53 subcarriers (including the value 0 at dc), which are modulated by the elements of the sequence L, given by

$$L_{-26,26} = \{1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 0,$$

$$1, -1, -1, 1, 1, -1, 1, -1, 1, -1, -1, -1, -1, -1, 1, 1, -1, -1, 1, -1, 1, -1, 1, 1, 1, 1\} \quad (17\text{-}8)$$

A long OFDM training symbol shall be generated according to the following equation:

$$r_{LONG}(t) = w_{TLONG}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} L_k \exp(j2\pi k\Delta_F (t - T_{G12})) \quad (17\text{-}9)$$

where

$T_{G\,12} = 1.6$ μs

Two periods of the long sequence are transmitted for improved channel estimation accuracy, yielding $T_{LONG} = 1.6 + 2 \times 3.2 = 8$ μs.

An illustration of the long training sequence generation is given in Table I-5 (Frequency domain representation of the long sequences).

The sections of short repetitions and long repetitions shall be concatenated to form the preamble

$$r_{PREAMBLE}(t) = r_{SHORT}(t) + r_{LONG}(t - T_{SHORT}) \quad (17\text{-}10)$$

### 17.3.4 SIGNAL field

#### 17.3.4.1 General

The OFDM training symbols shall be followed by the SIGNAL field, which contains the RATE and the LENGTH parameters(#1875) of the TXVECTOR. The RATE field conveys information about the type of modulation and the coding rate as used in the rest of the PPDU. The encoding of the SIGNAL single OFDM symbol shall be performed with BPSK modulation of the subcarriers and using convolutional coding at R = 1/2. The encoding procedure, which includes convolutional encoding, interleaving, modulation mapping processes, pilot insertion, and OFDM modulation, follows the steps described in 17.3.5.6 (Convolutional encoder), 17.3.5.7 (Data interleaving), and 17.3.5.9 (Pilot subcarriers), as used for transmission of data with BPSK-OFDM modulated at coding rate 1/2. The contents of the SIGNAL field are not scrambled.

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The SIGNAL field shall be composed of 24 bits, as shown in Figure 17-5 (SIGNAL field bit assignment). The four bits 0 to 3 shall encode the RATE. Bit 4 shall be reserved for future use. Bits 5–16 shall encode the LENGTH parameter(#1875) of the TXVECTOR, with the LSB being transmitted first.

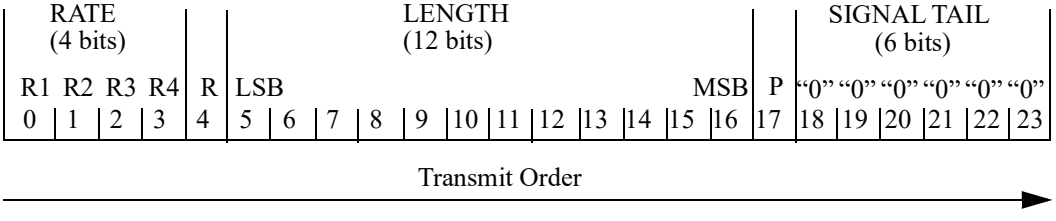


**Figure 17-5—SIGNAL field bit assignment**

The process of generating the SIGNAL OFDM symbol is illustrated in I.1.4 (Generation of the SIGNAL field).

### 17.3.4.2 RATE field

The bits R1–R4 shall be set, dependent on RATE, according to the values in Table 17-6 (Contents of the SIGNAL field).

**Table 17-6—Contents of the SIGNAL field**

| R1–R4 | Rate (Mb/s) (20 MHz channel spacing) | Rate (Mb/s) (10 MHz channel spacing) | Rate (Mb/s) (5 MHz channel spacing) |
|---|---|---|---|
| 1101 | 6 | 3 | 1.5 |
| 1111 | 9 | 4.5 | 2.25 |
| 0101 | 12 | 6 | 3 |
| 0111 | 18 | 9 | 4.5 |
| 1001 | 24 | 12 | 6 |
| 1011 | 36 | 18 | 9 |
| 0001 | 48 | 24 | 12 |
| 0011 | 54 | 27 | 13.5 |

### 17.3.4.3 PHY LENGTH field

The PHY LENGTH field shall be an unsigned 12-bit integer that indicates the number of octets in the PSDU that the MAC is currently requesting the PHY to transmit. This value is used by the PHY to determine the number of octet transfers that will occur between the MAC and the PHY after receiving a request to start transmission. The transmitted value shall be determined from the LENGTH parameter in the TXVECTOR issued with the PHY-TXSTART.request primitive described in 8.3.5.5 (PHY-TXSTART.request). The LSB shall be transmitted first in time. This field shall be encoded by the convolutional encoder described in 17.3.5.6 (Convolutional encoder).


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#### 17.3.4.4 Parity (P), Reserved (R), and SIGNAL TAIL fields

Bit 4 is reserved. It shall be set to 0 on transmit and ignored on receive. Bit 17 shall be a positive parity (even parity) bit for bits 0–16. The bits 18–23 constitute the SIGNAL TAIL field, and all 6 bits shall be set to 0.

### 17.3.5 DATA field

#### 17.3.5.1 General

The DATA field contains the SERVICE field, the PSDU, the TAIL bits, and the PAD bits, if needed, as described in 17.3.5.3 (PPDU TAIL field) and 17.3.5.4 (Pad bits (PAD)). All bits in the DATA field are scrambled, as described in 17.3.5.5 (PHY DATA scrambler and descrambler).

#### 17.3.5.2 SERVICE field

The SERVICE field has 16 bits, which shall be denoted as bits 0–15. The bit 0 shall be transmitted first in time. The bits from 0–6 of the SERVICE field, which are transmitted first, are set to 0s and are used to synchronize the descrambler in the receiver. The remaining 9 bits (7–15) of the SERVICE field shall be reserved for future use. All reserved bits shall be set to 0 on transmission and ignored on reception. Refer to Figure 17-6 (SERVICE field bit assignment).

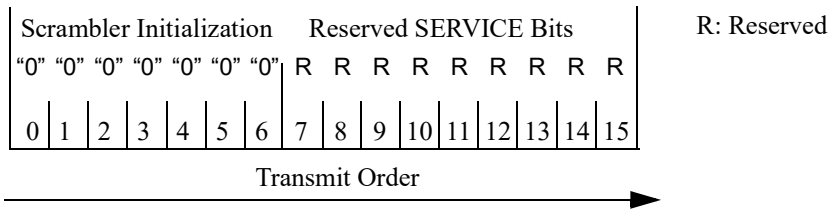


**Figure 17-6—SERVICE field bit assignment**

#### 17.3.5.3 PPDU TAIL field

The PPDU TAIL field shall be six bits of 0, which are required to return the convolutional encoder to the zero state. This procedure improves the error probability of the convolutional decoder, which relies on future bits when decoding and which may be not be available past the end of the message. The PPDU TAIL field shall be produced by replacing six scrambled zero bits following the message end with six nonscrambled zero bits.

#### 17.3.5.4 Pad bits (PAD)

The number of bits in the DATA field shall be a multiple of $N_{CBPS}$, the number of coded bits in an OFDM symbol (48, 96, 192, or 288 bits). To achieve that, the length of the message is extended so that it becomes a multiple of $N_{DBPS}$, the number of data bits per OFDM symbol. At least 6 bits are appended to the message, in order to accommodate the TAIL bits, as described in 17.3.5.3 (PPDU TAIL field). The number of OFDM symbols, $N_{SYM}$; the number of bits in the DATA field, $N_{DATA}$; and the number of pad bits, $N_{PAD}$, are computed from the length of the PSDU (LENGTH) as follows:

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$$N_{SYM} = \left\lceil \frac{16 + 8 \times \text{LENGTH} + 6}{N_{DBPS}} \right\rceil \quad (17\text{-}11)$$

$$N_{DATA} = N_{SYM} \times N_{DBPS} \quad (17\text{-}12)$$

$$N_{PAD} = N_{DATA} - (16 + 8 \times \text{LENGTH} + 6) \quad (17\text{-}13)$$

The appended bits ("pad bits") are set to 0 and are subsequently scrambled with the rest of the bits in the DATA field.

An example of a DATA field that contains the SERVICE field, DATA, tail, and pad bits is given in I.1.5.1 (Delineating, SERVICE field prepending, and zero padding).

### 17.3.5.5 PHY DATA scrambler and descrambler

The DATA field, composed of SERVICE, PSDU, tail, and pad parts, shall be scrambled with a length-127 PPDU-synchronous scrambler. The octets of the PSDU are placed in the transmit serial bit stream, bit 0 first and bit 7 last. The PPDU synchronous scrambler uses the generator polynomial *S(x)* as follows and is illustrated in Figure 17-7 (Data scrambler(11bd)(#602)(#7080)):

$$S(x) = x^7 + x^4 + 1 \quad (17\text{-}14)$$

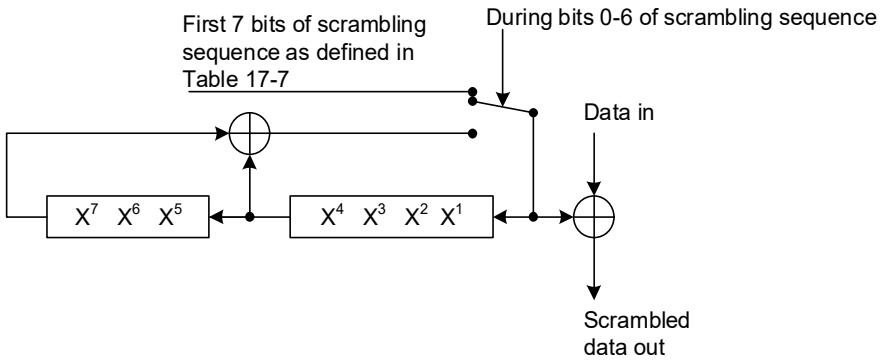


**Figure 17-7—Data scrambler(11bd)(#602)(#7080)**

NOTE 1—The 127-bit sequence generated repeatedly by the scrambler is (leftmost used first) 00001110 11110010 11001001 00000010 00100110 00101110 10110110 00001100 11010100 11100111 10110100 00101010 11111010 01010001 10111000 1111111, (#602)when the TXVECTOR parameter SCRAMBLER_INITIAL_VALUE is present and has the value 112 (1110000 in binary representation).

The same scrambler is used to scramble transmit data and to descramble receive data. (#602)The first 7 bits of the scrambling sequence shall be set as shown in Table 17-7 (Contents of the first 7 bits of the scrambling sequence). The scrambler shall generate the scrambling sequence as shown in Figure 17-7 (Data scrambler(11bd)(#602)(#7080)).

If the TXVECTOR parameter SCRAMBLER_RESET is (#1254)RESET_SCRAMBLER and dot11MACPrivacyActivated is true, (#602)the bits corresponding to pseudorandom integer within the first 7 bits of the scrambling sequence (see Table 17-7 (Contents of the first 7 bits of the scrambling sequence)) shall be set to a nonzero random value not based on the scrambler value at the end of the last transmitted PPDU.


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During reception by a VHT STA, RXVECTOR parameter CH_BANDWIDTH_IN_NON_HT shall be determined from selected bits in the scrambling sequence as shown in Table 17-7 (Contents of the first 7 bits of the scrambling sequence) and Table 17-10 (RXVECTOR parameter CH_BANDWIDTH_IN_NON_HT values). During reception by a VHT STA, the RXVECTOR parameter DYN_BANDWIDTH_IN_NON_HT shall be set to selected bits in the scrambling sequence as shown in Table 17-7 (Contents of the first 7 bits of the scrambling sequence). The fields shall be interpreted as being sent LSB-first.

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**Table 17-7—Contents of the first 7 bits of the scrambling sequence**

| Parameter | Condition | First 7 bits of scrambling sequence | | | |
|---|---|---|---|---|---|
| | | B0 | B3 | B4 | B5 B6 |
| | | Transmit order → | | | |
| TXVECTOR | CH_BANDWIDTH_IN_NON_HT is present and DYN_BANDWIDTH_IN_NON_HT is not present in TXVECTOR(#602)(11bd); or CH_BANDWIDTH_IN_NON_NGV is present and DYN_BANDWIDTH_IN_NON_NGV is not present in TXVECTOR | 5-bit pseudorandom nonzero integer if CH_BANDWIDTH_IN_NON_HT (11bd)(if present) equals CBW20 or CH_BANDWIDTH_IN_NON_NGV (if present) equals CBW10; and a 5-bit pseudorandom integer otherwise | | | CH_BANDWIDTH_IN_NON_HT (11bd)(if present) or CH_BANDWIDTH_IN_NON_NGV (if present) |
| TXVECTOR | CH_BANDWIDTH_IN_NON_HT is present and DYN_BANDWIDTH_IN_NON_HT is present in TXVECTOR(#602)(11bd); or CH_BANDWIDTH_IN_NON_NGV is present and DYN_BANDWIDTH_IN_NON_NGV is present in TXVECTOR | 4-bit pseudorandom nonzero integer if CH_BANDWIDTH_IN_NON_HT (11bd)(if present) equals CBW20 and DYN_BANDWIDTH_IN_NON_HT (if present) equals Static, or CH_BANDWIDTH_IN_NON_NGV (if present) equals CBW10 and DYN_BANDWIDTH_IN_NON_NGV (if present) equals Static; and a 4-bit pseudorandom integer otherwise | | DYN_BANDWIDTH_IN_NON_HT (11bd)(if present) or DYN_BANDWIDTH_IN_NON_NGV (if present) | |
| (#602)TXVECTOR | SCRAMBLER_INITIAL_VALUE is present | SCRAMBLER_INITIAL_VALUE | | | |
| (#602)TXVECTOR | CH_BANDWIDTH_IN_NON_HT and SCRAMBLER_INITIAL_VALUE are not present | 7-bit pseudorandom nonzero integer | | | |
| RXVECTOR | VHT STA(#602)(#7080) | — | | DYN_BANDWIDTH_IN_NON_HT (#7080) | CH_BANDWIDTH_IN_NON_HT_INDICATOR (#7080) (see Table 17-10 (RXVECTOR parameter CH_BANDWIDTH_IN_NON_HT values))(#7080) |



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**Table 17-7—Contents of the first 7 bits of the scrambling sequence**

| | | | | |
|---|---|---|---|---|
| (#7080)RXVECTOR | NGV STA | — | DYN_BANDWIDTH_IN_NON_NGV | CH_BANDWIDTH_IN_NON_NGV_INDICATOR (see Table 17-11 (RXVECTOR parameter CH_BANDWIDTH_IN_NON_NGV values)) |
| (#602)RXVECTOR | HE STA | SCRAMBLER_INITIAL_VALUE | | |

(#602)The encoding of CH_BANDWIDTH_IN_NON_HT is shown in Table 17-8 (TXVECTOR parameter CH_BANDWIDTH_IN_NON_HT values) and Table 17-10 (RXVECTOR parameter CH_BANDWIDTH_IN_NON_HT values) for TXVECTOR and RXVECTOR, respectively. The encoding of DYN_BANDWIDTH_IN_NON_HT is shown in Table 17-12 (DYN_BANDWIDTH_IN_NON_HT values).

(#602)(#3450)NOTE 1—Since CH_BANDWIDTH_IN_NON_HT and SCRAMBLER_INITIAL_VALUE are transmitted LSB first, if, for example, CH_BANDWIDTH_IN_NON_HT is CBW80 (whose (#4317)numeric value is 2), then B5=0 and B6=1.

(#602)NOTE 2—SCRAMBLER_INITIAL_VALUE is present in PPDUs carrying an MU-RTS Trigger frame and PPDUs carrying a CTS frame (#1926)sent in response to an MU-RTS Trigger frame. Also, CH_BANDWIDTH_IN_NON_HT and DYN_BANDWIDTH_IN_NON_HT are used when a bandwidth signaling TA is used. But the bandwidth signaling TA is not used in an MU-RTS Trigger frame or a CTS frame (#1926)sent in response to an MU-RTS Trigger frame (see 26.2.6.3 (CTS frame sent in response to an MU-RTS Trigger frame(#1926))). Hence, TXVECTOR parameters CH_BANDWIDTH_IN_NON_HT and DYN_BANDWIDTH_IN_NON_HT and TXVECTOR parameter SCRAMBLER_INITIAL_VALUE are not both present in a given PPDU.

**Table 17-8—TXVECTOR parameter CH_BANDWIDTH_IN_NON_HT values**

| Enumerated value | Value |
|---|---|
| CBW20 | 0 |
| CBW40 | 1 |
| CBW80 | 2 |
| CBW160 or CBW80+80 | 3 |

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**Table 17-9—TXVECTOR parameter CH_BANDWIDTH_IN_NON_NGV values(11bd)**

| Enumerated value | Value |
|---|---|
| CBW10 | 0 |
| CBW20 | 1 |

(11bd)During reception by an NGV STA, the RXVECTOR parameter CH_BANDWIDTH_IN_NON_NGV shall be determined from selected bits in the scrambling sequence as shown in Table 17-7 (Contents of the first 7 bits of the scrambling sequence) and Table 17-11 (RXVECTOR parameter CH_BANDWIDTH_IN_NON_NGV values(11bd)). During reception by an NGV STA, the RXVECTOR parameter DYN_BANDWIDTH_IN_NON_NGV shall be set to selected bits in the scrambling sequence as shown in Table 17-7 (Contents of the first 7 bits of the scrambling sequence) and Table 17-13 (DYN_BANDWIDTH_IN_NON_NGV values(11bd)). The fields shall be interpreted as being sent LSB-first.

**Table 17-10—RXVECTOR parameter CH_BANDWIDTH_IN_NON_HT values**

| CH_BANDWIDTH_IN_NON_HT_INDICATOR field of first 7 bits of scrambling sequence | dot11CurrentChannelCenterFrequencyIndex1 | RXVECTOR parameter CH_BANDWIDTH_IN_NON_HT |
|---|---|---|
| 0 | 0 | CBW20 |
| 1 | 0 | CBW40 |
| 2 | 0 | CBW80 |
| 3 | 0 | CBW160 |
| 3 | 1 to 200 | CBW80+80 |

**Table 17-11—RXVECTOR parameter CH_BANDWIDTH_IN_NON_NGV values(11bd)**

| CH_BANDWIDTH_IN_NON_NGV_INDICATOR field of first 7 bits of scrambling sequence | RXVECTOR parameter CH_BANDWIDTH_IN_NON_NGV |
|---|---|
| 0 | CBW10 |
| 1 | CBW20 |


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**Table 17-12—DYN_BANDWIDTH_IN_NON_HT values**

| Enumerated value | Value |
|---|---|
| Static | 0 |
| Dynamic | 1 |

**Table 17-13—DYN_BANDWIDTH_IN_NON_NGV values(11bd)**

| Enumerated value | Value |
|---|---|
| Static | 0 |
| Dynamic | 1 |

(#602)(#3409)During reception, an HE STA shall generate the RXVECTOR parameter SCRAMBLER_INITIAL_VALUE as the value in the first 7 bits of the SERVICE field prior to descrambling.

(#602)NOTE 2—An HE STA is also a VHT STA. Hence, an HE STA generates RXVECTOR parameter SCRAMBER_INITIAL_VALUE as well as RXVECTOR parameters CH_BANDWIDTH_IN_NON_HT and DYN_BANDWIDTH_IN_NON_HT when receiving a non-HT or non-HT duplicate PPDU.

(11bd)NOTE 3—An NGV STA generates RXVECTOR(#7080) parameters CH_BANDWIDTH_IN_NON_NGV and DYN_BANDWIDTH_IN_NON_NGV when receiving a non-NGV PPDU.

(#602)A non-HE STA (#7080)does not generate the RXVECTOR parameter SCRAMBLER_INITIAL_VALUE.

NOTE 4(#602)—The receiving PHY in a VHT STA cannot determine whether the CH_BANDWIDTH_IN_NON_HT and DYN_BANDWIDTH_IN_NON_HT parameters were present in the TXVECTOR of the transmitting PHY; therefore, the receiving PHY in a VHT STA always includes values for the CH_BANDWIDTH_IN_NON_HT and DYN_BANDWIDTH_IN_NON_HT parameters in the RXVECTOR if the PPDU is a non-HT PPDU. It is the responsibility of the MAC to determine the validity of the RXVECTOR parameters CH_BANDWIDTH_IN_NON_HT and DYN_BANDWIDTH_IN_NON_HT.

(#602)NOTE 5—The receiving PHY in an HE STA cannot determine whether the CH_BANDWIDTH_IN_NON_HT, DYN_BANDWIDTH_IN_NON_HT or SCRAMBLER_INITIAL_VALUE parameters were present in the TXVECTOR of the transmitting PHY; therefore, the receiving PHY in an HE STA always includes values for the CH_BANDWIDTH_IN_NON_HT, DYN_BANDWIDTH_IN_NON_HT, and SCRAMBLER_INITIAL_VALUE

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parameters in the RXVECTOR if the PPDU is a non-HT PPDU. It is the responsibility of the MAC to determine the validity of the RXVECTOR parameters CH_BANDWIDTH_IN_NON_HT, DYN_BANDWIDTH_IN_NON_HT, and SCRAMBLER_INITIAL_VALUE.

(11bd)NOTE 6—The receiving PHY in an NGV STA cannot determine whether the CH_BANDWIDTH_IN_NON_NGV and DYN_BANDWIDTH_IN_NON_NGV parameters were present in the TXVECTOR of the transmitting PHY; therefore, the receiving PHY in an NGV STA always includes values for the CH_BANDWIDTH_IN_NON_NGV and DYN_BANDWIDTH_IN_NON_NGV parameters in the RXVECTOR if the PPDU is a non-NGV PPDU, It is the responsibility of the MAC to determine the validity of the RXVECTOR parameters CH_BANDWIDTH_IN_NON_NGV and DYN_BANDWIDTH_IN_NON_NGV.

NOTE 7(#602)(#2160)—Descrambling the DATA field in a STA with dot11OCBActivated not equal to true is the same irrespective of whether any of the TXVECTOR parameters CH_BANDWIDTH_IN_NON_HT, DYN_BANDWIDTH_IN_NON_HT, or SCRAMBLER_INITIAL_VALUE were present. Descrambling the DATA field in a STA with dot11OCBActivated equal to true is the same irrespective of whether any of the TXVECTOR parameters CH_BANDWIDTH_IN_NON_NGV or DYN_BANDWIDTH_IN_NON_NGV were present.(#7080)

The seven LSBs of the SERVICE field shall be set to all 0s prior to scrambling to enable estimation of the initial state of the scrambler in the receiver.

An example of the scrambler output is illustrated in I.1.5.2 (Scrambling the BCC example) with the TXVECTOR parameter SCRAMBLER_INITIAL_VALUE present.

### 17.3.5.6 Convolutional encoder

The DATA field, composed of SERVICE, PSDU, tail, and pad parts, shall be coded with a convolutional encoder of coding rate R = 1/2, 2/3, or 3/4, corresponding to the TXVECTOR parameter RATE. The convolutional encoder shall use the industry-standard generator polynomials, $g_0 = 133_8$ and $g_1 = 171_8$, of rate R = 1/2, as shown in Figure 17-8 (Convolutional encoder (k = 7)). The bit denoted as "A" shall be output from the encoder before the bit denoted as "B." Higher rates are derived from it by employing "puncturing." Puncturing is a procedure for omitting some of the encoded bits in the transmitter (thus reducing the number of transmitted bits and increasing the coding rate) and inserting a dummy "zero" metric into the convolutional decoder on the receive side in place of the omitted bits. The puncturing patterns are illustrated in Figure 17-9 (Example of the bit-stealing and bit-insertion procedure (r = 3/4, 2/3)). Decoding by the Viterbi algorithm is recommended.

An example of encoding operation is shown in I.1.6.1 (Coding the DATA bits).

### 17.3.5.7 Data interleaving

All encoded data bits shall be interleaved by a block interleaver with a block size corresponding to the number of bits in a single OFDM symbol, $N_{CBPS}$. The interleaver is defined by a two-step permutation. The first permutation causes adjacent coded bits to be mapped onto nonadjacent subcarriers. The second causes adjacent coded bits to be mapped alternately onto less and more significant bits of the constellation and, thereby, long runs of low reliability (LSB) bits are avoided.

The index of the coded bit before the first permutation shall be denoted by $k$; $i$ shall be the index after the first and before the second permutation; and $j$ shall be the index after the second permutation, just prior to modulation mapping.

The first permutation is defined by the rule

$$i = (N_{CBPS}/16) \times (k \bmod 16) + \lfloor k/16 \rfloor \qquad k = 0, 1, \ldots, N_{CBPS} - 1 \text{(\#515)} \qquad (17\text{-}15)$$

The second permutation is defined by the rule


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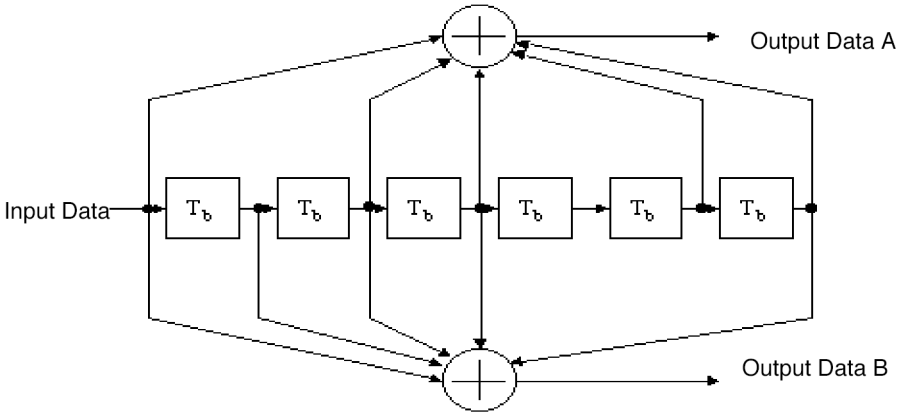


**Figure 17-8—Convolutional encoder (k = 7)**

$$j = s \times \left\lfloor \frac{i}{s} \right\rfloor + \left( i + N_{CBPS} - \left\lfloor \frac{16 \times i}{N_{CBPS}} \right\rfloor \right) \bmod s \quad i = 0, 1, \ldots, N_{CBPS} - 1 \text{(\#515)} \tag{17-16}$$

The value of s is determined by the number of coded bits per subcarrier, $N_{BPSC}$, according to

$$s = \max(N_{BPSC}/2,1) \tag{17-17}$$

The deinterleaver, which performs the inverse relation, is also defined by two permutations.

Here the index of the original received bit before the first permutation shall be denoted by *j*; *i* shall be the index after the first and before the second permutation; and *k* shall be the index after the second permutation, just prior to delivering the coded bits to the convolutional (Viterbi) decoder.

The first permutation is defined by the rule

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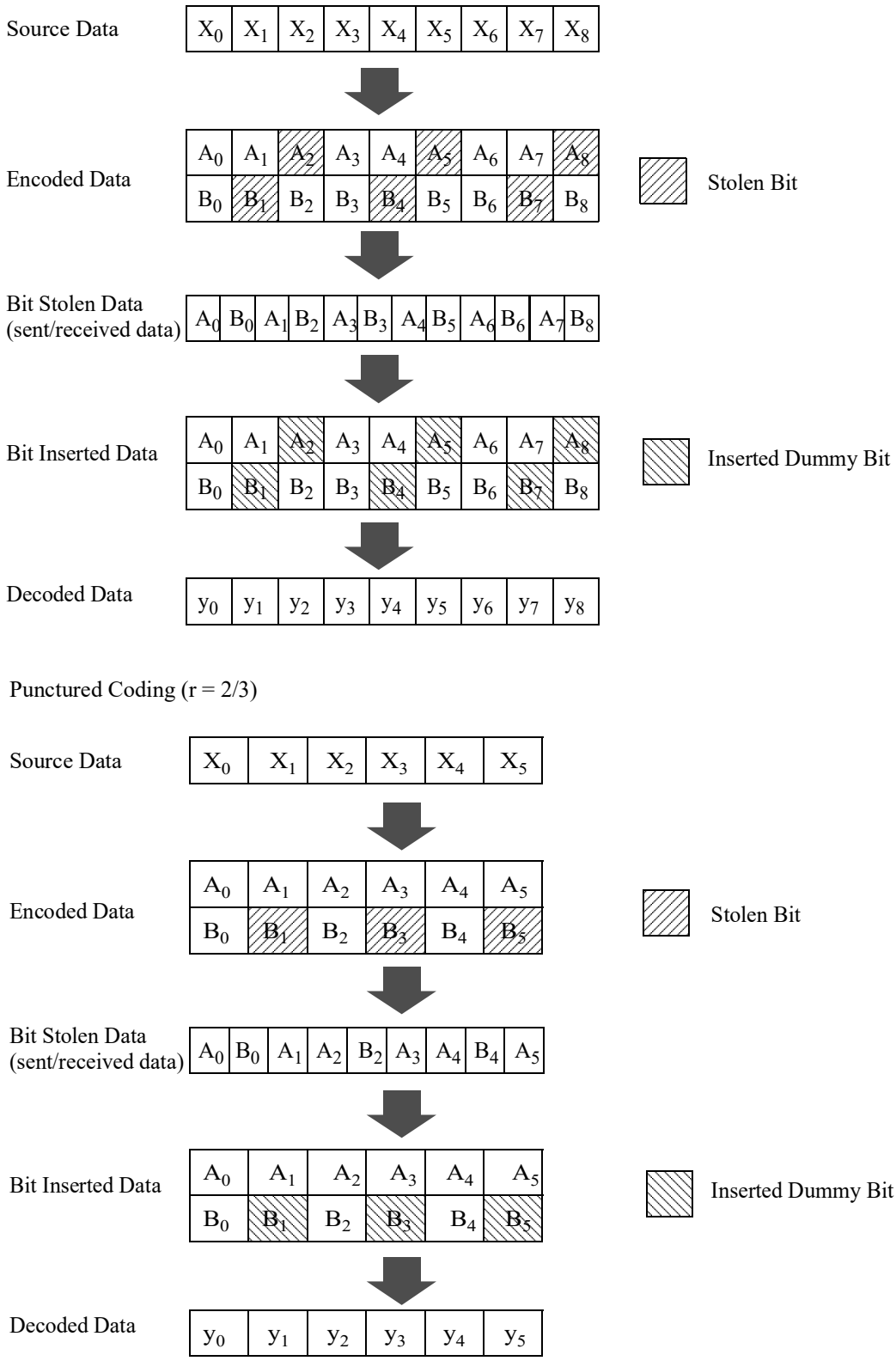


**Figure 17-9—Example of the bit-stealing and bit-insertion procedure (r = 3/4, 2/3)**



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$$i = s \times \lfloor j/s \rfloor + \left( j + \left\lfloor \frac{16 \times j}{N_{CBPS}} \right\rfloor \right) \bmod s \qquad j = 0, 1, \ldots, N_{CBPS} - 1 \text{(\#515)} \qquad (17\text{-}18)$$

where

$s$ is defined in Equation (17-17).

This permutation is the inverse of the permutation described in Equation (17-16).

The second permutation is defined by the rule

$$k = 16 \times i - (N_{CBPS} - 1) \times \left\lfloor \frac{16 \times i}{N_{CBPS}} \right\rfloor, \qquad i = 0, 1, \ldots, N_{CBPS} - 1 \text{(\#515)} \qquad (17\text{-}19)$$

This permutation is the inverse of the permutation described in Equation (17-15).

An example of interleaving operation is illustrated in I.1.6.2 (Interleaving the DATA bits).

#### 17.3.5.8 Subcarrier modulation mapping

The OFDM subcarriers shall be modulated by using BPSK, QPSK, 16-QAM, or 64-QAM, depending on the RATE requested. The encoded and interleaved binary serial input data shall be divided into groups of $N_{BPSC}$ (1, 2, 4, or 6) bits and converted into complex numbers representing BPSK, QPSK, 16-QAM, or 64-QAM constellation points. The conversion shall be performed according to Gray-coded constellation mappings,

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shown in Figure 17-10 (BPSK, QPSK, 16-QAM, and 64-QAM constellation bit encoding), with the input bit, $B_0$, being the earliest in the stream.

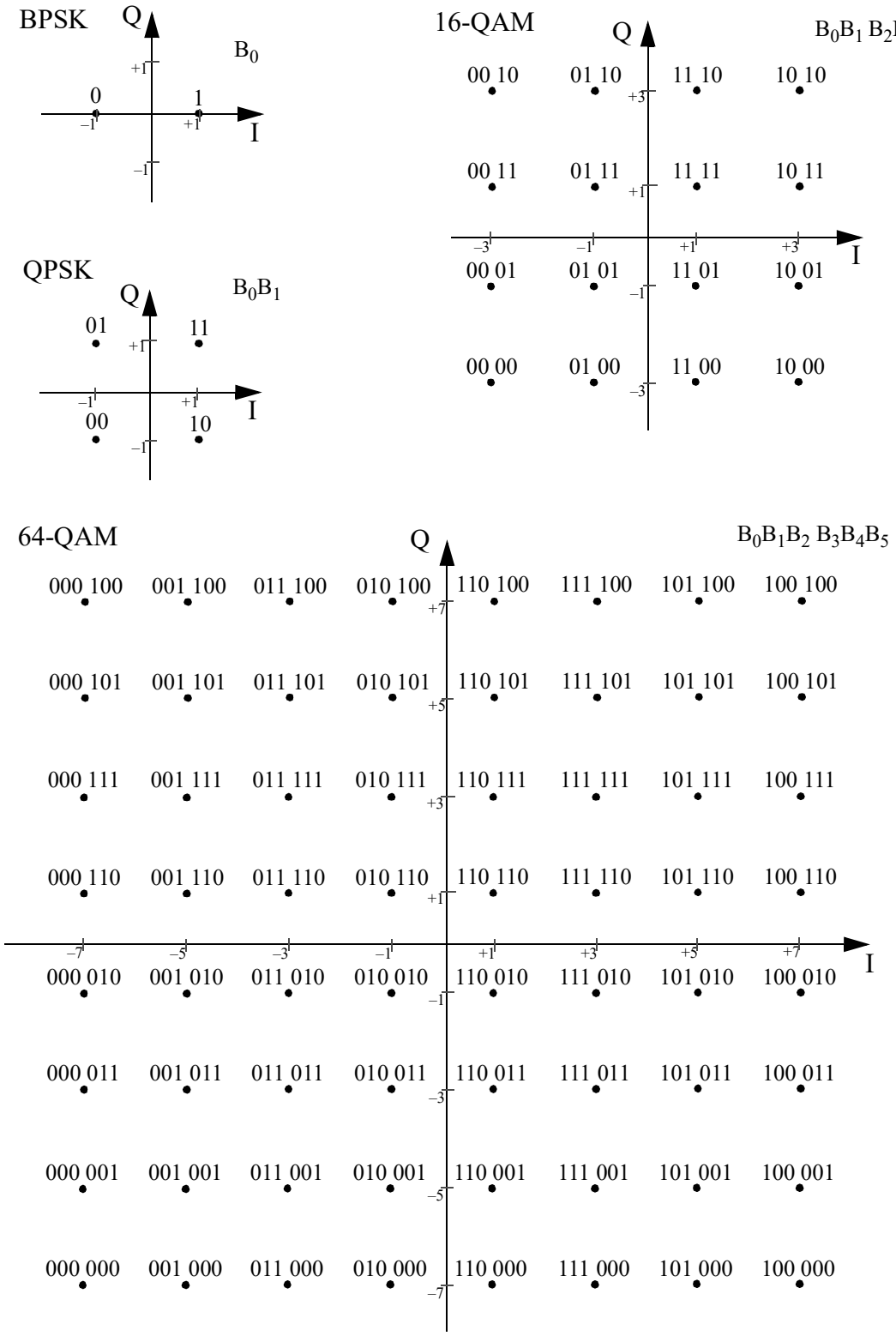


**Figure 17-10—BPSK, QPSK, 16-QAM, and 64-QAM constellation bit encoding**



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The output values, d, are formed by multiplying the resulting (I+jQ) value by a normalization factor $K_{MOD}$, as described in Equation (17-20).

$$d = (I + jQ) \times K_{MOD} \quad (17\text{-}20)$$

The normalization factor, $K_{MOD}$, depends on the base modulation mode, as prescribed in Table 17-14 (Modulation-dependent normalization factor $K_{MOD}$). Note that the modulation type can be different from the start to the end of the transmission, as the signal changes from SIGNAL to DATA, as shown in Figure 17-1 (PPDU format). The purpose of the normalization factor is to achieve the same average power for all mappings. In practical implementations, an approximate value of the normalization factor may be used, as long as the device complies with the modulation accuracy requirements described in 17.3.9.7 (Modulation accuracy).

**Table 17-14—Modulation-dependent normalization factor $K_{MOD}$**

| Modulation | $K_{MOD}$ |
|---|---|
| BPSK | 1 |
| QPSK | $1/\sqrt{2}$ |
| 16-QAM | $1/\sqrt{10}$ |
| 64-QAM | $1/\sqrt{42}$ |

For BPSK, $B_0$ determines the I value, as illustrated in Table 17-15 (BPSK encoding table). For QPSK, $B_0$ determines the I value and $B_1$ determines the Q value, as illustrated in Table 17-16 (QPSK encoding table). For 16-QAM, $B_0B_1$ determines the I value and $B_2B_3$ determines the Q value, as illustrated in Table 17-17 (16-QAM encoding table). For 64-QAM, $B_0B_1B_2$ determines the I value and $B_3B_4B_5$ determines the Q value, as illustrated in Table 17-18 (64-QAM encoding table).

**Table 17-15—BPSK encoding table**

| Input bit ($B_0$) | I-out | Q-out |
|---|---|---|
| 0 | –1 | 0 |
| 1 | 1 | 0 |

**Table 17-16—QPSK encoding table**

| Input bit ($B_0$) | I-out |
|---|---|
| 0 | –1 |
| 1 | 1 |

| Input bit ($B_1$) | Q-out |
|---|---|
| 0 | –1 |
| 1 | 1 |

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**Table 17-17—16-QAM encoding table**

| Input bits ($B_0$ $B_1$) | I-out |
|---|---|
| 00 | –3 |
| 01 | –1 |
| 11 | 1 |
| 10 | 3 |

| Input bits ($B_2$ $B_3$) | Q-out |
|---|---|
| 00 | –3 |
| 01 | –1 |
| 11 | 1 |
| 10 | 3 |

**Table 17-18—64-QAM encoding table**

| Input bits ($B_0$ $B_1$ $B_2$) | I-out |
|---|---|
| 000 | –7 |
| 001 | –5 |
| 011 | –3 |
| 010 | –1 |
| 110 | 1 |
| 111 | 3 |
| 101 | 5 |
| 100 | 7 |

| Input bits ($B_3$ $B_4$ $B_5$) | Q-out |
|---|---|
| 000 | –7 |
| 001 | –5 |
| 011 | –3 |
| 010 | –1 |
| 110 | 1 |
| 111 | 3 |
| 101 | 5 |
| 100 | 7 |

### 17.3.5.9 Pilot subcarriers

In each OFDM symbol, four of the subcarriers are dedicated to pilot signals in order to make the coherent detection robust against frequency offsets and phase noise. These pilot signals shall be put in subcarriers –21, –7, 7, and 21. The pilots shall be BPSK modulated by a pseudo-random binary sequence to prevent the generation of spectral lines. The contribution of the pilot subcarriers to each OFDM symbol is described in 17.3.5.10 (OFDM modulation).

### 17.3.5.10 OFDM modulation

The stream of complex numbers is divided into groups of $N_{SD} = 48$ complex numbers. This shall be denoted by writing the complex number $d_{k,n}$, which corresponds to subcarrier k of OFDM symbol n, as follows:

$$d_{k,n} \equiv d_{k+N_{SD}\times n}, \qquad k = 0, \ldots N_{SD} - 1,\ n = 0, \ldots N_{SYM} - 1 \tag{17-21}$$

The number of OFDM symbols, $N_{SYM}$, was introduced in 17.3.5.4 (Pad bits (PAD)).


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An OFDM symbol, $r_{DATA,n}(t)$, is defined as

$$r_{DATA,n}(t) = w_{TSYM}(t)\left(\sum_{k=0}^{N_{SD}-1} d_{k,n}\exp((j2\pi M(k)\Delta_F(t-T_{GI})) + p_{n+1}\sum_{k=-N_{ST}/2}^{N_{ST}/2} P_k\exp(j2\pi k\Delta_F(t-T_{GI}))\right) \quad (17\text{-}22)$$

where the function, *M(k)*, defines a mapping from the logical subcarrier number 0 to 47 into frequency offset index –26 to 26, while skipping the pilot subcarrier locations and the 0th (dc) subcarrier.

$$M(k) = \begin{cases} k-26 & 0 \le k \le 4 \\ k-25 & 5 \le k \le 17 \\ k-24 & 18 \le k \le 23 \\ k-23 & 24 \le k \le 29 \\ k-22 & 30 \le k \le 42 \\ k-21 & 43 \le k \le 47 \end{cases} \quad (17\text{-}23)$$

The contribution of the pilot subcarriers for the $n^{th}$ OFDM symbol is produced by inverse Fourier transform of sequence P, given by

$$P_{-26,26} = \{0,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0,$$

$$0,0,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,-1,0,0,0,0,0\} \quad (17\text{-}24)$$

The polarity of the pilot subcarriers is controlled by the sequence, $p_n$, which is a cyclic extension of the 127 elements sequence and is given by

$$p_{0..126v} = \{1,1,1,1,\ -1,-1,-1,1,\ -1,-1,-1,-1,\ 1,1,-1,1,\ -1,-1,1,1,\ -1,1,1,-1,\ 1,1,1,1,\ 1,1,-1,1,$$
$$1,1,-1,1,\ 1,-1,-1,1,\ 1,1,-1,1,\ -1,-1,-1,1,\ -1,1,-1,-1,\ 1,-1,-1,1,\ 1,1,1,1,\ -1,-1,1,1,$$
$$-1,-1,1,-1,\ 1,-1,1,1,\ -1,-1,-1,1,\ 1,-1,-1,-1,\ -1,1,-1,-1,\ 1,-1,1,1,\ 1,1,-1,1,\ -1,1,-1,1,$$
$$-1,-1,-1,-1,\ -1,1,-1,1,\ 1,-1,1,-1,\ 1,1,1,-1,\ -1,1,-1,-1,\ -1,1,1,1,\ -1,-1,-1,-1,\ -1,-1,-1\} \quad (17\text{-}25)$$

The sequence $p_n$ is generated by the scrambler defined by Figure 17-7 (Data scrambler(11bd)(#602)(#7080)) when the all 1s initial state is used, and by replacing all 1s with –1 and all 0s with 1. Each sequence element is used for one OFDM symbol. The first element, $p_0$, multiplies the pilot subcarriers of the SIGNAL symbol, while the elements from $p_1$ on are used for the DATA symbols.

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The subcarrier frequency allocation is shown in Figure 17-11 (Subcarrier frequency allocation). To avoid difficulties in D/A and A/D converter offsets and carrier feedthrough in the RF system, the subcarrier falling at DC ($0^{th}$ subcarrier) is not used.

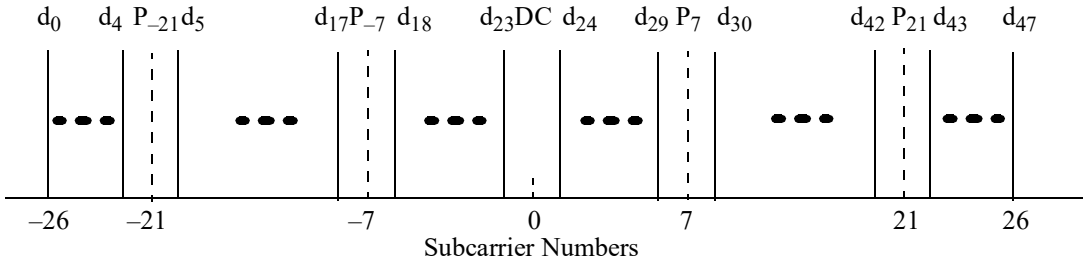


**Figure 17-11—Subcarrier frequency allocation**

The concatenation of $N_{SYM}$ OFDM symbols is written as

$$r_{DATA}(t) = \sum_{n=0}^{N_{SYM}-1} r_{DATA,n}(t - nT_{SYM}) \quad (17\text{-}26)$$

An example of mapping into symbols is shown in I.1.6.3 (Mapping into symbols), as well as the scrambling of the pilot signals (see I.1.7 (Generating the additional DATA symbols)). The final output of these operations is also shown in I.1.8 (The entire PPDU for the BCC example(#14)).

### 17.3.6 CCA

The PHY shall provide the capability to perform CCA and report the result to the MAC. The CCA mechanism shall detect a "medium busy" condition with requirements specified in 17.3.10.6 (CCA requirements) and 17.3.12 (Receive PHY). The PHY issues the PHY-CCA.indication primitive to provide this medium status report to the MAC.

### 17.3.7 PHY data modulation and modulation rate change

The SIGNAL field, which follows the non-HT preamble, shall indicate the modulation and coding rate that shall be used to transmit the (#14)PSDU. The transmitter (receiver) shall initiate the modulation (demodulation) constellation and the coding rate according to the RATE indicated in the SIGNAL field. The (#14)PSDU transmission rate shall be set by the DATARATE parameter in the TXVECTOR, issued with the PHY-TXSTART.request primitive described in 17.2.2 (TXVECTOR parameters(#1369)).

### 17.3.8 PHY operating specifications (general)

#### 17.3.8.1 General

General specifications for the BPSK OFDM, QPSK OFDM, 16-QAM OFDM, and 64-QAM OFDM PHY layers(#4114) are provided in 17.3.8.2 (Outline description) to 17.3.8.7 (Transmit and receive impedance at the antenna connector). These specifications apply to both the receive and transmit functions and general operation of the OFDM PHY.


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### 17.3.8.2 Outline description

The general block diagram of the transmitter and receiver for the OFDM PHY is shown in Figure 17-12 (Transmitter and receiver block diagram for the OFDM PHY). Major specifications for the OFDM PHY are listed in Table 17-19 (Major parameters of the OFDM PHY).

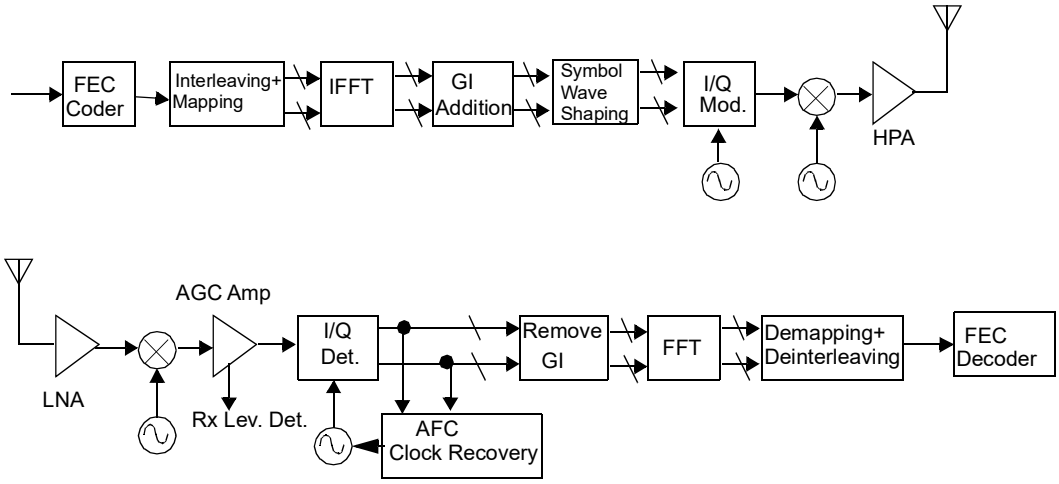


**Figure 17-12—Transmitter and receiver block diagram for the OFDM PHY**

**Table 17-19—Major parameters of the OFDM PHY**

| Information data rate | 6, 9, 12, 18, 24, 36, 48, and 54 Mb/s (6, 12, and 24 Mb/s are mandatory) (20 MHz channel spacing) | 3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s (3, 6, and 12 Mb/s are mandatory) (10 MHz channel spacing) | 1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s (1.5, 3, and 6 Mb/s are mandatory) (5 MHz channel spacing) |
|---|---|---|---|
| Modulation | BPSK OFDM<br>QPSK OFDM<br>16-QAM OFDM<br>64-QAM OFDM | BPSK OFDM<br>QPSK OFDM<br>16-QAM OFDM<br>64-QAM OFDM | BPSK OFDM<br>QPSK OFDM<br>16-QAM OFDM<br>64-QAM OFDM |
| Error correcting code | K = 7 (64 states) convolutional code | K = 7 (64 states) convolutional code | K = 7 (64 states) convolutional code |
| Coding rate | 1/2, 2/3, 3/4 | 1/2, 2/3, 3/4 | 1/2, 2/3, 3/4 |
| Number of subcarriers | 52 | 52 | 52 |
| OFDM symbol duration | 4.0 μs | 8.0 μs | 16.0 μs |
| GI | 0.8 μs[a] ($T_{GI}$) | 1.6 μs ($T_{GI}$) | 3.2 μs ($T_{GI}$) |
| Occupied bandwidth | 16.6 MHz | 8.3 MHz | 4.15 MHz |

[a]Refer to 17.3.2.5 (Mathematical conventions in the signal descriptions).

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#### 17.3.8.3 Regulatory requirements

WLANs implemented in accordance with this standard are subject to equipment certification and operating requirements established by regional and national regulatory administrations. The PHY specification establishes minimum technical requirements for interoperability, based upon established regulations at the time this standard was issued. These regulations are subject to revision, or may be superseded. Requirements that are subject to local geographic regulations are annotated within the PHY specification. Regulatory requirements that do not affect interoperability are not addressed in this standard. Implementers are referred to the regulatory sources in Annex D for further information. Operation in countries within defined regulatory domains may be subject to additional or alternative national regulations.

#### 17.3.8.4 Operating channel frequencies

##### 17.3.8.4.1 Operating frequency range

The OFDM PHY shall not operate in frequency bands not allocated by a regulatory body in its operational region. Regulatory requirements for a given frequency band are set by the regulatory authority responsible for spectrum management in a given geographic region or domain. The particular channelization to be used for this standard is dependent on such allocation, as well as the associated regulations for use of the allocations. These regulations are subject to revision, or may be superseded.

In some regulatory domains, several frequency bands may be available for OFDM PHY-based WLANs. These bands may be contiguous or not, and different regulatory limits may be applicable. An OFDM PHY shall support at least one frequency band in at least one regulatory domain. The support of specific regulatory domains, and bands within the domains, shall be indicated by PLME attributes dot11RegDomainsImplementedValue and dot11FrequencyBandsImplemented.

The PHYCONFIG_VECTOR carried in a PHY-CONFIG.request primitive for an OFDM PHY contains an OPERATING_CHANNEL parameter, which identifies the operating channel. The PHY shall set dot11CurrentFrequency to the value of this parameter.

##### 17.3.8.4.2 Channel numbering

Channel center frequencies are defined at every integer multiple of 5 MHz above the channel starting frequency. The relationship between center frequency and channel number is given by Equation (17-27):

$$\text{Channel center frequency} = \text{Channel starting frequency} + 5 \times n_{ch}\ (\text{MHz}) \quad (17\text{-}27)$$

where

$n_{ch}$ = 1, …, 200(#515).

Channel starting frequency is defined as dot11ChannelStartingFactor × 500 kHz or
is defined as 5 GHz where dot11OperatingClassesRequired is false or
not defined.

A channel center frequency of 5 GHz shall be indicated by dot11ChannelStartingFactor = 8000 and $n_{ch}$ = 200.

This definition provides a unique numbering system for all channels with 5 MHz between center frequencies, as well as the flexibility to define channelization sets for all current and future regulatory domains.


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#### 17.3.8.4.3 Channelization

The set of valid operating channel numbers by regulatory domain is defined in Annex E. As shown in Figure 17-11 (Subcarrier frequency allocation), no subcarrier is allocated on the channel center frequency.

### 17.3.8.5 Transmit and receive in-band and out-of-band spurious emissions

The OFDM PHY shall comply with in-band and out-of-band spurious emissions as set by regulatory bodies.

### 17.3.8.6 Slot time

The value of the slot time is found in Table 17-24 (OFDM PHY characteristics) (in 17.4.4 (OFDM PHY)).

### 17.3.8.7 Transmit and receive impedance at the antenna connector

The impedance at the transmit antenna connector and receive antenna connector shall be 50 Ω if that connector is exposed.

## 17.3.9 PHY transmit specifications

### 17.3.9.1 General

The transmit specifications associated with the PHY layer(#4114) are described in 17.3.9.2 (Transmit power levels) to 17.3.9.8 (Transmit modulation accuracy test).

### 17.3.9.2 Transmit power levels

The maximum allowable output power is measured in accordance with practices specified by the appropriate regulatory bodies.

### 17.3.9.3 Transmit spectrum mask

The transmit spectrum mask by regulatory domain is defined in Annex D and Annex E.

NOTE—In the presence of additional regulatory restrictions, the device needs to meet both the regulatory requirements and the mask defined here, i.e., its emissions need to be no higher at any frequency offset than the minimum of the values specified in the regulatory and default masks.

For rules regarding TX center frequency leakage levels by VHT STAs, see 21.3.17.4.2 (Transmit center frequency leakage).

For operation using 20 MHz channel spacing, the transmitted spectrum shall have a 0 dBr (dB relative to the maximum spectral density of the signal) bandwidth not exceeding 18 MHz, –20 dBr at 11 MHz frequency offset, –28 dBr at 20 MHz frequency offset, and the maximum of –40 dBr and –39 dBm/MHz(M25) at 30 MHz frequency offset and above. The transmitted spectral density of the transmitted signal shall fall within the spectral mask, as shown in Figure 17-13 (Transmit spectrum mask for 20 MHz transmission). The measurements shall be made using a 100 kHz resolution bandwidth and a 30 kHz video bandwidth.

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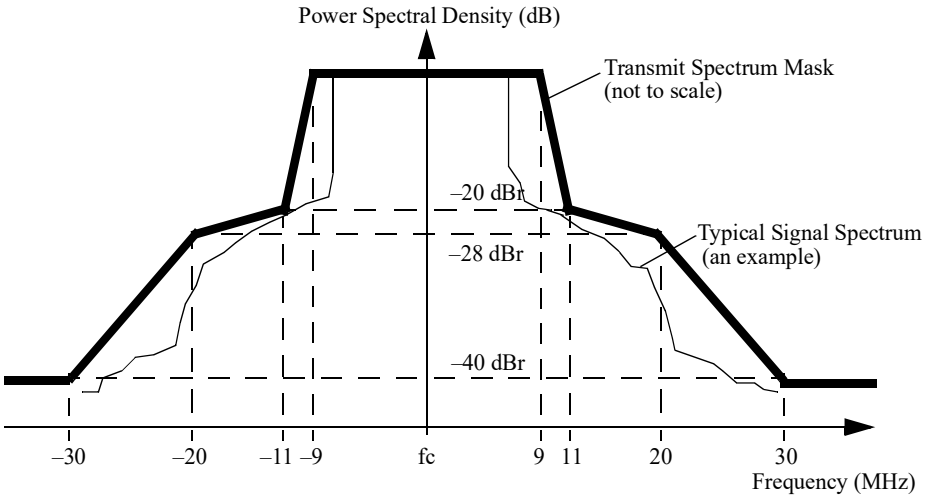


**Figure 17-13—Transmit spectrum mask for 20 MHz transmission**

For operation using 10 MHz channel spacing, the transmitted spectrum shall have a 0 dBr bandwidth not exceeding 9 MHz, –20 dBr at 5.5 MHz frequency offset, –28 dBr at 10 MHz frequency offset, and the maximum of –40 dBr and –50 dBm/MHz at 15 MHz frequency offset and above. The transmitted spectral density of the transmitted signal shall fall within the spectral mask, as shown in Figure 17-14 (Transmit spectrum mask for 10 MHz transmission). The measurements shall be made using a 100 kHz resolution bandwidth and a 30 kHz video bandwidth.

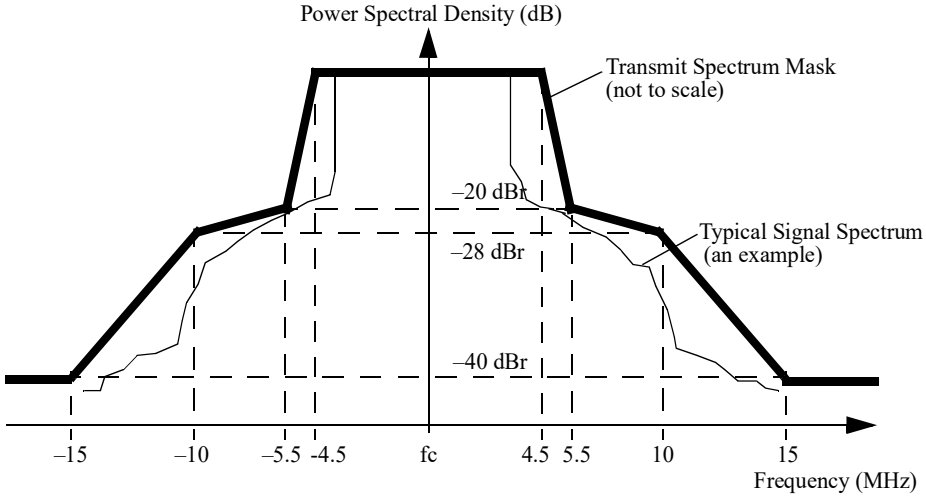


**Figure 17-14—Transmit spectrum mask for 10 MHz transmission**


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For operation using 5 MHz channel spacing, the transmitted spectrum shall have a 0 dBr bandwidth not exceeding 4.5 MHz, –20 dBr at 2.75 MHz frequency offset, –28 dBr at 5 MHz frequency offset, and the maximum of –40 dBr and –47 dBm/MHz at 7.5 MHz frequency offset and above. The transmitted spectral density of the transmitted signal shall fall within the spectral mask, as shown in Figure 17-15 (Transmit spectrum mask for 5 MHz transmission). The measurements shall be made using a 100 kHz resolution bandwidth and a 30 kHz video bandwidth.

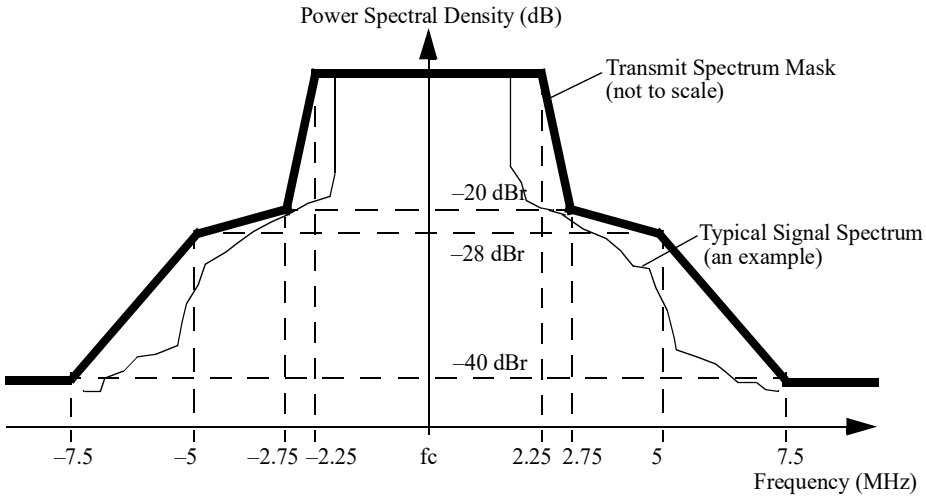


**Figure 17-15—Transmit spectrum mask for 5 MHz transmission**

#### 17.3.9.4 Transmission spurious

Spurious transmissions shall comply with national regulations.

#### 17.3.9.5 Transmit center frequency tolerance

The transmitted center frequency tolerance shall be ± 20 ppm for 20 MHz and 10 MHz channels and shall be ± 10 ppm for 5 MHz channels. The transmit center frequency and the symbol clock frequency shall be derived from the same reference oscillator.

#### 17.3.9.6 Symbol clock frequency tolerance

The symbol clock frequency tolerance shall be ± 20 ppm for 20 MHz and 10 MHz channels, and shall be ± 10 ppm for 5 MHz channels. The transmit center frequency and the symbol clock frequency shall be derived from the same reference oscillator.

#### 17.3.9.7 Modulation accuracy

##### 17.3.9.7.1 Introduction

Transmit modulation accuracy specifications are described in 17.3.9.7 (Modulation accuracy). The test method is described in 17.3.9.8 (Transmit modulation accuracy test).

##### 17.3.9.7.2 Transmitter center frequency leakage

For VHT STAs, the requirements on transmitter center frequency leakage are defined in 21.3.17.4.2 (Transmit center frequency leakage); otherwise, the requirements are defined in this subclause.

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Certain transmitter implementations might cause leakage of the center frequency component. Such leakage (which manifests itself in a receiver as energy in the center frequency component) shall not exceed $max(P - 15, -20)$ dBm or, equivalently, +2 dB relative to the average energy of the rest of the subcarriers. The data for this test shall be derived from the channel estimation phase.

#### 17.3.9.7.3 Transmitter spectral flatness

The average energy of the constellations in each of the spectral lines –16.. –1 and +1.. +16 shall deviate no more than ± 4 dB from their average energy. The average energy of the constellations in each of the spectral lines –26.. –17 and +17.. +26 shall deviate no more than +4/–6 dB from the average energy of spectral lines –16.. –1 and +1.. +16. The data for this test shall be derived from the channel estimation step.

#### 17.3.9.7.4 Transmitter constellation error

The relative constellation RMS error, averaged over subcarriers and OFDM PPDUs, shall not exceed a data-rate dependent value according to Table 17-20 (Allowed relative constellation error versus data rate).

**Table 17-20—Allowed relative constellation error versus data rate**

| Relative constellation error (dB) | Modulation | Coding rate (R) |
|---|---|---|
| –5 | BPSK | 1/2 |
| –8 | BPSK | 3/4 |
| –10 | QPSK | 1/2 |
| –13 | QPSK | 3/4 |
| –16 | 16-QAM | 1/2 |
| –19 | 16-QAM | 3/4 |
| –22 | 64-QAM | 2/3 |
| –25 | 64-QAM | 3/4 |

### 17.3.9.8 Transmit modulation accuracy test

The transmit modulation accuracy test shall be performed by instrumentation capable of converting the transmitted signal into a stream of complex samples at 20 Msample/s or more, with sufficient accuracy in terms of I/Q arm amplitude and phase balance, dc offsets, phase noise, etc. A possible embodiment of such a setup is converting the signal to a low IF with a microwave synthesizer, sampling the signal with a digital oscilloscope and decomposing it digitally into quadrature components.

The sampled signal shall be processed in a manner similar to an actual receiver, according to the following steps, or an equivalent procedure:

a) (#14)Start of PPDU shall be detected.

b) Transition from short sequences to channel estimation sequences shall be detected, and fine timing (with one sample resolution) shall be established.

c) Coarse and fine frequency offsets shall be estimated.

d) The PPDU shall be derotated according to estimated frequency offset.


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e) The complex channel response coefficients shall be estimated for each of the subcarriers.

f) For each of the data OFDM symbols: transform the symbol into subcarrier received values, estimate the phase from the pilot subcarriers, derotate the subcarrier values according to estimated phase, and divide each subcarrier value with a complex estimated channel response coefficient.

g) For each data-carrying subcarrier, find the closest constellation point and compute the Euclidean distance from it.

h) Compute the RMS average of all errors (#14)in the (#2261)DATA field of a PPDU. It is given by

$$Error_{RMS} = \frac{\sum_{i=1}^{N_f} \sqrt{\frac{\sum_{j=1}^{L_P}\left[\sum_{k=1}^{52}\{(I(i,j,k)-I_0(i,j,k))^2+(Q(i,j,k)-Q_0(i,j,k))^2\}\right]}{52L_P \times P_0}}}{N_f} \quad (17\text{-}28)$$

where

$L_P$ is the length of the (#14)DATA field

$N_f$ is the number of (#14)PPDUs for the measurement

$(I_0(i,j,k), Q_0(i,j,k))$ denotes the ideal symbol point of the $i^{th}$ (#14)PPDU, $j^{th}$ OFDM symbol of the DATA field, $k^{th}$ subcarrier of the OFDM symbol in the complex plane

$(I(i,j,k), Q(i,j,k))$ denotes the observed point of the $i^{th}$ (#14)PPDU, $j^{th}$ OFDM symbol of the DATA field, $k^{th}$ subcarrier of the OFDM symbol in the complex plane (see Figure 17-16 (Constellation error))

$P_0$ is the average power of the constellation

The vector error on a phase plane is shown in Figure 17-16 (Constellation error).

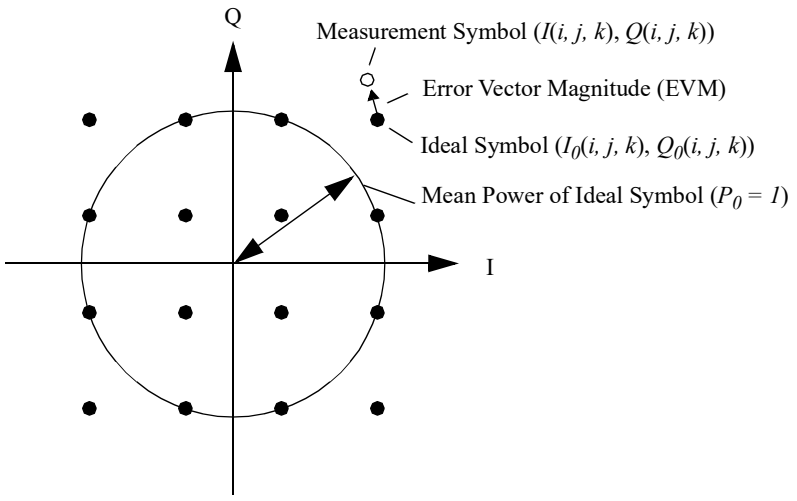


**Figure 17-16—Constellation error**

The test shall be performed over at least 20 (#14)PPDUs ($N_f$), and the RMS average shall be taken. The DATA fields under test shall be at least 16 OFDM symbols long. Random data shall be used for the symbols.

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#### 17.3.9.9 Time of Departure accuracy

(#8048)The RMS accuracy of the time of departure provided in TIME_OF_DEPARTURE shall be less than or equal to 80 ns.

The Time of Departure accuracy test evaluates TIME_OF_DEPARTURE against aTxPHYTxStartRMS and aTxPHYTxStartRMS against TIME_OF_DEPARTURE_ACCURACY_TEST_THRESH as defined Annex P with the following test parameters:

— MULTICHANNEL_SAMPLING_RATE is $20 \times 10^6\left(1 + \left\lceil \frac{f_H - f_L}{20\ \text{MHz}} \right\rceil\right)$ sample/s
where
$f_H$ is the nominal center frequency in Hz of the highest channel in the channel set
$f_L$ is the nominal center frequency in Hz of the lowest channel in the channel set, the channel set is the set of channels upon which (#14)PPDUs providing measurements are transmitted, the channel set comprises channels uniformly spaced across $f_H - f_L \geq 50$ MHz

— FIRST_TRANSITION_FIELD is the Short symbols.

— SECOND_TRANSITION_FIELD is the Long symbols.

— TRAINING_FIELD is the Long symbols windowed in a manner which should approximate the windowing described in 17.3.2.5 (Mathematical conventions in the signal descriptions) with $T_{TR}$ = 100 ns for 20 MHz channel spacing, $T_{TR}$ = 200 ns for 10 MHz channel spacing and $T_{TR}$ = 400 ns for 5 MHz channel spacing.

— TIME_OF_DEPARTURE_ACCURACY_TEST_THRESH is 80 ns.

NOTE—The indicated windowing applies to the time of departure accuracy test equipment, and not the transmitter or receiver.

### 17.3.10 PHY receiver specifications

#### 17.3.10.1 Introduction

The receive specifications associated with the PHY layer(#4114) are described in 17.3.10.2 (Receiver minimum input level sensitivity(#256)) to 17.3.10.6 (CCA requirements).

#### 17.3.10.2 Receiver minimum input level sensitivity(#256)

The (#14)PER shall be 10% or less when the PSDU length is 1000 octets and the rate-dependent input level is as shown in Table 17-21 (Receiver performance requirements). The minimum input levels are measured at the antenna connector (noise factor of 10 dB and 5 dB implementation margins are assumed).

**Table 17-21—Receiver performance requirements**

| Modulation | Coding rate (R) | Adjacent channel rejection (dB) | Alternate adjacent channel rejection (dB) | Minimum sensitivity (dBm) (20 MHz channel spacing) | Minimum sensitivity (dBm) (10 MHz channel spacing) | Minimum sensitivity (dBm) (5 MHz channel spacing) |
|---|---|---|---|---|---|---|
| BPSK | 1/2 | 16 | 32 | –82 | –85 | –88 |
| BPSK | 3/4 | 15 | 31 | –81 | –84 | –87 |
| QPSK | 1/2 | 13 | 29 | –79 | –82 | –85 |
| QPSK | 3/4 | 11 | 27 | –77 | –80 | –83 |


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**Table 17-21—Receiver performance requirements**

| Modulation | Coding rate (R) | Adjacent channel rejection (dB) | Alternate adjacent channel rejection (dB) | Minimum sensitivity (dBm) (20 MHz channel spacing) | Minimum sensitivity (dBm) (10 MHz channel spacing) | Minimum sensitivity (dBm) (5 MHz channel spacing) |
|---|---|---|---|---|---|---|
| 16-QAM | 1/2 | 8 | 24 | –74 | –77 | –80 |
| 16-QAM | 3/4 | 4 | 20 | –70 | –73 | –76 |
| 64-QAM | 2/3 | 0 | 16 | –66 | –69 | –72 |
| 64-QAM | 3/4 | –1 | 15 | –65 | –68 | –71 |

### 17.3.10.3 Adjacent channel rejection

The adjacent channel rejection shall be measured by setting the desired signal's strength 3 dB above the rate-dependent sensitivity specified in Table 17-21 (Receiver performance requirements) and raising the power of the interfering signal until 10% PER is caused for a PSDU length of 1000 octets. The difference in power between the signals in the interfering channel and the desired channel is the corresponding adjacent channel rejection. The interfering signal in the adjacent channel shall be a signal compliant with the OFDM PHY, unsynchronized with the signal in the channel under test. In an OFDM PHY the corresponding rejection shall be no less than specified in Table 17-21 (Receiver performance requirements).

An optional enhanced performance specification is provided for systems requiring improved immunity to out-of-channel interfering emissions. If a STA has dot11ACRType equal to 2, the adjacent channel rejection shall be no less than specified in Table 17-22 (Optional enhanced receiver performance requirements). The interfering signal in the adjacent channel shall be a signal compliant with the OFDM PHY, using transmit mask M (see D.2.4 (Transmit Mask M)), unsynchronized with the signal in the channel under test. The corresponding minimum receiver sensitivities for each modulation and coding rate are the same as in Table 17-21 (Receiver performance requirements).

NOTE—Transmit mask M is equivalent to class C (see D.2.2 (Transmit power levels)).

**Table 17-22—Optional enhanced receiver performance requirements**

| Modulation | Coding rate (R) | Adjacent channel rejection (dB) | Nonadjacent channel rejection (dB) |
|---|---|---|---|
| BPSK | 1/2 | 28 | 42 |
| BPSK | 3/4 | 27 | 41 |
| QPSK | 1/2 | 25 | 39 |
| QPSK | 3/4 | 23 | 37 |
| 16-QAM | 1/2 | 20 | 34 |
| 16-QAM | 3/4 | 16 | 30 |
| 64-QAM | 2/3 | 12 | 26 |
| 64-QAM | 3/4 | 11 | 25 |

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#### 17.3.10.4 Nonadjacent channel rejection

The nonadjacent channel rejection shall be measured by setting the desired signal's strength 3 dB above the rate-dependent sensitivity specified in Table 17-21 (Receiver performance requirements), and raising the power of the interfering signal until a 10% PER occurs for a PSDU length of 1000 octets. The difference in power between the signals in the interfering channel and the desired channel is the corresponding nonadjacent channel rejection. The interfering signal in the nonadjacent channel shall be a signal compliant with the OFDM PHY, unsynchronized with the signal in the channel under test. In an OFDM PHY, the corresponding rejection shall be no less than specified in Table 17-21 (Receiver performance requirements).

An optional enhanced performance specification is provided for systems requiring improved immunity to out-of-channel interfering emissions. If a STA has dot11ACRType equal to 2, the nonadjacent channel rejection shall be no less than specified in Table 17-22 (Optional enhanced receiver performance requirements). The interfering signal in the nonadjacent channel shall be a signal compliant with the OFDM PHY, using transmit mask M (see D.2.4 (Transmit Mask M)), unsynchronized with the signal in the channel under test. The corresponding minimum receiver sensitivities for each modulation and coding rate are the same as in Table 17-21 (Receiver performance requirements).

#### 17.3.10.5 Receiver maximum input level

The receiver shall provide a maximum PER of 10% at a PSDU length of 1000 octets, for a maximum input level of –30 dBm measured at the antenna connector for any baseband modulation.

#### 17.3.10.6 CCA requirements

##### 17.3.10.6.1 General(#2365)

The PHY shall indicate a medium busy condition by issuing a PHY-CCA.indication primitive when the carrier sense/clear channel assessment (CS/CCA) mechanism detects a channel busy condition.

The start of an OFDM transmission at a receive level greater than or equal to the minimum modulation and coding rate sensitivity (–82 dBm for 20 MHz channel spacing, –85 dBm for 10 MHz channel spacing, and –88 dBm for 5 MHz channel spacing) shall cause CS/CCA to detect a channel busy condition with a probability > 90% within 4 μs for 20 MHz channel spacing, 8 μs for 10 MHz channel spacing, and 16 μs for 5 MHz channel spacing.

NOTE—CS/CCA detect time is based on finding the short sequences in the preamble, so when $T_{SYM}$ doubles, so does CS/CCA detect time.(#3299)

Additionally, the CS/CCA mechanism shall detect a medium busy condition within 4 μs of any signal with a received energy that is 20 dB above the minimum modulation and coding rate sensitivity (minimum modulation and coding rate sensitivity + 20 dB resulting in –62 dBm for 20 MHz channel spacing, –65 dBm for 10 MHz channel spacing, and –68 dBm for 5 MHz channel spacing)(#3299).

##### 17.3.10.6.2 CCA requirements for operating classes requiring CCA-OCSED(#2365)

For improved spectrum sharing, CCA-Operating Class Specific Energy Detect (CCA-OCSED) is required in some bands. The behavior class indicating CCA-OCSED is given in Table D-2 (Behavior limits). The operating classes requiring the corresponding CCA-OCSED behavior class are given in E.1 (Country information and operating classes). The PHY of a STA that is operating within an operating class that requires CCA-OCSED shall operate with CCA-OCSED.

For the operating class requiring CCA-OCSED, the PHY shall also indicate a medium busy condition when CCA-OCSED detects a channel busy condition. CCA-OCSED shall detect a channel busy condition when


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the received signal strength exceeds the CCA-OCSED threshold as given by dot11OFDMOCSEDThreshold. The CCA-OCSED thresholds for the operating classes requiring CCA-OCSED are subject to the criteria in D.2.5 (CCA-OCSED threshold(#2365)).

NOTE—(#3299)The requirement to detect a channel busy condition as stated in 17.3.10.6.1 (General(#2365)) is a mandatory energy detect requirement on all Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) receivers. Support for CCA-OCSED is an additional requirement that relates specifically to the sensitivities described in D.2.5 (CCA-OCSED threshold(#2365)).

### 17.3.10.7 Received channel power indicator (RCPI) measurement

(#14)The RCPI is a measure of the received RF power in the selected channel for a received PPDU. This parameter shall be a (#1132)measurement by the PHY of the received RF power in the channel measured over the (#2011)SYNC field of the received PPDU or by other equivalent means that meet the specified accuracy.

RCPI shall equal the received RF power (#2011)in dBm within an accuracy of ± 5 dB (95% confidence interval) within the specified dynamic range of the receiver.

### 17.3.11 Transmit PHY

The transmit PHY is shown in Figure 17-17 (Transmit PHY). In order to transmit data, the PHY-TXSTART.request primitive shall be enabled so that the PHY entity shall be in the transmit state. Further, the PHY shall be set to operate at the appropriate frequency through STA management via the PLME. Other

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transmit parameters, such as DATARATE and TX power, are set via the PHY SAP with the PHY-TXSTART.request(TXVECTOR) primitive, as described in 17.2.2 (TXVECTOR parameters(#1369)).

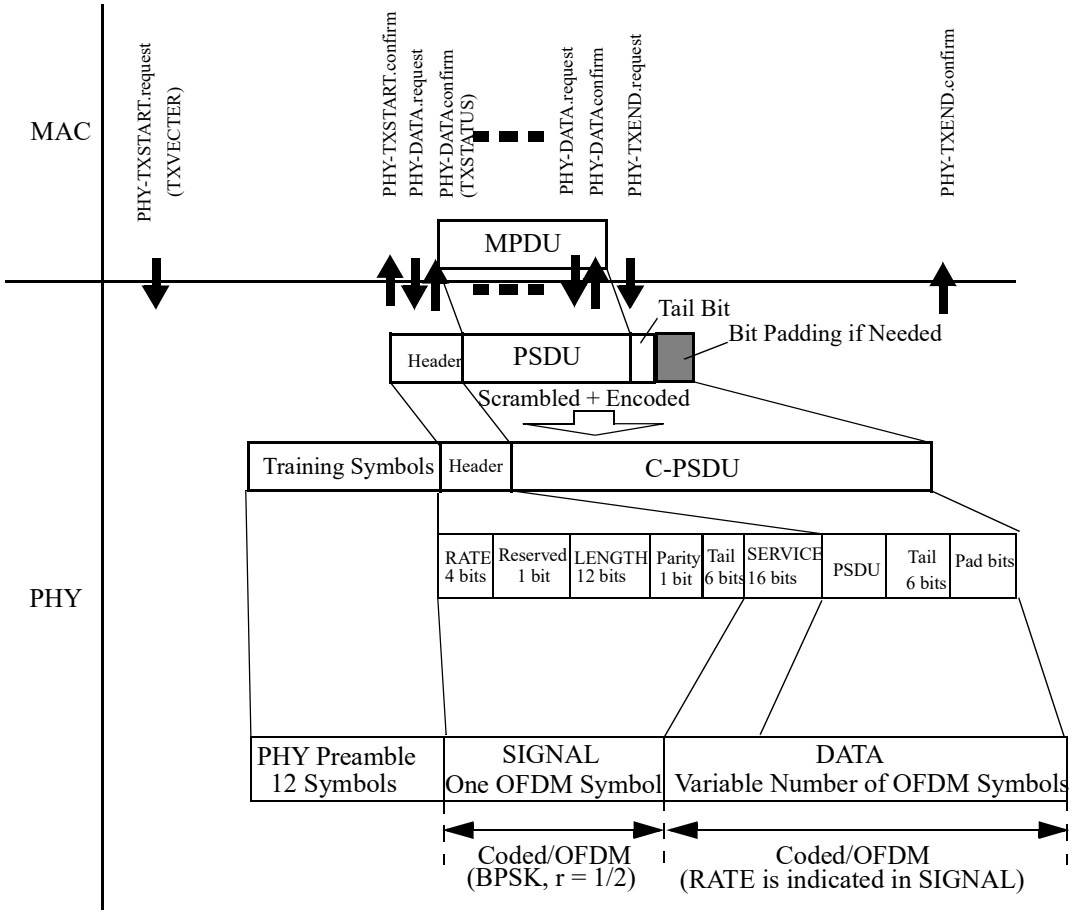


**Figure 17-17—Transmit PHY**

The PHY shall indicate a clear channel by issuing a PHY-CCA.indication(IDLE) primitive. The MAC considers this indication before issuing the PHY-TXSTART.request primitive. Transmission of the PPDU shall be initiated after receiving the PHY-TXSTART.request(TXVECTOR) primitive. The TXVECTOR elements for the PHY-TXSTART.request primitive are the PHY header parameters DATARATE, SERVICE, and LENGTH and the PHY parameters TXPWR_LEVEL_INDEX and TIME_OF_DEPARTURE_REQUESTED.


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The PHY is configured with the TXVECTOR elements DATARATE and TXPWR_LEVEL_INDEX. Transmission of the PHY preamble and PHY header, based on the parameters passed in the PHY-TXSTART.request primitive, shall be immediately initiated.

Once PHY preamble transmission is started, the PHY entity shall immediately initiate PHY header encoding then data scrambling and data encoding, where the data shall be exchanged between the MAC and the PHY through a series of PHY-DATA.request(DATA) primitives issued by the MAC, and PHY-DATA.confirm primitives issued by the PHY. The modulation rate change, if any, shall be initiated from the SERVICE field data of the PHY header, as described in 17.3.2 (PPDU format).

The PHY proceeds with PSDU transmission through a series of data octet transfers from the MAC. The PHY header parameter, SERVICE, and PSDU are encoded by the convolutional encoder with the bit-stealing function described in 17.3.5.6 (Convolutional encoder). Transmission can be prematurely terminated by the MAC through the PHY-TXEND.request primitive. Normal termination occurs after the transmission of the final bit of the last PSDU octet, according to the number supplied in the LENGTH field of the SIGNAL field.

(#14)The PPDU transmission shall be completed and the PHY entity shall enter the receive state. Each PHY-TXEND.request primitive is acknowledged with a PHY-TXEND.confirm primitive from the PHY. If the coded PSDU (C-PSDU) length is not a multiple of the OFDM symbol length $N_{CBPS}$, the PSDU is padded prior to scrambling and coding (see 17.3.5.4 (Pad bits (PAD))).

In the PHY, the GI shall be inserted in every OFDM symbol as a countermeasure against severe delay spread.

A typical state machine implementation of the transmit PHY is provided in Figure 17-18 (PHY transmit state machine(#14)). Requests (.request) and confirmations (.confirm) are issued once with designated states.

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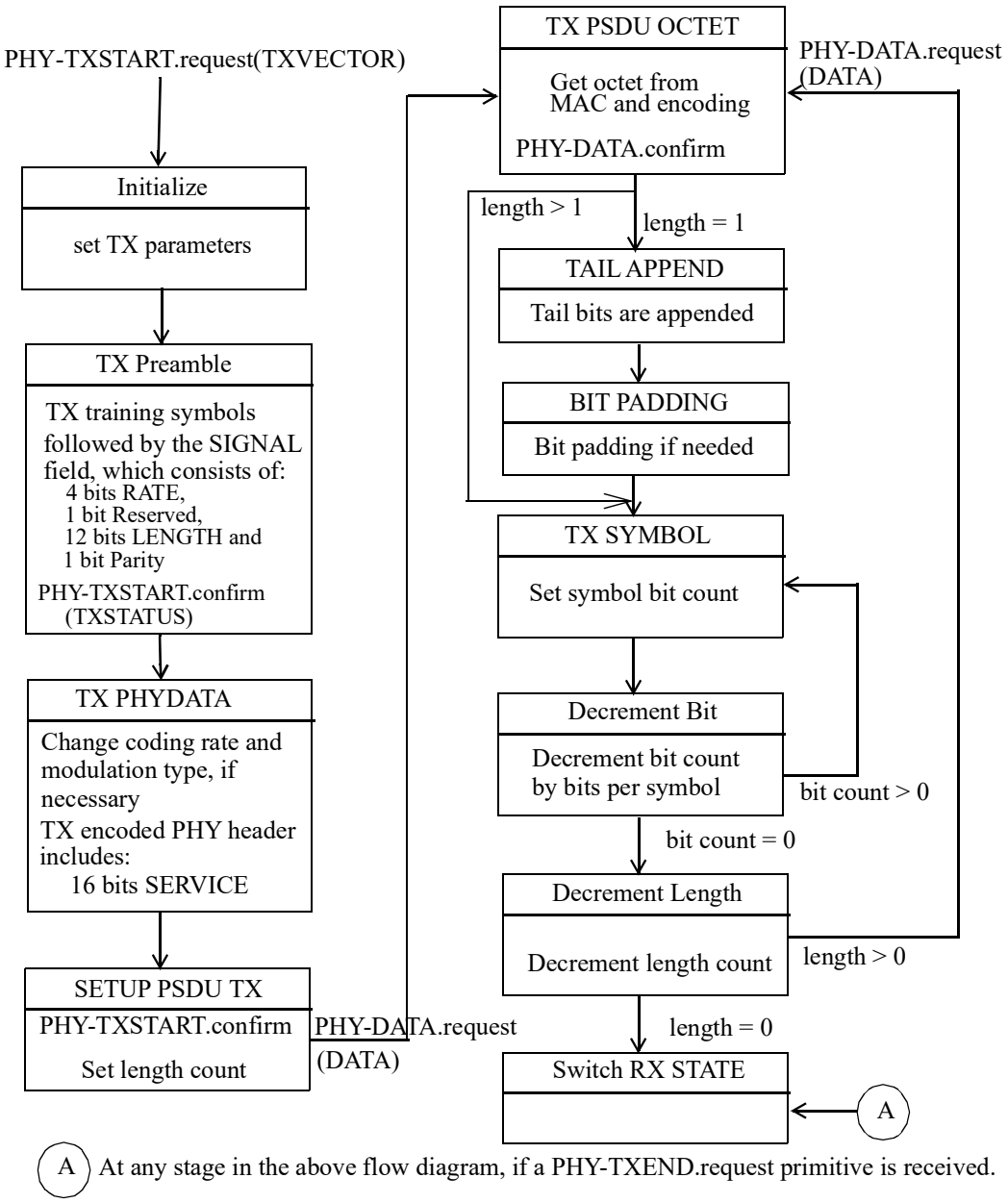


**Figure 17-18—PHY transmit state machine(#14)**



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### 17.3.12 Receive PHY

The receive PHY is shown in Figure 17-19 (Receive PHY(#1058)(#4122)). In order to receive data, the PHY-TXSTART.request primitive shall be disabled so that the PHY entity is in the receive state. Further, through STA management (via the PLME) the PHY is set to the appropriate frequency. Other receive parameters, such as RSSI, RCPI, and indicated DATARATE, may be accessed via the PHY SAP.

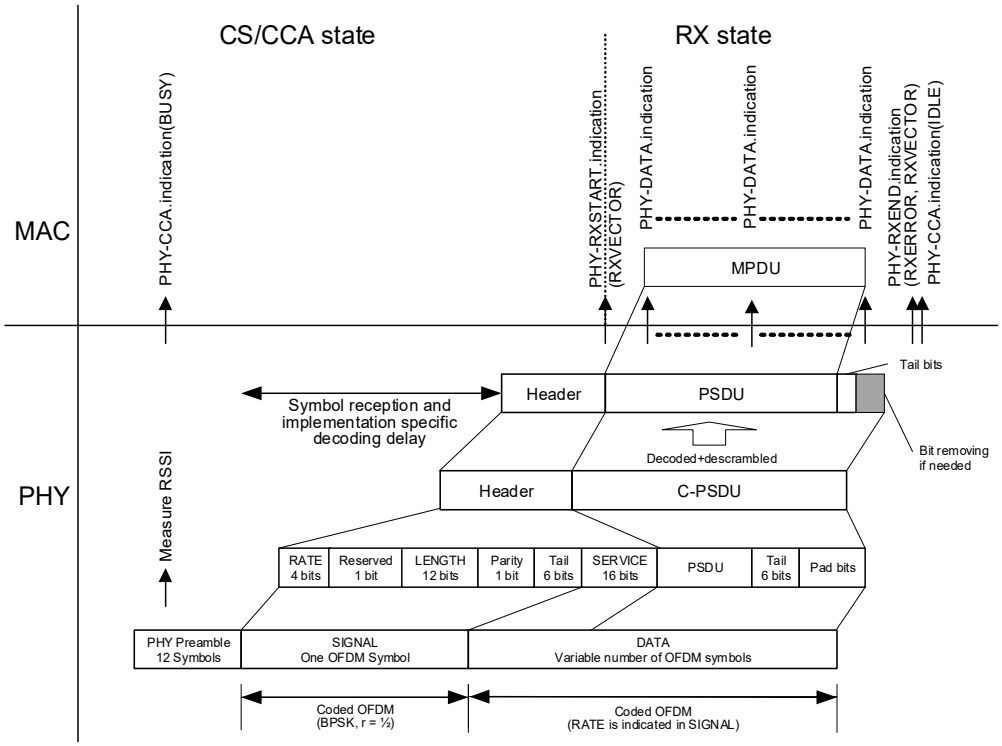


**Figure 17-19—Receive PHY(#1058)(#4122)**

Upon receiving the transmitted PHY preamble, the PHY measures the received signal strength level. This indicates activity to the MAC via PHY-CCA.indication primitive. A PHY-CCA.indication(BUSY) primitive shall be issued for reception of a signal prior to correct reception of the PPDU. The RSSI parameter is(#1759) reported to the MAC in the RXVECTOR.

After a PHY-CCA.indication primitive is issued, the PHY entity shall begin receiving the training symbols and searching for the SIGNAL in order to set the length of the PSDU(#2056), the demodulation type, and the decoding rate.

(#1062)(#3481)For an HT STA that determines it is receiving an ERP-OFDM format or OFDM PPDU, the STA's receive procedure shall resume here. Existing state, including knowledge of the L-SIG Parity and RATE checks, is retained.

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(#1062)If dot11TimingMsmtActivated is false, if the PHY header reception is successful (and the SIGNAL field is completely recognizable and supported), a PHY-RXSTART.indication(RXVECTOR) primitive shall be issued.

(#1062)If dot11TimingMsmtActivated is true, the PHY shall do the following:

— Complete receiving the PHY header and verify the validity of the PHY Header.

— If the PHY header reception is successful (and the SIGNAL field is completely recognizable and supported), a PHY-RXSTART.indication(RXVECTOR) primitive shall be issued and RX_START_OF_FRAME_OFFSET parameter within the RXVECTOR shall be forwarded (see 17.2.3 (RXVECTOR parameters(#1369))).

A VHT STA shall include the CH_BANDWIDTH_IN_NON_HT and DYN_BANDWIDTH_IN_NON_HT parameters in the RXVECTOR within the PHY-RXSTART.indication(RXVECTOR) primitive.

NOTE—The RX_START_OF_FRAME_OFFSET value is used (#3049)to estimate when the start of the preamble for the incoming (#14)PPDU was detected on the medium at the receive antenna connector.

The RXVECTOR associated with this primitive includes the SIGNAL field, the SERVICE field, the PSDU length in octets, and the RSSI. Also, in this case, the CCA of the OFDM PHY shall indicate a busy medium for the intended duration of the transmitted frame, as indicated by the LENGTH field.

The received PSDU bits are assembled into octets, decoded, and presented to the MAC using a series of PHY-DATA.indication(DATA) primitive exchanges. The rate change indicated in the SIGNAL field shall be initiated from the SERVICE field data of the PHY header, as described in 17.3.2 (PPDU format). The PHY shall proceed with PSDU reception. After the reception of the final bit of the last PSDU octet indicated by the LENGTH field of the SIGNAL field, the receiver shall be returned to the RX IDLE state, as shown in Figure 17-19 (Receive PHY(#1058)(#4122)). A PHY-RXEND.indication(NoError) primitive shall be issued.

In the event that a change in the RSSI causes the status of the CCA to return to the IDLE state before the complete reception of the PSDU, as indicated by the PHY LENGTH field, the error condition shall be reported to the MAC using a PHY-RXEND.indication(CarrierLost) primitive and the PHY receiver shall return to the RX IDLE state. The CCA of the OFDM PHY shall indicate a busy medium for the intended duration of the transmitted (#14)PPDU.

If the indicated rate in the SIGNAL field is not receivable, a PHY-RXSTART.indication primitive shall not be issued. The PHY shall indicate the error condition by issuing a PHY-RXEND.indication(UnsupportedRate) primitive and hold CCA busy for the calculated duration of the PPDU. If the PHY header is receivable, but the parity check of the PHY header is not valid (#18)or the RATE field is an undefined value, then a PHY-RXSTART.indication primitive shall not be issued. The PHY shall indicate the error condition using a PHY-RXEND.indication(FormatViolation) primitive.

Any data received after the indicated data length are considered pad bits (to fill out an OFDM symbol) and should be discarded.

A typical state machine implementation of the receive PHY is given in Figure 17-20 (PHY receive state machine(#1590)(#18)).


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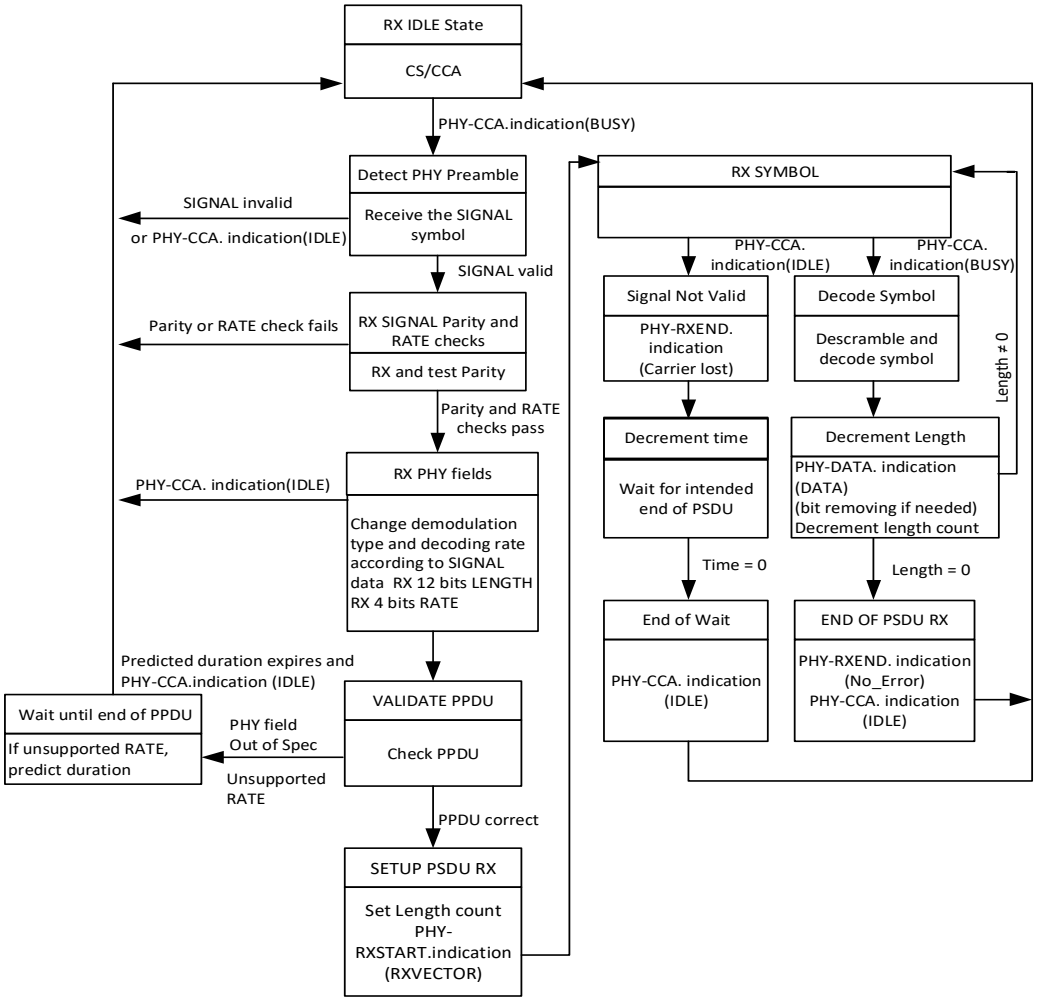


**Figure 17-20—PHY receive state machine(#1590)(#18)**

## 17.4 OFDM PLME

### 17.4.1 PLME SAP layer management primitives(#6320)

Table 17-23 (MIB attribute default values/ranges) lists the MIB attributes that may be accessed by the PHY entities and the intralayer of higher level LMEs. These attributes are accessed via the PLME-GET, PLME-SET, PLME-RESET, and PLME-CHARACTERISTICS primitives defined in 6.7 (PLME SAP interface).

**Table 17-23—MIB attribute default values/ranges**

| Managed object | Default value/range | Operational semantics |
|---|---|---|
| **dot11 PHY Operation Table** | | |
| dot11PHYType | OFDM-5. (04) | Static |
| dot11CurrentRegDomain | Implementation dependent | Dynamic |

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**Table 17-23—MIB attribute default values/ranges *(continued)***

| Managed object | Default value/range | Operational semantics |
|---|---|---|
| **dot11 PHY Antenna Table** | | |
| dot11CurrentTxAntenna | Implementation dependent | Dynamic |
| dot11DiversitySupportImplemented | Implementation dependent | Static |
| dot11CurrentRxAntenna | Implementation dependent | Dynamic |
| **dot11 PHY Tx Power Table** | | |
| dot11NumberSupportedPowerLevelsImplemented | Implementation dependent | Static |
| dot11TxPowerLevel1 | Implementation dependent | Static |
| dot11TxPowerLevel2 | Implementation dependent | Static |
| dot11TxPowerLevel3 | Implementation dependent | Static |
| dot11TxPowerLevel4 | Implementation dependent | Static |
| dot11TxPowerLevel5 | Implementation dependent | Static |
| dot11TxPowerLevel6 | Implementation dependent | Static |
| dot11TxPowerLevel7 | Implementation dependent | Static |
| dot11TxPowerLevel8 | Implementation dependent | Static |
| dot11CurrentTxPowerLevel | Implementation dependent | Dynamic |
| **dot11 Reg Domains Supported Table** | | |
| dot11RegDomainsImplementedValue | Implementation dependent | Static |
| dot11FrequencyBandsSupported | Implementation dependent | Static |
| **dot11 PHY Antennas List Table** | | |
| dot11SupportedTxAntenna | Implementation dependent | Static |
| dot11SupportedRxAntenna | Implementation dependent | Static |
| dot11DiversitySelectionRx | Implementation dependent | Dynamic |
| **dot11 Supported Data Rates Tx Table** | | |
| dot11ImplementedDataRatesTxValue | 6, 9, 12, 18, 24, 36, 48, and 54 Mb/s for 20 MHz channel spacing (Mandatory rates: 6, 12, and 24)<br><br>3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s for 10 MHz channel spacing (Mandatory rates: 3, 6, and 12)<br><br>1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s for 5 MHz channel spacing (Mandatory rates: 1.5, 3, and 6) | Static |


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**Table 17-23—MIB attribute default values/ranges *(continued)***

| Managed object | Default value/range | Operational semantics |
|---|---|---|
| **dot11 Supported Data Rates Rx Table** | | |
| dot11ImplementedDataRatesRxValue | 6, 9, 12, 18, 24, 36, 48, and 54 Mb/s for 20 MHz channel spacing (Mandatory rates: 6, 12, and 24)<br><br>3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s for 10 MHz channel spacing (Mandatory rates: 3, 6, and 12)<br><br>1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s for 5 MHz channel spacing (Mandatory rates: 1.5, 3, and 6) | Static |
| **dot11 PHY OFDM Table** | | |
| dot11CurrentFrequency | Implementation dependent | Dynamic |
| dot11TIThreshold | Implementation dependent | Dynamic |
| dot11ChannelStartingFactor | Implementation dependent | Dynamic |
| dot11OFDMEDThreshold | Implementation dependent | Dynamic |
| dot11ACRType | Implementation dependent | Dynamic |

### 17.4.2 OFDM PHY MIB

All OFDM PHY MIB attributes are defined in Annex C, with specific values defined in Table 17-23 (MIB attribute default values/ranges). The column titled “Operational semantics” in Table 17-23 (MIB attribute default values/ranges) contains two types: static and dynamic. Static MIB attributes are fixed and cannot be modified for a given PHY implementation. Dynamic MIB attributes can be modified by some management entity.

When MAX-ACCESS is read-only, the MIB attribute value may be updated by the PLME and read from the MIB attribute by management entities. When MAX-ACCESS is read-write, the MIB attribute may be read and written by management entities but shall not be updated by the PLME.

### 17.4.3 OFDM TXTIME calculation

The value of the TXTIME parameter returned by the PLME-TXTIME.confirm primitive shall be calculated according to the following equation:

$$\text{TXTIME} = T_{PREAMBLE} + T_{SIGNAL} + T_{SYM} \times N_{SYM} \quad (17\text{-}29)$$

where

$T_{PREAMBLE}$ is defined in Table 17-5 (Timing-related parameters)
$T_{SIGNAL}$ is defined in Table 17-5 (Timing-related parameters)
$T_{SYM}$ is defined in Table 17-5 (Timing-related parameters)
$N_{SYM}$ is given by Equation (17-11)

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### 17.4.4 OFDM PHY

(#2123)The OFDM PHY characteristics, provided through the PLME-CHARACTERISTICS service primitive, are shown in Table 17-24 (OFDM PHY characteristics). The definitions for these characteristics are given in 6.7.4 (PLME-CHARACTERISTICS.confirm).

**Table 17-24—OFDM PHY characteristics**

| Characteristics | Value (20 MHz channel spacing) | Value (10 MHz channel spacing) | Value (5 MHz channel spacing) |
|---|---|---|---|
| aSlotTime | If dot11OperatingClassesRequired is false, 9 µs<br><br>If dot11OperatingClassesRequired is true, 9 µs plus any coverage-class-dependent aAirPropagationTime (see Table 9-133 (Coverage Class field parameters)) | If dot11OperatingClassesRequired is false, 13 µs<br><br>If dot11OperatingClassesRequired is true, 13 µs plus any coverage-class-dependent aAirPropagationTime (see Table 9-133 (Coverage Class field parameters)) | If dot11OperatingClassesRequired is false, 21 µs<br><br>If dot11OperatingClassesRequired is true, 21 µs plus any coverage-class-dependent aAirPropagationTime (see Table 9-133 (Coverage Class field parameters)) |
| aSIFSTime | 16 µs | 32 µs | 64 µs |
| aCCATime | Implementation dependent, see 10.3.7 (DCF timing relations). | | |
| aRxPHYStartDelay | 20 µs | 40 µs | 80 µs |
| aRxTxTurnaroundTime | Implementation dependent, see 10.3.7 (DCF timing relations). | | |
| aTxPHYDelay | Implementation dependent, see 10.3.7 (DCF timing relations). | | |
| aRxPHYDelay | Implementation dependent, see 10.3.7 (DCF timing relations). | | |
| aRxTxSwitchTime | Implementation dependent, see 10.3.7 (DCF timing relations). | | |
| aTxRampOnTime | Implementation dependent, see 10.3.7 (DCF timing relations). | | |
| aAirPropagationTime | As indicated by the coverage class (see 10.22.5 (Operation with coverage classes)). | | |
| aMACProcessingDelay | Implementation dependent, see 10.3.7 (DCF timing relations). | | |
| aPSDUMaxLength | 4095 octets | 4095 octets | 4095 octets |
| aCWmin | 15 | 15 | 15 |
| aCWmax | 1023 | 1023 | 1023 |


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# 18. Extended Rate PHY (ERP) specification

## 18.1 Overview

### 18.1.1 General

This clause specifies further rate extension of the PHY for the DSSS system of Clause 15 (DSSS PHY specification for the 2.4 GHz band designated for ISM applications) and the extensions of Clause 16 (High rate direct sequence spread spectrum (HR/DSSS) PHY specification). Hereinafter the PHY defined in this clause is known as the ERP. This PHY operates in the 2.4 GHz ISM band. In addition, a variant capability PHY based on the ERP ("Class 2 ERP") is defined in this clause.

### 18.1.2 Introduction

The ERP builds on the payload data rates of 1 and 2 Mb/s, as described in Clause 15 (DSSS PHY specification for the 2.4 GHz band designated for ISM applications), that use DSSS modulation and builds on the payload data rates of 1, 2, 5.5, and 11 Mb/s, as described in Clause 16 (High rate direct sequence spread spectrum (HR/DSSS) PHY specification), that use DSSS and CCK. An ERP STA shall comply with all normative requirements of Clause 16 (High rate direct sequence spread spectrum (HR/DSSS) PHY specification). The ERP draws from Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) to provide additional payload data rates of 6, 9, 12, 18, 24, 36, 48, and 54 Mb/s. Of these rates, transmission and reception capability for 1, 2, 5.5, 6, 11, 12, and 24 Mb/s data rates is mandatory.

A non-AP STA is a Class 2 ERP STA if it satisfies all of the following requirements and is not an ERP STA:

1) The STA shall operate in the 2.4 GHz band, and shall have operating channel width 20 MHz.
2) The STA shall support transmission and reception of DSSS 1 Mb/s and 2 Mb/s.
3) The STA shall support transmission and reception of ERP-OFDM 6 Mb/s.
4) If the STA supports HR/DSSS 11 Mb/s, then it shall support HR/DSSS 5.5 Mb/s.
5) If the STA supports ERP-OFDM 24 Mb/s, then it shall support ERP-OFDM 12 Mb/s.
6) Subject to 4) and 5), each (non-DSSS) HR/DSSS, (non-6 Mb/s) ERP-OFDM, and HT data rate is optional.
7) The STA shall support transmission and reception of DSSS long preamble and short preamble.
8) The STA shall support short slot time.
9) The CCA functionality for ERP-OFDM in 18.4.6 (CCA performance) a), b) and for HT in 19.3.19.6.4 (CCA sensitivity in 20 MHz) shall be supported.
10) The minimum receiver sensitivity requirements of Clause 15 (DSSS PHY specification for the 2.4 GHz band designated for ISM applications), Clause 16 (High rate direct sequence spread spectrum (HR/DSSS) PHY specification), Clause 18 (Extended Rate PHY (ERP) specification), and Clause 19 (High Throughput (HT) PHY specification(#2297)) shall apply to all supported modes.
11) A class 2 ERP STA shall indicate support in the Supported Rates and BSS Membership Selectors element, and if applicable, the Extended Supported Rates and BSS Membership Selectors element, during association and reassociation, and in probe requests, for
    - 1, 2, 5.5, 11, 6, 12, and 24 Mb/s (whether it supports all of these rates of not), and
    - all ERP rates from the set 9, 18, 36, 48, and 54 Mb/s that the Class 2 ERP STA supports, and shall not indicate support for other ERP rates.
12) A class 2 ERP STA shall transmit the Supplemental Class 2 Capabilities element.
13) In all other respects the STA shall follow the requirements of the ERP.

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NOTE—A Class 2 ERP STA is not(M118) able to operate in a BSS whose AP includes in the basic rate set, and uses for transmission of (#1293)group addressed frames, only rates that the STA does not support.

### 18.1.3 Operational modes

(#4030)Clause 18 (Extended Rate PHY (ERP) specification) STAs implements all mandatory modes of Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) and Clause 16 (High rate direct sequence spread spectrum (HR/DSSS) PHY specification), except it uses the 2.4 GHz frequency band and channelization plan specified in 16.3.6 (PHY operating specifications, general). The ERP has the capability to decode Clause 15 (DSSS PHY specification for the 2.4 GHz band designated for ISM applications), Clause 16 (High rate direct sequence spread spectrum (HR/DSSS) PHY specification) and ERP PPDUs. An ERP shall support(#546) sending and receiving the short preamble that is (and remains) optional for Clause 16 (High rate direct sequence spread spectrum (HR/DSSS) PHY specification) PHYs.

The ERP has the capability to detect ERP and Clause 16 (High rate direct sequence spread spectrum (HR/DSSS) PHY specification) preambles whenever a CCA is requested. Because protection mechanisms are not required in all cases, the ERP CCA mechanisms for all preamble types shall be active at all times.

An ERP BSS is capable of operating in any combination of available ERP modes (Clause 18 (Extended Rate PHY (ERP) specification) PHYs) and non-ERP modes (Clause 15 (DSSS PHY specification for the 2.4 GHz band designated for ISM applications) or Clause 16 (High rate direct sequence spread spectrum (HR/DSSS) PHY specification) PHYs). For example, a BSS could operate in an ERP-OFDM-only mode, a mixed mode of ERP-OFDM and ERP-DSSS/CCK, or a mixed mode of ERP-DSSS/CCK and non-ERP. When options are enabled, combinations are also allowed.

The changes to other parts of this standard required to implement the ERP are summarized as follows:

a) ERP-DSSS/CCK
   1) The PHY uses the capabilities of Clause 16 (High rate direct sequence spread spectrum (HR/DSSS) PHY specification) with the following exceptions:
      i) Support of the short PPDU header format capability of 16.2.2.3 (Short PPDU format) is mandatory.
      ii) CCA (see 16.3.8.5 (CCA)) has a mechanism that detects all mandatory Clause 18 (Extended Rate PHY (ERP) specification) sync symbols.
      iii) The maximum input signal level (see 16.3.8.3 (Receiver maximum input level)) is –20 dBm.
      iv) Locking the transmit center frequency and the symbol clock frequency to the same reference oscillator is mandatory.

b) ERP-OFDM
   1) The PHY uses the capabilities of Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) with the following exceptions:
      i) The frequency plan is in accordance with 16.3.6.2 (Operating frequency range) and 16.3.6.3 (Channel Numbering of operating channels) instead of 17.3.8.4 (Operating channel frequencies).
      ii) CCA has a mechanism that detects all mandatory Clause 18 (Extended Rate PHY (ERP) specification) sync symbols.
      iii) The frequency accuracy (see 17.3.9.5 (Transmit center frequency tolerance) and 17.3.9.6 (Symbol clock frequency tolerance)) is ± 25 ppm.
      iv) The maximum input signal level (see 17.3.10.5 (Receiver maximum input level)) is –20 dBm.
      v) The value of the slot time is found in Table 18-5 (ERP characteristics).
      vi) SIFS is 10 μs in accordance with 16.3.3 (HR/DSSS PHY). See 18.3.2.4 (ERP-OFDM PPDU format) for more detail.


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The 2.4 GHz ISM band is a shared medium, and coexistence with other devices such as Clause 15 (DSSS PHY specification for the 2.4 GHz band designated for ISM applications) and Clause 16 (High rate direct sequence spread spectrum (HR/DSSS) PHY specification) STAs is an important issue for maintaining high performance in Clause 18 (Extended Rate PHY (ERP) specification) (ERP) STAs. The ERP modulation (ERP-OFDM) has been designed to coexist with existing Clause 15 (DSSS PHY specification for the 2.4 GHz band designated for ISM applications) and Clause 16 (High rate direct sequence spread spectrum (HR/DSSS) PHY specification) STAs. This coexistence is achieved by several means, including virtual CS (RTS/CTS or CTS-to-self), CSMA/CA protocols, and MSDU fragmentation.

### 18.1.4 Scope of ERP PHY services

This clause specifies the ERP entity and the deviations from earlier clauses to accommodate it. It is organized by reference to the relevant earlier clauses to avoid excessive duplication.

The ERP consists of the following protocol functions:

a) A function that defines a method for mapping the (#14)PSDUs into a PPDU format suitable for sending and receiving data, management, and control information between two or more STAs using the associated PHY system. The PHY exchanges PPDUs that contain PSDUs. The MAC uses the PHY service, so each MPDU corresponds to a PSDU that is carried in a PPDU.

b) A function that defines the characteristics and method of transmitting and receiving data through a WM between two or more STAs; each using the ERP.

### 18.1.5 ERP functions

The ERP contains two functional entities: the PHY function and the layer management function.

The ERP service is provided to the MAC through the PHY service primitives described in Clause 8 (PHY service specification). Interoperability is addressed by use of the CS mechanism specified in 10.3.2.1 (CS mechanism) and the protection mechanism in 10.27 (Protection mechanisms). This mechanism allows non-ERP STAs to know of ERP traffic that they cannot demodulate so that they may defer the medium to that traffic.

## 18.2 PHY-specific service parameter list

The architecture of the IEEE 802.11 MAC is intended to be PHY independent. Some PHY implementations require PHY-dependent MAC state machines running in the MAC sublayer in order to meet certain PHY requirements. The PHY-dependent MAC state machine resides in a sublayer defined as the MLME. In certain PHY implementations, the MLME may need to interact with the PLME as part of the normal PHY SAP primitives. These interactions are defined by the PLME parameter list currently defined in the PHY service primitives as TXVECTOR, TXSTATUS, and RXVECTOR. The list of these parameters and the values they may represent are defined in the specific PHY specifications for each PHY. This subclause addresses the TXVECTOR, TXSTATUS, and RXVECTOR for the ERP.

Several service primitives include a parameter vector. DATARATE and LENGTH are described in 8.3.4.4 (Vector descriptions). The remaining parameters are considered to be management parameters and are specific to this PHY.

The parameters in Table 18-1 (TXVECTOR parameters) are defined as part of the TXVECTOR parameter list in the PHY-TXSTART.request and PLME-TXTIME.request primitives. (#400)Any additional parameters in Table 15-1 (TXVECTOR parameters), Table 16-5 (Parameter vectors), and Table 17-1 (TXVECTOR parameters) are also defined as part of the TXVECTOR parameter list when the TXVECTOR parameter MODULATION is ERP-DSSS, ERP-CCK, and ERP-OFDM, respectively.

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**Table 18-1—TXVECTOR parameters**

| Parameter | Value |
|---|---|
| DATARATE | The rate used to transmit the PSDU in Mb/s.<br>Allowed value depends on value of MODULATION parameter:<br>ERP-DSSS: 1 and 2<br>ERP-CCK: 5.5 and 11<br>ERP-OFDM: 6, 9, 12, 18, 24, 36, 48, and 54 |
| LENGTH | The length of the PSDU in octets.<br>Range: 1–4095 |
| PREAMBLE_TYPE | The preamble used for the transmission of the PPDU.<br>Enumerated type for which the allowed value depends on value of MODULATION parameter:<br>ERP-OFDM: null<br>ERP-DSSS, ERP-CCK: SHORTPREAMBLE, LONGPREAMBLE |
| MODULATION | The modulation used for the transmission of this PSDU.<br>Enumerated type: ERP-DSSS, ERP-CCK, ERP-OFDM |
| SERVICE | The scrambler initialization vector.<br>Null. |
| TXPWR_LEVEL_INDEX | The transmit power level index. The definition of these levels is up to the implementer.<br>1–8 |
| TIME_OF_DEPARTURE_REQUESTED | false, true. When true, the MAC entity requests that the PHY entity measures and reports time of departure parameters corresponding to the time when the first (#14)PPDU energy is sent by the transmitting port; when false, the MAC entity requests that the PHY entity neither measures nor reports time of departure parameters. |
| CH_BAND-WIDTH_IN_NON_HT(11ax) | If present, CBW20 or CBW40. |
| DYN_BAND-WIDTH_IN_NON_HT(11ax) | If present, Static or Dynamic. |
| (#602)SCRAMBLER_INI-TIAL_VALUE | If present, an integer in the range 1–127. See 17.3.5.5 (PHY DATA scrambler and descrambler). |


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The parameters in Table 18-2 (TXSTATUS parameters) are defined as part of the TXSTATUS parameter list in the PHY-TXSTART. confirm service primitive.

**Table 18-2—TXSTATUS parameters**

| Parameter | Value |
|---|---|
| TIME_OF_DEPARTURE | 0 to $2^{32}$– 1. The locally measured time when the first (#14)PPDU energy is sent by the transmitting port, in units equal to 1/ TIME_OF_DEPARTURE_ClockRate. This parameter is present only if TIME_OF_DEPARTURE_REQUESTED is true in the corresponding request. |
| TIME_OF_DEPARTURE_ClockRate | 0 to $2^{16}$– 1. The clock rate, in units of MHz, is used to generate the TIME_OF_DEPARTURE value. This parameter is present only if TIME_OF_DEPARTURE_REQUESTED is true in the corresponding request. |
| TX_START_OF_FRAME_OFFSET | 0 to $2^{32}$– 1. An estimate of the offset (in 10 ns units) from the point in time at which the start of the preamble (#14)of the PPDU was transmitted at the transmit antenna connector to the point in time at which this primitive is issued to the MAC. |

The parameters in Table 18-3 (RXVECTOR parameters) are defined as part of the RXVECTOR parameter list in the PHY-RXSTART.indication primitive. (#400)Any additional parameters in Table 15-2 (RXVECTOR parameters), Table 16-5 (Parameter vectors), and Table 17-2 (RXVECTOR parameters) are also defined as part of the RXVECTOR parameter list when the RXVECTOR parameter MODULATION is ERP-DSSS, ERP-CCK, and ERP-OFDM, respectively. When implementations require the use of these vectors, some or all of these parameters may be used in the vectors.

**Table 18-3—RXVECTOR parameters**

| Parameter | Value |
|---|---|
| DATARATE | The rate at which the PSDU was received in Mb/s.<br>Allowed value depends on value of MODULATION parameter:<br>ERP-DSSS: 1 and 2<br>ERP-CCK: 5.5 and 11<br>ERP-OFDM: 6, 9, 12, 18, 24, 36, 48, and 54 |
| LENGTH | The length of the PSDU in octets.<br>Range: 1–4095 |
| PREAMBLE_TYPE | The preamble type detected during reception of the PPDU.<br>Enumerated type for which the allowed value depends on value of MODULATION parameter:<br>ERP-OFDM: null<br>ERP-DSSS, ERP-CCK: SHORTPREAMBLE, LONGPREAMBLE. |
| MODULATION | The modulation used for the reception of this PSDU.<br>Enumerated types: ERP-DSSS, ERP-CCK, ERP-OFDM |
| SERVICE | Null. |
| RSSI | The RSSI is a measure of the RF energy received by the ERP. The 8-bit value is in the range 0 to RSSI maximum as described in (#1369)17.2.3 (RXVECTOR parameters(#1369)). |

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**Table 18-3—RXVECTOR parameters *(continued)***

| Parameter | Value |
|---|---|
| RX_START_OF_FRAME_OFFSET | 0 to $2^{32}$– 1. An estimate of the offset (in 10 ns units) from the point in time at which the start of the preamble corresponding to the incoming frame arrived at the receive antenna connector to the point in time at which this primitive is issued to the MAC. |
| CH_BAND-WIDTH_IN_NON_HT(11ax) | If present, CBW20 or CBW40. |
| DYN_BAND-WIDTH_IN_NON_HT(11ax) | If present, Static or Dynamic. |
| (#602)SCRAMBLER_INI-TIAL_VALUE | If present, an integer in the range 1–127. See 17.3.5.5 (PHY DATA scrambler and descrambler). |

(#2115)The PHYCONFIG_VECTOR carried in a PHY-CONFIG.request primitive for an ERP PHY contains an OPERATING_CHANNEL parameter, which identifies the operating channel. The PHY shall set dot11CurrentChannel to the value of this parameter.

## 18.3 Extended Rate PHY layer(#4114)

### 18.3.1 Introduction

Subclause 18.3 (Extended Rate PHY layer(#4114)) provides a PHY for the ERP. The convergence procedure specifies how PSDUs are converted to and from PPDUs at the transmitter and receiver. The PPDU is formed during data transmission by appending the PSDU to the Extended Rate PHY preamble and header. At the receiver, the PHY preamble and header are processed to aid in the demodulation and delivery of the PSDU.

### 18.3.2 PPDU format

#### 18.3.2.1 General

An ERP STA shall support three different preamble and header formats. The first is the long preamble and header described in 18.3.2.2 (Long preamble PPDU format) (and based on 16.2.2.2 (Long PPDU format) with redefinition of reserved bits defined therein). This PPDU provides interoperability with Clause 16 (High rate direct sequence spread spectrum (HR/DSSS) PHY specification) STAs when using the 1, 2, 5.5, and 11 Mb/s data rates. The second is the short preamble and header described in 18.3.2.3 (Short preamble PPDU format) (and based on 16.2.2.3 (Short PPDU format) where it is optional). The short preamble supports the rates 2, 5.5, and 11 Mb/s. The third is the ERP-OFDM preamble and header specified in 18.3.2.4 (ERP-OFDM PPDU format) (and based on 17.3.2 (PPDU format)).

#### 18.3.2.2 Long preamble PPDU format

Figure 16-1 (Long PPDU format) of 16.2.2.2 (Long PPDU format) shows the basic format for the long preamble PPDU. This preamble is appropriate for use with the 1, 2, 5.5, and 11 Mb/s (Clause 16 (High rate direct sequence spread spectrum (HR/DSSS) PHY specification)) modes and is compatible with BSSs using these modes.


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The SERVICE field is defined in 16.2.3.5 (Long PHY SERVICE field). An ERP STA shall set the Locked clocks bit to 1, when transmitting at a data rate described in Clause 16 (High rate direct sequence spread spectrum (HR/DSSS) PHY specification).

#### 18.3.2.3 Short preamble PPDU format

Figure 16-2 (Short PPDU format) of 16.2.2.3 (Short PPDU format) shows the basic format for the short preamble PPDU. For the ERP, support for this preamble is mandatory. The short preamble is appropriate for use with 2, 5.5, and 11 Mb/s modes. The bits of the Short PHY SERVICE field and RATE field are the same as for the Long PHY SERVICE field and RATE field and are defined in 18.3.2.2 (Long preamble PPDU format).

#### 18.3.2.4 ERP-OFDM PPDU format

(#3290)The format of an ERP-OFDM PPDU is described in 17.3.2 (PPDU format) to 17.3.5 (DATA field).

(#3290)An ERP-OFDM PPDU is (#14)immediately followed by a period of no transmission with a duration of aSignalExtension(#14), and this period is called the signal extension. The purpose of this extension is to make the TXTIME calculation in 18.5.3 (TXTIME) result in a (#14)calculated time duration interval that includes an additional duration of aSignalExtension. The SIFS for Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) (#14)PPDUs is 16 µs, and the SIFS for Clause 16 (High rate direct sequence spread spectrum (HR/DSSS) PHY specification) (#14)PPDUs is 10 µs. The longer SIFS in Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) is to allow extra time for the convolutional decode process to finish. As Clause 18 (Extended Rate PHY (ERP) specification) (#14)PPDUs use a SIFS of 10 µs, this extra aSignalExtension length extension causes the transmitter to compute the Duration field in the MAC header incorporating the aSignalDuration of "idle time" following each ERP-OFDM transmission, which causes the NAV value of Clause 16 (High rate direct sequence spread spectrum (HR/DSSS) PHY specification) STAs to be set correctly.

(#14)The "CS mechanism" described in 10.3.2.1 (CS mechanism) combines the NAV state and the STA's transmitter status with physical CS to determine the busy/idle state of the medium. A STA shall determine that the medium is idle through the use of the CCA mechanism for the interval specified. The starting reference of slot boundaries is the end of the previous PPDU[+SigExt] on the medium. That is, for ERP-OFDM PPDUs, this includes the signal extension. For ERP-OFDM PPDUs, a STA shall generate the PHY-RXEND.indication aSignalDuration after the end of the last symbol of the previous PPDU on the medium. This adjustment shall be performed by the STA based on local configuration information set using the PLME SAP.

### 18.3.3 PHY data modulation and rate change

#### 18.3.3.1 Long and short preamble formats

The long and short PHY preamble and the long PHY header shall be transmitted using the 1 Mb/s DBPSK modulation. The short PHY header shall be transmitted using the 2 Mb/s modulation. The SIGNAL and SERVICE fields combined shall indicate the modulation and rate that shall be used to transmit the PSDU. The transmitter and receiver shall initiate the modulation and rate indicated by the SIGNAL and SERVICE fields, starting with the first octet of the PSDU. The PSDU transmission rate shall be set by the DATARATE parameter in the TXVECTOR, issued with the PHY-TXSTART.request primitive described in 16.3.5 (Vector descriptions).

Four modulation formats are mandatory, 1 Mb/s and 2 Mb/s ERP-DSSS and 5.5 Mb/s and 11 Mb/s ERP-CCK, and they are specified in 16.3.6.4 (Modulation and channel data rates).

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#### 18.3.3.2 ERP-OFDM format

PHY modulation and rate change for the ERP-OFDM (#14)PPDU format follows 17.3.7 (PHY data modulation and modulation rate change).

### 18.3.4 CCA

The PHY shall provide the capability to perform a CCA and report the results of the assessment to the MAC. The CCA mechanism shall detect a "medium busy" condition for all supported preamble and header types. That is, the CCA mechanism shall detect that the medium is busy for the PPDUs specified in 18.3.2 (PPDU format) and 16.2.2 (PPDU format). The CCA mechanism performance requirements are given in 18.4.6 (CCA performance).

The ERP shall provide the capability to perform CCA according to the following method:

> **CCA Mode** (ED and CS): A combination of CS and energy above threshold. CCA shall have a mechanism for CS that detects all mandatory Clause 18 (Extended Rate PHY (ERP) specification) sync symbols. This CCA's mode's CS shall include both Barker code sync detection and OFDM sync symbol detection. CCA shall report busy at least while a PPDU is being received with energy above the ED threshold at the antenna connector.

The PHY shall indicate a busy channel by issuing a PHY-CCA.indication(BUSY) primitive and shall indicate a clear channel by issuing a PHY-CCA.indication(IDLE) primitive.

### 18.3.5 PHY transmit procedure(#283)

The transmit procedure for Clause 18 (Extended Rate PHY (ERP) specification) when TXVECTOR parameter FORMAT is (#2157)NON_HT and TXVECTOR parameter NON_HT_MODULATION is ERP-DSSS or ERP-CCK is described in 15.3.6 (Transmit PHY) or 16.2.5 (Transmit PHY), respectively.

The transmit procedure and state machine when TXVECTOR parameter FORMAT is (#2157)NON_HT and TXVECTOR parameter NON_HT_MODULATION is ERP-OFDM is described in 17.3.11 (Transmit PHY), except for the signal extension (refer to 18.3.2.4 (ERP-OFDM PPDU format)).

### 18.3.6 PHY receive procedure

This subclause describes the procedure used by receivers of the ERP. An ERP receiver shall support(#546) receiving 1, 2, 5.5, and 11 Mb/s PPDUs using either the long or short preamble formats described in Clause 16 (High rate direct sequence spread spectrum (HR/DSSS) PHY specification) and shall support(#546) receiving the ERP-OFDM modulations at rates of 6, 12, and 24 Mb/s using the modulation and preamble described in Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification). The PHY may also be capable of receiving the ERP-OFDM modulations at rates of 9, 18, 36, 48, and 54 Mb/s using this modulation and preamble. The receiver shall support(#546) detecting the preamble type (ERP-OFDM, short preamble, or long preamble) and the modulation type. These values shall be reported in the RXVECTOR (see 18.2 (PHY-specific service parameter list)).

Upon the receipt of a PPDU, the receiver shall first distinguish between the ERP-OFDM preamble and the single carrier modulations (long or short preamble). In the case where the preamble is an ERP-OFDM preamble, the PHY receive procedure shall follow the procedure described in 17.3.12 (Receive PHY). Otherwise, the receiver shall then distinguish between the long preamble and short preamble as specified in 16.2.2 (PPDU format), except that the issuance of the PHY-RXEND.indication (and the following PHY-CCA.indication) is delayed by the signal extension (see 18.3.2.4 (ERP-OFDM PPDU format)). The receiver shall then demodulate the SERVICE field to determine the modulation type as specified in 18.3.2.2 (Long preamble PPDU format) or 18.3.2.3 (Short preamble PPDU format). For short preamble and long preamble


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using ERP-DSSS or ERP-CCK, the receiver shall then follow the receive procedure described in 16.2.6 (Receive PHY).

## 18.4 ERP operating specifications (general)

### 18.4.1 Introduction

Subclauses 18.4.2 (Regulatory requirements) to 18.4.7 (PHY transmit specifications) provide general specifications for the ERP. These specifications are based on 17.3.8 (PHY operating specifications (general)) except where noted.

### 18.4.2 Regulatory requirements

All systems shall comply with the appropriate regulatory requirements for operation in the 2.4 GHz band.

### 18.4.3 Operating channel frequencies

The ERP shall operate in the frequency ranges specified in 16.3.6.3 (Channel Numbering of operating channels), as allocated by regulatory bodies in the United States and its territories(#296), Europe, and Japan. The channel numbering and the number of operating channels shall follow Table 16-6 (HR/DSSS PHY frequency channel plan) of 16.3.6.3 (Channel Numbering of operating channels).

### 18.4.4 Transmit and receive in-band and out-of-band spurious emissions

The ERP shall comply with in-band and out-of-band spurious emissions as set by the appropriate regulatory bodies for the 2.4 GHz band.

### 18.4.5 SIFS

The ERP shall use a SIFS of 10 μs.

### 18.4.6 CCA performance

The CCA parameters are subject to the following criteria:

a) When the start of an ERP-OFDM signal or DSSS, HR-DSSS, ERP-DSSS or ERP-CCK sync symbols at a receive level greater than or equal to –82 dBm at the receiver antenna connector are present at the start of the MAC slot, the receiver's CCA indicator shall report the channel busy with probability CCA_Detect_Probability within a aCCATime. CCA_Detect_Probabilty is the probability that the CCA does respond correctly to a signal and shall be at least 99% for long slot time and at least 90% for short slot time. The values for the other parameters are found in Table 18-5 (ERP characteristics). Note that the CCA Detect Probability and the power level are performance requirements.

b) In the event that a correct PHY header is received, the ERP shall hold the CCA signal inactive (channel busy) for the full duration, as indicated by the PHY LENGTH field. Should a loss of CS occur in the middle of reception, the CCA shall indicate a busy medium for the intended duration of the transmitted PPDU.

c) CCA shall report a busy medium upon detection of any energy above –62 dBm.

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### 18.4.7 PHY transmit specifications

#### 18.4.7.1 General

The PHY transmit specifications shall follow 17.3.9 (PHY transmit specifications) with the exception of the transmit power level (17.3.9.2 (Transmit power levels)), the transmit center frequency tolerance (17.3.9.5 (Transmit center frequency tolerance)), the symbol clock frequency tolerance (17.3.9.6 (Symbol clock frequency tolerance)), and the time of departure accuracy (17.3.9.9 (Time of Departure accuracy)). Regulatory requirements may have an effect on the combination of maximum transmit power and spectral mask if the resulting signals violate restricted band emission limits.

#### 18.4.7.2 Transmit power levels

The maximum transmit power level shall meet the requirements of the local regulatory body.

#### 18.4.7.3 Transmit spectral mask

The transmit spectral mask for (#3290)ERP-OFDM PPDUs shall follow 17.3.9.3 (Transmit spectrum mask) and is shown in Figure 17-13 (Transmit spectrum mask for 20 MHz transmission) therein. The transmit spectral mask for ERP-DSSS/CCK PPDUs shall follow 16.3.7.4 (Transmit spectrum mask) and is shown in Figure 16-8 (Transmit spectrum mask) therein.

#### 18.4.7.4 Transmit center frequency tolerance

The transmit center frequency tolerance shall be ± 25 ppm. The transmit center frequency and symbol clock frequency shall be derived from the same reference oscillator (locked).

#### 18.4.7.5 Symbol clock frequency tolerance

The symbol clock frequency tolerance shall be ± 25 ppm. The transmit center frequency and symbol clock frequency shall be derived from the same reference oscillator (locked oscillators). This means that the error in ppm for the carrier and the symbol timing shall be the same.

#### 18.4.7.6 Time of Departure accuracy

The time of departure specifications shall follow 17.3.9.9 (Time of Departure accuracy) for PPDUs transmitted using ERP-OFDM format and 16.3.7.10 (Time of Departure accuracy) for PPDUs transmitted using ERP-DSSS/CCK.

### 18.4.8 PHY receive specifications

#### 18.4.8.1 General

Subclause 18.4.8 (PHY receive specifications) describes the receive specifications for the PHY layer(#4114). The receive specification for ERP-OFDM PPDUs shall follow 17.3.10 (PHY receiver specifications) with the exception of the receiver maximum input level (17.3.10.5 (Receiver maximum input level)) and the adjacent channel rejection (17.3.10.3 (Adjacent channel rejection)). The receive specification for ERP-DSSS/CCK PPDUs shall follow 16.3.8 (PHY receiver specifications) with the exception of the receiver maximum input level (16.3.8.3 (Receiver maximum input level)).(#3290)

#### 18.4.8.2 Receiver minimum input level sensitivity

(#3290)The PER for ERP-OFDM PPDUs shall be less than 10% at a PSDU length of 1000 octets for the input levels of Table 17-21 (Receiver performance requirements) of 17.3.10 (PHY receiver specifications).


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Input levels are specific for each data rate and are measured at the antenna connector. A noise figure of 10 dB and an implementation loss of 5 dB are assumed. (#1731)(#3290)The PER for ERP-CCK PPDUs shall be as specified in 16.3.8.2 (Receiver minimum input level sensitivity). The PER for ERP-DSSS PPDUs shall be as specified in 15.4.6.2 (Receiver minimum input level sensitivity).

#### 18.4.8.3 Adjacent channel rejection

Adjacent channels at 2.4 GHz are defined to be at ± 25 MHz spacing.

(#3290)For ERP-OFDM PPDUs, the adjacent channel rejection shall be measured by setting the desired signal's strength 3 dB above the rate-dependent sensitivity specified in Table 17-21 (Receiver performance requirements) of 17.3.10 (PHY receiver specifications) and raising the power of the interfering signal until 10% PER is caused for a PSDU length of 1000 octets. The difference in power between the signals in the interfering channel and the desired channel is the corresponding adjacent channel rejection. The interfering signal in the adjacent channel shall be a signal compliant with the ERP, unsynchronized with the signal in the channel under test. In an ERP the corresponding rejection shall be no less than specified in Table 17-21 (Receiver performance requirements) of 17.3.10 (PHY receiver specifications).

The alternative adjacent channel rejection of Table 17-21 (Receiver performance requirements) shall not be required for the ERP.

(#3290)For ERP-DSSS/CCK PPDUs, the adjacent channel rejection shall follow 16.3.8.4 (Receiver adjacent channel rejection).

#### 18.4.8.4 Receive maximum input level capability

The PER shall be less than 10% at a PSDU length of 1000 octets for an input level of –20 dBm measured at the antenna connector for any supported modulation signal or data rate (i.e., 1, 2, 5.5, 6, 9, 11, 12, 18, 22, 24, 33, 36, 48, 54 Mb/s).

## 18.5 ERP PLME

### 18.5.1 PLME SAP

Table 18-4 (MIB attribute default values/ranges) lists the additional MIB attributes that may be accessed by the PHY entities and the intralayer of higher LMEs. These attributes are accessed via the PLME-GET, PLME-SET, PLME-RESET, and PLME-CHARACTERISTICS primitives defined in 6.7 (PLME SAP interface).

### 18.5.2 MIB

HR/DSSS PHY MIB attributes are defined in Annex C with additions from this supplement and with specific values defined in Table 18-4 (MIB attribute default values/ranges).

**Table 18-4—MIB attribute default values/ranges**

| Managed object | Default value/range | Operational semantics |
|---|---|---|
| **dot11 PHY Operation Table** | | |
| dot11PHYType | ERP (X'06') | Static |
| dot11CurrentRegDomain | Implementation dependent | Static |

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**Table 18-4—MIB attribute default values/ranges *(continued)***

| Managed object | Default value/range | Operational semantics |
|---|---|---|
| **dot11 PHY Antenna Table** | | |
| dot11CurrentTxAntenna | Implementation dependent | Dynamic |
| dot11DiversitySupportImplemented | Implementation dependent | Static |
| dot11CurrentRxAntenna | Implementation dependent | Dynamic |
| **dot11 PHY Tx Power Table** | | |
| dot11NumberSupportedPowerLevelsImplemented | Implementation dependent | Static |
| dot11TxPowerLevel1 | Implementation dependent | Static |
| dot11TxPowerLevel2 | Implementation dependent | Static |
| dot11TxPowerLevel3 | Implementation dependent | Static |
| dot11TxPowerLevel4 | Implementation dependent | Static |
| dot11TxPowerLevel5 | Implementation dependent | Static |
| dot11TxPowerLevel6 | Implementation dependent | Static |
| dot11TxPowerLevel7 | Implementation dependent | Static |
| dot11TxPowerLevel8 | Implementation dependent | Static |
| dot11CurrentTxPowerLevel | Implementation dependent | Dynamic |
| **dot11 Phy DSSS Table** | | |
| dot11CurrentChannel | Implementation dependent | Dynamic |
| **dot11 Reg Domains Supported Table** | | |
| dot11RegDomainsImplementedValue(s) | Implementation dependent | Static |
| **dot11 PHY Antennas List Table** | | |
| dot11TxAntennaImplemented | Implementation dependent | Static |
| dot11RxAntennaImplemented | Implementation dependent | Static |
| dot11DiversitySelectionRxImplemented | Implementation dependent | Dynamic |
| **dot11 Supported Data Rates Tx Table** | | |
| dot11SupportedDataratesTxValue | X'02' = 1 Mb/s<br>X'04' = 2 Mb/s<br>X'0B' = 5.5 Mb/s<br>X'16' = 11 Mb/s<br>X'0C' = 6 Mb/s<br>X'12' = 9 Mb/s<br>X'18' = 12 Mb/s<br>X'24' = 18 Mb/s<br>X'30' = 24 Mb/s<br>X'48' = 36 Mb/s<br>X'60' = 48 Mb/s<br>X'6C' = 54 Mb/s | Static |


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**Table 18-4—MIB attribute default values/ranges *(continued)***

| Managed object | Default value/range | Operational semantics |
|---|---|---|
| **dot11 Supported Data Rates Rx Table** | | |
| dot11ImplementedDataRatesRxValue | X'02' = 1 Mb/s<br>X'04' = 2 Mb/s<br>X'0B' = 5.5 Mb/s<br>X'16' = 11 Mb/s<br>X'0C' = 6 Mb/s<br>X'12' = 9 Mb/s<br>X'18' = 12 Mb/s<br>X'24' = 18 Mb/s<br>X'30' = 24 Mb/s<br>X'48' = 36 Mb/s<br>X'60' = 48 Mb/s<br>X'6C' = 54 Mb/s | Static |
| **dot11 HRDSSS PHY Table** | | |
| dot11ShortPreambleOptionImplemented | true/Boolean | Static |
| **dot11 PHY ERP Table** | | |
| dot11ShortSlotTimeOptionImplemented | false/Boolean | Static |
| dot11ShortSlotTimeOptionActivated | false/Boolean | Dynamic |

When MAX-ACCESS is read-only, the MIB attribute value may be updated by the PLME and read from the MIB attribute by management entities. When MAX-ACCESS is read-write, the MIB attribute may be read and written by management entities but shall not be updated by the PLME.

### 18.5.3 TXTIME

#### 18.5.3.1 General

The value of TXTIME is calculated for each modulation type based on parameters in the TXVECTOR. For the 1, 2, 5.5, and 11 Mb/s modes with DSSS and CCK modulation formats, the value shall be calculated as described in 16.3.4 (HR/DSSS TXTIME calculation).

#### 18.5.3.2 ERP-OFDM TXTIME calculations

The value of the TXTIME parameter returned by the PLME-TXTIME.confirm primitive shall be calculated using the ERP-OFDM TXTIME calculation as shown in Equation (18-1).

$$\text{TXTIME} = T_{PREAMBLE} + T_{SIGNAL} + T_{SYM} \times \left\lceil \frac{16 + 8 \times \text{LENGTH} + 6}{N_{DBPS}} \right\rceil + T_{SE} \quad (18\text{-}1)$$

where

$T_{PREAMBLE}$, $T_{SIGNAL}$, and $T_{SYM}$ are defined in Table 17-5 (Timing-related parameters) in 17.3.2.4 (Timing-related parameters)

$N_{DBPS}$ is the number of data bits per symbol and is derived from the DATARATE parameter in Table 17-4 (Modulation-dependent parameters) in 17.3.2.3 (Modulation-dependent parameters)

$T_{SE}$ is aSignalExtension

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### 18.5.4 ERP

(#2123)The ERP characteristics, provided through the PLME-CHARACTERISTICS service primitive, are shown in Table 18-5 (ERP characteristics). The definitions for these characteristics are given in 6.7.4 (PLME-CHARACTERISTICS.confirm).(#2154)(#1761)

**Table 18-5—ERP characteristics**

| Characteristic | Value |
|---|---|
| aSlotTime | If dot11OperatingClassesRequired is false:<br>Long slot time = 20 μs<br>Short slot time = 9 μs<br><br>If dot11OperatingClassesRequired is true:<br>Long slot time = 20 μs plus any coverage-class-dependent aAirPropagationTime (see Table 9-133 (Coverage Class field parameters))<br>Short slot time = 9 μs plus any coverage-class-dependent aAirPropagationTime (see Table 9-133 (Coverage Class field parameters)) |
| aSIFSTime | 10 μs |
| aSignalExtension | 6 μs |
| aCCATime | Implementation dependent, see 10.3.7 (DCF timing relations). |
| aRxPHYStartDelay | 20 μs for ERP-OFDM,<br>192 μs for ERP-DSSS/CCK with long preamble, and<br>96 μs for ERP-DSSS/CCK with short preamble |
| aRxTxTurnaroundTime | Implementation dependent, see 10.3.7 (DCF timing relations). |
| aTxPHYDelay | Implementation dependent, see 10.3.7 (DCF timing relations). |
| aRxPHYDelay | Implementation dependent, see 10.3.7 (DCF timing relations). |
| aRxTxSwitchTime | Implementation dependent, see 10.3.7 (DCF timing relations). |
| aTxRampOnTime | Implementation dependent, see 10.3.7 (DCF timing relations). |
| aAirPropagationTime | As indicated by the coverage class (see 10.22.5 (Operation with coverage classes)). |
| aMACProcessingDelay | Implementation dependent, see 10.3.7 (DCF timing relations). |
| aPSDUMaxLength | 4095 octets |
| aCWmin(0) | 31 |
| aCWmin(1) | 15 |
| ACWmin | The set aCWmin() |
| aCWmax | 1023 |


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# 19. High Throughput (HT) PHY specification(#2297)

## 19.1 Introduction

### 19.1.1 Introduction to the HT PHY

Clause 19 (High Throughput (HT) PHY specification(#2297)) specifies the PHY entity for a (#2297)high throughput (HT) orthogonal frequency division multiplexing (OFDM) system. In addition, a variant capability PHY based on the HT PHY ("Class 2 HT PHY") is defined in this clause.

In addition to the requirements found in Clause 19 (High Throughput (HT) PHY specification(#2297)), an HT STA shall support(#546) transmitting and receiving frames that are compliant with the mandatory PHY specifications defined as follows:

— In Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) when the HT STA is operating in a 20 MHz channel width in the 5 GHz band

— In Clause 16 (High rate direct sequence spread spectrum (HR/DSSS) PHY specification) and Clause 18 (Extended Rate PHY (ERP) specification) when the HT STA is operating in a 20 MHz channel width in the 2.4 GHz band

An HT STA that operates in the 5 GHz band shall comply with all normative requirements of Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification). An HT STA that operates in the 2.4 GHz band shall comply with all normative requirements of Clause 18 (Extended Rate PHY (ERP) specification).

The HT PHY is based on the OFDM PHY defined in Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification), with extensibility up to four spatial streams, operating in 20 MHz bandwidth. Additionally, transmission using one to four spatial streams is defined for operation in 40 MHz bandwidth. These features are capable of supporting data rates up to 600 Mb/s (four spatial streams, 40 MHz bandwidth).

The HT PHY data subcarriers are modulated using binary phase shift keying (BPSK), quadrature phase shift keying (QPSK), 16-quadrature amplitude modulation (16-QAM), or 64-QAM. Forward error correction (FEC) coding (convolutional coding) is used with a coding rate of 1/2, 2/3, 3/4, or 5/6. LDPC codes are added as an optional feature.

Other optional features at both transmit and receive sides are 400 ns (short) guard interval (GI), transmit beamforming, HT-greenfield format, and STBC.

The maximum HT PSDU length is 65 535 octets.

A non-AP STA is a Class 2 HT STA if it satisfies all of the following requirements and is not an HT STA:

1) The STA shall operate in the 2.4 GHz band, and shall have operating channel width 20 MHz.
2) The STA shall support transmission and reception of DSSS 1 Mb/s and 2 Mb/s.
3) The STA shall support transmission and reception of ERP-OFDM 6 Mb/s.
4) If the STA supports HR/DSSS 11 Mb/s, then it shall support HR/DSSS 5.5 Mb/s.
5) If the STA supports ERP-OFDM 24 Mb/s, then it shall support ERP-OFDM 12 Mb/s.
6) If the STA supports any $N_{SS}$ = 1 HT-MCS > 0, then it shall support all $N_{SS}$ = 1 HT lower HT-MCSs and all lower ERP rates.
7) Except as noted in 4), 5), and 6), each (non-DSSS) HR/DSSS and ERP-OFDM data rate and each HT-MCS is optional.

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8) The STA shall support DSSS long preamble and short preamble.
9) The STA shall support short slot time.
10) The CCA functionality for ERP-OFDM in 18.4.6 (CCA performance) a) and b) and for HT in 19.3.19.6.4 (CCA sensitivity in 20 MHz) shall be supported.
11) The minimum receiver sensitivity requirements of Clause 15 (DSSS PHY specification for the 2.4 GHz band designated for ISM applications), Clause 16 (High rate direct sequence spread spectrum (HR/DSSS) PHY specification), Clause 18 (Extended Rate PHY (ERP) specification), and Clause 19 (High Throughput (HT) PHY specification(#2297)) shall apply to all supported modes.
12) A Class 2 HT STA shall indicate support in the Supported Rates and BSS Membership Selectors element, and, if applicable, the Extended Supported Rates and BSS Membership Selectors element, during association and reassociation, and in probe requests, for
    — 1, 2, 5.5, 11, 6, 12, and 24 Mb/s (whether it supports all of these rates of not), and
    — All ERP rates from the set 9, 18, 36, 48, and 54 Mb/s that the Class 2 HT STA supports, and shall not indicate support for other ERP rates.
13) A Class 2 HT STA shall transmit the HT Capabilities element during association and reassociation, and in probe requests, and shall indicate in the Supported MCS Set field support for HT-MCSs 0-7 (whether it supports all of these HT-MCSs or not).
14) A Class 2 HT STA shall transmit the Supplemental Class 2 Capabilities element.
15) In all other respects the STA shall follow the requirements of the ERP and the HT PHY.

NOTE—A Class 2 HT STA is not(M118) able to operate in a BSS whose AP includes in the basic rate/HT-MCS set, and uses for transmission of (#1293)group addressed frames, only rates/HT-MCSs that the STA does not support.

### 19.1.2 Scope of HT PHY services

The services provided to the MAC by the HT PHY consist of the following protocol functions:

a) A function that defines a method of mapping the PSDUs into a (#14)PPDU format suitable for sending and receiving PSDUs between two or more STAs.
b) A function that defines the characteristics and method of transmitting and receiving data through a wireless medium between two or more STAs. Depending on the PPDU format, these STAs support a mixture of HT PHY and Clause 15 (DSSS PHY specification for the 2.4 GHz band designated for ISM applications), Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification), Clause 16 (High rate direct sequence spread spectrum (HR/DSSS) PHY specification), or Clause 18 (Extended Rate PHY (ERP) specification) PHYs.

### 19.1.3 HT PHY functions

#### 19.1.3.1 General

The HT PHY contains two functional entities: the PHY and the layer management function (i.e., the PLME). Both of these functions are described in detail in 19.3 (HT PHY) and 19.4 (HT PLME).

The HT PHY service is provided to the MAC through the PHY service primitives defined in Clause 8 (PHY service specification).

#### 19.1.3.2 PHY management entity (PLME)

The PLME performs management of the local PHY functions in conjunction with the MLME.


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#### 19.1.3.3 Service specification method

The models represented by figures and state diagrams are intended to be illustrations of the functions provided. It is important to distinguish between a model and a real implementation. The models are optimized for simplicity and clarity of presentation, but do not necessarily reflect any particular implementation. The service of a layer or sublayer is the set of capabilities that it offers to a user in the next higher layer (or sublayer). Abstract services are specified here by describing the service primitives and parameters that characterize each service. This definition is independent of any particular implementation.

### 19.1.4 PPDU formats

The structure of the PPDU transmitted by an HT STA is determined by the TXVECTOR FORMAT, CH_BANDWIDTH, CH_OFFSET, and MCS parameters as defined in Table 19-1 (TXVECTOR and RXVECTOR parameters). The effect of the CH_BANDWIDTH, CH_OFFSET, and MCS parameters on PPDU format is described in 19.2.4 (Effect of CH_BANDWIDTH, CH_OFFSET, and MCS parameters on PPDU format).

The FORMAT parameter determines the overall structure of the PPDU as follows:

— *Non-HT format* **(NON_HT):** (#14)(#2262)PPDUs of this format are structured according to the Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) (OFDM) or Clause 18 (Extended Rate PHY (ERP) specification) (ERP) specification. Support for non-HT format is mandatory.

— *HT-mixed format* **(HT_MF):** (#14)(#2263)PPDUs of this format contain a preamble compatible with Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) and Clause 18 (Extended Rate PHY (ERP) specification) receivers. The non-HT-STF (L-STF), the non-HT-LTF (L-LTF), and the non-HT SIGNAL field (L-SIG) are defined so they can be decoded by non-HT Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) and Clause 18 (Extended Rate PHY (ERP) specification) STAs. The rest of the (#14)PPDU cannot be decoded by Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) or Clause 18 (Extended Rate PHY (ERP) specification) STAs. Support for HT-mixed format is mandatory.

— *HT-greenfield format* **(HT_GF):** (#14)(#2263)PPDUs of this format do not contain a non-HT compatible part. Support for HT-greenfield format is optional. (#181)An HT STA that does not support the reception of an HT-greenfield format (#14)PPDU shall support detection that an HT-greenfield format packet is an HT transmission (as opposed to a non-HT transmission). In this case, the receiver shall decode the HT-SIG and determine whether the HT-SIG cyclic redundancy check (CRC) passes.

## 19.2 HT PHY service interface

### 19.2.1 Introduction

The PHY interfaces to the MAC through the TXVECTOR, TXSTATUS, RXVECTOR, and PHYCONFIG_VECTOR. Using the TXVECTOR, the MAC supplies the PHY with per-PPDU transmit parameters. Status of the transmission is reported from PHY to MAC by parameters within TXSTATUS. Using the RXVECTOR, the PHY informs the MAC of the received (#14)PPDU's parameters. Using the PHYCONFIG_VECTOR, the MAC configures the PHY for operation, independent of (#14)PPDU transmission or reception.

This interface is an extension of the generic PHY service interface defined in 8.3.4 (Basic service and options).

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### 19.2.2 TXVECTOR and RXVECTOR parameters

The parameters in Table 19-1 (TXVECTOR and RXVECTOR parameters) are defined as part of the TXVECTOR parameter list in the PHY-TXSTART.request primitive and/or as part of the RXVECTOR parameter list in the PHY-RXSTART.indication primitive.

**Table 19-1—TXVECTOR and RXVECTOR parameters**

| Parameter | Condition | Value | TXVECTOR See NOTE 1 | RXVECTOR See NOTE 1 |
|---|---|---|---|---|
| FORMAT | | Determines the format of the PPDU.<br>Enumerated type:<br>NON_HT indicates DSSS, HR/DSSS, OFDM or ERP PPDU formats or non-HT duplicates PPDU format. In this case, the modulation is determined by the NON_HT_MODULATION parameter.<br>HT_MF indicates HT-mixed format.<br>HT_GF indicates HT-greenfield format. | Y | Y |
| NON_HT_MODULATION | FORMAT is NON_HT | Enumerated type:<br>ERP-DSSS<br>ERP-CCK<br>ERP-OFDM<br>OFDM<br>NON_HT_DUP_OFDM | Y | Y |
| | Otherwise | Not present | | |
| L_LENGTH | FORMAT is NON_HT | Indicates the length of the PSDU in octets in the range 1 to 4095. This value is used by the PHY to determine the number of octet transfers that occur between the MAC and the PHY. | Y | Y |
| | FORMAT is HT_MF | Indicates the value in the Length field of the L-SIG field(#4145) in the range 1 to 4095. This use is defined in 10.27.4 (L_LENGTH and L_DATARATE parameter values for HT-mixed format PPDUs). | Y | Y |
| | FORMAT is HT_GF | Not present | N | N |
| L_DATARATE | FORMAT is NON_HT | Indicates the rate used to transmit the PSDU in Mb/s(#4148). Allowed values depend on the value of the NON_HT_MODULATION parameter as follows:<br>ERP-DSSS: 1 and 2<br>ERP-CCK: 5.5 and 11<br>ERP-OFDM, NON_HT_DUP_OFDM:<br>6, 9, 12, 18, 24, 36, 48, and 54<br>OFDM: 6, 9, 12, 18, 24, 36, 48, and 54 | Y | Y |
| | FORMAT is HT_MF | Indicates the data rate value that is in the L-SIG field(#4145). This use is defined in 10.27.4 (L_LENGTH and L_DATARATE parameter values for HT-mixed format PPDUs). | Y | Y |
| | FORMAT is HT_GF | Not present | N | N |


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**Table 19-1—TXVECTOR and RXVECTOR parameters *(continued)***

| Parameter | Condition | Value | TXVECTOR | RXVECTOR |
|---|---|---|---|---|
| | | | See NOTE 1 | |
| LSIGVALI | FORMAT is HT_MF | true if L-SIG Parity is valid<br>false if L-SIG Parity is not valid | N | Y |
| | Otherwise | Not present | N | N |
| SERVICE | FORMAT is NON_HT and NON_HT_MODULATION is one of<br>— ERP-OFDM<br>— OFDM | Scrambler initialization, null | Y | N |
| | FORMAT is HT_MF or HT_GF | Scrambler initialization, null | Y | N |
| | Otherwise | Not present | N | N |
| TXPWR_LEVEL_INDEX | | The allowed values for the TXPWR_LEVEL_INDEX parameter are in the range 1 to 8. This parameter is used to indicate which of the available TxPowerLevel attributes defined in the MIB shall be used for the current transmission. | Y | N |
| RSSI | | The allowed values for the RSSI parameter are in the range 0 to 255. This parameter is a (#1132)measurement by the PHY of the power observed at the antenna connector used to receive the current PPDU. RSSI shall be measured during the reception of the PHY preamble. In HT-mixed format, the reported RSSI shall be measured during the reception of the HT-LTFs. RSSI is intended to be used in a relative manner, and it shall be a monotonically increasing function of the received power. | N | Y |
| PREAMBLE_TYPE | FORMAT is NON_HT and NON_HT_MODULATION is one of<br>— ERP-DSSS<br>— ERP-CCK | Enumerated type:<br>SHORTPREAMBLE<br>LONGPREAMBLE | Y | Y |
| | Otherwise | Not present | N | N |

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**Table 19-1—TXVECTOR and RXVECTOR parameters *(continued)***

| Parameter | Condition | Value | TXVECTOR See NOTE 1 | RXVECTOR See NOTE 1 |
|---|---|---|---|---|
| MCS | FORMAT is HT_MF or HT_GF | Selects the modulation and coding scheme used in the transmission of the (#14)PPDU. The value used in each MCS is the index defined in 19.5 (Parameters for HT-MCSs).<br>Integer: range 0 to 76. Values of 77 to 127 are reserved.<br>The interpretation of the MCS index is defined in 19.5 (Parameters for HT-MCSs). | Y | Y |
| | Otherwise | Not present | N | N |
| REC_MCS | FORMAT is HT_MF or HT_GF | Indicates the MCS that the STA's receiver recommends. | N | O |
| | Otherwise | Not present | N | N |
| CH_BANDWIDTH | FORMAT is HT_MF or HT_GF | Indicates whether the (#14)PPDU is transmitted using 40 MHz or 20 MHz channel width.<br>Enumerated type:<br>HT_CBW20 for 20 MHz and 40 MHz upper and 40 MHz lower modes<br>HT_CBW40 for 40 MHz | Y | Y |
| | FORMAT is NON_HT | Enumerated type:<br>NON_HT_CBW40 for non-HT duplicate format<br>NON_HT_CBW20 for all other non-HT formats | Y | Y |
| CH_OFFSET | | Indicates which portion of the channel is used for transmission. Refer to Table 19-2 (Interpretation of FORMAT, CH_BANDWIDTH, and CH_OFFSET parameters) for valid combinations of CH_OFFSET and CH_BANDWIDTH.<br><br>Enumerated type:<br>CH_OFF_20 indicates the use of a 20 MHz channel (that is not part of a 40 MHz channel).<br>CH_OFF_40 indicates the entire 40 MHz channel.<br>CH_OFF_20U indicates the upper 20 MHz of the 40 MHz channel<br>CH_OFF_20L indicates the lower 20 MHz of the 40 MHz channel. | Y | N |
| LENGTH | FORMAT is HT_MF or HT_GF | Indicates the length of an HT PSDU in the range 0 to 65 535 octets. A value of 0 indicates (#2137)an NDP that contains no data symbols after the HT preamble (see 19.3.9 (HT preamble)). | Y | Y |
| | Otherwise | Not present | N | N |
| SMOOTHING | FORMAT is HT_MF or HT_GF | Indicates whether frequency domain smoothing is recommended as part of channel estimation. (See NOTE 2.)<br>Enumerated type:<br>SMOOTHING_REC indicates that smoothing is recommended.<br>SMOOTHING_NOT_REC indicates that smoothing is not recommended. | Y | Y |
| | Otherwise | Not present | N | N |



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**Table 19-1—TXVECTOR and RXVECTOR parameters *(continued)***

| Parameter | Condition | Value | TXVECTOR See NOTE 1 | RXVECTOR See NOTE 1 |
|---|---|---|---|---|
| SOUNDING | FORMAT is HT_MF or HT_GF | Indicates whether this (#14)PPDU is a sounding PPDU.<br>Enumerated type:<br>SOUNDING indicates this is a sounding PPDU.<br>NOT_SOUNDING indicates this is not a sounding PPDU. | Y | Y |
| | Otherwise | Not present | N | N |
| AGGREGATION | FORMAT is HT_MF or HT_GF | Indicates whether the PSDU contains an A-MPDU.<br>Enumerated type:<br>AGGREGATED indicates this PSDU has A-MPDU aggregation.<br>NOT_AGGREGATED indicates this PSDU does not have A-MPDU aggregation. | Y | Y |
| | Otherwise | Not present | N | N |
| STBC | FORMAT is HT_MF or HT_GF | Indicates the difference between the number of space-time streams ($N_{STS}$) and the number of spatial streams ($N_{SS}$) indicated by the MCS as follows:<br>0 indicates no STBC ($N_{STS} = N_{SS}$).<br>1 indicates $N_{STS} - N_{SS} = 1$.<br>2 indicates $N_{STS} - N_{SS} = 2$.<br>Value of 3 is reserved. | Y | Y |
| | Otherwise | Not present | N | N |
| FEC_CODING | FORMAT is HT_MF or HT_GF | Indicates which FEC encoding is used.<br>Enumerated type:<br>BCC_CODING indicates binary convolutional code.<br>LDPC_CODING indicates low-density parity check code. | Y | Y |
| | Otherwise | Not present | N | N |
| GI_TYPE | FORMAT is HT_MF or HT_GF | Indicates whether a short guard interval is used in the transmission of the (#14)PPDU.<br>Enumerated type:<br>LONG_GI indicates short GI is not used in the (#14)PPDU.<br>SHORT_GI indicates short GI is used in the (#14)PPDU. | Y | Y |
| | Otherwise | Not present | N | N |
| NUM_EXTEN_SS | FORMAT is HT_MF or HT_GF | Indicates the number of extension spatial streams that are sounded during the extension HT-LTFs in the range 0 to 3. | Y | Y |
| | Otherwise | Not present | N | N |

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**Table 19-1—TXVECTOR and RXVECTOR parameters *(continued)***

| Parameter | Condition | Value | TXVECTOR See NOTE 1 | RXVECTOR See NOTE 1 |
|---|---|---|---|---|
| ANTENNA_SET | FORMAT is HT_MF or HT_GF | Indicates which antennas of the available antennas are used in the transmission. The length of the field is 8 bits. A 1 in bit position *n,* relative to the LSB, indicates that antenna *n* is used. At most 4 bits out of 8 may be set to 1.<br>This field is present only if ASEL is applied. | O | N |
| | Otherwise | Not present | N | N |
| N_TX | FORMAT is HT_MF or HT_GF | The N_TX parameter indicates the number of transmit chains. | Y | N |
| | Otherwise | Not present | N | N |
| EXPANSION_MAT | EXPANSION_MAT_TYPE is COMPRESSED_SV | Contains a set of compressed beamforming feedback matrices as defined in 19.3.12.3.6 (Compressed beamforming feedback matrix). The number of elements depends on the number of spatial streams and the number of transmit chains. | Y | N |
| | EXPANSION_MAT_TYPE is NON_COMPRESSED_SV | Contains a set of noncompressed beamforming feedback matrices as defined in 19.3.12.3.5 (Noncompressed beamforming feedback matrix). The number of complex elements is $N_{ST} \times N_r \times N_c$ where $N_{ST}$ is the total number of subcarriers, $N_c$ is the number of columns, and $N_r$ is the number of rows in each matrix. | Y | N |
| | EXPANSION_MAT_TYPE is CSI_MATRICES | Contains a set of CSI matrices as defined in 19.3.12.3.2 (CSI matrices feedback). The number of complex elements is $N_{ST} \times N_r \times N_c$ where $N_{ST}$ is the total number of subcarriers, $N_c$ is the number of columns, and $N_r$ is the number of rows in each matrix. | Y | N |
| | Otherwise | Not present | N | N |
| EXPANSION_MAT_TYPE | EXPANSION_MAT is present | Enumerated type:<br>COMPRESSED_SV indicates that EXPANSION_MAT is a set of compressed beamforming feedback matrices.<br>NON_COMPRESSED_SV indicates that EXPANSION_MAT is a set of noncompressed beamforming feedback matrices.<br>CSI_MATRICES indicates that EXPANSION_MAT is a set of channel state matrices. | Y | N |
| | Otherwise | Not present | N | N |



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**Table 19-1—TXVECTOR and RXVECTOR parameters *(continued)***

| Parameter | Condition | Value | TXVECTOR | RXVECTOR |
|---|---|---|---|---|
| | | | See NOTE 1 | |
| CHAN_MAT | CHAN_MAT_TYPE is COMPRESSED_SV | Contains a set of compressed beamforming feedback matrices as defined in 19.3.12.3.6 (Compressed beamforming feedback matrix) based on the channel measured during the training symbols of the received PPDU. The number of elements depends on the number of spatial streams and the number of transmit chains. | N | Y |
| | CHAN_MAT_TYPE is NON_COMPRESSED_SV | Contains a set of noncompressed beamforming feedback matrices as defined in 19.3.12.3.5 (Noncompressed beamforming feedback matrix) based on the channel measured during the training symbols of the received PPDU. The number of complex elements is $N_{ST} \times N_r \times N_c$ where $N_{ST}$ is the total number of subcarriers, $N_c$ is the number of columns, and $N_r$ is the number of rows in each matrix. | N | Y |
| | CHAN_MAT_TYPE is CSI_MATRICES | Contains a set of CSI matrices as defined in 19.3.12.3.2 (CSI matrices feedback) based on the channel measured during the training symbols of the received PPDU. The number of complex elements is $N_{ST} \times N_r \times N_c$ where $N_{ST}$ is the total number of subcarriers, $N_c$ is the number of columns, and $N_r$ is the number of rows in each matrix. | N | Y |
| | Otherwise | Not present | N | N |
| CHAN_MAT_TYPE | FORMAT is HT_MF or HT_GF | Enumerated type:<br>COMPRESSED_SV indicates that CHAN_MAT is a set of compressed beamforming vector matrices.<br>NON_COMPRESSED_SV indicates that CHAN_MAT is a set of noncompressed beamforming vector matrices.<br>CSI_MATRICES indicates that CHAN_MAT is a set of channel state matrices. | N | Y |
| | Otherwise | Not present | N | N |
| SNR | CHAN_MAT_TYPE is CSI_MATRICES | Is a measure of the received SNR per chain. SNR indications of 8 bits are supported. SNR shall be the decibel representation of linearly averaged values over the tones represented in each receive chain as described in 9.4.1.25 (CSI Report field) | N | Y |
| | CHAN_MAT_TYPE is COMPRESSED_SV or NON_COMPRESSED_SV | Is a measure of the received SNR per stream. SNR indications of 8 bits are supported. SNR shall be the sum of the decibel values of SNR per tone divided by the number of tones represented in each stream as described in 9.4.1.26 (Noncompressed Beamforming Report field) and 9.4.1.27 (Compressed Beamforming Report field) | N | Y |

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**Table 19-1—TXVECTOR and RXVECTOR parameters *(continued)***

| Parameter | Condition | Value | TXVECTOR | RXVECTOR |
|---|---|---|---|---|
| | | | See NOTE 1 | |
| NO_SIG_EXTN | FORMAT is HT_MF or HT_GF<br><br>Or<br><br>FORMAT is NON_HT and NON_HT_MODULATION is NON_HT_DUP_OFDM | Indicates whether signal extension needs to be applied (#14)immediately following the PPDU.<br><br>Boolean values:<br>true indicates no signal extension is present.<br>false indicates signal extension may be present depending on other TXVECTOR parameters (see 19.2.2 (TXVECTOR and RXVECTOR parameters)). | Y | N |
| | Otherwise | Not present | N | N |
| TIME_OF_DEPARTURE_REQUESTED | | Enumerated type:<br>true indicates that the MAC entity requests that the PHY entity measures and reports time of departure parameters corresponding to the time when the (#14)PPDU energy is sent by the transmitting port. false indicates that the MAC entity requests that the PHY entity neither measures nor reports time of departure parameters. | O | N |
| RX_START_OF_FRAME_OFFSET | | 0 to $2^{32}$– 1. An estimate of the offset (in 10 ns units) from the point in time at which the start of the preamble (#14)of the PPDU arrived at the receive antenna connector to the point in time at which this primitive is issued to the MAC. | N | O |


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**Table 19-1—TXVECTOR and RXVECTOR parameters *(continued)***

| Parameter | Condition | Value | TXVECTOR | RXVECTOR |
|---|---|---|---|---|
| | | | See NOTE 1 | |
| (#602)SCRAMBLER_INITIAL_VALUE | FORMAT is HT_MF or HT_GF, and the STA is an HE STA | The first 7 bits of the scrambling sequence (the first 7 bits in the SERVICE field prior to descrambling), with the first bit of the scrambling sequence being the LSB of SCRAMBLER_INITIAL_VALUE. | N | Y |
| | FORMAT is HT_MF or HT_GF, and the STA is not an HE STA | Not present | N | N |
| | Otherwise | (#1369)See corresponding entry in Table 17-1 (TXVECTOR parameters) and 17.2.2 (TXVECTOR parameters(#1369)), Table 17-2 (RXVECTOR parameters) and 17.2.3 (RXVECTOR parameters(#1369)), Table 18-1 (TXVECTOR parameters) and 17.2.2 (TXVECTOR parameters(#1369)), or Table 18-3 (RXVECTOR parameters) and 17.2.3 (RXVECTOR parameters(#1369)). | | |

NOTE 1—In the TXVECTOR and RXVECTOR columns, the following apply:
Y = Present; N = Not present; O = Optional.

NOTE 2—Setting the Smoothing bit is defined in 19.3.11.11.2 (Spatial mapping).

### 19.2.3 PHYCONFIG_VECTOR parameters

The PHYCONFIG_VECTOR carried in a PHY-CONFIG.request primitive for an HT PHY contains an OPERATING_CHANNEL parameter, which identifies the operating or primary channel. The PHY shall set dot11CurrentPrimaryChannel to the value of this parameter.

The PHYCONFIG_VECTOR carried in a PHY-CONFIG.request primitive for an HT PHY contains a SECONDARY_CHANNEL_OFFSET parameter, which takes one of the following values:

— SECONDARY_CHANNEL_NONE if no secondary channel is present; in this case the PHY shall set dot11CurrentSecondaryChannel to 0.

— SECONDARY_CHANNEL_ABOVE if the secondary channel is above the primary channel; in this case the PHY shall set dot11CurrentSecondaryChannel to dot11CurrentPrimaryChannel + 4.

— SECONDARY_CHANNEL_BELOW if the secondary channel is below the primary channel; in this case the PHY shall set dot11CurrentSecondaryChannel to dot11CurrentPrimaryChannel – 4.

### 19.2.4 Effect of CH_BANDWIDTH, CH_OFFSET, and MCS parameters on PPDU format

The structure of the PPDU transmitted by an HT STA is determined by the TXVECTOR FORMAT, CH_BANDWIDTH, CH_OFFSET, and MCS parameters as defined in Table 19-1 (TXVECTOR and RXVECTOR parameters). The effect of the FORMAT parameter is described in 19.1.4 (PPDU formats).

The operation of the PHY in the frequency domain is determined by the FORMAT, CH_BANDWIDTH, and CH_OFFSET parameters. Table 19-2 (Interpretation of FORMAT, CH_BANDWIDTH, and CH_OFFSET

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parameters) shows the valid combinations of FORMAT, CH_BANDWIDTH, and CH_OFFSET and the corresponding PPDU format. Other combinations are reserved.

**Table 19-2—Interpretation of FORMAT, CH_BANDWIDTH, and CH_OFFSET parameters**

| FORMAT | CH_BANDWIDTH | CH_OFFSET |
|---|---|---|
| HF_MF, HF_GF | HT_CBW20 | CH_OFF_20: *20 MHz HT format*—The STA has a 20 MHz operating channel width and transmits an HT-mixed or HT-greenfield format PPDU of 20 MHz bandwidth.<br>CH_OFF_20U: *40 MHz HT upper format*—The STA transmits an HT-mixed or HT-greenfield format PPDU of 20 MHz bandwidth in the upper 20 MHz of a 40 MHz channel.<br>CH_OFF_20L: *40 MHz HT lower format*—The STA transmits an HT-mixed or HT-greenfield format PPDU of 20 MHz bandwidth in the lower 20 MHz of a 40 MHz channel. |
| HT_MF, HT_GF | HT_CBW40 | CH_OFF_40: *40 MHz HT format*—The STA transmits an HT-mixed or HT-greenfield format PPDU of 40 MHz bandwidth. |
| NON_HT | NON_HT_CBW20 and the SECONDARY_CHANNEL_OFFSET parameter of the PHYCONFIG_VECTOR is SECONDARY_CHANNEL_NONE | CH_OFF_20: *20 MHz non-HT format*—The STA has a 20 MHz operating channel width and transmits an (#1368)ERP-DSSS, ERP-CCK or ERP-OFDM format PPDU, or OFDM PPDU. |
| NON_HT | NON_HT_CBW20 and the SECONDARY_CHANNEL_OFFSET parameter of the PHYCONFIG_VECTOR is SECONDARY_CHANNEL_BELOW | CH_OFF_20U: *40 MHz non-HT upper format*—The STA transmits an (#1368)ERP-DSSS, ERP-CCK or ERP-OFDM format PPDU, or OFDM PPDU, in the upper 20 MHz of a 40 MHz channel. |
| NON_HT | NON_HT_CBW20 and the SECONDARY_CHANNEL_OFFSET parameter of the PHYCONFIG_VECTOR is SECONDARY_CHANNEL_ABOVE | CH_OFF_20L: *40 MHz non-HT lower format*—The STA transmits an (#1368)ERP-DSSS, ERP-CCK or ERP-OFDM format PPDU, or OFDM PPDU, in the lower 20 MHz of a 40 MHz channel. |
| NON_HT | NON_HT_CBW40 | CH_OFF_40: *Non-HT duplicate format*—The STA transmits an (#2095)ERP-OFDM format PPDU or OFDM PPDU in each of the 20 MHz channels of a 40 MHz channel. The upper channel (higher frequency) is rotated by +90° relative to the lower channel. See 19.3.11.12 (Non-HT duplicate transmission). |


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### 19.2.5 Support for NON_HT formats

When the FORMAT parameter is equal to NON_HT, the behavior of the HT PHY is defined in other clauses as shown in Table 19-3 (Mapping of the HT PHY parameters for NON_HT operation), dependent on the operational band. In this case, the PHY-TXSTART.request primitive is handled by mapping the TXVECTOR parameters as defined in Table 19-3 (Mapping of the HT PHY parameters for NON_HT operation) and following the operation as defined in the referenced clause. Likewise the PHY-RXSTART.indication primitive emitted when a non-HT PPDU is received is defined in the referenced clauses, with mapping of RXVECTOR parameters as defined in Table 19-3 (Mapping of the HT PHY parameters for NON_HT operation).

**Table 19-3—Mapping of the HT PHY parameters for NON_HT operation**

| HT PHY parameter | 2.4 GHz operation defined by Clause 15 (DSSS PHY specification for the 2.4 GHz band designated for ISM applications) | 2.4 GHz operation defined by Clause 16 (High rate direct sequence spread spectrum (HR/ DSSS) PHY specification) | 2.4 GHz operation defined by Clause 18 (Extended Rate PHY (ERP) specification) | 5 GHz(#4147) operation defined by Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) |
|---|---|---|---|---|
| L_LENGTH | LENGTH | LENGTH | LENGTH | LENGTH |
| L_DATARATE | DATARATE | DATARATE | DATARATE | DATARATE |
| LSIGVALID | — | — | — | — |
| TXPWR_LEVEL_INDEX | TXPWR_LEVEL_INDEX | TXPWR_LEVEL_INDEX | TXPWR_LEVEL_INDEX | TXPWR_LEVEL_INDEX |
| RSSI | RSSI | RSSI | RSSI | RSSI |
| FORMAT | — | — | — | — |
| PREAMBLE_TYPE | — | — | PREAMBLE_TYPE | — |
| NON_HT_MODULATION | — | — | MODULATION | — |
| SERVICE | SERVICE | SERVICE | SERVICE | SERVICE |
| MCS | — | — | — | — |
| CH_BANDWIDTH | — | — | — | — |
| CH_OFFSET | — | — | — | — |
| LENGTH | — | — | — | — |
| SMOOTHING | — | — | — | — |
| SOUNDING | — | — | — | — |
| AGGREGATION | — | — | — | — |
| STBC | — | — | — | — |
| FEC_CODING | — | — | — | — |
| GI_TYPE | — | — | — | — |

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**Table 19-3—Mapping of the HT PHY parameters for NON_HT operation *(continued)***

| HT PHY parameter | 2.4 GHz operation defined by Clause 15 (DSSS PHY specification for the 2.4 GHz band designated for ISM applications) | 2.4 GHz operation defined by Clause 16 (High rate direct sequence spread spectrum (HR/DSSS) PHY specification) | 2.4 GHz operation defined by Clause 18 (Extended Rate PHY (ERP) specification) | 5 GHz(#4147) operation defined by Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) |
|---|---|---|---|---|
| NUM_EXTEN_SS | — | — | — | — |
| ANTENNA_SET | — | — | — | — |
| EXPANSION_MAT | — | — | — | — |
| EXPANSION_MAT_TYPE | — | — | — | — |
| CHAN_MAT | — | — | — | — |
| CHAN_MAT_TYPE | — | — | — | — |
| N_TX | — | — | — | — |
| RCPI | RCPI | RCPI | RCPI | RCPI |
| REC_MCS | — | — | — | — |
| NO_SIG_EXTN | — | — | — | — |
| TIME_OF_DEPARTURE_REQUESTED | TIME_OF_DEPARTURE_REQUESTED | TIME_OF_DEPARTURE_REQUESTED | TIME_OF_DEPARTURE_REQUESTED | TIME_OF_DEPARTURE_REQUESTED |

NOTE—A dash (—) in an entry above indicates that the related parameter is not present.

(#2095)Non-HT PPDUs structured according to Clause 15 (DSSS PHY specification for the 2.4 GHz band designated for ISM applications), Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification), Clause 16 (High rate direct sequence spread spectrum (HR/DSSS) PHY specification), or Clause 18 (Extended Rate PHY (ERP) specification) are transmitted

- Within the limits of the transmit spectrum mask specified in the respective clauses, or
- As non-HT duplicate PPDUs within the limits of the 40 MHz transmit spectrum mask defined in 19.3.18.1 (Transmit spectrum mask), or
- As 20 MHz format non-HT PPDUs, within the limits of the 40 MHz transmit spectrum mask defined in 19.3.18.1 (Transmit spectrum mask), in the upper (CH_BANDWIDTH of value NON_HT_CBW20 and CH_OFFSET of value CH_OFF_20U) or lower (CH_BANDWIDTH of value NON_HT_CBW20 and CH_OFFSET of value CH_OFF_20U) 20 MHz of the 40 MHz channel.

Non-HT PPDUs transmitted using the 40 MHz transmit spectrum mask are referred to as *40 MHz mask non-HT PPDUs*. Refer to 11.15.9 (STA CCA sensing in a 20/40 MHz BSS) for CCA sensing rules for transmission of 40 MHz mask non-HT PPDUs.


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### 19.2.6 TXSTATUS parameters

The parameters listed in Table 19-4 (TXSTATUS parameters) are defined as part of the TXSTATUS parameter list in the PHY-TXSTART.confirm service primitive.

**Table 19-4—TXSTATUS parameters**

| Parameter | Value |
|---|---|
| TIME_OF_DEPARTURE | 0 to $2^{32}$– 1. The locally measured time when the first (#14)PPDU energy is sent by the transmitting port, in units equal to 1/ TIME_OF_DEPARTURE_ClockRate. This parameter is present only if TIME_OF_DEPARTURE_REQUESTED is true in the corresponding request. |
| TIME_OF_DEPARTURE_ClockRate | 0 to $2^{16}$– 1. The clock rate, in units of MHz, is used to generate the TIME_OF_DEPARTURE value. This parameter is present only if TIME_OF_DEPARTURE_REQUESTED is true in the corresponding request. |
| TX_START_OF_FRAME_OFFSET | 0 to $2^{32}$– 1. An estimate of the offset (in 10 ns units) from the point in time at which the start of the preamble (#14)of the PPDU was transmitted at the transmit antenna connector to the point in time at which this primitive is issued to the MAC. |

## 19.3 HT PHY

### 19.3.1 Introduction

Subclause 19.3 (HT PHY) provides a procedure in which PSDUs are converted to and from PPDUs. During transmission, the PSDU is processed (i.e., scrambled and coded) and appended to the PHY preamble to create the PPDU. At the receiver, the PHY preamble is processed to aid in demodulation and delivery of the PSDU.

Two preamble formats are defined. For HT-mixed format operation, the preamble has a non-HT portion and an HT portion. The non-HT portion of the HT-mixed format preamble enables detection of the PPDU and acquisition of carrier frequency and timing by both HT STAs and STAs that are compliant with Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) and/or Clause 18 (Extended Rate PHY (ERP) specification). The non-HT portion of the HT-mixed format preamble also consists of the SIGNAL field defined in Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) and is thus decodable by STAs compliant with Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) and Clause 18 (Extended Rate PHY (ERP) specification) as well as HT STAs.

The HT portion of the HT-mixed format preamble enables estimation of the MIMO channel to support demodulation of the HT data by HT STAs. The HT portion of the HT-mixed format preamble also includes the HT-SIG field, which supports HT operation. The SERVICE field is prepended to the PSDU.

For HT-greenfield operation, compatibility with Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) and Clause 18 (Extended Rate PHY (ERP) specification) STAs is not required. Therefore, the non-HT portions of the preamble are not included in the HT-greenfield format preamble.

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### 19.3.2 PPDU format

Two formats are defined for the PPDU: HT-mixed format and HT-greenfield format. These two formats are called *HT formats*. Figure 19-1 (PPDU format) shows the non-HT format[42] and the HT formats. The HT formats can be used for MCS 32 that provides the lowest rate in a 40 MHz channel (see in 19.3.11.11.5 (Transmission in MCS 32 format)). In addition to the HT formats, there is a non-HT duplicate format (specified in 19.3.11.12 (Non-HT duplicate transmission)) that duplicates the 20 MHz non-HT (#14)PPDU in two 20 MHz halves of a 40 MHz channel.

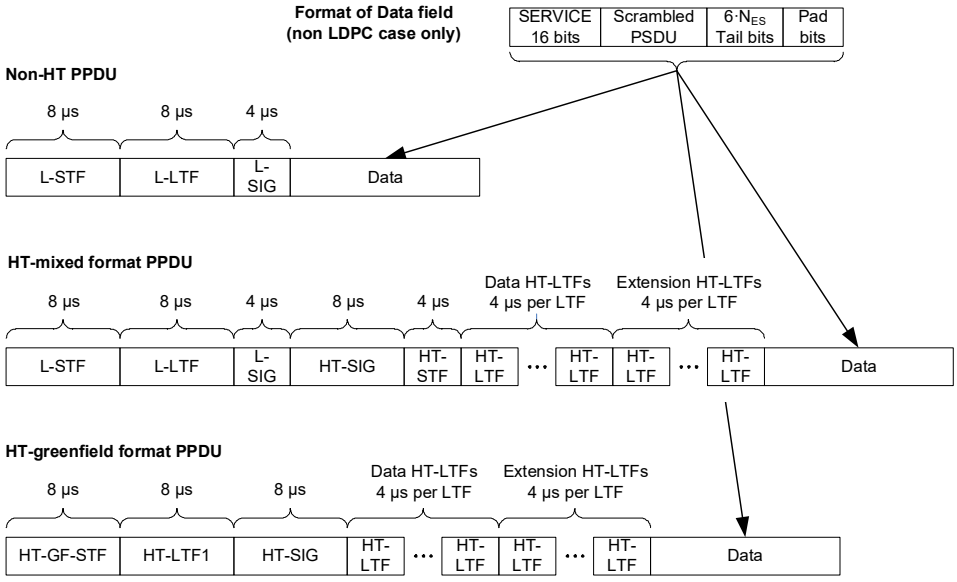


**Figure 19-1—PPDU format**

The elements of the PPDU are summarized in Table 19-5 (Elements of the HT PPDU).

**Table 19-5—Elements of the HT PPDU**

| Element | Description |
|---|---|
| L-STF | Non-HT Short Training field |
| L-LTF | Non-HT Long Training field |
| L-SIG | Non-HT SIGNAL field |
| HT-SIG | HT SIGNAL field |
| HT-STF | HT Short Training field |
| HT-GF-STF | HT-Greenfield Short Training field |
| HT-LTF1 | First HT Long Training field (Data) |

[42] The non-HT format is shown related to the terminology of this subclause. The (#2095)non-HT format is defined in 17.3.3 (PHY preamble (SYNC)) and 17.3.2 (PPDU format).


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**Table 19-5—Elements of the HT PPDU *(continued)***

| Element | Description |
|---|---|
| HT-LTFs | Additional HT Long Training fields (Data and Extension) |
| Data | The Data field includes the PSDU |

The HT-SIG, HT-STF, HT-GF-STF, HT-LTF1, and HT-LTFs exist only in HT PPDUs(#14). In non-HT packets only the L-STF, L-LTF, L-SIG, and Data fields exist.

In both HT-mixed format and HT-greenfield format PPDUs(#14), there are two types of HT-LTFs: Data HT-LTFs (HT-DLTFs) and Extension HT-LTFs (HT-ELTFs). HT-DLTFs are always included in HT PPDUs to provide the necessary reference for the receiver to form a channel estimate that allows it to demodulate (#14)the Data field. The number of HT-DLTFs, $N_{HT\text{-}DLTF}$, may be 1, 2, or 4 and is determined by the number of space-time streams being transmitted in the (#14)PPDU (see Table 19-13 (Number of HT-DLTFs required for data space-time streams(#83))). HT-ELTFs provide additional reference in sounding PPDUs so that the receiver can form an estimate of additional dimensions of the channel beyond those that are used by (#14)the Data field. The number of HT-ELTFs, $N_{HT\text{-}ELTF}$, may be 0, 1, 2, or 4 (see Table 19-14 (Number of HT-ELTFs required for extension spatial streams)). PHY preambles in which HT-DLTFs are followed by HT-ELTFs are referred to as *staggered preambles*. The HT-mixed format and HT-greenfield format (#14)PPDUs shown in Figure 19-1 (PPDU format) both contain staggered preambles for illustrative purposes.

(#14)A PPDU with the TXVECTOR parameter NO_SIG_EXTN equal to false is immediately followed by a period of no transmission for a duration of aSignalExtension. See 10.3.8 (Signal extension).

A signal extension shall be present in a transmitted PPDU, based on the parameters of the TXVECTOR, when the NO_SIG_EXTN parameter is equal to false and either of the following is true:

— The FORMAT parameter is equal to HT_MF or HT_GF.
— The FORMAT parameter is equal to NON_HT, and the NON_HT_MODULATION parameter is equal to ERP-OFDM, or NON_HT_DUP_OFDM.

A signal extension shall be assumed to be present (for the purpose of timing of PHY-RXEND.indication and PHY-CCA.indication primitives, as described below and in 19.3.21 (PHY receive procedure)) in a received PPDU when either of the following is true, based on the determined parameter values of the RXVECTOR:

— The FORMAT parameter is equal to HT_MF or HT_GF.
— The FORMAT parameter is equal to NON_HT, and the NON_HT_MODULATION parameter is equal to ERP-OFDM, or NON_HT_DUP_OFDM.

A PPDU containing a signal extension is called a *signal extended PPDU*. When transmitting a signal extended PPDU, the PHY-TXEND.indication primitive shall be emitted a period of aSignalExtension after the end of the last symbol of the PPDU. When receiving a signal extended PPDU, the PHY-RXEND.indication primitive shall be emitted a period of aSignalExtension after the end of the last symbol of the PPDU.

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### 19.3.3 Transmitter block diagram

HT-mixed format and HT-greenfield format transmissions can be generated using a transmitter consisting of the following blocks:

a) *Scrambler* scrambles the data to reduce the probability of long sequences of 0s or 1s; see 19.3.11.3 (Scrambler).

b) *Encoder parser*, if binary convolutional code (BCC) encoding is to be used, demultiplexes the scrambled bits among $N_{ES}$ (number of BCC encoders for the Data field) BCC encoders, in a round robin manner.

c) *FEC encoders* encode the data to enable error correction. An FEC encoder may include a binary convolutional encoder followed by a puncturing device, or it may include a low-density parity check (LDPC) encoder.

d) *Stream parser* divides the outputs of the encoders into blocks that are sent to different interleaver and mapping devices. The sequence of the bits sent to an interleaver is called a *spatial stream*.

e) *Interleaver* interleaves the bits of each spatial stream (changes order of bits) to prevent long sequences of adjacent noisy bits from entering the BCC decoder. Interleaving is applied only when BCC encoding is used.

f) *Constellation mapper* maps the sequence of bits in each spatial stream to constellation points (complex numbers).

g) *STBC* encoder spreads constellation points from $N_{SS}$ spatial streams into $N_{STS}$ space-time streams using a space-time block code. STBC is used only when $N_{SS} < N_{STS}$; see 19.3.11.9.2 (Space-time block coding (STBC)).

h) *Spatial mapper* maps space-time streams to transmit chains. This may include one of the following:

   1) *Direct mapping*: Constellation points from each space-time stream are mapped directly onto the transmit chains (one-to-one mapping).

   2) *Spatial expansion*: Vectors of constellation points from all of the space-time streams are expanded via matrix multiplication to produce the input to all of the transmit chains.

   3) *Beamforming*: Similar to spatial expansion, each vector of constellation points from all of the space-time streams is multiplied by a matrix of steering vectors to produce the input to the transmit chains.

i) *Inverse discrete Fourier transform (IDFT)* converts a block of constellation points to a time domain block.

j) *Cyclic shift (CSD) insertion* is where the insertion of the cyclic shifts prevents unintentional beamforming. CSD insertion may occur before or after the IDFT. There are three cyclic shift types as follows:

   1) A cyclic shift specified per transmitter chain with the values defined in Table 19-9 (Cyclic shift for non-HT portion of PPDU) (a possible implementation is shown in Figure 19-2 (Transmitter block diagram 1)).

   2) A cyclic shift specified per space-time stream with the values defined in Table 19-10 (Cyclic shift values of HT portion of PPDU) (a possible implementation is shown in Figure 19-3 (Transmitter block diagram 2)).

   3) A cyclic shift $M_{CSD}(k)$ that may be applied as a part of the spatial mapper; see 19.3.11.11.2 (Spatial mapping).

k) *GI insertion* prepends to the symbol a circular extension of itself.

l) *Windowing* optionally smooths the edges of each symbol to increase spectral decay.


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Figure 19-2 (Transmitter block diagram 1) and Figure 19-3 (Transmitter block diagram 2) show example transmitter block diagrams. In particular, Figure 19-2 (Transmitter block diagram 1) shows the transmitter blocks used to generate the HT-SIG of the HT-mixed format PPDU. These transmitter blocks are also used to generate the non-HT portion of the HT-mixed format PPDU, except that the BCC encoder and interleaver are not used when generating the L-STF and L-LTFs. Figure 19-3 (Transmitter block diagram 2) shows the transmitter blocks used to generate the Data field of the HT-mixed format and HT-greenfield format PPDUs. A subset of these transmitter blocks consisting of the constellation mapper and CSD blocks, as well as the blocks to the right of, and including, the spatial mapping block, are also used to generate the HT-STF, HT-GF-STF, and HT-LTFs. The HT-greenfield format SIGNAL field is generated using the transmitter blocks shown in Figure 19-2 (Transmitter block diagram 1), augmented by additional CSD and spatial mapping blocks.

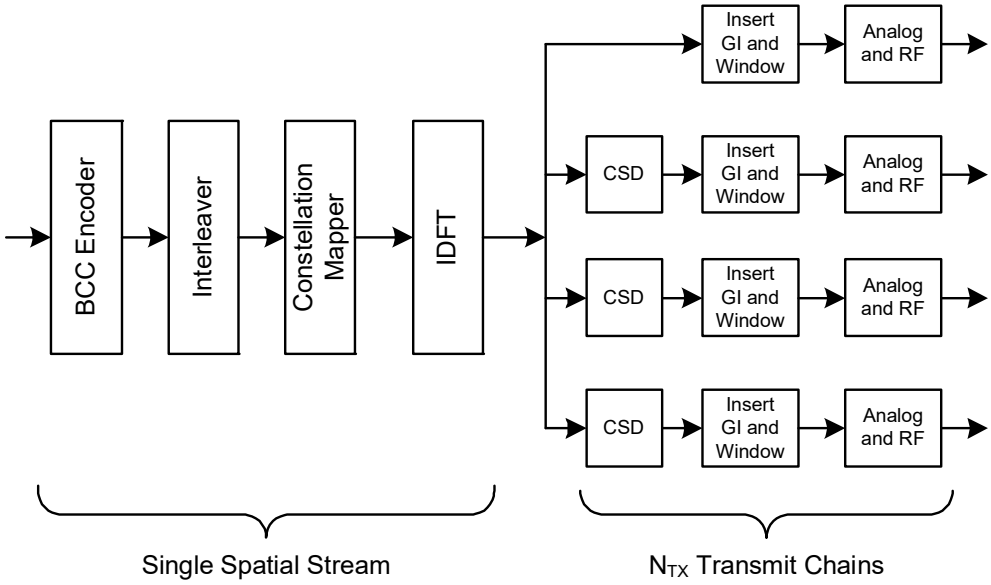


**Figure 19-2—Transmitter block diagram 1**

### 19.3.4 Overview of the PPDU encoding process

The encoding process is composed of the steps described below. The following overview is intended to facilitate an understanding of the details of the convergence procedure:

a) Determine the number of transmit chains, $N_{TX}$, from the N_TX parameter(#1875) of the TXVECTOR. Produce the PHY preamble training fields for each of the $N_{TX}$ transmit chains based on the FORMAT, NUM_EXTEN_SS, CH_BANDWIDTH, and MCS parameters of the TXVECTOR. The format and relative placement of the PHY preamble training fields vary depending on the (#14)PPDU format being used, as indicated by these parameters. Apply cyclic shifts. Determine spatial mapping to be used for HT-STF and HT-LTFs in (#14)an HT-mixed format PPDU and HT-GF-STF and HT-LTFs in an HT-greenfield format PPDU from the EXPANSION_MAT parameter of the TXVECTOR. Refer to 19.3.9 (HT preamble) for details.

b) Construct the PHY preamble SIGNAL fields from the appropriate parameters(#1875) of the TXVECTOR by adding tail bits, applying convolutional coding, formatting into one or more OFDM symbols, applying cyclic shifts, applying spatial processing, calculating an inverse Fourier transform for each OFDM symbol and transmit chain, and prepending a cyclic prefix or GI to each OFDM symbol in each transmit chain. The number and placement of the PHY preamble SIGNAL fields depend on the (#14)PPDU format being used. Refer to 19.3.9.3.5 (L-SIG definition), 19.3.9.4.3 (HT-SIG definition), and 19.3.9.5.4 (HT-greenfield format HT-SIG).

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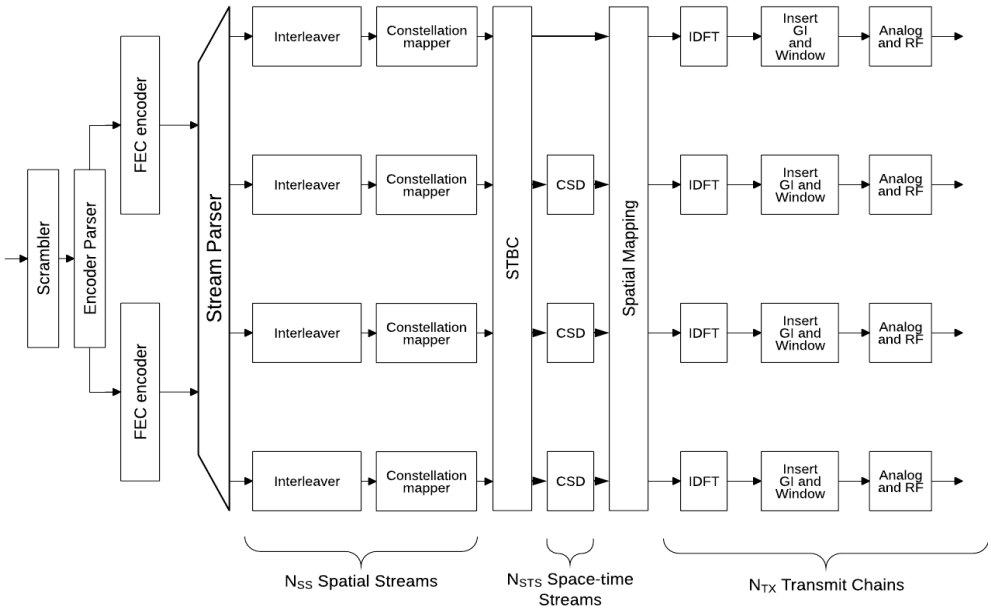


NOTE: The particular case shown here has two FEC encoders, four spatial streams, BCC coding, no STBC, and four transmit chains. The actual transmission mode may differ from the one shown here in various ways:
—There might be 1 or 2 FEC encoders when BCC encoding is used.
—The stream parser might have 1, 2, 3 or 4 outputs.
—When LDPC encoding is used, the interleavers are not used.
—When STBC is used, the STBC block has more outputs than inputs (otherwise the ouputs equal the inputs).
—When spatial mapping is used, there might be more transmit chains than space-time streams.
—The number of inputs to the spatial mapper might be 1, 2, 3, or 4.

**Figure 19-3—Transmitter block diagram 2**

c) Concatenate the PHY preamble training and SIGNAL fields for each transmit chain one field after another, in the appropriate order, as described in 19.3.2 (PPDU format) and 19.3.7 (Mathematical description of signals).

d) Use the MCS and CH_BANDWIDTH parameters of the TXVECTOR to determine the number of data bits per OFDM symbol ($N_{DBPS}$), the coding rate ($R$), the number of coded bits in each OFDM subcarrier ($N_{BPSC}$), and the number of coded bits per OFDM symbol ($N_{CBPS}$). Determine the number of encoding streams ($N_{ES}$) from the MCS, CH_BANDWIDTH, and FEC_CODING parameters of the TXVECTOR. Refer to 19.3.11.4 (Coding) for details.

e) Append the PSDU to the SERVICE field (see 19.3.11.2 (SERVICE field)). If BCC encoding is to be used, as indicated by the FEC_CODING parameter of the TXVECTOR, tail bits are appended to the PSDU. If a single BCC encoder is used (i.e., when the value of $N_{ES}$ is 1), the bit string is extended by 6 zero bits. If two BCC encoders are used (i.e., when the value of $N_{ES}$ is 2), the bit string is extended by 12 zero bits. The number of symbols, $N_{SYM}$, is calculated according to Equation (19-32), and if necessary, the bit string is further extended with zero bits so that the resulting length is a multiple of $N_{SYM} \times N_{DBPS}$, as described in 19.3.11 (Data field). If LDPC encoding is to be used, as indicated by the FEC_CODING parameter of the TXVECTOR, the resulting bit string is padded, if needed, by repeating coded bits rather than using zero bits, as given in the encoding procedure of 19.3.11.7.5 (LDPC PPDU encoding process). The number of resulting symbols is given by Equation (19-41), and the number of repeated coded bits used for padding is given by Equation (19-42). The resulting bit string constitutes the Data field of the (#14)PPDU.


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f) (#602)Generate a scrambling sequence, and exclusive-OR (XOR) it with the string of data bits, as described in 19.3.11.3 (Scrambler).

g) If BCC encoding is to be used, replace the scrambled zero bits that served as tail bits (6 bits if the value of $N_{ES}$ is 1, or 12 bits if the value of $N_{ES}$ is 2) following the data with the same number of nonscrambled zero bits, as described in 17.3.5.3 (PPDU TAIL field). (These bits return the convolutional encoder to the zero state.)

h) If BCC encoding is to be used and the value of $N_{ES}$ is 2, divide the scrambled data bits between two BCC encoders by sending alternating bits to the two different encoders, as described in 19.3.11.5 (Encoder parsing operation for two BCC FEC encoders).

i) If BCC encoding is to be used, encode the extended, scrambled data string with a rate 1/2 convolutional encoder (see 17.3.5.6 (Convolutional encoder)). Omit (puncture) some of the encoder output string (chosen according to puncturing pattern) to reach the coding rate, *R*, corresponding to the TXVECTOR parameters MCS or L_DATARATE. Refer to 19.3.11.6 (BCC coding and puncturing) for details. If LDPC encoding is to be used, encode the scrambled data stream according to 19.3.11.7.5 (LDPC PPDU encoding process).

j) Parse the coded bit stream that results from the BCC encoding or LDPC encoding into $N_{SS}$ spatial streams, where the value of $N_{SS}$ is determined from the MCS parameter of the TXVECTOR. See 19.3.11.8.2 (Stream parser) for details.

k) Divide each of the $N_{SS}$ encoded and parsed spatial streams of bits into groups of $N_{CBPSS}(i)$ bits. If BCC encoding is to be used, within each spatial stream and group, perform an interleaving (reordering) of the bits according to a rule corresponding to $N_{BPSCS}(i)$, where $i$ is the index of the spatial stream. Refer to 19.3.6 (Timing-related parameters) for details.

l) For each of the $N_{SS}$ encoded, parsed, and interleaved spatial streams, divide the resulting coded and interleaved data string into groups of $N_{BPSCS}(i)$ bits, where $i$ is the index of the spatial stream. For each of the bit groups, convert the bit group into a complex number according to the modulation encoding tables. Refer to 17.3.5.8 (Subcarrier modulation mapping) for details.

m) Divide the complex number string for each of the resulting $N_{SS}$ spatial streams into groups of $N_{SD}$ complex numbers, where the value of $N_{SD}$ is determined from the CH_OFFSET parameter of TXVECTOR and the CH_BANDWIDTH parameter of TXVECTOR. Each such group is associated with one OFDM symbol in one spatial stream. In each group, the complex numbers are indexed 0 to $N_{SD}-1$, and these indices have an associated one-to-one correspondence with subcarrier indices via the mapping function $M^{r}(k)$ as described in 19.3.11.11 (OFDM modulation), 19.3.11.11.3 (Transmission in 20 MHz HT format), 19.3.11.11.4 (Transmission in 40 MHz HT format), 19.3.11.11.5 (Transmission in MCS 32 format), and 19.3.11.12 (Non-HT duplicate transmission).

n) If STBC is to be applied, as indicated by the STBC parameter in the TXVECTOR, operate on the complex number associated with each data subcarrier in sequential pairs of OFDM symbols as described in 19.3.11.9.2 (Space-time block coding (STBC)) to generate $N_{STS}$ OFDM symbols for every $N_{SS}$ OFDM symbols associated with the $N_{SS}$ spatial streams. If STBC is not to be used, the number of space-time streams is the same as the number of spatial streams, and the sequences of OFDM symbols in each space-time stream are composed of the sequences of OFDM symbols in the corresponding spatial stream. In each group of $N_{SD}$ resulting complex numbers in each space-time stream, the complex numbers indexed 0 to $N_{SD}-1$ are mapped onto OFDM subcarriers via the mapping function $M^{r}(k)$ as described in 19.3.11.11 (OFDM modulation), 19.3.11.11.3 (Transmission in 20 MHz HT format), 19.3.11.11.4 (Transmission in 40 MHz HT format), 19.3.11.11.5 (Transmission in MCS 32 format), and 19.3.11.12 (Non-HT duplicate transmission).

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o) Determine whether 20 MHz or 40 MHz operation is to be used from the CH_BANDWIDTH parameter of the TXVECTOR. Specifically, when CH_BANDWIDTH is HT_CBW20 or NON_HT_CBW20, 20 MHz operation is to be used. When CH_BANDWIDTH is HT_CBW40 or NON_HT_CBW40, 40 MHz operation is to be used. For 20 MHz operation (with the exception of non-HT formats), insert four subcarriers as pilots into positions –21, –7, 7, and 21. The total number of the subcarriers, $N_{ST}$, is 56. For 40 MHz operation (with the exception of MCS 32 and non-HT duplicate format), insert six subcarriers as pilots into positions –53, –25, –11, 11, 25, and 53, resulting in a total of $N_{ST} = 114$ subcarriers. See 19.3.11.11.5 (Transmission in MCS 32 format) for pilot locations when using MCS 32 and 19.3.11.12 (Non-HT duplicate transmission) for pilot locations when using non-HT duplicate format. The pilots are modulated using a pseudorandom cover sequence. Refer to 19.3.11.10 (Pilot subcarriers) for details. For 40 MHz operation, apply a +90° phase shift to the complex value in each OFDM subcarrier with an index greater than 0, as described in 19.3.11.11.4 (Transmission in 40 MHz HT format), 19.3.11.11.5 (Transmission in MCS 32 format), and 19.3.11.12 (Non-HT duplicate transmission).

p) Map each of the complex numbers in each of the $N_{ST}$ subcarriers in each of the OFDM symbols in each of the $N_{STS}$ space-time streams to the $N_{TX}$ transmit chain inputs. For direct-mapped operation, $N_{TX} = N_{STS}$, and there is a one-to-one correspondence between space-time streams and transmit chains. In this case, the OFDM symbols associated with each space-time stream are also associated with the corresponding transmit chain. Otherwise, a spatial mapping matrix associated with each OFDM subcarrier, as indicated by the EXPANSION_MAT parameter of the TXVECTOR, is used to perform a linear transformation on the vector of $N_{STS}$ complex numbers associated with each subcarrier in each OFDM symbol. This spatial mapping matrix maps the vector of $N_{STS}$ complex numbers in each subcarrier into a vector of $N_{TX}$ complex numbers in each subcarrier. The sequence of $N_{ST}$ complex numbers associated with each transmit chain (where each of the $N_{ST}$ complex numbers is taken from the same position in the $N_{TX}$ vector of complex numbers across the $N_{ST}$ subcarriers associated with an OFDM symbol) constitutes an OFDM symbol associated with the corresponding transmit chain. For details, see 19.3.11.11 (OFDM modulation). Spatial mapping matrices may include cyclic shifts, as described in 19.3.11.11.2 (Spatial mapping).

q) If the CH_BANDWIDTH and CH_OFFSET parameters of the TXVECTOR indicate that upper or lower 20 MHz are to be used in 40 MHz, move the complex numbers associated with subcarriers –28 to 28 in each transmit chain to carriers 4 to 60 in the upper channel or –60 to –4 in the lower channel. Note that this shifts the signal in frequency from the center of the 40 MHz channel to +10 MHz or –10 MHz offset from the center of the 40 MHz channel. The complex numbers in the other subcarriers are set to 0.

r) For each group of $N_{ST}$ subcarriers and each of the $N_{TX}$ transmit chains, convert the subcarriers to time domain using IDFT. Prepend to the Fourier-transformed waveform a circular extension of itself, thus forming a GI, and truncate the resulting periodic waveform to a single OFDM symbol length by applying time domain windowing. Determine the length of the GI according to the GI_TYPE parameter of the TXVECTOR. Refer to 19.3.11.11 (OFDM modulation) and 19.3.11.12 (Non-HT duplicate transmission) for details. When beamforming is not used, it is sometimes possible to implement the cyclic shifts in the time domain.

s) Append the OFDM symbols associated with each transmit chain one after another, starting after the final field of the PHY preamble. Refer to 19.3.2 (PPDU format) and 19.3.7 (Mathematical description of signals) for details.

t) Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit. Refer to 19.3.7 (Mathematical description of signals) for details. The transmit chains are connected to antenna elements according to ANTENNA_SET of the TXVECTOR if ASEL is applied.


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### 19.3.5 Modulation and coding scheme (MCS)

The MCS is a value that determines the modulation, coding, and number of spatial channels. It is a compact representation that is carried in the HT-SIG. Rate-dependent parameters for the full set of MCSs are shown in Table 19-27 (MCS parameters for mandatory 20 MHz, $N_{SS}$ = 1, $N_{ES}$ = 1) to Table 19-41 (MCS parameters for optional 40 MHz, $N_{SS}$ = 4, UEQM) (in 19.5 (Parameters for HT-MCSs)). These tables give rate-dependent parameters for MCSs with indices 0 to 76. MCSs with indices 0 to 7 and 32 have a single spatial stream; MCSs with indices 8 to 31 have multiple spatial streams using equal modulation (EQM) on all of the streams; MCSs with indices 33 to 76 have multiple spatial streams using unequal modulation (UEQM) on the spatial streams. MCS indices 77 to 127 are reserved.

Table 19-27 (MCS parameters for mandatory 20 MHz, $N_{SS}$ = 1, $N_{ES}$ = 1) to Table 19-30 (MCS parameters for optional 20 MHz, $N_{SS}$ = 4, $N_{ES}$ = 1, EQM) show rate-dependent parameters for EQM MCSs for one, two, three, and four streams for 20 MHz operation. Table 19-31 (MCS parameters for optional 40 MHz, $N_{SS}$ = 1, $N_{ES}$ = 1) to Table 19-34 (MCS parameters for optional 40 MHz, $N_{SS}$ = 4, EQM) show rate-dependent parameters for EQM MCSs in one, two, three, and four streams for 40 MHz operation. The same EQM MCSs are used for 20 MHz and 40 MHz operation. Table 19-35 (MCS parameters for optional 40 MHz MCS 32 format, $N_{SS}$ = 1, $N_{ES}$ = 1) shows rate-dependent parameters for the 40 MHz, 6 Mb/s MCS 32 format.

The remaining tables, Table 19-36 (MCS parameters for optional 20 MHz, $N_{SS}$ = 2, $N_{ES}$ = 1, UEQM) to Table 19-41 (MCS parameters for optional 40 MHz, $N_{SS}$ = 4, UEQM), show rate-dependent parameters for the MCSs with UEQM of the spatial streams for use with $N_{SS} > 1$.

UEQM MCSs are detailed in the following tables:

- Table 19-36 (MCS parameters for optional 20 MHz, $N_{SS}$ = 2, $N_{ES}$ = 1, UEQM) to Table 19-38 (MCS parameters for optional 20 MHz, $N_{SS}$ = 4, $N_{ES}$ = 1, UEQM) are for 20 MHz operation.
- Table 19-39 (MCS parameters for optional 40 MHz, $N_{SS}$ = 2, $N_{ES}$ = 1, UEQM) to Table 19-41 (MCS parameters for optional 40 MHz, $N_{SS}$ = 4, UEQM) are for 40 MHz operation.

An HT STA shall support all equal modulation (EQM) rates for one spatial stream (MCSs 0 to 7) using a 20 MHz channel width. An HT AP that is not a VHT AP shall support all EQM rates for two spatial streams (MCSs 8 to 15) using a 20 MHz channel width. All other MCSs and modes are optional, specifically including transmit and receive support of 400 ns GI, operation in 40 MHz, and support of MCSs with indices 16 to 76.

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### 19.3.6 Timing-related parameters

Table 19-6 (Timing-related constants) defines the timing-related parameters.

**Table 19-6—Timing-related constants**

| Parameter | TXVECTOR CH_BANDWIDTH | | | |
|---|---|---|---|---|
| | NON_HT_CBW20 | HT_CBW20 | HT_CBW40 or NON_HT_CBW40 | |
| | | | HT format | MCS 32 and non-HT duplicate |
| $N_{SD}$: Number of complex data numbers | 48 | 52 | 108 | 48 |
| $N_{SP}$: Number of pilot values | 4 | 4 | 6 | 4 |
| $N_{ST}$: Total number of subcarriers See NOTE 1 | 52 | 56 | 114 | 104 |
| $N_{SR}$: Highest data subcarrier index | 26 | 28 | 58 | 58 |
| $\Delta_F$ : Subcarrier frequency spacing | 312.5 kHz (20 MHz/64) | 312.5 kHz | 312.5 kHz (40 MHz/128) | |
| $T_{DFT}$: IDFT/DFT period | 3.2 µs | 3.2 µs | 3.2 µs | |
| $T_{GI}$: Guard interval duration | 0.8 µs= $T_{DFT}$/4 | 0.8 µs | 0.8 µs | |
| $T_{GI2}$: Double guard interval | 1.6 µs | 1.6 µs | 1.6 µs | |
| $T_{GIS}$: Short guard interval duration | N/A | 0.4 µs = $T_{DFT}$/8 | 0.4 µs See NOTE 2 | |
| $T_{L\text{-}STF}$: Non-HT short training sequence duration | 8 µs=10× $T_{DFT}$/4 | 8 µs | 8 µs | |
| $T_{HT\text{-}GF\text{-}STF}$: HT-greenfield short training field duration | N/A | 8 µs=10× $T_{DFT}$/4 | 8 µs See NOTE 2 | |
| $T_{L\text{-}LTF}$: Non-HT long training field duration | 8 µs=2× $T_{DFT}$+$T_{GI2}$ | 8 µs | 8 µs | |
| $T_{SYM}$: Symbol interval | 4 µs= $T_{DFT}$+$T_{GI}$ | 4 µs | 4 µs | |
| $T_{SYMS}$: Short GI symbol interval | N/A | 3.6 µs = $T_{DFT}$+$T_{GIS}$ | 3.6 µs See NOTE 2 | |
| $T_{L\text{-}SIG}$: Non-HT SIGNAL field duration | 4 µs= $T_{SYM}$ | 4 µs | 4 µs | |
| $T_{HT\text{-}SIG}$: HT SIGNAL field duration | N/A | 8 µs= 2$T_{SYM}$ | 8 µs See NOTE 2 | |
| $T_{HT\text{-}STF}$: HT short training field duration | N/A | 4 µs | 4 µs See NOTE 2 | |


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**Table 19-6—Timing-related constants *(continued)***

| Parameter | TXVECTOR CH_BANDWIDTH | | | |
|---|---|---|---|---|
| | NON_HT_CBW20 | HT_CBW20 | HT_CBW40 or NON_HT_CBW40 | |
| | | | HT format | MCS 32 and non-HT duplicate |
| $T_{HT\text{-}LTF1}$: First HT long training field duration | N/A | 4 μs in HT-mixed format, 8 μs in HT-greenfield format | 4 μs in HT-mixed format, 8 μs in HT-greenfield format See NOTE 2 | |
| $T_{HT\text{-}LTFs}$: Second, and subsequent, HT long training fields duration | N/A | 4 μs | 4 μs See NOTE 2 | |

NOTE 1—$N_{ST} = N_{SD} + N_{SP}$ except in the cases of MCS 32 and non-HT duplicate, where the number of data subcarriers differs from the number of complex data numbers, and the number of pilot subcarriers differs from the number of pilot values. In those cases, data numbers and pilot values are replicated in upper and lower 20 MHz portions of 40 MHz signal to make a total of 104 subcarriers.

NOTE 2—Not applicable in non-HT formats.

NOTE 3—N/A = Not applicable.

Table 19-7 (Frequently used parameters) defines parameters used frequently in Clause 19 (High Throughput (HT) PHY specification(#2297)).

**Table 19-7—Frequently used parameters**

| Symbol | Explanation |
|---|---|
| $N_{CBPS}$ | Number of coded bits per symbol |
| $N_{CBPSS}(i)$ | Number of coded bits per symbol per the *i*-th spatial stream |
| $N_{DBPS}$ | Number of data bits per symbol |
| $N_{BPSC}$ | Number of coded bits per single carrier |
| $N_{BPSCS}(i)$ | Number of coded bits per single carrier for spatial stream *i* |
| $N_{RX}$ | Number of receive chains |
| $N_{STS}$ | Number of space-time streams |
| $N_{SS}$ | Number of spatial streams |
| $N_{ESS}$ | Number of extension spatial streams |
| $N_{TX}$ | Number of transmit chains |
| $N_{ES}$ | Number of BCC encoders for the Data field |
| $N_{HT\text{-}LTF}$ | Number of HT Long Training fields (see 19.3.9.4.6 (HT-LTF definition)) |
| $N_{HT\text{-}DLTF}$ | Number of Data HT Long Training fields |
| $N_{HT\text{-}ELTF}$ | Number of Extension HT Long Training fields |
| $R$ | Coding rate |

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### 19.3.7 Mathematical description of signals

For the description of the convention on mathematical description of signals, see 17.3.2.5 (Mathematical conventions in the signal descriptions).

In the case of either a 20 MHz non-HT format (TXVECTOR parameter FORMAT equal to NON_HT, MODULATION parameter equal to one of {ERP-OFDM, OFDM}) transmission or a 20 MHz HT format (TXVECTOR parameter FORMAT equal to HT_MF or HT_GF, CH_BANDWIDTH equal to HT_CBW20) transmission, the channel is divided into 64 subcarriers. In the 20 MHz non-HT format, the signal is transmitted on subcarriers –26 to –1 and 1 to 26, with 0 being the center (dc) carrier. In the 20 MHz HT format, the signal is transmitted on subcarriers –28 to –1 and 1 to 28.

In the case of the 40 MHz HT format, a 40 MHz channel is used. The channel is divided into 128 subcarriers. The signal is transmitted on subcarriers –58 to –2 and 2 to 58.

In the case of 40 MHz HT upper format or 40 MHz HT lower format, the upper or lower 20 MHz is divided into 64 subcarriers. The signal is transmitted on subcarriers –60 to –4 in the case of a 40 MHz HT lower format transmission and on subcarriers 4 to 60 in the case of a 40 MHz HT upper format transmission.

In the case of the MCS 32 and non-HT duplicate formats, the same data are transmitted over two adjacent 20 MHz channels. In this case, the 40 MHz channel is divided into 128 subcarriers, and the data are transmitted on subcarriers –58 to –6 and 6 to 58.

The transmitted signal is described in complex baseband signal notation. The actual transmitted signal is related to the complex baseband signal by the relation shown in Equation (19-1).

$$r_{RF}(t) = \mathrm{Re}\{r(t)\exp(j2\pi f_c t)\} \tag{19-1}$$

where

$f_c$ is the center frequency of the carrier

The transmitted RF signal is derived by modulating the complex baseband signal, which consists of several fields. The timing boundaries for the various fields are shown in Figure 19-4 (Timing boundaries for PPDU fields).

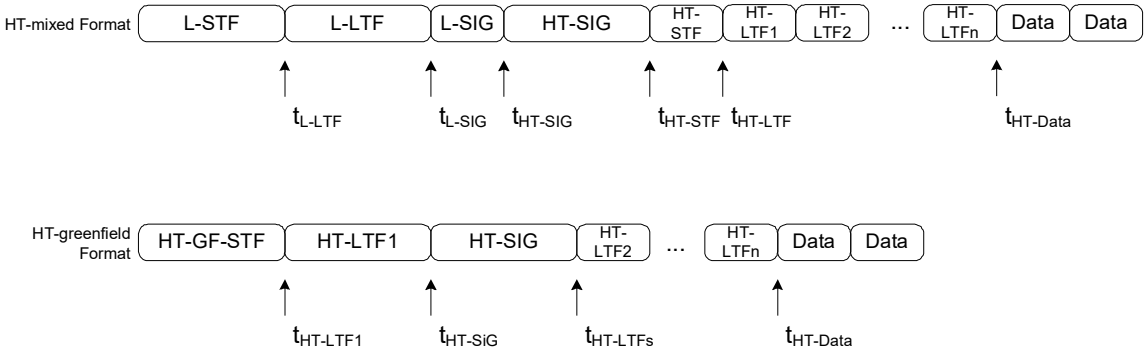


**Figure 19-4—Timing boundaries for PPDU fields**

The time offset, $t_{Field}$, determines the starting time of the corresponding field.


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In HT-mixed format, the signal transmitted on transmit chain $i_{TX}$ shall be as shown in Equation (19-2).

$$\begin{aligned} r_{PPDU}^{(i_{TX})}(t) &= r_{L\text{-}STF}^{(i_{TX})}(t) + r_{L\text{-}LTF}^{(i_{TX})}(t - t_{L\text{-}LTF}) \\ &+ r_{L\text{-}SIG}^{(i_{TX})}(t - t_{L\text{-}SIG}) + r_{HT\text{-}SIG}^{(i_{TX})}(t - t_{HT\text{-}SIG}) + r_{HT\text{-}STF}^{(i_{TX})}(t - t_{HT\text{-}STF}) \\ &+ \sum_{i_{LTF}=1}^{N_{HTLTF}} r_{HT\text{-}LTF}^{(i_{TX}, i_{LTF})}(t - t_{HT\text{-}LTF} - (i_{LTF} - 1)T_{HT\text{-}LTFs}) + r_{HT\text{-}DATA}^{(i_{TX})}(t - t_{HT\text{-}DATA}) \end{aligned} \quad (19\text{-}2)$$

where

$t_{L\text{-}LTF} = T_{L\text{-}STF}$

$t_{L\text{-}SIG} = t_{L\text{-}LTF} + T_{L\text{-}LTF}$

$t_{HT\text{-}SIG} = t_{L\text{-}SIG} + T_{L\text{-}SIG}$

$t_{HT\text{-}STF} = t_{HT\text{-}SIG} + T_{HT\text{-}SIG}$

$t_{HT\text{-}LTF} = t_{HT\text{-}STF} + T_{HT\text{-}STF}$

$t_{HT\text{-}Data} = t_{HT\text{-}LTF} + N_{HT\text{-}LTF} \cdot T_{HT\text{-}LTFs}$

In the case of HT-greenfield format, the transmitted signal on transmit chain $i_{TX}$ shall be as shown in Equation (19-3).

$$\begin{aligned} r_{PPDU}^{(i_{TX})}(t) &= r_{HT-GF-STF}^{(i_{TX})}(t) + r_{HT-LTF1}^{(i_{TX})}(t - t_{HT-LTF1}) \\ &+ r_{HT-SIG}^{(i_{TX})}(t - t_{HT-SIG}) \\ &+ \sum_{i_{LTF}=2}^{N_{HTLTF}} r_{HT-LTF}^{(i_{TX}, i_{LTF})}(t - t_{HT-LTFs} - (i_{LTF} - 2)T_{HT-LTFs}) \\ &+ r_{HT-DATA}^{(i_{TX})}(t - t_{HT-DATA}) \end{aligned} \quad (19\text{-}3)$$

where

$t_{HT-LTF1} = T_{HT-GF-STF}$

$t_{HT\text{-}SIG} = t_{HT\text{-}LTF1} + T_{HT\text{-}LTF1}$

$t_{HT\text{-}LTFs} = t_{HT\text{-}SIG} + T_{HT\text{-}SIG}$

$t_{HT\text{-}Data} = t_{HT\text{-}LTFs} + (N_{HT\text{-}LTF} - 1) \cdot T_{HT\text{-}LTFs}$

Each baseband waveform, $r_{\text{Field}}^{(i_{TX})}(t)$, is defined via the discrete Fourier transform (DFT) per OFDM symbol as shown in Equation (19-4).

$$r_{\text{Field}}^{(i_{TX})}(t) = \frac{1}{\sqrt{N_{\text{Field}}^{\text{Tone}} \cdot N_{Norm}}} w_{T_{\text{Field}}}(t) \sum_{k} \Upsilon_k X_k^{(i_{TX})} \exp(j2\pi k \Delta_F t) \quad (19\text{-}4)$$

(#569)

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This general representation holds for all fields. A suggested definition of the windowing function, $w_{\mathrm{T_{Field}}}(t)$, is given in 17.3.2.5 (Mathematical conventions in the signal descriptions). The frequency domain symbols $X_k^{(i_{TX})}$ represent the output of any spatial processing in subcarrier $k$ for transmit chain $i_{TX}$ required for the field.

The function $\Upsilon_k$ is used to represent a rotation of the upper tones in a 40 MHz channel as shown in Equation (19-5) and Equation (19-6).

$$\Upsilon_k = \begin{cases} 1, k \le 0, \text{ in a 40 MHz channel} \\ j, k > 0, \text{ in a 40 MHz channel} \end{cases} \quad (19\text{-}5)$$

$$\Upsilon_k = 1, \text{ in a 20 MHz channel} \quad (19\text{-}6)$$

The $1/\sqrt{N_{\mathrm{Field}}^{\mathrm{Tone}} \cdot N_{Norm}}$ (#569)scale factor in Equation (19-4) causes the total power of the time domain signal as summed over all transmit chains to be either 1 or lower than 1 when required. Table 19-8 (Value of tone scaling factor) summarizes the various values of $N_{\mathrm{Field}}^{\mathrm{Tone}}$. (#569)For L-STF, L-LTF, L-SIG, and HT-SIG

**Table 19-8—Value of tone scaling factor $N_{Field}^{Tone}$**

| Field | $N_{Field}^{Tone}$, see NOTE 1 | |
|---|---|---|
| | 20 MHz | 40 MHz |
| L-STF | 12 | 24 |
| HT-GF-STF | 12 | 24 |
| L-LTF | 52 | 104 |
| L-SIG | 52 | 104 |
| HT-SIG | 52/56, see NOTE 2 | 104/114, see NOTE 2 |
| HT-STF | 12 | 24 |
| HT-LTF | 56 | 114 |
| HT-DATA | 56 | 114 |
| MCS 32 | — | 104 |
| Non-HT Duplicate | — | 104 |

NOTE 1—The numbers in the table refer only to the value of $N_{Field}^{Tone}$ as it appears in Equation (19-4) and in subsequent specification of various fields. This value might be different from the actual number of tones being transmitted.
NOTE 2—The values 56 and 114 are for HT-greenfield format; the values 52 and 104 are for HT-mixed format.

fields in an HT PPDU using the HT-mixed format, $N_{Norm} = N_{TX}$. For all other fields in an HT PPDU using the HT-mixed format, $N_{Norm} = N_{STS}$. In an HT PPDU using the HT-greenfield format, $N_{Norm} = N_{STS}$ for all fields.


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### 19.3.8 Transmission in the upper/lower 20 MHz of a 40 MHz channel

When transmitting in the upper/lower 20 MHz portion of a 40 MHz channel, the mathematical definition of transmission shall follow that of a 20 MHz channel with $f_c$ in Equation (19-1) replaced by $f_c \pm 10$ MHz.

This rule applies to 20 MHz HT transmission in the upper/lower 20 MHz of a 40 MHz channel (TXVECTOR primitive CH_BANDWIDTH equal to HT_CBW20 and CH_OFFSET primitive equal to CH_OFF_20U or CH_OFF_20L) and to 20 MHz non-HT transmission in the upper/lower 20 MHz of a 40 MHz channel (TXVECTOR primitive CH_BANDWIDTH equal to NON_HT_CBW20 and CH_OFFSET primitive equal to CH_OFF_20U or CH_OFF_20L).

### 19.3.9 HT preamble

#### 19.3.9.1 Introduction

The HT preambles are defined in HT-mixed format and in HT-greenfield format to carry the required information to operate in a system with multiple transmit and multiple receive antennas.

In the HT-mixed format, to provide compatibility with non-HT STAs, specific non-HT fields are defined so that they can be received by non-HT STAs compliant with Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) or Clause 18 (Extended Rate PHY (ERP) specification) followed by the fields specific to HT STAs.

In the HT-greenfield format, all of the non-HT fields are omitted. The specific HT fields used are as follows:

— One HT-GF-STF for automatic gain control convergence, timing acquisition, and coarse frequency acquisition,

— One or several HT-LTFs, provided as a way for the receiver to estimate the channel between each spatial mapper input and receive chain. The first HT-LTFs (HT-DLTFs) are necessary for demodulation of the (#14)Data field and are followed, for sounding PPDUs only, by optional HT-LTFs (HT-ELTFs) to sound extra spatial dimensions of the MIMO channel,

— HT-SIG, which provides all the information required to interpret the (#14)HT PPDU format.

In the case of multiple transmit chains, the HT preambles use cyclic shift techniques to prevent unintentional beamforming.

#### 19.3.9.2 HT-mixed format preamble

In HT-mixed format (#14)PPDUs, the preamble has fields that support compatibility with Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) and Clause 18 (Extended Rate PHY (ERP) specification) STAs and fields that support HT operation. The non-HT portion of the HT-mixed format preamble enables detection of the PPDU and acquisition of carrier frequency and timing by both HT STAs and STAs that are compliant with Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) or Clause 18 (Extended Rate PHY (ERP) specification). The non-HT portion of the HT-mixed format preamble contains the SIGNAL field (L-SIG) defined in Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) and is thus decodable by STAs compliant with Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) and Clause 18 (Extended Rate PHY (ERP) specification) as well as HT STAs.

The HT portion of the HT-mixed format preamble enables estimation of the MIMO channel to support demodulation of the (#14)Data field by HT STAs. The HT portion of the HT-mixed format preamble also contains the HT-SIG field that supports HT operation.

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### 19.3.9.3 Non-HT portion of the HT-mixed format preamble

#### 19.3.9.3.1 Introduction

The transmission of the L-STF, L-LTF and the L-SIG fields(#4145) as part of an HT-mixed format (#14)PPDU is described in 19.3.9.3.2 (Cyclic shift definition) to 19.3.9.3.5 (L-SIG definition).

#### 19.3.9.3.2 Cyclic shift definition

The cyclic shift values defined in this subclause apply to the non-HT fields in the HT-mixed format preamble and the HT-SIG in the HT-mixed format preamble.

Cyclic shifts are used to prevent unintentional beamforming when the same signal or scalar multiples of one signal are transmitted through different spatial streams or transmit chains. A cyclic shift of duration $T_{CS}$ on a signal $s(t)$ on interval $0 \le t \le T$ is defined as follows, where $T$ is defined as $T_{DFT}$ as referenced in Table 19-6 (Timing-related constants).

With $T_{CS} \le 0$, replace $s(t)$ with $s(t - T_{CS})$ when $0 \le t < T + T_{CS}$ and with $s(t - T_{CS} - T)$ when $T + T_{CS} \le t \le T$. The cyclic-shifted signal is defined as shown in Equation (19-7).

$$s_{CS}(t;T_{CS})\big|_{T_{CS}<0} = \begin{cases} s(t - T_{CS}) & 0 \le t < T + T_{CS} \\ s(t - T_{CS} - T) & T + T_{CS} \le t \le T \end{cases} \quad (19\text{-}7)$$

The cyclic shift is applied to each OFDM symbol in the (#14)PPDU separately. Table 19-9 (Cyclic shift for non-HT portion of PPDU) specifies the values for the cyclic shifts that are applied in the L-STF (in an HT-mixed format (#14)PPDU), the L-LTF, and L-SIG. It also applies to the HT-SIG in an HT-mixed format (#14)PPDU.

**Table 19-9—Cyclic shift for non-HT portion of PPDU**

| $T_{CS}^{i_{TX}}$ values for non-HT portion of PPDU | | | | |
|---|---|---|---|---|
| **Number of transmit chains** | **Cyclic shift for transmit chain 1 (ns)** | **Cyclic shift for transmit chain 2 (ns)** | **Cyclic shift for transmit chain 3 (ns)** | **Cyclic shift for transmit chain 4 (ns)** |
| 1 | 0 | — | — | — |
| 2 | 0 | –200 | — | — |
| 3 | 0 | –100 | –200 | — |
| 4 | 0 | –50 | –100 | –150 |

With more than four transmit chains, each cyclic shift on the additional transmit chains shall be between –200 ns and 0 ns.


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#### 19.3.9.3.3 L-STF definition

The non-HT short training OFDM symbol in the 20 MHz channel width is shown in Equation (19-8).

$$S_{-26,26} = \sqrt{1/2} \{0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 0, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0\} \quad (19\text{-}8)$$

The normalization factor $\sqrt{1/2}$ is the QPSK normalization.

NOTE—Other than the scaling difference, Equation (19-8) represents the same BPSK constellations per subcarrier as those represented in Equation (17-8).

The non-HT short training OFDM symbol in a 40 MHz channel width is given by Equation (19-9), after rotating the tones in the upper subchannel (subcarriers 6–58) by +90° (#4181)(see Equation (19-10)).

$$S_{-58,58} = \sqrt{1/2} \{0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 0, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 0, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0\} \quad (19\text{-}9)$$

In HT-mixed format, the L-STF on transmit chain $i_{TX}$ shall be as shown in Equation (19-10).

$$r_{L-STF}^{(i_{TX})}(t) = \frac{1}{\sqrt{N_{TX} \cdot N_{L-STF}^{Tone}}} w_{T_{L-STF}}(t) \sum_{k=-N_{SR}}^{N_{SR}} \Upsilon_k S_k \exp(j2\pi k \Delta_F (t - T_{CS}^{i_{TX}})) \quad (19\text{-}10)$$

where

$T_{CS}^{i_{TX}}$ represents the cyclic shift for transmit chain $i_{TX}$ and takes values from Table 19-9 (Cyclic shift for non-HT portion of PPDU)

$\Upsilon_k$ is defined in Equation (19-5) and Equation (19-6)

The L-STF has a period of 0.8 µs. The entire STF includes ten such periods, with a total duration of $T_{L\text{-}STF}$ = 8 µs.

#### 19.3.9.3.4 L-LTF definition

The non-HT long training OFDM symbol is identical to the Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) long training OFDM symbol. In the 20 MHz channel width, the long training OFDM symbol is given by Equation (19-11).

$$L_{-26,26} = \{1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 0, 1, -1, -1, 1, 1, -1, 1, -1, 1, -1, -1, -1, -1, -1, 1, 1, -1, -1, 1, -1, 1, -1, 1, 1, 1, 1\} \quad (19\text{-}11)$$

The non-HT long training OFDM symbol in a 40 MHz channel width is given by Equation (19-12), after rotating the tones in the upper subchannel (subcarriers 6–58) by +90° (#4181)(see Equation (19-13)).

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$$L_{-58,58} = \{1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, -1, 1, 1, 1, 1, 1, 0,$$
$$1, -1, -1, 1, 1, 1, -1, 1, -1, 1, -1, -1, -1, -1, -1, 1, 1, 1, -1, 1, -1, 1, -1, 1, -1, 1, 1, 1, 1, 1, 0, 0, 0, 0, 0,$$
$$0, 0, 0, 0, 0, 0, 0, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, -1, 1, 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 0,$$
$$1, -1, -1, 1, 1, -1, 1, -1, 1, -1, -1, -1, -1, -1, 1, 1, -1, -1, 1, -1, 1, -1, 1, -1, 1, 1, 1, 1\} \quad (19\text{-}12)$$

The subcarriers at ± 32 in 40 MHz, which are the dc subcarriers for the non-HT 20 MHz transmission, are both nulled in the L-LTF. Such an arrangement allows proper synchronization of a 20 MHz non-HT STA.

The L-LTF waveform shall be as shown in Equation (19-13).

$$r_{L-LTF}^{(i_{TX})}(t) = \frac{1}{\sqrt{N_{TX} \cdot N_{L-LTF}^{Tone}}} w_{T_{L-LTF}}(t) \sum_{k=-N_{SR}}^{N_{SR}} \Upsilon_k L_k \exp(j2\pi k \Delta_F (t - T_{GI2} - T_{CS}^{i_{TX}})) \quad (19\text{-}13)$$

where

$T_{GI2}$ is 1.6 μs

$T_{CS}^{i_{TX}}$ represents the cyclic shift for transmit chain $i_{TX}$ and takes values specified in Table 19-9 (Cyclic shift for non-HT portion of PPDU)

$\Upsilon_k$ is defined in Equation (19-5) and Equation (19-6)

The entire LTF includes two 3.2 μs IDFT/DFT periods and an additional 1.6 μs double GI. The entire LTF is modulated with the L-LTF waveform.

#### 19.3.9.3.5 L-SIG definition

The L-SIG field(#4145) is used to communicate rate and length information. The structure of the L-SIG field(#4145) is shown in Figure 19-5 (L-SIG structure).

| Rate (4 bits) | | | | R | Length (12 bits) | | | | | | | | | | | | P | Tail (6 bits) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| R1 | R2 | R3 | R4 | | | | | | | | | | | | | | | "0" | "0" | "0" | "0" | "0" | "0" |
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 |

**Figure 19-5—L-SIG structure**

The value in the Rate field is obtained from the L_DATARATE parameter(#1875) of the TXVECTOR. The value in the Length field is obtained from the L_LENGTH parameter(#1875) of the TXVECTOR. The Length field is transmitted LSB first.

The reserved bit shall be set to 0 (#455)on transmit and ignored on receive.

The parity field has the even parity of bits 0–16.

The L-SIG field(#4145) shall be encoded, interleaved and mapped, and it shall have pilots inserted following the steps described in 17.3.5.6 (Convolutional encoder), 17.3.5.7 (Data interleaving), and 17.3.5.9 (Pilot subcarriers). The stream of 48 complex numbers generated by the steps described in 17.3.5.7 (Data interleaving) is denoted by $d_k, k = 0 \ldots 47$. The time domain waveform of the L-SIG field(#4145) in 20 MHz transmission shall be as given by Equation (19-14).


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$$r_{L-SIG}^{(i_{TX})}(t) = \frac{1}{\sqrt{N_{TX} \cdot N_{L-SIG}^{Tone}}} w_{T_{SYM}}(t) \sum_{k=-26}^{26} (D_k + p_0 P_k) \exp(j2\pi k \Delta_F (t - T_{GI} - T_{CS}^{i_{TX}})) \quad (19\text{-}14)$$

In a 40 MHz transmission the time domain waveform of the L-SIG field(#4145) shall be as given by Equation (19-15).

$$r_{L-SIG}^{(i_{TX})}(t) = \frac{1}{\sqrt{N_{TX} \cdot N_{L-SIG}^{Tone}}} w_{T_{SYM}}(t) \sum_{k=-26}^{26} (D_k + p_0 P_k) \cdot (\exp(j2\pi(k-32)\Delta_F(t - T_{GI} - T_{CS}^{i_{TX}})) + j\exp(j2\pi(k+32)\Delta_F(t - T_{GI} - T_{CS}^{i_{TX}}))) \quad (19\text{-}15)$$

where

$$D_k = \begin{cases} 0, k = 0, \pm 7, \pm 21 \\ d_{M^r(k)}, \text{otherwise} \end{cases}$$

$$M^r(k) = \begin{cases} k + 26, -26 \le k \le -22 \\ k + 25, -20 \le k \le -8 \\ k + 24, -6 \le k \le -1 \\ k + 23, 1 \le k \le 6 \\ k + 22, 8 \le k \le 20 \\ k + 21, 22 \le k \le 26 \end{cases}$$

$P_k$ is defined in 17.3.5.10 (OFDM modulation)

$p_0$ is the first pilot value in the sequence defined in 17.3.5.10 (OFDM modulation)

$N_{L-SIG}^{Tone}$ has the value given in Table 19-8 (Value of tone scaling factor)

$T_{CS}^{i_{TX}}$ represents the cyclic shift for transmit chain $i_{TX}$ and is defined by Table 19-9 (Cyclic shift for non-HT portion of PPDU) for HT-mixed format PPDUs

NOTE—$D_k$ exists for $-N_{SR} \le k \le N_{SR}$ and takes the values from $d_k$ that exists for $0 \le k \le N_{SD} - 1$. $M^r(k)$ is a "reverse" function of the function $M(k)$ defined in 17.3.5.10 (OFDM modulation).

### 19.3.9.4 HT portion of HT-mixed format preamble

#### 19.3.9.4.1 Introduction

When an HT-mixed format preamble is transmitted, the HT preamble consists of the HT-STF, the HT-LTFs, and the HT-SIG.

All numeric fields are transmitted in unsigned format, LSB first.

#### 19.3.9.4.2 Cyclic shift definition

The cyclic shift values defined in this subclause apply to the HT-STF and HT-LTFs of the HT-mixed format preamble. The cyclic shift values defined in 19.3.9.3.2 (Cyclic shift definition) apply to the HT-SIG in an HT-mixed format preamble.

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Throughout the HT portion of an HT-mixed format preamble, cyclic shift is applied to prevent beamforming when similar signals are transmitted in different space-time streams. The same cyclic shift is applied to these streams during the transmission of the (#14)Data field. The values of the cyclic shifts to be used during the HT portion of the HT-mixed format preamble (with the exception of the HT_SIG) and the (#14)Data field are specified in Table 19-10 (Cyclic shift values of HT portion of PPDU).

**Table 19-10—Cyclic shift values of HT portion of PPDU**

| $T_{CS}^{i_{STS}}$ values for HT portion of PPDU | | | | |
|---|---|---|---|---|
| **Number of space-time streams** | **Cyclic shift for space-time stream 1 (ns)** | **Cyclic shift for space-time stream 2 (ns)** | **Cyclic shift for space-time stream 3 (ns)** | **Cyclic shift for space-time stream 4 (ns)** |
| 1 | 0 | — | — | — |
| 2 | 0 | –400 | — | — |
| 3 | 0 | –400 | –200 | — |
| 4 | 0 | –400 | –200 | –600 |

### 19.3.9.4.3 HT-SIG definition

The HT-SIG is used to carry information required to interpret the HT (#14)PPDU formats. The fields of the HT-SIG are described in Table 19-11 (HT-SIG fields).

**Table 19-11—HT-SIG fields**

| Field | Number of bits | Explanation and coding |
|---|---|---|
| Modulation and Coding Scheme | 7 | Index into the MCS table. |
| CBW 20/40 | 1 | Set to 0 for 20 MHz or 40 MHz upper/lower.<br>Set to 1 for 40 MHz. |
| HT Length | 16 | The number of octets of data in the PSDU.<br>See NOTE. |
| Smoothing | 1 | Set to 1 indicates that channel estimate smoothing is recommended.<br>Set to 0 indicates that only per-carrier independent (unsmoothed) channel estimate is recommended.<br>See 19.3.11.11.2 (Spatial mapping). |
| Not Sounding | 1 | Set to 0 indicates that PPDU is a sounding PPDU.<br>Set to 1 indicates that the PPDU is not a sounding PPDU. |
| Reserved | 1 | (#455)Set to 1 on transmit. See 19.3.21 (PHY receive procedure) for behavior on receive. |
| Aggregation | 1 | Set to 1 to indicate that the (#14)PSDU contains an A-MPDU; otherwise, set to 0. |


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**Table 19-11—HT-SIG fields *(continued)***

| Field | Number of bits | Explanation and coding |
|---|---|---|
| STBC | 2 | Set to a nonzero number, to indicate the difference between the number of space-time streams ($N_{STS}$) and the number of spatial streams ($N_{SS}$) indicated by the MCS.<br>Set to 00 to indicate no STBC ($N_{STS} = N_{SS}$). |
| FEC Coding | 1 | Set to 1 for LDPC.<br>Set to 0 for BCC. |
| Short GI | 1 | Set to 1 to indicate that the short GI is used after the HT-LTFs.<br>Set to 0 otherwise. |
| Number of Extension Spatial Streams | 2 | Indicates the number of extension spatial streams ($N_{ESS}$).<br>Set to 0 for no extension spatial stream.<br>Set to 1 for 1 extension spatial stream.<br>Set to 2 for 2 extension spatial streams.<br>Set to 3 for 3 extension spatial streams. |
| CRC | 8 | CRC of bits 0–23 in HT-SIG$_1$ and bits 0–9 in HT-SIG$_2$. See 19.3.9.4.4 (CRC calculation for HT-SIG). The first bit to be transmitted is bit C7 as explained in 19.3.9.4.4 (CRC calculation for HT-SIG). |
| Tail Bits | 6 | Used to terminate the trellis of the convolution coder. Set to 0. |
| (#14)NOTE—A value of 0 in the HT Length field indicates a PPDU that does not include a Data field, i.e., NDP. NDP transmissions are used for sounding purposes only (see 10.35.2 (Transmission of an HT NDP)). The NDP ends after the last HT-LTF or the HT-SIG. | | |

The structure of the HT-SIG$_1$ and HT-SIG$_2$ fields is defined in Figure 19-6 (Format of HT-SIG1 and HT-SIG2).

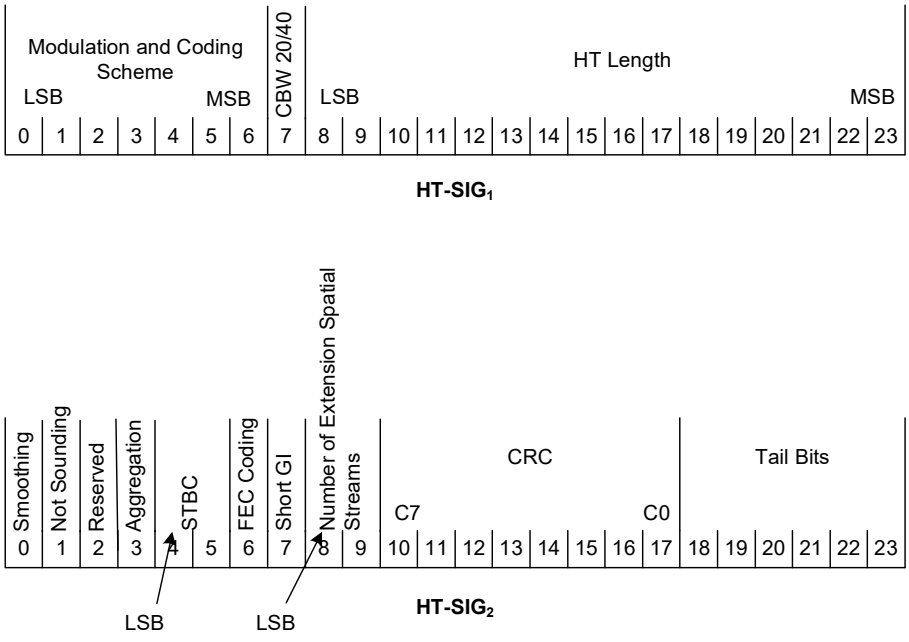


**Figure 19-6—Format of HT-SIG$_1$ and HT-SIG$_2$**

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The HT-SIG is composed of two parts, HT-SIG$_1$ and HT-SIG$_2$, each containing 24 bits, as shown in Figure 19-6 (Format of HT-SIG1 and HT-SIG2). All of the fields in the HT-SIG are transmitted LSB first, and HT-SIG$_1$ is transmitted before HT-SIG$_2$.

The HT-SIG parts shall be encoded at R = 1/2, interleaved, and mapped to a BPSK constellation, and they have pilots inserted following the steps described in 17.3.5.6 (Convolutional encoder), 17.3.5.7 (Data interleaving), 17.3.5.8 (Subcarrier modulation mapping), and 17.3.5.9 (Pilot subcarriers), respectively. The BPSK constellation is rotated by 90° relative to the L-SIG field(#4145) in order to accommodate detection of the start of the HT-SIG. The stream of 96 complex numbers generated by these steps is divided into two groups of 48 complex numbers: $d_{k,n}$, $0 \le k \le 47$, $n = 0, 1$ . The time domain waveform for the HT-SIG in an HT-mixed format (#14)PPDU in a 20 MHz transmission shall be as shown in Equation (19-16).

$$r_{HT-SIG}^{i_{TX}}(t) = \frac{1}{\sqrt{N_{TX} \cdot N_{HT-SIG}^{Tone}}} \sum_{n=0}^{1} w_{T_{SYM}}(t - nT_{SYM}) \cdot \sum_{k=-26}^{26} (jD_{k,n} + p_{n+1}P_k) \exp(j2\pi k\Delta_F(t - nT_{SYM} - T_{GI} - T_{CS}^{i_{TX}})) \quad (19\text{-}16)$$

In a 40 MHz transmission the time domain waveform shall be as shown in Equation (19-17).

$$r_{HT-SIG}^{i_{TX}}(t) = \frac{1}{\sqrt{N_{TX} \cdot N_{HT-SIG}^{Tone}}} \sum_{n=0}^{1} w_{T_{SYM}}(t - nT_{SYM}) \cdot \sum_{k=-26}^{26} (jD_{k,n} + p_{n+1}P_k)(\exp(j2\pi(k-32)\Delta_F(t - nT_{SYM} - T_{GI} - T_{CS}^{i_{TX}})) + j\exp(j2\pi(k+32)\Delta_F(t - nT_{SYM} - T_{GI} - T_{CS}^{i_{TX}}))) \quad (19\text{-}17)$$

where

$$D_{k,n} = \begin{cases} 0, k = 0, \pm 7, \pm 21 \\ d_{M^r(k),n}, \text{otherwise} \end{cases}$$

$M^r(k)$ is defined in 19.3.9.3 (Non-HT portion of the HT-mixed format preamble)

$P_k$ and $p_n$ are defined in 17.3.5.10 (OFDM modulation)

$N_{HT-SIG}^{Tone}$ has the value given in Table 19-8 (Value of tone scaling factor)

$T_{CS}^{i_{TX}}$ represents the cyclic shift for transmit chain $i_{TX}$ and is defined by Table 19-9 (Cyclic shift for non-HT portion of PPDU) for HT-mixed format PPDUs

NOTE—This definition results in a quadrature binary phase shift keying (QBPSK) modulation in which the constellation of the data tones is rotated by 90° relative to the L-SIG field(#4145) in HT-mixed format PPDUs and relative to the first HT-LTF in HT-greenfield format PPDUs (see Figure 19-7 (Data tone constellations in an HT-mixed format PPDU)). In HT-mixed format PPDUs, the HT-SIG is transmitted with the same number of subcarriers and the same cyclic shifts as the preceding non-HT portion of the preamble. This is done to accommodate the estimation of channel parameters needed to robustly demodulate and decode the information contained in the HT-SIG.


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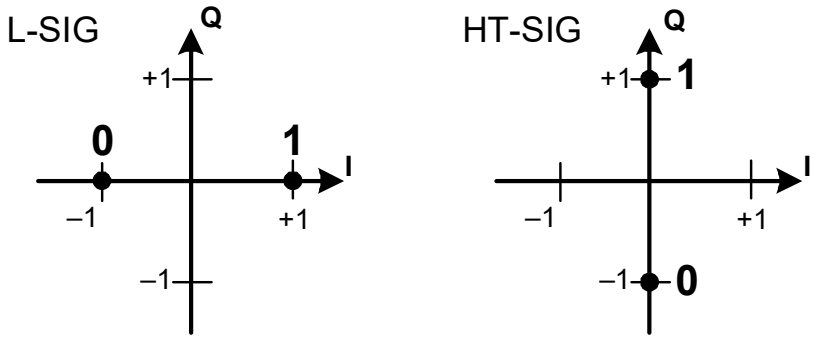


**Figure 19-7—Data tone constellations in an HT-mixed format PPDU**

#### 19.3.9.4.4 CRC calculation for HT-SIG

The CRC protects bits 0–33 of the HT-SIG (bits 0–23 of HT-SIG$_1$ and bits 0–9 of HT-SIG$_2$). The value of the CRC field shall be the 1s complement of

$$crc(D) = (M(D) \oplus I(D))D^8 \bmod G(D) \tag{19-18}$$

where

$M(D) = m_0 D^{33} + m_1 D^{32} + \ldots + m_{32} D + m_{33}$ is the HT-SIG represented as a polynomial

where

$m_0$ is bit 0 of HT-SIG$_1$

$m_{33}$ is bit 9 of HT-SIG$_2$

$I(D) = \sum_{i=26}^{33} D^i$ are initialization values that are added modulo 2 to the first 8 bits of HT-SIG$_1$

$G(D) = D^8 + D^2 + D + 1$ is the CRC generating polynomial

$crc(D) = c_0 D^7 + c_1 D^6 + \ldots + c_6 D + c_7$

The CRC field is transmitted with $c_7$ first.

Figure 19-8 (HT-SIG CRC calculation) shows the operation of the CRC. First, the shift register is reset to all 1s. The bits are then passed through the XOR operation at the input. When the last bit has entered, the output is generated by shifting the bits out of the shift register, C7 first, through an inverter.

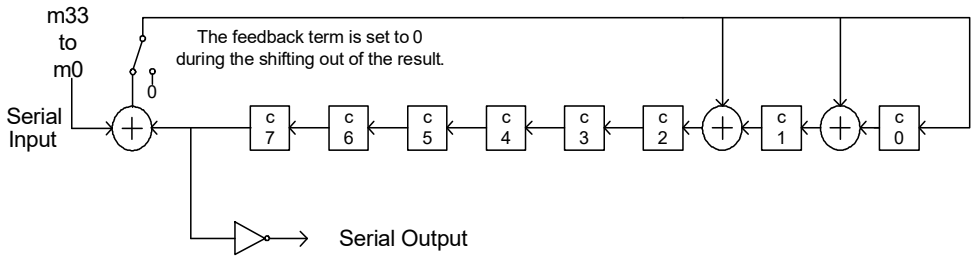


**Figure 19-8—HT-SIG CRC calculation**

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As an example, if bits $\{m_0 \ldots m_{33}\}$ are given by $\{1\,1\,1\,1\,0\,0\,0\,1\,0\,0\,1\,0\,0\,1\,1\,0\,0\,0\,0\,0\,0\,0\,0\,0\,1\,1\,1\,0\,0\,0\,0\,0\,0\}$, the output bits $\{B_7 \ldots B_0\}$, where $B_7$ is output first, are $\{1\,0\,1\,0\,1\,0\,0\,0\}$.

#### 19.3.9.4.5 HT-STF definition

The purpose of the HT-STF is to improve automatic gain control estimation in a MIMO system. The duration of the HT-STF is 4 μs. In a 20 MHz transmission, the frequency sequence used to construct the HT-STF is identical to L-STF. In a 40 MHz transmission, the HT-STF is constructed from the 20 MHz version by duplicating and frequency shifting and by rotating the upper subcarriers by 90°. The frequency sequences are shown in Equation (19-19) and Equation (19-20).

For 20 MHz:

$$\begin{aligned} HTS_{-28,28} = \sqrt{1/2} \\ \{&0, 0, 0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, \\ &0, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 0\} \end{aligned} \tag{19-19}$$

For 40 MHz:

$$\begin{aligned} HTS_{-58,58} = \sqrt{1/2} \\ \{&0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, \\ &0, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 0, 0, \\ &0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, \\ &0, 0, 0, 0, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0\} \end{aligned} \tag{19-20}$$

The time domain representation of the transmission in transmit chain $i_{TX}$ shall be as shown in Equation (19-21).

$$\begin{aligned} r_{HT-STF}^{i_{TX}}(t) = &\frac{1}{\sqrt{N_{STS} \cdot N_{HT-STF}^{Tone}}} w_{\mathrm{T}_{HT-STF}}(t) \\ &\sum_{k=-N_{SR}}^{N_{SR}} \sum_{i_{STS}=1}^{N_{STS}} [Q_k]_{i_{TX}, i_{STS}} \Upsilon_k HTS_k \exp(j2\pi k \Delta_F (t - T_{CS}^{i_{STS}})) \end{aligned} \tag{19-21}$$

where

$T_{CS}^{i_{STS}}$ represents the cyclic shift for the space-time stream $i_{STS}$ and takes the values given in Table 19-10 (Cyclic shift values of HT portion of PPDU)

$Q_k$ is defined in 19.3.11.11.2 (Spatial mapping)

$\Upsilon_k$ is defined in Equation (19-5) and Equation (19-6)

#### 19.3.9.4.6 HT-LTF definition

The HT-LTF provides a means for the receiver to estimate the MIMO channel between the set of QAM mapper outputs (or, if STBC is applied, the STBC encoder outputs) and the receive chains. If the transmitter is providing training for exactly the space-time streams (spatial mapper inputs) used for the transmission of the PSDU, the number of training symbols, $N_{LTF}$, is equal to the number of space-time streams, $N_{STS}$, except that for three space-time streams, four training symbols are required. If the transmitter is providing


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training for more space-time streams (spatial mapper inputs) than the number used for the transmission of the PSDU, the number of training symbols is greater than the number of space-time streams. This latter case happens in a sounding PPDU.

The HT-LTF portion has one or two parts. The first part consists of one, two, or four HT-LTFs that are necessary for demodulation of the (#14)Data field. These HT-LTFs are referred to as *HT-DLTFs*. The optional second part consists of zero, one, two, or four HT-LTFs that may be used to sound extra spatial dimensions of the MIMO channel that are not utilized by the (#14)Data field. These HT-LTFs are referred to as *HT-ELTFs*. If a receiver has not advertised its ability to receive HT-ELTFs, it shall either issue a PHY-RXEND.indication(UnsupportedRate) primitive upon reception of a (#14)PPDU that includes HT-ELTFs or decode that (#14)PPDU. (When an HT packet includes one or more HT-ELTFs, it is optional for a receiver that has not advertised its capability to receive HT-ELTFs to decode the (#14)Data field.)

The number of HT-DLTFs is denoted $N_{HT\text{-}DLTF}$. The number of HT-ELTFs is denoted $N_{HT\text{-}ELTF}$. The total number of HT-LTFs is shown in Equation (19-22).

$$N_{HT\text{-}LTF} = N_{HT\text{-}DLTF} + N_{HT\text{-}ELTF} \tag{19-22}$$

$N_{HT\text{-}LTF}$ shall not exceed 5. Table 19-12 (Determining the number of space-time streams) shows the determination of the number of space-time streams from the MCS and STBC fields in the HT-SIG. Table 19-13 (Number of HT-DLTFs required for data space-time streams(#83)) shows the number of HT-DLTFs as a function of the number of space-time streams ($N_{STS}$). Table 19-14 (Number of HT-ELTFs required for extension spatial streams) shows the number of HT-ELTFs as a function of the number of extension spatial streams ($N_{ESS}$). $N_{STS}$ plus $N_{ESS}$ is less than or equal to 4. In the case where $N_{STS}$ equals 3, $N_{ESS}$ cannot exceed one; if $N_{ESS}$ equals one in this case then $N_{LTF}$ equals 5.

**Table 19-12—Determining the number of space-time streams**

| Number of spatial streams (from MCS) $N_{SS}$ | STBC field | Number of space-time streams $N_{STS}$ |
|---|---|---|
| 1 | 0 | 1 |
| 1 | 1 | 2 |
| 2 | 0 | 2 |
| 2 | 1 | 3 |
| 2 | 2 | 4 |
| 3 | 0 | 3 |
| 3 | 1 | 4 |
| 4 | 0 | 4 |

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**Table 19-13—Number of HT-DLTFs required for data space-time streams(#83)**

| $N_{STS}$ | $N_{HT\text{-}DLTF}$ |
|---|---|
| 1 | 1 |
| 2 | 2 |
| 3 | 4 |
| 4 | 4 |

**Table 19-14—Number of HT-ELTFs required for extension spatial streams**

| $N_{ESS}$ | $N_{HT\text{-}ELTF}$ |
|---|---|
| 0 | 0 |
| 1 | 1 |
| 2 | 2 |
| 3 | 4 |

The HT-LTF sequence shown in Equation (19-23) is transmitted in the case of 20 MHz operation.

$$HT\text{-}LTF_{-28,28} = \{1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 0,$$
$$1, -1, -1, 1, 1, -1, 1, -1, 1, -1, -1, -1, -1, -1, 1, 1, -1, -1, 1, -1, 1, -1, 1, 1, 1, 1, -1, -1\} \quad (19\text{-}23)$$

NOTE 1—This sequence is an extension of the L-LTF where the four extra subcarriers are filled with +1 for negative frequencies and –1 for positive frequencies.

In 40 MHz transmissions, including MCS 32 format (#14)PPDUs, the sequence to be transmitted is shown in Equation (19-24).

$$HT\text{-}LTF_{-58,58} = \{1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 1,$$
$$1, -1, -1, 1, 1, -1, 1, -1, 1, -1, -1, -1, -1, -1, 1, 1, -1, -1, 1, -1, 1, -1, 1, 1, 1, 1, -1, -1, -1, 1, 0,$$
$$0, 0, -1, 1, 1, -1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 1,$$
$$1, -1, -1, 1, 1, -1, 1, -1, 1, -1, -1, -1, -1, -1, 1, 1, -1, -1, 1, -1, 1, -1, 1, 1, 1, 1, 1\} \quad (19\text{-}24)$$

NOTE 2—This sequence is also constructed by extending the L-LTF in the following way: first, the L-LTF is duplicated and shifted as explained in 19.3.9.3.4 (L-LTF definition) for the non-HT duplicate format; then the missing subcarriers [–32, –5, –4, –3, –2, 2, 3, 4, 5, 32] are filled with the values [1, –1, –1, –1, 1, –1, 1, 1, –1, 1], respectively.

This sequence, occupying 114 tones, is used even if the data portion is transmitted with MCS 32 format, which uses 104 tones.

NOTE 3—This sequence uses 114 tones when MCS 32 format is used to retain consistency with other 40 MHz formats and to facilitate channel estimation for beamforming and link adaptation.

In an HT-mixed format preamble, each HT-LTF consists of a single occurrence of the sequence plus a GI insertion and has a duration of 4 μs. In case of multiple space-time streams, cyclic shift is invoked as specified in Table 19-10 (Cyclic shift values of HT portion of PPDU).


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The generation of HT-DLTFs is shown in Figure 19-9 (Generation of HT-DLTFs). The generation of HT-ELTFs is shown in Figure 19-10 (Generation of HT-ELTFs). In these figures, and in the following text, the following notational conventions are used:

— $[X]_{m,\,n}$ indicates the element in row $m$ and column $n$ of matrix $X$

— $[X]_{N}$ indicates a matrix consisting of the first $N$ columns of matrix $X$

— $[X]_{M:N}$ indicates a matrix consisting of columns $M$ to $N$ of matrix $X$

where

$M \le N$

$X$ is either $Q_k$ or $P_{HT\text{-}LTF}$

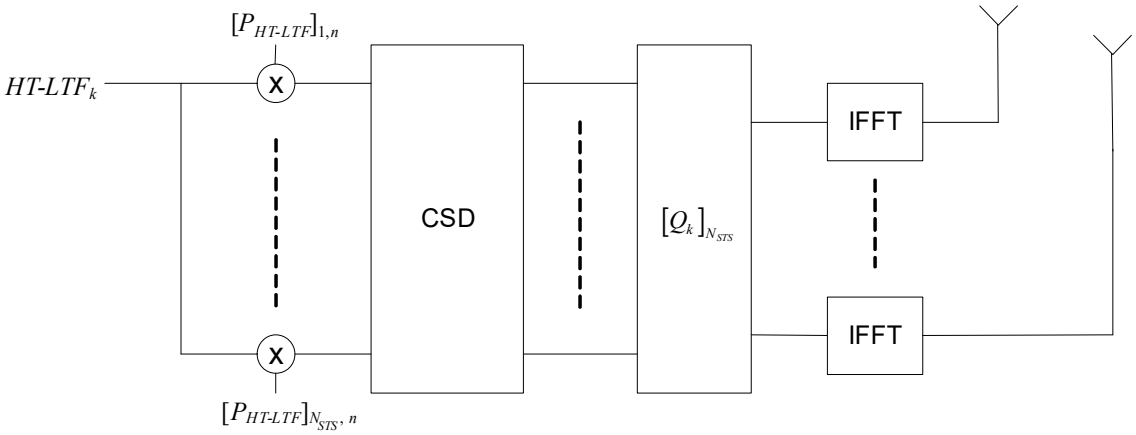


**Figure 19-9—Generation of HT-DLTFs**

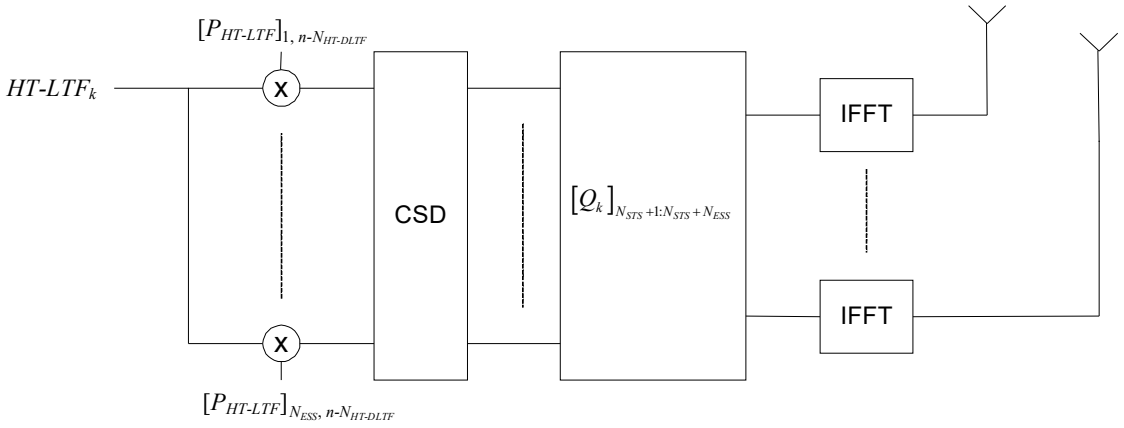


**Figure 19-10—Generation of HT-ELTFs**

The mapping between space-time streams and transmit chains is defined by the columns of an antenna map matrix $Q_k$ for subcarrier $k$. The first $N_{STS}$ columns define the space-time streams used for data transmission, and the next $N_{ESS}$ columns (up to $N_{TX} - N_{STS}$ columns) define the extension spatial streams. Thus, for the purpose of defining HT-LTFs, $Q_k$ is an $N_{TX} \times (N_{STS} + N_{ESS})$ dimension matrix. Columns

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$1 \ldots N_{STS}$ of $Q_k$ are excited by the HT-DLTFs, and columns $N_{STS}+1 \ldots N_{STS}+N_{ESS}$ are excited by the HT-ELTFs, where $N_{STS}+N_{ESS} \le N_{TX}$ is the total number of spatial streams being probed by the HT-LTFs.

Possible forms of $Q_k$ and other limitations on $Q_k$ are specified in 19.3.11.11.2 (Spatial mapping). $P_{HT\text{-}LTF}$ is defined in Equation (19-27).

The time domain representation of the waveform transmitted on transmit chain $i_{TX}$ during HT-DLTF $n$, where $1 \le n \le N_{HT\text{-}DLTF}$, shall be as shown in Equation (19-25).

$$r_{HT-LTF}^{n,i_{TX}}(t) = \frac{1}{\sqrt{N_{STS} \cdot N_{HT-LTF}^{Tone}}} w_{T_{HT-LTFs}}(t) \cdot \sum_{k=-N_{SR}}^{N_{SR}} \sum_{i_{STS}=1}^{N_{STS}} [Q_k]_{i_{TX}, i_{STS}} [P_{HT\text{-}LTF}]_{i_{STS}, n} \Upsilon_k HT\text{-}LTF_k \exp(j2\pi k \Delta_F (t - T_{GI} - T_{CS}^{i_{STS}})) \quad (19\text{-}25)$$

For the HT-ELTFs ($N_{HT\text{-}DLTF} < n \le N_{HT\text{-}LTF}$), it shall be as shown in Equation (19-26)(#83).

$$r_{HT-LTF}^{n,i_{TX}}(t) = \frac{1}{\sqrt{N_{HT-LTF}^{Tone} \cdot N_{ESS}}} w_{T_{HT-LTFs}}(t) \cdot \sum_{k=-N_{SR}}^{N_{SR}} \sum_{i_{ESS}=1}^{N_{ESS}} \Big( [Q_k]_{i_{TX}, N_{STS}+i_{ESS}} [P_{HT\text{-}LTF}]_{i_{ESS}, n-N_{HT\text{-}DLTF}} \Upsilon_k HT\text{-}LTF_k \cdot \exp(j2\pi k \Delta_F (t - T_{GI} - T_{CS}^{i_{ESS}})) \Big) \quad (19\text{-}26)$$

where

$T_{CS}^{i_{STS}}$ cyclic shift values are given in Table 19-10 (Cyclic shift values of HT portion of PPDU)

$T_{CS}^{i_{ESS}}$ cyclic shift values are given in Table 19-10 (Cyclic shift values of HT portion of PPDU) with $i_{ESS} = i_{STS}$

$Q_k$ is defined in 19.3.11.11.2 (Spatial mapping)

$\Upsilon_k$ is defined in Equation (19-5) and Equation (19-6)

$P_{HT\text{-}LTF}$ the HT-LTF mapping matrix, is given by Equation (19-27)

$$P_{HT\text{-}LTF} = \begin{bmatrix} 1 & -1 & 1 & 1 \\ 1 & 1 & -1 & 1 \\ 1 & 1 & 1 & -1 \\ -1 & 1 & 1 & 1 \end{bmatrix} \quad (19\text{-}27)$$


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#### 19.3.9.5 HT-greenfield format preamble

##### 19.3.9.5.1 General

For HT-greenfield operation, compatibility with Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) and Clause 18 (Extended Rate PHY (ERP) specification) STAs is not required. Therefore, the portions of the preamble that are compatible with Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) and Clause 18 (Extended Rate PHY (ERP) specification) STAs are not included. The result is a shorter and more efficient (#14)PPDU format that includes a STF, LTF(s), and an HT-SIG.

##### 19.3.9.5.2 Cyclic shift definition for HT-greenfield format preamble

Throughout the HT-greenfield format preamble, cyclic shift is applied to prevent beamforming when similar signals are transmitted on different spatial streams. The same cyclic shift is applied to these streams during the transmission of the (#14)Data field. The values of the cyclic shift to be used during the HT-greenfield format preamble, as well as the (#14)Data field of the HT-greenfield format PPDU, are specified in Table 19-10 (Cyclic shift values of HT portion of PPDU).

##### 19.3.9.5.3 HT-GF-STF definition

The HT-GF-STF is placed at the beginning of an HT-greenfield format (#14)PPDU. The time domain waveform for the HT-GF-STF on transmit chain $i_{TX}$ shall be as shown in Equation (19-28).

$$r_{HT-GF-STF}^{(i_{TX})}(t) = \frac{1}{\sqrt{N_{STS} \cdot N_{HT-GF-STF}^{Tone}}} w_{T_{HT-GF-STF}}(t) \cdot \sum_{k=-N_{SR}}^{N_{SR}} \sum_{i_{STS}=1}^{N_{STS}} [Q_k]_{i_{TX}, i_{STS}} [P_{HT\text{-}LTF}]_{i_{STS}, 1} \Upsilon_k S_k \exp(j2\pi k \Delta_F (t - T_{CS}^{i_{STS}})) \quad (19\text{-}28)$$

where

$T_{CS}^{i_{STS}}$ represents the cyclic shift for the space-time stream $i_{STS}$ and takes values from Table 19-10 (Cyclic shift values of HT portion of PPDU)

$Q_k$ is defined in 19.3.11.11.2 (Spatial mapping)

$P_{HT\text{-}LTF}$ is defined in Equation (19-27)

$S_k$ is defined in non-HT-STF (L-STF), Equation (19-8) for 20 MHz operation and Equation (19-9) for 40 MHz operation

$\Upsilon_k$ is defined in Equation (19-5) and Equation (19-6)

The waveform defined by Equation (19-28) has a period of 0.8 μs, and the HT-GF-STF includes ten such periods, with a total duration of $T_{HT-GF-STF} = 8$ μs.

##### 19.3.9.5.4 HT-greenfield format HT-SIG

The content and format of the HT-SIG of an HT-greenfield format (#14)PPDU is identical to the HT-SIG in an HT-mixed format (#14)PPDU as described in 19.3.9.4.3 (HT-SIG definition). The placement of the HT-SIG in an HT-greenfield format (#14)PPDU is shown in Figure 19-1 (PPDU format). In HT-greenfield format (#14)PPDUs, the HT-SIG is transmitted with the same cyclic shifts and the same spatial mapping as the preceding portions of the preamble. This use of the same cyclic shifts and spatial mapping is done to

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accommodate the estimation of channel parameters needed to robustly demodulate and decode the information contained in the HT-SIG.

The time domain waveform for the HT-SIG on transmit chain $i_{TX}$ with 20 MHz operation shall be as shown in Equation (19-29).

$$r_{HT-SIG}^{i_{TX}}(t) = \frac{1}{\sqrt{N_{STS} \cdot N_{HT-SIG}^{Tone}}} \sum_{n=0}^{1} w_{T_{SYM}}(t - nT_{SYM}) \cdot \sum_{k=-26}^{26} \sum_{i_{STS}=1}^{N_{STS}} [Q_k]_{i_{TX}, i_{STS}} [P_{HT\text{-}LTF}]_{i_{STS}, 1} (jD_{k,n} + p_n P_k) \cdot \exp(j2\pi k \Delta_F (t - nT_{SYM} - T_{GI} - T_{CS}^{i_{STS}})) \quad (19\text{-}29)$$

where

$P_k$ and $p_n$ are defined in 17.3.5.10 (OFDM modulation)

$D_{k,n}$ is defined in 19.3.9.4.3 (HT-SIG definition)

$T_{CS}^{i_{STS}}$ represents the cyclic shift for space-time stream $i_{STS}$ and takes values from Table 19-10 (Cyclic shift values of HT portion of PPDU)

$Q_k$ is defined in 19.3.11.11.2 (Spatial mapping)

$P_{HT\text{-}LTF}$ is defined in Equation (19-27)

The time domain waveform for the HT-SIG on transmit chain $i_{TX}$ with 40 MHz operation shall be as shown in Equation (19-30).

$$r_{HT-SIG}^{i_{TX}}(t) = \frac{1}{\sqrt{N_{STS} \cdot N_{HT-SIG}^{Tone}}} \sum_{n=0}^{1} w_{T_{SYM}}(t - nT_{SYM}) \cdot \sum_{k=-26}^{26} \sum_{i_{STS}=1}^{N_{STS}} [P_{HT\text{-}LTF}]_{i_{STS}, 1} (jD_{k,n} + p_n P_k) \cdot ([Q_{k-32}]_{i_{TX}, i_{STS}} \exp(j2\pi(k-32)\Delta_F (t - nT_{SYM} - T_{GI} - T_{CS}^{i_{STS}})) + j[Q_{k+32}]_{i_{TX}, i_{STS}} \exp(j2\pi(k+32)\Delta_F (t - nT_{SYM} - T_{GI} - T_{CS}^{i_{STS}}))) \quad (19\text{-}30)$$

where

$p_n$ and $P_k$ are defined in 17.3.5.10 (OFDM modulation)

$D_{k,n}$ is defined in 19.3.9.4.3 (HT-SIG definition)



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$T_{CS}^{i_{STS}}$ represents the cyclic shift for space-time stream $i_{STS}$ and takes values from Table 19-10 (Cyclic shift values of HT portion of PPDU)

$Q_k$ is defined in 19.3.11.11.2 (Spatial mapping)

$P_{HT\text{-}LTF}$ is defined in Equation (19-27)

#### 19.3.9.5.5 HT-greenfield format LTF

The format of the LTF portion of the preamble in an HT-greenfield format frame is similar to that of the HT-LTF in an HT-mixed format (#14)PPDU, as described in 19.3.9.4.6 (HT-LTF definition), with the difference that the first HT-LTF (HT-LTF1) is twice as long (8 μs) as the other HT-LTFs. The time domain waveform for the long training symbol on transmit chain $i_{TX}$ for the first HT-LTF in an HT-greenfield format (#14)PPDU shall be as shown in Equation (19-31).

$$r_{HT-LTF}^{1,i_{TX}}(t) = \frac{1}{\sqrt{N_{STS} \cdot N_{HT-LTF}^{Tone}}} w_{T_{HT-LTF1}}(t) \cdot \sum_{k=-N_{SR}}^{N_{SR}} \sum_{i_{STS}=1}^{N_{STS}} [Q_k]_{i_{TX}, i_{STS}} [P_{HT\text{-}LTF}]_{i_{STS},1} \Upsilon_k HT\text{-}LTF(k) \exp(j2\pi k \Delta_F (t - T_{GI2} - T_{CS}^{i_{STS}})) \quad (19\text{-}31)$$

where

$T_{CS}^{i_{STS}}$ represents the cyclic shift for space-time stream $i_{STS}$ and takes values from Table 19-10 (Cyclic shift values of HT portion of PPDU)

$Q_k$ is defined in 19.3.11.11.2 (Spatial mapping)

$P_{HT\text{-}LTF}$ is defined in Equation (19-27)

The first HT-LTF (HT-LTF1) consists of two periods of the long training symbol, preceded by a double-length (1.6 μs) cyclic prefix. The placement of the first and subsequent HT-LTFs in an HT-greenfield format (#14)PPDU is shown in Figure 19-1 (PPDU format).

### 19.3.10 Transmission of NON_HT PPDUs with more than one transmit chain(#2095)

When an HT device transmits a (#2095)NON_HT PPDU with the MODULATION parameter equal to OFDM or ERP-OFDM using more than one transmit chain, it shall apply the cyclic shifts defined in Table 19-9 (Cyclic shift for non-HT portion of PPDU) to the transmission in each chain.

### 19.3.11 Data field

#### 19.3.11.1 General

When BCC encoding is used, the Data field consists of the 16-bit SERVICE field, the PSDU, either six or twelve tail bits, depending on whether one or two encoding streams are represented, and pad bits. When LDPC encoding is used, the Data field consists of the 16-bit SERVICE field and the PSDU, processed by the procedure in 19.3.11.7.5 (LDPC PPDU encoding process).

The number of OFDM symbols in the (#14)Data field when BCC encoding is used is computed as shown in Equation (19-32).

$$N_{SYM} = m_{STBC} \left\lceil \frac{8 \cdot length + 16 + 6 \cdot N_{ES}}{m_{STBC} \cdot N_{DBPS}} \right\rceil \quad (19\text{-}32)$$

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where

$m_{STBC}$ is 2 if STBC is used and 1 otherwise (making sure that the number of symbols is even when STBC is used)

*length* is the value of the HT Length field in the HT-SIG field defined in Table 19-11 (HT-SIG fields)

$N_{DBPS}$ takes the values defined in Table 19-27 (MCS parameters for mandatory 20 MHz, $N_{SS}$ = 1, $N_{ES}$ = 1) to Table 19-41 (MCS parameters for optional 40 MHz, $N_{SS}$ = 4, UEQM)

The number of "zero" pad bits is thus $N_{SYM} \times N_{DBPS} - 8 \times length - 16 - 6 \times N_{ES}$. The number of symbols in the (#14)Data field when LDPC encoding is used is described in 19.3.11.7 (LDPC codes).

For LDPC encoding, the number of encoded data bits, $N_{\text{avbits}}$, is given by Equation (19-39); the number of OFDM symbols, $N_{\text{SYM}}$, is given by Equation (19-41); and the number of repeated encoded bits for padding, $N_{\text{rep}}$, is given by Equation (19-42), in 19.3.11.7.5 (LDPC PPDU encoding process).

### 19.3.11.2 SERVICE field

The SERVICE field is used for scrambler initialization. The SERVICE field is composed of 16 bits, all set to 0 before scrambling. In non-HT PPDUs, the SERVICE field is the same as in 17.3.5.2 (SERVICE field). In HT PPDUs, the SERVICE field is composed of 16 zero bits, scrambled by the scrambler, as defined in 19.3.11.3 (Scrambler).

### 19.3.11.3 Scrambler

The (#404)Data field shall be scrambled by the scrambler defined in 17.3.5.5 (PHY DATA scrambler and descrambler). The Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) TXVECTOR parameters (#602)CH_BANDWIDTH_IN_NON_HT, DYN_BANDWIDTH_IN_NON_HT, and SCRAMBLER_INITIAL_VALUE are not present in an HT PPDU; therefore, the first 7 bits of the scrambling sequence are set to a 7-bit pseudorandom nonzero integer.

### 19.3.11.4 Coding

The Data field shall be encoded using either the BCC defined in 17.3.5.6 (Convolutional encoder) or the LDPC code defined in 19.3.11.7 (LDPC codes). The encoder is selected by the FEC coding field in the HT-SIG, as described in 19.3.9.4.3 (HT-SIG definition). A single FEC encoder is always used when LDPC coding is used. When the BCC FEC encoder is used, a single encoder is used, except that two encoders are used when the selected MCS has a PHY rate greater than 300 Mb/s (see 19.5 (Parameters for HT-MCSs)). To determine whether to use one or two BCC FEC encoders, the rate is calculated based on the use of an 800 ns GI. The operation of the BCC FEC is described in 19.3.11.6 (BCC coding and puncturing). The operation of the LDPC coder is described in 19.3.11.7 (LDPC codes).

Support for the reception of (#14)PPDUs with BCC-encoded Data fields is mandatory.

### 19.3.11.5 Encoder parsing operation for two BCC FEC encoders

If two BCC encoders are used, the scrambled data bits are divided between the encoders by sending alternating bits to different encoders. Bit with index $i$ sent to the encoder $j$, denoted $x_i^{(j)}$, is shown in Equation (19-33).

$$x_i^{(j)} = b_{N_{ES} \cdot i + j} \quad ; \quad 0 \le j \le N_{ES} - 1 \tag{19-33}$$


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Following the parsing operation, 6 scrambled "zero" bits following the end of the message bits in each BCC input sequence are replaced by unscrambled "zero" bits, as described in 17.3.5.3 (PPDU TAIL field).

The replaced bits are shown in Equation (19-34).

$$x_i^{(j)} \quad : \quad 0 \le j \le N_{ES} - 1 \quad ; \quad \frac{length \cdot 8 + 16}{N_{ES}} \le i \le \frac{length \cdot 8 + 16}{N_{ES}} + 5 \tag{19-34}$$

### 19.3.11.6 BCC coding and puncturing

When BCC encoding is used, the encoder parser output sequences $\{x_i^0\}$, and $\{x_i^1\}$ where applicable, are each encoded by the rate 1/2 convolutional encoder defined in 17.3.5.6 (Convolutional encoder). After encoding, the encoded data shall be punctured by the method defined in 17.3.5.7 (Data interleaving) to achieve the rate selected by the MCS.

If rate 5/6 coding is selected, the puncturing scheme is defined in Figure 19-11 (Puncturing at rate 5/6).

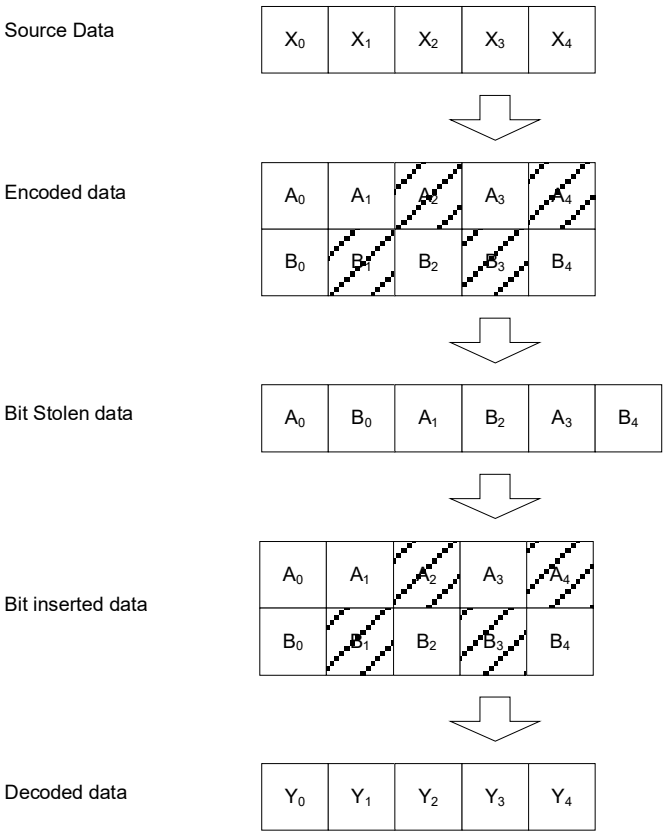


**Figure 19-11—Puncturing at rate 5/6**

### 19.3.11.7 LDPC codes

#### 19.3.11.7.1 Introduction

HT LDPC codes are described in 19.3.11.7.2 (LDPC coding rates and codeword block lengths) to 19.3.11.7.6 (LDPC parser). These codes are optionally used in the HT system as a high-performance error

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correcting code instead of the convolutional code (19.3.11.6 (BCC coding and puncturing)). The LDPC encoder shall use the rate-dependent parameters in Table 19-27 (MCS parameters for mandatory 20 MHz, $N_{SS}$ = 1, $N_{ES}$ = 1) to Table 19-41 (MCS parameters for optional 40 MHz, $N_{SS}$ = 4, UEQM), with the exception of the $N_{ES}$ parameter.

Support for LDPC codes is optional.

#### 19.3.11.7.2 LDPC coding rates and codeword block lengths

The supported coding rates, information block lengths, and codeword block lengths are described in Table 19-15 (LDPC parameters).

**Table 19-15—LDPC parameters**

| Coding rate (R) | LDPC information block length (bits) | LDPC codeword block length (bits) |
|---|---|---|
| 1/2 | 972 | 1944 |
| 1/2 | 648 | 1296 |
| 1/2 | 324 | 648 |
| 2/3 | 1296 | 1944 |
| 2/3 | 864 | 1296 |
| 2/3 | 432 | 648 |
| 3/4 | 1458 | 1944 |
| 3/4 | 972 | 1296 |
| 3/4 | 486 | 648 |
| 5/6 | 1620 | 1944 |
| 5/6 | 1080 | 1296 |
| 5/6 | 540 | 648 |

#### 19.3.11.7.3 LDPC encoder

For each of the three available codeword block lengths, the LDPC encoder supports rate 1/2, rate 2/3, rate 3/4, and rate 5/6 encoding. The LDPC encoder is systematic, i.e., it encodes an information block, $\mathbf{c}=(i_0, i_1, ..., i_{(k-1)})$, of size $k$, into a codeword, **c,** of size $n$, (#515)$\mathbf{c}=(i_0, i_1,..., i_{(k-1)}, p_0, p_1, ..., p_{(n-k-1)})$, by adding $n-k$ parity bits obtained so that $\mathbf{H}\times\mathbf{c}^T = \mathbf{0}$, where **H** is an $(n-k)\times n$ parity-check matrix. The selection of the codeword block length ($n$) is achieved via the LDPC PPDU encoding process described in 19.3.11.7.5 (LDPC PPDU encoding process).

#### 19.3.11.7.4 Parity-check matrices

Each of the parity-check matrices is partitioned into square subblocks (submatrices) of size $Z \times Z$. These submatrices are either cyclic-permutations of the identity matrix or null submatrices.


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The cyclic-permutation matrix $P_i$ is obtained from the $Z \times Z$ identity matrix by cyclically shifting the columns to the right by $i$ elements. The matrix $P_0$ is the $Z \times Z$ identity matrix. Figure 19-12 (Examples of cyclic-permutation matrices with Z=8(#577)) illustrates examples (for a subblock size of 8 × 8) of cyclic-permutation matrices $P_i$.

$$P_0 = \begin{bmatrix} 1&0&0&0&0&0&0&0 \\ 0&1&0&0&0&0&0&0 \\ 0&0&1&0&0&0&0&0 \\ 0&0&0&1&0&0&0&0 \\ 0&0&0&0&1&0&0&0 \\ 0&0&0&0&0&1&0&0 \\ 0&0&0&0&0&0&1&0 \\ 0&0&0&0&0&0&0&1 \end{bmatrix}, P_1 = \begin{bmatrix} 0&1&0&0&0&0&0&0 \\ 0&0&1&0&0&0&0&0 \\ 0&0&0&1&0&0&0&0 \\ 0&0&0&0&1&0&0&0 \\ 0&0&0&0&0&1&0&0 \\ 0&0&0&0&0&0&1&0 \\ 0&0&0&0&0&0&0&1 \\ 1&0&0&0&0&0&0&0 \end{bmatrix}, P_5 = \begin{bmatrix} 0&0&0&0&0&1&0&0 \\ 0&0&0&0&0&0&1&0 \\ 0&0&0&0&0&0&0&1 \\ 1&0&0&0&0&0&0&0 \\ 0&1&0&0&0&0&0&0 \\ 0&0&1&0&0&0&0&0 \\ 0&0&0&1&0&0&0&0 \\ 0&0&0&0&1&0&0&0 \end{bmatrix}$$

**Figure 19-12—Examples of cyclic-permutation matrices with Z=8(#577)**

Table F-1 (Matrix prototypes for codeword block length n = 648 bits, subblock size is Z = 27 bits) displays the "matrix prototypes" of parity-check matrices for all four coding rates at block length $n$=648 bits. The integer $i$ denotes the cyclic-permutation matrix $P_i$, as illustrated in Figure 19-12 (Examples of cyclic-permutation matrices with Z=8(#577)). Vacant entries of the table denote null (zero) submatrices.

Table F-2 (Matrix prototypes for codeword block length n = 1296 bits, subblock size is Z = 54 bits) displays the matrix prototypes of parity-check matrices for block length $n$=1296 bits, in the same fashion.

Table F-3 (Matrix prototypes for codeword block length n = 1944 bits, subblock size is Z = 81 bits) displays the matrix prototypes of parity-check matrices for block length $n$=1944 bits, in the same fashion.

### 19.3.11.7.5 LDPC PPDU encoding process

To encode an LDPC PPDU, step a) to step g) shall be performed in sequence:

a) Compute the number of available bits, $N_{avbits}$, in the minimum number of OFDM symbols in which the Data field of the (#14)PPDU may fit.

$$N_{pld} = length \times 8 + 16 \tag{19-35}$$

$$N_{avbits} = N_{CBPS} \times m_{STBC} \times \left\lceil \frac{N_{pld}}{N_{CBPS} \times R \times m_{STBC}} \right\rceil \tag{19-36}$$

where

| | |
|---|---|
| $m_{STBC}$ | is 2 if STBC is used and 1 otherwise |
| $length$ | is the value of the HT Length field in the HT-SIG field defined in Table 19-11 (HT-SIG fields) |
| $N_{pld}$ | is the number of bits in the PSDU and SERVICE field |

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b) Compute the integer number of LDPC codewords to be transmitted, $N_{CW}$, and the length of the codewords to be used, $L_{LDPC}$ from Table 19-16 (PPDU encoding parameters).

**Table 19-16—PPDU encoding parameters**

| Range of $N_{avbits}$ (bits) | Number of LDPC codewords ($N_{CW}$) | LDPC codeword length $L_{LDPC}$ (bits) |
|---|---|---|
| $N_{avbits} \le 648$ | 1 | 1296, if $N_{avbits} \ge N_{pld} + 912 \times (1\text{-}R)$<br>648, otherwise |
| $648 < N_{avbits} \le 1296$ | 1 | 1944, if $N_{avbits} \ge N_{pld} + 1464 \times (1\text{-}R)$<br>1296, otherwise |
| $1296 < N_{avbits} \le 1944$ | 1 | 1944 |
| $1944 < N_{avbits} \le 2592$ | 2 | 1944, if $N_{avbits} \ge N_{pld} + 2916 \times (1\text{-}R)$<br>1296, otherwise |
| $2592 < N_{avbits}$ | $\left\lceil \frac{N_{pld}}{1944 \cdot R} \right\rceil$ | 1944 |

c) Compute the number of shortening bits, $N_{shrt}$, to be padded to the $N_{pld}$ data bits before encoding, as shown in Equation (19-37).

$$N_{shrt} = \max(0, (N_{CW} \times L_{LDPC} \times R) - N_{pld}) \quad (19\text{-}37)$$

When $N_{shrt} = 0$, shortening is not performed. (Note that $N_{shrt}$ is inherently restricted to be non-negative due to the codeword length and count selection of Table 19-16 (PPDU encoding parameters)). When $N_{shrt} > 0$, shortening bits shall be equally distributed over all $N_{CW}$ codewords with the first $N_{shrt}$ mod $N_{CW}$ codewords shortened 1 bit more than the remaining codewords. Define $N_{spcw} = \lfloor N_{shrt} / N_{CW} \rfloor$. Then, when $N_{shrt} > 0$, the shortening is performed by setting information bits $i_{k-N_{spcw}-1}, \ldots, i_{k-1}$ to 0 in the first $N_{shrt}$ mod $N_{CW}$ codewords and setting information bits $i_{k-N_{spcw}}, \ldots, i_{k-1}$ to 0 in the remaining codewords. For all values of $N_{shrt}$, encode each of the $N_{CW}$ codewords using the LDPC encoding technique described in 19.3.11.7.2 (LDPC coding rates and codeword block lengths) to 19.3.11.7.4 (Parity-check matrices). When $N_{shrt} > 0$, the shortened bits shall be discarded after encoding.

d) Compute the number of bits to be punctured, $N_{punc}$, from the codewords after encoding, as shown in Equation (19-38).

$$N_{punc} = \max(0, (N_{CW} \times L_{LDPC}) - N_{avbits} - N_{shrt}) \quad (19\text{-}38)$$

If $\left((N_{punc} > 0.1 \times N_{CW} \times L_{LDPC} \times (1-R)) \text{ AND} \left(N_{shrt} < 1.2 \times N_{punc} \times \frac{R}{1-R}\right)\right)$ is true OR if $(N_{punc} > 0.3 \times N_{CW} \times L_{LDPC} \times (1-R))$ is true, increment $N_{avbits}$ and recompute $N_{punc}$ by the following two equations once:

$$N_{avbits} = N_{avbits} + N_{CBPS} \times m_{STBC} \quad (19\text{-}39)$$


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$$N_{punc} = \max(0, (N_{CW} \times L_{LDPC}) - N_{avbits} - N_{shrt}) \quad (19\text{-}40)$$

The punctured bits shall be equally distributed over all $N_{CW}$ codewords with the first $N_{punc} \bmod N_{CW}$ codewords punctured 1 bit more than the remaining codewords. Define $N_{\text{ppcw}} = \lfloor N_{\text{punc}} / N_{\text{CW}} \rfloor$. When $N_{\text{ppcw}} > 0$, the puncturing is performed by discarding parity bits $p_{n-k-N_{ppcw}-1}, \ldots, p_{n-k-1}$ of the first $N_{punc}$ mod $N_{CW}$ codewords and discarding parity bits $(p_{n-k-N_{ppcw}}, \ldots, p_{n-k-1})$ of the remaining codewords after encoding. The number of OFDM symbols to be transmitted in the PPDU is computed as shown in Equation (19-41).

$$N_{SYM} = N_{avbits} / N_{CBPS} \quad (19\text{-}41)$$

e) Compute the number of coded bits to be repeated, $N_{rep}$, as shown in Equation (19-42).

$$N_{rep} = \max(0, N_{avbits} - N_{CW} \times L_{LDPC} \times (1 - R) - N_{pld}) \quad (19\text{-}42)$$

The number of coded bits to be repeated shall be equally distributed over all $N_{CW}$ codewords with one more bit repeated for the first $N_{rep}$ mod $N_{CW}$ codewords than for the remaining codewords.

NOTE—When puncturing occurs, the coded bits are not repeated, and vice versa.

The coded bits to be repeated for any codeword shall be copied only from that codeword itself, starting from information bit $i_0$ and continuing sequentially through the information bits and, when necessary, into the parity bits, until the required number of repeated bits is obtained for that codeword. Note that these repeated bits are copied from the codeword after the shortening bits have been removed. If for a codeword the required number of repeated bits are not obtained in this manner (i.e., repeating the codeword once), the procedure is repeated until the required number is achieved. These repeated bits are then concatenated to the codeword after the parity bits in their same order. This process is illustrated in Figure 19-13 (LDPC PPDU encoding padding and puncturing of a single codeword). In this figure, the outlined arrows indicate the encoding procedure steps, while the solid arrows indicate the direction of puncturing and padding with repeated bits.

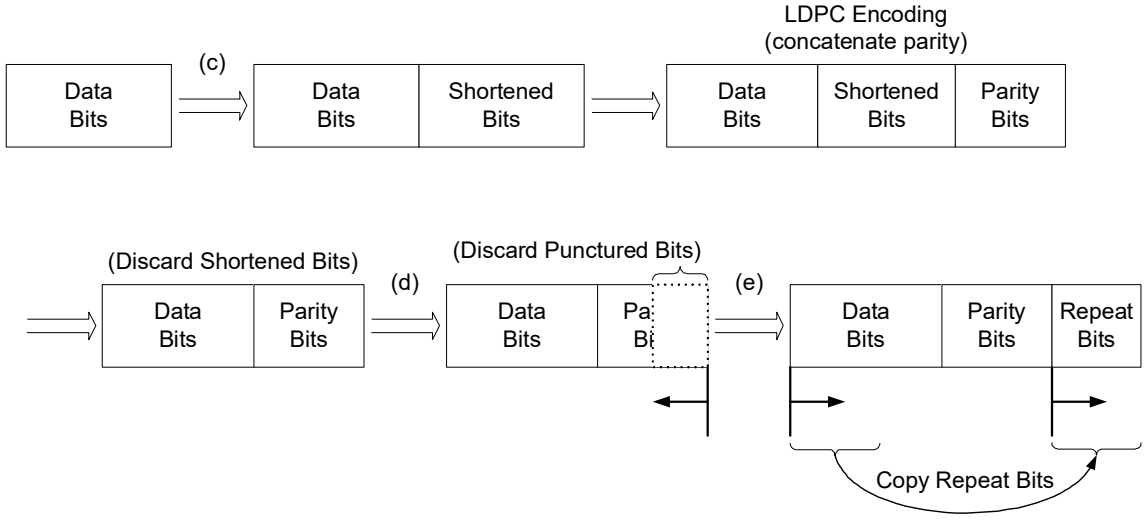


**Figure 19-13—LDPC PPDU encoding padding and puncturing of a single codeword**

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f) For each of the $N_{CW}$ codewords, process the data using the number of shortening bits per codeword as computed in step c) for encoding, and puncture or repeat bits per codeword as computed per step d) and step e), as illustrated in Figure 19-13 (LDPC PPDU encoding padding and puncturing of a single codeword).

g) Aggregate all codewords and parse as defined in 19.3.11.7.6 (LDPC parser).

#### 19.3.11.7.6 LDPC parser

The succession of LDPC codewords that result from the encoding process of 19.3.11.7.5 (LDPC PPDU encoding process) shall be converted into a bitstream in sequential fashion. Within each codeword, bit $i_0$ is ordered first. The parsing of this encoded data stream into spatial streams shall follow exactly the parsing rules defined for the BCC encoder, as defined in 19.3.11.8.1 (Overview). However, the frequency interleaver of 19.3.11.8.3 (Frequency interleaver) is bypassed.

### 19.3.11.8 Data interleaver

#### 19.3.11.8.1 Overview

After coding and puncturing, the data bit streams at the output of the FEC encoders are rearranged into blocks of $N_{CBPSS}(i_{SS})$ bits, where $i_{SS} = 1, 2, \ldots N_{SS}$ is the spatial stream index. This operation is referred to as *stream parsing* and is described in 19.3.11.8.2 (Stream parser). If BCC encoding was used, each of these blocks is then interleaved by an interleaver that is a modification of the Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) interleaver.

#### 19.3.11.8.2 Stream parser

The number of bits assigned to a single axis (real or imaginary) in a constellation point in spatial stream $i_{SS}$ is denoted by Equation (19-43).

$$s(i_{SS}) = \max\left\{1, \frac{N_{BPSCS}(i_{SS})}{2}\right\} \tag{19-43}$$

The sum of these over all streams is $S = \sum_{i_{SS}=1}^{N_{SS}} s(i_{SS})$.

NOTE—If equal MCS is used for all spatial streams, this sum becomes $N_{SS} \cdot s$, where $s$ is the number of bits for an axis common to all streams.

Consecutive blocks of $s(i_{SS})$ bits are assigned to different spatial streams in a round robin fashion.

If two encoders are present, the output of each encoder is used alternately for each round robin cycle, i.e., at the beginning $S$ bits from the output of first encoder are fed into all spatial streams, and then $S$ bits from the output of second encoder are used, and so on.

Input $k$ to spatial stream $i_{SS}$ shall be $y_i^{(j)}$, which is output bit $i$ of the encoder $j$,

where

$$j = \left\lfloor \frac{k}{s(i_{SS})} \right\rfloor \bmod N_{ES} \tag{19-44}$$


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$$i = \sum_{i' = 1}^{i_{SS}-1} s(i') + S \cdot \left\lfloor \frac{k}{N_{ES} \cdot s(i_{SS})} \right\rfloor + k \bmod s(i_{SS}) \qquad (19\text{-}45)$$

$$1 \le i_{SS} \le N_{SS}$$

For $i_{SS} = 1$, the first term in Equation (19-45) has a value of 0.

#### 19.3.11.8.3 Frequency interleaver

MCS 32 interleaving shall be as defined in 17.3.5.7 (Data interleaving). Interleaving for all other MCSs is defined in this subclause.

The bits at the output of the stream parser are divided into blocks of $N_{CBPSS}(i_{SS})$, $i_{SS} = 1, 2, \ldots N_{SS}$ bits; and if BCC encoding was used, each block shall be interleaved by an interleaver based on the Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) interleaver. This interleaver, which is based on entering the data in rows and reading them out in columns, has a different number of columns and rows depending on whether a 20 MHz channel or a 40 MHz channel is used. Table 19-17 (Number of rows and columns in the interleaver) defines the interleaver parameters. If LDPC encoding was used, no frequency interleaving is performed; hence the parsed streams are immediately mapped to symbols as defined in 19.3.11.9 (Constellation mapping).

**Table 19-17—Number of rows and columns in the interleaver**

| Parameter | 20 MHz | 40 MHz |
|---|---|---|
| $N_{COL}$ | 13 | 18 |
| $N_{ROW}$ | $4 \times N_{BPSCS}(i_{SS})$ | $6 \times N_{BPSCS}(i_{SS})$ |
| $N_{ROT}$ | 11 | 29 |

If more than one spatial stream exists after the operations based on the Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) interleaver have been applied, a third operation called *frequency rotation* shall be applied to the additional spatial streams. The parameter for the frequency rotation is $N_{ROT}$.

The interleaving is defined using three permutations. The first permutation is defined by the rule shown in Equation (19-46).

$$i = N_{ROW} \times (k \bmod N_{COL}) + \lfloor k / N_{COL} \rfloor, \qquad k = 0, 1, \ldots, N_{CBPSS}(i_{SS}) - 1 \qquad (19\text{-}46)$$

The second permutation is defined by the rule shown in Equation (19-47).

$$j = s(i_{SS}) \times \lfloor i / s(i_{SS}) \rfloor + (i + N_{CBPSS}(i_{SS}) - \lfloor N_{COL} \times i / N_{CBPSS}(i_{SS}) \rfloor) \bmod s(i_{SS}); \quad i = 0, 1, \ldots, N_{CBPSS}(i_{SS}) - 1 \qquad (19\text{-}47)$$

The value of $s(i_{SS})$ is determined by the number of coded bits per subcarrier as shown in Equation (19-48).

$$s(i_{SS}) = \max(N_{BPSCS}(i_{SS})/2, 1) \qquad (19\text{-}48)$$

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If more than one spatial stream exists, a frequency rotation is applied to the output of the second permutation as shown in Equation (19-49).

$$r = \left(j - \left(((i_{SS}-1)\times 2) \bmod 3 + 3\times\left\lfloor\frac{i_{SS}-1}{3}\right\rfloor\right)\times N_{ROT}\times N_{BPSCS}(i_{SS})\right) \bmod N_{CBPSS}(i_{SS}); \quad j = 0, 1, \ldots, N_{CBPSS}(i_{SS})-1 \tag{19-49}$$

where

$i_{SS} = 1, 2, \ldots, N_{SS}$ is the index of the spatial stream on which this interleaver is operating

The deinterleaver uses the following operations to perform the inverse rotation. The index of the bit in the received block (per spatial stream) is denoted by *r*. The first permutation reverses the third (frequency rotation) permutation of the interleaver as shown in Equation (19-50).

$$j = \left(r + \left(((i_{SS}-1)\times 2) \bmod 3 + 3\times\left\lfloor\frac{i_{SS}-1}{3}\right\rfloor\right)\times N_{ROT}\times N_{BPSCS}(i_{SS})\right) \bmod N_{CBPSS}(i_{SS}); \quad r = 0, 1, \ldots, N_{CBPSS}(i_{SS})-1 \tag{19-50}$$

The second permutation reverses the second permutation in the interleaver as shown in Equation (19-51).

$$i = s(i_{SS})\times\left\lfloor j/s(i_{SS})\right\rfloor + \left(j + \left\lfloor N_{COL}\times j/N_{CBPSS}(i_{SS})\right\rfloor\right) \bmod s(i_{SS}); \quad j = 0, 1, \ldots, N_{CBPSS}(i_{SS})-1 \tag{19-51}$$

where $s(i_{SS})$ is defined in Equation (19-48).

The third permutation reverses the first permutation of the interleaver as shown in Equation (19-52).

$$k = N_{COL}\times i - (N_{CBPSS}(i_{SS})-1)\times\left\lfloor i/N_{ROW}\right\rfloor \qquad i = 0, 1, \ldots, N_{CBPSS}(i_{SS})-1 \tag{19-52}$$

### 19.3.11.9 Constellation mapping

#### 19.3.11.9.1 General

The mapping between bits at the output of the interleaver and complex constellation points for BPSK, QPSK, 16-QAM, and 64-QAM follows the rules defined in 17.3.5.8 (Subcarrier modulation mapping).

The streams of complex numbers are denoted as shown in Equation (19-53).

$$d_{k,l,n},\ 0 \le k \le N_{SD}-1;1 \le l \le N_{SS};0 \le n \le N_{SYM}-1 \tag{19-53}$$

#### 19.3.11.9.2 Space-time block coding (STBC)

This subclause defines a set of optional robust transmission formats that are applicable only when $N_{STS}$ is greater than $N_{SS}$. In this case, $N_{SS}$ spatial streams are mapped to $N_{STS}$ space-time streams, which are mapped to $N_{TX}$ transmit chains. These formats are based on STBC. When the use of STBC is indicated in the STBC field of the HT-SIG, a symbol operation shall occur between the constellation mapper and the spatial mapper (see Figure 19-3 (Transmitter block diagram 2)) as defined in this subclause.

If STBC is applied, the stream of complex numbers, $d_{k,i,n}; k = 0\ldots N_{SD}-1; i = 1\ldots N_{SS}; n = 0\ldots N_{SYM}-1$, generated by the constellation mapper, is the input of the STBC encoder, which produces as output the


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stream of complex numbers $\tilde{d}_{k,i,n}; k = 0 \ldots N_{SD} - 1; i = 1 \ldots N_{STS}; n = 0 \ldots N_{SYM} - 1$. For given values of $k$ and $i$, STBC processing operates on the complex modulation symbols in sequential pairs of OFDM symbols so that the value of $\tilde{d}_{k,i,2m}$ depends on $d_{k,i,2m}$ and $d_{k,i,2m+1}$, and $\tilde{d}_{k,i,2m+1}$ also depends on $d_{k,i,2m}$ and $d_{k,i,2m+1}$, as defined in Table 19-18 (Constellation mapper output to spatial mapper input for STBC).

**Table 19-18—Constellation mapper output to spatial mapper input for STBC**

| $N_{STS}$ | HT-SIG MCS field (bits 0–6 in HT-SIG$_1$) | $N_{SS}$ | HT-SIG STBC field (bits 4–5 in HT-SIG$_2$) | $i_{STS}$ | $\tilde{d}_{k,i,2m}$ | $\tilde{d}_{k,i,2m+1}$ |
|---|---|---|---|---|---|---|
| 2 | 0–7 | 1 | 1 | 1 | $d_{k,1,2m}$ | $d_{k,1,2m+1}$ |
| | | | | 2 | $-d^*_{k,1,2m+1}$ | $d^*_{k,1,2m}$ |
| 3 | 8–15, 33–38 | 2 | 1 | 1 | $d_{k,1,2m}$ | $d_{k,1,2m+1}$ |
| | | | | 2 | $-d^*_{k,1,2m+1}$ | $d^*_{k,1,2m}$ |
| | | | | 3 | $d_{k,2,2m}$ | $d_{k,2,2m+1}$ |
| 4 | 8–15 | 2 | 2 | 1 | $d_{k,1,2m}$ | $d_{k,1,2m+1}$ |
| | | | | 2 | $-d^*_{k,1,2m+1}$ | $d^*_{k,1,2m}$ |
| | | | | 3 | $d_{k,2,2m}$ | $d_{k,2,2m+1}$ |
| | | | | 4 | $-d^*_{k,2,2m+1}$ | $d^*_{k,2,2m}$ |
| 4 | 16–23, 39, 41, 43, 46, 48, 50 | 3 | 1 | 1 | $d_{k,1,2m}$ | $d_{k,1,2m+1}$ |
| | | | | 2 | $-d^*_{k,1,2m+1}$ | $d^*_{k,1,2m}$ |
| | | | | 3 | $d_{k,2,2m}$ | $d_{k,2,2m+1}$ |
| | | | | 4 | $d_{k,3,2m}$ | $d_{k,3,2m+1}$ |

NOTE—The '*' operator represents the complex conjugate.

If STBC is not applied, $\tilde{d}_{k,i,n} = d_{k,i,n}$ and $N_{SS} = N_{STS}$.

NOTE 1—The specific STBC schemes for single spatial streams ($N_{SS} = 1$) with $N_{TX} \geq 3$ are not detailed in this subclause since they are covered through the use of spatial expansion as detailed in 19.3.11.11.2 (Spatial mapping).

NOTE 2—STBC is applied only for the HT-SIG MCS field values specified in Table 19-18 (Constellation mapper output to spatial mapper input for STBC) and is not used with MCS 32.

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### 19.3.11.10 Pilot subcarriers

In a 20 MHz transmission four pilot tones shall be inserted in the same subcarriers used in Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification), i.e., in subcarriers –21, –7, 7, and 21. The pilot sequence for the $n^{\text{th}}$ symbols and $i_{STS}{}^{\text{th}}$ space-time stream shall be as shown in Equation (19-54).

$$P^{-28,28}_{(i_{STS},n)} = \left\{ 0,0,0,0,0,0,0,\Psi^{(N_{STS})}_{i_{STS},\,n \bmod 4},0,0,0,0,0,0,0,0,0,0,0,0,0,0,\Psi^{(N_{STS})}_{i_{STS},\,(n+1) \bmod 4},0,0,0,0,0,0,0, \right.$$
$$\left. 0,0,0,0,0,0,\Psi^{(N_{STS})}_{i_{STS},\,(n+2) \bmod 4},0,0,0,0,0,0,0,0,0,0,0,0,0,\Psi^{(N_{STS})}_{i_{STS},\,(n+3) \bmod 4},0,0,0,0,0,0,0 \right\} \quad (19\text{-}54)$$

In a 40 MHz transmission (excluding MCS 32; see 19.3.11.11.5 (Transmission in MCS 32 format)), pilot signals shall be inserted in subcarriers –53, –25, –11, 11, 25, and 53. The pilot sequence for symbol $n$ and space-time stream $i_{STS}$ shall be as shown in Equation (19-55).

$$P^{-58,58}_{(i_{STS},n)} = \left\{ 0,0,0,0,0,0,\Psi^{(N_{STS})}_{i_{STS},\,n \bmod 6},0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0, \right.$$
$$0,0,\Psi^{(N_{STS})}_{i_{STS},\,(n+1) \bmod 6},0,0,0,0,0,0,0,0,0,0,0,0,0,0,\Psi^{(N_{STS})}_{i_{STS},\,(n+2) \bmod 6},0,0,0,0,0,0,0,0,0,$$
$$0,0,0,0,0,0,0,0,0,0,0,0,0,\Psi^{(N_{STS})}_{i_{STS},\,(n+3) \bmod 6},0,0,0,0,0,0,0,0,0,0,0,0,0,\Psi^{(N_{STS})}_{i_{STS},\,(n+4) \bmod 6}, \quad (19\text{-}55)$$
$$\left. 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,\Psi^{(N_{STS})}_{i_{STS},\,(n+5) \bmod 6},0,0,0,0,0 \right\}$$

where the patterns $\Psi^{(N_{STS})}_{i_{STS},n}$ are defined in Table 19-19 (Pilot values for 20 MHz transmission) and Table 19-20 (Pilots values for 40 MHz transmission (excluding MCS 32)).

NOTE—For each space-time stream, there is a different pilot pattern, and the pilot patterns are cyclically rotated over symbols.

The basic patterns are also different according to the total number of space-time streams for the (#14)Data field of the PPDU.

**Table 19-19—Pilot values for 20 MHz transmission**

| $N_{STS}$ | $i_{STS}$ | $\Psi^{(N_{STS})}_{i_{STS},0}$ | $\Psi^{(N_{STS})}_{i_{STS},1}$ | $\Psi^{(N_{STS})}_{i_{STS},2}$ | $\Psi^{(N_{STS})}_{i_{STS},3}$ |
|---|---|---|---|---|---|
| 1 | 1 | 1 | 1 | 1 | –1 |
| 2 | 1 | 1 | 1 | –1 | –1 |
| 2 | 2 | 1 | –1 | –1 | 1 |
| 3 | 1 | 1 | 1 | –1 | –1 |
| 3 | 2 | 1 | –1 | 1 | –1 |
| 3 | 3 | –1 | 1 | 1 | –1 |
| 4 | 1 | 1 | 1 | 1 | –1 |


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**Table 19-19—Pilot values for 20 MHz transmission *(continued)***

| $N_{STS}$ | $i_{STS}$ | $\Psi^{(N_{STS})}_{i_{STS},0}$ | $\Psi^{(N_{STS})}_{i_{STS},1}$ | $\Psi^{(N_{STS})}_{i_{STS},2}$ | $\Psi^{(N_{STS})}_{i_{STS},3}$ |
|---|---|---|---|---|---|
| 4 | 2 | 1 | 1 | –1 | 1 |
| 4 | 3 | 1 | –1 | 1 | 1 |
| 4 | 4 | –1 | 1 | 1 | 1 |

**Table 19-20—Pilots values for 40 MHz transmission (excluding MCS 32)**

| $N_{STS}$ | $i_{STS}$ | $\Psi^{(N_{STS})}_{i_{STS},0}$ | $\Psi^{(N_{STS})}_{i_{STS},1}$ | $\Psi^{(N_{STS})}_{i_{STS},2}$ | $\Psi^{(N_{STS})}_{i_{STS},3}$ | $\Psi^{(N_{STS})}_{i_{STS},4}$ | $\Psi^{(N_{STS})}_{i_{STS},5}$ |
|---|---|---|---|---|---|---|---|
| 1 | 1 | 1 | 1 | 1 | –1 | –1 | 1 |
| 2 | 1 | 1 | 1 | –1 | –1 | –1 | –1 |
| 2 | 2 | 1 | 1 | 1 | –1 | 1 | 1 |
| 3 | 1 | 1 | 1 | –1 | –1 | –1 | –1 |
| 3 | 2 | 1 | 1 | 1 | –1 | 1 | 1 |
| 3 | 3 | 1 | –1 | 1 | –1 | –1 | 1 |
| 4 | 1 | 1 | 1 | –1 | –1 | –1 | –1 |
| 4 | 2 | 1 | 1 | 1 | –1 | 1 | 1 |
| 4 | 3 | 1 | –1 | 1 | –1 | –1 | 1 |
| 4 | 4 | –1 | 1 | 1 | 1 | –1 | 1 |

### 19.3.11.11 OFDM modulation

#### 19.3.11.11.1 General

The time domain signal is composed from the stream of complex numbers as shown in Equation (19-56).

$$\tilde{d}_{k,l,n},\ 0 \le k \le N_{SD}-1; 1 \le l \le N_{STS}; 0 \le n \le N_{SYM}-1 \tag{19-56}$$

and from the pilot signals. In a 40 MHz transmission, the upper subcarriers are rotated 90° relative to the lower subcarriers.

#### 19.3.11.11.2 Spatial mapping

The transmitter may choose to rotate and/or scale the constellation mapper output vector (or the space-time block coder output, if applicable). This rotation and/or scaling is useful in the following cases:

— When there are more transmit chains than space-time streams, $N_{STS} < N_{TX}$

— As part of (an optional) sounding PPDU

— As part of (an optional) calibration procedure

— When the (#14)PPDU is transmitted using one of the (optional) beamforming techniques

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If the data to be transmitted on subcarrier $k$ on space-time stream $i_{STS}$ are $X_k^{(i_{STS})}$, the transmitted data on the transmit chain $i_{TX}$ shall be as shown in Equation (19-57).

$$r_{Field}^{(i_{TX})} = \frac{1}{\sqrt{N_{STS} \cdot N_{Field}^{Tone}}} w_{\mathrm{T}_{Field}}(t) \sum_{k=-N_{SR}}^{N_{SR}} \sum_{i_{STS}=1}^{N_{STS}} [Q_k]_{i_{TX}, i_{STS}} X_k^{(i_{STS})} \exp(j2\pi k \Delta_F (t - T_{CS}^{i_{STS}})) \quad (19\text{-}57)$$

where

$[Q_k]_{i_{TX}, i_{STS}}$ is the element in row $i_{TX}$ and column $i_{STS}$ in a matrix $Q_k$ with $N_{TX}$ rows and $N_{STS}$ columns; $Q_k$ may be frequency dependent

*Field* is any field, as defined in 19.3.7 (Mathematical description of signals), excluding L-STF, L-LTF, L-SIG, and HT-SIG in (#2095)HT-mixed format PPDU

Below are examples of spatial mapping matrices that might be used. There exist many other alternatives; implementation is not restricted to the spatial mapping matrices shown. The examples are as follows:

a) *Direct mapping*: $Q_k$ is a diagonal matrix of unit magnitude complex values that takes one of two forms:

   1) $Q_k = \mathbf{I}$, the identity matrix

   2) A CSD matrix in which the diagonal elements represent cyclic shifts in the time domain: $[Q_k]_{i,i} = \exp(-j2\pi k \Delta_F \tau_{CS}^i)$, where $\tau_{CS}^i$, $i = 1, \ldots, N_{TX}$ represents the CSD applied.

b) *Indirect mapping:* $Q_k$ may be the product of a CSD matrix and a unitary matrix such as the Hadamard matrix or the Fourier matrix.

c) *Spatial expansion:* $Q_k$ is the product of a CSD matrix and a square matrix formed of orthogonal columns. As an illustration:

   1) The spatial expansion may be performed by duplicating some of the $N_{STS}$ streams to form the $N_{TX}$ streams, with each stream being scaled by the normalization factor $\sqrt{N_{STS}/N_{TX}}$. The spatial expansion may be performed by using, for instance, one of the following matrices, denoted $D$, left-multiplied by a CSD matrix, denoted $M_{CSD}(k)$, and/or possibly multiplied by any unitary matrix. The resulting spatial mapping matrix is then $Q_k = M_{CSD}(k) \cdot D$, where $D$ may take on one of the following values:

      i) $N_{TX}$=2, $N_{STS}$=1, $D = \frac{1}{\sqrt{2}}\begin{bmatrix}1 & 1\end{bmatrix}^T$

      ii) $N_{TX}$=3, $N_{STS}$=1, $D = \frac{1}{\sqrt{3}}\begin{bmatrix}1 & 1 & 1\end{bmatrix}^T$

      iii) $N_{TX}$=4, $N_{STS}$=1, $D = \frac{1}{2}\begin{bmatrix}1 & 1 & 1 & 1\end{bmatrix}^T$

      iv) $N_{TX}$=3, $N_{STS}$=2, $D = \sqrt{\frac{2}{3}}\begin{bmatrix}1 & 0\\ 0 & 1\\ 1 & 0\end{bmatrix}$


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v) $N_{TX}$=4, $N_{STS}$=2, $D = \frac{1}{\sqrt{2}}\begin{bmatrix}1 & 0\\ 0 & 1\\ 1 & 0\\ 0 & 1\end{bmatrix}$

vi) $N_{TX}$=4, $N_{STS}$=3, $D = \frac{\sqrt{3}}{2}\begin{bmatrix}1 & 0 & 0\\ 0 & 1 & 0\\ 0 & 0 & 1\\ 1 & 0 & 0\end{bmatrix}$

2) Different spatial expansion over subcarriers should be used in HT-mixed format only and with the Smoothing bit equal to 0:

i) $N_{TX}$=2, $N_{STS}$=1, $[Q_k]_{N_{STS}} = \begin{bmatrix}1 & 0\end{bmatrix}^T$ or $[Q_k]_{N_{STS}} = \begin{bmatrix}0 & 1\end{bmatrix}^T$

ii) $N_{TX}$=3, $N_{STS}$=2, $[Q_k]_{N_{STS}} = \begin{bmatrix}1 & 0\\ 0 & 0\\ 0 & 1\end{bmatrix}, \begin{bmatrix}1 & 0\\ 0 & 1\\ 0 & 0\end{bmatrix}$ or $\begin{bmatrix}0 & 0\\ 1 & 0\\ 0 & 1\end{bmatrix}$

iii) $N_{TX}$=4, $N_{STS}$=2, $[Q_k]_{N_{STS}} = \begin{bmatrix}1 & 0\\ 0 & 0\\ 0 & 0\\ 0 & 1\end{bmatrix}, \begin{bmatrix}1 & 0\\ 0 & 0\\ 0 & 1\\ 0 & 0\end{bmatrix}, \begin{bmatrix}0 & 0\\ 1 & 0\\ 0 & 0\\ 0 & 1\end{bmatrix}$ or $\begin{bmatrix}0 & 0\\ 1 & 0\\ 0 & 1\\ 0 & 0\end{bmatrix}$

iv) $N_{TX}$=4, $N_{STS}$=3, $[Q_k]_{N_{STS}} = \begin{bmatrix}1 & 0 & 0\\ 0 & 1 & 0\\ 0 & 0 & 0\\ 0 & 0 & 1\end{bmatrix}$ or $\begin{bmatrix}1 & 0 & 0\\ 0 & 0 & 0\\ 0 & 1 & 0\\ 0 & 0 & 1\end{bmatrix}$

d) *Beamforming steering matrix:* $Q_k$ is any matrix that improves the reception in the receiver based on some knowledge of the channel between the transmitter and the receiver. With transmit beamforming with explicit feedback, the steering matrix $Q_k$ is determined using either $H_{eff}$ for CSI feedback or $V_k$ for noncompressed and compressed matrices feedback from the STA to which the beamformed (#14)PPDU is addressed.

When there are fewer space-time streams than transmit chains, the first $N_{STS}$ columns of the matrices above that are square might be used.

The same matrix $Q_k$ shall be applied to subcarrier *k* during all parts of the (#14)PPDU in HT-greenfield format and all parts of the (#14)PPDU following and including the HT-STF field in an HT-mixed format (#14)PPDU. This operation is transparent to the receiver.

When a beamforming steering matrix is applied, the Smoothing bit should be set to 0.

The CSD of Table 19-10 (Cyclic shift values of HT portion of PPDU) shall be applied at the input of the spatial mapper.

For the identity matrix direct mapping, the Smoothing bit should be set to 1.

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If no spatial mapping is applied, the matrix $Q_k$ is equal to the identity matrix and $N_{STS} = N_{TX}$.

Sounding PPDUs using spatial expansion shall use an orthonormal column matrix $Q_k$. When the number of rows and columns is equal, the orthonormal column matrix becomes a unitary matrix.

#### 19.3.11.11.3 Transmission in 20 MHz HT format

For 20 MHz HT transmissions, the signal from transmit chain $i_{TX}, 1 \le i_{TX} \le N_{TX}$ shall be as shown in Equation (19-58).

$$r_{HT-DATA}^{i_{TX}}(t) = \frac{1}{\sqrt{N_{STS} \cdot N_{HT-DATA}^{Tone}}} \sum_{n=0}^{N_{SYM}-1} w_{T_{SYM}}(t - nT_{SYM}) \cdot \sum_{k=-N_{SR}}^{N_{SR}} \sum_{i_{STS}=1}^{N_{STS}} ([Q_k]_{i_{TX}, i_{STS}} (\tilde{D}_{k, i_{STS}, n} + p_{n+z} P_{(i_{STS}, n)}^{k}) \cdot \exp(j2\pi k\Delta_F (t - nT_{SYM} - T_{GI} - T_{CS}^{i_{STS}})))) \quad (19\text{-}58)$$

where

$z$ (#14)is 3 in an HT-mixed format PPDU and 2 in an HT-greenfield format PPDU

$p_n$ is defined in 17.3.5.10 (OFDM modulation)

$$\tilde{D}_{k, i_{STS}, n} = \begin{cases} 0, k = 0, \pm 7, \pm 21 \\ \tilde{d}_{M^r(k), i_{STS}, n}, \text{otherwise} \end{cases}$$

$$M^r(k) = \begin{cases} k + 28, -28 \le k \le -22 \\ k + 27, -20 \le k \le -8 \\ k + 26, -6 \le k \le -1 \\ k + 25, 1 \le k \le 6 \\ k + 24, 8 \le k \le 20 \\ k + 23, 22 \le k \le 28 \end{cases}$$

$P_{(i_{STS}, n)}^{k}$ is defined in Equation (19-54)

#### 19.3.11.11.4 Transmission in 40 MHz HT format

For 40 MHz HT transmissions, the signal from transmit chain $i_{TX}$ shall be as shown in Equation (19-59).



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$$r_{HT-DATA}^{i_{TX}}(t) = \frac{1}{\sqrt{N_{STS} \cdot N_{HT-DATA}^{Tone}}} \sum_{n=0}^{N_{SYM}-1} w_{T_{SYM}}(t - nT_{SYM})$$

$$\cdot \sum_{k=-N_{SR}}^{N_{SR}} \sum_{i_{STS}=1}^{N_{STS}} ([Q_k]_{i_{TX}, i_{STS}} (\tilde{D}_{k, i_{STS}, n} + p_{n+z} P_{(i_{STS}, n)}^{k})) \Upsilon_k \quad (19\text{-}59)$$

$$\cdot \exp(j2\pi k \Delta_F (t - nT_{SYM} - T_{GI} - T_{CS}^{i_{STS}})))$$

where

$z$ (#14)is 3 in an HT-mixed format PPDU and 2 in an HT-greenfield format PPDU

$p_n$ is defined in 17.3.5.10 (OFDM modulation)

$$\tilde{D}_{k, i_{STS}, n} = \begin{cases} 0, k = 0, \pm 1, \pm 11, \pm 25, \pm 53 \\ \tilde{d}_{M^r(k), i_{STS}, n}, \text{otherwise} \end{cases}$$

$$M^r(k) = \begin{cases} k + 58, -58 \le k \le -54 \\ k + 57, -52 \le k \le -26 \\ k + 56, -24 \le k \le -12 \\ k + 55, -10 \le k \le -2 \\ k + 52, 2 \le k \le 10 \\ k + 51, 12 \le k \le 24 \\ k + 50, 26 \le k \le 52 \\ k + 49, 54 \le k \le 58 \end{cases}$$

$P_{(i_{STS}, n)}^{k}$ is defined in Equation (19-55)

NOTE—The 90° rotation that is applied to the upper part of the 40 MHz channel is applied in the same way to the HT-STF, HT-LTF, and HT-SIG. The rotation applies to both pilots and the data in the upper part of the 40 MHz channel.

### 19.3.11.11.5 Transmission in MCS 32 format

The use of MCS 32 format is deprecated.

MCS 32 format provides the lowest transmission rate in 40 MHz. It is used only for one spatial stream and only with BPSK modulation and rate 1/2 coding.

In the MCS 32 format, the signal shall be as shown in Equation (19-60).

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$$r_{HT-DATA}^{i_{TX}}(t) = \frac{1}{\sqrt{N_{HT-Duplicate}^{Tone}}} \sum_{n=0}^{N_{SYM}-1} w_{T_{SYM}}(t - nT_{SYM}) \cdot \sum_{k=-N_{SR}}^{N_{SR}} (D_{k,n} + p_{n+z}P_k)([Q_{k-32}]_{i_{TX},1} \exp(j2\pi(k-32)\Delta_F(t - nT_{SYM} - T_{GI})) + j[Q_{k+32}]_{i_{TX},1} \exp(j2\pi(k+32)\Delta_F(t - nT_{SYM} - T_{GI})))$$ (19-60)

where

$z$ is defined in 19.3.11.11.3 (Transmission in 20 MHz HT format)

$P_k$ and $p_n$ are defined in 17.3.5.10 (OFDM modulation)

$D_{k,n}$ is defined in 19.3.9.4.3 (HT-SIG definition)

$N_{SR}$ has the value defined for non-HT 20 MHz transmission

$[Q_k]_{i_{TX},1}$ is an element from a vector of length $N_{TX}$, which may be frequency dependent

$N_{HT-Duplicate}^{Tone}$ is defined in Table 19-8 (Value of tone scaling factor)

The rules of spatial expansion CSD limitation, as specified in 19.3.11.11.2 (Spatial mapping), shall apply to $[Q_k]_{i_{TX},1}$.

### 19.3.11.11.6 Transmission with a short GI

Short GI is used in the (#14)Data field of the (#14)PPDU when the Short GI field in the HT-SIG is equal to 1. When it is used, the same formula for the formation of the signal shall be used as in 19.3.11.11.3 (Transmission in 20 MHz HT format), 19.3.11.11.4 (Transmission in 40 MHz HT format), and 19.3.11.11.5 (Transmission in MCS 32 format), with $T_{GI}$ replaced by $T_{GIS}$ and $T_{SYM}$ replaced by $T_{SYMS}$.

NOTE—Short GI is not used in HT-greenfield format with one spatial stream, in which case the HT-SIG is immediately followed by data. It is very difficult to parse the HT-SIG in time to demodulate these data with the correct GI length if the GI length is not known in advance.

### 19.3.11.12 Non-HT duplicate transmission

Non-HT duplicate transmission is used to transmit to Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) STAs, Clause 18 (Extended Rate PHY (ERP) specification) STAs, and Clause 19 (High Throughput (HT) PHY specification(#2297)) STAs that may be present in either the upper or lower halves of the 40 MHz channel. The L-STF, L-LTF, and L-SIG shall be transmitted in the same way as in the HT 40 MHz transmission. The HT-SIG, HT-STF, and HT-LTF are not transmitted. Data transmission shall be as defined in Equation (19-61).(#568)


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$$r_{LEG-DUP}^{i_{TX}}(t) = \frac{1}{\sqrt{N_{TX} N_{Non\text{-}HT\ Duplicate}^{Tone}}} \sum_{n=0}^{N_{SYM}-1} w_{T_{SYM}}(t - nT_{SYM}) \cdot \sum_{k=-26}^{26} (D_{k,n} + p_{n+1}P_k)(\exp(j2\pi(k-32)\Delta_F(t - nT_{SYM} - T_{GI} - T_{CS}^{i_{TX}})) + j\exp(j2\pi(k+32)\Delta_F(t - nT_{SYM} - T_{GI} - T_{CS}^{i_{TX}}))) \quad (19\text{-}61)$$

where

$P_k$ and $p_n$ are defined in 17.3.5.10 (OFDM modulation)

$D_{k,n}$ is defined in 19.3.9.4.3 (HT-SIG definition)

$T_{CS}^{i_{TX}}$ represents the cyclic shift of the transmit chain $i_{TX}$ and is defined in Table 19-9 (Cyclic shift for non-HT portion of PPDU)

$N_{Non\text{-}HT\ Duplicate}^{Tone}$ is defined in Table 19-8 (Value of tone scaling factor)

## 19.3.12 Beamforming

### 19.3.12.1 General

Beamforming is a technique in which the beamformer utilizes the knowledge of the MIMO channel to generate a steering matrix $Q_k$ that improves reception in the beamformee.

The equivalent complex baseband MIMO channel model (3×2 example) is one in which, when a vector $\mathbf{x}_k = [x_1, x_2, \ldots x_{N_{TX}}]^T$ is transmitted in subcarrier $k$, the received vector $\mathbf{y}_k = [y_1, y_2, \ldots y_{N_{RX}}]^T$ is modeled as shown in Equation (19-62).

$$\mathbf{y}_k = H_k \mathbf{x}_k + \mathbf{n} \quad (19\text{-}62)$$

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where

$H_k$ is channel matrix of dimensions $N_{RX} \times N_{TX}$

**n** is white (spatially and temporally) Gaussian noise as illustrated in Figure 19-14 (Beamforming MIMO channel model (3×2 example))

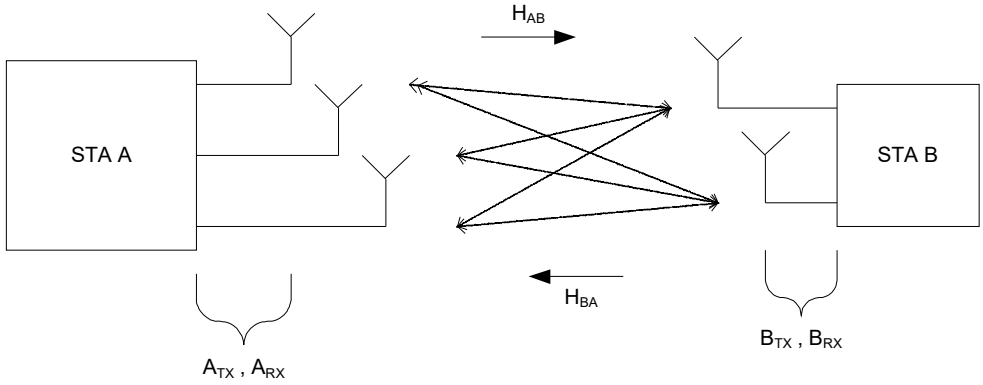


**Figure 19-14—Beamforming MIMO channel model (3×2 example)**

When beamforming is used, the beamformer replaces $\mathbf{x}_k$, which in this case has $N_{STS} \leq N_{TX}$ elements, with $Q_k\mathbf{x}_k$, where $Q_k$ has $N_{TX}$ rows and $N_{STS}$ columns, so that the received vector is as shown in Equation (19-63).

$$\mathbf{y}_k = H_k Q_k \mathbf{x}_k + \mathbf{n} \tag{19-63}$$

The beamforming steering matrix that is computed (or updated) from a new channel measurement replaces the existing $Q_k$ for the next beamformed data transmission. There are several methods of beamforming, differing in the way the beamformer acquires the knowledge of the channel matrices $H_k$ and on whether the beamformer generates $Q_k$ or the beamformee provides feedback information for the beamformer to generate $Q_k$.

### 19.3.12.2 Implicit feedback beamforming

Implicit feedback beamforming is a technique that relies on reciprocity in the time division duplex channel to estimate the channel over which a device is transmitting based on the MIMO reference that is received from the device to which it plans to transmit. This technique allows the transmitting device to calculate a set of transmit steering matrices, $Q_k$, one for each subcarrier, which are intended to optimize the performance of the link.

Referring to Figure 19-14 (Beamforming MIMO channel model (3×2 example)), beamforming transmissions from STA A to STA B using implicit techniques are enabled when STA B sends STA A a sounding PPDU, the reception of which allows STA A to form an estimate of the MIMO channel from STA B to STA A, for all subcarriers. In a TDD channel in which the forward and reverse channels are reciprocal, the channel from STA A to STA B in subcarrier $k$ is the matrix transpose of the channel from STA B to STA A in subcarrier $k$ to within a complex scaling factor, i.e., $H_{\mathrm{AB},k} = \rho[H_{\mathrm{BA},k}]^T$. Here $H_{\mathrm{AB},k}$ is the MIMO channel matrix from STA A to STA B at subcarrier $k$, and $H_{\mathrm{BA},k}$ is the channel matrix from STA B


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to STA A at subcarrier $k$. STA A uses this relationship to compute transmit steering matrices that are suitable for transmitting to STA B over $H_{\mathrm{AB},k}$.

NOTE 1—In order for the recipient of the sounding to compute steering matrices when steered or unsteered sounding is used, the steering matrices need to have the property $(H_kQ_k)(H_kQ_k)^H = H_kH_k^H$, where $X^H$ indicates the conjugate transpose of the matrix $X$.

While the over-the-air channel between the antenna(s) at one STA and the antenna(s) at a second STA is reciprocal, the observed baseband-to-baseband channel used for communication might not be, as it includes the transmit and receive chains of the STAs. Differences in the amplitude and phase characteristics of the transmit and receive chains associated with individual antennas degrade the reciprocity of the over-the-air channel and cause degradation of performance of implicit beamforming techniques. The over-the-air calibration procedure described in 10.33.2.4 (Calibration) may be used to restore reciprocity. The procedure provides the means for calculating a set of correction matrices that can be applied at the transmit side of a STA to correct the amplitude and phase differences between the transmit and receive chains in the STA. If this correction is done at least at the STA that serves as the beamformer, there is sufficient reciprocity for implicit feedback in the baseband-to-baseband response of the forward link and reverse channel.

Figure 19-15 (Baseband-to-baseband channel) illustrates the observed baseband-to-baseband channel, including reciprocity correction. Spatial mapping matrices $Q_{\mathrm{A},k}$ and $Q_{\mathrm{B},k}$ are assumed to be identity matrices here for simplicity of illustration.

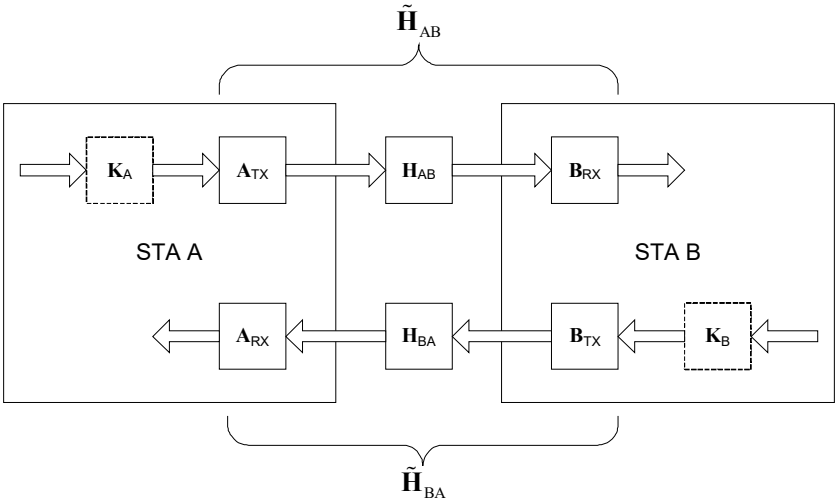


**Figure 19-15—Baseband-to-baseband channel**

NOTE 2—Spatial mapping matrix for sounding PPDUs are specified in 19.3.13.3 (Sounding PPDU for calibration).

The amplitude and phase responses of the transmit and receive chains can be expressed as diagonal matrices with complex valued diagonal entries, of the form $A_{TX,k}$ and $A_{RX,k}$ at STA A. The relationship between the baseband-to-baseband channel, $\tilde{H}_{\mathrm{AB},k}$, and the over-the-air channel, $H_{\mathrm{AB},k}$, is shown in Equation (19-64).

$$\tilde{H}_{\mathrm{AB},k} = B_{\mathrm{RX},k}H_{\mathrm{AB},k}A_{\mathrm{TX},k} \tag{19-64}$$

Similarly, the relationship between $\tilde{H}_{\mathrm{BA},k}$ and $H_{\mathrm{BA},k}$ is shown in Equation (19-65).

$$\tilde{H}_{\mathrm{BA},k} = A_{\mathrm{RX},k}H_{\mathrm{BA},k}B_{\mathrm{TX},k} \tag{19-65}$$

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As an example, consider the case where calibration is performed at both STA A and STA B. The objective is to compute correction matrices, $K_{\mathrm{A},k}$ and $K_{\mathrm{B},k}$, that restore reciprocity so that Equation (19-66) is true.

$$\tilde{H}_{\mathrm{AB},k}K_{\mathrm{A},k} = \rho[\tilde{H}_{\mathrm{BA},k}K_{\mathrm{B},k}]^{\mathrm{T}} \tag{19-66}$$

The correction matrices are diagonal matrices with complex valued diagonal entries. The reciprocity condition in Equation (19-66) is enforced when Equation (19-67) and Equation (19-68) are true.

$$K_{\mathrm{A},k} = \alpha_{\mathrm{A},k}[A_{\mathrm{TX},k}]^{-1}A_{\mathrm{RX},k} \tag{19-67}$$

and

$$K_{\mathrm{B},k} = \alpha_{\mathrm{B},k}[B_{\mathrm{TX},k}]^{-1}B_{\mathrm{RX},k} \tag{19-68}$$

where $\alpha_{\mathrm{A},k}$ and $\alpha_{\mathrm{B},k}$ are complex valued scaling factors.

Using these expressions for the correction matrices, the calibrated baseband-to-baseband channel between STA A and STA B is expressed as shown in Equation (19-69).

$$\hat{H}_{\mathrm{AB},k} = \tilde{H}_{\mathrm{AB},k}K_{\mathrm{A},k} = \alpha_{\mathrm{A},k}B_{\mathrm{RX},k}H_{\mathrm{AB},k}A_{\mathrm{RX},k} \tag{19-69}$$

If both sides apply the correction matrices, the calibrated baseband-to-baseband channel between STA A and STA B is expressed as shown in Equation (19-70).

$$\hat{H}_{\mathrm{BA},k} = \alpha_{\mathrm{B},k}A_{\mathrm{RX},k}H_{\mathrm{BA},k}B_{\mathrm{RX},k} = \frac{\alpha_{\mathrm{B},k}}{\alpha_{\mathrm{A},k}}[\hat{H}_{\mathrm{AB},k}]^{\mathrm{T}} \tag{19-70}$$

Focusing on STA A, the procedure for estimating $K_{\mathrm{A},k}$ is as follows:

a) STA A sends STA B a sounding PPDU, the reception of which allows STA B to estimate the channel matrices $\tilde{H}_{\mathrm{AB},k}$.

b) STA B sends STA A a sounding PPDU, the reception of which allows STA A to estimate the channel matrices $\tilde{H}_{\mathrm{BA},k}$.

c) STA B sends the quantized estimates of $\tilde{H}_{\mathrm{AB},k}$ to STA A.

d) STA A uses its local estimates of $\tilde{H}_{\mathrm{BA},k}$ and the quantized estimates of $\tilde{H}_{\mathrm{AB},k}$ received from STA B to compute the correction matrices $K_{\mathrm{A},k}$.

NOTE 3—When a nonidentity matrix is used for $Q_{A,k}$, STA A is responsible for accounting for the spatial mapping in its local channel estimate as well as in the quantized CSI fed back since the channel feedback received in step c) is actually $\tilde{H}_{\mathrm{AB},k}Q_{\mathrm{A},k}$ and not $\tilde{H}_{\mathrm{AB},k}$. Furthermore, since $Q_{\mathrm{B},k}$ is defined in 19.3.13.3 (Sounding PPDU for calibration), additional steps might be taken in STA A to remove the effect of $Q_{\mathrm{B},k}$ when computing the correction matrix $K_{A,k}$.

Steps a) and b) occur over a short time interval to so the channel changes as little as possible between measurements. A similar procedure is used to estimate $K_{\mathrm{B},k}$ at STA B. The details of the computation of the correction matrices is implementation specific and beyond the scope of this standard.


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### 19.3.12.3 Explicit feedback beamforming

#### 19.3.12.3.1 General

In explicit beamforming, in order for STA A to transmit a beamformed (#14)PPDU to STA B, STA B measures the channel matrices and sends STA A either the effective channel, $H_{eff,k}$, or the beamforming feedback matrix, $V_k$, for STA A to determine a steering matrix, $Q_{\text{steer},k} = Q_k V_k$, with $V_k$ found from $H_k Q_k$, where $Q_k$ is the orthonormal spatial mapping matrix that was used to transmit the sounding PPDU that elicited the $V_k$ feedback. The effective channel, $H_{eff,k} = H_k Q_k$, is the product of the spatial mapping matrix used on transmit with the channel matrix. When new steering matrix $Q_{\text{steer},k}$ is found, $Q_{\text{steer},k}$ may replace $Q_k$ for the next beamformed data transmission.

NOTE—$Q_{\text{steer},k}$ is a mathematical term to update a new steering matrix for $Q_k$ in the next beamformed data transmission.

#### 19.3.12.3.2 CSI matrices feedback

In CSI matrices feedback, the beamformer receives the quantized MIMO channel matrix, $H_{eff}$, from the beamformee. The beamformer then may use this matrix to compute a set of transmit steering matrices, $Q_k$. The CSI matrix, $H_{eff}$, shall be determined from the transmitter spatial mapper input to the receiver FFT outputs. The beamformee shall remove the CSD in Table 19-10 (Cyclic shift values of HT portion of PPDU) from the measured channel matrix.

The matrices $H_{eff}(k)$, where $k$ is the subcarrier index, are encoded so that applying the procedure in 19.3.12.3.3 (CSI matrices feedback decoding procedure) optimally reconstructs the matrix.

#### 19.3.12.3.3 CSI matrices feedback decoding procedure

The received, quantized matrix $H^{q}_{eff}(k)$ (of a specific subcarrier, $k$) shall be decoded as follows:

a) The real and imaginary parts of each element of the matrix, $H^{q(R)}_{eff(m,l)}(k)$ and $H^{q(I)}_{eff(m,l)}(k)$, are decoded as a pair of 2s complement numbers to create the complex element, where $1 \le m \le N_r$ and $1 \le l \le N_c$.

b) Each element in the matrix of subcarrier $k$ is then scaled using the value in the carrier matrix amplitude field (3 bits), $M_H(k)$, interpreted as a positive integer, in decibels, as follows:

   1) Calculate the linear value as defined in Equation (19-71).
   2) Calculate decoded values of the real and imaginary parts of the matrix element as defined in Equation (19-72) and Equation (19-73).

$$r(k) = 10^{M_H(k)/20} \tag{19-71}$$

$$\text{Re}\{\tilde{H}_{eff(m,l)}(k)\} = \frac{H^{q(R)}_{eff(m,l)}(k)}{r(k)} \tag{19-72}$$

$$\text{Im}\{\tilde{H}_{eff(m,l)}(k)\} = \frac{H^{q(I)}_{eff(m,l)}(k)}{r(k)} \tag{19-73}$$

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#### 19.3.12.3.4 Example of CSI matrices feedback encoding

The following is an example of an encoding process:

a) The maximums of the real and imaginary parts of each element of the matrix in each subcarrier are found, as defined by Equation (19-74).

$$m_H(k) = \max\left\{\max\left\{\left|\mathrm{Re}(H_{eff(m,l)}(k))\right|_{m=1,l=1}^{m=N_r,l=N_c}\right\}, \max\left\{\left|\mathrm{Im}(H_{eff(m,l)}(k))\right|_{m=1,l=1}^{m=N_r,l=N_c}\right\}\right\} \quad (19\text{-}74)$$

b) The scaling ratio is calculated and quantized to 3 bits as defined by Equation (19-75)(#315). A linear scaler is given by Equation (19-76).

$$M_H(k) = \min\left\{7, \left\lfloor 20\log 10\left(\frac{\max\{m_H(z)\}_{z=-N_{SR}}^{z=N_{SR}}}{m_H(k)}\right)\right\rfloor\right\} \quad (19\text{-}75)$$

where

$$M_H^{\mathrm{lin}}(k) = \frac{\max\{m_H(z)\}_{z=-N_{SR}}^{z=N_{SR}}}{10^{M_H(k)/20}} \quad (19\text{-}76)$$

c) The real and imaginary parts of each element in the matrix $H_{eff(m,l)}(k)$ are quantized to $N_b$ bits in 2s complement encoding as defined by Equation (19-77) and Equation (19-78).

$$H_{eff(m,l)}^{q(R)}(k) = \left\lfloor \frac{\mathrm{Re}\{H_{eff(m,l)}(k)\}}{M_H^{\mathrm{lin}}(k)}(2^{N_b-1}-1)+0.5 \right\rfloor \quad (19\text{-}77)$$

$$H_{eff(m,l)}^{q(I)}(k) = \left\lfloor \frac{\mathrm{Im}\{H_{eff(m,l)}(k)\}}{M_H^{\mathrm{lin}}(k)}(2^{N_b-1}-1)+0.5 \right\rfloor \quad (19\text{-}78)$$

Each matrix is encoded using $3 + 2 \times N_b \times N_r \times N_c$ bits, where $N_r$ and $N_c$ are the number of rows and columns, respectively, in the channel matrix estimate computed by the receiving station and where $N_b$ may have the value of 4, 5, 6, or 8 bits.

#### 19.3.12.3.5 Noncompressed beamforming feedback matrix

In noncompressed beamforming feedback matrix, the beamformee shall remove the space-time stream CSD in Table 19-10 (Cyclic shift values of HT portion of PPDU) from the measured channel before computing a set of matrices for feedback to the beamformer. The beamforming feedback matrices, $V(k)$, found by the beamformee are sent to the beamformer in the order of real and imaginary components per tone as specified in 9.4.1.26 (Noncompressed Beamforming Report field). The beamformer might use these matrices to determine the steering matrices, $Q_k$.

The beamformee shall encode the matrices $V(k)$ so a beamformer applying the procedure below optimally reconstructs the matrix.

The received matrix $V^q(k)$ (of a specific subcarrier $k$) shall be decoded as follows:

a) The real and imaginary parts of each element of the matrix, $V_{m,l}^{q,R}$ and $V_{m,l}^{q,I}$, shall be decoded as a pair of 2s complement numbers to create the complex element, where $1 \le m \le N_r$ and $1 \le l \le N_c$.


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b) The dimensions of the beamforming feedback matrices are $N_r \times N_c$, where $N_r$ and $N_c$ are the number of rows and columns, respectively, in the beamforming feedback matrix computed by the receiving station. Each matrix is encoded using $2 \times N_b \times N_r \times N_c$ bits. $N_b$ may have the value of 2, 4, 6, or 8 bits.

c) Columns $1 \ldots N_c$ of the beamforming feedback matrix correspond to spatial streams $1 \ldots N_c$, respectively. The mapping of spatial stream to modulation is defined in the MCS tables in 19.5 (Parameters for HT-MCSs). A transmitter shall not reorder the columns of the beamforming feedback matrices.

#### 19.3.12.3.6 Compressed beamforming feedback matrix

In compressed beamforming feedback matrix, the beamformee shall remove the space-time stream CSD in Table 19-10 (Cyclic shift values of HT portion of PPDU) from the measured channel before computing a set of matrices for feedback to the beamformer. The beamforming feedback matrices, $V(k)$, found by the beamformee are compressed in the form of angles, which are sent to the beamformer. The beamformer might use these angles to decompress the matrices and determine the steering matrices $Q_k$.

The matrix $V$ per tone shall be compressed as follows: The $N_r \times N_c$ beamforming feedback orthonormal column matrix $V$ found by the beamformee shall be represented as shown in Equation (19-79). When the number of rows and columns is equal, the orthonormal column matrix becomes a unitary matrix.

$$V = \left[ \prod_{i=1}^{\min(N_c, N_r - 1)} \left[ D_i\left( 1_{i-1} \; e^{j\phi_{i,i}} \; \ldots \; e^{j\phi_{N_r-1,i}} \; 1 \right) \prod_{l=i+1}^{N_r} G_{li}^{T}(\psi_{li}) \right] \right] \tilde{I}_{N_r \times N_c} \tag{19-79}$$

The matrix $D_i\left( 1_{i-1} \; e^{j\phi_{i,i}} \; \ldots \; e^{j\phi_{N_r-1,i}} \; 1 \right)$ is an $N_r \times N_r$ diagonal matrix, where $1_{i-1}$ represents a sequence of 1s with length of *i*–1, as shown in Equation (19-80).

$$D\left( 1_{i-1} \; e^{j\phi_{i,i}} \ldots \; e^{j\phi_{N_r-1,i}} \; 1 \right) = \begin{bmatrix} I_{i-1} & 0 & \ldots & \ldots & 0 \\ 0 & e^{j\phi_{i,i}} & 0 & \ldots & 0 \\ \ldots & 0 & \ddots & 0 & 0 \\ \ldots & \ldots & 0 & e^{j\phi_{N_r-1,i}} & 0 \\ 0 & 0 & 0 & 0 & 1 \end{bmatrix} \tag{19-80}$$

The matrix $G_{li}(\psi)$ is an $N_r \times N_r$ Givens rotation matrix as shown in Equation (19-81).

$$G_{li}(\psi) = \begin{bmatrix} I_{i-1} & 0 & 0 & 0 & 0 \\ 0 & \cos(\psi) & 0 & \sin(\psi) & 0 \\ 0 & 0 & I_{l-i-1} & 0 & 0 \\ 0 & -\sin(\psi) & 0 & \cos(\psi) & 0 \\ 0 & 0 & 0 & 0 & I_{N_r-l} \end{bmatrix} \tag{19-81}$$

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where each $I_m$ is an $m \times m$ identity matrix, and $\cos(\psi)$ and $\sin(\psi)$ are located at row $l$ and column $i$. $\tilde{I}_{N_r \times N_c}$ is an identity matrix padded with 0s to fill the additional rows or columns when $N_r \neq N_c$.

For example, a 4×2 $V$ matrix has the representation shown in Equation (19-82).

$$V = \begin{bmatrix} e^{j\phi_{11}} & 0 & 0 & 0 \\ 0 & e^{j\phi_{21}} & 0 & 0 \\ 0 & 0 & e^{j\phi_{31}} & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \times \begin{bmatrix} \cos\psi_{21} & \sin\psi_{21} & 0 & 0 \\ -\sin\psi_{21} & \cos\psi_{21} & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}^T \times \begin{bmatrix} \cos\psi_{31} & 0 & \sin\psi_{31} & 0 \\ 0 & 1 & 0 & 0 \\ -\sin\psi_{31} & 0 & \cos\psi_{31} & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}^T \times \begin{bmatrix} \cos\psi_{41} & 0 & 0 & \sin\psi_{41} \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ -\sin\psi_{41} & 0 & 0 & \cos\psi_{41} \end{bmatrix}^T$$
$$\times \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & e^{j\phi_{22}} & 0 & 0 \\ 0 & 0 & e^{j\phi_{32}} & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \times \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & \cos\psi_{32} & \sin\psi_{32} & 0 \\ 0 & -\sin\psi_{32} & \cos\psi_{32} & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}^T \times \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & \cos\psi_{42} & 0 & \sin\psi_{42} \\ 0 & 0 & 1 & 0 \\ 0 & -\sin\psi_{42} & 0 & \cos\psi_{42} \end{bmatrix}^T \times \begin{bmatrix} 1 & 0 \\ 0 & 1 \\ 0 & 0 \\ 0 & 0 \end{bmatrix} \quad (19\text{-}82)$$

The procedure for finding a compressed $V$ matrix is described as follows:

A $N_r \times N_c$ beamforming feedback orthonormal column matrix $V$ is column-wise phase invariant because the steering matrix needs a reference in phase per each column. When the number of rows and columns is equal, the orthonormal column matrix becomes a unitary matrix. In other words, $V$ is equivalent to $\tilde{V}\tilde{D}$, where $\tilde{D}$ is a column-wise phase shift matrix such as $\tilde{D} = \text{diag}\left(e^{j\theta_1}, e^{j\theta_2}, \ldots, e^{j\theta_{N_c}}\right)$. When the beamformee estimates the channel, it may find $\tilde{V}$ for the beamforming feedback matrix for the beamformer, but it should send $\tilde{V}\tilde{D}$ back to the beamformer, where $V = \tilde{V}\tilde{D}$. The angle, $\theta_i$, in $\tilde{D}$ is found to make the last row of $\tilde{V}\tilde{D}$ to be non-negative real numbers.

The angles $\phi_{1,1} \ldots \phi_{N_r-1,1}$ in the diagonal matrix $D_1\left(e^{j\phi_{11}} \ldots e^{j\phi_{N_r-1,1}} \; 1\right)^*$ shall satisfy the constraint that all elements in the first column of $D_1^* V$ are non-negative real numbers. Now, the first column of $(G_{N_r1} \ldots G_{31} G_{21} D_1^*) \times V$ can be $\begin{bmatrix} 1 & 0 & \ldots & 0 \end{bmatrix}^T$ by the Givens rotations $G_{l1}$ such as shown in Equation (19-83)(#2375).

$$\begin{bmatrix} \cos\psi_{N_r1} & 0 & \sin\psi_{N_r1} \\ 0 & I_{N_r-2} & 0 \\ -\sin\psi_{N_r1} & 0 & \cos\psi_{N_r1} \end{bmatrix} \ldots \begin{bmatrix} \cos\psi_{31} & 0 & \sin\psi_{31} & 0 \\ 0 & 1 & 0 & 0 \\ -\sin\psi_{31} & 0 & \cos\psi_{31} & 0 \\ 0 & 0 & 0 & I_{N_r-3} \end{bmatrix} \begin{bmatrix} \cos\psi_{21} & \sin\psi_{21} & 0 \\ -\sin\psi_{21} & \cos\psi_{21} & 0 \\ 0 & 0 & I_{N_r-2} \end{bmatrix} \begin{bmatrix} e^{j\phi_{11}} & 0 & 0 & 0 \\ 0 & \text{O} & 0 & 0 \\ 0 & 0 & e^{j\phi_{N_r-1,1}} & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}^* \times V = \begin{bmatrix} 1 & 0 \\ 0 & V_2 \end{bmatrix} \quad (19\text{-}83)$$

For a new $(N_r - 1) \times (N_c - 1)$ submatrix $V_2$, this process is applied in the same way. Then, the angles $\phi_{2,2} \ldots \phi_{N_r-1,2}$ in the diagonal matrix $D_2\left(1 \; e^{j\phi_{22}} \ldots e^{j\phi_{N_r-1,2}} \; 1\right)^*$ shall satisfy the constraint that all


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elements in the second column of $D_2^* \times \text{diag}(1, V_2)$ are non-negative real numbers. Now, the first two columns of $(G_{N_r 2} \ldots G_{32} D_2^*)(G_{N_r 1} \ldots G_{31} G_{21} D_1^*) \times V$ can be $\tilde{I}_{N_r \times 2}$ by the Givens rotations $G_{l2}$ such as shown in Equation (19-84)(#2375).

$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & \cos\psi_{N_r 2} & 0 & \sin\psi_{N_r 2} \\ 0 & 0 & I_{N_r-3} & 0 \\ 0 & -\sin\psi_{N_r 2} & 0 & \cos\psi_{N_r 2} \end{bmatrix} \cdots \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & \cos\psi_{32} & \sin\psi_{32} & 0 \\ 0 & -\sin\psi_{32} & \cos\psi_{32} & 0 \\ 0 & 0 & 0 & I_{N_r-3} \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ 0 & e^{j\phi_{22}} & 0 & 0 & 0 \\ 0 & 0 & \text{O} & 0 & 0 \\ 0 & 0 & 0 & e^{j\phi_{N_r-1,2}} & 0 \\ 0 & 0 & 0 & 0 & 1 \end{bmatrix}^* \times G_{N,1} \ldots G_{31} G_{21} D_1^* \times V = \begin{bmatrix} I_2 & 0 \\ 0 & V_3 \end{bmatrix} \quad (19\text{-}84)$$

This process continues until the first $N_c$ columns of the right side matrix become $\tilde{I}_{N_r \times N_c}$. When $N_c < N_r$, this process does not need to continue because $V_{N_c+1}$ is nulled out by $\tilde{I}_{N_r \times N_c}$. Then, by multiplying the complex conjugate transpose of the products of the $D_i$ and $G_{li}$ matrices on the left, $V$ can be expressed as shown in Equation (19-85).

$$V = D_1 G_{21}^T G_{31}^T \ldots G_{N_r 1}^T \times D_2 G_{32}^T G_{42}^T \ldots G_{N_r 2}^T \times \ldots \times D_p G_{p+1,p}^T G_{p+2,p}^T \ldots G_{N_r p}^T \times \tilde{I}_{N_r \times N_C} \quad (19\text{-}85)$$

where $p = \min(N_c, N_r - 1)$, which can be written in short form as in Equation (19-79).

The angles found from the decomposition process above, e.g., the values of $\psi_{i,j}$ and $\phi_{k,l}$, are quantized as described in 9.6.11.6 (Compressed Beamforming frame format).

Columns $1 \ldots N_c$ of the beamforming feedback matrix correspond to spatial streams $1 \ldots N_c$, respectively. The mapping of spatial stream to modulation is defined in the MCS tables in 19.5 (Parameters for HT-MCSs). A transmitter shall not reorder the columns of the beamforming feedback matrices in determining steering matrices.

### 19.3.13 HT Preamble format for sounding PPDUs

#### 19.3.13.1 General

The MIMO channel measurement takes place in every PPDU as a result of transmitting the HT-LTFs as part of the PHY preamble. The number of HT-LTFs transmitted shall be determined by the number of space-time streams transmitted unless additional dimensions are optionally sounded using HT-ELTFs and these are transmitted using the same spatial transformation that is used for the Data field of the HT PPDU. The use of the same spatial transformation enables the computation of the spatial equalization at the receiver.

When the number of space-time streams, $N_{STS}$, is less than the number of transmit antennas, or less than $\min(N_{TX}, N_{RX})$, sending only $N_{STS}$ HT-LTFs does not allow the receiver to recover a full characterization of the MIMO channel, even though the resulting MIMO channel measurement is sufficient for receiving the Data field of the HT PPDU.

However, it is often desirable to obtain as full a characterization of the channel as possible. This involves the transmission of a sufficient number of HT-LTFs to sound the full dimensionality of the channel, which is in some cases $N_{TX}$ and in other cases $\min(N_{TX}, N_{RX})$. These cases of MIMO channel measurement are referred to as *MIMO channel sounding*. A sounding PPDU may be used to sound available channel

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dimensions. A sounding PPDU is identified by setting the Not Sounding field in the HT-SIG to 0. A sounding PPDU may have any allowed number of HT-LTFs satisfying $N_{HT\text{-}LTF} \geq N_{STS}$. In general, if the Not Sounding field in the HT-SIG is equal to 0 and $N_{HT\text{-}LTF} > N_{STS}$, HT-ELTFs are used, except where $N_{SS} = 3$ and $N_{HT\text{-}LTF} = 4$ or in an NDP.

#### 19.3.13.2 Sounding with an NDP(#2137)

A STA may sound the channel using (#2137)an NDP (indicated by the HT Length field in the HT-SIG equal to 0) with the Not Sounding field equal to 0. The number of LTFs is the number implied by the MCS, which shall indicate two or more spatial streams. The last HT-LTF of an NDP shall not be followed by a Data field (see Figure 19-16 (Example of an NDP used for sounding)).

It is optional for a STA to process an NDP.

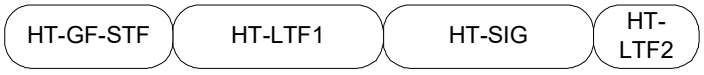


**Figure 19-16—Example of an NDP used for sounding**

#### 19.3.13.3 Sounding PPDU for calibration

In the case of a bidirectional calibration exchange, two STAs exchange sounding PPDUs, the exchange of which enables the receiving STA to compute an estimate of the MIMO channel matrix $H_k$ for each subcarrier $k$. In general, in an exchange of calibration messages, the number of spatial streams is less than the number of transmit antennas. In such cases, HT-ELTFs are used. In the case of sounding PPDUs for calibration, the antenna mapping matrix shall be as shown in Equation (19-86).

$$Q_k = C_{CSD}(k)P_{CAL} \tag{19-86}$$

where

$C_{CSD}(k)$ is a diagonal cyclic shift matrix in which the diagonal elements carry frequency domain representation of the cyclic shifts given in Table 19-9 (Cyclic shift for non-HT portion of PPDU)

$P_{CAL}$ is one of the following unitary matrices:

For $N_{TX} = 1, P_{CAL} = 1$

For $N_{TX} = 2, P_{CAL} = \frac{\sqrt{2}}{2}\begin{bmatrix} 1 & -1 \\ 1 & 1 \end{bmatrix}$

For $N_{TX} = 3, P_{CAL} = \frac{\sqrt{3}}{3}\begin{bmatrix} 1 & 1 & 1 \\ 1 & e^{-j2\pi/3} & e^{-j4\pi/3} \\ 1 & e^{-j4\pi/3} & e^{-j2\pi/3} \end{bmatrix}$

For $N_{TX} = 4, P_{CAL} = \frac{1}{2}\begin{bmatrix} 1 & -1 & 1 & 1 \\ 1 & 1 & -1 & 1 \\ 1 & 1 & 1 & -1 \\ -1 & 1 & 1 & 1 \end{bmatrix}$


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#### 19.3.13.4 Sounding PPDU for channel quality assessment

In response to an MRQ, sent by STA A to STA B, the responding STA B returns to the requesting STA A an MCS selection that STA B determines to be a suitable MCS for STA A to use in subsequent transmissions to STA B. In determining the MCS, STA B performs a channel quality assessment, which entails using whatever information STA B has about the channel, such as an estimate of the MIMO channel derived from the sounding PPDU that carries the MRQ. To enable this calculation, the MRQ is sent in conjunction with a sounding PPDU.

The STA sending the MRQ (STA A) determines how many HT-LTFs to send, and whether to use HT-ELTFs or an NDP, based on the Transmit Beamforming Capabilities field, number of space-time streams used in the PPDU carrying the MRQ, the number of transmit chains it is using ($N_{TX}$), whether the transmit and receive STAs support STBC, and in some cases, the number of receive chains at the responding STA ($N_{RX}$).

The maximum number of available space-time streams is set by the number of transmit and receive chains and the STBC capabilities of the transmitter and receiver, as is shown in Table 19-21 (Maximum available space-time streams). While the number of receive chains is not communicated in a capabilities indicator, the maximum number of space-time streams supported may be inferred from the MCS capabilities and the STBC capabilities of the receiving STA. When the number of receive chains is known at the transmitter, the number of HT-LTFs sent to obtain a full channel quality assessment is determined according to the maximum number of space-time streams indicated in Table 19-21 (Maximum available space-time streams). The number of HT-LTFs to use in conjunction with the indicated number of space-time streams is determined according to 19.3.9.4.6 (HT-LTF definition).

**Table 19-21—Maximum available space-time streams**

| $N_{TX}$ | $N_{RX}$ | $N_{STS,\,\max}$ without STBC | $N_{STS,\,\max}$ with STBC |
|---|---|---|---|
| 1 | 1 | 1 | N/A |
| 2 | 1 | 1 | 2 |
| 3 | 1 | 1 | 2 |
| 3 | 2 | 2 | 3 |
| 4 | 1 | 1 | 2 |
| 4 | 2 | 2 | 4 |

If the requesting STA A sends an MRQ in a PPDU that uses fewer space-time streams in the data portion than the maximum number of space-time streams possible given the number of antennas at STA A and the responding STA B, the channel quality assessment made by STA B may be based on the HT-DLTFs alone. In this case, the MFB is limited to MCSs using the number of streams used in the Data field of the HT PPDU, or fewer. To determine whether an MCS should be chosen that uses more spatial streams than the PPDU containing the MRQ, it is necessary for the requesting STA A to either use HT-ELTFs (i.e., send the MRQ in a staggered sounding PPDU) or use an NDP (i.e., send the MRQ in conjunction with an NDP).

The sounding PPDU may have nonidentity spatial mapping matrix $Q_k$. For different receiving STAs, $Q_k$ may vary.

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### 19.3.14 Regulatory requirements

Wireless LANs (WLANs) implemented in accordance with this standard are subject to equipment certification and operating requirements established by regional and national regulatory administrations. The PHY specification establishes minimum technical requirements for interoperability, based upon established regulations at the time this standard was issued. These regulations are subject to revision or may be superseded. Requirements that are subject to local geographic regulations are annotated within the PHY specification. Regulatory requirements that do not affect interoperability are not addressed in this standard. Implementers are referred to the regulatory sources in Annex D for further information. Operation in countries within defined regulatory domains may be subject to additional or alternative national regulations.

### 19.3.15 Channel numbering and channelization

#### 19.3.15.1 General

The STA may operate in the 5 GHz band and/or 2.4 GHz band. When using 20 MHz channels, it uses channels defined in 17.3.8.4 (Operating channel frequencies) (5 GHz band) or 16.3.6 (PHY operating specifications, general) (2.4 GHz band). When using 40 MHz channels, it can operate in the channels defined in 19.3.15.2 (Channel allocation in the 2.4 GHz band) and 19.3.15.3 (Channel allocation in the 5 GHz band).

The set of valid operating channel numbers by regulatory domain is defined in Annex E.

#### 19.3.15.2 Channel allocation in the 2.4 GHz band

Channel center frequencies are defined at every integer multiple of 5 MHz in the 2.4 GHz band. The relationship between center frequency and channel number is given by Equation (19-87).

$$\text{Channel center frequency} = 2407 + 5 \times n_{ch}(\text{MHz}) \tag{19-87}$$

where

$n_{ch}$ = 1, 2, …, 13

#### 19.3.15.3 Channel allocation in the 5 GHz band

Channel center frequencies are defined at every integer multiple of 5 MHz above the channel starting frequency. The relationship between center frequency and channel number is given in Equation (19-88).

$$\text{Channel center frequency} = \text{Channel starting frequency} + 5 \times n_{ch}(\text{MHz}) \tag{19-88}$$

where

$n_{ch}$ = 1, …, 200

Channel starting frequency is defined as dot11ChannelStartingFactor × 500 kHz or is defined as 5 GHz where dot11OperatingClassesRequired is false or not defined.

A channel center frequency of 5 GHz shall be indicated by dot11ChannelStartingFactor = 8000 and $n_{ch}$ = 200.

#### 19.3.15.4 40 MHz channelization

The set of valid operating channel numbers by regulatory domain is defined in Annex E.


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The 40 MHz channels are specified by two fields: (*Nprimary_ch*, *Secondary*). The first field represents the channel number of the primary channel, and the second field indicates whether the secondary channel is above or below the primary channel (1 indicates above, –1 indicates below). The secondary channel number shall be $Nprimary\_ch + Secondary \times 4$.

For example, a 40 MHz channel consisting of 40 MHz channel number 36 and Secondary 1 specifies the primary channel is 36 and the secondary channel is 40.

### 19.3.16 Slot time

The slot time shall follow 17.3.8.6 (Slot time) for 5 GHz bands and 18.5.4 (ERP) for 2.4 GHz bands.

The slot time for 40 MHz channel spacing shall be the same as that for 20 MHz channel spacing.

### 19.3.17 Transmit and receive impedance at the antenna connector

(#1247)The impedance of exposed transmit and receive antenna connectors are defined in 17.3.8.7 (Transmit and receive impedance at the antenna connector).

### 19.3.18 PHY transmit specification

### 19.3.18.1 Transmit spectrum mask

NOTE 1—In the presence of additional regulatory restrictions, the device has to meet both the regulatory requirements and the mask defined in this subclause, i.e., its emissions can be no higher at any frequency offset than the minimum of the values specified in the regulatory and default masks.

NOTE 2—The transmit spectral mask figures in this subclause are not drawn to scale.

For rules regarding TX center frequency leakage levels by VHT STAs, see 21.3.17.4.2 (Transmit center frequency leakage).

For the 2.4 GHz band, when transmitting in a 20 MHz channel, the transmitted spectrum shall have a 0 dBr (dB relative to the maximum spectral density of the signal) bandwidth not exceeding 18 MHz, –20 dBr at 11 MHz frequency offset, –28 dBr at 20 MHz frequency offset, and the maximum of (#3778)–40 dBr and –53 dBm/MHz at 30 MHz frequency offset and above. The transmitted spectral density of the transmitted signal shall fall within the spectral mask, as shown in Figure 19-17 (Transmit

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spectral mask for 20 MHz transmission in the 2.4 GHz band(#3778)). The measurements shall be made using a 100 kHz resolution bandwidth and a 30 kHz video bandwidth.

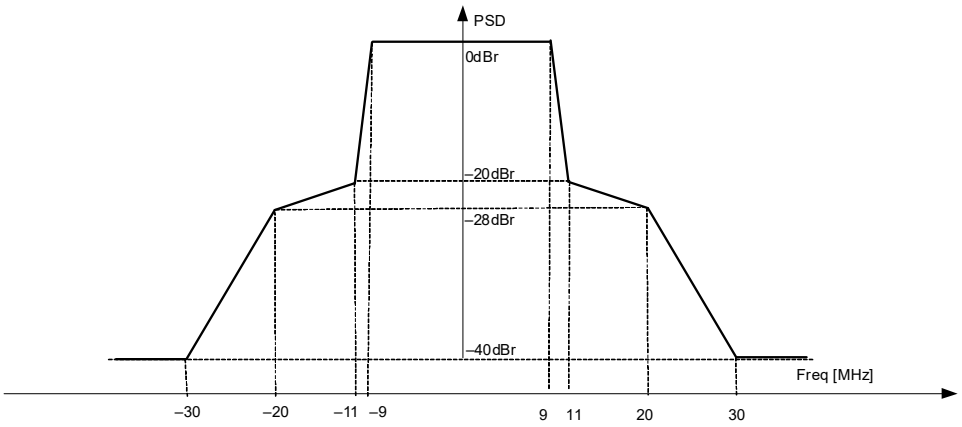


**Figure 19-17—Transmit spectral mask for 20 MHz transmission in the 2.4 GHz band(#3778)**

For the 2.4 GHz band, when transmitting in a 40 MHz channel, the transmitted spectrum shall have a 0 dBr bandwidth not exceeding 38 MHz, –20 dBr at 21 MHz frequency offset, –28 dBr at 40 MHz offset, and the maximum of (#3778)–40 dBr and –56 dBm/MHz at 60 MHz frequency offset and above. The transmitted spectral density of the transmitted signal shall fall within the spectral mask, as shown in Figure 19-18 (Transmit spectral mask for a 40 MHz channel in the 2.4 GHz band(#3778)).

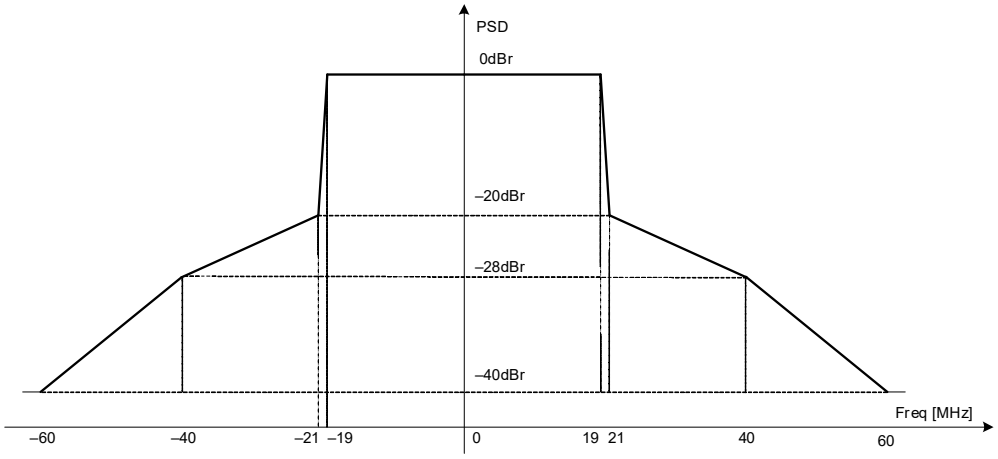


**Figure 19-18—Transmit spectral mask for a 40 MHz channel in the 2.4 GHz band(#3778)**

For the 5 GHz band, when transmitting in a 20 MHz channel, the transmitted spectrum shall have a 0 dBr (dB relative to the maximum spectral density of the signal) bandwidth not exceeding 18 MHz, –20 dBr at 11 MHz frequency offset, –28 dBr at 20 MHz frequency offset, and the maximum of –40 dBr and –39 dBm/MHz(M25) at 30 MHz frequency offset and above. The transmitted spectral density of the transmitted signal shall fall within the spectral mask, as shown in Figure 19-19 (Transmit


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spectral mask for 20 MHz transmission in the 5 GHz band). The measurements shall be made using a 100 kHz resolution bandwidth and a 30 kHz video bandwidth.

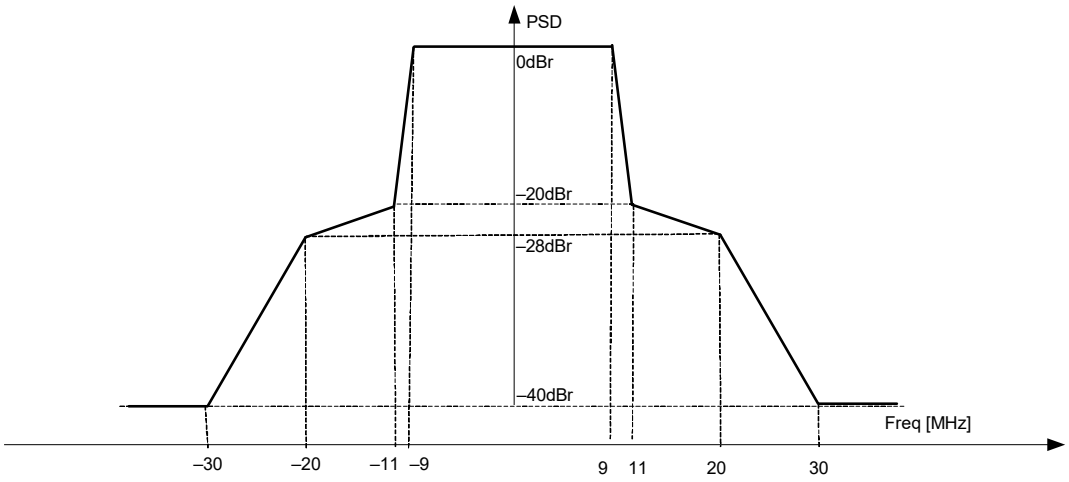


**Figure 19-19—Transmit spectral mask for 20 MHz transmission in the 5 GHz band**

For the 5 GHz band, when transmitting in a 40 MHz channel, the transmitted spectrum shall have a 0 dBr bandwidth not exceeding 38 MHz, –20 dBr at 21 MHz frequency offset, –28 dBr at 40 MHz offset, and the maximum of –40 dBr and –39 dBm/MHz(M25) at 60 MHz frequency offset and above. The transmitted spectral density of the transmitted signal shall fall within the spectral mask, as shown in Figure 19-20 (Transmit spectral mask for a 40 MHz channel in the 5 GHz band).

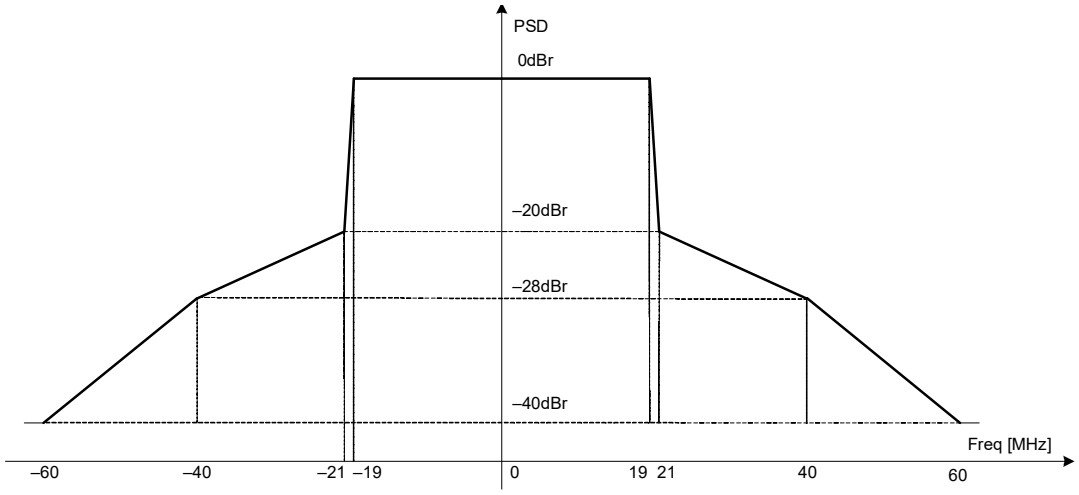


**Figure 19-20—Transmit spectral mask for a 40 MHz channel in the 5 GHz band**

Transmission with CH_OFF_20U, CH_OFF_20L, or CH_OFF_40 shall comply with the same mask that is used for the 40 MHz channel.

### 19.3.18.2 Spectral flatness

In a 20 MHz channel and in corresponding 20 MHz transmission in a 40 MHz channel, the average energy of the constellations in each of the subcarriers with indices –16 to –1 and +1 to +16 shall deviate no more

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than ± 4 dB from their average energy. The average energy of the constellations in each of the subcarriers with indices –28 to –17 and +17 to +28 shall deviate no more than +4/–6 dB from the average energy of subcarriers with indices –16 to –1 and +1 to +16.

In a 40 MHz transmission (excluding PPDUs in MCS 32 format and non-HT duplicate format), the average energy of the constellations in each of the subcarriers with indices –42 to –2 and +2 to +42 shall deviate no more than ± 4 dB from their average energy. The average energy of the constellations in each of the subcarriers with indices –43 to –58 and +43 to +58 shall deviate no more than +4/–6 dB from the average energy of subcarriers with indices –42 to –2 and +2 to +42.

In MCS 32 format and non-HT duplicate format, the average energy of the constellations in each of the subcarriers with indices –42 to –33, –31 to –6, +6 to +31, and +33 to +42 shall deviate no more than ± 4 dB from their average energy. The average energy of the constellations in each of the subcarriers with indices –43 to –58 and +43 to +58 shall deviate no more than +4/–6 dB from the average energy of subcarriers with indices –42 to –33, –31 to –6, +6 to +31, and +33 to +42.

The tests for the spectral flatness requirements may be performed with spatial mapping $Q_k$ = **I** (see 19.3.11.11.2 (Spatial mapping)).

#### 19.3.18.3 Transmit power

The maximum allowable output power is measured in accordance with practices specified by the appropriate regulatory bodies.

#### 19.3.18.4 Transmit center frequency tolerance

The transmitter center frequency tolerance shall be ± 20 ppm for the 5 GHz band and ± 25 ppm for the 2.4 GHz band. The different transmit chain center frequencies (LO) and each transmit chain symbol clock frequency shall all be derived from the same reference oscillator.

#### 19.3.18.5 PPDU alignment(#14)

If no signal extension is required (see 19.3.2 (PPDU format)), the receiver shall emit a PHY-CCA.indication(IDLE) primitive (see 8.3.5.12 (PHY-CCA.indication)) at the 4 µs boundary following the reception of the last symbol of the (#14)PPDU. If a signal extension is required, the receiver shall emit a PHY-CCA.indication(IDLE) primitive a duration of aSignalExtension after the 4 µs boundary following the reception of the last symbol of the (#14)PPDU. This situation is illustrated for an HT-greenfield format (#14)PPDU using short GI in Figure 19-21 (PHY-TXEND.confirm alignment (HT-greenfield format with short GI)).

If no signal extension is required, the transmitter shall emit a PHY-TXEND.confirm primitive (see 8.3.5.8 (PHY-TXEND.confirm)) at the 4 µs boundary following the trailing boundary of the last symbol of the PPDU on the WM. If a signal extension is required, the transmitter shall emit a PHY-TXEND.confirm primitive (see 8.3.5.8 (PHY-TXEND.confirm)) a duration of aSignalExtension after the 4 µs boundary following the trailing boundary of the last symbol of the PPDU on the WM. This situation is illustrated in Figure 19-21 (PHY-TXEND.confirm alignment (HT-greenfield format with short GI)).


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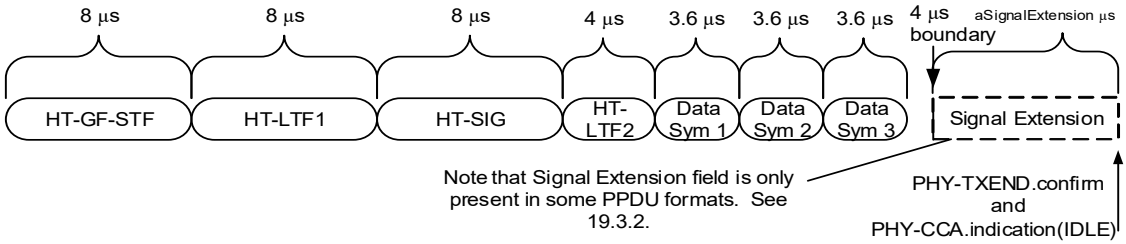


**Figure 19-21—PHY-TXEND.confirm alignment (HT-greenfield format with short GI)**

#### 19.3.18.6 Symbol clock frequency tolerance

The symbol clock frequency tolerance shall be ± 20 ppm for 5 GHz bands and ± 25 ppm for 2.4 GHz bands. The transmit center frequency and the symbol clock frequency for all transmit antennas shall be derived from the same reference oscillator.

#### 19.3.18.7 Modulation accuracy

##### 19.3.18.7.1 Introduction to modulation accuracy tests

Transmit modulation accuracy specifications are described in 19.3.18.7.2 (Transmit center frequency leakage) and 19.3.18.7.3 (Transmitter constellation error). The test method is described in 19.3.18.7.4 (Transmitter modulation accuracy (EVM) test).

##### 19.3.18.7.2 Transmit center frequency leakage

For VHT STAs the requirements on transmitter center frequency leakage are defined in 21.3.17.4.2 (Transmit center frequency leakage); otherwise, the requirements are defined in this subclause.

The transmitter center frequency leakage shall follow 17.3.9.7.2 (Transmitter center frequency leakage) for all transmissions in a 20 MHz channel width. For transmissions in a 40 MHz channel width, the center frequency leakage shall not exceed $max(P - 20, -20)$ dBm, or, equivalently, 0 dB relative to the average energy of the rest of the subcarriers. For upper or lower 20 MHz transmissions in a 40 MHz channel, the center frequency leakage (center of a 40 MHz channel) shall not exceed $max(P - 17, -20)$ dBm. The transmit center frequency leakage is specified per antenna.

##### 19.3.18.7.3 Transmitter constellation error

The relative constellation (#14)PPDU-averaged RMS error, calculated first by averaging over subcarriers, (#14)spatial streams, and OFDM symbols, shall not exceed a data-rate-dependent value according to Table 19-22 (Allowed relative constellation error versus constellation size and coding rate). The number of spatial streams under test shall be equal to the number of utilized transmitting STA antenna (output) ports and also equal to the number of utilized testing instrumentation input ports. In the test, $N_{SS} = N_{STS}$ with EQM MCSs shall be used and no beamforming steering matrix shall be used. Each output port of the transmitting STA shall be connected through a cable to one input port of the testing instrumentation. The same requirement applies both to 20 MHz channels and 40 MHz channels.

##### 19.3.18.7.4 Transmitter modulation accuracy (EVM) test

The transmit modulation accuracy test shall be performed by instrumentation capable of converting the transmitted signals into a streams of complex samples at 40 Msample/s or more, with sufficient accuracy in

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**Table 19-22—Allowed relative constellation error versus constellation size and coding rate**

| Modulation | Coding rate | Relative constellation error (dB) |
|---|---|---|
| BPSK | 1/2 | –5 |
| QPSK | 1/2 | –10 |
| QPSK | 3/4 | –13 |
| 16-QAM | 1/2 | –16 |
| 16-QAM | 3/4 | –19 |
| 64-QAM | 2/3 | –22 |
| 64-QAM | 3/4 | –25 |
| 64-QAM | 5/6 | –27 |

terms of I/Q arm amplitude and phase balance, dc offsets, phase noise, and analog-to-digital quantization noise. Each transmit chain is connected directly through a cable to the setup input port. A possible embodiment of such a setup is converting the signals to a low intermediate frequency with a microwave synthesizer, sampling the signal with a digital oscilloscope, and decomposing it digitally into quadrature components. The sampled signal shall be processed in a manner similar to an actual receiver, according to the following steps, or an equivalent procedure:

a) Detect the start of (#14)PPDU.

b) Detect the transition from short sequences to channel estimation sequences, and establish fine timing (with one sample resolution).

c) Estimate the coarse and fine frequency offsets.

d) Derotate the (#14)PPDU according to estimated frequency offset.

e) Estimate the complex channel response coefficients for each of the subcarriers and each of the transmit chains.

f) For each of the data OFDM symbols, transform the symbol into subcarrier received values, estimate the phase from the pilot subcarriers in all spatial streams, derotate the subcarrier values according to estimated phase, group the results from all of the receiver chains in each subcarrier to a vector, multiply the vector by a zero-forcing equalization matrix generated from the channel estimated during the channel estimation phase.

g) For each data-carrying subcarrier in each spatial stream, find the closest constellation point and compute the Euclidean distance from it.

h) Compute the average of the RMS of all errors (#14)in the Data field. It is given by Equation (19-89).

$$Error_{RMS} = \frac{\sum_{i_f=1}^{N_f} \sqrt{\frac{\sum_{i_s=1}^{N_{SYM}} \left[ \sum_{i_{ss}=1}^{N_{SS}} \left( \sum_{i_{sc}=1}^{N_{ST}} \left( (I(i_f, i_s, i_{ss}, i_{sc}) - I_0(i_f, i_s, i_{ss}, i_{sc}))^2 + (Q(i_f, i_s, i_{ss}, i_{sc}) - Q_0(i_f, i_s, i_{ss}, i_{sc}))^2 \right) \right) \right]}{N_{SYM} \times N_{SS} \times N_{ST} \times P_0}}}{N_f} \quad (19\text{-}89)$$

where

$N_f$ is the number of frames for the measurement



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| | |
|---|---|
| $I_0(i_f, i_s, i_{ss}, i_{sc}), Q_0(i_f, i_s, i_{ss}, i_{sc})$ | denotes the ideal symbol point in the complex plane in subcarrier $i_{sc}$, spatial stream $i_{ss}$, and OFDM symbol $i_s$ of (#14)the Data field in PPDU $i_f$ |
| $I(i_f, i_s, i_{ss}, i_{sc}), Q(i_f, i_s, i_{ss}, i_{sc})$ | denotes the observed symbol point in the complex plane in subcarrier $i_{sc}$, spatial stream $i_{ss}$, and OFDM symbol $i_s$ of (#14)the Data field in PPDU $i_f$ |
| $P_0$ | is the average power of the constellation |

The vector error on a phase plane is shown in Figure 17-16 (Constellation error).

The test shall be performed over at least 20 (#14)PPDUs ($N_f$), and the average of the RMS shall be taken. The (#14)Data fields under test shall be at least 16 OFDM symbols long. Random data shall be used for the symbols.

### 19.3.18.8 Time of Departure accuracy

(#8049)The RMS accuracy of the time of departure provided in TIME_OF_DEPARTURE shall be less than or equal to 80 ns.

The Time of Departure accuracy test evaluates TIME_OF_DEPARTURE against aTxPHYTxStartRMS and aTxPHYTxStartRMS against TIME_OF_DEPARTURE_ACCURACY_TEST_THRESH as defined in Annex P with the following test parameters:

— MULTICHANNEL_SAMPLING_RATE is

$20 \times 10^6 \left(1 + \left\lceil \frac{f_H - f_L}{20\ \text{MHz}} \right\rceil\right)$ sample/s, for a CH_BANDWIDTH parameter equal to HT_CBW20

$40 \times 10^6 \left(1 + \left\lceil \frac{f_H - f_L}{40\ \text{MHz}} \right\rceil\right)$ sample/s, for a CH_BANDWIDTH parameter equal to HT_CBW40

where

$f_H$ is the nominal center frequency in Hz of the highest channel in the channel set

$f_L$ is the nominal center frequency in Hz of the lowest channel in the channel set, the channel set is the set of channels upon which (#14)PPDUs providing measurements are transmitted, the channel set comprises channels uniformly spaced across $f_H - f_L \geq 50$ MHz

— FIRST_TRANSITION_FIELD is L-STF (for HT-mixed format) or HT-GF-STF (for HT-greenfield format)

— SECOND_TRANSITION_FIELD is L-LTF (for HT-mixed format) or HT-GF-LTF1 (for HT-greenfield format)

— TRAINING_FIELD is L-LTF (for HT-mixed format) or HT-LTF1 (for HT-greenfield format) windowed in a manner which should approximate the windowing described in 17.3.2.5 (Mathematical conventions in the signal descriptions) with $T_{TR}$ = 100 ns.

— TIME_OF_DEPARTURE_ACCURACY_TEST_THRESH is 80 ns (for a CH_BANDWIDTH parameter equal to HT_CBW20) or 80 ns (for a CH_BANDWIDTH parameter equal to HT_CBW40).

NOTE—The indicated windowing applies to the time of departure accuracy test equipment, and not the transmitter or receiver.

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### 19.3.19 HT PHY receiver specification

#### 19.3.19.1 General(#2091)

For tests in this subclause, the input levels are measured at the antenna connector and are referenced as the average power per receive antenna. For tests in 19.3.19.2 (Receiver minimum input level sensitivity(#256)), 19.3.19.3 (Adjacent channel rejection), and 19.3.19.4 (Nonadjacent channel rejection), the number of spatial streams under test shall be equal to the number of utilized transmitting STA antenna (output) ports and also equal to the number of utilized (#1768)receiving STA antenna (input) ports. Except where otherwise noted, each output port of the transmitting STA shall be connected through a cable to one input port of the (#1768)receiving STA.

#### 19.3.19.2 Receiver minimum input level sensitivity(#256)

The (#14)PER shall be less than 10% for a PSDU length of 4096 octets with the rate-dependent input levels listed in Table 19-23 (Receiver minimum input level sensitivity) or less(#2091). The test in this subclause and the minimum sensitivity levels specified in Table 19-23 (Receiver minimum input level sensitivity) apply only to non-STBC modes, MCSs 0–31, 800 ns GI, and BCC.

**Table 19-23—Receiver minimum input level sensitivity**

| Modulation | Rate (R) | Adjacent channel rejection (dB) | Nonadjacent channel rejection (dB) | Minimum sensitivity (20 MHz channel spacing) (dBm) | Minimum sensitivity (40 MHz channel spacing) (dBm) |
|---|---|---|---|---|---|
| BPSK | 1/2 | 16 | 32 | –82 | –79 |
| QPSK | 1/2 | 13 | 29 | –79 | –76 |
| QPSK | 3/4 | 11 | 27 | –77 | –74 |
| 16-QAM | 1/2 | 8 | 24 | –74 | –71 |
| 16-QAM | 3/4 | 4 | 20 | –70 | –67 |
| 64-QAM | 2/3 | 0 | 16 | –66 | –63 |
| 64-QAM | 3/4 | –1 | 15 | –65 | –62 |
| 64-QAM | 5/6 | –2 | 14 | –64 | –61 |

#### 19.3.19.3 Adjacent channel rejection

For all transmissions in a 20 MHz channel width, the adjacent channel rejection shall be measured by setting the desired signal's strength 3 dB above the rate-dependent sensitivity specified in Table 19-23 (Receiver minimum input level sensitivity) and raising the power of an interfering signal of 20 MHz bandwidth until 10% PER is caused for a PSDU length of 4096 octets. The difference in power between the signals in the interfering channel and the desired channel is the corresponding adjacent channel rejection. The adjacent channel center frequencies shall be separated by 20 MHz when operating in the 5 GHz band, and the adjacent channel center frequencies shall be separated by 25 MHz when operating in the 2.4 GHz band.

For all transmissions in a 40 MHz channel width, the adjacent channel rejection shall be measured by setting the desired signal's strength 3 dB above the rate-dependent sensitivity specified in Table 19-23 (Receiver minimum input level sensitivity) and raising the power of an interfering signal of 40 MHz bandwidth until 10% PER is caused for a PSDU length of 4096 octets. The difference in power between the signals in the


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interfering channel and the desired channel is the corresponding adjacent channel rejection. The adjacent channel center frequencies shall be separated by 40 MHz.

The interfering signal in the adjacent channel shall be a signal compliant with the HT PHY, unsynchronized with the signal in the channel under test. The corresponding rejection shall be no less than specified in Table 19-23 (Receiver minimum input level sensitivity). The interference signal shall have a minimum duty cycle of 50%.

The test in this subclause and the adjacent channel rejection levels specified in Table 19-23 (Receiver minimum input level sensitivity) apply only to non-STBC modes, MCSs 0–31, 800 ns GI, and BCC.

#### 19.3.19.4 Nonadjacent channel rejection

For all transmissions in a 20 MHz channel width in the 5 GHz band, the nonadjacent channel rejection shall be measured by setting the desired signal's strength 3 dB above the rate-dependent sensitivity specified in Table 19-23 (Receiver minimum input level sensitivity) and raising the power of an interfering signal of 20 MHz bandwidth until a 10% PER occurs for a PSDU length of 4096 octets. The difference in power between the signals in the interfering channel and the desired channel is the corresponding nonadjacent channel rejection. The nonadjacent channel center frequencies shall be separated by 40 MHz or more.

For all transmissions in a 40 MHz channel width in the 5 GHz band, the nonadjacent channel rejection shall be measured by setting the desired signal's strength 3 dB above the rate-dependent sensitivity specified in Table 19-23 (Receiver minimum input level sensitivity) and raising the power of an interfering signal of 40 MHz bandwidth until a 10% PER occurs for a PSDU length of 4096 octets. The difference in power between the signals in the interfering channel and the desired channel is the corresponding nonadjacent channel rejection. The nonadjacent channel center frequencies shall be separated by 80 MHz or more.

The interfering signal in the nonadjacent channel shall be a signal compliant with the HT PHY, unsynchronized with the signal in the channel under test. The corresponding rejection shall be no less than specified in Table 19-23 (Receiver minimum input level sensitivity). The interference signal shall have a minimum duty cycle of 50%. The nonadjacent channel rejection for transmissions in a 20 MHz or 40 MHz channel width is applicable only to 5 GHz band.

The test in this subclause and the nonadjacent channel rejection level specified in Table 19-23 (Receiver minimum input level sensitivity) apply only to non-STBC modes, MCSs 0–31, 800 ns GI, and BCC.

#### 19.3.19.5 Receiver maximum input level

The receiver shall provide a maximum PER of 10% at a PSDU length of 4096 octets, for a maximum input level of –30 dBm in the 5 GHz band and –20 dBm in the 2.4 GHz band, measured at each antenna for any baseband modulation.

#### 19.3.19.6 CCA sensitivity

#### 19.3.19.6.1 General

The thresholds in this subclause are compared with the signal level at each receiving antenna.

#### 19.3.19.6.2 CCA-Operating Class Specific Energy Detect (CCA-OCSED)(#2365)

For the operating classes requiring CCA-Operating Class Specific Energy Detect (CCA-OCSED), the PHY shall also indicate a medium busy condition when CCA-OCSED detects a channel busy condition.

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For improved spectrum sharing, CCA-OCSED is required in some bands. The behavior class indicating CCA-OCSED is given in Table D-2 (Behavior limits). The operating classes requiring the corresponding CCA-OCSED behavior class are given in E.1 (Country information and operating classes). The PHY of a STA that is operating within an operating class that requires CCA-OCSED shall operate with CCA-OCSED.

CCA-OCSED shall detect a channel busy condition when the received signal strength exceeds the CCA-OCSED threshold as given by dot11OFDMEDThreshold for the primary channel and dot11OFDMEDThreshold for the secondary channel (if present). The CCA-OCSED thresholds for the operating classes requiring CCA-OCSED are subject to the criteria in D.2.5 (CCA-OCSED threshold(#2365)).

NOTE—The requirement to detect a channel busy condition as stated in 19.3.19.6.3 (CCA sensitivity for non-HT PPDUs), 19.3.19.6.4 (CCA sensitivity in 20 MHz), and 19.3.19.6.5 (CCA sensitivity in 40 MHz) is a mandatory energy detection requirement on all Clause 19 (High Throughput (HT) PHY specification(#2297)) receivers. Support for CCA-OCSED is an additional requirement that relates specifically to the sensitivities described in D.2.5 (CCA-OCSED threshold(#2365)).

### 19.3.19.6.3 CCA sensitivity for non-HT PPDUs

CCA sensitivity requirements for non-HT PPDUs in the primary channel are described in 17.3.10.6 (CCA requirements) and 18.4.6 (CCA performance).

### 19.3.19.6.4 CCA sensitivity in 20 MHz

For an HT STA with the operating channel width equal to 20 MHz, the start of a 20 MHz HT signal at a receive level greater than or equal to the minimum modulation and coding rate sensitivity of –82 dBm shall cause the PHY to set PHY-CCA.indication(BUSY) with a probability > 90% within 4 μs. The receiver shall indicate a channel busy condition for any signal 20 dB or more above the minimum modulation and coding rate sensitivity (–82 + 20 = –62 dBm) in the 20 MHz channel.

An HT STA that does not support the reception of (#2095)HT-greenfield format PPDUs shall indicate a channel busy condition [PHY-CCA.indication(BUSY)] for any valid HT_GF signal in the 20 MHz channel at a receive level greater than or equal to –72 dBm.

### 19.3.19.6.5 CCA sensitivity in 40 MHz

This subclause describes the CCA sensitivity requirements for an HT STA with the operating channel width equal to 40 MHz.

The receiver of a 20/40 MHz STA with the operating channel width equal to 40 MHz shall provide CCA on both the primary and secondary channels.

When the secondary channel is idle, the start of a 20 MHz HT signal in the primary channel at a receive level greater than or equal to the minimum modulation and coding rate sensitivity of –82 dBm shall cause the PHY to generate a PHY-CCA.indication(BUSY, {primary}) primitive with a probability > 90% within 4 μs. The start of a 40 MHz HT signal that occupies both the primary and secondary channels at a receive level greater than or equal to the minimum modulation and coding rate sensitivity of –79 dBm shall cause the PHY to generate a PHY-CCA.indication(BUSY, {primary, secondary}) primitive for both the primary and secondary channels with a probability per channel > 90% within 4 μs.

An HT STA that does not support the reception of (#2095)HT-greenfield format PPDUs shall indicate a {primary} channel busy condition (PHY-CCA.indication(BUSY, {primary}) primitive) for any valid HT_GF signal in the primary channel at a receive level greater than or equal to –72 dBm when the secondary channel is idle. An HT STA that does not support the reception of (#2095)HT-greenfield format PPDUs shall indicate a {primary, secondary} channel busy condition (PHY-CCA.indication(BUSY, {primary,


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secondary}) primitive) for any valid 40 MHz HT_GF signal in both the primary and secondary channels at a receive level greater than or equal to –69 dBm.

The receiver shall indicate a {primary} channel busy condition for any signal at or above –62 dBm in the 20 MHz primary channel. This level is 20 dB above the minimum modulation and coding rate sensitivity for a 20 MHz PPDU. When the primary channel is idle, the receiver indicate a {secondary} channel busy condition for any signal at or above –62 dBm in the 20 MHz secondary channel. The receiver shall indicate a {primary, secondary} channel busy condition for any signal present in both the primary and secondary channels that is at or above –62 dBm in the primary channel and at or above –62 dBm in the secondary channel.

#### 19.3.19.7 Received channel power indicator (RCPI) measurement

The RCPI is a measure of the received RF power in the selected channel for a received (#14)PPDU. This parameter shall be a (#1132)measurement by the PHY of the received RF power in the channel measured over the (#2011)HT-STF or HT-LTF field of the received (#14)PPDU. The received power shall be the average of the power in all active receive chains.

RCPI shall equal the received RF power (#2011)in dBm within an accuracy of ± 5 dB (95% confidence interval) within the specified dynamic range of the receiver.

#### 19.3.19.8 Reduced interframe space (RIFS)

(#181)The receiver shall support decoding a PPDU that was transmitted with a RIFS separation from the previous PPDU.

### 19.3.20 PHY transmit procedure

There are three options for the transmit PHY procedure. The first two options, for which typical transmit procedures are shown in Figure 19-22 (PHY transmit procedure (HT-mixed format PPDU)) and Figure 19-23 (PHY transmit procedure (HT-greenfield format PPDU)), are selected if the FORMAT field of the PHY-TXSTART.request(TXVECTOR) primitive is equal to HT_MF or HT_GF, respectively. These transmit procedures do not describe the operation of optional features, such as LDPC or STBC. The third option is to follow the transmit procedure in Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) or Clause 18 (Extended Rate PHY (ERP) specification) if the FORMAT field is equal to NON_HT. Additionally, if the FORMAT field is equal to NON_HT, CH_BANDWIDTH indicates NON_HT_CBW20, and NON_HT_MODULATION indicates OFDM, follow the transmit procedure in Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification). If the FORMAT field is equal to NON_HT, CH_BANDWIDTH indicates NON_HT_CBW20, and NON_HT_MODULATION indicates other than OFDM, follow the transmit procedure in Clause 18 (Extended Rate PHY (ERP) specification). And furthermore, if the FORMAT field is equal to NON_HT and CH_BANDWIDTH indicates NON_HT_CBW40, follow the transmit procedure in Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification), except that the signal in Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) is generated simultaneously on each of the upper and lower 20 MHz channels that constitute the 40 MHz channel as defined in 19.3.8 (Transmission in the upper/lower 20 MHz of a 40 MHz channel) and 19.3.11.12 (Non-HT duplicate transmission). In all these options, in order to transmit data, the PHY-TXSTART.request primitive shall be enabled so that the PHY entity shall be in the transmit state. Further, the PHY shall be set to operate at the appropriate frequency through station management via the PLME, as specified in 19.4 (HT PLME). Other transmit parameters, such as MCS coding types and transmit power, are set via the PHY SAP with the PHY-TXSTART.request(TXVECTOR) primitive, as described in 19.2.2 (TXVECTOR and RXVECTOR parameters).

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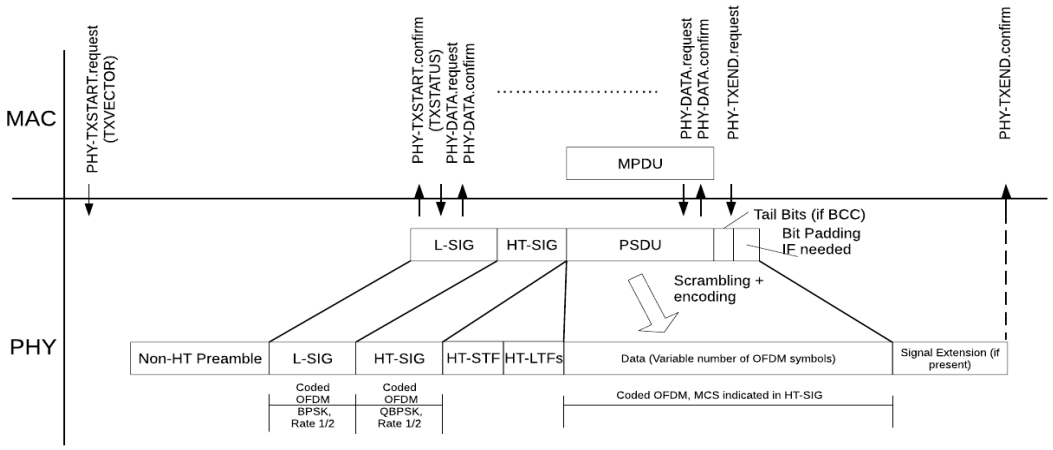
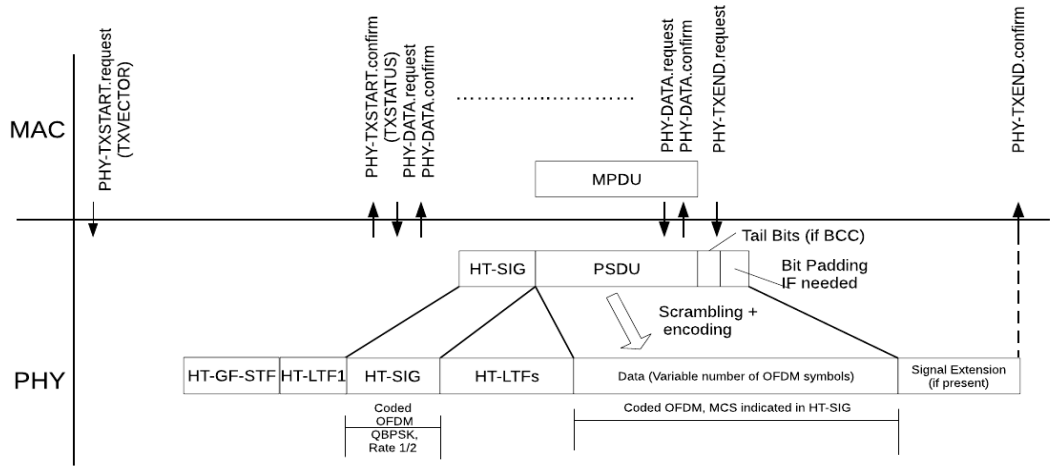



NOTE—This procedure does not describe the operation of optional features, such as LDPC or STBC

**Figure 19-22—PHY transmit procedure (HT-mixed format PPDU)**




NOTE—This procedure does not describe the operation of optional features, such as LDPC or STBC.

**Figure 19-23—PHY transmit procedure (HT-greenfield format PPDU)**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A clear channel shall be indicated by issuing a PHY-CCA.indication(IDLE) primitive. Note that under some circumstances, the MAC uses the latest value of the PHY-CCA.indication primitive before issuing the PHY-TXSTART.request primitive. Transmission of the PPDU shall be initiated after receiving the PHY-TXSTART.request(TXVECTOR) primitive. The TXVECTOR elements for the PHY-TXSTART.request primitive are specified in Table 19-1 (TXVECTOR and RXVECTOR parameters).

Transmission of the PHY preamble may start if TIME_OF_DEPARTURE_REQUESTED is false, and shall start immediately if TIME_OF_DEPARTURE_REQUESTED is true, based on the parameters passed in the PHY-TXSTART.request primitive.

The data shall then be exchanged between the MAC and the PHY through a series of PHY-DATA.request(DATA) primitives issued by the MAC and PHY-DATA.confirm primitives issued by the PHY. Once PHY preamble transmission is started, the PHY entity shall immediately initiate data scrambling and data encoding. The encoding method shall be based on the FEC_CODING, CH_BANDWIDTH, and MCS parameter of the TXVECTOR. A modulation rate change, if any, shall be initiated starting with the SERVICE field data, as described in 19.3.2 (PPDU format).

The PHY proceeds with PSDU transmission through a series of data octet transfers from the MAC. The SERVICE field and PSDU are encoded by the encoder selected by the FEC_CODING, CH_BANDWIDTH, and MCS parameters of the TXVECTOR as described in 19.3.3 (Transmitter block diagram). Transmission can be prematurely terminated by the MAC through the primitive PHY-TXEND.request primitive. Normal termination occurs after the transmission of the final bit of the last PSDU octet, according to the number supplied in the LENGTH field.

The (#14)PPDU transmission shall be completed, and the PHY entity shall enter the receive state. Each PHY-TXEND.request primitive is acknowledged with a PHY-TXEND.confirm primitive from the PHY. If the length of the coded PSDU is not an integer multiple of the OFDM symbol length, bits shall be stuffed to make the coded PSDU length an integer multiple of the OFDM symbol length.

The GI shall be inserted in every OFDM symbol as a countermeasure against delay spread.

In some PPDU formats (as defined in 19.3.2 (PPDU format)), a signal extension is present. When no signal extension is present, the PHY-TXEND.confirm primitive is generated at the end of last symbol of the PPDU. When a signal extension is present, the PHY-TXEND.confirm primitive is generated at the end of the signal extension.

A typical state machine implementation of the transmit PHY is provided in Figure 19-24 (PHY transmit state machine(#14)). Requests (.request) and confirmations (.confirm) are issued once per state as shown. This state machine does not describe the operation of optional features, such as LDPC or STBC. If the TXVECTOR parameter FORMAT is equal to NON_HT and NON_HT_MODULATION is equal to ERP-OFDM or OFDM, refer to the transmit procedure and state machine in 17.3.11 (Transmit PHY). If the TXVECTOR parameter FORMAT is equal to NON_HT and NON_HT_MODULATION is equal to ERP-DSSS or ERP-CCK, refer to the transmit procedure in 15.3.6 (Transmit PHY) or 16.2.5 (Transmit PHY), respectively.

NOTE—The transmit procedure and state machine for Clause 18 (Extended Rate PHY (ERP) specification) when TXVECTOR parameter NON_HT_MODULATION is ERP-OFDM is described in 17.3.11 (Transmit PHY), except for the signal extension (refer to 18.3.2.4 (ERP-OFDM PPDU format)).

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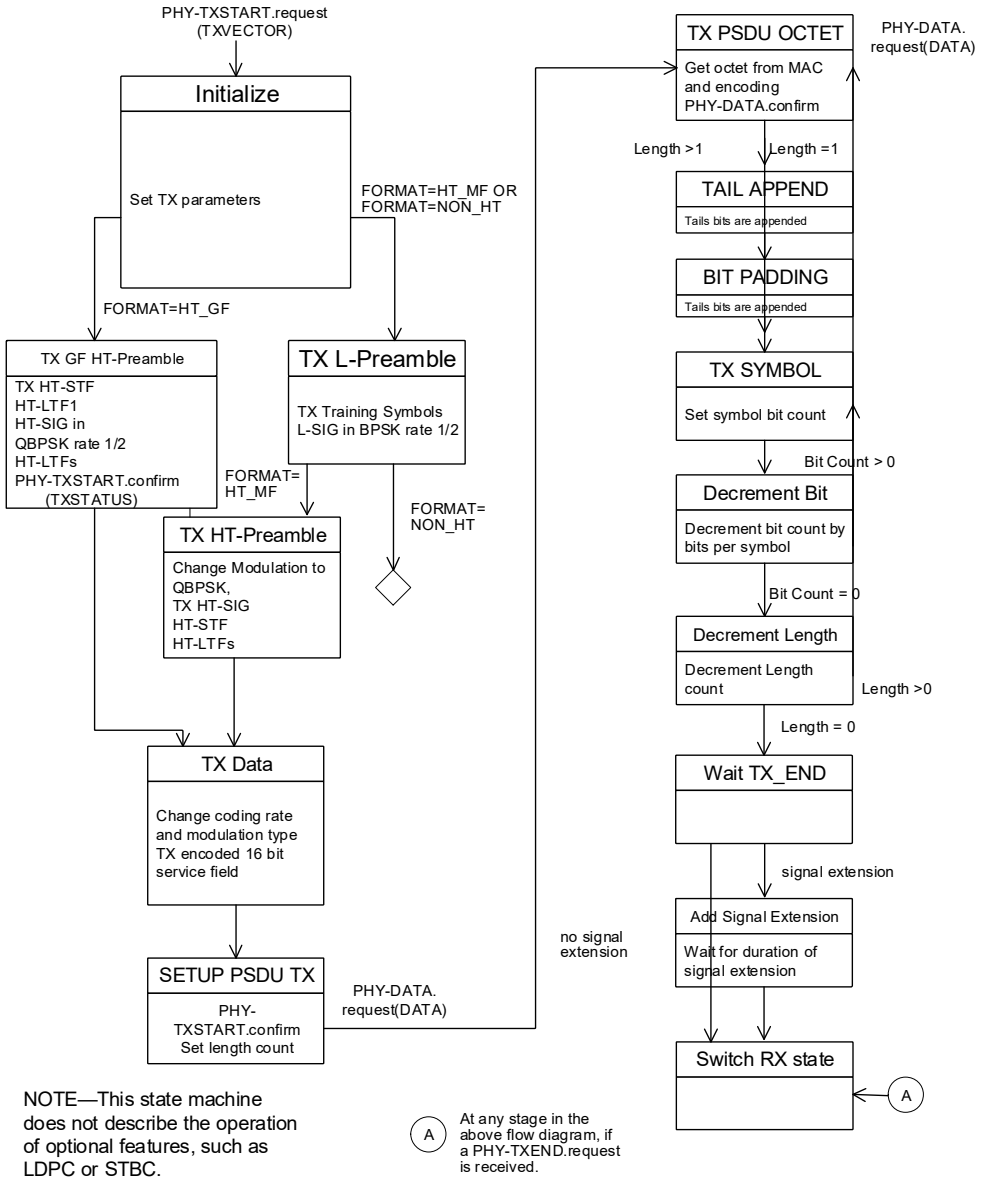


**Figure 19-24—PHY transmit state machine(#14)**

### 19.3.21 PHY receive procedure

Typical PHY receive procedures are shown in Figure 19-25 (PHY receive procedure for HT-mixed format PPDU(#1058)(#3480)(#4122)) and Figure 19-26 (PHY receive procedure for HT-greenfield format PPDU(#1058)(#3480)(#4122)). The receive procedures correspond to HT-mixed format and HT-greenfield format, respectively. A typical state machine implementation of the receive PHY is given in Figure 19-27 (PHY receive state machine(#1590)(#6467)). These receive procedures and state machine do not describe the operation of optional features, such as LDPC or STBC. If the detected format indicates (#2095)a non-HT format (denoted "Not HT-SIG" in Figure 19-27 (PHY receive state machine(#1590)(#6467))), refer to the receive procedure and state machine in 17.3.12 (Receive PHY) or 18.3.6 (PHY receive procedure). Further,


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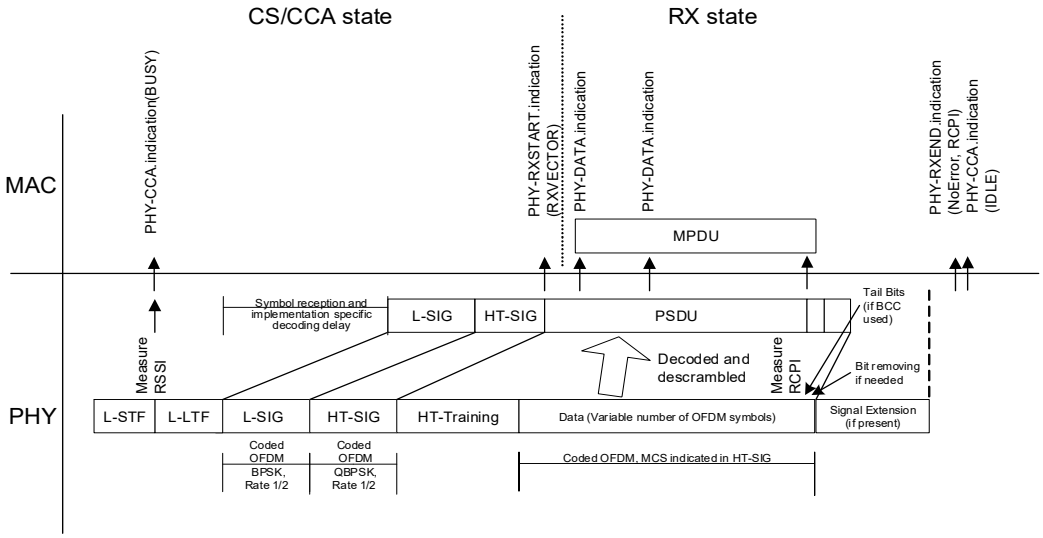
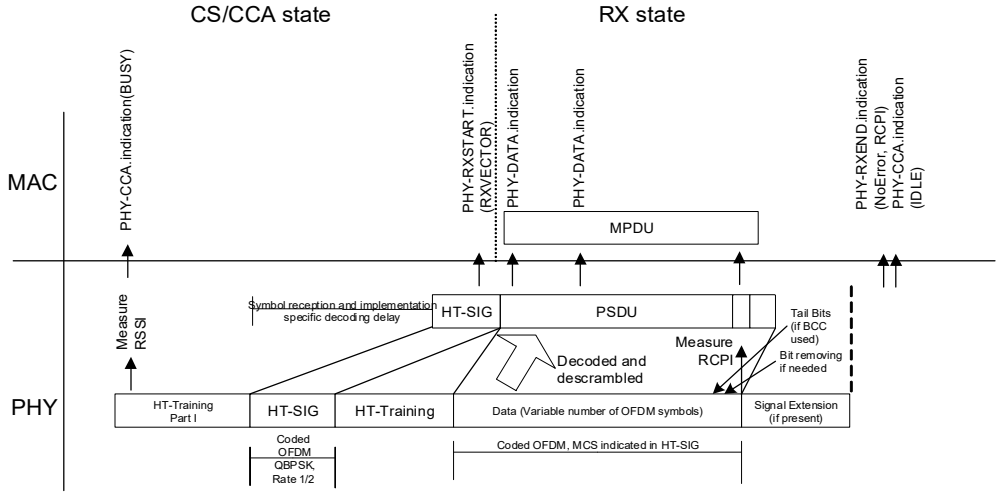
through station management (via the PLME), the PHY is set to the appropriate frequency, as specified in 19.4 (HT PLME). Other receive parameters, such as RSSI and indicated DATARATE, may be accessed via the PHY SAP.




NOTE—This procedure does not describe the operation of optional features, such as LDPC or STBC.

**Figure 19-25—PHY receive procedure for HT-mixed format PPDU(#1058)(#3480)(#4122)**




NOTE—This procedure does not describe the operation of optional features, such as LDPC or STBC.

**Figure 19-26—PHY receive procedure for HT-greenfield format PPDU(#1058)(#3480)(#4122)**

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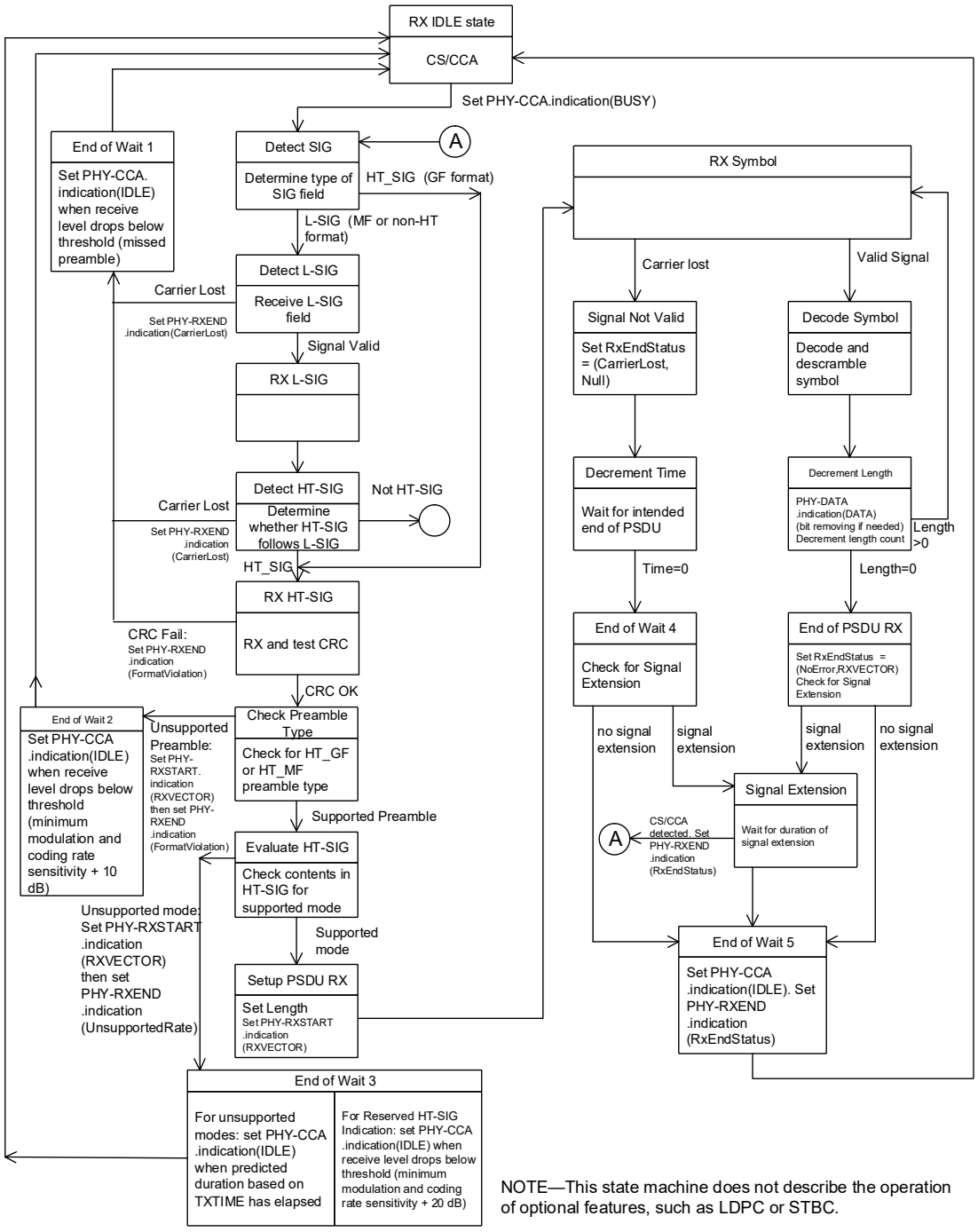


NOTE—This state machine does not describe the operation of optional features, such as LDPC or STBC.

**Figure 19-27—PHY receive state machine(#1590)(#6467)**



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Upon receiving the transmitted PHY preamble, the PHY measures a receive signal strength. This indicates activity to the MAC via the PHY-CCA.indication primitive. A PHY-CCA.indication(BUSY, channel-list) primitive shall also be issued as an initial indication of reception of a signal. The channel-list parameter of the PHY-CCA.indication primitive is set as follows:

- It is absent when the operating channel width is 20 MHz.
- It is set to {primary} when the operating channel width is 40 MHz and the signal is present only in the primary channel.
- It is set to {secondary} when the operating channel width is 40 MHz and the signal is present only in the secondary channel.
- It is set to {primary, secondary} when the operating channel width is 40 MHz and the signal is present in both the primary and secondary channels.

The RSSI parameter is reported to the MAC in the RXVECTOR.

After the PHY-CCA.indication(BUSY, channel-list) primitive is issued, the PHY entity shall begin receiving the training symbols and searching for SIGNAL and HT-SIG in order to set the length of the PSDU(#2056), the demodulation type, code type, and the decoding rate.

(#1062)For a VHT STA, or an HE STA operating in the 2.4 GHz band, that determines it is receiving an HT PPDU, the STA's receive procedure shall resume here. Existing state, including knowledge of the L-SIG Parity and RATE checks, is retained.

If signal loss occurs before validating L-SIG and/or HT-SIG, the HT PHY shall not generate a PHY-CCA.indication(IDLE) primitive until the received level drops below the CCA sensitivity level (for a missed preamble) specified in 19.3.19.6 (CCA sensitivity). If the check of the HT-SIG CRC is not valid, a PHY-RXSTART.indication primitive is not issued. The PHY shall indicate the error condition by issuing a PHY-RXEND.indication(FormatViolation) primitive. The HT PHY shall not generate a PHY-CCA.indication(IDLE) primitive until the received level drops below the CCA sensitivity level (for a missed preamble) specified in 19.3.19.6 (CCA sensitivity).

If the PHY preamble reception is successful and a valid HT-SIG CRC is indicated:

- Upon reception of an HT-mixed format preamble, the HT PHY shall not generate a PHY-CCA.indication(IDLE) primitive for the predicted duration of the (#14)PPDU, as defined by TXTIME in 19.4.3 (TXTIME calculation), for all supported and unsupported modes except Reserved HT-SIG Indication. Reserved HT-SIG Indication is defined in the fourth item below.
- Upon reception of a GF preamble by an HT STA that does not support GF, the HT PHY shall not generate a PHY-CCA.indication(IDLE) primitive until either the predicted duration of the (#14)PPDU from the contents of the HT-SIG field, as defined by TXTIME in 19.4.3 (TXTIME calculation), except Reserved HT-SIG Indication, elapses or until the received level drops below the receiver minimum sensitivity level of BPSK, R=1/2 in Table 19-23 (Receiver minimum input level sensitivity) + 10 dB (–72 dBm for 20 MHz, –69 dBm for 40 MHz). Reserved HT-SIG Indication is defined in the fourth item below.
- Upon reception of a GF preamble by an HT STA that supports GF, the HT PHY shall not generate a PHY-CCA.indication(IDLE) primitive for the predicted duration of the (#14)PPDU, as defined by TXTIME in 19.4.3 (TXTIME calculation), for all supported and unsupported modes except Reserved HT-SIG Indication. Reserved HT-SIG Indication is defined in the fourth item below.

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— If the HT-SIG indicates a Reserved HT-SIG Indication, the HT PHY shall not generate a PHY-CCA.indication(IDLE) primitive until the received level drops below the CCA sensitivity level (minimum modulation and coding rate sensitivity + 20 dB) specified in 19.3.19.6 (CCA sensitivity). Reserved HT-SIG Indication is defined as an HT-SIG with MCS field in the range 77–127 or Reserved field = 0 or STBC field = 3 and any other HT-SIG field bit combinations that do not correspond to modes of PHY operation defined in Clause 19 (High Throughput (HT) PHY specification(#2297)).

Subsequent to an indication of a valid HT-SIG CRC, a PHY-RXSTART.indication(RXVECTOR) primitive shall be issued. If dot11TimingMsmtActivated is true, the PHY shall do the following:

— Complete receiving the PHY header and verify the validity of the PHY Header.

— If the PHY header reception is successful (and the SIGNAL field is completely recognizable and supported), a PHY-RXSTART.indication(RXVECTOR) primitive shall be issued and RX_START_OF_FRAME_OFFSET parameter within the RXVECTOR shall be forwarded (see 19.2.2 (TXVECTOR and RXVECTOR parameters)).

NOTE—The RX_START_OF_FRAME_OFFSET value is used (#3049)to estimate when the start of the preamble for the incoming (#14)PPDU was detected on the medium at the receive antenna connector.

The RXVECTOR associated with this primitive includes the parameters specified in Table 19-1 (TXVECTOR and RXVECTOR parameters). Upon reception of a GF preamble by an HT STA that does not support GF, the FORMAT field of RXVECTOR is equal to HT_GF, the remaining fields may be empty, and the PHY shall indicate the error condition by issuing a PHY-RXEND.indication(FormatViolation) primitive. If the HT-SIG indicates an unsupported mode or Reserved HT-SIG Indication, the PHY shall indicate the error condition by issuing a PHY-RXEND.indication(UnsupportedRate) primitive.

Following training and SIGNAL fields, the coded PSDU (which comprises the coded PHY SERVICE field and scrambled and coded PSDU) shall be received. If signal loss occurs during reception prior to completion of the PSDU reception, the error condition shall be reported to the MAC using a PHY-RXEND.indication(CarrierLost) primitive. After waiting for the intended end of the PSDU, if no signal extension is present (as defined in 19.3.2 (PPDU format)), the PHY shall generate a PHY-CCA.indication(IDLE) primitive and return to RX IDLE state. Otherwise, the receiver waits for the duration of the signal extension before returning to the RX IDLE state.

The received PSDU bits are assembled into octets, decoded, and presented to the MAC using a series of PHY-DATA.indication(DATA) primitive exchanges. The number of PSDU octets is indicated in the HT Length field of the HT-SIG. The PHY shall proceed with PSDU reception. After the reception of the final bit of the last PSDU octet and possible tail and padding bits, the receiver shall be returned to the RX IDLE state if no signal extension is present (as defined in 19.3.2 (PPDU format)), as shown in Figure 19-27 (PHY receive state machine(#1590)(#6467)). Otherwise, the receiver waits for the duration of the signal extension before returning to the RX IDLE state. A PHY-RXEND.indication(NoError) primitive shall be issued on entry to the RX IDLE state.

While in the Signal Extension state, if the receiver detects a CS/CCA event, it issues an RXEND.indication primitive (with the RXERROR parameter set to NoError or CarrierLost, depending on whether a carrier lost event occurred during the reception of the PPDU), leaves the Signal Extension state, and enters the Detect SIG state. This sequence occurs when signal-extended PPDUs are transmitted while separated by a RIFS.

If the BCC is used, any data received after the indicated data length are considered pad bits (to fill out an OFDM symbol) and should be discarded.


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## 19.4 HT PLME

### 19.4.1 PLME SAP layer management primitives(#6320)

Table 19-24 (HT PHY MIB attributes) lists the MIB attributes that may be accessed by the PHY entities and the intralayer of higher level LMEs. These attributes are accessed via the PLME-GET, PLME-SET, PLME-RESET, and PLME-CHARACTERISTICS primitives defined in 6.2 (Generic management primitives) and 6.7.4 (PLME-CHARACTERISTICS.confirm).

**Table 19-24—HT PHY MIB attributes**

| Managed object | Default value/range | Operational semantics |
|---|---|---|
| **dot11PHYOperationTable** | | |
| dot11PHYType | HT (X'07') | Static |
| dot11CurrentRegDomain | Implementation dependent | Dynamic |
| **dot11PHYAntennaTable** | | |
| dot11CurrentTxAntenna | Implementation dependent | Dynamic |
| dot11DiversitySupportImplemented | Implementation dependent | Static |
| dot11CurrentRxAntenna | Implementation dependent | Dynamic |
| dot11AntennaSelectionOptionImplemented | false/Boolean | Static |
| dot11TransmitExplicitCSIFeedbackASOptionImplemented | false/Boolean | Static |
| dot11TransmitIndicesFeedbackASOptionImplemented | false/Boolean | Static |
| dot11ExplicitCSIFeedbackASOptionImplemented | false/Boolean | Static |
| dot11TransmitIndicesComputationASOptionImplemented | false/Boolean | Static |
| dot11ReceiveAntennaSelectionOptionImplemented | false/Boolean | Static |
| dot11TransmitSoundingPPDUOptionImplemented | false/Boolean | Static |
| **dot11PHYTxPowerTable** | | |
| dot11NumberSupportedPowerLevelsImplemented | Implementation dependent | Static |
| dot11TxPowerLevel1 | Implementation dependent | Static |
| dot11TxPowerLevel2 | Implementation dependent | Static |
| dot11TxPowerLevel3 | Implementation dependent | Static |
| dot11TxPowerLevel4 | Implementation dependent | Static |
| dot11TxPowerLevel5 | Implementation dependent | Static |
| dot11TxPowerLevel6 | Implementation dependent | Static |
| dot11TxPowerLevel7 | Implementation dependent | Static |
| dot11TxPowerLevel8 | Implementation dependent | Static |
| dot11CurrentTxPowerLevel | Implementation dependent | Dynamic |
| **dot11PhyDSSSTable** | | |

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**Table 19-24—HT PHY MIB attributes *(continued)***

| Managed object | Default value/range | Operational semantics |
|---|---|---|
| dot11CurrentChannel | Implementation dependent | Dynamic |
| **dot11RegDomainsSupportedTable** | | |
| dot11RegDomainsImplementedValue | Implementation dependent | Static |
| dot11FrequencyBandsSupported | Implementation dependent | Static |
| **dot11PHYAntennasListTable** | | |
| dot11SupportedTxAntenna | Implementation dependent | Dynamic |
| dot11SupportedRxAntenna | Implementation dependent | Static |
| dot11DiversitySelectionRx | Implementation dependent | Dynamic |
| **dot11SupportedDataRatesTxTable** | | |
| dot11SupportedDataratesTxValue | X'02' = 1 Mb/s (2.4)<br>X'04' = 2 Mb/s (2.4)<br>X'0B' = 5.5 Mb/s (2.4)<br>X'16' = 11 Mb/s (2.4)<br>X'0C' = 6 Mb/s<br>X'12' = 9 Mb/s<br>X'18' = 12 Mb/s<br>X'24' = 18 Mb/s<br>X'30' = 24 Mb/s<br>X'48' = 36 Mb/s<br>X'60' = 48 Mb/s<br>X'6C' = 54 Mb/s | Static |
| **dot11SupportedDataRatesRxTable** | | |
| dot11SupportedDataRatesRxTable | X'02' = 1 Mb/s (2.4)<br>X'04' = 2 Mb/s (2.4)<br>X'0B' = 5.5 Mb/s (2.4)<br>X'16' = 11 Mb/s (2.4)<br>X'0C' = 6 Mb/s<br>X'12' = 9 Mb/s<br>X'18' = 12 Mb/s<br>X'24' = 18 Mb/s<br>X'30' = 24 Mb/s<br>X'48' = 36 Mb/s<br>X'60' = 48 Mb/s<br>X'6C' = 54 Mb/s | Static |
| **dot11HRDSSSPHYTable** | | |
| dot11ShortPreambleOptionImplemented | true | Static |
| **dot11PHYOFDMTable** | | |
| dot11CurrentFrequency | Implementation dependent | Dynamic |
| dot11TIThreshold | Implementation dependent | Dynamic |
| dot11ChannelStartingFactor | Implementation dependent | Dynamic |
| **dot11PHYERPTable** | | |
| dot11ShortSlotTimeOptionImplemented | Implementation dependent | Static |


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**Table 19-24—HT PHY MIB attributes *(continued)***

| Managed object | Default value/range | Operational semantics |
|---|---|---|
| dot11ShortSlotTimeOptionActivated | Implementation dependent | Dynamic |
| **dot11PHYHTTable** | | |
| dot11FortyMHzOperationImplemented | false/Boolean | Static |
| dot11FortyMHzOperationActivated | false/Boolean | Dynamic |
| dot11CurrentPrimaryChannel | Implementation dependent | Dynamic |
| dot11CurrentSecondaryChannel | Implementation dependent | Dynamic |
| dot11NumberOfSpatialStreamsImplemented | Implementation dependent | Static |
| dot11NumberOfSpatialStreamsActivated | Implementation dependent | Dynamic |
| dot11HTGreenfieldOptionImplemented | false/Boolean | Static |
| dot11HTGreenfieldOptionActivated | false/Boolean | Dynamic |
| dot11ShortGIOptionInTwentyImplemented | false/Boolean | Static |
| dot11ShortGIOptionInTwentyActivated | false/Boolean | Dynamic |
| dot11ShortGIOptionInFortyImplemented | false/Boolean | Static |
| dot11ShortGIOptionInFortyActivated | false/Boolean | Dynamic |
| dot11LDPCCodingOptionImplemented | false/Boolean | Static |
| dot11LDPCCodingOptionActivated | false/Boolean | Dynamic |
| dot11TxSTBCOptionImplemented | false/Boolean | Static |
| dot11TxSTBCOptionActivated | false/Boolean | Dynamic |
| dot11RxSTBCOptionImplemented | false/Boolean | Static |
| dot11RxSTBCOptionActivated | false/Boolean | Dynamic |
| dot11BeamFormingOptionImplemented | false/Boolean | Static |
| dot11BeamFormingOptionActivated | false/Boolean | Dynamic |
| **dot11SupportedHTMCSTxTable** | | |
| dot11SupportedHTMCSTxValue | MCS 0–76 for 20 MHz; MCS 0–76 for 40 MHz (MCS 0–7 for 20 MHz mandatory at non-AP STA and at AP that is a VHT AP; MCS 0–15 for 20 MHz mandatory at AP that is not a VHT AP) | Static |

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**Table 19-24—HT PHY MIB attributes *(continued)***

| Managed object | Default value/range | Operational semantics |
|---|---|---|
| **dot11SupportedHTMCSRxTable** | | |
| dot11SupportedHTMCSRxValue | MCS 0–76 for 20 MHz; MCS 0–76 for 40 MHz (MCS 0–7 for 20 MHz mandatory at non-AP STA and at AP that is a VHT AP; MCS 0–15 for 20 MHz mandatory at AP that is not a VHT AP) | Static |
| **dot11TransmitBeamformingConfigTable** | | |
| dot11ReceiveStaggerSoundingOptionImplemented | false/Boolean | Static |
| dot11TransmitStaggerSoundingOptionImplemented | false/Boolean | Static |
| dot11ReceiveNDPOptionImplemented | false/Boolean | Static |
| dot11TransmitNDPOptionImplemented | false/Boolean | Static |
| dot11ImplicitTransmitBeamformingOptionImplemented | false/Boolean | Static |
| dot11CalibrationOptionImplemented | Implementation dependent | Static |
| dot11ExplicitCSITransmitBeamformingOptionImplemented | false/Boolean | Static |
| dot11ExplicitNonCompressedBeamformingMatrixOption-Implemented | false/Boolean | Static |
| dot11ExplicitTransmitBeamformingCSIFeedbackOption-Implemented | Implementation dependent | Static |
| dot11ExplicitNoncompressedBeamformingFeedbackOption-Implemented | Implementation dependent | Static |
| dot11ExplicitCompressedBeamformingFeedbackOption-Implemented | Implementation dependent | Static |
| dot11NumberBeamFormingCSISupportAntenna | Implementation dependent | Static |
| dot11NumberNonCompressedBeamformingMatrixSupport-Antenna | Implementation dependent | Static |
| dot11NumberCompressedBeamformingMatrixSupportAntenna | Implementation dependent | Static |
| dot11TxMCSSetDefined | false/Boolean | Static |
| dot11TxRxMCSSetNotEqual | false/Boolean | Static |
| dot11TxMaximumNumberSpatialStreamsSupported | false/Boolean | Static |
| dot11TxUnequalModulationSupported | false/Boolean | Static |


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### 19.4.2 PHY MIB

HT PHY MIB attributes are defined in Annex C with specific values defined in Table 19-24 (HT PHY MIB attributes). The (#4177)Operational semantics column in Table 19-24 (HT PHY MIB attributes) contains two types: static and dynamic.

— Static MIB attributes are fixed and cannot be modified for a given PHY implementation.

— Dynamic MIB attributes are interpreted according to the MAX-ACCESS field of the MIB attribute. When MAX-ACCESS is equal to read-only, the MIB attribute value may be updated by the PLME and read from the MIB attribute by management entities. When MAX-ACCESS is equal to read-write, the MIB attribute may be read and written by management entities.

### 19.4.3 TXTIME calculation

The value of the TXTIME parameter returned by the PLME-TXTIME.confirm primitive or calculated for the PHY receive procedure shall be calculated for HT-mixed format according to the Equation (19-90) and Equation (19-91) for short and long GI, respectively, and for HT-greenfield format according to Equation (19-92) and Equation (19-93) for short and long, respectively:

$$\text{TXTIME} = T_{LEG\_PREAMBLE} + T_{L\text{-}SIG} + T_{HT\_TRAINING} + T_{HT\text{-}SIG} + T_{SYM} \times \left\lceil \frac{T_{SYMS} \times N_{SYM}}{T_{SYM}} \right\rceil + SignalExtension \quad \text{(19-90)}$$

(#84)

$$\text{TXTIME} = T_{LEG\_PREAMBLE} + T_{L\text{-}SIG} + T_{HT\_TRAINING} + T_{HT\text{-}SIG} + T_{\text{SYM}} \times N_{SYM} + SignalExtension \quad \text{(19-91)}$$

(#85)

$$\text{TXTIME} = T_{GF\_HT\_TRAINING} + T_{HT\text{-}SIG} + T_{SYMS} \times N_{SYM} + SignalExtension \quad \text{(19-92)}$$

(#86)

$$\text{TXTIME} = T_{GF\_HT\_TRAINING} + T_{HT\text{-}SIG} + T_{SYM} \times N_{SYM} + SignalExtension \quad \text{(19-93)}$$

(#87)

where

$T_{LEG\_PREAMBLE} = T_{L\text{-}STF} + T_{L\text{-}LTF}$ is the duration of the non-HT preamble

$T_{HT\_TRAINING}$ is the duration of the HT-STF and HT-LTFs in HT-mixed format, given by $T_{HT-STF} + T_{HT-LTF1} + (N_{HT\text{-}LTF} - 1)T_{HT-LTFs}$

$T_{GF\_HT\_TRAINING}$ is the duration of the HT-GF-STF, HT-LTF1 and HT-LTFs in HT-greenfield format, given by $T_{HT-GF-STF} + T_{HT-LTF1} + (N_{HT\text{-}LTF} - 1)T_{HT-LTFs}$

$T_{SYM}$, $T_{SYMS}$, (#88)$T_{L\text{-}SIG}$, $T_{HT\text{-}SIG}$, $T_{L\text{-}STF}$, $T_{HT\text{-}STF}$, $T_{HT\text{-}GF\text{-}STF}$, $T_{L\text{-}LTF}$, $T_{HT\text{-}LTF1}$ and $T_{HT\text{-}LTFs}$ are defined in Table 19-6 (Timing-related constants)

*SignalExtension* is 0 µs when TXVECTOR parameter NO_SIG_EXTN is true and is aSignalExtension as defined in Table 19-25 (HT PHY characteristics) when TXVECTOR parameter NO_SIG_EXTN is false

$N_{HT\text{-}LTF}$ is defined in Equation (19-22)

$N_{SYM}$ is defined in Equation (19-32) for BCC and Equation (19-41) for LDPC

For non-HT modes of operation, refer to Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) and Clause 18 (Extended Rate PHY (ERP) specification) for TXTIME calculations, except that (#14)PPDUs transmitted with a value of NON_HT_DUP_OFDM for the TXVECTOR parameter NON_HT_MODULATION shall use Equation (18-1) for TXTIME calculation.

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### 19.4.4 HT PHY

(#2123)The HT PHY characteristics, provided through the PLME-CHARACTERISTICS service primitive, are shown in Table 19-25 (HT PHY characteristics). The definitions for these characteristics are given in 6.7.4 (PLME-CHARACTERISTICS.confirm)

**Table 19-25—HT PHY characteristics**

| Characteristics | Value |
|---|---|
| aRIFSTime | 2 μs |
| aSlotTime | When operating in the 2.4 GHz band:<br>If dot11OperatingClassesRequired is false, long slot time = 20 μs<br>If dot11OperatingClassesRequired is true, long slot time = 20 μs plus any coverage-class-dependent aAirPropagationTime (see Table 9-133 (Coverage Class field parameters))<br><br>If dot11OperatingClassesRequired is false, short slot time = 9 μs<br>If dot11OperatingClassesRequired is true, short slot time= 9 μs plus any coverage-class-dependent aAirPropagationTime (see Table 9-133 (Coverage Class field parameters))<br><br>When operating in the 5 GHz band:<br>If dot11OperatingClassesRequired is false, 9 μs<br>If dot11OperatingClassesRequired is true, 9 μs plus any coverage-class-dependent aAirPropagationTime (see Table 9-133 (Coverage Class field parameters)) |
| aSIFSTime | 10 μs when operating in the 2.4 GHz band<br>16 μs when operating in the 5 GHz bands |
| aSignalExtension | 0 μs when operating in the 5 GHz band<br>6 μs when operating in the 2.4 GHz band |
| aCCATime | Implementation dependent, see 10.3.7 (DCF timing relations). |
| aRxPHYStartDelay | (#3038)24 μs |
| aRxTxTurnaroundTime | Implementation dependent, see 10.3.7 (DCF timing relations). |
| aTxPHYDelay | Implementation dependent, see 10.3.7 (DCF timing relations). |
| aRxPHYDelay | Implementation dependent, see 10.3.7 (DCF timing relations). |
| aRxTxSwitchTime | Implementation dependent, see 10.3.7 (DCF timing relations). |
| aTxRampOnTime | Implementation dependent, see 10.3.7 (DCF timing relations). |
| aAirPropagationTime | As indicated by the coverage class (see 10.22.5 (Operation with coverage classes)). |
| aMACProcessingDelay | Implementation dependent, see 10.3.7 (DCF timing relations). |
| aPSDUMaxLength | 65 535 octets |
| aPPDUMaxTime | 10 ms(#3263) |
| aCWmin | 15 |
| aCWmax | 1023 |
| aMaxCSIMatricesReportDelay | 250 ms |


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For non-HT modes of operation, refer to Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) and Clause 18 (Extended Rate PHY (ERP) specification) for PHY characteristics.

## 19.5 Parameters for HT-MCSs

Table 19-26 (Symbols used in MCS parameter tables) defines the symbols used in the rate-dependent parameter tables.

**Table 19-26—Symbols used in MCS parameter tables**

| Symbol | Explanation |
|---|---|
| $N_{SS}$ | Number of spatial streams |
| $R$ | Coding rate |
| $N_{BPSC}$ | Number of coded bits per single carrier (total across spatial streams) |
| $N_{BPSCS}(i_{SS})$ | Number of coded bits per single carrier for each spatial stream, $i_{SS} = 1,...,N_{SS}$ |
| $N_{SD}$ | Number of complex data numbers per spatial stream per OFDM symbol |
| $N_{SP}$ | Number of pilot values per OFDM symbol |
| $N_{CBPS}$ | Number of coded bits per OFDM symbol |
| $N_{DBPS}$ | Number of data bits per OFDM symbol |
| $N_{ES}$ | Number of BCC encoders for the DATA field |

In the MCS parameter tables that follow, data rates for a 400 ns GI are rounded to 1 decimal place.

The rate-dependent parameters for mandatory 20 MHz, $N_{SS} = 1$ MCSs with $N_{ES} = 1$ shall be as shown in Table 19-27 (MCS parameters for mandatory 20 MHz, $N_{SS} = 1$, $N_{ES} = 1$).

**Table 19-27—MCS parameters for mandatory 20 MHz, $N_{SS} = 1$, $N_{ES} = 1$**

| MCS Index | Modulation | $R$ | $N_{BPSCS}(i_{SS})$ | $N_{SD}$ | $N_{SP}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 800 ns GI | 400 ns GI (see NOTE) |
| 0 | BPSK | 1/2 | 1 | 52 | 4 | 52 | 26 | 6.5 | 7.2 |
| 1 | QPSK | 1/2 | 2 | 52 | 4 | 104 | 52 | 13.0 | 14.4 |
| 2 | QPSK | 3/4 | 2 | 52 | 4 | 104 | 78 | 19.5 | 21.7 |
| 3 | 16-QAM | 1/2 | 4 | 52 | 4 | 208 | 104 | 26.0 | 28.9 |
| 4 | 16-QAM | 3/4 | 4 | 52 | 4 | 208 | 156 | 39.0 | 43.3 |
| 5 | 64-QAM | 2/3 | 6 | 52 | 4 | 312 | 208 | 52.0 | 57.8 |
| 6 | 64-QAM | 3/4 | 6 | 52 | 4 | 312 | 234 | 58.5 | 65.0 |

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**Table 19-27—MCS parameters for mandatory 20 MHz, $N_{SS}$ = 1, $N_{ES}$ = 1**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 7 | 64-QAM | 5/6 | 6 | 52 | 4 | 312 | 260 | 65.0 | 72.2 |
| NOTE—Support of 400 ns GI is optional on transmit and receive. | | | | | | | | | |

The rate-dependent parameters for optional 20 MHz, $N_{SS}$ = 2 MCSs with $N_{ES}$ = 1 and EQM of the spatial streams shall be as shown in Table 19-28 (MCS parameters for optional 20 MHz, $N_{SS}$ = 2, $N_{ES}$ = 1, EQM).

**Table 19-28—MCS parameters for optional 20 MHz, $N_{SS}$ = 2, $N_{ES}$ = 1, EQM**

| MCS Index | Modulation | *R* | $N_{BPSCS}(i_{SS})$ | $N_{SD}$ | $N_{SP}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 800 ns GI | 400 ns GI |
| 8 | BPSK | 1/2 | 1 | 52 | 4 | 104 | 52 | 13.0 | 14.4 |
| 9 | QPSK | 1/2 | 2 | 52 | 4 | 208 | 104 | 26.0 | 28.9 |
| 10 | QPSK | 3/4 | 2 | 52 | 4 | 208 | 156 | 39.0 | 43.3 |
| 11 | 16-QAM | 1/2 | 4 | 52 | 4 | 416 | 208 | 52.0 | 57.8 |
| 12 | 16-QAM | 3/4 | 4 | 52 | 4 | 416 | 312 | 78.0 | 86.7 |
| 13 | 64-QAM | 2/3 | 6 | 52 | 4 | 624 | 416 | 104.0 | 115.6 |
| 14 | 64-QAM | 3/4 | 6 | 52 | 4 | 624 | 468 | 117.0 | 130.0 |
| 15 | 64-QAM | 5/6 | 6 | 52 | 4 | 624 | 520 | 130.0 | 144.4 |

The rate-dependent parameters for optional 20 MHz, $N_{SS}$ = 3 MCSs with $N_{ES}$ = 1 and EQM of the spatial streams shall be as shown in Table 19-29 (MCS parameters for optional 20 MHz, $N_{SS}$ = 3, $N_{ES}$ = 1, EQM).

**Table 19-29—MCS parameters for optional 20 MHz, $N_{SS}$ = 3, $N_{ES}$ = 1, EQM**

| MCS Index | Modulation | *R* | $N_{BPSCS}(i_{SS})$ | $N_{SD}$ | $N_{SP}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 800 ns GI | 400 ns GI |
| 16 | BPSK | 1/2 | 1 | 52 | 4 | 156 | 78 | 19.5 | 21.7 |
| 17 | QPSK | 1/2 | 2 | 52 | 4 | 312 | 156 | 39.0 | 43.3 |
| 18 | QPSK | 3/4 | 2 | 52 | 4 | 312 | 234 | 58.5 | 65.0 |
| 19 | 16-QAM | 1/2 | 4 | 52 | 4 | 624 | 312 | 78.0 | 86.7 |
| 20 | 16-QAM | 3/4 | 4 | 52 | 4 | 624 | 468 | 117.0 | 130.0 |
| 21 | 64-QAM | 2/3 | 6 | 52 | 4 | 936 | 624 | 156.0 | 173.3 |
| 22 | 64-QAM | 3/4 | 6 | 52 | 4 | 936 | 702 | 175.5 | 195.0 |
| 23 | 64-QAM | 5/6 | 6 | 52 | 4 | 936 | 780 | 195.0 | 216.7 |


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The rate-dependent parameters for optional 20 MHz, $N_{SS}$ = 4 MCSs with $N_{ES}$ = 1 and EQM of the spatial streams shall be as shown in Table 19-30 (MCS parameters for optional 20 MHz, $N_{SS}$ = 4, $N_{ES}$ = 1, EQM).

**Table 19-30—MCS parameters for optional 20 MHz, $N_{SS}$ = 4, $N_{ES}$ = 1, EQM**

| MCS Index | Modulation | *R* | $N_{BPSCS}(i_{SS})$ | $N_{SD}$ | $N_{SP}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 800 ns GI | 400 ns GI |
| 24 | BPSK | 1/2 | 1 | 52 | 4 | 208 | 104 | 26.0 | 28.9 |
| 25 | QPSK | 1/2 | 2 | 52 | 4 | 416 | 208 | 52.0 | 57.8 |
| 26 | QPSK | 3/4 | 2 | 52 | 4 | 416 | 312 | 78.0 | 86.7 |
| 27 | 16-QAM | 1/2 | 4 | 52 | 4 | 832 | 416 | 104.0 | 115.6 |
| 28 | 16-QAM | 3/4 | 4 | 52 | 4 | 832 | 624 | 156.0 | 173.3 |
| 29 | 64-QAM | 2/3 | 6 | 52 | 4 | 1248 | 832 | 208.0 | 231.1 |
| 30 | 64-QAM | 3/4 | 6 | 52 | 4 | 1248 | 936 | 234.0 | 260.0 |
| 31 | 64-QAM | 5/6 | 6 | 52 | 4 | 1248 | 1040 | 260.0 | 288.9 |

The rate-dependent parameters for optional 40 MHz, $N_{SS}$ = 1 MCSs with $N_{ES}$ = 1 shall be as shown in Table 19-31 (MCS parameters for optional 40 MHz, $N_{SS}$ = 1, $N_{ES}$ = 1).

**Table 19-31—MCS parameters for optional 40 MHz, $N_{SS}$ = 1, $N_{ES}$ = 1**

| MCS Index | Modulation | *R* | $N_{BPSCS}(i_{SS})$ | $N_{SD}$ | $N_{SP}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 800 ns GI | 400 ns GI |
| 0 | BPSK | 1/2 | 1 | 108 | 6 | 108 | 54 | 13.5 | 15.0 |
| 1 | QPSK | 1/2 | 2 | 108 | 6 | 216 | 108 | 27.0 | 30.0 |
| 2 | QPSK | 3/4 | 2 | 108 | 6 | 216 | 162 | 40.5 | 45.0 |
| 3 | 16-QAM | 1/2 | 4 | 108 | 6 | 432 | 216 | 54.0 | 60.0 |
| 4 | 16-QAM | 3/4 | 4 | 108 | 6 | 432 | 324 | 81.0 | 90.0 |
| 5 | 64-QAM | 2/3 | 6 | 108 | 6 | 648 | 432 | 108.0 | 120.0 |
| 6 | 64-QAM | 3/4 | 6 | 108 | 6 | 648 | 486 | 121.5 | 135.0 |
| 7 | 64-QAM | 5/6 | 6 | 108 | 6 | 648 | 540 | 135.0 | 150.0 |

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The rate-dependent parameters for optional 40 MHz, $N_{SS}$ = 2 MCSs with $N_{ES}$ = 1 and EQM of the spatial streams shall be as shown in Table 19-32 (MCS parameters for optional 40 MHz, $N_{SS}$ = 2, $N_{ES}$ = 1, EQM).

**Table 19-32—MCS parameters for optional 40 MHz, $N_{SS}$ = 2, $N_{ES}$ = 1, EQM**

| MCS Index | Modulation | *R* | $N_{BPSCS}(i_{SS})$ | $N_{SD}$ | $N_{SP}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 800 ns GI | 400 ns GI |
| 8 | BPSK | 1/2 | 1 | 108 | 6 | 216 | 108 | 27.0 | 30.0 |
| 9 | QPSK | 1/2 | 2 | 108 | 6 | 432 | 216 | 54.0 | 60.0 |
| 10 | QPSK | 3/4 | 2 | 108 | 6 | 432 | 324 | 81.0 | 90.0 |
| 11 | 16-QAM | 1/2 | 4 | 108 | 6 | 864 | 432 | 108.0 | 120.0 |
| 12 | 16-QAM | 3/4 | 4 | 108 | 6 | 864 | 648 | 162.0 | 180.0 |
| 13 | 64-QAM | 2/3 | 6 | 108 | 6 | 1296 | 864 | 216.0 | 240.0 |
| 14 | 64-QAM | 3/4 | 6 | 108 | 6 | 1296 | 972 | 243.0 | 270.0 |
| 15 | 64-QAM | 5/6 | 6 | 108 | 6 | 1296 | 1080 | 270.0 | 300.0 |

The rate-dependent parameters for optional 40 MHz, $N_{SS}$ = 3 MCSs, with EQM of the spatial streams shall be as shown in Table 19-33 (MCS parameters for optional 40 MHz, $N_{SS}$ = 3, EQM).

**Table 19-33—MCS parameters for optional 40 MHz, $N_{SS}$ = 3, EQM**

| MCS Index | Modulation | *R* | $N_{BPSCS}(i_{SS})$ | $N_{SD}$ | $N_{SP}$ | $N_{CBPS}$ | $N_{DBPS}$ | $N_{ES}$ | Data rate (Mb/s) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | 800 ns GI | 400 ns GI |
| 16 | BPSK | 1/2 | 1 | 108 | 6 | 324 | 162 | 1 | 40.5 | 45.0 |
| 17 | QPSK | 1/2 | 2 | 108 | 6 | 648 | 324 | 1 | 81.0 | 90.0 |
| 18 | QPSK | 3/4 | 2 | 108 | 6 | 648 | 486 | 1 | 121.5 | 135.0 |
| 19 | 16-QAM | 1/2 | 4 | 108 | 6 | 1296 | 648 | 1 | 162.0 | 180.0 |
| 20 | 16-QAM | 3/4 | 4 | 108 | 6 | 1296 | 972 | 1 | 243.0 | 270.0 |
| 21 | 64-QAM | 2/3 | 6 | 108 | 6 | 1944 | 1296 | 2 | 324.0 | 360.0 |
| 22 | 64-QAM | 3/4 | 6 | 108 | 6 | 1944 | 1458 | 2 | 364.5 | 405.0 |
| 23 | 64-QAM | 5/6 | 6 | 108 | 6 | 1944 | 1620 | 2 | 405.0 | 450.0 |


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The rate-dependent parameters for optional 40 MHz, $N_{SS}$ = 4 MCSs, with EQM of the spatial streams shall be as shown in Table 19-34 (MCS parameters for optional 40 MHz, $N_{SS}$ = 4, EQM).

**Table 19-34—MCS parameters for optional 40 MHz, $N_{SS}$ = 4, EQM**

| MCS Index | Modulation | *R* | $N_{BPSCS}(i_{SS})$ | $N_{SD}$ | $N_{SP}$ | $N_{CBPS}$ | $N_{DBPS}$ | $N_{ES}$ | Data rate (Mb/s) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | 800 ns GI | 400 ns GI |
| 24 | BPSK | 1/2 | 1 | 108 | 6 | 432 | 216 | 1 | 54.0 | 60.0 |
| 25 | QPSK | 1/2 | 2 | 108 | 6 | 864 | 432 | 1 | 108.0 | 120.0 |
| 26 | QPSK | 3/4 | 2 | 108 | 6 | 864 | 648 | 1 | 162.0 | 180.0 |
| 27 | 16-QAM | 1/2 | 4 | 108 | 6 | 1728 | 864 | 1 | 216.0 | 240.0 |
| 28 | 16-QAM | 3/4 | 4 | 108 | 6 | 1728 | 1296 | 2 | 324.0 | 360.0 |
| 29 | 64-QAM | 2/3 | 6 | 108 | 6 | 2592 | 1728 | 2 | 432.0 | 480.0 |
| 30 | 64-QAM | 3/4 | 6 | 108 | 6 | 2592 | 1944 | 2 | 486.0 | 540.0 |
| 31 | 64-QAM | 5/6 | 6 | 108 | 6 | 2592 | 2160 | 2 | 540.0 | 600.0 |

The rate-dependent parameters for optional 40 MHz MCS 32 format with $N_{SS}$ = 1 and $N_{ES}$ = 1 shall be as shown in Table 19-35 (MCS parameters for optional 40 MHz MCS 32 format, $N_{SS}$ = 1, $N_{ES}$ = 1).

**Table 19-35—MCS parameters for optional 40 MHz MCS 32 format, $N_{SS}$ = 1, $N_{ES}$ = 1**

| MCS Index | Modulation | *R* | $N_{BPSCS}(i_{SS})$ | $N_{SD}$ | $N_{SP}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 800 ns GI | 400 ns GI |
| 32 | BPSK | 1/2 | 1 | 48 | 4 | 48 | 24 | 6.0 | 6.7 |

The rate-dependent parameters for optional 20 MHz, $N_{SS}$ = 2 MCSs with $N_{ES}$ = 1 and UEQM of the spatial streams shall be as shown in Table 19-36 (MCS parameters for optional 20 MHz, $N_{SS}$ = 2, $N_{ES}$ = 1, UEQM).

**Table 19-36—MCS parameters for optional 20 MHz, $N_{SS}$ = 2, $N_{ES}$ = 1, UEQM**

| MCS Index | Modulation | | *R* | $N_{BPSC}$ | $N_{SD}$ | $N_{SP}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Stream 1 | Stream 2 | | | | | | | 800 ns GI | 400 ns GI |
| 33 | 16-QAM | QPSK | 1/2 | 6 | 52 | 4 | 312 | 156 | 39 | 43.3 |
| 34 | 64-QAM | QPSK | 1/2 | 8 | 52 | 4 | 416 | 208 | 52 | 57.8 |
| 35 | 64-QAM | 16-QAM | 1/2 | 10 | 52 | 4 | 520 | 260 | 65 | 72.2 |
| 36 | 16-QAM | QPSK | 3/4 | 6 | 52 | 4 | 312 | 234 | 58.5 | 65.0 |
| 37 | 64-QAM | QPSK | 3/4 | 8 | 52 | 4 | 416 | 312 | 78 | 86.7 |
| 38 | 64-QAM | 16-QAM | 3/4 | 10 | 52 | 4 | 520 | 390 | 97.5 | 108.3 |

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The rate-dependent parameters for optional 20 MHz, $N_{SS}$ = 3 MCSs with $N_{ES}$ = 1 and UEQM of the spatial streams shall be as shown in Table 19-37 (MCS parameters for optional 20 MHz, $N_{SS}$ = 3, $N_{ES}$ = 1, UEQM).

**Table 19-37—MCS parameters for optional 20 MHz, $N_{SS}$ = 3, $N_{ES}$ = 1, UEQM**

| MCS Index | Modulation | | | $R$ | $N_{BPSC}$ | $N_{SD}$ | $N_{SP}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Stream 1 | Stream 2 | Stream 3 | | | | | | | 800 ns GI | 400 ns GI |
| 39 | 16-QAM | QPSK | QPSK | 1/2 | 8 | 52 | 4 | 416 | 208 | 52 | 57.8 |
| 40 | 16-QAM | 16-QAM | QPSK | 1/2 | 10 | 52 | 4 | 520 | 260 | 65 | 72.2 |
| 41 | 64-QAM | QPSK | QPSK | 1/2 | 10 | 52 | 4 | 520 | 260 | 65 | 72.2 |
| 42 | 64-QAM | 16-QAM | QPSK | 1/2 | 12 | 52 | 4 | 624 | 312 | 78 | 86.7 |
| 43 | 64-QAM | 16-QAM | 16-QAM | 1/2 | 14 | 52 | 4 | 728 | 364 | 91 | 101.1 |
| 44 | 64-QAM | 64-QAM | QPSK | 1/2 | 14 | 52 | 4 | 728 | 364 | 91 | 101.1 |
| 45 | 64-QAM | 64-QAM | 16-QAM | 1/2 | 16 | 52 | 4 | 832 | 416 | 104 | 115.6 |
| 46 | 16-QAM | QPSK | QPSK | 3/4 | 8 | 52 | 4 | 416 | 312 | 78 | 86.7 |
| 47 | 16-QAM | 16-QAM | QPSK | 3/4 | 10 | 52 | 4 | 520 | 390 | 97.5 | 108.3 |
| 48 | 64-QAM | QPSK | QPSK | 3/4 | 10 | 52 | 4 | 520 | 390 | 97.5 | 108.3 |
| 49 | 64-QAM | 16-QAM | QPSK | 3/4 | 12 | 52 | 4 | 624 | 468 | 117 | 130.0 |
| 50 | 64-QAM | 16-QAM | 16-QAM | 3/4 | 14 | 52 | 4 | 728 | 546 | 136.5 | 151.7 |
| 51 | 64-QAM | 64-QAM | QPSK | 3/4 | 14 | 52 | 4 | 728 | 546 | 136.5 | 151.7 |
| 52 | 64-QAM | 64-QAM | 16-QAM | 3/4 | 16 | 52 | 4 | 832 | 624 | 156 | 173.3 |

The rate-dependent parameters for optional 20 MHz, $N_{SS}$ = 4 MCSs with $N_{ES}$ = 1 and UEQM in the spatial streams shall be as shown in Table 19-38 (MCS parameters for optional 20 MHz, $N_{SS}$ = 4, $N_{ES}$ = 1, UEQM).

**Table 19-38—MCS parameters for optional 20 MHz, $N_{SS}$ = 4, $N_{ES}$ = 1, UEQM**

| MCS Index | Modulation | | | | $R$ | $N_{BPSC}$ | $N_{SD}$ | $N_{SP}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Stream 1 | Stream 2 | Stream 3 | Stream 4 | | | | | | | 800 ns GI | 400 ns GI |
| 53 | 16-QAM | QPSK | QPSK | QPSK | 1/2 | 10 | 52 | 4 | 520 | 260 | 65 | 72.2 |
| 54 | 16-QAM | 16-QAM | QPSK | QPSK | 1/2 | 12 | 52 | 4 | 624 | 312 | 78 | 86.7 |
| 55 | 16-QAM | 16-QAM | 16-QAM | QPSK | 1/2 | 14 | 52 | 4 | 728 | 364 | 91 | 101.1 |
| 56 | 64-QAM | QPSK | QPSK | QPSK | 1/2 | 12 | 52 | 4 | 624 | 312 | 78 | 86.7 |
| 57 | 64-QAM | 16-QAM | QPSK | QPSK | 1/2 | 14 | 52 | 4 | 728 | 364 | 91 | 101.1 |
| 58 | 64-QAM | 16-QAM | 16-QAM | QPSK | 1/2 | 16 | 52 | 4 | 832 | 416 | 104 | 115.6 |


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**Table 19-38—MCS parameters for optional 20 MHz, $N_{SS}$ = 4, $N_{ES}$ = 1, UEQM *(continued)***

| MCS Index | Modulation | | | | $R$ | $N_{BPSC}$ | $N_{SD}$ | $N_{SP}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Stream 1 | Stream 2 | Stream 3 | Stream 4 | | | | | | | 800 ns GI | 400 ns GI |
| 59 | 64-QAM | 16-QAM | 16-QAM | 16-QAM | 1/2 | 18 | 52 | 4 | 936 | 468 | 117 | 130.0 |
| 60 | 64-QAM | 64-QAM | QPSK | QPSK | 1/2 | 16 | 52 | 4 | 832 | 416 | 104 | 115.6 |
| 61 | 64-QAM | 64-QAM | 16-QAM | QPSK | 1/2 | 18 | 52 | 4 | 936 | 468 | 117 | 130.0 |
| 62 | 64-QAM | 64-QAM | 16-QAM | 16-QAM | 1/2 | 20 | 52 | 4 | 1040 | 520 | 130 | 144.4 |
| 63 | 64-QAM | 64-QAM | 64-QAM | QPSK | 1/2 | 20 | 52 | 4 | 1040 | 520 | 130 | 144.4 |
| 64 | 64-QAM | 64-QAM | 64-QAM | 16-QAM | 1/2 | 22 | 52 | 4 | 1144 | 572 | 143 | 158.9 |
| 65 | 16-QAM | QPSK | QPSK | QPSK | 3/4 | 10 | 52 | 4 | 520 | 390 | 97.5 | 108.3 |
| 66 | 16-QAM | 16-QAM | QPSK | QPSK | 3/4 | 12 | 52 | 4 | 624 | 468 | 117 | 130.0 |
| 67 | 16-QAM | 16-QAM | 16-QAM | QPSK | 3/4 | 14 | 52 | 4 | 728 | 546 | 136.5 | 151.7 |
| 68 | 64-QAM | QPSK | QPSK | QPSK | 3/4 | 12 | 52 | 4 | 624 | 468 | 117 | 130.0 |
| 69 | 64-QAM | 16-QAM | QPSK | QPSK | 3/4 | 14 | 52 | 4 | 728 | 546 | 136.5 | 151.7 |
| 70 | 64-QAM | 16-QAM | 16-QAM | QPSK | 3/4 | 16 | 52 | 4 | 832 | 624 | 156 | 173.3 |
| 71 | 64-QAM | 16-QAM | 16-QAM | 16-QAM | 3/4 | 18 | 52 | 4 | 936 | 702 | 175.5 | 195.0 |
| 72 | 64-QAM | 64-QAM | QPSK | QPSK | 3/4 | 16 | 52 | 4 | 832 | 624 | 156 | 173.3 |
| 73 | 64-QAM | 64-QAM | 16-QAM | QPSK | 3/4 | 18 | 52 | 4 | 936 | 702 | 175.5 | 195.0 |
| 74 | 64-QAM | 64-QAM | 16-QAM | 16-QAM | 3/4 | 20 | 52 | 4 | 1040 | 780 | 195 | 216.7 |
| 75 | 64-QAM | 64-QAM | 64-QAM | QPSK | 3/4 | 20 | 52 | 4 | 1040 | 780 | 195 | 216.7 |
| 76 | 64-QAM | 64-QAM | 64-QAM | 16-QAM | 3/4 | 22 | 52 | 4 | 1144 | 858 | 214.5 | 238.3 |

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The rate-dependent parameters for optional 40 MHz, $N_{SS}$ = 2 MCSs with $N_{ES}$ = 1 and UEQM of the spatial streams shall be as shown in Table 19-39 (MCS parameters for optional 40 MHz, $N_{SS}$ = 2, $N_{ES}$ = 1, UEQM).

**Table 19-39—MCS parameters for optional 40 MHz, $N_{SS}$ = 2, $N_{ES}$ = 1, UEQM**

| MCS Index | Modulation | | $R$ | $N_{BPSC}$ | $N_{SD}$ | $N_{SP}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Stream 1 | Stream 2 | | | | | | | 800 ns GI | 400 ns GI |
| 33 | 16-QAM | QPSK | 1/2 | 6 | 108 | 6 | 648 | 324 | 81 | 90 |
| 34 | 64-QAM | QPSK | 1/2 | 8 | 108 | 6 | 864 | 432 | 108 | 120 |
| 35 | 64-QAM | 16-QAM | 1/2 | 10 | 108 | 6 | 1080 | 540 | 135 | 150 |
| 36 | 16-QAM | QPSK | 3/4 | 6 | 108 | 6 | 648 | 486 | 121.5 | 135 |
| 37 | 64-QAM | QPSK | 3/4 | 8 | 108 | 6 | 864 | 648 | 162 | 180 |
| 38 | 64-QAM | 16-QAM | 3/4 | 10 | 108 | 6 | 1080 | 810 | 202.5 | 225 |

The rate-dependent parameters for optional 40 MHz, $N_{SS}$ = 3 MCSs, with UEQM of the spatial streams shall be as shown in Table 19-40 (MCS parameters for optional 40 MHz, $N_{SS}$ = 3, UEQM).

**Table 19-40—MCS parameters for optional 40 MHz, $N_{SS}$ = 3, UEQM**

| MCS Index | Modulation | | | $R$ | $N_{BPSC}$ | $N_{SD}$ | $N_{SP}$ | $N_{CBPS}$ | $N_{DBPS}$ | $N_{ES}$ | Data rate (Mb/s) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Stream 1 | Stream 2 | Stream 3 | | | | | | | | 800 ns GI | 400 ns GI |
| 39 | 16-QAM | QPSK | QPSK | 1/2 | 8 | 108 | 6 | 864 | 432 | 1 | 108 | 120 |
| 40 | 16-QAM | 16-QAM | QPSK | 1/2 | 10 | 108 | 6 | 1080 | 540 | 1 | 135 | 150 |
| 41 | 64-QAM | QPSK | QPSK | 1/2 | 10 | 108 | 6 | 1080 | 540 | 1 | 135 | 150 |
| 42 | 64-QAM | 16-QAM | QPSK | 1/2 | 12 | 108 | 6 | 1296 | 648 | 1 | 162 | 180 |
| 43 | 64-QAM | 16-QAM | 16-QAM | 1/2 | 14 | 108 | 6 | 1512 | 756 | 1 | 189 | 210 |
| 44 | 64-QAM | 64-QAM | QPSK | 1/2 | 14 | 108 | 6 | 1512 | 756 | 1 | 189 | 210 |
| 45 | 64-QAM | 64-QAM | 16-QAM | 1/2 | 16 | 108 | 6 | 1728 | 864 | 1 | 216 | 240 |
| 46 | 16-QAM | QPSK | QPSK | 3/4 | 8 | 108 | 6 | 864 | 648 | 1 | 162 | 180 |
| 47 | 16-QAM | 16-QAM | QPSK | 3/4 | 10 | 108 | 6 | 1080 | 810 | 1 | 202.5 | 225 |
| 48 | 64-QAM | QPSK | QPSK | 3/4 | 10 | 108 | 6 | 1080 | 810 | 1 | 202.5 | 225 |
| 49 | 64-QAM | 16-QAM | QPSK | 3/4 | 12 | 108 | 6 | 1296 | 972 | 1 | 243 | 270 |
| 50 | 64-QAM | 16-QAM | 16-QAM | 3/4 | 14 | 108 | 6 | 1512 | 1134 | 1 | 283.5 | 315 |
| 51 | 64-QAM | 64-QAM | QPSK | 3/4 | 14 | 108 | 6 | 1512 | 1134 | 1 | 283.5 | 315 |
| 52 | 64-QAM | 64-QAM | 16-QAM | 3/4 | 16 | 108 | 6 | 1728 | 1296 | 2 | 324 | 360 |


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The rate-dependent parameters for optional 40 MHz, $N_{SS}$ = 4 MCSs, with UEQM of the spatial streams shall be as shown in Table 19-41 (MCS parameters for optional 40 MHz, $N_{SS}$ = 4, UEQM).

**Table 19-41—MCS parameters for optional 40 MHz, $N_{SS}$ = 4, UEQM**

| MCS Index | Modulation | | | | $R$ | $N_{BPSC}$ | $N_{SD}$ | $N_{SP}$ | $N_{CBPS}$ | $N_{DBPS}$ | $N_{ES}$ | Data rate (Mb/s) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Stream 1 | Stream 2 | Stream 3 | Stream 4 | | | | | | | | 800 ns GI | 400 ns GI |
| 53 | 16-QAM | QPSK | QPSK | QPSK | 1/2 | 10 | 108 | 6 | 1080 | 540 | 1 | 135 | 150 |
| 54 | 16-QAM | 16-QAM | QPSK | QPSK | 1/2 | 12 | 108 | 6 | 1296 | 648 | 1 | 162 | 180 |
| 55 | 16-QAM | 16-QAM | 16-QAM | QPSK | 1/2 | 14 | 108 | 6 | 1512 | 756 | 1 | 189 | 210 |
| 56 | 64-QAM | QPSK | QPSK | QPSK | 1/2 | 12 | 108 | 6 | 1296 | 648 | 1 | 162 | 180 |
| 57 | 64-QAM | 16-QAM | QPSK | QPSK | 1/2 | 14 | 108 | 6 | 1512 | 756 | 1 | 189 | 210 |
| 58 | 64-QAM | 16-QAM | 16-QAM | QPSK | 1/2 | 16 | 108 | 6 | 1728 | 864 | 1 | 216 | 240 |
| 59 | 64-QAM | 16-QAM | 16-QAM | 16-QAM | 1/2 | 18 | 108 | 6 | 1944 | 972 | 1 | 243 | 270 |
| 60 | 64-QAM | 64-QAM | QPSK | QPSK | 1/2 | 16 | 108 | 6 | 1728 | 864 | 1 | 216 | 240 |
| 61 | 64-QAM | 64-QAM | 16-QAM | QPSK | 1/2 | 18 | 108 | 6 | 1944 | 972 | 1 | 243 | 270 |
| 62 | 64-QAM | 64-QAM | 16-QAM | 16-QAM | 1/2 | 20 | 108 | 6 | 2160 | 1080 | 1 | 270 | 300 |
| 63 | 64-QAM | 64-QAM | 64-QAM | QPSK | 1/2 | 20 | 108 | 6 | 2160 | 1080 | 1 | 270 | 300 |
| 64 | 64-QAM | 64-QAM | 64-QAM | 16-QAM | 1/2 | 22 | 108 | 6 | 2376 | 1188 | 1 | 297 | 330 |
| 65 | 16-QAM | QPSK | QPSK | QPSK | 3/4 | 10 | 108 | 6 | 1080 | 810 | 1 | 202.5 | 225 |
| 66 | 16-QAM | 16-QAM | QPSK | QPSK | 3/4 | 12 | 108 | 6 | 1296 | 972 | 1 | 243 | 270 |
| 67 | 16-QAM | 16-QAM | 16-QAM | QPSK | 3/4 | 14 | 108 | 6 | 1512 | 1134 | 1 | 283.5 | 315 |
| 68 | 64-QAM | QPSK | QPSK | QPSK | 3/4 | 12 | 108 | 6 | 1296 | 972 | 1 | 243 | 270 |
| 69 | 64-QAM | 16-QAM | QPSK | QPSK | 3/4 | 14 | 108 | 6 | 1512 | 1134 | 1 | 283.5 | 315 |
| 70 | 64-QAM | 16-QAM | 16-QAM | QPSK | 3/4 | 16 | 108 | 6 | 1728 | 1296 | 2 | 324 | 360 |

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**Table 19-41—MCS parameters for optional 40 MHz, $N_{SS}$ = 4, UEQM *(continued)***

| MCS Index | Modulation | | | | $R$ | $N_{BPSC}$ | $N_{SD}$ | $N_{SP}$ | $N_{CBPS}$ | $N_{DBPS}$ | $N_{ES}$ | Data rate (Mb/s) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Stream 1 | Stream 2 | Stream 3 | Stream 4 | | | | | | | | 800 ns GI | 400 ns GI |
| 71 | 64-QAM | 16-QAM | 16-QAM | 16-QAM | 3/4 | 18 | 108 | 6 | 1944 | 1458 | 2 | 364.5 | 405 |
| 72 | 64-QAM | 64-QAM | QPSK | QPSK | 3/4 | 16 | 108 | 6 | 1728 | 1296 | 2 | 324 | 360 |
| 73 | 64-QAM | 64-QAM | 16-QAM | QPSK | 3/4 | 18 | 108 | 6 | 1944 | 1458 | 2 | 364.5 | 405 |
| 74 | 64-QAM | 64-QAM | 16-QAM | 16-QAM | 3/4 | 20 | 108 | 6 | 2160 | 1620 | 2 | 405 | 450 |
| 75 | 64-QAM | 64-QAM | 64-QAM | QPSK | 3/4 | 20 | 108 | 6 | 2160 | 1620 | 2 | 405 | 450 |
| 76 | 64-QAM | 64-QAM | 64-QAM | 16-QAM | 3/4 | 22 | 108 | 6 | 2376 | 1782 | 2 | 445.5 | 495 |


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# 20. Directional multi-gigabit (DMG) PHY specification

## 20.1 DMG PHY introduction

### 20.1.1 Scope of DMG PHY services

The DMG PHY supports two modulation methods:

— A control modulation using MCS 0 (the DMG control mode; see 20.4 (DMG control mode))

— A single carrier (SC) modulation using MCS 1 to MCS 12, MCS 9.1, 12.1, 12.2, 12.3, 12.4, 12.5, and 12.6 (the DMG SC mode; see 20.5 (DMG SC mode)) and MCS 25 to MCS 31 (the DMG low-power SC mode; see 20.6 (DMG low-power SC mode))

All DMG modulation methods share a similar preamble (see 20.3.6 (Common preamble)).

The services provided to the MAC by the DMG PHY consist of the following protocol functions:

a) A function that defines a method of mapping the PHY service data units (PSDU) into a framing format (PPDU) suitable for sending and receiving PSDUs between two or more STAs.

b) A function that defines the characteristics and method of transmitting and receiving data through a wireless medium between two or more STAs. Depending on the DMG MCSs, these STAs support a mixture of DMG SC mode, DMG low-power SC mode, and DMG control mode.

### 20.1.2 DMG PHY functions

The DMG PHY contains two functional entities: the PHY and the layer management function (PLME). Each of these functions is described in detail in 20.3 (Common parameters) to 20.11 (DMG PLME). The DMG PHY service is provided to the MAC through the PHY service primitives defined in Clause 8 (PHY service specification).

#### 20.1.2.1 PHY management entity (PLME)

The PLME performs management of the local PHY functions in conjunction with the MLME.

#### 20.1.2.2 Service specification method

The models represented by figures and state diagrams are intended to be illustrations of the functions provided. It is important to distinguish between a model and a real implementation. The models are optimized for simplicity and clarity of presentation, but do not necessarily reflect any particular implementation. The service of a layer or sublayer is the set of capabilities that it offers to a user in the next higher layer (or sublayer). Abstract services are specified here by describing the service primitives and parameters that characterize each service. This definition is independent of any particular implementation.

## 20.2 DMG PHY service interface

### 20.2.1 Introduction

The PHY interfaces to the MAC through the TXVECTOR, RXVECTOR, and the PHYCONFIG_VECTOR. Using the TXVECTOR, the MAC supplies the PHY with per-PPDU transmit parameters. Using the RXVECTOR, the PHY informs the MAC of the received (#14)PPDU's parameters. Using the PHYCONFIG_VECTOR, the MAC configures the PHY for operation, independent of (#14)PPDU transmission or reception.

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This interface is an extension of the generic PHY service interface defined in 8.3.4 (Basic service and options).

### 20.2.2 TXVECTOR and RXVECTOR parameters

The parameters in Table 20-1 (TXVECTOR and RXVECTOR parameters) are defined as part of the TXVECTOR parameter list in the PHY-TXSTART.request primitive and/or as part of the RXVECTOR parameter list in the PHY-RXSTART.indication primitive.

**Table 20-1—TXVECTOR and RXVECTOR parameters**

| Parameter | Value | TXVECTOR | RXVECTOR |
|---|---|---|---|
| MCS | The MCS parameter is an enumerated type that indicates the modulation and coding scheme used in the transmission of the (#14)PPDU. Values are integers in the range 0 to 31 and the values 9.1, 12.1, 12.2, 12.3, 12.4, 12.5 and 12.6.<br>— An MCS value of 0 indicates the use of DMG control mode.<br>— MCS values of 1 to 12 and 9.1, 12.1, 12.2, 12.3, 12.4, 12.5, 12.6 indicate use of single carrier modulations. The value is an index to Table 20-15 (DMG SC mode modulation and coding schemes).<br>— MCS values of 25 to 31 indicate use of DMG low-power SC mode. The value is an index to Table 20-21 (DMG low-power SC mode modulation and coding schemes). | Y | Y |
| LENGTH | Indicates the number of octets in the PSDU in the range 1 to 262 143. | Y | Y |
| ADD_PPDU | Enumerated Type:<br>— ADD-PPDU indicates that this PPDU is immediately followed by another PPDU with no IFS or preamble on the subsequent PPDU.<br>— NO-ADD-PPDU indicates no additional PPDU follows this PPDU. | Y | Y |
| PPDU_TYPE | Enumerated Type:<br>— TRN-R indicates either a PPDU whose Data field is followed by one or more TRN subfields, or a PPDU that is requesting TRN subfields to be appended to a future response PPDU.<br>— TRN-T indicates a PPDU whose Data field is followed by one or more TRN subfields. The transmitter may change AWV configuration at the beginning of each TRN subfield.<br>This parameter is reserved if TRN_LEN is 0. | Y | Y |
| TRN_LEN | TRN_LEN indicates the length of the training field. Values are in the range 0–16 (see 20.9.2.2.3 (BRP PPDU Header field(#6409))). | Y | Y |
| AGGREGATION | Indicates whether the PSDU contains an A-MPDU.<br>Enumerated Type:<br>— AGGREGATED indicates this is a PSDU with A-MPDU aggregation.<br>— NOT_AGGREGATED indicates this is a PSDU without A-MPDU aggregation. | Y | Y |


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**Table 20-1—TXVECTOR and RXVECTOR parameters *(continued)***

| Parameter | Value | TXVECTOR | RXVECTOR |
|---|---|---|---|
| RSSI | The allowed values for the RSSI parameter are in the range 0 to 255. This parameter is a (#1132)measurement by the PHY of the power observed at the input of the antennas plus the antenna gain, or equivalent antenna gain for a phased-array antenna, used to receive the current PPDU. RSSI shall be measured during the reception of the PHY preamble. RSSI is intended to be used in a relative manner, and it shall be a monotonically increasing function of the received power. | N | Y |
| SNR | This parameter indicates the SNR measured during the reception of a DMG control mode (#14)PPDU. Values are –13 dB to 50.75 dB in 0.25 dB steps. | N | Y |
| RCPI | Is a measure of the received RF power measured over the preamble (#3475)of the current (#14)PPDU. Refer to 20.3.10 (Received channel power indicator (RCPI) measurement) for the definition of RCPI. | N | Y |
| ANT_CONFIG | Indicates which antenna configuration(s) is to be used throughout the transmission of the (#14)PPDU, and when to switch between configurations.<br>Values are implementation dependent. | Y | N |
| CHAN_MEASUREMENT | Channel as measured during the reception of TRN subfields. Each measurement includes 63 complex numbers. | N | Y |
| TIME_OF_DEPARTURE_REQUESTED | Enumerated type:<br>— true indicates that the MAC entity requests that the PHY PHY entity measures and reports time of departure parameters corresponding to the time when the first (#14)PPDU energy is sent by the transmitting port.<br>— false indicates that the MAC entity requests that the PHY PHY entity neither measures nor reports time of departure parameters. | O | N |
| RX_START_OF_FRAME_OFFSET | 0 to $2^{32}$–1. An estimate of the offset (in 10 ns(#7198) units) from the point in time at which the start of the preamble (#14)of the PPDU arrived at the receive antenna connector to the point in time at which this primitive is issued to the MAC. | N | See NOTE |
| BEAM_TRACKING_REQUEST | This parameter indicates whether beam tracking is requested.<br>Enumerated type:<br>BEAM-TRACKING-REQUESTED or BEAM-TRACKING-NOT-REQUESTED | Y | Y |
| LAST_RSSI | In the TXVECTOR, LAST_RSSI indicates the received power level of the last (#14)PPDU with a valid PHY header that was received a SIFS before transmission of the current (#14)PPDU; otherwise, it is set to 0(#464) (10.3.2.3.3 (SIFS)).<br><br>In the RXVECTOR, LAST_RSSI indicates the value of the LAST_RSSI field from the (#14)header of the received PPDU. Valid values are integers in the range 0 to 15:<br>— Values of 2 to 14 represent power levels (–71+value×2) dBm.<br>— A value of 15 represents power greater than or equal to –42 dBm.<br>— A value of 1 represents power less than or equal to –68 dBm.<br>— A value of 0 indicates that the previous (#14)PPDU was not received a SIFS before the current transmission. | Y | Y |

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**Table 20-1—TXVECTOR and RXVECTOR parameters *(continued)***

| Parameter | Value | TXVECTOR | RXVECTOR |
|---|---|---|---|
| TURNAROUND | Set to 1 or 0 as specified in 10.3.2.3.3 (SIFS). | Y | Y |
| PSK_APPLIED | Indicates if π/2-8-PSK is applied for MCS 10 or MCS 11. π/2-8-PSK cannot be applied for MCS other than 10 or 11.<br>Enumerated Type:<br>PSK_APPLIED: indicates that π/2-8-PSK is applied.<br>PSK_NOT_APPLIED: indicates that π/2-8-PSK is not applied. | Y | Y |
| (11ay)SCRAM-BLER_RESET | Indicates that the scrambler should be reset before the start of the PPDU.<br><br>Enumerated Type:<br>RESET_SCRAMBLER: The scrambler should be reset.<br>NO_SCRAMBLER_RESET: The scrambler should not be reset. | Y | N |
| NOTE— "Y" if dot11TimingMsmtActivated is true, otherwise "N". | | | |

### 20.2.3 PHYCONFIG_VECTOR parameters

The PHYCONFIG_VECTOR carried in a PHY-CONFIG.request primitive for a DMG PHY contains an OPERATING_CHANNEL parameter, which identifies the operating 2.16 GHz channel. The PHY shall set the channel number to 1, 2, 3, 4, 5, 6, 7, or 8 using the value of OPERATING_CHANNEL parameter, which shall be set to 1, 3, 5, 7, 9, 11, 13, or 15 as defined in 20.3.1 (Channelization). (#4384)Additional PHYCONFIG_VECTOR parameters are defined in Table 8-4 (Vector descriptions(#4383)).

### 20.2.4 TXSTATUS parameters

The parameters listed in Table 20-2 (TXSTATUS parameters) are defined as part of the TXSTATUS parameter list in the PHY-TXSTART.confirm primitive.

**Table 20-2—TXSTATUS parameters**

| Parameter | Value |
|---|---|
| TIME_OF_DEPARTURE | When the first (#14)PPDU energy is sent by the transmitting port, in units equal to 1/TIME_OF_DEPARTURE_ClockRate.<br>This parameter is present only if TIME_OF_DEPARTURE_REQUESTED is true in the corresponding request. |
| TIME_OF_DEPARTURE_ClockRate | 0 to $2^{16}$–1. The clock rate, in units of MHz, is used to generate the TIME_OF_DEPARTURE value. This parameter is present only if TIME_OF_DEPARTURE_REQUESTED is true in the corresponding request. |
| TX_START_OF_FRAME_OFFSET | 0 to $2^{32}$–1. An estimate of the offset (in 10 ns(#7198) units) from the point in time at which the start of the preamble (#14)of the PPDU was transmitted at the transmit antenna connector to the point in time at which this primitive is issued to the MAC. |


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## 20.3 Common parameters

### 20.3.1 Channelization

The DMG PHY operates in the channels defined in Annex E and shall support channel number 2 and may support the other channels.

The channel center frequency is defined as:

Channel center frequency = Channel starting frequency + Channel spacing × Channel number

where the channel starting frequency is equal to 56.16 GHz, and the channel spacing is defined in Annex E.

The OPERATING_CHANNEL parameter of PHYCONFIG_VECTOR is used to set up the operating channel number. The OPERATING_CHANNEL shall be set to 1, 3, 5, 7, 9, 11, 13, or 15. The relation between the channel number and OPERATING_CHANNEL is defined as follows:

*Channel number = ½ × (OPERATING_CHANNEL + 1)*

### 20.3.2 Transmit mask

The transmitted spectrum shall adhere to the transmit spectrum mask shown in (#6291)Figure 20-1 (Transmit mask). The transmit spectrum shall have a 0 dBr (dB relative to the maximum spectral density of the signal) bandwidth not exceeding 1.88 GHz, –17 dBr at a 1.2 GHz offset, –22 dBr at a 2.7 GHz offset and –30 dBr at a 3.06 GHz offset and above, inside the channels allowed for the regulatory domain in which the device is transmitting. The measurement shall be made using a 1 MHz resolution bandwidth and a 300 kHz video bandwidth.

The transmit mask shall be measured on PPDUs longer than 10 μs without training fields.

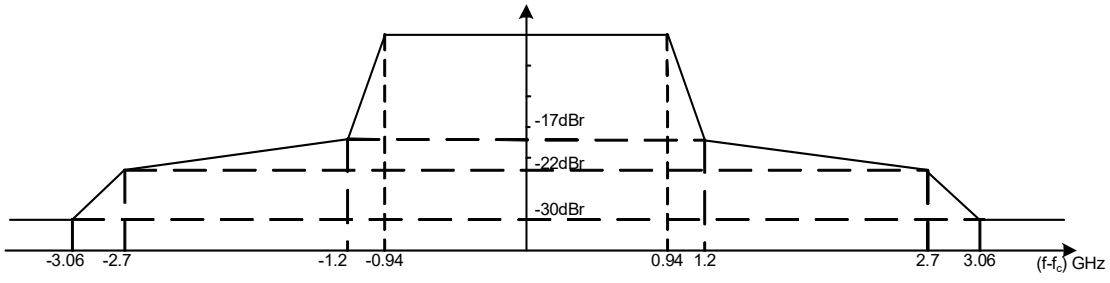


**Figure 20-1—Transmit mask**

### 20.3.3 Common requirements

#### 20.3.3.1 Introduction

This subclause describes the common requirement from all three DMG modes: control, SC, and low-power SC.

In all of the modes, all defined fields are transmitted bit 0 first in time.

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#### 20.3.3.2 Center frequency tolerance

##### 20.3.3.2.1 General

The transmitter center frequency tolerance shall be ± 20 ppm.

##### 20.3.3.2.2 Center frequency convergence

The transmitter center frequency shall converge to within 1 ppm of its final value within 0.9 μs from the start of the (#14)PPDU.

#### 20.3.3.3 Symbol clock tolerance

The symbol clock frequency tolerance shall be ± 20 ppm.

The transmit center frequency and the symbol clock frequency shall be derived from the same reference oscillator.

#### 20.3.3.4 Transmit center frequency leakage

The transmitter center frequency leakage shall not exceed –23 dB relative to the overall transmitted power.

#### 20.3.3.5 Transmit rampup and rampdown

The transmit power-on ramp is defined as the time it takes for a transmitter to rise from less than 10% to greater than 90% of the average power to be transmitted in the (#14)PPDU.

The transmit power-on ramp shall be less than 10 ns.

The transmit power-down ramp is defined as the time it takes the transmitter to fall from greater than 90% to less than 10% of the maximum power to be transmitted in the (#14)PPDU.

The transmit power-down ramp shall be less than 10 ns.

#### 20.3.3.6 Antenna setting

Antenna setting shall remain constant for the transmission of the entire (#14)PPDU except for the case of transmission of BRP-TX PPDUs (see 20.9.2.2 (Beam refinement)). During the transmission of BRP-TX PPDUs, it shall remain constant for the transmission of the STF, CE field, and Data field.

#### 20.3.3.7 Maximum input requirement

The receiver maximum input level is the maximum power level at the receive antenna(s) of the incoming signal, in dBm, present at the input of the receiver antenna for which the error rate criterion (defined in 20.3.3.8 (Receive minimum input level sensitivity(#256))) is met. A receiver shall have a receiver maximum input level at the receive antenna(s) of at least 10 $\mu W/cm^2$ for each of the modulation formats that the receiver supports.

#### 20.3.3.8 Receive minimum input level sensitivity(#256)

For MCS 0, the PER shall be less than 5% for a PSDU length of 256 octets with the MCS dependent input levels listed in Table 20-3 (Receiver minimum input level sensitivity) defined at the antenna connector. For


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the other MCSs, the PER shall be less than 1% for a PSDU length of 4096 octets with the MCS dependent input levels listed in Table 20-3 (Receiver minimum input level sensitivity) defined at the antenna connector.

NOTE—For RF power measurements performed over the air, the input level shall be corrected to compensate for the antenna gain in the implementation. The gain of the antenna is the maximum estimated gain by the manufacturer. In the case of the phased-array antenna, the gain of the phased-array antenna is the maximum sum of estimated element gain minus 3 dB implementation loss.(#4045)

**Table 20-3—Receiver minimum input level sensitivity**

| MCS | Receive sensitivity (dBm) |
|---|---|
| 0 | –78 |
| 1 | –68 |
| 2 | –66 |
| 3 | –65 |
| 4 | –64 |
| 5 | –62 |
| 6 | –63 |
| 7 | –62 |
| 8 | –61 |
| 9 | –59 |
| 9.1 | –57 |
| 10 | –55 |
| 11 | –54 |
| 12 | –53 |
| 12.1 | –51 |
| 12.2 | –50 |
| 12.3 | –48 |
| 12.4 | –46 |
| 12.5 | –44 |
| 12.6 | –42 |
| 25 | –64 |
| 26 | –60 |
| 27 | –57 |
| 28 | –57 |
| 29 | –57 |
| 30 | –57 |
| 31 | –57 |

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### 20.3.4 Timing-related parameters

Table 20-4 (Timing-related parameters) defines timing-related parameters.

**Table 20-4—Timing-related parameters**

| Parameter | Value |
|---|---|
| $N_{GI}$ | aSCGILength<br>NOTE—aSCGILength is defined in Table 20-30 (DMG PHY characteristics) |
| $N_{SPB}$ | 448 |
| $F_c$: chip rate | 1760 MHz |
| $T_c$: chip time | $1 / F_c$ (~0.57 ns) |
| $T_{seq}$ | $128 \times T_c$ (~72.7 ns) |
| $T_{STF}$: Detection sequence duration | $17 \times T_{seq}$ (~1236 ns) |
| $T_{CE}$: Channel Estimation sequence duration | $9 \times T_{seq}$ (~655 ns) |
| $T_{HEADER}$: header duration | $2 \times$ aSCBlockSize $\times T_c$ (~0.582 μs)<br>NOTE—aSCGIBlockSize is defined in Table 20-30 (DMG PHY characteristics) |
| $T_{STF\text{-}CM}$: control mode short training field duration | $50 \times T_{seq}$ (~3.636 μs) |
| $T_{CE\text{-}CM}$: control mode channel estimation field duration | $T_{CE}$ (~655 ns) |
| $T_{Data}$ | ($N_{BLKS} \times$ aSCBlockSize + aSCGILength) $\times T_c$<br>NOTE—$N_{BLKS}$ is defined in 20.5.3.2.3.3 (LDPC encoding process) and aSCBlockSize and aSCGILength are defined in Table 20-30 (DMG PHY characteristics). |

Table 20-5 (Frequently used parameters) defines parameters used frequently in Clause 20 (Directional multi-gigabit (DMG) PHY specification).

**Table 20-5—Frequently used parameters**

| Symbol | Explanation |
|---|---|
| $N_{CBPS}$ | Number of coded bits per symbol |
| $N_{DBPS}$ | Number of data bits per symbol |
| $R$ | Code rate |


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### 20.3.5 Mathematical conventions in the signal description

#### 20.3.5.1 General

The transmitted signal is described in complex baseband signal notation. The actual transmitted signal is related to the complex baseband signal $r(t)$ by the following relation:

$$r_{RF}(t) = \mathrm{Re}\{r(t)\exp(j2\pi f_c t)\}$$

where

$f_C$ is the center frequency of the carrier

The transmitted RF signal is generated by modulating the complex baseband signal, which consists of several fields. The fields and the timing boundaries for the various fields are shown in Figure 20-2 (PPDU structure).

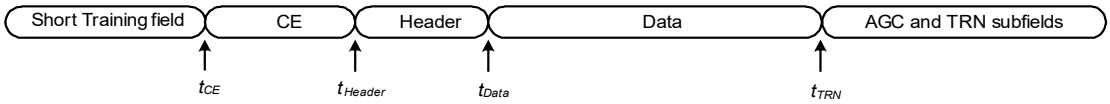


**Figure 20-2—PPDU structure**

The time offset, $t_{Field}$, determines the starting time of the corresponding field.

$$r_{PPDU}(t) = r_{STF}(t) + r_{CE}(t - t_{CE}) + r_{Header}(t - t_{Header}) + r_{Data}(t - t_{Data}) + r_{TRN}(t - t_{TRN})$$

where

$$t_{CE} = T_{STF}$$
$$t_{Header} = t_{CE} + T_{CE}$$
$$t_{Data} = t_{Header} + T_{Header}$$
$$t_{TRN} = t_{Data} + T_{Data}$$

The base band waveform for fields defined by time domain sequences or for single carrier transmission is

$$r_{Field}(nT_C) = x(n)$$

where

$x(n)$ is the constellation point $n$

Conversion from the sampled digital domain to the continuous time domain is beyond the scope of this document. Filtering for pulse shaping such as in GMSK is beyond the scope of this standard.

### 20.3.6 Common preamble

#### 20.3.6.1 General

The preamble is the part of the PPDU that is used for (#14)PPDU detection, AGC, frequency offset estimation, synchronization, and channel estimation. The format of the preamble consists of a Short

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Training field followed by a Channel Estimation field. Figure 20-3 (SC preamble) illustrates the SC (#14)PPDU preamble.

**Figure 20-3—SC preamble**

All numeric fields are transmitted in unsigned format, LSB first.

### 20.3.6.2 Short Training field

The Short Training field is composed of 16 repetitions of sequences $Ga_{128}(n)$ of length 128 defined in 20.10 (Golay sequences), followed by a single repetition of $-Ga_{128}(n)$.

The waveform for the Short Training field is

$$r_{STF}(nT_c) = \begin{cases} (Ga_{128}(n \bmod 128))\exp\left(j\pi\frac{n}{2}\right) & n = 0, 1, \ldots, 16 \times 128 - 1 \\ (-Ga_{128}(n \bmod 128))\exp\left(j\pi\frac{n}{2}\right) & n = 16 \times 128, \ldots, 17 \times 128 - 1 \end{cases}$$

where
*mod* is the modulus operation

### 20.3.6.3 Channel Estimation field

The Channel Estimation field is used for channel estimation, as well as indication of which modulation is going to be used for the (#14)PPDU. The Channel Estimation field is composed of a concatenation of two sequences $Gu_{512}(n)$ and $Gv_{512}(n)$, where the last 128 samples of $Gu_{512}(n)$ and $Gv_{512}(n)$ are equal to the last 128 samples used in the Short Training field. They are followed by a 128 samples sequence $Gv_{128}(n)$ equal to the first 128 samples of both $Gv_{512}(n)$ and $Gu_{512}(n)$.

The $Gu_{512}$ and $Gv_{512}$ sequences are defined as

$$G_{u_{512}} = \left[-Gb_{128} \quad -Ga_{128} \quad Gb_{128} \quad -Ga_{128}\right]$$

$$G_{v_{512}} = \left[-Gb_{128} \quad Ga_{128} \quad -Gb_{128} \quad -Ga_{128}\right]$$

where
$Ga_{128}$ and $Gb_{128}$ are as defined in 20.10 (Golay sequences)

When the (#404)Data field of the (#14)PPDU is modulated using single carrier, the $Gu_{512}$ and $Gv_{512}$ fields are concatenated in the order shown in Figure 20-4 (Channel Estimation field for SC PPDUs).


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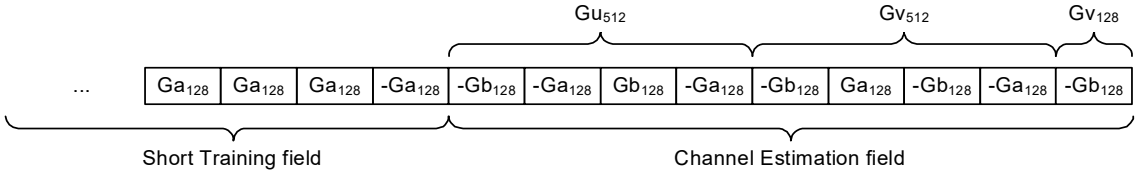


**Figure 20-4—Channel Estimation field for SC PPDUs**

The waveform for the channel estimation sequence is

$$r_{CE_{SC}}(nT_c) = (Gu_{512}(n) + Gv_{512}(n-512) + Gv_{128}(n-1024))\exp\left(j\pi\frac{n}{2}\right),\ n = 0, 1, \ldots, 1151$$

Note that sequences $Gu_{512}(n)$ and $Gv_{512}(n)$ are defined for $0 \le n \le 511$. For other values of $n$, $Gu_{512}(n)$ and $Gv_{512}(n)$ are set to 0.

### 20.3.7 HCS calculation for headers of DMG control mode and DMG SC mode

The header check sequence (HCS) is a CRC of the header bits. The header is considered to be a stream of bits $B_0, \ldots, B_{M-1}$. The CRC is based on CRC 16-CCITT. The value of the CRC field is the 1s complement of

$$CRC(D) = (M(D) \oplus I(D))D^{16} \bmod G(D)$$

where

$M(D) = B_0D^{M-1} + B_1D^{M-2} + \ldots + B_{M-1}$ is the header bits represented as polynomial (over the binary field) where $B_0$ is bit 0 of the header and $B_{M-1}$ is bit $M-1$ of the header

$I(D) = \sum_{k=M-16}^{M-1} D^k$ is an initialization polynomial added to the first 16 bits of the header (setting the shift register bits to 1)

$G(D) = D^{16} + D^{12} + D^5 + 1$ is the CRC generating polynomial

$CRC(D) = x_0D^{15} + x_1D^{14} + \ldots x_{14}D + x_{15}$

The CRC field is transmitted with $x_{15}$ first.

For a block diagram and an example of how to calculate the CRC, see 15.3.3.7 (PHY CRC field).

### 20.3.8 Common LDPC parity matrices

#### 20.3.8.1 General

Four low-density parity check (LDPC) codes are specified, each of a different rate but with a common codeword size of 672 bits.

Each of the parity-check matrices ***H*** is partitioned into square submatrices of size $Z \times Z$. The submatrices are either cyclic-permutations of the identity matrix, or null submatrices with all zero entries.

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(#577)A location with integer *i* denotes the cyclic-permutation submatrix $P_i$ obtained from the *Z x Z* identity matrix by cyclically shifting the columns to the right by *i* elements. The matrix $P_o$ is the *Z x Z* identity matrix. An empty location denotes a null submatrix of size *Z x Z*.

(#577)Examples with $Z = 4$:

$$P_0 = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad P_1 = \begin{bmatrix} 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 \end{bmatrix} \quad P_3 = \begin{bmatrix} 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix}$$

#### 20.3.8.2 Rate 1/2 LDPC code matrix H = 336 rows x 672 columns, Z = 42

**Table 20-6—Rate 1/2 LDPC code matrix**
**(Each nonblank element *i* in the table is the cyclic permutation matrix $P_i$ of size $Z \times Z$; blank entries represent the zero matrix of size $Z \times Z$)**

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 40 | | 38 | | 13 | | 5 | | 18 | | | | | | | |
| 34 | | 35 | | 27 | | | 30 | 2 | 1 | | | | | | |
| | 36 | | 31 | | 7 | | 34 | | 10 | 41 | | | | | |
| | 27 | | 18 | | 12 | 20 | | | | 15 | 6 | | | | |
| 35 | | 41 | | 40 | | 39 | | 28 | | | 3 | 28 | | | |
| 29 | | 0 | | | 22 | | 4 | | 28 | | 27 | | 23 | | |
| | 31 | | 23 | | 21 | | 20 | | | 12 | | | 0 | 13 | |
| | 22 | | 34 | 31 | | 14 | | 4 | | | | 13 | | 22 | 24 |

#### 20.3.8.3 Rate 5/8 LDPC code matrix H = 252 rows x 672 columns, Z = 42

**Table 20-7—Rate 5/8 LDPC code matrix**
**(Each nonblank element *i* in the table is the cyclic permutation matrix $P_i$ of size $Z \times Z$; blank entries represent the zero matrix of size $Z \times Z$)**

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 20 | 36 | 34 | 31 | 20 | 7 | 41 | 34 | | 10 | 41 | | | | | |
| 30 | 27 | | 18 | | 12 | 20 | 14 | 2 | 25 | 15 | 6 | | | | |
| 35 | | 41 | | 40 | | 39 | | 28 | | | 3 | 28 | | | |
| 29 | | 0 | | | 22 | | 4 | | 28 | | 27 | 24 | 23 | | |
| | 31 | | 23 | | 21 | | 20 | | 9 | 12 | | | 0 | 13 | |
| | 22 | | 34 | 31 | | 14 | | 4 | | | | | | 22 | 24 |


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#### 20.3.8.4 Rate 3/4 LDPC code matrix H = 168 rows x 672 columns, Z = 42

**Table 20-8—Rate 3/4 LDPC code matrix**
**(Each nonblank element $i$ in the table is the cyclic permutation matrix $P_i$ of size $Z \times Z$; blank entries represent the zero matrix of size $Z \times Z$)**

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 35 | 19 | 41 | 22 | 40 | 41 | 39 | 6 | 28 | 18 | 17 | 3 | 28 | | | |
| 29 | 30 | 0 | 8 | 33 | 22 | 17 | 4 | 27 | 28 | 20 | 27 | 24 | 23 | | |
| 37 | 31 | 18 | 23 | 11 | 21 | 6 | 20 | 32 | 9 | 12 | 29 | | 0 | 13 | |
| 25 | 22 | 4 | 34 | 31 | 3 | 14 | 15 | 4 | | 14 | 18 | 13 | 13 | 22 | 24 |

#### 20.3.8.5 Rate 13/16 LDPC code matrix H = 126 rows x 672 columns, Z = 42

**Table 20-9—Rate 13/16 LDPC code matrix**
**(Each nonblank element $i$ in the table is the cyclic permutation matrix $P_i$ of size $Z \times Z$; blank entries represent the zero matrix of size $Z \times Z$)**

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 29 | 30 | 0 | 8 | 33 | 22 | 17 | 4 | 27 | 28 | 20 | 27 | 24 | 23 | | |
| 37 | 31 | 18 | 23 | 11 | 21 | 6 | 20 | 32 | 9 | 12 | 29 | 10 | 0 | 13 | |
| 25 | 22 | 4 | 34 | 31 | 3 | 14 | 15 | 4 | 2 | 14 | 18 | 13 | 13 | 22 | 24 |

### 20.3.9 Scrambler

(#404)(#6409)The Header field and Data field following the scrambler initialization field (including data padding bits) shall be scrambled by XORing each bit in turn with a length 127 periodic sequence generated by the polynomial $S(x) = x^7 + x^4 + 1$. The PHY header bits, with the exception of the first seven bits for SC and the first five bits for control mode, are placed one after the other, bit 7 first (bit 5 first for DMG control mode). The octets of the PSDU and the pad bits shall be placed into a bit stream with bit 0 (LSB) of each octet first and bit 7 of each octet (MSB) last. The generation of the sequence and the XOR operation are defined in Figure 20-5 (Data scrambler).

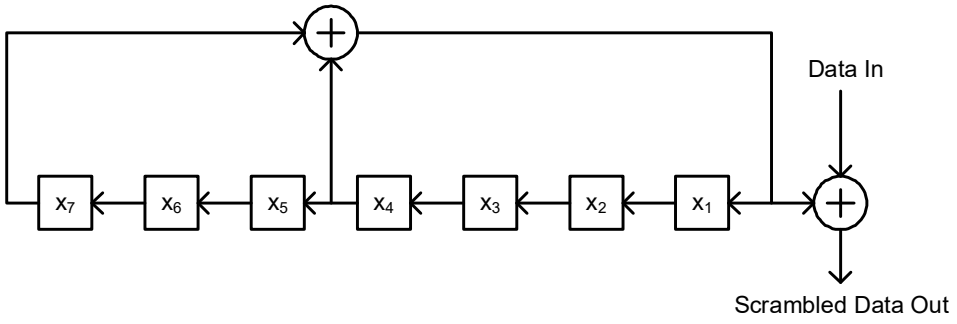


**Figure 20-5—Data scrambler**

For each PPDU, the transmitter shall select a nonzero seed value for the scrambler (bits $x_1$ to $x_7$). The seed value should be selected in a pseudorandom fashion. (11ay)If the SCRAMBLER_RESET parameter

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is(M118) equal to RESET_SCRAMBLER, the seed value should be set to a nonzero random value not based on the scrambler value at the end of the last transmitted PPDU, before changes required to indicate MCSs in the set {9.1, 12.1, 12.2, 12.3, 12.4, 12.5, 12.6} are applied. The seed value is sent in the Scrambler Initialization field of the PHY header. Each data bit in the (#404)Data field of the PPDU is then XORed with the scrambler output ($x_4 \oplus x_7$) and then the scrambler content is shifted once.

### 20.3.10 Received channel power indicator (RCPI) measurement

The RCPI is a measure of the received RF power in the selected channel for a received (#14)PPDU. This parameter shall be a (#1132)measurement by the PHY of the received RF power in the channel measured over the preamble of the received (#14)PPDU.

(#2011)RCPI shall equal the received RF power in dBm with an accuracy of ± 5 dB with 95% confidence interval within the specified dynamic range of the receiver. The relative error between RF power measurements made within a (#1153)one second interval should be less than ± 1 dB.

## 20.4 DMG control mode

### 20.4.1 Introduction

Transmission and reception of control mode PPDUs is mandatory. DMG control mode uses the same chip rate as the DMG SC mode. DMG control mode is transmitted when the TXVECTOR indicates MCS 0.

The modulation and coding scheme for the DMG control mode is shown in Table 20-10 (DMG control mode modulation and coding scheme).

**Table 20-10—DMG control mode modulation and coding scheme**

| MCS index | Modulation | Code rate | Data rate |
|---|---|---|---|
| 0 | DBPSK | 1/2[a] | 27.5 Mb/s[a] |

[a] Code rate and data rate might be lower due to codeword shortening.

### 20.4.2 PPDU format

(#1916)The DMG control mode PPDU is shown in Figure 20-6 (DMG control mode PPDU format).

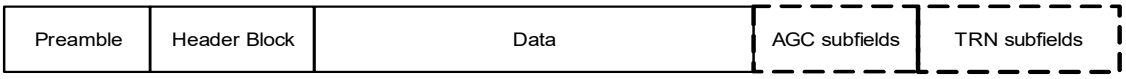


**Figure 20-6—DMG control mode PPDU format**


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### 20.4.3 Transmission

#### 20.4.3.1 Preamble

##### 20.4.3.1.1 General

The preamble is the part of the DMG control mode PPDU that is used for (#14)PPDU detection, AGC, frequency offset estimation, synchronization, indication of PPDU type and channel estimation.

The preamble is composed of two parts as shown in Figure 20-7 (DMG control mode preamble): the Short Training field and the Channel Estimation field.

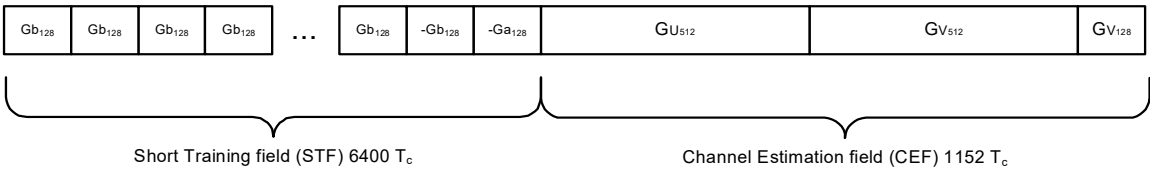


**Figure 20-7—DMG control mode preamble**

##### 20.4.3.1.2 Short Training field

The Short Training field is composed of 48 repetitions of the sequence $Gb_{128}(n)$ of length 128, followed by a single –Gb128(n) sequence (for synchronization) and then a single –Ga128(n) sequence. The sequences $Ga_{128}(n)$ and $Gb_{128}(n)$ are defined in 20.10 (Golay sequences).

The waveform for the Short Training field is

$$r_{STF}(nT_c) = \begin{cases} Gb_{128}(n \bmod 128)\exp\left(j\pi\frac{n}{2}\right) & n = 0, 1, \ldots, 48 \times 128 - 1 \\ -Gb_{128}(n \bmod 128)\exp\left(j\pi\frac{n}{2}\right) & n = 48 \times 128, \ldots, 49 \times 128 - 1 \\ -Ga_{128}(n \bmod 128)\exp\left(j\pi\frac{n}{2}\right) & n = 49 \times 128, \ldots, 50 \times 128 - 1 \end{cases}$$

where mod is the modulus operation. Note that sequences $Ga_{128}(n)$ and $Gb_{128}(n)$ are defined for $0 \le n \le 127$. For other $n$ they are set to 0.

##### 20.4.3.1.3 Channel Estimation field

The Channel Estimation field is the same as the Channel Estimation field of the DMG SC mode, as defined in Figure 20-4 (Channel Estimation field for SC PPDUs) of 20.3.6.3 (Channel Estimation field).

#### 20.4.3.2 Header

##### 20.4.3.2.1 General

In the DMG control mode, the preamble is followed by the header block. The header consists of several fields that define the details of the PPDU to be transmitted.

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The header fields are described in Table 20-11 (DMG control mode header fields).

**Table 20-11—DMG control mode header fields**

| Field name | Bit | Description |
|---|---|---|
| Differential Encoder Initialization | B0 | Used to initialize the differential encoding *c(0)* in 20.4.3.3.4 (Modulation). May be set to any value. |
| Scrambler Initialization | B1–B4 | Bits X1–X4 of the initial scrambler state (see 20.4.3.3.2 (Scrambler)). |
| Length | B5–B14 | Number of data octets in the PSDU.<br>Range 14–1023. |
| PPDU Type | B15 | As defined in Table 20-13 (DMG SC mode header fields). |
| Training Length | B16–B20 | Length of the training field. The use of this field is defined in 20.9.2.2.3 (BRP PPDU Header field(#6409)). |
| Turnaround | B21 | Contains a copy of the parameter TURNAROUND from the TXVECTOR. |
| Reserved bits | B22–B23 | |
| HCS | B24–B39 | Header check sequence. Calculation of the header check sequence is defined in 20.3.7 (HCS calculation for headers of DMG control mode and DMG SC mode). |

Reserved bits are set to 0 by the transmitter and shall be ignored by the receiver.

#### 20.4.3.2.2 Generation of HCS bits

The header check sequence (HCS) is calculated over bits 0-23 and uses CRC 16-CCITT as described in 20.3.7 (HCS calculation for headers of DMG control mode and DMG SC mode).

#### 20.4.3.2.3 Header encoding and modulation

The header bits followed by the HCS bits are prepended to the (#404)Data field bits and passed into the (#14)Data field encoder per 20.4.3.3 (Data field). The minimal payload length is 14 octets.

### 20.4.3.3 Data field

#### 20.4.3.3.1 General

The Data field consists of the payload data of the PSDU. The PSDU is scrambled, encoded, modulated and spread as described in the following subclauses.

#### 20.4.3.3.2 Scrambler

The operation of the scrambler is defined in 20.3.9 (Scrambler). Bits x1, x2, x3, x4 of the scrambler shift register are initialized using the bits in the scrambler initialization bits from the header, bits x5, x6, x7 are set to 1. The header is scrambled starting from bit 5. The scrambling of the (#404)Data field continues the scrambling of the header with no reset.


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#### 20.4.3.3.3 Encoder

The DMG control mode header and data is encoded using an effective LDPC code rate less than or equal to 1/2, generated from the data PHY rate 3/4 LDPC parity check matrix, with shortening. The following steps are used for the encoding:

1) $L_{CWD} = 168$ is the maximal number of data bits in each LDPC codeword. $L_{HDR}$=5 is the length of the header (including HCS) in octets. $L_{FDCW}$=6 is the length of the additional data in the first LDPC codeword in octets.

2) The total (header and additional data) number of bits in the first LDPC codeword is $L_{DPFCW} = (L_{HDR} + L_{FDCW}) \times 8 = 88$.

3) The number of LDPC codewords is $N_{CW} = 1 + \left\lceil \frac{(Length - 6) \times 8}{L_{CWD}} \right\rceil$.

4) The number of bits in the second and any subsequent LDPC codeword (if present), except the last, is $L_{DPCW} = \left\lceil \frac{(Length - 6) \times 8}{N_{CW} - 1} \right\rceil$.

5) The number of bits in the last LDPC codeword is $L_{DPLCW} = (Length - 6) \times 8 - (N_{CW} - 2) \times L_{DPCW}$.

NOTE—For example, if $Length = 128$, then $N_{CW} = 1 + \left\lceil \frac{(128 - 6) \times 8}{L_{CWD}} \right\rceil = 7$, $L_{DPCW} = 163$, and $L_{DPLCW} = 161$. In the first LDPC block, the 88 bits of $L_{DPFCW}$ consist of 40 header+HCS bits along with 48 bits of the data.

#### 20.4.3.3.4 Modulation

The scrambled and coded bit stream $c(k)$, $k = 0, 1, 2, ...$, is converted into a stream of complex constellation points $d(k)$ using differential binary phase shift keying (DBPSK) as follows.

$c(k)$ is converted to the nondifferential stream $s(k) = 2c(k) - 1$. This is converted to the differential stream $d(k) = s(k) \times d(k-1)$, where $d(-1)$ is defined to be 1. $c(0)$ is the Differential Encoder Initialization field of the DMG control mode header.

NOTE—The scrambling process does not affect the Differential Encoder Initialization field of the DMG control mode header.

#### 20.4.3.3.5 Spreading

The constellation points are spread using the sequence $Ga_{32}(n)$, which is defined in 20.10 (Golay sequences).

The waveform for the modulated and spread (#404)Data field is

$$r_{DATA}(nT_c) = \left(Ga_{32}(n \bmod 32) \cdot d\left(\left\lfloor \frac{n}{32} \right\rfloor\right)\right) \exp\left(j\pi \frac{n}{2}\right), n = 0, 1, 2, \ldots$$

where $d(k)$ is the modulated constellation point $k$.

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### 20.4.4 Performance requirements

#### 20.4.4.1 Transmit requirements

##### 20.4.4.1.1 Introduction

Transmitter performance requirements of the DMG control mode are defined in 20.4.4.1.2 (Transmit EVM).

##### 20.4.4.1.2 Transmit EVM

The transmit EVM accuracy test shall be performed by instrumentation capable of converting the transmitted signal into a stream of complex samples, with sufficient accuracy in terms of I/Q arm amplitude and phase balance, dc offsets, phase noise, etc. The instrumentation shall perform carrier lock, symbol timing recovery, and amplitude adjustment while making the measurements. The instrumentation shall incorporate a rake receiver or equalizer to minimize error resulting from multipath. If used, the equalizer shall be trained using information in the preamble (STF and/or CEF). For the DMG control mode EVM, the signal is first despread using $Ga_{32}$. The EVM is then calculated on the resulting symbols according to the formula below:(#315)(#2264)

$$EVM = 20\log 10\left(\sqrt{\left(\frac{1}{N_s P_{avg}}\sum_{i=1}^{N_s}[(I_i - I_i^* - I_0)^2 + (Q_i - Q_i^* - Q_0)^2]\right)}\right)$$

where

$N_S$ is the number of symbols to be measured

$N_S$ should be greater than 511

$P_{avg}$ is the average power of the constellation

$(I_i,Q_i)$ is the complex coordinates of the measured symbol $i$

$(I_i^*,Q_i^*)$ is the complex coordinates of the ideal constellation point for the measured symbol $i$

$(I_0,Q_0)$ is the complex DC term chosen to minimize EVM

The test equipment should use a root-raised cosine filter with roll-off factor of 0.25 for the pulse shaping filter when conducting EVM measurement.

The transmit pulse shaping used is left to the implementer.

The EVM shall not exceed a data-rate dependent value according to Table 20-12 (DMG control mode EVM requirements).

**Table 20-12—DMG control mode EVM requirements**

| MCS index | Description | EVM value [dB] |
|---|---|---|
| 0 | DMG control mode modulation | –6 |



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#### 20.4.4.2 Receive requirements

##### 20.4.4.2.1 Introduction

Subclause 20.4.4.2 (Receive requirements) describes the performance requirement from the DMG control mode receiver.

##### 20.4.4.2.2 CCA sensitivity

The start of a DMG control mode transmission at a receive level greater than –68 dBm shall cause CCA to indicate busy with a probability > 90% within 3 μs.

## 20.5 DMG SC mode

### 20.5.1 Introduction

Transmission and reception of DMG SC mode PPDUs is mandatory for selected MCSs.

### 20.5.2 PPDU format

(#3626)An(#1424) SC (#14)PPDU is shown in Figure 20-8 (SC PPDU format(#14)).

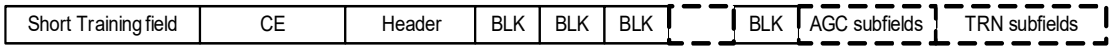


**Figure 20-8—SC PPDU format(#14)**

### 20.5.3 Transmission

#### 20.5.3.1 Header

##### 20.5.3.1.1 General

In the DMG SC mode, the preamble is followed by the header. The header consists of several fields that define the details of the PPDU to be transmitted. The encoding and modulation of the header is described in 20.5.3.1.4 (Header encoding and modulation).

The header fields are described in Table 20-13 (DMG SC mode header fields).

**Table 20-13—DMG SC mode header fields**

| Field name | Bit | Description |
|---|---|---|
| Scrambler Initialization | B0–B6 | Bits X1–X7 of the initial scrambler state (see 20.3.9 (Scrambler)). |
| Base MCS | B7–B11 | Modulation and Coding Scheme (see Table 20-15 (DMG SC mode modulation and coding schemes)) |

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**Table 20-13—DMG SC mode header fields *(continued)***

| Field name | Bit | Description |
|---|---|---|
| Length | B12–B29 | If the Extended SC MCS Indication field is 0, indicates the number of data octets in the PSDU; range 1–262 143.<br>If the Extended SC MCS Indication field is 1, the Length field value is set to $Base\_Length1 - \lfloor (Base\_Length2 - N)/4 \rfloor$, where $N$ is the number of data octets in the PSDU in the range 1 to 262 143, and *Base_Length1* and *Base_Length2* are computed according to Table 20-14 (Parameters for computing Length field value in SC header when Extended SC MCS Indication field is(M118) 1). |
| Additional PPDU | B30 | Contains a copy of the parameter ADD_PPDU from the TXVECTOR. A value of 1 indicates that this PPDU is immediately followed by another PPDU with no IFS or preamble on the subsequent PPDU. A value of 0 indicates that no additional PPDU follows this PPDU. |
| PPDU Type | B31 | Corresponds to the TXVECTOR parameter PPDU_TYPE.<br>— PPDU Type = 0 (BRP-RX PPDU, see 20.9.2.2.3 (BRP PPDU Header field(#6409))), indicates either a PPDU whose Data field is followed by one or more TRN subfields (when the Beam Tracking Request field is 0 or in DMG control mode), or a PPDU that contains a request for TRN subfields to be appended to a future response PPDU (when the Beam Tracking Request field is 1).<br>— PPDU Type = 1 (BRP-TX PPDU, see 20.9.2.2.3 (BRP PPDU Header field(#6409))), indicates a PPDU whose Data field is followed by one or more TRN subfields. The transmitter may change AWV at the beginning of each TRN subfield.<br>The field is reserved when the Training Length field is 0. |
| Training Length | B32–B36 | Corresponds to the TXVECTOR parameter TRN_LEN.<br>If the Beam Tracking Request field is 0, the Training Length field indicates the length of the training field. The use of this field is defined in 20.9.2.2.3 (BRP PPDU Header field(#6409)). A value of 0 indicates that no training field is present in this PPDU.<br>If the Beam Tracking Request field is 1 and the PPDU Type field is 1, the Training Length field indicates the length of the training field appended to this PPDU. If the PPDU Type field is 0, the Training Length field indicates the length of the training field requested for receive training. |
| Aggregation | B37 | Set to 1 to indicate that the (#14)PSDU contains an A-MPDU; otherwise, set to 0. |
| Beam Tracking Request | B38 | Corresponds to the TXVECTOR parameter BEAM_TRACKING_REQUEST.<br>Set to 1 to indicate the need for beam tracking (10.41.7 (Beam tracking)); otherwise, set to 0.<br>The Beam Tracking Request field is reserved when the Training Length field is 0. |


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**Table 20-13—DMG SC mode header fields *(continued)***

| Field name | Bit | Description |
|---|---|---|
| Last RSSI | B39–B42 | Contains a copy of the parameter LAST_RSSI from the TXVECTOR. The value is an unsigned integer:<br>Values 2 to 14 represent power levels (–71+value×2) dBm.<br>A value of 15 represents a power greater than or equal to –42 dBm.<br>A value of 1 represents a power less than or equal to –68 dBm.<br>A value of 0 indicates that the previous (#14)PPDU was not received a SIFS before the current transmission. |
| Turnaround | B43 | Contains a copy of the parameter TURNAROUND from the TXVECTOR. |
| Extended SC MCS Indication | B44 | The Extended SC MCS Indication field combined with the Base MCS field indicates the MCS.<br>The Extended SC MCS Indication field indicates whether the Length field shall be calculated according to Table 20-14 (Parameters for computing Length field value in SC header when Extended SC MCS Indication field is(M118) 1). |
| π/2-8-PSK Applied | B45 | Corresponds to TXVECTOR parameter PSK_APPLIED. If this field is(M118) 1, π/2-8-PSK with corresponding LDPC shortening code with rates 2/3 or 5/6 is applied at the transmitter for MCS 10 or 11, respectively. If set to 0, π/2-16-QAM with LDPC code with rates 1/2 or 5/8 is applied at the transmitter for MCS 10 or 11, respectively. |
| Reserved | B46–B47 | |
| HCS | B48–B63 | Header check sequence |

Reserved bits are set to 0 by the transmitter and shall be ignored by the receiver.

If the Additional PPDU field is equal to 1, the Training Length field shall be set to 0.

When the MCS belongs to the set {9.1, 12.1, 12.2, 12.3, 12.4, 12.5, 12.6}, bits X6, X7 of the initial scrambler state are set so that X6+X7×2 = (*Base_Length2* – *N*) mod 4, where *N* is the number of data octets in the PSDU, and *Base_Length2* is computed according to Table 20-14 (Parameters for computing Length field value in SC header when Extended SC MCS Indication field is(M118) 1). Bits X1–X5 are selected in a pseudorandom fashion making sure that at least one bit in X1–X7 is nonzero.

NOTE—The combination of the values of the X6 and X7 in the Scrambler Initialization field and the Length field is unique for different PSDU lengths, i.e., there is a one-to-one mapping between a combination (X6, X7, Length) and a PSDU length, so the receiver can recover the actual PSDU length from the header fields. See 20.5.3.1.5 (Length recovery for extended SC MCSs at receiver) for an example algorithm for the length recovery.

X1–X7 are sent in the Scrambler Initialization field, as defined in 20.5.3.1.4 (Header encoding and modulation) and 20.5.3.2.2 (Scrambler).

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**Table 20-14—Parameters for computing Length field value in SC header when Extended SC MCS Indication field is(M118) 1**

| MCS | *Base_Length1* (See NOTEs 1 and 2) | *Base_Length2* (See NOTEs 1 and 3) |
|---|---|---|
| 9.1 | $\left\lfloor \frac{N_{BLKS} \times 4}{3} \right\rfloor \times 42$ | $\left\lfloor \left\lfloor \frac{N_{BLKS} \times 56}{39} \right\rfloor \times 68.25 \right\rfloor$ |
| 12.1 | $\left\lfloor \left\lfloor \frac{N_{BLKS} \times 4}{3} \right\rfloor \times 52.5 \right\rfloor$ | $\left\lfloor \left\lfloor \frac{N_{BLKS} \times 8}{3} \right\rfloor \times 68.25 \right\rfloor$ |
| 12.2 | $\left\lfloor \frac{N_{BLKS} \times 4}{3} \right\rfloor \times 63$ | $\left\lfloor \left\lfloor \frac{N_{BLKS} \times 112}{39} \right\rfloor \times 68.25 \right\rfloor$ |
| 12.3 | $\left\lfloor \left\lfloor \frac{N_{BLKS} \times 4}{3} \right\rfloor \times 68.25 \right\rfloor$ | $N_{BLKS} \times 210$ |
| 12.4 | $\left\lfloor \frac{N_{BLKS} \times 8}{3} \right\rfloor \times 42$ | $N_{BLKS} \times 252$ |
| 12.5 | $\left\lfloor \left\lfloor \frac{N_{BLKS} \times 8}{3} \right\rfloor \times 52.5 \right\rfloor$ | $N_{BLKS} \times 273$ |
| 12.6 | $\left\lfloor \frac{N_{BLKS} \times 8}{3} \right\rfloor \times 63$ | $\left\lfloor \left\lfloor \frac{N_{BLKS} \times 56}{13} \right\rfloor \times 68.25 \right\rfloor$ |

NOTE 1—$N_{BLKS}$ is the number of symbol blocks defined in 20.5.3.2.3.3 (LDPC encoding process).

NOTE 2—*Base_Length1* is the maximum Length value such that the (#14)PPDU with the base MCS specified in SC header has the given $N_{BLKS}$.

NOTE 3—*Base_Length2* is the maximum number of data octets in PSDU such that the (#14)PPDU with the extended MCS has the given $N_{BLKS}$.

### 20.5.3.1.2 Modulation and coding scheme

The modulation and coding scheme defines the modulation and code rate that is used in the PPDU. The modulation and coding schemes for SC are defined in Table 20-15 (DMG SC mode modulation and coding schemes) and Table 20-16 (DMG SC mode modulation and coding schemes when π/2-8-PSK Applied field is 1). PPDUs that have the π/2-8-PSK Applied field set to 0 in Table 20-13 (DMG SC mode header fields) follow Table 20-15 (DMG SC mode modulation and coding schemes). PPDUs that have the π/2-8-PSK Applied field set to 1 in Table 20-13 (DMG SC mode header fields) follow Table 20-15 (DMG SC mode modulation and coding schemes), except that MCS 10 and MCS 11 in this table shall be replaced by those in Table 20-16 (DMG SC mode modulation and coding schemes when π/2-8-PSK Applied field is 1).

NOTE—The LDPC code with rate 2/3 is generated by employing the LDPC code with rate 3/4 and applying the codeword shortening procedure to achieve the effective code rate. The LDPC code with rate 5/6 is generated by employing the LDPC code with rate 13/16 and applying the codeword shortening and puncturing procedure. See 20.5.3.2.3.3 (LDPC encoding process).

Transmit and receive support for MCS 4 and below is mandatory. Other MCSs are optional. For STAs that support MCS 10, the support for π/2-16-QAM for MCS 10 is mandatory and the support for π/2-8-PSK (#4037)for MCS 10 is optional. For STAs that support MCS 11, the support for (#4038)π/2-16-QAM for MCS 11 is mandatory and the support for π/2-8-PSK for MCS 11 is optional.


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**Table 20-15—DMG SC mode modulation and coding schemes**

| MCS | Base MCS field | Extended SC MCS Indication field | Modulation | $N_{CBPS}$ | Repetition | Code rate | Data rate (Mb/s) |
|---|---|---|---|---|---|---|---|
| 1 | 1 | 0 | π/2-BPSK | 1 | 2 | 1/2 | 385 |
| 2 | 2 | 0 | π/2-BPSK | 1 | 1 | 1/2 | 770 |
| 3 | 3 | 0 | π/2-BPSK | 1 | 1 | 5/8 | 962.5 |
| 4 | 4 | 0 | π/2-BPSK | 1 | 1 | 3/4 | 1155 |
| 5 | 5 | 0 | π/2-BPSK | 1 | 1 | 13/16 | 1251.25 |
| 6 | 6 | 0 | π/2-QPSK | 2 | 1 | 1/2 | 1540 |
| 7 | 7 | 0 | π/2-QPSK | 2 | 1 | 5/8 | 1925 |
| 8 | 8 | 0 | π/2-QPSK | 2 | 1 | 3/4 | 2310 |
| 9 | 9 | 0 | π/2-QPSK | 2 | 1 | 13/16 | 2502.5 |
| 9.1 | 6 | 1 | π/2-QPSK | 2 | 1 | 7/8 | 2695 |
| 10 | 10 | 0 | π/2-16-QAM | 4 | 1 | 1/2 | 3080 |
| 11 | 11 | 0 | π/2-16-QAM | 4 | 1 | 5/8 | 3850 |
| 12 | 12 | 0 | π/2-16-QAM | 4 | 1 | 3/4 | 4620 |
| 12.1 | 7 | 1 | π/2-16-QAM | 4 | 1 | 13/16 | 5005 |
| 12.2 | 8 | 1 | π/2-16-QAM | 4 | 1 | 7/8 | 5390 |
| 12.3 | 9 | 1 | π/2-64-QAM | 6 | 1 | 5/8 | 5775 |
| 12.4 | 10 | 1 | π/2-64-QAM | 6 | 1 | 3/4 | 6930 |
| 12.5 | 11 | 1 | π/2-64-QAM | 6 | 1 | 13/16 | 7507.5 |
| 12.6 | 12 | 1 | π/2-64-QAM | 6 | 1 | 7/8 | 8085 |

**Table 20-16—DMG SC mode modulation and coding schemes when π/2-8-PSK Applied field is 1**

| MCS | Base MCS field | Extended SC MCS Indication field | Modulation | $N_{CBPS}$ | Repetition | Code rate | Data rate (Mb/s) |
|---|---|---|---|---|---|---|---|
| 10 | 10 | 0 | π/2-8-PSK | 3 | 1 | 2/3 | 3080 |
| 11 | 11 | 0 | π/2-8-PSK | 3 | 1 | 5/6 | 3850 |

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#### 20.5.3.1.3 Generation of the HCS bits

Calculation of the HCS for bits 0–47 of the header is defined in 20.3.7 (HCS calculation for headers of DMG control mode and DMG SC mode).

#### 20.5.3.1.4 Header encoding and modulation

The header is encoded using a two SC block of $N_{SPB}$ symbols with $N_{GI}$ guard symbols. The bits are scrambled and encoded as follows:

1) The input header bits ($B_1$, $B_2$, …, $B_{LH}$), where LH = 64, are scrambled as described in 20.3.9 (Scrambler), starting from the eighth bit. to create $\mathbf{d_{1s}}=(q_1,q_2,\ldots,q_{LH})$
2) The LDPC codeword $\mathbf{c} = (q_1,q_2,\ldots,q_{LH},0_1,0_2,\ldots,0_{504\text{-}LH},p_1,p_2,\ldots,p_{168})$ is created by concatenating 504-LH 0s(M118) to the LH bits of $\mathbf{d_{1s}}$ and then generating the parity bits $p_1,p_2,\ldots,p_{168}$ such that $\mathbf{Hc}^T = \mathbf{0}$, where **H** is the parity check matrix for the rate 3/4 LDPC code specified in 20.5.3.2.3.2 (Parity check matrices).
3) Remove bits LH+1 to 504 and bits 665 to 672 of the codeword **c** to create the sequence $\mathbf{cs1}=(q_1,q_2,\ldots,q_{LH},p_1,p_2,\ldots,p_{160})$.
4) Remove bits LH+1 to 504 and bits 657 to 664 of the codeword **c** to create the sequence **cs2** = $(q_1,q_2,\ldots,q_{LH},p_1,p_2,\ldots,p_{152},p_{161},p_{162},\ldots,p_{168})$ and then XOR with a PN sequence that is generated from the LFSR used for data scramblings defined in 20.3.9 (Scrambler). The LFSR is initialized to the all 1s vector.
5) **cs1** and **cs2** are concatenated to form the sequence (**cs1**, **cs2**). The resulting 448 bits are then mapped as $\pi/2$-BPSK as described in 20.5.3.2.4.2 (π/2-BPSK modulation). The $N_{GI}$ guard symbols are then prepended to the resulting $N_{CBPB}$ symbols as described in 20.5.3.2.5 (Symbol blocking and guard insertion).

The same resulting $N_{CBPB}$ symbols are multiplied by –1 and repeated, and then prepended with $N_{GI}$ guard symbols as described in 20.5.3.2.5 (Symbol blocking and guard insertion). The resulting sequence is then appended after the sequence created in step 5).

#### 20.5.3.1.5 Length recovery for extended SC MCSs at receiver

This subclause describes an example steps to calculate the PSDU length *N* at the receiver when the Extended SC MCS Indication field of the received PPDU is set to 1.

1) Compute $N_{BLKS}$ using the values of the Base MCS and Length fields in the PHY header as if the Extended SC MCS Indication field is set to 0.
2) Compute *Base_Length1* and *Base_Length2* using $N_{BLKS}$ computed in step 1) as defined in Table 20-14 (Parameters for computing Length field value in SC header when Extended SC MCS Indication field is(M118) 1)
3) Compute the PSDU length *N* using the following equation:

$$N = Base\_Length2 - (4 \cdot (Base\_Length1 - Length) + (X6 + 2 \cdot X7))$$

where

*Length* is the value of the Length field in the PHY header

*X6* and *X7* are the 6th and 7th bits of the Scrambler Initialization field in the PHY header

NOTE—The equation is derived by the following equations a) to c).

a) The equation that defines the Length field value in the PHY header (see Table 20-13 (DMG SC mode header fields)),

$$Length = Base\_Length1 - \lfloor (Base\_Length2 - N)/4 \rfloor$$

where


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$N$ is the PSDU length.

b) The equation that defines the two MSBs of the Scrambler Initialization field, X6 and X7 (see 20.5.3.1.1 (General)),

$$X6 + 2 \cdot X7 = (Base\_Length2 - N) \bmod 4$$

c) The equations a) and b) mean that ($Base\_Length1 - Length$) and ($X6 + 2 \cdot X7$) are respectively the quotient and remainder of dividing ($Base\_Length2 - N$) by 4. Thus, the following equation is obtained,

$$Base\_Length2 - N = 4 \cdot (Base\_Length1 - Length) + (X6 + 2 \cdot X7)$$

and the equation in step 3) of this subclause is obtained after applying simple rearrangement.

Table 20-17 (Examples of length recovery) shows several examples of length recovery.

**Table 20-17—Examples of length recovery**

| PHY header values | | | Recovered values at receiver | | | | |
|---|---|---|---|---|---|---|---|
| Base MCS | Length (Octets) | X6, X7 of Scramble Initialization | MCS | $N_{BLKS}$ | Base_Length1 (Octets) | Base_Length2 (Octets) | PSDU Length, $N$ (Octets) |
| 6 | 150 | 1, 0 | 9.1 | 3 | 168 | 273 | 200 |
| 7 | 95 | 1, 0 | 12.1 | 2 | 105 | 341 | 300 |
| 8 | 464 | 0, 0 | 12.2 | 6 | 504 | 1160 | 1000 |
| 9 | 403 | 0, 1 | 12.3 | 5 | 409 | 1050 | 1024 |
| 10 | 838 | 0, 1 | 12.4 | 8 | 840 | 2016 | 2006 |
| 11 | 1323 | 0, 1 | 12.5 | 10 | 1365 | 2730 | 2560 |
| 12 | 1713 | 1, 1 | 12.6 | 11 | 1764 | 3207 | 3000 |

### 20.5.3.2 Data field

#### 20.5.3.2.1 General

The (#404)Data field consists of the payload data of the PSDU and possible padding. The data are padded with 0s(M118), scrambled, encoded and modulated as described in the following subclauses. The amount of padding is defined in 20.5.3.2.3 (Encoding).

#### 20.5.3.2.2 Scrambler

The operation of the scrambler is defined in 20.3.9 (Scrambler). The scrambling of the PSDU continues the scrambling of the header with no reset of the scrambler.

#### 20.5.3.2.3 Encoding

##### 20.5.3.2.3.1 General

The data are encoded by a systematic LDPC encoder. The LDPC is a block code. Each block of information bits $(B_1, B_2, ..., B_k)$ is concatenated with a block of parity bits $(p_1, p_2, ..., p_{n-k})$(#515) to create a codeword $\boldsymbol{c}=(B_1, B_2, ..., B_k, p_1, p_2, ..., p_{n-k})$(#515) such that $\mathbf{Hc}^{\mathbf{T}}=\mathbf{0}$, where $\mathbf{H}$ is the $(n-k)\times n$ parity check matrix. The block size $n$ is 672 bits. The code rate, R, is equal to $k/n$. The set of code rates is defined in Table 20-18

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(LDPC code rates). The parity check matrices are defined in 20.5.3.2.3.2 (Parity check matrices). The encoding process is defined in 20.5.3.2.3.3 (LDPC encoding process).

**Table 20-18—LDPC code rates**

| Code rate | Codeword size | Number of data bits |
|---|---|---|
| 1/2 | 672 | 336 |
| 5/8 | 672 | 420 |
| 2/3 | 504 | 336 |
| 3/4 | 672 | 504 |
| 13/16 | 672 | 546 |
| 5/6 | 468 | 390 |
| 7/8 | 624 | 546 |

#### 20.5.3.2.3.2 Parity check matrices

See 20.3.8 (Common LDPC parity matrices).

#### 20.5.3.2.3.3 LDPC encoding process

The LDPC encoding process is composed of several steps that includes deciding the number of shortening/ repetition bits in every codeword, the shortening itself, the coding of each word and then any repetition of bits.

a) First the total number of data pad bits $N_{DATA\_PAD}$ is calculated, using the number of LDPC codewords $N_{CW}$(#14):

$$N_{CW} = \left\lceil \frac{Length \cdot 8}{\frac{L_{CW}}{\rho} \cdot R} \right\rceil$$

if BRP PPDU and $N_{CW} < N_{CWmin}$; $N_{CW} = N_{CWmin}$

$$N_{DATA\_PAD} = N_{CW} \cdot \frac{L_{CW}}{\rho} \cdot R - Length \cdot 8$$

where

$L_{CW}$ is the LDPC codeword length , which is 624 for code rate R=7/8, 504 for code rate R=2/3, 468 for code rate R=5/6, or 672 for all other code rates

$Length$ is the length of the PSDU indicated by the TXVECTOR parameter LENGTH (in octets)

$\rho$ is the repetition factor (1 or 2)

$R$ is the code rate

$N_{CWmin}$ is defined for BRP PPDUs in Table 20-22 (Zero filling for DMG SC mode BRP PPDUs).

The scrambled PSDU is concatenated with $N_{DATA\_PAD}$ 0s(M118). They are scrambled using the continuation of the scrambler sequence that scrambled the PSDU input bits.

b) The procedure for converting the scrambled PSDU data to LDPC codewords depends on the repetition factor.


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1) If ρ = 1 and the code rate is not one of 2/3, 5/6, 7/8,
   i) The output stream of the scrambler is broken into blocks of $L_{CWD} = L_{CW} \times R$ bits such that the $m^{\text{th}}$ data word is $(b_1^{(m)}, b_2^{(m)}, \ldots b_{L_{CWD}}^{(m)})$, $m \le N_{CW}$.
   ii) To each data word, $n\text{-}k = L_{CW} - R \times L_{CW}$ parity bits $(p_1^{(m)}, p_2^{(m)}, \ldots, p_{n-k}^{(m)})$ are added to create the codeword $\mathrm{c}^{(m)} = (b_1^{(m)}, b_2^{(m)}, \ldots, b_{L_{CWD}}^{(m)}, p_1^{(m)}, \ldots p_{n-k}^{(m)})$ such that $\mathbf{H}\boldsymbol{c}^{(m)^{\mathrm{T}}} = 0$
2) If ρ = 1 and the code rate is 7/8, 48 bits are punctured from the parity bits of the rate 13/16 parity bits:
   i) The output stream of the scrambler is broken into blocks of 546 bits such that the $m^{\text{th}}$ data word is $(b_1^{(m)}, b_2^{(m)}, \ldots, b_{546}^{(m)})$, $m \le N_{CW}$.
   ii) To each data word, 126 parity bits $(p_1^{(m)}, p_2^{(m)}, \ldots, p_{126}^{(m)})$ are added to create the code word $\tilde{\boldsymbol{c}}^{(m)} = (b_1^{(m)}, b_2^{(m)}, \ldots, b_{546}^{(m)}, p_1^{(m)}, \ldots p_{126}^{(m)})$ such that $\boldsymbol{H}\tilde{\boldsymbol{c}}^{(m)^{\mathrm{T}}} = \mathbf{0}$. The code word $\boldsymbol{c}^{(m)}$ is generated from $\tilde{\boldsymbol{c}}^{(m)}$ by removing the first 48 parity bits so that $\boldsymbol{c}^{(m)} = (b_1^{(m)}, b_2^{(m)}, \ldots, b_{546}^{(m)}, p_{49}^{(m)}, p_{50}^{(m)}, \ldots p_{126}^{(m)})$
3) If ρ = 1 and the code rate is 2/3,
   i) The output stream of the scrambler is broken into blocks of $L_{CWD} = 336$ bits such that (#3245)the $m^{\text{th}}$ data word is $(b_1^{(m)}, b_2^{(m)}, \ldots b_{L_{CWD}}^{(m)})$, $m \le N_{CW}$.
   ii) To each data word, 168 zero bits $\mathbf{0}^{(m)} = (0_1, 0_2, \ldots 0_{168})$ and parity bits $\mathbf{p}^{(m)} = (p_1, p_2, \ldots p_{168})$ are added to create the codeword $\mathbf{c}^{(m)} = (\mathbf{b}^{(m)}, \mathbf{0}^{(m)}, \mathbf{p}^{(m)})$ such that $\boldsymbol{H}\boldsymbol{c}^{(m)^{\mathrm{T}}} = \mathbf{0}$, applying the rate 3/4 LDPC code matrix.
   iii) Finally, the zero bits are discarded to create the output codeword $\boldsymbol{c}^{(m)} = (b_1^{(m)}, b_2^{(m)}, \ldots, b_{LWD}^{(m)}, p_1^{(m)}, \ldots p_{n-k}^{(m)})$.
4) If ρ = 1 and the code rate is 5/6,
   i) The output stream of the scrambler is broken into blocks of $L_{CWD} = 390$ bits such that (#3245)the $m^{\text{th}}$ data word is $(b_1^{(m)}, b_2^{(m)}, \ldots b_{L_{CWD}}^{(m)})$, $m \le N_{CW}$.
   ii) To each data word, 156 zero bits $\mathbf{0}^{(m)} = (0_1, 0_2, \ldots 0_{156})$ and parity bits parity bits $\mathbf{p}^{(m)} = (p_1, p_2, \ldots p_{126})$ are added to create the codeword $\tilde{\boldsymbol{c}}^{(m)} = (\mathbf{b}^{(m)}, \mathbf{0}^{(m)}, \mathbf{p}^{(m)})$ such that $\boldsymbol{H}\tilde{\boldsymbol{c}}^{(m)^{\mathrm{T}}} = \mathbf{0}$, applying the rate 13/16 LDPC code matrix.
   iii) Finally, the zero bits are discarded to create the output codeword $\boldsymbol{c}^{(m)} = (b_1^{(m)}, b_2^{(m)}, \ldots, b_{390}^{(m)}, p_{49}^{(m)}, \ldots p_{126}^{(m)})$.
5) If ρ = 2,
   i) The data bits in each codeword $(b_1, b_2, \ldots, b_{L_Z})$ where $L_Z = L_{CW}/2\rho$ are concatenated with $L_{CW}/2\rho$ 0s(M118) to produce a sequence of length of $2L_Z$ $(b_1, b_2, \ldots, b_{L_Z}, 0_1, 0_2, \ldots, 0_{L_Z})$.
   ii) The LDPC codeword $\mathbf{c} = (b_1, b_2, \ldots, b_{L_Z}, 0_1, 0_2, \ldots, 0_{L_Z}, p_1, p_2, \ldots, p_{336})$ is created by generating the parity bits $p_1, p_2, \ldots, p_{336}$ such that $\mathbf{H}\mathbf{c}^{\boldsymbol{T}} = \mathbf{0}$, where $\mathbf{H}$ is the parity matrix for rate 1/2 LDPC coding specified in 20.3.8 (Common LDPC parity matrices).

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iii) Replace bits $L_Z + 1$ to 336 of the codeword **c** with bits from the sequence $b_1, b_2, \ldots, b_{L_Z}$ XORed by a PN sequence that is generated from the LFSR used for data scrambling as defined in 20.3.9 (Scrambler). The LFSR is initialized to the all 1s vector and reinitialized to the same vector after every codeword.

c) The codewords are then concatenated one after the other to create the coded bits stream $(c_1, c_2, \ldots, c_{L_{CW} \cdot N_{CW}})$.

d) The number of symbol blocks, $N_{BLKS}$, and the number of symbol block padding bits, $N_{BLK\_PAD}$, are calculated:

$$N_{BLKS} = \left\lceil \frac{N_{CW} \cdot L_{CW}}{N_{CBPB}} \right\rceil$$

$$N_{BLK\_PAD} = N_{BLKS} \cdot N_{CBPB} - N_{CW} \cdot L_{CW}$$

where $N_{CBPB}$ is the number of coded bits per symbol block, per Table 20-19 (Values of NCBPB) in 20.5.3.2.5 (Symbol blocking and guard insertion).

e) The coded bit stream is concatenated with $N_{BLK\_PAD}$ 0s(M118). They are scrambled using the continuation of the scrambler sequence that scrambled the PSDU input bits.

#### 20.5.3.2.4 Modulation mapping

##### 20.5.3.2.4.1 General

The coded and padded bit stream is converted into a stream of complex constellation points according to the modulation specified in the MCS table.

##### 20.5.3.2.4.2 π/2-BPSK modulation

In π/2-BPSK modulation, the input bit stream is mapped according to the following equation: $\tilde{s}_k = 2 \cdot c_k - 1$, where $c_k$ is the $k^{th}$ input coded (or scrambled pad) bit. Each output symbol is then rotated according to the following equation: $s_k = \tilde{s}_k \cdot e^{j\pi k/2}$. The constellation bit encoding for BPSK is shown in Figure 20-9 (BPSK constellation bit encoding).

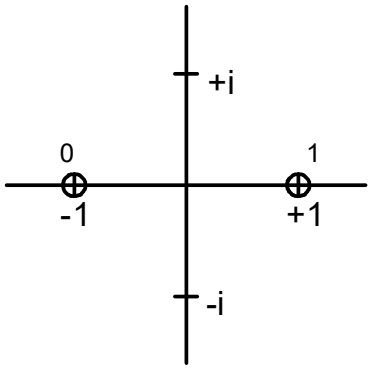


**Figure 20-9—BPSK constellation bit encoding**

NOTE—With appropriate choice of transmit filtering, π/2-BPSK is equivalent to a precoded pulse-shaped MSK (e.g., GMSK). The precoder is simply $b_{out,k} = b_{in,k} \oplus b_{in,k-1}, k = 0, 1, \ldots$, where $b_{in,k}$ is the scrambled input stream, $b_{in,-1}$ is 0, $b_{out,k}$ is the input to the (G)MSK modulator.


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#### 20.5.3.2.4.3 π/2-QPSK modulation

In π/2-QPSK modulation, the input bit stream is grouped into sets of 2 bits and mapped according to the following equation: $\tilde{s}_k = \frac{1}{\sqrt{2}}((2c_{2k}-1)+j(2c_{2k+1}-1))\exp\left(-j\frac{\pi}{4}\right)$, where k is the output symbol index, k = 0, 1, …. Each output symbol is then rotated according to the following equation: $s_k = \tilde{s}_k \cdot e^{j\pi k/2}$. The constellation bit encoding for QPSK is shown in Figure 20-10 (QPSK constellation bit encoding).

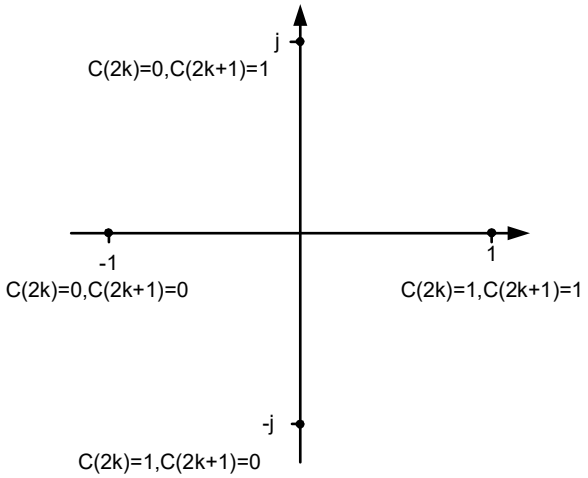


**Figure 20-10—QPSK constellation bit encoding**

#### 20.5.3.2.4.4 π/2-8-PSK modulation

A DMG STA shall only apply π/2-8-PSK modulation to a PPDU transmitted to a peer STA if the π/2-8-PSK Supported field in the peer STA's DMG Capabilities element is equal to 1.

In π/2-8-PSK modulation, the input stream is grouped into sets of 3 bits and mapped according to the following equation:

$$\tilde{s}_k = \exp\left(j\frac{\pi}{4}(c_{3k}-3c_{3k+1}-c_{3k+2}-2c_{3k}c_{3k+1}+2c_{3k+1}c_{3k+2}+2c_{3k}c_{3k+2}+4c_{3k}c_{3k+1}c_{3k+2}+4)\right)$$

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where $k$ is the symbol output index, $k$ = 0, 1, …. Each output symbol is then rotated according to the following equation: $s_k = \tilde{s}_k \cdot e^{j\pi k/2}$. The constellation bit encoding for 8-PSK before π/2 rotation is in Figure 20-11 (8-PSK constellation bit encoding (before π/2 rotation)).

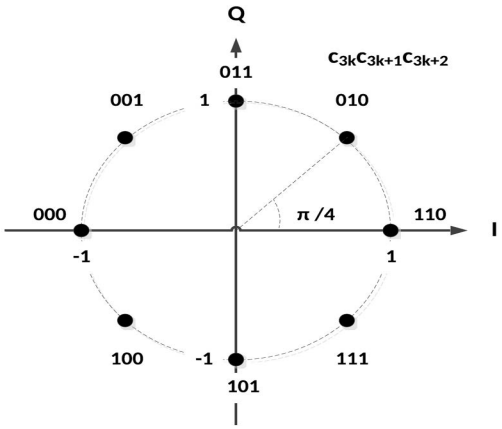


**Figure 20-11—8-PSK constellation bit encoding (before π/2 rotation)**

### 20.5.3.2.4.5 π/2-16-QAM modulation

In π/2-16-QAM modulation, the input bit stream is grouped into sets of 4 bits and mapped according to the following equation:

$$\tilde{s}_k = \frac{1}{\sqrt{10}}\{(4c_{4k}-2)-(2c_{4k}-1)(2c_{4k+1}-1)+j(4c_{4k+2}-2)-j(2c_{4k+2}-1)(2c_{4k+3}-1)\}$$

where k is the output symbol index, k =0, 1, …. Each output symbol is then rotated according to the following equation: $s_k = \tilde{s}_k \cdot e^{j\cdot\pi\cdot k/2}$. The constellation bit encoding for 16-QAM is shown in Figure 20-12 (16-QAM constellation bit encoding).

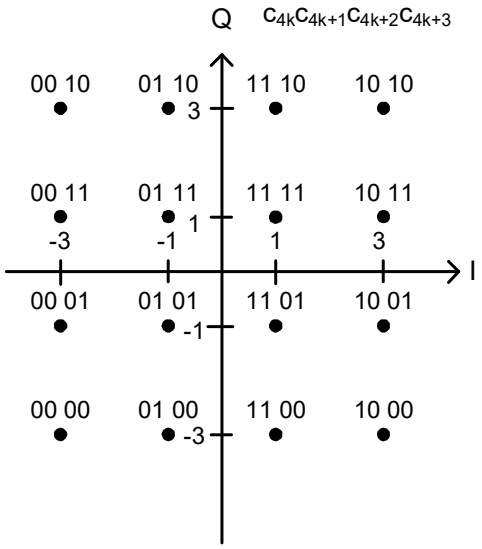


**Figure 20-12—16-QAM constellation bit encoding**


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#### 20.5.3.2.4.6 π/2-64-QAM modulation

In π/2-64-QAM modulation, the input bit stream is grouped in sets of 6 bits and mapped according to the following equation:

$$\tilde{s}_k =$$

$$\frac{1}{\sqrt{42}}((8c_{6k}-4)-(2c_{6k}-1)(4c_{6k+1}-2)+(2c_{6k}-1)(2c_{6k+1}-1)(2c_{6k+2}-1))+$$

$$\frac{j}{\sqrt{42}}((8c_{6k+3}-4)-(2c_{6k+3}-1)(4c_{6k+4}-2)+(2c_{6k+3}-1)(2c_{6k+4}-1)(2c_{6k+5}-1))$$

where k is the output symbol index, k=0,1, …. Each output symbol is then rotated according to the following equation $s_k = \tilde{s}_k \cdot e^{\frac{j\pi k}{2}}$. The constellation bit encoding for 64-QAM is shown in Figure 20-13 (64-QAM constellation bit encoding).

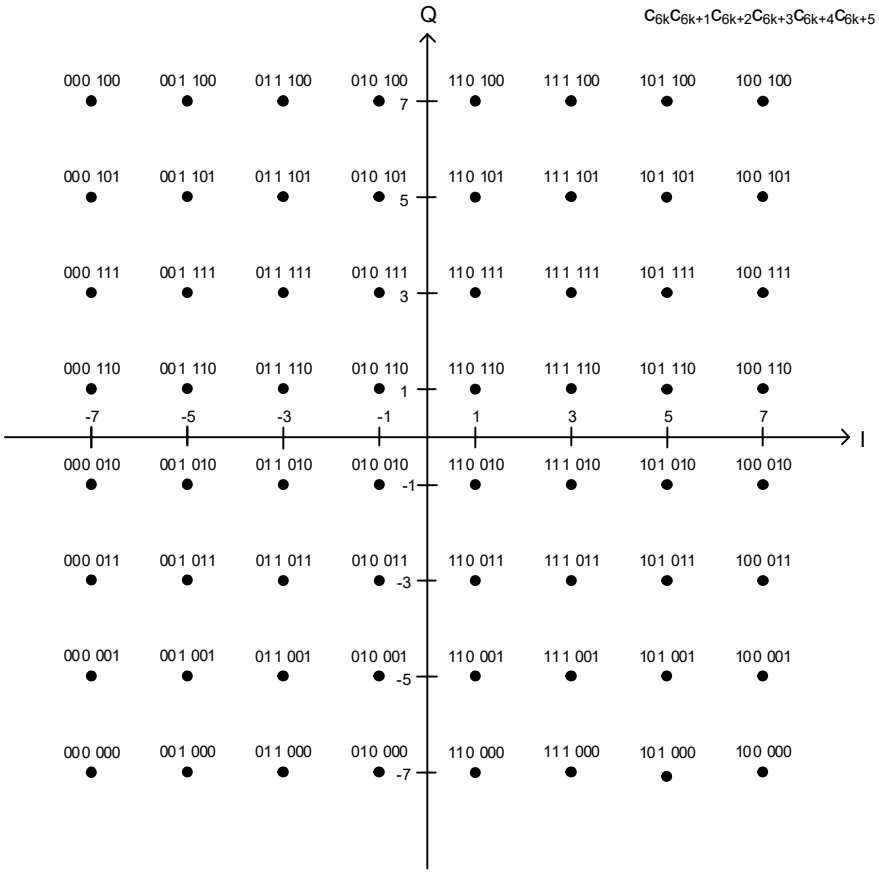


**Figure 20-13—64-QAM constellation bit encoding**

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#### 20.5.3.2.5 Symbol blocking and guard insertion

Each group of $N_{CBPB}$ bits is prepended by π/2-BPSK symbols generated by the 64 point Golay sequence $Ga_{64}$ defined in 20.10 (Golay sequences). $N_{CBPB}$ values are shown in Table 20-19 (Values of NCBPB). The starting index for the first symbol for π/2 rotation is 0.

**Table 20-19—Values of $N_{CBPB}$**

| Symbol mapping | $N_{CBPB}$ |
|---|---|
| π/2-BPSK | 448 |
| π/2-QPSK | 896 |
| π/2-16-QAM | 1792 |
| π/2-64-QAM | 2688 |

If the Additional PPDU field within the PHY header is equal to 0, the final block transmitted is followed by the same Golay sequence guard interval. See Figure 20-14 (Block transmission). If the Additional PPDU field within the PHY header is equal to 1, the final block transmitted of the last PPDU in an A-PPDU is followed by the same Golay sequence guard interval.

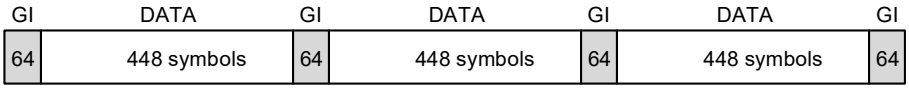


**Figure 20-14—Block transmission**

### 20.5.4 Performance requirements

#### 20.5.4.1 Transmit requirements

##### 20.5.4.1.1 Transmit EVM

The transmit EVM accuracy test shall be performed by instrumentation capable of converting the transmitted signal into a stream of complex samples, with sufficient accuracy in terms of I/Q arm amplitude and phase balance, dc offsets, phase noise, etc.

The instrumentation shall perform carrier lock, symbol timing recovery and amplitude adjustment and equalization while making the measurements. The equalizer shall be trained using information in the SC preamble (STF and/or CEF). For the DMG SC mode EVM, measuring Ns samples at the sample rate, the measured symbols should not contain the first and the last hundred symbols of a given (#14)PPDU (ramp up/down). The EVM is calculated according to the formula below:(#315)

$$EVM = 20\log 10\left(\sqrt{\left(\frac{1}{N_s P_{avg}}\sum_{i=1}^{N_s}[(I_i - I_i^* - I_0)^2 + (Q_i - Q_i^* - Q_0)^2]\right)}\right)$$

where $N_s$ is the number of samples to be measured and $N_s$ shall be 1000, $P_{avg}$ is the average power of the constellation, $(I_i, Q_i)$ is the complex coordinates of the measured symbol $i$, $(I_i^*, Q_i^*)$ is the complex coordinates of the ideal constellation point for the measured symbol $i$, and $(I_o, Q_o)$ is the complex DC term chosen to minimize EVM.


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The test equipment should use a root-raised cosine filter with roll-off factor of 0.25 for the pulse shaping filter when conducting EVM measurement.

The transmit pulse shaping used is left to the implementer.

The relative constellation error (EVM) shall not exceed an MCS dependent value according to Table 20-20 (DMG SC mode EVM requirements).

**Table 20-20—DMG SC mode EVM requirements**

| MCS | Modulation | Coding rate | EVM value [dB] |
|---|---|---|---|
| 1 | π/2-BPSK | 1/2 with repetition | –6 |
| 2 | π/2-BPSK | 1/2 | –7 |
| 3 | π/2-BPSK | 5/8 | –9 |
| 4 | π/2-BPSK | 3/4 | –10 |
| 5 | π/2-BPSK | 13/16 | –12 |
| 6 | π/2-QPSK | 1/2 | –11 |
| 7 | π/2-QPSK | 5/8 | –12 |
| 8 | π/2-QPSK | 3/4 | –13 |
| 9 | π/2-QPSK | 13/16 | –15 |
| 9.1 | π/2-QPSK | 7/8 | –16 |
| 10 | π/2-16-QAM | 1/2 | –19 |
| 11 | π/2-16-QAM | 5/8 | –20 |
| 12 | π/2-16-QAM | 3/4 | –21 |
| 12.1 | π/2-16-QAM | 13/16 | –22 |
| 12.2 | π/2-16-QAM | 7/8 | –23 |
| 12.3 | π/2-64-QAM | 5/8 | –26 |
| 12.4 | π/2-64-QAM | 3/4 | –27 |
| 12.5 | π/2-64-QAM | 13/16 | –29 |
| 12.6 | π/2-64-QAM | 7/8 | –31 |

#### 20.5.4.1.2 Time of Departure accuracy

(#8050)The RMS accuracy of the time of departure provided in TIME_OF_DEPARTURE shall be less than or equal to 80 ns.

The Time of Departure accuracy test evaluates TIME_OF_DEPARTURE against aTxPHYTxStartRMS and aTxPHYTxStartRMS against TIME_OF_DEPARTURE_ACCURACY_TEST_THRESH as defined in Annex P with the following test parameters:

— MULTICHANNEL_SAMPLING_RATE is $1760 \times 10^6$ sample/s

— FIRST_TRANSITION_FIELD is Short Training field

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— SECOND_TRANSITION_FIELD is Channel Estimation field
— TRAINING_FIELD is Channel Estimation field
— TIME_OF_DEPARTURE_ACCURACY_TEST_THRESH is 80 ns

NOTE—The indicated windowing applies to the time of departure accuracy test equipment, and not the transmitter or receiver.

#### 20.5.4.2 Receive requirements

##### 20.5.4.2.1 Introduction

This subclause describes the receiver requirements of the DMG SC mode.

##### 20.5.4.2.2 CCA sensitivity

The start of a DMG SC mode transmission at a receive level greater than the minimum sensitivity for MCS 1 (–68 dBm) shall cause CCA to indicate busy with a probability > 90% within 1 μs. The receiver shall hold the carrier sense signal busy for any signal 20 dB above the minimum sensitivity for MCS 1.

## 20.6 DMG low-power SC mode

### 20.6.1 Introduction

The DMG low-power SC mode is obsolete, and support for this mode might be subject to removal in a future revision of the standard.

The DMG low-power SC mode is an optional SC mode that can provide lower processing power requirements for DMG transceivers.

### 20.6.2 Transmission

#### 20.6.2.1 Preamble

The DMG low-power SC mode uses the same preamble as the DMG SC mode.

#### 20.6.2.2 Header

##### 20.6.2.2.1 General

The DMG low-power SC mode header fields are the same fields as in the DMG SC mode (see Table 20-13 (DMG SC mode header fields) in 20.5.3.1 (Header)).

The DMG low-power SC mode modulation and coding schemes are listed in Table 20-21 (DMG low-power SC mode modulation and coding schemes).

##### 20.6.2.2.2 Header encoding and modulation

The DMG low-power SC mode header is encoded and modulated as defined in 20.5.3.1.4 (Header encoding and modulation).


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**Table 20-21—DMG low-power SC mode modulation and coding schemes**

| MCS | Modulation | Effective code rate | Coding scheme | $N_{CPB}$ | Rate (Mb/s) |
|---|---|---|---|---|---|
| 25 | π/2-BPSK | 13/28 | RS(224,208)+Block-Code(16,8) | 392 | 626 |
| 26 | π/2-BPSK | 13/21 | RS(224,208)+Block-Code(12,8) | 392 | 834 |
| 27 | π/2-BPSK | 52/63 | RS(224,208)+SPC(9,8) | 392 | 1112 |
| 28 | π/2-QPSK | 13/28 | RS(224,208)+Block-Code(16,8) | 392 | 1251 |
| 29 | π/2-QPSK | 13/21 | RS(224,208)+Block-Code(12,8) | 392 | 1668 |
| 30 | π/2-QPSK | 52/63 | RS(224,208)+SPC(9,8) | 392 | 2224 |
| 31 | π/2-QPSK | 13/14 | RS(224,208)+Block-Code(8,8) | 392 | 2503 |

### 20.6.2.3 Data field

#### 20.6.2.3.1 General

The (#404)Data field consists of the payload data of the PSDU and possible padding. The data are padded with 0s(M118), scrambled, encoded and modulated as described in the following subclauses.

#### 20.6.2.3.2 Scrambler

The operation of the scrambler is defined in 20.3.9 (Scrambler). The scrambling of the PSDU continues the scrambling of the header with no reset of the scrambler. The padding bits are also scrambled.

#### 20.6.2.3.3 Encoding

##### 20.6.2.3.3.1 General

Data is encoded using an outer RS(224,208) block code and a short inner code. The inner code is a (16,8) block code for MCSs 25 and 28, a (12,8) block code for MCSs 26 and 29, and a (9,8) single parity check (SPC) block code for MCSs 27 and 30 and the identity block-code for MCS 31. The encoding is further detailed in the following steps:

1) First, the number of block padding bits is calculated:
   a) The total number of Reed Solomon codewords is $N_{RS} = \lceil (Length)/208 \rceil$ and the total number of RS encoded symbols is given by $Length + N_{RS} \times 16$;
   b) After Reed Solomon encoding, the data is encoded with a short block code ($N$,8) where $N$ can take one of the following values 8, 9, 12, or 16 depending on the MCS as shown in Table 20-21 (DMG low-power SC mode modulation and coding schemes). Therefore:
      i) The total number of encoded bits is $N_{EB} = N \times (Length + N_{RS} \times 16)$;
      ii) The total number of 512 (in length) blocks (each containing 392 data symbols) is $N_{BLKS} = \lceil N_{EB}/(N_{CBPS} \times 392) \rceil$. If BRP PPDU and $N_{BLKS} < N_{BLKS\_MIN}$; $N_{BLKS} = N_{BLKS\_MIN}$, where $N_{BLKS\_MIN} = 18$. The total number of zero block padding bits is $N_{BLK\_PAD} = N_{BLKS} \times N_{CBPS} \times 392 - N_{EB}$.
2) The data is broken into blocks of length 208×8 bits (except for possibly the last block).

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3) Each block is encoded using the RS(224,208) block code as described in 20.6.2.3.3.2 (RS encoding), except perhaps the last block, which is encoded by a shortened version of the code (i.e., if the last block length is K, the shortened block code is RS(16+K,K).
4) The Reed Solomon encoded (#2056)bit stream is further encoded using the block code(N,8) as described in 20.6.2.3.3.3 ((N,8) Block-coding).
5) The coded bit stream is concatenated with $N_{BLK\_PAD}$ 0s(M118). They are scrambled with the continuation of the scrambler sequence that scrambled the PSDU input bits.
6) Each set of 7 octets is interleaved using a uniform interleaver of 7 rows and 8 columns. The 7 octets are written row wise and read column wise, i.e., the index *i* of a bit after interleaving is related to the index *k* of a bit before interleaving by the following rule:

   $i = 8 \times (k \bmod 7) + \lfloor k/7 \rfloor$, $k = 0, 1, \ldots, 55$

7) The resulting bit stream is modulated and then blocked as described in 20.6.2.3.4 (Modulation) and 20.6.2.3.5 (Blocking).

#### 20.6.2.3.3.2 RS encoding

The RS block code is based on the polynomial

$$g(x) = \prod_{k=1}^{16} (x + a^k)$$

where $a = 0x02$ is a root of the primitive polynomial $p(x) = 1 + x^2 + x^3 + x^4 + x^8$. Assume that an octet $b_0 b_1 b_2 b_3 b_4 b_5 b_6 b_7$ ($b_0$ is the LSB) represented by the polynomial

$$M = b_7 x^7 + b_6 x^6 + b_5 x^5 + b_4 x^4 + b_3 x^3 + b_2 x^2 + b_1 x + b_0 .$$

The RS is a systematic block code. Given a block of octets $\mathbf{m} = (m_{M-1}, m_{M-2}, \ldots m_0)$, the additional parity octets $\mathbf{r} = (r_{15}, r_{14}, \ldots r_0)$ are calculated by setting $r = x^{16}\mathbf{m}(x) \bmod g(x)$, where $\mathbf{r}(x) = \sum_{k=0}^{15} r_k x^k$ and $\mathbf{m}(x) = \sum_{k=0}^{M-1} m_k x^k$ and where the calculation is performed over $GF(2^8)$. The parity octets $\mathbf{r}$ are appended to the uncoded block $\mathbf{m}$ to generate the encoded RS block $m_{M-1}, m_{M-2}, \ldots m_0, r_{15}, r_{14}, \ldots, r_0$.

#### 20.6.2.3.3.3 (N,8) Block-coding

Every octet $\mathbf{b}_{1\times 8} = [b_0 b_1 b_2 b_3 b_4 b_5 b_6 b_7]$ is encoded into an *N*-bit codeword $\mathbf{c}_{1\times N} = \left[ \mathbf{b}_{1\times 8} \; \mathbf{p}_{1\times(N-8)} \right]$ such that $\mathbf{c}_{1\times N} = \mathbf{b}_{1\times 8}\mathbf{G}_{8\times N}$, where the generator matrix $\mathbf{G}_{8\times N}$ is given by the following expressions for $N = 8, 9, 12,$ *and* 16, respectively: $G_{8x8}$ is the identity matrix.


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$$\mathbf{G}_{8\times 9} = \begin{bmatrix} 1&0&0&0&0&0&0&0&1 \\ 0&1&0&0&0&0&0&0&1 \\ 0&0&1&0&0&0&0&0&1 \\ 0&0&0&1&0&0&0&0&1 \\ 0&0&0&0&1&0&0&0&1 \\ 0&0&0&0&0&1&0&0&1 \\ 0&0&0&0&0&0&1&0&1 \\ 0&0&0&0&0&0&0&1&1 \end{bmatrix}$$

$$\mathbf{G}_{8\times 12} = \begin{bmatrix} 1&0&0&0&0&0&0&0&1&1&0&0 \\ 0&1&0&0&0&0&0&0&1&0&1&0 \\ 0&0&1&0&0&0&0&0&0&1&0&1 \\ 0&0&0&1&0&0&0&0&0&0&1&1 \\ 0&0&0&0&1&0&0&0&1&0&1&1 \\ 0&0&0&0&0&1&0&0&1&1&0&1 \\ 0&0&0&0&0&0&1&0&1&1&1&0 \\ 0&0&0&0&0&0&0&1&0&1&1&1 \end{bmatrix}$$

$$\mathbf{G}_{8\times 16} = \begin{bmatrix} 1&0&0&0&0&0&0&0&0&1&1&0&1&0&1&0 \\ 0&1&0&0&0&0&0&0&0&0&1&1&0&1&0&1 \\ 0&0&1&0&0&0&0&0&1&0&0&1&1&0&1&0 \\ 0&0&0&1&0&0&0&0&0&1&0&0&1&1&0&1 \\ 0&0&0&0&1&0&0&0&1&0&1&0&0&1&1&0 \\ 0&0&0&0&0&1&0&0&0&1&0&1&0&0&1&1 \\ 0&0&0&0&0&0&1&0&1&0&1&0&1&0&0&1 \\ 0&0&0&0&0&0&0&1&1&1&0&1&0&1&0&0 \end{bmatrix}$$

#### 20.6.2.3.4 Modulation

The same π/2-BPSK described in 20.5.3.2.4.2 (π/2-BPSK modulation) and π/2-QPSK described in 20.5.3.2.4.2 (π/2-BPSK modulation) are used in the DMG low-power SC mode.

#### 20.6.2.3.5 Blocking

The blocking for the low-power SC is illustrated in Figure 20-15 (Blocking for DMG low-power SC mode). The data is partitioned into blocks of length 512 wherein each 512-block is constructed from 8 subblocks. Each subblock is of length 64. The first subblock is a $G_{64}$, which is the π/2-BPSK symbols sequence generated by the 64 point Golay sequence $Ga_{64}$ defined in 20.10 (Golay sequences). The starting index for the first symbol π/2 rotation is 0, and subblocks 2 to 8 are constructed in the same way, i.e., a data portion of 56 symbols followed by a guard interval of 8 symbols. Note that each 512-block carries 392 symbols of data and 120 symbols of guard.

If the Additional PPDU field within the PHY header is equal to 0, the final block transmitted is followed by $Ga_{64}$. If the Additional PPDU field within the PHY header is equal to 1, the final block transmitted of the last PPDU in an A-PPDU is followed by $Ga_{64}$.

The $G_8$ guard interval is a copy of the last 8 samples of $Ga_{64}$.

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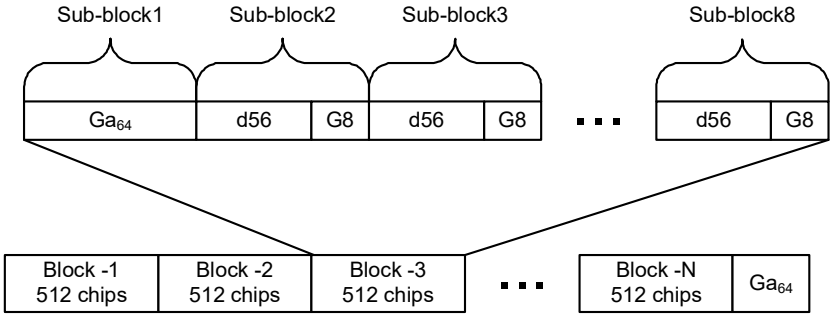


**Figure 20-15—Blocking for DMG low-power SC mode**

NOTE—A STA might estimate the channel impulse response from the CEF, and decides whether to equalize using the 512-block or the short 64-subblock. For example, if the channel impulse response energy is almost concentrated in 8 taps, a 64-equalizer can be used; otherwise, a 512-equalizer is used.

## 20.7 PHY transmit procedure

The PHY transmit procedure is shown in Figure 20-16 (PHY transmit procedure). In order to transmit data, a PHY-TXSTART.request primitive shall be enabled so that the PHY entity shall be in the transmit state. Further, the PHY shall be set to operate at the appropriate frequency through station management via the PLME, as specified in 20.11 (DMG PLME). Other transmit parameters, such as MCS and transmit power, are set via the PHY SAP with the PHY-TXSTART.request(TXVECTOR) primitive, as described in 20.2.2 (TXVECTOR and RXVECTOR parameters).

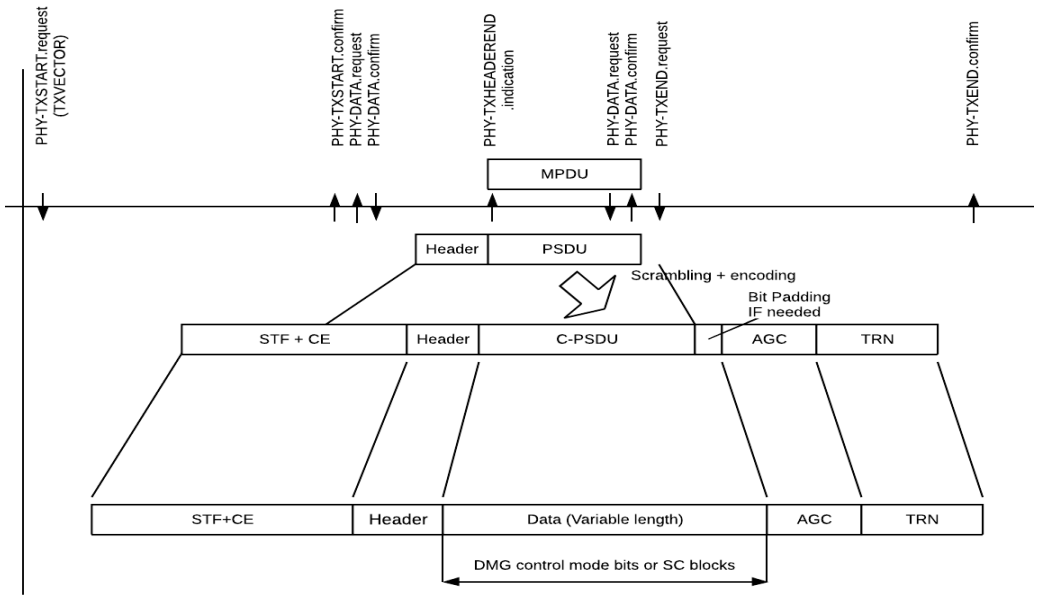


**Figure 20-16—PHY transmit procedure**

Transmission of the PHY preamble may start if TIME_OF_DEPARTURE_REQUESTED is false, and shall start immediately if TIME_OF_DEPARTURE_REQUESTED is true, based on the parameters passed in the PHY-TXSTART.request primitive.


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The preamble format (control or SC mode) depend on the MCS in the PHY-TXSTART.request primitive. The PHY shall calculate the length of the (#14)PPDU according the MCS and the length specified in the PHY-TXSTART.request primitive, adding padding bits if necessary.

The PHY continues with the encoding and transmission of the header according to the parameters of the PHY-TXSTART.request(TXVECTOR) primitive. The PHY proceeds with PSDU transmission through a series of data octet transfers from the MAC. The data are encoded as described in 20.4.3.2.3 (Header encoding and modulation) and 20.5.3.2.3 (Encoding). The encoded data are then modulated as described in 20.4 (DMG control mode), 20.5 (DMG SC mode), and 20.6 (DMG low-power SC mode), depending on the MCS requested in the PHY-TXSTART.request primitive. Transmission can be prematurely terminated by the MAC through the PHY-TXEND.request primitive.

Transmission of the PSDU is completed with the transmission of the last bits of the (encoded) PSDU. If no TRN-T/R fields are specified in the PHY-TXSTART.request primitive, the PHY shall issue a PHY-TXEND.confirm primitive after the transmission of the last bits. If TRN units are requested in the PHY-TXSTART.request primitive, the transmission continues with the transmission of AGC subfields and TRN units. The PHY issues the PHY-TXEND.confirm primitive to the MAC after the transmission of the last TRN unit. The (#14)PPDU transmission shall be completed, and the PHY entity shall enter the receive state. Each PHY-TXEND.request primitive is acknowledged with a PHY-TXEND.confirm primitive from the PHY.

A typical transmit state machine is shown in Figure 20-17 (Typical Tx state machine (Training Length = 0 is assumed; some optional features such as DMG SC low-power mode are not shown)(#410)).

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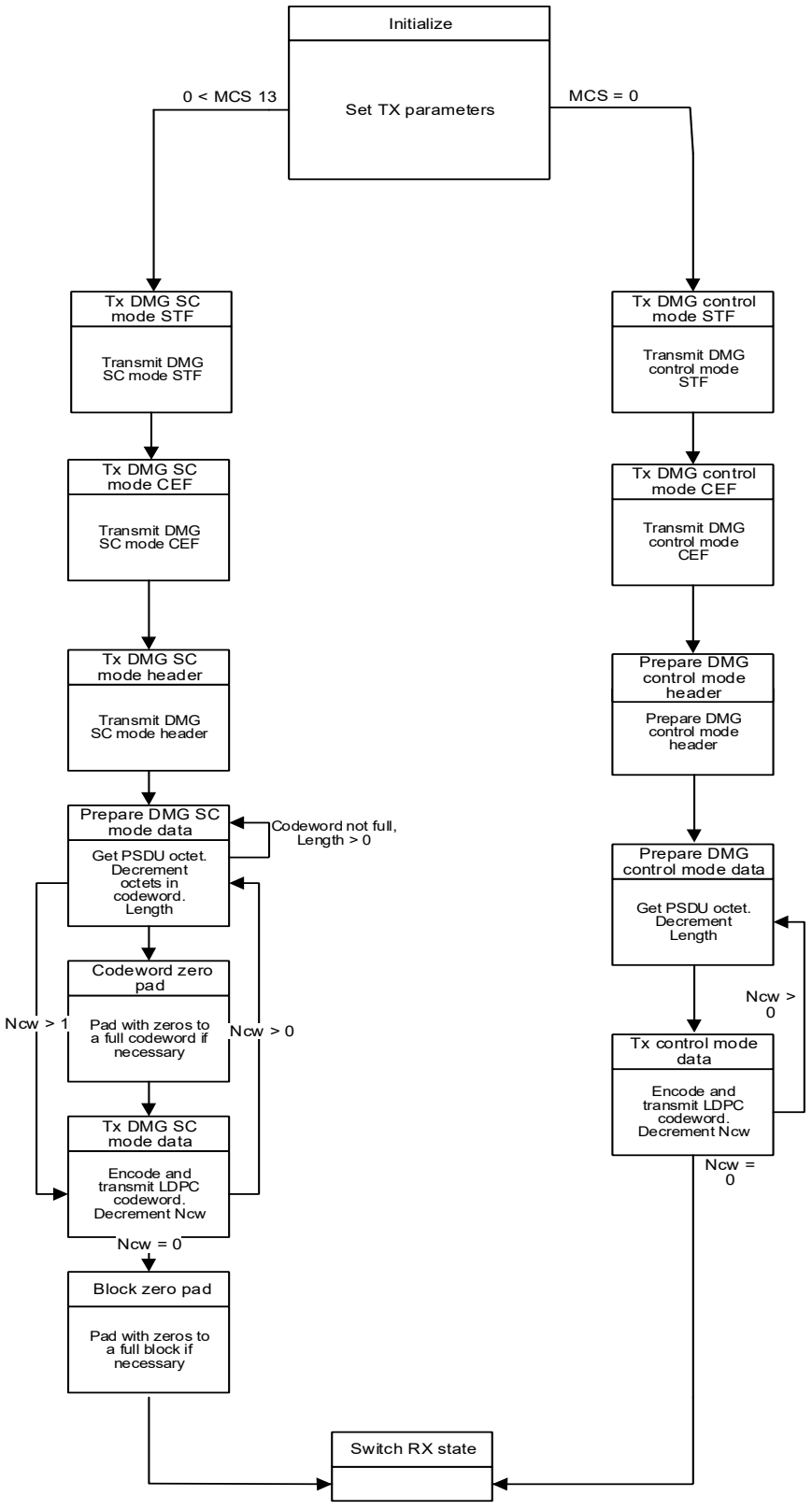


**Figure 20-17—Typical Tx state machine (Training Length = 0 is assumed; some optional features such as DMG SC low-power mode are not shown)(#410)**



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## 20.8 PHY receive procedure

A typical PHY receive procedure is shown in Figure 20-18 (PHY receive procedure(#1058)(#3480)).

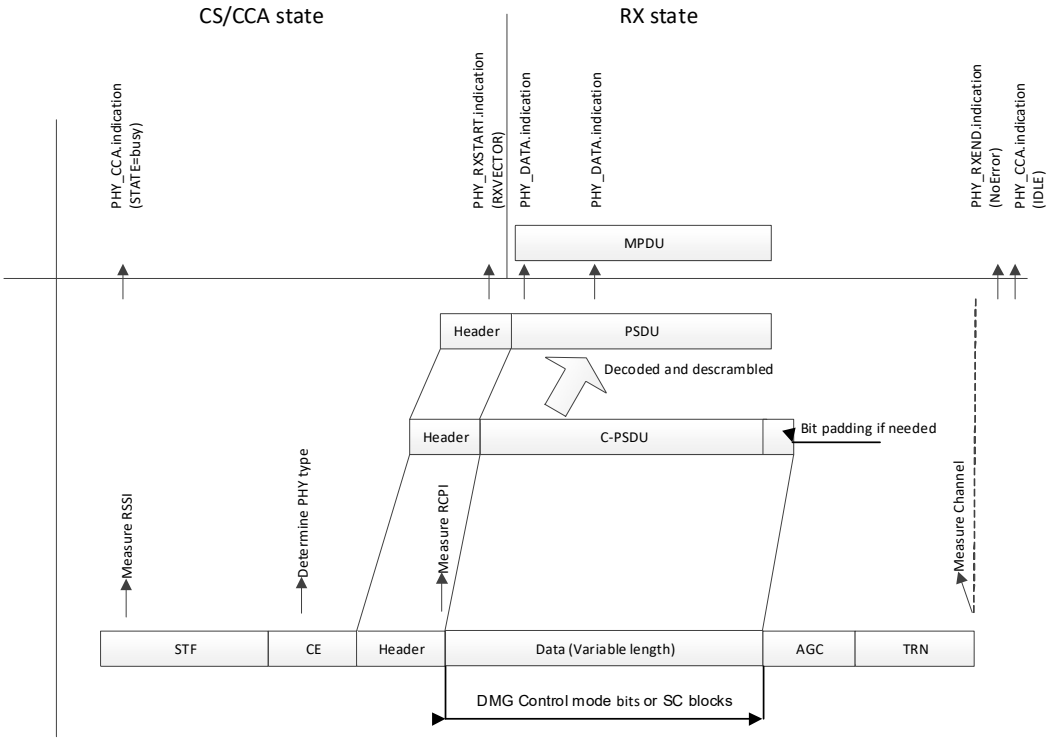


**Figure 20-18—PHY receive procedure(#1058)(#3480)**

Upon receiving the STF, the PHY measures signal strength. This activity is indicated by the PHY to the MAC by issuing a PHY-CCA.indication(BUSY) primitive.

After the PHY-CCA.indication(BUSY) primitive is issued, the PHY entity shall search for the CE field and begin receiving the CE field. The PHY demodulates the header following the reception of the CE field. If the receiver is capable of receiving low-power SC mode, and dot11LowPowerSCPHYActivated is true, then the PHY shall attempt to demodulate both an(#1424) SC header and an SC low-power header. The PHY shall decode the header and determine the MCS, length and other parameters needed for the demodulation of (#14)the remainder of the PPDU.

Subsequently, if dot11TimingMsmtActivated is true, a PHY-RXSTART.indication(RXVECTOR) primitive shall be issued and RX_START_OF_FRAME_OFFSET parameter within the RXVECTOR shall be forwarded (see 20.2.2 (TXVECTOR and RXVECTOR parameters)).

NOTE—The RX_START_OF_FRAME_OFFSET value is used (#3049)to estimate when the start of the preamble for the incoming (#14)PPDU was detected on the medium at the receive antenna connector.

(#14)At the end of the Data field that has the Training Length field in the PHY header equal to 0, the PHY shall issue a PHY-RXEND.indication(No_Error) primitive to the MAC. If the Training Length field in the PHY header is greater than 0, the PHY shall continue to receive these training fields after the data portion of

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the packet and measure the channel. After the end of the training fields, the PHY shall generate a PHY-CCA.indication(IDLE) primitive and the PHY-RXEND.indication(NoError) primitive.

In the case of signal loss before the decoding of the header or in the case of an invalid header, the PHY shall not generate a PHY-CCA.indication(IDLE) primitive until the received level drops below a value that is 20 dB higher than the receive sensitivity of MCS 1. In the case of signal loss after decoding of a valid header, the PHY shall not generate a PHY-CCA.indication(IDLE) primitive until the expected end of the (#14)PPDU, including AGC and TRN fields.

A typical receive state machine is shown in Figure 20-19 (Typical Rx state machine (some optional features such as DMG low-power SC mode are not shown)).

## 20.9 Beamforming

### 20.9.1 Beamforming concept

Beamforming enables a pair of STAs to train their transmit and receive antennas for subsequent communication. A beamformed link is established following the successful completion of BF training, which is described in 10.41 (DMG beamforming).

(11ay)DMG STAs use a quasi-omni antenna pattern. For a STA that is not operating in a TDD SP (see 10.39.6.2.2 (SP with TDD channel access)), the antenna gain of the main beam of a quasi-omni antenna pattern should be at most 15 dB lower than the antenna gain in the main beam for a directional pattern, unless the STA is an EDMG STA that supports beamforming for asymmetric links (see 10.42.10.3 (Beamforming for asymmetric links)). In this case, the difference in antenna gain may be greater than 15 dB.

### 20.9.2 Beamforming PPDU format(#14)

#### 20.9.2.1 Sector-level sweep

PPDUs transmitted during transmit sector sweep are DMG control mode PPDUs. PPDUs transmitted during receive sector sweep are DMG control mode or DMG SC mode PPDUs.

#### 20.9.2.2 Beam refinement

##### 20.9.2.2.1 General

Beam refinement is a process where a STA can improve its antenna configuration (or antenna weight vectors) both for transmission and reception. If the SLS beamforming training did not include an RSS, as in the case where both devices have more than one transmit sector per antenna, beam refinement can serve as the first receive antenna configuration training. The procedure of beam refinement is described in 10.41.6.4 (BRP phase execution).

In the beam refinement procedure, BRP PPDUs are used to train the receiver and transmitter antenna. There are two types of BRP PPDUs: BRP-RX PPDUs and BRP-TX PPDUs:

— BRP-RX PPDUs are PPDUs that have an AGC field and a TRN field following the Data field. These PPDUs enable receiver antenna weight vector training. A BRP-RX PPDU has the (#6409)Header field Training Length greater than zero, PPDU Type equal to zero and Beam Tracking Request (if present) equal to 0.

— BRP-TX PPDUs are PPDUs that have an AGC field and a TRN field following the Data field. The transmitting STA may change antenna configuration at the beginning of each subfield. The receiving STA performs measurements on these subfields and sends feedback to the STA that


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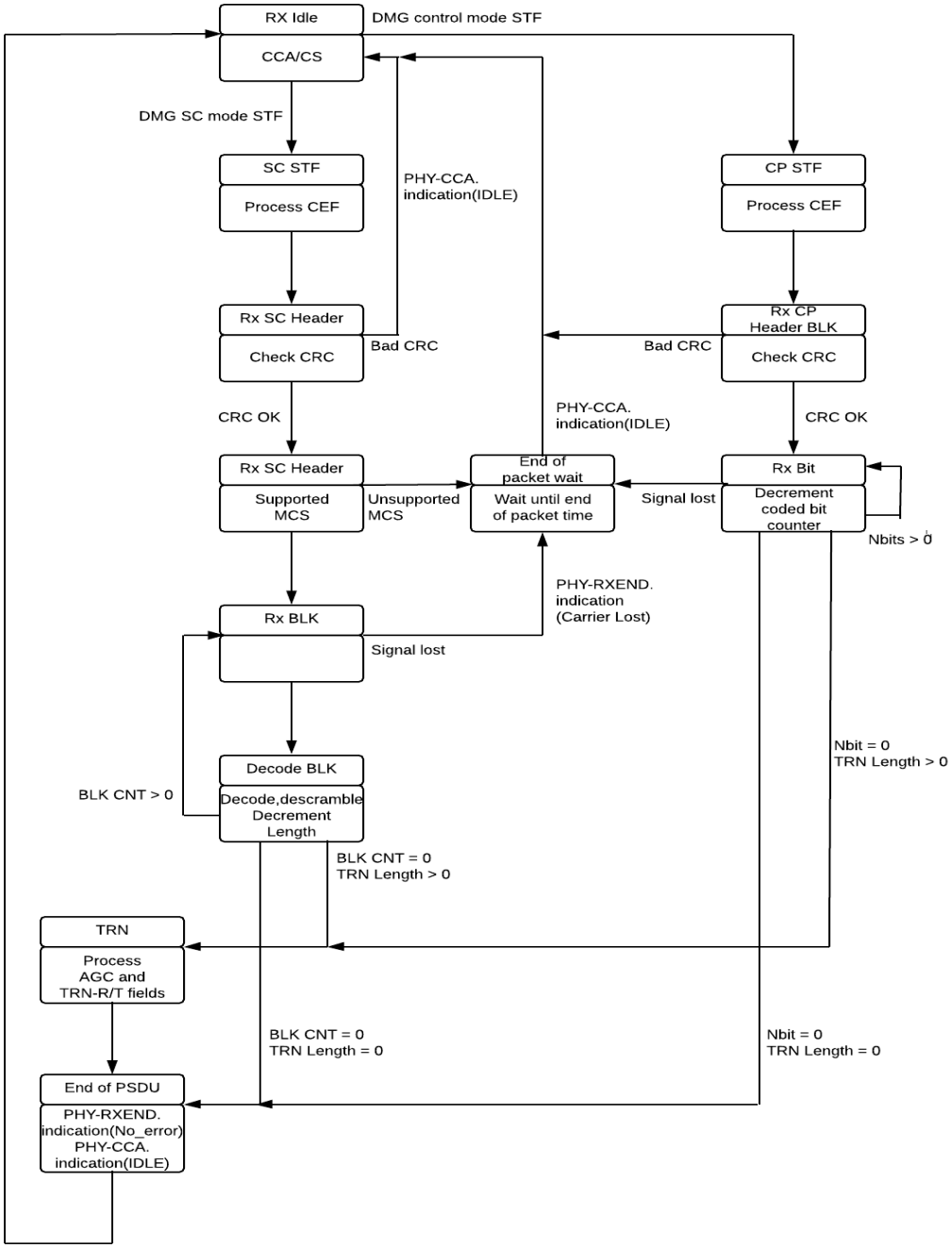


**Figure 20-19—Typical Rx state machine**
**(some optional features such as DMG low-power SC mode are not shown)**

transmits the BRP-TX PPDU. A BRP-RX PPDU has the (#6409)Header field Training Length greater than zero and PPDU Type equal to 1.

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#### 20.9.2.2.2 BRP PPDU structure

(#3626)Each BRP PPDU is shown in Figure 20-20 (BRP PPDU structure).

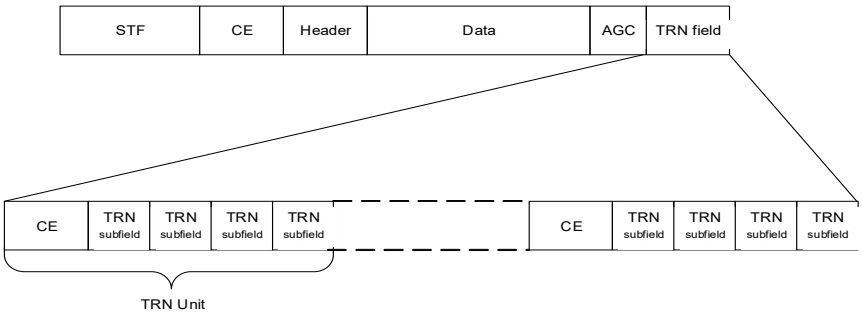


**Figure 20-20—BRP PPDU structure**

#### 20.9.2.2.3 BRP PPDU Header field(#6409)

The PPDU Type and Training Length fields present within the SC mode header, control mode header and LP SC mode header are used to indicate that a (#14)PPDU is BRP PPDU and the length of the training fields, respectively.

A value of 0 in both the PPDU Type field and the Beam Tracking Request field indicates a BRP-RX PPDU.

A value of 1 in the PPDU Type field indicates a BRP-TX PPDU.

A value of *N* in the Training Length field indicates 4×*N* AGC subfields and that the TRN-R/T field has *N* TRN Units.

The value *N* in the Training Length field of a BRP-RX PPDU is equal to the value of the L-RX field requested by the intended receiver of the BRP-RX PPDU at a previously received BRP Request field (see 9.5.4 (BRP Request field)).

#### 20.9.2.2.4 BRP PPDU duration

The minimum duration of the (#404)Data field of a BRP PPDU when sent in an SC mode is aBRPminSCblocks SC blocks (see 20.5.3.2.5 (Symbol blocking and guard insertion)) and, if needed, the (#404)Data field of the (#14)PPDU shall be extended by extra zero padding to generate the required number of SC blocks. Table 20-22 (Zero filling for DMG SC mode BRP PPDUs) contains the values of $N_{CWmin}$ for each MCS necessary to compute the padding described in 20.5.3.2.3.3 (LDPC encoding process).

The minimum duration of the (#404)Data field of a BRP PPDU when sent with the low-power SC mode is $N_{BLKS\_MIN}$ low-power SC blocks (see 20.6.2.3.3 (Encoding)).


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**Table 20-22—Zero filling for DMG SC mode BRP PPDUs**

| MCS index | Modulation | $N_{CBPS}$ | Repetition | Code rate | Data rate (Mb/s) | $N_{CWmin}$ |
|---|---|---|---|---|---|---|
| 1 | π/2-BPSK | 1 | 2 | 1/2 | 385 | 12 |
| 2 | π/2-BPSK | 1 | 1 | 1/2 | 770 | 12 |
| 3 | π/2-BPSK | 1 | 1 | 5/8 | 962.5 | 12 |
| 4 | π/2-BPSK | 1 | 1 | 3/4 | 1155 | 12 |
| 5 | π/2-BPSK | 1 | 1 | 13/16 | 1251.25 | 12 |
| 6 | π/2-QPSK | 2 | 1 | 1/2 | 1540 | 23 |
| 7 | π/2-QPSK | 2 | 1 | 5/8 | 1925 | 23 |
| 8 | π/2-QPSK | 2 | 1 | 3/4 | 2310 | 23 |
| 9 | π/2-QPSK | 2 | 1 | 13/16 | 2502.5 | 23 |
| 9.1 | π/2-QPSK | 2 | 1 | 7/8 | 2695 | 25 |
| 10 | π/2-16-QAM | 4 | 1 | 1/2 | 3080 | 46 |
| 11 | π/2-16-QAM | 4 | 1 | 5/8 | 3850 | 46 |
| 12 | π/2-16-QAM | 4 | 1 | 3/4 | 4620 | 46 |
| 12.1 | π/2-16-QAM | 4 | 1 | 13/16 | 5005 | 46 |
| 12.2 | π/2-16-QAM | 4 | 1 | 7/8 | 5390 | 49 |
| 12.3 | π/2-64-QAM | 6 | 1 | 5/8 | 5775 | 69 |
| 12.4 | π/2-64-QAM | 6 | 1 | 3/4 | 6930 | 69 |
| 12.5 | π/2-64-QAM | 6 | 1 | 13/16 | 7507.5 | 69 |
| 12.6 | π/2-64-QAM | 6 | 1 | 7/8 | 8085 | 74 |

### 20.9.2.2.5 AGC field

(#14)The AGC field in the BRP PPDU is composed of 4*N* AGC subfields. Each AGC subfield consists of the sequence [$Ga_{64}$ $Ga_{64}$ $Ga_{64}$ $Ga_{64}$ $Ga_{64}$] when the PPDU is transmitted using the SC mode and [$Gb_{64}$ $Gb_{64}$ $Gb_{64}$ $Gb_{64}$ $Gb_{64}$] when the PPDU is transmitted using the control mode. The sequences $Ga_{64}$ and $Gb_{64}$ are defined in 20.10 (Golay sequences). The sequences are transmitted using rotated π/2-BPSK modulation.

In a BRP-TX PPDU, the transmitter may change the TX AWV configuration at the beginning of each AGC subfield. Any transmit signal transients that occur due to this TX AWV configuration change shall completely settle by the end of the first Ga64 or Gb64 subsequence. The set of AWVs used for the AGC subfields should be the same as that used for the TRN-T subfields. In a BRP-RX PPDU, the transmitter shall use the same TX AWV as in the preamble and (#404)Data fields of the PPDU.

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#### 20.9.2.2.6 TRN field

The TRN field enables transmitter and receiver AWV training. The TRN field has the form shown in Figure 20-21 (TRN field definition).

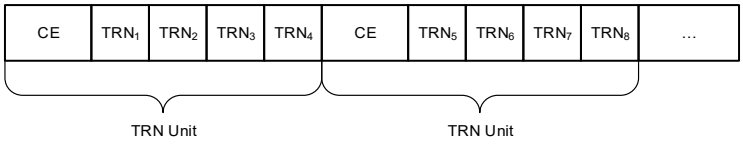


**Figure 20-21—TRN field definition**

The TRN field is composed of *N* TRN Units. Each TRN Unit is composed of a CE subfield and 4 TRN subfields. Each subfield CE matches the Channel Estimation field defined in 20.3.6.3 (Channel Estimation field). The 4N subfields $TRN_1$ to $TRN_{4N}$ each consist of the sequence $[Ga_{128}\ -Gb_{128}\ Ga_{128}\ Gb_{128}\ Ga_{128}]$. The sequences $Ga_{128}$ and $Gb_{128}$ are defined in Table 20-23 (The sequence Ga128(n)) and Table 20-24 (The sequence Gb128(n)), respectively, in 20.10 (Golay sequences). The sequences are transmitted using rotated π/2-BPSK modulation.

In a BRP-RX PPDU, all of the TRN and CE subfields are transmitted using the same AWV as the preamble and (#404)Data field of the (#14)PPDU. In a BRP-TX PPDU, the CE subfield shall be transmitted using the same AWV as the preamble and (#404)Data field of the (#14)PPDU. In a BRP-TX PPDU, the transmitter may change AWV at the beginning of each TRN subfield. Any transmit signal transients that occur due to TX AWV configuration changes at the beginning of TRN subfields shall settle by the end of the first 64 samples of the subfield.

#### 20.9.2.2.7 Channel measurement

The good autocorrelation properties of the Golay sequence enable reconstructing part of the impulse response of the channel between the transmitter and the receiver. The receiver should find the tap with largest amplitude in the channel during the CE field of the BRP-RX. It selects thereafter the set of taps that is measured around the tap with the largest amplitude, according to dot11ChanMeasFBCKNtaps. It can select a contiguous set of taps or select a noncontiguous set of taps, and include the tap delays subfield as part of the subfield measurement. It then measures the phase and amplitude of the corresponding channel taps in each of the TRN-T subfields (except for those using the CE AWV configuration). The beam refinement feedback subfield k-1 is the relative amplitude and phase of this tap in the k'th repetition compared to this tap in the first TRN-T subfield.

## 20.10 Golay sequences

The following Golay sequences are used in the preamble, in the single carrier guard interval and in beam refinement TRN-R/T and AGC fields: $Ga_{128}(n)$, $Gb_{128}(n)$, $Ga_{64}(n)$, $Gb_{64}(n)$, $Ga_{32}(n)$, $Gb_{32}(n)$. These are 3 pairs of complementary sequences. The subscript denotes the length of the sequences. These sequences are generated using the following recursive procedure:

$$A_0(n) = \delta(n)$$
$$B_0(n) = \delta(n)$$
$$A_k(n) = W_k A_{k-1}(n) + B_{k-1}(n - D_k)$$
$$B_k(n) = W_k A_{k-1}(n) - B_{k-1}(n - D_k)$$


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where

$$\delta(n) = \begin{cases} 1 & n=0 \\ 0 & \text{otherwise} \end{cases}$$

Note that $A_k(n), B_k(n)$ are zero for n < 0 and for $n \geq 2^k$.

$Ga_{128}(n)=A_7(127-n)$, $Gb_{128}(n)=B_7(127-n)$ when the procedure uses $D_k$ = [1 8 2 4 16 32 64] (k=1,2,…,7) and $W_k$ = [–1 –1 –1 –1 +1 –1 –1].

$Ga_{64}(n)=A_6(63-n)$, $Gb_{64}(n)=B_6(63-n)$ when the procedure uses $D_k$= [2 1 4 8 16 32] and $W_k$ =[1 1 -1 -1 1 -1].

$Ga_{32}(n)=A_5(31-n)$, $Gb_{32}(n)=B_5(31-n)$ when the procedure uses $D_k$=[1 4 8 2 16] and $W_k$ =[-1 1 -1 1 -1].

The sequences are defined in Table 20-23 (The sequence Ga128(n)) through Table 20-28 (The sequence Gb32(n)).

**Table 20-23—The sequence $Ga_{128}(n)$**

| The Sequence $Ga_{128}(n)$, to be transmitted from left to right, up to down |
|---|
| +1 +1 −1 −1 −1 −1 −1 −1 −1 +1 −1 +1 +1 −1 −1 +1 +1 +1 −1 −1 +1 +1 +1 +1 −1 +1 −1 +1 −1 +1 +1 −1 |
| −1 −1 +1 +1 +1 +1 +1 +1 +1 −1 +1 −1 −1 +1 +1 −1 +1 +1 −1 −1 +1 +1 +1 +1 −1 +1 −1 +1 −1 +1 +1 −1 |
| +1 +1 −1 −1 −1 −1 −1 −1 −1 +1 −1 +1 +1 −1 −1 +1 +1 +1 −1 −1 +1 +1 +1 +1 −1 +1 −1 +1 −1 +1 +1 −1 |
| +1 +1 −1 −1 −1 −1 −1 −1 −1 +1 −1 +1 +1 −1 −1 +1 −1 −1 +1 +1 −1 −1 −1 −1 +1 −1 +1 −1 +1 −1 −1 +1 |

**Table 20-24—The sequence $Gb_{128}(n)$**

| The Sequence $Gb_{128}(n)$, to be transmitted from left to right, up to down |
|---|
| −1 −1 +1 +1 +1 +1 +1 +1 +1 −1 +1 −1 −1 +1 +1 −1 −1 −1 +1 +1 −1 −1 −1 −1 +1 −1 +1 −1 +1 −1 −1 +1 |
| +1 +1 −1 −1 −1 −1 −1 −1 −1 +1 −1 +1 +1 −1 −1 +1 −1 −1 +1 +1 −1 −1 −1 −1 +1 −1 +1 −1 +1 −1 −1 +1 |
| +1 +1 −1 −1 −1 −1 −1 −1 −1 +1 −1 +1 +1 −1 −1 +1 +1 +1 −1 −1 +1 +1 +1 +1 −1 +1 −1 +1 −1 +1 +1 −1 |
| +1 +1 −1 −1 −1 −1 −1 −1 −1 +1 −1 +1 +1 −1 −1 +1 −1 −1 +1 +1 −1 −1 −1 −1 +1 −1 +1 −1 +1 −1 −1 +1 |

**Table 20-25—The sequence $Ga_{64}(n)$**

| The Sequence $Ga_{64}(n)$, to be transmitted from left to right, up to down |
|---|
| −1 −1 +1 −1 +1 −1 −1 −1 +1 +1 −1 +1 +1 −1 −1 −1 −1 −1 +1 −1 +1 −1 −1 −1 −1 −1 +1 −1 −1 +1 +1 +1 |
| −1 −1 +1 −1 +1 −1 −1 −1 +1 +1 −1 +1 +1 −1 −1 −1 +1 +1 −1 +1 −1 +1 +1 +1 +1 +1 −1 +1 +1 −1 −1 −1 |

**Table 20-26—The sequence $Gb_{64}(n)$**

| The sequence $Gb_{64}(n)$, to be transmitted from left to right, up to down |
|---|
| +1 +1 −1 +1 −1 +1 +1 +1 −1 −1 +1 −1 −1 +1 +1 +1 +1 +1 −1 +1 −1 +1 +1 +1 +1 +1 −1 +1 +1 −1 −1 −1 |
| −1 −1 +1 −1 +1 −1 −1 −1 +1 +1 −1 +1 +1 −1 −1 −1 +1 +1 −1 +1 −1 +1 +1 +1 +1 +1 −1 +1 +1 −1 −1 −1 |

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**Table 20-27—The sequence $Ga_{32}(n)$**

| The Sequence $Ga_{32}(n)$, to be transmitted from left to right |
|---|
| +1 +1 +1 +1 +1 −1 +1 −1 −1 −1 +1 +1 +1 −1 −1 +1 +1 +1 −1 −1 +1 −1 −1 +1 −1 −1 −1 −1 +1 −1 +1 −1 |

**Table 20-28—The sequence $Gb_{32}(n)$**

| The Sequence $Gb_{32}(n)$, to be transmitted from left to right |
|---|
| −1 −1 −1 −1 −1 +1 −1 +1 +1 +1 −1 −1 −1 +1 +1 −1 +1 +1 −1 −1 +1 −1 −1 +1 −1 −1 −1 −1 +1 −1 +1 −1 |

## 20.11 DMG PLME

### 20.11.1 PLME SAP layer management primitives(#6320)

Table 20-29 (DMG PHY MIB attribute default values) lists the MIB attributes that may be accessed by the PHY entities and the intra-layer of higher level LMEs. These attributes are accessed via the PLME-GET, PLME-SET, PLME-RESET, and PLME-CHARACTERISTICS primitives defined in 6.7 (PLME SAP interface).

### 20.11.2 DMG PHY MIB

All DMG PHY MIB attributes are defined in Annex C, with specific values defined in Table 20-29 (DMG PHY MIB attribute default values). The column titled “Operational semantics” in Table 20-29 (DMG PHY MIB attribute default values) contains two types: static and dynamic. Static MIB attributes are fixed and cannot be modified for a given PHY implementation. Dynamic MIB attributes can be modified by some management entity.

**Table 20-29—DMG PHY MIB attribute default values**

| Managed object | Default value/range | Operational semantics |
|---|---|---|
| **dot11PHYOperationTable** | | |
| dot11PHYType | DMG | Static |
| **dot11PHYDMGTable** | | |
| dot11LowPowerSCPHYImplemented | Boolean | Static |
| dot11LowPowerSCPHYActivated | Boolean | Dynamic |

When MAX-ACCESS is read-only, the MIB attribute value may be updated by the PLME and read from the MIB attribute by management entities. When MAX-ACCESS is read-write, the MIB attribute may be read and written by management entities but shall not be updated by the PLME.


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### 20.11.3 TXTIME calculation

The value of the TXTIME parameter returned by the PLME-TXTIME.confirm primitive shall be calculated according to the following equations.

For the DMG SC mode ($N_{TRN}$ is Training Length field defined in the header):

$$TXTIME = \begin{cases} T_{STF} + T_{CE} + T_{header} + T_{Data} & N_{TRN} = 0 \\ T_{STF} + T_{CE} + T_{header} + \max\{T_{Data}, (\alpha \times \beta + \gamma) \times T_C\} + N_{TRN} \times T_{TRN-Unit} & N_{TRN} > 0 \text{ and SC} \end{cases}$$

where

$\alpha$ = aBRPminSCblocks
$\beta$ = aSCBlockSize
$\gamma$ = aSCGILength
$T_{TRN-Unit}$ = aBRPTRNBlock $\times$ $T_C$

For the DMG control mode:

$$TXTIME = T_{STF-CM} + T_{CE-CM} + (11 \times 8 + (Length - 6) \times 8 + N_{CW} \times 168) \times T_C \times 32 + N_{TRN} \times T_{TRN-Unit}$$

where $N_{CW}$ calculation is defined in 20.4.3.3.3 (Encoder).

### 20.11.4 DMG PHY

(#2123)The DMG PHY characteristics, provided through the PLME-CHARACTERISTICS service primitive, are shown in Table 20-30 (DMG PHY characteristics). The definitions for these characteristics are given in 6.7.4 (PLME-CHARACTERISTICS.confirm).

**Table 20-30—DMG PHY characteristics**

| PHY parameter | Value |
|---|---|
| aRIFSTime | 1 μs |
| aSIFSTime | 3 μs |
| aRxPHYDelay | Implementation dependent, see 10.3.7 (DCF timing relations). |
| aRxTxTurnaroundTime | Implementation dependent, see 10.3.7 (DCF timing relations). |
| aCCATime | Implementation dependent, see 10.3.7 (DCF timing relations). |
| aRxTxSwitchTime | Implementation dependent, see 10.3.7 (DCF timing relations). |
| aRxPHYStartDelay | DMG control mode: 10 μs; DMG SC and SC low-power modes: 3.6 μs |
| aMACProcessingDelay | Implementation dependent, see 10.3.7 (DCF timing relations). |

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**Table 20-30—DMG PHY characteristics *(continued)***

| PHY parameter | Value |
|---|---|
| aTxPHYDelay | Implementation dependent, see 10.3.7 (DCF timing relations). |
| aTxRampOnTime | Implementation dependent, see 10.3.7 (DCF timing relations). |
| aSBIFSTime | 1 μs |
| aSBIFSAccuracy | 0.03 μs |
| aAirPropagationTime | 100 ns |
| aDMGDetectionThres | –48 dBm |
| aBRPIFS | 40 μs |
| aSlotTime | 5 μs |
| aCWmin | 15 |
| aCWmax | 1023 |
| aBRPminSCblocks | 18 |
| aBRPTRNBlock | 4992 |
| aSCGILength | 64 |
| aSCBlockSize | 512 |
| aPPDUMaxTime | 2 ms |
| aPSDUMaxLength | 262 143 octets |
| (11ay)aTDDAirPropagationTime | 1 μs |
| (11ay)aDMGActiveThresholdPercentage | 10% |


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# 21. Very high throughput (VHT) PHY specification

## 21.1 Introduction

### 21.1.1 Introduction to the VHT PHY

Clause 21 (Very high throughput (VHT) PHY specification) specifies the PHY entity for a very high throughput (VHT) orthogonal frequency division multiplexing (OFDM) system operating in the 5 GHz band.

In addition to the requirements in Clause 21 (Very high throughput (VHT) PHY specification), a VHT STA shall support(#546) transmitting and receiving PPDUs that are compliant with the mandatory PHY specifications defined in Clause 19 (High Throughput (HT) PHY specification(#2297)) in the 5 GHz band.

The VHT PHY is based on the HT PHY defined in Clause 19 (High Throughput (HT) PHY specification(#2297)), which in turn is based on the OFDM PHY defined in Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification). The VHT PHY extends the maximum number of space-time streams supported to eight and provides support for downlink multi-user (MU) transmissions. A downlink MU transmission supports up to four users with up to four space-time streams per user with the total number of space-time streams not exceeding eight.

NOTE—MU transmission is different from VHT SU group addressed transmission.

The VHT PHY provides support for 20 MHz, 40 MHz, 80 MHz, and 160 MHz contiguous channel widths and support for 80+80 MHz noncontiguous channel width.

The VHT PHY data subcarriers are modulated using binary phase shift keying (BPSK), quadrature phase shift keying (QPSK), 16-quadrature amplitude modulation (16-QAM), 64-QAM, and 256-QAM. Forward error correction (FEC) coding (convolutional or LDPC coding) is used with coding rates of 1/2, 2/3, 3/4, and 5/6.

A VHT STA shall support the following features:

- Non-HT and non-HT duplicate formats (transmit and receive) for all channel widths supported by the VHT STA
- HT-mixed format (transmit and receive)
- VHT format (transmit and receive)
- 20 MHz, 40 MHz, and 80 MHz channel widths
- Single spatial stream VHT-MCSs 0 to 7 (transmit and receive) in all supported channel widths
- BCC coding

A VHT STA may support the following features:

- HT-greenfield format (transmit and receive)
- 2 or more spatial streams (transmit and receive)
- 400 ns short guard interval (transmit and receive)
- Beamforming sounding (by sending a VHT NDP)
- Responding to transmit beamforming sounding (by providing compressed beamforming feedback)
- STBC (transmit and receive)
- LDPC (transmit and receive)
- VHT MU PPDUs (transmit and receive)

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- Support for 160 MHz channel width
- Support for 80+80 MHz channel width
- VHT-MCSs 8 and 9 (transmit and receive)

### 21.1.2 Scope of VHT PHY services

The services provided to the MAC by the VHT PHY consist of the following protocol functions:

a) A function that defines a method of mapping the PSDUs into (#14)a PPDU format suitable for sending and receiving PSDUs between two or more STAs.

b) A function that defines the characteristics and method of transmitting and receiving data through a wireless medium between two or more STAs. Depending on the PPDU format, these STAs support a mixture of VHT, Clause 19 (High Throughput (HT) PHY specification(#2297)) and Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) PHYs.

### 21.1.3 VHT PHY functions

#### 21.1.3.1 General

The VHT PHY contains two functional entities: the PHY function and the physical layer management function (i.e., the PLME). Both of these functions are described in detail in 21.3 (VHT PHY) and 21.4 (VHT PLME).

The VHT PHY service is provided to the MAC through the PHY service primitives defined in Clause 8 (PHY service specification). The VHT PHY service interface is described in 21.2 (VHT PHY service interface).

#### 21.1.3.2 PHY management entity (PLME)

The PLME performs management of the local PHY functions in conjunction with the MLME.

#### 21.1.3.3 Service specification method

The models represented by figures and state diagrams are intended to be illustrations of the functions provided. It is important to distinguish between a model and a real implementation. The models are optimized for simplicity and clarity of presentation, but do not necessarily reflect any particular implementation.

The service of a layer is the set of capabilities that it offers to a user in the next higher layer. Abstract services are specified here by describing the service primitives and parameters that characterize each service. This definition is independent of any particular implementation.

### 21.1.4 PPDU formats

The structure of the PPDU transmitted by a VHT STA is determined by the TXVECTOR parameters as defined in Table 21-1 (TXVECTOR and RXVECTOR parameters(#12)).

In a VHT STA the FORMAT parameter determines the overall structure of the PPDU and can take one of the following values:

- Non-HT format (NON_HT), based on Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) and including non-HT duplicate format.
- HT-mixed format (HT_MF) as specified in Clause 19 (High Throughput (HT) PHY specification(#2297)).


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- HT-greenfield format (HT_GF) as specified in Clause 19 (High Throughput (HT) PHY specification(#2297)).
- VHT format (VHT). PPDUs of this format contain a preamble compatible with Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) and Clause 19 (High Throughput (HT) PHY specification(#2297)) STAs. The non-VHT portion of the VHT format preamble (the parts of VHT preamble preceding the VHT-SIG-A field) is defined so that it can be decoded by these STAs.

NOTE—Required support for these formats is defined in 11.38 (VHT BSS operation), 19.1.1 (Introduction to the HT PHY), and 21.1.1 (Introduction to the VHT PHY).

A VHT PPDU can be further categorized as a VHT SU PPDU or a VHT MU PPDU. A VHT PPDU using a group ID value of 0 or 63 is a VHT SU PPDU and either carries only one PSDU or no PSDU. A VHT PPDU using a group ID value in the range 1 to 62 is a VHT MU PPDU and carries one or more PSDUs to one or more users.

## 21.2 VHT PHY service interface

### 21.2.1 Introduction

The PHY provides an interface to the MAC through an extension of the generic PHY service interface defined in 8.3.4 (Basic service and options). The interface includes TXVECTOR, RXVECTOR, and PHYCONFIG_VECTOR.

Using the TXVECTOR, the MAC supplies the PHY with per-PPDU transmit parameters. Using the RXVECTOR, the PHY informs the MAC of the received (#14)PPDU's parameters. Using the PHYCONFIG_VECTOR, the MAC configures the PHY for operation, independent of (#14)PPDU transmission or reception.

### 21.2.2 TXVECTOR and RXVECTOR parameters

The parameters in Table 21-1 (TXVECTOR and RXVECTOR parameters(#12)) are defined as part of the TXVECTOR parameter list in the PHY-TXSTART.request primitive and/or as part of the RXVECTOR parameter list in the PHY-RXSTART.indication primitive. (#12)TXVECTOR and RXVECTOR parameters for transmitting or receiving a DSSS, HR/DSSS, OFDM, ERP or HT PPDU are defined in:

- DSSS PPDU: Table 15-1 (TXVECTOR parameters) and Table 15-2 (RXVECTOR parameters)
- HR/DSSS PPDU: Table 16-5 (Parameter vectors)
- OFDM PPDU: Table 17-1 (TXVECTOR parameters) and Table 17-2 (RXVECTOR parameters)
- ERP PPDU: Table 18-1 (TXVECTOR parameters) and Table 18-3 (RXVECTOR parameters)

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— HT PPDU: Table 19-1 (TXVECTOR and RXVECTOR parameters).

**Table 21-1—TXVECTOR and RXVECTOR parameters(#12)**

| Parameter | Condition | Value | TXVECTOR | RXVECTOR |
|---|---|---|---|---|
| FORMAT | | Determines the format of the PPDU.<br>Enumerated type:<br>NON_HT indicates OFDM or non-HT duplicate PPDU format. In this case, the modulation is determined by the NON_HT_MODULATION parameter.<br>HT_MF indicates HT-mixed format.<br>HT_GF indicates HT-greenfield format.<br>VHT indicates VHT format. | Y | Y |
| NON_HT_MDULATION | FORMAT is NON_HT | In TXVECTOR, indicates the format type of the transmitted non-HT PPDU.<br>In RXVECTOR, indicates the estimated format type of the received non-HT PPDU.<br>Enumerated type:<br>OFDM indicates OFDM format. NON_HT_DUP_OFDM indicates non-HT duplicate format | Y | Y |
| | Otherwise | Not present | N | N |
| L_LENGTH(#3291) | FORMAT is VHT | Not present<br><br>NOTE—The Length field of the L-SIG field(#4145) in VHT PPDUs is defined in Equation (21-24) using the TXTIME value defined byEquation (21-109) and Equation (21-110), which in turn depend on other parameters including the TXVECTOR parameter APEP_LENGTH. | N | N |
| | Otherwise | See corresponding entry in Table 19-1 (TXVECTOR and RXVECTOR parameters) | | |
| L_DATARATE(#3291) | FORMAT is VHT | Not present<br><br>NOTE—The RATE field in the L-SIG field in a VHT PPDU is set to the value representing 6 Mb/s in the 20 MHz channel spacing column of Table 17-6 (Contents of the SIGNAL field). | N | N |
| | Otherwise | See corresponding entry in Table 19-1 (TXVECTOR and RXVECTOR parameters) | | |
| N_TX | FORMAT is VHT | Indicates the number of transmit chains. | Y | N |
| | Otherwise | See corresponding entry in Table 19-1 (TXVECTOR and RXVECTOR parameters) | | |


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**Table 21-1—TXVECTOR and RXVECTOR parameters(#12) *(continued)***

| Parameter | Condition | Value | TXVECTOR | RXVECTOR |
|---|---|---|---|---|
| EXPANSION_MAT_TYPE | FORMAT is VHT and EXPANSION_MAT is present. | Set to COMPRESSED_SV | Y | N |
| | Otherwise | See corresponding entry in Table 19-1 (TXVECTOR and RXVECTOR parameters) | | |
| EXPANSION_MAT | FORMAT is VHT | Contains a vector in the number of selected subcarriers containing feedback matrices as defined in 21.3.11.2 (Beamforming Feedback Matrix V) based on the channel measured during the training symbols of a previous VHT NDP. | M<br>U | N |
| | Otherwise | See corresponding entry in Table 19-1 (TXVECTOR and RXVECTOR parameters) | | |
| CHAN_MAT_TYPE | FORMAT is VHT and PSDU_LENGTH equals 0 | Set to COMPRESSED_SV | N | Y |
| | FORMAT is VHT and PSDU_LENGTH is greater than 0 | Not present | N | N |
| | Otherwise | See corresponding entry in Table 19-1 (TXVECTOR and RXVECTOR parameters) | | |
| CHAN_MAT | FORMAT is VHT and PSDU_LENGTH equals 0 | Contains a set of compressed beamforming feedback matrices as defined in 21.3.11.2 (Beamforming Feedback Matrix V) based on the channel measured during the training symbols of the received VHT NDP. | N | Y |
| | FORMAT is VHT and PSDU_LENGTH is greater than 0 | Not present | N | N |
| | Otherwise | See corresponding entry in Table 19-1 (TXVECTOR and RXVECTOR parameters) | | |
| DELTA_SNR | FORMAT is VHT | Contains an array of delta SNR values as defined in 9.4.1.49 (MU Exclusive Beamforming Report field) based on the channel measured during the training symbols of the received VHT NDP.<br><br>NOTE—In the RXVECTOR this parameter is present only for VHT NDPs for MU sounding. | M<br>U | Y |
| | Otherwise | Not present | N | N |

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**Table 21-1—TXVECTOR and RXVECTOR parameters(#12) *(continued)***

| Parameter | Condition | Value | TXVECTOR | RXVECTOR |
|---|---|---|---|---|
| SNR | FORMAT is VHT | Contains an array of received SNR measurements for each spatial stream. SNR indications of 8 bits are supported. SNR shall be the sum of the decibel values of SNR per tone divided by the number of tones represented in each stream as described in 9.4.1.47 (VHT Compressed Beamforming Report field) | N | Y |
| | Otherwise | See corresponding entry in Table 19-1 (TXVECTOR and RXVECTOR parameters) | | |
| FEC_CODING | FORMAT is VHT | Indicates which FEC encoding is used.<br>Enumerated type:<br>BCC_CODING indicates binary convolutional code.<br>LDPC_CODING indicates low-density parity check code. | M<br>U | Y |
| | Otherwise | See corresponding entry in Table 19-1 (TXVECTOR and RXVECTOR parameters) | | |
| STBC | FORMAT is VHT | Indicates whether STBC is used.<br>0 indicates no STBC ($N_{STS}=N_{SS}$ in the Data field).<br>1 indicates STBC is used ($N_{STS}=2N_{SS}$ in the Data field).<br>This parameter is 0 for a VHT MU PPDU. | Y | Y |
| | Otherwise | See corresponding entry in Table 19-1 (TXVECTOR and RXVECTOR parameters) | | |
| GI_TYPE | FORMAT is VHT | Indicates whether a short guard interval is used in the transmission of the Data field of the PPDU.<br>Enumerated type:<br>LONG_GI indicates short GI is not used in the Data field of the PPDU.<br>SHORT_GI indicates short GI is used in the Data field of the PPDU. | Y | Y |
| | Otherwise | See corresponding entry in Table 19-1 (TXVECTOR and RXVECTOR parameters) | | |
| TXPWR_LEVEL_INDEX | FORMAT is VHT | The allowed values for the TXPWR_LEVEL_INDEX parameter are in the range 1 to $N/2$, where $N$ is the number of octets in dot11TxPowerLevelExtended. This parameter is used to indicate which of the available transmit output power levels defined in dot11TxPowerLevelExtended shall be used for the current transmission. | Y | N |
| | Otherwise | See corresponding entry in Table 19-1 (TXVECTOR and RXVECTOR parameters) | | |
| RSSI | FORMAT is VHT | The allowed values for the RSSI parameter are in the range 0 to 255. This parameter is a (#1132)measurement by the PHY of the power observed at the antenna connector used to receive the current PPDU measured during the reception of the VHT-LTF field. RSSI is intended to be used in a relative manner, and it is a monotonically increasing function of the received power. | N | Y |
| | Otherwise | See corresponding entry in Table 19-1 (TXVECTOR and RXVECTOR parameters) | | |


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**Table 21-1—TXVECTOR and RXVECTOR parameters(#12) *(continued)***

| Parameter | Condition | Value | TXVECTOR | RXVECTOR |
|---|---|---|---|---|
| MCS | FORMAT is VHT | Indicates the modulation and coding scheme used in the transmission of the PPDU.<br>Integer: range 0 to 9 | M<br>U | Y |
| | Otherwise | See corresponding entry in Table 19-1 (TXVECTOR and RXVECTOR parameters) | | |
| REC_MCS | FORMAT is HT_MF, HT_GF or VHT | Indicates the MCS that the STA's receiver recommends. | N | O |
| | Otherwise | Not present | N | N |
| CH_BANDWIDTH | FORMAT is HT_MF or HT_GF | See corresponding entry in Table 19-1 (TXVECTOR and RXVECTOR parameters) | | |
| | FORMAT is VHT | Indicates the channel width of the transmitted PPDU:<br>Enumerated type:<br>CBW20 for 20 MHz<br>CBW40 for 40 MHz<br>CBW80 for 80 MHz<br>CBW160 for 160 MHz<br>CBW80+80 for 80+80 MHz | Y | Y |
| | FORMAT is NON_HT | In TXVECTOR, indicates the channel width of the transmitted PPDU.<br>In RXVECTOR, indicates the estimated channel width of the received PPDU.<br>Enumerated type:<br>CBW40, CBW80, CBW160, or CBW80+80 if NON_HT_MODULATION equals NON_HT_DUP_OFDM<br>CBW20 if NON_HT_MODULATION equals OFDM<br><br>NOTE—On reception, where valid, the CH_BANDWIDTH_IN_NON_HT parameter is likely to be a more reliable indication of subformat and channel width than the NON_HT_MODULATION and CH_BANDWIDTH parameters, since for non-HT or non-HT duplicate (#14)PPDUs, CH_BANDWIDTH is a receiver estimate of the bandwidth, whereas CH_BANDWIDTH_IN_NON_HT is the signaled bandwidth. | Y | Y |
| APEP_LENGTH | FORMAT is VHT | If equal to 0, indicates a VHT NDP for both RXVECTOR and TXVECTOR.<br><br>If greater than 0 in the TXVECTOR, indicates the number of octets in the range 1 to 1 048 575 in the A-MPDU pre-EOF padding (see 10.12.2 (A-MPDU length limit rules)) carried in the PSDU.<br><br>If greater than 0 in the RXVECTOR, this parameter is the value obtained from the VHT-SIG-B Length field multiplied by 4. | M<br>U | O |
| | Otherwise | Not present | N | N |

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**Table 21-1—TXVECTOR and RXVECTOR parameters(#12) *(continued)***

| Parameter | Condition | Value | TXVECTOR | RXVECTOR |
|---|---|---|---|---|
| PSDU_LENGTH | FORMAT is VHT | Indicates the number of octets in the VHT PSDU in the range 0 to aPSDUMaxLength octets (see Table 21-28 (VHT PHY characteristics)). A value of 0 indicates a VHT NDP. | N | Y |
| | Otherwise | Not present | N | N |
| USER_POSITION | FORMAT is VHT and 1 ≤ GROUP_ID ≤ 62 | User position in MU transmission using the group ID GROUP_ID. Integer range: 0-3.<br><br>NOTE—The entries in the USER_POSITION array are in ascending order. | M<br>U | O |
| | Otherwise | Not present | N | N |
| NUM_STS | FORMAT is VHT | Indicates the number of space-time streams.<br>Integer: range 1-8 for SU, 1-4 per user in the TXVECTOR and 0-4 in the RXVECTOR for MU.<br>NUM_STS summed over all users is in the range 1 to 8. | M<br>U | Y |
| | Otherwise | Not present | N | N |
| GROUP_ID | FORMAT is VHT | Indicates the group ID.<br>Integer: range 0-63 (see Table 21-12 (Fields in the VHT-SIG-A field))<br>A value of 0 or 63 indicates a VHT SU PPDU. A value in the range 1 to 62 indicates a VHT MU PPDU. | Y | Y |
| | Otherwise | Not present | N | N |
| PARTIAL_AID | FORMAT is VHT and GROUP_ID is 0 or 63 | Provides an abbreviated indication of the intended recipient(s) of the PSDU (see 10.19 (Group ID and partial AID in VHT and CMMG PPDUs)).<br>Integer: range 0-511. | Y | Y |
| | Otherwise | Not present | N | N |
| NUM_USERS | FORMAT is VHT | Indicates the number of users with nonzero space-time streams.<br>Integer: range 1 to 4. | Y | N |
| | Otherwise | Not present | N | N |
| BEAMFORMED | FORMAT is VHT and GROUP_ID is 0 or 63 | Set to 1 if a beamforming steering matrix is applied to the waveform in an SU transmission. Set to 0 otherwise.<br><br>NOTE—When BEAMFORMED is(M118) 1, frequency domain smoothing as part of channel estimation is not recommended. | Y | O |
| | Otherwise | Not present | N | N |



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**Table 21-1—TXVECTOR and RXVECTOR parameters(#12) *(continued)***

| Parameter | Condition | Value | TXVECTOR | RXVECTOR |
|---|---|---|---|---|
| TXOP_PS_NOT_ALLOWED | FORMAT is VHT | Indicates whether a VHT AP allows non-AP VHT STAs in TXOP power save mode to enter doze state during the TXOP.<br><br>0 indicates that the VHT AP allows non-AP VHT STAs to enter doze state during a TXOP.<br><br>1 indicates that the VHT AP does not allow non-AP VHT STAs to enter doze state during a TXOP. | Y | Y |
| | Otherwise | Not present | N | N |
| TIME_OF_DEPARTURE_REQUESTED | | See corresponding entry in Table 19-1 (TXVECTOR and RXVECTOR parameters) | | |
| RX_START_OF_FRAME_OFFSET | dot11TimingMsmtActivated is true | 0 to $2^{32}$– 1. An estimate of the offset (in 10 ns units) from the point in time at which the start of the preamble (#14)of the PPDU arrived at the receive antenna connector to the point in time at which this primitive is issued to the MAC. | N | Y |
| | Otherwise | Not present | N | N |

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**Table 21-1—TXVECTOR and RXVECTOR parameters(#12) *(continued)***

| Parameter | Condition | Value | TXVECTOR | RXVECTOR |
|---|---|---|---|---|
| (#602)SCRAMBLER_INITIAL_VALUE | FORMAT is VHT, GROUP_ID is neither 0 nor 63, and STA is an HE STA | The first 7 bits of the scrambling sequence (the first 7 bits in the SERVICE field prior to descrambling), with the first bit of the scrambling sequence being the LSB of SCRAMBLER_INITIAL_VALUE. | N | Y |
| | FORMAT is VHT and GROUP_ID is 0 or 63 | Not present | N | N |
| | FORMAT is VHT and STA is not an HE STA | Not present | N | N |
| | Otherwise | See corresponding entry in Table 19-1 (TXVECTOR and RXVECTOR parameters) | | |

NOTE—In the TXVECTOR and RXVECTOR columns, the following apply:
Y indicates that the parameter is always present in that vector;
N indicates that the parameter is never present in that vector;
O indicates that the parameter's presence is an implementation option;
MU indicates that the parameter is present once for a VHT SU PPDU and present per user for a VHT MU PPDU. Parameters specified to be present per user are conceptually supplied as an array of values indexed by *u*, where *u* takes values 0 to NUM_USERS-1.

### 21.2.3 PHYCONFIG_VECTOR parameters

The PHYCONFIG_VECTOR carried in a PHY-CONFIG.request primitive for a VHT PHY contains an OPERATING_CHANNEL parameter, which identifies the operating or primary channel. The PHY shall set dot11CurrentPrimaryChannel to the value of this parameter.

The PHYCONFIG_VECTOR carried in a PHY-CONFIG.request primitive for a VHT PHY contains a CHANNEL_WIDTH parameter, which identifies the operating channel width and takes one of the values 20 MHz, 40 MHz, 80 MHz, 160 MHz, and 80+80 MHz. The PHY shall set dot11CurrentChannelWidth to the value of this parameter.

The PHYCONFIG_VECTOR carried in a PHY-CONFIG.request primitive for a VHT PHY contains a CENTER_FREQUENCY_SEGMENT_0 parameter, which identifies the center frequency of the channel (or of segment 0 if the CHANNEL_WIDTH parameter indicates 80+80 MHz) and takes a value between 1 and 200. The PHY shall set dot11CurrentChannelCenterFrequencyIndex0 to the value of this parameter.

The PHYCONFIG_VECTOR carried in a PHY-CONFIG.request primitive for a VHT PHY contains a CENTER_FREQUENCY_SEGMENT_1 parameter, which takes the value 0 if the CHANNEL_WIDTH parameter does not indicate 80+80 MHz, and otherwise identifies the center frequency of segment 1 and takes a value between 1 and 200. The PHY shall set dot11CurrentChannelCenterFrequencyIndex1 to the value of this parameter.

(#4383)The PHYCONFIG_VECTOR carried in a PHY-CONFIG.request primitive for a VHT PHY contains a GROUP_ID_MANAGEMENT parameter, which specifies membership status and STA position for each of the group IDs as described in 9.6.22.3 (Group ID Management frame format).


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(#4383)The PHYCONFIG_VECTOR carried in a PHY-CONFIG.request primitive for a VHT PHY contains a PARTIAL_AID_LIST_GID00 parameter, which includes the list of partial AIDs, of which the STA is an intended recipient, associated with group ID 0. The settings of the PARTIAL_AID are specified in 10.19 (Group ID and partial AID in VHT and CMMG PPDUs).

(#4383)The PHYCONFIG_VECTOR carried in a PHY-CONFIG.request primitive for a VHT PHY contains a PARTIAL_AID_LIST_GID63 parameter, which includes the list of partial AIDs, of which the STA is an intended recipient, associated with group ID 63. The settings of the PARTIAL_AID are specified in 10.19 (Group ID and partial AID in VHT and CMMG PPDUs).

(#4383)The PHYCONFIG_VECTOR carried in a PHY-CONFIG.request primitive for a VHT PHY contains a LISTEN_TO_GID00 parameter, which, when true, indicates to the PHY not to filter out PPDUs with GROUP_ID field equal to 0.

(#4383)The PHYCONFIG_VECTOR carried in a PHY-CONFIG.request primitive for a VHT PHY contains a LISTEN_TO_GID63 parameter, which, when true, indicates to the PHY not to filter out PPDUs with GROUP_ID field equal to 63.

(#4384)Additional PHYCONFIG_VECTOR parameters are defined in Table 8-4 (Vector descriptions(#4383)).

### 21.2.4 Effects of CH_BANDWIDTH parameter on PPDU format

Table 21-2 (Interpretation of FORMAT, NON_HT_MODULATION, CH_BANDWIDTH, and CH_OFFSET parameters) shows the valid combinations of the FORMAT, NON_HT_MODULATION, and CH_BANDWIDTH parameters and the corresponding PPDU format and value of CH_OFFSET (if applicable). Other combinations are reserved.

**Table 21-2—Interpretation of FORMAT, NON_HT_MODULATION, CH_BANDWIDTH, and CH_OFFSET parameters**

| FORMAT | NON_HT_ MODULATION | CH_BANDWIDTH | CH_OFFSET | PPDU format |
|---|---|---|---|---|
| VHT | N/A | CBW20 | N/A | The STA transmits a VHT PPDU (when FORMAT is VHT) of 20 MHz bandwidth. If the BSS bandwidth is wider than 20 MHz, then the transmission shall use the primary 20 MHz channel. |
| VHT | N/A | CBW40 | N/A | The STA transmits a VHT PPDU (when FORMAT is VHT) of 40 MHz bandwidth. If the BSS bandwidth is wider than 40 MHz, then the transmission shall use the primary 40 MHz channel. |
| HT_MF or HT_GF | N/A | HT_CBW20 and CHANNEL_WIDTH in PHYCONFIG_VECTOR > 20 MHz and $f_{S20,\,idx} < f_{P20,\,idx}$ | CH_OFF_20U | The STA transmits an (#2095)(#1366)HT-mixed format PPDU (when FORMAT is HT_MF) or (#1367)HT-greenfield format PPDU (when FORMAT is HT_GF) of 20 MHz bandwidth. The transmission shall use the primary 20 MHz channel. |

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**Table 21-2—Interpretation of FORMAT, NON_HT_MODULATION, CH_BANDWIDTH, and CH_OFFSET parameters *(continued)***

| FORMAT | NON_HT_ MODULATION | CH_BANDWIDTH | CH_OFFSET | PPDU format |
|---|---|---|---|---|
| HT_MF or HT_GF | N/A | HT_CBW20 and CHANNEL_WIDTH in PHYCONFIG_VECTOR > 20 MHz and $f_{S20,\,idx} > f_{P20,\,idx}$ | CH_OFF_20L | The STA transmits an (#2095)(#1366)HT-mixed format PPDU (when FORMAT is HT_MF) or (#1367)HT-greenfield format PPDU (when FORMAT is HT_GF) of 20 MHz bandwidth. The transmission shall use the primary 20 MHz channel. |
| HT_MF or HT_GF | N/A | HT_CBW20 and CHANNEL_WIDTH in PHYCONFIG_VECTOR = 20 MHz | CH_OFF_20 | The STA transmits an (#2095)(#1366)HT-mixed format PPDU (when FORMAT is HT_MF) or (#1367)HT-greenfield format PPDU (when FORMAT is HT_GF) of 20 MHz bandwidth. |
| HT_MF or HT_GF | N/A | HT_CBW40 | CH_OFF_40 | The STA transmits an (#2095)(#1366)HT-mixed format PPDU (when FORMAT is HT_MF) or (#1367)HT-greenfield format PPDU (when FORMAT is HT_GF) of 40 MHz bandwidth. If the BSS bandwidth is wider than 40 MHz, then the transmission shall use the primary 40 MHz channel. |
| VHT | N/A | CBW80 | | The STA transmits a VHT PPDU of 80 MHz bandwidth. If the BSS bandwidth is 160 MHz or 80+80 MHz, then the transmission shall use the primary 80 MHz channel. |
| VHT | N/A | CBW160 | | The STA transmits a VHT PPDU of 160 MHz bandwidth. |
| VHT | N/A | CBW80+80 | | The STA transmits a VHT PPDU of 80+80 MHz bandwidth. |
| NON_HT | OFDM | CBW20 | | The STA transmits a non-HT PPDU(#238) with NON_HT_MODULATION set to OFDM using the primary 20 MHz channel as defined in Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification). |


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**Table 21-2—Interpretation of FORMAT, NON_HT_MODULATION, CH_BANDWIDTH, and CH_OFFSET parameters *(continued)***

| FORMAT | NON_HT_ MODULATION | CH_BANDWIDTH | CH_OFFSET | PPDU format |
|---|---|---|---|---|
| NON_HT | NON_HT_DUP_ OFDM | CBW40 | | The STA transmits a non-HT PPDU(#238) with NON_HT_MODULATION set to NON_HT_DUP_OFDM using two adjacent 20 MHz channels as defined in 21.3.10.12 (Non-HT duplicate transmission). If the BSS bandwidth is wider than 40 MHz, then the transmission shall use the primary 40 MHz channel. The one 20 MHz channel higher in frequency is rotated +90º relative to the 20 MHz channel lowest in frequency as defined in Equation (21-15). |
| NON_HT | NON_HT_DUP_ OFDM | CBW80 | | The STA transmits a non-HT PPDU(#238) with NON_HT_MODULATION set to NON_HT_DUP_OFDM using four adjacent 20 MHz channels as defined in 21.3.10.12 (Non-HT duplicate transmission). If the BSS bandwidth is 160 MHz or 80+80 MHz, then the transmission shall use the primary 80 MHz channel. The three 20 MHz channels higher in frequency are rotated +180º relative to the 20 MHz channel lowest in frequency as defined in Equation (21-16). |

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**Table 21-2—Interpretation of FORMAT, NON_HT_MODULATION, CH_BANDWIDTH, and CH_OFFSET parameters *(continued)***

| FORMAT | NON_HT_ MODULATION | CH_BANDWIDTH | CH_OFFSET | PPDU format |
|---|---|---|---|---|
| NON_HT | NON_HT_DUP_ OFDM | CBW160 | | The STA transmits a non-HT PPDU(#238) with NON_HT_MODULATION set to NON_HT_DUP_OFDM using eight adjacent 20 MHz channels as defined in 21.3.10.12 (Non-HT duplicate transmission). The second, third, fourth, sixth, seventh, and eighth 20 MHz channels in the order of increasing frequency are rotated +180º relative to the 20 MHz channel lowest in frequency as defined in Equation (21-17). |
| NON_HT | NON_HT_DUP_ OFDM | CBW80+80 | | The STA transmits a non-HT PPDU(#238) with NON_HT_MODULATION set to NON_HT_DUP_OFDM using two nonadjacent frequency segments, with each frequency segment consisting of four adjacent 20 MHz channels as defined in 21.3.10.12 (Non-HT duplicate transmission). In each frequency segment, the three 20 MHz channels higher in frequency are rotated +180º relative to the 20 MHz channel lowest in frequency as defined in Equation (21-16). |

### 21.2.5 Support for NON_HT and HT formats

#### 21.2.5.1 General

A VHT STA logically contains Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification), Clause 19 (High Throughput (HT) PHY specification(#2297)), and Clause 21 (Very high throughput (VHT) PHY specification) PHYs. The MAC interfaces to the PHYs via the Clause 21 (Very high throughput (VHT) PHY specification) PHY service interface, which in turn interacts with the Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) and Clause 19 (High Throughput (HT) PHY specification(#2297)) PHY service interfaces as shown in Figure 21-1 (PHY interaction on transmit for various PPDU formats), Figure 21-2 (PHY interaction on receive for various PPDU formats), and Figure 21-3 (PHY-CONFIG and CCA interaction with Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification), Clause 19 (High Throughput (HT) PHY specification(#2297)), and Clause 21 (Very high throughput (VHT) PHY specification) PHYs).

#### 21.2.5.2 Support for NON_HT format when NON_HT_MODULATION is OFDM

When a PHY-TXSTART.request(TXVECTOR) primitive with the FORMAT parameter equal to NON_HT and the NON_HT_MODULATION parameter equal to OFDM is issued, the behavior of the VHT PHY is defined in Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) with additional requirements described in the following subclauses:


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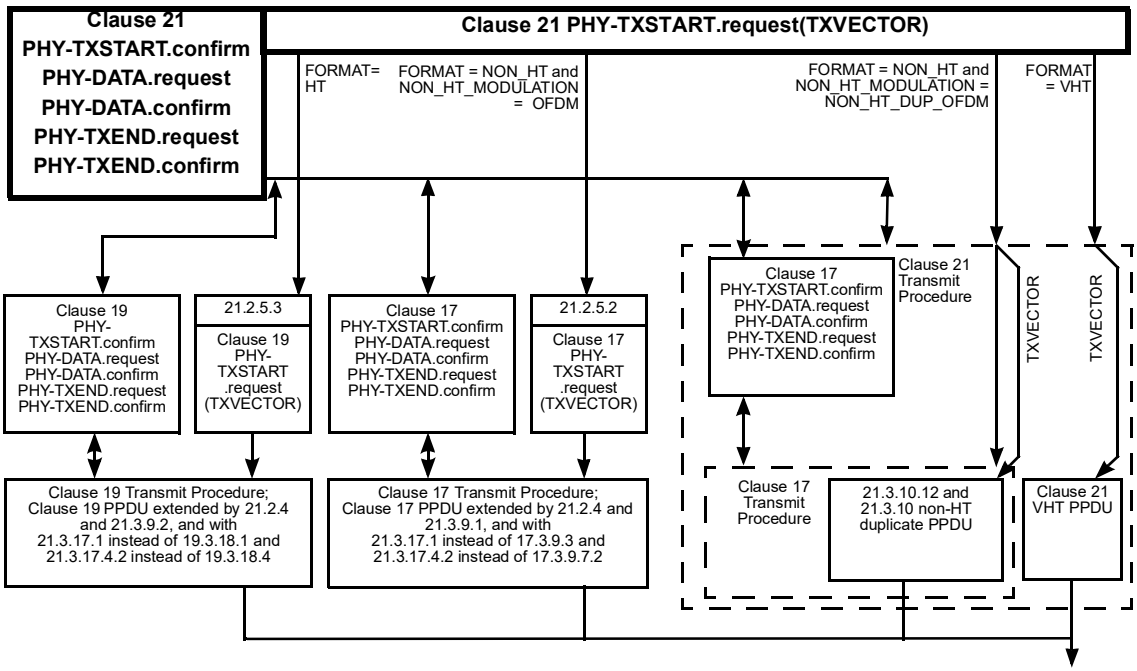


**Figure 21-1—PHY interaction on transmit for various PPDU formats**

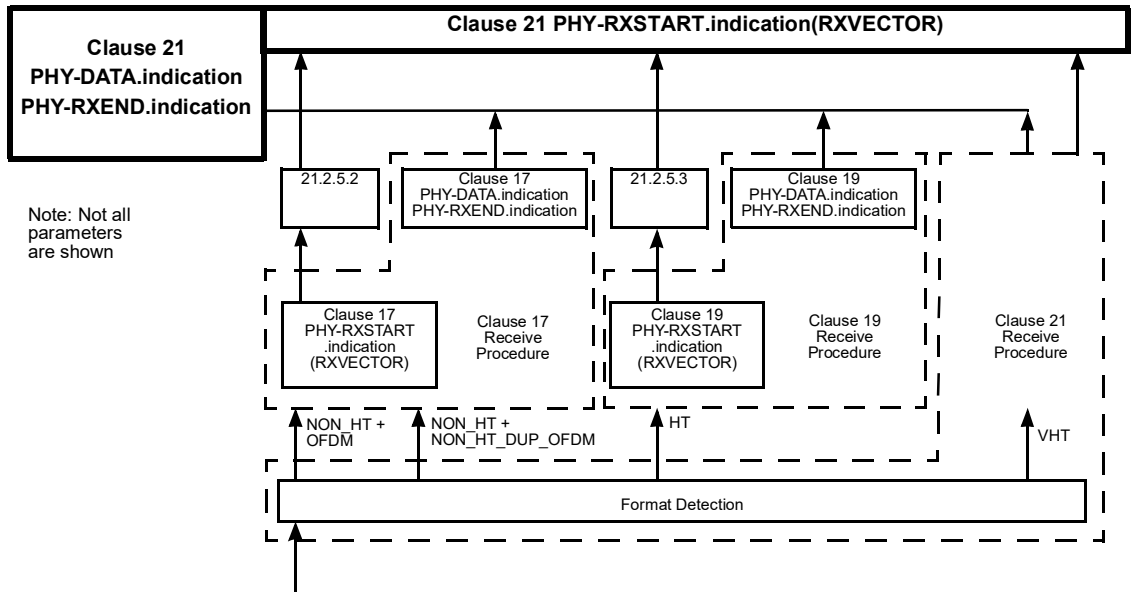


**Figure 21-2—PHY interaction on receive for various PPDU formats**

— 21.3.9.1 (Transmission of 20 MHz non-HT PPDUs(#238) with more than one transmit chain)

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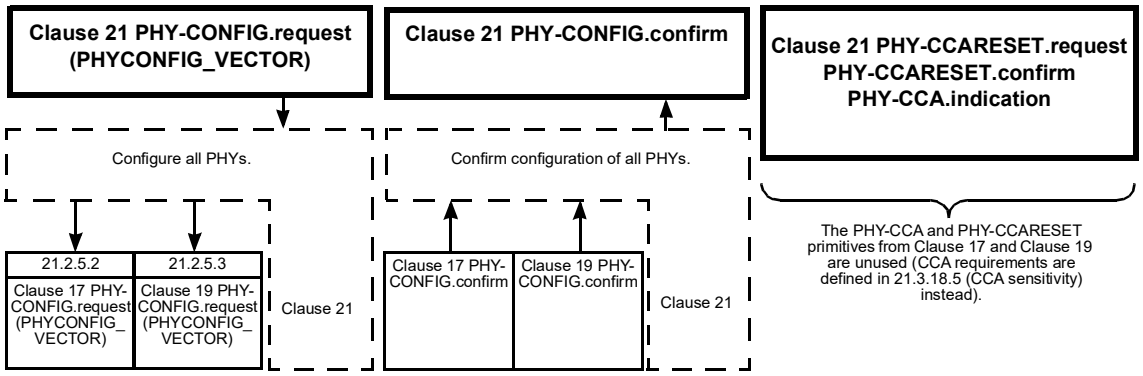


**Figure 21-3—PHY-CONFIG and CCA interaction with Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification), Clause 19 (High Throughput (HT) PHY specification(#2297)), and Clause 21 (Very high throughput (VHT) PHY specification) PHYs**

— 21.3.17.1 (Transmit spectrum mask) instead of 17.3.9.3 (Transmit spectrum mask)

— 21.3.17.4.2 (Transmit center frequency leakage) instead of 17.3.9.7.2 (Transmitter center frequency leakage)

where the Clause 21 (Very high throughput (VHT) PHY specification) TXVECTOR parameters in Table 21-1 (TXVECTOR and RXVECTOR parameters(#12)) are mapped to Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) TXVECTOR parameters in Table 17-1 (TXVECTOR parameters) according to Table 21-3 (Mapping of VHT PHY parameters for NON_HT operation).

NOTE—When the FORMAT parameter is (M118)equal to NON_HT and the NON_HT_MODULATION parameter is (M118)equal to NON_HT_DUP_OFDM in a PHY-TXSTART.request(TXVECTOR) primitive, the behavior of the VHT PHY is defined in Clause 21 (Very high throughput (VHT) PHY specification).

When the VHT PHY receives a Clause 21 (Very high throughput (VHT) PHY specification) PHY-CONFIG.request(PHYCONFIG_VECTOR) primitive, the VHT PHY shall, for the purposes of OFDM PPDU transmission and reception, behave as if it were a Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) PHY that had received a PHY-CONFIG.request(PHYCONFIG_VECTOR) primitive but with the CHANNEL_WIDTH, CENTER_FREQUENCY_SEGMENT_0, and CENTER_FREQUENCY_SEGMENT_1 parameters discarded from PHYCONFIG_VECTOR.

As defined in 21.3.20 (PHY receive procedure), once a PPDU is received and detected as a non-HT PPDU(#238), the behavior of the VHT PHY is defined in Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification). The RXVECTOR parameters from the Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) PHY-RXSTART.indication primitive are mapped to the Clause 21 (Very high throughput (VHT) PHY specification) RXVECTOR parameters as defined in Table 21-3 (Mapping of VHT PHY parameters for NON_HT operation). VHT PHY parameters not listed in the table are not present.


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**Table 21-3—Mapping of VHT PHY parameters for NON_HT operation**

| VHT PHY Parameter | 5 GHz operation defined by Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) | Parameter List |
|---|---|---|
| L_LENGTH | LENGTH | TXVECTOR/RXVECTOR |
| L_DATARATE | DATARATE | TXVECTOR/RXVECTOR |
| TXPWR_LEVEL_INDEX | TXPWR_LEVEL_INDEX | TXVECTOR |
| RSSI | RSSI | RXVECTOR |
| SERVICE | SERVICE | TXVECTOR/RXVECTOR |
| CH_BANDWIDTH_IN_NON_HT | CH_BANDWIDTH_IN_NON_HT | TXVECTOR/RXVECTOR |
| DYN_BANDWIDTH_IN_NON_HT | DYN_BANDWIDTH_IN_NON_HT | TXVECTOR/RXVECTOR |
| OPERATING_CHANNEL | OPERATING_CHANNEL | PHYCONFIG_VECTOR |
| CHANNEL_WIDTH | discarded | PHYCONFIG_VECTOR |
| CENTER_FREQUENCY_SEGMENT_0 | discarded | PHYCONFIG_VECTOR |
| CENTER_FREQUENCY_SEGMENT_1 | discarded | PHYCONFIG_VECTOR |

#### 21.2.5.3 Support for HT formats

When a PHY-TXSTART.request(TXVECTOR) primitive is received with the TXVECTOR parameter FORMAT equal to HT_MF or HT_GF, the behavior of the PHY is defined by Clause 19 (High Throughput (HT) PHY specification(#2297)) with additional requirements defined in the following subclauses:

— 21.3.9.2 (Transmission of HT PPDUs with more than four transmit chains)

— 21.3.17.1 (Transmit spectrum mask) instead of 19.3.18.1 (Transmit spectrum mask)

— 21.3.17.4.2 (Transmit center frequency leakage) instead of 19.3.18.4 (Transmit center frequency tolerance)

The Clause 21 (Very high throughput (VHT) PHY specification) TXVECTOR parameters in Table 21-1 (TXVECTOR and RXVECTOR parameters(#12)) are mapped directly to Clause 19 (High Throughput (HT) PHY specification(#2297)) TXVECTOR parameters in Table 19-1 (TXVECTOR and RXVECTOR parameters) and the Clause 19 (High Throughput (HT) PHY specification(#2297)) PHY-TXSTART.request(TXVECTOR) primitive is issued. The PHY shall use a value of CH_OFFSET in the Clause 19 (High Throughput (HT) PHY specification(#2297)) TXVECTOR that is consistent with Table 21-2 (Interpretation of FORMAT, NON_HT_MODULATION, CH_BANDWIDTH, and CH_OFFSET parameters).

When the VHT PHY receives a Clause 21 (Very high throughput (VHT) PHY specification) PHY-CONFIG.request(PHYCONFIG_VECTOR) primitive, the VHT PHY shall, for the purposes of HT PPDU transmission and reception, behave as if it were a Clause 19 (High Throughput (HT) PHY specification(#2297)) PHY that had received PHY-CONFIG.request(PHYCONFIG_VECTOR) primitive but with the CHANNEL_WIDTH, CENTER_FREQUENCY_SEGMENT_0, and CENTER_FREQUENCY_SEGMENT_1 parameters discarded from the PHYCONFIG_VECTOR and the SECONDARY_CHANNEL_OFFSET parameter set to SECONDARY_CHANNEL_NONE if

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dot11CurrentChannelWidth indicates 20 MHz, to SECONDARY_CHANNEL_ABOVE if $f_{\text{P20, idx}} < f_{\text{S20, idx}}$, or to SECONDARY_CHANNEL_BELOW otherwise.

As defined in 21.3.20 (PHY receive procedure), once a PPDU is received and detected as an HT PPDU, the behavior of the VHT PHY is defined in Clause 19 (High Throughput (HT) PHY specification(#2297)). The RXVECTOR parameters in Table 19-1 (TXVECTOR and RXVECTOR parameters) from the Clause 19 (High Throughput (HT) PHY specification(#2297)) PHY-RXSTART.indication primitive are mapped directly to the RXVECTOR parameters in Table 21-1 (TXVECTOR and RXVECTOR parameters(#12)) and a Clause 21 (Very high throughput (VHT) PHY specification) PHY-RXSTART.indication primitive is issued.

### 21.2.6 TXSTATUS parameters

The parameters listed in Table 19-4 (TXSTATUS parameters) are defined as part of the TXSTATUS parameter list in the PHY-TXSTART.confirm primitive.

## 21.3 VHT PHY

### 21.3.1 Introduction

This subclause provides the procedure by which PSDUs are converted to and from transmissions on the wireless medium.

During transmission, a PSDU (in the SU case) or one or more PSDUs (in the MU case) are processed (i.e., scrambled and coded) and appended to the PHY preamble to create the PPDU. At the receiver, the PHY preamble is processed to aid in the detection, demodulation, and delivery of the PSDU.

Pre-VHT modulated fields refer to the L-STF, L-LTF, L-SIG, and VHT-SIG-A fields, while VHT modulated fields refer to the VHT-STF, VHT-LTF, VHT-SIG-B, and Data fields (see Figure 21-17 (Timing boundaries for VHT PPDU fields)).

### 21.3.2 VHT PPDU format

A single PPDU format is defined for this PHY: the VHT PPDU format. Figure 21-4 (VHT PPDU format) shows the VHT PPDU format.

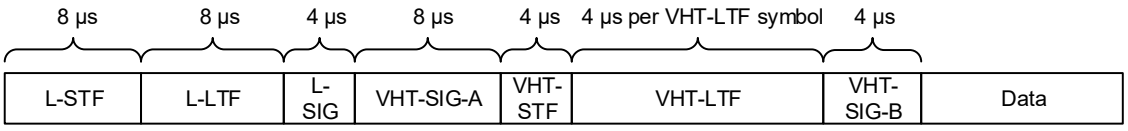


**Figure 21-4—VHT PPDU format**


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The fields of the VHT PPDU format are summarized in Table 21-4 (Fields of the VHT PPDU).

**Table 21-4—Fields of the VHT PPDU**

| Field | Description |
|---|---|
| L-STF | Non-HT Short Training field |
| L-LTF | Non-HT Long Training field |
| L-SIG | Non-HT SIGNAL field |
| VHT-SIG-A | VHT Signal A field |
| VHT-STF | VHT Short Training field |
| VHT-LTF | VHT Long Training field |
| VHT-SIG-B | VHT Signal B field |
| Data | The Data field carrying the PSDU(s) |

The VHT-SIG-A, VHT-STF, VHT-LTF, and VHT-SIG-B fields exist only in VHT PPDUs. In a VHT NDP the Data field is not present. The number of symbols in the VHT-LTF field, $N_{VHT\text{-}LTF}$, can be either 1, 2, 4, 6, or 8 and is determined by the total number of space-time streams across all users being transmitted in the VHT PPDU (see Table 21-13 (Number of VHT-LTFs required for different numbers of space-time streams)).

### 21.3.3 Transmitter block diagram

The generation of each field in a VHT PPDU uses many of the following blocks:

a) PHY padding
b) Scrambler
c) BCC encoder parser
d) FEC (BCC or LDPC) encoders
e) Stream parser
f) Segment parser (for 160 MHz and 80+80 MHz transmissions)
g) BCC interleaver
h) Constellation mapper
i) Pilot insertion
j) Replicate over multiple 20 MHz (if BW > 20 MHz)
k) Multiply by first column of $P_{VHT\text{-}LTF}$
l) LDPC tone mapper
m) Segment deparser
n) Space time block code (STBC) encoder
o) Cyclic shift diversity (CSD) per STS insertion
p) Spatial mapper
q) Inverse discrete Fourier transform (IDFT)
r) Cyclic shift diversity (CSD) per chain insertion
s) Guard interval (GI) insertion

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t) Windowing

Figure 21-5 (Transmitter block diagram for the L-SIG and VHT-SIG-A fields) to Figure 21-16 (Transmitter block diagram for the Data field of an 80+80 MHz VHT SU PPDU with LDPC encoding) show example transmitter block diagrams. The actual structure of the transmitter is implementation dependent. In particular, Figure 21-5 (Transmitter block diagram for the L-SIG and VHT-SIG-A fields) shows the transmit process for the L-SIG and VHT-SIG-A fields of a VHT PPDU using one frequency segment. These transmit blocks are also used to generate L-STF and L-LTF fields, except that the BCC encoder and interleaver are not used for these fields.

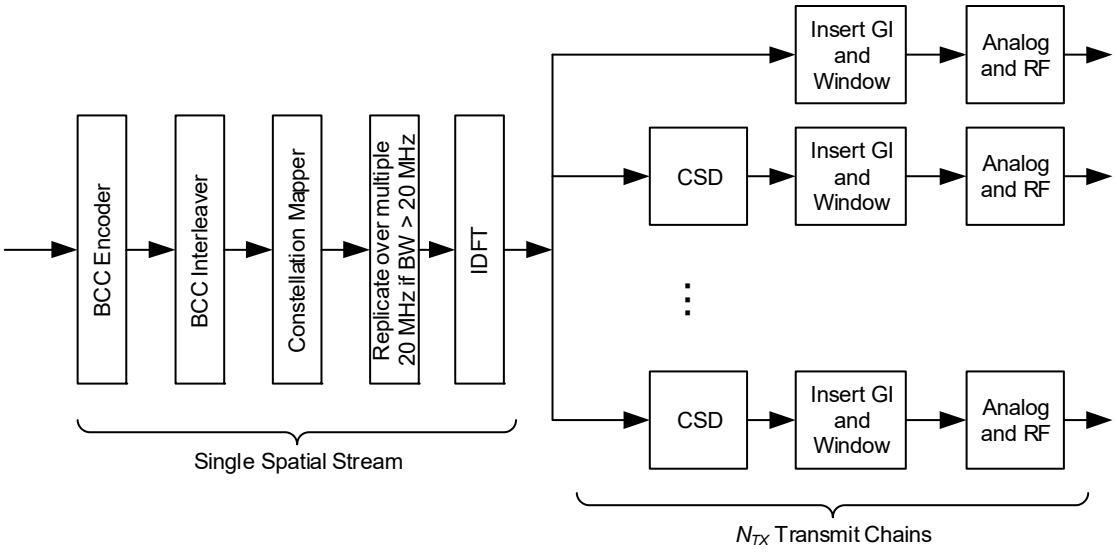


**Figure 21-5—Transmitter block diagram for the L-SIG and VHT-SIG-A fields**

Figure 21-6 (Transmitter block diagram for the VHT-SIG-B field of a 20 MHz, 40 MHz, and 80 MHz VHT SU PPDU) and Figure 21-7 (Transmitter block diagram for the VHT-SIG-B field of a 20 MHz, 40 MHz, and 80 MHz VHT MU PPDU(#2259)(#7214)) show the transmit process for generating the VHT-SIG-B field of a VHT SU PPDU and VHT MU PPDU, respectively, in 20 MHz, 40 MHz, and 80 MHz channel widths. Figure 21-8 (Transmitter block diagram for the VHT-SIG-B field of a 160 MHz VHT SU PPDU(#7214)) and Figure 21-9 (Transmitter block diagram for the VHT-SIG-B field of an 80+80 MHz VHT SU PPDU) show the transmit process for generating the VHT_SIG-B field of a 160 MHz and 80+80 MHz VHT SU PPDU, respectively.

Figure 21-10 (Transmitter block diagram for the Data field of a 20 MHz, 40 MHz, or 80 MHz VHT SU PPDU with BCC encoding) shows the transmitter blocks used to generate the Data field of a 20 MHz, 40 MHz, and 80 MHz VHT SU PPDU with BCC encoding. A subset of these transmitter blocks consisting of the constellation mapper and CSD blocks, as well as the blocks to the right of, and including, the spatial mapping block, are also used to generate the VHT-LTF fields. This is illustrated in Figure 21-21 (Generation of VHT-LTF symbols per frequency segment). A subset of these transmitter blocks consisting of the constellation mapper and CSD blocks, as well as the blocks to the right of, and including, the spatial mapping block, are also used to generate the VHT-STF field but without the multiplication by $A^k_{VHT\text{-}LTF}$ [defined in Equation (21-40)].


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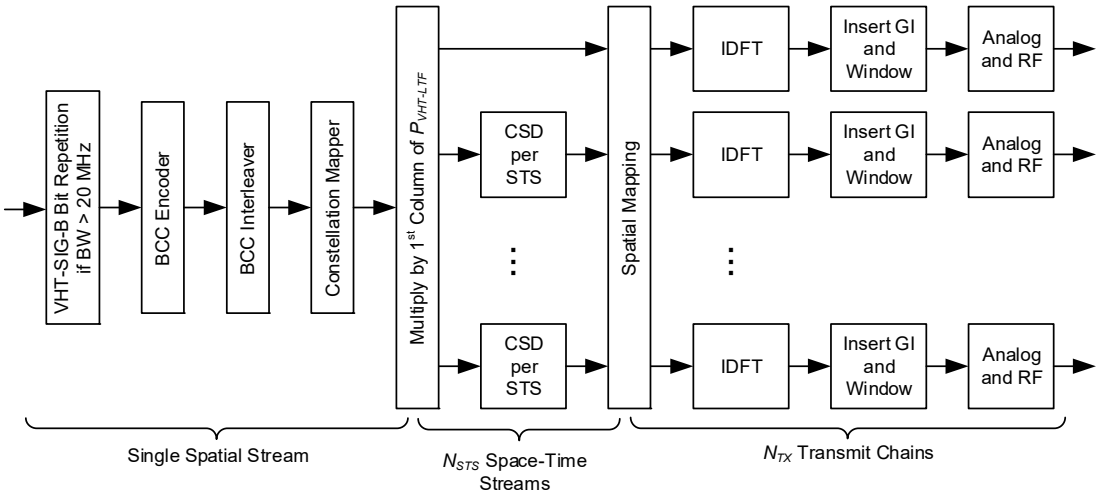


**Figure 21-6—Transmitter block diagram for the VHT-SIG-B field of a 20 MHz, 40 MHz, and 80 MHz VHT SU PPDU**

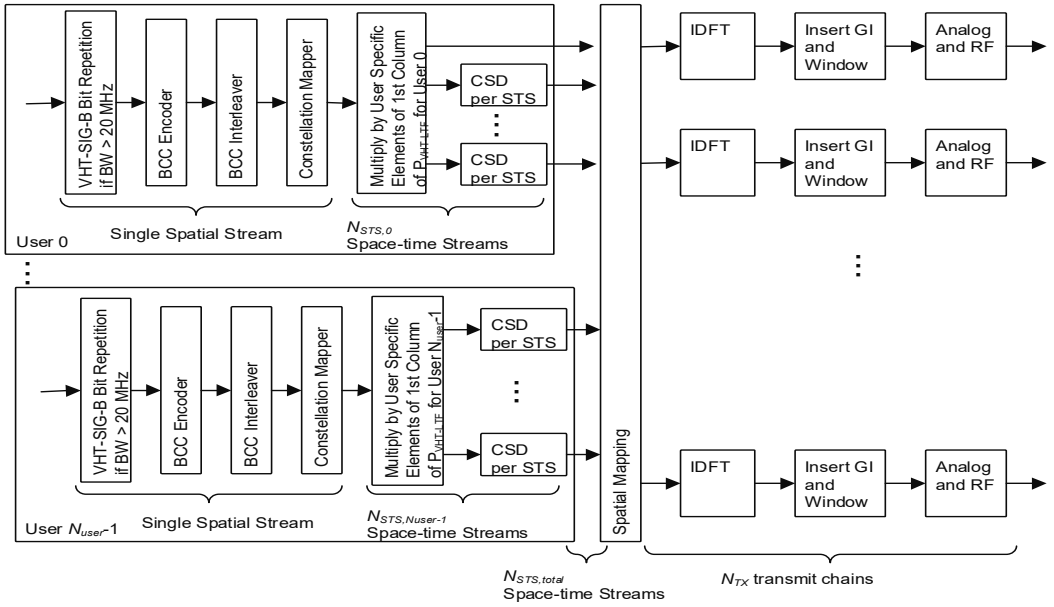


**Figure 21-7—Transmitter block diagram for the VHT-SIG-B field of a 20 MHz, 40 MHz, and 80 MHz VHT MU PPDU(#2259)(#7214)**

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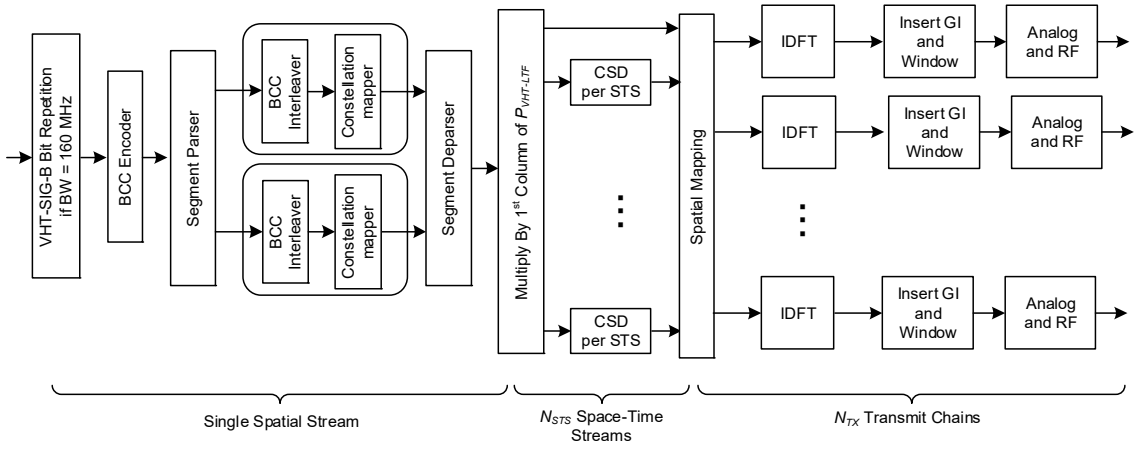


**Figure 21-8—Transmitter block diagram for the VHT-SIG-B field of a 160 MHz VHT SU PPDU(#7214)**

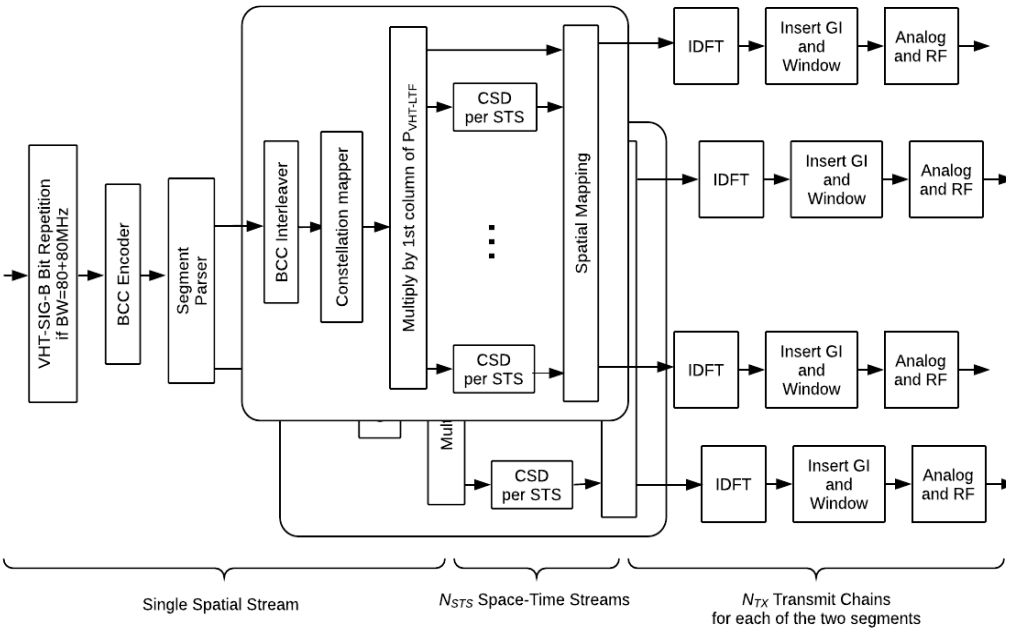


**Figure 21-9—Transmitter block diagram for the VHT-SIG-B field of an 80+80 MHz VHT SU PPDU**



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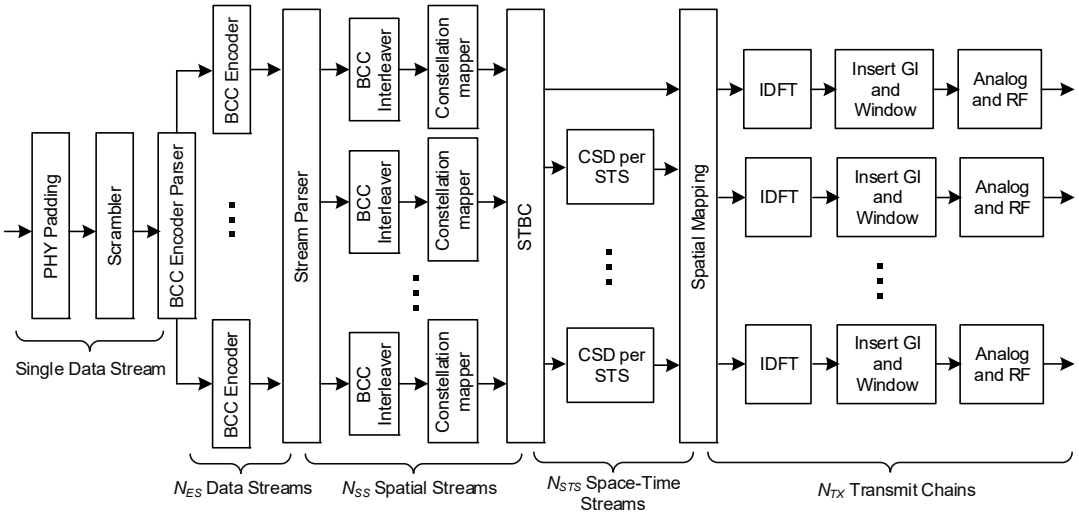


**Figure 21-10—Transmitter block diagram for the Data field of a 20 MHz, 40 MHz, or 80 MHz VHT SU PPDU with BCC encoding**

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Figure 21-11 (Transmitter block diagram for the Data field of a 20 MHz, 40 MHz, or 80 MHz VHT SU PPDU with LDPC encoding) shows the transmitter blocks used to generate the Data field of a 20 MHz, 40 MHz, and 80 MHz VHT SU PPDU with LDPC encoding for a single frequency segment.

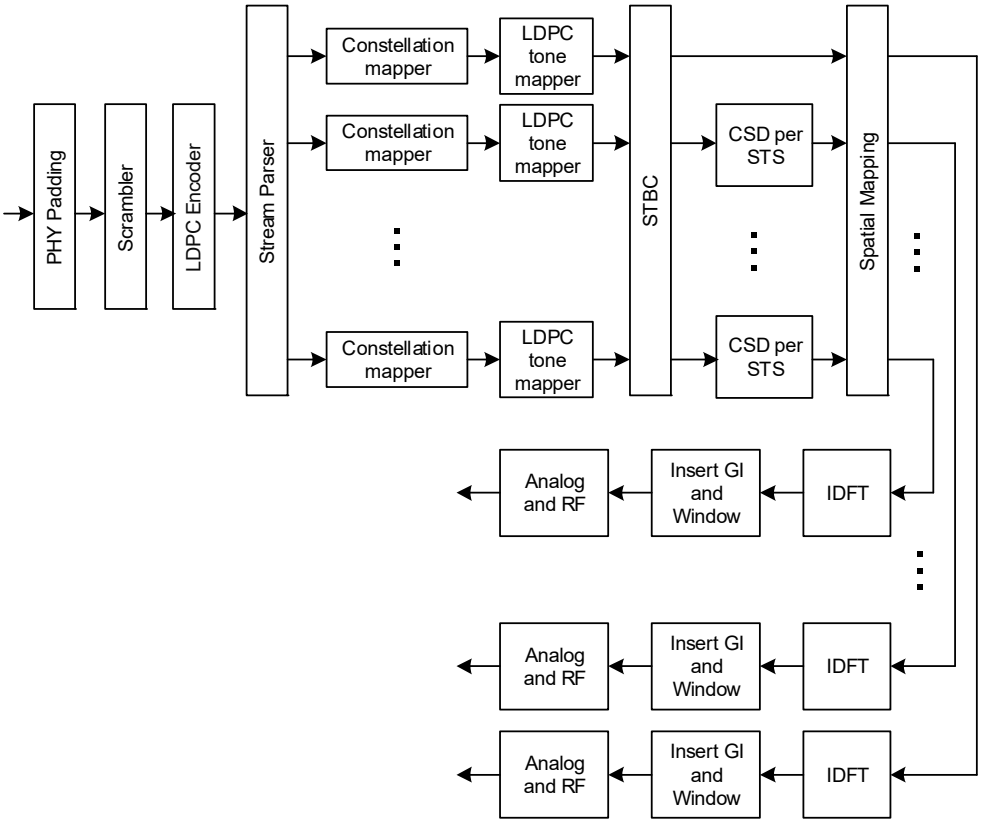


**Figure 21-11—Transmitter block diagram for the Data field of a 20 MHz, 40 MHz, or 80 MHz VHT SU PPDU with LDPC encoding**


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Figure 21-12 (Transmitter block diagram for the Data field of a 20 MHz, 40 MHz, or 80 MHz VHT MU PPDU) shows the transmit process for generating the Data field of a 20 MHz, 40 MHz, or 80 MHz VHT MU PPDU with BCC and LDPC encoding.

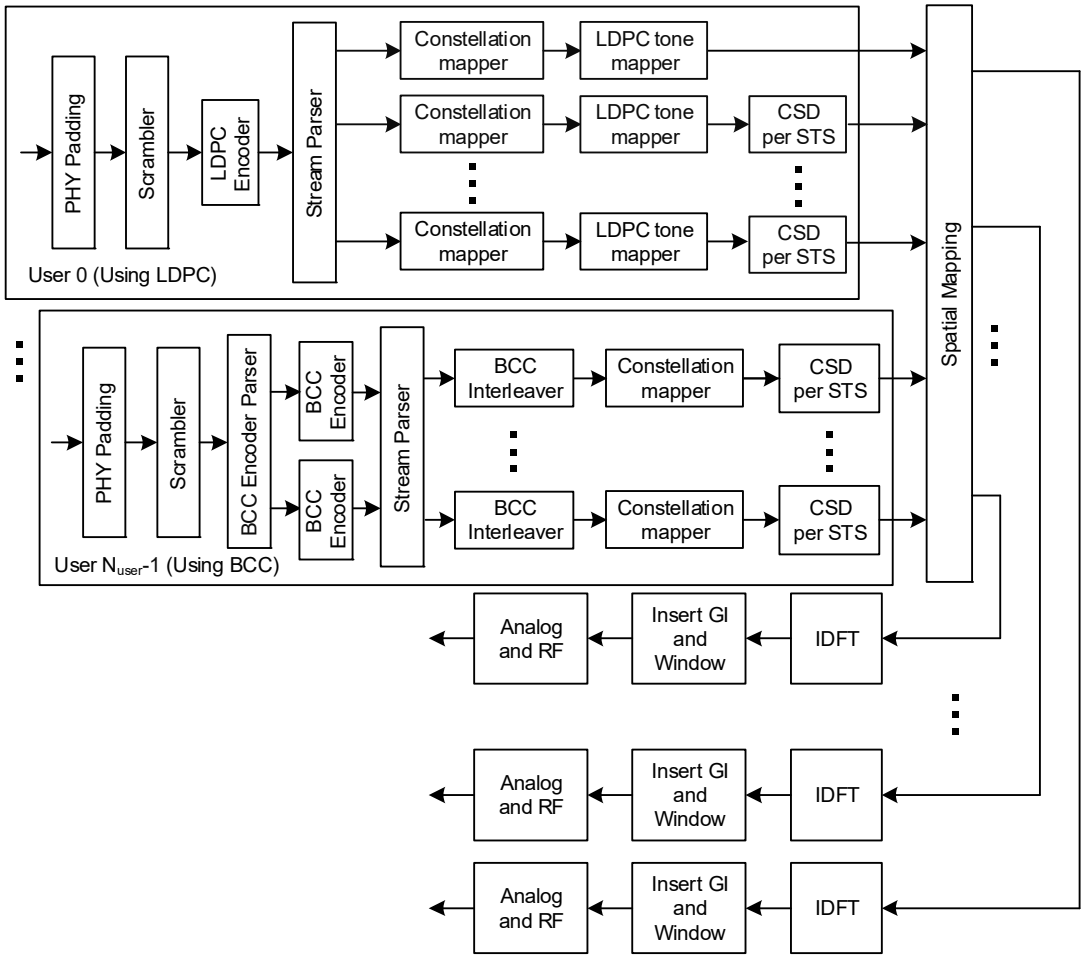


**Figure 21-12—Transmitter block diagram for the Data field of a 20 MHz, 40 MHz, or 80 MHz VHT MU PPDU**

Figure 21-13 (Transmitter block diagram for the Data field of a 160 MHz VHT SU PPDU with BCC encoding) and Figure 21-14 (Transmitter block diagram for the Data field of a 160 MHz

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VHT SU PPDU with LDPC encoding) show the transmit process for generating the Data field of a 160 MHz VHT SU PPDU with BCC and LDPC encoding, respectively.

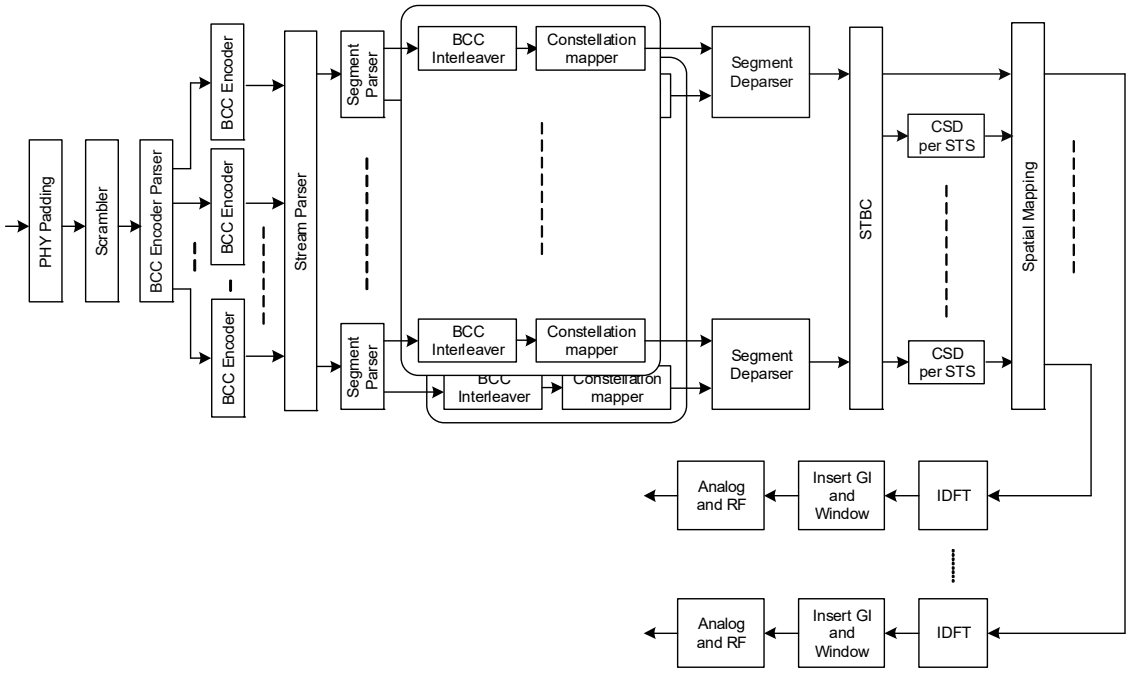


**Figure 21-13—Transmitter block diagram for the Data field of a 160 MHz VHT SU PPDU with BCC encoding**

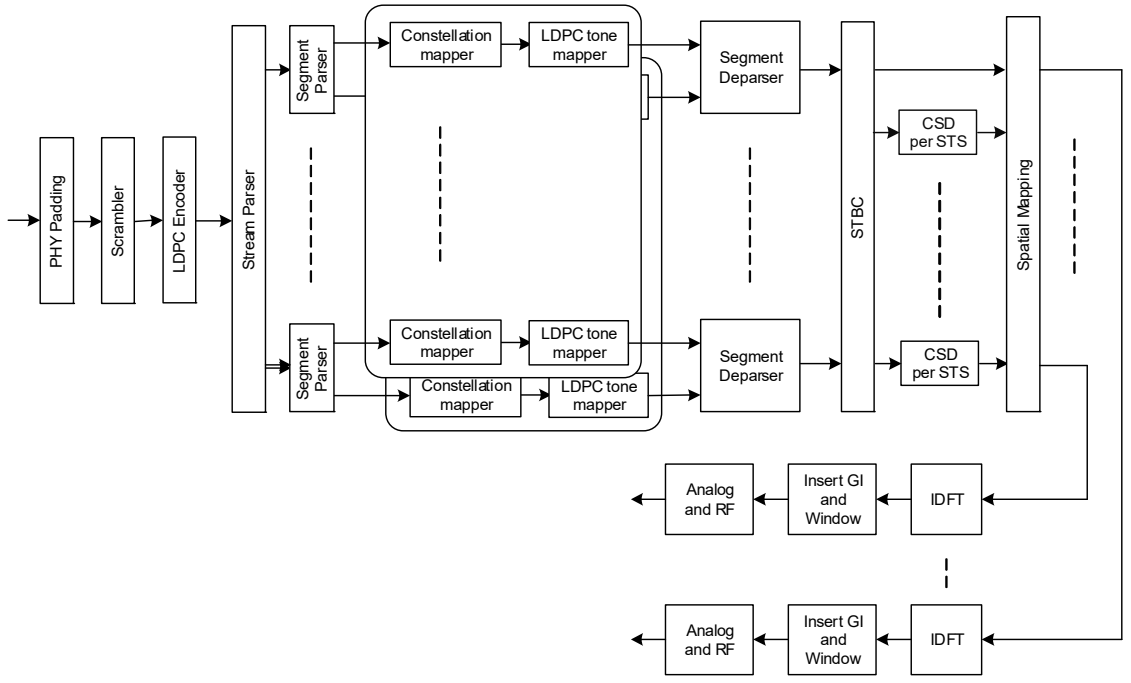


**Figure 21-14—Transmitter block diagram for the Data field of a 160 MHz VHT SU PPDU with LDPC encoding**


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Figure 21-15 (Transmitter block diagram for the Data field of an 80+80 MHz VHT SU PPDU with BCC encoding) and Figure 21-16 (Transmitter block diagram for the Data field of an 80+80 MHz VHT SU PPDU with LDPC encoding) show the transmit process for generating the Data field of an 80+80 MHz VHT SU PPDU with BCC and LDPC encoding, respectively.

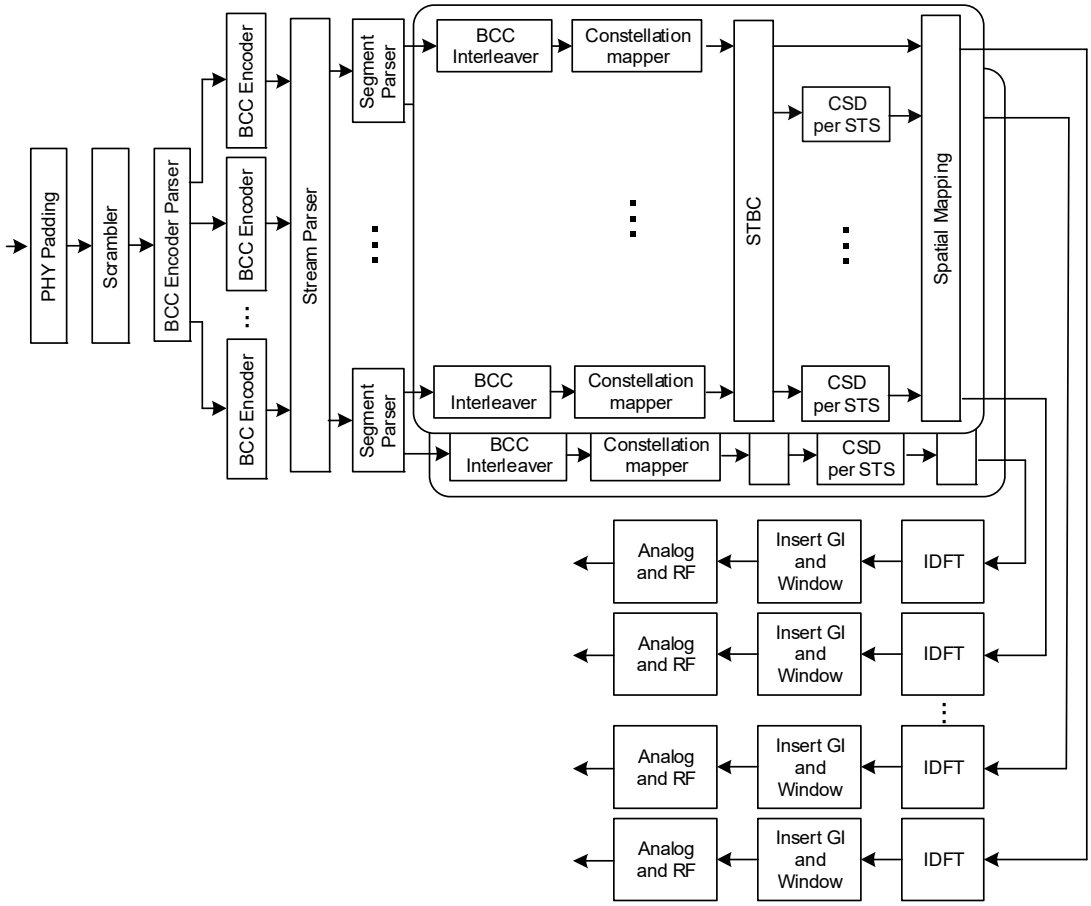


**Figure 21-15—Transmitter block diagram for the Data field of an 80+80 MHz VHT SU PPDU with BCC encoding**

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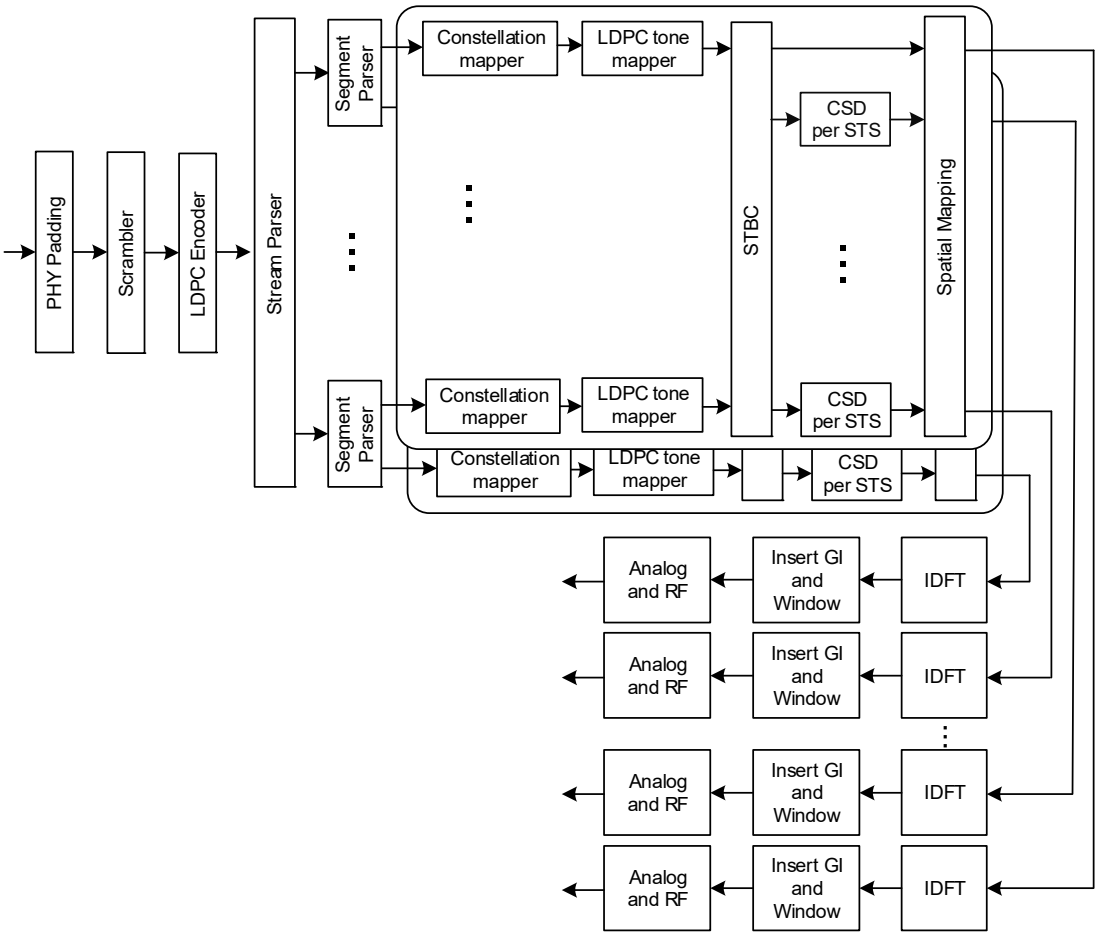


**Figure 21-16—Transmitter block diagram for the Data field of an 80+80 MHz VHT SU PPDU with LDPC encoding**

### 21.3.4 Overview of the PPDU encoding process

#### 21.3.4.1 General

This subclause provides an overview of the VHT PPDU encoding process.

#### 21.3.4.2 Construction of L-STF

Construct the L-STF field as defined in 21.3.8.2.2 (L-STF definition) with the following highlights:

a) Determine the CH_BANDWIDTH from the TXVECTOR.

b) Sequence generation: Generate the L-STF sequence over the CH_BANDWIDTH as described in 21.3.8.2.2 (L-STF definition).

c) Phase rotation: Apply appropriate phase rotation for each 20 MHz subchannel as described in 21.3.7.4 (Transmitted signal) and 21.3.7.5 (Definition of tone rotation).

d) IDFT: Compute the inverse discrete Fourier transform.

e) CSD: Apply CSD for each transmit chain and frequency segment as described in 21.3.8.2.1 (Cyclic shift for pre-VHT modulated fields).


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f) Insert GI and apply windowing: Prepend a GI (LONG_GI) and apply windowing as described in 21.3.7.4 (Transmitted signal).

g) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit. Refer to 21.3.7.4 (Transmitted signal) and 21.3.8 (VHT preamble) for details.

#### 21.3.4.3 Construction of the L-LTF

Construct the L-LTF field as defined in 21.3.8.2.3 (L-LTF definition) with the following highlights:

a) Determine the CH_BANDWIDTH from the TXVECTOR.

b) Sequence generation: Generate the L-LTF sequence over the CH_BANDWIDTH as described in 21.3.8.2.3 (L-LTF definition).

c) Phase rotation: Apply appropriate phase rotation for each 20 MHz subchannel as described in 21.3.7.4 (Transmitted signal) and 21.3.7.5 (Definition of tone rotation).

d) IDFT: Compute the inverse discrete Fourier transform.

e) CSD: Apply CSD for each transmit chain and frequency segment as described in 21.3.8.2.1 (Cyclic shift for pre-VHT modulated fields).

f) Insert GI and apply windowing: Prepend a GI ($2 \times$ LONG_GI ) and apply windowing as described in 21.3.7.4 (Transmitted signal).

g) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit. Refer to 21.3.7.4 (Transmitted signal) and 21.3.8 (VHT preamble) for details.

#### 21.3.4.4 Construction of L-SIG

Construct the L-SIG field as the SIGNAL field defined by 21.3.8.2.4 (L-SIG definition) with the following highlights:

a) In a VHT PPDU set the RATE subfield in the SIGNAL field to 6 Mb/s. Set the Length, Parity, and Tail bits in the SIGNAL field as described in 21.3.8.2.4 (L-SIG definition).

b) BCC encoder: Encode the SIGNAL field by a convolutional encoder at the rate of R=1/2 as described in 21.3.10.5.3 (BCC coding and puncturing).

c) BCC interleaver: Interleave as described in 21.3.10.8 (BCC interleaver).

d) Constellation Mapper: BPSK modulate as described in 21.3.10.9 (Constellation mapping).

e) Pilot insertion: Insert pilots as described in 21.3.10.11 (OFDM modulation).

f) Duplication and phase rotation: Duplicate the L-SIG field over each 20 MHz of the CH_BANDWIDTH. Apply appropriate phase rotation for each 20 MHz subchannel as described in 21.3.7.4 (Transmitted signal) and 21.3.7.5 (Definition of tone rotation).

g) IDFT: Compute the inverse discrete Fourier transform.

h) CSD: Apply CSD for each transmit chain and frequency segment as described in 21.3.8.2.1 (Cyclic shift for pre-VHT modulated fields).

i) Insert GI and apply windowing: Prepend a GI (LONG_GI) and apply windowing as described in 21.3.7.4 (Transmitted signal).

j) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit. Refer to 21.3.7.4 (Transmitted signal) and 21.3.8 (VHT preamble) for details.

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#### 21.3.4.5 Construction of VHT-SIG-A

The VHT-SIG-A field consists of two symbols, VHT-SIG-A1 and VHT-SIG-A2, as defined in 21.3.8.3.3 (VHT-SIG-A definition) and is constructed as follows:

a) Obtain the CH_BANDWIDTH, STBC, GROUP_ID, PARTIAL_AID (SU only), NUM_STS, GI_TYPE, FEC_CODING, MCS (SU only), BEAMFORMED (SU only), NUM_USERS, and TXOP_PS_NOT_ALLOWED from the TXVECTOR. Add the reserved bits, append the calculated CRC, then append the $N_{tail}$ tail bits as shown in 21.3.8.3.3 (VHT-SIG-A definition). This results in 48 uncoded bits.

b) BCC encoder: Encode the data by a convolutional encoder at the rate of R=1/2 as described in 17.3.5.6 (Convolutional encoder)

c) BCC interleaver: Interleave as described in 17.3.5.7 (Data interleaving).

d) Constellation mapper: BPSK modulate the first 48 interleaved bits as described in 17.3.5.8 (Subcarrier modulation mapping) to form the first symbol of VHT-SIG-A. BPSK modulate the second 48 interleaved bits and rotate by 90° counter-clockwise relative to the first symbol to form the second symbol of VHT-SIG-A.

e) Pilot insertion: Insert pilots as described in 17.3.5.9 (Pilot subcarriers).

f) Duplication and phase rotation: Duplicate VHT-SIG-A1 and VHT-SIG-A2 over each 20 MHz of the CH_BANDWIDTH. Apply the appropriate phase rotation for each 20 MHz subchannel as described in 21.3.7.4 (Transmitted signal) and 21.3.7.5 (Definition of tone rotation).

g) IDFT: Compute the inverse discrete Fourier transform.

h) CSD: Apply CSD for each transmit chain and frequency segment as described in 21.3.8.2.1 (Cyclic shift for pre-VHT modulated fields).

i) Insert GI and apply windowing: Prepend a GI (LONG_GI) and apply windowing as described in 21.3.7.4 (Transmitted signal).

j) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit. Refer to 21.3.7.4 (Transmitted signal) and 21.3.8 (VHT preamble) for details.

#### 21.3.4.6 Construction of VHT-STF

The VHT-STF field is defined in 21.3.8.3.4 (VHT-STF definition) and is constructed as follows:

a) Sequence generation: Generate the VHT-STF in the frequency domain over the bandwidth indicated by CH_BANDWIDTH as described in 21.3.8.3.4 (VHT-STF definition).

b) Phase rotation: Apply appropriate phase rotation for each 20 MHz subchannel as described in 21.3.7.4 (Transmitted signal) and 21.3.7.5 (Definition of tone rotation).

c) CSD: Apply CSD for each space-time stream and frequency segment as described in 21.3.8.3.2 (Cyclic shift for VHT modulated fields).

d) Spatial mapping: Apply the $Q$ matrix as described in 21.3.10.11.1 (Transmission in VHT format).

e) IDFT: Compute the inverse discrete Fourier transform.

f) Insert GI and apply windowing: Prepend a GI (LONG_GI) and apply windowing as described in 21.3.7.4 (Transmitted signal).

g) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit. Refer to 21.3.7.4 (Transmitted signal) and 21.3.8 (VHT preamble) for details.

#### 21.3.4.7 Construction of VHT-LTF

The VHT-LTF field is defined in 21.3.8.3.5 (VHT-LTF definition) and constructed as follows:


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a) Sequence generation: Generate the VHT-LTF sequence in the frequency domain over the bandwidth indicated by CH_BANDWIDTH as described in 21.3.8.3.5 (VHT-LTF definition).

b) Phase rotation: Apply appropriate phase rotation for each 20 MHz subchannel as described in 21.3.7.4 (Transmitted signal) and 21.3.7.5 (Definition of tone rotation).

c) $A_{VHT\text{-}LTF}$ matrix mapping: Apply the $P_{VHT\text{-}LTF}$ matrix to the data tones of the VHT-LTF sequence and apply the $R_{VHT\text{-}LTF}$ matrix to the pilot tones as described in 21.3.8.3.5 (VHT-LTF definition).

d) CSD: Apply CSD for each space-time stream and frequency segment as described in 21.3.8.3.2 (Cyclic shift for VHT modulated fields).

e) Spatial mapping: Apply the $Q$ matrix as described in 21.3.10.11.1 (Transmission in VHT format).

f) IDFT: Compute the inverse discrete Fourier transform.

g) Insert GI and apply windowing: Prepend a GI (LONG_GI) and apply windowing as described in 21.3.7.4 (Transmitted signal).

h) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit. Refer to 21.3.7.4 (Transmitted signal) and 21.3.8 (VHT preamble) for details.

#### 21.3.4.8 Construction of VHT-SIG-B

The VHT-SIG-B field is constructed per-user as follows:

a) Obtain the VHT-MCS (for MU only) and APEP_LENGTH from the TXVECTOR.

b) VHT-SIG-B bits: Set the VHT-MCS (for MU only) and VHT-SIG-B Length field as described in 21.3.8.3.6 (VHT-SIG-B definition). Add the reserved bits (for SU only) and $N_{tail}$ bits of tail. In an NDP set VHT-SIG-B to the fixed bit pattern for the bandwidth used as described in 21.3.8.3.6 (VHT-SIG-B definition).

c) VHT-SIG-B Bit Repetition: Repeat the VHT-SIG-B bits as a function of CH_BANDWIDTH as defined in 21.3.8.3.6 (VHT-SIG-B definition).

d) BCC encoder: Encode the VHT-SIG-B field using BCC at rate R=1/2 as described in 17.3.5.6 (Convolutional encoder).

e) Segment parser (if needed): In a 160 MHz or 80+80 MHz transmission, divide the output bits of the BCC encoder into two frequency subblocks as described in 21.3.10.7 (Segment parser). This block is bypassed for 20 MHz, 40 MHz, and 80 MHz VHT PPDU transmissions.

f) BCC interleaver: Interleave as described in 21.3.10.8 (BCC interleaver).

g) Constellation mapper: Map to a BPSK constellation as defined in 17.3.5.8 (Subcarrier modulation mapping).

h) Segment deparser (if needed): In a 160 MHz transmission, merge the two frequency subblocks into one frequency segment as described in 21.3.10.9.3 (Segment deparser). This block is bypassed for 20 MHz, 40 MHz, 80 MHz, and 80+80 MHz VHT PPDU transmissions.

i) Pilot insertion: Insert pilots following the steps described in 21.3.10.10 (Pilot subcarriers).

j) $P_{VHT\text{-}LTF}$ matrix mapping: Apply the mapping of the first column of the $P_{VHT\text{-}LTF}$ matrix to the data subcarriers as described in 21.3.8.3.6 (VHT-SIG-B definition). The total number of data and pilot subcarriers is the same as in the Data field.

k) CSD: Apply CSD for each space-time stream and frequency segment as described in 21.3.8.3.2 (Cyclic shift for VHT modulated fields).

l) Spatial mapping: Apply the $Q$ matrix as described in 21.3.10.11.1 (Transmission in VHT format).

m) Phase rotation: Apply the appropriate phase rotations for each 20 MHz subchannel as described in 21.3.7.4 (Transmitted signal) and 21.3.7.5 (Definition of tone rotation).

n) IDFT: Compute the inverse discrete Fourier transform.

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o) Insert GI and apply windowing: Prepend a GI (LONG_GI) and apply windowing as described in 21.3.7.4 (Transmitted signal).

p) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit. Refer to 21.3.7.4 (Transmitted signal) and 21.3.8 (VHT preamble) for details.

#### 21.3.4.9 Construction of the Data field in a VHT SU PPDU

##### 21.3.4.9.1 Using BCC

The construction of the Data field in a VHT SU PPDU with BCC encoding proceeds as follows:

a) Insert the CRC calculated for VHT-SIG-B in the SERVICE field as described in 21.3.10.2 (SERVICE field) and append the PSDU to the SERVICE field.

b) PHY padding: Append the PHY pad bits and tail bits to the PSDU.

c) Scrambler: Scramble the PHY padded data.

d) BCC encoder: Divide the scrambled bits between the encoders by sending bits to different encoders in a round robin manner. The number of encoders is determined by rate-dependent parameters described in 21.5 (Parameters for VHT-MCSs). BCC encode as described in 21.3.10.5.2 (BCC encoder parsing operation) and 21.3.10.5.3 (BCC coding and puncturing).

e) Stream parser: Rearrange the output of the BCC encoders into blocks as described in 21.3.10.6 (Stream parser).

f) Segment parser (if needed): In a 160 MHz or 80+80 MHz transmission, divide the output bits of each stream parser into two frequency subblocks as described in 21.3.10.7 (Segment parser). This block is bypassed for 20 MHz, 40 MHz, and 80 MHz VHT PPDU transmissions.

g) BCC interleaver: Interleave as described in 21.3.10.8 (BCC interleaver).

h) Constellation mapper: Map to BPSK, QPSK, 16-QAM, 64-QAM, or 256-QAM constellation points as described in 21.3.10.9 (Constellation mapping).

i) Segment deparser (if needed): In a 160 MHz transmission, merge the two frequency subblocks into one frequency segment as described in 21.3.10.9.3 (Segment deparser). This block is bypassed for 20 MHz, 40 MHz, 80 MHz, and 80+80 MHz VHT PPDU transmissions.

j) STBC: Apply STBC as described in 21.3.10.9.4 (Space-time block coding).

k) Pilot insertion: Insert pilots following the steps described in 21.3.10.10 (Pilot subcarriers).

l) CSD: Apply CSD for each space-time stream and frequency segment as described in 21.3.8.3.2 (Cyclic shift for VHT modulated fields).

m) Spatial mapping: Apply the $Q$ matrix as described in 21.3.10.11.1 (Transmission in VHT format).

n) Phase rotation: Apply the appropriate phase rotations for each 20 MHz subchannel as described in 21.3.7.4 (Transmitted signal) and 21.3.7.5 (Definition of tone rotation).

o) IDFT: In an 80+80 MHz transmission, map each frequency subblock to a separate IDFT. Compute the inverse discrete Fourier transform.

p) Insert GI and apply windowing: Prepend a GI (SHORT_GI or LONG_GI) and apply windowing as described in 21.3.7.4 (Transmitted signal).

q) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit. Refer to 21.3.7.4 (Transmitted signal) and 21.3.8 (VHT preamble) for details.

##### 21.3.4.9.2 Using LDPC

The construction of the Data field in a VHT SU PPDU with LDPC encoding proceeds as follows:


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a) Insert the CRC calculated for VHT-SIG-B in the SERVICE field as described in 21.3.10.2 (SERVICE field) and append the PSDU to the SERVICE field.

b) PHY padding: Append the PHY pad bits to the PSDU. There are no tail bits.

c) Scrambler: Scramble the PHY padded data.

d) LDPC encoder: The scrambled bits are encoded using the LDPC code with the APEP_LENGTH in the TXVECTOR as described in 21.3.10.5.4 (LDPC coding).

e) Stream parser: The output of the LDPC encoder is rearranged into blocks as described in 21.3.10.6 (Stream parser).

f) Segment parser (if needed): In a 160 MHz or 80+80 MHz transmission, divide the output bits of each stream parser into two frequency subblocks as described in 21.3.10.7 (Segment parser). This block is bypassed for 20 MHz, 40 MHz, and 80 MHz VHT PPDU transmissions.

g) Constellation mapper: Map to BPSK, QPSK, 16-QAM, 64-QAM or 256-QAM constellation points as described in 21.3.10.9 (Constellation mapping).

h) LDPC tone mapper: The LDPC tone mapping shall be performed on all LDPC encoded streams as described in 21.3.10.9.2 (LDPC tone mapping).

i) Segment deparser (if needed): In a 160 MHz transmission, merge the two frequency subblocks into one frequency segment as described in 21.3.10.9.3 (Segment deparser). This block is bypassed for 20 MHz, 40 MHz, 80 MHz, and 80+80 MHz VHT PPDU transmissions.

j) STBC: Apply STBC as described in 21.3.10.9.4 (Space-time block coding).

k) Pilot insertion: Insert pilots following the steps described in 21.3.10.10 (Pilot subcarriers).

l) CSD: Apply CSD for each space-time stream and frequency segment as described in 21.3.8.3.2 (Cyclic shift for VHT modulated fields).

m) Spatial mapping: Apply the $Q$ matrix as described in 21.3.10.11.1 (Transmission in VHT format).

n) Phase rotation: Apply the appropriate phase rotations for each 20 MHz subchannel as described in 21.3.7.4 (Transmitted signal) and 21.3.7.5 (Definition of tone rotation).

o) IDFT: In an 80+80 MHz transmission, map each frequency subblock to a separate IDFT. Compute the inverse discrete Fourier transform.

p) Insert GI and apply windowing: Prepend a GI (SHORT_GI or LONG_GI) and apply windowing as described in 21.3.7.4 (Transmitted signal).

q) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit. Refer to 21.3.7.4 (Transmitted signal) and 21.3.8 (VHT preamble) for details.

#### 21.3.4.10 Construction of the Data field in a VHT MU PPDU

##### 21.3.4.10.1 General

In an MU transmission, the PPDU encoding process is performed independently on a per-user basis up to the input of the Spatial Mapping block, except that CSD is performed with a knowledge of the space time stream starting index for that user. All user data is combined and mapped to the transmit chains in the Spatial Mapping block.

##### 21.3.4.10.2 Using BCC

A Data field with BCC encoding is constructed using steps a) to k) in 21.3.4.9.1 (Using BCC), then applying CSD for a VHT MU PPDU (as described in 21.3.8.3.2 (Cyclic shift for VHT modulated fields)).

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#### 21.3.4.10.3 Using LDPC

A Data field with LDPC encoding is constructed using steps a) to k) in 21.3.4.9.2 (Using LDPC), then applying CSD as for a VHT MU PPDU (as described in 21.3.8.3.2 (Cyclic shift for VHT modulated fields)).

#### 21.3.4.10.4 Combining to form a VHT MU PPDU

The per-user data is combined as follows:

a) Spatial Mapping: The $Q$ matrix is applied as described in 21.3.10.11.1 (Transmission in VHT format). The combining of all user data is done in this block.

b) Phase rotation: Apply the appropriate phase rotations for each 20 MHz subchannel as described in 21.3.7.4 (Transmitted signal) and 21.3.7.5 (Definition of tone rotation).

c) IDFT: Compute the inverse discrete Fourier transform.

d) Insert GI and apply windowing: Prepend a GI (SHORT_GI or LONG_GI) and apply windowing as described in 21.3.7.4 (Transmitted signal).

e) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit. Refer to 21.3.7.4 (Transmitted signal) and 21.3.8 (VHT preamble) for details.

### 21.3.5 VHT modulation and coding scheme (VHT-MCS)

The VHT-MCS is a value that determines the modulation and coding used in the Data field of the PPDU. It is a compact representation that is carried in the VHT-SIG-A field for VHT SU PPDUs and in the VHT-SIG-B field for VHT MU PPDUs. Rate-dependent parameters for the full set of VHT-MCSs are shown in Table 21-29 (VHT-MCSs for mandatory 20 MHz, NSS = 1) to Table 21-60 (VHT-MCSs for optional 160 MHz and 80+80 MHz, NSS = 8) (in 21.5 (Parameters for VHT-MCSs)). These tables give rate-dependent parameters for VHT-MCSs with indices 0 to 9, with number of spatial streams from 1 to 8 and bandwidth options of 20 MHz, 40 MHz, 80 MHz, and either 160 MHz or 80+80 MHz. Equal modulation (EQM) is applied to all streams for a particular user.

### 21.3.6 Timing-related parameters

Refer to Table 19-6 (Timing-related constants) for timing-related parameters for non-VHT formats.


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Table 21-5 (Timing-related constants) defines the timing-related parameters for VHT format.

**Table 21-5—Timing-related constants**

| Parameter | CBW20 | CBW40 | CBW80 | CBW80+80 | CBW160 | Description |
|---|---|---|---|---|---|---|
| $N_{SD}$ | 52 | 108 | 234 | 234 | 468 | Number of complex data numbers per frequency segment |
| $N_{SP}$ | 4 | 6 | 8 | 8 | 16 | Number of pilot values per frequency segment |
| $N_{ST}$ | 56 | 114 | 242 | 242 | 484 | Total number of subcarriers per frequency segment. See NOTE. |
| $N_{SR}$ | 28 | 58 | 122 | 122 | 250 | Highest data subcarrier index per frequency segment |
| $N_{Seg}$ | 1 | 1 | 1 | 2 | 1 | Number of frequency segments |
| $\Delta_F$ | 312.5 kHz | | | | | Subcarrier frequency spacing |
| $T_{DFT}$ | 3.2 μs | | | | | IDFT/DFT period |
| $T_{GI}$ | 0.8 μs = $T_{DFT}$/4 | | | | | Guard interval duration |
| $T_{GI2}$ | 1.6 μs | | | | | Double guard interval |
| $T_{GIS}$ | 0.4 μs = $T_{DFT}$/8 | | | | | Short guard interval duration |
| $T_{SYML}$ | 4 μs = $T_{DFT}$ + $T_{GI}$ = 1.25 × $T_{DFT}$ | | | | | Long GI symbol interval |
| $T_{SYMS}$ | 3.6 μs = $T_{DFT}$ + $T_{GIS}$ = 1.125 × $T_{DFT}$ | | | | | Short GI symbol interval |
| $T_{SYM}$ | $T_{SYML}$ or $T_{SYMS}$ depending on the GI used (see Table 21-8 (Tone scaling factor and guard interval duration values for PHY fields)) | | | | | Symbol interval |
| $T_{L\text{-}STF}$ | 8 μs = 10 x $T_{DFT}$/4 | | | | | Non-HT Short Training field duration |
| $T_{L\text{-}LTF}$ | 8 μs = 2 x $T_{DFT}$ + $T_{GI2}$ | | | | | Non-HT Long Training field duration |
| $T_{L\text{-}SIG}$ | 4 μs = $T_{SYML}$ | | | | | Non-HT SIGNAL field duration |
| $T_{VHT\text{-}SIG\text{-}A}$ | 8 μs = 2$T_{SYML}$ | | | | | VHT Signal A field duration |
| $T_{VHT\text{-}STF}$ | 4 μs = $T_{SYML}$ | | | | | VHT Short Training field duration |
| $T_{VHT\text{-}LTF}$ | 4 μs = $T_{SYML}$ | | | | | Duration of each VHT-LTF symbol |

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**Table 21-5—Timing-related constants *(continued)***

| Parameter | CBW20 | CBW40 | CBW80 | CBW80+80 | CBW160 | Description |
|---|---|---|---|---|---|---|
| $T_{VHT\text{-}SIG\text{-}B}$ | 4 μs = $T_{SYML}$ | | | | | VHT Signal B field duration |
| $N_{service}$ | 16 | | | | | Number of bits in the SERVICE field |
| $N_{tail}$ | 6 | | | | | Number of tail bits per BCC encoder |
| NOTE—$N_{ST} = N_{SD} + N_{SP}$ | | | | | | |

Table 21-6 (Frequently used parameters) defines parameters used frequently in Clause 21 (Very high throughput (VHT) PHY specification).

**Table 21-6—Frequently used parameters**

| Symbol | Explanation |
|---|---|
| $N_{CBPS}$, $N_{CBPS,u}$ | Number of coded bits per symbol for user $u$, $u = 0, ..., N_{user}–1$.<br>For a VHT SU PPDU, $N_{CBPS} = N_{CBPS,0}$<br>For a VHT MU PPDU, $N_{CBPS}$ is undefined |
| $N_{CBPSS}$, $N_{CBPSS,u}$ | Number of coded bits per symbol per spatial stream.<br>For the VHT-SIG-B field, $N_{CBPSS}$ is common for all users.<br>$N_{CBPSS} = \begin{cases} N_{SD}, \text{ for a 20 MHz, 40 MHz, 80 MHz, and 160 MHz PPDU} \\ 2N_{SD}, \text{ for an 80+80 MHz PPDU} \end{cases}$<br>for all users.<br>For the Data field, $N_{CBPSS,u}$ equals the number of coded bits per symbol per spatial stream for user $u$, $u = 0, ..., N_{user}–1$.<br>For the Data field of a VHT SU PPDU, $N_{CBPSS} = N_{CBPSS,0}$<br>For the Data field of a VHT MU PPDU, $N_{CBPSS}$ is undefined |
| $N_{CBPSSI}$, $N_{CBPSSI,u}$ | Number of coded bits per symbol per spatial stream per BCC interleaver block.<br>For a VHT SU PPDU,<br>$N_{CBPSSI} = \begin{cases} N_{CBPSS}, \text{ for a 20 MHz, 40 MHz, or 80 MHz PPDU} \\ \frac{N_{CBPSS}}{2}, \text{ for a 160 MHz or 80+80 MHz PPDU} \end{cases}$<br>For a VHT MU PPDU for user $u$, $u = 0, ..., N_{user}–1$<br>$N_{CBPSSI,u} = \begin{cases} N_{CBPSS,u}, \text{ for a 20 MHz, 40 MHz, or 80 MHz PPDU} \\ \frac{N_{CBPSS,u}}{2}, \text{ for a 160 MHz or 80+80 MHz PPDU} \end{cases}$<br>For a VHT MU PPDU, $N_{CBPSSI}$ is undefined. |


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**Table 21-6—Frequently used parameters *(continued)***

| Symbol | Explanation |
|---|---|
| $N_{DBPS}$, $N_{DBPS,u}$ | Number of data bits per symbol for user $u$, $u = 0, ..., N_{user}–1$.<br>For a VHT SU PPDU, $N_{DBPS} = N_{DBPS,0}$<br>For a VHT MU PPDU, $N_{DBPS}$ is undefined |
| $N_{BPSCS}$, $N_{BPSCS,u}$ | Number of coded bits per subcarrier per spatial stream for user $u$, $u = 0, ..., N_{user}–1$.<br>For a VHT SU PPDU, $N_{BPSCS} = N_{BPSCS,0}$<br>For a VHT MU PPDU, $N_{BPSCS}$ is undefined |
| $N_{RX}$ | Number of receive chains |
| $N_{user}$ | For pre-VHT modulated fields, $N_{user} = 1$. For VHT modulated fields, $N_{user}$ represents the number of users in the transmission (equal to the TXVECTOR parameter NUM_USERS). |
| $N_{STS}$, $N_{STS,u}$ | For pre-VHT modulated fields, $N_{STS,u} = 1$ (see NOTE). For VHT modulated fields, $N_{STS,u}$ is the number of space-time streams for user $u$, $u = 0, ..., N_{user}–1$.<br>For a VHT SU PPDU, $N_{STS} = N_{STS,0}$.<br>For a VHT MU PPDU, $N_{STS}$ is undefined. |
| $N_{STS,total}$ | For VHT modulated fields, $N_{STS,total}$ is the total number of space-time streams in a PPDU.<br>$N_{STS,total} = \sum_{u=0}^{N_{user}-1} N_{STS,u}$<br>For pre-VHT modulated fields, $N_{STS,total}$ is undefined.<br>Note that $N_{STS,total} = N_{STS}$ for a VHT SU PPDU. |
| $N_{SS}$, $N_{SS,u}$ | Number of spatial streams.<br>For the VHT-SIG-B field, $N_{SS} = 1$ for each user.<br>For the Data field, $N_{SS,u}$ is the number of spatial streams for user $u$, $u = 0, ..., N_{user}–1$.<br>For the Data field of a VHT SU PPDU, $N_{SS} = N_{SS,0}$.<br>For the Data field of a VHT MU PPDU, $N_{SS}$ is undefined. |
| $N_{TX}$ | Number of transmit chains |
| $N_{ES}$, $N_{ES,u}$ | The number of BCC encoders.<br>For the VHT-SIG-B field, $N_{ES} = 1$ for each user.<br>For a Data field encoded using BCC, $N_{ES,u}$ is the number of BCC encoders for user $u$, $u = 0, ..., N_{user}–1$.<br>For the Data field encoded using LDPC, $N_{ES} = 1$ for a VHT SU PPDU and $N_{ES,u} = 1$ for a VHT MU PPDU for user $u$, $u = 0, ...N_{user}–1$.<br>For the Data field of a VHT SU PPDU, $N_{ES} = N_{ES,0}$.<br>For the Data field of a VHT MU PPDU, $N_{ES}$ is undefined. |
| $N_{VHT-LTF}$ | Number of VHT-LTF symbols (see 21.3.8.3.5 (VHT-LTF definition)) |
| $R$, $R_u$ | $R_u$ is the coding rate for user $u$, $u = 0, ..., N_{user}–1$.<br>For a VHT SU PPDU, $R = R_0$<br>For a VHT MU PPDU, $R$ is undefined |

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**Table 21-6—Frequently used parameters *(continued)***

| Symbol | Explanation |
|---|---|
| $M_u$ | For pre-VHT modulated fields, $M_u = 0$. For VHT modulated fields, $M_0 = 0$ for $u = 0$ and $M_u = \sum_{u'=0}^{u-1} N_{STS,u'}$ for $u = 1, \ldots N_{user}-1$. |
| NOTE—For pre-VHT modulated fields, $u$ is 0 only since $N_{user} = 1$. | |

### 21.3.7 Mathematical description of signals

#### 21.3.7.1 Notation

For a description of the conventions used for the mathematical description of the signals, see 17.3.2.5 (Mathematical conventions in the signal descriptions). In addition, the following notational conventions are used in Clause 21 (Very high throughput (VHT) PHY specification):

$[Q]_{m,n}$ indicates the element in row $m$ and column $n$ of matrix $Q$, where $1 \le m \le N_{row}$ and $1 \le n \le N_{col}$

$N_{row}$ and $N_{col}$ are the number of rows and columns, respectively, of the matrix $Q$

$[Q]_{M:N}$ indicates a matrix consisting of columns $M$ to $N$ of matrix $Q$

#### 21.3.7.2 Subcarrier indices in use

For description on subcarrier indices over which the signal is transmitted for non-HT and HT PPDUs, see 19.3.7 (Mathematical description of signals).

For a 20 MHz VHT PPDU transmission, the 20 MHz is divided into 64 subcarriers. The signal is transmitted on subcarriers –28 to –1 and 1 to 28, with 0 being the center (DC) subcarrier.

For a 40 MHz VHT PPDU transmission, the 40 MHz is divided into 128 subcarriers. The signal is transmitted on subcarriers –58 to –2 and 2 to 58.

For an 80 MHz VHT PPDU transmission, the 80 MHz is divided into 256 subcarriers. The signal is transmitted on subcarriers –122 to –2 and 2 to 122.

For a 160 MHz VHT PPDU transmission, the 160 MHz is divided into 512 subcarriers. The signal is transmitted on subcarriers –250 to –130, –126 to –6, 6 to 126, and 130 to 250.

For an 80+80 MHz VHT PPDU transmission, each 80 MHz frequency segment is divided into 256 subcarriers. In each frequency segment, the signal is transmitted on subcarriers –122 to –2 and 2 to 122.

#### 21.3.7.3 Channel frequencies

Let

$$f_{c,\,\mathrm{idx0}} = \mathrm{dot11CurrentChannelCenterFrequencyIndex0} \quad (21\text{-}1)$$


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$$f_{c,\,\mathrm{idx1}} = \mathrm{dot11CurrentChannelCenterFrequencyIndex1} \tag{21-2}$$

$$f_{\mathrm{P20,\,idx}} = \mathrm{dot11CurrentPrimaryChannel} \tag{21-3}$$

$$f_{\mathrm{CH,\,start}} = \mathrm{dot11ChannelStartingFactor} \times 500\ \mathrm{kHz} \tag{21-4}$$

where

dot11CurrentChannelCenterFrequencyIndex0, dot11CurrentChannelCenterFrequencyIndex1, and dot11CurrentPrimaryChannel are defined in Table 21-22 (Fields to specify VHT channels).

When dot11CurrentChannelWidth (see Table 21-22 (Fields to specify VHT channels)) is 20 MHz, $f_{\mathrm{P20,\,idx}} = f_{c,\,\mathrm{idx0}}$. For dot11CurrentChannelWidth greater than 20 MHz, $f_{\mathrm{P20,\,idx}}$ and $f_{c,\,\mathrm{idx0}}$ shall have the relationship specified in Equation (21-5).

$$f_{\mathrm{P20,\,idx}} = f_{c,\,\mathrm{idx0}} - 4 \cdot \left( \frac{N_{\mathrm{20MHz}}}{2} - n_{\mathrm{P20}} \right) + 2 \tag{21-5}$$

where

$$N_{\mathrm{20MHz}} = \begin{cases} 2, \text{ if dot11CurrentChannelWidth indicates 40 MHz} \\ 4, \text{ if dot11CurrentChannelWidth indicates 80 MHz and 80+80 MHz} \\ 8, \text{ if dot11CurrentChannelWidth indicates 160 MHz} \end{cases}$$

$n_{\mathrm{P20}}$ is an integer with possible range $0 \le n_{\mathrm{P20}} \le N_{\mathrm{20MHz}} - 1$

When dot11CurrentChannelWidth is 40 MHz, 80 MHz, 160 MHz, or 80+80 MHz,

— The primary 20 MHz channel is the channel with 20 MHz bandwidth centered at $f_{\mathrm{CH,\,start}} + 5 \times f_{\mathrm{P20,\,idx}}$ MHz.

— The secondary 20 MHz channel is the channel with 20 MHz bandwidth centered at $f_{\mathrm{CH,\,start}} + 5 \times f_{S20,\,\mathrm{idx}}$, where $f_{S20,\,\mathrm{idx}}$ is given in Equation (21-6).

$$f_{\mathrm{S20,\,idx}} = \begin{cases} f_{\mathrm{P20,\,idx}} + 4, & \text{if } n_{\mathrm{P20}} \text{ is even} \\ f_{\mathrm{P20,\,idx}} - 4, & \text{if } n_{\mathrm{P20}} \text{ is odd} \end{cases} \tag{21-6}$$

When dot11CurrentChannelWidth is 80 MHz, 160 MHz, or 80+80 MHz,

— The primary 40 MHz channel is the channel with 40 MHz bandwidth centered at $f_{\mathrm{CH,\,start}} + 5 \times f_{\mathrm{P40,\,idx}}$ MHz, where $f_{\mathrm{P40,\,idx}}$ is given in Equation (21-7).

— The secondary 40 MHz channel is the channel with 40 MHz bandwidth centered at $f_{\mathrm{CH,\,start}} + 5 \times f_{S40,\,\mathrm{idx}}$ MHz, where $f_{S40,\,\mathrm{idx}}$ is given in Equation (21-8).

$$f_{\mathrm{P40,\,idx}} = f_{c,\,\mathrm{idx0}} - 8 \cdot \left( \frac{N_{\mathrm{20MHz}}}{4} - n_{\mathrm{P40}} \right) + 4 \tag{21-7}$$

$$f_{\mathrm{S40,\,idx}} = \begin{cases} f_{\mathrm{P40,\,idx}} + 8, & \text{if } n_{\mathrm{P40}} \text{ is even} \\ f_{\mathrm{P40,\,idx}} - 8, & \text{if } n_{\mathrm{P40}} \text{ is odd} \end{cases} \tag{21-8}$$

where $n_{\mathrm{P40}} = \lfloor n_{\mathrm{P20}} / 2 \rfloor$.

When dot11CurrentChannelWidth is 160 MHz,

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— The primary 80 MHz channel is the channel with 80 MHz bandwidth centered at $f_{\text{CH, start}} + 5 \times f_{\text{P80, idx}}$ MHz, where $f_{\text{P80, idx}}$ is given in Equation (21-9).
— The secondary 80 MHz channel is the channel with 80 MHz bandwidth centered at $f_{\text{CH, start}} + 5 \times f_{\text{S80, idx}}$ MHz where $f_{\text{S80, idx}}$ is given in Equation (21-10).

$$f_{\text{P80, idx}} = f_{c,\text{ idx0}} - 16 \cdot \left( \frac{N_{\text{20MHz}}}{8} - n_{\text{P80}} \right) + 8 \tag{21-9}$$

$$f_{\text{S80, idx}} = \begin{cases} f_{\text{P80, idx}} + 16, & \text{if } n_{\text{P80}} \text{ is even} \\ f_{\text{P80, idx}} - 16, & \text{if } n_{\text{P80}} \text{ is odd} \end{cases} \tag{21-10}$$

where $n_{\text{P80}} = \lfloor n_{\text{P20}} / 4 \rfloor$.

When dot11CurrentChannelWidth is 80+80 MHz,

— The primary 80 MHz channel is the channel with 80 MHz bandwidth centered at $f_{\text{CH, start}} + 5 \times f_{\text{P80, idx}}$ MHz, where $f_{\text{P80, idx}} = f_{c,\text{ idx0}}$.
— The secondary 80 MHz channel is the channel with 80 MHz bandwidth centered at $f_{\text{CH, start}} + 5 \times f_{\text{S80, idx}}$ MHz where $f_{\text{S80, idx}} = f_{c,\text{ idx1}}$.

### 21.3.7.4 Transmitted signal

The transmitted signal is described in complex baseband signal notation. The actual transmitted signal is related to the complex baseband signal by the relation shown in Equation (21-11).

$$r_{RF}^{(i_{Seg}, i_{TX})}(t) = \text{Re}\left\{ \frac{1}{\sqrt{N_{Seg}}} r_{\text{PPDU}}^{(i_{Seg}, i_{TX})}(t) \exp(j2\pi f_c^{(i_{Seg})} t) \right\}, \quad i_{Seg} = 0, \ldots, N_{Seg} - 1; \quad i_{TX} = 1, \ldots, N_{TX} \tag{21-11}$$

where

$N_{Seg}$ represents the number of frequency segments in the transmit signal, as defined in Table 21-5 (Timing-related constants)

$r_{\text{PPDU}}^{(i_{Seg}, i_{TX})}(t)$ represents the complex baseband signal of frequency segment $i_{Seg}$ and transmit chain $i_{TX}$

$f_c^{(i_{Seg})}$ represents the center frequency of the portion of the PPDU transmitted in frequency segment $i_{Seg}$. Table 21-7 (Center frequency of the portion of the PPDU transmitted in frequency segment iSeg) shows $f_c^{(i_{Seg})}$ as a function of the channel starting frequency and dot11CurrentChannelWidth (see Table 21-22 (Fields to specify VHT channels)) where $f_{\text{P20, idx}}$, $f_{\text{P40, idx}}$, and $f_{\text{P80, idx}}$ are given in Equation (21-4), Equation (21-5), Equation (21-7), and Equation (21-9), respectively.

NOTE—Transmitted signals might have different impairments such as phase offset or phase noise between the two frequency segments, which is not shown in Equation (21-11) for simplicity. See 21.3.17.3 (Transmit center frequency and symbol clock frequency tolerance).

The transmitted RF signal is derived by upconverting the complex baseband signal, which consists of several fields. The timing boundaries for the various fields are shown in Figure 21-17 (Timing boundaries


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**Table 21-7—Center frequency of the portion of the PPDU transmitted in frequency segment $i_{Seg}$**

| dot11CurrentChannel Width | CH_BANDWIDTH | $f_c^{(i_{Seg})} = f_{\text{CH, start}} + 5 \times f_{(i_{Seg})}$ | |
|---|---|---|---|
| | | $f_{(0)}$ | $f_{(1)}$ |
| 20 MHz | CBW20 | $f_{c,\text{ idx0}}$ | — |
| 40 MHz | CBW20 | $f_{\text{P20, idx}}$ | — |
| | CBW40 | $f_{c,\text{ idx0}}$ | — |
| 80 MHz | CBW20 | $f_{\text{P20, idx}}$ | — |
| | CBW40 | $f_{\text{P40, idx}}$ | — |
| | CBW80 | $f_{c,\text{ idx0}}$ | — |
| 160 MHz | CBW20 | $f_{\text{P20, idx}}$ | — |
| | CBW40 | $f_{\text{P40, idx}}$ | — |
| | CBW80 | $f_{\text{P80, idx}}$ | — |
| | CBW160 | $f_{c,\text{ idx0}}$ | — |
| 80+80 MHz | CBW20 | $f_{\text{P20, idx}}$ | — |
| | CBW40 | $f_{\text{P40, idx}}$ | — |
| | CBW80 | $f_{\text{P80, idx}}$ | — |
| | CBW80+80 | $\min(f_{c,\text{ idx0}}, f_{c,\text{ idx1}})$ | $\max(f_{c,\text{ idx0}}, f_{c,\text{ idx1}})$ |

for VHT PPDU fields) where $N_{VHT\text{-}LTF}$ is the number of VHT-LTF symbols and is defined in Table 21-13 (Number of VHT-LTFs required for different numbers of space-time streams).

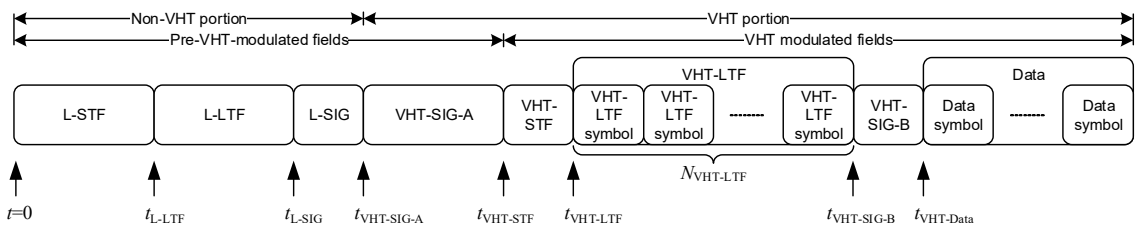


**Figure 21-17—Timing boundaries for VHT PPDU fields**

The time offset, $t_{Field}$, determines the starting time of the corresponding field relative to the start of L-STF ($t$ = 0).

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The signal transmitted on frequency segment $i_{Seg}$ and transmit chain $i_{TX}$ shall be as shown in Equation (21-12).

$$\begin{aligned} r_{\text{PPDU}}^{(i_{Seg}, i_{TX})}(t) = {} & r_{\text{L-STF}}^{(i_{Seg}, i_{TX})}(t) + r_{\text{L-LTF}}^{(i_{Seg}, i_{TX})}(t - t_{\text{L-LTF}}) \\ & + r_{\text{L-SIG}}^{(i_{Seg}, i_{TX})}(t - t_{\text{L-SIG}}) + r_{\text{VHT-SIG-A}}^{(i_{Seg}, i_{TX})}(t - t_{\text{VHT-SIG-A}}) \\ & + r_{\text{VHT-STF}}^{(i_{Seg}, i_{TX})}(t - t_{\text{VHT-STF}}) + r_{\text{VHT-LTF}}^{(i_{Seg}, i_{TX})}(t - t_{\text{VHT-LTF}}) \\ & + r_{\text{VHT-SIG-B}}^{(i_{Seg}, i_{TX})}(t - t_{\text{VHT-SIG-B}}) + r_{\text{VHT-Data}}^{(i_{Seg}, i_{TX})}(t - t_{\text{VHT-Data}}) \end{aligned} \tag{21-12}$$

where

$0 \le i_{Seg} \le N_{Seg} - 1$

$1 \le i_{TX} \le N_{TX}$

$t_{\text{L-LTF}} = T_{\text{L-STF}}$

$t_{\text{L-SIG}} = t_{\text{L-LTF}} + T_{\text{L-LTF}}$

$t_{\text{VHT-SIG-A}} = t_{\text{L-SIG}} + T_{\text{L-SIG}}$

$t_{\text{VHT-STF}} = t_{\text{VHT-SIG-A}} + T_{\text{VHT-SIG-A}}$

$t_{\text{VHT-LTF}} = t_{\text{VHT-STF}} + T_{\text{VHT-STF}}$

$t_{\text{VHT-SIG-B}} = t_{\text{VHT-LTF}} + N_{VHT\text{-}LTF} T_{\text{VHT-LTF}}$

$t_{\text{VHT-Data}} = t_{\text{VHT-SIG-B}} + T_{\text{VHT-SIG-B}}$

Each field, $r_{Field}^{(i_{Seg}, i_{TX})}(t)$, is defined as the summation of one or more subfields, where each subfield is defined to be an inverse discrete Fourier transform as specified in Equation (21-13).

$$\begin{aligned} r_{\text{Subfield}}^{(i_{Seg}, i_{TX})}(t) = {} & \frac{1}{\sqrt{N_{\text{Field}}^{\text{Tone}} N_{\text{Norm}}}} w_{T_{\text{Subfield}}}(t) \sum_{k=-N_{SR}}^{N_{SR}} \sum_{u=0}^{N_{user}-1} \sum_{m=1}^{N_{STS,u}} \left[ Q_k^{(i_{Seg})} \right]_{i_{TX}, (M_u + m)} \Upsilon_{k, BW} X_{k,u}^{(i_{Seg}, m)} \\ & \exp(j 2\pi k \Delta_F (t - T_{\text{GI, Field}} - T_{\text{CS, VHT}}(M_u + m))) \end{aligned} \tag{21-13}$$

This general representation holds for all subfields. The total power of the time domain VHT modulated field signals summed over all transmit chains should not exceed the total power of the time domain pre-VHT modulated field signals summed over all transmit chains. For notational simplicity, the parameter BW is omitted from some bandwidth dependent terms.

In Equation (21-13) the following notions are used:

$N_{\text{Field}}^{\text{Tone}}$ Table 21-8 (Tone scaling factor and guard interval duration values for PHY fields) summarizes the various values of $N_{\text{Field}}^{\text{Tone}}$ as a function of bandwidth per frequency segment.

**Table 21-8—Tone scaling factor and guard interval duration values for PHY fields**

| Field | $N_{\text{Field}}^{\text{Tone}}$ as a function of bandwidth per frequency segment | | | | Guard interval duration |
|---|---|---|---|---|---|
| | 20 MHz | 40 MHz | 80 MHz | 160 MHz | |
| L-STF | 12 | 24 | 48 | 96 | — |
| L-LTF | 52 | 104 | 208 | 416 | $T_{GI2}$ |


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**Table 21-8—Tone scaling factor and guard interval duration values for PHY fields**

| | | | | | |
|---|---|---|---|---|---|
| L-SIG | 52 | 104 | 208 | 416 | $T_{GI}$ |
| VHT-SIG-A | 52 | 104 | 208 | 416 | $T_{GI}$ |
| VHT-STF | 12 | 24 | 48 | 96 | — |
| VHT-LTF | 56 | 114 | 242 | 484 | $T_{GI}$ |
| VHT-SIG-B | 56 | 114 | 242 | 484 | $T_{GI}$ |
| VHT-Data | 56 | 114 | 242 | 484 | $T_{GI}$ or $T_{GIS}$ (see NOTE 2) |
| NON_HT_DUP_OFDM-Data (see NOTE 1) | — | 104 | 208 | 416 | $T_{GI}$ |

NOTE 1—For notational convenience, NON_HT_DUP_OFDM-Data is used as a label for the Data field of a non-HT PPDU(#238) with format type NON_HT_DUP_OFDM.

NOTE 2—$T_{GI}$ denotes guard interval duration when TXVECTOR parameter GI_TYPE equals LONG_GI, $T_{GIS}$ denotes short guard interval duration when TXVECTOR parameter GI_TYPE equals SHORT_GI.

$N_{\text{Norm}}$ For pre-VHT modulated fields, $N_{\text{Norm}} = N_{TX}$. For VHT modulated fields, $N_{\text{Norm}} = N_{STS,\,total}$ where $N_{STS,\,total}$ is given in Table 21-6 (Frequently used parameters).

$w_{T_{\text{Subfield}}}(t)$ is a windowing function. An example function, $w_{T_{\text{Subfield}}}(t)$, is given in 17.3.2.5 (Mathematical conventions in the signal descriptions). $T_{\text{Subfield}}$ is $T_{L\text{-}STF}$ for L-STF, $T_{L\text{-}LTF}$ for L-LTF, $T_{L\text{-}SIG}$ for L-SIG, $T_{SYML}$ for VHT-SIG-A, $T_{VHT\text{-}STF}$ for VHT-STF, $T_{VHT\text{-}LTF}$ for VHT-LTF and $T_{VHT\text{-}SIG\text{-}B}$ for VHT-SIG-B. $T_{\text{Subfield}}$ is $T_{SYM}$ for VHT-Data, that is $T_{SYML}$ when not using the short guard interval (Short GI field of VHT-SIG-A is 0) and $T_{SYMS}$ when using the short guard interval (Short GI field of VHT-SIG-A is 1).

$Q_k^{(i_{Seg})}$ is the spatial mapping matrix for the subcarrier $k$ in frequency segment $i_{Seg}$. For pre-VHT modulated fields, $Q_k^{(i_{Seg})}$ is a column vector with $N_{TX}$ elements with element $i_{TX}$ being $\exp(-j2\pi k\Delta_F T_{CS}^{i_{TX}})$, where $T_{CS}^{i_{TX}}$ represents the cyclic shift for transmitter chain $i_{TX}$ whose values are given in Table 21-10 (Cyclic shift values for L-STF, L-LTF, L-SIG, and VHT-SIG-A fields of the PPDU). For VHT modulated fields, $Q_k^{(i_{Seg})}$ is a matrix with $N_{TX}$ rows and $N_{STS,\,total}$ columns.

$\Upsilon_{k,\,\text{BW}}$ is defined in 21.3.7.5 (Definition of tone rotation)

$\Delta_F$ is the subcarrier frequency spacing given in Table 21-5 (Timing-related constants).

$X_{k,\,u}^{(i_{Seg},\,m)}$ is the frequency domain symbol in subcarrier $k$ of user $u$ for frequency segment $i_{Seg}$ of space-time stream $m$. Some of the $X_{k,\,u}^{(i_{Seg},\,m)}$ within $-N_{SR} \le k \le N_{SR}$ have a value of 0. Examples of such cases include the DC tones, guard tones on each side of the transmit spectrum, as well as the unmodulated tones of L-STF and VHT-STF fields. Note that the multiplication matrices $A_{VHT\text{-}LTF}^{k}$ and $P_{VHT\text{-}LTF}$ are included in the calculation of $X_{k,\,u}^{(i_{Seg},\,m)}$ for the VHT-LTF and VHT-SIG-B fields, respectively.

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$T_{\text{GI, Field}}$ is the guard interval duration used for each OFDM symbol in the field. For L-STF and VHT-STF, $T_{\text{GI, Field}} = T_{\text{GI}}$ but it can be omitted from Equation (21-13) due to the periodic property of L-STF and VHT-STF over every 0.8 μs. For the L-SIG, VHT-SIG-A, VHT-LTF, and VHT-SIG-B fields, $T_{\text{GI, Field}}$ is defined in the (#4177)Guard interval duration column of Table 21-8 (Tone scaling factor and guard interval duration values for PHY fields).

$T_{\text{CS, VHT}}(l)$ For pre-VHT modulated fields, $T_{\text{CS, VHT}}(l) = 0$. For VHT modulated fields, $T_{\text{CS, VHT}}(l)$ represents the cyclic shift per space-time stream, whose value is defined in Table 21-11 (Cyclic shift values for the VHT modulated fields of a PPDU).

$M_u$ is defined in Table 21-6 (Frequently used parameters).

### 21.3.7.5 Definition of tone rotation

The function $\Upsilon_{k, \text{BW}}$ is used to represent a rotation of the tones. BW in $\Upsilon_{k, \text{BW}}$ is determined by the TXVECTOR parameter CH_BANDWIDTH as defined in Table 21-9 (CH_BANDWIDTH and).

**Table 21-9—CH_BANDWIDTH and $\Upsilon_{k, \text{BW}}$**

| CH_BANDWIDTH | $\Upsilon_{k, \text{BW}}$ |
|---|---|
| CBW20 | $\Upsilon_{k, 20}$ |
| CBW40 | $\Upsilon_{k, 40}$ |
| CBW80 | $\Upsilon_{k, 80}$ |
| CBW160 | $\Upsilon_{k, 160}$ |
| CBW80+80 | $\Upsilon_{k, 80}$ per frequency segment |

For a 20 MHz PPDU transmission,

$$\Upsilon_{k, 20} = 1 \tag{21-14}$$

For a 40 MHz PPDU transmission,

$$\Upsilon_{k, 40} = \begin{cases} 1, & k < 0 \\ j, & k \geq 0 \end{cases} \tag{21-15}$$

For an 80 MHz PPDU transmission,

$$\Upsilon_{k, 80} = \begin{cases} 1, & k < -64 \\ -1, & k \geq -64 \end{cases} \tag{21-16}$$

For an 80+80 MHz PPDU transmission, each 80 MHz frequency segment shall use the phase rotation for 80 MHz PPDU transmissions as defined in Equation (21-16).


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For a 160 MHz PPDU transmission,

$$\Upsilon_{k,160} = \begin{cases} 1, & k < -192 \\ -1, & -192 \le k < 0 \\ 1, & 0 \le k < 64 \\ -1, & k \ge 64 \end{cases} \quad (21\text{-}17)$$

### 21.3.8 VHT preamble

#### 21.3.8.1 Introduction

A VHT preamble is defined to carry the required information to operate in either single user or multi-user mode. To maintain compatibility with non-VHT STAs, specific non-VHT fields are defined that can be received by non-VHT STAs compliant with Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) or Clause 19 (High Throughput (HT) PHY specification(#2297)). The non-VHT fields are followed by VHT fields specific to VHT STAs.

#### 21.3.8.2 Non-VHT portion of VHT format preamble

##### 21.3.8.2.1 Cyclic shift for pre-VHT modulated fields

The cyclic shift value $T_{CS}^{i_{TX}}$ for the L-STF, L-LTF, L-SIG, and VHT-SIG-A fields of the PPDU for transmit chain $i_{TX}$ out of a total of $N_{TX}$ are defined in Table 21-10 (Cyclic shift values for L-STF, L-LTF, L-SIG, and VHT-SIG-A fields of the PPDU).

**Table 21-10—Cyclic shift values for L-STF, L-LTF, L-SIG, and VHT-SIG-A fields of the PPDU**

| $T_{CS}^{i_{TX}}$ values for L-STF, L-LTF, L-SIG, and VHT-SIG-A fields of the PPDU | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Total number of transmit chains ($N_{TX}$) per frequency segment** | **Cyclic shift for transmit chain $i_{TX}$ (in units of ns)** | | | | | | | | |
| | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **>8** |
| 1 | 0 | – | – | – | – | – | – | – | – |
| 2 | 0 | –200 | – | – | – | – | – | – | – |
| 3 | 0 | –100 | –200 | – | – | – | – | – | – |
| 4 | 0 | –50 | –100 | –150 | – | – | – | – | – |
| 5 | 0 | –175 | –25 | –50 | –75 | – | – | – | – |
| 6 | 0 | –200 | –25 | –150 | –175 | –125 | – | – | – |
| 7 | 0 | –200 | –150 | –25 | –175 | –75 | –50 | – | – |
| 8 | 0 | –175 | –150 | –125 | –25 | –100 | –50 | –200 | – |
| >8 | 0 | –175 | –150 | –125 | –25 | –100 | –50 | –200 | Between –200 and 0 |

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#### 21.3.8.2.2 L-STF definition

The L-STF field for a 20 MHz or 40 MHz transmission is defined by Equation (19-8) and Equation (19-9), respectively, in 19.3.9.3.3 (L-STF definition). For 80 MHz, the L-STF field is defined by Equation (21-18). Note that these equations do not include the phase rotation per 20 MHz subchannel.

$$S_{-122,\,122} = \{S_{-58,\,58}, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, S_{-58,\,58}\} \tag{21-18}$$

where

$S_{-58,\,58}$ is defined in Equation (19-9)

For 160 MHz, the L-STF is defined by Equation (21-19).

$$S_{-250,\,250} = \{S_{-122,\,122}, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, S_{-122,\,122}\} \tag{21-19}$$

For an 80+80 MHz transmission, each 80 MHz frequency segment shall use the L-STF pattern for the 80 MHz ($S_{-122,\,122}$) defined in Equation (21-18).

The time domain representation of the signal on frequency segment $i_{Seg}$ and transmit chain $i_{TX}$ shall be as specified in Equation (21-20).

$$r_{\text{L-STF}}^{(i_{Seg},\,i_{TX})}(t) = \frac{1}{\sqrt{N_{\text{L-STF}}^{\text{Tone}} N_{\text{TX}}}} w_{T_{\text{L-STF}}}(t) \sum_{k=-26}^{26} \Upsilon_{k,\,\text{BW}} S_k \exp(j2\pi k \Delta_F (t - T_{CS}^{i_{TX}})) \tag{21-20}$$

where

$T_{CS}^{i_{TX}}$ represents the cyclic shift for transmit chain $i_{TX}$ with a value given in Table 21-10 (Cyclic shift values for L-STF, L-LTF, L-SIG, and VHT-SIG-A fields of the PPDU)

$\Upsilon_{k,\,\text{BW}}$ is defined by Equation (21-14), Equation (21-15), Equation (21-16). and Equation (21-17)

$N_{\text{L-STF}}^{\text{Tone}}$ has the value given in Table 21-8 (Tone scaling factor and guard interval duration values for PHY fields)

#### 21.3.8.2.3 L-LTF definition

For a 20 MHz or 40 MHz transmission, the L-LTF pattern in the VHT preamble is defined by Equation (19-11) and Equation (19-12) in 19.3.9.3.4 (L-LTF definition), respectively. For an 80 MHz transmission, the L-LTF pattern is defined by Equation (21-21). Note that these equations do not include the phase rotation per 20 MHz subchannel.

$$L_{-122,\,122} = \{L_{-58,\,58}, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, L_{-58,\,58}\} \tag{21-21}$$

where

$L_{-58,\,58}$ is defined in Equation (19-12)

For a 160 MHz transmission, the L-LTF is defined by Equation (21-22). Note that this equation does not include the phase rotations per 20 MHz subchannel.

$$L_{-250,\,250} = \{L_{-122,\,122}, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, L_{-122,\,122}\} \tag{21-22}$$


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For an 80+80 MHz transmission, each 80 MHz frequency segment shall use the L-LTF pattern for the 80 MHz L-LTF pattern ($L_{-122,\,122}$) defined in Equation (21-21).

The time domain representation of the signal on frequency segment $i_{Seg}$ and transmit chain $i_{TX}$ shall be as defined in Equation (21-23).

$$r_{\text{L-LTF}}^{(i_{Seg},\,i_{TX})}(t) = \frac{1}{\sqrt{N_{\text{L-LTF}}^{\text{Tone}} N_{\text{TX}}}} w_{T_{\text{L-LTF}}}(t) \sum_{k=-N_{SR}}^{N_{SR}} \Upsilon_{k,\,\text{BW}} L_k \exp(j2\pi k \Delta_F (t - T_{\text{GI2}} - T_{CS}^{i_{TX}})) \quad (21\text{-}23)$$

where

$T_{CS}^{i_{TX}}$ represents the cyclic shift for transmitter chain $i_{TX}$ with a value given in Table 21-10 (Cyclic shift values for L-STF, L-LTF, L-SIG, and VHT-SIG-A fields of the PPDU)

$\Upsilon_{k,\,\text{BW}}$ is defined by Equation (21-14), Equation (21-15), Equation (21-16). and Equation (21-17)

$N_{\text{L-LTF}}^{\text{Tone}}$ has the value given in Table 21-8 (Tone scaling factor and guard interval duration values for PHY fields)

#### 21.3.8.2.4 L-SIG definition

The L-SIG field is used to communicate rate and length information. The structure of the L-SIG field is defined in Figure 17-5 (SIGNAL field bit assignment).

In a VHT PPDU, the RATE field shall be set to the value representing 6 Mb/s in the 20 MHz channel spacing column of Table 17-6 (Contents of the SIGNAL field). In a non-HT duplicate PPDU, the RATE field is defined in 17.3.4.2 (RATE field) using the L_DATARATE parameter in the TXVECTOR.

The LENGTH field shall be set to the value given by Equation (21-24).

$$\text{Length} = \frac{\text{TXTIME} - 20}{4} \times 3 - 3 \quad (21\text{-}24)$$

where

TXTIME (in μs) is defined in 21.4.3 (TXTIME and PSDU_LENGTH calculation)

The LSB of the binary expression of the Length value shall be mapped to B5. In a non-HT duplicate PPDU, the LENGTH field is defined in 17.3.4.3 (PHY LENGTH field) using the L_LENGTH parameter in the TXVECTOR.

The Reserved (R) field shall be set to 0 (#455)on transmit and ignored on receive.

The Parity (P) field has the even parity of bits 0-16.

The SIGNAL TAIL field shall be set to 0.

The L-SIG field shall be encoded, interleaved, and mapped following the steps described in 17.3.5.6 (Convolutional encoder), 17.3.5.7 (Data interleaving), and 17.3.5.8 (Subcarrier modulation mapping). The stream of 48 complex numbers generated by these steps is denoted by $d_k, k = 0, \ldots, 47$. Pilots shall be inserted as described in 17.3.5.9 (Pilot subcarriers). The time domain waveform of the L-SIG field shall be as given by Equation (21-25).

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$$r_{\text{L-SIG}}^{(i_{Seg}, i_{TX})}(t) = \frac{1}{\sqrt{N_{\text{L-SIG}}^{\text{Tone}} N_{TX}}} w_{T_{\text{L-SIG}}}(t) \cdot \sum_{i_{\text{BW}}=0}^{N_{20\text{MHz}}-1} \sum_{k=-26}^{26} \left( \Upsilon_{(k-K_{\text{Shift}}(i_{\text{BW}})),\,\text{BW}}(D_{k,20} + p_0 P_k) \cdot \exp(j2\pi(k - K_{\text{Shift}}(i_{\text{BW}}))\Delta_F(t - T_{GI} - T_{CS}^{i_{TX}})) \right) \quad (21\text{-}25)$$

where

$N_{20\text{MHz}}$ is defined in 21.3.7.3 (Channel frequencies)

$K_{\text{Shift}}(i) = (N_{20\text{MHz}} - 1 - 2i) \cdot 32$

$$D_{k,20} = \begin{cases} 0, k = 0, \pm 7, \pm 21 \\ d_{M_{20}^r(k)}, \text{otherwise} \end{cases} \quad (21\text{-}26)$$

$$M_{20}^r(k) = \begin{cases} k + 26, -26 \le k \le -22 \\ k + 25, -20 \le k \le -8 \\ k + 24, -6 \le k \le -1 \\ k + 23, 1 \le k \le 6 \\ k + 22, 8 \le k \le 20 \\ k + 21, 22 \le k \le 26 \end{cases} \quad (21\text{-}27)$$

$P_k$ is defined in 17.3.5.10 (OFDM modulation)

$p_0$ is the first pilot value in the sequence defined in 17.3.5.10 (OFDM modulation)

$N_{\text{L-SIG}}^{\text{Tone}}$ has the value given in Table 21-8 (Tone scaling factor and guard interval duration values for PHY fields)

$\Upsilon_{k,\text{BW}}$ is defined in Equation (21-14), Equation (21-15), Equation (21-16). and Equation (21-17)

$T_{CS}^{i_{TX}}$ represents the cyclic shift for transmitter chain $i_{TX}$ with a value given in Table 21-10 (Cyclic shift values for L-STF, L-LTF, L-SIG, and VHT-SIG-A fields of the PPDU)

NOTE—$M_{20}^r(k)$ is a "reverse" function of the function $M(k)$ defined in 17.3.5.10 (OFDM modulation).

### 21.3.8.3 VHT portion of VHT format preamble

#### 21.3.8.3.1 Introduction

The VHT portion of the VHT format preamble consists of the VHT-SIG-A, VHT-STF, VHT-LTF, and VHT-SIG-B fields.

All numeric fields are transmitted in unsigned format, LSB first.

#### 21.3.8.3.2 Cyclic shift for VHT modulated fields

The cyclic shift values defined in this subclause apply to the VHT-STF, VHT-LTF, VHT-SIG-B, and Data fields of the VHT PPDU. The cyclic shift values defined in 21.3.8.2.1 (Cyclic shift for pre-VHT modulated fields) apply to VHT-SIG-A field in the VHT format preamble.


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Throughout the VHT modulated fields of the preamble, cyclic shifts are applied to prevent unintended beamforming when correlated signals are transmitted in multiple space-time streams. The same cyclic shift is also applied to these streams during the transmission of the Data field of the VHT PPDU. The cyclic shift value $T_{CS,VHT}(n)$ for the VHT modulated fields for space-time stream $n$ out of $N_{STS,total}$ total space-time streams is shown in Table 21-11 (Cyclic shift values for the VHT modulated fields of a PPDU).

**Table 21-11—Cyclic shift values for the VHT modulated fields of a PPDU**

| $T_{CS,VHT}(n)$ values for the VHT modulated fields of a PPDU | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Total number of space-time streams ($N_{STS,total}$) | Cyclic shift for space-time stream $n$ (ns) | | | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 1 | 0 | – | – | – | – | – | – | – |
| 2 | 0 | –400 | – | – | – | – | – | – |
| 3 | 0 | –400 | –200 | – | – | – | – | – |
| 4 | 0 | –400 | –200 | –600 | – | – | – | – |
| 5 | 0 | –400 | –200 | –600 | –350 | – | – | – |
| 6 | 0 | –400 | –200 | –600 | –350 | –650 | – | – |
| 7 | 0 | –400 | –200 | –600 | –350 | –650 | –100 | – |
| 8 | 0 | –400 | –200 | –600 | –350 | –650 | –100 | –750 |

In a VHT MU PPDU, the cyclic shifts are applied sequentially across the space-time streams as follows: the cyclic shift of the space-time stream number $m$ of user $u$ is given by $T_{CS,VHT}(M_u + m)$ of the row corresponding to $N_{STS,total}$ in Table 21-11 (Cyclic shift values for the VHT modulated fields of a PPDU).

### 21.3.8.3.3 VHT-SIG-A definition

The VHT-SIG-A field carries information required to interpret VHT PPDUs. The structure of the VHT-SIG-A field for the first part (VHT-SIG-A1) is shown in Figure 21-18 (VHT-SIG-A1 structure) and for the second part (VHT-SIG-A2) is shown in Figure 21-19 (VHT-SIG-A2 structure).

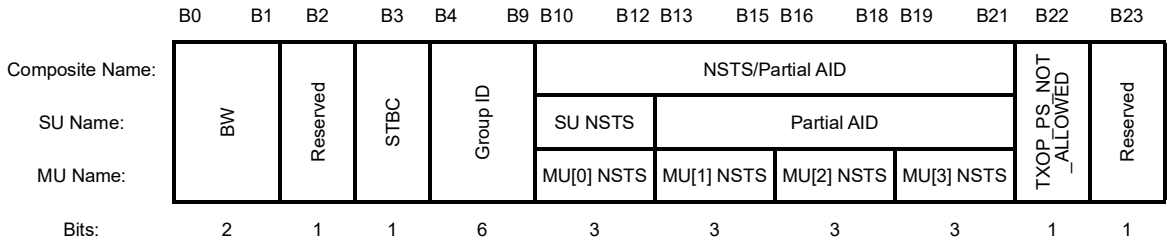


**Figure 21-18—VHT-SIG-A1 structure**

The VHT-SIG-A field contains the fields listed in Table 21-12 (Fields in the VHT-SIG-A field). The mapping of the fields is also described in Table 21-12 (Fields in the VHT-SIG-A field). Note that the mapping of the STBC field, the NSTS/Partial AID field, the SU/MU[0] Coding field, the SU VHT-MCS/MU[1-3] Coding field, and the Beamformed field is different for VHT SU and MU PPDUs.

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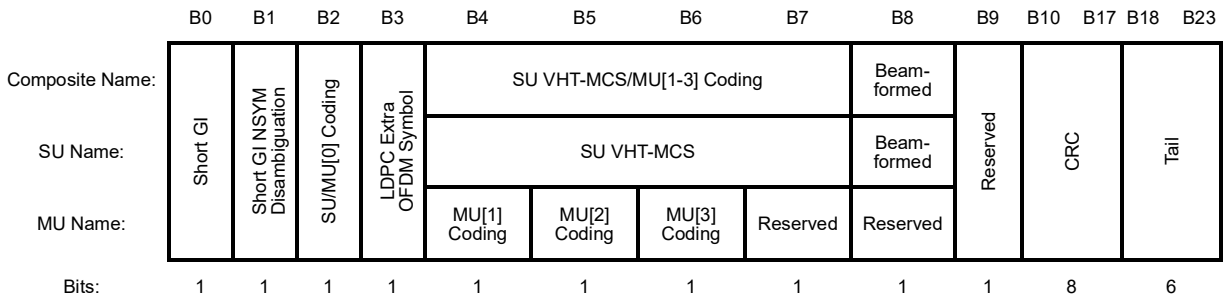


**Figure 21-19—VHT-SIG-A2 structure**

The VHT-SIG-A field is composed of two parts, VHT-SIG-A1 and VHT-SIG-A2, each containing 24 data bits, as shown in Table 21-12 (Fields in the VHT-SIG-A field). VHT-SIG-A1 is transmitted before VHT-SIG-A2. The VHT-SIG-A symbols shall be BCC encoded at rate, R = 1/2, be interleaved, be mapped to a BPSK constellation, and have pilots inserted following the steps described in 17.3.5.6 (Convolutional encoder), 17.3.5.7 (Data interleaving), 17.3.5.8 (Subcarrier modulation mapping), and 17.3.5.9 (Pilot subcarriers), respectively. The first and second half of the stream of 96 complex numbers generated by these steps (before pilot insertion) is divided into two groups of 48 complex numbers $d_{k,n}, k = 0 \ldots 47$, where $n = 0, 1$, respectively. The first 48 complex numbers form the first symbol of VHT-SIG-A and the second 48 complex numbers form the second symbol of VHT-SIG-A after rotating by 90° counter-clockwise relative to the first symbol. The first symbol of VHT-SIG-A, which does not have the 90° rotation, is used to differentiate VHT PPDUs from HT PPDUs, while the second symbol of VHT-SIG-A, which has the 90° rotation, is used to differentiate VHT PPDUs from non-HT PPDUs.

The time domain waveform for the VHT-SIG-A field in a VHT PPDU shall be as specified in Equation (21-28).

$$r_{\text{VHT-SIG-A}}^{(i_{Seg}, i_{TX})}(t) = \frac{1}{\sqrt{N_{\text{VHT-SIG-A}}^{\text{Tone}} N_{\text{TX}}}} \sum_{n=0}^{1} w_{T_{SYML}}(t - nT_{SYML}) \cdot \sum_{i_{\text{BW}}=0}^{N_{20\text{MHz}}-1} \left( \sum_{k=-26}^{26} \Upsilon_{(k-K_{\text{Shift}}(i_{\text{BW}})),\,\text{BW}} (j^n D_{k,n,20} + p_{n+1} P_k) \cdot \exp(j2\pi(k - K_{\text{Shift}}(i_{\text{BW}}))\Delta_F(t - nT_{SYML} - T_{\text{GI}} - T_{CS}^{j_{TX}})) \right) \quad (21\text{-}28)$$

where

$N_{20\text{MHz}}$ and $K_{\text{Shift}}(i)$ are defined in 21.3.8.2.4 (L-SIG definition)

$$D_{k,n,20} = \begin{cases} 0, k = 0, \pm 7, \pm 21 \\ d_{M_{20}^r(k),n}, \text{otherwise} \end{cases}$$

$M_{20}^r(k)$ is defined in Equation (21-27)

$P_k$ and $p_n$ are defined in 17.3.5.10 (OFDM modulation)

$N_{\text{VHT-SIG-A}}^{\text{Tone}}$ has the value given in Table 21-8 (Tone scaling factor and guard interval duration values for PHY fields)


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**Table 21-12—Fields in the VHT-SIG-A field**

| Two parts of VHT-SIG-A | Bit | Field | Description |
|---|---|---|---|
| VHT-SIG-A1 | B0-B1 | BW | Set to 0 for 20 MHz, 1 for 40 MHz, 2 for 80 MHz, and 3 for 160 MHz and 80+80 MHz |
| | B2 | Reserved | Reserved. Set to 1(#455) on transmit. See 21.3.20 (PHY receive procedure) for behavior on receive. |
| | B3 | STBC | For a VHT SU PPDU:<br>Set to 1 if space-time block coding (see 21.3.10.9.4 (Space-time block coding)) is used and set to 0 otherwise.<br>For a VHT MU PPDU:<br>Set to 0. |
| | B4-B9 | Group ID | A value of 0 or 63 indicates a VHT SU PPDU; otherwise, indicates a VHT MU PPDU.<br>(See TXVECTOR parameter GROUP_ID.) |
| | B10-B21 | NSTS/Partial AID | For a VHT MU PPDU: NSTS is divided into 4 user positions of 3 bits each. User position $p$, where $0 \le p \le 3$, uses bits B($10 + 3p$) to B($12 + 3p$). The number of space-time streams for user $u$ are indicated at user position $p$ = USER_POSITION[$u$] where $u$ = 0, 1, …, NUM_USERS – 1 and the notation A[$b$] denotes the value of array A at index $b$. Zero space-time streams are indicated at positions not listed in the USER_POSITION array. Each user position is set as follows:<br>Set to 0 for 0 space-time streams<br>Set to 1 for 1 space-time stream<br>Set to 2 for 2 space-time streams<br>Set to 3 for 3 space-time streams<br>Set to 4 for 4 space-time streams<br>Values 5-7 are reserved<br>For a VHT SU PPDU:<br>B10-B12<br>Set to 0 for 1 space-time stream<br>Set to 1 for 2 space-time streams<br>Set to 2 for 3 space-time streams<br>Set to 3 for 4 space-time streams<br>Set to 4 for 5 space-time streams<br>Set to 5 for 6 space-time streams<br>Set to 6 for 7 space-time streams<br>Set to 7 for 8 space-time streams<br>B13-B21<br>Partial AID: Partial AID provides an abbreviated indication of the intended recipient(s) of the PSDU (see TXVECTOR parameter PARTIAL_AID and 10.19 (Group ID and partial AID in VHT and CMMG PPDUs)). |
| | B22 | TXOP_PS_NOT_ALLOWED | Set to 0 by VHT AP if it allows non-AP VHT STAs in TXOP power save mode to enter doze state during a TXOP. Set to 1 otherwise.<br><br>The bit is reserved and set to 1 in VHT PPDUs transmitted by a non-AP VHT STA. |
| | B23 | Reserved | (#455)Reserved. Set to 1 on transmit. See 21.3.20 (PHY receive procedure) for behavior on receive. |

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**Table 21-12—Fields in the VHT-SIG-A field *(continued)***

| Two parts of VHT-SIG-A | Bit | Field | Description |
|---|---|---|---|
| VHT-SIG-A2 | B0 | Short GI | Set to 0 if short guard interval is not used in the Data field. Set to 1 if short guard interval is used in the Data field. |
| | B1 | Short GI $N_{SYM}$ Disambiguation | Set to 1 if short guard interval is used and $N_{SYM}$ mod 10 = 9; otherwise, set to 0. $N_{SYM}$ is defined in 21.4.3 (TXTIME and PSDU_LENGTH calculation). |
| | B2 | SU/MU[0] Coding | For a VHT SU PPDU, B2 is set to 0 for BCC, 1 for LDPC<br>For a VHT MU PPDU, if the MU[0] NSTS field is nonzero, then B2 indicates the coding used for user $u$ with USER_POSITION[$u$] = 0; set to 0 for BCC and 1 for LDPC. If the MU[0] NSTS field is 0, then this field is reserved and set to 1. |
| | B3 | LDPC Extra OFDM Symbol | Set to 1 if the LDPC PPDU encoding process (if an SU PPDU), or at least one LDPC user's PPDU encoding process (if a VHT MU PPDU), results in an extra OFDM symbol (or symbols) as described in 21.3.10.5.4 (LDPC coding) and 21.3.10.5.5 (Encoding process for VHT MU PPDUs). Set to 0 otherwise. |
| | B4-B7 | SU VHT-MCS/MU[1-3] Coding | For a VHT SU PPDU:<br>VHT-MCS index<br>For a VHT MU PPDU:<br>If the MU[1] NSTS field is nonzero, then B4 indicates coding for user $u$ with USER_POSITION[$u$] = 1: set to 0 for BCC, 1 for LDPC. If the MU[1] NSTS field is 0, then B4 is reserved and set to 1.<br>If the MU[2] NSTS field is nonzero, then B5 indicates coding for user $u$ with USER_POSITION[$u$] = 2: set to 0 for BCC, 1 for LDPC. If the MU[2] NSTS field is 0, then B5 is reserved and set to 1.<br>If the MU[3] NSTS field is nonzero, then B6 indicates coding for user $u$ with USER_POSITION[$u$] = 3: set to 0 for BCC, 1 for LDPC. If the MU[3] NSTS field is 0, then B6 is reserved and set to 1.<br>B7 is reserved and set to 1 |
| | B8 | Beamformed | For a VHT SU PPDU:<br>Set to 1 if a beamforming steering matrix is applied to the waveform in an SU transmission, set to 0 otherwise.<br>For a VHT MU PPDU:<br>Reserved and set to 1<br><br>NOTE—If equal to 1 smoothing is not recommended. |
| | B9 | Reserved | (#455)Reserved. Set to 1 on transmit. See 21.3.20 (PHY receive procedure) for behavior on receive. |
| | B10-B17 | CRC | CRC calculated as in 19.3.9.4.4 (CRC calculation for HT-SIG) with c7 in B10. Bits 0-23 of HT-SIG1 and bits 0-9 of HT-SIG2 are replaced by bits 0-23 of VHT-SIG-A1 and bits 0-9 of VHT-SIG-A2, respectively. |
| | B18-B23 | Tail | Used to terminate the trellis of the convolutional decoder. Set to 0. |


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$\Upsilon_{k,\mathrm{BW}}$ is defined in Equation (21-14), Equation (21-15), Equation (21-16). and Equation (21-17)

$T_{CS}^{i_{TX}}$ represents the cyclic shift for transmitter chain $i_{TX}$ with a value given in Table 21-10 (Cyclic shift values for L-STF, L-LTF, L-SIG, and VHT-SIG-A fields of the PPDU)

NOTE—This definition results in a QBPSK modulation on the second symbol of VHT-SIG-A where the constellation of the data tones is rotated by 90º counter-clockwise relative to the first symbol of VHT-SIG-A and relative to the (#3815)L-SIG in VHT PPDUs (Figure 21-20 (Data tone constellation in the VHT PPDU pre-VHT modulated fields)). In VHT PPDUs, the VHT-SIG-A is transmitted with the same number of subcarriers and the same cyclic shifts as the preceding non-HT portion of the preamble.

For an 80+80 MHz transmission, each frequency segment shall use the time domain waveform for 80 MHz transmissions.

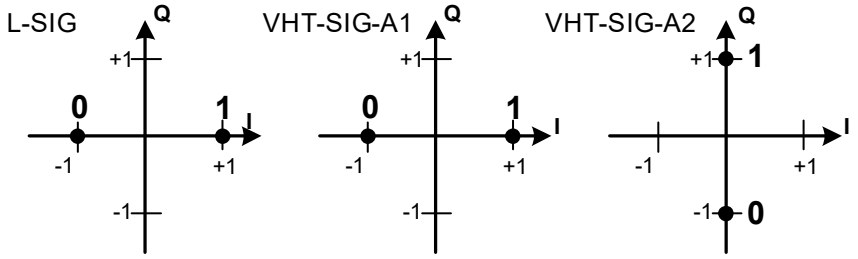


**Figure 21-20—Data tone constellation in the VHT PPDU pre-VHT modulated fields**

### 21.3.8.3.4 VHT-STF definition

The main purpose of the VHT-STF field is to improve automatic gain control estimation in a MIMO transmission. The duration of the VHT-STF field is $T_{VHT\text{-}STF}$ regardless of the Short GI field setting in VHT-SIG-A. The frequency domain sequence used to construct the VHT-STF field in a 20 MHz transmission is identical to the HT-STF field. In a 40 MHz and an 80 MHz transmission, the VHT-STF field is constructed from the 20 MHz version by frequency shifting a duplicate of it to each 20 MHz subchannel and applying appropriate phase rotations per 20 MHz subchannel.

For a 20 MHz transmission, the frequency domain sequence is given by Equation (21-29).

$$VHTS_{-28,28} = HTS_{-28,28} \tag{21-29}$$

where

$HTS_{-28,28}$ is defined in Equation (19-19)

For a 40 MHz transmission, the frequency domain sequence is given by Equation (21-30).

$$VHTS_{-58,58} = HTS_{-58,58} \tag{21-30}$$

where

$HTS_{-58,58}$ is defined in Equation (19-20)

For an 80 MHz transmission, the frequency domain sequence is given by Equation (21-31).

$$VHTS_{-122,122} = \{VHTS_{-58,58}, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, VHTS_{-58,58}\} \tag{21-31}$$

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For a 160 MHz transmission, the frequency domain sequence is given by Equation (21-32).

$$VHTS_{-250,250} = \{VHTS_{-122,122}, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, VHTS_{-122,122}\} \quad (21\text{-}32)$$

NOTE—Equation (21-29), Equation (21-30), Equation (21-31), and Equation (21-32) do not show the phase rotation per 20 MHz subchannel.

For an 80+80 MHz transmission, each 80 MHz frequency segment shall use the VHT-STF pattern for the 80 MHz ($VHTS_{-122,122}$) defined in Equation (21-31).

The time domain representation of the signal on frequency segment $i_{Seg}$ and transmit chain $i_{TX}$ shall be as specified in Equation (21-33).

$$r_{\text{VHT-STF}}^{(i_{Seg}, i_{TX})}(t) = \frac{1}{\sqrt{N_{\text{VHT-STF}}^{\text{Tone}} N_{STS,total}}} w_{T_{\text{VHT-STF}}}(t) \cdot \sum_{k=-N_{SR}}^{N_{SR}} \sum_{u=0}^{N_{user}-1} \sum_{m=1}^{N_{STS,u}} \left( \left[ Q_k^{(i_{Seg})} \right]_{i_{TX},(M_u+m)} \Upsilon_{k,\text{BW}} VHTS_k \cdot \exp(j2\pi k \Delta_F (t - T_{\text{CS,VHT}}(M_u+m))) \right) \quad (21\text{-}33)$$

where

$N_{\text{VHT-STF}}^{\text{Tone}}$ has the value given in Table 21-8 (Tone scaling factor and guard interval duration values for PHY fields)

$T_{\text{CS,VHT}}(n)$ is given in Table 21-11 (Cyclic shift values for the VHT modulated fields of a PPDU)

$Q_k^{(i_{Seg})}$ is defined in 21.3.10.11.1 (Transmission in VHT format)

$\Upsilon_{k,\text{BW}}$ is defined in Equation (21-14), Equation (21-15), Equation (21-16). and Equation (21-17)

### 21.3.8.3.5 VHT-LTF definition

The VHT Long Training field (VHT-LTF) field provides a means for the receiver to estimate the MIMO channel between the set of constellation mapper outputs (or, if STBC is applied, the STBC encoder outputs) and the receive chains. The transmitter provides training for $N_{STS,total}$ space-time streams (spatial mapper inputs) used for the transmission of the PSDU(s). For each tone, the MIMO channel that can be estimated is an $N_{RX} \times N_{STS,total}$ matrix. A VHT transmission has a preamble that contains VHT-LTF symbols, where the data tones of each VHT-LTF symbol are multiplied by entries belonging to a matrix $P_{VHT\text{-}LTF}$, to enable channel estimation at the receiver. The pilot tones of each VHT-LTF symbol are multiplied by the entries of a matrix $R_{VHT\text{-}LTF}$ defined in the following text. The multiplication of the pilot tones in the VHT-LTF symbol by the $R_{VHT\text{-}LTF}$ matrix instead of the $P_{VHT\text{-}LTF}$ matrix allows receivers to track phase and frequency offset during MIMO channel estimation using the VHT-LTF. The number of VHT-LTF symbols, $N_{VHT\text{-}LTF}$, is a function of the total number of space-time streams $N_{STS,total}$ as shown in Table 21-13 (Number of VHT-


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LTFs required for different numbers of space-time streams). As a result the VHT-LTF field consists of one, two, four, six or eight symbols.

**Table 21-13—Number of VHT-LTFs required for different numbers of space-time streams**

| $N_{STS,total}$ | $N_{VHT\text{-}LTF}$ |
|---|---|
| 1 | 1 |
| 2 | 2 |
| 3 | 4 |
| 4 | 4 |
| 5 | 6 |
| 6 | 6 |
| 7 | 8 |
| 8 | 8 |

Let $LTF_{\text{left}}$ and $LTF_{\text{right}}$ be the sequences defined in Equation (21-34) and Equation (21-35), respectively.

$$LTF_{\text{left}} = \{1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1\} \quad (21\text{-}34)$$

$$LTF_{\text{right}} = \{1, -1, -1, 1, 1, -1, 1, -1, 1, -1, -1, -1, -1, -1, -1, 1, 1, -1, -1, 1, -1, 1, -1, 1, 1, 1, 1, 1\} \quad (21\text{-}35)$$

NOTE 1—$LTF_{\text{left}}$ is identical to the leftmost 26 elements of Equation (17-8), and $LTF_{\text{right}}$ is identical to the rightmost 26 elements of Equation (17-8).

In a 20 MHz transmission, the VHT-LTF sequence transmitted is given by Equation (21-36).

$$\begin{aligned} VHT\text{-}LTF_{-28,28} &= \{1, 1, LTF_{\text{left}}, 0, LTF_{\text{right}}, -1, -1\} \\ &= HT\text{-}LTF_{-28,28} \end{aligned} \quad (21\text{-}36)$$

where

$HT\text{-}LTF_{-28,28}$ is defined in Equation (19-23)

In a 40 MHz transmission, the VHT-LTF sequence transmitted is given by Equation (21-37).

$$\begin{aligned} VHT\text{-}LTF_{-58,58} &= \{LTF_{\text{left}}, 1, LTF_{\text{right}}, -1, -1, -1, 1, 0, 0, 0, -1, 1, 1, -1, LTF_{\text{left}}, 1, LTF_{\text{right}}\} \\ &= HT\text{-}LTF_{-58,58} \end{aligned} \quad (21\text{-}37)$$

where

$HT\text{-}LTF_{-58,58}$ is defined in Equation (19-24)

In an 80 MHz transmission, the VHT-LTF sequence transmitted is given by Equation (21-38).

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$$VHT\text{-}LTF_{-122,\,122} = \{LTF_{\text{left}}, 1, LTF_{\text{right}}, -1, -1, -1, 1, 1, -1, 1, -1, 1, 1, -1, LTF_{\text{left}}, 1, LTF_{\text{right}}, 1, -1, 1, -1, 0, 0, 0, 1, -1, -1, 1, LTF_{\text{left}}, 1, LTF_{\text{right}}, -1, -1, -1, 1, 1, -1, 1, -1, 1, 1, -1, LTF_{\text{left}}, 1, LTF_{\text{right}}\} \quad (21\text{-}38)$$

In a 160 MHz transmission, the VHT-LTF sequence transmitted is given by Equation (21-39).

$$VHT\text{-}LTF_{-250,\,250} = \{VHT\text{-}LTF_{-122,\,122}, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, VHT\text{-}LTF_{-122,\,122}\} \quad (21\text{-}39)$$

where

$VHT\text{-}LTF_{-122,\,122}$ is given in Equation (21-38)

NOTE 2—Equation (21-36), Equation (21-37), Equation (21-38), and Equation (21-39) do not show the phase rotation per 20 MHz subchannel.

For a 80+80 MHz transmission, each 80 MHz frequency segment shall use the 80 MHz VHT-LTF sequence, $VHT\text{-}LTF_{-122,\,122}$, defined in Equation (21-38).

The generation of the time domain VHT-LTF symbols per frequency segment is shown in Figure 21-21 (Generation of VHT-LTF symbols per frequency segment) where $A^{k}_{VHT\text{-}LTF}$ is given in Equation (21-40).

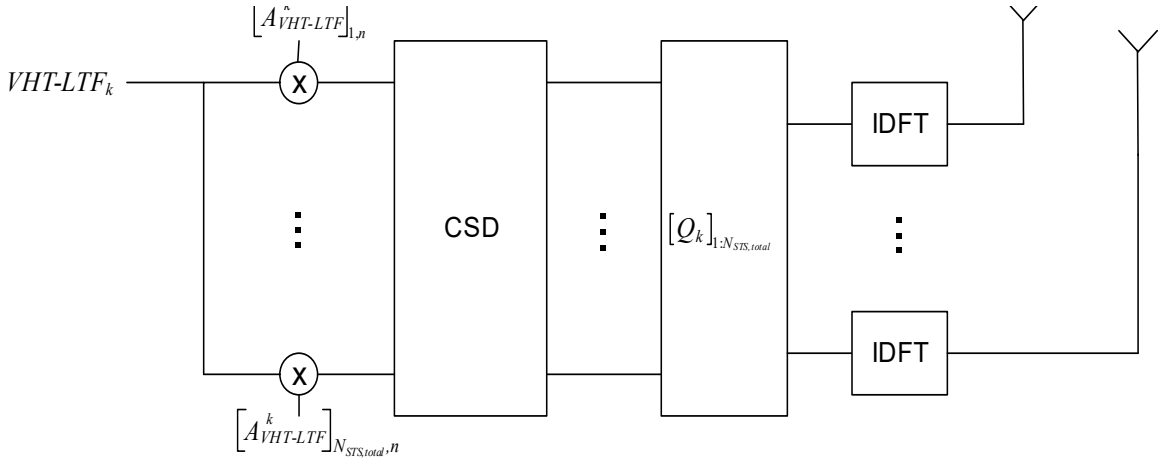


**Figure 21-21—Generation of VHT-LTF symbols per frequency segment**

$$A^{k}_{VHT\text{-}LTF} = \begin{cases} R_{VHT\text{-}LTF}, \text{ if } k \in K_{\text{Pilot}} \\ P_{VHT\text{-}LTF}, \text{ otherwise} \end{cases} \quad (21\text{-}40)$$

where

$K_{\text{Pilot}}$ is the set of subcarrier indices for the pilot tones:

For a 20 MHz transmission, $K_{\text{Pilot}} = \{\pm 7, \pm 21\}$.

For a 40 MHz transmission, $K_{\text{Pilot}} = \{\pm 11, \pm 25, \pm 53\}$.

For an 80 MHz transmission, $K_{\text{Pilot}} = \{\pm 11, \pm 39, \pm 75, \pm 103\}$.

For a 160 MHz transmission,
$K_{\text{Pilot}} = \{\pm 25, \pm 53, \pm 89, \pm 117, \pm 139, \pm 167, \pm 203, \pm 231\}$.


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For an 80+80 MHz transmission, $K_{\text{Pilot}}$ for each 80 MHz frequency segment is identical to $K_{\text{Pilot}}$ for an 80 MHz transmission.

$R_{VHT\text{-}LTF}$ is a $N_{VHT\text{-}LTF} \times N_{VHT\text{-}LTF}$ matrix whose elements are defined in Equation (21-41).

$$\left[R_{VHT\text{-}LTF}\right]_{m,\,n} = \left[P_{VHT\text{-}LTF}\right]_{1,\,n},\ 1 \le m, n \le N_{VHT\text{-}LTF} \tag{21-41}$$

$P_{VHT\text{-}LTF}$ is defined in (#8068)Equation (21-43)

The time domain representation of the waveform transmitted on frequency segment $i_{Seg}$ of transmit chain $i_{TX}$ shall be as described by Equation (21-42).

$$r^{(i_{Seg},\,i_{TX})}_{\text{VHT-LTF}}(t) = \frac{1}{\sqrt{N^{\text{Tone}}_{\text{VHT-LTF}} N_{STS,\,total}}} \sum_{n=0}^{N_{VHT\text{-}LTF}-1} w_{T_{\text{VHT-LTF}}}(t - nT_{\text{VHT-LTF}}) \cdot \sum_{k=-N_{SR}}^{N_{SR}} \sum_{u=0}^{N_{user}-1} \sum_{m=1}^{N_{STS,u}} \left( \begin{array}{l} \left[Q_k^{(i_{Seg})}\right]_{i_{TX},\,(M_u+m)} \Upsilon_{k,\,\text{BW}} \left[A^k_{VHT\text{-}LTF}\right]_{(M_u+m),\,(n+1)} VHT\text{-}LTF_k \\ \quad \cdot \exp(j2\pi k\Delta_F(t - nT_{\text{VHT-LTF}} - T_{\text{GI}} - T_{\text{CS,VHT}}(M_u+m))) \end{array} \right) \tag{21-42}$$

where

$N^{\text{Tone}}_{\text{VHT-LTF}}$ has the value given in Table 21-8 (Tone scaling factor and guard interval duration values for PHY fields)

$T_{\text{CS,VHT}}(n)$ is given in Table 21-11 (Cyclic shift values for the VHT modulated fields of a PPDU)

$Q_k^{(i_{Seg})}$ is defined in 21.3.10.11.1 (Transmission in VHT format)

$\Upsilon_{k,\,\text{BW}}$ is defined in Equation (21-14), Equation (21-15), Equation (21-16). and Equation (21-17)

$A^k_{VHT\text{-}LTF}$ is defined in Equation (21-40)

$$P_{VHT\text{-}LTF} = \begin{cases} P_{4\times 4},\ N_{STS,\,total} \le 4 \\ P_{6\times 6},\ N_{STS,\,total} = 5, 6 \\ P_{8\times 8},\ N_{STS,\,total} = 7, 8 \end{cases} \tag{21-43}$$

where

$P_{4\times 4}$ is defined in Equation (19-27)

The VHT-LTF mapping matrix for six VHT-LTF symbols, $P_{6\times 6}$, is defined in Equation (21-44).

$$P_{6\times 6} = \begin{bmatrix} 1 & -1 & 1 & 1 & 1 & -1 \\ 1 & -w^1 & w^2 & w^3 & w^4 & -w^5 \\ 1 & -w^2 & w^4 & w^6 & w^8 & -w^{10} \\ 1 & -w^3 & w^6 & w^9 & w^{12} & -w^{15} \\ 1 & -w^4 & w^8 & w^{12} & w^{16} & -w^{20} \\ 1 & -w^5 & w^{10} & w^{15} & w^{20} & -w^{25} \end{bmatrix} \tag{21-44}$$

where

$w = \exp(-j2\pi/6)$

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The VHT-LTF mapping matrix for eight VHT-LTF symbols, $P_{8\times 8}$, is defined in Equation (21-45).

$$P_{8\times 8} = \begin{bmatrix} P_{4\times 4} & P_{4\times 4} \\ P_{4\times 4} & -P_{4\times 4} \end{bmatrix} \quad (21\text{-}45)$$

where

$P_{4\times 4}$ is defined in Equation (19-27)

As defined in Table 21-5 (Timing-related constants), the duration of each VHT-LTF symbol is $T_{\text{VHT-LTF}}$ regardless of the Short GI field setting in VHT-SIG-A.

#### 21.3.8.3.6 VHT-SIG-B definition

The VHT-SIG-B field is one symbol and contains 26 bits in a 20 MHz PPDU, 27 bits in a 40 MHz PPDU, and 29 bits in 80 MHz, 160 MHz, and 80+80 MHz PPDUs for each user. The fields in the VHT-SIG-B field are listed in Table 21-14 (Fields in the VHT-SIG-B field). For example, for an MU transmission using VHT-MCS 5 (0101 in binary) in 20 MHz bandwidth, the VHT-SIG-B field bits are set as follows: B16=1, B17=0, B18=1, and B19=0.

**Table 21-14—Fields in the VHT-SIG-B field**

| Field | VHT MU PPDU Allocation (bits) | | | VHT SU PPDU Allocation (bits) | | | Description |
|---|---|---|---|---|---|---|---|
| | 20 MHz | 40 MHz | 80 MHz, 160 MHz, 80+80 MHz | 20 MHz | 40 MHz | 80 MHz, 160 MHz, 80+80 MHz | |
| VHT-SIG-B Length | B0-B15 (16) | B0-B16 (17) | B0-B18 (19) | B0-B16 (17) | B0-B18 (19) | B0-B20 (21) | Length of A-MPDU pre-EOF padding in units of four octets |
| VHT-MCS | B16-B19 (4) | B17-B20 (4) | B19-B22 (4) | N/A | N/A | N/A | |
| Reserved | N/A | N/A | N/A | B17-B19 (3) | B19-B20 (2) | B21-B22 (2) | (#455)Set to all 1s on transmit and ignored on receive. |
| Tail | B20-B25 (6) | B21-B26 (6) | B23-B28 (6) | B20-B25 (6) | B21-B26 (6) | B23-B28 (6) | All 0s |
| Total # bits | 26 | 27 | 29 | 26 | 27 | 29 | |

NOTE—Due to the limitations in the maximum A-MPDU length, B19-20 are always 0 for an 80 MHz, 160 MHz, and 80+80 MHz VHT SU PPDU.

The VHT-SIG-B Length field for user $u$ shall be set using Equation (21-46).

$$\text{VHT-SIG-B Length (for user } u \text{ in units of 4 octets)} = \left\lceil \frac{\text{APEP\_LENGTH}_u}{4} \right\rceil \quad (21\text{-}46)$$

where


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APEP_LENGTH$_u$ is the TXVECTOR parameter APEP_LENGTH for user $u$ (in octets)

The VHT-SIG-B bits for an NDP transmission in various channel widths shall be set as defined in Table 21-15 (VHT-SIG-B bits (before Tail field) in NDP for various channel widths).

**Table 21-15—VHT-SIG-B bits (before Tail field) in NDP for various channel widths**

| Channel width | B0 | B1 | B2 | B3 | B4 | B5 | B6 | B7 | B8 | B9 | B10 | B11 | B12 | B13 | B14 | B15 | B16 | B17 | B18 | B19 | B20 | B21 | B22 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 20 MHz | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | – | – | – |
| 40 MHz | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | — | – |
| 80 MHz, 160 MHz, or 80+80 MHz | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 0 |

For a 40 MHz transmission, the VHT-SIG-B bits are repeated twice. For an 80 MHz transmission, the VHT-SIG-B bits are repeated four times and a pad bit appended that is set to 0. For a 160 MHz and 80+80 MHz transmission, the VHT-SIG-B bits are first repeated four times and a pad bit appended that is set to 0 as in the 80 MHz transmission. Then, the resulting 117 bits are repeated again to fill the 234 available bits. The repetition of the VHT-SIG-B bits for various channel width PPDUs is shown in Figure 21-22 (VHT-SIG-B bits in 20 MHz, 40 MHz, 80 MHz, 160 MHz, and 80+80 MHz transmissions).

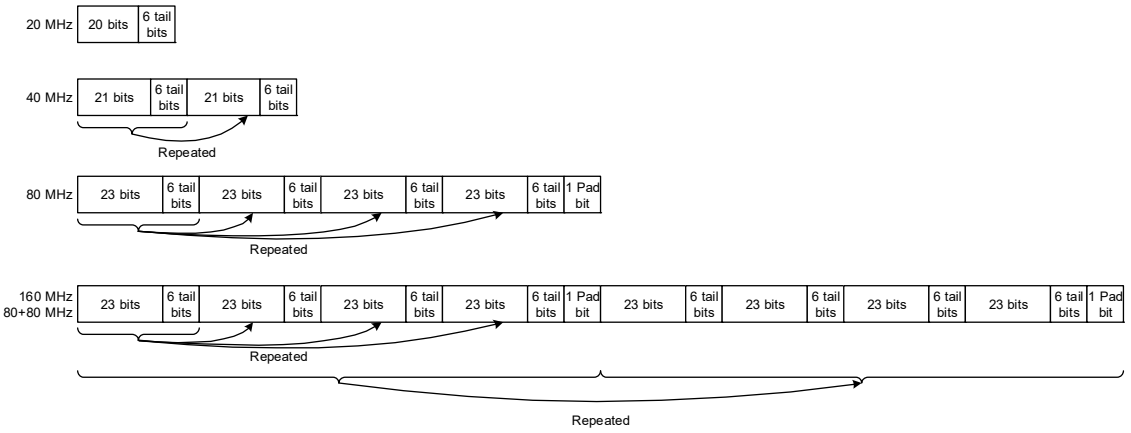


**Figure 21-22—VHT-SIG-B bits in 20 MHz, 40 MHz, 80 MHz, 160 MHz, and 80+80 MHz transmissions**

For each user $u$, the VHT-SIG-B field shall be BCC encoded at rate R = 1/2 as defined in 17.3.5.6 (Convolutional encoder), be segment parsed as defined in 21.3.10.7 (Segment parser), be interleaved as defined in 21.3.10.8 (BCC interleaver), be mapped to a BPSK constellation as defined in 17.3.5.8 (Subcarrier modulation mapping), be segment deparsed as defined in 21.3.10.9.3 (Segment deparser), and (#20)have pilots inserted following the steps described in 21.3.10.10 (Pilot subcarriers). The data subcarriers of the VHT-SIG-B field constellation points are mapped to $N_{STS,u}$ space-time streams by the user-specific elements of the first column of the $P_{VHT\text{-}LTF}$ matrix, which is defined in 21.3.8.3.5 (VHT-LTF definition). The total number of data subcarriers and pilot subcarriers are the same as in the Data field. The space-time streams per each frequency segment are input into the CSD block, which is defined in Table 21-11 (Cyclic shift values for the VHT modulated fields of a PPDU) and follow the same transmission flow as the Data field from there on. The duration of the VHT-SIG-B field is $T_{VHT\text{-}SIG\text{-}B}$, regardless of the value of the

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TXVECTOR parameter GI_TYPE. The time domain waveform for the VHT-SIG-B field in a VHT PPDU is specified by Equation (21-47).

$$r_{\text{VHT-SIG-B}}^{(i_{Seg},\, i_{TX})}(t) = \frac{1}{\sqrt{N_{\text{VHT-SIG-B}}^{\text{Tone}} N_{STS,\,total}}} w_{T_{\text{VHT-SIG-B}}}(t) \cdot \sum_{k=-N_{SR}}^{N_{SR}} \sum_{u=0}^{N_{user}-1} \sum_{m=1}^{N_{STS,\,u}} \left( \begin{array}{l} \left[ Q_k^{(i_{Seg})} \right]_{i_{TX},\,(M_u+m)} \Upsilon_{k,\,\text{BW}} \left( \left[ P_{VHT\text{-}LTF} \right]_{(M_u+m),\,1} D_{k,\,BW}^{(i_{Seg},\,u)} + p_3 P_0^k \right) \\ \cdot \exp(j2\pi k \Delta_F (t - T_{\text{GI}} - T_{\text{CS,VHT}}(M_u+m))) \end{array} \right) \tag{21-47}$$

where

$N_{\text{VHT-SIG-B}}^{\text{Tone}}$ has the value given in Table 21-8 (Tone scaling factor and guard interval duration values for PHY fields)

$T_{\text{CS,VHT}}(n)$ is given in Table 21-11 (Cyclic shift values for the VHT modulated fields of a PPDU)

$Q_k^{(i_{Seg})}$ is defined in 21.3.10.11.1 (Transmission in VHT format)

$p_n$ is defined in 17.3.5.10 (OFDM modulation)

$P_n^k$ is defined in 21.3.10.10 (Pilot subcarriers)

$\Upsilon_{k,\,\text{BW}}$ is defined in Equation (21-14), Equation (21-15), Equation (21-16). and Equation (21-17)

$P_{VHT\text{-}LTF}$ is given in Equation (21-43)

Let $d_k^{(i_{Seg},\,u)}$ be the stream of complex numbers generated for VHT-SIG-B for user $u$ at subcarrier $k$ (logical index, starting with 0) on frequency segment $i_{Seg}$ (prior to multiplication by $P_{VHT\text{-}LTF}$). For a 20 MHz VHT transmission,

$$D_{k,\,20}^{(i_{Seg},\,u)} = \begin{cases} 0, k = 0, \pm 7, \pm 21 \\ d_{M_{20}^r(k)}^{(i_{Seg},\,u)}, \text{otherwise} \end{cases} \tag{21-48}$$

$$M_{20}^r(k) = \begin{cases} k + 28, -28 \le k \le -22 \\ k + 27, -20 \le k \le -8 \\ k + 26, -6 \le k \le -1 \\ k + 25, 1 \le k \le 6 \\ k + 24, 8 \le k \le 20 \\ k + 23, 22 \le k \le 28 \end{cases} \tag{21-49}$$



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For a 40 MHz VHT transmission,

$$D_{k,40}^{(i_{Seg},u)} = \begin{cases} 0, k = 0, \pm 1, \pm 11, \pm 25, \pm 53 \\ d_{M_{40}^r(k)}^{(i_{Seg},u)}, \text{otherwise} \end{cases} \quad (21\text{-}50)$$

$$M_{40}^r(k) = \begin{cases} k+58, -58 \le k \le -54 \\ k+57, -52 \le k \le -26 \\ k+56, -24 \le k \le -12 \\ k+55, -10 \le k \le -2 \\ k+52, 2 \le k \le 10 \\ k+51, 12 \le k \le 24 \\ k+50, 26 \le k \le 52 \\ k+49, 54 \le k \le 58 \end{cases} \quad (21\text{-}51)$$

For an 80 MHz VHT transmission,

$$D_{k,80}^{(i_{Seg},u)} = \begin{cases} 0, k = 0, \pm 1, \pm 11, \pm 39, \pm 75, \pm 103 \\ d_{M_{80}^r(k)}^{(i_{Seg},u)}, \text{otherwise} \end{cases} \quad (21\text{-}52)$$

$$M_{80}^r(k) = \begin{cases} k+122, -122 \le k \le -104 \\ k+121, -102 \le k \le -76 \\ k+120, -74 \le k \le -40 \\ k+119, -38 \le k \le -12 \\ k+118, -10 \le k \le -2 \\ k+115, 2 \le k \le 10 \\ k+114, 12 \le k \le 38 \\ k+113, 40 \le k \le 74 \\ k+112, 76 \le k \le 102 \\ k+111, 104 \le k \le 122 \end{cases} \quad (21\text{-}53)$$

For a 160 MHz VHT transmission,

$$D_{k,160}^{(i_{Seg},u)} = \begin{cases} 0, k = 0, \pm 1, \pm 2, \pm 3, \pm 4, \pm 5, \pm 25, \pm 53, \pm 89, \pm 117, \pm 127, \pm 128, \pm 129, \pm 139, \pm 167, \pm 203, \pm 231 \\ d_{M_{160}^r(k)}^{(i_{Seg},u)}, \text{otherwise} \end{cases} \quad (21\text{-}54)$$

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$$M^{r}_{160}(k) = \begin{cases} k+250, -250 \le k \le -232 \\ k+249, -230 \le k \le -204 \\ k+248, -202 \le k \le -168 \\ k+247, -166 \le k \le -140 \\ k+246, -138 \le k \le -130 \\ k+243, -126 \le k \le -118 \\ k+242, -116 \le k \le -90 \\ k+241, -88 \le k \le -54 \\ k+240, -52 \le k \le -26 \\ k+239, -24 \le k \le -6 \\ k+228, 6 \le k \le 24 \\ k+227, 26 \le k \le 52 \\ k+226, 54 \le k \le 88 \\ k+225, 90 \le k \le 116 \\ k+224, 118 \le k \le 126 \\ k+221, 130 \le k \le 138 \\ k+220, 140 \le k \le 166 \\ k+219, 168 \le k \le 202 \\ k+218, 204 \le k \le 230 \\ k+217, 232 \le k \le 250 \end{cases} \quad (21\text{-}55)$$

For an 80+80 MHz VHT transmission, each frequency segment shall follow the 80 MHz VHT transmission format as specified in Equation (21-52) and Equation (21-53).

### 21.3.9 Transmission of NON_HT and HT PPDUs with multiple transmit chains

#### 21.3.9.1 Transmission of 20 MHz non-HT PPDUs(#238) with more than one transmit chain

A VHT STA that transmits a non-HT PPDU(#238) shall apply the cyclic shifts defined in Table 21-10 (Cyclic shift values for L-STF, L-LTF, L-SIG, and VHT-SIG-A fields of the PPDU) to the preamble and Data field.

#### 21.3.9.2 Transmission of HT PPDUs with more than four transmit chains

A VHT STA that transmits an HT PPDU with FORMAT equal to HT_MF shall apply the cyclic shifts defined in Table 21-10 (Cyclic shift values for L-STF, L-LTF, L-SIG, and VHT-SIG-A fields of the PPDU) for the non-HT portion of the PPDU, including the HT-SIG field.

### 21.3.10 Data field

#### 21.3.10.1 General

The number of OFDM symbols in the Data field is determined by the Length field in L-SIG (#4181)(see Equation (21-24)), the preamble duration and the setting of the Short GI field in VHT-SIG-A (see 21.3.8.3.3 (VHT-SIG-A definition)).

When BCC encoding is used, the Data field shall consist of the SERVICE field, the PSDU, the PHY pad bits, and the tail bits ($N_{tail}N_{ES}$ bits for SU and $N_{tail}N_{ES,u}$ bits for each user $u$ in MU). When LDPC


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encoding is used, the Data field shall consist of the SERVICE field, the PSDU, and the PHY pad bits. No tail bits are present when LDPC encoding is used.

The padding flow is as follows. The MAC delivers a PSDU that fills the available octets in the Data field of the PPDU for each user *u*. The PHY determines the number of pad bits to add and appends them to the PSDU. The number of pad bits added is(M118) 0 to 7 per user. When user *u* of a VHT MU PPDU uses BCC encoding, the number of pad bits is calculated using Equation (21-56). In the case of SU ignore *u* in Equation (21-56).

$$N_{PAD,u} = N_{SYM}N_{DBPS,u} - 8 \cdot \text{PSDU\_LENGTH}_u - N_{service} - N_{tail}N_{ES,u} \quad (21\text{-}56)$$

where

| | |
|---|---|
| $\text{PSDU\_LENGTH}_u$ | is defined in 21.4.3 (TXTIME and PSDU_LENGTH calculation) |
| $N_{SYM}$ | is the number of symbols in the Data field and is given by Equation (21-111) for a VHT SU PPDU and by Equation (21-67) for a VHT MU PPDU |

For an SU PPDU, if LDPC encoding is used then the PHY padding bits are calculated using Equation (21-57).

$$N_{PAD} = N_{SYM,init}N_{DBPS} - 8 \cdot \text{PSDU\_LENGTH} - N_{service} \quad (21\text{-}57)$$

where

| | |
|---|---|
| PSDU_LENGTH | is defined in 21.4.3 (TXTIME and PSDU_LENGTH calculation) |
| $N_{SYM,init}$ | is given by Equation (21-62) |

For a VHT MU PPDU, if LDPC encoding is used for user *u* then the PHY padding bits are calculated using Equation (21-58).

$$N_{PAD,u} = N_{\text{SYM\_max\_init}}N_{DBPS,u} - 8 \cdot \text{PSDU\_LENGTH}_u - N_{service} \quad (21\text{-}58)$$

where

| | |
|---|---|
| $\text{PSDU\_LENGTH}_u$ | is defined in 21.4.3 (TXTIME and PSDU_LENGTH calculation) |
| $N_{\text{SYM\_max\_init}}$ | is given by Equation (21-65) |

The Data field of the VHT PPDU contains data for one or more users. For a VHT MU PPDU, the data processing, from scrambling to constellation mapping shall happen on a per-user basis. In the following subclauses, this process is described from a single user's point of view.

### 21.3.10.2 SERVICE field

The SERVICE field is as shown in Table 21-16 (SERVICE field).

**Table 21-16—SERVICE field**

| Bits | Field | Description |
|---|---|---|
| B0-B6 | Scrambler Initialization | Set to 0 |
| B7 | Reserved | (#455)Set to 0 on transmit and ignored on receive |
| B8-B15 | CRC | CRC calculated over VHT-SIG-B (excluding tail bits) |

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### 21.3.10.3 CRC calculation for VHT-SIG-B

The CRC calculation and insertion is illustrated in Figure 21-23 (VHT-SIG-B and SERVICE field relationship).

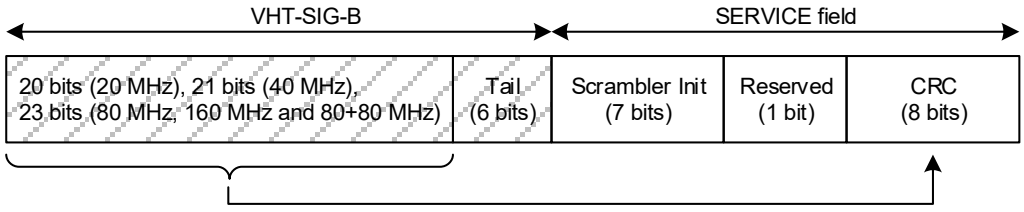


**Figure 21-23—VHT-SIG-B and SERVICE field relationship**

The value of the CRC field shall be the 1s complement of Equation (21-59).

$$crc(D) = (M(D) \oplus I(D))D^8 \bmod G(D) \quad (21\text{-}59)$$

where

$M(D) = m_0 D^{N-1} + m_1 D^{N-2} + \ldots + m_{N-2} D + m_{N-1}$

$N$ is the number of bits over which the CRC is generated; 20 for 20 MHz, 21 for 40 MHz, and 23 for 80 MHz/160 MHz/80+80 MHz

$m_i$ is bit $i$ of VHT-SIG-B

$I(D) = \sum_{i=N-8}^{N-1} D^i$ are initialized values that are added modulo 2 to the first 8 bits of VHT-SIG-B

$G(D) = D^8 + D^2 + D + 1$ is the CRC generating polynomial

$crc(D) = c_0 D^7 + c_1 D^6 + \ldots + c_6 D + c_7$

Figure 19-8 (HT-SIG CRC calculation) shows the operation of the CRC. First, the shift register is reset to all 1s. The bits are then passed through the XOR operation at the input. When the last bit has entered, the output is generated by shifting the bits out of the shift register, $c_7$ first, through an inverter.

As an example, if bits $\{m_0, \ldots m_{22}\}$ are given by {1 0 0 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1}, the CRC bits $\{c_7, \ldots c_0\}$ are {0 0 0 1 1 1 0 0}.

The CRC field is transmitted with $c_7$ first. Hence, $c_7$ is mapped to B8 of the SERVICE field, $c_6$ is mapped to B9, …, and $c_0$ is mapped to B15 of the SERVICE field.

### 21.3.10.4 Scrambler

The SERVICE, PSDU, and PHY pad parts of the Data field shall be scrambled by the scrambler defined in 17.3.5.5 (PHY DATA scrambler and descrambler). The Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) (#602)TXVECTOR parameters CH_BANDWIDTH_IN_NON_HT, DYN_BANDWIDTH_IN_NON_HT, and SCRAMBLER_INITIAL_VALUE are not present; therefore, the first 7 bits of the scrambling sequence are set to a 7-bit pseudorandom nonzero integer. Different users in a VHT MU PPDU may use different pseudorandom nonzero seeds.


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### 21.3.10.5 Coding

#### 21.3.10.5.1 General

The Data field shall be encoded using either the binary convolutional code (BCC) defined in 21.3.10.5.2 (BCC encoder parsing operation) and 21.3.10.5.3 (BCC coding and puncturing) or the low-density parity check (LDPC) code defined in 21.3.10.5.4 (LDPC coding). The encoder is selected by the SU/MU[0] Coding, MU[1] Coding, MU[2] Coding, or MU[3] Coding fields in VHT-SIG-A, as defined in 21.3.8.3.3 (VHT-SIG-A definition). When BCC FEC encoding is used, the number of encoders is determined by rate-dependent parameters as defined in 21.5 (Parameters for VHT-MCSs). The operation of the BCC FEC is described in 21.3.10.5.2 (BCC encoder parsing operation) and 21.3.10.5.3 (BCC coding and puncturing). The operation of the LDPC coder is described in 21.3.10.5.4 (LDPC coding). Support for the reception of a BCC encoded Data field is mandatory.

#### 21.3.10.5.2 BCC encoder parsing operation

If multiple encoders are used, the scrambled SERVICE, PSDU, and PHY pad bits are divided between the encoders by sending bits to different encoders in a round robin manner. Bit $i$ to encoder $j$ of user $u$, denoted $x_{i,u}^{(j)}$, is as specified in Equation (21-60).

$$x_{i,u}^{(j)} = \begin{cases} b_{N_{ES}\cdot i+j,u}; & 0 \le i < N_{SYM}\dfrac{N_{DBPS,u}}{N_{ES,u}} - N_{tail}, \quad 0 \le j \le N_{ES,u} - 1 \\ 0; & N_{SYM}\dfrac{N_{DBPS,u}}{N_{ES,u}} - N_{tail} \le i < N_{SYM}\dfrac{N_{DBPS,u}}{N_{ES,u}}, \quad 0 \le j \le N_{ES,u} - 1 \end{cases} \tag{21-60}$$

where

$b_{k,u}$ is bit k of the scrambled SERVICE, PSDU, and pad bits of user u

$N_{SYM}$ is the number of symbols in the Data field and is given by Equation (21-111) for a VHT SU PPDU and by Equation (21-67) for a VHT MU PPDU

NOTE—Tail bits with value 0 are being appended to each BCC encoder parser output sequence in Equation (21-60).

#### 21.3.10.5.3 BCC coding and puncturing

The BCC encoder parser output sequences of user $u$ $\{x_{i,u}^{(j)}\}$, $0 \le i < N_{SYM}N_{DBPS,u}/N_{ES,u}$, $0 \le j \le N_{ES,u} - 1$ each of which is separately encoded by a rate R = ½ convolutional encoder defined in 17.3.5.6 (Convolutional encoder). After encoding, the encoded data is punctured by the method defined in 17.3.5.6 (Convolutional encoder) (except for rate 5/6), to achieve the rate selected by the modulation and coding scheme. In the case that rate 5/6 coding is selected, the puncturing scheme is(M118) the same as described in 19.3.11.6 (BCC coding and puncturing).

#### 21.3.10.5.4 LDPC coding

For a VHT SU PPDU using LDPC coding to encode the Data field, the LDPC code and encoding process described in 19.3.11.7 (LDPC codes) shall be used with the following modifications. First, all bits in the Data field including the scrambled SERVICE, PSDU, and pad bits are encoded. Thus, $N_{pld}$ for VHT PPDUs shall be computed using Equation (21-61) instead of Equation (19-35).

$$N_{pld} = N_{SYM,init}N_{DBPS} \tag{21-61}$$

where

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$N_{SYM,init}$ is given by Equation (21-62)

$$N_{SYM,init} = m_{STBC} \times \left\lceil \frac{8 \cdot \text{APEP\_LENGTH} + N_{service}}{m_{STBC} \cdot N_{DBPS}} \right\rceil \quad (21\text{-}62)$$

where

$m_{STBC}$ is equal to 2 when STBC is used, and 1 otherwise

APEP_LENGTH is the TXVECTOR parameter APEP_LENGTH

Following the calculation of $N_{pld}$, $N_{avbits}$ shall be computed using Equation (21-63) instead of Equation (19-36).

$$N_{avbits} = N_{SYM,init} N_{CBPS} \quad (21\text{-}63)$$

In addition, if $N_{SYM}$ computed in Equation (19-41) in step d) of 19.3.11.7.5 (LDPC PPDU encoding process) is greater than $N_{SYM,init}$, then the LDPC Extra OFDM Symbol field of VHT-SIG-A shall be set to 1. Otherwise, the LDPC Extra OFDM Symbol field of VHT-SIG-A shall be set to 0.

LDPC codes used in VHT MU PPDUs shall also follow the definitions in 19.3.11.7 (LDPC codes). Refer to 21.3.10.5.5 (Encoding process for VHT MU PPDUs) for a description of the LDPC encoding process for VHT MU PPDUs.

### 21.3.10.5.5 Encoding process for VHT MU PPDUs

For a VHT MU PPDU, first compute the initial number of OFDM symbols for each user using Equation (21-64).

$$N_{\text{SYM\_init},u} = \begin{cases} \left\lceil \dfrac{8 \cdot \text{APEP\_LENGTH}_u + N_{service} + N_{tail} \cdot N_{ES,u}}{N_{DBPS,u}} \right\rceil & \text{when user } u \text{ uses BCC} \\ \left\lceil \dfrac{8 \cdot \text{APEP\_LENGTH}_u + N_{service}}{N_{DBPS,u}} \right\rceil & \text{when user } u \text{ uses LDPC} \end{cases} \quad (21\text{-}64)$$

where

$\text{APEP\_LENGTH}_u$ is the TXVECTOR parameter APEP_LENGTH for user $u$

Based on the above equation, compute the largest initial number of symbols over all users using Equation (21-65).

$$N_{\text{SYM\_max\_init}} = \max\{N_{\text{SYM\_init},u}\}_{u=0}^{N_{user}-1} \quad (21\text{-}65)$$

Then, for each user $u$ that uses LDPC in the VHT MU PPDU, the final number of symbols in the Data field ($N_{SYM,u}$) shall be computed as follows. First, perform step a) in 19.3.11.7.5 (LDPC PPDU encoding process) with the exception that $N_{pld}$ is computed using Equation (21-66) instead of Equation (19-35).

$$N_{pld} = N_{\text{SYM\_max\_init}} N_{DBPS,u} \quad (21\text{-}66)$$

Then, perform steps b) to d) in 19.3.11.7.5 (LDPC PPDU encoding process) with $N_{CBPS}$ and $R$ replaced with $N_{CBPS,u}$ and $R_u$, respectively. $N_{SYM,u}$ for user $u$ shall then be equal to the value of $N_{SYM}$ obtained at the end of step d) using Equation (19-41).


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The purpose of going through steps a) to d) in 19.3.11.7.5 (LDPC PPDU encoding process) in the above paragraph is to compute $N_{SYM,u}$. Thus, at this stage $N_{SYM,u}$ for each user may be calculated without actually encoding the data using LDPC.

For BCC users, $N_{SYM,\,u} = N_{\mathrm{SYM\_init},\,u}$.

Then, compute the number of symbols in the Data field using Equation (21-67).

$$N_{SYM} = \max\{N_{SYM,\,u}\}_{u=0}^{N_{user}-1} \tag{21-67}$$

When constructing the Data field for user $u$ encoded using LDPC code, the MAC follows the padding procedure described in 10.12.6 (A-MPDU padding for VHT, HE(11ax) or S1G PPDU) and delivers a PSDU that contains $\mathrm{PSDU\_LENGTH}_u$ octets (see 21.4.3 (TXTIME and PSDU_LENGTH calculation)). The PHY follows the padding procedure described in 21.3.10.1 (General) to fill $N_{\mathrm{SYM\_max\_init}}$ symbols, where $N_{\mathrm{SYM\_max\_init}}$ is defined in Equation (21-65). Then, for each user, all bits in the Data field including the scrambled SERVICE, PSDU, and pad bits shall be encoded using the LDPC encoding process specified in 19.3.11.7.5 (LDPC PPDU encoding process) with the following modifications. First, $N_{pld}$ shall be computed using Equation (21-66) instead of Equation (19-35). Also, replace $N_{CBPS}$ and $R$ with $N_{CBPS,u}$ and $R_u$, respectively. Next, step d) in 19.3.11.7.5 (LDPC PPDU encoding process) is replaced with step d) below:

d) If $N_{SYM}$ computed in Equation (21-67) is equal to $N_{\mathrm{SYM\_max\_init}}$, then the number of bits to be punctured, $N_{punc}$, from the codewords after encoding is computed as shown in Equation (19-38).

If $N_{SYM}$ computed in Equation (21-67) is greater than $N_{\mathrm{SYM\_max\_init}}$, then the number of bits to be punctured, $N_{punc}$, from the codewords after encoding is computed using Equation (19-39) and Equation (19-40). Note also that $N_{avbits}$ has now been updated in Equation (19-39) in this case.

The punctured bits shall be equally distributed over all $N_{CW}$ codewords with the first $\mathrm{rem}(N_{punc}, N_{CW})$ codewords punctured 1 bit more than the remaining codewords. Define $N_{ppcw} = \lfloor N_{punc}/N_{CW} \rfloor$. When $N_{ppcw} > 0$, the puncturing is performed by discarding parity bits $p_{n-k-N_{ppcw}-1}, \ldots, p_{n-k-1}$ of the first $\mathrm{rem}(N_{punc}, N_{CW})$ codewords and discarding parity bits $p_{n-k-N_{ppcw}}, \ldots, p_{n-k-1}$ of the remaining codewords after encoding.

When constructing the Data field for users encoded using BCC, the MAC follows the padding procedure described in 10.12.6 (A-MPDU padding for VHT, HE(11ax) or S1G PPDU) and delivers a PSDU that contains $\mathrm{PSDU\_LENGTH}_u$ octets. The PHY follows the padding procedure described in 21.3.10.1 (General) to fill up $N_{SYM}$ symbols computed in Equation (21-67). Then, for each user, all bits in the Data field including the scrambled SERVICE, PSDU, and pad bits shall be encoded using the BCC encoding process specified in 21.3.10.5.2 (BCC encoder parsing operation) and 21.3.10.5.3 (BCC coding and puncturing). Note that this process results in the BCC tail bits being placed at the very end of the PPDU.

In addition, if $N_{SYM}$ computed in Equation (21-67) is greater than $N_{\mathrm{SYM\_max\_init}}$ computed in Equation (21-65), then the LDPC Extra OFDM Symbol field of VHT-SIG-A2 shall be set to 1. Otherwise, the LDPC Extra OFDM Symbol field of VHT-SIG-A2 shall be set to 0.

### 21.3.10.6 Stream parser

After coding and puncturing, the data bit streams at the output of the FEC encoders are processed in groups of $N_{CBPS}$ bits. Each of these groups is rearranged into $N_{SS}$ blocks of $N_{CBPSS}$ bits ($N_{SS,u}$ blocks of $N_{CBPSS,u}$ bits in the case of an MU transmission). This operation is referred to as *stream parsing* and is described in this subclause.

The description is given in terms of an SU transmission. For MU transmissions, the rearrangements are carried out in the same way per user.

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The number of bits assigned to a single axis (real or imaginary) of a constellation point in a spatial stream is denoted by Equation (21-68).

$$s = \max\left\{1, \frac{N_{BPSCS}}{2}\right\} \tag{21-68}$$

The sum of these over all streams is $S = N_{SS} \cdot s$

Consecutive blocks of $s$ bits are assigned to different spatial streams in a round robin fashion.

Let

$$N_{\text{Block}} = \left\lfloor \frac{N_{CBPS}}{N_{ES} \cdot S} \right\rfloor \tag{21-69}$$

and

$$M = \frac{N_{CBPS} - N_{\text{Block}} \cdot N_{ES} \cdot S}{s \cdot N_{ES}} \tag{21-70}$$

For the first $N_{\text{Block}} \cdot N_{ES} \cdot S$ bits of each OFDM symbol, $S$ bits from the output of first encoder are divided among all spatial streams, $s$ bits per stream. Then, $S$ bits from the output of next encoder are used, and so on. If $N_{CBPS}$ is greater than $N_{\text{Block}} \cdot N_{ES} \cdot S$, then for the last $N_{CBPS} - N_{\text{Block}} \cdot N_{ES} \cdot S$ bits of each OFDM symbol, $M \cdot s$ bits from the output of the first encoder are fed into spatial streams 1 to $M$ ($s$ bits per spatial stream), and then $M \cdot s$ bits from the output of the next encoder are used for spatial stream $M + 1$ to $[(2M - 1) \bmod N_{SS}] + 1$, and so on, where $z \bmod t$ is the remainder resulting from the division of integer $z$ by integer $t$.

The following equations are an equivalent description to the above procedure. Bit $i$ at the output of encoder $j$ is assigned to input bit $k$ of spatial stream $i_{SS}$ where

$$j = \begin{cases} \left\lfloor \frac{k}{s} \right\rfloor \bmod N_{ES}, & k = 0, 1, \ldots, N_{\text{Block}} \cdot N_{ES} \cdot s - 1 \\ \left\lfloor \frac{L}{M} \right\rfloor, & k = N_{\text{Block}} \cdot N_{ES} \cdot s, \ldots, N_{CBPSS} - 1 \end{cases} \tag{21-71}$$

and

$$i = \begin{cases} (i_{SS} - 1)s + S \cdot \left\lfloor \frac{k}{N_{ES} \cdot s} \right\rfloor + k \bmod s, & k = 0, 1, \ldots, N_{\text{Block}} \cdot N_{ES} \cdot s - 1 \\ (L \bmod M) \cdot s + N_{\text{Block}} \cdot S + k \bmod s, & k = N_{\text{Block}} \cdot N_{ES} \cdot s, \ldots, N_{CBPSS} - 1 \end{cases} \tag{21-72}$$

where

$i_{SS} = 1, 2, \ldots, N_{SS}$

$i = 0, 1, \ldots, N_{CBPS}/N_{ES} - 1$

$j = 0, 1, \ldots, N_{ES} - 1$

$k = 0, 1, \ldots, N_{CBPSS} - 1$



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$$L = \left\lfloor \frac{k'}{s} \right\rfloor N_{SS} + (i_{SS} - 1)$$

$$k' = k - N_{\text{Block}} \cdot N_{ES} \cdot s$$

NOTE—$N_{CBPS}$ is greater than $N_{\text{Block}} \cdot N_{ES} \cdot S$ in only the following cases:

a) 160 MHz and 80+80 MHz, $N_{SS}$ = 5, VHT-MCS = 5
b) 160 MHz and 80+80 MHz, $N_{SS}$ = 5, VHT-MCS = 6
c) 160 MHz and 80+80 MHz, $N_{SS}$ = 7, VHT-MCS = 5
d) 160 MHz and 80+80 MHz, $N_{SS}$ = 7, VHT-MCS = 6

### 21.3.10.7 Segment parser

NOTE —The output of the operation described in this subclause is named a frequency subblock rather than a segment because it applies to both 80+80 and 160 MHz PPDUs, where the 160 MHz PPDU has two parser outputs yet one frequency segment (see Table 21-5 (Timing-related constants)). A more precise name for this operation would be frequency subblock deparser.(#19)

The description in this subclause is given in terms of an SU transmission. For MU transmissions, the rearrangements are carried out in the same way per user.

For a 160 MHz or an 80+80 MHz transmission, the output bits of each stream parser are first divided into blocks of $N_{CBPSS}$ bits ($N_{CBPSS,u}$ bits in the case of an MU transmission). Then, each block is further divided into two frequency subblocks of $N_{CBPSS}/2$ bits as shown in Equation (21-73).

$$y_{k,l} = x_{2s \cdot N_{ES}\left\lfloor \frac{k}{s \cdot N_{ES}} \right\rfloor + l \cdot s \cdot N_{ES} + k \bmod (s \cdot N_{ES})}, \qquad k = 0, 1, \ldots, \frac{N_{CBPSS}}{2} - 1 \tag{21-73}$$

where

$x_m$ is the $m$ th bit of a block of $N_{CBPSS}$ bits, $m$= 0 to $N_{CBPSS} - 1$
$l$ is the frequency subblock index, $l = 0, 1$
$y_{k,l}$ is bit $k$ of the frequency subblock $l$
$s$ is defined in Equation (21-68)

If $N_{CBPSS}$ is not divisible by $2s \cdot N_{ES}$, then apply the segment parsing method described in Equation (21-73) for $\lfloor N_{CBPSS}/(2s \cdot N_{ES}) \rfloor$ sets of $2s \cdot N_{ES}$ segment parser input bits. At this point, each stream parser output has $2s \cdot N_{res}$ ($N_{res} = \frac{N_{CBPSS} \bmod (2s \cdot N_{ES})}{2s} < N_{ES}$, integer ) residue bits. Then, the residue bits are divided into subsets of $s$ bits, with each subset being assigned to different subblock ($l = 0, 1$ ) in a round robin fashion. The first $s$ bits are assigned to the subblock with index $l = 0$. Repeat $N_{res}$ times (until all bits are distributed to the two subblocks). That is, if $N_{CBPSS}$ is not divisible by $2s \cdot N_{ES}$, each block is further divided into two subblocks of $N_{CBPSS}/2$ bits as shown in Equation (21-74).

$$y_{k,l} = \begin{cases} x_{2s \cdot N_{ES}\left\lfloor \frac{k}{s \cdot N_{ES}} \right\rfloor + l \cdot s \cdot N_{ES} + k \bmod (s \cdot N_{ES})}, & k = 0, 1, \ldots, \lfloor N_{CBPSS}/(2s \cdot N_{ES}) \rfloor \cdot s \cdot N_{ES} - 1 \\ x_{2s \cdot N_{ES}\left\lfloor \frac{k}{s \cdot N_{ES}} \right\rfloor + 2s \cdot \left\lfloor \frac{k \bmod (s \cdot N_{ES})}{s} \right\rfloor + l \cdot s + k \bmod s}, & k = \lfloor N_{CBPSS}/(2s \cdot N_{ES}) \rfloor \cdot s \cdot N_{ES}, \ldots, \frac{N_{CBPSS}}{2} - 1 \end{cases} \tag{21-74}$$

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Segment parser is bypassed for a 20 MHz, 40 MHz, or 80 MHz VHT PPDU transmission, i.e., as specified in Equation (21-75).

$$y_{k,l} = x_k, \quad k = 0, 1, \ldots, N_{CBPSS} - 1 \tag{21-75}$$

where

$l$ is the frequency subblock index. $l = 0$ for a 20, 40 or 80 MHz VHT PPDU transmission.

$y_{k,l}$ is bit $k$ of the frequency subblock $l$

$x_m$ is bit $m$ of a block of $N_{CBPSS}$ bits, $m = 0$ to $N_{CBPSS} - 1$

### 21.3.10.8 BCC interleaver

For ease of explanation, the operation of the interleaver is described for the SU case. For user $u$ of an MU transmission, the interleaver operates in the same way on the output bits for the user from the stream parser by replacing $N_{SS}$, $N_{CBPSS}$, $N_{CBPSSI}$, and $N_{BPSCS}$ with $N_{SS,u}$, $N_{CBPSS,u}$, $N_{CBPSSI,u}$, and $N_{BPSCS,u}$, respectively. That is, the operation of the interleaver is the same as if the transmission were an SU one, consisting of bits from only that user.

This subclause describes the interleaver used in the case of BCC encoding. The interleaver described in this subclause shall be bypassed in the case of LDPC encoding.

In a 20 MHz, 40 MHz, or 80 MHz VHT PPDU transmission, the bits at the output of the stream parser are processed in groups of $N_{CBPS}$ bits. Each of these groups is divided into $N_{SS}$ blocks of $N_{CBPSS}$ bits, and each block shall be interleaved by an interleaver based on the Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) interleaver. In a 160 MHz or an 80+80 MHz VHT PPDU transmission, each frequency subblock of $N_{CBPSS}/2$ output bits from the segment parser is interleaved by the interleaver for 80 MHz defined in this subclause. This interleaver, which is based on entering the data in rows, and reading it out in columns, has a different number of columns $N_{COL}$ and rows $N_{ROW}$ for different bandwidths. The values of $N_{COL}$ and $N_{ROW}$ are given in Table 21-17 (Number of rows and columns in the interleaver).

**Table 21-17—Number of rows and columns in the interleaver**

| Parameter | 20 MHz | 40 MHz | 80 MHz |
|---|---|---|---|
| $N_{COL}$ | 13 | 18 | 26 |
| $N_{ROW}$ | $4 \times N_{BPSCS}$ | $6 \times N_{BPSCS}$ | $9 \times N_{BPSCS}$ |
| $N_{ROT}$ ($N_{SS} \leq 4$) | 11 | 29 | 58 |
| $N_{ROT}$ ($N_{SS} > 4$) | 6 | 13 | 28 |

After the operations based on the Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) interleaver have been applied and if more than one spatial stream exists, a third operation called *frequency rotation* is applied to the additional spatial streams. The parameter for the frequency rotation is $N_{ROT}$. The values of $N_{ROT}$ are given in Table 21-17 (Number of rows and columns in the interleaver).


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An additional parameter is the spatial stream index $i_{SS} = 1, 2, \ldots, N_{SS}$. The output of the third operation is a function of the spatial stream index.

The interleaving is defined using three permutations. The first permutation is given by the rule shown in Equation (21-76).

$$i = N_{ROW}(k \bmod N_{COL}) + \left\lfloor \frac{k}{N_{COL}} \right\rfloor, k = 0, 1, \ldots, N_{CBPSSI} - 1 \quad (21\text{-}76)$$

The second permutation is defined by the rule shown in Equation (21-77).

$$j = s\left\lfloor \frac{i}{s} \right\rfloor + \left(i + N_{CBPSSI} - \left\lfloor \frac{N_{COL} \cdot i}{N_{CBPSSI}} \right\rfloor\right) \bmod s, \quad i = 0, 1, \ldots, N_{CBPSSI} - 1 \quad (21\text{-}77)$$

where

$s$ is defined in Equation (21-68)

If $2 \le N_{SS} \le 4$, a frequency rotation is applied to the output of the second permutation as shown in Equation (21-78).

$$r = \left\{ j - \left[ (2(i_{SS} - 1)) \bmod 3 + 3\left\lfloor \frac{i_{SS} - 1}{3} \right\rfloor \right] \cdot N_{ROT} \cdot N_{BPSCS} \right\} \bmod N_{CBPSSI}, \quad (21\text{-}78)$$

$$j = 0, 1, \ldots, N_{CBPSSI} - 1$$

where

$i_{SS} = 1, 2, \ldots, N_{SS}$ is the spatial steam index on which this interleaver is operating

If $N_{SS} > 4$, a frequency rotation is applied to the output of the second permutation as shown in Equation (21-79).

$$r = \{j - J(i_{SS}) \cdot N_{ROT} \cdot N_{BPSCS}\} \bmod N_{CBPSSI}, j = 0, 1, \ldots, N_{CBPSSI} - 1 \quad (21\text{-}79)$$

where

$i_{SS} = 1, 2, \ldots, N_{SS}$ is the spatial steam index on which this interleaver is operating, and $J(i_{SS})$ is an integer as defined in Table 21-18 (J(iSS) values).

**Table 21-18—$J(i_{SS})$ values**

| $i_{SS}$ | $J(i_{SS})$ |
|---|---|
| 1 | 0 |
| 2 | 5 |
| 3 | 2 |
| 4 | 7 |
| 5 | 3 |
| 6 | 6 |
| 7 | 1 |
| 8 | 4 |

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The deinterleaver uses the following three operations to perform the inverse permutations. Let $r$ denote the index of the bit in the received block (per spatial stream). The first operation reverses the third (frequency rotation) permutation of the interleaver. When $N_{SS} = 1$, this reversal is performed by $j = r$ ($r = 0, 1, \ldots, N_{CBPSSI} - 1$). When $2 \le N_{SS} \le 4$, this reversal is performed by as shown in Equation (21-80).

$$j = \left\{ r + \left[ (2(i_{SS} - 1)) \bmod 3 + 3 \left\lfloor \frac{i_{SS} - 1}{3} \right\rfloor \right] \cdot N_{ROT} \cdot N_{BPSCS} \right\} \bmod N_{CBPSSI}, \quad r = 0, 1, \ldots, N_{CBPSSI} - 1 \tag{21-80}$$

When $N_{SS} > 4$, this reversal is performed by Equation (21-81).

$$j = \{ r + J(i_{SS}) \cdot N_{ROT} \cdot N_{BPSCS} \} \bmod N_{CBPSSI}, \quad r = 0, 1, \ldots, N_{CBPSSI} - 1 \tag{21-81}$$

where

$J(i_{SS})$ is defined in Table 21-18 (J(iSS) values)

The second operation defined by Equation (21-82) reverses the second permutation in the interleaver.

$$i = s \left\lfloor \frac{j}{s} \right\rfloor + \left( j + \left\lfloor \frac{N_{COL} \cdot j}{N_{CBPSSI}} \right\rfloor \right) \bmod s, \quad j = 0, 1, \ldots, N_{CBPSSI} - 1 \tag{21-82}$$

where

$s$ is defined in Equation (21-68)

The third operation defined in Equation (21-83) reverses the first permutation of the interleaver.

$$k = N_{COL} \cdot i - (N_{CBPSSI} - 1) \left\lfloor \frac{i}{N_{ROW}} \right\rfloor, \quad i = 0, 1, \ldots, N_{CBPSSI} - 1 \tag{21-83}$$

### 21.3.10.9 Constellation mapping

#### 21.3.10.9.1 General

The mapping between bits at the output of the interleaver and complex constellation points for BPSK, QPSK, 16-QAM, and 64-QAM follows the rules defined in 17.3.5.8 (Subcarrier modulation mapping). For 256-QAM, the mapping is shown in Figure 21-24 (Constellation bit encoding for 256-QAM (1st quadrant)) through Figure 21-27 (Constellation bit encoding for 256-QAM (4th quadrant)).

The bit string convention in Figure 21-24 (Constellation bit encoding for 256-QAM (1st quadrant)) through Figure 21-27 (Constellation bit encoding for 256-QAM (4th quadrant)) follows the bit string convention outlined in 17.3.5.8 (Subcarrier modulation mapping).

The streams of complex numbers in frequency subblock $l$ for user $u$ are denoted as follows:


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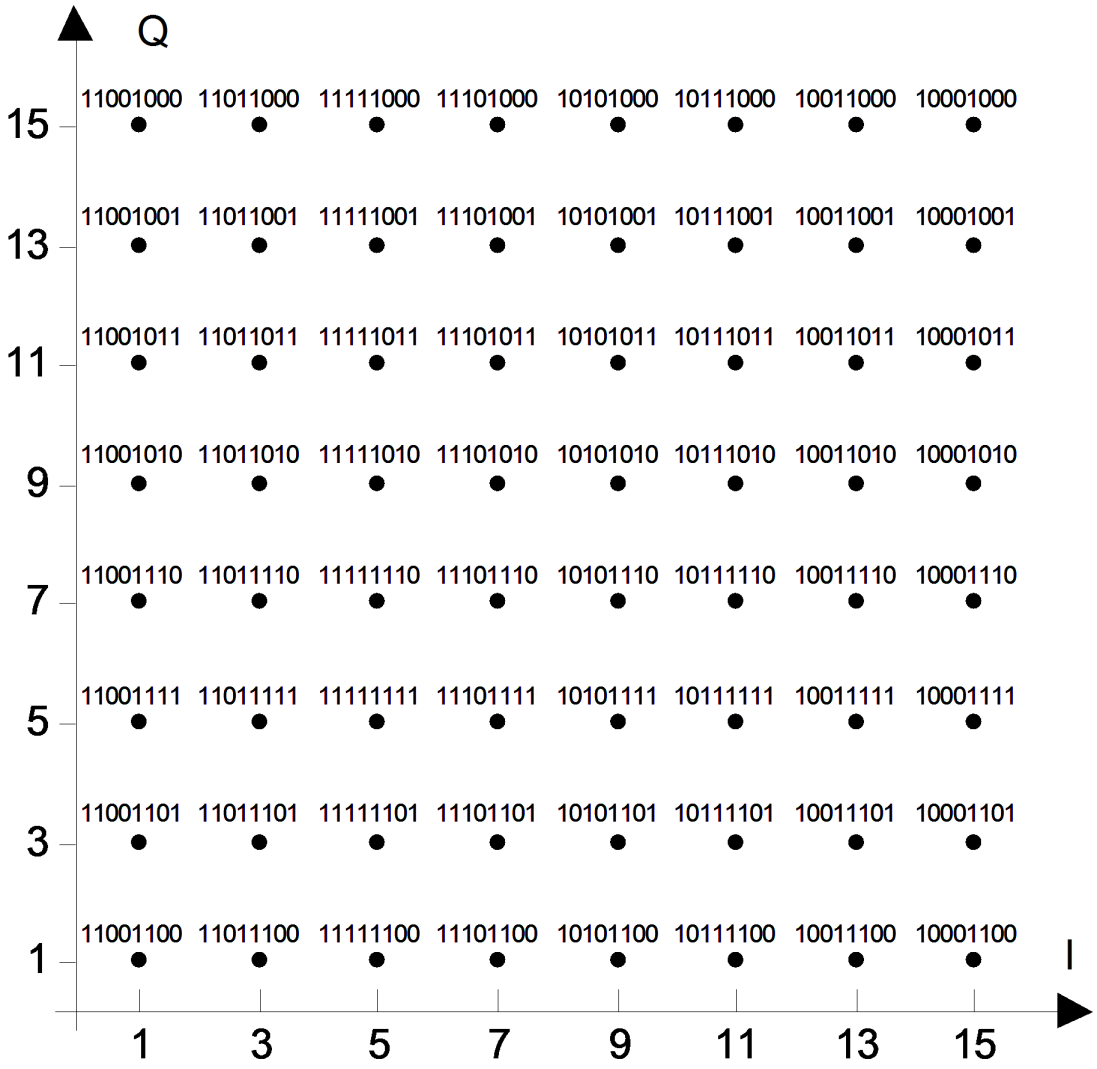


**Figure 21-24—Constellation bit encoding for 256-QAM (1st quadrant)**

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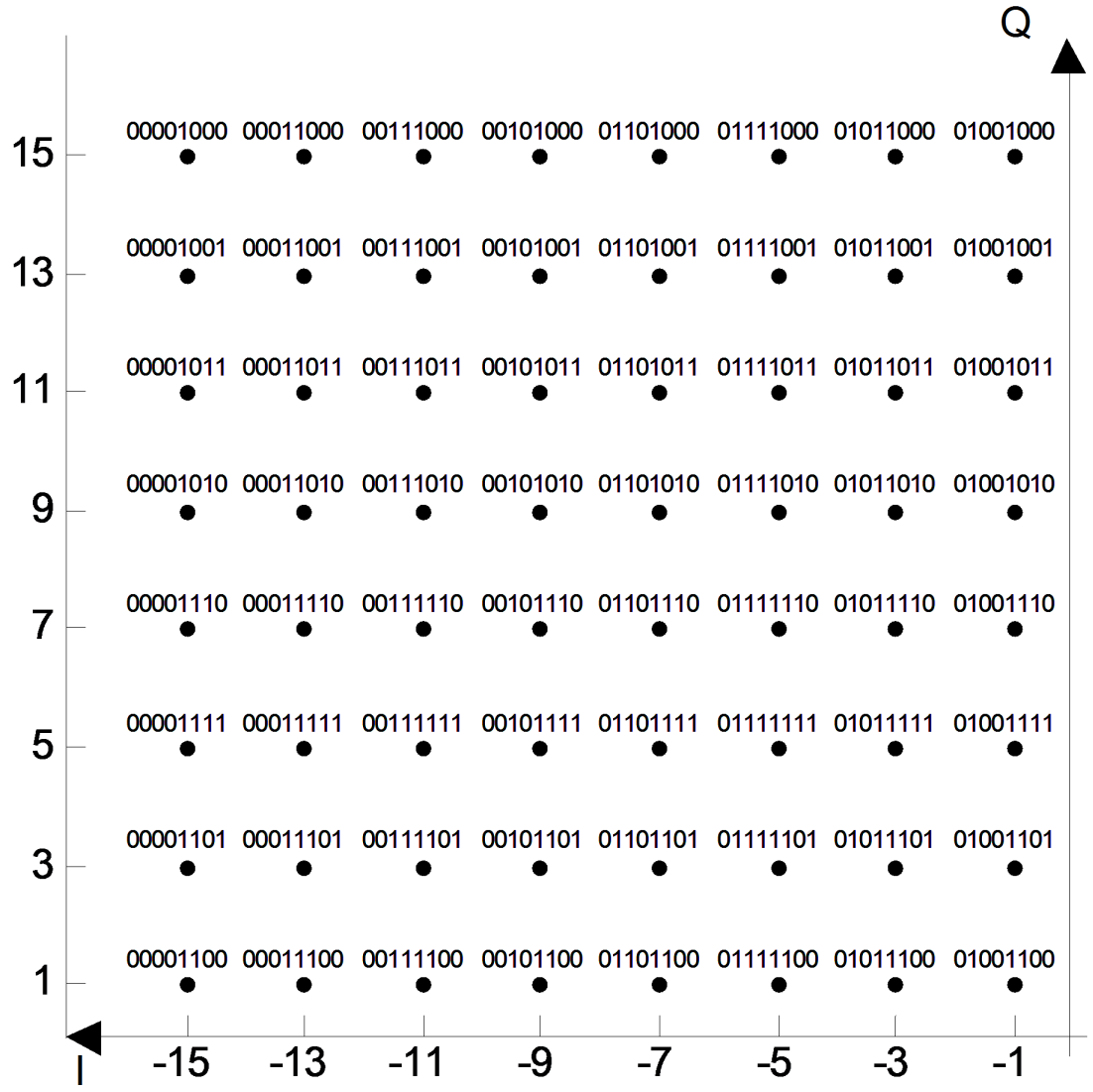


**Figure 21-25—Constellation bit encoding for 256-QAM (2nd quadrant)**



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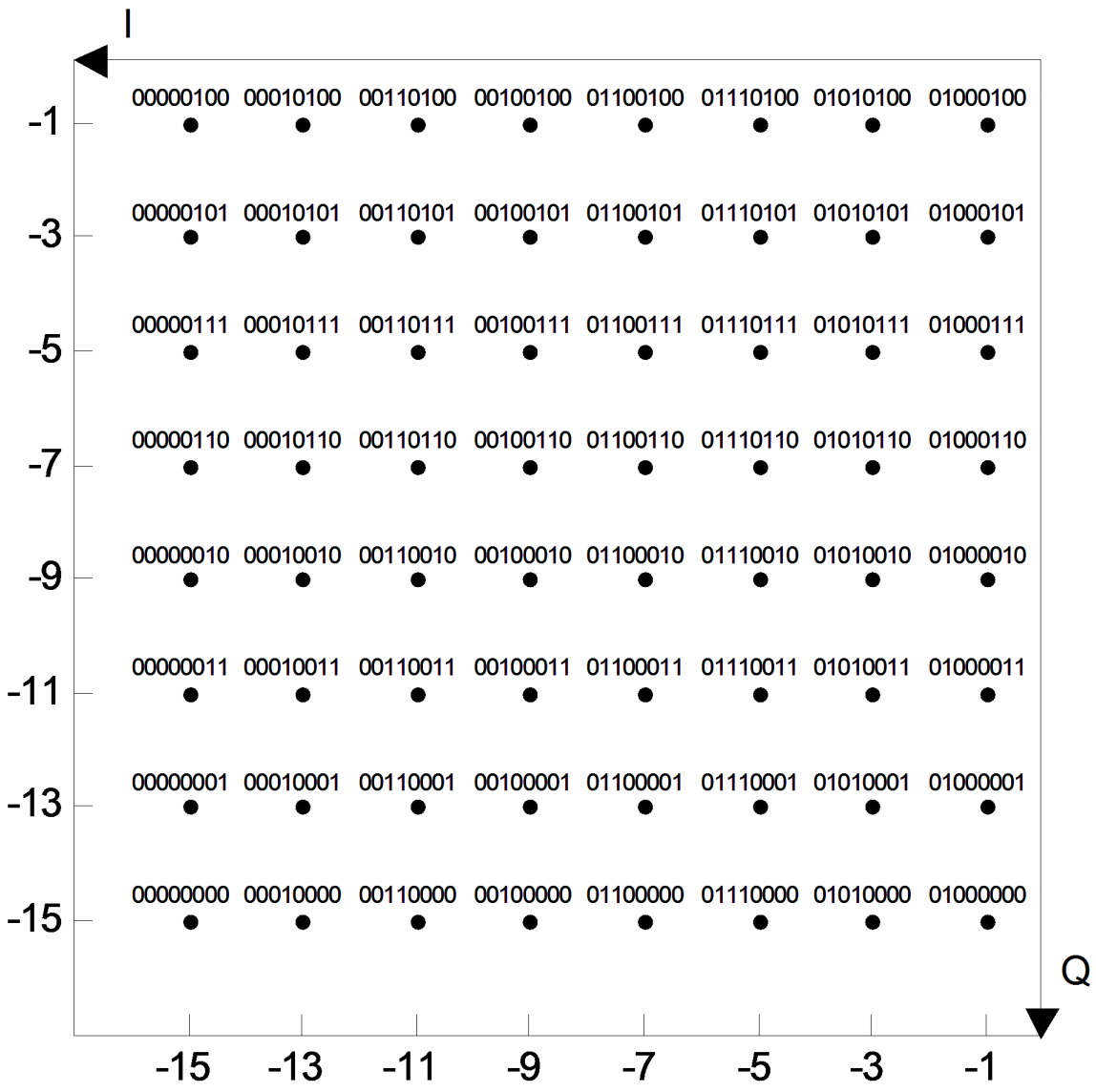


**Figure 21-26—Constellation bit encoding for 256-QAM (3rd quadrant)**

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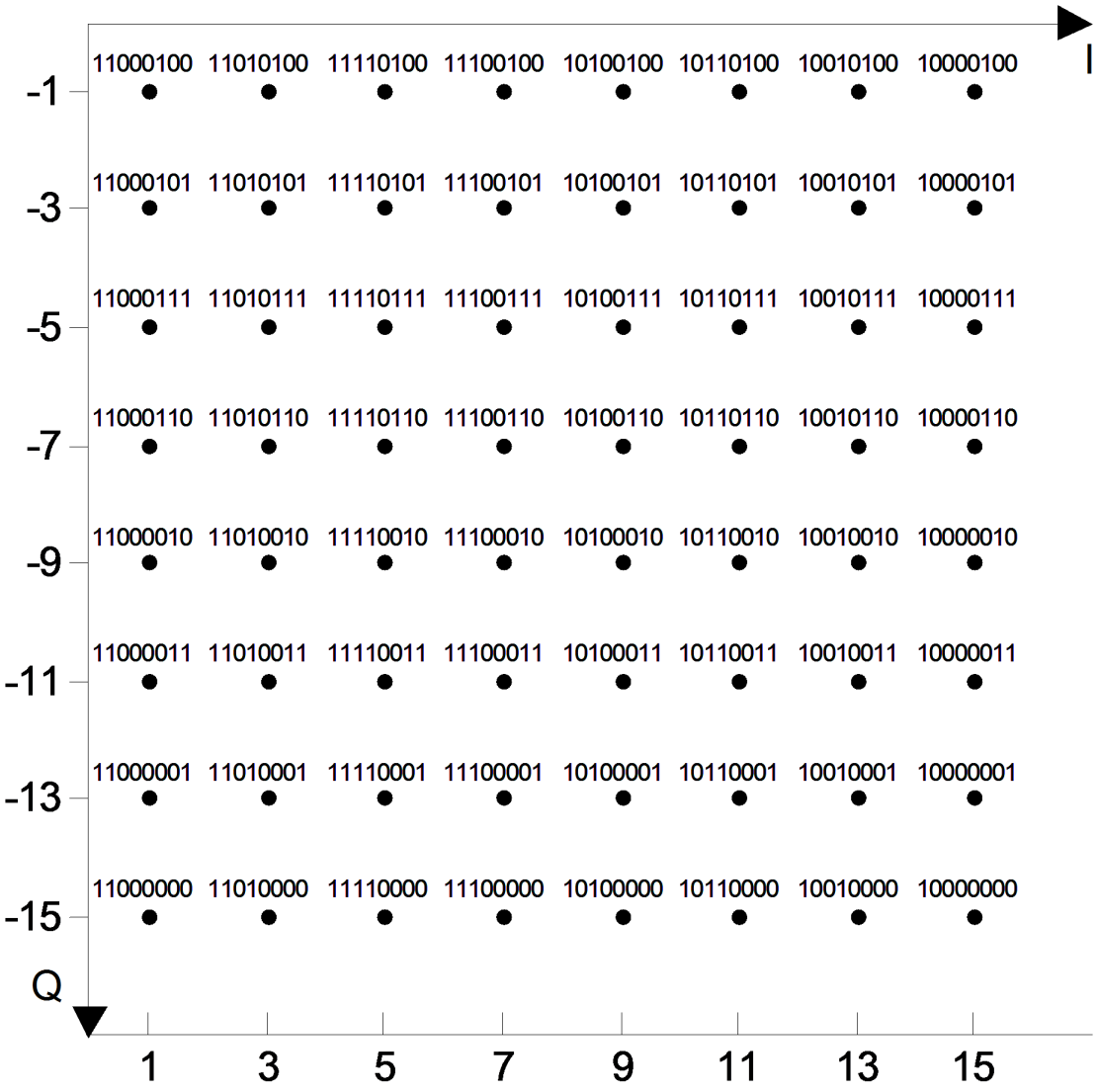


**Figure 21-27—Constellation bit encoding for 256-QAM (4th quadrant)**



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$d''_{k,i,n,l,u}$; $k = 0, 1, \ldots, N_{SD} - 1$ for 20 MHz, 40 MHz, 80 MHz, and 80+80 MHz; (21-84)

$k = 0, 1, \ldots, \frac{N_{SD}}{2} - 1$ for 160 MHz;

$i = 1, \ldots, N_{SS,u}$;

$n = 0, 1, \ldots, N_{SYM} - 1$;

$l = 0$ for 20 MHz, 40 MHz, and 80 MHz;

$l = 0, 1$ for 160 MHz and 80+80 MHz;

$u = 0, \ldots, N_{user} - 1$

The normalization factor, $K_{MOD}$, for 256-QAM is $1/\sqrt{170}$.

### 21.3.10.9.2 LDPC tone mapping

The LDPC tone mapping shall be performed on all LDPC encoded streams as described in this subclause and using an LDPC tone-mapping distance parameter $D_{TM}$. $D_{TM}$ is constant for each bandwidth and its value for different bandwidths is given in Table 21-19 (LDPC tone mapping distance for each bandwidth). LDPC tone mapping shall not be performed on streams that are encoded using BCC.

**Table 21-19—LDPC tone mapping distance for each bandwidth**

| Parameter | 20 MHz | 40 MHz | 80 MHz | 160 MHz, 80+80 MHz |
|---|---|---|---|---|
| $D_{TM}$ | 4 | 6 | 9 | 9 |

For a VHT PPDU transmission, the LDPC tone mapping for LDPC-coded streams corresponding to user $u$ is done by permuting the stream of complex numbers generated by the constellation mappers (#4181)(see Equation (21-84)) to obtain

$d''_{t(k),i,n,l,u} = d''_{k,i,n,l,u}$; $k = 0, 1, \ldots, N_{SD} - 1$ for 20 MHz, 40 MHz, 80 MHz and 80+80 MHz; (21-85)

$k = 0, 1, \ldots, \frac{N_{SD}}{2} - 1$ for 160 MHz;

$i = 1, \ldots, N_{SS,u}$;

$n = 0, 1, \ldots, N_{SYM} - 1$;

$l = 0$ for 20 MHz, 40 MHz, and 80 MHz;

$l = 0, 1$ for 160 MHz and 80+80 MHz;

$u = 0, \ldots, N_{user} - 1$

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where

$$t(k) = \begin{cases} D_{TM}\left(k \bmod \frac{N_{SD}}{D_{TM}}\right) + \left\lfloor \frac{k \cdot D_{TM}}{N_{SD}} \right\rfloor, & \text{for 20 MHz, 40 MHz, 80 MHz, and 80+80 MHz} \\ D_{TM}\left(k \bmod \frac{N_{SD}/2}{D_{TM}}\right) + \left\lfloor \frac{k \cdot D_{TM}}{N_{SD}/2} \right\rfloor, & \text{for 160 MHz} \end{cases} \quad (21\text{-}86)$$

As a result of the LDPC tone mapping operation above, each two consecutively generated complex constellation numbers $d'_{k,i,n,l,u}$ and $d'_{k+1,i,n,l,u}$ are(M118) transmitted on two data tones that are separated by at least $D_{TM} - 1$ other data tones. Note that the operation above is equivalent to block-interleaving the complex numbers $d'_{0,i,n,l,u}, \ldots, d'_{N_{SD}-1,i,n,l,u}$ for each $i$, $n$, and $u$ using a matrix with $D_{TM}$ rows and $N_{SD}/D_{TM}$ (for 20 MHz, 40 MHz, 80 MHz, or 80+80 MHz) or $\frac{N_{SD}}{2 \cdot D_{TM}}$ (for 160 MHz) columns, where $d'_{0,i,n,l,u}, \ldots, d'_{N_{SD}-1,i,n,l,u}$ are written row-wise into the matrix, and $d''_{0,i,n,l,u}, \ldots, d''_{N_{SD}-1,i,n,l,u}$ are read column-wise from the matrix.

NOTE—LDPC tone mapping is performed separately for the upper and lower 80 MHz frequency subblocks of a 160 MHz or 80+80 MHz transmission as indicated by the frequency subblock index $l$ in Equation (21-85) and Equation (21-86).

Since LDPC tone mapping is not performed on BCC-coded streams, for BCC-coded streams, the following applies:

$$d''_{k,i,n,l,u} = d'_{k,i,n,l,u}; \quad k = 0, 1, \ldots, N_{SD} - 1 \text{ for 20 MHz, 40 MHz, 80 MHz and 80+80 MHz;} \quad (21\text{-}87)$$

$$k = 0, 1, \ldots, \frac{N_{SD}}{2} - 1 \text{ for 160 MHz;}$$

$$i = 1, \ldots, N_{SS,u};$$

$$n = 0, 1, \ldots, N_{SYM} - 1;$$

$$l = 0 \text{ for 20 MHz, 40 MHz, and 80 MHz;}$$

$$l = 0, 1 \text{ for 160 MHz and 80+80 MHz;}$$

$$u = 0, \ldots, N_{user} - 1$$

### 21.3.10.9.3 Segment deparser

NOTE 1—The input of the operation described in this subclause is named a frequency subblock rather than a segment because it applies to 160 MHz PPDUs which has two deparser inputs yet one frequency segment (see Table 21-5 (Timing-related constants)). A more precise name for this operation would be frequency subblock deparser.(#19)

In a 160 MHz VHT PPDU transmission, the two frequency subblocks at the output of the LDPC tone mapper for LDPC or constellation mapper for BCC are combined into one frequency segment as shown in Equation (21-88).


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$$d_{k,i,n,u}^{(i_{Seg})} = \begin{cases} d''_{k,i,n,0,u}, & \text{if } 0 \le k \le \frac{N_{SD}}{2} - 1 \\ d''_{k-N_{SD}/2,i,n,1,u}, & \text{if } \frac{N_{SD}}{2} \le k \le N_{SD} - 1 \end{cases}, \quad i_{Seg} = 0 \tag{21-88}$$

In a 20 MHz, 40 MHz, or 80 MHz VHT PPDU transmission, the segment deparsing is not performed. Hence,

$$d_{k,i,n,u}^{(i_{Seg})} = d''_{k,i,n,0,u}, \quad 0 \le k \le N_{SD} - 1, \quad i_{Seg} = 0 \tag{21-89}$$

In an 80+80 MHz VHT PPDU transmission, the segment deparsing is not performed. Hence,

$$d_{k,i,n,u}^{(i_{Seg})} = d''_{k,i,n,i_{Seg},u}, \quad 0 \le k \le N_{SD} - 1, \quad i_{Seg} = 0, 1 \tag{21-90}$$

NOTE 2—As per Table 21-7 (Center frequency of the portion of the PPDU transmitted in frequency segment iSeg), $f_c^{(0)}$ (center frequency for frequency segment $i_{Seg}$=0) is always less than $f_c^{(1)}$ in case of 80+80 MHz VHT PPDU transmissions. Hence, $d''_{k,i,n,0,u}$ (frequency subblock 0) is always transmitted in the frequency segment lower in frequency, while $d''_{k,i,n,1,u}$ (frequency subblock 1) is always transmitted in the frequency segment higher in frequency.

### 21.3.10.9.4 Space-time block coding

This subclause defines a set of optional robust transmission techniques that are applicable only when using STBC coding for VHT SU PPDUs. In this case, $N_{SS,0}$ spatial streams are mapped to $N_{STS,0}$ space-time streams. These techniques are based on STBC. When the VHT-SIG-A STBC field is 1, a symbol operation shall occur between the constellation mapper and the spatial mapper as defined in this subclause. STBC shall not be applied in a VHT MU PPDU. Hence, the user subscript $u$ is 0 in this subclause.

If STBC is applied, the stream of complex numbers, $d_{k,i,n,0}^{(i_{Seg})}$; $k = 0, \ldots, N_{SD} - 1$; $i = 1, \ldots, N_{SS,0}$; $n = 0, \ldots, N_{SYM} - 1$, generated by the segment deparser, is the input to the STBC encoder, which produces as output the stream of complex numbers $\tilde{d}_{k,i_{STS},n,0}^{(i_{Seg})}$; $k = 0, \ldots, N_{SD} - 1$; $i_{STS} = 1, \ldots, N_{STS,0}$; $n = 0, \ldots, N_{SYM} - 1$. For given values of $k$ and $i$, STBC processing operates on the complex modulation symbols in sequential pairs of OFDM symbols so that the value of $\tilde{d}_{k,2i-1,2m,0}^{(i_{Seg})}$ and $\tilde{d}_{k,2i,2m,0}^{(i_{Seg})}$ depend on $d_{k,i,2m,0}^{(i_{Seg})}$ and $d_{k,i,2m+1,0}^{(i_{Seg})}$. Also, $\tilde{d}_{k,2i-1,2m+1,0}^{(i_{Seg})}$ and $\tilde{d}_{k,2i,2m+1,0}^{(i_{Seg})}$ depend on $d_{k,i,2m,0}^{(i_{Seg})}$ and $d_{k,i,2m+1,0}^{(i_{Seg})}$. This is defined in Table 21-20 (Constellation mapper output to spatial mapper input for STBC). Note that the segment index $i_{Seg}$ is omitted in Table 21-20 (Constellation mapper output to spatial mapper input for STBC) for simplicity.

**Table 21-20—Constellation mapper output to spatial mapper input for STBC**

| $N_{STS}$ | $N_{SS}$ | $i_{STS}$ | $\tilde{d}_{k,i_{STS},2m,0}$ | $\tilde{d}_{k,i_{STS},2m+1,0}$ |
|---|---|---|---|---|
| 2 | 1 | 1 | $d_{k,1,2m,0}$ | $d_{k,1,2m+1,0}$ |
| | | 2 | $-d^*_{k,1,2m+1,0}$ | $d^*_{k,1,2m,0}$ |

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**Table 21-20—Constellation mapper output to spatial mapper input for STBC *(continued)***

| $N_{STS}$ | $N_{SS}$ | $i_{STS}$ | $\tilde{d}_{k, i_{STS}, 2m, 0}$ | $\tilde{d}_{k, i_{STS}, 2m+1, 0}$ |
|---|---|---|---|---|
| 4 | 2 | 1 | $d_{k, 1, 2m, 0}$ | $d_{k, 1, 2m+1, 0}$ |
| | | 2 | $-d^*_{k, 1, 2m+1, 0}$ | $d^*_{k, 1, 2m, 0}$ |
| | | 3 | $d_{k, 2, 2m, 0}$ | $d_{k, 2, 2m+1, 0}$ |
| | | 4 | $-d^*_{k, 2, 2m+1, 0}$ | $d^*_{k, 2, 2m, 0}$ |
| 6 | 3 | 1 | $d_{k, 1, 2m, 0}$ | $d_{k, 1, 2m+1, 0}$ |
| | | 2 | $-d^*_{k, 1, 2m+1, 0}$ | $d^*_{k, 1, 2m, 0}$ |
| | | 3 | $d_{k, 2, 2m, 0}$ | $d_{k, 2, 2m+1, 0}$ |
| | | 4 | $-d^*_{k, 2, 2m+1, 0}$ | $d^*_{k, 2, 2m, 0}$ |
| | | 5 | $d_{k, 3, 2m, 0}$ | $d_{k, 3, 2m+1, 0}$ |
| | | 6 | $-d^*_{k, 3, 2m+1, 0}$ | $d^*_{k, 3, 2m, 0}$ |
| 8 | 4 | 1 | $d_{k, 1, 2m, 0}$ | $d_{k, 1, 2m+1, 0}$ |
| | | 2 | $-d^*_{k, 1, 2m+1, 0}$ | $d^*_{k, 1, 2m, 0}$ |
| | | 3 | $d_{k, 2, 2m, 0}$ | $d_{k, 2, 2m+1, 0}$ |
| | | 4 | $-d^*_{k, 2, 2m+1, 0}$ | $d^*_{k, 2, 2m, 0}$ |
| | | 5 | $d_{k, 3, 2m, 0}$ | $d_{k, 3, 2m+1, 0}$ |
| | | 6 | $-d^*_{k, 3, 2m+1, 0}$ | $d^*_{k, 3, 2m, 0}$ |
| | | 7 | $d_{k, 4, 2m, 0}$ | $d_{k, 4, 2m+1, 0}$ |
| | | 8 | $-d^*_{k, 4, 2m+1, 0}$ | $d^*_{k, 4, 2m, 0}$ |

If STBC is not applied, $\tilde{d}^{(i_{Seg})}_{k, i, n, 0} = d^{(i_{Seg})}_{k, i, n, 0}$ and $N_{STS, 0} = N_{SS, 0}$.

NOTE—When STBC is applied, an odd number of space-time streams is not allowed, and $N_{STS, 0} = 2N_{SS, 0}$.

### 21.3.10.10 Pilot subcarriers

In a 20 MHz transmission, four pilot tones shall be inserted in subcarriers $k \in \{-21, -7, 7, 21\}$. The pilot mapping $P^k_n$ for subcarrier *k* for symbol *n* shall be as specified in Equation (21-91).


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$$P_n^{\{-21,-7,7,21\}} = \{\Psi^{(1)}_{1,n \bmod 4}, \Psi^{(1)}_{1,(n+1) \bmod 4}, \Psi^{(1)}_{1,(n+2) \bmod 4}, \Psi^{(1)}_{1,(n+3) \bmod 4}\}$$
$$P_n^{k \notin \{-21,-7,7,21\}} = 0 \quad (21\text{-}91)$$

where

$\Psi^{(1)}_{1,m}$ is given by the $N_{STS} = 1$ row of Table 19-19 (Pilot values for 20 MHz transmission)

In a 40 MHz transmission, six pilot tones shall be inserted in subcarriers –53, –25, –11, 11, 25, and 53. The pilot mapping $P_n^k$ for subcarrier *k* for symbol *n* shall be as specified in Equation (21-92).

$$P_n^{\{-53,-25,-11,11,25,53\}} = \{\Psi^{(1)}_{1,n \bmod 6}, \Psi^{(1)}_{1,(n+1) \bmod 6}, \ldots, \Psi^{(1)}_{1,(n+5) \bmod 6}\}$$
$$P_n^{k \notin \{-53,-25,-11,11,25,53\}} = 0 \quad (21\text{-}92)$$

where

$\Psi^{(1)}_{1,m}$ is given by the $N_{STS} = 1$ row of Table 19-20 (Pilots values for 40 MHz transmission (excluding MCS 32))

In an 80 MHz transmission, eight pilot tones shall be inserted in subcarriers –103, –75, –39, –11, 11, 39, 75, and 103. The pilot mapping $P_n^k$ for subcarrier *k* for symbol *n* shall be as specified in Equation (21-93).

$$P_n^{\{-103,-75,-39,-11,11,39,75,103\}} = \{\Psi_{n \bmod 8}, \Psi_{(n+1) \bmod 8}, \ldots, \Psi_{(n+7) \bmod 8}\}$$
$$P_n^{k \notin \{-103,-75,-39,-11,11,39,75,103\}} = 0 \quad (21\text{-}93)$$

where

$\Psi_m$ is defined in Table 21-21 (Pilot values for 80 MHz transmission)

**Table 21-21—Pilot values for 80 MHz transmission**

| $\Psi_0$ | $\Psi_1$ | $\Psi_2$ | $\Psi_3$ | $\Psi_4$ | $\Psi_5$ | $\Psi_6$ | $\Psi_7$ |
|---|---|---|---|---|---|---|---|
| 1 | 1 | 1 | –1 | –1 | 1 | 1 | 1 |

In a 160 MHz transmission, the 80 MHz pilot mapping is replicated in the two 80 MHz subchannels of the 160 MHz transmission. Specifically, 16 pilot tones shall be inserted in subcarriers –231, –203, –167, –139, –117, –89, –53, –25, 25, 53, 89, 117, 139, 167, 203, and 231. The pilot mapping $P_n^k$ for subcarrier *k* for symbol *n* shall be as specified in Equation (21-94).

$$P_n^{\{-231,-203,-167,-139,-117,-89,-53,-25,25,53,89,117,139,167,203,231\}}$$
$$= \{\Psi_{n \bmod 8}, \Psi_{(n+1) \bmod 8}, \Psi_{(n+2) \bmod 8}, \Psi_{(n+3) \bmod 8}, \Psi_{(n+4) \bmod 8}, \Psi_{(n+5) \bmod 8}, \Psi_{(n+6) \bmod 8}, \Psi_{(n+7) \bmod 8},$$
$$\Psi_{n \bmod 8}, \Psi_{(n+1) \bmod 8}, \Psi_{(n+2) \bmod 8}, \Psi_{(n+3) \bmod 8}, \Psi_{(n+4) \bmod 8}, \Psi_{(n+5) \bmod 8}, \Psi_{(n+6) \bmod 8}, \Psi_{(n+7) \bmod 8}\} \quad (21\text{-}94)$$
$$P_n^{k \notin \{-231,-203,-167,-139,-117,-89,-53,-25,25,53,89,117,139,167,203,231\}} = 0$$

where

$\Psi_m$ is given in Table 21-21 (Pilot values for 80 MHz transmission)

In an 80+80 MHz transmission, each frequency segment shall follow the 80 MHz pilot tone allocation and values defined for 80 MHz transmission as specified in Equation (21-93) and Table 21-21 (Pilot values for 80 MHz transmission).

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The above pilot mapping shall be copied to all space-time streams before the space-time stream cyclic shifts are applied.

### 21.3.10.11 OFDM modulation

#### 21.3.10.11.1 Transmission in VHT format

The time domain waveform of the Data field of a VHT PPDU from frequency segment $i_{Seg}$ and transmit chain $i_{TX}$, $1 \le i_{TX} \le N_{TX}$ shall be as defined in Equation (21-95).

$$r_{\text{VHT-Data}}^{(i_{Seg}, i_{TX})}(t) = \frac{1}{\sqrt{N_{\text{VHT-Data}}^{\text{Tone}} N_{STS,\,total}}} \sum_{n=0}^{N_{SYM}-1} w_{T_{\text{SYM}}}(t - nT_{SYM}) \cdot \sum_{k=-N_{SR}}^{N_{SR}} \sum_{u=0}^{N_{user}-1} \sum_{m=1}^{N_{STS,\,u}} \left( \left[ Q_k^{(i_{Seg})} \right]_{i_{TX},\,(M_u+m)} \Upsilon_{k,\,\text{BW}} (\tilde{D}_{k,\,m,\,n,\,BW}^{(i_{Seg},\,u)} + p_{n+4} P_n^k) \cdot \exp(j2\pi k \Delta_F (t - nT_{SYM} - T_{\text{GI, Data}} - T_{\text{CS,VHT}}(M_u + m))) \right) \quad (21\text{-}95)$$

where

$p_n$ is defined in 17.3.5.10 (OFDM modulation)

$P_n^k$ is defined in 21.3.10.10 (Pilot subcarriers)

$\Upsilon_{k,\,\text{BW}}$ is defined in Equation (21-14), Equation (21-15), Equation (21-16). and Equation (21-17)

$\tilde{D}_{k,\,m,\,n,\,BW}^{(i_{Seg},\,u)}$ is the transmitted constellation for user $u$ at subcarrier $k$, space-time stream $m$, and Data field OFDM symbol $n$ and is defined in Equation (21-96) to Equation (21-99)

$N_{\text{VHT-Data}}^{\text{Tone}}$ has the value given in Table 21-8 (Tone scaling factor and guard interval duration values for PHY fields)

$T_{\text{CS,VHT}}(n)$ is given in Table 21-11 (Cyclic shift values for the VHT modulated fields of a PPDU)

$T_{\text{GI, Data}}$ is the guard interval duration. $T_{\text{GI, Data}} = T_{\text{GI}}$ when not using the short guard interval (Short GI field of VHT-SIG-A2 is 0) and $T_{\text{GI, Data}} = T_{\text{GIS}}$ when using the short guard interval (Short GI field of VHT-SIG-A2 is 1). $T_{\text{GI}}$ and $T_{\text{GIS}}$ are given in Table 21-5 (Timing-related constants)

In a 20 MHz VHT transmission,

$$\tilde{D}_{k,\,m,\,n,\,20}^{(i_{Seg},\,u)} = \begin{cases} 0, k = 0, \pm 7, \pm 21 \\ \tilde{d}_{M_{20}^r(k),\,m,\,n,\,u}^{(i_{Seg})}, \text{otherwise} \end{cases} \quad (21\text{-}96)$$

where

$M_{20}^r(k)$ is defined in Equation (21-49)

In a 40 MHz VHT transmission,

$$\tilde{D}_{k,\,m,\,n,\,40}^{(i_{Seg},\,u)} = \begin{cases} 0, k = 0, \pm 1, \pm 11, \pm 25, \pm 53 \\ \tilde{d}_{M_{40}^r(k),\,m,\,n,\,u}^{(i_{Seg})}, \text{otherwise} \end{cases} \quad (21\text{-}97)$$

where



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$M^r_{40}(k)$ is defined in Equation (21-51)

In an 80 MHz transmission,

$$\tilde{D}^{(i_{Seg},u)}_{k,m,n,80} = \begin{cases} 0, k = 0, \pm1, \pm11, \pm39, \pm75, \pm103 \\ \tilde{d}^{(i_{Seg})}_{M^r_{80}(k),m,n,u}, \text{otherwise} \end{cases} \quad (21\text{-}98)$$

where

$M^r_{80}(k)$ is defined in Equation (21-53)

In a 160 MHz transmission,

$$\tilde{D}^{(i_{Seg},u)}_{k,m,n,160} = \begin{cases} 0, k = 0, \pm1, \pm2, \pm3, \pm4, \pm5, \pm25, \pm53, \pm89, \pm117, \pm127, \pm128, \pm129, \pm139, \pm167, \pm203, \pm231 \\ \tilde{d}^{(i_{Seg})}_{M^r_{160}(k),m,n,u}, \text{otherwise} \end{cases} \quad (21\text{-}99)$$

where

$M^r_{160}(k)$ is defined in Equation (21-55)

In an 80+80 MHz transmission, each frequency segment shall follow the 80 MHz VHT subcarrier mapping as specified in Equation (21-98) and Equation (21-53).

$Q^{(i_{Seg})}_k$ is a spatial mapping/steering matrix with $N_{TX}$ rows and $N_{STS,total}$ columns for subcarrier $k$ in frequency segment $i_{Seg}$. $Q^{(i_{Seg})}_k$ may be frequency dependent. Refer to the examples of $Q_k$ listed in 19.3.11.11.2 (Spatial mapping) for examples of $Q^{(i_{Seg})}_k$ that could be used for VHT SU PPDUs. Note that implementations are not restricted to the spatial mapping matrix examples listed in 19.3.11.11.2 (Spatial mapping) and the number of transmit chains $N_{TX}$ could be greater than 4. For VHT SU PPDUs to which beamforming is applied, $Q^{(i_{Seg})}_k$ is a beamforming steering matrix and is derived from the TXVECTOR parameter EXPANSION_MAT. For VHT MU PPDUs, $Q^{(i_{Seg})}_k$ is the (#3367)DL MU-MIMO steering matrix and is derived from the TXVECTOR parameter EXPANSION_MAT. The beamforming steering matrices and (#3367)DL MU-MIMO steering matrices are implementation specific.

### 21.3.10.12 Non-HT duplicate transmission

When the TXVECTOR parameter FORMAT is NON_HT and the TXVECTOR parameter NON_HT_MODULATION is NON_HT_DUP_OFDM, the transmitted PPDU is a non-HT duplicate. Non-HT duplicate transmission is used to transmit to non-HT OFDM STAs, HT STAs, or VHT STAs that may be present in a part of a 40 MHz, 80 MHz, or 160 MHz channel (see Table 21-2 (Interpretation of FORMAT, NON_HT_MODULATION, CH_BANDWIDTH, and CH_OFFSET parameters)). The VHT-SIG-A, VHT-STF, VHT-LTF, and VHT-SIG-B fields are not transmitted. The L-STF, L-LTF, and L-SIG fields shall be transmitted in the same way as in the VHT transmission, with the exceptions for the Rate and Length fields which shall follow 17.3.4 (SIGNAL field).

In a 40 MHz non-HT duplicate transmission, the Data field shall be as defined by Equation (19-61).

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For 80 MHz and 160 MHz non-HT duplicate transmissions, the Data field shall be as defined by Equation (21-100).(#567)

$$r^{i_{TX}}_{\text{non-HT},\,BW}(t) = \frac{1}{\sqrt{N_{TX} N^{\text{Tone}}_{\text{NON\_HT\_DUP\_OFDM-Data}}}} \sum_{n=0}^{N_{SYM}-1} w_{T_{SYM}}(t - nT_{SYM}) \cdot \sum_{i_{BW}=0}^{N_{20\text{MHz}}-1} \left( \sum_{k=-26}^{26} \Upsilon_{(k - K_{\text{Shift}}(i_{BW})),\,BW}(D_{k,\,n} + p_{n+1}P_k) \cdot \exp(j2\pi(k - K_{\text{Shift}}(i_{BW}))\Delta_F(t - nT_{SYM} - T_{GI} - T^{i_{TX}}_{\text{CS}})) \right) \quad (21\text{-}100)$$

where

| | |
|---|---|
| $N_{20\text{MHz}}$ and $K_{\text{Shift}}(i)$ | are defined in 21.3.8.2.4 (L-SIG definition) |
| $P_k$ and $p_n$ | are defined in 17.3.5.10 (OFDM modulation) |
| $D_{k,n}$ | is defined in Equation (21-26) |
| $\Upsilon_{k,\,BW}$ | is defined in Equation (21-16) and Equation (21-17) |
| $T^{i_{TX}}_{\text{CS}}$ | represents the cyclic shift for transmitter chain $i_{TX}$ with a value given in Table 21-10 (Cyclic shift values for L-STF, L-LTF, L-SIG, and VHT-SIG-A fields of the PPDU) |
| $N^{\text{Tone}}_{\text{NON\_HT\_DUP\_OFDM-Data}}$ | has the value given in Table 21-8 (Tone scaling factor and guard interval duration values for PHY fields) |

In an 80+80 MHz non-HT duplicate transmission, data transmission in each frequency segment shall be as defined for an 80 MHz non-HT duplicate transmission in Equation (21-100).

### 21.3.11 SU-MIMO and (#3367)DL MU-MIMO Beamforming

#### 21.3.11.1 General

SU-MIMO and (#3367)DL MU-MIMO beamforming are techniques used by a STA with multiple antennas (the beamformer) to steer signals using knowledge of the channel to improve throughput. With SU-MIMO beamforming all space-time streams in the transmitted signal are intended for reception at a single STA. With (#3367)DL MU-MIMO beamforming, disjoint subsets of the space-time streams are intended for reception at different STAs.

For SU-MIMO beamforming, the steering matrix $Q_k$ can be determined from the beamforming feedback matrix $V_k$ that is sent back to the beamformer by the beamformee using the compressed beamforming feedback matrix format as defined in 19.3.12.3.6 (Compressed beamforming feedback matrix). The feedback report format is described in 9.4.1.47 (VHT Compressed Beamforming Report field).

For (#3367)DL MU-MIMO beamforming, the receive signal vector in subcarrier $k$ at beamformee $u$, $\boldsymbol{y}_{k,\,u} = [y_{k,\,0}, y_{k,\,1}, \ldots, y_{k,\,N_{RX_u}-1}]^T$, is shown in Equation (21-101), where $\boldsymbol{x}_k = [\boldsymbol{x}^T_{k,\,0}, \boldsymbol{x}^T_{k,\,1}, \ldots, \boldsymbol{x}^T_{k,\,N_{user}-1}]^T$ denotes the transmit signal vector in subcarrier $k$ for all $N_{user}$ beamformees, with $\boldsymbol{x}_{k,\,u} = [x_{k,\,0}, x_{k,\,1}, \ldots, x_{k,\,N_{STS,\,u}-1}]^T$ being the transmit signal for beamformee $u$.

$$\boldsymbol{y}_{k,\,u} = \boldsymbol{H}_{k,\,u} \times [Q_{k,\,0}, Q_{k,\,1}, \ldots, Q_{k,\,N_{user}-1}] \times \boldsymbol{x}_k + \boldsymbol{n} \quad (21\text{-}101)$$

where


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$\boldsymbol{H}_{k,u}$ is the channel matrix from the beamformer to beamformee $u$ in subcarrier $k$ with dimensions $N_{RX_u} \times N_{TX}$

$N_{RX_u}$ is the number of receive antennas at beamformee $u$

$Q_{k,u}$ is a steering matrix for beamformee $u$ in subcarrier $k$ with dimensions $N_{TX} \times N_{STS_u}$

$N_{user}$ is the number of VHT MU PPDU recipients (see Table 21-6 (Frequently used parameters))

$\boldsymbol{n}$ is a vector of additive noise and may include interference

The (#3367)DL MU-MIMO steering matrix $Q_k = [Q_{k,0}, Q_{k,1}, \ldots, Q_{k,N_{user}-1}]$ can be determined by the beamformer using the beamforming feedback matrices for subcarrier $k$ from beamformee $u$, $V_{k,u,}$ and SNR information for subcarrier $k$ from beamformee $u$, $SNR_{k,u}$, where $u = 0, 1, \ldots, N_{user} - 1$ . The steering matrix that is computed (or updated) using new beamforming feedback matrices and new SNR information from some or all of participating beamformees might replace the existing steering matrix $Q_k$ for the next (#3367)DL MU-MIMO data transmission. The beamformee group for the MU transmission is signaled using the Group ID field in VHT-SIG-A (see 21.3.8.3.3 (VHT-SIG-A definition) and 21.3.11.4 (Group ID)).

### 21.3.11.2 Beamforming Feedback Matrix *V*

Upon receipt of a VHT NDP sounding PPDU, the beamformee shall remove the space-time stream CSD in Table 21-11 (Cyclic shift values for the VHT modulated fields of a PPDU) from the measured channel before computing a set of matrices for feedback to the beamformer. The beamforming feedback matrix, $V_{k,u}$, found by the beamformee $u$ for subcarrier $k$ shall be compressed in the form of angles using the method described in 19.3.12.3.6 (Compressed beamforming feedback matrix). The angles, $\phi(k,u)$ and $\psi(k,u)$, are quantized according to Table 9-104 (Quantization of angles). The number of bits for quantization is chosen by the beamformee, based on the indication from the beamformer as to whether the feedback is requested for SU-MIMO beamforming or (#3367)DL MU-MIMO beamforming. The compressed beamforming feedback using 19.3.12.3.6 (Compressed beamforming feedback matrix) is the only Clause 21 (Very high throughput (VHT) PHY specification) beamforming feedback format defined.

The beamformee shall generate the beamforming feedback matrices with the number of rows ($Nr$) equal to the $N_{STS}$ of the NDP.

After receiving the angle information, $\phi(k,u)$ and $\psi(k,u)$, the beamformer reconstructs $V_{k,u}$ using Equation (19-79). For SU-MIMO beamforming, the beamformer can use this $V_{k,0}$ matrix to determine the steering matrix $Q_k$. For (#3367)DL MU-MIMO beamforming, the beamformer may calculate a steering matrix $Q_k = [Q_{k,0}, Q_{k,1}, \ldots, Q_{k,N_{user}-1}]$ using $V_{k,u}$ and $SNR_{k,u}$ $(0 \le u \le N_{user} - 1)$ in order to suppress crosstalk between participating beamformees. The method used by the beamformer to calculate the steering matrix $Q_k$ is implementation specific.

The beamformee decides the tone grouping and codebook size to be used in the beamforming feedback matrix $V$. A beamformer shall support all tone groups and codebook sizes.

### 21.3.11.3 Maximum Number of Total Spatial Streams in VHT MU PPDUs

An MU beamformee capable STA shall support reception of VHT MU PPDUs with the total number of space-time streams across the N_user users being less than or equal to the value indicated in the Maximum NSTS, total subfield of the Supported VHT-MCS and NSS Set field of the VHT Capabilities element.

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#### 21.3.11.4 Group ID

A value in the Group ID field in VHT-SIG-A (see 21.3.8.3.3 (VHT-SIG-A definition)) in the range 1 to 62 indicates a VHT MU PPDU. Prior to transmitting a VHT MU PPDU, group assignments have been established by the AP for (#3367)DL MU-MIMO capable STAs using the Group ID Management frame as defined in 9.6.22.3 (Group ID Management frame format).

After the PHY is configured using the PHYCONFIG_VECTOR parameter GROUP_ID_MANAGEMENT, the following lookup tables are populated:

a) Group ID to Membership Status, denoted by MembershipStatusInGroupID[$g$] for $1 \le g \le 62$

b) Group ID to User Position, denoted by UserPositionInGroupID[$g$] for $1 \le g \le 62$

When a STA receives a VHT MU PPDU where the Group ID field in VHT-SIG-A has the value $k$ and where MembershipStatusInGroupID[$k$] is equal to 1, then the number of space-time streams for that STA is indicated in the MU[UserPositionInGroupID[$k$]] NSTS field in VHT-SIG-A. The space-time streams of different users are ordered in accordance to user position values, i.e., the space-time streams for the user in user position 0 come first, followed by the space-time streams for the user in position 1, followed by the space-time streams for the user in position 2, and followed by the space-time streams for the user in position 3.

A STA is also able to identify the space-time streams intended for other STAs that act as interference. VHT-LTF symbols in the VHT MU PPDU are used to measure the channel for the space-time streams intended for the STA and can also be used to measure the channel for the interfering space-time streams. To successfully demodulate the space-time streams intended for the STA, the STA may use the channel state information for all space-time streams to reduce the effect of interfering space-time streams.

If a STA finds that it is not a member of the group, or the STA is a member of the group but the corresponding MU NSTS field in VHT-SIG-A indicates that there are zero space-time streams for the STA in the PPDU, then the STA may elect to not process the remainder of the PPDU.

### 21.3.12 VHT preamble format for sounding PPDUs

NDP is the only VHT sounding format.

The format of a VHT NDP is shown in Figure 21-28 (VHT NDP format).

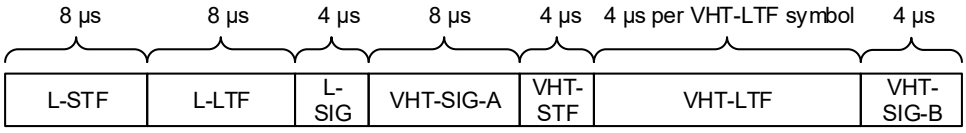


**Figure 21-28—VHT NDP format**

NOTE—The number of VHT-LTF symbols in the NDP is determined by the SU NSTS field in VHT-SIG-A.

The VHT NDP has the following properties:

— Uses the VHT PPDU format but without the Data field.

— Is a VHT SU PPDU as indicated by the VHT-SIG-A field.

— Has the data bits of the VHT-SIG-B field set to a fixed bit pattern (see 21.3.8.3.6 (VHT-SIG-B definition)).


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### 21.3.13 Regulatory requirements

Wireless LANs (WLANs) implemented in accordance with this standard are subject to equipment certification and operating requirements established by regional and national regulatory administrations. The PHY specification establishes minimum technical requirements for interoperability, based upon established regulations at the time this standard was issued. These regulations are subject to revision or may be superseded. Requirements that are subject to local geographic regulations are annotated within the PHY specification. Regulatory requirements that do not affect interoperability are not addressed in this standard. Implementers are referred to the regulatory sources in Annex D for further information. Operation in countries within defined regulatory domains might be subject to additional or alternative national regulations.

### 21.3.14 Channelization

A VHT channel is specified by the four PLME MIB fields specified in Table 21-22 (Fields to specify VHT channels).

**Table 21-22—Fields to specify VHT channels**

| Field | Meaning |
|---|---|
| dot11CurrentChannelWidth | Channel width. Possible values represent 20 MHz, 40 MHz, 80 MHz, 160 MHz, and 80+80 MHz channels. |
| dot11CurrentChannelCenterFrequencyIndex0 | For a 20 MHz, 40 MHz, 80 MHz, or 160 MHz channel, denotes the channel center frequency.<br>For an 80+80 MHz channel, denotes the center frequency of the frequency segment 0, which is the frequency segment containing the primary channel.<br>Valid range is 1 to 200.<br>See Equation (21-102). |
| dot11CurrentChannelCenterFrequencyIndex1 | For an 80+80 MHz channel, denotes the center frequency of the frequency segment 1, which is the frequency segment that does not contain the primary channel.<br>Valid range is 1 to 200.<br>See Equation (21-102).<br>For a 20 MHz, 40 MHz, 80 MHz, or 160 MHz channel, set to 0. |
| dot11CurrentPrimaryChannel | Denotes the location of the primary 20 MHz channel.<br>Valid range is 1 to 200.<br>See Equation (21-103). |

Given dot11CurrentChannelCenterFrequencyIndex0 and dot11CurrentChannelCenterFrequencyIndex1, the respective channel center frequency is given by Equation (21-102).

$$\text{Channel center frequency [MHz]} = \text{Channel starting frequency} + 5 \times \text{dot11CurrentChannelCenterFrequencyIndex} \quad (21\text{-}102)$$

where

Channel starting frequency is given by the operating class (Annex E)

dot11CurrentChannelCenterFrequencyIndex is either dot11CurrentChannelCenterFrequencyIndex0 or dot11CurrentChannelCenterFrequencyIndex1

The center frequency of the primary 20 MHz channel is given by Equation (21-103).

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Primary 20 MHz channel center frequency [MHz] = Channel starting frequency + 5 × dot11CurrentPrimaryChannel (21-103)

where

Channel starting frequency is defined as dot11ChannelStartingFactor × 500 kHz.

A channel center frequency of 5 GHz shall be indicated by dot11ChannelStartingFactor = 8000 and dot11CurrentPrimaryChannel = 200.

For an 80+80 MHz channel, any two channels that would each be allowed as 80 MHz channels and whose center frequencies are separated by greater than 80 MHz (difference between dot11CurrentChannelCenterFrequencyIndex0 and dot11CurrentChannelCenterFrequencyIndex1 corresponds to a frequency difference greater than 80 MHz) may be used.

For example, a channel specified by

Channel starting frequency = 5000 MHz
dot11CurrentChannelWidth = 80 MHz
dot11CurrentChannelCenterFrequencyIndex0 = 42
dot11CurrentPrimaryChannel = 36

is an 80 MHz channel with a center frequency of 5210 MHz and the primary 20 MHz channel centered at 5180 MHz.

A channel specified by

Channel starting frequency = 5000 MHz
dot11CurrentChannelWidth = 160 MHz
dot11CurrentChannelCenterFrequencyIndex0 = 50
dot11CurrentPrimaryChannel = 56

is a 160 MHz channel with a center frequency of 5250 MHz and the primary 20 MHz channel centered at 5280 MHz.

A channel specified by

Channel starting frequency = 5000 MHz
dot11CurrentChannelWidth = 80+80 MHz
dot11CurrentChannelCenterFrequencyIndex0 =155
dot11CurrentChannelCenterFrequencyIndex1 = 106
dot11CurrentPrimaryChannel = 161

is an 80+80 MHz channel in which frequency segment 0 has 80 MHz bandwidth and center frequency of 5775 MHz. Frequency segment 1 also has 80 MHz bandwidth and center frequency of 5530 MHz. The primary 20 MHz channel is centered at 5805 MHz.

### 21.3.15 Slot time

The slot time for the VHT PHY shall be 9 μs for 20 MHz, 40 MHz, 80 MHz, 160 MHz, and 80+80 MHz channel spacing.

### 21.3.16 Transmit and receive port impedance

(#1247)The impedance of exposed transmit and receive antenna connectors are defined in 17.3.8.7 (Transmit and receive impedance at the antenna connector).


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## 21.3.17 VHT transmit specification

### 21.3.17.1 Transmit spectrum mask

NOTE 1—In the presence of additional regulatory restrictions, the device has to meet both the regulatory requirements and the mask defined in this subclause.

NOTE 2—Transmit spectral mask figures in this subclause are not drawn to scale.

NOTE 3—For rules regarding TX center frequency leakage levels, see 21.3.17.4.2 (Transmit center frequency leakage). The spectral mask requirements in this subclause do not apply to the RF LO.

(#1471)The overall transmit spectral mask is constructed using two components. First, an interim spectral mask is constructed whose mask level is determined relative to the maximum spectral density of the signal. Second, an absolute transmit spectral limit is computed based on the mask bandwidth. The overall transmit spectral mask is then constructed by taking the higher of the interim transmit spectral mask and the absolute transmit spectral limit at each frequency offset.

For a 20 MHz mask PPDU of non-HT, HT or VHT format, the interim transmit spectral mask shall have a 0 dBr (dB relative to the maximum spectral density of the signal) bandwidth of 18 MHz, –20 dBr at 11 MHz frequency offset, –28 dBr at 20 MHz frequency offset, and –40 dBr at 30 MHz frequency offset and above. The interim transmit spectral mask for frequency offsets in between 9 and 11 MHz, 11 and 20 MHz, and 20 and 30 MHz shall be linearly interpolated in dB domain from the requirements for 9 MHz, 11 MHz, 20 MHz, and 30 MHz frequency offsets. The transmit spectrum shall not exceed the maximum of the interim transmit spectral mask and –39 dBm/MHz(M25) at any frequency offset. Figure 21-29 (Example transmit spectral mask for 20 MHz mask PPDU) shows an example of the resulting overall spectral mask when the –40 dBr spectrum level is above –39 dBm/MHz.(M25)

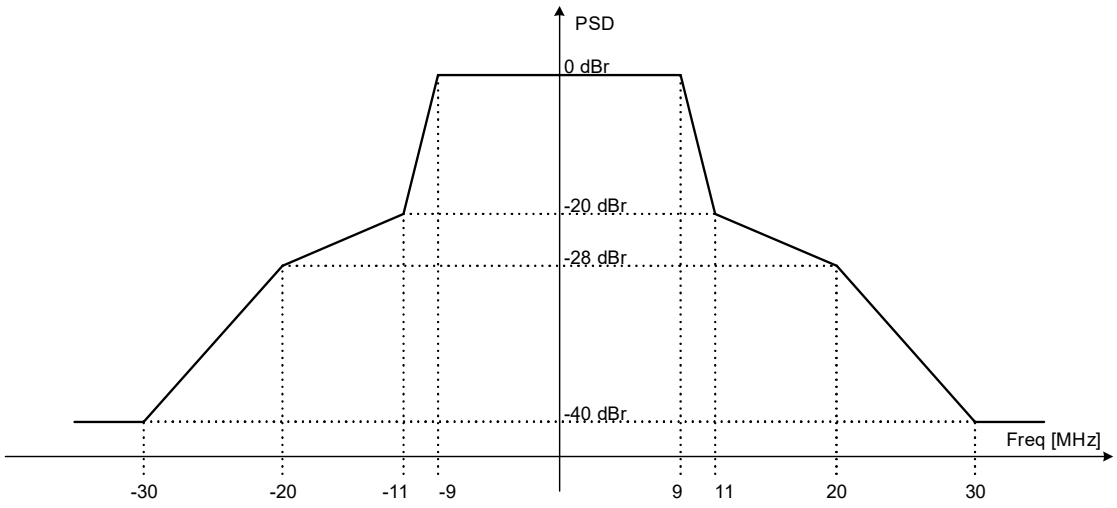


**Figure 21-29—Example transmit spectral mask for 20 MHz mask PPDU**

For a 40 MHz mask PPDU of non-HT, non-HT duplicate, HT or VHT format, the interim transmit spectral mask shall have a 0 dBr (dB relative to the maximum spectral density of the signal) bandwidth of 38 MHz, –20 dBr at 21 MHz frequency offset, –28 dBr at 40 MHz frequency offset, and –40 dBr at 60 MHz frequency offset and above. The interim transmit spectral mask for frequency offsets in between 19 and 21 MHz, 21 and 40 MHz, and 40 and 60 MHz shall be linearly interpolated in dB domain from the requirements for 19 MHz, 21 MHz, 40 MHz, and 60 MHz frequency offsets. The transmit

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spectrum shall not exceed the maximum of the interim transmit spectral mask and –39 dBm/MHz(M25) at any frequency offset greater than 19 MHz. Figure 21-30 (Example transmit spectral mask for 40 MHz mask PPDU) shows an example of the resulting overall spectral mask when the –40 dBr spectrum level is above –39 dBm/MHz.(M25)

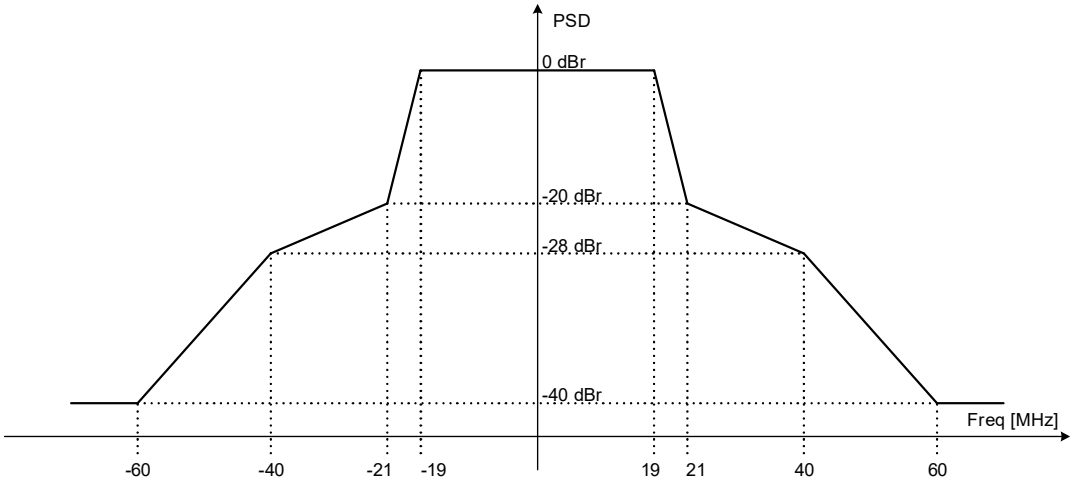


**Figure 21-30—Example transmit spectral mask for 40 MHz mask PPDU**

For an 80 MHz mask PPDU of non-HT, non-HT duplicate, HT or VHT format, the interim transmit spectral mask shall have a 0 dBr (dB relative to the maximum spectral density of the signal) bandwidth of 78 MHz, –20 dBr at 41 MHz frequency offset, –28 dBr at 80 MHz frequency offset, and –40 dBr at 120 MHz frequency offset and above. The interim transmit spectral mask for frequency offsets in between 39 and 41 MHz, 41 and 80 MHz, and 80 and 120 MHz shall be linearly interpolated in dB domain from the requirements for 39 MHz, 41 MHz, 80 MHz, and 120 MHz frequency offsets. The transmit spectrum shall not exceed the maximum of the interim transmit spectrum mask and –39 dBm/MHz(M25) at any frequency offset. Figure 21-31 (Example transmit spectral mask for 80 MHz mask PPDU) shows an example of the resulting overall spectral mask when the –40 dBr spectrum level is above –39 dBm/MHz.(M25)

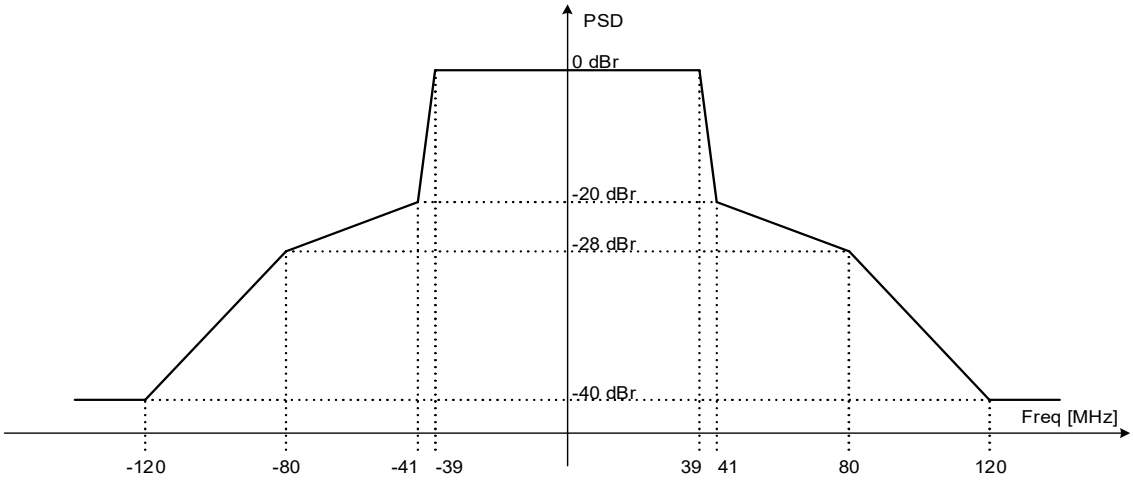


**Figure 21-31—Example transmit spectral mask for 80 MHz mask PPDU**


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For a 160 MHz mask PPDU of non-HT, non-HT duplicate, HT or VHT format, the interim transmit spectral mask shall have a 0 dBr (dB relative to the maximum spectral density of the signal) bandwidth of 158 MHz, –20 dBr at 81 MHz frequency offset, –28 dBr at 160 MHz frequency offset, and –40 dBr at 240 MHz frequency offset and above. The interim transmit spectral mask for frequency offsets in between 79 and 81 MHz, 81 and 160 MHz, and 160 and 240 MHz shall be linearly interpolated in dB domain from the requirements for 79 MHz, 81 MHz, 160 MHz, and 240 MHz frequency offsets. The transmit spectrum shall not exceed the maximum of the interim transmit spectrum mask and –39 dBm/MHz(M25) at any frequency offset. Figure 21-32 (Example transmit spectral mask for 160 MHz mask PPDU) shows an example of the resulting overall spectral mask when the –40 dBr spectrum level is above –39 dBm/MHz(M25).

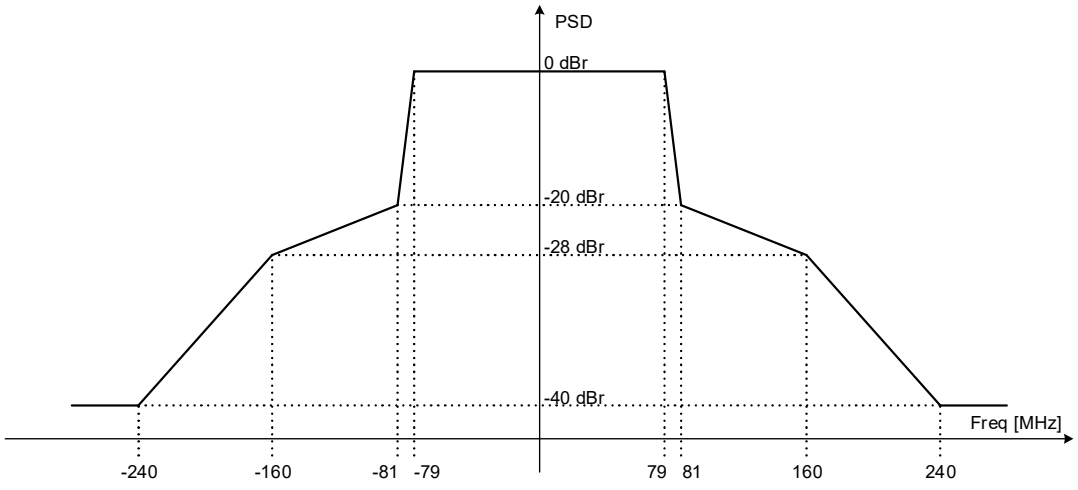


**Figure 21-32—Example transmit spectral mask for 160 MHz mask PPDU**

For an 80+80 MHz mask PPDU of non-HT duplicate or VHT format, the overall transmit spectral mask is constructed in the following manner. First, the 80 MHz interim spectral mask is placed on each of the two 80 MHz frequency segments. Then, for each frequency at which both of the 80 MHz interim spectral masks have values greater than –40 dBr and less than –20 dBr, the sum of the two interim mask values (summed in linear domain) shall be taken as the overall spectral mask value. Next, for each frequency at which neither of the two 80 MHz interim masks have values greater than or equal to –20 dBr and less than or equal to 0 dBr, the higher value of the two interim masks shall be taken as the overall interim spectral value. Finally, for any frequency region where the mask value has not been defined yet, linear interpolation (in dB domain) between the nearest two frequency points with the interim spectral mask value defined shall be used to define the interim spectral mask value. The transmit spectrum shall not exceed the maximum of the interim transmit spectrum mask and –39 dBm/MHz(M25) at any frequency offset. Figure 21-33 (Example transmit spectral mask for 80+80 MHz mask PPDU) shows an example of a transmit spectral mask for a noncontiguous transmission using two 80 MHz channels where the center frequency of the two 80 MHz channels are separated by 160 MHz and the –40 dBr spectrum level is above –39 dBm/MHz(M25).

Different center frequency separation between the two 80 MHz frequency segments of the spectral mask as well as different peak levels of each 80 MHz frequency segment of the spectral mask are possible, in which case a similar procedure in determining the spectral mask as in Figure 21-33 (Example transmit spectral mask for 80+80 MHz mask PPDU) is followed.

The transmit spectral mask for noncontiguous transmissions using two nonadjacent 80 MHz channels is applicable only in regulatory domains that allow for such transmissions.

Measurements shall be made using a 100 kHz resolution bandwidth and a 30 kHz video bandwidth.

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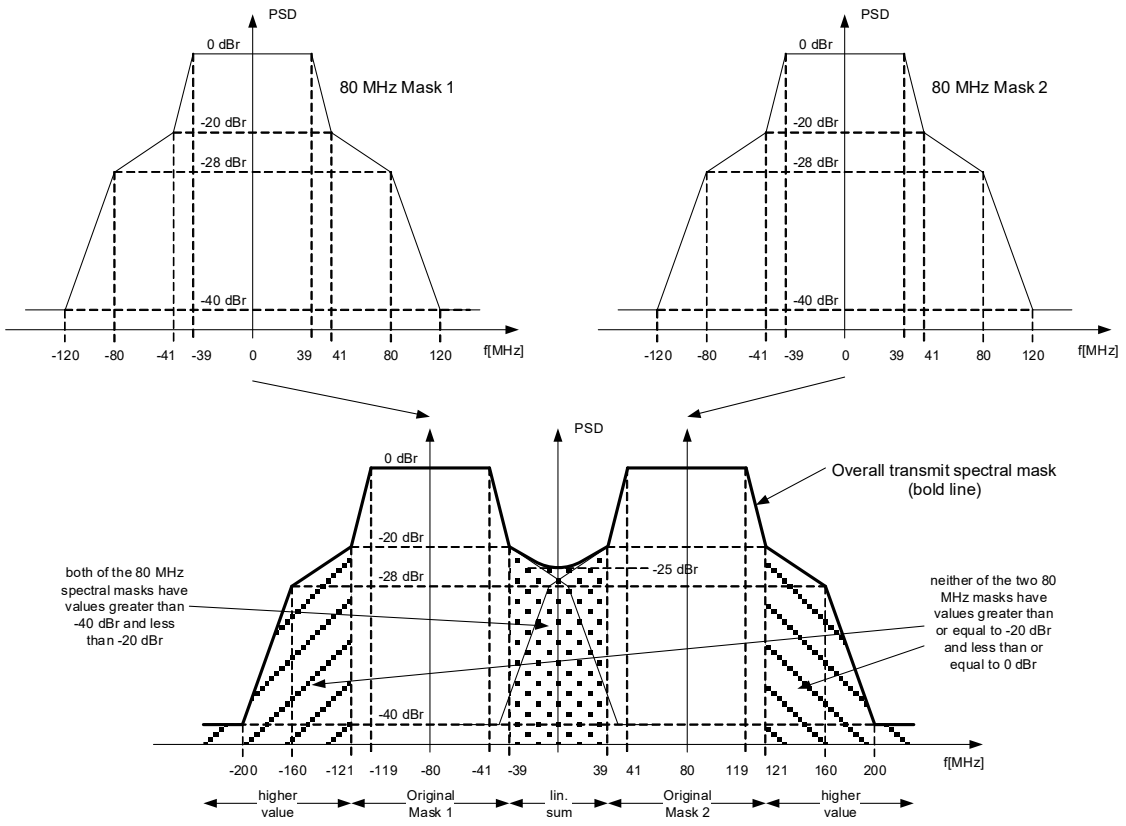


**Figure 21-33—Example transmit spectral mask for 80+80 MHz mask PPDU**

### 21.3.17.2 Spectral flatness

Spectral flatness measurements shall be conducted using BPSK modulated PPDUs. Demodulate the PPDUs according to the following (or equivalent) procedure:

a) Start of PPDU shall be detected.

b) Transition from L-STF to L-LTF shall be detected and fine timing shall be established.

c) Coarse and fine frequency offsets shall be estimated.

d) Symbols in a PPDU shall be derotated according to estimated frequency offset.

e) For each VHT-LTF symbol, transform the symbol into subcarrier received values, estimate the phase from the pilot subcarriers, and derotate the subcarrier values according to the estimated phase.

f) For each of the data OFDM symbols: transform the symbol into subcarrier received values.

The spectral flatness test shall be performed over at least 20 PPDUs. The PPDUs under test shall be at least 16 data OFDM symbols long.

Evaluate spectral flatness using the subcarrier received values or the magnitude of the channel estimation.

Let $E_{i,\,avg}$ denote the magnitude of the channel estimation on subcarrier $i$ or the average constellation energy of a BPSK modulated subcarrier $i$ in a VHT data symbol.

In a contiguous non-HT duplicate or VHT transmission having a bandwidth listed in Table 21-23 (Maximum transmit spectral flatness deviations), $E_{i,\,avg}$ of each of the subcarriers with indices listed as


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tested subcarrier indices shall not deviate by more than the specified maximum deviation in Table 21-23 (Maximum transmit spectral flatness deviations) from the average of $E_{i,\,avg}$ over subcarrier indices listed as averaging subcarrier indices. Averaging of $E_{i,\,avg}$ is done in the linear domain.

**Table 21-23—Maximum transmit spectral flatness deviations**

| Format | Bandwidth of transmission (MHz) | Averaging subcarrier indices | Tested subcarrier indices | Maximum deviation (dB) |
|---|---|---|---|---|
| VHT | 20 | –16 to –1 and +1 to +16 | –16 to –1 and +1 to +16 | ± 4 |
| | | | –28 to –17 and +17 to +28 | +4/–6 |
| | 40 | –42 to –2 and +2 to +42 | –42 to –2 and +2 to +42 | ± 4 |
| | | | –58 to –43 and +43 to +58 | +4/–6 |
| | 80 | –84 to –2 and +2 to +84 | –84 to –2 and +2 to +84 | ± 4 |
| | | | –122 to –85 and +85 to +122 | +4/–6 |
| | 160 | –172 to –130, –126 to –44, +44 to +126, and +130 to +172 | –172 to –130, –126 to –44, +44 to +126, and +130 to +172 | ± 4 |
| | | | –250 to –173, –43 to –6, +6 to +43, and +173 to +250 | +4/–6 |
| non-HT duplicate | 40 | –42 to –33, –31 to –6, +6 to +31, and +33 to +42 | –42 to –33, –31 to –6, +6 to +31, and +33 to +42 | ± 4 |
| | | | –43 to –58 and +43 to +58 | +4/–6 |
| | 80 | –84 to –70, –58 to –33, –31 to –6, +6 to +31, +33 to +58, +70 to +84 | –84 to –70,–58 to –33, –31 to –6, +6 to +31, +33 to +58, +70 to +84 | ± 4 |
| | | | –122 to –97, –95 to –85 and +85 to +95, +97 to +122 | +4/–6 |
| | 160 | –172 to –161, –159 to –134, –122 to –97, –95 to –70, –58 to –44, +44 to +58, +70 to +95, +97 to +122, +134 to +159, +161 to +172 | –172 to –161, –159 to –134, –122 to –97, –95 to –70, –58 to –44, +44 to +58, +70 to +95, +97 to +122, +134 to +159, +161 to +172 | ± 4 |
| | | | –250 to –225, –223 to –198, –186 to –173, –43 to –33, –31 to –6, +6 to +31, +33 to +43, +173 to +186, +198 to +223, +225 to +250 | +4/–6 |

In an 80+80 MHz transmission, each segment shall meet the spectral flatness requirement for an 80 MHz transmission.

For the spectral flatness test, the transmitting STA shall be configured to use a spatial mapping matrix $Q_k$ (see 21.3.10.11 (OFDM modulation)) with flat frequency response. Each output port under test of the transmitting STA shall be connected through a cable to one input port of the testing instrumentation. The requirements apply to 20 MHz, 40 MHz, 80 MHz, and 160 MHz contiguous transmissions as well as 80+80 MHz transmissions.

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#### 21.3.17.3 Transmit center frequency and symbol clock frequency tolerance

The symbol clock frequency and transmit center frequency tolerance shall be ± 20 ppm. The transmit center frequency and the symbol clock frequency for all transmit antennas and frequency segments shall be derived from the same reference oscillator. Transmit signals with the TXVECTOR parameter CH_BANDWIDTH set to CBW160 or CBW80+80 may be generated using two separate RF LOs, one for each of the lower and upper 80 MHz frequency portions.

NOTE—The signal phase of the two 80 MHz frequency portions might not be correlated.

#### 21.3.17.4 Modulation accuracy

##### 21.3.17.4.1 Introduction to modulation accuracy tests

Transmit modulation accuracy specifications are described in 21.3.17.4.2 (Transmit center frequency leakage) and 21.3.17.4.3 (Transmitter constellation error). The test method is described in 21.3.17.4.4 (Transmitter modulation accuracy (EVM) test).

##### 21.3.17.4.2 Transmit center frequency leakage

TX LO leakage shall meet the following requirements for all formats and bandwidths except 80+80 MHz where the RF LO falls outside both frequency segments:

— When the RF LO is in the center of the transmitted PPDU BW, the power measured at the center of transmission BW using resolution BW 312.5 kHz shall not exceed the maximum of the average power per-subcarrier of the transmitted PPDU and –20 dBm, or equivalently, $max(P - 10\log 10(N_{ST}), -20)$, where $P$ is the transmit power per antenna in dBm, and $N_{ST}$ is defined in Table 21-5 (Timing-related constants).

— When the RF LO is not at the center of the transmitted PPDU BW, the power measured at the location of the RF LO using resolution BW 312.5 kHz shall not exceed the maximum of –32 dB relative to the total transmit power and –20 dBm, or equivalently $max(P - 32, -20)$, where $P$ is the transmit power per antenna in dBm.

For an 80+80 MHz transmission where the RF LO falls outside both frequency segments, the RF LO shall follow the spectral mask requirements as defined in 21.3.17.1 (Transmit spectrum mask).

The transmit center frequency leakage is specified per antenna.

##### 21.3.17.4.3 Transmitter constellation error

The relative constellation RMS error, calculated by first averaging over subcarriers, frequency segments, VHT PPDUs, and spatial streams (#4181)(see Equation (19-89)) shall not exceed a data-rate dependent value according to Table 21-24 (Allowed relative constellation error versus constellation size and coding rate). The number of spatial streams under test shall be equal to the number of utilized transmitting STA antenna (output) ports and also equal to the number of utilized testing instrumentation input ports. In the test, $N_{SS} = N_{STS}$ (no STBC) shall be used and no beamforming steering matrix shall be used. Each output port of the transmitting STA shall be connected through a cable to one input port of the testing instrumentation. The requirements apply to 20 MHz, 40 MHz, 80 MHz, and 160 MHz contiguous transmissions as well as 80+80 MHz noncontiguous transmissions.

For non-HT duplicate transmissions, requirements defined in 17.3.9.7.4 (Transmitter constellation error) apply to each 20 MHz subchannel.


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**Table 21-24—Allowed relative constellation error versus constellation size and coding rate**

| Modulation | Coding rate | Relative constellation error (dB) |
|---|---|---|
| BPSK | 1/2 | –5 |
| QPSK | 1/2 | –10 |
| QPSK | 3/4 | –13 |
| 16-QAM | 1/2 | –16 |
| 16-QAM | 3/4 | –19 |
| 64-QAM | 2/3 | –22 |
| 64-QAM | 3/4 | –25 |
| 64-QAM | 5/6 | –27 |
| 256-QAM | 3/4 | –30 |
| 256-QAM | 5/6 | –32 |

#### 21.3.17.4.4 Transmitter modulation accuracy (EVM) test

The transmit modulation accuracy test shall be performed by instrumentation capable of converting the transmitted signals into a stream of complex samples at sampling rate greater than or equal to the bandwidth of the signal being transmitted; except that

— For non-HT duplicate transmissions, each 20 MHz subchannel may be tested independently while all subchannels are being transmitted and

— For noncontiguous transmissions, each frequency segment may be tested independently while both segments are being transmitted.

In this case, transmit modulation accuracy of each segment shall meet the required value in Table 21-24 (Allowed relative constellation error versus constellation size and coding rate) using only the subcarriers within the corresponding segment.

The instrument shall have sufficient accuracy in terms of I/Q arm amplitude and phase balance, DC offsets, phase noise, and analog to digital quantization noise. A possible embodiment of such a setup is converting the signals to a low IF frequency with a microwave synthesizer, sampling the signal with a digital oscilloscope and decomposing it digitally into quadrature components. The sampled signal shall be processed in a manner similar to an actual receiver, according to the following steps, or equivalent procedure:

a) Start of PPDU shall be detected.

b) Transition from L-STF to L-LTF shall be detected and fine timing shall be established.

c) Coarse and fine frequency offsets shall be estimated.

d) Symbols in a PPDU shall be derotated according to estimated frequency offset.

e) For each VHT-LTF symbol, transform the symbol into subcarrier received values, estimate the phase from the pilot subcarriers, and derotate the subcarrier values according to the estimated phase.

f) Estimate the complex channel response coefficient for each of the subcarriers and each of the transmit streams.

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g) For each of the data OFDM symbols: transform the symbol into subcarrier received values, estimate the phase from the pilot subcarriers, derotate the subcarrier values according to the estimated phase, group the results from all of the receiver chains in each subcarrier to a vector, and multiply the vector by a zero-forcing equalization matrix generated from the estimated channel.

h) For each data-carrying subcarrier in each spatial stream, find the closest constellation point and compute the Euclidean distance from it.

i) Compute the average across PPDUs of the RMS of all (#14)Data field errors per PPDU as given by Equation (19-89).

NOTE—In the case the transmit modulation accuracy test is performed simultaneously for the two frequency segments of the 80+80 MHz transmissions, $N_{ST}$ in Equation (19-89) represents the total number of subcarriers of both 80 MHz frequency segments.

The test shall be performed over at least 20 PPDUs [$N_f$ as defined in Equation (19-89)]. The PPDUs under test shall be at least 16 data OFDM symbols long. Random data shall be used for the symbols.

### 21.3.17.5 Time of Departure accuracy

(#8051)The RMS accuracy of the time of departure provided in TIME_OF_DEPARTURE shall be less than or equal to 80 ns.

The Time of Departure accuracy test evaluates TIME_OF_DEPARTURE against aTxPHYTxStartRMS and aTxPHYTxStartRMS against TIME_OF_DEPARTURE_ACCURACY_TEST_THRESH as defined in Annex P with the following test parameters:

— MULTICHANNEL_SAMPLING_RATE is

$20 \times 10^6\left(1 + \left\lceil \frac{f_H - f_L}{20\ \text{MHz}} \right\rceil\right)$ sample/s, for a CH_BANDWIDTH parameter equal to CBW20

$40 \times 10^6\left(1 + \left\lceil \frac{f_H - f_L}{40\ \text{MHz}} \right\rceil\right)$ sample/s, for a CH_BANDWIDTH parameter equal to CBW40

$80 \times 10^6\left(1 + \left\lceil \frac{f_H - f_L}{80\ \text{MHz}} \right\rceil\right)$ sample/s, for a CH_BANDWIDTH parameter equal to CBW80

$160 \times 10^6\left(1 + \left\lceil \frac{f_H - f_L}{160\ \text{MHz}} \right\rceil\right)$ sample/s, for a CH_BANDWIDTH parameter equal to CBW160 or CBW80+80

where

$f_H$ is the nominal center frequency in Hz of the highest channel in the channel set

$f_L$ is the nominal center frequency in Hz of the lowest channel in the channel set, the channel set is the set of channels upon which (#14)PPDUs providing measurements are transmitted, the channel set comprises channels uniformly spaced across $f_H - f_L \leq 50$ MHz

— FIRST_TRANSITION_FIELD is L-STF.

— SECOND_TRANSITION_FIELD is L-LTF.

— TRAINING_FIELD is L-LTF windowed in a manner which should approximate the windowing described in 17.3.2.5 (Mathematical conventions in the signal descriptions) with TTR = 100 ns.

— TIME_OF_DEPARTURE_ACCURACY_TEST_THRESH is 80 ns.

NOTE—The indicated windowing applies to the time of departure accuracy test equipment, and not the transmitter or receiver.


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### 21.3.18 VHT receiver specification

For tests in this subclause, the input levels are measured at the antenna connector and are referenced as the average power per receive antenna. (#98)For tests in 21.3.18.1 (Receiver minimum input level sensitivity(#256)), 21.3.18.2 (Adjacent channel rejection), and 21.3.18.3 (Nonadjacent channel rejection), the number of spatial streams under test shall be equal to the number of utilized transmitting STA antenna (output) ports and also equal to the number of utilized (#1768)receiving STA antenna (input) ports. Except where otherwise noted, each output port of the transmitting STA shall be connected through a cable to one input port of the (#1768)receiving STA.

#### 21.3.18.1 Receiver minimum input level sensitivity(#256)

The (#14)PER shall be less than 10% for a PSDU length of 4096 octets with the rate-dependent input levels listed in Table 21-25 (Receiver minimum input level sensitivity). The test in this subclause and the minimum sensitivity levels specified in Table 21-25 (Receiver minimum input level sensitivity) apply only to non-STBC modes, 800 ns GI, BCC, and VHT PPDUs.

**Table 21-25—Receiver minimum input level sensitivity**

| Modulation | Rate (R) | Minimum sensitivity (20 MHz PPDU) (dBm) | Minimum sensitivity (40 MHz PPDU) (dBm) | Minimum sensitivity (80 MHz PPDU) (dBm) | Minimum sensitivity (160 MHz or 80+80 MHz PPDU) (dBm) |
|---|---|---|---|---|---|
| BPSK | 1/2 | –82 | –79 | –76 | –73 |
| QPSK | 1/2 | –79 | –76 | –73 | –70 |
| QPSK | 3/4 | –77 | –74 | –71 | –68 |
| 16-QAM | 1/2 | –74 | –71 | –68 | –65 |
| 16-QAM | 3/4 | –70 | –67 | –64 | –61 |
| 64-QAM | 2/3 | –66 | –63 | –60 | –57 |
| 64-QAM | 3/4 | –65 | –62 | –59 | –56 |
| 64-QAM | 5/6 | –64 | –61 | –58 | –55 |
| 256-QAM | 3/4 | –59 | –56 | –53 | –50 |
| 256-QAM | 5/6 | –57 | –54 | –51 | –48 |

#### 21.3.18.2 Adjacent channel rejection

Adjacent channel rejection for *W* MHz channels (where *W* is 20, 40, 80 or 160) shall be measured by setting the desired signal's strength 3 dB above the rate-dependent sensitivity specified in Table 21-25 (Receiver minimum input level sensitivity) and raising the power of the interfering signal of *W* MHz bandwidth until 10% PER is caused for a PSDU length of 4096 octets. The difference in power between the signals in the interfering channel and the desired channel is the corresponding adjacent channel rejection. The center frequency of the adjacent channel shall be placed *W* MHz away from the center frequency of the desired signal.

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Adjacent channel rejection for 80+80 MHz channels shall be measured by setting the desired signal's strength 3 dB above the rate-dependent sensitivity specified in Table 21-25 (Receiver minimum input level sensitivity). Then, an interfering signal of 80 MHz bandwidth is introduced, where the center frequency of the interfering signal is placed 80 MHz away from the center frequency of the frequency segment lower in frequency of the desired signal. The power of the interfering signal is raised until 10% PER is caused for a PSDU length of 4096 octets. Let $\Delta P_1$ be the power difference between the interfering and desired signal. Next, the interfering signal of 80 MHz bandwidth is moved to a frequency where the center frequency of the interfering signal is 80 MHz away from the center frequency of the frequency segment higher in frequency of the desired signal. The power of the interfering signal is raised until 10% PER is caused for a PSDU length of 4096 octets. Let $\Delta P_2$ be the power difference between the interfering and desired signal. The smaller value between $\Delta P_1$ and $\Delta P_2$ is the corresponding adjacent channel rejection.

The interfering signal in the adjacent channel shall be a signal compliant with the VHT PHY, unsynchronized with the signal in the channel under test, and shall have a minimum duty cycle of 50%. The corresponding rejection shall be no less than specified in Table 21-26 (Minimum required adjacent and nonadjacent channel rejection levels).

The test in this subclause and the adjacent sensitivity levels specified in Table 21-26 (Minimum required adjacent and nonadjacent channel rejection levels) apply only to non-STBC modes, 800 ns GI, BCC, and VHT PPDUs.

**Table 21-26—Minimum required adjacent and nonadjacent channel rejection levels**

| Modulation | Rate (R) | Adjacent channel rejection (dB) | | Nonadjacent channel rejection (dB) | |
|---|---|---|---|---|---|
| | | 20/40/80/ 160 MHz Channel | 80+80 MHz Channel | 20/40/80/ 160 MHz Channel | 80+80 MHz Channel |
| BPSK | 1/2 | 16 | 13 | 32 | 29 |
| QPSK | 1/2 | 13 | 10 | 29 | 26 |
| QPSK | 3/4 | 11 | 8 | 27 | 24 |
| 16-QAM | 1/2 | 8 | 5 | 24 | 21 |
| 16-QAM | 3/4 | 4 | 1 | 20 | 17 |
| 64-QAM | 2/3 | 0 | –3 | 16 | 13 |
| 64-QAM | 3/4 | –1 | –4 | 15 | 12 |
| 64-QAM | 5/6 | –2 | –5 | 14 | 11 |
| 256-QAM | 3/4 | –7 | –10 | 9 | 6 |
| 256-QAM | 5/6 | –9 | –12 | 7 | 4 |

The measurement of adjacent channel rejection for 160 MHz operation in a regulatory domain is required only if such a frequency band plan is permitted in that regulatory domain.

### 21.3.18.3 Nonadjacent channel rejection

Nonadjacent channel rejection for *W* MHz channels (where *W* is 20, 40, 80, or 160) shall be measured by setting the desired signal's strength 3 dB above the rate-dependent sensitivity specified in Table 21-25


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(Receiver minimum input level sensitivity), and raising the power of the interfering signal of $W$ MHz bandwidth until a 10% PER occurs for a PSDU length of 4096 octets. The difference in power between the signals in the interfering channel and the desired channel is the corresponding nonadjacent channel rejection. The nonadjacent channel rejection shall be met with any nonadjacent channels located at least $2\times W$ MHz away from the center frequency of the desired signal.

Nonadjacent channel rejection for 80+80 MHz channels shall be measured by setting the desired signal's strength 3 dB above the rate-dependent sensitivity specified in Table 21-25 (Receiver minimum input level sensitivity). Then, an interfering signal of 80 MHz bandwidth is introduced, where the center frequency of the interfering signal is placed at least 160 MHz away from the center frequency of the frequency segment lower in frequency of the desired signal. The center frequency of the interfering signal shall also be at least 160 MHz away from the center frequency of the frequency segment higher in frequency of the desired signal. The power of the interfering signal is raised until 10% PER is caused for a PSDU length of 4096 octets. Let $\Delta P_1$ be the power difference between the interfering and desired signal. Next, the interfering signal of 80 MHz bandwidth is moved to a frequency where the center frequency of the interfering signal is at least 160 MHz away from the center frequency of the frequency segment higher in frequency of the desired signal. The center frequency of the interfering signal shall also be at least 160 MHz away from the center frequency of the frequency segment lower in frequency of the desired signal. The power of the interfering signal is raised until 10% PER is caused for a PSDU length of 4096 octets. Let $\Delta P_2$ be the difference in power between the signals in the interfering channel and the desired channel. The smaller value between $\Delta P_1$ and $\Delta P_2$ is the corresponding nonadjacent channel rejection.

The interfering signal in the nonadjacent channel shall be a signal compliant with the VHT PHY, unsynchronized with the signal in the channel under test, and shall have a minimum duty cycle of 50%. The corresponding rejection shall be no less than specified in Table 21-26 (Minimum required adjacent and nonadjacent channel rejection levels).

The test in this subclause and the nonadjacent sensitivity levels specified in Table 21-26 (Minimum required adjacent and nonadjacent channel rejection levels) apply only to non-STBC modes, 800 ns GI, BCC, and VHT PPDUs.

The measurement of nonadjacent channel rejection for 160 MHz operation in a regulatory domain is required only if such a frequency band plan is permitted in that regulatory domain.

#### 21.3.18.4 Receiver maximum input level

The receiver shall provide a maximum PER of 10% at a PSDU length of 4096 octets, for a maximum input level of –30 dBm, measured at each antenna for any baseband VHT modulation.

#### 21.3.18.5 CCA sensitivity

#### 21.3.18.5.1 General

The thresholds in this subclause are compared with the signal level at each receiving antenna.

#### 21.3.18.5.2 CCA sensitivity for operating classes requiring CCA-OCSED(#2365)

For the operating classes requiring CCA-Operating Class Specific Energy Detect (CCA-OCSED), the PHY shall also indicate a medium busy condition when CCA-OCSED detects a channel busy condition.

For improved spectrum sharing, CCA-OCSED is required in some bands. The behavior class indicating CCA-OCSED is given in Table D-2 (Behavior limits). The operating classes requiring the corresponding CCA-OCSED behavior class are given in E.1 (Country information and operating classes). The PHY of a STA that is operating within an operating class that requires CCA-OCSED shall operate with CCA-OCSED.

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CCA-OCSED shall detect a channel busy condition when the received signal strength exceeds the CCA-OCSED threshold as given by dot11OFDMEDThreshold for the primary 20 MHz channel, dot11OFDMEDThreshold for the secondary 20 MHz channel (if present), dot11OFDMEDThreshold + 3 dB for the secondary 40 MHz channel (if present), and dot11OFDMEDThreshold + 6 dB for the secondary 80 MHz channel (if present). The CCA-OCSED thresholds for the operating classes requiring CCA-OCSED are subject to the criteria in D.2.5 (CCA-OCSED threshold(#2365)).

NOTE—The requirement to detect a channel busy condition as stated in 21.3.18.5.3 (CCA sensitivity for signals occupying the primary 20 MHz channel) and 21.3.18.5.4 (CCA sensitivity for signals not occupying the primary 20 MHz channel) is a mandatory energy detect requirement on all Clause 21 (Very high throughput (VHT) PHY specification) receivers. Support for CCA-OCSED is an additional requirement that relates specifically to the sensitivities described in D.2.5 (CCA-OCSED threshold(#2365)).

### 21.3.18.5.3 CCA sensitivity for signals occupying the primary 20 MHz channel

A VHT STA with a *W* MHz operating channel width shall detect, with >90% probability, the start of a PPDU that occupies at least the primary 20 MHz channel in an otherwise idle *W* MHz operating channel width, and issue a PHY-CCA.indication(BUSY, {primary}) primitive within a period of aCCATime (see 21.4.4 (VHT PHY)) if one of the following conditions is met:

- The start of a non-HT PPDU as defined in 17.3.10.6 (CCA requirements).
- The start of an HT PPDU as defined in 19.3.19.6 (CCA sensitivity).
- The start of a non-HT duplicate or VHT PPDU for which the power measured within the primary 20 MHz channel is or above –82 dBm.

The CCA signal shall be held busy (PHY-CCA.indication(BUSY, {primary}) primitive) for the duration of the PPDU.

The receiver shall issue a PHY-CCA.indication(BUSY, {primary}) primitive for any signal that exceeds a threshold equal to 20 dB above the minimum modulation and coding rate sensitivity (–82 + 20 = –62 dBm) in the primary 20 MHz channel within a period of aCCATime after the signal arrives at the receiver's antenna(s); then the receiver shall not issue a PHY-CCA.indication(BUSY,{secondary}), PHY-CCA.indication(BUSY,{secondary40}), PHY-CCA.indication(BUSY,{secondary80}), or PHY-CCA.indication(IDLE) primitive while the threshold continues to be exceeded.

### 21.3.18.5.4 CCA sensitivity for signals not occupying the primary 20 MHz channel

The PHY shall issue a PHY-CCA.indication(BUSY, {secondary}) primitive if the conditions for issuing PHY-CCA.indication(BUSY, {primary}) primitive are not present and one of the following conditions are present in an otherwise idle 40 MHz, 80 MHz, 160 MHz, or 80+80 MHz operating channel width:

- Any signal within the secondary 20 MHz channel at or above a threshold of –62 dBm within a period of aCCATime after the signal arrives at the receiver's antenna(s); then the PHY shall not issue a PHY-CCA.indication(BUSY,{secondary40}), PHY-CCA.indication(BUSY,{secondary80}), or PHY-CCA.indication(IDLE) primitive while the threshold continues to be exceeded.
- A 20 MHz (#2095)non-HT, HT-mixed format, HT-greenfield format or VHT PPDU detected in the secondary 20 MHz channel at or above –72 dBm with >90% probability within a period aCCAMidTime (see 21.4.4 (VHT PHY)).

The PHY shall issue a PHY-CCA.indication(BUSY, {secondary40}) primitive if the conditions for issuing a PHY-CCA.indication(BUSY, {primary}) and PHY-CCA.indication(BUSY, {secondary}) primitive are not present and one of the following conditions are present in an otherwise idle 80 MHz, 160 MHz, or 80+80 MHz operating channel width:

- Any signal within the secondary 40 MHz channel at or above a threshold of –59 dBm within a period of aCCATime after the signal arrives at the receiver's antenna(s); then the PHY shall not issue a


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PHY-CCA.indication(BUSY, {secondary80}) primitive or PHY-CCA.indication(IDLE) primitive while the threshold continues to be exceeded.

— A 40 MHz (#2095)non-HT duplicate, HT-mixed format, HT-greenfield format or VHT PPDU detected in the secondary 40 MHz channel at or above –72 dBm with >90% probability within a period aCCAMidTime (see 21.4.4 (VHT PHY)).

— A 20 MHz (#2095)non-HT, HT-mixed format, HT-greenfield format or VHT PPDU detected in any 20 MHz subchannel of the secondary 40 MHz channel at or above –72 dBm with >90% probability within a period aCCAMidTime.

The PHY shall issue a PHY-CCA.indication(BUSY, {secondary80}) primitive if the conditions for PHYCCA.indication(BUSY, {primary}), PHY-CCA.indication(BUSY, {secondary}), and PHY-CCA.indication(BUSY, {secondary40}) primitive are not present and one of the following conditions are present in an otherwise idle 160 MHz or 80+80 MHz operating channel width:

— Any signal within the secondary 80 MHz channel at or above –56 dBm.

— An 80 MHz non-HT duplicate or VHT PPDU detected in the secondary 80 MHz channel at or above –69 dBm with >90% probability within a period aCCAMidTime (see 21.4.4 (VHT PHY)).

— A 40 MHz (#2095)non-HT duplicate, HT-mixed format, HT-greenfield format or VHT PPDU detected in any 40 MHz subchannel of the secondary 80 MHz channel at or above –72 dBm with >90% probability within a period aCCAMidTime.

— A 20 MHz (#2095)non-HT, HT-mixed format, HT-greenfield format or VHT PPDU detected in any 20 MHz subchannel of the secondary 80 MHz channel at or above –72 dBm with >90% probability within a period aCCAMidTime.

#### 21.3.18.6 RSSI

The RSSI parameter returned in the RXVECTOR shall be calculated during the reception of the VHT-LTFs and shall be a monotonically increasing function of the received power.

#### 21.3.18.7 Received channel power indicator (RCPI) measurement(#2011)

The RCPI is a measure of the received RF power in the selected channel for a received PPDU. This parameter shall be a measurement by the PHY of the received RF power in the channel measured over the VHT-STF or VHT-LTF field of the received PPDU. The received power shall be the average of the power in all active receive chains.

RCPI shall equal the received RF power in dBm within an accuracy of ± 5 dB (95% confidence interval) within the specified dynamic range of the receiver.

### 21.3.19 PHY transmit procedure

There are two paths for the transmit PHY procedure:

— The first path, for which typical transmit procedures are shown in Figure 21-34 (PHY transmit procedure for SU transmission), is selected if the FORMAT parameter of the PHY-TXSTART.request(TXVECTOR) primitive is VHT. These transmit procedures do not describe the operation of optional features, such as LDPC, STBC or MU.

— The second path is to follow the transmit procedure in Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) if the FORMAT parameter of the PHY-TXSTART.request(TXVECTOR) primitive is NON_HT and the NON_HT_MODULATION parameter is set to NON_HT_DUP_OFDM except that the signal referred to in Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) is instead generated simultaneously on each of the 20 MHz channels that are indicated by the CH_BANDWIDTH parameter as defined in 21.3.8 (VHT preamble) and 21.3.10.12 (Non-HT duplicate transmission).

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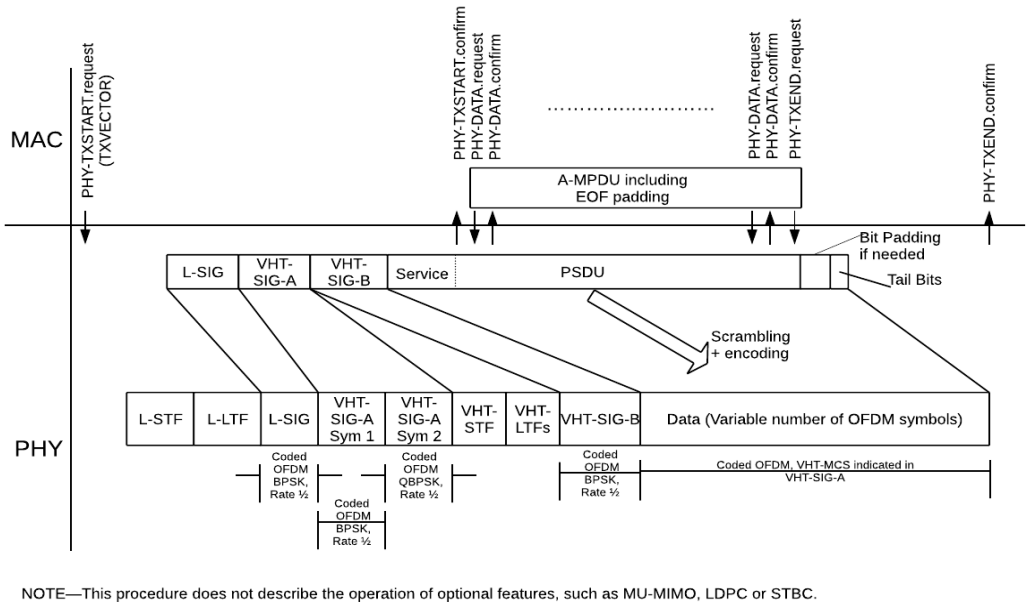


NOTE—This procedure does not describe the operation of optional features, such as MU-MIMO, LDPC or STBC.

**Figure 21-34—PHY transmit procedure for SU transmission**

NOTE 1—For a VHT MU PPDU the A-MPDU is per user in the MAC sublayer and the VHT-STF, VHT-LTFs, VHT-SIG-B, and Data are per user in the PHY in Figure 21-34 (PHY transmit procedure for SU transmission), with the number of VHT-LTF symbols depending on the total number of space-time streams across all users.

NOTE 2—The transmit procedure for NON_HT format where NON_HT_MODULATION is OFDM is specified in 21.2.5.2 (Support for NON_HT format when NON_HT_MODULATION is OFDM). The transmit procedure for (#2095)HT-mixed and HT-greenfield formats is specified in 21.2.5.3 (Support for HT formats).

In both paths, in order to transmit data, the MAC generates a PHY-TXSTART.request primitive, which causes the PHY entity to enter the transmit state. Further, the PHY is set to operate at the appropriate frequency through station management via the PLME, as specified in 21.4 (VHT PLME). Other transmit parameters, such as VHT-MCS Coding types and transmit power, are set via the PHY SAP using the PHY-TXSTART.request(TXVECTOR) primitive, as described in 21.2.2 (TXVECTOR and RXVECTOR parameters). The remainder of the clause applies to the first path.

The PHY indicates the state of the primary channel and other channels (if any) via the PHY-CCA.indication primitive (see 21.3.18.5 (CCA sensitivity) and 8.3.5.12 (PHY-CCA.indication)). Transmission of the PPDU shall be initiated by the PHY after receiving the PHY-TXSTART.request(TXVECTOR) primitive. The TXVECTOR elements for the PHY-TXSTART.request primitive are specified in Table 21-1 (TXVECTOR and RXVECTOR parameters(#12)).

Transmission of the PHY preamble may start if TIME_OF_DEPARTURE_REQUESTED is false, and shall start immediately if TIME_OF_DEPARTURE_REQUESTED is true, based on the parameters passed in the PHY-TXSTART.request primitive.

If all of the following conditions are met:

— If dot11TODImplemented and dot11TODActivated are true or if dot11TimingMsmtActivated is true,

— The TXVECTOR parameter TIME_OF_DEPARTURE_REQUESTED is true,


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then the PHY shall issue a PHY-TXSTART.confirm primitive to the MAC, forwarding the TIME_OF_DEPARTURE corresponding to the time when the first (#14)PPDU energy is sent by the transmitting port and TIME_OF_DEPARTURE_ClockRate parameter within the TXSTATUS. If dot11TimingMsmtActivated is true, then the PHY shall forward the value of TX_START_OF_FRAME_OFFSET in the TXSTATUS.

After the PHY preamble transmission is started, the PHY entity immediately initiates data scrambling and data encoding. The encoding method for the Data field is based on the FEC_CODING, CH_BANDWIDTH, NUM_STS, STBC, MCS, and NUM_USERS parameter of the TXVECTOR, as described in 21.3.2 (VHT PPDU format).

The SERVICE field and PSDU are encoded as described in 21.3.3 (Transmitter block diagram). The data shall be exchanged between the MAC and the PHY through a series of PHY-DATA.request(DATA) primitives issued by the MAC, and PHY-DATA.confirm primitives issued by the PHY. Zero to seven PHY padding bits are appended to the PSDU to make the number of bits in the coded PSDU an integer multiple of the number of coded bits per OFDM symbol.

Transmission can be prematurely terminated by the MAC through the PHY-TXEND.request primitive. PSDU transmission is terminated by receiving a PHY-TXEND.request primitive. Each PHY-TXEND.request primitive is acknowledged with a PHY-TXEND.confirm primitive from the PHY. In an SU transmission, normal termination occurs after the transmission of the final bit of the last PSDU octet, according to the number of OFDM symbols indicated by $N_{SYM}$ (see 21.4.3 (TXTIME and PSDU_LENGTH calculation)).

In the PHY, the GI or short GI is inserted in every data OFDM symbol as a countermeasure against delay spread.

When the PPDU transmission is completed the PHY entity enters the receive state.

A typical state machine implementation of the transmit PHY for an SU transmission is provided in Figure 21-35 (PHY transmit state machine for SU transmission(#14)). Request (.request) and confirmation (.confirm) primitives are issued once per state as shown. This state machine does not describe the operation of optional features, such as multi-user, LDPC or STBC. If the TXVECTOR parameter FORMAT is equal to NON_HT, refer to the transmit procedure and state machine in 17.3.11 (Transmit PHY). If the TXVECTOR parameter FORMAT is equal to HT_MF or HT_GF, refer to the transmit procedure and state machine in 19.3.20 (PHY transmit procedure).

### 21.3.20 PHY receive procedure

A typical PHY receive procedure is shown in Figure 21-36 (PHY receive procedure for SU transmission(#3038)(#4122)) for VHT format. A typical state machine implementation of the receive PHY is given in Figure 21-37 (PHY receive state machine(#18)(#1934)(#3038)(#6467)). This receive procedure and state machine do not describe the operation of optional features, such as LDPC or STBC. If the detected format indicates (#2095)a non-HT PPDU(#238) (denoted “Not VHT-SIG-A” in Figure 21-37 (PHY receive state machine(#18)(#1934)(#3038)(#6467))), refer to the receive procedure and state machine in 17.3.12 (Receive PHY). If the detected format indicates an HT PPDU format (denoted “HT_SIG (HT GF preamble)” and “HT_SIG (HT MF preamble)” in Figure 21-37 (PHY receive state machine(#18)(#1934)(#3038)(#6467))), refer to the receive procedure and state machine in 19.3.21 (PHY receive procedure). Further, through station management (via the PLME) the PHY is set to the appropriate frequency, as specified in 21.4 (VHT PLME). The PHY has also been configured with group information (i.e., group membership and position in group) so that it can receive data intended for the STA. Other receive parameters, such as RSSI and indicated DATARATE, may be accessed via the PHY SAP.

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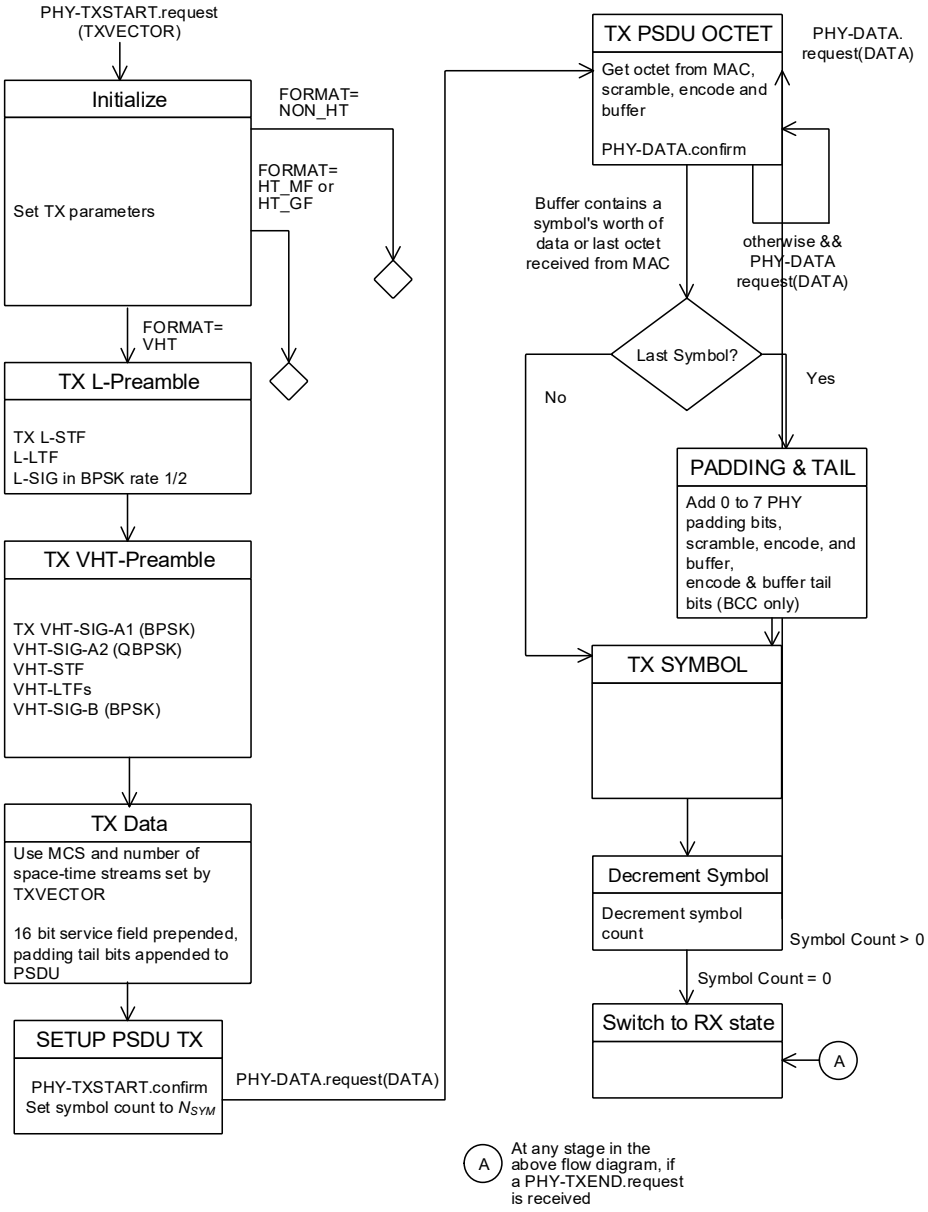


NOTE—This state machine does not describe the operation of optional features, such as MU-MIMO, LDPC or STBC.

**Figure 21-35—PHY transmit state machine for SU transmission(#14)**

Upon receiving the transmitted PHY preamble overlapping the primary 20 MHz channel, the PHY measures a receive signal strength. The PHY indicates this activity to the MAC by issuing a PHY-CCA.indication primitive. A PHY-CCA.indication(BUSY, channel-list) primitive is also issued as an initial indication of reception of a signal as specified in 21.3.18.5 (CCA sensitivity). The channel-list parameter of the PHY-CCA.indication primitive is absent when the operating channel width is 20 MHz. The channel-list parameter


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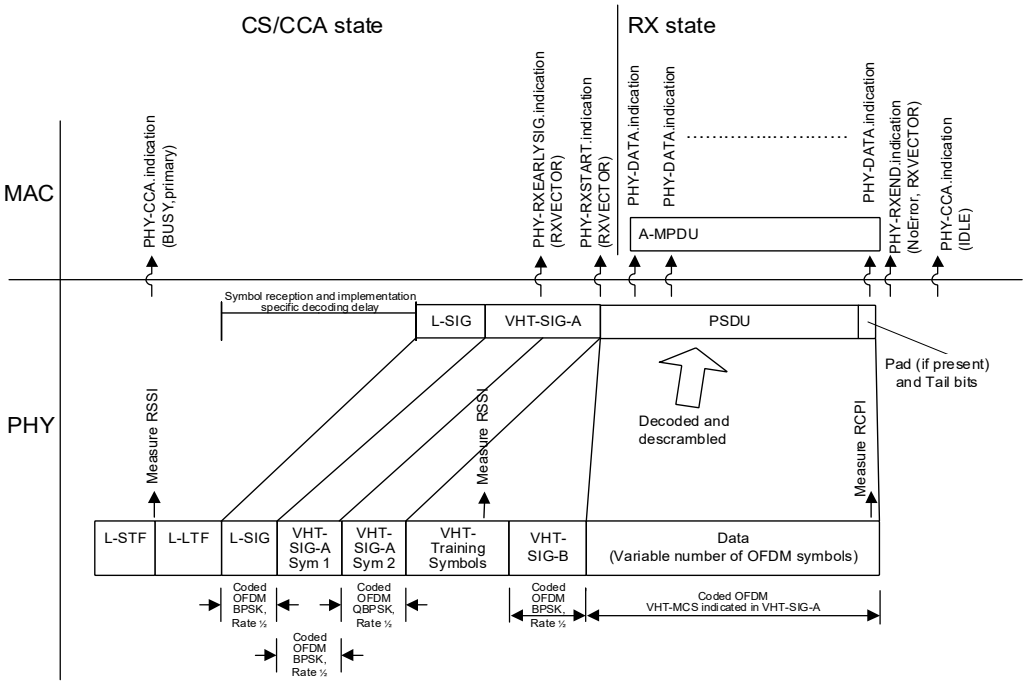


NOTE—This procedure does not describe the operation of optional features, such as LDPC or STBC. This procedure describes the case where VHT-SIG-A indicates a mode not requiring decoding of VHT-SIG-B.

**Figure 21-36—PHY receive procedure for SU transmission(#3038)(#4122)**

is present and includes the entry primary when the operating channel width is 40 MHz, 80 MHz, 160 MHz, or 80+80 MHz.

The PHY shall not issue a PHY-RXSTART.indication primitive in response to a PPDU that does not overlap the primary 20 MHz channel.

The PHY includes the most recently measured RSSI value in the PHY-RXSTART.indication(RXVECTOR) primitive issued to the MAC.

After the PHY-CCA.indication(BUSY, channel-list) primitive is issued, the PHY entity shall begin receiving the training symbols and searching for L-SIG in order to set the duration of the PPDU(#2056).

(#1062)For an HE STA that determines it is receiving a VHT PPDU, the STA's receive procedure shall resume here. Existing state, including knowledge of the L-SIG Parity and RATE checks, is retained.

(#3038)If a valid L-SIG parity bit is indicated, the RATE field indicates 6 Mbps, the L-SIG field indicates at least six OFDM symbols after the L-SIG field, and the first OFDM symbol after the L-LTF field is using BPSK modulation, then the PHY entity shall issue a PHY-RXEARLYSIG.indication primitive.

(#3038)If the check of the L-SIG parity bit is not valid or the RATE field is an undefined value(#18), neither a PHY-RXEARLYSIG.indication nor a PHY-RXSTART.indication primitive is issued, and instead the PHY shall issue the error condition PHY-RXEND.indication(FormatViolation) primitive. If a valid L-SIG parity bit is indicated,(#18) the RATE field indicates 6 Mb/s(#1144), the L-SIG field indicates at least (#1052)six OFDM symbols after the L-SIG field (i.e., the L-SIG LENGTH is at least 13 octets at 6 Mb/s), the first two OFDM symbols after the L-LTF field are using BPSK modulation, and the third OFDM symbol

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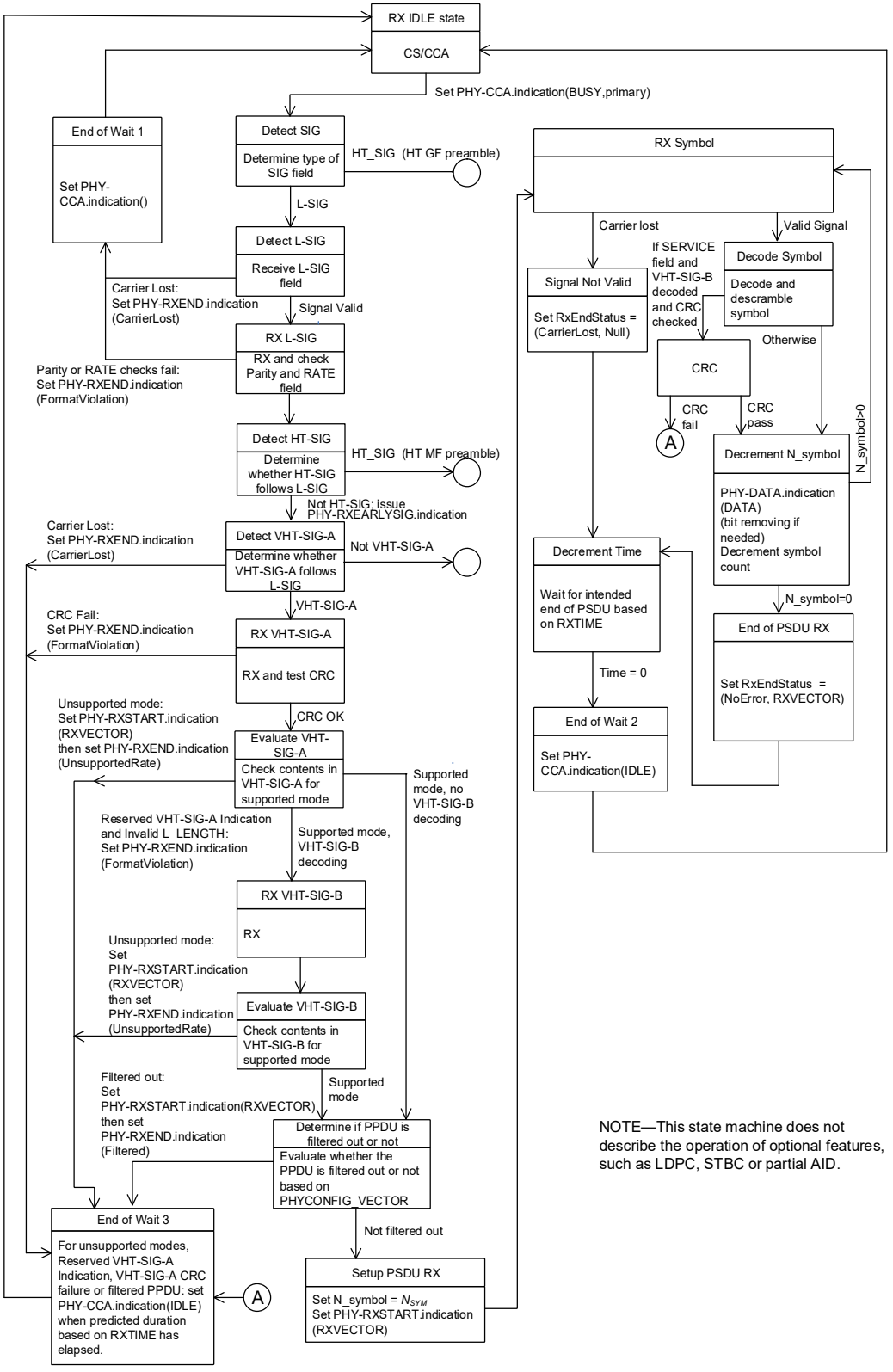


**Figure 21-37—PHY receive state machine(#18)(#1934)(#3038)(#6467)**



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after the L-LTF field is using QBPSK modulation, then the VHT PHY shall maintain PHY-CCA.indication(BUSY, channel-list) primitive for the predicted duration of the transmitted PPDU, as defined by RXTIME in Equation (21-105), for all supported modes, unsupported modes, Reserved VHT-SIG-A Indication, invalid VHT-SIG-A CRC and invalid L-SIG Length field value. The L-SIG Length field value of a VHT PPDU is invalid if it is not divisible by 3. Reserved VHT-SIG-A Indication is defined as a VHT-SIG-A with Reserved bits equal to 0 or MU[$u$] NSTS fields ($u$ = 0, 1, 2, 3) set to 5-7 or Short GI field set to 0 and Short GI NSYM Disambiguation field set to 1, or a combination of VHT-MCS and $N_{STS}$ not included in 21.5 (Parameters for VHT-MCSs) or any other VHT-SIG-A field bit combinations that do not correspond to modes of PHY operation defined in Clause 21 (Very high throughput (VHT) PHY specification). If the VHT-SIG-A indicates an unsupported mode, the PHY shall issue a PHY-RXEND.indication(UnsupportedRate) primitive. If the VHT-SIG-A indicates an invalid CRC or Reserved VHT-SIG-A Indication or if the L-SIG Length field is invalid, the PHY shall issue the error condition PHY-RXEND.indication(FormatViolation) primitive.

After receiving a valid L-SIG and VHT-SIG-A indicating a supported mode, the PHY entity shall begin receiving the VHT-STF, VHT-LTFs and VHT-SIG-B. If the received group ID in VHT-SIG-A has a value indicating a VHT SU PPDU (see 10.19 (Group ID and partial AID in VHT and CMMG PPDUs)), the PHY entity may choose not to decode VHT-SIG-B. If VHT-SIG-B is not decoded, subsequent to an indication of a valid VHT-SIG-A CRC, a PHY-RXSTART.indication(RXVECTOR) primitive shall be issued.

Subsequently, if dot11TimingMsmtActivated is true, a PHY-RXSTART.indication(RXVECTOR) primitive shall be issued and RX_START_OF_FRAME_OFFSET parameter within the RXVECTOR shall be forwarded (see 20.2.2 (TXVECTOR and RXVECTOR parameters)).

NOTE—The RX_START_OF_FRAME_OFFSET value is used (#3049)to estimate when the start of the preamble for the incoming (#14)PPDU was detected on the medium at the receive antenna connector.

The RXVECTOR associated with this primitive includes the parameters specified in Table 21-1 (TXVECTOR and RXVECTOR parameters(#12)).

If the Group ID field in VHT-SIG-A has a value indicating a VHT MU PPDU (see 10.19 (Group ID and partial AID in VHT and CMMG PPDUs)), the PHY, in a STA that is MU beamformee capable, shall decode VHT-SIG-B. If the VHT-SIG-B indicates an unsupported mode, the PHY shall issue the error condition PHY-RXEND.indication(UnsupportedRate) primitive.

If VHT-SIG-B was decoded the PHY may check the VHT-SIG-B CRC in the SERVICE field. If the VHT-SIG-B CRC in the SERVICE field is not checked a PHY-RXSTART.indication(RXVECTOR) primitive shall be issued. The RXVECTOR associated with this primitive includes the parameters specified in Table 21-1 (TXVECTOR and RXVECTOR parameters(#12)).

The PHY optionally filters out the PPDU based on the GroupID, MU[0-3] NSTS and Partial AID fields of VHT-SIG-A and the contents of the PHYCONFIG_VECTOR as follows:

- The PHY shall not filter out the PPDU if one of the following is true:
  - ($g$ = 0) and ($l_{00}$ is true) and (*partialaid* is included in PARTIAL_AID_LIST_GID00)
  - ($g$ = 63) and ($l_{63}$ is true) and (*partialaid* is included in PARTIAL_AID_LIST_GID63)
  - ($1 \le g \le 62$) and (MembershipStatusInGroupID[$g$] = 1) and ($n_{STS}$[UserPositionInGroupID[$g$]] > 0)
- where
  - $l_{NN}$ is the one of the LISTEN_TO_GID*NN* parameters of the PHYCONFIG_VECTOR
  - MembershipStatusInGroupID[$g$] is the Membership Status Array field of the GROUP_ID_MANAGEMENT parameter of the PHYCONFIG_VECTOR for group $g$

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- $g$ is the value of the GroupID field of VHT-SIG-A
- $n_{STS}[u]$ is the value of the MU[$u$] NSTS field of VHT-SIG-A
- UserPositionInGroupID[$g$] is the User Position Array field of the GROUP_ID_MANAGEMENT parameter of the PHYCONFIG_VECTOR for group $g$
- *partialaid* is the value of the Partial AID field of VHT-SIG-A

— Otherwise, the PHY may filter out the PPDU.

If the PPDU is filtered out, the PHY shall issue a PHY-RXEND.indication(Filtered) primitive.

Following training and signal fields, the Data field shall be received. The number of symbols in the Data field is determined by Equation (21-104).

$$N_{SYM} = \begin{cases} N'_{SYM} - 1, \text{ if Short GI = 1 and Short GI NSYM Disambiguation = 1} \\ N'_{SYM}, \text{ otherwise} \end{cases} \quad (21\text{-}104)$$

where

$$N'_{SYM} = \left\lfloor \frac{\text{RXTIME} - \left( \begin{array}{l} T_{\text{L-STF}} + T_{\text{L-LTF}} + T_{\text{L-SIG}} + T_{\text{VHT-SIG-A}} + \\ \quad T_{\text{VHT-STF}} + N_{VHT\text{-}LTF} T_{\text{VHT-LTF}} + T_{\text{VHT-SIG-B}} \end{array} \right)}{T_{SYM}} \right\rfloor$$

$$\text{RXTIME}(\mu s) = \left\lceil \frac{\text{LENGTH} + 3}{3} \right\rceil \cdot 4 + 20 \quad (21\text{-}105)$$

where LENGTH is the LENGTH field in L-SIG.

The value of the PSDU_LENGTH parameter returned in the RXVECTOR using BCC encoding is calculated using Equation (21-106).

$$\text{PSDU\_LENGTH} = \left\lfloor \frac{N_{SYM} N_{DBPS} - N_{service} - N_{tail} \cdot N_{ES}}{8} \right\rfloor \quad (21\text{-}106)$$

For a VHT SU PPDU, the SU/MU[0] Coding field of VHT-SIG-A2 indicates the type of coding. The PHY entity shall use an LDPC decoder to decode the C-PSDU if this bit is 1; otherwise, BCC decoding shall be used. For an MU transmission, the SU/MU[0] Coding, MU[1] Coding, MU[2] Coding and MU[3] Coding fields of VHT-SIG-A2 indicate the type of coding for user $u$ with USER_POSITION[$u$] = 0, 1, 2, and 3, respectively. The PHY entity shall use an LDPC decoder to decode the C-PSDU for the respective user if its bit for its C-PSDU is 1. BCC decoding shall be used otherwise. When an LDPC decoder is to be used, $N_{SYM,init}$ is obtained from Equation (21-107).

$$N_{SYM,init} = \begin{cases} N_{SYM,init}, \text{ if LDPC Extra OFDM Symbol = 0} \\ N_{SYM,init} - 1, \text{ if LDPC Extra OFDM Symbol = 1 and STBC = 0} \\ N_{SYM,init} - 2, \text{ if LDPC Extra OFDM Symbol = 1 and STBC = 1} \end{cases} \quad (21\text{-}107)$$

where

LDPC Extra OFDM Symbol and STBC are fields in VHT-SIG-A (see Table 21-12 (Fields in the VHT-SIG-A field))

The value of the PSDU_LENGTH parameter returned in the RXVECTOR using LDPC encoding is calculated using Equation (21-108).


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$$\text{PSDU\_LENGTH} = \left\lfloor \frac{N_{SYM,init} N_{DBPS} - N_{service}}{8} \right\rfloor \quad (21\text{-}108)$$

The value of the PSDU_LENGTH parameter returned in the RXVECTOR for an NDP is 0.

If VHT-SIG-B is decoded and the VHT-SIG-B CRC in the SERVICE field is checked and not valid, the PHY shall issue the error condition PHY-RXEND.indication(FormatViolation) primitive. If the VHT-SIG-B field is decoded and the VHT-SIG-B CRC field is checked and valid, a PHY-RXSTART.indication(RXVECTOR) primitive shall be issued. The RXVECTOR associated with this primitive includes the parameters specified in Table 21-1 (TXVECTOR and RXVECTOR parameters(#12)).

If signal loss occurs during reception prior to completion of the PSDU reception, the error condition shall be reported to the MAC using a PHY-RXEND.indication(CarrierLost) primitive. After waiting for the intended end of the PSDU as determined by Equation (21-105), the PHY shall generate a PHY-CCA.indication(IDLE) primitive and return to RX IDLE state.

The received PSDU bits are assembled into octets, decoded, and presented to the MAC using a series of PHY-DATA.indication(DATA) primitive exchanges. Any final bits that cannot be assembled into a complete octet are considered pad bits and discarded. After the reception of the final bit of the last PSDU octet, and possible padding and tail bits, the receiver shall be returned to the RX IDLE state, as shown in Figure 21-37 (PHY receive state machine(#18)(#1934)(#3038)(#6467)). A PHY-RXEND.indication(NoError) primitive shall be issued on entry to the RX IDLE state.

## 21.4 VHT PLME

### 21.4.1 PLME SAP layer management primitives(#6320)

Table 21-27 (VHT PHY MIB attributes) lists the MIB attributes that may be accessed by the PHY entities and the intralayer of higher level LMEs. These attributes are accessed via the PLME-GET, PLME-SET, PLME-RESET, and PLME-CHARACTERISTICS primitives defined in 6.7 (PLME SAP interface).

**Table 21-27—VHT PHY MIB attributes**

| Managed object | Default value/ range | Operational semantics |
|---|---|---|
| **dot11PHYOperationTable** | | |
| dot11PHYType | vht(9) | Static |
| **dot11PHYTxPowerTable** | | |
| dot11NumberSupportedPowerLevelsImplemented | Implementation dependent | Static |
| dot11TxPowerLevel1 | Implementation dependent | Static |
| dot11TxPowerLevel2 | Implementation dependent | Static |
| dot11TxPowerLevel3 | Implementation dependent | Static |

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**Table 21-27—VHT PHY MIB attributes *(continued)***

| Managed object | Default value/ range | Operational semantics |
|---|---|---|
| dot11TxPowerLevel4 | Implementation dependent | Static |
| dot11TxPowerLevel5 | Implementation dependent | Static |
| dot11TxPowerLevel6 | Implementation dependent | Static |
| dot11TxPowerLevel7 | Implementation dependent | Static |
| dot11TxPowerLevel8 | Implementation dependent | Static |
| dot11CurrentTxPowerLevel | Implementation dependent | Static |
| dot11TxPowerLevelExtended | Implementation dependent | Static |
| dot11CurrentTxPowerLevelExtended | Implementation dependent | Static |
| **dot11PHYHTTable** | | |
| dot11CurrentPrimaryChannel | Implementation dependent | Dynamic |
| dot11CurrentSecondaryChannel | Implementation dependent | Dynamic |
| dot11FortyMHzOperationImplemented | false/Boolean | Static |
| dot11FortyMHzOperationActivated | false/Boolean | Dynamic |
| dot11NumberOfSpatialStreamsImplemented | Implementation dependent | Static |
| dot11NumberOfSpatialStreamsActivated | Implementation dependent | Dynamic |
| dot11HTGreenfieldOptionImplemented | false/Boolean | Static |
| dot11HTGreenfieldOptionActivated | false/Boolean | Dynamic |
| dot11ShortGIOptionInTwentyImplemented | false/Boolean | Static |
| dot11ShortGIOptionInTwentyActivated | false/Boolean | Dynamic |
| dot11ShortGIOptionInFortyImplemented | false/Boolean | Static |
| dot11ShortGIOptionInFortyActivated | false/Boolean | Dynamic |
| dot11LDPCCodingOptionImplemented | false/Boolean | Static |
| dot11LDPCCodingOptionActivated | false/Boolean | Dynamic |
| dot11TxSTBCOptionImplemented | false/Boolean | Static |
| dot11TxSTBCOptionActivated | false/Boolean | Dynamic |
| dot11RxSTBCOptionImplemented | false/Boolean | Static |


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**Table 21-27—VHT PHY MIB attributes *(continued)***

| Managed object | Default value/ range | Operational semantics |
|---|---|---|
| dot11RxSTBCOptionActivated | false/Boolean | Dynamic |
| dot11BeamFormingOptionImplemented | false/Boolean | Static |
| dot11BeamFormingOptionActivated | false/Boolean | Dynamic |
| **dot11PHYVHTTable** | | |
| dot11CurrentChannelWidth | Implementation dependent | Dynamic |
| dot11CurrentChannelCenterFrequencyIndex0 | Implementation dependent | Dynamic |
| dot11CurrentChannelCenterFrequencyIndex1 | Implementation dependent | Dynamic |
| dot11VHTChannelWidthOptionImplemented | Implementation dependent | Static |
| dot11VHTShortGIOptionIn80Implemented | false/Boolean | Static |
| dot11VHTShortGIOptionIn80Activated | false/Boolean | Dynamic |
| dot11VHTShortGIOptionIn160and80p80Implemented | false/Boolean | Static |
| dot11VHTShortGIOptionIn160and80p80Activated | false/Boolean | Dynamic |
| dot11VHTLDPCCodingOptionImplemented | false/Boolean | Static |
| dot11VHTLDPCCodingOptionActivated | false/Boolean | Dynamic |
| dot11VHTTxSTBCOptionImplemented | false/Boolean | Static |
| dot11VHTTxSTBCOptionActivated | false/Boolean | Dynamic |
| dot11VHTRxSTBCOptionImplemented | false/Boolean | Static |
| dot11VHTRxSTBCOptionActivated | false/Boolean | Dynamic |
| dot11VHTMaxNTxChainsImplemented | Implementation dependent | Static |
| dot11VHTMaxNTxChainsActivated | Implementation dependent | Dynamic |
| **dot11TransmitBeamformingConfigTable** | | |
| dot11ReceiveStaggerSoundingOptionImplemented | false/Boolean | Static |
| dot11TransmitStaggerSoundingOptionImplemented | false/Boolean | Static |
| dot11ReceiveNDPOptionImplemented | false/Boolean | Static |
| dot11TransmitNDPOptionImplemented | false/Boolean | Static |
| dot11ImplicitTransmitBeamformingOptionImplemented | false/Boolean | Static |
| dot11CalibrationOptionImplemented | Implementation dependent | Static |
| dot11ExplicitCSITransmitBeamformingOptionImplemented | false/Boolean | Static |

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**Table 21-27—VHT PHY MIB attributes *(continued)***

| Managed object | Default value/ range | Operational semantics |
|---|---|---|
| dot11ExplicitNonCompressedBeamformingMatrixOptionImplemented | false/Boolean | Static |
| dot11ExplicitTransmitBeamformingCSIFeedbackOptionImplemented | Implementation dependent | Static |
| dot11ExplicitNoncompressedBeamformingFeedbackOptionImplemented | Implementation dependent | Static |
| dot11ExplicitCompressedBeamformingFeedbackOptionImplemented | Implementation dependent | Static |
| dot11NumberBeamFormingCSISupportAntenna | Implementation dependent | Static |
| dot11NumberNonCompressedBeamformingMatrixSupportAntenna | Implementation dependent | Static |
| dot11NumberCompressedBeamformingMatrixSupportAntenna | Implementation dependent | Static |
| **dot11VHTTransmitBeamformingConfigTable** | | |
| dot11VHTSUBeamformeeOptionImplemented | false/Boolean | Static |
| dot11VHTSUBeamformerOptionImplemented | false/Boolean | Static |
| dot11VHTMUBeamformeeOptionImplemented | false/Boolean | Static |
| dot11VHTMUBeamformerOptionImplemented | false/Boolean | Static |
| dot11VHTNumberSoundingDimensions | Implementation dependent | Static |
| dot11VHTBeamformeeNTxSupport | Implementation dependent | Static |
| (#4284)dot11VHTMaxNstsTotal | Implementation dependent | Static |

### 21.4.2 PHY MIB

VHT PHY MIB attributes are defined in Annex C with specific values defined in Table 21-27 (VHT PHY MIB attributes). The (#4177)Operational semantics column in Table 21-27 (VHT PHY MIB attributes) contains two types: static and dynamic.

— Static MIB attributes are fixed and cannot be modified for a given PHY implementation.

— Dynamic MIB attributes are interpreted according to the MAX-ACCESS field of the MIB attribute.

When MAX-ACCESS is read-only, the MIB attribute value may be updated by the PLME and read from the MIB attribute by management entities. When MAX-ACCESS is read-write, the MIB attribute may be read and written by management entities but shall not be updated by the PLME.

### 21.4.3 TXTIME and PSDU_LENGTH calculation

The value of the TXTIME parameter returned by the PLME-TXTIME.confirm primitive shall be calculated for a VHT PPDU using Equation (21-109) for short GI and Equation (21-110) for long GI.


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$$\text{TXTIME} = T_{\text{LEG\_PREAMBLE}} + T_{\text{L-SIG}} + T_{\text{VHT-SIG-A}} + T_{\text{VHT\_PREAMBLE}} + T_{\text{VHT-SIG-B}} + T_{SYML} \times \left\lceil \frac{T_{SYMS} \times N_{SYM}}{T_{SYML}} \right\rceil \quad (21\text{-}109)$$

$$\text{TXTIME} = T_{\text{LEG\_PREAMBLE}} + T_{\text{L-SIG}} + T_{\text{VHT-SIG-A}} + T_{\text{VHT\_PREAMBLE}} + T_{\text{VHT-SIG-B}} + T_{SYML} \times N_{SYM} \quad (21\text{-}110)$$

where

$T_{\text{LEG\_PREAMBLE}} = T_{\text{L-STF}} + T_{\text{L-LTF}}$

$T_{\text{VHT\_PREAMBLE}} = T_{\text{VHT-STF}} + N_{VHT\text{-}LTF} T_{\text{VHT-LTF}}$

$T_{SYML}$, $T_{SYMS}$, $T_{\text{L-SIG}}$, $T_{\text{VHT-SIG-A}}$, $T_{\text{VHT-SIG-B}}$, $T_{\text{L-STF}}$, $T_{\text{VHT-STF}}$, $T_{\text{L-LTF}}$, and $T_{\text{VHT-LTF}}$ (#89)are defined in Table 21-5 (Timing-related constants)

$N_{VHT\text{-}LTF}$ is defined in Table 21-13 (Number of VHT-LTFs required for different numbers of space-time streams)

For an NDP, there is no Data field and $N_{SYM} = 0$.

For a VHT SU PPDU using BCC encoding, the total number of data symbols in the Data field is given by Equation (21-111).

$$N_{SYM} = m_{\text{STBC}} \times \left\lceil \frac{8 \cdot \text{APEP\_LENGTH} + N_{service} + N_{tail} \cdot N_{ES}}{m_{\text{STBC}} \cdot N_{DBPS}} \right\rceil \quad (21\text{-}111)$$

where

$m_{\text{STBC}}$ is equal to 2 when STBC is used, and 1 otherwise

For a VHT SU PPDU using LDPC encoding, the total number of data symbols in the Data field, $N_{SYM}$, is given in 21.3.10.5.4 (LDPC coding) (computed using Equation (19-41) in step d) of 19.3.11.7.5 (LDPC PPDU encoding process)).

For a VHT MU PPDU, the total number of data symbols in the Data field, $N_{SYM}$, is given by Equation (21-67).

The value of the PSDU_LENGTH parameter returned in the PLME-TXTIME.confirm primitive for a VHT SU PPDU using BCC encoding is calculated using Equation (21-112).

$$\text{PSDU\_LENGTH} = \left\lfloor \frac{N_{SYM} N_{DBPS} - N_{service} - N_{tail} \cdot N_{ES}}{8} \right\rfloor \quad (21\text{-}112)$$

The value of the PSDU_LENGTH parameter returned in the PLME-TXTIME.confirm primitive for a VHT SU PPDU using LDPC encoding is calculated using Equation (21-113).

$$\text{PSDU\_LENGTH} = \left\lfloor \frac{N_{SYM,init} N_{DBPS} - N_{service}}{8} \right\rfloor \quad (21\text{-}113)$$

where

$N_{SYM,init}$ is given by Equation (21-62)

The value of the PSDU_LENGTH parameter for user $u$ returned in the PLME-TXTIME.confirm primitive and in the RXVECTOR for a VHT MU PPDU is calculated using Equation (21-114).

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$$\text{PSDU\_LENGTH}_u = \begin{cases} \left\lfloor \dfrac{N_{SYM} N_{DBPS,u} - N_{service} - N_{tail} \cdot N_{ES,u}}{8} \right\rfloor & \text{when BCC is used for user } u \\ \left\lfloor \dfrac{N_{\text{SYM\_max\_init}} N_{DBPS,u} - N_{service}}{8} \right\rfloor & \text{when LDPC is used for user } u \end{cases} \quad (21\text{-}114)$$

where

$N_{SYM}$ is given by Equation (21-67)

$N_{\text{SYM\_max\_init}}$ is given by Equation (21-65)

The value of the PSDU_LENGTH parameter returned in the PLME-TXTIME.confirm primitive for an NDP is 0.

### 21.4.4 VHT PHY

(#2123)The VHT PHY characteristics, provided through the PLME-CHARACTERISTICS service primitive, are shown in Table 19-25 (HT PHY characteristics) unless otherwise listed in Table 21-28 (VHT PHY characteristics). The definitions for these characteristics are given in 6.7.4 (PLME-CHARACTERISTICS.confirm).

**Table 21-28—VHT PHY characteristics**

| Characteristics | Value |
|---|---|
| aCCAMidTime | 25 µs |
| aPPDUMaxTime | 5.484 ms |
| aPSDUMaxLength | (#3166)4 692 478 octets (see NOTE 1) |
| aRxPHYStartDelay | (#3038)24 µs (see NOTE 2) |
| aAPEPMaxLengthVHTMU20 | 262 140 octets (see NOTE 3) |
| aAPEPMaxLengthVHTMU40 | 524 284 octets (see NOTE 3) |
| aAPEPMaxLengthVHTMU80orMore | 2 097 148 octets (see NOTE 3 and NOTE 4) |

NOTE 1—This is the maximum length in octets for a VHT SU PPDU with a bandwidth of 160 MHz or 80+80 MHz, VHT-MCS 9, and 8 spatial streams, and limited by 1504 possible Short GI data symbols in aPPDUMaxTime. This is the maximum PSDU length a VHT PHY could support assuming no restrictions in MAC. See (#2369)10.12.2 (A-MPDU length limit rules) and 9.2.4.8.1 (General) for additional restrictions on the maximum number of octets the MAC could support.

NOTE 2—This value arises from the time to the end of (#3038)when the HT_MF PPDU format is excluded, which is at the end of the first OFDM symbol after the L-SIG field (see Figure 21-4 (VHT PPDU format)).

NOTE 3—This value is derived inversely from Equation (21-46) using corresponding VHT-SIG-B Length in Table 21-14 (Fields in the VHT-SIG-B field).

NOTE 4—This value is larger than the constraint by the Maximum A-MPDU Length Exponent of 7 and the maximum A-MPDU length is(M118) limited by the Maximum A-MPDU Length Exponent (see 10.12.2 (A-MPDU length limit rules) and 10.13 (PPDU duration constraint)).


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## 21.5 Parameters for VHT-MCSs

The rate-dependent parameters for 20 MHz, 40 MHz, 80 MHz, 160 MHz, and 80+80 MHz $N_{SS}$ = 1, …, 8 are given in Table 21-29 (VHT-MCSs for mandatory 20 MHz, NSS = 1) to Table 21-60 (VHT-MCSs for optional 160 MHz and 80+80 MHz, NSS = 8). Support for 400 ns GI is optional in all cases. Support for VHT-MCS 8 and 9 (when valid) is optional in all cases. A VHT STA shall support single spatial stream VHT-MCSs within the range VHT-MCS 0 to VHT-MCS 7 for all channel widths for which it has indicated support regardless of the Tx or Rx Highest Supported Long GI Data Rate subfield values in the Supported VHT-MCS and NSS Set field. When more than one spatial stream is supported, the Tx or Rx Highest Supported Long GI Data Rate subfield values in the Supported VHT-MCS and NSS Set field may result in a reduced VHT-MCS range (cut-off) for $N_{SS}$ = 2, …, 8 . Support for 20 MHz, 40 MHz, and 80 MHz with $N_{SS}$ = 1 is mandatory. Support for 20 MHz, 40 MHz, and 80 MHz with $N_{SS}$ = 2, …, 8 is optional. Support for 160 MHz and 80+80 MHz with $N_{SS}$ = 1, …, 8 is optional. $N_{ES}$ values were chosen to yield an integer number of punctured blocks for each BCC encoder per OFDM symbol.

Table 21-29 (VHT-MCSs for mandatory 20 MHz, NSS = 1) to Table 21-32 (VHT-MCSs for optional 20 MHz, NSS = 4), Table 21-37 (VHT-MCSs for mandatory 40 MHz, NSS = 1) to Table 21-40 (VHT-MCSs for optional 40 MHz, NSS = 4), Table 21-45 (VHT-MCSs for mandatory 80 MHz, NSS = 1) to Table 21-48 (VHT-MCSs for optional 80 MHz, NSS = 4), and Table 21-53 (VHT-MCSs for optional 160 MHz and 80+80 MHz, NSS = 1) to Table 21-56 (VHT-MCSs for optional 160 MHz and 80+80 MHz, NSS = 4) define VHT-MCSs not only for SU transmission but also for user *u* of MU transmission. In the case of VHT-MCSs for MU transmission, the parameters, $N_{SS}$, $R$, $N_{BPSCS}$, $N_{CBPS}$, $N_{DBPS}$, and $N_{ES}$ are replaced with $N_{SS,u}$, $R_u$, $N_{BPSCS,u}$, $N_{CBPS,u}$, $N_{DBPS,u}$, and $N_{ES,u}$, respectively. Note that the 400 ns GI rate values are rounded to 1 decimal place.

**Table 21-29—VHT-MCSs for mandatory 20 MHz, $N_{SS}$ = 1**

| VHT-MCS Index | Modulation | $R$ | $N_{BPSCS}$ | $N_{SD}$ | $N_{SP}$ | $N_{CBPS}$ | $N_{DBPS}$ | $N_{ES}$ | Data rate (Mb/s) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | 800 ns GI | 400 ns GI (see NOTE) |
| 0 | BPSK | 1/2 | 1 | 52 | 4 | 52 | 26 | 1 | 6.5 | 7.2 |
| 1 | QPSK | 1/2 | 2 | 52 | 4 | 104 | 52 | 1 | 13.0 | 14.4 |
| 2 | QPSK | 3/4 | 2 | 52 | 4 | 104 | 78 | 1 | 19.5 | 21.7 |
| 3 | 16-QAM | 1/2 | 4 | 52 | 4 | 208 | 104 | 1 | 26.0 | 28.9 |
| 4 | 16-QAM | 3/4 | 4 | 52 | 4 | 208 | 156 | 1 | 39.0 | 43.3 |
| 5 | 64-QAM | 2/3 | 6 | 52 | 4 | 312 | 208 | 1 | 52.0 | 57.8 |
| 6 | 64-QAM | 3/4 | 6 | 52 | 4 | 312 | 234 | 1 | 58.5 | 65.0 |
| 7 | 64-QAM | 5/6 | 6 | 52 | 4 | 312 | 260 | 1 | 65.0 | 72.2 |
| 8 | 256-QAM | 3/4 | 8 | 52 | 4 | 416 | 312 | 1 | 78.0 | 86.7 |
| 9 | Not valid | | | | | | | | | |

NOTE—Support of 400 ns GI is optional on transmit and receive.

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**Table 21-30—VHT-MCSs for optional 20 MHz, $N_{SS}$ = 2**

| VHT-MCS Index | Modulation | *R* | $N_{BPSCS}$ | $N_{SD}$ | $N_{SP}$ | $N_{CBPS}$ | $N_{DBPS}$ | $N_{ES}$ | Data rate (Mb/s) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | 800 ns GI | 400 ns GI |
| 0 | BPSK | 1/2 | 1 | 52 | 4 | 104 | 52 | 1 | 13.0 | 14.4 |
| 1 | QPSK | 1/2 | 2 | 52 | 4 | 208 | 104 | 1 | 26.0 | 28.9 |
| 2 | QPSK | 3/4 | 2 | 52 | 4 | 208 | 156 | 1 | 39.0 | 43.3 |
| 3 | 16-QAM | 1/2 | 4 | 52 | 4 | 416 | 208 | 1 | 52.0 | 57.8 |
| 4 | 16-QAM | 3/4 | 4 | 52 | 4 | 416 | 312 | 1 | 78.0 | 86.7 |
| 5 | 64-QAM | 2/3 | 6 | 52 | 4 | 624 | 416 | 1 | 104.0 | 115.6 |
| 6 | 64-QAM | 3/4 | 6 | 52 | 4 | 624 | 468 | 1 | 117.0 | 130.0 |
| 7 | 64-QAM | 5/6 | 6 | 52 | 4 | 624 | 520 | 1 | 130.0 | 144.4 |
| 8 | 256-QAM | 3/4 | 8 | 52 | 4 | 832 | 624 | 1 | 156.0 | 173.3 |
| 9 | Not valid | | | | | | | | | |

**Table 21-31—VHT-MCSs for optional 20 MHz, $N_{SS}$ = 3**

| VHT-MCS Index | Modulation | *R* | $N_{BPSCS}$ | $N_{SD}$ | $N_{SP}$ | $N_{CBPS}$ | $N_{DBPS}$ | $N_{ES}$ | Data rate (Mb/s) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | 800 ns GI | 400 ns GI |
| 0 | BPSK | 1/2 | 1 | 52 | 4 | 156 | 78 | 1 | 19.5 | 21.7 |
| 1 | QPSK | 1/2 | 2 | 52 | 4 | 312 | 156 | 1 | 39.0 | 43.3 |
| 2 | QPSK | 3/4 | 2 | 52 | 4 | 312 | 234 | 1 | 58.5 | 65.0 |
| 3 | 16-QAM | 1/2 | 4 | 52 | 4 | 624 | 312 | 1 | 78.0 | 86.7 |
| 4 | 16-QAM | 3/4 | 4 | 52 | 4 | 624 | 468 | 1 | 117.0 | 130.0 |
| 5 | 64-QAM | 2/3 | 6 | 52 | 4 | 936 | 624 | 1 | 156.0 | 173.3 |
| 6 | 64-QAM | 3/4 | 6 | 52 | 4 | 936 | 702 | 1 | 175.5 | 195.0 |
| 7 | 64-QAM | 5/6 | 6 | 52 | 4 | 936 | 780 | 1 | 195.0 | 216.7 |
| 8 | 256-QAM | 3/4 | 8 | 52 | 4 | 1248 | 936 | 1 | 234.0 | 260.0 |
| 9 | 256-QAM | 5/6 | 8 | 52 | 4 | 1248 | 1040 | 1 | 260.0 | 288.9 |


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**Table 21-32—VHT-MCSs for optional 20 MHz, $N_{SS}$ = 4**

| VHT-MCS Index | Modulation | $R$ | $N_{BPSCS}$ | $N_{SD}$ | $N_{SP}$ | $N_{CBPS}$ | $N_{DBPS}$ | $N_{ES}$ | Data rate (Mb/s) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | 800 ns GI | 400 ns GI |
| 0 | BPSK | 1/2 | 1 | 52 | 4 | 208 | 104 | 1 | 26.0 | 28.9 |
| 1 | QPSK | 1/2 | 2 | 52 | 4 | 416 | 208 | 1 | 52.0 | 57.8 |
| 2 | QPSK | 3/4 | 2 | 52 | 4 | 416 | 312 | 1 | 78.0 | 86.7 |
| 3 | 16-QAM | 1/2 | 4 | 52 | 4 | 832 | 416 | 1 | 104.0 | 115.6 |
| 4 | 16-QAM | 3/4 | 4 | 52 | 4 | 832 | 624 | 1 | 156.0 | 173.3 |
| 5 | 64-QAM | 2/3 | 6 | 52 | 4 | 1248 | 832 | 1 | 208.0 | 231.1 |
| 6 | 64-QAM | 3/4 | 6 | 52 | 4 | 1248 | 936 | 1 | 234.0 | 260.0 |
| 7 | 64-QAM | 5/6 | 6 | 52 | 4 | 1248 | 1040 | 1 | 260.0 | 288.9 |
| 8 | 256-QAM | 3/4 | 8 | 52 | 4 | 1664 | 1248 | 1 | 312.0 | 346.7 |
| 9 | Not valid | | | | | | | | | |

**Table 21-33—VHT-MCSs for optional 20 MHz, $N_{SS}$ = 5**

| VHT-MCS Index | Modulation | $R$ | $N_{BPSCS}$ | $N_{SD}$ | $N_{SP}$ | $N_{CBPS}$ | $N_{DBPS}$ | $N_{ES}$ | Data rate (Mb/s) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | 800 ns GI | 400 ns GI |
| 0 | BPSK | 1/2 | 1 | 52 | 4 | 260 | 130 | 1 | 32.5 | 36.1 |
| 1 | QPSK | 1/2 | 2 | 52 | 4 | 520 | 260 | 1 | 65.0 | 72.2 |
| 2 | QPSK | 3/4 | 2 | 52 | 4 | 520 | 390 | 1 | 97.5 | 108.3 |
| 3 | 16-QAM | 1/2 | 4 | 52 | 4 | 1040 | 520 | 1 | 130.0 | 144.4 |
| 4 | 16-QAM | 3/4 | 4 | 52 | 4 | 1040 | 780 | 1 | 195.0 | 216.7 |
| 5 | 64-QAM | 2/3 | 6 | 52 | 4 | 1560 | 1040 | 1 | 260.0 | 288.9 |
| 6 | 64-QAM | 3/4 | 6 | 52 | 4 | 1560 | 1170 | 1 | 292.5 | 325.0 |
| 7 | 64-QAM | 5/6 | 6 | 52 | 4 | 1560 | 1300 | 1 | 325.0 | 361.1 |
| 8 | 256-QAM | 3/4 | 8 | 52 | 4 | 2080 | 1560 | 1 | 390.0 | 433.3 |
| 9 | Not valid | | | | | | | | | |

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**Table 21-34—VHT-MCSs for optional 20 MHz, $N_{SS}$ = 6**

| VHT-MCS Index | Modulation | *R* | $N_{BPSCS}$ | $N_{SD}$ | $N_{SP}$ | $N_{CBPS}$ | $N_{DBPS}$ | $N_{ES}$ | Data rate (Mb/s) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | 800 ns GI | 400 ns GI |
| 0 | BPSK | 1/2 | 1 | 52 | 4 | 312 | 156 | 1 | 39.0 | 43.3 |
| 1 | QPSK | 1/2 | 2 | 52 | 4 | 624 | 312 | 1 | 78.0 | 86.7 |
| 2 | QPSK | 3/4 | 2 | 52 | 4 | 624 | 468 | 1 | 117.0 | 130.0 |
| 3 | 16-QAM | 1/2 | 4 | 52 | 4 | 1248 | 624 | 1 | 156.0 | 173.3 |
| 4 | 16-QAM | 3/4 | 4 | 52 | 4 | 1248 | 936 | 1 | 234.0 | 260.0 |
| 5 | 64-QAM | 2/3 | 6 | 52 | 4 | 1872 | 1248 | 1 | 312.0 | 346.7 |
| 6 | 64-QAM | 3/4 | 6 | 52 | 4 | 1872 | 1404 | 1 | 351.0 | 390.0 |
| 7 | 64-QAM | 5/6 | 6 | 52 | 4 | 1872 | 1560 | 1 | 390.0 | 433.3 |
| 8 | 256-QAM | 3/4 | 8 | 52 | 4 | 2496 | 1872 | 1 | 468.0 | 520.0 |
| 9 | 256-QAM | 5/6 | 8 | 52 | 4 | 2496 | 2080 | 1 | 520.0 | 577.8 |

**Table 21-35—VHT-MCSs for optional 20 MHz, $N_{SS}$ = 7**

| VHT-MCS Index | Modulation | *R* | $N_{BPSCS}$ | $N_{SD}$ | $N_{SP}$ | $N_{CBPS}$ | $N_{DBPS}$ | $N_{ES}$ | Data rate (Mb/s) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | 800 ns GI | 400 ns GI |
| 0 | BPSK | 1/2 | 1 | 52 | 4 | 364 | 182 | 1 | 45.5 | 50.6 |
| 1 | QPSK | 1/2 | 2 | 52 | 4 | 728 | 364 | 1 | 91.0 | 101.1 |
| 2 | QPSK | 3/4 | 2 | 52 | 4 | 728 | 546 | 1 | 136.5 | 151.7 |
| 3 | 16-QAM | 1/2 | 4 | 52 | 4 | 1456 | 728 | 1 | 182.0 | 202.2 |
| 4 | 16-QAM | 3/4 | 4 | 52 | 4 | 1456 | 1092 | 1 | 273.0 | 303.3 |
| 5 | 64-QAM | 2/3 | 6 | 52 | 4 | 2184 | 1456 | 1 | 364.0 | 404.4 |
| 6 | 64-QAM | 3/4 | 6 | 52 | 4 | 2184 | 1638 | 1 | 409.5 | 455.0 |
| 7 | 64-QAM | 5/6 | 6 | 52 | 4 | 2184 | 1820 | 1 | 455.0 | 505.6 |
| 8 | 256-QAM | 3/4 | 8 | 52 | 4 | 2912 | 2184 | 2 | 546.0 | 606.7 |
| 9 | Not valid | | | | | | | | | |



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**Table 21-36—VHT-MCSs for optional 20 MHz, $N_{SS}$ = 8**

| VHT-MCS Index | Modulation | *R* | $N_{BPSCS}$ | $N_{SD}$ | $N_{SP}$ | $N_{CBPS}$ | $N_{DBPS}$ | $N_{ES}$ | Data rate (Mb/s) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | 800 ns GI | 400 ns GI |
| 0 | BPSK | 1/2 | 1 | 52 | 4 | 416 | 208 | 1 | 52.0 | 57.8 |
| 1 | QPSK | 1/2 | 2 | 52 | 4 | 832 | 416 | 1 | 104.0 | 115.6 |
| 2 | QPSK | 3/4 | 2 | 52 | 4 | 832 | 624 | 1 | 156.0 | 173.3 |
| 3 | 16-QAM | 1/2 | 4 | 52 | 4 | 1664 | 832 | 1 | 208.0 | 231.1 |
| 4 | 16-QAM | 3/4 | 4 | 52 | 4 | 1664 | 1248 | 1 | 312.0 | 346.7 |
| 5 | 64-QAM | 2/3 | 6 | 52 | 4 | 2496 | 1664 | 1 | 416.0 | 462.2 |
| 6 | 64-QAM | 3/4 | 6 | 52 | 4 | 2496 | 1872 | 1 | 468.0 | 520.0 |
| 7 | 64-QAM | 5/6 | 6 | 52 | 4 | 2496 | 2080 | 1 | 520.0 | 577.8 |
| 8 | 256-QAM | 3/4 | 8 | 52 | 4 | 3328 | 2496 | 2 | 624.0 | 693.3 |
| 9 | Not valid | | | | | | | | | |

**Table 21-37—VHT-MCSs for mandatory 40 MHz, $N_{SS}$ = 1**

| VHT-MCS Index | Modulation | *R* | $N_{BPSCS}$ | $N_{SD}$ | $N_{SP}$ | $N_{CBPS}$ | $N_{DBPS}$ | $N_{ES}$ | Data rate (Mb/s) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | 800 ns GI | 400 ns GI (See NOTE) |
| 0 | BPSK | 1/2 | 1 | 108 | 6 | 108 | 54 | 1 | 13.5 | 15.0 |
| 1 | QPSK | 1/2 | 2 | 108 | 6 | 216 | 108 | 1 | 27.0 | 30.0 |
| 2 | QPSK | 3/4 | 2 | 108 | 6 | 216 | 162 | 1 | 40.5 | 45.0 |
| 3 | 16-QAM | 1/2 | 4 | 108 | 6 | 432 | 216 | 1 | 54.0 | 60.0 |
| 4 | 16-QAM | 3/4 | 4 | 108 | 6 | 432 | 324 | 1 | 81.0 | 90.0 |
| 5 | 64-QAM | 2/3 | 6 | 108 | 6 | 648 | 432 | 1 | 108.0 | 120.0 |
| 6 | 64-QAM | 3/4 | 6 | 108 | 6 | 648 | 486 | 1 | 121.5 | 135.0 |
| 7 | 64-QAM | 5/6 | 6 | 108 | 6 | 648 | 540 | 1 | 135.0 | 150.0 |
| 8 | 256-QAM | 3/4 | 8 | 108 | 6 | 864 | 648 | 1 | 162.0 | 180.0 |
| 9 | 256-QAM | 5/6 | 8 | 108 | 6 | 864 | 720 | 1 | 180.0 | 200.0 |

NOTE—Support of 400 ns GI is optional on transmit and receive.

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**Table 21-38—VHT-MCSs for optional 40 MHz, $N_{SS}$ = 2**

| VHT-MCS Index | Modulation | *R* | $N_{BPSCS}$ | $N_{SD}$ | $N_{SP}$ | $N_{CBPS}$ | $N_{DBPS}$ | $N_{ES}$ | Data rate (Mb/s) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | 800 ns GI | 400 ns GI |
| 0 | BPSK | 1/2 | 1 | 108 | 6 | 216 | 108 | 1 | 27.0 | 30.0 |
| 1 | QPSK | 1/2 | 2 | 108 | 6 | 432 | 216 | 1 | 54.0 | 60.0 |
| 2 | QPSK | 3/4 | 2 | 108 | 6 | 432 | 324 | 1 | 81.0 | 90.0 |
| 3 | 16-QAM | 1/2 | 4 | 108 | 6 | 864 | 432 | 1 | 108.0 | 120.0 |
| 4 | 16-QAM | 3/4 | 4 | 108 | 6 | 864 | 648 | 1 | 162.0 | 180.0 |
| 5 | 64-QAM | 2/3 | 6 | 108 | 6 | 1296 | 864 | 1 | 216.0 | 240.0 |
| 6 | 64-QAM | 3/4 | 6 | 108 | 6 | 1296 | 972 | 1 | 243.0 | 270.0 |
| 7 | 64-QAM | 5/6 | 6 | 108 | 6 | 1296 | 1080 | 1 | 270.0 | 300.0 |
| 8 | 256-QAM | 3/4 | 8 | 108 | 6 | 1728 | 1296 | 1 | 324.0 | 360.0 |
| 9 | 256-QAM | 5/6 | 8 | 108 | 6 | 1728 | 1440 | 1 | 360.0 | 400.0 |

**Table 21-39—VHT-MCSs for optional 40 MHz, $N_{SS}$ = 3**

| VHT-MCS Index | Modulation | *R* | $N_{BPSCS}$ | $N_{SD}$ | $N_{SP}$ | $N_{CBPS}$ | $N_{DBPS}$ | $N_{ES}$ | Data rate (Mb/s) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | 800 ns GI | 400 ns GI |
| 0 | BPSK | 1/2 | 1 | 108 | 6 | 324 | 162 | 1 | 40.5 | 45.0 |
| 1 | QPSK | 1/2 | 2 | 108 | 6 | 648 | 324 | 1 | 81.0 | 90.0 |
| 2 | QPSK | 3/4 | 2 | 108 | 6 | 648 | 486 | 1 | 121.5 | 135.0 |
| 3 | 16-QAM | 1/2 | 4 | 108 | 6 | 1296 | 648 | 1 | 162.0 | 180.0 |
| 4 | 16-QAM | 3/4 | 4 | 108 | 6 | 1296 | 972 | 1 | 243.0 | 270.0 |
| 5 | 64-QAM | 2/3 | 6 | 108 | 6 | 1944 | 1296 | 1 | 324.0 | 360.0 |
| 6 | 64-QAM | 3/4 | 6 | 108 | 6 | 1944 | 1458 | 1 | 364.5 | 405.0 |
| 7 | 64-QAM | 5/6 | 6 | 108 | 6 | 1944 | 1620 | 1 | 405.0 | 450.0 |
| 8 | 256-QAM | 3/4 | 8 | 108 | 6 | 2592 | 1944 | 1 | 486.0 | 540.0 |
| 9 | 256-QAM | 5/6 | 8 | 108 | 6 | 2592 | 2160 | 1 | 540.0 | 600.0 |


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**Table 21-40—VHT-MCSs for optional 40 MHz, $N_{SS}$ = 4**

| VHT-MCS Index | Modulation | $R$ | $N_{BPSCS}$ | $N_{SD}$ | $N_{SP}$ | $N_{CBPS}$ | $N_{DBPS}$ | $N_{ES}$ | Data rate (Mb/s) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | 800 ns GI | 400 ns GI |
| 0 | BPSK | 1/2 | 1 | 108 | 6 | 432 | 216 | 1 | 54.0 | 60.0 |
| 1 | QPSK | 1/2 | 2 | 108 | 6 | 864 | 432 | 1 | 108.0 | 120.0 |
| 2 | QPSK | 3/4 | 2 | 108 | 6 | 864 | 648 | 1 | 162.0 | 180.0 |
| 3 | 16-QAM | 1/2 | 4 | 108 | 6 | 1728 | 864 | 1 | 216.0 | 240.0 |
| 4 | 16-QAM | 3/4 | 4 | 108 | 6 | 1728 | 1296 | 1 | 324.0 | 360.0 |
| 5 | 64-QAM | 2/3 | 6 | 108 | 6 | 2592 | 1728 | 1 | 432.0 | 480.0 |
| 6 | 64-QAM | 3/4 | 6 | 108 | 6 | 2592 | 1944 | 1 | 486.0 | 540.0 |
| 7 | 64-QAM | 5/6 | 6 | 108 | 6 | 2592 | 2160 | 1 | 540.0 | 600.0 |
| 8 | 256-QAM | 3/4 | 8 | 108 | 6 | 3456 | 2592 | 2 | 648.0 | 720.0 |
| 9 | 256-QAM | 5/6 | 8 | 108 | 6 | 3456 | 2880 | 2 | 720.0 | 800.0 |

**Table 21-41—VHT-MCSs for optional 40 MHz, $N_{SS}$ = 5**

| VHT-MCS Index | Modulation | $R$ | $N_{BPSCS}$ | $N_{SD}$ | $N_{SP}$ | $N_{CBPS}$ | $N_{DBPS}$ | $N_{ES}$ | Data rate (Mb/s) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | 800 ns GI | 400 ns GI |
| 0 | BPSK | 1/2 | 1 | 108 | 6 | 540 | 270 | 1 | 67.5 | 75.0 |
| 1 | QPSK | 1/2 | 2 | 108 | 6 | 1080 | 540 | 1 | 135.0 | 150.0 |
| 2 | QPSK | 3/4 | 2 | 108 | 6 | 1080 | 810 | 1 | 202.5 | 225.0 |
| 3 | 16-QAM | 1/2 | 4 | 108 | 6 | 2160 | 1080 | 1 | 270.0 | 300.0 |
| 4 | 16-QAM | 3/4 | 4 | 108 | 6 | 2160 | 1620 | 1 | 405.0 | 450.0 |
| 5 | 64-QAM | 2/3 | 6 | 108 | 6 | 3240 | 2160 | 1 | 540.0 | 600.0 |
| 6 | 64-QAM | 3/4 | 6 | 108 | 6 | 3240 | 2430 | 2 | 607.5 | 675.0 |
| 7 | 64-QAM | 5/6 | 6 | 108 | 6 | 3240 | 2700 | 2 | 675.0 | 750.0 |
| 8 | 256-QAM | 3/4 | 8 | 108 | 6 | 4320 | 3240 | 2 | 810.0 | 900.0 |
| 9 | 256-QAM | 5/6 | 8 | 108 | 6 | 4320 | 3600 | 2 | 900.0 | 1000.0 |

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**Table 21-42—VHT-MCSs for optional 40 MHz, $N_{SS}$ = 6**

| VHT-MCS Index | Modulation | *R* | $N_{BPSCS}$ | $N_{SD}$ | $N_{SP}$ | $N_{CBPS}$ | $N_{DBPS}$ | $N_{ES}$ | Data rate (Mb/s) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | 800 ns GI | 400 ns GI |
| 0 | BPSK | 1/2 | 1 | 108 | 6 | 648 | 324 | 1 | 81.0 | 90.0 |
| 1 | QPSK | 1/2 | 2 | 108 | 6 | 1296 | 648 | 1 | 162.0 | 180.0 |
| 2 | QPSK | 3/4 | 2 | 108 | 6 | 1296 | 972 | 1 | 243.0 | 270.0 |
| 3 | 16-QAM | 1/2 | 4 | 108 | 6 | 2592 | 1296 | 1 | 324.0 | 360.0 |
| 4 | 16-QAM | 3/4 | 4 | 108 | 6 | 2592 | 1944 | 1 | 486.0 | 540.0 |
| 5 | 64-QAM | 2/3 | 6 | 108 | 6 | 3888 | 2592 | 2 | 648.0 | 720.0 |
| 6 | 64-QAM | 3/4 | 6 | 108 | 6 | 3888 | 2916 | 2 | 729.0 | 810.0 |
| 7 | 64-QAM | 5/6 | 6 | 108 | 6 | 3888 | 3240 | 2 | 810.0 | 900.0 |
| 8 | 256-QAM | 3/4 | 8 | 108 | 6 | 5184 | 3888 | 2 | 972.0 | 1080.0 |
| 9 | 256-QAM | 5/6 | 8 | 108 | 6 | 5184 | 4320 | 2 | 1080.0 | 1200.0 |

**Table 21-43—VHT-MCSs for optional 40 MHz, $N_{SS}$ = 7**

| VHT-MCS Index | Modulation | *R* | $N_{BPSCS}$ | $N_{SD}$ | $N_{SP}$ | $N_{CBPS}$ | $N_{DBPS}$ | $N_{ES}$ | Data rate (Mb/s) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | 800 ns GI | 400 ns GI |
| 0 | BPSK | 1/2 | 1 | 108 | 6 | 756 | 378 | 1 | 94.5 | 105.0 |
| 1 | QPSK | 1/2 | 2 | 108 | 6 | 1512 | 756 | 1 | 189.0 | 210.0 |
| 2 | QPSK | 3/4 | 2 | 108 | 6 | 1512 | 1134 | 1 | 283.5 | 315.0 |
| 3 | 16-QAM | 1/2 | 4 | 108 | 6 | 3024 | 1512 | 1 | 378.0 | 420.0 |
| 4 | 16-QAM | 3/4 | 4 | 108 | 6 | 3024 | 2268 | 2 | 567.0 | 630.0 |
| 5 | 64-QAM | 2/3 | 6 | 108 | 6 | 4536 | 3024 | 2 | 756.0 | 840.0 |
| 6 | 64-QAM | 3/4 | 6 | 108 | 6 | 4536 | 3402 | 2 | 850.5 | 945.0 |
| 7 | 64-QAM | 5/6 | 6 | 108 | 6 | 4536 | 3780 | 2 | 945.0 | 1050.0 |
| 8 | 256-QAM | 3/4 | 8 | 108 | 6 | 6048 | 4536 | 3 | 1134.0 | 1260.0 |
| 9 | 256-QAM | 5/6 | 8 | 108 | 6 | 6048 | 5040 | 3 | 1260.0 | 1400.0 |


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**Table 21-44—VHT-MCSs for optional 40 MHz, $N_{SS}$ = 8**

| VHT-MCS Index | Modulation | $R$ | $N_{BPSCS}$ | $N_{SD}$ | $N_{SP}$ | $N_{CBPS}$ | $N_{DBPS}$ | $N_{ES}$ | Data rate (Mb/s) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | 800 ns GI | 400 ns GI |
| 0 | BPSK | 1/2 | 1 | 108 | 6 | 864 | 432 | 1 | 108.0 | 120.0 |
| 1 | QPSK | 1/2 | 2 | 108 | 6 | 1728 | 864 | 1 | 216.0 | 240.0 |
| 2 | QPSK | 3/4 | 2 | 108 | 6 | 1728 | 1296 | 1 | 324.0 | 360.0 |
| 3 | 16-QAM | 1/2 | 4 | 108 | 6 | 3456 | 1728 | 1 | 432.0 | 480.0 |
| 4 | 16-QAM | 3/4 | 4 | 108 | 6 | 3456 | 2592 | 2 | 648.0 | 720.0 |
| 5 | 64-QAM | 2/3 | 6 | 108 | 6 | 5184 | 3456 | 2 | 864.0 | 960.0 |
| 6 | 64-QAM | 3/4 | 6 | 108 | 6 | 5184 | 3888 | 2 | 972.0 | 1080.0 |
| 7 | 64-QAM | 5/6 | 6 | 108 | 6 | 5184 | 4320 | 2 | 1080.0 | 1200.0 |
| 8 | 256-QAM | 3/4 | 8 | 108 | 6 | 6912 | 5184 | 3 | 1296.0 | 1440.0 |
| 9 | 256-QAM | 5/6 | 8 | 108 | 6 | 6912 | 5760 | 3 | 1440.0 | 1600.0 |

**Table 21-45—VHT-MCSs for mandatory 80 MHz, $N_{SS}$ = 1**

| VHT-MCS Index | Modulation | $R$ | $N_{BPSCS}$ | $N_{SD}$ | $N_{SP}$ | $N_{CBPS}$ | $N_{DBPS}$ | $N_{ES}$ | Data rate (Mb/s) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | 800 ns GI | 400 ns GI (See NOTE) |
| 0 | BPSK | 1/2 | 1 | 234 | 8 | 234 | 117 | 1 | 29.3 | 32.5 |
| 1 | QPSK | 1/2 | 2 | 234 | 8 | 468 | 234 | 1 | 58.5 | 65.0 |
| 2 | QPSK | 3/4 | 2 | 234 | 8 | 468 | 351 | 1 | 87.8 | 97.5 |
| 3 | 16-QAM | 1/2 | 4 | 234 | 8 | 936 | 468 | 1 | 117.0 | 130.0 |
| 4 | 16-QAM | 3/4 | 4 | 234 | 8 | 936 | 702 | 1 | 175.5 | 195.0 |
| 5 | 64-QAM | 2/3 | 6 | 234 | 8 | 1404 | 936 | 1 | 234.0 | 260.0 |
| 6 | 64-QAM | 3/4 | 6 | 234 | 8 | 1404 | 1053 | 1 | 263.3 | 292.5 |
| 7 | 64-QAM | 5/6 | 6 | 234 | 8 | 1404 | 1170 | 1 | 292.5 | 325.0 |
| 8 | 256-QAM | 3/4 | 8 | 234 | 8 | 1872 | 1404 | 1 | 351.0 | 390.0 |
| 9 | 256-QAM | 5/6 | 8 | 234 | 8 | 1872 | 1560 | 1 | 390.0 | 433.3 |

NOTE—Support of 400 ns GI is optional on transmit and receive.

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**Table 21-46—VHT-MCSs for optional 80 MHz, $N_{SS}$ = 2**

| VHT-MCS Index | Modulation | *R* | $N_{BPSCS}$ | $N_{SD}$ | $N_{SP}$ | $N_{CBPS}$ | $N_{DBPS}$ | $N_{ES}$ | Data rate (Mb/s) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | 800 ns GI | 400 ns GI |
| 0 | BPSK | 1/2 | 1 | 234 | 8 | 468 | 234 | 1 | 58.5 | 65.0 |
| 1 | QPSK | 1/2 | 2 | 234 | 8 | 936 | 468 | 1 | 117.0 | 130.0 |
| 2 | QPSK | 3/4 | 2 | 234 | 8 | 936 | 702 | 1 | 175.5 | 195.0 |
| 3 | 16-QAM | 1/2 | 4 | 234 | 8 | 1872 | 936 | 1 | 234.0 | 260.0 |
| 4 | 16-QAM | 3/4 | 4 | 234 | 8 | 1872 | 1404 | 1 | 351.0 | 390.0 |
| 5 | 64-QAM | 2/3 | 6 | 234 | 8 | 2808 | 1872 | 1 | 468.0 | 520.0 |
| 6 | 64-QAM | 3/4 | 6 | 234 | 8 | 2808 | 2106 | 1 | 526.5 | 585.0 |
| 7 | 64-QAM | 5/6 | 6 | 234 | 8 | 2808 | 2340 | 2 | 585.0 | 650.0 |
| 8 | 256-QAM | 3/4 | 8 | 234 | 8 | 3744 | 2808 | 2 | 702.0 | 780.0 |
| 9 | 256-QAM | 5/6 | 8 | 234 | 8 | 3744 | 3120 | 2 | 780.0 | 866.7 |

**Table 21-47—VHT-MCSs for optional 80 MHz, $N_{SS}$ = 3**

| VHT-MCS Index | Modulation | *R* | $N_{BPSCS}$ | $N_{SD}$ | $N_{SP}$ | $N_{CBPS}$ | $N_{DBPS}$ | $N_{ES}$ | Data rate (Mb/s) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | 800 ns GI | 400 ns GI |
| 0 | BPSK | 1/2 | 1 | 234 | 8 | 702 | 351 | 1 | 87.8 | 97.5 |
| 1 | QPSK | 1/2 | 2 | 234 | 8 | 1404 | 702 | 1 | 175.5 | 195.0 |
| 2 | QPSK | 3/4 | 2 | 234 | 8 | 1404 | 1053 | 1 | 263.3 | 292.5 |
| 3 | 16-QAM | 1/2 | 4 | 234 | 8 | 2808 | 1404 | 1 | 351.0 | 390.0 |
| 4 | 16-QAM | 3/4 | 4 | 234 | 8 | 2808 | 2106 | 1 | 526.5 | 585.0 |
| 5 | 64-QAM | 2/3 | 6 | 234 | 8 | 4212 | 2808 | 2 | 702.0 | 780.0 |
| 6 | Not valid | | | | | | | | | |
| 7 | 64-QAM | 5/6 | 6 | 234 | 8 | 4212 | 3510 | 2 | 877.5 | 975.0 |
| 8 | 256-QAM | 3/4 | 8 | 234 | 8 | 5616 | 4212 | 2 | 1053.0 | 1170.0 |
| 9 | 256-QAM | 5/6 | 8 | 234 | 8 | 5616 | 4680 | 3 | 1170.0 | 1300.0 |


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**Table 21-48—VHT-MCSs for optional 80 MHz, $N_{SS}$ = 4**

| VHT-MCS Index | Modulation | $R$ | $N_{BPSCS}$ | $N_{SD}$ | $N_{SP}$ | $N_{CBPS}$ | $N_{DBPS}$ | $N_{ES}$ | Data rate (Mb/s) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | 800 ns GI | 400 ns GI |
| 0 | BPSK | 1/2 | 1 | 234 | 8 | 936 | 468 | 1 | 117.0 | 130.0 |
| 1 | QPSK | 1/2 | 2 | 234 | 8 | 1872 | 936 | 1 | 234.0 | 260.0 |
| 2 | QPSK | 3/4 | 2 | 234 | 8 | 1872 | 1404 | 1 | 351.0 | 390.0 |
| 3 | 16-QAM | 1/2 | 4 | 234 | 8 | 3744 | 1872 | 1 | 468.0 | 520.0 |
| 4 | 16-QAM | 3/4 | 4 | 234 | 8 | 3744 | 2808 | 2 | 702.0 | 780.0 |
| 5 | 64-QAM | 2/3 | 6 | 234 | 8 | 5616 | 3744 | 2 | 936.0 | 1040.0 |
| 6 | 64-QAM | 3/4 | 6 | 234 | 8 | 5616 | 4212 | 2 | 1053.0 | 1170.0 |
| 7 | 64-QAM | 5/6 | 6 | 234 | 8 | 5616 | 4680 | 3 | 1170.0 | 1300.0 |
| 8 | 256-QAM | 3/4 | 8 | 234 | 8 | 7488 | 5616 | 3 | 1404.0 | 1560.0 |
| 9 | 256-QAM | 5/6 | 8 | 234 | 8 | 7488 | 6240 | 3 | 1560.0 | 1733.3 |

**Table 21-49—VHT-MCSs for optional 80 MHz, $N_{SS}$ = 5**

| VHT-MCS Index | Modulation | $R$ | $N_{BPSCS}$ | $N_{SD}$ | $N_{SP}$ | $N_{CBPS}$ | $N_{DBPS}$ | $N_{ES}$ | Data rate (Mb/s) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | 800 ns GI | 400 ns GI |
| 0 | BPSK | 1/2 | 1 | 234 | 8 | 1170 | 585 | 1 | 146.3 | 162.5 |
| 1 | QPSK | 1/2 | 2 | 234 | 8 | 2340 | 1170 | 1 | 292.5 | 325.0 |
| 2 | QPSK | 3/4 | 2 | 234 | 8 | 2340 | 1755 | 1 | 438.8 | 487.5 |
| 3 | 16-QAM | 1/2 | 4 | 234 | 8 | 4680 | 2340 | 2 | 585.0 | 650.0 |
| 4 | 16-QAM | 3/4 | 4 | 234 | 8 | 4680 | 3510 | 2 | 877.5 | 975.0 |
| 5 | 64-QAM | 2/3 | 6 | 234 | 8 | 7020 | 4680 | 3 | 1170.0 | 1300.0 |
| 6 | 64-QAM | 3/4 | 6 | 234 | 8 | 7020 | 5265 | 3 | 1316.3 | 1462.5 |
| 7 | 64-QAM | 5/6 | 6 | 234 | 8 | 7020 | 5850 | 3 | 1462.5 | 1625.0 |
| 8 | 256-QAM | 3/4 | 8 | 234 | 8 | 9360 | 7020 | 4 | 1755.0 | 1950.0 |
| 9 | 256-QAM | 5/6 | 8 | 234 | 8 | 9360 | 7800 | 4 | 1950.0 | 2166.7 |

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**Table 21-50—VHT-MCSs for optional 80 MHz, $N_{SS}$ = 6**

| VHT-MCS Index | Modulation | *R* | $N_{BPSCS}$ | $N_{SD}$ | $N_{SP}$ | $N_{CBPS}$ | $N_{DBPS}$ | $N_{ES}$ | Data rate (Mb/s) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | 800 ns GI | 400 ns GI |
| 0 | BPSK | 1/2 | 1 | 234 | 8 | 1404 | 702 | 1 | 175.5 | 195.0 |
| 1 | QPSK | 1/2 | 2 | 234 | 8 | 2808 | 1404 | 1 | 351.0 | 390.0 |
| 2 | QPSK | 3/4 | 2 | 234 | 8 | 2808 | 2106 | 1 | 526.5 | 585.0 |
| 3 | 16-QAM | 1/2 | 4 | 234 | 8 | 5616 | 2808 | 2 | 702.0 | 780.0 |
| 4 | 16-QAM | 3/4 | 4 | 234 | 8 | 5616 | 4212 | 2 | 1053.0 | 1170.0 |
| 5 | 64-QAM | 2/3 | 6 | 234 | 8 | 8424 | 5616 | 3 | 1404.0 | 1560.0 |
| 6 | 64-QAM | 3/4 | 6 | 234 | 8 | 8424 | 6318 | 3 | 1579.5 | 1755.0 |
| 7 | 64-QAM | 5/6 | 6 | 234 | 8 | 8424 | 7020 | 4 | 1755.0 | 1950.0 |
| 8 | 256-QAM | 3/4 | 8 | 234 | 8 | 11 232 | 8424 | 4 | 2106.0 | 2340.0 |
| 9 | Not valid | | | | | | | | | |

**Table 21-51—VHT-MCSs for optional 80 MHz, $N_{SS}$ = 7**

| VHT-MCS Index | Modulation | *R* | $N_{BPSCS}$ | $N_{SD}$ | $N_{SP}$ | $N_{CBPS}$ | $N_{DBPS}$ | $N_{ES}$ | Data rate (Mb/s) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | 800 ns GI | 400 ns GI |
| 0 | BPSK | 1/2 | 1 | 234 | 8 | 1638 | 819 | 1 | 204.8 | 227.5 |
| 1 | QPSK | 1/2 | 2 | 234 | 8 | 3276 | 1638 | 1 | 409.5 | 455.0 |
| 2 | QPSK | 3/4 | 2 | 234 | 8 | 3276 | 2457 | 3 | 614.3 | 682.5 |
| 3 | 16-QAM | 1/2 | 4 | 234 | 8 | 6552 | 3276 | 2 | 819.0 | 910.0 |
| 4 | 16-QAM | 3/4 | 4 | 234 | 8 | 6552 | 4914 | 3 | 1228.5 | 1365.0 |
| 5 | 64-QAM | 2/3 | 6 | 234 | 8 | 9828 | 6552 | 4 | 1638.0 | 1820.0 |
| 6 | Not valid | | | | | | | | | |
| 7 | 64-QAM | 5/6 | 6 | 234 | 8 | 9828 | 8190 | 6 | 2047.5 | 2275.0 |
| 8 | 256-QAM | 3/4 | 8 | 234 | 8 | 13 104 | 9828 | 6 | 2457.0 | 2730.0 |
| 9 | 256-QAM | 5/6 | 8 | 234 | 8 | 13 104 | 10 920 | 6 | 2730.0 | 3033.3 |


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**Table 21-52—VHT-MCSs for optional 80 MHz, $N_{SS}$ = 8**

| VHT-MCS Index | Modulation | *R* | $N_{BPSCS}$ | $N_{SD}$ | $N_{SP}$ | $N_{CBPS}$ | $N_{DBPS}$ | $N_{ES}$ | Data rate (Mb/s) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | 800 ns GI | 400 ns GI |
| 0 | BPSK | 1/2 | 1 | 234 | 8 | 1872 | 936 | 1 | 234.0 | 260.0 |
| 1 | QPSK | 1/2 | 2 | 234 | 8 | 3744 | 1872 | 1 | 468.0 | 520.0 |
| 2 | QPSK | 3/4 | 2 | 234 | 8 | 3744 | 2808 | 2 | 702.0 | 780.0 |
| 3 | 16-QAM | 1/2 | 4 | 234 | 8 | 7488 | 3744 | 2 | 936.0 | 1040.0 |
| 4 | 16-QAM | 3/4 | 4 | 234 | 8 | 7488 | 5616 | 3 | 1404.0 | 1560.0 |
| 5 | 64-QAM | 2/3 | 6 | 234 | 8 | 11 232 | 7488 | 4 | 1872.0 | 2080.0 |
| 6 | 64-QAM | 3/4 | 6 | 234 | 8 | 11 232 | 8424 | 4 | 2106.0 | 2340.0 |
| 7 | 64-QAM | 5/6 | 6 | 234 | 8 | 11 232 | 9360 | 6 | 2340.0 | 2600.0 |
| 8 | 256-QAM | 3/4 | 8 | 234 | 8 | 14 976 | 11 232 | 6 | 2808.0 | 3120.0 |
| 9 | 256-QAM | 5/6 | 8 | 234 | 8 | 14 976 | 12 480 | 6 | 3120.0 | 3466.7 |

**Table 21-53—VHT-MCSs for optional 160 MHz and 80+80 MHz, $N_{SS}$ = 1**

| VHT-MCS Index | Modulation | *R* | $N_{BPSCS}$ | $N_{SD} \cdot N_{Seg}$ | $N_{SP}$ | $N_{CBPS}$ | $N_{DBPS}$ | $N_{ES}$ | Data rate (Mb/s) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | 800 ns GI | 400 ns GI |
| 0 | BPSK | 1/2 | 1 | 468 | 16 | 468 | 234 | 1 | 58.5 | 65.0 |
| 1 | QPSK | 1/2 | 2 | 468 | 16 | 936 | 468 | 1 | 117.0 | 130.0 |
| 2 | QPSK | 3/4 | 2 | 468 | 16 | 936 | 702 | 1 | 175.5 | 195.0 |
| 3 | 16-QAM | 1/2 | 4 | 468 | 16 | 1872 | 936 | 1 | 234.0 | 260.0 |
| 4 | 16-QAM | 3/4 | 4 | 468 | 16 | 1872 | 1404 | 1 | 351.0 | 390.0 |
| 5 | 64-QAM | 2/3 | 6 | 468 | 16 | 2808 | 1872 | 1 | 468.0 | 520.0 |
| 6 | 64-QAM | 3/4 | 6 | 468 | 16 | 2808 | 2106 | 1 | 526.5 | 585.0 |
| 7 | 64-QAM | 5/6 | 6 | 468 | 16 | 2808 | 2340 | 2 | 585.0 | 650.0 |
| 8 | 256-QAM | 3/4 | 8 | 468 | 16 | 3744 | 2808 | 2 | 702.0 | 780.0 |
| 9 | 256-QAM | 5/6 | 8 | 468 | 16 | 3744 | 3120 | 2 | 780.0 | 866.7 |

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**Table 21-54—VHT-MCSs for optional 160 MHz and 80+80 MHz, $N_{SS}$ = 2**

| VHT-MCS Index | Modulation | *R* | $N_{BPSCS}$ | $N_{SD} \cdot N_{Seg}$ | $N_{SP}$ | $N_{CBPS}$ | $N_{DBPS}$ | $N_{ES}$ | Data rate (Mb/s) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | 800 ns GI | 400 ns GI |
| 0 | BPSK | 1/2 | 1 | 468 | 16 | 936 | 468 | 1 | 117.0 | 130.0 |
| 1 | QPSK | 1/2 | 2 | 468 | 16 | 1872 | 936 | 1 | 234.0 | 260.0 |
| 2 | QPSK | 3/4 | 2 | 468 | 16 | 1872 | 1404 | 1 | 351.0 | 390.0 |
| 3 | 16-QAM | 1/2 | 4 | 468 | 16 | 3744 | 1872 | 1 | 468.0 | 520.0 |
| 4 | 16-QAM | 3/4 | 4 | 468 | 16 | 3744 | 2808 | 2 | 702.0 | 780.0 |
| 5 | 64-QAM | 2/3 | 6 | 468 | 16 | 5616 | 3744 | 2 | 936.0 | 1040.0 |
| 6 | 64-QAM | 3/4 | 6 | 468 | 16 | 5616 | 4212 | 2 | 1053.0 | 1170.0 |
| 7 | 64-QAM | 5/6 | 6 | 468 | 16 | 5616 | 4680 | 3 | 1170.0 | 1300.0 |
| 8 | 256-QAM | 3/4 | 8 | 468 | 16 | 7488 | 5616 | 3 | 1404.0 | 1560.0 |
| 9 | 256-QAM | 5/6 | 8 | 468 | 16 | 7488 | 6240 | 3 | 1560.0 | 1733.3 |

**Table 21-55—VHT-MCSs for optional 160 MHz and 80+80 MHz, $N_{SS}$ = 3**

| VHT-MCS Index | Modulation | *R* | $N_{BPSCS}$ | $N_{SD} \cdot N_{Seg}$ | $N_{SP}$ | $N_{CBPS}$ | $N_{DBPS}$ | $N_{ES}$ | Data rate (Mb/s) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | 800 ns GI | 400 ns GI |
| 0 | BPSK | 1/2 | 1 | 468 | 16 | 1404 | 702 | 1 | 175.5 | 195.0 |
| 1 | QPSK | 1/2 | 2 | 468 | 16 | 2808 | 1404 | 1 | 351.0 | 390.0 |
| 2 | QPSK | 3/4 | 2 | 468 | 16 | 2808 | 2106 | 1 | 526.5 | 585.0 |
| 3 | 16-QAM | 1/2 | 4 | 468 | 16 | 5616 | 2808 | 2 | 702.0 | 780.0 |
| 4 | 16-QAM | 3/4 | 4 | 468 | 16 | 5616 | 4212 | 2 | 1053.0 | 1170.0 |
| 5 | 64-QAM | 2/3 | 6 | 468 | 16 | 8424 | 5616 | 3 | 1404.0 | 1560.0 |
| 6 | 64-QAM | 3/4 | 6 | 468 | 16 | 8424 | 6318 | 3 | 1579.5 | 1755.0 |
| 7 | 64-QAM | 5/6 | 6 | 468 | 16 | 8424 | 7020 | 4 | 1755.0 | 1950.0 |
| 8 | 256-QAM | 3/4 | 8 | 468 | 16 | 11 232 | 8424 | 4 | 2106.0 | 2340.0 |
| 9 | Not valid | | | | | | | | | |


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**Table 21-56—VHT-MCSs for optional 160 MHz and 80+80 MHz, $N_{SS}$ = 4**

| VHT-MCS Index | Modulation | *R* | $N_{BPSCS}$ | $N_{SD} \cdot N_{Seg}$ | $N_{SP}$ | $N_{CBPS}$ | $N_{DBPS}$ | $N_{ES}$ | Data rate (Mb/s) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | 800 ns GI | 400 ns GI |
| 0 | BPSK | 1/2 | 1 | 468 | 16 | 1872 | 936 | 1 | 234.0 | 260.0 |
| 1 | QPSK | 1/2 | 2 | 468 | 16 | 3744 | 1872 | 1 | 468.0 | 520.0 |
| 2 | QPSK | 3/4 | 2 | 468 | 16 | 3744 | 2808 | 2 | 702.0 | 780.0 |
| 3 | 16-QAM | 1/2 | 4 | 468 | 16 | 7488 | 3744 | 2 | 936.0 | 1040.0 |
| 4 | 16-QAM | 3/4 | 4 | 468 | 16 | 7488 | 5616 | 3 | 1404.0 | 1560.0 |
| 5 | 64-QAM | 2/3 | 6 | 468 | 16 | 11 232 | 7488 | 4 | 1872.0 | 2080.0 |
| 6 | 64-QAM | 3/4 | 6 | 468 | 16 | 11 232 | 8424 | 4 | 2106.0 | 2340.0 |
| 7 | 64-QAM | 5/6 | 6 | 468 | 16 | 11 232 | 9360 | 6 | 2340.0 | 2600.0 |
| 8 | 256-QAM | 3/4 | 8 | 468 | 16 | 14 976 | 11 232 | 6 | 2808.0 | 3120.0 |
| 9 | 256-QAM | 5/6 | 8 | 468 | 16 | 14 976 | 12 480 | 6 | 3120.0 | 3466.7 |

**Table 21-57—VHT-MCSs for optional 160 MHz and 80+80 MHz, $N_{SS}$ = 5**

| VHT-MCS Index | Modulation | *R* | $N_{BPSCS}$ | $N_{SD} \cdot N_{Seg}$ | $N_{SP}$ | $N_{CBPS}$ | $N_{DBPS}$ | $N_{ES}$ | Data rate (Mb/s) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | 800 ns GI | 400 ns GI |
| 0 | BPSK | 1/2 | 1 | 468 | 16 | 2340 | 1170 | 1 | 292.5 | 325.0 |
| 1 | QPSK | 1/2 | 2 | 468 | 16 | 4680 | 2340 | 2 | 585.0 | 650.0 |
| 2 | QPSK | 3/4 | 2 | 468 | 16 | 4680 | 3510 | 2 | 877.5 | 975.0 |
| 3 | 16-QAM | 1/2 | 4 | 468 | 16 | 9360 | 4680 | 3 | 1170.0 | 1300.0 |
| 4 | 16-QAM | 3/4 | 4 | 468 | 16 | 9360 | 7020 | 4 | 1755.0 | 1950.0 |
| 5 | 64-QAM | 2/3 | 6 | 468 | 16 | 14 040 | 9360 | 5 | 2340.0 | 2600.0 |
| 6 | 64-QAM | 3/4 | 6 | 468 | 16 | 14 040 | 10 530 | 5 | 2632.5 | 2925.0 |
| 7 | 64-QAM | 5/6 | 6 | 468 | 16 | 14 040 | 11 700 | 6 | 2925.0 | 3250.0 |
| 8 | 256-QAM | 3/4 | 8 | 468 | 16 | 18 720 | 14 040 | 8 | 3510.0 | 3900.0 |
| 9 | 256-QAM | 5/6 | 8 | 468 | 16 | 18 720 | 15 600 | 8 | 3900.0 | 4333.3 |

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**Table 21-58—VHT-MCSs for optional 160 MHz and 80+80 MHz, $N_{SS}$ = 6**

| VHT-MCS Index | Modulation | *R* | $N_{BPSCS}$ | $N_{SD} \cdot N_{Seg}$ | $N_{SP}$ | $N_{CBPS}$ | $N_{DBPS}$ | $N_{ES}$ | Data rate (Mb/s) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | 800 ns GI | 400 ns GI |
| 0 | BPSK | 1/2 | 1 | 468 | 16 | 2808 | 1404 | 1 | 351.0 | 390.0 |
| 1 | QPSK | 1/2 | 2 | 468 | 16 | 5616 | 2808 | 2 | 702.0 | 780.0 |
| 2 | QPSK | 3/4 | 2 | 468 | 16 | 5616 | 4212 | 2 | 1053.0 | 1170.0 |
| 3 | 16-QAM | 1/2 | 4 | 468 | 16 | 11 232 | 5616 | 3 | 1404.0 | 1560.0 |
| 4 | 16-QAM | 3/4 | 4 | 468 | 16 | 11 232 | 8424 | 4 | 2106.0 | 2340.0 |
| 5 | 64-QAM | 2/3 | 6 | 468 | 16 | 16 848 | 11 232 | 6 | 2808.0 | 3120.0 |
| 6 | 64-QAM | 3/4 | 6 | 468 | 16 | 16 848 | 12 636 | 6 | 3159.0 | 3510.0 |
| 7 | 64-QAM | 5/6 | 6 | 468 | 16 | 16 848 | 14 040 | 8 | 3510.0 | 3900.0 |
| 8 | 256-QAM | 3/4 | 8 | 468 | 16 | 22 464 | 16 848 | 8 | 4212.0 | 4680.0 |
| 9 | 256-QAM | 5/6 | 8 | 468 | 16 | 22 464 | 18 720 | 9 | 4680.0 | 5200.0 |

**Table 21-59—VHT-MCSs for optional 160 MHz and 80+80 MHz, $N_{SS}$ = 7**

| VHT-MCS Index | Modulation | *R* | $N_{BPSCS}$ | $N_{SD} \cdot N_{Seg}$ | $N_{SP}$ | $N_{CBPS}$ | $N_{DBPS}$ | $N_{ES}$ | Data rate (Mb/s) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | 800 ns GI | 400 ns GI |
| 0 | BPSK | 1/2 | 1 | 468 | 16 | 3276 | 1638 | 1 | 409.5 | 455.0 |
| 1 | QPSK | 1/2 | 2 | 468 | 16 | 6552 | 3276 | 2 | 819.0 | 910.0 |
| 2 | QPSK | 3/4 | 2 | 468 | 16 | 6552 | 4914 | 3 | 1228.5 | 1365.0 |
| 3 | 16-QAM | 1/2 | 4 | 468 | 16 | 13 104 | 6552 | 4 | 1638.0 | 1820.0 |
| 4 | 16-QAM | 3/4 | 4 | 468 | 16 | 13 104 | 9828 | 6 | 2457.0 | 2730.0 |
| 5 | 64-QAM | 2/3 | 6 | 468 | 16 | 19 656 | 13 104 | 7 | 3276.0 | 3640.0 |
| 6 | 64-QAM | 3/4 | 6 | 468 | 16 | 19 656 | 14 742 | 7 | 3685.5 | 4095.0 |
| 7 | 64-QAM | 5/6 | 6 | 468 | 16 | 19 656 | 16 380 | 9 | 4095.0 | 4550.0 |
| 8 | 256-QAM | 3/4 | 8 | 468 | 16 | 26 208 | 19 656 | 12 | 4914.0 | 5460.0 |
| 9 | 256-QAM | 5/6 | 8 | 468 | 16 | 26 208 | 21 840 | 12 | 5460.0 | 6066.7 |


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**Table 21-60—VHT-MCSs for optional 160 MHz and 80+80 MHz, $N_{SS}$ = 8**

| VHT-MCS Index | Modulation | *R* | $N_{BPSCS}$ | $N_{SD} \cdot N_{Seg}$ | $N_{SP}$ | $N_{CBPS}$ | $N_{DBPS}$ | $N_{ES}$ | Data rate (Mb/s) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | 800 ns GI | 400 ns GI |
| 0 | BPSK | 1/2 | 1 | 468 | 16 | 3744 | 1872 | 1 | 468.0 | 520.0 |
| 1 | QPSK | 1/2 | 2 | 468 | 16 | 7488 | 3744 | 2 | 936.0 | 1040.0 |
| 2 | QPSK | 3/4 | 2 | 468 | 16 | 7488 | 5616 | 3 | 1404.0 | 1560.0 |
| 3 | 16-QAM | 1/2 | 4 | 468 | 16 | 14 976 | 7488 | 4 | 1872.0 | 2080.0 |
| 4 | 16-QAM | 3/4 | 4 | 468 | 16 | 14 976 | 11 232 | 6 | 2808.0 | 3120.0 |
| 5 | 64-QAM | 2/3 | 6 | 468 | 16 | 22 464 | 14 976 | 8 | 3744.0 | 4160.0 |
| 6 | 64-QAM | 3/4 | 6 | 468 | 16 | 22 464 | 16 848 | 8 | 4212.0 | 4680.0 |
| 7 | 64-QAM | 5/6 | 6 | 468 | 16 | 22 464 | 18 720 | 9 | 4680.0 | 5200.0 |
| 8 | 256-QAM | 3/4 | 8 | 468 | 16 | 29 952 | 22 464 | 12 | 5616.0 | 6240.0 |
| 9 | 256-QAM | 5/6 | 8 | 468 | 16 | 29 952 | 24 960 | 12 | 6240.0 | 6933.3 |

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# 22. Television very high throughput (TVHT) PHY specification

## 22.1 Introduction

### 22.1.1 Introduction to the TVHT PHY

Clause 22 (Television very high throughput (TVHT) PHY specification) specifies the PHY entity for a television very high throughput (TVHT) orthogonal frequency division multiplexing (OFDM) system.

Three basic channel units (BCUs) are defined as 6 MHz, 7 MHz, or 8 MHz, depending on the regulatory domain, and denoted in the rest of this clause as a BCU or TVHT_W. Many of the terms used in this clause refer to different bands, depending on the regulatory domain. These terms include

— TVHT_2W, which represents two contiguous BCUs (12 MHz, 14 MHz, or 16 MHz)
— TVHT_W+W, which represents two noncontiguous BCU (6+6 MHz, 7+7 MHz, or 8+8 MHz)
— TVHT_4W, which represents four contiguous BCUs (24 MHz, 28 MHz, or 32 MHz)
— TVHT_2W+2W, which represents two noncontiguous frequency segments, each of which is composed of two BCUs (12+12 MHz, 14+14 MHz, or 16+16 MHz)

The TVHT PHY is based on the VHT PHY, as defined in 21.3 (VHT PHY), 21.4 (VHT PLME), and 21.5 (Parameters for VHT-MCSs), and on Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification).

All TVHT transmissions in one BCU shall use the VHT PHY parameters for 40 MHz channel defined in 21.3 (VHT PHY), 21.4 (VHT PLME), and 21.5 (Parameters for VHT-MCSs) with a sampling clock change to fit into each of the BCU bandwidths and with the number of encoders ($N_{ES}$) always being 1 (for SU-MIMO and per user in MU-MIMO).

Table 22-8 (Timing-related parameters) describes the sampling clock for each of the BCUs and the basic PHY parameters for transmission over one BCU.

For all VHT PPDUs and non-HT PPDUs in TVWS band, timing-related parameters shall be used as defined in Table 22-5 (Timing-related constants in Non-HT PPDU) and Table 22-8 (Timing-related parameters); frequently used parameters shall be used as defined in Table 22-6 (Tone location in Non-HT PPDU) and Table 22-9 (Tone location); phase rotation parameter $\Upsilon_{k,\mathrm{BW}}$ shall be replaced by $\Upsilon_{k,\mathrm{M}}$, which is defined in Table 22-12 (Transmission mode and Gamma subk,m); and cyclic shift parameters shall be used as defined in 22.3.8.3.2 (Cyclic shift for TVHT modulated fields).

As shown in Table 22-8 (Timing-related parameters), the design is based on defining 144 OFDM tones in the 6 MHz and 8 MHz channel units and using up to tone 58 on each side of the DC tone for data and pilots, exactly matching the VHT 40 MHz PHY parameters. The 7 MHz channel unit is split into 168 tones to maintain the same tone spacing and PHY design as used for 6 MHz channels (note the ratio of 168 to 144 is identical to the ratio of 7 to 6). The choice of 144 and not 128 was made to reduce the PHY channel BW from 6 MHz to 5 1/3 MHz in order to allow sharper filtering to achieve 55 dB ACLR.

The TVHT PHY defines the following transmission modes that incorporate transmission on one, two, or four BCUs:

a) Mandatory transmission mode - one BCU (TVHT_MODE_1)
b) Optional transmission modes - multi-BCUs
    1) Two contiguous BCUs (TVHT_MODE_2C)
    2) Two noncontiguous BCUs (TVHT_MODE_2N)
    3) Four contiguous BCUs (TVHT_MODE_4C)


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4) Two noncontiguous frequency segments, each of which comprises two contiguous BCUs (TVHT_MODE_4N)

The tone spacing, DFT duration, and other timing parameters remain unchanged for all optional modes compared with the definition in Table 22-8 (Timing-related parameters).

The number of occupied tones in each BCU of any optional mode is the same as the number defined in Table 22-8 (Timing-related parameters).

The location of the occupied tones in each BCU of any optional mode is shown in Table 22-9 (Tone location).

The DATA encoding process for multi-BCUs transmission is similar to one BCU transmission and is defined in 22.3.10 (Data field).

A TVHT STA shall support the following features:

— TVHT_MODE_1 (one BCU)
— Single spatial stream MCSs 0 to 7 (transmit and receive)
— BCC coding
— Normal and short guard interval (transmit and receive)

A TVHT STA may support the following features:

— TVHT_MODE_2C, TVHT_MODE_2N, TVHT_MODE_4C, or TVHT_MODE_4N (two or four BCUs)
— Two or more spatial streams (transmit and receive)
— Beamforming sounding (by sending a VHT NDP)
— Respond to transmit beamforming sounding (provide compressed beamforming feedback)
— STBC (transmit and receive)
— LDPC (transmit and receive)
— VHT MU PPDUs (transmit and receive)
— MCSs 8 and 9 (transmit and receive)

### 22.1.2 Scope of TVHT PHY services

The services provided to the MAC by the TVHT PHY consist of a protocol function that defines the characteristics and method of transmitting and receiving data through a wireless medium between two or more STAs. These STAs support a TVHT PHY.

### 22.1.3 TVHT PHY functions

#### 22.1.3.1 General

See 21.1.3.1 (General) with “TVHT” replacing “VHT”.

#### 22.1.3.2 PHY management entity (PLME)

See 21.1.3.2 (PHY management entity (PLME)).

#### 22.1.3.3 Service specification method

See 21.1.3.3 (Service specification method) with “TVHT” replacing “VHT”.

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### 22.1.4 PPDU formats

The structure of the PPDU transmitted by a TVHT STA is determined by the TXVECTOR parameters as defined in 22.2.2 (TXVECTOR and RXVECTOR parameters).

The FORMAT parameter determines the overall structure of the PPDU and includes the following:

— Non-HT format (NON_HT), based on Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification). Support for non-HT format is mandatory.

— VHT format (VHT). Support for TVHT_W VHT format is mandatory.

## 22.2 TVHT PHY service interface

### 22.2.1 Introduction

See 21.2.1 (Introduction).

### 22.2.2 TXVECTOR and RXVECTOR parameters

The TXVECTOR and RXVECTOR parameters are defined in Table 22-1 (TXVECTOR and RXVECTOR parameters).

The TXVECTOR parameter FORMAT shall be set to NON_HT or VHT. When the TXVECTOR parameter FORMAT equals NON_HT, then NON_HT_MODULATION shall be set to NON_HT_DUP_OFDM.

When the TXVECTOR parameter FORMAT equals NON_HT, the TXVECTOR parameter L_DATARATE indicates the data rate used to transmit the PSDU in Mb/s. The allowed values are 6 Mb/s, 9 Mb/s, 12 Mb/s, 18 Mb/s, 24 Mb/s, 36 Mb/s, 48 Mb/s, and 54 Mb/s divided by 7.5 for 6 MHz and 7 MHz unit channels and by 5.625 for 8 MHz channels.

When the TXVECTOR parameter FORMAT equals VHT, the TXVECTOR parameter CH_BANDWIDTH indicates the channel width of the transmitted PPDU:

Enumerated type:

— TVHT_W for one BCU

— TVHT_2W for two contiguous BCUs

— TVHT_W+W for two noncontiguous BCUs

— TVHT_4W for four contiguous BCUs

— TVHT_2W+2W for two noncontiguous frequency segments, each of which comprises two contiguous BCUs

Note that TVHT_W represents the broadcast channel bandwidth for the regulatory domain, e.g., TVHT_W is 6 MHz, 7 MHz, or 8 MHz. TVHT_2W represents two contiguous BCUs with the same regulatory domain, e.g., TVHT_2W is 12 MHz, 14 MHz, or 16 MHz.

When the TXVECTOR parameter FORMAT equals NON_HT, the TXVECTOR parameter CH_BANDWIDTH indicates the channel width of the transmitted PPDU on transmission and the estimated channel width of the received PPDU on reception:

Enumerated type:

— TVHT_W, TVHT_2W, TVHT_W+W, TVHT_4W, TVHT_2W+2W


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When the TXVECTOR parameter FORMAT equals VHT, the TXVECTOR parameter NUM_STS indicates the number of space-time streams: range 1 to 4 for SU, 1 to 3 per user for MU. NUM_STS summed over all users shall be less than or equal to 4. The TXVECTOR parameter NUM_STS is not present when the TXVECTOR parameter FORMAT equals to NON_HT.

**Table 22-1—TXVECTOR and RXVECTOR parameters**

| Parameter | Condition | Value | TXVECTOR | RXVECTOR |
|---|---|---|---|---|
| FORMAT | | Determines the format of the PPDU.<br>Enumerated type:<br>NON_HT indicates non-HT duplicated PPDU format. In this case, the modulation is determined by the NON_HT_MODULATION parameter.<br>VHT indicates VHT format. | Y | Y |
| NON_HT_MODULATION | FORMAT is NON_HT | In TXVECTOR, indicates the format type of the transmitted non-HT PPDU.<br>In RXVECTOR, indicates the estimated format type of the received non-HT PPDU.<br>Enumerated type:<br>NON_HT_DUP_OFDM indicates non-HT duplicate format. | Y | Y |
| | Otherwise | Not present | N | N |
| L_LENGTH | FORMAT is NON_HT | Indicates the length of the PSDU in octets in the range 1 to 4095. This value is used by the PHY to determine the number of octet transfers that occur between the MAC and the PHY. | Y | Y |
| | FORMAT is VHT | Not present<br>NOTE—The Length field of the L-SIG field(#4145) in VHT PPDUs is defined in Equation (22-9) using the scaling factor defined in 22.3.8.2.1 (Cyclic shift definition for pre-TVHT modulated fields). | N | N |
| L_DATARATE | FORMAT is NON_HT | Indicates the data rate used to transmit the PSDU in Mb/s. The allowed values are 6, 9, 12, 18, 24, 36, 48, and 54 divided by 7.5 for 6 MHz and 7 MHz unit channels and by 5.625 for 8 MHz channels. | Y | Y |
| | FORMAT is VHT | Not present<br>NOTE—The RATE field in the L-SIG field in a VHT PPDU is set to the value representing 6/*X* Mb/s in TVWS band "Modulation BPSK and Coding rate 1/2" row of Table 22-4 (RATE field in L-SIG). | N | N |
| N_TX | FORMAT is VHT | Indicates the number of transmit chains. | Y | N |
| | Otherwise | Not present | N | N |

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**Table 22-1—TXVECTOR and RXVECTOR parameters *(continued)***

| Parameter | Condition | Value | TXVECTOR | RXVECTOR |
|---|---|---|---|---|
| EXPANSION_MAT_TYPE | FORMAT is VHT and EXPANSION_MAT is present. | Set to COMPRESSED_SV | Y | N |
| | Otherwise | See corresponding entry in Table 19-1 (TXVECTOR and RXVECTOR parameters) | | |
| EXPANSION_MAT | FORMAT is VHT | Contains a vector in the number of selected subcarriers containing feedback matrices as defined in 22.3.11.2 (Beamforming Feedback Matrix V) based on the channel measured during the training symbols of a previous VHT NDP. | M<br>U | N |
| | Otherwise | See corresponding entry in Table 19-1 (TXVECTOR and RXVECTOR parameters) | | |
| CHAN_MAT_TYPE | FORMAT is VHT and PSDU_LENGTH equals zero | Set to COMPRESSED_SV<br>NOTE—This parameter is present only for TVHT NDPs. | N | Y |
| | FORMAT is VHT and PSDU_LENGTH is greater than zero | Not present | N | N |
| | Otherwise | See corresponding entry in Table 19-1 (TXVECTOR and RXVECTOR parameters) | | |
| CHAN_MAT | FORMAT is VHT and PSDU_LENGTH equals zero | Contains a set of compressed beamforming feedback matrices as defined in 21.3.11.2 (Beamforming Feedback Matrix V) based on the channel measured during the training symbols of the received VHT NDP. | N | Y |
| | FORMAT is VHT and PSDU_LENGTH is greater than zero | Not present | N | N |
| | Otherwise | See corresponding entry in Table 19-1 (TXVECTOR and RXVECTOR parameters) | | |
| DELTA_SNR | FORMAT is VHT | Contains an array of delta SNR values as defined in 9.4.1.50 (TVHT MU Exclusive Beamforming Report field) based on the channel measured during the training symbols of the received VHT NDP.<br>NOTE—In the RXVECTOR this parameter is present only for VHT NDPs for MU sounding. | M<br>U | Y |
| | Otherwise | Not present | N | N |


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**Table 22-1—TXVECTOR and RXVECTOR parameters *(continued)***

| Parameter | Condition | Value | TXVECTOR | RXVECTOR |
|---|---|---|---|---|
| SNR | FORMAT is VHT | Contains an array of measures of the received SNR for each spatial stream. SNR indications of 8 bits are supported. SNR shall be the sum of the decibel values of SNR per tone divided by the number of tones represented in each stream as described in 9.4.1.48 (TVHT Compressed Beamforming Report field). | N | Y |
| | Otherwise | See corresponding entry in Table 19-1 (TXVECTOR and RXVECTOR parameters) | | |
| NO_SIG_EXTN | FORMAT is VHT | Not present | N | N |
| | Otherwise | See corresponding entry in Table 19-1 (TXVECTOR and RXVECTOR parameters) | | |
| FEC_CODING | FORMAT is HT | Indicates which FEC encoding is used.<br>Enumerated type:<br>BCC_CODING indicates binary convolutional code.<br>LDPC_CODING indicates low-density parity check code. | M<br>U | Y |
| | Otherwise | See corresponding entry in Table 19-1 (TXVECTOR and RXVECTOR parameters) | | |
| STBC | FORMAT is VHT | Indicates whether STBC is used.<br>0 indicates no STBC ($N_{STS}=N_{SS}$ in the Data field).<br>1 indicates STBC is used ($N_{STS}=2N_{SS}$ in the Data field). | Y | Y |
| | Otherwise | See corresponding entry in Table 19-1 (TXVECTOR and RXVECTOR parameters) | | |
| GI_TYPE | FORMAT is VHT | Indicates whether a short guard interval is used in the transmission of the Data field of the PPDU.<br>Enumerated type:<br>LONG_GI indicates short GI is not used in the Data field of the PPDU.<br>SHORT_GI indicates short GI is used in the Data field of the PPDU. | Y | Y |
| | Otherwise | Not present | N | N |
| TXPWR_LEVEL_INDEX | FORMAT is VHT | The allowed values for the TXPWR_LEVEL_INDEX parameter are in the range 1 to $N/2$, where $N$ is the number of octets in dot11TxPowerLevelExtended. This parameter is used to indicate which of the available transmit output power levels defined in dot11TxPowerLevelExtended shall be used for the current transmission. | Y | N |
| | Otherwise | See corresponding entry in Table 19-1 (TXVECTOR and RXVECTOR parameters) | | |

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**Table 22-1—TXVECTOR and RXVECTOR parameters *(continued)***

| Parameter | Condition | Value | TXVECTOR | RXVECTOR |
|---|---|---|---|---|
| RSSI | FORMAT is VHT | The allowed values for the RSSI parameter are in the range 0 to 255. This parameter is a (#1132)measurement by the PHY of the power observed at the antenna connector used to receive the current PPDU measured during the reception of the TVHT-LTF field. RSSI is intended to be used in a relative manner, and it is a monotonically increasing function of the received power. | N | Y |
| | Otherwise | See corresponding entry in Table 19-1 (TXVECTOR and RXVECTOR parameters) | | |
| MCS | FORMAT is VHT | Indicates the modulation and coding scheme used in the transmission of the PPDU.<br>Integer: range 0 to 9 | M<br>U | Y |
| | Otherwise | See corresponding entry in Table 19-1 (TXVECTOR and RXVECTOR parameters) | | |
| REC_MCS | FORMAT is VHT | Indicates the MCS that the STA's receiver recommends. | N | O |
| | Otherwise | Not present | N | N |
| CH_BANDWIDTH | FORMAT is VHT | Indicates the channel width of the transmitted PPDU:<br>Enumerated type:<br>TVHT_W for one BCU<br>TVHT_2W for two contiguous BCUs<br>TVHT_W+W for two noncontiguous BCUs<br>TVHT_4W for four contiguous BCUs<br>TVHT_2W+2W for two noncontiguous frequency segments, each of which comprises two contiguous BCUs | Y | Y |
| | FORMAT is NON_HT | In TXVECTOR, indicates the channel width of the transmitted PPDU.<br>In RXVECTOR, indicates the estimated channel width of the received PPDU.<br>Enumerated type:<br>TVHT_W, TVHT_2W, TVHT_W+W, TVHT_4W, TVHT_2W+2W if NON_HT_MODULATION equals NON_HT_DUP_OFDM | Y | Y |
| DYN_BANDWIDTH_IN_NON_HT | FORMAT is NON_HT | (#1782)In TXVECTOR, if present, indicates whether the transmitter is capable of dynamic bandwidth operation as an RTS originator. In RXVECTOR, if valid, indicates whether the transmitter is capable of dynamic bandwidth operation as an RTS originator (see 10.3.2.9 (CTS and DMG CTS procedure)).<br>Enumerated type:<br>— Static if the transmitter is only capable of static bandwidth operation.<br>— Dynamic if the transmitter is capable of dynamic bandwidth operation.<br>NOTE—In the RXVECTOR, the validity of this parameter is determined by the MAC based on the contents of the received MPDU. | O | Y |
| | Otherwise | Not present | N | N |



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**Table 22-1—TXVECTOR and RXVECTOR parameters *(continued)***

| Parameter | Condition | Value | TXVECTOR | RXVECTOR |
|---|---|---|---|---|
| CH_BANDWIDTH_IN_NON_HT | FORMAT is NON_HT | In TXVECTOR, if present, indicates the channel width of the transmitted PPDU, which is signaled via the scrambling sequence. In RXVECTOR, if valid, indicates the channel width of the received PPDU, which is signaled via the scrambling sequence. Enumerated type: TVHT_W, TVHT_2W, TVHT_W+W, TVHT_4W, TVHT_2W+2W. NOTE—In the RXVECTOR, the validity of this parameter is determined by the MAC based on the contents of the received MPDU. | O | Y |
| | Otherwise | Not present | N | N |
| APEP_LENGTH | FORMAT is VHT | If equal to 0, indicates a TVHT NDP for both RXVECTOR and TXVECTOR. If greater than zero, in the TXVECTOR, indicates the number of octets in the range 1 to 1 048 575 in the A-MPDU pre-EOF padding (see 10.12.2 (A-MPDU length limit rules)) carried in the PSDU. If greater than zero, in the RXVECTOR, is the value obtained from the VHT-SIG-B Length field multiplied by 4. | M U | O |
| | Otherwise | Not present | N | N |
| PSDU_LENGTH | FORMAT is VHT | Indicates the number of octets in the VHT PSDU in the range 0 to 1 065 600 octets. A value of 0 indicates a VHT NDP. | N | Y |
| | Otherwise | Not present | N | N |
| USER_POSITION | FORMAT is VHT and 1 ≤ GROUP_ID ≤ 62 | Index for user in MU transmission. Integer: range 0 to 3. NOTE—The entries in the USER_POSITION array are in ascending order. | M U | O |
| | Otherwise | Not present | N | N |
| NUM_STS | FORMAT is VHT | Indicates the number of space-time streams. Integer: range 1 to 4 for SU, 1 to 3 per user in the TXVECTOR, and 0 to 4 in the RXVECTOR for MU. NUM_STS summed over all users is between 1 and 4. | M U | Y |
| | Otherwise | Not present | N | N |
| GROUP_ID | FORMAT is VHT | Indicates the group ID. Integer: range 0 to 63 (see Table 22-12 (Transmission mode and Gamma subk,m)) A value of 0 or 63 indicates a VHT SU PPDU. A value in the range 1 to 62 indicates a VHT MU PPDU. | Y | Y |
| | Otherwise | Not present | N | N |

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**Table 22-1—TXVECTOR and RXVECTOR parameters *(continued)***

| Parameter | Condition | Value | TXVECTOR | RXVECTOR |
|---|---|---|---|---|
| PARTIAL_AID | FORMAT is VHT and GROUP_ID is 0 or 63 | Provides an abbreviated indication of the intended recipient(s) of the PSDU (see 10.19 (Group ID and partial AID in VHT and CMMG PPDUs)).<br>Integer: range 0 to 511. | Y | Y |
| | Otherwise | Not present | N | N |
| NUM_USERS | FORMAT is VHT | Indicates the number of users with nonzero space-time streams.<br>Integer: range 1 to 4. | Y | N |
| | Otherwise | Not present | N | N |
| BEAMFORMED | FORMAT is VHT and GROUP_ID is 0 or 63 | Set to 1 if a beamforming steering matrix is applied to the waveform in an SU transmission. Set to 0 otherwise.<br>NOTE—When BEAMFORMED is(M118) 1, smoothing is not recommended. | Y | O |
| | Otherwise | Not present | N | N |
| TXOP_PS_NOT_ALLOWED | FORMAT is VHT | Indicates whether a TVHT AP allows non-AP TVHT STAs in TXOP power save mode to enter doze state during the TXOP.<br><br>0 indicates that the TVHT AP allows non-AP TVHT STAs to enter doze state during a TXOP.<br><br>1 indicates that the TVHT AP does not allow non-AP TVHT STAs to enter doze state during a TXOP. | Y | Y |
| | Otherwise | Not present | N | N |
| TIME_OF_DEPARTURE_REQUESTED | | Boolean value:<br>true indicates that the MAC entity requests that the PHY entity measures and reports time of departure parameters corresponding to the time when the first PPDU energy is sent by the transmitting port.<br>false indicates that the MAC entity requests that the PHY entity neither measures nor reports time of departure parameters. | O | N |


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**Table 22-1—TXVECTOR and RXVECTOR parameters *(continued)***

| Parameter | Condition | Value | TXVECTOR | RXVECTOR |
|---|---|---|---|---|
| RX_START_OF_FRAME_OFFSET | dot11TimingMsmtActivated is true | 0 to $2^{32}$– 1. An estimate of the offset (in 10 ns units) from the point in time at which the start of the preamble (#14)of the PPDU arrived at the receive antenna connector to the point in time at which this primitive is issued to the MAC. | N | Y |
| | Otherwise | Not present | N | N |

NOTE 1—In the TXVECTOR and RXVECTOR columns, the following apply:
Y = Present;
N = Not present;
O = Optional;
MU indicates that the parameter is present once for a VHT SU PPDU and present per user for a VHT MU PPDU. Parameters specified to be present per user are conceptually supplied as an array of values indexed by *u*, where *u* takes values 0 to NUM_USERS – 1.

NOTE 2—On reception, where valid, the CH_BANDWIDTH_IN_NON_HT parameter is likely to be a more reliable indication of subformat and channel width than the NON_HT_MODULATION and CH_BANDWIDTH parameters, since for non-HT or non-HT duplicate (#14)PPDUs, CH_BANDWIDTH is a receiver estimate of the bandwidth, whereas CH_BANDWIDTH_IN_NON_HT is the signaled bandwidth.

### 22.2.3 Effects of CH_BANDWIDTH parameter on PPDU format

Table 22-2 (PPDU format as a function of CH_BANDWIDTH parameter) shows the PPDU format as a function of the CH_BANDWIDTH and FORMAT parameters.

**Table 22-2—PPDU format as a function of CH_BANDWIDTH parameter**

| FORMAT | CH_BANDWIDTH | PPDU format |
|---|---|---|
| VHT | TVHT_W | The STA transmits a VHT PPDU in TVWS bands (when FORMAT is VHT) with TVHT_MODE_1. |
| VHT | TVHT_2W | The STA transmits a VHT PPDU in TVWS bands (when FORMAT is VHT) with TVHT_MODE_2C. |
| VHT | TVHT_4W | The STA transmits a VHT PPDU in TVWS bands (when FORMAT is VHT) with TVHT_MODE_4C. |
| VHT | TVHT_W+W | The STA transmits a VHT PPDU in TVWS bands (when FORMAT is VHT) with TVHT_MODE_2N. |
| VHT | TVHT_2W+2W | The STA transmits a VHT PPDU in TVWS bands (when FORMAT is VHT) with TVHT_MODE_4N. |

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**Table 22-2—PPDU format as a function of CH_BANDWIDTH parameter *(continued)***

| FORMAT | CH_BANDWIDTH | PPDU format |
|---|---|---|
| NON_HT | TVHT_W | The STA transmits a non-HT PPDU(#238) with NON_HT_MODULATION set to NON_HT_DUP_OFDM using one TVHT_W channel as defined in 22.3.10.12 (Non-HT duplicate transmission). If the BSS bandwidth is wider than TVHT_W, then the transmission shall use the primary TVHT_W channel. |
| NON_HT | TVHT_2W | The STA transmits a non-HT PPDU(#238) with NON_HT_MODULATION set to NON_HT_DUP_OFDM using two adjacent TVHT_W channels as defined in 22.3.10.12 (Non-HT duplicate transmission). If the BSS bandwidth is wider than TVHT_2W, then the transmission shall use the primary TVHT_2W channel. |
| NON_HT | TVHT_4W | The STA transmits a non-HT PPDU(#238) with NON_HT_MODULATION set to NON_HT_DUP_OFDM using four adjacent TVHT_W channels as defined in 22.3.10.12 (Non-HT duplicate transmission). |
| NON_HT | TVHT_W+W | The STA transmits a non-HT PPDU(#238) with NON_HT_MODULATION set to NON_HT_DUP_OFDM using two nonadjacent frequency segments, with each frequency segment consisting of single TVHT_W channels as defined in 22.3.10.12 (Non-HT duplicate transmission). |
| NON_HT | TVHT_2W+2W | The STA transmits a non-HT PPDU(#238) with NON_HT_MODULATION set to NON_HT_DUP_OFDM using two nonadjacent frequency segments, with each frequency segment consisting of two adjacent TVHT_W channels as defined in 22.3.10.12 (Non-HT duplicate transmission). |

### 22.2.4 Support for NON_HT and HT formats

Transmission of HT PPDUs is not supported in Clause 22 (Television very high throughput (TVHT) PHY specification). Except for Non-HT duplicate transmission defined in 22.3.10.12 (Non-HT duplicate transmission), transmission of NON_HT is not supported in Clause 22 (Television very high throughput (TVHT) PHY specification).

Non-HT duplicate transmission is based on Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification), unless otherwise stated in Clause 22 (Television very high throughput (TVHT) PHY specification).

(#3423)Non-HT PPDU format is shown in Figure 17-1 (PPDU format). The PPDU encoding process is defined in 17.3.2.2 (Overview of the PPDU encoding process) except for following modifications:

Modulation-dependent parameters for Non-HT duplicate mode in TVWS band is defined in Table 22-3 (Modulation-dependent parameters for Non-HT duplicate mode in TVWS band). Timing related parameters are defined in Table 22-5 (Timing-related constants in Non-HT PPDU). $t_{SIGNAL}$ in Equation (17-2) is equal to 16 multiplied by $X$ µs, and $t_{DATA}$ in Equation (17-2) is equal to 20 multiplied by $X$ µs where $X$ is 7.5 for 6 MHz and 7 MHz unit channels and $X$ is 5.625 for 8 MHz channels.

The timings for preamble are multiplied by $X$ where $X$ is 7.5 for 6 MHz and 7 MHz unit channels and $X$ is 5.625 for 8 MHz channels.


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**Table 22-3—Modulation-dependent parameters for Non-HT duplicate mode in TVWS band**

| Modulation | Coding rate ($R$) | Coded bits per subcarrier ($N_{BPSC}$) | Coded bits per OFDM symbol ($N_{CBPS}$) | Data bits per OFDM symbol ($N_{DBPS}$) | Data rate (Mb/s) (TVWS band) |
|---|---|---|---|---|---|
| BPSK | 1/2 | 1 | 48 | 24 | 6/$X$ (see NOTE) |
| BPSK | 3/4 | 1 | 48 | 36 | 9/$X$ (see NOTE) |
| QPSK | 1/2 | 2 | 96 | 48 | 12/$X$ (see NOTE) |
| QPSK | 3/4 | 2 | 96 | 72 | 18/$X$ (see NOTE) |
| 16-QAM | 1/2 | 4 | 192 | 96 | 24/$X$ (see NOTE) |
| 16-QAM | 3/4 | 4 | 192 | 144 | 36/$X$ (see NOTE) |
| 64-QAM | 2/3 | 6 | 288 | 192 | 48/$X$ (see NOTE) |
| 64-QAM | 3/4 | 6 | 288 | 216 | 54/$X$ (see NOTE) |
| NOTE—In TVWS band, $X$ depends on regulatory domain, i.e., 7.5 for 6 MHz and 7 MHz unit channels and 5.625 for 8 MHz channels. | | | | | |

Constructions of L-STF, L-LTF, and L-SIG are same as in 22.3.4.2 (Construction of L-STF), 22.3.4.3 (Construction of the L-LTF), and 22.3.4.4 (Construction of L-SIG) except for the value field parameters in L-SIG.

Interpretation of the bits R1-R4 in the SIGNAL field is modified as in Table 22-4 (RATE field in L-SIG).

**Table 22-4—RATE field in L-SIG**

| R1-R4 | Modulation | Coding rate |
|---|---|---|
| 1101 | BPSK | 1/2 |
| 1111 | BPSK | 3/4 |
| 0101 | QPSK | 1/2 |
| 0111 | QPSK | 3/4 |
| 1001 | 16-QAM | 1/2 |
| 1011 | 16-QAM | 3/4 |
| 0001 | 64-QAM | 2/3 |
| 0011 | 64-QAM | 3/4 |

Table 22-5 (Timing-related constants in Non-HT PPDU) and Table 22-6 (Tone location in Non-HT PPDU) define the timing-related parameters for Non-HT format and location of occupied tones.

Other timing parameters are derived as in Table 17-5 (Timing-related parameters) using the definition of $T_{FFT}$ in Table 22-5 (Timing-related constants in Non-HT PPDU). Table 22-6 (Tone location in Non-HT

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**Table 22-5—Timing-related constants in Non-HT PPDU**

| Parameter | 6 MHz | 7 MHz | 8 MHz | Description |
|---|---|---|---|---|
| $N_{SD}$ | 96 | 96 | 96 | Number of complex data numbers per BCU |
| $N_{SP}$ | 8 | 8 | 8 | Number of pilot values per BCU |
| $N_{ST}$ | 104 | 104 | 104 | Total number of subcarriers per BCU |
| $N_{SR}$ | 58 | 58 | 58 | Highest data subcarrier index per BCU |
| $\Delta_F$ | $\frac{6\text{ MHz}}{144} = 41\frac{2}{3}$ kHz | $\frac{7\text{ MHz}}{168} = 41\frac{2}{3}$ kHz | $\frac{8\text{ MHz}}{144} = 55\frac{5}{9}$ kHz | Subcarrier frequency spacing |
| $T_{DFT}$ | 24 μs | 24 μs | 18 μs | IDFT/DFT period |
| $T_{GI}$ | 6 μs = $T_{DFT}$/4 | 6 μs = $T_{DFT}$/4 | 4.5 μs = $T_{DFT}$/4 | Guard interval duration |
| $T_{GIS}$ | 3 μs = $T_{DFT}$/8 | 3 μs = $T_{DFT}$/8 | 2.25 μs = $T_{DFT}$/8 | Short guard interval duration |

**Table 22-6—Tone location in Non-HT PPDU**

| Parameter | TVHT_MODE_1 | TVHT_MODE_2C | TVHT_MODE_2N | TVHT_MODE_4C | TVHT_MODE_4N | Description |
|---|---|---|---|---|---|---|
| $N_{ST}$ | 104 | 104 | 104 | 104 | 104 | Total number of occupied subcarriers per BCU |
| $N_{TT}$ | 104 | 208 | 208 | 416 | 416 | Total number of occupied subcarriers across all BCUs |
| Subcarrier index | –58 to –33, –31 to –6, +6 to +31, and +33 to +58 | –130 to –105, –103 to –78, –66 to –41, –39 to –14, +14 to +39, +41 to +66, +78 to +103, and +105 to +130 | –58 to –33, –31 to –6, +6 to +31, and +33 to +58 for each BCU | –274 to –249, –247 to –222, –210 to –185, –183 to –158, –130 to –105, –103 to –78, –66 to –41, –39 to –14, +14 to +39, +41 to +66, +78 to +103, +105 to +130, +158 to +183, +185 to +210, +222 to +247, and +249 to +274 | –130 to –105, –103 to –78, –66 to –41, –39 to –14, +14 to +39, +41 to +66, +78 to +103, and +105 to +130 for each BCU | Location of occupied subcarriers for 6 MHz and 8 MHz channel units |


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**Table 22-6—Tone location in Non-HT PPDU *(continued)***

| Parameter | TVHT_ MODE_1 | TVHT_ MODE_2C | TVHT_ MODE_2N | TVHT_ MODE_4C | TVHT_ MODE_4N | Description |
|---|---|---|---|---|---|---|
| Subcarrier index | –58 to –33, –31 to –6, +6 to +31, and +33 to +58 | –142 to –117, –115 to –90, –78 to –53, –51 to –26, +26 to +51, +53 to +78, +90 to +115, and +117 to +142 | –58 to –33, –31 to –6, +6 to +31, and +33 to +58 for each BCU | –310 to –285, –283 to –258, –246 to –221, –219 to –194, –142 to –117, –115 to –90, –78 to –53, –51 to –26, +26 to +51, +53 to +78, +90 to +115, +117 to +142, +194 to +219, +221 to +246, +258 to +283, and +285 to +310 | –142 to –117, –115 to –90, –78 to –53, –51 to –26, +26 to +51, +53 to +78, +90 to +115, and +117 to +142 for each BCU | Location of occupied subcarriers for 7 MHz |

PPDU) defines the number of occupied tones and their location in all transmission modes. Zero denotes the DC tone of any contiguous segment.

Refer to Table 21-6 (Frequently used parameters) for parameters definition. The definitions in the table are applicable to Clause 22 (Television very high throughput (TVHT) PHY specification) with the exception that in each transmission mode in Clause 22 (Television very high throughput (TVHT) PHY specification) $N_{CBPSSI} = N_{CBPSS}$ for SU and MU PPDUs.

### 22.2.5 PHYCONFIG_VECTOR parameters(#2115)

The PHYCONFIG_VECTOR carried in a PHY-CONFIG.request primitive for a TVHT PHY contains a BASIC_CHANNEL_UNIT parameter, which identifies the basic channel unit with possible values being 6 MHz, 7 MHz, and 8 MHz.

The PHYCONFIG_VECTOR carried in a PHY-CONFIG.request primitive for a TVHT PHY contains an OPERATING_CHANNEL parameter, which identifies the operating or primary channel. The PHY shall set dot11CurrentPrimaryChannel to the value of this parameter.

The PHYCONFIG_VECTOR carried in a PHY-CONFIG.request primitive for a TVHT PHY contains a CHANNEL_WIDTH parameter, which identifies the operating channel and takes one of the values TVHT_W, TVHT_2W, TVHT_W+W, TVHT_4W, and TVHT_2W+2W. The PHY shall set dot11CurrentTVHTChannelWidth to the value of this parameter.

The PHYCONFIG_VECTOR carried in a PHY-CONFIG.request primitive for a TVHT PHY contains a CENTER_FREQUENCY_SEGMENT0 parameter. The PHY shall set dot11CurrentTVHTChannelCenterFrequencyIndex0 to the value of this parameter.

The PHYCONFIG_VECTOR carried in a PHY-CONFIG.request primitive for a TVHT PHY contains a CENTER_FREQUENCY_SEGMENT1 parameter. The PHY shall set dot11CurrentTVHTChannelCenterFrequencyIndex1 to the value of this parameter.

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(#4383)The PHYCONFIG_VECTOR carried in a PHY-CONFIG.request primitive for a TVHT PHY contains a GROUP_ID_MANAGEMENT parameter, which specifies membership status and STA position for each of the group IDs as described in 9.6.22.3 (Group ID Management frame format).

(#4383)The PHYCONFIG_VECTOR carried in a PHY-CONFIG.request primitive for a TVHT PHY contains a PARTIAL_AID_LIST_GID00 parameter, which includes the list of partial AIDs, of which the STA is an intended recipient, associated with group ID 0. The settings of the PARTIAL_AID are specified in 10.19 (Group ID and partial AID in VHT and CMMG PPDUs).

(#4383)The PHYCONFIG_VECTOR carried in a PHY-CONFIG.request primitive for a TVHT PHY contains a PARTIAL_AID_LIST_GID63 parameter, which includes the list of partial AIDs, of which the STA is an intended recipient, associated with group ID 63. The settings of the PARTIAL_AID are specified in 10.19 (Group ID and partial AID in VHT and CMMG PPDUs).

(#4383)The PHYCONFIG_VECTOR carried in a PHY-CONFIG.request primitive for a TVHT PHY contains a LISTEN_TO_GID00 parameter, which, when true, indicates to the PHY not to filter out PPDUs with GROUP_ID field equal to 0.

(#4383)The PHYCONFIG_VECTOR carried in a PHY-CONFIG.request primitive for a TVHT PHY contains a LISTEN_TO_GID63 parameter, which, when true, indicates to the PHY not to filter out PPDUs with GROUP_ID field equal to 63.

(#4384)Additional PHYCONFIG_VECTOR parameters are defined in Table 8-4 (Vector descriptions(#4383)).

## 22.3 TVHT PHY layer(#4114)

### 22.3.1 Introduction

See 21.3.1 (Introduction).

### 22.3.2 VHT PPDU format in TVWS bands

A single PPDU format is defined for this PHY: the VHT PPDU format in TVWS bands. Figure 22-1 (VHT PPDU format in TVWS bands) shows the VHT PPDU format in TVWS bands, with the timing parameters (8 μs and 4 μs) in Figure 21-4 (VHT PPDU format) replaced by numbers from Table 22-8 (Timing-related parameters).

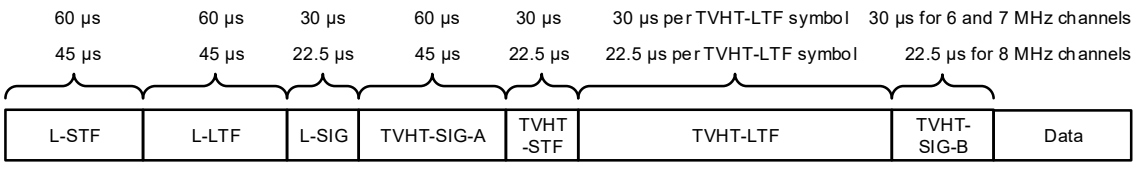


**Figure 22-1—VHT PPDU format in TVWS bands**

The fields of the VHT PPDU format in TVWS bands are summarized in Table 22-7 (Fields of the VHT PPDU in TVWS bands).

The TVHT-SIG-A, TVHT-STF, TVHT-LTF, and TVHT-SIG-B fields exist only in VHT PPDU in TVWS bands. In a TVHT NDP, the Data field is not present. The number of symbols in the TVHT-LTF field,


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**Table 22-7—Fields of the VHT PPDU in TVWS bands**

| Field | Description |
|---|---|
| L-STF | Non-HT Short Training field |
| L-LTF | Non-HT Long Training field |
| L-SIG | Non-HT SIGNAL field |
| TVHT-SIG-A | TVHT Signal A field |
| TVHT-STF | TVHT Short Training field |
| TVHT-LTF | TVHT Long Training field |
| TVHT-SIG-B | TVHT Signal B field |
| Data | The Data field includes the PSDU |

$N_{TVHT\text{-}LTF}$, can be 1, 2, or 4 and is determined by the total number of space-time streams across all users being transmitted in the VHT PPDU in TVWS bands (see Table 21-13 (Number of VHT-LTFs required for different numbers of space-time streams)).

### 22.3.3 Transmitter block diagram

The transmit process for the L-SIG and TVHT-SIG-A fields of a VHT PPDU using one BCU is shown in Figure 21-5 (Transmitter block diagram for the L-SIG and VHT-SIG-A fields), with "TVHT" replacing "VHT" and with bandwidth corrected according to TVHT bandwidth.

The transmit process for generating the TVHT-SIG-B field of a VHT SU PPDU and VHT MU PPDU using one frequency segment is shown in Figure 21-5 (Transmitter block diagram for the L-SIG and VHT-SIG-A fields) and Figure 21-7 (Transmitter block diagram for the VHT-SIG-B field of a 20 MHz, 40 MHz, and 80 MHz VHT MU PPDU(#2259)(#7214)), respectively, with "TVHT" replacing "VHT" and with bandwidth corrected according to TVHT bandwidth.

The transmit process for generating the Data field of an SU PPDU in TVHT_MODE_1, TVHT_MODE_2C, or TVHT_MODE_4C with BCC and LDPC encodings, using one BCU, is shown Figure 21-10 (Transmitter block diagram for the Data field of a 20 MHz, 40 MHz, or 80 MHz VHT SU PPDU with BCC encoding) and Figure 21-11 (Transmitter block diagram for the Data field of a 20 MHz, 40 MHz, or 80 MHz VHT SU PPDU with LDPC encoding), respectively, with "TVHT" replacing "VHT" and with bandwidth corrected according to TVHT bandwidth. Single BCC encoder shall be assumed in Figure 21-10 (Transmitter block diagram for the Data field of a 20 MHz, 40 MHz, or 80 MHz VHT SU PPDU with BCC encoding).

The transmit process for generating the Data field of an MU PPDU in TVHT_MODE_1, TVHT_MODE_2C, or TVHT_MODE_4C with BCC and LDPC encoding is shown in Figure 21-12 (Transmitter block diagram for the Data field of a 20 MHz, 40 MHz, or 80 MHz VHT MU PPDU), with "TVHT" replacing "VHT" and with bandwidth corrected according to TVHT bandwidth. In the case of BCC encoding, single BCC encoder shall be assumed in Figure 21-12 (Transmitter block diagram for the Data field of a 20 MHz, 40 MHz, or 80 MHz VHT MU PPDU).

Figure 22-2 (Transmitter block diagram for the Data field of a TVHT_MODE_2N or TVHT_MODE_4N SU PPDU with BCC encoding) and Figure 22-3 (Transmitter block diagram for the Data field of a TVHT_MODE_2N or TVHT_MODE_4N SU PPDU with LDPC encoding) show the transmit process for generating the Data field of a TVHT_MODE_2N or TVHT_MODE_4N SU PPDU with BCC and LDPC encoding, respectively, where the subcarrier allocation block allocates the subcarriers for the two IDFTs in

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each transmit path by the subcarrier mapper as described in 22.3.10.11 (OFDM modulation transmission in VHT format).

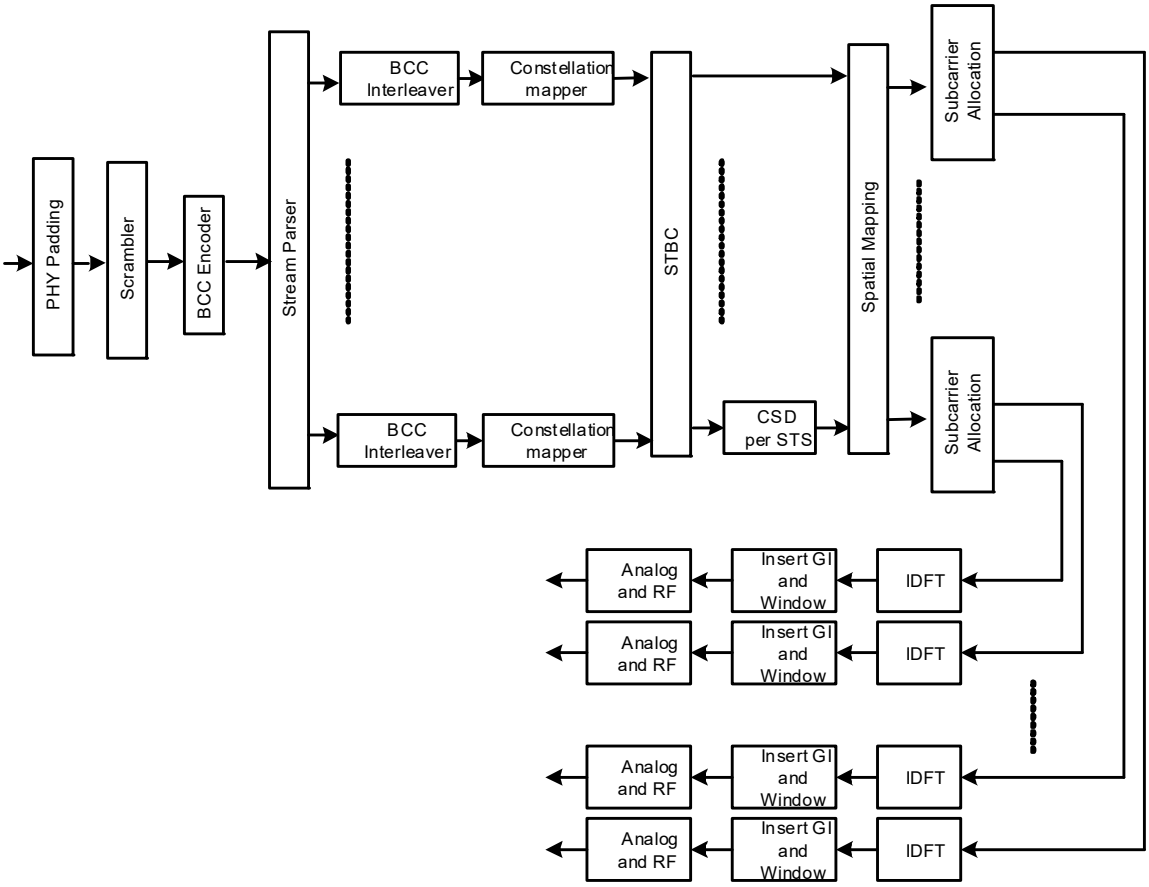


**Figure 22-2—Transmitter block diagram for the Data field of a TVHT_MODE_2N or TVHT_MODE_4N SU PPDU with BCC encoding**


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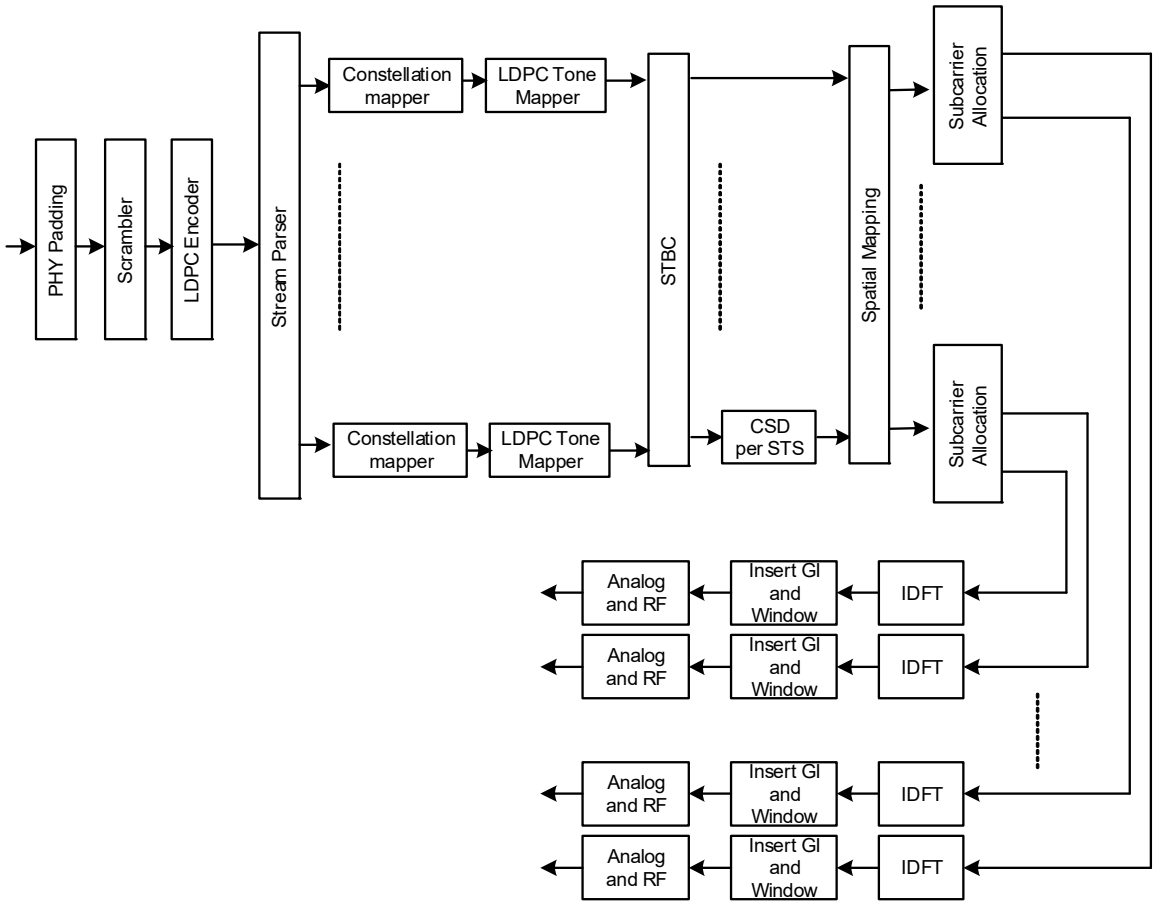


**Figure 22-3—Transmitter block diagram for the Data field of a TVHT_MODE_2N or TVHT_MODE_4N SU PPDU with LDPC encoding**

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### 22.3.4 Overview of the PPDU encoding process

#### 22.3.4.1 General

This subclause provides an overview of the VHT PPDU in TVWS bands encoding process.

#### 22.3.4.2 Construction of L-STF

Construct the L-STF field as defined in 22.3.8.2.2 (L-STF definition) following the procedure in 21.3.4.2 (Construction of L-STF) reading "Clause 22 (Television very high throughput (TVHT) PHY specification)" for references to "Clause 21 (Very high throughput (VHT) PHY specification)" except the following:

c) Duplication and phase rotation: Duplicate the L-STF over the BCUs of the CH_BANDWIDTH. Apply appropriate phase rotation as defined in 22.3.7 (Mathematical description of signals).

#### 22.3.4.3 Construction of the L-LTF

Construct the L-LTF field as defined in L-LTF definition following the procedure in 21.3.4.3 (Construction of the L-LTF) reading "Clause 22 (Television very high throughput (TVHT) PHY specification)" for references to "Clause 21 (Very high throughput (VHT) PHY specification)" except the following:

c) Duplication and phase rotation: Duplicate the L-LTF over the BCUs of the CH_BANDWIDTH. Apply appropriate phase rotation as defined in 22.3.7 (Mathematical description of signals).

#### 22.3.4.4 Construction of L-SIG

Construct the L-SIG field as the SIGNAL field defined by 22.3.8.2.4 (L-SIG definition) following the procedure in 21.3.4.4 (Construction of L-SIG) reading "Clause 22 (Television very high throughput (TVHT) PHY specification)" for references to "Clause 21 (Very high throughput (VHT) PHY specification)" except the following:

a) For a VHT PPDU in TVWS bands, set the RATE subfield in the SIGNAL field R1-R4 to 1101. Set the Length, Parity, and Tail bits in the SIGNAL field as defined in 22.3.8.2.4 (L-SIG definition). Add calculated one bit parity and $N_{tail}$ bits into the L-SIG symbol.

f) Duplication and phase rotation: Duplicate the L-SIG field over the BCUs of the CH_BANDWIDTH. Apply appropriate phase rotation as defined in 22.3.7 (Mathematical description of signals).

#### 22.3.4.5 Construction of TVHT-SIG-A

The TVHT-SIG-A field consists of two symbols, TVHT-SIG-A1 and TVHT-SIG-A2, constructed as defined in 22.3.8.3.3 (TVHT-SIG-A definition) following the procedure in 21.3.4.5 (Construction of VHT-SIG-A) reading "Clause 22 (Television very high throughput (TVHT) PHY specification)" for references to "Clause 21 (Very high throughput (VHT) PHY specification)" except the following:

e) Pilot insertion: Insert pilots following the steps defined in 22.3.10.10 (Pilot subcarriers).

f) Duplication and phase rotation: Duplicate TVHT-SIG-A1 and TVHT-SIG-A2 over of the BCUs of the CH_BANDWIDTH. Apply the appropriate phase rotation as defined in 22.3.7 (Mathematical description of signals).

i) Insert GI and apply windowing: Prepend a GI (LONG_GI) and apply windowing as defined in 22.3.7 (Mathematical description of signals).

#### 22.3.4.6 Construction of TVHT-STF

Construct the TVHT-STF field for each BCU as defined in 22.3.8.3.4 (TVHT-STF definition) with channel bandwidth being 40 MHz, following the procedure in 21.3.4.6 (Construction of VHT-STF) reading


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"Clause 22 (Television very high throughput (TVHT) PHY specification)" for references to "Clause 21 (Very high throughput (VHT) PHY specification)" except the following:

b) Phase rotation: Apply appropriate phase rotation as defined in 22.3.7 (Mathematical description of signals).

f) Insert GI and apply windowing: Prepend a GI (LONG_GI) and apply windowing as defined in 22.3.7 (Mathematical description of signals).

In multiple BCU transmissions TVHT_MODE_2C, TVHT_MODE_2N, TVHT_MODE_4C, and TVHT_MODE_4N, the TVHT-STF subcarriers of one BCU are repeated in each BCU with an appropriate phase rotation factor being applied as described in 22.3.8.3.4 (TVHT-STF definition).

### 22.3.4.7 Construction of TVHT-LTF

Construct the TVHT-LTF field for each BCU as defined in 22.3.8.3.5 (TVHT-LTF definition) with channel bandwidth being 40 MHz, following the procedure in 21.3.4.7 (Construction of VHT-LTF) reading "Clause 22 (Television very high throughput (TVHT) PHY specification)" for references to "Clause 21 (Very high throughput (VHT) PHY specification)" except the following:

b) Phase rotation: Apply appropriate phase rotation as defined in 22.3.7 (Mathematical description of signals).

g) Insert GI and apply windowing: Prepend a GI (LONG_GI) and apply windowing as defined in 22.3.7 (Mathematical description of signals).

In multiple BCU transmissions TVHT_MODE_2C, TVHT_MODE_2N, TVHT_MODE_4C, and TVHT_MODE_4N, the TVHT-LTF subcarriers of one BCU are repeated in each BCU with an appropriate phase rotation factor being applied as described in 22.3.8.3.5 (TVHT-LTF definition).

### 22.3.4.8 Construction of TVHT-SIG-B

The TVHT-SIG-B field is constructed per-user for each BCU as defined in 21.3.4.8 (Construction of VHT-SIG-B) with channel bandwidth being 40 MHz, reading "Clause 22 (Television very high throughput (TVHT) PHY specification)" for references to "Clause 21 (Very high throughput (VHT) PHY specification)" except the following:

i) Pilot insertion: Insert pilots following the steps defined in 22.3.10.10 (Pilot subcarriers).

m) Phase rotation: Apply the appropriate phase rotations as defined in 22.3.7 (Mathematical description of signals).

o) Insert GI and apply windowing: Prepend a GI (LONG_GI) and apply windowing as defined in 22.3.7 (Mathematical description of signals).

In multiple BCU transmissions TVHT_MODE_2C, TVHT_MODE_2N, TVHT_MODE_4C, and TVHT_MODE_4N, the TVHT-SIG-B subcarriers of one BCU are repeated in each BCU with an appropriate phase rotation factor being applied as described in 22.3.8.3.6 (TVHT-SIG-B definition).

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### 22.3.4.9 Construction of the Data field in an SU PPDU

#### 22.3.4.9.1 Using BCC

The construction of the Data field in a VHT SU PPDU with BCC encoding proceeds as defined in 21.3.4.9.1 (Using BCC) reading "Clause 22 (Television very high throughput (TVHT) PHY specification)" for references to "Clause 21 (Very high throughput (VHT) PHY specification)" except the following:

d) BCC encoder: Only one encoder is used.

f) Segment parser is omitted.

i) Segment deparser is omitted.

l) CSD: Apply CSD for each space-time stream and frequency segment as described in 22.3.8.3.2 (Cyclic shift for TVHT modulated fields).

n) Phase rotation: Apply the appropriate phase rotations as defined in 22.3.7 (Mathematical description of signals).

o) IDFT: When in TVHT_MODE_2N or VHT_MODE_4N, allocate the subcarriers for the two IDFTs in each transmit path as described in 22.3.10.11 (OFDM modulation transmission in VHT format).

p) Insert GI and apply windowing: Prepend a GI (SHORT_GI or LONG_GI) and apply windowing as defined in 22.3.7 (Mathematical description of signals).

#### 22.3.4.9.2 Using LDPC

The construction of the Data field in a VHT SU PPDU with LDPC encoding proceeds as defined in 21.3.4.9.2 (Using LDPC) reading "Clause 22 (Television very high throughput (TVHT) PHY specification)" for references to "Clause 21 (Very high throughput (VHT) PHY specification)" except the following:

f) Segment parser is omitted.

i) Segment deparser is omitted.

l) CSD: Apply CSD for each space-time stream and frequency segment as described in 22.3.8.3.2 (Cyclic shift for TVHT modulated fields).

n) Phase rotation: Apply the appropriate phase rotations as defined in 22.3.7 (Mathematical description of signals). When in TVHT_MODE_2N or VHT_MODE_4N, allocate the subcarriers for the two IDFTs in each transmit path as described in 21.3.10.11.1 (Transmission in VHT format).

o) IDFT: When in TVHT_MODE_2N or VHT_MODE_4N, allocate the subcarriers for the two IDFTs in each transmit path as described in 22.3.10.11 (OFDM modulation transmission in VHT format).

p) Insert GI and apply windowing: Prepend a GI (SHORT_GI or LONG_GI) and apply windowing as defined in 22.3.7 (Mathematical description of signals).

### 22.3.4.10 Construction of the Data field in an MU PPDU

#### 22.3.4.10.1 General

See 21.3.4.10.1 (General).

#### 22.3.4.10.2 Using BCC

A Data field with BCC encoding is constructed using the process defined in 22.3.4.9.1 (Using BCC) before the spatial mapping block and repeated for each user that uses BCC encoding.


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#### 22.3.4.10.3 Using LDPC

A Data field with LDPC encoding is constructed using the process defined in 22.3.4.9.2 (Using LDPC) before the spatial mapping block and repeated for each user that uses LDPC encoding.

#### 22.3.4.10.4 Combining to form an MU PPDU

The per-user data is combined as defined in 21.3.4.10.4 (Combining to form a VHT MU PPDU) except the following:

a) Spatial mapping: The *Q* matrix is applied as defined in 22.3.10.11 (OFDM modulation transmission in VHT format). The combining of all user data is done in this block.

b) Phase rotation: Apply the appropriate phase rotations as defined in 22.3.7 (Mathematical description of signals).

d) Insert GI and apply windowing: Prepend a GI (SHORT_GI or LONG_GI) and apply windowing as defined in 22.3.7 (Mathematical description of signals).

e) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit. Refer to 22.3.7 (Mathematical description of signals) and 22.3.8 (TVHT preamble) for details.

### 22.3.5 Modulation and coding scheme (MCS)

The MCS is a value that determines the modulation and coding used in the Data field of the PPDU. It is a compact representation that is carried in the TVHT-SIG-A field for SU PPDUs and in the TVHT-SIG-B field for MU PPDUs. Rate-dependent parameters for the full set of MCSs are shown in Table 22-26 (TVHT-MCSs for TVHT_MODE_1, NSS = 1) to Table 22-37 (TVHT-MCSs for TVHT_MODE_4C and TVHT_MODE_4N, NSS = 4) (in 22.5 (Parameters for TVHT-MCSs)). These tables give rate-dependent parameters for MCSs with indices 0 to 9, with number of spatial streams from 1 to 4 and bandwidth options of one, two, or four BCUs. Equal modulation (EQM) is applied to all streams for a particular user.

Table 22-26 (TVHT-MCSs for TVHT_MODE_1, NSS = 1) to Table 22-29 (TVHT-MCSs for TVHT_MODE_1, NSS = 4) show rate-dependent parameters for MCSs for one to four streams for one BCU operation. Table 22-30 (TVHT-MCSs for TVHT_MODE_2C and TVHT_MODE_2N, NSS = 1) to Table 22-33 (TVHT-MCSs for TVHT_MODE_2C and TVHT_MODE_2N, NSS = 4) show rate-dependent parameters for MCSs for one to four streams for dual BCU operation. Table 22-34 (TVHT-MCSs for TVHT_MODE_4C and TVHT_MODE_4N, NSS = 1) to Table 22-37 (TVHT-MCSs for TVHT_MODE_4C and TVHT_MODE_4N, NSS = 4) show rate-dependent parameters for MCSs for one to four streams for quad BCU operation.

### 22.3.6 Timing-related parameters

Table 22-8 (Timing-related parameters) and Table 22-9 (Tone location) define the timing-related parameters for VHT format and location of occupied tones in TVWS bands.

**Table 22-8—Timing-related parameters**

| Parameter | 6 MHz | 7 MHz | 8 MHz | Description |
|---|---|---|---|---|
| $N_{SD}$ | 108 | 108 | 108 | Number of complex data numbers per BCU |
| $N_{SP}$ | 6 | 6 | 6 | Number of pilot values per BCU |

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**Table 22-8—Timing-related parameters**

| Parameter | 6 MHz | 7 MHz | 8 MHz | Description |
|---|---|---|---|---|
| $N_{ST}$ | 114 | 114 | 114 | Total number of subcarriers per BCU |
| $N_{SR}$ | 58 | 58 | 58 | Highest data subcarrier index per BCU |
| $\Delta_F$ | $\frac{6\text{ MHz}}{144} = 41\frac{2}{3}$ kHz | $\frac{7\text{ MHz}}{168} = 41\frac{2}{3}$ kHz | $\frac{8\text{ MHz}}{144} = 55\frac{5}{9}$ kHz | Subcarrier frequency spacing |
| $T_{DFT}$ | 24 μs | 24 μs | 18 μs | IDFT/DFT period |
| $T_{GI}$ | 6 μs = $T_{DFT}$/4 | 6 μs = $T_{DFT}$/4 | 4.5 μs = $T_{DFT}$/4 | Guard interval duration |

**Table 22-9—Tone location**

| Parameter | TVHT_MODE_1 | TVHT_MODE_2C | TVHT_MODE_2N | TVHT_MODE_4C | TVHT_MODE_4N | Description |
|---|---|---|---|---|---|---|
| $N_{ST}$ | 114 | 114 | 114 | 114 | 114 | Total number of occupied subcarriers per BCU |
| $N_{TT}$ | 114 | 228 | 228 | 456 | 456 | Total number of occupied subcarriers across all BCUs |
| Subcarrier index | –58 to –2 and +2 to +58 | –130 to –74, –70 to –14, +14 to +70, and +74 to +130 | –58 to –2 and +2 to +58 for each BCU | –274 to –218, –214 to –158, –130 to –74, –70 to –14, +14 to +70, +74 to +130, +158 to +214, and +218 to +274 | –130 to –74, –70 to –14, +14 to +70, and +74 to +130 for each BCU | Location of occupied subcarriers for 6 MHz and 8 MHz channel units |
| Subcarrier index | –58 to –2 and +2 to +58 | –142 to –86, –82 to –26, +26 to +82, and +86 to +142 | –58 to –2 and +2 to +58 for each BCU | –310 to –254, –250 to –194, –142 to –86, –82 to –26, +26 to +82, +86 to +142, +194 to +250, and +254 to +310 | –142 to –86, –82 to –26, +26 to +82, and +86 to +142 for each BCU | Location of occupied subcarriers for 7 MHz |

The rest of the timing parameters are derived as in Table 21-5 (Timing-related constants) using the definition of $T_{DFT}$ in Table 22-8 (Timing-related parameters). Table 22-9 (Tone location) defines the number of occupied tones and their location in all transmission modes. Zero denotes the DC tone of any contiguous segment.

Refer to Table 21-6 (Frequently used parameters) for the frequency parameters. The definitions in the table are applicable to Clause 22 (Television very high throughput (TVHT) PHY specification) with the exception


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that in each transmission mode in Clause 22 (Television very high throughput (TVHT) PHY specification) $N_{CBPSSI} = N_{CBPSS}$ for SU and MU PPDUs.

### 22.3.7 Mathematical description of signals

For a description of the conventions used for the mathematical description of the signals, see 17.3.2.5 (Mathematical conventions in the signal descriptions).

For all VHT PPDU in TVWS bands transmission modes the signal is transmitted on subcarriers as defined in Table 22-9 (Tone location).

Let

$f_{c,\,\mathrm{idx0}}$ = dot11CurrentTVHTChannelCenterFrequencyIndex0 (see Table 22-17 (Fields to specify TVHT channels))

$f_{c,\,\mathrm{idx1}}$ = dot11CurrentTVHTChannelCenterFrequencyIndex1 (see Table 22-17 (Fields to specify TVHT channels))

$f_{\mathrm{PW,\,idx}}$ = dot11CurrentPrimaryChannel (see Table 22-17 (Fields to specify TVHT channels)), where TVHT_W refers to a BCU of 6 MHz, 7 MHz, or 8 MHz

$f_{\mathrm{CH,\,start}}$ = Channel starting frequency given in the operation class (E.1 (Country information and operating classes))

When dot11CurrentTVHTChannelWidth is TVHT_W, TVHT_2W, TVHT_W+W, TVHT_4W, or TVHT_2W+2W, $f_{PW,idx}$ and $f_{c,idx1}$ shall have the relationship specified in Equation (22-1).

$$f_{\mathrm{PW,\,idx}} = f_{c,\,\mathrm{idx0}} + n_{\mathrm{PW}} \tag{22-1}$$

where

$$N_{PW} = \begin{cases} 1 \text{ in TVHT\_W and TVHT\_W+W} \\ 2 \text{ in TVHT\_2W and TVHT\_2W+2W} \\ 4 \text{ in TVHT\_4W} \end{cases}$$

$n_{\mathrm{PW}}$ is an integer with possible range $0 \le n_{\mathrm{PW}} \le N_{PW} - 1$

When dot11CurrentTVHTChannelWidth is TVHT_W, TVHT_2W, TVHT_W+W, TVHT_4W, or TVHT_2W+2W,

— The primary TVHT_W channel is the channel with TVHT_W bandwidth centered at $f_{\mathrm{CH,\,start}} + \mathrm{TVHT\_W} \times f_{\mathrm{PW,\,idx}}$, where $f_{\mathrm{PW,\,idx}}$ is given in Equation (22-1).

When dot11CurrentTVHTChannelWidth is TVHT_2W, TVHT_4W, or TVHT_2W+2W,

— The secondary TVHT_W channel is the channel with TVHT_W bandwidth centered at $f_{\mathrm{CH,\,start}} + \mathrm{TVHT\_W} \times f_{\mathrm{SW,\,idx}}$, where $f_{\mathrm{SW,\,idx}}$ is given in Equation (22-2).

$$f_{\mathrm{SW,\,idx}} = \begin{cases} f_{\mathrm{PW,\,idx}} + 1, & \text{if } n_{\mathrm{PW}} \text{ is even} \\ f_{\mathrm{PW,\,idx}} - 1, & \text{if } n_{\mathrm{PW}} \text{ is odd} \end{cases} \tag{22-2}$$

When dot11CurrentTVHTChannelWidth is TVHT_W+W,

— The secondary TVHT_W channel is the channel with TVHT_W bandwidth centered at $f_{\mathrm{CH,\,start}} + \mathrm{TVHT\_W} \times f_{\mathrm{SW,\,idx}}$, where $f_{\mathrm{SW,\,idx}}$ is given in Equation (22-3).

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$$f_{\mathrm{SW,\,idx}} = f_{c,\,\mathrm{idx1}} \tag{22-3}$$

When dot11CurrentTVHTChannelWidth is TVHT_2W, TVHT_4W, or TVHT_2W+2W,

— The primary TVHT_2W channel is the channel with TVHT_2W bandwidth centered at $f_{\mathrm{CH,\,start}} + \mathrm{TVHT\_W} \times f_{\mathrm{P2W,\,idx}} + 0.5 \times \mathrm{TVHT\_W}$ MHz, where $f_{\mathrm{P2W,\,idx}}$ is given in Equation (22-4).

— The secondary TVHT_2W channel is the channel with TVHT_2W bandwidth centered at $f_{\mathrm{CH,\,start}} + \mathrm{TVHT\_W} \times f_{S2W,\,\mathrm{idx}} + 0.5 \times \mathrm{TVHT\_W}$ MHz, where $f_{S2W,\,\mathrm{idx}}$ is given in Equation (22-5).

$$f_{\mathrm{P2W,\,idx}} = f_{c,\,\mathrm{idx0}} + 2 \times n_{\mathrm{P2W}} \quad 0 \le n_{\mathrm{P2W}} \le N_{P2W} - 1 \quad N_{P2W} = \begin{cases} 1 \text{ in TVHT\_2W and TVHT\_2W+2W} \\ 2 \text{ in TVHT\_4W} \end{cases} \tag{22-4}$$

When dot11CurrentTVHTChannelWidth is TVHT_4W,

— The secondary TVHT_2W channel is the channel with TVHT_2W bandwidth centered at $f_{\mathrm{CH,\,start}} + \mathrm{TVHT\_W} \times f_{S2W,\,\mathrm{idx}} + 0.5 \times \mathrm{TVHT\_W}$ MHz, where $f_{S2W,\,\mathrm{idx}}$ is given in Equation (22-5).

$$f_{\mathrm{S2W,\,idx}} = \begin{cases} f_{\mathrm{P2W,\,idx}} + 2, & \text{if } n_{\mathrm{P2W}} \text{ is even} \\ f_{\mathrm{P2W,\,idx}} - 2, & \text{if } n_{\mathrm{P2W}} \text{ is odd} \end{cases} \tag{22-5}$$

When dot11CurrentTVHTChannelWidth is TVHT_2W+2W,

— The secondary TVHT_2W channel is the channel with TVHT_2W bandwidth centered at $f_{\mathrm{CH,\,start}} + \mathrm{TVHT\_W} \times f_{S2W,\,\mathrm{idx}} + 0.5 \times \mathrm{TVHT\_W}$ MHz, where $f_{S2W,\,\mathrm{idx}}$ is given in Equation (22-3).

The transmitted signal is defined in complex baseband signal notation. The actual transmitted signal is related to the complex baseband signal by the relation shown in Equation (21-11) in Clause 21 (Very high throughput (VHT) PHY specification).

$f_c^{(i_{Seg})}$ represents the center frequency of the PPDU transmitted in frequency segment $i_{Seg}$ in each transmission mode in Clause 22 (Television very high throughput (TVHT) PHY specification).

Note that in TVHT_MODE_2C and TVHT_MODE_4C, the gap between the center frequencies of the adjacent segments is as shown in Table 22-9 (Tone location).

Table 22-10 (Center frequency of a PPDU transmitted in frequency segment iSeg) shows $f_c^{(i_{Seg})}$ as a function of dot11CurrentTVHTChannelWidth.

**Table 22-10—Center frequency of a PPDU transmitted in frequency segment $i_{Seg}$**

| dot11CurrentTVHTChannelWidth | CH_BANDWIDTH | $f_c^{(i_{Seg})} = f_{\mathrm{CH,\,start}} + \mathrm{TVHT\_W} \times f_{(i_{Seg})} + Correction$ | |
|---|---|---|---|
| | | $(f_{(0)}, Correction)$ | $(f_{(1)}, Correction)$ |
| TVHT_W | TVHT_W | $(f_{c,\,\mathrm{idx0}}, 0)$ | — |
| TVHT_2W | TVHT_W | $(f_{\mathrm{PW,\,idx}}, 0)$ | — |
| | TVHT_2W | $(f_{c,\,\mathrm{idx0}}, 0.5 \times \mathrm{TVHT\_W})$ | — |
| TVHT_W+W | TVHT_W | $(f_{\mathrm{PW,\,idx}}, 0)$ | |
| | TVHT_W+W | $(f_{c,\,\mathrm{idx0}}, 0)$ | $(f_{c,\,\mathrm{idx1}}, 0)$ |


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**Table 22-10—Center frequency of a PPDU transmitted in frequency segment $i_{Seg}$ (contin-**

| dot11CurrentTVHTChannelWidth | CH_BANDWIDTH | $f_c^{(i_{Seg})} = f_{\text{CH, start}} + \text{TVHT\_W} \times f_{(i_{Seg})} + Correction$ | |
|---|---|---|---|
| | | $(f_{(0)}, Correction)$ | $(f_{(1)}, Correction)$ |
| TVHT_4W | TVHT_W | $(f_{\text{PW, idx}}, 0)$ | — |
| | TVHT_2W | $(f_{\text{P2W, idx}}, 0.5 \times \text{TVHT\_W})$ | — |
| | TVHT_4W | $(f_{c,\text{ idx0}}, 1.5 \times \text{TVHT\_W})$ | — |
| TVHT_2W+2W | TVHT_W | $(f_{c,\text{ idx0}}, 0)$ | |
| | TVHT_2W | $(f_{c,\text{ idx0}}, 0.5 \times \text{TVHT\_W})$ | |
| | TVHT_2W+2W | $(f_{c,\text{ idx0}}, 0.5 \times \text{TVHT\_W})$ | $(f_{c,\text{ idx1}}, 0.5 \times \text{TVHT\_W})$ |

NOTE—Transmitted signals in TVHT_MODE_2N and TVHT_MODE_4N might have different impairments such as phase offset or phase noise between the two frequency segments in TVHT_MODE_2N or TVHT_MODE_4N, which is not shown in Equation (21-11) for simplicity. See 22.3.17.3 (Transmit center frequency and symbol clock frequency tolerance).

The transmitted RF signal is derived by upconverting the complex baseband signal, which consists of several fields. The signal transmitted on frequency segment $i_{Seg}$ of transmit chain $i_{TX}$ is described by Equation (21-12) in 21.3.7 (Mathematical description of signals). The timing boundaries for the various fields are shown in Figure 21-17 (Timing boundaries for VHT PPDU fields).

Each field is defined as the summation of one or more subfields, where each subfield is defined to be an inverse discrete Fourier transform as specified in Equation (21-13) and where references to Table 21-5 (Timing-related constants), Table 21-6 (Frequently used parameters), Table 21-8 (Tone scaling factor and guard interval duration values for PHY fields), Table 21-9 (CH_BANDWIDTH and), Table 21-10 (Cyclic shift values for L-STF, L-LTF, L-SIG, and VHT-SIG-A fields of the PPDU), and Table 21-11 (Cyclic shift values for the VHT modulated fields of a PPDU) are replaced by the corresponding descriptions in Clause 22 (Television very high throughput (TVHT) PHY specification) including Table 22-8 (Timing-related parameters), Table 22-9 (Tone location), Table 22-11 (Tone scaling factor and guard interval duration values for PHY fields), and Table 22-12 (Transmission mode and Gamma subk,m).

Table 22-11 (Tone scaling factor and guard interval duration values for PHY fields) summarizes the various values of $N_{\text{Field}}^{\text{Tone}}$ as a function of number of BCUs (TVHT_MODE_1 has one BCU, TVHT_MODE_2C and TVHT_MODE_2N have two BCUs, and TVHT_MODE_4C and TVHT_MODE_4N have four BCUs).

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**Table 22-11—Tone scaling factor and guard interval duration values for PHY fields**

| Field | $N_{\text{Field}}^{\text{Tone}}$ as a function of the number of BCUs | | | Guard interval duration |
|---|---|---|---|---|
| | One | Two | Four | |
| L-STF | 24 | 48 | 96 | — |
| L-LTF | 104 | 208 | 416 | $T_{GI2}$ |
| L-SIG | 104 | 208 | 416 | $T_{GI}$ |
| TVHT-SIG-A | 104 | 208 | 416 | $T_{GI}$ |
| TVHT-STF | 24 | 48 | 96 | - |
| TVHT-LTF | 114 | 228 | 456 | $T_{GI}$ |
| TVHT-SIG- | 114 | 228 | 456 | $T_{GI}$ |
| VHT-Data | 114 | 228 | 484 | $T_{GI}$ or $T_{GIS}$ (see NOTE 2) |
| NON_HT_DUP_OFDM-Data (see NOTE 1) | 104 | 208 | 416 | $T_{GI}$ |

NOTE 1—For notational convenience, NON_HT_DUP_OFDM-Data is used as a label for the Data field of a non-HT PPDU(#238) with format type NON_HT_DUP_OFDM.

NOTE 2—$T_{GI}$ denotes guard interval duration when TXVECTOR parameter GI_TYPE equals LONG_GI, $T_{GIS}$ denotes short guard interval duration when TXVECTOR parameter GI_TYPE equals SHORT_GI.

In addition, the parameter $\Upsilon_{k,\text{BW}}$ in Equation (21-13) is replaced by $\Upsilon_{k,\text{M}}$ as defined in Table 22-12 (Transmission mode and Gamma subk,m).

**Table 22-12—Transmission mode and Gamma sub$_{k,\text{M}}$**

| Transmission mode | $\Upsilon_{k,\text{M}}$ |
|---|---|
| TVHT_MODE_1, TVHT_MODE_2N | $\Upsilon_{k,1}$ per segment |
| TVHT_MODE_2C, TVHT_MODE_4N | $\Upsilon_{k,2}$ per two contiguous segments |
| TVHT_MODE_4C | $\Upsilon_{k,4}$ |

For TVHT_MODE_1 and TVHT_MODE_2N PPDU transmission,

$$\Upsilon_{k,1} = \begin{cases} 1, & k < 0 \\ j, & k \geq 0 \end{cases} \tag{22-6}$$

For TVHT_MODE_2C and TVHT_MODE_4N PPDU transmission,

$$\Upsilon_{k,2} = \begin{cases} 1, & k < -72 \text{ for 6 MHz and 8 MHz channels, } k < -84 \text{ for 7 MHz channels} \\ -1, & k \geq -72 \text{ for 6 MHz and 8 MHz channels, } k \geq -84 \text{ for 7 MHz channels} \end{cases} \tag{22-7}$$


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For TVHT_MODE_4C PPDU transmission,

$$\Upsilon_{k,4} = \begin{cases} 1, & k < -216 \text{ for 6 MHz and 8 MHz channels, } k < -252 \text{ for 7 MHz channels} \\ -1, & -216 \le k < 0 \text{ for 6 MHz and 8 MHz channels, } -252 \le k < 0 \text{ for 7 MHz channels} \\ 1, & 0 \le k < 72 \text{ for 6 MHz and 8 MHz channels, } 0 \le k < 84 \text{ for 7 MHz channels} \\ -1, & k \ge 72 \text{ for 6 MHz and 8 MHz channels, } k \ge 84 \text{ for 7 MHz channels} \end{cases} \quad (22\text{-}8)$$

### 22.3.8 TVHT preamble

#### 22.3.8.1 Introduction

A TVHT preamble is defined to carry the required information to operate in either single user or multi-user mode.

#### 22.3.8.2 Non-TVHT portion of TVHT format preamble

##### 22.3.8.2.1 Cyclic shift definition for pre-TVHT modulated fields

The cyclic shift value $T_{CS}^{i_{TX}}$ for the L-STF, L-LTF, L-SIG, and TVHT-SIG-A fields of the PPDU for transmit chain $i_{TX}$ out of a total of $N_{TX}$ is defined in Table 21-10 (Cyclic shift values for L-STF, L-LTF, L-SIG, and VHT-SIG-A fields of the PPDU) with a scaling factor to account for the change in sampling clock frequency. The CSD delay values shall be multiplied by the corresponding correction values for the 6 MHz, 7 MHz, and 8 MHz channels, respectively.

The scaling factor for transmissions over 6 MHz and 7 MHz channels is 7.5.

The scaling factor for transmissions over 8 MHz channels is 5.625.

As an example, the CSD value for antenna-2 with 2-transmit antennas is –200 ns, and the corresponding CSD value for 6 MHz channels is –1.5 μs.

##### 22.3.8.2.2 L-STF definition

The L-STF field for each BCU in any transmission mode is defined by Equation (19-9) in 19.3.9.3.3 (L-STF definition).

The time domain representation of the signal on BCU $i_{Seg}$ in transmit chain $i_{TX}$ is specified in Equation (21-20), where $\Upsilon_{k,\mathrm{BW}}$ is replaced by $\Upsilon_{k,\mathrm{M}}$ as defined in Table 22-12 (Transmission mode and Gamma subk,m) and where $N_{\mathrm{SR}}$ and $\Delta_F$ are defined in Table 22-8 (Timing-related parameters).

##### 22.3.8.2.3 L-LTF definition

The L-LTF field for each BCU in any transmission mode is defined by Equation (19-12) in 19.3.9.3.4 (L-LTF definition).

Note that these equations do not include the phase rotations as defined in Table 22-12 (Transmission mode and Gamma subk,m).

The time domain representation of the signal in transmit chain $i_{TX}$ is specified in Equation (21-23), where $\Upsilon_{k,\mathrm{BW}}$ is replaced by $\Upsilon_{k,\mathrm{M}}$ as defined in Table 22-12 (Transmission mode and Gamma subk,m) and where $N_{\mathrm{SR}}$ is defined in Table 22-8 (Timing-related parameters).

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#### 22.3.8.2.4 L-SIG definition

The L-SIG field is used to communicate data rate and length information. The structure of the L-SIG field is defined in Figure 17-5 (SIGNAL field bit assignment).

In a VHT PPDU, the RATE field shall be set to the value corresponding to 6 Mb/s in the 20 MHz channel spacing column of Table 17-6 (Contents of the SIGNAL field).

In a non-HT duplicate PPDU(#238), the RATE field is defined in 17.3.4.2 (RATE field) using the L_DATARATE parameter in the TXVECTOR.

The LENGTH field shall be set to the value given by Equation (22-9).

$$\text{LENGTH} = [(\text{TXTIME} - (20 \times \text{scaling factor}))/(4 \times \text{scaling factor})] \times 3 - 3 \quad (22\text{-}9)$$

where the scaling factor is defined in 22.3.8.2.1 (Cyclic shift definition for pre-TVHT modulated fields) and TXTIME is defined in 22.4.3 (TXTIME and PSDU_LENGTH calculation). In a non-HT duplicate PPDU, the LENGTH field is defined in 17.3.4.3 (PHY LENGTH field) using the L_LENGTH parameter in the TXVECTOR.

The time domain waveform of the L-SIG field in each BCU is specified in Equation (21-25) using $N_{20\text{MHz}} = 2$, where $\Upsilon_{k,\text{BW}}$ is replaced by $\Upsilon_{k,\text{M}}$ as defined in Table 22-12 (Transmission mode and Gamma subk,m) and where the rest of the parameters are specified in 22.3.7 (Mathematical description of signals).

### 22.3.8.3 TVHT portion of TVHT format preamble

#### 22.3.8.3.1 Introduction

The TVHT portion of the VHT format preamble consists of the TVHT-SIG-A, TVHT-STF, TVHT-LTF, and TVHT-SIG-B fields.

Notational conventions are specified in 21.3.8.3.1 (Introduction).

#### 22.3.8.3.2 Cyclic shift for TVHT modulated fields

The definition, application, and CSD values are defined in 21.3.8.3.2 (Cyclic shift for VHT modulated fields) with scaling factors as defined in 22.3.8.2.1 (Cyclic shift definition for pre-TVHT modulated fields).

#### 22.3.8.3.3 TVHT-SIG-A definition

The TVHT-SIG-A field carries information required to interpret VHT PPDU in TVWS bands and is defined in 21.3.8.3.3 (VHT-SIG-A definition).

The time domain waveform of the TVHT-SIG-A field in each BCU is specified in Equation (21-28), where $N_{20\text{MHz}} = 2$ and where the rest of the parameters are specified in 22.3.7 (Mathematical description of signals).

Fields in the TVHT-SIG-A fields are the same as in Table 21-12 (Fields in the VHT-SIG-A field) except for the description B0-B1 (BW) and B10-B21 in TVHT-SIG-A1. Description of B0-B1 is specified in Table 22-13 (B0-B1 (BW) in TVHT-SIG-A1).


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**Table 22-13—B0-B1 (BW) in TVHT-SIG-A1**

| B0-B1 | TVHT_MODE |
|---|---|
| 00 | Not used |
| 10 | TVHT_MODE_1 |
| 01 | TVHT_MODE_2C and TVHT_MODE_2N |
| 11 | TVHT_MODE_4C and TVHT_MODE_4N |

Description of B10-B21 ($N_{STS}$/Partial AID) is specified as follows:

For an MU PPDU:

$N_{STS}$ is divided into 4 user positions of 3 bits each. User position $p$, where

$0 \le p \le 3$, uses bits B(10+3$p$)-B(12+3$p$). The number of space-time streams for user $u$ is indicated at user position $p$ = USER_POSITION[$u$] where $u$ = 0, 1, ..., NUM_USER − 1 and where the notation A[$b$] denotes the value of array A at index $b$. Zero space-time streams are indicated at positions not listed in the USER_POSITION array.

Set to 0 for 0 space-time streams
Set to 1 for 1 space-time stream
Set to 2 for 2 space-time streams
Set to 3 for 3 space-time streams
Values 4 to 7 are reserved

For an SU PPDU:

B10-B12

Set to 0 for 1 space-time stream
Set to 1 for 2 space-time streams
Set to 2 for 3 space-time streams
Set to 3 for 4 space-time streams
Values 4 to 7 are reserved

B13-B21

Partial AID: Set to the value of the TXVECTOR parameter PARTIAL_AID. Partial AID provides an abbreviated indication of the intended recipient(s) of the PSDU (see 10.19 (Group ID and partial AID in VHT and CMMG PPDUs)).

### 22.3.8.3.4 TVHT-STF definition

The TVHT-STF field for each BCU in any transmission mode is defined by Equation (21-30) in 21.3.8.3.4 (VHT-STF definition).

The time domain waveform of the TVHT-STF field in each BCU is specified in Equation (21-33), where $\Upsilon_{k,\mathrm{BW}}$ is replaced by $\Upsilon_{k,\mathrm{M}}$ as defined in Table 22-12 (Transmission mode and Gamma subk,m) and where $N_{\mathrm{SR}}$ is defined in Table 22-8 (Timing-related parameters).

### 22.3.8.3.5 TVHT-LTF definition

The TVHT-LTF field is defined in 21.3.8.3.5 (VHT-LTF definition).

The TVHT-LTF sequence transmitted for each BCU in any transmission mode is defined by Equation (21-37).

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The time domain waveform of the TVHT-LTF field in each BCU is specified in Equation (21-42), where $\Upsilon_{k,\mathrm{BW}}$ is replaced by $\Upsilon_{k,\mathrm{M}}$ as defined in Table 22-12 (Transmission mode and Gamma subk,m) and where $N_{\mathrm{SR}}$ is defined in Table 22-8 (Timing-related parameters).

#### 22.3.8.3.6 TVHT-SIG-B definition

The TVHT-SIG-B field for each BCU in any transmission mode is defined in 21.3.8.3.6 (VHT-SIG-B definition) for 40 MHz bandwidth.

The 27 TVHT-SIG-B bits are first repeated twice, then BCC encoded, interleaved, and made into constellations as described by Figure 21-22 (VHT-SIG-B bits in 20 MHz, 40 MHz, 80 MHz, 160 MHz, and 80+80 MHz transmissions) and the corresponding text in 21.3.8.3.6 (VHT-SIG-B definition). If the channel bandwidth of the current PPDU is TVHT_W, then the IDFT is conducted as defined in 21.3.8.3.6 (VHT-SIG-B definition).

The time domain waveform for the TVHT-SIG-B field in each BCU in a VHT PPDU is the same as Equation (21-47) with channel bandwidth being 40 MHz. If the channel bandwidth of the current PPDU is larger than TVHT_W, then the TVHT-SIG-B subcarriers as described above are repeated in each BCU, with appropriate phase rotation factors $\Upsilon_{k,\mathrm{M}}$ being applied as shown in Table 22-12 (Transmission mode and Gamma subk,m), before conducting IDFT.

### 22.3.9 Transmission of NON_HT and HT PPDUs with multiple antennas

A TVHT STA that transmits a non-HT PPDU(#238) shall apply the cyclic shifts defined in 22.3.8.2.1 (Cyclic shift definition for pre-TVHT modulated fields) for L-STF, L-LTF, and L-SIG fields of the PPDU.

### 22.3.10 Data field

#### 22.3.10.1 General

See 21.3.10.1 (General), with “TVHT” replacing “VHT”.

#### 22.3.10.2 SERVICE field

See 21.3.10.2 (SERVICE field), with “TVHT” replacing “VHT”.

#### 22.3.10.3 CRC calculation for TVHT-SIG-B

The CRC calculation and insertion is illustrated in Figure 21-23 (VHT-SIG-B and SERVICE field relationship).

The value of the CRC field shall be the 1s complement of Equation (21-59) with the values of *N* set to 21 for all Modes.

#### 22.3.10.4 Scrambler

See 21.3.10.4 (Scrambler) with “TVHT” replacing “VHT”.

#### 22.3.10.5 Coding

See 21.3.10.5 (Coding) with “TVHT” replacing “VHT”.


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#### 22.3.10.6 Stream parser

After coding and puncturing, the data bit streams at the output of the FEC encoders are processed in groups of $N_{CBPS}$ bits. Each of these groups is rearranged into $N_{SS}$ blocks of $N_{CBPSS}$ bits ($N_{SS,u}$ blocks of $N_{CBPSS,u}$ bits in the case of an MU transmission). This operation is referred to as *stream parsing* and is described in 21.3.10.6 (Stream parser).

#### 22.3.10.7 Segment parser

The segment parser as described in 21.3.10.7 (Segment parser) is not used in Clause 22 (Television very high throughput (TVHT) PHY specification). All modes of operation use a common interleaver in the case of BCC or use a common tone mapper in the case of LDPC.

#### 22.3.10.8 BCC interleaver

The BCC interleaver and deinterleaver for one BCU (TVHT_MODE_1) is defined in 21.3.10.8 (BCC interleaver) for 40 MHz.

The BCC interleaver and deinterleaver for TVHT_MODE_2C, TVHT_MODE_2N, TVHT_MODE_4C, and TVHT_MODE_4N reuse the same formulas as described in 21.3.10.8 (BCC interleaver) for 40 MHz with new values for $N_{COL}$ , $N_{ROW}$, and $N_{ROT}$ as defined in Table 22-14 (Number of rows and columns in the interleaver).

**Table 22-14—Number of rows and columns in the interleaver**

| Parameter | TVHT_MODE_1 | TVHT_MODE_2C, TVHT_MODE_2N | TVHT_MODE_4C, TVTH_MODE_4N |
|---|---|---|---|
| $N_{COL}$ | 18 | 27 | 48 |
| $N_{ROW}$ | $6 \times N_{BPSCS}$ | $8 \times N_{BPSCS}$ | $9 \times N_{BPSCS}$ |
| $N_{ROT}$ ($N_{SS} \leq 4$) | 29 | 46 | 78 |

#### 22.3.10.9 Constellation mapping

#### 22.3.10.9.1 General

The mapping between bits at the output of the interleaver and complex constellation points is as described in 21.3.10.9.1 (General).

The streams of complex numbers in frequency subblock $l$ for user $u$ are denoted

$d'_{k,i,n,l,u}$; $k = 0, 1, \ldots, N_{SD} - 1$; $i = 1, \ldots, N_{SS,u}$; $n = 0, 1, \ldots, N_{SYM} - 1$;
$l = 0$ for all transmission modes.

#### 22.3.10.9.2 LDPC tone mapping

The LDPC tone mapping for one BCU (TVHT_MODE_1) is defined in 21.3.10.9.2 (LDPC tone mapping) for 40 MHz.

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The LDPC tone mapping for TVHT_MODE_2C, TVHT_MODE_2N, TVHT_MODE_4C, and TVHT_MODE_4N reuses the same formulas as described in 21.3.10.9.2 (LDPC tone mapping) for 40 MHz with values for $D_{TM}$ as defined in Table 22-15 (LDPC Tone Mapping Distance for each transmission mode).

**Table 22-15—LDPC Tone Mapping Distance for each transmission mode**

| Parameter | TVHT_MODE_1 | TVHT_MODE_2C, TVHT_MODE_2N | TVHT_MODE_4C, TVHT_MODE_4N |
|---|---|---|---|
| $D_{TM}$ | 6 | 8 | 9 |

For all Clause 22 (Television very high throughput (TVHT) PHY specification) transmission Modes, the LDPC tone mapping for LDPC-coded streams corresponding to user $u$ is done by permuting the stream of complex numbers

$$d'_{k,i,n,l,u};\quad k = 0, 1, \ldots, N_{SD}-1;\quad i = 1, \ldots, N_{SS,u};\quad n = 0, 1, \ldots, N_{SYM}-1;$$
$$l = 0 \text{ for all transmission modes.}$$

generated by the constellation mappers, to obtain

$$d'_{t(k),i,n,l,u};\quad k = 0, 1, \ldots, N_{SD}-1;\quad i = 1, \ldots, N_{SS,u};\quad n = 0, 1, \ldots, N_{SYM}-1;$$
$$l = 0 \text{ for all transmission modes.}$$

where

$$t(k) = D_{TM}\left(k \bmod \frac{N_{SD}}{D_{TM}}\right) + \left\lfloor \frac{k \times D_{TM}}{N_{SD}} \right\rfloor \quad \text{for all transmission modes}$$

### 22.3.10.9.3 Segment deparser

The segment deparser is not used in Clause 22 (Television very high throughput (TVHT) PHY specification) as no segment parser is used in Clause 22 (Television very high throughput (TVHT) PHY specification).

### 22.3.10.9.4 Space-time block coding

See 21.3.10.9.4 (Space-time block coding) with “TVHT” replacing “VHT”.

### 22.3.10.10 Pilot subcarriers

For TVHT_MODE_1 transmission, six pilot tones shall be inserted in subcarriers –53, –25, –11, 11, 25, and 53. The pilots are generated as described in 21.3.10.10 (Pilot subcarriers) for 40 MHz transmission.

When multiple BCUs are used (TVHT_MODE_2C, TVHT_MODE_2N, TVHT_MODE_4C, and TVHT_MODE_4N), each BCU shall use the same pilot tones, which are generated as described in 21.3.10.10 (Pilot subcarriers) for 40 MHz transmission.

### 22.3.10.11 OFDM modulation transmission in VHT format

For TVHT transmissions, the signal from transmit chain $i_{TX}$, $1 \le i_{TX} \le N_{TX}$ shall be as specified in Equation (21-95), where $\Upsilon_{k,\mathrm{BW}}$ is replaced by $\Upsilon_{k,\mathrm{M}}$ as defined in Table 22-12 (Transmission mode and Gamma subk,m) and where $N_{\mathrm{SR}}$ and $\Delta_F$ are defined in Table 22-8 (Timing-related parameters).


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For TVHT_MODE_1 transmission, parameters shall be selected to be the same with 40 MHz VHT transmission as defined in 21.3.10.11.1 (Transmission in VHT format).

For multi-segment transmissions TVHT_MODE_2C and TVHT_MODE_4C, each frequency segment shall follow the waveform as described in Equation (21-95), and the data and pilot subcarriers are allocated to the IDFT block according to the subcarrier mapping as specified in Table 22-9 (Tone location) in consecutive order from the lowest subcarrier to the highest subcarrier.

For multi-segment transmissions TVHT_MODE_2N and TVHT_MODE_4N, each frequency segment shall follow the waveform as described in Equation (21-95), and the data and pilot subcarriers are allocated by the subcarrier allocation block, as shown in Figure 22-2 (Transmitter block diagram for the Data field of a TVHT_MODE_2N or TVHT_MODE_4N SU PPDU with BCC encoding), to the two IDFT blocks according to the subcarrier mapping as specified in Equation (21-95) and Table 22-9 (Tone location) in consecutive order from the lowest subcarrier to the highest subcarrier in each of the two frequency segments, the lower half of the subcarriers are mapped to the IDFT corresponding to the lower frequency segment, and the upper half of the subcarriers are mapped to the IDFT corresponding to the upper frequency segment.

### 22.3.10.12 Non-HT duplicate transmission

When the TXVECTOR parameter FORMAT is NON_HT and the TXVECTOR parameter NON_HT_MODULATION is NON_HT_DUP_OFDM, the transmitted PPDU shall be a non-HT duplicate. Multiple BCUs non-HT duplicate transmission is used to transmit to TVHT STAs that may be present in a part of a channel.

For non-HT duplicate transmission, the Data field shall be as defined in 21.3.10.12 (Non-HT duplicate transmission), with "TVHT" replacing "VHT" and with references to "Clause 22 (Television very high throughput (TVHT) PHY specification)" replacing references to "Clause 21 (Very high throughput (VHT) PHY specification)", using the parameter values defined in Table 22-16 (Parameters for Non-HT duplicate transmissions). The Data field shall be as defined by Equation (21-100) with following modifications. $N_{20\text{MHz}}$ is defined in Table 22-16 (Parameters for Non-HT duplicate transmissions). $K_{\text{Shift}}(i)$ in Equation (21-100) is replaced by $K_{\text{Shift}}(i) = (N_{20\text{MHz}} - 1 - 2i) \times 32 + 8 \cdot \lfloor N_{20\text{MHz}}/4 \rfloor + 8 \times \lfloor N_{20\text{MHz}}/8 \rfloor - (16 \times \lfloor i/2 \rfloor)$.

$T_{\text{CS}}^{i_{TX}}$ represents the cyclic shift of the transmit chain $i_{TX}$ and is defined in 22.3.8.2.1 (Cyclic shift definition for pre-TVHT modulated fields). $N_{\text{NON\_HT\_DUP\_OFDM-Data}}^{\text{Tone}}$ is defined in Table 22-16 (Parameters for Non-HT duplicate transmissions).

**Table 22-16—Parameters for Non-HT duplicate transmissions**

| Parameter | TVHT_MODE_1 | TVHT_MODE_2C | TVHT_MODE_2N | TVHT_MODE_4C | TVHT_MODE_4N |
|---|---|---|---|---|---|
| $N_{20\text{MHz}}$ | 2 | 4 | 2 | 8 | 4 |
| $N_{\text{NON\_HT\_DUP\_OFDM-Data}}^{\text{Tone}}$ | 104 | 208 | 104 | 416 | 208 |

In addition, the parameter $\Upsilon_{k,BW}$ is replaced by $\Upsilon_{k,M}$ as defined in Table 22-12 (Transmission mode and Gamma subk,m). For a noncontiguous TVHT_W+W or TVHT_2W+2W non-HT duplicate transmission, data transmission in each frequency segment shall be as defined for a TVHT_W or TVHT_2W non-HT duplicate transmission, respectively.

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### 22.3.11 SU-MIMO and MU-MIMO Beamforming

#### 22.3.11.1 General

SU-MIMO and (#3367)DL MU-MIMO beamforming in TVWS band is used as defined in 21.3.11.1 (General) reading "Clause 22 (Television very high throughput (TVHT) PHY specification)" for references to "Clause 21 (Very high throughput (VHT) PHY specification)" except for feedback report format described in 9.4.1.48 (TVHT Compressed Beamforming Report field).

#### 22.3.11.2 Beamforming Feedback Matrix V

Beamforming Feedback Matrix V is constructed as defined in 21.3.11.2 (Beamforming Feedback Matrix V) reading "Clause 22 (Television very high throughput (TVHT) PHY specification)" for reference to "Clause 21 (Very high throughput (VHT) PHY specification)" except for CSD values defined in 22.3.8.3.2 (Cyclic shift for TVHT modulated fields).

#### 22.3.11.3 Group ID

See 21.3.11.4 (Group ID) with "TVHT" replacing "VHT".

### 22.3.12 TVHT preamble format for sounding PPDUs

The format of a VHT NDP in TVWS bands is constructed as defined Figure 22-1 (VHT PPDU format in TVWS bands).

NOTE—The number of TVHT-LTF symbols in the NDP is determined by the SU $N_{STS}$ field in TVHT-SIG-A.

The TVHT NDP has the following properties:

— Uses the TVHT PPDU format but without the Data field.
— Is a TVHT SU PPDU as indicated by the TVHT-SIG-A field.
— Has the data bits of the TVHT-SIG-B field set to a fixed bit pattern (see 22.3.8.3.6 (TVHT-SIG-B definition)).

### 22.3.13 Regulatory requirements

See 21.3.13 (Regulatory requirements).


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### 22.3.14 Channelization

A TVHT channel is specified by the four PLME MIB fields specified in Table 22-17 (Fields to specify TVHT channels).

**Table 22-17—Fields to specify TVHT channels**

| Field | Meaning |
|---|---|
| dot11CurrentTVHTChannelWidth | Channel width. Possible values represent TVHT_W, TVHT_2W, TVHT_W+W, TVHT_4W, TVHT_2W+2W. |
| dot11CurrentTVHTChannelCenterFrequencyIndex0 | In TVHT_MODE_1, TVHT_MODE_2C, and TVHT_MODE_4C operation denotes the center frequency of the lowest TV channel.<br>In TVHT_MODE_2N and TVHT_MODE_4N operation, denotes the center frequency of the lowest TV channel in the frequency segment that contains the primary channel.<br>Valid range is 1 to 200.<br>See Equation (22-10). |
| dot11CurrentTVHTChannelCenterFrequencyIndex1 | In TVHT_MODE_2N and TVHT_MODE_4N operation, denotes the center frequency of the lowest TV channel in the frequency segment that does not contain the primary channel.<br>Valid range is 1 to 200.<br>See Equation (22-10).<br>Undefined for TVHT_MODE_1, TVHT_MODE_2C, and TVHT_MODE_4C operation. |
| dot11CurrentPrimaryChannel | Denotes the location of the primary TVHT_W channel.<br>Valid range is 1 to 200.<br>See Equation (22-11). |

Given dot11CurrentTVHTChannelCenterFrequencyIndex0 and dot11CurrentTVHTChannelCenterFrequencyIndex1, the respective channel center frequency is given by Equation (22-10).

$$\text{Channel center frequency [MHz]} = \text{Channel starting frequency} + \text{TVHT\_W} \times \text{dot11CurrentChannelCenterFrequencyIndex} + \text{ChannelCenterFrequencyCorrection} \quad (22\text{-}10)$$

where

Channel starting frequency is given by the Operating Class (E.1 (Country information and operating classes))

dot11CurrentTVHTChannelCenterFrequencyIndex is either
dot11CurrentTVHTChannelCenterFrequencyIndex0 or
dot11CurrentTVHTChannelCenterFrequencyIndex1 and

ChannelCenterFrequencyCorrection is
0 for TVHT_MODE_1 and TVHT_MODE_2N
0.5 × TVHT_W for TVHT_MODE_2C and TVHT+MODE_4N
1.5 × TVHT_W for TVHT_MODE_4C.

NOTE—Channel starting frequency is the frequency that results in the regulatory domain's channel number being the RLAN channel number, i.e., the center frequency of the channel for index 0. For example, the center frequency of United States and its territories(#296) TV channel 2 is 57 MHz. The center frequency of United States and its territories(#296) TV channel 2 is obtained by Equation (22-10) as follows:

Channel center frequency [MHz] = Channel starting frequency + TVHT_W × dot11CurrentTVHTChannelCenterFrequencyIndex + ChannelCenterFrequencyCorrection = (0.045 × 1000) + 6 × 2 + 0 = 57 MHz.

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The center frequency of the primary TVHT_W channel is given by Equation (22-11).

$$\text{Primary channel center frequency [MHz]} = \text{Channel starting frequency} + \text{TVHT\_W} \times \text{dot11CurrentPrimaryChannel} \quad (22\text{-}11)$$

where

Channel starting frequency is given by the Operating Class (see E.1 (Country information and operating classes))

For TVHT_MODE_2N operation, any two nonidentical channels may be used.

For TVHT_MODE_4N operation, any two channels that would each be allowed as TVHT_2W channels and whose center frequencies are separated by greater than TVHT_2W (difference between dot11CurrentTVHTChannelCenterFrequencyIndex0 and dot11CurrentTVHTChannelCenterFrequencyIndex1 corresponds to a frequency difference greater than 2) may be used.

For example, in the United States and its territories(#296), a channel specified by

dot11CurrentTVHTChannelWidth = TVHT_2W (12 MHz)
dot11CurrentTVHTChannelCenterFrequencyIndex0 = 15
dot11CurrentPrimaryChannel = 16

is a 12 MHz channel with a center frequency of 482 MHz and the primary 6 MHz channel centered at 485 MHz.

A channel specified by

dot11CurrentTVHTChannelWidth = TVHT_4W (24 MHz)
dot11CurrentTVHTChannelCenterFrequencyIndex0 = 14
dot11CurrentPrimaryChannel = 17

is a 24 MHz channel with a center frequency of 482 MHz and the primary 6 MHz channel centered at 491 MHz.

A channel specified by

dot11CurrentTVHTChannelWidth = TVHT_2W+2W (12+12 MHz)
dot11CurrentTVHTChannelCenterFrequencyIndex0 =15
dot11CurrentTVHTChannelCenterFrequencyIndex1 = 40
dot11CurrentPrimaryChannel = 16

is an 12+12 MHz channel in which frequency segment 0 has 12 MHz bandwidth and center frequency of 482 MHz. Frequency segment 1 also has 12 MHz bandwidth and center frequency of 632 MHz. The primary 6 MHz channel is centered at 485 MHz.

### 22.3.15 Slot time

The slot time for the TVHT PHY shall be 24 μs for 6 MHz and 7 MHz channel units and 20 μs for 8 MHz channel units.


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### 22.3.16 Transmit and receive port impedance

(#1247)The impedance of exposed transmit and receive antenna connectors are defined in 17.3.8.7 (Transmit and receive impedance at the antenna connector).

### 22.3.17 TVHT transmit specification

#### 22.3.17.1 Transmit spectrum mask

(#1471)The overall transmit spectral mask is constructed using two components. First, an interim spectral mask is constructed whose mask level is determined relative to the maximum spectral density of the signal. Second, an absolute transmit spectral limit is computed based on the mask bandwidth. The overall transmit spectral mask is then constructed by taking the higher of the interim transmit spectral mask and the absolute transmit spectral limit at each frequency offset.

For transmission in TVHT_MODE_1, TVHT_MODE_2C, and TVHT_MODE_4C, the transmit spectral mask shall be as described for 40 MHz mask PPDU in 21.3.17.1 (Transmit spectrum mask) with the frequency axis multiplied by the frequency scaling factor as defined in Table 22-18 (Spectral mask frequency scaling factor for contiguous transmission).

**Table 22-18—Spectral mask frequency scaling factor for contiguous transmission**

| Mode | Scaling for 6 MHz channels | Scaling for 7 MHz channels | Scaling for 8 MHz channels |
|---|---|---|---|
| TVHT_MODE_1 | 6 / 40 | 7 / 40 | 8 / 40 |
| TVHT_MODE_2C | 12 / 40 | 14 / 40 | 16 / 40 |
| TVHT_MODE_4C | 24 / 40 | 28 / 40 | 32 / 40 |

For transmission in mode TVHT_MODE_4N, the transmit spectral mask shall be as described for 80+80 MHz mask PPDU in 21.3.17.1 (Transmit spectrum mask) with the frequency axis multiplied by the frequency scaling factor as defined in Table 22-19 (Spectral mask frequency scaling factor for TVHT_MODE_4N).

**Table 22-19—Spectral mask frequency scaling factor for TVHT_MODE_4N**

| Mode | Scaling for 6 MHz channels | Scaling for 7 MHz channels | Scaling for 8 MHz channels |
|---|---|---|---|
| TVHT_MODE_4N | 12 / 80 | 14 / 80 | 16 / 80 |

NOTE 1—In the presence of additional regulatory restrictions, the device has to meet both the regulatory requirements (measured as defined in the relevant regulation) and the mask defined in this subclause.

NOTE 2—For rules regarding TX center frequency leakage levels, see 22.3.17.4.2 (Transmit center frequency leakage).

For a TVHT_W+W mask PPDU of VHT or non-HT duplicate format, the overall transmit spectral mask is constructed in the following manner. First, the 40 MHz interim transmit spectral mask shall have a 0 dBr (dB relative to the maximum spectral density of the signal) bandwidth of 38 MHz, –20 dBr at 21 MHz

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frequency offset, –28 dBr at 40 MHz frequency offset, and –40 dBr at 60 MHz frequency offset and above. The 40 MHz interim transmit spectral mask for frequency offsets in between 19 MHz and 21 MHz, 21 MHz and 40 MHz, and 40 MHz and 60 MHz shall be linearly interpolated in dB domain from the requirements for 19 MHz, 21 MHz, 40 MHz, and 60 MHz frequency offsets. Then the 40 MHz interim spectral mask frequency points are scaled as defined in Table 22-20 (Spectral mask frequency scaling factor for TVHT_MODE_2N) to produce a TVHT_W interim spectral mask. Then, the TVHT_W interim spectral mask is placed on each of the two segments to produce the TVHT_W+W interim spectral mask. Then, for each frequency at which both of the TVHT_W interim spectral masks have values greater than –40 dBr and less than –20 dBr, the sum of the two TVHT_W interim mask values (summed in linear domain) shall be taken as the overall TVHT_W+W interim spectral mask value. Next, for each frequency at which neither of the two TVHT_W interim masks has values greater than or equal to –20 dBr and less than or equal to 0 dBr, the higher value of the two interim masks shall be taken as the overall TVHT_W+W interim mask spectral value. Finally, for any frequency region where the TVHT_W+W interim mask value has not been defined yet, linear interpolation (in dB domain) between the nearest two frequency points with the TVHT_W+W interim spectral mask value defined shall be used to define the TVHT_W+W interim spectral mask value. The transmit spectrum shall not exceed the maximum of the TVHT_W+W interim transmit spectrum mask and –59 dBm/MHz at any frequency offset.

**Table 22-20—Spectral mask frequency scaling factor for TVHT_MODE_2N**

| Mode | Scaling for 6 MHz channels | Scaling for 7 MHz channels | Scaling for 8 MHz channels |
|---|---|---|---|
| TVHT_MODE_2N | 6 / 40 | 7 / 40 | 8 / 40 |

Example transmit spectral mask for a TVHT_W+W mask PPDU for BCU of 6 MHz and spacing of 12 MHz is shown in Figure 22-4 (Example transmit spectral mask for an 6+6 MHz mask PPDU).

### 22.3.17.2 Spectral flatness

Spectral flatness measurements shall be conducted using BPSK modulated PPDUs. See 22.3.17.4.4 (Transmitter modulation accuracy (EVM) test) for the demodulation procedure of the PPDUs as well as the number of PPDUs and OFDM symbols to be used for testing.

Let $E_{i,\,avg}$ denote the average constellation energy of a BPSK modulated subcarrier $i$ in a TVHT data symbol.


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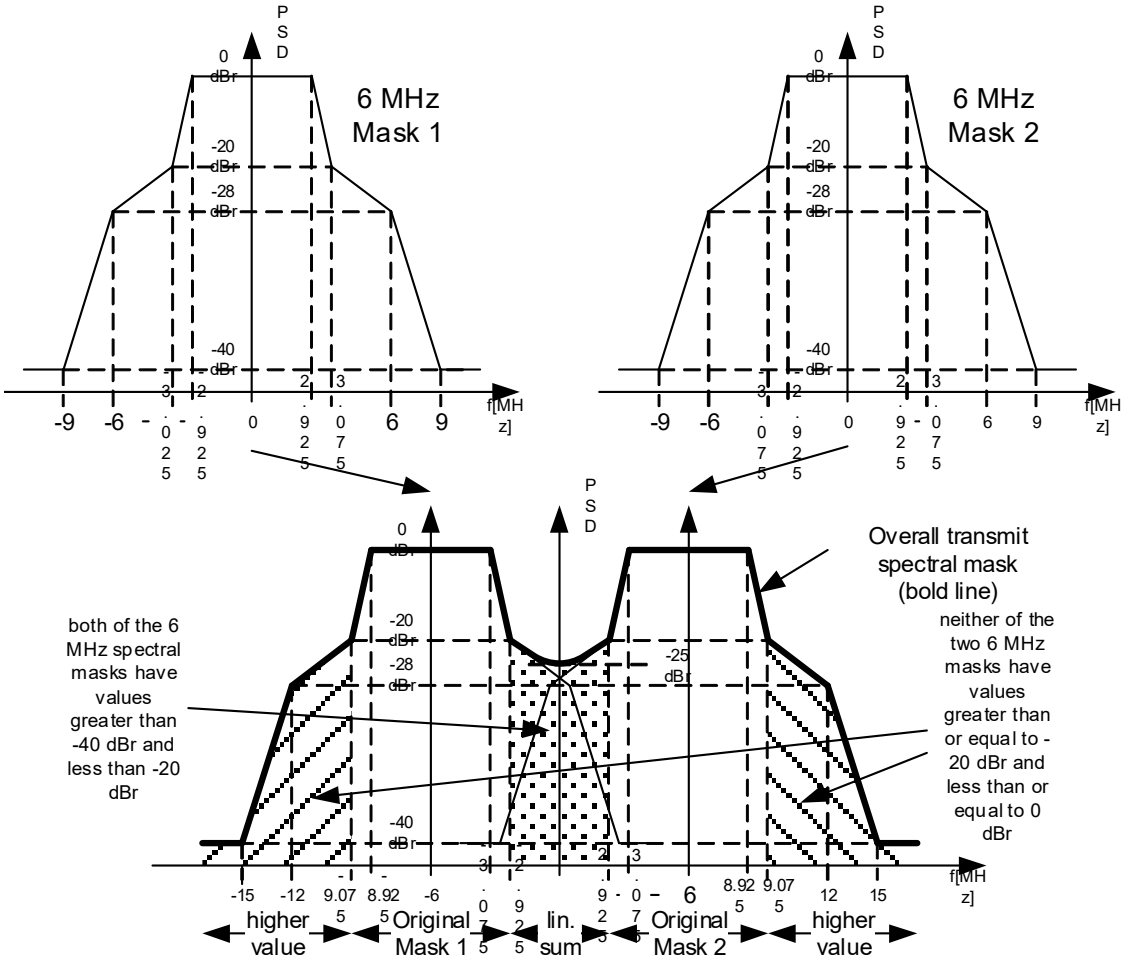


**Figure 22-4—Example transmit spectral mask for an 6+6 MHz mask PPDU**

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For TVHT_MODE_1 contiguous non-HT duplicate or TVHT transmission having a bandwidth listed in Table 22-21 (Maximum transmit spectral flatness deviations), $E_{i,\,avg}$ of each of the subcarriers with indices listed as tested subcarrier indices shall not deviate by more than the specified maximum deviation in Table 22-21 (Maximum transmit spectral flatness deviations) from the average of $E_{i,\,avg}$ over subcarrier indices listed as averaging subcarrier indices. Averaging of $E_{i,\,avg}$ is done in the linear domain.

**Table 22-21—Maximum transmit spectral flatness deviations**

| Format | Bandwidth of transmission (MHz) | Averaging subcarrier indices | Tested subcarrier indices | Maximum deviation (dB) |
|---|---|---|---|---|
| VHT | TVHT_W | –42 to –2 and +2 to +42 | –42 to –2 and +2 to +42 | ± 4 |
| | | | –58 to –43 and +43 to +58 | +4/–6 |
| non-HT duplicate | TVHT_W | –42 to –33, –31 to –6, +6 to +31, and +33 to +42 | –42 to –33, –31 to –6, +6 to +31, and +33 to +42 | ± 4 |
| | | | –43 to –58 and +43 to +58 | +4/–6 |

For transmissions consisting of multiple contiguous or noncontiguous BCUs, each BCU shall meet the spectral flatness requirement for TVHT_MODE_1 transmission.

For the spectral flatness test, the transmitting STA shall be configured to use a spatial mapping matrix $Q_k$ (see 22.3.10.11 (OFDM modulation transmission in VHT format)) with flat frequency response. Each output port under test of the transmitting STA shall be connected through a cable to one input port of the testing instrumentation.

### 22.3.17.3 Transmit center frequency and symbol clock frequency tolerance

The transmitter center frequency tolerance shall be ± 25 ppm. Carrier (LO) and symbol clock frequencies for the all transmit chains and BCUs shall be derived from the same reference oscillator.

NOTE—For multichannel operation, the signal phase of each BCU might be uncorrelated.

The symbol clock frequency tolerance shall be ± 25 ppm. The transmit center frequency and the symbol clock frequency for all transmit antennas and contiguous BCUs shall be derived from the same reference oscillator.

### 22.3.17.4 Modulation accuracy

#### 22.3.17.4.1 Introduction to modulation accuracy tests

Transmit modulation accuracy specifications are defined in 22.3.17.4.2 (Transmit center frequency leakage) and 22.3.17.4.3 (Transmitter constellation error). The test method is described in 21.3.17.4.4 (Transmitter modulation accuracy (EVM) test).

#### 22.3.17.4.2 Transmit center frequency leakage

For transmissions using all formats except noncontiguous where the RF LO falls outside both BCUs, TX LO leakage shall meet the following requirements:

— When the RF LO is in the center of the transmitted PPDU BW, the power measured at the center of transmission BW using resolution BW (6/144 or 8/144) MHz shall not exceed the average power per


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subcarrier of the transmitted PPDU, or equivalently ($P - 10\log 10(N_{ST})$), where $P$ is the transmit power per antenna in dBm and $N_{ST}$ is defined in Table 22-8 (Timing-related parameters).

— When the RF LO is not at the center of the transmitted PPDU BW, the power measured at the location of the RF LO using resolution BW (6/144 or 8/144) MHz shall not exceed the maximum of –32 dB relative to the total transmit power and –20 dBm, or equivalently $max(P - 32, -20)$, where $P$ is the transmit power per antenna in dBm.

For transmissions using TVHT_MODE_2N and TVHT_MODE_4N, where the RF LO falls outside both BCUs, the RF LO shall follow the spectral mask requirements as defined in 22.3.17.1 (Transmit spectrum mask).

#### 22.3.17.4.3 Transmitter constellation error

For all modes defined in TVHT PHY, the requirements for transmit constellation RMS error are same as defined in 21.3.17.4.3 (Transmitter constellation error).

For non-HT duplicate transmissions, requirements defined in 17.3.9.7.4 (Transmitter constellation error) apply to all parts of the channel bandwidth. The channel bandwidth is determined by the TXVECTOR parameter CH_BANDWIDTH.

#### 22.3.17.4.4 Transmitter modulation accuracy (EVM) test

For the transmit modulation accuracy test, the same methodology as that defined in 21.3.17.4.4 (Transmitter modulation accuracy (EVM) test) shall be applied per BCU (termed frequency segment in Clause 21 (Very high throughput (VHT) PHY specification)). The channel bandwidth is determined by the TXVECTOR parameter CH_BANDWIDTH.

### 22.3.17.5 Time of Departure accuracy

For Time of Departure accuracy test, the test parameters defined in 21.3.17.5 (Time of Departure accuracy) shall be used for evaluation of TOD except the channel bandwidth, TTR and TIME_OF_DEPARTURE_ACCURACY_TEST_THRESH. The channel bandwidth is determined by TXVECTOR parameter CH_BANDWIDTH in 22.2.2 (TXVECTOR and RXVECTOR parameters). TTR and TIME_OF_DEPARTURE_ACCURACY_TEST_THRESH shall be multiplied by the corresponding scaling factor for the 6 MHz, 7 MHz, and 8 MHz channels, where the scaling factor is defined in 22.3.8.2.1 (Cyclic shift definition for pre-TVHT modulated fields).

## 22.3.18 TVHT receiver specification

### 22.3.18.1 General

See 21.3.18 (VHT receiver specification).

### 22.3.18.2 Receiver minimum input level sensitivity(#256)

The (#14)PER shall be less than 10% for a PSDU length of 4096 octets with the rate-dependent input levels listed in Table 22-22 (Receiver minimum input level sensitivity). The test in this subclause and the minimum sensitivity levels specified in Table 22-22 (Receiver minimum input level sensitivity) apply only to non-STBC modes, long GI, BCC, and VHT PPDU in TVWS bands.

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**Table 22-22—Receiver minimum input level sensitivity**

| Modulation | Rate (R) | Minimum sensitivity (dBm) | | | | | |
|---|---|---|---|---|---|---|---|
| | | 6 or 7 MHz (TVHT_ MODE_1) | 12/14 MHz (TVHT_ MODE_2C) or 6+6/7+7 MHz (TVHT_ MODE_2N) | 24/28 MHz (TVHT_ MODE_4C or 12+12/ 14+14 MHz (TVHT_ MODE_4N) | 8 MHz (TVHT_ MODE_1) | 16 MHz (TVHT_ MODE_2C) or 8+8 MHz (TVHT_ MODE_2N) | 32 MHz (TVHT_ MODE_4C) or 16+16/ 16+16 MHz (TVHT_ MODE_4N) |
| BPSK | 1/2 | –88 | –85 | –82 | –87 | –84 | –81 |
| QPSK | 1/2 | –85 | –82 | –79 | –84 | –81 | –78 |
| QPSK | 3/4 | –83 | –80 | –77 | –82 | –79 | –76 |
| 16-QAM | 1/2 | –80 | –77 | –74 | –79 | –76 | –73 |
| 16-QAM | 3/4 | –76 | –73 | –70 | –75 | –72 | –69 |
| 64-QAM | 2/3 | –72 | –69 | –66 | –71 | –68 | –65 |
| 64-QAM | 3/4 | –71 | –68 | –65 | –70 | –67 | –64 |
| 64-QAM | 5/6 | –70 | –67 | –64 | –69 | –66 | –63 |
| 256-QAM | 3/4 | –65 | –62 | –59 | –64 | –61 | –58 |
| 256-QAM | 5/6 | –63 | –60 | –57 | –62 | –59 | –56 |

### 22.3.18.3 Adjacent channel rejection

Adjacent channel rejection for TVHT_MODE_1, TVHT_MODE_2C, and TVHT_MODE_4C follow the definition in the first paragraph of 21.3.18.2 (Adjacent channel rejection) and use the values in Table 22-23 (Minimum required adjacent and nonadjacent channel rejection levels).

Adjacent channel rejection for TVHT_MODE_2N (TVHT_W+W) and TVHT_MODE_4N (TVWT_2W+2W) follows the definition in the second paragraph of 21.3.18.2 (Adjacent channel rejection), where “80 MHz” is replaced by “TVHT_W” for TVHT_MODE_2N and “TVHT_2W” for TVHT_MODE_4N, and uses the values in Table 22-23 (Minimum required adjacent and nonadjacent channel rejection levels).

The definitions in the rest of 21.3.18.2 (Adjacent channel rejection) apply to Clause 22 (Television very high throughput (TVHT) PHY specification) using the values in Table 22-23 (Minimum required adjacent and nonadjacent channel rejection levels).


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**Table 22-23—Minimum required adjacent and nonadjacent channel rejection levels**

| Modulation | Rate (R) | Adjacent channel rejection (dB) | | Nonadjacent channel rejection (dB) | |
|---|---|---|---|---|---|
| | | 6 MHz, 7 MHz, 8 MHz, 12 MHz (TVHT_MODE_2C), 14 MHz (TVHT_MODE_2C), 16 MHz (TVHT_MODE_2C), 24 MHz (TVHT_MODE_4C), 28 MHz (TVHT_MODE_4C), 32 MHz (TVHT_MODE_4C) | 6+6 MHz (TVHT_MODE_2N), 7+7 MHz (TVHT_MODE_2N), 8+8 MHz (TVHT_MODE_2N), 12+12 MHz (TVHT_MODE_4N), 14+14 MHz (TVHT_MODE_4N), 16+16 MHz (TVHT_MODE_4N) | 6 MHz, 7 MHz, 8 MHz, 12 MHz (TVHT_MODE_2C), 14 MHz (TVHT_MODE_2C), 16 MHz (MTVHT_MODE_2C), 24 MHz (TVHT_MODE_4C), 28 MHz (TVHT_MODE_4C), 32 MHz (TVHT_MODE_4C) | 6+6 MHz (TVHT_MODE_2N), 7+7 MHz (TVHT_MODE_2N), 8+8 MHz (TVHT_MODE_2N), 12+12 MHz (TVHT_MODE_4N), 14+14 MHz (TVHT_MODE_4N), 16+16 MHz (TVHT_MODE_4N) |
| BPSK | 1/2 | 16 | 13 | 32 | 29 |
| QPSK | 1/2 | 13 | 10 | 29 | 26 |
| QPSK | 3/4 | 11 | 8 | 27 | 24 |
| 16-QAM | 1/2 | 8 | 5 | 24 | 21 |
| 16-QAM | 3/4 | 4 | 1 | 20 | 17 |
| 64-QAM | 2/3 | 0 | –3 | 16 | 13 |
| 64-QAM | 3/4 | –1 | –4 | 15 | 12 |
| 64-QAM | 5/6 | –2 | –5 | 14 | 11 |
| 256-QAM | 3/4 | –7 | –10 | 9 | 6 |
| 256-QAM | 5/6 | –9 | –12 | 7 | 4 |

### 22.3.18.4 Nonadjacent channel rejection

Nonadjacent channel rejection for TVHT_MODE_1, TVHT_MODE_2C, and TVHT_MODE_4C channels follows the definition in the first paragraph of 21.3.18.3 (Nonadjacent channel rejection) and use the values in Table 22-23 (Minimum required adjacent and nonadjacent channel rejection levels).

Nonadjacent channel rejection for TVHT_MODE_2N (TVHT_W+W) and TVHT_MODE_4N (TVWT_2W+2W) follows the definition in the second paragraph of 21.3.18.3 (Nonadjacent channel rejection), where “80 MHz” is replaced by “TVHT_W” for TVHT_MODE_2N and “TVHT_2W” for TVHT_MODE_4N, and uses the values in Table 22-23 (Minimum required adjacent and nonadjacent channel rejection levels).

The definitions in the rest of 21.3.18.3 (Nonadjacent channel rejection) apply to Clause 22 (Television very high throughput (TVHT) PHY specification) using the values in Table 22-23 (Minimum required adjacent and nonadjacent channel rejection levels).

### 22.3.18.5 Receiver maximum input level

The receiver shall provide a maximum PER of 10% at a PSDU length of 4096 octets, for a maximum input level of –20 dBm, measured at each antenna for any baseband TVHT modulation.

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### 22.3.18.6 CCA sensitivity

#### 22.3.18.6.1 General

The thresholds in this subclause are compared with the signal level at each receiving antenna(#2365).

#### 22.3.18.6.2 CCA sensitivity for signals occupying the primary channel

The PHY shall issue a PHY-CCA.indication(BUSY, {primary}) primitive if one of the conditions listed in Table 22-24 (Conditions for CCA BUSY on the primary channel) is met in an otherwise idle TVHT_W (TVHT_MODE_1), TVHT_2W (TVHT_MODE_2C), TVHT_4W (TVHT_MODE_4C), TVHT_W+W (TVHT_MODE_2N), and TVHT_2W+2W (TVHT_MODE_4N) operating channel width. With >90% probability, the PHY shall detect the start of a PPDU that occupies at least the primary TVHT_W channel under the conditions listed in Table 22-24 (Conditions for CCA BUSY on the primary channel) within a period of aCCATime (see 22.4.4 (TVHT PHY)) and hold the CCA signal busy [PHY-CCA.indication(BUSY, channel-list)] for the duration of the PPDU.

**Table 22-24—Conditions for CCA BUSY on the primary channel**

| Frequency segment width | Conditions |
|---|---|
| 6 MHz | The start of a 6 MHz non-HT duplicate or VHT PPDU in TVWS bands in the primary 6 MHz channel at or above –88 dBm. |
| 7 MHz | The start of a 7 MHz non-HT duplicate or VHT PPDU in TVWS bands in the primary 7 MHz channel at or above –88 dBm. |
| 8 MHz | The start of a 8 MHz non-HT duplicate or VHT PPDU in TVWS bands in the primary 8 MHz channel at or above –87 dBm. |

The receiver shall issue a PHY-CCA.indication(BUSY, {primary}) primitive for any signal that exceeds a threshold equal to 20 dB above the minimum modulation and coding rate sensitivity (–88 + 20 = –68 dBm in the case of 6 MHz channel) in the primary TVHT_W channel within a period of aCCATime after the signal arrives at the receiver's antenna(s); then the receiver shall not issue a PHY-CCA.indication(BUSY,{secondary}), PHY-CCA.indication(BUSY,{secondaryTVHT_2W}), or PHY-CCA.indication(IDLE) primitive while the threshold continues to be exceeded.

#### 22.3.18.6.3 CCA sensitivity for signals not occupying the primary channel

The PHY shall issue a PHY-CCA.indication(BUSY, {secondary}) primitive if the conditions for issuing a PHY-CCA.indication(BUSY, {primary}) primitive are not present and one of the following conditions is present in an otherwise idle TVHT_2W (TVHT_MODE_2C), TVHT_4W (TVHT_MODE_4C), TVHT_W+W (TVHT_MODE_2N), and TVHT_2W+2W (TVHT_MODE_4N) operating channel width:

— Any signal within the secondary channel at or above a threshold (–68 dBm for 6 MHz, –68 dBm for 7 MHz, and –67 dBm for 8 MHz) within a period of aCCATime after the signal arrives at the receiver's antenna(s); then the PHY shall not issue a PHY-CCA.indication(BUSY,{secondaryTVHT_2W}) or PHY-CCA.indication(IDLE) primitive while the threshold continues to be exceeded.

— A TVHT_W non-HT duplicate or VHT PPDU in TVWS bands detected in the secondary channel at or above a threshold (–81 dBm for 6 MHz, –81 dBm for 7 MHz, and –80 dBm for 8 MHz) with >90% probability within a period aCCAMidTime (see 22.4.4 (TVHT PHY)).

The PHY shall issue a PHY-CCA.indication(BUSY, {secondaryTVHT_2W}) primitive if the conditions for issuing a PHY-CCA.indication(BUSY, {primary}) primitive and a PHY-CCA.indication(BUSY,


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{secondary}) primitive are not present and one of the following conditions is present in an otherwise idle TVHT_4W (TVHT_MODE_4C) and TVHT_2W+2W (TVHT_MODE_4N) operating channel width:

— Any signal within the secondary TVHT_2W channel at or above a threshold (–65 dBm for 12 MHz, –65 dBm for 14 MHz, and –64 dBm for 16 MHz) within a period of aCCATime after the signal arrives at the receiver's antenna(s); then the PHY shall not issue a PHY-CCA.indication(IDLE) primitive while the threshold continues to be exceeded.

— A TVHT_2W non-HT duplicate or VHT PPDU in TVWS bands detected in the secondary TVHT_2W channel at or above a threshold (–78 dBm for 6+6 MHz, –78 dBm for 7+7 MHz, and –77 dBm for 8+8 MHz or 16 MHz) with >90% probability within a period aCCAMidTime (see 22.4.4 (TVHT PHY)).

— A TVHT_W non-HT duplicate or VHT PPDU in TVWS bands detected in any TVHT_W subchannel of the secondary TVHT_2W channel at or above a threshold (–81 dBm for 6 MHz, –81 dBm for 7 MHz, and –80 dBm for 8 MHz) with >90% probability within a period aCCAMidTime.

#### 22.3.18.7 RSSI

See 21.3.18.6 (RSSI) with "TVHT" replacing "VHT".

#### 22.3.18.8 Received channel power indicator (RCPI) measurement(#2011)

See 21.3.18.7 (Received channel power indicator (RCPI) measurement(#2011)) with "TVHT" replacing "VHT".

#### 22.3.19 PHY transmit procedure

See 21.3.19 (PHY transmit procedure) with "TVHT" replacing "VHT".

#### 22.3.20 PHY receive procedure

See 21.3.20 (PHY receive procedure) with "TVHT" replacing "VHT".

### 22.4 TVHT PLME

#### 22.4.1 PLME SAP layer management primitives(#6320)

See 21.4.1 (PLME SAP layer management primitives(#6320)) with "TVHT" replacing "VHT".

#### 22.4.2 PHY MIB

See 21.4.2 (PHY MIB) with "tvht(10)" replacing "vht(9)", "TVHT" replacing "VHT", and "In4W" replacing "In80" and with the removal of "dot11VHTShortGIOptionIn160and80p80Implemented" and "dot11VHTShortGIOptionIn160and80p80Activated".

#### 22.4.3 TXTIME and PSDU_LENGTH calculation

See 21.4.3 (TXTIME and PSDU_LENGTH calculation) with "TVHT" replacing "VHT".

#### 22.4.4 TVHT PHY

(#2123)The TVHT PHY characteristics, provided through the PLME-CHARACTERISTICS service primitive, are shown in Table 19-25 (HT PHY characteristics), unless otherwise listed in Table 22-25

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(TVHT PHY characteristics). The definitions for these characteristics are given in 6.7.4 (PLME-CHARACTERISTICS.confirm).

**Table 22-25—TVHT PHY characteristics**

| Characteristics | Value |
|---|---|
| aSlotTime | 24 μs (BCUs: 6 MHz or 7 MHz) plus any coverage-class-dependent aAirPropagationTime (see Table 9-133 (Coverage Class field parameters))<br>20 μs (BCUs: 8 MHz) plus any coverage-class-dependent aAirPropagationTime (see Table 9-133 (Coverage Class field parameters)) |
| aSIFSTime | 120 μs (BCUs: 6 MHz or 7 MHz)<br>90 μs (BCUs: 8 MHz) |
| aSignalExtension | 0 μs |
| aCCATime | < 15 μs (6 MHz or 7 MHz)<br>< 11.25 μs (8 MHz) |
| aCCAMidTime | < 94 μs (6 MHz or 7 MHz)<br>< 70 μs (8 MHz) |
| aAirPropagationTime | As indicated by the coverage class (see 10.22.5 (Operation with coverage classes)) |
| aPPDUMaxTime | 20 ms |
| aPSDUMaxLength | 1 401 120 octets (see NOTE 1) |
| aRxPHYStartDelay | (#3038)20 μs×<br>7.5 (6 and 7 MHz channels) or 5.625 (8 MHz channels) (see NOTE 2) |
| NOTE 1—This is the maximum length in octets for SU PPDUs with a bandwidth of 32 MHz or 16+16 MHz, MCS 9 and 4 spatial streams, limited by 973 possible Short GI data symbols in aPPDUMaxTime.<br>NOTE 2—This value arises from the time to the end of (#3038)the L-SIG field (see Figure 22-1 (VHT PPDU format in TVWS bands)). | |

## 22.5 Parameters for TVHT-MCSs

The rate-dependent parameters for one BCU mode (6 MHz, 7 MHz, and/or 8 MHz) and corresponding two and four BCU modes with $N_{SS} = 1, \ldots, 4$ are given in Table 22-26 (TVHT-MCSs for TVHT_MODE_1, NSS = 1) to Table 22-37 (TVHT-MCSs for TVHT_MODE_4C and TVHT_MODE_4N, NSS = 4). Support for MCS 8 and 9 (when valid) is optional in all cases. A TVHT STA shall support single spatial stream MCSs within the range MCS 0 to MCS 7 for all channel widths for which it has indicated support regardless of the Tx or Rx Highest Supported Data Rate subfield values in the TVHT Supported MCS Set field. When more than one spatial stream is supported, the Tx or Rx Highest Supported Data Rate subfield values in the TVHT Supported MCS Set field may result in a reduced MCS range (cut-off) for $N_{SS} = 2, \ldots, 4$. Support for 6 MHz, 7 MHz, or 8 MHz with $N_{SS} = 1$ is mandatory. Support for 6 MHz, 7 MHz, and 8 MHz with $N_{SS} = 2, \ldots, 4$ is optional. Support for two BCU modes with 12 MHz, 14 MHz, and 16 MHz or with 6+6 MHz, 7+7 MHz, and 8+8 MHz with $N_{SS} = 1, \ldots, 4$ is optional. Support for four BCU modes with 24 MHz, 28 MHz, and 32 MHz or with 12+12 MHz, 14+14 MHz, and 16+16 MHz with $N_{SS} = 1, \ldots, 4$ is optional. $N_{ES}$ values were chosen to yield an integer number of punctured blocks per OFDM symbol. Note that $N_{ES}$ values are 1 for all Clause 22 (Television very high throughput (TVHT) PHY specification) modulations.

Table 22-26 (TVHT-MCSs for TVHT_MODE_1, NSS = 1) to Table 22-37 (TVHT-MCSs for TVHT_MODE_4C and TVHT_MODE_4N, NSS = 4) define TVHT-MCSs not only for SU transmission but


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also for user $u$ of MU transmission. In the case of TVHT-MCSs for MU transmission, the parameters, $N_{SS}$, $R$, $N_{BPSCS}$, $N_{CBPS}$, and $N_{DBPS}$ are replaced with $N_{SS,u}$, $R_u$, $N_{BPSCS,u}$, $N_{CBPS,u}$, and $N_{DBPS,u}$, respectively.

In the MCS parameter tables that follow, data rates for a 400 ns GI are rounded to 1 decimal place.

**Table 22-26—TVHT-MCSs for TVHT_MODE_1, $N_{SS}$ = 1**

| MCS Index | Modulation | $R$ | $N_{BPSCS}$ | $N_{SD}$ | $N_{SP}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) for 6 MHz or 7 MHz | | Data rate (Mb/s) for 8 MHz | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 6.0 µs GI | 3.0 µs GI | 4.5 µs GI | 2.25 µs GI |
| 0 | BPSK | 1/2 | 1 | 108 | 6 | 108 | 54 | 1.8 | 2.0 | 2.4 | 2.7 |
| 1 | QPSK | 1/2 | 2 | 108 | 6 | 216 | 108 | 3.6 | 4.0 | 4.8 | 5.3 |
| 2 | QPSK | 3/4 | 2 | 108 | 6 | 216 | 162 | 5.4 | 6.0 | 7.2 | 8.0 |
| 3 | 16-QAM | 1/2 | 4 | 108 | 6 | 432 | 216 | 7.2 | 8.0 | 9.6 | 10.7 |
| 4 | 16-QAM | 3/4 | 4 | 108 | 6 | 432 | 324 | 10.8 | 12.0 | 14.4 | 16.0 |
| 5 | 64-QAM | 2/3 | 6 | 108 | 6 | 648 | 432 | 14.4 | 16.0 | 19.2 | 21.3 |
| 6 | 64-QAM | 3/4 | 6 | 108 | 6 | 648 | 486 | 16.2 | 18.0 | 21.6 | 24.0 |
| 7 | 64-QAM | 5/6 | 6 | 108 | 6 | 648 | 540 | 18.0 | 20.0 | 24.0 | 26.7 |
| 8 | 256-QAM | 3/4 | 8 | 108 | 6 | 864 | 648 | 21.6 | 24.0 | 28.8 | 32.0 |
| 9 | 256-QAM | 5/6 | 8 | 108 | 6 | 864 | 720 | 24.0 | 26.7 | 32.0 | 35.6 |

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**Table 22-27—TVHT-MCSs for TVHT_MODE_1, $N_{SS}$ = 2**

| MCS Index | Modulation | *R* | $N_{BPSCS}$ | $N_{SD}$ | $N_{SP}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) for 6 MHz or 7 MHz | | Data rate (Mb/s) for 8 MHz | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 6.0 µs GI | 3.0 µs GI | 4.5 µs GI | 2.25 µs GI |
| 0 | BPSK | 1/2 | 1 | 108 | 6 | 216 | 108 | 3.6 | 4.0 | 4.8 | 5.3 |
| 1 | QPSK | 1/2 | 2 | 108 | 6 | 432 | 216 | 7.2 | 8.0 | 9.6 | 10.7 |
| 2 | QPSK | 3/4 | 2 | 108 | 6 | 432 | 324 | 10.8 | 12.0 | 14.4 | 16.0 |
| 3 | 16-QAM | 1/2 | 4 | 108 | 6 | 864 | 432 | 14.4 | 16.0 | 19.2 | 21.3 |
| 4 | 16-QAM | 3/4 | 4 | 108 | 6 | 864 | 648 | 21.6 | 24.0 | 28.8 | 32.0 |
| 5 | 64-QAM | 2/3 | 6 | 108 | 6 | 1296 | 864 | 28.8 | 32.0 | 38.4 | 42.7 |
| 6 | 64-QAM | 3/4 | 6 | 108 | 6 | 1296 | 972 | 32.4 | 36.0 | 43.2 | 48.0 |
| 7 | 64-QAM | 5/6 | 6 | 108 | 6 | 1296 | 1080 | 36.0 | 40.0 | 48.0 | 53.3 |
| 8 | 256-QAM | 3/4 | 8 | 108 | 6 | 1728 | 1296 | 43.2 | 48.0 | 57.6 | 64.0 |
| 9 | 256-QAM | 5/6 | 8 | 108 | 6 | 1728 | 1440 | 48.0 | 53.3 | 64.0 | 71.1 |

**Table 22-28—TVHT-MCSs for TVHT_MODE_1, $N_{SS}$ = 3**

| MCS Index | Modulation | *R* | $N_{BPSCS}$ | $N_{SD}$ | $N_{SP}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) for 6 MHz or 7 MHz | | Data rate (Mb/s) for 8 MHz | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 6.0 µs GI | 3.0 µs GI | 4.5 µs GI | 2.25 µs GI |
| 0 | BPSK | 1/2 | 1 | 108 | 6 | 324 | 162 | 5.4 | 6.0 | 7.2 | 8.0 |
| 1 | QPSK | 1/2 | 2 | 108 | 6 | 648 | 324 | 10.8 | 12.0 | 14.4 | 16.0 |
| 2 | QPSK | 3/4 | 2 | 108 | 6 | 648 | 486 | 16.2 | 18.0 | 21.6 | 24.0 |
| 3 | 16-QAM | 1/2 | 4 | 108 | 6 | 1296 | 648 | 21.6 | 24.0 | 28.8 | 32.0 |
| 4 | 16-QAM | 3/4 | 4 | 108 | 6 | 1296 | 972 | 32.4 | 36.0 | 43.2 | 48.0 |
| 5 | 64-QAM | 2/3 | 6 | 108 | 6 | 1944 | 1296 | 43.2 | 48.0 | 57.6 | 64.0 |
| 6 | 64-QAM | 3/4 | 6 | 108 | 6 | 1944 | 1458 | 48.6 | 54.0 | 64.8 | 72.0 |
| 7 | 64-QAM | 5/6 | 6 | 108 | 6 | 1944 | 1620 | 54.0 | 60.0 | 72.0 | 80.0 |
| 8 | 256-QAM | 3/4 | 8 | 108 | 6 | 2592 | 1944 | 64.8 | 72.0 | 86.4 | 96.0 |
| 9 | 256-QAM | 5/6 | 8 | 108 | 6 | 2592 | 2160 | 72.0 | 80.0 | 96.0 | 106.7 |


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**Table 22-29—TVHT-MCSs for TVHT_MODE_1, $N_{SS}$ = 4**

| MCS Index | Modulation | $R$ | $N_{BPSCS}$ | $N_{SD}$ | $N_{SP}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) for 6 MHz or 7 MHz | | Data rate (Mb/s) for 8 MHz | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 6.0 µs GI | 3.0 µs GI | 4.5 µs GI | 2.25 µs GI |
| 0 | BPSK | 1/2 | 1 | 108 | 6 | 432 | 216 | 7.2 | 8.0 | 9.6 | 10.7 |
| 1 | QPSK | 1/2 | 2 | 108 | 6 | 864 | 432 | 14.4 | 16.0 | 19.2 | 21.3 |
| 2 | QPSK | 3/4 | 2 | 108 | 6 | 864 | 648 | 21.6 | 24.0 | 28.8 | 32.0 |
| 3 | 16-QAM | 1/2 | 4 | 108 | 6 | 1728 | 864 | 28.8 | 32.0 | 38.4 | 42.7 |
| 4 | 16-QAM | 3/4 | 4 | 108 | 6 | 1728 | 1296 | 43.2 | 48.0 | 57.6 | 64.0 |
| 5 | 64-QAM | 2/3 | 6 | 108 | 6 | 2592 | 1728 | 57.6 | 64.0 | 76.8 | 85.3 |
| 6 | 64-QAM | 3/4 | 6 | 108 | 6 | 2592 | 1944 | 64.8 | 72.0 | 86.4 | 96.0 |
| 7 | 64-QAM | 5/6 | 6 | 108 | 6 | 2592 | 2160 | 72.0 | 80.0 | 96.0 | 106.7 |
| 8 | 256-QAM | 3/4 | 8 | 108 | 6 | 3456 | 2592 | 86.4 | 96.0 | 115.2 | 128.0 |
| 9 | 256-QAM | 5/6 | 8 | 108 | 6 | 3456 | 2880 | 96.0 | 106.7 | 128.0 | 142.2 |

**Table 22-30—TVHT-MCSs for TVHT_MODE_2C and TVHT_MODE_2N, $N_{SS}$ = 1**

| MCS Index | Modulation | $R$ | $N_{BPSCS}$ | $N_{SD} \cdot N_{Seg}$ | $N_{SP}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) for 6 MHz or 7 MHz | | Data rate (Mb/s) for 8 MHz | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 6.0 µs GI | 3.0 µs GI | 4.5 µs GI | 2.25 µs GI |
| 0 | BPSK | 1/2 | 1 | 216 | 12 | 216 | 108 | 3.6 | 4.0 | 4.8 | 5.3 |
| 1 | QPSK | 1/2 | 2 | 216 | 12 | 432 | 216 | 7.2 | 8.0 | 9.6 | 10.7 |
| 2 | QPSK | 3/4 | 2 | 216 | 12 | 432 | 324 | 10.8 | 12.0 | 14.4 | 16.0 |
| 3 | 16-QAM | 1/2 | 4 | 216 | 12 | 864 | 432 | 14.4 | 16.0 | 19.2 | 21.3 |
| 4 | 16-QAM | 3/4 | 4 | 216 | 12 | 864 | 648 | 21.6 | 24.0 | 28.8 | 32.0 |
| 5 | 64-QAM | 2/3 | 6 | 216 | 12 | 1296 | 864 | 28.8 | 32.0 | 38.4 | 42.7 |
| 6 | 64-QAM | 3/4 | 6 | 216 | 12 | 1296 | 972 | 32.4 | 36.0 | 43.2 | 48.0 |
| 7 | 64-QAM | 5/6 | 6 | 216 | 12 | 1296 | 1080 | 36.0 | 40.0 | 48.0 | 53.3 |
| 8 | 256-QAM | 3/4 | 8 | 216 | 12 | 1728 | 1296 | 43.2 | 48.0 | 57.6 | 64.0 |
| 9 | 256-QAM | 5/6 | 8 | 216 | 12 | 1728 | 1440 | 48.0 | 53.3 | 64.0 | 71.1 |

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**Table 22-31—TVHT-MCSs for TVHT_MODE_2C and TVHT_MODE_2N, $N_{SS}$ = 2**

| MCS Index | Modulation | $R$ | $N_{BPSCS}$ | $N_{SD} \cdot N_{Seg}$ | $N_{SP}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) for 6 MHz or 7 MHz | | Data rate (Mb/s) for 8 MHz | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 6.0 µs GI | 3.0 µs GI | 4.5 µs GI | 2.25 µs GI |
| 0 | BPSK | 1/2 | 1 | 216 | 12 | 432 | 216 | 7.2 | 8.0 | 9.6 | 10.7 |
| 1 | QPSK | 1/2 | 2 | 216 | 12 | 864 | 432 | 14.4 | 16.0 | 19.2 | 21.3 |
| 2 | QPSK | 3/4 | 2 | 216 | 12 | 864 | 648 | 21.6 | 24.0 | 28.8 | 32.0 |
| 3 | 16-QAM | 1/2 | 4 | 216 | 12 | 1728 | 864 | 28.8 | 32.0 | 38.4 | 42.7 |
| 4 | 16-QAM | 3/4 | 4 | 216 | 12 | 1728 | 1296 | 43.2 | 48.0 | 57.6 | 64.0 |
| 5 | 64-QAM | 2/3 | 6 | 216 | 12 | 2592 | 1728 | 57.6 | 64.0 | 76.8 | 85.3 |
| 6 | 64-QAM | 3/4 | 6 | 216 | 12 | 2592 | 1944 | 64.8 | 72.0 | 86.4 | 96.0 |
| 7 | 64-QAM | 5/6 | 6 | 216 | 12 | 2592 | 2160 | 72.0 | 80.0 | 96.0 | 106.7 |
| 8 | 256-QAM | 3/4 | 8 | 216 | 12 | 3456 | 2592 | 86.4 | 96.0 | 115.2 | 128.0 |
| 9 | 256-QAM | 5/6 | 8 | 216 | 12 | 3456 | 2880 | 96.0 | 106.7 | 128.0 | 142.2 |

**Table 22-32—TVHT-MCSs for TVHT_MODE_2C and TVHT_MODE_2N, $N_{SS}$ = 3**

| MCS Index | Modulation | $R$ | $N_{BPSCS}$ | $N_{SD} \cdot N_{Seg}$ | $N_{SP}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) for 6 MHz or 7 MHz | | Data rate (Mb/s) for 8 MHz | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 6.0 µs GI | 3.0 µs GI | 4.5 µs GI | 2.25 µs GI |
| 0 | BPSK | 1/2 | 1 | 216 | 12 | 648 | 324 | 10.8 | 12.0 | 14.4 | 16.0 |
| 1 | QPSK | 1/2 | 2 | 216 | 12 | 1296 | 648 | 21.6 | 24.0 | 28.8 | 32.0 |
| 2 | QPSK | 3/4 | 2 | 216 | 12 | 1296 | 972 | 32.4 | 36.0 | 43.2 | 48.0 |
| 3 | 16-QAM | 1/2 | 4 | 216 | 12 | 2592 | 1296 | 43.2 | 48.0 | 57.6 | 64.0 |
| 4 | 16-QAM | 3/4 | 4 | 216 | 12 | 2592 | 1944 | 64.8 | 72.0 | 86.4 | 96.0 |
| 5 | 64-QAM | 2/3 | 6 | 216 | 12 | 3888 | 2592 | 86.4 | 96.0 | 115.2 | 128.0 |
| 6 | 64-QAM | 3/4 | 6 | 216 | 12 | 3888 | 2916 | 97.2 | 108.0 | 129.6 | 144.0 |
| 7 | 64-QAM | 5/6 | 6 | 216 | 12 | 3888 | 3240 | 108. | 120.0 | 144.0 | 160.0 |
| 8 | 256-QAM | 3/4 | 8 | 216 | 12 | 5184 | 3888 | 129.6 | 144.0 | 172.8 | 192.0 |
| 9 | 256-QAM | 5/6 | 8 | 216 | 12 | 5184 | 4320 | 144.0 | 160.0 | 192.0 | 213.3 |


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**Table 22-33—TVHT-MCSs for TVHT_MODE_2C and TVHT_MODE_2N, $N_{SS}$ = 4**

| MCS Index | Modulation | $R$ | $N_{BPSCS}$ | $N_{SD}$· $N_{Seg}$ | $N_{SP}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) for 6 MHz or 7 MHz | | Data rate (Mb/s) for 8 MHz | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 6.0 µs GI | 3.0 µs GI | 4.5 µs GI | 2.25 µs GI |
| 0 | BPSK | 1/2 | 1 | 216 | 12 | 864 | 432 | 14.4 | 16.0 | 19.2 | 21.3 |
| 1 | QPSK | 1/2 | 2 | 216 | 12 | 1728 | 864 | 28.8 | 32.0 | 38.4 | 42.7 |
| 2 | QPSK | 3/4 | 2 | 216 | 12 | 1728 | 1296 | 43.2 | 48.0 | 57.6 | 64.0 |
| 3 | 16-QAM | 1/2 | 4 | 216 | 12 | 3456 | 1728 | 57.6 | 64.0 | 76.8 | 85.3 |
| 4 | 16-QAM | 3/4 | 4 | 216 | 12 | 3456 | 2592 | 86.4 | 96.0 | 115.2 | 128.0 |
| 5 | 64-QAM | 2/3 | 6 | 216 | 12 | 5184 | 3456 | 115.2 | 128.0 | 153.6 | 170.7 |
| 6 | 64-QAM | 3/4 | 6 | 216 | 12 | 5184 | 3888 | 129.6 | 144.0 | 172.8 | 192.0 |
| 7 | 64-QAM | 5/6 | 6 | 216 | 12 | 5184 | 4320 | 144.0 | 160.0 | 192.0 | 213.3 |
| 8 | 256-QAM | 3/4 | 8 | 216 | 12 | 6912 | 5184 | 172.8 | 192.0 | 230.4 | 256.0 |
| 9 | 256-QAM | 5/6 | 8 | 216 | 12 | 6912 | 5760 | 192.0 | 213.3 | 256.0 | 284.4 |

**Table 22-34—TVHT-MCSs for TVHT_MODE_4C and TVHT_MODE_4N, $N_{SS}$ = 1**

| MCS Index | Modulation | $R$ | $N_{BPSCS}$ | $N_{SD}$ | $N_{SP}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) for 6 MHz or 7 MHz | | Data rate (Mb/s) for 8 MHz | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 6.0 µs GI | 3.0 µs GI | 4.5 µs GI | 2.25 µs GI |
| 0 | BPSK | 1/2 | 1 | 432 | 24 | 432 | 216 | 7.2 | 8.0 | 9.6 | 10.7 |
| 1 | QPSK | 1/2 | 2 | 432 | 24 | 864 | 432 | 14.4 | 16.0 | 19.2 | 21.3 |
| 2 | QPSK | 3/4 | 2 | 432 | 24 | 864 | 648 | 21.6 | 24.0 | 28.8 | 32.0 |
| 3 | 16-QAM | 1/2 | 4 | 432 | 24 | 1728 | 864 | 28.8 | 32.0 | 38.4 | 42.7 |
| 4 | 16-QAM | 3/4 | 4 | 432 | 24 | 1728 | 1296 | 43.2 | 48.0 | 57.6 | 64.0 |
| 5 | 64-QAM | 2/3 | 6 | 432 | 24 | 2592 | 1728 | 57.6 | 64.0 | 76.8 | 85.3 |
| 6 | 64-QAM | 3/4 | 6 | 432 | 24 | 2592 | 1944 | 64.8 | 72.0 | 86.4 | 96.0 |
| 7 | 64-QAM | 5/6 | 6 | 432 | 24 | 2592 | 2160 | 72.0 | 80.0 | 96.0 | 106.7 |
| 8 | 256-QAM | 3/4 | 8 | 432 | 24 | 3456 | 2592 | 86.4 | 96.0 | 115.2 | 128.0 |
| 9 | 256-QAM | 5/6 | 8 | 432 | 24 | 3456 | 2880 | 96.0 | 106.7 | 128.0 | 142.2 |

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**Table 22-35—TVHT-MCSs for TVHT_MODE_4C and TVHT_MODE_4N, $N_{SS}$ = 2**

| MCS Index | Modulation | $R$ | $N_{BPSCS}$ | $N_{SD}$ | $N_{SP}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) for 6 MHz or 7 MHz | | Data rate (Mb/s) for 8 MHz | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 6.0 µs GI | 3.0 µs GI | 4.5 µs GI | 2.25 µs GI |
| 0 | BPSK | 1/2 | 1 | 432 | 24 | 864 | 432 | 14.4 | 16.0 | 19.2 | 21.3 |
| 1 | QPSK | 1/2 | 2 | 432 | 24 | 1728 | 864 | 28.8 | 32.0 | 38.4 | 42.7 |
| 2 | QPSK | 3/4 | 2 | 432 | 24 | 1728 | 1296 | 43.2 | 48.0 | 57.6 | 64.0 |
| 3 | 16-QAM | 1/2 | 4 | 432 | 24 | 3456 | 1728 | 57.6 | 64.0 | 76.8 | 85.3 |
| 4 | 16-QAM | 3/4 | 4 | 432 | 24 | 3456 | 2592 | 86.4 | 96.0 | 115.2 | 128.0 |
| 5 | 64-QAM | 2/3 | 6 | 432 | 24 | 5184 | 3456 | 115.2 | 128.0 | 153.6 | 170.7 |
| 6 | 64-QAM | 3/4 | 6 | 432 | 24 | 5184 | 3888 | 129.6 | 144.0 | 172.8 | 192.0 |
| 7 | 64-QAM | 5/6 | 6 | 432 | 24 | 5184 | 4320 | 144.0 | 160.0 | 192.0 | 213.3 |
| 8 | 256-QAM | 3/4 | 8 | 432 | 24 | 6912 | 5184 | 172.8 | 192.0 | 230.4 | 256.0 |
| 9 | 256-QAM | 5/6 | 8 | 432 | 24 | 6912 | 5760 | 192.0 | 213.3 | 256.0 | 284.4 |

**Table 22-36—TVHT-MCSs for TVHT_MODE_4C and TVHT_MODE_4N, $N_{SS}$ = 3**

| MCS Index | Modulation | $R$ | $N_{BPSCS}$ | $N_{SD}$ | $N_{SP}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) for 6 MHz or 7 MHz | | Data rate (Mb/s) for 8 MHz | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 6.0 µs GI | 3.0 µs GI | 4.5 µs GI | 2.25 µs GI |
| 0 | BPSK | 1/2 | 1 | 432 | 24 | 1296 | 648 | 21.6 | 24.0 | 28.8 | 32.0 |
| 1 | QPSK | 1/2 | 2 | 432 | 24 | 2592 | 1296 | 43.2 | 48.0 | 57.6 | 64.0 |
| 2 | QPSK | 3/4 | 2 | 432 | 24 | 2592 | 1944 | 64.8 | 72.0 | 86.4 | 96.0 |
| 3 | 16-QAM | 1/2 | 4 | 432 | 24 | 5184 | 2592 | 86.4 | 96.0 | 115.2 | 128.0 |
| 4 | 16-QAM | 3/4 | 4 | 432 | 24 | 5184 | 3888 | 129.6 | 144.0 | 172.8 | 192.0 |
| 5 | 64-QAM | 2/3 | 6 | 432 | 24 | 7776 | 5184 | 172.8 | 192.0 | 230.4 | 256.0 |
| 6 | 64-QAM | 3/4 | 6 | 432 | 24 | 7776 | 5832 | 194.4 | 216.0 | 259.2 | 288.0 |
| 7 | 64-QAM | 5/6 | 6 | 432 | 24 | 7776 | 6480 | 216.0 | 240.0 | 288.0 | 320.0 |
| 8 | 256-QAM | 3/4 | 8 | 432 | 24 | 10 368 | 7776 | 259.2 | 288.0 | 345.6 | 384.0 |
| 9 | 256-QAM | 5/6 | 8 | 432 | 24 | 10 368 | 8640 | 288.0 | 320.0 | 384.0 | 426.7 |


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**Table 22-37—TVHT-MCSs for TVHT_MODE_4C and TVHT_MODE_4N, $N_{SS}$ = 4**

| MCS Index | Modulation | *R* | $N_{BPSCS}$ | $N_{SD}$ | $N_{SP}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) for 6 MHz or 7 MHz | | Data rate (Mb/s) for 8 MHz | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 6.0 µs GI | 3.0 µs GI | 4.5 µs GI | 2.25 µs GI |
| 0 | BPSK | 1/2 | 1 | 432 | 24 | 1728 | 864 | 28.8 | 32.0 | 38.4 | 42.7 |
| 1 | QPSK | 1/2 | 2 | 432 | 24 | 3456 | 1728 | 57.6 | 64.0 | 76.8 | 85.3 |
| 2 | QPSK | 3/4 | 2 | 432 | 24 | 3456 | 2592 | 86.4 | 96.0 | 115.2 | 128.0 |
| 3 | 16-QAM | 1/2 | 4 | 432 | 24 | 6912 | 3456 | 115.2 | 128.0 | 153.6 | 170.7 |
| 4 | 16-QAM | 3/4 | 4 | 432 | 24 | 6912 | 5184 | 172.8 | 192.0 | 230.4 | 256.0 |
| 5 | 64-QAM | 2/3 | 6 | 432 | 24 | 10 368 | 6912 | 230.4 | 256.0 | 307.2 | 341.3 |
| 6 | 64-QAM | 3/4 | 6 | 432 | 24 | 10 368 | 7776 | 259.2 | 288.0 | 345.6 | 384.0 |
| 7 | 64-QAM | 5/6 | 6 | 432 | 24 | 10 368 | 8640 | 288.0 | 320.0 | 384.0 | 426.7 |
| 8 | 256-QAM | 3/4 | 8 | 432 | 24 | 13 824 | 10 368 | 345.6 | 384.0 | 460.8 | 512.0 |
| 9 | 256-QAM | 5/6 | 8 | 432 | 24 | 13 824 | 11 520 | 384.0 | 426.7 | 512.0 | 568.9 |

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# 23. Sub 1 GHz (S1G) PHY specification(#4095)

## 23.1 Introduction

### 23.1.1 Introduction to the S1G PHY

Clause 23 (Sub 1 GHz (S1G) PHY specification(#4095)) specifies the PHY entity for an S1G orthogonal frequency division multiplexing (OFDM) system.

The S1G PHY is based on the VHT PHY defined in Clause 21 (Very high throughput (VHT) PHY specification), which in turn is based on HT PHY defined in Clause 19 (High Throughput (HT) PHY specification(#2297)) and the OFDM PHY defined in Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification). The S1G PHY defines an OFDM PHY in the sub-1 GHz bands using narrower bandwidths than those in 2.4 GHz and 5 GHz bands, with maximum number of space-time streams supported being four, and with support for downlink multi-user (MU) transmissions. A downlink MU transmission supports up to four users with up to three space-time streams per user with the total number of space-time streams not exceeding four.

The S1G PHY provides support for 1 MHz, 2 MHz, 4 MHz, 8 MHz, and 16 MHz contiguous channel widths. A tone spacing of 31.25 kHz is used in all the bandwidths.

Transmissions of PPDUs with channel bandwidth 2 MHz, 4 MHz, 8 MHz, and 16 MHz are in general modulated the same way as 20 MHz, 40 MHz, 80 MHz and 160 MHz contiguous mode as specified in Clause 21 (Very high throughput (VHT) PHY specification), respectively, except with a 1/10 clock rate. For details refer to Table 23-5 (Timing-related constants) (in 23.3.6 (Timing-related parameters)). Transmissions of PPDUs with 1 MHz channel bandwidth are modulated as described in 23.3.4.4 (Construction of the Preamble part in an S1G_1M PPDU).

The S1G PHY data subcarriers are modulated using binary phase shift keying (BPSK), quadrature phase shift keying (QPSK), 16-quadrature amplitude modulation (16-QAM), 64-QAM, 256-QAM and 1024 QAM.(M102) Forward error correction (FEC) coding (convolutional or LDPC coding) is used with coding rates of 1/2, 2/3, 3/4, and 5/6.

(#306)A non-AP S1G STA shall support the following Clause 23 (Sub 1 GHz (S1G) PHY specification(#4095)) features:

- 1 MHz and 2 MHz channel width
- S1G_1M, S1G_SHORT PPDU
- S1G_LONG PPDU, if ≥ 4 MHz channel width is supported
- Detect and decode SIG-A field of the S1G_LONG preamble.
- Single spatial stream MCSs 0 to 2, and MCS 10 (for 1 MHz PPDU only)
- BCC coding
- Normal Guard Interval $T_{GI}$ as defined in Table 23-5 (Timing-related constants) (in 23.3.6 (Timing-related parameters))
- Fixed Pilots

An S1G AP shall support the following Clause 23 (Sub 1 GHz (S1G) PHY specification(#4095)) features:

- 1 MHz and 2 MHz channel width
- S1G_1M, S1G_SHORT PPDU
- S1G_LONG PPDU, if ≥4 MHz channel width is supported
- Detect and decode SIG-A field of the S1G_LONG preamble.


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- Single spatial stream MCSs 0 to 7, and MCS 10 (for 1 MHz PPDU only)
- BCC coding
- Normal Guard Interval $T_{GI}$ as defined in Table 23-5 (Timing-related constants) (in 23.3.6 (Timing-related parameters))
- Fixed Pilots

An S1G STA may support the following Clause 23 (Sub 1 GHz (S1G) PHY specification(#4095)) features:

- 2 or more spatial streams (transmit and receive)
- S1G_LONG preamble when maximum channel width supported is less than 4 MHz
- Beamforming sounding (through S1G NDP) for an AP
- Beamforming sounding response (i.e., providing compressed beamforming feedback) for a non-AP STA
- STBC (transmit and receive)
- LDPC (transmit and receive)
- S1G MU PPDUs (transmit and receive)
- 4 MHz channel widths
- 8 MHz channel widths
- 16 MHz channel widths
- S1G-MCSs 8 and 9 (transmit and receive) for an AP, and S1G-MCSs 3-9 (transmit and receive) for a non-AP STA
- Short Guard Interval
- Traveling Pilots

### 23.1.2 Scope of S1G PHY services

The services provided to the MAC by the S1G PHY consist of the following protocol functions:

a) A function that defines a method of mapping the PSDUs into a (#14)PPDU format suitable for sending and receiving PSDUs between two or more STAs.

b) A function that defines the characteristics and method of transmitting and receiving data through a wireless medium between two or more STAs.

### 23.1.3 S1G PHY features

#### 23.1.3.1 General

The S1G PHY contains two functional entities: the PHY function, and the physical layer management function (i.e., the PLME). Both of these functions are described in detail in 23.3 (S1G PHY layer(#4114)) and 23.4 (S1G PLME(#6321)).

The S1G PHY service is provided to the MAC through the PHY service primitives defined in Clause 8 (PHY service specification). The S1G PHY service interface is described in 23.2 (S1G PHY service interface).

#### 23.1.3.2 PHY management entity (PLME)

The PLME performs management of the local PHY functions in conjunction with the MLME.

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#### 23.1.3.3 Service specification method

The models represented by figures and state diagrams are intended to be illustrations of the functions provided. It is important to distinguish between a model and a real implementation. The models are optimized for simplicity and clarity of presentation; the actual method of implementation is left to the discretion of the developer.

The service of a layer is the set of capabilities that it offers to a user in the next higher layer. Abstract services are specified here by describing the service primitives and parameters that characterize each service. This definition is independent of any particular implementation.

### 23.1.4 PPDU formats

The structure of the PPDU transmitted by an S1G STA is determined by the TXVECTOR parameters as defined in Table 23-1 (TXVECTOR and RXVECTOR parameters) (in 23.2.2 (TXVECTOR and RXVECTOR parameters)).

The FORMAT parameter determines the overall structure of the PPDU, and the allowed values are:

- S1G, for S1G non-duplicate PPDUs
- S1G_DUP_2M, for S1G 2 MHz duplicate PPDUs
- S1G_DUP_1M, for S1G 1 MHz duplicate PPDUs

The PPDU bandwidth is determined by the CH_BANDWIDTH parameter, and the preamble type (i.e., S1G_1M preamble, S1G_SHORT preamble, and S1G_LONG preamble) is determined by the PREAMBLE_TYPE parameter.

- The 1 MHz format PPDU (S1G_1M) is used for non-duplicate S1G transmissions at 1 MHz bandwidth (i.e., CH_BANDWIDTH = CBW1), and for S1G_DUP_1M transmissions of any bandwidth (i.e., CH_BANDWIDTH = CBW1, CBW2, CBW4, CBW8, or CBW16). The S1G_1M preamble (see 23.3.8.3 (Format for 1 MHz)) is used. Support for the S1G_1M is mandatory.
- The greater than or equal to 2 MHz short format (S1G_SHORT) is used for non-duplicate S1G transmissions and for S1G_DUP_2M transmissions, at bandwidths of 2 MHz and higher (i.e., CH_BANDWIDTH = CBW2, CBW4, CBW8, or CBW16). The S1G_SHORT preamble (see 23.3.8.2.1 (Introduction)) is used. This PPDU format is similar to the HT-greenfield format in Clause 19 (High Throughput (HT) PHY specification(#2297)), which does not contain a legacy portion in the preamble. Support for S1G_SHORT is mandatory.
- The greater than or equal to 2 MHz long format (S1G_LONG) is used for non-duplicate S1G transmissions at bandwidths of 2 MHz and higher (i.e., CH_BANDWIDTH = CBW2, CBW4, CBW8, or CBW16). The S1G_LONG format is not used for S1G_DUP_2M transmissions. The S1G_LONG preamble (see 23.3.8.2.2 (S1G_SHORT preamble)) is used. This PPDU format is similar to the HT-mixed format in Clause 19 (High Throughput (HT) PHY specification(#2297)). Support for S1G_LONG is optional if a STA supports only 1 MHz and 2 MHz PPDUs, and is mandatory if a STA supports wider than 2 MHz PPDUs. All S1G STAs shall support detecting and decoding up to the SIG-A field of S1G_LONG PPDUs.

An S1G_LONG PPDU can be further categorized as an S1G SU PPDU or an S1G MU PPDU. An S1G_LONG PPDU with MU_SU = MU is an S1G MU PPDU, otherwise it is an S1G SU PPDU. An S1G MU PPDU carries one or more PSDUs to one or more STAs and shall be an S1G_LONG PPDU.


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## 23.2 S1G PHY service interface

### 23.2.1 Introduction

The PHY provides an interface to the MAC through an extension of the generic PHY service interface defined in 8.3.4 (Basic service and options). The interface includes TXVECTOR, RXVECTOR, and PHYCONFIG_VECTOR.

The TXVECTOR supplies the PHY with per-PPDU transmit parameters. Using the RXVECTOR, the PHY informs the MAC of the received (#14)PPDU's parameters. Using the PHYCONFIG_VECTOR, the MAC configures the PHY for operation, independent of (#14)PPDU transmission or reception.

### 23.2.2 TXVECTOR and RXVECTOR parameters

The parameters in Table 23-1 (TXVECTOR and RXVECTOR parameters) are defined as part of the TXVECTOR parameter list in the PHY-TXSTART.request primitive and/or as part of the RXVECTOR parameter list in the PHY-RXSTART.indication primitive.

**Table 23-1—TXVECTOR and RXVECTOR parameters**

| Parameter | Condition | Value | TXVECTOR | RXVECTOR |
|---|---|---|---|---|
| FORMAT | | Determines the format of the PPDU.<br>Enumerated type:<br>S1G indicates S1G PPDU format.<br>(#2095)S1G_DUP_1M indicates S1G 1 MHz Duplicate format PPDU<br>(#2095)S1G_DUP_2M indicates S1G 2 MHz Duplicate format PPDU | Y | Y |
| PREAMBLE_TYPE | FORMAT is S1G<br>and<br>(CH_BANDWIDTH is CBW2 or CBW4 or CBW8 or CBW16) | Determine the type of preamble of the S1G PPDU.<br>Enumerated type:<br>S1G_SHORT_PREAMBLE indicates the short preamble defined in 23.3.8.2.2 (S1G_SHORT preamble).<br>S1G_LONG_PREAMBLE indicates the long preamble defined in 23.3.8.2.3 (S1G_LONG preamble). | Y | Y |
| | (#447)(FORMAT is S1G and CH_BANDWIDTH is CBW1) or FORMAT is S1G_DUP_1M | Set to S1G_1M_PREAMBLE defined in 23.3.8.3 (Format for 1 MHz) | Y | Y |
| | FORMAT is S1G_DUP_2M | Set to S1G_SHORT_PREAMBLE. | Y | Y |
| | Otherwise | Not present | N | N |

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**Table 23-1—TXVECTOR and RXVECTOR parameters *(continued)***

| Parameter | Condition | Value | TXVECTOR | RXVECTOR |
|---|---|---|---|---|
| MU_SU | FORMAT is S1G<br>and<br>PREAMBLE_TYPE is S1G_LONG_PREAMBLE<br>and<br>(CH_BANDWIDTH is CBW2 or CBW4 or CBW8 or CBW16) | Determine whether MU or SU of the S1G PPDU<br>Enumerated type:<br>Set to MU if NUM_USERS is 2 to 4.<br>Set to SU if NUM_USERS is 1. | Y | Y |
| | Otherwise | Not present | N | N |
| NDP_INDICATION | | Determine the type of S1G (#14)PPDU.<br>Set to 1 if this (#14)PPDU is one of NDP CMAC PPDUs as defined in 23.3.12 (NDP CMAC PPDUs).<br>Set to 0 otherwise. | Y | Y |
| NDP_CMAC_PPDU_BODY | NDP_INDICATION is 1 | Set to concatenated fields(#291), which describe the NDP CMAC PPDU body content in one of NDP CMAC PPDU types defined in Table 23-30 (NDP CMAC PPDU Type field values).<br>(See 23.3.12 (NDP CMAC PPDUs)). | Y | Y |
| | Otherwise | Not present | N | N |
| SMOOTHING | FORMAT is S1G<br>and<br>(CH_BANDWIDTH is CBW2 or CBW4 or CBW8 or CBW16)<br>and<br>PREAMBLE_TYPE is S1G_LONG_PREAMBLE<br>and<br>NUM_STS is larger than 1 | Indicates whether frequency domain smoothing is recommended as part of channel estimation.<br>Set to 1 if frequency domain smoothing is recommended.<br>Set to 0 otherwise. | Y | Y |
| | FORMAT is S1G<br>and<br>(CH_BANDWIDTH is CBW2 or CBW4 or CBW8 or CBW16)<br>and<br>PREAMBLE_TYPE is S1G_LONG_PREAMBLE<br>and<br>NUM_STS is 1 | Not present | N | N |
| | Otherwise | Indicates whether frequency domain smoothing is recommended as part of channel estimation.<br>Set to 1 if frequency domain smoothing is recommended.<br>Set to 0 otherwise. | Y | Y |


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**Table 23-1—TXVECTOR and RXVECTOR parameters *(continued)***

| Parameter | Condition | Value | TXVECTOR | RXVECTOR |
|---|---|---|---|---|
| AGGREGATION | | Indicates whether the PSDU contains an A-MPDU.<br>Enumerated type:<br>AGGREGATED indicates this (#14)PSDU contains an A-MPDU.<br>NOT_AGGREGATED indicates this (#14)PSDU does not contain an A-MPDU. | Y | Y |
| SECTOR_ID | FORMAT is S1G<br>and<br>PREAMBLE_TYPE(#40) is S1G_LONG_PREAMBLE | Indicates which sectorized beam of the available sectorized beams are used in the transmission. The length of the parameter is 8 bits. A 1 in bit position n, relative to the LSB, indicates that Sector n is used.<br>This parameter is present only if sectorization is applied. | O | N |
| | Otherwise | Not present | N | N |
| N_TX | | Indicates the number of transmit chains. | Y | N |
| EXPANSION_MAT | FORMAT is S1G<br>and<br>(CH_BANDWIDTH is CBW2 or CBW4 or CBW8 or CBW16)<br>and<br>MU_SU is MU | Contains a vector in the number of selected subcarriers containing feedback matrices as defined in 23.3.10.2 (Beamforming Feedback Matrix V) based on the channel measured during the training symbols of a previous S1G NDP. | M<br>U | N |
| | FORMAT is S1G<br>and<br>(CH_BANDWIDTH is CBW2 or CBW4 or CBW8 or CBW16)<br>and<br>MU_SU is SU | Contains a vector in the number of selected subcarriers containing feedback matrices as defined in 23.3.10.2 (Beamforming Feedback Matrix V) based on the channel measured during the training symbols of a previous S1G NDP. | O | N |
| | Otherwise | Not present | N | N |
| CHAN_MAT | PSDU_LENGTH equals 0<br>and<br>NDP_INDICATION is 0 | Contains a set of compressed beamforming feedback matrices as defined in 23.3.10.2 (Beamforming Feedback Matrix V) based on the channel measured during the training symbols of the received S1G NDP. | N | Y |
| | Otherwise | Not present | N | N |
| DELTA_SNR | FORMAT is S1G<br>and<br>(CH_BANDWIDTH is CBW2 or CBW4 or CBW8 or CBW16) | Contains an array of delta SNR values as defined in 9.4.1.49 (MU Exclusive Beamforming Report field) based on the channel measured during the training symbols of the received S1G NDP.<br><br>NOTE—In the RXVECTOR this parameter is present only for S1G NDPs for MU sounding. | M<br>U | Y |
| | Otherwise | Not present | N | N |

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**Table 23-1—TXVECTOR and RXVECTOR parameters *(continued)***

| Parameter | Condition | Value | TXVECTOR | RXVECTOR |
|---|---|---|---|---|
| RCPI | | Is a measure of the received RF power averaged over all the receive chains in the STF or LTF fields (#3475)of the current PPDU.<br>Refer to 23.3.18.7 (Received channel power indicator (RCPI) measurement(#2011)) for the definition of RCPI.(#1718) | N | Y |
| SNR | | Contains an array of measures of the received SNR for each spatial stream. SNR indications of 8 bits are supported. SNR shall be the sum of the decibel values of SNR per tone divided by the number of tones represented in each stream as described in 9.4.1.47 (VHT Compressed Beamforming Report field). | N | Y |
| FEC_CODING | FORMAT is S1G | Indicates which FEC encoding is used.<br>Enumerated type:<br>BCC_CODING indicates binary convolutional code.<br>LDPC_CODING indicates low-density parity check code. | M<br>U | Y |
| | FORMAT is S1G_DUP_2M or S1G_DUP_1M | Indicates which FEC encoding is used.<br>Enumerated type:<br>BCC_CODING indicates binary convolutional code.<br>LDPC_CODING indicates low-density parity check code. | Y | Y |
| STBC | | Indicates whether or not STBC is used.<br>0 indicates no STBC ($N_{STS}=N_{SS}$ in the Data field).<br>1 indicates STBC is used ($N_{STS}=2N_{SS}$ in the Data field). | Y | Y |
| GI_TYPE | | Indicates whether a short guard interval is used in the transmission of the Data field of the PPDU.<br>Enumerated type:<br>LONG_GI indicates short GI is not used in the Data field of the PPDU.<br>SHORT_GI indicates short GI is used in the Data field of the PPDU. | Y | Y |
| TXPWR_LEVEL | | The allowed values for the TXPWR_LEVEL parameter are in the range from 1 to $N/2$, where $N$ is the number of octets in dot11TxPowerLevelExtended. This parameter is used to indicate which of the available transmit output power levels defined in dot11TxPowerLevelExtended shall be used for the current transmission. | Y | N |
| RSSI | | The allowed values for the RSSI parameter are in the range 0 to 255. This parameter is a (#1132)measurement by the PHY of the power observed at the antenna connector used to receive the current PPDU measured during the reception of the LTF field. RSSI is intended to be used in a relative manner, and it is a monotonically increasing function of the received power. | N | Y |



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**Table 23-1—TXVECTOR and RXVECTOR parameters *(continued)***

| Parameter | Condition | Value | TXVECTOR | RXVECTOR |
|---|---|---|---|---|
| MCS | FORMAT is S1G and (CH_BANDWIDTH is CBW2 or CBW4 or CBW8 or CBW16) | Indicates the modulation and coding scheme used in the transmission of the PPDU. Integer: range 0 to 9, 11 and 12(M102) | M U | Y |
| | FORMAT is S1G_DUP_2M | Indicates the modulation and coding scheme used in the transmission of the PPDU. Integer: range 0 to 9, 11 and 12(M102) | Y | Y |
| | Otherwise | Indicates the modulation and coding scheme used in the transmission of the PPDU. Integer: range 0 to 2(M102) | Y | Y |
| REC_MCS | FORMAT is [S1G with (CH_BANDWIDTH is CBW2 or CBW4 or CBW8 or CBW16)] or S1G_DUP_2M | Indicates the MCS that the STA's receiver recommends. Integer: range 0 to 9, 11 and 12(M102) | N | O |
| | Otherwise | Indicates the MCS that the STA's receiver recommends. Integer: range 0 to 2(M102) | N | O |
| CH_BANDWIDTH | FORMAT is S1G | Indicates the channel width of the transmitted PPDU: Enumerated type: CBW1 for 1 MHz CBW2 for 2 MHz CBW4 for 4 MHz CBW8 for 8 MHz CBW16 for 16 MHz | Y | Y |
| | FORMAT is S1G_DUP_2M | In TXVECTOR, indicates the channel width of the transmitted S1G 2 MHz Duplicate PPDU. In RXVECTOR, indicates the estimated channel width of the received S1G 2 MHz Duplicate PPDU. Enumerated type: CBW4 for 4 MHz CBW8 for 8 MHz CBW16 for 16 MHz | Y | Y |
| | FORMAT is S1G_DUP_1M | In TXVECTOR, indicates the channel width of the transmitted S1G 1 MHz Duplicate PPDU. In RXVECTOR, indicates the estimated channel width of the received S1G 1 MHz Duplicate PPDU. Enumerated type: CBW2 for 2 MHz CBW4 for 4 MHz CBW8 for 8 MHz CBW16 for 16 MHz | Y | Y |
| LENGTH | AGGREGATION is AGGREGATED | Indicates the (#14)PPDU duration in number of symbols in the PSDU | Y | Y |
| | AGGREGATION is NOT_AGGREGATED | Indicates the (#14)PPDU duration in number of octets in the PSDU | Y | Y |

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**Table 23-1—TXVECTOR and RXVECTOR parameters *(continued)***

| Parameter | Condition | Value | TXVECTOR | RXVECTOR |
|---|---|---|---|---|
| APEP_LENGTH | FORMAT is S1G<br>and<br>AGGREGATION is AGGREGATED | If equal to 0, indicates an S1G NDP for both RXVECTOR and TXVECTOR.<br>If greater than 0 in the TXVECTOR, indicates the number of octets in the A-MPDU pre-EOF padding (see 10.12.2) carried in the PSDU. This parameter is used to determine the number of OFDM symbols in the Data field that do not appear after (#14)an A-MPDU subframe with 1 in the EOF/ Tag(#4367) subfield. | M<br>U | O |
| | (FORMAT is S1G_DUP_2M or SIG_DUP_1M)<br>and<br>AGGREGATION is AGGREGATED | If equal to 0, indicates an S1G NDP for both RXVECTOR and TXVECTOR.<br>(#6104)If greater than 0 in the TXVECTOR, indicates the number of octets in the A-MPDU pre-EOF padding (see 10.12.2) carried in the PSDU. This parameter is used to determine the number of OFDM symbols in the Data field that do not appear after (#14)an A-MPDU subframe with 1 | Y | O |
| | Otherwise | Not present | N | N |
| PSDU_LENGTH | FORMAT is S1G<br>and<br>(CH_BANDWIDTH is CBW2 or CBW4 or CBW8 or CBW16)<br>and<br>MU_SU is MU | Indicates the value in the RXVECTOR obtained from 23.4.3 (TXTIME and PSDU_LENGTH calculation). | N | Y |
| | Otherwise | If greater than 0 in the TXVECTOR and AGGREGATION is NOT_AGGREGATED, indicates the number of octets in the PSDU.<br>If greater than 0 in the RXVECTOR, this parameter is the value obtained from 23.4.3 (TXTIME and PSDU_LENGTH calculation).<br>A value of 0 indicates an S1G NDP for both RXVECTOR and TXVECTOR. | Y | Y |
| USER_POSITION | FORMAT is S1G<br>and<br>(CH_BANDWIDTH is CBW2 or CBW4 or CBW8 or CBW16)<br>and<br>MU_SU is MU | Index for user in MU transmission. Integer: range 0–3.<br><br>NOTE—The entries in the USER_POSITION array are in ascending order. | Y | Y |
| | Otherwise | Not present | N | N |
| NUM_STS | FORMAT is S1G | Indicates the number of space-time streams.<br>Integer: range 1–4 per user in the TXVECTOR and 0–4 in the RXVECTOR.<br>NUM_STS summed over all users is in the range 1 to 4 for MU-MIMO. | M<br>U | Y |
| | FORMAT is S1G_DUP_2M or S1G_DUP_1M | Indicates the number of space-time streams.<br>Integer: range 1–4 per user in the TXVECTOR and 0–4 in the RXVECTOR. | Y | Y |



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**Table 23-1—TXVECTOR and RXVECTOR parameters *(continued)***

| Parameter | Condition | Value | TXVECTOR | RXVECTOR |
|---|---|---|---|---|
| GROUP_ID | FORMAT is S1G<br>and<br>(CH_BANDWIDTH is CBW2 or CBW4 or CBW8 or CBW16)<br>and<br>MU_SU is MU | Indicates the group ID.<br>Integer: range 1–62 (see Table 23-15 (Fields in the SIG-A field of S1G_LONG preamble MU PPDU) in 23.3.8.2.3.2.5). | Y | Y |
| | Otherwise | Not present | N | N |
| PARTIAL_AID | (#447)(FORMAT is S1G, CH_BANDWIDTH is CBW2 or CBW4 or CBW8 or CBW16, and MU_SU is SU) or FORMAT is S1G_DUP_2M | Provides an abbreviated indication of the intended recipient(s) of the PSDU (see 10.21).<br>Integer: range 0–511 if UPLINK_INDICATION is 1, and range 0–63 if UPLINK_INDICATION is 0. | Y | Y |
| | Otherwise | Not present | N | N |
| NUM_USERS | FORMAT is S1G<br>and<br>(CH_BANDWIDTH is CBW2 or CBW4 or CBW8 or CBW16)<br>and<br>MU_SU is MU | Indicates the number of users with nonzero space-time streams.<br>Integer: range 1 to 4. | Y | N |
| | Otherwise | Set to 1 | Y | N |
| BEAM_CHANGE | FORMAT is S1G<br>and<br>MU_SU is SU<br>and<br>(CH_BANDWIDTH is CBW2 or CBW4 or CBW8 or CBW16)<br>and<br>PREAMBLE_TYPE is S1G_LONG_PREAMBLE<br>and<br>NUM_STS is 1 | Set to 1 if the Q matrix is changed from the omnidirectional portion to the beam changeable portion of the long preamble, in at least one of the nonzero subcarrier of the omnidirectional portion as described in 23.3.8.2.3.2.5 (SIG-A definition).<br>Set to 0 if the Q matrix is unchanged in all the nonzero subcarriers of the omnidirectional portion.<br><br>NOTE—If BEAM_CHANGE is 0 and PREAMBLE_TYPE is S1G_LONG_PREAMBLE, (#185)the receiver may perform channel smoothing. Otherwise, smoothing is not recommended. | Y | Y |
| | Otherwise | Not present | N | N |
| RESPONSE_INDICATION | | Set to 0 if No Response.<br>Set to 1 if NDP Response.<br>Set to 2 if Normal Response.<br>Set to 3 if Long Response. | Y | Y |
| TRAVELING_PILOTS | | Set to 1 if traveling pilots are used in the (#14)PPDU.<br>Set to 0 otherwise. | Y | O |

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**Table 23-1—TXVECTOR and RXVECTOR parameters *(continued)***

| Parameter | Condition | Value | TXVECTOR | RXVECTOR |
|---|---|---|---|---|
| TIME_OF_DEPARTURE_REQUESTED | | Boolean value:<br>true indicates that the MAC entity requests that the PHY entity measures and reports time of departure parameters corresponding to the time when the first PPDU energy is sent by the transmitting port.<br>false indicates that the MAC entity requests that the PHY entity neither measures nor reports time of departure parameters. | O | N |
| RX_START_OF_FRAME_OFFSET | (#1244)dot11TimingMsmtActivated is true | 0 to $2^{32}$– 1. An estimate of the offset (in 10 ns units) from the point in time at which the start of the preamble (#14)of the PPDU arrived at the receive antenna port to the point in time at which this primitive is issued to the MAC. | N | Y |
| | Otherwise | Not present | N | N |
| UPLINK_INDICATION | NDP_INDICATION is 0<br>and<br>FORMAT is S1G<br>and<br>CH_BANDWIDTH is not CBW1 | Set to 1 if the S1G PPDU is addressed to AP<br>Set to 0 otherwise<br>(See 10.21). | Y | Y |
| | Otherwise | Not present | N | N |
| COLOR | UPLINK_INDICATION is 0<br>and<br>NDP_INDICATION is 0<br>and<br>(FORMAT is S1G or S1G_DUP_2M)<br>and<br>CH_BANDWIDTH is not CBW1<br>and<br>MU_SU is SU | Set to a value of its choosing within the range 0 to 7<br>(See 10.21) | Y | Y |
| | Otherwise | Not present | N | N |



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**Table 23-1—TXVECTOR and RXVECTOR parameters *(continued)***

| Parameter | Condition | Value | TXVECTOR | RXVECTOR |
|---|---|---|---|---|
| SCRAMBLER_OR_CRC | NDP_INDICATION is 0 | Indicates the (#8126)scrambler initialization value in the (#3409)SERVICE field (as defined in 23.3.9.2 (SERVICE field)) prior to descrambling.<br>Bit sequence of 7 bits in length: [B0:B6] of the SERVICE field value prior to descrambling. | N | Y |
| | FORMAT is S1G<br>and<br>NDP_INDICATION is 1 | Indicates the value of the calculated CRC in the SIG field.<br>Bit sequence of 4 bits in length: Either [B26:B29] of the 1 MHz SIG field or [B38:B41] of the ≥ 2 MHz SIG field. | N | Y |
| | FORMAT is S1G_DUP_2M<br>and<br>NDP_INDICATION is 1 | Indicates the value of the calculated CRC in the SIG field.<br>Bit sequence of 4 bits in length: [B38:B41] of the ≥ 2 MHz SIG field. | N | Y |
| | FORMAT is S1G_DUP_1M<br>and<br>NDP_INDICATION is 1 | Indicates the value of the calculated CRC in the SIG field.<br>Bit sequence of 4 bits in length: [B26:B29] of the 1 MHz SIG field. | N | Y |
| | Otherwise | Not present | N | N |

NOTE—In the TXVECTOR and RXVECTOR columns, the following apply:
Y = Present.
N = Not present.
O = Optionally present.
MU indicates that the parameter is present once for an S1G SU PPDU and present per user for an S1G MU PPDU. Parameters specified to be present per user are conceptually supplied as an array of values indexed by *u*, where *u* takes values 0 to NUM_USERS-1.

### 23.2.3 Effect of CH_BANDWIDTH parameter on PPDU format

Table 23-2 (PPDU format as a function of CH_BANDWIDTH parameter) shows the PPDU format as a function of the CH_BANDWIDTH parameter.

**Table 23-2—PPDU format as a function of CH_BANDWIDTH parameter**

| FORMAT | CH_BANDWIDTH | PPDU format |
|---|---|---|
| S1G | CBW1 | The STA transmits an S1G PPDU of 1 MHz bandwidth. If the operating channel width is wider than 1 MHz, then the transmission shall use the primary 1 MHz channel. |
| S1G | CBW2 | The STA transmits an S1G PPDU of 2 MHz bandwidth. If the operating channel width is wider than 2 MHz, then the transmission shall use the primary 2 MHz channel. |
| S1G | CBW4 | The STA transmits an S1G PPDU of 4 MHz bandwidth. If the operating channel width is wider than 4 MHz, then the transmission shall use the primary 4 MHz channel. |
| S1G | CBW8 | The STA transmits an S1G PPDU of 8 MHz bandwidth. If the operating channel width is wider than 8 MHz, then the transmission shall use the primary 8 MHz channel. |

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**Table 23-2—PPDU format as a function of CH_BANDWIDTH parameter *(continued)***

| FORMAT | CH_BANDWIDTH | PPDU format |
|---|---|---|
| S1G | CBW16 | The STA transmits an S1G PPDU of 16 MHz bandwidth. |
| S1G_DUP_2M | CBW4 | The STA transmits an S1G 2 MHz Duplicate PPDU using two adjacent 2 MHz channels as defined in 23.3.9.12.2 (S1G 2 MHz duplicate transmission). If the operating channel width is wider than 4 MHz, then the transmission shall use the primary 4 MHz channel. Phase rotation pattern for each 2 MHz channel is [1 j] from the lowest frequency as defined in Equation (23-7). |
| S1G_DUP_2M | CBW8 | The STA transmits an S1G 2 MHz Duplicate PPDU using four adjacent 2 MHz channels as defined in 23.3.9.12.2 (S1G 2 MHz duplicate transmission). If the BSS operating channel width is 16 MHz, then the transmission shall use the primary 8 MHz channel. Phase rotation pattern for each 2 MHz channel is [1 -1 -1 -1] from the lowest frequency as defined in Equation (23-8). |
| S1G_DUP_2M | CBW16 | The STA transmits an S1G 2 MHz Duplicate PPDU using eight adjacent 2 MHz channels as defined in 23.3.9.12.2 (S1G 2 MHz duplicate transmission). Phase rotation pattern for each 2 MHz channel is [1 -1 -1 -1 1 -1 -1 -1] from the lowest frequency as defined in Equation (23-9). |
| S1G_DUP_1M | CBW2 | The STA transmits an S1G 1 MHz Duplicate PPDU using two adjacent 1 MHz channels as defined in 23.3.9.12.1 (S1G 1 MHz duplicate transmission). If the operating channel width is wider than 2 MHz, then the transmission shall use the primary 2 MHz channel. Phase rotation pattern for each Equation (23-10). |
| S1G_DUP_1M | CBW4 | The STA transmits an S1G 1 MHz Duplicate PPDU using four adjacent 1 MHz channels as defined in 23.3.9.12.1 (S1G 1 MHz duplicate transmission). If the operating channel width is wider than 4 MHz, then the transmission shall use the primary 4 MHz channel. Phase rotation pattern for each 1 MHz channel is [1 j -j -1] from the lowest frequency as defined in Equation (23-11). |
| S1G_DUP_1M | CBW8 | The STA transmits an S1G 1 MHz Duplicate PPDU using eight adjacent 1 MHz channels as defined in 23.3.9.12.1 (S1G 1 MHz duplicate transmission). If the BSS operating channel width is 16 MHz, then the transmission shall use the primary 8 MHz channel. Phase rotation pattern for each 1 MHz channel is [1 -1 1 1 1 1 -1 -1] from the lowest frequency as defined in Equation (23-12). |
| S1G_DUP_1M | CBW16 | The STA transmits an S1G 1 MHz Duplicate PPDU using sixteen adjacent 1 MHz channels as defined in 23.3.9.12.1 (S1G 1 MHz duplicate transmission). Phase rotation pattern for each 1 MHz channel is [1 1 1 -1 1 1 1 -1 -1 -1 1 -1 1 1 -1 1] from the lowest frequency as defined in Equation (23-13). |


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### 23.2.4 TXSTATUS parameters(#2017)

The parameters listed in Table 23-3 (TXSTATUS parameters(#2017)) are defined as part of the TXSTATUS parameter list in the PHY-TXSTART.confirm service primitive.

**Table 23-3—TXSTATUS parameters(#2017)**

| Parameter | Value |
|---|---|
| TIME_OF_DEPARTURE | 0 to $2^{32} - 1$. The locally measured time when the first PPDU energy is sent by the transmitting port, in units equal to 1/TIME_OF_DEPARTURE_ClockRate. This parameter is present only if TIME_OF_DEPARTURE_REQUESTED is true in the corresponding request. |

### 23.2.5 PHYCONFIG_VECTOR parameters(#4383)

The PHYCONFIG_VECTOR carried in a PHY-CONFIG.request primitive for a S1G PHY contains a GROUP_ID_MANAGEMENT parameter, which specifies membership status and STA position for each of the group IDs as described in 9.6.22.3 (Group ID Management frame format).

The PHYCONFIG_VECTOR carried in a PHY-CONFIG.request primitive for a S1G PHY contains a PARTIAL_AID_LIST_GID00 parameter, which includes the list of partial AIDs, of which the S1G STA is an intended recipient, in which a frame is addressed to an AP. The settings of the PARTIAL_AID are specified in 10.21 (Group ID, partial AID, Uplink Indication, and COLOR in S1G PPDUs).

The PHYCONFIG_VECTOR carried in a PHY-CONFIG.request primitive for a S1G PHY contains a PARTIAL_AID_LIST_GID63 parameter, which includes the list of partial AIDs, of which the S1G STA is an intended recipient, in which a frame is addressed to a non-AP STA. The settings of the PARTIAL_AID are specified in 10.21 (Group ID, partial AID, Uplink Indication, and COLOR in S1G PPDUs).

The PHYCONFIG_VECTOR carried in a PHY-CONFIG.request primitive for a S1G PHY contains a LISTEN_TO_GID00 parameter, which, when true, indicates to the PHY not to filter out PPDUs with GROUP_ID field equal to 0.

The PHYCONFIG_VECTOR carried in a PHY-CONFIG.request primitive for a S1G PHY contains a LISTEN_TO_GID63 parameter, which, when true, indicates to the PHY not to filter out PPDUs with GROUP_ID field equal to 63.

The PHYCONFIG_VECTOR carried in a PHY-CONFIG.request primitive for a S1G PHY contains a CCA_SENSITIVITY_TYPE parameter, which is an enumerated type that can take the following values:

— CCA_SENSITIVITY_TYPE_1 indicates that the PHY issues a PHYCCA. indication primitive based on the CCA conditions listed in Table 23-37 (Additional conditions for CCA BUSY on the primary 2 MHz in type 1 channelization) and 23.3.18.5.4 (CCA sensitivity for signals not occupying the primary 2 MHz channel).

— CCA_SENSITIVITY_TYPE_2 indicates that the PHY issues a PHYCCA. indication primitive based on the CCA conditions listed in Table 23-38 (Additional conditions for CCA BUSY on the primary 2 MHz in type 2 channelization) and 23.3.18.5.4 (CCA sensitivity for signals not occupying the primary 2 MHz channel).

— CCA_SENSITIVITY_TYPE_2_WIDEBAND indicates that the PHY issues a PHY-CCA.indication primitive based on the CCA conditions listed in Table 23-39 (Additional conditions for CCA BUSY

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on the primary 2 MHz in type 2 channelization for 8/16 MHz intended channel width) and 23.3.18.5.4 (CCA sensitivity for signals not occupying the primary 2 MHz channel).

## 23.3 S1G PHY layer(#4114)

### 23.3.1 Introduction

This subclause provides the procedure by which PSDUs are converted to and from transmissions on the wireless medium.

During transmission, a PSDU (in the SU case) or one or more PSDUs (in the MU case) are processed (e.g., scrambled and coded) and appended to the PHY preamble to create the PPDU. At the receiver, the PHY preamble is processed to aid in the detection, demodulation and delivery of the PSDU.

### 23.3.2 S1G PPDU format

Three formats are defined for the S1G PHY: S1G_SHORT, S1G_LONG, and S1G_1M.

The general structure for S1G_SHORT is defined as in Figure 23-1 (S1G_SHORT format(#7158)). This format is used for SU transmission using 2 MHz, 4 MHz, 8 MHz, and 16 MHz PPDUs.

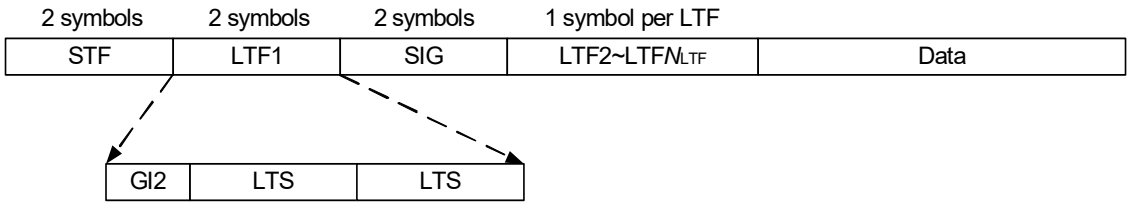


**Figure 23-1—S1G_SHORT format(#7158)**

The general structure for S1G_LONG is defined as in Figure 23-2 (S1G_LONG format(#7158)). This (#14)PPDU format can be used for MU and SU beamformed transmissions using 2 MHz, 4 MHz, 8 MHz, and 16 MHz PPDUs.

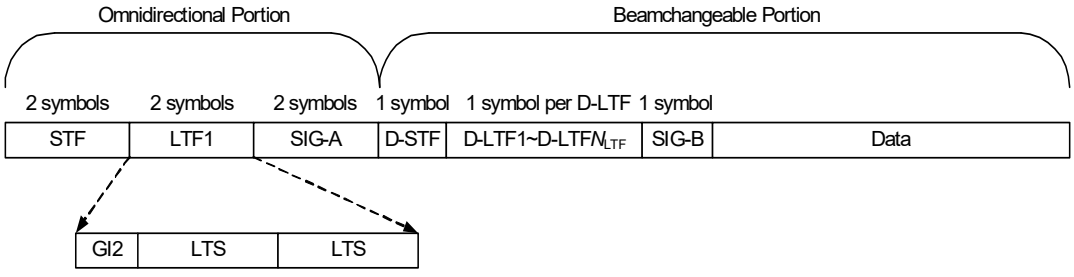


**Figure 23-2—S1G_LONG format(#7158)**


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The general structure for S1G_1M is defined as in Figure 23-3 (S1G_1M format(#7158)). This (#14)PPDU format is used for S1G_1M PPDU SU transmission.

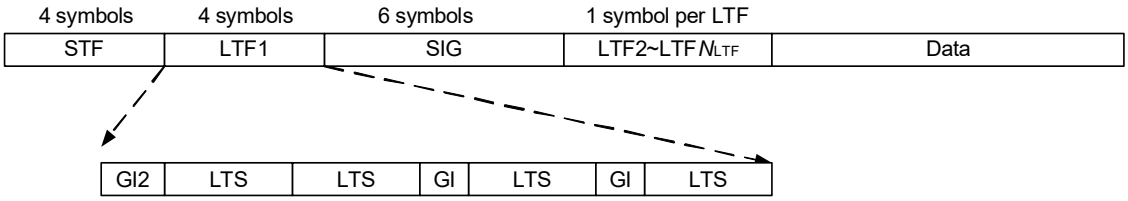


**Figure 23-3—S1G_1M format(#7158)**

The fields of the S1G PPDU formats are summarized in Table 23-4 (Fields of the S1G PPDU).

**Table 23-4—Fields of the S1G PPDU**

| Field | Description |
|---|---|
| STF | Short Training field |
| LTF | Long Training field |
| SIG | SIGNAL field |
| SIG-A | Signal A field |
| D-STF | Short Training field for the beam changeable portion |
| D-LTF | Long Training field for the beam changeable portion |
| SIG-B | Signal B field |
| Data | The Data field carries the PSDU(s) |
| GI | Guard interval |
| GI2 | Double guard interval |
| LTS | Long training symbol |

The SIG-A, D-STF, D-LTF, and SIG-B fields exist only in S1G_LONG format. In an S1G NDP, the Data field is not present (see 23.3.11 (S1G preamble format for NDPs). The number of symbols in the LTF field of S1G_1M and S1G_SHORT, or in the D-LTF field of S1G_LONG, $N_{VHTLTF}$, can be either 1, 2, or 4 and is determined by the total number of space-time streams across all users being transmitted in the S1G PPDU (see Table 23-11 (Number of LTFs required for different numbers of space-time streams) in 23.3.8.2.2 (S1G_SHORT preamble)).

### 23.3.3 Transmitter block diagram

Each field in an S1G PPDU can be generated using a subset of the following blocks (only select blocks are listed below):

a) PHY padding
b) Scrambler
c) BCC encoder parser

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d) FEC (BCC or LDPC) encoders
e) Stream parser
f) Segment parser (for 16 MHz)
g) BCC Interleaver
h) Replicate the encoded bits (for 1 MHz MCS 10)
i) Constellation mapper
j) Pilot insertion
k) Replicate over multiple 1 MHz or 2 MHz widths
l) Multiply by first column of $P_{HTLTF}$
m) LDPC tone mapper
n) Segment deparser (for 16 MHz)
o) Space-time block code (STBC) encoder
p) Cyclic shift diversity (CSD) per STS insertion
q) Spatial mapper
r) Inverse discrete Fourier transform (IDFT)
s) Cyclic shift diversity (CSD) per chain insertion
t) Guard interval (GI) insertion
u) Windowing

The general transmission flow for S1G_1M MCS 0–9, and all the MCSs for S1G_SHORT and S1G_LONG formats are the same as the corresponding portions in 21.3 (VHT PHY).

Specifically, Figure 21-5 (Transmitter block diagram for the L-SIG and VHT-SIG-A fields), with “20 MHz” replaced by “2 MHz”, shows the transmit process for the SIG-A field of an S1G PPDU in S1G_LONG. These transmit blocks are also used to generate the omnidirectional portion of the S1G_LONG PPDU, except that the BCC encoder and interleaver are not used when generating the STF and LTF1 fields.

Figure 21-6 (Transmitter block diagram for the VHT-SIG-B field of a 20 MHz, 40 MHz, and 80 MHz VHT SU PPDU) and Figure 21-7 (Transmitter block diagram for the VHT-SIG-B field of a 20 MHz, 40 MHz, and 80 MHz VHT MU PPDU(#2259)(#7214)), with “20 MHz” replaced by “2 MHz”, show the transmit process for generating the SIG-B field of a 2 MHz, 4 MHz, and 8 MHz long format S1G PPDU for SU PPDU and MU PPDU, respectively. Figure 21-8 (Transmitter block diagram for the VHT-SIG-B field of a 160 MHz VHT SU PPDU(#7214)), with “160 MHz” replaced by “16 MHz”, shows the transmit process for generating the SIG-B field of a 16 MHz long format S1G SU PPDU.

Figure 21-10 (Transmitter block diagram for the Data field of a 20 MHz, 40 MHz, or 80 MHz VHT SU PPDU with BCC encoding) shows the transmitter blocks used to generate the BCC encoded Data field of a 2 MHz, 4 MHz, and 8 MHz SU PPDU in short or long format, and of an S1G_1M PPDU except MCS 10. It should be noted that the number of encoders is fixed to one for BCC (i.e., $N_{ES}$=1), in S1G operation. A subset of these transmitter blocks consisting of the constellation mapper and CSD blocks, as well as the blocks to the right of, and including, the spatial mapping block, are also used to generate the STF and LTF fields in S1G_1M and S1G_SHORT, or the D-STF and D-LTF fields in S1G_LONG. This is illustrated in Figure 23-6 (Generation of LTF symbols) in 23.3.8.2.2.4 (LTF definition) for the mentioned LTF fields. A similar set of transmit blocks is used to generate the mentioned STF fields.

Figure 21-11 (Transmitter block diagram for the Data field of a 20 MHz, 40 MHz, or 80 MHz VHT SU PPDU with LDPC encoding) shows the transmitter blocks used to generate the LDPC encoded Data field of a 2 MHz, 4 MHz, and 8 MHz SU PPDU in short or long format, and of an S1G_1M PPDU except MCS 10.


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Figure 21-12 (Transmitter block diagram for the Data field of a 20 MHz, 40 MHz, or 80 MHz VHT MU PPDU) shows the transmit process for generating the Data field of a 2 MHz, 4 MHz, and 8 MHz MU PPDU in long format with BCC and/or LDPC encoding. The number of encoders is fixed to one (i.e., $N_{ES}$=1) for BCC in S1G operation.

Figure 21-13 (Transmitter block diagram for the Data field of a 160 MHz VHT SU PPDU with BCC encoding) and Figure 21-14 (Transmitter block diagram for the Data field of a 160 MHz VHT SU PPDU with LDPC encoding) show the transmit process for generating the Data field of a 16 MHz SU PPDU in short or long format, with BCC and LDPC encoding, respectively. The number of encoders is fixed to one (i.e., $N_{ES}$=1) for BCC in S1G operation.

Figure 23-4 (Transmitter block diagram for the Data field of an S1G_1M PPDU with BCC or LDPC encoding and MCS 10) below shows the transmit process for generating the Data field of an S1G_1M PPDU with MCS 10, either BCC or LDPC encoded.

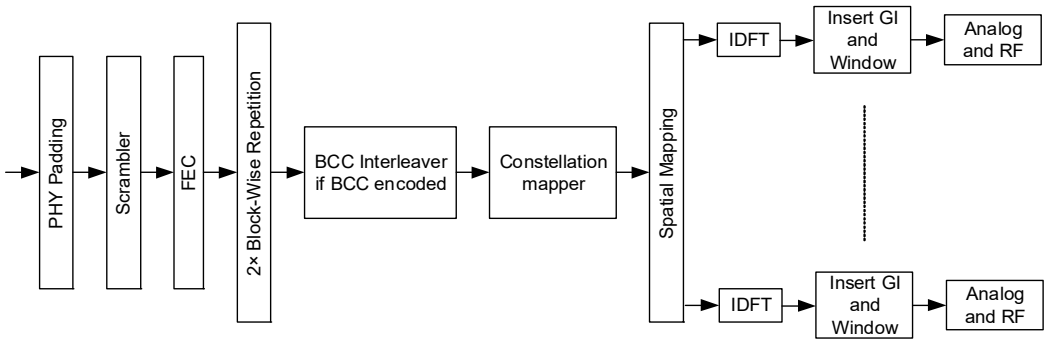


**Figure 23-4—Transmitter block diagram for the Data field of an S1G_1M PPDU with BCC or LDPC encoding and MCS 10**

### 23.3.4 Overview of the PPDU encoding process

#### 23.3.4.1 General

This subclause provides an overview of the S1G PPDU encoding process.

#### 23.3.4.2 Construction of the Preamble part in an S1G_LONG PPDU

##### 23.3.4.2.1 Construction of STF

Construct the STF field as defined in 23.3.8.2.2.3 (STF definition) with the following highlights:

a) Determine the CH_BANDWIDTH from the TXVECTOR.

b) Sequence generation: Generate the STF field sequence over the CH_BANDWIDTH as described in 23.3.8.2.3.2.3 (STF definition).

c) Phase rotation: Apply appropriate phase rotation for each 2 MHz subchannel as described in 23.3.9.11 (OFDM modulation), 23.3.9.12 (S1G 1 MHz and 2 MHz duplicate transmission), and 23.3.7 (Mathematical description of signals).

d) IDFT: Compute the inverse discrete Fourier transform.

e) CSD: Apply CSD for each transmit chain and frequency segment as described in 23.3.8.2.3.2.2 (Cyclic shift for S1G modulated fields).

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f) Insert GI and apply windowing: Prepend a GI of 8 μs in duration and apply windowing as described in 23.3.7 (Mathematical description of signals).

g) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the requested channel and transmit. Refer to 23.3.7 (Mathematical description of signals) and 23.3.8 (S1G preamble) for details.

#### 23.3.4.2.2 Construction of LTF1

Construct the LTF1 field as defined in 23.3.8.2.2.4 (LTF definition) with the following highlights:

a) Determine the CH_BANDWIDTH from the TXVECTOR.

b) Sequence generation: Generate the LTF1 field sequence over the CH_BANDWIDTH as described in 23.3.8.2.2.4 (LTF definition).

c) Phase rotation: Apply appropriate phase rotation for each 2 MHz subchannel as described in 23.3.9.11 (OFDM modulation), 23.3.9.12 (S1G 1 MHz and 2 MHz duplicate transmission), and 23.3.7 (Mathematical description of signals).

d) IDFT: Compute the inverse discrete Fourier transform.

e) CSD: Apply CSD for each transmit chain and frequency segment as described in 23.3.8.2.3.2.2 (Cyclic shift for S1G modulated fields).

f) Insert GI and apply windowing: Prepend a GI of 16 μs in duration and apply windowing as described in 23.3.7 (Mathematical description of signals).

g) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the requested channel and transmit. Refer to 23.3.7 (Mathematical description of signals) and 23.3.8 (S1G preamble) for details.

#### 23.3.4.2.3 Construction of SIG-A

The SIG-A field consists of two symbols, SIG-A1 and SIG-A2, as defined in 23.3.8.2.3.2.5 (SIG-A definition) and is constructed as follows:

a) Obtain the CH_BANDWIDTH, STBC, MU_SU, GROUP_ID (MU only), PARTIAL_AID (SU only), NUM_STS, GI_TYPE, FEC_CODING, MCS (SU only), NUM_USERS, LENGTH, AGGREGATION (SU only), RESPONSE_INDICATION, BEAM_CHANGE (SU only for single space-time stream), SMOOTHING and TRAVELING_PILOTS from the TXVECTOR. Add the reserved bits, append the calculated 4-bit CRC, then append the $N_{tail}$ tail bits as shown in 23.3.8.2.3.2.5 (SIG-A definition). This operation gives as a result 48 uncoded bits.

b) BCC encoder: Encode the data by a convolutional encoder at the rate of R=1/2 as described in 17.3.5.6 (Convolutional encoder).

c) BCC interleaver: Interleave as described in 17.3.5.7 (Data interleaving).

d) Constellation mapper: QBPSK modulate the first 48 interleaved bits by rotating by 90° counter-clockwise relative to the original BPSK as described in 23.3.8.2.3.2.5 (SIG-A definition) to form the first symbol of SIG-A field. BPSK modulate the second 48 interleaved bits to form the second symbol of SIG-A field.

e) Pilot insertion: Insert pilots as described in 17.3.5.10 (OFDM modulation).

f) Duplication and phase rotation: Duplicate SIG-A1 and SIG-A2 over each 2 MHz of the CH_BANDWIDTH. Apply the appropriate phase rotation for each 2 MHz subchannel as described in 23.3.9.11 (OFDM modulation), 23.3.9.12 (S1G 1 MHz and 2 MHz duplicate transmission), and 23.3.7 (Mathematical description of signals).

g) IDFT: Compute the inverse discrete Fourier transform.

h) CSD: Apply CSD for each transmit chain as described in 23.3.8.2.3.2.2 (Cyclic shift for S1G modulated fields).


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i) Insert GI and apply windowing: Prepend a GI of 8 μs in duration and apply windowing as described in 17.3.2.5 (Mathematical conventions in the signal descriptions).

j) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the requested channel and transmit. Refer to 23.3.7 (Mathematical description of signals) and 23.3.8 (S1G preamble) for details.

#### 23.3.4.2.4 Construction of D-STF

The D-STF field is defined in 23.3.8.2.3.3.3 (D-STF definition) and constructed as follows:

a) Sequence generation: Generate the D-STF field in the frequency domain over the bandwidth indicated by CH_BANDWIDTH as described in 23.3.8.2.3.3.3 (D-STF definition).

b) Phase rotation: Apply appropriate phase rotation for each 2 MHz subchannel as described in 23.3.9.11 (OFDM modulation), 23.3.9.12 (S1G 1 MHz and 2 MHz duplicate transmission), and 23.3.7 (Mathematical description of signals).

c) CSD: Apply CSD for each space-time stream and frequency segment as described in 23.3.8.2.3.2.2 (Cyclic shift for S1G modulated fields).

d) Spatial mapping: Apply the $Q$ matrix as described in 23.3.10 (SU-MIMO and (#3367)DL MU-MIMO Beamforming) and 23.3.9.11 (OFDM modulation).

e) IDFT: Compute the inverse discrete Fourier transform.

f) Insert GI and apply windowing: Prepend a GI of 8 μs in duration and apply windowing as described in 17.3.2.5 (Mathematical conventions in the signal descriptions).

g) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the requested channel and transmit. Refer to 23.3.7 (Mathematical description of signals) and 23.3.8 (S1G preamble) for details.

#### 23.3.4.2.5 Construction of D-LTF

The D-LTF field is defined in 23.3.8.2.3.3.4 (D-LTF definition) and constructed as follows:

a) Sequence generation: Generate the D-LTF field sequence in the frequency domain over the bandwidth indicated by CH_BANDWIDTH as described in 23.3.8.2.3.3.4 (D-LTF definition).

b) Phase rotation: Apply appropriate phase rotation for each 2 MHz subchannel as described in 23.3.9.11 (OFDM modulation), 23.3.9.12 (S1G 1 MHz and 2 MHz duplicate transmission), and 23.3.7 (Mathematical description of signals).

c) $A_{LTF}$ matrix mapping: Apply the $P_{HTLTF}$ matrix to the D-LTF field sequence (the pilot tones are processed differently) as described in 23.3.8.2.3.3.4 (D-LTF definition).

d) CSD: Apply CSD for each space-time stream and frequency segment as described in 23.3.8.2.3.2.2 (Cyclic shift for S1G modulated fields).

e) Spatial mapping: Apply the $Q$ matrix as described in 23.3.10 (SU-MIMO and (#3367)DL MU-MIMO Beamforming) and 23.3.9.11 (OFDM modulation).

f) IDFT: Compute the inverse discrete Fourier transform.

g) Insert GI and apply windowing: Prepend a GI of 8 μs in duration and apply windowing as described in 17.3.2.5 (Mathematical conventions in the signal descriptions).

h) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the requested channel and transmit. Refer to 23.3.7 (Mathematical description of signals) and 23.3.8 (S1G preamble) for details.

#### 23.3.4.2.6 Construction of SIG-B

The SIG-B field is constructed per user as follows:

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a) Obtain the MCS (for MU only) from the TXVECTOR.

b) SIG-B bits: Set the MCS (for MU only) as described in 23.3.8.2.3.3.5 (SIG-B definition). Add the reserved bits and $N_{tail}$ bits of tail.

c) SIG-B field Bit Repetition: Repeat the SIG-B field bits as a function of CH_BANDWIDTH as defined in 23.3.8.2.3.3.5 (SIG-B definition).

d) BCC encoder: Encode the SIG-B field using BCC at rate R=1/2 as described in 17.3.5.6 (Convolutional encoder).

e) Segment parser (if needed): For a 16 MHz transmission, divide the output bits of the BCC encoder into two frequency subblocks as described in 23.3.9.7 (Segment parser). This block is bypassed for 2 MHz, 4 MHz, and 8 MHz S1G PPDU transmissions.

f) BCC interleaver: Interleave as described in 23.3.9.8 (BCC interleaver).

g) Constellation mapper: Map to a BPSK constellation as defined in 17.3.5.8 (Subcarrier modulation mapping).

h) Segment deparser (if needed): For a 16 MHz transmission, merge the two frequency subblocks into one frequency segment as described in 23.3.9.9.3 (Segment deparser). This block is bypassed for 2 MHz, 4 MHz, and 8 MHz S1G PPDU transmissions.

i) Pilot insertion: Insert pilots following the steps described in 21.3.10.10 (Pilot subcarriers).

j) $P_{HTLTF}$ matrix mapping: Apply the mapping of the first column of the $P_{HTLTF}$ matrix to the data subcarriers as described in 23.3.8.2.3.3.5 (SIG-B definition). The total number of data and pilot subcarriers is the same as in the Data field.

k) CSD: Apply CSD for each space-time stream and frequency segment as described in 23.3.8.2.3.2.2 (Cyclic shift for S1G modulated fields).

l) Spatial mapping: Apply the $Q$ matrix as described in 23.3.10 (SU-MIMO and (#3367)DL MU-MIMO Beamforming) and 23.3.9.11 (OFDM modulation).

m) Phase rotation: Apply the appropriate phase rotations for each 2 MHz subchannel as described in 23.3.9.11 (OFDM modulation), 23.3.9.12 (S1G 1 MHz and 2 MHz duplicate transmission), and 23.3.7 (Mathematical description of signals).

n) IDFT: Compute the inverse discrete Fourier transform.

o) Insert GI and apply windowing: Prepend a GI of 8 μs in duration and apply windowing as described in 17.3.2.5 (Mathematical conventions in the signal descriptions).

p) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the requested channel and transmit. Refer to 23.3.7 (Mathematical description of signals) and 23.3.8 (S1G preamble) for details.

#### 23.3.4.3 Construction of the Preamble part in an S1G_SHORT PPDU

##### 23.3.4.3.1 Construction of STF

The STF field is defined in 23.3.8.2.2.3 (STF definition) and constructed as follows:

a) Determine the CH_BANDWIDTH from the TXVECTOR.

b) Sequence generation: Generate the STF field in the frequency domain over the bandwidth indicated by CH_BANDWIDTH as described in 23.3.8.2.2.3 (STF definition).

c) Phase rotation: Apply appropriate phase rotation for each 2 MHz subchannel as described in 23.3.9.11 (OFDM modulation), 23.3.9.12 (S1G 1 MHz and 2 MHz duplicate transmission), and 23.3.7 (Mathematical description of signals).

d) $P_{HTLTF}$ matrix mapping: Apply the mapping of the first column of the $P_{HTLTF}$ matrix to the STF field sequence as described in 23.3.8.2.2.4 (LTF definition).

e) CSD: Apply CSD for each space-time stream and frequency segment as described in 23.3.8.2.2.2 (Cyclic shift for S1G modulated fields).


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f) Spatial mapping: Apply the $Q$ matrix as described in 23.3.10 (SU-MIMO and (#3367)DL MU-MIMO Beamforming) and 23.3.9.11 (OFDM modulation).

g) IDFT: Compute the inverse discrete Fourier transform.

h) Insert GI and apply windowing: Prepend a GI of 8 μs in duration and apply windowing as described in 17.3.2.5 (Mathematical conventions in the signal descriptions).

i) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the requested channel and transmit. Refer to 23.3.7 (Mathematical description of signals) and 23.3.8 (S1G preamble) for details.

#### 23.3.4.3.2 Construction of LTF1

The LTF1 field is defined in 23.3.8.2.2.4 (LTF definition) and constructed as follows:

a) Determine FORMAT from TXVECTOR.

b) Sequence generation: If FORMAT is S1G, generate the LTF1 field sequence in the frequency domain over the bandwidth indicated by CH_BANDWIDTH as described in 23.3.8.2.2.4 (LTF definition). If format is S1G_DUP_2M, generate the LTF1 field sequence in the frequency domain over a 2 MHz bandwidth.

c) Phase rotation: Apply appropriate phase rotation for each 2 MHz subchannel as described in 23.3.9.11 (OFDM modulation), 23.3.9.12 (S1G 1 MHz and 2 MHz duplicate transmission), and 23.3.7 (Mathematical description of signals).

d) $A_{LTF}$ matrix mapping: Apply the mapping of the first column of the $P_{HTLTF}$ matrix to the LTF1 field sequence (the pilot tones are processed differently) as described in 23.3.8.2.2.4 (LTF definition).

e) CSD: Apply CSD for each space-time stream and frequency segment as described in 23.3.8.2.2.2 (Cyclic shift for S1G modulated fields).

f) Spatial mapping: Apply the $Q$ matrix as described in 23.3.10 (SU-MIMO and (#3367)DL MU-MIMO Beamforming) and 23.3.9.11 (OFDM modulation).

g) IDFT: Compute the inverse discrete Fourier transform.

h) Insert GI and apply windowing: Prepend a GI of 16 μs in duration and apply windowing as described in 17.3.2.5 (Mathematical conventions in the signal descriptions).

i) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the requested channel and transmit. Refer to 23.3.7 (Mathematical description of signals) and 23.3.8 (S1G preamble) for details.

#### 23.3.4.3.3 Construction of SIG

The SIG field is constructed per-user as follows:

a) Obtain the CH_BANDWIDTH, STBC, PARTIAL_AID, NUM_STS, GI_TYPE, FEC_CODING, MCS, SMOOTHING, NUM_USERS, LENGTH, AGGREGATION, RESPONSE_INDICATION, NDP_INDICATION, TRAVELING_PILOTS, UPLINK_INDICATION, and COLOR, from the TXVECTOR. Add the reserved bits, append the calculated 4-bit CRC, then append the $N_{tail}$ tail bits as shown in 23.3.8.2.2.5 (SIG definition). This operation gives as a result 48 uncoded bits.

b) BCC encoder: Encode the data by a convolutional encoder at the rate of R=1/2 as described in 17.3.5.6 (Convolutional encoder).

c) BCC interleaver: Interleave as described in 17.3.5.7 (Data interleaving).

d) Constellation mapper: QBPSK modulate the first 48 interleaved bits as described in 17.3.5.8 (Subcarrier modulation mapping) to form the first symbol of SIG field. QBPSK modulate the second 48 interleaved bits to form the second symbol of SIG field.

e) Pilot insertion: Insert pilots as described in 17.3.5.10 (OFDM modulation).

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f) $P_{HTLTF}$ matrix mapping: Apply the mapping of the first column of the $P_{HTLTF}$ matrix to the data subcarriers as described in 23.3.8.2.2.5 (SIG definition).

g) CSD: Apply CSD for each space-time stream and frequency segment as described in 23.3.8.2.2.2 (Cyclic shift for S1G modulated fields).

h) Spatial mapping: Apply the $Q$ matrix as described in 23.3.10 (SU-MIMO and (#3367)DL MU-MIMO Beamforming) and 23.3.9.11 (OFDM modulation).

i) Duplication and phase rotation: Duplicate two symbols of SIG field over each 2 MHz of the CH_BANDWIDTH. Apply the appropriate phase rotation for each 2 MHz subchannel as described in 23.3.9.11 (OFDM modulation), 23.3.9.12 (S1G 1 MHz and 2 MHz duplicate transmission), and 23.3.7 (Mathematical description of signals).

j) IDFT: Compute the inverse discrete Fourier transform.

k) Insert GI and apply windowing: Prepend a GI of 8 μs in duration and apply windowing as described in 17.3.2.5 (Mathematical conventions in the signal descriptions).

l) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the requested channel and transmit. Refer to 23.3.7 (Mathematical description of signals) and 23.3.8 (S1G preamble) for details.

#### 23.3.4.3.4 Construction of LTF2-LTF$N_{LTF}$ (#7158)

The LTF2-LTF$N_{LTF}$ field is defined in 23.3.8.2.2.4 (LTF definition) and constructed as follows:

a) Sequence generation: Generate the (#7158)LTF2-LTF$N_{LTF}$ field sequence in the frequency domain over the bandwidth indicated by CH_BANDWIDTH as described in 23.3.8.2.2.4 (LTF definition).

b) Phase rotation: Apply appropriate phase rotation for each 2 MHz subchannel as described in 23.3.9.11 (OFDM modulation), 23.3.9.12 (S1G 1 MHz and 2 MHz duplicate transmission), and 23.3.7 (Mathematical description of signals).

c) $A_{LTF}$ matrix mapping: Apply the mapping of the $P_{HTLTF}$ matrix (from the second column to the last column) to the (#7158)LTF2-LTF$N_{LTF}$ field sequence (the pilot tones are processed differently) as described in 23.3.8.2.2.4 (LTF definition).

d) CSD: Apply CSD for each space-time stream and frequency segment as described in 23.3.8.2.2.2 (Cyclic shift for S1G modulated fields).

e) Spatial mapping: Apply the $Q$ matrix as described in 23.3.10 (SU-MIMO and (#3367)DL MU-MIMO Beamforming) and 23.3.9.11 (OFDM modulation).

f) IDFT: Compute the inverse discrete Fourier transform.

g) Insert GI and apply windowing: Prepend a GI of 8 μs in duration and apply windowing as described in 17.3.2.5 (Mathematical conventions in the signal descriptions).

h) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the requested channel and transmit. Refer to 23.3.7 (Mathematical description of signals) and 23.3.8 (S1G preamble) for details.

### 23.3.4.4 Construction of the Preamble part in an S1G_1M PPDU

#### 23.3.4.4.1 Construction of 1 MHz STF

The 1 MHz STF field is defined in 23.3.8.3.3 (STF definition) and constructed as follows:

a) Determine the CH_BANDWIDTH from the TXVECTOR if S1G 1 MHz Duplicate PPDU.

b) Sequence generation: Generate the 1 MHz STF field in the frequency domain over the bandwidth indicated by CH_BANDWIDTH as described in 23.3.8.3.3 (STF definition). Apply the 3 dB power boosting if the MCS from the TXVECTOR equals MCS 10 as described in 23.3.8.3.3 (STF definition).


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c) Phase rotation: Apply appropriate phase rotation for each 1 MHz subchannel if S1G 1 MHz Duplicate PPDU as described in 23.3.9.12 (S1G 1 MHz and 2 MHz duplicate transmission) and 23.3.7 (Mathematical description of signals).

d) $P_{HTLTF}$ matrix mapping: Apply the mapping of the first column of the $P_{HTLTF}$ matrix to the 1 MHz STF field sequence as described in 23.3.8.3.4 (LTF definition).

e) CSD: Apply CSD for each space-time stream and frequency segment as described in 23.3.8.3.2 (Cyclic shift for S1G modulated fields).

f) Spatial mapping: Apply the $Q$ matrix as described in 23.3.9.11 (OFDM modulation).

g) IDFT: Compute the inverse discrete Fourier transform.

h) Insert GI and apply windowing: Prepend a GI of 8 μs in duration and apply windowing as described in 17.3.2.5 (Mathematical conventions in the signal descriptions).

i) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the requested channel and transmit. Refer to 23.3.7 (Mathematical description of signals) and 23.3.8 (S1G preamble) for details.

#### 23.3.4.4.2 Construction of 1 MHz LTF1

The 1 MHz LTF1 field is defined in 23.3.8.3.4 (LTF definition) and constructed as follows:

a) Determine FORMAT from TXVECTOR.

b) Sequence generation: If FORMAT is S1G, generate the 1 MHz LTF1 field sequence in the frequency domain over the bandwidth indicated by CH_BANDWIDTH as described in 23.3.8.3.4 (LTF definition). If FORMAT is S1G_DUP_1M, generate the LTF1 field sequence in the frequency domain over a 1 MHz bandwidth.

c) Phase rotation: Apply appropriate phase rotation for each 1 MHz subchannel if S1G 1 MHz Duplicate PPDU as described in 23.3.9.12 (S1G 1 MHz and 2 MHz duplicate transmission) and 23.3.7 (Mathematical description of signals).

d) $A_{LTF}$ matrix mapping: Apply the mapping of the first column of the $P_{HTLTF}$ matrix to the 1 MHz LTF1 field sequence (the pilot tones are processed differently) as described in 23.3.8.3.4 (LTF definition).

e) CSD: Apply CSD for each space-time stream and frequency segment as described in 23.3.8.3.2 (Cyclic shift for S1G modulated fields).

f) Spatial mapping: Apply the $Q$ matrix as described in 23.3.9.11 (OFDM modulation).

g) IDFT: Compute the inverse discrete Fourier transform.

h) Insert GI and apply windowing: Prepend a GI of 16 μs in duration for the first two symbols and insert a GI of 8 μs in duration per each subsequent symbol. Apply windowing as described in 17.3.2.5 (Mathematical conventions in the signal descriptions).

i) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the requested channel and transmit. Refer to 23.3.7 (Mathematical description of signals) and 23.3.8 (S1G preamble) for details.

#### 23.3.4.4.3 Construction of 1 MHz SIG

The SIG field is constructed per-user as follows:

a) Obtain the STBC, NUM_STS, GI_TYPE, FEC_CODING, MCS, SMOOTHING, LENGTH, AGGREGATION, RESPONSE_INDICATION, NDP_INDICATION and TRAVELING_PILOTS from the TXVECTOR. Add the reserved bits, append the calculated 4-bit CRC, then append the $N_{tail}$ tail bits as shown in 23.3.8.3.5 (SIG definition). This operation gives as a result 36 uncoded bits.

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b) BCC encoder: Encode the data by a convolutional encoder at the rate of R=1/2 as described in 17.3.5.6 (Convolutional encoder) and apply the block-wise 2 times repetition on a per-OFDM symbol basis.

c) BCC interleaver: Interleave as described in 23.3.9.8 (BCC interleaver).

d) Constellation mapper: BPSK modulate the interleaved bits as described in 17.3.5.8 (Subcarrier modulation mapping) to form the 6 symbols of SIG field.

e) Pilot insertion: Insert pilots as described in 17.3.5.10 (OFDM modulation).

f) $P_{HTLTF}$ matrix mapping: Apply the mapping of the first column of the $P_{HTLTF}$ matrix to the data subcarriers as described in 23.3.8.3.5 (SIG definition).

g) CSD: Apply CSD for each space-time stream and frequency segment as described in 23.3.8.3.2 (Cyclic shift for S1G modulated fields).

h) Spatial mapping: Apply the $Q$ matrix as described in 23.3.9.11 (OFDM modulation).

i) Duplication and phase rotation: Duplicate 6 symbols of SIG field over each 1 MHz of the CH_BANDWIDTH if S1G 1 MHz Duplicate PPDU. Apply the appropriate phase rotation for each 1 MHz subchannel as described in 23.3.9.12 (S1G 1 MHz and 2 MHz duplicate transmission) and 23.3.7 (Mathematical description of signals).

j) IDFT: Compute the inverse discrete Fourier transform.

k) Insert GI and apply windowing: Prepend a GI of 8 μs in duration and apply windowing as described in 17.3.2.5 (Mathematical conventions in the signal descriptions).

l) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the requested channel and transmit. Refer to 23.3.7 (Mathematical description of signals) and 23.3.8 (S1G preamble) for details.

#### 23.3.4.4.4 Construction of 1 MHz LTF2-LTF$N_{LTF}$ (#7158)

The 1 MHz LTF2-LTF$N_{LTF}$ field is defined in 23.3.8.3.4 (LTF definition) and constructed as follows:

a) Sequence generation: Generate the 1 MHz (#7158)LTF2-LTF$N_{LTF}$ field sequence in the frequency domain over the bandwidth indicated by CH_BANDWIDTH as described in 23.3.8.3.4 (LTF definition).

b) Phase rotation: Apply appropriate phase rotation for each 1 MHz subchannel as described in 23.3.9.12 (S1G 1 MHz and 2 MHz duplicate transmission) and 23.3.7 (Mathematical description of signals) if S1G 1 MHz Duplicate PPDU.

c) $A_{LTF}$ matrix mapping: Apply the mapping of the $P_{HTLTF}$ matrix (from the second column to the last column) to the 1 MHz (#7158)LTF2-LTF$N_{LTF}$ field sequence (the pilot tones are processed differently) as described in 23.3.8.3.4 (LTF definition).

d) CSD: Apply CSD for each space-time stream and frequency segment as described in 23.3.8.3.2 (Cyclic shift for S1G modulated fields).

e) Spatial mapping: Apply the $Q$ matrix as described in 23.3.9.11 (OFDM modulation).

f) IDFT: Compute the inverse discrete Fourier transform.

g) Insert GI and apply windowing: Prepend a GI of 8 μs in duration and apply windowing as described in 17.3.2.5 (Mathematical conventions in the signal descriptions).

h) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the requested channel and transmit. Refer to 23.3.7 (Mathematical description of signals) and 23.3.8 (S1G preamble) for details.


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#### 23.3.4.5 Construction of Preambles for S1G_DUP_2M and S1G_DUP_1M

For S1G_DUP_2M and S1G_DUP_1M, the preambles are initially constructed according to 23.3.4.3 (Construction of the Preamble part in an S1G_SHORT PPDU) and 23.3.4.4 (Construction of the Preamble part in an S1G_1M PPDU), respectively.

In the case of S1G_DUP_2M, the initial 2 MHz preamble is duplicated in frequency with phase rotation as defined in 23.3.4.3 (Construction of the Preamble part in an S1G_SHORT PPDU) to fill the final transmission bandwidth (i.e., 4 MHz, 8 MHz, or 16 MHz) indicated by the TXVECTOR parameter CH_BANDWIDTH.

In the case of S1G_DUP_1M, the initial 1 MHz preamble is duplicated in frequency with phase rotation as defined in 23.3.4.4 (Construction of the Preamble part in an S1G_1M PPDU) to fill the final transmission bandwidth (i.e., 2 MHz, 4 MHz, 8 MHz, or 16 MHz) indicated by the TXVECTOR parameter CH_BANDWIDTH.

#### 23.3.4.6 Construction of Data field in S1G SU PPDUs for all cases except 1 MHz MCS 10

##### 23.3.4.6.1 Using BCC

The construction of the Data field in an S1G SU PPDU with BCC encoding proceeds as follows:

a) SERVICE field: Generate the SERVICE field as described in 23.3.9.2 (SERVICE field) and append the PSDU to the SERVICE field.

b) PHY padding: Append the PHY pad bits to the PSDU as described in 23.3.9.4.3.2 (Padding for BCC).

c) Scrambler: Scramble the PHY padded data as described in 23.3.9.3 (Scrambler).

d) BCC encoder: Divide the scrambled bits between the encoders by sending bits to different encoders in a round robin manner. The number of encoders is determined by rate-dependent parameters described in 23.5 (Parameters for S1G-MCSs). BCC encode as described in 23.3.9.4.2 (BCC encoder parsing operation) and 23.3.9.4.3 (BCC coding and puncturing).

e) Stream parser: Rearrange the output of the BCC encoders into blocks as described in 23.3.9.6 (Stream parser).

f) Segment parser (if needed): For a contiguous 16 MHz transmission, divide the output bits of each stream parser into two frequency subblocks as described in 23.3.9.7 (Segment parser). This block is bypassed for 1 MHz, 2 MHz, 4 MHz, and 8 MHz S1G PPDU transmissions.

g) BCC interleaver: Interleave as described in 23.3.9.8 (BCC interleaver).

h) Constellation mapper: Map to BPSK, QPSK, 16-QAM, 64-QAM, 256-QAM, or 1024-QAM(M102) constellation points as described in 23.3.9.9 (Constellation mapping).

i) Segment deparser (if needed): For a contiguous 16 MHz transmission, merge the two frequency subblocks into one frequency segment as described in 23.3.9.9.3 (Segment deparser). This block is bypassed for 1 MHz, 2 MHz, 4 MHz, and 8 MHz S1G PPDU transmissions.

j) STBC: Apply STBC as described in 23.3.9.9.4 (Space-time block coding).

k) Pilot insertion: Insert pilots following the steps described in 23.3.9.10 (Pilot subcarriers).

l) CSD: Apply CSD for each space-time stream and frequency segment as described in 23.3.8.2.2.2 (Cyclic shift for S1G modulated fields) if S1G_SHORT preamble is used, 23.3.8.2.3.3.2 (Cyclic shift for S1G modulated fields) if S1G_LONG preamble is used and 23.3.8.3.2 (Cyclic shift for S1G modulated fields) if S1G_1M preamble is used.

m) Spatial mapping: Apply the $Q$ matrix as described in 23.3.10 (SU-MIMO and (#3367)DL MU-MIMO Beamforming) and in 23.3.9.11 (OFDM modulation).

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n) Phase rotation: Apply the appropriate phase rotations for each 2 MHz subchannel if 2 MHz preamble is used or for each 1 MHz subchannel if S1G 1 MHz Duplicate PPDU as described in 23.3.9.11 (OFDM modulation), 23.3.9.12 (S1G 1 MHz and 2 MHz duplicate transmission), and 23.3.7 (Mathematical description of signals).

o) IDFT: Compute the inverse discrete Fourier transform.

p) Insert GI and apply windowing: Prepend a GI and apply windowing as described in 17.3.2.5 (Mathematical conventions in the signal descriptions). If the TXVECTOR parameter GI_TYPE equals LONG_GI, the GI duration shall be 8 μs. If the GI_TYPE parameter is SHORT_GI, the GI duration shall be 8 μs for the first OFDM symbol of the Data field, and 4 μs for all subsequent OFDM symbols.

q) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the requested channel and transmit. Refer to 23.3.7 (Mathematical description of signals) and 23.3.8 (S1G preamble) for details.

#### 23.3.4.6.2 Using LDPC

The construction of the Data field in an S1G SU PPDU with LDPC encoding proceeds as follows:

a) SERVICE field: Generate the SERVICE field as described in 23.3.9.2 (SERVICE field) and append the PSDU to the SERVICE field.

b) PHY padding: Append the PHY pad bits to the PSDU as described in 23.3.9.4.4.2 (Padding for LDPC).

c) Scrambler: Scramble the PHY padded data as described in 23.3.9.3 (Scrambler).

d) LDPC encoder: The scrambled bits are encoded using the LDPC code with the LENGTH from the TXVECTOR as described in 23.3.9.4.4 (LDPC coding).

e) Stream parser: The output of the LDPC encoder is rearranged into blocks as described in 23.3.9.6 (Stream parser).

f) Segment parser (if needed): For a contiguous 16 MHz transmission, divide the output bits of each stream parser into two frequency subblocks as described in 23.3.9.7 (Segment parser). This block is bypassed for 1 MHz, 2 MHz, 4 MHz, and 8 MHz S1G PPDU transmissions.

g) Constellation mapper: Map to BPSK, QPSK, 16-QAM, 64-QAM, 256-QAM, or 1024-QAM(M102) constellation points as described in 23.3.9.9 (Constellation mapping).

h) LDPC tone mapper: The LDPC tone mapping shall be performed on all LDPC encoded streams as described in 23.3.9.9.2 (LDPC tone mapping). LDPC tone mapper is bypassed for 1 MHz transmission.

i) Segment deparser (if needed): For a contiguous 16 MHz transmission, merge the two frequency subblocks into one frequency segment as described in 23.3.9.9.3 (Segment deparser). This block is bypassed for 1 MHz, 2 MHz, 4 MHz, and 8 MHz S1G PPDU transmissions.

j) STBC: Apply STBC as described in 23.3.9.9.4 (Space-time block coding).

k) Pilot insertion: Insert pilots following the steps described in 23.3.9.10 (Pilot subcarriers).

l) CSD: Apply CSD for each space-time stream and frequency segment as described in 23.3.8.2.2.2 (Cyclic shift for S1G modulated fields) if S1G_SHORT preamble is used, 23.3.8.2.3.3.2 (Cyclic shift for S1G modulated fields) if S1G_LONG preamble is used and 23.3.8.3.2 (Cyclic shift for S1G modulated fields) if S1G_1M preamble is used.

m) Spatial mapping: Apply the $Q$ matrix as described in 23.3.10 (SU-MIMO and (#3367)DL MU-MIMO Beamforming) and in 23.3.9.11 (OFDM modulation).

n) Phase rotation: Apply the appropriate phase rotations for each 2 MHz subchannel if 2 MHz preamble is used or for each 1 MHz subchannel if S1G 1 MHz Duplicate PPDU as described in 23.3.9.11 (OFDM modulation), 23.3.9.12 (S1G 1 MHz and 2 MHz duplicate transmission), and 23.3.7 (Mathematical description of signals).


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o) IDFT: Compute the inverse discrete Fourier transform.

p) Insert GI and apply windowing: Prepend a GI and apply windowing as described in 17.3.2.5 (Mathematical conventions in the signal descriptions). If the TXVECTOR parameter GI_TYPE equals LONG_GI, the GI duration shall be 8 μs. If the GI_TYPE parameter is SHORT_GI, the GI duration shall be 8 μs for the first OFDM symbol of the Data field, and 4 μs for all subsequent OFDM symbols.

q) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the requested channel and transmit. Refer to 23.3.7 (Mathematical description of signals) and 23.3.8 (S1G preamble) for details.

### 23.3.4.7 Construction of the Data field in an S1G SU PPDU (1 MHz MCS 10 mode)

#### 23.3.4.7.1 Using BCC

The construction of the Data field in an S1G SU PPDU (1 MHz MCS 10 mode) with BCC encoding proceeds as follows:

a) SERVICE field: Generate the SERVICE field as described in 23.3.9.2 (SERVICE field) and append the PSDU to the SERVICE field.

b) PHY padding: Append the PHY pad bits to the PSDU as described in 23.3.9.4.3.2 (Padding for BCC).

c) Scrambler: Scramble the PHY padded data as described in 23.3.9.3 (Scrambler).

d) BCC encoder: BCC encode as described in 23.3.9.4.2 (BCC encoder parsing operation) and 23.3.9.4.3 (BCC coding and puncturing).

e) Block repetition: Apply the block-wise 2 times repetition on a per-OFDM symbol basis as described in 23.3.9.5 (Repetition for 1 MHz MCS 10).

f) BCC interleaver: Interleave as described in 23.3.9.8 (BCC interleaver).

g) Constellation mapper: Map to BPSK constellation points as described in 23.3.9.9 (Constellation mapping).

h) Pilot insertion: Insert pilots following the steps described in 23.3.9.10 (Pilot subcarriers).

i) Spatial mapping: Apply the $Q$ matrix as described in 23.3.9.11 (OFDM modulation).

j) Phase rotation: Apply appropriate phase rotation for each 1 MHz subchannel if S1G 1 MHz Duplicate PPDU as described in 23.3.9.12 (S1G 1 MHz and 2 MHz duplicate transmission) and 23.3.7 (Mathematical description of signals).

k) IDFT: Compute the inverse discrete Fourier transform.

l) Insert GI and apply windowing: Prepend a GI and apply windowing as described in 17.3.2.5 (Mathematical conventions in the signal descriptions). If the TXVECTOR parameter GI_TYPE equals LONG_GI, the GI duration shall be 8 μs. If the GI_TYPE parameter is SHORT_GI, the GI duration shall be 8 μs for the first OFDM symbol of the Data field, and 4 μs for all subsequent OFDM symbols.

m) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the requested channel and transmit. Refer to 23.3.7 (Mathematical description of signals) and 23.3.8 (S1G preamble) for details.

#### 23.3.4.7.2 Using LDPC

The construction of the Data field in an S1G SU PPDU (1 MHz MCS 10 mode) with LDPC encoding proceeds as follows:

a) SERVICE field: Generate the SERVICE field as described in 23.3.9.2 (SERVICE field) and append the PSDU to the SERVICE field.

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b) PHY padding: Append the PHY pad bits to the PSDU as described in 23.3.9.4.4.2 (Padding for LDPC).

c) Scrambler: Scramble the PHY padded data as described in 23.3.9.3 (Scrambler).

d) LDPC encoder: The scrambled bits are encoded using the LDPC code with the LENGTH from the TXVECTOR as described in 23.3.9.4.4 (LDPC coding).

e) Block repetition: Apply the block-wise 2 times repetition on a per-OFDM symbol basis as described in 23.3.9.5 (Repetition for 1 MHz MCS 10).

f) Constellation mapper: Map to BPSK constellation points as described in 23.3.9.9 (Constellation mapping).

g) Pilot insertion: Insert pilots following the steps described in 23.3.9.10 (Pilot subcarriers).

h) Spatial mapping: Apply the $Q$ matrix as described in 23.3.9.11 (OFDM modulation).

i) Phase rotation: Apply appropriate phase rotations for each 1 MHz subchannel if S1G 1 MHz Duplicate PPDU as described in 23.3.9.12 (S1G 1 MHz and 2 MHz duplicate transmission) and 23.3.7 (Mathematical description of signals).

j) IDFT: Compute the inverse discrete Fourier transform.

k) Insert GI and apply windowing: Prepend a GI and apply windowing as described in 17.3.2.5 (Mathematical conventions in the signal descriptions). If the TXVECTOR parameter GI_TYPE equals LONG_GI, the GI duration shall be 8 μs. If the GI_TYPE parameter is SHORT_GI, the GI duration shall be 8 μs for the first OFDM symbol of the Data field, and 4 μs for all subsequent OFDM symbols.

l) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the requested channel and transmit. Refer to 23.3.7 (Mathematical description of signals) and 23.3.8 (S1G preamble) for details.

### 23.3.4.8 Construction of the Data field in an S1G MU PPDU

#### 23.3.4.8.1 General

For an MU transmission, the PPDU encoding process is performed on a per-user basis up to the input of the spatial mapping block except that the CSD is applied across users as described in 23.3.8.2.3.3.2 (Cyclic shift for S1G modulated fields) if an S1G_LONG preamble is used. All user data is combined and mapped to the transmit chains in the spatial mapping block. An S1G_1M PPDU, or an S1G_SHORT PPDU, or an 2 MHz S1G duplicate PPDU in S1G_LONG format shall not be used for an MU transmission.

#### 23.3.4.8.2 Using BCC

A Data field with BCC encoding is constructed using the process described in 23.3.4.6.1 (Using BCC) and 23.3.4.7.1 (Using BCC) before the spatial mapping block and repeated for each user that uses BCC encoding.

#### 23.3.4.8.3 Using LDPC

A Data field with LDPC encoding is constructed using the process described in 23.3.4.6.2 (Using LDPC) and 23.3.4.7.2 (Using LDPC) before the spatial mapping block and repeated for each user that uses LDPC encoding.

#### 23.3.4.8.4 Combining to form an S1G MU PPDU

The per-user data is combined as follows:

a) Spatial Mapping: Apply the $Q$ matrix as described in 23.3.10 (SU-MIMO and (#3367)DL MU-MIMO Beamforming). The combining of all user data is done in this block.


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b) Phase rotation: Apply the appropriate phase rotations for each 2 MHz subchannel as described in 23.3.9.11 (OFDM modulation) and 23.3.7 (Mathematical description of signals).

c) IDFT: Compute the inverse discrete Fourier transform.

d) Insert GI and apply windowing: Prepend a GI and apply windowing as described in 17.3.2.5 (Mathematical conventions in the signal descriptions). If the TXVECTOR parameter GI_TYPE equals LONG_GI, the GI duration shall be 8 μs. If the GI_TYPE parameter is SHORT_GI, the GI duration shall be 8 μs for the first OFDM symbol of the Data field, and 4 μs for all subsequent OFDM symbols.

e) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the requested channel and transmit. Refer to 23.3.7 (Mathematical description of signals) and 23.3.8 (S1G preamble) for details.

### 23.3.5 Modulation and coding scheme

The S1G-MCS is a value that determines the modulation and coding used in the Data field of the PPDU. It is a compact representation that is carried in the SIG field or SIG-A field for S1G SU PPDUs and in the SIG-B field for S1G MU PPDUs using S1G_LONG. Rate-dependent parameters for the full set of S1G-MCSs are shown in Table 23-42 (S1G-MCSs for 1 MHz, Nss = 1) to Table 23-61 (S1G-MCSs for 16 MHz, Nss = 4) (in 23.5 (Parameters for S1G-MCSs)).

Table 23-42 (S1G-MCSs for 1 MHz, Nss = 1) to Table 23-61 (S1G-MCSs for 16 MHz, Nss = 4) give rate-dependent parameters for S1G-MCSs with indices 0 to 9 (and index 10 solely for 1 MHz, $N_{SS}$ = 1), with number of spatial streams from 1 to 4 and bandwidth options of 1 MHz, 2 MHz, 4 MHz, 8 MHz, and 16 MHz. Equal modulation is applied to all streams for a particular user.

### 23.3.6 Timing-related parameters

Table 23-5 (Timing-related constants) defines the timing-related parameters for all S1G PPDU formats, except the SIG field in S1G_SHORT, and the SIG-A field in S1G_LONG. Note that the timing-related parameters for the SIG field in S1G_1M PPDU and the SIG-B field in S1G_LONG are the same as those defined for the Data field as shown in Table 23-5 (Timing-related constants).

**Table 23-5—Timing-related constants**

| Parameter | CBW1 | CBW2 | CBW4 | CBW8 | CBW16 | Description |
|---|---|---|---|---|---|---|
| $N_{SD}$ | 24 | 52 | 108 | 234 | 468 | Number of data subcarriers per OFDM symbol |
| $N_{SP}$ | 2 | 4 | 6 | 8 | 16 | Number of pilot subcarrier per OFDM symbol |
| $N_{ST}$ | 26 | 56 | 114 | 242 | 484 | Total number of useful subcarriers per OFDM symbol |
| $N_{SR}$ | 13 | 28 | 58 | 122 | 250 | Highest data subcarrier index per OFDM symbol |
| $\Delta_F$ | 31.25 kHz | | | | | Subcarrier frequency spacing |

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**Table 23-5—Timing-related constants *(continued)***

| Parameter | CBW1 | CBW2 | CBW4 | CBW8 | CBW16 | Description |
|---|---|---|---|---|---|---|
| $T_{DFT}$ | 32 μs = $1/\Delta_F$ | | | | | IDFT/DFT period |
| $T_{GI}$ | 8 μs = $T_{DFT}/4$ | | | | | Guard interval duration |
| $T_{GI2}$ | 16 μs | | | | | Double guard interval |
| $T_{GIS}$ | 4 μs = $T_{DFT}/8$ | | | | | Short guard interval duration |
| $T_{SYML}$ | 40 μs = $T_{DFT} + T_{GI} = 1.25 \times T_{DFT}$ | | | | | Duration of OFDM symbol with normal guard interval |
| $T_{SYMS}$ | 36 μs = $T_{DFT} + T_{GIS} = 1.125 \times T_{DFT}$ | | | | | Duration of OFDM symbol with short guard interval |
| $T_{SYM}$ | $T_{SYML}$ or $T_{SYMS}$ depending on the GI used | | | | | OFDM symbol duration |
| $T_{STF}$ | 160 μs = $4 \times T_{SYML}$ | 80 μs = $2 \times T_{SYML}$ | | | | STF field duration |
| $T_{DSTF}$ | N/A | 40 μs = $T_{SYML}$ | | | | S1G_LONG preamble D-STF field duration |
| $T_{LTF1}$ | 160 μs = $4 \times T_{DFT} + 2 \times T_{GI} + T_{GI2}$ | 80 μs = $2 \times T_{DFT} + T_{GI2}$ | | | | First LTF field duration |
| $T_{LTF}$ | 40 μs = $T_{SYML}$ | | | | | Second and subsequent LTF field duration |
| $T_{DLTF}$ | N/A | 40 μs = $T_{SYML}$ | | | | S1G_LONG preamble D-LTF field duration |
| $T_{SIG}$ | 240 μs = $6 \times T_{SYML}$ | 80 μs = $2 \times T_{SYML}$ | | | | SIG field duration |
| $T_{SIG\text{-}A}$ | N/A | 80 μs = $2 \times T_{SYML}$ | | | | S1G_LONG preamble SIG-A field duration |
| $T_{SIG\text{-}B}$ | N/A | 40 μs = $T_{SYML}$ | | | | S1G_LONG preamble SIG-B field duration |
| *Nservice* | 8 | | | | | Number of bits in the SERVICE field |
| $N_{tail}$ | 6 | | | | | Number of tail bits per BCC encoder |

NOTE— $N_{ST} = N_{SD} + N_{SP}$.



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Table 23-6 (Timing-related constants for SIG/SIG-A field in ≥ 2 MHz PPDUs) defines the timing-related parameters for the SIG field in S1G_SHORT, or the SIG-A field in S1G_LONG. Note that short/double guard interval is not used for SIG/SIG-A field in ≥ 2 MHz PPDUs.

**Table 23-6—Timing-related constants for SIG/SIG-A field in ≥ 2 MHz PPDUs**

| Parameter | CBW1 | CBW2 | CBW4 | CBW8 | CBW16 | Description |
|---|---|---|---|---|---|---|
| $N_{SD}$ | N/A | 48 | 48 | 48 | 48 | Number of data subcarriers per OFDM symbol per 2 MHz subchannel |
| $N_{SP}$ | N/A | 4 | 4 | 4 | 4 | Number of pilot subcarrier per OFDM symbol per 2 MHz subchannel |
| $N_{ST}$ | N/A | 52 | 52 | 52 | 52 | Total number of useful subcarriers per OFDM symbol per 2 MHz subchannel |
| $N_{SR}$ | N/A | 26 | 56 | 120 | 248 | Highest data subcarrier index per OFDM symbol |
| $\Delta_F$ | N/A | 31.25 kHz | | | | Subcarrier frequency spacing |
| $T_{DFT}$ | N/A | 32 μs = $1/\Delta_F$ | | | | IDFT/DFT period |
| $T_{GI}$ | N/A | 8 μs = $T_{DFT}/4$ | | | | Guard interval duration |
| $T_{SYM}$ | N/A | 40 μs = $T_{DFT} + T_{GI} = 1.25 \times T_{DFT}$ | | | | OFDM symbol duration |
| $T_{SIG}$ | N/A | 80 μs = $2 \times T_{SYM}$ | | | | SIG field duration |
| $T_{SIG\text{-}A}$ | N/A | 80 μs = $2 \times T_{SYM}$ | | | | S1G_LONG preamble SIG-A field duration |

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Table 23-7 (Frequently used parameters) defines parameters used frequently in Clause 23 (Sub 1 GHz (S1G) PHY specification(#4095)).

**Table 23-7—Frequently used parameters**

| Symbol | Explanation |
|---|---|
| $N_{CBPS}$, $N_{CBPS,u}$ | Number of coded bits per symbol for user $u$, $u = 0, ..., N_u–1$.<br>For an S1G SU PPDU, $N_{CBPS} = N_{CBPS,0}$.<br>For an S1G MU PPDU, $N_{CBPS}$ is undefined. |
| $N_{CBPSS}$, $N_{CBPSS,u}$ | Number of coded bits per symbol per spatial stream.<br>For the SIG-B field in S1G_LONG, $N_{CBPSS} = N_{SD}$ for all users.<br>For the Data field, $N_{CBPSS,u}$ equals the number of coded bits per symbol per spatial stream for user $u$, $u = 0, ..., N_u–1$.<br>For the Data field of an S1G SU PPDU, $N_{CBPSS} = N_{CBPSS,0}$.<br>For the Data field of an S1G MU PPDU, $N_{CBPSS}$ is undefined. |
| $N_{CBPSSI}$, $N_{CBPSSI,u}$ | Number of coded bits per symbol per spatial stream per BCC interleaver block.<br>For an S1G SU PPDU,<br>$N_{CBPSSI} = \begin{cases} N_{CBPSS}, \text{ for 1 MHz, 2 MHz, 4 MHz, or 8 MHz} \\ \frac{N_{CBPSS}}{2}, \text{ for a 16 MHz PPDU} \end{cases}$<br>For an S1G MU PPDU for user $u$, $u = 0, ..., N_u–1$<br>$N_{CBPSSI,u} = \begin{cases} N_{CBPSS,u}, \text{ for 1 MHz, 2 MHz, 4 MHz, or 8 MHz} \\ \frac{N_{CBPSS,u}}{2}, \text{ for a 16 MHz PPDU} \end{cases}$ |
| $N_{DBPS}$, $N_{DBPS,u}$ | Number of data bits per symbol for user $u$, $u = 0, ..., N_u–1$.<br>For an S1G SU PPDU, $N_{DBPS} = N_{DBPS,0}$.<br>For an S1G MU PPDU, $N_{DBPS}$ is undefined. |
| $N_{BPSCS}$, $N_{BPSCS,u}$ | Number of coded bits per subcarrier per spatial stream for user $u$, $u = 0, ..., N_u–1$.<br>For an S1G SU PPDU, $N_{BPSCS} = N_{BPSCS,0}$.<br>For an S1G MU PPDU, $N_{BPSCS}$ is undefined. |
| $N_{RX}$ | Number of receive chains. |
| $N_u$ | For S1G_LONG, the omnidirectional portion always has $N_u$=1, and in the beam changeable portion, $N_u$ represents the number of users in the transmission (equal to the TXVECTOR parameter NUM_USERS).<br>For S1G_1M and S1G_SHORT, $N_u$=1. |
| $N_{STS}$, $N_{STS,u}$ | Number of space-time streams.<br>For S1G_LONG, the omnidirectional portion always has $N_{STS,u}$=1 (see NOTE); and for the beam changeable portion $N_{STS,u}$ is the number of space-time streams for user $u$, $u = 0,…, N_u–1$.<br>For S1G_1M and S1G_SHORT,$N_{STS} = N_{STS,0}$.<br>For an S1G SU PPDU, $N_{STS} = N_{STS,0}$; for an S1G MU PPDU, $N_{STS}$ is undefined. |


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**Table 23-7—Frequently used parameters *(continued)***

| Symbol | Explanation |
|---|---|
| $N_{STS,total}$ | For S1G_1M, S1G_SHORT, and the beam changeable portion of S1G_LONG, $N_{STS,total}$ is the total number of space-time streams in a PPDU.<br>$N_{STS,total} = \sum_{u=0}^{N_u-1} N_{STS,u}$<br>For the omnidirectional portion of S1G_LONG, $N_{STS,total}$ is undefined.<br>Note that $N_{STS,total} = N_{STS}$ for an S1G SU PPDU. |
| $N_{SS}$, $N_{SS,u}$ | Number of spatial streams.<br>For S1G_LONG, the omnidirectional portion always has $N_{SS,u}=1$ (see NOTE); and for the beam changeable portion $N_{SS,u}$ is the number of spatial streams for user $u$, $u = 0,\ldots, N_u-1$.<br>For S1G_1M and S1G_SHORT, $N_{SS} = N_{SS,0}$.<br>For an S1G SU PPDU, $N_{SS} = N_{SS,0}$; for an S1G MU PPDU, $N_{SS}$ is undefined. |
| $N_{TX}$ | Number of transmit chains. |
| $N_{ES}$, $N_{ES,u}$ | The number of BCC encoders.<br>For the SIG-B field of S1G_LONG, $N_{ES}=1$ for each user.<br>For the beam changeable portion of S1G_LONG, $N_{ES,u}$ is the number of BCC encoders for the Data field for user $u$, $u = 0,\ldots, N_u-1$(#515).<br>For the Data field of an S1G SU PPDU, $N_{ES} = N_{ES,0}$.<br>For the Data field of an S1G MU PPDU, $N_{ES}$ is undefined.<br>For the Data field encoded using LDPC, $N_{ES}=1$ for an S1G SU PPDU and $N_{ES,u}=1$ for an S1G MU PPDU for user $u$, $u = 0,\ldots, N_u-1$(#515). |
| $N_{LTF}$ | Number of long training fields in S1G_1M or S1G_SHORT; or the number of data long training fields in S1G_LONG (see 23.3.8.2.2.4 (LTF definition), 23.3.8.2.3.3.3 (D-STF definition), and 23.3.8.3.4 (LTF definition)) |
| $R$, $R_u$ | $R_u$ is the coding rate for user $u$, $u = 0, \ldots, N_u-1$.<br>For an S1G SU PPDU, $R = R_0$<br>For an S1G MU PPDU, $R$ is undefined |
| $M_u$ | For the omnidirectional portion of S1G_LONG, $M_u = 0$. Otherwise,<br>$M_u = \sum_{u'=0}^{u-1} N_{STS,u'}$ with $M_0 = 0$. |
| NOTE—For the omnidirectional portion of S1G_LONG, $u$ is 0 only since $N_u=1$. | |

### 23.3.7 Mathematical description of signals

For a description of the conventions used for the mathematical description of the signals, see 17.3.2.5 (Mathematical conventions in the signal descriptions).

For a 1 MHz S1G PPDU transmission, the 1 MHz is divided into 32 subcarriers. The signal is transmitted on subcarriers –13 to –1 and 1 to 13, with 0 being the center (DC) subcarrier.

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For a 2 MHz S1G PPDU transmission, the 2 MHz is divided into 64 subcarriers. The signal is transmitted on subcarriers –28 to –1 and 1 to 28, with 0 being the center (DC) subcarrier.

For a 4 MHz S1G PPDU transmission, the 4 MHz is divided into 128 subcarriers. The signal is transmitted on subcarriers –58 to –2 and 2 to 58.

For an 8 MHz S1G PPDU transmission, the 8 MHz is divided into 256 subcarriers. The signal is transmitted on subcarriers –122 to –2 and 2 to 122.

For a 16 MHz S1G PPDU transmission, the 16 MHz is divided into 512 subcarriers. The signal is transmitted on subcarriers –250 to –130, –126 to –6, 6 to 126, and 130 to 250.

The transmitted signal is described in complex baseband signal notation. The actual transmitted signal is related to the complex baseband signal by the relation shown in Equation (23-1).

$$r_{RF}(t) = \mathrm{Re}\{r(t)\exp(j2\pi f_c t)\} \quad (23\text{-}1)$$

where

$f_c$ represents the center frequency of the carrier

The transmitted RF signal is derived by upconverting the complex baseband signal, which consists of several fields. The timing boundaries for the various fields of the different (#14)PPDU formats are shown in Figure 23-5 (Timing boundaries for S1G PPDU fields(#7158)), where $N_{LTF}$ is the number of LTF or D-LTF field symbols and is defined in Table 23-11 (Number of LTFs required for different numbers of space-time streams) (in 23.3.8.2.2.4 (LTF definition)), for up to $N_{STS,Total} = 4$.

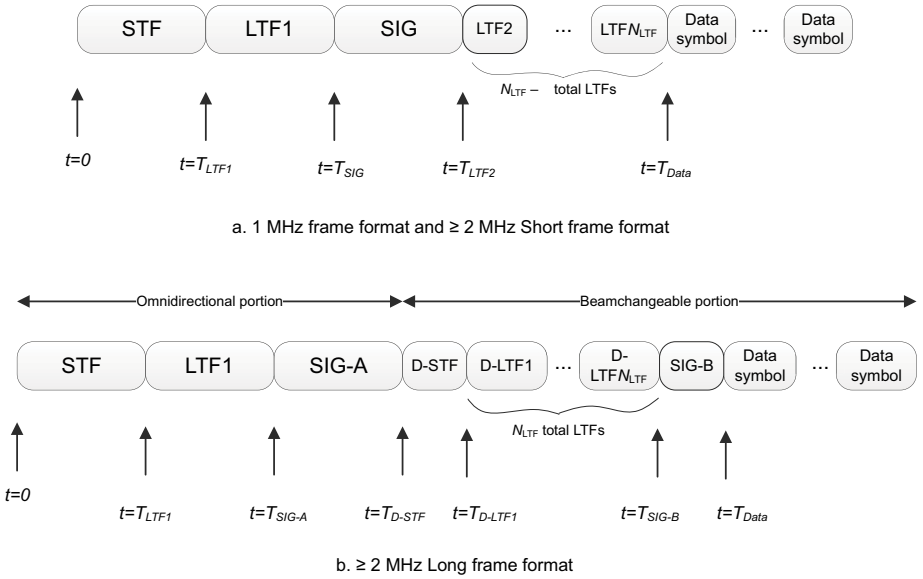


**Figure 23-5—Timing boundaries for S1G PPDU fields(#7158)**


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The time offset, $t_{Field}$ , determines the starting time of the corresponding field.

For the S1G_1M PPDU (#14)PPDU format and the S1G_SHORT PPDU (#14)PPDU format, the signal transmitted on transmitted on transmit chain $i_{TX}$ shall be as shown in Equation (23-2).

$$r_{PPDU}^{i_{TX}}(t) = r_{STF}^{i_{TX}}(t) + r_{LTF1}^{i_{TX}}(t - t_{LTF1}) + r_{SIG}^{i_{TX}}(t - t_{SIG}) + \sum_{i_{LTF}=2}^{N_{LTF}} r_{LTF}^{(i_{TX}, i_{LTF})}(t - t_{LTF2} - (i_{LTF} - 2)T_{LTF}) + r_{Data}^{i_{TX}}(t - t_{Data}) \quad (23\text{-}2)$$

where

$$t_{LTF} = T_{STF}$$
$$t_{SIG} = t_{LTF1} + T_{LTF1}$$
$$t_{LTF2} = t_{SIG} + T_{SIG}$$
$$t_{Data} = t_{LTF2} + (N_{LTF} - 1)T_{LTF}$$

For the S1G_LONG PPDU format, the signal transmitted on transmit chain *iTX* shall be as shown in Equation (23-3).

$$r_{\text{PPDU}}^{(i_{\text{TX}})}(t) = r_{\text{STF}}^{(i_{\text{TX}})}(t) + r_{\text{LTF1}}^{(i_{\text{TX}})}(t - t_{\text{LTF1}}) + r_{\text{SIG-A}}^{(i_{\text{TX}})}(t - t_{\text{SIG}}) + r_{\text{D-STF}}^{(i_{\text{TX}})}(t - t_{D-STF}) + \sum_{i_{\text{LTF}}=1}^{N_{\text{LTF}}} r_{\text{D-LTF}}^{(i_{\text{TX}}, i_{\text{LTF}})}(t - t_{\text{D-LTF1}} - (i_{\text{LTF}} - 1)T_{\text{LTF}}) + r_{\text{SIG-B}}^{(i_{\text{TX}})}(t - t_{\text{SIG-B}}) + r_{\text{Data}}^{(i_{\text{TX}})}(t - t_{\text{Data}}) \quad (23\text{-}3)$$

where

$$t_{\text{LTF1}} = T_{\text{STF}}$$
$$t_{\text{SIG-A}} = t_{\text{LTF1}} + T_{\text{LTF1}}$$
$$t_{\text{D-STF}} = t_{\text{SIG-A}} + T_{\text{SIG-A}}$$
$$t_{\text{D-LTF1}} = t_{\text{D-STF}} + T_{\text{D-STF}}$$
$$t_{\text{SIG-B}} = t_{\text{D-LTF1}} + N_{\text{LTF1}} \cdot T_{\text{LTF}}$$
$$t_{\text{Data}} = t_{\text{SIG-B}} + T_{\text{SIG-B}}$$

Each field, $r_{Field}^{(i_{\text{TX}})}(t)$ , is defined as the summation of one or more subfields, where each subfield is defined to be an inverse discrete Fourier transform as specified in Equation (23-4).

$$r_{\text{Field}}^{(i_{\text{TX}})}(t) = \frac{1}{\sqrt{N_{\text{Field}}^{\text{Tone}} N_{\text{Norm}}}} w_{T_{\text{Field}}}(t) \sum_{k=-N_{SR}}^{N_{SR}} \sum_{u=0}^{N_u - 1} \sum_{m=1}^{N_{STS,u}} \left[Q_k\right]_{i_{TX},(M_u+m)} \Upsilon_{k,\text{BW}} X_{k,u}^{(m)} \exp\left(j2\pi k \Delta_F (t - T_{GI,Field} - T_{CS}(M_u + m))\right) \quad (23\text{-}4)$$

This general representation holds for all subfields. When the bandwidth is greater than or equal to 2 MHz and the S1G_LONG format is used, the total power of the time domain beam changeable portion field signals summed over all transmit chains should not exceed the total power of the time domain omnidirectional portion signals summed over all transmit chains. For notational simplicity, the parameter BW is omitted from some bandwidth dependent terms.

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Table 23-8 (Tone scaling factor and guard interval duration values for PHY fields) summarizes the various values of $N_{\text{Field}}^{\text{Tone}}$ as a function of bandwidth per frequency segment.

**Table 23-8—Tone scaling factor and guard interval duration values for PHY fields**

| Field | $N_{\text{Field}}^{\text{Tone}}$ as a function of bandwidth per frequency segment | | | | | Guard interval duration |
|---|---|---|---|---|---|---|
| | 1 MHz | 2 MHz | 4 MHz | 8 MHz | 16 MHz | |
| STF | 6 | 12 | 24 | 48 | 96 | N/A (See NOTE 2) |
| LTF1 | 26 | 56 | 114 | 242 | 484 | For bandwidths ≥ 2 MHz, duration is $T_{GI2}$. For 1 MHz bandwidth, duration is $T_{GI2}$ for first and second symbols, and $T_{GI}$ for third and fourth symbols. |
| (#6048)S1G_DUP_1M-LTF1 (see NOTE 4) | N/A | 52 | 104 | 208 | 416 | Duration is $T_{GI2}$ for first and second symbols, and $T_{GI}$ for third and fourth symbols. |
| (#6048)S1G_DUP_2M-LTF1 (see NOTE 4) | N/A | N/A | 112 | 224 | 448 | $T_{GI2}$ |
| SIG | 26 | 52 | 104 | 208 | 416 | $T_{GI}$ |
| SIG-A for long format | N/A | 52 | 104 | 208 | 416 | $T_{GI}$ |
| D-STF for long format | N/A | 12 | 24 | 48 | 96 | N/A |
| (#7158)LTF2~LTF$N_{\text{LTF}}$ | 26 | 56 | 114 | 242 | 484 | $T_{GI}$ |
| (#6048)S1G_DUP_1M-(#7158)LTF2~LTF$N_{\text{LTF}}$ (see NOTE 4) | N/A | 52 | 104 | 208 | 416 | $T_{GI}$ |
| (#6048)S1G_DUP_2M-(#7158)LTF2~LTF$N_{\text{LTF}}$ (see NOTE 4) | N/A | N/A | 112 | 224 | 448 | $T_{GI}$ |
| D-LTF for long format | N/A | 56 | 114 | 242 | 484 | $T_{GI}$ |
| SIG-B for long format | N/A | 56 | 114 | 242 | 484 | $T_{GI}$ |



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**Table 23-8—Tone scaling factor and guard interval duration values for PHY fields *(continued)***

| Field | $N_{\text{Field}}^{\text{Tone}}$ as a function of bandwidth per frequency segment | | | | | Guard interval duration |
|---|---|---|---|---|---|---|
| | 1 MHz | 2 MHz | 4 MHz | 8 MHz | 16 MHz | |
| First Data Symbol | 26 | 56 | 114 | 242 | 484 | $T_{GI}$ (see NOTE 3) |
| From second to the last Data Symbols | 26 | 56 | 114 | 242 | 484 | $T_{GI}$ or $T_{GIS}$ (see NOTE 3) |
| S1G_DUP_1M-Data (see NOTE 1) | N/A | 52 | 104 | 208 | 416 | $T_{GI}$ or $T_{GIS}$ (see NOTE 3) |
| S1G_DUP_2M-Data (see NOTE 1) | N/A | N/A | 112 | 224 | 448 | $T_{GI}$ or $T_{GIS}$ (see NOTE 3) |

NOTE 1—For notational convenience, S1G_DUP_1M-Data and S1G_DUP_2M-Data is used as a label for the Data field of a duplicate PPDU with format type S1G_DUP_1M or S1G_DUP-2M, respectively.

NOTE 2—The OFDM symbols of the STF field do not have a guard interval, therefore its duration is not applicable.

NOTE 3—$T_{GI}$ denotes guard interval duration when TXVECTOR parameter GI_TYPE equals LONG_GI, $T_{GIS}$ denotes short guard interval duration when TXVECTOR parameter GI_TYPE equals SHORT_GI. Regardless of the GI_TYPE value in TXVECTOR, the first Data OFDM symbol always uses $T_{GI}$ as its guard interval duration.

(#6048)(#7158)NOTE 4—For notational convenience, S1G_DUP_1M-LTF1 and S1G_DUP_2M-LTF1 are used as a label for the LTF1 of a duplicate PPDU with format type S1G_DUP_1M or S1G_DUP_2M, respectively, and S1G_DUP_1M-LTF2~LTF$N_{\text{LTF}}$ and S1G_DUP_2M-LTF2~LTF$N_{\text{LTF}}$ are used as a label for the LTF2~LTF$N_{\text{LTF}}$ of a duplicate PPDU with format type S1G_DUP_1M or S1G_DUP_2M, respectively.

$N_{\text{Norm}}$ for the omnidirectional portion of the S1G_LONG, $N_{\text{Norm}} = N_{\text{TX}}$, for all other cases, $N_{\text{Norm}} = N_{STS,total}$, where $N_{STS,total}$ is given in Table 23-7 (Frequently used parameters).

$w_{\text{T}_{\text{Field}}}(t)$ is a windowing function. An example function, $w_{\text{T}_{\text{Field}}}(t)$, is given in 17.3.2.5 (Mathematical conventions in the signal descriptions).

$T_{\text{Subfield}}$ is the duration of the subfield being referenced, and its usage is as follows:

- $T_{STF}$ for the STF field, $T_{D\text{-}STF}$ for the D-STF field
- $T_{LTF1}$ for the LTF1 field
- $T_{SIG}$ for the SIG field, $T_{SIG\text{-}A}$ for the SIG-A field
- $T_{LTF}$ for the (#7158)LTF2~LTF$N_{\text{LTF}}$ fields for the S1G_1M, the S1G_SHORT format, and for the D-LTFs fields in the S1G_LONG format
- $T_{SIG\text{-}B}$ field for the SIG-B

$N_u$ is defined in Table 23-7 (Frequently used parameters).

$N_{\text{SR}}$ is the highest data subcarrier index per frequency segment and has values listed in Table 23-5 (Timing-related constants) and in Table 23-6 (Timing-related constants for SIG/SIG-A field in ≥ 2 MHz PPDUs).

$N_{STS,u}$ is defined in Table 23-7 (Frequently used parameters).

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$M_u$ is defined in Table 23-7 (Frequently used parameters).

$[X]_{a,b}$ indicates the element in row $a$ and column $b$ of the matrix $X$, where $1 \le a \le N_{\text{row}}$, and $1 \le b \le N_{\text{col}}$. $N_{\text{row}}$ and $N_{\text{col}}$ are the number of rows and columns, respectively, of the matrix $X$.

$Q_k$ is the spatial mapping matrix for the subcarrier $k$. For the omnidirectional portion of S1G_LONG, $Q_k$ is a column vector, denoted as $Q_k^{(omni)}$, with $N_{TX}$ elements with element $i_{TX}$ being $\exp(-j2\pi k\Delta_F T_{CS}^{i_{TX}})$, where $T_{CS}^{i_{TX}}$ represents the cyclic shift for transmitter chain $i_{TX}$ whose values are given in Table 23-13 (Per antenna cyclic shift values of S1G_LONG preamble PPDU) (in 23.3.8.2.3.2.2). For other cases, $Q_k$ is a matrix with $N_{TX}$ rows and $N_{STS,total}$ columns.

$\Delta_F$ is the subcarrier frequency spacing given in Table 23-5 (Timing-related constants).

$X_{k,u}^{(m)}$ is the frequency domain symbol in subcarrier $k$ of user $u$ for of space-time stream $m$. Some of the $X_{k,u}^{(m)}$ within $-N_{\text{SR}} \le k \le N_{\text{SR}}$ have a value of zero. Examples of such cases include the DC tones, guard tones on each side of the transmit spectrum, as well as the unmodulated tones of STF and D-STF fields.

$T_{GI,Field}$ is the guard interval duration used for each OFDM symbol in the field. The value for each field is defined in Table 23-8 (Tone scaling factor and guard interval duration values for PHY fields). $T_{GI}$, $T_{GI2}$ and $T_{GIS}$ are defined in Table 23-5 (Timing-related constants).

$T_{CS}(l)$ for the omnidirectional portion of S1G_LONG, $T_{CS}(l) = 0$. For the other cases, $T_{CS}(l)$ represents the cyclic shift per space-time stream, whose value is defined in Table 23-10 (Cyclic shift values for the S1G_SHORT preamble PPDU) (in 23.3.8.2.2.2) for ≥ 2 MHz, and Table 23-18 (Cyclic shift values of S1G_1M PPDU) (in 23.3.8.3.2).

The function $\Upsilon_{k,\text{BW}}$ is used to represent a rotation of the tones. BW in $\Upsilon_{k,\text{BW}}$ is determined by the TXVECTOR parameter CH_BANDWIDTH as defined in Table 23-9 (CH_BANDWIDTH and Gamma sub$_{\text{k, BW}}$ (#4079)).

**Table 23-9—CH_BANDWIDTH and Gamma sub$_{\text{k, BW}}$ (#4079)**

| CH_BANDWIDTH | $\Upsilon_{k,\text{BW}}$ |
|---|---|
| CBW1 | $\Upsilon_{k,1}$ |
| CBW2 | $\Upsilon_{k,2}$ |
| CBW4 | $\Upsilon_{k,4}$ |
| CBW8 | $\Upsilon_{k,8}$ |
| CBW16 | $\Upsilon_{k,16}$ |


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(#14)If CH_BANDWIDTH is CBW1,

$$\Upsilon_{k,1} = 1 \tag{23-5}$$

(#14)If CH_BANDWIDTH is CBW2,

$$\Upsilon_{k,2} = 1 \tag{23-6}$$

(#14)If FORMAT is S1G or S1G_DUP_2M and CH_BANDWIDTH is CBW4,

$$\Upsilon_{k,4} = \begin{cases} 1, & k < 0 \\ j, & k \geq 0 \end{cases} \tag{23-7}$$

(#14)If FORMAT is S1G or S1G_DUP_2M and CH_BANDWIDTH is CBW8,

$$\Upsilon_{k,8} = \begin{cases} 1, k < -64 \\ -1, k \geq -64 \end{cases} \tag{23-8}$$

(#14)If FORMAT is S1G or S1G_DUP_2M and CH_BANDWIDTH is CBW16,

$$\Upsilon_{k,16} = \begin{cases} 1, & k < -192 \\ -1, & -192 \leq k < 0 \\ 1, & 0 \leq k < 64 \\ -1, & 64 \leq k \end{cases} \tag{23-9}$$

(#14)If FORMAT is S1G_DUP_1M and CH_BANDWIDTH is CBW2,

$$\Upsilon_{k,2} = \begin{cases} 1, k < 0 \\ -1, k \geq 0 \end{cases} \tag{23-10}$$

(#14)If FORMAT is S1G_DUP_1M and CH_BANDWIDTH is CBW4,

$$\Upsilon_{k,4} = \begin{cases} 1, k < -32 \\ j, -32 \leq k < 0 \\ -j, 0 \leq k < 32 \\ -1, 32 \leq k \end{cases} \tag{23-11}$$

(#14)If FORMAT is S1G_DUP_1M and CH_BANDWIDTH is CBW8,

$$\Upsilon_{k,8} = \begin{cases} 1, k < -96 \\ -1, -96 \leq k < -64 \\ 1, -64 \leq k < 64 \\ -1, 64 \leq k \end{cases} \tag{23-12}$$

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(#14)If FORMAT is S1G_DUP_1M and CH_BANDWIDTH is CBW16,

$$\Upsilon_{k,16} = \begin{cases} 1, & k < -160 \\ -1, & -160 \le k < -128 \\ 1, & -128 \le k < -32 \\ -1, & -32 \le k < 64 \\ 1, & 64 \le k < 96 \\ -1, & 96 \le k < 128 \\ 1, & 128 \le k < 192 \\ -1, & 192 \le k < 224 \\ 1, & 224 \le k \end{cases} \quad (23\text{-}13)$$

### 23.3.8 S1G preamble

#### 23.3.8.1 Introduction

Three preamble formats are defined that correspond to the three non-duplicate S1G PPDU formats: the S1G_1M preamble, the S1G_SHORT preamble, and the S1G_LONG preamble. The first two preamble formats are defined solely for single user, and the third preamble format may be used in either single user or multi-user PPDUs. The duplicate mode PPDU formats S1G_DUP_2M and S1G_DUP_1M use the S1G_SHORT and S1G_1M preambles, respectively.

All numeric fields are transmitted in unsigned format, LSB first.

#### 23.3.8.2 Formats for greater than or equal to 2 MHz

##### 23.3.8.2.1 Introduction

This subclause describes the preamble formats used for non-duplicate S1G PPDUs of 2 MHz and greater and duplicate S1G_DUP_2M PPDUs.

##### 23.3.8.2.2 S1G_SHORT preamble

###### 23.3.8.2.2.1 General

The S1G_SHORT preamble is used for the S1G_SHORT and S1G_DUP_2M PPDU formats and is only used for SU transmissions. The S1G_SHORT preamble is structured similarly to the Greenfield format as defined in Clause 19 (High Throughput (HT) PHY specification(#2297)).

###### 23.3.8.2.2.2 Cyclic shift for S1G modulated fields

The cyclic shift values defined in this subclause apply to the STF, LTF, SIG and Data fields of the S1G_SHORT preamble PPDU, for ≥ 2 MHz transmit bandwidths. Throughout the S1G_SHORT preamble, cyclic shifts are applied to prevent beamforming when similar signals are transmitted in different space-time streams. The STF, LTF, and SIG fields start as single stream during generation but are replicated up to $N_{STS,total}$ streams. For the LTF, these replicated streams undergo P-matrix mapping prior to CSD application as shown in Figure 23-6 (Generation of LTF symbols) (in 23.3.8.2.2.4 (LTF definition)). For the STF and SIG the CSDs are applied per stream immediately after replication. The same cyclic shift is applied to the $N_{STS,total}$ streams during the transmission of the Data field of the S1G_SHORT preamble PPDU. The cyclic shift value $T_{CS}(n)$ for space-time stream $n$ out of $N_{STS,total}$ total space-time streams is shown in Table 23-10 (Cyclic shift values for the S1G_SHORT preamble PPDU).


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**Table 23-10—Cyclic shift values for the S1G_SHORT preamble PPDU**

| $T_{CS}(n)$ for ≥ 2 MHz, S1G_SHORT Preamble PPDU | | | | |
|---|---|---|---|---|
| Total number of space-time streams ($N_{STS,total}$) | Cyclic shift for space-time stream $n$ (μs) | | | |
| | 1 | 2 | 3 | 4 |
| 1 | 0 | — | — | — |
| 2 | 0 | −4 | — | — |
| 3 | 0 | −4 | −2 | — |
| 4 | 0 | −4 | −2 | −6 |

### 23.3.8.2.2.3 STF definition

The STF field for a 2 MHz or 4 MHz transmission is defined by Equation (19-8) and Equation (19-9), respectively, in 19.3.9.3.3 (L-STF definition). For a 8 MHz or 16 MHz transmission, the STF field is defined by Equation (21-18) and Equation (21-19), respectively, in 21.3.8.2.2 (L-STF definition). Note that these equations do not include the phase rotation per 2 MHz subchannel.

The time domain representation of the STF field signal at transmit chain $i_{TX}$ shall be as specified in Equation (23-14).

$$r_{\mathrm{STF}}^{(i_{\mathrm{TX}})}(t) = \frac{1}{\sqrt{N_{\mathrm{STF}}^{\mathrm{Tone}} N_{\mathrm{STS}}}} w_{T_{\mathrm{STF}}}(t) \sum_{k=-N_{SR}}^{N_{SR}} \sum_{m=1}^{N_{STS}} \left[ Q_k \right]_{i_{TX},m} \left[ P_{HTLTF} \right]_{m,1} \Upsilon_{k,\mathrm{BW}} S_k \exp\left( j2\pi k \Delta_F (t - T_{CS}(m)) \right) \quad (23\text{-}14)$$

where

$N_{SR}$ is 26 for a 2 MHz transmission or defined in Table 23-5 (Timing-related constants) for a 4 MHz, 8 MHz, or 16 MHz transmission

$S_k$ is defined in Equation (19-8), Equation (19-9), Equation (21-8), or Equation (21-9) for a 2 MHz, 4 MHz, 8 MHz, or 16 MHz transmission, respectively.

$T_{CS}(m)$ represents the cyclic shift for space-time stream $m$ with a value given in Table 23-10 (Cyclic shift values for the S1G_SHORT preamble PPDU)

$\Upsilon_{k,BW}$ is defined by Equation (23-6) to Equation (23-9)

$\Delta_F$ is defined in Table 23-5 (Timing-related constants)

$N_{STS}$ is defined in Table 23-7 (Frequently used parameters)

$P_{HTLTF}$ is defined in 19.3.9.4.6 (HT-LTF definition)

$N_{STF}^{Tone}$ has the value given in Table 23-8 (Tone scaling factor and guard interval duration values for PHY fields)

$Q_k$ is defined in 23.3.7 (Mathematical description of signals)

### 23.3.8.2.2.4 LTF definition

The LTF field provides means for the receiver to estimate the MIMO channel between the set of constellation mapper outputs (or, if STBC is applied, the STBC encoder outputs) and the receive chains. The transmitter provides training for $N_{STS}$ space-time streams (spatial mapper inputs) used for the transmission of the PSDU. For each tone, the MIMO channel that can be estimated is an $N_{RX} \times N_{STS}$ matrix. All S1G

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transmissions have a preamble that contains LTF symbols, where the data tones of each LTF symbol are multiplied by entries belonging to a matrix $P_{HTLTF}$, to enable channel estimation at the receiver.

The pilot tones of each LTF symbol are multiplied by the first column of the $P_{HTLTF}$ matrix. The multiplication of the pilot tones in the LTF symbols by the first column of the $P_{HTLTF}$ matrix instead of the whole $P_{HTLTF}$ matrix is to allow receivers to track phase and frequency offset during MIMO channel estimation using the LTF. The number of LTF symbols, $N_{LTF}$, is a function of the total number of space-time streams $N_{STS}$ as shown in Table 23-11 (Number of LTFs required for different numbers of space-time streams). As a result, the LTF field consists of one, two, or four symbols that are necessary for the demodulation of the Data field in the PPDU or for channel estimation in an NDP.

**Table 23-11—Number of LTFs required for different numbers of space-time streams**

| $N_{STS}$ | $N_{LTF}$ |
|---|---|
| 1 | 1 |
| 2 | 2 |
| 3 | 4 |
| 4 | 4 |

The LTF field for a 2 MHz, 4 MHz, 8 MHz, or 16 MHz transmission is defined by Equation (21-36) Equation (21-37), Equation (21-38), and Equation (21-39), respectively, in 21.3.8.3.5 (VHT-LTF definition). Note that these equations do not include the phase rotation per 2 MHz subchannel.

The generation of the time domain LTF symbols is shown in Figure 23-6 (Generation of LTF symbols) where $A^{k}_{LTF}$ is given in Equation (23-15).

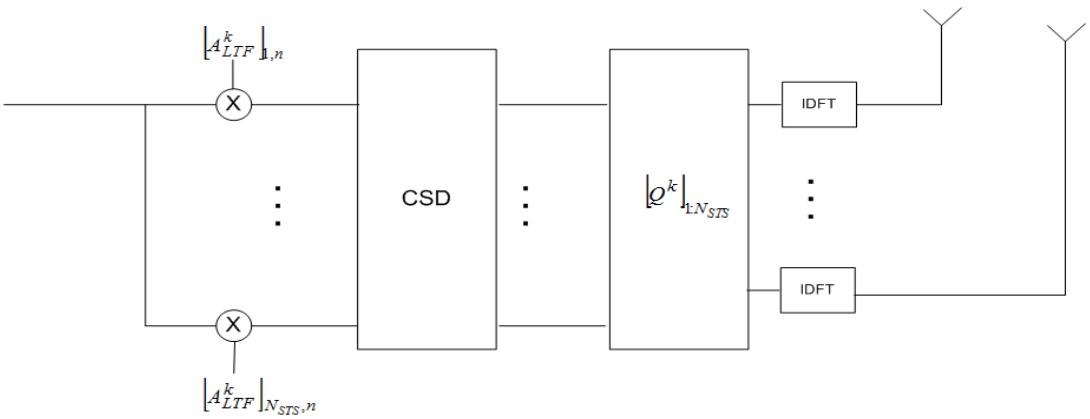


**Figure 23-6—Generation of LTF symbols**

$$A^{k}_{LTF} = \begin{cases} \left[P_{HTLTF}\right]_{*,1} \times \left[1\ 1\ 1\ 1\right], if\ k \in K_{Pilot\_Fix} \\ P_{HTLTF},\ \text{otherwise} \end{cases} \quad (23\text{-}15)$$

where



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$K_{Pilot\_Fix}$ is the subcarrier indices for the fixed pilot tones:

For a 2 MHz transmission, $K_{Pilot\_Fix} = \{\pm 7, \pm 21\}$

For a 4 MHz transmission, $K_{Pilot\_Fix} = \{\pm 11, \pm 25, \pm 53\}$

For an 8 MHz transmission, $K_{Pilot\_Fix} = \{\pm 11, \pm 39, \pm 75, \pm 103\}$

For a 16 MHz transmission,

$K_{Pilot\_Fix} = \{\pm 25, \pm 53, \pm 89, \pm 117, \pm 139, \pm 167, \pm 203, \pm 231\}$

$[P_{HTLTF}]_{*,1}$ is the first column of the $P_{HTLTF}$ matrix

The time domain representation of the LTF1 field, and (#7158)LTF2~LTF$N_{\mathrm{LTF}}$ fields signals at transmit chain $i_{TX}$ shall be as specified in Equation (23-16) and Equation (23-17), respectively.

$$r_{\mathrm{LTF1}}^{(i_{\mathrm{TX}})}(t) = \frac{1}{\sqrt{N_{\mathrm{LTF}}^{\mathrm{Tone}} N_{\mathrm{STS}}}} w_{T_{\mathrm{LTF1}}}(t) \sum_{k=-N_{SR}}^{N_{SR}} \sum_{m=1}^{N_{STS}} \left( \begin{array}{l} \left[ Q_k \right]_{i_{TX},m} \Upsilon_{k,\mathrm{BW}} \left[ A_{LTF}^{k} \right]_{m,1} LTF_k \\ \quad \cdot \exp\left( j 2\pi k \Delta_F (t - T_{GI2} - T_{CS}(m)) \right) \end{array} \right) \tag{23-16}$$

$$\begin{aligned} r_{\mathrm{LTF2\sim LTF}_{\mathrm{N_{LTF}}}}^{(i_{\mathrm{TX}})}(t) = & \frac{1}{\sqrt{N_{\mathrm{LTF}}^{\mathrm{Tone}} N_{\mathrm{STS}}}} \sum_{n=1}^{N_{LTF}-1} w_{T_{\mathrm{LTF}}}(t - (n-1)T_{LTF}) \\ & \sum_{k=-N_{SR}}^{N_{SR}} \sum_{m=1}^{N_{STS}} \left( \begin{array}{l} \left[ Q_k \right]_{i_{TX},m} \Upsilon_{k,\mathrm{BW}} \left[ A_{LTF}^{k} \right]_{m,(n+1)} LTF_k \\ \quad \cdot \exp\left( j 2\pi k \Delta_F (t - (n-1)T_{LTF} - T_{GI} - T_{CS}(m)) \right) \end{array} \right) \end{aligned} \tag{23-17}$$

where

$LTF_k$ is defined in Equation (21-36), Equation (21-37), Equation (21-38), or Equation (21-39) for a 2 MHz, 4 MHz, 8 MHz, or 16 MHz transmission, respectively

$N_{SR}$ and $T_{LTF}$ are defined in Table 23-5 (Timing-related constants)

$T_{CS}(m)$ represents the cyclic shift for space-time stream $m$ with a value given in Table 23-10 (Cyclic shift values for the S1G_SHORT preamble PPDU)

$\Upsilon_{k,BW}$ is defined by Equation (23-6) to Equation (23-9)

$\Delta_F$ is defined in Table 23-5 (Timing-related constants)

$N_{STS}$ is defined in Table 23-7 (Frequently used parameters)

$A_{LTF}^{k}$ is defined in Equation (23-15)

$N_{LTF}^{Tone}$ has the value given in Table 23-8 (Tone scaling factor and guard interval duration values for PHY fields)

$Q_k$ is defined in 23.3.7 (Mathematical description of signals)

The first LTF (LTF1) field consists of two periods of the long training symbol, preceded by a double length (16 μs) cyclic prefix. The placement of the first and subsequent LTF fields in an S1G_SHORT PPDU is shown in Figure 23-1 (S1G_SHORT format(#7158)).

#### 23.3.8.2.2.5 SIG definition

The SIG field carries information required to interpret (#2095)S1G PPDUs sent with a short preamble. The structure of the SIG field for the first symbol (SIG-1) is shown in Figure 23-7 (SIG-1 structure) and for

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the second symbol (SIG-2) is shown in Figure 23-8 (SIG-2 structure). The SIG field format of NDP CMAC PPDUs is described in Figure 23-21 (SIG field format for ≥ 2 MHz NDP CMAC PPDU) (in 23.3.11).

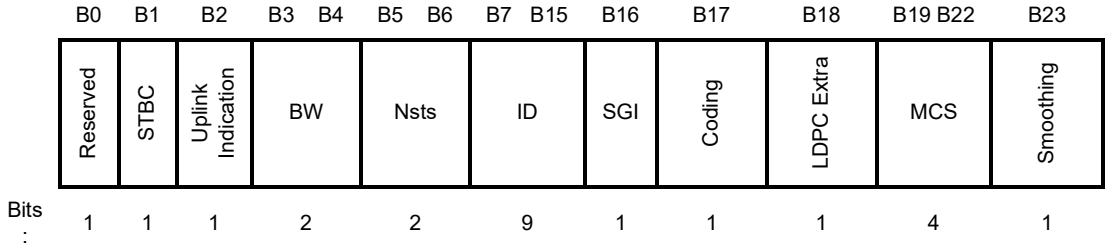


**Figure 23-7—SIG-1 structure**

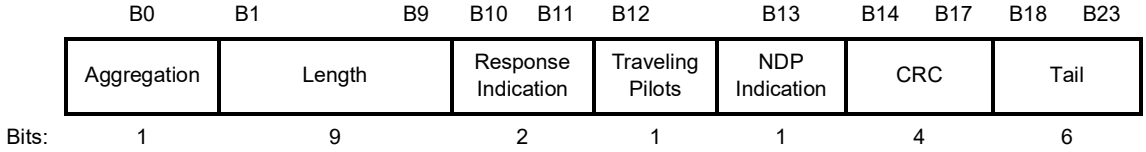


**Figure 23-8—SIG-2 structure**

The SIG field of (#2095)S1G PPDUs sent with a short preamble contains the fields listed in Table 23-12 (Fields in the SIG field of short preamble).

The SIG field is composed of two OFDM symbols, SIG-1 and SIG-2, each providing 24 data bits, as shown in Table 23-12 (Fields in the SIG field of short preamble). SIG-1 is transmitted before SIG-2. The SIG field symbols shall be BCC encoded at rate, R = 1/2, interleaved, mapped to a BPSK constellation, and have pilots inserted following the steps described in 17.3.5.6 (Convolutional encoder), 17.3.5.7 (Data interleaving), 17.3.5.8 (Subcarrier modulation mapping), and 17.3.5.9 (Pilot subcarriers), respectively.


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**Table 23-12—Fields in the SIG field of short preamble**

| Symbol | Bit | Field | Description |
|---|---|---|---|
| SIG-1 | B0 | Reserved | (#455)Reserved. Set to 1 on transmit. See 23.3.20 (PHY receive procedure) for behavior on receive. |
| | B1 | STBC | Set to 1 if all spatial streams have space-time block coding and set to 0 if no spatial streams has space-time block coding. |
| | B2 | Uplink Indication | Set to 1 if the PPDU is addressed to an AP. Set to 0 otherwise. (See TXVECTOR parameter UPLINK_INDICATION.) |
| | B3–B4 | BW | If FORMAT is S1G in TXVECTOR, set to<br>0 when CH_BANDWIDTH is CBW2<br>1 when CH_BANDWIDTH is CBW4<br>2 when CH_BANDWIDTH is CBW8<br>3 when CH_BANDWIDTH is CBW16<br><br>If FORMAT is S1G_DUP_2M in TXVECTOR, set to 0. |
| | B5–B6 | Nsts | Set to 0 for 1 space-time stream<br>Set to 1 for 2 space-time streams<br>Set to 2 for 3 space-time streams<br>Set to 3 for 4 space-time streams |
| | B7–B15 | ID | If Uplink Indication field is not present or (M118)1, B7–B15 are the partial AID to provide an abbreviated indication of the intended recipient(s) of the PSDU (see 10.21). If Uplink Indication field is(M118) 0, B7–B9 are an identifier of the BSS and B10–B15 are the partial AID.<br>(See TXVECTOR parameter COLOR and TXVECTOR parameter PARTIAL_AID.) |
| | B16 | Short GI | Set to 0 if short guard interval is not used in the Data field.<br>Set to 1 if short guard interval is used in the Data field. |
| | B17 | Coding | Set to 0 for BCC and 1 for LDPC |
| | B18 | LDPC Extra | If Coding field is 1, set to 1 if the LDPC PPDU encoding process (of an SU PPDU), results in an extra OFDM symbol (or symbols) as described in 21.3.10.5.4 (LDPC coding), otherwise set to 0.<br><br>If Coding field is 0, this field is set to 1. |
| | B19–B22 | MCS | MCS Index |
| | B23 | Smoothing | A value of 1 indicates that channel smoothing is recommended.<br>A value of 0 indicates that channel smoothing is not recommended. |

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**Table 23-12—Fields in the SIG field of short preamble *(continued)***

| Symbol | Bit | Field | Description |
|---|---|---|---|
| SIG-2 | B0 | Aggregation | Set to 1 when aggregation is ON (as indicated by AGGREGATION parameter of TXVECTOR), and 0 otherwise.<br>NOTE— S1G PPDUs are transmitted with aggregation ON when PSDU to be carried is greater than 511 octets, as defined in 10.12.5. |
| | B1–B9 | Length | When the Aggregation subfield is equal to 0, set to the number of octets in the PSDU. When the Aggregation subfield is equal to 1, set to $N_{\mathrm{SYM}_i}$ given in 23.4.3 (TXTIME and PSDU_LENGTH calculation).<br>(See TXVECTOR parameter PSDU_LENGTH.) |
| | B10–B11 | Response Indication | Set to the value obtained from the TXVECTOR parameter RESPONSE_INDICATION. The Response Indication field indicates the presence and type of (#14)the PPDU that is expected to follow SIFS after the current (#14)transmission (see 10.3.2.5). |
| | B12 | Traveling Pilots | Set to 1 to indicate traveling pilots usage in (#14)PPDU. Otherwise 0 to indicate regular pilot tone locations. |
| | B13 | NDP Indication | Differentiate the PPDU from an NDP CMAC PPDU:<br>Set to 0 to indicate that the PPDU is not an NDP CMAC PPDU. |
| | B14–B17 | CRC | CRC calculated as in 23.3.8.2.2.6 (CRC calculation for S1G SIG-A fields). |
| | B18–B23 | Tail | Used to terminate the trellis of the convolutional decoder.<br>Set to 0. |

The first and second half of the stream of 96 complex numbers generated by these steps (before pilot insertion) is divided into two groups of 48 complex numbers $d_{k,n}$, $k = 0, \ldots, 47$, where $n = 0, 1$, respectively. All the 96 complex numbers are rotated by 90° counter-clockwise relative to their original BPSK constellation points in order to accommodate differentiation of the S1G_SHORT PPDU from an S1G_1M PPDU, or from an S1G_LONG PPDU. The first rotated 48 complex numbers form the first symbol of SIG field; and the second rotated 48 complex numbers form the second symbol of SIG field, which follow the constellation diagram shown in Figure 23-9 (Data constellation in SIG field of S1G_SHORT).

**Figure 23-9—Data constellation in SIG field of S1G_SHORT**


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The time domain waveform for the SIG field in an S1G_SHORT PPDU at transmit chain $i_{TX}$ shall be as specified in Equation (23-18).

$$r_{\mathrm{SIG}}^{(i_{\mathrm{TX}})}(t) = \frac{1}{\sqrt{N_{\mathrm{SIG}}^{\mathrm{Tone}} N_{\mathrm{STS}}}} \sum_{n=0}^{1} w_{T_{\mathrm{SYML}}}\left(t - nT_{SYML}\right) \sum_{i_{BW}=0}^{N_{2MHz}-1} \left( \sum_{k=-26}^{26} \sum_{m=1}^{N_{STS}} \Upsilon_{(k-K_{shift}(i_{BW})),\mathrm{BW}} \left[Q_k\right]_{i_{TX},m} \left[P_{HTLTF}\right]_{m,1} \left(j.D_{k,n,2} + p_n P_k\right) \cdot \exp\left(j2\pi(k - K_{Shift}(i_{BW}))\Delta_F(t - nT_{SYML} - T_{GI} - T_{CS}(m))\right) \right) \tag{23-18}$$

where

$N_{2MHz}$ is the number of 2 MHz subchannels that are contained within the whole bandwidth of the current PPDU (e.g., $N_{2MHz} = 2$ for a 4 MHz PPDU)

$$K_{Shift}(i) = (N_{2MHz} - 1 - 2i).32 \tag{23-19}$$

$$D_{k,n,2} = \begin{cases} 0, & k = 0, \pm 7, \pm 21 \\ d_{M_2'(k),n}, & \text{otherwise} \end{cases} \tag{23-20}$$

where $M'_2(k)$ is defined in Equation (23-21)

$$M_2'(k) = \begin{cases} k + 26, & -26 \le k \le -22 \\ k + 25, & -20 \le k \le -8 \\ k + 24, & -6 \le k \le -1 \\ k + 23, & 1 \le k \le 6 \\ k + 22, & 8 \le k \le 20 \\ k + 21, & 22 \le k \le 26 \end{cases} \tag{23-21}$$

$p_n$ and $P_k$ are defined in 17.3.5.10 (OFDM modulation)

$T_{CS}(m)$ represents the cyclic shift for space-time stream $m$ with a value given in Table 23-10 (Cyclic shift values for the S1G_SHORT preamble PPDU)

$T_{SYML}$ is defined in Table 23-5 (Timing-related constants)

$\Upsilon_{k,BW}$ is defined by Equation (23-6) to Equation (23-9)

$\Delta_F$ is defined in Table 23-5 (Timing-related constants)

$N_{STS}$ is defined in Table 23-7 (Frequently used parameters)

$P_{HTLTF}$ is defined in 19.3.9.4.6 (HT-LTF definition)

$N_{SIG}^{Tone}$ has the value given in Table 23-8 (Tone scaling factor and guard interval duration values for PHY fields)

$Q_k$ is defined in 23.3.7 (Mathematical description of signals)

NOTE—This definition results in a QBPSK modulation on the two symbols of SIG field, where the constellation of the data tones is rotated by 90º counter-clockwise relative to the third and fourth repetitions of LTF1 field in S1G_1M preamble, and relative to the second symbol of SIG-A field of the S1G_LONG preamble, respectively, as shown in Figure 23-1 (S1G_SHORT format(#7158)) to Figure 23-3 (S1G_1M format(#7158)), to facilitate the differentiation among the three preamble formats at the receiver.

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#### 23.3.8.2.2.6 CRC calculation for S1G SIG-A fields

The CRC protects bits 0–25 of the 1 MHz SIG field and bits 0–37 of the ≥ 2 MHz SIG-A field. The value of the CRC field shall be the 1s complement of

$$crc(D) = (M(D) \oplus I(D))D^4 \bmod G(D) \quad (23\text{-}22)$$

where

$M(D) = m_0D^N + m_1D^{N-1} + \ldots + m_ND^0$ is the SIG field or SIG-A represented as a polynomial

where

$N$ is 25 for the 1 MHz SIG field and 37 for the ≥ 2 MHz SIG-A field

$m_i$ is the $i$th bit of the corresponding SIG/SIG-A field

$I(D) = \sum_{i=N-3}^{N} D^i$ are initialization values that are added modulo 2 to the first 4 bits of SIG/SIG-A field

$G(D) = D^4 + D^1 + 1$ is the CRC generating polynomial

$crc(D) = c_3D^3 + c_2D^2 + c_1D^1 + c_0D^0$

The CRC field is transmitted with $c_3$ first.

Figure 23-10 (4-bit CRC calculation) shows the operation of the CRC. First, the shift register is reset to all 1s. The bits are then passed through the XOR operation at the input. When the last bit has entered, the output is generated by shifting the bits out of the shift register, C3 first, through an inverter.

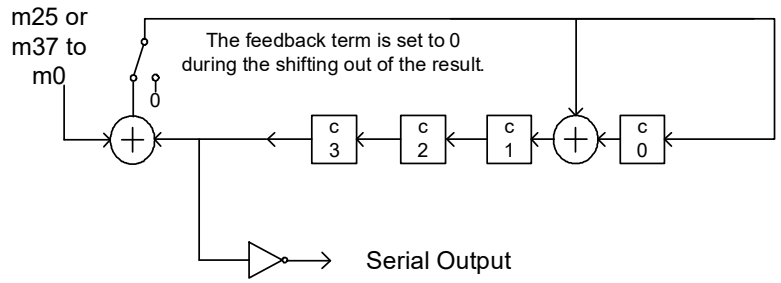


**Figure 23-10—4-bit CRC calculation**

As an example, if bits $\{m_0 \ldots m_{25}\}$ are given by {11 0110 0111 0110 1001 1110 1111}, the output bits $\{b_3 \ldots b_0\}$, where $b_3$ is output first, are {0101}.

### 23.3.8.2.3 S1G_LONG preamble

#### 23.3.8.2.3.1 General

The S1G_LONG preamble is used for the S1G_LONG PPDU format. In contrast to the S1G_1M and S1G_SHORT preambles, the S1G_LONG preamble can be used for MU transmissions, in addition to SU transmissions. The S1G_LONG preamble is structured similarly to the Mixed mode format as defined in Clause 19 (High Throughput (HT) PHY specification(#2297)) and Clause 21 (Very high throughput (VHT) PHY specification).


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#### 23.3.8.2.3.2 Omnidirectional portion

##### 23.3.8.2.3.2.1 General

The omnidirectional portion of the S1G_LONG preamble is single user and single-space-time stream modulated. By definition, to be omnidirectional, no spatial mapping (Q-matrix multiplication) is applied.

##### 23.3.8.2.3.2.2 Cyclic shift for S1G modulated fields

This subclause describes the set of cyclic shift values (defined per-antenna) to be applied to the omnidirectional portion of the S1G_LONG preamble, namely the STF, LTF, and SIG-A fields. The STF, LTF, and SIG-A fields start as single-stream during generation but are replicated up to $N_{TX}$ streams. These fields are mapped to the transmit antennas, at which point the cyclic shifts are applied. The cyclic shift values are defined in Table 23-13 (Per antenna cyclic shift values of S1G_LONG preamble PPDU), which specifies the per-antenna cyclic shift value $T_{CS}^{i_{TX}}$ for antenna $i_{TX}$ of the $N_{TX}$ total transmit antennas.

**Table 23-13—Per antenna cyclic shift values of S1G_LONG preamble PPDU**

| $T_{CS}^{i_{TX}}$ for ≥ 2 MHz, omnidirectional portion of S1G_LONG Preamble PPDU | | | | |
|---|---|---|---|---|
| Total number of Tx antennas | Cyclic shift (for Tx Antenna $i_{TX}$) (μs) | | | |
| | 1 | 2 | 3 | 4 |
| 1 | 0 | N/A | N/A | N/A |
| 2 | 0 | –4 | N/A | N/A |
| 3 | 0 | –4 | –2 | N/A |
| 4 | 0 | –4 | –2 | –6 |
| NOTE—N/A = not applicable. | | | | |

##### 23.3.8.2.3.2.3 STF definition

The STF field for 2 MHz, 4 MHz, 8 MHz, and 16 MHz are the same as the STF field in short preamble as specified in 23.3.8.2.2.3 (STF definition).

The time domain representation of the STF field signal at transmit chain $i_{TX}$ shall be as specified in Equation (23-23).

$$r_{STF}^{(i_{TX})}(t) = \frac{1}{\sqrt{N_{STF}^{Tone} N_{TX}}} w_{T_{STF}}(t) \sum_{k=-N_{SR}}^{N_{SR}} [Q_k^{(\text{omni})}]_{i_{TX},1} \Upsilon_{k,\text{BW}} S_k \exp(j2\pi k \Delta_F t) \quad (23\text{-}23)$$

where

$N_{SR}$ is 26 for a 2 MHz transmission or defined in Table 23-5 (Timing-related constants) for a 4 MHz, 8 MHz or 16 MHz transmission.

$S_k$ is defined in Equation (19-8), Equation (19-9), Equation (21-8), or Equation (21-9) for a 2 MHz, 4 MHz, 8 MHz, or 16 MHz transmission, respectively.

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$\Upsilon_{k,BW}$ is defined by Equation (23-6) to Equation (23-9)

$\Delta_F$ is defined in Table 23-5 (Timing-related constants)

$N_{STF}^{Tone}$ has the value given in tone scaling factor and guard interval duration values for PHY fields in Table 23-8 (Tone scaling factor and guard interval duration values for PHY fields)

$Q_k^{(omni)}$ is defined in 23.3.7 (Mathematical description of signals)

#### 23.3.8.2.3.2.4 LTF1 definition

The LTF1 field values for 2 MHz, 4 MHz, 8 MHz, and 16 MHz are the same as the LTF field in short preamble as specified in 23.3.8.2.2.4 (LTF definition).

The time domain representation of the LTF1 field signal at transmit chain $i_{TX}$ shall be as specified in Equation (23-24).

$$r_{\mathrm{LTF1}}^{(i_{TX})}(t) = \frac{1}{\sqrt{N_{LTF}^{Tone} N_{TX}}} w_{\mathrm{T}_{LTF1}}(t) \sum_{k=-N_{SR}}^{N_{SR}} [Q_k^{(\mathrm{omni})}]_{i_{TX},1} \Upsilon_{k,\mathrm{BW}} LTF_k \exp(j2\pi k\Delta_F(t - T_{GI2})) \quad (23\text{-}24)$$

where

$LTF_k$ is defined in Equation (21-36), Equation (21-37), Equation (21-38), or Equation (21-39) for a 2 MHz, 4 MHz, 8 MHz, or 16 MHz transmission, respectively

$N_{SR}$ is defined in Table 23-5 (Timing-related constants)

$\Upsilon_{k,BW}$ is defined by Equation (23-6) to Equation (23-9)

$\Delta_F$ is defined in Table 23-5 (Timing-related constants)

$N_{STF}^{Tone}$ has the value given in Table 23-8 (Tone scaling factor and guard interval duration values for PHY fields)

$Q_k^{(omni)}$ is defined in 23.3.7 (Mathematical description of signals).

The LTF1 field consists of two periods of the long training symbol, preceded by a double length (16 μs) cyclic prefix. The placement of the first and subsequent LTF fields in an S1G_SHORT PPDU is shown in Figure 23-1 (S1G_SHORT format(#7158)).

#### 23.3.8.2.3.2.5 SIG-A definition

The SIG-A field of the long preamble carries information required to interpret (#2095)S1G PPDUs sent using the long preamble. The structure of the SIG-A field is different for SU PPDUs and MU PPDUs. The structure of the SIG-A field for SU PPDUs for the first symbol (SIG-A1) is shown in Figure 23-11 (SIG-A1 structure for SU PPDU) and for the second symbol (SIG-A2) is shown in Figure 23-12 (SIG-A2 structure for SU PPDU). The structure of the SIG-A field for MU PPDUs for the first symbol (SIG-A1) is shown in Figure 23-13 (SIG-A1 structure for MU PPDU) and for the second symbol (SIG-A2) is shown in Figure 23-14 (SIG-A2 structure for MU PPDU).

The SIG-A field of (#2095)S1G PPDUs sent with an S1G_LONG preamble for SU contains the fields listed in Table 23-14 (Fields in the SIG-A field of S1G_LONG preamble SU PPDU) and for MU, the fields listed in Table 23-15 (Fields in the SIG-A field of S1G_LONG preamble MU PPDU).


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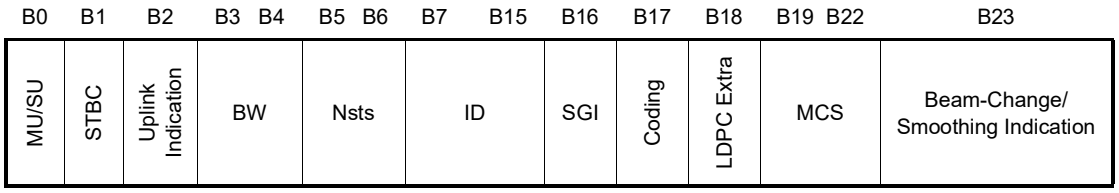


**Figure 23-11—SIG-A1 structure for SU PPDU**

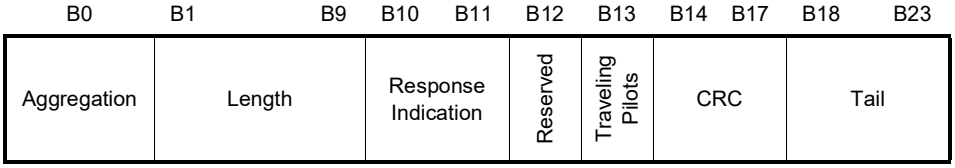


**Figure 23-12—SIG-A2 structure for SU PPDU**

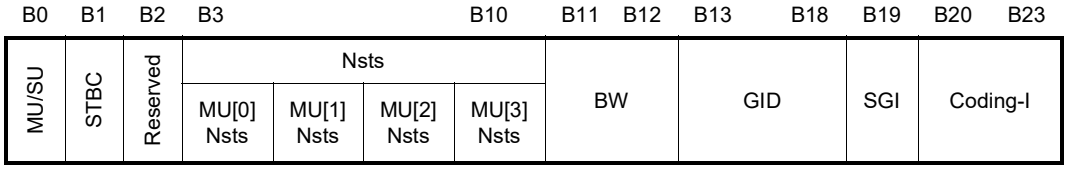


**Figure 23-13—SIG-A1 structure for MU PPDU**

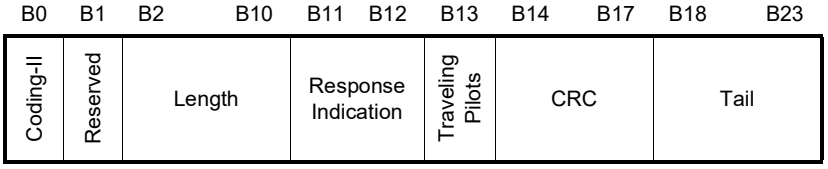


**Figure 23-14—SIG-A2 structure for MU PPDU**

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**Table 23-14—Fields in the SIG-A field of S1G_LONG preamble SU PPDU**

| Symbol | Bit | Field | Description |
|---|---|---|---|
| SIG-A1 | B0 | MU/SU | Set to 0 for SU PPDUs. |
| | B1 | STBC | Set to 1 if all spatial streams have space-time block coding and set to 0 if no spatial streams has space-time block coding. |
| | B2 | Uplink Indication | Set to 1 if the PPDU is addressed to an AP. Set to 0 otherwise. (See TXVECTOR parameter UPLINK_INDICATION.) |
| | B3–B4 | BW | Set to 0 for 2 MHz, 1 for 4 MHz, 2 for 8 MHz, 3 for 16 MHz |
| | B5–B6 | Nsts | Set to 0 for 1 space-time stream<br>Set to 1 for 2 space-time streams<br>Set to 2 for 3 space-time streams<br>Set to 3 for 4 space-time streams |
| | B7–B15 | ID | If Uplink Indication field is not present or(M118) 1, B7–B15 are the partial AID to provide an abbreviated indication of the intended recipient(s) of the PSDU (see 10.21). If Uplink Indication field is(M118) 0, B7-B9 are an identifier of the BSS and B10–B15 are the partial AID.<br>(See TXVECTOR parameter COLOR and TXVECTOR parameter PARTIAL_AID.) |
| | B16 | Short GI | Set to 0 if short guard interval is not used in the Data field.<br>Set to 1 if short guard interval is used in the Data field. |
| | B17 | Coding | Set to 0 for BCC and 1 for LDPC |
| | B18 | LDPC Extra | If Coding field is 1, set to 1 if the LDPC PPDU encoding process (of an SU PPDU), results in an extra OFDM symbol (or symbols) as described in 21.3.10.5.4 (LDPC coding), otherwise set to 0.<br><br>If Coding field is 0, this field is set to 1. |
| | B19–B22 | MCS | MCS Index |
| | B23 | Beam Change/ Smoothing Indication | If Nsts subfield indicates 1 space-time stream, this field is a Beam Change Indication field:<br>— A value of 1 indicates that the Q matrix is changed from the omnidirectional portion to the beam changeable portion of the preamble, in at least one of the nonzero subcarriers of the omnidirectional portion.<br>— A value of 0 indicates that the Q matrix is unchanged in all the nonzero subcarriers of the omnidirectional portion.<br><br>If Nsts subfield indicates more than 1 space-time stream, this field is a Smoothing Indication field:<br>— A value of 1 indicates that channel smoothing is recommended,<br>— A value of 0 indicates that channel smoothing is not recommended.<br><br>See NOTE 1.<br>See NOTE 2. |


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**Table 23-14—Fields in the SIG-A field of S1G_LONG preamble SU PPDU *(continued)***

| Symbol | Bit | Field | Description |
|---|---|---|---|
| SIG-A2 | B0 | Aggregation | Set to 1 when aggregation is ON (as indicated by AGGREGATION parameter of TXVECTOR), and 0 otherwise.<br><br>NOTE—S1G PPDUs are transmitted with aggregation ON when PSDU to be carried is greater than 511 octets, as defined in 10.12.5. |
| | B1–B9 | Length | When the Aggregation subfield is equal to 0, set to the number of octets in the PSDU. When the Aggregation subfield is equal to 1, set to $N_{\mathrm{SYM}_i}$, given in 23.4.3 (TXTIME and PSDU_LENGTH calculation). (See TXVECTOR parameter PSDU_LENGTH.) |
| | B10–B11 | Response Indication | Set to the value obtained from the TXVECTOR parameter RESPONSE_INDICATION. The Response Indication field indicates the presence and type of (#14)the PPDU that is expected to follow SIFS after the current (#14)transmission (see 10.3.2.5). |
| | B12 | Reserved | (#455)Reserved. Set to 1 on transmit. See 23.3.20 (PHY receive procedure) for behavior on receive. |
| | B13 | Traveling Pilots | Set to 1 to indicate traveling pilots usage in (#14)PPDU. Otherwise 0 to indicate regular pilot tone locations. |
| | B14–B17 | CRC | CRC calculated as in 23.3.8.2.2.6 (CRC calculation for S1G SIG-A fields). |
| | B18–B23 | Tail | Used to terminate the trellis of the convolutional decoder. Set to 0. |

NOTE 1—When the Nsts subfield indicates 1 space-time stream, if Beam Change/Smoothing Indication field is set to 0, the receiver may (#185)perform channel smoothing. Otherwise, smoothing is not recommended.

NOTE 2—The Q matrix for omnidirectional portion is $Q_k^{(\mathrm{omni})}$ as defined in 23.3.7 (Mathematical description of signals).

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**Table 23-15—Fields in the SIG-A field of S1G_LONG preamble MU PPDU**

| Symbol | Bit | Field | Description |
|---|---|---|---|
| SIG-A1 | B0 | MU/SU | Set to 1 for MU PPDUs |
| | B1 | STBC | Set to 0 in MU PPDUs. |
| | B2 | Reserved | (#455)Reserved. Set to 1 on transmit. See 23.3.20 (PHY receive procedure) for behavior on receive. |
| | B3–B10 | NSTS | NSTS is divided into 4 user positions of 2 bits each, denoted by 4 subfields MU[0] Nsts …MU[3] Nsts. User position *p*, where $0 \le p \le 3$, uses bits $B(3+2p) - B(4+2p)$. The space-time streams of user u are indicated at user position $p = \text{USER\_POSITION}[u]$ where $u = 0, 1, \ldots \text{NUM\_USERS} - 1$ and the notation A[*b*] denotes the value of array A at index *b*. Zero space-time streams are indicated at positions not listed in the USER_POSITION array.<br>Set to 0 for 0 space-time streams<br>Set to 1 for 1 space-time stream<br>Set to 2 for 2 space-time streams<br>Set to 3 for 3 space-time streams |
| | B11–B12 | BW | Set to 0 for 2 MHz, 1 for 4 MHz, 2 for 8 MHz, 3 for 16 MHz |
| | B13–B18 | GID | In an MU PPDU the Group ID is set as defined in 23.3.10.4 (Group ID) |
| | B19 | Short GI | Set to 0 if short guard interval is not used in the Data field.<br>Set to 1 if short guard interval is used in the Data field. |
| | B20–B23 | Coding-I | If the MU[0] NSTS field is nonzero, then B20 indicates coding for user 0: set to 0 for BCC, 1 for LDPC.<br>If the MU[0] NSTS field is 0, then B20 is reserved and set to 1.<br>If the MU[1] NSTS field is nonzero, then B21 indicates coding for user 1: set to 0 for BCC, 1 for LDPC.<br>If the MU[1] NSTS field is 0, then B21 is reserved and set to 1.<br>If the MU[2] NSTS field is nonzero, then B22 indicates coding for user 2: set to 0 for BCC, 1 for LDPC.<br>If the MU[2] NSTS field is 0, then B22 is reserved and set to 1.<br>If the MU[3] NSTS field is nonzero, then B23 indicates coding for user 3: set to 0 for BCC, 1 for LDPC.<br>If the MU[3] NSTS field is 0, then B23 is reserved and set to 1. |


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**Table 23-15—Fields in the SIG-A field of S1G_LONG preamble MU PPDU *(continued)***

| Symbol | Bit | Field | Description |
|---|---|---|---|
| SIG-A2 | B0 | Coding-II | Set to 1 if at least one LDPC user's PPDU encoding process results in an extra OFDM symbol (or symbols) as described in 21.3.10.5.4 (LDPC coding) and 21.3.10.5.5 (Encoding process for VHT MU PPDUs). Set to 0 otherwise. |
| | B1 | Reserved | (#455)Reserved. Set to 1 on transmit. See 23.3.20 (PHY receive procedure) for behavior on receive. |
| | B2–B10 | Length | Set to the $N_{sym}$, given in 23.4.3 (TXTIME and PSDU_LENGTH calculation).<br><br>NOTE— A-MPDU is always used for MU PPDUs. |
| | B11–B12 | Response Indication | Set to the value obtained from the TXVECTOR parameter RESPONSE_INDICATION. The Response Indication field indicates the presence and type of (#14)the PPDU that is expected to follow SIFS after the current (#14)transmission (see 10.3.2.5). |
| | B13 | Traveling Pilots | Set to 1 to indicate traveling pilots usage in (#14)PPDU. Otherwise 0 to indicate regular pilot tone locations. |
| | B14–B17 | CRC | CRC calculated as in 23.3.8.2.2.6 (CRC calculation for S1G SIG-A fields). |
| | B18–B23 | Tail | Used to terminate the trellis of the convolutional decoder.<br>Set to 0. |

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The SIG-A field is composed of two OFDM symbols, SIG-A1 and SIG-A2, each containing 24 data bits, as shown in Table 23-14 (Fields in the SIG-A field of S1G_LONG preamble SU PPDU). SIG-A1 is transmitted before SIG-A2. The SIG-A field symbols shall be BCC encoded at rate, R = 1/2, interleaved, mapped to a BPSK constellation, and have pilots inserted following the steps described in 17.3.5.6 (Convolutional encoder), 17.3.5.7 (Data interleaving), 17.3.5.8 (Subcarrier modulation mapping), and 17.3.5.9 (Pilot subcarriers), respectively. The first and second half of the stream of 96 complex numbers generated by these steps (before pilot insertion) is divided into two groups of 48 complex numbers $d_{k,n}$, $k = 0, \ldots, 47$, where $n = 0, 1$, respectively. The first group of the 48 complex numbers are rotated by 90° counter-clockwise relative to their original BPSK constellation points in order to accommodate differentiation of the S1G_LONG PPDU from an S1G_1M PPDU. The second group of the 48 complex numbers without rotations may be used to accommodate differentiation of the S1G_LONG PPDU from an S1G_SHORT PPDU. The first rotated 48 complex numbers form the first symbol of SIG-A; and the second unrotated 48 complex numbers form the second symbol of SIG-A, which follow the constellation diagram shown in Figure 23-15 (Data constellation in SIG-A field of S1G_LONG).

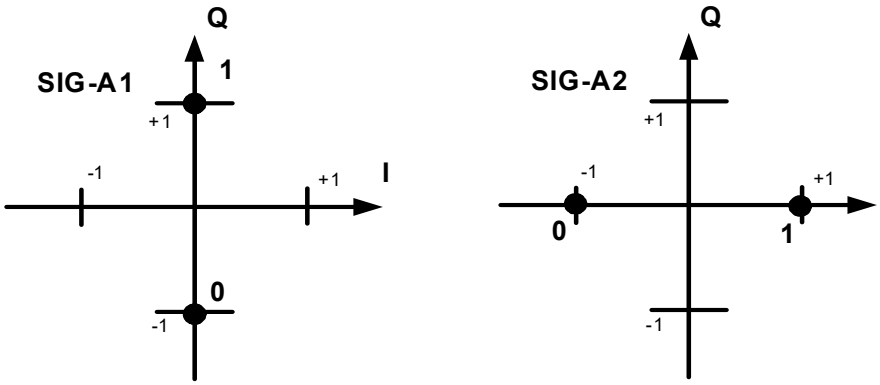


**Figure 23-15—Data constellation in SIG-A field of S1G_LONG**

The time domain waveform for the SIG-A field in an S1G_LONG PPDU at transmit chain $i_{TX}$ shall be as specified in Equation (23-25).

$$r_{SIG-A}^{(i_{TX})}(t) = \frac{1}{\sqrt{N_{SIG-A}^{Tone} N_{TX}}} \sum_{n=0}^{1} w_{T_{SYML}}(t - nT_{SYML}) \sum_{i_{BW}=0}^{N_{2MHz}-1} \left( \sum_{k=-26}^{26} [Q_k^{(\text{omni})}]_{i_{TX},1} \Upsilon_{(k-K_{Shift}(i_{BW})),BW}((-1)^n j^{n+1} D_{k,n,2} + p_n P_k) \exp(j2\pi(k - K_{Shift}(i_{BW}))\Delta_F(t - nT_{SYML} - T_{GI})) \right) \quad (23\text{-}25)$$

where

$N_{2MHz}$, $K_{Shift}(i)$, and $D_{k,n,2}$ are the same as those defined in 23.3.8.2.2.5 (SIG definition)

$p_n$ and $P_k$ are defined in 17.3.5.10 (OFDM modulation)

$T_{SYML}$ is defined in Table 23-5 (Timing-related constants)

$\Upsilon_{k,BW}$ is defined by Equation (23-6) to Equation (23-9)

$\Delta_F$ is defined in Table 23-5 (Timing-related constants)

$N_{SIG\text{-}A}^{Tone}$ has the value given in tone scaling factor and guard interval duration values for PHY fields in Table 23-8 (Tone scaling factor and guard interval duration values for PHY fields)


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$Q_k^{(omni)}$ is defined in 23.3.7 (Mathematical description of signals)

NOTE—As shown in Figure 23-1 (S1G_SHORT format(#7158)) to Figure 23-3 (S1G_1M format(#7158)), this definition results in a QBPSK modulation on the first symbol of SIG-A field, where the constellation of the data tones is rotated by 90º counter-clockwise relative to the third repetition of LTF1 field in S1G_1M preamble, facilitating its differentiation from S1G_1M; and the second symbol of SIG-A field is BPSK modulated, facilitating its differentiation from S1G_SHORT.

#### 23.3.8.2.3.3 Beamchangeable portion

##### 23.3.8.2.3.3.1 General

The beamchangeable portion of the S1G_LONG preamble can be either single-user or multi-user modulated with single or multiple space-time streams. Beamforming can be applied through spatial mapping (Q-matrix multiplication) starting with the beamchangeable portion of the preamble and continuing into the Data field.

Beamchangeable portion of the long preamble could be either single user or multi-user modulated.

##### 23.3.8.2.3.3.2 Cyclic shift for S1G modulated fields

This subclause describes the set of cyclic shift values (defined per space-time stream) to be applied to the beamchangeable portion of the S1G_LONG preamble, namely the D-STF, D-LTF, and SIG-B fields. In a transmission, these fields start as single stream and are replicated up to $N_{STS,total}$ streams at which point the cyclic shifts are applied. The cyclic shift values are defined in Table 23-16 (Per space-time stream cyclic shift values of S1G_LONG preamble PPDU), which specifies the per-stream cyclic shift value $T_{CS}(n)$ for space-time stream *n* out of $N_{STS,total}$ total space-time streams.

When the S1G_LONG preamble PPDU is used for an MU transmission, the cyclic shifts of the beamchangeable portion are applied sequentially, first per user and then per space-time stream up to the total number of users and space-time streams $N_{STS,total}$ as follows: the cyclic shift of the space-time stream number m for user *u* is given by $T_{CS}(M_u + m)$, of the row corresponding to $N_{STS,total}$ in Table 23-16 (Per space-time stream cyclic shift values of S1G_LONG preamble PPDU). In this case, the index *n* takes into account the cyclic shifts already applied to space-time streams of prior users ($M_u$), and the space-time stream index ($m$) of the current user *u* in the sequence.

$M_u$ is given by Table 23-7 (Frequently used parameters).

**Table 23-16—Per space-time stream cyclic shift values of S1G_LONG preamble PPDU**

| $T_{CS,S1G}^{long}(n)$ for ≥2 MHz, beam changeable portion of S1G_LONG preamble PPDU | | | | |
|---|---|---|---|---|
| **Total number of space-time streams ($N_{STS,total}$)** | **Cyclic for space-time stream n (μs)** | | | |
| | **1** | **2** | **3** | **4** |
| 1 | 0 | N/A | N/A | N/A |
| 2 | 0 | –4 | N/A | N/A |
| 3 | 0 | –4 | –2 | N/A |
| 4 | 0 | –4 | –2 | –6 |
| NOTE—N/A = not applicable. | | | | |

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#### 23.3.8.2.3.3.3 D-STF definition

The main purpose of the D-STF field is to improve automatic gain control estimation in an SU or MU MIMO transmission. The duration of the D-STF field is 40 μs. The frequency domain sequence $\{S_k\}$ used to construct the D-STF field is the same as the STF field in short or long preamble as indicated in 23.3.8.2.2.3 (STF definition).

The time domain representation of the D-STF field signals at transmit chain $i_{TX}$ shall be as specified in Equation (23-26).

$$r_{\text{D-STF}}^{(i_{\text{TX}})}(t) = \frac{1}{\sqrt{N_{\text{D-STF}}^{\text{Tone}} N_{\text{STS,total}}}} w_{T_{\text{D-STF}}}(t) \sum_{k=-N_{SR}}^{N_{SR}} \sum_{u=0}^{N_u-1} \sum_{m=1}^{N_{STS,u}} \left( \begin{array}{l} \left[Q_k\right]_{i_{TX},(M_u+m)} \Upsilon_{k,\text{BW}} \cdot S_k \\ \cdot \exp\left(j2\pi k\Delta_F (t - T_{CS}(M_u+m))\right) \end{array} \right) \quad (23\text{-}26)$$

where

$N_{SR}$ is defined in Table 23-5 (Timing-related constants)

$T_{CS(m)}$ represents the cyclic shift for space-time stream *m* with a value given in Table 23-16 (Per space-time stream cyclic shift values of S1G_LONG preamble PPDU)

$\Upsilon_{k,\text{BW}}$ is defined by Equation (23-6) to Equation (23-9)

$\Delta_F$ is defined in Table 23-5 (Timing-related constants)

$N_{STS,total}$, $N_{STS,u}$, $N_u$, and $M_u$ are defined in Table 23-7 (Frequently used parameters).

$N_{\text{D-STF}}^{\text{Tone}}$ has the value given in tone scaling factor and guard interval duration values for PHY fields in Table 23-8 (Tone scaling factor and guard interval duration values for PHY fields)

$Q_k$ is defined in 23.3.7 (Mathematical description of signals)

The duration of the D-STF field is $T_{\text{D-STF}}$ regardless of the Short GI field setting in SIG-A.

#### 23.3.8.2.3.3.4 D-LTF definition

The D-LTF field values for 2 MHz, 4 MHz, 8 MHz, and 16 MHz are the same as the LTF field in short preamble as specified in 23.3.8.2.2.4 (LTF definition).

The generation of the time domain D-LTF field symbols per frequency segment is shown in Figure 23-6 (Generation of LTF symbols).

The time domain representation of the D-LTF field signals at transmit chain $i_{TX}$ shall be as specified in Equation (23-27).

$$\begin{aligned} r_{\text{D-LTF}}^{(i_{\text{TX}})}(t) = & \frac{1}{\sqrt{N_{\text{D-LTF}}^{\text{Tone}} N_{\text{STS,total}}}} \sum_{n=0}^{N_{LTF}-1} w_{T_{\text{D-LTF}}}(t - nT_{D-LTF}) \\ & \sum_{k=-N_{SR}}^{N_{SR}} \sum_{u=0}^{N_u-1} \sum_{m=1}^{N_{STS,u}} \left( \begin{array}{l} \left[Q_k\right]_{i_{TX},(M_u+m)} \Upsilon_{k,\text{BW}} \cdot \left[A_{LTF}^k\right]_{(M_u+m),(n+1)} LTF_k \\ \cdot \exp\left(j2\pi k\Delta_F (t - nT_{D-LTF} - T_{GI} - T_{CS}(M_u+m))\right) \end{array} \right) \end{aligned} \quad (23\text{-}27)$$

where

$N_{SR}$ is defined in Table 23-5 (Timing-related constants)



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$T_{CS(m)}$ represents the cyclic shift for space-time stream $m$ with a value given in Table 23-16 (Per space-time stream cyclic shift values of S1G_LONG preamble PPDU)

$\Upsilon_{k,\mathrm{BW}}$ is defined by Equation (23-6) to Equation (23-9)

$\Delta_F$ is defined in Table 23-5 (Timing-related constants)

$N_{STS,total}$, $N_{STS,u}$, $N_u$, and $M_u$ are defined in Table 23-7 (Frequently used parameters)

$A_{LTF}^{k}$ is defined in Equation (23-15)

$N_{\mathrm{D\text{-}STF}}^{\mathrm{Tone}}$ has the value given in tone scaling factor and guard interval duration values for PHY fields in Table 23-8 (Tone scaling factor and guard interval duration values for PHY fields)

$Q_k$ is defined in 23.3.7 (Mathematical description of signals)

As indicated by Equation (23-27), the duration of each symbol of the D-LTF field is $T_{\mathrm{D\text{-}LTF}}$ regardless of the Short GI field setting in SIG-A.

The generation of the time domain D-LTF field symbols is the same as Figure 23-6 (Generation of LTF symbols), with $N_{STS}$ replaced by $N_{STS,total}$.

#### 23.3.8.2.3.3.5 SIG-B definition

If the SU/MU Indication subfield in SIG-A field is(M118) 0 (SU), then SIG-B field is one symbol that is identical to the first D-LTF field (D-LTF1). In this case, the time domain representation of the SIG-B field at transmit chain $i_{TX}$ shall be as specified in Equation (23-27) with $n$=0.

If the SU/MU Indication subfield in SIG-A field is(M118) 1 (MU), then SIG-B field is one symbol and contains 26 bits in a 2 MHz PPDU, 27 bits in a 4 MHz PPDU and 29 bits in 8 MHz and 16 MHz PPDUs for each user. The fields in the SIG-B field are listed in Table 23-17 (Fields in the SIG-B field for MU PPDU).

**Table 23-17—Fields in the SIG-B field for MU PPDU**

| Field | Bit Allocation | | | | Description |
|---|---|---|---|---|---|
| | 2 MHz | 4 MHz | 8 MHz | 16 MHz | |
| MCS | B0–B3 | B0–B3 | B0–B3 | B0–B3 | Per-user MCS in MU-MIMO |
| Reserved | B4–B11 | B4–B12 | B4–B14 | B4–B14 | (#455)Set to all 1s on transmit. See 23.3.20 (PHY receive procedure) for behavior on receive. |
| CRC | B12–B19 | B13–B20 | B15–B22 | B15–B22 | |
| Tail | B20–B25 | B21–B26 | B23–B28 | B23–B28 | All 0s |

The 8-bit CRC is calculated according to the procedure described in 23.3.8.2.3.3.6 (CRC calculation for SIG SIG-B field).

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In this case, the repetition, encoding, interleaving and modulation flow for the data subcarriers of SIG-B field in 2 MHz, 4 MHz, 8 MHz, and 16 MHz are identical to those specified for 20 MHz, 40 MHz, 80 MHz, and 160 MHz, respectively, as shown in 21.3.8.3.6 (VHT-SIG-B definition). Different from the VHT-SIG-B field defined in Clause 21 (Very high throughput (VHT) PHY specification), the pilot subcarriers of SIG-B field are mapped by the first column of $P_{\mathrm{HTLTF}}$ matrix to $N_{\mathrm{STS}}$, total space-time streams, and the pilot polarity of the SIG-B symbol is $p_2$ instead of $p_3$. The time domain representation for SIG-B field signal at transmit chain $i_{TX}$ shall be as specified in Equation (23-28).

$$r_{\mathrm{SIG\text{-}B}}^{(i_{\mathrm{TX}})}(t)=\frac{1}{\sqrt{N_{\mathrm{SIG\text{-}B}}^{\mathrm{Tone}}N_{\mathrm{STS,total}}}}w_{T_{\mathrm{SIG\text{-}B}}}(t)\sum_{k=-N_{SR}}^{N_{SR}}\sum_{u=0}^{N_u-1}\sum_{m=1}^{N_{STS,u}}\left(\begin{array}{l}\left[Q_k\right]_{i_{TX},(M_u+m)}\Upsilon_{k,\mathrm{BW}}\cdot\left[P_{HTLTF}\right]_{(M_u+m),1}\left(D_{k,BW}^{(u)}+p_2P_0^k\right)\\ \cdot\exp\left(j2\pi k\Delta_F(t-T_{GI}-T_{CS}(M_u+m))\right)\end{array}\right) \tag{23-28}$$

where

$N_{SR}$ is defined in Table 23-5 (Timing-related constants)

$T_{CS(m)}$ represents the cyclic shift for space-time stream $m$ with a value given in Table 23-16 (Per space-time stream cyclic shift values of S1G_LONG preamble PPDU)

$\Upsilon_{k,\mathrm{BW}}$ is defined by Equation (23-6) to Equation (23-9)

$\Delta_F$ is defined in Table 23-5 (Timing-related constants)

$N_{STS,total}$ , $N_{STS,u}$ , $N_u$ , and $M_u$ are defined in Table 23-7 (Frequently used parameters)

$P_{HTLTF}$ is defined in Equation (19-27) in 19.3.9.4.6 (HT-LTF definition)

$p_n$ is defined in 17.3.5.10 (OFDM modulation)

$P_n^k$ is defined in 21.3.10.10 (Pilot subcarriers)

$N_{\mathrm{SIG\text{-}B}}^{\mathrm{Tone}}$ has the value given in tone scaling factor and guard interval duration values for PHY fields in Table 23-8 (Tone scaling factor and guard interval duration values for PHY fields)

$Q_k$ is defined in 23.3.7 (Mathematical description of signals)

For a 2 MHz transmission,

$$D_{k,2}^{(u)}=\begin{cases}0, k=0,\pm7,\pm21\\ d_{M_2'(k)}^{(u)}, \text{otherwise}\end{cases} \tag{23-29}$$

$$M_2'(k)=\begin{cases}k+28, & -28\le k\le -22\\ k+27, & -20\le k\le -8\\ k+26, & -6\le k\le -1\\ k+25, & 1\le k\le 6\\ k+24, & 8\le k\le 20\\ k+23, & 22\le k\le 28\end{cases} \tag{23-30}$$


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For a 4 MHz transmission,

$$D_{k,4}^{(u)} = \begin{cases} 0, k = 0, \pm 1, \pm 11, \pm 25, \pm 53 \\ d_{M_4'(k)}^{(u)}, \text{otherwise} \end{cases} \quad (23\text{-}31)$$

$$M_4'(k) = \begin{cases} k+58, & -58 \le k \le -54 \\ k+57, & -52 \le k \le -26 \\ k+56, & -24 \le k \le -12 \\ k+55, & -10 \le k \le -2 \\ k+52, & 2 \le k \le 10 \\ k+51, & 12 \le k \le 24 \\ k+50, & 26 \le k \le 52 \\ k+49, & 54 \le k \le 58 \end{cases} \quad (23\text{-}32)$$

For an 8 MHz transmission,

$$D_{k,8}^{(u)} = \begin{cases} 0, k = 0, \pm 1, \pm 11, \pm 39, \pm 75, \pm 103 \\ d_{M_8'(k)}^{(u)}, \text{otherwise} \end{cases} \quad (23\text{-}33)$$

$$M_8'(k) = \begin{cases} k+122, & -122 \le k \le -104 \\ k+121, & -102 \le k \le -76 \\ k+120, & -74 \le k \le -40 \\ k+119, & -38 \le k \le -12 \\ k+118, & -10 \le k \le -2 \\ k+115, & 2 \le k \le 10 \\ k+114, & 12 \le k \le 38 \\ k+113, & 40 \le k \le 74 \\ k+112, & 76 \le k \le 102 \\ k+111, & 104 \le k \le 122 \end{cases} \quad (23\text{-}34)$$

For a 16 MHz transmission

$$D_{k,16}^{(u)} = \begin{cases} 0, k = 0, \pm 1, \pm 2, \pm 3, \pm 4, \pm 5, \pm 25, \pm 53, \pm 89, \pm 117, \pm 127, \pm 128, \pm 129, \pm 139, \pm 167, \pm 203, \pm 231 \\ d_{M_{16}'(k)}^{(u)}, \text{otherwise} \end{cases}$$

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$$M'_{16}(k) = \begin{cases} k+250, & -250 \le k \le -232 \\ k+249, & -230 \le k \le -204 \\ k+248, & -202 \le k \le -168 \\ k+247, & -166 \le k \le -140 \\ k+246, & -138 \le k \le -130 \\ k+243, & -126 \le k \le -118 \\ k+242, & -116 \le k \le -90 \\ k+241, & -88 \le k \le -54 \\ k+240, & -52 \le k \le -26 \\ k+239, & -24 \le k \le -6 \\ k+228, & 6 \le k \le 24 \\ k+227, & 26 \le k \le 52 \\ k+226, & 54 \le k \le 88 \\ k+225, & 90 \le k \le 116 \\ k+224, & 118 \le k \le 126 \\ k+221, & 130 \le k \le 138 \\ k+220, & 140 \le k \le 166 \\ k+219, & 168 \le k \le 202 \\ k+218, & 204 \le k \le 230 \\ k+217, & 232 \le k \le 250 \end{cases} \quad (23\text{-}35)$$

#### 23.3.8.2.3.3.6 CRC calculation for SIG SIG-B field

The CRC protects the MCS and Reserved field bits of the SIG-B field. The value of the CRC field shall be the 1s complement of

$$crc(D) = (M(D) \oplus I(D))D^8 \bmod G(D) \quad (23\text{-}36)$$

where

$M(D) = m_0 D^N + m_1 D^{N-1} + \ldots + m_N D^0$ is the MCS and Reserved field appended (bits 0–$N$ of SIG B) and represented as a polynomial

where

$N$ is 11, 12, 14, and 14 for 2 MHz, 4 MHz, 8 MHz, and 16 MHz SIG-B fields, respectively

$m_i$ is the $i$th bit of the corresponding SIG-B field

$I(D) = \sum_{i=N-7}^{N} D^i$ are the initialization values that are added to the first 8 bits of the SIG-B field

$G(D) = D^8 + D^2 + D^1 + 1$ is the CRC generating polynomial

$crc(D) = c_0 D^7 + c_1 D^6 + \ldots + c_6 D^1 + c_7$

The CRC field is transmitted with $c_7$ first.

Figure 19-8 (HT-SIG CRC calculation) in 19.3.9.4.4 (CRC calculation for HT-SIG) shows the operation of the CRC using the same generator polynomial. For SIG-B CRC operation specifically, the bits are(M118) input serially from $m_N$ to $m_0$.


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### 23.3.8.3 Format for 1 MHz

#### 23.3.8.3.1 Introduction

This subclause describes the preamble format used for non-duplicate S1G PPDUs of 1 MHz and duplicate S1G_DUP_1M PPDUs.

#### 23.3.8.3.2 Cyclic shift for S1G modulated fields

The cyclic shift values defined in this subclause apply to the STF, LTF, SIG and Data fields of the S1G_1M PPDU. Throughout the S1G_1M preamble, cyclic shifts are applied to prevent beamforming when similar signals are transmitted in different space-time streams. The STF, LTF, and SIG fields start as single stream during generation but are replicated up to $N_{STS,total}$ streams. For the LTF, these replicated streams undergo P-matrix mapping prior to CSD application as shown in Figure 23-6 (Generation of LTF symbols). For the STF and SIG the CSDs are applied per stream immediately after replication. The same cyclic shift is applied to the $N_{STS,total}$ streams during the transmission of the Data field of the S1G_1M PPDU. The cyclic shift value $T_{CS}(n)$ for space-time stream $n$ out of $N_{STS,total}$ total space-time streams is shown in Table 23-18 (Cyclic shift values of S1G_1M PPDU).

**Table 23-18—Cyclic shift values of S1G_1M PPDU**

| $T_{CS}(n)$ values for S1G_1M PPDU | | | | |
|---|---|---|---|---|
| **Total number of space-time streams ($N_{STS,total}$)** | **Cyclic shift for space-time stream *n* (μs)** | | | |
| | **1** | **2** | **3** | **4** |
| 1 | 0 | — | — | — |
| 2 | 0 | –4 | — | — |
| 3 | 0 | –4 | –1 | — |
| 4 | 0 | –4 | –1 | –5 |

#### 23.3.8.3.3 STF definition

The STF field in S1G_1M preamble is repeated with 4 OFDM symbols, i.e., twice the duration of the STF fields in S1G_SHORT preamble and S1G_LONG preamble.

The time domain representation of the STF field signal at transmit chain $i_{TX}$ shall be as specified in Equation (23-37).

$$r_{\mathrm{STF}}^{(i_{\mathrm{TX}})}(t) = \frac{\alpha(\mathrm{MCS})}{\sqrt{N_{\mathrm{STF}}^{\mathrm{Tone}} N_{\mathrm{STS}}}} w_{T_{\mathrm{STF}}}(t) \sum_{k=-N_{SR}}^{N_{SR}} \sum_{m=1}^{N_{STS}} \left[Q_k\right]_{i_{TX},m} \left[P_{HTLTF}\right]_{m,1} \cdot S_k \exp\left(j2\pi k\Delta_F (t - T_{CS}(m))\right) \quad (23\text{-}37)$$

where

$N_{SR}$ is defined in Table 23-5 (Timing-related constants)

$T_{CS}(m)$ represents the cyclic shift for space-time stream $m$ with a value given in Table 23-18 (Cyclic shift values of S1G_1M PPDU)

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$\Delta_F$ is defined in Table 23-5 (Timing-related constants)

$N_{STS}$ is defined in Table 23-7 (Frequently used parameters)

$P_{HTLTF}$ is defined in Equation (19-27) in 19.3.9.4.6 (HT-LTF definition)

$N_{\mathrm{STF}}^{\mathrm{Tone}}$ has the value given in tone scaling factor and guard interval duration values for PHY fields in Table 23-8 (Tone scaling factor and guard interval duration values for PHY fields)

$S_k$ has nonzero values $[0.5, -1, 1, -1, -1, -0.5] \times (1+j) \times \sqrt{2/3}$ on tones $k = [-12,-8,-4,4,8,12]$, respectively

$\alpha(MCS)$ is an MCS dependent scaling factor, with the following value $\alpha(MCS) = \begin{cases} \sqrt{2}, & \text{MCS=10} \\ 1, & \text{otherwise} \end{cases}$

$Q_k$ is defined in 23.3.7 (Mathematical description of signals)

### 23.3.8.3.4 LTF definition

The duration of the first LTF (LTF1) field in S1G_1M preamble is of 4 OFDM symbols with repetitions, i.e., twice the duration of the LTF1 fields in S1G_LONG preamble and S1G_SHORT preamble. The first two repetitions have the same structure as the LTF1 field in S1G_LONG preamble and S1G_SHORT preamble, i.e., they consist of two periods of the long training symbol, preceded by a double length (16 μs) cyclic prefix. Each of the last two repetitions of LTF1 field consists one period of the long training symbol preceded by a normal length (8 μs) cyclic prefix. The duration of the each of the remaining LTFs in S1G_1M preamble is of one OFDM symbol.

The placement of the first and subsequent LTFs in an S1G_1M PPDU is shown in Figure 23-3 (S1G_1M format(#7158)).

The generation of the time domain LTF symbols is the same as Table 23-7 (Frequently used parameters).

The time domain representation of the first two repetitions of the LTF1 field, and the last two repetitions of the LTF1 field shall be as specified in Equation (23-38) and Equation (23-39), respectively

$$r_{\mathrm{LTF1\_1,2}}^{(i_{\mathrm{TX}})}(t) = \frac{1}{\sqrt{N_{\mathrm{LTF}}^{\mathrm{Tone}} N_{\mathrm{STS}}}} w_{T_{\mathrm{LTF1}}}(t) \sum_{k=-N_{SR}}^{N_{SR}} \sum_{m=1}^{N_{STS}} \left( \begin{array}{l} \left[ Q_k \right]_{i_{TX},m} \Upsilon_{k,\mathrm{BW}} \left[ A_{LTF}^{k} \right]_{m,1} LTF_k \\ \cdot \exp\left( j2\pi k \Delta_F (t - T_{GI2} - T_{CS}(m)) \right) \end{array} \right) \quad (23\text{-}38)$$

$$r_{\mathrm{LTF1\_3,4}}^{(i_{\mathrm{TX}})}(t) = \frac{1}{\sqrt{N_{\mathrm{LTF}}^{\mathrm{Tone}} N_{\mathrm{STS}}}} w_{T_{\mathrm{LTF}}}(t) \sum_{k=-N_{SR}}^{N_{SR}} \sum_{m=1}^{N_{STS}} \left( \begin{array}{l} \left[ Q_k \right]_{i_{TX},m} \Upsilon_{k,\mathrm{BW}} \left[ A_{LTF}^{k} \right]_{m,1} LTF_k \\ \cdot \exp\left( j2\pi k \Delta_F (t - T_{GI} - T_{CS}(m)) \right) \end{array} \right) \quad (23\text{-}39)$$

where

$N_{SR}$, $T_{LTF1}$, and $T_{LTF}$ are defined in Table 23-5 (Timing-related constants)

$T_{CS(m)}$ represents the cyclic shift for space-time stream $m$ with a value given in Table 23-18 (Cyclic shift values of S1G_1M PPDU)

$\Upsilon_{k,\mathrm{BW}}$ is defined by Equation (23-6) to Equation (23-9)

$\Delta_F$ is defined in Table 23-5 (Timing-related constants)

$N_{STS}$ is defined in Table 23-7 (Frequently used parameters)


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$N_{\mathrm{LTF}}^{\mathrm{Tone}}$ has the value given in tone scaling factor and guard interval duration values for PHY fields in Table 23-8 (Tone scaling factor and guard interval duration values for PHY fields)

$A_{LTF}^{k}$ is defined in Equation (23-40)

$Q_k$ is defined in 23.3.7 (Mathematical description of signals)

$$A_{LTF}^{k} = \begin{cases} \left[P_{HTLTF}\right]_{*,1} \times \left[1 \quad 1 \quad 1 \quad 1\right], \text{ if } k \in K_{\text{Pilot\_Fix}} \\ P_{HTLTF}, \text{ otherwise} \end{cases} \tag{23-40}$$

where

$K_{\text{Pilot\_Fix}}$ is the subcarrier indices for the fixed pilot tones. For a 1 MHz transmission, $K_{\text{Pilot\_Fix}} = \{\pm 7\}$ .

$[P_{HTLTF}]_{*,1}$ is the first column of the $P_{HTLTF}$ matrix.

$LTF_{\text{-16:15}} = \{0, 0, 0, 1, -1, 1, -1, -1, 1, -1, 1, 1, -1, 1, 1, 1, 0, -1, -1, -1, 1, -1, -1, -1, 1, -1, 1, 1, 1, -1, 0, 0\}$

NOTE 1—This LTF sequence is chosen to be orthogonal to both halves of the 2 MHz LTF sequence in order to facilitate the differentiation of S1G_1M preambles from S1G_SHORT and S1G_LONG preambles. The orthogonality metric used to select the sequences satisfied the criteria

$$\sum_{k} A(k)B(k)A(k+1)^{*}B(k+1)^{*} = 0$$

where {A} and {B} are the 1 MHz sequence and either of the halves of the 2 MHz sequence, and where k=1,2,3,...,16,18,19,...,31 skipping the 1 MHz DC location on k=17.

NOTE 2—This definition results in a BPSK modulation on the last two symbols of LTF1 field, to facilitate the differentiation of S1G_1M preambles from S1G_SHORT and S1G_LONG preamble.

The time domain representation of the (#7158)LTF2~LTF$N_{\mathrm{LTF}}$ field signals at transmit chain $i_{TX}$ shall be as specified in Equation (23-41).

$$r_{\mathrm{LTF2\sim LTF}_{N_{\mathrm{LTF}}}}^{(i_{\mathrm{TX}})}(t) = \frac{1}{\sqrt{N_{\mathrm{LTF}}^{\mathrm{Tone}} N_{\mathrm{STS}}}} \sum_{n=1}^{N_{LTF}-1} w_{T_{\mathrm{LTF}}}\left(t-(n-1)T_{LTF}\right) \sum_{k=-N_{SR}}^{N_{SR}} \sum_{m=1}^{N_{STS}} \left( \begin{array}{l} \left[Q_k\right]_{i_{TX},m} \cdot \left[A_{LTF}^{k}\right]_{m,(n+1)} LTF_k \\ \quad \cdot \exp\left(j2\pi k \Delta_F (t-(n-1)T_{LTF} - T_{GI} - T_{CS}(m))\right) \end{array} \right) \tag{23-41}$$

where

$N_{SR}$ and $T_{LTF}$ are defined in Table 23-5 (Timing-related constants)

$T_{CS(m)}$ represents the cyclic shift for space-time stream $m$ with a value given in Table 23-16 (Per space-time stream cyclic shift values of S1G_LONG preamble PPDU)

$\Delta_F$ is defined in Table 23-5 (Timing-related constants)

$N_{STS}$ is defined in Table 23-7 (Frequently used parameters)

$A_{LTF}^{k}$ is defined in Equation (23-40)

$N_{\mathrm{LTF}}^{\mathrm{Tone}}$ has the value given in tone scaling factor and guard interval duration values for PHY fields in Table 23-8 (Tone scaling factor and guard interval duration values for PHY fields)

$Q_k$ is defined in 23.3.7 (Mathematical description of signals)

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#### 23.3.8.3.5 SIG definition

The SIG field carries information required to interpret S1G_1M PPDUs. The structure of the 6 symbol SIG field (which carries 6 information bits per symbol) is shown in Figure 23-16 (Structure of the 6 symbol SIG field of S1G_1M PPDU). Note that unlike other SIG field structures the indexing of the bits incorporates all the SIG field symbols, i.e., B0–B5 denote the first symbol, B6–B11 the second, and so on. The SIG field format of NDP CMAC PPDUs is described in Figure 23-20 (SIG field format for 1 MHz NDP CMAC PPDU) and Figure 23-21 (SIG field format for ≥ 2 MHz NDP CMAC PPDU) (in 23.3.11).

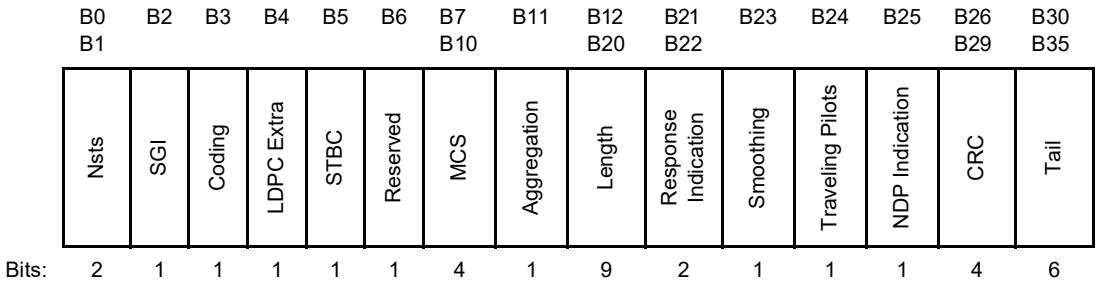


**Figure 23-16—Structure of the 6 symbol SIG field of S1G_1M PPDU**

The SIG field of S1G_1M PPDU contains the fields listed in Table 23-19 (Fields in the SIG field of S1G_1M PPDU).

**Table 23-19—Fields in the SIG field of S1G_1M PPDU**

| Symbol | Bit | Field | Description |
|---|---|---|---|
| SIG-1 | B0–B1 | NSTS | Set to 0 for 1 space-time stream<br>Set to 1 for 2 space-time streams<br>Set to 2 for 3 space-time streams<br>Set to 3 for 4 space-time streams |
| | B2 | Short GI | Set to 0 if short guard interval is not used in the Data field.<br>Set to 1 if short guard interval is used in the Data field. |
| | B3 | Coding | Set to 0 for BCC and 1 for LDPC |
| | B4 | LDPC Extra | If Coding field is 1, set to 1 if the LDPC PPDU encoding process (of an SU PPDU), results in an extra OFDM symbol (or symbols) as described in 21.3.10.5.4 (LDPC coding), otherwise set to 0.<br><br>If Coding field is 0, this field is set to 1. |
| | B5 | STBC | Set to 1 if all spatial streams have space-time block coding and set to 0 if no spatial streams has space-time block coding. |


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**Table 23-19—Fields in the SIG field of S1G_1M PPDU *(continued)***

| Symbol | Bit | Field | Description |
|---|---|---|---|
| SIG-2 | B6 | Reserved | (#455)Reserved. Set to 1 on transmit. See 23.3.20 (PHY receive procedure) for behavior on receive. |
| | B7–B10 | MCS | MCS Index |
| | B11 | Aggregation | Set to 1 when aggregation is ON (as indicated by AGGREGATION parameter of TXVECTOR), and 0 otherwise.<br><br>NOTE— S1G PPDUs are transmitted with aggregation ON when PSDU to be carried is greater than 511 octets, as defined in 10.12.5. |
| SIG-3 and SIG-4 | B12–B20 | Length | When the Aggregation subfield is equal to 0, set to the number of octets in the PSDU. When the Aggregation subfield is equal to 1, set to $N_{\mathrm{SYM}_i}$, given in 23.4.3 (TXTIME and PSDU_LENGTH calculation).<br>(See TXVECTOR parameter PSDU_LENGTH.) |
| | B21–B22 | Response Indication | Set to the value obtained from the TXVECTOR parameter RESPONSE_INDICATION. The Response Indication field indicates the presence and type of (#14)the PPDU that is expected to follow SIFS after the current (#14)transmission (see 10.3.2.5). |
| | B23 | Smoothing | A value of 1 indicates that channel smoothing is recommended. A value of 0 indicates that channel smoothing is not recommended. |
| SIG-5 | B24 | Traveling Pilots | Set to 1 to indicate traveling pilots usage in (#14)PPDU. Otherwise 0 to indicate regular pilot tone locations. |
| | B25 | NDP Indication | Differentiate the PPDU from an NDP CMAC PPDU:<br>Set to 0 to indicate that the PPDU is not an NDP CMAC PPDU. |
| | B26–B29 | CRC | CRC calculated as in 23.3.8.2.2.6 (CRC calculation for S1G SIG-A fields). |
| SIG-6 | B30–B35 | Tail | Used to terminate the trellis of the convolutional decoder.<br>Set to 0. |

The SIG field of S1G_1M is composed of six OFDM symbols, SIG-1 ~ SIG-6, each containing 6 data bits, as shown in Table 23-19 (Fields in the SIG field of S1G_1M PPDU). SIG-1 is transmitted first and SIG-6 is the last. The SIG field symbols shall be BCC encoded at rate, R = 1/2, and repeated two times for the encoded bits within each OFDM symbol, interleaved, mapped to a BPSK constellation, and have pilots inserted, following the steps for MCS 10 transmission flow described in 23.3.9 (Data field). The stream of 144 complex numbers generated by these steps (before pilot insertion) is divided into six groups of 24 complex numbers $d_{k,n}$, $k = 0, \ldots, 23$, where $n = 0, 1, \ldots, 5$, respectively. All the 144 complex numbers are BPSK modulated. The first 24 complex numbers form the first symbol of SIG field; and the second 24 complex numbers form the second symbol of SIG field, and so forth.

The time domain waveform for the SIG field in an S1G_1M PPDU at transmit chain $i_{TX}$ shall be as specified in Equation (23-42).

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$$r_{\mathrm{SIG}}^{(i_{TX})}(t) = \frac{1}{\sqrt{N_{\mathrm{SIG}}^{\mathrm{Tone}} N_{\mathrm{STS}}}} \sum_{n=0}^{5} w_{T_{\mathrm{SYML}}}(t - nT_{SYML}) \cdot \sum_{k=-13}^{13} \sum_{m=1}^{N_{STS}} \left[Q_k\right]_{i_{TX},m} \left[P_{HTLTF}\right]_{m,1} \left(D_{k,n,1} + p_n P_n^k\right) \cdot \exp\left(j2\pi k \Delta_F (t - nT_{SYML} - T_{GI} - T_{CS}(m))\right) \quad (23\text{-}42)$$

where

$p_n$ is defined in 17.3.5.10 (OFDM modulation), and $P_n^k$ for S1G_1M is defined in 23.3.9.10 (Pilot subcarriers)

$T_{CS(m)}$ represents the cyclic shift for space-time stream $m$ with a value given in Table 23-18 (Cyclic shift values of S1G_1M PPDU)

$T_{SYML}$ is defined in Table 23-5 (Timing-related constants)

$\Delta_F$ is defined in Table 23-5 (Timing-related constants)

$N_{STS}$ is defined in Table 23-7 (Frequently used parameters)

$P_{HTLTF}$ is defined in Equation (19-27) in 19.3.9.4.6 (HT-LTF definition)

$N_{\mathrm{SIG}}^{\mathrm{Tone}}$ has the value given in tone scaling factor and guard interval duration values for PHY fields in Table 23-8 (Tone scaling factor and guard interval duration values for PHY fields)

$Q_k$ is defined in 23.3.7 (Mathematical description of signals)

$$D_{k,n,1} = \begin{cases} 0, & k = 0, \pm 7 \\ d_{M_1'(k),n}, & \text{otherwise} \end{cases} \quad (23\text{-}43)$$

where

$M'_1(k)$ is defined in Equation (23-44)

$$M_1'(k) = \begin{cases} k+13, & -13 \le k \le -8 \\ k+12, & -6 \le k \le -1 \\ k+11, & 1 \le k \le 6 \\ k+10, & 8 \le k \le 13 \end{cases} \quad (23\text{-}44)$$

### 23.3.9 Data field

#### 23.3.9.1 General

The number of OFDM symbols in the Data field is determined by the Length field in SIG field or SIG-A field of the three S1G PPDU formats, the preamble duration and the setting of the Short GI field in SIG field or SIG-A field, (see 23.3.8.2.2.5 (SIG definition), 23.3.8.2.3.2.5 (SIG-A definition), and 23.3.8.3.5 (SIG definition)). When BCC encoding is used, the Data field shall consist of the SERVICE field, the PSDU, the PHY pad bits and the tail bits (bits for SU and bits for each user *u* in MU). When LDPC encoding is used, the Data field shall consist of the SERVICE field, the PSDU and the PHY pad bits. No tail bits are present when LDPC encoding is used.

#### 23.3.9.2 SERVICE field

In S1G PPDUs, the SERVICE field has 8 bits, which shall be denoted as bits 0–7. The bit 0 shall be transmitted first in time.


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The SERVICE field is as shown in Table 23-20 (SERVICE field).

**Table 23-20—SERVICE field**

| Bits | Field | Description |
|---|---|---|
| B0–B6 | Scrambler Initialization | Set to 0 |
| B7 | Reserved | (#455)Set to 0 on transmit and ignored on receive |

#### 23.3.9.3 Scrambler

The SERVICE, PSDU and PHY pad parts of the Data field shall be scrambled by the scrambler defined in 17.3.5.5 (PHY DATA scrambler and descrambler).

#### 23.3.9.4 Coding

##### 23.3.9.4.1 General

The Data field shall be encoded using either the binary convolutional code (BCC) defined in 23.3.9.4.2 (BCC encoder parsing operation) and 23.3.9.4.3 (BCC coding and puncturing), or the low-density parity check (LDPC) code defined in 23.3.9.4.4 (LDPC coding). The encoder is selected by the coding bit(s) in SIG field or SIG-A field of the three S1G PPDU formats, as defined in 23.3.8.2.2.5 (SIG definition), 23.3.8.2.3.2.5 (SIG-A definition), and 23.3.8.3.5 (SIG definition). When BCC FEC encoding is used, the number of encoders is determined by rate-dependent parameters as defined in 23.5 (Parameters for S1G-MCSs). The operation of the BCC FEC is described in 23.3.9.4.2 (BCC encoder parsing operation) and 23.3.9.4.3 (BCC coding and puncturing). The operation of the LDPC coder is described in 23.3.9.4.4 (LDPC coding). Support for the reception of a BCC encoded Data field is mandatory.

##### 23.3.9.4.2 BCC encoder parsing operation

The BCC encoder parsing operation for S1G PPDUs is the same as those specified in 21.3.10.5.2 (BCC encoder parsing operation).

##### 23.3.9.4.3 BCC coding and puncturing

###### 23.3.9.4.3.1 General

The BCC coding and puncturing operation for S1G PPDUs is the same as those specified in 21.3.10.5.3 (BCC coding and puncturing).

###### 23.3.9.4.3.2 Padding for BCC

For a BCC encoder, the number of PHY padding bits, $N_{PAD,u}$, is calculated as

$$N_{PAD,u} = N_{SYM} \times N_{DBPS,u} - 8 \times PSDU\_LENGTH_u - N_{service} - N_{tail} \times N_{ES,u}$$

where

$PSDU\_LENGTH_u$ is the value of the TXVECTOR parameter PSDU_LENGTH for user $u$

$N_{SYM}$ is the number of symbols in the Data field and is given in 23.4.3 (TXTIME and PSDU_LENGTH calculation) by Equation (23-79) for S1G SU PPDUs and Equation (23-82) for S1G MU PPDUs

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For SU, $N_{PAD} = N_{PAD,0}$ .

The padding flow for BCC encoded PPDUs is as follows:

For an S1G MU PPDU, or an S1G SU PPDU with the Aggregation subfield equal to 1 in its SIG field or SIG-A field, the MAC delivers a PSDU that fills the available octets in the Data field of the PPDU for each user $u$ (i.e., append the maximum number of octets that is less than or equal to $N_{PAD,u}$ ). The PHY determines the number of PHY pad bits, which is $N_{PAD,u}$ modulo 8, and appends them to the PSDU, each of the PHY padding bits could be either 0 or 1. In this case, the Length subfield in SIG field or SIG-A field shall set the appropriate value indicating $N_{SYM}$ data symbols.

For an S1G SU PPDU with the Aggregation subfield equal to 0 in its SIG field or SIG-A field, MAC padding is not conducted and the PHY directly appends $N_{PAD}$ padding bits to the PSDU, each of the PHY padding bits could be either 0 or 1. In this case, the Length field shall set the appropriate value indicating PSDU_LENGTH in number of octets.

Both the PSDU and the PHY padding bits are scrambled and finally the $6.N_{ES}$ zero tail bits are appended after the scrambled PSDU and PHY padding bits.

#### 23.3.9.4.4 LDPC coding

##### 23.3.9.4.4.1 General

For an S1G SU PPDU using LDPC coding to encode the Data field, the LDPC code and encoding process described in 19.3.11.7 (LDPC codes) shall be used with the following modifications. First, all bits in the Data field including the scrambled SERVICE, PSDU, and pad bits are encoded. Thus, $N_{pld}$ for S1G SU PPDUs shall be computed using Equation (23-45) instead of Equation (19-35).

$$N_{pld} = N_{SYM,init} \times N_{DBPS} \tag{23-45}$$

where

$N_{SYM,init}$ is given by Equation (23-46) if the Aggregation subfield in its SIG field or SIG-A field is set to 1 or Equation (23-47) otherwise.

$$N_{SYM,init} = m_{STBC} \times \left\lceil \frac{8 \cdot APEP\_LENGTH + N_{service}}{m_{STBC} \cdot N_{DBPS}} \right\rceil \tag{23-46}$$

$$N_{SYM,init} = m_{STBC} \times \left\lceil \frac{8 \cdot PSDU\_LENGTH + N_{service}}{m_{STBC} \cdot N_{DBPS}} \right\rceil \tag{23-47}$$

where

| | |
|---|---|
| $m_{STBC}$ | is equal to 2 when STBC is used, and 1 otherwise |
| $APEP\_LENGTH$ | is the value of TXVECTOR parameter APEP_LENGTH |
| $PSDU\_LENGTH$ | is the value of TXVECTOR parameter PSDU_LENGTH |

Following the calculation of $N_{pld}$, $N_{avbits}$ shall be computed using Equation (23-48) instead of Equation (19-36).

$$N_{avbits} = N_{SYM,init} \times N_{CBPS} \tag{23-48}$$


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In addition, if $N_{SYM}$ computed in Equation (19-41) in step d) of 19.3.11.7.5 (LDPC PPDU encoding process) is greater than $N_{SYM,init}$, then the LDPC Extra field of its SIG field or SIG-A field shall be set to 1. Otherwise, the LDPC Extra field of its SIG field or SIG-A field shall be set to 0.

LDPC codes used in S1G MU PPDUs shall follow the definitions in 19.3.11.7 (LDPC codes). Refer to 23.3.9.4.5 (Encoding process for S1G MU PPDUs) for a description of the LDPC encoding process for S1G MU PPDUs.

#### 23.3.9.4.4.2 Padding for LDPC

For LDPC encoding, the number of PHY padding bits for user $u$, $N_{PAD,u}$ is calculated as

$$N_{PAD,u} = N_{SYM,init} \times N_{DBPS,u} - 8 \times PSDU\_LENGTH_u - N_{service}$$

where

$PSDU\_LENGTH_u$ is the value of the TXVECTOR parameter PSDU_LENGTH for user $u$

$N_{SYM,init}$ is the initial number of symbols for the Data field when using LDPC given in 23.4.3 (TXTIME and PSDU_LENGTH calculation) by Equation (23-82) for S1G SU PPDUs and Equation (23-83) for S1G MU PPDUs.

For SU, there is only one user, hence $N_{PAD} = N_{PAD,0}$.

The padding flow for LDPC encoded PPDUs is as follows:

The initial parameter computation $N_{SYM,init}$, $N_{pld}$ and $N_{avbits}$ are identical to those defined in 21.3.10.5.4 (LDPC coding).

For an S1G MU PPDU, or an S1G SU PPDU with the Aggregation subfield equal to 1 in its SIG field or SIG-A field, the MAC delivers a PSDU that fills the available octets in the Data field of the PPDU for each user $u$ (i.e., append the maximum number of octets that is less than or equal to $N_{PAD}$ or $N_{PAD,u}$ ). The PHY determines the number of pad bits, which is $N_{PAD}$ mod 8 or $N_{PAD,u}$ mod 8, and appends them to the PSDU, each of the PHY padding bits could be either 0 or 1. In this case, the Length subfield in SIG field or SIG-A field shall set the appropriate value indicating $N_{SYM}$ data symbols.

For an S1G SU PPDU with the Aggregation subfield equal to 0 in its SIG field or SIG-A field, MAC padding is not conducted and the PHY directly appends $N_{PAD}$ padding bits to the PSDU, each of the PHY padding bits could be either 0 or 1. In this case, the Length field shall set the appropriate value indicating PSDU_LENGTH in number of octets

Both the PSDU and the PHY padding bits are scrambled, and then finally the scrambled PSDU and PHY padding bits are LDPC encoded according to 21.3.10.5.4 (LDPC coding).

In both cases, if $N_{SYM} > N_{SYM,init}$, the LDPC Extra subfield of SIG field or SIG-A field shall be set to 1 (see 23.3.8.2.2.5 (SIG definition), 23.3.8.2.3.2.5 (SIG-A definition), and 23.3.8.3.5 (SIG definition)).

#### 23.3.9.4.5 Encoding process for S1G MU PPDUs

The encoding process for S1G MU PPDUs using S1G_LONG is the same as those specified in 21.3.10.5.5 (Encoding process for VHT MU PPDUs).

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#### 23.3.9.5 Repetition for 1 MHz MCS 10

In an 1 MHz PPDU that is modulated by MCS 10, the 6 information bits of each OFDM symbol are encoded with R=1/2, then the 12 encoded bits in each OFDM symbol is block-wise repeated by the following steps.

Assume that the sequence $[C_1 \ldots C_{12}]$ represents the 12 encoded bits in each OFDM symbol, the output bit stream after the repetition is:

$$C_{out}=[[C_1 \ldots C_{12}], [C_1 \ldots C_{12}] \text{ XOR } s], \quad (23\text{-}49)$$

where

s = [1 0 0 0 0 1 0 1 0 1 1 1]

The 24 output bits of the repetition are then sent to BCC interleaver (if BCC encoded) or the constellation mapper (if LDPC encoded).

#### 23.3.9.6 Stream parser

The stream parser for S1G PPDUs is the same as those specified in 21.3.10.6 (Stream parser) with up to 4 spatial streams.

For S1G_1M PPDU modulated using MCS 10, more than one spatial stream shall not be applied.

#### 23.3.9.7 Segment parser

The segment parser for S1G 16 MHz PPDUs is the same as those specified for 160 MHz PPDUs in 21.3.10.7 (Segment parser).

#### 23.3.9.8 BCC interleaver

The BCC interleavers for S1G 2 MHz, 4 MHz, 8 MHz, and 16 MHz PPDUs are the same as those defined for 20 MHz, 40 MHz, 80 MHz, and 160 MHz PPDUs, respectively, as specified in 21.3.10.8 (BCC interleaver).

For S1G_1M PPDU, the interleaver parameters are defined by Table 23-21 (Number of rows and columns in the interleaver for 1 MHz).

**Table 23-21—Number of rows and columns in the interleaver for 1 MHz**

| Parameter | 1 MHz |
|---|---|
| $N_{COL}$ | 8 |
| $N_{ROW}$ | $3 \times N_{BPSCS}$ |
| $N_{ROT}$ ($N_{SS} \leq 4$) | 2 |

The interleaver parameters for 1 MHz MCS 10 is identical to the parameters used for 1 MHz MCS 0.


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#### 23.3.9.9 Constellation mapping

##### 23.3.9.9.1 General

The constellation mappings for S1G PPDUs modulated using MCS 0 to MCS 9 are the same as those specified in 21.3.10.9.1 (General) with the same MCS indices. The constellation mappings for S1G PPDUs modulated using MCS 11 and MCS 12 are the same as those specified in 27.3.12.9 (Constellation mapping) for 1024-QAM.(M102)

The constellation mapping for 1 MHz MCS 10 is identical to the BPSK constellation mapping that is applied in MCS 0.

##### 23.3.9.9.2 LDPC tone mapping

The LDPC tone mappings for S1G 2 MHz, 4 MHz, 8 MHz, and 16 MHz PPDUs are the same as those defined for 20 MHz, 40 MHz, 80 MHz, and 160 MHz PPDUs, respectively, as specified in 21.3.10.9.2 (LDPC tone mapping).

For LDPC encoded S1G_1M PPDU, LDPC tone mapping is not applied.

##### 23.3.9.9.3 Segment deparser

The segment deparser for S1G 16 MHz PPDUs is the same as those specified for 160 MHz PPDUs in 21.3.10.9.3 (Segment deparser).

##### 23.3.9.9.4 Space-time block coding

The STBC for S1G PPDUs is the same as those specified in 21.3.10.9.4 (Space-time block coding).

For S1G_1M PPDU modulated using MCS 10, STBC shall not be applied.

#### 23.3.9.10 Pilot subcarriers

For an S1G_1M SIG field and Data field, two pilot tones shall be inserted in subcarriers. For fixed pilots, the pilot mapping for subcarrier $k$ for symbol $n$ shall be as specified in Equation (23-50).

$$P_n^{\{-7,7\}} = \{\Psi_{(n \bmod 2)+2}, \Psi_{((n+1) \bmod 2)+2}\} \tag{23-50}$$

$$P_n^{k \notin \{-7,7\}} = 0$$

where

$\Psi_m$ is given in Table 21-21 (Pilot values for 80 MHz transmission) in 21.3.10.10 (Pilot subcarriers)

For S1G_SHORT PPDU and S1G_LONG PPDU, with fixed pilots, $P_n^k$ with same FFT sizes is identical to what is defined in 21.3.10.10 (Pilot subcarriers).

For traveling pilots, at symbol $n$, $P_n^k$ is defined as follows:

$$P_n^k = \begin{cases} 1.5 \times P_{n,\,\text{fix}}^{k_{\text{Pilot\_Fix}}^{(l)}}, k \in K_{\text{Pilot\_Travel}}(n) \text{ and } k = K_{\text{Pilot\_Travel}}^{(l)}(n) \\ 0, \text{ otherwise} \end{cases} \tag{23-51}$$

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where

$K_{\text{Pilot\_Travel}}(n)$ is the set of traveling pilot subcarrier positions corresponding to data symbol $n$ ($n$ = 0, 1, 2, …, $N_{SYM}$–1)(#515)

$K^{(l)}_{\text{Pilot\_Travel}}(n)$ is the pilot tone position in the pilot subcarrier set $K_{\text{Pilot\_Travel}}(n)$ corresponding to pilot index $l$, as shown in Table 23-22 (Traveling pilot positions for NSTS=1, 1 MHz S1G PPDU) to Table 23-29 (Traveling pilot positions for NSTS=2 and STBC=1, 8 MHz S1G PPDU)

$P^{k}_{n,\text{ fix}}$ is identical to $P^{k}_{n}$ for fixed pilots

$k^{(l)}_{\text{Pilot\_Fix}}$ is the pilot tone position corresponding to pilot index $l$ in the case of fixed pilots, specifically:

For 1 MHz, $\{k^{(0)}_{\text{Pilot\_Fix}}, k^{(1)}_{\text{Pilot\_Fix}}\} = \{-7, 7\}$

For 2 MHz, $\{k^{(0)}_{\text{Pilot\_Fix}}, \ldots, k^{(3)}_{\text{Pilot\_Fix}}\} = \{-21, -7, 7, 21\}$

For 4 MHz, $\{k^{(0)}_{\text{Pilot\_Fix}}, \ldots, k^{(5)}_{\text{Pilot\_Fix}}\} = \{-53, -25, -11, 11, 25, 53\}$

For 8 MHz, $\{k^{(0)}_{\text{Pilot\_Fix}}, \ldots, k^{(7)}_{\text{Pilot\_Fix}}\} = \{-103, -75, -39, -11, 11, 39, 75, 103\}$

For 16 MHz,

$\{k^{(0)}_{\text{Pilot\_Fix}}, \ldots, k^{(15)}_{\text{Pilot\_Fix}}\} = \{-231, -203, -167, -139, -117, -89, -53, -25, 25, 53, 89, 117, 139, 167, 203, 231\}$

The traveling pilot positions for symbol $n$, $K_{\text{Pilot\_Travel}}(n)$ , are derived by the following paragraphs.

For an S1G SU PPDU where in its SIG field or SIG-A field the NSTS subfield indicates one space-time stream and the Traveling Pilots subfield is set to 1, the traveling pilots positions $K_{\text{Pilot\_Travel}}(n)$ varies from symbol to symbol according to Table 23-22 (Traveling pilot positions for NSTS=1, 1 MHz S1G PPDU) to Table 23-25 (Traveling pilot positions for NSTS=1, 8 MHz S1G PPDU) for bandwidth 1 MHz, 2 MHz, 4 MHz, and 8 MHz. In this case, for data symbol $n$ ($n$ = 0, 1, 2, …, $N_{SYM}$–1)(#515), the pilot positions $K_{\text{Pilot\_Travel}}(n)$ equal to those in the column corresponding to the pattern index.:

$$m(n) = n \bmod N_{TP,BW} \tag{23-52}$$

where

$N_{TP,BW}$ is the traveling pilot pattern period with the following values:

$N_{TP,1\text{MHz}} = 13$

$N_{TP,2\text{MHz}} = 14$

$N_{TP,4\text{MHz}} = 19$

$N_{TP,8\text{MHz}} = 32$

$N_{TP,16\text{MHz}} = 32$

**Table 23-22—Traveling pilot positions for NSTS=1, 1 MHz S1G PPDU**

| Pilot Index *l* | Pattern Index *m* | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** |



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**Table 23-22—Traveling pilot positions for NSTS=1, 1 MHz S1G PPDU**

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | –2 | –10 | –5 | –13 | –8 | –3 | –11 | –6 | –1 | –9 | –4 | –12 | –7 |
| 1 | 12 | 4 | 9 | 1 | 6 | 11 | 3 | 8 | 13 | 5 | 10 | 2 | 7 |

**Table 23-23—Traveling pilot positions for NSTS=1, 2 MHz S1G PPDU**

| Pilot Index *l* | Pattern Index *m* | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** |
| 0 | –28 | –24 | –20 | –16 | –26 | –22 | –18 | –27 | –23 | –19 | –15 | –25 | –21 | –17 |
| 1 | –12 | –8 | –4 | –2 | –14 | –10 | –6 | –11 | –7 | –3 | 1 | –13 | –9 | –5 |
| 2 | 4 | 8 | 12 | 16 | 2 | 6 | 10 | 5 | 9 | 13 | 17 | –1 | 3 | 7 |
| 3 | 20 | 24 | 28 | 26 | 14 | 18 | 22 | 21 | 25 | 23 | 27 | 11 | 15 | 19 |

**Table 23-24—Traveling pilot positions for NSTS=1, 4 MHz S1G PPDU**

| Pilot Index *l* | Pattern Index *m* | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **15** | **16** | **17** | **18** |
| 0 | –49 | –41 | –33 | –25 | –17 | –9 | –58 | –50 | –42 | –34 | –26 | –18 | –10 | –2 | –51 | –43 | –35 | –27 | –19 |
| 1 | –30 | –22 | –14 | –6 | –55 | –47 | –39 | –31 | –23 | –15 | –7 | –56 | –48 | –40 | –32 | –24 | –16 | –8 | –57 |
| 2 | –11 | –3 | –52 | –44 | –36 | –28 | –20 | –12 | –4 | –53 | –45 | –37 | –29 | –21 | –13 | –5 | –54 | –46 | –38 |
| 3 | 11 | 19 | 27 | 35 | 43 | 51 | 2 | 10 | 18 | 26 | 34 | 42 | 50 | 58 | 9 | 17 | 25 | 33 | 41 |
| 4 | 30 | 38 | 46 | 54 | 5 | 13 | 21 | 29 | 37 | 45 | 53 | 4 | 12 | 20 | 28 | 36 | 44 | 52 | 3 |
| 5 | 49 | 57 | 8 | 16 | 24 | 32 | 40 | 48 | 56 | 7 | 15 | 23 | 31 | 39 | 47 | 55 | 6 | 14 | 22 |

For an S1G SU PPDU where in its SIG field or SIG-A field the NSTS subfield indicates two space-time streams, STBC subfield is set to 1 and the Traveling Pilots subfield is set to 1, the traveling pilots positions $K_{\text{Pilot\_Travel}}(n)$ varies every other symbol according to Table 23-26 (Traveling pilot positions for NSTS=2 and STBC=1, 1 MHz S1G PPDU) to Table 23-29 (Traveling pilot positions for NSTS=2 and STBC=1, 8 MHz S1G PPDU) for bandwidth 1 MHz, 2 MHz, 4 MHz, and 8 MHz. In this case, for data symbol $n$ ($n$ = 0, 1, 2, …, $N_{SYM}$–1)(#515), the pilot positions $K_{\text{Pilot\_Travel}}(n)$ equal to those in the column corresponding to the pattern index.

$$m(n) = \left\lfloor \frac{n}{2} \right\rfloor \bmod N_{TP,BW} \tag{23-53}$$

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**Table 23-25—Traveling pilot positions for NSTS=1, 8 MHz S1G PPDU**

| Pilot Index *l* | Pattern Index *m* | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **15** |
| 0 | –122 | –118 | –114 | –110 | –106 | –102 | –98 | –94 | –120 | –116 | –112 | –108 | –104 | –100 | –96 | –92 |
| 1 | –90 | –86 | –82 | –78 | –74 | –70 | –66 | –62 | –88 | –84 | –80 | –76 | –72 | –68 | –64 | –60 |
| 2 | –58 | –54 | –50 | –46 | –42 | –38 | –34 | –30 | –56 | –52 | –48 | –44 | –40 | –36 | –32 | –28 |
| 3 | –26 | –22 | –18 | –14 | –10 | –6 | –2 | 2 | –24 | –20 | –16 | –12 | –8 | –4 | 2 | 4 |
| 4 | 6 | 10 | 14 | 18 | 22 | 26 | 30 | 34 | 8 | 12 | 16 | 20 | 24 | 28 | 32 | 36 |
| 5 | 38 | 42 | 46 | 50 | 54 | 58 | 62 | 66 | 40 | 44 | 48 | 52 | 56 | 60 | 64 | 68 |
| 6 | 70 | 74 | 78 | 82 | 86 | 90 | 94 | 98 | 72 | 76 | 80 | 84 | 88 | 92 | 96 | 100 |
| 7 | 102 | 106 | 110 | 114 | 118 | 122 | 120 | –120 | 104 | 108 | 112 | 116 | 120 | 122 | –2 | –122 |

| Pilot Index *l* | Pattern Index *m* | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **16** | **17** | **18** | **19** | **20** | **21** | **22** | **23** | **24** | **25** | **26** | **27** | **28** | **29** | **30** | **31** |
| 0 | –121 | –117 | –113 | –109 | –105 | –101 | –97 | –93 | –119 | –115 | –111 | –107 | –103 | –99 | –95 | –91 |
| 1 | –89 | –85 | –81 | –77 | –73 | –69 | –65 | –61 | –87 | –83 | –79 | –75 | –71 | –67 | –63 | –59 |
| 2 | –57 | –53 | –49 | –45 | –41 | –37 | –33 | –29 | –55 | –51 | –47 | –43 | –39 | –35 | –31 | –27 |
| 3 | –25 | –21 | –17 | –13 | –9 | –5 | –2 | 3 | –23 | –19 | –15 | –11 | –7 | –3 | 2 | 5 |
| 4 | 7 | 11 | 15 | 19 | 23 | 27 | 31 | 35 | 9 | 13 | 17 | 21 | 25 | 29 | 33 | 37 |
| 5 | 39 | 43 | 47 | 51 | 55 | 59 | 63 | 67 | 41 | 45 | 49 | 53 | 57 | 61 | 65 | 69 |
| 6 | 71 | 75 | 79 | 83 | 87 | 91 | 95 | 99 | 73 | 77 | 81 | 85 | 89 | 93 | 97 | 101 |
| 7 | 103 | 107 | 111 | 115 | 119 | 121 | 2 | –121 | 105 | 109 | 113 | 117 | 121 | 121 | –2 | –121 |

where

$N_{TP,BW}$ is the traveling pilot pattern period with the following values:

$N_{TP,1\text{MHz}} = 7$

$N_{TP,2\text{MHz}} = 7$

$N_{TP,4\text{MHz}} = 10$

$N_{TP,8\text{MHz}} = 16$

$N_{TP,16\text{MHz}} = 16$

**Table 23-26—Traveling pilot positions for NSTS=2 and STBC=1, 1 MHz S1G PPDU**

| Pilot Index *l* | Pattern Index *m* | | | | | | |
|---|---|---|---|---|---|---|---|
| | **0** | **1** | **2** | **3** | **4** | **5** | **6** |



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**Table 23-26—Traveling pilot positions for NSTS=2 and STBC=1, 1 MHz S1G PPDU**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 0 | –3 | –13 | –9 | –5 | –1 | –11 | –7 |
| 1 | 11 | 1 | 5 | 9 | 13 | 3 | 7 |

**Table 23-27—Traveling pilot positions for NSTS=2 and STBC=1, 2 MHz S1G PPDU**

| Pilot Index *l* | Pattern Index *m* | | | | | | |
|---|---|---|---|---|---|---|---|
| | **0** | **1** | **2** | **3** | **4** | **5** | **6** |
| 0 | –28 | –24 | –20 | –16 | –26 | –22 | –18 |
| 1 | –12 | –8 | –4 | –2 | –14 | –10 | –6 |
| 2 | 4 | 8 | 12 | 16 | 2 | 6 | 10 |
| 3 | 20 | 24 | 28 | 26 | 14 | 18 | 22 |

**Table 23-28—Traveling pilot positions for NSTS=2 and STBC=1, 4 MHz S1G PPDU**

| Pilot Index *l* | Pattern Index *m* | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** |
| 0 | –50 | –44 | –38 | –32 | –26 | –20 | –14 | –8 | –2 | –56 |
| 1 | –30 | –24 | –18 | –12 | –6 | –58 | –54 | –48 | –42 | –36 |
| 2 | –10 | –4 | –58 | –52 | –46 | –40 | –34 | –28 | –22 | –16 |
| 3 | 10 | 16 | 22 | 28 | 34 | 40 | 46 | 52 | 58 | 4 |
| 4 | 30 | 36 | 42 | 48 | 54 | 58 | 6 | 12 | 18 | 24 |
| 5 | 50 | 56 | 2 | 8 | 14 | 20 | 26 | 32 | 38 | 44 |

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**Table 23-29—Traveling pilot positions for NSTS=2 and STBC=1, 8 MHz S1G PPDU**

| Pilot Index *l* | Pattern Index *m* | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **15** |
| 0 | –122 | –118 | –114 | –110 | –106 | –102 | –98 | –94 | –120 | –116 | –112 | –108 | –104 | –100 | –96 | –92 |
| 1 | –90 | –86 | –82 | –78 | –74 | –70 | –66 | –62 | –88 | –84 | –80 | –76 | –72 | –68 | –64 | –60 |
| 2 | –58 | –54 | –50 | –46 | –42 | –38 | –34 | –30 | –56 | –52 | –48 | –44 | –40 | –36 | –32 | –28 |
| 3 | –26 | –22 | –18 | –14 | –10 | –6 | –2 | 2 | –24 | –20 | –16 | –12 | –8 | –4 | 2 | 4 |
| 4 | 6 | 10 | 14 | 18 | 22 | 26 | 30 | 34 | 8 | 12 | 16 | 20 | 24 | 28 | 32 | 36 |
| 5 | 38 | 42 | 46 | 50 | 54 | 58 | 62 | 66 | 40 | 44 | 48 | 52 | 56 | 60 | 64 | 68 |
| 6 | 70 | 74 | 78 | 82 | 86 | 90 | 94 | 98 | 72 | 76 | 80 | 84 | 88 | 92 | 96 | 100 |
| 7 | 102 | 106 | 110 | 114 | 118 | 122 | 120 | –120 | 104 | 108 | 112 | 116 | 120 | 122 | –2 | –122 |

For a 16 MHz S1G PPDU with traveling pilots, in the data symbol $n$ ($n$ = 0, 1, 2, …, $N_{SYM}$–1)(#515), there are a total of 16 pilot subcarriers, whose positions $K_{\text{Pilot\_Travel}}(n)$ are expressed as

$$K_{\text{Pilot\_Travel}}(n) = \begin{cases} K_{\text{Pilot\_Travel,8MHz}}(n) - 128, \text{ for pilot indices } 0 \le l \le 7 \\ K_{\text{Pilot\_Travel,8MHz}}(n) + 128, \text{ for pilot indices } 8 \le l \le 15 \end{cases} \quad (23\text{-}54)$$

where $K_{\text{Pilot\_Travel,8MHz}}(n)$ is the traveling pilot positions of the 8 pilot subcarriers for symbol index $n$ and 8 MHz, calculated based on Table 23-25 (Traveling pilot positions for NSTS=1, 8 MHz S1G PPDU) for a single space-time stream, or based on Table 23-29 (Traveling pilot positions for NSTS=2 and STBC=1, 8 MHz S1G PPDU) for STBC with two space-time streams.

For S1G MU PPDUs, or S1G SU PPDUs with more than two space-time streams, or S1G SU PPDUs with two space-time streams without STBC, traveling pilots are not defined.

### 23.3.9.11 OFDM modulation

For S1G transmissions using S1G_SHORT, the Data field signal from transmit chain $i_{TX}$, $1 \le i_{TX} \le N_{TX}$, shall be as specified in Equation (23-55).

$$r_{Data}^{(i_{TX})}(t) = \frac{1}{\sqrt{N_{\text{Data}}^{\text{Tone}} N_{\text{STS}}}} \sum_{n=0}^{N_{SYM}-1} w_{T_{SYM}}(t - T_{Accum}(n)) \sum_{k=-N_{SR}}^{N_{SR}} \sum_{m=1}^{N_{STS}} ([Q_k]_{i_{TX},m} \gamma_{k,BW} (\tilde{D}_{k,m,n,BW} + [P_{HTLTF}]_{m,g(n)} \cdot p_{n+2} P_n^k) \exp(j2\pi k \Delta_F (t - T_{Accum}(n) - T_{GI,Data}(n) - T_{CS}(m)))) \quad (23\text{-}55)$$

where



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$$g(n)=\begin{cases}(n \bmod 2)+1, & \text{if the STBC bit and Traveling Pilots bit in SIG field are both set to 1}\\ 1, & \text{otherwise}\end{cases}$$

For S1G transmissions using S1G_LONG, the Data field signal from transmit chain $i_{TX}$, $1 \le i_{TX} \le N_{TX}$, shall be as specified in Equation (23-56).

$$\begin{aligned}{}^{(i_{TX})}_{Data}(t) = & \frac{1}{\sqrt{N^{\text{Tone}}_{\text{Data}} N_{\text{STS,total}}}} \sum_{n=0}^{N_{SYM}-1} w_{T_{SYM}}(t - T_{Accum}(n)) \\ & \sum_{k=-N_{SR}}^{N_{SR}} \sum_{u=0}^{N_u-1} \sum_{m=1}^{N_{STS,u}} ([Q_k]_{i_{TX},(M_u+m)} \gamma_{k,BW} (\tilde{D}_{k,m,n,BW} + [P_{HTLTF}]_{m,g(n)} \cdot p_{z(n)} P^k_{(z(n)-2)}) \\ & \exp(j2\pi k \Delta_F (t - T_{Accum}(n) - T_{GI,Data}(n) - T_{CS}(m))))\end{aligned} \quad (23\text{-}56)$$

where

$$g(n)=\begin{cases}(n \bmod 2)+1, & \text{if the STBC bit and Traveling Pilots bit in SIG-A field are both set to 1}\\ 1, & \text{otherwise}\end{cases}$$

For S1G transmissions using S1G_1M, the Data field signal from transmit chain $i_{TX}$, $1 \le i_{TX} \le N_{TX}$, shall be as specified in Equation (23-57)(#6052).

$$\begin{aligned}r^{(i_{TX})}_{Data}(t) = & \frac{1}{\sqrt{N^{\text{Tone}}_{\text{Data}} N_{\text{STS}}}} \sum_{n=0}^{N_{SYM}-1} w_{T_{SYM}}(t - T_{Accum}(n)) \\ & \sum_{k=-N_{SR}}^{N_{SR}} \sum_{m=1}^{N_{STS}} ([Q_k]_{i_{TX},m} \gamma_{k,BW} (\tilde{D}_{k,m,n,BW} + [P_{HTLTF}]_{m,g(n)} \cdot p_{n+6} P^k_n) \\ & \exp(j2\pi k \Delta_F (t - T_{Accum}(n) - T_{GI,Data}(n) - T_{CS}(m))))\end{aligned} \quad (23\text{-}57)$$

where

$N_{SR}$ is defined in Table 23-5 (Timing-related constants)

$p_n$ is defined in 17.3.5.10 (OFDM modulation)

$P^k_n$ is defined in 23.3.9.10 (Pilot subcarriers)

$T_{CS(m)}$ represents the cyclic shift for space-time stream $m$ with a value given in Table 23-10 (Cyclic shift values for the S1G_SHORT preamble PPDU) in the case of ≥ 2 MHz formats, and in Table 23-18 (Cyclic shift values of S1G_1M PPDU) in the case of S1G_1M

$\Upsilon_{k,\text{BW}}$ is defined by Equation (23-6) to Equation (23-9)

$\Delta_F$ is defined in Table 23-5 (Timing-related constants)

$N_{STS}$, $N_{STS,total}$, and $N_{STS,u}$ are defined in Table 23-7 (Frequently used parameters)

$P_{HTLTF}$ is defined in Equation (19-27) in 19.3.9.4.6 (HT-LTF definition)

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$N_{\text{Data}}^{\text{Tone}}$ has the value given in tone scaling factor and guard interval duration values for PHY fields in Table 23-8 (Tone scaling factor and guard interval duration values for PHY fields)

$N_u$, and $M_u$ are defined in Table 23-7 (Frequently used parameters)

$z(n)$ in Equation (23-56) is defined as follows:(M118)

$$z(n) = \begin{cases} n+2, \text{ if the MU/SU bit in SIG-A field is 0} \\ n+3, \text{ if the MU/SU bit in SIG-A field is 1} \end{cases}$$

$T_{GI,Data}(n)$ is the guard interval duration with the value as follows:

$$T_{GI,Data}(n) = \begin{cases} T_{GI}, \text{ if } n = 0 \\ T_{GI}, \text{ if } n > 0 \text{ and Short GI subfield of SIG or SIG-A field is 0} \\ T_{SGI}, \text{ if } n > 0 \text{ and Short GI subfield of SIG or SIG-A field is 1} \end{cases} \quad (23\text{-}58)$$

$\tilde{D}_{k,m,n,BW}$ is defined by Equation (23-59).

$$\tilde{D}_{k,m,n,BW} = \begin{cases} 0, & \text{if } k \in K_{\text{Pilot}}(n) \\ d_{M'_{BW}(k),m,n,} & \text{otherwise} \end{cases} \quad (23\text{-}59)$$

where

$$K_{Pilot}(n) = \begin{cases} K_{Pilot\_\text{Fix}}, & \text{if the Traveling Pilot bit in SIG or SIG-A field is 0} \\ K_{Pilot\_\text{Travel}}(n), & \text{if the Traveling Pilot bit in SIG or SIG-A field is 1} \end{cases} \quad (23\text{-}60)$$

in which $K_{\text{Pilot\_Fix}}$ is defined in 23.3.8.2.2.4 (LTF definition) for ≥ 2 MHz and 23.3.8.3.4 (LTF definition) for 1 MHz, and $K_{\text{Pilot\_Travel}}(n)$ is defined in 23.3.9.10 (Pilot subcarriers); and $M'_{BW}(k)$ is defined in Equation (23-30) to Equation (23-35) in 23.3.8.2.3.3.5 (SIG-B definition) for 2 MHz, 4 MHz, 8 MHz, and 16 MHz, as well as Equation (23-44) in 23.3.8.3.5 (SIG definition) for 1 MHz.

$T_{Accum}(n)$ is the accumulated duration from data symbol 0 to data symbol (*n-1*).

$$T_{Accum}(n) = \begin{cases} 0, & \text{if } n = 0 \\ T_{SYML} + (n-1)T_{SYM}, & \text{if } n > 0 \end{cases} \quad (23\text{-}61)$$

where

$T_{SYML}$ and $T_{SYM}$ are defined in Table 23-5 (Timing-related constants)

$Q_k$ is a spatial mapping/steering matrix with $N_{TX}$ rows and $N_{STS}$ or $N_{STS,total}$ columns for subcarrier *k*. $Q_k$ may be frequency dependent. Refer to the examples of listed in 19.3.11.11.2 (Spatial mapping) for examples of that could be used for S1G SU PPDUs. Note that implementations are not restricted to the spatial mapping matrix examples listed in 19.3.11.11.2 (Spatial mapping) and the number of transmit chains $N_{TX}$ could be up to 4. For SU PPDUs to which beamforming is applied, $Q_k$ is a beamforming steering matrix and is derived from the TXVECTOR parameter EXPANSION_MAT. For S1G MU PPDUs, $Q_k$ is the (#3367)DL MU-MIMO steering matrix and is derived from the TXVECTOR parameter EXPANSION_MAT. The beamforming steering matrices and (#3367)DL MU-MIMO steering matrices are implementation specific.


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The autodetection between 1 MHz and 2 MHz preambles assumes channel smoothness. It is recommended that the spatial mapping matrix $Q_k$ applied to LTF1 field is chosen such that it preserves the smoothness of the physical channel. This can, for example, be achieved by minimizing the amplitude and phase variation of each element of $Q_k$ in successive tones.

*Examples:*

a) The following may be used $Q_k$: $Q_k$ as defined for cyclic shift diversity using the values specified in the corresponding tables.

b) The following $Q_k$ should not be used:
   — Antenna hopping as described in 19.3.11.11.2 (Spatial mapping) c) 2)
   — The values of $Q_k$ on successive tones flip between 1 and 0

### 23.3.9.12 S1G 1 MHz and 2 MHz duplicate transmission

#### 23.3.9.12.1 S1G 1 MHz duplicate transmission

An S1G 1 MHz duplicate transmission is used to transmit to S1G STAs that may be present in a part of a 2 MHz, 4 MHz, 8 MHz, or 16 MHz channel.

In an S1G 1 MHz duplicate PPDU, both the S1G_1M preamble and Data field are duplicated in each 1 MHz subchannel of the 2 MHz, 4 MHz, 8 MHz, or 16 MHz channel. Both an 1 MHz data PPDU and an 1 MHz NDP may be duplicated.

For S1G 1 MHz duplicate transmission, the Data field signal from transmit chain $i_{TX}$, $1 \le i_{TX} \le N_{TX}$, shall be as specified in Equation (23-62).

$$r_{Data}^{(i_{TX})}(t) = \frac{1}{\sqrt{N_{\text{1MHz\_DUP\_Data}}^{\text{Tone}} N_{STS}}} \sum_{n=0}^{N_{SYM}-1} w_{T_{SYM}}(t - T_{Accum}(n)) \sum_{i_{BW}=0}^{N_{1MHz}-1} \Bigg( \sum_{k=-13}^{13} \sum_{m=1}^{N_{STS}} \Big( [Q_k]_{i_{TX}, m} \gamma_{1MHz,\, k-(K_{Shift,\,1MHz}(i_{BW})),\, BW} (\tilde{D}_{k,\,m,\,n,\,1MHz} + [P_{HTLTF}]_{m,\,g(n)} \cdot p_{n+6} P_n^k) \exp(j2\pi(k - K_{Shift,\,1MHz}(i_{BW}))\Delta_F \cdot (t - T_{Accum}(n) - T_{GI,\,Data}(n) - T_{CS}(m))) \Big) \Bigg) \quad (23\text{-}62)$$

where

| | |
|---|---|
| $p_n$ | is defined in 17.3.5.10 (OFDM modulation) |
| $P_n^k$ | is defined in 23.3.9.10 (Pilot subcarriers) |
| $T_{CS(m)}$ | represents the cyclic shift for space-time stream *m* with a value given in Table 23-18 (Cyclic shift values of S1G_1M PPDU) |
| $\Upsilon_{1MHz,k,\text{BW}}$ | is defined by Equation (23-10) to Equation (23-13) |
| $\Delta_F$ | is defined in Table 23-5 (Timing-related constants) |
| $N_{STS}$ | is defined in Table 23-7 (Frequently used parameters) |
| $P_{HTLTF}$ | is defined in Equation (19-27) in 19.3.9.4.6 (HT-LTF definition) |
| $N_{\text{1MHz\_DUP\_Data}}^{\text{Tone}}$ | has the value given in tone scaling factor and guard interval duration values for PHY fields in Table 23-8 (Tone scaling factor and guard interval duration values for PHY fields) |

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$T_{GI,Data}(n)$ is defined in Equation (23-58)

$\tilde{D}_{k,n,n,BW}$ is defined in Equation (23-59)

$T_{Accum}(n)$ is defined in Equation (23-61)

$N_{1MHz}$ is the number of 1 MHz subchannels that are contained within the whole bandwidth of the current PPDU (e.g., $N_{1MHz} = 4$ for a 4 MHz PPDU)

$$g(n) = \begin{cases} (n \bmod 2) + 1, & \text{if the STBC bit and Traveling Pilots bit in SIG-A field are both set to 1} \\ 1, & \text{otherwise} \end{cases}$$

$$K_{Shift,1MHz}(i) = (N_{1MHz} - 1 - 2i).16 \quad (23\text{-}63)$$

### 23.3.9.12.2 S1G 2 MHz duplicate transmission

An S1G 2 MHz duplicate transmission is used to transmit to S1G STAs that may be present in a part of a 4 MHz, 8 MHz, or 16 MHz channel.

In an S1G 2 MHz duplicate PPDU, the S1G_SHORT preamble and Data field are duplicated in each 2 MHz subchannel of the 4 MHz, 8 MHz, or 16 MHz channel.

A 2 MHz NDP sounding shall not be duplicated. Instead, a 4 MHz, 8 MHz, or 16 MHz NDP shall be transmitted whenever needed. NDP CMAC PPDUs transmitted over a 4 MHz, 8 MHz, or 16 MHz channel shall be carried in an S1G 2 MHz duplicate (#14)PPDU.

For an S1G 2 MHz duplicate PPDU, the Data field signal from transmit chain $i_{TX}$, $1 \le i_{TX} \le N_{TX}$, shall be as specified in Equation (23-64).

$$r_{Data}^{(i_{TX})}(t) = \frac{1}{\sqrt{N_{2MHz\_DUP\_Data}^{Tone} N_{STS}}} \sum_{n=0}^{N_{SYM}-1} w_{T_{SYM}}(t - T_{Accum}(n)) \sum_{i_{BW}=0}^{N_{2MHz}-1} \left( \sum_{k=-28}^{28} \sum_{m=1}^{N_{STS}} \right.$$

$$([Q_k]_{i_{TX},m} \gamma_{(k - K_{Shift}(i_{BW})),BW} (\tilde{D}_{k,m,n,2MHz} + [P_{HTLTF}]_{m,g(n)} \cdot p_{n+2} P_n^k) \quad (23\text{-}64)$$

$$\left. \exp(j2\pi(k - K_{Shift}(i_{BW}))\Delta_F \cdot (t - T_{Accum}(n) - T_{GI,Data}(n) - T_{CS}(m)))) \right)$$

where

$p_n$ is defined in 17.3.5.10 (OFDM modulation)

$P_n^k$ is defined in 23.3.9.10 (Pilot subcarriers)

$T_{CS(m)}$ represents the cyclic shift for space-time stream $m$ with a value given in Table 23-10 (Cyclic shift values for the S1G_SHORT preamble PPDU)

$\Upsilon_{k,\mathrm{BW}}$ is defined by Equation (23-6) to Equation (23-9)

$\Delta_F$ is defined in Table 23-5 (Timing-related constants)

$N_{STS}$ is defined in Table 23-7 (Frequently used parameters)

$P_{HTLTF}$ is defined in Equation (19-27) in 19.3.9.4.6 (HT-LTF definition)

$N_{2MHz\_DUP\_Data}^{Tone}$ has the value given in tone scaling factor and guard interval duration values for PHY fields in Table 23-8 (Tone scaling factor and guard interval duration values for PHY fields)



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$T_{GI,Data}(n)$ is defined in Equation (23-58)

$\tilde{D}_{k,n,n,BW}$ is defined in Equation (23-59)

$T_{Accum}(n)$ is defined in Equation (23-61)

$N_{2MHz}$ is the number of 2 MHz subchannels that are contained within the whole bandwidth of the current PPDU (e.g., $N_{2MHz} = 2$ for a 4 MHz PPDU)

$$g(n) = \begin{cases} (n \bmod 2) + 1, & \text{if the STBC bit and Traveling Pilots bit in SIG-A field are both set to 1} \\ 1, & \text{otherwise} \end{cases}$$

$K_{Shift}(i)$ is defined in Equation (23-19)

### 23.3.10 SU-MIMO and (#3367)DL MU-MIMO Beamforming

#### 23.3.10.1 General

S1G SU-MIMO and (#3367)DL MU-MIMO beamforming are techniques used by a STA with multiple antennas (the beamformer) to steer signals using knowledge of the channel to improve throughput. The general description of SU-MIMO and (#3367)DL MU-MIMO beamforming is identical to its VHT counterparts as described in 21.3.11.1 (General) with VHT replaced by S1G.

In S1G operation, the SU-MIMO allows beamforming up to 4 space-time streams, and (#3367)DL MU-MIMO beamforming allows up to 4 total number of space-time streams for all users each with up to 3 space-time streams.

S1G beamforming exchange is defined only for 2 MHz, 4 MHz, 8 MHz, and 16 MHz.

#### 23.3.10.2 Beamforming Feedback Matrix V

The description of beamforming feedback matrix V in an S1G band is identical to its VHT counterpart as described in 21.3.11.2 (Beamforming Feedback Matrix V) with VHT replaced by S1G.

Compressed beamforming feedback using 19.3.12.3.6 (Compressed beamforming feedback matrix) is the only beamforming feedback format defined for S1G operation. In certain cases when the ψ angle is not included in the feedback frame (e.g., for SU feedback with $N_c = 1$), the ψ angles not included in the feedback report are given the values below, which (M118)corresponds to a single column V matrix having elements with equal magnitude:

If $N_r \times N_c = 4 \times 1$, $\Psi_{21} = 0.25\pi$, $\Psi_{31} = 0.196\pi$, $\Psi_{41} = 0.167\pi$
If $N_r \times N_c = 3 \times 1$, $\Psi_{21} = 0.25\pi$, $\Psi_{31} = 0.196\pi$
If $N_r \times N_c = 2 \times 1$, $\Psi_{21} = 0.25\pi$

#### 23.3.10.3 Maximum Number of Total Spatial Streams in S1G MU PPDUs

An MU capable STA shall support reception of S1G MU PPDUs with the total number of space-time streams across the NUM_USERS users being less than or equal to its Compressed Steering Number of Beamformer Antennas Supported in the S1G Capabilities Information field. The upper limit is 4 spatial streams.

#### 23.3.10.4 Group ID

The description of Group ID in an S1G band is identical to its VHT counterpart as described in 21.3.11.4 (Group ID) with VHT replaced by S1G.

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### 23.3.11 S1G preamble format for NDPs

An NDP may be used for sounding or for NDP CMAC PPDUs. In the case of NDP sounding, the SIG field in an NDP shall indicate multiple space-time streams and more than one LTF fields; NDP CMAC PPDUs only contain single space-time stream with one LTF field.

NDP is the only S1G sounding format.

NDP for sounding is defined only using the S1G_SHORT, and NDP for sounding is not allowed for 1 MHz transmissions. NDP CMAC PPDUs may either use an S1G_SHORT, or an S1G_1M.

The format of an S1G NDP for sounding is shown in Figure 23-17 (S1G NDP for sounding format(#7158)).

| 2 symbols | 2 symbols | 2 symbols | 1 symbol per LTF |
|---|---|---|---|
| STF | LTF1 | SIG | LTF2 ~ LTF$N_{LTF}$ |

**Figure 23-17—S1G NDP for sounding format(#7158)**

NOTE—The number of LTF symbols in the NDP is determined by the NSTS subfield in SIG field.

Transmission of an S1G NDP for sounding shall comply with the following rules:

- Shall use the S1G PPDU format but without the Data field.
- Shall use the S1G_SHORT.
- Shall use the following settings in SIG field:
  - MCS field is set to 0.
  - Length field is set to 0.
  - Bandwidth field is set to the same value as the TXVECTOR parameter CH_BANDWIDTH in the preceding VHT NDP Announcement frame carried in an S1G PPDU.
  - NSTS field indicates two or more space-time streams.
  - Partial AID field is set as described in 10.21.
  - The NDP indication bit is set to 0.
  - Response Indication field is set to Long Response (see TXVECTOR parameter RESPONSE_INDICATION).

The format of an NDP CMAC PPDU in 2 MHz, 4 MHz, 8 MHz, or 16 MHz is shown in Figure 23-18 (NDP CMAC PPDU for ≥ 2 MHz). The > 2 MHz NDP CMAC PPDUs are 2 MHz NDP CMAC PPDUs duplicated up to the transmission bandwidth according to CH_BANDWIDTH in TXVECTOR.

| 2 symbols | 2 symbols | 2 symbols |
|---|---|---|
| STF | LTF1 | SIG |

**Figure 23-18—NDP CMAC PPDU for ≥ 2 MHz**

The format of an S1G NDP CMAC PPDU in 1 MHz is shown in Figure 23-19 (NDP CMAC PPDU for 1 MHz). S1G NDP CMAC PPDUs for 1 MHz are duplicated up to their transmission bandwidth according to CH_BANDWIDTH in TXVECTOR.

Transmission of an NDP CMAC PPDU shall comply with the following rules:

- Shall use the S1G PPDU format but without the Data field.


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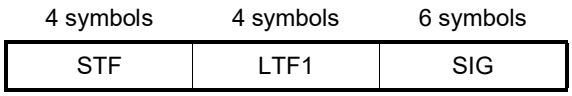


**Figure 23-19—NDP CMAC PPDU for 1 MHz**

— Shall use either the S1G_SHORT or the S1G_1M.
— Shall use the following settings in SIG field:
  — The NDP indication bit is set to 1.
— Shall contain only one LTF field.

The SIG field formats of NDP CMAC PPDUs are shown in Figure 23-20 (SIG field format for 1 MHz NDP CMAC PPDU) and Figure 23-21 (SIG field format for ≥ 2 MHz NDP CMAC PPDU).

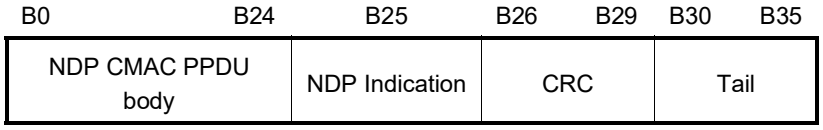


**Figure 23-20—SIG field format for 1 MHz NDP CMAC PPDU**

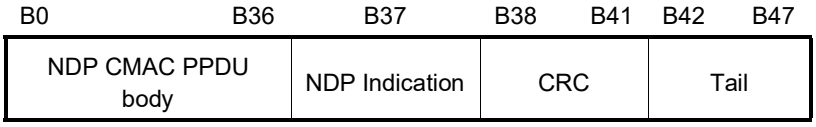


**Figure 23-21—SIG field format for ≥ 2 MHz NDP CMAC PPDU**

The NDP CMAC PPDU body field is described in 23.3.12 (NDP CMAC PPDUs).

The NDP Indication field is set to 1.

The CRC field is described in 23.3.8.2.2.6 (CRC calculation for S1G SIG-A fields). Tail field is set to 0.

### 23.3.12 NDP CMAC PPDUs

#### 23.3.12.1 General

The format of NDP CMAC PPDUs that use the S1G_1M format is shown in Figure 23-19 (NDP CMAC PPDU for 1 MHz). Figure 23-20 (SIG field format for 1 MHz NDP CMAC PPDU) shows the SIG field format that contains the NDP CMAC PPDU body field. B25 of the SIG field (the second bit of the fifth symbol) is set to 1 to indicate an NDP CMAC PPDU. The NDP CMAC PPDU body field is 25 bits for NDP CMAC PPDUs that are transmitted using the S1G_1M format (NDP_1M).

The format of NDP CMAC PPDUs that use the S1G_SHORT format is shown in Figure 23-18 (NDP CMAC PPDU for ≥ 2 MHz). Figure 23-21 (SIG field format for ≥ 2 MHz NDP CMAC PPDU) shows the SIG field format that contains the NDP CMAC PPDU body field. B37 of the SIG field (the fourteenth bit of the second symbol) is set to 1 to indicate an NDP CMAC PPDU. The NDP CMAC PPDU body field is 37 bits for NDP CMAC PPDUs that are transmitted using the S1G_SHORT format (NDP_2M).

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An NDP CMAC PPDU is indicated by setting the TXVECTOR parameter NDP_INDICATION to 1. The TXVECTOR parameter NDP_CMAC_PPDU_BODY is set to the concatenated bits of the NDP CMAC PPDU body field.

An RXVECTOR parameter NDP_INDICATION equal to 1 indicates reception of an NDP CMAC PPDU, and the NDP CMAC PPDU body field of the frame is obtained from the RXVECTOR parameter NDP_CMAC_PPDU_BODY.

The PHY preamble format for transmission of NDP CMAC PPDUs is defined in 23.3.11 (S1G preamble format for NDPs).

This subclause describes the NDP CMAC PPDU body field content for each of the NDP CMAC PPDU types. The type of the NDP CMAC PPDU is indicated in the NDP CMAC PPDU Type field and its values are defined in Table 23-30 (NDP CMAC PPDU Type field values).

NDP CMAC PPDUs(#1400) are not MPDUs but NDPs, but they obey the rules for equivalent MPDUs, as shown in Table 23-30 (NDP CMAC PPDU Type field values).

**Table 23-30—NDP CMAC PPDU Type field values**

| Value | Meaning | Equivalent MPDU | See subclause |
|---|---|---|---|
| 0 | NDP CTS or NDP CF-End | CTS or CF-End | 23.3.12.2.1 (NDP CTS), 23.3.12.2.2 (NDP CF-End) |
| 1 | NDP PS-Poll | PS-Poll | 23.3.12.2.3 (NDP PS-Poll) |
| 2 | NDP Ack | Ack | 23.3.12.2.4 (NDP Ack) |
| 3 | NDP PS-Poll-Ack | Ack to PS-Poll | 23.3.12.2.5 (NDP PS-Poll-Ack) |
| 4 | NDP BlockAck | BlockAck | 23.3.12.2.6 (NDP BlockAck) |
| 5 | NDP Beamforming Report Poll | Beamforming Report Poll | 23.3.12.2.7 (NDP Beamforming Report Poll) |
| 6 | NDP Paging | Action | 23.3.12.2.8 (NDP Paging) |
| 7 | NDP Probe Request | Probe Request | 23.3.12.2.9 (NDP Probe Request) |

### 23.3.12.2 NDP CMAC PPDU details

### 23.3.12.2.1 NDP CTS

#### 23.3.12.2.1.1 NDP_1M CTS

The format of the NDP CMAC PPDU body field of the NDP_1M CTS frame is shown in Figure 23-22 (NDP CMAC PPDU body field of the NDP_1M CTS frame).

The NDP CMAC PPDU Type field is set to 0.

The CTS/CF-End Indicator field is set to 0.


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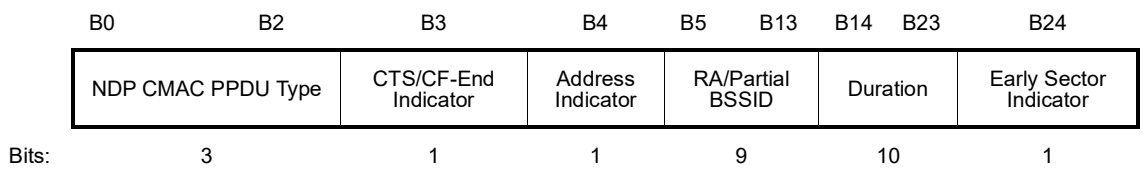


**Figure 23-22—NDP CMAC PPDU body field of the NDP_1M CTS frame**

The Address Indicator field is set to 0 to indicate that the RA/Partial BSSID field contains the partial identifier of the receiving STA. It is set to 1 to indicate that the RA/Partial BSSID field contains the partial BSSID of the BSS of the AP transmitting the frame and is interpreted as a broadcast address (see 10.3.2.9 (CTS and DMG CTS procedure) for the receiving STA's behavior). When the NDP CTS frame is used in the sector training it is set to 1.

The RA/Partial BSSID (PBSSID) field indicates:

— RA: the partial AID of the receiving non-AP STA or the partial BSSID of the receiving AP's BSS as described in 10.21 (Group ID, partial AID, Uplink Indication, and COLOR in S1G PPDUs)

— Partial BSSID: the partial BSSID of the BSS of the transmitting AP as described in 10.21 (Group ID, partial AID, Uplink Indication, and COLOR in S1G PPDUs)

The Duration field is expressed in units of OFDM symbol duration (40 μs) (Table 23-5 (Timing-related constants)) and follows the definitions in 9.3.1.3 (CTS frame format).

The Early Sector Indicator field is set to 1 to indicate that the NDP CTS frame is followed by the sectorized beam frame exchange sequence(#109). It is set to 0 to indicate that the NDP CTS frame is not followed by the sectorized beam frame exchange sequence(#109).

### 23.3.12.2.1.2 NDP_2M CTS

The format of the NDP CMAC PPDU body field of the NDP_2M CTS frame is shown in Figure 23-23 (NDP CMAC PPDU body field of the NDP_2M CTS frame).

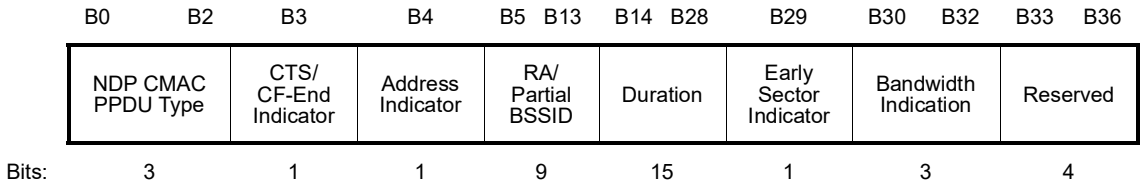


**Figure 23-23—NDP CMAC PPDU body field of the NDP_2M CTS frame**

The NDP CMAC PPDU Type field is set to 0.

The CTS/CF-End Indicator field is set to 0.

The Address Indicator field is set to 0 to indicate that the RA/Partial BSSID field contains the partial identifier of the receiving STA. It is set to 1 to indicate that the RA/Partial BSSID field contains the partial BSSID of the BSS of the AP transmitting the frame and is interpreted as a broadcast address (see 10.3.2.9 (CTS and DMG CTS procedure) for the receiving STA's behavior). When the NDP CTS frame is used in the sector training it is set to 1.

The RA/Partial BSSID (PBSSID) field indicates

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— RA: the partial AID of the receiving non-AP STA or the partial BSSID of the receiving AP's BSS as described in 10.21 (Group ID, partial AID, Uplink Indication, and COLOR in S1G PPDUs)
— Partial BSSID: the partial BSSID of the BSS of the transmitting AP as described in 10.21 (Group ID, partial AID, Uplink Indication, and COLOR in S1G PPDUs)

The Duration field is expressed in units of microseconds and follows the definitions in 9.3.1.3 (CTS frame format).

The Early Sector Indicator field is set to 1 to indicate that the NDP CTS frame is followed by the sectorized beam frame exchange sequence(#109). It is set to 0 to indicate that the NDP CTS frame is not followed by the sectorized beam frame exchange sequence(#109).

The Bandwidth Indication field is described in 9.2.4.1.11 (Bandwidth Indication and Dynamic Indication subfields).

(#455)The Reserved field shall be set to all 0s on transmit and ignored on receive.

#### 23.3.12.2.2 NDP CF-End

##### 23.3.12.2.2.1 NDP_1M CF-End

The format of the NDP CMAC PPDU body field of the NDP_1M CF-End frame is shown in Figure 23-24 (NDP CMAC PPDU body field of the NDP_1M CF-End frame).

| B0 – B2 | B3 | B4 – B12 | B13 – B22 | B23 – B24 |
|---|---|---|---|---|
| NDP CMAC PPDU Type | CTS/CF-End Indicator | Partial BSSID (TA) | Duration | Reserved |
| Bits: 3 | 1 | 9 | 10 | 2 |

**Figure 23-24—NDP CMAC PPDU body field of the NDP_1M CF-End frame**

The NDP CMAC PPDU Type field is set to 0.

The CTS/CF-End Indicator field is set to 1.

The Partial BSSID field indicates the PARTIAL_AID of the address of the STA contained in the AP.

The Duration field is expressed in units of OFDM symbol time (40 μs) and follows the definitions in 9.3.1.6 (CF-End frame format).

(#455)The Reserved field shall be set to all 0s on transmit and ignored on receive.

##### 23.3.12.2.2.2 NDP_2M CF-End

The format of the NDP CMAC PPDU body field of the NDP_2M CF-End frame is shown in Figure 23-25 (NDP CMAC PPDU body field of the NDP_2M CF-End frame).

The NDP CMAC PPDU Type field is set to 0.

The CTS/CF-End Indicator field is set to 1.

The Partial BSSID field indicates the PARTIAL_AID of the address of the STA contained in the AP.


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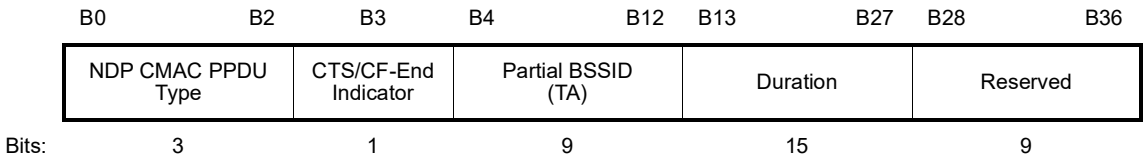


**Figure 23-25—NDP CMAC PPDU body field of the NDP_2M CF-End frame**

The Duration field is expressed in units of microseconds and follows the definitions in 9.3.1.6 (CF-End frame format).

(#455)The Reserved field shall be set to all 0s on transmit and ignored on receive.

### 23.3.12.2.3 NDP PS-Poll

#### 23.3.12.2.3.1 NDP_1M PS-Poll

The format of the NDP CMAC PPDU body field of the NDP_1M PS-Poll frame is shown in Figure 23-26 (NDP CMAC PPDU body field of the NDP_1M PS-Poll frame).

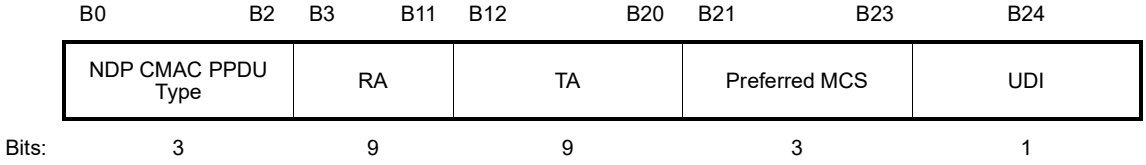


**Figure 23-26—NDP CMAC PPDU body field of the NDP_1M PS-Poll frame**

The NDP CMAC PPDU Type field is set to 1.

The RA field indicates the partial AID of the STA contained in the AP as described in 10.21 (Group ID, partial AID, Uplink Indication, and COLOR in S1G PPDUs).

The TA field indicates the partial AID of the STA transmitting the frame as described in 10.21 (Group ID, partial AID, Uplink Indication, and COLOR in S1G PPDUs).

The Preferred MCS field indicates the preferred MCS level for an 1 MHz channel width of the STA for downlink transmission. Mapping between Preferred MCS value and corresponding MCS index is shown in Table 23-31 (Preferred MCS subfield values for NDP_1M PS-Poll frame).

**Table 23-31—Preferred MCS subfield values for NDP_1M PS-Poll frame**

| Preferred MCS value | MCS Index | Description |
|---|---|---|
| 0 | 0 | BPSK 1/2 |
| 1 | 1 or 2 | QPSK 1/2 or QPSK 3/4 |
| 2 | 3 or 4 | 16-QAM 1/2 or 16-QAM 3/4 |
| 3 | 5 or 6 | 64-QAM 2/3 or 64-QAM 3/4 |
| 4 | 7 or 8 | 64-QAM 5/6 or 256-QAM 3/4 |

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**Table 23-31—Preferred MCS subfield values for NDP_1M PS-Poll frame**

| | | |
|---|---|---|
| 5 | 9 | 64-QAM 5/6 |
| 6 | 10 | BPSK 1/4 |
| 7 | No Preference | |

The Uplink Data Indicator (UDI) subfield indicates if the STA has uplink data to transmit:

— Set to 0 to indicate that there is no uplink data present

— Set to 1 to indicate that there is uplink data present

#### 23.3.12.2.3.2 NDP_2M PS-Poll

The format of the NDP CMAC PPDU body field of the NDP_2M PS-Poll frame is shown in Figure 23-27 (NDP CMAC PPDU body field of the NDP_2M PS-Poll frame).

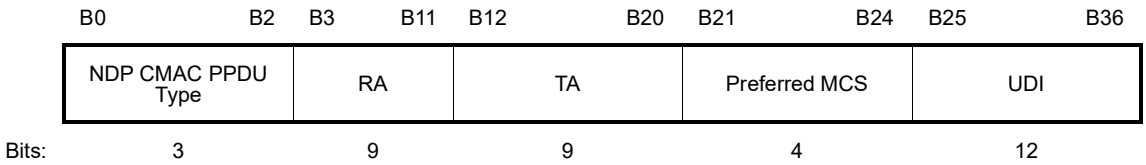


**Figure 23-27—NDP CMAC PPDU body field of the NDP_2M PS-Poll frame**

The NDP CMAC PPDU Type field is set to 1.

The RA field indicates the partial AID of the address of the STA contained in the AP as described in 10.21 (Group ID, partial AID, Uplink Indication, and COLOR in S1G PPDUs).

The TA field indicates the partial AID of the address of the STA transmitting the frame as described in 10.21 (Group ID, partial AID, Uplink Indication, and COLOR in S1G PPDUs).

The Preferred MCS field indicates the preferred MCS level for a 2 MHz channel width of the STA for downlink transmission. Mapping between Preferred MCS value and corresponding MCS index is shown in Table 23-32 (Preferred MCS subfield values for NDP_2M PS-Poll frame).

**Table 23-32—Preferred MCS subfield values for NDP_2M PS-Poll frame**

| Preferred MCS value | MCS Index | Description |
|---|---|---|
| 0–9 | 0–9 | The value represents the MCS index for the STA's preferred MCS level. |
| 10 | No Preference | |
| 11–12(M102) | 11–12 | The value represents the MCS index for the STA's preferred MCS level. |
| 13–15(M102) | Reserved | |

The Uplink Data Indicator (UDI) subfield indicates if the STA has uplink data to transmit and is used by an SST STA to indicate its selected SST channel:

— Set to 0 to indicate that there is no uplink data present


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— Set to 1 to indicate that there is uplink data present but the estimated time for the transmission of the uplink Data frames that are present at the STA is not determined.
— Set to a value between 2 and 9 to indicate the relative position of the selected SST channel with respect to the lowest numbered channel in the SST Enabled Channel Bitmap field of a received SST Operation element. For example, setting the UDI to 2 indicates that the selected SST channel is the first channel in the SST Enabled Channel Bitmap field, while setting the UDI to 3 indicates that the selected SST channel is the second channel in the SST Enabled Channel Bitmap field, etc.
— Set to a value greater than 9 to indicate the estimated time, in units of 40 μs, required for the transmission of the uplink Data frames that are present at the STA, excluding the duration of their response and applicable IFS durations.

#### 23.3.12.2.4 NDP Ack

##### 23.3.12.2.4.1 General

The NDP Ack frame, used to respond to an S1G frame, other than an NDP PS-Poll frame, is described in this subclause.

##### 23.3.12.2.4.2 NDP_1M Ack

The format of the NDP CMAC PPDU body field of the NDP_1M Ack frame is shown in Figure 23-28 (NDP CMAC PPDU body field of the NDP_1M Ack frame).

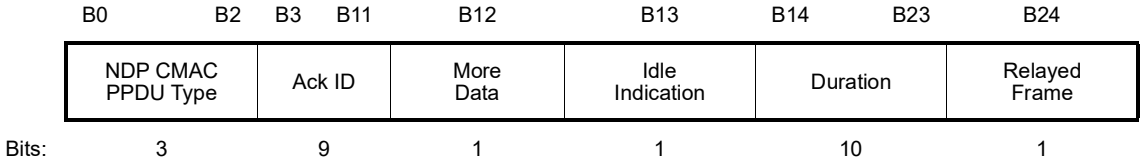


**Figure 23-28—NDP CMAC PPDU body field of the NDP_1M Ack frame**

The NDP CMAC PPDU Type field is set to 2.

The Ack ID field is set to the bit sequence Scrambler Initialization [0:6] || FCS[30:31] obtained from the scrambler initialization value in the (#3409)SERVICE field (as defined in 23.3.9.2 (SERVICE field)) prior to descrambling, and the FCS field of the PSDU that carries the soliciting frame. The scrambler initialization value is obtained from the RXVECTOR parameter SCRAMBLER_OR_CRC.

The More Data field is described in 9.2.4.1.8 (More Data subfield).

The Idle Indication field is set to 0 if the value of the Duration field sets the NAV as described in 9.2.5.6 (Setting for control response frames). Otherwise, it is set to 1 if the value of the Duration field indicates an idle period.

If the Idle Indication field is 0, the Duration field is set as described in 9.2.5.6 (Setting for control response frames) where the value is expressed in units of 40 μs. If the Idle Indication field is 1, the Duration field is set to the duration of time, in milliseconds, during which an idle period (during which there is no frame transmission) is expected from the STA that elicited the response, starting from the end of the NDP Ack frame response.

The Relayed Frame field is set as described in 10.53.5 (Procedures of TXOP sharing for S1G relay operation) and 10.60 (S1G flow control).

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#### 23.3.12.2.4.3 NDP_2M Ack

The format of the NDP CMAC PPDU body field of the NDP_2M Ack frame is shown in Figure 23-29 (NDP CMAC PPDU body field of the NDP_2M Ack frame).

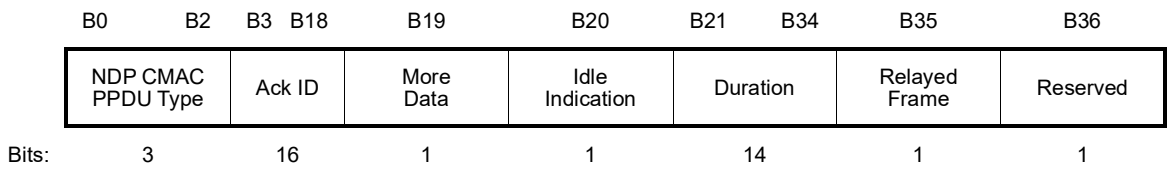


**Figure 23-29—NDP CMAC PPDU body field of the NDP_2M Ack frame**

The NDP CMAC PPDU Type field is set to 2.

The Ack ID field is set to the bit sequence Scrambler Initialization [0:6] || FCS[23:31] obtained from the scrambler initialization value in the (#3409)SERVICE field (as defined in 23.3.9.2 (SERVICE field)) prior to descrambling, and the FCS field of the PSDU that carries the soliciting frame. The scrambler initialization value is obtained from the RXVECTOR parameter SCRAMBLER_OR_CRC.

The More Data field is described in 9.2.4.1.8 (More Data subfield).

The Idle Indication field is set to 0 if the value of the Duration field sets the NAV as described in 9.2.5.6 (Setting for control response frames). Otherwise, it is set to 1 if the value of the Duration field indicates an idle period.

If the Idle Indication field is 0, the Duration field is set as described in 9.2.5.6 (Setting for control response frames) where the value is expressed in units of 1 μs(#8087)(#7198). If the Idle Indication field is 1, the Duration field is set to the duration of time, in milliseconds, during which an idle period (during which there is no frame transmission) is expected from the STA that elicited the response, starting from the end of the NDP Ack frame response.

The Relayed Frame field is set as described in 10.53.5 (Procedures of TXOP sharing for S1G relay operation) and 10.60 (S1G flow control).

(#455)The Reserved field shall be set to all 0s on transmit and ignored on receive.

### 23.3.12.2.5 NDP PS-Poll-Ack

#### 23.3.12.2.5.1 General

The NDP PS-Poll-Ack frame, used to respond to an NDP PS-Poll frame, is described in this subclause.

#### 23.3.12.2.5.2 NDP_1M PS-Poll-Ack

The format of the NDP CMAC PPDU body field of the NDP_1M PS-Poll-Ack frame is shown in Figure 23-30 (NDP CMAC PPDU body field of the NDP_1M PS-Poll-Ack frame).

The NDP CMAC PPDU Type field is set to 3.

The Ack ID field is set to the bit sequence CRC[0:3] || TA[4:8] obtained from the CRC and TA field of the NDP PS-Poll frame that elicited the response. The CRC value is obtained from the RXVECTOR parameter SCRAMBLER_OR_CRC.


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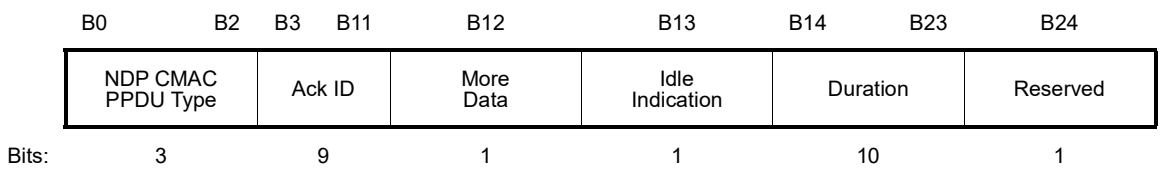


**Figure 23-30—NDP CMAC PPDU body field of the NDP_1M PS-Poll-Ack frame**

The More Data field is described in 9.2.4.1.8 (More Data subfield).

The Idle Indication field is set to 0 if the value of the Duration field is an extension of the Ack ID. Otherwise, it is set to 1 if the value of the Duration field indicates an idle period.

If the Idle Indication field is 0, the Duration field is set to the bit sequence TA[3] || RA[0:8] obtained from the RA and TA fields of the NDP PS-Poll frame that elicited the response. If the Idle Indication is 1, the Duration field is set to the duration of time, in milliseconds, during which an idle period (during which there is no frame transmission) is expected from the STA that elicited the response, starting from the end of the NDP PS-Poll-Ack frame response.

(#455)The Reserved field shall be set to all 0s on transmit and ignored on receive.

#### 23.3.12.2.5.3 NDP_2M PS-Poll-Ack

The format of the NDP CMAC PPDU body field of the NDP_2M PS-Poll-Ack frame is shown in Figure 23-31 (NDP CMAC PPDU body field of the NDP_2M PS-Poll-Ack frame).

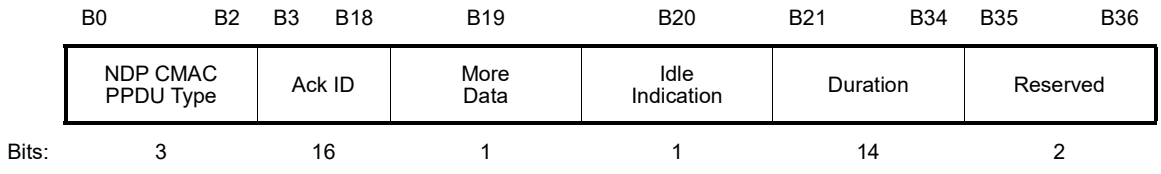


**Figure 23-31—NDP CMAC PPDU body field of the NDP_2M PS-Poll-Ack frame**

The NDP CMAC PPDU Type field is set to 3.

The Ack ID field is set to the bit sequence CRC[0:3] || TA[0:8] || RA[6:8]] obtained from the CRC, TA, and RA field of the NDP PS-Poll frame that elicited the response. The CRC value is obtained from the RXVECTOR parameter SCRAMBLER_OR_CRC.

The More Data field is described in 9.2.4.1.8 (More Data subfield).

The Idle Indication field is set to 0 if the value of the Duration field sets the NAV as described in 10.3.2.15 (NAV distribution). Otherwise, it is set to 1 if the value of the Duration field indicates an idle period.

If the Idle Indication field is 0, the Duration field is set as described in 10.3.2.15 (NAV distribution), where the value is expressed in units of 1 μs(#8087)(#7198).

If the Idle Indication field is 1, the Duration field is set to the duration of time, in milliseconds, during which an idle period (during which there is no frame transmission) is expected from the STA that elicited the response, starting from the end of the NDP PS-Poll-Ack frame response.

(#455)The Reserved field shall be set to all 0s on transmit and ignored on receive.

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#### 23.3.12.2.6 NDP BlockAck

##### 23.3.12.2.6.1 NDP_1M BlockAck

The format of the NDP CMAC PPDU body field of the NDP_1M BlockAck frame is shown in Figure 23-32 (NDP CMAC PPDU body field of the NDP_1M BlockAck frame).

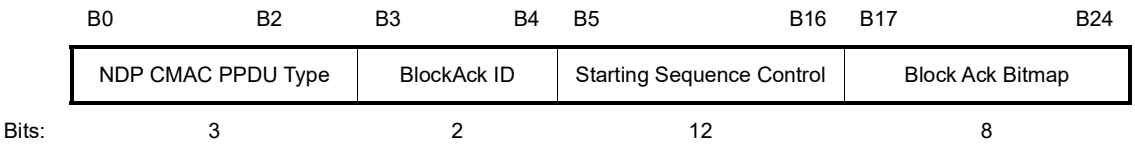


**Figure 23-32—NDP CMAC PPDU body field of the NDP_1M BlockAck frame**

The NDP CMAC PPDU Type field is set to 4.

The BlockAck ID field contains the identifier of the NDP BlockAck frame. It is set to the 2 LSBs of the bit sequence of the scrambler initialization value in the SERVICE field (as defined in 23.3.9.2 (SERVICE field)), prior to descrambling, of the PSDU that carries the soliciting frame. The scrambler initialization value is obtained from the RXVECTOR parameter SCRAMBLER_OR_CRC.

The Starting Sequence Control field contains the sequence number of the first MSDU or A-MSDU for which the NDP BlockAck frame is sent. This field is defined in 10.25.6.5 (Generation and transmission of BlockAck frames by an HT STA, DMG STA, or S1G STA) when the NDP BlockAck is used during a block ack agreement and is defined in 10.3.2.12 (Fragment BA procedure) when it is used in a fragment BA procedure.

The Block Ack Bitmap field of the NDP BlockAck frame is used to indicate the received status of:

— Up to 8 MSDUs and A-MSDUs when the NDP BlockAck is used during a block ack agreement. Each bit that is equal to 1 in the NDP BlockAck bitmap acknowledges the reception of a single MSDU or A-MSDU in the order of sequence number, with the first bit of the NDP BlockAck bitmap corresponding to the MSDU or A-MSDU with the sequence number that matches the value of the Starting Sequence Control field.

— Up to 8 fragments of an MSDU when the NDP BlockAck is used in a fragment BA procedure (see 10.3.2.12 (Fragment BA procedure)). Each bit that is equal to 1 in the BlockAck Bitmap acknowledges the reception of a single fragment of an MSDU, in the order of the fragment number, with the first bit of the BlockAck Bitmap corresponding to the MPDU with fragment number equal to 0 or 8.

The transmitting (receiving) STA encodes (decodes) the BlockAck ID field and the Starting Sequence Control field of the NDP BlockAck frames applying the protection mechanism described in 10.56 (Bitmap protection for NDP BlockAck frames).

##### 23.3.12.2.6.2 NDP_2M BlockAck

The format of the NDP CMAC PPDU body field of the NDP_2M BlockAck frame is shown in Figure 23-33 (NDP CMAC PPDU body field of the NDP_2M BlockAck frame).

The NDP CMAC PPDU Type field is set to 4.

The BlockAck ID field contains the identifier of the NDP BlockAck frame. It is set to the 6 LSBs of the bit sequence of the scrambler initialization value in the SERVICE field (as defined in 23.3.9.2 (SERVICE


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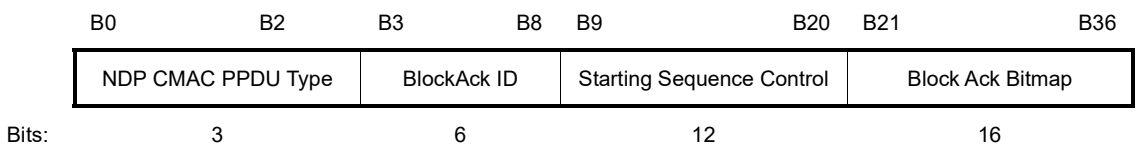


**Figure 23-33—NDP CMAC PPDU body field of the NDP_2M BlockAck frame**

field)), prior to descrambling, of the PSDU that carries the soliciting frame. The scrambler initialization value is obtained from the RXVECTOR parameter SCRAMBLER_OR_CRC.

The Starting Sequence Control field contains the sequence number of the first MSDU or A-MSDU for which the NDP BlockAck frame is sent. This field is defined in when the NDP BlockAck is used during a block ack agreement and is defined in 10.3.2.12 (Fragment BA procedure) when it is used in a fragment BA procedure.

The Block Ack Bitmap field of the NDP BlockAck frame is used to indicate the received status of:

— Up to 16 MSDUs and A-MSDUs when the NDP BlockAck is used during a block ack agreement. Each bit that is equal to 1 in the NDP BlockAck bitmap acknowledges the reception of a single MSDU or A-MSDU in the order of sequence number, with the first bit of the NDP BlockAck bitmap corresponding to the MSDU or A-MSDU with the sequence number that matches the value of the Starting Sequence Control field.

— Up to 16 fragments of an MSDU when the NDP BlockAck is used in a fragment BA procedure (see 10.3.2.12 (Fragment BA procedure)). Each bit that is equal to 1 in the BlockAck Bitmap acknowledges the reception of a single fragment of an MSDU, in the order of the fragment number, with the first bit of the BlockAck Bitmap corresponding to the MPDU with fragment number equal to 0.

The transmitting (receiving) STA encodes (decodes) the BlockAck ID field and the Starting Sequence Control field of the NDP BlockAck frames applying the protection mechanism described in 10.56 (Bitmap protection for NDP BlockAck frames).

#### 23.3.12.2.7 NDP Beamforming Report Poll

##### 23.3.12.2.7.1 NDP_2M Beamforming Report Poll

The format of the NDP CMAC PPDU body field of the NDP_2M Beamforming Report Poll frame is shown in Figure 23-34 (NDP CMAC PPDU body field of the NDP_2M Beamforming Report Poll frame).

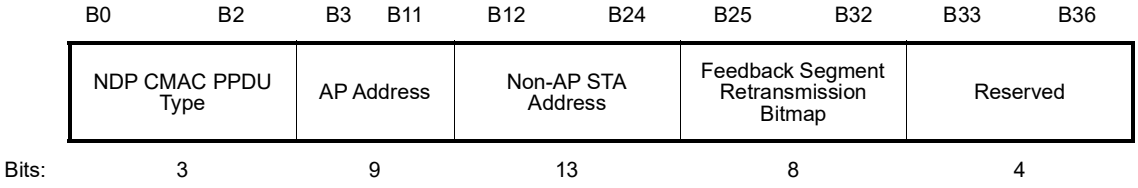


**Figure 23-34—NDP CMAC PPDU body field of the NDP_2M Beamforming Report Poll frame**

The NDP CMAC PPDU Type field is set to 5.

The AP Address field indicates the partial BSSID of the AP's BSS as described in 10.21 (Group ID, partial AID, Uplink Indication, and COLOR in S1G PPDUs).

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The Non-AP STA Address field indicates the AID of the non-AP STA.

The Feedback Segment Retransmission Bitmap field indicates the feedback segments to be polled in VHT compressed beamforming feedback(#4014)(#317), which is contained in one or more VHT Compressed Beamforming frames.

(#455)The Reserved field shall be set to all 0s on transmit and ignored on receive.

#### 23.3.12.2.8 NDP Paging

##### 23.3.12.2.8.1 General(#8179)

(#8179)An NDP Paging frame is an NDP_1M Paging frame or an NDP_2M Paging frame, as defined in this subclause.

##### 23.3.12.2.8.2 NDP_1M Paging

The format of the NDP CMAC PPDU body field of the NDP_1M Paging frame is shown in Figure 23-35 (NDP CMAC PPDU body field of the NDP_1M Paging frame).

| | B0 – B2 | B3 – B11 | B12 – B20 | B21 | B22 – B24 |
|---|---|---|---|---|---|
| | NDP CMAC PPDU Type | P-ID | APDI/partial AID | Direction | Reserved |
| Bits: | 3 | 9 | 9 | 1 | 3 |

**Figure 23-35—NDP CMAC PPDU body field of the NDP_1M Paging frame**

The NDP CMAC PPDU Type field is set to 6.

The P-ID field is the identifier of the NDP paging requester, as described in 10.46.6 (NDP paging setup).

If the Direction field is 1 the APDI/partial AID field indicates the AP direction information (APDI), where

- The 8 MSBs of the APDI, depending on the value of the Action subfield of the NDP paging response,(#8182) contain
  - The PTSF subfield if the Action subfield is not equal to 4. The PTSF subfield is set to the value of the partial TSF of the transmitting STA as defined in 10.46.6 (NDP paging setup).
  - The ASD subfield if the Action subfield is equal to 4. The ASD subfield is the additional sleep duration and is set to the time, in units of SIFS, after which the receiver STA is in awake state as described in 10.46.6 (NDP paging setup).
- The LSB of the APDI is the Check Beacon Flag subfield and is an indicator of critical changes in the Beacon frame as described in 10.46.6 (NDP paging setup).

If the Direction field is 0, the APDI/partial AID field indicates the partial AID of the NDP paging responder STA.

The Direction field is set to 1, if the NDP paging responder is an AP, otherwise it is set to 0.

(#455)The Reserved field shall be set to all 0s on transmit and ignored on receive.


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#### 23.3.12.2.8.3 NDP_2M Paging

The format of the NDP CMAC PPDU body field of the NDP_2M Paging frame is shown in Figure 23-36 (NDP CMAC PPDU body field of the NDP_2M Paging frame).

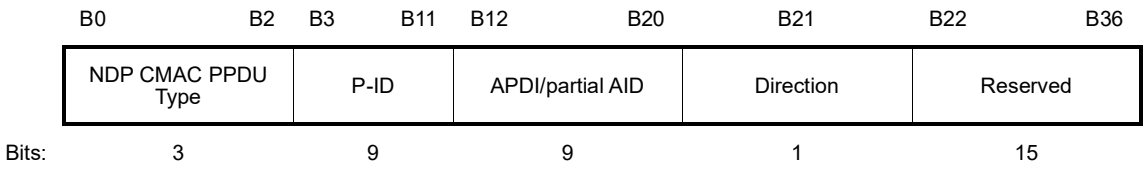


**Figure 23-36—NDP CMAC PPDU body field of the NDP_2M Paging frame**

The NDP CMAC PPDU Type field is set to 6.

The P-ID field is the identifier of the NDP paging requester, as described in 10.46.6 (NDP paging setup).

If the Direction field is 1, the APDI/partial AID field indicates the APDI (AP Direction Information) where:

- The 8 MSBs of the APDI, depending on the value of the Action subfield of the NDP paging response,(#8182) contain
  - The PTSF subfield if the Action subfield is not equal to 4. The PTSF subfield is set to the value of the partial TSF of the transmitting STA as defined in 10.46.6 (NDP paging setup).
  - The ASD subfield if the Action subfield is equal to 4. The ASD subfield is the additional sleep duration and is set to the time, in units of SIFS, after which the receiver STA is in awake state as described in 10.46.6 (NDP paging setup).
- The LSB of the APDI is the Check Beacon Flag subfield and is an indicator of critical changes in the Beacon frame as described in 10.46.6 (NDP paging setup).

If the Direction field is 0, the APDI/partial AID field indicates the partial AID of the NDP paging responder STA.

The Direction field is set to 1, if the NDP paging responder is an AP, otherwise it is set to 0.

(#455)The Reserved field shall be set to all 0s on transmit and ignored on receive.

### 23.3.12.2.9 NDP Probe Request

#### 23.3.12.2.9.1 General

NDP Probe Request frames are used in the procedures described in 11.1.4.3.6 (NDP Probing).

#### 23.3.12.2.9.2 NDP_1M Probe Request

The format of the NDP CMAC PPDU body field of the NDP_1M Probe Request frame is shown in Figure 23-37 (NDP CMAC PPDU body field of the NDP_1M Probe Request frame).

The NDP CMAC PPDU Type field is set to 7.

The CSSID/ANO Present field indicates if the NDP Probe Request frame contains a Compressed SSID field or an Access Network Option field:

- Set to 0 if the NDP Probe Request frame contains the Compressed SSID field.
- Set to 1 if the NDP Probe Request frame contains the Access Network Option field.

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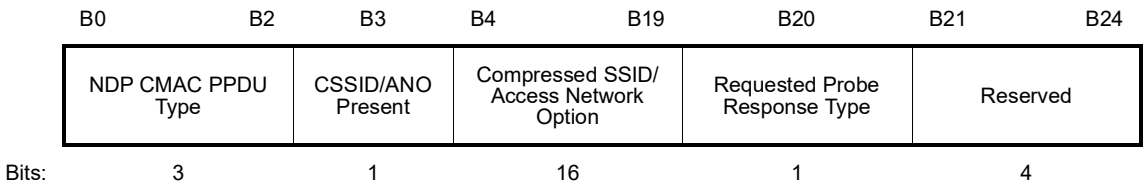


**Figure 23-37—NDP CMAC PPDU body field of the NDP_1M Probe Request frame**

When the CSSID/ANO Present field is 0, the Compressed SSID/Access Network Option field is set to (#8219)the compressed SSID, which is the 2 least significant octets of a 32-bit CRC calculated as defined 9.2.4.9 (FCS field), wherein the calculated fields is the (#8128)SSID.

(#8218)NOTE—This is encoded per 9.2.2 (Conventions). For example, if the short SSID has the coefficient of the highest order term set, and the coefficient of the next-to-lowest order term set, and all other coefficients clear, then the Compressed SSID/Access Network Option field contains 0x02 followed by 0x00.

When the CSSID/ANO Present field is 1, the Compressed SSID/Access Network Option field bits [0:7] are set to Access Network Option, which is defined in 9.4.2.90 (Interworking element) (see Figure 9-564 (Interworking element format)). The Compressed SSID/Access Network Option field bits [8:15] are reserved (#455)and shall be set to all 0s on transmit and ignored on receive.

The Requested Probe Response Type field indicates the Probe Response type:

— Set to 0 if the STA requests a PV1 Probe Response frame.
— Set to 1 if the STA requests a Probe Response frame.

(#455)The Reserved field shall be set to all 0s on transmit and ignored on receive.

### 23.3.12.2.9.3 NDP_2M Probe Request

The format of the NDP CMAC PPDU body field of the NDP_2M Probe Request frame is shown in Figure 23-38 (NDP CMAC PPDU body field of the NDP_2M Probe Request frame(#8219)).

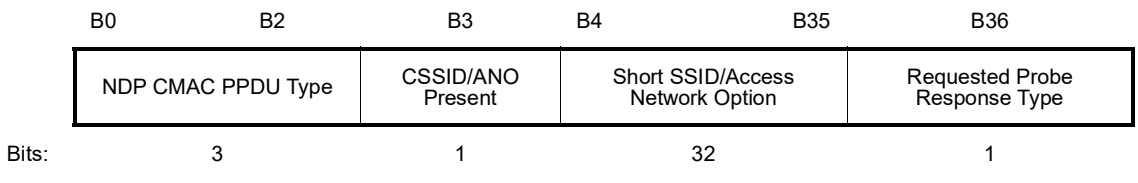


**Figure 23-38—NDP CMAC PPDU body field of the NDP_2M Probe Request frame(#8219)**

The NDP CMAC PPDU Type field is set to 7.

The CSSID/ANO Present field indicates if the NDP Probe Request frame contains a (#8219)Short SSID field or an Access Network Option field:

— Set to 0 if the NDP Probe Request contains the (#8219)Short SSID field.
— Set to 1 if the NDP Probe Request contains the Access Network Option field.

When the CSSID/ANO Present field is 0, (#8219)the Short SSID/Access Network Option field (#8218)is set to the short SSID, which is a 32-bit CRC calculated as defined in 9.2.4.9 (FCS field), wherein the calculated fields is the (#8128)SSID.

When the CSSID/ANO Present field is 1, the (#8219)Short SSID/Access Network Option field bits [0:7] are set to Access Network Option, which is defined in 9.4.2.90 (Interworking element) (see Figure 9-564


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(Interworking element format)). The(#8219) Short SSID/Access Network Option field bits [8:31] are reserved (#455)and shall be set to all 0s on transmit and ignored on receive.

The Requested Probe Response Type field indicates the Probe Response type:

— Set to 0 if the STA requests a PV1 Probe Response frame.
— Set to 1 if the STA requests a Probe Response frame.

### 23.3.13 Regulatory requirements

WLANs implemented in accordance with this standard are subject to equipment certification and operating requirements established by regional and national regulatory administrations. The PHY specification establishes minimum technical requirements for interoperability, based upon established regulations at the time this standard was issued. These regulations are subject to revision, or may be superseded. Requirements that are subject to local geographic regulations are annotated within the PHY specification. Regulatory requirements that do not affect interoperability are not addressed in this standard. Implementers are referred to the regulatory sources in Annex D for further information. Operation in countries within defined regulatory domains may be subject to additional or alternative national regulations.

### 23.3.14 Channelization

STAs compliant with the physical layer defined in Clause 23 (Sub 1 GHz (S1G) PHY specification(#4095)) operate in the channels (700 MHz – 1 GHz) defined in Annex E.

The channel center frequency, $f_c$, is defined as(#6420)

$$f_c\,[\text{MHz}] = \mathit{ChannelStartingFrequency} + f_{\text{separation}} \times \mathit{ChannelCenterChannelNumber}$$

where

$f_{\text{separation}}$ is the frequency separation between channels, and has the value of 0.5 MHz

*ChannelStartingFrequency* and *ChannelCenterChannelNumber*(#6420) are region and operating class specific and given in Annex E. The Channel spacing column in Annex E denotes the corresponding bandwidth for S1G operation.

The center frequency of the primary 1 MHz or primary 2 MHz channel, $f_{c,\,\text{primary}}$, is defined as:

$$f_{c,\,\text{primary}}\,[\text{MHz}] = \mathit{ChannelStartingFrequency} + f_{\text{separation}} \times \mathit{PrimaryChannelNumber}$$

where

$f_{\text{separation}}$ is the frequency separation between channels, and has the value of 0.5 MHz

*PrimaryChannelNumber* is the subchannel index of the primary 1 or 2 MHz channel within the overall bandwidth for S1G operation

### 23.3.15 Slot time

The slot time for the S1G PHY shall be 52 μs.

### 23.3.16 Transmit and receive port impedance

(#1247)The impedance of exposed transmit and receive antenna ports are defined in 17.3.8.7 (Transmit and receive impedance at the antenna connector).

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## 23.3.17 S1G transmit specification

### 23.3.17.1 Transmit spectrum mask

NOTE 1—In the presence of additional regulatory restrictions, the device has to meet both the regulatory requirements and the mask defined in this subclause.

NOTE 2—Transmit spectral mask figures in this subclause are not drawn to scale.

NOTE 3—For rules regarding TX center frequency leakage levels see 23.3.17.4.2 (Transmitter center frequency leakage). Transmit modulation accuracy specifications are described in 23.3.17.4.2 (Transmitter center frequency leakage) and 23.3.17.4.3 (Transmitter constellation error). The test method is described in 23.3.17.4.4 (Transmitter modulation accuracy (EVM) test). The spectral mask requirements in this subclause do not apply to the RF LO leakage.

(#1471)The overall transmit spectral mask is constructed using two components. First, an interim spectral mask is constructed whose mask level is determined relative to the maximum spectral density of the signal. Second, an absolute transmit spectral limit is computed based on the mask bandwidth. The overall transmit spectral mask is then constructed by taking the higher of the interim transmit spectral mask and the absolute transmit spectral limit at each frequency offset.

For a 1 MHz mask PPDU, the interim transmit spectral mask shall have a 0 dBr (dB relative to the maximum spectral density of the signal) bandwidth of 0.9 MHz, –20 dBr at 0.6 MHz frequency offset, –28 dBr at 1 MHz frequency offset and –40 dBr at 1.5 MHz frequency offset and above. The interim transmit spectral mask for frequency offsets in between 0.45 and 0.6 MHz, 0.6 and 1 MHz, and 1 and 1.5 MHz shall be linearly interpolated in dB domain from the requirements for 0.45, 0.6, 1 and 1.5 MHz frequency offsets. The transmit spectrum shall not exceed the maximum of the interim transmit spectral mask and –40 dBm/MHz at any frequency offset. Figure 23-39 (Transmit spectral mask for 1 MHz channel) shows an example of the resulting overall spectral mask when the –40 dBr spectrum level is above –40 dBm/MHz.

Measurements shall be made using a 10 kHz resolution bandwidth and a 100 Hz video bandwidth.

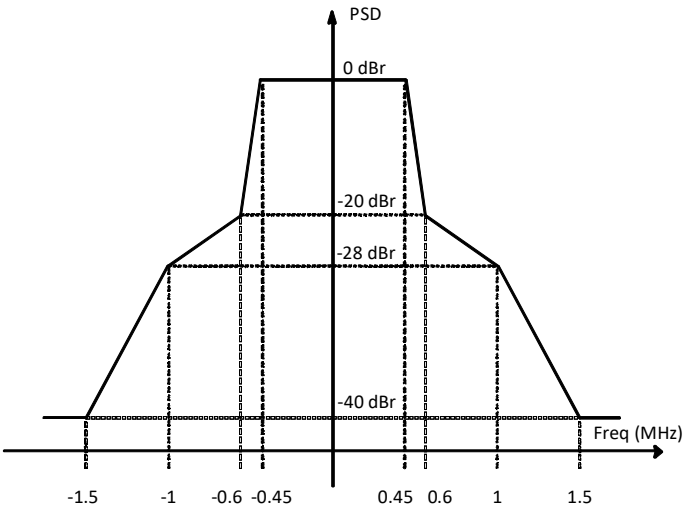


**Figure 23-39—Transmit spectral mask for 1 MHz channel**


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For a 2 MHz mask PPDU, the interim transmit spectral mask shall have a 0 dBr (dB relative to the maximum spectral density of the signal) bandwidth of 1.8 MHz, –20 dBr at 1.1 MHz frequency offset, –28 dBr at 2 MHz frequency offset and –40 dBr at 3 MHz frequency offset and above. The interim transmit spectral mask for frequency offsets in between 0.9 and 1.1 MHz, 1.1 and 2 MHz, and 2 and 3 MHz shall be linearly interpolated in dB domain from the requirements for 0.9, 1.1, 2 and 3 MHz frequency offsets. The transmit spectrum shall not exceed the maximum of the interim transmit spectral mask and –43 dBm/MHz at any frequency offset. Figure 23-40 (Transmit spectral mask for 2 MHz channel) shows an example of the resulting overall spectral mask when the –40 dBr spectrum level is above –43 dBm/MHz.

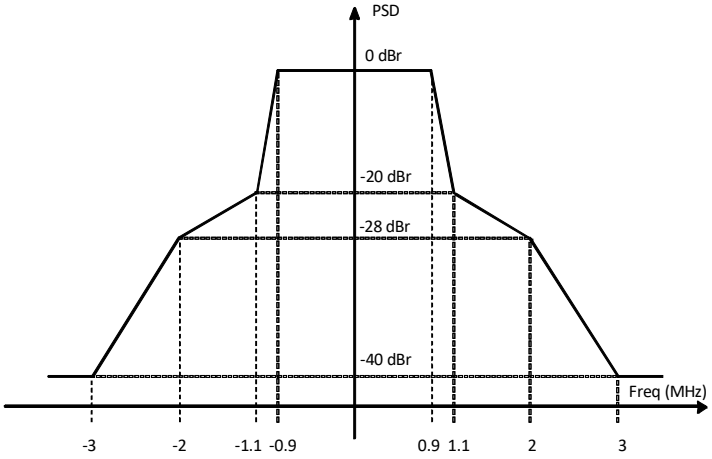


**Figure 23-40—Transmit spectral mask for 2 MHz channel**

For a 4 MHz mask PPDU, the interim transmit spectral mask shall have a 0 dBr (dB relative to the maximum spectral density of the signal) bandwidth of 3.8 MHz, –20 dBr at 2.1 MHz frequency offset, –28 dBr at 4 MHz frequency offset and –40 dBr at 6 MHz frequency offset and above. The interim transmit spectral mask for frequency offsets in between 1.9 and 2.1 MHz, 2.1 and 4 MHz, and 4 and 6 MHz shall be linearly interpolated in dB domain from the requirements for 1.9, 2.1, 4 and 6 MHz frequency offsets. The transmit spectrum shall not exceed the maximum of the interim transmit spectral mask and –46 dBm/MHz at any frequency offset. Figure 23-41 (Transmit spectral mask for 4 MHz channel) shows an example of the resulting overall spectral mask when the –40 dBr spectrum level is above –46 dBm/MHz.

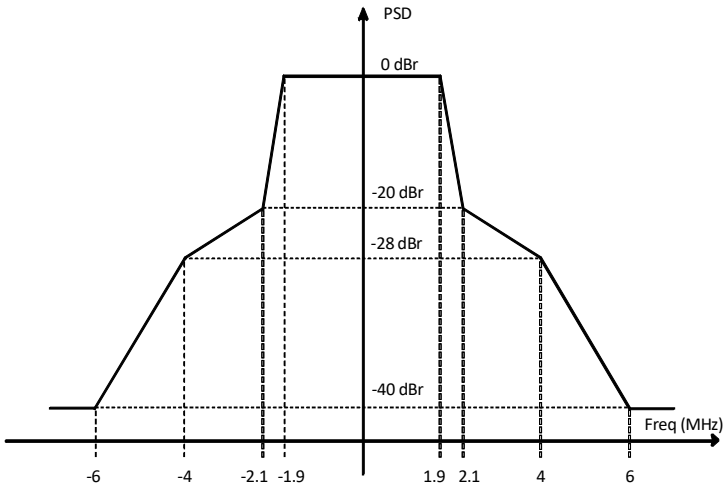


**Figure 23-41—Transmit spectral mask for 4 MHz channel**

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For a 8 MHz mask PPDU, the interim transmit spectral mask shall have a 0 dBr (dB relative to the maximum spectral density of the signal) bandwidth of 7.8 MHz, –20 dBr at 4.1 MHz frequency offset, –28 dBr at 8 MHz frequency offset and –40 dBr at 12 MHz frequency offset and above. The interim transmit spectral mask for frequency offsets in between 3.9 and 4.1 MHz, 4.1 and 8 MHz, and 8 and 12 MHz shall be linearly interpolated in dB domain from the requirements for 3.9, 4.1, 8 and 12 MHz frequency offsets. The transmit spectrum shall not exceed the maximum of the interim transmit spectral mask and –49 dBm/MHz at any frequency offset. Figure 23-42 (Transmit spectral mask for 8 MHz channel) shows an example of the resulting overall spectral mask when the –40 dBr spectrum level is above –49 dBm/MHz.

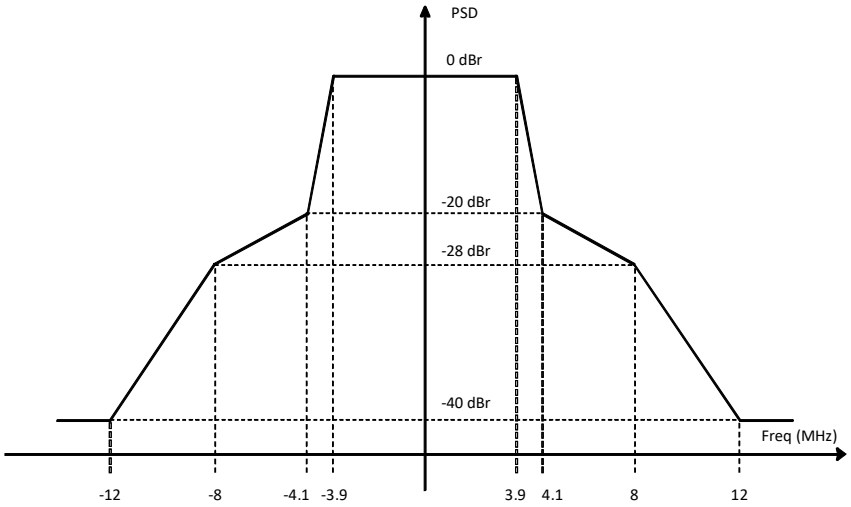


**Figure 23-42—Transmit spectral mask for 8 MHz channel**

For a 16 MHz mask PPDU, the interim transmit spectral mask shall have a 0 dBr (dB relative to the maximum spectral density of the signal) bandwidth of 15.8 MHz, –20 dBr at 8.1 MHz frequency offset, –28 dBr at 16 MHz frequency offset and –40 dBr at 24 MHz frequency offset and above. The interim transmit spectral mask for frequency offsets in between 7.9 and 8.1 MHz, 8.1 and 16 MHz, and 16 and 24 MHz shall be linearly interpolated in dB domain from the requirements for 7.9, 8.1, 16 and 24 MHz frequency offsets. The transmit spectrum shall not exceed the maximum of the interim transmit spectral mask and –49 dBm/MHz at any frequency offset. Figure 23-43 (Transmit spectral mask for 16 MHz


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channel) shows an example of the resulting overall spectral mask when the –40 dBr spectrum level is above –49 dBm/MHz.

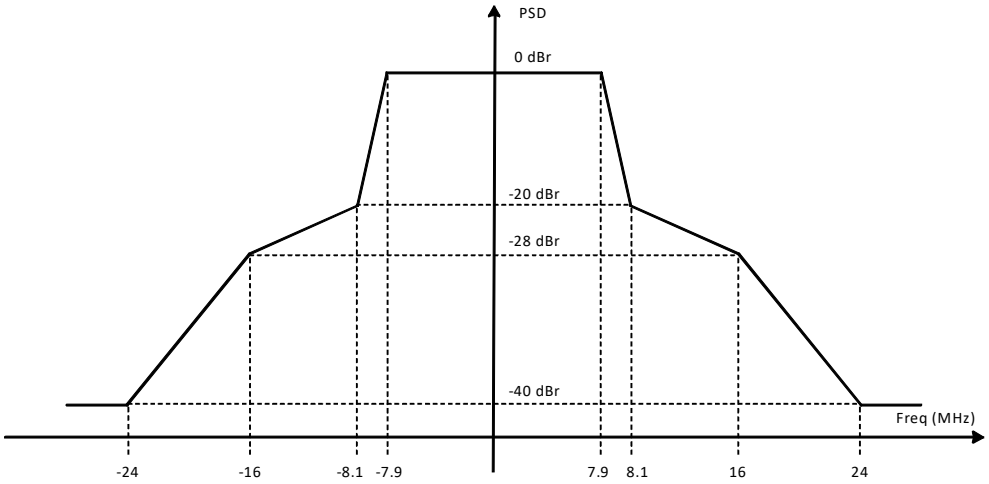


**Figure 23-43—Transmit spectral mask for 16 MHz channel**

### 23.3.17.2 Spectral flatness

Spectral flatness measurements shall be conducted using BPSK modulated PPDUs.

Let $E_{i,\,avg}$ denote the average constellation energy of a BPSK modulated subcarrier $i$ in an S1G data symbol.

In a normal mode S1G transmission or contiguous S1G 1 MHz or 2 MHz Duplicate mode transmission having a bandwidth listed in Table 23-33 (Maximum spectral flatness deviations), $E_{i,\,avg}$ of each of the subcarriers with indices listed as tested subcarrier indices shall not deviate by more than the specified maximum deviation in Table 23-33 (Maximum spectral flatness deviations) from the average of $E_{i,\,avg}$ over subcarrier indices listed as averaging subcarrier indices. Averaging of $E_{i,\,avg}$ is done in the linear domain.

For the spectral flatness test, the transmitting STA shall be configured to use a spatial mapping matrix $Q_k$ with flat frequency response. Each output port under test of the transmitting STA shall be connected through a cable to one input port of the testing instrumentation. The requirements apply to 1 MHz, 2 MHz, 4 MHz, 8 MHz, and 16 MHz normal mode transmissions and transmissions based on 1 and 2 MHz duplicated segments.

### 23.3.17.3 Transmit center frequency and symbol clock frequency tolerance

The symbol clock frequency and transmit center frequency tolerance shall be ± 20 ppm. The transmit center frequency and the symbol clock frequency for all transmit antennas and frequency segments shall be derived from the same reference oscillator.

### 23.3.17.4 Modulation accuracy

#### 23.3.17.4.1 Introduction to modulation accuracy tests

Transmit modulation accuracy specifications are described in 23.3.17.4.2 (Transmitter center frequency leakage) and 23.3.17.4.3 (Transmitter constellation error). The test method is described in 23.3.17.4.4 (Transmitter modulation accuracy (EVM) test).

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**Table 23-33—Maximum spectral flatness deviations**

| Format | BW of transmission (MHz) | Averaging subcarrier indices | Tested subcarrier indices | Maximum deviation (dB) |
|---|---|---|---|---|
| Normal Mode S1G | 1 | –8 to –1 and +1 to +8 | –8 to –1 and +1 to +8 | ± 4 |
| | | | –13 to –9 and +9 to +13 | +4/–6 |
| | 2 | –16 to –1 and +1 to +16 | –16 to –1 and +1 to +16 | ± 4 |
| | | | –28 to –17 and +17 to +28 | +4/–6 |
| | 4 | –42 to –2 and +2 to +42 | –42 to –2 and +2 to +42 | ± 4 |
| | | | –58 to –43 and +43 to +58 | +4/–6 |
| | 8 | –84 to –2 and +2 to +84 | –84 to –2 and +2 to +84 | ± 4 |
| | | | –122 to –85 and +85 to +122 | +4/–6 |
| | 16 | –172 to –130, –126 to –44, +44 to +126, and +130 to +172 | –172 to –130, –126 to –44, +44 to +126, and +130 to +172 | ± 4 |
| | | | –250 to –173, –43 to –6, +6 to +43, and +173 to +250 | +4/–6 |
| S1G 1 MHz Duplicate Mode | 2 | –15 to –3 and +3 to +15 | –15 to –3 and +3 to +15 | ± 4 |
| | | | –29 to –17 and +17 to +29 | |
| | 4 | –42 to –35, –29 to –17, –15 to –3, +3 to +15, +17 to +29, and +35 to +42 | –42 to –35, –29 to –17, –15 to –3, +3 to +15, +17 to +29, and +35 to +42 | ± 4 |
| | | | –61 to –49, –47 to –43, +43 to +47, and +49 to +61 | +4/–6 |
| | 8 | –84 to –81, –79 to –67, –61 to –49, –47 to –35, –29 to –17, –15 to –3, +3 to +15, +17 to +29, +35 to +47, +49 to +61, +67 to +79, and +81 to +84 | –84 to –81, –79 to –67, –61 to –49, –47 to –35, –29 to –17, –15 to –3, +3 to +15, +17 to +29, +35 to +47, +49 to +61, +67 to +79, and +81 to +84 | ± 4 |
| | | | –125 to –113, –111 to –99, –93 to –85, +85 to +93, +99 to +111, and +113 to +125 | +4/–6 |
| | 16 | –172 to –163, –157 to –145, –143 to –131, –125 to –113, –111 to –99, –93 to –81, –79 to –67, –61 to –49, –47 to –44, +44 to +47, +49 to +61, +67 to +79, +81 to +93, +99 to +111, +113 to +125, +131 to +143, +145 to +157, and +163 to +172 | –172 to –163, –157 to –145, –143 to –131, –125 to –113, –111 to –99, –93 to –81, –79 to –67, –61 to –49, –47 to –44, +44 to +47, +49 to +61, +67 to +79, +81 to +93, +99 to +111, +113 to +125, +131 to +143, +145 to +157, and +163 to +172 | ± 4 |
| | | | –253 to –241, –239 to –227, –221 to –209, –207 to –195, –189 to –177, –175 to –173, –43 to –35, –29 to –17, –15 to –3, +3 to +15, +17 to +29, +35 to +43,+173 to +175, +177 to +189, +195 to +207, +209 to +221, +227 to +239, and +241 to +253 | +4/–6 |


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**Table 23-33—Maximum spectral flatness deviations *(continued)***

| Format | BW of transmission (MHz) | Averaging subcarrier indices | Tested subcarrier indices | Maximum deviation (dB) |
|---|---|---|---|---|
| S1G 2 MHz Duplicate Mode | 4 | –42 to –33, –31 to –6, +6 to +31, and +33 to +42 | –42 to –33, –31 to –6, +6 to +31, and +33 to +42 | ± 4 |
| | | | –58 to –43 and +43 to +58 | +4/–6 |
| | 8 | –84 to –70, –58 to –33, +33 to +58, +70 to +84 | –84 to –70, –58 to –33, –31 to –6, +6 to +31, +33 to +58, and +70 to +84 | ± 4 |
| | | | –122 to –97, –95 to –85, +85 to +95, and+97 to +122 | +4/–6 |
| | 16 | –172 to –161, –159 to –134, –122 to –97, –95 to –70, –58 to –44, +44 to +58, +70 to +95, +97 to +122, +134 to +159, +161 to +172 | –172 to –161, –159 to –134, –122 to –97, –95 to –70, –58 to –44, +44 to +58, +70 to +95, +97 to +122, +134 to 159, and +161 to +172 | ± 4 |
| | | | –250 to –225, –223 to –198, –186 to –173, –43 to –33, –31 to –6, +6 to +31, +33 to +43, +173 to +186, +198 to 223, and +225 to +250 | +4/–6 |

### 23.3.17.4.2 Transmitter center frequency leakage

TX LO leakage is a consequence of the RF local oscillator (LO) and is the DC power emitted at its tuned center frequency. This TX LO leakage shall meet the following requirements for all formats and bandwidths:

— When the RF LO is in the center of the transmitted PPDU BW, the power measured at the center of transmission BW using resolution BW 31.25 kHz shall not exceed the average power per-subcarrier of the transmitted PPDU, or equivalently,( $P - 10\log 10(N_{ST})$ )(#315), where $P$ is the transmit power per antenna in dBm, and $N_{ST}$ is defined in Table 23-5 (Timing-related constants).

— When the RF LO is not at the center of the transmitted PPDU BW, the power measured at the location of the RF LO using resolution BW 31.25 kHz shall fall within that resolution BW of a 2 MHz channelization boundary and shall not exceed the maximum of –27 dB relative to the total transmit power and –15 dBm, or equivalently max($P$–27,–15), where $P$ is the transmit power per antenna in dBm. If 2 MHz channelization is not allowed in the regulatory region of operation, the TX LO leakage shall fall within the resolution BW of a 1 MHz channelization boundary and shall not exceed the maximum of –27 dB relative to the total transmit power and –15 dBm, or equivalently max($P$–27,–15), where $P$ is the transmit power per antenna in dBm.

The transmit center frequency leakage is specified per antenna.

### 23.3.17.4.3 Transmitter constellation error

The relative constellation RMS error, calculated by first averaging over subcarriers, OFDM PPDUs and spatial streams (#4181)(see Equation (19-89)) shall not exceed a data-rate dependent value according to Table 23-34 (Allowed relative constellation error versus constellation size and coding rate). The number of spatial streams under test shall be equal to the number of utilized transmitting STA antenna (output) ports and also equal to the number of utilized testing instrumentation input ports. In the test, $N_{SS}$=$N_{STS}$ (no STBC) shall be used. Each output port of the transmitting STA shall be connected through a cable to one input port

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of the testing instrumentation. The requirements apply to 1 MHz, 2 MHz, 4 MHz, 8 MHz, and 16 MHz transmissions.

**Table 23-34—Allowed relative constellation error versus constellation size and coding rate**

| Modulation | Coding rate | Relative constellation error (dB) |
|---|---|---|
| BPSK | 1/2 with 2× repetition | –4 |
| BPSK | 1/2 | –5 |
| QPSK | 1/2 | –10 |
| QPSK | 3/4 | –13 |
| 16-QAM | 1/2 | –16 |
| 16-QAM | 3/4 | –19 |
| 64-QAM | 2/3 | –22 |
| 64-QAM | 3/4 | –25 |
| 64-QAM | 5/6 | –27 |
| 256-QAM | 3/4 | –30 |
| 256-QAM | 5/6 | –32 |
| 1024-QAM(M102) | 3/4 | –35/–32 |
| 1024-QAM(M102) | 5/6 | –35/–32 |

(M102)For 1024-QAM, the relative constellation error shall meet the following requirements:

— The relative constellation error shall be less than or equal to –35 dB with amplitude drift compensation enabled in the test equipment, and the relative constellation error shall be less than or equal to –32 dB with amplitude drift compensation disabled in the test equipment.

(M102)For all other constellations, the relative constellation error shall be less than or equal to the values in Table 23-34 (Allowed relative constellation error versus constellation size and coding rate) regardless of whether amplitude drift compensation is enabled in the test equipment.


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#### 23.3.17.4.4 Transmitter modulation accuracy (EVM) test

The transmit modulation accuracy test shall be performed by instrumentation capable of converting the transmitted signals into a stream of complex samples at sampling rate greater than or equal to the bandwidth of the signal being transmitted; except that for duplicate transmissions, each 1 MHz or 2 MHz subchannel may be tested independently while all subchannels are being transmitted.

The instrument shall have sufficient accuracy in terms of I/Q arm amplitude and phase balance, DC offsets, phase noise, and analog to digital quantization noise. A possible embodiment of such a setup is converting the signals to a low IF frequency with a microwave synthesizer, sampling the signal with a digital oscilloscope and decomposing it digitally into quadrature components. The sampled signal shall be processed in a manner similar to an actual receiver, according to the following steps, or equivalent procedure:

a) Start of PPDU shall be detected.
b) Transition from STF field to LTF1 field shall be detected and fine timing shall be established.
c) Coarse and fine frequency offsets shall be estimated.
d) Symbols in a PPDU shall be derotated according to estimated frequency offset.
e) For each LTF symbol, transform the symbol into subcarrier received values, estimate the phase from the pilot subcarriers, and derotate the subcarrier values according to the estimated phase.
f) Estimate the complex channel response coefficient for each of the subcarriers and each of the transmit streams.
g) For each of the data OFDM symbols: transform the symbol into subcarrier received values, estimate the phase from the pilot subcarriers, derotate the subcarrier values according to the estimated phase, group the results from all the receiver chains in each subcarrier to a vector, and multiply the vector by a zero-forcing equalization matrix generated from the estimated channel.
h) For each data-carrying subcarrier in each spatial stream, find the closest constellation point and compute the Euclidean distance from it.
i) Compute the average across PPDUs of the RMS of all errors per PPDU as given by Equation (19-89).

The test shall be performed over at least 20 PPDUs [as defined in Equation (19-89)]. The PPDUs under test shall be at least 16 data OFDM symbols long. Random data shall be used for the symbols.

### 23.3.17.5 Time of Departure accuracy

(#8052)The RMS accuracy of the time of departure provided in TIME_OF_DEPARTURE shall be less than or equal to 80 ns.

The Time of Departure accuracy test evaluates TIME_OF_DEPARTURE against aTxPHYTxStartRMS and aTxPHYTxStartRMS against TIME_OF_DEPARTURE_ACCURACY_TEST_THRESH as defined in Annex T with the following test parameters:

— MULTICHANNEL_SAMPLING_RATE is

$1 \times 10^6 \left(1 + \left\lceil \frac{f_H - f_L}{1\ \text{MHz}} \right\rceil\right)$ sample/s, for a CH_BANDWIDTH parameter equal to CBW1

$2 \times 10^6 \left(1 + \left\lceil \frac{f_H - f_L}{2\ \text{MHz}} \right\rceil\right)$ sample/s, for a CH_BANDWIDTH parameter equal to CBW2

$4 \times 10^6 \left(1 + \left\lceil \frac{f_H - f_L}{4\ \text{MHz}} \right\rceil\right)$ sample/s, for a CH_BANDWIDTH parameter equal to CBW4

$8 \times 10^6 \left(1 + \left\lceil \frac{f_H - f_L}{8\ \text{MHz}} \right\rceil\right)$ sample/s, for a CH_BANDWIDTH parameter equal to CBW8

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$16 \times 10^6\left(1 + \left\lceil \frac{f_H - f_L}{16\ \text{MHz}} \right\rceil\right)$ sample/s, for a CH_BANDWIDTH parameter equal to CBW16

where

$f_H$ is the nominal center frequency in Hz of the highest channel in the channel set

$f_L$ is the nominal center frequency in Hz of the lowest channel in the channel set, the channel set is the set of channels upon which (#14)PPDUs providing measurements are transmitted.

— FIRST_TRANSITION_FIELD is the STF field.

— SECOND_TRANSITION_FIELD is the LTF1 field.

— TRAINING_FIELD is the LTF1 field windowed in a manner that should approximate the windowing described in 17.3.2.5 (Mathematical conventions in the signal descriptions) with TTR = 1000 ns.

— TIME_OF_DEPARTURE_ACCURACY_TEST_THRESH is 80 ns for a CH_BANDWIDTH parameter equal to CBW16, and unspecified otherwise.

NOTE—The indicated windowing applies to the time of departure accuracy test equipment, and not the transmitter or receiver.

### 23.3.18 S1G receiver specification

#### 23.3.18.1 Receiver minimum input level sensitivity(#256)

The (#14)PER shall be less than 10% for a PSDU length of 256 octets with the rate-dependent input levels listed in Table 23-35 (Receiver minimum input level sensitivity). The test in this subclause and the minimum sensitivity levels specified in Table 23-35 (Receiver minimum input level sensitivity) apply only to non-STBC modes, 8 μs GI, BCC, and S1G PPDU.

**Table 23-35—Receiver minimum input level sensitivity**

| Modulation | Rate (R) | Minimum sensitivity (1 MHz PPDU) (dBm) | Minimum sensitivity (2 MHz PPDU) (dBm) | Minimum sensitivity (4 MHz PPDU) (dBm) | Minimum sensitivity (8 MHz PPDU) (dBm) | Minimum sensitivity (16 MHz PPDU) (dBm) |
|---|---|---|---|---|---|---|
| BPSK | 1/2 with 2× repetition | –98 | N/A | N/A | N/A | N/A |
| BPSK | 1/2 | –95 | –92 | –89 | –86 | –83 |
| QPSK | 1/2 | –92 | –89 | –86 | –83 | –80 |
| QPSK | 3/4 | –90 | –87 | –84 | –81 | –78 |
| 16-QAM | 1/2 | –87 | –84 | –81 | –78 | –75 |
| 16-QAM | 3/4 | –83 | –80 | –77 | –74 | –71 |
| 64-QAM | 2/3 | –79 | –76 | –73 | –70 | –67 |
| 64-QAM | 3/4 | –78 | –75 | –72 | –69 | –66 |
| 64-QAM | 5/6 | –77 | –74 | –71 | –68 | –65 |
| 256-QAM | 3/4 | –72 | –69 | –66 | –63 | –60 |
| 256-QAM | 5/6 | –70 | –67 | –64 | –61 | –58 |



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**Table 23-35—Receiver minimum input level sensitivity**

| | | | | | | |
|---|---|---|---|---|---|---|
| 1024-QAM(M102) | 3/4 | –67 | –64 | –61 | –58 | –55 |
| 1024-QAM(M102) | 3/4 | –65 | –62 | –59 | –56 | –53 |

### 23.3.18.2 Adjacent channel rejection

Adjacent channel rejection for *W* MHz channels (where *W* is 1, 2, 4, 8, or 16) shall be measured by setting the requested signal's strength 3 dB above the rate dependent sensitivity specified in 23.3.18.1 (Receiver minimum input level sensitivity(#256)) and raising the power of the interfering signal of *W* MHz bandwidth until 10% PER is caused for a PSDU length of 256 octets. The power difference between the interfering and requested channel is the corresponding adjacent channel rejection. The center frequency of the adjacent channel shall be placed *W* MHz away from the center frequency of the requested signal.

The interfering signal in the adjacent channel shall be a conformant S1G signal, unsynchronized with the signal in the channel under test, and shall have a minimum duty cycle of 50%. For a conforming S1G PHY, the corresponding rejection shall be no less than specified in Table 23-36 (Minimum required adjacent and nonadjacent channel rejection levels).

The test in this subclause and the adjacent sensitivity levels specified in Table 23-36 (Minimum required adjacent and nonadjacent channel rejection levels) only apply to non-STBC modes with 8 μs GI and BCC.

The measurement of adjacent channel rejection for 2/4/8/16 MHz operation in a regulatory domain is only required if such a frequency band plan is permitted in that regulatory domain.

**Table 23-36—Minimum required adjacent and nonadjacent channel rejection levels**

| Modulation | Rate, R | Adjacent Channel Rejection (dB) | | Nonadjacent Channel Rejection (dB) | |
|---|---|---|---|---|---|
| | | 1 MHz Channel | 2/4/8/16 MHz Channel | 1 MHz Channel | 2/4/8/16 MHz Channel |
| BPSK | 1/2 with 2× repetition | 19 | N/A | 35 | N/A |
| BPSK | 1/2 | 16 | 16 | 32 | 32 |
| QPSK | 1/2 | 13 | 13 | 29 | 29 |
| QPSK | 3/4 | 11 | 11 | 27 | 27 |
| 16-QAM | 1/2 | 8 | 8 | 24 | 24 |
| 16-QAM | 3/4 | 4 | 4 | 20 | 20 |
| 64-QAM | 2/3 | 0 | 0 | 16 | 16 |
| 64-QAM | 3/4 | –1 | –1 | 15 | 15 |
| 64-QAM | 5/6 | –2 | –2 | 14 | 14 |

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**Table 23-36—Minimum required adjacent and nonadjacent channel rejection levels *(contin-***

| | | | | | |
|---|---|---|---|---|---|
| 256-QAM | 3/4 | –7 | –7 | 9 | 9 |
| 256-QAM | 5/6 | –9 | –9 | 7 | 7 |
| 1024-QAM(M102) | 3/4 | –12 | –12 | 4 | 4 |
| 1024-QAM(M102) | 5/6 | –14 | –14 | 2 | 2 |

### 23.3.18.3 Nonadjacent channel rejection

Nonadjacent channel rejection for *W* MHz channels (where *W* is 1, 2, 4, 8, or 16) shall be measured by setting the requested signal's strength 3 dB above the rate-dependent sensitivity specified in Table 23-36 (Minimum required adjacent and nonadjacent channel rejection levels), and raising the power of the interfering signal of W MHz bandwidth until a 10% PER occurs for a PSDU length of 256 octets. The power difference between the interfering and requested channel is the corresponding nonadjacent channel rejection. The center frequency of the nonadjacent channel shall be placed 2×*W* MHz or more away from the center frequency of the requested signal.

The interfering signal in the nonadjacent channel shall be a conformant S1G signal, unsynchronized with the signal in the channel under test, and shall have a minimum duty cycle of 50%. For a conforming OFDM PHY, the corresponding rejection shall be no less than specified in Table 23-36 (Minimum required adjacent and nonadjacent channel rejection levels).

The test in this subclause and the nonadjacent sensitivity levels specified in Table 23-36 (Minimum required adjacent and nonadjacent channel rejection levels) only apply to non-STBC modes with 8 μs GI and BCC.

The measurement of nonadjacent channel rejection for 2/4/8/16 MHz operation in a regulatory domain is only required if such a frequency band plan is permitted in that regulatory domain.

### 23.3.18.4 Receiver maximum input level

The receiver shall provide a maximum PER of 10% at a PSDU length of 256 octets, for a maximum input level of –30 dBm, measured at each antenna for any baseband S1G modulation.

### 23.3.18.5 CCA sensitivity

### 23.3.18.5.1 General

The thresholds in this subclause are compared with the signal level at each receiving antenna.

### 23.3.18.5.2 Type 1 and type 2 channelization for CCA levels

In S1G operation, the CCA sensitivity levels are defined such that they are dependent and specific to country channelization and channel location within the frequency band. For S1G channelizations in all regions of the world, there are to be two available classifications for channels and CCA levels, defined as type 1 and type 2.

For BSSs set up on channels classified as using type 1, STAs are to use what are referred to in this subclause as type 1 CCA levels when performing their CCA procedures. Likewise, if the BSS is set up on channels


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classified as type 2, STAs are required to use type 2 specific CCA levels. For SST BSS setups (see 10.51 (Subchannel selective transmission (SST))) where the SST BSS can include both type 1 and type 2 channels, the device in the SST BSS shall use the CCA level (type 1 or type 2) that corresponds to the current channel that is being accessed when performing their CCA procedures. The type 1 and type 2 channel classification for different operating classes in different regions of the world are denoted by "CCA Level Classification" in Table E-4 (Global operating classes) to Table E-5 (S1G operating classes) in Annex E.

In general, type 1 channels have CCA levels set to favor protection of ongoing transmissions and range of devices, relative to type 2 channels. Type 2 channels have CCA levels set to favor higher bandwidth and data rate transmissions, and to allow for higher reuse within the total network across different BSSs (relative to type 1 channels). To achieve this, type 2 channel CCA levels (i.e., thresholds) are defined to be higher than type 1 channel CCA levels.

CCA levels (M118)impact system behavior and performance increasingly with loading, therefore it is generally advantageous for BSSs primarily serving devices requiring more channel and transmission protection to set up on type 1 channels, and for BSSs expected to service devices with higher bandwidth and data rate transmissions to set up on type 2 channels if the region/country has both type 1 and type 2 channels available.

An S1G STA configures its active CCA conditions by generating a PHY-CONFIG.request(PHYCONFIG_VECTOR) primitive with the CCA_SENSITIVITY_TYPE parameter. For operating in type 1 channels, the MAC sublayer generates a PHY-CONFIG.request primitive with a PHYCONFIG_VECTOR parameter CCA_SENSITIVITY_TYPE set to CCA_SENSITIVITY_TYPE_1. For operating in type 2 channels, the MAC sublayer generates a PHY-CONFIG.request primitive with a PHYCONFIG_VECTOR parameter CCA_SENSITIVITY_TYPE set to CCA_SENSITIVITY_TYPE_2. For operating the 8/16 MHz intended channel width in type 2 channels, the MAC sublayer generates a PHY-CONFIG.request primitive with a PHYCONFIG_VECTOR parameter CCA_SENSITIVITY_TYPE set to CCA_SENSITIVITY_TYPE_2_WIDEBAND(#2365).

#### 23.3.18.5.3 CCA sensitivity for signals occupying the primary 2 MHz and/or primary 1 MHz channel

##### 23.3.18.5.3.1 General

In S1G operation, the CCA sensitivity levels a device shall use when detecting the start of S1G PPDUs are based on whether the occupied primary channel in question is classified as type 1 or type 2.

For devices operating in type 1 channels, the PHY shall issue a PHY-CCA.indication(BUSY, {primary1}) if one of the following conditions is present in an otherwise idle primary 1 MHz channel:

— The start of an S1G_1M PPDU or duplicate S1G_1M PPDU detected in the primary 1 MHz channel at or above –98 dBm within the primary 1 MHz channel with > 90% probability within a period aCCATime (see 23.4.4 (PHY characteristics)).

— Any S1G PPDU detected at or above –89 dBm within the primary 1 MHz channel with > 90% probability within a period of aCCAMidTime (see 23.4.4 (PHY characteristics)).

For devices operating in type 2 channels, the PHY shall issue a PHY-CCA.indication(BUSY, {primary1}) if one of the following conditions is present in an otherwise idle primary 1 MHz channel:

— The start of an S1G_1M PPDU or duplicate S1G_1M PPDU detected in the primary 1 MHz channel at or above –89 dBm within the primary 1 MHz channel with > 90% probability within a period aCCATime (see 23.4.4 (PHY characteristics)).

— Any S1G PPDU detected at or above –86 dBm within the primary 1 MHz channel with > 90% probability within a period of aCCAMidTime (see 23.4.4 (PHY characteristics)).

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The device shall not issue a PHY-CCA.indication(BUSY, {primary2}), PHY-CCA.indication(BUSY, {secondary2}), PHY-CCA.indication(BUSY, {secondary4}), or PHY-CCA.indication(BUSY, {secondary8}) until the end of the duration indicated by the (#14)PPDU or until all conditions above are no longer satisfied. Additionally, for both type 1 and type 2 channels, the device shall issue a PHY-CCA.indication(BUSY, {primary1}) if any received signal in the primary 1 MHz channel (#2365)exceeds –75 dBm within a period aCCATime.

For devices operating in type 1 channels, the PHY shall issue a PHY-CCA.indication(BUSY, {primary2}) if the conditions for issuing PHY-CCA.indication(BUSY, {primary1}) are not present and one of the following conditions is met in an otherwise idle 2 MHz, 4 MHz, 8 MHz, or 16 MHz operating channel width:

— An S1G_1M PPDU detected in the nonprimary 1 MHz portion of the primary 2 MHz channel at or above –89 dBm within the nonprimary 1 MHz with > 90% probability within a period of aCCAMidTime (see 23.4.4 (PHY characteristics)).

— A ≥ 2 MHz S1G PPDU at or above –89 dBm within the primary 2 MHz channel with > 90% probability within a period of aCCAMidTime (see 23.4.4 (PHY characteristics)).

— Any of the applicable conditions listed in Table 23-37 (Additional conditions for CCA BUSY on the primary 2 MHz in type 1 channelization). An applicable condition shall be met (i.e., triggered) if the PHY detects the start of the described PPDU(s) in Table 23-37 (Additional conditions for CCA BUSY on the primary 2 MHz in type 1 channelization) with > 90% probability within a period of aCCATime (see 23.4.4 (PHY characteristics)).

**Table 23-37—Additional conditions for CCA BUSY on the primary 2 MHz in type 1 channelization**

| Operating Channel Width | Conditions |
|---|---|
| 2 MHz, 4 MHz, 8 MHz, 16 MHz | The start of a 2 MHz S1G_SHORT or S1G_LONG PPDU, or of a duplicate S1G_SHORT or S1G_LONG PPDU at or above –92 dBm in the primary 2 MHz channel. |
| 4 MHz, 8 MHz, 16 MHz | The start of a 4 MHz S1G_SHORT or S1G_LONG PPDU, or of a duplicate S1G_SHORT or S1G_LONG PPDU at or above –89 dBm in the primary 4 MHz channel. |
| 8 MHz, 16 MHz | The start of an 8 MHz S1G_SHORT or S1G_LONG PPDU, or of a duplicate S1G_SHORT or S1G_LONG PPDU at or above –86 dBm in the primary 8 MHz channel. |
| 16 MHz | The start of a 16 MHz S1G_SHORT or S1G_LONG PPDU, or of a duplicate S1G_SHORT or S1G_LONG PPDU at or above –83 dBm. |

For devices operating in type 2 channels, the PHY shall issue a PHY-CCA.indication(BUSY, {primary2}) if the conditions for issuing PHY-CCA.indication(BUSY, {primary1}) are not present and one of the following conditions is met in an otherwise idle 2 MHz, 4 MHz, 8 MHz, or 16 MHz operating channel width:

— An S1G_1M PPDU is detected in the nonprimary 1 MHz portion of the primary 2 MHz channel at or above –86 dBm within the nonprimary 1 MHz with > 90% probability within a period of aCCAMidTime (see 23.4.4 (PHY characteristics)).

— A ≥ 2 MHz S1G PPDU at or above –86 dBm within the primary 2 MHz channel with > 90% probability within a period of aCCAMidTime (see 23.4.4 (PHY characteristics)).


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— Any of the applicable conditions listed in Table 23-38 (Additional conditions for CCA BUSY on the primary 2 MHz in type 2 channelization). An applicable condition shall be met (i.e., triggered) if the PHY detects the start of the described PPDU(s) in Table 23-38 (Additional conditions for CCA BUSY on the primary 2 MHz in type 2 channelization) with > 90% probability within a period of aCCATime (see 23.4.4 (PHY characteristics)).

**Table 23-38—Additional conditions for CCA BUSY on the primary 2 MHz in type 2 channelization**

| Operating Channel Width | Conditions |
|---|---|
| 2 MHz, 4 MHz, 8 MHz, 16 MHz | The start of a 2 MHz S1G_SHORT or S1G_LONG PPDU, or of a duplicate S1G_SHORT or S1G_LONG PPDU at or above –89 dBm in the primary 2 MHz channel. |
| 4 MHz, 8 MHz, 16 MHz | The start of a 4 MHz S1G_SHORT or S1G_LONG PPDU, or of a duplicate S1G_SHORT or S1G_LONG PPDU at or above –86 dBm in the primary 4 MHz channel. |
| 8 MHz, 16 MHz | The start of an 8 MHz S1G_SHORT or S1G_LONG PPDU, or of a duplicate S1G_SHORT or S1G_LONG PPDU at or above –83 dBm in the primary 8 MHz channel. |
| 16 MHz | The start of a 16 MHz S1G_SHORT or S1G_LONG PPDU, or of a duplicate S1G_SHORT or S1G_LONG PPDU at or above –80 dBm. |

The device shall not issue a PHY-CCA.indication(BUSY, {secondary2}), PHY-CCA.indication(BUSY, {secondary4}), or PHY-CCA.indication(BUSY, {secondary8}) until the end of the duration indicated by the (#14)PPDU or until all conditions above are no longer satisfied. Additionally, for both type 1 and type 2 channels, the device shall issue a PHY-CCA.indication(BUSY, {primary2}) if any received signal in the primary 2 MHz channel (#2365)exceeds –72 dBm within a period aCCATime.

Additionally, when a STA detects an S1G_SHORT or S1G_LONG PPDU with a Partial AID field of its SIG field indicating a partial AID or COLOR value that matches its (#3403)partial AID or BSSID, the PHY shall issue a PHY-CCA.indication(BUSY, {primary2}) for the remaining duration of the PPDU as indicated in its preamble.

#### 23.3.18.5.3.2 CCA sensitivity for devices in type 2 channels implementing intended 8 or 16 MHz transmit channel width channel access procedure

For devices operating in type 2 channels, if the device intends to transmit an 8 or 16 MHz channel width PPDU and the device implements the procedure and rules for high intended BW transmission channel access described in 10.23.2.6, the PHY shall issue a PHY-CCA.indication(BUSY, {primary1}) if one of the following conditions is present in an otherwise idle primary 1 MHz channel:

— The start of an S1G_1M PPDU or duplicate S1G_1M PPDU detected in the primary 1 MHz channel at or above –86 dBm within the primary 1 MHz channel with > 90% probability within a period aCCATime (see 23.4.4 (PHY characteristics)).

— Any S1G PPDU detected at or above –86 dBm with > 90% probability within a period of aCCAMidTime (see 23.4.4 (PHY characteristics)).

The device shall not issue a PHY-CCA.indication(BUSY, {primary2}), PHY-CCA.indication(BUSY, {secondary2}), PHY-CCA.indication(BUSY, {secondary4}), or PHY-CCA.indication(BUSY, {secondary8}) until the end of the duration indicated by the (#14)PPDU or until all conditions above are no

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longer satisfied. Additionally, the device shall issue a PHY-CCA.indication(BUSY, {primary1}) if any received signal in the primary 1 MHz channel (#2365)exceeds –75 dBm within a period aCCATime.

The PHY shall issue a PHY-CCA.indication(BUSY, {primary2}) if the conditions for issuing PHY-CCA.indication(BUSY, {primary1}) are not present and one of the following conditions is met in an otherwise idle 8 MHz or 16 MHz operating channel width:

— An S1G_1M PPDU is detected in the nonprimary 1 MHz portion of the primary 2 MHz channel at or above –86 dBm within the nonprimary 1 MHz with > 90% probability within a period of aCCAMidTime (see 23.4.4 (PHY characteristics)).

— A ≥ 2 MHz S1G PPDU at or above –86 dBm within the primary 2 MHz channel with > 90% probability within a period of aCCAMidTime (see 23.4.4 (PHY characteristics)).

— Any of the applicable conditions listed in Table 23-39 (Additional conditions for CCA BUSY on the primary 2 MHz in type 2 channelization for 8/16 MHz intended channel width). An applicable condition shall be met (i.e., triggered) if the PHY detects the start of the described PPDU(s) in Table 23-39 (Additional conditions for CCA BUSY on the primary 2 MHz in type 2 channelization for 8/16 MHz intended channel width) with > 90% probability within a period of aCCATime (see 23.4.4 (PHY characteristics)).

**Table 23-39—Additional conditions for CCA BUSY on the primary 2 MHz in type 2 channelization for 8/16 MHz intended channel width**

| Operating Channel Width | Conditions |
|---|---|
| 8 MHz, 16 MHz | The start of a 2 MHz S1G_SHORT or S1G_LONG PPDU, or of a duplicate S1G_SHORT or S1G_LONG PPDU at or above –86 dBm in the primary 2 MHz channel. |
| 8 MHz, 16 MHz | The start of a 4 MHz S1G_SHORT or S1G_LONG PPDU, or of a duplicate S1G_SHORT or S1G_LONG PPDU at or above –83 dBm in the primary 4 MHz channel. |
| 8 MHz, 16 MHz | The start of an 8 MHz S1G_SHORT or S1G_LONG PPDU, or of a duplicate S1G_SHORT or S1G_LONG PPDU at or above –80 dBm in the primary 8 MHz channel. |
| 16 MHz | The start of a 16 MHz S1G_SHORT or S1G_LONG PPDU, or of a duplicate S1G_SHORT or S1G_LONG PPDU at or above –77 dBm. |

The device shall not issue a PHY-CCA.indication(BUSY, {secondary2}), PHY-CCA.indication(BUSY, {secondary4}), or PHY-CCA.indication(BUSY, {secondary8}) until the end of the duration indicated by the packet or until all conditions above are no longer satisfied. Additionally, for both type 1 and type 2 channels, the device shall issue a PHY-CCA.indication(BUSY, {primary2}) if any received signal in the primary 2 MHz channel (#2365)exceeds –72 dBm within a period of aCCATime.

Additionally, when a STA detects an S1G_SHORT or S1G_LONG PPDU with a Partial AID field of its SIG field indicating a partial AID or COLOR value that matches its (#3403)partial AID or BSSID, the PHY shall issue a PHY-CCA.indication(BUSY, {primary2}) for the remaining duration of the PPDU as indicated in its preamble.


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#### 23.3.18.5.4 CCA sensitivity for signals not occupying the primary 2 MHz channel

In S1G operation, the CCA sensitivity levels for detecting signals in the secondary channels may be classified separately for type 1 or type 2 channels.

The PHY shall issue a PHY-CCA.indication(BUSY, {secondary2}) if the conditions for issuing PHY-CCA.indication(BUSY, {primary2}) are not present and one of the following conditions are present in an otherwise idle 4 MHz, 8 MHz, 16 MHz operating channel width:

- For both type 1 and type 2 channels, any signal within the secondary 2 MHz channel at or above a threshold of –72 dBm within a period of aCCATime after the signal arrives at the receiver's antenna(s); then the PHY shall not issue a PHY-CCA.indication(BUSY,{secondary4}), PHY-CCA.indication(BUSY,{secondary8}) or PHY-CCA.indication(IDLE) while the threshold continues to be exceeded.
- For type 1 channels, a 2 MHz S1G PPDU detected in the secondary 2 MHz channel at or above –86 dBm with > 90% probability within a period of aCCAMidTime (see 23.4.4 (PHY characteristics)).
- For type 2 channels, a 2 MHz S1G PPDU detected in the secondary 2 MHz channel at or above –82 dBm with > 90% probability within a period of aCCAMidTime (see 23.4.4 (PHY characteristics)).

The PHY shall issue a PHY-CCA.indication(BUSY, {secondary4}) if the conditions for issuing PHY-CCA.indication(BUSY, {primary2}) and PHY-CCA.indication(BUSY, {secondary2}) are not present and one of the following conditions are present in an otherwise idle 8 MHz, 16 MHz operating channel width:

- For both type 1 and type 2 channels, any signal within the secondary 4 MHz channel at or above a threshold of –69 dBm within a period of aCCATime after the signal arrives at the receiver's antenna(s); then the PHY shall not issue a PHY-CCA.indication(BUSY, {secondary8}) or PHY-CCA.indication(IDLE) while the threshold continues to be exceeded.
- For type 1 channels:
  - A 4 MHz S1G PPDU detected in the secondary 4 MHz channel at or above –86 dBm with > 90% probability within a period of aCCAMidTime (see 23.4.4 (PHY characteristics)).
  - A 2 MHz S1G PPDU detected in any 2 MHz subchannel of the secondary 4 MHz channel at or above –86 dBm with > 90% probability within a period of aCCAMidTime.
- For type 2 channels:
  - A 4 MHz S1G PPDU detected in the secondary 4 MHz channel at or above –82 dBm with > 90% probability within a period of aCCAMidTime (see 23.4.4 (PHY characteristics)).
  - A 2 MHz S1G PPDU detected in any 2 MHz subchannel of the secondary 4 MHz channel at or above –82 dBm with > 90% probability within a period of aCCAMidTime.

The PHY shall issue a PHY-CCA.indication(BUSY, {secondary8}) if the conditions for PHY-CCA.indication(BUSY, {primary2}), PHY-CCA.indication(BUSY, {secondary2}) and PHY-CCA.indication(BUSY,{secondary4}) are not present and one of the following conditions are present in an otherwise idle 16 MHz operating channel width:

- For both type 1 and type 2 channels, any signal within the secondary 8 MHz channel at or above –66 dBm.
- For type 1 channels:
  - An 8 MHz S1G PPDU detected in the secondary 8 MHz channel at or above –83 dBm with > 90% probability within a period of aCCAMidTime (see 23.4.4 (PHY characteristics)).
  - A 4 MHz S1G PPDU detected in any 4 MHz subchannel of the secondary 8 MHz channel at or above –86 dBm with > 90% probability within a period of aCCAMidTime.

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- A 2 MHz S1G PPDU detected in any 2 MHz subchannel of the secondary 8 MHz channel at or above –86 dBm with > 90% probability within a period of aCCAMidTime.

- For type 2 channels:
  - An 8 MHz S1G PPDU detected in the secondary 8 MHz channel at or above –79 dBm with > 90% probability within a period aCCAMidTime (see 23.4.4 (PHY characteristics)).
  - A 4 MHz S1G PPDU detected in any 4 MHz subchannel of the secondary 8 MHz channel at or above –82 dBm with > 90% probability within a period of aCCAMidTime.
  - A 2 MHz S1G PPDU detected in any 2 MHz subchannel of the secondary 8 MHz channel at or above –82 dBm with > 90% probability within a period of aCCAMidTime.

#### 23.3.18.6 RSSI

The RSSI parameter returned in the RXVECTOR shall be calculated during the reception of the (D-)LTFs and shall be a monotonically increasing function of the received power.

#### 23.3.18.7 Received channel power indicator (RCPI) measurement(#2011)

The RCPI is a measure of the received RF power in the selected channel for a received PPDU. This parameter shall be a measurement by the PHY of the received RF power in the channel measured over the STF or LTF fields of the received PPDU. If the RCPI is measured over the STF field for an S1G 1 MHz PPDU using MCS 10, then (#3473)the reported RCPI value is 3 dB less than the measured power over the STF field. The received power shall be the average of the power in all active receive chains.

NOTE—The STF field in an S1G 1 MHz PPDU using MCS 10 has 3 dB higher power than the Data field, hence the reported RCPI value is subtracting from 3 dB from the measured power.

RCPI shall equal the received RF power in dBm within an accuracy of ± 5 dB (95% confidence interval) (#3476)within the specified dynamic range of the receiver.

### 23.3.19 PHY transmit procedure

The typical transmit procedure is shown in Figure 23-44 (PHY transmit procedure for an SU transmission using S1G_1M procedure(#213)), Figure 23-45 (PHY transmit procedure for an SU transmission using S1G_SHORT procedure(#213)), and Figure 23-46 (PHY transmit procedure for an SU transmission using S1G_LONG procedure(#213)). For this transmit procedure, the FORMAT parameter of the PHY-


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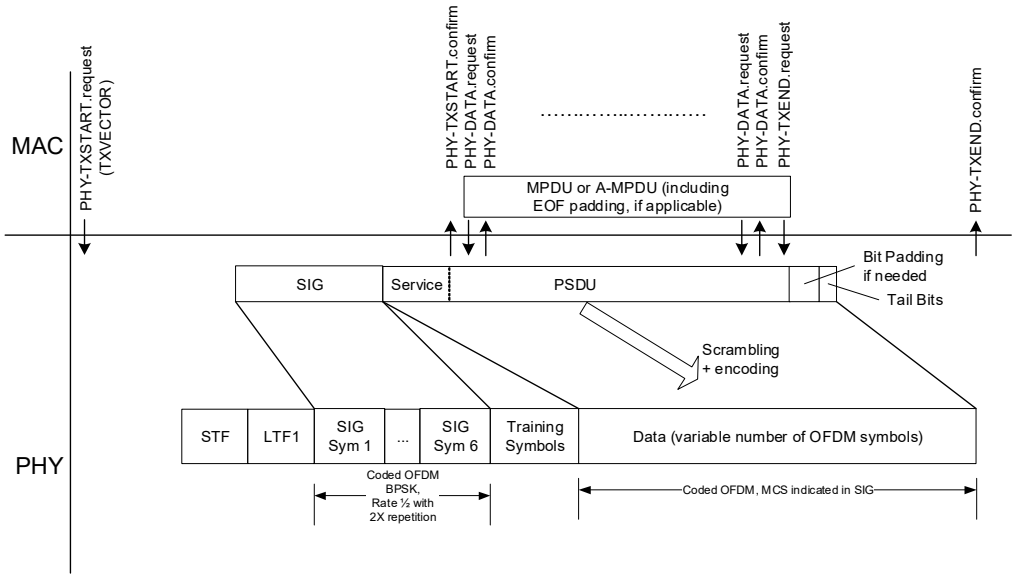
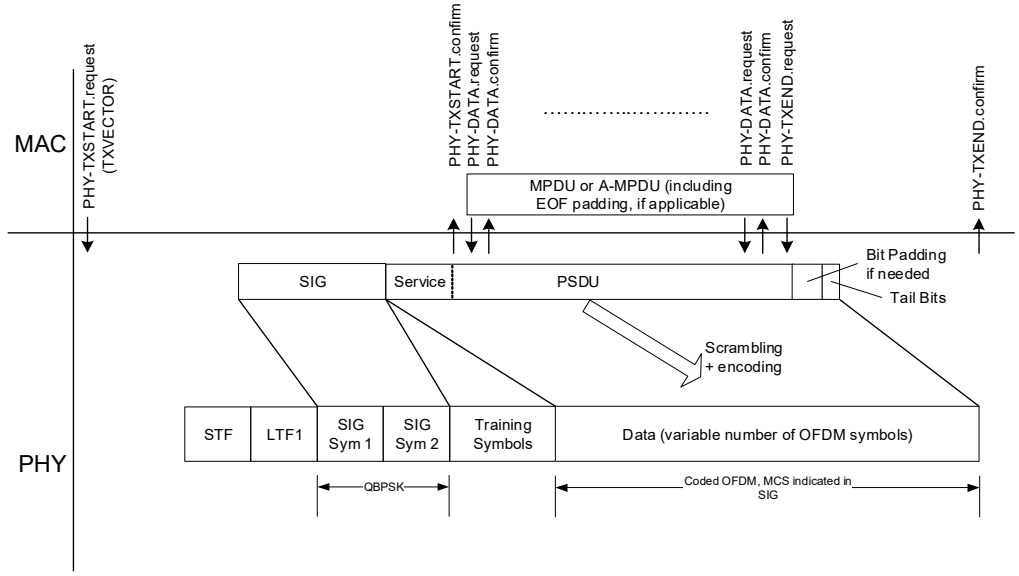
TXSTART.request(TXVECTOR) primitive is S1G. These transmit procedures do not describe the operation of optional features, such as LDPC, STBC, or MU.




NOTE—This procedure does not describe the operation of optional features, such as MU-MIMO, LDPC or STBC.

**Figure 23-44—PHY transmit procedure for an SU transmission using S1G_1M procedure(#213)**




NOTE—This procedure does not describe the operation of optional features, such as MU-MIMO, LDPC or STBC.

**Figure 23-45—PHY transmit procedure for an SU transmission using S1G_SHORT procedure(#213)**

NOTE—For an MU PPDU the A-MPDU is per user in the MAC sublayer and the S1G training symbols, SIG-B, and Data are per user in the PHY layer in Figure 23-46 (PHY transmit procedure for an SU transmission using S1G_LONG

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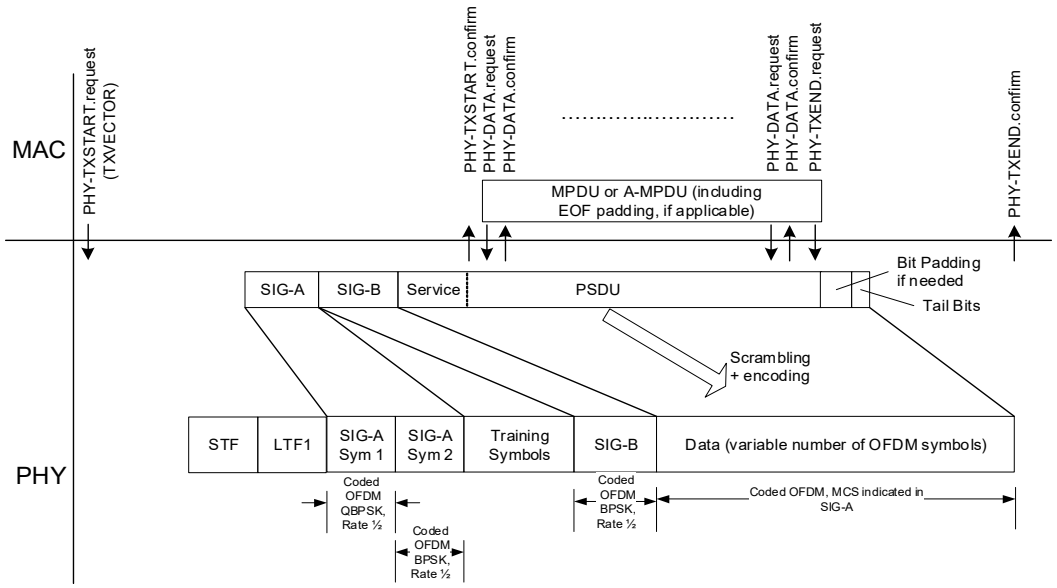
procedure(#213)), with the number S1G training symbols depending on the total number of space-time streams across all users.

In order to transmit data, the MAC generates a PHY-TXSTART.request primitive, which causes the PHY entity to enter the transmit state. Further, the PHY is set to operate at the appropriate frequency through station management via the PLME, as specified in 23.4 (S1G PLME(#6321)).




NOTE—This procedure does not describe the operation of optional features, such as MU-MIMO, LDPC or STBC.

**Figure 23-46—PHY transmit procedure for an SU transmission using S1G_LONG procedure(#213)**

Other transmit parameters, such as S1G-MCS coding types and transmit power, are set via the PHY SAP using the PHY-TXSTART.request(TXVECTOR) primitive, as described in 23.2.2 (TXVECTOR and RXVECTOR parameters).

The PHY indicates the state of the primary channel and other channels (if any) via the PHY-CCA.indication primitive (see 23.3.18.5 (CCA sensitivity) and 8.3.5.12 (PHY-CCA.indication)). Note that under some circumstances, the MAC uses the value of the PHY-CCA.indication primitive before (and if) issuing the PHY-TXSTART.request primitive. Transmission of the PPDU shall be initiated by the PHY after receiving the PHY-TXSTART.request(TXVECTOR) primitive. The TXVECTOR elements for the PHY-TXSTART.request primitive are specified in Table 23-1 (TXVECTOR and RXVECTOR parameters).

Transmission of the PHY preamble shall start immediately, using the parameters passed in the PHY-TXSTART.request primitive and the PHY shall issue a PHY-TXSTART.confirm primitive to the MAC.

After the PHY preamble transmission is started, the PHY entity immediately initiates data scrambling and data encoding. The encoding method for the Data field is based on the FEC_CODING, CH_BANDWIDTH, NUM_STS, STBC, MCS, and NUM_USERS parameter of the TXVECTOR, as described in 23.3.2 (S1G PPDU format).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The SERVICE field and PSDU are encoded as described in 23.3.3 (Transmitter block diagram). The data shall be exchanged between the MAC and the PHY through a series of PHY-DATA.request(DATA) primitives issued by the MAC, and PHY-DATA.confirm primitives issued by the PHY. Zero to seven PHY padding bits are appended to the PSDU to make the number of bits in the coded PSDU an integer multiple of the number of coded bits per OFDM symbol.

Transmission can be prematurely terminated by the MAC through the primitive PHY-TXEND.request primitive. PSDU transmission is terminated by receiving a PHY-TXEND.request primitive. Each PHY-TXEND.request primitive is acknowledged with a PHY-TXEND.confirm primitive from the PHY. In an SU transmission, normal termination occurs after the transmission of the final bit of the last PSDU octet, according to the number of OFDM symbols indicated by NSYM (see 23.4.3 (TXTIME and PSDU_LENGTH calculation)).

In the PHY, the GI or short GI is inserted in every data OFDM symbol as a countermeasure against delay spread.

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(#2137)An NDP CMAC PPDU(#1400) transmit procedure is shown in Figure 23-47 (PHY transmit procedure for an NDP CMAC PPDU transmission using S1G_1M format) and Figure 23-48 (PHY transmit procedure for an NDP CMAC PPDU transmission using S1G_SHORT format).

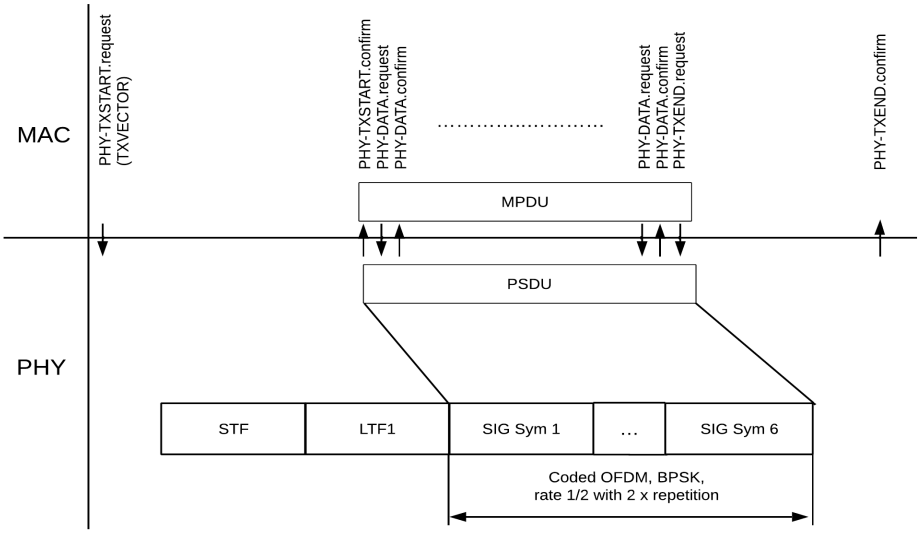


**Figure 23-47—PHY transmit procedure for an NDP CMAC PPDU transmission using S1G_1M format**

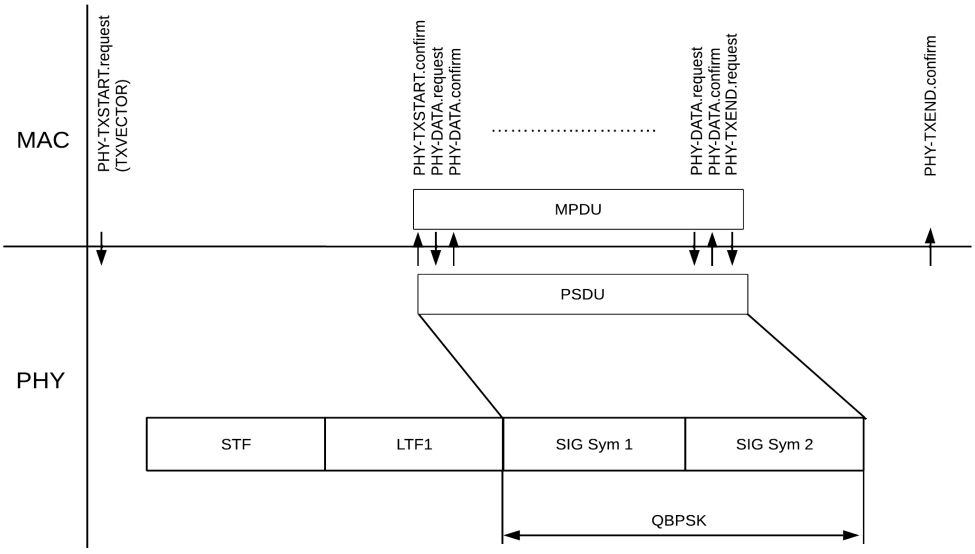


**Figure 23-48—PHY transmit procedure for an NDP CMAC PPDU transmission using S1G_SHORT format**

In case of transmission of the NDP CMAC PPDU, the PHY performs the same procedure like the typical transmit procedure as described in this subclause except as follows

— No service field appended
— No PHY padding bits appended to the PSDU
— No scrambling applied to PSDU


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— PSDU is mapping to the SIG field

When the PPDU transmission is completed the PHY entity enters the receive state.

A typical state machine implementation of the transmit PHY for an S1G PPDU transmission is provided in Figure 23-49 (PHY transmit state machine for an S1G PPDU transmission(#2260)(#3409)). Request (.request) and confirmation (.confirm) primitives are issued once per state as shown. This state machine does not describe the operation of optional features, such as multi-user, LDPC, or STBC.

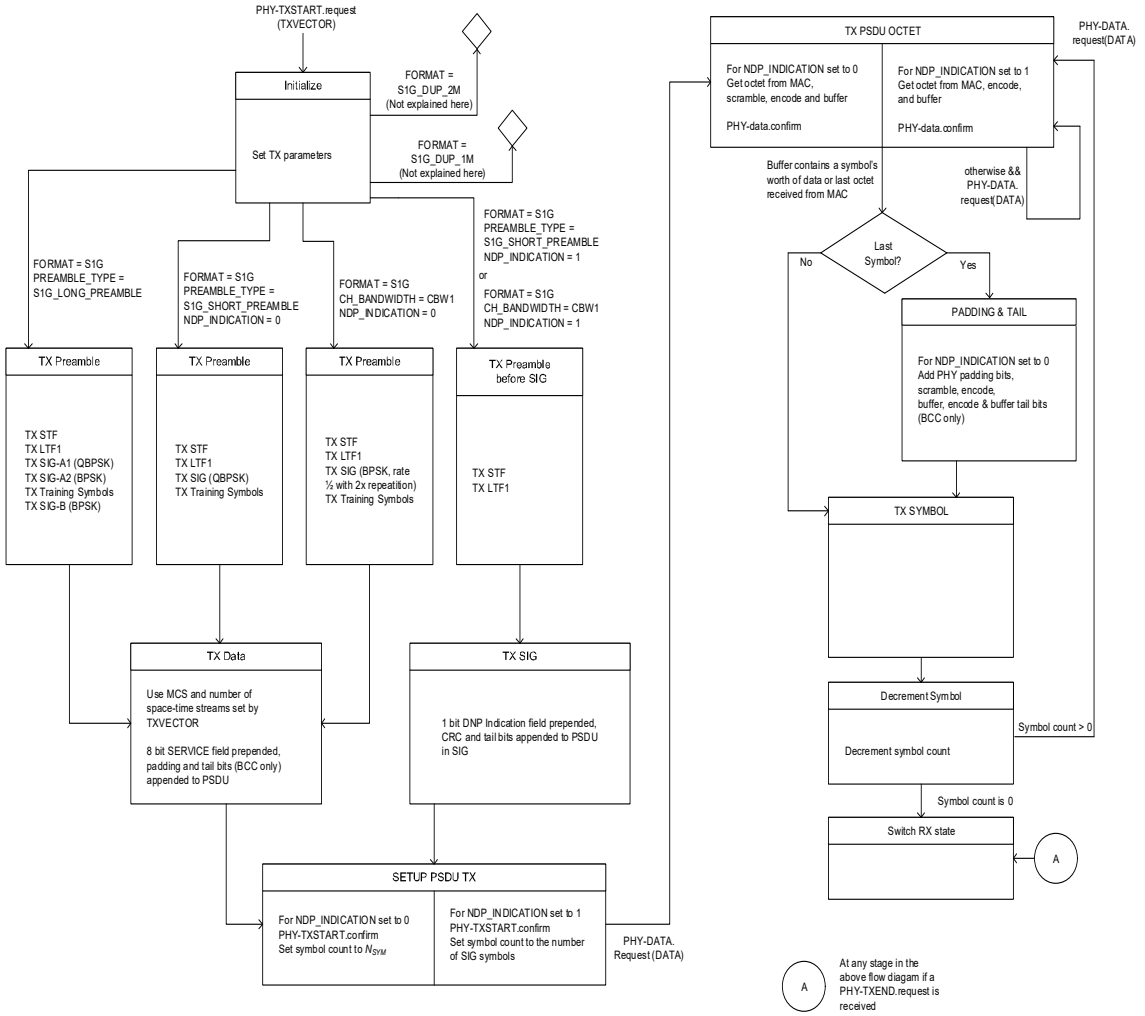


**Figure 23-49—PHY transmit state machine for an S1G PPDU transmission(#2260)(#3409)**

### 23.3.20 PHY receive procedure

Typical PHY receive procedures are shown in Figure 23-50 (PHY receive procedure for an SU transmission, S1G_1M procedure), Figure 23-51 (PHY receive procedure for an SU transmission, S1G_SHORT procedure), and Figure 23-52 (PHY receive procedure for an SU transmission, S1G_LONG procedure), corresponding to S1G_1M preamble format, S1G_SHORT preamble format, and S1G_LONG preamble format, respectively. A typical state machine implementation of the receive PHY is given in Figure 23-53 (PHY receive state machine(#3038)(#342)(#8210)). This receive procedure and state machine do not describe the operation of optional features, such as LDPC or STBC. Through station management (via the

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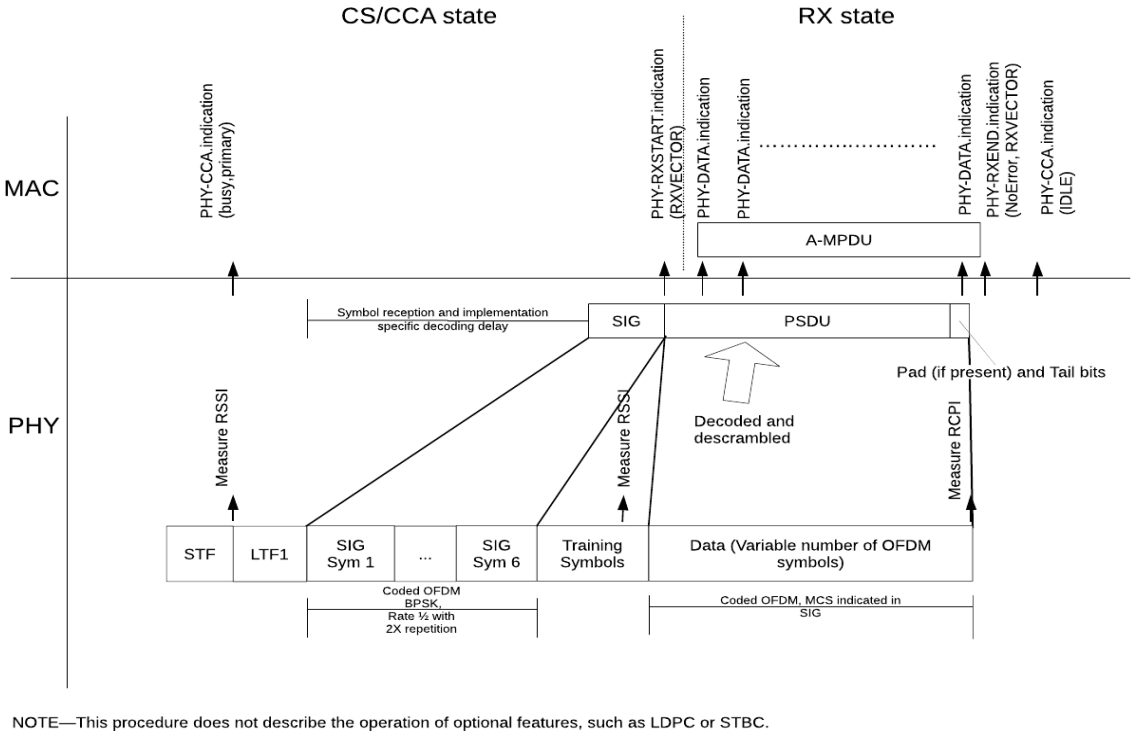
PLME) the PHY is set to the appropriate frequency, as specified in 23.4 (S1G PLME(#6321)). The PHY has also been configured with group information (i.e., group membership and position in group) so that it can receive data intended for the STA. Other receive parameters, such as RSSI and indicated DATARATE, may be accessed via the PHY SAP.




NOTE—This procedure does not describe the operation of optional features, such as LDPC or STBC.

**Figure 23-50—PHY receive procedure for an SU transmission, S1G_1M procedure**

Upon receiving the transmitted PHY preamble overlapping the primary 2 MHz channel in a greater than or equal to 2 MHz BSS, or primary 1 MHz channel in a 1 MHz BSS, the PHY measures a receive signal strength. This activity is indicated by the PHY to the MAC via a PHY-CCA.indication primitive. A PHY-CCA.indication(BUSY, channel-list) primitive is also issued as an initial indication of reception of a signal as specified in 23.3.18.5 (CCA sensitivity). The CH_BANDWIDTH parameter indicates one of the 1 MHz, 2 MHz, 4 MHz, 8 MHz and 16 MHz channel widths.

The PHY shall not issue a PHY-RXSTART.indication primitive in response to a PPDU that does not overlap the primary channel.

The PHY includes the most recently measured RSSI value in the PHY-RXSTART.indication(RXVECTOR) primitive issued to the MAC.

After the PHY-CCA.indication(BUSY, channel-list) is issued, the PHY entity shall begin receiving the training symbols and searching for SIG or SIG-A in order to set the duration of the PPDU(#2056) and get other PHY parameters such as the demodulation type, code type, and the decoding rate. If the check of the SIG or SIG-A CRC is not valid, (#3038)no PHY-RXEARLYSIG.indication or PHY-RXSTART.indication primitive is issued, and instead the PHY shall issue the error condition PHY-RXEND.indication(FormatViolation) primitive, and set PHY_CCA.indication(IDLE) when receive level drops below threshold (minimum modulation and coding rate sensitivity + 20 dB). If a valid SIG or SIG-A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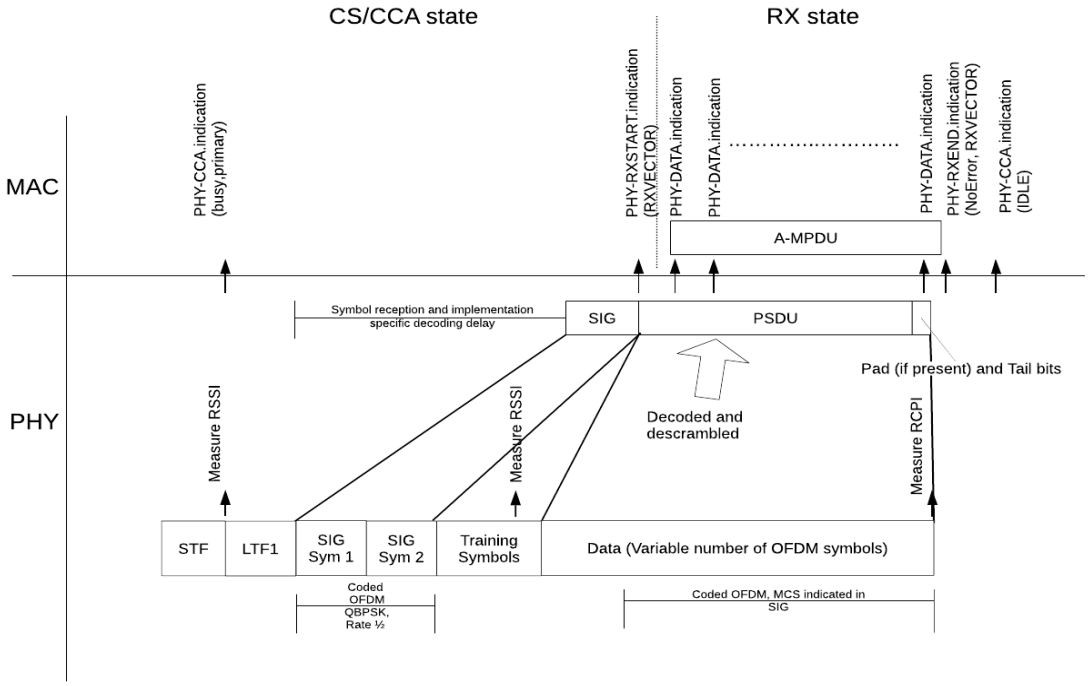
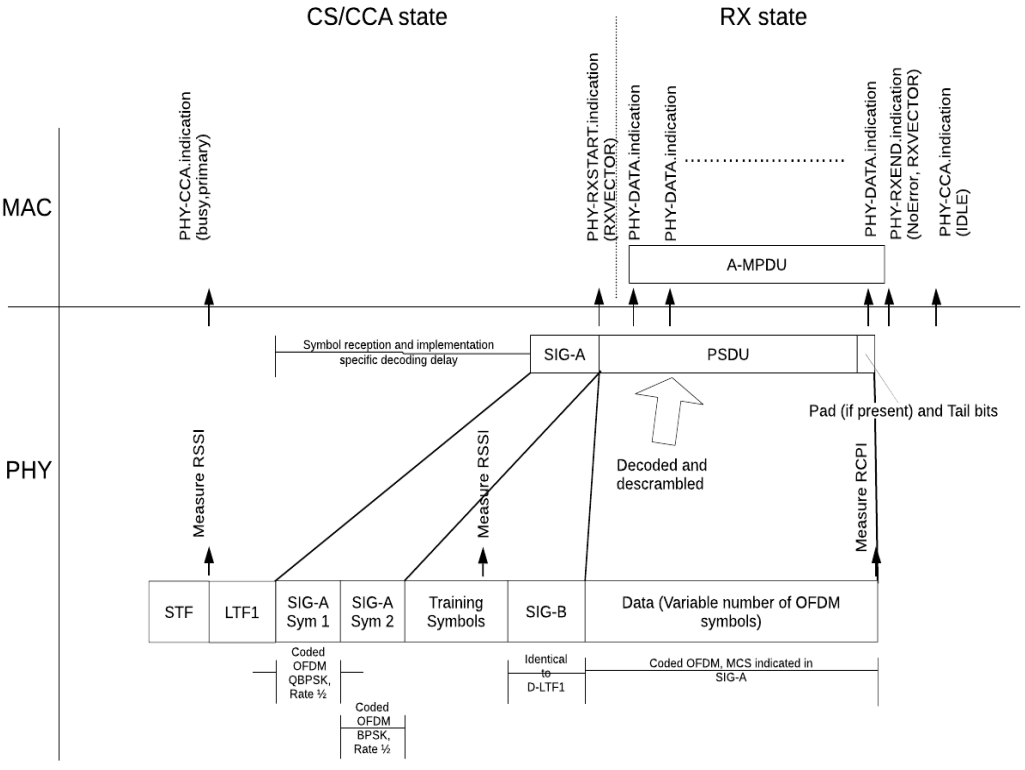



NOTE—This procedure does not describe the operation of optional features, such as LDPC or STBC.

**Figure 23-51—PHY receive procedure for an SU transmission, S1G_SHORT procedure**




NOTE—This procedure does not describe the operation of optional features, such as LDPC or STBC. This procedure describes the case where SIG-A indicates a mode not requiring decoding of SIG-B.

**Figure 23-52—PHY receive procedure for an SU transmission, S1G_LONG procedure**

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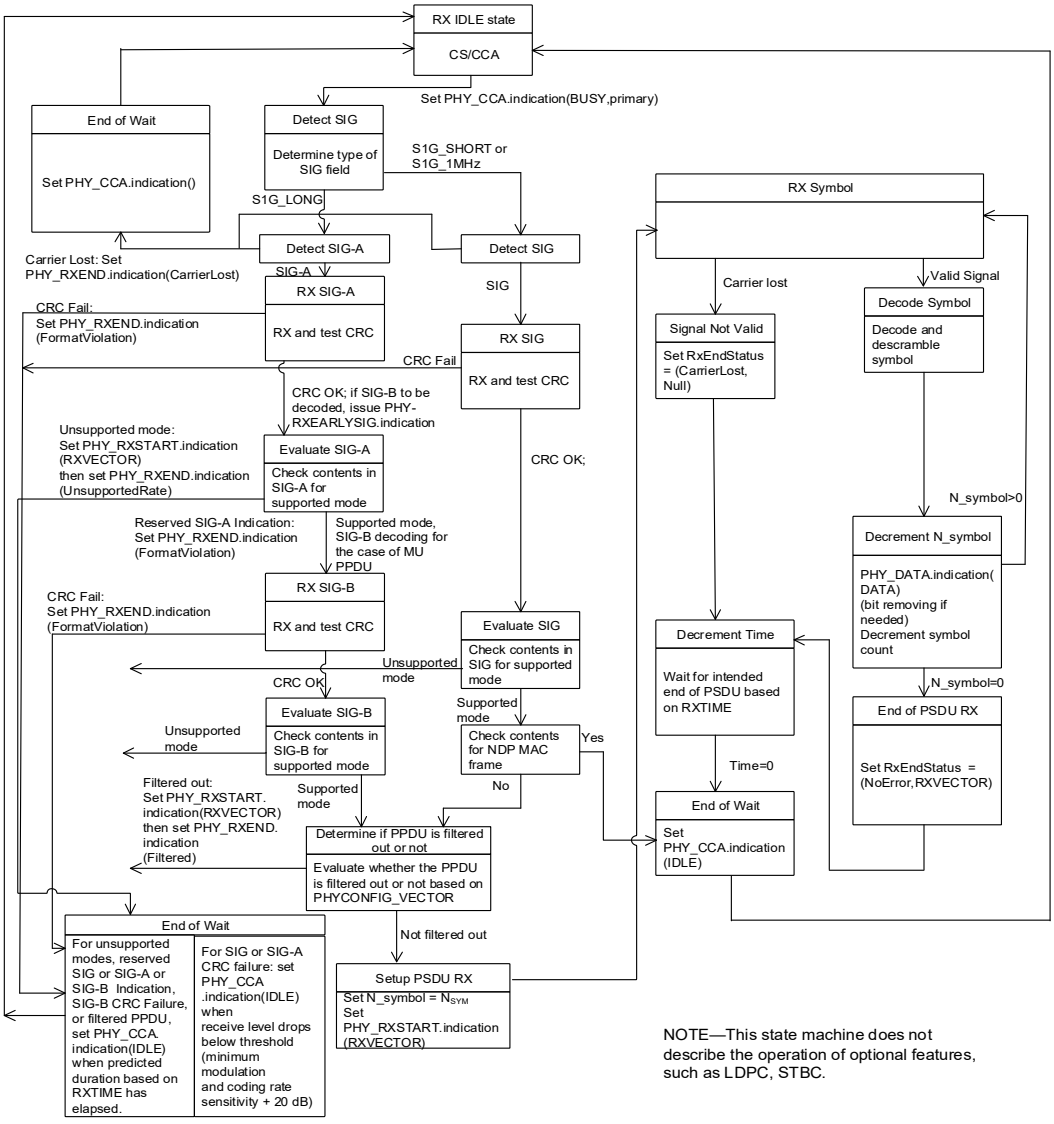


**Figure 23-53—PHY receive state machine(#3038)(#342)(#8210)**

CRC is indicated, and the Uplink Indication bit is 1 and the ID field value matches the PBSSID of the BSS of which the STA is a member or the Uplink Indication bit is 0 and the COLOR field value matches the COLOR indicated by the AP to which the STA is associated, then the S1G PHY shall maintain PHY-CCA.indication(BUSY, channel-list) for the predicted duration of the transmitted PPDU, as defined by RXTIME in Equation (23-69) or Equation (23-70), for all supported modes, unsupported modes, and Reserved SIG or SIG-A Indication. If a valid SIG or SIG-A CRC is indicated, and the Uplink Indication bit is 1 and the ID field value does not match the PBSSID of the BSS of which the STA is a member or the Uplink Indication bit is 0 and the COLOR field value does not match the COLOR indicated by the AP to which the STA is associated, then the S1G PHY shall maintain PHY-CCA.indication(BUSY, channel-list) for the predicted duration of the transmitted PPDU, as defined by RXTIME in Equation (23-69) or Equation (23-70), for all supported modes, unsupported modes, and Reserved SIG-A Indication if the reception meets the minimum CCA sensitivity level specified in 23.3.18.5.3 (CCA sensitivity for signals occupying the primary 2 MHz and/or primary 1 MHz channel). Reserved SIG or SIG-A Indication is


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defined as an SIG or SIG-A with Reserved bits equal to 0 or a combination not valid as defined in 23.3.8.2.2.5 (SIG definition), 23.3.8.2.3.2.5 (SIG-A definition), or 23.3.8.3.5 (SIG definition), or a combination of S1G-MCS and NSTS not included in 23.5 (Parameters for S1G-MCSs) or any other SIG or SIG-A field bit combinations that do not correspond to modes of PHY operation defined in Clause 23 (Sub 1 GHz (S1G) PHY specification(#4095)).

(#455)NOTE 1—From Figure 23-53 (PHY receive state machine(#3038)(#342)(#8210)), Reserved SIG or SIG-A Indication does not apply to the Reserved fields in NDP CMAC PPDUs since NDP CMAC PPDUs do not use S1G_LONG format.

Subsequently, if dot11TimingMsmtActivated is true, a PHY-RXSTART.indication (RXVECTOR) shall be issued and RX_START_OF_FRAME_OFFSET parameter within the RXVECTOR shall be forwarded (see 23.2.2 (TXVECTOR and RXVECTOR parameters)).

NOTE 2—The RX_START_OF_FRAME_OFFSET value is used (#3049)to estimate when the start of the preamble for the incoming (#14)PPDU was detected on the medium at the receive antenna connector.

If the SIG or SIG-A indicates an unsupported mode, the PHY shall issue PHY-RXEND.indication(UnsupportedRate). If the SIG or SIG-A indicates an invalid CRC or Reserved SIG or SIG-A Indication, the PHY shall issue the error condition PHY-RXEND.indication(FormatViolation).

If the PHY preamble reception is successful and a valid SIG or SIG-A CRC is indicated:

— Upon reception of an S1G_LONG format preamble, after receiving a valid SIG-A indicating a supported mode, the PHY entity shall begin receiving the rest of S1G training symbols and SIG-B. If the received MU/SU subfield in SIG-A has a value indicating SU PPDU (see 23.3.8.2.3.2.5 (SIG-A definition)), the PHY entity does not need to decode SIG-B since in this case SIG-B does not carry any information bit (see 23.3.8.2.3.3.5 (SIG-B definition)). (#3038)If SIG-A is valid and indicates that SIG-B is not to be decoded, then a PHY-RXSTART.indication (RXVECTOR) primitive shall be issued, and otherwise a PHY-RXEARLYSIG.indication primitive shall be issued.

  If the received MU/SU subfield in SIG-A has a value indicating MU PPDU (see 23.3.8.2.3.2.5 (SIG-A definition)), SIG-B shall be decoded. If the check of the SIG-B CRC is not valid, a PHY-RXSTART.indication primitive is not issued, and instead the PHY shall issue the error condition PHY-RXEND.indication(FormatViolation) primitive, and the S1G PHY shall maintain PHYCCA.indication(BUSY, channel-list) for the predicted duration of the transmitted PPDU, as defined by RXTIME in Equation (23-69) or Equation (23-70), for all supported modes, unsupported modes, and Reserved SIG-B Indication. Reserved SIG-B Indication is defined as a SIG-B with the bits of the Reserved field not all 1s or MCS not included in 23.5 (Parameters for S1G-MCSs). If the SIG-B indicates an unsupported mode, the PHY shall issue the error condition PHY-RXEND.indication(UnsupportedRate) primitive, and a PHY-RXSTART.indication primitive shall not be issued. If the check of the SIG-B CRC is valid and it indicates a supported mode, a PHY-RXSTART.indication(RXVECTOR) primitive shall be issued. The RXVECTOR associated with this primitive includes the parameters specified in Table 23-1 (TXVECTOR and RXVECTOR parameters).

— Upon reception of an S1G_SHORT or S1G_1M format preamble, after receiving a valid SIG indicating a supported mode, the PHY entity shall begin receiving the rest of S1G training symbols, and then a PHY-RXSTART.indication(RXVECTOR) primitive shall be issued. The RXVECTOR associated with this primitive includes the parameters specified in Table 23-1 (TXVECTOR and RXVECTOR parameters).

  In this case, if the NDP Indication subfield in SIG field has a value indicating an NDP CMAC PPDU, the PHY shall generate a PHYCCA.indication(IDLE) primitive and return to RX IDLE state, and it shall not issue the PHY-RXSTART.indication(RXVECTOR) primitive.

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The PHY optionally filters out the PPDU based on the GID, MU[0-3] NSTS, UPLINK_INDICATION and ID fields of SIG or SIG-A and the contents of the PHYCONFIG_VECTOR as follows:

- The PHY shall not filter out the PPDU if one of the following is true:
  - ($g = 0$) and ($l_{00}$ is true) and (*partialaid* is included in PARTIAL_AID_LIST_GID00)
  - ($g = 63$) and ($l_{63}$ is true) and (*partialaid* is included in PARTIAL_AID_LIST_GID63)
  - ($1 \leq g \leq 62$) and (MembershipStatusInGroupID[$g$] = 1) and ($n_{STS}$[UserPositionInGroupID[$g$]] > 0)
- where
  - $l_{NN}$ is the one of the LISTEN_TO_GID*NN* parameters of the PHYCONFIG_VECTOR
  - MembershipStatusInGroupID[$g$] is the Membership Status Array field of the GROUP_ID_MANAGEMENT parameter of the PHYCONFIG_VECTOR for group $g$
  - $g$ is defined to be
    - The value of the GroupID field of the SIG-A for an S1G MU PPDU
    - 0 for an S1G SU PPDU when UPLINK_INDICATION is equal to 1
    - 63, in all other cases
  - $n_{STS}[u]$ is the value of the MU[$u$] NSTS field of SIG or SIG-A
  - UserPositionInGroupID[$g$] is the User Position Array field of the GROUP_ID_MANAGEMENT parameter of the PHYCONFIG_VECTOR for group $g$
  - *partialaid* is the value of the ID field of SIG or SIG-A
- Otherwise, the PHY may filter out the PPDU.

If the PPDU is filtered out, the PHY shall issue a PHY-RXEND.indication(Filtered) primitive.

The Data field follows the training and signal fields. When the Coding subfield in SIG or SIG-A field indicates BCC, the number of symbols in the Data field is determined by Equation (23-65).

$$N_{SYM} = \begin{cases} \text{LENGTH}, & \text{if Aggregation} = 1 \\ m_{STBC} \times \left\lceil \dfrac{8 \times LENGTH + N_{service} + N_{tail} \times N_{ES}}{m_{STBC} \times N_{DBPS}} \right\rceil, & \text{if Aggregation} = 0 \end{cases} \quad (23\text{-}65)$$

where

| | |
|---|---|
| $N_{ES}$ and $N_{DBPS}$ | are defined in Table 23-7 (Frequently used parameters) |
| $N_{service}$ and $N_{tail}$ | are defined in Table 23-5 (Timing-related constants) |
| $m_{STBC}$ | is equal to 2 when STBC is used, and 1 otherwise |
| LENGTH and Aggregation | are the values indicated by the LENGTH and Aggregation subfields of SIG or SIG-A field, respectively |


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When the Coding subfield in SIG or SIG-A indicates LDPC and Aggregation subfield in SIG or SIG-A field is 1, the number of symbols in the Data field is determined by Equation (23-66).

$$N_{SYM} = LENGTH \tag{23-66}$$

where

LENGTH is the value indicated by the LENGTH subfield of SIG or SIG-A field

When the Coding subfield in SIG or SIG-A indicates LDPC and Aggregation subfield in SIG or SIG-A field is 0, the parameter $N_{SYM, init}$ is determined by Equation (23-67).

$$N_{SYM, init} = m_{STBC} \times \left\lceil \frac{8 \times LENGTH + N_{service}}{m_{STBC} \times N_{DBPS}} \right\rceil \tag{23-67}$$

where

$N_{DBPS}$ is defined in Table 23-7 (Frequently used parameters)

$N_{service}$ is defined in Table 23-5 (Timing-related constants)

$m_{STBC}$ is equal to 2 when STBC is used, and 1 otherwise

LENGTH is the value indicated by the LENGTH subfield of SIG or SIG-A field

In this case, the number of symbols in the Data field $N_{SYM}$ is determined by Equation (23-68).

$$N_{SYM} = \begin{cases} N_{SYM, init}, & \text{if LDPC Extra OFDM Symbol = 0} \\ N_{SYM, init} + 1, & \text{if LDPC Extra OFDM Symbol = 1 and STBC = 0} \\ N_{SYM, init} + 2, & \text{if LDPC Extra OFDM Symbol = 1 and STBC = 1} \end{cases} \tag{23-68}$$

where

LENGTH is the value indicated by the LENGTH subfield of SIG or SIG-A field

LDPC Extra OFDM Symbol is the value indicated by LDPC Extra subfield in SIG or SIG-A field

STBC is the value indicated by the STBC subfield in SIG or SIG-A field

The PHY parameter RXTIME for the case of S1G_SHORT or S1G_1M format is determined by Equation (23-69).

$$RXTIME(\mu s) = \begin{cases} T_{DSTF} + T_{LTF}(N_{LTF} - 1) + N_{SYM} T_{SYML}, & \text{if Short GI = 0} \\ T_{DSTF} + T_{LTF}(N_{LTF} - 1) + T_{SYML} + (N_{SYM} - 1).T_{SYMS}, & \text{if Short GI = 1} \end{cases} \tag{23-69}$$

where

$T_{LTF}$ , $T_{SYML}$ and $T_{SYMS}$ are defined in Table 23-5 (Timing-related constants)

$N_{LTF}$ is defined in Table 23-11 (Number of LTFs required for different numbers of space-time streams)

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The PHY parameter RXTIME for the case of S1G_LONG format is determined by Equation (23-70).

$$RXTIME(\mu s) = \begin{cases} T_{DSTF} + N_{LTF}T_{DLTF} + T_{SIG-B} + N_{SYM}T_{SYML}, & \text{if Short GI = 0} \\ T_{DSTF} + N_{LTF}T_{DLTF} + T_{SIG-B} + T_{SYML} + (N_{SYM} - 1).T_{SYMS}, & \text{if Short GI = 1} \end{cases} \quad (23\text{-}70)$$

where

$T_{DLTF}$ , $T_{SIG-B}$ , $T_{SYML}$ and $T_{SYMS}$ are defined in Table 23-5 (Timing-related constants)

$N_{LTF}$ is defined in Table 23-11 (Number of LTFs required for different numbers of space-time streams)

When the Aggregation subfield in the SIG or SIG-A field is equal to 0, the value of the PSDU_LENGTH parameter returned in the RXVECTOR using is set to the LENGTH field of the SIG/SIG-A.

When the Aggregation subfield in the SIG or SIG-A field is equal to 1, the value of the PSDU_LENGTH parameter returned in the RXVECTOR using BCC encoding is calculated using Equation (23-71).

$$\text{PSDU\_LENGTH} = \left\lfloor \frac{N_{SYM}N_{DBPS} - N_{service} - N_{tail} \cdot N_{ES}}{8} \right\rfloor \quad (23\text{-}71)$$

where

$N_{ES}$ is defined in Table 23-7 (Frequently used parameters)

$N_{DBPS}$ is defined in Table 23-7 (Frequently used parameters)

$N_{service}$ and $N_{tail}$ are defined in Table 23-5 (Timing-related constants)

The value of the PSDU_LENGTH parameter returned in the RXVECTOR using LDPC encoding is calculated using Equation (23-72).

$$PSDU\_LENGTH = \left\lfloor \frac{N_{SYM}.N_{DBPS} - N_{service}}{8} \right\rfloor \quad (23\text{-}72)$$

where

$N_{DBPS}$ is defined in Table 23-7 (Frequently used parameters)

$N_{service}$ is defined in Table 23-5 (Timing-related constants)

When the Aggregation subfield in the SIG or SIG-A field is equal to 1, the value of the PSDU_LENGTH parameter returned in the RXVECTOR for an NDP sounding or an NDP CMAC PPDU is 0.

If signal loss occurs during reception prior to completion of the PSDU reception, the error condition PHY-RXEND.indication(CarrierLost) shall be reported to the MAC. After waiting for the end of the PSDU as determined by Equation (23-69) or Equation (23-70), the PHY shall set the PHY-CCA.indication(IDLE) primitive and return to the RX IDLE state.

The received PSDU bits are assembled into octets, decoded, and presented to the MAC using a series of PHY-DATA.indication(DATA) primitive exchanges. Any final bits that cannot be assembled into a complete octet are considered pad bits and discarded. After the reception of the final bit of the last PSDU octet, and possible padding and tail bits, the receiver shall be returned to the RX IDLE state, as shown in Figure 23-53 (PHY receive state machine(#3038)(#342)(#8210)).


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## 23.4 S1G PLME(#6321)

### 23.4.1 PLME SAP sublayer management primitives(#6321)

Table 23-40 (S1G PHY MIB attributes) lists the MIB attributes that may be accessed by the PHY entities and the intra-layer of higher level LMEs. These attributes are accessed via the PLME-GET, PLME-SET, PLME-RESET, and PLME-CHARACTERISTICS primitives defined in 6.7 (PLME SAP interface).

**Table 23-40—S1G PHY MIB attributes**

| Managed object | Default value/range | Operational semantics |
|---|---|---|
| **dot11PHYOperationTable** | | |
| dot11PHYType | s1g | Static |
| **dot11PHYTxPowerTable** | | |
| dot11NumberSupportedPowerLevels | Implementation dependent | Static |
| dot11TxPowerLevel1 | Implementation dependent | Static |
| dot11TxPowerLevel2 | Implementation dependent | Static |
| dot11TxPowerLevel3 | Implementation dependent | Static |
| dot11TxPowerLevel4 | Implementation dependent | Static |
| dot11TxPowerLevel5 | Implementation dependent | Static |
| dot11TxPowerLevel6 | Implementation dependent | Static |
| dot11TxPowerLevel7 | Implementation dependent | Static |
| dot11TxPowerLevel8 | Implementation dependent | Static |
| dot11CurrentTxPowerLevel | Implementation dependent | Static |
| dot11TxPowerLevelExtended | Implementation dependent | Static |
| dot11CurrentTxPowerLevelExtended | Implementation dependent | Static |
| **dot11PHYS1GTable** | | |
| dot11CurrentPrimaryChannel | Implementation dependent | Dynamic |
| dot11CurrentChannelWidth | Implementation dependent | Dynamic |
| dot11CurrentChannelCenterFrequencyIndex | Implementation dependent | Dynamic |
| dot11S1GChannelWidthOptionImplemented | Implementation dependent | Static |
| dot11ShortGIOptionIn1MImplemented | false/Boolean | Static |
| dot11ShortGIOptionIn1MActivated | false/Boolean | Dynamic |
| dot11ShortGIOptionIn2MImplemented | false/Boolean | Static |
| dot11ShortGIOptionIn2MActivated | false/Boolean | Dynamic |
| dot11ShortGIOptionIn4MImplemented | false/Boolean | Static |
| dot11ShortGIOptionIn4MActivated | false/Boolean | Dynamic |

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**Table 23-40—S1G PHY MIB attributes *(continued)***

| Managed object | Default value/range | Operational semantics |
|---|---|---|
| dot11ShortGIOptionIn8MImplemented | false/Boolean | Static |
| dot11ShortGIOptionIn8MActivated | false/Boolean | Dynamic |
| dot11ShortGIOptionIn16MImplemented | false/Boolean | Static |
| dot11ShortGIOptionIn16MActivated | false/Boolean | Dynamic |
| dot11S1GLDPCCodingOptionImplemented | false/Boolean | Static |
| dot11S1GLDPCCodingOptionActivated | false/Boolean | Dynamic |
| dot11S1GTxSTBCOptionImplemented | false/Boolean | Static |
| dot11S1GTxSTBCOptionActivated | false/Boolean | Dynamic |
| dot11S1GRxSTBCOptionImplemented | false/Boolean | Static |
| dot11S1GRxSTBCOptionActivated | false/Boolean | Dynamic |
| dot11S1GMaxNTxChainsImplemented | Implementation dependent | Static |
| dot11S1GMaxNTxChainsActivated | Implementation dependent | Dynamic |
| dot11S1GTravelingPilotOptionImplemented | Implementation dependent | Static |
| dot11S1GTravelingPilotOptionActivated | Implementation dependent | Dynamic |
| **dot11S1GTransmitBeamformingConfigTable** | | |
| dot11ReceiveStaggerSoundingOptionImplemented | false/Boolean | Static |
| dot11TransmitStaggerSoundingOptionImplemented | false/Boolean | Static |
| dot11ReceiveNDPOptionImplemented | false/Boolean | Static |
| dot11TransmitNDPOptionImplemented | false/Boolean | Static |
| dot11ImplicitTransmitBeamformingOptionImplemented | false/Boolean | Static |
| dot11CalibrationOptionImplemented | Implementation dependent | Static |
| dot11ExplicitCSITransmitBeamformingOptionImplemented | false/Boolean | Static |
| dot11ExplicitNonCompressedBeamformingMatrixOptionImplemented | false/Boolean | Static |
| dot11ExplicitTransmitBeamformingCSIFeedbackOptionImplemented | Implementation dependent | Static |
| dot11ExplicitNoncompressedBeamformingFeedbackOptionImplemented | Implementation dependent | Static |
| dot11ExplicitCompressedBeamformingFeedbackOptionImplemented | Implementation dependent | Static |
| dot11NumberBeamformingCSISupportAntenna | Implementation dependent | Static |
| dot11NumberNonCompressedBeamformingMatrixSupportAntenna | Implementation dependent | Static |
| dot11NumberCompressedBeamformingMatrixSupportAntenna | Implementation dependent | Static |
| dot11S1GSUBeamformerOptionImplemented | false/Boolean | Static |


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**Table 23-40—S1G PHY MIB attributes *(continued)***

| Managed object | Default value/range | Operational semantics |
|---|---|---|
| dot11S1GSUBeamformeeOptionImplemented | false/Boolean | Static |
| dot11S1GMUBeamformerOptionImplemented | false/Boolean | Static |
| dot11S1GMUBeamformeeOptionImplemented | false/Boolean | Static |
| dot11S1GNumberSoundingDimensions | Implementation dependent | Static |
| dot11S1GBeamformeeNTxSupport | Implementation dependent | Static |

### 23.4.2 PHY MIB

S1G PHY MIB attributes are defined in Annex C with specific values defined in Table 23-40 (S1G PHY MIB attributes). The (#4177)Operational semantics column in Table 23-40 (S1G PHY MIB attributes) contains two types: static and dynamic.

— Static MIB attributes are fixed and cannot be modified for a given PHY implementation.

— Dynamic MIB attributes are interpreted according to the MAX-ACCESS field of the MIB attribute.

When MAX-ACCESS is read-only, the MIB attribute value may be updated by the PLME and read from the MIB attribute by management entities. When MAX-ACCESS is read-write, the MIB attribute may be read and written by management entities but shall not be updated by the PLME.

### 23.4.3 TXTIME and PSDU_LENGTH calculation

For S1G_SHORT preamble, the value of the TXTIME parameter returned by the PLME-TXTIME.confirm primitive shall be calculated for an S1G PPDU using Equation (23-73) for short GI and Equation (23-74) for long GI.

$$\text{TXTIME} = \begin{cases} T_{PREAMBLE} + T_{SIG} + T_{LTF} \cdot (N_{LTF} - 1), \text{ if } N_{SYM} = 0 \\ T_{PREAMBLE} + T_{SIG} + T_{LTF} \cdot (N_{LTF} - 1) + T_{SYML} + T_{SYMS} \cdot (N_{SYM} - 1), \text{ if} N_{SYM} > 0 \end{cases} \quad (23\text{-}73)$$

$$\text{TXTIME} = T_{PREAMBLE} + T_{SIG} + T_{LTF} \cdot (N_{LTF} - 1) + T_{SYML} \cdot N_{SYM} \quad (23\text{-}74)$$

where

$T_{PREAMBLE} = T_{STF} + T_{LTF1}$

$T_{STF}$, $T_{LTF1}$, $T_{LTF}$, $T_{SYML}$ and $T_{SYMS}$ are defined in Table 23-5 (Timing-related constants)

$T_{SIG}$ is defined in Table 23-6 (Timing-related constants for SIG/SIG-A field in ≥ 2 MHz PPDUs)

$N_{LTF}$ is defined in Table 23-11 (Number of LTFs required for different numbers of space-time streams)

For S1G_LONG preamble, the value of the TXTIME parameter returned by the PLME-TXTIME.confirm primitive shall be calculated for an S1G PPDU using Equation (23-75) for short GI and Equation (23-76) for long GI.

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$$\text{TXTIME} = \begin{cases} T_{PREAMBLE} + T_{SIG-A} + T_{D\_PREAMBLE} + T_{SIG-B}, \text{ if } N_{SYM} = 0 \\ T_{PREAMBLE} + T_{SIG-A} + T_{D\_PREAMBLE} + T_{SIG-B} + T_{SYML} + T_{SYMS} \cdot (N_{SYM} - 1), \text{ if } N_{SYM} > 0 \end{cases} \quad (23\text{-}75)$$

$$\text{TXTIME} = T_{PREAMBLE} + T_{SIG-A} + T_{D\_PREAMBLE} + T_{SIG-B} + T_{SYML} N_{SYM} \quad (23\text{-}76)$$

where

$T_{PREAMBLE} = T_{STF} + T_{LTF1}$

$T_{D\_PREAMBLE} = T_{DSTF} + T_{DLTF} \cdot N_{LTF}$

$T_{STF}$, $T_{LTF1}$, $T_{DSTF}$, $T_{DLTF}$, $T_{SIG-B}$, $T_{SYML}$ and $T_{SYMS}$ are defined in Table 23-5 (Timing-related constants)

$T_{SIG-A}$ is defined in Table 23-6 (Timing-related constants for SIG/SIG-A field in ≥ 2 MHz PPDUs).

$N_{LTF}$ is defined in Table 23-11 (Number of LTFs required for different numbers of space-time streams).

For S1G_1M preamble, the value of the TXTIME parameter returned by the PLME-TXTIME.confirm primitive shall be calculated for an S1G PPDU using Equation (23-77) for short GI and Equation (23-78) for long GI.

$$\text{TXTIME} = \begin{cases} T_{PREAMBLE} + T_{SIG} + T_{LTF} \cdot (N_{LTF} - 1), \text{ if } N_{SYM} = 0 \\ T_{PREAMBLE} + T_{SIG} + T_{LTF} \cdot (N_{LTF} - 1) + T_{SYML} + T_{SYMS}(N_{SYM} - 1), \text{ if } N_{SYM} > 0 \end{cases} \quad (23\text{-}77)$$

$$\text{TXTIME} = T_{PREAMBLE} + T_{SIG} + T_{LTF} \cdot (N_{LTF} - 1) + T_{SYML} N_{SYM} \quad (23\text{-}78)$$

where

$T_{PREAMBLE} = T_{STF} + T_{LTF1}$

$T_{STF}$, $T_{LTF1}$, $T_{LTF}$, $T_{SIG}$, $T_{SYML}$ and $T_{SYMS}$ are defined in Table 23-5 (Timing-related constants)

$N_{LTF}$ is defined in Table 23-11 (Number of LTFs required for different numbers of space-time streams)

For an NDP, there is no Data field and $N_{SYM} = 0$.

For an S1G SU PPDU using BCC encoding, the total number of data symbols in the Data field, $N_{SYM,}$ is given by Equation (23-79) if the Aggregation subfield in its SIG field or SIG-A field is(M118) 1 or Equation (23-80) otherwise.

$$N_{SYM} = m_{STBC} \times \left\lceil \frac{8 \cdot APEP\_LENGTH + N_{service} + N_{tail} \cdot N_{ES}}{m_{STBC} \cdot N_{DBPS}} \right\rceil \quad (23\text{-}79)$$

$$N_{SYM} = m_{STBC} \times \left\lceil \frac{8 \cdot PSDU\_LENGTH + N_{service} + N_{tail} \cdot N_{ES}}{m_{STBC} \cdot N_{DBPS}} \right\rceil \quad (23\text{-}80)$$

where

$m_{STBC}$ is equal to 2 when STBC is used, and 1 otherwise

$N_{ES}$ and $N_{DBPS}$ are defined in Table 23-7 (Frequently used parameters)


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$N_{service}$ and $N_{tail}$ are defined in Table 23-5 (Timing-related constants)

*PSDU_LENGTH* is the value of TXVECTOR parameter PSDU_LENGTH

For an S1G SU PPDU using LDPC encoding, the total number of data symbols in the Data field, $N_{SYM}$, is given in 23.3.9.4.4 (LDPC coding).

For an S1G MU PPDU, the total number of data symbols in the Data field, $N_{SYM}$, is given by

$$N_{SYM} = \max\{N_{SYM,u}\}_{u=0}^{N_{user}-1}$$

where

$N_{SYM,u}$ is defined in Equation (23-79) replacing $N_{SYM}$, *APEP_LENGTH*, $N_{ES}$, and $N_{DBPS}$ with $N_{SYM,u}$, $APEP\_LENGTH_u$, $N_{ES,u}$, and $N_{DBPS,u}$ for BCC and in 23.3.9.4.4 (LDPC coding) for LDPC

The value of the PSDU_LENGTH parameter returned in the PLME-TXTIME.confirm primitive for an S1G SU PPDU using BCC encoding is calculated using Equation (23-81)

$$PSDU\_LENGTH = \left\lfloor \frac{N_{SYM} \cdot N_{DBPS} - N_{service} - N_{tail} N_{ES}}{8} \right\rfloor \quad (23\text{-}81)$$

where

$N_{SYM}$ is given by Equation (23-79) or Equation (23-80)

$N_{ES}$ and $N_{DBPS}$ are defined in Table 23-7 (Frequently used parameters)

$N_{service}$ and $N_{tail}$ are defined in Table 23-5 (Timing-related constants)

The value of the PSDU_LENGTH parameter returned in the PLME-TXTIME.confirm primitive for an S1G SU PPDU using LDPC encoding is calculated using Equation (23-82)

$$PSDU\_LENGTH = \left\lfloor \frac{N_{SYM,init} \cdot N_{DBPS} - N_{service}}{8} \right\rfloor \quad (23\text{-}82)$$

where

$N_{SYM,init}$ is given by Equation (23-46) or Equation (23-47)

$N_{DBPS}$ is defined in Table 23-7 (Frequently used parameters)

$N_{service}$ is defined in Table 23-5 (Timing-related constants)

The value of the PSDU_LENGTH parameter for user $u$ returned in the PLME-TXTIME.confirm primitive and in the RXVECTOR for an S1G MU PPDU is calculated using Equation (23-83)

$$PSDU\_LENGTH_u = \begin{cases} \left\lfloor \frac{N_{SYM} \cdot N_{DBPS,u} - N_{service} - N_{tail} N_{ES,u}}{8} \right\rfloor & \text{when BCC is used for user } u \\ \left\lfloor \frac{N_{SYM\_max\_init} \cdot N_{DBPS,u} - N_{service}}{8} \right\rfloor & \text{when LDPC is used for user } u \end{cases} \quad (23\text{-}83)$$

where

$N_{SYM\_max\_init}$ is given by Equation (21-65)

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| | |
|---|---|
| $N_{ES,u}$ | is $N_{ES}$ for user $u$, where $N_{ES}$ is defined in Table 23-7 (Frequently used parameters) |
| $N_{DBPS,u}$ | is $N_{DBPS}$ for user $u$, where $N_{DBPS}$ is defined in Table 23-7 (Frequently used parameters) |
| $N_{service}$ and $N_{tail}$ | are defined in Table 23-5 (Timing-related constants) |

The value of the PSDU_LENGTH parameter returned in the PLME-TXTIME.confirm primitive for an NDP is 0.

### 23.4.4 PHY characteristics

(#2123)The S1G PHY characteristics, provided through the PLME-CHARACTERISTICS service primitive, are shown in Table 23-41 (S1G PHY characteristics). The definitions for these characteristics are given in 6.7.4 (PLME-CHARACTERISTICS.confirm).

**Table 23-41—S1G PHY characteristics**

| Characteristics | Value |
|---|---|
| aSlotTime | 52 μs |
| aSIFSTime | 160 μs |
| aCCATime | < 40 μs |
| aRxPHYStartDelay | 600 μs for S1G_1M preamble;<br>280 μs for S1G_SHORT preamble and S1G_LONG preamble. |
| aRxTxTurnaroundTime | Implementation dependent, see 10.3.7 (DCF timing relations). |
| aTxPHYDelay | Implementation dependent, see 10.3.7 (DCF timing relations). |
| aRxPHYDelay | Implementation dependent, see 10.3.7 (DCF timing relations). |
| aRxTxSwitchTime | Implementation dependent, see 10.3.7 (DCF timing relations). |
| aTxRampOnTime | Implementation dependent, see 10.3.7 (DCF timing relations). |
| aAirPropagationTime | 6 μs |
| aMACProcessingDelay | Implementation dependent, see 10.3.7 (DCF timing relations).(#3263) |
| aCCAMidTime | 212 μs |
| aPPDUMaxTime | 27 920 μs (see NOTE 1) |
| aPSDUMaxLengthWithNoAggregation | 511 octets (see NOTE 2) |
| aPSDUMaxLength | 797 159 octets (see NOTE 3) |

NOTE 1—This is the maximum PPDU duration in μs for an S1G_1M PPDU with a bandwidth of 1 MHz, S1G-MCS 10 and 1 spatial stream, limited by PSDU length of 511 octets.

NOTE 2—This is the maximum PSDU length in octets for an S1G PPDU supported by the Length field in the S1G SIG field when the Aggregation field is 0.

NOTE 3—This is the maximum length in octets for an S1G SU PPDU with a bandwidth of 16 MHz, S1G-MCS 9 and 4 spatial streams, limited by 511 data symbols supported by the Length field in the S1G SIG field, excluding the SERVICE field and tail bits.


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## 23.5 Parameters for S1G-MCSs

The rate-dependent parameters for 1 MHz, 2 MHz, 4 MHz, 8 MHz, and 16 MHz, $N_{SS}$ = 1,...,4 are given in Table 23-42 (S1G-MCSs for 1 MHz, Nss = 1) to Table 23-61 (S1G-MCSs for 16 MHz, Nss = 4). Support for 4 μs GI is optional in all cases. Support for MCS 8 and 9 (when valid) is optional in all cases. Support for MCS 11 and 12 (when valid) is optional in all cases.(M102) An S1G AP-STA shall support single spatial stream MCSs within the range MCS 0 to MCS 7 for all channel widths for which it has indicated support regardless of the Tx or Rx Highest Supported Data Rate subfield values in the Supported S1G-MCS and NSS Set and Extended Supported S1G-MCS and NSS Set fields.(M102) (#306)A non-AP S1G STA shall support single spatial stream MCSs within the range MCS 0 to MCS 2 for 1 and 2 MHz channel widths. When more than one spatial stream is supported, the Tx or Rx Highest Supported Data Rate subfield values in the Supported S1G-MCS and NSS Set and Extended Supported S1G-MCS and NSS Set fields(M102) may result in a reduced MCS range (cut-off) for greater than one spatial stream. Support for 1 MHz and 2 MHz with $N_{SS}$ = 1 is mandatory. Support for 1 and 2 MHz with $N_{SS}$ = 2,3,4 is optional. Support for 4 MHz, 8 MHz, and 16 MHz with $N_{SS}$ = 1,...,4 is optional.

NOTE—When LDPC is used with MCS 10, the resulting $N_{CBPS}$ is 12 because the 2× repetition is applied after the LDPC encoding procedure.

**Table 23-42—S1G-MCSs for 1 MHz, $N_{SS}$ = 1**

| MCS Idx | Mod | R | $N_{BPSCS}$ | $N_{SD}$ | $N_{SP}$ | $N_{CBPS}$ | $N_{DBPS}$ | $N_{ES}$ | Data_rate (kb/s) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | 8 μs GI | 4 μs GI |
| 0 | BPSK | 1/2 | 1 | 24 | 2 | 24 | 12 | 1 | 300.0 | 333.3 |
| 1 | QPSK | 1/2 | 2 | 24 | 2 | 48 | 24 | 1 | 600.0 | 666.7 |
| 2 | QPSK | 3/4 | 2 | 24 | 2 | 48 | 36 | 1 | 900.0 | 1000.0 |
| 3 | 16-QAM | 1/2 | 4 | 24 | 2 | 96 | 48 | 1 | 1200.0 | 1333.3 |
| 4 | 16-QAM | 3/4 | 4 | 24 | 2 | 96 | 72 | 1 | 1800.0 | 2000.0 |
| 5 | 64-QAM | 2/3 | 6 | 24 | 2 | 144 | 96 | 1 | 2400.0 | 2666.7 |
| 6 | 64-QAM | 3/4 | 6 | 24 | 2 | 144 | 108 | 1 | 2700.0 | 3000.0 |
| 7 | 64-QAM | 5/6 | 6 | 24 | 2 | 144 | 120 | 1 | 3000.0 | 3333.3 |
| 8 | 256-QAM | 3/4 | 8 | 24 | 2 | 192 | 144 | 1 | 3600.0 | 4000.0 |
| 9 | 256-QAM | 5/6 | 8 | 24 | 2 | 192 | 160 | 1 | 4000.0 | 4444.4 |
| 10 | BPSK | 1/2 with 2× repetition | 1 | 24 | 2 | 24 | 6 | 1 | 150.0 | 166.7 |
| 11(M102) | 1024-QAM | 3/4 | 10 | 24 | 2 | 240 | 180 | 1 | 4500 | 5000.0 |
| 12(M102) | 1024-QAM | 5/6 | 10 | 24 | 2 | 240 | 200 | 1 | 5000 | 5555.6 |

**Table 23-43—S1G-MCSs for 1 MHz, $N_{SS}$ = 2**

| MCS Idx | Mod | R | $N_{BPSCS}$ | $N_{SD}$ | $N_{SP}$ | $N_{CBPS}$ | $N_{DBPS}$ | $N_{ES}$ | Data_rate (kb/s) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | 8 μs GI | 4 μs GI |
| 0 | BPSK | 1/2 | 1 | 24 | 2 | 48 | 24 | 1 | 600.0 | 666.7 |
| 1 | QPSK | 1/2 | 2 | 24 | 2 | 96 | 48 | 1 | 1200.0 | 1333.3 |
| 2 | QPSK | 3/4 | 2 | 24 | 2 | 96 | 72 | 1 | 1800.0 | 2000.0 |
| 3 | 16-QAM | 1/2 | 4 | 24 | 2 | 192 | 96 | 1 | 2400.0 | 2666.7 |
| 4 | 16-QAM | 3/4 | 4 | 24 | 2 | 192 | 144 | 1 | 3600.0 | 4000.0 |

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**Table 23-43—S1G-MCSs for 1 MHz, $N_{SS}$ = 2**

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 5 | 64-QAM | 2/3 | 6 | 24 | 2 | 288 | 192 | 1 | 4800.0 | 5333.3 |
| 6 | 64-QAM | 3/4 | 6 | 24 | 2 | 288 | 216 | 1 | 5400.0 | 6000.0 |
| 7 | 64-QAM | 5/6 | 6 | 24 | 2 | 288 | 240 | 1 | 6000.0 | 6666.7 |
| 8 | 256-QAM | 3/4 | 8 | 24 | 2 | 384 | 288 | 1 | 7200.0 | 8000.0 |
| 9 | 256-QAM | 5/6 | 8 | 24 | 2 | 384 | 320 | 1 | 8000.0 | 8888.9 |
| 10(M102) | Not valid | | | | | | | | | |
| 11(M102) | 1024-QAM | 3/4 | 10 | 24 | 2 | 480 | 360 | 1 | 9000 | 10000.0 |
| 12(M102) | 1024-QAM | 5/6 | 10 | 24 | 2 | 480 | 400 | 1 | 10000 | 11111.1 |

**Table 23-44—S1G-MCSs for 1 MHz, $N_{SS}$ = 3**

| MCS Idx | Mod | R | $N_{BPSCS}$ | $N_{SD}$ | $N_{SP}$ | $N_{CBPS}$ | $N_{DBPS}$ | $N_{ES}$ | Data_rate (kb/s) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | 8 μs GI | 4 μs GI |
| 0 | BPSK | 1/2 | 1 | 24 | 2 | 72 | 36 | 1 | 900.0 | 1000.0 |
| 1 | QPSK | 1/2 | 2 | 24 | 2 | 144 | 72 | 1 | 1800.0 | 2000.0 |
| 2 | QPSK | 3/4 | 2 | 24 | 2 | 144 | 108 | 1 | 2700.0 | 3000.0 |
| 3 | 16-QAM | 1/2 | 4 | 24 | 2 | 288 | 144 | 1 | 3600.0 | 4000.0 |
| 4 | 16-QAM | 3/4 | 4 | 24 | 2 | 288 | 216 | 1 | 5400.0 | 6000.0 |
| 5 | 64-QAM | 2/3 | 6 | 24 | 2 | 432 | 288 | 1 | 7200.0 | 8000.0 |
| 6 | 64-QAM | 3/4 | 6 | 24 | 2 | 432 | 324 | 1 | 8100.0 | 9000.0 |
| 7 | 64-QAM | 5/6 | 6 | 24 | 2 | 432 | 360 | 1 | 9000.0 | 10 000.0 |
| 8 | 256-QAM | 3/4 | 8 | 24 | 2 | 576 | 432 | 1 | 10800.0 | 12000.0 |
| 9 | 256-QAM | 5/6 | 8 | 24 | 2 | 576 | 480 | 1 | 12000.0 | 13333.3 |
| 10(M102) | Not valid | | | | | | | | | |
| 11(M102) | 1024-QAM | 3/4 | 10 | 24 | 2 | 720 | 540 | 1 | 13500 | 15000.0 |
| 12(M102) | 1024-QAM | 5/6 | 10 | 24 | 2 | 720 | 600 | 1 | 15000 | 16666.7 |

**Table 23-45—S1G-MCSs for 1 MHz, $N_{SS}$ = 4**

| MCS Idx | Mod | R | $N_{BPSCS}$ | $N_{SD}$ | $N_{SP}$ | $N_{CBPS}$ | $N_{DBPS}$ | $N_{ES}$ | Data_rate (kb/s) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | 8 μs GI | 4 μs GI |
| 0 | BPSK | 1/2 | 1 | 24 | 2 | 96 | 48 | 1 | 1200.0 | 1333.3 |
| 1 | QPSK | 1/2 | 2 | 24 | 2 | 192 | 96 | 1 | 2400.0 | 2666.7 |
| 2 | QPSK | 3/4 | 2 | 24 | 2 | 192 | 144 | 1 | 3600.0 | 4000.0 |
| 3 | 16-QAM | 1/2 | 4 | 24 | 2 | 384 | 192 | 1 | 4800.0 | 5333.3 |
| 4 | 16-QAM | 3/4 | 4 | 24 | 2 | 384 | 288 | 1 | 7200.0 | 8000.0 |
| 5 | 64-QAM | 2/3 | 6 | 24 | 2 | 576 | 384 | 1 | 9600.0 | 10 666.7 |
| 6 | 64-QAM | 3/4 | 6 | 24 | 2 | 576 | 432 | 1 | 10 800.0 | 12 000.0 |
| 7 | 64-QAM | 5/6 | 6 | 24 | 2 | 576 | 480 | 1 | 12 000.0 | 13 333.3 |
| 8 | 256-QAM | 3/4 | 8 | 24 | 2 | 768 | 576 | 1 | 14 400.0 | 16 000.0 |


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**Table 23-45—S1G-MCSs for 1 MHz, $N_{SS}$ = 4**

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 9 | 256-QAM | 5/6 | 8 | 24 | 2 | 768 | 640 | 1 | 16 000.0 | 17 777.8 |
| 10(M102) | Not valid | | | | | | | | | |
| 11(M102) | 1024-QAM | 3/4 | 10 | 24 | 2 | 960 | 720 | 1 | 18000 | 20000.0 |
| 12(M102) | 1024-QAM | 5/6 | 10 | 24 | 2 | 960 | 800 | 1 | 20000 | 22222.2 |

**Table 23-46—S1G-MCSs for 2 MHz, $N_{SS}$ = 1**

| MCS Idx | Mod | R | $N_{BPSCS}$ | $N_{SD}$ | $N_{SP}$ | $N_{CBPS}$ | $N_{DBPS}$ | $N_{ES}$ | Data_rate (kb/s) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | 8 μs GI | 4 μs GI |
| 0 | BPSK | 1/2 | 1 | 52 | 4 | 52 | 26 | 1 | 650.0 | 722.2 |
| 1 | QPSK | 1/2 | 2 | 52 | 4 | 104 | 52 | 1 | 1300.0 | 1444.4 |
| 2 | QPSK | 3/4 | 2 | 52 | 4 | 104 | 78 | 1 | 1950.0 | 2166.7 |
| 3 | 16-QAM | 1/2 | 4 | 52 | 4 | 208 | 104 | 1 | 2600.0 | 2888.9 |
| 4 | 16-QAM | 3/4 | 4 | 52 | 4 | 208 | 156 | 1 | 3900.0 | 4333.3 |
| 5 | 64-QAM | 2/3 | 6 | 52 | 4 | 312 | 208 | 1 | 5200.0 | 5777.8 |
| 6 | 64-QAM | 3/4 | 6 | 52 | 4 | 312 | 234 | 1 | 5850.0 | 6500.0 |
| 7 | 64-QAM | 5/6 | 6 | 52 | 4 | 312 | 260 | 1 | 6500.0 | 7222.2 |
| 8 | 256-QAM | 3/4 | 8 | 52 | 4 | 416 | 312 | 1 | 7800.0 | 8666.7 |
| 9 | Not valid | | | | | | | | | |
| 10(M102) | Not valid | | | | | | | | | |
| 11(M102) | 1024-QAM | 3/4 | 10 | 52 | 4 | 520 | 390 | 1 | 9750 | 10833.3 |
| 12(M102) | (#4395)Not valid | | | | | | | | | |

**Table 23-47—S1G-MCSs for 2 MHz, $N_{SS}$ = 2**

| MCS Idx | Mod | R | $N_{BPSCS}$ | $N_{SD}$ | $N_{SP}$ | $N_{CBPS}$ | $N_{DBPS}$ | $N_{ES}$ | Data_rate (kb/s) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | 8 μs GI | 4 μs GI |
| 0 | BPSK | 1/2 | 1 | 52 | 4 | 104 | 52 | 1 | 1300.0 | 1444.4 |
| 1 | QPSK | 1/2 | 2 | 52 | 4 | 208 | 104 | 1 | 2600.0 | 2888.9 |
| 2 | QPSK | 3/4 | 2 | 52 | 4 | 208 | 156 | 1 | 3900.0 | 4333.3 |
| 3 | 16-QAM | 1/2 | 4 | 52 | 4 | 416 | 208 | 1 | 5200.0 | 5777.8 |
| 4 | 16-QAM | 3/4 | 4 | 52 | 4 | 416 | 312 | 1 | 7800.0 | 8666.7 |
| 5 | 64-QAM | 2/3 | 6 | 52 | 4 | 624 | 416 | 1 | 10 400.0 | 11 555.6 |
| 6 | 64-QAM | 3/4 | 6 | 52 | 4 | 624 | 468 | 1 | 11 700.0 | 13 000.0 |
| 7 | 64-QAM | 5/6 | 6 | 52 | 4 | 624 | 520 | 1 | 13 000.0 | 14 444.4 |
| 8 | 256-QAM | 3/4 | 8 | 52 | 4 | 832 | 624 | 1 | 15 600.0 | 17 333.3 |
| 9 | Not valid | | | | | | | | | |
| 10(M102) | Not valid | | | | | | | | | |
| 11(M102) | 1024-QAM | 3/4 | 10 | 52 | 4 | 1024 | 780 | 1 | 19500 | 21666.7 |
| 12(M102) | (#4395)Not valid | | | | | | | | | |

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**Table 23-48—S1G-MCSs for 2 MHz, $N_{SS}$ = 3**

| MCS Idx | Mod | R | $N_{BPSCS}$ | $N_{SD}$ | $N_{SP}$ | $N_{CBPS}$ | $N_{DBPS}$ | $N_{ES}$ | Data_rate (kb/s) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | 8 μs GI | 4 μs GI |
| 0 | BPSK | 1/2 | 1 | 52 | 4 | 156 | 78 | 1 | 1950.0 | 2166.7 |
| 1 | QPSK | 1/2 | 2 | 52 | 4 | 312 | 156 | 1 | 3900.0 | 4333.3 |
| 2 | QPSK | 3/4 | 2 | 52 | 4 | 312 | 234 | 1 | 5850.0 | 6500.0 |
| 3 | 16-QAM | 1/2 | 4 | 52 | 4 | 624 | 312 | 1 | 7800.0 | 8666.7 |
| 4 | 16-QAM | 3/4 | 4 | 52 | 4 | 624 | 468 | 1 | 11 700.0 | 13 000.0 |
| 5 | 64-QAM | 2/3 | 6 | 52 | 4 | 936 | 624 | 1 | 15 600.0 | 17 333.3 |
| 6 | 64-QAM | 3/4 | 6 | 52 | 4 | 936 | 702 | 1 | 17 550.0 | 19 500.0 |
| 7 | 64-QAM | 5/6 | 6 | 52 | 4 | 936 | 780 | 1 | 19 500.0 | 21 666.7 |
| 8 | 256-QAM | 3/4 | 8 | 52 | 4 | 1248 | 936 | 1 | 23 400.0 | 26 000.0 |
| 9 | 256-QAM | 5/6 | 8 | 52 | 4 | 1248 | 1040 | 1 | 26 000.0 | 28 888.9 |
| 10(M102) | Not valid | | | | | | | | | |
| 11(M102) | 1024-QAM | 3/4 | 10 | 52 | 4 | 1560 | 1170 | 1 | 29250 | 32500.0 |
| 12(M102) | 1024-QAM | 5/6 | 10 | 52 | 4 | 1560 | 1300 | 1 | 32500 | 36111.1 |

**Table 23-49—S1G-MCSs for 2 MHz, $N_{SS}$ = 4**

| MCS Idx | Mod | R | $N_{BPSCS}$ | $N_{SD}$ | $N_{SP}$ | $N_{CBPS}$ | $N_{DBPS}$ | $N_{ES}$ | Data_rate (kb/s) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | 8 μs GI | 4 μs GI |
| 0 | BPSK | 1/2 | 1 | 52 | 4 | 208 | 104 | 1 | 2600.0 | 2888.9 |
| 1 | QPSK | 1/2 | 2 | 52 | 4 | 416 | 208 | 1 | 5200.0 | 5777.8 |
| 2 | QPSK | 3/4 | 2 | 52 | 4 | 416 | 312 | 1 | 7800.0 | 8666.7 |
| 3 | 16-QAM | 1/2 | 4 | 52 | 4 | 832 | 416 | 1 | 10 400.0 | 11 555.6 |
| 4 | 16-QAM | 3/4 | 4 | 52 | 4 | 832 | 624 | 1 | 15 600.0 | 17 333.3 |
| 5 | 64-QAM | 2/3 | 6 | 52 | 4 | 1248 | 832 | 1 | 20 800.0 | 23 111.1 |
| 6 | 64-QAM | 3/4 | 6 | 52 | 4 | 1248 | 936 | 1 | 23 400.0 | 26 000.0 |
| 7 | 64-QAM | 5/6 | 6 | 52 | 4 | 1248 | 1040 | 1 | 26 000.0 | 28 888.9 |
| 8 | 256-QAM | 3/4 | 8 | 52 | 4 | 1664 | 1248 | 1 | 31 200.0 | 34 666.7 |
| 9 | Not valid | | | | | | | | | |
| 10(M102) | Not valid | | | | | | | | | |
| 11(M102) | 1024-QAM | 3/4 | 10 | 52 | 4 | 2080 | 1560 | 1 | 39000 | 43333.3 |
| 12(M102) | (#4395)Not valid | | | | | | | | | |

**Table 23-50—S1G-MCSs for 4 MHz, $N_{SS}$ = 1**

| MCS Idx | Mod | R | $N_{BPSCS}$ | $N_{SD}$ | $N_{SP}$ | $N_{CBPS}$ | $N_{DBPS}$ | $N_{ES}$ | Data_rate (kb/s) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | 8 μs GI | 4 μs GI |
| 0 | BPSK | 1/2 | 1 | 108 | 6 | 108 | 54 | 1 | 1350.0 | 1500.0 |
| 1 | QPSK | 1/2 | 2 | 108 | 6 | 216 | 108 | 1 | 2700.0 | 3000.0 |
| 2 | QPSK | 3/4 | 2 | 108 | 6 | 216 | 162 | 1 | 4050.0 | 4500.0 |
| 3 | 16-QAM | 1/2 | 4 | 108 | 6 | 432 | 216 | 1 | 5400.0 | 6000.0 |


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**Table 23-50—S1G-MCSs for 4 MHz, $N_{SS}$ = 1**

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 4 | 16-QAM | 3/4 | 4 | 108 | 6 | 432 | 324 | 1 | 8100.0 | 9000.0 |
| 5 | 64-QAM | 2/3 | 6 | 108 | 6 | 648 | 432 | 1 | 10 800.0 | 12 000.0 |
| 6 | 64-QAM | 3/4 | 6 | 108 | 6 | 648 | 486 | 1 | 12 150.0 | 13 500.0 |
| 7 | 64-QAM | 5/6 | 6 | 108 | 6 | 648 | 540 | 1 | 13 500.0 | 15 000.0 |
| 8 | 256-QAM | 3/4 | 8 | 108 | 6 | 864 | 648 | 1 | 16 200.0 | 18 000.0 |
| 9 | 256-QAM | 5/6 | 8 | 108 | 6 | 864 | 720 | 1 | 18 000.0 | 20 000.0 |
| 10(M102) | Not valid | | | | | | | | | |
| 11(M102) | 1024-QAM | 3/4 | 10 | 108 | 6 | 1080 | 810 | 1 | 20250 | 22500.0 |
| 12(M102) | 1024-QAM | 5/6 | 10 | 108 | 6 | 1080 | 900 | 1 | 22500 | 25000.0 |

**Table 23-51—S1G-MCSs for 4 MHz, $N_{SS}$ = 2**

| MCS Idx | Mod | R | $N_{BPSCS}$ | $N_{SD}$ | $N_{SP}$ | $N_{CBPS}$ | $N_{DBPS}$ | $N_{ES}$ | Data_rate (kb/s) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | 8 μs GI | 4 μs GI |
| 0 | BPSK | 1/2 | 1 | 108 | 6 | 216 | 108 | 1 | 2700.0 | 3000.0 |
| 1 | QPSK | 1/2 | 2 | 108 | 6 | 432 | 216 | 1 | 5400.0 | 6000.0 |
| 2 | QPSK | 3/4 | 2 | 108 | 6 | 432 | 324 | 1 | 8100.0 | 9000.0 |
| 3 | 16-QAM | 1/2 | 4 | 108 | 6 | 864 | 432 | 1 | 10 800.0 | 12 000.0 |
| 4 | 16-QAM | 3/4 | 4 | 108 | 6 | 864 | 648 | 1 | 16 200.0 | 18 000.0 |
| 5 | 64-QAM | 2/3 | 6 | 108 | 6 | 1296 | 864 | 1 | 21 600.0 | 24 000.0 |
| 6 | 64-QAM | 3/4 | 6 | 108 | 6 | 1296 | 972 | 1 | 24 300.0 | 27 000.0 |
| 7 | 64-QAM | 5/6 | 6 | 108 | 6 | 1296 | 1080 | 1 | 27 000.0 | 30 000.0 |
| 8 | 256-QAM | 3/4 | 8 | 108 | 6 | 1728 | 1296 | 1 | 32 400.0 | 36 000.0 |
| 9 | 256-QAM | 5/6 | 8 | 108 | 6 | 1728 | 1440 | 1 | 36 000.0 | 40 000.0 |
| 10(M102) | Not valid | | | | | | | | | |
| 11(M102) | 1024-QAM | 3/4 | 10 | 108 | 6 | 2160 | 1620 | 1 | 40500 | 45000.0 |
| 12(M102) | 1024-QAM | 5/6 | 10 | 108 | 6 | 2160 | 1800 | 1 | 45000 | 50000.0 |

**Table 23-52—S1G-MCSs for 4 MHz, $N_{SS}$ = 3**

| MCS Idx | Mod | R | $N_{BPSCS}$ | $N_{SD}$ | $N_{SP}$ | $N_{CBPS}$ | $N_{DBPS}$ | $N_{ES}$ | Data_rate (kb/s) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | 8 μs GI | 4 μs GI |
| 0 | BPSK | 1/2 | 1 | 108 | 6 | 324 | 162 | 1 | 4050.0 | 4500.0 |
| 1 | QPSK | 1/2 | 2 | 108 | 6 | 648 | 324 | 1 | 8100.0 | 9000.0 |
| 2 | QPSK | 3/4 | 2 | 108 | 6 | 648 | 486 | 1 | 12 150.0 | 13 500.0 |
| 3 | 16-QAM | 1/2 | 4 | 108 | 6 | 1296 | 648 | 1 | 16 200.0 | 18 000.0 |
| 4 | 16-QAM | 3/4 | 4 | 108 | 6 | 1296 | 972 | 1 | 24 300.0 | 27 000.0 |
| 5 | 64-QAM | 2/3 | 6 | 108 | 6 | 1944 | 1296 | 1 | 32 400.0 | 36 000.0 |
| 6 | 64-QAM | 3/4 | 6 | 108 | 6 | 1944 | 1458 | 1 | 36 450.0 | 40 500.0 |
| 7 | 64-QAM | 5/6 | 6 | 108 | 6 | 1944 | 1620 | 1 | 40 500.0 | 45 000.0 |
| 8 | 256-QAM | 3/4 | 8 | 108 | 6 | 2592 | 1944 | 1 | 48 600.0 | 54 000.0 |
| 9 | 256-QAM | 5/6 | 8 | 108 | 6 | 2592 | 2160 | 1 | 54 000.0 | 60 000.0 |
| 10(M102) | Not valid | | | | | | | | | |

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**Table 23-52—S1G-MCSs for 4 MHz, $N_{SS}$ = 3**

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 11(M102) | 1024-QAM | 3/4 | 10 | 108 | 6 | 3240 | 2430 | 1 | 60750 | 67500.0 |
| 12(M102) | 1024-QAM | 5/6 | 10 | 108 | 6 | 3240 | 2700 | 1 | 67500 | 75000.0 |

**Table 23-53—S1G-MCSs for 4 MHz, $N_{SS}$ = 4**

| MCS Idx | Mod | R | $N_{BPSCS}$ | $N_{SD}$ | $N_{SP}$ | $N_{CBPS}$ | $N_{DBPS}$ | $N_{ES}$ | Data_rate (kb/s) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | 8 μs GI | 4 μs GI |
| 0 | BPSK | 1/2 | 1 | 108 | 6 | 432 | 216 | 1 | 5400.0 | 6000.0 |
| 1 | QPSK | 1/2 | 2 | 108 | 6 | 864 | 432 | 1 | 10 800.0 | 12 000.0 |
| 2 | QPSK | 3/4 | 2 | 108 | 6 | 864 | 648 | 1 | 16 200.0 | 18 000.0 |
| 3 | 16-QAM | 1/2 | 4 | 108 | 6 | 1728 | 864 | 1 | 21 600.0 | 24 000.0 |
| 4 | 16-QAM | 3/4 | 4 | 108 | 6 | 1728 | 1296 | 1 | 32 400.0 | 36 000.0 |
| 5 | 64-QAM | 2/3 | 6 | 108 | 6 | 2592 | 1728 | 1 | 43 200.0 | 48 000.0 |
| 6 | 64-QAM | 3/4 | 6 | 108 | 6 | 2592 | 1944 | 1 | 48 600.0 | 54 000.0 |
| 7 | 64-QAM | 5/6 | 6 | 108 | 6 | 2592 | 2160 | 1 | 54 000.0 | 60 000.0 |
| 8 | 256-QAM | 3/4 | 8 | 108 | 6 | 3456 | 2592 | 1 | 64 800.0 | 72 000.0 |
| 9 | 256-QAM | 5/6 | 8 | 108 | 6 | 3456 | 2880 | 1 | 72 000.0 | 80 000.0 |
| 10(M102) | Not valid | | | | | | | | | |
| 11(M102) | 1024-QAM | 3/4 | 10 | 108 | 6 | 4320 | 3240 | 1 | 81000 | 90000.0 |
| 12(M102) | 1024-QAM | 5/6 | 10 | 108 | 6 | 4320 | 3600 | 1 | 90000 | 100000.0 |

**Table 23-54—S1G-MCSs for 8 MHz, $N_{SS}$ = 1**

| MCS Idx | Mod | R | $N_{BPSCS}$ | $N_{SD}$ | $N_{SP}$ | $N_{CBPS}$ | $N_{DBPS}$ | $N_{ES}$ | Data_rate (kb/s) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | 8 μs GI | 4 μs GI |
| 0 | BPSK | 1/2 | 1 | 234 | 8 | 234 | 117 | 1 | 2925.0 | 3250.0 |
| 1 | QPSK | 1/2 | 2 | 234 | 8 | 468 | 234 | 1 | 5850.0 | 6500.0 |
| 2 | QPSK | 3/4 | 2 | 234 | 8 | 468 | 351 | 1 | 8775.0 | 9750.0 |
| 3 | 16-QAM | 1/2 | 4 | 234 | 8 | 936 | 468 | 1 | 11 700.0 | 13 000.0 |
| 4 | 16-QAM | 3/4 | 4 | 234 | 8 | 936 | 702 | 1 | 17 550.0 | 19 500.0 |
| 5 | 64-QAM | 2/3 | 6 | 234 | 8 | 1404 | 936 | 1 | 23 400.0 | 26 000.0 |
| 6 | 64-QAM | 3/4 | 6 | 234 | 8 | 1404 | 1053 | 1 | 26 325.0 | 29 250.0 |
| 7 | 64-QAM | 5/6 | 6 | 234 | 8 | 1404 | 1170 | 1 | 29 250.0 | 32 500.0 |
| 8 | 256-QAM | 3/4 | 8 | 234 | 8 | 1872 | 1404 | 1 | 35 100.0 | 39 000.0 |
| 9 | 256-QAM | 5/6 | 8 | 234 | 8 | 1872 | 1560 | 1 | 39 000.0 | 43 333.3 |
| 10(M102) | Not valid | | | | | | | | | |
| 11(M102) | 1024-QAM | 3/4 | 10 | 234 | 8 | 2340 | 1755 | 1 | 43875 | 48750.0 |
| 12(M102) | 1024-QAM | 5/6 | 10 | 234 | 8 | 2340 | 1950 | 1 | 48750 | 54166.7 |


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**Table 23-55—S1G-MCSs for 8 MHz, $N_{SS}$ = 2**

| MCS Idx | Mod | R | $N_{BPSCS}$ | $N_{SD}$ | $N_{SP}$ | $N_{CBPS}$ | $N_{DBPS}$ | $N_{ES}$ | Data_rate (kb/s) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | 8 μs GI | 4 μs GI |
| 0 | BPSK | 1/2 | 1 | 234 | 8 | 468 | 234 | 1 | 5850.0 | 6500.0 |
| 1 | QPSK | 1/2 | 2 | 234 | 8 | 936 | 468 | 1 | 11 700.0 | 13 000.0 |
| 2 | QPSK | 3/4 | 2 | 234 | 8 | 936 | 702 | 1 | 17 550.0 | 19 500.0 |
| 3 | 16-QAM | 1/2 | 4 | 234 | 8 | 1872 | 936 | 1 | 23 400.0 | 26 000.0 |
| 4 | 16-QAM | 3/4 | 4 | 234 | 8 | 1872 | 1404 | 1 | 35 100.0 | 39 000.0 |
| 5 | 64-QAM | 2/3 | 6 | 234 | 8 | 2808 | 1872 | 1 | 46 800.0 | 52 000.0 |
| 6 | 64-QAM | 3/4 | 6 | 234 | 8 | 2808 | 2106 | 1 | 52 650.0 | 58 500.0 |
| 7 | 64-QAM | 5/6 | 6 | 234 | 8 | 2808 | 2340 | 1 | 58 500.0 | 65 000.0 |
| 8 | 256-QAM | 3/4 | 8 | 234 | 8 | 3744 | 2808 | 1 | 70 200.0 | 78 000.0 |
| 9 | 256-QAM | 5/6 | 8 | 234 | 8 | 3744 | 3120 | 1 | 78 000.0 | 86 666.7 |
| 10(M102) | Not valid | | | | | | | | | |
| 11(M102) | 1024-QAM | 3/4 | 10 | 234 | 8 | 4680 | 3510 | 1 | 87750 | 97500.0 |
| 12(M102) | 1024-QAM | 5/6 | 10 | 234 | 8 | 4680 | 3900 | 1 | 97500 | 108333.3 |

**Table 23-56—S1G-MCSs for 8 MHz, $N_{SS}$ = 3**

| MCS Idx | Mod | R | $N_{BPSCS}$ | $N_{SD}$ | $N_{SP}$ | $N_{CBPS}$ | $N_{DBPS}$ | $N_{ES}$ | Data_rate (kb/s) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | 8 μs GI | 4 μs GI |
| 0 | BPSK | 1/2 | 1 | 234 | 8 | 702 | 351 | 1 | 8775.0 | 9750.0 |
| 1 | QPSK | 1/2 | 2 | 234 | 8 | 1404 | 702 | 1 | 17 550.0 | 19 500.0 |
| 2 | QPSK | 3/4 | 2 | 234 | 8 | 1404 | 1053 | 1 | 26 325.0 | 29 250.0 |
| 3 | 16-QAM | 1/2 | 4 | 234 | 8 | 2808 | 1404 | 1 | 35 100.0 | 39 000.0 |
| 4 | 16-QAM | 3/4 | 4 | 234 | 8 | 2808 | 2106 | 1 | 52 650.0 | 58 500.0 |
| 5 | 64-QAM | 2/3 | 6 | 234 | 8 | 4212 | 2808 | 1 | 70 200.0 | 78 000.0 |
| 6 | 64-QAM | 3/4 | 6 | 234 | 8 | 4212 | 3159 | 1 | 78 975.0 | 87 750.0 |
| 7 | 64-QAM | 5/6 | 6 | 234 | 8 | 4212 | 3510 | 1 | 87 750.0 | 97 500.0 |
| 8 | 256-QAM | 3/4 | 8 | 234 | 8 | 5616 | 4212 | 1 | 105 300.0 | 117 000.0 |
| 9 | 256-QAM | 5/6 | 8 | 234 | 8 | 5616 | 4680 | 1 | 117 000.0 | 130 000.0 |
| 10(M102) | Not valid | | | | | | | | | |
| 11(M102) | 1024-QAM | 3/4 | 10 | 234 | 8 | 7020 | 5265 | 1 | 131625 | 146250.0 |
| 12(M102) | 1024-QAM | 5/6 | 10 | 234 | 8 | 7020 | 5850 | 1 | 146250 | 162500.0 |

**Table 23-57—S1G-MCSs for 8 MHz, $N_{SS}$ = 4**

| MCS Idx | Mod | R | $N_{BPSCS}$ | $N_{SD}$ | $N_{SP}$ | $N_{CBPS}$ | $N_{DBPS}$ | $N_{ES}$ | Data_rate (kb/s) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | 8 μs GI | 4 μs GI |
| 0 | BPSK | 1/2 | 1 | 234 | 8 | 936 | 468 | 1 | 11 700.0 | 13 000.0 |
| 1 | QPSK | 1/2 | 2 | 234 | 8 | 1872 | 936 | 1 | 23 400.0 | 26 000.0 |
| 2 | QPSK | 3/4 | 2 | 234 | 8 | 1872 | 1404 | 1 | 35 100.0 | 39 000.0 |
| 3 | 16-QAM | 1/2 | 4 | 234 | 8 | 3744 | 1872 | 1 | 46 800.0 | 52 000.0 |

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**Table 23-57—S1G-MCSs for 8 MHz, $N_{SS}$ = 4**

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 4 | 16-QAM | 3/4 | 4 | 234 | 8 | 3744 | 2808 | 1 | 70 200.0 | 78 000.0 |
| 5 | 64-QAM | 2/3 | 6 | 234 | 8 | 5616 | 3744 | 1 | 93 600.0 | 104 000.0 |
| 6 | 64-QAM | 3/4 | 6 | 234 | 8 | 5616 | 4212 | 1 | 105 300.0 | 117 000.0 |
| 7 | 64-QAM | 5/6 | 6 | 234 | 8 | 5616 | 4680 | 1 | 117 000.0 | 130 000.0 |
| 8 | 256-QAM | 3/4 | 8 | 234 | 8 | 7488 | 5616 | 1 | 140 400.0 | 156 000.0 |
| 9 | 256-QAM | 5/6 | 8 | 234 | 8 | 7488 | 6240 | 1 | 156 000.0 | 173 333.3 |
| 10(M102) | Not valid | | | | | | | | | |
| 11(M102) | 1024-QAM | 3/4 | 10 | 234 | 8 | 9360 | 7020 | 1 | 175500 | 195000.0 |
| 12(M102) | 1024-QAM | 5/6 | 10 | 234 | 8 | 9360 | 7800 | 1 | 195000 | 216666.7 |

**Table 23-58—S1G-MCSs for 16 MHz, $N_{SS}$ = 1**

| MCS Idx | Mod | R | $N_{BPSCS}$ | $N_{SD}$ | $N_{SP}$ | $N_{CBPS}$ | $N_{DBPS}$ | $N_{ES}$ | Data_rate (kb/s) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | 8 μs GI | 4 μs GI |
| 0 | BPSK | 1/2 | 1 | 468 | 16 | 468 | 234 | 1 | 5850.0 | 6500.0 |
| 1 | QPSK | 1/2 | 2 | 468 | 16 | 936 | 468 | 1 | 11 700.0 | 13 000.0 |
| 2 | QPSK | 3/4 | 2 | 468 | 16 | 936 | 702 | 1 | 17 550.0 | 19 500.0 |
| 3 | 16-QAM | 1/2 | 4 | 468 | 16 | 1872 | 936 | 1 | 23 400.0 | 26 000.0 |
| 4 | 16-QAM | 3/4 | 4 | 468 | 16 | 1872 | 1404 | 1 | 35 100.0 | 39 000.0 |
| 5 | 64-QAM | 2/3 | 6 | 468 | 16 | 2808 | 1872 | 1 | 46 800.0 | 52 000.0 |
| 6 | 64-QAM | 3/4 | 6 | 468 | 16 | 2808 | 2106 | 1 | 52 650.0 | 58 500.0 |
| 7 | 64-QAM | 5/6 | 6 | 468 | 16 | 2808 | 2340 | 1 | 58 500.0 | 65 000.0 |
| 8 | 256-QAM | 3/4 | 8 | 468 | 16 | 3744 | 2808 | 1 | 70 200.0 | 78 000.0 |
| 9 | 256-QAM | 5/6 | 8 | 468 | 16 | 3744 | 3120 | 1 | 78 000.0 | 86 666.7 |
| 10(M102) | Not valid | | | | | | | | | |
| 11(M102) | 1024-QAM | 3/4 | 10 | 468 | 16 | 4680 | 3510 | 1 | 87750 | 97500.0 |
| 12(M102) | 1024-QAM | 5/6 | 10 | 468 | 16 | 4680 | 3900 | 1 | 97500 | 108333.3 |

**Table 23-59—S1G-MCSs for 16 MHz, $N_{SS}$ = 2**

| MCS Idx | Mod | R | $N_{BPSCS}$ | $N_{SD}$ | $N_{SP}$ | $N_{CBPS}$ | $N_{DBPS}$ | $N_{ES}$ | Data_rate (kb/s) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | 8 μs GI | 4 μs GI |
| 0 | BPSK | 1/2 | 1 | 468 | 16 | 936 | 468 | 1 | 11 700.0 | 13 000.0 |
| 1 | QPSK | 1/2 | 2 | 468 | 16 | 1872 | 936 | 1 | 23 400.0 | 26 000.0 |
| 2 | QPSK | 3/4 | 2 | 468 | 16 | 1872 | 1404 | 1 | 35 100.0 | 39 000.0 |
| 3 | 16-QAM | 1/2 | 4 | 468 | 16 | 3744 | 1872 | 1 | 46 800.0 | 52 000.0 |
| 4 | 16-QAM | 3/4 | 4 | 468 | 16 | 3744 | 2808 | 1 | 70 200.0 | 78 000.0 |
| 5 | 64-QAM | 2/3 | 6 | 468 | 16 | 5616 | 3744 | 1 | 93 600.0 | 104 000.0 |
| 6 | 64-QAM | 3/4 | 6 | 468 | 16 | 5616 | 4212 | 1 | 105 300.0 | 117 000.0 |
| 7 | 64-QAM | 5/6 | 6 | 468 | 16 | 5616 | 4680 | 1 | 117 000.0 | 130 000.0 |
| 8 | 256-QAM | 3/4 | 8 | 468 | 16 | 7488 | 5616 | 1 | 140 400.0 | 156 000.0 |
| 9 | 256-QAM | 5/6 | 8 | 468 | 16 | 7488 | 6240 | 1 | 156 000.0 | 173 333.3 |
| 10(M102) | Not valid | | | | | | | | | |



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**Table 23-59—S1G-MCSs for 16 MHz, $N_{SS}$ = 2**

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 11(M102) | 1024-QAM | 3/4 | 10 | 468 | 16 | 9360 | 7020 | 1 | 175500 | 195000.0 |
| 12(M102) | 1024-QAM | 5/6 | 10 | 468 | 16 | 9360 | 7800 | 1 | 195000 | 216666.7 |

**Table 23-60—S1G-MCSs for 16 MHz, $N_{SS}$ = 3**

| MCS Idx | Mod | R | $N_{BPSCS}$ | $N_{SD}$ | $N_{SP}$ | $N_{CBPS}$ | $N_{DBPS}$ | $N_{ES}$ | Data_rate (kb/s) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | 8 μs GI | 4 μs GI |
| 0 | BPSK | 1/2 | 1 | 468 | 16 | 1404 | 702 | 1 | 17 550.0 | 19 500.0 |
| 1 | QPSK | 1/2 | 2 | 468 | 16 | 2808 | 1404 | 1 | 35 100.0 | 39 000.0 |
| 2 | QPSK | 3/4 | 2 | 468 | 16 | 2808 | 2106 | 1 | 52 650.0 | 58 500.0 |
| 3 | 16-QAM | 1/2 | 4 | 468 | 16 | 5616 | 2808 | 1 | 70 200.0 | 78 000.0 |
| 4 | 16-QAM | 3/4 | 4 | 468 | 16 | 5616 | 4212 | 1 | 105 300.0 | 117 000.0 |
| 5 | 64-QAM | 2/3 | 6 | 468 | 16 | 8424 | 5616 | 1 | 140 400.0 | 156 000.0 |
| 6 | 64-QAM | 3/4 | 6 | 468 | 16 | 8424 | 6318 | 1 | 157 950.0 | 175 500.0 |
| 7 | 64-QAM | 5/6 | 6 | 468 | 16 | 8424 | 7020 | 1 | 175 500.0 | 195 000.0 |
| 8 | 256-QAM | 3/4 | 8 | 468 | 16 | 11 232 | 8424 | 1 | 210 600.0 | 234 000.0 |
| 9 | 256-QAM | 5/6 | 8 | 468 | 16 | 11 232 | 9360 | 1 | 234 000.0 | 260 000.0 |
| 10(M102) | Not valid | | | | | | | | | |
| 11(M102) | 1024-QAM | 3/4 | 10 | 468 | 16 | 14040 | 10530 | 1 | 263250 | 292500.0 |
| 12(M102) | 1024-QAM | 5/6 | 10 | 468 | 16 | 14040 | 11700 | 1 | 292500 | 325000.0 |

**Table 23-61—S1G-MCSs for 16 MHz, $N_{SS}$ = 4**

| MCS Idx | Mod | R | $N_{BPSCS}$ | $N_{SD}$ | $N_{SP}$ | $N_{CBPS}$ | $N_{DBPS}$ | $N_{ES}$ | Data_rate (kb/s) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | 8 μs GI | 4 μs GI |
| 0 | BPSK | 1/2 | 1 | 468 | 16 | 1872 | 936 | 1 | 23400.0 | 26000.0 |
| 1 | QPSK | 1/2 | 2 | 468 | 16 | 3744 | 1872 | 1 | 46800.0 | 52000.0 |
| 2 | QPSK | 3/4 | 2 | 468 | 16 | 3744 | 2808 | 1 | 70200.0 | 78000.0 |
| 3 | 16-QAM | 1/2 | 4 | 468 | 16 | 7488 | 3744 | 1 | 93600.0 | 104000.0 |
| 4 | 16-QAM | 3/4 | 4 | 468 | 16 | 7488 | 5616 | 1 | 140400.0 | 156000.0 |
| 5 | 64-QAM | 2/3 | 6 | 468 | 16 | 11 232 | 7488 | 1 | 187200.0 | 208000.0 |
| 6 | 64-QAM | 3/4 | 6 | 468 | 16 | 11 232 | 8424 | 1 | 210600.0 | 234000.0 |
| 7 | 64-QAM | 5/6 | 6 | 468 | 16 | 11 232 | 9360 | 1 | 234000.0 | 260000.0 |
| 8 | 256-QAM | 3/4 | 8 | 468 | 16 | 14 976 | 11 232 | 1 | 280800.0 | 312000.0 |
| 9 | 256-QAM | 5/6 | 8 | 468 | 16 | 14 976 | 12 480 | 1 | 312000.0 | 346666.7 |
| 10(M102) | Not valid | | | | | | | | | |
| 11(M102) | 1024-QAM | 3/4 | 10 | 468 | 16 | 18720 | 14040 | 1 | 351000 | 390000.0 |
| 12(M102) | 1024-QAM | 5/6 | 10 | 468 | 16 | 18720 | 15600 | 1 | 390000 | 433333.3 |

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# 24. China directional multi-gigabit (CDMG) PHY specification

## 24.1 CDMG PHY introduction

### 24.1.1 Scope

The CDMG PHY supports a 1.08 GHz channel width in comparison with the DMG PHY in Clause 20 (Directional multi-gigabit (DMG) PHY specification), which supports a 2.16 GHz channel width. As many aspects of CDMG PHY are the same as DMG PHY, this clause mainly lists the new features corresponding to Clause 20 (Directional multi-gigabit (DMG) PHY specification).

The CDMG PHY supports two modulation methods:

— A control modulation using MCS 0 of the CDMG Control mode defined in 24.4 (CDMG control mode)

— A single carrier (SC) modulation using MCS 1 to MCS 16 of the CDMG SC mode defined in 24.5 (CDMG SC mode) and MCS 17 to MCS 23 of the CDMG low-power SC mode defined in 24.6 (CDMG low-power SC mode)

All CDMG modulation methods share a similar preamble (see 24.3.6 (Common preamble)).

The services provided to the MAC by the CDMG PHY consist of the following protocol functions, defined as follows:

a) A function that defines a method of mapping the PHY service data units (PSDU) into a framing format (PPDU) suitable for sending and receiving PSDUs between two or more STAs.

b) A function that defines the characteristics and method of transmitting and receiving data through a wireless medium between two or more STAs. Depending on the MCSs, these STAs support a mixture of CDMG SC mode, CDMG low-power SC mode, and CDMG control mode.

### 24.1.2 CDMG PHY functions

#### 24.1.2.1 General

The CDMG PHY contains two functional entities: the PHY and the layer management function (PLME). Each of these functions is described in detail in 24.3 (Common parameters) to 24.9 (Beamforming). The CDMG PHY service is provided to the MAC through the PHY service primitives defined in Clause 8 (PHY service specification).

#### 24.1.2.2 PHY management entity

The PLME performs management of the local PHY functions in conjunction with the MLME.

#### 24.1.2.3 Service specification method

The description for service specification method is the same as that contained in 20.1.2.2 (Service specification method).

## 24.2 CDMG PHY service interface

### 24.2.1 Introduction

The introduction for CDMG PHY service interface is the same as that contained in 20.2.1 (Introduction).

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### 24.2.2 TXVECTOR and RXVECTOR parameters

The parameters in Table 24-1 (TXVECTOR and RXVECTOR parameters) are defined as part of the TXVECTOR parameter list in the PHY-TXSTART.request primitive and/or as part of the RXVECTOR parameter list in the PHY-RXSTART.indication primitive.

**Table 24-1—TXVECTOR and RXVECTOR parameters**

| Parameter | Value | TXVECTOR | RXVECTOR |
|---|---|---|---|
| MCS | The MCS parameter is an enumerated type that indicates the modulation and coding scheme used in the transmission of the (#14)PPDU. Values are integers in the range 0–23.<br>— A MCS value of 0 indicates the use of CDMG control mode or CDMG robust PHY mode.<br>— MCS values of 1 to 16 indicate use of Single Carrier modulations. The value is an index to Table 24-9 (CDMG SC mode modulation and coding schemes).<br>— MCS values of 17–23 indicate use of CDMG low-power SC mode. The value is an index toTable 24-11 (CDMG low-power SC mode modulation and coding schemes). The CDMG low-power SC mode is obsolete. Support for this mechanism might be removed in a later revision of the standard. | Y | Y |
| LENGTH | Indicates the number of octets in the PSDU in the range 1–262 143. | Y | Y |
| ADD_PPDU | Enumerated type:<br>— ADD-PPDU indicates that this PPDU is immediately followed by another PPDU with no IFS or preamble on the subsequent PPDU.<br>— NO-ADD-PPDU indicates no additional PPDU follows this PPDU. | Y | Y |
| PPDU_TYPE | Enumerated type:<br>— TRN-R indicates either a PPDU whose Data field is followed by one or more TRN subfields, or a PPDU that is requesting TRN subfields to be appended to a future response PPDU.<br>— TRN-T indicates a PPDU whose Data field is followed by one or more TRN subfields. The transmitter may change AWV configuration at the beginning of each TRN subfield.<br>This parameter is reserved if TRN_LEN is 0. | Y | Y |
| TRN_LEN | TRN_LEN indicates the length of the training field. Values are in the range 0–16 (see 24.9.2.2.3 (BRP PPDU Header field(#6409))). | Y | Y |
| AGGREGATION | Indicates whether the PSDU contains an A-MPDU.<br>Enumerated type:<br>— AGGREGATED indicates this is a PSDU with A-MPDU aggregation.<br>— NOT_AGGREGATED indicates this is a PSDU without A-MPDU aggregation. | Y | Y |
| RSSI | The allowed values for the RSSI parameter are in the range from 0 to 255. This parameter is a (#1132)measurement by the PHY of the power observed at the input of the antennas plus the antenna gain, or equivalent antenna gain for a phase-array antenna, used to receive the current PPDU. RSSI shall be measured during the reception of the PHY preamble. RSSI is intended to be used in a relative manner, and it shall be a monotonically increasing function of the received power. | N | Y |


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**Table 24-1—TXVECTOR and RXVECTOR parameters *(continued)***

| Parameter | Value | TXVECTOR | RXVECTOR |
|---|---|---|---|
| SNR | This parameter indicates the SNR measured during the reception of a CDMG control mode (#14)PPDU. Values are –10 dB to 53.75 dB in 0.25 dB steps. | N | Y |
| ANT_CONFIG | Indicates which antenna configuration(s) is to be used throughout the transmission of the (#14)PPDU and when to switch between configurations.<br>Values are implementation dependent. | Y | N |
| CHAN_MEASUREMENT | Channel as measured during the reception of the TRN subfields. Each measurement includes 63 complex numbers. | N | Y |
| TIME_OF_DEPARTURE_REQUESTED | Enumerated type:<br>— true indicates that the MAC entity requests that the PHY entity measure and report time of departure parameters corresponding to the time when the first (#14)PPDU energy is sent by the transmitting port.<br>— false indicates that the MAC entity requests that the PHY entity neither measure nor report time of departure parameters. | O | N |
| RX_START_OF_FRAME_OFFSET | 0 to $2^{32}$–1. An estimate of the offset (in 10 ns(#7198) units) from the point in time at which the start of the preamble (#14)of the PPDU arrived at the receive antenna connector to the point in time at which this primitive is issued to the MAC. | N | See NOTE |
| BEAM_TRACKING_REQUEST | This parameter indicates whether beam tracking is requested.<br>Enumerated type:<br>— BEAM-TRACKING-REQUESTED or BEAM-TRACKING-NOT-REQUESTED. | Y | Y |
| LAST_RSSI | In the TXVECTOR, LAST_RSSI indicates the received power level of the last (#14)PPDU with a valid PHY header that was received a SIFS before transmission of the current (#14)PPDU; otherwise, it is set to 0(#464) (10.3.2.3.3 (SIFS)). In the RXVECTOR, LAST_RSSI indicates the value of the LAST_RSSI field from the (#14)header of the received PPDU.<br>Valid values are integers in the range 0 to 15:<br>— Values of 2 to 14 represent power levels (–74+value×2) dBm.<br>— A value of 15 represents power greater than or equal to –45 dBm.<br>— A value of 1 represents power less than or equal to –71 dBm.<br>— A value of 0 indicates that the previous (#14)PPDU was not received a SIFS before the current transmission. | Y | Y |
| Turnaround | Set to 1 or 0 as specified in 10.3.2.3.3 (SIFS). | Y | Y |
| ENHANCED_BEAM_TRACKING_REQUEST | This parameter indicates whether enhanced beam tracking is requested.<br>Enumerated type:<br>— ENHANCED-BEAM-TRACKING-REQUESTED or ENHANCED-BEAM-TRACKING-NOT-REQUESTED. | Y | Y |

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**Table 24-1—TXVECTOR and RXVECTOR parameters *(continued)***

| Parameter | Value | TXVECTOR | RXVECTOR |
|---|---|---|---|
| ROBUST_MODE | This parameter incorporating with the MCS parameter is an enumerated type that indicates CDMG control mode or CDMG robust PHY mode used in the transmission of the (#14)PPDU. It is present if MCS index is 0. Values are integers in the range 0–2.<br>— A CDMG ROBUST_MODE value of 0 indicates the use of CDMG control mode.<br>— A CDMG ROBUST_MODE value of 1 indicates the use of CDMG robust PHY mode 0.<br>— A CDMG ROBUST_MODE value of 2 indicates the use of CDMG robust PHY mode 1.<br>This parameter is not present if MCS index is not 0. | Y | Y |
| NOTE—"Y" if dot11TimingMsmtActivated is true; otherwise, "N". | | | |

### 24.2.3 TXSTATUS parameters

The parameters listed in Table 24-2 (TXSTATUS parameters) are defined as part of the TXSTATUS parameter list in the PHY-TXSTART.confirm primitive.

**Table 24-2—TXSTATUS parameters**

| Parameter | Value |
|---|---|
| TIME_OF_DEPARTURE | When the first (#14)PPDU energy is sent by the transmitting port, in units equal to 1/TIME_OF_DEPARTURE_ClockRate.<br>This parameter is present only if TIME_OF_DEPARTURE_REQUESTED is true in the corresponding request. |
| TIME_OF_DEPARTURE_ClockRate | 0 to $2^{16}$–1. The clock rate, in units of MHz, is used to generate the TIME_OF_DEPARTURE value. This parameter is present only if TIME_OF_DEPARTURE_REQUESTED is true in the corresponding request. |
| TX_START_OF_FRAME_OFFSET | 0 to $2^{32}$–1. An estimate of the offset (in 10 ns(#7198) units) from the point in time at which the start of the preamble (#14)of the PPDU was transmitted at the transmit antenna connector to the point in time at which this primitive is issued to the MAC. |

## 24.3 Common parameters

### 24.3.1 Channelization

The CDMG PHY operates in the channels defined in Annex E and shall support at least channel numbers 2, 35, and 36.

The channel center frequency is defined as:

Channel center frequency = Channel starting frequency + Channel spacing × (Channel number mod 32)


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where the channel starting frequency is equal to 56.16 GHz, and the channel spacing is defined in Table E-6 (Operating classes in China) in Annex E.

### 24.3.2 Transmit mask

The transmitted spectrum shall adhere to the transmit spectrum mask shown in Figure 24-1 (Transmit mask). The transmit spectrum shall have a 0 dBr (dB relative to the maximum spectral density of the signal) bandwidth not exceeding 0.94 GHz, –17 dBr at a 0.6 GHz offset, –22 dBr at a 1.35 GHz offset, and –30 dBr at a 1.53 GHz offset and above, inside the channels allowed for the regulatory domain in which the STA is transmitting. The measurement shall be made using a 1 MHz resolution bandwidth and a 300 kHz video bandwidth.

The transmitted spectrum shall be measured on data (#14)PPDUs longer than 10 μs without the training fields.

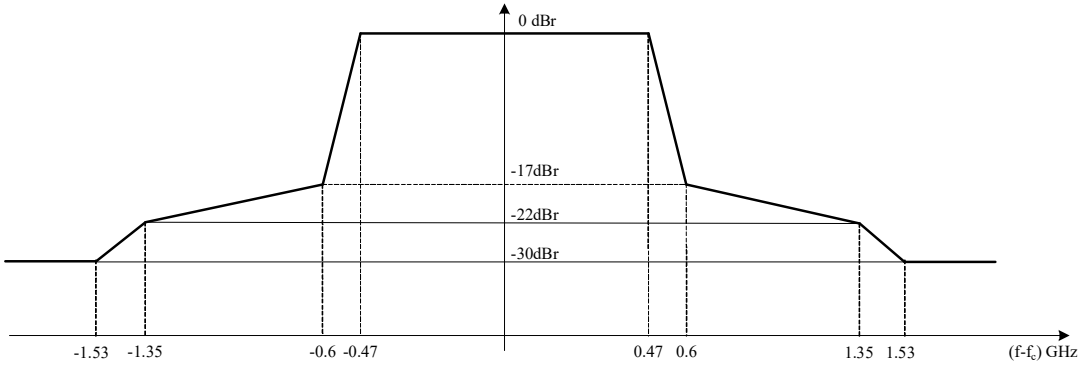


**Figure 24-1—Transmit mask**

### 24.3.3 Common requirements

#### 24.3.3.1 Introduction

This subclause describes the common requirement from all three CDMG modes: control, SC, and low-power SC.

In all of the modes, all defined fields are transmitted bit 0 first in time.

#### 24.3.3.2 Center frequency tolerance

##### 24.3.3.2.1 General

The transmitter center frequency tolerance shall be ± 20 ppm.

##### 24.3.3.2.2 Center frequency convergence

The transmitter center frequency shall converge to within 1 ppm of its final value within 0.9 μs from the start of the (#14)PPDU.

#### 24.3.3.3 Symbol clock tolerance

The symbol clock frequency tolerance shall be ± 20 ppm.

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The transmit center frequency and the symbol clock frequency shall be derived from the same reference oscillator.

#### 24.3.3.4 Transmit center frequency leakage

The transmitter center frequency leakage shall not exceed –23 dB relative to the overall transmitted power.

#### 24.3.3.5 Transmit rampup and rampdown

The description for transmit rampup and rampdown for CDMG PHY is the same as that contained in 20.3.3.5 (Transmit rampup and rampdown).

#### 24.3.3.6 Antenna setting

Antenna setting shall remain constant for the transmission of the entire (#14)PPDU except for the case of transmission of BRP-TX PPDU (see 24.9.2.2 (Beam refinement)). During the transmission of BRP-TX PPDUs it shall remain constant for the transmission of the STF, CE field, and Data field.

#### 24.3.3.7 Maximum input requirement

The receiver maximum input level is the maximum power level at the receive antenna(s) of the incoming signal, in dBm, present at the input of the receiver for which the error rate criterion (defined in 24.3.3.8 (Receiver minimum input level sensitivity(#256))) is met. A receiver shall have a receiver maximum input level at the receive antenna(s) of at least 10 $\mu W/cm^2$ for each of the modulation formats that the receiver supports.

#### 24.3.3.8 Receiver minimum input level sensitivity(#256)

For MCS 0, the PER shall be less than 5% for a PSDU length of 256 octets with the MCS dependent input levels listed in Table 24-3 (Receiver minimum input level sensitivity) defined at the antenna connector. For the other MCSs, the PER shall be less than 1% for a PSDU length of 4096 octets with the MCS dependent input levels listed in Table 24-3 (Receiver minimum input level sensitivity) defined at the antenna connector.

NOTE—For RF power measurements performed over the air, the input level is corrected to compensate for the antenna gain in the implementation. The gain of the antenna is the maximum estimated gain by the manufacturer. In the case of the phased-array antenna, the gain of the phased-array antenna is the maximum sum of estimated element gain minus 3 dB implementation loss.(#4045)

### 24.3.4 Timing-related parameters

Table 24-4 (Timing-related parameters) defines timing-related parameters.

### 24.3.5 Mathematical conventions in the signal description

The description for CDMG (#14)PPDU structure and related equations is the same as that contained in 20.3.5.1 (General).

### 24.3.6 Common preamble

#### 24.3.6.1 General

The preamble is the part of the PPDU that is used for (#14)PPDU detection, AGC, frequency offset estimation, synchronization, I/Q imbalance estimation, indication of modulation (SC), and channel


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**Table 24-3—Receiver minimum input level sensitivity**

| MCS | Receive sensitivity (dBm) |
|---|---|
| 0 | –81 |
| 1 | –71 |
| 2 | –69 |
| 3 | –68 |
| 4 | –67 |
| 5 | –65 |
| 6 | –66 |
| 7 | –65 |
| 8 | –64 |
| 9 | –62 |
| 10 | –58 |
| 11 | –57 |
| 12 | –56 |
| 13 | –54 |
| 14 | –49 |
| 15 | –48 |
| 16 | –46 |
| 17 | –67 |
| 18 | –63 |
| 19 | –60 |
| 20 | –60 |
| 21 | –60 |
| 22 | –60 |
| 23 | –60 |

**Table 24-4—Timing-related parameters**

| Parameter | Value |
|---|---|
| $N_{GI}$ | 64 |
| $N_{SPB}$ | 448 |
| $F_c$: chip rate | 880 MHz |
| $T_c$: chip time | $1 / F_c$ (~1.14 ns) |
| $T_{seq}$ | $128 \times T_c$ (~146 ns) |

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**Table 24-4—Timing-related parameters *(continued)***

| Parameter | Value |
|---|---|
| $T_{STF}$: Detection sequence duration | $18 \times T_{seq}$ (~2618.2 ns) |
| $T_{CE}$: Channel estimation sequence duration | $9 \times T_{seq}$ (~1309.1 ns) |
| $T_{HEADER}$: header duration | $3 \times 512 \times T_c$ (~1.75 μs) |
| $T_{STF\text{-}CP}$: Control mode short training field duration | $50 \times T_{seq}$ (~7.2727 μs) |
| $T_{CE\text{-}CP}$: Control mode channel estimation field duration | $T_{CE}$ (~1309.1 ns) |
| $T_{Data}$ | ($N_{BLKS}$ × aSCBlockSize + aSCGILength) × $T_c$<br>NOTE—$N_{BLKS}$ is defined in 20.5.3.2.3.3 (LDPC encoding process) and aSCBlockSize and aSCGILength are defined in Table 20-30 (DMG PHY characteristics). |

estimation. The SFS field in the preamble enables the receiver to perform estimation and compensation for the (#14)PPDU in a time domain and frequency domain according to the STF. The format of the preamble consists of a Short Training field followed by a Channel Estimation field. Figure 24-2 (CDMG SC mode preamble) illustrates the SC (#14)PPDU preamble.

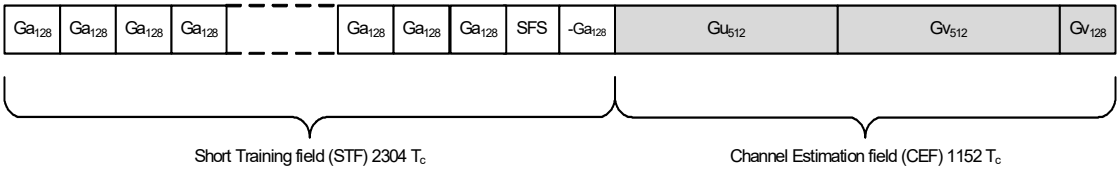


**Figure 24-2—CDMG SC mode preamble**

All numeric fields are transmitted in unsigned format, LSB first.

### 24.3.6.2 Short training field

The Short Training field is composed of 16 repetitions of sequences $Ga_{128}(n)$ of length 128 defined in 20.10 (Golay sequences), a single frequency sequence (SFS) of (#6036)length 128 that used for I/Q imbalance estimation, followed by a single sequence $-Ga_{128}(n)$. The SFS is defined as

$$SFS(n) = \exp\left(j\pi\frac{n}{2}\right), n = 0, 1, \ldots$$

The waveform for the Short Training field is

$$r_{STF}(nT_c) = \begin{cases} (Ga_{128}(n \bmod 128))\exp\left(j\pi\frac{n}{2}\right), n = 0, 1, \ldots, 16 \times 128 - 1 \\ \exp\left(j\pi\frac{n}{2}\right), n = 16 \times 128, \ldots, 17 \times 128 - 1 \\ (-Ga_{128}(n \bmod 128))\exp\left(j\pi\frac{n}{2}\right), n = 17 \times 128, \ldots, 18 \times 128 - 1 \end{cases}$$


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#### 24.3.6.3 Channel estimation field

The Channel Estimation field is used for channel estimation, as well as indication of which modulation is going to be used for the (#14)PPDU, and enables the receiver to suppress nonlinear impact generated in a power amplification process according to the CE field. The Channel Estimation field is composed of a concatenation of two sequences $Gu_{512}(n)$ and $Gv_{512}(n)$ where the last 128 samples of $Gu_{512}(n)$ are equal to the last 128 samples used in the Short Training field. They are followed by a 128 samples sequence $Gv_{128}(n)$ equal to the first 128 samples of both $Gu_{512}(n)$ and $Gv_{512}(n)$.

The $Gu_{512}$ and $Gv_{512}$ sequences are defined as

$$Gu_{512} = \left[-Gb_{128}\ -Ga_{128}\ Gb_{128}\ -Ga_{128}\right]$$

$$Gv_{512} = \left[-Gb_{128}\ Ga_{128}\ -Gb_{128}\ -Ga_{128}\right]$$

When the (#404)Data field of the (#14)PPDU is modulated using single carrier, the $Gu_{512}$ and $Gv_{512}$ fields are concatenated in the order illustrated in Figure 24-3 (Channel Estimation field for SC PPDUs(#14)).

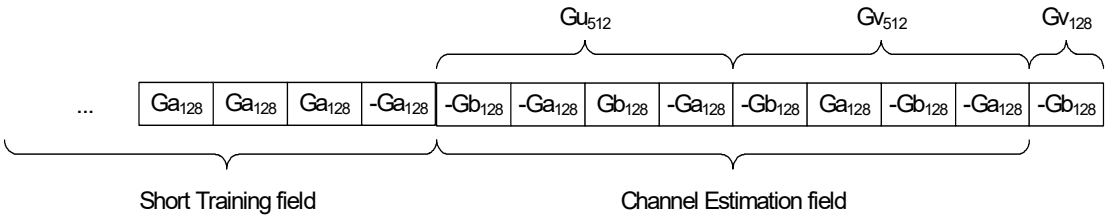


**Figure 24-3—Channel Estimation field for SC PPDUs(#14)**

The waveform for the channel estimation sequence is

$$r_{CE_{SC}}(nT_c) = (Gu_{512}(n) + Gv_{512}(n-512) + Gv_{128}(n-1024))\exp\left(j\pi\frac{n}{2}\right),\ n = 0, 1, \ldots, 1151$$

Note that sequences $Gu_{512}(n)$ and $Gv_{512}(n)$ are defined for $0 \le n \le 511$. For other values of $n$, $Gu_{512}(n)$ and $Gv_{512}(n)$ are set to 0.

### 24.3.7 HCS calculation for headers of CDMG control mode and CDMG SC mode

The description for HCS calculation for headers of CDMG control mode and CDMG SC mode is the same as that contained in 20.3.7 (HCS calculation for headers of DMG control mode and DMG SC mode).

### 24.3.8 Common LDPC parity matrices

The description for common LDPC parity matrices for CDMG PHY is the same as that contained in 20.3.8 (Common LDPC parity matrices).

### 24.3.9 Scrambler

The description for CDMG PHY scrambler is the same as that contained in 20.3.9 (Scrambler).

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### 24.3.10 Received channel power indicator (RCPI) measurement

The description for received channel power indicator (RCPI) measurement for CDMG PHY is the same as that contained in 20.3.10 (Received channel power indicator (RCPI) measurement).

## 24.4 CDMG control mode

### 24.4.1 Introduction

Transmission and reception of control mode PPDUs are mandatory. CDMG control mode uses the same chip rate as the CDMG SC mode. CDMG control mode is transmitted when the TXVECTOR indicates MCS 0.

The modulation and coding scheme for the CDMG control mode is shown in Table 24-5 (CDMG control mode modulation and coding scheme).

**Table 24-5—CDMG control mode modulation and coding scheme**

| MCS index | Modulation | Code rate | Data rate |
|---|---|---|---|
| 0 | DBPSK | 1/2[a] | 13.75 Mb/s[a] |

[a] Code rate and data rate might be lower due to codeword shortening.

### 24.4.2 PPDU format

(#3626)The CDMG control mode PPDU is shown in Figure 24-4 (CDMG control mode PPDU format).

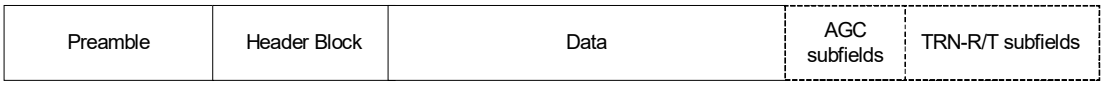


**Figure 24-4—CDMG control mode PPDU format**

### 24.4.3 Transmission

#### 24.4.3.1 Preamble

##### 24.4.3.1.1 General

The preamble is the part of the CDMG control mode PPDU that is used for (#14)PPDU detection, AGC, frequency offset estimation, synchronization, indication of (#14)PPDU type, and channel estimation.


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The preamble is composed of two parts as shown in Figure 24-5 (CDMG control mode preamble): the Short Training field and the Channel Estimation field.

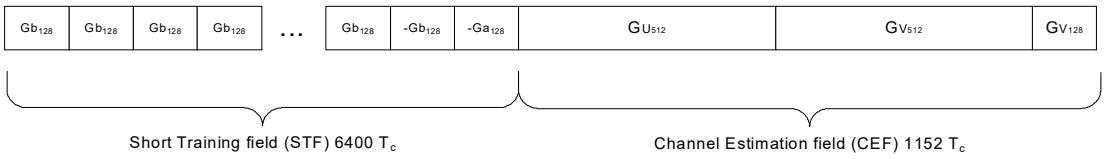


**Figure 24-5—CDMG control mode preamble**

#### 24.4.3.1.2 Short Training field

The Short Training field is composed of 48 repetitions of sequences $Gb_{128}(n)$ of length 128, followed by a single $-Gb_{128}(n)$ sequence (for synchronization) and then a single $-Ga_{128}(n)$ sequence. The sequences $Ga_{128}(n)$ and $Gb_{128}(n)$ are defined in 20.10 (Golay sequences).

The waveform for the Short Training field is

$$r_{STF}(nT_c) = \begin{cases} Gb_{128}(n \bmod 128)\exp\left(j\pi\frac{n}{2}\right), & n = 0, 1, \ldots, 48 \times 128 - 1 \\ -Gb_{128}(n \bmod 128)\exp\left(j\pi\frac{n}{2}\right), & n = 48 \times 128, \ldots, 49 \times 128 - 1 \\ -Ga_{128}(n \bmod 128)\exp\left(j\pi\frac{n}{2}\right), & n = 49 \times 128, \ldots, 50 \times 128 - 1 \end{cases}$$

Note that sequences $Ga_{128}(n)$ and $Gb_{128}(n)$ are defined for $0 \le n \le 127$. For other values of $n$, they are set to 0.

#### 24.4.3.1.3 Channel Estimation field

The Channel Estimation field is the same as the Channel Estimation field of the CDMG SC mode, as defined in Figure 24-3 (Channel Estimation field for SC PPDUs(#14)) of 24.3.6.3 (Channel estimation field).

### 24.4.3.2 Header

#### 24.4.3.2.1 General

In the CDMG control mode, the preamble is followed by the header block. The header consists of several fields that define the details of the PPDU to be transmitted.

The header fields are described in Table 24-6 (CDMG control mode header fields).

(#455)Reserved bits shall be set to 0 by the transmitter and shall be ignored by the receiver.

(#1647)All numeric fields are transmitted in unsigned format, LSB first.

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**Table 24-6—CDMG control mode header fields**

| Field name | Bit | Description |
|---|---|---|
| Differential Encoder Initialization | B0 | Used to initialize the differential encoding *c(0)* in 20.4.3.3.4 (Modulation). May be set to any value. |
| Scrambler Initialization | B1–B4 | Bits X1–X4 of the initial scrambler state (see 20.4.3.3.2 (Scrambler)). |
| Length | B5–B14 | Number of data octets in the PSDU.<br>Range 14–1023. |
| PPDU Type | B15 | As defined in Table 24-8 (CDMG SC mode header fields). |
| Training Length | B16–B20 | Length of the training field. The use of this field is defined in 24.9.2.2.3 (BRP PPDU Header field(#6409)). |
| Turnaround | B21 | Contains a copy of the parameter TURNAROUND from the TXVECTOR. |
| Robust PHY Mode Indication(#8102) | B22–B23 | — (#456)Set to 0: control mode.<br>— Set to 1: robust PHY mode 1.<br>— Set to 2: robust PHY mode 0.<br>The value 3 is reserved. |
| HCS | B24–B39 | Header check sequence. Calculation of the header check sequence is defined in 24.3.7 (HCS calculation for headers of CDMG control mode and CDMG SC mode). |

#### 24.4.3.2.2 Generation of HCS bits

The header check sequence (HCS) is calculated over bits 0–23 and uses CRC 16-CCITT as described in 24.3.7 (HCS calculation for headers of CDMG control mode and CDMG SC mode).

#### 24.4.3.2.3 Header encoding and modulation

The header bits followed by the HCS bits are prepended to the (#14)Data field bits and passed into the (#404)Data field encoder per 24.4.3.3 (Data field). The minimal payload length is 14 octets

### 24.4.3.3 Data field

The description for Data field for CDMG control mode is the same as that contained in 20.4.3.3 (Data field).

## 24.4.4 Performance requirements

### 24.4.4.1 Transmit requirements

#### 24.4.4.1.1 Introduction

Transmitter performance requirements of the CDMG control mode are defined in 24.4.4.1.2 (Transmit EVM).

#### 24.4.4.1.2 Transmit EVM

The description for transmit EVM for CDMG control mode is the same as that contained in 20.4.4.1.2 (Transmit EVM).


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#### 24.4.4.2 Receive requirements

##### 24.4.4.2.1 Introduction

This subclause describes the performance requirement from the CDMG control mode receiver.

##### 24.4.4.2.2 CCA

The start of a CDMG control mode transmission at a receive level greater than –71 dBm shall cause CCA to indicate busy with a probability > 90% within 3 μs.

## 24.5 CDMG SC mode

### 24.5.1 Introduction

Transmission and reception of CDMG SC mode PPDUs are mandatory for selected MCSs.

### 24.5.2 PPDU format

(#3626)An(#1424) SC (#14)PPDU is shown in Figure 24-6 (SC PPDU format(#14)).

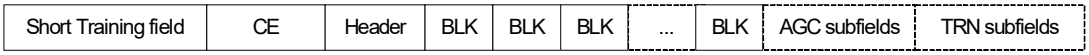


**Figure 24-6—SC PPDU format(#14)**

The robust PHY modes use the CDMG control mode with short spreading sequences for the data. (See Table 24-7 (CDMG robust PHY modes).) The following Golay complementary sequences Ga(8) and Ga(4) are used as spreading sequences for robust PHY mode 0 and 1, respectively.

Ga(8)=(+1, +1, +1, −1, +1, +1, −1, +1)

Ga(4)=(+1, +1, +1, −1)

**Table 24-7—CDMG robust PHY modes**

| CDMG-Robust mode | Modulation | Code rate | Spreading sequence | Data rate (Mb/s) |
|---|---|---|---|---|
| 0 | DBPSK | 1/2 | Ga(8) | 55 |
| 1 | DBPSK | 1/2 | Ga(4) | 110 |

### 24.5.3 Transmission

#### 24.5.3.1 Header

##### 24.5.3.1.1 General

In the CDMG SC mode, the preamble is followed by the header. The header consists of several fields that define the details of the PPDU to be transmitted. The encoding and modulation of the header are described in 24.5.3.1.4 (Header encoding and modulation).

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The header fields are described in Table 24-8 (CDMG SC mode header fields).

**Table 24-8—CDMG SC mode header fields**

| Field name | Number of bits | Start bit | Description |
|---|---|---|---|
| Scrambler Initialization | 7 | 0 | Bits X1–X7 of the initial scrambler state (see 20.3.9 (Scrambler)). |
| MCS | 6 | 7 | Modulation and coding scheme (see Table 24-9 (CDMG SC mode modulation and coding schemes)). |
| Length | 18 | 13 | Number of data octets in the PSDU. Range 1–262 143. |
| Additional PPDU | 1 | 31 | Contains a copy of the parameter ADD_PPDU from the TXVECTOR. A value of 1 indicates that this PPDU is immediately followed by another PPDU with no IFS or preamble on the subsequent PPDU. A value of 0 indicates that no additional PPDU follows this PPDU. |
| PPDU Type | 1 | 32 | Corresponds to the TXVECTOR parameter PPDU_TYPE.<br>— PPDU Type = 0 (BRP-RX PPDU, see 20.9.2.2.3 (BRP PPDU Header field(#6409))), indicates either a (#14)PPDU whose Data field is followed by one or more TRN subfields (when the Beam Tracking Request field is 0 or in CDMG control mode), or a PPDU that contains TRN subfields to be appended to a future response PPDU (when the Beam Tracking Request field is 1).<br>— PPDU Type = 1 (BRP-RX PPDU, see 20.9.2.2.3 (BRP PPDU Header field(#6409))), indicates a PPDU whose Data field is followed by one or more TRN subfields. The transmitter may change AWV at the beginning of each TRN subfield.<br>The field is reserved when the Training Length field is 0. |
| Training Length | 5 | 33 | Corresponds to the TXVECTOR parameter TRN_LEN.<br><br>If the Beam Tracking Request field is 0, the Training Length field indicates the length of the training field. The use of this field is defined in 24.9.2.2.3 (BRP PPDU Header field(#6409)). A value of 0 indicates that no training field is present in this PPDU.<br><br>If the Beam Tracking Request field is 1 and the PPDU Type field is 1, the Training Length field indicates the length of the training field appended to this PPDU. If the PPDU Type field is 0, the Training Length field indicates the length of the training field requested for receive training. |
| Aggregation | 1 | 38 | Set to 1 to indicate that the PPDU in the data portion of the packet contains an A-MPDU; otherwise, set to 0. |
| Beam Tracking Request | 1 | 39 | Corresponds to the TXVECTOR parameter BEAM_TRACKING_REQUEST.<br>Set to 1 to indicate the need for beam tracking (10.41.7 (Beam tracking)); otherwise, set to 0.<br>The Beam Tracking Request field is reserved when the Training Length field is 0. |


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**Table 24-8—CDMG SC mode header fields *(continued)***

| Field name | Number of bits | Start bit | Description |
|---|---|---|---|
| Last RSSI | 4 | 40 | Contains a copy of the parameter LAST_RSSI from the TXVECTOR.<br>The value is an unsigned integer:<br>Values of 2 to 14 represent power levels (–74+value×2) dBm.<br>A value of 15 represents a power greater than or equal to –45 dBm.<br>A value of 1 represents a power less than or equal to –71 dBm.<br>A value of 0 indicates that the previous (#14)PPDU was not received a SIFS(#320) before the current transmission. |
| Turnaround | 1 | 44 | As defined in Table 24-1 (TXVECTOR and RXVECTOR parameters). |
| Enhanced Beam Tracking Request | 1 | 45 | Corresponds to the TXVECTOR parameter ENHANCED_BEAM_TRACKING_REQUEST.<br>Set to 1 to indicate that one STF and CE field are appended to the Data and TRN fields.<br>Otherwise, set to 0. |
| Reserved | 2 | 46 | |
| HCS | 16 | 48 | Header check sequence. Definition of this field calculation is in 24.5.3.1.3 (Generation of the HCS bits). |

Reserved bits are set to 0 by the transmitter and shall be ignored by the receiver.

If the Additional PPDU field is equal to 1, the Training Length field shall be set to 0.

(#1647)All numeric fields are transmitted in unsigned format, LSB first.

#### 24.5.3.1.2 Modulation and coding scheme

The modulation and coding scheme (MCS) field specifies the modulation and code rate that is used in the PPDU. The modulation and coding schemes for the SC mode are defined in Table 24-9 (CDMG SC mode modulation and coding schemes).

**Table 24-9—CDMG SC mode modulation and coding schemes**

| MCS index | Modulation | $N_{CBPS}$ | Repetition | Code rate | Data rate (Mb/s) |
|---|---|---|---|---|---|
| 1 | π/2-BPSK | 1 | 2 | 1/2 | 192.5 |
| 2 | π/2-BPSK | 1 | 1 | 1/2 | 385 |
| 3 | π/2-BPSK | 1 | 1 | 5/8 | 481.25 |
| 4 | π/2-BPSK | 1 | 1 | 3/4 | 577.5 |
| 5 | π/2-BPSK | 1 | 1 | 13/16 | 625.625 |
| 6 | π/2-QPSK | 2 | 1 | 1/2 | 770 |
| 7 | π/2-QPSK | 2 | 1 | 5/8 | 962.5 |

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**Table 24-9—CDMG SC mode modulation and coding schemes *(continued)***

| MCS index | Modulation | $N_{CBPS}$ | Repetition | Code rate | Data rate (Mb/s) |
|---|---|---|---|---|---|
| 8 | π/2-QPSK | 2 | 1 | 3/4 | 1155 |
| 9 | π/2-QPSK | 2 | 1 | 13/16 | 1251.25 |
| 10 | π/2-16-QAM | 4 | 1 | 1/2 | 1540 |
| 11 | π/2-16-QAM | 4 | 1 | 5/8 | 1925 |
| 12 | π/2-16-QAM | 4 | 1 | 3/4 | 2310 |
| 13 | π/2-16-QAM | 4 | 1 | 13/16 | 2502.5 |
| 14 | π/2-64-QAM | 6 | 1 | 5/8 | 2887.5 |
| 15 | π/2-64-QAM | 6 | 1 | 3/4 | 3465 |
| 16 | π/2-64-QAM | 6 | 1 | 13/16 | 3453.75 |

Transmit and receive support for MCS 9 and below is mandatory. Other MCSs are optional.

#### 24.5.3.1.3 Generation of the HCS bits

Calculation of the HCS for bits 0–47 of the header is defined in 24.3.7 (HCS calculation for headers of CDMG control mode and CDMG SC mode).

#### 24.5.3.1.4 Header encoding and modulation

The description for header encoding and modulation for CDMG SC mode is the same as that contained in 20.5.3.1.4 (Header encoding and modulation).

### 24.5.3.2 The Data field

#### 24.5.3.2.1 General

The (#404)Data field consists of the payload data of the PSDU and possible padding. The data are padded with 0s(M118), scrambled, encoded, and modulated as described in the following subclauses. The amount of padding is defined in 24.5.3.2.3 (Encoding).

#### 24.5.3.2.2 Scrambler

The description for CDMG SC mode scrambler is the same as that contained in 20.5.3.2.2 (Scrambler).

#### 24.5.3.2.3 Encoding

The description for CDMG SC mode encoding is the same as that contained in 20.5.3.2.3 (Encoding).

#### 24.5.3.2.4 Modulation mapping

##### 24.5.3.2.4.1 General

The coded and padded bit stream is converted into a stream of complex constellation points according to the modulation specified in the MCS table.


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#### 24.5.3.2.4.2 π/2-BPSK modulation

The description for CDMG SC mode π/2-BPSK modulation is the same as that contained in 20.5.3.2.4.2 (π/2-BPSK modulation).

#### 24.5.3.2.4.3 π/2-QPSK modulation

The description for CDMG SC mode π/2-QPSK modulation is the same as that contained in 20.5.3.2.4.3 (π/2-QPSK modulation).

#### 24.5.3.2.4.4 π/2-16-QAM modulation

The description for CDMG SC mode π/2-16-QAM modulation is the same as that contained in 20.5.3.2.4.5 (π/2-16-QAM modulation).

#### 24.5.3.2.4.5 π/2-64-QAM modulation

In π/2-64-QAM modulation, the input bit stream is grouped into sets of 6 bits and mapped according to the following equation:

$$\tilde{s}(k) = \frac{1}{\sqrt{42}}((8c_{6k}-4)-(2c_{6k}-1)(4c_{6k+1}-2)+(2c_{6k}-1)(2c_{6k+1}-1)(2c_{6k+2}-1)) + j\frac{1}{\sqrt{42}}((8c_{6k+3}-4)-(2c_{6k+3}-1)(4c_{6k+4}-2)+(2c_{6k+3}-1)(2c_{6+4}-1)(2c_{6k+5}-1))$$

where $k$ is the output symbol index, $k = 0, 1, \ldots$. Each output symbol is then rotated according to the following equation:

$$s_k = s_k \cdot e^{j \cdot \pi \cdot k/2}$$

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The constellation bit encoding for 64-QAM is shown in Figure 24-7 (64-QAM constellation bit encoding).

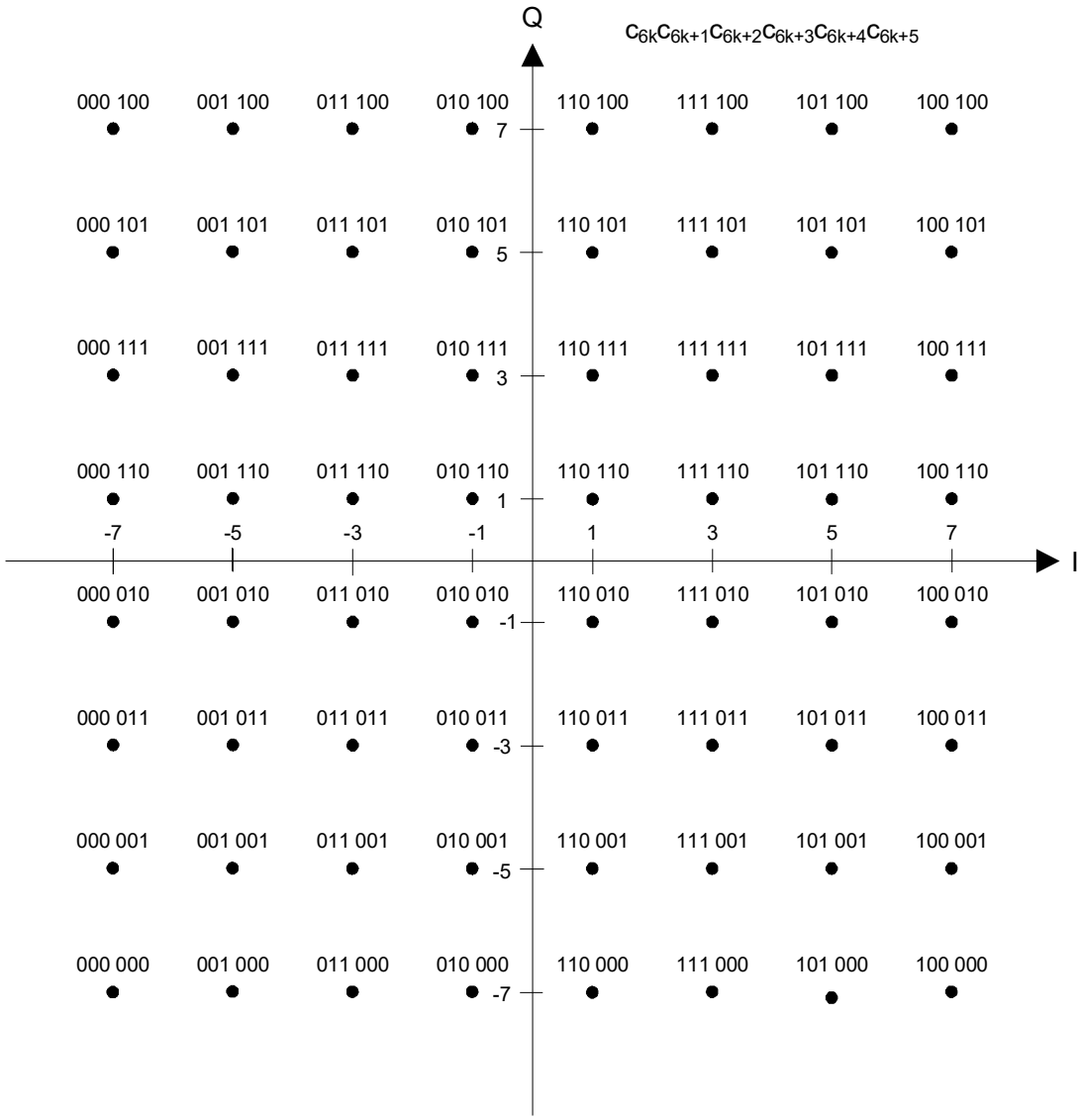


**Figure 24-7—64-QAM constellation bit encoding**

### 24.5.3.2.5 Symbol blocking and guard insertion

The description for CDMG SC mode symbol blocking and guard insertion is the same as that contained in 20.5.3.2.5 (Symbol blocking and guard insertion).


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### 24.5.4 Performance requirements

#### 24.5.4.1 Transmit requirements

##### 24.5.4.1.1 Transmit EVM

The transmit EVM accuracy test shall be performed by instrumentation capable of converting the transmitted signal into a stream of complex samples, with sufficient accuracy in terms of I/Q arm amplitude and phase balance, dc offsets, phase noise, etc.

The instrumentation shall perform carrier lock, symbol timing recovery, and amplitude adjustment while making the measurements. The equalizer shall be trained using information in the SC preamble (STF and/or CE field). For the CDMG SC mode EVM, measuring $N_s$ samples at the sample rate, the measured symbols should not contain the first and the last hundred symbols of a given (#14)PPDU (ramp up/down). The EVM is calculated according to the formula below: (#315)

$$EVM = 20\log 10\left(\sqrt{\left(\frac{1}{N_s P_{avg}}\sum_{i=1}^{N_S}[(I_i - I_i^* - I_0)^2 + (Q_i - Q_i^* - Q_0)^2]\right)}\right)$$

where

$N_s$ is the number of samples to be measured and $N_s$ should be 1000

$P_{avg}$ is the average power of the constellation

$(I_i, Q_i)$ is the complex coordinates of the measured symbol $i$

$(I_i^*, Q_i^*)$ is the complex coordinates of the ideal constellation point for the measured symbol $i$

$(I_0, Q_0)$ is the complex DC term chosen to reduce EVM

The test equipment should use a root-raised cosine filter with roll-off factor of 0.25 for the pulse shaping filter when conducting EVM measurement.

The transmit pulse shaping used is left to the implementer.

The relative constellation error (EVM) shall not exceed a MCS dependent value according to Table 24-10 (CDMG SC mode EVM requirements).

**Table 24-10—CDMG SC mode EVM requirements**

| MCS index | Modulation | Coding rate | EVM value (dB) |
|---|---|---|---|
| 1 | π/2-BPSK | 1/2 with repetition | –6 |
| 2 | π/2-BPSK | 1/2 | –7 |
| 3 | π/2-BPSK | 5/8 | –9 |
| 4 | π/2-BPSK | 3/4 | –10 |
| 5 | π/2-BPSK | 13/16 | –12 |
| 6 | π/2-QPSK | 1/2 | –11 |
| 7 | π/2-QPSK | 5/8 | –12 |

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**Table 24-10—CDMG SC mode EVM requirements *(continued)***

| MCS index | Modulation | Coding rate | EVM value (dB) |
|---|---|---|---|
| 8 | π/2-QPSK | 3/4 | –13 |
| 9 | π/2-QPSK | 13/16 | –15 |
| 10 | π/2-16-QAM | 1/2 | –19 |
| 11 | π/2-16-QAM | 5/8 | –20 |
| 12 | π/2-16-QAM | 3/4 | –21 |
| 13 | π/2-16-QAM | 13/16 | –23 |
| 14 | π/2-64-QAM | 5/8 | –25 |
| 15 | π/2-64-QAM | 3/4 | –26 |
| 16 | π/2-64-QAM | 13/16 | –28 |

#### 24.5.4.1.2 Time of departure accuracy

(#8053)The RMS accuracy of the time of departure provided in TIME_OF_DEPARTURE shall be less than or equal to 80 ns.

The Time of Departure accuracy test evaluates TIME_OF_DEPARTURE against aTxPHYTxStartRMS and aTxPHYTxStartRMS against TIME_OF_DEPARTURE_ACCURACY_TEST_THRESH as defined in Annex P with the following test parameters:

— MULTICHANNEL_SAMPLING_RATE is $880 \times 10^6$ sample/s.
— FIRST_TRANSITION_FIELD is Short Training field.
— SECOND_TRANSITION_FIELD is Channel Estimation field.
— TRAINING_FIELD is Channel Estimation field.
— TIME_OF_DEPARTURE_ACCURACY_TEST_THRESH is 80 ns.

NOTE—The indicated windowing applies to the time of departure accuracy test equipment, and not the transmitter or receiver.

### 24.5.4.2 Receive requirements

#### 24.5.4.2.1 Introduction

This subclause describes the receiver requirements of the CDMG SC mode.

#### 24.5.4.2.2 CCA sensitivity

The start of a CDMG SC mode transmission at a receive level greater than the minimum sensitivity for MCS 1 (–71 dBm) shall cause CCA to indicate busy with a probability > 90% within 1 μs. The receiver shall hold the carrier sense signal busy for any signal 20 dB above the minimum sensitivity for MCS 1.


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## 24.6 CDMG low-power SC mode

### 24.6.1 Introduction

The CDMG low-power SC mode is obsolete. Support for this mechanism might be removed in a later revision of the standard.

The CDMG low-power SC mode is an optional SC mode. This mode can provide lower processing power requirements for CDMG transceivers.

### 24.6.2 Transmission

#### 24.6.2.1 Preamble

The CDMG low-power SC mode uses the same preamble as the CDMG SC mode.

#### 24.6.2.2 Header

##### 24.6.2.2.1 General

The CDMG low-power SC mode header fields are the same fields as in the CDMG SC mode (see Table 24-8 (CDMG SC mode header fields) in 24.5.3.1 (Header)).

The CDMG low-power SC mode modulation and coding schemes are listed in Table 24-11 (CDMG low-power SC mode modulation and coding schemes).

**Table 24-11—CDMG low-power SC mode modulation and coding schemes**

| MCS | Modulation | Effective code rate | Coding scheme | $N_{CPB}$ | Rate (Mb/s) |
|---|---|---|---|---|---|
| 17 | π/2-BPSK | 13/28 | RS(224,208)+Block-Code(16,8) | 392 | 313 |
| 18 | π/2-BPSK | 13/21 | RS(224,208)+Block-Code(12,8) | 392 | 417 |
| 19 | π/2-BPSK | 52/63 | RS(224,208)+SPC(9,8) | 392 | 556 |
| 20 | π/2-QPSK | 13/28 | RS(224,208)+Block-Code(16,8) | 392 | 625.5 |
| 21 | π/2-QPSK | 13/21 | RS(224,208)+Block-Code(12,8) | 392 | 834 |
| 22 | π/2-QPSK | 52/63 | RS(224,208)+SPC(9,8) | 392 | 1112 |
| 23 | π/2-QPSK | 13/14 | RS(224,208)+Block-Code(8,8) | 392 | 1251.5 |

##### 24.6.2.2.2 Header encoding and modulation

The description for header encoding and modulation for CDMG low-power SC mode is the same as that contained in 20.6.2.2.2 (Header encoding and modulation).

#### 24.6.2.3 Data field

The description for CDMG SC mode Data field is the same as that contained in 20.6.2.3 (Data field).

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## 24.7 PHY transmit procedure

The PHY transmit procedure is shown in Figure 24-8 (Typical Tx state machine (Training Length=0 is assumed; some optional features such as CDMG SC low-power mode are not shown)). In order to transmit data, a PHY-TXSTART.request primitive shall be enabled so that the PHY entity shall be in the transmit state. Further, the PHY shall be set to operate at the appropriate frequency through station management via the PLME, as specified in 24.10 (CDMG PLME). Other transmit parameters, such as MCS and transmit power, are set via the PHY SAP with the PHY-TXSTART.request(TXVECTOR) primitive, as described in 24.2.2 (TXVECTOR and RXVECTOR parameters).

Transmission of the PHY preamble may start if TIME_OF_DEPARTURE_REQUESTED is false and shall start immediately if TIME_OFDEPARTURE_REQUESTED is true, based on the parameters passed in the PHY-TXSTART.request primitive.

The preamble format (control or SC mode) depends on the MCS in the PHY-TXSTART.request primitive. The PHY shall calculate the length of the (#14)PPDU according the MCS and the length specified in the PHY-TXSTART.request primitive, adding padding bits if necessary.

The PHY continues with the encoding and transmission of the header according to the parameters of the PHY-TXSTART.request(TXVECTOR) primitive. The PHY proceeds with PSDU transmission through a series of data octet transfers from the MAC. The data are encoded as described in 20.4.3.3.3 (Encoder), 20.5.3.2.3 (Encoding), and 20.6.2.3.3 (Encoding). The encoded data are then modulated as described in 24.4 (CDMG control mode), 24.5 (CDMG SC mode), and 24.6 (CDMG low-power SC mode), depending on the MCS requested in the PHY-TXSTART.request primitive. Transmission can be prematurely terminated by the MAC through the PHY-TXEND.request primitive. PHY-TXSTART shall be disabled by receiving a PHY-TXEND.request primitive.

Transmission of the PSDU is completed with the transmission of the last bits of the (encoded) PSDU. If no TRN units are specified in the PHY-TXSTART.request primitive, the PHY shall issue a PHY-TXEND primitive after the transmission of the last bits. If TRN units are requested in the PHY-TXSTART.request primitive, the transmission continues with the transmission of the AGC subfields and TRN units. The PHY issues the PHY-TXEND.confirm primitive to the MAC after the transmission of the last TRN unit. The (#14)PPDU transmission shall be completed, and the PHY entity shall enter the receive state (i.e., PHY-TXSTART shall be disabled). Each PHY-TXEND.request primitive is acknowledged with a PHY-TXEND.confirm primitive from the PHY.


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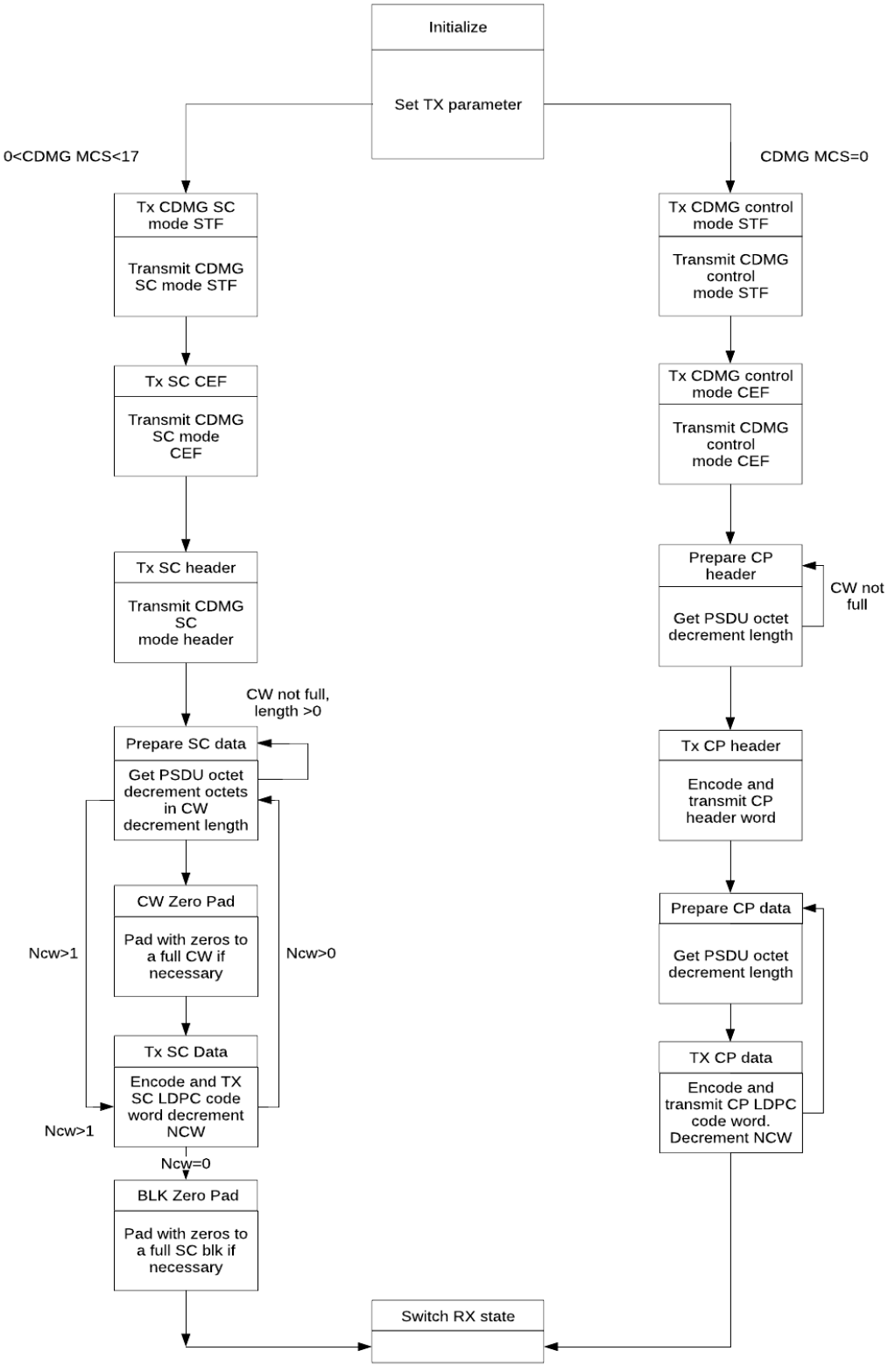


**Figure 24-8—Typical Tx state machine (Training Length=0 is assumed; some optional features such as CDMG SC low-power mode are not shown)**

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## 24.8 PHY receive procedure

A CDMG STA shall follow the DMG receive procedure defined in 20.8 (PHY receive procedure) when a DMG PPDU is detected on a 2.16 GHz channel.

The CDMG PHY receive procedure follows similar rules as descrived in 20.8 (PHY receive procedure).

## 24.9 Beamforming

### 24.9.1 Beamforming concept

The beamforming concept is the same as that contained in 20.9.1 (Beamforming concept).

### 24.9.2 Beamforming frame format

#### 24.9.2.1 Sector-level sweep

PPDUs transmitted during transmit sector sweep are CDMG control mode PPDUs. PPDUs transmitted during receive sector sweep are CDMG control mode or CDMG SC mode PPDUs.

#### 24.9.2.2 Beam refinement

##### 24.9.2.2.1 General

See 20.9.2.2.1 (General) for the general description of beam refinement.

In addition to DMG beam refinement features, enhanced beam tracking is a process that the CDMG STAs can use to improve their antenna configurations (or antenna weight vectors) both for transmission and reception and measure the backup channel performance of an alternative link via beam tracking. Once the current link has poor quality due to blockage or antenna rotation, the CDMG STAs can switch to an alternative link. Only if the alternative link has been set and enhanced beam tracking is enabled, can CDMG STAs perform enhanced beam tracking. The procedure of enhanced beam tracking is described in 10.41.9 (CDMG enhanced beam tracking).

In addition to TRN training sequences appended, CDMG enhanced beam tracking uses BRP-RX or BRP-TX PPDUs that have an STF and a CE field appended to them.

— BRP-RX PPDUs are PPDUs that have e-TRN-R/TRN-R training sequences following the Data field. These PPDUs with TRN-R sequences enable receiver antenna weight vector training, and these PPDUs with e-TRN-R sequences enable receiver antenna weight vector training and measuring one alternative link.

— BRP-TX PPDUs are PPDUs that have e-TRN-T/TRN-T training sequences following the Data field. The transmitting STA may change antenna configuration at the beginning of each sequence. The receiving STA performs measurements on these sequences and sends feedback to the STA that transmits the BRP-TX PPDU, including the measurement results of alternative link.

##### 24.9.2.2.2 BRP PPDU structure

(#6552)If the Enhanced Beam Tracking Request field in the PHY header is equal to:

— 0, each (#14)BRP PPDU structure is shown in Figure 20-20 (BRP PPDU structure).

— 1, each BRP PPDU structure is shown in Figure 24-9 (BRP PPDU structure (CDMA STAs)).


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The STF and CE fields at the end of the BRP PPDU have the same structure as those at the beginning of the PPDU as defined in 24.3.6 (Common preamble). The collection of the AGC field, TRN field, STF, and CE field at the end of BRP PPDU is termed an *e-TRN field*. The AGC fields and TRN fields are used to train the current link and the adjacent links of the current link during beam tracking process. The alternative link is a beam link with different propagation characteristic that cannot be measured accurately by the AGC field and the training field (TRN-R/T) that are used for measuring the adjacent beam links. The STF and the CE field at the end of BRP PPDU are used for measuring and training the alternative link of CDMG STAs during enhanced beam tracking (see 10.41.9 (CDMG enhanced beam tracking)). The BRP PPDU structure for CDMG STAs that perform enhanced beam tracking is shown in Figure 24-9 (BRP PPDU structure (CDMA STAs)).

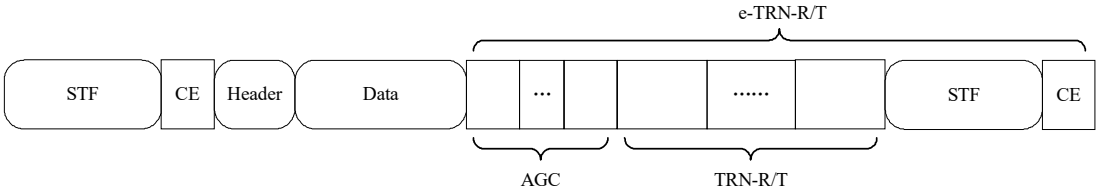


**Figure 24-9—BRP PPDU structure (CDMA STAs)**

### 24.9.2.2.3 BRP PPDU Header field(#6409)

The description for (#6409)BRP PPDU Header field is the same as that contained in 20.9.2.2.3 (BRP PPDU Header field(#6409)).

### 24.9.2.2.4 BRP PPDU duration

The minimum duration of the (#404)Data field of a BRP PPDU when sent in an SC mode is aBRPminSCblocks SC blocks (see 24.5.3.2.5 (Symbol blocking and guard insertion)), and, if needed, the (#404)Data field of the (#14)PPDU shall be extended by extra 0 padding to generate the required number of SC blocks. Table 24-12 (Zero filling for SC BRP PPDUs with MCSs 1 to 9) contains the values of $N_{CWmin}$ for MCSs 1 to 9 necessary to compute the padding described in 20.5.3.2.3.3 (LDPC encoding process).

**Table 24-12—Zero filling for SC BRP PPDUs with MCSs 1 to 9**

| MCS index | Modulation | $N_{CBPS}$ | Repetition | Code rate | Data rate (Mb/s) | $N_{CWmin}$ |
|---|---|---|---|---|---|---|
| 1 | π/2-BPSK | 1 | 2 | 1/2 | 192.5 | 12 |
| 2 | π/2-BPSK | 1 | 1 | 1/2 | 385 | 12 |
| 3 | π/2-BPSK | 1 | 1 | 5/8 | 481.25 | 12 |
| 4 | π/2-BPSK | 1 | 1 | 3/4 | 577.5 | 12 |
| 5 | π/2-BPSK | 1 | 1 | 13/16 | 625.625 | 12 |
| 6 | π/2-QPSK | 2 | 1 | 1/2 | 770 | 23 |
| 7 | π/2-QPSK | 2 | 1 | 5/8 | 962.5 | 23 |
| 8 | π/2-QPSK | 2 | 1 | 3/4 | 1155 | 23 |
| 9 | π/2-QPSK | 2 | 1 | 13/16 | 1251.25 | 23 |

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The minimum duration of the (#404)Data field of a BRP PPDU when sent with the low-power SC mode is $N_{BLK\_MIN}$ low-power SC blocks (see 20.6.2.3.3 (Encoding)).

#### 24.9.2.2.5 AGC field

(#14)The AGC fields in the BRP PPDU are composed of 4*N* repetitions of the sequence [$Ga_{64}$ $Ga_{64}$ $Ga_{64}$ $Ga_{64}$ $Ga_{64}$] when the PPDU is transmitted using the SC mode and [$Gb_{64}$ $Gb_{64}$ $Gb_{64}$ $Gb_{64}$ $Gb_{64}$] when the PPDU is transmitted using the control mode. The sequences Ga64 and Gb64 are defined in 20.10 (Golay sequences). The sequences are transmitted using rotated π/2-BPSK modulation.

In a BRP-TX PPDU, the transmitter may change the TX AWV configuration at the beginning of each AGC field. Any transmit signal transients that occur due to this TX AWV configuration change shall completely settle by the end of the first Ga64 or Gb64 subsequence. The set of AWVs used for the AGC subfields should be the same as that used for the TRN-T fields. In a BRP-RX PPDU, the transmitter shall use the same TX AWV as in the preamble and (#404)Data fields of the (#14)PPDU.

#### 24.9.2.2.6 TRN field

The description for TRN field is the same as that contained in 20.9.2.2.6 (TRN field).

#### 24.9.2.2.7 Channel measurement

The description for channel measurement is the same as that contained in 20.9.2.2.7 (Channel measurement).

## 24.10 CDMG PLME

### 24.10.1 PLME SAP layer management primitives(#6320)

Table 24-13 (CDMG PHY MIB attribute default values) lists the MIB attributes that may be accessed by the PHY entities and the intra-layer of higher level LMEs. These attributes are accessed via the PLME-GET, PLME-SET, PLME-RESET, and PLME-CHARACTERISTICS primitives defined in 6.7 (PLME SAP interface).

### 24.10.2 CDMG PHY MIB

All CDMG PHY MIB attributes are defined in Annex C, with specific values defined in Table 24-13 (CDMG PHY MIB attribute default values). The column titled “Operational semantics” in Table 24-13 (CDMG PHY MIB attribute default values) contains two types: static and dynamic. Static MIB attributes are fixed and cannot be modified for a given PHY implementation. Dynamic MIB attributes can be modified by some management entity.

When MAX-ACCESS is read-only, the MIB attribute value may be updated by the PLME and read from the MIB attribute by management entities. When MAX-ACCESS is read-write, the MIB attribute may be read and written by management entities but shall not be updated by the PLME.


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**Table 24-13—CDMG PHY MIB attribute default values**

| Managed object | Default value/range | Operational semantics |
|---|---|---|
| **dot11PHYOperationTable** | | |
| dot11PHYType | cdmg(12) | Static |
| **dot11PHYCDMGTable** | | |
| dot11LowPowerSCPHYImplemented | Boolean | Static |
| dot11LowPowerSCPHYActivated | Boolean | Dynamic |

### 24.10.3 TXTIME calculation

The value of the TXTIME parameter returned by the PLME-TXTIME.confirm primitive shall be calculated according to the following equations.

For the CDMG SC PHY ($N_{TRN}$ is Training Length field defined in the header; see, for example, Table 24-8 (CDMG SC mode header fields)):

$$TXTIME = \begin{cases} T_{STF} + T_{CE} + T_{header} + T_{Data} & N_{TRN} = 0 \\ T_{STF} + T_{CE} + T_{header} + \max\{T_{Data}, (\alpha \times \beta + \gamma) \times T_C\} + N_{TRN} \times T_{TRN-Unit} & N_{TRN} > 0 \text{ and SC} \end{cases}$$

where

$\alpha$ = aBRPminSCblocks
$\beta$ = aSCBlockSize
$\gamma$ = aSCGILength
$T_{TRN-Unit}$ = aBRPTRNBlock $\times$ $T_C$

For the CDMG control PHY:

$$TXTIME = T_{STF-CP} + T_{CE-CP} + (11 \times 8 + (Length - 6) \times 8 + N_{CW} \times 168) \times T_C \times 32 + N_{TRN} \times T_{TRN-Unit}$$

where $N_{CW}$ calculation is defined in 20.4.3.3.3 (Encoder).

### 24.10.4 PHY characteristics

(#2123)The CDMG PHY characteristics, provided through the PLME-CHARACTERISTICS service primitive, are shown in Table 24-14 (CDMG PHY characteristics). The definitions for these characteristics are given in 6.7.4 (PLME-CHARACTERISTICS.confirm).

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**Table 24-14—CDMG PHY characteristics**

| PHY parameter | Value |
|---|---|
| aPPDUMaxTime | 4 ms |
| aPSDUMaxLength | 262 143 octets |


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# 25. China millimeter-wave multi-gigabit (CMMG) PHY specification

## 25.1 Introduction

### 25.1.1 Introduction to CMMG PHY

Clause 25 (China millimeter-wave multi-gigabit (CMMG) PHY specification) specifies the PHY entities for China millimeter-wave multi-gigabit (CMMG) single carrier (SC) and orthogonal frequency division multiplexing (OFDM) systems.

The maximum number of space-time streams supported in CMMG SC and OFDM system is four.

The CMMG PHY provides support for 540 MHz and 1080 MHz channel widths.

The CMMG PHY data are modulated using binary phase shift keying (BPSK), quadrature phase shift keying (QPSK), 16-quadrature amplitude modulation (16-QAM), and 64-QAM. Forward error correction (FEC) coding (LDPC coding) is used with coding rates of 1/2, 3/4, 5/8, and 13/16.

A CMMG STA shall support the following features:

- 540 MHz channel width
- (#7168)CMMG control mode and (#7168)CMMG SC mode (directional transmit and receive)
- Single spatial stream MCS 0 ((#7168)CMMG control mode transmit and receive) in all supported channel widths
- Single spatial stream MCSs 1 to 3 ((#7168)CMMG SC mode transmit and receive) in all supported channel widths
- LDPC coding with length 672
- Normal guard interval as defined in Table 25-3 (Timing-related parameters(#7171)(M118))

A CMMG STA may support the following features:

- Support for 1080 MHz channel width
- CMMG-MCSs 4 to 8 ((#7168)CMMG SC mode transmit and receive)
- CMMG-MCSs 9 to 16 ((#7168)CMMG OFDM mode transmit and receive)
- Two or more spatial streams (transmit and receive)
- Short guard interval (transmit and receive)
- LDPC coding with length 2016
- Support MIMO transmission (#7168)CMMG SC mode and CMMG OFDM mode with omnidirectional antenna pattern or quasi-omni antenna pattern transceiver)
- STBC (transmit and receive)
- Transmit beamforming sounding (by sending a CMMG NDP)
- Responding to transmit beamforming sounding

NOTE—MIMO transmission only applies in the case where the antenna pattern is the omnidirectional antenna pattern or quasi-omni antenna pattern.

### 25.1.2 Scope of CMMG PHY services

The CMMG PHY supports three modulation methods:

- A control modulation using MCS 0 (the CMMG control mode; see 25.4 (CMMG control mode))

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— A single carrier (SC) modulation using MCS 1 to MCS 8 (the CMMG SC mode; see 25.5 (CMMG SC mode))
— An OFDM modulation using MCS 9 to MCS 16 (the CMMG OFDM mode; see 25.6 (CMMG OFDM mode))

All these modulation methods share a common preamble (see 25.3.5 (CMMG PHY preamble)).

The services provided to the MAC by the CMMG PHY consist of the following protocol functions:

a) A function that defines a method of mapping the PSDUs into a (#14)PPDU format suitable for sending and receiving PSDUs between two or more STAs.
b) A function that defines the characteristics and method of transmitting and receiving data through a wireless medium between two or more STAs. Depending on the PPDU format, these STAs support a mixture of CMMG control mode, CMMG SC mode, and CMMG OFDM mode.

### 25.1.3 CMMG PHY functions

#### 25.1.3.1 General

The CMMG PHY contains two functional entities: the PHY function and the physical layer management function (PLME). Each of these functions is described in detail in 25.4 (CMMG control mode) (for CMMG control mode), 25.5 (CMMG SC mode) (for CMMG SC mode), 25.6 (CMMG OFDM mode) (for CMMG OFDM mode), and 25.14 (CMMG PLME) (for CMMG PLME). The CMMG PHY service is provided to the MAC through the PHY service primitives defined in Clause 6 (Layer management).

#### 25.1.3.2 PHY management entity (PLME)

The PLME performs management of the local PHY functions in conjunction with the MLME.

#### 25.1.3.3 Service specification method

The models represented by figures and state diagrams are intended to be illustrations of the functions provided. It is important to distinguish between a model and a real implementation. The models are optimized for simplicity and clarity of presentation; the actual method of implementation is left to the discretion of the CMMG PHY compliant developer. The service of a layer or sublayer is the set of capabilities that it offers to a user in the next higher layer (or sublayer). Abstract services are specified here by describing the service primitives and parameters that characterize each service. This definition is independent of any particular implementation.

#### 25.1.3.4 PPDU formats

The structure of the PPDU transmitted by a CMMG STA is determined by the TXVECTOR parameters as defined in Table 25-1 (TXVECTOR and RXVECTOR parameters).

A CMMG PPDU can be further categorized as a CMMG control mode PPDU, a CMMG SC mode PPDU, or a CMMG OFDM mode PPDU.

## 25.2 CMMG PHY service interface

### 25.2.1 Introduction

The PHY provides an interface to the MAC through an extension of the generic PHY service interface defined in 8.3.4. The interface includes TXVECTOR, RXVECTOR, and PHYCONFIG_VECTOR.


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The TXVECTOR supplies the PHY with per-PPDU transmit parameters. Using the RXVECTOR, the PHY informs the MAC of the received (#14)PPDU's parameters. Using the PHYCONFIG_VECTOR, the MAC configures the PHY for operation, independent of (#14)PPDU transmission or reception.

### 25.2.2 TXVECTOR and RXVECTOR parameters

The parameters in Table 25-1 (TXVECTOR and RXVECTOR parameters) are defined as part of the TXVECTOR parameter list in the PHYTXSTART.request primitive and/or as part of the RXVECTOR parameter list in the PHYRXSTART.indication primitive.

**Table 25-1—TXVECTOR and RXVECTOR parameters**

| Parameter | Value | TXVECTOR | RXVECTOR |
|---|---|---|---|
| MCS | The MCS parameter(#1878) indicates the modulation and coding scheme used in the transmission of the packet. Values are integers in the range from 0 to 31.<br>— An MCS value of 0 indicates the use of (#7168)CMMG control mode.<br>— MCS values of 1 to 8 indicate use of single carrier modulations. The value is an index to Table 25-38 (CMMG SC MCSs for mandatory 540 MHz, Nss=1) to Table 25-45 (CMMG SC MCSs for optional 1080 MHz, Nss=4 (Optional)).<br>— MCS values of 9 to 16 indicates use of OFDM modulations. The value is an index to Table 25-46 (CMMG OFDM MCSs for optional 540 MHz, Nss=1 (Optional)) to Table 25-53 (CMMG OFDM MCSs for optional 1080 MHz, Nss=4 (Optional)). | Y | Y |
| LENGTH | Indicates the number of octets in the PSDU in the range from 0 to 262 143. A value of zero indicates a (#14)PPDU in which no Data field follows the SIG. | Y | Y |
| N_TX | Indicates the number of transmit chains. | Y | N |
| NSS | Indicates the number of spatial streams. | Y | N |
| EXPANSION_MAT | If PPDU transmission mode is (#7168)CMMG OFDM mode, contains a set of compressed beamforming feedback matrices as defined in 25.6.8.13.2 (Compressed Beamforming feedback matrix). The number of elements depends on the number of spatial streams and the number of transmit chains. Otherwise, not present. | Y | N |
| CHAN_MAT | If PSDU LENGTH equals 0, contains a set of compressed beamforming feedback matrices as defined in 25.6.8.13.2 (Compressed Beamforming feedback matrix) based on the channel measured during the training symbols of the received PPDU. The number of elements depends on the number of spatial streams and the number of transmit chains. Otherwise, not present. | N | Y |
| ADD_PPDU | Enumerated type:<br>— ADD-PPDU indicates that this PPDU is immediately followed by another PPDU with no IFS or preamble on the subsequent PPDU.<br>— NO-ADD-PPDU indicates no additional PPDU follows this PPDU. | Y | Y |

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**Table 25-1—TXVECTOR and RXVECTOR parameters *(continued)***

| Parameter | Value | TXVECTOR | RXVECTOR |
|---|---|---|---|
| AGGREGATION | Indicates whether the PSDU contains an A-MPDU.<br>Enumerated type:<br>— AGGREGATED indicates this is a packet with A-MPDU aggregation.<br>— NOT_AGGREGATED indicates this is a packet without A-MPDU aggregation. | Y | Y |
| RSSI | The allowed values for the RSSI parameter are in the range from 0 to 255. This parameter is a (#1132)measurement by the PHY of the power observed at the antennas used to receive the current PPDU. RSSI shall be measured during the reception of the PHY preamble. RSSI is intended to be used in a relative manner, and it shall be a monotonically increasing function of the received power. | N | Y |
| REC_MCS | Indicates the MCS that the STA's receiver recommends. | N | O |
| SNR | Contains an array of received SNR measurements for each spatial stream. SNR indications of 8 bits are supported. SNR shall be the sum of the decibel values of SNR per tone divided by the number of tones represented in each stream as described in 9.4.1.47 (VHT Compressed Beamforming Report field). | N | Y |
| STBC | Indicates whether STBC is used.<br>0 indicates no STBC (NSTS=NSS in the Data field).<br>1 indicates STBC is used (NSTS=2NSS in the Data field).<br>This parameter is 0 for a CMMG OFDM MU PPDU. | Y | Y |
| RCPI | Is a measure of the received RF power measured over the preamble of a received frame. Refer to 20.3.10 (Received channel power indicator (RCPI) measurement) for the definition of RCPI. | N | Y |
| TXOP_PS_NOT_ALLOWED | Indicates whether a CMMG AP allows non-AP CMMG STAs in TXOP power save mode to enter doze state during the TXOP.<br>0 indicates that the CMMG AP allows non-AP CMMG STAs to enter doze state during a TXOP.<br>1 indicates that the CMMG AP does not allow non-AP CMMG STAs to enter doze state during a TXOP. | Y | Y |
| PARTIAL_AID | Provides an abbreviated indication of the intended recipient(s) of the PSDU (see 10.19 (Group ID and partial AID in VHT and CMMG PPDUs)).<br>Integer: range from 0 to 511 if UPLINK_INDICATION is 1, and range from 0 to 63 if UPLINK_INDICATION is 0. | Y | Y |
| UPLINK_INDICATION | Set to 1 if the CMMG PPDU is addressed to AP.<br>Set to 0 otherwise (see 10.19 (Group ID and partial AID in VHT and CMMG PPDUs)). | Y | Y |
| COLOR | If UPLINK_INDICATION is 0, set to a value of its choosing within the range from 0 to 7 and shall maintain that value for the duration of the existence of the BSS.<br>Otherwise, not present (see 10.19 (Group ID and partial AID in VHT and CMMG PPDUs)). | Y | Y |


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**Table 25-1—TXVECTOR and RXVECTOR parameters *(continued)***

| Parameter | Value | TXVECTOR | RXVECTOR |
|---|---|---|---|
| CH_BANDWIDTH | Indicates the channel width of the transmitted PPDU:<br>Enumerated type:<br>— CBW540 for 540 MHz<br>— CBW1080 for 1080 MHz | Y | Y |
| DUPLICATE_MODULATION | In TXVECTOR, indicates the PPDU transmitted with CMMG duplicate format.<br>In RXVECTOR, indicates the estimated PPDU transmitted with CMMG duplicate format;<br>— Present if CH_BANDWIDTH equals CBW1080 and the PPDU is transmitted with duplicate format.<br>— Otherwise not present. | O | O |
| DYN_BANDWIDTH | (#1782)In TXVECTOR, if present, indicates whether the transmitter is capable of dynamic bandwidth operation as an RTS originator.<br>In RXVECTOR, if valid, indicates whether the transmitter is capable of dynamic bandwidth operation as an RTS originator (see 10.3.2.9 (CTS and DMG CTS procedure)).<br><br>Enumerated type:<br>— Static if the transmitter is only capable of static bandwidth operation.<br>— Dynamic if the transmitter is capable of dynamic bandwidth operation.<br><br>NOTE—In the RXVECTOR, the validity of this parameter is determined by the MAC based on the contents of the received MPDU. | O | Y |
| BEAMFORMED | Set to 1 if a beamforming steering matrix is applied to the waveform in a CMMG OFDM mode transmission as described in 19.3.11.11.2 (Spatial mapping).<br>Set to 0 otherwise.<br><br>NOTE—When BEAMFORMED is equal to 1, smoothing is not recommended. | Y | O |
| TIME_OF_DEPARTURE_REQUESTED | Enumerated type:<br>— true indicates that the MAC entity requests that the PHY entity measure and report time of departure parameters corresponding to the time when the first frame energy is sent by the transmitting port.<br>— false indicates that the MAC entity requests that the PHY entity neither measure nor report time of departure parameters. | O | N |
| RX_START_OF_FRAME_OFFSET | 0 to $2^{32}$–1. An estimate of the offset (in 100 ps(#7198) units) from the point in time at which the start of the preamble (#14)of the PPDU arrived at the receive antenna port to the point in time at which this primitive is issued to the MAC. | N | Y |
| PPDU_TYPE | Enumerated type:<br>— TRN-R indicates either a PPDU whose Data field is followed by one or more TRN-R subfields, or a PPDU that is requesting TRN-R subfields to be appended to a future response PPDU.<br>— TRN-T indicates a PPDU whose Data field is followed by one or more TRN-T subfields.<br>This parameter(#1878) is reserved if TRN_LEN is 0. | Y | Y |

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**Table 25-1—TXVECTOR and RXVECTOR parameters *(continued)***

| Parameter | Value | TXVECTOR | RXVECTOR |
|---|---|---|---|
| BEAM_TRACKING_REQUEST | This parameter indicates whether beam tracking is requested.<br>Enumerated type:<br>— BEAM-TRACKING-REQUESTED or BEAM-TRACKING-NOT-REQUESTED. | Y | Y |
| LAST_RSSI | In the TXVECTOR, LAST_RSSI indicates the received power level of the last PPDU(#3243) with a valid PHY SIG that was received (#319)(#320)a SIFS before transmission of the current packet; otherwise, it is set to 0(#464) (see 10.3.2.3.3 (SIFS)).<br>In the RXVECTOR, LAST_RSSI indicates the value of the LAST_RSSI field from the (#1879)header of the received PPDU(#3243). Valid values are integers in the range from 0 to 15:<br>— Values of 2 to 14 represent power levels (–71+value×2) dBm.<br>— A value of 15 represents power greater than or equal to –42 dBm.<br>— A value of 1 represents power less than or equal to –68 dBm.<br>— A value of 0 indicates that the previous packet was not received (#319)(#320)a SIFS before the current transmission. | Y | Y |
| SPREADING_FACTOR | Indicates the spreading factor used in the (#7168)CMMG control mode:<br>— 0 indicates that the spread factor is 13.<br>— 1 indicates that the spread factor is 7.<br>— 2 indicates that the spread factor is 4.<br>— 3 indicates no spreading. | | |
| Turnaround | Set to 1 or 0 as specified in 10.3.2.3.3 (SIFS). | Y | Y |
| NOTE—In the TXVECTOR and RXVECTOR columns, the following apply:<br>Y = Present<br>N = Not present<br>O = Optional | | | |

## 25.3 Common parameters

### 25.3.1 Introduction

This subclause introduces some common parameters.

### 25.3.2 Common requirements

#### 25.3.2.1 Introduction

This subclause describes the common requirements from all 3 modes: control, SC, and OFDM.

#### 25.3.2.2 Transmit RF delay

The transmit RF delay is defined in 17.3.8.6 (Slot time), and its value is implementation dependent.


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#### 25.3.2.3 Center frequency tolerance

##### 25.3.2.3.1 General

The transmitter center frequency tolerance shall be ± 20 ppm.

##### 25.3.2.3.2 Center frequency convergence

The transmitter center frequency shall converge to within 1 ppm of its final value within 2.5 μs from the start of the (#14)PPDU.

##### 25.3.2.3.3 Symbol clock tolerance

The symbol clock frequency tolerance shall be ± 20 ppm.

The transmit center frequency and the symbol clock frequency shall be derived from the same reference oscillator.

##### 25.3.2.3.4 Transmit rampup and rampdown

The transmit power-on ramp is defined as the time it takes for a transmitter to rise from less than 10% to greater than 90% of the average power to be transmitted in the frame.

The transmit power-on ramp shall be less than 30 ns.

The transmit power-down ramp is defined as the time it takes the transmitter to fall from greater than 90% to less than 10% of the maximum power to be transmitted in the frame.

The transmit power-down ramp shall be less than 30 ns.

##### 25.3.2.3.5 Maximum input requirement

The receiver maximum input level is the maximum power level at the receive antenna(s) of the incoming signal, in dBm, present at the input of the receiver antenna for which the error rate criterion (defined in 25.3.2.3.6 (Receive sensitivity)) is met. A compliant receiver shall have a receiver maximum input level at the receive antenna(s) of at least 10 $\mu W/cm^2$ for each of the modulation formats that the receiver supports.

##### 25.3.2.3.6 Receive sensitivity

The (#14)PER shall be less than 10% for a PSDU length of 4096 octets with the rate-dependent input levels listed in Table 25-2 (Receiver sensitivity in dBm(#7171)).

**Table 25-2—Receiver sensitivity in dBm(#7171)**

| MCS Index | 540 MHz | 1080 MHz |
|---|---|---|
| 0 | –81 | –78 (see NOTE)(#4050) |
| 1 | –74 | –71 |
| 2 | –69 | –66 |
| 3 | –67 | –64 |
| 4 | –61 | –58 |

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**Table 25-2—Receiver sensitivity in dBm(#7171) *(continued)***

| MCS Index | 540 MHz | 1080 MHz |
|---|---|---|
| 5 | –59 | –56 |
| 6 | –55 | –52 |
| 7 | –53 | –50 |
| 8 | –51 | –48 |
| 9 | –74 | –71 |
| 10 | –69 | –66 |
| 11 | –66 | –63 |
| 12 | –64 | –61 |
| 13 | –60 | –57 |
| 14 | –57 | –54 |
| 15 | –55 | –52 |
| 16 | –53 | –50 |
| NOTE—The sensitivity is for the largest spreading factor for MCS 0. | | |

### 25.3.3 Timing-related parameters(M118)

Table 25-3 (Timing-related parameters(#7171)(M118)) defines the timing-related parameters for CMMG format.

**Table 25-3—Timing-related parameters(#7171)(M118)**

| Parameter | CBW540 | CBW1080 | Description |
|---|---|---|---|
| $N_{SD}$ | 168 | 336 | Number of complex data numbers per OFDM symbol |
| $N_{SP}$ | 8 | 16 | Number of pilot subcarriers per OFDM symbol |
| $N_{DC}$ | 3 | 3 | Number of DC subcarriers per OFDM symbol |
| $N_{ST}$ | 179 | 355 | Total number of subcarriers per OFDM symbol |
| $N_{SR}$ | 89 | 177 | Highest data subcarrier index per OFDM symbol |
| $F_S$ | 660 MHz | 1320 MHz | OFDM sample rate |
| $T_S$ | $1/F_S$ (~1.515 ns) | $1/F_S$ (~0.758 ns) | OFDM sample time |
| $F_C$ | 440 MHz = 2/3 $F_S$ | 880 MHz = 2/3 $F_S$ | SC chip rate |
| $T_C$ | $1/F_C$ (~2.273 ns) | $1/F_C$ (~1.136 ns) | SC chip time |
| $N_{DFT}$ | 256 | 512 | DFT length |


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**Table 25-3—Timing-related parameters(#7171)(M118) *(continued)***

| Parameter | CBW540 | CBW1080 | Description |
|---|---|---|---|
| $\Delta_F$ | $F_S / N_{DFT}$ = 2.578125 MHz | | Subcarrier frequency spacing |
| $T_{DFT}$ | $N_{DFT} \times T_S$ (~387.879 ns) | | IDFT/DFT period |
| $T_{GI}$ | $T_{DFT}/4$ (~96.97 ns) | | Guard interval duration |
| $T_{GIS}$ | $T_{DFT}/8$ (~48.485 ns) | | Short guard interval duration |
| $T_{SYML}$ | $T_{DFT} + T_{GI} = 1.25T_{DFT}$ (~484.8 ns) | | Long GI symbol interval |
| $T_{SYMS}$ | $T_{DFT} + T_{GIS} = 1.125T_{DFT}$ (~436.4 ns) | | Short GI symbol interval |
| $T_{SYM}$ | $T_{SYML}$ or $T_{SYMS}$ depending on the GI used | | Symbol interval |
| $T_{seq}$ | 256 $T_C$ (~581.8 ns) | | ZCZ block duration (see NOTE)(#6037) |
| $T_{CSTF}$ | 50 × 32 × $T_C$ (~3636.8 ns)(#6037) | | Short training field duration for CMMG control mode (see NOTE)(#6037) |
| $T_{STF}$ | 17 × 32 × $T_C$ (~1236.5 ns)(#6037) | | Short training field duration for CMMG SC/OFDM mode (see NOTE)(#6037) |
| $T_{CEF}$ | 4 $T_{seq}$ (~2327.3 ns) | | Channel estimation field duration for CMMG control/SC/ OFDM mode (see NOTE)(#6037) |
| $T_{SIG}$ | 1024 × 13 × $T_C$ (~30258.2 ns)(#6037) | | SIG field duration for CMMG control mode (see NOTE)(#6037) |
| | 4 × (254 + 64) × $T_C$ (~2909.4 ns)(#6037) | | SIG field duration for CMMG SC mode (see NOTE)(#6037) |
| | 4 $T_{SYML}$ (~1939.2 ns)(#6037) | | SIG field duration for CMMG OFDM mode (see NOTE)(#6037) |
| $T_{OSTF}$ | $T_{SYML}$ (~484.8 ns) | | Duration of each OSTF |
| $T_{OCEF}$ | $T_{SYML}$ (~484.8 ns) | | Duration of each OCEF |

(#7171)(#6037)NOTE—Since the construction of the STF, CEF, and SIG field for transmissions over 1080 MHz are based on duplication transmission of the STF, CEF, and SIG field for transmissions over 540 MHz (see 25.3.10 (CMMG duplication transmission on a 1080 MHz channel)), the durations of the STF, CEF, and SIG field for CBW1080 are equivalent to those for CBW540. The durations of the STF and CEF for CMMG control mode, CMMG SC mode, and the durations of the SIG field for CMMG control mode and CMMG SC mode are calculated based on the SC chip time for 540 MHz transmission. The durations of the CMMG OFDM mode SIG field, the CMMG OFDM mode STF (OSTF), and the CMMG OFDM mode CEF (OCEF) are calculated based on the OFDM symbol time for 540 MHz transmission.

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Table 25-4 (Frequently used parameters) defines parameters used frequently in Clause 25 (China millimeter-wave multi-gigabit (CMMG) PHY specification).

**Table 25-4—Frequently used parameters**

| Symbol | Explanation |
|---|---|
| $N_{BL}$ | Number of the data blocks for SC transmission. |
| $N_{CBPB}$ | Number of coded bits per block. |
| $N_{CBPS}$ | For OFDM transmission: Number of coded bits per OFDM symbol.<br>For SC transmission: Number of coded bits per constellation symbol. |
| $N_{CBPSS}$ | Number of coded bits per symbol per spatial stream. |
| $N_{DBPS}$ | Number of data bits per symbol. |
| $N_{DSPB}$ | Number of data constellation symbols per block for SC transmission. |
| $N_{UWPB}$ | Length of the UW in each block for SC transmission. |
| $N_{BLS} = N_{DSPB} + N_{UWPB}$ | Number of the symbols in each block for SC transmission. |
| $N_{BPSCS}$ | Number of coded bits per subcarrier per spatial stream. |
| $N_{RX}$ | Number of receive chains. |
| $N_{STS}$ | For pre-CMMG modulated fields, $N_{STS} = 1$(see NOTE).<br>For CMMG modulated fields, $N_{STS}$ is the number of space-time streams. |
| $N_{OCEF}$ | Number of OCEF symbols 25.6.7 (OCEF definition). |
| $N_{SS}$ | Number of spatial streams. |
| $N_{TX}$ | Number of transmit chains. |
| $R$ | $R$ is the coding rate. |

NOTE—Pre-CMMG modulated fields refer to the STF, CEF, and CMMG SIG field, while CMMG modulated fields refer to the OCEF and Data field (see Figure 25-1 (PPDU structure for the CMMG SC mode PPDU with CBW540(#7168)(#7171)(#14)), Figure 25-2 (PPDU structure for the CMMG SC mode PPDU with CBW1080(#7168)(#7171)(#14)), and Figure 25-3 (PPDU structure for the CMMG OFDM mode PPDU(#7168)(#14))).

### 25.3.4 Mathematical conventions in the signal description

#### 25.3.4.1 Notation

$[\mathbf{Q}]_{m,n}$ indicates the element in row $m$ and column $n$ of matrix $\mathbf{Q}$.

#### 25.3.4.2 Subcarrier indices in use

For a 540 MHz (#7168)CMMG OFDM mode PPDU transmission, the 540 MHz is divided into 256 subcarriers. The signal is transmitted on subcarrier –89 to –2 and 2 to 89, with –1, 0, and 1 being the center (DC) subcarriers.

For a 1080 MHz (#7168)CMMG OFDM mode PPDU transmission, the 1080 MHz is divided into 512 subcarriers. The signal is transmitted on subcarrier –177 to –2 and 2 to 177, with –1, 0, and 1 being the center (DC) subcarriers.


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### 25.3.4.3 Transmitted signal

The transmitted signal is described in complex baseband signal notation. The actual transmitted signal is defined by the complex baseband signal in Equation (25-1).

$$r_{RF}^{i_{TX}} = \mathrm{Re}\left\{ r_{PPDU}^{i_{TX}}(t) \exp(j2\pi f_c t) \right\} \quad (25\text{-}1)$$

where

$r_{PPDU}$ represents the complex baseband signal in transmit chain $i_{TX}$

$f_c$ represents the center frequency of the portion of the transmitted PPDU

The transmitted RF signal is derived by upconverting the complex baseband signal, which consists of several fields. The fields and timing boundaries for various fields are shown in Figure 25-1 (PPDU structure for the CMMG SC mode PPDU with CBW540(#7168)(#7171)(#14)) to Figure 25-3 (PPDU structure for the CMMG OFDM mode PPDU(#7168)(#14)).

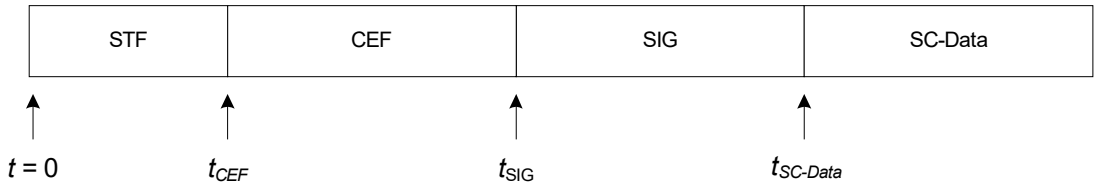


**Figure 25-1—PPDU structure for the CMMG SC mode PPDU with CBW540(#7168)(#7171)(#14)**

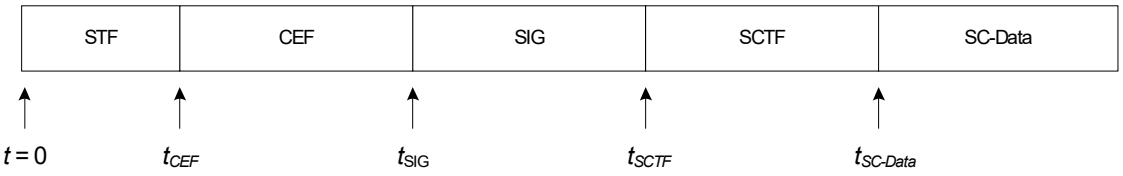


**Figure 25-2—PPDU structure for the CMMG SC mode PPDU with CBW1080(#7168)(#7171)(#14)**

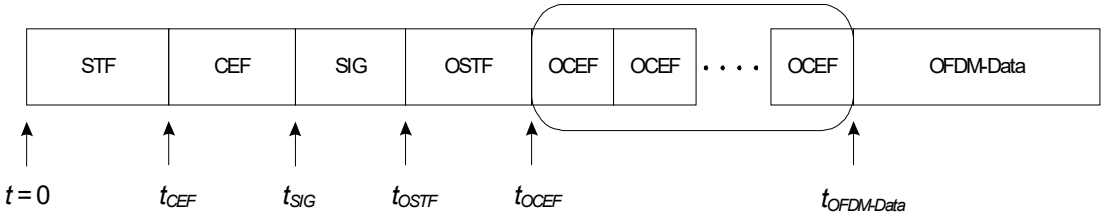


**Figure 25-3—PPDU structure for the CMMG OFDM mode PPDU(#7168)(#14)**

The time offset, $t_{Field}$, determines the starting time of the corresponding field.

For the (#7168)CMMG SC mode transmission with 540 MHz,

$$r_{PPDU}^{i_{TX}}(t) = r_{STF}^{i_{TX}}(t) + r_{CEF}^{i_{TX}}(t - t_{CEF}) + r_{SIG}^{i_{TX}}(t - t_{SIG}) + r_{SC-Data}^{i_{TX}}(t - t_{SC-Data}) \quad (25\text{-}2)$$

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For the (#7168)CMMG SC mode transmission with 1080 MHz,

$$r^{i_{TX}}_{PPDU}(t) = r^{i_{TX}}_{STF}(t) + r^{i_{TX}}_{CEF}(t - t_{CEF}) + r^{i_{TX}}_{SIG}(t - t_{SIG}) + r^{i_{TX}}_{SCTF}(t - t_{SCTF}) + r^{i_{TX}}_{SC-Data}(t - t_{SC-Data}) \quad (25\text{-}3)$$

For the (#7168)CMMG OFDM mode transmission,

$$r^{i_{TX}}_{PPDU}(t) = r^{i_{TX}}_{STF}(t) + r^{i_{TX}}_{CEF}(t - t_{CEF}) + r^{i_{TX}}_{SIG}(t - t_{SIG}) + r^{i_{TX}}_{MCTF}(t - t_{MCTF}) + r^{i_{TX}}_{OFDM-Data}(t - t_{OFDM-Data}) \quad (25\text{-}4)$$

where

$t_{CEF} = T_{STF}$

$t_{SIG} = t_{CEF} + T_{CEF}$

$t_{SCEF} = t_{SIG} + T_{SIG}$

$T_{OSTF} = t_{SIG} + T_{SIG}$

$t_{OCEF} = t_{OSTF} + T_{OSTF}$

$t_{SC-Data} = t_{SCTF} + T_{SCTF}$

$t_{OFDM-Data} = t_{OCTF} + N_{OCEF} T_{OCEF}$

Each (#7168)CMMG OFDM mode baseband waveform $r_{subfield}(nT_s)$, for the fields above, is defined via the inverse discrete Fourier transform (IDFT) as,

$$r^{i_{TX}}_{subfield}(t) = \frac{1}{\sqrt{N_{Tone} N_{STS}}} w_{Tsubfield}(t) \sum_{k=-N_{SR}}^{N_{SR}} \sum_{m=0}^{N_{STS}-1} [Q_k]_{i_{TX}, m} \gamma_{k, CBW} X_{k, m} \exp((j2\pi k \Delta_F (t - T_{GI} - T_{CS}(m)))) \quad (25\text{-}5)$$

In Equation (25-5) the following notions are used:

| | |
|---|---|
| $n_{Tone}$ | is, for 540 MHz transmission, 176 and, for 1080 MHz transmission, 352 |
| $N_{STS}$ | is the number of the space-time streams |
| $T_{GI}$ | is the guard interval duration used for each OFDM symbol |
| $Q_k$ | is the spatial mapping matrix with (#2259)$N_{TX}$ rows and $N_{STS}$ for the subcarrier $k$ |
| $w_{Tsubfield}$ | is a windowing function. An example function, $w_{Tsubfield}$, is given in 25.3.4.5 (The windowing function) |
| $\gamma_{k, CBW}$ | is defined in 25.3.4.4 (Definition of tone rotation for CMMG OFDM mode transmission(#7168)) |
| $\Delta_F$ | is the subcarrier frequency spacing given in Table 25-3 (Timing-related parameters(#7171)(M118)) |
| $T_{CS}(m)$ | represents the cyclic shift per space-time stream, whose value is defined in Table 25-27 (Cyclic shift values for the Data fields of a CMMG OFDM mode PPDU(#7168)(#404)) |
| $X_{k,m}$ | is the frequency-domain symbol in subcarrier $k$ of space-time stream $m$. Some of the $X_{k,m}$ within $-N_{SR} \le k \le N_{SR}$ have a value of 0, such as the DC tones |

The base band waveform for fields defined by time domain sequence or for single carrier transmission is

$$r_{Field}(nT_C) = x(n) \quad (25\text{-}6)$$

where $x(n)$ is the constellation point $n$.

Conversion from the sampled digital domain to the continuous time domain is beyond the scope of this document. Filtering for pulse shaping such as in GMSK is beyond the scope of this standard.


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#### 25.3.4.4 Definition of tone rotation for CMMG OFDM mode transmission(#7168)

The function $\Upsilon_{k,CBW}$ is used to represent a rotation of the tones. $\Upsilon_{k,CBW}$ is determined by the TXVECTOR parameter CH_BANDWIDTH as defined in Table 25-5 (CH_BANDWIDTH and ϒk,CBW).

**Table 25-5—CH_BANDWIDTH and $\Upsilon_{k,CBW}$**

| CH_BANDWIDTH | $\Upsilon_{k,CBW}$ |
|---|---|
| CBW540 | $\Upsilon_{k,540}$ |
| CBW1080 | $\Upsilon_{k,1080}$ |

For a 540 MHz (#7168)CMMG OFDM mode PPDU transmission,

$$\Upsilon_{k,540} = 1 \tag{25-7}$$

For a 1080 MHz (#7168)CMMG OFDM mode PPDU transmission,

$$\Upsilon_{k,1080} = \begin{cases} 1, k < 0 \\ j, k \geq 0 \end{cases} \tag{25-8}$$

#### 25.3.4.5 The windowing function

The windowing function $w_{TField}(nT_S)$ is used to smooth the transition between adjacent fields in the (#14)PPDU where (#7168)CMMG OFDM mode modulation is employed. No windowing is applied to preamble fields or to SC modulated fields. The windowing function is different from being equivalent to "1" only in the transition region.

An example of a windowing function is given by

$$w_T(t) = \begin{cases} \sin^2\left(\frac{\pi}{2}\left(\frac{1}{2} + \frac{t}{T_R}\right)\right), \frac{-T_R}{2} < t \leq \frac{T_R}{2} \\ 1, \frac{T_R}{2} < t \leq T - \frac{T_R}{2} \\ \sin^2\left(\frac{\pi}{2}\left(\frac{1}{2} - \frac{t}{T_R}\right)\right), T - \frac{T_R}{2} < t \leq T + \frac{T_R}{2} \end{cases} \tag{25-9}$$

The transition region creates an overlap (with length $T_R$) between adjacent fields. The field wave form is extended cyclically to fill the part of the transition region in which it is undefined. If the transition region vanishes (i.e., $T_R$=0), the windowing function degenerates to a rectangular window. The choice of windowing function is implementation dependent, as long as transmit EVM and transmit mask requirements are met.

### 25.3.5 CMMG PHY preamble

#### 25.3.5.1 General

The CMMG PHY preamble is the part of the PHY PPDU that is used for (#14)PPDU detection, AGC, frequency offset estimation, synchronization, indication of transmission mode ((#7168)CMMG Control

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mode, (#7168)CMMG SC mode, or (#7168)CMMG OFDM mode), indication of transmission bandwidth (540 MHz or 1080 MHz), and channel estimation. The format of the preamble is common to both (#14)SC PPDUs and OFDM PPDUs and consists of a Short Training field followed by a Channel Estimation field. The content of the Short Training field is the same between SC and OFDM (#14)PPDUs (see 25.3.5.2 (CMMG Short Training field)), but the content of the Channel Estimation field is not the same between such (#14)PPDUs (see 25.3.5.3 (CMMG Channel Estimation field)).

NOTE 1—For SC and OFDM MIMO transmission, different transmit antenna transmit a different preamble that is composed of one of the four ZCZ sequences with the order of $Z_{256}^{1}, Z_{256}^{2}, Z_{256}^{3}, Z_{256}^{4}$, such as for the case of one transmit antenna, the preamble sequence is composed of $Z_{256}^{1}$, for the case of two transmit antennas, the preamble sequences are composed of $Z_{256}^{1}$, $Z_{256}^{2}$, respectively.

NOTE 2—For CMMG Control mode and CMMG SC mode preambles, all fields are transmitted with (#7168)CMMG SC mode transmission. For CMMG OFDM mode preamble, the STFs, the CEFs, and the SIG fields are transmitted with (#7168)CMMG SC mode transmission. For 1080 MHz SC transmission, the STFs, the CEFs, and the SIG fields are transmitted in duplicate format as defined in 25.3.10 (CMMG duplication transmission on a 1080 MHz channel).

### 25.3.5.2 CMMG Short Training field

#### 25.3.5.2.1 STF of CMMG control mode(#7168)

The Short Training field is composed of 50 repetitions of the sequence $Z(n)$ of length 32. The sequences $Z(n)$ is defined in 25.8 (ZCZ sequence).

The waveform for the STF is

$$r_{STF}(nT_C) = Z(n \bmod 32)\exp\left(j\pi\frac{n}{2}\right), n = 0, 1, \ldots, 50 \times 32 - 1 \quad (25\text{-}10)$$

where $T_C$ is (#6037)SC chip time of CBW540(#7171).

#### 25.3.5.2.2 STF of CMMG SC and OFDM modes(#7168)

The Short Training fields of (#7168)CMMG SC and OFDM modes share the same definition. The common Short Training field is composed of 17 repetitions of the sequence $Z(n)$ of length 32. The sequences $Z(n)$ is defined in 25.8 (ZCZ sequence).

The waveform for the Short Training field is

$$r_{STF}(nT_C) = Z(n \bmod 32)\exp\left(j\pi\frac{n}{2}\right), n = 0, 1, \ldots, 17 \times 32 - 1 \quad (25\text{-}11)$$

where $T_C$ is (#6037)SC chip time of CBW540(#7171).

### 25.3.5.3 CMMG Channel Estimation field

#### 25.3.5.3.1 CEF of CMMG control mode(#7168)

The CEF of CMMG control mode is composed of four concatenated $Z(n)$ sequences where each sequence is multiplied by an individual sign assignment. As shown in Figure 25-4 (CMMG Control mode preamble(#7168)), the CEF of (#7168)CMMG control mode is defined as $-Z(n)$, $Z(n)$, $-Z(n)$, $-Z(n)$, where the sequence is defined in 25.8 (ZCZ sequence).

The waveform for the CEF is


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$$r_{CEF}(nT_C) = \begin{cases} -Z(n \bmod 256)\exp\left(j\pi\frac{n}{2}\right), n = 0, 1, \ldots, 256-1 \\ Z(n \bmod 256)\exp\left(j\pi\frac{n}{2}\right), n = 256, \ldots, 256\times 2-1 \\ -Z(n \bmod 256)\exp\left(j\pi\frac{n}{2}\right), n = 256\times 2, \ldots, 256\times 3-1 \\ -Z(n \bmod 256)\exp\left(j\pi\frac{n}{2}\right), n = 256\times 3, \ldots, 256\times 4-1 \end{cases} \quad (25\text{-}12)$$

where $T_C$ is (#6037)SC chip time of CBW540(#7171). The (#7168)CMMG control mode preamble is defined in Figure 25-4 (CMMG Control mode preamble(#7168)).

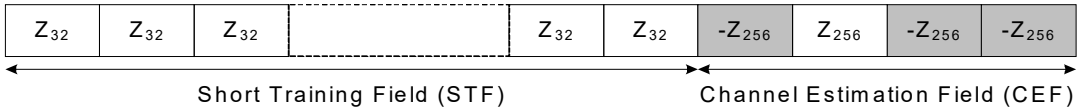


**Figure 25-4—CMMG Control mode preamble(#7168)**

### 25.3.5.3.2 CEF of CMMG SC mode(#7168)

The CEF of (#7168)CMMG SC mode is also composed of four concatenated *Z(n)* sequences but is with different sign assignment patterns. As shown in Figure 25-5 (CMMG SC mode preamble for CBW540(#7171)) and Figure 25-6 (CMMG SC mode preamble for CBW1080(#7171)), the CEF of SC 540 MHz PHY is defined as [–*Z*(*n*), *Z*(*n*), *Z*(*n*), –*Z*(*n*)], and the CEF of SC 1080 MHz PHY is defined as [–*Z*(*n*), –*Z*(*n*), *Z*(*n*), *Z*(*n*)], where the sequence *Z(n)* is defined in 25.8 (ZCZ sequence).

The waveform for the CEF of SC 540 MHz mode is

$$r_{CEF}(nT_C) = \begin{cases} -Z(n \bmod 256)\exp\left(j\pi\frac{n}{2}\right), n = 0, 1, \ldots, 256-1 \\ Z(n \bmod 256)\exp\left(j\pi\frac{n}{2}\right), n = 256, \ldots, 256\times 2-1 \\ Z(n \bmod 256)\exp\left(j\pi\frac{n}{2}\right), n = 256\times 2, \ldots, 256\times 3-1 \\ -Z(n \bmod 256)\exp\left(j\pi\frac{n}{2}\right), n = 256\times 3, \ldots, 256\times 4-1 \end{cases} \quad (25\text{-}13)$$

and the waveform for the CEF of SC 1080 MHz mode is

$$r_{CEF}(nT_C) = \begin{cases} -Z(n \bmod 256)\exp\left(j\pi\frac{n}{2}\right), n = 0, 1, \ldots, 256-1 \\ -Z(n \bmod 256)\exp\left(j\pi\frac{n}{2}\right), n = 256, \ldots, 256\times 2-1 \\ Z(n \bmod 256)\exp\left(j\pi\frac{n}{2}\right), n = 256\times 2, \ldots, 256\times 3-1 \\ Z(n \bmod 256)\exp\left(j\pi\frac{n}{2}\right), n = 256\times 3, \ldots, 256\times 4-1 \end{cases} \quad (25\text{-}14)$$

where $T_C$ is (#6037)SC chip time of CBW540(#7171).

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The (#7168)CMMG SC mode preambles are defined in Figure 25-5 (CMMG SC mode preamble for CBW540(#7171)) and Figure 25-6 (CMMG SC mode preamble for CBW1080(#7171)).

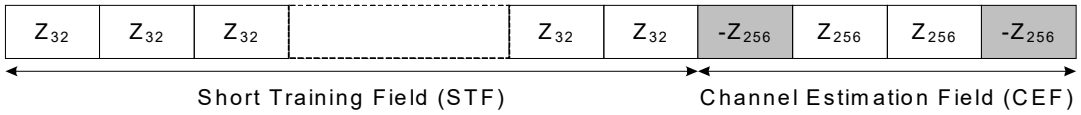


**Figure 25-5—CMMG SC mode preamble for CBW540(#7171)**

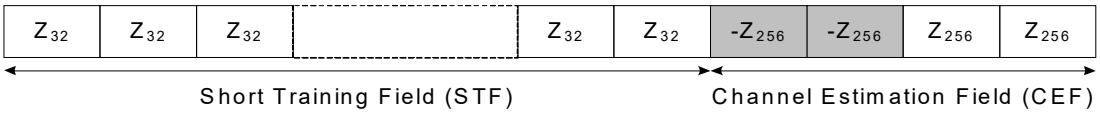


**Figure 25-6—CMMG SC mode preamble for CBW1080(#7171)**

#### 25.3.5.3.3 CEF of CMMG OFDM mode(#7168)

The CEF of (#7168)CMMG OFDM mode is also composed of four concatenated $Z(n)$ sequences but is with different sign assignment patterns. As shown in Figure 25-7 (CMMG OFDM mode preamble for CBW540(#7171)) and Figure 25-8 (CMMG OFDM mode preamble for CBW1080(#7171)), the CEF of OFDM 540 MHz PHY is defined as $[-Z(n), Z(n), Z(n), Z(n)]$, and the CEF of OFDM 1080 MHz PHY is defined as $[-Z(n), -Z(n), -Z(n), Z(n)]$, where the sequence $Z(n)$ is defined in 25.8 (ZCZ sequence).

The waveform for the CEF of OFDM 540 MHz mode is

$$r_{CEF}(nT_C) = \begin{cases} -Z(n \bmod 256)\exp\left(j\pi\frac{n}{2}\right), n = 0, 1, \ldots, 256-1 \\ Z(n \bmod 256)\exp\left(j\pi\frac{n}{2}\right), n = 256, \ldots, 256\times 2-1 \\ Z(n \bmod 256)\exp\left(j\pi\frac{n}{2}\right), n = 256\times 2, \ldots, 256\times 3-1 \\ Z(n \bmod 256)\exp\left(j\pi\frac{n}{2}\right), n = 256\times 3, \ldots, 256\times 4-1 \end{cases} \quad (25\text{-}15)$$

and the waveform for the CEF of OFDM 1080 MHz mode is

$$r_{CEF}(nT_C) = \begin{cases} -Z(n \bmod 256)\exp\left(j\pi\frac{n}{2}\right), n = 0, 1, \ldots, 256-1 \\ -Z(n \bmod 256)\exp\left(j\pi\frac{n}{2}\right), n = 256, \ldots, 256\times 2-1 \\ -Z(n \bmod 256)\exp\left(j\pi\frac{n}{2}\right), n = 256\times 2, \ldots, 256\times 3-1 \\ Z(n \bmod 256)\exp\left(j\pi\frac{n}{2}\right), n = 256\times 3, \ldots, 256\times 4-1 \end{cases} \quad (25\text{-}16)$$


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where $T_C$ is SC chip time of CBW540(#7171).

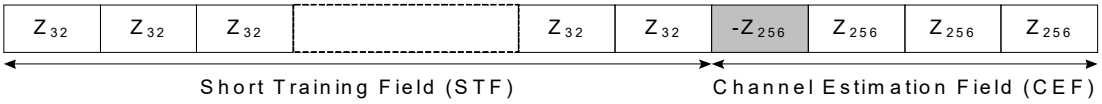


**Figure 25-7—CMMG OFDM mode preamble for CBW540(#7171)**

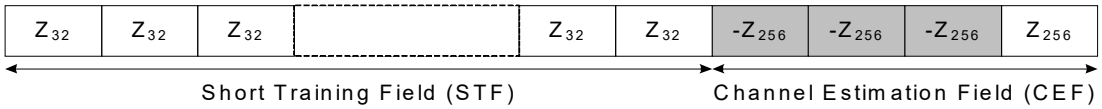


**Figure 25-8—CMMG OFDM mode preamble for CBW1080(#7171)**

### 25.3.6 CRC calculation

The value of cyclic redundancy check (CRC) field is the 1s complement of Equation (25-17).

$$CRC(D) = (M(D) \oplus I(D))D^{K} \bmod G(D) \tag{25-17}$$

where

$m(D) = m_0 D^{N-1} + m_1 D^{N-2} + \ldots + m_{N-1}$

$N$ is the number of bits over which the CRC is generated

$m_i$ is bit $i$ of the input bit sequence

$I(D) = \sum_{i=N-K}^{N-1} D^i$ are initialized values that are added modulo 2 to the first $K$ bits of the input bit sequence

$K$ is the length of CRC sequence: $K = 16$ for CRC of the CMMG SIG, and $K = 8$ for the (#404)Data field

$G(D) = D^{16} + D^{12} + D^5 + 1$ is the CRC generating polynomial of 8 bits

$crc(D) = x_0 D^{15} + x_1 D^{14} + \ldots + x_{14} D + x_{15}$

Figure 25-9 (16-bit CRC calculation) shows the operation of the CRC of 16 bits. First, the shift register is reset to all 1s. The bits are then passed through the XOR operation at the input. When the last bit has entered, the output is generated by shifting the bits out of the shift register, $x_{15}$ first, through an inverter.

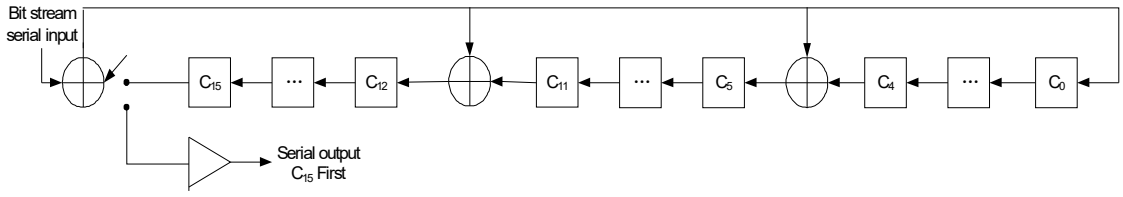


**Figure 25-9—16-bit CRC calculation**

$G(D) = D^8 + D^7 + D^4 + D^3 + D + 1$ is the CRC generating polynomial of 8 bits.

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$$crc(D) = x_0D^7 + x_1D^6 + \ldots + x_6D + x_7$$

Figure 25-10 (8-bit CRC calculation) shows the operation of the CRC of 8 bits.

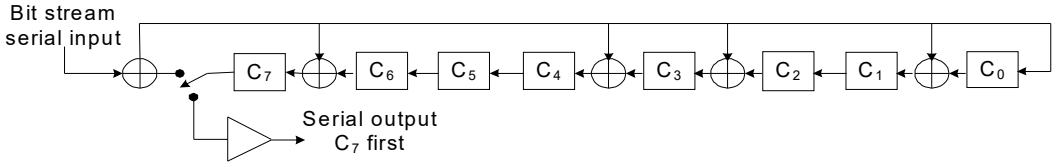


**Figure 25-10—8-bit CRC calculation**

### 25.3.7 Scrambler

The CMMG control mode SIG, CMMG SC/OFDM mode SIG, and the (#404)Data fields following the scrambler initialization field (including data padding bits) shall be scrambled by XORing each bit in turn with a length 127 periodic sequence generated by the polynomial $S(x) = x^7 + x^4 + 1$. The octets of the PSDU and the pad bits shall be placed into a bit stream with bit 0 (LSB) of each octet first and bit 7 of each octet (MSB) last. The generation of the sequence and the XOR operation are defined in Figure 25-11 (Scrambler).

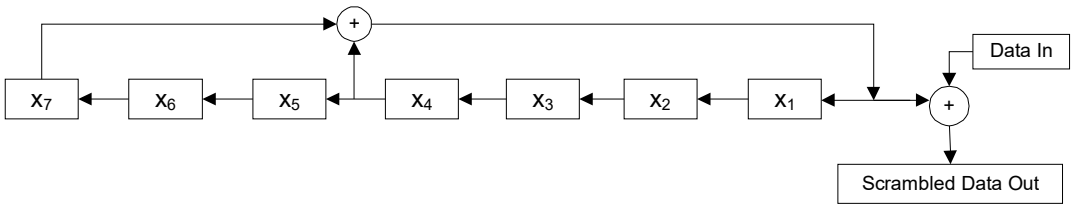


**Figure 25-11—Scrambler**

For each PPDU, the transmitter shall select a nonzero seed value for the scrambler (bits $x_1$ to $x_7$). The seed value should be selected in a pseudo random fashion. The seed value is sent in the Scrambler Initialization field of the PHY header. Each data bit in the (#404)Data field of the PPDU is then XORed with the scrambler output ($x_4$ XOR $x_7$), and the scrambler content shifts once.

### 25.3.8 Common LDPC parity matrices

#### 25.3.8.1 Introduction

Transmission/reception of LDPC with codeword length of 672 bits (expansion factor $z = 42$) is mandatory, and transmission/reception of LDPC with codeword length 2016 bits (expansion factor $z = 126$) is optional.

#### 25.3.8.2 General

The structured LDPC code is defined by a parity check matrix $\mathbf{H}$ of size $(m \times z) \times (n \times z)$, which is determined by a base matrix $\overline{\mathbf{H}}$ of size $m \times n$, an expansion factor $z$, and a base permutation matrix $\mathbf{P}$ of size $z \times z$. The number of information bits is $k = (n - m) \times z$, the number of codeword bits is $nz$, then the coding rate is $r = k/(nz)$. If each element $\overline{h}_{ij}$ in the base matrix $\overline{\mathbf{H}}$ is replaced by zero subblock matrix of size $z \times z$ or the subblock matrix $\mathbf{P}^{\overline{h}_{ij}}$, the parity check matrix $\mathbf{H}$ can be obtained.

The base matrix $\overline{\mathbf{H}}$ is defined as follows:


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$$\overline{\mathbf{H}} = \begin{bmatrix} \bar{h}_{00} & \bar{h}_{01} & \dots & \bar{h}_{0(n-1)} \\ \bar{h}_{10} & \bar{h}_{11} & \dots & \bar{h}_{1(n-1)} \\ \dots & \dots & \dots & \dots \\ \bar{h}_{(m-1)0} & \bar{h}_{(m-1)1} & \dots & \bar{h}_{(m-1)(n-1)} \end{bmatrix} \quad (25\text{-}18)$$

The parity check matrix **H** is defined as follows:

$$\mathbf{H} = \begin{bmatrix} \mathbf{P}^{\bar{h}_{00}} & \mathbf{P}^{\bar{h}_{01}} & \dots & \mathbf{P}^{\bar{h}_{0(n-1)}} \\ \mathbf{P}^{\bar{h}_{10}} & \mathbf{P}^{\bar{h}_{11}} & \dots & \mathbf{P}^{\bar{h}_{1(n-1)}} \\ \dots & \dots & \dots & \dots \\ \mathbf{P}^{\bar{h}_{(m-1)0}} & \mathbf{P}^{\bar{h}_{(m-1)1}} & \dots & \mathbf{P}^{\bar{h}_{(m-1)(n-1)}} \end{bmatrix} \quad (25\text{-}19)$$

where, if $\overline{h}_{ij} = -1$, $\mathbf{P}^{\bar{h}_{ij}}$ equals a zero matrix of size $z \times z$; otherwise, $\mathbf{P}^{\bar{h}_{ij}}$ equals the base permutation matrix **P** to $h_{ij}$ power. The base permutation matrix **P** of size $z \times z$ is defined as follows:

$$\mathbf{P} = \begin{bmatrix} 0 & 1 & 0 & \dots & 0 \\ 0 & 0 & 1 & \dots & 0 \\ \dots & \dots & \dots & \dots & \dots \\ 0 & 0 & 0 & \dots & 1 \\ 1 & 0 & 0 & \dots & 0 \end{bmatrix} \quad (25\text{-}20)$$

Table 25-6 (Base matrix prototypes for codeword block length nz bits, subblock size is z bits) defines the base matrix prototypes of the parity-check matrices for a codeword block length *nz* bits, with a subblock size *z* bits.

**Table 25-6—Base matrix prototypes for codeword block length *nz* bits, subblock size is *z* bits**

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (a) Coding rate=1/2 | | | | | | | | | | | | | | | |
| -1 | 0 | -1 | 0 | -1 | 0 | -1 | 0 | 0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 |
| 0 | -1 | -1 | 34 | -1 | 12 | -1 | 36 | 18 | 0 | -1 | -1 | -1 | -1 | -1 | -1 |
| 8 | -1 | 0 | -1 | 0 | -1 | 0 | -1 | -1 | 13 | 0 | -1 | -1 | -1 | -1 | -1 |
| -1 | 16 | 40 | -1 | 32 | -1 | 22 | -1 | -1 | -1 | 19 | 0 | -1 | -1 | -1 | -1 |
| -1 | 20 | -1 | 22 | -1 | 2 | -1 | 28 | 32 | -1 | -1 | 21 | 0 | -1 | -1 | -1 |
| 30 | -1 | 18 | -1 | -1 | 14 | -1 | 30 | -1 | 37 | -1 | -1 | 31 | 0 | -1 | -1 |
| 40 | -1 | 12 | -1 | 38 | -1 | 6 | -1 | -1 | -1 | 26 | -1 | -1 | 13 | 0 | -1 |
| -1 | 24 | -1 | 20 | 10 | -1 | 2 | -1 | -1 | -1 | -1 | 18 | -1 | -1 | 5 | 0 |
| (b) Coding rate=5/8 | | | | | | | | | | | | | | | |
| -1 | 0 | -1 | 0 | 0 | 0 | 0 | 0 | 0 | -1 | 0 | -1 | -1 | -1 | -1 | -1 |
| 0 | -1 | 0 | -1 | 32 | -1 | 22 | -1 | 18 | 0 | 19 | 0 | -1 | -1 | -1 | -1 |
| 8 | 16 | 40 | 34 | -1 | 12 | -1 | 36 | 32 | -1 | -1 | 21 | 0 | -1 | -1 | -1 |
| 30 | 20 | 18 | 22 | 38 | -1 | 6 | -1 | -1 | 13 | -1 | -1 | 31 | 0 | -1 | -1 |

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**Table 25-6—Base matrix prototypes for codeword block length *nz* bits, subblock size is *z* bits *(continued)***

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| -1 | 24 | -1 | 20 | -1 | 2 | -1 | 28 | 16 | 37 | -1 | -1 | -1 | 13 | 0 | -1 |
| 40 | -1 | 12 | -1 | 10 | 14 | 2 | 30 | -1 | 19 | -1 | -1 | -1 | -1 | 5 | 0 |
| (c) Coding rate=3/4 | | | | | | | | | | | | | | | |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -1 | -1 | -1 |
| 8 | 16 | 40 | 34 | 32 | 12 | 22 | 36 | 18 | 13 | 19 | 0 | -1 | 0 | -1 | -1 |
| 30 | 20 | 18 | 22 | 38 | 2 | 6 | 28 | 32 | 37 | 26 | 21 | 31 | -1 | 0 | -1 |
| 40 | 24 | 12 | 20 | 10 | 14 | 2 | 30 | 16 | 19 | 34 | 18 | -1 | 13 | 5 | 0 |
| (d) Coding rate=13/16 | | | | | | | | | | | | | | | |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -1 | -1 |
| 30 | 20 | 18 | 22 | 38 | 2 | 6 | 28 | 32 | 37 | 26 | 21 | 34 | -1 | 0 | -1 |
| 40 | 24 | 12 | 20 | 10 | 14 | 2 | 30 | 16 | 19 | 34 | 18 | 8 | 13 | 5 | 0 |

### 25.3.9 CMMG SIG

#### 25.3.9.1 General

The CMMG SIG field carries information required to interpret PPDUs. The preamble and the CMMG SIG fields are all transmitted using modulation. The structure of the CMMG SIG field is shown in Figure 25-12 (CMMG SIG structure).

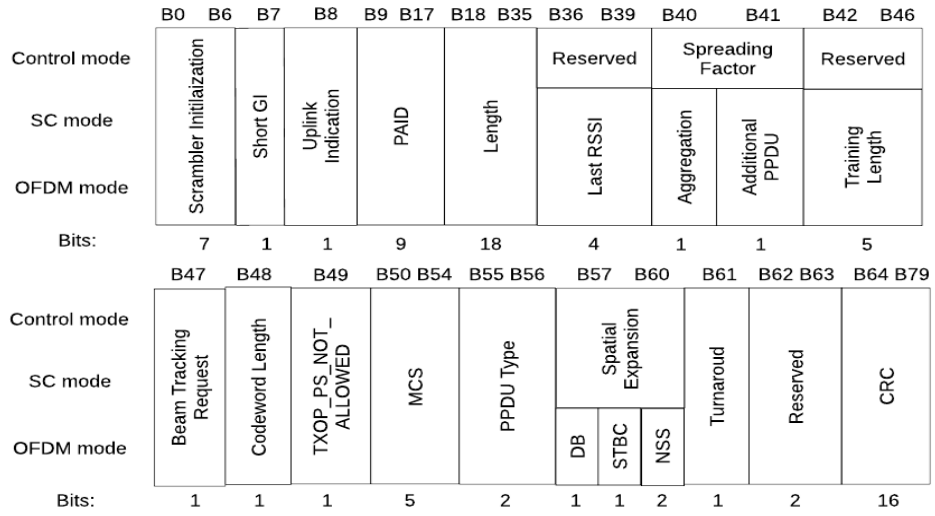


**Figure 25-12—CMMG SIG structure**


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The CMMG SIG field contains the fields listed in Table 25-7 (Fields in the CMMG SIG field). The mapping of the fields is also described in Table 25-7 (Fields in the CMMG SIG field).

**Table 25-7—Fields in the CMMG SIG field**

| Bit | Fields | Number of bits | Description |
|---|---|---|---|
| B0–B6 | Scrambler Initialization | 7 | Bits X1-X7 of the initial scrambler state (see 25.3.7 (Scrambler)). |
| B7 | Short GI | 1 | Set to 0 if short guard interval is not used in the Data field.<br>Set to 1 if short guard interval is used in the Data field. |
| B8 | Uplink Indication | 1 | Set to 1 if the PPDU is addressed to an AP. Set to 0 otherwise.<br>(See TXVECTOR parameter UPLINK_INDICATION.) |
| B9–B17 | PAID | 9 | If Uplink Indication is not present or set to 1, B9–B17 are the partial AID to provide an abbreviated indication of the intended recipient(s) of the PSDU (see 10.19 (Group ID and partial AID in VHT and CMMG PPDUs)). If Uplink Indication is equal to 0, B9–B11 are an identifier of the BSS and B12–B17 are the partial AID.<br>(See TXVECTOR parameter COLOR and TXVECTOR parameter PARTIAL_AID.) |
| B18–B35 | Length | 18 | Number of data octets in the PSDU, Range from 0 to 262 143 |
| B36–B39 | Last RSSI | 4 | For (#7168)CMMG SC/OFDM mode:<br>Contains a copy of the parameter LAST_RSSI from the TXVECTOR. When set to 0, this field is reserved and ignored by the receiver.<br>The value is an unsigned integer:<br>— Values of 2 to 14 represent power levels (–71+value×2) dBm.<br>— A value of 15 represents a power greater than or equal to –42 dBm.<br>— A value of 1 represents a power less than or equal to –68 dBm.<br>Value of 0 indicates that the previous (#14)PPDU was not received (#319)(#320)a SIFS before the current transmission.<br>For (#7168)CMMG control mode: Reserved. |

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**Table 25-7—Fields in the CMMG SIG field *(continued)***

| Bit | Fields | Number of bits | Description |
|---|---|---|---|
| B40–B41 | Spreading Factor/ Aggregation/Additional PPDU | 2 | For (#7168)CMMG control mode:<br>— Set to 0: spreading by 13<br>— Set to 1: spreading by 7<br>— Set to 2: spreading by 4<br>— Set to 3: no spreading<br>For (#7168)CMMG SC/OFDM mode:<br>Aggregation:<br>— Set to 1 indicate that the (#14)PSDU contains an A-MPDU; otherwise, set to 0.<br>Additional PPDU:<br>— Contains a copy of the parameter ADD_PPDU from the TXVECTOR. A value of 1 indicates that this PPDU is immediately followed by another PPDU with no IFS or preamble on the subsequent PPDU.<br>— A value of 0 indicates that no additional PPDU follows this PPDU. |
| B42–B46 | Training Length | 5 | For (#7168)CMMG SC/OFDM mode:<br>Corresponds to the TXVECTOR parameter TRNLEN.<br>If the Beam Tracking Request field is 0, the Training Length field indicates the length of the training field. The use of this field is defined in 25.7.2.3 (BRP PPDU SIG fields). A value of 0 indicates that no training field is present in this PPDU.<br>If the Beam Tracking Request field is 1 and the PPDU Type field is 10, the Training Length field indicates the length of the training field. If the PPDU Type field is 11, the Training Length field indicates the length of the training field requested for receive training.<br>For (#7168)CMMG control mode: Reserved. |
| B47 | Beam Tracking Request | 1 | Corresponds to the TXVECTOR parameter BEAM_TRACKING_REQUEST.<br>Set to 1 to indicate the need for beam tracking (10.41.7 (Beam tracking)); otherwise, set to 0.<br>The Beam Tracking Request field is reserved when the Training Length field is 0. |
| B48 | Codeword Length | 1 | Set to 0 indicate that the codeword length is 672.<br>Set to 1 indicate that the codeword length is 2016. |
| B49 | TXOP_PS_NOT_ALLOWED | 1 | Set to 0 by CMMG AP if it allows non-AP CMMG STAs in TXOP power save mode to enter doze state during a TXOP.<br>Set to 1 otherwise.<br>The bit is reserved and set to 1 in CMMG PPDUs transmitted by a non-AP CMMG STA. |
| B50–B54 | MCS | 5 | MCS index (see 25.15 (Parameters for CMMG-MCSs)). |


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**Table 25-7—Fields in the CMMG SIG field *(continued)***

| Bit | Fields | Number of bits | Description |
|---|---|---|---|
| B55–B56 | PPDU Type | 2 | When the Training Length field is nonzero, corresponds to the TXVECTOR parameter PPDU_TYPE.<br>— PPDU Type = 11 indicates either a (#14)PPDU whose Data field is followed by one or more TRN-R subfields, or a (#14)PPDU that is requesting TRN-R subfields to be appended to a future response (#14)PPDU.<br>— PPDU Type = 10 indicates a (#14)PPDU whose Data field is followed by one or more TRN-T subfields.<br>When the Training Length field is zero and PPDU Type = 01, indicates that PPDU is a sounding PPDU.<br>This field is reserved when the Training Length field is zero and PPDU Type = 00. |
| B57–B60 | Spatial Expansion | 4 | For (#7168)CMMG control/SC mode:<br>Index into the corresponding spatial expansion method defined in Table 25-15 (Constellation mapper output to spatial mapper input). |
| | DB | 1 | For (#7168)CMMG OFDM mode:<br>If the PPDU is transmitted on 1080 MHz channel:<br>Set DB to 1 for allowing dynamic bandwidth.<br>Set to 0 for not allowing dynamic bandwidth.<br>Otherwise set to 0 (Reserved).<br>For (#7168)CMMG control and SC modes: Reserved. |
| | STBC | 1 | For (#7168)CMMG OFDM mode:<br>Set to 1 if space-time block coding is used; otherwise, set to 0. |
| | NSS | 2 | For OFDM mode:<br>Set to 0 for 1 spatial stream.<br>Set to 1 for 2 spatial streams.<br>Set to 2 for 3 spatial streams.<br>Set to 3 for 4 spatial streams. |
| B61 | Turnaround | 1 | As defined in Table 25-1 (TXVECTOR and RXVECTOR parameters). |
| B62–B63 | Reserved | 2 | Reserved. |
| B64–B79 | CRC | 16 | CMMG SIG check sequence. Definition of this field calculation is in 25.3.6 (CRC calculation). |
| NOTE—A value of 0 in the CMMG Length field indicates a PPDU that does not include a (#404)Data field, i.e., NDP. NDP transmissions are used for sounding purposes only (see 10.35.2 (Transmission of an HT NDP)). The (#14)NDP ends after the last CMMG OCEF or the CMMG SIG. | | | |

Reserved bits are set to 0 by the transmitter and shall be ignored by the receiver.

All numeric fields are transmitted in unsigned format, LSB first.

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#### 25.3.9.2 Encoding of SIG

The scrambled SIG sequence consists of 80 bits, shown as $x = (x_0, x_1, x_2, \ldots, x_{79})$ and encoded with LDPC of rate-1/2 and length 672, as follows:

a) The scrambled SIG sequence is padded with 4 0s bits to create 84 bits. The 84-bit sequence include two contiguous subsequences with length of 42 bits, shown as $[[0, 0, 0, x_0, \ldots, x_{37}], [x_{38}, \ldots, x_{79}]]$, and the two subsequences are repeated once, respectively, to obtain 168 bits, such as $\mathbf{a}' = [[0]_{1\times 4}, x_0, \ldots, x_{37}, [0]_{1\times 4}, x_0, \ldots, x_{37}, x_{38}, \ldots, x_{79}, x_{38}, \ldots, x_{79}]$. Then, the repeated data sequence is padded with 168 zero bits to create 336 bits.

b) Then, using rate-1/2 LDPC base matrix and setting $\overline{h}_{26} = -1$, the 336-bit sequence is added with parity bits $[p_0, \ldots, p_{335}]$ to create LDPC codeword, shown as $\mathbf{c} = [[0]_{1\times 168}, \mathbf{a}', [p_0, \ldots, p_{335}]]$, such that $\mathbf{H} \times \mathbf{c}^{\mathrm{T}} = \mathbf{0}$, where $\mathbf{H}$ is revised LDPC parity check matrix.

The basic code is $\mathbf{c}' = [x_0, x_1, \ldots, x_{79}, p_0, p_1, \ldots, p_{335}]$. Using rate-matching to obtain transmitting sequence of 1024 bits: $S = [\mathbf{c}', \mathbf{c}', \mathbf{c}'(0, \ldots, 191)]$.

### 25.3.10 CMMG duplication transmission on a 1080 MHz channel

The STFs, the CEFs, and the SIG fields that are transmitted using SC modulation are specified at the SC chip rate $F_C$ equal to 440 MHz. For transmission on the 1080 MHz channel, the signal is resampled with a 2 rate change, applied appreciate phase rotation for each 540 MHz subband, and then summed to form the transmitted signal.

Let $r(nT_C) = r_{STF}(nT_C) + r_{CEF}(nT_C - t_{CEF}) + r_{SIG}(nT_C - t_{SIG})$, where $T_C$ is the SC chip duration for 540 MHz channel bandwidth and $r_{CEF}$ is described in 25.3.5 (CMMG PHY preamble).

Then

$$r^{(1)}\left(n\frac{T_C}{2}\right) = \begin{cases} r\left(n\frac{T_C}{2}\right), n = 0, 2, 4, \ldots \\ 0, otherwise \end{cases} \tag{25-21}$$

$$r^{(2)}\left(n\frac{T_C}{2}\right) = \sum_{k=0}^{K-1} r^{(1)}\left((n-k)\frac{T_C}{2}\right) h_{Filt}(k), n = 0, 1, 2, \ldots \tag{25-22}$$

$$\bar{r}\left(n\frac{T_C}{2}\right) = r^{(2)}\left(\left(n + \frac{K-1}{2}\right)\frac{T_C}{2}\right), n = 0, 1, 2, \ldots \tag{25-23}$$

where $K$ is the length of the filter defined in at chip rate 880 MHz whose definition is out of scope of this standard. The transmitted signal is given as

$$\bar{r}\left(n\frac{T_C}{2}\right) = \bar{r}\left(n\frac{T_C}{2}\right) \cdot \frac{1}{\sqrt{2}} e^{-j\pi Bn\frac{T_C}{2}} + \bar{r}\left(n\frac{T_C}{2}\right) \cdot \frac{1}{\sqrt{2}} e^{j\pi Bn\frac{T_C}{2}}$$

$$\bar{r}\left(n\frac{T_C}{2}\right) = \bar{r}\left(n\frac{T_C}{2}\right) \cdot \frac{1}{\sqrt{2}} e^{-j\pi Bn\frac{T_C}{2}} + \bar{r}\left(n\frac{T_C}{2}\right) \cdot \frac{1}{\sqrt{2}} e^{j\pi Bn\frac{T_C}{2}} \tag{25-24}$$

where $B$ = 540 MHz.


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### 25.3.11 $h_{Filt}$ definition

The filter $h_{Filt}$ is defined by the following coefficients (from $h_0$ to $h_{70}$):

[1,–6,–5,3,8,0,–8,–4,6,8,–4,–13, –2,16,14,–9,–23,–4,23,15, –20,–27,20,57,4,–99, –102,70,247,144,–264, –558,–175,991,2327,2917,2327,991,–175,–558,–264,144,247,70,–102, –99,4,57,20,–27,–20, 15,23,–4, –23,–9,14,16,–2,–13,–4,8,6,–4,–8,0,8,3,–5,–6,1].

Normalized to have a norm of $\sqrt{3}$ so that $h_{Filt}(k) = \frac{\sqrt{3}h_k}{\sqrt{\sum_{l=0}^{70}|h_l|^2}}$.

### 25.3.12 Encoding of Data field

The scrambled Data field is encoded with LDPC codeword length of $n$ bits, information length of $k$ bits, and expansion factor of $z$ as follows:

a) $L_{DPCW} = k - 8$ is the maximal number of data bits in each LDPC codeword. The number of LDPC codeword is calculated as

$$N_{CW} = \lceil Length \times 8 / L_{DPCW} \rceil .$$

b) The number of data bits in the $i^{th}$ LDPC codeword is

$$L_i = \begin{cases} L_{DPCW1}, i = 0, 1, \ldots, N_{CW1} - 1 \\ L_{DPCW1} - 1, i = N_{CW1}, N_{CW1} + 1, \ldots, N_{CW} - 1 \end{cases}$$

where

$$L_{DPCW1} = \lceil Length \times 8 / N_{CW} \rceil$$

$$N_{CW1} = \mathrm{mod}((Length \times 8), (L_{DPCW1} - 1))$$

c) The (#404)Data field is broken into $N_{CW}$ blocks of data word $\mathbf{b}_i$, $i = 0, 1, \ldots, N_{CW}–1$. Each data word is added with 8-bit CRC sequence, see 25.3.6 (CRC calculation), then padded with $f_i = k–L_i– 8$ zero bits to create $k$ bits, such as $\mathbf{b'}_i = (0, \ldots, 0, \mathbf{b}_i, crc_0^i, \ldots, crc_7^i)$.

d) For each data word, $n–k$ parity bits are added to create the LDPC codeword $\mathbf{d}_i = (\mathbf{b'}_i, p_0^i, p_1^i, \ldots, p_{(n-k-1)}^i)$, such that $\mathbf{H} \times \mathbf{d}_i^T = \mathbf{0}$.

e) (#14)Data field encoding: The $j^{th}$ bit set that is composed of all the $j^{th}$ bits of $N_{CW}$ LDPC codeword is encoded with 1-bit parity check to create a parity bit $T_j$, $j = 0, 1, \ldots, n–1$. All the parity bits $T_j$ ($j = 0, 1, \ldots, n–1$) are combined into a parity data word $\mathbf{d}_{N_{CW}}$ with length of $n$ bits. That is, $\mathbf{d}_{N_{CW}} = \mathbf{d}_0 \oplus \mathbf{d}_1 \ldots \oplus \mathbf{d}_{(N_{CW}-1)}$.

f) Bits selection parameter: the punctured-bit index set of $i^{th}$ codeword that are not belong to padding bits are $\mathbf{S}_i$ ($i = 0, 1, \ldots, N_{CW}–1$), and the punctured-bit index set of parity data word $\mathbf{d}_{N_{CW}}$ is $\bar{\mathbf{S}}_{N_{CW}}$. The intersection of any two different sets of $\bar{\mathbf{S}}_i$ ($i = 0, 1, \ldots, N_{CW}$) is empty set. The length of $\bar{\mathbf{S}}_i$ is $e_i$ ($i = 0,\ldots, N_{CW}$), such as: (where $n' = n - f_0$ ).

1) if $N_{CW} = 1$: $e_0 = 0$, $e_1 = n'$ ;

2) if $1 < N_{CW} \le 15$ : $e_i = z$, $i = 0, 1, \ldots N_{CW}–1$, $e_{N_{CW}} = n' - \sum_{i=0}^{N_{CW}-1} e_i$ ;

3) if $N_{CW} > 15$:

$$e_i = \begin{cases} a + 1, i = 0, 1, \ldots, g - 1 \\ a, i = g, g + 1, \ldots, N_{CW} \end{cases} ,$$

where $a = \lfloor n'/(N_{CW} + 1) \rfloor$ , $g = n' - a \times (N_{CW} + 1)$ .

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g) Bits selection: the first element of $\bar{\mathbf{S}}_i$ is equal to the last element of $\bar{\mathbf{S}}_{(i-1)}$ plus 1, such as,

$$\bar{\mathbf{S}}_i = \left[f_0 + \sum_{j=0}^{i-1} e_j, f_0 + \sum_{j=0}^{i-1} e_j + 1, \ldots, f_0 + \sum_{j=0}^{i} e_j - 1\right],$$

where $f_0$ is the length of padding bits for the 0th codeword. Remove the zero padding bits and the punctured bits from $\mathbf{d}_i$ to obtain codeword $\mathbf{c}_i$, where $i = 0, 1, \ldots, N_{CW}-1$. The punctured-bit index set of parity data word $\mathbf{d}_{N_{CW}}$is

$$\bar{\mathbf{S}}_{N_{CW}} = \left[f_0 + \sum_{j=0}^{N_{CW}-1} e_j, f_0 + \sum_{j=0}^{N_{CW}-1} e_j + 1, \ldots, f_0 + \sum_{j=0}^{N_{CW}} e_j - 1\right].$$

Remove the padding-bit-generated bits and the punctured bits from $\mathbf{d}_{N_{CW}}$ to obtain $\mathbf{c}_{N_{CW}}$, where the padding-bit-generated bits are totally generated from the zero padding bits.

**Example of (#404)Data field encoding:**

The (#404)Data field contains *Length* = 512 octets. The parameter of LDPC: $n = 672$, $k = 336$, $R = 1/2$, $z = 42$.

a) $L_{DPCW} = k - 8 = 328$, the number of LDPC codeword: $N_{CW} = \lceil Length \times 8 / L_{DPCW} \rceil = 13$;

b) $L_{DPCW1} = \lceil Length \times 8 / N_{CW} \rceil = 316$, $N_{CW1} = \mathrm{mod}((Length \times 8), (L_{DPCW1} - 1)) = 1$,

$$L_i = \begin{cases} 316, i = 0 \\ 315, i = 1, 2, \ldots, 12 \end{cases};$$

that is, the number of data bits in the *0*th LDPC codeword is 316, and the 1st–12th LDPC codeword is 315.

c) The (#14)Data field is broken into $N_{CW} = 13$ blocks of data word. Each data word is added with 8 bits *CRC* sequence, see 25.3.6 (CRC calculation). Then padded with zero bits: the *0*th data word is padded with 12 bits and the 1st-12th data word are padded with 13 bits.

d) All the data words are encoded to obtain LDPC codeword $\mathbf{d}_i = (\mathbf{b}'_i, p_0^i, p_1^i, \ldots, p_{(n-k-1)}^i)$, $i = 0, 1, \ldots, 12$.

e) (#14)Data field encoding: Encoded with 1-bit parity check to create $\mathbf{d}_{13}$, length of 672 bits.

f) Bits selection parameter: because of $(N_{CW} = 13) \le 15$, $e_i = 42$, $i = 0, 1, \ldots, 12$, and $n' = n - f_0 = 672 - 12 = 660$, $e_{13} = 660 - \sum_{i=0}^{12} e_i = 114$.

Bits selection: Remove the zero padding bits [0, 1, …, 11] and the punctured bits $\bar{\mathbf{S}}_0 = [12, 13, \ldots, 53]$ from $\mathbf{d}_0$ to obtain codeword $\mathbf{c}_0$ with length of 618 bits; Remove the zero padding bits [0, 1, …, 12] and the punctured bits $\bar{\mathbf{S}}_1 = [54, 55, \ldots, 95]$ from $\mathbf{d}_1$ to obtain codeword $\mathbf{c}_1$ with length of 617 bits; the same operating to obtain $\mathbf{c}_2$, …, $\mathbf{c}_{12}$. Remove the padding-bit-generated bits [0, 1, …, 11] and the punctured bits $\bar{\mathbf{S}}_{13} = [558, 559, \ldots, 671]$ from $\mathbf{d}_{13}$ to obtain codeword $\mathbf{c}_{13}$ with length of 546 bits.

### 25.3.13 Received channel power indicator (RCPI) measurement

The RCPI is a measure of the received RF power in the selected channel for a received frame. This parameter shall be a (#1132)measurement by the PHY of the received RF power in the channel measured over the (#2011)STF or the CEF field of the received (#3474)PPDU.

RCPI shall equal the received RF power (#2011)in dBm with an accuracy of ± 5 dB (95% confidence interval) within the specified dynamic range of the receiver. The relative error between RF power measurements made within a one(#1154) second interval should be less than ± 1 dB.


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## 25.4 CMMG control mode

### 25.4.1 Introduction

Transmission and reception of the CMMG control mode PPDUs are mandatory. The CMMG control mode uses the same chip rate as the CMMG SC mode. The CMMG control mode is transmitted when the TXVECTOR indicates MCS 0. The modulation and coding scheme for the CMMG control mode is shown in Table 25-8 (Modulation and coding scheme for the CMMG control mode).

**Table 25-8—Modulation and coding scheme for the CMMG control mode**

| MCS index | Modulation | Code rate | Data rate |
|---|---|---|---|
| 0 | π/2-BPSK | 1/2 | 25.38 Mb/s for SF 13, 47.14 Mb/s for SF 11,<br>82.5 Mb/s for SF 4, and 330 Mb/s for no spreading |

### 25.4.2 PPDU format

(#3626)The CMMG control mode (#14)PPDU is shown in Figure 25-13 (CMMG control mode PPDU format).

**Figure 25-13—CMMG control mode PPDU format**

### 25.4.3 CMMG preamble transmission

In CMMG control mode preamble is transmitted using SC transmission (see 25.3.5 (CMMG PHY preamble)).

### 25.4.4 CMMG control mode SIG transmission

#### 25.4.4.1 General

The CMMG control mode SIG and data are modulated by π/2-BPSK and are spread by Barker sequences.

#### 25.4.4.2 Generation of CRC bits

The CRC sequence is calculated over bits 0–63 and uses CRC 16-CCITT as described in 25.3.6 (CRC calculation).

#### 25.4.4.3 Scrambler

The operation of the scrambler is defined in 25.3.7 (Scrambler). Bits $x_1, x_2, x_3, x_4, x_5, x_6, x_7$ of the scrambler shift register are initialized using the bits in the scrambler initialization bits from the SIG. The SIG is scrambled starting from bit 7.

#### 25.4.4.4 Encoding

See 25.3.9.2 (Encoding of SIG).

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#### 25.4.4.5 Modulation

The CMMG control mode SIG is modulated with π/2-BPSK modulation, the input bit stream is mapped according to the following equation $\tilde{s}_k = 2 \cdot c_k - 1$ . Each output symbol is then rotated according to the following equation: $s_k = \tilde{s}_k e^{(j\pi k)/2}$ .

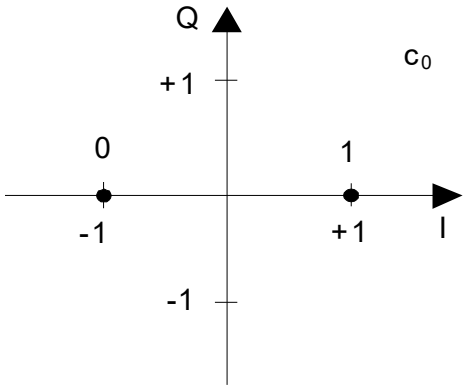


**Figure 25-14—Constellation bit encoding for BPSK**

#### 25.4.4.6 Spreading

The constellation points are spread using the Barker sequence Barker(*L*) defined as follows in Table 25-9 (The Barker(L) sequences), where *L* is the spreading length.

**Table 25-9—The Barker(*L*) sequences**

| Length *L* | Barker(*L*) sequences |
|---|---|
| 4 | +1,+1, –1,+1 |
| 7 | +1, +1, +1, −1, −1,+1, −1 |
| 13 | +1, +1, +1, +1, +1, −1, −1, +1, +1, −1, +1, −1, +1 |

The waveform for the modulated and spread (#404)Data field is

$$r_{DATA}(nT_C) = \left(\text{Barker}(n \bmod L)d\left(\left\lfloor \frac{n}{L} \right\rfloor\right)\right) \times \exp\left(j\pi\frac{n}{2}\right), n = 0, 1, 2, \ldots \quad (25\text{-}25)$$

where $d(k)$ is the modulated constellation point $k$ and $T_C$ is the SC chip time.

For CMMG control mode SIG, the spreading factor is always Barker(13).

### 25.4.5 CMMG control mode Data field

#### 25.4.5.1 General

The Data field consists of the payload data of the PSDU. The PSDU is scrambled, encoded, modulated, and spread as described in the following subclauses.


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#### 25.4.5.2 Scrambler

The operation of the scrambler is defined in 25.3.7 (Scrambler). The scrambling of the (#404)Data field continues the scrambling of the CMMG control mode SIG with no reset.

#### 25.4.5.3 Encoding

Use the LDPC of rate-1/2 and length 672. See 25.3.12 (Encoding of Data field).

#### 25.4.5.4 Modulation

See 25.4.4.5 (Modulation).

#### 25.4.5.5 Spreading

Spreading factor of CMMG control mode (#404)Data field is indicated in CMMG control mode SIG. See 25.4.4.6 (Spreading).

### 25.4.6 CMMG control mode performance requirements

#### 25.4.6.1 Transmit requirements

##### 25.4.6.1.1 Introduction

Transmitter performance requirements of the (#7168)CMMG control mode are defined in 25.4.6.1.2 (Transmit EVM).

##### 25.4.6.1.2 Transmit EVM

The transmit EVM accuracy test shall be performed by instrumentation capable of converting the transmitted signal into a stream of complex samples, with sufficient accuracy in terms of I/Q arm amplitude and phase balance, dc offsets, phase noise, etc. The instrumentation shall perform carrier lock, symbol timing recovery, and amplitude adjustment while making the measurements. The instrumentation shall incorporate a rake receiver or equalizer to reduce error resulting from multipath. If used, the equalizer shall be trained using information in the preamble (STF/CEF). For CMMG control mode EVM, the signal is first despread using the spreading Barker sequence, the EVM is then calculated on the resulting symbols according to Equation (25-26).(#315)

$$EVM = 20\log 10\left(\sqrt{\frac{1}{N_S P_{avg}}\sum_{i=1}^{N_S}[(I_i - I_i^*)^2 + (Q_i - Q_i^*)^2]}\right) \quad (25\text{-}26)$$

where $N_S$ is the number of samples to be measured and $N_S$ shall be 1000, $P_{ave}$ is the average power of the constellation, $(I_i, Q_i)$ is the complex coordinates of the measured symbol $i$, $(I_i^*, Q_i^*)$ is the complex coordinates of the ideal constellation point for the measured symbol $i$.

The test equipment should use a root-raised cosine filter with roll-off factor of 0.25 for the pulse shaping filter when conducting EVM measurement.

The transmit pulse shaping used is left to the implementer.

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The relative constellation error (EVM) shall not exceed an MCS dependent value according to Table 25-10 (EVM requirement for CMMG control mode(#7168)).

**Table 25-10—EVM requirement for CMMG control mode(#7168)**

| MCS index | Description | EVM value (dB) |
|---|---|---|
| 0 | (#7168)CMMG Control mode modulation | –6 |

### 25.4.6.2 Receive requirements

#### 25.4.6.2.1 Introduction

Subclause 25.4.6.2.2 (CCA) describes the performance requirement from the CMMG control mode receiver.

#### 25.4.6.2.2 CCA

The start of a CMMG control mode transmission at a receive level greater than the minimum sensitivity for CMMG control mode (–78 dBm) shall cause CCA to indicate busy with a probability > 90% within 3 μs.

## 25.5 CMMG SC mode

### 25.5.1 Introduction

Transmission and reception of CMMG SC mode PPDUs in MCSs 1 to 3 is mandatory. Transmission and reception of CMMG SC mode PPDUs with MIMO may be supported.

### 25.5.2 Transmitter block diagram

Figure 25-15 (Transmitter block diagram for CMMG SC mode SIG field(#7174)(#7170)(#6589)(#7214)) shows the transmit process for the CMMG SC mode SIG transmission. The actual structure of the transmitter is implementation dependent.

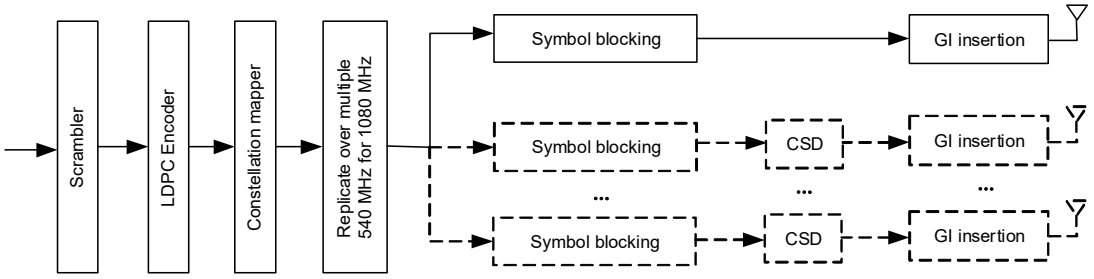


**Figure 25-15—Transmitter block diagram for CMMG SC mode SIG field(#7174)(#7170)(#6589)(#7214)**


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Figure 25-16 (Transmitter block diagram for Data fields of a CMMG SC mode PPDU(#14)(#404)) shows the transmit block used to generate the (#404)Data fields of 540 MHz and 1080 MHz using (#7168)CMMG SC mode transmission.

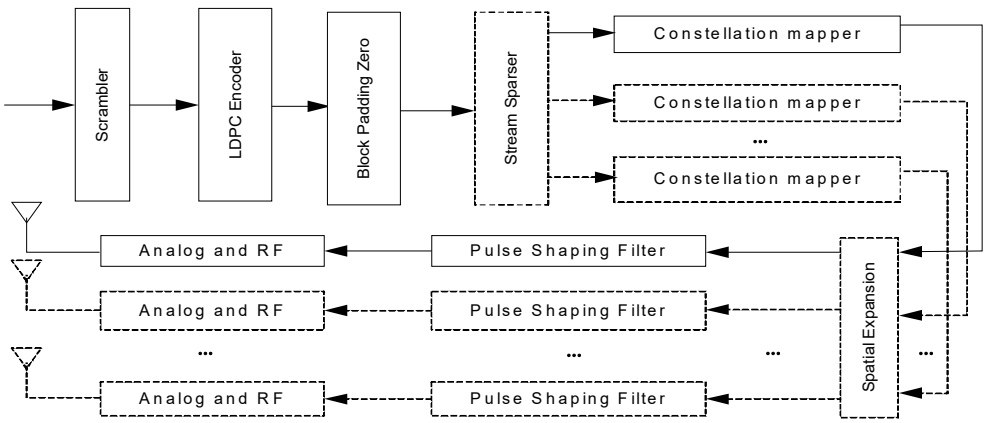


**Figure 25-16—Transmitter block diagram for Data fields of a CMMG SC mode PPDU(#14)(#404)**

NOTE—The operations denoted by the dotted line arrows and dotted line boxes in the above two figures are optional and are applied for SC MIMO transmission.

### 25.5.3 Overview of the PPDU encoding process

#### 25.5.3.1 General

This subclause provides an overview of the CMMG SC mode PPDU encoding process.

#### 25.5.3.2 Construction of CMMG SC mode SIG

The construction of the CMMG SC mode SIG field proceeds as follows:

a) Obtain the parameters from TXVECTOR. Add the reserved bits, append the calculated CRC. The calculation of the CRC of the CMMG SC mode SIG is described in 25.3.6 (CRC calculation).

b) Scrambler: Scramble the CMMG SC mode SIG bits. The scrambler is described in 25.3.7 (Scrambler).

c) LDPC encoder: The scrambled bits are encoded using the LDPC code as described in 25.5.5.4.2 (Encoding).

d) Constellation mapper: BPSK modulate the coded bits as described in 25.5.5.4.3 (Modulation) to form the transmitted symbol blocks of CMMG SC mode SIG.

e) Duplication and phase rotation: Apply the appropriate phase rotations for each 540 MHz subchannel as 25.5.5.4.4 (Duplication).

f) Symbol blocking: Divide the encoded SIG field into symbol block of length 256.

g) CSD: Apply CSD for each transmit chain as described in 25.5.5.4.5 (Symbol blocking, CSD, and GI insertion). This only applies to the CMMG SC mode MIMO mechanism.

h) GI insertion: Prepend a GI for each symbol block of length 256.

i) Pulse filter, Analog, and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit.

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NOTE—Conversion from the sampled digital domain to the continuous time domain is beyond the scope of this document. Filtering for pulse shaping such as in GMSK is beyond the scope of this standard.

#### 25.5.3.3 Construction of CMMG SC mode PPDUs

The construction of the (#404)Data field in a CMMG SC mode PPDU LDPC encoding proceeds as follows:

a) Scrambler: Scramble the PHY padded data.

b) LDPC encoder: The scrambled bits are encoded using the LDPC code as described in 25.3.12 (Encoding of Data field).

c) Blocking Padding Zero: Append the PHY pad bits to the PSDU as described in 25.5.6.4 (Symbol block padding zeros).

d) Stream parser: The output of the LDPC encoder is rearranged into blocks as described in 25.5.6.5 (Stream parser).

e) Constellation mapper: Map to π/2-BPSK, π/2-QPSK, π/2-16-QAM, or π/2-64-QAM constellation points as described in 25.5.6.6 (Constellation mapping).

f) Spatial Expansion: Apply the spatial expansion mechanism according to the combination of the number of the spatial streams and the number of the transmit antennas as described in 25.5.6.7 (Spatial expansion).

g) Pulse filter, Analog, and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit.

### 25.5.4 CMMG SC mode PPDU format

(#6552)The format of a CMMG SC mode PPDU is shown in Figure 25-17 (Format of CMMG SC mode PPDU) where the SCTF field is transmitted for 1080 MHz channel bandwidth.

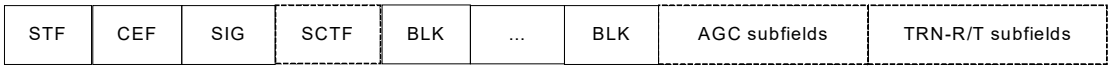


**Figure 25-17—Format of CMMG SC mode PPDU**

NOTE—The SCTF is only transmitted for 1080 MHz channel bandwidth and is composed of a ZCZ sequence of length 512. For MIMO transmission, different transmit antenna transmit a different preamble that is composed of one the four ZCZ sequences with the order of $Z_{512}^{1}, Z_{512}^{2}, Z_{512}^{3}, Z_{512}^{4}$ , such as for the case of one transmit antenna, the preamble sequence is composed of $Z_{512}^{1}$ , for the case of two transmit antennas, the preamble sequences are composed of $Z_{512}^{1}, Z_{512}^{2}$ , respectively.

### 25.5.5 CMMG SC mode SIG transmission

#### 25.5.5.1 SIG field

The CMMG SC mode SIG field carries information required to interpret PPDUs. The preamble and the CMMG SC mode SIG fields all are transmitted with SC mode modulation.

#### 25.5.5.2 Generation of the CRC bits of SIG

The calculation of the CRC of the CMMG SC mode SIG is described in 25.3.6 (CRC calculation).


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#### 25.5.5.3 Scrambler

The operation of the scrambler is defined in 25.3.7. Bits $x_1, x_2, x_3, x_4, x_5, x_6, x_7$ of the scrambler shift register are initialized using the bits in the scrambler initialization bits from the SIG. The CMMG SC mode SIG is scrambled starting from bit 7.

#### 25.5.5.4 Encoding and modulations

##### 25.5.5.4.1 General

The modulation and coding scheme defines the modulation and code rate that is used in the PPDU. The modulation and coding schemes are defined in 25.5.6.6 (Constellation mapping).

##### 25.5.5.4.2 Encoding

See 25.3.9.2 (Encoding of SIG).

##### 25.5.5.4.3 Modulation

See 25.4.4.5 (Modulation).

##### 25.5.5.4.4 Duplication

If the channel bandwidth is 1080 MHz, the modulated SIG symbols are transmitted in duplicate format as defined in 25.3.10 (CMMG duplication transmission on a 1080 MHz channel).

##### 25.5.5.4.5 Symbol blocking, CSD, and GI insertion

The modulated CMMG SC mode SIG symbols are divided into four symbols blocks of length 256. For each block, the cyclic shift values for the CMMG SC mode SIG field of the PPDU for transmit chain $i_{TX}$ out of a total of $N_{TX}$ are defined in Table 25-11 (Cyclic shift values for the CMMG SIG field).

**Table 25-11—Cyclic shift values for the CMMG SIG field**

| $T_{CS}^{i_{TX}}$ values for the CMMG-SIG field | | | | |
|---|---|---|---|---|
| Total number of transmit chains ($N_{TX}$) | Cyclic shift for transmit chain $i_{TX}$ (in units of ns) | | | |
| | 1 | 2 | 3 | 4 |
| 1 | 0 | — | — | — |
| 2 | 0 | $-128T_C$ | — | — |
| 3 | 0 | $-85T_C$ | $-170T_C$ | — |
| 4 | 0 | $-64T_C$ | $-128T_C$ | $-192T_C$ |

After the CSD operations, each group of 256 symbols is prepended by the last 64 symbols that form the cyclic prefix.

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### 25.5.6 Data field transmission

#### 25.5.6.1 General

The subclause describes the transmission of the SC (#404)Data field.

#### 25.5.6.2 Scrambler

The operation of the scrambler is defined in 25.3.7 (Scrambler). The scrambling of the Data field continues the scrambling of the CMMG SC mode SIG with no reset for CMMG SC mode transmission.

#### 25.5.6.3 Encoding

See 25.3.12 (Encoding of Data field).

#### 25.5.6.4 Symbol block padding zeros

The number of symbol blocks, $N_{BL}$, is calculated as follows:

$$N_{BL} = m_{SE}\left\lceil \frac{Length \times 8 + (8 + L_{CHECK}) \times N_{CW}}{m_{SE} N_{CBPB}} \right\rceil \quad (25\text{-}27)$$

where $L_{CHECK}$ is the number of LDPC parity bits, $m_{SE}$ values are listed in Table 25-12 (Values of mSE), and $N_{CBPB}$ values are shown in Table 25-13 (Values of NCBPB).

**Table 25-12—Values of $m_{SE}$**

| $N_{SS}$ | $N_{TX}$ | $m_{SE}$ |
|---|---|---|
| 1 | 1 | 1 |
| | 2 | 2 |
| | 3 | 3 |
| | 4 | 4 |
| 2 | 2 | 2 |
| | 3 | 4 |
| | 4 | 4 |
| 3 | 3 | 3 |
| | 4 | 6 |
| 4 | 4 | 4 |

**Table 25-13—Values of $N_{CBPB}$**

| Symbol mapping | $N_{CBPB}$ (540 MHz) | | $N_{CBPB}$ (1080 MHz) | |
|---|---|---|---|---|
| | Long GI | Short GI | Long GI | Short GI |
| π/2-BPSK | 192 | 224 | 384 | 448 |
| π/2-QPSK | 384 | 448 | 768 | 896 |


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**Table 25-13—Values of $N_{CBPB}$ *(continued)***

| Symbol mapping | $N_{CBPB}$ (540 MHz) | | $N_{CBPB}$ (1080 MHz) | |
|---|---|---|---|---|
| | Long GI | Short GI | Long GI | Short GI |
| π/2-16-QAM | 768 | 896 | 1536 | 1792 |
| π/2-64-QAM | 1152 | 1344 | 2304 | 2688 |

The number of padding 0s(M118) is given by

$$N_{BPAD} = N_{BL}N_{CBPB} - (Length \times 8 + (8 + L_{CHECK}) \times N_{CW}) \quad (25\text{-}28)$$

The PSDU is concatenated with $N_{BPAD}$ 0s. They are scrambled using the continuation of the scrambler sequence that scrambled the PSDU.

### 25.5.6.5 Stream parser

After coding and puncturing, the data bit streams at the output of the FEC encoder are processed in groups of $N_{CBPB}$. Each of these groups is rearranged into $N_{SS}$ blocks of $N_{CBPSS}$ bits.

The number of bits assigned to a single axis (real or imaginary) of a constellation point in a spatial stream is denoted by Equation (25-29).

$$s = \max\left\{1, \frac{N_{CBPS}}{2}\right\} \quad (25\text{-}29)$$

Consecutive blocks of $s$ bits are assigned to different spatial streams in a round robin fashion.

Bit $i$ at the output of encoder is assigned to input bit $k$ of spatial stream where

$$i = (i_{SS} - 1) \cdot s + N_{SS} \cdot s \cdot \left\lfloor \frac{k}{s} \right\rfloor + k \bmod s \quad (25\text{-}30)$$

where $i_{SS} = 1, 2, \ldots, N_{SS}$, $i = 0, 1, \ldots, N_{CBPB}-1$, $k = 0, 1, \ldots, N_{CBPSS}-1$.

### 25.5.6.6 Constellation mapping

The modulation and coding scheme (MCS) field specifies the modulation and code rate used in the PPDU.

A CMMG STA shall support all equal modulation (EQM) rates for one spatial stream (MCSs 1 to 3). MCSs 4 to 8 are optional.

The coded and padded bit stream is converted into a stream of complex constellation points according to the modulation specified in the MCS table.

In π/2-BPSK modulation, the input bit stream is mapped according to the following equation:

$$\tilde{s}_k = 2 \cdot c_k - 1$$

where $c_k$ is the $k^{\text{th}}$ input coded (or scrambled pad) bit. Each output symbol is then rotated according to the following equation:

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$$s_k = \tilde{s}_k e^{(j\pi k)/2}$$

NOTE—With appropriate choice of transmit filtering, π/2-BPSK is equivalent to a precoded pulse-shaped MSK (e.g., GMSK). The precoder is simply $b_{out,k} = b_{in,k} \oplus b_{in,k-1}$, where $b_{in,k}$ is the scrambled input stream, $b_{in,-1}$ is 0, and $b_{out,k}$ is the input to the (G)MSK modulator.

In π/2-QPSK modulation (see Figure 25-18 (QPSK constellation bit encoding)), the input bit stream is mapped according to the following equation:

$$\tilde{s}(k) = \frac{1}{\sqrt{2}}((2c_{2k}-1)+j(2c_{2k+1}-1))\exp\left(-j\frac{\pi}{4}\right)$$

where $k$ is the output symbol index, $k$ = 0, 1, …. Each output symbol is then rotated according to the following equation:

$$s_k = \tilde{s}_k e^{(j\pi k)/2}$$

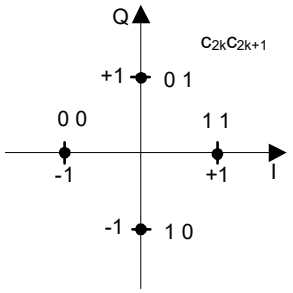


**Figure 25-18—QPSK constellation bit encoding**

In π/2-16-QAM modulation (see Figure 25-19 (16-QAM constellation bit encoding)), the input bit stream is mapped according to the following equation:

$$\tilde{s}_k = \frac{1}{\sqrt{10}}\{(4c_{4k}-2)-(2c_{4k}-1)(2c_{4k+1}-1)+j(4c_{4k+2}-2)-j(2c_{4k+2}-1)(2c_{4k+3}-1)\} \quad (25\text{-}31)$$

where $k$ is the output symbol index, $k$ = 0, 1, …. Each output symbol is then rotated according to the following equation:


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$$s_k = \tilde{s}_k e^{(j\pi k)/2}$$

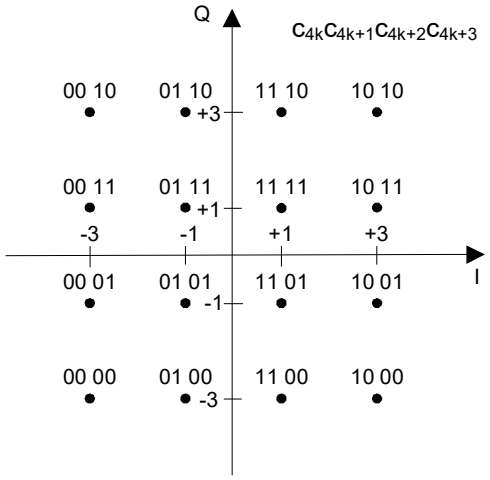


**Figure 25-19—16-QAM constellation bit encoding**

In π/2-64-QAM modulation (see Figure 25-20 (64-QAM constellation bit encoding)), the input bit stream is mapped according to the following equation:

$$\begin{aligned}\tilde{s}_k = {} & \frac{1}{\sqrt{42}}((8c_{6k}-4)-(2c_{6k}-1)(4c_{6k+1}-2)+(2c_{6k}-1)(2c_{6k+1}-1)(2c_{6k+2}-1)) \\ & + j\frac{1}{\sqrt{42}}((8c_{6k+3}-4)-(2c_{6k+3}-1)(4c_{6k+4}-2)+(2c_{6k+3}-1)(2c_{6+4}-1)(2c_{6k+5}-1))\end{aligned} \quad (25\text{-}32)$$

where $k$ is the output symbol index, $k$ = 0, 1, …. Each output symbol is then rotated according to the following equation:

$$s_k = \tilde{s}_k e^{(j\pi k)/2}$$

### 25.5.6.7 Spatial expansion

Each spatial stream is divided into many subblocks that each subblock includes $N_{DSPB}$ constellation symbols. Values of $N_{DSPB}$ and $N_{UWPB}$ are shown in Table 25-14 (Values of NDSPB and NUWPB(#7171)).

**Table 25-14—Values of $N_{DSPB}$ and $N_{UWPB}$(#7171)**

| | $N_{CBPB}$ (CBW540) | | $N_{CBPB}$ (CBW1080) | |
|---|---|---|---|---|
| | **Long GI** | **Short GI** | **Long GI** | **Short GI** |
| $N_{DSPB}$ | 192 | 224 | 384 | 448 |
| $N_{UWPB}$ | 64 | 32 | 128 | 64 |

The spatial stream of complex numbers, $\mathbf{d}_{i,n}$, $i$ = 1, …, $N_{SS}$, $n$ = 0, 1, …, $N_{BL}$–1, is the input to the spatial expansion module, which produces as output the stream of complex numbers $\mathbf{x}_{i_{TXT},n}$, $i_{TXT}$ = 1, …, $N_{TXT}$. The relation between the spatial streams and the output streams is given in Table 25-15 (Constellation map-

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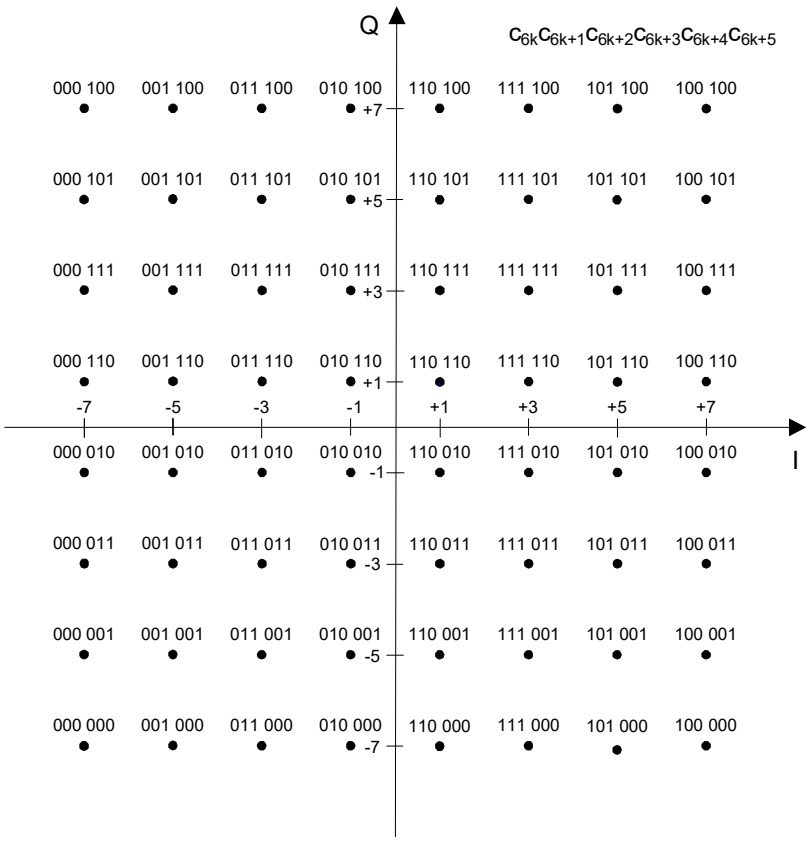


**Figure 25-20—64-QAM constellation bit encoding**

per output to spatial mapper input) where $\mathbf{x}_{i_{TXT},n} = (\tilde{\mathbf{x}}_{i_{TXT},n})^T$, $\tilde{\mathbf{d}}_{i,n} = [\mathbf{d}_{i,n}, \mathbf{0}_{1\times N_{UWPB}}]^T$, $\tilde{\mathbf{u}}_{i_{TXT}} = \left[\mathbf{0}_{1\times N_{DSPB}}, Z_{N_{UWPB}}^{i_{TXT}}\right]^T$, and $\mathbf{Q}_{N_{BLS}}$ is defined as

$$\mathbf{Q}_{N_{BLS}} = \begin{bmatrix} \mathbf{Q}_1 & \mathbf{Q}_2 \\ \mathbf{Q}_3 & \mathbf{Q}_4 \end{bmatrix} \tag{25-33}$$

where $\mathbf{Q}_2 = \mathbf{0}_{N_{DSPB}\times N_{UWPB}}$, $\mathbf{Q}_3 = \mathbf{0}_{N_{UWPB}\times N_{DSPB}}$, and

$$\mathbf{Q}_1 = \begin{bmatrix} 0 & 0 & 0 & \dots & 0 & 0 & 1 \\ 0 & 0 & 0 & \dots & 0 & 1 & 0 \\ \dots & \dots & \dots & \dots & \dots & \dots & \dots \\ 0 & 1 & 0 & \dots & 0 & 0 & 0 \\ 1 & 0 & 0 & \dots & 0 & 0 & 0 \end{bmatrix}_{N_{DSPB}\times N_{DSPB}}, \mathbf{Q}_4 = \begin{bmatrix} 0 & 0 & 0 & \dots & 0 & 0 & 1 \\ 0 & 0 & 0 & \dots & 0 & 1 & 0 \\ \dots & \dots & \dots & \dots & \dots & \dots & \dots \\ 0 & 1 & 0 & \dots & 0 & 0 & 0 \\ 1 & 0 & 0 & \dots & 0 & 0 & 0 \end{bmatrix}_{N_{UWPB}\times N_{UWPB}} \tag{25-34}$$

The starting index for the first symbol for π/2 rotation is 0. If the Additional PPDU field within the SIG field is equal to 0, the same ZCZ sequence guard interval is prepended to the first block transmitted. If the


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Additional PPDU field within the SIG field is equal to 1, the same ZCZ sequence guard interval is prepended to the first block transmitted. See Figure 25-21 (Block transmission).

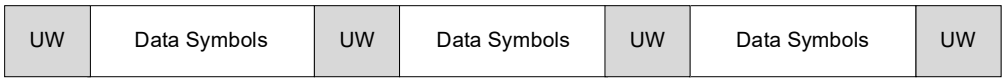


**Figure 25-21—Block transmission**

**Table 25-15—Constellation mapper output to spatial mapper input**

| Index | $N_{SS}$ | $N_{TXT}$ | $i_{TXT}$ | $\tilde{\mathbf{x}}_{i_{TXT},2^a m}$ | $\tilde{\mathbf{x}}_{i_{TXT},2^a m+1}$ | $\tilde{\mathbf{x}}_{i_{TXT},2^a m+2}$ | $\tilde{\mathbf{x}}_{i_{TXT},2^a m+3}$ |
|---|---|---|---|---|---|---|---|
| 1 | 1 | 1 | 1 | $\tilde{\mathbf{d}}_{1,2^a m}+\tilde{\mathbf{u}}_{i_{TXT}}$ | $\tilde{\mathbf{d}}_{1,2^a m+1}+\tilde{\mathbf{u}}_{i_{TXT}}$ | — | — |
| 2 | | 2 | 1 | $\tilde{\mathbf{d}}_{1,2^a m}+\tilde{\mathbf{u}}_{i_{TXT}}$ | $-\mathbf{Q}_{N_{BLS}}\tilde{\mathbf{d}}^{*}_{1,2^a m+1}+\tilde{\mathbf{u}}_{i_{TXT}}$ | — | — |
| | | | 2 | $\tilde{\mathbf{d}}_{1,2^a m+1}+\tilde{\mathbf{u}}_{i_{TXT}}$ | $\mathbf{Q}_{N_{BLS}}\tilde{\mathbf{d}}^{*}_{1,2^a m}+\tilde{\mathbf{u}}_{i_{TXT}}$ | — | — |
| 3 | | 3 | 1 | $\tilde{\mathbf{d}}_{1,3m}+\tilde{\mathbf{u}}_{i_{TXT}}$ | $\mathbf{Q}_{N_{BLS}}\tilde{\mathbf{d}}^{*}_{1,3m+1}+\tilde{\mathbf{u}}_{i_{TXT}}$ | $\mathbf{Q}_{N_{BLS}}\tilde{\mathbf{d}}^{*}_{1,3m+2}+\tilde{\mathbf{u}}_{i_{TXT}}$ | $\mathbf{0}$ |
| | | | 2 | $-\tilde{\mathbf{d}}_{1,3m+1}+\tilde{\mathbf{u}}_{i_{TXT}}$ | $\mathbf{Q}_{N_{BLS}}\tilde{\mathbf{d}}^{*}_{1,3m}+\tilde{\mathbf{u}}_{i_{TXT}}$ | $\mathbf{0}$ | $-\mathbf{Q}_{N_{BLS}}\tilde{\mathbf{d}}^{*}_{1,3m+2}+\tilde{\mathbf{u}}_{i_{TXT}}$ |
| | | | 3 | $-\tilde{\mathbf{d}}_{1,3m+2}+\tilde{\mathbf{u}}_{i_{TXT}}$ | $\mathbf{0}$ | $\mathbf{Q}_{N_{BLS}}\tilde{\mathbf{d}}^{*}_{1,3m}+\tilde{\mathbf{u}}_{i_{TXT}}$ | $\mathbf{Q}_{N_{BLS}}\tilde{\mathbf{d}}^{*}_{1,3m+1}+\tilde{\mathbf{u}}_{i_{TXT}}$ |
| 4 | | 4 | 1 | $\tilde{\mathbf{d}}_{1,2^a m}+\tilde{\mathbf{u}}_{i_{TXT}}$ | $-\mathbf{Q}_{N_{BLS}}\tilde{\mathbf{d}}^{*}_{1,2^a m+1}+\tilde{\mathbf{u}}_{i_{TXT}}$ | $-\mathbf{Q}_{N_{BLS}}\tilde{\mathbf{d}}^{*}_{1,2^a m+2}+\tilde{\mathbf{u}}_{i_{TXT}}$ | $\tilde{\mathbf{d}}_{1,2^a m+3}+\tilde{\mathbf{u}}_{i_{TXT}}$ |
| | | | 2 | $\tilde{\mathbf{d}}_{1,2^a m+1}+\tilde{\mathbf{u}}_{i_{TXT}}$ | $\mathbf{Q}_{N_{BLS}}\tilde{\mathbf{d}}^{*}_{1,2^a m}+\tilde{\mathbf{u}}_{i_{TXT}}$ | $-\mathbf{Q}_{N_{BLS}}\tilde{\mathbf{d}}^{*}_{1,2^a m+3}+\tilde{\mathbf{u}}_{i_{TXT}}$ | $-\tilde{\mathbf{d}}_{1,2^a m+2}+\tilde{\mathbf{u}}_{i_{TXT}}$ |
| | | | 3 | $\tilde{\mathbf{d}}_{1,2^a m+2}+\tilde{\mathbf{u}}_{i_{TXT}}$ | $-\mathbf{Q}_{N_{BLS}}\tilde{\mathbf{d}}^{*}_{1,2^a m+3}+\tilde{\mathbf{u}}_{i_{TXT}}$ | $\mathbf{Q}_{N_{BLS}}\tilde{\mathbf{d}}^{*}_{1,2^a m}+\tilde{\mathbf{u}}_{i_{TXT}}$ | $-\tilde{\mathbf{d}}_{1,2^a m+1}+\tilde{\mathbf{u}}_{i_{TXT}}$ |
| | | | 4 | $\tilde{\mathbf{d}}_{1,2^a m+3}+\tilde{\mathbf{u}}_{i_{TXT}}$ | $\mathbf{Q}_{N_{BLS}}\tilde{\mathbf{d}}^{*}_{1,2^a m+2}+\tilde{\mathbf{u}}_{i_{TXT}}$ | $\mathbf{Q}_{N_{BLS}}\tilde{\mathbf{d}}^{*}_{1,2^a m+1}+\tilde{\mathbf{u}}_{i_{TXT}}$ | $\tilde{\mathbf{d}}_{1,2^a m}+\tilde{\mathbf{u}}_{i_{TXT}}$ |
| 5 | 2 | 2 | 1 | $\tilde{\mathbf{d}}_{1,2^a m}+\tilde{\mathbf{u}}_{i_{TXT}}$ | $\tilde{\mathbf{d}}_{1,2^a m+1}+\tilde{\mathbf{u}}_{i_{TXT}}$ | — | — |
| | | | 2 | $\tilde{\mathbf{d}}_{2,2^a m}+\tilde{\mathbf{u}}_{i_{TXT}}$ | $\tilde{\mathbf{d}}_{2,2^a m+1}+\tilde{\mathbf{u}}_{i_{TXT}}$ | — | — |
| 6 | | 3 | 1 | $\tilde{\mathbf{d}}_{1,2^a m}+\tilde{\mathbf{u}}_{i_{TXT}}$ | $-\mathbf{Q}_{N_{BLS}}\tilde{\mathbf{d}}^{*}_{1,2^a m+1}+\tilde{\mathbf{u}}_{i_{TXT}}$ | — | — |
| | | | 2 | $\tilde{\mathbf{d}}_{1,2^a m+1}+\tilde{\mathbf{u}}_{i_{TXT}}$ | $\mathbf{Q}_{N_{BLS}}\tilde{\mathbf{d}}^{*}_{1,2^a m}+\tilde{\mathbf{u}}_{i_{TXT}}$ | — | — |
| | | | 3 | $\tilde{\mathbf{d}}_{2,2^a m}+\tilde{\mathbf{u}}_{i_{TXT}}$ | $\mathbf{Q}_{N_{BLS}}\tilde{\mathbf{d}}^{*}_{2,2^a m+1}+\tilde{\mathbf{u}}_{i_{TXT}}$ | — | — |
| 7 | | 4 | 1 | $\tilde{\mathbf{d}}_{1,2^a m}+\tilde{\mathbf{u}}_{i_{TXT}}$ | $-\mathbf{Q}_{N_{BLS}}\tilde{\mathbf{d}}^{*}_{1,2^a m+1}+\tilde{\mathbf{u}}_{i_{TXT}}$ | — | — |
| | | | 2 | $\tilde{\mathbf{d}}_{1,2^a m+1}+\tilde{\mathbf{u}}_{i_{TXT}}$ | $\mathbf{Q}_{N_{BLS}}\tilde{\mathbf{d}}^{*}_{1,2^a m}+\tilde{\mathbf{u}}_{i_{TXT}}$ | — | — |
| | | | 3 | $\tilde{\mathbf{d}}_{2,2^a m}+\tilde{\mathbf{u}}_{i_{TXT}}$ | $-\mathbf{Q}_{N_{BLS}}\tilde{\mathbf{d}}^{*}_{2,2^a m+1}+\tilde{\mathbf{u}}_{i_{TXT}}$ | — | — |
| | | | 4 | $\tilde{\mathbf{d}}_{2,2^a m+1}+\tilde{\mathbf{u}}_{i_{TXT}}$ | $\mathbf{Q}_{N_{BLS}}\tilde{\mathbf{d}}^{*}_{2,2^a m}+\tilde{\mathbf{u}}_{i_{TXT}}$ | — | — |

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**Table 25-15—Constellation mapper output to spatial mapper input *(continued)***

| Index | $N_{SS}$ | $N_{TXT}$ | $i_{TXT}$ | $\tilde{\mathbf{x}}_{i_{TXT},2^a m}$ | $\tilde{\mathbf{x}}_{i_{TXT},2^a m+1}$ | $\tilde{\mathbf{x}}_{i_{TXT},2^a m+2}$ | $\tilde{\mathbf{x}}_{i_{TXT},2^a m+3}$ |
|---|---|---|---|---|---|---|---|
| 8 | 3 | 3 | 1 | $\tilde{\mathbf{d}}_{1,2^a m}+\tilde{\mathbf{u}}_{i_{TXT}}$ | $\tilde{\mathbf{d}}_{1,2^a m+1}+\tilde{\mathbf{u}}_{i_{TXT}}$ | — | — |
| | | | 2 | $\tilde{\mathbf{d}}_{2,2^a m}+\tilde{\mathbf{u}}_{i_{TXT}}$ | $\tilde{\mathbf{d}}_{2,2^a m+1}+\tilde{\mathbf{u}}_{i_{TXT}}$ | — | — |
| | | | 3 | $\tilde{\mathbf{d}}_{3,2^a m}+\tilde{\mathbf{u}}_{i_{TXT}}$ | $\mathbf{d}_{3,2^a m+1}+\tilde{\mathbf{u}}_{i_{TXT}}$ | — | — |
| 9 | | 4 | 1 | $\tilde{\mathbf{d}}_{1,2^a m}+\tilde{\mathbf{u}}_{i_{TXT}}$ | $-\mathbf{Q}_{N_{BLS}}\tilde{\mathbf{d}}^{*}_{1,2^a m+1}+\tilde{\mathbf{u}}_{i_{TXT}}$ | — | — |
| | | | 2 | $\tilde{\mathbf{d}}_{1,2^a m+1}+\tilde{\mathbf{u}}_{i_{TXT}}$ | $\mathbf{Q}_{N_{BLS}}\tilde{\mathbf{d}}^{*}_{1,2^a m}+\tilde{\mathbf{u}}_{i_{TXT}}$ | — | — |
| | | | 3 | $\tilde{\mathbf{d}}_{2,2^a m}+\tilde{\mathbf{u}}_{i_{TXT}}$ | $\mathbf{Q}_{N_{BLS}}\tilde{\mathbf{d}}_{2,2^a m+1}+\tilde{\mathbf{u}}_{i_{TXT}}$ | — | — |
| | | | 4 | $\tilde{\mathbf{d}}_{3,2^a m}+\tilde{\mathbf{u}}_{i_{TXT}}$ | $\mathbf{Q}_{N_{BLS}}\tilde{\mathbf{d}}_{3,2^a m+1}+\tilde{\mathbf{u}}_{i_{TXT}}$ | — | — |
| 10 | 4 | 4 | 1 | $\tilde{\mathbf{d}}_{1,2^a m}+\tilde{\mathbf{u}}_{i_{TXT}}$ | $\tilde{\mathbf{d}}_{1,2^a m+1}+\tilde{\mathbf{u}}_{i_{TXT}}$ | — | — |
| | | | 2 | $\tilde{\mathbf{d}}_{2,2^a m}+\tilde{\mathbf{u}}_{i_{TXT}}$ | $\tilde{\mathbf{d}}_{2,2^a m+1}+\tilde{\mathbf{u}}_{i_{TXT}}$ | — | — |
| | | | 3 | $\tilde{\mathbf{d}}_{3,2^a m}+\tilde{\mathbf{u}}_{i_{TXT}}$ | $\tilde{\mathbf{d}}_{3,2^a m+1}+\tilde{\mathbf{u}}_{i_{TXT}}$ | — | — |
| | | | 4 | $\tilde{\mathbf{d}}_{4,2^a m}+\tilde{\mathbf{u}}_{i_{TXT}}$ | $\tilde{\mathbf{d}}_{4,2^a m+1}+\tilde{\mathbf{u}}_{i_{TXT}}$ | — | — |

NOTE 1—$a = 2$, for $N_{SS} = 1$ and $N_{TXT} = 4$; otherwise, $a = 1$.
NOTE 2—* indicates conjugate operation.

#### 25.5.6.8 Duplication transmission

When the TXVECTOR parameter DUPLICATE_MODULATION is present, the transmitted PPDU is a duplicate. The modulated data symbols are duplicated as described in 25.3.10 (CMMG duplication transmission on a 1080 MHz channel).

### 25.5.7 Performance requirements

#### 25.5.7.1 Transmit requirements

#### 25.5.7.1.1 Introduction

Transmitter performance requirements of the (#7168)CMMG SC mode are defined in 25.5.7.1.2 (Transmit EVM).

#### 25.5.7.1.2 Transmit EVM

The transmit EVM accuracy test shall be performed by instrumentation capable of converting the transmitted signal into a stream of complex samples, with sufficient accuracy in terms of I/Q arm amplitude and phase balance, DC offsets, phase noise, etc.

The instrumentation shall perform carrier lock, symbol timing recovery, amplitude adjustment, and equalization while making the measurements. The equalizer shall be trained using information in the CMMG SC mode preamble (STF/CEF). For the CMMG SC mode EVM, measuring samples at the sample rate, the measured symbols should not contain the first and the last hundred symbols of a given (#14)PPDU (ramp up/down). The EVM is calculated according to the formula below(#315):


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$$EVM = 20\log 10\left(\sqrt{\left(\frac{1}{N_s P_{avg}}\sum_{i=1}^{N_S}[(I_i - I_i^* - I_0)^2 + (Q_i - Q_i^* - Q_0)^2]\right)}\right)$$

$$EVM = 20\log 10\left(\sqrt{\left(\frac{1}{N_s P_{avg}}\sum_{i=1}^{N_S}[(I_i - I_i^* - I_0)^2 + (Q_i - Q_i^* - Q_0)^2]\right)}\right) \quad (25\text{-}35)$$

where

$N_S$ is the number of samples to be measured and $N_S$ should be 1000

$P_{avg}$ is the average power of the constellation

$(I_i, Q_i)$ is the complex coordinates of the measured symbol $i$

$(I_i^*, Q_i^*)$ is the complex coordinates of the ideal constellation point for the measured symbol $i$

$(I_0, Q_0)$ is the complex DC term chosen to reduce EVM

The test equipment should use a root-raised cosine filter with roll-off factor of 0.25 for the pulse shaping filter when conducting EVM measurement.

The transmit pulse shaping used is left to the implementer.

The relative constellation error (EVM) shall not exceed an MCS dependent value according to Table 25-16 (EVM requirements for CMMG SC mode(#7168)).

**Table 25-16—EVM requirements for CMMG SC mode(#7168)**

| CMMG-MCS indices(#4136) | Modulation | Coding rate | EVM value (dB) |
|---|---|---|---|
| 1 | π/2-BPSK | 1/2 | –7 |
| 2 | π/2-QPSK | 1/2 | –11 |
| 3 | π/2-QPSK | 3/4 | –13 |
| 4 | π/2-16-QAM | 1/2 | –19 |
| 5 | π/2-16-QAM | 3/4 | –21 |
| 6 | π/2-64-QAM | 5/8 | –25 |
| 7 | π/2-64-QAM | 3/4 | –26 |
| 8 | π/2-64-QAM | 13/16 | –28 |

#### 25.5.7.1.3 Time of Departure accuracy

(#8054)The RMS accuracy of the time of departure provided in TIME_OF_DEPARTURE shall be less than or equal to 80 ns.

The Time of Departure accuracy test evaluates TIME_OF_DEPARTURE against aTxPHYTxStartRMS and aTxPHYTxStartRMS against TIME_OF_DEPARTURE_ACCURACY_TEST_THRESH as defined in Annex P with the following test parameters:

— (#385)MULTICHANNEL_SAMPLING_RATE is $440\times10^6$ sample/s for a 540 MHz channel and $880\times10^6$ sample/s for a 1080 MHz channel.

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— (#385)FIRST_TRANSITION_FIELD is Short Training field.
— (#385)SECOND_TRANSITION_FIELD is Channel Estimation field.
— (#385)TRAINING_FIELD is Channel Estimation field.
— TIME_OF_DEPARTURE_ACCURACY_TEST_THRESH is 80 ns

NOTE—The indicated windowing applies to the time of departure accuracy test equipment, and not the transmitter or receiver.

#### 25.5.7.2 Receive requirements

##### 25.5.7.2.1 Introduction

This subclause describes the receiver requirements of the CMMG SC mode.

##### 25.5.7.2.2 CCA

The start of a CMMG SC mode transmission at a receive level greater than the minimum sensitivity for MCS 0 (–81 dBm for 540 MHz, –78 dBm for 1080 MHz) shall cause CCA to indicate busy with a probability > 90% within 1 μs. The receiver shall hold the carrier sense signal busy for any signal 20 dB above the minimum sensitivity for MCS 0.

## 25.6 CMMG OFDM mode

### 25.6.1 Introduction

Transmission and reception of (#7168)CMMG OFDM mode PPDUs are optional.

### 25.6.2 CMMG OFDM mode PPDU format

(#6552)The format of a CMMG OFDM mode PPDU (#14)is shown in Figure 25-22 (Format of the CMMG OFDM mode PPDU).

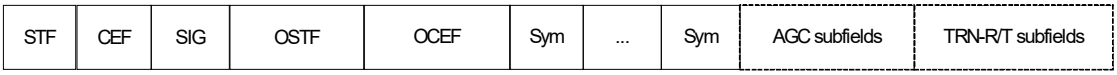


**Figure 25-22—Format of the CMMG OFDM mode PPDU**


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### 25.6.3 Transmission block diagram

Figure 25-23 (Transmitter block diagram for CMMG OFDM mode SIG fields(#6589)) shows the transmit process for the CMMG OFDM mode SIG transmission. The actual structure of the transmitter is implementation dependent.

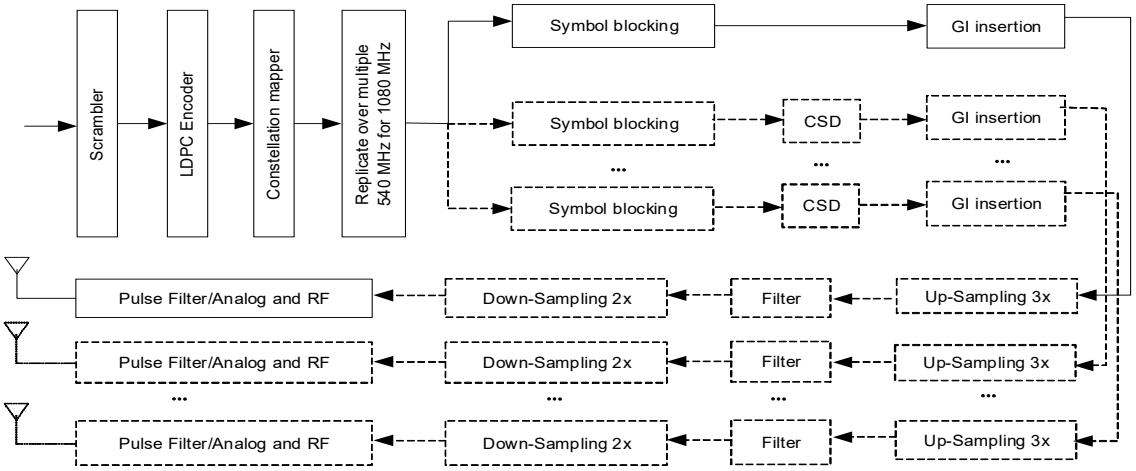


**Figure 25-23—Transmitter block diagram for CMMG OFDM mode SIG fields(#6589)**

Figure 25-24 (Transmitter block diagram for the Data field of CMMG OFDM mode(#404)) shows the transmitter blocks used to generate the Data field of OFDM mode PPDU with LDPC encoding.

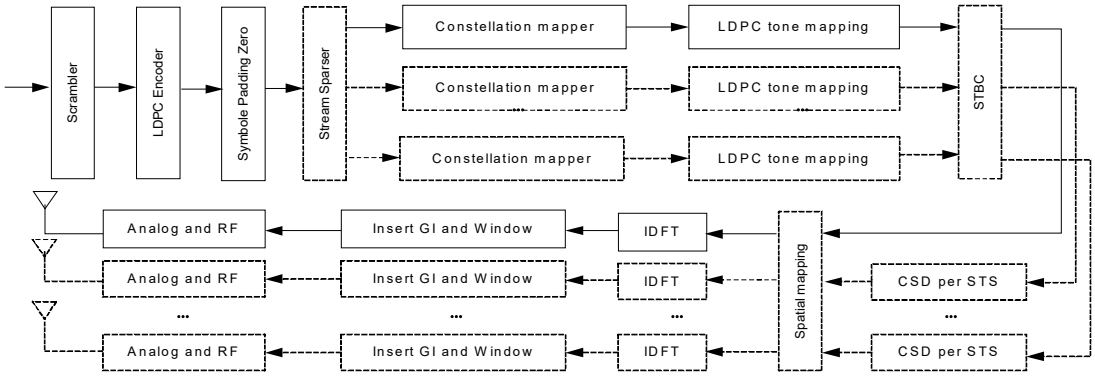


**Figure 25-24—Transmitter block diagram for the Data field of CMMG OFDM mode(#404)**

NOTE—The operation denoted by the dotted line arrows and dotted line boxes in the above two figures are optional and are applied for OFDM MIMO transmission.

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### 25.6.4 Overview of CMMG OFDM mode PPDU encoding process

#### 25.6.4.1 General

This subclause provides an overview of the CMMG OFDM mode PPDU encoding process.

#### 25.6.4.2 Construction of CMMG OFDM mode SIG

The construction of the CMMG OFDM mode SIG field proceeds as follows:

a) Obtain the parameters from TXVECTOR. Add the reserved bits, append the calculated CRC. The calculation of the CRC of the CMMG OFDM mode SIG is described in 25.3.6 (CRC calculation).

b) Scrambler: Scramble the CMMG OFDM mode SIG bits. The Scrambler is described in 25.3.7 (Scrambler).

c) LDPC encoder: The scrambled bits are encoded using the LDPC code as described in 25.5.5.4.2 (Encoding).

d) Constellation mapper: BPSK modulate the coded bits as described in 25.5.5.4.3 (Modulation) to form the transmitted symbol blocks of CMMG PHY SIG.

e) Duplication and phase rotation: Apply the appropriate phase rotations for each 540 MHz subchannel as 25.5.5.4.4 (Duplication).

f) CSD: Apply CSD for each transmit chain as described in 25.5.5.4.5 (Symbol blocking, CSD, and GI insertion). This is need only for the CMMG OFDM MIMO mechanism.

g) Symbol blocking and GI insertion: Prepend a GI and generate the transmission symbol block.

h) Upsampling, filtering, and downsampling: Sample rate change in CMMG OFDM mode transmission as described in 25.6.5.4 (Symbol blocking, CSD, and GI insertion). This only applies to the CMMG OFDM mode MIMO mechanism.

i) Pulse filter, Analog, and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit.

NOTE—Conversion from the sampled digital domain to the continuous time domain is beyond the scope of this document. Filtering for pulse shaping such as in GMSK is beyond the scope of this standard.

#### 25.6.4.3 Construction of CMMG OFDM mode PPDU

The construction of the Data field in a (#7168)CMMG OFDM mode PPDU with LDPC encoding proceeds as follows:

a) Scrambler: Scramble the PHY padded data. The scrambler is described in 25.3.7 (Scrambler).

b) LDPC encoder: The scrambled bits are encoded using the LDPC code with the APEP_LENGTH in the TXVECTOR as described in 25.6.8.3 (Encoding).

c) Stream parser: The output of the LDPC encoder is rearranged into blocks as described in 25.6.8.5 (Stream parser).

d) Constellation mapper: Map to BPSK, QPSK, 16-QAM, or 64-QAM constellation points as described in 25.6.8.6 (Subcarrier modulation mapping).

e) LDPC tone mapper: The LDPC tone mapping shall be performed on all LDPC encoded streams as described in 25.6.8.7 (Tone mapping).

f) OFDM symbol padding 0s(M118): Append the CMMG OFDM mode pad bits to the PSDU as described in 25.6.8.4 (OFDM symbol padding 0s(M118)).

g) STBC: Apply STBC as described in 25.6.8.8 (Space-time block coding).

h) Pilot insertion: Insert pilots following the steps described in 25.6.8.9 (Pilot subcarriers).


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i) CSD: Apply CSD for each space-time stream as described in 25.6.8.10 (Cyclic shift diversity (CSD) for CMMG OFDM mode Data fields transmission(#7168)(#404)).

j) Spatial mapping: Apply the **Q** matrix as described in 25.6.8.11 (OFDM modulation).

k) Phase rotation: Apply the appropriate phase rotations for each 540 MHz subchannel as described in 25.3.4.4 (Definition of tone rotation for CMMG OFDM mode transmission(#7168)).

l) IDFT: Compute the inverse discrete Fourier transform.

m) Insert GI and apply windowing: Prepend a GI and apply windowing.

n) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit.

#### 25.6.4.4 Construction of OSTF

The OSTF is defined in 25.6.6 (OSTF definition) and is constructed as follows:

a) Sequence generation: Generate the OSTF in the frequency-domain over the bandwidth indicated by CH_BANDWIDTH as described in 25.6.6 (OSTF definition).

b) Phase rotation: Apply appropriate phase rotation for each 540 MHz subchannel as described in 25.3.4.3 (Transmitted signal) and 25.3.4.4 (Definition of tone rotation for CMMG OFDM mode transmission(#7168)).

c) CSD: Apply CSD for each space-time stream and frequency segment as described in 25.6.8.10 (Cyclic shift diversity (CSD) for CMMG OFDM mode Data fields transmission(#7168)(#404)).

d) Spatial mapping: Apply the **Q** matrix as described in 25.6.8.11 (OFDM modulation).

e) IDFT: Compute the inverse discrete Fourier transform.

f) Insert GI and apply windowing: Prepend a GI (LONG_GI) and apply windowing as described in 25.3.4.3 (Transmitted signal).

g) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit. Refer to 25.3.4.3 (Transmitted signal) and 25.6.6 (OSTF definition) for details.

#### 25.6.4.5 Construction of OCEF

The OCEF is defined in 25.6.7 (OCEF definition) and constructed as follows:

a) Sequence generation: Generate the OCEF sequence in the frequency-domain over the bandwidth indicated by CH_BANDWIDTH as described in 25.6.7 (OCEF definition).

b) Phase rotation: Apply appropriate phase rotation for each 540 MHz subchannel as described in 25.3.4.3 (Transmitted signal) and 25.3.4.4 (Definition of tone rotation for CMMG OFDM mode transmission(#7168)).

c) Matrix mapping: Apply the matrix to the OCEF sequence and apply the matrix to the pilot tones as described in 25.6.7 (OCEF definition).

d) CSD: Apply CSD for each space-time stream and frequency segment as described in 25.6.8.10 (Cyclic shift diversity (CSD) for CMMG OFDM mode Data fields transmission(#7168)(#404)).

e) Spatial mapping: Apply the **Q** matrix as described in 25.6.8.11 (OFDM modulation).

f) IDFT: Compute the inverse discrete Fourier transform.

g) Insert GI and apply windowing: Prepend a GI (LONG_GI) and apply windowing as described in 25.3.4.3 (Transmitted signal).

h) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit. Refer to 25.3.4.3 (Transmitted signal) and 25.6.7 (OCEF definition) for details.

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### 25.6.5 CMMG OFDM mode SIG fields

#### 25.6.5.1 SIG fields

See 25.5.5.1 (SIG field) to 25.5.5.4.2 (Encoding).

#### 25.6.5.2 Modulation

See 25.4.4.5 (Modulation).

#### 25.6.5.3 Duplication

If the channel bandwidth is 1080 MHz, the modulated SIG symbols are duplicated as described in 25.3.10 (CMMG duplication transmission on a 1080 MHz channel).

#### 25.6.5.4 Symbol blocking, CSD, and GI insertion

See 25.5.5.4.5 (Symbol blocking, CSD, and GI insertion).

#### 25.6.5.5 Symbol rate change

If the channel bandwidth is 540 MHz, the preamble sequence and the CMMG OFDM mode SIG fields defined in the above subclauses are specified at the SC chip rate ($T_C$). For transmission in the OFDM (nominal) sample rate, the signal is resampled with a 3/2 rate change. The resampling is done by upsampling by a factor of 3, filtering by the filter $h_{Filt}$ defined in 25.3.11 (hFilt definition), and downsampling by a factor of 2 (see equation below). To define the transmission of the preamble when the (#14)PPDU is an OFDM (#14)mode PPDU, the preamble waveform is defined below.

Let $r(nT_C) = r_{STF}(nT_C) + r_{CEF}(nT_C - t_{ce}) + r_{SIG}(nT_C - t_{SIG})$, then

$$r\left(n\frac{T_s}{2}\right) = \begin{cases} r\left(n\frac{T_c}{3}\right), n = 0, 3, 6, \ldots \\ 0, otherwise \end{cases} \quad (25\text{-}36)$$

$$\tilde{r}\left(n\frac{T_s}{2}\right) = \sum_{k=0}^{K-1} r\left((n-k)\cdot\frac{T_s}{2}\right) h_{Filt}(k), n = 0, 1, \ldots \quad (25\text{-}37)$$

$$r(nT_s) = \tilde{r}\left(2n\frac{T_s}{2} - \frac{K-1}{2}\frac{T_s}{2}\right), n = 0, 1, \ldots \quad (25\text{-}38)$$

where $K$ is the length of the filter defined in 25.3.11 (hFilt definition), $\tilde{r}(n=0)$ for $n<0$.

### 25.6.6 OSTF definition

The main purpose of the OFDM Short Training Field (OSTF) is to improve automatic gain control estimation in a MIMO transmission. The duration of the OSTF is $T_{OSTF}$ regardless of the Short GI field setting in CMMG OFDM SIG.

For a 540 MHz transmission, the frequency domain sequence is given by Equation (25-39).

$$OSTF_{-89,\,89} = \{0, \mathbf{a, a, b, a, a, a, b, b, a, b, b, b, a, a, b, a, b, b, a, b, a, a,} 0, 0, 0, 0, \mathbf{b, b, b, b, a, b, b, b, a, a, a, a, b, a, a, a, b, a, b, a, a,} 0, 0\} \quad (25\text{-}39)$$


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where **a** = [1, 0, 0, 0] and **b** = [–1, 0, 0, 0].

For a 1080 MHz transmission, the frequency domain sequence is given by Equation (25-40).

$$OSTF_{-177,\,177} = \frac{1+j}{\sqrt{2}}\{\,0,\ \mathbf{b, a, a, a, b, b, b, a, a, b, a, a, a, a, b, b, b, b, a, b, a, b, b, b, a,}$$
$$\mathbf{b, b, a, b, a, b, a, a, b, b, a, a, b, a, a, a, b, a, b, 0, 0, 0, 0, a, a, b, b, b, b, b, b, b, a, a,} \qquad (25\text{-}40)$$
$$\mathbf{b, b, a, a, a, a, a, a, b, a, a, a, a, a, b, a, a, a, b, a, b, a, a, a, a, a, a, a, a, b, b,}\ -1,\ 0\,\}$$

where **a** = [1, 0, 0, 0] and **b** = [–1, 0, 0, 0].

The time domain representation of the signal of transmit chain $i_{TXT}$ shall be as specified in Equation (25-41).

$$r^{i_{TX}}_{OSTF}(t) = \frac{w_{T_{OCEF}}(t)}{\sqrt{N_{Tone}N_{STS}}} \sum_{k=-N_{SR}}^{N_{SR}} \sum_{m=1}^{N_{STS}} [Q_k]_{i_{TX},\,m}\ \Upsilon_{k,\,CBW}\, OSTF_k \exp(j2\pi\Delta_F(t - T_{CS}(m))) \qquad (25\text{-}41)$$

where

$N_{Tone}$ is, for 540 MHz transmission, 176, and, for 1080 MHz transmission, 352

$T_{CS}$ is given in Table 25-27 (Cyclic shift values for the Data fields of a CMMG OFDM mode PPDU(#7168)(#404))

$Q_k$ is defined in 25.6.8.13 (Beamforming)

$\Upsilon_{k,\,CBW}$ is defined in 25.3.4.4 (Definition of tone rotation for CMMG OFDM mode transmission(#7168))

### 25.6.7 OCEF definition

The OCEF provides a means for the receiver to estimate the MIMO channel between the set of constellation mapper outputs (or, if STBC is applied, the STBC encoder outputs) and the receive chains. The transmitter provides training for $N_{STS}$ space-time streams (spatial mapper inputs) used for the transmission of the PSDU(s). For each tone, the MIMO channel that can be estimated is a $N_{RX} \times N_{STS}$ matrix. A (#14)PPDU transmission has a preamble that contains OCEF symbols, where the data tones of each OCEF symbol are multiplied by entries belonging to a matrix $\mathbf{P}_{OCEF}$, to enable channel estimation at the receiver. The pilot tones of each OCEF symbol are multiplied by the entries of a matrix $\mathbf{R}_{OCEF}$ defined in the following text. The multiplication of the pilot tones in the OCEF symbol by the $\mathbf{R}_{OCEF}$ matrix instead of the $\mathbf{P}_{OCEF}$ matrix allows receivers to track phase and frequency offset during MIMO channel estimation using the OCEF. The number of OCEF symbols, $N_{OCEF}$, is a function of the number of space-time streams $N_{STS}$ as shown in Table 25-17 (Number of OCEFs required for different numbers of space-time streams). As a result the OCEF consists of one, two, or four symbols.

**Table 25-17—Number of OCEFs required for different numbers of space-time streams**

| $N_{STS}$ | $N_{OCEF}$ |
|---|---|
| 1 | 1 |
| 2 | 2 |

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**Table 25-17—Number of OCEFs required for different numbers of space-time streams**

| $N_{STS}$ | $N_{OCEF}$ |
|---|---|
| 3 | 4 |
| 4 | 4 |

In a 540 MHz transmission, let $OCEF_{left}$ and $OCEF_{right}$ be the sequences defined in Equation (25-42) and Equation (25-43), respectively.

$$\begin{aligned} OCEF_{left} = \{&1,-1,-1,1,1,-1,-1,1,1,-1,1,1,1,1,1,1,1,-1,-1,1,-1,1,1,1,\\ &-1,1,1,-1,1,-1,-1,1,1,-1,-1,1,-1,1,1,1,1,1,1,1,-1,-1,1,1,1,\\ &-1,1,1,-1,1,-1,1,-1,-1,-1,1,-1,-1,-1,-1,1,1,-1,-1,-1,-1,-1,\\ &-1,1,-1,-1,-1,1,1,1,1,-1,-1,1,1,-1,1,1\} \end{aligned} \tag{25-42}$$

$$\begin{aligned} OCEF_{right} = \{&-1,1,-1,1,1,-1,1,-1,-1,-1,1,1,1,1,1,-1,-1,-1,1,1,1,1,-1,-1,\\ &-1,-1,-1,-1,-1,1,-1,1,-1,1,1,1,-1,-1,-1,-1,1,1,-1,-1,-1,1,\\ &1,-1,1,1,-1,1,1,1,1,-1,1,-1,-1,-1,1,-1,1,-1,1,-1,1,-1,1,1,\\ &1,1,-1,1,-1,1,-1,-1,1,1,1,-1,1,1,-1,-1,-1,1\} \end{aligned} \tag{25-43}$$

In a 540 MHz transmission, the OCEF sequence transmitted is given by Equation (25-44).

$$OCEF_{-89,89} = \{OCEF_{left}, 0, 0, 0, OCEF_{right}\} \tag{25-44}$$

In a 1080 MHz transmission, let $OCEF_{left}$ and $OCEF_{right}$ be the sequences defined in Equation (25-45) and Equation (25-46), respectively.

$$\begin{aligned} OCEF_{left} = \{&1,-1,1,-1,-1,-1,-1,-1,1,1,-1,-1,1,1,1,1,1,-1,-1,-1,-1,1,\\ &-1,1,-1,1,1,1,1,-1,1,1,-1,-1,1,1,1,-1,1,1,-1,-1,1,-1,-1,-1,\\ &1,-1,1,1,-1,1,1,1,-1,-1,1,-1,-1,-1,-1,-1,1,1,-1,-1,-1,-1,\\ &-1,1,-1,1,1,1,-1,-1,-1,-1,1,1,1,-1,1,1,1,1,-1,-1,1,1,-1,1,1,\\ &1,1,1,-1,-1,-1,1,-1,1,1,-1,1,1,-1,1,1,-1,1,-1,1,1,1,1,-1,1,\\ &1,-1,1,-1,1,1,1,1,1,1,-1,-1,1,-1,-1,-1,1,-1,1,1,-1,1,1,1,-1,\\ &-1,1,-1,1,1,1,1,-1,1,1,1,-1,1,1,1,1,-1,1,-1,-1,-1,1,-1,1,1,1,\\ &-1,-1,-1,-1,-1,-1,1\} \end{aligned} \tag{25-45}$$

$$\begin{aligned} OCEF_{right} = \{&-1,1,-1,-1,1,1,1,-1,1,-1,1,1,1,1,-1,-1,1,1,-1,1,1,-1,-1,-1,\\ &1,1,1,-1,-1,1,-1,-1,-1,1,-1,1,-1,1,-1,1,1,1,-1,1,-1,-1,-1,\\ &-1,1,1,-1,1,-1,1,1,1,-1,1,1,1,1,-1,-1,-1,-1,1,1,1,1,1,-1,1,\\ &-1,1,1,-1,1,-1,-1,1,-1,-1,-1,-1,1,1,1,1,-1,1,1,1,1,1,-1,1,\\ &1,-1,-1,-1,1,-1,-1,-1,1,-1,1,1,1,1,-1,-1,-1,1,1,-1,1,-1,1,\\ &-1,1,-1,-1,-1,-1,-1,-1,1,-1,-1,-1,1,-1,1,1,1,1,1,-1,-1,-1,\\ &1,1,1,-1,-1,-1,1,-1,-1,-1,-1,1,-1,1,-1,1,1,1,1,1,1,-1,1,-1,\\ &1,-1,1,1,1,-1,1,-1,1,-1,1,1\} \end{aligned} \tag{25-46}$$

In a 1080 MHz transmission, the OCEF sequence transmitted is given by Equation (25-47).


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$$OCEF_{-177,\,177} = \{OCEF_{left},\, 0,\, 0,\, 0,\, OCEF_{right}\} \tag{25-47}$$

The generation of the time domain OCEF symbols per frequency segment is shown in Figure 25-25 (Generation of OCEF symbols per frequency segment) where $A_{OCEF}$ is given in Equation (25-48).

$$A^{k}_{OCEF} = \begin{cases} R_{OCEF}, k \in K_{Pilot} \\ P_{OCEF}, otherwise \end{cases} \tag{25-48}$$

where $K_{Pilot}$ is the set of subcarrier indices for the pilot tones.

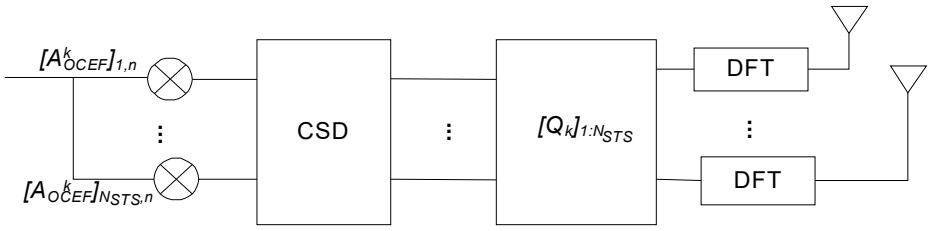


**Figure 25-25—Generation of OCEF symbols per frequency segment**

For a 540 MHz transmission, $K_{Pilot} = \{\pm 11, \pm 33, \pm 55, \pm 77\}$.

For a 1080 MHz transmission, $K_{Pilot} = \{\pm 11, \pm 33, \pm 55, \pm 77, \pm 99, \pm 121, \pm 143, \pm 165\}$.

$\mathbf{R}_{OCEF}$ is a $N_{OCEF} \times N_{OCEF}$ matrix whose elements are defined in Equation (25-49).

$$[R_{OCEF}]_{m,n} = [P_{OCEF}]_{1,n},\ 1 \le m, n \le N_{OCEF} \tag{25-49}$$

$$P_{OCEF} = \begin{bmatrix} 1 & -1 & 1 & 1 \\ 1 & 1 & -1 & 1 \\ 1 & 1 & 1 & -1 \\ -1 & 1 & 1 & 1 \end{bmatrix} \tag{25-50}$$

The time domain representation of the waveform transmitted on transmit chain $i_{TX}$ shall be as described by Equation (25-51).

$$r^{i_{TX}}_{OCEF}(t) = \sum_{n=0}^{N_{OCEF}-1} \frac{w_{T_{OCEF}}(t - nT_{OCEF})}{\sqrt{N_{Tone} N_{STS}}} \left( \sum_{k=-N_{SR}}^{N_{SR}} \sum_{m=1}^{N_{STS}} [Q_k]_{i_{TX},m} [A^{k}_{OCEF}] \Upsilon_{k,CBW} OCEF_k \exp(j2\pi\Delta_F(t - nT_{OCEF} - T_{GI} - T_{CM}(m))) \right) \tag{25-51}$$

where

$N_{Tone}$ is, for 540 MHz transmission, 176, and, for 1080 MHz transmission, 352

$T_{CS}$ is given in Table 25-27 (Cyclic shift values for the Data fields of a CMMG OFDM mode PPDU(#7168)(#404))

$Q_k$ is defined in 25.6.8.13 (Beamforming)

$\Upsilon_{k,CBW}$ is defined in 25.3.4.4 (Definition of tone rotation for CMMG OFDM mode transmission(#7168))

$T_{OCEF}$ is the duration of each OCEF symbol

$A_{OCEF}$ is defined in Equation (25-49)

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### 25.6.8 Data fields

#### 25.6.8.1 General

The LDPC encoding process is composed of several steps including determining the number of padding bits, padding with 0s(M118), and the coding of every word.

#### 25.6.8.2 Scrambler

The operation of the scrambler is defined in 25.3.7 (Scrambler). The scrambling of the Data field continues the scrambling of the CMMG OFDM mode SIG with no reset for OFDM transmission.

#### 25.6.8.3 Encoding

See 25.3.12 (Encoding of Data field).

#### 25.6.8.4 OFDM symbol padding 0s(M118)

The number of symbol blocks, $N_{SYM}$, is calculated as

$$N_{SYM} = \left\lceil \frac{Length \times 8 + (8 + L_{CHECK}) \times N_{CW}}{R \cdot lcm\{m_{STBC}N_{CBPS}, L_{CW}\}} \right\rceil \cdot \frac{lcm\{m_{STBC}N_{CBPS}, L_{CW}\}}{N_{CBPS}} \quad (25\text{-}52)$$

where

$L_{CHECK}$ is the number of LDPC parity bits
$lcm\{a,b\}$ denotes the least common multiple of $a$ and $b$
$L_{CW}$ denotes the LDPC code word length
$Length$ is the length of the PSDU defined in the CMMG SIG field
$R$ is the code rate
$N_{CBPS}$ is the number of code bits per symbol as defined in the MCS table
$m_{STBC} = 2$ if STBC is used; else $m_{STBC} = 1$

$$N_{SPAD} = R \times N_{SYM} \times N_{CBPS} - (Length \times 8 + (8 + L_{CHECK}) \times N_{CW}) \quad (25\text{-}53)$$

The PSDU is concatenated with $N_{SPAD}$ 0s(M118). They are scrambled using the continuation of the scrambler sequence that scrambled the PSDU.

#### 25.6.8.5 Stream parser

After coding and puncturing, the data bit streams at the output of the FEC encoder are processed in groups of $N_{CBPS}$. Each of these groups is rearranged into $N_{ss}$ blocks of $N_{CBPSS}$ bits.

The number of bits assigned to a single axis (real or imaginary) of a constellation point in a spatial stream is denoted by Equation (25-54).

$$s = \max\left\{1, \frac{N_{BPSCS}}{2}\right\} \quad (25\text{-}54)$$

Consecutive blocks of $s$ bits are assigned to different spatial streams in a round robin fashion.

Bit $i$ at the output of encoder is assigned to input bit $k$ of spatial stream where

$$i = (i_{SS} - 1) \cdot s + N_{ss} \cdot s \cdot \left\lfloor \frac{k}{s} \right\rfloor + k \mod s \quad (25\text{-}55)$$

where $i_{SS} = 1, 2, \ldots, N_{SS}$, $i = 0, 1, \ldots, N_{CBPS} - 1$, $k = 0, 1, \ldots, N_{CBPSS} - 1$.


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#### 25.6.8.6 Subcarrier modulation mapping

The OFDM subcarriers shall be modulated by using BPSK, QPSK, 16-QAM, or 64-QAM, depending on the RATE requested. The encoded and interleaved binary serial input data shall be divided into groups of (1, 2, 4, or 6) bits and converted into complex numbers representing BPSK, QPSK, 16-QAM, or 64-QAM constellation points. The conversion shall be performed according to Gray-coded constellation mappings, illustrated in Figure 25-26 (BPSK, QPSK, 16-QAM, and 64-QAM constellation bit encoding), with the input bit, $B_0$ being the earliest in the stream. The output values, $d$, are formed by multiplying the resulting ($I$+j$Q$) value by a normalization factor $K_{MOD}$, as described in Equation (25-56).

$$d = (I + jQ) \times K_{MOD} \tag{25-56}$$

The normalization factor, $K_{MOD}$, depends on the base modulation mode, as prescribed in Table 25-18 (Modulation-dependent normalization factor). Note that the modulation type can be different from the start to the end of the transmission, as the signal changes from SIGNAL to DATA, as shown in Figure 25-20 (64-QAM constellation bit encoding) and Figure 25-26 (BPSK, QPSK, 16-QAM, and 64-QAM constellation bit encoding). The purpose of the normalization factor is to achieve the same average power for all mappings. In practical implementations, an approximate value of the normalization factor may be used, as long as the device conforms with the modulation accuracy requirements described in 25.6.9.1.2 (Transmit EVM).

**Table 25-18—Modulation-dependent normalization factor**

| Modulation | $K_{MOD}$ |
|---|---|
| BPSK | 1 |
| QPSK | $1/\sqrt{2}$ |
| 16-QAM | $1/\sqrt{10}$ |
| 64-QAM | $1/\sqrt{42}$ |

For BPSK, $B_0$ determines the $I$ value, as illustrated in Table 25-19 (BPSK encoding table). For QPSK, $B_0$ determines the $I$ value, and $B_1$ determines the $Q$ value, as illustrated in Table 25-20 (QPSK encoding table). For 16-QAM, $B_0$ and $B_1$ determine the $I$ value, and $B_2$ and $B_3$ determine the $Q$ value, as illustrated in Table 25-21 (16-QAM encoding table). For 64-QAM, $B_0$, $B_1$, and $B_2$ determine the $I$ value, and $B_3$, $B_4$, and $B_5$ determine the $Q$ value, as illustrated in Table 25-22 (64-QAM encoding table).

**Table 25-19—BPSK encoding table**

| Input bit ($B_0$) | I-out | Q-out |
|---|---|---|
| 0 | –1 | 0 |
| 1 | 1 | 0 |

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**Table 25-20—QPSK encoding table**

| Input bit ($B_0$) | I-out | Input bit ($B_1$) | Q-out |
|---|---|---|---|
| 0 | –1 | 0 | –1 |
| 1 | 1 | 1 | 1 |

**Table 25-21—16-QAM encoding table**

| Input bits ($B_0B_1$) | I-out | Input bits ($B_2B_3$) | Q-out |
|---|---|---|---|
| 00 | –3 | 00 | –3 |
| 01 | –1 | 01 | –1 |
| 11 | 1 | 11 | 1 |
| 10 | 3 | 10 | 3 |

**Table 25-22—64-QAM encoding table**

| Input bits ($B_0B_1B_2$) | I-out | Input bits ($B_3B_4B_5$) | Q-out |
|---|---|---|---|
| 000 | –7 | 000 | –7 |
| 001 | –5 | 001 | –5 |
| 011 | –3 | 011 | –3 |
| 010 | –1 | 010 | –1 |
| 110 | 1 | 110 | 1 |
| 111 | 3 | 111 | 3 |
| 101 | 5 | 101 | 5 |
| 100 | 7 | 100 | 7 |


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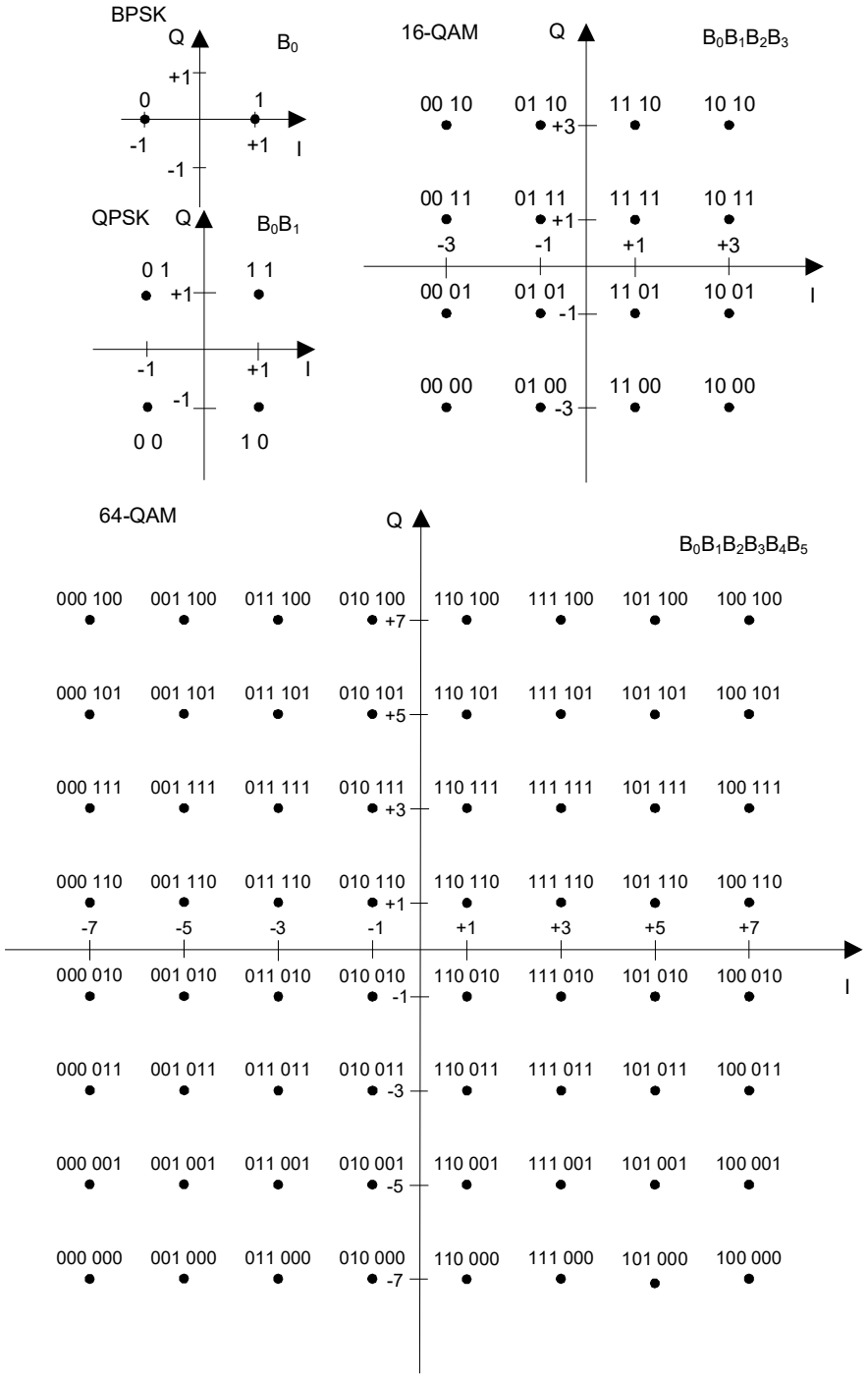


**Figure 25-26—BPSK, QPSK, 16-QAM, and 64-QAM constellation bit encoding**

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### 25.6.8.7 Tone mapping

The LDPC tone mapping shall be performed on all LDPC encoded streams using an LDPC tone-mapping distance parameter, $D_{TM}$. $D_{TM}$ is constant for each bandwidth, and its value for different bandwidths is given in Table 25-23 (Value of tone mapping parameter(#7171)).

**Table 25-23—Value of tone mapping parameter(#7171)**

| Parameter | CBW540 | CBW1080 |
|---|---|---|
| $D_{TM}$ | 6 | 12 |

LDPC tone mapping for LDPC-coded streams is done by permuting the stream of complex numbers generated by the constellation mappers to obtain

$$d''_{t(k),i,n} = d'_{k,i,n} \quad (25\text{-}57)$$

where

$i = 1, 2, \ldots, N_{SS}$

$$t(k) = D_{TM}\left(k \bmod \frac{N_{SD}}{D_{TM}}\right) + \left\lfloor \frac{kD_{TM}}{N_{SD}} \right\rfloor \quad (25\text{-}58)$$

The two consecutively generated complex constellation numbers are transmitted on two data tones that are separated by at least $D_{TM} - 1$ from other data tones.

### 25.6.8.8 Space-time block coding

This subclause defines a set of optional robust transmission techniques that are applicable only when using STBC coding for (#7168)CMMG OFDM mode PPDUs. In this case, $N_{SS}$ spatial streams are mapped to $N_{STS}$ space-time streams. These techniques are based on STBC. When the STBC field in the CMMG SIG is 1, a symbol operation shall occur between the constellation mapper and the spatial mapper as defined in this subclause.

If STBC is applied, the stream of complex numbers $d_{k,i,n}$, $k = 0, 1, \ldots, N_{SD}-1$, $i = 1, 2, \ldots, N_{SS}$, $n = 0, 1, \ldots, N_{SYM}-1$, is the input to the STBC encoder, which produces as output the stream of complex numbers $\tilde{d}_{k,i_{STS},n}$, $k = 0, 1, \ldots, N_{SD}-1$, $i_{STS} = 1, 2, \ldots, N_{STS}$, $n = 0, 1, \ldots, N_{SYM}-1$. For given values of $k$ and $i$, STBC processing operates on the complex modulation symbols in sequential pairs of OFDM symbols so that the values of $\tilde{d}_{k,2i-1,2m}$ and $\tilde{d}_{k,2i,2m}$ depend on $\tilde{d}_{k,2i,2m}$ and $d_{k,i,2m+1}$. Also, $\tilde{d}_{k,2i-1,2m+1}$ and $\tilde{d}_{k,2i,2m+1}$ depend on $d_{k,i,2m}$ and $d_{k,i,2m+1}$. This is defined in Table 25-24 (Constellation mapper output to spatial mapper input for STBC).

If STBC is not applied, $d_{k,i,n} = \tilde{d}_{k,i,n}$ and $N_{STS} = N_{SS}$.

NOTE—When STBC is applied, an odd number of space-time streams is not allowed, and $N_{STS} = 2N_{SS}$.


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**Table 25-24—Constellation mapper output to spatial mapper input for STBC**

| $N_{STS}$ | $N_{SS}$ | $i_{STS}$ | $\tilde{d}_{k,i_{STS},2m}$ | $\tilde{d}_{k,i_{STS},2m+1}$ |
|---|---|---|---|---|
| 2 | 1 | 1 | $d_{k,1,2m}$ | $d_{k,1,2m+1}$ |
| | | 2 | $-d^*_{k,1,2m+1}$ | $d^*_{k,1,2m}$ |
| 4 | 2 | 1 | $d_{k,1,2m}$ | $d_{k,1,2m+1}$ |
| | | 2 | $-d^*_{k,1,2m+1}$ | $d^*_{k,1,2m}$ |
| | | 3 | $d_{k,2,2m}$ | $d_{k,2,2m+1}$ |
| | | 4 | $-d^*_{k,2,2m+1}$ | $d^*_{k,2,2m}$ |

### 25.6.8.9 Pilot subcarriers

For a 540 MHz transmission, eight pilot tones shall be inserted in subcarriers {± 77, ± 55, ± 33, ± 11}. The pilot mapping $P_n^k$ for subcarrier $k$ for symbol $n$ shall be as specified in Equation (25-59).

$$\begin{aligned} P_n^k \in \{-77,-55,-33,-11,11,33,55,77\} &= \{\Psi_{n \bmod 8}, \Psi_{(n+1) \bmod 8}, \ldots, \Psi_{(n+7) \bmod 8}\} \\ P_n^k \notin \{-77,-55,-33,-11,11,33,55,77\} &= 0 \end{aligned} \quad (25\text{-}59)$$

where $\Psi_m$ is defined in Table 25-25 (Pilot values for 540 MHz transmission(#7171)).

**Table 25-25—Pilot values for 540 MHz transmission(#7171)**

| $\Psi_0$ | $\Psi_1$ | $\Psi_2$ | $\Psi_3$ | $\Psi_4$ | $\Psi_5$ | $\Psi_6$ | $\Psi_7$ |
|---|---|---|---|---|---|---|---|
| 1 | 1 | 1 | –1 | –1 | 1 | 1 | 1 |

For a 1080 MHz transmission, 16 pilot tones shall be inserted in subcarriers –165, –143, –121, –99, –77, –55, –33, –11, 11, 33, 55, 77, 99, 121, 143, 165. The pilot mapping $P_n^k$ for subcarrier $k$ for symbol $n$ shall be as specified in Equation (25-60).

$$\begin{aligned} P_n^k \in \{-165,-143,-121,-99,-77,-55,-33,-11,11,33,55,77,99,121,143,165\} &= \{\Psi_{n \bmod 16}, \Psi_{(n+1) \bmod 16}, \ldots, \Psi_{(n+15) \bmod 16}\} \\ P_n^k \notin \{-165,-143,-121,-99,-77,-55,-33,-11,11,33,55,77,99,121,143,165\} &= 0 \end{aligned} \quad (25\text{-}60)$$

where $\Psi_m$ is defined in Table 25-26 (Pilot values for 1080 MHz transmission(#7171)).

**Table 25-26—Pilot values for 1080 MHz transmission(#7171)**

| $\Psi_0$ | $\Psi_1$ | $\Psi_2$ | $\Psi_3$ | $\Psi_4$ | $\Psi_5$ | $\Psi_6$ | $\Psi_7$ | $\Psi_8$ | $\Psi_9$ | $\Psi_{10}$ | $\Psi_{11}$ | $\Psi_{12}$ | $\Psi_{13}$ | $\Psi_{14}$ | $\Psi_{15}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| –1 | 1 | –1 | 1 | 1 | –1 | –1 | –1 | –1 | –1 | 1 | 1 | 1 | –1 | 1 | 1 |

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### 25.6.8.10 Cyclic shift diversity (CSD) for CMMG OFDM mode Data fields transmission(#7168)(#404)

The cyclic shift values defined in this subclause apply to the (#404)Data fields of the PPDU. Cyclic shifts are applied eliminate unintended beamforming when correlated signals are transmitted in multiple space-time streams $T_{CS}(n)$. The cyclic shift value for the (#404)Data fields for space-time stream $n$ out of $N_{STS}$ total space-time streams is shown in Table 25-27 (Cyclic shift values for the Data fields of a CMMG OFDM mode PPDU(#7168)(#404)).

**Table 25-27—Cyclic shift values for the Data fields of a CMMG OFDM mode PPDU(#7168)(#404)**

| $T_{CS}(n)$ values for the Data field of a PPDU | | | | |
|---|---|---|---|---|
| $N_{STS}$ | Cyclic shift for space-time stream $n$ (ns) | | | |
| | 1 | 2 | 3 | 4 |
| 1 | 0 | — | — | — |
| 2 | 0 | $-128T_S$ | — | — |
| 3 | 0 | $-170T_S$ | $-85T_S$ | — |
| 4 | 0 | $-128T_S$ | $-64T_S$ | $-192T_S$ |

### 25.6.8.11 OFDM modulation

The time domain waveform of the Data field of a CMMG OFDM mode PPDU from transmit chain, shall be as defined in Equation (25-61).

$$r_{Data}^{i_{TX}}(t) = \frac{1}{\sqrt{N_{Tone}N_{STS,total}}} \sum_{n=0}^{N_{SYM}-1} w_{T_{SYM}}(t - nT_{SYM}) \sum_{k=-N_{SR}}^{N_{SR}} \sum_{m=1}^{N_{STT}} [Q_K]_{i_{TX},m} \Upsilon_{k,CBW} (\tilde{D}_{k,m,n,CBW} + p_n P_n^k) \exp(j2\pi k\Delta_F(t - nT_{SYM} - T_{GI} - T_{CS}m)) \quad (25\text{-}61)$$

where

$p_n$ is defined in 17.3.5.10 (OFDM modulation)

$N_{Tone}$ is, for 540 MHz transmission, 176 and, for 1080 MHz transmission, 352

$\tilde{D}_{k,m,n,CBW}$ is the transmitted constellation on subcarrier $k$, space-time stream $m$, and Data field OFDM symbol $n$ and is defined in Equation (25-62) to Equation (25-64)

$T_{GI}$ is the (short) guard interval duration and is given in Table 25-3 (Timing-related parameters(#7171)(M118))

$T_{CS}(n)$ is given in 25.6.8.10 (Cyclic shift diversity (CSD) for CMMG OFDM mode Data fields transmission(#7168)(#404))

$P_n^k$ is defined in 25.6.8.9 (Pilot subcarriers)

$\Upsilon_{k,CBW}$ is defined in 25.3.4.4 (Definition of tone rotation for CMMG OFDM mode transmission(#7168))



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For a 540 MHz transmission,

$$\tilde{D}_{k,m,n,540} = \begin{cases} 0, k = 0, \pm 1, \pm 11, \pm 33, \pm 55, \pm 77 \\ \tilde{d}_{M^r_{540}(k),m,n}, otherwise \end{cases} \quad (25\text{-}62)$$

and $M^r_{540}(k)$ is defined as

$$M^r_{540}(k) = \begin{cases} k+89, -89 \le k \le -78 \\ k+88, -76 \le k \le -56 \\ k+87, -54 \le k \le -34 \\ k+86, -32 \le k \le -12 \\ k+85, -10 \le k \le -2 \\ k+82, 2 \le k \le 10 \\ k+81, 12 \le k \le 32 \\ k+80, 34 \le k \le 54 \\ k+79, 56 \le k \le 76 \\ k+78, 78 \le k \le 89 \end{cases} \quad (25\text{-}63)$$

For a 1080 MHz transmission,

$$\tilde{D}_{k,m,n,1080} = \begin{cases} 0, k = 0, \pm 1, \pm 11, \pm 33, \pm 55, \pm 77, \pm 99, \pm 121, \pm 143, \pm 165 \\ \tilde{d}_{M^r_{1080}(k),m,n}, otherwise \end{cases} \quad (25\text{-}64)$$

and $M^r_{1080}(k)$ is defined as

$$M^r_{1080}(k) = \begin{cases} k+177, -177 \le k \le -166 \\ k+176, -164 \le k \le -144 \\ k+174, -142 \le k \le -122 \\ k+173, -120 \le k \le -100 \\ k+172, -98 \le k \le -78 \\ k+171, -76 \le k \le -56 \\ k+170, -54 \le k \le -34 \\ k+169, -32 \le k \le -12 \\ k+168, -10 \le k \le -2 \\ k+165, 2 \le k \le 10 \\ k+164, 12 \le k \le 32 \\ k+163, 34 \le k \le 54 \\ k+162, 56 \le k \le 76 \\ k+161, 78 \le k \le 98 \\ k+160, 100 \le k \le 120 \\ k+159, 122 \le k \le 142 \\ k+158, 144 \le k \le 164 \\ k+157, 166 \le k \le 177 \end{cases} \quad (25\text{-}65)$$

$\mathbf{Q}_k$ is a spatial mapping/steering matrix with $N_{TX}$ rows and columns $N_{STS}$ for subcarrier $k$. $\mathbf{Q}_k$ may be frequency dependent. Refer to the examples of listed in 19.3.11.11.2 (Spatial mapping) for examples of that could be used for (#7168)CMMG OFDM mode PPDU. Note that implementations are not restricted to the spatial mapping matrix examples listed in 19.3.11.11.2 (Spatial mapping).

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### 25.6.8.12 Duplication transmission

When the TXVECTOR parameter DUPLICATE_MODULATION is present, the transmitted PPDU is a duplicate. For 1080 MHz, the Data field shall be as defined by Equation (25-66).

$$r_{Data}^{i_{TX}}(t) = \frac{1}{\sqrt{N_{Tone}N_{STS,total}}} \sum_{n=0}^{N_{SYM}-1} w_{T_{SYM}}(t - nT_{SYM}) \sum_{k=-89}^{89} \sum_{m=1}^{N_{STS}} (\tilde{D}_{k,m,n} + p_n P_n^k)([Q_{k-88}]_{i_{TX,m}} \Upsilon_{k,CBW} \exp(j2\pi(k-88)\Delta_F(t - nT_{SYM} - T_{GI} - T_{CS}(m))) + j[Q_{k-88}]_{i_{TX,m}} \Upsilon_{k,CBW} \exp(j2\pi(k+88)\Delta_F(t - nT_{SYM} - T_{GI} - T_{CS}(m))))$$ (25-66)

where

$p_n$ is defined in 17.3.5.10

$N_{Tone}$ is 352

$\tilde{D}_{k,m,n}$ is the transmitted constellation on subcarrier $k$, space-time stream $m$, and Data field OFDM symbol $n$ and is defined in Equation (25-62) to Equation (25-64)

$T_{GI}$ is the (short) guard interval duration and is given in Table 25-3 (Timing-related parameters(#7171)(M118))

$T_{CS}(n)$ is given in 25.6.8.10 (Cyclic shift diversity (CSD) for CMMG OFDM mode Data fields transmission(#7168)(#404))

$P_n^k$ is defined in 25.6.8.9 (Pilot subcarriers)

$\Upsilon_{k,CBW}$ is defined in 25.3.4.4 (Definition of tone rotation for CMMG OFDM mode transmission(#7168))

### 25.6.8.13 Beamforming

#### 25.6.8.13.1 General

CMMG OFDM MIMO beamforming is used by a STA with multiple antennas (the beamformer) to steer signals using knowledge of the channel to improve throughput. With CMMG OFDM MIMO beamforming, all space-time streams in the transmitted signal are intended for reception at a single STA.

For CMMG OFDM MIMO beamforming, the steering matrix $\mathbf{Q}_k$ can be determined from the effective channel $\mathbf{H}_{eff,k}$, or the beamforming feedback matrix, $\mathbf{V}_k$, that is sent back to the beamformer by the beamformee using compressed beamforming feedback matrix format as defined in 25.6.8.13.2 (Compressed Beamforming feedback matrix). The feedback report format is described in 9.6.29.2 (CMMG Compressed Beamforming frame format).

#### 25.6.8.13.2 Compressed Beamforming feedback matrix

Upon receipt of (#2137)an NDP sounding PPDU, the beamformee shall remove the space-time stream CSD in Table 25-27 (Cyclic shift values for the Data fields of a CMMG OFDM mode PPDU(#7168)(#404)) from the measured channel before computing a set of matrices for feedback to the beamformer. The beamforming feedback matrix $\mathbf{V}_k$, found by the beamformee for subcarrier $k$ shall be compressed in the form of angles using the method described in 19.3.12.3.6 (Compressed beamforming feedback matrix). The angles, $\phi(k)$ and $\psi(k)$, are quantized according to Table 9-117 (Quantization of angles).

The beamformee shall generate the beamforming feedback matrices with the number of rows ($N_r$) equal to the $N_{STS}$ of the NDP.


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After receiving the angle information, $\phi(k)$ and $\psi(k)$, the beamformer reconstructs $\mathbf{V}_k$ using Equation (19-79). For CMMG OFDM MIMO beamforming, the beamformer can use this $\mathbf{V}_k$ matrix to determine the steering matrix $\mathbf{Q}_k$. The method used by the beamformer to calculate the steering matrix $\mathbf{Q}_k$ is implementation specific.

The beamformee decides the tone grouping value to be used in the beamforming feedback matrix **V**. A beamformer shall support all tone grouping values and codebook information values.

### 25.6.8.14 CMMG preamble format for sounding PPDU

#### 25.6.8.14.1 General

The MIMO channel measurement takes place in every PPDU as a result of transmitting the OCEFs as part of the PHY preamble. The number of OCEFs transmitted shall be determined by the number of space-time streams transmitted. The use of the same spatial transformation enables the computation of the spatial equalization at the receiver.

When the number of space-time streams, $N_{STS}$, is less than the number of transmit antennas, or less than min($N_{TX}$, $N_{RX}$), sending only $N_{STS}$ OCEFs does not allow the receiver to recover a full characterization of the MIMO channel, even though the resulting MIMO channel measurement is sufficient for receiving the Data field of the CMMG PPDU.

However, there are several cases where it is desirable to obtain as full a characterization of the channel as possible, thus requiring the transmission of a sufficient number of OCEFs to sound the full dimensionality of the channel, which is in some cases $N_{STS}$ and in other cases min($N_{TX}$, $N_{RX}$). These cases of MIMO channel measurement are referred to as MIMO channel sounding. A sounding PPDU may be used to sound available channel dimensions. A sounding PPDU is identified by setting the Not Sounding field in the CMMG SIG to 0. A sounding PPDU may have any allowed number of OCEFs satisfying $N_{OCEFs} \geq N_{STS}$ as shown in Table 25-17 (Number of OCEFs required for different numbers of space-time streams).

#### 25.6.8.14.2 Sounding with an NDP

A STA may sound the channel using (#2137)an NDP (indicated by zero in the Length field in the CMMGSIG field) with the Not Sounding field set to 0. The number of OCEFs is the number implied by the $2^{STBC}$ $N_{ss}$, which shall indicate spatial time streams. The last OCEF of an NDP shall not be followed by a Data field as shown in Figure 25-27 (CMMG NDP format).

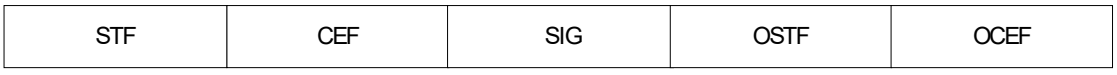


**Figure 25-27—CMMG NDP format**

It is optional for a STA to process an NDP.

#### 25.6.8.14.3 Sounding PPDU for channel quality assessment

In response to an MRQ, sent by STA A to STA B, the responding STA B returns to the requesting STA A an MCS selection that STA B determines to be a suitable MCS for STA A to use in subsequent transmissions to STA B. In determining the MCS, STA B performs a channel quality assessment, which entails using whatever information STA B has about the channel, such as an estimate of the MIMO channel derived from the sounding PPDU that carries the MRQ. To enable this calculation, the MRQ is sent in conjunction with a sounding PPDU.

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The STA sending the MRQ (STA A) determines how many OCEFs to send and whether to use an NDP or not, based on the Transmit Beamforming Capabilities field, number of space-time streams used in the PPDU carrying the MRQ, the number of transmit chains it is using ($N_{TX}$), whether the transmit and receive STAs support STBC, and in some cases, the number of receive chains at the responding STA ($N_{RX}$).

The maximum number of available space-time streams is set by the number of transmit and receive chains and the STBC capabilities of the transmitter and receiver, as is shown in Table 25-28 (Maximum available space-time streams). While the number of receive chains at a STA is not communicated in a capabilities indicator, the maximum number of space-time streams supported may be inferred from the STBC capabilities of the receiving STA. When the number of receive chains is known at the transmitter, the number of OCEFs sent to obtain a full channel quality assessment is determined according to the maximum number of space-time streams indicated in Table 25-28 (Maximum available space-time streams). The number of OCEFs to use in conjunction with the indicated number of space-time streams is determined according to Table 25-17 (Number of OCEFs required for different numbers of space-time streams).

**Table 25-28—Maximum available space-time streams**

| $N_{TX}$ | $N_{RX}$ | $N_{STS,max}$ **without STBC** | $N_{STS,max}$ **with STBC** |
|---|---|---|---|
| 1 | 1 | 1 | N/A |
| 2 | 1 | 1 | 2 |
| 4 | 1 | 1 | 2 |
| 4 | 2 | 2 | 4 |

The sounding PPDU may have nonidentity spatial mapping matrix $\mathbf{Q}_k$. For different receiving STAs, $\mathbf{Q}_k$ may vary.

### 25.6.9 Performance requirements

#### 25.6.9.1 Transmit requirements

##### 25.6.9.1.1 Introduction

This subclause describes the performance requirement from the (#7168)CMMG OFDM mode transmitter.

##### 25.6.9.1.2 Transmit EVM

The transmit EVM accuracy test shall be performed by instrumentation capable of converting the transmitted signal into a stream of complex samples, with sufficient accuracy in terms of I/Q arm amplitude and phase balance, DC offsets, phase noise, etc.

The sampled signal shall be processed in a manner similar to an actual receiver, according to the following steps, or an equivalent procedure:

a) (#14)Start of PPDU shall be detected.

b) Transition from short sequences to channel estimation sequences shall be detected, and fine timing (with one sample resolution) shall be established.

c) Frequency offsets shall be estimated and corrected.

d) The (#14)PPDU shall be (Ed)derotated according to estimated frequency offset.


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e) The complex channel response coefficients shall be estimated for each of the subcarriers using information contained in the preamble (STF/CEF and/or OCEF).

f) For each of the OFDM symbols: transform the symbol into subcarrier received values, estimate the phase from the pilot subcarriers, derotate the subcarrier values according to estimated phase, and divide each subcarrier value with a complex estimated channel response coefficient.

g) For each data-carrying subcarrier, compute the Euclidean distance to the ideal location for the symbol, or pilot.

h) Compute the RMS average of all errors in (#14)the Data field of a PPDU. It is given by(#315)

$$EVM = 20\log 10\left(\frac{1}{N_f}\sum_{i=1}^{N_f}\sqrt{\frac{\sum_{j=1}^{N_{SYM}}\left\{\sum_{k\in K}\left[(I(i,j,k)-I^{*}(i,j,k))^{2}+(Q(i,j,k)-Q^{*}(i,j,k))^{2}\right]\right\}}{(N_{ST}-N_{DC})N_{SYM}P_{0}}}\right) \quad (25\text{-}67)$$

where

$N_f$ is the number of PPDUs(#14)

$i$ is the (#14)PPDU index

$k$ is the carrier index

$K$ is the set of pilot and data subcarriers $\{1,2, \ldots, (N_{SR}-1), (N_{SR}+N_{DC}), (N_{SR}+N_{DC}+1),\ldots, N_{ST}\}$

$j$ is the symbol index

$N_{SYM}$ is the number of symbols

$N_{ST}$ is the total number of subcarriers

$I^{*},Q^{*}$ is the ideal constellation point for I and Q, respectively

$P_0$ is the average power of the constellation $(I^{*},Q^{*})$ computed over the $i^{th}$ (#14)PPDU

The measurements shall occur on the OFDM symbols and shall not occur on the other kinds of symbols. The measurement shall be performed on at least 10 (#14)PPDUs with 16 symbols at least in each of them. Random data shall be used.

The EVM RMS error shall not exceed an MCS dependent value as found in Table 25-29 (EVM requirements for OFDM).

**Table 25-29—EVM requirements for OFDM**

| MCS index | Modulation | Coding rate | EVM value (dB) |
|---|---|---|---|
| 9 | BPSK | 1/2 | –7 |
| 10 | QPSK | 1/2 | –11 |
| 11 | QPSK | 3/4 | –13 |
| 12 | 16-QAM | 1/2 | –15 |
| 13 | 16-QAM | 3/4 | –19 |
| 14 | 64-QAM | 5/8 | –22 |
| 15 | 64-QAM | 3/4 | –24 |
| 16 | 64-QAM | 13/16 | –26 |

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#### 25.6.9.2 TX flatness

##### 25.6.9.2.1 TX flatness for 540 MHz channel

(#6209)Let $E_i$ denote the constellation energy averaged over OFDM symbols for the subcarrier with index $i$, $E_{avg}$ denote $E_i$ averaged over $i$ equal to –70 to –2 and +2 to +70. When using the (#7168)CMMG OFDM mode and only while transmitting OFDM symbols, $E_i$ with $i$ equal to –70 to –2 and +2 to +70 shall not deviate by more than ± 2 dB from $E_{avg}$. And $E_i$ with $i$ equal to –71 to –89 and (#7157)+71 to +89 shall not deviate by more than +2/–4 dB from $E_{avg}$.

##### 25.6.9.2.2 TX flatness for 1080 MHz channel

(#6209)Let $E_i$ denote the constellation energy averaged over OFDM symbols for the subcarrier with index $i$, $E_{avg}$ denote $E_i$ averaged over $i$ equal to (#7157)–146 to –2 and +2 to +146. When using the (#7168)CMMG OFDM mode and only while transmitting OFDM symbols, $E_i$ with $i$ equal to –146 to –2 and +2 to +146 shall not deviate by more than ± 2 dB from $E_{avg}$. And $E_i$ with $i$ equal to –147 to –177 and +147 to +177 shall not deviate by more than +2/–4 dB from $E_{avg}$.

##### 25.6.9.2.3 Time of Departure accuracy

(#8055)The RMS accuracy of the time of departure provided in TIME_OF_DEPARTURE shall be less than or equal to 80 ns.

The Time of Departure accuracy test evaluates TIME_OF_DEPARTURE against aTxPHYTxStartRMS and aTxPHYTxStartRMS against TIME_OF_DEPARTURE_ACCURACY_TEST_THRESH as defined in Annex P with the following test parameters:

— (#385)MULTICHANNEL_SAMPLING_RATE is $660\times10^6$ sample/s for a 540 MHz channel and $1320\times10^6$ sample/s for a 1080 MHz channel.
— FIRST_TRANSITION_FIELD is Short Training field.
— SECOND_TRANSITION_FIELD is Channel Estimation field.
— TRAINING_FIELD is Channel Estimation field.
— TIME_OF_DEPARTURE_ACCURACY_TEST_THRESH is 80 ns.

NOTE—The indicated windowing applies to the time of departure accuracy test equipment, and not the transmitter or receiver.

#### 25.6.9.3 Receive requirements

##### 25.6.9.3.1 Introduction

Subclause 25.6.9.3.2 (CCA) describes the performance requirement for a (#7168)CMMG OFDM mode receiver.

##### 25.6.9.3.2 CCA

The start of a CMMG OFDM mode or CMMG SC mode transmission at a receive level greater than the minimum sensitivity for MCS 0 (–81 dBm for 540 MHz, –78 dBm for 1080 MHz) shall cause CCA to indicate busy with a probability > 90% within 1 µs.


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## 25.7 Analog beamforming PPDU format(#14)

### 25.7.1 TX sector sweep

The (#14)PPDUs sent during TX sector sweep are (#7168)CMMG control mode packets as defined in 25.4 (CMMG control mode).

### 25.7.2 Beam refinement

#### 25.7.2.1 General

Beam refinement is a process where a STA can improve its antenna configuration (or antenna weight vectors) both for transmission and reception. If the SLS beamforming training did not include an RSS, as in the case where both devices have more than one transmit sector per antenna, beam refinement can serve as the first receive antenna configuration training. The procedure of beam refinement is described in 10.41.6.4 (BRP phase execution). In the beam refinement procedure, BRP PPDUs are used to train the receiver and transmitter antenna. There are two types of BRP PPDUs: BRP-RX PPDUs and BRP-TX PPDUs.

— BRP-RX PPDUs are PPDUs that have TRN-R training sequences following the Data field. These (#14)PPDUs enable receiver antenna weight vector training.

— BRP-TX PPDUs are PPDUs that have TRN-T training sequences following the Data field. The transmitting STA may change antenna configuration at the beginning of each sequence. The receiving STA performs measurements on these sequences and sends feedback to the STA that transmits the BRP-TX PPDU.

#### 25.7.2.2 BRP PPDU structure

(#3626)Each BRP PPDU is shown in Figure 25-28 (BRP PPDU structure).

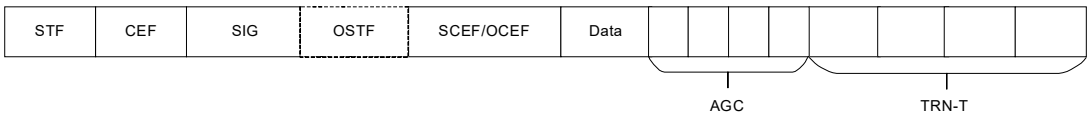


**Figure 25-28—BRP PPDU structure**

#### 25.7.2.3 BRP PPDU SIG fields

The PPDU Type field in a BRP PPDU is defined in Table 25-7 (Fields in the CMMG SIG field).

A value of *N* in the Training Length field indicates that the AGC has 4*N* subfields and that the TRN- R/T field has *N* subfields.

The value *N* in the Training Length field of a BRP-RX PPDU is equal to the value of the L-RX field requested by the intended receiver of the BRP-RX PPDU at a previously received BRP Request field (see 9.5.4 (BRP Request field)).

#### 25.7.2.4 Beam refinement AGC field

The beam refinement AGC fields are composed of 4*N* repetitions of the sequence $[Z^1_{64}\ Z^1_{64}\ Z^1_{64}\ Z^1_{64}\ Z^1_{64}]$ when the (#14)PPDU is transmitted using the (#7168)CMMG control mode in bandwidth 540 MHz, $[Z^2_{64}\ Z^2_{64}\ Z^2_{64}\ Z^2_{64}\ Z^2_{64}]$ when the (#14)PPDU is transmitted using the (#7168)CMMG SC mode in bandwidth 540 MHz, $[Z^3_{64}\ Z^3_{64}\ Z^3_{64}\ Z^3_{64}\ Z^3_{64}]$ when the (#14)PPDU is transmitted using the (#7168)CMMG OFDM mode in bandwidth 540 MHz, $[Z^1_{128}\ Z^1_{128}\ Z^1_{128}\ Z^1_{128}\ Z^1_{128}]$ when the (#14)PPDU is transmitted using the

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(#7168)CMMG control mode in bandwidth 1080 MHz, $[Z_{128}^{2}\ Z_{128}^{2}\ Z_{128}^{2}\ Z_{128}^{2}\ Z_{128}^{2}]$ when the (#14)PPDU is transmitted using the (#7168)CMMG SC mode in bandwidth 1080 MHz, and $[Z_{128}^{3}\ Z_{128}^{3}\ Z_{128}^{3}\ Z_{128}^{3}\ Z_{128}^{3}]$ when the (#14)PPDU is transmitted using the (#7168)CMMG OFDM mode in bandwidth 1080 MHz. The sequences $Z_{64}^{1}$, $Z_{64}^{2}$, $Z_{64}^{3}$, $Z_{128}^{1}$, $Z_{128}^{2}$, and $Z_{128}^{3}$ are defined in 25.8 (ZCZ sequence). The sequences are transmitted using rotated π/2-QPSK modulation.

In a BRP-TX PPDU, the transmitter may change the TX AWV configuration at the beginning of each AGC subfield. Any transmit signal transients that occur due to this TX AWV configuration change shall completely settle by the end of the first $Z_{64}^{1}$, $Z_{64}^{2}$, or $Z_{64}^{3}$ subsequence in bandwidth 540 MHz and $Z_{128}^{1}$, $Z_{128}^{2}$, or $Z_{128}^{3}$ subsequence in bandwidth 1080 MHz. The set of AWVs used for the AGC subfields should be the same as that used for the TRN-T subfields. In a BRP-RX PPDU, the transmitter shall use the same TX AWV as in the preamble and (#404)Data fields of the (#14)PPDU.

#### 25.7.2.5 Beam refinement TRN-R subfield

The TRN-R subfields enable receiver AWV training. The TRN-R subfields have the form shown in Figure 25-29 (TRN-R subfield definition).

| CEF | $R_1$ | $R_2$ | $R_3$ | $R_4$ | CEF | $R_5$ | $R_6$ | $R_7$ | $R_8$ | ... |
|---|---|---|---|---|---|---|---|---|---|---|

**Figure 25-29—TRN-R subfield definition**

Each subfield CEF matches the Channel Estimation field defined in 25.3.5 (CMMG PHY preamble). The $4N$ subfields $R_1$ to $R_{4N}$ each consist of the sequence $[Z_{256}^{1}\ Z_{256}^{3}\ Z_{256}^{1}\ Z_{256}^{2}\ Z_{256}^{4}\ Z_{256}^{2}]$ in bandwidth 540 MHz and $[Z_{512}^{1}\ Z_{512}^{3}\ Z_{512}^{1}\ Z_{512}^{2}\ Z_{512}^{4}\ Z_{512}^{2}]$ in bandwidth 1080 MHz. The sequences $Z_{256}^{1}$, $Z_{256}^{2}$, $Z_{256}^{3}$, and $Z_{256}^{4}$ are defined in Table 25-33 (The sequence set Zi256, i=1,2,3,4), and $Z_{512}^{1}$, $Z_{512}^{2}$, $Z_{512}^{3}$, and $Z_{512}^{4}$ are defined in Table 25-34 (The sequence set Zi512, i=1,2,3,4) in 25.8 (ZCZ sequence). The sequences are transmitted using rotated π/2-QPSK modulation.

#### 25.7.2.6 Beam refinement TRN-T subfield

The TRN-T subfield enables transmitter AWV training. The TRN-T subfields have the form shown in Figure 25-30 (TRN-T subfield definition).

| CEF | $T_1$ | $T_2$ | $T_3$ | $T_4$ | CEF | $T_5$ | $T_6$ | $T_7$ | $T_8$ | ... |
|---|---|---|---|---|---|---|---|---|---|---|

**Figure 25-30—TRN-T subfield definition**

Each subfield CEF matches the Channel Estimation field defined in 25.3.5 (CMMG PHY preamble). The $4N$ subfields $T_1$ to $T_{4N}$ each consist of the sequence $[Z_{256}^{1}\ Z_{256}^{3}\ Z_{256}^{1}\ Z_{256}^{2}\ Z_{256}^{4}\ Z_{256}^{2}]$ in bandwidth 540 MHz and $[Z_{512}^{1}\ Z_{512}^{3}\ Z_{512}^{1}\ Z_{512}^{2}\ Z_{512}^{4}\ Z_{512}^{2}]$ in bandwidth 1080 MHz. The sequences $Z_{256}^{1}$, $Z_{256}^{2}$, $Z_{256}^{3}$, and $Z_{256}^{4}$ are defined in Table 25-33 (The sequence set Zi256, i=1,2,3,4), and $Z_{512}^{1}$, $Z_{512}^{2}$, $Z_{512}^{3}$, and $Z_{512}^{4}$ are defined in Table 25-34 (The sequence set Zi512, i=1,2,3,4) in 25.8 (ZCZ sequence). The sequences are transmitted using rotated π/2-QPSK modulation. When transmitting the CEF subfield, the transmitter shall use the same AWV as in the preamble and (#404)Data fields of the (#14)PPDU. Any transmit signal transients that occur due to TX AWV configuration changes between subfields shall settle by the end of the first 64 samples of the subfield.


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#### 25.7.2.7 Channel measurement

The good autocorrelation properties of the ZCZ sequences enable reconstructing part of the impulse response of the channel between the transmitter and the receiver. The receiver should find the tap with largest amplitude in the channel during the CEF of the BRP-RX. It selects thereafter the set of taps that is measured around the tap with the largest amplitude, according to the value of dot11ChanMeasFBCKNtaps. It can select a contiguous set of taps or select a noncontiguous set of taps and include the tap delays subfield as part of the subfield measurement. It then measures the phase and amplitude of the corresponding channel taps in each of the TRN-T subfield repetition (except for those using the CEF AWV configuration). The beam refinement feedback subfield $k$–1 is the relative amplitude and phase of this tap in the $k$'th repetition compared to this tap in the first TRN-T subfield.

#### 25.7.2.8 BRP resampling in a CMMG OFDM mode PPDU(#7168)(#14)

The BRP AGC field, the CEF, and Tn/Rn field are specified at the SC chip rate ($T_c$). When appended to an OFDM (#14)mode PPDU, the signal is resampled as defined in 25.3.10 (CMMG duplication transmission on a 1080 MHz channel).

## 25.8 ZCZ sequence

The following ZCZ sequences set is used in the STF, the CEF, the SCTF, and the Unique Word (UW). These are 5 ZCZ sequences sets, namely, $Z_{32}^{i}$, $Z_{64}^{i}$, $Z_{128}^{i}$, $Z_{256}^{i}$, and $Z_{512}^{i}$, with $i$ = 1, 2, 3, 4where the subscript denotes the length of the sequences and the superscript denotes the index of the ZCZ sequence. The sets are generated using the following recursive procedure, illustrated as in Figure 25-31 (Generation of ZCZ sequences set).

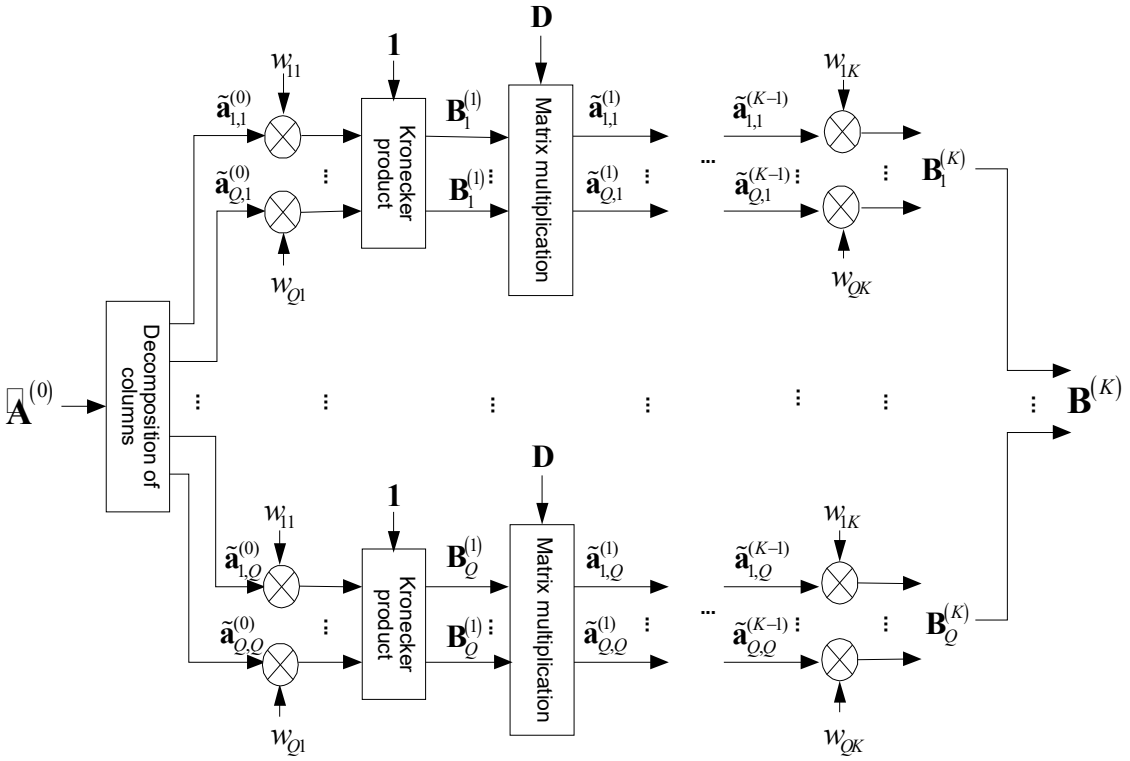


**Figure 25-31—Generation of ZCZ sequences set**

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$\tilde{\mathbf{A}}^{(0)}$, $\mathbf{B}^{(k)}$, and $\tilde{\mathbf{A}}^{(k)}$ used in Figure 25-31 (Generation of ZCZ sequences set) are defined as follows, respectively.

$$\tilde{\mathbf{A}}^{(0)} = \begin{bmatrix} \tilde{\mathbf{a}}_{1,1}^{(0)} & \cdots & \tilde{\mathbf{a}}_{1,Q}^{(0)} \\ \cdots & \cdots & \cdots \\ \tilde{\mathbf{a}}_{Q,1}^{(0)} & \cdots & \tilde{\mathbf{a}}_{Q,Q}^{(0)} \end{bmatrix} \tag{25-68}$$

$$\mathbf{B}^{(k)} = \begin{bmatrix} w_{1,k}\mathbf{I}_{Q^{k-1}L} & \mathbf{0}_{Q^{k-1}L} & \cdots & \mathbf{0}_{Q^{k-1}L} \\ \mathbf{0}_{Q^{k-1}L} & w_{2,k}\mathbf{I}_{Q^{k-1}L} & \cdots & \mathbf{0}_{Q^{k-1}L} \\ \cdots & \cdots & \cdots & \cdots \\ \mathbf{0}_{Q^{k-1}L} & \mathbf{0}_{Q^{k-1}L} & \cdots & w_{Q,k}\mathbf{I}_{Q^{k-1}L} \end{bmatrix} \tilde{\mathbf{A}}^{(k-1)}, \tilde{\mathbf{A}}^{(k)} = \mathbf{D}(\mathbf{1} \otimes \mathbf{B}^{(k)}) \tag{25-69}$$

where

| | |
|---|---|
| $\tilde{\mathbf{a}}_{i,j}^{(0)}, i = 1, ..., Q, j = 1, ..., Q$ | denotes the initial sequence |
| $Q$ | is the number of ZCZ sequences |
| $\mathbf{I}_{Q^{k-1}L}$ | denotes the identity matrix of size $Q^{k-1}L \times Q^{k-1}L$ |
| $L$ | denotes the length of the initial sequence |
| $\mathbf{0}_{Q^{k-1}L}$ | denotes all zero matrix of size $Q^{k-1}L \times Q^{k-1}L$ |
| $w_{i,j}, i = 1, \ldots, Q, j = 1, \ldots, K$ | are elements of the coefficient matrix $\mathbf{W}$ of size $Q \times K$ |
| $K$ | is the number of the iterations |
| $\mathbf{D} = Diag(f_{1,1}\mathbf{I}_{Q^{k-1}L}, ..., f_{1,Q}\mathbf{I}_{Q^{k-1}L}, ..., f_{Q,1}\mathbf{I}_{Q^{k-1}L}, ..., f_{Q,Q}\mathbf{I}_{Q^{k-1}L})$ | with $Diag(\upsilon)$ denoting the diagonal matrix with diagonal element $\upsilon$ |
| $f_{i,j}, i = 1, \ldots, Q, j = 1, \ldots, Q$ | are elements of the Discrete Fourier Transform (DFT) matrix $\mathbf{F}_Q$ of size $Q \times Q$ |
| $\mathbf{1}$ | denotes all 1 column vector |
| $\otimes$ | denotes Kronecker product |

Note that $M = \{e^{(j2\pi\theta)/Q}\}_{\theta=0}^{Q-1}$, the elements of $\tilde{\mathbf{A}}^{(0)}$ belongs to $M$, and $w_{i,k} \in M, i = 1, ..., Q$.

When $\tilde{\mathbf{A}}^{(0)}$, $\mathbf{F}_4$, and $\mathbf{W}$ are given by Equation (25-70), the generated ZCZ sequence set $Z_{32}^i$ is listed in Table 25-30 (The sequence set Zi32, i=1,2,3,4) where 0, 1, 2, and 3 denote +1,+$j$,–1,–$j$.

$$\tilde{\mathbf{A}}^{(0)} = \begin{bmatrix} (-1,-1)^T & (-1,1)^T & (-1,-1)^T & (-1,1)^T \\ (-1,-1)^T & (-1,1)^T & (1,1)^T & (1,-1)^T \\ (-1,1)^T & (-1,-1)^T & (-1,1)^T & (-1,-1)^T \\ (-1,1)^T & (-1,-1)^T & (1,-1)^T & (1,1)^T \end{bmatrix}, \mathbf{F}_4 = \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & j & -1 & -j \\ 1 & -1 & 1 & -1 \\ 1 & -j & -1 & j \end{bmatrix}, \mathbf{W} = \begin{bmatrix} 1 \\ -j \\ -1 \\ 1 \end{bmatrix} \tag{25-70}$$

When $\tilde{\mathbf{A}}^{(0)}$, $\mathbf{F}_4$, and $\mathbf{W}$ are given by Equation (25-71), the generated ZCZ sequence set $Z_{64}^i$ is listed in Table 25-31 (The sequence set Zi64, i=1,2,3,4) where 0, 1, 2, and 3 denote +1,+$j$,–1,–$j$.

$$\tilde{\mathbf{A}}^{(0)} = \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & j & -1 & -j \\ 1 & -1 & 1 & -1 \\ 1 & -j & -1 & j \end{bmatrix}, \mathbf{F}_4 = \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & j & -1 & -j \\ 1 & -1 & 1 & -1 \\ 1 & -j & -1 & j \end{bmatrix}, \mathbf{W} = \begin{bmatrix} -j & -1 \\ -1 & j \\ j & -j \\ -1 & -j \end{bmatrix} \tag{25-71}$$


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When $\tilde{\mathbf{A}}^{(0)}$, $\mathbf{F}_4$, and $\mathbf{W}$ are given by Equation (25-72), the generated ZCZ sequence set $Z_{128}^i$ is listed in Table 25-32 (The sequence set Zi128, i=1,2,3,4) where 0, 1, 2, and 3 denote +1,+*j*,–1,–*j*.

$$\tilde{\mathbf{A}}^{(0)} = \begin{bmatrix} (-1,-1)^T & (-1,1)^T & (-1,-1)^T & (-1,1)^T \\ (-1,-1)^T & (-1,1)^T & (1,1)^T & (1,-1)^T \\ (-1,1)^T & (-1,-1)^T & (-1,1)^T & (-1,-1)^T \\ (-1,1)^T & (-1,-1)^T & (1,-1)^T & (1,1)^T \end{bmatrix}, \mathbf{F}_4 = \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & j & -1 & -j \\ 1 & -1 & 1 & -1 \\ 1 & -j & -1 & j \end{bmatrix}, \mathbf{W} = \begin{bmatrix} j & j \\ 1 & -j \\ -j & -j \\ -j & j \end{bmatrix} \quad (25\text{-}72)$$

When $\tilde{\mathbf{A}}^{(0)}$, $\mathbf{F}_4$, and $\mathbf{W}$ are given by Equation (25-73), the generated ZCZ sequence set $Z_{256}^i$ is listed in Table 25-33 (The sequence set Zi256, i=1,2,3,4) where 0, 1, 2, and 3 denote +1,+*j*,–1,–*j*.

$$\tilde{\mathbf{A}}^{(0)} = \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & j & -1 & -j \\ 1 & -1 & 1 & -1 \\ 1 & -j & -1 & j \end{bmatrix}, \mathbf{F}_4 = \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & j & -1 & -j \\ 1 & -1 & 1 & -1 \\ 1 & -j & -1 & j \end{bmatrix}, \mathbf{W} = \begin{bmatrix} 1 & -1 & -j & -j \\ -1 & j & -j & -j \\ -j & -1 & -j & 1 \\ j & -j & -1 & j \end{bmatrix} \quad (25\text{-}73)$$

When $\tilde{\mathbf{A}}^{(0)}$, $\mathbf{F}_4$, and $\mathbf{W}$ are given by Equation (25-74), the generated ZCZ sequence set $Z_{512}^i$ $Z_{512}^i$ is listed in Table 25-34 (The sequence set Zi512, i=1,2,3,4) where 0, 1, 2, and 3 denote +1,+*j*,–1,–*j*, respectively.

$$\tilde{\mathbf{A}}^{(0)} = \begin{bmatrix} (-1,-1)^T & (-1,1)^T & (-1,-1)^T & (-1,1)^T \\ (-1,-1)^T & (-1,1)^T & (1,1)^T & (1,-1)^T \\ (-1,1)^T & (-1,-1)^T & (-1,1)^T & (-1,-1)^T \\ (-1,1)^T & (-1,-1)^T & (1,-1)^T & (1,1)^T \end{bmatrix}, \mathbf{F}_4 = \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & j & -1 & -j \\ 1 & -1 & 1 & -1 \\ 1 & -j & -1 & j \end{bmatrix}, \mathbf{W} = \begin{bmatrix} 1 & -j & -j & -j \\ j & -j & j & -j \\ j & j & -j & -1 \\ -j & -j & 1 & -j \end{bmatrix} \quad (25\text{-}74)$$

.

**Table 25-30—The sequence set $Z_{32}^i$, *i*=1,2,3,4**

| | **The sequence set $Z_{32}^i$, $i$ = 1, …, 4 to be transmitted from left to right, up to down** |
|---|---|
| $Z_{32}^1$ | 22110220222220132233020222002031 |
| $Z_{32}^2$ | 20130022202022112031000020022233 |
| $Z_{32}^3$ | 22330202220020312211022022222013 |
| $Z_{32}^4$ | 20310000200222332013002220202211 |

**Table 25-31—The sequence set $Z_{64}^i$, *i*=1,2,3,4**

| | **The sequence set $Z_{64}^i$, $i$ = 1, …, 4 to be transmitted from left to right, up to down** |
|---|---|
| $Z_{64}^1$ | 21010002230313112101111301210200210122202303313321013331012120 22 |
| $Z_{64}^2$ | 22200121202210302220123202000323222023032022321222203010020021 01 |
| $Z_{64}^3$ | 23030200210111132303131103230002230320222101333123033133032322 20 |
| $Z_{64}^4$ | 20220323222012322022103000020121202221012220301020223212000223 03 |

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**Table 25-32—The sequence set $Z^i_{128}$, $i$=1,2,3,4**

| | The sequence set $Z^i_{128}$, $i = 1, \ldots, 4$ to be transmitted from left to right, up to down |
|---|---|
| $Z^1_{128}$ | 00112020222220132211022000220213001120201111302003320021133132<br>00112020000002312211022022002031001120203333312000332002331131 02 |
| $Z^2_{128}$ | 02132222202022112013002202200011021322221313110002312200133111 22<br>02132222020200332013002220022233021322223131332202312200311333 00 |
| $Z^3_{128}$ | 00332002220020312233020200000231003320021133132000112020111113 02<br>00332002002202132233020222222013003320023311310200112020333331 20 |
| $Z^4_{128}$ | 02312200200222332031000002020033023122001331112202132222131311 00<br>02312200022000112031000020202211023122003113330002132222313133 22 |

**Table 25-33—The sequence set $Z^i_{256}$, $i$=1,2,3,4**

| | The sequence set $Z^i_{256}$, $i = 1, \ldots, 4$ to be transmitted from left to right, up to down |
|---|---|
| $Z^1_{256}$ | 13020310110023301302102133221223130221321100011202312132221123 30<br>13020310110023302013213200332330312003103322233031201021110012 23<br>13020310110023303120320311003001130221321100011220130310003301 12<br>13020310110023300231031022110112312003103322233013023203332230 01 |
| $Z^2_{256}$ | 10210033122320131021110030011302102122111223023103102211233020 13<br>10210033122320132132221101122013320300333001201332031100122313 02<br>10210033122320133203332212233120102122111223023121320033011202 31<br>10210033122320130310003323300231320300333001201310213322300131 20 |
| $Z^3_{256}$ | 11000112130221321100122331201021110023301302031000332330201321 32<br>11000112130221322211233002312132332201123120213233221223130210 21<br>11000112130221323322300113023203110023301302031022110112023103 10<br>11000112130221320033011220130310332201123120213211003001312032 03 |
| $Z^4_{256}$ | 12230231102122111223130232031100122320131021003301122013213222 11<br>12230231102122112330201303102211300102313203221130011302102111 00<br>12230231102122113001312010213322122320131021003323300231031000 33<br>12230231102122110112023121320033300102313203221112233123203320 33 |



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**Table 25-34—The sequence set $Z^{i}_{512}$, $i$=1,2,3,4**

| | The sequence set $Z^{i}_{512}$, $i = 1, \ldots, 4$ to be transmitted from left to right, up to down |
|---|---|
| $Z^{1}_{512}$ | 00111331002231202211313100003102223331133311201322113131111110213<br>00111331220013022211313122221320112220020022312011002020222221320<br>00111331002231202211313100003102330002200022312033220202222221320<br>22333113002231200033131300003102001113313311201300331313111110213<br>00111331002231202211313100003102001113311133023100331313333332031<br>00111331220013022211313122221320330002202200130233220202000003102<br>00111331002231202211313100003102112220022200130211002020000003102<br>22333113002231200033131300003102223331131133023122113131333332031 |
| $Z^{2}_{512}$ | 02131133022033222013333302023300203133113113221120133333131300 11<br>02131133200211002013333320201122132022000220332213022222202011 22<br>02131133022033222013333302023300310200220220332231200000202011 22<br>20313311022033220231111102023300021311333113221102311111131300 11<br>02131133022033222013333302023300021311331331003302311111313122 33<br>02131133200211002013333320201122310200222002110031200000020233 00<br>02131133022033222013333302023300132022002002110013022222020233 00<br>20313311022033220231111102023300203133111331003320133333313122 33 |
| $Z^{3}_{512}$ | 00331313000031022233311300223120221131313333203122333113113302 31<br>00331313222213202233311322001302110020200000310211222002220013 02<br>00331313000031022233311300223120332202020000310233000220220013 02<br>22113131000031020011133100223120003313133333203100111331113302 31<br>00331313000031022233311300223120003313131111021300111331331120 13<br>00331313222213202233311322001302332202022222132033000220002231 20<br>00331313000031022233311300223120110020202222132011222002002231 20<br>22113131000031020011133100223120221131311111021322331133331120 13 |
| $Z^{4}_{512}$ | 02311111020233002031331102203322013333331312233203133111331003 3<br>02311111202011222031331120021100130222220202330013202200200211 00<br>02311111020233002031331102203322312000000202330031020022200211 00<br>20133333020233000213113302203322023111113131223302131133133100 33<br>02311111020233002031331102203322023111111313001102131133311322 11<br>02311111202011222031331120021100312000002020112231020022022033 22<br>02311111020233002031331102203322130222222020112213202200022033 22<br>20133333020233000213113302203322201333331313001120313311311322 11 |

## 25.9 Regulatory requirements

Wireless LANs (WLANs) implemented in accordance with this standard are subject to equipment certification and operating requirements established by regional and national regulatory administrations. The PHY specification establishes minimum technical requirements for interoperability, based upon established regulations at the time this standard was issued. These regulations are subject to revision or may be superseded.

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## 25.10 Channelization

A CMMG channel is specified by the two PLME MIB fields specified in Table 25-35 (Fields to specify CMMG channels).

**Table 25-35—Fields to specify CMMG channels**

| Field | Meaning |
|---|---|
| dot11CMMGCurrentChannelWidth | Channel width. Possible values represent 540 MHz and 1080 MHz channels. |
| dot11CMMGCurrentChannelCenterFrequencyIndex | For a 540 MHz or 1080 MHz channel, denotes the channel center frequency. |

If dot11CMMGCurrentChannelWidth indicates a 540 MHz channel, the channel center frequency is given by Equation (25-75) (see Figure 25-32 (Channelization for CBW540(#7171))).

$$f(n)\ [GHz] = \quad (25\text{-}75)$$

$$\begin{cases} 42.66 + 0.54 \times (\text{dot11CMMGCurrentChannelCenterFrequencyIndex} - 1),\ 1 \le \text{dot11CMMGCurrentChannelCenterFrequencyIndex} \le 8 \\ 47.52 + 0.54 \times (\text{dot11CMMGCurrentChannelCenterFrequencyIndex} - 9),\ \text{dot11CMMGCurrentChannelCenterFrequencyIndex} = 9, 10 \end{cases}$$

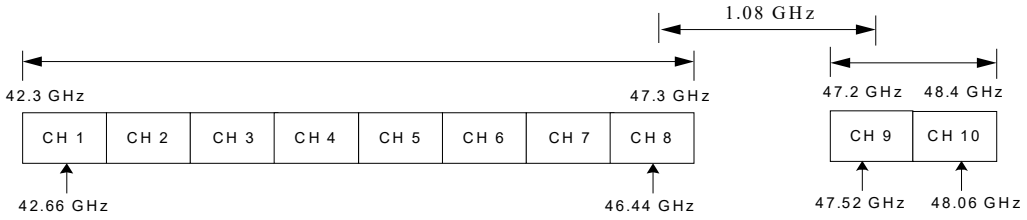


**Figure 25-32—Channelization for CBW540(#7171)**

If dot11CMMGCurrentChannelWidth indicates a 1080 MHz channel, the channel center frequency is given by Equation (25-76) (see Figure 25-33 (Channelization for CBW1080(#7171))).

$$f(n)\ [GHz] = \quad (25\text{-}76)$$

$$\begin{cases} 42.93 + 1.08 \times (\text{dot11CMMGCurrentChannelCenterFrequencyIndex} - 1),\ 1 \le \text{dot11CMMGCurrentChannelCenterFrequencyIndex} \le 4 \\ 47.79,\ \text{dot11CMMGCurrentChannelCenterFrequencyIndex} = 5 \end{cases}$$

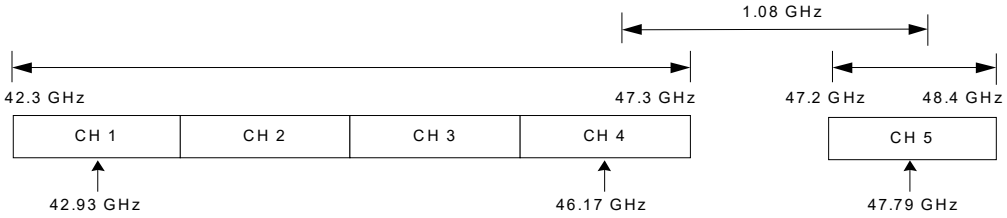


**Figure 25-33—Channelization for CBW1080(#7171)**


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## 25.11 Transmit spectrum mask

For a 540 MHz or 1080 MHz mask PPDU, the interim transmit spectral mask shall have a 0 dBr (dB relative to the maximum spectral density of the signal) bandwidth of 470 MHz or 940 MHz, –17 dBr at 330 MHz or 660 MHz frequency offset, –22 dBr at 1350 MHz or 2670 MHz frequency offset, and –30 dBr at 1530 MHz or 3060 MHz frequency offset and above. The interim transmit spectral mask for frequency offsets in between 235 MHz or 470 MHz and 330 MHz or 660 MHz, in between 330 MHz or 660 MHz and 1350 MHz or 2700 MHz, and in between 1350 MHz or 2700 MHz and 1530 MHz or 3060 MHz shall be linearly interpolated in dB domain from the requirements for 235 MHz, 330 MHz, 1350 MHz, and 1530 MHz frequency offsets. The transmit spectrum shall not exceed the maximum of the interim transmit spectral mask.

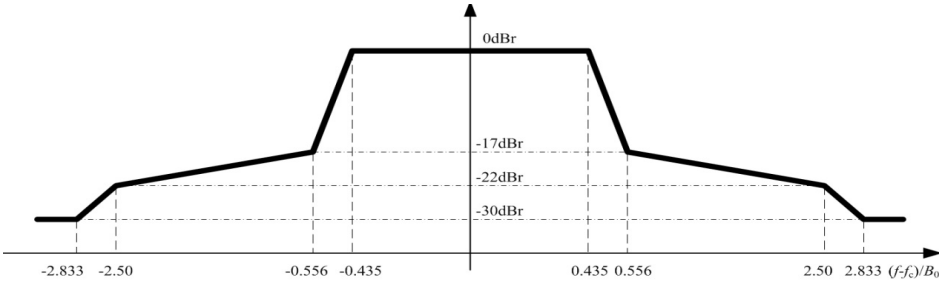


**Figure 25-34—Example transmit spectral mask for a PPDU**

## 25.12 PHY transmit procedure

### 25.12.1 PHY transmit procedure for a CMMG SC mode transmission

The PHY transmit procedure for a CMMG SC mode transmission is shown in Figure 25-35 (PHY transmit procedure for a CMMG SC mode transmission(#213)). In order to transmit data, a PHY-TXSTART.request primitive shall be enabled so that the PHY entity shall be in the transmit state. Further, the PHY shall be set to operate at the appropriate frequency through station management via the PLME, as specified in 25.14 (CMMG PLME). Other transmit parameters, such as MCS and transmit power, are set via the PHY SAP with the PHYTXSTART.request (TXVECTOR) primitive, as described in Table 25-1 (TXVECTOR and RXVECTOR parameters).

The PHY shall then issue a PHY-TXSTART.request primitive, and transmission of the PHY preamble shall start, based on the parameters passed in the PHY-TXSTART.request primitive. The PHY shall calculate the length of the (#14)PPDU according the MCS and the length specified in the PHY-TXSTART.request primitive, adding padding bits if necessary.

The PHY continues with the scrambling, encoding, and transmission of the CMMG-SIG-A according to the PHY-TXSTART.request(TXVECTOR) primitive parameters. The PHY proceeds with PSDU transmission through a series of data octet transfers from the MAC. The data are encoded as described in 25.5.6.3 (Encoding). The encoded data are then modulated as described in 25.5.6.6 (Constellation mapping), depending on the MCS requested in the PHY_TXSTART.request primitive. Transmission can be prematurely terminated by the MAC through the PHY-TXEND.request primitive. PHY-TXSTART shall be disabled by receiving a PHY-TXEND.request primitive.

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Transmission of the PSDU is completed with the transmission of the last bits of the (encoded) PSDU. If no TRN-T/R fields are specified in the PHY-TXSTART.request primitive, the PHY shall issue a PHY-TXEND.confirm primitive after the transmission of the last bits. If TRN-T and TRN-R fields are requested in the PHY-TXSTART.request primitive, the transmission continues with the transmission of AGC subfields and TRN-T/R subfields. The PHY issues the PHY-TXEND.confirm primitive to the MAC after the transmission of the last TRN-T/R subfield. The (#14)PPDU transmission shall be completed, and the PHY entity shall enter the receive state (i.e., PHYTXSTART shall be disabled). Each PHY-TXEND.request primitive is acknowledged with a PHY-TXEND.confirm primitive from the PHY.

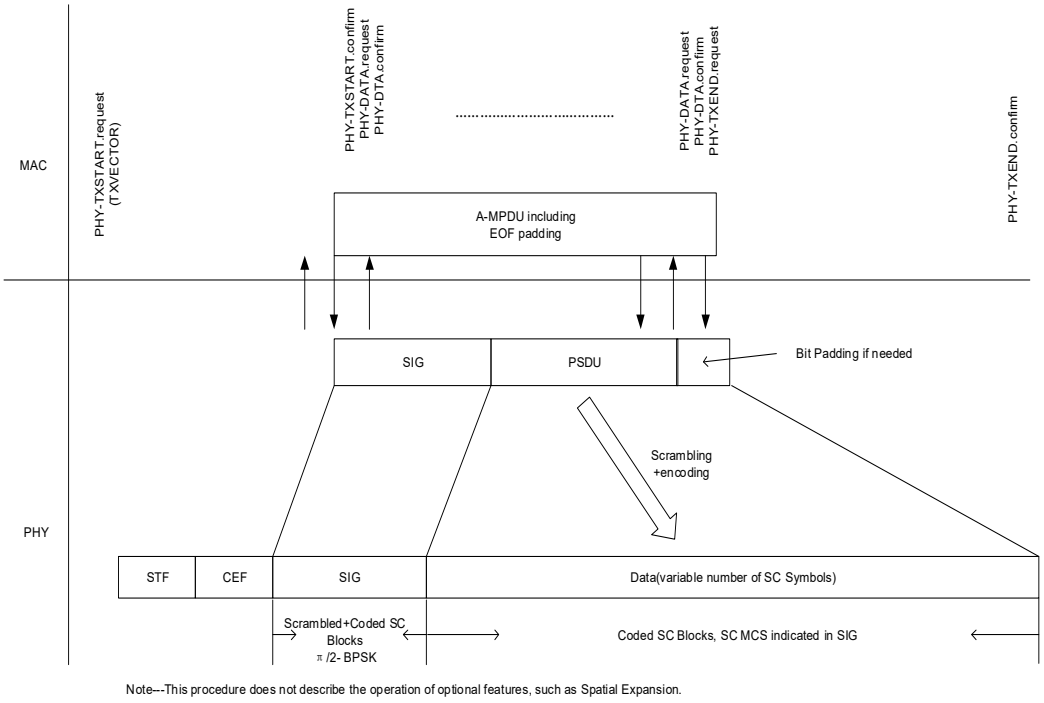


**Figure 25-35—PHY transmit procedure for a CMMG SC mode transmission(#213)**

### 25.12.2 PHY transmit procedure for a CMMG OFDM mode transmission

The PHY transmit procedure for a CMMG OFDM transmission is shown in Figure 25-36 (PHY transmit procedure for a CMMG OFDM mode transmission(#213)). In order to transmit data, a PHY-TXSTART.request primitive shall be enabled so that the PHY entity shall be in the transmit state. Further, the PHY shall be set to operate at the appropriate frequency through station management via the PLME, as specified in 25.14 (CMMG PLME). Other transmit parameters, such as MCS and transmit power, are set via the PHY SAP with the PHYTXSTART.request(TXVECTOR) primitive, as described in Table 25-1 (TXVECTOR and RXVECTOR parameters).

The PHY shall then issue a PHY-TXSTART.request primitive, and transmission of the PHY preamble shall start, based on the parameters passed in the PHY-TXSTART.request primitive. The PHY shall calculate the length of the packet according the MCS and the length specified in the PHY-TXSTART.request primitive, adding padding bits if necessary.

The PHY continues with the scrambling, encoding, and transmission of the CMMG SIG according to the PHY-TXSTART.request(TXVECTOR) primitive parameters. The PHY proceeds with PSDU transmission through a series of data octet transfers from the MAC. The data are scrambled and encoded as described


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in 25.6.8.2 (Scrambler) and 25.6.8.3 (Encoding), respectively. The encoded data are then modulated as described in 25.6.8.6 (Subcarrier modulation mapping), depending on the MCS requested in the PHY-TXSTART.request primitive. Transmission can be prematurely terminated by the MAC through the PHY-TXEND.request primitive. PHY-TXSTART shall be disabled by receiving a PHY-TXEND.request primitive.

Transmission of the PSDU is completed with the transmission of the last bits of the (encoded) PSDU. If no TRN-T/R fields are specified in the PHY-TXSTART.request primitive, the PHY shall issue a PHY-TXEND.confirm primitive after the transmission of the last bits. If TRN-T and TRN-R fields are requested in the PHY-TXSTART.request primitive, the transmission continues with the transmission of AGC subfields and TRN-T/R subfields. The PHY issues the PHY-TXEND.confirm primitive to the MAC after the transmission of the last TRN-T/R subfield. The (#14)PPDU transmission shall be completed, and the PHY entity shall enter the receive state (i.e., PHYTXSTART shall be disabled). Each PHY-TXEND.request primitive is acknowledged with a PHY-TXEND.confirm primitive from the PHY.

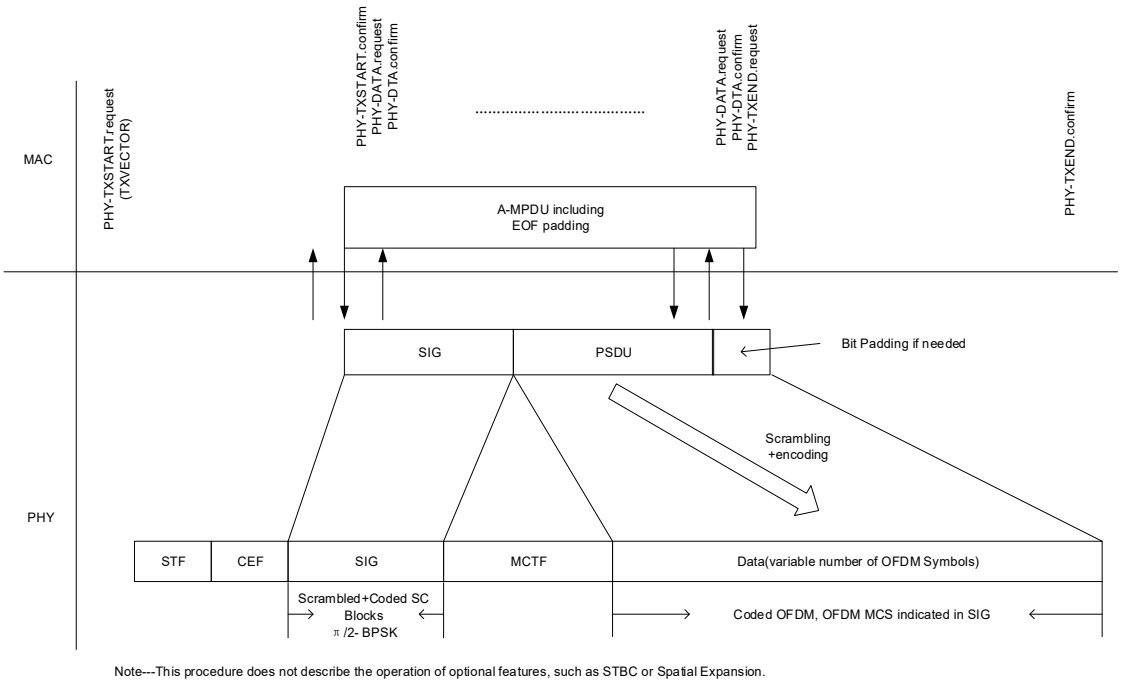


**Figure 25-36—PHY transmit procedure for a CMMG OFDM mode transmission(#213)**

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A typical state machine implementation of the transmit PHY for a (#7168)CMMG OFDM mode transmission is provided in Figure 25-37 (Typical Tx state machine(#8150)). This state machine does not describe the operation of optional features, such as STBC.

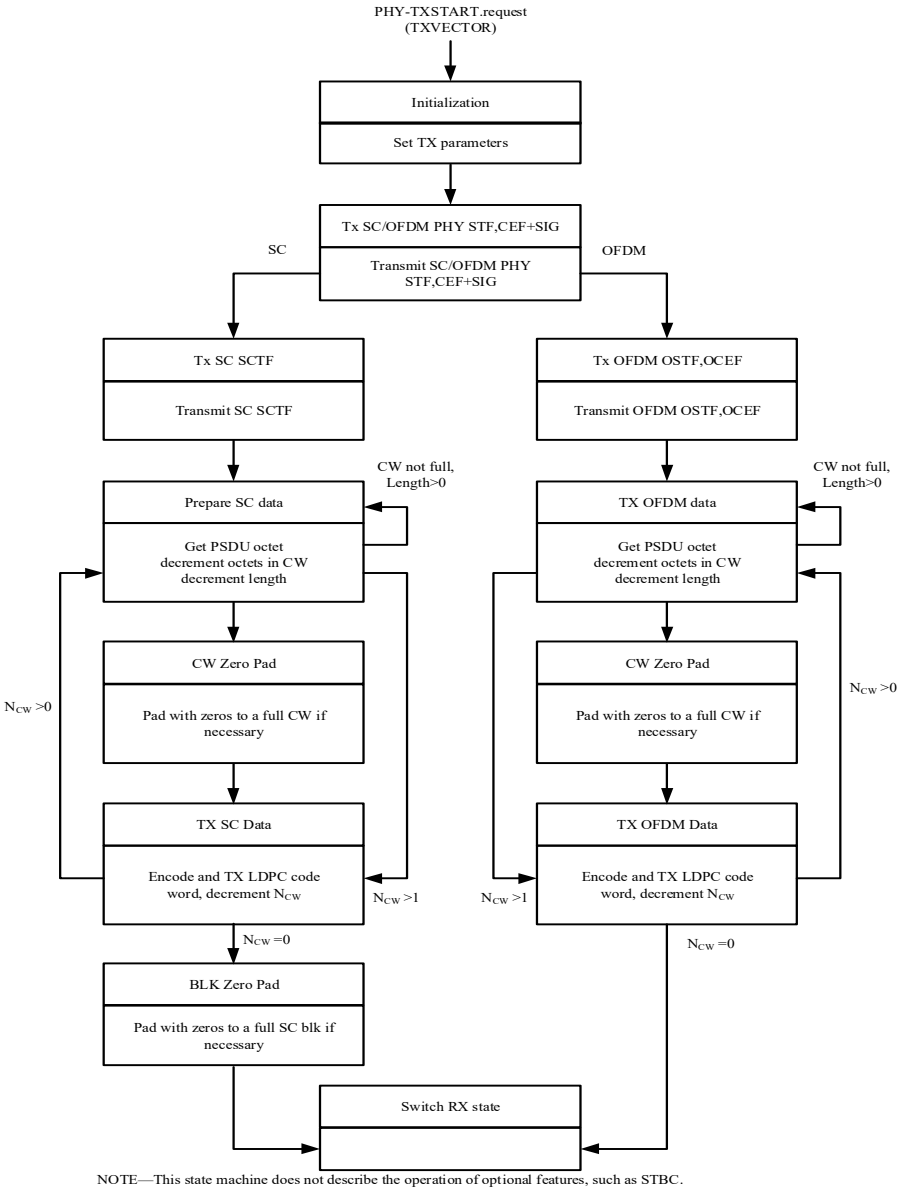


**Figure 25-37—Typical Tx state machine(#8150)**

## 25.13 Receive procedure

A typical PHY receive procedure is shown in Figure 25-39 (Typical Rx state machine(#14)(#1574)(#6313)) for a CMMG SC mode transmission.

Upon receiving the transmitted PHY preamble overlapping the primary 540 MHz channel, the PHY measures a receive signal strength. This activity is indicated by the PHY to the MAC via a PHY-CCA.indication primitive. A PHY-CCA.indication (BUSY, channel-list) primitive is also issued as an


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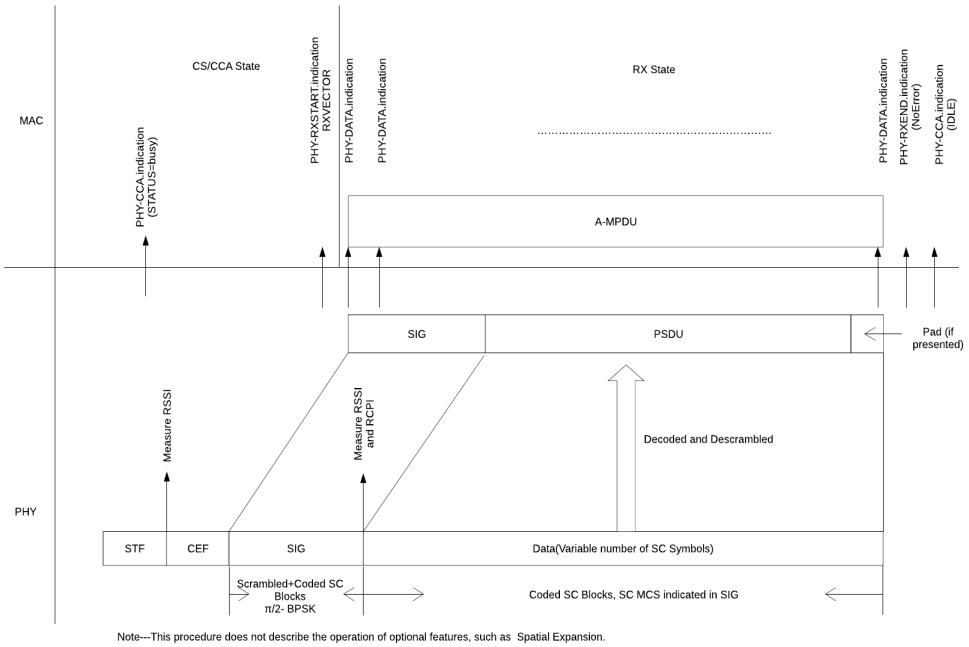


**Figure 25-38—PHY receive procedure for a CMMG SC mode transmission**

initial indication of reception of a signal as specified in 25.6.9.3.2 (CCA). The channel-list parameter of the PHY-CCA.indication primitive is absent when the operating channel width is 540 MHz. The channel-list parameter is present and includes the entry primary when the operating channel width is 1080 MHz.

After the PHY-CCA.indication(BUSY) primitive is issued, the PHY entity shall use the following ZCZ sequences of length 256 for synchronization and channel estimation. If the CE field indicated a(#1424) (#7168)CMMG SC mode, the receiver is capable of receiving (#7168)CMMG SC mode. The PHY shall decode the CMMG SIG and determine the MCS, length, and other parameters needed for the demodulation of (#14)the remainder of the PPDU.

Subsequently, if dot11TimingMsmtActivated is true, a PHY-RXSTART.indication(RXVECTOR) primitive shall be issued, and the RX-START_OF_FRAME_OFFSET parameter within the RXVECTOR shall be forwarded (see 25.2.2 (TXVECTOR and RXVECTOR parameters)).

NOTE—The RX_START_OF_FRAME_OFFSET value is used (#3049)to estimate when the start of the preamble for the incoming (#14)PPDU was detected on the medium at the receive antenna connector.

(#14)At the end of the Data field, the PHY shall indicate PHY-RXEND.indication(No_Error) primitive to the MAC. If the CMMG SIG indicated the presence of the training field, the PHY shall continue to receive these training fields (#14)after the Data field and measure the channel. After the end of the training fields, the PHY shall generate a PHY-CCA.indication(IDLE) primitive.

In the case of signal loss before the decoding of the CMMG SIG or in the case of an invalid header, the PHY shall not generate a PHY-CCA.indication(IDLE) primitive until the received level drops below a value that is 20 dB higher than the receiver sensitivity of MCS 1. In the case of signal loss after decoding of a valid CMMG SIG, the PHY shall not generate a PHY-CCA.indication(IDLE) primitive until the expected end of the packet, including the AGC and TRN fields.

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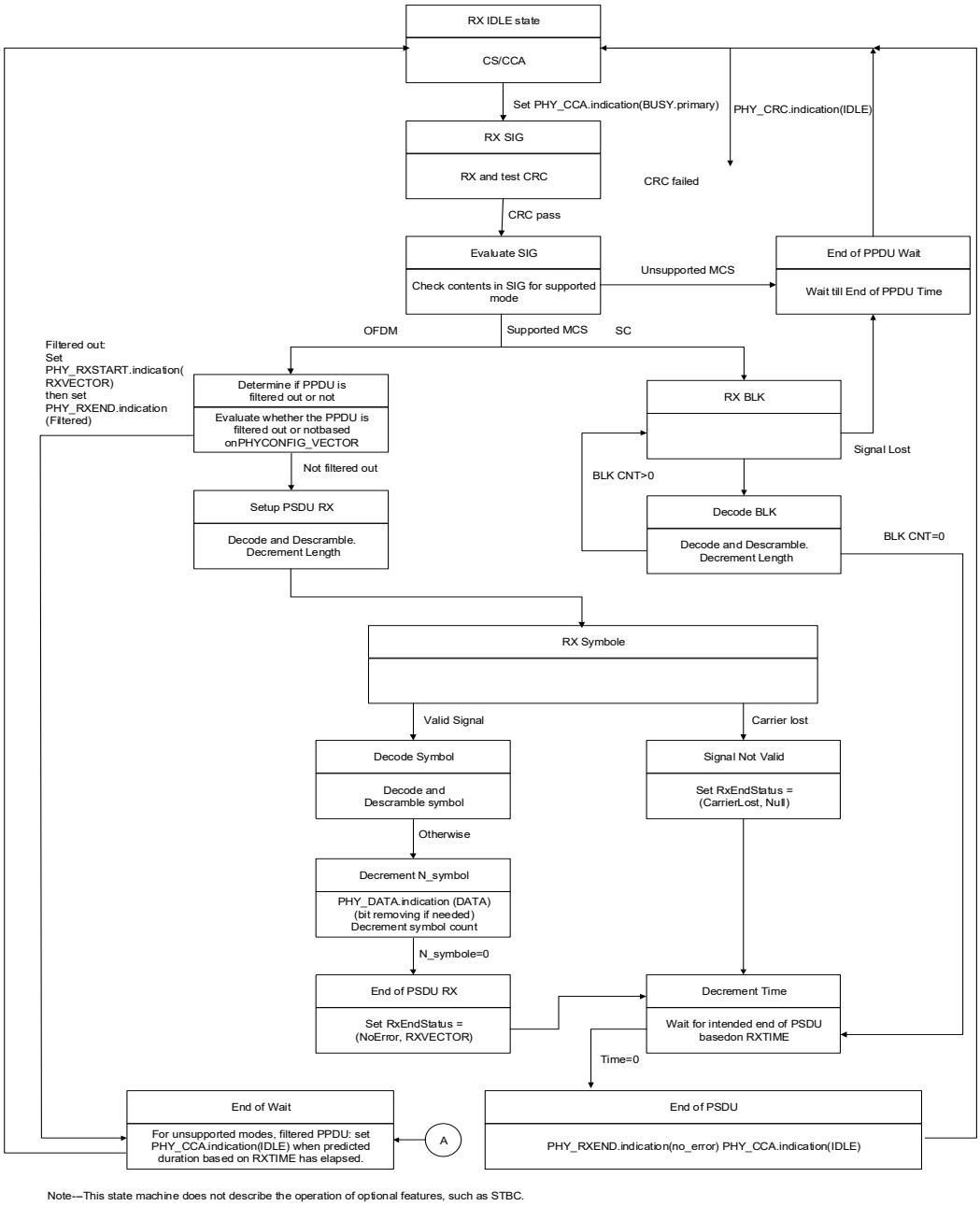
A typical state machine implementation of the receive PHY is given in Figure 25-39 (Typical Rx state machine(#14)(#1574)(#6313)). This receive procedure and state machine do not describe the operation of optional features, such as STBC.




Note---This state machine does not describe the operation of optional features, such as STBC.

**Figure 25-39—Typical Rx state machine(#14)(#1574)(#6313)**



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## 25.14 CMMG PLME

### 25.14.1 PLME SAP layer management primitive(#6320)

Table 25-36 (CMMG PHY MIB attributes) lists the MIB attributes that may be accessed by the PHY entities and the intralayer of higher level LMEs. These attributes are accessed via the PLME-GET, PLME-SET, PLME-RESET, and PLME-CHARACTERISTICS primitives defined in 6.7 (PLME SAP interface).

### 25.14.2 PHY MIB

CMMG PHY MIB attributes are defined in Annex C with specific values defined in Table 25-36 (CMMG PHY MIB attributes). The (#4177)Operational semantics column in Table 25-36 (CMMG PHY MIB attributes) contains two types: static and dynamic.

— Static MIB attributes are fixed and cannot be modified for a given PHY implementation.

— Dynamic MIB attributes are interpreted according to the MAX-ACCESS field of the MIB attribute.

When MAX-ACCESS is read-only, the MIB attribute value may be updated by the PLME and read from the MIB attribute by management entities. When MAX-ACCESS is read-write, the MIB attribute may be read and written by management entities but shall not be updated by the PLME.

**Table 25-36—CMMG PHY MIB attributes**

| Managed object | Default value/ range | Operational semantics |
|---|---|---|
| **dot11PHYOperationTable** | | |
| dot11PHYType | cmmg(13) | Static |
| **dot11PHYCMMGTable** | | |
| dot11CMMGCurrentChannelWidth | Implementation dependent | Dynamic |
| dot11CMMGCurrentChannelCenterFrequencyIndex | Implementation dependent | Dynamic |
| dot11CMMGShortGIOptionImplemented | false/Boolean | Static |
| dot11CMMGShortGIOptionActivated | false/Boolean | Dynamic |
| dot11CMMGTxSTBCOptionImplemented | false/Boolean | Static |
| dot11CMMGTxSTBCOptionActivated | false/Boolean | Dynamic |
| dot11CMMGRxSTBCOptionImplemented | false/Boolean | Static |
| dot11CMMGRxSTBCOptionActivated | false/Boolean | Dynamic |
| dot11CMMGBeamFormingOptionImplemented | false/Boolean | Static |
| dot11CMMGBeamFormingOptionActivated | false/Boolean | Dynamic |
| dot11CMMGMaxNTxChainsImplemented | Implementation dependent | Static |
| dot11CMMGMaxNTxChainsActivated | Implementation dependent | Dynamic |

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**Table 25-36—CMMG PHY MIB attributes *(continued)***

| Managed object | Default value/ range | Operational semantics |
|---|---|---|
| **dot11TransmitBeamformingConfigTable** | | |
| dot11ReceiveNDPOptionImplemented | false/Boolean | Static |
| dot11TransmitNDPOptionImplemented | false/Boolean | Static |
| dot11ExplicitCSITransmitBeamformingOptionImplemented | false/Boolean | Static |
| dot11ExplicitTransmitBeamformingCSIFeedbackOptionImplemented | Implementation dependent | Static |
| dot11ExplicitCompressedBeamformingFeedbackOptionImplemented | Implementation dependent | Static |
| dot11NumberBeamFormingCSISupportAntenna | Implementation dependent | Static |
| dot11NumberCompressedBeamformingMatrixSupportAntenna | Implementation dependent | Static |
| dot11BeamformeeOptionImplemented | false/Boolean | Static |
| dot11BeamformerOptionImplemented | false/Boolean | Static |
| dot11NumberSoundingDimensions | Implementation dependent | Static |
| dot11BeamformeeNTxSupport | Implementation dependent | Static |

### 25.14.3 TXTIME calculation

The value of the TXTIME parameter returned by the PLME-TXTIME.confirm primitive shall be calculated for a(#1424) (#7168)CMMG SC mode PPDU using Equation (25-77) and for a (#7168)CMMG OFDM mode PPDU using Equation (25-78).

$$TXTIME = T_{STF} + T_{CEF} + T_{SIG} + T_{SCTF} + N_{BL} \times T_{BLK} \quad (25\text{-}77)$$

$$TXTIME = T_{STF} + T_{CEF} + T_{SIG} + T_{OSTF} + N_{OCEF} T_{OCEF} + N_{SYM} \times T_{SYM} \quad (25\text{-}78)$$

where $T_{STF}$, $T_{CEF}$, $T_{SIG}$, $T_{SCTF}$, $T_{OSTF}$, and $T_{OCEF}$ are defined in Table 25-3 (Timing-related parameters(#7171)(M118)).

For an NDP, there is no Data field, and $N_{SYM} = 0$.

For a(#1424) (#7168)CMMG SC mode PPDU, the total number of data blocks in the Data field, $N_{BL}$, is given by Equation (25-27).


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### 25.14.4 PHY characteristics

(#2123)The CMMG PHY characteristics, provided through the PLME-CHARACTERISTICS service primitive, are shown in Table 25-37 (CMMG PHY characteristics). The definitions for these characteristics are given in 6.7.4 (PLME-CHARACTERISTICS.confirm).

**Table 25-37—CMMG PHY characteristics**

| PHY parameter | Value |
|---|---|
| aRIFSTime | 1 μs |
| aSIFSTime | 3 μs |
| aRxRFDelay | Implementation dependent |
| aRxPHYDelay | Implementation dependent |
| aRxTxTurnaroundTime | 1 μs |
| aCCATime | 3 μs |
| aCMMGPPMinListeningTime | 150 μs |
| aTxRFDelay | Implementation dependent |
| aTxPHYDelay | Implementation dependent |
| aRxTxSwitchTime | 1 μs |
| aTxRampOnTime | Implementation dependent |
| aTxRampOffTime | Implementation dependent |
| aAirPropagationTime | < 600 ns |
| aRxPHYStartDelay | 11 μs |
| aMACProcessingDelay | Implementation dependent |
| aSlotTime | 5 μs |
| aCWmin | 15 |
| aCWmax | 1023 |
| aPPDUMaxTime | 12 ms |
| aPSDUMaxLength | 262 143 octets |
| aSCBlockSize | 256 for 540 MHz<br>512 for 1080 MHz |

## 25.15 Parameters for CMMG-MCSs

### 25.15.1 General

The rate-dependent parameters for 540 MHz and 1080 MHz are given in 25.15.2 (Parameters for CMMG-MCSs with CMMG SC mode transmission(#7168)) and 25.15.3 (Parameters for CMMG-MCSs with CMMG OFDM mode transmission(#7168)). Support for short GI is optional in all cases. Support for CMMG-MCSs 4 to 16 is optional in all cases. A CMMG STA shall support single spatial stream CMMG-MCSs within the range CMMG-MCS 0 to 3 for 540 MHz channel widths for which it has indicated support

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regardless of the Tx or Rx Highest Supported Long GI Data Rate subfield values in the Supported CMMG-MCS and NSS Set field. When more than one spatial stream is supported, the Tx or Rx Highest Supported Long GI Data Rate subfield values in the Supported CMMG-MCS and NSS Set field may result in a reduced CMMG-MCS range (cut-off) for $N_{SS}$ = 2, 3, 4. Support for 540 MHz with $N_{SS}$ = 1 and SC transmission is mandatory. Support for 540 MHz and 1080 MHz with $N_{SS}$ = 2, 3, 4 and SC transmission is optional. Support for 540 MHz and 1080 MHz with OFDM transmission is optional.

### 25.15.2 Parameters for CMMG-MCSs with CMMG SC mode transmission(#7168)

The related parameters for different modulation are summarized in Table 25-38 (CMMG SC MCSs for mandatory 540 MHz, Nss=1) to Table 25-41 (CMMG SC MCSs for optional 540 MHz, Nss=4 (Optional)) for 540 MHz channel bandwidth with (#7168)CMMG SC mode transmission.

**Table 25-38—CMMG SC MCSs for mandatory 540 MHz, $N_{ss}$=1**

| MCS index | Modulation | *R* | $N_{CBPS}$ | Data rate (Mb/s) | |
|---|---|---|---|---|---|
| | | | | Long GI | Short GI |
| 1 | π/2-BPSK | 1/2 | 1 | 165.00 | 192.50 |
| 2 | π/2-QPSK | 1/2 | 2 | 330.00 | 385.00 |
| 3 | π/2-QPSK | 3/4 | 2 | 495.00 | 577.50 |
| 4 | π/2-16-QAM | 1/2 | 4 | 660.00 | 770.00 |
| 5 | π/2-16-QAM | 3/4 | 4 | 990.00 | 1155.00 |
| 6 | π/2-64-QAM | 5/8 | 6 | 1237.50 | 1443.75 |
| 7 | π/2-64-QAM | 3/4 | 6 | 1485.00 | 1732.50 |
| 8 | π/2-64-QAM | 13/16 | 6 | 1608.75 | 1876.88 |

**Table 25-39—CMMG SC MCSs for optional 540 MHz, $N_{ss}$=2 (Optional)**

| MCS index | Modulation | *R* | $N_{CBPS}$ | Data rate (Mb/s) | |
|---|---|---|---|---|---|
| | | | | Long GI | Short GI |
| 1 | π/2-BPSK | 1/2 | 1 | 330.00 | 385.00 |
| 2 | π/2-QPSK | 1/2 | 2 | 660.00 | 770.00 |
| 3 | π/2-QPSK | 3/4 | 2 | 990.00 | 1155.00 |
| 4 | π/2-16-QAM | 1/2 | 4 | 1320.00 | 1540.00 |
| 5 | π/2-16-QAM | 3/4 | 4 | 1980.00 | 2310.00 |
| 6 | π/2-64-QAM | 5/8 | 6 | 2475.00 | 2887.50 |
| 7 | π/2-64-QAM | 3/4 | 6 | 2970.00 | 3465.00 |
| 8 | π/2-64-QAM | 13/16 | 6 | 3217.50 | 3753.75 |


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**Table 25-40—CMMG SC MCSs for optional 540 MHz, $N_{SS}$=3 (Optional)**

| MCS index | Modulation | *R* | $N_{CBPS}$ | Data rate (Mb/s) | |
|---|---|---|---|---|---|
| | | | | Long GI | Short GI |
| 1 | π/2-BPSK | 1/2 | 1 | 495.00 | 577.50 |
| 2 | π/2-QPSK | 1/2 | 2 | 990.00 | 1155.00 |
| 3 | π/2-QPSK | 3/4 | 2 | 1485.00 | 1732.50 |
| 4 | π/2-16-QAM | 1/2 | 4 | 1980.00 | 2310.00 |
| 5 | π/2-16-QAM | 3/4 | 4 | 2970.00 | 3465.00 |
| 6 | π/2-64-QAM | 5/8 | 6 | 3712.50 | 4331.25 |
| 7 | π/2-64-QAM | 3/4 | 6 | 4455.00 | 5197.50 |
| 8 | π/2-64-QAM | 13/16 | 6 | 4826.50 | 5630.63 |

**Table 25-41—CMMG SC MCSs for optional 540 MHz, $N_{SS}$=4 (Optional)**

| MCS index | Modulation | *R* | $N_{CBPS}$ | Data rate (Mb/s) | |
|---|---|---|---|---|---|
| | | | | Long GI | Short GI |
| 1 | π/2-BPSK | 1/2 | 1 | 660.00 | 770.00 |
| 2 | π/2-QPSK | 1/2 | 2 | 1320.00 | 1540.00 |
| 3 | π/2-QPSK | 3/4 | 2 | 1980.00 | 2310.00 |
| 4 | π/2-16-QAM | 1/2 | 4 | 2640.00 | 3080.00 |
| 5 | π/2-16-QAM | 3/4 | 4 | 3960.00 | 4620.00 |
| 6 | π/2-64-QAM | 5/8 | 6 | 4950.00 | 5775.00 |
| 7 | π/2-64-QAM | 3/4 | 6 | 5940.00 | 6930.00 |
| 8 | π/2-64-QAM | 13/16 | 6 | 6435.00 | 7507.50 |

The related parameters for different modulation are summarized in Table 25-42 (CMMG SC MCSs for mandatory 1080 MHz, Nss=1) to Table 25-45 (CMMG SC MCSs for optional 1080 MHz, Nss=4 (Optional)) for 1080 MHz channel bandwidth with (#7168)CMMG SC mode transmission.

**Table 25-42—CMMG SC MCSs for mandatory 1080 MHz, $N_{SS}$=1**

| MCS index | Modulation | *R* | $N_{CBPS}$ | Data rate (Mb/s) | |
|---|---|---|---|---|---|
| | | | | Long GI | Short GI |
| 1 | π/2-BPSK | 1/2 | 1 | 330.00 | 385.00 |
| 2 | π/2-QPSK | 1/2 | 2 | 660.00 | 770.00 |
| 3 | π/2-QPSK | 3/4 | 2 | 990.00 | 1155.00 |

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**Table 25-42—CMMG SC MCSs for mandatory 1080 MHz, $N_{SS}$=1**

| MCS index | Modulation | *R* | $N_{CBPS}$ | Data rate (Mb/s) | |
|---|---|---|---|---|---|
| | | | | Long GI | Short GI |
| 4 | π/2-16-QAM | 1/2 | 4 | 1320.00 | 1540.00 |
| 5 | π/2-16-QAM | 3/4 | 4 | 1980.00 | 2310.00 |
| 6 | π/2-64-QAM | 5/8 | 6 | 2475.00 | 2887.50 |
| 7 | π/2-64-QAM | 3/4 | 6 | 2970.00 | 3465.00 |
| 8 | π/2-64-QAM | 13/16 | 6 | 3217.50 | 3753.75 |

**Table 25-43—CMMG SC MCSs for optional 1080 MHz, $N_{SS}$=2 (Optional)**

| MCS index | Modulation | *R* | $N_{CBPS}$ | Data rate (Mb/s) | |
|---|---|---|---|---|---|
| | | | | Long GI | Short GI |
| 1 | π/2-BPSK | 1/2 | 1 | 660.00 | 770.00 |
| 2 | π/2-QPSK | 1/2 | 2 | 1320.00 | 1540.00 |
| 3 | π/2-QPSK | 3/4 | 2 | 1980.00 | 2310.00 |
| 4 | π/2-16-QAM | 1/2 | 4 | 2640.00 | 3080.00 |
| 5 | π/2-16-QAM | 3/4 | 4 | 3960.00 | 4620.00 |
| 6 | π/2-64-QAM | 5/8 | 6 | 4950.00 | 5775.00 |
| 7 | π/2-64-QAM | 3/4 | 6 | 5940.00 | 6930.00 |
| 8 | π/2-64-QAM | 13/16 | 6 | 6435.00 | 7507.50 |

**Table 25-44—CMMG SC MCSs for optional 1080 MHz, $N_{SS}$=3 (Optional)**

| MCS index | Modulation | *R* | $N_{CBPS}$ | Data rate (Mb/s) | |
|---|---|---|---|---|---|
| | | | | Long GI | Short GI |
| 1 | π/2-BPSK | 1/2 | 1 | 990.00 | 1155.00 |
| 2 | π/2-QPSK | 1/2 | 2 | 1980.00 | 2310.00 |
| 3 | π/2-QPSK | 3/4 | 2 | 2970.00 | 3465.00 |
| 4 | π/2-16-QAM | 1/2 | 4 | 3960.00 | 4620.00 |
| 5 | π/2-16-QAM | 3/4 | 4 | 5940.00 | 6930.00 |
| 6 | π/2-64-QAM | 5/8 | 6 | 7425.00 | 8662.50 |
| 7 | π/2-64-QAM | 3/4 | 6 | 8910.00 | 10395.00 |
| 8 | π/2-64-QAM | 13/16 | 6 | 9652.50 | 11261.25 |


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**Table 25-45—CMMG SC MCSs for optional 1080 MHz, $N_{SS}$=4 (Optional)**

| MCS index | Modulation | *R* | $N_{CBPS}$ | Data rate (Mb/s) | |
|---|---|---|---|---|---|
| | | | | Long GI | Short GI |
| 1 | π/2-BPSK | 1/2 | 1 | 1320.00 | 1540.00 |
| 2 | π/2-QPSK | 1/2 | 2 | 2640.00 | 3080.00 |
| 3 | π/2-QPSK | 3/4 | 2 | 3960.00 | 4620.00 |
| 4 | π/2-16-QAM | 1/2 | 4 | 5280.00 | 6160.00 |
| 5 | π/2-16-QAM | 3/4 | 4 | 7920.00 | 9240.00 |
| 6 | π/2-64-QAM | 5/8 | 6 | 9900.00 | 11550.00 |
| 7 | π/2-64-QAM | 3/4 | 6 | 11880.00 | 13860.00 |
| 8 | π/2-64-QAM | 13/16 | 6 | 12870.00 | 15015.00 |

### 25.15.3 Parameters for CMMG-MCSs with CMMG OFDM mode transmission(#7168)

The related parameters for different modulation are summarized in Table 25-46 (CMMG OFDM MCSs for optional 540 MHz, Nss=1 (Optional)) to Table 25-49 (CMMG OFDM MCSs for optional 540 MHz, Nss=4 (Optional)) for 540 MHz channel bandwidth with (#7168)CMMG OFDM mode transmission.

**Table 25-46—CMMG OFDM MCSs for optional 540 MHz, $N_{SS}$=1 (Optional)**

| MCS index | Modulation | *R* | $N_{CBPS}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) | |
|---|---|---|---|---|---|---|---|
| | | | | | | Long GI | Short GI |
| 9 | BPSK | 1/2 | 1 | 168 | 84 | 173.25 | 192.50 |
| 10 | QPSK | 1/2 | 2 | 336 | 168 | 346.50 | 385.00 |
| 11 | QPSK | 3/4 | 2 | 336 | 252 | 519.75 | 577.50 |
| 12 | 16-QAM | 1/2 | 4 | 672 | 336 | 693.00 | 770.00 |
| 13 | 16-QAM | 3/4 | 4 | 672 | 504 | 1039.50 | 1155.00 |
| 14 | 64-QAM | 5/8 | 6 | 1008 | 630 | 1299.38 | 1443.75 |
| 15 | 64-QAM | 3/4 | 6 | 1008 | 756 | 1559.25 | 1732.50 |
| 16 | 64-QAM | 13/16 | 6 | 1008 | 819 | 1689.19 | 1876.88 |

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**Table 25-47—CMMG OFDM MCSs for optional 540 MHz, $N_{SS}$=2 (Optional)**

| MCS index | Modulation | $R$ | $N_{CBPS}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) | |
|---|---|---|---|---|---|---|---|
| | | | | | | Long GI | Short GI |
| 9 | BPSK | 1/2 | 1 | 336 | 168 | 346.50 | 385.00 |
| 10 | QPSK | 1/2 | 2 | 672 | 336 | 693.00 | 770.00 |
| 11 | QPSK | 3/4 | 2 | 672 | 504 | 1039.50 | 1155.00 |
| 12 | 16-QAM | 1/2 | 4 | 1344 | 672 | 1386.00 | 1540.00 |
| 13 | 16-QAM | 3/4 | 4 | 1344 | 1008 | 2079.00 | 2310.00 |
| 14 | 64-QAM | 5/8 | 6 | 2016 | 1260 | 2598.75 | 2887.50 |
| 15 | 64-QAM | 3/4 | 6 | 2016 | 1512 | 3118.50 | 3465.00 |
| 16 | 64-QAM | 13/16 | 6 | 2016 | 1638 | 3378.38 | 3753.75 |

**Table 25-48—CMMG OFDM MCSs for optional 540 MHz, $N_{SS}$=3 (Optional)**

| MCS index | Modulation | $R$ | $N_{CBPS}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) | |
|---|---|---|---|---|---|---|---|
| | | | | | | Long GI | Short GI |
| 9 | BPSK | 1/2 | 1 | 504 | 252 | 519.75 | 577.50 |
| 10 | QPSK | 1/2 | 2 | 1008 | 504 | 1039.50 | 1155.00 |
| 11 | QPSK | 3/4 | 2 | 1008 | 756 | 1559.25 | 1732.50 |
| 12 | 16-QAM | 1/2 | 4 | 2016 | 1008 | 2079.00 | 2310.00 |
| 13 | 16-QAM | 3/4 | 4 | 2016 | 1512 | 3118.50 | 3465.00 |
| 14 | 64-QAM | 5/8 | 6 | 3024 | 1890 | 3898.13 | 4331.25 |
| 15 | 64-QAM | 3/4 | 6 | 3024 | 2268 | 4677.75 | 5197.50 |
| 16 | 64-QAM | 13/16 | 6 | 3024 | 2457 | 5067.56 | 5630.63 |

**Table 25-49—CMMG OFDM MCSs for optional 540 MHz, $N_{SS}$=4 (Optional)**

| MCS index | Modulation | $R$ | $N_{CBPS}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) | |
|---|---|---|---|---|---|---|---|
| | | | | | | Long GI | Short GI |
| 9 | BPSK | 1/2 | 1 | 672 | 336 | 693.00 | 770.00 |
| 10 | QPSK | 1/2 | 2 | 1344 | 672 | 1386.00 | 1540.00 |
| 11 | QPSK | 3/4 | 2 | 1344 | 1008 | 2079.00 | 2310.00 |
| 12 | 16-QAM | 1/2 | 4 | 2688 | 1344 | 2772.00 | 3080.00 |
| 13 | 16-QAM | 3/4 | 4 | 2688 | 2016 | 4158.00 | 4620.00 |


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**Table 25-49—CMMG OFDM MCSs for optional 540 MHz, $N_{SS}$=4 (Optional)**

| MCS index | Modulation | *R* | $N_{CBPS}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) | |
|---|---|---|---|---|---|---|---|
| | | | | | | Long GI | Short GI |
| 14 | 64-QAM | 5/8 | 6 | 4032 | 2520 | 5197.50 | 5775.00 |
| 15 | 64-QAM | 3/4 | 6 | 4032 | 3024 | 6237.00 | 6930.00 |
| 16 | 64-QAM | 13/16 | 6 | 4032 | 3276 | 6756.75 | 7507.50 |

The related parameters for different modulation are summarized in Table 25-50 (CMMG OFDM MCSs for optional 1080 MHz, Nss=1 (Optional)) to Table 25-53 (CMMG OFDM MCSs for optional 1080 MHz, Nss=4 (Optional)) for 1080 MHz channel bandwidth with (#7168)CMMG OFDM mode transmission.

**Table 25-50—CMMG OFDM MCSs for optional 1080 MHz, $N_{SS}$=1 (Optional)**

| MCS index | Modulation | *R* | $N_{CBPS}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) | |
|---|---|---|---|---|---|---|---|
| | | | | | | Long GI | Short GI |
| 9 | BPSK | 1/2 | 1 | 336 | 168 | 346.50 | 385.00 |
| 10 | QPSK | 1/2 | 2 | 672 | 336 | 693.00 | 770.00 |
| 11 | QPSK | 3/4 | 2 | 672 | 504 | 1039.50 | 1155.00 |
| 12 | 16-QAM | 1/2 | 4 | 1344 | 672 | 1386.00 | 1540.00 |
| 13 | 16-QAM | 3/4 | 4 | 1344 | 1008 | 2079.00 | 2310.00 |
| 14 | 64-QAM | 5/8 | 6 | 2016 | 1260 | 2598.75 | 2887.50 |
| 15 | 64-QAM | 3/4 | 6 | 2016 | 1512 | 3118.50 | 3465.00 |
| 16 | 64-QAM | 13/16 | 6 | 2016 | 1638 | 3378.38 | 3753.75 |

**Table 25-51—CMMG OFDM MCSs for optional 1080 MHz, $N_{SS}$=2 (Optional)**

| MCS index | Modulation | *R* | $N_{CBPS}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) | |
|---|---|---|---|---|---|---|---|
| | | | | | | Long GI | Short GI |
| 9 | BPSK | 1/2 | 1 | 672 | 336 | 693.00 | 770.00 |
| 10 | QPSK | 1/2 | 2 | 1344 | 672 | 1386.00 | 1540.00 |
| 11 | QPSK | 3/4 | 2 | 1344 | 1008 | 2079.00 | 2310.00 |
| 12 | 16-QAM | 1/2 | 4 | 2688 | 1344 | 2772.00 | 3080.00 |
| 13 | 16-QAM | 3/4 | 4 | 2688 | 2016 | 4158.00 | 4620.00 |
| 14 | 64-QAM | 5/8 | 6 | 4032 | 2520 | 5197.50 | 5775.00 |
| 15 | 64-QAM | 3/4 | 6 | 4032 | 3024 | 6237.00 | 6930.00 |
| 16 | 64-QAM | 13/16 | 6 | 4032 | 3276 | 6756.75 | 7507.50 |

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**Table 25-52—CMMG OFDM MCSs for optional 1080 MHz, $N_{SS}$=3 (Optional)**

| MCS index | Modulation | $R$ | $N_{CBPS}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) | |
|---|---|---|---|---|---|---|---|
| | | | | | | Long GI | Short GI |
| 9 | BPSK | 1/2 | 1 | 1008 | 504 | 1039.50 | 1155.00 |
| 10 | QPSK | 1/2 | 2 | 2016 | 1008 | 2079.00 | 2310.00 |
| 11 | QPSK | 3/4 | 2 | 2016 | 1512 | 3118.50 | 3465.00 |
| 12 | 16-QAM | 1/2 | 4 | 4032 | 2016 | 4158.00 | 4620.00 |
| 13 | 16-QAM | 3/4 | 4 | 4032 | 3024 | 6237.00 | 6930.00 |
| 14 | 64-QAM | 5/8 | 6 | 6048 | 3780 | 7796.25 | 8662.50 |
| 15 | 64-QAM | 3/4 | 6 | 6048 | 4536 | 9355.50 | 10 395.00 |
| 16 | 64-QAM | 13/16 | 6 | 6048 | 4914 | 10 135.13 | 11 261.25 |

**Table 25-53—CMMG OFDM MCSs for optional 1080 MHz, $N_{SS}$=4 (Optional)**

| MCS index | Modulation | $R$ | $N_{CBPS}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) | |
|---|---|---|---|---|---|---|---|
| | | | | | | Long GI | Short GI |
| 9 | BPSK | 1/2 | 1 | 1344 | 672 | 1386.00 | 1540.00 |
| 10 | QPSK | 1/2 | 2 | 2688 | 1344 | 2772.00 | 3080.00 |
| 11 | QPSK | 3/4 | 2 | 2688 | 2016 | 4158.00 | 4620.00 |
| 12 | 16-QAM | 1/2 | 4 | 5376 | 2688 | 5544.00 | 6160.00 |
| 13 | 16-QAM | 3/4 | 4 | 5376 | 4032 | 8316.00 | 9240.00 |
| 14 | 64-QAM | 5/8 | 6 | 8064 | 5040 | 10 395.00 | 11 550.00 |
| 15 | 64-QAM | 3/4 | 6 | 8064 | 6048 | 12 474.00 | 13 860.00 |
| 16 | 64-QAM | 13/16 | 6 | 8064 | 6552 | 13 513.50 | 15 015.00 |


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# 26. High-efficiency (HE) MAC specification(11ax)

## 26.1 Introduction

An HE STA (#7024)has a MAC and MLME that comprises the functions defined in Clause 26 (High-efficiency (HE) MAC specification(11ax)) as well as the functions defined in Clause 10 (MAC sublayer functional description), the MLME functions defined in Clause 11 (MLME), and the security functions defined in Clause 12 (Security), except when the functions in Clause 26 (High-efficiency (HE) MAC specification(11ax)) supersede the functions in Clause 10 (MAC sublayer functional description) or Clause 11 (MLME).

(#7024)A frame successfully transmitted by a non-AP STA in response to a Basic Trigger frame is a successful frame exchange sequence(#109) initiated by the STA as referred to in Clause 11 (MLME) and Clause 12 (Security).

## 26.2 HE channel access

### 26.2.1 TXOP duration-based RTS/CTS

In an HE BSS, the use of RTS/CTS can be TXOP duration based or PSDU length based. An HE AP may configure a non-AP HE STA to use the TXOP duration-based RTS/CTS exchanges to help mitigate interference in dense environments.

An HE AP may set the TXOP Duration RTS Threshold subfield in the HE Operation Parameters field in the HE Operation element it transmits to a value between 1 and 1022 to enable TXOP duration-based RTS/CTS exchanges of its associated STAs. The AP may set the TXOP Duration RTS Threshold field to 1023 to disable TXOP duration-based RTS/CTS exchanges of its associated STAs. In Beacon and Probe Response frames, the AP may set the TXOP Duration RTS Threshold field to 0 to make no changes to TXOP duration-based RTS/CTS exchanges of its associated STAs.

If the TXOP Duration RTS Threshold subfield in the HE Operation Parameters field in the most recently received HE Operation element sent by the AP with which a non-AP HE STA is associated is equal to a nonzero value, then the non-AP HE STA shall set dot11TXOPDurationRTSThreshold to the value of the TXOP Duration RTS Threshold subfield. Otherwise, the non-AP HE STA shall not update dot11TXOPDurationRTSThreshold.

The TXOP duration-based RTS/CTS exchange is disabled at a non-AP HE STA if dot11TXOPDurationRTSThreshold is 1023. The TXOP duration-based RTS/CTS exchange is enabled at a non-AP HE STA when dot11TXOPDurationRTSThreshold is less than 1023.

A non-AP HE STA shall use an RTS/CTS exchange to initiate a TXOP if TXOP duration-based RTS/CTS exchange is enabled at a non-AP HE STA and the following conditions are met:

— The STA intends to transmit individually addressed frames to the HE AP or to a TDLS peer STA
— The TXOP duration is greater than or equal to 32 μs × dot11TXOPDurationRTSThreshold

Otherwise, the non-AP HE STA follows the rules defined in 10.3.1 (General).

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### 26.2.2 Intra-BSS and inter-BSS PPDU classification

A STA shall classify a received PPDU as an inter-BSS PPDU if at least one of the following conditions is true:

— (#1023)The BSS color is not disabled (see 26.17.3.3 (Disabling BSS color)) and the(#8140) RXVECTOR parameter BSS_COLOR is not 0 and is not the BSS color of the BSS of which the STA is a member.

— The PPDU is a VHT PPDU with RXVECTOR parameter PARTIAL_AID not equal to the BSSID[39:47] of the BSS in which the STA is associated or any of the other BSSs in the same multiple BSSID set or co-hosted BSSID set to which its BSS belongs and the RXVECTOR parameter GROUP_ID is 0.

— The PPDU is a VHT PPDU with RXVECTOR parameter PARTIAL_AID[5:8] not equal to the 4 LSBs of the BSS color announced by the BSS of which the STA whose dot11PartialBSSColorImplemented is equal to true is a member and RXVECTOR parameter GROUP_ID equal to 63 when the Partial BSS Color field in the most recent HE Operation element is 1.

— The PPDU is either a VHT MU PPDU or an HE MU PPDU with the RXVECTOR parameter UPLINK_FLAG equal to 0, and the STA is an AP.

— The PPDU carries a frame that has a BSSID field, the value of which is not the BSSID of the BSS in which the STA is associated or any of the other BSSs in the same multiple BSSID set or co-hosted BSSID set to which its BSS belongs or the wildcard BSSID.

— The PPDU carries a frame that does not have a BSSID field but has both an RA field and TA field, neither value of which is equal to the BSSID of the BSS in which the STA is associated or any of the other BSSs in the same multiple BSSID set or co-hosted BSSID set to which its BSS belongs. The Individual/Group bit in the TA field(#3522) is forced to 0 prior to comparison.

A STA shall classify the received PPDU as an intra-BSS PPDU if at least one of the following conditions is true:

— (#1023)The BSS color is not disabled (see 26.17.3.3 (Disabling BSS color)) and the RXVECTOR parameter BSS_COLOR(#1021) is the BSS color of the BSS of which the STA is a member or the BSS color of any (#2152)TDLS direct links to which the STA belongs if the STA is an HE STA associated with a non-HE AP.

— The PPDU is a VHT PPDU with RXVECTOR parameter PARTIAL_AID equal to the BSSID[39:47] of the BSS in which the STA is associated or any of the other BSSs in the same multiple BSSID set or co-hosted BSSID set to which its BSS belongs and the RXVECTOR parameter GROUP_ID equal to 0.

— The PPDU is a VHT PPDU with RXVECTOR parameter PARTIAL_AID[5:8] equal to the 4 LSBs of the BSS color announced by of the BSS of which the STA whose dot11PartialBSSColorImplemented is equal to true is a member, the RXVECTOR parameter GROUP_ID is equal to 63, and the Partial BSS Color field in the most recent HE Operation element is 1.

— The PPDU carries a frame that has an RA, TA, or BSSID field value that is equal to the BSSID of the BSS or the BSSID of any BSS in which the STA is associated or any of the other BSSs in the same multiple BSSID set or co-hosted BSSID set to which its BSS belongs. The Individual/Group bit in the TA field(#3522) is forced to 0 prior to the comparison.

— The PPDU carries a Control frame that does not have a TA field and that has an RA field value that matches the saved TXOP holder address of the BSS or any BSS in which the STA is associated or any of the other BSSs in the same multiple BSSID set or co-hosted BSSID set to which its BSS belongs.

NOTE—See 10.19 for the definition of PARTIAL_AID[5:8] and BSSID[39:47].


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Otherwise, the PPDU cannot be determined as an intra-BSS or inter-BSS PPDU.

If, based on the MAC address information of a frame carried in a received PPDU, the received PPDU satisfies both intra-BSS and inter-BSS conditions, then the received PPDU is classified as an intra-BSS PPDU.

If the received PPDU satisfies the intra-BSS conditions using the RXVECTOR parameter BSS_COLOR and also satisfies the inter-BSS conditions using MAC address information of a frame carried in the PPDU, then the classification made using the MAC address information takes precedence. (#1023)

### 26.2.3 SRG PPDU identification

Identification of SRG and non-SRG PPDUs is used during SRG OBSS PD spatial reuse operation as described in 26.10 (HE spatial reuse operation(#2389)).

A non-AP HE STA that has received a Spatial Reuse Parameter Set element from its associated AP with a value of 1 in the SRG Information Present subfield shall use information provided in the Spatial Reuse Parameter Set element to identify BSSs that are members of the STA's SRG to determine if a received inter-BSS PPDU is an SRG PPDU. An HE AP may use an SRG that is different from the SRG that it transmits to other STAs in Spatial Reuse Parameter Set elements to determine whether a received inter-BSS PPDU is an SRG PPDU.

A received HE PPDU that is an inter-BSS PPDU is an SRG PPDU if the bit in the SRG BSS Color Bitmap field indexed by the value of the RXVECTOR parameter BSS_COLOR is 1(#1124). A received VHT PPDU that is an inter-BSS PPDU is an SRG PPDU if the GROUP_ID parameter of the RXVECTOR has a value of 0 and the bit in the SRG Partial BSSID Bitmap field that corresponds to the (#4317)numeric value of PARTIAL_AID[0:5] of the RXVECTOR is 1(#1124).

A received PPDU that is an inter-BSS PPDU is an SRG PPDU if BSSID information from a frame carried in the PPDU is correctly received and the bit in the SRG Partial BSSID Bitmap field that corresponds to the (#4317)numeric value of BSSID[39:44] is 1.

A VHT PPDU that is an inter-BSS PPDU and that is received with RXVECTOR parameter GROUP_ID equal to 0 is an SRG PPDU if the bit in the SRG Partial BSSID Bitmap field that corresponds to the (#4317)numeric value of bits [39:44] of the RA field of any correctly received frame from the PPDU is 1.

A VHT PPDU that is an inter-BSS PPDU and that is received with RXVECTOR parameter GROUP_ID equal to 63 is an SRG PPDU if the bit in the SRG Partial BSSID Bitmap field that corresponds to the (#4317)numeric value of bits [39:44] of the TA field of any correctly received frame from the PPDU is 1.

An HE SU PPDU, HE ER SU PPDU, or HE MU PPDU that is an inter-BSS PPDU and that is received with the RXVECTOR parameter UPLINK_FLAG equal to 1 is an SRG PPDU if the bit in the SRG Partial BSSID Bitmap field that corresponds to the (#4317)numeric value of bits [39:44] of the RA field of any correctly received frame from the PPDU is 1.

Otherwise, the PPDU is not determined to be an SRG PPDU. A non-AP HE STA that has not received a Spatial Reuse Parameter Set element from its associated AP with a value of 1 in the SRG Information Present subfield shall not classify any received PPDUs as an SRG PPDU. An HE AP that has not transmitted a Spatial Reuse Parameter Set element with a value of 1 in the SRG Information Present subfield may classify received PPDUs as SRG PPDUs using information that it has not transmitted.

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### 26.2.4 Updating two NAVs

A non-AP HE STA shall maintain two NAVs, and an HE AP may maintain two NAVs: an intra-BSS NAV and a basic NAV. The intra-BSS NAV is updated by an intra-BSS PPDU. The basic NAV is updated by an inter-BSS PPDU or a PPDU that cannot be classified as intra-BSS or inter-BSS. The mechanism by which a PPDU is classified intra-BSS or inter-BSS is defined in 26.2.2 (Intra-BSS and inter-BSS PPDU classification).

Maintaining two NAVs is beneficial in dense deployment scenarios in which a STA requires protection from frames transmitted by STAs within its BSS, i.e., intra-BSS, and wants to avoid interference from frames transmitted by STAs in a neighboring BSS, i.e., inter-BSS. For example, in a TXOP initiated by the AP with which a STA is associated for an HE TB PPDU transmission, the intra-BSS NAV of the STA is set by the AP to prevent the STA from contending for the channel. The basic NAV of the STA is not updated by transmissions from the AP during the TXOP so that if the basic NAV of the STA is nonzero and the STA receives, from the AP, a Trigger frame with the CS Required subfield equal to 1, the STA does(M118) not respond (see 26.5.2.5 (UL MU CS mechanism)).

The requirements in 10.3.2.1 (CS mechanism) apply to an HE STA maintaining two NAVs, with the exception of the virtual CS indication of medium. For an HE STA maintaining two NAVs, if both the NAV timers are 0, the virtual CS indication is that the medium is idle; if at least one of the two NAV timers is nonzero, the virtual CS indication is that the medium is busy.

The procedure in 10.3.2.9 (CTS and DMG CTS procedure) applies to an HE STA maintaining two NAVs, and the NAV referred by the description in 10.3.2.4 (Setting and resetting the NAV) is the basic NAV.(#2384)

A STA shall update the intra-BSS NAV with the duration information indicated by the received frame in a PSDU (#7220)if all the following conditions are met:

- The frame is identified as intra-BSS according to the rule described in 26.2.2 (Intra-BSS and inter-BSS PPDU classification).
- The indicated duration is greater than the current intra-BSS NAV value.
- The RA of the received frame is not the STA's MAC address; or the STA is not a TXOP holder, and the PPDU carrying the frame does not contain a frame that solicits an immediate response from the STA; or the STA is not a TXOP holder, and the received frame is a Trigger frame.

Otherwise it shall not so update the intra-BSS NAV.(#7220)

A STA shall update the basic NAV with the duration information indicated by the received frame in a PSDU (#7220)if all the following conditions are met:

- The frame is identified as inter-BSS or cannot be identified as intra-BSS or inter-BSS according to the rule described in 26.2.2 (Intra-BSS and inter-BSS PPDU classification).
- The indicated duration is greater than the current basic NAV value.
- The RA of the received frame is not the STA's MAC address.

Otherwise it shall not so update the basic NAV.(#7220)

A STA that is a TXOP holder shall not update the intra-BSS NAV with the duration information indicated by the RXVECTOR parameter TXOP_DURATION.

A STA that is not a TXOP holder shall update the intra-BSS NAV with the duration information indicated by the RXVECTOR parameter TXOP_DURATION for an HE PPDU (#7220)if all the following conditions are met:


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- The RXVECTOR parameter TXOP_DURATION is not UNSPECIFIED.
- The PPDU that carried information of the RXVECTOR parameter is identified as intra-BSS according to the rule described in 26.2.2 (Intra-BSS and inter-BSS PPDU classification).
- The STA does not receive a frame with a Duration field in the PPDU.
- The duration information indicated by the RXVECTOR parameter TXOP_DURATION is greater than the current intra-BSS NAV of the STA.

Otherwise it shall not so update the intra-BSS NAV.(#7220)

A STA shall update the basic NAV with the duration information indicated by the RXVECTOR parameter TXOP_DURATION for an HE PPDU (#7220)if all the following conditions are met:

- The RXVECTOR parameter TXOP_DURATION is not UNSPECIFIED.
- The PPDU that carried information for the RXVECTOR parameter is identified as inter-BSS or cannot be identified as intra-BSS or inter-BSS according to the rule described in 26.2.2 (Intra-BSS and inter-BSS PPDU classification).
- The STA does not receive a frame with a Duration field in the PPDU.
- The duration information indicated by the RXVECTOR parameter TXOP_DURATION is greater than the current basic NAV of the STA.

Otherwise it shall not so update the basic NAV.(#7220)

NOTE 1—If a PS-Poll frame is received in an HE SU PPDU, HE ER SU PPDU, or HE MU PPDU, then the RXVECTOR parameter TXOP_DURATION does not indicate duration information (see 26.11.5 (TXOP_DURATION)).

NOTE 2—If a STA receives an HE PPDU with the duration information indicated by both a frame with a Duration field and the RXVECTOR parameter TXOP_DURATION, then the duration information indicated by the RXVECTOR parameter TXOP_DURATION is ignored.

NOTE 3—The additional rules of NAV consideration for a STA that is solicited for an immediate response are described in 10.3.2.9 (CTS and DMG CTS procedure), 10.3.2.11 (Acknowledgment procedure), and 26.5.2.5 (UL MU CS mechanism).

A PHY-CCARESET.request primitive shall be issued if one of the following condition is met:

- One NAV is reset, and the other NAV timer is 0.
- Both NAVs are reset simultaneously.

The NAVs (if any) are updated at the expected end of the PPDU as defined in 10.3.2.4 (Setting and resetting the NAV).

An HE STA that used information from an RTS or MU-RTS Trigger frame as the most recent basis to update its NAV may reset the NAV that is updated by the RTS or MU-RTS Trigger frame if no (#3038)PHY-RXEARLYSIG.indication or PHY-RXSTART.indication primitive is received from the PHY during a period with a duration of 2 × aSIFSTime + CTS_Time + aRxPHYStartDelay + 2 × aSlotTime starting when the MAC receives a PHY-RXEND.indication primitive corresponding to the detection of the RTS or MU-RTS Trigger frame (see 10.3.2.4 (Setting and resetting the NAV) for the definition of CTS_Time).

### 26.2.5 Truncation of TXOP

A non-AP HE STA that is not associated with an HE AP shall interpret the reception of a CF-End frame as a NAV reset, i.e., it resets its maintained NAV to 0 at the end of the PPDU containing this frame.

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An HE AP that maintains one NAV (see 10.3.2.1 (CS mechanism)) and receives a CF-End frame should reset the NAV, unless either of following conditions is met:

— The received CF-End frame is carried in an inter-BSS PPDU, and the most recently updated NAV was due to a frame carried in an intra-BSS PPDU (see 26.2.2 (Intra-BSS and inter-BSS PPDU classification)).

— The received CF-End frame is carried in an intra-BSS PPDU, and the most recently updated NAV was due to a frame carried in an inter-BSS PPDU (see 26.2.2 (Intra-BSS and inter-BSS PPDU classification)).

An HE STA that maintains two NAVs (see 26.2.4 (Updating two NAVs)) and receives a CF-End frame should reset the basic NAV if the received CF-End frame is carried in an inter-BSS PPDU and reset the intra-BSS NAV if the received CF-End frame is carried in an intra-BSS PPDU.

An HE STA that maintains two NAVs may reset both NAVs if the received CF-End frame is carried in an intra-BSS PPDU and the basic NAV was updated due to a frame carried in a PPDU that cannot be identified as either an inter-BSS PPDU or intra-BSS PPDU.

An HE STA that receives a CF-End frame and resets all its maintained NAV(s) can start contending for the medium without further delay.

### 26.2.6 MU-RTS Trigger/CTS frame exchange sequence procedure(#109)

#### 26.2.6.1 General

The MU-RTS Trigger/CTS frame exchange sequence(#109) procedure allows an AP to initiate a TXOP and protect the TXOP frame exchange sequences(#109). An AP may transmit an MU-RTS Trigger frame to solicit simultaneous CTS frame (#1926)transmissions from one or more non-AP STAs.

Figure 26-1 (Example of MU-RTS/CTS/DL MU PPDU/Acknowledgment Response and NAV setting(11ax)) shows an example of the exchange of MU-RTS and simultaneous CTS responses to protect the DL MU PPDU and the acknowledgment responses.

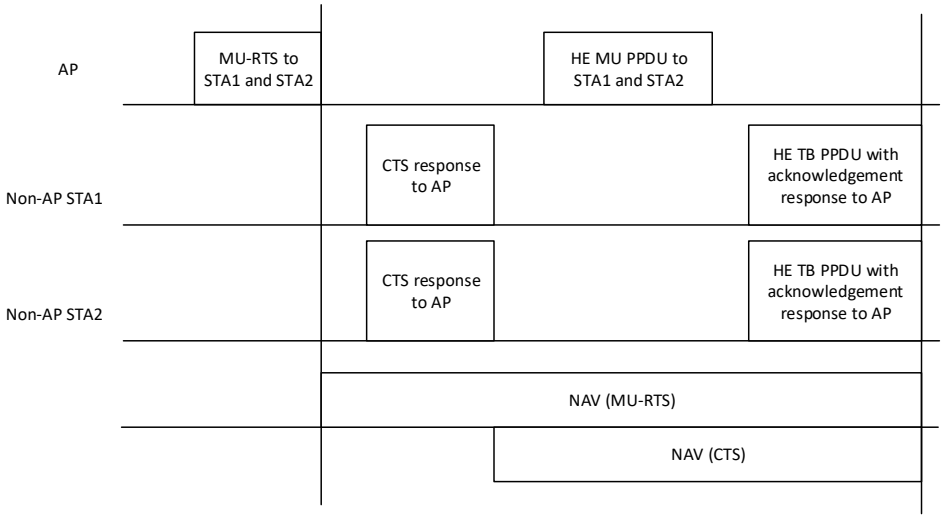


**Figure 26-1—Example of MU-RTS/CTS/DL MU PPDU/Acknowledgment Response and NAV setting(11ax)**


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Figure 26-2 (Example of MU-RTS/CTS/Trigger/HE TB PPDU/Multi-STA BlockAck and NAV setting(11ax)) shows an example of the exchange of MU-RTS and simultaneous CTS responses to protect the HE TB PPDU and Multi-STA BlockAck frame.

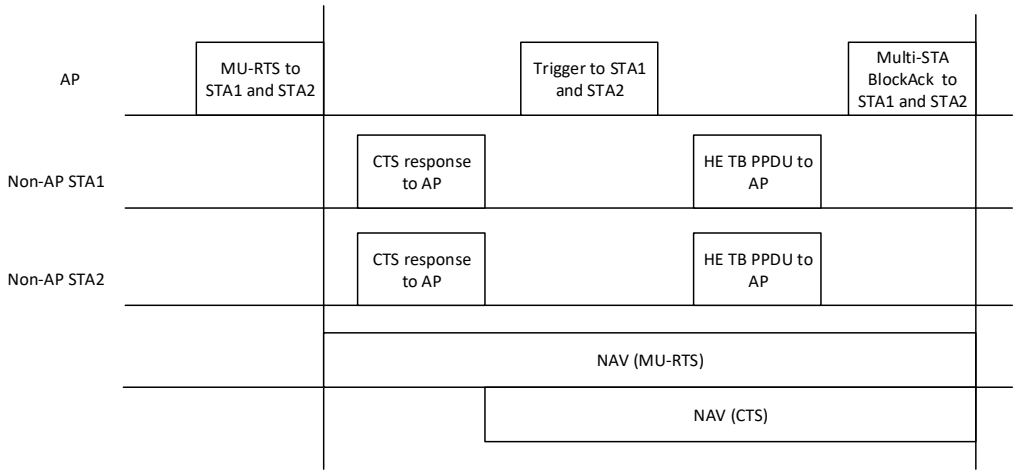


**Figure 26-2—Example of MU-RTS/CTS/Trigger/HE TB PPDU/Multi-STA BlockAck and NAV setting(11ax)**

### 26.2.6.2 MU-RTS Trigger frame transmission

In each 20 MHz channel occupied by the PPDU that contains an MU-RTS Trigger frame, the transmitter of the MU-RTS Trigger frame shall request at least one non-AP STA to send a CTS frame(#1926) that occupies the 20 MHz channel. The transmitter of an MU-RTS Trigger frame shall not request a non-AP STA to send a CTS frame(#1926) in a 20 MHz channel that is not occupied by the PPDU that contains the MU-RTS Trigger frame.

After transmitting an MU-RTS Trigger frame, the AP shall wait for a CTSTimeout interval of aSIFSTime + aSlotTime + aRxPHYStartDelay that begins when the MAC receives the PHY-TXEND.confirm primitive for the transmitted MU-RTS Trigger frame. If the MAC does not receive a (#3038)PHY-RXEARLYSIG.indication or PHY-RXSTART.indication primitive during the CTSTimeout interval, the AP shall conclude that the transmission of the MU-RTS Trigger frame has failed, and, if the MU-RTS Trigger frame initiated a TXOP, the AP shall invoke its backoff procedure. If the MAC receives a (#3038)PHY-RXEARLYSIG.indication or PHY-RXSTART.indication primitive during the CTSTimeout interval, then the MAC shall wait for the corresponding PHY-RXEND.indication primitive to determine whether the MU-RTS Trigger frame transmission was successful. The receipt of a CTS frame from any non-AP STA addressed by the MU-RTS Trigger frame before the PHY-RXEND.indication primitive shall be interpreted as the successful transmission of the MU-RTS Trigger frame, permitting the frame exchange sequence to continue. The receipt of any other type of frame shall be interpreted as a failure of the MU-RTS Trigger frame transmission. In this instance, the AP may process the received frame and, if the MU-RTS Trigger frame initiated a TXOP, shall invoke its backoff procedure at the PHY-RXEND.indication primitive.

NOTE—If an AP transmits an MU-RTS Trigger frame in an already initiated TXOP and the MU-RTS Trigger frame transmission fails, then the AP might perform a PIFS recovery as described in 10.23.2.8 (Multiple frame exchange sequences in an EDCA TXOP(#109)) or invoke the backoff procedure described in 10.23.2.2 (EDCA backoff procedure).

An MU-RTS Trigger frame shall not be carried in a VHT MU PPDU or an HE MU PPDU.

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### 26.2.6.3 CTS frame sent in response to an MU-RTS Trigger frame(#1926)

If a non-AP STA receives an MU-RTS Trigger frame, the non-AP STA shall commence the transmission of a CTS frame(#1926) at the SIFS time boundary after the end of a received PPDU when all the following conditions are met:

— The MU-RTS Trigger frame has one of the User Info fields addressed to the non-AP STA. The User Info field is addressed to a non-AP STA if the AID12 subfield is equal to the 12 LSBs of the AID of the STA and the MU-RTS Trigger frame is sent by the AP with which the non-AP STA is associated or by the AP corresponding to the transmitted BSSID if the non-AP STA is associated with an AP corresponding to a nontransmitted BSSID and has indicated support for receiving Control frames with TA field set to the transmitted BSSID by setting the Rx Control Frame To MultiBSS subfield to 1 in the HE Capabilities element that the non-AP STA transmits.

— The UL MU CS condition indicates that the medium is idle (see 26.5.2.5 (UL MU CS mechanism)).

Otherwise, the non-AP STA shall not send a CTS frame(#1926).

NOTE 1—The RU Allocation subfield in the User Info field addressed to the non-AP STA indicates whether the CTS frame(#1926) is to be sent on the primary 20 MHz channel, primary 40 MHz channel, primary 80 MHz channel, 160 MHz channel, or 80+80 MHz channel as described in 9.3.1.22.5 (MU-RTS Trigger frame format).

NOTE 2—A combination of virtual CS and ED-based CCA during the SIFS after the PPDU containing the MU-RTS Trigger frame is used to determine the state of the medium (see 26.5.2.5 (UL MU CS mechanism)).

The CTS frame sent in response to an MU-RTS Trigger frame shall be carried in a non-HT or non-HT duplicate PPDU (see Clause 17) with a 6 Mb/s rate and with the TXVECTOR parameter SCRAMBLER_INITIAL_VALUE set to the same value as the RXVECTOR parameter SCRAMBLER_INITIAL_VALUE of the PPDU carrying the MU-RTS Trigger frame. The PPDU carrying the CTS frame shall be transmitted on the 20 MHz channels indicated in the RU Allocation subfield of the User Info field of the MU-RTS Trigger frame.

NOTE 3—A bandwidth signaling TA is not used in an MU-RTS Trigger frame or a CTS frame (#1926)sent in response to an MU-RTS Trigger frame (see 9.3.1.22 (Trigger frame format(11ax)) and 9.3.1.3 (CTS frame format)). As a result, the TXVECTOR parameter CH_BANDWIDTH_IN_NON_HT is not present when transmitting an MU-RTS Trigger frame or CTS frame (#1926)sent in response to an MU-RTS Trigger frame(#602).

The Power Management and More Data subfields in a CTS frame sent in response to an MU-RTS Trigger frame shall be set to 0.

NOTE 4—Other subfields of the Frame Control field of the CTS frames sent in response to an MU-RTS Trigger frame are set as described in Figure 9-37 (Frame Control field subfield values within Control frames carried in a non-S1G PPDU).

Figure 26-3 (Example of MU-RTS Trigger frame soliciting CTS frame transmissions on primary 40 MHz channel(#1926)(11ax)) shows an example of the exchange of an MU-RTS Trigger frame and simultaneous CTS frame (#1926)transmissions on the primary 40 MHz channel. In this example, MU-RTS Trigger frame is transmitted in a 40 MHz non-HT duplicate PPDU on the primary 40 MHz channel. Further, the MU-RTS Trigger frame requests non-AP STA1 to transmit a CTS frame(#1926) in a non-HT PPDU on the primary 20 MHz channel and non-AP STA2 to transmit a CTS frame(#1926) in a 40 MHz non-HT duplicate PPDU on the primary 40 MHz channel.

A non-AP STA that transmits a CTS frame in response to an MU-RTS Trigger frame shall follow the (M118)precorrection requirements defined in 27.3.15.3 (Precorrection accuracy requirements(M118)).

NOTE 5—The AP Tx Power and UL Target Receive Power fields in an MU-RTS Trigger frame are reserved, and there is no power (M118)precorrection requirement for the CTS frame sent in response to an MU-RTS Trigger frame (i.e., the AP that sends the MU-RTS frame does not specify the transmission power of the solicited CTS frame).


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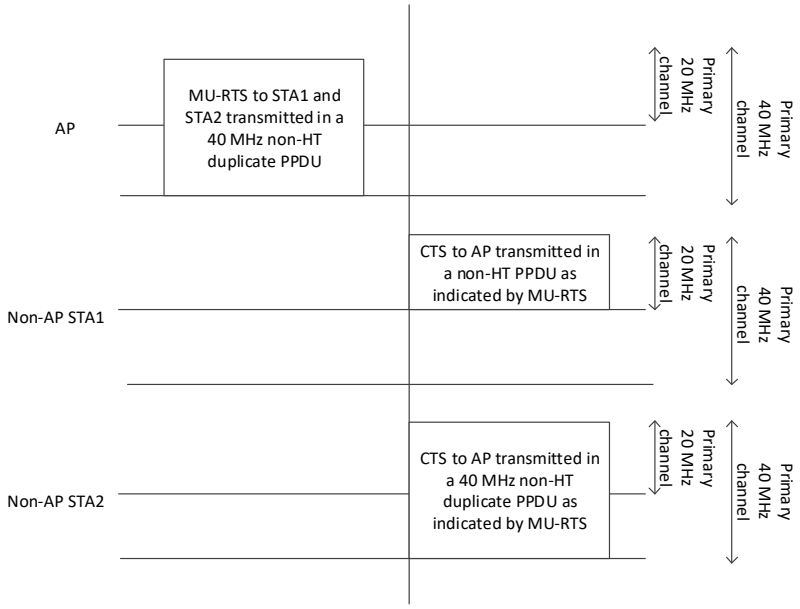


**Figure 26-3—Example of MU-RTS Trigger frame soliciting CTS frame transmissions on primary 40 MHz channel(#1926)(11ax)**

### 26.2.7 EDCA operation using MU EDCA parameters

An HE AP shall set the QoS Info field of an MU EDCA Parameter Set element (if present) to the same value as the QoS Info field of an EDCA Parameter Set element (if present). An HE AP may change the MU EDCA parameters by including the MU EDCA Parameter Set element with updated MU EDCA parameters in the Beacon frames and Probe Response frames it transmits. The EDCA Parameter Set Update Count subfield in the QoS Info field of the EDCA Parameter Set element and MU EDCA Parameter Set element is incremented every time any EDCA parameters or MU EDCA parameters change.

A non-AP HE STA shall update the dot11EDCATable and dot11MUEDCATable that correspond to fields in an EDCA Parameter Set element or an MU EDCA Parameter Set element within an interval of time equal to one beacon interval after receiving an updated EDCA or MU EDCA parameter set from its associated AP. When updating its MIB attributes, an HE STA stores the value of the EDCA Parameter Set Update Count subfield in the QoS Info field of the received EDCA Parameter Set element or MU EDCA Parameter Set element.

A non-AP HE STA shall use the EDCA Parameter Set Update Count subfield in the QoS Capability element of Beacon frames, where present, to determine whether the STA is using the current EDCA (and optionally MU EDCA) (#1660)parameters. If the EDCA Parameter Set Update Count subfield value is different from the value that has been stored, the STA shall query the updated EDCA (and any MU EDCA) (#1660)parameters by sending a Probe Request frame to the AP.

NOTE 1—If the QoS Capability element is present in a Beacon frame, the EDCA Parameter Set element and the MU EDCA Parameter Set element are not present. In this case, the only way for an HE STA to obtain the updated parameters is to send a Probe Request frame to the AP.

A non-AP HE STA that receives a Basic Trigger frame that contains a User Info field addressed to the STA shall update its CWmin[AC], CWmax[AC], AIFSN[AC], and MUEDCATimer[AC] state variables to the values contained in the dot11MUEDCATable, for all the ACs from which at least one QoS Data frame was transmitted successfully in an HE TB PPDU in response to the Trigger frame. A QoS Data frame is

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transmitted successfully by the STA in an HE TB PPDU for an AC if it requires immediate acknowledgment and the STA receives an immediate acknowledgment for that frame, or if the QoS Data frame does not require immediate acknowledgment.

The MUEDCATimer[AC] state variable is updated with the value contained in the MU EDCA Timer subfield of the MU EDCA Parameter Set element. The backoff counter maintenance corresponding to the updated state variables shall follow the rules in 10.23.2.2 (EDCA backoff procedure), except that if AIFSN[AC] is 0, then the EDCAF corresponding to that AC shall be suspended until the MUEDCATimer[AC] reaches 0 or is reset to 0. The updated MUEDCATimer[AC] shall start at the end of the immediate response if the transmitted HE TB PPDU contains at least one QoS Data frame for that AC that requires immediate acknowledgment, and shall start at the end of the HE TB PPDU if the transmitted HE TB PPDU does not contain any QoS Data frames for that AC that require immediate acknowledgment.

In a non-AP HE STA, each MUEDCATimer[AC] shall uniformly count down without suspension to 0 when its value is nonzero.

NOTE 2—A non-AP STA that sends a frame to the AP with an OM Control subfield containing a value of 1 in the UL MU Disable subfield or a value of 0 in the UL MU Disable subfield and a value of 1 in the UL MU Data Disable subfield does not participate in UL MU operation. As such it is exempt from updating its EDCA access parameters to the values contained in the MU EDCA Parameter Set element as defined in this subclause.

NOTE 3—A non-AP STA does not update its state variables to the values contained in the MU EDCA Parameter Set element if any of the following applies:

a) The Trigger frame addressed to the STA is not a Basic Trigger frame.
b) The STA does not include QoS Data frames in the HE TB PPDU response sent in response to the Basic Trigger frame.
c) The STA transmits the HE TB PPDU in response to a Basic Trigger frame following the rules defined in 26.5.4 (UL OFDMA-based random access (UORA)).

NOTE 4—The TXOP limits are not updated by the procedure defined in this subclause, but by the procedure in 10.23.2.9 (TXOP limits).

A non-AP STA that sends frames that are not addressed to its associated AP may use the EDCA parameters(#1660) that are contained in the most recently received EDCA Parameter Set element sent by the AP with which the STA is associated or the default EDCA parameters(#1660) (see Table 9-194 (Default EDCA Parameter Set element (#1660)parameters if dot11OCBActivated is false and the STA is a non-sensor STA(#251))), following the rules in 10.2.3.2 (HCF contention based channel access (EDCA)).

If the MUEDCATimer[AC] of a non-AP HE STA reaches 0, either by counting down or due to a reset following the reception of an MU EDCA Reset frame, the STA shall update CWmin[AC], CWmax[AC], and AIFSN[AC] to the values that are contained in the most recently received EDCA Parameter Set element sent by the AP with which the STA is associated.

A non-AP HE STA that sends a frame with an OM Control subfield with the UL MU Disable subfield set to 1 or with the UL MU Disable subfield set to 0 and the UL MU Data Disable subfield set to 1 as defined in 26.9.3 (Transmit operating mode (TOM) indication) may set the MUEDCATimer[AC] for all ACs to 0 on receiving an immediate acknowledgment from the OMI responder. The STA continues the current EDCA backoff procedure without modifying the QSRC[AC](#3781) or the backoff counter for the associated EDCAF, regardless of whether the MUEDCATimer[AC] has reached zero, until the STA invokes a new EDCA backoff procedure. The STA follows the rules defined in 10.23.2.2 (EDCA backoff procedure) for updating CWmin, CWmax, and AIFSN for that AC.

A non-AP HE STA that receives an individually addressed MU EDCA Reset frame from its associated AP may reset the MUEDCATimer[AC] to 0 for an AC if the bit corresponding to that AC in the Affected ACs subfield is equal to 1 when the MUEDCATimer[AC] of the STA is not equal to 0. The STA may invoke a


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new EDCA backoff procedure after the MUEDCATimer[AC] is reset for that AC and after CWmin[AC], CWmax[AC], and AIFSN[AC] are updated for that AC, as per this subclause, in response to the MUEDCATimer[AC] reset.

### 26.2.8 Multiple frame exchange sequences in an EDCA TXOP in the 6 GHz band(#109)

A STA that operates in the 6 GHz band and transmits multiple frames shall follow the rules defined in 10.23.2.7 (Sharing an EDCA TXOP) with the exceptions described in this subclause.

NOTE 1—In the 6 GHz band, the TXOP field in the HE-SIG-A field can be understood by all STAs. The TXOP field provides TXOP protection equivalent to non-HT duplicate RTS/CTS.

In a TXOP without non-HT duplicate PPDUs, if the TXOP is protected by the TXOP field in the HE-SIG-A field of the first HE PPDU in the TXOP, i.e., the TXOP field is not set to UNSPECIFIED, the TXOP holder shall set the TXVECTOR parameter CH_BANDWIDTH of the subsequent PPDUs in the TXOP to indicate a bandwidth that is the same or narrower than the bandwidth indicated by the CH_BANDWIDTH parameter of the first HE PPDU in the TXOP.

NOTE 2—Frame exchange sequences(#109) in a TXOP that is protected by RTS/CTS follow the rules in 10.23.2.8 (Multiple frame exchange sequences in an EDCA TXOP(#109)).

Additionally, if the first HE PPDU whose TXOP field in the HE-SIG-A field is not set to UNSPECIFIED is a DL HE MU PPDU with preamble puncture, then the TXOP holder shall use the 20 MHz channels for the non-initial PPDU that are within the set of 20 MHz channels where pre-HE modulated fields of the first HE PPDU whose TXOP field in the HE-SIG-A field is not set to UNSPECIFIED are located.

Within an obtained TXOP that does not include HE PPDUs whose TXOP field in the HE-SIG-A field is not UNSPECIFIED nor non-HT duplicate PPDUs, the TXOP holder shall set the TXVECTOR parameter CH_BANDWIDTH of a non-initial PPDU to be equal to or less than the TXVECTOR parameter CH_BANDWIDTH of the preceding PPDU that was transmitted in the same TXOP, subject to the following constraints:

— If the preceding PPDU is a DL HE MU PPDU with preamble puncture, the TXOP holder shall set the TXVECTOR parameter CH_BANDWIDTH of the non-initial PPDU to a value whose corresponding 20 MHz channels are within a set of 20 MHz channels where pre-HE modulated fields of the preceding PPDU are located.

— If the non-initial PPDU is a DL HE MU PPDU with preamble puncture, the TXOP holder shall set the TXVECTOR parameter RU_ALLOCATION of the non-initial PPDU to a value whose corresponding RU is within a set of 20 MHz channels where pre-HE modulated fields of the preceding PPDU are located.

## 26.3 Fragmentation and defragmentation

### 26.3.1 General

An HE STA shall follow the fragmentation procedures defined in (#1234)10.2.7 (Fragmentation/ defragmentation overview)(#3092), 10.4 (MSDU, (11ax)A-MSDU, and MMPDU fragmentation), and 10.5 (MSDU, (11ax)A-MSDU, and MMPDU defragmentation), except that some of the rules are relaxed as defined in the subclauses of 26.3 (Fragmentation and defragmentation). Dynamic fragmentation provides further flexibility in aggregating data to fit in a constrained PPDU duration (see 26.5 (MU operation)).

Subclauses (#1235)10.2.7 (Fragmentation/defragmentation overview) and 10.4 (MSDU, (11ax)A-MSDU, and MMPDU fragmentation) define the procedure to generate uniformly fragmented MSDUs or MMPDUs,

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where the length of each fragment is the same, except for the last fragment. These fragments are not included in an A-MPDU under HT-immediate block ack agreements.

An HE STA can negotiate the use of different levels of dynamic fragmentation:

- Level 1: support for one dynamic fragment that is a non-A-MPDU; no support for dynamic fragments in an A-MPDU that does not contain an S-MPDU.
- Level 2: support for dynamic fragments in an A-MPDU that does not contain an S-MPDU, subject to the following conditions:
  - No more than one dynamic fragment of any given MSDU or A-MSDU in the A-MPDU; this dynamic fragment is sent under a block ack agreement.
  - No more than one MPDU that is a dynamic fragment of an MMPDU in the A-MPDU (see 26.6.2 (A-MPDU padding in an HE PPDU) and 26.6.3 (Multi-TID A-MPDU and ack-enabled single-TID A-MPDU)).
- Level 3: support for dynamic fragments in an A-MPDU that does not contain an S-MPDU, subject to the following conditions:
  - No more than four dynamic fragments of any given MSDU or A-MSDU in the A-MPDU; these dynamic fragments are sent under a block ack agreement.
  - No more than one MPDU that is a dynamic fragment of an MMPDU in the A-MPDU (see 26.6.2 (A-MPDU padding in an HE PPDU) and 26.6.3 (Multi-TID A-MPDU and ack-enabled single-TID A-MPDU)).

NOTE 1—An HE STA that is operating in level 2 or level 3 also supports transmitting and receiving level 1 dynamic fragments.

NOTE 2—Under level 2, there might be multiple Data frames that are dynamic fragments, but these have different sequence numbers and/or UPs.

This subclause defines the procedure for generating nonuniformly fragmented MSDUs, A-MSDUs, or MMPDUs, where the length of each fragment is not necessarily the same. The length of the first fragment shall be greater than or equal to the minimum fragment size indicated in the Minimum Fragment Size subfield in the HE Capabilities Information field in the HE Capabilities element sent by the recipient STA. If the length of the MSDU, A-MSDU, or MMPDU is less than the minimum fragment size, then the MSDU, A-MSDU, or MMPDU shall not be fragmented. The fragments generated with dynamic fragmentation are referred to as dynamic fragments.

These procedures allow the inclusion of one dynamic fragment that is a non-A-MPDU in level 1, level 2, and level 3 and allow the inclusion of one or more dynamic fragments within an A-MPDU that contains one or more MPDUs in level 2 and level 3.

An HE STA follows the rules defined in 26.3.2 (Dynamic fragmentation) for generating these fragments and the rules defined in 26.3.3 (Dynamic defragmentation) for defragmenting of the received dynamic fragments. In 26.3.2 (Dynamic fragmentation) and 26.3.3 (Dynamic defragmentation), the HE STA follows the fragmentation level that is indicated in the Dynamic Fragmentation Support subfield in the HE MAC Capabilities Information field in the HE Capabilities element it transmits, unless an ADDBA Extension element is included in the ADDBA Request and ADDBA Response frames exchanged during the block ack setup procedure. In this case, the HE STA follows the fragmentation level that is indicated in an ADDBA Extension element in the ADDBA Response frame it receives (see 26.3.3.1 (General)) during the block ack setup procedure.

An HE STA shall set the HE Fragmentation Operation subfield in the ADDBA Extension element, if present, in the ADDBA Request or ADDBA Response frame to a value that is less than or equal to the value of the Dynamic Fragmentation Support subfield in the HE Capabilities element it transmits.


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An HE STA shall set the HE Fragmentation Operation subfield in the ADDBA Extension element, if present, in the ADDBA Response frame to a value that is less than or equal to the value of HE Fragmentation Operation subfield in the ADDBA Extension element, if present, in the received ADDBA Request frame.

### 26.3.2 Dynamic fragmentation

#### 26.3.2.1 General

With level 1 and level 2 dynamic fragmentation, the following apply:

— An originator STA transmitting one or more dynamic fragments shall solicit an immediate response from the recipient STA for each of the fragments.

— The originator STA shall transmit the fragments in order as defined in 10.4 (MSDU, (11ax)A-MSDU, and MMPDU fragmentation).

With level 3 dynamic fragmentation, not all dynamic fragments require an immediate response, and dynamic fragments are not required to be sent in order.

An HE STA may transmit dynamic fragments of an A-MSDU, provided the A-MSDU Fragmentation Support subfield in the HE Capabilities element transmitted by the recipient is 1.

The originator STA shall not transmit concurrently the dynamic fragments of a number of outstanding MSDUs and A-MSDUs (if supported) to the same recipient STA that is greater than $N_{max}$, where $N_{max}$ for MSDUs and A-MSDUs (if supported) is calculated based on the Maximum Number of Fragmented MSDUs/A-MSDUs subfield in the HE Capabilities element transmitted by the recipient STA. The term *outstanding* refers to an MPDU containing all or part of an MSDU, A-MSDU, or MMPDU for which transmission has been started and for which delivery of the MSDU, A-MSDU, or MMPDU has not yet been completed (i.e., an acknowledgment of the final fragment has not been received and the MSDU, A-MSDU, or MMPDU has not been discarded due to retries, lifetime, or some other reason).

NOTE—Dynamic fragments of outstanding MMPDUs are not counted in the check against the $N_{max}$ limit.

An originator STA may retransmit the full MSDU, A-MSDU, or MMPDU if all the previously transmitted dynamic fragments of that MSDU, A-MSDU, or MMPDU have explicitly failed at the receiving STA. An originator STA may retransmit a failed fragment if one or more of the previously transmitted fragments of that MSDU, A-MSDU, or MMPDU have explicitly failed at the receiving STA (see the next paragraph for a definition of the term *explicitly failed*). The frame body length and contents of the retransmitted fragment shall be the same as the initially transmitted fragment and shall remain fixed for the lifetime of the MSDU, A-MSDU, or MMPDU at that STA, except when the frame is not encrypted, all the fragments preceding the initial transmitted fragment were received, and all the fragments following the initial transmitted fragment either have explicitly failed or have not been transmitted. In such cases, the frame body length and contents of the retransmitted fragment may be different from the initially transmitted fragment.

A fragment has explicitly failed at the receiving STA if the originator STA receives an immediate response that contains the following:

— A valid first MPDU that is not an Ack frame, Compressed BlockAck frame, or Multi-STA BlockAck frame, of which all the preceding pre-EOF MPDU delimiters are received.

— A Multi-STA BlockAck frame that does not contain a BA Information field with TID equal to that of the fragment.

— A Compressed BlockAck frame or Multi-STA BlockAck frame that contains a BA Information field with TID equal to that of the fragment, but does not acknowledge receipt of the fragment.

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An originator STA shall not transmit to a recipient STA an MPDU that is not carried in an A-MPDU or an A-MPDU that carries dynamic fragments that do not satisfy the conditions in 26.3.2.2 (Level 1 dynamic fragmentation), 26.3.2.3 (Level 2 dynamic fragmentation), and 26.3.2.4 (Level 3 dynamic fragmentation).

### 26.3.2.2 Level 1 dynamic fragmentation

An originator STA may transmit one dynamic fragment of an MSDU, A-MSDU (if supported by the recipient), or MMPDU that is a non-A-MPDU and that is not sent under a block ack agreement to a recipient STA using level 1 dynamic fragmentation if the Dynamic Fragmentation Support subfield in the HE MAC Capabilities Information field in the HE Capabilities element received from the recipient STA is 1, 2, or 3.

An originator STA may transmit a fragmented MSDU or A-MSDU (if supported by the recipient) under a block ack agreement to a recipient STA using level 1 dynamic fragmentation, provided the following condition is met: the Dynamic Fragmentation Support subfield in the HE Capabilities element received from the recipient STA is 1, 2, or 3; and for the block ack agreement associated with the TID of the MSDU or A-MSDU, the HE Fragmentation Operation subfield is 1 if the ADDBA Extension element is present in the ADDBA Response frame received from the recipient STA.

### 26.3.2.3 Level 2 dynamic fragmentation

An originator STA may transmit fragmented MSDUs or A-MSDU (if supported by the recipient) under a block ack agreement to a recipient STA using level 2 dynamic fragmentation, provided one of the following conditions is met:

— The Dynamic Fragmentation Support subfield in the HE Capabilities element received from the recipient STA is 2; and for the block ack agreement associated with the TID of the MSDU or A-MSDU, the HE Fragmentation Operation subfield is 2 if the ADDBA Extension element is present in the ADDBA Response frame received from the recipient STA.

— The Dynamic Fragmentation Support subfield in the HE Capabilities element received from the recipient STA is 3; and for the block ack agreement associated with the TID of the MSDU or A-MSDU, the ADDBA Extension element is present, and the HE Fragmentation Operation subfield is 2 in the ADDBA Response frame received from the recipient STA.

An originator STA may transmit to a recipient STA the following:

— One dynamic fragment of an MSDU, A-MSDU (if supported by the recipient), or MMPDU that is a non-A-MPDU using level 1 dynamic fragmentation.

— Up to one dynamic fragment of an MSDU or A-MSDU (if supported by the recipient) for each MSDU or A-MSDU and up to one dynamic fragment of an MMPDU in an A-MPDU where the A-MPDU contains at least one dynamic fragment using level 2 dynamic fragmentation; the dynamic fragment of an MSDU or A-MSDU shall be sent under a block ack agreement.

NOTE—The originator STA follows the rules in 10.12.8 (Transport of S-MPDUs) for generating the S-MPDU, the rules in 10.25.6.7 (Originator's behavior) for generating the A-MPDU, and the rules in 26.6.3 (Multi-TID A-MPDU and ack-enabled single-TID A-MPDU) for generating a multi-TID A-MPDU that can contain the fragment of the MMPDU.

### 26.3.2.4 Level 3 dynamic fragmentation

An originator STA may transmit fragmented MSDUs or A-MSDU (if supported by the recipient) under a block ack agreement or fragmented MMPDU to a recipient STA using level 3 dynamic fragmentation, provided the following conditions are met:

— The Dynamic Fragmentation Support subfield in the HE Capabilities element received from the recipient STA is 3.


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— For the block ack agreement associated with the TID of the MSDU or A-MSDU, the HE Fragmentation Operation subfield is 3 if the ADDBA Extension element is present in the ADDBA Response frame received from the recipient STA.

Level 3 fragmentation allows multiple fragments of an MSDU or A-MSDU included in the same A-MPDU, reducing the fragments' transmission delay.

An originator STA may transmit to a recipient STA the following:

— One dynamic fragment of an MSDU, A-MSDU (if supported by the recipient), or MMPDU that is a non-A-MPDU using level 1 dynamic fragmentation.
  — The originator STA shall follow the rules defined in 10.12.8 (Transport of S-MPDUs) for generating the S-MPDU.
— Up to four dynamic fragments of an MSDU or A-MSDU (if supported by the recipient) for each MSDU or A-MSDU and up to one dynamic fragment of an MMPDU in an A-MPDU, where the A-MPDU contains at least one dynamic fragment using level 3 dynamic fragmentation; the dynamic fragment of an MSDU or A-MSDU shall be sent under block ack agreement.
  — The originator STA shall set the Fragment Number subfield of each MPDU to a value less than 4.
  — The originator STA shall follow the rules defined in 10.25.6.7 (Originator's behavior) for generating the A-MPDU with the exception that the A-MPDU shall contain MPDUs whose range of the Sequence Number subfields does not exceed $B_L$ / 4, where $B_L$ is the length of the Block Ack Bitmap field of the Compressed BlockAck or Multi-STA BlockAck frame that corresponds to a TID of a transmitted fragment (see 10.25.6 (HT-immediate block ack extensions) and 26.4 (HE acknowledgment procedure)).
  — The originator STA shall ensure that $WinSize_O$ does not exceed $B_L$ / 4, where $B_L$ is the length of the Block Ack Bitmap field of the Compressed BlockAck or Multi-STA BlockAck frame that corresponds to a TID of a transmitted fragment (see 10.25.6 (HT-immediate block ack extensions) and 26.4 (HE acknowledgment procedure)).

### 26.3.3 Dynamic defragmentation

#### 26.3.3.1 General

An HE STA shall set the Dynamic Fragmentation Support subfield in the HE MAC Capabilities Information field in the HE Capabilities element it transmits to 0 if it does not support dynamic fragments. Otherwise, the HE STA shall set the Dynamic Fragmentation Support subfield as follows:

— Set to 1, 2, or 3 if the STA supports reception of dynamic fragments following the procedure defined in 26.3.2.2 (Level 1 dynamic fragmentation).
— Set to 2 or 3 if the STA supports reception of dynamic fragments following the procedure defined in 26.3.2.3 (Level 2 dynamic fragmentation).
— Set to 3 if the STA supports reception of dynamic fragments following the procedure defined in 26.3.2.4 (Level 3 dynamic fragmentation).

An HE STA shall set dot11HEDynamicFragmentationLevel to the value of Dynamic Fragmentation Support subfield in the HE Capabilities element it transmits if it supports reception of dynamic fragments.

If a fragment is sent under level 1, level 2, or level 3 fragmentation, it belongs to dynamic fragment.

Defragmentation of dynamic fragments shall follow the rules defined in 10.5 (MSDU, (11ax)A-MSDU, and MMPDU defragmentation) with the following exceptions:

— The recipient STA shall support the concurrent reception of dynamic fragments of a number of *outstanding* MSDUs and A-MSDUs when supported from the same transmitting STA that is equal

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to $N_{max}$, where $N_{max}$ for MSDUs and A-MSDUs (if supported) is obtained from the Maximum Number Of Fragmented MSDUs/A-MSDUs Exponent subfield in the HE Capabilities element transmitted by the STA. The term *outstanding* refers to an MPDU containing all or part of an MSDU or A-MSDU for which transmission has been started and for which delivery of the MSDU or A-MSDU has not yet been completed (i.e., an acknowledgment of the final fragment has not been received and the MSDU, A-MSDU, or MMPDU has not been discarded due to retries, lifetime, or some other reason). The recipient STA shall support the concurrent reception of dynamic fragments of one outstanding MMPDU from a transmitting STA.

— The recipient STA may be subject to the receive timer rules for each of the MSDUs, A-MSDUs, and MMPDUs defined in 10.5.

— (#2128)The A-MSDU Present subfield of all QoS Data frames containing fragments of a given MSDU (not in an A-MSDU) or of a given A-MSDU shall be the same.

A STA that has dot11AMSDUFragmentationOptionImplemented true shall set the A-MSDU Fragmentation Support subfield in the HE Capabilities element to 1. Otherwise, the STA shall set the A-MSDU Fragmentation Support subfield in the HE Capabilities element to 0.

#### 26.3.3.2 Level 1 dynamic defragmentation

Upon reception of a non-A-MPDU or A-MPDU that carries a dynamic fragment, the recipient STA responds with an Ack frame or a Multi-STA BlockAck frame if the received fragment is contained in an MPDU that solicits an immediate response. The receiver STA shall follow the rules defined in 10.3.2.11 (Acknowledgment procedure) for generating the Ack frame for the soliciting dynamic fragment that is an MPDU or carried in an S-MPDU or ack-enabled single-TID A-MPDU and the rules defined in 26.4 (HE acknowledgment procedure) for generating the Multi-STA BlockAck frame that contains the acknowledgment for the soliciting S-MPDU that carries one dynamic fragment and carried in an HE TB PPDU, ack-enabled single-TID A-MPDU or ack-enabled multi-TID A-MPDU.

#### 26.3.3.3 Level 2 dynamic defragmentation

Upon reception of a non-A-MPDU that is a dynamic fragment or A-MPDU that carries one or more dynamic fragments, the recipient STA responds with one of the following frames:

— An Ack frame or Multi-STA BlockAck frame if the received fragment is a non-A-MPDU or contained in an A-MPDU and solicits the immediate response. The recipient STA shall follow the rules defined in 10.3.2.11 (Acknowledgment procedure) for generating the Ack frame for the soliciting dynamic fragment that is an MPDU or carried in an S-MPDU or ack-enabled single-TID A-MPDU and the rules defined in 26.4 (HE acknowledgment procedure) for generating the Multi-STA BlockAck frame that contains the acknowledgment for the soliciting S-MPDU carried in an HE TB PPDU, ack-enabled single-TID A-MPDU, or ack-enabled multi-TID A-MPDU.

— A Compressed BlockAck frame or Multi-STA BlockAck frame if the received fragments of an MSDU or A-MSDU (if any) (up to one fragment for each MSDU or A-MSDU) are contained in an A-MPDU that contains an MPDU that solicits an immediate response. The recipient STA shall follow the rules defined in 10.25.6.5 (Generation and transmission of BlockAck frames by an HT STA, DMG STA, or S1G STA) for generating the BlockAck frame and the rules in 26.4 (HE acknowledgment procedure) for generating the Multi-STA BlockAck frame, except that the STA shall:

  — Set to 0 the LSB of the Fragment Number subfield in the Block Ack Starting Sequence Control subfield of the Compressed BlockAck frame or Multi-STA BlockAck frame that corresponds to a TID of a received fragment that is sent under a block ack agreement.

  — Set to 1 each bit of the Block Ack Bitmap field that corresponds to a Sequence Number subfield and TID subfield of a received fragment that is sent under a block ack agreement contained in the soliciting A-MPDU that is not an S-MPDU.


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— The STA shall update the corresponding block acknowledgment record for an MSDU or A-MSDU for which fragments are received only if that MSDU or A-MSDU is successfully reconstructed (see 10.5). Otherwise, the STA shall not update the block ack record for that MSDU or A-MSDU.

NOTE—The recipient STA sets the bits of the Block Ack Bitmap field that correspond to a Sequence Number and TID subfield of an MPDU that is not a fragment as defined in 10.25.6.5 (Generation and transmission of BlockAck frames by an HT STA, DMG STA, or S1G STA).

A recipient STA shall discard any fragments of incomplete MSDUs or A-MSDUs that have been received during an HT-immediate block ack session for a TID if it receives a BlockAckReq frame from the originator STA for that TID if the fragments have a Sequence Number field value that is less than the value of the Starting Sequence Number field of the BlockAckReq frame or have a sequence number that is less than (#6310)$WinStart_B$ (see 10.25.6.6 (Receive reordering buffer control operation)). The comparison of the two values is performed circular modulo 4096 as described in 10.25.1 (Introduction).

### 26.3.3.4 Level 3 dynamic defragmentation

Upon reception of a non-A-MPDU that is a dynamic fragment or A-MPDU that carries one or more dynamic fragments, the recipient STA responds with one of the following frames:

— An Ack frame or a Multi-STA BlockAck frame if the received fragment is a non-A-MPDU or contained in an A-MPDU that solicits the immediate response. The recipient STA shall follow the rules defined in 10.3.2.11 for generating the Ack frame for the soliciting dynamic fragment that is a MPDU or carried in an S-MPDU or ack-enabled single-TID A-MPDU and the rules defined in 26.4 (HE acknowledgment procedure) for generating the Multi-STA BlockAck frame that contains the acknowledgment for the soliciting S-MPDU carried in an HE TB PPDU, ack-enabled single-TID A-MPDU, or ack-enabled multi-TID A-MPDU.

— A Compressed BlockAck frame or Multi-STA BlockAck frame if the received fragments of an MSDU or A-MSDU (if any) corresponding to a TID (one or more fragments for each MSDU or A-MSDU) are contained in an A-MPDU where at least one received MPDU's Fragment Number field corresponding to the same TID as the received fragments is of nonzero value that solicits the immediate response. The recipient STA shall follow the rules in 10.25.6.5 (Generation and transmission of BlockAck frames by an HT STA, DMG STA, or S1G STA) for generating the BlockAck frame and the rules in 26.4 (HE acknowledgment procedure) for generating the Multi-STA BlockAck frame, except that the STA shall

  — Set to 1 the LSB of the Fragment Number subfield in the Block Ack Starting Sequence Control subfield of the Compressed BlockAck frame or Multi-STA BlockAck frame that corresponds to a TID of a received fragment that is sent under a block ack agreement.

  — Set to 1 each bit in position $B$ of the Block Ack Bitmap field that corresponds to a received fragment that is sent under a block ack agreement and shall set it to 0 otherwise, with $B$ calculated as $B = 4 \times (SN - SSN) + FN$, where the operations on the sequence numbers are performed modulo 4096.
  *SN* is the value of the Sequence Number subfield of an MPDU containing the fragment for which the receive status is indicated.
  *SSN* is the value of the Starting Sequence Number subfield of the Block Ack Starting Sequence Control subfield of the BlockAck frame.
  *FN* is the value in the Fragment Number subfield.

— A Compressed BlockAck frame or Multi-STA BlockAck frame if the received fragments of an MSDU or A-MSDU (if any) corresponding to a TID (one or more fragments for each MSDU or A-MSDU) are contained in an A-MPDU where all the received MPDUs' Fragment Number fields corresponding to the same TID as the received fragments are of zero value that solicits the immediate response. The recipient STA shall follow the rules in 10.25.6.5 (Generation and transmission of BlockAck frames by an HT STA, DMG STA, or S1G STA) for generating the

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BlockAck frame and the rules in 26.4 (HE acknowledgment procedure) for generating the Multi-STA BlockAck frame, except that the STA shall

- Set to 0 the LSB of the Fragment Number subfield in the Block Ack Starting Sequence Control subfield of the Compressed BlockAck frame or Multi-STA BlockAck frame that corresponds to a TID of a received fragment that is sent under a block ack agreement.
- Set to 1 each bit of the Block Ack Bitmap field that corresponds to a Sequence Number subfield and TID subfield of a received fragment that is sent under a block ack agreement contained in the soliciting A-MPDU that is not an S-MPDU.

— The STA shall update the corresponding block acknowledgment record for an MSDU or A-MSDU for which fragments are received only if that MSDU or A-MSDU is successfully reconstructed (see 10.5 (MSDU, (11ax)A-MSDU, and MMPDU defragmentation)). Otherwise, the STA shall not update the block ack record for that MSDU or A-MSDU.

NOTE—The recipient STA sets the bits of the Block Ack Bitmap field that correspond to a Sequence Number and TID subfield of an MPDU that is not a fragment as defined in 10.25.6.5 (Generation and transmission of BlockAck frames by an HT STA, DMG STA, or S1G STA).

The recipient STA shall discard any fragments of incomplete MSDUs or A-MSDUs that have been received during an HT-immediate block ack session for a TID if it receives a BlockAckReq frame from the originator STA for that TID and the fragments have a Sequence Number field value that is less than the value of the Starting Sequence Number field of the BlockAckReq frame or have a sequence number that is less than (#6310)$WinStart_B$ (see 10.25.6.6 (Receive reordering buffer control operation)). The comparison of the two values is performed circular modulo 4096 as described in 10.25.1 (Introduction).

## 26.4 HE acknowledgment procedure

### 26.4.1 Overview

The HE acknowledgment procedure builds on the features defined for HT-immediate block ack (see 10.25.6 (HT-immediate block ack extensions)), with the following extensions:

- Support for a Multi-STA BlockAck frame
- Support for a MU-BAR Trigger frame
- Support for a Multi-TID BlockAckReq frame
- Support for BlockAck Bitmap field lengths of 32, 64, 128, and 256
- Acknowledging QoS Data frames with two or more TIDs using a Multi-STA BlockAck frame
- Acknowledging QoS Data frames with one or more TIDs and a Management frame using a Multi-STA BlockAck frame
- Acknowledging all MPDUs in a PPDU using a variant of the Multi-STA BlockAck frame
- Acknowledging MPDUs from multiple associated STAs using a single Multi-STA BlockAck frame
- Acknowledging MPDUs from multiple unassociated STAs with a single Multi-STA BlockAck frame

An HE STA shall be able to respond with Compressed BlockAck frames if HT-immediate block ack is supported in the role of recipient (see 10.25.6.1 (Introduction to HT-immediate block ack extensions)). An HE STA shall be able to respond with a Multi-STA BlockAck frame if multi-TID A-MPDU operation (26.6.3 (Multi-TID A-MPDU and ack-enabled single-TID A-MPDU)) is supported in the role of recipient.

A non-AP HE STA that is associated with an AP and that sends a Multi-STA BlockAck frame shall set the AID11 subfield in the Per AID TID Info field of the Multi-STA BlockAck frame to 0 and the RA field to the MAC address of the intended recipient. A non-AP HE STA that is not associated with an AP shall not send a Multi-STA BlockAck frame.


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An HE AP that sends a Multi-STA BlockAck frame where the Per AID TID Info fields are addressed to more than one STA shall set the RA field to the broadcast address. An HE AP that sends a Multi-STA BlockAck frame where the Per AID TID Info fields are all addressed to a single recipient STA and that is sent in response to an HE TB PPDU may set the RA field of the Multi-STA BlockAck frame either to the address of the recipient STA or to the broadcast address. An HE AP that sends a Multi-STA BlockAck frame where the Per AID TID Info fields are all addressed to a single recipient STA and that is not sent in response to an HE TB PPDU shall set the RA field of the Multi-STA BlockAck frame to the address of the recipient STA.

An HE AP that sends a Multi-STA BlockAck frame to an associated STA shall set the AID11 subfield in the Per AID TID Info field of the Multi-STA BlockAck frame to the 11 LSBs of the AID of the intended STA. An HE AP that sends a Multi-STA BlockAck frame to an unassociated STA shall set the AID11 subfield in the Per AID TID Info field of the Multi-STA BlockAck frame to 2045.

An HE STA that transmits a Multi-STA BlockAck frame shall use a rate, HT-MCS, <VHT-MCS, NSS> tuple, or <HE-MCS, NSS> tuple that is supported by all recipient STAs.

An HE STA that receives a Multi-STA BlockAck frame that is a response to frames requiring acknowledgment shall examine the Per AID TID Info field received in the Multi-STA BlockAck frame and shall process each Per AID TID Info field using the procedure defined in 26.4.2 (Acknowledgment context in a Multi-STA BlockAck frame).

A non-AP HE STA that receives a Multi-STA BlockAck frame that is a response to frames requiring acknowledgment but that do not belong to an established block ack agreement shall examine each Per AID TID Info field received in the Multi-STA BlockAck frame as follows:

— If the Ack Type field is 1 and the TID field is less than 8, then the Per AID TID Info field indicates the acknowledgment of a tagged MPDU that is a QoS Data frame with the indicated TID. The BA Information field is addressed to the STA if the AID of the BA Information field contains the STA's AID(#2385).

— If the Ack Type field is 1 and the TID field is 15, then the Per AID TID Info field indicates the acknowledgment of a tagged MPDU that is a Management frame that solicits acknowledgment or a PS-Poll frame. The BA Information field is addressed to the STA if the AID of the BA Information field contains the STA's AID(#2385).

— If the Ack Type field is 0, the AID field is 2045, and the TID field is 15, then the Per AID TID Info field indicates the acknowledgment of a tagged MPDU that is a Management frame soliciting immediate acknowledgment. The RA field in the Per AID TID Info field is the MAC address of an unassociated STA for which the Per AID TID Info subfield is intended. The BA Information field is addressed to the STA if the RA field of the BA Information field contains the STA's MAC address(#2385).

(#2385)If the BA Information field is addressed to the STA, it is processed according to the procedure defined in 26.4.2 (Acknowledgment context in a Multi-STA BlockAck frame).

An HE AP with dot11MultiBSSIDImplemented equal to true shall not send to a non-AP STA that is associated with an AP corresponding to a nontransmitted BSSID in the multiple BSSID set a Multi-STA BlockAck frame with the TA field set to the transmitted BSSID, unless the HE AP has received from the non-AP STA an HE Capabilities element with the Rx Control Frame To MultiBSS subfield in HE MAC Capabilities Information field equal to 1.

An AP that transmits a Multi-STA BlockAck frame addressed to HE STAs shall set the TA field of the frame to the MAC address of the AP, unless dot11MultiBSSIDImplemented is true and the Multi-STA BlockAck frame is directed to STAs from at least two different BSSs of the multiple BSSID set. In this case, the AP shall set the TA field of the frame to the transmitted BSSID.

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NOTE—An AP sets the TA field of the Multi-STA BlockAck frame that is not carried in HE MU PPDU to the transmitted BSSID when the TXOP is obtained from the transmitted BSSID (see 10.23.2.4 (Obtaining an EDCA TXOP)).

An HE STA that transmits a Multi-TID BlockAckReq frame in a PPDU that is not an HE TB PPDU shall set the TID Value subfields in the Per TID Info subfields of the BAR Information field of the Multi-TID BlockAckReq frame to TIDs that correspond to ACs that have the same or higher priority as the primary AC. An HE STA that transmits a Multi-TID BlockAckReq frame in an HE TB PPDU may set each of the TID Value subfields in the Per TID Info subfields of the BAR Information field of the Multi-TID BlockAckReq frame to a TID that corresponds to any AC.

An HE STA that transmits a BlockAckReq frame in an HE TB PPDU may set the TID subfield in the AID TID Info field in the BAR Information field of the BlockAckReq frame to a TID that corresponds to any AC.

### 26.4.2 Acknowledgment context in a Multi-STA BlockAck frame

A recipient of an A-MPDU shall set the Ack Type subfield and TID subfield in the Per AID TID Info field of the Multi-STA BlockAck frame sent as a response depending on the acknowledgment context as follows:

- An HE AP that receives, prior to association, an A-MPDU that includes one tagged MPDU that is a Management frame soliciting an acknowledgment but does not include any other MPDUs may generate a Multi-STA BlockAck frame using the procedure defined in the (M118)*preassociation ack context* [described in item b) below in this subclause].
- An HE STA that receives an A-MPDU that does not include a tagged MPDU but does include one or more untagged MPDUs that are QoS Data frames with Normal Ack or Implicit BAR ack policy belonging to the same block ack agreement may generate a Multi-STA BlockAck frame as follows:
  - If all MPDUs in the A-MPDU are received successfully, then the recipient may follow the procedure defined in the *all ack context* [described in item a) below in this subclause].
  - Otherwise, the recipient shall follow the procedure defined in the *block ack context* [described in item d) below in this subclause].
- If an HE STA supports ack-enabled aggregation by setting the Ack-Enabled Aggregation Support subfield in the HE MAC Capabilities Information field to 1 and if the A-MPDU includes a tagged MPDU that is a Management frame that solicits acknowledgment and includes one or more MPDUs (either tagged MPDUs or untagged MPDUs) that are QoS Data frames with Normal Ack or Implicit BAR ack policy, then the recipient shall generate Multi-STA BlockAck frame as follows:
  - If all the MPDUs in the A-MPDU are received successfully, then the recipient may follow the procedure defined in the all ack context.
  - Otherwise:
    - For the MPDU that is a Management frame, the recipient shall create a Per AID TID info field using the procedure defined in the *ack context* [described in item c) below in this subclause] with the TID value set to 15.
    - For the tagged MPDUs that are QoS Data frames, the recipient shall create a Per AID TID info field using the procedure defined in the ack context with the TID set to the TID of the QoS Data frame.
    - For the untagged MPDUs that are QoS Data frames, the recipient shall create a Per AID TID info field using the procedure defined in block ack context with the TID set to the TID of the QoS Data frame.
- If an HE STA supports multi-TID aggregation and the A-MPDU does not include a tagged MPDU but does include untagged MPDUs that are QoS Data frames with Implicit BAR ack policy and belonging to more than one block ack agreement, then the recipient shall generate a Multi-STA BlockAck frame as follows:


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- If all MPDUs in the A-MPDU are received successfully, then the recipient may follow the procedure defined in the all ack context.
- Otherwise, for each TID included the received A-MPDU, the recipient shall create a per AID TID info field using the procedure defined in the block ack context with the TID set to the TID of the QoS Data frame.

NOTE—A STA indicates the maximum number of Per AID TID Info fields with the same AID excluding the one for a Management frame that it can include in the Multi-STA BlockAck frame in the Multi-TID Aggregation Rx Support field in the HE Capabilities element it transmits.

The procedures for the different acknowledgment contexts for generating a Multi-STA BlockAck frame are defined as follows:

a) *All ack context:* If the originator had set the All Ack Support subfield in the HE Capabilities element to 1, then the recipient may set the Ack Type field to 1 and the TID subfield to 14 to indicate the reception of all the MPDUs carried in the eliciting A-MPDU or multi-TID A-MPDU. Otherwise, the recipient shall not set the Ack Type field to 1 and the TID subfield to 14. The Multi-STA BlockAck frame shall contain only one Per AID TID Info field addressed to an originator in the Multi-STA BlockAck frame. The recipient determines that all the MPDUs carried in the eliciting A-MPDU were received if there were no MPDU delimiter CRC errors and no MPDU FCS errors in that A-MPDU.

b) (M118)*Preassociation ack context:* A recipient receiving a Management frame from an unassociated STA that requires an acknowledgment shall set the Ack Type field to 0, AID subfield to 2045, and TID field to 15 in the Per AID TID Info field and set the RA field of the Per AID TID Info field to the intended recipient's MAC address to indicate the reception of that Management frame.

c) *Ack context:* A recipient that sets the Ack-Enabled Aggregation Support subfield in the HE Capabilities element to 1 and that receives a tagged MPDU soliciting acknowledgment shall set the Ack Type field to 1 and, if the tagged MPDU is a QoS Data frame, set the TID field to the TID of the QoS Data frame or, if the tagged MPDU is a Management frame or PS-Poll frame, set the TID field to 15.

   If a received A-MPDU contains more than one tagged MPDU that solicits an immediate acknowledgment, then the Multi-STA BlockAck frame shall contain multiple Per AID TID Info fields, with Ack Type field equal to 1, one for each such received tagged MPDU requesting an acknowledgment.

   The TID field is set to the TID of the QoS Data or QoS Null frame that is being acknowledged and set to 15 for a (#4258)PS-Poll frame or Management frame that is being acknowledged.

d) *Block ack context:* The recipient shall set the Ack Type field to 0 and the TID field of a Per AID TID Info field to the TID value of MPDUs requesting block acknowledgment that are carried in the eliciting A-MPDU or multi-TID A-MPDU.

   The Multi-STA BlockAck frame may contain multiple occurrences of these Per AID TID Info fields addressed to an originator, one for each MPDU that is requesting block acknowledgment. In such cases, the Block Ack Starting Sequence Control and Block Ack Bitmap fields shall be set according to 10.25.6 for each block ack session and according to 26.3 (Fragmentation and defragmentation) for each block ack session with dynamic fragmentation.

   The allowed values for the TID field in this context are 0 to 7 (for indicating block acknowledgment of QoS Data frames).

   Variable bitmap lengths may be included in the Per AID TID Info field when the originator and recipient negotiate their use as defined in 26.4.3 (Negotiation of block ack bitmap lengths).

The Ack Type subfield(s) in a Multi-STA BlockAck frame shall be set to 0 if the Multi-STA BlockAck frame is sent in response to an MU-BAR Trigger frame.

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Upon receipt of a Multi-STA BlockAck frame, the originator shall examine each Per AID TID Info field and shall perform the following operations:

— If the AID subfield is 0 for an AP originator or the non-AP STA's AID for a non-AP STA originator, the Ack Type field is 0, and the TID field is less than 8, then the (#4200)Block Ack Starting Sequence Control, TID, and Block Ack Bitmap fields of the Per AID TID Info field are processed according to 10.25.6 (HT-immediate block ack extensions), 26.3 (Fragmentation and defragmentation), and 26.4.4 (Per-PPDU acknowledgment selection rules).

— If the AID subfield is 2045, the Ack Type field is 0, and the TID field is 15, then the Per AID TID Info field indicates the acknowledgment of a single Management frame sent by the unassociated STA as defined by the acknowledgment context.

— If the AID subfield is 0 for an AP originator or the non-AP STA's AID for a non-AP STA originator, the Ack Type field is 1, and the TID is less than or equal to 7 or is equal to 15, then the Per AID TID Info field indicates the acknowledgment of an tagged MPDU that is a QoS Data frame identified by the value of the TID, a Management frame, or a PS-Poll frame.

— If the AID subfield is 0 for an AP originator or the non-AP STA's AID for a non-AP STA originator, the Ack Type field is 1, and the TID subfield of AID TID Info field is 14, then the Per AID TID Info field indicates the acknowledgment of all MPDUs carried in the eliciting A-MPDU as defined by the acknowledgment context.

If an associated non-AP STA that does not support the UORA procedure receives a Multi-STA BlockAck frame in response to an eliciting frame, and if the Multi-STA BlockAck frame contains a Per AID TID Info subfield with the AID11 subfield set to 2045, then the STA shall ignore this Per AID TID Info subfield, and shall continue to parse the following Per AID TID Info subfields (if any).

### 26.4.3 Negotiation of block ack bitmap lengths

Both the Compressed BlockAck frame and Multi-STA BlockAck frame allow different Block Ack Bitmap subfield lengths. The length of the Block Ack Bitmap subfield is indicated in the Fragment Number subfield of the Block Ack Starting Sequence Control field as defined in 9.3.1.8 (BlockAck frame format). The allowed Block Ack Bitmap lengths for each of the negotiated buffer sizes are defined in Table 26-1 (Negotiated buffer size and Block Ack Bitmap subfield length(11ax)).

**Table 26-1—Negotiated buffer size and Block Ack Bitmap subfield length(11ax)**

| Negotiated buffer size | Block Ack Bitmap subfield length in a Compressed BlockAck frame (bits) | Block Ack Bitmap subfield length in a Multi-STA BlockAck frame (bits) |
|---|---|---|
| 1–64 | 64 | 32 or 64 |
| 65–128 | 64 or 256 | 32, 64, or 128 |
| 129–256 | 64 or 256 | 32, 64, 128, or 256 |
| NOTE—A 32-bit Block Ack Bitmap subfield length is not allowed, unless the originator has set the 32-bit BA Bitmap Support field in the HE MAC Capabilities Information field in the HE Capabilities element to 1. | | |

An HE STA that transmits a Compressed BlockAck frame or a Multi-STA BlockAck frame shall use a Block Ack Bitmap subfield length identified in Table 26-1 (Negotiated buffer size and Block Ack Bitmap subfield length(11ax)) for the negotiated buffer size of the block ack agreement to which the BA Information field corresponds.


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The recipient is allowed to respond with a Block Ack Bitmap subfield in the BA Information field that is less than the maximum allowed Block Ack Bitmap for the negotiated buffer size. The length of the Block Ack Bitmap subfield in a Compressed BlockAck frame or a Multi-STA BlockAck frame may be less than the maximum allowed Block Ack Bitmap but shall be sufficient to include the recipient's scoreboard state for MPDUs beginning with the MPDU for which the Sequence Number subfield value is $WinStart_R$ and ending with a successfully received MPDU for which the Sequence Number subfield is less than or equal to $WinEnd_R$.

The recipient shall not include in the Buffer Size field of an ADDBA Response frame a value that would cause the BlockAck Bitmap length of its block ack responses to exceed the BlockAck Bitmap length that is derived by the Buffer Size field of the ADDBA Request frame sent by the originator. When the Buffer Size field in the ADDBA Request frame is 0, the Buffer Size field of an ADDBA Response frame is in the range 1 to 64.

NOTE 1—Refer to Block Ack Bitmap subfield length identified in Table 26-1 (Negotiated buffer size and Block Ack Bitmap subfield length(11ax)) for the negotiated buffer size of the block ack agreement.

A recipient shall not include in a Multi-STA BlockAck frame a Per AID TID Info field with a 32-bit BlockAck Bitmap field addressed to an originator if the 32-bit BA Bitmap Support field in the HE MAC Capabilities Information field in the HE Capabilities element received from that originator is 0.

NOTE 2—A Multi-STA BlockAck frame might include Per AID TID Info fields with a 32-bit BlockAck Bitmap field addressed to other originators, and the nonsupporting originator needs to able to parse these fields to locate a possible Per AID TID Info field addressed to it.

The originator of a BlockAckReq frame, MU-BAR Trigger frame, GCR MU-BAR Trigger frame, or a A-MPDU that includes QoS Data frames that solicits an immediate BlockAck frame response or Management frame that solicits acknowledgment shall set the Duration field accounting for the largest BlockAck Bitmap length based on negotiated buffer size.

A recipient shall not transmit a Compressed BlockAck frame or a Multi-STA BlockAck frame with the LSB of the Fragment Number subfield set to 1, unless the recipient has received from the originator an HE Capabilities element with the Dynamic Fragmentation Support subfield equal to 3. If the LSB of the Fragment Number subfield of the BlockAck frame is 1, then the Block Ack Bitmap fields are set as defined in 26.3.2.4 (Level 3 dynamic fragmentation).

### 26.4.4 Per-PPDU acknowledgment selection rules

#### 26.4.4.1 General

A STA that transmits a PPDU can solicit different immediate responses for frames contained in the PPDU by using the Ack Policy Indicator subfield of QoS Data or QoS Null frames, the type of the frame, PPDU format, number of TIDs in the A-MPDU, and the EOF/Tag field setting of the A-MPDU delimiter.

#### 26.4.4.2 Responding to an HE SU PPDU or HE ER SU PPDU with an SU PPDU

An HE STA that receives an HE SU PPDU or HE ER SU PPDU carrying an A-MPDU that includes MPDUs, solicits acknowledgment, and does not include a triggering frame shall respond using an SU PPDU as follows:

a) If the A-MPDU includes only one MPDU and the MPDU is a tagged MPDU that either is a QoS Data frame or QoS Null frame with Normal Ack ack policy or is a Management frame that solicits acknowledgment, then the STA shall respond with an Ack frame.

b) If the A-MPDU includes only one MPDU and the MPDU is an EOF MPD that is a PS-Poll frame, the STA shall respond with an Ack frame or a QoS Data frame.

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c) If the HE STA supports ack-enabled aggregation by setting the Ack-Enabled Aggregation Support subfield in the HE MAC Capabilities Information field to 1, and if the A-MPDU includes more than one MPDU, only one of which solicits acknowledgment and the MPDU that solicits acknowledgment is a tagged MPDU that either is a QoS Data frame or a QoS Null frame with Normal Ack ack policy or is a Management frame that solicits acknowledgment, then the HE STA shall respond with an Ack frame.

d) If the A-MPDU does not include a tagged MPDU but does include one or more untagged MPDUs that are QoS Data frames belonging to the same block ack agreement and with the Ack Policy Indicator subfield equal to Implicit BAR for at least one MPDU, then the STA shall respond with a Compressed BlockAck frame as defined in 10.25.6.5 (Generation and transmission of BlockAck frames by an HT STA, DMG STA, or S1G STA). Alternatively, if all the MPDUs carried in the eliciting A-MPDU were received, the STA may respond with a Multi-STA BlockAck frame with Ack Type field set to 1 and the TID field set to 14 as defined in 26.4.2 (Acknowledgment context in a Multi-STA BlockAck frame) if the originator of the A-MPDU has indicated support for the all ack context by setting the All Ack Support subfield in the HE MAC Capabilities Information field to 1.

e) If the HE STA supports ack-enabled aggregation by setting the Ack-Enabled Aggregation Support subfield in the HE MAC Capabilities Information field to 1, and if the A-MPDU includes a Management frame that solicits an acknowledgment and includes one or more QoS Data frames with Normal Ack or Implicit BAR ack policy, then the STA shall respond with a Multi-STA BlockAck frame as defined in 26.4.2 (Acknowledgment context in a Multi-STA BlockAck frame).

f) If the HE STA supports multi-TID aggregation and if the A-MPDU includes two or more QoS Data frames with Implicit BAR ack policy and belonging to more than one block ack agreement, then the STA shall respond with a Multi-STA BlockAck frame as defined in 26.4.2 (Acknowledgment context in a Multi-STA BlockAck frame).

#### 26.4.4.3 Responding to an HE MU PPDU with an SU PPDU

If an AP intends to solicit an immediate response in an SU PPDU, the following apply:

— An AP shall set the Ack Policy Indicator subfield in the QoS Data and QoS Null frames to Normal Ack or Implicit BAR in at most one A-MPDU in the HE MU PPDU (see 10.3.2.10.1 (Dual CTS protection procedure) for an example of this sequence).

— The A-MPDUs in the HE MU PPDU shall not contain a Management frame that solicits acknowledgment.

An HE STA that receives an HE MU PPDU with an A-MPDU that contains MPDUs that solicit acknowledgment and that does not include a triggering frame shall respond using an SU PPDU as follows:

a) If the A-MPDU carries only one MPDU and the MPDU is a tagged MPDU that is either a QoS Data frame or QoS Null frame with Normal Ack ack policy, then the STA shall respond with an Ack frame.

b) If the HE STA supports ack-enabled aggregation by setting the Ack-Enabled Aggregation Support subfield in the HE MAC Capabilities Information field to 1, and if the A-MPDU includes more than one MPDU, only one of which solicits acknowledgment and the MPDU that solicits acknowledgment is a tagged MPDU that is a QoS Data frame or a QoS Null frame with Normal Ack ack policy, then the HE STA shall respond with an Ack frame.

c) If the A-MPDU does not include a tagged MPDU but does include one or more untagged MPDUs that are QoS Data frames belonging to the same block ack agreement and with the Ack Policy Indicator subfield equal to Implicit BAR for at least one MPDU, then the STA shall respond with a Compressed BlockAck frame as defined in 10.25.6.5 (Generation and transmission of BlockAck frames by an HT STA, DMG STA, or S1G STA). Alternatively, if all the MPDUs carried in the eliciting A-MPDU were received, the STA may respond with a Multi-STA BlockAck frame with the Ack Type set to 1 and the TID field set to 14 as defined in 26.4.2 (Acknowledgment context in a


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Multi-STA BlockAck frame) if the originator of the A-MPDU has indicated support for the all ack context by setting the All Ack Support subfield in the HE MAC Capabilities Information field to 1.

d) If the HE STA supports multi-TID aggregation and if the A-MPDU includes two or more QoS Data frames with Implicit BAR ack policy addressed to it and belonging to more than one block ack agreement, then the STA shall respond with a Multi-STA BlockAck frame as defined in 26.4.2 (Acknowledgment context in a Multi-STA BlockAck frame).

NOTE—A control response frame carried in an SU PPDU that is an immediate response to an HE MU PPDU follows the rules defined in 10.6.6.5 (Rate selection for control response frames)

An AP that sends an HE MU PPDU shall not set the Ack Policy Indicator subfield to Normal Ack or Implicit BAR for any of the MPDUs carried in the HE MU PPDU if the PPDU containing a control response would occupy one or more 20 MHz channels where pre-HE modulated fields of the HE MU PPDU are not located.

#### 26.4.4.4 Responding to an HE MU PPDU, HE SU PPDU, or HE ER SU PPDU with an HE TB PPDU

An AP that sends an HE MU PPDU, HE SU PPDU, or HE ER SU PPDU that contains an MPDU that solicits an immediate response carried in an HE TB PPDU shall set the Ack Policy Indicator subfield to HETP Ack for each of the QoS Data frames for which it intends to solicit an immediate response (see 10.3.2.13.2 (Acknowledgment procedure for DL MU PPDU in MU format(11ax))). If a Management frame that solicits acknowledgment is carried in an HE MU PPDU, then the response is carried in an HE TB PPDU. A non-AP STA that receives an HE MU PPDU, HE SU PPDU, or HE ER SU PPDU with an A-MPDU that contains a QoS Data frame with HETP Ack ack policy addressed to it or contains a Management frame that solicits an immediate acknowledgment shall not respond, unless it has also received a triggering frame in the A-MPDU.

A non-AP STA that receives an HE MU PPDU, HE SU PPDU, or HE ER SU PPDU with an A-MPDU that contains one or more MPDUs soliciting acknowledgment and includes a triggering frame shall respond with an HE TB PPDU as follows:

a) If the A-MPDU includes only one MPDU and the MPDU is a tagged MPDU that either is a QoS Data or QoS Null frame with HETP Ack ack policy or is a Management frame that solicits acknowledgment, then the STA shall respond with an Ack frame.

b) If the HE STA supports ack-enabled aggregation by setting the Ack-Enabled Aggregation Support subfield in the HE MAC Capabilities Information field to 1, and if the A-MPDU includes more than one MPDU, only one of which solicits acknowledgment and the MPDU that solicits acknowledgment is a tagged MPDU that either is a QoS Data or QoS Null frame with HETP Ack ack policy or is a Management frame that solicits acknowledgment, then the HE STA shall respond with an Ack frame.

c) If the A-MPDU does not include a tagged MPDU but does include one or more untagged MPDUs that are QoS Data frames belonging to the same block ack agreement and with the Ack Policy Indicator subfield equal to HETP Ack for at least one MPDU, then the STA shall respond with a Compressed BlockAck frame as defined in 10.25.6.5 (Generation and transmission of BlockAck frames by an HT STA, DMG STA, or S1G STA). Alternatively, if all the MPDUs carried in the eliciting A-MPDU were received, the STA may respond with a Multi-STA BlockAck frame with the Ack Type set to 1 and the TID field set to 14 as defined in 26.4.2 (Acknowledgment context in a Multi-STA BlockAck frame) if the originator of the A-MPDU has indicated support for the all ack context by setting the All Ack Support subfield in the HE MAC Capabilities Information field to 1.

d) If the HE STA supports ack-enabled aggregation by setting the Ack-Enabled Aggregation Support subfield in the HE MAC Capabilities Information field to 1, and if the A-MPDU includes a Management frame that solicits an acknowledgment and contains one or more QoS Data frames with HETP Ack or Implicit BAR ack policy, then the STA shall respond with a Multi-STA BlockAck frame as defined in 26.4.2 (Acknowledgment context in a Multi-STA BlockAck frame).

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e) If the HE STA supports multi-TID aggregation and if the A-MPDU includes two or more QoS Data frames with HETP Ack ack policy and belonging to more than one block ack agreement, then the STA shall respond with a Multi-STA BlockAck frame.

#### 26.4.4.5 Responding to an HE TB PPDU with an SU PPDU

A non-AP STA that sends an HE TB PPDU as a response to a Basic Trigger frame shall set the Ack Policy Indicator subfield of the QoS Data frames or QoS Null frames to Normal Ack or Implicit BAR (see 10.3.2.13.3 (Acknowledgment procedure for UL MU transmission(11ax)) for an example of this sequence).

If the HE TB PPDU carries MPDUs only from one STA and if the HE AP intends to send the response in an SU PPDU, then the HE AP shall respond using an SU PPDU as follows:

a) If the A-MPDU includes only one MPDU, and the MPDU is a tagged MPDU that either is a QoS Data frame or QoS Null frame with Normal Ack ack policy or is a Management frame that solicits acknowledgment, then the HE AP shall respond with either an Ack frame or a Multi-STA BlockAck frame with the Ack Type field set to 1.

b) If the HE AP supports ack-enabled aggregation by setting the Ack-Enabled Aggregation Support subfield in the HE MAC Capabilities Information field to 1, and if the A-MPDU includes more than one MPDU, only one of which solicits acknowledgment and the MPDU that solicits acknowledgment is a tagged MPDU that either is a QoS Data or QoS Null frame with Normal Ack ack policy or is a Management frame that solicits acknowledgment, then the HE AP shall respond with an Ack frame or a Multi-STA BlockAck frame with the Ack Type field set to 1.

c) If the A-MPDU does not include a tagged MPDU but does include one or more untagged MPDUs that are QoS Data frames belonging to the same block ack agreement and with Ack Policy Indicator subfield equal to Implicit BAR for at least one MPDU, then the HE AP shall respond with a Compressed BlockAck frame as defined in 10.25.6.5 (Generation and transmission of BlockAck frames by an HT STA, DMG STA, or S1G STA) or a Multi-STA BlockAck frame with the Ack Type field set to 0. Alternatively, if all the MPDUs carried in the eliciting A-MPDU were received, the HE AP may respond with a Multi-STA BlockAck frame with the Ack Type field set to 1 and the TID field set to 14 if the originator of the A-MPDU has indicated support for the all ack context by setting the All Ack Support subfield in the HE MAC Capabilities Information field to 1, as defined in 26.4.2 (Acknowledgment context in a Multi-STA BlockAck frame).

d) If the HE AP supports ack-enabled aggregation by setting the Ack-Enabled Aggregation Support subfield in the HE MAC Capabilities Information field to 1, and if the A-MPDU carries a Management frame that solicits acknowledgment and carries one or more QoS Data frames with Implicit BAR ack policy, then the HE AP shall respond with a Multi-STA BlockAck frame as defined in 26.4.2 (Acknowledgment context in a Multi-STA BlockAck frame).

e) If the HE AP supports multi-TID aggregation and if the A-MPDU includes two or more QoS Data frames with Normal Ack or Implicit BAR ack policy and belonging to more than one block ack agreement, then the HE AP shall respond with a Multi-STA BlockAck frame as defined in 26.4.2 (Acknowledgment context in a Multi-STA BlockAck frame).

If the AP receives HE TB PPDUs from more than one STA, and if the AP intends to send the response in an SU PPDU, then the AP shall respond with a Multi-STA BlockAck frame carried in an SU PPDU that contains the appropriate settings in each Per AID TID Info field addressed to each STA as defined in 26.4.2 (Acknowledgment context in a Multi-STA BlockAck frame).

#### 26.4.4.6 Responding to an HE TB PPDU with an HE MU PPDU

A non-AP STA that sends an HE TB PPDU as a response to a Basic Trigger frame that solicits an immediate response shall set the Ack Policy Indicator subfield to Normal Ack or Implicit BAR for each of the QoS


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Data frames carried in the A-MPDU (see 10.3.2.13.3 (Acknowledgment procedure for UL MU transmission(11ax)) for an example of this sequence).

If an HE AP sends a response to an HE TB PPDU that it received using an HE MU PPDU, then the AP shall respond to each A-MPDU that it received using the following procedure:

a) If the A-MPDU received from a STA includes only one MPDU and the MPDU is a tagged MPDU that either is a QoS Data frame or QoS Null frame with Normal Ack ack policy or is a Management frame that solicits acknowledgment, then the STA shall respond with an Ack frame or a Multi-STA BlockAck frame with the Ack Type field set to 1 carried in the HE MU PPDU.

b) If the HE AP supports ack-enabled aggregation by setting the Ack-Enabled Aggregation Support subfield in the HE MAC Capabilities Information field to 1, and if the A-MPDU includes more than one MPDU, only one of which solicits acknowledgment and the MPDU that solicits acknowledgment is a tagged MPDU that either is a QoS Data frame with Normal Ack ack policy or is a Management frame that solicits acknowledgment, then the HE AP shall respond with an Ack frame or a Multi-STA BlockAck frame with the Ack Type field set to 1 carried in the HE MU PPDU.

c) If the A-MPDU does not include a tagged MPDU but does include one or more untagged MPDUs that are QoS Data frames belonging to the same block ack agreement and with the Ack Policy Indicator subfield equal to Implicit BAR for at least one MPDU, then the HE AP shall respond with a Compressed BlockAck frame as defined in 10.25.6.5 (Generation and transmission of BlockAck frames by an HT STA, DMG STA, or S1G STA) or a Multi-STA BlockAck frame with the Ack Type field set to 0. Alternatively, if all the MPDUs carried in the eliciting A-MPDU were received, the HE AP may respond with a Multi-STA BlockAck frame with the Ack Type field set to 1 and the TID field set to 14 if the originator of the A-MPDU has indicated support for the all ack context by setting the All Ack Support subfield in the HE MAC Capabilities Information field to 1 as defined in 26.4.2 (Acknowledgment context in a Multi-STA BlockAck frame) carried in the HE MU PPDU.

d) If the HE AP supports ack-enabled aggregation by setting the Ack-Enabled Aggregation Support subfield in the HE MAC Capabilities Information field to 1, and if the A-MPDU carries a Management frame that solicits acknowledgment and carries one or more QoS Data frames with Implicit BAR ack policy, then the HE AP shall respond with a Multi-STA BlockAck frame as defined in 26.4.2 (Acknowledgment context in a Multi-STA BlockAck frame) carried in the HE MU PPDU.

e) If the HE AP supports multi-TID aggregation and if the A-MPDU includes two or more QoS Data frames with Implicit BAR ack policy and belonging to more than one block ack agreement, then the HE AP shall respond with a Multi-STA BlockAck frame as defined in 26.4.2 (Acknowledgment context in a Multi-STA BlockAck frame).

In addition, an AP with dot11MultiBSSIDImplemented equal to true may do one of the following:

— For each BSS belonging to the multiple BSSID set for which the AP has received an HE TB PPDU, the AP responds with a Multi-STA BlockAck frame with RA field set to the broadcast address and carried in a DL HE MU PPDU (see 9.3.1.8.6 (Multi-STA BlockAck variant(11ax))). The AP shall set the TXVECTOR parameter STA_ID for the RU carrying the Multi-STA BlockAck frame to the value of the BSSID Index field as defined in 26.11.1 (STA_ID).

— The AP may respond with a Multi-STA BlockAck frame with the TA field set to the transmitted BSSID and carried in a DL HE MU PPDU to acknowledge the STA's transmission, if the recipient non-AP STA is associated with an AP corresponding to a nontransmitted BSSID of the multiple BSSID set and the AP has received an HE Capabilities element from the STA with the Rx Control Frame To MultiBSS subfield equal to 1 (see 9.3.1.8.6 (Multi-STA BlockAck variant(11ax))). The AP shall set the TXVECTOR parameter STA_ID for the RU carrying the Multi-STA BlockAck frame to 2047.

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NOTE—An AP includes at most one Ack or BlockAck frame (group addressed Multi-STA BlockAck frame included) in an A-MPDU as specified in 9.7.3 (A-MPDU contents).

### 26.4.5 HE block acknowledgment request and response rules

An HE AP may solicit BlockAck frame responses from multiple HE STAs using an MU-BAR Trigger frame or GCR MU-BAR Trigger frame. An HE AP shall not send a Multi-TID BlockAckReq (as part of a User Info field addressed to the STA in an MU-BAR Trigger frame or as a BlockAckReq frame) to a STA that has not indicated support for multi-TID A-MPDU. The Block Ack Bitmap length of the block ack sent in response to an eliciting Multi-TID BlockAckReq frame, BlockAckReq frame, GCR MU-BAR Trigger frame, or MU-BAR Trigger frame is determined as defined in 26.4.3 (Negotiation of block ack bitmap lengths).

An HE STA that receives a BlockAckReq frame or an MU-BAR Trigger frame that contains a Compressed BlockAckReq variant in the User Info field addressed to the STA or receives a GCR MU-BAR Trigger frame that contains a Compressed BlockAckReq variant in the Common Info field shall respond with a Compressed BlockAck frame as defined in 10.25.6 (HT-immediate block ack extensions) or a Multi-STA BlockAck frame as defined in 26.4 (HE acknowledgment procedure) with the Starting Sequence Number subfield set to the Starting Sequence Number subfield of the Block Ack (#4200)Starting Sequence Control subfield and the length of the Block Ack Bitmap subfield calculated as defined in 26.4.3 (Negotiation of block ack bitmap lengths).

An HE STA that receives a Multi-TID BlockAckReq frame or an MU-BAR Trigger frame that contains a Multi-TID BlockAckReq variant in the User Info field addressed to the STA or receives a GCR MU-BAR Trigger frame that contains a Multi-TID BlockAckReq variant in the Common Info field shall respond with a Multi-STA BlockAck frame that contains a Per AID TID Info field with a Block Ack Bitmap subfield for each of the TIDs (with values less than 8) contained in the BlockAckReq frame, with the Starting Sequence Number subfield set to the Starting Sequence Number subfield of the Block Ack (#4200)Starting Sequence Control subfield, and with the length of the Block Ack Bitmap subfield calculated as defined in 26.4.3 (Negotiation of block ack bitmap lengths).

A non-AP HE STA that responds to a Compressed BlockAckReq frame, Multi-TID BlockAckReq frame, MU-BAR Trigger frame, or GCR MU-BAR Trigger frame with a Multi-STA BlockAck frame shall set the Ack Type subfield of the Multi-STA BlockAck frame to 0.

## 26.5 MU operation

### 26.5.1 HE DL MU operation

#### 26.5.1.1 General

HE DL MU operation allows an AP to transmit simultaneously to one or more non-AP STAs in DL OFDMA, DL MU-MIMO, or both.

The PSDU on each RU in an HE MU PPDU shall be padded to end at the same time, indicated by the L-SIG field as described in 27.3.11.5 (L-SIG field).

The padding procedure for each A-MPDU in an HE MU PPDU is defined in 26.6.2.2 (A-MPDU padding in an HE SU PPDU, HE ER SU PPDU, and HE MU PPDU).

An AP shall not transmit an HE MU PPDU with an RU that is narrower than the PPDU bandwidth and that is allocated to more than one STA (DL MU-MIMO), unless the AP has received from each STA an HE


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Capabilities element with the Partial Bandwidth DL MU-MIMO subfield in the HE PHY Capabilities Information field equal to 1.

An AP shall not send to a STA an A-MPDU contained in an HE MU PPDU that contains one of the following combinations of frames, unless the AP has received from the STA an HE Capabilities element with the Ack-Enabled Aggregation Support subfield in the HE MAC Capabilities Information field equal to 1:

— A QoS Data frame with HETP Ack ack policy carried in an A-MPDU subframe with the EOF/Tag field set to 1 and a Trigger frame.

— A Management frame carried in an A-MPDU subframe with the EOF/Tag field set to 1, where the Management frame is a Disassociation frame, (Re)Association Response frame, Authentication frame, or Action frame, and a Trigger frame.

(#3777)The AP follows the EDCA procedure in 10.23 (HCF) with the following modifications:

— The definition of transmission success (see 10.23.2.2 (EDCA backoff procedure)) is extended such that if a DL MU PPDU includes a triggering frame and the AP receives an MPDU in response from at least one of the STAs addressed by the triggering frame, then transmission is a success; otherwise the transmission is a failure.

— The aggregation rules in 26.6 (A-MPDU operation in an HE PPDU) supersede the rules in 10.23.2.7 (Sharing an EDCA TXOP).

An AP shall not transmit an HE MU PPDU where the number of OFDM symbols in the HE-SIG-B field is greater than 16 to a non-AP STA with a 20 MHz operating channel width.

#### 26.5.1.2 RU addressing in an HE MU PPDU

The Type and Subtype subfields in the Frame Control field and address type (individually addressed or group addressed) of MPDUs may be different across A-MPDUs in different PSDUs within the same HE MU PPDU.

An AP includes in the TXVECTOR for an HE MU PPDU at least one parameter STA_ID for each RU in the HE MU PPDU as defined in 26.11.1 (STA_ID). The AP shall not include in the TXVECTOR more than one parameter STA_ID with the same value, unless the value is 2046 (indicating an unallocated RU).

An HE AP with dot11MultiBSSIDImplemented equal to false shall not include in an HE MU PPDU anything other than one or more of the following:

— One or more individually addressed RUs, corresponding to the parameter STA_ID equal to the AID(s) of STA(s) associated with the AP, to carry information intended for the STA(s).

— A broadcast RU corresponding to parameter STA_ID equal to 0 to carry information intended for the STAs associated with the AP that are not the recipient of a individually addressed RU.

— A broadcast RU corresponding to parameter STA_ID equal to 2045 to carry information intended for STAs not associated with the AP.

— One or more RUs corresponding to parameter STA_ID equal to 2046 for (#3024)unallocated RUs.

An HE AP with dot11MultiBSSIDImplemented equal to true shall not include in an HE MU PPDU anything other than one or more of the following:

— One or more individually addressed RUs, corresponding to the parameter STA_ID equal to the AID(s) of STA(s) associated with any AP in the multiple BSSID set, to carry information intended for that associated STA.

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- A broadcast RU corresponding to parameter STA_ID equal to 0 to carry information intended for STAs associated with the AP corresponding to the transmitted BSSID and not the recipient of an individually addressed RU.
- A broadcast RU corresponding to parameter STA_ID equal to the BSSID Index of a BSSID in a multiple BSSID set to carry information intended for STAs associated with the AP corresponding to that BSSID and not the recipient of an individually addressed RU.
- A broadcast RU corresponding to parameter STA_ID equal to 2047 to carry information intended for STAs associated with the APs in the multiple BSSID set and not the recipient of an individually addressed RU or another broadcast RU corresponding to parameter STA_ID equal 0 or equal to the BSSID Index of a BSSID in a multiple BSSID set.
- A broadcast RU corresponding to parameter STA_ID equal to 2045 to carry information intended for STAs not associated with any AP in the multiple BSSID set.
- One or more RUs corresponding to parameter STA_ID equal to 2046 for (#3024)unallocated RUs.

A non-AP STA that receives an HE MU PPDU where the RXVECTOR includes a parameter STA_ID that matches the 11 LSBs of the non-AP STA's AID shall disregard any broadcast RU in the HE MU PPDU. A non-AP STA that receives an HE MU PPDU where the RXVECTOR includes a parameter STA_ID that is equal to the BSSID Index of the BSSID of the AP with which the STA is associated (see 9.4.2.72 (Multiple BSSID-Index element)) shall disregard a broadcast RU corresponding to parameter STA_ID equal to 2047.

For an AP with dot11MultiBSSIDImplemented equal to false, the AP shall set the TA and BSSID fields (when present) to the BSSID of the AP's BSS for all the frames carried in a broadcast RU that corresponds to parameter STA_ID equal to 0 or 2045.

For an AP with dot11MultiBSSIDImplemented equal to true, the AP shall set the TA and BSSID fields (when present) to the transmitted BSSID for all the frames carried in a broadcast RU corresponding to parameter STA_ID equal to 0 or 2045 or 2047.

For an AP with dot11MultiBSSIDImplemented equal to true, the AP shall set the TA and BSSID fields (when present) to the BSSID of the corresponding nontransmitted BSSID for the all frames carried in a broadcast RU corresponding to parameter STA_ID equal to the BSSID Index of a nontransmitted BSSID in a multiple BSSID set.

#### 26.5.1.3 RU allocation in an HE MU PPDU

An AP shall not transmit a 40 MHz HE MU PPDU in the 2.4 GHz band with an RU allocated to a 20 MHz operating non-AP HE STA, unless the AP has received from the 20 MHz operating non-AP HE STA an HE Capabilities element with the 20 MHz In 40 MHz HE PPDU In 2.4 GHz Band subfield in the HE PHY Capabilities Information field equal to 1.

An AP shall not transmit a 160 MHz or 80+80 MHz HE MU PPDU with an RU allocated to a 20 MHz operating non-AP HE STA, unless the AP has received from the 20 MHz operating non-AP HE STA an HE Capabilities element with the 20 MHz In 160/80+80 MHz HE PPDU subfield in the HE PHY Capabilities Information field equal to 1.

An AP shall not transmit a 160 MHz or 80+80 MHz HE MU PPDU with an RU allocated to an 80 MHz operating non-AP HE STA, unless the AP has received from the 80 MHz operating non-AP HE STA an HE Capabilities element with the 80 MHz In 160/80+80 MHz HE PPDU subfield in the HE PHY Capabilities Information field equal to 1.

An AP shall follow the RU restriction rules defined in 27.3.2.8 when assigning an RU to a 20 MHz operating non-AP STA in a 40 MHz, 80 MHz, 160 MHz, or 80+80 MHz HE MU PPDU. An AP shall follow the rules in 27.3.2.7 (20 MHz operating non-AP HE STAs) and 27.3.2.9 (80 MHz operating non-AP HE


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STAs) or the SST subchannel (if applicable) in which the STA is operating (see 26.8.7 (HE subchannel selective transmission)) if allocating RUs to a non-AP STA.

An AP shall not transmit a 40 MHz HE MU PPDU in the 2.4 GHz band with a 242-tone RU allocated to a 20 MHz operating non-AP HE STA, unless the AP has received from the 20 MHz operating non-AP HE STA an HE Capabilities element with B4 of the Supported Channel Width Set subfield of the HE PHY Capabilities Information field equal to 1.

An AP shall not transmit a 40 MHz, 80 MHz, 160 MHz, or 80+80 MHz HE MU PPDU in the 5 GHz band with a 242-tone RU allocated to a 20 MHz operating non-AP HE STA, unless the AP has received from the 20 MHz operating non-AP HE STA an HE Capabilities element with B5 of the Supported Channel Width Set subfield of the HE PHY Capabilities Information field equal to 1.

An HE MU PPDU shall have a sufficient number of RUs allocated to users such that all of the following conditions are satisfied:

a) At least $N \times 4 \times 26$ subcarriers are modulated by the allocated RUs within the entire PPDU, where $N$ is the number of 20 MHz subchannels that are not preamble punctured in the PPDU.
b) For each 20 MHz subchannel $S$ within the bandwidth of the HE MU PPDU, at least $2 \times 26$ subcarriers are modulated by the allocated RUs in the 20 MHz subchannel $S$ if all of the following are true:
    1) At least one RU is allocated in the 20 MHz subchannel $S$.
    2) Transmitter is an AP.
    3) The AP is operating in an operating class for which the behavior limits set listed in Annex E includes the DFS_50_100_Behavior.
    4) The AP has received at least one Beacon frame from OBSS $B$ within the past dot11ObssNbRuToleranceTime in the current operating channel in which any of the following are true:
        i) The Extended Capabilities element is not present.
        ii) The OBSS Narrow Bandwidth RU In OFDMA Tolerance Support field in the Extended Capabilities element is not present.
        iii) The OBSS Narrow Bandwidth RU In OFDMA Tolerance Support field in the Extended Capabilities element is 0.
    5) The 20 MHz subchannel $S$ overlaps with the operating bandwidth of the OBSS $B$.
c) At least one RU is allocated in the primary 20 MHz.

### 26.5.2 UL MU operation

#### 26.5.2.1 General

UL MU operation allows an AP to solicit simultaneous immediate response frames from one or more non-AP HE STAs. A non-AP HE STA shall follow the rules in this subclause for the transmission of response frames in an HE TB PPDU, unless the Trigger frame is an MU-RTS Trigger frame, in which case the response is a CTS frame sent in a non-HT PPDU (see 26.2.6 (MU-RTS Trigger/CTS frame exchange sequence procedure(#109))).

A non-AP STA shall not send a triggering frame.

An HE STA that is a mesh STA shall not transmit and shall not receive HE TB PPDUs.

A non-AP HE STA shall set the TRS Support subfield in the HE Capabilities element it transmits to 1 if its dot11TRSOptionImplemented is true; otherwise, the STA shall set it to 0.

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A non-AP HE STA shall set the UL 2×996-tone RU Support subfield in HE Capabilities element to 1 if it supports receiving a frame that carries a TRS Control subfield that allocates a 2×996-tone RU or a Trigger frame with User Info field addressed to the STA with RU Allocation subfield indicating a 2×996-tone RU.

If a non-AP HE STA supports transmitting an HE TB PPDU that uses UL MU-MIMO within an RU that spans the entire PPDU bandwidth, then the STA shall set dot11HEFullBWULMUMIMOImplemented to true and the Full Bandwidth UL MU-MIMO subfield of the HE PHY Capabilities Information field in the HE Capabilities element it transmits to 1. Otherwise, the HE STA shall set dot11HEFullBWULMUMIMOImplemented to false and the Full Bandwidth UL MU-MIMO subfield to 0.

If a non-AP HE STA with dot11HEFullBWULMUMIMOImplemented equal to true also supports transmitting an HE TB PPDU that uses UL MU-MIMO within an RU that does not span the entire PPDU bandwidth, then the STA shall set dot11HEPartialBWULMUMIMOImplemented to true and the Partial Bandwidth UL MU-MIMO subfield in the HE PHY Capabilities Information field in the HE Capabilities element it transmits to 1. Otherwise, the non-AP HE STA shall set dot11HEPartialBWULMUMIMOImplemented to false and the Partial Bandwidth UL MU-MIMO subfield to 0.

If a non-AP STA has dot11HEDeviceClass equal to ClassA (1), then it indicates Class A in the Device Class subfield in the HE PHY Capabilities Information field in the HE Capabilities element, and the HE TB PPDUs it transmits shall meet the Class A requirements in 27.3.15 (Transmit requirements for PPDUs sent in response to a triggering frame). Otherwise, it indicates Class B in the Device Class subfield in the HE PHY Capabilities Information field in the HE Capabilities element, and the HE TB PPDUs it transmits shall meet the Class B requirements in 27.3.15 (Transmit requirements for PPDUs sent in response to a triggering frame).

A non-AP HE STA with dot11HTVHTTriggerOptionImplemented equal to true shall set the HT And VHT Trigger Frame Rx Support field to 1 in the HE MAC Capabilities Information field in HE Capabilities elements that it transmits. A non-AP HE STA with dot11HTVHTTriggerOptionImplemented equal to false shall set the HT And VHT Trigger Frame Rx Support field to 0.

#### 26.5.2.2 Rules for soliciting UL MU frames

##### 26.5.2.2.1 General

An HE AP shall not allocate an RU for a 40 MHz HE TB PPDU to a 20 MHz operating non-AP HE STA in the 2.4 GHz band, unless the AP has received from the 20 MHz operating non-AP HE STA an HE Capabilities element with the 20 MHz In 40 MHz HE PPDU In 2.4 GHz Band subfield in the HE PHY Capabilities Information field in its HE Capabilities element equal to 1.

An HE AP shall not allocate an RU for an 160 MHz or 80+80 MHz HE TB PPDU to a 20 MHz operating non-AP HE STA, unless the AP has received from the 20 MHz operating non-AP HE STA an HE Capabilities element with the 20 MHz In 160/80+80 MHz HE PPDU in the HE PHY Capabilities Information field equal to 1.

An AP shall not allocate to a 20 MHz operating non-AP HE STA a 242-tone RU for a 40 MHz, 80 MHz, 160 MHz, or 80+80 MHz HE TB PPDU transmission.

An AP shall not transmit a Trigger frame soliciting an HE TB PPDU that uses UL MU-MIMO within an RU that does not span the entire PPDU bandwidth to a non-AP STA from which it has not received an HE Capabilities element with the Partial Bandwidth UL MU-MIMO subfield of the HE PHY Capabilities Information field equal to 1.


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An AP shall not transmit a Trigger frame soliciting an HE TB PPDU that uses UL MU-MIMO within an RU that spans the full bandwidth to a non-AP STA from which it has not received an HE Capabilities element with the Full Bandwidth UL MU-MIMO subfield of the HE PHY Capabilities Information field equal to 1.

An AP shall not send a frame that carries a TRS Control subfield to a non-AP STA that has not set the TRS Support subfield to 1 in the HE MAC Capabilities Information field in the HE Capabilities element it transmits.

An AP shall not send a frame that carries a TRS Control subfield that allocates a 2×996-tone RU to a non-AP STA or a Trigger frame with a User Info field that allocates a 2×996-tone RU to a non-AP STA, unless the AP has received from the non-AP STA an HE MAC Capabilities element with the UL 2×996-tone RU Support subfield in the MAC Capabilities Information field equal to 1.

NOTE 1—An AP does not send a Trigger frame containing a User Info field with AID12 subfield carrying the 12 LSBs of the AID of a non-AP STA or a frame addressed to a non-AP STA that carries a TRS Control subfield if the AP has received from the non-AP STA an OM Control subfield with UL MU Disabled subfield set to 1 and UL MU Data Disable subfield set to 0 (see 26.9.3 (Transmit operating mode (TOM) indication)).

An AP that transmits a PPDU may solicit an HE TB PPDU from one or more non-AP STAs through one of the following mechanisms:

- Including in the PPDU one or more Trigger frames that include one or more User Info fields with one of the following AID12 subfield settings:
  - The AID12 subfield is set to the 12 LSBs of the AID of the non-AP STA if the User Info field is addressed to a STA that is associated with the AP.
  - The AID12 subfield is set to the 12 LSBs of the AID of the non-AP STA if the User Info field is addressed to a STA that is associated with an AP corresponding to a nontransmitted BSSID in a multiple BSSID set to which the AP belongs, the TA field of the Trigger frame is set to the transmitted BSSID, and the non-AP STA has set the Rx Control Frame To MultiBSS subfield in the HE Capabilities element it transmits to 1.
  - The AID12 subfield indicates that one or more contiguous RA-RUs are allocated (see 26.5.4 (UL OFDMA-based random access (UORA))).
- Including in the PPDU one or more individually addressed frames that include a TRS Control subfield and that are carried in one of the following:
  - An S-MPDU that solicits an immediate Ack frame (see 10.12.8 (Transport of S-MPDUs)).
  - An A-MPDU that solicits an immediate BlockAck frame (see 10.25.6.7 (Originator's behavior)).
  - A multi-TID A-MPDU that solicits an immediate Multi-STA BlockAck frame (see 26.6.3 (Multi-TID A-MPDU and ack-enabled single-TID A-MPDU)).

The AP shall follow the rules in 26.3.2 (Dynamic fragmentation) if any MPDUs are fragments.

More than one Trigger frame may be aggregated in an A-MPDU. If more than one Trigger frame is aggregated in an A-MPDU, all of them shall have the same content. An AP may include a frame carrying a TRS Control subfield in an HE MU PPDU, HE SU PPDU, or HE ER SU PPDU.

NOTE 2—The TRS Control subfields within MPDUs carried in an A-MPDU have the same value (see 10.8 (HT Control field operation)).

An A-MPDU shall not include both a Trigger frame and a frame carrying a TRS Control subfield.

An AP shall not transmit a triggering frame if all of the following conditions are satisfied:

- The AP is operating in an operating class for which the behavior limits set listed in Annex E includes the DFS_50_100_Behavior (see Table E-1).

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- The AP has received at least one Beacon frame from OBSS *B* within the past dot11ObssNbRuToleranceTime in the current operating channel in which any of the following is true:
  - The Extended Capabilities element is not present.
  - The OBSS Narrow Bandwidth RU In OFDMA Tolerance Support field in the Extended Capabilities element is not present.
  - The OBSS Narrow Bandwidth RU In OFDMA Tolerance Support field in the Extended Capabilities element is 0.
- The triggering frame allocates at least one 26-tone RU whose location in frequency overlaps with the operating bandwidth of the OBSS *B*.

If a non-AP HE STA operating in an operating class for which the behavior limits set listed in Annex E includes the DFS_50_100_Behavior does not respond to a triggering frame in which the non-AP HE STA is allocated a 26-tone RU, then the AP should not allocate a 26-tone RU to the non-AP HE STA in the next triggering frame.

An AP shall not transmit a Trigger frame with a User Info field addressed to a non-AP STA in an HT or VHT PPDU, unless the AP has received from the non-AP STA an HE Capabilities element with the HT And VHT Trigger Frame Rx Support subfield in HE MAC Capabilities Information field equal to 1.

An AP shall not use the short guard interval for an HT or VHT PPDU that carries a Trigger frame. A Trigger frame shall not be carried in a DSSS or HR/DSSS PPDU. An AP shall not use STBC encoding for a PPDU that carries a triggering frame.

(#2368)An AP shall not set the UL STBC subfield in the Common Info field in a Trigger frame it transmits if any of the RUs allocated in that Trigger frame is assigned to more than 1 user.

#### 26.5.2.2.2 Requirements for allocating resources

An AP that sends a Basic Trigger frame, a BQRP Trigger frame, or a BSRP Trigger frame that is not aggregated with a QoS Data frame with HETP Ack ack policy or with a Management frame that solicits acknowledgment shall allocate sufficient resources for the responding STA indicated by each User Info field for the solicited associated non-AP STA or the UORA response from an associated non-AP STA to send at least one QoS Null frame that carries an HT Control field.

NOTE—An AP that sends a Basic Trigger frame uses an (M118)implementation specific method to decide the amount of resources indicated for UORA allocations.

An AP that solicits an Ack or BlockAck frame carried in an HE TB PPDU from a non-AP STA shall allocate sufficient resources for the non-AP STA to send the expected acknowledgment. If the AP solicits a BlockAck frame, the allocated resource shall be sufficient for the non-AP STA to send the BlockAck frame with Block Ack Bitmap subfields that are the negotiated block ack bitmap length (see 26.4.3 (Negotiation of block ack bitmap lengths)).

An AP that sends a BFRP Trigger frame shall allocate sufficient resources for the HE TB PPDU response from each HE beamformee to include all the solicited feedback, including feedback that is segmented and including an HT Control field in each frame.

#### 26.5.2.2.3 Padding for a triggering frame

An AP transmitting a PPDU that contains a BCC-encoded triggering frame soliciting a response from a non-AP STA shall ensure that the number of bits in the PSDU following the last bit of *SCH* is at least $L_{PAD,MAC}$ as defined in Equation (26-1), which is based on the *MinTrigProcTime* indicated by the non-AP STA (see Table 9-375 (Subfields of the HE MAC Capabilities Information field(11ax))), where *SCH* is either


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— The User Info field addressed to the STA of the last or only Trigger frame, or

— The last TRS Control subfield in the PSDU.

$$L_{PAD,MAC} = N_{DBPS} m_{PAD} \quad (26\text{-}1)$$

where

$N_{DBPS}$ is defined in Table 17-4 (Modulation-dependent parameters) for a non-HT PPDU, Table 19-7 (Frequently used parameters)for an HT PPDU, Table 21-6 (Frequently used parameters) for a VHT PPDU, and Table 27-16 (Frequently used parameters(11ax)) for an HE PPDU. If the triggering frame is carried in an HE MU PPDU, $N_{DBPS}$ is replaced by $N_{DBPS,u}$ of the target user in Equation (26-1).

$m_{PAD}$ is as follows:

— For a non-HT PPDU, HT PPDU, and VHT PPDU:

$$m_{PAD} = \begin{cases} 0, \text{ if } MinTrigProcTime \text{ is } 0 \\ 2, \text{ if } MinTrigProcTime \text{ is } 8\ \mu s \\ 4, \text{ if } MinTrigProcTime \text{ is } 16\ \mu s \end{cases}$$

— For an HE PPDU:

$$m_{PAD} = \begin{cases} 0, \text{ if } MinTrigProcTime \text{ is } 0 \\ 1, \text{ if } MinTrigProcTime \text{ is } 8 \text{ or } 16\ \mu s \end{cases}$$

An AP transmitting a Trigger frame that contains at least one User Info field with AID12 subfield indicating allocation of one or more contiguous RA-RUs for associated STAs shall ensure that the number of bits following the last bit of *SCH* is at least $L_{PAD,MAC}$ as defined in Equation (26-1), which is based on the largest *MinTrigProcTime* of all associated non-AP STAs, where *SCH* is the last User Info field with AID12 subfield equal to either 0 or 2046.

An AP transmitting a Trigger frame that contains at least one User Info field with AID12 subfield indicating allocation of one or more contiguous RA-RUs for unassociated non-AP STAs should ensure that the number of bits following the last bit of *SCH* is at least $4 \times N_{DBPS}$ for a non-HT PPDU, HT PPDU, or VHT PPDU or $N_{DBPS}$ for an HE PPDU, where S*CH* is the last User Info field with AID12 subfield equal to either 2045 or 2046.

An AP transmitting an NFRP Trigger frame shall ensure that the number of bits following the last User Info field with an AID12 subfield not equal to 4095 is at least $4 \times N_{DBPS}$ for a non-HT PPDU, HT PPDU, or VHT PPDU or $N_{DBPS}$ for an HE PPDU.

An AP may use any type of padding to satisfy the *MinTrigProcTime* requirement of a non-AP STA, such as using the Padding field in a Trigger frame, using post-EOF A-MPDU padding, or aggregating other MPDUs in the A-MPDU.

If a triggering frame is LDPC encoded, then the transmitting AP ensures that $T_{TrigProc}$ meets the following requirements:

— $T_{TrigProc}$ shall be greater than or equal to the *MinTrigProcTime* specified by the non-AP STAs that are the recipients of the Trigger frame.

— For a Trigger frame that contains at least one User Info field with AID12 subfield indicating allocation of one or more contiguous RA-RUs for associated STAs, $T_{TrigProc}$ shall be greater than or equal to the largest *MinTrigProcTime* of all associated non-AP STAs.

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— For a Trigger frame that contains at least one User Info field with AID12 subfield indicating allocation of one or more contiguous RA-RUs for unassociated STAs, $T_{TrigProc}$ should be at least 16 μs.

— For an NFRP Trigger frame, $T_{TrigProc}$ shall be at least 16 μs.

$T_{TrigProc}$ is defined as the duration of PPDU that is after the OFDM symbol containing the last coded bit of the LDPC codeword that encodes the last bit of *SCH* minus $T_{PE,nominal}$ defined in 27.3.13 (Packet extension).

#### 26.5.2.2.4 Allowed settings of the Trigger frame fields and TRS Control subfield

An AP with dot11MultiBSSIDImplemented equal to true shall not send a Trigger frame (other than an NFRP Trigger frame (11az)or Ranging Trigger frame) with the TA field set to the transmitted BSSID to a non-AP STA that is associated with (11az)a nontransmitted BSSID in the multiple BSSID set(11az) unless the AP has received an HE Capabilities element from non-AP STA with the Rx Control Frame To MultiBSS subfield in the HE MAC Capabilities Information field equal to 1. An AP with dot11MultiBSSIDImplemented equal to true may send an NFRP Trigger frame with the TA field set to the transmitted BSSID to a non-AP STA that is associated with(11az) a nontransmitted BSSID in a multiple BSSID set. An AP with dot11MultiBSSIDImplemented equal to true (11az)may send a Ranging Trigger frame, with the TA field set to a transmitted BSSID, (11az)to an ISTA during a TB ranging measurement exchange (11.21.6.4.3 (TB ranging measurement exchange(11az))) when the FTM session was established using a nontransmitted BSSID in the multiple BSSID set {of, associated with} the transmitted BSSID.

An AP that transmits a Trigger frame shall set the TA field of the frame to the MAC address of the AP, except if dot11MultiBSSIDImplemented is true and the Trigger frame is directed to non-AP STAs from at least two different BSSs of a multiple BSSID set. In this case, the AP shall set the TA field of the frame to the transmitted BSSID.

The AP shall set the UL Length subfield of a Trigger frame to the value given by Equation (27-11) with $m = 2$.

If an AP transmits a Trigger frame that allocates an RU that spans the entire HE TB PPDU bandwidth and assigns the RU to more than one non-AP STA (i.e., for UL MU-MIMO) and with the GI And HE-LTF Type subfield of the Common Info field set to indicate either 2x HE-LTF + 1.6 μs GI or 4x HE-LTF + 3.2 μs GI, the AP may set the MU-MIMO HE-LTF Mode subfield in the Common Info field of the Trigger frame to indicate either HE single stream pilot HE-LTF mode or HE masked HE-LTF sequence mode. Otherwise, the AP shall set the MU-MIMO HE-LTF Mode subfield in the Common Info field to indicate HE single stream pilot HE-LTF mode.

An AP that transmits Trigger frames in more than one A-MPDU in an HE MU PPDU shall set each subfield, except the Trigger Type, More TF, CS Required, and Trigger Dependent Common Info subfields, in the Common Info field of the Trigger frame in one A-MPDU to the same value as the corresponding subfield in the Common Info field of the Trigger frames in the other A-MPDUs.

An AP that transmits frames carrying a TRS Control subfield in more than one A-MPDU in an HE MU PPDU shall set the UL Data Symbols and AP Tx Power subfields of the TRS Control subfield in the frames of one A-MPDU to the same value as the corresponding subfields of the TRS Control subfield in the frames of the other A-MPDUs.

An AP that transmits one or more Trigger frames in one or more A-MPDUs and frames carrying a TRS Control subfield in one or more other A-MPDUs in an HE MU PPDU shall set the Common Info field of the Trigger frames and the TRS Control subfields in each A-MPDU as follows:


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- The UL Length subfield in the Common Info field of the Trigger frames and the UL Data Symbols subfield in the TRS Control subfields indicate the same HE TB PPDU duration.
- The AP Tx Power subfield in the Common Info field of the Trigger frames and the AP Tx Power subfield in the TRS Control subfields indicate the same transmit power.
- In the Common Info field of the Trigger frames:
  - The MU-MIMO HE-LTF Mode and UL STBC subfields are set to 0.
  - The Number Of HE-LTF Symbols And Midamble Periodicity subfield is set to 0.
  - The Doppler subfield is set to 0.
  - The Pre-FEC Padding Factor subfield is set to 0 (i.e., to indicate a pre-FEC padding factor of 4).
  - The UL Length subfield and the PE Disambiguity subfield are set to indicate the PE duration calculated with Equation (27-114) is the default PE duration value, which is indicated by the AP in the Default PE Duration subfield of the HE Operation element it transmits.
  - The UL Spatial Reuse subfield is set to PSR_AND_NON_SRG_OBSS_PD_PROHIBITED.
  - If the TXVECTOR parameters HE_LTF_TYPE and GI_TYPE of the HE PPDU carrying the Trigger frame are either 4xHE-LTF and 3u2s_GI, respectively, or 2xHE-LTF and 1u6s_GI, respectively, then the GI And HE-LTF Type subfield is set to 2. Otherwise, the GI And HE-LTF Type subfield is set to 1.

NOTE 1—A non-AP STA obtains the information required to prepare an HE TB PPDU explicitly and implicitly. Explicit information is obtained in the triggering frame contained in the triggering PPDU. Implicit information is obtained in previously exchanged frames with the AP, e.g., in the BSS Color and the Default PE Duration subfields of the HE Operation element, or from default values specified in 26.5.2.3 (Non-AP STA behavior for UL MU operation).

An AP shall not set any subfields of the Common Info field of a Trigger frame to a value that is not supported by all the recipient non-AP STAs of the Trigger frame and the AP. An AP shall not set any subfields of the User Info field of a Trigger frame to a value that is not supported by the recipient non-AP STA of the User Info field and the AP. An AP shall set the values of the subfields of the Common Info field and User Info field of a Trigger frame such that the combination together would cause the solicited non-AP STA to construct a valid HE TB PPDU. An AP shall not set any subfields of a TRS Control subfield to a value that is not supported by the recipient non-AP STA of the TRS Control subfield and the AP. An AP shall set the values of the subfields of a TRS Control subfield such that the combination together would cause the solicited non-AP STA to construct a valid HE TB PPDU. If an RU is allocated to only one non-AP STA, the Starting Spatial Stream subfield for that non-AP STA shall be set to 0.

NOTE 2—Subclauses 27.3.4 (HE PPDU formats) and 27.3.6.10 (Construction of the Data field in an HE SU PPDU, HE ER SU PPDU, and HE TB PPDU) specify the requirements on each of the other remaining subfields, such that the solicited non-AP STAs each construct a valid HE TB PPDU in response to the Trigger frame.

An AP shall follow the RU restriction rules defined in 27.3.2.8 (RU restrictions for 20 MHz operation) when assigning an RU to a 20 MHz operating non-AP STA for a 40 MHz, 80 MHz, 160 MHz, or 80+80 MHz HE TB PPDU. An AP shall not set the RU Allocation subfield of the User Info field of a triggering frame that is addressed to a non-AP STA to a value such that the RU allocated to the STA lies outside the channel in which the STA is operating (see 27.3.2.6 (Resource allocation for an HE TB PPDU) and 27.3.2.9 (80 MHz operating non-AP HE STAs)) or outside the SST subchannel (if applicable) in which the STA is operating (see 26.8.7 (HE subchannel selective transmission)).

If a Trigger frame is transmitted in the broadcast RU of an HE MU PPDU, then the Trigger frame shall not include any User Info fields addressed to a non-AP STA that is identified as a recipient of another RU or spatial stream of the same HE MU PPDU.

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A TRS Control subfield shall not be included in a group addressed frame.

If an AP transmits one or more Trigger frames or frames carrying a TRS Control subfield, then the frames shall collectively elicit HE TB PPDU responses such that at least one scheduled RU is allocated for each 20 MHz channel occupied by the eliciting PPDU. An AP shall not allocate an RU in any 20 MHz channel that is not occupied by the immediately preceding DL PPDU.

An AP may indicate an unallocated RU in a Trigger frame by including a User Info field with the AID12 subfield set to 2046. The AP shall place any User Info fields with the AID12 subfield set to 2046 after User Info fields with the AID12 subfield set to a value less than 2046.

An AP shall not transmit a Trigger frame that contains more than one User Info field with the same value in the AID12 subfield, unless the value in the AID12 subfield is 0 or greater than 2007. The AP shall place User Info fields with the same value in the AID12 subfield together as a contiguous block in the Trigger frame. The AP shall place User Info fields with the AID12 subfield set to 0 or a value greater than 2007 after User Info fields with the AID12 subfield set to a value in the range 1 to 2007 (if any present).

An AP that transmits an individually addressed Trigger frame shall include only one User Info field in the Trigger frame with the AID12 subfield set to the 12 LSBs of the AID of the non-AP STA addressed by the RA field.

An example of User Info field ordering in a Trigger frame and the relationship to RU locations is shown in Figure 26-4 (Example of User Info field ordering and RU location mapping(11ax)(#3024)).

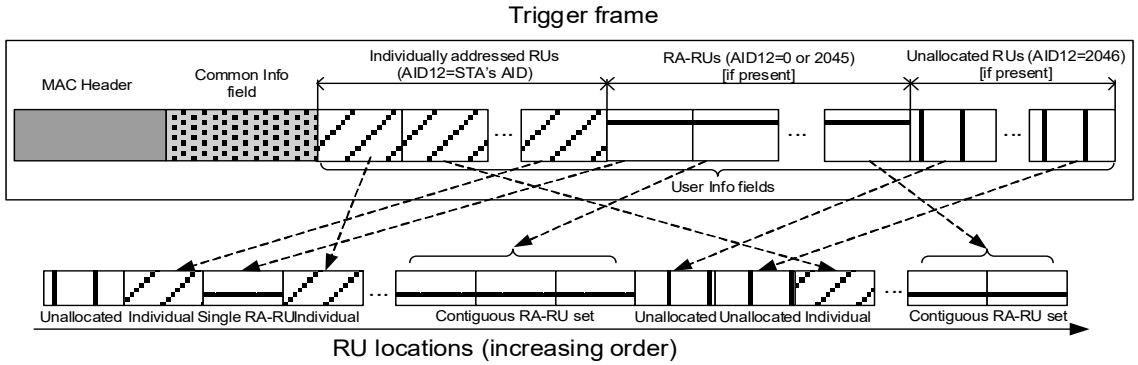


**Figure 26-4—Example of User Info field ordering and RU location mapping(11ax)(#3024)**

An AP that sends a Basic Trigger frame shall set the TID Aggregation Limit subfield of a User Info field that is addressed to a non-AP STA to a value between 0 and 1 plus the value of the Multi-TID Aggregation Tx Support subfield in the HE Capabilities element most recently received from the non-AP STA. A value 0 in the TID Aggregation Limit subfield indicates to the non-AP STA that it shall not solicit any immediate response for the MPDUs that the non-AP STA aggregates in the HE TB PPDU. A value of 7 in the TID Aggregation Limit subfield indicates to the non-AP STA that it may aggregate QoS Data frames from any number of different TID values in the multi-TID A-MPDU. Table 26-2 (Relation between TID Aggregation Limit field, Multi-TID Aggregation Tx Support field, and solicited immediate response(11ax)) provides a summary of the possible combinations.


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**Table 26-2—Relation between TID Aggregation Limit field, Multi-TID Aggregation Tx Support field, and solicited immediate response(11ax)**

| AP: TID Aggregation Limit field | Non-AP STA: Multi-TID Aggregation Tx Support field | Non-AP STA: Solicited immediate response? |
|---|---|---|
| 0 | Any value | No |
| 1 | Any value | Yes for at most one TID and/or one Management frame |
| *tal* (0 to *mta* + 1) | *mta* | Yes at most *tal* TIDs and/or at most one Management frame |

Legend:
*tal* is the value in the TID Aggregation Limit field.
*mta* is the value in the Multi-TID Aggregation Tx Support field.

The AP may assign any ACI value defined in Table 9-193 (ACI-to-AC coding) in the Preferred AC subfield in the Trigger Dependent User Info field for an HE STA and identified by the AID12 subfield of the User Info field of a Basic Trigger frame. If the AP does not have a recommendation, then it shall set the Preferred AC subfield to the value 0 (AC_BE).

When transmitting a PPDU carrying a triggering frame, an AP should not apply transmit beamforming to the following:

— Non-HT PPDUs
— Fields prior to the HT-STF field of an HT mixed format PPDU
— Pre-VHT modulated fields of an VHT PPDU
— Pre-HE modulated fields of an HE PPDU

An AP shall transmit an HE PPDU that carries a triggering frame with the TXVECTOR parameter BEAM_CHANGE set to 1.

An AP should set the TID Aggregation Limit subfield in the User Info fields of a Basic Trigger frame to 0 if the CS Required subfield in the Common Info field of the Basic Trigger frame is 0.

An AP shall set the TID Aggregation Limit subfield in the User info fields of a Basic Trigger frame to 0 if the solicited HE TB PPDU is the last PPDU of the TXOP.

NOTE 3—An HE TB PPDU is the last PPDU if the Duration/ID field is equal to 0 in the MPDU(s) contained in the HE TB PPDU.

### 26.5.2.2.5 AP access procedures for UL MU operation

The AP shall follow the EDCA procedure defined in 10.23 (HCF) and the additional rules in this subclause.

If an AP receives an immediate response with at least one frame from at least one non-AP STA solicited by a triggering frame, the frame exchange sequence(#109) is successful.

If an AP does not receive an immediate response with at least one frame from at least one non-AP STA solicited by a PPDU that contains at least one Trigger frame, then the frame exchange sequence(#109) is not successful, and the AP shall follow the backoff procedure in 10.23.2.2 (EDCA backoff procedure).

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An AP may use any AC for sending a PPDU that contains only Trigger frames.

If the PPDU contains frames that are not Trigger frames in addition to a Trigger frame, then the AP follows the MPDU aggregation rules in 26.6 (A-MPDU operation in an HE PPDU), which supersede the rules in 10.23.2.7 (Sharing an EDCA TXOP).

#### 26.5.2.3 Non-AP STA behavior for UL MU operation

##### 26.5.2.3.1 General

A non-AP STA shall not send an HE TB PPDU, unless it is explicitly triggered by an AP in one of the operation modes described in this subclause.

The interframe space between a PPDU that contains a triggering frame and the HE TB PPDU is a SIFS.

A non-AP STA shall not transmit an HE TB PPDU if all of the conditions in 26.5.2.3.2 (Conditions for not responding with an HE TB PPDU) are satisfied. Otherwise, a non-AP STA shall transmit an HE TB PPDU a SIFS after a received PPDU if all of the following conditions are met:

- The received PPDU contains either a Trigger frame (that is not an MU-RTS variant) with a User Info field addressed to the non-AP STA or a frame addressed to the non-AP STA that contains an TRS Control subfield. A User Info field in the Trigger frame is addressed to a non-AP STA if one of the following conditions are met:
  - The AID12 subfield is equal to the 12 LSBs of the AID of the non-AP STA, and the Trigger frame is sent by the AP with which the non-AP STA is associated or by the AP corresponding to the transmitted BSSID if the non-AP STA is associated with an AP corresponding to a nontransmitted BSSID and has indicated support for receiving Control frames with TA field set to the transmitted BSSID by setting the Rx Control Frame To MultiBSS subfield to 1 in the HE Capabilities element that the STA transmits.
  - The AID12 subfield indicates allocation of one or more contiguous RA-RUs for associated STAs, the non-AP STA is associated with the AP that sent the Trigger frame, the non-AP STA supports the UORA procedure, and the conditions in 26.5.4 (UL OFDMA-based random access (UORA)) are satisfied.
  - The AID12 subfield indicates allocation of one or more contiguous RA-RUs for unassociated STAs, the non-AP STA is not associated with the AP that sent the Trigger frame, the non-AP STA supports the UORA procedure, the conditions in 26.5.4 (UL OFDMA-based random access (UORA)) are satisfied, and the resource to which the non-AP STA gains access is sufficient for the non-AP STA to include the pending frame.
- The CS Required subfield in the Trigger frame is 1, and the UL MU CS condition described in 26.5.2.5 (UL MU CS mechanism) indicates the medium is idle; or the CS Required subfield in a Trigger frame is 0; or the response was solicited by a frame containing a TRS Control subfield.
- The UL MU Disable subfield is 0, and the UL MU Data Disable subfield is 0 in the most recent OM Control subfield (if any) sent by the non-AP STA to the AP; or the UL MU Disable subfield is 0, the UL MU Data Disable subfield is 1 in the most recent OM Control subfield (if any) sent by the non-AP STA to the AP, and the frame that is being triggered is an acknowledgment (see 26.9.3 (Transmit operating mode (TOM) indication)).

A non-AP STA addressed by a User Info field in a Trigger frame (i.e., the AID12 subfield is equal to the 12 LSBs of the AID of the non-AP STA) may ignore the remainder of User Info fields in the Trigger frame.

A non-AP STA generates the A-MPDU carried in the HE TB PPDU as defined in 26.5.2.4 (A-MPDU contents in an HE TB PPDU).


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#### 26.5.2.3.2 Conditions for not responding with an HE TB PPDU

A non-AP STA shall not transmit an HE TB PPDU that is not an HE TB feedback NDP if all the following conditions are satisfied:

- The non-AP STA is operating in an operating class for which the behavior limits set listed in Annex E includes the DFS_50_100_Behavior (see Table E-1 (Operating classes in the United States and its territories(#296)).
- The HE TB PPDU would be in response to one of the following:
  - A Trigger frame containing a User Info field with AID12 subfield carrying the 12 LSBs of the AID of the STA.
  - A frame addressed to the non-AP STA that includes a TRS Control subfield.
  - A Trigger frame that allocates at least one RA-RU.
- The RU is a 26-tone RU.
- The non-AP STA has received at least one Beacon frame within the past dot11ObssNbRuToleranceTime from an AP with which the non-AP STA is not associated, and the Beacon frame meets any of the following conditions:
  - The Extended Capabilities element is not present.
  - The OBSS Narrow Bandwidth RU In OFDMA Tolerance Support field in the Extended Capabilities element is not present.
  - The OBSS Narrow Bandwidth RU In OFDMA Tolerance Support field in the Extended Capabilities element is 0.

A non-AP STA may choose to not respond to a Trigger frame that contains one or more subfields in the Common Info field or in the User Info field addressed to or selected by the non-AP STA with values that are not recognized, are not supported, or cannot be satisfied by the non-AP STA.

NOTE—The User Info field in this context corresponds to the one directed to the non-AP STA (i.e., value in the AID12 subfield matches the STA's AID) or the one allocating an RA-RU (single or within a contiguous set) that is selected by the non-AP STA.

A non-AP STA may choose to not respond a TRS Control subfield in a frame addressed to the non-AP STA if the TRS Control subfield contains one or more subfields with values that are not recognized, are not supported, or cannot be satisfied by the non-AP STA.

A non-AP STA shall update the intra-BSS NAV (see 26.2.4 (Updating two NAVs)) based on the duration information of the triggering frame even if it decides to not respond to the frame.

#### 26.5.2.3.3 TXVECTOR parameters for HE TB PPDU response to Trigger frame

A non-AP STA transmitting an HE TB PPDU in response to a Trigger frame that is not an MU-RTS Trigger frame shall set the TXVECTOR parameters as follows (subject to, in the case of an NFRP Trigger frame, the exceptions given in 26.5.7.2 (STA behavior)):

- The FORMAT parameter is set to HE_TB.
- The TRIGGER_METHOD parameter is set to TRIGGER_FRAME.
- The TXOP_DURATION parameter is set as defined in 26.11.5 (TXOP_DURATION).
- The BSS_COLOR parameter is set as follows:
  - If the Trigger frame was received in an HE PPDU, then set to the value of the RXVECTOR parameter BSS_COLOR of the HE PPDU.
  - If the Trigger frame was received in a non-HE PPDU, then set to the value of the active BSS color as defined in 26.11.4 (BSS_COLOR).

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- The L_LENGTH parameter is set to the value indicated by the UL Length subfield in the Common Info field of the Trigger frame.
- The GI_TYPE and HE_LTF_TYPE parameters are set to the value indicated by the GI and HE-LTF Type subfield of the Common Info field of the Trigger frame.
- The NUM_STS parameter is set to the number of space-time streams indicated by the Number Of Spatial Streams subfield of the SS Allocation field of the User Info field and UL STBC subfield in the Common Info field of the Trigger frame. The NUM_STS parameter is set to 1 if the HE TB PPDU is sent on an RA-RU following the UORA procedure.
- The CH_BANDWIDTH parameter is set to the value of the UL BW subfield in the Common Info field of the Trigger frame.
- The HE_LTF_MODE parameter is set to the value indicated by the MU-MIMO HE-LTF Mode subfield of the Common Info field of the Trigger frame if the HE_LTF_TYPE parameter does not indicate 1x HE-LTF and the Trigger frame indicated full-bandwidth MU-MIMO. Otherwise, the parameter is not present.
- The NUM_HE_LTF parameter is set to the value indicated by the Number Of HE-LTF Symbols And Midamble Periodicity subfield of the Common Info field of the Trigger frame.
- The STBC parameter is set to the value indicated by the UL STBC subfield of the Common Info field of the Trigger frame.
- The LDPC_EXTRA_SYMBOL parameter is set to the value indicated by the LDPC Extra Symbol Segment subfield of the Common Info field of the Trigger frame.
- The SPATIAL_REUSE parameter is set to the value of the UL Spatial Reuse subfield in the Common Info field of the eliciting Trigger frame.
- The DOPPLER parameter is set to the value of the Doppler subfield in the Common Info field of the Trigger frame.
- The MIDAMBLE_PERIODICITY parameter is present if the Doppler subfield in the Common Info field of the Trigger frame is 1. If present, it is set to the value indicated by the Number Of HE-LTF Symbols And Midamble Periodicity subfield in the Common Info field of the Trigger frame.
- The HE_SIG_A2_RESERVED parameter is set to the value of the UL HE-SIG-A2 Reserved subfield in the Common Info field of the Trigger frame.
- The MCS parameter is set to the value of the UL HE-MCS subfield in the User Info field of the Trigger frame.
- The DCM parameter is set to the value indicated by the UL DCM subfield of the User Info field of the Trigger frame.
- The STARTING_STS_NUM parameter is set to the value of the Starting Spatial Stream subfield in the SS Allocation field in the User Info field of the Trigger frame. The STARTING_STS_NUM parameter is set to 0 if the HE TB PPDU is sent on an RA-RU following the UORA procedure.
- The FEC_CODING parameter is set to the value indicated by the UL FEC Coding Type subfield of the User Info field of the Trigger frame.
- The RU_ALLOCATION parameter is set as follows:
  - If the RU is not an RA-RU or an RA-RU with the Number Of RA-RU subfield of the User Info subfield of the Trigger frame set to 0, it is set to the value indicated by the RU Allocation subfield of the User Info subfield of the Trigger frame.
  - If the RU is the $k^{th}$ RU of a set of contiguous RA-RUs starting with an RA-RU with Number Of RA-RU subfield of the User Info subfield of the Trigger frame set to a nonzero value, it is set to the value indicated by the RU Allocation subfield of the corresponding User Info subfield of the Trigger frame plus $k$ minus 1.
- The TXPWR_LEVEL_INDEX parameter is set to a value based on the computed transmission power (see 27.3.15.2 (Power precorrection(M118))) for an HE TB PPDU and the value of the AP Tx


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Power subfield in the Common Info field and the UL Target Receive Power subfield in the User Info field of the Trigger frame.

— The HE_TB_PE_DISAMBIGUITY parameter is set to the value indicated by the PE Disambiguity subfield in the Common Info field in the Trigger frame.

— The PRE_FEC_PADDING_FACTOR parameter is set to the value indicated by the Pre-FEC Padding Factor subfield in the Common Info field in the Trigger frame.

#### 26.5.2.3.4 TXVECTOR parameters for HE TB PPDU response to TRS Control subfield

A non-AP STA transmitting an HE TB PPDU in response to a frame containing a TRS Control subfield shall set the TXVECTOR parameters as follows:

— The FORMAT parameter is set to HE_TB.

— The TRIGGER_METHOD parameter is set to TRS.

— The L_LENGTH parameter is computed as described in Equation (27-11) using the TXTIME value. The TXTIME is defined by Equation (27-149) where $N_{SYM}$ is set to $F_{VAL}$ + 1, where $F_{VAL}$ is the value of the UL Data Symbols subfield of the TRS Control subfield.

— The RU_ALLOCATION and MCS parameters are set to the values of the RU Allocation and UL HE-MCS subfields of the TRS Control subfield, respectively.

— The CH_BANDWITDTH parameter is set to the value of the RXVECTOR parameter CH_BANDWIDTH of the soliciting DL HE PPDU (see Table 27-1 (TXVECTOR and RXVECTOR parameters(#12)(11ax))).

— The BSS_COLOR and DCM parameters are set to the values of the RXVECTOR parameters BSS_COLOR and DCM of the soliciting DL HE PPDU, respectively.

— The DOPPLER parameter is set to 0, and the MIDAMBLE_PERIODICITY parameter is absent.

— The NUM_HE_LTF parameter is set to 1.

— The STARTING_STS_NUM parameter is set to 0.

— The STBC parameter is set to 0, and the NUM_STS parameter is set to 1 (the HE_LTF_MODE parameter is not present).

— The FEC_CODING parameter is set to BCC_CODING if the RU Allocation subfield indicates an RU that is smaller than a 484-tone RU; otherwise, it is set to LDPC_CODING.

— The LDPC_EXTRA_SYMBOL parameter is set to 0 if the RU Allocation subfield indicates less than a 484-tone RU; otherwise, it is set to 1.

— The SPATIAL_REUSE parameter is set to PSR_AND_NON_SRG_OBSS_PD_PROHIBITED.

— The DEFAULT_PE_DURATION parameter is set to the default PE duration value for UL MU response scheduling, which is indicated by the AP in the Default PE Duration subfield of the HE Operation element it transmits.

— The TXOP_DURATION parameter is set as defined in 26.11.5 (TXOP_DURATION).

— The HE_SIG_A2_RESERVED parameter is set to 511 (all 1s).

— If the RXVECTOR parameters HE_LTF_TYPE and GI_TYPE of HE MU PPDU carrying the frame with the TRS Control subfield are either 4xHE-LTF and 3u2s_GI, respectively, or 2xHE-LTF and 1u6s_GI, respectively, then the HE_LTF_TYPE and GI_TYPE parameters are set to 4xHE-LTF and 3u2s_GI, respectively. Otherwise, the HE_LTF_TYPE and GI_TYPE parameters are set to 2xHE-LTF and 1u6s_GI, respectively.

— The TXPWR_LEVEL_INDEX parameter is set to a value based on the computed transmission power (see 27.3.15.2 (Power precorrection(M118))) for an HE TB PPDU and the value of the AP Tx Power subfield of the TRS Control subfield and the UL Target Receive Power subfield of the TRS Control subfield.

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NOTE 1—A non-AP STA transmitting an HE TB PPDU in response to a frame carrying a TRS Control subfield considers both physical CS and virtual CS to be 0 (see 26.5.2.5 (UL MU CS mechanism)).

NOTE 2—The only permissible values for CH_BANDWIDTH are CBW20, CBW40, CBW80, CBW80+80, and CBW160 if the triggering PPDU is an HE SU PPDU or HE MU PPDU. The only permissible value for CH_BANDWIDTH is CBW20 if the triggering PPDU is an HE ER SU PPDU.

#### 26.5.2.3.5 RA field for frames carried in an HE TB PPDU

The RA field of the frames sent in response to a MU-RTS Trigger frame is set as defined in 9.3.1.3 (CTS frame format). The RA field of the frames sent in response of a GCR MU-BAR Trigger frame or MU-BAR Trigger frame is set as defined in 9.3.1.8 (BlockAck frame format). The RA field of the QoS Null frames, QoS Data frames, and Management frames sent in response to a Trigger frame shall be set to the MAC address of the destination AP (see 9.3.2.1 (Format of Data frames) and 9.3.3.1 (Format of (PV0) Management frames)). The RA field of a QoS Null frame or Action No Ack frame sent in response to a frame carrying TRS Control subfield shall be the MAC address of the destination AP (see 9.3.2.1 (Format of Data frames) and 9.3.3.1 (Format of (PV0) Management frames)).

NOTE 1—If dot11MultiBSSIDImplemented is true and the TA field of the soliciting Trigger frame contains the transmitted BSSID, the destination AP is the BSSID to which the non-AP STA intends to send the frame.

NOTE 2—All MPDUs within an A-MPDU carried in an HE TB PPDU have the same RA (see 9.7.3 (A-MPDU contents)). The settings of the address fields of MPDUs within the A-MPDU depend on the type and subtype of the MPDU as defined in 9.3 (Format of individual frame types).

### 26.5.2.4 A-MPDU contents in an HE TB PPDU

A non-AP STA that receives a triggering frame other than an MU-RTS Trigger frame or an NFRP Trigger frame and that transmits an HE TB PPDU response shall follow the A-MPDU padding procedure described in 26.6.2.3 (A-MPDU padding in an HE TB PPDU) and construct the A-MPDU carried in the HE TB PPDU as described below in this subclause, provided the AP allocates sufficient resources for the non-AP STA to include MPDU(s) in the A-MPDU. Otherwise, the non-AP STA is not required to include MPDUs in the A-MPDU and includes only padding in the A-MPDU.

NOTE 1—The responses to a MU-RTS Trigger frame and a NFRP Trigger frame are exempt from these construction rules since the MU-RTS Trigger frame does not solicit an HE TB PPDU and the NFRP Trigger frame solicits an HE TB PPDU that does not carry an A-MPDU.

A non-AP STA shall follow the rules in 26.5.4.5 (Additional considerations for unassociated STAs) to construct an HE TB PPDU in response to a Trigger frame that is not an MU-RTS Trigger frame from an AP with which it is not associated and that allocates RA-RUs for unassociated STAs.

A non-AP STA that responds to a DL MU PPDU containing one or more frames addressed to it that include a TRS Control subfield follows the rules defined in 10.3.2.11 (Acknowledgment procedure) for generating the Ack frame, the rules defined in 10.25.6.5 (Generation and transmission of BlockAck frames by an HT STA, DMG STA, or S1G STA) for generating the BlockAck frame, and the rules defined in 26.4 (HE acknowledgment procedure) for generating the Multi-STA BlockAck frame if at least one of the received MPDUs solicits an immediate acknowledgment. The contents of the A-MPDU carried in the HE TB PPDU shall be as defined in the following:

— Table 9-663 (A-MPDU contents in the control response context) if at least one of the received MPDUs solicits an immediate acknowledgment.
— Table 9-662 (A-MPDU contents in the data enabled no immediate response context) with the exception that the A-MPDU does not contain QoS Data frames, if none of the received MPDUs solicit an immediate acknowledgment.


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NOTE 2—The non-AP STA additionally follows the rules in 26.3.2 (Dynamic fragmentation) if fragments are present in the soliciting A-MPDU.

NOTE 3—An AP might transmit an HE MU PPDU with an RU allocated to STA-ID 2045 with an A-MPDU that includes a Management frame that is addressed to an unassociated non-AP STA, solicits an acknowledgment, and carries a TRS Control subfield. The TRS Control subfield allocates resources for the unassociated non-AP STA to respond with an HE TB PPDU that carries the acknowledgment.

An associated non-AP STA that responds to a Basic Trigger frame addressed to it shall construct the A-MPDU carried in the HE TB PPDU as defined in the following:

- Table 9-663 (A-MPDU contents in the control response context) if the Trigger frame is contained in an A-MPDU and the non-AP STA received in the same A-MPDU at least one MPDU that solicits an immediate acknowledgment. The TID Aggregation Limit field of the User Info field addressed to the non-AP STA may have any value.
- Table 9-662 (A-MPDU contents in the data enabled no immediate response context) with the exception that the A-MPDU does not contain QoS Data frames, if the Trigger frame either is not carried in an A-MPDU or is carried in an A-MPDU but the non-AP STA receives no other MPDUs that solicit an immediate acknowledgment. The TID Aggregation Limit field of the User Info field addressed to the non-AP STA may have any value.
- Table 9-664 (A-MPDU contents in the S-MPDU context(#1762))with the following restrictions:
  - The S-MPDU shall be a control response frame if the non-AP STA received in the same A-MPDU at least one MPDU that solicits an immediate acknowledgment. The TID Aggregation Limit field of the User Info field addressed to the non-AP STA may have any value.
  - The S-MPDU may be a Multi-TID BlockAckReq frame, provided that the number of TIDs present in the Multi-TID BlockAckReq frame does not exceed the TID aggregation limit indicated by the TID Aggregation Limit field of the User Info field addressed to the non-AP STA.
  - The S-MPDU may be a QoS Data, QoS Null, Management, BlockAckReq, or PS-Poll frame if the TID Aggregation Limit field of the User Info field addressed to the non-AP STA is greater than 0.
  - Otherwise, the S-MPDU shall be a QoS Data, QoS Null, or Management frame that does not solicit an immediate acknowledgment.
- Table 9-665 (A-MPDU contents in the HE non-ack-enabled single-TID immediate response context(11ax)) or Table 9-667 (A-MPDU contents in the HE non-ack-enabled multi-TID immediate response context(11ax)) if the TID Aggregation Limit field of the User Info field addressed to the non-AP STA in the Trigger frame is greater than 0 and the non-AP STA intends to carry one or more untagged MPDUs (see 10.12 (A-MPDU operation) and 26.6.3.3 (Non-ack-enabled multi-TID A-MPDU operation)). The A-MPDU is subject to the following restrictions:
  - It shall contain a control response frame if the non-AP STA received in the same A-MPDU at least one MPDU that solicits an immediate acknowledgment.
  - The number of TIDs present in the A-MPDU shall count towards reaching the TID aggregation limit indicated by the TID Aggregation Limit field of the User Info field addressed to the non-AP STA in the Trigger frame.
- Table 9-666 (A-MPDU contents in the HE ack-enabled single-TID immediate response context(11ax)) or Table 9-668 (A-MPDU contents in the HE ack-enabled multi-TID immediate response context(11ax)) if the TID Aggregation Limit field of the User Info field addressed to the non-AP STA in the Trigger frame is greater than 0 and the non-AP STA intends to carry an ack-enabled single-TID A-MPDU or ack-enabled multi-TID A-MPDU (see 26.6.3.1 (General) and 26.6.3.4 (Ack-enabled multi-TID A-MPDU operation)). The A-MPDU is subject to the following restrictions:
  - It shall contain a control response frame if the non-AP STA receives at least another MPDU that solicits an immediate acknowledgment.

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— The number of TIDs present in the A-MPDU, in either QoS Data or BlockAckReq frames, shall count towards reaching the TID aggregation limit that is obtained from the TID Aggregation Limit field of the User Info field addressed to the non-AP STA in the Trigger frame.

If the associated non-AP STA has no frames pending or is unable to include pending frames in response to a Basic Trigger frame because the allocated resource is insufficient, then the associated non-AP STA shall include in the A-MPDU at least one QoS Null frame if the allocated resource is sufficient for containing a QoS Null frame.

NOTE 4—The non-AP STA can transmit one QoS Null frame as defined in 9-664 (A-MPDU contents in the S-MPDU context(#1762)) or one or more QoS Null frames as defined in Table 9-662 (A-MPDU contents in the data enabled no immediate response context).

A non-AP STA that responds to a BFRP Trigger frame addressed to it shall construct an A-MPDU carried in the HE TB PPDU with one or more HE Compressed Beamforming/CQI frames (see 26.7 (HE sounding operation(#2388))); other frames shall not be allowed in the A-MPDU.

NOTE 5—It is not always possible to (#6006)segment the HE Compressed Beamforming/CQI Report field (see 26.7.4 (Rules for generating segmented feedback)). If the length (#6006)of the HE TB PPDU is insufficient to contain the HE compressed beamforming/CQI report requested by a BFRP Trigger frame, no feedback is sent.

A non-AP STA that responds to an MU-BAR Trigger frame addressed to it shall construct the A-MPDU carried in the HE TB PPDU as defined in Table 9-663 (A-MPDU contents in the control response context). The non-AP STA includes either a BlockAck frame or a Multi-STA BlockAck frame in the A-MPDU as defined in 26.4 (HE acknowledgment procedure).

A non-AP STA that responds to a GCR MU-BAR Trigger frame addressed to it shall construct the A-MPDU carried in the HE TB PPDU as defined in Table 9-663 (A-MPDU contents in the control response context). The non-AP STA includes a GCR BlockAck frame in the A-MPDU as defined in 10.25.8.

A non-AP STA that responds to a BSRP or BQRP Trigger frame addressed to it and that is not aggregated with any MPDUs that solicit an immediate acknowledgment shall construct the A-MPDU carried in the HE TB PPDU as defined in 9-662 (A-MPDU contents in the data enabled no immediate response context) with the exception that the A-MPDU does not contain QoS Data frames. The non-AP STA shall include in the A-MPDU at least one QoS Null frame. A non-AP STA that responds to a BSRP or BQRP Trigger frame addressed to it and that is aggregated with at least one MPDU that solicits an immediate acknowledgment, shall construct the A-MPDU carried in the HE TB PPDU as defined in (#2317)Table 9-663 (A-MPDU contents in the control response context).

NOTE 6—The frame type of MPDUs might(M118) be different across A-MPDUs within the same HE TB PPDU subject to A-MPDU context.

NOTE 7—A non-AP STA follows the rules in 26.6.3 (Multi-TID A-MPDU and ack-enabled single-TID A-MPDU) for aggregating the QoS Data frames with multiple TIDs in HE TB PPDUs.

A non-AP STA may set dot11HEUPHControlActivated to false if the most recent OM Control field sent (if any) to the AP had the UL MU Disable field equal to 1; otherwise, the non-AP STA shall set dot11HEUPHControlActivated to true.

A STA that transmits an HE TB PPDU transmits the decibel value of its UL power headroom, $HR_{STA}$, in the UPH Control subfield of frames (that can carry an HE-variant HT Control field) carried in the HE TB PPDU, to assist in the AP's HE-MCS selection. The UL power headroom for the assigned HE-MCS is defined in Equation (26-2).


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$$HR_{STA} = Tx_{pwr}^{Max} - Tx_{pwr}^{STA} \quad (26\text{-}2)$$

where

$Tx_{pwr}^{Max}$ represents the maximum UL transmit power of an HE TB PPDU with the assigned HE-MCS after considering hardware capability, regulatory requirements, and local maximum transmit power levels (see 11.7.5 (Specification of regulatory and local maximum transmit power levels)) as well as non-IEEE-802.11 in-device coexistence requirements

$Tx_{pwr}^{STA}$ represents the current UL transmit power of the HE TB PPDU for the assigned HE-MCS, which is determined by power control and subject to the non-AP STA's capabilities and other requirements as defined in 27.3.15.2 (Power precorrection(M118))

$HR_{STA}$ is the UL power headroom, in dB, of the HE TB PPDU, the encoding of which is specified in 9.2.4.7.5 (UPH Control)

NOTE 8—If the Minimum Transmit Power Flag subfield in the UPH Control subfield is 1, then the non-AP STA is transmitting the HE TB PPDU at its minimum $Tx_{pwr}^{STA}$ for the assigned HE-MCS. The UL power headroom is calculated for the assigned HE-MCS and is independent of TOM parameters provided in any OM Control field contained in the same A-Control field (see 26.9.3 (Transmit operating mode (TOM) indication)).

NOTE 9—The uplink power headroom is not normalized to 20 MHz bandwidth, unlike the value in the AP Tx Power subfield.

A non-AP STA shall include an HE variant HT Control field containing the UPH Control subfield in the frames carried in the A-MPDU of the HE TB PPDU with the following exceptions:

— A UPH Control subfield is not included in any frame if the remaining space in the A-MPDU, after inclusion of solicited frames that are required to be included in the A-MPDU but cannot contain an HE variant HT Control field, is not sufficient to contain a frame that can be included in the A-MPDU and can contain an HE variant HT Control field.

— A UPH Control subfield is not included in a frame if the frame contains Control subfields other than UPH Control and ONES Control subfields and the remaining space in the HE variant HT Control field of the frame is not sufficient to contain a UPH Control subfield as well.

— A UPH Control subfield is not included in a frame that is a Control frame.

A non-AP STA shall not include a ONES Control subfield in the HE variant HT Control field of the frames carried in an HE TB PPDU.

#### 26.5.2.5 UL MU CS mechanism

The ED-based CCA and virtual CS functions are used to determine the state of the medium if CS is required before responding to a received Trigger frame. ED-based CCA for the UL MU CS mechanism is defined in 27.3.22.6.4 (CCA sensitivity for signals not occupying the primary 20 MHz channel), and virtual CS is defined in 10.3.2.1 (CS mechanism).

If the CS Required subfield in a received Trigger frame is 0 or a frame that includes a TRS Control subfield and solicits a response is received, then the non-AP STA may respond without regard to the busy/idle state of the medium.

NOTE 1—Responding without regard to the busy/idle state of the medium means that a non-AP STA can respond without the need to check the medium indication from physical CS and virtual CS (i.e., basic NAV and intra-BSS NAV).

A non-AP STA does not consider the intra-BSS NAV in determining whether to respond to a Trigger frame sent by the AP with which the non-AP STA is associated.

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A non-AP STA considers the basic NAV in determining whether to respond to a Trigger frame sent by the AP with which the non-AP STA is associated.

A non-AP STA considers the NAV in determining whether to respond to a Trigger frame sent by an AP with which the non-AP STA is not associated, through the UORA procedure (see 26.5.4 (UL OFDMA-based random access (UORA))), unless the NAV was set by a frame originating from the AP sending the Trigger frame.

NOTE 2—A non-AP STA considers the intra-BSS NAV associated with an AP in determining whether to respond to a Trigger frame with RU allocations for unassociated STAs sent by another AP.

NOTE 3—The details of how a non-AP STA is solicited by the Trigger frame for transmission are described in 26.5.2.2.4 (Allowed settings of the Trigger frame fields and TRS Control subfield).

NOTE 4—If a non-AP STA responds to a Trigger frame from an AP with which it is not associated through the UORA procedure, the method to identify that a NAV was set by a frame originating from the AP sending the Trigger frame is implementation specific. For example, the non-AP STA can save the TXOP holder address and match the saved TXOP holder address with the TA field of the Trigger frame.

For a non-AP STA that is solicited by a Trigger frame for transmission, the indication of the virtual CS is described as follows. If the non-AP STA does not consider any NAV, then the virtual CS indicates idle. If all NAVs that the non-AP STA considers have their NAV counter equal to 0, then the virtual CS indicates idle. Otherwise, the virtual CS indicates busy.

If the CS Required subfield in a Trigger frame is 1, then the non-AP STA shall consider the status of the CCA [using energy detect defined in (#2365)27.3.22.6 (CCA sensitivity) and the virtual carrier sense (NAV)] during the SIFS between the Trigger frame and the PPDU sent in response to the Trigger frame. In this case, the non-AP STA shall sense the medium using energy detect after receiving the PPDU that contains the Trigger frame (i.e., during the SIFS), and it shall perform the energy detect at least in the subchannel that contains the non-AP STA's UL allocation, where the sensed subchannel consists of one or more 20 MHz channels. The non-AP STA may transmit the solicited PPDU if the 20 MHz channels containing the RUs allocated in the Trigger frame are considered idle. If the non-AP STA detects that the 20 MHz channels containing the allocated RUs are not all idle, then the non-AP STA shall not transmit.

NOTE 5—The solicited PPDU is a non-HT or non-HT duplicate PPDU if the Trigger frame is an MU-RTS Trigger frame (see 26.2.6 (MU-RTS Trigger/CTS frame exchange sequence procedure(#109))); otherwise, the solicited PPDU is an HE TB PPDU (see 26.5.2.3 (Non-AP STA behavior for UL MU operation)).

The CS Required subfield in the MU-RTS Trigger frame shall be set to 1.

An AP that transmits a BFRP Trigger frame with the UL Length subfield in the Common Info field set to a value greater than 76 shall set the CS Required subfield in the Common Info field to 1.

An AP that transmits a Basic, BSRP, MU-BAR, BQRP, or GCR MU-BAR Trigger frame shall set the CS Required subfield to 1, unless one of the following conditions is met:

— The RA of the Trigger frame is an individually addressed non-AP STA's MAC address, a QoS Data frame with HETP Ack ack policy and/or a Management frame that solicits an acknowledgment is aggregated with the Trigger frame in an A-MPDU, and the UL Length subfield in the Common Info field of the Trigger frame is less than or equal to 418.
— The Trigger frame is either an MU-BAR or a GCR MU-BAR Trigger frame, and the UL Length subfield in the Common Info field of the Trigger frame is less than or equal to 418.
— The UL Length subfield in the Common Info field of the Trigger frame is less than or equal to 76.


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NOTE 6—The threshold value 418 of the UL Length subfield in the Common Info field of the Trigger frame is obtained from the maximum HE TB PPDU duration, 584 μs, that can be solicited by the TRS Control subfield based on Equation (27-16). This duration is the sum of 20 μs for the L-STF, L-LTF, and L-SIG fields; 20 μs for the RL-SIG, HE-SIG-A, and HE-STF fields; 16 μs for the 4x HE-LTF field with 3.2 μs GI; 512 μs for 32 OFDM symbols in the Data field with 3.2 μs GI; and 16 μs for the PE field (see 9.2.4.7.1 (TRS Control), 26.5.2.3 (Non-AP STA behavior for UL MU operation), and 27.3.4 (HE PPDU formats)).

NOTE 7—The UL Length subfield value 76 is derived from the duration 128 μs, which is the duration of an HE TB PPDU with 4 HE-LTF symbols and a PE field.

An AP may transmit an NFRP Trigger frame with the CS Required subfield set to 0 or 1.

(11az)An RSTA that transmits a Ranging Trigger frame shall set the CS Required subfield to 1 unless one of the following conditions is met:

— The Ranging Trigger frame is of subvariant Poll, Sounding, Secure Sounding, or Passive Sounding.
— The Ranging Trigger frame is of subvariant Report and the UL Length subfield in the Common Info field of the Trigger frame is less than or equal to 418.

### 26.5.3 MU cascading sequence

An MU cascading sequence is a frame exchange sequence between an AP and one or more non-AP STAs in which the AP, within a single PPDU, acknowledges one or more frames from a STA and triggers the STA for a further UL transmission. An example of an MU cascading sequence is shown in Figure 26-5 (Example of MU cascading sequence(11ax)(#1866)). In this figure the second HE MU PPDU contains an Ack or BlockAck frame and a triggering frame.

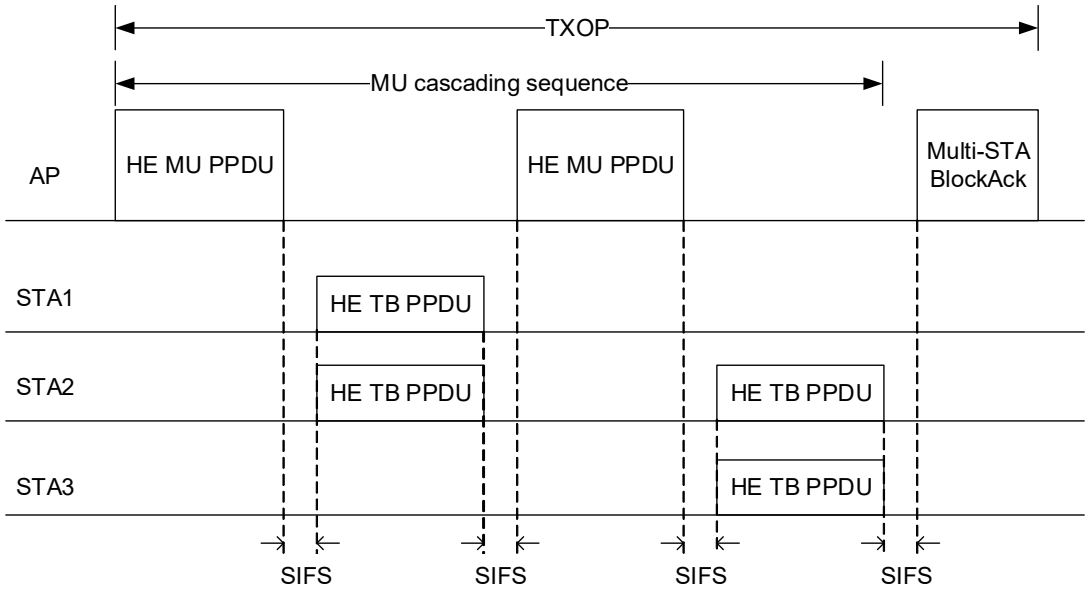


**Figure 26-5—Example of MU cascading sequence(11ax)(#1866)**

An AP shall not transmit an A-MPDU to a non-AP STA that includes an Ack or BlockAck frame together with a triggering frame, unless both the AP and the non-AP STA have indicated support by setting the MU Cascading Support subfield to 1 in the MAC Capabilities Information field in the HE Capabilities element they transmit.

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NOTE—An A-MPDU sent by an AP in an MU cascading sequence typically includes, in addition to the acknowledgement and triggering frames, one or more QoS Data frames with HETP Ack ack policy and/or a Management frame soliciting acknowledgement, subject to the rules in 26.6 (A-MPDU operation in an HE PPDU).

In an MU cascading sequence, the receivers of an HE MU PPDU may differ from the transmitters of preceding HE TB PPDUs. An MU cascading sequence is sent within a single TXOP.

An AP follows the procedure in 26.5.2.2.5 (AP access procedures for UL MU operation).

### 26.5.4 UL OFDMA-based random access (UORA)

#### 26.5.4.1 General

An HE STA with dot11OFDMARandomAccessOptionImplemented equal to true shall set the OFDMA RA Support subfield in the HE MAC Capabilities Information field in the HE Capabilities element to 1. Otherwise, it shall set the OFDMA RA Support subfield to 0.

NOTE 1—A non-AP STA that does not support UORA can contend for the WM using EDCA for sending UL frames to the AP with which it intends to communicate.

A non-AP STA with dot11OFDMARandomAccessOptionImplemented set to true shall follow the procedure defined in 26.5.4.3 (Transmission procedure for UORA) and 26.5.4.5 (Additional considerations for unassociated STAs) to contend for an eligible RA-RU.

An HE AP may transmit a Basic Trigger frame, BQRP Trigger frame, or BSRP Trigger frame that contains one or more RUs for random access. An AP that transmits a Trigger frame that is not a Basic Trigger frame shall not set the AID12 subfield of any User Info field of the frame to indicate allocation of one or more RA-RUs for unassociated STAs. An AP that transmits a Trigger frame that is not a Basic Trigger frame, BQRP Trigger frame, or BSRP Trigger frame shall not set the AID12 subfield of any User Info field of the frame to indicated allocation of one or more RA-RUs for associated STAs.

NOTE 2—A(#1426) non-AP HE STA that changes the maximum number of receiving spatial streams to 1 and sets the OFDMA RA Support subfield in the HE MAC Capabilities Information field in the HE Capabilities element to 1 cannot receive a Trigger frame sent with more than one spatial stream. As a result, if the Trigger frame indicates eligible RA-RUs for associated non-AP STAs, the non-AP HE STA cannot perform UORA defined in 26.5.4 (UL OFDMA-based random access (UORA))). An AP might take this behavior into consideration when sending a Trigger frame indicating eligible RA-RUs for associated non-AP STAs.

An HE AP that transmits a Basic Trigger frame should set the TID Aggregation Limit subfield in the User Info field indicating an RA-RU to 0 or 1.

An AP shall set the More RA-RU subfield in the User Info field to 1 if it intends to transmit additional Trigger frames in the current broadcast TWT SP that allocate RA-RUs matching the AID12 subfield value in the User Info field (see Table 9-52 (AID12 subfield encoding(11ax))).

A non-AP HE STA shall ignore the More RA-RU subfield if the More TF field in the Trigger frame is equal to 0.

The HE AP may include the UORA Parameter Set element (see 9.4.2.249 (UORA Parameter Set element(11ax))) in Management frames that it transmits. The AP shall indicate the range of OFDMA contention window (OCW) in the UORA Parameter Set element for non-AP STAs to initiate random access following the Trigger frame transmission. An AP corresponding to a nontransmitted BSSID in a multiple BSSID set shall follow the rules in 11.1.3.8.4 (Inheritance of element values(11ax)).

NOTE 3—An AP with dot11MultiBSSIDImplemented equal to true can allocate RA-RUs for non-AP STAs associated with different BSSIDs in a multiple BSSID set by transmitting a DL MU PPDU carrying broadcast RUs, one per BSS in


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the set (see 26.5.1.2 (RU addressing in an HE MU PPDU)), with an A-MPDU in each broadcast RU carrying a Trigger frame with at least one User Info field with the AID12 subfield set to 0.

A non-AP HE STA shall maintain an internal OCW and an internal OBO counter. OCW is an integer in the range *OCWmin* to *OCWmax*. The *OCWmin* and *OCWmax* parameters are defined by dot11OCWmin and dot11OCWmax. A non-AP HE STA shall update dot11OCWmin and dot11OCWmax from an UORA Parameter Set element within an interval of time equal to one beacon interval after receiving an updated UORA Parameter Set element carried in a Beacon, Probe Response, or (Re)Association Response frame transmitted by its associated AP, unless the non-AP HE STA is associated with an AP corresponding to a nontransmitted BSSID of a multiple BSSID set. In this case, it shall update dot11OCWmin and dot11OCWmax by following the rules in 11.1.3.8.4 (Inheritance of element values(11ax)).

Each time a non-AP HE STA associates with a different AP and prior to the initial attempt of RA-RU transmission towards it, the non-AP STA shall set the value of OCW to the *OCWmin* value and shall initialize its OBO counter in the range 0 to OCW as defined in 26.5.4.3 (Transmission procedure for UORA).

NOTE 4—For a non-AP STA with dot11MultiBSSIDImplemented equal to true, associating with a different AP includes associating with an AP corresponding to a different BSSID in the same multiple BSSID set.

### 26.5.4.2 Eligible RA-RUs

A non-AP STA that is the intended receiver of a User Info field in a Trigger frame (i.e., the AID12 subfield equal to the 12 LSBs of the AID of the non-AP STA) shall not contend for an RA-RU that is indicated by a Trigger frame contained in the same PPDU and shall not decrement its OBO counter.

A non-AP STA shall consider an RU as an eligible RA-RU if it is capable of transmitting an HE TB PPDU in that RU according to the parameters indicated in the Common Info field and in the User Info field that allocates the RU (as described in 26.5.2.3 (Non-AP STA behavior for UL MU operation)), the non-AP STA is associated with the BSS whose BSSID is the value in the TA field of the Trigger frame, and the RA-RU is allocated for associated STAs.

NOTE 1—If the STA is a 20 MHz operating non-AP HE STA, RUs that are excluded as specified in 27.3.2.8 (RU restrictions for 20 MHz operation) are not present in the list of eligible RA-RUs.

A non-AP STA may consider an RU as an eligible RA-RU if it supports all the transmit parameters indicated in the Common Info field and in the User Info field that allocates that RU (as described in 26.5.2.3 (Non-AP STA behavior for UL MU operation)), the non-AP STA is not associated with the BSS, and the RA-RU is allocated for unassociated STAs.

An HE AP may allocate a contiguous set of RUs for random access by setting the Number Of RA-RU subfield in the User Info field of the Trigger frame to a value greater than 1. The RA-RU indicated by the RU Allocation subfield in the User Info field shall represent the starting RU of the set. The size of all RA-RUs in the set shall be the same and equal to the size of the RA-RU indicated by the RU Allocation subfield in the User Info field. The remaining subfields of the User Info field apply to each RA-RU in the set. An AP allocating a contiguous set of RA-RUs in a Trigger frame with (#2318)a UL BW subfield that indicates 80+80 MHz or 160 MHz shall set the Number Of RA-RU(#3522) subfield so that all the RA-RUs in the set lie in one 80 MHz frequency segment.

NOTE 2—An AP can transmit a Trigger frame carrying more than one User Info field, each allocating a single or a contiguous set of RA-RUs, to ensure that an RA-RU set does not overlap with other RUs allocated by the frame.

A non-AP HE STA shall determine the total number of eligible RA-RUs in a contiguous set from the Number Of RA-RU subfields (see Table 9-95 (RA-RU Information subfield format(11ax)(M118))) in the

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User Info field corresponding to an eligible RA-RU, excluding RA-RUs that are not within its operating bandwidth.

A non-AP HE STA may consider as eligible RA-RUs all or a subset of the RA-RUs indicated by the User Info fields in a Trigger frame that carries more than one User Info field that allocates RA-RUs. The number of eligible RA-RUs that the non-AP STA considers for OBO countdown and transmission (see 26.5.4.3 (Transmission procedure for UORA)) shall be the total number of eligible RA-RUs indicated by the selected subset of User Info fields.

NOTE 3—A STA that considers only a subset of User Info fields can randomly select User Info fields from the available set of User Info fields that allocate RA-RUs so that the UORA contention is not concentrated at the RA-RU set indicated by the first User Info field.

### 26.5.4.3 Transmission procedure for UORA

In this subclause, the transmit procedure using RA-RUs is described with respect to UORA parameters. The procedure is also illustrated in Figure 26-6 (Illustration of UORA procedure(11ax)).

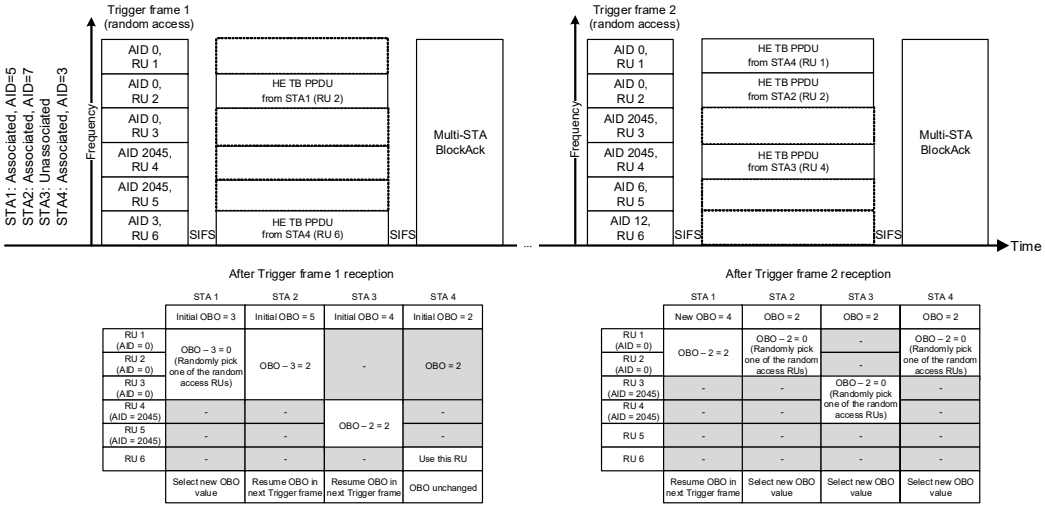


**Figure 26-6—Illustration of UORA procedure(11ax)**

A non-AP STA shall not contend for an eligible RA-RU or decrement its OBO counter if it does not have pending frames for the AP.

If an HE STA has a pending frame for the AP upon the reception of a Trigger frame containing at least one eligible RA-RU and if the OBO counter of an HE STA is not greater than the number of eligible RA-RUs in a Trigger frame from that AP, then the HE STA shall set its OBO counter to zero and randomly select one of the eligible RA-RUs to be considered for transmission. Otherwise, the HE STA decrements its OBO counter by the number of eligible RA-RUs in the Trigger frame.

In the example in Figure 26-6 (Illustration of UORA procedure(11ax)):

— Before Trigger frame 1 was sent by the AP, HE STA 1, STA 2, STA 3, and STA 4 had initial OBO values of 3, 5, 4, and 2, respectively.

— Upon receiving Trigger frame 1:


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- STA 4, which is associated with the AP and has pending frames for the AP, is allocated a dedicated RU (RU6). The STA does not contend for RA-RUs and instead transmits its pending frames on RU6.
- STA 1 and STA 2, both associated with the AP and having pending frames for the AP, decrement their respective OBO counters by the number of eligible RA-RUs indicated in the Trigger frame (i.e., three RA-RUs for associated STAs). Since STA 1's OBO counter decrements to 0, it transmits its pending frames on RU2 that it randomly selects from the eligible set of RUs (i.e., RU1, RU2, and RU3). Since STA 2's OBO counter decrements to a nonzero value, it maintains the new OBO value (2) until it receives a later Trigger frame carrying RA-RUs for associated STAs.
- STA 3, which is not associated with the AP but has a pending frame for the AP, decrements its OBO counter by the number of eligible RA-RUs indicated in the Trigger frame (i.e., two RA-RUs for unassociated STAs). Since STA 3's OBO counter decrements to a nonzero value, it maintains the new OBO value (2) until it receives a later Trigger frame carrying RA-RUs for unassociated STAs.

— After transmission of HE TB PPDU in response to Trigger frame 1:
  - STA 4 has additional frames pending for the AP. Therefore, it maintains its initial OBO value (2) until it receives a later Trigger frame carrying RA-RUs for associated STAs.
  - STA 1 has additional frames pending for the AP and randomly selects a new OBO value (4).

— Upon receiving Trigger frame 2:
  - STA 1, STA 2, and STA 4 decrement their respective OBO counters by the number of eligible RA-RUs (two in this case). Since STA 2 and STA 4's OBO counters decrements to 0, they both transmit their pending frames on a randomly selected RU (RU2 in the case of STA 2 and RU1 in the case of STA 4). If either STAs have additional frames pending for the AP, each would randomly select a new OBO value. Since STA 1's OBO decrements to a nonzero value, it maintains the new OBO value (2) until it receives a later Trigger frame carrying RA-RUs for associated STAs.
  - STA 3 decrements its OBO counter by the number of eligible RA-RUs (two in this case). Since the STA's OBO counter decrements to 0, it transmits its pending frame on a randomly selected RU (RU4 in this case).

A non-AP STA shall follow the rules in 26.5.2.3 (Non-AP STA behavior for UL MU operation) to construct an HE TB PPDU and shall follow the rules as defined in 26.5.2.5 (UL MU CS mechanism) to determine the state of the medium before transmitting the HE TB PPDU. If CS is required and the selected RU is considered busy, then the non-AP STA shall not transmit the HE TB PPDU and the non-AP STA shall set its OBO counter to a random value drawn from a uniform distribution in the range 0 to OCW.

The MU acknowledgment procedure for UORA follows the procedure as defined in 10.3.2.13.3 (Acknowledgment procedure for UL MU transmission(11ax)).

If a non-AP STA transmits an HE TB PPDU that contains a frame that solicits an immediate response in an RA-RU and the expected response is not received, the transmission is considered unsuccessful. Otherwise, the transmission is considered successful. After each successful HE TB PPDU transmission in an RA-RU, a non-AP HE STA shall set the value of OCW to the *OCWmin* obtained from the most recent *OCWmin* indicated in the UORA Parameter Set element from the HE AP or the default (if UORA Parameter Set element was not received) and shall initialize its OBO counter to an integer value randomly selected from a uniform distribution in the range 0 to OCW. The non-AP STA shall follow the retransmission procedure defined in 26.5.4.4 (Retransmission procedure for UORA) if the transmission is not successful.

NOTE—A non-AP STA that transmits an HE TB PPDU in response to a Trigger frame that is not an MU-RTS Trigger frame that allocates RA-RU(s) by following the UORA procedure does not update its state variables to the values contained in the MU EDCA Parameter Set element (see 26.2.7 (EDCA operation using MU EDCA parameters)).

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#### 26.5.4.4 Retransmission procedure for UORA

A non-AP STA whose HE TB PPDU transmission sent in an RA-RU of a Trigger frame is unsuccessful, may attempt to retransmit the failed PPDU using EDCA or as a response to a Trigger frame.

If the HE TB PPDU is not successfully transmitted in the selected RA-RU, then the non-AP STA shall update its OCW to 2 × OCW + 1 when the OCW is less than the value of *OCWmax*, and shall randomly select its OBO counter in the range(#3482) 0 and OCW. Once the OCW reaches *OCWmax* for successive retransmission attempts, the OCW shall remain at the value of *OCWmax* until the OCW is reset as described in 26.5.4.3 (Transmission procedure for UORA).

A non-AP STA shall update its OCW value under the condition that the updated OCW remains in the range *OCWmin* to *OCWmax* obtained from the most recently received UORA Parameter Set element (see 9.4.2.249 (UORA Parameter Set element(11ax))). If the updated OCW becomes greater than *OCWmax* as a consequence of receiving a modified UORA Parameter Set element, then the non-AP STA shall set the value of OCW to the new *OCWmax* value.

#### 26.5.4.5 Additional considerations for unassociated STAs

An AP transmitting a Trigger frame that allocates one or more RA-RUs for unassociated STAs shall transmit the Trigger frame in an HE PPDU.(#3318)

NOTE 1—This allows an unassociated non-AP STA to determine the BSS color. The non-AP STA needs this information to indicate it in the HE TB PPDU.(#3318)

An HE AP that supports the UORA procedure and broadcast TWT operation and that intends to transmit Trigger frames that allocate one or more RA-RUs for unassociated STAs shall schedule the transmission of at least one such Trigger frame within each TWT SP corresponding to a Broadcast TWT Parameter Set field in a TWT element with a Broadcast TWT ID subfield equal to 0, Flow Type subfield equal to 0, Trigger subfield equal to 1, and Broadcast TWT Recommendation subfield equal to 2.

An AP that receives an Authentication frame within an RA-RU should schedule for transmission, at a time no less than 3 TUs and no greater than 5 TUs subsequent to the transmission of the Authentication frame that is a response to that reception, a Trigger frame that allocates one or more RA-RUs for unassociated STAs.

NOTE 2—This Trigger frame provides a potential opportunity for an unassociated STA that transmitted the Authentication frame to transmit another Authentication frame or an Association Request frame.

An AP that supports the UORA procedure, broadcasts TWT operation, operates a BSS with a width of 80 MHz or greater, and transmits a Trigger frame that allocates one or more RA-RUs for unassociated STAs shall include at least 2 RA-RUs for unassociated STAs for at least one transmission of such a Trigger frame within a Broadcast TWT SP that meets the conditions described above.

An AP that intends to transmit Trigger frames that allocates one or more RA-RUs for unassociated STAs should transmit FILS Discovery frames as described in 11.45.2.1 (FILS Discovery frame transmission) at regular intervals within a beacon period to assist unassociated STA discovery of the BSS and its operating parameters.

The TWT scheduling AP (see 26.8.3.1 (General)) that supports the UORA procedure may include a broadcast TWT element in FILS Discovery frames and in broadcast Probe Response frames to indicate the TWT SPs during which the AP intends to schedule for transmission at least one Trigger frame allocating one or more RA-RUs for STAs not associated with the AP. The broadcast TWT element shall carry only a broadcast TWT parameter set with the Broadcast TWT Recommendation subfield set to 2, the Trigger


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subfield set to 1, the Flow Type subfield set to 0, and the Broadcast TWT ID subfield set to 0. The AP transmits broadcast Probe Response frames if it has dot11FILSOmitReplicateProbeResponses equal to true.

A non-AP STA that receives a FILS Discovery frame from an AP with which it is not associated may use the values carried in the frame to determine the operating parameters for that AP and may use the information when responding to a Trigger frame from the AP containing RA-RUs for unassociated non-AP STAs.

An unassociated non-AP STA that has not received an UORA Parameter Set element from the AP with which it intends to communicate shall use the default OCW values as defined in 26.5.4.1 (General). Each time an unassociated non-AP STA communicates with a different AP using random access, it shall initialize its OCW using the default values or the parameters from the UORA Parameter Set element received from that AP and shall initialize its OBO counter as defined in 26.5.4.3 (Transmission procedure for UORA).

An unassociated non-AP STA that supports the UORA and TWT procedure may begin listening for Trigger frames at the start of a particular broadcast TWT SP after receiving a Beacon frame, a broadcast Probe Response frame, or a FILS Discovery frame containing a TWT element with a Broadcast TWT Parameter Set field that has the Broadcast TWT ID subfield equal to 0, the Flow Type subfield equal to 0, the Trigger subfield equal to 1, and the Broadcast TWT Recommendation subfield equal to 2.

A non-AP STA shall include at most one Management frame that is an S-MPDU when it transmits an HE TB PPDU in response to a Trigger frame that is not an MU-RTS Trigger frame sent by an AP with which the non-AP STA is not associated.

An AP that receives Management frames from one or more unassociated non-AP STAs carried in HE TB PPDUs transmitted on RA-RUs shall respond with a Multi-STA BlockAck frame carried either in an SU PPDU or in a DL HE MU PPDU on a broadcast RU corresponding to parameter STA-ID equal to 2045.

An AP with dot11FILSOmitReplicateProbeResponses equal to true shall follow the procedure defined in 11.1.4.3.4 (Criteria for sending a response) to respond with a broadcast Probe Response frame or the next Beacon frame if it receives one or more Probe Request frames via the UORA procedure.

### 26.5.5 Buffer status report operation

A non-AP STA delivers buffer status reports (BSRs) to assist its AP in allocating UL MU resources. The non-AP STA can either implicitly deliver BSRs in the QoS Control field or BSR Control subfield of any frame transmitted to the AP (unsolicited BSR) or explicitly deliver BSRs in any frame sent to the AP in response to a BSRP Trigger frame (solicited BSR). The buffer status reported in the QoS Control field consists of a queue size value for a given TID (see 9.2.4.5.6 (Queue Size subfield)). The buffer status reported in the BSR Control field consists of an ACI bitmap, delta TID, a high priority AC, and two queue sizes (see 9.2.4.7.4 (BSR Control)).

An HE STA shall set the BSR Support subfield in the HE Capabilities element it transmits to 1 if dot11HEBSRControlImplemented is true; otherwise, the HE STA shall set the BSR Support subfield to 0.

A non-AP STA reports its buffer status (unsolicited BSR) to the AP with which it is associated in the QoS Control field in QoS Null and QoS Data frames and in the BSR Control subfield (if present) in QoS Null, QoS Data, and Management frames as defined below:

— The HE STA shall report the queue size for a given TID in the Queue Size subfield of the QoS Control field in QoS Data or QoS Null frames it transmits; the STA may set the Queue Size subfield to 255 to indicate an unknown/unspecified queue size for that TID.

— The HE STA may aggregate multiple QoS Data frames or QoS Null frames in an A-MPDU to report the queue size for different TIDs. The HE STA shall follow the A-MPDU aggregation rules defined in 26.6.3 (Multi-TID A-MPDU and ack-enabled single-TID A-

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MPDU) for aggregating QoS Data frames with multiple TIDs. The HE STA does not follow the rules defined in 26.6.3 (Multi-TID A-MPDU and ack-enabled single-TID A-MPDU) for QoS Null frames with No Ack ack policy.

— The HE STA may report the buffer status in the BSR Control subfield of frames it transmits if the AP has indicated its support in the BSR Support subfield of its HE Capabilities element; otherwise, the STA shall not report the buffer status in the BSR Control subfield.
  — The HE STA shall report the queue size for its preferred AC, indicated by the ACI High subfield, in the Queue Size High subfield of the BSR Control subfield; the STA may set the Queue Size High subfield to 255 to indicate an unknown/unspecified queue size for that AC.
  — The HE STA shall report the queue size for the ACs, indicated by the ACI Bitmap subfield, in the Queue Size All subfield of the BSR Control subfield; the STA may set the Queue Size All subfield to 255 to indicate an unknown/unspecified BSR for those ACs.
  — The HE STA shall set the Delta TID subfield according to Table 9-32 (Delta TID subfield encoding(11ax)) and the Scaling Factor subfield as defined in 9.2.4.7.4 (BSR Control).

NOTE 1—The STA can send an unsolicited BSR in response to certain Trigger frames except MU-RTS and BSRP (with or without RA-RUs, as defined in 26.5.2.3 (Non-AP STA behavior for UL MU operation) and 26.5.4 (UL OFDMA-based random access (UORA))), or it can send the unsolicited BSR after accessing the WM using EDCA.

NOTE 2—The STA might include a BSR Control subfield in a QoS Data or QoS Null frame. In this case the Queue Size subfield in the QoS Control field and the Queue Size High and Queue Size All subfields in the BSR Control subfield might differ, and any of the three subfields might be set to 255 to indicate unspecified/unknown queue size. The STA might include only the BSR Control subfield in a Management frame.

An AP can also solicit one or more associated non-AP STAs for their BSR(s) by sending a BSRP Trigger frame (see 9.3.1.22.6 (BSRP Trigger frame format)). The non-AP STA responds (solicited BSR) as defined below:

— The non-AP STA that receives a BSRP Trigger frame shall follow the rules defined in 26.5.2.3 (Non-AP STA behavior for UL MU operation) to generate the HE TB PPDU if the Trigger frame contains the 12 LSBs of the non-AP STA's AID in any of the User Info fields; otherwise, if the non-AP STA's buffers are not empty and the non-AP STA supports the UORA procedure, it may follow the rules defined in 26.5.4 (UL OFDMA-based random access (UORA)) to gain access to an RA-RU and generate the HE TB PPDU when the Trigger frame contains one or more RA-RUs.
— The non-AP STA shall include in the HE TB PPDU one or more QoS Null frames containing one or more of the following:
  — The QoS Control field(s) with Queue Size subfields for each of the TIDs for which the non-AP STA has queue size to report to the AP.
  — The BSR Control subfield with the Queue Size All subfield indicating the queue size for the ACs, indicated by the ACI Bitmap subfield, for which the non-AP STA has queue size to report to the AP if the AP has indicated its support in the BSR Support subfield of its HE Capabilities element. The non-AP STA shall set Delta TID, Scaling Factor, ACI High, and Queue Size High subfields of the BSR Control subfield as defined in 9.2.4.7.4 (BSR Control).
— The non-AP STA shall not solicit an immediate response for the frames carried in the HE TB PPDU (e.g., the Ack Policy Indicator subfield of a QoS Null frame shall not be set to Normal Ack or Implicit BAR).

NOTE 3—As with unsolicited BSR, the STA might include a BSR Control subfield in a QoS Null frame that is sent in response to the BSRP Trigger frame. In this case, the Queue Size subfield in the QoS Control field and the Queue Size High and Queue Size All subfields in the BSR Control subfield might differ, and any of the three subfields might be set to 255 to indicate an unspecified/unknown queue size.

NOTE 4—An AP does not send a BSRP Trigger frame containing the 12 LSBs of the AID of the non-AP STA that sets the UL MU Disable field to 1.


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An AP may include a BSRP Trigger frame together with other Control, Data, and Management frames in one A-MPDU to a non-AP STA if the HE Capabilities element received from the non-AP STA has the BSRP BQRP A-MPDU Aggregation field equal to 1. A non-AP STA constructs the A-MPDU contained in the HE TB PPDU sent in response to a BSRP Trigger frame as described in 26.5.2.4 (A-MPDU contents in an HE TB PPDU).

The NDP feedback report procedure described in 26.5.7 (NDP feedback report procedure) can be used for buffer status feedback operation. An AP that sent an NFRP Trigger frame to one or more non-AP STAs may send a BSRP Trigger frame to those non-AP STAs to get more precise buffer status information.

### 26.5.6 Bandwidth query report operation

A non-AP STA may send bandwidth query reports (BQRs) to assist its AP in allocating DL MU and UL MU resources. The non-AP STA may either implicitly deliver BQRs in the BQR Control subfield of a frame transmitted to the AP (unsolicited BQR) or explicitly deliver BQRs in a frame sent to the AP in response to a BQRP Trigger frame (solicited BQR).

An HE STA shall set the BQR Support subfield in the HE Capabilities element it transmits to 1 if dot11HEBQRControlImplemented is true; otherwise, the HE STA shall set the BQR Support subfield to 0.

The HE STA may report the channel availability information as specified in 27.3.22.6.5 (Per 20 MHz CCA sensitivity) in the BQR Control subfield of frames it transmits if the AP has indicated its support in the BQR Support subfield of its HE Capabilities element; otherwise, the STA shall not report the channel availability information in the BQR Control subfield.

The availability of each 20 MHz subchannel reported in the BQR Control field shall be reported for the 20 MHz subchannels located in the operating channel of the reporting STA (see 9.2.4.7.6 (BQR Control)).

NOTE 1—The STA can send an unsolicited BQR in response to certain Trigger frames except NFRP, MU-RTS, and BQRP (with or without RA-RUs, as defined in 26.5.2.3 (Non-AP STA behavior for UL MU operation) and 26.5.4 (UL OFDMA-based random access (UORA))), or it can send the unsolicited BQR after accessing the WM using EDCA.

An AP may solicit BQRs from a non-AP STA only if the non-AP STA has indicated support by setting the BQR Support field in the HE Capabilities element it transmits to 1; otherwise, the AP shall not solicit BQRs from the non-AP STA. An AP may solicit BQRs from one or more non-AP HE STAs that support generating BQRs, by sending a BQRP Trigger frame (see 9.3.1.22.8 (BQRP Trigger frame format)).

An AP shall not transmit a BQR Trigger frame with the User Info field addressed to a non-AP STA, unless it has received from the non-AP STA an HE Capabilities element with the BQR Support subfield equal to 1.

If a non-AP STA supports BQR operation and receives a BQRP Trigger frame with a User Info field addressed to the non-AP STA, then the non-AP STA shall respond by following the procedure in 26.5.2.3.1 (General).

If a non-AP STA supports both BQR operation and the UORA procedure and receives a BQRP Trigger frame from the AP with which it is associated and that allocates RA-RUs for associated STAs but that does contain a User Info field addressed to the non-AP STA, then the non-AP STA shall respond by following the procedure in 26.5.4 (UL OFDMA-based random access (UORA)).

If the non-AP STA responds with an HE TB PPDU using one of the above procedures, then the A-MPDU carried in the HE TB PPDU shall include one or more QoS Null frames containing a BQR Control subfield with the channel availability information of the STA. The non-AP STA shall not solicit an immediate response for the frames carried in the HE TB PPDU. The Ack Policy Indication subfield of the frame shall be set to No Ack.

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NOTE 2—An AP does not send a BQRP Trigger frame addressed to a STA that has set the UL MU Disable field to 1.

NOTE 3—The channel availability information of the STA is limited to the STA's operating channel width. See 9.2.4.7.6 (BQR Control).

An AP may include a BQRP Trigger frame together with other Control, Data, and Management frames in one A-MPDU to a STA if the HE Capabilities element received from the STA has the BSRP BQRP A-MPDU Aggregation field equal to 1. A non-AP STA constructs the A-MPDU contained in the HE TB PPDU sent in response to a BQRP Trigger frame as described in 26.5.2.4 (A-MPDU contents in an HE TB PPDU).

### 26.5.7 NDP feedback report procedure

#### 26.5.7.1 General

The NDP feedback report procedure allows an HE AP to collect feedback that is not channel sounding from multiple non-AP HE STAs.

An HE AP sends an NFRP Trigger frame to solicit NDP feedback report response from many non-AP STAs that are identified by a range of scheduled AIDs in the Trigger frame. The NDP feedback report response from a non-AP STA is an HE TB feedback NDP (see 27.3.18 (HE TB feedback NDP)). A non-AP STA uses the information carried in the NFRP Trigger frame to know if it is scheduled and, in this case, to derive the parameters for the transmission of the response.

The NDP feedback report procedure is described in 26.5.7.2 (STA behavior) through 26.5.7.5 (Power save operation with NDP feedback report procedure).

#### 26.5.7.2 STA behavior

A non-AP STA shall set the NDP Feedback Report Support subfield in the HE Capabilities element to 1 if it supports NDP feedback report and set it 0, otherwise.

A non-AP STA shall not transmit an NDP feedback report response, unless it is explicitly enabled by an AP in one of the operation modes described in this subclause. The interframe space between a PPDU that contains an NFRP Trigger frame and the (#1182)NDP feedback report response is SIFS. A non-AP STA shall commence the transmission of an NDP feedback report response at the SIFS time boundary after the end of a received PPDU if all the following conditions are met:

- The received PPDU contains an NFRP Trigger frame.
- The non-AP STA is scheduled by the NFRP Trigger frame.
- The NDP feedback report support subfield in HE MAC Capabilities Information field is set to 1.
- The non-AP STA intends to provide a response to the type of the NDP feedback contained in the NFRP Trigger frame, as described in 26.5.7.4 (NDP feedback report for a resource request).

A non-AP STA that does not satisfy all of the above conditions shall not respond to the NFRP Trigger frame.

A non-AP STA is scheduled to respond to the NFRP Trigger frame if all the following conditions are met:

- The non-AP STA is associated with an AP corresponding to the BSSID indicated in the TA field of the NFRP Trigger frame; or the non-AP STA is associated with an AP corresponding to a nontransmitted BSSID of a multiple BSSID set, and the TA field of the NFRP Trigger frame is set to the transmitted BSSID of that multiple BSSID set.
- The non-AP STA's AID is greater than or equal to the starting AID and less than the starting AID + $N_{STA}$, using the Starting AID subfield in the eliciting Trigger frame and $N_{STA}$ as the total


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number of non-AP STAs that are scheduled to respond to the NFRP Trigger frame. $N_{STA}$ is calculated by the following equation, using UL BW subfield and Number Of Spatially Multiplexed Users subfield from the eliciting Trigger frame:

$$N_{STA} = 18 \times 2^{BW} \times (\text{value of the Number Of Spatially Multiplexed Users subfield} + 1)$$

A non-AP STA shall obtain NDP feedback report parameter values from the most recently received NDP Feedback Report Parameter Set element carried in a Beacon, Probe Response, or (Re)Association Response frame from its associated AP, unless the non-AP STA is associated with an AP corresponding to a nontransmitted BSSID of a multiple BSSID set. In this case, it shall follow the rules in 11.1.3.8.4 (Inheritance of element values(11ax)) to determine the NDP feedback parameter values. If the NDP Feedback Report Parameter Set element is not received in a Management frame with a TA equal to the BSSID of the associated AP or to the transmitted BSSID of the multiple BSSID set, the non-AP STA shall use default values for the NDP Feedback Report parameters.

An NDP feedback report response is an HE TB feedback NDP as defined in 27.3.4 (HE PPDU formats).

A non-AP STA transmitting an (#1182)NDP feedback report response shall set the TXVECTOR parameters as for transmitting an HE TB PPDU in response to a Trigger frame that is not an MU-RTS Trigger frame as described in 26.5.2.3 (Non-AP STA behavior for UL MU operation), except for the following parameters:

- The FORMAT parameter shall be set to HE_TB.
- The APEP_LENGTH parameter shall be set to 0.
- The RU_ALLOCATION parameter shall be set to be maximum RU size for the BW.
- The RU_TONE_SET_INDEX parameter shall be set using the following equation, with the value of the Starting AID subfield in the User Info field of the eliciting Trigger frame:

  $$\text{RU\_TONE\_SET\_INDEX} = 1 + ((\text{AID} - \text{Starting AID}) \bmod (18 \times 2^{BW}))$$

- The NUM_STS parameter shall be set to 1.
- The SPATIAL_REUSE parameter shall be set to PSR_DISALLOW.
- The STARTING_STS_NUM parameter shall be set with the following equation, using the values of the Starting AID subfield in the User Info field of the eliciting Trigger frame:

  $$\text{STARTING\_STS\_NUM} = \lfloor (\text{AID} - \text{Starting AID}) / 18 / 2^{BW} \rfloor$$

- The MCS parameter shall be set to 0.
- The DCM parameter shall be set to 0.
- The FEC_CODING parameter shall be set to BCC_CODING.
- The TXPWR_LEVEL_INDEX parameter shall be set to the value based on the Transmit Power Control for an HE TB PPDU and based on the value of the AP Tx Power subfield and the UL Target Receive Power subfield in the User Info field of the eliciting Trigger frame (see 27.3.15.2 (Power precorrection(M118))).

NOTE—The subcarriers for each RU_TONE_SET index are contained in a 20 MHz channel and can be transmitted by a 20 MHz operating STA.

### 26.5.7.3 AP behavior

An AP shall set the NDP Feedback Report Support subfield in the HE Capabilities element to 1 if it supports NDP feedback report and set it 0 otherwise.

An AP may include the NDP Feedback Report Parameter Set element in Beacon frames, Probe Response frames, and (Re)Association Response frames in order to modify parameters for NDP Feedback Report

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operation. The procedure of NDP Feedback report described in this subclause allows operation even if the NDP Feedback Report Parameter Set element is not sent by the AP.

The NFRP Trigger frame shall be transmitted in a non-HT PPDU or HT PPDU, or as a tagged MPDU in a VHT, HE ER SU PPDU, or HE SU PPDU.

An AP that transmits an NFRP Trigger frame shall set the TA field of the frame to the MAC address of the AP, unless dot11MultiBSSIDImplemented is true and the Trigger frame is directed to STAs from at least two different BSSs of a multiple BSSID set. In this case, the AP shall set the TA field of the frame to the transmitted BSSID.

Following the transmission from an AP of an NFRP Trigger frame, multiple STAs may simultaneously send NDP feedback report responses to the AP. Based on the RXVECTOR parameter NDP_REPORT, which provides the detected status array for the resources of each spatial stream and tone set assigned by the Trigger frame, the AP can derive the list of AIDs from the resources to which an NDP feedback report response was sent and their responses.

The AP shall not send any acknowledgment in response to the reception of NDP feedback report responses.

#### 26.5.7.4 NDP feedback report for a resource request

If the Feedback Type subfield in the User Info field of the NFRP Trigger frame is 0, a STA that is scheduled may send an NDP feedback report response in order to signal to the AP that it is in the awake state and that it might have frames in its queues for UL MU. If the STA does not satisfy either of the conditions in Table 26-3 (FEEDBACK_STATUS description(11ax)), then the STA shall not respond to the NFRP Trigger frame.

Each STA that is scheduled is assigned a STARTING_STS_NUM and an RU_TONE_SET_INDEX to transmit a FEEDBACK_STATUS bit.

The meaning of the FEEDBACK_STATUS bit is defined in Table 26-3 (FEEDBACK_STATUS description(11ax)):

**Table 26-3—FEEDBACK_STATUS description(11ax)**

| FEEDBACK_STATUS | Condition |
|---|---|
| 0 | The STA is in the awake state and reports buffered octets for transmission not exceeding the resource request buffer threshold.<br><br>NOTE—The STA can use this value to indicate that it is in the awake state even if it does not have any buffered octets for transmission, e.g., to solicit delivery of BUs known to be buffered at the AP. |
| 1 | The STA is in the awake state and reports buffered octets for transmission exceeding the resource request buffer threshold. |

The resource request buffer threshold is equal to $2^{(\text{Resource request buffer threshold exponent})}$ octets, using the Resource Request Buffer Threshold Exponent subfield in the most recently received NDP Feedback Report Parameter Set element sent by the AP with which the STA is associated. The resource request buffer threshold is equal to 256 octets if the STA did not receive an NDP Feedback Report Parameter Set element from the AP with which the STA is associated.


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#### 26.5.7.5 Power save operation with NDP feedback report procedure

An HE AP that sends an NFRP Trigger frame to a non-AP STA in PS mode and receives an NDP feedback report response from the STA shall assume the STA to be in, or to have transitioned to, the awake state and shall follow the rules defined in

— 11.2.3.5 to deliver BUs to the STA as if the STA had sent a U-APSD trigger frame if the STA is using U-APSD.
— 11.2.3.1 to deliver BUs to the STA as if the STA had sent a PS-Poll frame, if the STA is not using U-APSD.
— 26.8 (TWT operation) for delivery of BUs during the TWT SP if the STA operates with TWT.

NOTE—As the AP does not send an acknowledgment in response to the NDP Feedback Report response, a STA that sends an NDP Feedback Report response and indicates that it is in the awake state might still schedule for transmission a PS-Poll or U-APSD trigger frame in order to indicate that it is in the awake state.

### 26.5.8 Use of TSPEC by HE STAs

In addition to the TS Setup operations as described in 11.4.4 (TS setup), a non-AP HE STA may use a TSPEC contained in a Basic ADDTS Request frame to provide its traffic characteristics and QoS requirements to an HE AP that supports the reception of Basic ADDTS Request frame in order to facilitate efficient scheduling for HE AP's UL and DL MU operations. A TSPEC provided by a non-AP HE STA is used by a receiving HE AP to facilitate the creation of a schedule for contention based channel access (EDCA) or MU operation. How the HE AP uses the information provided by the non-AP HE STA is beyond the scope of this standard.

An HE AP transmits an ADDTS Response frame as a response to ADDTS Request frame as described in 11.4.4 (TS setup).

A non-AP HE STA should send a DELTS frame with the corresponding TSID if the traffic associated with the TSID has been terminated. When receiving a DELTS from a non-AP HE STA, the HE AP shall consider the information provided in the TSPEC as no longer valid.

### 26.5.9 UL MU transmit power capabilities

A non-AP HE STA may use the UL MU Power Capabilities element in a (Re)Association Request frame in order to inform an HE AP of the relative maximum transmit power at which the non-AP HE STA is capable of transmitting an HE TB PPDU for each HE-MCS when using an RU size greater than or equal to 242 subcarriers.

An HE AP might use this information as an input into the algorithm used to schedule the non-AP HE STA for UL MU transmission. The specification of the algorithm is beyond the scope of this standard.

## 26.6 A-MPDU operation in an HE PPDU

### 26.6.1 General

A-MPDU operation for an HE PPDU follows the procedures defined in 10.12 (A-MPDU operation) and the additional rules in this subclause.

An HE STA that sends a Class 1 frame or a Class 2 frame in an HE PPDU shall send the frame as an S-MPDU (see Table 9-664 (A-MPDU contents in the S-MPDU context(#1762))).

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An HE STA that sends a VHT Capabilities element, an HT Capabilities element, or an HE 6 GHz Band Capabilities element and an HE Capabilities element with Maximum A-MPDU Length Exponent Extension field of 0 shall support in reception an A-MPDU pre-EOF padding with maximum length defined in Table 10.12.2 (A-MPDU length limit rules).

An HE STA that sends a VHT Capabilities element and an HE Capabilities element with Maximum A-MPDU Length Exponent Extension subfield greater than 0 shall support reception of an HE PPDU with an A-MPDU pre-EOF padding as defined in Table 10.12.2 (A-MPDU length limit rules), except that the maximum length for the A-MPDU pre-EOF padding shall be equal to $min(2^{(20 + \text{Maximum A-MPDU Length Exponent Extension})} - 1, 6\,500\,631)$. An HE STA that sets the Maximum A-MPDU Length Exponent Extension subfield in the HE Capabilities element to a value greater than 0 shall set the Maximum A-MPDU Length Exponent subfield of the VHT Capabilities element to 7.

NOTE 1—The value 6 500 631 is defined in Table 9-34 (Maximum data unit sizes and durations(#1327)(#4013)) as the upper bound of A-MPDU size.

An HE STA that does not send a VHT Capabilities element but sends an HT Capabilities element and an HE Capabilities element with Maximum A-MPDU Length Exponent Extension subfield greater than 0 shall support in reception an A-MPDU pre-EOF padding in an HE PPDU as defined in Table 10.12.2 (A-MPDU length limit rules), except that the maximum length for the A-MPDU pre-EOF padding shall be equal to $2^{(16 + \text{Maximum A-MPDU Length Exponent Extension})} - 1$. An HE STA that sets the Maximum A-MPDU Length Exponent Extension subfield in the HE Capabilities element to a value greater than 0 shall set the Maximum A-MPDU Length Exponent subfield of the HT Capabilities element to 3.

NOTE 2—An HE STA that is a VHT STA sends a VHT Capabilities element. An HE STA that is not a VHT STA does not send a VHT Capabilities element.

An HE STA that sends an HE 6 GHz Band Capabilities element and an HE Capabilities element with Maximum A-MPDU Length Exponent Extension subfield greater than 0 shall support in reception an A-MPDU pre-EOF padding in an HE PPDU as defined in Table 10.12.2 (A-MPDU length limit rules), except that the maximum length for the A-MPDU pre-EOF padding shall be equal to $min(2^{(20 + \text{Maximum A-MPDU Length Exponent Extension})} - 1, 6\,500\,631)$. An HE STA that sets the Maximum A-MPDU Length Exponent Extension subfield in the HE Capabilities element to a value greater than 0 shall set the Maximum A-MPDU Length Exponent subfield of the HE 6 GHz Band Capabilities element to 7.

An HE STA shall not transmit an A-MPDU in an HE PPDU to a STA that exceeds the maximum A-MPDU length capability indicated in the HE Capabilities, VHT Capabilities, and HT Capabilities elements received from the recipient STA. If a VHT Capabilities element is received from the recipient STA, then the maximum A-MPDU length capability is derived from the Maximum A-MPDU Length Exponent Extension subfield in the HE Capabilities and the Maximum A-MPDU Length Exponent subfield in the VHT Capabilities element. Otherwise, the maximum A-MPDU length capability is derived from the Maximum A-MPDU Length Exponent subfields in the HE Capabilities element and the Maximum A-MPDU Length Exponent subfield in the HT Capabilities element or in the HE 6 GHz Band Capabilities element.

An HE STA may transmit an HE SU PPDU or HE MU PPDU that carries an A-MPDU with contents defined in Table 9-662 (A-MPDU contents in the data enabled no immediate response context) or Table 9-665 (A-MPDU contents in the HE non-ack-enabled single-TID immediate response context(11ax)).

An A-MPDU with any number of QoS Null frames with any TID and with No Ack ack policy and aggregated with or without other frames may be transmitted to a recipient STA in an HE PPDU that is not an HE TB PPDU regardless of the value of the Multi-TID Aggregation Rx/Tx Support subfield in the HE MAC Capabilities Information field in the HE Capabilities element received from the recipient STA.


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An A-MPDU with any number of QoS Null frames with any TID and with No Ack ack policy and aggregated with or without other frames in an A-MPDU may be transmitted in the HE TB PPDU regardless of the value of the TID Aggregation Limit subfield and the value of the Preferred AC subfield in the Basic Trigger frame and the value of the Multi-TID Aggregation Rx Support of the AP that solicits the A-MPDU.

NOTE 3—A QoS Null frame with Normal Ack or Implicit BAR ack policy is not allowed to be sent in an A-MPDU, except for a QoS Null frame with Normal Ack ack policy in an S-MPDU (as defined in Table 9-662 (A-MPDU contents in the data enabled no immediate response context), Table 9-663 (A-MPDU contents in the control response context), Table 9-665 (A-MPDU contents in the HE non-ack-enabled single-TID immediate response context(11ax)), Table 9-666 (A-MPDU contents in the HE ack-enabled single-TID immediate response context(11ax)), Table 9-667 (A-MPDU contents in the HE non-ack-enabled multi-TID immediate response context(11ax)), and Table 9-668 (A-MPDU contents in the HE ack-enabled multi-TID immediate response context(11ax))).

### 26.6.2 A-MPDU padding in an HE PPDU

#### 26.6.2.1 General

In an HE PPDU, a STA shall not add an A-MPDU subframe with the EOF/Tag field set to 1 and with the MPDU Length field set to 0 before an A-MPDU subframe with a nonzero MPDU Length field. In an HE PPDU, a STA should add an A-MPDU subframe with the EOF/Tag field set to 1 and with the MPDU Length field set to 0 (i.e., EOF padding) immediately after the last A-MPDU subframe with a nonzero MPDU Length field.

#### 26.6.2.2 A-MPDU padding in an HE SU PPDU, HE ER SU PPDU, and HE MU PPDU

An HE STA that transmits a DL HE MU PPDU that contains one or more PSDUs, each of which carries an A-MPDU, shall construct the A-MPDUs as described in 10.12.6 (A-MPDU padding for VHT, HE(11ax) or S1G PPDU), except that one or more A-MPDU subframes with a nonzero MPDU Length field and with an EOF/Tag field equal to 1 may be added if the A-MPDU is an ack-enabled single-TID A-MPDU (see 26.6.3 (Multi-TID A-MPDU and ack-enabled single-TID A-MPDU)).

An HE STA that transmits an HE SU PPDU, HE ER SU PPDU, or UL HE MU PPDU that contains one A-MPDU shall construct the A-MPDU as described in 10.12.6 (A-MPDU padding for VHT, HE(11ax) or S1G PPDU), except that one or more A-MPDU subframes with a nonzero MPDU Length field and with an EOF/Tag field equal to 1 may be added if the A-MPDU is an ack-enabled single-TID A-MPDU (see 26.6.3 (Multi-TID A-MPDU and ack-enabled single-TID A-MPDU)).

#### 26.6.2.3 A-MPDU padding in an HE TB PPDU

A non-AP STA that transmits an HE TB PPDU shall construct the PSDU carried in the HE TB PPDU as described in this subclause.

The STA calculates the PSDU_LENGTH as defined in 6.7 (PLME SAP interface) and initializes A-MPDU_Length to 0.

The STA may add A-MPDU subframes to the A-MPDU contained in the PSDU, provided that the following constraints are fulfilled:

- The A-MPDU content constraints (see 10.12.1 (A-MPDU contents) and 26.6.3 (Multi-TID A-MPDU and ack-enabled single-TID A-MPDU)) for the intended recipient
- The Length limit constraints (see 9.7.1 (A-MPDU format) and 10.12.2 (A-MPDU length limit rules)) for the intended recipient
- The MPDU start spacing constraints (see 10.12.3 (Minimum MPDU start spacing rules)) for the intended recipient

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and provided that the following conditions are met:

— The A-MPDU subframes have a value greater than 0 in the MPDU Length field, or have a value 0 in the MPDU Length field and a value 0 in the EOF/Tag field.

— After incrementing the A-MPDU_Length with the length of each such added A-MPDU subframe, the relationship A-MPDU_Length ≤ PSDU_LENGTH is true.

Padding is then added so that the resulting A-MPDU contains exactly PSDU_LENGTH octets as follows:

— First, while A-MPDU_Length < PSDU_LENGTH and A-MPDU_Length mod 4 ≠ 0, add an octet to the final A-MPDU subframe's Padding subfield, and increment A-MPDU_Length by 1.

— Then, while A-MPDU_Length + 4 ≤ PSDU_LENGTH, add an EOF padding subframe to the EOF Padding Subframes field, and increment A-MPDU_Length by 4.

— Finally, while A-MPDU_Length < PSDU_LENGTH, add an octet to the EOF Padding Octets subfield, and increment A-MPDU_Length by 1.

An A-MPDU pre-EOF padding is constructed from each user from any of the following:

— A-MPDU subframes constructed from the MPDUs available for transmission from any AC that is selected by the STA.

— A-MPDU subframes with 0 in the MPDU Length field and 0 in the EOF/Tag field.

### 26.6.3 Multi-TID A-MPDU and ack-enabled single-TID A-MPDU

#### 26.6.3.1 General

A non-ack-enabled multi-TID A-MPDU is an A-MPDU that does not contain a tagged MPDU but does contain untagged MPDUs from at least two TIDs (see Table 9-667 (A-MPDU contents in the HE non-ack-enabled multi-TID immediate response context(11ax))).

An ack-enabled multi-TID A-MPDU is an A-MPDU that contains at least one tagged MPDU that solicits acknowledgment and one or more MPDUs from at least one TID (see Table 9-668 (A-MPDU contents in the HE ack-enabled multi-TID immediate response context(11ax))).

An ack-enabled single-TID A-MPDU is an A-MPDU that contains one tagged MPDU that solicits acknowledgment and one or more untagged MPDUs that do not solicit an immediate response (see Table 9-666 (A-MPDU contents in the HE ack-enabled single-TID immediate response context(11ax))).

An HE STA with dot11HEAMPDUwithMultipleTIDOptionImplemented equal to true shall set the Multi-TID Aggregation Rx Support subfield to a nonzero value in the HE MAC Capabilities Information field in the HE Capabilities element it transmits. An HE STA with dot11HEAMPDUwithMultipleTIDOptionImplemented equal to false shall set the Multi-TID Aggregation Rx Support subfield to 0.

An HE STA with dot11AckEnabledAMPDUOptionImplemented equal to true shall set the Ack-Enabled Aggregation Support subfield to 1 in the HE MAC Capabilities Information field in the HE Capabilities element it transmits. An HE STA with dot11AckEnabledAMPDUOptionImplemented equal to false shall set the Ack-Enabled Aggregation Support subfield to 0.

A multi-TID A-MPDU is either a non-ack-enabled multi-TID A-MPDU or an ack-enabled multi-TID A-MPDU. A first HE STA may transmit a non-ack-enabled multi-TID A-MPDU to a second HE STA if the first HE STA has received from the second STA an HE Capabilities element where the Multi-TID Aggregation Rx Support subfield is nonzero. A first HE STA may transmit an ack-enabled multi-TID A-MPDU or a non-ack-enabled multi-TID A-MPDU to a second HE STA if the first HE STA has received from the second HE STA an HE Capabilities element where the Multi-TID Aggregation Rx Support subfield


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is nonzero and the Ack-Enabled Aggregation Support subfield is 1. Otherwise, the first HE STA shall not transmit a multi-TID A-MPDU to the second HE STA.

An HE STA shall not transmit a multi-TID A-MPDU or ack-enabled single-TID A-MPDU in a VHT PPDU or a HT PPDU.

A non-AP STA shall not send a non-ack-enabled multi-TID A-MPDU in an HE TB PPDU, unless it is in response to a Basic Trigger frame where the TID Aggregation Limit field of the User Info field addressed to the STA is greater than 1. A non-AP STA shall not send an ack-enabled multi-TID A-MPDU in an HE TB PPDU, unless it is in response to a Basic Trigger frame where the TID Aggregation Limit field of the User Info field addressed to the STA is greater than 0.

NOTE 1—An ack-enabled multi-TID A-MPDU solicited by a Basic Trigger frame with TID Aggregation Limit field equal to 1 can contain one Management frame that solicits acknowledgment and one or more QoS Data frames from the same TID if the AP supports reception of ack-enabled multi-TID A-MPDUs.

A multi-TID A-MPDU shall not be transmitted in an HE SU PPDU, HE ER SU PPDU, or HE MU PPDU, unless the TXOP limit is greater than 0 for the AC that is used to gain access to the medium. The AC used to gain access to the medium is the primary AC (see 10.23.2.9 (TXOP limits)). If the TXOP limit of the primary AC is greater than 0, then the STA may aggregate QoS Data frames from one or more TIDs in the A-MPDU under the following conditions:

— The A-MPDU shall be carried in either an HE SU PPDU or an HE ER SU PPDU transmitted by the STA within the obtained TXOP or in an HE MU PPDU transmitted by a non-AP STA within the obtained TXOP.
— The A-MPDU shall contain one or more MPDUs with any of the TIDs that correspond to the primary AC.
— If no more MPDUs can be aggregated in the A-MPDU from any of the TIDs that correspond to the primary AC, then the A-MPDU may additionally contain one or more MPDUs with TIDs that do not correspond to the primary AC if the TIDs correspond to any AC that has a higher priority with respect to the primary AC and the addition of these MPDUs does not cause the STA to exceed the TXOP limit of the primary AC.

An HE AP may aggregate MPDUs from any TIDs in a multi-TID A-MPDU for DL HE MU PPDU transmission, and the number of TIDs in the multi-TID A-MPDU shall not be more than the Multi-TID Aggregation Rx Support announced by the recipient.

The Multi-STA BlockAck frame is used to acknowledge the MPDUs in a multi-TID A-MPDU as defined in 26.4 (HE acknowledgment procedure).

In a multi-TID A-MPDU, MPDUs with the same TID are not necessarily contiguous.

A non-AP HE STA that transmits a multi-TID A-MPDU in an HE TB PPDU should aggregate QoS Data frames in the following order:

— First, any and all MPDUs that correspond to the Preferred AC subfield of the Trigger Dependent User Info field addressed to the STA in the Trigger frame.
— Then, any and all MPDUs that correspond to any AC that has a higher priority.
— Then, any MPDUs that correspond to any AC that has a lower priority.

The aggregation of the QoS Data frames is subject to the following:

— The limit indicated in the TID Aggregation Limit subfield in the Trigger Dependent User Info field addressed to the STA in the Trigger frame.

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- The restrictions in Table 26-2 (Relation between TID Aggregation Limit field, Multi-TID Aggregation Tx Support field, and solicited immediate response(11ax)).
- The duration indicated in the UL Length subfield in the Common Info field of the Trigger frame.

NOTE 2—These rules permit a STA to not aggregate any MPDUs from the preferred AC or a higher priority AC, and permit a STA to aggregate MPDUs in any order.

NOTE 3—A multi-TID A-MPDU allows the aggregation of a Management frame regardless of the value indicated in the Multi-TID Aggregation Rx Support subfield in the HE MAC Capabilities Information field in the HE Capabilities element as long as the indicated value of the TID Aggregation Limit subfield in the Trigger Dependent User Info field of a the Basic Trigger frame is nonzero.

A(#1426) non-AP HE STA that transmits a single-TID A-MPDU in an HE TB PPDU should select the TID in the following order:

- A TID that corresponds to the Preferred AC subfield of the Trigger Dependent User Info field addressed to the STA in the Trigger frame if there is a corresponding MPDU for that TID.
- Otherwise, a TID that corresponds to any AC that has a higher priority, if there is a corresponding MPDU for that TID.
- Otherwise, a TID that corresponds to any AC that has a lower priority.

The TID selection is subject to the following:

- The limit indicated in the TID Aggregation Limit subfield in the Trigger Dependent User Info field addressed to the STA in the Trigger frame.
- The duration indicated in the UL Length subfield in the Common Info field of the Trigger frame.

NOTE 4—These rules permit a STA to not select MPDUs from the preferred AC or a higher priority AC.

#### 26.6.3.2 Ack-enabled single-TID A-MPDU operation

An ack-enabled single-TID A-MPDU is an A-MPDU with contents defined in Table 9-666 (A-MPDU contents in the HE ack-enabled single-TID immediate response context(11ax)).

NOTE—An ack-enabled single-TID A-MPDU does not contain more than one of the following frames: (a) a QoS Data frame or (b) a Management frame that solicits acknowledgment. In this case, the Management frame that solicits acknowledgment is treated as if it were a QoS Data frame with TID equal to 15.

An HE STA shall not transmit an ack-enabled single-TID A-MPDU to a recipient STA, unless it has received from the recipient STA an HE Capabilities element with the Ack-Enabled Aggregation Support subfield equal to 1.

#### 26.6.3.3 Non-ack-enabled multi-TID A-MPDU operation

A non-ack-enabled multi-TID A-MPDU is an A-MPDU with contents defined in Table 9-667 (A-MPDU contents in the HE non-ack-enabled multi-TID immediate response context(11ax)).

NOTE—A non-ack-enabled multi-TID A-MPDU might include other frames such as a Trigger frame, BlockAck frame, or QoS Null frame (see Table 9-661 (A-MPDU contents in the non-HE(11ax) data enabled immediate response context)).

An HE STA shall not transmit a non-ack-enabled multi-TID A-MPDU to a recipient STA, unless it has received from the recipient STA an HE Capabilities element where the Multi-TID Aggregation Rx Support subfield is nonzero.


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A STA that receives a non-ack-enabled multi-TID A-MPDU responds as defined in 26.4.4 (Per-PPDU acknowledgment selection rules).

#### 26.6.3.4 Ack-enabled multi-TID A-MPDU operation

An ack-enabled multi-TID A-MPDU is an A-MPDU with contents defined in Table 9-668 (A-MPDU contents in the HE ack-enabled multi-TID immediate response context(11ax)).

QoS Data frames with the same TID shall have the same ack policy.

QoS Data frames with the same TID shall be carried in A-MPDU subframes with the same value in the EOF/Tag field setting.

In an ack-enabled multi-TID A-MPDU, the EOF/Tag field in the MPDU delimiter of each A-MPDU subframe carrying a frame that solicits an Ack frame as defined in Table 9-668 (A-MPDU contents in the HE ack-enabled multi-TID immediate response context(11ax)) shall be set to 1. The EOF/Tag field in all other A-MPDU subframes in the A-MPDU that carry frames shall be set to 0.

An HE STA shall not transmit an ack-enabled multi-TID A-MPDU to a recipient STA, unless it has received from the recipient STA an HE Capabilities element where the Multi-TID Aggregation Rx Support subfield is nonzero and the Ack-Enabled Aggregation Support subfield is 1.

A STA that receives an ack-enabled multi-TID A-MPDU responds as defined in 26.4.4 (Per-PPDU acknowledgment selection rules).

A STA that transmits an ack-enabled multi-TID A-MPDU that contains at least two tagged MPDUs shall (#3683)discard the immediate response if it is an Ack frame.

## 26.7 HE sounding operation(#2388)

### 26.7.1 General

Transmit beamforming and DL MU-MIMO require knowledge of the channel state to compute a steering matrix that is applied to the transmit signal to optimize reception at one or more receivers. HE STAs use the HE sounding protocol to determine the channel state information. The HE sounding protocol provides explicit feedback mechanisms, defined as HE non-trigger-based (non-TB) sounding and HE trigger-based (TB) sounding, where the HE beamformee measures the channel using a training signal (i.e., an HE sounding NDP) transmitted by the HE beamformer and sends back a transformed estimate of the channel state. The HE beamformer uses this estimate to derive the steering matrix.

The HE beamformee returns an estimate of the channel state in an HE compressed beamforming/CQI report carried in (#6006)the HE Compressed Beamforming/CQI Report field. There are three types of HE compressed beamforming/CQI report:

— SU feedback: The HE Compressed Beamforming/CQI Report field(#6006) consists of an HE Compressed Beamforming Report field.

— MU feedback: The HE Compressed Beamforming/CQI Report field(#6006) consists of an HE Compressed Beamforming Report field and HE MU Exclusive Beamforming Report field.

— CQI feedback: The HE Compressed Beamforming/CQI Report field(#6006) consists of an HE CQI Report field.

NOTE—Use of HE TB sounding does not necessarily imply MU feedback. HE TB sounding is also used to obtain SU feedback and CQI feedback.

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The HE Compressed Beamforming/CQI Report field(#6006) is carried in a single HE Sounding Feedback Segment field if the resulting HE Compressed Beamforming/CQI frame is less than or equal to 11 454 octets in length (see 26.7.3 (Rules for HE sounding protocol sequences)). Otherwise, the HE Compressed Beamforming/CQI Report field is segmented, with each segment carried in an HE Sounding Feedback Segment field, and each HE Sounding Feedback Segment field carried in separate HE Compressed Beamforming/CQI frames.(#6006)

An HE beamformer shall support a maximum MPDU length for an HE Compressed Beamforming/CQI frame(#7156) that is the minimum of 11 454 octets and the maximum length of the HE Compressed Beamforming/CQI frame(#7156) that the HE beamformer intends to solicit from its HE beamformees.(#6006)

### 26.7.2 HE sounding protocol

An SU beamformer is an HE STA that sets the SU Beamformer subfield in the HE PHY Capabilities Information field in the HE Capabilities element it transmits to 1.

An SU beamformee is an HE STA that sets the SU Beamformee subfield in the HE PHY Capabilities Information field in the HE Capabilities element it transmits to 1. A non-AP HE STA shall set the SU Beamformee subfield to 1. An HE AP may set the SU Beamformee subfield to 1.

An MU beamformer is an HE AP that sets the MU Beamformer subfield in the HE PHY Capabilities Information field in the HE Capabilities element it transmits to 1. An HE AP that indicates support for 4 or more space-time streams in the Tx HE-MCS Map ≤ 80 MHz subfield in the Supported HE-MCS And NSS field in the HE Capabilities element shall set the MU Beamformer subfield to 1. A non-AP HE STA shall set the MU Beamformer subfield to 0. An MU beamformer is also an SU beamformer and shall set the SU Beamformer subfield to 1.

NOTE—A non-AP STA might use the setting of the MU Beamformer subfield to determine the AP with which it will associate.

A non-AP HE STA shall support operation as an MU beamformee. An HE AP does not support operation as an MU beamformee.

The term *HE beamformer* refers to both the SU beamformer and MU beamformer. The term *HE beamformee* refers to both the SU beamformee and MU beamformee.

The type of feedback (SU, MU, or CQI) solicited by an HE beamformer from an HE beamformee is indicated in the Feedback Type And Ng and Codebook subfields in the STA Info field identifying the HE beamformee in the HE NDP Announcement frame as defined in Table 9-45 (Feedback Type And Ng subfield and Codebook Size subfield encoding for HE TB sounding(11ax)) and Table 9-46 (Feedback Type And Ng subfield and Codebook Size subfield encoding for HE non-TB sounding(11ax)).

The bandwidth (partial or full) of the feedback solicited by an HE beamformer from an HE beamformee depends on the Partial BW Info subfield in the STA Info field identifying the HE beamformee in the HE NDP Announcement frame, (#2337)the bandwidth of the PPDU carrying the HE NDP Announcement frame, and the value of the Disallowed Subchannel Bitmap subfield, if present. Full bandwidth feedback is solicited if the RU Start Index subfield in the Partial BW Info subfield is 0, the Disallowed Subchannel Bitmap subfield is absent or contains all zeroes, and the RU End Index subfield in the Partial BW subfield is the value shown in Table 26-4 (Settings for BW, RU Start Index, and RU End Index fields in HE NDP Announcement frame(11ax)) where partial bandwidth is not supported by the HE beamformer, for (#2337)the bandwidth of the PPDU carrying the HE NDP Announcement frame.


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Other settings of the Partial BW Info subfield solicit partial-bandwidth feedback. Punctured sounding is indicated by the inclusion of a nonzero Disallowed Subchannel Bitmap subfield in the HE NDP Announcement frame. In such a case, the disallowed subchannels are applied to the tone information to be included in the feedback after selecting tones for feedback based on the RU Start Index and RU End Index subfield values and HE NDP Announcement frame bandwidth as described above. See Table 26-4 (Settings for BW, RU Start Index, and RU End Index fields in HE NDP Announcement frame(11ax)).

The RU Start Index and RU End Index subfields shall cover at least one allowed subchannel.

An SU beamformer may solicit full-bandwidth SU feedback from an SU beamformee in an HE non-TB sounding sequence. An SU beamformer shall not solicit partial-bandwidth SU feedback in an HE non-TB sounding sequence. An SU beamformer may solicit partial-bandwidth or full-bandwidth SU feedback from an SU beamformee in an HE TB sounding sequence if the SU beamformee indicates support by setting the Triggered SU Beamforming Feedback subfield in the HE PHY Capabilities Information field in the HE Capabilities element it transmits to 1.

An MU beamformer may solicit full-bandwidth MU feedback from an MU beamformee in an HE TB sounding sequence. An MU beamformer may solicit partial-bandwidth MU feedback from an MU beamformee in an HE TB sounding sequence if the MU beamformee indicates support by setting the Triggered MU Beamforming Partial BW Feedback subfield to 1. An MU beamformer shall not solicit MU feedback in an HE non-TB sounding sequence.

An MU beamformer may solicit full-bandwidth or partial-bandwidth CQI feedback from an MU beamformee in an HE TB sounding sequence if the MU beamformee indicates support by setting the Triggered CQI Beamforming Feedback subfield to 1.

An MU beamformer may solicit full-bandwidth CQI feedback from an MU beamformee in an HE non-TB sounding sequence if the MU beamformee indicates support by setting the Non-Triggered CQI Beamforming Feedback subfield to 1.

An HE beamformer may solicit punctured SU feedback from an HE beamformee in an HE TB sounding sequence if the HE beamformee indicates support for punctured sounding by setting the Punctured Sounding Support subfield in the HE Capabilities elements it transmits to 1. An HE beamformer shall indicate punctured subchannels in the HE sounding NDP of an HE TB sounding sequence by setting the appropriate bits of the Disallowed Subchannel Bitmap subfield of the STA Info field with the AID11 subfield set to 2047 in the preceding HE NDP Announcement frame. An SU beamformer that indicates punctured subchannels in an HE NDP Announcement frame in an HE TB sounding sequence shall set the TXVECTOR parameter INACTIVE_SUBCHANNELS of the non-HT duplicate PPDU carrying the HE NDP Announcement frame and the HE sounding NDP as described in 26.11.7 (INACTIVE_SUBCHANNELS and RU_ALLOCATION).

An SU beamformee that supports punctured sounding shall generate feedback corresponding to the subchannels indicated in the STA Info field addressed to it in an HE NDP Announcement frame, but excluding subcarriers that are disallowed according to the value of the Disallowed Subchannel Bitmap subfield in that frame.

An HE beamformer shall not send an HE NDP Announcement frame that initiates an HE TB sounding sequence with a STA Info field identifying an HE beamformee if the STA Info field and the PHY Capabilities Information field in the HE Capabilities element most recently received from the HE beamformee meet any of the following conditions (see Table 9-45 (Feedback Type And Ng subfield and Codebook Size subfield encoding for HE TB sounding(11ax))):

— The Feedback Type And Ng subfield in the STA Info field indicates SU and $Ng = 16$, and the $Ng = 16$ SU Feedback subfield in the HE PHY Capabilities Information field is 0.

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- The Feedback Type And Ng subfield in the STA Info field indicates MU and *Ng* = 16, and the *Ng* = 16 MU Feedback subfield in the HE PHY Capabilities Information field is 0.
- The Feedback Type And Ng subfield in the STA Info field indicates SU, the Codebook Size subfield indicates codebook resolution ($\phi$, $\psi$) = {4, 2}, and the Codebook Size ($\phi$, $\psi$) ={4, 2} SU Feedback subfield in the HE PHY Capabilities Information field is 0.
- The Feedback Type And Ng subfield in the STA Info field indicates MU, the Codebook Size subfield in the STA Info field indicates codebook resolution ($\phi$, $\psi$) = {7, 5}, and the Codebook Size ($\phi$, $\psi$) ={7, 5} MU Feedback subfield in the HE PHY Capabilities Information field is 0.
- The Feedback Type And Ng and Codebook Size subfields in the STA Info field indicate CQI, and the Triggered CQI Beamforming Feedback subfield in the HE PHY Capabilities Information field is 0.
- The Feedback Type And Ng subfield in the STA Info field indicates MU, the Partial BW Info subfield in the STA Info field indicates partial bandwidth, and the Triggered MU Beamforming Partial BW Feedback subfield in the HE PHY Capabilities Information field is 0.
- The Feedback Type And Ng subfield indicates SU, and the Triggered SU Beamforming Feedback subfield in the HE PHY Capabilities Information field is 0.

An HE beamformee indicates the maximum number of HE-LTF symbols it can receive in a 20 MHz, 40 MHz, or 80 MHz HE sounding NDP in the Beamformee STS ≤ 80 MHz subfield in the PHY Capabilities Information field in the HE Capabilities element it transmits.

An HE beamformee shall set the Beamformee STS ≤ 80 MHz subfield to indicate a maximum number of HE-LTF symbols of 4 or greater.

An HE beamformee that supports 160 MHz or 80+80 MHz channel widths indicates the maximum number of HE-LTF symbols it can receive in a 160 MHz or 80+80 MHz HE sounding NDP in the Beamformee STS > 80 MHz subfield in the PHY Capabilities Information field in the HE Capabilities element it transmits.

An HE beamformer shall not transmit a 20 MHz, 40 MHz, or 80 MHz HE sounding NDP with a TXVECTOR parameter NUM_STS that is greater than the maximum number of HE-LTF symbols indicated in the Beamformee STS ≤ 80 MHz subfield of any STA identified by a STA Info field in the preceding HE NDP Announcement frame.

An HE beamformer shall not transmit a 160 MHz or 80+80 MHz HE sounding NDP with a TXVECTOR parameter NUM_STS that is greater than the maximum number of HE-LTF symbols indicated in the Beamformee STS > 80 MHz subfield of any STA identified by a STA Info field in the preceding HE NDP Announcement frame.

An HE beamformer indicates the maximum number of HE-LTF symbols it might transmit in a 20 MHz, 40 MHz, or 80 MHz HE sounding NDP in the Number Of Sounding Dimensions ≤ 80 MHz subfield.

An HE beamformer indicates the maximum number of HE-LTF symbols it might transmit in an 80+80 MHz or 160 MHz HE sounding NDP in the Number Of Sounding Dimensions > 80 MHz subfield.

An HE beamformer shall not transmit a 20 MHz, 40 MHz, or 80 MHz HE sounding NDP where the number of HE-LTF symbols exceeds the value indicated in the Number Of Sounding Dimensions ≤ 80 MHz subfield.

An HE beamformer shall not transmit an 80+80 MHz or 160 MHz HE sounding NDP where the number of HE-LTF symbols exceeds the value indicated in the Number Of Sounding Dimensions > 80 MHz subfield.


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### 26.7.3 Rules for HE sounding protocol sequences

An HE non-TB sounding sequence is initiated by an HE beamformer with an individually addressed HE NDP Announcement frame comprising exactly one STA Info field, followed after a SIFS(#6587) by an HE sounding NDP. The triggered(#2345) HE beamformee responds after a SIFS(#6587) with an HE Compressed Beamforming/CQI frame.

The AID11 subfield of the STA Info field shall be set to the AID of the STA identified by the RA field of the HE NDP Announcement frame, or to 0 if the STA identified by the RA field is a mesh STA, AP, or IBSS STA.

An example of an HE non-TB sounding sequence with a single HE beamformee is shown in Figure 26-7 (Example of HE non-TB sounding(11ax)).

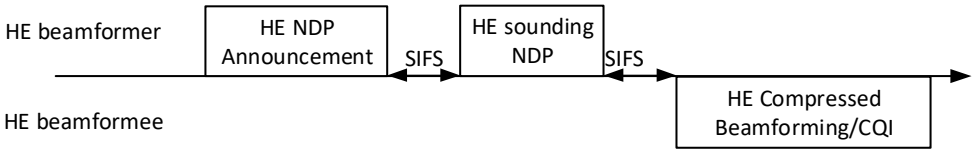


**Figure 26-7—Example of HE non-TB sounding(11ax)**

An HE beamformer that initiates the HE non-TB sounding sequence shall transmit the HE NDP Announcement frame with a single STA Info field, and the value in the AID11 field of that STA Info field shall be other than 2047 and set to the AID of the STA identified by the RA field or to 0 if the STA identified by the RA field is a mesh STA, AP, or IBSS member STA.

An HE beamformer may initiate an HE non-TB sounding sequence with an HE beamformee to solicit SU feedback over full bandwidth.

An HE beamformer shall not initiate an HE non-TB sounding sequence with an HE NDP Announcement frame that has a Partial BW Info subfield that indicates less than full bandwidth (see Table 26-4 (Settings for BW, RU Start Index, and RU End Index fields in HE NDP Announcement frame(11ax))).

An HE TB sounding sequence is initiated by an HE beamformer with a broadcast HE NDP Announcement frame with two or more STA Info fields, followed after a SIFS by an HE sounding NDP, followed after a SIFS by a BFRP Trigger frame. (#2343)Each triggered HE beamformee responds after a SIFS with an HE TB PPDU containing one or more HE Compressed Beamforming/CQI frame.

An example of an HE TB sounding sequence with more than one HE beamformee is shown in Figure 26-8 (Example of HE TB sounding(11ax)).

An HE beamformer that initiates an HE TB sounding sequence shall transmit the HE NDP Announcement frame with two or more STA Info fields and the RA field set to the broadcast address.

An HE beamformer may initiate an HE TB sounding sequence to solicit MU feedback over full bandwidth.

An HE beamformer may initiate an HE TB sounding sequence to solicit a feedback variant only if the feedback variant is computed based on parameters supported by the HE beamformee; otherwise, the HE beamformer shall not solicit a feedback variant computed based on parameters not supported by the HE beamformee (see 26.7.2 (HE sounding protocol)).

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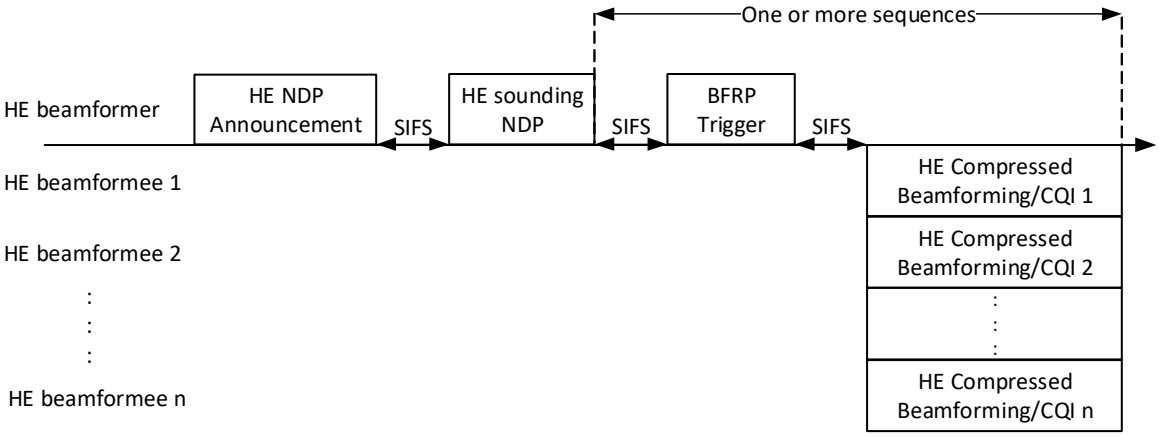


**Figure 26-8—Example of HE TB sounding(11ax)**

An HE AP with dot11MultiBSSIDImplemented equal to true shall not send an HE NDP Announcement frame with the TA field set to the transmitted BSSID to a non-AP STA that is associated with an AP corresponding to a nontransmitted BSSID in the multiple BSSID set, unless the AP has received from the non-AP STA an HE Capabilities element with the Rx Control Frame To MultiBSS subfield in the HE MAC Capabilities Information field equal to 1. An AP with dot11MultiBSSIDImplemented equal to true shall not send an individually addressed HE NDP Announcement frame with the TA field set to the transmitted BSSID to a non-AP STA associated with an AP corresponding to a nontransmitted BSSID.

An AP that transmits an HE NDP Announcement frame identifying HE STAs shall set the TA field of the frame to the MAC address of the AP, unless dot11MultiBSSIDImplemented is true and the HE NDP Announcement frame identifies STAs from at least two different BSSs of the multiple BSSID set. In this case, the AP shall set the TA field of the frame to the transmitted BSSID. If the HE NDP Announcement frame is transmitted in a non-HT duplicate PPDU, then the TA field of the HE NDP Announcement frame is a bandwidth signaling TA (see 10.6.6.6 (Channel Width selection for Control frames)).

An HE beamformer that transmits an HE NDP Announcement frame to an HE beamformee that is an AP, TDLS peer STA, mesh STA, or IBSS STA shall include one STA Info field in the HE NDP Announcement frame and shall set the AID11 field in the STA Info field of the frame to 0.

An HE beamformer that is an AP and that transmits an HE NDP Announcement frame to one or more HE beamformees shall set the AID11 field in the STA Info field identifying a non-AP STA to the 11 LSBs of the AID of the non-AP STA.

An HE NDP Announcement frame shall not include multiple STA Info fields that have the same value in the AID11 subfield.

An HE beamformer that transmits an HE NDP Announcement frame initiating an HE TB sounding sequence may include a STA Info field with an AID11 subfield value of 2047 to indicate disallowed subchannels during punctured channel operation. When present, the STA Info field with AID11 value of 2047 shall be the first STA Info field in the frame. An HE beamformer that transmits an HE NDP Announcement frame shall not include more than one STA Info field with an AID11 subfield value of 2047. An HE beamformer that transmits an HE NDP Announcement frame initiating a HE non-TB sounding sequence shall not include a STA Info field with an AID11 subfield value of 2047.


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In an HE TB sounding sequence, a STA Info field in the HE NDP Announcement frame that solicits SU or MU feedback indicates the subcarrier grouping (*Ng*), codebook size, and number of columns (*Nc*) to be used by the HE beamformee identified by the STA Info field for the generation of the SU or MU feedback.

In an HE non-TB sounding sequence where the STA Info field in the HE NDP Announcement frame solicits SU feedback, the *Ng*, codebook size, and the *Nc* used for the generation of the SU feedback are determined by the HE beamformee.

In an HE TB sounding sequence, a STA Info field in the HE NDP Announcement frame that solicits CQI feedback indicates the *Nc* to be used by the HE beamformee identified by the STA Info field for the generation of the CQI feedback.

In an HE non-TB sounding sequence where the STA Info field in the HE NDP Announcement frame solicits CQI feedback, the *Nc* used for the generation of the CQI feedback is determined by the HE beamformee.

An HE beamformer that has initiated an HE TB sounding sequence (#2345)shall transmit a BFRP Trigger frame to solicit feedback and may send one or more additional BFRP Trigger frames in the same TXOP as shown in Figure 26-8 (Example of HE TB sounding(11ax)). The HE beamformer uses the additional BFRP Trigger frames to solicit HE compressed beamforming/CQI reports from HE beamformees not addressed in a previous BFRP Trigger frame or to solicit retransmission of an HE compressed beamforming/CQI report. An HE beamformer shall not transmit a BFRP Trigger frame that identifies a STA identified in the HE NDP Announcement frame of an HE TB sounding sequence, unless it is in the same TXOP as the HE TB sounding sequence.

An HE beamformer that transmits an HE NDP Announcement frame as part of an HE TB sounding sequence shall set the Nc subfield of the STA Info field to indicate a value less than or equal to the minimum of the following:

— The maximum number of supported spatial streams according to the corresponding HE beamformee's Rx HE-MCS Map ≤ 80 MHz, Rx HE-MCS Map 160 MHz, and Rx HE-MCS Map 80+80 MHz subfields in the Supported HE-MCS And NSS Set field in the HE Capabilities element sent by the HE beamformee.

— The maximum number of supported spatial streams according to the Rx NSS subfield value in the most recently received Operating Mode Notification frame, Operating Mode Notification element with the Rx NSS Type subfield equal to 0, or OM Control subfield sent by the corresponding HE beamformee (see 26.9 (Operating mode indication)).

— The maximum *Nc* indicated by the Max Nc subfield in the HE PHY Capabilities Information field in the HE Capabilities element sent by the HE beamformee.

An HE beamformer that transmits an HE NDP Announcement frame shall set the RU Start Index and RU End Index subfields in a STA Info field to indicate the starting 26-tone RU and the ending 26-tone RU, respectively, of the solicited HE compressed beamforming/CQI report (see 9.3.1.19 (VHT/HE/Ranging NDP Announcement frame format(11ax)(11az))). For preamble punctured sounding, the RU Start Index and RU End Index correspond to the bandwidth before puncturing, and the Disallowed Subchannel Bitmap subfield is used to indicate the subcarriers that are punctured in the HE sounding NDP and in the solicited feedback.

NOTE 1—In order to maximize the channel estimate quality after interpolation/extrapolation resulting from grouping, the subcarriers for which feedback is requested using the RU Start Index and RU End Index subfields do not necessarily lie within the actual RU as defined in Table 27-8 (Data and pilot subcarrier indices for RUs in a 20 MHz HE PPDU and in a non-OFDMA 20 MHz HE PPDU(11ax)), Table 27-9 (Data and pilot subcarrier indices for RUs in a 40 MHz HE PPDU and in a non-OFDMA 40 MHz HE PPDU(11ax)), and Table 27-10 (Data and pilot subcarrier indices for RUs in an 80 MHz HE PPDU and in a non-OFDMA 80 MHz HE PPDU(11ax)). Rather, they are defined in Table 9-124 (Subcarrier indices scidx(0) and scidx(Ns – 1) for Ng = 4(11ax)) and Table 9-125 (Subcarrier indices scidx(0) and scidx(Ns – 1) for Ng = 16(11ax)).

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(#2337)The bandwidth of the PPDU carrying the HE NDP Announcement frame is obtained from the RXVECTOR parameter CH_BANDWIDTH of the HE NDP Announcement frame if received in an HE, VHT, or HT PPDU; is obtained from the RXVECTOR parameter CH_BANDWIDTH_IN_NON_HT if the HE NDP Announcement frame is received in a non-HT duplicate PPDU; and is 20 MHz if the HE NDP Announcement frame is received in a non-HT PPDU.

In an HE non-TB sounding sequence, an HE beamformer shall solicit full-bandwidth feedback. In an HE TB sounding sequence, an HE beamformer shall solicit full-bandwidth feedback in a STA Info field identifying an HE beamformee that has not indicated support for partial-bandwidth feedback. In an HE TB sounding sequence, an HE beamformer may solicit full-bandwidth or partial-bandwidth feedback in a STA Info field identifying an HE beamformee that has indicated support for partial-bandwidth feedback (see 26.7.2 (HE sounding protocol)).

For 80+80 MHz, feedback is not requested for the gap between the 80 MHz segments.

The HE beamformer shall set the TXVECTOR parameter CH_BANDWIDTH or CH_BANDWIDTH_IN_NON_HT, the RU Start Index field, and the RU End Index field of the HE NDP Announcement frame, depending on the operating channel width and partial BW support of the HE beamformee, as defined in Table 26-4 (Settings for BW, RU Start Index, and RU End Index fields in HE NDP Announcement frame(11ax)). (#2337)The bandwidth of the PPDU carrying the HE NDP Announcement frame is determined before applying puncturing based on disallowed subchannels.

**Table 26-4—Settings for BW, RU Start Index, and RU End Index fields in HE NDP Announcement frame(11ax)**

| Partial bandwidth supported by HE beamformer | Operating channel width of the HE beamformee (MHz) | Bandwidth of HE NDP Announcement frame | RU Start Index field | RU End Index field |
|---|---|---|---|---|
| No | 20, 40, 80, 160/80+80 | 20 MHz | 0 | 8 |
| Yes | 20, 40, 80, 160/80+80 | | 0–8 | 0–8 |
| No | 40, 80, 160/80+80 | 40 MHz | 0 | 17 |
| Yes | 40, 80, 160/80+80 | | 0–17 | 0–17 |
| No | 80, 160/80+80 | 80 MHz | 0 | 36 |
| Yes | 80, 160/80+80 | | 0–36 | 0–36 |
| No | 160/80+80 | 160 MHz or 80+80 MHz | 0 | 73 |
| Yes | 160/80+80 | | 0–73 | 0–73 |

NOTE 1—The value of the RU Start Index field is always less than or equal to the value of the RU End Index field.

NOTE 2—Partial BW feedback can be solicited only with an HE TB sounding sequence and cannot be solicited with an HE non-TB sounding sequence.


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The HE beamformer shall use the lowest 26-tone RU, which is the lower bound of the starting 26-tone in the RU Start Index subfield of a STA Info field that is equal to the maximum of the following:

— The minimum 26-tone RU located within the channel width indicated in the VHT Operation Information field of either the HE Operation element or the VHT Operation element, whichever is present, and within the channel width indicated in the HT Operation element.

— The minimum 26-tone RU located within the channel width indicated in the most recently received Operating Mode Notification frame, Operating Mode Notification element with the Rx NSS Type subfield equal to 0, or OM Control subfield sent by the corresponding HE beamformee (see 26.9 (Operating mode indication)).

The HE beamformer shall use the highest 26-tone RU, which is the upper bound of the ending 26-tone RU in the RU End Index subfield of a STA Info field that is equal to the minimum of the following:

— The maximum 26-tone RU located within the channel width indicated in the VHT Operation Information field of either the HE Operation element or the VHT Operation element, whichever is present, and within the channel width indicated in the HT Operation element.

— The maximum 26-tone RU located within the channel width indicated in the most recently received Operating Mode Notification frame, Operating Mode Notification element with the Rx NSS Type subfield equal to 0, or OM Control field sent by the corresponding HE beamformee (see 26.9 (Operating mode indication)).

In an HE non-TB sounding sequence soliciting SU feedback, B26 (in the Feedback Type And Ng subfield), the Codebook Size subfield, and the Nc subfield in the STA Info field of the HE NDP Announcement frame are reserved.

In an HE non-TB sounding sequence soliciting CQI feedback, the Nc subfield in an HE NDP Announcement frame is reserved.

An HE beamformee that receives an HE NDP Announcement frame soliciting SU feedback as part of an HE non-TB sounding sequence shall generate an HE compressed beamforming/CQI report for SU feedback with *Nc* in the range 1 to 8, *Ng* = 4 or *Ng* = 16, and codebook size ($\phi$, $\psi$) = {4, 2} or ($\phi$, $\psi$) = {6, 4}. The HE beamformee shall transmit the HE compressed beamforming/CQI report a SIFS after the HE sounding NDP.

An HE beamformee that receives an HE NDP Announcement frame soliciting CQI feedback as part of an HE non-TB sounding sequence shall generate an HE compressed beamforming/CQI report for CQI feedback with *Nc* determined by the HE beamformee.

An HE beamformee that receives an HE NDP Announcement frame soliciting CQI feedback as part of an HE TB sounding sequence shall generate an HE compressed beamforming/CQI report for CQI feedback with *Nc* determined by the HE beamformer.

An HE beamformee that receives an HE NDP Announcement frame from an HE beamformer with which it is associated and that contains the HE beamformee's MAC address in the RA field (indicating a non-TB sounding sequence) and also receives an HE sounding NDP a SIFS after the HE NDP Announcement frame shall transmit its HE compressed beamforming/CQI report a SIFS after the HE sounding NDP. The TXVECTOR parameter CH_BANDWIDTH for the PPDU containing the HE compressed beamforming/ CQI report shall be set to indicate a bandwidth not wider than that indicated by the RXVECTOR parameter CH_BANDWIDTH of the HE sounding NDP.

An HE beamformee that receives an HE NDP Announcement frame as part of an HE TB sounding sequence with a STA Info field identifying it soliciting SU or MU feedback shall generate an HE compressed beamforming/CQI report using the feedback type, *Ng*, codebook size, and *Nc* indicated in the STA Info field. If the HE beamformee then receives a BFRP Trigger frame with a matching STA Info field, the HE beamformee transmits an HE TB PPDU containing the HE compressed beamforming/CQI report following

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the rules defined in 26.5.2.3 (Non-AP STA behavior for UL MU operation). If the HE NDP Announcement frame has the TA field set to the transmitted BSSID and the HE beamformee is a non-AP STA associated with an AP corresponding to a nontransmitted BSSID that supports receiving Control frames with TA field set to the transmitted BSSID, then the (#6006)HE Compressed Beamforming/CQI frame(s) sent in response shall have the RA field set to as defined in 26.5.2.3.5 (RA field for frames carried in an HE TB PPDU).

NOTE 2—A non-AP HE beamformee that transmits an OM Control subfield with the UL MU Disable field set to 1 does not respond to BFRP Trigger frames (see 26.9 (Operating mode indication)).

An HE beamformee that is a non-AP STA that transmits an HE Compressed Beamforming/CQI frame(#6006) shall set the RU Start Index and RU End Index subfields of the HE MIMO Control field to indicate the range of tones for which compressed beamforming/CQI information is provided. If the HE NDP Announcement frame that solicited the feedback includes a Disallowed Subchannel Bitmap field with a nonzero value, then a beamformee that indicates support for punctured sounding by setting the Punctured Sounding Support subfield in the HE Capabilities elements that it transmits to 1 shall include a Disallowed Subchannel Bitmap subfield in the solicited feedback with the same value as the Disallowed Subchannel Bitmap subfield of the HE NDP Announcement frame that solicited the feedback to indicate subcarriers for which feedback information is not provided from within the range of subcarriers indicated by the RU Start Index and RU End Index subfields.

An HE beamformee that transmits HE compressed beamforming/CQI report shall include neither the HE Compressed Beamforming Report field nor the HE MU Exclusive Beamforming Report field in the HE Compressed Beamforming/CQI Report field if the transmission duration of the PPDU carrying the HE Compressed Beamforming/CQI Report field would exceed the maximum PPDU duration. In this case, the HE Compressed Beamforming/CQI frame does not include the HE Sounding Feedback Segment field.(#6006)

The Sounding Dialog Token Number field in the HE MIMO Control field shall be set to the same value as the Sounding Dialog Token Number field in the corresponding HE NDP Announcement frame.

An HE beamformer that sends a BFRP Trigger frame shall set the Feedback Segment Retransmission Bitmap fields of the BFRP Trigger frame to all 1s, except when the HE beamformer intends to solicit the retransmission of segmented feedback as defined in 26.7.4 (Rules for generating segmented feedback).

NOTE 3—The BFRP Trigger frame contains one or more User Info fields, each of which identifies an HE beamformee.

The SNR per subcarrier computation (#161)should be done on at least 4 subcarriers in a 26-tone RU.

### 26.7.4 Rules for generating segmented feedback

(#6006)The HE Sounding Feedback Segment field consists of bits in octet number $N1$ to octet number $N2$ of the HE Compressed Beamforming/CQI Report field (see 9.4.1.66 (HE Compressed Beamforming/CQI Report field(#6006))). Let $L_{HCBCR}$ denote the length of the HE Compressed Beamforming/CQI Report field in octets.

(#6006)If the HE Compressed Beamforming/CQI Report field would result in an HE Compressed Beamforming/CQI frame that does not exceed 11 454 octets in length, then the HE Compressed Beamforming/CQI Report field shall be included in a single HE Sounding Feedback Segment field. In this case, $N1 = 1$ and $N2 = L_{HCBCR}$ for the HE Sounding Feedback Segment field.

(#6006)If the HE Compressed Beamforming/CQI Report field would result in an HE Compressed Beamforming/CQI frame that exceeds 11 454 octets in length, then the HE Compressed Beamforming/CQI Report field shall be split into $K$ HE Sounding Feedback Segment fields. Let $L$ be the length of the HE Sounding Feedback Segment field in octets that results in the length of the HE Compressed Beamforming/


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CQI frame being 11 454 octets (see NOTE 1). Then, the number of HE Sounding Feedback Segment fields is $K$ = Ceil ($L_{HCBCR}$ / $L$). For the $k$-th HE Sounding Feedback Segment field that is not the last HE Sounding Segment field ($k$ = 1, …, $K$-1), $N1 = (k\text{-}1) \times L + 1$ and $N2 = k \times L$. For the last HE Sounding Segment field, $N1 = (K\text{-}1) \times L + 1$ and $N2 = L_{HCBCR}$ (see NOTE 3). Each HE Sounding Feedback Segment field shall be included in a separate HE Compressed Beamforming/CQI frame. Each HE Sounding Feedback Segment field is identified by the value of the Remaining Feedback Segments subfield and the First Feedback Segment subfield in the HE MIMO Control field in the HE Compressed Beamforming/CQI frame containing the HE Sounding Feedback Segment field as defined in 9.4.1.62 (HE MIMO Control field(11ax)); the other nonreserved subfields of the HE MIMO Control field shall be the same for all HE Compressed Beamforming/CQI frames carrying different HE Sounding Feedback Segment fields of the same HE Compressed Beamforming/CQI Report field. All HE Compressed Beamforming/CQI frames carrying different portions of the same HE Compressed Beamforming/CQI Report field shall be sent in a single A-MPDU contained in a PPDU and shall be included in the A-MPDU in the descending order of the Remaining Feedback Segments subfield values.

NOTE 1—An HE Sounding Feedback Segment field together with the other fields in the Frame Body field of the HE Compressed Beamforming/CQI frame (see Figure 9-128 (Management frame format) and Table 9-643 (HE Action field values(#3764)(11ax)), constitutes a single unfragmented MMPDU.(#6006)

NOTE 2—The maximum length of the HE Compressed Beamforming/CQI Report field is 30 008 octets (160 MHz MU type feedback with 8 columns, 8 rows, $Ng$ = 4 and ($\phi$, $\psi$) = {9, 7} bits, see Table 9-122 (HE MIMO Control field encoding(11ax))). Therefore, the maximum number of the HE Compressed Beamforming/CQI frames needed to carry an HE Compressed Beamforming/CQI Report field is 3.(#6006)

NOTE 3—This results in all HE Sounding Feedback Segment fields that are not the last HE Sounding Segment field to have equal length. All HE Compressed Beamforming/CQI frames that do not contain the last HE Sounding Feedback Segment field have equal length of 11 454 octets. The last HE Sounding Feedback Segment field might have length smaller than the other HE Sounding Feedback Segment fields. The HE Compressed Beamforming/CQI frame containing the last HE Sounding Feedback Segment field has a length less than or equal to 11 454 octets.(#6006)

An HE beamformer that sends a BFRP Trigger frame, in its first attempt to retrieve an HE compressed beamforming/CQI report from an HE beamformee, shall solicit all possible feedback segments by setting all of the bits in the Feedback Segment Retransmission Bitmap subfield to 1 in the User Info field identifying the HE beamformee.

An HE beamformer that fails to receive some or all of the feedback segments of the HE compressed beamforming/CQI report from the HE beamformee may solicit the selective retransmission of missing feedback segments by sending a BFRP Trigger frame that indicates in the Feedback Segment Retransmission Bitmap subfield of the User Info field identifying the HE beamformee the list of feedback segments solicited for retransmission (see 9.3.1.22.3 (BFRP Trigger frame format)).

NOTE 4—In an HE non-TB sounding sequence, if the HE beamformer does not receive all feedback segments from the HE beamformee, the HE beamformer cannot use a BFRP Trigger frame to request retransmission of the feedback segments. In this case the HE beamformee can only repeat the entire non-TB sounding sequence.

An HE beamformer that fails to receive the first feedback segment (identified by the First Feedback Segment field set to 1), may solicit the selective retransmission of the missing feedback segments assuming the HE Compressed Beamforming/CQI Report field(#6006) is split into 8 feedback segments. The HE beamformer may also solicit the retransmission of all feedback segments by setting all of the bits in the Feedback Segment Retransmission Bitmap subfield to 1 in the User Info field identifying the HE beamformee.

An HE beamformee that transmits an HE compressed beamforming/CQI report including the HE Compressed Beamforming Report information and any HE MU Exclusive Beamforming Report information in response to a BFRP Trigger frame shall either transmit only the feedback segments indicated in the Feedback Segment Retransmission Bitmap field in the User Info field of the BFRP Trigger frame

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identifying the HE beamformee or transmit all the feedback segments available at the HE beamformee, excluding the feedback segments that do not exist at the HE beamformee.

NOTE 5—If an HE beamformer solicits the missing feedback segments from a beamformee and does not receive a response from the beamformee, the HE beamformer might either initiate an HE TB sounding sequence or transmit an additional BFRP Trigger frame to the HE beamformee.

### 26.7.5 HE sounding NDP transmission

The TXVECTOR parameters for an HE sounding NDP shall be set as follows:

- FORMAT is set to HE_SU.
- APEP_LENGTH is set to 0.
- HE_LTF_TYPE is set to either 2xHE-LTF or 4xHE-LTF.
- If HE_LTF_TYPE is 2xHE-LTF, then GI_TYPE is set to either 0u8s_GI or 1u6s_GI.
- If HE_LTF_TYPE is 4xHE-LTF, then GI_TYPE is set to 3u2s_GI.
- NUM_STS indicates two or more space-time streams if the Feedback Type field in the HE MIMO Control field of the preceding HE NDP Announcement frame indicates either SU or MU, or one or more space-time streams if the Feedback Type field in the HE MIMO Control field of the preceding HE NDP Announcement frame indicates CQI.
- CH_BANDWIDTH is set to the same value as the TXVECTOR parameter CH_BANDWIDTH in the preceding HE NDP Announcement frame.
- INACTIVE_SUBCHANNELS is set to the value of the Disallowed Subchannel Bitmap subfield of the STA Info field with the AID11 subfield set to 2047 in the preceding HE NDP Announcement frame.
- SPATIAL_REUSE is set to PSR_AND_NON_SRG_OBSS_PD_PROHIBITED (see 26.11.6 (SPATIAL_REUSE)).
- BSS_COLOR is set to the value indicated in the BSS Color subfield of the HE Operation element received or transmitted by the HE AP.
- TXOP_DURATION set to either 127 or a value defined in Equation (26-3).

$$\max\left(\min\left(8\left\lfloor\frac{\lceil D_{\text{HE\_NDPA}} - \text{SIFS} - \text{TXTIME}\rceil}{8}\right\rfloor, 504\right), \min\left(128\left\lfloor\frac{\lceil D_{\text{HE\_NDPA}} - \text{SIFS} - \text{TXTIME}\rceil}{128}\right\rfloor, 8448\right)\right) \quad (26\text{-}3)$$

where

$D_{\text{HE\_NDPA}}$ is the value of the Duration/ID field in the MAC header of the preceding HE NDP Announcement frame

TXTIME is the transmission time of an HE sounding NDP defined in Equation (27-149)

The Supported HE-MCS and NSS Set field in the HE Capabilities element transmitted by the transmitter and the receiver of the HE sounding NDP do not affect the values used for the NUM_STS parameter for the TXVECTOR of an HE sounding NDP.

The destination of an HE sounding NDP is equal to the RA of the immediately preceding HE NDP Announcement frame.

The source of an HE sounding NDP is equal to the TA of the immediately preceding HE NDP Announcement frame.


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## 26.8 TWT operation

### 26.8.1 General

Target wake time (TWT) allows an AP to manage activity in the BSS in order to minimize contention between STAs and to reduce the required amount of time that a STA utilizing a power management mode needs to be awake. This is achieved by allocating STAs to operate at nonoverlapping times and/or frequencies, and concentrate the frame exchange sequences(#109) in predefined service periods.

An HE STA negotiates individual TWT agreements, as defined in 10.46 (Target wake time (TWT)), subject to the additional rules and restrictions that are defined in 26.8.2 (Individual TWT agreements) and 26.8.7 (HE subchannel selective transmission). A non-AP HE STA establishes membership in broadcast TWT schedules, as defined in 26.8.3 (Broadcast TWT operation), which are used as defined in 26.8.3.3 (Rules for TWT scheduled STA), 26.14.2 (Power save with UORA and TWT), and 26.14.3 (Opportunistic power save). An HE AP delivers broadcast TWT parameter sets to non-AP HE STAs as described in 26.8.3.2 (Rules for TWT scheduling AP), 26.14.2 (Power save with UORA and TWT), and 26.14.3 (Opportunistic power save).

A STA does not need to be aware of the values of TWT parameters of the TWT agreements of other STAs in the BSS of the STA or of TWT agreements of STAs in other BSSs. A STA does not need to be aware that a TWT service period (SP) is used to exchange frames with other STAs. Frames transmitted during a TWT SP are carried in any PPDU format supported by the pair of STAs that have established the TWT agreement corresponding to that TWT SP, including HE MU PPDU, HE TB PPDU, etc.

An HE STA with dot11TWTOptionImplemented equal to true shall set the following:

— The TWT Requester Support subfield to 1 in the HE Capabilities element that it transmits if it supports operating in the role of a TWT requesting STA; otherwise, to 0.

— The TWT Responder Support subfield to 1 in the HE Capabilities elements that it transmits if it supports operating in the role of a TWT responding STA; otherwise, to 0.

— The Broadcast TWT Support subfield to 1 in the HE Capabilities element that it transmits if it supports operating in the role of a TWT scheduled STA or in the role of a TWT scheduling AP; otherwise, to 0.

An HE AP shall set the TWT Responder Support subfield of the Extended Capabilities element and HE Capabilities element to 1.

An HE AP may request TWT participation by all associated STAs that have declared support for TWT. A non-AP STA declares support for the role of TWT requesting STA by setting the TWT Requester Support subfield in the Extended Capabilities element or in the HE Capabilities element to 1 and declares support for the role of TWT scheduled STA by setting the Broadcast TWT Support subfield in the HE Capabilities element to 1. The HE AP makes the request for TWT participation by setting the TWT Required subfield to 1 in HE Operation elements it transmits. A STA that supports TWT and that has received an HE Operation element with the TWT Required subfield equal to 1 from the HE AP with which it is associated shall either negotiate individual TWT agreements, as defined in 26.8.2 (Individual TWT agreements), or participate in broadcast TWT operation, as defined in 26.8.3 (Broadcast TWT operation).

NOTE—The AP sets the TWT Required subfield to 1 if it is not available outside TWT SPs (see 26.8.2 (Individual TWT agreements) and 26.8.3 (Broadcast TWT operation)). The AP might not be available outside TWT SPs if it sets the Responder PM Mode subfield to 1 (see 10.46.7 (TWT Sleep setup).

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### 26.8.2 Individual TWT agreements

An HE STA may negotiate individual TWT agreements with another HE STA as defined in 10.46.1 (TWT overview), except that the STA

- May set the Responder PM Mode subfield to 1 if it is a TWT responding STA that intends to go to doze state outside of TWT SPs.
  - If the TWT responding STA is an AP then it may set the Responder PM Mode subfield to 1 only if all non-AP STAs that are associated to it indicate support of TWT and the AP has set the TWT Required subfield to 1 in the HE Operation element it transmits; otherwise, it shall set the Responder PM Mode subfield to 0.
  - An AP that sets the Responder PM Mode subfield to 1 follows the rules defined in 10.46.7 (TWT Sleep setup).
- Shall set the Implicit subfield to 1 and the NDP Paging Indicator/Unavailability Mode(#4010) subfield to 0 in all TWT elements that it transmits during the TWT setup.
- May set the Trigger subfield to 1 in the TWT element it transmits during the TWT setup to negotiate a trigger-enabled TWT.
  - A successful TWT agreement whose Trigger subfield in the TWT response sent by the AP is 1 is a trigger-enabled TWT; otherwise, it is not a trigger-enabled TWT.
- Shall set the TWT Channel subfield in the TWT element it transmits to 0, unless the HE STA sets up a subchannel selective transmission operation as defined in 26.8.7 (HE subchannel selective transmission).
- May set the TWT Protection field to 1 to indicate that TXOPs within the TWT SPs shall be initiated with a NAV protection mechanism, such as (MU) RTS/CTS or CTS-to-self frame; otherwise, it shall set it to 0.
- Shall not use the RAW mechanism for protection of TWT SPs.

NOTE 1—Whether the Responder PM Mode subfield is set to 0 or 1, the AP unavailability both inside and outside of the TWT SP is affected by any advertised broadcast TWT element with Broadcast TWT ID subfield equal to 0 and with Responder PM Mode subfield equal to 1 (see 26.8.3.2 (Rules for TWT scheduling AP)).(#4010)

An HE STA that successfully sets up a TWT agreement with another HE STA shall follow the rules defined in 10.46.1 (TWT overview) and 10.46.4 (Implicit TWT operation) except that all the additional rules defined in 26.8 (TWT operation) supersede all the respective rules defined in 10.46.1 (TWT overview) and 10.46.4 (Implicit TWT operation). A TWT or TWT SP that is set up under an implicit TWT agreement is an implicit TWT or implicit TWT SP, respectively (see 10.46.1 (TWT overview)). A TWT or TWT SP that is set up under a trigger-enabled TWT agreement is a trigger-enabled TWT or trigger-enabled TWT SP, respectively. The TWT responding STA of a trigger-enabled TWT agreement is an HE AP.

An example of individual TWT operation is shown in Figure 26-9 (Example of individual TWT operation(11ax)), where the AP is the TWT responding STA and STA 1 and STA 2 are the TWT requesting STAs.

In this example, STA 1 sends a TWT request to the TWT responding STA to setup a trigger-enabled TWT agreement. The TWT responding STA accepts the TWT agreement with STA 1 and confirms the acceptance in the TWT response sent to STA 1. Subsequently, the TWT responding STA sends an unsolicited TWT response to STA 2 to set up a trigger-enabled TWT agreement with STA 2. Both these TWT agreements are set up as announced TWTs. During the trigger-enabled TWT SP, the TWT responding STA sends a Basic Trigger frame to which the TWT requesting STAs indicate that they are awake during the TWT SP. STA 1 indicates that it is awake by sending a PS-Poll frame, and STA 2 indicates that it is awake by sending a QoS Null frame in response to the Basic Trigger frame. STA 1 and STA 2 receive their DL BUs in a subsequent exchange with the TWT responding STA and go to doze state outside of this TWT SP.


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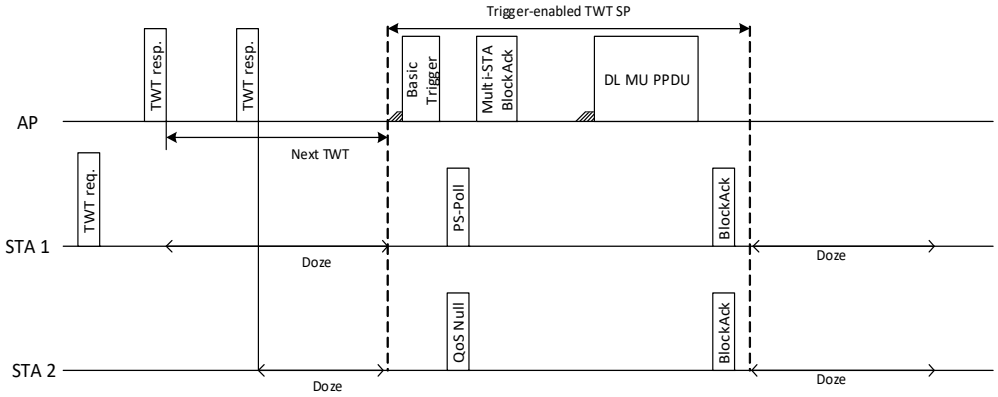


**Figure 26-9—Example of individual TWT operation(11ax)**

An HE STA may execute the individual TWT setup exchanges defined in Table 26-5 (TWT setup exchange for unsolicited TWT and recommended broadcast TWT switch (11ax)) in addition to the exchanges defined in 10.46 (Target wake time (TWT)). An HE STA that intends to set up an individual TWT shall set the Negotiation Type subfield to 0 as defined in 10.46 (Target wake time (TWT)) or as defined in Table 26-5 (TWT setup exchange for unsolicited TWT and recommended broadcast TWT switch (11ax)). The HE STA may respond to the TWT request with a TWT response that has the Negotiation Type subfield equal to 3 as indicated in Table 26-5 (TWT setup exchange for unsolicited TWT and recommended broadcast TWT switch (11ax)) to provide recommended broadcast TWT schedules for the requesting STA.

**Table 26-5—TWT setup exchange for unsolicited TWT and recommended broadcast TWT switch (11ax)**

| TWT Setup Command field in an initiating frame | TWT Setup Command field in a response frame | TWT condition after the completion of the exchange |
|---|---|---|
| Request TWT, Suggest TWT, or Demand TWT with Broadcast subfield = 0 | Accept TWT with Broadcast subfield = 1 | This response is not allowed. |
| Request TWT, Suggest TWT, or Demand TWT with Broadcast subfield = 0 | Dictate TWT with Broadcast subfield = 1 | No individual TWT agreement exists with the associated TWT Flow identifier. One or more broadcast TWT schedules exist that use the TWT parameters identified in the response frame including a Broadcast TWT ID. The broadcast TWT schedules are not necessarily newly created. The responding STA does(M118) not create any new individual TWT agreement with the requester at this time. The STA transmitting the initiating frame is not a member of the broadcast TWT; however, the STA (#161)may join any of the broadcast TWT schedules. |
| Accept TWT with Broadcast subfield set to 0 | No frame transmitted | The STA receiving this frame now has an individual TWT agreement with the transmitter of the frame where the parameters of the individual TWT agreement are identified by the initiating frame. |

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**Table 26-5—TWT setup exchange for unsolicited TWT and recommended broadcast TWT switch *(continued)*(11ax)**

| TWT Setup Command field in an initiating frame | TWT Setup Command field in a response frame | TWT condition after the completion of the exchange |
|---|---|---|
| Alternate TWT or Dictate TWT with Broadcast subfield = 0 | No frame transmitted | The STA receiving this frame is not, through the receipt of this frame, a member of the TWT identified by the initiating frame but can use the information provided to create a request to set up a TWT in a subsequent initiating frame that it transmits. |
| NOTE 1—The Negotiation Type subfield in the TWT element contained in these frames is 0 if the Broadcast subfield is 0 and is 3 if the Broadcast subfield is 1.<br>NOTE 2—The initiating frame and response frame settings not listed in the tables in 10.46 (Target wake time (TWT)) or 26.8 (TWT operation) are not allowed. The initiating frame is a TWT request if the TWT element carried in the frame has the TWT Request field set to 1; otherwise, it is a TWT response (see Table 9-347 (TWT Setup Command field values(11ax))). The response frame is a TWT response if the TWT element contained in the frame has the TWT Request field equal to 0. | | |

An HE STA that successfully sets up an individual TWT agreement and operates in PS mode may listen to Beacon frames, but is exempt from the requirements for receiving Beacon frames as defined in 11.2.3.1 (General). The HE STA follows the rules in 11.2.3 (Power management in a non-DMG infrastructure network) to receive group addressed frames.

NOTE 2—An HE AP sets the bit in the TIM element of the Beacon frame that corresponds to the AID of the TWT requesting STA to 1 to indicate the presence of available buffered BUs for the STA (see 11.2.3.7 (Receive operation for STAs in PS mode)).

NOTE 3—The TWT responding STA might inform the TWT requesting STA, if it supports TIM Broadcast, of any critical update (as defined in 11.2.3.14 (TIM Broadcast)) by sending a Management frame to the TWT requesting STA when the STA is in the awake state.

An HE STA may tear down an individual TWT agreement by sending a TWT Teardown frame with the Negotiation Type subfield set to 0. An HE STA may tear down all individual TWT agreements by sending a TWT Teardown frame with the Teardown All TWT field set to 1.

An HE AP may send an unsolicited TWT response with the Trigger subfield equal to 1 to a non-AP HE STA that has set the TWT Requester Support subfield to 1 in the HE Capabilities elements that it transmits to the AP. The TWT response shall have one of these values in the TWT Setup Command field: Accept TWT, Alternate TWT, or Dictate TWT. An unsolicited TWT response with TWT Setup Command field of Alternate TWT or Dictate TWT contains an advisory notification to the recipient of TWT parameters that are likely to be accepted by the AP if the recipient transmits a subsequent TWT request to the AP that includes those TWT parameters. An unsolicited TWT response with the TWT Setup Command field of Accept TWT creates a TWT agreement between the two STAs. A STA that receives an unsolicited TWT response with the TWT Setup Command field of Accept TWT may transmit a TWT Teardown frame to delete the unsolicited individual TWT agreement.

NOTE 4—The HE AP might send an unsolicited TWT response to a non-AP HE STA with a TWT Flow Identifier that corresponds to an existing TWT agreement. The unsolicited TWT response with TWT Setup Command field of Accept TWT (M118)indicates new TWT parameters that are different from the previously negotiated TWT parameters for that TWT agreement.

An HE STA shall not transmit BAT, TACK, or STACK frames, which are allowed in 10.46.2 (TWT acknowledgment procedure).


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A TWT requesting STA should not transmit frames to the TWT responding STA outside of negotiated TWT SPs and should not transmit frames that are not contained within HE TB PPDUs to the TWT responding STA within trigger-enabled TWT SPs.

NOTE 5—The TWT requesting STA decides which frames to transmit within or outside a TWT SP; and while it is recommended that the TWT requesting STA not transmit using EDCA within or outside TWT SPs, the TWT requesting STA might still do so. If the STA decides to transmit, then the STA might contend for access to the medium as defined in 10.23.2 (HCF contention based channel access (EDCA)) and in 26.2.7 (EDCA operation using MU EDCA parameters).

The TWT responding STA of a trigger-enabled TWT agreement shall schedule for transmission a Trigger frame for the TWT requesting STA, as described in 26.5.2 (UL MU operation), within each TWT SP for that TWT agreement, except that the Trigger frame may be replaced by a frame carrying a TRS Control subfield, provided that the frame is carried in a DL MU PPDU and the AP allocates enough resources in the HE TB PPDU for the STA to at least deliver its BSRs in response to the soliciting DL MU PPDU. The TWT responding STA should solicit buffer status reports from the TWT requesting STA at the start of the TWT SP following the procedure described in 26.5.5 (Buffer status report operation) or as described in 26.5.7 (NDP feedback report procedure). The TWT responding STA that intends to schedule for transmission additional Trigger frames during a trigger-enabled TWT SP shall set the More TF subfield in the Common Info field of the Trigger frame to 1 to indicate that it will schedule for transmission another Trigger frame within the same TWT SP. The TWT responding STA shall set the More TF subfield to 0 when the Trigger frame is the last scheduled Trigger frame of the TWT SP or when the Trigger frame is scheduled for transmission outside of a TWT SP.

NOTE 6—The TWT responding STA can cancel the transmission of a scheduled Trigger frame if the STA gains access to the wireless medium outside of the TWT SP. The TWT responding STA does not schedule for transmission a Trigger frame for the TWT requesting STA when the TWT agreement is not a trigger-enabled TWT agreement or when the TWT requesting STA has sent an OM Control subfield that has the UL MU Disable subfield equal to 1 (see 26.9 (Operating mode indication)).

NOTE 7—If the AP replaces the Trigger frame with a frame carrying a TRS Control field, then it is recommended that the AP allocate enough resources in subsequent Trigger frames sent during the TWT SP so that the STA can send as much as possible of the data reported in the BSR.

A TWT requesting STA transmits an HE TB PPDU as a response to a Trigger frame that identifies it and is sent during a trigger-enabled TWT SP (see 26.5.2 (UL MU operation)). A TWT requesting STA that is in PS mode and is awake shall include a PS-Poll frame or a U-APSD trigger frame in the HE TB PPDU if the TWT is an announced TWT, unless the STA has already transmitted a PS-Poll or U-APSD trigger frame or transmitted any other indication that the STA is in the awake state within that TWT SP or has, previous to the start of the TWT SP but after the end of the most recent TWT SP, indicated to the AP that it is currently in the awake state. The STA may include other frames in the HE TB PPDU when other rules do not prohibit their inclusion (see 26.5.2 (UL MU operation) and 9.7.3 (A-MPDU contents)).

NOTE 8–A Trigger frame identifies a TWT requesting STA if it is sent by the AP with which the STA is associated and the frame contains the 12 LSBs of the STA's AID in any of its User Info fields. The Trigger frame can have multiple recipients, each of which is identified by the presence of the 12 LSBs of the recipient's AID in any of its User Info fields (see 26.5.2 (UL MU operation)), and can have in the TA field the MAC address of the AP or the transmitted BSSID under the conditions defined in 26.5.2.2.4 (Allowed settings of the Trigger frame fields and TRS Control subfield).

NOTE 9—Other indications that the STA is in the awake state are the transmission of an HE TB feedback NDP in response to an NFRP Trigger frame (see 26.5.7 (NDP feedback report procedure)) or the transmission of a frame that indicates that the STA is in active mode (see 11.2.3.2 (Non-AP STA power management modes)).

A TWT responding STA that receives a PS-Poll frame or a U-APSD trigger frame or any other indication from a TWT requesting STA in PS mode, during or before an announced TWT SP but after the end of the most recent TWT SP, that the TWT requesting STA is in the awake state during the TWT SP shall follow the rules defined in 11.2.3.6 (AP operation), except that the TWT responding STA should deliver to the

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TWT requesting STA as many buffered BUs as are available at the TWT responding STA, provided that the BU delivery does not exceed the duration of the TWT SP, the TWT requesting STA has indicated that it is in the awake state for that TWT SP, and the TWT requesting STA has not entered the doze state (see 26.8.4.2 (TWT Information frame exchange for individual TWT) and 26.8.5 (Power save operation during TWT SPs)).

NOTE 10—The indication that the TWT requesting STA is in the awake state for that TWT SP might be a PS-Poll, U-APSD trigger frame, or any frame for which an immediate response is solicited and that follows the rules in 11.2.3.2 (Non-AP STA power management modes) but the corresponding immediate response frame is not received by the TWT requesting STA. Other indications that the STA is in the awake state are the transmission of an HE TB feedback NDP in response to an NFRP Trigger frame (see 26.5.7 (NDP feedback report procedure)) or the transmission of a frame that indicates that the STA is in active mode (see 11.2.3.2 (Non-AP STA power management modes)).

A TWT responding STA that sends frames to a TWT requesting STA that is in PS mode during an unannounced TWT SP shall follow the rules defined in 11.2.3.6 (AP operation), except that the TWT responding STA should deliver to the TWT requesting STA as many buffered BUs as are available at the TWT responding STA, provided that the BU delivery does not exceed the duration of the TWT SP and the TWT requesting STA has not entered the doze state (see 26.8.4.2 (TWT Information frame exchange for individual TWT) and 26.8.5 (Power save operation during TWT SPs)).

NOTE 11—The TWT responding STA can deliver the buffered BUs in A-MPDUs sent under a block ack agreement if the TWT is an announced TWT and the TWT requesting STA is awake for that TWT SP, or if the TWT is an unannounced TWT (at the start of which the TWT requesting STA is assumed to already be awake). The buffered BUs can be delivered in multiple PPDUs transmitted within the TWT SP. The TWT responding STA can transmit frames to TWT requesting STA after the end of the TWT SP if the STA is in active mode.

A TWT responding STA may transmit to a TWT requesting STA that is in active mode at any time (see 11.2.3.2 (Non-AP STA power management modes)). A TWT responding STA may transmit to a TWT requesting STA that is in PS mode and awake outside of a TWT SP following the rules in 11.2.3.6 (AP operation).

### 26.8.3 Broadcast TWT operation

#### 26.8.3.1 General

A TWT scheduling AP is an HE AP with dot11TWTOptionActivated equal to true that sets the Broadcast TWT Support field in the HE Capabilities element it transmits to 1 and that follows the rules for TWT scheduling APs in 26.8.3.2 (Rules for TWT scheduling AP), for power save with UORA and TWT in 26.14.2 (Power save with UORA and TWT), and for periodic opportunistic power save (OPS) defined in 26.14.3 (Opportunistic power save).

A TWT scheduling AP includes a broadcast TWT element in the Beacon frame as described in 26.8.3.2 (Rules for TWT scheduling AP). An AP corresponding to a nontransmitted BSSID in a multiple BSSID set shall follow the rules in 11.1.3.8.4 (Inheritance of element values(11ax)).

A TWT scheduling AP may include a TWT element with the Negotiation Type subfield equal to 3 in a (Re)Association Response frame or in a TWT setup frame to assign the recipient STA to a broadcast TWT schedule without having received a request from the STA to become a member of the broadcast TWT schedule if that STA has set the Broadcast TWT Support field of HE Capabilities element it transmits to 1.

A non-AP HE STA shall obtain TWT parameter values from the most recently received TWT element carried in a Beacon, Probe Response, or (Re)Association Response frame from its associated AP, unless the non-AP HE STA is associated with an AP corresponding to a nontransmitted BSSID of a multiple BSSID set. In this case, it shall follow the rules in 11.1.3.8.4 (Inheritance of element values(11ax)) to determine the TWT parameter values.


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(#7083)The non-AP HE STA determines the start time of subsequent TWTs of a TWT parameter set from the Target Wake Time field of the TWT parameter set contained in the received TWT element, (#8162)TSF timer, and the TWT wake interval (see 26.8.3.2 (Rules for TWT scheduling AP)).

NOTE—The Target Wake Time field carries only B10:B25 of the relevant target TSF time, and changes in B26:B63 of the corresponding TSF timer are not explicitly communicated to the receiving STA. Hence, the STA must consider when setting up a broadcast TWT schedule the rollover of B26:B63 of the target TSF time that might happen at the receiving STA during the lifetime of the broadcast TWT schedule (i.e., resulting from the Target Wake Time field and the Broadcast TWT Persistence field).(#7083)

A TWT scheduled STA is a non-AP HE STA that sets the Broadcast TWT Support field in the HE Capabilities element it transmits to 1 and receives a broadcast TWT element transmitted by an HE AP that is a TWT scheduling AP.

A TWT scheduled STA follows the schedule provided by the TWT scheduling AP as described in 26.8.3.3 (Rules for TWT scheduled STA) and, in addition, the rules in 26.14.2 (Power save with UORA and TWT) if the STA supports the UORA procedure and the rules in 26.14.3 (Opportunistic power save) if the STA supports OPS operation. A TWT scheduled STA can negotiate the wake TBTT and wake interval for Beacon frames it intends to receive as described in 26.8.6 (Negotiation of wake TBTT and wake interval) or can join a particular broadcast TWT as described below in this subclause.

An example of broadcast TWT operation is shown in Figure 26-10 (Example of broadcast TWT operation with optional TBTT negotiation(11ax)), where the AP is the TWT scheduling AP and STA 1 and STA 2 are the TWT scheduled STAs.

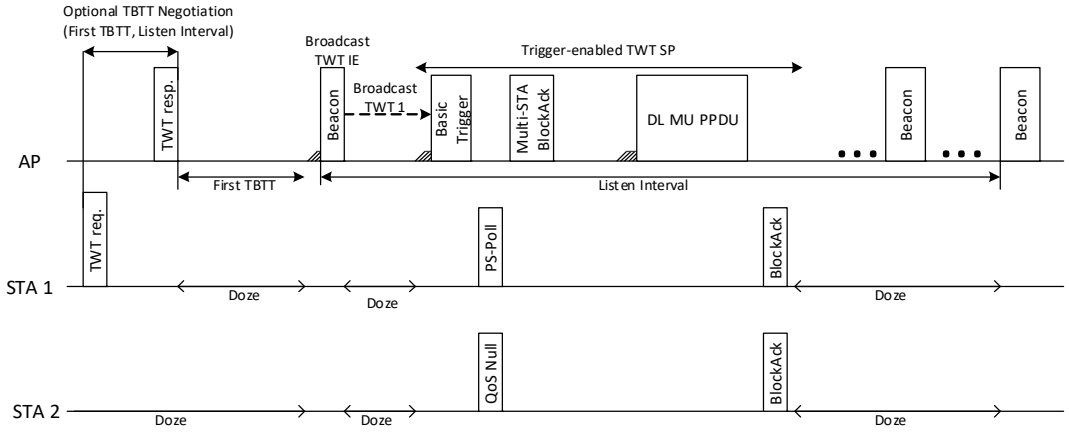


**Figure 26-10—Example of broadcast TWT operation with optional TBTT negotiation(11ax)**

The TWT scheduling AP includes a broadcast TWT element in the Beacon frame that indicates a broadcast TWT SP during which the AP intends to send Trigger frames, or DL BUs to the TWT scheduled STAs. STA 1 and STA 2 wake to receive the Beacon frame to determine the broadcast TWT. During the trigger-enabled TWT SP, the AP sends a Basic Trigger frame to which STA 1 and STA 2 indicate that they are awake during the TWT SP. STA 1 indicates that it is awake by sending a PS-Poll, and STA 2 indicates that it is awake by sending a QoS Null frame in response to the Basic Trigger frame. STA 1 and STA 2 receive their DL BUs in a subsequent exchange with the AP and go to doze state outside of this TWT SP.

Each broadcast TWT is uniquely identified by the <broadcast TWT ID, MAC address> tuple, where the broadcast TWT ID is the value of the Broadcast TWT ID subfield and is greater than 0 and the MAC address is the address of the TWT scheduling AP.

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Broadcast TWT schedules are advertised by the TWT scheduling AP in frames that carry TWT elements with the Negotiation Type subfield set to 2 as described in 26.8.3.2 (Rules for TWT scheduling AP). Broadcast TWT schedules that are intended for member TWT scheduled STAs are identified by a Broadcast TWT ID subfield that is greater than 0, and broadcast TWT schedules that are intended for all TWT scheduled STAs are identified by a Broadcast TWT ID subfield equal to 0.

Negotiations to become a member of or terminate membership in a broadcast TWT, identified by a Broadcast TWT ID subfield greater than 0, are performed with an exchange of frames that carry TWT elements with the Negotiation Type subfield set to 3 as described in 26.8.3.3 (Rules for TWT scheduled STA).

The TWT scheduling AP may send an unsolicited TWT response with the Trigger subfield set to 1 to a non-AP HE STA that has set the Broadcast TWT Support subfield to 1 in the HE Capabilities elements that it transmits to the AP. The TWT response shall indicate one of the following values in the TWT Setup Command field: Accept TWT, Alternate TWT, or Dictate TWT. An unsolicited TWT response with TWT Setup Command field indicating Alternate TWT or Dictate TWT contains an advisory notification to the recipient of TWT parameters that are likely to be accepted by the AP if the recipient transmits a subsequent TWT request to the AP that includes those TWT parameters. An unsolicited TWT response with a TWT Setup Command field that indicates Accept TWT allocates a broadcast TWT schedule to the receiving STA. A STA that receives an unsolicited TWT response with a TWT Setup Command field that indicates Accept TWT may transmit a TWT Teardown frame or a TWT response with TWT Setup Command field indicating Reject TWT to withdraw from the unsolicited broadcast TWT schedule.

### 26.8.3.2 Rules for TWT scheduling AP

A TWT scheduling AP may include a broadcast TWT element in a Beacon frame that is scheduled at a TBTT (see 11.1.3.2 (Beacon generation in non-DMG infrastructure networks)). The TWT scheduling AP shall include one or more TWT parameter sets in the TWT element, and each TWT parameter set may indicate a periodic occurrence of TWTs. The TWT scheduling AP shall set the Last Broadcast Parameter Set subfield to 0 in each TWT parameter set, except for the last (or only) TWT parameter set of the TWT element that shall have the Last Broadcast Parameter Set subfield set to 1. The TWT scheduling AP shall set (#4010)the Negotiation Type subfield to 2 and may set the Responder PM Mode subfield to 0 in the TWT element (see 10.46.7 (TWT Sleep setup)). (#4010)The TWT scheduling AP may set the NDP Paging Indicator/Unavailability Mode subfield to 0 or 1 subject to the additional rules defined in this subclause if the Broadcast TWT ID subfield is equal to 0 and the Responder PM Mode subfield is equal to 1, otherwise, the NDP Paging Indicator/Unavailability Mode subfield is reserved for a TWT scheduling AP. Each TWT parameter set specifies the TWT parameters of a specific broadcast TWT that are valid within a broadcast TWT SP. Each specific broadcast TWT is identified as indicated in 26.8.3.1 (General). Individual STAs may have membership in broadcast TWTs as a result of negotiation with a TWT scheduling AP as described in 26.8.3.1 (General).

The TWT scheduling AP sets the TWT parameters of each TWT parameter set as described below in this subclause.

The TWT scheduling AP shall set the TWT Request subfield to 0 and the TWT Setup Command subfield as defined in Table 26-6 (Broadcast TWT announcements(11ax)) and shall include the broadcast TWT element in the Beacon frames for as long as there is at least one active broadcast TWT schedule. Broadcast TWT announcements are broadcast TWT schedules advertised in broadcast TWT elements contained in broadcast Management frames.


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**Table 26-6—Broadcast TWT announcements(11ax)**

| TWT Setup Command field in an initiating frame | TWT Setup Command field in a response frame | Condition after the completion of the exchange |
|---|---|---|
| Accept TWT | No frame transmitted | Only an HE AP is permitted to transmit this sequence.<br><br>TWT scheduled STAs that receive this frame use the provided TWT parameters to determine the broadcast TWT schedule.<br><br>The broadcast TWT schedule is identified by the broadcast TWT ID and the TA of the initiating frame. |
| Alternate TWT | No frame transmitted | When transmitted by a TWT scheduling AP, some of the parameters of the broadcast TWT schedule identified by the broadcast TWT ID and the TA of the initiating frame will change at the TBTT that occurs after the Broadcast TWT Persistence field of that broadcast TWT parameter set reaches 0. The new parameters will be present in the first Beacon frame transmitted by the TWT scheduling AP at the TBTT that has a broadcast TWT parameter set with the same broadcast TWT ID and same TA, but with the TWT command value set to Accept TWT. |
| Reject TWT | No frame transmitted | When transmitted by a TWT scheduling AP, the broadcast TWT schedule identified by the broadcast TWT ID and the TA of the initiating frame will be terminated at the TBTT that occurs after the Broadcast TWT Persistence field of that broadcast TWT parameter reaches 0. The termination occurs at the TBTT at which a Beacon frame is transmitted by the TWT scheduling AP that does not include a broadcast TWT parameter set with the same broadcast TWT ID and same TA as the initiating frame. |

NOTE 1—The Negotiation Type subfield of the TWT element contained in these frames is 2.

NOTE 2—The initiating frame and response frame settings not listed in the tables in 10.46 (Target wake time (TWT)) or 26.8 (TWT operation) are not allowed. The initiating frame is a TWT response.

NOTE 3—MMPDUs that contain a broadcast TWT element generated by a TWT scheduling AP can be broadcast Probe Response, FILS Discovery, and Beacon frames. The TWT element has the TWT Request field equal to 0 and the Negotiation Type subfield equal to 2. The TWT scheduling AP can include a TWT parameter set with Broadcast TWT ID value 0 to indicate a TWT allocated for all STAs, and Broadcast TWT ID greater than 0 to indicate a TWT intended to TWT scheduled STAs that are members of that broadcast TWT.

The TWT scheduling AP shall set the Broadcast TWT Persistence subfield for each broadcast TWT to the number of TBTTs for which the Broadcast TWT schedule will be in existence, counting forward from the current TBTT. The AP may change the value of the Broadcast TWT Persistence subfield for any Broadcast TWT within any transmitted TWT element. If the AP reduces the value of the subfield, it shall not reduce the value by more than one as compared to the value transmitted during the immediately preceding beacon interval. If the AP increases the value of the Broadcast TWT Persistence subfield, it may increase the value by any amount as compared to the value transmitted during the immediately preceding TBTT.

A TWT scheduling AP that sets the TWT Setup Command subfield to Reject TWT shall indicate the TBTT at which the periodic broadcast TWT will be terminated by setting the value of the Broadcast TWT Persistence subfield to indicate the number of TBTTs that remain until the broadcast TWT schedule is terminated. The broadcast TWT schedule terminates at the next TBTT that follows the TBTT at which the TWT scheduling AP transmits the broadcast TWT element with Broadcast TWT Persistence subfield for that broadcast TWT schedule equal to 0.A TWT scheduling AP may terminate the membership of a TWT

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scheduled STA in all broadcast TWTs by transmitting a TWT Teardown frame with the Teardown All TWT field set to 1.

A TWT scheduling AP that sets the TWT Setup Command subfield to Alternate TWT shall indicate the TBTT at which the periodic broadcast TWT parameter set will be modified by setting the Broadcast TWT Persistence subfield to indicate the number of TBTTs that remain until the broadcast TWT schedule is modified. The broadcast TWT schedule will be modified at the next TBTT that follows the TBTT at which the TWT scheduling AP transmits the broadcast TWT element with Broadcast TWT Persistence subfield for that broadcast TWT schedule equal to 0. The AP shall include in the broadcast TWT element the future broadcast TWT parameter set that will take effect at that TBTT. The future broadcast TWT parameter set shall have the same values in the TWT Setup Command and Broadcast TWT ID subfields as the current broadcast TWT parameter set that is being modified and switch the TWT Setup Command subfield from Alternate TWT to Accept TWT at that TBTT. The future broadcast TWT parameter set shall be in a Broadcast TWT Parameter Set field that is located after the Broadcast TWT Parameter Set field that contains the current broadcast TWT parameter set.

NOTE 1—TWT scheduled STAs follow the broadcast TWT parameters that are included in the current broadcast TWT parameter set and switch to following the broadcast TWT parameters in the future broadcast TWT parameter set only if the TWT Setup Command field is equal to Accept TWT in the Broadcast TWT Parameter Set field that contains the future broadcast TWT parameter set.

A TWT scheduling AP should indicate Alternate TWT or Reject TWT in the TWT Setup Command field of the broadcast TWT element for as many TBTTs as needed to exceed the longest interval any STA is expected to not receive Beacon frames either when the TWT parameters of a periodic TWT will change, or when the periodic TWT specified by that TWT parameter set will be terminated.

The TWT scheduling AP shall set the Trigger field to 1 to indicate a trigger-enabled TWT. Otherwise, it shall set the Trigger field to 0 (i.e., the TWT is not a trigger-enabled TWT). The AP is not expected to schedule for transmission Trigger frames during a non-trigger-enabled TWT SP and is expected to schedule Trigger frames during a trigger-enabled TWT SP as described below in this subclause.

The TWT scheduling AP shall schedule for transmission of a Trigger frame addressed to one or more TWT scheduled STAs during a trigger-enabled TWT SP, except that the Trigger frame may be replaced by a frame carrying a TRS Control subfield, provided that the frame is carried in a DL MU PPDU and the AP allocates enough resources in the HE TB PPDU for the STA to at least deliver its BSRs in response to the soliciting DL MU PPDU. A TWT scheduling AP should not include the 12 LSBs of the STA's AID in a User Info field of a Trigger frame transmitted within a broadcast TWT SP, unless the STA is in the awake state, has established membership in the broadcast TWT with that Broadcast TWT ID, or has indicated to receive the Beacon frame preceding the beacon interval that contains this TWT SP (see 26.8.6 (Negotiation of wake TBTT and wake interval)). A TWT scheduling AP may cancel the transmission of a Trigger frame during a trigger-enabled TWT SP if the AP does not expect any member TWT scheduled STAs to be in the awake state at the time of transmitting the Trigger frame.(#2202)

The TWT scheduling AP that schedules for transmission additional Trigger frames during a trigger-enabled TWT SP shall set the More TF subfield in the Common Info field of the Trigger frame to 1 to indicate that it will schedule for transmission another Trigger frame within the same TWT SP. The TWT scheduling AP shall set the More TF subfield to 0 if the Trigger frame is the last scheduled Trigger frame of the TWT SP or if the Trigger frame is scheduled for transmission outside of a trigger-enabled TWT SP. The TWT scheduling AP should poll as many STAs as possible among TWT scheduled STAs that are members of that nonzero Broadcast TWT ID so that the STAs can perform a frame exchange with the TWT scheduling AP during that TWT SP.

NOTE 2—The TWT scheduling AP does not intend to schedule for transmission of a Trigger frame for the TWT scheduled STA when the broadcast TWT is not a trigger-enabled TWT or when the TWT scheduled STA has sent an OM Control subfield that has the UL MU disable bit equal to 1 (see 26.9 (Operating mode indication)).


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NOTE 3—The TWT scheduling AP can cancel the transmission of a scheduled Trigger frame if the AP gains access to the wireless medium outside of the TWT SP.

NOTE 4—If the AP replaces the Trigger frame with a frame carrying a TRS Control field, then it is recommended that the AP allocate enough resources in subsequent Trigger frames sent during the TWT SP so that the STA can send as much as possible of the data reported in the BSR.

The TWT scheduling AP shall set the Flow Type field to 1 to indicate an unannounced TWT. Otherwise, it shall set the Flow Type field to 0 to indicate an announced TWT.

The TWT scheduling AP should schedule delivery of individually addressed DL BUs during unannounced TWT SPs with nonzero Broadcast TWT ID subfield.

The TWT scheduling AP shall set the Broadcast TWT Recommendation subfield according to Table 9-348 (Broadcast TWT Recommendation field for a broadcast TWT element(11ax)). The TWT scheduling AP shall set the Trigger field to 1 if the Broadcast TWT Recommendation subfield is 1 or 2 and may set the Trigger field to any value if the Broadcast TWT Recommendation subfield is 0 or 3.

A TWT scheduling AP that has advertised a broadcast TWT with a Broadcast TWT ID equal to 0 shall schedule the following:

— The delivery of group addressed DL BUs during the broadcast TWT SPs located within the beacon interval that follows the DTIM beacon(#3309) if the TWT parameter set indicated non-trigger enabled unannounced TWT SP and had the Broadcast TWT Recommendation subfield equal to 0.

— The transmission of a Trigger frame that does not contain an RA-RU during the broadcast TWT SPs if the TWT parameter set indicated trigger-enabled announced TWT SP and had the Broadcast TWT Recommendation subfield equal to 1. The Trigger frame shall contain at least one User Info field addressed to a TWT scheduled STA whose TIM bit in the Beacon frame is 1 and that is not a member of any nonzero broadcast TWT during this beacon interval.

— The transmission of a Trigger frame that contains at least one RA-RU (see 26.5.4 (UL OFDMA-based random access (UORA))) during the broadcast TWT SPs if the TWT parameter set indicated a trigger enabled announced TWT SP and had the Broadcast TWT Recommendation subfield set to 2 (see 26.14.2 (Power save with UORA and TWT)).

— The transmission of a TIM frame or FILS Discovery frame at the start of a broadcast TWT SP if the TWT parameter set indicated a non-trigger enabled unannounced TWT SP and had the Broadcast TWT Recommendation subfield set to 3 (see 26.14.3.2 (AP operation for opportunistic power save)).

(#4010)If a TWT scheduling AP has advertised a TWT element that carries one or more Broadcast TWT Parameter Set fields with a Broadcast TWT ID subfield equal to 0 and a Responder PM Mode subfield equal to 1, then:

— If the NDP Paging Indicator/Unavailability Mode subfield is set to 0, the AP may be unavailable outside of these broadcast TWT SPs, except within any other TWT SP that is setup with the AP or advertised by the AP.

— If the NDP Paging Indicator/Unavailability Mode subfield is set to 1, the AP may be unavailable outside of these broadcast TWT SPs, even if that time falls within any other TWT SP that is setup with the AP or advertised by the AP.

NOTE 5—An AP that is unavailable is not capable of receiving PPDUs, following the definition in 11.2.1 (General).(#4010)

A Trigger frame transmitted during a broadcast TWT SP whose TWT parameter set has the Broadcast TWT Recommendation subfield equal to 0 or 3 may contain zero or more RA-RUs (see 26.5.4 (UL OFDMA-

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based random access (UORA))). A Trigger frame transmitted during a broadcast TWT SP whose TWT parameter set has the Broadcast TWT Recommendation subfield equal to 1 shall contain no RA-RU.

(#7083)The TWT scheduling AP shall set the Target Wake Time field to (#2360)$TSF_{Ref}$ [10:25], where $TSF_{Ref}$ corresponds a TWT scheduled for this TWT parameter set that will occur after the AP has queued for transmission the frame that contains the TWT element. The TSF timer at which that TWT is scheduled has bits 0 to 9 equal to 0 and bits 26 to 63 equal to the same value as the respective bits in the (#8162)current value of the TSF timer.

The TWT scheduling AP shall include a nonzero value for the TWT wake interval in the TWT Wake Interval Exponent and TWT Wake Interval Mantissa fields for a periodic TWT and a zero value for an aperiodic TWT. The TWT wake interval shall be a multiple of 1 TU.(#4413)

The TWT parameters are valid for each successive TWT of a periodic TWT and for the only TWT of an aperiodic TWT.

The TWT scheduling AP shall include a unique value in the Broadcast TWT ID subfield for each Broadcast TWT to allow identification of each Broadcast TWT, unless the TWT Setup Command field is Alternate TWT or the Broadcast TWT ID subfield is zero.

NOTE 6—The broadcast TWT element contains two Broadcast TWT Parameter Set fields with the same Broadcast TWT ID subfield value if the TWT Setup Command field indicates Alternate TWT in one of the Broadcast TWT Parameter Set fields. The broadcast TWT element might contain multiple Broadcast TWT Parameter Set fields with the Broadcast TWT ID subfield equal to 0.

A TWT scheduling AP that receives a PS-Poll or a U-APSD trigger frame or any other indication from a TWT scheduled STA in PS mode, during or before a specific announced TWT SP but after the end of the most recent TWT SP preceding the specific TWT SP (if any), that the TWT scheduled STA is in the awake state during the TWT SP shall follow the rules defined in 11.2.3.6 (AP operation), except that the AP should deliver to the TWT scheduled STA as many buffered BUs as are available at the AP, provided that the BU delivery does not exceed the duration of the TWT SP, the TWT scheduled STA has indicated that it is in the awake state for that TWT SP, and the TWT scheduled STA has not entered the doze state (see 26.8.4.3 (TWT Information frame exchange for broadcast TWT) and 26.8.5 (Power save operation during TWT SPs)).

NOTE 7—The indication that the TWT scheduled STA is in the awake state for that TWT SP might be a PS-Poll, U-APSD trigger frame, or any frame for which an immediate response is solicited and that follows the rules in 11.2.3.2 (Non-AP STA power management modes) but the corresponding immediate response frame is not received by the TWT scheduled STA. Other indications that the STA is in the awake state are the transmission of an HE TB feedback NDP in response to an NFRP Trigger frame (see 26.5.7 (NDP feedback report procedure)) or the transmission of a frame that indicates that the STA is in active mode (see 11.2.3.2 (Non-AP STA power management modes)).

A TWT scheduling AP that sends frames to a TWT scheduled STA that is in PS mode during an unannounced TWT SP shall follow the rules defined in 11.2.3.6 (AP operation), except that the AP should deliver to the TWT scheduled STA as many buffered BUs as available at the AP, provided that the BU delivery does not exceed the duration of the TWT SP and the TWT scheduled STA has not entered the doze state (see 26.8.4.3 (TWT Information frame exchange for broadcast TWT) and 26.8.5 (Power save operation during TWT SPs)).

NOTE 8—The TWT scheduling AP can deliver the buffered BUs in A-MPDUs sent under a block ack agreement(#3741) if the TWT is an announced TWT and the TWT scheduled STA is awake for that TWT SP or if the TWT is an unannounced TWT (at the start of which the TWT scheduled STA is assumed to already be awake). The buffered BUs can be delivered in multiple PPDUs transmitted within the TWT SP. The TWT scheduling AP can exceed the duration of the TWT SP if the TWT scheduled STA is in active mode.


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A TWT scheduling AP may transmit to a TWT scheduled STA that is in active mode at any time (see 11.2.3.2 (Non-AP STA power management modes)). A TWT scheduling AP may transmit to a TWT scheduled STA that is in PS mode and awake outside of a TWT SP following the rules in 11.2.3.6 (AP operation).

A TWT scheduling AP that receives a TWT element with the TWT Request field equal to 1, the Negotiation Type subfield equal to 3, and the TWT Setup Command field set to Suggest or Demand may respond with a frame containing a TWT element as shown in Table 26-7 (Broadcast TWT membership exchanges(11ax)) (in 26.8.3.3 (Rules for TWT scheduled STA)).

A TWT scheduling AP that receives a TWT element with the TWT Request field equal to 1, the Negotiation Type subfield equal to 3, and the TWT Setup Command field set to Reject shall delete the membership of the STA corresponding to the TA of the MMPDU that contained the TWT element from the broadcast TWT schedule that has the Broadcast TWT ID value that is equal to the value of the Broadcast TWT ID field of the TWT element.

A TWT scheduling AP may transmit a broadcast TWT announcement at any time. Valid broadcast TWT announcements are described in Table 26-6 (Broadcast TWT announcements(11ax)).

### 26.8.3.3 Rules for TWT scheduled STA

A TWT scheduled STA that receives a broadcast TWT element in a Beacon frame shall follow the rules defined in this subclause to interact with the TWT scheduling AP.

A TWT scheduled STA should not transmit frames to the TWT scheduling AP outside of broadcast TWT SPs and should not transmit frames that are not contained within HE TB PPDUs to the TWT scheduling AP within trigger-enabled broadcast TWT SPs, except that the STA can transmit frames within negotiated individual TWT SPs as defined in 26.8.2 (Individual TWT agreements).

NOTE 1—The TWT scheduled STA decides which frames to transmit within or outside a TWT SP; and while it is recommended that the TWT scheduled STA not transmit using EDCA within or outside TWT SPs, the TWT scheduled STA might still do so. If the STA decides to transmit, then the STA might contend for accessing the medium as defined in 10.23.2 (HCF contention based channel access (EDCA)) and in 26.2.7 (EDCA operation using MU EDCA parameters).

A TWT scheduled STA may request to become a member of a broadcast TWT by transmitting a frame to its associated AP that contains a TWT element with the Negotiation Type subfield set to 3 and the TWT Setup Command field set to Request TWT, Suggest TWT, or Demand TWT. The TWT Parameter set indicates the Broadcast TWT ID of the broadcast TWT that the STA is requesting to join. See Table 26-7 (Broadcast TWT membership exchanges(11ax)).

A TWT scheduled STA may terminate membership in a broadcast TWT by transmitting a frame to its associated AP that contains a TWT element with the Negotiation Type subfield set to 3 and the TWT Setup Command field set to Reject TWT or by transmitting a TWT Teardown frame that has the Negotiation Type subfield set to 3. A TWT scheduled STA may terminate membership in all broadcast TWTs by transmitting a TWT Teardown frame with the Teardown All TWT field set to 1.

A TWT scheduled STA that receives a TWT element with the TWT Request field equal to 0, the Negotiation Type subfield equal to 3, and the TWT Setup Command field indicating Accept TWT is a member of the broadcast TWT identified by the <broadcast TWT ID, MAC address> tuple, where the broadcast TWT ID is the value of the Broadcast TWT ID subfield in the TWT element and the MAC address that is the TA of the MMPDU that contained the TWT element is equal to the MAC address of the AP with which the STA is associated, regardless of whether the TWT scheduled STA had previously transmitted a corresponding TWT element to the AP with the TWT Setup Command field indicating Request TWT, Suggest TWT, or Demand TWT.

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Valid broadcast TWT membership exchanges are described in Table 26-7 (Broadcast TWT membership exchanges(11ax)).

**Table 26-7—Broadcast TWT membership exchanges(11ax)**

| TWT Setup Command field in an initiating frame | TWT Setup Command field in a response frame | Condition after the completion of the exchange |
|---|---|---|
| Demand TWT | Accept TWT | A broadcast TWT schedule exists or has been created with the TWT parameters indicated in the initiating frame and repeated in the response frame.<br><br>The TWT scheduled STA transmitting the initiating frame is a member of the Broadcast TWT schedule identified by the Broadcast TWT ID and the TA of the response frame. |
| Request TWT or Suggest TWT | Accept TWT | A broadcast TWT schedule exists or has been created with the TWT parameters indicated in the response frame.<br><br>The TWT scheduled STA transmitting the initiating frame is a member of the broadcast TWT schedule identified by the broadcast TWT ID and the TA of the response frame. |
| Suggest TWT or Demand TWT | Alternate TWT | No new broadcast TWT schedule has been created with the TWT parameters indicated in the initiating frame.<br><br>The TWT scheduling AP is offering an alternative set of parameters to those indicated in the initiating frame as a means of negotiating TWT parameters with the TWT scheduled STA.<br><br>The TWT scheduled STA can send a new request with any set of TWT parameters, and the TWT scheduling AP might create a new broadcast TWT schedule using the parameters indicated in the response frame. |
| Suggest TWT or Demand TWT | Dictate TWT | A broadcast TWT schedule either is created or already exists and is using the TWT parameters identified in the response frame, including a broadcast TWT ID.<br><br>The TWT scheduling AP will not create any new broadcast TWT schedule with the TWT scheduled STA at this time.<br><br>The TWT scheduled STA transmitting the initiating frame is not a member of the broadcast TWT schedule identified by the broadcast TWT ID and the TA of the response frame.<br><br>The TWT scheduled STA can send a new request, but will receive an Accept TWT only if it uses the dictated TWT parameters. |
| Request TWT, Suggest TWT, or Demand TWT | Reject TWT | The TWT scheduled STA transmitting the initiating frame is a not a member of a broadcast TWT identified by the broadcast TWT ID and the TA of the response frame, if such a broadcast TWT exists.<br><br>The TWT scheduling AP will not accept any new request from the TWT scheduled STA to join or create a broadcast TWT at this time. |


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**Table 26-7—Broadcast TWT membership exchanges(11ax) *(continued)***

| TWT Setup Command field in an initiating frame | TWT Setup Command field in a response frame | Condition after the completion of the exchange |
|---|---|---|
| Accept TWT | No frame transmitted | Not permitted to be transmitted by a TWT scheduled STA.<br><br>When transmitted by a TWT scheduling AP, the recipient STA's membership in the broadcast TWT schedule identified by the broadcast TWT ID and the TA of the initiating frame is established. |
| Alternate TWT or Dictate TWT | No frame transmitted | Not permitted to be transmitted by a TWT scheduled STA.<br><br>When transmitted by a TWT scheduling AP, the TWT scheduled STA receiving this frame is not, through the receipt of this frame, a member of the broadcast TWT identified by the initiating frame.<br><br>The TWT scheduled STA can use the information provided to create a request to join a TWT in a subsequent initiating frame that it transmits. |
| Reject TWT | No frame transmitted | When transmitted by a TWT scheduled STA, the transmitting STA's membership in the broadcast TWT schedule identified by the broadcast TWT ID and the RA of the initiating frame is terminated.<br><br>When transmitted by a TWT scheduling AP, the receiving STA's membership in the broadcast TWT schedule identified by the broadcast TWT ID and the TA of the initiating frame is terminated. |

NOTE 1—The Negotiation Type subfield of the TWT element contained in these frames is 3.

NOTE 2—The initiating frame and response frame settings not listed in the tables in 10.46 (Target wake time (TWT)) or 26.8 (TWT operation) are not allowed. The initiating frame is a TWT request if the TWT element contained in the frame has the TWT Request field equal to 1 (see Table 9-347 (TWT Setup Command field values(11ax))); otherwise, it is a TWT response. The response frame is a TWT response.

NOTE 3—In addition to these exchanges, the TWT scheduling AP might respond to an initiating frame that solicits membership in a broadcast TWT schedule with an indication or solicitation of the establishment of an individual TWT agreement.

NOTE 4—MMPDUs that contain a broadcast TWT element generated by a TWT scheduled STA can be (Re)Association Request frames and can be TWT Setup frames with TWT Request field equal to 1. The TWT element has the Negotiation Type subfield equal to 3 and the Broadcast TWT ID(s) that the STA intends to join or withdraw. MMPDUs that contain a broadcast TWT element generated by a TWT scheduled AP can be (Re)Association Response frames and can be TWT Setup frames with TWT Request field equal to 0. The TWT element has the Negotiation Type subfield equal to 3 and the Broadcast TWT ID(s) to which the STA is assigned or from which the STA is withdrawn.

A TWT scheduled STA that is in PS mode may enter the doze state after receiving a Beacon frame with a TWT element indicating the existence of a broadcast TWT and shall be in the awake state at (#1034)specific broadcast TWT start times for which the STA has indicated it will be awake by any of the following means:

— Establishing a membership for the unannounced broadcast TWT with the applicable broadcast TWT IDs, in which case the specific broadcast TWTs are the unannounced broadcast TWTs.(#1034)

— Negotiating a wake TBTT and wake interval between Beacon frames that the STA receives, as defined in 26.8.6 (Negotiation of wake TBTT and wake interval), in which case the specific

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broadcast TWTs are those that occur during the beacon interval, and the Beacon frame that is sent at the start of that beacon interval and that had the TIM bit corresponding to that STA equal to 1.(#1034)

— Having sent a PS-Poll or U-APSD trigger frame during the beacon interval, in which case the specific broadcast TWT is the first broadcast TWT that occurs during that beacon interval and either during or after sending that frame.(#1034)

— Having sent another indication that it is in the awake state during that beacon interval, in which case the specific broadcast TWT is the first broadcast TWT that occurs during that beacon interval and either during or after sending that indication.(#1034)

NOTE 2—Other indications that the STA is in the awake state are the transmission of an HE TB feedback NDP in response to an NFRP Trigger frame (see 26.5.7 (NDP feedback report procedure)) or the transmission of a frame that indicates that the STA is in active mode (see 11.2.3.2 (Non-AP STA power management modes)).

NOTE 3—The STA might indicate that it will not be awake at certain broadcast TWT start times by sending a TWT Information frame. The AP might indicate to a STA that it need not be awake at certain broadcast TWT start times by sending a TWT information frame (see 26.8.4 (Use of TWT Information frames)).

A TWT scheduled STA is not required to be in the awake state at broadcast TWT SP start times corresponding to the broadcast TWT that has the broadcast TWT ID value of 0.

A TWT scheduled STA that did not receive a Beacon frame at a TBTT shall act as if it had received the expected Beacon frame containing a TWT element for a broadcast TWT if the missed beacon corresponds to a TBTT that is within the next *n* TBTTs beyond the most recently received Beacon frame that included a TWT element for that broadcast TWT, where *n* is equal to 1 plus the value obtained from the Broadcast TWT Persistence subfield of the corresponding Broadcast TWT, except that *n* is infinite if the Broadcast TWT Persistence subfield is 255.

A TWT scheduled STA transmits an HE TB PPDU as a response to a Trigger frame that is addressed to it and is sent during a trigger-enabled TWT SP (see 26.5.2 (UL MU operation)). A TWT scheduled STA that is in PS mode and is awake during an announced TWT SP shall include a PS-Poll frame or a U-APSD trigger frame in the HE TB PPDU if it intends to solicit buffered BUs from the TWT scheduling AP (see 11.2.3.7 (Receive operation for STAs in PS mode)), unless the STA has already transmitted within that TWT SP a PS-Poll or U-APSD trigger frame, or has transmitted any other indication that the STA is in the awake state within that TWT SP, or has, previous to the start of the TWT SP but after the end of the most recent TWT SP, indicated to the AP that it is currently in the awake state. A TWT scheduled STA that is in PS mode shall transition to the awake state at the start of an unannounced TWT SP of which it is a member. The STA may include other frames in the HE TB PPDU when other rules do not prohibit their inclusion (see 26.5.2 (UL MU operation) and 9.7.3 (A-MPDU contents)).

NOTE 4—A TWT scheduling AP sets the bit in the TIM element of the Beacon frame that corresponds to the AID of the TWT scheduled STA to 1 to indicate that it expects the TWT scheduled STA to solicit available buffered BUs (see 11.2.3.7 (Receive operation for STAs in PS mode)).

NOTE 5—Other indications that the STA is in the awake state are the transmission of an HE TB feedback NDP in response to an NFRP Trigger frame (see 26.5.7 (NDP feedback report procedure)) or the transmission of a frame that indicates that the STA is in active mode (see 11.2.3.2 (Non-AP STA power management modes)).

A TWT scheduled STA should not send frames that do not satisfy the Broadcast TWT Recommendation subfield recommendations in Table 9-348 (Broadcast TWT Recommendation field for a broadcast TWT element(11ax)) during the corresponding TWT SP(s). Frames sent as a response to a Trigger frame are subject to further restrictions as defined in 26.5.2 (UL MU operation) and 9.7.3 (A-MPDU contents).


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## 26.8.4 Use of TWT Information frames

### 26.8.4.1 General

An HE STA may transmit a TWT Information frame to its peer STA during an individual TWT agreement, during broadcast TWT schedule, or at any time as defined in 26.8.4.2 (TWT Information frame exchange for individual TWT), 26.8.4.3 (TWT Information frame exchange for broadcast TWT), and 26.8.4.4 (TWT Information frame exchange for flexible wake time), respectively.

NOTE 1—An HE AP might include multiple TWT Information frames, each addressed to a different peer STA, in an HE MU PPDU (see 26.5.1 (HE DL MU operation)).

The TWT Information frame shall have the Response Requested subfield equal to 0, the Next TWT Request subfield equal to 0, and one of the following:

- The Next TWT subfield that is equal to a nonzero value if the frame is transmitted by a TWT responding STA, by a TWT scheduling AP, or by any HE STA to a peer STA that has set the Flexible TWT Schedule Support field to 1 in the HE Capabilities element it transmits.
  - The value of the Next TWT subfield shall be selected from (#6196)the future target wake times of an individual TWT agreement if the Flexible TWT Schedule Support field in the HE Capabilities element received from the peer STA is 0 and shall be selected from (#6196)the future target wake times of a broadcast TWT schedule regardless of the value of the Flexible TWT Schedule Support field received from the peer STA.
  - The Next TWT subfield may contain any nonzero value if the Flexible TWT Schedule Support field in the HE Capabilities element received from the peer STA is 1.
  - The All TWT subfield is 1 if the resumption applies to all broadcast TWT schedules followed by the TWT scheduled STA and/or to all individual TWT agreements followed by the TWT responding STA.
- A Next TWT subfield that is present if the frame is transmitted by a TWT requesting STA, by a TWT scheduled STA, or by any HE STA to a peer STA that has set the Flexible TWT Schedule Support field to 1 in the HE Capabilities element it transmits.
  - The Next TWT subfield indicates the earliest TWT at which the individual TWT agreement or broadcast TWT schedule is resumed and shall be selected from (#6196)the future target wake times of that TWT agreement or broadcast TWT schedule if the Flexible TWT Schedule Support field in the HE Capabilities element received from the peer STA is 0.
  - The All TWT subfield is 1 if the resumption applies to all broadcast TWT schedules followed by the TWT scheduled STA and/or to all individual TWT agreements followed by the TWT requesting STA.
  - The Next TWT subfield may contain any nonzero value if Flexible TWT Schedule Support field in the HE Capabilities element received from the peer STA is 1.
- A Next TWT subfield that is not present if the frame is transmitted by a TWT requesting STA or a TWT scheduled STA to indicate suspension of the individual TWT agreement or broadcast TWT schedule.
  - The All TWT subfield is 1 if the suspension applies to all broadcast TWT schedules followed by the TWT scheduled STA and/or to all individual TWT agreements followed by the TWT requesting STA.

NOTE 2—Information exchanged with TWT Information frames does not modify the TWT parameters of any existing TWT session, except if the TWT Information frame is sent under flexible TWT (see 26.8.4.4 (TWT Information frame exchange for flexible wake time)).

The use of TWT Information frames for suspending and/or resuming existing individual TWT agreements is described in 26.8.4.2 (TWT Information frame exchange for individual TWT). The use of TWT Information frames for suspending and/or resuming existing broadcast TWT schedules is described in 26.8.4.3 (TWT

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Information frame exchange for broadcast TWT). The use of TWT Information frames for providing a flexible TWT that is independent of any existing TWT agreements or TWT schedules is described in 26.8.4.4 (TWT Information frame exchange for flexible wake time).

### 26.8.4.2 TWT Information frame exchange for individual TWT

An HE STA that has an individual TWT agreement may transmit a TWT Information frame to a peer STA with which it has the agreement if the peer STA has set the TWT Information Frame Disabled field to 0 in the TWT element sent during TWT setup; otherwise, the HE STA shall not transmit a TWT Information frame to the peer STA. The HE STA sets the fields of the TWT Information frame as defined in 26.8.4.1 (General).

A TWT requesting STA that receives a TWT Information frame containing a Next TWT subfield follows the rules in 10.46.4 (Implicit TWT operation) and the rules below in this subclause.

A TWT requesting STA that receives an acknowledgment in response to a TWT Information frame transmitted by the STA that does not contain a Next TWT subfield shall consider the corresponding TWT agreement suspended until the TWT session is resumed. A TWT requesting STA that receives an acknowledgment in response to a TWT Information frame transmitted by the STA that does contain a Next TWT subfield shall consider the corresponding TWT agreement suspended and shall resume the TWT agreement starting from the value indicated in the Next TWT subfield of the transmitted TWT Information frame. A TWT requesting STA that receives an acknowledgment in response to a TWT Information frame transmitted by the STA assumes that any other individual TWT agreements and broadcast TWT schedules (see 26.8.3 (Broadcast TWT operation)) are not affected by the transmission of this TWT Information frame, except when the All TWT subfield of the TWT Information frame is equal to 1. Other default PS procedures are not affected by the transmission of this TWT Information frame (see 11.2 (Power management)).

NOTE—The TWT Flow Identifier, together with the MAC addresses of the TWT requesting STA and TWT responding STA, identifies the TWT agreement for which the TWT Information frame is sent (see 10.46.1 (TWT overview)).

If the TWT Information frame contains an All TWT subfield equal to 1, then the above rules apply to all individual TWT agreements, except that the resumptions of the respective TWTs shall occur at the first TWT of the respective TWT agreement that occurs not earlier than the Next TWT value contained in the TWT Information frame, regardless of the value of the Flexible TWT Schedule Support field in the HE Capabilities element exchanged between the two STAs.

A TWT requesting STA that is in PS mode and that transmits a TWT Information frame to a TWT responding STA shall suspend the corresponding TWT agreement and may transition to doze state after receiving the acknowledgment even if it has previously transmitted a PS-Poll or U-APSD trigger frame and has not yet received the expected frames from the AP in response. The STA shall resume TWT operation for the corresponding TWT agreement at the specified TWT indicated (if any) in the TWT Information frame. A TWT requesting STA that is in PS mode and that receives a TWT Information frame from a TWT responding STA shall suspend the TWT agreement and may go to doze state after transmitting the acknowledgment even if it has previously transmitted a PS-Poll or U-APSD trigger frame and has not yet received the expected frames from the TWT responding STA in response. The STA shall resume TWT operation for the corresponding TWT agreement at the specified TWT indicated (if any) in the TWT Information frame.

### 26.8.4.3 TWT Information frame exchange for broadcast TWT

An HE STA that is a TWT scheduling AP may transmit a TWT Information frame to any of the members of a broadcast TWT schedule if the member has set the TWT Information Frame Disabled field to 0 in the TWT element sent when joining the broadcast TWT schedule. An HE STA that is a TWT scheduled STA


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may transmit a TWT Information frame to the TWT scheduling AP corresponding to a broadcast TWT schedule established by that STA if the AP has set the TWT Information Frame Disabled field to 0 in the broadcast TWT element it transmits. The HE STA sets the fields of the TWT Information frame as defined in 26.8.4.1 (General).

A TWT scheduled STA that receives a TWT Information frame that contains an All TWT subfield equal to 1 follows the rules defined in 26.8.3.3 (Rules for TWT scheduled STA), except that the TWT scheduled STA shall consider all the broadcast TWT schedules as suspended and shall resume each broadcast TWT schedule at the first TWT that occurs not earlier than the Next TWT subfield value contained in the received TWT Information frame.

A TWT scheduled STA that receives an acknowledgment in response to a TWT Information frame transmitted by the STA that contains an All TWT subfield equal to 1 and that does not contain a Next TWT subfield shall consider all broadcast TWT schedules suspended and can follow the default PS procedure defined in 11.2 until the broadcast TWT schedules are resumed.

A TWT scheduled STA that receives an acknowledgment in response to a TWT Information frame transmitted by the STA that contains an All TWT subfield equal to 1 and contains a Next TWT subfield shall suspend all broadcast TWT schedules and shall resume the broadcast TWT schedules at the first scheduled TWT for each respective broadcast TWT schedule that occurs not earlier than the value indicated in the Next TWT subfield contained in the transmitted TWT Information frame, regardless of the values of the Flexible TWT Schedule Support field in the HE Capabilities element exchanged between the two STAs.

NOTE—TWT suspension and resumption as indicated by a TWT Information frame with the All TWT subfield equal to 1 applies to all broadcast TWT schedules of the TWT scheduling AP.

A TWT scheduled STA that is in PS mode and that transmits a TWT Information frame to a TWT scheduling AP shall suspend the corresponding broadcast TWT schedule and may transition to doze state after receiving the acknowledgment, even if it has previously transmitted a PS-Poll or U-APSD trigger frame and has not yet received the expected frames from the TWT scheduling AP in response. The STA shall resume TWT operation for the corresponding broadcast TWT schedule at the specified TWT indicated (if any) in the TWT Information frame. A TWT scheduled STA that is in PS mode and that receives a TWT Information frame from a TWT scheduling AP shall suspend the corresponding broadcast TWT schedule and may transition to doze state after transmitting the acknowledgment, even if it has previously transmitted a PS-Poll or U-APSD trigger frame and has not yet received the expected frames from the TWT scheduling AP in response. The STA shall resume TWT operation for the corresponding broadcast TWT schedule at the specified TWT indicated (if any) in the TWT Information frame.

#### 26.8.4.4 TWT Information frame exchange for flexible wake time

An HE STA may transmit a TWT Information frame that contains a flexible TWT to a peer STA if the peer STA has set the Flexible TWT Schedule Support field in the HE Capabilities it transmits to 1; otherwise, the HE STA shall not transmit a TWT Information frame that contains a flexible TWT to the peer STA.

A flexible TWT is a nonzero value indicated in the Next TWT subfield of a TWT Information frame with All TWT subfield equal to 0, and the value is independent from any existing TWT values of TWT agreements that the HE STA might be following (if any). The HE STA sets the fields of the transmitted TWT Information frame as defined in 26.8.4.1 (General).

NOTE 1—Flexible TWT support does not depend on the STA's TWT capabilities, i.e., the STA can use flexible TWT without being required to set up an individual TWT agreement or broadcast TWT schedule.

An HE STA that receives an acknowledgment for a TWT Information frame with flexible TWT that contains a TWT Flow Identifier (#3308)field that identifies an existing individual TWT agreement shall

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replace the next TWT SP start time for that TWT agreement with the value contained in the Next TWT subfield of the TWT Information frame.

(#1203)An HE STA that receives a TWT Information frame with flexible TWT that contains a TWT Flow Identifier (#3308)field that identifies an existing individual TWT agreement shall replace the next TWT SP start time for that TWT agreement with the value contained in the Next TWT subfield of the TWT Information frame.

A non-AP HE STA that receives an acknowledgment for a TWT Information frame with flexible TWT that contains a TWT Flow Identifier (#3308)field that does not identify any existing individual TWT agreement (#1199)will use the same PM mode that the STA has at time *t1*, which is the time the acknowledgment for the TWT Information frame was received(#1205), (#1199)at time *t2*, which is the time indicated in the Next TWT subfield of the TWT Information frame as described below in this subclause.

(#1204)A non-AP HE STA that receives a TWT Information frame with flexible TWT that contains a TWT Flow Identifier (#3308)field that does not identify any existing individual TWT agreement preserves the PM mode from the time the acknowledgment of the TWT Information frame was transmitted to the time indicated in the Next TWT subfield of the TWT Information frame as described below in this subclause.

NOTE 2—If the TWT Information frame has the All TWT field equal to 1, then the TWTs are suspended and resumed as described in 26.8.4.2 (TWT Information frame exchange for individual TWT) and 26.8.4.3 (TWT Information frame exchange for broadcast TWT).

A non-AP HE STA that transmits a TWT Information frame with flexible TWT to a peer STA

- May go to doze state after receiving the acknowledgment sent in response to the TWT Information frame if it is in PS mode (i.e., the PM subfield of the Frame Control field of the TWT Information frame is 1).
- May be unavailable if it is in active mode (i.e., the PM subfield of the Frame Control field of the TWT Information frame is 0).
- Shall be in the awake state at the time indicated in the Next TWT subfield of the TWT Information frame.(#1201)
- Shall be in the PS mode if the PM subfield of the TWT Information frame was 1 and in active mode if the PM subfield of the TWT Information frame was 0.

The STA, once in the awake state, shall follow the rules that correspond to the power management mode of the STA, which are defined in 11.2.3 (Power management in a non-DMG infrastructure network) for the active and PS modes and in 26.8 (TWT operation) when the STA operates within TWT SPs.

NOTE 3—An HE AP delivers DL BUs to the STA at or after the flexible TWT indicated in the flexible TWT by following the rules in 11.2.3.6 (AP operation) if the STA does not follow TWT and by following the rules in 26.8 (TWT operation) if the STA follows TWT and the delivery falls within a TWT SP. The STA is not required to send a frame at or after the flexible TWT to indicate its awake state to the AP. If the STA is following U-APSD, then the operation is resumed at a time that occurs at the flexible TWT; and if the STA is following an APSD schedule, then the operation is resumed at a time that occurs at or after the flexible TWT.

A non-AP HE STA that receives a TWT Information frame with flexible TWT from a peer STA

- May go to doze state after transmitting the acknowledgment if it is in PS mode.
- May be unavailable if it is in active mode.
- Shall be in the awake state at the time it indicated in the Next TWT subfield of the TWT Information frame.
- Shall be in the PS mode if the STA was in PS mode when it received the TWT Information frame and in active mode if the STA was in active mode when it received the TWT Information frame.


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The STA, once in the awake state, shall follow the rules that correspond to the power management mode of the STA, which are defined in 11.2.3 (Power management in a non-DMG infrastructure network) for the active and PS modes and in 26.8 (TWT operation) when the STA operates within TWT SPs.

### 26.8.5 Power save operation during TWT SPs

The following rules apply to TWT SPs for both broadcast TWT schedules and individual TWT agreements where the TWT SP of a broadcast TWT is uniquely identified by the <broadcast TWT ID, MAC address of TWT scheduling AP> tuple and the TWT SP of an individual TWT is uniquely identified by the <TWT flow identifier, MAC address of TWT requesting STA, MAC address of TWT responding STA> triple.

A TWT requesting STA or a TWT scheduled STA that is not in PS mode and that transmits a frame with the Power Management subfield set to 1 during a TWT SP shall remain in the awake state until the AdjustedMinimumTWTWakeDuration time has elapsed from the TWT SP start time or until a TWT SP termination event is detected, whichever occurs first for that particular TWT SP.

A TWT requesting STA or a TWT scheduled STA in PS mode that is in the awake state for a TWT SP may transition to the doze state after AdjustedMinimumTWTWakeDuration time has elapsed from the TWT SP start time even if it has previously transmitted a PS-Poll frame or U-APSD trigger frame and has not yet received the expected frames from the AP in response. For a trigger-enabled TWT SP, if the AdjustedMinimumTWTWakeDuration time has elapsed from the scheduled TWT SP start time and no Trigger frames are received by the STA, the HE STA may enter doze state if no other condition requires the STA to remain awake.

When a TWT SP termination event is detected within a TWT SP by a STA in PS mode that is participating in the TWT SP, the STA may transition to the doze state without waiting for the expiration of the AdjustedMinimumTWTWakeDuration time as described in 10.46.1 (TWT overview), even if it has previously transmitted a PS-Poll frame or U-APSD trigger frame and has not yet received the expected frames from the AP in response.

A TWT requesting STA or a TWT scheduled STA shall classify any of the following events as a TWT SP termination event:

a) The transmission by the TWT requesting STA of an acknowledgment in response to an individually addressed QoS Data or QoS Null frame sent by the TWT responding STA that had the EOSP subfield equal to 1.

b) The transmission by the TWT scheduled STA of an acknowledgment in response to an individually addressed QoS Data or QoS Null frame sent by the TWT scheduling AP that had the EOSP subfield equal to 1.

c) The transmission by the TWT requesting STA of an acknowledgment in response to an individually addressed frame that is neither a QoS Data frame nor a QoS Null frame, but that was sent by the TWT responding STA with the More Data field equal to 0.

d) The transmission by the TWT scheduled STA of an acknowledgment in response to an individually addressed frame that is neither a QoS Data frame nor a QoS Null frame, but that was sent by the TWT scheduling AP with the More Data field equal to 0.

e) The reception of an individually addressed or broadcast QoS Data or QoS Null frame sent by the TWT responding STA or TWT scheduling AP that does not solicit an immediate response and had the EOSP subfield equal to 1.

f) The reception of an individually addressed frame that is neither a QoS Data frame nor a QoS Null frame, but that was sent by the TWT responding STA or TWT scheduling AP, does not solicit an immediate response, and had the More Data field equal to 0.

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g) The reception of a Trigger frame sent by the TWT responding STA or TWT scheduling AP that has the More TF field equal to 0 and is not addressed to the TWT requesting STA or TWT scheduled STA, provided that the TWT requesting STA or TWT scheduled STA either is awake for an announced trigger-enabled TWT SP but did not transmit an indication that it is in the awake state to the TWT responding STA or TWT scheduling AP or is awake for an unannounced trigger-enabled TWT SP.

h) The transmission or reception by the TWT requesting STA of the acknowledgment for a TWT Information frame that satisfies specific conditions in 26.8.4.2 (TWT Information frame exchange for individual TWT) and 26.8.4.4 (TWT Information frame exchange for flexible wake time).

i) The transmission or reception by the TWT scheduled STA of the acknowledgment for a TWT Information frame that satisfies specific conditions in 26.8.4.3 (TWT Information frame exchange for broadcast TWT) and 26.8.4.4 (TWT Information frame exchange for flexible wake time).

The classification of a More Data field equal to 0 in an Ack, BlockAck, or individually addressed Multi-STA BlockAck frame as an event that terminates a TWT SP is possible only when both STAs have indicated support of transmitting or receiving the frame with a nonzero More Data subfield, which is indicated in the More Data Ack subfield of the QoS Info field of frames they transmit (see 11.2.3 (Power management in a non-DMG infrastructure network)).

NOTE 1—A STA participating in multiple TWT SPs that overlap in time stays in the awake state until the latest AdjustedMinimumTWTWakeDuration time of all of the TWT SPs expires, except that a TWT SP termination event causes all of the overlapping TWT SPs to terminate.

NOTE 2—A Trigger frame is addressed to the STA if the Trigger frame contains the AID of the STA in one of its User Info fields (see 26.5.2 (UL MU operation)) and has in its TA field either the MAC address of its associated AP or the transmitted BSSID (see 26.5.2.2.4 (Allowed settings of the Trigger frame fields and TRS Control subfield)). Otherwise, the Trigger frame is not addressed to the STA. If the Trigger frame contains one or more RA-RUs for which the STA can gain access according to 26.5.4 (UL OFDMA-based random access (UORA)), then the STA can follow the rules defined in 26.14.2 (Power save with UORA and TWT) to determine an early TWT SP termination event.

### 26.8.6 Negotiation of wake TBTT and wake interval

A TBTT scheduled STA that intends to operate in power save mode (see 11.2.3.2 (Non-AP STA power management modes)) may transmit a TWT request to the TBTT scheduling AP that identifies the wake TBTT of the first Beacon frame and the wake interval between subsequent Beacon frames it intends to receive. The TWT request shall contain the following:

— The Negotiation Type subfield equal to 1 and the TWT Setup Command field equal to Suggest TWT or Demand TWT.
— The requested first wake TBTT in the Target Wake Time field.
— The requested wake interval between consecutive TBTTs in the TWT Wake Interval Mantissa and TWT Wake Interval Exponent fields.
— The requested TBTT wake duration in the Nominal Minimum TWT Wake Duration field.
— All other fields in the TWT element reserved.

A TBTT scheduling AP that receives a TWT request from a STA whose value of the Negotiation Type subfield is 1 shall respond with a TWT response that contains Accept TWT, Alternate TWT, or Reject TWT in the TWT Setup Command field. For an Accept TWT, it shall also contain the following:

— The Negotiation Type subfield equal to 1.
— The allocated first wake TBTT in the Target Wake Time field.
— The allocated wake interval between consecutive TBTTs in the TWT Wake Interval Mantissa and TWT Wake Interval Exponent fields.
— The allocated TBTT wake duration in the Nominal Minimum TWT Wake Duration field.
— All other fields in the TWT element reserved.


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After successfully completing the negotiation, the TBTT scheduled STA may go to doze state until its TSF matches the next negotiated wake TBTT, provided that the STA is in power save mode and no other condition requires the STA to remain awake. The TBTT scheduled STA shall be in the awake state to listen to Beacon frames transmitted at negotiated wake TBTTs and shall operate as described in 26.8.3.3 (Rules for TWT scheduled STA).

If the TBTT scheduled STA receives a Beacon frame from the TBTT scheduling AP at or after TBTT, the TBTT scheduled STA may go to doze state until the next wake TBTT if no other condition requires the STA to remain awake. The TBTT scheduled STA may go to doze state after a nominal minimum TBTT wake duration time has elapsed from the TBTT start time if no other condition requires the STA to remain awake.

Either STA that is a party to an established wake TBTT agreement can tear down the wake TBTT agreement by following the teardown procedure described in 10.47.8 and by setting the Negotiation Type subfield to 1 in the TWT Teardown frame.

Table 26-8 (Wake TBTT negotiation exchanges(11ax)) summarizes the interactions between devices that negotiate a Wake TBTT agreement.

**Table 26-8—Wake TBTT negotiation exchanges(11ax)**

| TWT Setup Command field in an initiating frame | TWT Setup Command field in a response frame | Condition after the completion of the exchange |
|---|---|---|
| Request TWT | Accept TWT, Alternate TWT, Dictate TWT, Reject TWT, or no response | This exchange is not allowed. |
| Demand TWT or Suggest TWT | Accept TWT | A Wake TBTT agreement has been created with the Wake TBTT parameters indicated in the initiating frame. |
| Demand TWT or Suggest TWT | Reject TWT | No Wake TBTT agreement has been created. |
| Demand TWT or Suggest TWT | Alternate TWT | No Wake TBTT agreement has been created. The TBTT scheduling AP is offering an alternative set of parameters to those indicated in the initiating frame. The TBTT scheduled STA can send a new request with any set of Wake TBTT parameters, and the responder might create a Wake TBTT agreement using those parameters.<br><br>The TBTT scheduled STA is unlikely to send a new request if the TWT Setup Command is Demand TWT and is very likely to send a new request if the TWT Setup Command is Suggest TWT. |
| NOTE 1—The Negotiation Type subfield of the TWT element contained in these frames is equal to 1.<br><br>NOTE 2—The initiating frame and response frame settings not listed in the tables in 10.46 (Target wake time (TWT)) or 26.8 (TWT operation) are not allowed. The initiating frame is a TWT request, and the response frame is a TWT response. | | |

## 26.8.7 HE subchannel selective transmission

### 26.8.7.1 General

An HE STA that supports HE subchannel selective transmission (SST) operation shall set dot11HESubchannelSelectiveTransmissionImplemented to true and shall set the HE Subchannel Selective

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Transmission Support field in the HE Capabilities element it transmits to 1. An HE STA that does not support HE SST operation shall set the HE Subchannel Selective Transmission Support field in the HE Capabilities element it transmits to 0.

A non-AP HE STA with dot11HESubchannelSelectiveTransmissionImplemented equal to true is a HE SST non-AP STA.

An HE AP with dot11HESubchannelSelectiveTransmissionImplemented equal to true is an HE SST AP.

An HE SST non-AP STA and an HE SST AP may set up SST operation by negotiating a trigger-enabled TWT as defined in 26.8.2 (Individual TWT agreements) with the following exceptions:

- The TWT request may have a TWT Channel field with up to one bit set to 1 to indicate the secondary channel requested to contain the RU allocations addressed to the HE SST non-AP STA that is a 20 MHz operating STA.
- The TWT request may have a TWT Channel field with all 4 LSBs or all 4 MSBs set to 1 to indicate whether the primary 80 MHz channel or the secondary 80 MHz channel is requested to contain the RU allocations addressed to the HE SST non-AP STA that is an 80 MHz operating STA.
- The TWT response shall have a TWT Channel field with up to one bit set to 1 to indicate the secondary channel that will contain the RU allocations addressed to the HE SST non-AP STA that is a 20 MHz operating STA.
- The TWT response shall have a TWT Channel field with all 4 LSBs or all 4 MSBs set to 1 to indicate whether the primary 80 MHz channel or the secondary 80 MHz channel will contain the RU allocations addressed to the HE SST non-AP STA that is a 80 MHz operating STA.

#### 26.8.7.2 SST operation

An HE SST non-AP STA and HE SST AP that successfully set up SST operation shall follow the rules defined in this subclause.

If an HE SST AP causes its operating channel or channel width to change and if any secondary channel of a trigger-enabled TWT is not within the new operating channel or channel width, then the HE SST AP and the HE SST non-AP STA implicitly terminate the trigger-enabled TWT.

The HE SST AP follows the rules in 26.8.2 (Individual TWT agreements) to exchange frames with the HE SST non-AP STA during trigger-enabled TWT SPs, except that the AP shall ensure the following:

- The individually addressed RUs allocated in DL MU PPDUs and in Trigger frames addressed to the HE SST non-AP STA are within the subchannel indicated in the TWT Channel field of the TWT response and follow the RU restriction rules defined in 27.3.2.8 (RU restrictions for 20 MHz operation) if the HE SST non-AP STA is a 20 MHz operating STA and in 27.3.2.9 (80 MHz operating non-AP HE STAs) if the HE SST non-AP STA is an 80 MHz operating STA.
- The TXVECTOR parameter CH_BANDWIDTH of a DL MU PPDU is not set to HE-CBW-PUNC160-PRI20, HE-CBW-PUNC80+80-PRI20, HE-CBW-PUNC160-SEC40, or HE-CBW-PUNC80+80-SEC40 if the DL MU PPDU is addressed to at least one HE SST non-AP STA that is an 80 MHz operating STA operating in a secondary channel.
- The trigger-enabled TWT SPs do not overlap with TBTTs at which DTIM beacons(#3309) are sent.
- The same subchannel is used for all trigger-enabled TWT SPs with the same HE SST non-AP STA that overlap in time.

An HE SST non-AP STA operating on the secondary channel shall not conduct OMI operation as defined in 26.9 (Operating mode indication) or (#7113)operating mode notification operation as defined in (#1314)11.40 (Notification of operating mode changes) to change the operating bandwidth.


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The HE SST non-AP STA follows the rules in 26.8.2 (Individual TWT agreements) to exchange frames with the HE SST AP during trigger-enabled TWT SPs, except that the STA

- Shall be available in the subchannel indicated in the TWT Channel field of the TWT response at TWT start times.
- Shall not access the medium in the subchannel using DCF or EDCAF.
- Shall not respond to Trigger frames addressed to it (see 26.5 (MU operation) and 26.8.2 (Individual TWT agreements)), unless it has performed CCA until a frame is detected by which it can set its NAV, or until a period equal to NAVSyncDelay has transpired, whichever is earlier.
- Shall update its NAV according to 26.2.4 (Updating two NAVs) if it receives a PPDU in the subchannel.

An HE SST non-AP STA may include a Channel Switch Timing element in (M118)(#4154)(Re)Association Request frames it transmits to an HE SST AP to indicate the time required by the STA to switch between different subchannels. The received channel switch time informs the HE SST AP of the duration of time that the HE SST non-AP STA might not be available to receive frames before the TWT start time and after the end of the trigger-enabled TWT SP.

NOTE—An HE SST STA in PS mode is not required to move to the primary channel after the end of the trigger-enabled TWT SP.

## 26.9 Operating mode indication

### 26.9.1 General

OMI is a procedure used between an OMI initiator and an OMI responder. An HE STA that transmits a frame including an OM Control subfield is defined as an OMI initiator. An HE STA with dot11OMIOptionImplemented equal to true that receives a frame including an OM Control subfield is defined as an OMI responder.

An HE STA with dot11OMIOptionImplemented equal to true shall set the OM Control Support subfield in the HE MAC Capabilities Information field in the HE Capabilities element it transmits to 1; otherwise, the HE STA shall set the OM Control Support subfield to 0. An HE AP shall set dot11OMIOptionImplemented to true, and the HE AP shall implement the reception of the OM Control subfield.

An OMI initiator may send to an OMI responder an individually addressed QoS Data, QoS Null, or Class 3 Management frame after association that contains the OM Control subfield and that solicits an immediate acknowledgment to indicate a change in its receive operating mode (ROM) as defined in 26.9.2 (Receive operating mode (ROM) indication) and/or transmit operating parameters (TOM) as defined in 26.9.3 (Transmit operating mode (TOM) indication). An OMI responder implements the reception of an individually addressed QoS Data, QoS Null, or Class 3 Management frame that contains the OM Control subfield that indicates a change in ROM and/or TOM parameters.

The OMI initiator shall indicate a change in its ROM parameters by including the OM Control subfield in a QoS Data, QoS Null, or Class 3 Management frame that solicits acknowledgment and is addressed to the OMI responder as defined in 26.9.2 (Receive operating mode (ROM) indication).

NOTE 1—Frames that solicit an immediate acknowledgment are, for example, QoS Null frames and QoS Data frames with Normal Ack or Implicit BAR ack policy and Action frames.

An HE STA can change its operating mode setting using either the operating mode notification as described in (#7036)11.40 (Notification of operating mode changes) or the operating mode indication (OMI) procedure described in this subclause. An HE STA should not transmit an OM Control subfield and an Operating Mode field in the same PPDU. If a STA transmits both an OM Control subfield and Operating

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Mode field in the same PPDU, then the OMI responder shall use the channel width and the maximum number of spatial streams indicated by the most recently received OM Control subfield or Operating Mode field from the OMI initiator.

NOTE 2—An OM Control field is transmitted before an Operating Mode field in the same frame.

The OMI initiator supports receiving PPDUs with a bandwidth up to the value indicated by the Channel Width subfield and with a number of spatial streams, *Nss*, as indicated in the Rx NSS subfield of the OM Control subfield and calculated in (#6291)Equation (26-4).

If the operating channel width of the STA is greater than 80 MHz, then the maximum number of spatial streams that the STA supports in reception for a given HE-MCS as a function of the received HE PPDU bandwidth *BW* at an HE STA transmitting an OM Control subfield is defined in Equation (26-4).

$$\text{Floor}\left(Rx\text{-}NSS\text{-}from\text{-}OMI \times \left(Max\text{-}HE\text{-}NSS\text{-}at\text{-}BW \,/\, Max\text{-}HE\text{-}NSS\text{-}at\text{-}80\right)\right) \quad (26\text{-}4)$$

where

*Rx-NSS-from-OMI* is Rx NSS from the OM Control subfield transmitted by the STA

*Max-HE-NSS-at-BW* is the maximum NSS among all HE-MCS at *BW* MHz from the Supported HE-MCS And NSS Set field transmitted by the STA as described in 26.15.4 (Rate selection constraints for HE STAs)

*Max-HE-NSS-at-80* is the maximum NSS among all HE-MCS at 80 MHz from the Supported HE-MCS And NSS Set field transmitted by the STA

NOTE 3—If the operating channel width of the STA is greater than 80 MHz, then the Rx NSS subfield indicates the maximum number of spatial streams for PPDU bandwidths that are equal to or less than 80 MHz. If the operating channel width of the STA is less than or equal to 80 MHz, then the Rx NSS subfield indicates the maximum number of spatial streams, $N_{SS}$, that the STA supports in reception.

The VHT channel width and the VHT NSS allowed at an HE STA transmitting an OM Control subfield are defined in Table 26-9 (Setting of VHT Channel Width and VHT NSS at an HE STA transmitting the OM Control subfield) to determine the allowed NSS when operating as HE STA using channel bandwidth of 160 MHz or 80+80 MHz.

**Table 26-9—Setting of VHT Channel Width and VHT NSS at an HE STA transmitting the OM Control subfield**

| OM Control subfield | VHT capabilities of STA transmitting OM Control subfield | | VHT NSS support of STA transmitting the OM Control subfield as a function of the PPDU bandwidth (× Max VHT NSS) (see requirements R1 and R2 at end of this table) | | | | | Location of 160 MHz center frequency if BSS bandwidth is 160 MHz | Location of secondary 80 MHz center frequency if BSS bandwidth is 80+80 MHz |
|---|---|---|---|---|---|---|---|---|---|
| Channel Width | Supported Channel Width | Extended NSS BW Support | 20 MHz | 40 MHz | 80 MHz | 160 MHz | 80+80 MHz | | |
| 0 | 0–2 | 0–3 | 1 | | | | | | |
| 1 | 0–2 | 0–3 | 1 | 1 | | | | | |
| 2 | 0–2 | 0–3 | 1 | 1 | 1 | | | | |
| 3 | 0 | 1 | 1 | 1 | 1 | 1/2 | | CCFS2 | |
| 3 | 0 | 2 | 1 | 1 | 1 | 1/2 | 1/2 | CCFS2 | CCFS2 |


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**Table 26-9—Setting of VHT Channel Width and VHT NSS at an HE STA transmitting the OM Control subfield *(continued)***

| OM Control subfield | VHT capabilities of STA transmitting OM Control subfield | | VHT NSS support of STA transmitting the OM Control subfield as a function of the PPDU bandwidth (× Max VHT NSS) (see requirements R1 and R2 at end of this table) | | | | | Location of 160 MHz center frequency if BSS bandwidth is 160 MHz | Location of secondary 80 MHz center frequency if BSS bandwidth is 80+80 MHz |
|---|---|---|---|---|---|---|---|---|---|
| Channel Width | Supported Channel Width | Extended NSS BW Support | 20 MHz | 40 MHz | 80 MHz | 160 MHz | 80+80 MHz | | |
| 3 | 0 | 3 | 1 | 1 | 1 | 3/4 | 3/4 | CCFS2 | CCFS2 |
| 3 | 1 | 0 | 1 | 1 | 1 | 1 | | CCFS1 | |
| 3 | 1 | 1 | 1 | 1 | 1 | 1 | 1/2 | CCFS1 | CCFS2 |
| 3 | 1 | 2 | 1 | 1 | 1 | 1 | 3/4 | CCFS1 | CCFS2 |
| 3 | 1 | 3 | 2 | 2 | 2 | 2 | 1 | CCFS1 | CCFS1 |
| 3 | 2 | 0 | 1 | 1 | 1 | 1 | 1 | CCFS1 | CCFS1 |
| 3 | 2 | 3 | 2 | 2 | 2 | 1 | 1 | CCFS1 | CCFS1 |

R1: NSS support shall be rounded down to the nearest integer.
R2: The maximum NSS support shall be 8.

NOTE 1—Max VHT NSS as indicated by the value of the Rx NSS field. The Rx NSS field indicates the same Max HE NSS and Max VHT NSS. Max VHT NSS is at the bandwidth indicated in the VHT Capabilities element. For all allowed MCS values, the Max VHT NSS values are same, but the supported NSS can be different.

NOTE 2—1/2 × or 3/4 × Max VHT NSS support might end up being 0, indicating no support.

NOTE 3—Any other combination than the ones listed in this table is reserved.

NOTE 4—CCFS1 refers to the value of the Channel Center Frequency Segment 1 field of the most recently transmitted VHT Operation element (if any) or HE Operation element.

NOTE 5—CCFS2 refers to the value of the Channel Center Frequency Segment 2 field of the most recently transmitted HT Operation element.

NOTE 6—CCFS1 is nonzero when the current BSS bandwidth is 160 MHz or 80+80 MHz and the NSS support is at least Max VHT NSS. CCFS2 is zero in this case.

NOTE 7—CCFS2 is nonzero when the current BSS bandwidth is 160 MHz or 80+80 MHz and the NSS support is less than Max VHT NSS. CCFS1 is zero in this case.

NOTE 8—At most one of CCFS1 and CCFS2 is nonzero.

NOTE 9—A supported multiple of Max VHT NSS applies to both transmit and receive. A supported multiple of Max HE NSS applies to receive.

NOTE 10—Some combinations of Supported Channel Width Set and Extended NSS BW support might not occur in practice.

The OMI initiator shall indicate a change in its TOM parameters by including the OM Control subfield in a QoS Data, QoS Null, or Class 3 Management frame that solicits an immediate acknowledgment frame and is addressed to the OMI responder as defined in 26.9.3 (Transmit operating mode (TOM) indication).

A non-AP STA OMI initiator that sends an OM Control subfield with UL MU Disable subfield equal to 0, supports transmitting an HE TB PPDU with an RU allocation that is within the operating channel width indicated in the Channel Width subfield and with a number of space-time streams, $N_{STS}$, that is up to the

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value indicated by the Tx NSTS subfield of the OM Control subfield as defined in 26.9.3 (Transmit operating mode (TOM) indication).

NOTE 4—To avoid possible frame loss, an OMI initiator can continue with its current operating channel width, active receive chains, and active transmit chains in HE TB PPDUs and not suspend HE TB PPDUs or Data frames in HE TB PPDUs until it infers that the OMI responder has processed an OM Control subfield from the OMI initiator indicating any of the following changes:

— Reduced operating channel width
— Reduction in the number of active receive chains
— Reduction in the number of active transmit chains in HE TB PPDUs
— Suspension of UL MU operation

The OMI initiator might make this inference from any combination of the following:

— By receiving a frame addressed to itself from the second HE STA in a PPDU with a bandwidth and NSS that are less than or equal to the channel width and NSS, respectively, indicated in the OM Control subfield.
— Based on the passage of time in some implementation-dependent way, which is beyond the scope of this standard.

NOTE 5—It might take a long time for a STA to change its operating mode following the transmission of the OM Control subfield. During that time the STA might not be able to receive frames, and this situation may result in frame loss. If a non-AP STA cannot tolerate frame loss during that period, it can set the Power Management subfield of the Frame Control field of the frame that carries the OM Control subfield to 1 to indicate that the STA has entered power save. When the non-AP STA has completed its operating mode change, it can send another frame (such as a QoS Null) with the Frame Control field Power Management subfield set to 0 to indicate that the STA has exited power save.

### 26.9.2 Receive operating mode (ROM) indication

ROM indication allows the OMI initiator to adapt the maximum operating channel width and/or the maximum number of spatial streams, *Nss*, it can receive from the OMI responder.

An OMI initiator that sends a frame that includes an OM Control subfield should change its OMI parameters, Rx NSS and Channel Width as follows:

— When the OMI initiator changes a ROM parameter from higher to lower, it should make the change for that parameter only after the TXOP in which it received the immediate acknowledgment from the OMI responder.
— When the OMI initiator changes a ROM parameter from lower to higher, it should make the change for that parameter only after the TXOP in which it expects to receive acknowledgment from the OMI responder.

An OMI initiator that is an HE AP should be capable of receiving within an operating channel width and with $N_{SS}$ that are up to the values of the most recently transmitted Channel Width subfield and Rx NSS subfield that the OMI initiator has successfully indicated in the OM Control subfield or in the Operating Mode field sent to any associated STA.

NOTE 1—In the event of transmission failure of the frame containing the OM Control subfield, the OMI initiator attempts the recovery procedure defined in 10.23.2.8 (Multiple frame exchange sequences in an EDCA TXOP(#109)).

The OMI responder shall update the operating channel width and the maximum $N_{SS}$ values as obtained from the Channel Width and Rx NSS subfields, respectively, of the most recently received OM Control subfield sent by the OMI initiator to send SU PPDUs and to assign an RU allocation in sent MU PPDUs, subject to restrictions defined in 27.3.1.2 (OFDMA), addressed to the OMI initiator in subsequent TXOPs. The OMI responder shall update the maximum $N_{SS}$ value to a value determined from the Rx NSS subfield and Table 26-9 (Setting of VHT Channel Width and VHT NSS at an HE STA transmitting the OM Control subfield) if the Channel Width subfield of the OM Control field indicates 160 MHz or 80+80 MHz.

After transmitting the acknowledgment for the frame containing the OM Control subfield, the OMI responder may transmit subsequent SU PPDUs or MU PPDUs that are addressed to the OMI initiator.


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NOTE 2—The acknowledgment is transmitted a SIFS after the frame. A subsequent PPDU is a PPDU that is intended for the OMI initiator and need not be the PPDU immediately following the acknowledgment.

An OMI initiator that is a non-AP STA may set the DL MU-MIMO Resound Recommendation subfield to 1 in the OM Control field in frames addressed to an OMI responder that is an AP to indicate that the non-AP STA suggests that the AP resound the channel with the non-AP STA. An OMI initiator that is a non-AP STA and that has no recommendation on the AP's DL MU-MIMO operation shall set DL MU-MIMO Resound Recommendation subfield to 0.

An OMI responder that receives a frame that carries an OM Control field with the DL MU-MIMO Resound Recommendation field equal to 1 from an OMI initiator may resound the channel or increase the frequency of the channel sounding with the OMI initiator if the OMI responder sends a DL MU-MIMO PPDU addressed to the OMI initiator.

### 26.9.3 Transmit operating mode (TOM) indication

TOM indication allows the OMI initiator to suspend and resume responding to variants of the Trigger frame and TRS Control subfields per the UL MU Disable and UL MU Data Disable subfields settings as indicated in Table 9-29 (UL MU Disable and UL MU Data Disable subfields encoding(11ax)) or to adapt the maximum operating channel width and/or the maximum number of space-time streams, $N_{STS}$, that it can transmit in response to a triggering frame sent by the OMI responder

NOTE 1—TOM indication does not relate to transmissions in PPDUs other than HE TB PPDUs. An AP does not perform TOM indication as an OMI initiator.

An OMI initiator that is a non-AP STA may indicate changes in its transmit parameters by sending a frame that contains the OM Control subfield to the OMI responder. The OMI initiator shall set

- The UL MU Disable subfield to 1 to indicate that responding to a triggering frame is suspended (see 26.5.2 (UL MU operation)).
  - An AP that is an OMI initiator shall set the UL MU Disable subfield to 0.
- The Tx NSTS subfield to the maximum $N_{STS}$ that the STA will use for an HE TB PPDU sent in response to a triggering frame.
- The Channel Width subfield to the maximum operating channel width that the STA will use for an HE TB PPDU sent in response to a triggering frame.

NOTE 2—Responding to all Trigger frame variants, including MU-RTS Trigger frames and NFRP Trigger frames, is suspended.

If a non-AP HE STA has received the OM Control UL MU Data Disable RX Support field in the HE Capabilities element set to 1, then the non-AP HE STA, acting as an OMI initiator, may set the UL MU Disable subfield to 0 and the UL MU Data Disable subfield to 1 to indicate that only UL MU Data frame transmission is suspended. In other words, UL MU control response frame transmissions in response to a Basic Trigger frame are not suspended (see 26.5.2 (UL MU operation)), responses to other Trigger frame variants are not suspended, and management frame transmissions are not suspended.

An OMI initiator shall set the UL MU Disable subfield to 0 and the UL MU Data Disable subfield to 0 to indicate resumption or continuation of participation in all triggered UL MU operations.

If an HE AP has set the OM Control UL MU Data Disable RX Support field in the HE Capabilities element it transmits to 0, an associated STA shall not set the UL MU Data Disable subfield in the OM Control field to 1.

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An OMI initiator that sent a frame including the OM Control subfield should change its TOM parameters, Tx NSTS, UL MU Disable, UL MU Data Disable, and Channel Width as follows:

— If the OMI initiator changes a TOM parameter from higher to lower, it should make the change for that parameter only after the TXOP in which it received the immediate acknowledgment from the OMI responder.

— If the OMI initiator changes a TOM parameter from lower to higher, it should make the change for that parameter only after the TXOP in which it expects to receive acknowledgment from the OMI responder.

The TOM parameters UL MU Disable and UL MU Data Disable change from higher to lower if their values change from 0 to 1. The change of UL MU Disable from 1 to 0 and UL MU Data Disable from 0 to 1 is a change from lower to higher.

An OMI responder that receives a frame containing an OM Control subfield from an OMI initiator performs the operations described below in this subclause.

An AP OMI responder shall not send any triggering frames to a non-AP STA OMI initiator for subsequent TXOPs (see 26.5.2 (UL MU operation)) if the UL MU Disable subfield is 1 in the most recently received OM Control subfield sent by the STA.

NOTE 3—A device might have multiple radios that can create difficult in-device coexistence challenges. The device might set UL MU Disable subfield to 1 and the UL MU Data Disable subfield to 0 if it has trouble responding to a triggering frame because the timing or high transmit power would cause interference with another radio in the device.

An OMI responder shall consider the OMI initiator as participating in UL MU operation for subsequent TXOPs if the UL MU Disable subfield is 0 in the most recently received OM Control subfield with the following restrictions:

— The maximum $N_{STS}$ that the OMI initiator can transmit in an HE TB PPDU is indicated in the Tx NSTS subfield of the OM Control subfield.

— The maximum operating channel width over which the OMI initiator can transmit in an HE TB PPDU is indicated in the Channel Width subfield of the OM Control subfield.

An OMI responder that has transmitted the OM Control UL MU Data Disable RX Support subfield set to 1 shall regard an OMI initiator as capable of participating in UL MU operation only for transmitting acknowledgments if the UL MU Disable subfield is equal to 0 and the UL MU Data Disable subfield is equal to 1 in the most recently received OM Control subfield from that OMI initiator.

The OMI responder shall indicate a number of spatial streams, $N_{SS}$, in the User Info field of a Trigger frame, which contains the AID of the OMI initiator, that is less than or equal to the $N_{STS}$ that is calculated from the Tx NSTS subfield of the OM Control subfield received from the OMI initiator.

The OMI responder shall indicate, in the RU Allocation subfield of the User Info field of a triggering frame addressed to the OMI initiator, an RU allocation that is within the operating channel width specified in the Channel Width subfield of the OM Control subfield received from the OMI initiator and subject to the restrictions defined in 27.3.1.2 (OFDMA).

## 26.10 HE spatial reuse operation(#2389)

### 26.10.1 General

The objective of HE spatial reuse operation is to allow the medium to be reused more often between OBSSs in dense deployment scenarios by the early identification of signals from overlapping basic service sets (OBSSs) and interference management.


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There are two independent spatial reuse modes: OBSS PD-based spatial reuse and PSR-based spatial reuse.

An HE AP participating in spatial reuse may request an associated non-AP HE STA to gather information regarding the neighborhood by sending a Beacon request (see 9.4.2.20.7 (Beacon report)) following the procedure described in 11.11 (DSE procedures). An HE AP shall not set a measurement mode in a Beacon request to an associated STA to a mode for which the STA has not explicitly indicated support via the RM Enabled Capabilities element (see 9.4.2.43 (RM Enabled Capabilities element)). An HE AP that sends a Beacon request for this purpose

- May request that the non-AP HE STA gather information of BSSs matching a particular BSSID and/or SSID.
- May request that the non-AP HE STA generate a report that is only for the channel on which the requesting AP is operating or to which the requesting AP is considering switching.
- Shall request that the non-AP HE STA include the HE Operation element of neighboring HE APs in order to help determine the BSS color information of the neighboring APs.

A non-AP HE STA that performs spatial reuse operation shall have dot11RadioMeasurementActivated set to true and shall respond to a Beacon request from its associated AP with a Beacon report as described in 11.11 (DSE procedures).

A Class B device as defined in 27.3.15.3 (Precorrection accuracy requirements(M118)) shall not operate with the procedures defined in this subclause.

### 26.10.2 OBSS PD-based spatial reuse operation

#### 26.10.2.1 General

OBSS PD-based spatial reuse operation comprises two types of operation. The first type is defined in 26.10.2.2 (General operation with non-SRG OBSS PD level) and allows a STA, under specific conditions, to ignore an inter-BSS PPDU using a non-SRG OBSS PD level. The second type is defined in 26.10.2.3 (General operation with SRG OBSS PD level) and allows a STA, under specific conditions, to ignore inter-BSS PPDUs that are identified as being SRG PPDUs, using an SRG OBSS PD level. In addition to these differences between the two types, Non-SRG OBSS PD Min offset is fixed and defined in the specification while the SRG OBSS PD Min offset can be defined by the AP. A STA may operate using one of the two types, neither type, or both types simultaneously.

#### 26.10.2.2 General operation with non-SRG OBSS PD level

If the PHY of a STA issues a PHY-CCA.indication(BUSY) followed by a (#3038)PHY-RXEARLYSIG.indication or PHY-RXSTART.indication due to a PPDU reception, then the STA's MAC sublayer may(#1120)(#1119):

a) (#1120)issue a PHY-CCARESET.request primitive before the end of the PPDU and not update its basic NAV timer based on the PPDU, or

b) (#1120)treat the PPDU as not having been received for purposes of its basic NAV timer (i.e., not update its basic NAV timer),

(#1120)if (for either (a) or (b)) all the following conditions are met:

1) The STA has not set the TXVECTOR parameter SPATIAL_REUSE to the value PSR_AND_NON_SRG_OBSS_PD_PROHIBITED in any HE PPDU it has transmitted in the current beacon period and in the previous beacon period.

2) The most recently received Spatial Reuse Parameter Set element from its associated AP had the Non-SRG OBSS PD SR Disallowed subfield equal to 0, or the non-AP STA has not received a Spatial Reuse Parameter Set element from its associated AP, or the STA is an AP and its most

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recently transmitted Spatial Reuse Parameter Set element had the Non-SRG OBSS PD SR Disallowed subfield equal to 0, or the STA is an AP and has not transmitted a Spatial Reuse Parameter Set element.

3) The received PPDU is an inter-BSS PPDU (see 26.2.2 (Intra-BSS and inter-BSS PPDU classification)), and the received PPDU is not a non-HT PPDU carrying a response frame (Ack, BlockAck, or CTS frame); or the received PPDU contains a CTS, a PHY-CCA.indication transition from BUSY to IDLE occurred within the PIFS time immediately preceding the received CTS, and that transition corresponded to the end of an inter-BSS PPDU that contained an RTS that was (#3683)discarded following this procedure.

4) The STA is operating with an SRG OBSS PD level as described in 26.10.2.3 (General operation with SRG OBSS PD level), and the received PPDU is not an SRG PPDU; or the STA is not operating with an SRG OBSS PD level.

5) The SPATIAL_REUSE subfield in the HE-SIG-A field (if present) of the received PPDU is not set to PSR_AND_NON_SRG_OBSS_PD_PROHIBITED.

6) The received signal strength level, which is measured from the L-STF or L-LTF fields of the PPDU or the PHY SYNC field, shortSYNC field, or Long PHY SYNC field, whichever exists and is used to determine PHY-CCA.indication, is below the non-SRG OBSS PD level. The non-SRG OBSS PD level is defined in 26.10.2.4 (Adjustment of OBSS PD and transmit power). If the STA has dot11HEPSROptionImplemented set to true, it also follows the rules defined in 26.10.4 (Interaction of OBSS PD and PSR-based spatial reuse) to determine non-SRG OBSS PD level.

7) The PPDU is not one of the following:

   i) A non-HE PPDU that carries a frame where the RA field is equal to the STA MAC address

   ii) A non-HE PPDU that carries a Public Action frame

   iii) A non-HE PPDU that carries a VHT/HE NDP Announcement frame or FTM frame(#7223)

   iv) A non-HE NDP

NOTE 1—A STA cannot perform SR over an HE sounding NDP or HE TB feedback NDP (see 26.11.6 (SPATIAL_REUSE)).

If the frame is carried in an HE ER SU PPDU that is identified as an inter-BSS PPDU (where power of the L-STF/L-LTF symbols is boosted 3 dB), 3 dB shall be subtracted from the received signal strength measured from the L-STF or L-LTF fields of the PPDU, prior to using it to determine PHY-CCA.indication and to comparing it to the non-SRG OBSS PD level as described in this subclause, to compensate for the power difference.

NOTE 2—If a received CF-End frame satisfies the conditions above, neither the issuance of a PHY-CCARESET.request nor the choice to not update the basic NAV timer results in the cancellation of the NAV, which would normally occur following the reception of a CF-End frame.

The PHY-CCARESET.request primitive shall be issued at the end of the PPDU if the PPDU is an HE SU PPDU or an HE ER SU PPDU and the RXVECTOR parameter SPATIAL_REUSE indicates SR_DELAYED.

NOTE 3—A STA sets the TXVECTOR parameter SPATIAL_REUSE to SR_DELAYED in a PPDU if it allows OBSS PD-based spatial reuse operation, but only after the end of the PPDU.

NOTE 4—An AP can get protection equivalent to SR_DELAYED by transmitting the Trigger frame in a non-HT PPDU or HT PPDU with the TXVECTOR parameter AGGREGATION set to 0 instead of in a VHT PPDU.


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If the PHY-CCARESET.request primitive is issued before the end of the received PPDU, and a TXOP is initiated within the duration of the received PPDU, then the TXOP and the duration of the transmitted PPDU within that TXOP shall be limited to the duration of the received PPDU if the received PPDU is an HE MU PPDU and the RXVECTOR parameter SPATIAL_REUSE indicates SR_RESTRICTED.

NOTE 5—A STA sets the TXVECTOR parameter SPATIAL_REUSE to SR_RESTRICTED in a PPDU if it allows OBSS PD-based spatial reuse operation, but only before the end of the PPDU.

A STA that ignores a PPDU following the procedure described in this subclause is deemed to perform non-SRG OBSS PD-based spatial reuse.

### 26.10.2.3 General operation with SRG OBSS PD level

If the PHY of a STA issues a PHY-CCA.indication(BUSY) followed by a (#3038)PHY-RXEARLYSIG.indication or PHY-RXSTART.indication due to a PPDU reception, then the STA's MAC sublayer may(#1121):

a) (#1121)issue a PHY-CCARESET.request primitive before the end of the PPDU and not update its basic NAV timer based on the PPDU, or

b) (#1121)treat the PPDU as not having been received for purposes of its basic NAV timer (i.e., not update its basic NAV timer),

(#1121)if (for either (a) or (b)) all the following conditions are met:

1) The received PPDU is an SRG PPDU (see 26.2.3 (SRG PPDU identification))

2) The received signal strength level, which is measured from the L-STF or L-LTF fields of the PPDU or the PHY SYNC field, shortSYNC field, or Long PHY SYNC field, whichever exists and is used to determine PHY-CCA.indication, is below the SRG OBSS PD level. The SRG OBSS PD level is defined in 26.10.2.4 (Adjustment of OBSS PD and transmit power). If the STA has dot11HEPSROptionImplemented set to true, it also follows the rules defined in 26.10.4 (Interaction of OBSS PD and PSR-based spatial reuse) to determine SRG OBSS PD level.

3) The PPDU is not one of the following:

   i) A non-HE PPDU that carries a frame where the RA field is equal to the STA MAC address

   ii) A non-HE PPDU that carries a Public Action frame

   iii) A non-HE PPDU that carries a VHT/HE NDP Announcement frame or FTM frame(#7223)

   iv) A non-HE NDP

NOTE 1—A STA cannot perform SR over an HE sounding NDP or HE TB feedback NDP (see 26.11.6 (SPATIAL_REUSE)).

If the frame is carried in an HE ER SU PPDU that is identified as an inter-BSS PPDU (where power of the L-STF/L-LTF symbols is boosted 3 dB), 3 dB shall be subtracted from the received signal strength measured from the L-STF or L-LTF fields of the PPDU, prior to using it to determine PHY-CCA.indication and to comparing it to the SRG OBSS PD level as described in this subclause, to compensate for the power difference.

NOTE 2—If a received CF-End frame satisfies the conditions above, neither the issuance of a PHY-CCARESET.request nor the choice to not update the basic NAV timer results in the cancellation of the NAV, which would normally occur following the reception of a CF-End frame.

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The PHY-CCARESET.request primitive shall be issued at the end of the PPDU if the PPDU is an HE SU PPDU or an HE ER SU PPDU and the RXVECTOR parameter SPATIAL_REUSE indicates SR_DELAYED.

NOTE 3—An AP can get protection equivalent to SR_DELAYED by transmitting the Trigger frame in a non-HT PPDU or HT PPDU with the TXVECTOR parameter AGGREGATION set to 0 instead of in a VHT PPDU.

If the PHY-CCARESET.request primitive is issued before the end of the received PPDU, and a TXOP is initiated within the duration of the received PPDU, then the TXOP and the duration of the transmitted PPDU within that TXOP shall be limited to the duration of the received PPDU if the received PPDU is an HE MU PPDU and the RXVECTOR parameter SPATIAL_REUSE indicates SR_RESTRICTED.

NOTE 4—The restriction, in addition to the TXOP limit, of the PPDU duration within the TXOP is included in the above paragraph related to SR_RESTRICTED as there are conditions where the TXOP limit can be exceeded (see 10.23.2.9 (TXOP limits)).

An AP that sends a Spatial Reuse Parameter Set element with the SRG Information Present subfield in the SR Control field set to 1 shall set the SRG BSS Color Bitmap and SRG Partial BSSID Bitmap fields as follows:

— If the transmitting AP is in the same ESS as another AP (i.e., with the same SSID and connected by a DS) or is controlled by the same external management entity as another AP (irrespective of SSID), then the transmitting AP may set the SRG BSS Color Bitmap and/or SRG Partial BSSID Bitmap fields that correspond to that other AP to 1.

— Otherwise, the AP shall set the bits in the SRG BSS Color Bitmap and/or SRG Partial BSSID Bitmap to 0.

If an HE AP determines values for dot11SRGAPBSSColorBitmap and dot11SRGAPBSSIDBitmap (i.e., the SRG for the AP's own transmissions), then the values shall be determined according to the rules above in this subclause.

### 26.10.2.4 Adjustment of OBSS PD and transmit power

If using OBSS PD-based spatial reuse, an HE STA shall maintain an OBSS PD level and may adjust this OBSS PD level in conjunction with its transmit power and a value, *PPDU_BW*, derived from the received PPDU. The adjustment shall be made in accordance with Equation (26-5).(#2379)

$$OBSS\_PD_{level} \le max(OBSS\_PD_{min}, min(OBSS\_PD_{max}, OBSS\_PD_{min} + (TX\_PWR_{ref} - TX\_PWR))) + 10\log 10(PPDU\_BW/20\ \text{MHz}) \quad (26\text{-}5)$$

where *PPDU_BW* is determined by Table 26-10 (PPDU_BW determination) using the following RXVECTOR parameter of the received PPDU:

— CH_BANDWIDTH if present

— CH_BANDWIDTH_IN_NON_HT if present and if CH_BANDWIDTH is not present

— DATARATE if neither CH_BANDWIDTH nor CH_BANDWIDTH_IN_NON_HT is present

**Table 26-10—*PPDU_BW* determination**

| DATARATE | CH_BANDWIDTH or CH_BANDIWDTH_IN_NON_HT | *PPDU_BW* |
|---|---|---|
| N/A | CBW20, HT_CBW20, NON_HT_CBW20 | 20 MHz |
| N/A | CBW40, HT_CBW40, NON_HT_CBW40 | 40 MHz |
| N/A | CBW80, HE-CBW-PUNC80-PRI, HE-CBW-PUNC80-SEC | 80 MHz |


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**Table 26-10—*PPDU_BW* determination *(continued)***

| | | |
|---|---|---|
| N/A | CBW160, CBW80+80, HE-CBW-PUNC160-PRI20, HE-CBW-PUNC80+80-PRI20, HE-CBW-PUNC160-SEC40, HE-CBW-PUNC80+80-SEC40 | 160 MHz |
| 1, 2, 5.5, or 11 | N/A | 20 MHz |

The value of the $OBSS\_PD_{level}$ is applicable to the start of a 20 MHz PPDU received on the primary 20 MHz channel. If the bandwidth of the received PPDU differs from 20 MHz, then the value of the $OBSS\_PD_{level}$ is increased by(#2379) 10 log10 (bandwidth/20 MHz), using the bandwidth in MHz indicated by the value of RXVECTOR parameter CH_BANDWIDTH or CH_BANDWIDTH_IN_NON_HT if present.

$TX\_PWR_{ref}$ = 21 dBm for non-AP STAs.

$TX\_PWR_{ref}$ = 21 dBm for an AP with the Max HE-MCS For 3 SS subfield in the Tx HE-MCS Map ≤ 80 MHz subfield in the Supported HE-MCS and NSS Set field of its HE Capabilities element field set to 3.

$TX\_PWR_{ref}$ = 25 dBm for an AP with the Max HE-MCS For 3 SS subfield in the Tx HE-MCS Map ≤ 80 MHz subfield in the Supported HE-MCS and NSS Set field of its HE Capabilities element field set to a value other than 3.

*TX_PWR* is the combined transmit power at the transmit antenna connector of all antennas in dBm and is set following the rules in (#1085)11.7.6 (Transmit power selection) and, for transmission of HE TB PPDU, also following the rules in 27.3.15.2 (Power precorrection(M118)).

NOTE 1—The $TX\_PWR_{ref}$ is 4 dB higher for APs with more than 2 spatial streams because those APs typically have higher transmit power than other devices and the OBSS PD procedure is based on a relative reduction of power.

NOTE 2—A STA might adjust its OBSS PD level, provided that Equation (26-5) is satisfied. As an example, a non-AP HE STA might monitor the beacons transmitted by the AP to which it is associated, measure their RSSI, subtract a value of 25 dB (as an approximation to the required RSNI) to provide a candidate OBSS PD level, and if Equation (26-5) is satisfied, adjust its OBSS PD level to the candidate level.

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The adjustment rule is illustrated in Figure 26-11 (Illustration of the adjustment rule for OBSS PD and TX_PWR(11ax)).

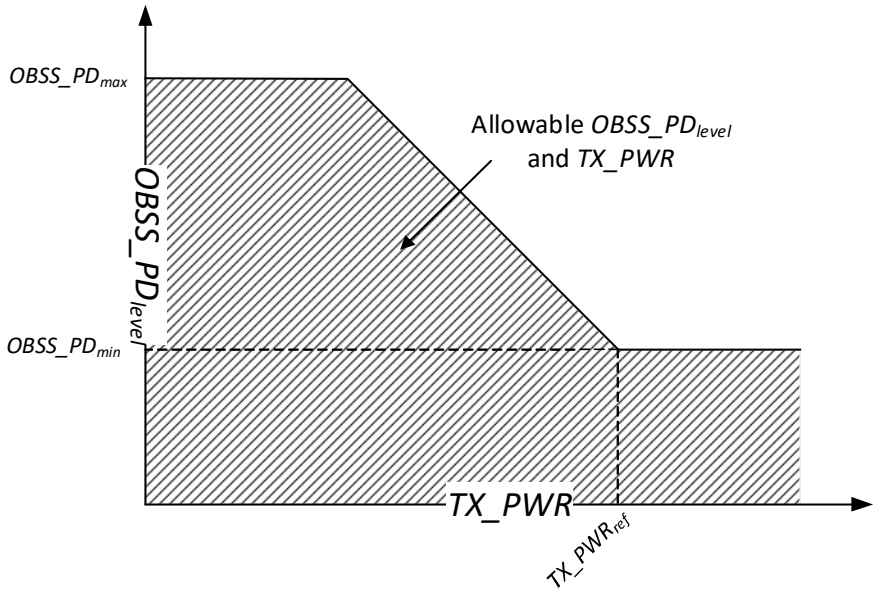


**Figure 26-11—Illustration of the adjustment rule for OBSS PD and TX_PWR(11ax)**

An AP may define SRG OBSS PD Min Offset and SRG OBSS PD Max Offset values that are used by its associated STAs to derive an SRG OBSS PD level for determining reception behavior for inter-BSS PPDUs that are determined to be SRG PPDUs. An AP may define a non-SRG OBSS PD Max Offset value that is used by its associated STAs to derive a non-SRG OBSS PD level for determining reception behavior for inter-BSS PPDUs that are not determined to be SRG PPDUs. The values of SRG OBSS PD Min Offset, SRG OBSS PD Max Offset, and Non-SRG OBSS PD Max Offset are transmitted to associated STAs within the Spatial Reuse Parameter Set element.

An AP transmitting a Spatial Reuse Parameter Set element shall respect the following constraints:

— $-82 \leq -82 + \text{SRG OBSS PD Min Offset} \leq -62$
— $\text{SRG OBSS PD Min Offset} \leq \text{SRG OBSS PD Max Offset}$
— $-82 + \text{SRG OBSS PD Max Offset} \leq -62$
— $-82 + \text{Non-SRG OBSS PD Max Offset} \leq -62$

An HE STA shall maintain a non-SRG OBSS PD level, with its value selected by respecting the OBSS PD level condition in Equation (26-5) but with Non-SRG OBSS PD Min and Non-SRG OBSS PD Max in place of $OBSS\_PD_{min}$ and $OBSS\_PD_{max}$, respectively. A non-AP STA shall determine Non-SRG OBSS PD Min and Non-SRG OBSS PD Max according to Table 26-11 (Non-SRG OBSS PD Min and Non-SRG OBSS PD Max values for non-AP STAs(11ax)). An HE AP shall set Non-SRG OBSS PD Min to –82 dBm and Non-SRG OBSS PD Max to –82 dBm + dot11NonSRGAPOBSSPDMaxOffset.


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**Table 26-11—Non-SRG OBSS PD Min and Non-SRG OBSS PD Max values for non-AP STAs(11ax)**

| Non-SRG OBSS PD SR Disallowed field in Spatial Reuse Parameter Set element | Non-SRG Offset Present field in Spatial Reuse Parameter Set element | Value of Non-SRG OBSS PD Min (dBm) | Value of Non-SRG OBSS PD Max (dBm) |
|---|---|---|---|
| Not applicable if the Spatial Reuse Parameter Set element is not received | Not applicable if the Spatial Reuse Parameter Set element is not received | –82 | –62 |
| 0 | 0 | –82 | –62 |
| 0 | 1 | –82 | –82 + Non-SRG OBSS PD Max Offset |
| 1 | N/A | –82 | –82 |

An HE STA shall maintain an SRG OBSS PD level, with its value selected by respecting the OBSS PD level condition in Equation (26-5) but with SRG OBSS PD Min and SRG OBSS PD Max in place of $OBSS\_PD_{min}$ and $OBSS\_PD_{max}$, respectively. A non-AP STA shall determine SRG OBSS PD Min and SRG OBSS PD Max using Table 26-12 (SRG OBSS PD Min and SRG OBSS PD Max values for non-AP STAs(11ax)). An HE AP shall set SRG OBSS PD Min to –82 + dot11SRGAPOBSSPDMinOffset dBm and SRG OBSS PD Max to –82 + dot11SRGAPOBSSPDMaxOffset dBm. An HE AP may transmit SRG OBSS PD Min and SRG OBSS PD Max offset values that are different from the ones that it uses.

**Table 26-12—SRG OBSS PD Min and SRG OBSS PD Max values for non-AP STAs(11ax)**

| SRG Information Present field in Spatial Reuse Parameter Set element | Value of SRG OBSS PD Min (dBm) | Value of SRG OBSS PD Max (dBm) |
|---|---|---|
| Not applicable if the Spatial Reuse Parameter Set element is not received | N/A see NOTE | N/A see NOTE |
| 0 | N/A see NOTE | N/A see NOTE |
| 1 | –82 + SRG OBSS PD Min Offset | –82 + SRG OBSS PD Max Offset |
| NOTE—If SRG Information is not present, a STA cannot determine a PPDU to be SRG and therefore will not use SRG OBSS PD Min or SRG OBSS PD Max values. | | |

The Spatial Reuse Parameter Set element is optionally present in Beacon frames, Probe Response frames, and (Re)Association Response frames.

### 26.10.2.5 OBSS PD SR transmit power restriction period

If a STA ignores an inter-BSS PPDU following the procedure in 26.10.2.3 (General operation with SRG OBSS PD level) using a chosen SRG OBSS PD level, or following the procedure in 26.10.2.2 (General operation with non-SRG OBSS PD level) using a chosen non-SRG OBSS PD level, then the STA shall start

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an OBSS PD SR transmit power restriction period. This OBSS PD SR transmit power restriction period shall be terminated at the end of the TXOP that the STA gains once its backoff reaches zero.

If a STA starts an OBSS PD SR transmit power restriction period with a chosen non-SRG OBSS PD level, the STA's transmit power as measured at the transmit antenna connector shall be equal to or lower than the $TX\_PWR_{max}$, calculated with the chosen non-SRG OBSS PD level using Equation (26-6) and the appropriate non-SRG parameters according to Table 26-11 (Non-SRG OBSS PD Min and Non-SRG OBSS PD Max values for non-AP STAs(11ax)), for the transmissions of any PPDU that is not carrying a frame that is allowed to be sent without regard to the busy/idle state of the medium until the end of the OBSS PD SR transmit power restriction period.

If a STA starts an OBSS PD SR transmit power restriction period with a chosen SRG OBSS PD level, the STA's transmit power as measured at the transmit antenna connector shall be equal to or lower than the $TX\_PWR_{max}$, calculated with the chosen SRG OBSS PD level using Equation (26-6) and the appropriate SRG parameters according to Table 26-12 (SRG OBSS PD Min and SRG OBSS PD Max values for non-AP STAs(11ax)), for the transmissions of any PPDU that is not carrying a response frame that is allowed to be sent without regard to the busy/idle state of the medium until the end of the OBSS PD SR transmit power restriction period.

NOTE 1—Examples of frames that are transmitted without regard to the busy/idle state of the medium include but are not limited to a frame contained in an HE TB PPDU that is a response to a Trigger frame with the CS Required subfield set to 0 and an Ack or BlockAck frame sent as an immediate response.

A STA may have multiple ongoing OBSS PD SR transmit power restriction periods that overlap in time.

NOTE 2—The STA's transmit power is always equal to or lower than the minimum $TX\_PWR_{max}$ among all $TX\_PWR_{max}$ from ongoing OBSS PD SR transmit power restriction periods.

NOTE 3—Equation (26-6) is equivalent to the condition defined in Equation (26-5). The STA can derive $OBSS\_PD_{level}$ from its transmit power or can derive $TX\_PWR_{max}$ from $OBSS\_PD_{level}$(#1317).

$$TX\_PWR_{max} = \begin{cases} \text{unconstrained, if } OBSS\_PD_{level} \le OBSS\_PD_{min} \\ TX\_PWR_{ref} - (OBSS\_PD_{level} - OBSS\_PD_{min}), \text{ if } OBSS\_PD_{max} \ge OBSS\_PD_{level} > OBSS\_PD_{min} \end{cases} \quad (26\text{-}6)$$

NOTE 4—Anytime, even if $TX\_PWR_{max}$ is unconstrained, the STA has to respect the transmit power restrictions defined in 11.7.6.

An example of OBSS PD SR operation is shown in Figure 26-12 (Example of OBSS PD SR operation(11ax)). In this example, STA SR S2

- Receives the PPDU from S1 and, if it classifies the PPDU as inter-BSS PPDU, ignores the PPDU using OBSS PD-based spatial reuse with non-SRG OBSS PD, starts the OBSS PD SR transmit power restriction period 1 with TX_PWRmax 1, and decrements its backoff counter until the reception of the PPDU from D1.
- Receives the PPDU from D1 and, if it classifies the PPDU as inter-BSS PPDU, ignores the PPDU (if it chooses to do so) using OBSS PD-based spatial reuse with non-SRG OBSS PD, starts the OBSS PD SR transmit power restriction period 2 with TX_PWRmax 2, and decrements its backoff counter until the reception of the PPDU from S1".
- Defers during the TXOP S1" set by the intra-BSS PPDU from S1" that belongs to its own BSS and, at the end of the TXOP S1", resumes the decrement of its backoff until the reception of the PPDU from S1'.
- Receives the PPDU from S1' and, if it classifies the PPDU as SRG PPDU, ignores the PPDU (if it chooses to do so) using OBSS PD-based spatial reuse with SRG OBSS PD, starts the OBSS PD SR


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transmit power restriction period 3 with TX_PWRmax 3, and decrements its backoff counter until the counter reaches zero because it does not receive the PPDU from D1'.

— Starts transmitting a PPDU with a TX_PWRmax equal to min(TX_PWRmax 1, TX_PWRmax 2, TX_PWRmax 3) and respects this transmit power restriction until the end of the SR TXOP.

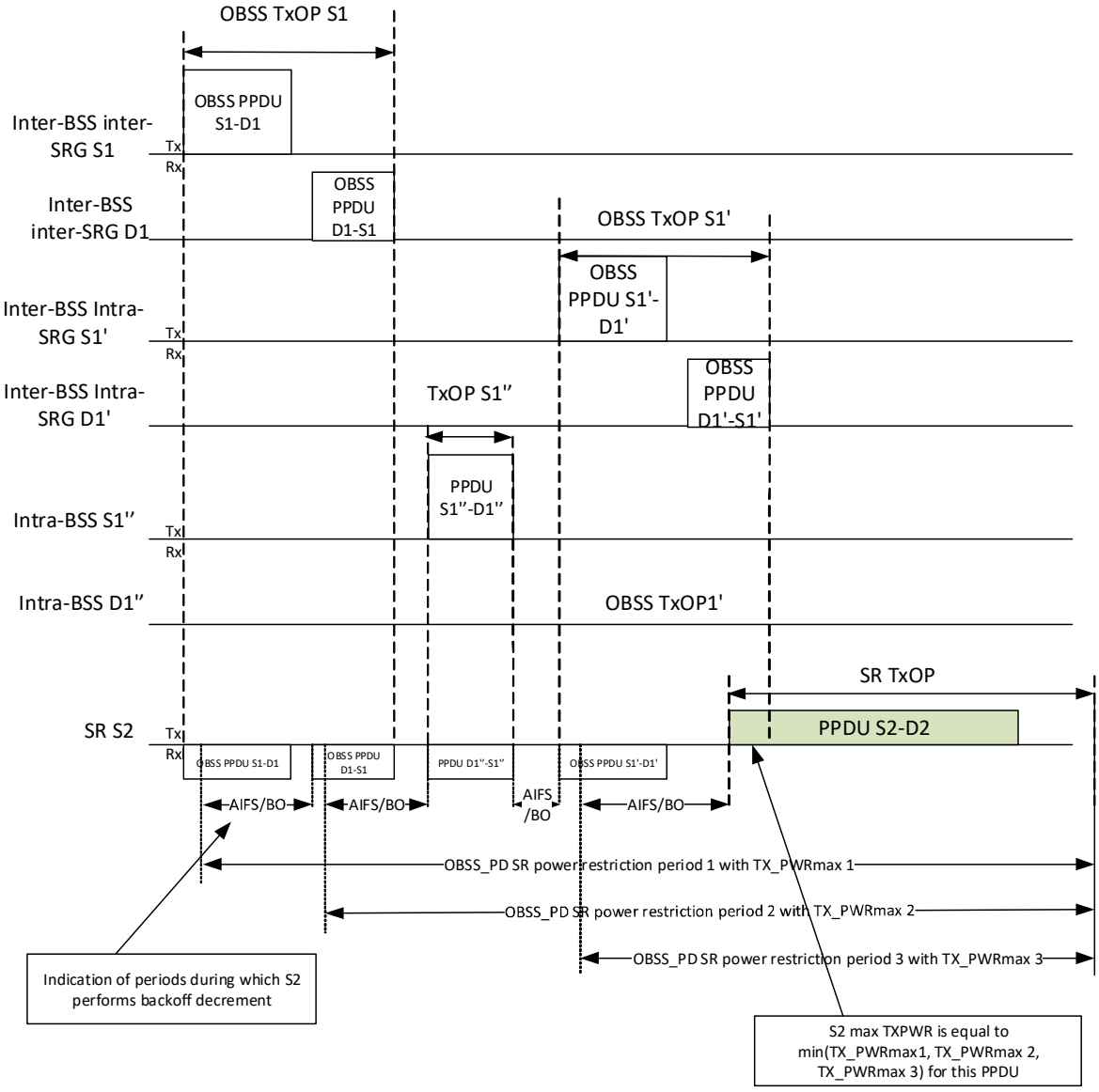


**Figure 26-12—Example of OBSS PD SR operation(11ax)**

### 26.10.2.6 OBSS PD-based spatial reuse backoff procedure

If an HE STA ignores an inter-BSS PPDU following the procedure in 26.10.2.2 (General operation with non-SRG OBSS PD level), the HE STA may resume EDCAF procedures after the PHY-CCARESET.request primitive is sent, provided that the medium condition is not otherwise indicated as BUSY.

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### 26.10.3 PSR-based spatial reuse operation

#### 26.10.3.1 General

An HE STA supporting PSR-based PSRT PPDU transmission indicates this support by setting the PSR-based SR Support subfield to 1 in the HE PHY Capabilities Information field in the HE Capabilities element (see Table 9-376 (Subfields of the HE PHY Capabilities Information field(11ax))). An HE-STA supporting PSR-based PSRT PPDU reception indicates this support by setting the PSR Responder subfield to 1 in the HE MAC Capabilities Information field in the HE Capabilities element (see Table 9-375 (Subfields of the HE MAC Capabilities Information field(11ax))).

An HE STA shall set the PSR-based SR Support field to 1 in the HE Capabilities element it transmits if it supports transmitting an PSRT PPDU under the conditions specified in this subclause; otherwise, the STA shall set the PSR-based SR Support field to 0.

STAs that receive a Spatial Reuse Parameter Set element from their associated AP that has a value of 1 in the PSR Disallowed subfield shall not perform PSR-based SR transmissions.

An PSR opportunity is identified from the value of the RXVECTOR parameter SPATIAL_REUSE of an HE TB PPDU and/or the contents of a Trigger frame. An HE STA may initiate an SR transmission during an PSR opportunity for the duration of an ongoing PPDU when certain conditions, designed to avoid interfering with the reception of the ongoing PPDU at the recipient, are met. If the RXVECTOR parameter SPATIAL_REUSE of the ongoing PPDU has the value PSR_DISALLOW or PSR_AND_NON_SRG_OBSS_PD_PROHIBITED, no PSR-based SR transmission is allowed for the duration of that PPDU.

An AP sending a Trigger frame may set the Spatial Reuse *n* field(s) in the UL Spatial Reuse subfield in the Common Info field of the Trigger frame to PSR_DISALLOW or, if permitted by the rules in 26.11.6 (SPATIAL_REUSE), to PSR_AND_NON_SRG_OBSS_PD_PROHIBITED to disallow OBSS STAs from performing PSR-based SR transmission during the ensuing uplink PPDU duration. An AP sending a Trigger frame shall not set the SR field in the Common Info field of the Trigger frame to SR_DELAYED or SR_RESTRICTED.

An HE STA shall set the PSR Responder subfield in the HE Capabilities element it transmits to 1 if dot11SRResponderOptionImplemented is true; otherwise, the HE STA shall set the PSR Responder subfield to 0.(#3035)(#3036)

#### 26.10.3.2 PSR-based spatial reuse initiation

An HE STA identifies an PSR opportunity if the following two conditions are met:

a) The STA receives a (#3038)PHY-RXEARLYSIG.indication or PHY-RXSTART.indication corresponding to the reception of a PSRR PPDU that is identified as an inter-BSS PPDU (see 26.2.2 (Intra-BSS and inter-BSS PPDU classification)).

b) An PSRT PPDU is queued for transmission, and the intended transmit power of the PSRT PPDU in dBm meets the following condition:(#2243)(#3360)(#4316)

$$TxPower_{PSRT} - 10 \times log10(N_{PSRT,nonpunc}) \leq PSR_{min} - RPL_{PSRR,20MHz}$$

where,

$TxPower_{PSRT}$ is the intended transmit power over the entire bandwidth of the PSRT PPDU in dBm
$N_{PSRT,nonpunc}$ is the number of nonpunctured 20 MHz subchannels of the PSRT PPDU
$RPL_{PSRR,20MHz}$ is the normalized received signal power in units of dBm/20 MHz, measured at the antenna connector in at least one 20 MHz subchannel. The measured 20 MHz subchannel(s)


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shall be the subchannel(s) in which the preamble of both the PSRR PPDU and the PSRT PPDU are present. The measurement method is implementation dependent.

$PSR_{min}$ is equal to the PSR value if there exists one PSR value within the bandwidth of the PSRT PPDU or the smallest of the PSR values if there exist multiple PSR values within the bandwidth of the PSRT PPDU. Each PSR value is specified per 20 MHz. They are obtained from the Meaning column of Table 27-24 (Spatial Reuse field encoding for an HE TB PPDU(11ax)) based on at least one of the following:

i) The value of the UL Spatial Reuse subfield in the Common Info field of the Trigger frame of the PSRR PPDU.

ii) The value of the RXVECTOR parameter Spatial Reuse of the HE TB PPDU that follows the PSRR PPDU.

(#2243)The PSR value is determined for each 20 MHz subchannel for a 20 MHz, 40 MHz, or 80 MHz PPDU. In the case of a 160 MHz or 80+80 MHz PSRR PPDU or HE TB PPDU that follows the PSRR PPDU, the UL Spatial Reuse subfield or the RXVECTOR parameter SPATIAL_REUSE represent the PSR value per 20 MHz and the two 20 MHz subchannels within each 40 MHz subband have the same PSR value, see Table 27-22 (HE-SIG-A field of an HE TB PPDU(11ax)).

An HE STA that identifies an PSR opportunity may choose to not perform NAV update operations normally executed based on the receipt of the RXVECTOR parameter TXOP_DURATION and the Trigger frame Duration field. (#2245)An OBSS STA, shown as $STA_{OBSS-A}$ in Figure 26-13 (PSRR PPDU spatial reuse(#2245)(11ax)(#3277)), that identifies an PSR opportunity to transmit a PSRT PPDU to another OBSS STA, shown as $STA_{OBSS-B}$ in the same figure, may issue a PHY-CCARESET.request to (#3683)discard the associated HE TB PPDU(s) that are triggered by the Trigger frame of the PSRR PPDU and that occur within aSIFSTime + aRxPHYStartDelay + 2 × aSlotTime of the end of the last symbol on the air of the triggering PPDU (which is also the PSRR PPDU), provided that the value of the RXVECTOR parameter BSS_COLOR of the HE TB PPDU matches the BSS color of the PSRR PPDU. An OBSS STA that identifies an PSR opportunity shall not transmit an PSRT PPDU that terminates beyond the PPDU duration of the HE TB PPDU that is triggered by the Trigger frame of the PSRR PPDU.

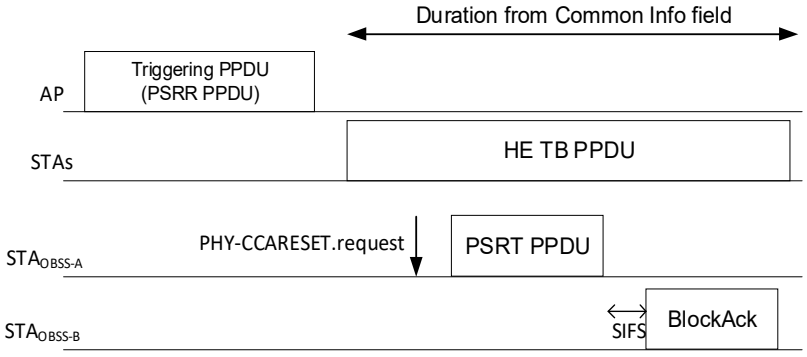


**Figure 26-13—PSRR PPDU spatial reuse(#2245)(11ax)(#3277)**

### 26.10.3.3 PSR-based spatial reuse backoff procedure

If an HE STA identifies an PSR opportunity as allowed in 26.10.3.2 (PSR-based spatial reuse initiation), the HE STA may continue the countdown of an existing backoff procedure, provided that the medium condition is not otherwise indicated as BUSY. If the HE STA receives another PPDU during the backoff procedure, it shall suspend its backoff; subsequently, if an PSR opportunity is identified based on the identification of the new PPDU as an PSRR PPDU, then the STA may resume its backoff procedure. The TXOP that the HE

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STA gains once its backoff reaches zero shall not extend beyond the PSR opportunity endpoint that is the earliest ending of all durations of all PSRR PPDUs that were used to confirm the PSR opportunity and all durations indicated in the Common Info fields of Trigger frames within all PSRR PPDUs that were used to confirm the PSR opportunity.

If the HE STA is employing $OBSS\_PD_{level}$ as a threshold for determination of an IDLE medium condition prior to the reception of an PSRR PPDU per the rules specified in 26.10.2 (OBSS PD-based spatial reuse operation), the intended transmit power of the next PSRT PPDU in the transmission queue as measured at the transmit antenna connector shall be equal to or lower than the $TX\_PWR_{max}$, calculated with this specific $OBSS\_PD_{level}$ using Equation (26-6).

After a STA has identified the start of an PSR opportunity, and until the PSR opportunity endpoint is reached, the transmission of any PPDU by the STA shall be limited by the transmit power restrictions identified in 26.10.3 (PSR-based spatial reuse operation).

### 26.10.3.4 UL Spatial Reuse subfield of Trigger frame

An AP with dot11HEPSROptionImplemented set to true that transmits a Trigger frame may determine the value of the UL Spatial Reuse subfield of the Common Info field of the Trigger frame for each 20 MHz subchannel for a 20 MHz, 40 MHz, or 80 MHz PPDU or for each 40 MHz subchannel for an 80+80 MHz or 160 MHz PPDU by selecting the row in Table 27-24 (Spatial Reuse field encoding for an HE TB PPDU(11ax)) that has a(#3435) value in the (#4177)Meaning column that is the highest value that is less than or equal to the numeric(#3435) value of the computed MAC parameter PSR_INPUT as follows:

$$\text{PSR\_INPUT} = TX\_PWR_{AP} + \text{Acceptable Receiver Interference Level}_{\text{AP}} \quad (26\text{-}7)$$

where

$TX\_PWR_{AP}$ is the total power at the antenna connector, in dBm, for that 20 MHz subchannel for a 20 MHz, 40 MHz, or 80 MHz PPDU or for that 40 MHz subchannel for an 80+80 MHz or 160 MHz PPDU, over all antennas used to transmit the PSRR PPDU containing the Trigger frame

Acceptable Receiver Interference $\text{Level}_{\text{AP}}$ is a value in dBm for that 20 MHz subchannel for a 20 MHz, 40 MHz, or 80 MHz PPDU or for that 40 MHz subchannel for an 80+80 MHz or 160 MHz PPDU and should be set to the expected receive signal power indicated by the UL Target Receive Power subfield in the Trigger frame for the highest HE-MCS of the ensuing HE TB PPDUs minus the minimum SNR value that yields ≤ 10% PER for that MCS minus a safety margin value not to exceed 5 dB as determined by the AP

An AP with dot11HEPSROptionImplemented set to true that transmits a Trigger frame may set the value of the UL Spatial Reuse subfield of the Common Info field of the Trigger frame in each 20 MHz bandwidth for a 20 MHz, 40 MHz, or 80 MHz PPDU or in each 40 MHz bandwidth for an 80+80 or 160 MHz PPDU to PSR_DISALLOW.

An AP with dot11HEPSROptionImplemented set to false that transmits a Trigger frame shall set the value of the UL Spatial Reuse subfield of the Common Info field of the Trigger frame in each 20 MHz bandwidth for a 20 MHz, 40 MHz, or 80 MHz PPDU or in each 40 MHz bandwidth for an 80+80 or 160 MHz PPDU to PSR_DISALLOW.

### 26.10.3.5 PSRT PPDU transmission requirements

An HE STA that identifies an PSR opportunity shall not transmit a frame during the PSR opportunity that elicits a response transmission from a STA from which it has not received an HE Capabilities element with the PSR Responder subfield equal to 1. An HE STA that identifies an PSR opportunity shall not transmit a


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frame that does not include a CAS Control subfield with the PSRT PPDU subfield set to 1 and that solicits a response transmission during that PSR opportunity.

#### 26.10.3.6 PSRT PPDU reception and response transmission requirements

An HE STA that receives a PPDU that contains at least one frame with a CAS Control subfield with an PSRT PPDU subfield equal to 1 shall not transmit a response PPDU elicited by the received PPDU if all outstanding PSR and OBSS PD transmit power requirements are not met by the response transmission.

### 26.10.4 Interaction of OBSS PD and PSR-based spatial reuse

An HE STA with dot11HEPSROptionImplemented set to true that receives a PPDU that is identified as an inter-BSS PPDU with a value other than PSR_DISALLOW or PSR_AND_NON_SRG_OBSS_PD_PROHIBITED for the RXVECTOR parameter SPATIAL_REUSE and fails to identify an PSR opportunity based on the receipt of the PPDU shall disable OBSS PD SR operation on this PPDU.

An HE STA with dot11HEPSROptionImplemented set to true that receives a PPDU that is identified as an inter-BSS PPDU with a value other than PSR_DISALLOW, SR_DELAYED, or PSR_AND_NON_SRG_OBSS_PD_PROHIBITED for the RXVECTOR parameter SPATIAL_REUSE and identifies an PSR opportunity based on the receipt of the PPDU may disable OBSS PD SR operation on this PPDU.

An HE STA with dot11HEPSROptionImplemented set to true that receives a PPDU that is identified as an inter-BSS PPDU with a value other than PSR_DISALLOW or PSR_AND_NON_SRG_OBSS_PD_PROHIBITED in the UL Spatial Reuse subfield of the Common Info field of a Trigger frame and fails to identify an PSR opportunity based on the receipt of the PPDU shall disable OBSS PD SR operation on the HE TB PPDU that is elicited by the Trigger frame.

An HE STA with dot11HEPSROptionImplemented set to true that receives a PPDU that is identified as an inter-BSS PPDU with a value other than PSR_DISALLOW in the UL Spatial Reuse subfield of the Common Info field of a Trigger frame and identifies an PSR opportunity based on the receipt of the PPDU may disable OBSS PD SR operation on the Data field of the HE TB PPDU that is elicited by the Trigger frame.

## 26.11 Rules for setting some TXVECTOR parameters for PPDUs transmitted by an HE STA

### 26.11.1 STA_ID

Each parameter STA_ID in the TXVECTOR identifies the STA or group of STAs that is the recipient of an RU in the HE MU PPDU transmitted with the TXVECTOR parameter UPLINK_FLAG set to 0. For an individually addressed RU the parameter STA_ID is set to the 11 LSBs of the AID of the STA receiving the PSDU contained in that RU. If an RU is intended for one or more unassociated non-AP STAs, then the parameter STA_ID for that RU is set to 2045. If an RU is intended for no user, then the parameter STA_ID for that RU is set to 2046.

If an RU is intended for an AP (i.e., the TXVECTOR parameter UPLINK_FLAG is 1), then the parameter STA_ID contains one element that is set to the 11 LSBs of the AID of the non-AP STA transmitting the PPDU. If the parameter STA_ID has more than one element, then all other elements are set to 2046.(#4409)

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NOTE 1—When the UL HE MU PPDU is a 20 MHz HE MU PPDU with just a 106-tone RU, the parameter STA_ID contains two or more elements, one for the RU allocated to the AP and the others for unallocated RUs (see Table 27-27 (RU Allocation subfield(11ax))).(#4409)

NOTE 2—A non-AP STA can transmit (#2318)a UL HE MU PPDU to help the AP identify the transmitter of a failed PPDU so that the AP can allocate resources for that non-AP STA in a later TXOP. All unassociated STAs share the same parameter STA_ID value (i.e., 2045), which does not uniquely identify the transmitter. Therefore an unassociated STA is not allowed to transmit (#2318)a UL HE MU PPDU.

If an RU is intended for multiple STAs for MU-MIMO, then multiple STAs identified by STA-IDs in the parameter STA_ID (M118)use the same resource unit (see 26.5.2 (UL MU operation)). If an RU is intended for multiple associated STAs and carries a single A-MPDU, then the parameter STA_ID is set as follows:

— For an AP with dot11MultiBSSIDImplemented equal to false, if the RU is intended for more than one associated STA in the BSS that is not a recipient of an individually addressed RU, the parameter STA_ID is set to 0.

— For an AP with dot11MultiBSSIDImplemented equal to true, if the RU is intended for more than one associated STA in any of its BSSs that is not a recipient of an individually addressed RU, the parameter STA_ID is set to 0 for a transmitted BSSID or to the value of the BSSID Index field corresponding to that BSS (see 9.4.2.72 (Multiple BSSID-Index element)) for a nontransmitted BSSID. The number of such elements shall not exceed the maximum number of BSSs of the multiple BSSID set.

— For an AP with dot11MultiBSSIDImplemented equal to true, if the RU is intended for more than one associated STA on any of its BSSs that is not a recipient of an individually addressed RU or another broadcast RU corresponding to parameter STA_ID equal 0 or equal to the BSSID Index of a BSSID in a multiple BSSID set, the parameter STA_ID is set to 2047.

The parameter STA_ID values between 2008 and 2044 are reserved.

A non-AP STA shall not transmit an HE MU PPDU where the TXVECTOR parameter STA_ID includes more than one entry in the range 1 to 2007.

### 26.11.2 UPLINK_FLAG

An HE STA transmitting an HE SU PPDU, HE ER SU PPDU, or HE MU PPDU sets the TXVECTOR parameter UPLINK_FLAG as follows:

— A STA transmitting an HE PPDU containing frames that are addressed to an AP shall set the TXVECTOR parameter UPLINK_FLAG to 1, unless the HE PPDU is an HE ER SU PPDU with the TXVECTOR parameter TXOP_DURATION set to UNSPECIFIED and contains an RTS or CTS frame. In this case, the STA may set the TXVECTOR parameter UPLINK_FLAG to 0.

— Otherwise, the HE STA shall set the TXVECTOR parameter UPLINK_FLAG to 0.

### 26.11.3 BEAM_CHANGE

An HE STA uses the TXVECTOR parameter BEAM_CHANGE to indicate a change in the spatial mapping of the pre-HE-STF portion of the PPDU and the first symbol of HE-LTF (see Table 27-1 (TXVECTOR and RXVECTOR parameters(#12)(11ax))).

An HE STA that transmits an HE SU PPDU or an HE ER SU PPDU shall set the TXVECTOR parameter BEAM_CHANGE to 1 if one or more of the following conditions are met:

— The number of spatial streams is greater than 2.

— The PPDU is the first PPDU in a TXOP.

— The PPDU carries a Trigger frame.


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### 26.11.4 BSS_COLOR

An HE STA that transmits an HE Operation element shall select and advertise a BSS color as described in 26.17.3 (BSS color).

An HE STA that transmitted an HE Operation element shall set the TXVECTOR parameter BSS_COLOR as follows:

— For an HE SU PPDU, HE ER SU PPDU, or DL HE MU PPDU, the parameter BSS_COLOR is set to the value indicated in the BSS Color subfield of the HE Operation element if all the recipient STAs are members of the HE STA's BSS or the PPDU carries at least one triggering frame.

— For an HE SU PPDU, HE ER SU PPDU, or DL HE MU PPDU, the parameter BSS_COLOR is set to 0 if the HE STA expects that at least one intended recipient STA is not a member of the HE STA's BSS and the PPDU does not carry a triggering frame.

A non-AP HE STA that transmits an HE SU PPDU or HE ER SU PPDU to a STA that is not a member of the transmitting STA's HE BSS shall set the TXVECTOR parameter BSS_COLOR to 0.

NOTE 1—An HE AP that is starting an infrastructure BSS or an HE STA that is starting an IBSS or MBSS selects a nonzero BSS color as described in 26.17.3.2 (Initial BSS color).(#1022)

The active BSS color is one of the following:

— The value of the BSS Color field in the most recently received HE Operation element if an HE STA receives an HE Operation element from a peer HE STA.

— The value of the New BSS Color field in the most recently received BSS Color Change Announcement element if an HE STA receives a BSS Color Change Announcement element from a peer HE STA and the BSS color change TBTT has passed (see 26.17.3.4 (Selecting and advertising a new BSS color)).

An HE STA shall set the TXVECTOR parameter BSS_COLOR for an HE SU PPDU, HE ER SU PPDU, or UL HE MU PPDU that is addressed to a peer STA to the active BSS color value, if the HE STA has established any of the following:

— An association with the peer STA

— A (#2152)TDLS direct link with the peer STA

— An IBSS membership with the peer STA

NOTE 2—A non-AP HE STA sets the TXVECTOR parameter BSS_COLOR for an HE TB PPDU to the active color (see 26.5.2.3 (Non-AP STA behavior for UL MU operation)).

NOTE 3—An HE mesh STA sets the TXVECTOR parameter BSS_COLOR for an HE PPDU that it transmits to a peer HE mesh STA to the value in the BSS Color subfield of its transmitted HE Operation element.

An HE STA that receives an HE PPDU with RXVECTOR parameter BSS_COLOR with a value between 1 and 63 follows the spatial reuse rule described in 26.10 (HE spatial reuse operation(#2389)).

NOTE 4—An HE STA that receives an HE PPDU with the RXVECTOR parameter BSS_COLOR equal to 0 might not follow the spatial reuse rules described in 26.10 (HE spatial reuse operation(#2389)).

An HE STA that receives an HE SU PPDU, HE ER SU PPDU, or HE MU PPDU with the RXVECTOR parameter BSS_COLOR equal to 0 shall not discard the HE PPDU on that basis.

While the BSS Color Disabled subfield is 1, an HE STA shall continue to advertise a nonzero value (same as before the color was disabled) in the BSS Color subfield of HE Operation element and in the TXVECTOR parameter BSS_COLOR of an HE PPDU that it transmits.

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NOTE 5—A non-AP HE STA sets the TXVECTOR parameter BSS_COLOR of an HE PPDU that it transmits to the value advertised by the AP with which it intends to communicate even if the AP has disabled BSS color.

If the value of TXVECTOR parameter PARTIAL_AID[5:8] for VHT PPDUs with the TXVECTOR parameter GROUP_ID equal to 63 transmitted by an HE AP to any associated STA would not be consistent with the partial BSS color (i.e., *BCB*(0:3) described in 26.17.4 (AID assignment)) announced by the HE AP, then the HE AP shall set the Partial BSS Color field in the HE Operation element to 0. Otherwise, the HE AP may set the Partial BSS Color subfield in the HE Operation element to 1 (see 26.17.4 (AID assignment)).

### 26.11.5 TXOP_DURATION

The TXVECTOR parameter TXOP_DURATION of an HE PPDU indicates duration information for NAV setting and protection of the TXOP, except that the TXVECTOR parameter TXOP_DURATION is set to UNSPECIFIED to indicate no duration information.

NOTE 1—The value of TXVECTOR parameter TXOP_DURATION is converted to an indication in the TXOP field of the HE-SIG-A field as described in Table 27-19 (HE-SIG-A field of an HE SU PPDU and HE ER SU PPDU(11ax)), Table 27-21 (HE-SIG-A field of an HE MU PPDU(11ax)), and Table 27-22 (HE-SIG-A field of an HE TB PPDU(11ax)). The indication in the TXOP field of the HE-SIG-A field is converted to the RXVECTOR parameter TXOP_DURATION as described in Table 27-1 (TXVECTOR and RXVECTOR parameters(#12)(11ax)).

A STA that is not a TXOP responder and that transmits an HE SU PPDU, HE ER SU PPDU, or HE MU PPDU may set the TXVECTOR parameter TXOP_DURATION to UNSPECIFIED.

A STA that transmits an HE SU PPDU, HE ER SU PPDU, or HE MU PPDU that carries a PS-Poll frame shall set the TXVECTOR parameter TXOP_DURATION to UNSPECIFIED.

A STA that is a TXOP responder that transmits an HE SU PPDU, HE ER SU PPDU, or HE TB PPDU shall set the TXVECTOR parameter TXOP_DURATION to UNSPECIFIED if the RXVECTOR parameter TXOP_DURATION of the HE PPDU that solicits a response from the STA is UNSPECIFIED.

An HE AP that has set the BSS Color Disabled field in the HE Operation element to 1 shall set the TXVECTOR parameter TXOP_DURATION to UNSPECIFIED for an HE PPDU that it transmits to non-AP STAs associated to it.

If the BSS Color Disabled field is 1 in the HE Operation element most recently received from an AP by a non-AP STA, then the non-AP STA should set the TXVECTOR parameter TXOP_DURATION to UNSPECIFIED for an HE PPDU that is not an HE TB PPDU sent to that AP.

A STA that transmits an HE TB PPDU shall not set the TXVECTOR parameter TXOP_DURATION to UNSPECIFIED if any one of the following conditions is met:

- The RXVECTOR parameter TXOP_DURATION is present for the PPDU that solicits a response from the STA and is not UNSPECIFIED.
- The PPDU that solicits a response from the STA is not an HE PPDU.

A STA that transmits a frame with a Duration field in an HE PPDU with the TXVECTOR parameter TXOP_DURATION not set to UNSPECIFIED shall set the TXVECTOR parameter TXOP_DURATION to the smaller of the duration information indicated by the Duration field and 8448.

NOTE 2—For a TXOP responder, the Duration field in a frame carried in a response PPDU is set based on the Duration field in a frame carried in the PPDU that solicits a response from the TXOP responder as described in 9.2.5.6 (Setting for control response frames) or 9.2.5.7 (Setting for other response frames)

If a STA transmits either an HE TB feedback NDP or an HE TB PPDU carrying a PS-Poll frame with the TXVECTOR parameter TXOP_DURATION not set to UNSPECIFIED, it shall calculate the duration


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information and set the TXVECTOR parameter TXOP_DURATION for the HE TB feedback NDP or HE TB PPDU to the value of the computed duration information. The TXOP responder shall calculate duration information equal to the duration information indicated by the Duration field of the frame that solicits the response minus the time, in microseconds, between the end of the PPDU carrying the frame that is soliciting the HE TB PPDU and the end of the HE TB PPDU. If the calculated duration information includes a fractional microsecond, the duration information is rounded up to the next higher integer. If the calculated duration information is smaller than 8448 μs, the TXVECTOR parameter TXOP_DURATION shall be set to the calculated duration information. Otherwise, the TXVECTOR parameter TXOP_DURATION shall be set to 8448.

NOTE 3—The time is equal to SIFS plus the duration of the HE TB PPDU, where the duration of the HE TB PPDU is defined in Equation (27-147).

In the 6 GHz band, a TXOP holder shall not set the TXVECTOR parameter TXOP_DURATION for a transmitted HE PPDU to UNSPECIFIED, unless at least one of the following conditions is true:

— The BSS Color Disabled field is 1 in the HE Operation element transmitted within the BSS of which the TXOP holder is a member.

— The HE PPDU carries a PS-Poll frame.

### 26.11.6 SPATIAL_REUSE

The contents of the Spatial Reuse fields are carried in the TXVECTOR parameter SPATIAL_REUSE for an HE PPDU indicating spatial reuse information. The behavior of STAs upon reception of an HE PPDU with different SPATIAL_REUSE values is described in 26.10.2 (OBSS PD-based spatial reuse operation) and 26.10.3 (PSR-based spatial reuse operation). The different values that may be indicated in the SPATIAL_REUSE parameter of the TXVECTOR are listed in Table 27-23 (Spatial Reuse field encoding for an HE SU PPDU, HE ER SU PPDU, and HE MU PPDU(11ax)) and Table 27-24 (Spatial Reuse field encoding for an HE TB PPDU(11ax)). The value PSR_DISALLOW is used to prohibit PSR-based spatial reuse during the transmission of the corresponding PPDU. The value PSR_AND_NON_SRG_OBSS_PD_PROHIBITED is used to prohibit both PSR-based spatial reuse and non-SRG OBSS PD-based spatial reuse during the transmission of the corresponding PPDU. The interpretations of other values are described in this subclause and in 26.10. The conditions for a STA to set the SPATIAL_REUSE parameter to its different values are described in this subclause.

For a PPDU with a value of HE_TB for the TXVECTOR parameter FORMAT, the SPATIAL_REUSE parameter contains an array of one to four values, depending on the TXVECTOR parameter CH_BANDWIDTH. If the TXVECTOR parameter CH_BANDWIDTH is CBW20, CBW40, or CBW80, the first value in the array is the SPATIAL_REUSE parameter that applies to the lowest frequency 20 MHz subband, the second value, if present, applies to the second lowest frequency 20 MHz subband, the third value, if present, applies to the third lowest frequency 20 MHz subband, and the fourth value, if present, applies to the highest frequency 20 MHz subband. If the TXVECTOR parameter CH_BANDWIDTH is CBW160 or CBW80+80, the first value in the array is the SPATIAL_REUSE parameter that applies to the lowest frequency 40 MHz subband, the second value applies to the second lowest frequency 40 MHz subband, the third value applies to the third lowest frequency 40 MHz subband, and the fourth value applies to the highest frequency 40 MHz subband. Each value in the SPATIAL_REUSE parameter array shall individually conform to the rules in this subclause.

An HE STA that transmits an HE TB PPDU sets the TXVECTOR parameter SPATIAL_REUSE as defined in 26.5.2.3 (Non-AP STA behavior for UL MU operation).

An AP with dot11HEPSROptionImplemented set to true that transmits an HE ER SU PPDU that does not contain a Trigger frame should set the TXVECTOR parameter SPATIAL_REUSE to PSR_DISALLOW.

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A non-AP STA with dot11HEPSROptionImplemented set to true that transmits an HE SU PPDU, HE ER SU PPDU, or HE MU PPDU may set the TXVECTOR parameter SPATIAL_REUSE, when permitted by other conditions, to PSR_AND_NON_SRG_OBSS_PD_PROHIBITED if the (#3060)HESIGA Spatial Reuse Value15 Allowed subfield of the SR Control field of the most recently received Spatial Reuse Parameter Set element from its associated AP is equal to 1. Otherwise, the non-AP STA shall set it to PSR_DISALLOW.

An HE STA that transmits an HE TB PPDU determines the value of the TXVECTOR parameter SPATIAL_REUSE according to 26.5.2.3 (Non-AP STA behavior for UL MU operation).

An HE AP with dot11HEPSROptionImplemented set to true that transmits an HE SU PPDU, HE ER SU PPDU, or HE MU PPDU may set the TXVECTOR parameter SPATIAL_REUSE to PSR_DISALLOW to disallow OBSS STAs from performing PSR-based SR transmission during the duration of the corresponding PPDU.

An HE STA with dot11HEPSROptionImplemented set to false may set the TXVECTOR parameter SPATIAL_REUSE to PSR_DISALLOW for any PPDU that is not an HE TB PPDU, an HE NDP PPDU, a PPDU containing an HE NDP Announcement frame, or a PPDU containing a response to an HE NDP Announcement frame.

A STA shall set the TXVECTOR parameter SPATIAL_REUSE of an HE PPDU to PSR_DISALLOW or, if permitted by the other rules in this subclause, to PSR_AND_NON_SRG_OBSS_PD_PROHIBITED, if the STA is a non-AP HE STA and the PSR Disallowed subfield of the SR Control field of the most recently received Spatial Reuse Parameter Set element from its associated AP is equal to 1.

An HE STA shall set the TXVECTOR parameter SPATIAL_REUSE to PSR_AND_NON_SRG_OBSS_PD_PROHIBITED for an HE NDP PPDU.

An HE STA shall set the TXVECTOR parameter SPATIAL_REUSE to PSR_AND_NON_SRG_OBSS_PD_PROHIBITED for a PPDU containing an NDP Announcement frame and in any frame that is transmitted as a response to an NDP Announcement frame.

A non-AP HE STA may set the TXVECTOR parameter SPATIAL_REUSE of an HE PPDU to PSR_AND_NON_SRG_OBSS_PD_PROHIBITED if the (#3060)HESIGA Spatial Reuse Value15 Allowed subfield of the SR Control field of the most recently received Spatial Reuse Parameter Set element from its associated AP is equal to 1. If the (#3060)HESIGA Spatial Reuse Value15 Allowed subfield of the SR Control field of the most recently received Spatial Reuse Parameter Set element from its associated AP is equal to 0 or if STA has not received a Spatial Reuse Parameter Set element from its associated AP, the STA shall not set the TXVECTOR parameter SPATIAL_REUSE of any HE PPDU to PSR_AND_NON_SRG_OBSS_PD_PROHIBITED, unless the HE PPDU contains an NDP, contains an NDP Announcement frame, or is a frame that is transmitted as a response to an NDP Announcement frame.

An AP HE STA may set the TXVECTOR parameter SPATIAL_REUSE of an HE PPDU to PSR_AND_NON_SRG_OBSS_PD_PROHIBITED if the (#3060)HESIGA Spatial Reuse Value15 Allowed subfield of the SR Control field of the most recently transmitted Spatial Reuse Parameter Set element is equal to 1. If the (#3060)HESIGA Spatial Reuse Value15 Allowed subfield of the SR Control field of the most recently transmitted Spatial Reuse Parameter Set element is equal to 0, or if the AP has not transmitted a Spatial Reuse Parameter Set element, the AP shall not set the TXVECTOR parameter SPATIAL_REUSE of any HE PPDU to PSR_AND_NON_SRG_OBSS_PD_PROHIBITED.

An HE AP that transmits an HE SU PPDU or an HE ER SU PPDU that contains a Trigger frame should set the TXVECTOR parameter SPATIAL_REUSE to SR_DELAYED. An HE STA that transmits an HE MU PPDU shall not set the TXVECTOR parameter SPATIAL_REUSE to SR_DELAYED.


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An HE STA that transmits an HE SU PPDU or HE ER SU PPDU shall not set the TXVECTOR parameter SPATIAL_REUSE to SR_RESTRICTED.

An HE AP that transmits an HE MU PPDU that contains a Trigger frame should set the TXVECTOR parameter SPATIAL_REUSE to SR_RESTRICTED.

An HE STA that transmits a PPDU that does not contain a Trigger frame shall not set the TXVECTOR parameter SPATIAL_REUSE to SR_DELAYED or SR_RESTRICTED.

### 26.11.7 INACTIVE_SUBCHANNELS and RU_ALLOCATION

The indication of which subchannels are punctured in an HE sounding NDP or in an HE NDP Announcement frame that is carried in a non-HT duplicate PPDU is conveyed from the MAC to the PHY through the TXVECTOR parameters INACTIVE_SUBCHANNELS and RU_ALLOCATION. The parameter INACTIVE_SUBCHANNELS may be present in the TXVECTOR of a non-HT duplicate PPDU that carries an HE NDP Announcement frame or of an HE sounding PPDU. The parameter INACTIVE_SUBCHANNELS shall not be present otherwise. The setting of the RU_ALLOCATION parameter for other PPDUs is specified in 26.5.2.3.3 (TXVECTOR parameters for HE TB PPDU response to Trigger frame), 26.5.2.3.4 (TXVECTOR parameters for HE TB PPDU response to TRS Control subfield), and 26.5.7.2 (STA behavior).

INACTIVE_SUBCHANNELS is an 8-bit bitmap with an encoding that is the same as the encoding for the Disallowed Subchannel Bitmap subfield defined in 9.3.1.19 (VHT/HE/Ranging NDP Announcement frame format(11ax)(11az)). A bit in the INACTIVE_SUBCHANNELS bitmap is set to 1 to indicate that no energy is transmitted on the corresponding subchannel for the corresponding PPDU. The RU_ALLOCATION parameter is set to a value that corresponds to the puncturing signaled by the INACTIVE_SUBCHANNELS bitmap. If a bit in the INACTIVE_SUBCHANNELS bitmap corresponds to a 20 MHz subchannel outside the PPDU bandwidth, then the bit is set to 1.

A STA transmitting an HE sounding NDP may set the TXVECTOR parameter INACTIVE_SUBCHANNELS to any value, provided that the bit representing the primary 20 MHz channel is set to 0.

If an HE AP transmits an HE NDP Announcement frame in a PPDU with punctured channels, then the TXVECTOR parameters FORMAT, NON_HT_MODULATION, INACTIVE_SUBCHANNELS, and CH_BANDWIDTH shall be set as follows:

- The TXVECTOR parameter FORMAT shall be set to NON_HT.
- The TXVECTOR parameter NON_HT_MODULATION shall be set to NON_HT_DUP_OFDM.
- The INACTIVE_SUBCHANNELS parameter may have any value, except that the bit in the bitmap representing the primary 20 MHz subchannel shall be set to 0.
- The CH_BANDWIDTH parameter value shall be set to CBW80 if there are no bits set to 0 in the INACTIVE_SUBCHANNELS bitmap that correspond to any 20 MHz subchannel of the secondary 80 MHz and at least one bit set to 0 that corresponds to any 20 MHz subchannel of the secondary 40 MHz.
- The CH_BANDWIDTH parameter value shall be set to CBW160 if there is at least one bit set to 0 in the INACTIVE_SUBCHANNELS bitmap that corresponds to any 20 MHz subchannel of the secondary 80 MHz.

Each 8 bits of the RU_ALLOCATION are set to 113 (01110001 in binary representation) for the 242-tone RU that is most closely aligned in frequency with the 20 MHz subchannel that is indicated as disallowed by the value 1 in the INACTIVE_SUBCHANNELS parameter. Each 8 bits of the RU_ALLOCATION are set to 192 (11000000 in binary representation) for the 242-tone RU that is most closely aligned in frequency

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with the 20 MHz subchannel that is indicated as not disallowed by the value 0 in the INACTIVE_SUBCHANNELS parameter.

### 26.11.8 TRIGGER_RESPONDING

A(#1426) non-AP HE STA that transmits a non-HT or non-HT duplicate PPDU shall set the TXVECTOR parameter TRIGGER_RESPONDING to true if the PPDU is sent in response to an MU-RTS Trigger frame. Otherwise, the non-AP HE STA shall set the TXVECTOR parameter TRIGGER_RESPONDING to false.

### 26.11.9 STBC and DCM

An HE STA shall not transmit an HE SU PPDU or HE ER SU PPDU with the TXVECTOR parameter STBC set to 1 if any of the following conditions is met:

— TXVECTOR parameter DCM is set to 1.
— TXVECTOR parameter NUM_STS is not equal to 2.
— TXVECTOR parameters HE_LTF_TYPE and GI_TYPE are set to 4x HE-LTF and 0u8s_GI, respectively.

An HE STA shall not transmit an HE TB PPDU with the TXVECTOR parameter STBC set to 1 if any of the following conditions is met:

— TXVECTOR parameter DCM is set to 1.
— TXVECTOR parameter NUM_STS is not equal to 2.

An HE STA shall not transmit an HE MU PPDU with the TXVECTOR parameter STBC set to 1 if any of the following conditions is met:

— At least one element in the TXVECTOR parameter DCM is set to 1.
— At least one element in the TXVECTOR parameter NUM_STS is not equal to 2.
— Two or more STA_ID parameters in the TXVECTOR use the same RU.

NOTE—Two or more STA_ID parameters in the TXVECTOR using the same RU means that DL MU-MIMO is used.

An HE STA shall not transmit an HE SU PPDU or HE ER SU PPDU with the TXVECTOR parameter STBC or DCM set to 1 if the TXVECTOR parameters HE_LTF_TYPE and GI_TYPE are set to 4x HE-LTF and 0u8s_GI, respectively.

### 26.11.10 POWER_BOOST_FACTOR(#1067)

For an OFDMA HE MU PPDU, (#3483)the POWER_BOOST_FACTOR parameter for an occupied RU in the TXVECTOR shall be in the range $[1/\sqrt{2}, \sqrt{2}]$ if the Power Boost Factor Support subfield of the HE PHY Capabilities Information field in the HE Capabilities element from any recipient STA of the PPDU equals 0; otherwise (#3483)the POWER_BOOST_FACTOR parameter shall be in the range (#4161)[1/2, 2].

For an HE SU PPDU, non-OFDMA HE MU PPDU and HE ER SU PPDU, (#3483)the POWER_BOOST_FACTOR parameter in the TXVECTOR shall be set to 1.

NOTE—For an HE TB PPDU, (#3483)the POWER_BOOST_FACTOR parameter is not present in the TXVECTOR.

## 26.12 HE PPDU post-FEC padding and packet extension

An HE STA with dot11PPEThresholdsRequired set to false may set the PPE Thresholds Present subfield in HE Capabilities elements that it transmits to 0.


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An HE STA with dot11PPEThresholdsRequired set to true shall set the PPE Thresholds Present subfield in HE Capabilities elements that it transmits to 1.

A STA that sets the PPE Thresholds Present subfield to 0 and the Nominal Packet Padding subfield to 0 in HE Capabilities elements that it transmits has as a nominal packet padding of 0 μs for all constellations, NSS, and RU allocations that it supports.

A STA that sets the PPE Thresholds Present subfield to 0 and the Nominal Packet Padding subfield to 1 in the HE Capabilities elements that it transmits has a nominal packet padding of 8 μs for all constellations, NSS, and RU allocations that it supports.

A STA that sets the PPE Thresholds Present subfield to 0 and the Nominal Packet Padding subfield to 2 in the HE Capabilities elements that it transmits has nominal packet padding of 16 μs for all constellations, NSS, and RU allocations that it supports.

A STA that sets the PPE Thresholds Present subfield to 1 in the HE Capabilities elements that it transmits shall indicate its nominal packet padding per constellation, NSS and RU allocation by setting the subfields of the PPE Thresholds field according to 9.4.2.247 (HE Capabilities element(11ax)) and using the corresponding values from dot11PPEThresholdsMappingTable.

After receiving the PPE Thresholds field from a second STA, the first STA uses the combination of the PPET8 NSTS*n* RU*b* subfield and PPET16 NSTS*n* RU*b* subfield values to determine the nominal packet padding for HE PPDUs that are transmitted to the second STA, using NSTS = *n* and an RU allocation corresponding to RU Allocation Index b, for each value of NSTS and RU specified by the field. The nominal packet padding is used in computing the PE field duration (see 27.3.13 (Packet extension)).

NOTE 1—If the pre-FEC padding factor is 4, then the value of nominal $T_{PE}$ is equal to the nominal packet padding (see Table 27-47 (Nominal TPE values(11ax))).

For all values of *n* and *b* for which PPET8 and PPET16 are not present, the nominal packet padding is 0 for HE PPDUs that are transmitted to the STA using NSTS = *n* and an RU allocation corresponding to RU allocation index *b*. The nominal packet padding as a function of the PPE thresholds, the number of spatial streams, and the RU allocation index is described in Table 26-13 (PPE thresholds per PPET8 and PPET16(11ax)).

**Table 26-13—PPE thresholds per PPET8 and PPET16(11ax)**

| **Result of comparison of constellation index *x* of an HE PPDU with NSTS value *n* and RU allocation size that corresponds to RU Allocation index = (*b* + DCM) to the value in . . .** | | **Nominal packet padding for an HE PPDU transmitted to this STA using constellation index = *x*, NSTS = *n*, and RU allocation size that corresponds to RU Allocation index = (*b* + DCM)** |
|---|---|---|
| **PPET8 NSTS*n* RU (*b* + DCM) subfield** | **PPET16 NSTS*n* RU (*b* + DCM) subfield** | |
| *x* greater than or equal to PPET8 | *x* less than PPET16 or PPET16 equal to None | 8 μs |
| *x* greater than PPET8 or PPET8 equal to None | *x* greater than or equal to PPET16 | 16 μs |
| All other combinations not otherwise listed in this table | | 0 |
| NOTE—DCM = 1 if the HE PPDU uses DCM; DCM = 0 otherwise. | | |

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In Table 26-13 (PPE thresholds per PPET8 and PPET16(11ax)), "RU Allocation index = ($b$ + DCM)" means the following. With the exception of a 2×996-tone RU, if DCM is applied in a given RU, the nominal packet padding value is based on the next larger RU size (RU index + 1). For example, if DCM is applied to a 242-tone RU, then the nominal packet padding value for a 484-tone RU is used. If DCM is applied to 106-tone RU, then the nominal packet padding value for a 242-tone RU is used. If DCM is applied to a 2×996-tone RU, then the nominal packet padding value for a 2×996-tone RU is used.

The nominal packet padding value shall be 0 for all RU less than 242, unless the RU size is 106 and DCM is enabled.

A STA transmitting an HE PPDU provides the nominal packet padding in the TXVECTOR parameter NOMINAL_PACKET_PADDING for the minimal PE calculation (see 27.3.13 (Packet extension)).

A STA transmitting an HE PPDU that carries a broadcast frame shall set the value of the TXVECTOR parameter NOMINAL_PACKET_PADDING to 16 µs. A STA transmitting an HE PPDU that carries a group addressed, but not broadcast, frame shall not set the value of the TXVECTOR parameter NOMINAL_PACKET_PADDING to a value that is less than that required for any of the recipients in the group.

A STA transmitting an HE PPDU to a receiving STA shall include post-FEC padding determined by the pre-FEC padding factor (see 27.3.12 (Data field)); and after including the post-FEC padding, the transmitting STA shall include a packet extension with a duration indicated by the TXVECTOR parameter NOMINAL_PACKET_PADDING (see 27.3.13 (Packet extension)).

(11az)A STA A shall set the value of the TXVECTOR parameter NOMINAL_PACKET_PADDING to 16 µs when transmitting to a STA B if the STA A has not received a frame including the HE Capabilities element from the STA B.

NOTE 2—One such situation is an AP transmitting to an unassociated STA. Another such situation is an unassociated STA transmitting to an AP without having received a management frame including an HE Capabilities element from the AP, such as a Beacon or Probe Response frame.(11az)

## 26.13 Link adaptation using the HLA Control subfield

This subclause applies to frame exchange sequences that include PPDUs containing an HE variant HT Control field.

An HE STA shall set the HE Link Adaptation Support subfield in the HE Capabilities Information field in the HE Capabilities element it transmits to the value of dot11HEMCSFeedbackOptionImplemented.

A STA that supports HE link adaptation using the HLA Control subfield shall set the HE Link Adaptation Support subfield in the HE Capabilities Information field in the HE Capabilities element to 2 or 3, depending on its own link adaptation feedback capability. A STA shall not send an MRQ to a STA that has not set the HE Link Adaptation Support subfield to 3 in the HE Capabilities Information field in the HE Capabilities element. A STA shall not send an unsolicited MFB in any frame that contains an HLA Control subfield to a STA that has not set the HE Link Adaptation Support subfield to either 2 or 3 in the HE Capabilities Information field in the HE Capabilities element.

The MFB requester may set the MRQ subfield to 1 and Unsolicited MFB subfield to 0 in the HLA Control subfield of a frame to request a STA to provide link adaptation feedback. In each request, the MFB requester shall set the MSI field to a value ranging from 0 to 6. For the MFB requester, how to choose the MSI value is implementation dependent.


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The appearance of more than one instance of an HLA Control subfield with the MRQ field equal to 1 within a single PPDU shall be interpreted by the receiver as a single request for link adaptation feedback.

The MFB requester shall specify the RU index and BW requesting the link adaptation feedback.

On receipt of an HLA Control subfield with the MRQ subfield equal to 1, an MFB responder computes the HE-MCS, NSS, and DCM of the RU and BW specified in the MRQ, and these estimates are based on the same RU of the PPDU carrying the MRQ. The PPDU carrying MRQ shall include the RU requested for MFB. The MFB responder labels the result of this computation with the MSI value from the HLA Control subfield in the received frame carrying the MRQ. The MFB responder may include the received MSI value in the MSI field of the corresponding response frame. In the case of a delayed response, this allows the MFB requester to associate the MFB with the soliciting MRQ.

An MFB responder that sends a solicited MFB shall set the Unsolicited MFB subfield to 0 and MRQ subfield to 0 in the HLA Control subfield.

The STA receiving MFB may use the received MFB to compute the appropriate HE-MCS, DCM, and NSS.

The MFB responder may send a solicited response frame with any of the following combinations of HE-MCS, NSS, and MSI:

- HE-MCS = 15, NSS = 7, MSI = 0–6: the responder does(M118) not provide feedback for the request that had the MSI value.
- HE-MCS = valid value, NSS = valid value, MSI = 0–6: the responder is providing feedback for the request that had the MSI value. The MSI value in the response frame matches the MSI value of the MRQ request.

A STA sending unsolicited MFB using the HLA Control subfield shall set the Unsolicited MFB subfield to 1.

Unsolicited HE-MCS, NSS, DCM, BW, and RU estimates reported in an HLA Control subfield sent by a STA are computed based on the most recent PPDU received by the STA that matches the description indicated by the PPDU format, Tx Beamforming, and Coding Type subfields in the same HLA Control subfield.

In an unsolicited MFB response the PPDU Formats, Coding Type, and Tx Beamforming subfields are set according to the RXVECTOR parameters of the received PPDU from which the HE-MCS, RU, BW, and NSS are estimated, as follows:

- The PPDU format subfield is set and encoded as follows:
  - 0 if the parameter FORMAT is equal to HE_SU
  - 1 if the parameter FORMAT is equal to HE_MU
  - 2 if the parameter FORMAT is equal to HE_ER_SU
  - 3 if the parameter FORMAT is equal to HE_TB
- The Coding Type subfield is set to 0 if the parameter FEC_CODING is equal to BCC_CODING and set to 1 if that parameter is equal to LDPC_CODING.
- The Tx Beamforming subfield is set to 1 if the parameter BEAMFORMED is equal to 1 and set to 0 if that parameter is equal to 0.
- The BW subfield shall indicate a bandwidth less than or equal to the bandwidth indicated by the parameter CH_BANDWIDTH.
- The RU subfield indicates the RU at which the recommended HE-MCS is applied. The recommended RU shall be within an RU or a bandwidth in which the received HE PPDU is located.

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For either a solicited or an unsolicited response, the recommended HE-MCS and NSS subfields of HLA Control subfield shall be selected from the HE-MCS and NSS set supported by the recipient STA.

The HE-MCS subfield of HLA Control subfield is the recommended data rate, for given transmission properties carried in the RXVECTOR of the PPDU used for MFB estimation, which results in an estimated frame error rate of 10% or lower for an MPDU length of 3895 octets.

NOTE—Some HE PPDU might not be able to carry 3895 octets due to PPDU duration limitations.

If the MFB requester sets the MRQ subfield to 1 and sets the MSI subfield to a value that matches the MSI subfield value of a previous request for which the responder has not yet provided feedback, the responder shall discard or abandon the computation for the MRQ that corresponds to the previous use of that MSI subfield value and start a new computation based on the new request.

A STA may respond immediately to a current request for MFB with a frame containing an MSI field value and NSS, HE-MCS, and DCM subfields that correspond to a request that precedes the current request.

A non-AP HE STA may set the UL HE TB PPDU MFB to 1 in the HLA Control field it transmits to the AP to indicate that the NSS, HE-MCS, DCM, BW, and RU Allocation in the HLA Control field represent the recommended MFB for the HE TB PPDU sent from the non-AP HE STA. The AP should not exceed the recommended RU size indicated in the most recently received RU Allocation field of the HLA Control field when it sends a triggering frame addressed to the STA.

## 26.14 Power management

### 26.14.1 Intra-PPDU power save for non-AP HE STAs

Intra-PPDU power save is the power save mechanism for an HE STA to enter the doze state or become unavailable until the end of a received PPDU that is identified as an intra-BSS PPDU. The STA can enter the doze state if it is in PS mode and can become unavailable if it is in active mode (see 11.2.3.2 (Non-AP STA power management modes)).

A non-AP HE STA that has dot11IntraPPDUPowerSaveOptionActivated equal to true operates in intra-PPDU power save mode.

A non-AP HE STA that is in intra-PPDU power save mode may enter the doze state or become unavailable until the end of a PPDU currently being received if one of the following conditions is met:

- The PPDU is an HE MU PPDU where the RXVECTOR parameter BSS_COLOR is the BSS color of the BSS in which the STA is associated, the RXVECTOR parameter UPLINK_FLAG is 0, the RXVECTOR parameters STA_ID do not include the identifier of the STA or the broadcast identifier(s) intended for the STA, and the BSS Color Disabled subfield is 0 in the most recently received HE Operation element from the AP with which it is associated.
- The PPDU is an HE MU PPDU, HE SU PPDU, or HE ER SU PPDU and one of the following conditions is true:
  - The RXVECTOR parameter BSS_COLOR is the BSS color of the BSS in which the STA is associated, the RXVECTOR parameter UPLINK_FLAG is 1, and the BSS Color Disabled subfield is 0 in the most recently received HE Operation element from the AP with which it is associated.
  - The RXVECTOR parameter BSS_COLOR is the BSS color of the BSS in which the STA is associated, the RXVECTOR parameter UPLINK_FLAG is 0, a PHY-RXEND.indication(UnsupportedRate) primitive was received, and the BSS Color Disabled subfield is 0 in the most recently received HE Operation element from the AP with which it is associated.


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- The PPDU is an HE TB PPDU where the RXVECTOR parameter BSS_COLOR is the BSS color of the BSS in which the STA is associated and the BSS Color Disabled subfield is 0 in the most recently received HE Operation element from the AP with which it is associated.
- The PPDU is a VHT PPDU where the RXVECTOR parameter PARTIAL_AID is the BSSID[39:47] of the BSS in which the STA is associated or any of the other BSSs in the same multiple BSSID set or co-hosted BSSID set to which its BSS belongs and the RXVECTOR parameter GROUP_ID is 0.
- The PPDU contains:(#2183)
  - An A-MPDU including an MPDU with a TA or an RA equal to either the BSSID of the BSS to which the STA is associated, or any of the other BSSs in the same multiple BSSID set, or co-hosted BSSID set to which the STA belongs, and(#2183)
  - The RA is not (#1653)the individual address of the STA or the group address(es) of the STA.
- The PPDU is either an HE MU PPDU with the RXVECTOR parameter UPLINK_FLAG set to 0 or a VHT MU PPDU containing an A-MPDU and
  - The RAs of the MPDUs in the A-MPDU are equal to the STA's individual address and(#2183)
  - The STA has received in the A-MPDU at least one MPDU delimiter with the value of EOF equal to 1 and with an MPDU length field equal to 0.(#2183)

A non-AP HE STA that is in intra-PPDU power save mode and has entered doze state or has become unavailable shall continue to operate its NAV timers and to consider the medium busy and shall transition to the awake state at the end of the PPDU.

A non-AP HE STA that is in intra-PPDU power save mode may discard a PPDU identified as an inter-BSS PPDU as defined in 26.2.2 (Intra-BSS and inter-BSS PPDU classification) until the end of the PPDU.

NOTE—The STA can contend for access to the medium immediately on the expiry of the NAV timers.

### 26.14.2 Power save with UORA and TWT

This subclause defines the power save mechanisms for a non-AP HE STA that is operating in PS mode and is UORA and TWT capable.

An HE AP may indicate start times for one or more broadcast TWT SPs containing Trigger frames with random access allocations in the broadcast TWT element that is included in a Management frame as described in 26.8.3.2 (Rules for TWT scheduling AP). An example of power save operation is shown in Figure 26-14 (Example of power save operation with UORA and TWT(11ax)).

A TWT SP with RA-RU is a TWT SP corresponding to a Broadcast TWT Parameter Set field in a TWT element that has a Broadcast TWT ID subfield equal to 0, Flow Type subfield equal to 0, Trigger subfield equal to 1, and a Broadcast TWT Recommendation subfield equal to 2. An associated HE STA that supports the TWT and UORA procedure when operating in PS mode, upon receiving a Beacon frame from its associated AP carrying a TWT element indicating a schedule for TWT SP(s) with RA-RU, may enter the doze state if no other condition requires it to be awake. The STA may transition to awake state at the start of a TWT SP with RA-RU and follow the procedure in 26.5.4 (UL OFDMA-based random access (UORA))) to send an HE TB PPDU to its associated AP.

An HE STA shall follow the procedure described in 26.8.5 (Power save operation during TWT SPs) to determine if a TWT SP termination event has occurred and may enter doze state if no other condition requires the STA to remain awake.

A non-AP HE STA shall decrement its OBO counter by following the procedure in 26.5.4.3 (Transmission procedure for UORA). If the OBO counter decrements to a nonzero value, then the STA may enter the doze state until the end of the current TWT SP if the STA has not declared to the AP that it is in awake state (as

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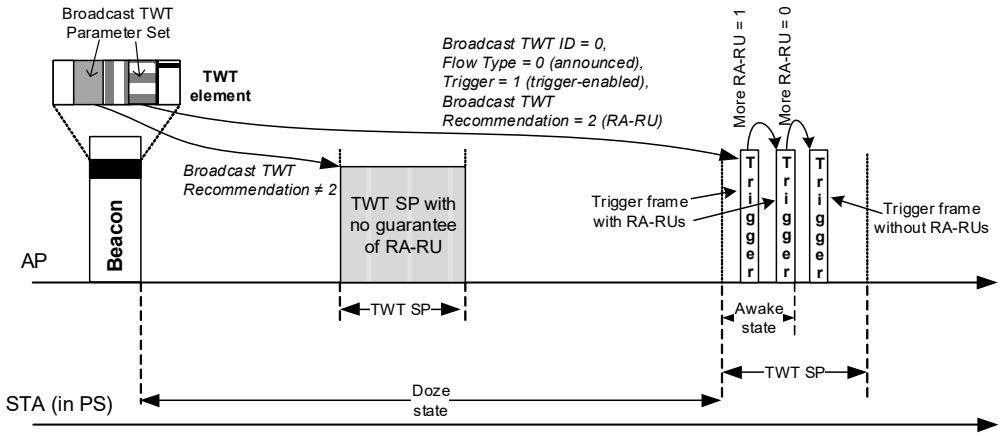


**Figure 26-14—Example of power save operation with UORA and TWT(11ax)**

described in 26.8.3.3 (Rules for TWT scheduled STA)), no other condition requires it to remain awake, and one of the following conditions is met:

— The More TF subfield in the Common Info field of the Trigger frame is equal to 0.

— The More TF subfield in the Common Info field of the Trigger frame is equal to 1, and the More RA-RU subfield in the User Info field is equal to 0 indicating that subsequent Trigger frames in the current broadcast TWT SP will not include RA-RUs matching the value in AID12 subfield (see Table 9-52 (AID12 subfield encoding(11ax))).

### 26.14.3 Opportunistic power save

#### 26.14.3.1 General

An OPS non-AP STA is a non-AP HE STA that sets the OPS Support subfield in the HE MAC Capabilities Information field in the HE Capabilities element to 1.

An OPS AP is an AP HE STA that sets the OPS Support subfield in the HE MAC Capabilities Information field in HE Capabilities element to 1.

The objective of the opportunistic power save mechanism is to allow OPS non-AP STAs to be unavailable or to be in doze state so that they can save power for a defined period.

The opportunistic power save mechanism has two modes: aperiodic and periodic.

In the aperiodic mode, an OPS AP sends an OPS frame or a FILS Discovery frame at any time to provide the scheduling information for all OPS non-AP STAs for the OPS period that follows the transmission of the OPS frame or FILS Discovery frame. Based on this information, the OPS non-AP STAs that are in active mode may be unavailable during the OPS period, and the OPS non-AP STAs that are in PS mode may be in doze state during the OPS period.

In the periodic mode, an OPS AP splits a beacon interval into several periodic broadcast TWT SPs and provides, at the beginning of each SP, the scheduling information for all OPS non-AP STAs. Based on this information, the OPS non-AP STAs that are in active mode may be unavailable until the next TWT SP, and the OPS non-AP STAs that are in PS mode may be in doze state until the next TWT SP.


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### 26.14.3.2 AP operation for opportunistic power save

To enable aperiodic opportunistic power save, an OPS AP shall schedule for transmission an OPS frame or a FILS Discovery frame with the RA field set to the broadcast address that includes a TIM element (see 9.4.2.5 (TIM element)) and an OPS element (see 9.4.2.256 (OPS element(11ax))). The AP should transmit a FILS Discovery frame instead of an OPS frame if the target transmission time closely aligns with the transmission time of a FILS Discovery frame. The OPS Duration field in the OPS element shall be set to the duration of the OPS period that immediately follows the transmission of the OPS frame or FILS Discovery frame. The TIM element is encoded specifically as defined in 9.4.2.5 (TIM element) in order to identify which STAs are not scheduled during the OPS period. If the OPS AP sets the bit corresponding to an OPS non-AP STA in the traffic indication virtual bitmap field carried by the Partial Virtual Bitmap field(#8131) of the TIM element of the OPS frame or FILS Discovery frame to 0, the AP should send neither individually addressed frames to the STA nor Trigger frames with a User Info field that addresses the STA during the OPS period.

(#3758)For the APs in a multiple BSSID set, only the AP corresponding to the transmitted BSSID may transmit an OPS frame; other APs corresponding to nontransmitted BSSIDs shall not transmit an OPS frame.

To enable periodic opportunistic power save, an OPS AP shall include a TWT element in beacons to set a periodic Broadcast TWT SP with the following information:

— The Broadcast TWT Recommendation field set to 3
— The Broadcast TWT ID subfield set to 0

At the beginning of these periodic TWT SPs with the Broadcast TWT Recommendation field set to 3, the AP shall schedule for transmission a TIM frame or a FILS Discovery frame with the RA field set to the broadcast address that includes a TIM element (see 9.4.2.5 (TIM element)). The FILS Discovery frame may include an OPS element. The AP should transmit a FILS Discovery frame instead of a TIM frame if the TWT SP start time closely aligns with the transmission time of a FILS Discovery frame. If the OPS AP also operates with TIM Broadcast and uses TIM frames for opportunistic power save, the OPS AP should align the transmission time of a TIM frame for TIM Broadcast with the start time of the broadcast TWT SP with the Broadcast TWT Recommendation field set to 3. If the OPS AP sets the bit corresponding to an OPS non-AP STA in the traffic indication virtual bitmap carried in the Partial Virtual Bitmap field of the TIM element of the TIM frame or FILS Discovery frame to 0, the AP should send neither individually addressed frames to the STA nor Trigger frames with a User Info field that addresses the STA during the TWT SP, until the next TWT SP with the Broadcast TWT Recommendation field set to 3.

### 26.14.3.3 STA operation for opportunistic power save

With aperiodic opportunistic power save, if an OPS non-AP STA with AID *N* that is in the awake state receives a TIM element and an OPS element in an OPS frame or a FILS Discovery frame from the associated OPS AP, then the STA may be unavailable if the STA is in active mode or may be in doze state if the STA is in PS mode until the end of the OPS period indicated in the OPS element, if the bit *N* in the traffic indication virtual bitmap carried in the Partial Virtual Bitmap field of the current TIM element is 0, unless other conditions not related to operation with the OPS AP require the STA to be in the awake state. At the end of the OPS period, the STA shall be in the awake state, unless determined otherwise by other power save protocols.

With periodic opportunistic power save, if an OPS non-AP STA with AID *N* that is in the awake state receives from the associated OPS AP a TIM element with bit *N* of the traffic indication virtual bitmap field equal to 0 in a TIM frame or FILS Discovery frame within a broadcast TWT SP with the Broadcast TWT Recommendation field set to 3, then the STA may be unavailable if the STA is in active mode or may be in doze state if the STA is in PS mode during the TWT SP and until the next TWT SP with the Broadcast TWT

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Recommendation field set to 3, unless other conditions not related to operation with the OPS AP require the STA to be in the awake state.

An OPS non-AP STA shall not operate with TIM broadcast procedure if its associated AP is an OPS AP.

### 26.14.4 HE dynamic SM power save

A STA that supports HE dynamic SM power save has dot11HEDynamicSMPowerSaveOptionImplemented set to true and shall set the HE Dynamic SM Power Save subfield in the HE MAC Capabilities Information field in the HE Capabilities element it transmits to 1.

A non-AP HE STA in dynamic SM power save mode (see 11.2.6 (SM power save)) that sets the HE Dynamic SM Power Save subfield in the HE MAC Capabilities Information field in the HE Capabilities element it transmits to 1 shall follow the dynamic SM power save procedures defined in 11.2.6 (SM power save) and shall also enable its multiple receive chains if it responds to a Trigger frame that starts a frame exchange sequence that satisfies the following conditions:

— The Trigger frame is transmitted with a single spatial stream.
— The Trigger frame is from the associated AP or from the AP corresponding to the transmitted BSSID if the non-AP HE STA is associated with an AP corresponding to a nontransmitted BSSID and has indicated support for receiving Control frames with TA set to the transmitted BSSID by setting the Rx Control Frame To MultiBSS subfield to 1 in the HE Capabilities element that the non-AP HE STA transmits.
— The Trigger frame is an MU-RTS Trigger frame, BSRP Trigger frame, or BQRP Trigger frame that includes a User Info field with the AID12 subfield equal to the 12 LSBs of the AID of the non-AP HE STA (see 26.5.2.2.1 (General)).

The non-AP HE STA shall, subject to its spatial stream capabilities (see 9.4.2.54.4 (Supported MCS Set field), 9.4.2.156.3 (Supported VHT-MCS and NSS Set field), and 9.4.2.247 (HE Capabilities element(11ax))) and operating mode (see 11.40 (Notification of operating mode changes) and 26.9 (Operating mode indication)), be capable of receiving a PPDU that is sent using more than one spatial stream a SIFS after the end of the PPDU that it sends in response. The STA may switch back to single receive chain mode immediately after the end of the frame exchange sequence.

NOTE 1—A Trigger frame always solicits an immediate response.

NOTE 2—A non-AP HE STA that is in dynamic SM power save mode and that sets the HE Dynamic SM Power Save subfield in the HE MAC Capabilities Information field in the HE Capabilities element it transmits to 1 cannot distinguish between a Trigger frame that precedes a MIMO transmission and a Trigger frame that does not precede a MIMO transmission and, therefore, always enables its multiple receive chains if it responds to an MU-RTS Trigger frame, BSRP Trigger frame, or BQRP Trigger frame that has a User Info field addressed to it.

NOTE 3—The STA determines the end of the frame exchange sequence as described in 11.2.6 (SM power save).

## 26.15 PPDU format, BW, MCS, NSS, and DCM selection rules

### 26.15.1 General

(#1230)An HE STA can transmit different PPDU formats, and use different transmit parameters such as channel width, MCS, NSS, DCM. Subclause 26.15 defines the rules followed by an HE STA for selecting these parameters depending on the capabilities of the intended receiver(s) and other considerations.


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### 26.15.2 PPDU format selection

An HE STA that transmits non-HT, HT, or VHT PPDUs shall follow the rules in 10.6 (Multirate support). An HE STA may transmit an HE SU PPDU to a peer HE STA subject to the restrictions defined in this subclause.

An HE AP may transmit an HE MU PPDU as defined in 26.5.1 (HE DL MU operation). A non-AP HE STA transmits HE TB PPDUs as defined in 26.5.2 (UL MU operation).

A STA shall not transmit a 242-tone HE ER SU PPDU to a peer non-AP STA if the most recently received OM Control field from that peer non-AP STA, if any, has the ER SU Disable subfield equal to 1.

A STA shall not transmit a 242-tone HE ER SU PPDU to an AP if the most recently received HE Operation element from that AP has the ER SU Disable subfield equal to 1.

A STA shall not transmit a 106-tone HE ER SU PPDU to a peer STA if the HE Capabilities element received from that peer STA has the Partial Bandwidth Extended Range field equal to 0.

A non-AP STA, TDLS STA, or IBSS STA shall not transmit a 20 MHz HE MU PPDU with only a 106-tone RU to a peer STA, unless it has received from the peer STA an HE Capabilities element with the Rx Partial BW SU In 20 MHz HE MU PPDU subfield in the HE PHY Capabilities Information field equal to 1.

NOTE 1—A non-AP STA transmitting an HE MU PPDU sets the TXVECTOR parameter UPLINK_FLAG to 1 if the PPDU is sent to the AP and to 0 if the PPDU is sent to a TDLS STA (see 26.11.2 (UPLINK_FLAG)). The HE MU PPDU format enables the non-AP STA to include its AID (i.e., transmitter's AID if the UPLINK_FLAG is 1 and the receiver's AID if the UPLINK_FLAG is 0) in the PHY header of the PPDU, and its use is beyond the scope of this standard.

NOTE 2—Only a 106-tone RU is allowed for a 20 MHz HE MU PPDU that (#6147)does not span the entire 20 MHz bandwidth and is intended for a single user according to the rules for RU allocation (see 26.5.1.3 (RU allocation in an HE MU PPDU))(#4408).

NOTE 3—Since there is no entry for an RU Allocation subfield in a n HE-SIG-B field (see Table 27-27 (RU Allocation subfield(11ax))) defined for just a single 106-tone RU, at least two RUs are indicated in the RU Allocation subfield and two or more corresponding User fields are required in the HE-SIG-B field.(#4408)

An HE STA shall not transmit an HE MU PPDU with a single user being allocated an RU occupying the entire PPDU bandwidth and a compressed HE-SIG-B field to a peer STA, unless the HE STA has received from the peer STA an HE Capabilities element with the Rx Full BW SU Using HE MU PPDU With Compressed HE-SIG-B subfield in the HE PHY Capabilities Information field equal to 1.

An HE STA shall not transmit an HE MU PPDU with a single user being allocated an RU occupying the entire PPDU bandwidth and a noncompressed HE-SIG-B field to a peer STA, unless the PPDU bandwidth is less than or equal to 80 MHz and the HE STA has received from the peer STA an HE Capabilities element with the Rx Full BW SU Using HE MU PPDU With Non-Compressed HE-SIG-B subfield in the HE PHY Capabilities Information field equal to 1.

NOTE 4—An HE AP does not transmit an HE MU PPDU for full-bandwidth MU-MIMO transmission with noncompressed HE-SIG-B field format (see 27.3.2.5 (Resource indication and User identification in an HE MU PPDU)).(#4408)

An HE STA shall send Control frames following the rules defined in 10.6.6 (Rate selection for Control frames) with the following exceptions:

— A Control frame shall be carried in an HT PPDU, VHT PPDU, HE ER SU PPDU, or HE SU PPDU when the Control frame is sent using an STBC frame.

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- A Control frame sent by the AP as a response to an HE TB PPDU may be carried in any PPDU format that is supported by the intended receivers.
- A Trigger frame that is not an MU-RTS Trigger frame may be carried in any PPDU format that is supported by the intended receivers subject to the restrictions in 26.5.2 (UL MU operation).
- A Control frame is carried in an HE TB PPDU if it is sent as a response to a PPDU that contains a Trigger frame that is not an MU-RTS Trigger frame or if it is sent as a response to a PPDU that contains a frame containing a TRS Control subfield (see 26.5.2 (UL MU operation)).
- A Control frame sent by an HE STA as a response to an HE ER SU PPDU that does not contain a triggering frame should be carried in an HE ER SU PPDU, unless the most recent PPDU sent by the HE STA to the recipient of the Control frame, after association, was not an HE ER SU PPDU. In this case, the Control frame should be carried in a non-HT PPDU.
- A Control frame sent by an HE STA as a response to an HE SU PPDU or a non-HT PPDU that does not contain a triggering frame should be carried in a non-HT PPDU, unless the most recent PPDU sent by the HE STA to the recipient of the Control frame, after association, was an HE ER SU PPDU. In this case, the Control frame should be carried in an HE ER SU PPDU.
- A control response frame shall not be sent in an HE ER SU PPDU if the channel bandwidth of the PPDU containing the frame that elicited the response is greater than 20 MHz.
- A Control frame that is not solicited by another frame and is not a Trigger frame may be carried in an HE ER SU PPDU.
- A Control frame that is sent in the 6 GHz band as a response to an HE SU PPDU or HE MU PPDU but that is not carried in an HE TB PPDU may be carried in an HE SU PPDU if the transmit time of HE SU PPDU is less than or equal to the PPDU duration of a non-HT PPDU containing the Control frame sent at the primary rate (see 10.6.6.5.2 (Selection of a rate or MCS)).

NOTE 5—A change in the format of the PPDU containing the control response frame (between non-HT and HE ER SU PPDU) occurs in subsequent TXOPs. A STA that solicits a control response frame from a responding STA accounts for the PPDU format of the control response frame to calculate the expected duration of the TXOP. The responding STA determines that the most recent PPDU sent to the soliciting STA is received if it receives an immediate acknowledgment by the soliciting STA in response to the PPDU.

NOTE 6—A STA does not transmit a Control frame in an HE ER SU PPDU to a receiving STA, unless the receiving STA indicates that HE ER SU PPDU reception is enabled.

During an EDCA FTM session, an HE STA should send an Ack frame that is the response to (#8020)an FTM frame carried in a VHT PPDU or HT PPDU in the same PPDU format as the PPDU carrying the FTM frame. It shall also send an Ack frame in an HE SU PPDU in response to an FTM frame carried in an HE SU PPDU format; see 26.17.2 (HE BSS operation in the 6 GHz band).(11az)

### 26.15.3 MCS, NSS, BW, and DCM selection

An HE STA shall follow the rules defined in 10.6 (Multirate support) and 26.15.4 (Rate selection constraints for HE STAs) for selecting the rate, MCS, and NSS and the rules defined in 10.3.2.7 (VHT and S1G RTS procedure), 10.3.2.9 (CTS and DMG CTS procedure), 10.6.6 (Rate selection for Control frames), and 10.6.12 (Channel Width in non-HT and non-HT duplicate PPDUs) for selecting the channel width (BW) of transmitted PPDUs with the following exceptions:

- HE-MCS, NSS, and BW selection for an HE TB PPDU is defined in 26.5.2.3 (Non-AP STA behavior for UL MU operation).
- Rate and BW selection for a CTS sent in response to an MU-RTS Trigger frame is defined in 26.2.6 (MU-RTS Trigger/CTS frame exchange sequence procedure(#109)).
- A STA that transmits a Control frame carried in a non-HT PPDU that is a response to a frame received in an HE ER SU PPDU shall set the rate of the non-HT PPDU to 6 Mb/s.


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- A STA that transmits a Control frame that is an S-MPDU carried in an HE ER SU PPDU and that is a response to a frame received in an HE ER SU PPDU shall use the <HE-MCS, NSS> tuple <HE-MCS 0, 1>.
- NSS and BW selection is further constrained as defined in 11.40 (Notification of operating mode changes), 26.9 (Operating mode indication), 26.15.2 (PPDU format selection), 26.15.4 (Rate selection constraints for HE STAs) through 26.15.8 (Additional rules for PPDUs sent in the 6 GHz band), and 26.17 (HE BSS operation).

An HE STA that transmits an HE PPDU to a receiving STA shall use an <HE-MCS, NSS> tuple that is supported by the receiving STA as indicated by the Supported HE-MCS And NSS Set field in the HE Capabilities element that the receiving STA transmits. If the Supported HE-MCS and NSS set of a receiving STA is not known, the transmitting STA shall transmit using a <HE-MCS, NSS> tuple in the basic HE-MCS and NSS set if the basic HE-MCS and NSS set is not empty. Otherwise, the transmitting STA shall transmit using a <HE-MCS, NSS> tuple in the mandatory HE-MCS and NSS set. An HE STA is subject to all of the rules for HT STAs and VHT STAs that apply to its operating band (see 10.27 (Protection mechanisms)).

An HE STA may transmit an HE PPDU with 1024-QAM on a 26-, 52-, and 106-tone RU to a recipient STA if it has received from the recipient STA an HE Capabilities element with the Rx 1024-QAM < 242-tone RU Support subfield in the HE PHY Capabilities Information field equal to 1; otherwise, the HE STA shall not transmit an HE PPDU with 1024-QAM on a 26-, 52-, and 106-tone RU.

An HE AP shall not set the UL HE-MCS subfield of a User Info field in a Trigger frame to 10 or 11 for a 26-, 52-, or 106-tone RU allocation, unless the User Info field is addressed to a non-AP HE STA from which the HE AP has received an HE Capabilities element with the Tx 1024-QAM < 242-tone RU Support subfield in the HE PHY Capabilities Information field equal to 1.

An HE STA that sends a Control frame in response to a frame carried in an HE SU PPDU, or HE ER SU PPDU, or HE MU PPDU that carries a frame with the Normal Ack or Implicit BAR ack policy shall set the TXVECTOR parameter CH_BANDWIDTH to indicate a channel width that is the same as the channel width indicated by the RXVECTOR parameter CH_BANDWIDTH of the frame eliciting the response. If the most recently received PPDU sent by the responding STA to the soliciting STA after association was an HE ER SU PPDU, the soliciting STA shall set the TXVECTOR parameter CH_BANDWIDTH to CBW20 for an HE SU PPDU and to ER-RU-242 or ER-RU-H-106 for an HE ER SU PPDU.

NOTE 1—A preamble punctured HE MU PPDU cannot carry a frame with Normal Ack or Implicit BAR ack policy whose acknowledgment would be transmitted in one or more punctured 20 MHz channels of the preamble punctured HE MU PPDU (see 26.4.4.3 (Responding to an HE MU PPDU with an SU PPDU)).

If a control response frame is transmitted in an HE SU PPDU or HE MU PPDU, the channel width (CH_BANDWIDTH parameter of the TXVECTOR) shall be selected first according to 10.6.6.6 (Channel Width selection for Control frames), and then the <HE-MCS, NSS> tuple shall be selected from a set of <HE-MCS, NSS> tuples called the *CandidateMCSSet*. The CandidateMCSSet is defined in 10.6.6.5.3 (Control response frame MCS computation), except that the set additionally contains the <HE-MCS, NSS> tuples for an HE STA.

An HE STA may transmit an HE SU PPDU or HE ER SU PPDU with DCM applied to the Data field to a recipient STA if it has received from the recipient STA an HE Capabilities element with the DCM Max Constellation Rx subfield in the HE PHY Capabilities Information field greater than 0; otherwise, the HE STA shall not transmit an HE SU PPDU or HE ER SU PPDU with DCM applied to the Data field to the recipient STA.

An HE STA may transmit to a recipient STA an HE MU PPDU with DCM applied to the HE-SIG-B field and/or an RU in the Data field addressed to the STA if it has received from the recipient STA an HE Capabilities element with the DCM Max Constellation Rx subfield in the HE PHY Capabilities Information

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field greater than 0; otherwise, the HE STA shall not transmit to the recipient STA an HE MU PPDU with DCM applied to the HE-SIG-B field and/or an RU in the Data field addressed to the STA.

An HE STA transmits an HE TB PPDU with DCM as defined in 26.5.2.3 (Non-AP STA behavior for UL MU operation). An HE AP shall not set the DCM subfield of a User Info field in a Trigger frame to 1 if it has not received from the recipient STA an HE Capabilities element with the DCM Max Constellation Tx subfield in the HE PHY Capabilities Information field greater than 0.

An HE STA that transmits an HE PPDU with DCM applied to the Data field to a recipient STA shall use an RU size that is less than or equal to the maximum RU size indicated in the DCM Max RU subfield in the HE PHY Capabilities Information field in the HE Capabilities element received from the recipient STA.

An HE AP that transmits a Trigger frame addressed to a recipient STA that solicits an HE TB PPDU with DCM shall set the RU Allocation subfield in the Trigger frame to indicate an RU size that is less than or equal to the maximum RU size indicated in the DCM Max RU subfield in HE PHY Capabilities Information field in the HE Capabilities element received from the recipient STA.

An HE STA that transmits an HE PPDU with DCM applied to the Data field to a recipient STA shall use an NSS that is less than or equal to the value indicated in the DCM Max NSS Rx subfield in the HE PHY Capabilities Information field in the HE Capabilities element received from the recipient STA.

An HE AP that transmits a Trigger frame with a User Info field addressed to a recipient STA and with the UL DCM subfield in the User Info field set to 1 shall set the Number Of Spatial Streams subfield in the SS Allocation subfield in the User Info field to less than or equal to the DCM Max NSS Tx subfield in HE PHY Capabilities Information field in the HE Capabilities element received from the recipient STA.

An HE AP shall not transmit a Trigger frame with the UL STBC subfield set to 1 and the UL BW subfield set to indicate a bandwidth less than or equal to 80 MHz if at least one User Info field is addressed to a non-AP HE STA from which the HE AP has received an HE Capabilities element with the STBC Tx ≤ 80 MHz subfield in HE PHY Capabilities Information field equal to 0.

An HE AP shall not transmit a Trigger frame with the UL STBC subfield set to 1 and the UL BW subfield set to indicate 80+80 MHz or 160 MHz if at least one User Info field is addressed to a non-AP HE STA from which the HE AP has received an HE Capabilities element with the STBC Tx > 80 MHz subfield in HE PHY Capabilities Information field equal to 0.

An HE STA that sends a Control frame in an HE ER SU PPDU format should use

— DCM encoding if the most recently received PPDU sent by the HE STA, after association, to the STA soliciting the Control frame used DCM; otherwise, the STA should not use DCM for the Control frame.

— 106-tone HE ER SU PPDU if the most recently received PPDU sent by the HE STA, after association, to the STA soliciting the Control frame was a 106-tone HE ER SU PPDU; otherwise, the STA should not use a 106-tone HE ER SU PPDU for the Control frame.

NOTE 2—Transmit parameter switching occurs in subsequent TXOPs. A STA that solicits a Control frame from a peer STA accounts for the transmit parameter of the Control frame to calculate the expected duration of the TXOP. The responding STA determines that the most recent PPDU sent to the soliciting STA is received if it receives an immediate acknowledgment by the soliciting STA in response to the PPDU.


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### 26.15.4 Rate selection constraints for HE STAs

#### 26.15.4.1 Receive HE-MCS and NSS Set

The receive HE-MCS and NSS set is the set of <HE-MCS, NSS> tuples for PPDU bandwidths less than or equal to 80 MHz, 160 MHz, or 80+80 MHz PPDUs that an HE STA is capable of receiving. The receive HE-MCS and NSS set for a first HE STA is determined by a second HE STA for each <HE-MCS, NSS> tuple, NSS = 1, …, 8, and PPDU bandwidth (less than or equal to 80 MHz, 160 MHz, or 80+80 MHz) from the Supported HE-MCS And NSS Set field in the HE Capabilities element received from the first HE STA as follows:

- If support for the <HE-MCS, NSS> tuple at that PPDU bandwidth is mandatory (see 27.1.1 (Introduction to the HE PHY)), then the <HE-MCS, NSS> tuple at that bandwidth is supported by the first HE STA on receive.
- Otherwise, if the Max HE-MCS For *n* SS subfield (*n* = NSS) in each Rx HE-MCS Map *b* subfield for $b \in \{\leq 80$ MHz, 160 MHz, 80+80 MHz$\}$ indicates support and neither the Operating Mode field nor the OM Control subfield is received from the first HE STA, then the <HE-MCS, NSS> tuple at PPDU bandwidth *b* for a given operating channel width is supported by the first HE STA on receive as defined in 9.4.2.247.4 (Supported HE-MCS And NSS Set field).
- Otherwise,
  - If the Operating Mode field is received from the first HE STA, the <HE-MCS, NSS> tuple at that PPDU bandwidth for a given operating channel width is supported by the first HE STA on receive as defined in 9.4.2.247.4 (Supported HE-MCS And NSS Set field) and by Equation (9-5).
  - If the OM Control subfield is received from the first HE STA, the <HE-MCS, NSS> tuple at that PPDU bandwidth for a given operating channel width is supported by the first HE STA on receive as defined in 9.4.2.247.4 (Supported HE-MCS And NSS Set field) and by Equation (26-4).
- Otherwise, the <HE-MCS, NSS> tuple at that PPDU bandwidth is not supported by the first HE STA on receive.

The <HE-MCS, NSS> tuples excluded by 26.15.4.3 (Additional rate selection constraints for HE PPDUs) can also be eliminated from the receive HE-MCS and NSS set.

An HE STA shall not, unless explicitly stated otherwise, transmit an HE PPDU, unless the <HE-MCS, NSS> tuple and bandwidth used are in the receive HE-MCS and NSS set of the receiving HE STA(s).

#### 26.15.4.2 Transmit HE-MCS and NSS Set

The transmit HE-MCS and NSS set is the set of <HE-MCS, NSS> tuples for PPDU bandwidth less than or equal to 80 MHz, 106 MHz, or 80+80 MHz PPDUs that a HE STA is capable of transmitting. The transmit HE-MCS and NSS set of a first HE STA is determined by a second HE STA for each <HE-MCS, NSS> tuple, NSS = 1, …, 8, and PPDU bandwidth (less than or equal to 80 MHz, 160 MHz, or 80+80 MHz) from the Supported HE-MCS And NSS Set field received from the first HE STA as follows:

- If support for the <HE-MCS, NSS> tuple at that PPDU bandwidth is mandatory (see 27.1.1 (Introduction to the HE PHY)), then the <HE-MCS, NSS> tuple at that bandwidth is supported by the first HE STA on transmit.
- Otherwise, if the Max HE-MCS For *n* SS subfield (*n* = NSS) in each Tx HE-MCS Map *b* subfield for $b \in \{\leq 80$ MHz, 160 MHz, 80+80 MHz$\}$ indicates support, then the <HE-MCS, NSS> tuple at PPDU bandwidth *b* for a given operating channel width is supported by the first HE STA on transmit as defined in 9.4.2.247.4 (Supported HE-MCS And NSS Set field).
- Otherwise, the <HE-MCS, NSS> tuple at that PPDU bandwidth is not supported by the first HE STA on transmit.

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A non-AP STA may exclude certain numbers of space-time streams, $N_{STS}$, as defined in 26.9.3 (Transmit operating mode (TOM) indication) from its transmit HE-MCS and NSS set.

### 26.15.4.3 Additional rate selection constraints for HE PPDUs

A HE STA shall not transmit a 20 MHz or 40 MHz HE PPDU with an <HE-MCS, NSS> tuple that has HE-MCS 0, 1, 2, or 3 and NSS less than or equal to 4 to a receiver HE STA that has marked as unsupported the HT-MCS with value HE-MCS + 8 × (NSS – 1) in the Rx MCS Bitmask subfield in the Supported MCS Set field in the HT Capabilities element it transmits. The transmission of a 20 MHz or 40 MHz HE PPDU with HE-MCS greater than 3 is not subject to this constraint.

A HE STA shall not transmit an 80 MHz, 160 MHz, or 80+80 MHz HE PPDU with an <HE-MCS, NSS> tuple that has HE-MCS 0 or 1 and NSS less than or equal to 4 to a receiver HE STA that has marked as unsupported the HT-MCS values of both 2 × HE-MCS + 8 × (NSS – 1) and 2 × HE-MCS + 1 + 8 × (NSS – 1) in the Rx MCS Bitmask subfield in the Supported MCS Set field in the HT Capabilities element it transmits. The transmission of an 80 MHz, 160 MHz, or 80+80 MHz HE PPDU with HE-MCS greater than 1 is not subject to this constraint.

An example tabulation of this behavior is given in Table 26-14 (Example of rate selection for HE PPDUs(11ax)).

**Table 26-14—Example of rate selection for HE PPDUs(11ax)**

| HT-MCSs that are marked as unsupported | <HE-MCS, NSS> tuples that are not used for CBW20 and CBW40 | <HE-MCS, NSS> tuples that are not used for CBW80, CBW160, and CBW80+80 |
|---|---|---|
| 0, 8, 16 | <0, 1>, <0, 2>, <0, 3> | — |
| 1, 9 | <1, 1>, <1, 2> | — |
| 10 | <2, 2> | — |
| 3 | <3, 1> | — |
| 0, 1 | <0, 1>, <1, 1> | <0, 1> |
| 2, 3 | <2, 1>, <3, 1> | <1, 1> |
| 0, 1, 8, 9 | <0, 1>, <1, 1>, <0, 2>, <1, 2> | <0, 1>, <0, 2> |

### 26.15.4.4 Rx Supported VHT-MCS and NSS Set

For each <VHT-MCS, NSS> tuple, NSS = 1, …, 8, and bandwidth (20 MHz, 40 MHz, 80 MHz, 160 MHz, or 80+80 MHz) from the Supported VHT-MCS and NSS Set field received from a first HE STA, a second HE STA shall follow the rules in 10.6.13.1 to determine the Rx Supported VHT-MCS and NSS Set of the first HE STA with the following exception:

— If the second HE STA receives OM Control subfield from the first HE STA, the receive (#3817)VHT-MCS and NSS Set of a first HE STA is determined by a second HE STA according to 9.4.2.156.3 (Supported VHT-MCS and NSS Set field) and Table 26-9 (Setting of VHT Channel Width and VHT NSS at an HE STA transmitting the OM Control subfield).

NOTE—If the second HE STA receives both an Operating Mode field and an OM Control subfield from the first HE STA, the rules in 26.9.1 (General) apply.


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### 26.15.5 Additional rules for ER beacons and group addressed frames

An AP that transmits group addressed frames in an HE ER SU PPDU shall transmit the HE ER SU PPDU with an <HE-MCS, NSS> tuple where the HE-MCS is a mandatory HE-MCS and NSS = 1.

A group addressed frame (including a Beacon frame) transmitted in an HE ER SU PPDU shall be sent as an S-MPDU (see Table 9-534), except for group addressed Data frames, which are not required to be sent as an S-MPDU but are required to follow the rules in 10.12.4 (A-MPDU aggregation of group addressed Data frames).

The HE AP transmitting the HE ER SU PPDU shall set the TXVECTOR parameters as follows:

- CH_BANDWIDTH to ER-RU-242
- HE_LTF_TYPE to 2xHE-LTF and GI_TYPE to 0u8s_GI or 1u6s_GI, or HE_LTF_TYPE to 4xHE-LTF and GI_TYPE to 3u2s_GI
- FEC_CODING to BCC_CODING
- STBC to 0
- DCM to 0
- DOPPLER to 0
- BEAMFORMED to 0
- NUM_STS to 1
- NOMINAL_PACKET_PADDING to 16 μs
- NO_SIG_EXTN to false in the 2.4 GHz band and true otherwise
- BEAM_CHANGE as defined in 26.11.3 (BEAM_CHANGE)

### 26.15.6 Additional rules for HE beacons and group addressed frames

An AP that transmits group addressed frames in an HE SU PPDU shall transmit the HE SU PPDU with an <HE-MCS, NSS> tuple where the HE-MCS is a mandatory HE-MCS and NSS = 1.

NOTE—An AP does not send a Beacon frame in an HE SU PPDU (an HE beacon), unless it is operating in the 6 GHz band (see 26.17.2.2 (Beacons in the 6 GHz band)).

(#2356)A HE beacon or other group addressed frame transmitted in an HE SU PPDU shall be sent as an S-MPDU (see Table 9-534), except for group addressed Data frames, which are not required to be sent as an S-MPDU but are required to follow the rules in 10.12.4 (A-MPDU aggregation of group addressed Data frames).

If the HE SU PPDU contains a group addressed frame intended for at least one STA that is not associated to the AP, then the HE AP shall set the TXVECTOR parameters for the HE PPDU as follows:

- CH_BANDWIDTH to CBW20
- HE_LTF_TYPE to 2xHE-LTF and GI_TYPE to 0u8s_GI or 1u6s_GI, or HE_LTF_TYPE to 4xHE-LTF and GI_TYPE to 3u2s_GI
- FEC_CODING to BCC_CODING
- STBC to 0
- DCM to 0
- DOPPLER to 0
- BEAMFORMED to 0
- (#2355) NUM_STS to 1
- NOMINAL_PACKET_PADDING to 16 μs
- NO_SIG_EXTN to false in the 2.4 GHz band and true otherwise

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— BEAM_CHANGE as defined in 26.11.3 (BEAM_CHANGE)

Otherwise, if the HE SU PPDU contains group addressed frames intended only for associated STAs then the AP shall set the TXVECTOR parameters listed above to values that are indicated as supported by all the intended STAs, except that the CH_BANDWIDTH shall be set to CBW20 if at least one of the intended STAs is currently not in the awake state.

### 26.15.7 Additional rules for group addressed frames in an HE MU PPDU

An HE AP may include group addressed frames in an HE MU PPDU subject to the rules defined in this subclause.

An HE AP shall not include a Beacon frame in an HE MU PPDU.

An HE AP that includes a group addressed frame in an HE MU PPDU shall ensure that the frame is included in a broadcast RU in the HE MU PPDU. The HE AP shall additionally ensure that the following conditions are satisfied for the broadcast RU:

- The RU allocation shall comply with the rules in 26.5.1.3 (RU allocation in an HE MU PPDU) and 27.3.2.8 (RU restrictions for 20 MHz operation).
- The <HE-MCS, NSS> tuple shall have a mandatory HE-MCS and NSS = 1.
- The broadcast RU shall be located within
  - The primary 20 MHz channel if the group addressed frame is a FILS Discovery or a Probe Response frame, except when the primary 20 MHz channel does not coincide with a PSC and the AP is a 6 GHz-only AP. For this exception, the broadcast RU may be in a PSC that is within the BSS operating channel width (see 26.17.2.3 (Scanning in the 6 GHz band)). The broadcast RU size shall not exceed 106 subcarriers if the MU PPDU has a bandwidth that is greater than 20 MHz.
  - The primary 20 MHz channel if the group addressed frame is addressed to at least one associated non-AP STA that has not declared to be in the awake state. The broadcast RU size shall not exceed 106 subcarriers if the MU PPDU has a bandwidth that is greater than 20 MHz.
  - A bandwidth that is indicated as supported in reception by one or more associated non-AP STAs, if the group addressed frame is addressed only to those non-AP STAs and the STAs have declared to be in the awake state. The broadcast RU size shall not exceed the minimum common bandwidth that is supported in reception by all STAs in the HE Capabilities element they transmit or in the most recently sent OM Control or Operating Mode Notification frames(#7202).
  - The SST subchannel if the group addressed frame is addressed to one or more HE SST STAs, the primary 20 MHz channel does not coincide with the subchannel assigned to the HE SST STAs and the frame is not addressed to any STAs other than the HE SST STAs in that subchannel (see 26.8.7.2 (SST operation)). The broadcast RU size shall not exceed 106 subcarriers if the SST subchannel is 20 MHz.
- The TXVECTOR parameters listed below shall be set as follows:
  - HE_LTF_TYPE to 2xHE-LTF and GI_TYPE to 0u8s_GI or 1u6s_GI, or HE_LTF_TYPE to 4xHE-LTF and GI_TYPE to 3u2s_GI
  - FEC_CODING to BCC_CODING
  - STBC to 0
  - DCM to 0
  - DOPPLER to 0
  - BEAMFORMED to 0
  - NOMINAL_PACKET_PADDING to 16 µs
  - NO_SIG_EXTN to false in the 2.4 GHz band and true otherwise


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- BEAM_CHANGE as defined in 26.11.3 (BEAM_CHANGE)
- STA_ID as defined in 26.11.1 (STA_ID)

Group addressed frames transmitted in an HE MU PPDU shall be sent as an S-MPDU (see Table 9-535), except for group addressed Data frames, which are not required to be sent as an S-MPDU but are required to follow the rules in 10.12.4 (A-MPDU aggregation of group addressed Data frames).

### 26.15.8 Additional rules for PPDUs sent in the 6 GHz band

An HE STA that transmits a PPDU that is not sent in response to a Trigger frame in the 6 GHz band and that contains a frame that is not a control response frame with the Address 1 field set to the MAC address of an HE AP with which it is not associated and from which it has received a FILS Discovery frame or an HE Operation element shall ensure that the PPDU meets the following conditions:

- The bandwidth of the PPDU is less than or equal to the operating bandwidth of the HE BSS as indicated in the BSS Operating Channel Width subfield of the FILS Discovery frame or in the Channel Width subfield of the HE Operation element sent by the AP.
- The PPDU is transmitted with a number of spatial streams that is less than or equal to the maximum number of spatial streams of the HE BSS as indicated in the Maximum Number of Spatial Stream subfield of the FILS Discovery frame or in the Basic HE-MCS And NSS Set field of the HE Operation element sent by the AP.
- If the PPDU is an HE PPDU, then the PPDU is transmitted with an <HE-MCS, NSS> tuple providing a data rate that is greater than or equal to the minimum rate indicated in the FILS Minimum Rate field (if present) of the FILS Discovery frame or in the Minimum Rate field of the HE Operation element sent by the AP.
- If the PPDU is a non-HT PPDU, then the PPDU is transmitted with a data rate that is greater than or equal to the minimum of <R, 54 Mb/s>, where R is the minimum rate indicated in the FILS Minimum Rate field (if present) of the FILS Discovery frame or in the Minimum Rate field of the HE Operation element sent by the AP.

An HE STA that transmits a PPDU that is not sent in response to a Trigger frame in the 6 GHz band and that contains a frame that is not a control response frame with Address 1 field set to the MAC address of the AP with which it is associated shall ensure that the PPDU meets the following conditions:

- If the PPDU is a non-HT (duplicate) PPDU, then the PPDU is transmitted with a data rate that is greater than or equal to the minimum of <R, 54 Mb/s>, where R is the minimum rate indicated in the Minimum Rate field of the HE Operation element sent by the AP.
- If the PPDU is an HE PPDU, then the PPDU is transmitted with an <HE-MCS, NSS> tuple providing a data rate that is not less than the data rate indicated in the Minimum Rate field of the HE Operation element sent by the AP.

An HE STA that transmits a PPDU that is not an HE TB PPDU in the 6 GHz band and that contains a frame that is not a control response frame with Address 1 field set to the MAC address of an AP with which it is not associated shall determine a local maximum transmit power for that transmission following the rules in 11.7.5 (Specification of regulatory and local maximum transmit power levels) if the local maximum transmit power is received in Transmit Power Envelope elements and combinations of Country elements and Power Constraint elements in the most recent Beacon or Probe Response frame, on the channel from that AP.

## 26.16 Midamble parameter setting rules

A STA shall not set the TXVECTOR parameter DOPPLER to 1 for an HE SU PPDU, HE ER SU PPDU, or HE MU PPDU, unless the STA has received from each of the intended recipient STAs an HE Capabilities element with the Doppler Rx subfield in the HE PHY Capabilities Information field equal to 1.

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A STA shall not send a Trigger frame with the Doppler subfield in the Common Info field set to 1, unless the STA has received from each of the intended recipient STAs of the Trigger frame an HE Capabilities element with the Doppler Tx subfield in the HE PHY Capabilities Information field equal to 1.

A STA shall not set the TXVECTOR parameter HE_LTF_TYPE to 1xHE-LTF and the parameter DOPPLER to 1 for an HE SU PPDU, unless the STA has received an HE Capabilities element from each of the intended recipient STAs where the HE PHY Capabilities Information field meets the following conditions:

— The Midamble Tx/Rx 2x And 1x HE-LTF subfield is 1.
— The HE SU PPDU With 1x HE-LTF And 0.8 μs GI subfield is 1.

A STA shall not set the TXVECTOR parameter HE_LTF_TYPE to 1xHE-LTF and the parameter DOPPLER to 1 for an HE ER SU PPDU, unless the HE STA has received from each of the intended recipient STAs an HE Capabilities element in which the HE PHY Capabilities Information field meets the following conditions:

— The Midamble Tx/Rx 2x And 1x HE-LTF subfield is 1.
— The HE ER SU PPDU With 1x HE-LTF And 0.8 μs GI subfield is 1.

A STA shall not set the TXVECTOR parameter HE_LTF_TYPE to 2xHE-LTF and the parameter DOPPLER to 1 for an HE SU PPDU, HE ER SU PPDU, or HE MU PPDU, unless the HE STA has received an HE Capabilities element with the Midamble Tx/Rx 2x And 1x HE-LTF subfield in the HE PHY Capabilities Information field equal to 1.

A non-AP STA shall not transmit an HE Capabilities element with the Doppler Tx subfield in the HE PHY Capabilities Information field set to 1, unless the non-AP STA meets all of the following conditions:

— The non-AP STA is capable of transmitting an HE TB PPDU with midambles and a 4x HE-LTF.
— If the non-AP STA has set the Midamble Tx/Rx 2x And 1x HE-LTF subfield in the HE PHY Capabilities Information field to 1, the non-AP STA is capable of transmitting an HE TB PPDU with midambles and a 2x HE-LTF.
— If the non-AP STA has set both the Midamble Tx/Rx 2x And 1x HE-LTF and the Full Bandwidth UL MU-MIMO subfields in the HE PHY Capabilities Information field to 1, the non-AP STA is capable of transmitting an HE TB PPDU with midambles, using full-bandwidth UL MU-MIMO, and a 1x HE-LTF.

A STA that transmits an HE SU PPDU or HE ER SU PPDU with the TXVECTOR parameter DOPPLER set to 1 shall not set the TXVECTOR parameter NUM_STS to indicate a number of space-time streams that is greater than indicated in the Midamble Tx/Rx Max NSTS subfield in the HE PHY Capabilities Information subfield in the HE Capabilities element received from any of the intended recipient STAs.

A STA transmitting an HE MU PPDU with the TXVECTOR parameter DOPPLER set to 1 shall not set the TXVECTOR parameter NUM_STS[$u$] to indicate a number of space-time streams that is greater than indicated in the Midamble Tx/Rx Max NSTS subfield in the HE PHY Capabilities Information subfield in the HE Capabilities element received from the intended recipient STA $u$.

An AP transmitting a Trigger frame with the Doppler subfield in the Common Info field set to 1 shall not set the Number Of Spatial Streams subfield in a User Info field in the Trigger frame to indicate a number of space-time streams that is greater than indicated in the Midamble Tx/Rx Max NSTS subfield in the HE PHY Capabilities Information subfield in the HE Capabilities element received from the STA addressed by the User Info field.


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## 26.17 HE BSS operation

### 26.17.1 Basic HE BSS operation

The Beacon frames generated within an HE BSS contain an HE Operation element.

An HE STA has dot11HEOptionImplemented equal to true.

A STA that is operating in an HE BSS shall be able to receive and transmit at each of the <HE-MCS, NSS> tuple values indicated by the Basic HE-MCS And NSS Set field of the HE Operation parameter of the MLME-START.request primitive and shall be able to receive at each of the <HE-MCS, NSS> tuple values indicated by the Supported HE-MCS and NSS Set field in the HE Capabilities parameter of the MLME-START.request primitive.

The basic HE-MCS and NSS set is the set of <HE-MCS, NSS> tuples that are supported by all HE STAs that are members of an HE BSS. It is established by the STA that starts the HE BSS and indicated by the Basic HE-MCS And NSS Set field of the HE Operation parameter in the MLME-START.request primitive. Other HE STAs determine the basic HE-MCS and NSS set from the Basic HE-MCS And NSS Set field of the HE Operation element in the BSSDescription derived through the scan mechanism (see 11.1.4.1 (General)).

An HE STA shall not attempt to join (MLME-JOIN.request primitive) a BSS, unless it supports (i.e., is able to both transmit and receive using) all of the <HE-MCS, NSS> tuples in the basic HE-MCS and NSS set.

NOTE 1—An HE STA does not attempt to (re)associate with an HE AP, unless the STA supports (i.e., is able to both transmit and receive using) all of the <HE-MCS, NSS> tuples in the Basic HE-MCS And NSS Set field in the HE Operation element transmitted by the AP because the MLME-JOIN.request primitive is a necessary precursor to (re)association.

A STA operating in the 2.4 GHz band that sets dot11HEOptionImplemented to true shall set dot11HighThroughputOptionImplemented to true. A STA operating in the 5 GHz or 6 GHz band that sets dot11HEOptionImplemented to true shall set both dot11VHTOptionImplemented and dot11HighThroughputOptionImplemented to true. A non-AP STA that sets dot11HEOptionImplemented to true shall set dot11MultiBSSIDImplemented to true.

An HE STA operating in the 6 GHz band is a VHT STA, except that it is exempt from following VHT and HT functionalities and/or requirements that are not applicable or that are superseded by equivalent HE functionalities and/or requirements (see Clause 26 (High-efficiency (HE) MAC specification(11ax)) and Clause 27 (High-efficiency (HE) PHY specification(11ax))) and except that it shall use the HE format instead of the VHT, (#2095)HT-greenfield or HT-mixed format for PPDUs transmitted in the 6 GHz band. Additional HE functionalities and/or requirements for the 6 GHz band are defined in 26.17.2 (HE BSS operation in the 6 GHz band).

A STA that is an HE AP or an HE mesh STA declares the channel widths at which it is capable of operating in the PHY Capabilities Information field in the HE Capabilities element that it transmits (see Table 9-376 (Subfields of the HE PHY Capabilities Information field(11ax))).

An HE AP operating in the 5 GHz or 6 GHz bands shall set B1 in the Supported Channel Width Set field in the PHY Capabilities Information field in the HE Capabilities element to indicate support for 40 MHz and 80 MHz channel width.

A STA transmitting an HT Capabilities element and HE Capabilities element shall set the Supported Channel Width Set subfield of the HT Capabilities element to 1 if either B0 or B1 of the Supported Channel

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Width Set subfield in the HE Capabilities element is 1, unless the STA is a 20 MHz-only non-AP HE STA. In this case, the Supported Channel Width Set subfield of the HT Capabilities element shall be set to 0.

A STA transmitting a VHT Capabilities element and HE Capabilities element shall set the Supported Channel Width Set subfield of the VHT Capabilities element to indicate the same channel width as indicated in the HE Capabilities element, unless the STA is a 20 MHz-only non-AP HE STA. In this case, the Supported Channel Width Set subfield of the VHT Capabilities element is reserved.

At a minimum, an HE STA sets the Rx MCS Bitmask subfield of the Supported MCS Set field of its HT Capabilities element according to the setting of each Rx HE-MCS Map $b$ subfield for $b \in \{\leq 80$ MHz, 160 MHz, 80+80 MHz$\}$ of the Supported HE-MCS And NSS Set field of its HE Capabilities element as follows: For each Max HE-MCS For $n$ SS subfield (where $1 \leq n \leq 4$) of each Rx HE-MCS Map $b$ subfield for $b \in \{\leq 80$ MHz, 160 MHz, 80+80 MHz$\}$ with a value other than 3 (i.e., no support for that number of spatial streams), the STA shall indicate support for HT MCSs $8 \times (n - 1)$ to $8 \times (n - 1) + 7$ in the Rx MCS Bitmask subfield, where $n$ is the number of spatial streams, except for HT-MCSs marked as unsupported as described in 26.15.4.3 (Additional rate selection constraints for HE PPDUs).

An HE AP or an HE mesh STA shall set the VHT Operation Information Present field in the HE Operation element to 0 if a VHT Operation element is present in the frame that carries the HE Operation element or if the frame that carries the HE Operation element is sent in the 2.4 GHz band. An HE AP or HE mesh STA shall set the VHT Operation Information Present field in the HE Operation element to 1 if a VHT Operation element is not present in the frame that carries the HE Operation element and the frame is sent in the 5 GHz band.

An HE AP or an HE mesh STA that transmits an HE Operation element that has the VHT Operation Information Present field set to 1 shall do one of the following to set the BSS operating channel:

— Set the STA Channel Width subfield and Channel Center Frequency Segment 2 subfield in the HT Operation Information field in the HT Operation element, the Channel Width subfield in the VHT Operation Information field in the HE Operation element, and the Channel Center Frequency Segment 0 and Channel Center Frequency Segment 1 subfields in the VHT Operation Information field in the HE Operation element to indicate the BSS bandwidth as defined in Table 11-29 (VHT BSS bandwidth) and Table 11-31 (Extended NSS channel width) based on the Extended NSS BW Support and Supported Channel Width Set fields.

— Set the STA Channel Width subfield and Channel Center Frequency Segment 2 subfield in the HT Operation Information field in the HT Operation element, the Channel Width subfield in the VHT Operation Information field in the HE Operation element, and the Channel Center Frequency Segment 0 and Channel Center Frequency Segment 1 subfields in the VHT Operation Information field in the HE Operation element to indicate the BSS bandwidth as defined in Table 11-29 (VHT BSS bandwidth) and Table 11-31 (Extended NSS channel width) based on the Rx HE-MCS Map ≤ 80 MHz, Rx HE-MCS Map 160 MHz, and Rx HE-MCS Map 80+80 MHz fields.

NOTE 2—The Channel Center Frequency Segment 2 is 0 if Table 11-30 (Setting of Channel Center Frequency Segment 0, Channel Center Frequency Segment 1, and Channel Center Frequency Segment 2 subfields) is applied.

NOTE 3—These two methods give the same result.

The setting of the Channel Center Frequency Segment 0, Channel Center Frequency Segment 1, and Channel Center Frequency Segment 2 subfields is defined in Table 11-30 (Setting of Channel Center Frequency Segment 0, Channel Center Frequency Segment 1, and Channel Center Frequency Segment 2 subfields), except that the Max NSS support is provided by the HE STA in frames that contain an HE Capabilities element (see 9.4.2.247 (HE Capabilities element(11ax))) and an Operating Mode field (see 9.4.1.51 (Operating Mode field)), where in the table the maximum NSS support refers to the HE maximum NSS support instead of the VHT maximum NSS support for an HE STA.


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An HE STA shall determine the channelization using the information in the Primary Channel field of the HT Operation element when operating in 2.4 GHz and using the combination of the information in the Primary Channel field in the HT Operation element and the Channel Center Frequency Segment 0 and Channel Center Frequency Segment 1 subfields in the VHT Operation Information field in the VHT Operation element if operating in the 5 GHz band (see 21.3.14 (Channelization)). An HE STA determines the channelization as defined in 26.17.2 (HE BSS operation in the 6 GHz band) if operating in the 6 GHz band.

An HE AP or an HE mesh STA shall set the Secondary Channel Offset subfield in the HT Operation Information field in the HT Operation element to indicate the secondary 20 MHz channel as defined in (#6596)Table 9-230 (HT Operation element fields and subfields), if the BSS bandwidth is more than 20 MHz.

An HE STA that is a member of an HE BSS shall follow the rules in 11.38.1 when transmitting a 20 MHz, 40 MHz, 80 MHz, 160 MHz, or 80+80 MHz HE PPDU with the following exceptions:

— An HE TB PPDU sent in response to a triggering frame follows the rules defined in 26.5.2.3 (Non-AP STA behavior for UL MU operation).

— An 80 MHz, 160 MHz, or 80+80 MHz DL HE MU PPDU with preamble puncturing may be transmitted if the primary 20 MHz or the primary 40 MHz channel is occupied by the transmission and certain 20 MHz subchannels of the secondary channel are idle (see Table 27-21 (HE-SIG-A field of an HE MU PPDU(11ax)) and (#6595)10.23.2.5 (EDCA channel access in a VHT or TVHT BSS)).

An HE STA shall not transmit to a recipient HE STA using a channel width that is not indicated as supported in the Supported Channel Width Set subfield in the HE Capabilities element received from that HE STA.

An HE STA shall not transmit to a recipient HE STA using a channel width that exceeds the BSS channel width in the Channel Width field that is contained in the following:

— The HE Operation element most recently exchanged with the recipient STA, if any, and if the Channel Width field is present.

— Otherwise, the VHT Operation element most recently exchanged with the recipient STA, if any.

— Otherwise, the HT Operation element most recently exchanged with the recipient STA, if any.

A STA shall not transmit an HE PPDU to a recipient STA that carries a frame that is not an HE Compressed Beamforming/CQI frame (see 26.7.3 (Rules for HE sounding protocol sequences)) and that exceeds the maximum MPDU length capability indicated in the VHT Capabilities element (#4275)received from the recipient STA in the 2.4 GHz or 5 GHz band or, if a VHT Capabilities element has not been received from the recipient STA, (#4365)a frame that carries an A-MSDU that exceeds the maximum A-MSDU length indicated in the HT Capabilities element (#4275)received from the recipient STA in the 2.4 GHz or 5 GHz band(#3750).

An HE AP shall set the RIFS Mode field in the HT Operation element to 0.

An HE STA follows the rules in 11.38 for channel selection, scanning requirements, channel switching, NAV assertion, and antenna indication when operating in the 5 GHz or 6 GHz band unless explicitly stated otherwise in Clause 26 (High-efficiency (HE) MAC specification(11ax)). An HE STA shall additionally follow the rules in 26.17.2 (HE BSS operation in the 6 GHz band) for scanning and operation in the 6 GHz band.

An HE STA shall follow the rules in 11.15 (20/40 MHz BSS operation)for channel selection, scanning requirements, channel switching, and NAV assertion when operating in 2.4 GHz unless explicitly stated otherwise in Clause 26 (High-efficiency (HE) MAC specification(11ax)).

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The AP of an ER BSS shall not transmit a Probe Response or (Re)Association Response frame in response to a Probe Request or (Re)Association Request frame, respectively, sent by a non-HE STA. An HE AP that is not operating an ER BSS may set the ER SU Disable subfield in the HE Operation element it transmits to 1.

A STA shall have the same value of maximum HE NSS(#3818) defined by its Rx HE-MCS Map ≤ 80 MHz subfield in the HE Capabilities element as the maximum NSS value indicated by its Rx VHT-MCS Map field in the VHT Capabilities element. If a STA supports 160 MHz, the Maximum NSS defined by its Rx VHT-MCS Map field and Extended NSS BW Support field in the VHT Capabilities element at 160 MHz shall not be more than the maximum NSS defined by its Rx HE-MCS Map 160 MHz subfield in the HE Capabilities element at 160 MHz. If a STA supports 80+80 MHz, the maximum NSS defined by its Rx VHT-MCS Map field and Extended NSS BW Support field in the VHT Capabilities element at 80+80 MHz shall not be more than the maximum NSS defined by its Rx HE-MCS Map 80+80 MHz subfield in the HE Capabilities element at 80+80 MHz. For every NSS in VHT Capabilities elements and HE Capabilities elements transmitted by a STA, if the maximum HE-MCS is 9 or more, the maximal VHT-MCS shall be 9. Otherwise, the maximal VHT-MCS shall be the same as the HE-MCS. An HE STA shall not transmit a VHT Capabilities element with the Supported Channel Width Set field equal to 1 and the Extended NSS BW Support field equal to 3 or with the Supported Channel Width Set field equal to 2 and the Extended NSS BW Support field equal to 3.

If an HE STA supports 160 MHz, the maximum NSS defined by its Rx HE-MCS Map 160 MHz subfield for an HE-MCS in the HE Capabilities element at 160 MHz shall not be more than the maximum NSS defined by its Rx HE-MCS Map ≤ 80 MHz subfield for the HE-MCS in the HE Capabilities element at 80 MHz.

If an HE STA supports 80+80 MHz, the maximum NSS defined by its Rx HE-MCS Map 80+80 MHz subfield for an HE-MCS in the HE Capabilities element at 80+80 MHz shall not be more than the maximum NSS defined by its Rx HE-MCS Map ≤ 80 MHz subfield for the HE-MCS in the HE Capabilities element at 80 MHz.

### 26.17.2 HE BSS operation in the 6 GHz band

#### 26.17.2.1 General

A STA that supports operation in the 6 GHz band sets dot11HE6GOptionImplemented to true.

A STA with dot11HE6GOptionImplemented equal to true and operating in the 6 GHz band is a STA 6G.

An AP with dot11HE6GOptionImplemented equal to true and operating in the 6 GHz band is a 6 GHz AP.

A mesh STA with dot11HE6GOptionImplemented equal to true and operating in the 6 GHz band is a 6 GHz mesh STA.

A non-AP STA with dot11HE6GOptionImplemented equal to true and operating in the 6 GHz band is a 6 GHz non-AP STA.

NOTE—A STA 6G sets dot11HighThroughputOptionImplemented and dot11VHTOptionImplemented to true, but certain VHT and HT functionalities do not apply when operating in the 6 GHz band. See 26.17.1 (Basic HE BSS operation).

A STA 6G shall have dot11ExtendedChannelSwitchActivated, dot11MultiDomainCapabilityActivated, and dot11OperatingClassesRequired equal to true and shall set the Extended Channel Switching field to 1 in the Extended Capabilities elements it transmits.


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A STA 6G shall meet the Class A requirements in 27.3.15 (Transmit requirements for PPDUs sent in response to a triggering frame).

A 6 GHz AP shall indicate support for at least 80 MHz channel width.

A 6 GHz AP shall set the Co-Hosted BSS subfield in HE Operation element to 0.

A STA 6G shall not transmit an HT Capabilities element, VHT Capabilities element, HT Operation element, VHT Operation element, or an HE Operation element that contains a VHT Operation Information field.

A STA 6G shall not transmit in an HE PPDU a frame that is not an HE Compressed Beamforming/CQI frame (see 26.7.3 (Rules for HE sounding protocol sequences)) and that exceeds the maximum MPDU length capability indicated in the HE 6 GHz Band Capabilities element received from the recipient STA.

A 6 GHz AP or 6 GHz mesh STA shall include the 6 GHz Operation Information field in the HE Operation elements it transmits. The AP or mesh STA shall set the Channel Width subfield, the Channel Center Frequency Segment 0, and the Channel Center Frequency Segment 1 subfields of the 6 GHz Operation Information field as defined in Table 26-15 (6 GHz BSS channel width(11ax)), based on the Rx HE-MCS Map ≤ 80 MHz, Rx HE-MCS Map 160 MHz, and Rx HE-MCS Map 80+80 MHz subfields of the Supported HE MCS And NSS Set field in the HE Capabilities element transmitted by the AP.

**Table 26-15—6 GHz BSS channel width(11ax)**

| Channel Width field | Center Frequency Segment 1 field | BSS channel width (MHz) |
|---|---|---|
| 0 | 0 | 20 |
| 1 | 0 | 40 |
| 2 | 0 | 80 |
| 3 | CCFS1 > 0 and \|CCFS1 – CCFS0\| = 8 | 160 |
| 3 | CCFS1 > 0 and \|CCFS1 – CCFS0\| > 16 | 80+80 |

NOTE—CCFS0 represents the value of the Channel Center Frequency Segment 0 field, and CCFS1 represents the value of the Channel Center Frequency Segment 1 field.

A STA 6G shall determine the BSS channelization using the Primary Channel, Channel Center Frequency Segment 0, and Channel Center Frequency Segment 1 subfields in the 6 GHz Operation Information field in the HE Operation element when operating in 6 GHz band (see 21.3.14 (Channelization) for the channelization and 27.3.25.2 (Channel allocation in the 6 GHz band) for the equation defining the channel center frequencies in the 6 GHz band).

A STA 6G shall not transmit an HT PPDU.

A STA 6G shall not transmit a VHT PPDU.

A STA 6G shall not transmit a DSSS PPDU.

A STA 6G shall not transmit an HR/DSSS PPDU.

A STA 6G shall not transmit an ERP-OFDM PPDU.

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A STA 6G shall set dot11SpectrumManagementRequired to true and operate as defined in 11.7 (TPC procedures).

A 6 GHz AP shall set dot11FILSOmitReplicateProbeResponses to true.

A 6 GHz AP may respond with a (Re)Association Response frame with the Status Code field indicating DENIED_POOR_CHANNEL_CONDITIONS if it receives a (Re)Association Request frame from a non-AP STA below a minimum RSSI threshold value. A 6 GHz AP may send a Disassociation frame with the Reason Code field indicating POOR_RSSI_CONDITIONS to an associated non-AP STA if it receives frames from the STA below a minimum RSSI threshold value for a sufficiently long period of time. How an AP selects a minimum RSSI threshold value or sufficient interval of time is beyond the scope of this standard.

A 6 GHz non-AP STA that receives a (Re)Association Response frame with the Status Code field indicating DENIED_POOR_CHANNEL_CONDITIONS or a Disassociation frame with the Reason Code field indicating POOR_RSSI_CONDITIONS from a 6 GHz AP should not transmit a (Re)Association Request frame or a Probe Request frame to the AP until one of the following conditions is met:

— Sufficient time has passed since it received the (Re)Association Response frame or Disassociation frame from the AP.

— The STA has determined that a (Re)Association Request frame or Probe Request frame that it transmits will be received by the AP at a sufficiently high RSSI level and in sufficiently good conditions compared with its previous transmission to the AP.

How a 6 GHz non-AP STA determines sufficient time has passed or a suitable RSSI threshold is beyond the scope of this standard.

(11az)A 6 GHz STA that negotiates an EDCA based FTM session, as defined in 11.21.6 (FTM procedure(#7065)), shall set the Format And Bandwidth subfield, in the FTM Parameters field, to a value that corresponds to an EDCA based HE format, see Table 9-325 (Format And Bandwidth subfield), in the IFTMR frame for the ISTA, and in the IFTM frame for the RSTA.

(11az)A 6 GHz STA that negotiates an EDCA FTM session shall transmit FTM frames in an HE SU PPDU and FTM Request frames in either a non-HT PPDU, or an HE SU PPDU. The HE SU PPDU shall use 2x HE-LTF and 1.6 μs GI for both the FTM frame and corresponding the acknowledgement frame.

#### 26.17.2.2 Beacons in the 6 GHz band

A 6 GHz AP transmits Beacon frames as defined in 11.1 (Synchronization), and they may be contained in a non-HT PPDU, non-HT duplicate PPDU, or HE SU PPDU.

A 6 GHz AP that transmits a Beacon frame in a non-HT PPDU follows the rules in 10.6.5.1 (Rate selection for non-STBC Beacon (#3263)frames).

A 6 GHz AP that transmits a Beacon frame in a non-HT duplicate PPDU shall follow the rules in 10.6.5.1 (Rate selection for non-STBC Beacon (#3263)frames) and shall set the TXVECTOR parameter CH_BANDWIDTH of the PPDU to a value that is up to the operating channel width of the BSS.

If a 6 GHz AP schedules a Beacon frame for transmission in a non-HT duplicate PPDU, then it shall set the Duplicate Beacon subfield to 1 in the 6 GHz Operation Information field of the HE Operation element it transmits; otherwise, the AP shall set the Duplicate Beacon subfield to 0.

A 6 GHz AP that transmits a Beacon frame in an HE SU PPDU shall follow the rules defined in 26.15.6 (Additional rules for HE beacons and group addressed frames).


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NOTE—An AP does not transmit a Beacon frame in an HE SU PPDU or non-HT duplicate PPDU in the 2.4 GHz or 5 GHz bands.

### 26.17.2.3 Scanning in the 6 GHz band

#### 26.17.2.3.1 General

A STA 6G shall perform the subset of the operations defined for a FILS STA that is described in 26.17.2.3 (Scanning in the 6 GHz band) and may perform all the other operations defined for a FILS STA.

A 6 GHz AP may set dot11ColocatedRNRImplemented to true and shall set dot11ShortSSIDListImplemented to true. An AP that is in the same (#2210)colocated AP set as a 6 GHz AP shall set dot11ColocatedRNRImplemented to true and dot11ShortSSIDListImplemented to true.

A STA 6G shall not transmit a Probe Request frame to the broadcast address(#1313) that includes a Short SSID List element with more than one Short SSID field.

NOTE—In bands other than the 6 GHz band, there might be more than one Short SSID field in a Short SSID List element in a Probe Request frame to the broadcast address(#1313). A Probe Request frame does not contain more than one Short SSID List element (see Table 9-68 (Probe Request frame body)). A Probe Request frame transmitted to the broadcast address(#1313) that contains a Short SSID List element has the SSID field of the SSID element set to the SSID of a known AP or set to the one-octet value 128 if the STA does not know any SSID (see 11.1.4.3.2 (Active scanning procedure for a non-DMG STA)).

#### 26.17.2.3.2 AP behavior for fast passive scanning

A 6 GHz AP that does not share the same (#2210)colocated AP set as an AP operating in the 2.4 GHz band or 5 GHz band is referred to as a 6 GHz-only AP.

A 6 GHz-only AP that intends to be efficiently discovered by STAs using scanning in the 6 GHz band shall have dot11FILSFDFrameBeaconMaximumInterval set to a nonzero value that is less than or equal to 20 TUs.

NOTE 1—A 6 GHz-only AP intends to be efficiently discovered by STAs using scanning in the 6 GHz band if it schedules for transmission FILS Discovery, Beacon, or unsolicited Probe Response frames every 20 TUs or less.

If a 6 GHz AP has dot11UnsolicitedProbeResponseOptionActivated equal to true, then the AP shall have dot11FILSFDFrameBeaconMaximumInterval set to a nonzero value that is less than or equal to 20 TUs; otherwise, the AP may have dot11FILSFDFrameBeaconMaximumInterval set to any value.

A 6 GHz AP that has dot11FILSFDFrameBeaconMaximumInterval equal to a nonzero value shall schedule for transmission FILS Discovery frames as described in 11.45.2.1 (FILS Discovery frame transmission), except that the following apply:

- If the FILS Discovery frame is contained in a DL HE MU PPDU, then it shall be included in a broadcast RU of the DL HE MU PPDU as defined in 26.15.7 (Additional rules for group addressed frames in an HE MU PPDU).
- If dot11UnsolicitedProbeResponseOptionActivated is true, all FILS Discovery frames shall be omitted, and an unsolicited broadcast Probe Response frame, instead of each omitted FILS Discovery frame, shall be scheduled for transmission at the target transmit time.
- If dot11UnsolicitedProbeResponseOptionActivated is false, then a FILS Discovery frame may be omitted, and an unsolicited broadcast Probe Response frame, instead of the omitted FILS Discovery frame, shall be scheduled for transmission at the target transmit time.

A 6 GHz AP may send an unsolicited broadcast Probe Response frame. The Probe Response frame may be included in a broadcast RU of a DL HE MU PPDU as defined in 26.15.7 (Additional rules for group

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addressed frames in an HE MU PPDU). The Probe Response may be carried in a non-HT duplicate PPDU in which case the PPDU shall have the TXVECTOR parameter CH_BANDWIDTH set to a value that is up to the operating channel width of the BSS.

A 6 GHz AP that transmits a FILS Discovery frame carrying an FD Capability field shall set the PHY Index subfield to 4.

An AP that corresponds to a nontransmitted BSSID does not schedule for transmission FILS Discovery frames (see 11.45.2.1 (FILS Discovery frame transmission)) or unsolicited broadcast Probe Response frames (see 11.1.4.3.4 (Criteria for sending a response)).

See 11.1.3.8 (Multiple BSSID procedure) for procedures on advertisement of nontransmitted BSSIDs in a multiple BSSID set.

A 6 GHz-only AP should set up the BSS with a primary 20 MHz channel that coincides with a preferred scanning channel (PSC) (see 26.17.2.3.3 (Non-AP STA scanning behavior)).

NOTE 2—An AP might initiate a BSS with a primary channel that coincides with a PSC in order to assist STAs that are scanning the 6 GHz band to discover the BSS. The AP might subsequently switch its operating channel to a non-PSC (e.g., using a CSA mechanism) if it does not expect that additional (not yet associated) STAs (M118)need to discover the BSS.

A 6 GHz AP shall not respond to a Probe Request frame if the frame carries a FILS Request Parameters element and the AP is unable to satisfy the response time constraint specified in the Max Channel Time field in the element (see 11.1.4.3.4 (Criteria for sending a response)). If a 6 GHz AP receives a Probe Request frame and responds with a Probe Response frame (per 11.1.4.3.4 (Criteria for sending a response)), the Address 1 field of the Probe Response frame shall be set to the broadcast address.(#3025)

#### 26.17.2.3.3 Non-AP STA scanning behavior

The 20 MHz channels in the 6 GHz band, with channel center frequency (ch_a = Channel starting frequency – 55 + 80 × $n$, in megahertz) are referred to as *preferred scanning channels* (PSCs). Channel starting frequency is defined in 27.3.25.2 (Channel allocation in the 6 GHz band), and $n$ = 1, …, 15.

NOTE 1—PSCs might not all be available in a specific location due to regulatory restrictions. A STA scanning the 6 GHz band knows where these PSCs are located since their position is fixed.

A non-AP STA that is actively scanning a channel in the 6 GHz band shall operate as defined in 11.1.4.3.2 (Active scanning procedure for a non-DMG STA), unless a given rule is superseded by the rules defined in 26.17.2.3 (Scanning in the 6 GHz band).

The non-AP STA shall not transmit a Probe Request frame to the broadcast address(#1313) with the Address 3 field set to the wildcard BSSID and the SSID set to the wildcard SSID.

The non-AP STA shall not send a Probe Request frame to the broadcast address(#1313) with the Address 3 field (BSSID) set to the BSSID of an AP from which it has already received a Probe Response or a Beacon frame since the start of its scanning on that channel.

The non-AP STA shall not send a Probe Request frame to the broadcast address(#1313) with the Address 3 field (BSSID) set to the BSSID of a nontransmitted BSSID if it has already received the nontransmitted BSSID profile for that BSSID via a Beacon frame or Probe Response frame sent by the transmitted BSSID since the start of its scanning on that channel.

Until the FILSProbeTimer reaches dot11FILSProbeDelay, the non-AP STA shall not send a Probe Request frame to the broadcast address(#1313) with the SSID field set to the SSID of an AP for which it has received


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a Reduced Neighbor Report or Neighbor Report element with the Unsolicited Probe Responses Active subfield corresponding to that AP set to 1 and that indicates that the AP is operating in that channel. Until the FILSProbeTimer reaches dot11FILSProbeDelay, the non-AP STA shall not send a Probe Request frame to the broadcast address(#1313) with the Address 3 field set to the BSSID of an AP for which it has received a Reduced Neighbor Report or Neighbor Report element with the Unsolicited Probe Responses Active subfield corresponding to that AP set to 1 and that indicates that the AP is operating in that channel. Until the FILSProbeTimer reaches dot11FILSProbeDelay, the non-AP STA shall not send a Probe Request frame to the broadcast address(#1313) with the Short SSID field set to the short SSID that corresponds to the SSID of an AP for which it has received a Reduced Neighbor Report or Neighbor Report element with the Unsolicited Probe Responses Active subfield corresponding to that AP set to 1 and that indicates that the AP is operating in that channel.

The non-AP STA shall not transmit more than one Probe Request frame to the broadcast address(#1313) with the Address 3 field set to the wildcard BSSID and the SSID field not set to the wildcard SSID during each 20 TU period scanning the channel. The non-AP STA shall not transmit more than three Probe Request frames to the broadcast address(#1313) with Address 3 field set to a non-wildcard BSSID during each 20 TU period scanning the channel.

The non-AP STA shall set dot11FILSProbeDelay to a value equal to or greater than 20 TU.

NOTE 2—A non-AP STA waits for at least 20 TU so that it maximizes the probability of receiving FILS Discovery or broadcast Probe Response frames, if any, sent by an AP in that channel (see 26.17.2.3.2 (AP behavior for fast passive scanning)).

If the non-AP STA is scanning a channel, then the following apply:

— If the STA has received a FILS Discovery frame indicating that an AP is operating in that channel, or if the STA has received a Reduced Neighbor Report or Neighbor Report element indicating that an AP is operating in that channel, then the STA may, subject to the other rules in this clause, send a Probe Request frame to the broadcast address(#1313) in that channel, with the SSID field set to the SSID that corresponds to that AP or with the Short SSID field of the Short SSID List element set to the short SSID that corresponds to that AP and/or with the Address 3 field set to the BSSID of that AP, starting from step c) of 11.1.4.3.2 (Active scanning procedure for a non-DMG STA).

— Otherwise, if the channel is a PSC and the STA has determined the medium to be idle for a continuous period of at least dot11MinPSCProbeDelay from the start of the scan on the channel, then the STA may, subject to other rules in this subclause, send a Probe Request frame to the broadcast address(#1313) in that channel, with the SSID field set to the SSID that corresponds to an AP or with the Short SSID field of the Short SSID List element set to the short SSID that corresponds to an AP, and/or with the Address 3 field set to the BSSID of an AP, after invoking the backoff procedure, described in 10.23.2.2 (EDCA backoff procedure), starting from step c) of 11.1.4.3.2 (Active scanning procedure for a non-DMG STA).

— Otherwise, if the STA has discovered the presence of an AP in that channel through means that are beyond the scope of this standard and the AP (#2310)is on the same channel and is range of the STA, then the STA may send a Probe Request frame to the broadcast address(#1313) in that channel, with the Address 3 field set to the BSSID of that AP, starting from step c) of 11.1.4.3.2 (Active scanning procedure for a non-DMG STA).

— Otherwise, if the FILSProbeTimer reaches dot11FILSProbeDelay and the channel is a PSC, then the STA may, subject to the other rules in this subclause, send a Probe Request to the broadcast address(#1313) in that channel, starting from step c) of 11.1.4.3.2 (Active scanning procedure for a non-DMG STA).

— Otherwise, the STA shall not send a Probe Request frame to the broadcast address(#1313) in that channel.

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NOTE 3—The STA might send an individually addressed Probe Request frame to an AP for reasons other than active scan (e.g., to obtain an updated EDCA parameter set) even if it has already received a FILS Discovery, Probe Response, or Beacon frame from that AP.

If a non-AP STA sends a Probe Request frame in the 6 GHz band that includes a FILS Request Parameters element, then the non-AP STA shall set the value of PHY Support Criterion subfield in the element to either 0 or 3.

See 11.1.3.8 (Multiple BSSID procedure) for procedures on discovery of nontransmitted BSSIDs in a multiple BSSID set.

#### 26.17.2.4 HE STA antenna indication

A 6 GHz HE STA that does not change its receive antenna pattern after association shall set the Rx Antenna Pattern Consistency subfield in the HE 6 GHz Band Capabilities element to 1; otherwise, the STA shall set the Rx Antenna Pattern Consistency subfield in the HE 6 GHz Band Capabilities element to 0.

A 6 GHz HE STA that does not change its transmit antenna pattern after association shall set the Tx Antenna Pattern Consistency subfield in the HE 6 GHz Band Capabilities element to 1; otherwise, the STA shall set the Tx Antenna Pattern Consistency subfield in the HE 6 GHz Band Capabilities element to 0.

### 26.17.3 BSS color

#### 26.17.3.1 General

BSS color identifies a BSS and assists a STA receiving a PPDU that carries BSS color in identifying the BSS from which the PPDU originates so that the STA can use the channel access rules in 26.10 (HE spatial reuse operation(#2389)), reduce power consumption as described in 26.14.1 (Intra-PPDU power save for non-AP HE STAs), or update its NAV as described in 26.2.4 (Updating two NAVs).

All APs that are members of a multiple BSSID set or co-hosted BSSID set shall use the same BSS color.

An HE STA that transmits an HE Operation element shall select an initial BSS color by following the procedure in 26.17.3.2 (Initial BSS color).

An HE STA that transmits an HE Operation element may disable BSS color by following the procedure in 26.17.3.3 (Disabling BSS color).

An HE AP may follow the procedure in 26.17.3.4 (Selecting and advertising a new BSS color) to select and advertise a new BSS color.

An HE STA may follow the procedure in 26.17.3.5 (Detecting and reporting BSS color collision) to determine and report a BSS color collision.

#### 26.17.3.2 Initial BSS color

An HE AP starting an infrastructure BSS or an HE STA starting an IBSS or MBSS shall set the BSS Color subfield of the first HE Operation element it transmits to a value in the range 1 to 63 and shall maintain that value in subsequent HE Operation elements it transmits for the lifetime of the BSS or until the BSS color is changed as described in 26.17.3.4 (Selecting and advertising a new BSS color). When selecting a BSS color, the HE STA should consider the BSS colors in use by neighboring OBSSs.

A non-AP HE STA that is associated with an HE AP and that is the initiating STA of a (#2152)TDLS direct link shall set the BSS Color subfield of the HE Operation element it transmits to the TDLS peer HE STA to


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the value indicated in the BSS Color subfield of the HE Operation element received from its associated HE AP. A non-AP HE STA that is associated with a non-HE AP and that is the initiating STA of the (#2152)TDLS direct link shall use the same BSS color for all its (#2152)TDLS direct links by setting the BSS Color subfield of the HE Operation element it transmits to the TDLS peer HE STA to the value of dec(BSSID[39:44]) of the non-HE AP or the dec(transmitted BSSID[39:44]) of the non-HE AP if the AP indicates the support of multiple BSSID in its Extended Capabilities element.

#### 26.17.3.3 Disabling BSS color

An HE STA that transmits an HE Operation element and that decides to disable the use of BSS color in the BSS to which it belongs, for example, after detecting a BSS color collision with an OBSS (see 26.17.3.5 (Detecting and reporting BSS color collision)), shall set the value of BSS Color Disabled subfield in the HE Operation element to 1 to inform other STAs in the BSS that the BSS color is disabled; otherwise, the HE STA shall set the BSS Color Disabled subfield to 0.

NOTE—It is recommended that an HE STA that transmits an HE Operation element does not disable the BSS color for an extended period of time, so that other HE STAs can benefit from features relying on BSS color.

If the most recently received HE Operation element from the AP with which it is associated contained a value of 1 in the BSS Color Disabled subfield, then the following apply:

— A non-AP HE STA should use the Address 1, Address 2, and Duration/ID fields of the frames contained in the received HE PPDUs, instead of the RXVECTOR parameters BSS_COLOR and TXOP_DURATION, to determine whether the STA should update the intra-BSS NAV.

— A non-AP HE STA should use the Address 1 and Address 2 fields of the frames contained in the received HE PPDUs, instead of the RXVECTOR parameters BSS_COLOR and STA_ID, to determine whether the STA may go to doze state for the duration of that PPDU (see 26.14.1 (Intra-PPDU power save for non-AP HE STAs)).

A non-AP HE STA may use the RXVECTOR parameter BSS_COLOR of an HE PPDU to determine whether it should update the intra-BSS NAV (see 26.2.4 (Updating two NAVs)), and/or the STA may go to doze state for the duration of the PPDU (see 26.14.1 (Intra-PPDU power save for non-AP HE STAs)) if the most recently received HE Operation element from the AP with which it is associated contained a value of 0 in the BSS Color Disabled subfield.

#### 26.17.3.4 Selecting and advertising a new BSS color

An HE STA that transmits an HE Operation element shall select a BSS color as defined in 26.17.3.2 (Initial BSS color) for its BSS. An HE AP may change the BSS color under certain conditions, for example, if it detects that an OBSS is using the same color. An HE AP shall announce an upcoming BSS color change using the BSS Color Change Announcement element. A non-AP HE STA shall not transmit a BSS Color Change Announcement element.

NOTE—A non-AP HE STA includes a STA participating in an IBSS or MBSS. The color change mechanism described in this subclause does not apply to an IBSS or a mesh BSS since these BSSs do not have a single coordinator.

When changing the BSS color, the HE AP should consider the BSS colors of OBSSs that the HE AP has identified by itself or via the autonomous collision reports received from associated non-AP HE STAs (see 26.17.3.5 (Detecting and reporting BSS color collision)).

The BSS Color Change Announcement element may be carried in the Beacon, Probe Response, (Re)Association Response, and HE BSS Color Change Announcement frames transmitted by the AP. An HE AP should announce an upcoming BSS color change for a period of time that is sufficiently long for all STAs in the BSS, including STAs in PS mode, to have an opportunity to receive at least one frame carrying a BSS Color Change Announcement element before the BSS color change.

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If the Color Switch Countdown field in the BSS Color Change Announcement element has a value greater than 1, then at the next TBTT the AP shall decrement the Color Switch Countdown field value by 1. The BSS color change TBTT is the TBTT following a frame containing a BSS Color Change Announcement element with the Color Switch Countdown field containing the value 1. An HE AP shall not alter the BSS color change TBTT after it has announced a pending BSS color change. An AP belonging to a co-hosted BSSID set (see 26.17.7 (Co-hosted BSSID set)) should select the value of Color Switch Countdown field such that the BSS color change TBTT interval between the BSSs in the set shall not be greater than one beacon interval of the BSS with largest beacon interval in the set.

During the time leading up to the BSS color change TBTT,

- An HE AP shall set the BSS Color Disabled subfield to 1 and shall continue to advertise the existing BSS color via the BSS Color subfield in the HE Operation element.
- An HE AP shall not change the value it advertises in the New BSS Color subfield of the BSS Color Change Announcement element.
- An HE AP shall set the TXVECTOR parameter BSS_COLOR of an HE PPDU to the existing BSS color.

At the BSS color change TBTT, an HE AP shall

- Set the BSS Color Disabled subfield in the HE Operation element that it transmits to 0, unless the HE AP belongs to a co-hosted BSSID set. In this case, it shall continue to set the BSS Color Disabled subfield to 1 until all the BSSs in the co-hosted BSSID set have passed their respective BSS color change TBTT.
- Start advertising the new BSS color in the BSS Color subfield in the HE Operation element.
- Start using the new BSS color for all frames that it transmits after the TBTT.

A co-hosted AP should not transmit an HE PPDU during the transition period until all the BSSs in the co-hosted set have completed their switch to the new color.

A non-AP HE STA that receives a BSS Color Change Announcement element from an AP shall use the value specified in the New BSS Color field of the element as the BSS color when communicating with that AP following the BSS color change TBTT.

#### 26.17.3.5 Detecting and reporting BSS color collision

##### 26.17.3.5.1 General

An HE AP may determine that a BSS color collision has occurred if it receives HE PPDUs on its primary channel from an OBSS STA containing the same BSS color as the one it has selected for its BSS or if it receives autonomous BSS color collision event reports from its associated STAs. The HE AP shall set the BSS Color Disabled subfield to 1 in the HE Operation element that it transmits if the BSS color collision persists for a duration of at least dot11BSSColorCollisionAPPeriod and if dot11BSSColorCollisionAPPeriod is not –1. The value –1 means that the BSS color is not disabled in the case of a collision.

##### 26.17.3.5.2 Autonomous reporting of BSS color collision

A STA that supports autonomous reporting of BSS color collision shall set dot11AutonomousBSSColorCollisionReportingImplemented to true.

A non-AP HE STA that supports autonomous reporting of BSS color collision may send a color collision report to its associated AP when it detects that color collision has occurred. The STA shall declare that a color collision has occurred if it receives, on its associated AP's primary channel, an HE PPDU with at least


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three Address fields in the MAC header and with the same color as its associated BSS in which none of the Address fields match the BSSID of the BSS with which the STA is associated or any of the other BSSs in the same multiple BSSID set or co-hosted BSSID set to which its BSS belongs.

The HE STA's autonomous report shall include BSS color information of all OBSSs from which the STA is able to detect frames in order to help its associated AP select a new nonoverlapping BSS color when the AP decides to switch to a different BSS color.

A non-AP HE STA that is autonomously reporting a BSS color collision shall transmit an Event Report frame (see 9.6.13.3 (Event Report frame format)) containing a single Event Report element (see 9.4.2.66 (Event Report element)). The Event Report element shall carry Event Token field value set to 0 (autonomous report) and Event Type field value set to 4 (BSS Color Collision). The Event Report Status field shall be set to 0 (Successful), and the Event Report field shall carry information about the BSS color used by OBSSs that the reporting STA is able to detect.

A non-AP HE STA that has dot11AutonomousBSSColorCollisionReportingImplemented equal to true shall transmit a BSS Color Collision Event Report frame to its associated HE AP when it determines that a color collision has occurred. (#1112)Subsequently, the STA shall schedule for transmission a BSS color collision event report every dot11BSSColorCollisionSTAPeriod, unless the BSS color collision no longer exists, the AP has set the BSS Color Disabled field to 1 in the HE Operation element that it transmits, or the STA has successfully transmitted a certain number of collision reports to the AP.

### 26.17.4 AID assignment

An HE AP that transmits an HE Operation element with the Partial BSS Color subfield in the BSS Color Information field set to 1 shall allocate AIDs that meet the constraint in Equation (26-8).

$$\text{AID}(5{:}8) = bin[(BCB(0{:}3) - (BSSID[44{:}47] \oplus BSSID[40{:}43])) \bmod 2^4, 4] \quad (26\text{-}8)$$

where *BCB*(0:3) represents bits 0 to 3 inclusive of the BSS color in the transmitted HE Operation element with bit 0 being the first transmitted and AID(5:8) represents bits 5 to 8 inclusive of the allocated AID with bit 5 being the first transmitted.

NOTE—See 1.5 for the behavior of the mod operator with a negative first operand.

### 26.17.5 Quiet HE STAs in an HE BSS

#### 26.17.5.1 General

Quiet time period (QTP) is an optional feature that defines a period of time that is intended to be used primarily for the exchange of specific frames between a STA requesting a QTP and its peers using peer-to-peer links. The particular frames to be exchanged using peer-to-peer links during the QTP are identified by a service-specific identifier. The determination of which frames are associated with the service-specific identifier is beyond the scope of this standard. The method for selection of the service-specific identifier by the peer-to-peer operation is beyond the scope of this standard.

An AP with dot11QTPOptionImplemented equal to true is a QTP AP and shall set the QTP Support field to 1 in HE Capabilities elements that it transmits; otherwise, an AP shall set the QTP Support field to 0. A non-AP HE STA with dot11QTPOptionImplemented equal to true is a QTP non-AP STA and shall set the QTP Support field to 1 in HE Capabilities elements that it transmits; otherwise, a non-AP HE AP shall set the QTP Support field to 0.

A QTP non-AP STA may request its QTP AP to set up a QTP, and if successful, the QTP AP informs other associated QTP non-AP STAs of the QTP and of the service-specific identifier associated with that QTP.

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The QTP mechanism informs other HE STAs of the period and the intended peer-to-peer operation and requests that, during the QTP, the QTP non-AP STAs should not exchange frames that are not associated with the service-specific identifier.

A QTP non-AP STA may ignore the QTP. A QTP non-AP STA that decides to stay quiet during a QTP suspends the decrementing of its backoff counters at the start time of the QTP and resumes them when the QTP ends.

NOTE—Otherwise, a STA that does not stay quiet does not suspend the decrementing of its backoff counters.

### 26.17.5.2 QTP Requesting STA procedure

A QTP requesting STA is a QTP non-AP STA that requests a quiet time period (QTP). Figure 26-15 (Quiet time period operation(11ax)) illustrates a QTP operation.

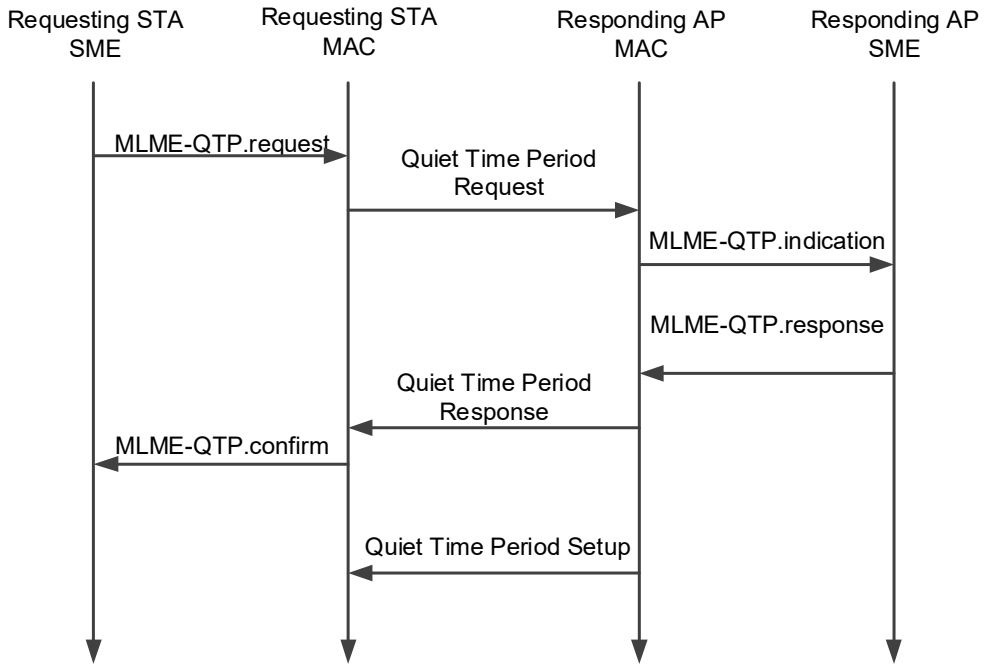


**Figure 26-15—Quiet time period operation(11ax)**

Upon the reception of an MLME-QTP.request primitive, a QTP requesting STA shall perform the following procedure:

a) If a QTP requesting STA is associated with a QTP AP, the QTP requesting STA sends a QTP Request frame that is a Quiet Time Period Action frame (9.6.31.3 (Quiet Time Period action frame format)) with the Control field of the Quiet Time Period element indicating the Quiet Time Period Request subtype. The QTP Request frame indicates the duration, interval, and type of operation (indicated by the Service Specific Identifier parameter). The QTP requesting STA may include multiple Quiet Time Period elements with Request subtype in one QTP Request frame for multiple types of frames associated with different service-specific identifiers.

b) A QTP Response frame is a Quiet Time Period Action frame (9.6.31.3 (Quiet Time Period action frame format)) with the Control field of the Quiet Time Period element indicating Quiet Time Period Response subtype. If a QTP Response frame is received with the dialog token matching the request token with a status code set to a value of SUCCESS, the QTP AP has confirmed the


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reception of the QTP Request frame, and the MLME shall issue an MLME-QTP.confirm primitive indicating the success of the procedure.

c) A QTP Setup frame is a Quiet Time Period Action frame (9.6.31.3 (Quiet Time Period action frame format)) with the Control field of the Quiet Time Period element indicating Quiet Time Period Setup subtype. If a QTP Setup frame is received, at the start time for a QTP, the QTP requesting STA may schedule frames for transmission that are associated with the service-specific identifier indicated in the QTP Setup frame and should not transmit frames that are not associated with the service-specific identifier.

#### 26.17.5.3 Responding AP procedure

Upon receipt of a QTP request, a QTP AP shall operate as follows (Figure 26-15 (Quiet time period operation(11ax))):

a) The MLME of the AP shall issue an MLME-QTP.response primitive.

b) Upon receipt of the MLME-QTP.response primitive, the AP may respond by sending a broadcast QTP Response frame.

   1) If the status code in the broadcast QTP Response frame is SUCCESS, the AP accepts the request. The AP shall schedule the quiet period(s) according to the accepted request. Contained in the transmitted QTP Response frame is a copy of the dialog token from the QTP requesting STA. The QTP procedure shall be terminated if the number of quiet periods exceeds the value of the Repetition Count field specified.

   2) If the status code in the broadcast QTP Response frame is REJECTED, the AP indicates that the request cannot be fulfilled.

   3) If the status code in the broadcast QTP Response frame is COUNTERED, the AP counters the request with recommended values, and the current request is rejected. Upon receiving the counter-proposal, a QTP STA can send a QTP Request frame to set up another QTP.

c) At the start time for a quiet time period, the AP may schedule for transmission a QTP Setup frame. The AP shall set the Quiet Period Duration field of the QTP Setup frame to a value no larger than indicated in the Quiet Period Duration field of the QTP Request frame sent by the QTP requesting STA.

NOTE—The AP is not required to transmit a QTP Setup frame at a scheduled QTP. The interference mitigation protocol is to provide an AP a tool to manage and avoid interference. How or whether the AP will transmit QTP Setup frame at a scheduled QTP is beyond the scope of this standard.

### 26.17.6 ER beacon generation in an ER BSS

An ER beacon is a Beacon frame carried in an HE ER SU PPDU using a 242-tone RU and transmitted in the primary 20 MHz channel. An ER beacon provides additional link budget for downlink transmissions to compensate for the link budget imbalance between downlink and uplink due to the introduction of UL OFDMA transmission. An HE AP shall operate an ER BSS in addition to a non-ER BSS operated by another AP that is in the same (#2210)colocated AP set. An ER BSS, if present, shall operate independently of the (#2210)colocated non-ER BSS that is in the same (#2210)colocated AP set, and the AP operating the ER BSS shall have a BSSID different from the AP operating the non-ER BSS.

NOTE—An AP that uses ER beacons can balance the link budget by allocating narrow RUs to STAs. An ER BSS is expected to have a larger coverage area than a non-ER BSS.

The HE AP of an ER BSS shall not set the ER SU Disable subfield to 1 in HE Operation elements it transmits.

The HE AP of an ER BSS shall transmit Beacon frames and group addressed frames in HE ER SU PPDUs following the rules in 26.15.5 (Additional rules for ER beacons and group addressed frames).

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### 26.17.7 Co-hosted BSSID set

HE BSSs that are not part of a multiple BSSID set (i.e., dot11MultiBSSIDImplemented is false) but share the same operating class, channel, receive antenna connector, and transmit antenna connector belong to a co-hosted BSSID set.

A STA that supports co-hosted BSSID capability shall have dot11CoHostedBSSIDImplemented equal to true.

An AP that belongs to a co-hosted BSSID set shall perform the following operations:

— Set the Co-Hosted BSS subfield in the HE Operation element that it transmits to 1.

— Set the Max Co-Hosted BSSID Indicator field in the HE Operation element that it transmits to a nonzero value $n$, where $1 \leq n \leq 8$, such that $2^n$ indicates the maximum number of BSSIDs in the co-hosted set.

Members of the co-hosted BSSID set have the same $48 - n$ bits (BSSID[0:(47 – $n$)]) in their BSSIDs.

If its associated AP has set the Co-Hosted BSS subfield in the HE Operation Parameters field to 1, a non-AP STA shall identify a BSS as a co-hosted BSS, if the $48 - n$ bits (BSSID[0:(47 – $n$)]) of the BSSID of the BSS are the same as the $48 - n$ bits (BSSID[0:(47 – $n$)]) of the BSSID of its associated AP, where $n$ is the value carried in the Max Co-Hosted BSSID Indicator field of the HE Operation element transmitted by the associated AP.


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# 27. High-efficiency (HE) PHY specification(11ax)

## 27.1 Introduction

### 27.1.1 Introduction to the HE PHY

Clause 27 (High-efficiency (HE) PHY specification(11ax)) specifies the PHY entity for a high-efficiency (HE) orthogonal frequency division multiplexing (OFDM) system. In addition to the requirements in Clause 27 (High-efficiency (HE) PHY specification(11ax)), an HE STA shall support(#546) transmitting and receiving PPDUs that are compliant with the mandatory requirements of the following PHY specifications:

— Clause 19 (High Throughput (HT) PHY specification(#2297)) and Clause 21 (Very high throughput (VHT) PHY specification) if the HE STA supports an operating channel width greater than or equal to 80 MHz and is operating in the 5 GHz band.

— Clause 19 (High Throughput (HT) PHY specification(#2297)) and Clause 21 (Very high throughput (VHT) PHY specification) transmission and reception on 20 MHz channel width (see 26.17.1 (Basic HE BSS operation)) if the HE STA is a 20 MHz-only non-AP HE STA and is operating in the 5 GHz band.

— Clause 19 (High Throughput (HT) PHY specification(#2297)) if the HE STA is operating in the 2.4 GHz band.

— Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) if the HE STA is operating in the 6 GHz band.

For 2.4 GHz band operation, the HE PHY is based on HT PHY defined in Clause 19 (High Throughput (HT) PHY specification(#2297)), which in turn is based on the OFDM PHY defined in Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification).

For 5 GHz band operation, the HE PHY is based on the VHT PHY defined in Clause 21 (Very high throughput (VHT) PHY specification), which in turn is based on the HT PHY defined in Clause 19 (High Throughput (HT) PHY specification(#2297)), which in turn is further based on the OFDM PHY defined in Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification).

For 6 GHz band operation, the HE PHY is based on the OFDM PHY defined in Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification).

The HE PHY extends the maximum number of users supported for DL MU-MIMO transmissions to 8 users per resource unit (RU) and provides support for DL and UL orthogonal frequency division multiple access (OFDMA) as well as for UL MU-MIMO. Both DL and UL MU-MIMO transmissions are supported on portions of the PPDU bandwidth (on resource units greater than or equal to 106 tones). In an MU-MIMO resource unit, there is support for up to 8 users with up to 4 space-time streams per user with the total across all users not exceeding 8 space-time streams.

The HE PHY provides support for 20 MHz, 40 MHz, 80 MHz, and 160 MHz contiguous channel widths and support for 80+80 MHz noncontiguous channel width, depending on the frequency band and capability. For PPDU bandwidths greater than or equal to 80 MHz, the HE PHY supports preamble punctured HE MU PPDU transmissions where pre-HE modulated fields (see Figure 27-23 (Timing boundaries for HE PPDU fields if midamble is not present(11ax)) in 27.3.10 (Mathematical description of signals)) are not transmitted in one or more of the nonprimary 20 MHz channels, and RUs associated with those punctured 20 MHz channels as defined in 27.3.11.8.3 (Common field) are not allocated.

The HE PHY provides support for 0.8 μs, 1.6 μs, and 3.2 μs guard interval durations.

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The HE PHY provides support for 3.2 μs (1x), 6.4 μs (2x), and 12.8 μs (4x) HE-LTF symbol durations, excluding the GI duration. The HE PHY supports a DFT period of 3.2 μs and 12.8 μs for the pre-HE modulated fields and the HE modulated fields in an HE PPDU, respectively. The HE PHY data subcarrier frequency spacing is a quarter of VHT PHY and HT PHY subcarrier frequency spacing defined in Clause 21 (Very high throughput (VHT) PHY specification) and Clause 19 (High Throughput (HT) PHY specification(#2297)), respectively.

The HE PHY data subcarriers are modulated using BPSK, BPSK DCM, QPSK, QPSK DCM, 16-QAM, 16-QAM DCM, 64-QAM, 256-QAM, and 1024-QAM. Forward error correction (FEC) coding (convolutional or LDPC coding) is used with coding rates of 1/2, 2/3, 3/4, and 5/6.

The HE PHY provides support for midambles. Midambles facilitate updating of the channel estimate during HE PPDU reception and might be of use in high mobility scenarios that often result in significant variations of the wireless channel over the duration of a PPDU.

An HE STA shall support the following features:

- Transmission and reception of an HE SU PPDU that consists of a single RU spanning the entire PPDU bandwidth.
- Transmission and reception of an HE ER SU PPDU that consists of a 242-tone RU spanning the entire primary 20 MHz PPDU bandwidth.
- BCC coding (transmit and receive). BCC coding is not used in the following cases:
  - An HE SU PPDU with a bandwidth greater than 20 MHz
  - An RU of size greater than 242 subcarriers in an HE MU PPDU or an HE TB PPDU
  - An HE SU PPDU with number of spatial streams greater than 4
  - An RU allocated to a single user in an HE MU PPDU or for an HE TB PPDU with a number of spatial streams greater than 4
  - An HE SU PPDU using HE-MCSs 10 or 11
  - An RU in an HE MU PPDU or an HE TB PPDU using HE-MCSs 10 or 11
- LDPC coding (transmit and receive) in all supported HE PPDU types, RU sizes, and number of spatial streams if the STA supports transmitting and receiving in channel bandwidths greater than 20 MHz.
- LDPC coding (transmit and receive) in all supported HE PPDU types, RU sizes, and number of spatial streams if the STA declares support for transmitting or receiving more than 4 spatial streams.
- LDPC coding (transmit and receive) in all supported HE PPDU types, RU sizes, and number of spatial streams if the STA declares support for HE-MCSs 10 and 11 (transmit and receive).
- Single spatial stream HE-MCSs 0 to 7 (transmit and receive) in all supported channel widths for HE SU PPDUs.
- HE SU PPDUs and HE ER SU PPDUs with a 2x HE-LTF and 0.8 μs GI duration on the HE-LTF and Data field OFDM symbols (transmit and receive).
- HE SU PPDUs and HE ER SU PPDUs with a 2x HE-LTF and 1.6 μs GI duration on the HE-LTF and Data field OFDM symbols (transmit and receive).
- HE SU PPDUs and HE ER SU PPDUs with a 4x HE-LTF and 3.2 μs GI duration on the HE-LTF and Data field OFDM symbols (transmit and receive).
- Full bandwidth UL MU-MIMO with a 1x HE-LTF and 1.6 μs GI duration on the HE-LTF and Data field OFDM symbols if the STA supports UL MU-MIMO.
- HE SU PPDUs with a 4x HE-LTF and 0.8 μs GI duration on the HE-LTF and Data field OFDM symbols if the STA supports HE ER SU PPDUs with a 4x HE-LTF and 0.8 μs GI duration on the HE-LTF and Data field OFDM symbols (transmit and receive).
- Single spatial stream HE-MCSs 0 to 2 in primary 20 MHz channel for HE ER SU PPDUs.
- HE ER SU PPDU is not used in the following cases:


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- Number of spatial streams greater than 1
- HE-MCS greater than 2 when 242 subcarriers are used in the Data field OFDM symbols
- HE-MCS greater than 0 when 106 subcarriers are used in the Data field OFDM symbols
- Bandwidth greater than 20 MHz

— 20 MHz channel width and all RU sizes and locations applicable to the 20 MHz channel width in 2.4 GHz, 5 GHz, and 6 GHz bands (transmit and receive).

An HE STA may support the following features:

— HE-MCSs 8 to 11 (transmit and receive).

— Two or more spatial streams (transmit and receive).

— DCM (transmit and receive).

— HE SU PPDUs and HE ER SU PPDUs with a 1x HE-LTF and 0.8 μs GI duration on the HE-LTF and Data field OFDM symbols (transmit and receive).

— HE SU PPDUs with a 4x HE-LTF and 0.8 μs GI duration on the HE-LTF and Data field OFDM symbols if the STA does not support HE ER SU PPDUs with a 4x HE-LTF and 0.8 μs GI duration on both the HE-LTF and Data field OFDM symbols (transmit and receive).

— HE ER SU PPDUs with a 4x HE-LTF and 0.8 μs GI duration on both the HE-LTF and Data field OFDM symbols (transmit and receive).

— LDPC coding (transmit and receive) if the maximum number of spatial streams the STA is capable of transmitting or receiving in an HE SU PPDU is less than or equal to 4.

— Single spatial stream HE-MCS 0 in the higher frequency 106-tone RU of the primary 20 MHz channel for an HE ER SU PPDU.

— STBC (transmit and receive).

— (11az)HE Ranging NDP (transmit and receive).

— (11az)HE TB Ranging NDP (transmit and receive).

(11az)NOTE—Support for HE Ranging NDP and HE TB Ranging NDP are indicated in the Extended Capabilities element.

An HE AP shall support the following features:

— Transmission of an HE MU PPDU where none of the RUs utilize MU-MIMO (DL OFDMA).

— Reception of an HE TB PPDU where none of the RUs utilize MU-MIMO (UL OFDMA).

— Transmission of an HE MU PPDU consisting of a single RU spanning the entire PPDU bandwidth and utilizing MU-MIMO (DL MU-MIMO), provided the AP is capable of transmitting 4 or more spatial streams.

— Transmission of the HE-SIG-B field in an HE MU PPDU at HE-MCSs 0 to 5.

— Single spatial stream HE-MCSs 0 to 7 in all supported channel widths and RU sizes for HE MU PPDUs (transmit) or HE TB PPDUs (receive).

— 40 MHz and 80 MHz channel widths and all RU sizes and locations applicable to the 40 MHz and 80 MHz channel width in 5 GHz and 6 GHz bands (transmit and receive).

— HE MU PPDUs with a 2x HE-LTF and 0.8 μs GI duration on the HE-LTF and Data field OFDM symbols (transmit).

— HE MU PPDUs with a 2x HE-LTF and 1.6 μs GI duration on the HE-LTF and Data field OFDM symbols (transmit).

— Reception of an HE TB PPDU with a 2x HE-LTF and 1.6 μs GI duration on the HE-LTF and Data field OFDM symbols.

— Reception of an HE TB PPDU with a 4x HE-LTF and 3.2 μs GI duration on the HE-LTF and Data field OFDM symbols.

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- Transmission of an HE MU PPDU with a 4x HE-LTF and 3.2 μs GI duration on the HE-LTF and Data field OFDM symbols.
- Transmission of an HE MU PPDU with a 4x HE-LTF and 0.8 μs GI duration on the HE-LTF and Data field OFDM symbols if the HE AP supports HE ER SU PPDUs with the same HE-LTF and GI combinations.
- All RU sizes and locations applicable to 40 MHz channel width in the 2.4 GHz band if 40 MHz channel width is supported in the 2.4 GHz band (transmit and receive).

An HE AP may support the following features:

- MU-MIMO transmission on an RU in an HE MU PPDU where the RU does not span the entire PPDU bandwidth (DL MU-MIMO within OFDMA).
- MU-MIMO reception on an RU in an HE TB PPDU where the RU spans the entire PPDU bandwidth (UL MU-MIMO).
- MU-MIMO reception on an RU in an HE TB PPDU where the RU does not span the entire PPDU bandwidth (UL MU-MIMO within OFDMA).
- Reception of the payload on an RU in an HE MU PPDU where RU spans the entire PPDU bandwidth or a 106-tone RU within 20 MHz PPDU bandwidth.
- 40 MHz channel width in the 2.4 GHz band (transmit and receive).
- 160 MHz and 80+80 MHz channel widths and 2×996-tone RU size applicable to the 160/ 80+80 MHz channel width in the 5 GHz and 6 GHz bands (transmit and receive).
- Transmission of an HE MU PPDU with preamble puncturing.
- HE MU PPDUs with a 4x HE-LTF and 0.8 μs GI duration on the HE-LTF and Data field OFDM symbols if the STA does not support HE ER SU PPDUs with a 4x HE-LTF and 0.8 μs GI duration on the HE-LTF and Data field OFDM symbols (transmit).
- Punctured sounding operation.

A non-AP HE STA shall support the following features:

- Reception of an HE MU PPDU from an AP(#4408) where the RU allocated to the non-AP STA is not utilizing MU-MIMO (DL OFDMA).
- Transmission of an HE TB PPDU where the RU allocated to the non-AP STA is not utilizing MU-MIMO (UL OFDMA).
- Reception of an HE MU PPDU consisting of a single RU spanning the entire PPDU bandwidth and utilizing MU-MIMO (DL MU-MIMO). The maximum number of spatial streams per user the non-AP STA can receive in the DL MU-MIMO transmission shall be equal to the minimum of 4 and the maximum number of spatial streams supported for reception of HE SU PPDUs. The non-AP STA shall be able to receive its intended spatial streams in a DL MU-MIMO transmission with a total number of spatial streams across all users of at least 4.
- Reception of an HE MU PPDU with up to 4 HE-LTF OFDM symbols, where the RU allocated to the non-AP STA does not span the entire PPDU bandwidth.
- Responding with the requested beamforming feedback in an HE sounding procedure with the maximum number of space-time streams in the HE sounding NDP that the non-AP STA can respond to being at least 4.
- Reception of the HE-SIG-B field in an HE MU PPDU at HE-MCSs 0 to 5.
- Single spatial stream HE-MCSs 0 to 7 in all supported channel widths and RU sizes for HE MU PPDUs (receive) or HE TB PPDUs (transmit).
- 40 MHz and 80 MHz channel widths and all RU sizes and locations applicable to the 40 MHz and 80 MHz channel widths in the 5 GHz band (transmit and receive), except for a 20 MHz-only non-AP HE STA in which case the 40 MHz and 80 MHz channel widths, 996-tone RU, and 484-tone RU sizes in the 5 GHz and 6 GHz bands are not applicable.


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- Reception of an HE MU PPDU with a 2x HE-LTF and 0.8 μs GI duration on the HE-LTF and Data field OFDM symbols.
- Reception of an HE MU PPDU with a 2x HE-LTF and 1.6 μs GI duration on the HE-LTF and Data field OFDM symbols.
- Transmission of an HE TB PPDU with a 2x HE-LTF and 1.6 μs GI duration on the HE-LTF and Data field OFDM symbols.
- Reception of an HE MU PPDU with a 4x HE-LTF and 3.2 μs GI duration on the HE-LTF and Data field OFDM symbols.
- Transmission of an HE TB PPDU with a 4x HE-LTF and 3.2 μs GI duration on the HE-LTF and Data field OFDM symbols.
- Reception of an HE MU PPDU with a 4x HE-LTF and 0.8 μs GI duration on the HE-LTF and the Data field OFDM symbols if the non-AP HE STA supports HE ER SU PPDUs with the same HE-LTF and GI combinations.
- 26-, 52-, and 106-tone RU sizes on locations allowed in 27.3.2.8 (RU restrictions for 20 MHz operation) in the primary 20 MHz channel within 40 MHz channel width if the non-AP HE STA is a 20 MHz operating non-AP HE STA and that is capable of supporting 40 MHz channel width (B0 of the Supported Channel Width Set subfield in the HE PHY Capabilities Information field in the HE Capabilities element is 1) (transmit and receive).
- 26-, 52-, and 106-tone RU sizes on locations allowed in 27.3.2.8 (RU restrictions for 20 MHz operation) in the primary 20 MHz channel within 80 MHz channel width if the non-AP HE STA is a 20 MHz operating non-AP HE STA and is operating in the 5 GHz or 6 GHz bands (transmit and receive).

A non-AP HE STA may support the following:

- Transmission of an HE MU PPDU with a single RU spanning the entire PPDU bandwidth or a 20 MHz HE MU PPDU with a single 106-tone RU in the primary 20 MHz channel.
- 40 MHz channel width in the 2.4 GHz band (transmit and receive). If 40 MHz channel width in the 2.4 GHz band is supported, then all RU sizes and locations applicable to 40 MHz channel width are supported, except for a 20 MHz-only non-AP HE STA in which case the 40 MHz channel width and all RU sizes and locations of 40 MHz channel width in 2.4 GHz band are not applicable.
- 160 MHz and 80+80 MHz channel width and 2×996-tone RU size applicable to the 160 MHz and 80+80 MHz channel width in the 5 GHz and 6 GHz bands (transmit and receive), except for a 20 MHz-only non-AP HE STA in which case the 160 MHz and 80+80 MHz channel width and 2×996-tone RU size in the 5 GHz and 6 GHz bands are not applicable.
- MU-MIMO reception on an RU in an HE MU PPDU where the RU does not span the entire PPDU bandwidth (DL MU-MIMO within OFDMA). The maximum number of spatial streams per user in the DL MU-MIMO within OFDMA transmission that the non-AP STA can receive shall be a minimum of 4 and the maximum number of spatial streams supported for reception of HE SU PPDUs. The total number of spatial streams (across all users) in the DL MU-MIMO within OFDMA transmission that the non-AP STA can receive shall be at least 4.
- Reception of an HE MU PPDU with up to 8 HE-LTF OFDM symbols, where the RU allocated to the non-AP STA does not span the entire PPDU bandwidth.
- MU-MIMO transmission on an RU in an HE TB PPDU where the RU spans the entire PPDU bandwidth (UL MU-MIMO). If supported, then the non-AP HE STA shall support transmitting UL MU-MIMO where the total space-time streams summed across all users is less than or equal to 8.
- MU-MIMO transmission on an RU in an HE TB PPDU where the RU does not span the entire PPDU bandwidth (UL MU-MIMO within OFDMA). If supported, then the non-AP HE STA shall support transmitting UL MU-MIMO where the total space-time streams summed across all users is less than or equal to 8.

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- The reception of a 160 MHz or 80+80 MHz HE MU PPDU, or the transmission of a 160 MHz or 80+80 MHz HE TB PPDU where the assigned RU is in the primary 80 MHz channel if the non-AP HE STA is capable of up to 80 MHz channel width and operating with 80 MHz channel width.
- HE MU PPDUs with a 4x HE-LTF and 0.8 μs GI duration on the HE-LTF and Data field OFDM symbols if the non-AP HE STA does not support HE ER SU PPDUs with a 4x HE-LTF and 0.8 μs GI duration on the HE-LTF and Data field OFDM symbols (receive).
- Punctured sounding operation.

A 20 MHz-only non-AP HE STA may support the following:

- 26-, 52-, 106-, and 242-tone RU sizes on locations allowed in 27.3.2.8 (RU restrictions for 20 MHz operation) in the primary 20 MHz channel within 40 MHz channel width in the 2.4 GHz band if the 20 MHz-only non-AP HE STA does not support the HE subchannel selective transmission operation described in 26.8.7 (HE subchannel selective transmission).
- 26-, 52-, 106-, and 242-tone RU sizes on locations allowed in 27.3.2.8 (RU restrictions for 20 MHz operation) in any 20 MHz channel within 40 MHz channel width in the 2.4 GHz band if the 20 MHz-only non-AP HE STA supports the HE subchannel selective transmission operation as described in 26.8.7 (HE subchannel selective transmission).
- 26-, 52-, 106-, and 242-tone RU sizes on locations allowed in 27.3.2.8 (RU restrictions for 20 MHz operation) in any 20 MHz channel within 40 MHz, 80 MHz, 160 MHz, and 80+80 MHz channel widths in the 5 GHz and 6 GHz bands if the 20 MHz-only non-AP HE STA supports the HE subchannel selective transmission operation as described in 26.8.7 (HE subchannel selective transmission).

A 20 MHz operating non-AP HE STA may support 26-, 52-, 106-, and 242-tone RU sizes on locations allowed in 27.3.2.8 (RU restrictions for 20 MHz operation)in the primary 20 MHz channel within 160 MHz and 80+80 MHz channel widths in the 5 GHz and 6 GHz bands.

### 27.1.2 Scope

The services provided to the MAC by the HE PHY consist of the following protocol functions:

a) A function that maps the PSDU received from the MAC into a PPDU for transmission to one or more receiving STAs.

b) A function that defines the characteristics and method of transmitting and receiving data through a wireless medium between two or more STAs. Depending on the PPDU format, these STAs support (#1345)a mixture of Clause 27 (High-efficiency (HE) PHY specification(11ax)), Clause 21 (Very high throughput (VHT) PHY specification), Clause 19 (High Throughput (HT) PHY specification(#2297)), Clause 18 (Extended Rate PHY (ERP) specification), Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification), Clause 16 (High rate direct sequence spread spectrum (HR/DSSS) PHY specification), and Clause 15 (DSSS PHY specification for the 2.4 GHz band designated for ISM applications) PHYs. A 20 MHz-only non-AP HE STA supports (#1346)a mixture of Clause 27 (High-efficiency (HE) PHY specification(11ax)), Clause 21 (Very high throughput (VHT) PHY specification), Clause 19 (High Throughput (HT) PHY specification(#2297)) and Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) PHYs, and also supports transmission and reception of VHT PPDUs of 20 MHz PPDU bandwidth.

### 27.1.3 HE PHY functions

#### 27.1.3.1 General

The HE PHY contains two functional entities: the PHY function and the physical layer management function (i.e., the PLME). These functions are described in detail in 27.3 (HE PHY) and 27.4 (HE PLME),


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respectively. The HE PHY service is provided to the MAC through the PHY service primitives defined in Clause 8 (PHY service specification). The HE PHY service interface is described in 27.2 (HE PHY service interface).

#### 27.1.3.2 PHY management entity (PLME)

The PLME performs management of the local PHY functions in conjunction with the MLME.

#### 27.1.3.3 Service specification method

The models represented by figures and state diagrams are intended to be illustrations of the functions provided. It is important to distinguish between a model and a real implementation. The models are optimized for simplicity and clarity of presentation.

The service of a layer is the set of capabilities that it offers to a user in the next higher layer. Abstract services are specified here by describing the service primitives and parameters that characterize each service. This definition is independent of any particular implementation.

### 27.1.4 PPDU formats

The structure of the PPDU transmitted by an HE STA is determined by the TXVECTOR parameters as defined in Table 27-1 (TXVECTOR and RXVECTOR parameters(#12)(11ax)).

The FORMAT parameter determines the overall structure of the PPDU and can take on one of the following values:

- Non-HT format (NON_HT), based on Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) or Clause 18 (Extended Rate PHY (ERP) specification) and including non-HT duplicate format.
- HT-mixed format (HT_MF) as specified in Clause 19 (High Throughput (HT) PHY specification(#2297)).
- HT-greenfield format (HT_GF) as specified in Clause 19 (High Throughput (HT) PHY specification(#2297)).
- VHT format (VHT) as defined in Clause 21 (Very high throughput (VHT) PHY specification).
- HE SU PPDU format (HE_SU) that carries a single PSDU. With this format the HE-SIG-A field is not repeated.
- HE ER SU PPDU format (HE_ER_SU) that carries a single PSDU. It is similar to the HE SU PPDU format, except that the HE-SIG-A field is repeated.
- HE MU PPDU format (HE_MU) that carries one or more PSDUs to one or more users.
- HE TB PPDU format (HE_TB) that carries a single PSDU and is sent in response to a PPDU that carries a triggering frame. The preamble format prior to the HE-STF field is identical to the HE SU PPDU.

## 27.2 HE PHY service interface

### 27.2.1 Introduction

The PHY provides an interface to the MAC through an extension of the generic PHY service interface defined in 8.3.4 (Basic service and options). The interface includes TXVECTOR, RXVECTOR, PHYCONFIG_VECTOR, and (#1068)TRIGVECTOR.

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The MAC uses the TXVECTOR to supply the PHY with per-PPDU transmit parameters. The PHY uses the RXVECTOR to inform the MAC of the received PPDU parameters. The MAC uses the PHYCONFIG_VECTOR to configure the PHY for operation that is independent of (#1065)PPDU transmission or reception. The MAC uses the (#1068)TRIGVECTOR to configure the PHY to receive HE TB PPDUs over each assigned RU.

### 27.2.2 TXVECTOR and RXVECTOR parameters

The parameters in Table 27-1 (TXVECTOR and RXVECTOR parameters(#12)(11ax)) are defined as part of the TXVECTOR parameter list in the PHY-TXSTART.request primitive and/or as part of the RXVECTOR parameter list in the PHY-RXSTART.indication and PHY-RXEND.indication primitives. (#12)TXVECTOR and RXVECTOR parameters for transmitting or receiving a DSSS, HR/DSSS, OFDM, ERP, HT or VHT PPDU are defined in:

- DSSS PPDU: Table 15-1 (TXVECTOR parameters) and Table 15-2 (RXVECTOR parameters)
- HR/DSSS PPDU: Table 16-5 (Parameter vectors)
- OFDM PPDU: Table 17-1 (TXVECTOR parameters) and Table 17-2 (RXVECTOR parameters)
- ERP PPDU: Table 18-1 (TXVECTOR parameters) and Table 18-3 (RXVECTOR parameters)
- HT PPDU: Table 19-1 (TXVECTOR and RXVECTOR parameters)
- VHT PPDU: Table 21-1 (TXVECTOR and RXVECTOR parameters(#12)).

**Table 27-1—TXVECTOR and RXVECTOR parameters(#12)(11ax)**

| Parameter | Condition | Value | TXVECTOR | RXVECTOR |
|---|---|---|---|---|
| FORMAT | | Determines the format of the PPDU.<br><br>Enumerated type:<br>NON_HT indicates Clause 15, Clause 16, Clause 17, Clause 18, or non-HT duplicate PPDU format. In this case, the modulation is determined by the NON_HT_MODULATION parameter.<br>HT_MF indicates HT-mixed format.<br>HT_GF indicates HT-greenfield format.<br>VHT indicates VHT format.<br>HE_SU indicates HE SU PPDU format.<br>HE_MU indicates HE MU PPDU format.<br>HE_ER_SU indicates HE ER SU PPDU format.<br>HE_TB indicates HE TB PPDU format. | Y | Y |
| NON_HT_MODULATION | See corresponding entry in Table 19-1 (TXVECTOR and RXVECTOR parameters). | | | |


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**Table 27-1—TXVECTOR and RXVECTOR parameters(#12)(11ax) *(continued)***

| Parameter | Condition | Value | TXVECTOR | RXVECTOR |
|---|---|---|---|---|
| L_DATARATE(#1057) | FORMAT is NON_HT | Indicates the rate used to transmit the PSDU in Mb/s(#4148). Allowed values depend on the value of the NON_HT_MODULATION parameter as follows:<br>ERP-DSSS: 1 and 2<br>ERP-CCK: 5.5 and 11<br>ERP-OFDM, NON_HT_DUP_OFDM: 6, 9, 12, 18, 24, 36, 48, and 54<br>OFDM: 6, 9, 12, 18, 24, 26, 48, and 54 | Y | Y |
| | Otherwise | Not present. | | |
| L_LENGTH | FORMAT is HE_SU, HE_MU, or HE_ER_SU | Not present<br><br>NOTE—The LENGTH field of the L-SIG field for HE PPDU is defined in Equation (27-11) using the TXTIME value defined in 27.4.3 (TXTIME and PSDU_LENGTH calculation), which in turn depends on other parameters including the TXVECTOR parameter APEP_LENGTH. | N | N |
| | FORMAT is HE_TB | Indicates the value in the LENGTH field of the L-SIG field in the range(#3482) 1 to 4095. The value is obtained from the triggering frame to which the HE TB PPDU is a response. | Y | N |
| | Otherwise | See corresponding entry in Table 19-1 (TXVECTOR and RXVECTOR parameters) or Table 21-1 (TXVECTOR and RXVECTOR parameters(#12)). | | |
| N_TX | FORMAT is HE_SU, HE_MU, HE_ER_SU, or HE_TB | Indicates the number of transmit chains. | Y | N |
| | Otherwise | See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters(#12)). | | |
| EXPANSION_MAT | FORMAT is HE_SU, HE_ER_SU, or HE_TB | Contains a vector in the number of selected subcarriers containing feedback matrices as defined in 27.3.16.2 (Beamforming feedback matrix V) based on the channel measured during the training symbols of previous HE sounding NDPs or VHT NDPs. | Y | N |
| | FORMAT is HE_MU | For each user, contains a vector in the number of all the subcarriers in the RU that is assigned to this user. The vector for each subcarrier contains feedback matrices as defined in 27.3.16.2 (Beamforming feedback matrix V) based on the channel measured during the training symbols of previous HE sounding NDPs or VHT NDPs. | M<br>U | N |
| | Otherwise | See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters(#12)). | | |

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**Table 27-1—TXVECTOR and RXVECTOR parameters(#12)(11ax) *(continued)***

| Parameter | Condition | Value | TXVECTOR | RXVECTOR |
|---|---|---|---|---|
| CHAN_MAT | FORMAT is HE_SU and PSDU_LENGTH is 0 | Contains a vector in the number of selected subcarriers containing feedback matrices as defined in 27.3.16.2 (Beamforming feedback matrix V) based on the channel measured during the training symbols of previous HE sounding NDP. | N | Y |
| | FORMAT is HE_MU, HE_ER_SU, or HE_TB. FORMAT is HE_SU and PSDU_LENGTH is greater than 0. | Not present | N | N |
| | Otherwise | See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters(#12)). | | |
| DELTA_SNR | FORMAT is HE_MU | Contains an array of delta SNR values as defined in 9.4.1.64 (HE MU Exclusive Beamforming Report field(11ax)) based on the channel measured during the training symbols of the received HE sounding NDP. | MU | N |
| | FORMAT is HE_SU and PSDU_LENGTH greater than 0, or FORMAT is HE_ER_SU or HE_TB | | O | N |
| | FORMAT is HE_SU and PSDU_LENGTH is 0 | | N | Y |
| | Otherwise | See corresponding entry in Table 19-1 (TXVECTOR and RXVECTOR parameters) or Table 21-1 (TXVECTOR and RXVECTOR parameters(#12)). | | |
| RCPI | See corresponding entry in Table 19-1 (TXVECTOR and RXVECTOR parameters) or Table 21-1 (TXVECTOR and RXVECTOR parameters(#12)). | | | |
| SNR | FORMAT is HE_SU and PSDU_LENGTH is 0 | Contains an array of average values of received SNR measurements for each spatial stream. SNR indications of 8 bits are supported. Average value of SNR shall be the sum of the decibel values of SNR per subcarrier divided by the number of subcarriers represented in each stream as described in 9.4.1.63 (HE Compressed Beamforming Report field(11ax)). | N | Y |
| | FORMAT is HE_MU, HE_ER_SU, or HE_TB, or FORMAT is HE_SU and PSDU_LENGTH is greater than 0 | Not present | N | N |
| | Otherwise | See corresponding entry in Table 19-1 (TXVECTOR and RXVECTOR parameters) or Table 21-1 (TXVECTOR and RXVECTOR parameters(#12)). | | |
| CQI | FORMAT is HE_SU and PSDU_LENGTH is 0 | Contains an array of received per-RU average SNRs for each space-time stream, where each per-RU average SNR is the arithmetic mean of the SNR in decibels over a 26-tone RU as described in 9.4.1.65 (HE CQI Report field(11ax)). | N | Y |
| | Otherwise | Not present | N | N |


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**Table 27-1—TXVECTOR and RXVECTOR parameters(#12)(11ax) *(continued)***

| Parameter | Condition | Value | TXVECTOR | RXVECTOR |
|---|---|---|---|---|
| NO_SIG_EXTN | FORMAT is HE_SU, HE_MU, HE_ER_SU, or HE_TB | Indicates whether signal extension needs to be applied at the end of transmission.<br><br>Boolean:<br>true indicates that no signal extension is present.<br>false indicates that a signal extension is present. | Y | N |
| | Otherwise | See corresponding entry in Table 19-1 (TXVECTOR and RXVECTOR parameters) or Table 21-1 (TXVECTOR and RXVECTOR parameters(#12)). | | |
| FEC_CODING | FORMAT is HE_SU, HE_MU, HE_ER_SU, or HE_TB | Indicates the FEC encoding used.<br><br>Enumerated type:<br>BCC_CODING indicates BCC coding.<br>LDPC_CODING indicates LDPC coding. | M<br>U | M<br>U |
| | Otherwise | See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters(#12)). | | |
| LDPC_EXTRA_SYMBOL | FORMAT is HE_TB | Indicates the presence of the LDPC extra symbol segment in an HE TB PPDU.<br><br>Integer:<br>1 indicates that an LDPC extra symbol segment is present.<br>0 indicates that an LDPC extra symbol segment is not present. | Y | N |
| | Otherwise | Not present | N | N |
| STBC | FORMAT is HE_SU, HE_MU, HE_ER_SU, or HE_TB | Indicates if STBC is used.<br><br>For an HE MU PPDU and HE TB PPDU where each RU includes no more than 1 user:<br>Set to 1 to indicate that for all RUs the Data field is STBC encoded.<br>Set to 0 to indicate that in no RU is the Data field STBC encoded.<br><br>For an HE SU PPDU or HE ER SU PPDU:<br>Set to 1 to indicate that the Data field is STBC encoded.<br>Set to 0 to indicate that the Data field is not STBC encoded. | Y | Y |
| | Otherwise | See corresponding entry in Table 19-1 (TXVECTOR and RXVECTOR parameters) or Table 21-1 (TXVECTOR and RXVECTOR parameters(#12)). | | |

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**Table 27-1—TXVECTOR and RXVECTOR parameters(#12)(11ax) *(continued)***

| Parameter | Condition | Value | TXVECTOR | RXVECTOR |
|---|---|---|---|---|
| GI_TYPE | FORMAT is HE_SU, HE_MU, HE_ER_SU, or HE_TB | Indicates the length of the GI for the HE-LTF and Data fields.<br><br>Enumerated type:<br>0u8s_GI indicates 0.8 µs.<br>1u6s_GI indicates 1.6 µs.<br>3u2s_GI indicates 3.2 µs.<br><br>NOTE—the length of GI for pre-HE modulated fields is 0.8 µs. | Y | Y |
| | Otherwise | See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters(#12)). | | |
| TXPWR_LEVEL_INDEX | FORMAT is HE_SU, HE_MU, HE_ER_SU, or HE_TB | The allowed values for the TXPWR_LEVEL_INDEX parameter are in the range from 1 to numberOfOctets (dot11TxPowerLevelExtended)/2. This parameter is used to indicate which of the available transmit output power levels defined in dot11TxPowerLevelExtended shall be used for the current transmission. | Y | N |
| | Otherwise | See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters(#12)). | | |
| RSSI | FORMAT is HE_SU, HE_ER_SU, HE_MU, or HE_TB | The allowed values for the RSSI parameter are in the range 0 to 255 inclusive. This parameter is a (#1132)measurement by the PHY of the power observed at the antennas used to receive the current PPDU measured during the reception of the HE-LTF field. RSSI is intended to be used in a relative manner, and it is a monotonically increasing function of the received power. | N | Y |
| | Otherwise | See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters(#12)). | | |
| RSSI_LEGACY | FORMAT is HE_SU, HE_MU, HE_ER_SU, or HE_TB | The allowed values for the RSSI_LEGACY parameter are in the range 0 to 255 inclusive. This parameter is a (#1132)measurement by the PHY of the power observed at the antennas used to receive the current PPDU measured during the reception of non-HE portion of the HE PPDU preamble. RSSI_LEGACY is intended to be used in a relative manner, and it is a monotonically increasing function of the received | N | Y |
| | Otherwise | Not present | N | N |
| MCS | FORMAT is HE_SU, HE_MU or HE_TB | Indicates the modulation and coding schemes used in the transmission of the PPDU.<br><br>Integer: range 0 to 11. | M<br>U | M<br>U |
| | FORMAT is HE_ER_SU | Indicates the modulation and coding schemes used in the transmission of the PPDU.<br><br>Integer: range 0 to 2. | Y | Y |
| | Otherwise | See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters(#12)). | | |



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**Table 27-1—TXVECTOR and RXVECTOR parameters(#12)(11ax) *(continued)***

| Parameter | Condition | Value | TXVECTOR | RXVECTOR |
|---|---|---|---|---|
| DCM | FORMAT is HE_SU, HE_MU, HE_ER_SU, or HE_TB | Set to 1 to indicate that DCM is used for the Data field.<br>Set to 0 to indicate that DCM is not used for the Data field.<br><br>NOTE—DCM is applicable to only HE-MCSs 0, 1, 3, and 4. DCM is applicable to only 1 and 2 spatial streams. | M<br>U | M<br>U |
| | Otherwise | Not present | | |
| MCS_SIG_B | FORMAT is HE_MU | Indicates the modulation and coding scheme used for the HE-SIG-B field.<br><br>Integer:<br>0 indicates HE-MCS 0.<br>1 indicates HE-MCS 1.<br>2 indicates HE-MCS 2.<br>3 indicates HE-MCS 3.<br>4 indicates HE-MCS 4.<br>5 indicates HE-MCS 5. | Y | Y |
| | Otherwise | Not present | N | N |
| DCM_SIG_B | FORMAT is HE_ MU | Set to 1 to indicate that DCM is used for the HE-SIG-B field.<br>Set to 0 to indicate that DCM is not used for the HE-SIG-B field. | Y | Y |
| | Otherwise | Not present | N | N |
| SIG_B_COMPRESSION_MODE | FORMAT is HE_MU | Indicates whether the Common field is present in the HE-SIG-B field.<br><br>Integer:<br>0 indicates that the Common field is present.<br>1 indicates that the Common field is not present. | Y | N |
| | Otherwise | Not present | N | N |
| REC_MCS | FORMAT is HE_SU, HE_MU, or HE_ER_SU | Indicates the HE-MCS that the receiver recommends. | N | O |
| | FORMAT is HE_TB | Not present | N | N |
| | Otherwise | See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters(#12)). | | |

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**Table 27-1—TXVECTOR and RXVECTOR parameters(#12)(11ax) *(continued)***

| Parameter | Condition | Value | TXVECTOR | RXVECTOR |
|---|---|---|---|---|
| CH_BANDWIDTH | FORMAT is HE_SU | Indicates the channel width of the PPDU.<br><br>Enumerated type:<br>CBW20 for 20 MHz.<br>CBW40 for 40 MHz.<br>CBW80 for 80 MHz.<br>CBW160 for 160 MHz. | Y | Y |
| | FORMAT is HE_ER_SU | Indicates the channel width of the PPDU.<br><br>Enumerated type:<br>ER-RU-242 for the 242-tone RU in the primary 20 MHz channel.<br>ER-RU-H-106 for the higher frequency 106-tone RU in the primary 20 MHz channel. | Y | Y |


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**Table 27-1—TXVECTOR and RXVECTOR parameters(#12)(11ax) *(continued)***

| Parameter | Condition | Value | TXVECTOR | RXVECTOR |
|---|---|---|---|---|
| CH_BANDWIDTH *(continued)* | FORMAT is HE_MU | Indicates the channel width of the PPDU.<br><br>Enumerated type:<br>CBW20 for full 20 MHz.<br>CBW40 for full 40 MHz.<br>CBW80 for full 80 MHz.<br>CBW160 for full 160 MHz.<br>CBW80+80 for 80+80 MHz.<br>HE-CBW-PUNC80-PRI for preamble puncturing in 80 MHz, where in the preamble the only punctured subchannel is the secondary 20 MHz channel.<br>HE-CBW-PUNC80-SEC for preamble puncturing in 80 MHz, where in the preamble the only punctured subchannel is one of the two 20 MHz subchannels in the secondary 40 MHz channel.<br>HE-CBW-PUNC160-PRI20 for preamble puncturing in 160 MHz, where in the preamble the only punctured subchannels are the secondary 20 MHz channel and zero to two of the 20 MHz subchannels in the secondary 80 MHz channel. See Table 27-21 (HE-SIG-A field of an HE MU PPDU(11ax)) for allowed 20 MHz punctured subchannel combinations.<br>HE-CBW-PUNC80+80-PRI20 for preamble puncturing in 80+80 MHz, where in the preamble the only punctured subchannels are the secondary 20 MHz channel and zero to two of the 20 MHz subchannels in the secondary 80 MHz channel. See Table 27-21 (HE-SIG-A field of an HE MU PPDU(11ax)) for allowed 20 MHz punctured subchannel combinations.<br>HE-CBW-PUNC160-SEC40 for preamble puncturing in 160 MHz, where in the preamble the only punctured subchannels are zero, one or both of the 20 MHz subchannels in the secondary 40 MHz channel and zero to two of the 20 MHz subchannels in the secondary 80 MHz channel. At least one 20 MHz subchannel is punctured. See Table 27-21 (HE-SIG-A field of an HE MU PPDU(11ax)) for allowed 20 MHz punctured subchannel combinations.<br>HE-CBW-PUNC80+80-SEC40 for preamble puncturing in 80+80 MHz, where in the preamble the only punctured subchannels are zero, one or both of the 20 MHz subchannels in the secondary 40 MHz channel and zero to two of the 20 MHz subchannels in the secondary 80 MHz channel. At least one 20 MHz subchannel is punctured. See Table 27-21 (HE-SIG-A field of an HE MU PPDU(11ax)) for allowed 20 MHz punctured subchannel combinations. | Y | Y |
| | FORMAT is HE_TB | Indicates the Bandwidth field of the HE-SIG-A field in the transmitted or received PPDU.<br><br>Enumerated type:<br>CBW20 for 20 MHz.<br>CBW40 for 40 MHz.<br>CBW80 for 80 MHz.<br>CBW160 for 160 MHz.<br>CBW80+80 for 80+80 MHz. | Y | Y |

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**Table 27-1—TXVECTOR and RXVECTOR parameters(#12)(11ax) *(continued)***

| Parameter | Condition | Value | TXVECTOR | RXVECTOR |
|---|---|---|---|---|
| INACTIVE_SUBCHANNELS | FORMAT is HE_MU and CH_BANDWIDTH is any value for preamble puncturing, or FORMAT is NON_HT and NON_HT_MODULATION is NON_HT_DUP_OFDM, or FORMAT is HE_SU and PSDU_LENGTH is 0 | Indicates the 20 MHz subchannels that are punctured.<br><br>A bitmap indexed by the 20 MHz subchannels in ascending order with the LSB indicating the lowest frequency 20 MHz subchannel. A bit is set to 1 to indicate that the corresponding 20 MHz subchannel is punctured and set to 0 to indicate the corresponding 20 MHz subchannel is not punctured. | Y | N |
| | Otherwise | Not present | N | N |
| APEP_LENGTH | FORMAT is HE_SU or HE_ER_SU | Integer.<br><br>If 0 and FORMAT is HE_SU, indicates an HE sounding NDP (11az)or HE Ranging NDP.<br><br>(11az)If 0 and FORMAT is HE_TB, indicates an HE TB Ranging NDP.<br><br>Otherwise, indicates the number of octets in the range 1 to *aPSDUMaxLength* in the A-MPDU pre-EOF padding (see | Y | O |
| | FORMAT is HE_MU or HE_TB | | MU | O |
| | Otherwise | See corresponding entry in Table 19-1 (TXVECTOR and RXVECTOR parameters) or Table 21-1 (TXVECTOR and RXVECTOR parameters(#12)). | | |
| PSDU_LENGTH | FORMAT is HE_SU, HE_MU, HE_ER_SU, or HE_TB | Indicates the number of octets in the PSDU in the range(#3482) 0 to *aPSDUMaxLength* octets (see Table 27-61 (HE PHY characteristics(11ax))). A value of 0 indicates an HE sounding NDP(11az), HE Ranging NDP, or HE TB Ranging NDP. | N | Y |
| | Otherwise | See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters(#12)). | | |


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**Table 27-1—TXVECTOR and RXVECTOR parameters(#12)(11ax) *(continued)***

| Parameter | Condition | Value | TXVECTOR | RXVECTOR |
|---|---|---|---|---|
| NUM_STS | FORMAT is HE_SU | Indicates the number of space-time streams.<br><br>Integer: range 1 to 8. | Y | Y |
| | FORMAT is HE_ER_SU | Indicates the number of space-time streams.<br><br>Integer: range 1 to 2.<br><br>NOTE—NUM_STS set to 1 is valid only if STBC is not used. NUM_STS set to 2 is valid only if STBC is used. | Y | Y |
| | FORMAT is HE_MU | Indicates the number of space-time streams.<br><br>Integer in the range:<br>1–4 per user per MU-MIMO RU in the TXVECTOR.<br>1–4 per MU-MIMO RU in the RXVECTOR.<br>1–8 per RU assigned to no more than 1 user in the TXVECTOR and RXVECTOR.<br><br>NUM_STS summed over all users per RU is not greater than 8. | MU | Y |
| | FORMAT is HE_TB | Indicates the number of space-time streams.<br><br>Integer in the range:<br>1–4 for a MU-MIMO RU in the TXVECTOR<br>1–4 per user per MU-MIMO RU in the RXVECTOR<br>1–8 for an RU assigned to no more than 1 user in the TXVECTOR and RXVECTOR<br><br>NUM_STS summed over all users per RU is not greater than 8. | Y | N |
| | Otherwise | See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters(#12)). | | |

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**Table 27-1—TXVECTOR and RXVECTOR parameters(#12)(11ax) *(continued)***

| Parameter | Condition | Value | TXVECTOR | RXVECTOR |
|---|---|---|---|---|
| TXOP_DURATION | FORMAT is HE_SU, HE_MU, HE_ER_SU, or HE_TB | Indicates the TXOP duration.<br><br>Enumerated type or integer:<br>UNSPECIFIED indicates no NAV value specified.<br>0–8448 indicates a value in units of 1 μs that is used to update the NAV for this TXOP (see 26.2.4 (Updating two NAVs)).<br><br>TXVECTOR parameter TXOP_DURATION is converted to a value in the TXOP subfield of the HE-SIG-A field (see Table 27-19 (HE-SIG-A field of an HE SU PPDU and HE ER SU PPDU(11ax)), Table 27-21 (HE-SIG-A field of an HE MU PPDU(11ax)), and Table 27-22 (HE-SIG-A field of an HE TB PPDU(11ax))) as follows:<br>TXOP_DURATION = UNSPECIFIED: B0–B6 = 127.<br>TXOP_DURATION < 512: B0 = 0, B1–B6 = ⌊TXOP_DURATION / 8⌋.<br>(#1200)Otherwise: B0 = 1, B1–B6 = ⌊(TXOP_DURATION – 512) / 128⌋.<br><br>RXVECTOR parameter TXOP_DURATION is determined from the value in the TXOP subfield of the HE-SIG-A field (see Table 27-19 (HE-SIG-A field of an HE SU PPDU and HE ER SU PPDU(11ax)), Table 27-21 (HE-SIG-A field of an HE MU PPDU(11ax)), and Table 27-22 (HE-SIG-A field of an HE TB PPDU(11ax))) as follows:<br>B0–B6 = 127: TXOP_DURATION = UNSPECIFIED.<br>B0 = 0: TXOP_DURATION = 8 × B1-B6.<br>Otherwise: TXOP_DURATION = 512 + 128 × B1–B6.<br><br>See 26.11.5 (TXOP_DURATION) for more details. | Y | Y |
| | Otherwise | Not present | N | N |
| SPATIAL_REUSE | FORMAT is HE_SU, HE_MU, HE_ER_SU, or HE_TB | Indicates the spatial reuse parameter value. There is one value of the parameter for each of an HE SU PPDU, HE ER SU PPDU, and HE MU PPDU. There are one to four values of the parameter present for an HE TB PPDU, with the number of values present dependent on the bandwidth of the PPDU. See the Spatial Reuse field definition in 27.3.11.7.2 (Content).<br><br>See 26.5.2.3 (Non-AP STA behavior for UL MU operation) and 26.11.6 (SPATIAL_REUSE). | Y | Y |
| | Otherwise | Not present | N | N |
| DOPPLER | FORMAT is HE_SU, HE_MU, HE_ER_SU, or HE_TB | Set to 1 to indicate that either the midamble is present for the PPDU or that the channel is with high Doppler. Set to 0 otherwise. | Y | Y |
| | Otherwise | Not present | N | N |



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**Table 27-1—TXVECTOR and RXVECTOR parameters(#12)(11ax) *(continued)***

| Parameter | Condition | Value | TXVECTOR | RXVECTOR |
|---|---|---|---|---|
| RU_ALLOCATION | FORMAT is HE_MU and SIG_B_COMPRESSION_MODE is 0 | For the TXVECTOR, indicates the RU Allocation subfield of Common field in the HE-SIG-B field of the transmitted PPDU.<br>8 bits for a 20 MHz PPDU.<br>16 bits for a 40 MHz PPDU.<br>32 bits for an 80 MHz PPDU.<br>64 bits for a 160 MHz or 80+80 MHz PPDU.<br><br>See 27.3.11.8.3 (Common field) for details.<br><br>For the RXVECTOR, 8 bits are used to indicate the RU allocated in the whole bandwidth.<br><br>See 9.3.1.22 (Trigger frame format(11ax)) for details. | Y | Y |
| | FORMAT is HE_TB | 8 bits are used to indicate the RU allocated in the whole bandwidth per user.<br><br>See 9.3.1.22 (Trigger frame format(11ax)) for details. | Y | N |
| | FORMAT is HE_SU, APEP_LENGTH is 0, and CH_BANDWIDTH is not CBW20 or CBW40 | For the TXVECTOR, indicates the active RUs.<br>32 bits for 80 MHz PPDU.<br>64 bits for 160 MHz and 80+80 MHz PPDU.<br><br>For each 8 bits, only the following values are allowed:<br>113 (01110001 in binary representation).<br>192 (11000000 in binary representation).<br><br>See 27.3.11.8.3 (Common field) for details. | Y | N |
| | FORMAT is NON_HT, NON_HT_MODULATION is NON_HT_DUP_OFDM, and CH_BANDWIDTH is not CBW20 or CBW40 | | | |
| | Otherwise | Not present | N | N |
| BEAMFORMED | FORMAT is HE_SU or HE_ER_SU | Set to 1 if a beamforming steering matrix is applied to the HE modulated fields. Set to 0 otherwise. | Y | Y |
| | FORMAT is HE_MU or HE_TB | For an RU with no more than 1 user allocated, set to 1 if a beamforming steering matrix is applied to this non-MU-MIMO allocation, and set to 0 otherwise.<br><br>For each user in an RU assigned to more than 1 user, always set to 0. | MU | O |
| | Otherwise | See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters(#12)). | | |

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**Table 27-1—TXVECTOR and RXVECTOR parameters(#12)(11ax) *(continued)***

| Parameter | Condition | Value | TXVECTOR | RXVECTOR |
|---|---|---|---|---|
| CENTER_26_TONE_RU | FORMAT is HE_MU and CH_BANDWIDTH is CBW80, CBW160, CBW80+80, HE-CBW-PUNC80-PRI, HE-CBW-PUNC80-SEC, HE-CBW-PUNC160-PRI20, HE-CBW-PUNC80+80-PRI20, HE-CBW-PUNC160-SEC40, or HE-CBW-PUNC80+80-SEC40. | Indicate the presence of the center 26-tone RU with regard to bandwidth.<br><br>If the CH_BANDWIDTH parameter is CBW80, HE-CBW-PUNC80-PRI or HE-CBW-PUNC80-SEC:<br>Set to 1 to indicate that a user is allocated to the center 26-tone RU (see Figure 27-7 (RU locations in an 80 MHz HE PPDU(11ax))).<br>Set to 0 to indicate that no user is allocated to the center 26-tone RU.<br><br>If the CH_BANDWIDTH parameter is CBW160, CBW80+80, HE-CBW-PUNC160-PRI20, HE-CBW-PUNC80+80-PRI20, HE-CBW-PUNC160-SEC40, or HE-CBW-PUNC80+80-SEC40:<br>Set to 0 to indicate that no user is allocated to either the center 26-tone RU of the lower frequency 80 MHz or that of the higher frequency 80 MHz.<br>Set to 1 to indicate that a user is allocated to the center 26-tone RU of the lower frequency 80 MHz.<br>Set to 2 to indicate that a user is allocated to the center 26-tone RU of the higher frequency 80 MHz.<br>Set to 3 to indicate that a user is allocated to each of the center 26-tone RU of the lower frequency 80 MHz and that of the higher frequency 80 MHz individually.<br><br>See 27.3.11.8.3 (Common field). | Y | N |
| | Otherwise | Not present | N | N |
| HE_LTF_TYPE | FORMAT is HE_SU, HE_MU, HE_ER_SU, or HE_TB | Indicates the type of HE-LTF.<br><br>Enumerated type:<br>1xHE-LTF indicates a 1x HE-LTF.<br>2xHE-LTF indicates a 2x HE-LTF.<br>4xHE-LTF indicates a 4x HE-LTF.<br><br>See 27.3.11.10 (HE-LTF field). | Y | Y |
| | Otherwise | Not present | N | N |
| HE_LTF_MODE | FORMAT is HE_TB | Integer:<br>Set to 0 to indicate that the transmitted PPDU uses HE single stream pilot HE-LTF mode.<br>Set to 1 to indicate the transmitted PPDU uses HE masked HE-LTF sequence mode.<br><br>Present for full-bandwidth MU-MIMO not using 1x HE-LTF and not present otherwise.<br><br>See 27.3.11.10 (HE-LTF field). | O | N |
| | Otherwise | Not present | N | N |



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**Table 27-1—TXVECTOR and RXVECTOR parameters(#12)(11ax) *(continued)***

| Parameter | Condition | Value | TXVECTOR | RXVECTOR |
|---|---|---|---|---|
| NUM_HE_LTF | FORMAT is HE_MU or HE_TB | Indicates the number of OFDM symbols in the HE-LTF field.<br><br>See 26.5.2.3 (Non-AP STA behavior for UL MU operation) and 27.3.11.7.2 (Content). | Y | N |
| | Otherwise | Not present | N | N |
| HE_SIG_A2_RESERVED | FORMAT is HE_TB | Indicates the Reserved field setting for the HE-SIG-A2 subfield of HE TB PPDU.<br><br>See 26.5.2.3 (Non-AP STA behavior for UL MU operation) and Table 27-22 (HE-SIG-A field of an HE TB PPDU(11ax)) for details. | Y | N |
| | Otherwise | Not present | N | N |
| STARTING_STS_NUM | FORMAT is HE_TB | The sum of the number of space-time streams assigned to other users with lower space-time stream indices than this user. | Y | N |
| | Otherwise | Not present | N | N |
| RX_START_OF_FRAME_OFFSET | See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters(#12)). | | | |
| PREAMBLE_TYPE | FORMAT is NON_HT and NON_HT_MODULATION is one of<br>ERP-DSSS<br>ERP-CCK | Enumerated type:<br>SHORTPREAMBLE.<br>LONGPREAMBLE. | Y | Y |
| | Otherwise | Not present | N | N |

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**Table 27-1—TXVECTOR and RXVECTOR parameters(#12)(11ax) *(continued)***

| Parameter | Condition | Value | TXVECTOR | RXVECTOR |
|---|---|---|---|---|
| NOMINAL_PACKET_PADDING | FORMAT is HE_SU, HE_MU, or HE_ER_SU | The nominal packet padding as defined in 9.4.2.247.5 (PPE Thresholds field).<br><br>Possible values are 0 µs, 8 µs, and 16 µs. | M<br>U | N |
| | Otherwise | Not present | N | N |
| TRIGGER_METHOD | FORMAT is HE_TB | Indicates the method used to trigger this HE TB PPDU transmission.<br><br>Enumerated type:<br>TRIGGER_FRAME for Trigger frame.<br>TRS for TRS Control subfield. | Y | N |
| | Otherwise | Not present | N | N |
| PRE_FEC_PADDING_FACTOR | FORMAT is HE_TB and TRIGGER_METHOD is TRIGGER_FRAME | Indicates the pre-FEC padding factor used by the HE TB PPDU transmission. | Y | N |
| | Otherwise | Not present | N | N |
| DEFAULT_PE_DURATION | FORMAT is HE_TB and TRIGGER_METHOD is TRS | Duration of the PE field to be transmitted (see 26.5.2.3 (Non-AP STA behavior for UL MU operation)). A value 0, 4, 8, 12, or 16 indicating the PE field duration in µs. | Y | N |
| | Otherwise | Not present | N | N |



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**Table 27-1—TXVECTOR and RXVECTOR parameters(#12)(11ax) *(continued)***

| Parameter | Condition | Value | TXVECTOR | RXVECTOR |
|---|---|---|---|---|
| BEAM_CHANGE | FORMAT is HE_SU or HE_ER_SU | Integer:<br>Set to 0 to indicate that the spatial mapping of the pre-HE modulated fields are the same as the first symbol of HE-LTF field.<br>Set to 1 to indicate that the spatial mapping of the pre-HE modulated fields are different from the first symbol of HE-LTF field. | Y | Y |
| | Otherwise | Not present | N | N |
| BSS_COLOR | FORMAT is HE_SU, HE_MU, HE_ER_SU, or HE_TB | Set to a value in the range 0 to 63 (see 26.11 (Rules for setting some TXVECTOR parameters for PPDUs transmitted by an HE STA)). | Y | Y |
| | Otherwise | Not present | N | N |
| UPLINK_FLAG | FORMAT is HE_SU or HE_MU | Set to 1 if the PPDU is addressed to an AP.<br>Set to 0 otherwise. | Y | Y |
| | FORMAT is HE_ER_SU | Set to 0 if the PPDU is not addressed to an AP, or if the PPDU is addressed to an AP and meets the exception in 26.11.2 (UPLINK_FLAG).<br>Set to 1 otherwise. | Y | Y |
| | Otherwise | Not present | N | N |
| STA_ID | FORMAT is HE_MU | Indicates the list of STA-IDs for an HE MU PPDU (see 26.11 (Rules for setting some TXVECTOR parameters for PPDUs transmitted by an HE STA)). | MU | MU |
| | Otherwise | Not present | N | N |
| SCRAMBLER_INITIAL_VALUE | FORMAT is HE_SU or HE_ER_SU(#602) | The first 7 bits of the scrambling sequence (the value of the Scrambler Initialization field prior to descrambling), with the first bit of the scrambling sequence being the LSB of SCRAMBLER_INITIAL_VALUE. | N | Y |
| | FORMAT is HE_MU or HE_TB | Not present | N | N |
| | Otherwise(#602) | See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters(#12)) | | |

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**Table 27-1—TXVECTOR and RXVECTOR parameters(#12)(11ax) *(continued)***

| Parameter | Condition | Value | TXVECTOR | RXVECTOR |
|---|---|---|---|---|
| TRIGGER_RESPONDING | FORMAT is NON_HT | Boolean value:<br>true indicates that the MAC entity requests that the PHY entity follow the (M118)precorrection requirements defined in 27.3.15.3 (Precorrection accuracy requirements(M118)).<br>false indicates that the MAC entity does not request that the PHY entity follow the (M118)precorrection requirements defined in 27.3.15.3 (Precorrection accuracy requirements(M118)). | Y | N |
| | Otherwise | Not present | N | N |
| NDP_REPORT | FORMAT is HE_TB and PSDU_LENGTH = 0 | Provides the detected status array on the resources assigned by the Trigger frame. The array has $N_{STA}$ entries ($N_{STA}$ is defined in 26.5.7.2 (STA behavior)) where each entry takes on the value:<br>1 if transmission is detected on the first group of the tone set.<br>0 if transmission is detected on the second group of the tone set.<br>NONE if transmission is not detected on either group of the tone set. | N | Y |
| | Otherwise | Not present | N | N |
| FEEDBACK_STATUS | FORMAT is HE_TB and APEP_LENGTH = 0 | Indicates the value of the one bit used to modulate the tones in each tone set. See 27.3.4 (HE PPDU formats) and 26.5.7 (NDP feedback report procedure). | Y | N |
| | Otherwise | Not present | N | N |
| RU_TONE_SET_INDEX | FORMAT is HE_TB and APEP_LENGTH = 0 | Indicates the RU tone set used for an HE TB feedback NDP. See 27.3.18 (HE TB feedback NDP). | Y | N |
| | Otherwise | Not present | N | N |



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**Table 27-1—TXVECTOR and RXVECTOR parameters(#12)(11ax) *(continued)***

| Parameter | Condition | Value | TXVECTOR | RXVECTOR |
|---|---|---|---|---|
| MIDAMBLE_PERIODICITY | FORMAT is HE_SU, HE_MU, HE_ER_SU, or HE_TB, and DOPPLER is 1 | Indicates the midamble periodicity in number of OFDM symbols in the Data field. Set to 10 or 20. | Y | N |
| | Otherwise | Not present | N | N |
| HE_TB_PE_DISAMBIGUITY | FORMAT is HE_TB and TRIGGER_METHOD is TRIGGER_FRAME | Indicates PE disambiguity for the HE TB PPDU transmission.<br>Set to 0 to indicate no PE disambiguity.<br>Set to 1 to indicate PE disambiguity. | Y | N |
| | Otherwise | Not present | N | N |
| POWER_BOOST_FACTOR(#1067) | FORMAT is HE_SU, HE_MU or HE_ER_SU | For an occupied RU, set to the power boost factor of the RU in the range(#3482) 0.5 to 2 (see 26.11.10 (POWER_BOOST_FACTOR(#1067))) | M<br>R | N |
| | Otherwise | Not present | N | N |
| TIME_OF_DEPARTURE_REQUESTED (11az) | FORMAT is HE_SU or (HE_TB and RANGING_FLAG is present) | Enumerated type:<br><br>True indicates that the MAC entity requests that the PHY entity measures and reports time of departure parameters corresponding to the time when the first frame energy is sent by the transmitting port.<br><br>False indicates that the MAC entity requests that the PHY entity neither measures nor reports time of departure parameters. | O | N |
| | FORMAT is HE_ER_SU or HE_MU | Not present. | N | N |
| | Otherwise | See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters(#12)). | | |
| LTF_KEY (11az) | FORMAT is either HE_SU or HE_TB and RANGING_FLAG is present and SECURE_LTF_FLAG is 1 | Contains the *rsta-ltf-key* or *ista-ltf-key* (see 11.21.6.4.5.4 (Overview of secure HE-LTF octet stream generation(11az))) when the secure HE-LTFs are used (see 11.21.6.4.5 (Secure HE-LTF in the TB and non-TB ranging measurement exchange protocol(11az))). | Y | N |
| | Otherwise | Not present. | | |

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**Table 27-1—TXVECTOR and RXVECTOR parameters(#12)(11ax) *(continued)***

| Parameter | Condition | Value | TXVECTOR | RXVECTOR |
|---|---|---|---|---|
| LTF_IV (11az) | FORMAT is either HE_SU or HE_TB and RANGING_FLAG is present and SECURE_LTF_FLAG is 1 | Contains the *ltf-iv* (see 11.21.6.4.5.4 (Overview of secure HE-LTF octet stream generation(11az))) used to generate the secure HE-LTFs. | Y | N |
| | Otherwise | Not present. | | |
| LTF_REP (11az) | FORMAT is either HE_SU or HE_TB and RANGING_FLAG is present | Indicates the number of HE-LTF repetitions. | Y | N |
| | Otherwise | Not present. | | |
| RANGING_FLAG (11az) | FORMAT is HE_SU | If present, indicates that the PPDU is an HE Ranging NDP.<br><br>Not present otherwise. | O | N |
| | FORMAT is HE_TB | If present, indicates that the PPDU is an HE TB Ranging NDP.<br><br>Not present otherwise. | O | N |
| | Otherwise | Not present. | N | N |
| SECURE_LTF_FLAG(11az) | FORMAT is either HE_SU or HE_TB and the RANGING_FLAG is present. | Set to 1 to indicate that the HE Ranging NDP or HE TB Ranging NDP will use secure HE-LTF.<br><br>Set to 0 otherwise. | Y | N |
| | Otherwise | Not present. | | |
| TX_WINDOW_FLAG (11az) | FORMAT is either HE_SU or HE_TB and RANGING_FLAG is present and SECURE_LTF_FLAG is 1 | Set to 1 to indicate that the secure HE-LTF of an HE Ranging NDP or HE TB Ranging NDP will use the optional frequency domain Tx window.<br><br>Set to 0 otherwise. | Y | N |
| | Otherwise | Not present. | | |

NOTE 1—In the (#4177)TXVECTOR and RXVECTOR columns, the following apply:
Y = Present.
N = Not present.
O = Optional.
MU indicates that the parameter is present once for an HE SU PPDU and HE ER SU PPDU and present per user for an HE MU PPDU. For an HE TB PPDU, MU in the (#4177)TXVECTOR column indicates that the parameter is present once and MU in the (#4177)RXVECTOR column indicates the parameter is not present (the receiver knows the values since they were specified in the triggering PPDU). Parameters specified to be present per user are conceptually supplied as an array of values indexed by *u*, where *u* takes values 0 to NUM_USERS – 1.
(#1067)MR indicates that the parameter is present once for an HE SU PPDU and HE ER SU PPDU and is present per RU for an HE MU PPDU. Parameters specified to be present per RU are conceptually supplied as an array of values indexed by *r*, where *r* takes values 0 to the number of RUs minus 1.
NOTE 2—Refer to Clause 15, Clause 16, Clause 17, Clause 18, Clause 19, and Clause 21 for the TXVECTOR and RXVECTOR parameters that are not present in this table when FORMAT is not HE_SU, HE_MU, HE_ER_SU, or HE_TB.


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### 27.2.3 TRIGVECTOR parameters

The TRIGVECTOR is carried in a PHY-TRIGGER.request primitive and provides the PHY of the AP with the parameters needed to receive an HE TB PPDU over each assigned RU. The parameters in Table 27-2 (TRIGVECTOR parameters(11ax)) are defined as part of the TRIGVECTOR parameter list in the PHY-TRIGGER.request primitive.

**Table 27-2—TRIGVECTOR parameters(11ax)**

| Parameter | Value |
|---|---|
| CH_BANDWIDTH | Indicates the bandwidth in the HE-SIG-A field of the expected HE TB PPDU(s).<br><br>Enumerated type:<br>CBW20 for 20 MHz.<br>CBW40 for 40 MHz.<br>CBW80 for 80 MHz.<br>CBW160 for 160 MHz.<br>CBW80+80 for 80+80 MHz. |
| UL_LENGTH | Indicates the value of the LENGTH field in the L-SIG field of the expected HE TB PPDU(s). |
| GI_AND_HE_LTF_TYPE | Indicates the GI and HE-LTF type of the expected HE TB PPDU(s).<br><br>Enumerated type:<br>1x HE-LTF + 1.6 μs GI.<br>2x HE-LTF + 1.6 μs GI.<br>4x HE-LTF + 3.2 μs GI. |
| MU_MIMO_HE_LTF_MODE | Indicates the HE-LTF mode of the expected UL MU-MIMO HE TB PPDU(s), if it uses full-bandwidth MU-MIMO and does not use 1x HE-LTF.<br>Set to 0 to indicate that HE single stream pilot HE-LTF mode is used.<br>Set to 1 to indicate that HE masked HE-LTF sequence mode is used. |
| NUMBER_OF_HE_LTF_SYMBOLS | Indicates the number of HE-LTF symbols present in the expected HE TB PPDU(s).<br><br>If the parameter DOPPLER is 0:<br>Set to 0 for 1 HE-LTF symbol.<br>Set to 1 for 2 HE-LTF symbols.<br>Set to 2 for 4 HE-LTF symbols.<br>Set to 3 for 6 HE-LTF symbols.<br>Set to 4 for 8 HE-LTF symbols.<br><br>If the parameter DOPPLER is 1:<br>Set to 0 for 1 HE-LTF symbol.<br>Set to 1 for 2 HE-LTF symbols.<br>Set to 2 for 4 HE-LTF symbols. |
| MIDAMBLE_PREIODICITY | Indicates the midamble periodicity. Present only if the parameter DOPPLER is 1.<br><br>Integer value:<br>Set to 10 to indicate a 10 symbol midamble periodicity.<br>Set to 20 to indicate a 20 symbol midamble periodicity. |
| STBC | Indicates the status of STBC encoding in the expected HE TB PPDU(s).<br>Set to 1 if STBC encoding is used.<br>Set to 0 otherwise. |

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**Table 27-2—TRIGVECTOR parameters(11ax) *(continued)***

| Parameter | Value |
|---|---|
| LDPC_EXTRA_SYMBOL | Indicates the status of the LDPC extra symbol segment in the expected HE TB PPDU(s).<br>Set to 1 if LDPC extra symbol segment is present.<br>Set to 0 otherwise. |
| PRE_FEC_FACTOR | Indicates the pre-FEC padding factor for the expected HE TB PPDU(s).<br>Set to 0 to indicate a pre-FEC padding factor of 4.<br>Set to 1 to indicate a pre-FEC padding factor of 1.<br>Set to 2 to indicate a pre-FEC padding factor of 2.<br>Set to 3 to indicate a pre-FEC padding factor of 3. |
| PE_DISAMBIGUITY | Indicates the PE disambiguity for the expected HE TB PPDU(s).<br>Set to 0 to indicate no PE disambiguity.<br>Set to 1 to indicate PE disambiguity. |
| DOPPLER | Indicates a high Doppler mode for the expected HE TB PPDU(s).<br>Set to 1 to indicate that midambles are present.<br>Set to 0 otherwise. |
| AID12_LIST | Each entry of AID12_LIST is (12-bit) AID of the corresponding HE TB PPDU. See the AID12 subfield in 9.3.1.22 (Trigger frame format(11ax)).<br><br>NOTE—The MSB of the 12-bit AID is always 0. |
| RU_ALLOCATION_LIST | 8 bits are used per STA to indicate the RU allocated in the whole bandwidth. See 9.3.1.22 (Trigger frame format(11ax)). |
| FEC_CODING_LIST | Each entry indicates the coding type of the corresponding HE TB PPDU. See the UL FEC Coding Type subfield description in 9.3.1.22 (Trigger frame format(11ax)). |
| HE_MCS_LIST | Each entry of HE_MCS_LIST indicates the HE-MCS of the corresponding HE TB PPDU. See the UL HE-MCS subfield in 9.3.1.22 (Trigger frame format(11ax)) for more information of each entry. |
| UL_DCM_LIST | Each entry indicates whether DCM is applied to the corresponding HE TB PPDU. See the UL DCM subfield description in 9.3.1.22 (Trigger frame format(11ax)) for details. |
| SS_ALLOCATION_LIST | Each entry indicates the spatial streams of the corresponding HE TB PPDU. See the SS Allocation subfield description in 9.3.1.22 (Trigger frame format(11ax)). |

### 27.2.4 LTFVECTOR parameters(11az)

The LTFVECTOR is carried in a PHY-RXLTFSEQUENCE.request for the PHY of a STA to receive an HE Ranging NDP or an HE TB Ranging NDP. The parameters in Table 27-3 (LTFVECTOR parameters(11az)) are defined as part of the LTFVECTOR parameter list in the PHY-RXLTFSEQUENCE.request primitive.

**Table 27-3—LTFVECTOR parameters(11az)**

| Parameter | Value |
|---|---|
| LTF_NSTS | Indicates the number of space-time streams in the following HE Ranging NDP or the following HE TB Ranging NDP. |


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**Table 27-3—LTFVECTOR parameters(11az) *(continued)***

| Parameter | Value |
|---|---|
| LTF_REP | Indicates the number of HE-LTF repetitions in the following HE Ranging NDP or the following HE TB Ranging NDP. |
| SECURE_LTF_FLAG | Set to 1 to indicate that the HE Ranging NDP or HE TB Ranging NDP uses secure HE-LTF. |
| LTF_KEY | Present when SECURE_LTF_FLAG is set to 1.<br><br>Contains the *rsta-ltf-key* or *ista-ltf-key* (see 11.21.6.4.5.4 (Overview of secure HE-LTF octet stream generation(11az))) when receiving the secure HE-LTFs. |
| LTF_IV | Present when SECURE_LTF_FLAG is set to 1.<br><br>Contains the ltf-iv (see 11.21.6.4.5.4 (Overview of secure HE-LTF octet stream generation(11az))) for secure HE-LTFs or null otherwise. |
| LTF_OFFSET | Present when SECURE_LTF_FLAG is set to 1.<br><br>Indicates the number of HE-LTF to skip before beginning to process the HE-LTF symbols. |
| TX_WINDOW_FLAG | Present when SECURE_LTF_FLAG is set to 1.<br><br>Set to 1 to indicate that the secure HE-LTF of an HE Ranging NDP or HE TB Ranging NDP will use the optional frequency domain Tx Window. |

### 27.2.5 PHYCONFIG_VECTOR parameters

The PHYCONFIG_VECTOR carried in a PHY-CONFIG.request primitive for an HE PHY contains an OPERATING_CHANNEL parameter, which identifies the operating or primary channel. The PHY shall set dot11CurrentPrimaryChannel to the value of this parameter.

The PHYCONFIG_VECTOR carried in a PHY-CONFIG.request primitive for an HE PHY contains a CHANNEL_WIDTH parameter, which identifies the operating channel width and takes one of the values 20 MHz, 40 MHz, 80 MHz, 160 MHz, and 80+80 MHz. The PHY shall set dot11CurrentChannelWidth to the value of this parameter. The PHY shall set dot11HECurrentChannelWidthSet to a value that is obtained from the Supported Channel Width Set subfield in the HE Capabilities element transmitted by the STA.

The PHYCONFIG_VECTOR carried in a PHY-CONFIG.request primitive for an HE PHY contains a CENTER_FREQUENCY_SEGMENT_0 parameter, which identifies the center frequency of the channel (or of segment 0 if the CHANNEL_WIDTH parameter indicates 80+80 MHz) and takes a value between 1 and 255. The PHY shall set dot11CurrentChannelCenterFrequencyIndex0 to the value of this parameter. The PHYCONFIG_VECTOR carried in a PHY-CONFIG.request primitive for an HE PHY contains a CENTER_FREQUENCY_SEGMENT_1 parameter, which takes the value 0 if the CHANNEL_WIDTH parameter does not indicate 80+80 MHz, and otherwise identifies the center frequency of segment 1 and takes a value between 1 and 200. The PHY shall set dot11CurrentChannelCenterFrequencyIndex1 to the value of this parameter.

(#4385)The PHYCONFIG_VECTOR carried in a PHY-CONFIG.request primitive for an HE PHY contains a BSS_COLOR_LIST parameter, which indicates a list of color values for which PPDUs have to be processed. Processing of PPDUs with color values not in BSS_COLOR_LIST can be terminated as soon as their color is determined.

(#4384)Additional PHYCONFIG_VECTOR parameters are defined in Table 8-4 (Vector descriptions(#4383)).

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### 27.2.6 Effects of CH_BANDWIDTH parameter on PPDU format

Table 27-4 (Interpretation of FORMAT, NON_HT_MODULATION, CH_BANDWIDTH, and CH_OFFSET parameters(11ax)) shows the valid combinations of the FORMAT, NON_HT_MODULATION, and CH_BANDWIDTH parameters and the corresponding PPDU format and value of CH_OFFSET (if applicable). Other combinations are reserved.

**Table 27-4—Interpretation of FORMAT, NON_HT_MODULATION, CH_BANDWIDTH, and CH_OFFSET parameters(11ax)**

| FORMAT | NON_HT_ MODULATION | CH_BANDWIDTH | CH_OFFSET | PPDU format |
|---|---|---|---|---|
| HE | N/A | CBW20 | N/A | The STA transmits an HE PPDU of 20 MHz bandwidth. If the BSS bandwidth is wider than 20 MHz, then the transmission shall use the primary 20 MHz channel. |
| HE | N/A | CBW40 | N/A | The STA transmits an HE PPDU of 40 MHz bandwidth. If the BSS bandwidth is wider than 40 MHz, then the transmission shall use the primary 40 MHz channel. |
| HE | N/A | CBW80 | N/A | The STA transmits an HE PPDU of 80 MHz bandwidth. If the BSS bandwidth is wider than 80 MHz, then the transmission shall use the primary 80 MHz channel. |
| HE | N/A | CBW160 | N/A | The STA transmits an HE PPDU of 160 MHz bandwidth. |
| HE | N/A | CBW80+80 | N/A | The STA transmits an HE PPDU of 80+80 MHz bandwidth. |
| HE | N/A | HE-CBW-PUNC80-PRI | N/A | The STA transmits an 80 MHz HE PPDU where the only punctured subchannel is the secondary 20 MHz channel. |
| HE | N/A | HE-CBW-PUNC80-SEC | N/A | The STA transmits an 80 MHz HE PPDU where the only punctured subchannel is one of the two 20 MHz subchannels in the secondary 40 MHz channel. |
| HE | N/A | HE-CBW-PUNC160-PRI20 | N/A | The STA transmits a 160 MHz HE PPDU where the only punctured subchannels are the secondary 20 MHz channel and zero to two of the 20 MHz subchannels in the secondary 80 MHz channel. See Table 27-21 (HE-SIG-A field of an HE MU PPDU(11ax)) for allowed 20 MHz punctured subchannel combinations. |


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**Table 27-4—Interpretation of FORMAT, NON_HT_MODULATION, CH_BANDWIDTH, and CH_OFFSET parameters(11ax) *(continued)***

| FORMAT | NON_HT_ MODULATION | CH_BANDWIDTH | CH_OFFSET | PPDU format |
|---|---|---|---|---|
| HE | N/A | HE-CBW-PUNC80+80-PRI20 | N/A | The STA transmits an 80+80 MHz HE PPDU where the only punctured subchannels are the secondary 20 MHz channel and zero to two of the 20 MHz subchannels in the secondary 80 MHz channel. See Table 27-21 (HE-SIG-A field of an HE MU PPDU(11ax)) for allowed 20 MHz punctured subchannel combinations. |
| HE | N/A | HE-CBW-PUNC160-SEC40 | N/A | The STA transmits a 160 MHz HE PPDU where the only punctured subchannels are zero, one or both of the 20 MHz subchannels in the secondary 40 MHz channel and zero to two of the 20 MHz subchannels in the secondary 80 MHz channel. At least one 20 MHz subchannel is punctured. See Table 27-21 (HE-SIG-A field of an HE MU PPDU(11ax)) for allowed 20 MHz punctured subchannel combinations. |
| HE | N/A | HE-CBW-PUNC80+80-SEC40 | N/A | The STA transmits an 80+80 MHz HE PPDU where the only punctured subchannels are zero, one or both of the 20 MHz subchannels in the secondary 40 MHz channel and zero to two of the 20 MHz subchannels in the secondary 80 MHz channel; at least one 20 MHz subchannel is punctured. See Table 27-21 (HE-SIG-A field of an HE MU PPDU(11ax)) for allowed 20 MHz punctured subchannel combinations. |
| HT_MF, HT_GF, VHT | See Table 21-2 (Interpretation of FORMAT, NON_HT_MODULATION, CH_BANDWIDTH, and CH_OFFSET parameters) and Table 19-2 (Interpretation of FORMAT, CH_BANDWIDTH, and CH_OFFSET parameters). | | | |
| NON_HT | If INACTIVE_SUBCHANNELS is not present, see Table 21-2 (Interpretation of FORMAT, NON_HT_MODULATION, CH_BANDWIDTH, and CH_OFFSET parameters) and Table 19-2 (Interpretation of FORMAT, CH_BANDWIDTH, and CH_OFFSET parameters). | | | |
| NON_HT | If INACTIVE_SUBCHANNELS is present, see Table 27-5 (Interpretation of CH_BANDWIDTH and INACTIVE_SUBCHANNELS parameters when FORMAT is equal to NON_HT and NON_HT_MODULATION is equal to NON_HT_DUP_OFDM(11ax)). | | | |

Valid combinations of the CH_BANDWIDTH and INACTIVE_SUBCHANNELS parameters when FORMAT is NON_HT and the corresponding PPDU and CH_OFFSET (if applicable) are shown in Table 27-5 (Interpretation of CH_BANDWIDTH and INACTIVE_SUBCHANNELS parameters when

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FORMAT is equal to NON_HT and NON_HT_MODULATION is equal to NON_HT_DUP_OFDM(11ax)). Other combinations are reserved.

**Table 27-5— Interpretation of CH_BANDWIDTH and INACTIVE_SUBCHANNELS parameters when FORMAT is equal to NON_HT and NON_HT_MODULATION is equal to NON_HT_DUP_OFDM(11ax)**

| CH_BANDWIDTH | INACTIVE_SUBCHANNELS | CH_OFFSET | PPDU format |
|---|---|---|---|
| CBW80 | All bits set to 1, except for the four bits corresponding to the primary 80 MHz channel, which are set to 0 | N/A | The STA transmits a non-HT PPDU of 80 MHz bandwidth. If the BSS bandwidth is wider than 80 MHz, then the transmission shall use the primary 80 MHz channel. |
| CBW80 | The bit corresponding to the primary 20 MHz channel set to 0 and two other bits set to 0 that correspond to any other subchannels in the primary 80 MHz, all other bits set to 1 | N/A | The STA transmits a punctured non-HT PPDU of 80 MHz bandwidth. If the BSS bandwidth is wider than 80 MHz, then the transmission shall use the primary 80 MHz channel. |
| CBW160 | All bits set to 0 | N/A | The STA transmits a non-HT PPDU of 160 MHz bandwidth. |
| CBW160 | Either the bit corresponding to the secondary 20 MHz channel or zero, one or both bits corresponding to the secondary 40 MHz channel set to 1. Zero to two bits corresponding to 20 MHz subchannels in the secondary 80 MHz channel set to 1. All other bits set to 0. Not all bits set to 0. If two bits corresponding to 20 MHz subchannels in the secondary 80 MHz channel are set to 1 these correspond to the lower two or higher two 20 MHz subchannels. No more than two bits corresponding to adjacent 20 MHz subchannels set to 1. | N/A | The STA transmits a punctured non-HT PPDU of 160 MHz bandwidth. |
| CBW80+80 | All bits set to 0 | N/A | The STA transmits a non-HT PPDU of 80+80 MHz bandwidth. |


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**Table 27-5— Interpretation of CH_BANDWIDTH and INACTIVE_SUBCHANNELS parameters when FORMAT is equal to NON_HT and NON_HT_MODULATION is equal to NON_HT_DUP_OFDM(11ax) *(continued)***

| CH_BANDWIDTH | INACTIVE_SUBCHANNELS | CH_OFFSET | PPDU format |
|---|---|---|---|
| CBW80+80 | Either the bit corresponding to the secondary 20 MHz channel or zero, one or both bits corresponding to the secondary 40 MHz channel set to 1. Zero to two bits corresponding to 20 MHz subchannels in the secondary 80 MHz channel set to 1. All other bits set to 0. Not all bits set to 0. If two bits corresponding to 20 MHz subchannels in the secondary 80 MHz channel are set to 1 these correspond to the lower two or higher two 20 MHz subchannels. | N/A | The STA transmits a punctured non-HT PPDU of 80+80 MHz bandwidth. |

### 27.2.7 Support for non-HT, HT, and VHT formats

#### 27.2.7.1 General

An HE STA logically contains Clause 15, Clause 16, Clause 17, Clause 18, Clause 19, Clause 21, and Clause 27 PHYs. The MAC interacts with the PHYs via the Clause 27 PHY service interface, which in turn interacts with the Clause 15, Clause 16, Clause 17, Clause 18, and Clause 19, and Clause 21 PHY service interfaces as shown in Figure 27-1 (PHY interaction on transmit for various PPDU formats(11ax)), Figure 27-2 (PHY interaction on receive for various PPDU formats(11ax)), and Figure 27-3 (PHY-CONFIG and CCA interaction with various PPDU formats(11ax)).

#### 27.2.7.2 Support for non-HT format

The behavior of the HE PHY on receipt of a PHY-TXSTART.request(TXVECTOR) primitive with the FORMAT parameter equal to NON_HT and the NON_HT_MODULATION parameter not equal to NON_HT_DUP_OFDM is defined in Clause 15, Clause 16, Clause 17, and Clause 18 and depends on the parameter NON_HT_MODULATION. If the parameter NON_HT_MODULATION is OFDM or NON_HT_DUP_OFDM, then the following additional requirements apply:

— The requirements in 21.3.9.1 (Transmission of 20 MHz non-HT PPDUs(#238) with more than one transmit chain)

— The requirements in 21.3.17.1 (Transmit spectrum mask) instead of the requirements in 17.3.9.3 (Transmit spectrum mask)

— The requirements in 27.3.21.3 (Transmit center frequency and symbol clock frequency tolerance) instead of the requirements in 17.3.9.7.2 (Transmitter center frequency leakage)

The modulation equation for non-HT duplicate transmission is defined in 27.3.14 (Non-HT duplicate transmission).

The HE PHY TXVECTOR parameters in Table 27-1 (TXVECTOR and RXVECTOR parameters(#12)(11ax)) are mapped to Clause 15, Clause 16, Clause 17, and Clause 18 TXVECTOR

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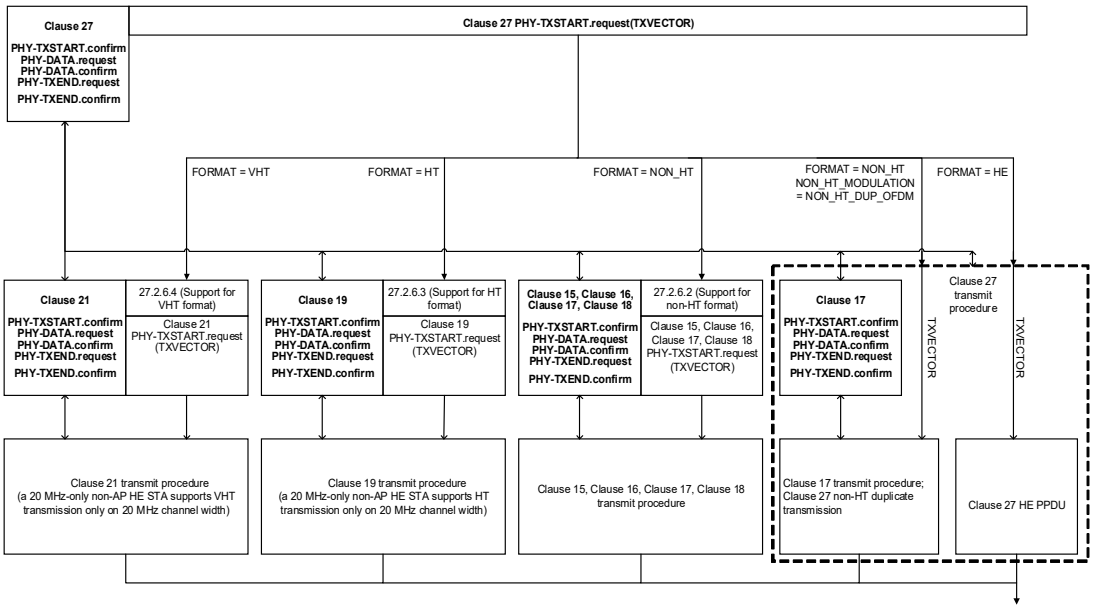


**Figure 27-1—PHY interaction on transmit for various PPDU formats(11ax)**

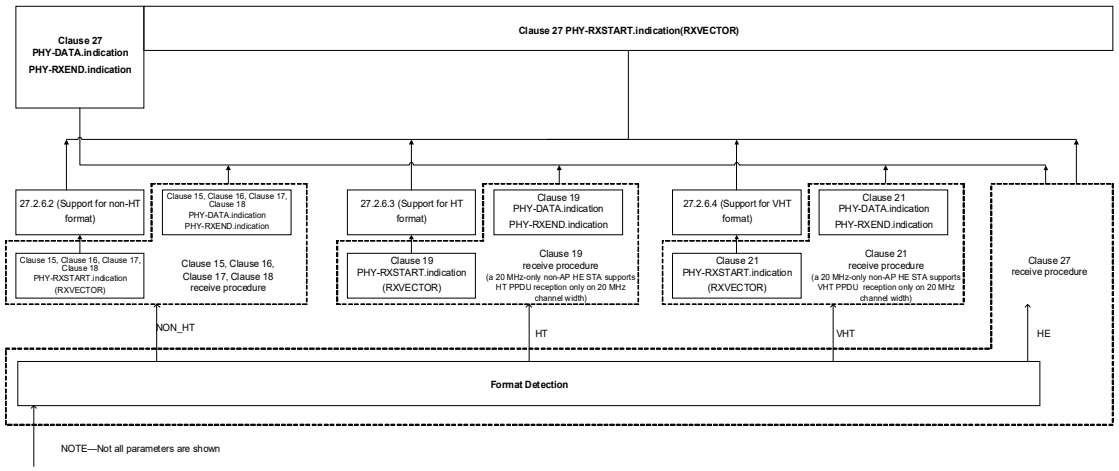


**Figure 27-2—PHY interaction on receive for various PPDU formats(11ax)**

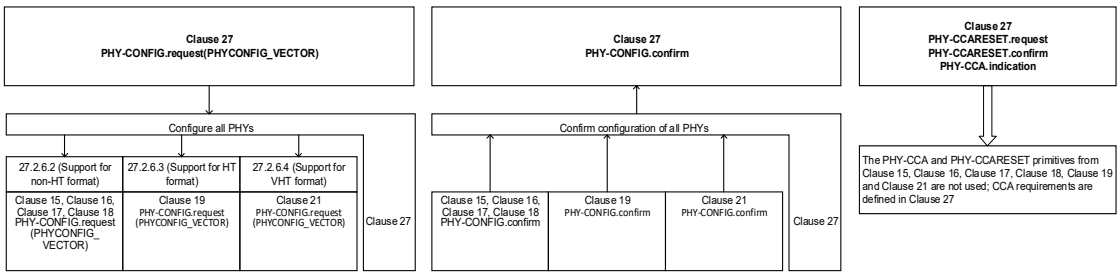


**Figure 27-3—PHY-CONFIG and CCA interaction with various PPDU formats(11ax)**


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parameters according to Table 27-6 (Mapping of the HE PHY parameters for non-HT operation(11ax)). The HE PHY parameters not listed in the table are not present.

**Table 27-6—Mapping of the HE PHY parameters for non-HT operation(11ax)**

| HE PHY parameter | 2.4 GHz operation defined by Clause 15 | 2.4 GHz operation defined by Clause 16 | 2.4 GHz operation defined by Clause 18 | 5 GHz and 6 GHz operation defined by Clause 17 | Parameter list |
|---|---|---|---|---|---|
| L_LENGTH | LENGTH | LENGTH | LENGTH | LENGTH | TXVECTOR/ RXVECTOR |
| L_DATARATE | DATARATE | DATARATE | DATARATE | DATARATE | TXVECTOR/ RXVECTOR |
| TXPWR_LEVEL_INDEX | TXPWR_LEVEL_INDEX | TXPWR_LEVEL_INDEX | TXPWR_LEVEL_INDEX | TXPWR_LEVEL_INDEX | TXVECTOR |
| RSSI | RSSI | RSSI | RSSI | RSSI | RXVECTOR |
| SERVICE | SERVICE | SERVICE | SERVICE | SERVICE | TXVECTOR/ RXVECTOR |
| RCPI | RCPI | RCPI | RCPI | RCPI | RXVECTOR |
| CH_BANDWIDTH_IN_NON_HT | discarded | discarded | CH_BANDWIDTH_IN_NON_HT | CH_BANDWIDTH_IN_NON_HT | TXVECTOR/ RXVECTOR |
| DYN_BANDWIDTH_IN_NON_HT | discarded | discarded | DYN_BANDWIDTH_IN_NON_HT | DYN_BANDWIDTH_IN_NON_HT | TXVECTOR/ RXVECTOR |
| OPERATING_CHANNEL | discarded | discarded | discarded | OPERATING_CHANNEL | PHYCONFIG_VECTOR |

The behavior of the HE PHY on receipt of a PHY-TXSTART.request(TXVECTOR) primitive with the FORMAT parameter equal to NON_HT and the NON_HT_MODULATION parameter equal to NON_HT_DUP_OFDM is defined in 27.3.14 (Non-HT duplicate transmission).

To support the non-HT format, the HE PHY, on receipt of a PHY-CONFIG.request(PHYCONFIG_VECTOR) primitive, behaves as if it were a Clause 15, Clause 16, Clause 17, or Clause 18 PHY that had received a PHY-CONFIG.request(PHYCONFIG_VECTOR) primitive but without the PHYCONFIG_VECTOR parameters CHANNEL_WIDTH, CENTER_FREQUENCY_SEGMENT_0, and CENTER_FREQUENCY_SEGMENT_1.

As defined in 27.3.24 (HE receive procedure), once a PPDU is received and detected as a non-HT PPDU, the behavior of the HE PHY is defined in Clause 15, Clause 16, Clause 17, or Clause 18 depending on the PPDU format. The RXVECTOR parameters from Clause 15, Clause 16, Clause 17, and Clause 18 are mapped to the HE PHY RXVECTOR parameters as defined in Table 27-6 (Mapping of the HE PHY parameters for non-HT operation(11ax)). The HE PHY parameters not listed in the table are not present.

#### 27.2.7.3 Support for HT format

The behavior of an HE PHY on receipt of a PHY-TXSTART.request(TXVECTOR) primitive with the TXVECTOR parameter FORMAT equal to HT_MF or HT_GF is defined in Clause 19 with the following additional requirements:

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— The requirements in 21.3.9.2 (Transmission of HT PPDUs with more than four transmit chains)
— The requirements in 27.3.21.3 (Transmit center frequency and symbol clock frequency tolerance) instead of the requirements in 19.3.18.4 (Transmit center frequency tolerance)

The HE PHY TXVECTOR parameters in Table 27-1 (TXVECTOR and RXVECTOR parameters(#12)(11ax)) are mapped directly to Clause 19 TXVECTOR parameters in Table 19-1 (TXVECTOR and RXVECTOR parameters). The HE PHY parameters not listed in Table 19-1 (TXVECTOR and RXVECTOR parameters) are not present. The PHY shall use a value of CH_OFFSET in the Clause 19 TXVECTOR that is consistent with Table 27-4 (Interpretation of FORMAT, NON_HT_MODULATION, CH_BANDWIDTH, and CH_OFFSET parameters(11ax)). A 20 MHz-only non-AP HE STA supports HT transmission only on 20 MHz channel width.

On receipt of a PHY-CONFIG.request(PHYCONFIG_VECTOR) primitive, the HE PHY behaves, for the purposes of HT PPDU transmission and reception, as if it were a Clause 19 PHY that had received PHY-CONFIG.request(PHYCONFIG_VECTOR) primitive but without the PHYCONFIG_VECTOR parameters CHANNEL_WIDTH, CENTER_FREQUENCY_SEGMENT_0, and CENTER_FREQUENCY_SEGMENT_1 and with the PHYCONFIG_VECTOR parameter SECONDARY_CHANNEL_OFFSET set to SECONDARY_CHANNEL_NONE if dot11CurrentChannelWidth indicates 20 MHz, to SECONDARY_CHANNEL_ABOVE if $f_{P20,idx} < f_{S20,idx}$, or to SECONDARY_CHANNEL_BELOW otherwise.

As defined in 27.3.24 (HE receive procedure), once a PPDU is received and detected as an HT PPDU, the behavior of the HE PHY is defined in Clause 19. The RXVECTOR parameters in Table 19-1 (TXVECTOR and RXVECTOR parameters) are mapped directly to the RXVECTOR parameters in Table 27-1 (TXVECTOR and RXVECTOR parameters(#12)(11ax)). The HE PHY parameters not listed in Table 19-1 (TXVECTOR and RXVECTOR parameters) are not present. A 20 MHz-only non-AP HE STA supports HT reception only on 20 MHz channel width.

#### 27.2.7.4 Support for VHT format

The behavior of an HE PHY on receipt of a PHY-TXSTART.request(TXVECTOR) primitive with the TXVECTOR parameter FORMAT equal to VHT is defined in Clause 21 (Very high throughput (VHT) PHY specification), except that the requirements in 27.3.21.3 (Transmit center frequency and symbol clock frequency tolerance) apply instead of the requirements in 21.3.17.4.2 (Transmit center frequency leakage).

The HE PHY TXVECTOR parameters in Table 27-1 (TXVECTOR and RXVECTOR parameters(#12)(11ax)) are mapped directly to the Clause 21 TXVECTOR parameters in Table 21-1 (TXVECTOR and RXVECTOR parameters(#12)). The HE PHY parameters not listed in Table 21-1 (TXVECTOR and RXVECTOR parameters(#12)) are not present. The 20 MHz-only non-AP HE STA supports VHT transmission only on 20 MHz channel width.

On receipt of a PHY-CONFIG.request(PHYCONFIG_VECTOR) primitive, the HE PHY behaves, for the purposes of VHT PPDU transmission and reception, as if it were a Clause 21 (Very high throughput (VHT) PHY specification) PHY that received the PHY-CONFIG.request(PHYCONFIG_VECTOR) primitive.

As defined in 27.3.24 (HE receive procedure), once a PPDU is received and detected as an VHT PPDU, the behavior of the HE PHY is defined in Clause 21 (Very high throughput (VHT) PHY specification). The RXVECTOR parameters in Table 21-1 (TXVECTOR and RXVECTOR parameters(#12)) are mapped directly to the RXVECTOR parameters in Table 27-1 (TXVECTOR and RXVECTOR parameters(#12)(11ax)). The HE PHY parameters not listed in Table 21-1 (TXVECTOR and RXVECTOR parameters(#12)) are not present. A 20 MHz-only non-AP HE STA supports VHT reception only on 20 MHz channel width.


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# 27.3 HE PHY

## 27.3.1 Introduction

Subclause 27.3 (HE PHY) provides the procedure by which PSDUs are converted to and from transmissions on the wireless medium.

During transmission, a PSDU (in the SU case) or one or more PSDUs (in the MU case) are processed (i.e., scrambled and coded) and appended to the PHY preamble to create the PPDU. At the receiver, the PHY preamble is processed to aid in the detection, demodulation, and delivery of the PSDU.

### 27.3.1.1 MU transmission

The MU transmissions include DL MU transmissions and UL MU transmissions(#2246).

DL MU transmission allows an AP to simultaneously transmit information to more than one non-AP STA. For a DL MU transmission, the AP uses the HE MU PPDU format and employs either DL OFDMA or DL MU-MIMO, or a mixture of both. UL MU transmission allows an AP to simultaneously receive information from more than one non-AP STA. UL MU transmissions are preceded by a triggering frame from the AP. The non-AP STAs transmit using the HE TB PPDU format and employ either UL OFDMA or UL MU-MIMO, or a mixture of both.

The HE PHY supports OFDMA transmissions, in both the DL and the UL where different users can occupy different RUs in a PPDU (see 27.3.10 (Mathematical description of signals)). The transmission within an RU in a PPDU may be a single stream to one user(#2255), multiple streams spatially multiplexed to one user (SU-MIMO), or multiple streams spatially multiplexed to multiple users (MU-MIMO).

NOTE—The VHT PHY supports only full-bandwidth DL MU-MIMO as described in 21.3.11 (SU-MIMO and (#3367)DL MU-MIMO Beamforming).

The HE PHY supports DL MU-MIMO and UL MU-MIMO, for both the full-bandwidth case and the partial-bandwidth case where MU-MIMO is used only on certain RUs in the PPDU. The combination of non-MU-MIMO allocations for some RUs and MU-MIMO allocations on different RUs in one PPDU is also supported.

### 27.3.1.2 OFDMA

OFDMA is an OFDM-based multiple access scheme where different subsets of subcarriers are allocated to different users, and this scheme allows simultaneous data transmission to or from one or more users. In OFDMA, users are allocated different subsets of subcarriers that can change from one PPDU to the next. The difference between OFDM and OFDMA is illustrated in Figure 27-4 (Illustration of OFDM and OFDMA concepts(11ax)). Similar to OFDM, OFDMA employs multiple subcarriers, but the subcarriers are

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divided into several groups where each group is referred to as an RU. With OFDMA, different transmit powers may be applied to different RUs.

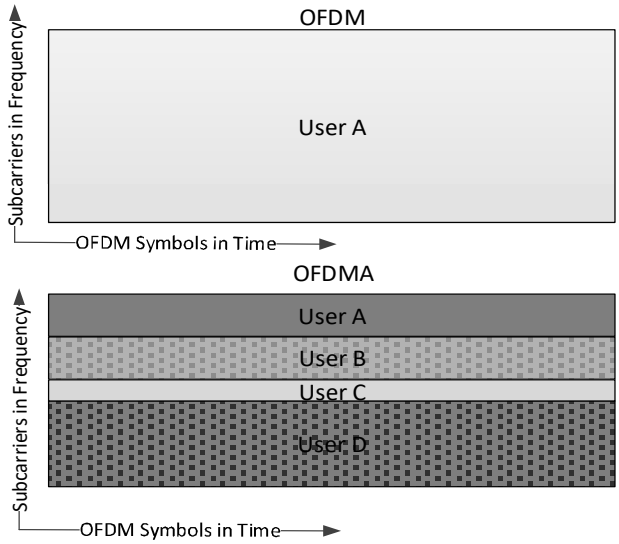


**Figure 27-4—Illustration of OFDM and OFDMA concepts(11ax)**

### 27.3.2 Subcarrier and resource allocation

#### 27.3.2.1 General

An OFDM symbol is constructed of subcarriers, the number of which is a function of the PPDU bandwidth. There are several subcarrier types:

a) Data subcarriers, which are used for data transmission (see 27.3.2.2 (Resource unit, guard, and DC subcarriers)).

b) Pilot subcarriers, which are used for phase information and parameter tracking (see 27.3.2.4 (Pilot subcarriers)).

c) Unused subcarriers, which are not used for either data or pilot transmission. The unused subcarriers are the DC subcarriers (see 27.3.2.2 (Resource unit, guard, and DC subcarriers)), the Guard band subcarriers at the band edges (see 27.3.2.2 (Resource unit, guard, and DC subcarriers)), and the Null subcarriers (see 27.3.2.3 (Null subcarriers)).

The following notations are used to describe the indices for a set of subcarriers:

— $[x1{:}y1]$ represents the set of subcarriers with index $k$ that satisfies $x1 \le k \le y1$.

— $[x1{:}y1, x2{:}y2]$ represents the set of subcarriers with index $k$ that satisfies either $x1 \le k \le y1$ or $x2 \le k \le y2$.

#### 27.3.2.2 Resource unit, guard, and DC subcarriers

The RUs defined for DL and UL transmission are as follows: 26-tone RU, 52-tone RU, 106-tone RU, 242-tone RU, 484-tone RU, 996-tone RU, and 2×996-tone RU.

The 26-tone RU, 52-tone RU, 106-tone RU, and 242-tone RU are used in the 20 MHz, 40 MHz, 80 MHz, 160 MHz, and 80+80 MHz HE MU PPDU format. The 52-tone RU, 106-tone RU and 242-tone RU are used in the 20 MHz, 40 MHz, 80 MHz, 160 MHz, and 80+80 MHz HE TB PPDU format. The 26-tone RU is used in the 20 MHz, 40 MHz, 80 MHz, 160 MHz, and 80+80 MHz HE TB PPDU format unless a STA is


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operating in an operating class for which the behavior limits set listed in Annex E includes the DFS_50_100_Behavior (see 26.5.2.2.1 (General) and 26.5.2.2.3 (Padding for a triggering frame)). The 106-tone RU is used in the HE ER SU PPDU format.

The 484-tone RU is used in the 40 MHz, 80 MHz, 160 MHz, and 80+80 MHz HE MU PPDU and HE TB PPDU formats. The 996-tone RU is used in the 80 MHz, 160 MHz, and 80+80 MHz HE MU PPDU and HE TB PPDU formats. The 2×996-tone RU is used in the 160 MHz and 80+80 MHz HE MU PPDU format and 160 MHz and 80+80 MHz HE TB PPDU format.

The 242-tone and larger RUs are used in the HE SU PPDU format. The 242-tone RU is used in the 20 MHz HE SU PPDU and HE ER SU PPDU formats. The 484-tone RU is used in the 40 MHz HE SU PPDU format. The 996-tone RU is used in the 80 MHz HE SU PPDU format. The 2×996-tone RU is used in the 160 MHz and 80+80 MHz HE SU PPDU formats.

The maximum number of RUs in the 20 MHz, 40 MHz, 80 MHz, 160 MHz, and 80+80 MHz HE PPDU formats is defined in Table 27-7 (Maximum number of RUs for each channel width(11ax)).

**Table 27-7—Maximum number of RUs for each channel width(11ax)**

| RU type | CBW20 | CBW40 | CBW80 | CBW80+80 and CBW160 |
|---|---|---|---|---|
| 26-tone RU | 9 | 18 | 37 | 74 |
| 52-tone RU | 4 | 8 | 16 | 32 |
| 106-tone RU | 2 | 4 | 8 | 16 |
| 242-tone RU | 1 | 2 | 4 | 8 |
| 484-tone RU | N/A | 1 | 2 | 4 |
| 996-tone RU | N/A | N/A | 1 | 2 |
| 2×996 tone RU | N/A | N/A | N/A | 1 |

An HE MU PPDU using OFDMA transmission can carry a mixture of 26-, 52-, 106-, 242-, 484-, and 996-tone RUs.

A 26-tone RU consists of 24 data subcarriers and 2 pilot subcarriers. The positions of the pilots for the 26-tone RU are defined in 27.3.2.4 (Pilot subcarriers). The locations of the 26-tone RUs are fixed as defined in Table 27-8 (Data and pilot subcarrier indices for RUs in a 20 MHz HE PPDU and in a non-OFDMA 20 MHz HE PPDU(11ax)), Table 27-9 (Data and pilot subcarrier indices for RUs in a 40 MHz HE PPDU and

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in a non-OFDMA 40 MHz HE PPDU(11ax)), and Table 27-10 (Data and pilot subcarrier indices for RUs in an 80 MHz HE PPDU and in a non-OFDMA 80 MHz HE PPDU(11ax)).

**Table 27-8—Data and pilot subcarrier indices for RUs in a 20 MHz HE PPDU and in a non-OFDMA 20 MHz HE PPDU(11ax)**

| RU type | RU index and subcarrier range | | | | |
|---|---|---|---|---|---|
| 26-tone RU | RU 1 [–121: –96] | RU 2 [–95: –70] | RU 3 [–68: –43] | RU 4 [–42: –17] | RU 5 [–16: –4, 4: 16] |
| | RU 6 [17: 42] | RU 7 [43: 68] | RU 8 [70: 95] | RU 9 [96: 121] | |
| 52-tone RU | RU 1 [–121: –70] | RU 2 [–68: –17] | RU 3 [17: 68] | RU 4 [70: 121] | |
| 106-tone RU | RU 1 [–122: –17] | | RU 2 [17: 122] | | |
| 242-tone RU | RU 1 [–122: –2, 2:122] | | | | |

NOTE 1—The subcarrier index of 0 corresponds to the DC tone. Negative subcarrier indices correspond to subcarriers with a frequency lower than the DC tone, and positive subcarrier indices correspond to subcarriers with a frequency higher than the DC tone.

NOTE 2—RU 5 is the middle 26-tone RU.

**Table 27-9—Data and pilot subcarrier indices for RUs in a 40 MHz HE PPDU and in a non-OFDMA 40 MHz HE PPDU(11ax)**

| RU type | RU index and subcarrier range | | | | |
|---|---|---|---|---|---|
| 26-tone RU | RU 1 [–243: –218] | RU 2 [–217: –192] | RU 3 [–189: –164] | RU 4 [–163: –138] | RU 5 [–136: –111] |
| | RU 6 [–109: –84] | RU 7 [–83: –58] | RU 8 [–55: –30] | RU 9 [–29: –4] | |
| | RU 10 [4: 29] | RU 11 [30: 55] | RU 12 [58: 83] | RU 13 [84: 109] | RU 14 [111: 136] |
| | RU 15 [138: 163] | RU 16 [164: 189] | RU 17 [192: 217] | RU 18 [218: 243] | |
| 52-tone RU | RU 1 [–243: –192] | RU 2 [–189: –138] | RU 3 [–109: –58] | RU 4 [–55: –4] | |
| | RU 5 [4: 55] | RU 6 [58: 109] | RU 7 [138: 189] | RU 8 [192: 243] | |
| 106-tone RU | RU 1 [–243: –138] | RU 2 [–109: –4] | RU 3 [4: 109] | RU 4 [138: 243] | |
| 242-tone RU | RU 1 [–244: –3] | | RU 2 [3: 244] | | |
| 484-tone RU | RU 1 [–244: –3, 3: 244] | | | | |


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**Table 27-9—Data and pilot subcarrier indices for RUs in a 40 MHz HE PPDU and in a non-OFDMA 40 MHz HE PPDU(11ax) *(continued)***

| RU type | RU index and subcarrier range |
|---|---|
| NOTE—The subcarrier index of 0 corresponds to the DC tone. Negative subcarrier indices correspond to subcarriers with a frequency lower than the DC tone, and positive subcarrier indices correspond to subcarriers with a frequency higher than the DC tone. | |

**Table 27-10—Data and pilot subcarrier indices for RUs in an 80 MHz HE PPDU and in a non-OFDMA 80 MHz HE PPDU(11ax)**

| RU type | RU index and subcarrier range | | | | |
|---|---|---|---|---|---|
| 26-tone RU | RU 1<br>[–499: –474] | RU 2<br>[–473: –448] | RU 3<br>[–445: –420] | RU 4<br>[–419: –394] | RU 5<br>[–392: –367] |
| | RU 6<br>[–365: –340] | RU 7<br>[–339: –314] | RU 8<br>[–311: –286] | RU 9<br>[–285: –260] | |
| | RU 10<br>[–257: –232] | RU 11<br>[–231: –206] | RU 12<br>[–203: –178] | RU 13<br>[–177: –152] | RU 14<br>[–150: –125] |
| | RU 15<br>[–123: –98] | RU 16<br>[–97: –72] | RU 17<br>[–69: –44] | RU 18<br>[–43: –18] | RU 19<br>[–16: –4, 4: 16] |
| | RU 20<br>[18: 43] | RU 21<br>[44: 69] | RU 22<br>[72: 97] | RU 23<br>[98: 123] | RU 24<br>[125: 150] |
| | RU 25<br>[152: 177] | RU 26<br>[178: 203] | RU 27<br>[206: 231] | RU28<br>[232: 257] | |
| | RU 29<br>[260: 285] | RU 30<br>[286: 311] | RU 31<br>[314: 339] | RU 32<br>[340: 365] | RU 33<br>[367: 392] |
| | RU 34<br>[394: 419] | RU 35<br>[420: 445] | RU 36<br>[448: 473] | RU37<br>[474: 499] | |
| 52-tone RU | RU 1<br>[–499: –448] | RU 2<br>[–445: –394] | RU 3<br>[–365: –314] | RU 4<br>[–311: –260] | |
| | RU 5<br>[–257: –206] | RU 6<br>[–203: –152] | RU 7<br>[–123: –72] | RU 8<br>[–69: –18] | |
| | RU 9<br>[18: 69] | RU 10<br>[72: 123] | RU 11<br>[152: 203] | RU 12<br>[206: 257] | |
| | RU 13<br>[260: 311] | RU 14<br>[314: 365] | RU 15<br>[394: 445] | RU 16<br>[448: 499] | |
| 106-tone RU | RU 1<br>[–499: –394] | RU 2<br>[–365: –260] | RU 3<br>[–257: –152] | RU 4<br>[–123: –18] | |
| | RU 5<br>[18: 123] | RU 6<br>[152: 257] | RU 7<br>[260: 365] | RU 8<br>[394: 499] | |
| 242-tone RU | RU 1<br>[–500: –259] | RU 2<br>[–258: –17] | RU 3<br>[17: 258] | RU 4<br>[259: 500] | |
| 484-tone RU | RU 1<br>[–500: –17] | | RU 2<br>[17: 500] | | |

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**Table 27-10—Data and pilot subcarrier indices for RUs in an 80 MHz HE PPDU and in a non-OFDMA 80 MHz HE PPDU(11ax)**

| RU type | RU index and subcarrier range | |
|---|---|---|
| 996-tone RU | RU 1<br>[–500: –3, 3: 500] | |

NOTE 1—The subcarrier index of 0 corresponds to the DC tone. Negative subcarrier indices correspond to subcarriers with a frequency lower than the DC tone, and positive subcarrier indices correspond to subcarriers with a frequency higher than the DC tone.

NOTE 2—RU 19 is the center 26-tone RU.

The data and pilot subcarrier indices for a non-OFDMA 80 MHz HE PPDU are the same as those for a 996-tone RU.

The locations of the 26-tone RUs are shown in Figure 27-5 (RU locations in a 20 MHz HE PPDU(11ax)), Figure 27-6 (RU locations in a 40 MHz HE PPDU(11ax)), and Figure 27-7 (RU locations in an 80 MHz HE PPDU(11ax)) for the 20 MHz, 40 MHz, and 80 MHz HE MU PPDU formats or HE TB PPDU formats using OFDMA transmission, respectively. The same structure as used for the 80 MHz HE MU PPDU formats or HE TB PPDU formats using OFDMA transmission is used for both the primary 80 MHz and secondary 80 MHz channels in the 160 MHz and 80+80 MHz HE MU PPDU or HE TB PPDU formats using OFDMA transmission.

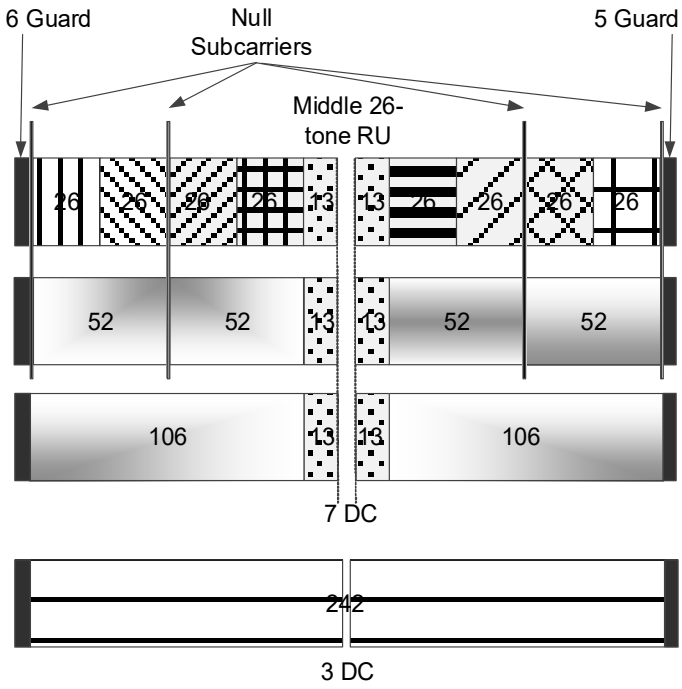


**Figure 27-5—RU locations in a 20 MHz HE PPDU(11ax)**

A 52-tone RU consists of 48 data subcarriers and 4 pilot subcarriers. The positions of the pilots for the 52-tone RU are defined in 27.3.2.4 (Pilot subcarriers). The locations of the 52-tone RUs are fixed as defined in Table 27-8 (Data and pilot subcarrier indices for RUs in a 20 MHz HE PPDU and in a non-OFDMA 20 MHz HE PPDU(11ax)), Table 27-9 (Data and pilot subcarrier indices for RUs in a 40 MHz HE PPDU and


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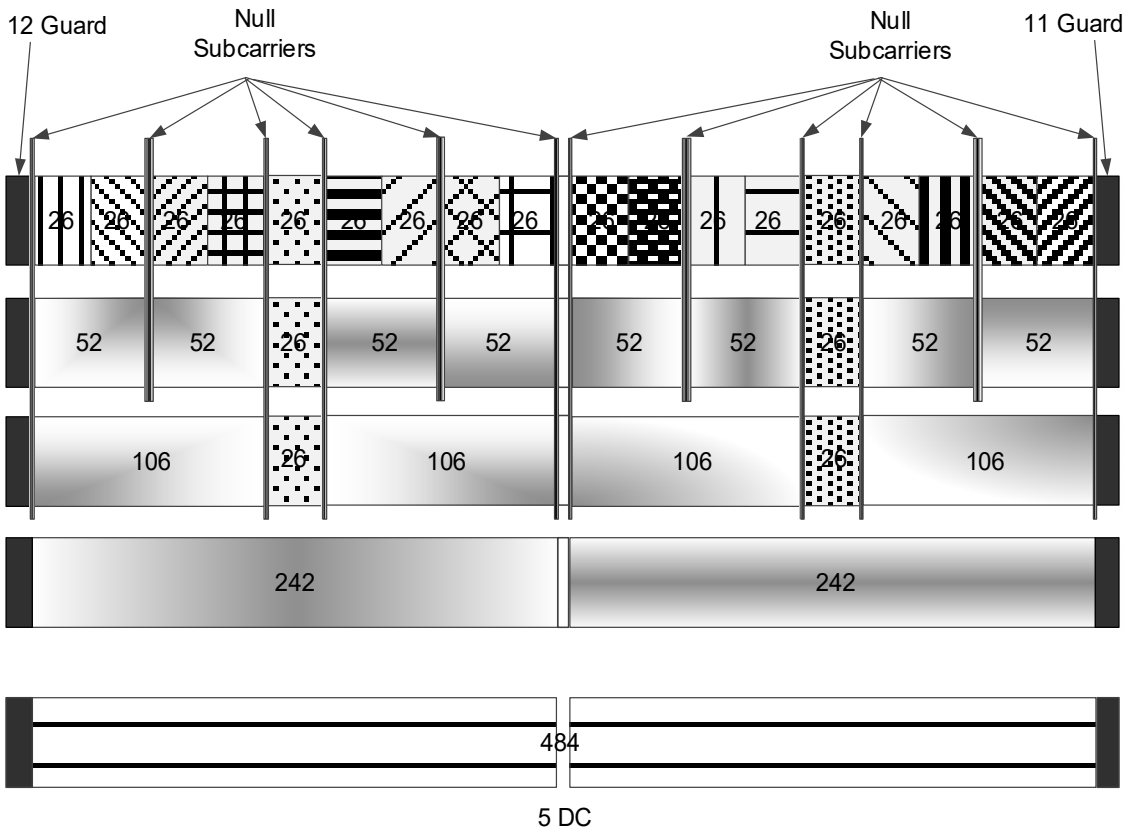


**Figure 27-6—RU locations in a 40 MHz HE PPDU(11ax)**

in a non-OFDMA 40 MHz HE PPDU(11ax)), and Table 27-10 (Data and pilot subcarrier indices for RUs in an 80 MHz HE PPDU and in a non-OFDMA 80 MHz HE PPDU(11ax)) and illustrated in Figure 27-5 (RU locations in a 20 MHz HE PPDU(11ax)), Figure 27-6 (RU locations in a 40 MHz HE PPDU(11ax)), and Figure 27-7 (RU locations in an 80 MHz HE PPDU(11ax)) for the 20 MHz, 40 MHz, and 80 MHz HE MU PPDU formats or HE TB PPDU formats using OFDMA transmission, respectively. The same structure as used in the 80 MHz HE MU PPDU format or HE TB PPDU formats using OFDMA transmission is used for both the Primary 80 MHz and Secondary 80 MHz channels in the 160 MHz and 80+80 MHz HE MU PPDU formats or HE TB PPDU formats using OFDMA transmission.

A 106-tone RU consists of 102 data subcarriers and 4 pilot subcarriers. The positions of the pilots for the 106-tone RU are defined in 27.3.2.4 (Pilot subcarriers). The locations of the 106-tone RUs are fixed as defined in Table 27-8 (Data and pilot subcarrier indices for RUs in a 20 MHz HE PPDU and in a non-OFDMA 20 MHz HE PPDU(11ax)), Table 27-9 (Data and pilot subcarrier indices for RUs in a 40 MHz HE PPDU and in a non-OFDMA 40 MHz HE PPDU(11ax)), and Table 27-10 (Data and pilot subcarrier indices for RUs in an 80 MHz HE PPDU and in a non-OFDMA 80 MHz HE PPDU(11ax)) and illustrated in Figure 27-5 (RU locations in a 20 MHz HE PPDU(11ax)), Figure 27-6 (RU locations in a 40 MHz HE PPDU(11ax)), and Figure 27-7 (RU locations in an 80 MHz HE PPDU(11ax)) for the 20 MHz, 40 MHz, and 80 MHz HE MU PPDU formats or HE TB PPDU formats using OFDMA transmission, respectively. The same structure as used in the 80 MHz HE MU PPDU formats or HE TB PPDU formats using OFDMA transmission is used for both the Primary 80 MHz and Secondary 80 MHz channels in the 160 MHz and 80+80 MHz HE MU PPDU formats or HE TB PPDU formats using OFDMA transmission.

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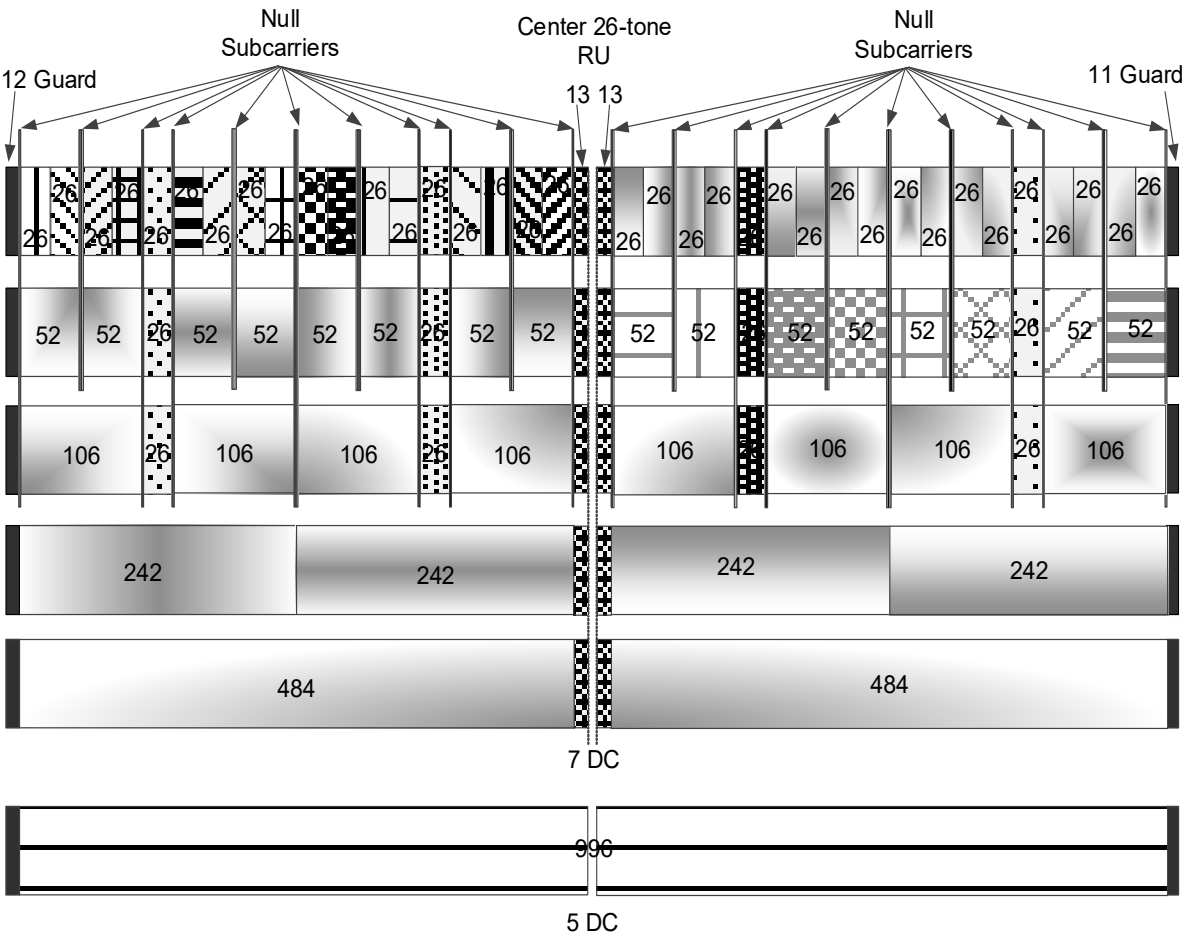


**Figure 27-7—RU locations in an 80 MHz HE PPDU(11ax)**

A 242-tone RU consists of 234 data subcarriers and 8 pilot subcarriers. The positions of pilots for the 242-tone RU are defined in 27.3.2.4 (Pilot subcarriers). The locations of the 242-tone RUs are fixed as defined in Table 27-8 (Data and pilot subcarrier indices for RUs in a 20 MHz HE PPDU and in a non-OFDMA 20 MHz HE PPDU(11ax)), Table 27-9 (Data and pilot subcarrier indices for RUs in a 40 MHz HE PPDU and in a non-OFDMA 40 MHz HE PPDU(11ax)), and Table 27-10 (Data and pilot subcarrier indices for RUs in an 80 MHz HE PPDU and in a non-OFDMA 80 MHz HE PPDU(11ax)) and illustrated in Figure 27-5 (RU locations in a 20 MHz HE PPDU(11ax)), Figure 27-6 (RU locations in a 40 MHz HE PPDU(11ax)), and Figure 27-7 (RU locations in an 80 MHz HE PPDU(11ax)) for the 20 MHz, 40 MHz, and 80 MHz HE PPDU formats, respectively. The same structure as used in the 80 MHz HE PPDU formats is used for both the Primary 80 MHz and Secondary 80 MHz channels in both the Primary 80 MHz and Secondary 80 MHz channels in the 160 MHz and 80+80 MHz HE PPDU formats.

A 484-tone RU consists of 468 data subcarriers and 16 pilot subcarriers. The positions of the pilots for the 484-tone RU are defined in 27.3.2.4 (Pilot subcarriers). The locations of the 484-tone RUs are fixed as defined in Table 27-9 (Data and pilot subcarrier indices for RUs in a 40 MHz HE PPDU and in a non-OFDMA 40 MHz HE PPDU(11ax)) and Table 27-10 (Data and pilot subcarrier indices for RUs in an 80 MHz HE PPDU and in a non-OFDMA 80 MHz HE PPDU(11ax)) and illustrated in Figure 27-6 (RU locations in a 40 MHz HE PPDU(11ax)) and Figure 27-7 (RU locations in an 80 MHz HE PPDU(11ax)) for the 40 MHz and 80 MHz HE PPDU formats. The same structure as used for the 80 MHz HE PPDU formats


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is used for both the Primary 80 MHz and Secondary 80 MHz channels in the 160 MHz and 80+80 MHz HE PPDU formats.

A 996-tone RU consists of 980 data subcarriers and 16 pilot subcarriers. The positions of the pilots for the 996-tone RU are defined in 27.3.2.4 (Pilot subcarriers). The locations of the 996-tone RUs are fixed and located on subcarriers [–1012: –515, –509: –12] and [12: 509, 515: 1012] for each half of the bandwidth, respectively, for the 160 MHz and 80+80 MHz HE PPDU formats.

A 2×996-tone RU consists of two 996-tone RUs, one RU in each of the 80 MHz channels for the 160 MHz and 80+80 MHz HE PPDU formats.

The 20 MHz HE MU PPDU and HE TB PPDU with one or more RUs with less than 242 tones have 7 DC subcarriers located at [–3: 3]. The 20 MHz HE SU PPDU, HE MU PPDU, and HE TB PPDU with a 242-tone RU have 3 DC subcarriers located at [–1: 1]. The 40 MHz HE PPDU has 5 DC subcarriers located at [–2: 2]. The 80 MHz HE MU PPDU and HE TB PPDU with one or more RUs with less than 996 tones have 7 DC subcarriers located at [–3: 3]. The 80 MHz HE SU PPDU, HE MU PPDU, and HE TB PPDU with a 996-tone RU have 5 DC subcarriers located at [–2: 2]. The structure used in the 80 MHz HE PPDU is used for both the Primary 80 MHz and Secondary 80 MHz channels in the 160 MHz and 80+80 MHz HE PPDU. The DC subcarriers are located on subcarriers [–11: 11].

The 20 MHz HE PPDU has 11 guard subcarriers: the 6 lowest frequency subcarriers [–128: –123] and the 5 highest frequency subcarriers [123: 127] as shown in Figure 27-5 (RU locations in a 20 MHz HE PPDU(11ax)). The 40 MHz HE PPDU has 23 guard subcarriers: the 12 lowest frequency subcarriers [–256: –245] and the 11 highest frequency subcarriers [245: 255] as shown in Figure 27-6 (RU locations in a 40 MHz HE PPDU(11ax)). The 80 MHz HE PPDU has 23 guard subcarriers: the 12 lowest frequency subcarriers [–512: –501] and the 11 highest frequency subcarriers [501: 511] as shown in Figure 27-7 (RU locations in an 80 MHz HE PPDU(11ax)). For the 160 MHz and 80+80 MHz HE PPDU, the same number of lowest frequency and highest frequency guard subcarriers as 80 MHz are defined at each edge of the 160 MHz and 80+80 MHz.

### 27.3.2.3 Null subcarriers

There are null subcarriers between the 26-, 52-, and 106-tone RU locations as illustrated in Figure 27-5 (RU locations in a 20 MHz HE PPDU(11ax)), Figure 27-6 (RU locations in a 40 MHz HE PPDU(11ax)), and Figure 27-7 (RU locations in an 80 MHz HE PPDU(11ax)). The null subcarriers are located near the DC or edge tones to provide protection from transmit center frequency leakage, receiver DC offset, and interference from neighboring RUs. The null subcarriers have zero energy. The indices of the null subcarrier are enumerated in Table 27-11 (Null subcarrier indices(11ax)).

**Table 27-11— Null subcarrier indices(11ax)**

| Channel width | RU size | Null subcarrier indices |
|---|---|---|
| 20 MHz | 26, 52 | ± 69, ± 122 |
| | 106 | none |
| | 242 | none |
| 40 MHz | 26, 52 | ± 3, ± 56, ± 57, ± 110, ± 137, ± 190, ± 191, ± 244 |
| | 106 | ± 3, ± 110, ± 137, ± 244 |
| | 242, 484 | none |

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**Table 27-11— Null subcarrier indices(11ax) *(continued)***

| Channel width | RU size | Null subcarrier indices |
|---|---|---|
| 80 MHz | 26, 52 | ± 17, ± 70, ± 71, ± 124, ± 151, ± 204, ± 205, ± 258, ± 259, ± 312, ± 313, ± 366, ± 393, ± 446, ± 447, ± 500 |
| | 106 | ± 17, ± 124, ± 151, ± 258, ± 259, ± 366, ± 393, ± 500 |
| | 242, 484 | none |
| | 996 | none |
| 160 MHz | 26, 52, 106 | {null subcarrier indices in 80 MHz – 512, null subcarrier indices in 80 MHz + 512} |
| | 242, 484, 996, 2×996 | none |

The null subcarriers locations for each 80 MHz frequency segment of an 80+80 MHz HE PPDU shall follow the locations of an 80 MHz HE PPDU.

### 27.3.2.4 Pilot subcarriers

Within the HE modulated fields (see 27.3.10 (Mathematical description of signals)) of an HE PPDU, pilot subcarriers are present in the Data field and may be present in the HE-LTF field (see 27.3.11.10 (HE-LTF field)). The pilot subcarrier indices for the Data field OFDM symbols are defined in 27.3.12.13 (Pilot subcarriers).

One of three HE-LTF types is used in the HE-LTF field of an HE PPDU: 1x HE-LTF, 2x HE-LTF, or 4x HE-LTF (see 27.3.11.10 (HE-LTF field)). If pilot subcarriers are present in the HE-LTF field of an HE PPDU, then, for a 4x HE-LTF and 2x HE-LTF, the pilot subcarrier locations in the HE-LTF field are the same as the pilot subcarrier locations in the Data field. For a 1x HE-LTF, the pilot subcarrier locations in the HE-LTF field are the pilot subcarriers locations in the Data field that are multiples of 4.

### 27.3.2.5 Resource indication and User identification in an HE MU PPDU

An AP that transmits an HE MU PPDU shall set the UL/DL field in the HE-SIG-A field to 0.

The HE-SIG-B field consists of one or two HE-SIG-B content channels, with each HE-SIG-B content channel conveying user allocation for one or more 20 MHz subchannels. A 20 MHz HE MU PPDU has one HE-SIG-B content channel, while an HE MU PPDU with greater than 20 MHz PPDU bandwidth has two HE-SIG-B content channels.

A full-bandwidth MU-MIMO transmission using the HE MU PPDU format shall have a value of 1 for the HE-SIG-B Compression field in the HE-SIG-A field, where the Common field in the HE-SIG-B field is not present, the HE modulated fields of the PPDU consist of one RU that spans the entire PPDU bandwidth, and the preamble is not punctured. The number of users in the MU-MIMO group is indicated in the Number Of HE-SIG-B Symbols Or MU-MIMO Users field in the HE-SIG-A field. The allocated spatial streams for each user and the total number of spatial streams are indicated in the Spatial Configuration field of the User field in the HE-SIG-B field containing the STA-ID of the designated MU-MIMO STA as defined in Table 27-31 (Spatial Configuration subfield encoding(11ax)).

If the value of the HE-SIG-B Compression field in the HE-SIG-A field is 0, then the RU Allocation subfield in the Common field in each HE-SIG-B content channel indicates the combination of RUs in the current


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PPDU and the number of User fields included in the corresponding HE-SIG-B content channel for each RU. See 27.3.11.8.2 (HE-SIG-B content channels) for a description of the HE-SIG-B content channels.

If there is only one User field (see Table 27-29 (User field format for non-MU-MIMO allocation(11ax))) for an RU in the HE-SIG-B content channel, then the number of spatial streams for the user in the RU is indicated by the NSTS field in the User field.

If there is more than one User field (see Table 27-30 (User field format for MU-MIMO allocation(11ax))) for an RU in the HE-SIG-B content channel, then the number of allocated spatial streams for each user in the RU is indicated by the Spatial Configuration field of the User field in the HE-SIG-B field. Note that, if the value of the HE-SIG-B Compression field in the HE-SIG-A field is 0, for an RU with 484 or more subcarriers and having two or more intended users, the User fields corresponding to the RU may be split between two HE-SIG-B content channels. In this case, the total number of users and the total number of spatial streams in the RU are the sum of the number of users and number of spatial streams per user, respectively, indicated in both HE-SIG-B content channels. For PPDU bandwidths greater than 20 MHz, the split is an equitable split for full-bandwidth DL MU-MIMO (see 27.3.11.8.4 (User Specific field)) or a dynamic split when the HE-SIG-B Compression field in the HE-SIG-A field is equal to 0 (see 27.3.11.8.3 (Common field)).

In each HE-SIG-B content channel, the User fields are ordered so that, together with the HE-SIG-B Compression field in the HE-SIG-A field and the Common field in the HE-SIG-B field (if present), the RU location and spatial streams allocated to each user can be identified (see 27.3.11.8.4 (User Specific field)). If the UL/DL field in the HE-SIG-A field is(M118) 0, the STA-ID field in each User field indicates the intended recipient user of the corresponding spatial streams and the RU. Otherwise, the STA-ID field indicates the STA that transmits the PPDU in the corresponding spatial streams and the RU.

HE-LTF symbols in the DL HE MU PPDU are used to measure the channel for the space-time streams intended for the STA and can also be used to measure the channel for the interfering space-time streams. To successfully demodulate the space-time streams intended for the STA, it is recommended that the STA use the channel knowledge for all space-time streams to reduce the effect of space-time streams allocated to other users.

If a STA is included as a member of the MU-MIMO group in RU $r$, its corresponding $N_{STS,r,u}$ contained in the User field in the HE-SIG-B field for user $u$ shall not be zero. If a STA determines that it is not a member of the MU-MIMO group in RU $r$, then the STA may elect not to process RU $r$ in the remainder of the PPDU.

### 27.3.2.6 Resource allocation for an HE TB PPDU

UL MU transmissions are preceded by a triggering frame from the AP. The triggering frame indicates the parameters, such as the duration of the HE TB PPDU, RU allocation, target RSSI, and HE-MCS (see 9.3.1.22 (Trigger frame format(11ax)), 9.2.4.7.1 (TRS Control), and 26.5.2.3 (Non-AP STA behavior for UL MU operation)), required to transmit an HE TB PPDU.

The Trigger frame indicates whether the UL MU transmission following it uses HE single stream pilot HE-LTF mode or HE masked HE-LTF sequence mode if the HE-LTF type of the HE TB PPDU is 2x HE-LTF or 4x HE-LTF. HE no pilot HE-LTF mode is used if the HE-LTF type of the HE TB PPDU is 1x HE-LTF. If HE single stream pilot HE-LTF mode is used, no masking is applied to the HE-LTF. HE single stream pilot HE-LTF mode is used for any UL OFDMA transmission, including UL OFDMA with MU-MIMO transmissions.

### 27.3.2.7 20 MHz operating non-AP HE STAs

A 20 MHz-only non-AP HE STA is a non-AP HE STA that indicates support for only 20 MHz channel width for the frequency band in which it is operating using the Supported Channel Width Set subfield in the

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HE PHY Capabilities Information field in the HE Capabilities element that it transmits (see 9.4.2.247.3 (HE PHY Capabilities Information field)). A 20 MHz operating non-AP HE STA is a non-AP HE STA that is operating in 20 MHz channel width mode, such as a 20 MHz-only non-AP HE STA or an HE STA that reduced its operating channel width to 20 MHz using operating mode indication (OMI).

A 20 MHz operating non-AP HE STA shall operate in the primary 20 MHz channel, except when the 20 MHz operating non-AP HE STA sets dot11HESubchannelSelectiveTransmissionImplemented equal to true. In this case, the 20 MHz operating non-AP HE STA may operate in any 20 MHz channel within the BSS bandwidth by following the procedure in 26.8.7 (HE subchannel selective transmission).

An HE AP operating in the 5 GHz or 6 GHz band shall be able to interoperate with non-AP HE STAs, regardless of the indicated value of B1 in the Supported Channel Width Set subfield in the HE PHY Capabilities Information field in the HE Capabilities element (see 9.4.2.247.3 (HE PHY Capabilities Information field)).

A 20 MHz operating non-AP HE STA shall support tone mapping of 26-tone RU, 52-tone RU, 106-tone RU, and 242-tone RU for a 20 MHz HE PPDU (see Table 27-8 (Data and pilot subcarrier indices for RUs in a 20 MHz HE PPDU and in a non-OFDMA 20 MHz HE PPDU(11ax))) in the 2.4 GHz, 5 GHz, and 6 GHz frequency bands.

A 20 MHz operating non-AP HE STA indicates support for tone mapping of 26-tone RU, 52-tone RU, and 106-tone RU for a 40 MHz HE PPDU (see Table 27-9 (Data and pilot subcarrier indices for RUs in a 40 MHz HE PPDU and in a non-OFDMA 40 MHz HE PPDU(11ax))) in the 2.4 GHz band using the 20 MHz In 40 MHz HE PPDU In 2.4 GHz Band subfield in the HE PHY Capabilities Information field in the HE Capabilities element (see 9.4.2.247.3 (HE PHY Capabilities Information field)), with the exception of RUs that are restricted from operation as specified in 27.3.2.8 (RU restrictions for 20 MHz operation).

A 20 MHz operating non-AP HE STA indicates support for tone mapping of 26-tone RU, 52-tone RU, and 106-tone RU for 80+80 MHz PPDU and 160 MHz HE PPDUs using the 20 MHz In 160/80+80 MHz HE PPDU subfield in the HE PHY Capabilities Information field in the HE Capabilities element (see 9.4.2.247.3 (HE PHY Capabilities Information field)), with the exception of RUs that are restricted from operation as specified in 27.3.2.8 (RU restrictions for 20 MHz operation).

A 20 MHz operating non-AP HE STA may support tone mapping of 242-tone RU for the reception of a 40 MHz HE MU PPDU (see Table 27-9 (Data and pilot subcarrier indices for RUs in a 40 MHz HE PPDU and in a non-OFDMA 40 MHz HE PPDU(11ax))) in the 2.4 GHz, 5 GHz, and 6 GHz bands and 80 MHz, 80+80 MHz, and 160 MHz HE MU PPDUs (see Table 27-10 (Data and pilot subcarrier indices for RUs in an 80 MHz HE PPDU and in a non-OFDMA 80 MHz HE PPDU(11ax))) in the 5 GHz and 6 GHz bands. This support is indicated in the Supported Channel Width Set subfield in the HE PHY Capabilities Information field in the HE Capabilities element (see 9.4.2.247.3 (HE PHY Capabilities Information field)).

### 27.3.2.8 RU restrictions for 20 MHz operation

If a 20 MHz operating non-AP HE STA is the receiver of a 40 MHz, 80 MHz, 80+80 MHz, or 160 MHz HE MU PPDU or the transmitter of a 40 MHz, 80 MHz, 80+80 MHz, or 160 MHz HE TB PPDU, then the RU tone mapping in 20 MHz is not aligned with the 40 MHz, 80 MHz, 80+80 MHz, or 160 MHz RU tone mapping (see 27.3.2.2 (Resource unit, guard, and DC subcarriers)).

An AP shall not assign the following RUs to a 20 MHz operating non-AP HE STA where the RU index is defined in Table 27-9 (Data and pilot subcarrier indices for RUs in a 40 MHz HE PPDU and in a non-OFDMA 40 MHz HE PPDU(11ax)):

— 26-tone RU 5 and 14 of a 40 MHz HE MU PPDU and HE TB PPDU


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An AP shall not assign the following RUs to a 20 MHz operating non-AP HE STA where the RU index is defined in Table 27-10 (Data and pilot subcarrier indices for RUs in an 80 MHz HE PPDU and in a non-OFDMA 80 MHz HE PPDU(11ax)):

- 26-tone RU 5, 10, 14, 19, 24, 28, and 33 of an 80 MHz HE MU PPDU and HE TB PPDU
- 26-tone RU 5, 10, 14, 19, 24, 28, and 33 of the lower 80 MHz of an 80+80 MHz and 160 MHz HE MU PPDU and HE TB PPDU
- 26-tone RU 5, 10, 14, 19, 24, 28, and 33 of the upper 80 MHz of an 80+80 MHz HE MU PPDU and HE TB PPDU
- 52-tone RU 5 and 12 of an 80 MHz HE MU PPDU and HE TB PPDU
- 52-tone RU 5 and 12 of the lower 80 MHz of an 80+80 MHz and 160 MHz HE MU PPDU and HE TB PPDU
- 52-tone RU 5 and 12 of the upper 80 MHz of an 80+80 MHz HE MU PPDU and HE TB PPDU
- 106-tone RU 3 and 6 of an 80 MHz HE MU PPDU and HE TB PPDU
- 106-tone RU 3 and 6 of the lower 80 MHz of an 80+80 MHz and 160 MHz HE MU PPDU and HE TB PPDU
- 106-tone RU 3 and 6 of the upper 80 MHz of an 80+80 MHz HE MU PPDU and HE TB PPDU

#### 27.3.2.9 80 MHz operating non-AP HE STAs

An HE AP shall not allocate an RU in a 160 MHz or 80+80 MHz HE MU or HE TB PPDU to an 80 MHz operating non-AP HE STA if the non-AP STA has set the 80 MHz In 160/80+80 MHz HE PPDU subfield in the HE PHY Capabilities Information field in the HE Capabilities element to 0.

An HE AP shall not allocate an RU outside of the primary 80 MHz in a 160 MHz or 80+80 MHz HE MU or HE TB PPDU to an 80 MHz operating non-AP HE STA if the non-AP STA has set the HE Subchannel Selective Transmission Support subfield in the HE MAC Capabilities Information field in the HE Capabilities element to 0.

An HE AP shall not allocate an RU outside of the primary 80 MHz in a 160 MHz or 80+80 MHz HE MU or HE TB PPDU to an 80 MHz operating non-AP HE STA if the non-AP STA has set the HE Subchannel Selective Transmission Support subfield in the HE MAC Capabilities Information field in the HE Capabilities element to 1 but has not set up SST operation on the secondary 80 MHz channel with the HE AP.

### 27.3.3 MU-MIMO

#### 27.3.3.1 DL MU-MIMO

##### 27.3.3.1.1 Supported RU sizes in DL MU-MIMO

A STA that sets the Partial Bandwidth DL MU-MIMO subfield of the HE PHY Capabilities Information field in the HE Capabilities element that it transmits to 1 shall support receiving an RU in an HE MU PPDU where MU-MIMO is employed in the RU, the RU size is greater than or equal to 106 tones, and the RU does not span the entire PPDU bandwidth.

##### 27.3.3.1.2 Maximum number of spatial streams in an HE MU PPDU

An HE STA shall support the reception of DL MU-MIMO transmissions on full bandwidth with a maximum number of space-time streams (per user) that is the minimum of 4 and the maximum number of space-time streams supported for reception of HE SU PPDUs. The maximum number of space-time streams supported

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for reception of HE SU PPDUs is indicated for various bandwidths in the Supported HE-MCS and NSS Set field in the HE Capabilities element.

For transmissions using bandwidth less than or equal to 80 MHz, an HE STA shall support reception of DL MU-MIMO transmissions on full bandwidth with the total number of space-time streams (across all users) up to the value indicated by the Beamformee STS $\leq$ 80 MHz subfield in the HE PHY Capabilities Information field in the HE Capabilities element. For transmissions using bandwidth greater than 80 MHz, an HE STA shall support reception of DL MU-MIMO transmissions on full bandwidth with the total number of space-time streams (across all users) up to the value indicated by the Beamformee STS > 80 MHz subfield in the HE PHY Capabilities Information field in the HE Capabilities element.

An HE AP that is capable of transmitting 4 or more space-time streams shall support DL MU-MIMO transmissions on full bandwidth.

All of the aforementioned requirements in this subclause on the per user and total number of space-time-streams are also applicable to an MU-MIMO transmission on an RU in an HE MU PPDU where the RU does not span the entire PPDU bandwidth.

#### 27.3.3.2 UL MU-MIMO

##### 27.3.3.2.1 Introduction

UL MU-MIMO is a technique to allow multiple STAs to transmit simultaneously over the same frequency resource to the receiver. The concept is very similar to SU-MIMO where multiple space-time streams are transmitted simultaneously over the same frequency resource utilizing spatial multiplexing through multiple antennas at the transmitter and receiver. The key difference from SU-MIMO is that in UL MU-MIMO, the transmitted streams originate from multiple STAs.

##### 27.3.3.2.2 Supported RU sizes in UL MU-MIMO

An AP that sets the Partial Bandwidth UL MU-MIMO subfield of the HE PHY Capabilities Information field in the HE Capabilities element that it transmits to 1 shall support receiving an RU in an HE TB PPDU where MU-MIMO is employed in the RU, the RU size is greater than or equal to 106 tones, and the RU does not span the entire PPDU bandwidth.

A non-AP STA that sets the Partial Bandwidth UL MU-MIMO subfield of the HE PHY Capabilities Information field in the HE Capabilities element that it transmits to 1 shall support transmitting an RU in an HE TB PPDU where UL MU-MIMO is employed in the RU, the RU size is greater than or equal to 106 tones, and the RU does not span the entire PPDU bandwidth.

A STA that sets the Partial Bandwidth UL MU-MIMO subfield to 1 shall set the Full Bandwidth UL MU-MIMO subfield in the HE PHY Capabilities Information field to 1.

##### 27.3.3.2.3 MU-MIMO HE-LTF modeSupported RU sizes in UL MU-MIMO

A non-AP STA that sets the Full Bandwidth UL MU-MIMO subfield of the HE PHY Capabilities Information field in the HE Capabilities element it transmits to 1 shall support both the HE single stream pilot HE-LTF mode and the HE masked HE-LTF sequence mode as defined in Equation (27-59) for the transmission of an HE TB PPDU with one RU spanning the entire PPDU bandwidth and the RU using MU-MIMO.

An AP that sets the Partial Bandwidth UL MU-MIMO subfield of the HE PHY Capabilities Information field in the HE Capabilities element it transmits to 1 shall support receiving HE TB PPDUs using the HE


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single stream pilot HE-LTF mode if the HE TB PPDUs use MU-MIMO in an RU that does not span the entire PPDU bandwidth.

A non-AP STA that sets the Partial Bandwidth UL MU-MIMO subfield of the HE PHY Capabilities Information field in the HE Capabilities element it transmits to 1 shall support transmitting an HE TB PPDU using the HE single stream pilot HE-LTF mode if the HE TB PPDU uses MU-MIMO in an RU that does not span the entire PPDU bandwidth.

#### 27.3.3.2.4 Maximum number of spatial streams in UL MU-MIMO

A non-AP STA that supports UL MU-MIMO shall support transmitting an HE TB PPDU using MU-MIMO where

— The number of spatial streams allocated to the non-AP STA ranges from 1 to *N*, where *N* is the smaller of 4 and the maximum number of spatial streams supported by the non-AP STA for transmitting HE SU PPDUs.

— The number of total spatial streams (summed over all users) is less than or equal to 8.

The maximum number of spatial streams supported by a STA for the transmission of an HE SU PPDU is indicated in the Supported HE-MCS And NSS Set field in the HE Capabilities element.

All the requirements in this subclause on the per user and total number of spatial streams are applicable to both full-bandwidth and partial-bandwidth MU-MIMO.

### 27.3.4 HE PPDU formats

Four HE PPDU formats are defined: HE SU PPDU, HE MU PPDU, HE ER SU PPDU, and HE TB PPDU. The HE sounding NDP (11az)and HE Ranging NDP are variants of the HE SU PPDU and are defined in 27.3.17 (HE sounding NDP) and 27.3.19.1 (HE Ranging NDP(11az)), respectively. The HE NDP TB PPDU feedback and the HE TB Ranging NDP are variants of the HE TB PPDU and defined in 27.3.18 (HE TB feedback NDP) and 27.3.19.2 (HE TB Ranging NDP(11az)), respectively.

NOTE—The HE ER SU PPDU is not a variant of the HE SU PPDU. Requirements related to HE SU PPDUs and HE ER SU PPDUs are specified separately.

The format of the HE SU PPDU is defined as in Figure 27-8 (HE SU PPDU format(11ax)). This PPDU format is used for SU transmission, and in this format, the HE-SIG-A field is not repeated.

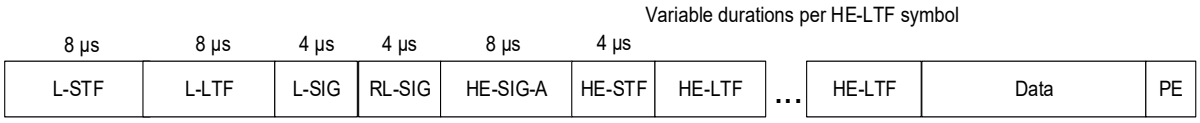


**Figure 27-8—HE SU PPDU format(11ax)**

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The format of the HE MU PPDU is defined as in Figure 27-9 (HE MU PPDU format(11ax)). This format is used for transmission to one or more users if the PPDU is not a response of a Trigger frame. In the HE MU PPDU, the HE-SIG-A field is not repeated. The HE-SIG-B field is present in this format.

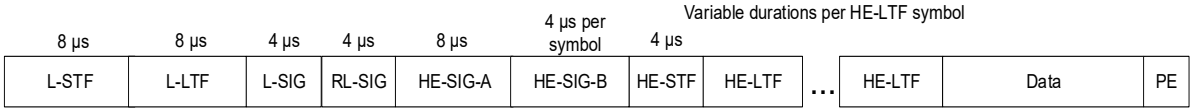


**Figure 27-9—HE MU PPDU format(11ax)**

The format of the HE ER SU PPDU is defined as in Figure 27-10 (HE ER SU PPDU format(11ax)). This format is used for SU transmission, and in this format, the HE-SIG-A field is twice as long as the HE-SIG-A field in other HE PPDU formats.

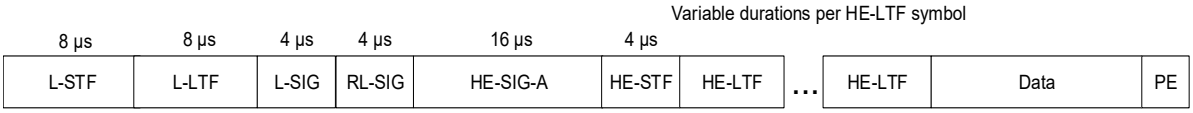


**Figure 27-10—HE ER SU PPDU format(11ax)**

The format of the HE TB PPDU is defined as in Figure 27-11 (HE TB PPDU format(11ax)). This format is used for a transmission that is a response to a triggering frame from an AP.

The format of the HE TB PPDU is the same as the HE SU PPDU, except that the duration of the HE-STF field in the HE TB PPDU is twice the duration of the HE-STF field in the HE SU PPDU.

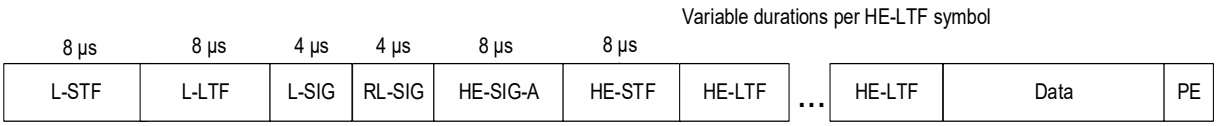


**Figure 27-11—HE TB PPDU format(11ax)**

The fields of the HE PPDU formats are summarized in Table 27-12 (HE PPDU fields(11ax)).

**Table 27-12—HE PPDU fields(11ax)**

| Field | Description |
|---|---|
| L-STF | Non-HT Short Training field |
| L-LTF | Non-HT Long Training field |
| L-SIG | Non-HT SIGNAL field |
| RL-SIG | Repeated Non-HT SIGNAL field |
| HE-SIG-A | HE SIGNAL A field |
| HE-SIG-B | HE SIGNAL B field |
| HE-STF | HE Short Training field |


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**Table 27-12—HE PPDU fields(11ax) *(continued)***

| Field | Description |
|---|---|
| HE-LTF | HE Long Training field |
| Data | The Data field carrying the PSDU(s) |
| PE | Packet extension field |

The RL-SIG, HE-SIG-A, HE-STF, HE-LTF, and PE fields are present in all HE PPDU formats. The HE-SIG-B field is present only in the HE MU PPDU. The PE field is defined in 27.3.13 (Packet extension).

The L-STF, L-LTF, L-SIG, RL-SIG, HE-SIG-A, and HE-SIG-B fields are referred to as *pre-HE modulated fields*, while the HE-STF, HE-LTF, Data, and PE fields are referred to as *HE modulated fields*.

In the HE TB PPDU, the pre-HE modulated fields are sent only on the 20 MHz channels where the STA's HE modulated fields are located. If the HE modulated fields are located in more than one 20 MHz channel, the pre-HE modulated fields are duplicated over the multiple 20 MHz channels. Figure 27-12 (Number of 20 MHz channels that need to be modulated for the pre-HE modulated fields for each RU size and location in an HE TB PPDU(11ax)(#2371)) shows how many 20 MHz channels need to be modulated for the pre-HE modulated fields for each RU size and location in an HE TB PPDU.

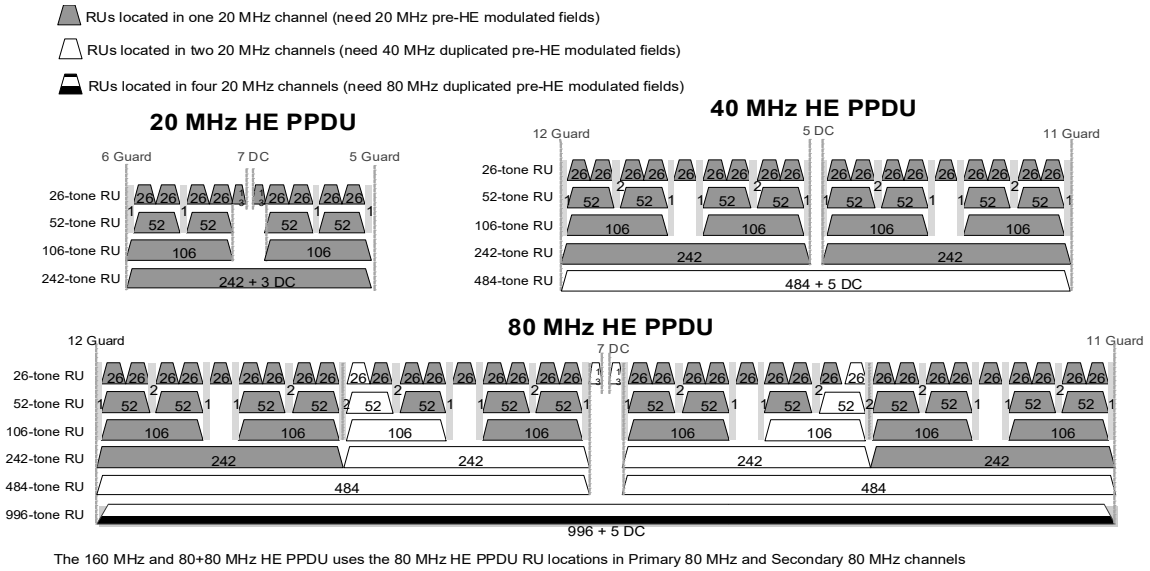


**Figure 27-12—Number of 20 MHz channels that need to be modulated for the pre-HE modulated fields for each RU size and location in an HE TB PPDU(11ax)(#2371)**

A PPDU transmitted with the TXVECTOR parameter NO_SIG_EXTN set to false is followed by a period of duration aSignalExtension without transmission. See 10.3.8 (Signal extension).

A signal extension shall be present in a transmitted PPDU if the TXVECTOR parameter NO_SIG_EXTN is false and one of the following conditions apply:

— The TXVECVTOR parameter FORMAT is HE, HT_MF or HT_GF

— The TXVECTOR parameter FORMAT is NON_HT and the TXVECTOR parameter NON_HT_MODULATION is ERP-OFDM or NON_HT_DUP_OFDM

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A signal extension shall be assumed to be present (for the purpose of timing PHY-RXEND.indication and PHY-CCA.indication primitives, as described below in this subclause and in 27.3.24 (HE receive procedure)) in a received PPDU if one of the following conditions apply:

— The RXVECTOR parameter FORMAT is HE, HT_MF or HT_GF

— The RXVECTOR parameter FORMAT is NON_HT and the RXVECTOR parameter NON_HT_MODULATION is ERP-OFDM or NON_HT_DUP_OFDM

A PPDU containing a signal extension is called a signal extended PPDU. When transmitting a signal extended PPDU, the PHY-TXEND.indication primitive shall be emitted a period of aSignalExtension after the end of the actual ending time of the PPDU. When receiving a signal extended PPDU, the PHY-RXEND.indication primitive shall be emitted a period of aSignalExtension after the end of the actual ending time of the PPDU.

### 27.3.5 Transmitter block diagram

The generation of each field in an HE PPDU uses many of the following blocks:

a) pre-FEC PHY padding
b) Scrambler
c) FEC (BCC or LDPC) encoders
d) post-FEC PHY padding
e) Stream parser
f) Segment parser (for contiguous 160 MHz and noncontiguous 80+80 MHz transmissions)
g) BCC interleaver
h) Constellation mapper
i) DCM tone mapper
j) Pilot insertion
k) Replication over multiple 20 MHz (for BW > 20 MHz)
l) Multiplication by 1st column of $P_{HE\text{-}LTF}$
m) LDPC tone mapper
n) Segment deparser
o) Space time block code (STBC) encoder for one spatial stream
p) Cyclic shift diversity (CSD) per STS insertion
q) Spatial mapper
r) Frequency mapping
s) Inverse discrete Fourier transform (IDFT)
t) Cyclic shift diversity (CSD) per chain insertion
u) Guard interval (GI) insertion
v) Windowing

Example transmitter block diagrams are shown in Figure 27-13 (Transmitter block diagram for L-SIG, RL-SIG, and HE-SIG-A fields for an HE SU PPDU and HE ER SU PPDU if Beam Change subfield is 1(11ax)) to Figure 27-22 (Transmitter block diagram for the Data field of an HE SU PPDU in 80+80 MHz with LDPC encoding(11ax)). The actual structure of the transmitter is implementation dependent.


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In particular, Figure 27-13 (Transmitter block diagram for L-SIG, RL-SIG, and HE-SIG-A fields for an HE SU PPDU and HE ER SU PPDU if Beam Change subfield is 1(11ax)) shows the transmit process for the L-SIG, RL-SIG, and HE-SIG-A fields of an HE PPDU using one frequency segment when the Beam Change subfield in the HE-SIG-A field is 1. These transmit blocks are also used to generate the L-STF and L-LTF fields of the HE PPDU when the Beam Change subfield in the HE-SIG-A field is 1, with the following exceptions:

— The BCC encoder and interleaver and the constellation mapper are not used when generating the L-STF and L-LTF fields.

— The BCC interleaver is not applied in the 2nd and the 4th OFDM symbols of the HE-SIG-A field in the HE ER SU PPDU.

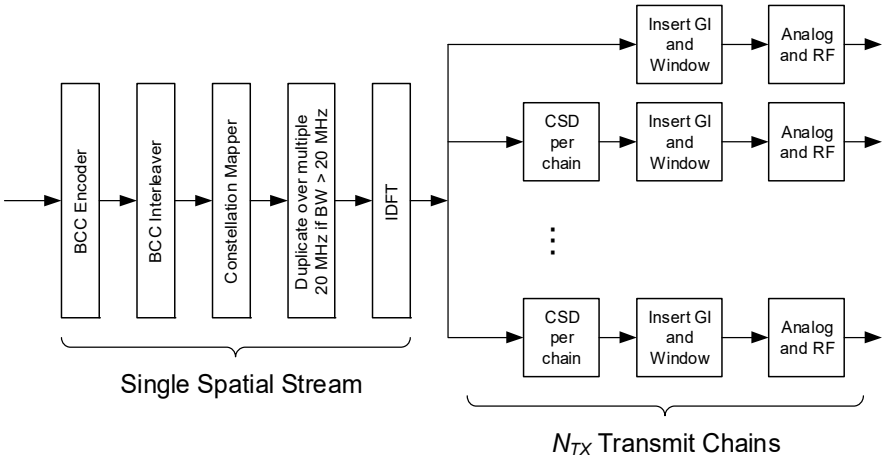


**Figure 27-13—Transmitter block diagram for L-SIG, RL-SIG, and HE-SIG-A fields for an HE SU PPDU and HE ER SU PPDU if Beam Change subfield is 1(11ax)**

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Figure 27-14 (Transmitter block diagram for L-SIG, RL-SIG, and HE-SIG-A fields for an HE SU PPDU and HE ER SU PPDU if Beam Change subfield is 0(11ax)) shows the transmit process for the L-SIG, RL-SIG, and HE-SIG-A fields of an HE PPDU using one frequency segment when the Beam Change subfield in the HE-SIG-A field is 0. These transmit blocks are also used to generate the L-STF and L-LTF fields of the HE PPDU if the Beam Change subfield in the HE-SIG-A field is 0, with the following exceptions:

— The BCC encoder and interleaver and the constellation mapper are not used when generating the L-STF and L-LTF fields.

— The BCC interleaver is not applied in the 2nd and the 4th OFDM symbols of the HE-SIG-A field in the HE ER SU PPDU.

NOTE—For an HE MU PPDU, the duplication on 20 MHz channels is subject to the availability of 20 MHz channels in the case of preamble puncturing.

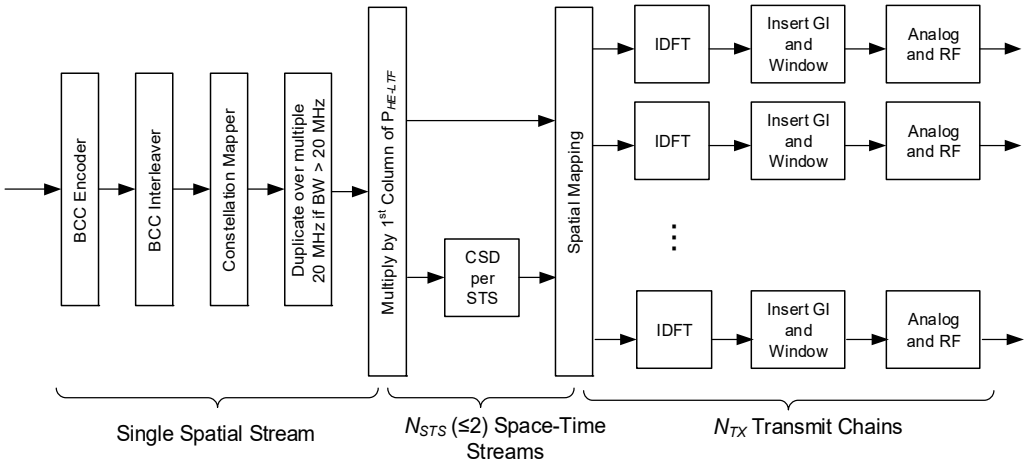


**Figure 27-14—Transmitter block diagram for L-SIG, RL-SIG, and HE-SIG-A fields for an HE SU PPDU and HE ER SU PPDU if Beam Change subfield is 0(11ax)**


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Figure 27-15 (Transmitter block diagram for L-SIG, RL-SIG, and HE-SIG-A fields of an HE TB PPDU(11ax)) shows the transmit process for the L-SIG, RL-SIG, and HE-SIG-A fields of an HE TB PPDU using one frequency segment. In the HE TB PPDU, the transmission of the pre-HE modulated fields refers to the description in 27.3.4 (HE PPDU formats) and is also shown in Figure 27-15 (Transmitter block diagram for L-SIG, RL-SIG, and HE-SIG-A fields of an HE TB PPDU(11ax)). The BCC encoder and interleaver are not used when generating the L-STF and L-LTF fields.

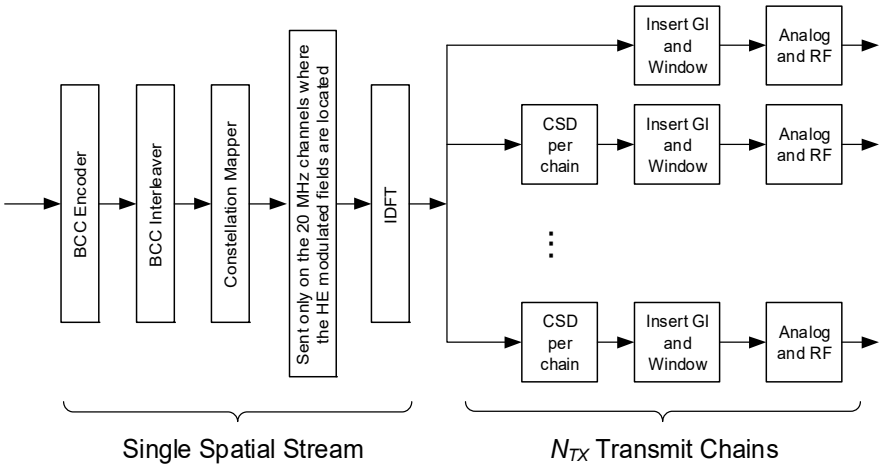


**Figure 27-15—Transmitter block diagram for L-SIG, RL-SIG, and HE-SIG-A fields of an HE TB PPDU(11ax)**

Figure 27-16 (Transmitter block diagram for HE-SIG-B field(11ax)) shows the transmit process for the HE-SIG-B field of an HE MU PPDU using one frequency segment. This block diagram is for transmitting an HE-SIG-B field in one 20 MHz subchannel. Refer to 27.3.11.8.2 (HE-SIG-B content channels) for the methods of transmitting an HE-SIG-B field in 40 MHz, 80 MHz, and 160 MHz. The DCM tone mapper, which is defined in 27.3.12.9 (Constellation mapping), is applied only if the HE-SIG-B DCM field in the HE-SIG-A field is 1.

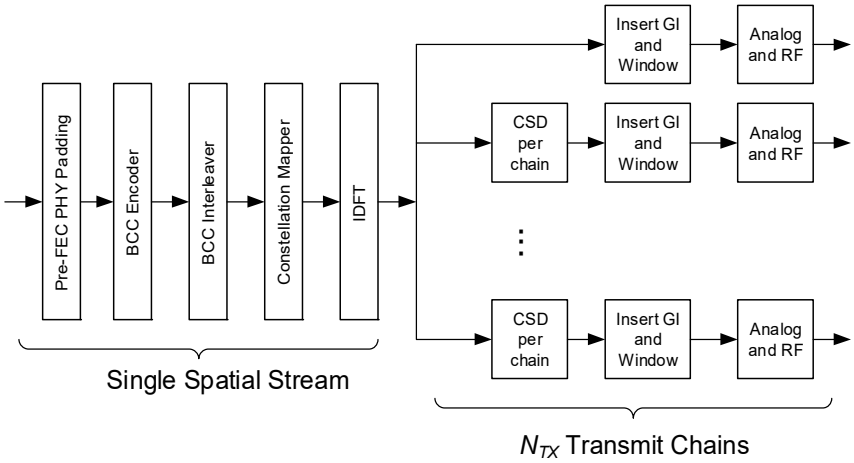


**Figure 27-16—Transmitter block diagram for HE-SIG-B field(11ax)**

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Figure 27-17 (Transmitter block diagram for UL transmission or DL non-MU-MIMO transmission of a Data field with BCC encoding on a 26-, 52-, 106-, or 242-tone RU(11ax)) shows the transmitter blocks for the UL transmission or DL non-MU-MIMO transmission of a Data field with BCC encoding on a 26-, 52-, 106-, or 242-tone RU for a single frequency segment if the number of spatial streams is less than or equal to 4. Figure 27-17 applies to the Data field of an HE MU PPDU that is transmitted on an RU allocated to a single user, the Data field of an HE SU PPDU, and the Data field of an HE TB PPDU (regardless of whether it is spatially multiplexed with other users).

The DCM tone mapper, which is part of the constellation mapper, is applied only if DCM is indicated for the RU. A subset of these transmitter blocks consisting of the constellation mapper and CSD blocks and the blocks to the right of, and including, the spatial mapping block is also used to generate the HE-LTF fields. This is illustrated in Figure 27-32 (Generation of HE-LTF symbols per frequency segment in an HE SU PPDU, HE MU PPDU, and HE ER SU PPDU(11ax)) (in 27.3.11.10 (HE-LTF field)). A subset of these transmitter blocks consisting of the constellation mapper and CSD blocks and the blocks to the right of, and including, the spatial and frequency mapping block of Figure 27-17 (Transmitter block diagram for UL transmission or DL non-MU-MIMO transmission of a Data field with BCC encoding on a 26-, 52-, 106-, or 242-tone RU(11ax)) is also used to generate the HE-STF field. This figure also applies to the Data field with BCC encoding in an HE TB PPDU.

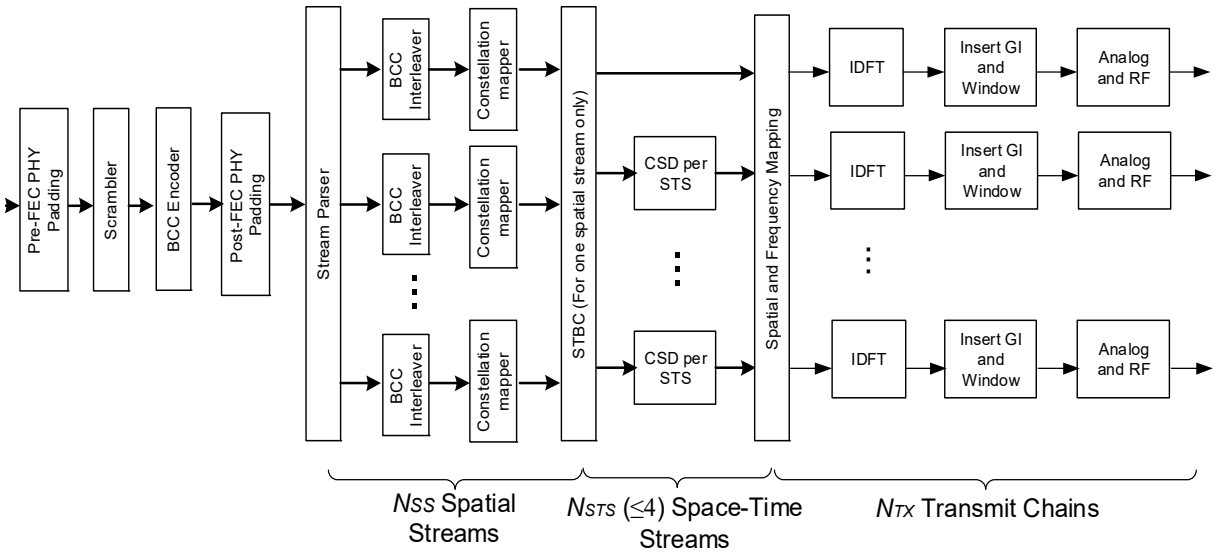


**Figure 27-17—Transmitter block diagram for UL transmission or DL non-MU-MIMO transmission of a Data field with BCC encoding on a 26-, 52-, 106-, or 242-tone RU(11ax)**


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Figure 27-18 (Transmitter block diagram for UL transmission or DL non-MU-MIMO transmission of a Data field with LDPC encoding on a 26-, 52-, 106-, 242-, 484-, or 996-tone RU(11ax)) shows the transmitter blocks for the UL transmission or DL non-MU-MIMO transmission of a Data field with LDPC encoding on a 26-, 52-, 106-, 242-, 484-, or 996-tone RU for a single frequency segment. Figure 27-18 (Transmitter block diagram for UL transmission or DL non-MU-MIMO transmission of a Data field with LDPC encoding on a 26-, 52-, 106-, 242-, 484-, or 996-tone RU(11ax)) applies to the Data field of an HE MU PPDU that is transmitted on an RU allocated to a single user, the Data field of an HE SU PPDU, and the Data field of an HE TB PPDU (regardless of whether it is spatially multiplexed with other users). This figure also applies to the Data field with LDPC encoding in an HE TB PPDU.

The DCM tone mapper, which is part of the constellation mapper, is applied only if DCM is indicated for the RU. This figure also applies to the Data field with LDPC encoding in an HE TB PPDU.

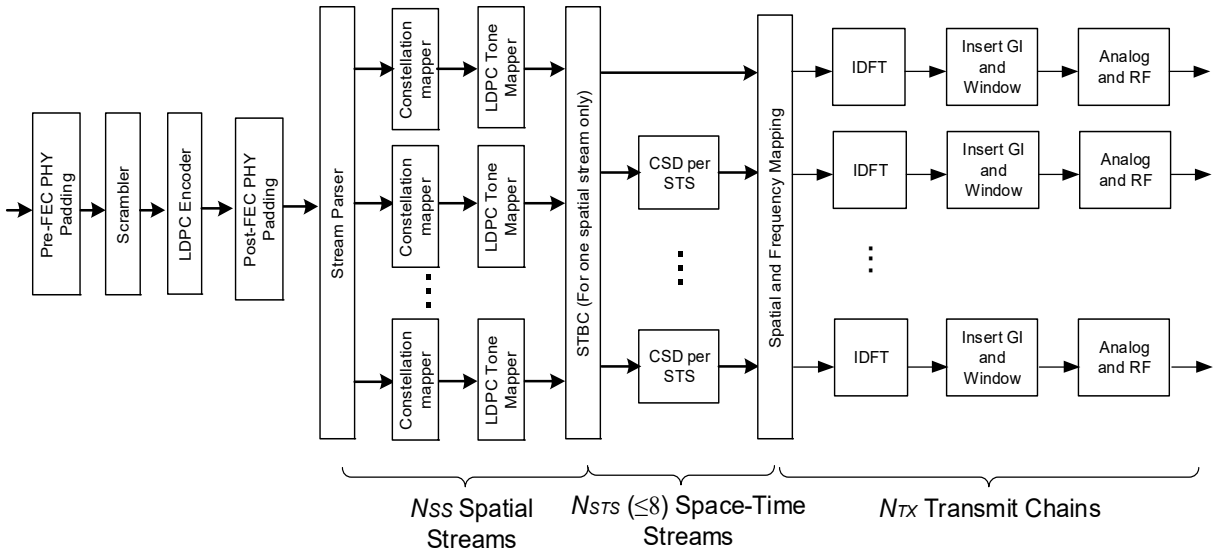


**Figure 27-18—Transmitter block diagram for UL transmission or DL non-MU-MIMO transmission of a Data field with LDPC encoding on a 26-, 52-, 106-, 242-, 484-, or 996-tone RU(11ax)**

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Figure 27-19 (Transmitter block diagram for DL MU-MIMO transmission of a Data field with BCC encoding on a 106- or 242-tone RU(11ax)) shows the transmitter blocks for the transmission, in an HE MU PPDU, of the Data field with BCC encoding on a 106- or 242-tone RU allocated to more than one user.

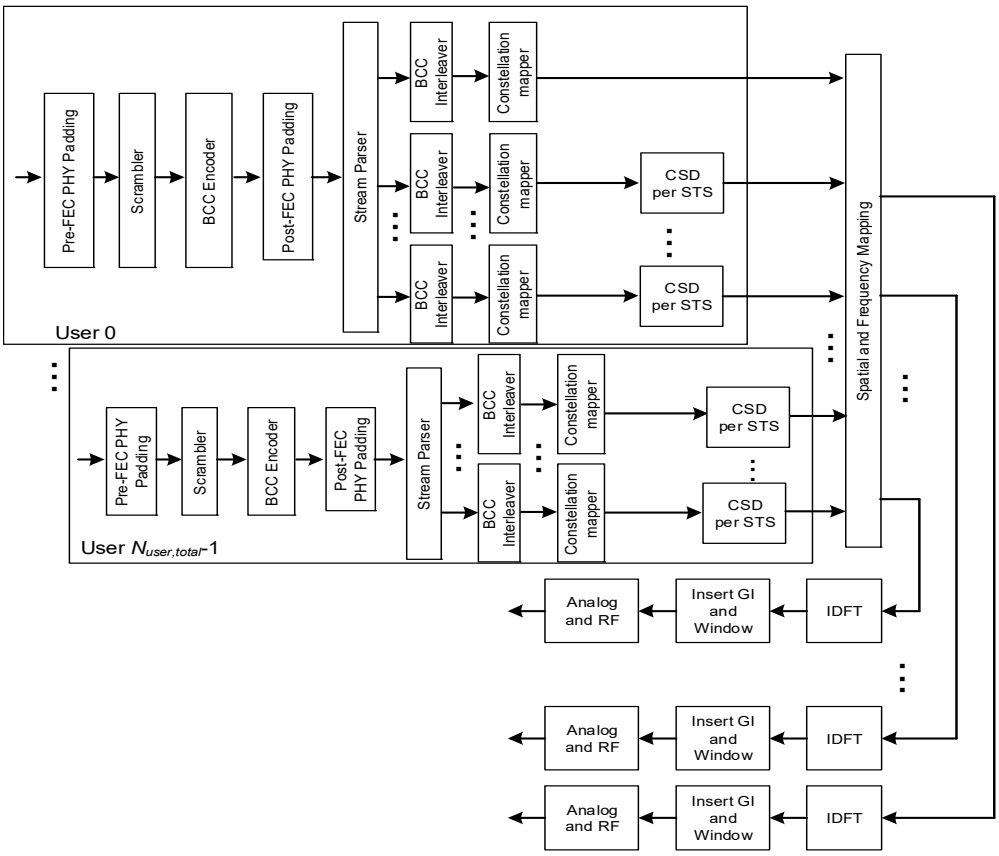


**Figure 27-19—Transmitter block diagram for DL MU-MIMO transmission of a Data field with BCC encoding on a 106- or 242-tone RU(11ax)**

Figure 27-20 (Transmitter block diagram for DL MU-MIMO transmission of a Data field with LDPC encoding on a 106-, 242-, 484-, or 996-tone RU(11ax)) shows the transmitter blocks for the transmission, in


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an HE MU PPDU, of the Data field with LDPC encoding on a 106-, 242-, 484-, or 996-tone RU allocated to more than one user.

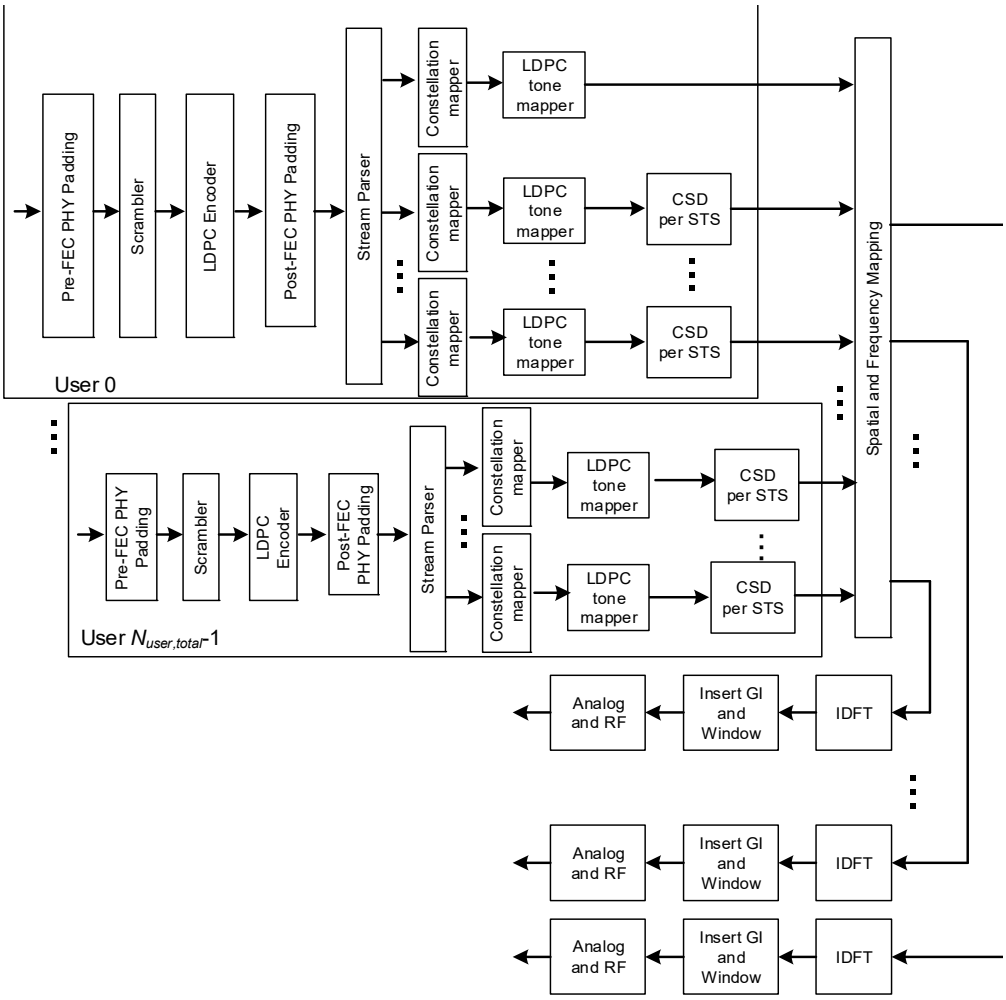


**Figure 27-20—Transmitter block diagram for DL MU-MIMO transmission of a Data field with LDPC encoding on a 106-, 242-, 484-, or 996-tone RU(11ax)**

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Figure 27-21 (Transmitter block diagram for the Data field of an HE SU PPDU in 160 MHz with LDPC encoding(11ax)) shows the transmitter blocks used to generate the Data field of a single-user HE transmission in 160 MHz with LDPC encoding.

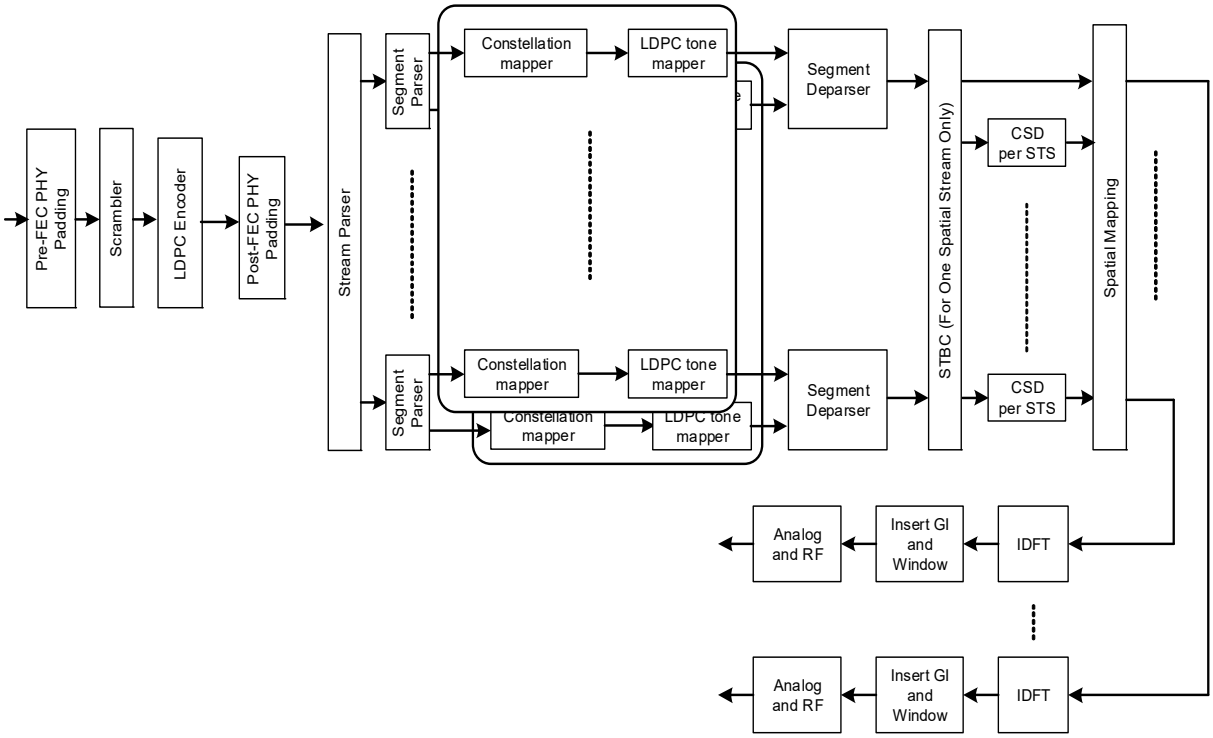


**Figure 27-21—Transmitter block diagram for the Data field of an HE SU PPDU in 160 MHz with LDPC encoding(11ax)**



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Figure 27-22 (Transmitter block diagram for the Data field of an HE SU PPDU in 80+80 MHz with LDPC encoding(11ax)) shows the transmitter blocks used to generate the Data field of a single-user HE transmission in 80+80 MHz with LDPC encoding.

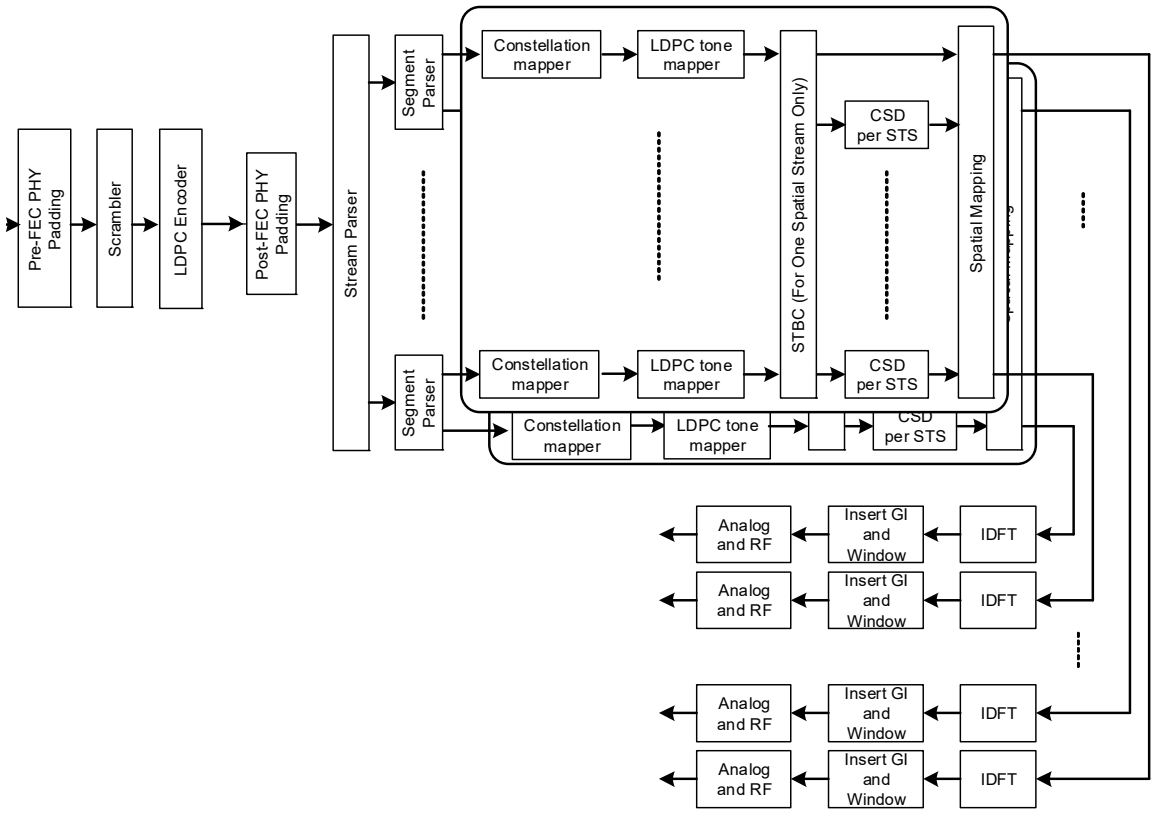


**Figure 27-22—Transmitter block diagram for the Data field of an HE SU PPDU in 80+80 MHz with LDPC encoding(11ax)**

### 27.3.6 Overview of the PPDU encoding process

#### 27.3.6.1 General

Subclause 27.3.6 (Overview of the PPDU encoding process) provides an overview of the HE PPDU encoding process.

#### 27.3.6.2 Construction of L-STF field

Construct the L-STF field as defined in 27.3.11.3 (L-STF field) with the following highlights:

a) Determine the channel bandwidth from the TXVECTOR parameter CH_BANDWIDTH.

b) Sequence generation: Generate the L-STF sequence over the channel bandwidth as described in 27.3.11.3 (L-STF field). Apply a 3 dB power boost if transmitting an HE ER SU PPDU as described in 27.3.11.3 (L-STF field).

c) Phase rotation: Apply appropriate phase rotation for each 20 MHz subchannel as described in 27.3.10 (Mathematical description of signals) and 21.3.7.5 (Definition of tone rotation).

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d) CSD per STS: If the TXVECTOR parameter BEAM_CHANGE is 0, apply CSD per STS for each space-time stream and frequency segment as described in 27.3.11.2.2 (Cyclic shift for HE modulated fields).

e) Spatial mapping: If the TXVECTOR parameter BEAM_CHANGE is 0, apply the $A$ matrix and the $Q$ matrix as described in 27.3.11.3 (L-STF field).

f) IDFT: Compute the inverse discrete Fourier transform.

g) CSD per chain: If the TXVECTOR parameter BEAM_CHANGE is 1 or not present, apply CSD per chain for each transmit chain and frequency segment as described in 27.3.11.2.1 (Cyclic shift for pre-HE modulated fields).

h) GI and windowing: Prepend a GI ($T_{GI,\text{Pre-HE}}$), and apply windowing as described in 27.3.10 (Mathematical description of signals).

i) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit. Refer to 27.3.10 (Mathematical description of signals) and 27.3.11 (HE preamble) for details.

#### 27.3.6.3 Construction of L-LTF field

Construct the L-LTF field as defined in 27.3.11.4 (L-LTF field) with the following highlights:

a) Determine the channel bandwidth from the TXVECTOR parameter CH_BANDWIDTH.

b) Sequence generation: Generate the L-LTF sequence over the channel bandwidth as described in 27.3.11.4 (L-LTF field). Apply a 3 dB power boost if transmitting an HE ER SU PPDU as described in 27.3.11.4 (L-LTF field).

c) Phase rotation: Apply appropriate phase rotation for each 20 MHz subchannel as described in 27.3.10 (Mathematical description of signals) and 21.3.7.5 (Definition of tone rotation).

d) CSD per STS: If the TXVECTOR parameter BEAM_CHANGE is 0, apply CSD per STS for each space-time stream and frequency segment as described in 27.3.11.2.2 (Cyclic shift for HE modulated fields) before spatial mapping.

e) Spatial mapping: If the TXVECTOR parameter BEAM_CHANGE is 0, apply the $A$ matrix and the $Q$ matrix as described in 27.3.11.4 (L-LTF field).

f) IDFT: Compute the inverse discrete Fourier transform.

g) CSD per chain: If the TXVECTOR parameter BEAM_CHANGE is 1 or not present, apply CSD per chain for each transmit chain and frequency segment as described in 27.3.11.2.1 (Cyclic shift for pre-HE modulated fields).

h) GI and windowing: Prepend a GI ($T_{GI,\text{L-LTF}}$), and apply windowing as described in 27.3.10 (Mathematical description of signals).

i) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the carrier frequency of the desired channel and transmit. Refer to 27.3.10 (Mathematical description of signals) and 27.3.11 (HE preamble) for details.

#### 27.3.6.4 Construction of L-SIG field

Construct the L-SIG field as the SIGNAL field defined in 27.3.11.5 (L-SIG field) with the following highlights:

a) Set the RATE subfield in the SIGNAL field to 6 Mb/s. Set the LENGTH, Parity, and Tail fields in the SIGNAL field as described in 27.3.11.5 (L-SIG field).

b) BCC encoder: Encode the SIGNAL field by a convolutional encoder at the rate $R$ = 1/2 as described in 27.3.12.5.1 (BCC coding and puncturing).

c) BCC interleaver: Interleave as described in 17.3.5.7 (Data interleaving).

d) Constellation mapper: BPSK modulate as described in 27.3.12.9 (Constellation mapping).


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e) Pilot insertion: Insert pilots as described in 27.3.11.5 (L-SIG field).

f) Extra subcarrier insertion: Four extra subcarriers are inserted at $k \in \{-28, -27, 27, 28\}$ for channel estimation purpose, and the values on these four extra subcarriers are {–1, –1, –1, 1}, respectively. Apply a 3 dB power boost to the four extra subcarriers if transmitting an HE ER SU PPDU as described in 27.3.11.5 (L-SIG field).

g) Duplication and phase rotation: Duplicate the L-SIG field over each occupied 20 MHz subchannel of the channel bandwidth. Apply appropriate phase rotation for each occupied 20 MHz subchannel as described in 27.3.10 (Mathematical description of signals) and 21.3.7.5 (Definition of tone rotation).

h) CSD per STS: If the TXVECTOR parameter BEAM_CHANGE is 0, apply CSD per STS for each space-time stream and frequency segment as described in 27.3.11.2.2 (Cyclic shift for HE modulated fields) before spatial mapping.

i) Spatial mapping: If the TXVECTOR parameter BEAM_CHANGE is 0, apply the $A$ matrix and $Q$ matrix as described in 27.3.11.5 (L-SIG field).

j) IDFT: Compute the inverse discrete Fourier transform.

k) CSD per chain: If the TXVECTOR parameter BEAM_CHANGE is 1 or not present, apply CSD per chain for each transmit chain and frequency segment as described in 27.3.11.2.1 (Cyclic shift for pre-HE modulated fields).

l) GI and windowing: Prepend a GI ($T_{GI,\text{Pre-HE}}$), and apply windowing as described in 27.3.10 (Mathematical description of signals).

m) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain. Refer to 27.3.10 (Mathematical description of signals) and 27.3.11 (HE preamble) for details.

#### 27.3.6.5 Construction of RL-SIG field

Construct the RL-SIG field as the repeat SIGNAL field defined in 27.3.11.6 (RL-SIG field) with the following highlights:

a) Set the RATE subfield in the repeat SIGNAL field to 6 Mb/s. Set the LENGTH, Parity, and Tail fields in the repeat SIGNAL field as described in 27.3.11.6 (RL-SIG field).

b) BCC encoder: Encode the repeat SIGNAL field by a convolutional encoder at the rate $R = 1/2$ as described in 27.3.12.5.1 (BCC coding and puncturing).

c) BCC interleaver: Interleave as described in 17.3.5.7 (Data interleaving).

d) Constellation mapper: BPSK modulate as described in 27.3.12.9 (Constellation mapping).

e) Pilot insertion: Insert pilots as described in 27.3.11.6 (RL-SIG field).

f) Extra subcarrier insertion: Four extra subcarriers are inserted at $k \in \{-28, -27, 27, 28\}$ for channel estimation purpose, and the values on these four extra subcarriers are {–1, –1, –1, 1}, respectively. Apply a 3 dB power boost to the four extra subcarriers if transmitting an HE ER SU PPDU as described in 27.3.11.6 (RL-SIG field).

g) Duplication and phase rotation: Duplicate the RL-SIG field over each occupied 20 MHz subchannel of the channel bandwidth. Apply appropriate phase rotation for each occupied 20 MHz subchannel as described in 27.3.10 (Mathematical description of signals) and 21.3.7.5 (Definition of tone rotation).

h) CSD per STS: If the TXVECTOR parameter BEAM_CHANGE is 0, apply CSD per STS for each space-time stream and frequency segment as described in 27.3.11.2.2 (Cyclic shift for HE modulated fields) before spatial mapping.

i) Spatial mapping: If the TXVECTOR parameter BEAM_CHANGE is 0, apply the $A$ matrix and the $Q$ matrix as described in 27.3.11.6 (RL-SIG field).

j) IDFT: Compute the inverse discrete Fourier transform.

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k) CSD per chain: If the TXVECTOR parameter BEAM_CHANGE is 1 or not present, apply CSD per chain for each transmit chain and frequency segment as described in 27.3.11.2.1 (Cyclic shift for pre-HE modulated fields).

l) GI and windowing: Prepend a GI ($T_{GI,\text{Pre-HE}}$), and apply windowing as described in 27.3.10 (Mathematical description of signals).

m) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain. Refer to 27.3.10 (Mathematical description of signals) and 27.3.11 (HE preamble) for details.

### 27.3.6.6 Construction of HE-SIG-A field

a) For an HE SU PPDU, HE MU PPDU, and HE TB PPDU, the HE-SIG-A field consists of two subfields, HE-SIG-A1 and HE-SIG-A2 (#1054)and two OFDM symbols, HE-SIG-A-sym-1 and HE-SIG-A-sym2 as defined in 27.3.11.7 (HE-SIG-A field), and is constructed as follows:

1) Obtain the HE-SIG-A field values from the TXVECTOR. Add the reserved bits, append the calculated CRC, and then append the $N_{tail}$ tail bits as shown in 27.3.11.7 (HE-SIG-A field). This results in 52 uncoded bits.

2) BCC encoder: Encode the data by a convolutional encoder at the rate $R = 1/2$ as described in 17.3.5.6 (Convolutional encoder).

3) BCC interleaver: Interleave as described in 27.3.12.8 (BCC interleavers).

4) Constellation mapper: BPSK modulate the first 52 interleaved bits as described in 17.3.5.8 (Subcarrier modulation mapping) (#2248)to form the first OFDM symbol of the HE-SIG-A field. BPSK modulate the second 52 interleaved bits to form the second OFDM symbol of the HE-SIG-A field.

5) Pilot insertion: Insert pilots as described in 17.3.5.9 (Pilot subcarriers).

6) Duplicate and phase rotation: Duplicate the HE-SIG-A OFDM symbols over each occupied 20 MHz subchannel of the channel width. Apply the appropriate phase rotation for each occupied 20 MHz subchannel as described in 27.3.10 (Mathematical description of signals) and 21.3.7.5 (Definition of tone rotation).

7) CSD per STS: If the TXVECTOR parameter BEAM_CHANGE is 0, apply CSD per STS for each space-time stream and frequency segment as described in 27.3.11.2.2 (Cyclic shift for HE modulated fields) before spatial mapping.

8) Spatial mapping: If the TXVECTOR parameter BEAM_CHANGE is 0, apply the $A$ matrix and the $Q$ matrix as described in 27.3.11.7.4 (Encoding and modulation).

9) IDFT: Compute the inverse discrete Fourier transform.

10) CSD per chain: If the TXVECTOR parameter BEAM_CHANGE is 1 or not present, apply CSD per chain for each transmit chain and frequency segment as described in 27.3.11.2.1 (Cyclic shift for pre-HE modulated fields).

11) GI and windowing: Prepend a GI ($T_{GI,\text{Pre-HE}}$), and apply windowing as described in 27.3.10 (Mathematical description of signals).

12) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit. Refer to 27.3.10 (Mathematical description of signals) and 27.3.11 (HE preamble)for details.

b) For an HE ER SU PPDU, the HE-SIG-A field consists of (#1054)two subfields, HE-SIG-A1 and HE-SIG-A2, and four OFDM symbols: HE-SIG-A-sym-1, HE-SIG-A-sym-1-R, HE-SIG-A-sym-2, and HE-SIG-A-sym-2-R. The HE-SIG-A-sym-1 and HE-SIG-A-sym-1-R OFDM symbols are calculated from one set of coded bits common to both OFDM symbols while the HE-SIG-A-sym-2 and HE-SIG-A-sym-2-R OFDM symbols are calculated from a second set of coded bits common to both OFDM symbols as defined in 27.3.11.7 (HE-SIG-A field). The HE-SIG-A field is constructed as follows:


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1) Obtain the HE-SIG-A fields from the TXVECTOR. Add the reserved bits, append the calculated CRC, and then append the $N_{tail}$ tail bits as shown in 27.3.11.7 (HE-SIG-A field). This results in 52 uncoded bits.
2) BCC encoder: Encode the data by a convolutional encoder at the rate $R = 1/2$ as described in 17.3.5.6 (Convolutional encoder).
3) BCC interleaver: Interleave the (#1054)first and second half of coded bits of the HE-SIG-A field as described in 27.3.12.8 (BCC interleavers). The coded bits of the HE-SIG-A-sym-1-R and HE-SIG-A-sym-2-R subfields are not interleaved.
4) Constellation mapper: BPSK modulate the (#1054)BCC interleaver output of the HE-SIG-A-sym-1, HE-SIG-A-sym-2, and HE-SIG-A-sym-2-R OFDM symbols as described in 17.3.5.8 (Subcarrier modulation mapping) to form the first, third, and fourth OFDM symbols of the HE-SIG-A field, respectively. QBPSK modulate the BCC interleaver output of the HE-SIG-A-sym-1-R OFDM symbol to form the second OFDM symbol of the HE-SIG-A field.
5) Pilot insertion: Insert pilots as described in 17.3.5.9 (Pilot subcarriers).
6) Duplication and phase rotation: Duplicate the HE-SIG-A field over each occupied 20 MHz subchannel of the channel bandwidth. Apply appropriate phase rotation for each occupied 20 MHz subchannel as described in 27.3.10 (Mathematical description of signals) and 21.3.7.5 (Definition of tone rotation).
7) CSD per STS: If the TXVECTOR parameter BEAM_CHANGE is 0, apply CSD per STS for each space-time stream and frequency segment as described in 27.3.11.2.2 (Cyclic shift for HE modulated fields) before spatial mapping.
8) Spatial mapping: If the TXVECTOR parameter BEAM_CHANGE is 0, apply the $A$ matrix and the $Q$ matrix as described in 27.3.11.7.4 (Encoding and modulation).
9) IDFT: Compute the inverse Fourier transform.
10) CSD per chain: If the TXVECTOR parameter BEAM_CHANGE is 1 or not present, apply CSD per chain for each transmit chain and frequency segment as described in 27.3.11.2.1 (Cyclic shift for pre-HE modulated fields).
11) GI and windowing: Prepend a GI ($T_{GI,\text{Pre-HE}}$), and apply windowing as described in 27.3.10 (Mathematical description of signals).
12) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit. Refer to 27.3.10 (Mathematical description of signals) and 27.3.11 (HE preamble)for details.

### 27.3.6.7 Construction of HE-SIG-B field

For an HE MU PPDU, the HE-SIG-B field consists of a Common field followed by a User Specific field as defined in 27.3.11.8 (HE-SIG-B field) and is constructed as follows:

a) Obtain the HE-SIG-B field values from the TXVECTOR. Add the reserved bits, append the calculated CRC, and then append the $N_{tail}$ tail bits as shown in 27.3.11.8 (HE-SIG-B field).
b) BCC encoder: Encode the Common field data and each User Block field data individually by a convolutional encoder as described in 27.3.12.5.1 (BCC coding and puncturing).
c) BCC interleaver: Interleave as described in 27.3.12.8 (BCC interleavers).
d) Constellation mapper: Obtain MCS_SIG_B from the TXVECTOR and use it to modulate the interleaved bits as described in 27.3.12.9 (Constellation mapping) to form the HE-SIG-B OFDM symbols.
e) Pilot insertion: Insert pilots as described in 17.3.5.9 (Pilot subcarriers).

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f) Duplicate and phase rotation: Duplicate HE-SIG-B OFDM symbols as described in 27.3.11.8.5 (Encoding and modulation). Apply the appropriate phase rotation for each 20 MHz subchannel as described in 27.3.10 (Mathematical description of signals) and 21.3.7.5 (Definition of tone rotation).

g) IDFT: Compute the inverse Fourier transform.

h) CSD per chain: Apply CSD per chain for each transmit chain and frequency segment as described in 27.3.11.2.1 (Cyclic shift for pre-HE modulated fields).

i) GI and windowing: Prepend a GI ($T_{GI,\text{Pre-HE}}$), and apply windowing as described in 27.3.10 (Mathematical description of signals).

j) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit. Refer to 27.3.10 (Mathematical description of signals) and 27.3.11 (HE preamble) for details.

#### 27.3.6.8 Construction of HE-STF field

The HE-STF field is defined in 27.3.11.9 (HE-STF field) and is constructed as follows:

a) Sequence generation: Generate the HE-STF in the frequency domain over the bandwidth indicated by the TXVECTOR parameter CH_BANDWIDTH as described in 27.3.11.9 (HE-STF field). Apply a 3 dB power boost if transmitting an HE ER SU PPDU as described in 27.3.11.9 (HE-STF field).

b) CSD: Apply CSD for each space-time stream and frequency segment as described in 27.3.11.2.2 (Cyclic shift for HE modulated fields).

c) Spatial mapping: Apply the $Q$ matrix as described in 27.3.11.9 (HE-STF field).

d) IDFT: Compute the inverse discrete Fourier transform.

e) GI and windowing: Prepend a GI, i.e., 0.8 μs GI for an HE SU PPDU, HE ER SU PPDU, and HE MU PPDU and 1.6 μs GI for an HE TB PPDU. Apply windowing as described in 27.3.10 (Mathematical description of signals).

f) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit. Refer to 27.3.10 (Mathematical description of signals) and 27.3.11 (HE preamble) for details.

#### 27.3.6.9 Construction of HE-LTF field

The HE-LTF field is defined in 27.3.11.10 (HE-LTF field) and is constructed as follows:

a) Sequence generation: Generate the HE-LTF sequence in frequency domain over the bandwidth indicated by CH_BANDWIDTH as described in 27.3.11.10 (HE-LTF field). Apply a 3 dB power boost if transmitting an HE ER SU PPDU as described in 27.3.11.10 (HE-LTF field).

b) $A_{\text{HE-LTF}}$ matrix mapping: Apply the $P_{\text{HE-LTF}}$ matrix to the data tones of the HE-LTF sequence, and apply the $R_{\text{HE-LTF}}$ matrix to pilot subcarriers of the HE-LTF sequence, except the UL MU-MIMO transmission not using HE single stream pilot HE-LTF mode as described in 27.3.11.10 (HE-LTF field). There is no pilot mapping for an HE TB feedback NDP.

c) CSD: Apply CSD for each space-time stream and frequency segment as described in 27.3.11.2.2 (Cyclic shift for HE modulated fields).

d) Spatial mapping: Apply the $Q$ matrix as described in 27.3.11.10 (HE-LTF field).

e) IDFT: Compute the inverse discrete Fourier transform.

f) GI and windowing: Prepend a GI indicated by the TXVECTOR parameter GI_TYPE, and apply windowing as described in 27.3.10 (Mathematical description of signals).

g) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit. Refer to 27.3.10 (Mathematical description of signals) and 27.3.11 (HE preamble) for details.


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### 27.3.6.10 Construction of the Data field in an HE SU PPDU, HE ER SU PPDU, and HE TB PPDU

#### 27.3.6.10.1 Using BCC

The construction of the Data field in an HE SU PPDU, HE ER SU PPDU, and HE TB PPDU with BCC encoding proceeds as follows:

a) Construct the SERVICE field as described in 27.3.12.3 (SERVICE field), and append the PSDU to the SERVICE field.

b) Pre-FEC padding: Append the pre-FEC pad bits and tail bits as described in 27.3.12 (Data field).

c) Scrambler: Scramble the pre-FEC padded data.

d) BCC encoder: BCC encode as described in 27.3.12.5.1 (BCC coding and puncturing).

e) Post-FEC padding: Append the post-FEC pad bits and PE field as described in 27.3.12 (Data field).

f) Stream parser: Rearrange the output of BCC encoder into blocks as described in 27.3.12.6 (Stream parser).

g) BCC interleaver: Interleave as described in 27.3.12.8 (BCC interleavers).

h) Constellation mapper: Map to BPSK, BPSK DCM, QPSK, QPSK DCM, 16-QAM, 16-QAM DCM, 64-QAM, or 256-QAM constellation points as described in 27.3.12.9 (Constellation mapping).

i) STBC: Apply STBC as described in 27.3.12.12 (Space-time block coding).

j) Pilot insertion: Insert pilots following the steps described in 27.3.12.13 (Pilot subcarriers).

k) CSD: Apply CSD for each space-time stream and frequency segment as described in 27.3.11.2.2 (Cyclic shift for HE modulated fields).

l) Spatial mapping: Apply the $Q$ matrix as described in 27.3.12.14 (OFDM modulation).

m) IDFT: In an 80+80 MHz transmission, map each frequency subblock to a separate IDFT. Compute the inverse discrete Fourier transform.

n) GI and windowing: Prepend a GI determined by the TXVECTOR parameter GI_TYPE, and apply windowing as described in 27.3.10 (Mathematical description of signals).

o) Analog and RF: Upconvert the resulting complex baseband waveform with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit. Refer to 27.3.10 (Mathematical description of signals) and 27.3.11 (HE preamble) for details.

#### 27.3.6.10.2 Using LDPC

The construction of the Data field in an HE SU PPDU, HE ER SU PPDU, and HE TB PPDU with LDPC encoding proceeds as follows:

a) Construct the SERVICE field as described in 27.3.12.3 (SERVICE field), and append the PSDU to the SERVICE field.

b) Pre-FEC padding: Append the pre-FEC padding bits as described in 27.3.12 (Data field). There are no tail bits.

c) Scrambler: Scramble the pre-FEC padded data.

d) LDPC encoder: LDPC encode as described in 27.3.12.5.2 (LDPC coding).

e) Post-FEC padding: Append the post-FEC pad bits and PE field as described in 27.3.12 (Data field).

f) Stream parser: Rearrange the output of LDPC encoder into blocks as described in 27.3.12.6 (Stream parser).

g) Segment parser (if needed): In a 160 MHz or 80+80 MHz transmission with a 2×996-tone RU, divide the output of each stream parser into two frequency subblocks as described in 27.3.12.6 (Stream parser). This block is bypassed for 20 MHz, 40 MHz, and 80 MHz transmissions.

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h) Constellation mapper: Map to BPSK, BPSK DCM, QPSK, QPSK DCM, 16-QAM, 16-QAM DCM, 64-QAM, 256-QAM, or 1024-QAM constellation points as described in 27.3.12.9 (Constellation mapping).

i) LDPC tone mapper: the LDPC tone mapping shall be performed on all LDPC encoded streams as described in 27.3.12.10 (LDPC tone mapper).

j) Segment deparser (if needed): In 160 MHz transmission, merge the two frequency subblocks into one frequency segment as described in 27.3.12.11 (Segment deparser). This block is bypassed for 20 MHz, 40 MHz, 80 MHz, and 80+80 MHz transmissions.

k) STBC: Apply STBC as described in 27.3.12.12 (Space-time block coding).

l) Pilot insertion: Insert pilots following the steps described in 27.3.12.13 (Pilot subcarriers).

m) CSD: Apply CSD for each space-time stream and frequency segment as described in 27.3.11.2.2 (Cyclic shift for HE modulated fields).

n) Spatial mapping: Apply the $Q$ matrix as described in 27.3.12.14 (OFDM modulation).

o) IDFT: In an 80+80 MHz transmission, map each frequency subblock to a separate IDFT. Compute the inverse discrete Fourier transform.

p) GI and windowing: Prepend a GI determined by the TXVECTOR parameter GI_TYPE, and apply windowing as described in 27.3.10 (Mathematical description of signals).

q) Analog and RF: Upconvert the resulting complex baseband waveform with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit. Refer to 27.3.10 (Mathematical description of signals) and 27.3.11 (HE preamble) for details.

#### 27.3.6.11 Construction of the Data field in an HE MU PPDU

##### 27.3.6.11.1 General

In an HE MU transmission, the PPDU encoding process is performed independently in an RU on a per user basis up to the input of the spatial mapping block, except that CSD is performed with knowledge of the space-time streams starting index for that user. All user data in an RU is combined and mapped to the transmit chains in the spatial mapping block.

##### 27.3.6.11.2 Using BCC

A Data field with BCC encoding is constructed using steps a) to l) in 27.3.6.10.1 (Using BCC) and then applying CSD for an HE MU PPDU as described in 27.3.11.2.2 (Cyclic shift for HE modulated fields).

##### 27.3.6.11.3 Using LDPC

A Data field with LDPC encoding is constructed using steps a) to l) in 27.3.6.10.2 (Using LDPC) and then applying CSD for an HE MU PPDU as described in 27.3.11.2.2 (Cyclic shift for HE modulated fields).

##### 27.3.6.11.4 Combining to form an HE MU PPDU

The per user data is combined as follows:

a) Spatial mapping: The $Q$ matrix is applied as described in 27.3.12.14 (OFDM modulation). The combining of all user data of an RU is done in this block.

b) IDFT: Compute the inverse discrete Fourier transform.

c) GI and windowing: Prepend a GI determined by the TXVECTOR parameter GI_TYPE, and apply windowing as described in 27.3.10 (Mathematical description of signals).


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d) Analog and RF: Upconvert the resulting complex baseband waveform with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit. Refer to 27.3.10 (Mathematical description of signals) and 27.3.11 (HE preamble) for details.

### 27.3.7 HE modulation and coding schemes (HE-MCSs)

The HE-MCS is a compact representation of the modulation and coding used in the Data field of the PPDU. For an HE SU PPDU and an HE ER SU PPDU, it is carried in the HE-SIG-A field. For an HE MU PPDU, it is carried per user in the User Specific field of the HE-SIG-B field. For an HE TB PPDU, it is carried in the User Info field of the Trigger frame soliciting the HE TB PPDU.

Rate-dependent parameters for the full set of HE-MCSs are shown in Table 27-62 (HE-MCSs for 26-tone RU, NSS = 1(11ax)) to Table 27-117 (HE-MCSs for 2×996-tone RU, NSS = 8(11ax))(in 27.5 (Parameters for HE-MCSs)). These tables give rate-dependent parameters for HE-MCSs with indices 0 to 11; number of spatial streams from 1 to 8; RU options of 26-tone RU, 52-tone RU, 106-tone RU, 242-tone RU, 484-tone RU, and 996-tone RU; and bandwidth options of 20 MHz, 40 MHz, 80 MHz, 160 MHz, and 80+80 MHz.

The HE ER SU PPDU supports only a single 242-tone or 106-tone RU. An HE ER SU PPDU with a 242-tone RU shall be transmitted with only the <HE-MCS, NSS> tuples <HE-MCS 0, 1>, <HE-MCS 1, 1>, and <HE-MCS 2, 1>. An HE ER SU PPDU with a 106-tone RU shall be transmitted with only the <HE-MCS, NSS> tuple <HE-MCS 0, 1>. The 106-tone RU location within the 20 MHz tone plan is fixed as the one that is higher in frequency.

DCM is an optional modulation scheme used for the HE-SIG-B field and the Data field in an HE PPDU. The use of DCM for the HE-SIG-B field in an HE MU PPDU is indicated in the HE-SIG-A field. For the HE-SIG-B field, DCM is applicable to only the HE-SIG-B-MCSs 0, 1, 3, and 4. The use of DCM on the Data field of an HE SU PPDU and HE ER SU PPDU is indicated in the HE-SIG-A field. The use of DCM in the Data field of an HE MU PPDU is indicated in the HE-SIG-B field. For the Data field, DCM is applicable to only the HE-MCSs 0, 1, 3, and 4.

The pre-HE modulated fields (see Figure 27-23 (Timing boundaries for HE PPDU fields if midamble is not present(11ax))) are not transmitted in 20 MHz subchannels in which the preamble is punctured as described in 27.3.11.3 (L-STF field).

### 27.3.8 HE-SIG-B modulation and coding schemes (HE-SIG-B-MCSs)

The HE-SIG-B-MCS is a compact representation of the modulation and coding used in the HE-SIG-B field of the HE MU PPDU. The HE-SIG-B modulation and coding scheme is carried in the HE-SIG-B-MCS subfield of the HE-SIG-A field in the HE MU PPDU and indicates an HE-SIG-B-MCS in the range 0 to 5.

### 27.3.9 Timing-related parameters

Refer to Table 19-6 (Timing-related constants) and Table 21-5 (Timing-related constants) for timing-related parameters for non-HE PPDU formats.

Table 27-13 (Timing-related constants(11ax)) defines the timing-related parameters for HE PPDU formats.

**Table 27-13—Timing-related constants(11ax)**

| Parameter | Values | Description |
|---|---|---|
| $\Delta_{F,\text{ Pre-HE}}$ | 312.5 kHz | Subcarrier frequency spacing for the pre-HE modulated fields. |

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**Table 27-13—Timing-related constants(11ax) *(continued)***

| Parameter | Values | Description |
|---|---|---|
| $\Delta_{F,\text{HE}}$ | 78.125 kHz | Subcarrier frequency spacing for the HE modulated fields. |
| $T_{DFT,\text{Pre-HE}}$ | 3.2 μs | IDFT/DFT period for the pre-HE modulated fields. |
| $T_{DFT,\text{HE}}$ | 12.8 μs | IDFT/DFT period for the Data field. |
| $T_{GI,\text{Pre-HE}}$ | 0.8 μs | Guard interval duration for the pre-HE modulated fields. |
| $T_{GI,\text{L-LTF}}$ | 1.6 μs | Guard interval duration for the L-LTF field. |
| $T_{GI1,Data}$ | 0.8 μs | Base guard interval duration for the Data field. |
| $T_{GI2,Data}$ | 1.6 μs | Double guard interval duration for the Data field. |
| $T_{GI4,Data}$ | 3.2 μs | Quadruple guard interval duration for the Data field. |
| $T_{GI,\text{HE-LTF}}$ | $T_{GI1,Data}$, $T_{GI2,Data}$ or $T_{GI4,Data}$ depending on the GI used for data | Guard interval duration for the HE-LTF field, same as $T_{GI,Data}$. |
| $T_{GI,Data}$ | $T_{GI1,Data}$, $T_{GI2,Data}$ or $T_{GI4,Data}$ depending on the GI used for data | Guard interval duration for the Data field. |
| $T_{SYM1}$ | 13.6 μs = $T_{DFT,\text{HE}} + T_{GI1,Data} = 1.0625 \times T_{DFT,HE}$ | OFDM symbol duration with base GI. |
| $T_{SYM2}$ | 14.4 μs = $T_{DFT,\text{HE}} + T_{GI2,Data} = 1.125 \times T_{DFT,HE}$ | OFDM symbol duration with double GI. |
| $T_{SYM4}$ | 16 μs = $T_{DFT,\text{HE}} + T_{GI4,Data} = 1.25 \times T_{DFT,\text{HE}}$ | OFDM symbol duration with quadruple GI. |
| $T_{SYM}$ | $T_{SYM1}$, $T_{SYM2}$, or $T_{SYM4}$ depending on the GI used for data | OFDM symbol interval for HE PPDU fields. See Table 27-17 (Number of modulated subcarriers and guard interval duration values for HE PPDU fields(11ax)). |
| $T_{\text{L-STF}}$ | 8 μs = $10 \times T_{DFT,\text{Pre-HE}}$ /4 | Non-HT Short Training field duration. |
| $T_{\text{L-LTF}}$ | 8 μs = $2 \times T_{DFT,\text{Pre-HE}} + T_{GI,\text{L-LTF}}$ | Non-HT Long Training field duration. |
| $T_{\text{L-SIG}}$ | 4 μs | Non-HT SIGNAL field duration. |
| $T_{\text{RL-SIG}}$ | 4 μs | Repeated non-HT SIGNAL field duration. |
| $T_{\text{HE-SIG-A}}$ | 8 μs = 2 × 4 μs | HE-SIG-A field duration in an HE SU PPDU, HE MU PPDU, and HE TB PPDU. |
| $T_{\text{HE-SIG-A-R}}$ | 16 μs = 4 × 4 μs | HE-SIG-A field duration in an HE ER SU PPDU. |
| $T_{\text{HE-SIG-B}}$ | 4 μs = $T_{DFT,\text{Pre-HE}} + T_{GI,\text{Pre-HE}}$ | Duration of each OFDM symbol in the HE-SIG-B field. |
| $T_{\text{HE-STF-T}}$ | 8 μs = 5 × 1.6 μs | HE-STF field duration for an HE TB PPDU. |
| $T_{\text{HE-STF-NT}}$ | 4 μs = 5 × 0.8 μs | HE-STF field duration for an HE SU PPDU, HE ER SU PPDU, and HE MU PPDU. |
| $T_{\text{HE-LTF-1X}}$ | 3.2 μs | Duration of each 1x HE-LTF OFDM symbol without GI. |


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**Table 27-13—Timing-related constants(11ax) *(continued)***

| Parameter | Values | Description |
|---|---|---|
| $T_{\text{HE-LTF-2X}}$ | 6.4 µs | Duration of each 2x HE-LTF OFDM symbol without GI. |
| $T_{\text{HE-LTF-4X}}$ | 12.8 µs | Duration of each 4x HE-LTF OFDM symbol without GI. |
| $T_{\text{HE-LTF}}$ | $T_{\text{HE-LTF-1X}}$, $T_{\text{HE-LTF-2X}}$ or $T_{\text{HE-LTF-4X}}$ depending upon the HE-LTF duration used | Duration of each OFDM symbol without GI in the HE-LTF field. |
| $T_{\text{HE-LTF-SYM}}$ | $T_{\text{HE-LTF}} + T_{GI,\text{HE-LTF}}$ | Duration of each OFDM symbol including GI in the HE-LTF field. |
| $N_{service}$ | 16 | Number of bits in the SERVICE field. |
| $N_{tail}$, $N_{tail,u}$ | 6 for BCC encoder, 0 for LDPC encoder | Number of tail bits per encoder (for user $u$). |
| $T_{SYML}$ | 4 µs | OFDM symbol duration including GI prior to the HE-STF field. |
| $T_{PE}$ | 0, 4 µs, 8 µs, 12 µs or 16 µs depending on the actual extension duration used | Duration of the PE field. |

Table 27-14 (Subcarrier allocation related constants for the HE-modulated fields in a non-OFDMA HE PPDU(11ax)) defines tone allocation related parameters for a non-OFDMA HE PPDU.

**Table 27-14—Subcarrier allocation related constants for the HE-modulated fields in a non-OFDMA HE PPDU(11ax)**

| Parameter | CBW20 | CBW40 | CBW80 | CBW80+80 | CBW160 | Description |
|---|---|---|---|---|---|---|
| $N_{SD}$ | See 27.5 (Parameters for HE-MCSs) | | | | | Number of data subcarriers per frequency segment |
| $N_{SP}$ | 8 | 16 | 16 | 16 | 32 | Number of pilot subcarriers per frequency segment |
| $N_{ST}$ | 242 | 484 | 996 | 996 | 1992 | Total number of subcarriers per frequency segment |
| $N_{SR}$ | 122 | 244 | 500 | 500 | 1012 | Highest data subcarrier index per frequency segment |
| $N_{Seg}$ | 1 | 1 | 1 | 2 | 1 | Number of frequency segments |
| $N_{DC}$ | 3 | 5 | 5 | 5 | 23 | Number of null subcarriers at DC per segment |

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Table 27-15 (Subcarrier allocation related constants for RUs in an OFDMA HE PPDU(11ax)) defines tone allocation related parameters for an OFDMA HE PPDU.

**Table 27-15—Subcarrier allocation related constants for RUs in an OFDMA HE PPDU(11ax)**

| Parameter | RU Size (subcarriers) | | | | | | | Description |
|---|---|---|---|---|---|---|---|---|
| | 26 | 52 | 106 | 242 | 484 | 996 | 2×996 | |
| $N_{SD}$ | See 27.5 (Parameters for HE-MCSs) | | | | | | | Number of data subcarriers per RU |
| $N_{SP}$ | 2 | 4 | 4 | 8 | 16 | 16 | 32 | Number of pilot subcarriers per RU |
| $N_{ST}$ | 26 | 52 | 106 | 242 | 484 | 996 | 1992 | Total number of subcarriers per RU |

Table 27-16 (Frequently used parameters(11ax)) defines parameters used frequently in Clause 27 (High-efficiency (HE) PHY specification(11ax)).

**Table 27-16—Frequently used parameters(11ax)**

| Symbol | Explanation |
|---|---|
| $N_{RU}$ | For pre-HE modulated fields, $N_{RU} = 1$.<br>For HE modulated fields, $N_{RU}$ represents the number of occupied RUs in the transmission. |
| $N_{user,r}$ | For pre-HE modulated fields, $N_{user,r} = 1$. For HE modulated fields, $N_{user,r}$ represents the total number of users in the $r^{th}$ occupied RU of the transmission. |
| $N_{user,total}$ | Total number of users in all occupied RUs of an HE transmission, i.e.,<br>$N_{user,total} = \sum_{r=0}^{N_{RU}-1} N_{user,r}$ |
| $N_{CBPS}$, $N_{CBPS,u}$ | Number of coded bits per OFDM symbol for user $u$, $u = 0, \ldots, N_{user,total} - 1$.<br>For an HE SU PPDU and HE ER SU PPDU, $N_{CBPS} = N_{CBPS,0}$.<br>For an HE MU PPDU, $N_{CBPS}$ is undefined. |
| $N_{CBPSS}$, $N_{CBPSS,u}$ | Number of coded bits per OFDM symbol per spatial stream for user $u$, $u = 0, \ldots, N_{user,total} - 1$.<br>For the Data field of an HE SU PPDU and HE ER SU PPDU, $N_{CBPSS} = N_{CBPSS,0}$.<br>For the Data field of an HE MU PPDU, $N_{CBPSS}$ is undefined. |
| $N_{DBPS}$, $N_{DBPS,u}$ | Number of data bits per OFDM symbol for user $u$, $u = 0, \ldots, N_{user,total} - 1$.<br>For an HE SU PPDU and HE ER SU PPDU, $N_{DBPS} = N_{DBPS,0}$.<br>For an HE MU PPDU, $N_{DBPS}$ is undefined. |
| $N_{BPSCS}$, $N_{BPSCS,u}$ | Number of coded bits per subcarrier per spatial stream for user $u$, $u = 0, \ldots, N_{user,total} - 1$.<br>For an HE SU PPDU and HE ER SU PPDU, $N_{BPSCS} = N_{BPSCS,0}$.<br>For an HE MU PPDU, $N_{BPSCS}$ is undefined. |
| $N_{RX}$ | Number of receive chains. |


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**Table 27-16—Frequently used parameters(11ax) *(continued)***

| Symbol | Explanation |
|---|---|
| $N_{STS}$, $N_{STS,r,u}$ | For HE modulated fields, $N_{STS,r,u}$ represents the number of space-time streams in the $r^{th}$ occupied RU for user $u$, $u = 0, \ldots, N_{user,r} - 1$. For STBC, $N_{STS,r,u} = 2$.<br><br>For an HE SU PPDU and HE ER SU PPDU, $N_{STS} = N_{STS,0,0}$.<br>For an HE MU PPDU, $N_{STS}$ is undefined if any one of the RUs is assigned to more than one user, and $N_{STS} = 2$ if all RUs are assigned to no more than one user and the STBC field is set to 1. |
| $N_{STS,r,total}$ | For HE modulated fields, $N_{STS,r,total}$ is the total number of space-time streams over all the users in the $r^{th}$ occupied RU.<br>$N_{STS,r,total} = \sum_{u=0}^{N_{user,r}-1} N_{STS,r,u}$<br>For pre-HE modulated fields, $N_{STS,r,total}$ is undefined if the TXVECTOR parameter BEAM_CHANGE is 1 or not present and $N_{STS,r,total} = N_{STS}$ if BEAM_CHANGE is 0.<br><br>NOTE—$N_{STS,r,total} = N_{STS}$ for an HE SU PPDU and HE ER SU PPDU. |
| $N_{SS}$, $N_{SS,r,u}$, $N_{SS,u}$ | Number of spatial streams. For the Data field, $N_{SS,r,u}$ is the number of spatial streams at $r^{th}$ RU for user $u$, $u = 0, \ldots, N_{user,r} - 1$ and $N_{SS,u}$ is the number of spatial streams for user $u$, $u = 0, \ldots, N_{user,total} - 1$.<br><br>For the Data field of an HE SU PPDU and HE ER SU PPDU, $N_{SS} = N_{SS,0,0}$.<br><br>For the Data field of an HE MU PPDU, $N_{SS} = max_{r=0}^{N_{RU}-1} N_{SS,r,total}$. |
| $N_{SS,r,total}$ | For HE modulated fields, $N_{SS,r,total}$ is the total number of spatial streams at $r^{th}$ RU in a PPDU.<br>$N_{SS,r,total} = \sum_{u=0}^{N_{user,r}-1} N_{SS,r,u}$<br>For pre-HE modulated fields, $N_{SS,r,total}$ is undefined.<br><br>NOTE—$N_{SS,r,total} = N_{SS}$ for an HE SU PPDU and HE ER SU PPDU. |
| $N_{TX}$ | Number of transmit chains. |
| $N_{HE\text{-}LTF}$ | The number of OFDM symbols in the HE-LTF field (see 27.3.11.10 (HE-LTF field). |
| $N_{HE\text{-}SIG\text{-}B}$ | The number of OFDM symbols in the HE-SIG-B field (see 27.3.11.8 (HE-SIG-B field)). |
| $K_r$ | Set of used subcarrier indices in the $r^{th}$ occupied RU. |
| $R$, $R_u$ | $R_u$ is the coding rate for user $u$, $u = 0, \ldots, N_{user,total} - 1$.<br>For an HE SU PPDU, $R = R_0$.<br>For an HE MU PPDU, $R$ is undefined. |
| $M_{r,u}$ | The sum of the number of space-time streams of users prior to user $u$ in RU $r$. For pre-HE modulated fields, $M_{r,u} = 0$. For HE modulated fields, $M_{r,0} = 0$ for $u = 0$ and<br>$M_{r,u} = \sum_{u'=0}^{u-1} N_{STS,r,u'}$ for $u = 1, \ldots, N_{user,r} - 1$. |

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### 27.3.10 Mathematical description of signals

For a description of the conventions used for the mathematical description of the signals, see 17.3.2.5 (Mathematical conventions in the signal descriptions). In addition, the following notational conventions are used in Clause 27 (High-efficiency (HE) PHY specification(11ax)):

— $[Q]_{m,n}$ indicates the element in row $m$ and column $n$ of matrix $Q$, where $1 \le m \le N_{row}$ and $1 \le n \le N_{col}$(#4401), with $N_{row}$ and $N_{col}$ being the number of rows and columns of matrix $Q$, respectively.

— $[Q]_{m:n}$ indicates a matrix consisting of columns $m$ to $n$ of matrix $Q$.

For a description on subcarrier indices over which the signal is transmitted for non-HT, HT, and VHT PPDUs, see 27.3.7 (HE modulation and coding schemes (HE-MCSs)).

For (#4402)the HE modulated fields of a 20 MHz non-OFDMA HE PPDU transmission, the 20 MHz is divided into 256 subcarriers. The signal is transmitted on all or a subset of subcarriers –122 to –2 and 2 to 122, with 0 being the center subcarrier.

For (#4402)the HE modulated fields of a 20 MHz OFDMA HE PPDU transmission, the 20 MHz is divided into 256 subcarriers. The signal is transmitted on all or a subset of the subcarriers –122 to –4 and 4 to 122, with 0 being the center subcarrier.

For (#4402)the HE modulated fields of a 40 MHz non-OFDMA HE PPDU transmission, the 40 MHz is divided into 512 subcarriers. The signal is transmitted on subcarriers –244 to –3 and 3 to 244, with 0 being the center subcarrier.

For (#4402)the HE modulated fields of a 40 MHz OFDMA HE PPDU transmission, the 40 MHz is divided into 512 subcarriers. The signal is transmitted on all or a subset of subcarriers –244 to –3 and 3 to 244, with 0 being the center subcarrier.

For (#4402)the HE modulated fields of an 80 MHz non-OFDMA HE PPDU transmission, the 80 MHz is divided into 1024 subcarriers. The signal is transmitted on subcarriers –500 to –3 and 3 to 500, with 0 being the center subcarrier.

For (#4402)the HE modulated fields of an 80 MHz OFDMA HE PPDU transmission, the 80 MHz is divided into 1024 subcarriers. The signal is transmitted on all or a subset of the subcarriers –500 to –4 and 4 to 500, with 0 being the center subcarrier.

For (#4402)the HE modulated fields of a 160 MHz HE PPDU transmission(#4403), each half 80 MHz bandwidth is divided into 1024 subcarriers, (#6324)and the subcarriers on which the signal is transmitted in each 80 MHz bandwidth are identical to an 80 MHz HE PPDU transmission with a corresponding subcarrier index shift, depending on non-OFDMA or OFDMA transmission within the corresponding 80 MHz.

(#4402)(#4403)For the HE modulated fields of a noncontiguous 80+80 MHz transmission, each half 80 MHz bandwidth is divided into 1024 subcarriers, (#6324)and the subcarriers on which the signal is transmitted in each 80 MHz bandwidth are identical to an 80 MHz HE PPDU transmission, depending on non-OFDMA or OFDMA transmission within the corresponding 80 MHz.

The transmitted signal is described in complex baseband signal notation. The actual transmitted signal on transmit chain $i_{TX}$ and frequency segment $i_{Seg}$ is related to the complex baseband signal by the relation shown in Equation (27-1).

$$r_{RF}^{(i_{Seg}, i_{TX})}(t) = \mathrm{Re}\left\{ \frac{1}{\sqrt{N_{Seg}}} r_{PPDU}^{(i_{Seg}, i_{TX})}(t) \exp\left( j2\pi f_c^{(i_{Seg})} t \right) \right\}, \quad i_{Seg} = 0, \ldots, N_{Seg} - 1; \; i_{TX} = 1, \ldots, N_{TX} \quad (27\text{-}1)$$

where



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$N_{Seg}$ represents the number of frequency segments in the transmit signal as defined in Table 27-14 (Subcarrier allocation related constants for the HE-modulated fields in a non-OFDMA HE PPDU(11ax))

$r_{PPDU}^{(i_{Seg}, i_{TX})}$ represents the complex baseband signal of frequency segment $i_{Seg}$ and transmit chain $i_{TX}$

$f_c^{(i_{Seg})}$ represents the center frequency of the portion of the PPDU transmitted in frequency segment $i_{Seg}$. Table 21-7 (Center frequency of the portion of the PPDU transmitted in frequency segment iSeg) shows $f_c^{(i_{Seg})}$ as a function of the channel starting frequency, dot11CurrentChannelWidth (see Table 21-22 (Fields to specify VHT channels)) and CH_BANDWIDTH where $f_{CH,\,start}$, $f_{P20,\,idx}$, $f_{P40,\,idx}$, and $f_{P80,\,idx}$ are given in Equation (21-4), Equation (21-5), Equation (21-7), and Equation (21-9), respectively.
For an HE STA operating in the 6 GHz band, see 27.3.25.2 (Channel allocation in the 6 GHz band) for the value of channel starting frequency and the valid range of dot11CurrentChannelCenterFrequencyIndex0 and dot11CurrentChannelCenterFrequencyIndex1.

The transmitted RF signal is derived by upconverting the complex baseband signal, which consists of several fields. The timing boundaries for the various fields when the midamble is not present are shown in Figure 27-23 (Timing boundaries for HE PPDU fields if midamble is not present(11ax)), where $N_{\text{HE-LTF}}$ is the number of HE-LTF symbols and is defined in Table 27-16 (Frequently used parameters(11ax)), $N_{\text{HE-SIG-B}}$ is the number of OFDM symbols in the HE-SIG-B field present in an HE MU PPDU, and $N_{SYM}$ is the number of data OFDM symbols.

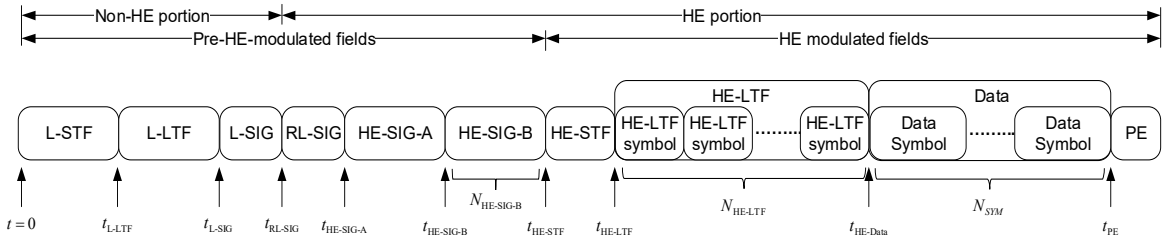


**Figure 27-23—Timing boundaries for HE PPDU fields if midamble is not present(11ax)**

NOTE 1—Data OFDM symbols are OFDM symbols in the Data field of an HE PPDU that are not midamble symbols.

The time offset, $t_{Field}$, determines the starting time of the corresponding field relative to the start of L-STF ($t = 0$).

The signal transmitted on frequency segment $i_{Seg}$ and transmit chain $i_{TX}$ shall be as shown in Equation (27-2) if midamble is not present.

$$\begin{aligned} r_{PPDU}^{(i_{Seg}, i_{TX})}(t) \;=\; & r_{\text{L-STF}}^{(i_{Seg}, i_{TX})}(t) + r_{\text{L-LTF}}^{(i_{Seg}, i_{TX})}(t - t_{\text{L-LTF}}) \\ & + r_{\text{L-SIG}}^{(i_{Seg}, i_{TX})}(t - t_{\text{L-SIG}}) + r_{\text{RL-SIG}}^{(i_{Seg}, i_{TX})}(t - t_{\text{RL-SIG}}) + r_{\text{HE-SIG-A}}^{(i_{Seg}, i_{TX})}(t - t_{\text{HE-SIG-A}}) + r_{\text{HE-SIG-B}}^{(i_{Seg}, i_{TX})}(t - t_{\text{HE-SIG-B}}) \\ & + r_{\text{HE-STF}}^{(i_{Seg}, i_{TX})}(t - t_{\text{HE-STF}}) + r_{\text{HE-LTF}}^{(i_{Seg}, i_{TX})}(t - t_{\text{HE-LTF}}) + r_{\text{HE-Data}}^{(i_{Seg}, i_{TX})}(t - t_{\text{HE-Data}}) + r_{\text{HE-PE}}^{(i_{Seg}, i_{TX})}(t - t_{\text{HE-PE}}) \end{aligned} \tag{27-2}$$

where

$r_{\text{HE-SIG-B}}^{(i_{Seg}, i_{TX})}(t - t_{\text{HE-SIG-B}})$ is only applicable to an HE MU PPDU

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$0 \le i_{Seg} \le N_{Seg} - 1$

$1 \le i_{TX} \le N_{TX}$

$t_{\text{L-LTF}} = T_{\text{L-STF}}$

$t_{\text{L-SIG}} = t_{\text{L-LTF}} + T_{\text{L-LTF}}$

$t_{\text{RL-SIG}} = t_{\text{L-SIG}} + T_{\text{L-SIG}}$

$t_{\text{HE-SIG-A}} = t_{\text{RL-SIG}} + T_{\text{RL-SIG}}$

$$t_{\text{HE-SIG-B}} = \begin{cases} t_{\text{HE-SIG-A}} + T_{\text{HE-SIG-A}}, & \text{for an HE MU PPDU} \\ undefined, & \text{otherwise} \end{cases}$$

$$t_{\text{HE-STF}} = \begin{cases} t_{\text{HE-SIG-A}} + T_{\text{HE-SIG-A}}, & \text{for an HE SU PPDU and HE TB PPDU} \\ t_{\text{HE-SIG-A}} + T_{\text{HE-SIG-A-R}}, & \text{for an HE ER SU PPDU} \\ t_{\text{HE-SIG-B}} + N_{\text{HE-SIG-B}} T_{\text{HE-SIG-B}}, & \text{for an HE MU PPDU} \end{cases}$$

$$t_{\text{HE-LTF}} = \begin{cases} t_{\text{HE-STF}} + T_{\text{HE-STF-T}}, & \text{for an HE TB PPDU} \\ t_{\text{HE-STF}} + T_{\text{HE-STF-NT}}, & \text{otherwise} \end{cases}$$

$t_{\text{HE-Data}} = t_{\text{HE-LTF}} + N_{\text{HE-LTF}} T_{\text{HE-LTF-SYM}}$

$t_{\text{HE-PE}} = t_{\text{HE-Data}} + N_{SYM} T_{SYM}$

In an HE SU PPDU, HE MU PPDU, and HE ER SU PPDU, for each field excluding the PE field, $r_{Field}^{(i_{Seg}, i_{TX})}(t)$ is defined as the summation of one or more subfields. Each subfield, $r_{Subfield}^{(i_{Seg}, i_{TX})}(t)$, is defined to be an inverse discrete Fourier transform in Equation (27-3).

$$r_{Subfield}^{(i_{Seg}, i_{TX})}(t) = w_{T_{Subfield}}(t) \sum_{r=0}^{N_{RU}-1} \frac{\alpha_r \beta_r^{Field}}{\sqrt{N_{Norm,r}}} \sum_{k \in K_r} \eta_{Field,k} \sum_{u=0}^{N_{user,r}-1} \sum_{m=1}^{N_{STS,r,u}} \left[ Q_k^{(i_{Seg})} \right]_{i_{TX}, (M_{r,u}+m)} \Upsilon_{k,BW} \quad (27\text{-}3)$$

$$X_{k,r,u}^{i_{Seg}, m} \exp(j2\pi k \Delta_{F,Field}(t - T_{GI,Field} - T_{CS,\text{HE}}(M_{r,u} + m)))$$

In an HE TB PPDU, transmitted by user $u$ in the $r^{\text{th}}$ occupied RU, each subfield, $r_{Subfield,r,u}^{(i_{Seg}, i_{TX})}(t)$, is defined in Equation (27-4).

$$r_{Subfield,r,u}^{(i_{Seg}, i_{TX})}(t) = \frac{\beta_r^{Field}}{\sqrt{N_{Norm,r}}} w_{T_{Subfield}}(t) \sum_{k \in K_r} \eta_{Field,k} \sum_{m=1}^{N_{STS,r,u}} \left[ Q_{k,u}^{(i_{Seg})} \right]_{i_{TX}, m} \Upsilon_{k,BW} \quad (27\text{-}4)$$

$$X_{k,r,u}^{(i_{Seg}, m)} \exp(j2\pi k \Delta_{F,Field}(t - T_{GI,Field} - T_{CS,\text{HE}}(M_{r,u} + m)))$$

For an HE SU PPDU, HE MU PPDU, and HE ER SU PPDU, the total power of the time domain HE modulated field signals summed over all transmit chains should not exceed the total power of the time domain pre-HE modulated field signals summed over all transmit chains if the TXVECTOR parameter BEAM_CHANGE is 1 or not present and power boost in HE modulated fields is not present.

For an HE TB PPDU, the total power of the time domain HE modulated field signals summed over all transmit chains may exceed the total power of the time domain pre-HE modulated field signals summed over all transmit chains by up to 3 dB.


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For notational simplicity, the parameter BW is omitted from some bandwidth-dependent terms.

In Equation (27-3) and Equation (27-4), the following notations are used:

$N_{Norm,r}$ If the TXVECTOR parameter BEAM_CHANGE is 1 or not present, then for pre-HE modulated fields, $N_{Norm,r} = N_{TX}$. If the TXVECTOR parameter BEAM_CHANGE is 0, then for pre-HE modulated fields $N_{Norm,r} = N_{STS,r,total}$, where $N_{STS,r,total}$ is given in Table 27-16 (Frequently used parameters(11ax)). For HE modulated fields $N_{Norm,r} = N_{STS,r,total}$.

$w_{Subfield}(t)$ is a windowing function. An example function, $w_{Subfield}(t)$, is given in 17.3.2.5 (Mathematical conventions in the signal descriptions).

$K_r$ For pre-HE modulated fields, $K_r$ is the set of subcarriers indices in the allocated 20 MHz channels. For HE modulated fields in a non-OFDMA HE PPDU, $K_r$ is the set of subcarriers indices from $-N_{SR}$ to $N_{SR}$ as defined in Table 27-14 (Subcarrier allocation related constants for the HE-modulated fields in a non-OFDMA HE PPDU(11ax)) excluding DC subcarriers. For HE modulated fields in an OFDMA HE PPDU, $K_r$ is the set of subcarrier indices for the tones in the $r^{th}$ RU as defined in Table 27-8 (Data and pilot subcarrier indices for RUs in a 20 MHz HE PPDU and in a non-OFDMA 20 MHz HE PPDU(11ax)), Table 27-9 (Data and pilot subcarrier indices for RUs in a 40 MHz HE PPDU and in a non-OFDMA 40 MHz HE PPDU(11ax)), and Table 27-10 (Data and pilot subcarrier indices for RUs in an 80 MHz HE PPDU and in a non-OFDMA 80 MHz HE PPDU(11ax)).

$\eta_{Field,k}$ is the power scale factor of the $k^{th}$ subcarrier of a given field within an OFDM symbol, which is $\sqrt{2}$ for all the subcarriers of the L-STF, L-LTF, HE-STF, and HE-LTF fields in the HE ER SU PPDU. For the L-SIG and RL-SIG fields of an HE ER SU PPDU,

$$\eta_{Field,k} = \begin{cases} \sqrt{2}, k = -28, -27, 27, 28 \\ 1, \text{ otherwise} \end{cases}$$

For the HE-SIG-A and Data fields in an HE ER SU PPDU, $\eta_{Field,k} = 1$. For the pre-HE portion of the HE TB PPDU, $\eta_{Field,k} = \left[\frac{1}{\sqrt{2}}, 1\right]$, meaning in the range $\frac{1}{\sqrt{2}}$ to 1. For all other fields in other HE PPDUs $\eta_{Field,k} = 1$.

$\alpha_r$ (#1067)is the power boost factor of the $r^{th}$ occupied RU in an HE PPDU, and equals the associated POWER_BOOST_FACTOR parameter in the TXVECTOR.

NOTE 2—$\alpha_r$ is constrained as defined in 26.11.10 (POWER_BOOST_FACTOR(#1067)), i.e., for an HE MU PPDU, $\alpha_r$ is in the range $[1/\sqrt{2}, \sqrt{2}]$ if the Power Boost Factor Support subfield of the HE PHY Capabilities Information field in the HE Capabilities element from any recipient STA of the PPDU equals 0; and otherwise $\alpha_r$ is in the range $[1/2, 2]$; further, for an HE SU PPDU, non-OFDMA HE MU PPDU, and HE ER SU PPDU, $\alpha_r$ is set to 1.

$\beta_r^{Field}$ is the power normalization factor and is defined in Equation (27-5)(#1053).

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$$\beta_r^{Field} = \begin{cases} \dfrac{\varepsilon_{Field}}{\sqrt{N_{Field}^{\text{Tone}} \cdot \dfrac{|\Omega_{20\text{MHz}}|}{N_{20\text{MHz}}}}}, \text{ for pre-HE modulated fields} \\ \dfrac{1}{\sqrt{|\Gamma_r^{Field}|}}, \text{ for HE modulated fields in an HE TB PPDU} \\ \sqrt{\dfrac{|K_r|}{|\Gamma_r^{Field}|}} \Big/ \sqrt{\sum_{r=0}^{N_{RU}-1} \alpha_r^2 |K_r|}, \text{ otherwise} \end{cases} \quad (27\text{-}5)$$

$|K_r|$ is the cardinality of the set of subcarriers $K_r$

$\Gamma_r^{Field}$ (#1053)equals the number of modulated subcarriers within the HE-STF and Data fields. For the HE-LTF field, $\Gamma_r^{Field}$ is defined as below to ensure per tone power is the same for both HE-STF and Data fields, regardless of 1×, 2×, or 4× HE-LTF:

$$\Gamma_r^{HE\text{-}LTF} = \begin{cases} |K_r|, \text{ for a 4x HE-LTF} \\ |K_r|/2, \text{ for a 2x HE-LTF} \\ |K_r|/4, \text{ for a 1x HE-LTF} \end{cases}$$

$N_{RU}$ is defined in Table 27-16 (Frequently used parameters(11ax)).

$$\varepsilon_{Field} = \begin{cases} \sqrt{\dfrac{N_{\text{L-LTF}}^{\text{Tone}}}{N_{\text{L-SIG}}^{\text{Tone}}}}, \text{ for the L-STF and L-LTF fields} \\ 1, \text{ otherwise} \end{cases}$$

$N_{Field}^{\text{Tone}}$ is given in Table 27-17 (Number of modulated subcarriers and guard interval duration values for HE PPDU fields(11ax)), which summarizes the various values of $N_{Field}^{\text{Tone}}$ as a function of bandwidth per frequency segment.

**Table 27-17—Number of modulated subcarriers and guard interval duration values for HE PPDU fields(11ax)**

| Field | $N_{Field}^{Tone}$ as a function of PPDU bandwidth | | | | Guard interval duration |
|---|---|---|---|---|---|
| | 20 MHz | 40 MHz | 80 MHz | 160 MHz | |
| L-STF | 12 | 24 | 48 | 96 | — |
| L-LTF | 52 | 104 | 208 | 416 | $T_{\text{GI,L-LTF}}$ |
| L-SIG in an HE PPDU | 56 | 112 | 224 | 448 | $T_{GI,\text{Pre-HE}}$ |
| L-SIG in a non-HT duplicate PPDU | — | 104 | 208 | 416 | |
| NOTE—For notational convenience, NON_HT_DUP_OFDM-Data is used as a label for the Data field of a (#238)non-HT PPDU with format type NON_HT_DUP_OFDM. | | | | | |


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**Table 27-17—Number of modulated subcarriers and guard interval duration values for HE PPDU fields(11ax) *(continued)***

| | | | | | |
|---|---|---|---|---|---|
| RL-SIG | 56 | 112 | 224 | 448 | $T_{GI,\text{Pre-HE}}$ |
| HE-SIG-A | 56 | 112 | 224 | 448 | $T_{GI,\text{Pre-HE}}$ |
| HE-SIG-B | 56 | 112 | 224 | 448 | $T_{GI,\text{Pre-HE}}$ |
| NON_HT_DUP_OFDM-Data (see NOTE) | — | 104 | 208 | 416 | $T_{GI,\text{Pre-HE}}$ |

NOTE—For notational convenience, NON_HT_DUP_OFDM-Data is used as a label for the Data field of a (#238)non-HT PPDU with format type NON_HT_DUP_OFDM.

$Q_k^{(i_{Seg})}$ is the spatial mapping matrix for the subcarrier $k$ in frequency segment $i_{Seg}$. For HE modulated fields, $Q_k^{(i_{Seg})}$ is a matrix with $N_{TX}$ rows and $N_{STS,r,total}$ columns. When beamforming or DL MU-MIMO is applied, $Q_k^{(i_{Seg})}$ is a beamforming or DL MU-MIMO steering matrix that is derived from the TXVECTOR parameter EXPANSION_MAT. The beamforming steering matrices and DL MU-MIMO steering matrices are implementation specific. If the TXVECTOR parameter BEAM_CHANGE is 1 or not present, then for pre-HE modulated fields $Q_k^{(i_{Seg})}$ is a column vector with $N_{TX}$ elements with element $i_{TX}$ being $\exp(-j2\pi k\Delta_{F,\text{Pre-HE}}T_{CS}^{i_{TX}})$, where $T_{CS}^{i_{TX}}$ represents the cyclic shift for the transmitter chain whose values are defined in 27.3.11.2.1 (Cyclic shift for pre-HE modulated fields); otherwise it is identical to the spatial mapping $Q_k^{(i_{Seg})}$ for HE modulated fields.

$Q_{k,u}^{(i_{Seg})}$ is the spatial mapping matrix for user $u$ on subcarrier $k$ in frequency segment $i_{Seg}$. For HE modulated fields, $Q_{k,u}^{(i_{Seg})}$ is a matrix with $N_{TX}$ rows and $N_{STS,r,u}$ columns. For pre-HE modulated fields, $Q_{k,u}^{(i_{Seg})}$ is a column vector with $N_{TX}$ elements with element $i_{TX}$ being $\exp(-j2\pi k\Delta_{F,\text{Pre-HE}}T_{CS}^{i_{TX}})$, where $T_{CS}^{i_{TX}}$ represents the cyclic shift for the transmitter chain whose values are defined in 27.3.11.2.1 (Cyclic shift for pre-HE modulated fields).

$\Delta_{F,Field}$ is the subcarrier frequency spacing. For pre-HE modulated fields, $\Delta_{F,Field} = \Delta_{F,\text{Pre-HE}}$ given in Table 27-13 (Timing-related constants(11ax)). For HE modulated fields, $\Delta_{F,Field} = \Delta_{F,\text{HE}}$ given in Table 27-13 (Timing-related constants(11ax)).

$M_{r,u}$ is given in Table 27-16 (Frequently used parameters(11ax)).

$X_{k,r,u}^{(i_{Seg},m)}$ is the frequency-domain symbol in subcarrier $k$ of user $u$ in the $r^{\text{th}}$ RU for frequency segment $i_{Seg}$ of space-time stream $m$. Some of the $X_{k,r,u}^{(i_{Seg},m)}$ within $-N_{SR} \le k \le N_{SR}$ have a value of zero. Examples of such cases include the DC tones, guard tones on each side of the transmit spectrum, the null subcarriers in an HE OFDMA PPDU, and the unmodulated tones of L-STF, HE-STF, and HE-LTF fields.

$T_{GI,Field}$ is the guard interval duration used for each OFDM symbol in the field. The value for each field is defined in Table 27-13 (Timing-related constants(11ax)).

$T_{CS,\text{HE}}(l)$ For pre-HE modulated fields, if the TXVECTOR parameter BEAM_CHANGE is 1 or not present, $T_{CS,\text{HE}}(l) = 0$. For HE modulated fields and pre-HE modulated fields if the TXVECTOR parameter BEAM_CHANGE is 0, $T_{CS,\text{HE}}(l)$ represents the cyclic shift per

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space-time stream, whose value is defined in 27.3.11.2.2 (Cyclic shift for HE modulated fields).

$\Upsilon_{k,BW}$ is used to represent tone rotation. $BW$ in $\Upsilon_{k,BW}$ is determined by the TXVECTOR parameter CH_BANDWIDTH as defined in Table 27-18 (CH_BANDWIDTH and for pre-HE modulated fields(11ax)). In HE modulated fields, $\Upsilon_{k,BW} = 1$ for all the subcarriers. In pre-HE modulated fields, $\Upsilon_{k,BW}$ is defined as in 21.3.7.5 (Definition of tone rotation) if TXVECTOR parameter BEAM_CHANGE is 1 and $\Upsilon_{k,BW} = 1$ for all the subcarriers if TXVECTOR parameter BEAM_CHANGE is 0. If the TXVECTOR parameter BEAM_CHANGE is not present (such as in an HE MU PPDU and HE TB PPDU), BEAM_CHANGE is assumed to be 1.

**Table 27-18—CH_BANDWIDTH and $\Upsilon_{k,BW}$ for pre-HE modulated fields(11ax)**

| CH_BANDWIDTH | $\Upsilon_{k,BW}$ |
|---|---|
| CBW20 | $\Upsilon_{k,20}$ |
| CBW40 | $\Upsilon_{k,40}$ |
| CBW80 | $\Upsilon_{k,80}$ |
| CBW160 | $\Upsilon_{k,160}$ |
| CBW80+80 | $\Upsilon_{k,80}$ per frequency segment |
| HE-CBW-PUNC80-PRI | $\Upsilon_{k,80}$ |
| HE-CBW-PUNC80-SEC | $\Upsilon_{k,80}$ |
| HE-CBW-PUNC160-PRI20 | $\Upsilon_{k,160}$ |
| HE-CBW-PUNC80+80-PRI20 | $\Upsilon_{k,80}$ per frequency segment |
| HE-CBW-PUNC160-SEC40 | $\Upsilon_{k,160}$ |
| HE-CBW-PUNC80+80-SEC40 | $\Upsilon_{k,80}$ per frequency segment |

$\Omega_{20MHz}$ is a set of 20 MHz channels where pre-HE modulated fields are located. The set of 20 MHz channels contains one or more values in the range 0 to $N_{20MHz} - 1$ for an HE TB PPDU, HE sounding NDP, or HE MU PPDU with preamble puncturing, and it contains all values in the range 0 to $N_{20MHz} - 1$ for other HE PPDU formats.

$|\Omega_{20MHz}|$ is the cardinality of the set of 20 MHz channels where pre-HE modulated fields are located.

$$N_{20MHz} = \begin{cases} 1, \text{ if CH\_BANDWIDTH is CBW20} \\ 2, \text{ if CH\_BANDWIDTH is CBW40} \\ 4, \text{ if CH\_BANDWIDTH is CBW80, HE-CBW-PUNC80-PRI,} \\ \quad \text{HE-CBW-PUNC80-SEC, CBW80+80, HE-CBW-PUNC80+80-PRI20,} \\ \quad \text{or HE-CBW-PUNC80+80-SEC40} \\ 8, \text{ if CH\_BANDWIDTH is CBW160, HE-CBW-PUNC160-PRI20,} \\ \quad \text{or HE-CBW-PUNC160-SEC40} \end{cases}$$


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## 27.3.11 HE preamble

### 27.3.11.1 Introduction

The HE preamble consists of pre-HE modulated fields and HE modulated fields. The pre-HE modulated fields for the various HE PPDU formats are the following:

— L-STF, L-LTF, L-SIG, RL-SIG, and HE-SIG-A fields of an HE SU PPDU, HE ER SU PPDU, and HE TB PPDU

— L-STF, L-LTF, L-SIG, RL-SIG, HE-SIG-A, and HE-SIG-B fields of an HE MU PPDU

The HE modulated fields in the preamble for all HE PPDU formats are the HE-STF and HE-LTF fields.

(11az)See 27.3.20 (HE-LTF field using secure HE-LTF(11az)) for the description of the HE-LTF field using secure HE-LTF in the preamble of HE Ranging NDP and HE TB Ranging NDP.

### 27.3.11.2 Cyclic shift

#### 27.3.11.2.1 Cyclic shift for pre-HE modulated fields

If the TXVECTOR parameter BEAM_CHANGE is 1 or not present, then the cyclic shift value $T_{CS}^{i_{TX}}$ for the L-STF, L-LTF, L-SIG, RL-SIG, HE-SIG-A, and HE-SIG-B fields of the PPDU for transmit chain $i_{TX}$ out of a total of $N_{TX}$ are defined in Table 21-10 (Cyclic shift values for L-STF, L-LTF, L-SIG, and VHT-SIG-A fields of the PPDU). In UL MU transmission, the cyclic shift value $T_{CS}^{i_{TX}}$ is based on the local transmit chain indices at each STA.

If the TXVECTOR parameter BEAM_CHANGE is 0, then the cyclic shift value $T_{CS,\mathrm{HE}}(n)$ for the L-STF, L-LTF, L-SIG, RL-SIG, and HE-SIG-A fields is specified in 27.3.11.2.2 (Cyclic shift for HE modulated fields).

#### 27.3.11.2.2 Cyclic shift for HE modulated fields

The cyclic shift values defined in this subclause apply to the HE-STF, HE-LTF, and Data fields of the HE PPDU if the TXVECTOR parameter BEAM_CHANGE is 1 or not present and apply to the entire PPDU if the TXVECTOR parameter BEAM_CHANGE is 0.

Throughout the HE modulated fields of the preamble, cyclic shifts are applied to prevent unintended beamforming when correlated signals are transmitted in multiple space-time streams. The same cyclic shifts are also applied to these streams during the transmission of the Data field of the HE PPDU. For the $r^{\mathrm{th}}$ RU, the cyclic shift value $T_{CS,\mathrm{HE}}(n)$ for the HE modulated fields for space-time stream $n$ out of $N_{STS,r,total}$ total space-time streams is shown in Table 21-11 (Cyclic shift values for the VHT modulated fields of a PPDU).

### 27.3.11.3 L-STF field

If the TXVECTOR parameter BEAM_CHANGE is 1 or not present, the time domain representation of the L-STF field, transmitted on frequency segment $i_{Seg}$ and transmit chain $i_{TX}$, shall be as specified in Equation (27-6). The equation applies to signals up to a contiguous 160 MHz PPDU bandwidth and noncontiguous 80+80 MHz PPDU bandwidth.

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$$r_{\text{L-STF}}^{(i_{Seg}, i_{TX})}(t) = \frac{\varepsilon}{\sqrt{N_{TX} \cdot N_{\text{L-STF}}^{\text{Tone}} \cdot \frac{|\Omega_{20\text{MHz}}|}{N_{20\text{MHz}}}}} w_{T_{\text{L-STF}}}(t) \sum_{i_{BW} \in \Omega_{20\text{MHz}}} \sum_{k=-26}^{26} \eta_{\text{L-STF}, k} \left( \Upsilon_{(k - K_{\text{Shift}}(i_{BW})), \text{BW}} S_{k, 20} \cdot \exp(j2\pi(k - K_{\text{Shift}}(i_{\text{BW}}))\Delta_{F, \text{Pre-HE}}(t - T_{CS}^{i_{TX}})) \right) \quad (27\text{-}6)$$

where

$\varepsilon$ is a power scaling factor with the value $\varepsilon = \sqrt{\frac{N_{\text{L-LTF}}^{\text{Tone}}}{N_{\text{L-SIG}}^{\text{Tone}}}}$

$\eta_{\text{L-STF}, k}$ is a PPDU format-dependent scaling factor for the L-STF field on subcarrier index $k$ with the following value:

$$\eta_{\text{L-STF}, k} = \begin{cases} \sqrt{2}, & \text{for an HE ER SU PPDU} \\ \left[\frac{1}{\sqrt{2}}, 1\right], & \text{for an HE TB PPDU} \\ 1, & \text{otherwise} \end{cases} \quad (27\text{-}7)$$

$K_{Shift}(i) = (N_{20\text{MHz}} - 1 - 2i) \times 32$ (M118)

$T_{CS}^{i_{TX}}$ represents the cyclic shift for transmit chain $i_{TX}$ with a value given in 27.3.11.2.1 (Cyclic shift for pre-HE modulated fields)

$N_{\text{L-STF}}^{\text{Tone}}$ has the value given in Table 27-17 (Number of modulated subcarriers and guard interval duration values for HE PPDU fields(11ax))

$S_{k,20}$ is defined as $S_{-26,26}$ in Equation (19-8)

$i_{BW}$ is the index of 20 MHz channels, $0 \le i_{BW} \le N_{20\text{MHz}} - 1$

If the TXVECTOR parameter BEAM_CHANGE is 0, the time domain representation of the L-STF field shall be as specified in Equation (27-8). The equation applies to signals up to a contiguous 160 MHz PPDU bandwidth and noncontiguous 80+80 MHz PPDU bandwidth.

$$r_{\text{L-STF}}^{(i_{Seg}, i_{TX})}(t) = \frac{\varepsilon}{\sqrt{N_{STS} \cdot N_{\text{L-STF}}^{\text{Tone}} \cdot \frac{|\Omega_{20\text{MHz}}|}{N_{20\text{MHz}}}}} w_{T_{\text{L-STF}}}(t) \sum_{i_{BW}=0}^{N_{20\text{MHz}}-1} \sum_{k=-26}^{26} \sum_{m=1}^{N_{STS}} \eta_{\text{L-STF}, k} \left( \left[ Q_{4(k - K_{\text{Shift}}(i_{BW}))}^{(i_{Seg})} \right]_{i_{TX}, m} \left[ A_{\text{HE-LTF}}^{4(k - K_{\text{Shift}}(i_{BW}))} \right]_{m, 1} S_{k, 20} \cdot \exp(j2\pi(k - K_{\text{Shift}}(i_{\text{BW}}))\Delta_{F, \text{Pre-HE}}(t - T_{CS, \text{HE}}(m))) \right) \quad (27\text{-}8)$$

where

$T_{CS, \text{HE}}(m)$ represents the cyclic shift for space-time stream $m$ as defined in 27.3.11.2.2 (Cyclic shift for HE modulated fields)


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$Q_k^{(i_{Seg})}$ is the spatial mapping/steering matrix for subcarrier $k$, in frequency segment $i_{Seg}$ on the data OFDM symbols over subcarrier spacing $\Delta_{F,\,\mathrm{HE}}$ as defined in Table 27-13 (Timing-related constants(11ax)). Refer to the descriptions in 21.3.10.11.1 (Transmission in VHT format) for examples of $Q_k^{(i_{Seg})}$.

$A^k_{\text{HE-LTF}}$ is defined in Equation (27-55)

$N_{STS}$ is the number of space-time streams of the HE-modulated fields in an HE SU PPDU or HE ER SU PPDU as defined in Table 27-16 (Frequently used parameters(11ax))

### 27.3.11.4 L-LTF field

If the TXVECTOR parameter BEAM_CHANGE is 1 or not present, the time domain representation of the L-LTF field, transmitted on frequency segment $i_{Seg}$ and transmit chain $i_{TX}$, shall be as specified in Equation (27-9). The equation applies to signals up to a contiguous 160 MHz PPDU bandwidth and noncontiguous 80+80 MHz PPDU bandwidth.

$$r_{\text{L-LTF}}^{(i_{Seg},\,i_{TX})}(t) = \frac{\varepsilon}{\sqrt{N_{TX}\cdot N_{\text{L-LTF}}^{\text{Tone}}\cdot\dfrac{|\Omega_{20\text{MHz}}|}{N_{20\text{MHz}}}}} w_{T_{\text{L-LTF}}}(t) \sum_{i_{BW}\in\Omega_{20\text{MHz}}}\sum_{k=-26}^{26}\eta_{\text{L-LTF},\,k}\left(\begin{array}{l}\Upsilon_{(k-K_{\text{Shift}}(i_{BW})),\,\text{BW}}L_{k,\,20}\\ \cdot\exp(j2\pi(k-K_{\text{Shift}}(i_{\text{BW}}))\Delta_{F,\,\text{Pre-HE}}(t-T_{GI,\,\text{L-LTF}}-T_{CS}^{i_{TX}}))\end{array}\right) \tag{27-9}$$

where

$\eta_{\text{L-LTF},\,k}$ is a PPDU format-dependent scaling factor for the L-LTF field on subcarrier index $k$ with the same value as $\eta_{\text{L-STF},\,k}$

$\varepsilon$ is a power scaling factor with the value $\varepsilon = \sqrt{\dfrac{N_{\text{L-LTF}}^{\text{Tone}}}{N_{\text{L-SIG}}^{\text{Tone}}}}$

$T_{GI,\text{L-LTF}}$ is given in Table 27-13 (Timing-related constants(11ax))

$K_{Shift}(i) = (N_{20\text{MHz}} - 1 - 2i)\times 32$ (M118)

$T_{CS}^{i_{TX}}$ represents the cyclic shift for transmit chain $i_{TX}$ with a value given in 27.3.11.2.1 (Cyclic shift for pre-HE modulated fields)

$N_{\text{L-LTF}}^{\text{Tone}}$ has the value given in Table 27-17 (Number of modulated subcarriers and guard interval duration values for HE PPDU fields(11ax))

$L_{k,20}$ is defined as $L_{-26,26}$ in Equation (17-8)

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If the TXVECTOR parameter BEAM_CHANGE is 0, the time domain representation of the L-LTF field shall be as specified in Equation (27-10). The equation applies to signals up to a contiguous 160 MHz PPDU bandwidth and noncontiguous 80+80 MHz PPDU bandwidth.

$$r_{\text{L-LTF}}^{(i_{Seg}, i_{TX})}(t) = \frac{\varepsilon}{\sqrt{N_{STS} \cdot N_{\text{L-LTF}}^{\text{Tone}} \cdot \frac{|\Omega_{20\text{MHz}}|}{N_{20\text{MHz}}}}} w_{T_{\text{L-LTF}}}(t) \quad (27\text{-}10)$$

$$\sum_{i_{BW}=0}^{N_{20\text{MHz}}-1} \sum_{k=-26}^{26} \sum_{m=1}^{N_{STS}} \eta_{\text{L-LTF}, k} \left( \left[ Q_{4(k-K_{\text{Shift}}(i_{BW}))}^{(i_{Seg})} \right]_{i_{TX}, m} \left[ A_{\text{HE-LTF}}^{4(k-K_{\text{Shift}}(i_{BW}))} \right]_{m, 1} L_{k, 20} \cdot \exp(j2\pi(k - K_{\text{Shift}}(i_{\text{BW}}))\Delta_{F, \text{Pre-HE}}(t - T_{GI, \text{L-LTF}} - T_{CS, \text{HE}}(m))) \right)$$

where

$T_{CS, \text{HE}}(m)$ represents the cyclic shift for space-time stream $m$ as defined in 27.3.11.2.2 (Cyclic shift for HE modulated fields)

$Q_k^{(i_{Seg})}$ is defined in 27.3.10 (Mathematical description of signals)

$A_{\text{HE-LTF}}^k$ is defined in Equation (27-55)

### 27.3.11.5 L-SIG field

The L-SIG field is used to communicate rate and length information. The structure of the L-SIG field is defined in Figure 17-5 (SIGNAL field bit assignment).

In an HE PPDU, the RATE field shall be set to the value representing 6 Mb/s in the (#4177)Rate (20 MHz channel spacing) column of Table 17-6 (Contents of the SIGNAL field). In a non-HT duplicate PPDU, the RATE field is defined in 17.3.4.2 (RATE field)using the L_DATARATE parameter in the TXVECTOR.

For an HE TB PPDU, the LENGTH field is set to the TXVECTOR parameter L_LENGTH. For an HE SU PPDU, HE ER SU PPDU, and HE MU PPDU, the LENGTH field is set to the value given by the Equation (27-11).

$$\text{Length} = \left\lceil \frac{\text{TXTIME} - \textit{SignalExtension} - 20}{4} \right\rceil \times 3 - 3 - m \quad (27\text{-}11)$$

where

TXTIME is defined in 27.4.3 (TXTIME and PSDU_LENGTH calculation) (in μs)

$m$ is 1 for an HE MU PPDU and HE ER SU PPDU and 2 otherwise

*SignalExtension* is 0 μs if the TXVECTOR parameter NO_SIG_EXTN is true and is aSignalExtension as defined in Table 27-61 (HE PHY characteristics(11ax)) if the TXVECTOR parameter NO_SIG_EXTN is false

In a non-HT duplicate PPDU, the LENGTH field is defined in 17.3.4.3 (PHY LENGTH field) using the L_LENGTH parameter in the TXVECTOR.

The Reserved (R) field shall be set to 0.

The Parity (P) field has the even parity of bits 0-16.

The SIGNAL TAIL field shall be set to 0.


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The L-SIG field shall be encoded, interleaved, and mapped following the steps described in 17.3.5.6 (Convolutional encoder), 17.3.5.7 (Data interleaving), and 17.3.5.8 (Subcarrier modulation mapping). The stream of 48 complex numbers generated by these steps is denoted by $d_k, k = 0, \ldots, 47$ and is mapped to subcarriers [–26, 26]. In addition, values [–1, –1, –1, 1] are mapped to the extra subcarriers [–28, –27, 27, 28] of the L-SIG field of a 20 MHz HE PPDU. Subcarriers [–28, –27, 27, 28] are also BPSK modulated. Pilots shall be inserted as described in 17.3.5.9 (Pilot subcarriers).

If the TXVECTOR parameter BEAM_CHANGE is 1 or not present, the time domain waveform of the L-SIG field, transmitted on frequency segment $i_{Seg}$ and transmit chain $i_{TX}$, shall be as given by Equation (27-12).

$$r_{\text{L-SIG}}^{(i_{Seg}, i_{TX})}(t) = \frac{1}{\sqrt{N_{TX} \cdot N_{\text{L-SIG}}^{\text{Tone}} \cdot \frac{|\Omega_{20\text{MHz}}|}{N_{20\text{MHz}}}}} w_{T_{\text{L-SIG}}}(t) \sum_{i_{BW} \in \Omega_{20\text{MHz}}} \sum_{k=-28}^{28} \left( \begin{array}{l} \Upsilon_{(k - K_{\text{Shift}}(i_{BW})), \text{BW}} \eta_{\text{L-SIG}, k} (D_{k, 20} + p_0 P_k) \\ \cdot \exp(j2\pi(k - K_{\text{Shift}}(i_{\text{BW}})) \Delta_{F, \text{Pre-HE}} (t - T_{GI, \text{Pre-HE}} - T_{CS}^{i_{TX}})) \end{array} \right) \quad (27\text{-}12)$$

where

$\eta_{\text{L-SIG}, k}$ is a PPDU-dependent scaling factor for the L-SIG field on the subcarrier $k$ defined as follows:

$$\eta_{\text{L-SIG}, k} = \begin{cases} \sqrt{2}, & k = \pm 28, \pm 27 \text{ for an HE ER SU PPDU} \\ \left[\frac{1}{\sqrt{2}}, 1\right], & \text{for an HE TB PPDU} \\ 1, & \text{otherwise} \end{cases}$$

$T_{GI,\text{Pre-HE}}$ is given in Table 27-13 (Timing-related constants(11ax))

$K_{Shift}(i) = (N_{20\text{MHz}} - 1 - 2i) \times 32$ (M118)

$$D_{k, 20} = \begin{cases} 0, k = 0, \pm 7, \pm 21 \\ -1, k = -28, -27, 27 \\ 1, k = 28 \\ d_{M_{20}^r(k)}, \text{otherwise} \end{cases}$$

$$M_{20}^r(k) = \begin{cases} k + 26, -26 \le k \le -22 \\ k + 25, -20 \le k \le -8 \\ k + 24, -6 \le k \le -1 \\ k + 23, 1 \le k \le 6 \\ k + 22, 8 \le k \le 20 \\ k + 21, 22 \le k \le 26 \end{cases}$$

$P_k$ is defined in 17.3.5.10 (OFDM modulation)

$p_0$ is the first pilot value in the sequence defined in 17.3.5.10 (OFDM modulation)

$N_{\text{L-SIG}}^{\text{Tone}}$ is defined in Table 27-17 (Number of modulated subcarriers and guard interval duration values for HE PPDU fields(11ax))

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$T_{CS}^{i_{TX}}$ represents the cyclic shift for transmit chain $i_{TX}$ with a value given in 27.3.11.2.1 (Cyclic shift for pre-HE modulated fields)

NOTE—$M_{20}^{r}(k)$ is a "reverse" function of the function $M(k)$ defined in 17.3.5.10 (OFDM modulation).

If the TXVECTOR parameter BEAM_CHANGE is 0, the time domain waveform of the L-SIG field, transmitted on frequency segment $i_{Seg}$ and transmit chain $i_{TX}$, shall be as given by Equation (27-13).

$$r_{\text{L-SIG}}^{(i_{Seg}, i_{TX})}(t) = \frac{1}{\sqrt{N_{STS} \cdot N_{\text{L-SIG}}^{\text{Tone}} \cdot \frac{|\Omega_{20\text{MHz}}|}{N_{20\text{MHz}}}}} w_{T_{\text{L-SIG}}}(t) \sum_{i_{BW}=0}^{N_{20\text{MHz}}-1} \sum_{k=-28}^{28} \sum_{m=1}^{N_{STS}} \left( \begin{array}{l} \left[ Q_{4(k-K_{\text{Shift}}(i_{BW}))}^{(i_{Seg})} \right]_{i_{TX}, m} \left[ A_{\text{HE-LTF}}^{4(k-K_{\text{Shift}}(i_{BW}))} \right]_{m, 1} \eta_{\text{L-SIG}, k}(D_{k,20} + p_0 P_k) \\ \cdot \exp(j2\pi(k - K_{\text{Shift}}(i_{\text{BW}}))\Delta_{F, \text{Pre-HE}}(t - T_{GI, \text{Pre-HE}} - T_{CS, \text{HE}}(m))) \end{array} \right) \quad (27\text{-}13)$$

where

$T_{CS, \text{HE}}(m)$ represents the cyclic shift for space-time stream $m$ as defined in 27.3.11.2.2 (Cyclic shift for HE modulated fields)

$Q_k^{(i_{Seg})}$ is defined in 27.3.10 (Mathematical description of signals)

$A_{\text{HE-LTF}}^{k}$ is defined in Equation (27-55)

### 27.3.11.6 RL-SIG field

The RL-SIG field is a repeat of the L-SIG field and is used to differentiate an HE PPDU from a non-HT PPDU, HT PPDU, and VHT PPDU.

If the TXVECTOR parameter BEAM_CHANGE is 1 or not present, the time domain waveform of the RL-SIG field, transmitted on frequency segment $i_{Seg}$ and transmit chain $i_{TX}$, shall be as given by Equation (27-14).

$$r_{\text{RL-SIG}}^{(i_{Seg}, i_{TX})}(t) = \frac{1}{\sqrt{N_{TX} \cdot N_{\text{RL-SIG}}^{\text{Tone}} \cdot \frac{|\Omega_{20\text{MHz}}|}{N_{20\text{MHz}}}}} w_{T_{\text{RL-SIG}}}(t) \sum_{i_{BW} \in \Omega_{20\text{MHz}}} \sum_{k=-28}^{28} \left( \begin{array}{l} \Upsilon_{(k-K_{\text{Shift}}(i_{BW})), \text{BW}} \eta_{\text{L-SIG}, k}(D_{k,20} + p_1 P_k) \\ \cdot \exp(j2\pi(k - K_{\text{Shift}}(i_{\text{BW}}))\Delta_{F, \text{Pre-HE}}(t - T_{GI, \text{Pre-HE}} - T_{CS}^{i_{TX}})) \end{array} \right) \quad (27\text{-}14)$$

If the TXVECTOR parameter BEAM_CHANGE is 0, the time domain waveform of the RL-SIG field, transmitted on frequency segment $i_{Seg}$ and transmit chain $i_{TX}$, shall be as given by Equation (27-15).

$$r_{\text{RL-SIG}}^{(i_{Seg}, i_{TX})}(t) = \frac{1}{\sqrt{N_{STS} \cdot N_{\text{RL-SIG}}^{\text{Tone}} \cdot \frac{|\Omega_{20\text{MHz}}|}{N_{20\text{MHz}}}}} w_{T_{\text{RL-SIG}}}(t) \sum_{i_{BW}=0}^{N_{20\text{MHz}}-1} \sum_{k=-28}^{28} \sum_{m=1}^{N_{STS}} \left( \begin{array}{l} \left[ Q_{4(k-K_{\text{Shift}}(i_{BW}))}^{(i_{Seg})} \right]_{i_{TX}, m} \left[ A_{\text{HE-LTF}}^{4(k-K_{\text{Shift}}(i_{BW}))} \right]_{m, 1} \eta_{\text{L-SIG}, k}(D_{k,20} + p_1 P_k) \\ \cdot \exp(j2\pi(k - K_{\text{Shift}}(i_{\text{BW}}))\Delta_{F, \text{Pre-HE}}(t - T_{GI, \text{Pre-HE}} - T_{CS, \text{HE}}(m))) \end{array} \right) \quad (27\text{-}15)$$


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where

| | |
|---|---|
| $p_1$ | is the second pilot value in the sequence defined in 17.3.5.10 (OFDM modulation) |
| other variables | are defined after Equation (27-1), Equation (27-3), Equation (27-4), Equation (27-6), Equation (27-8), and Equation (27-12) |

### 27.3.11.7 HE-SIG-A field

#### 27.3.11.7.1 General

The HE-SIG-A field carries information necessary to interpret HE PPDUs. The integer fields of the HE-SIG-A field are transmitted in unsigned binary format, LSB first, where the LSB is in the lowest numbered bit position.

#### 27.3.11.7.2 Content

The HE-SIG-A field for an HE SU PPDU or an HE ER SU PPDU contains the fields listed in Table 27-19 (HE-SIG-A field of an HE SU PPDU and HE ER SU PPDU(11ax)).

**Table 27-19—HE-SIG-A field of an HE SU PPDU and HE ER SU PPDU(11ax)**

| Bit | Field | Number of bits | Description |
|---|---|---|---|
| **HE-SIG-A1 subfield of HE-SIG-A field** | | | |
| B0 | Format | 1 | Differentiate an HE SU PPDU and HE ER SU PPDU from an HE TB PPDU:<br>Set to 1 for an HE SU PPDU and HE ER SU PPDU. |
| B1 | Beam Change | 1 | Set to 1 to indicate that the pre-HE modulated fields of the PPDU may be spatially mapped differently from the first symbol of the HE-LTF. Equation (27-6), Equation (27-9), Equation (27-12), Equation (27-14), Equation (27-16), and Equation (27-18) apply if the Beam Change field is 1.<br>Set to 0 to indicate that the pre-HE modulated fields of the PPDU are spatially mapped the same way as the first symbol of the HE-LTF on each subcarrier. Equation (27-8), Equation (27-10), Equation (27-13), Equation (27-15), Equation (27-17), and Equation (27-19)apply if the Beam Change field is 0. |
| B2 | UL/DL | 1 | Indicates whether the PPDU is sent (#2249)in the UL or DL. Set to 1 if the PPDU is addressed to an AP. Set to 0 otherwise. See TXVECTOR parameter UPLINK_FLAG. |
| B3–B6 | HE-MCS | 4 | For an HE SU PPDU:<br>Set to *n* for HE-MCS *n*, where *n* = 0, 1, 2, …, 11.<br>Values 12–15 are reserved.<br><br>For an HE ER SU PPDU with Bandwidth field set to 0 (242-tone RU):<br>Set to *n* for HE-MCS *n*, where *n* = 0, 1, 2.<br>Values 3–15 are reserved.<br><br>For an HE ER SU PPDU with Bandwidth field set to 1 (upper frequency 106-tone RU):<br>Set to 0 for HE-MCS 0.<br>Values 1–15 are reserved. |

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**Table 27-19—HE-SIG-A field of an HE SU PPDU and HE ER SU PPDU(11ax) *(continued)***

| Bit | Field | Number of bits | Description |
|---|---|---|---|
| B7 | DCM | 1 | Indicates whether DCM is applied to the Data field for the HE-MCS indicated. See Table 27-20 (Interpretation of DCM, STBC, and GI+HE-LTF Size subfields(11ax)) for the interpretation of this field.<br><br>NOTE—DCM is applicable to only HE-MCSs 0, 1, 3, and 4. DCM is applicable to only 1 and 2 spatial streams. |
| B8–B13 | BSS Color | 6 | An identifier of the BSS.<br><br>See TXVECTOR parameter BSS_COLOR. |
| B14 | Reserved | 1 | Reserved and set to 1. |
| B15–B18 | Spatial Reuse | 4 | Indicates whether spatial reuse modes are allowed during the transmission of this PPDU:<br>Set to a value from Table 27-23 (Spatial Reuse field encoding for an HE SU PPDU, HE ER SU PPDU, and HE MU PPDU(11ax)) (see 26.11.6 (SPATIAL_REUSE) and 26.10 (HE spatial reuse operation(#2389))). |
| B19–B20 | Bandwidth | 2 | For an HE SU PPDU:<br>Set to 0 for 20 MHz.<br>Set to 1 for 40 MHz.<br>Set to 2 for 80 MHz.<br>Set to 3 for 160 MHz and 80+80 MHz.<br><br>For an HE ER SU PPDU:<br>Set to 0 for 242-tone RU.<br>Set to 1 for upper frequency 106-tone RU within the primary 20 MHz.<br>Values 2 and 3 are reserved. |
| B21–B22 | GI+HE-LTF Size | 2 | Indicates the GI duration and HE-LTF size. See Table 27-20 (Interpretation of DCM, STBC, and GI+HE-LTF Size subfields(11ax)) for the interpretation of this field. |
| B23–B25 | NSTS And Midamble Periodicity | 3 | If the Doppler field is 0, indicates the number of space-time streams. Set to the number of space-time streams minus 1. For an HE ER SU PPDU, values 2–7 are reserved.<br><br>If the Doppler field is 1, then B23-B24 indicates the number of space time streams, up to 4, and B25 indicates the midamble periodicity. B23-B24 is set to the number of space time streams minus 1. For an HE ER SU PPDU, values 2 and 3 are reserved.<br><br>B25 is set to 0 for 10 symbol midamble periodicity, to 1 for 20 symbol midamble periodicity. See TXVECTOR parameter MIDAMBLE_PERIODICITY. |
| **HE-SIG-A2 subfield of HE-SIG-A field** | | | |



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**Table 27-19—HE-SIG-A field of an HE SU PPDU and HE ER SU PPDU(11ax) *(continued)***

| Bit | Field | Number of bits | Description |
|---|---|---|---|
| B0–B6 | TXOP | 7 | Set to 127 to indicate no duration information.<br><br>Set to a value less than 127 to indicate the closest minimum bound on the duration information for NAV setting and protection of the TXOP as follows:<br>If B0 is 0, the TXOP duration indicated is B1-B6, in units of 8 μs.<br>If B0 is 1, the TXOP duration indicated is B1-B6, in units of 128 μs, plus 512 μs.<br><br>See TXVECTOR parameter TXOP_DURATION. |
| B7 | Coding | 1 | Indicates whether BCC or LDPC is used:<br>Set to 0 to indicate BCC<br>Set to 1 to indicate LDPC |
| B8 | LDPC Extra Symbol Segment | 1 | Indicates the presence of the LDPC extra symbol segment:<br>Set to 1 if an LDPC extra symbol segment is present.<br>Set to 0 if an LDPC extra symbol segment is not present.<br><br>Reserved and set to 1 if the Coding field is 0. |
| B9 | STBC | 1 | Indicates whether STBC is applied to the Data field. See Table 27-20 (Interpretation of DCM, STBC, and GI+HE-LTF Size subfields(11ax)) for the interpretation of this field. |
| B10 | Beamformed | 1 | Set to 1 if a beamforming steering matrix is applied to the HE modulated fields.<br>Set to 0 otherwise. |
| B11–B12 | Pre-FEC Padding Factor | 2 | Indicates the pre-FEC padding factor:<br>Set to 0 to indicate a pre-FEC padding factor of 4.<br>Set to 1 to indicate a pre-FEC padding factor of 1.<br>Set to 2 to indicate a pre-FEC padding factor of 2.<br>Set to 3 to indicate a pre-FEC padding factor of 3. |
| B13 | PE Disambiguity | 1 | Indicates PE disambiguity as defined in 27.3.13 (Packet extension). |
| B14 | Reserved | 1 | Reserved and set to 1. |
| B15 | Doppler | 1 | Set to 1 if one of the following applies:<br>— The number of OFDM symbols in the Data field is larger than the signaled midamble periodicity plus 1 and the midamble is present.<br>— The number of OFDM symbols in the Data field is less than or equal to the signaled midamble periodicity plus 1 (see 27.3.12.16 (Midambles), the midamble is not present, but the channel is fast varying. It recommends that midamble may be used for the PPDUs of the reverse link.<br>Set to 0 otherwise. |
| B16–B19 | CRC | 4 | CRC for bits 0–41 of the HE-SIG-A field (see 27.3.11.7.3 ((CRC computation)).<br>Bits 0–41 of the HE-SIG-A field correspond to bits 0–25 of the HE-SIG-A1 subfield followed by bits 0–15 of the HE-SIG-A2 subfield. |
| B20–B25 | Tail | 6 | Used to terminate the trellis of the convolutional decoder. Set to 0. |

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For an HE SU PPDU and HE ER SU PPDU, the DCM, STBC, and GI+HE-LTF Size subfields in the HE-SIG-A field are interpreted as defined in Table 27-20 (Interpretation of DCM, STBC, and GI+HE-LTF Size subfields(11ax)).

**Table 27-20—Interpretation of DCM, STBC, and GI+HE-LTF Size subfields(11ax)**

| Subfields in the HE-SIG-A field of an HE SU PPDU or HE ER SU PPDU (see Table 27-19 (HE-SIG-A field of an HE SU PPDU and HE ER SU PPDU(11ax))) | | | Interpretation | | |
|---|---|---|---|---|---|
| **DCM** | **STBC** | **GI+HE-LTF Size** | **DCM Applied** | **STBC Applied** | **GI+HE-LTF size** |
| 0 | 0 | 0 | No | No | 1x HE-LTF and 0.8 μs GI |
| | | 1 | | | 2x HE-LTF and 0.8 μs GI |
| | | 2 | | | 2x HE-LTF and 1.6 μs GI |
| | | 3 | | | 4x HE-LTF and 3.2 μs GI |
| 1 | 0 | 0 | Yes | No | 1x HE-LTF and 0.8 μs GI |
| | | 1 | | | 2x HE-LTF and 0.8 μs GI |
| | | 2 | | | 2x HE-LTF and 1.6 μs GI |
| | | 3 | | | 4x HE-LTF and 3.2 μs GI |
| 0 | 1 | 0 | No | Yes | 1x HE-LTF and 0.8 μs GI |
| | | 1 | | | 2x HE-LTF and 0.8 μs GI |
| | | 2 | | | 2x HE-LTF and 1.6 μs GI |
| | | 3 | | | 4x HE-LTF and 3.2 μs GI |
| 1 | 1 | 0–2 | Reserved | | |
| | | 3 | No | No | 4x HE-LTF and 0.8 μs GI |

The HE-SIG-A field of an HE MU PPDU contains the fields listed in Table 27-21 (HE-SIG-A field of an HE MU PPDU(11ax)).

**Table 27-21—HE-SIG-A field of an HE MU PPDU(11ax)**

| Bit | Field | Number of bits | Description |
|---|---|---|---|
| **HE-SIG-A1 subfield of HE-SIG-A field** | | | |
| B0 | UL/DL | 1 | Indicates whether the PPDU is sent UL or DL:<br>Set to 1 if the PPDU is addressed to an AP.<br>Set to 0 otherwise. See TXVECTOR parameter UPLINK_FLAG.<br><br>NOTE—The TDLS peer can identify the TDLS frame by (#278)To DS and From DS subfields in the MAC header of the frame. |


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**Table 27-21—HE-SIG-A field of an HE MU PPDU(11ax) *(continued)***

| Bit | Field | Number of bits | Description |
|---|---|---|---|
| B1–B3 | HE-SIG-B-MCS | 3 | Indicates the HE-MCS of the HE-SIG-B field:<br>Set to 0 for HE-SIG-B-MCS 0.<br>Set to 1 for HE-SIG-B-MCS 1.<br>Set to 2 for HE-SIG-B-MCS 2.<br>Set to 3 for HE-SIG-B-MCS 3.<br>Set to 4 for HE-SIG-B-MCS 4.<br>Set to 5 for HE-SIG-B-MCS 5.<br>Values 6 and 7 are reserved. |
| B4 | HE-SIG-B DCM | 1 | Set to 1 indicates that the HE-SIG-B field is modulated with DCM for the HE-MCS.<br>Set to 0 indicates that the HE-SIG-B field is not modulated with DCM for the HE-MCS.<br><br>NOTE—DCM is applicable to only HE-SIG-B-MCS 0, 1, 3, and 4. |
| B5–B10 | BSS Color | 6 | An identifier of the BSS.<br><br>See(#1111) TXVECTOR parameter BSS_COLOR. |
| B11–B14 | Spatial Reuse | 4 | Indicates whether spatial reuse modes are allowed during the transmission of this PPDU:<br>Set to a value from Table 27-23 (Spatial Reuse field encoding for an HE SU PPDU, HE ER SU PPDU, and HE MU PPDU(11ax)) (see 26.11.6 (SPATIAL_REUSE) and 26.10 (HE spatial reuse operation(#2389))).<br>See TXVECTOR parameter SPATIAL_REUSE. |

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**Table 27-21—HE-SIG-A field of an HE MU PPDU(11ax) *(continued)***

| Bit | Field | Number of bits | Description |
|---|---|---|---|
| B15–B17 | Bandwidth | 3 | Set to 0 for 20 MHz.<br>Set to 1 for 40 MHz.<br>Set to 2 for 80 MHz non-preamble puncturing mode.<br>Set to 3 for 160 MHz and 80+80 MHz non-preamble puncturing mode.<br><br>If the HE-SIG-B Compression field is 0:<br>Set to 4 for preamble puncturing in 80 MHz, where in the preamble the only punctured subchannel is the secondary 20 MHz channel.<br>Set to 5 for preamble puncturing in 80 MHz, where in the preamble the only punctured subchannel is one of the two 20 MHz subchannels in secondary 40 MHz channel.<br>Set to 6 for preamble puncturing in 160 MHz or 80+80 MHz, where in the preamble the only punctured subchannels are the secondary 20 MHz channel and zero to two of the 20 MHz subchannels in the secondary 80 MHz channel. If two of the 20 MHz subchannels in the secondary 80 MHz channel are punctured, these are either the lower two or the higher two. No more than two adjacent 20 MHz subchannels are punctured across 160 MHz.<br>Set to 7 for preamble puncturing in 160 MHz or 80+80 MHz, where in the preamble the only punctured subchannels are zero, one or both of the 20 MHz subchannels in the secondary 40 MHz channel and zero to two of the 20 MHz subchannels in the secondary 80 MHz channel; at least one 20 MHz subchannel is punctured. If two of the 20 MHz subchannels in the secondary 80 MHz channel are punctured, these are either the lower two or the higher two. No more than two adjacent 20 MHz subchannels are punctured across 160 MHz.<br><br>If the HE-SIG-B Compression field is 1, then values 4–7 are reserved. |


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**Table 27-21—HE-SIG-A field of an HE MU PPDU(11ax) *(continued)***

| Bit | Field | Number of bits | Description |
|---|---|---|---|
| B18–B21 | Number Of HE-SIG-B Symbols Or MU-MIMO Users | 4 | If the HE-SIG-B Compression field is 0, indicates the number of OFDM symbols in the HE-SIG-B field:<br>Set to the number of OFDM symbols in the HE-SIG-B field minus 1 if the number of OFDM symbols in the HE-SIG-B field is less than 16.<br>Set to 15 to indicate that the number of OFDM symbols in the HE-SIG-B field is equal to 16 if Longer Than 16 HE-SIG-B OFDM Symbols Support subfield in the HE Capabilities element transmitted by at least one recipient STA is 0.<br>Set to 15 to indicate that the number of OFDM symbols in the HE-SIG-B field is greater than or equal to 16 if the Longer Than 16 HE-SIG-B OFDM Symbols Support subfield in the HE Capabilities element transmitted by all the recipient STAs are 1 and if the HE-SIG-B-MCS field is set to 0, 1, 2, or 3 regardless of the value of the HE-SIG-B DCM field, or the HE-SIG-B-MCS field is set to 4 and the HE-SIG-B DCM field is set to 1. The exact number of OFDM symbols in the HE-SIG-B field is calculated based on the number of User fields in the HE-SIG-B content channel, which is indicated by the Common field of the HE-SIG-B field in this case.<br><br>If the HE-SIG-B Compression field is 1, indicates the number of users and is set to the number of users minus 1. If the number of users is greater than 1, then MU-MIMO is used in the HE modulated fields. |
| B22 | HE-SIG-B Compression | 1 | Set to 0 if the Common field in the HE-SIG-B field is present.<br>Set to 1 if the Common field in the HE-SIG-B field is not present. |
| B23–B24 | GI+HE-LTF Size | 2 | Indicates the GI duration and HE-LTF size:<br>Set to 0 to indicate a 4x HE-LTF and 0.8 μs GI.<br>Set to 1 to indicate a 2x HE-LTF and 0.8 μs GI.<br>Set to 2 to indicate a 2x HE-LTF and 1.6 μs GI.<br>Set to 3 to indicate a 4x HE-LTF and 3.2 μs GI. |
| B25 | Doppler | 1 | Set to 1 if one of the following applies:<br>— The number of OFDM symbols in the Data field is larger than the signaled midamble periodicity plus 1 and the midamble is present.<br>— The number of OFDM symbols in the Data field is less than or equal to the signaled midamble periodicity plus 1 (see 27.3.12.16 (Midambles), the midamble is not present, but the channel is fast varying. It recommends that midamble may be used for the PPDUs of the reverse link.<br>Set to 0 otherwise. |
| **HE-SIG-A2 subfield of HE-SIG-A field** | | | |
| B0–B6 | TXOP | 7 | Set to 127 to indicate no duration information.<br><br>Set to a value less than 127 to indicate the closest minimum bound on the duration information for NAV setting and protection of the TXOP as follows:<br>If B0 is 0, the TXOP duration indicated is B1-B6, in units of 8 μs.<br>If B0 is 1, the TXOP duration indicated is B1-B6, in units of 128 μs, plus 512 μs.<br><br>See TXVECTOR parameter TXOP_DURATION. |

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**Table 27-21—HE-SIG-A field of an HE MU PPDU(11ax) *(continued)***

| Bit | Field | Number of bits | Description |
|---|---|---|---|
| B7 | Reserved | 1 | Reserved and set to 1. |
| B8–B10 | Number of HE-LTF Symbols And Midamble Periodicity | 3 | If the Doppler field is 0, indicates the number of HE-LTF symbols:<br>Set to 0 for 1 HE-LTF symbol.<br>Set to 1 for 2 HE-LTF symbols.<br>Set to 2 for 4 HE-LTF symbols.<br>Set to 3 for 6 HE-LTF symbols.<br>Set to 4 for 8 HE-LTF symbols.<br>Other values are reserved.<br><br>If the Doppler field is 1, B8–B9 indicates the number of HE-LTF symbols and B10 indicates midamble periodicity. B8–B9 is encoded as follows:<br>0 indicates 1 HE-LTF symbol.<br>1 indicates 2 HE-LTF symbols.<br>2 indicates 4 HE-LTF symbols.<br>3 is reserved.<br>B10 is set to 0 to indicate 10 symbols midamble periodicity and set to 1 to indicate 20 symbols midamble periodicity. |
| B11 | LDPC Extra Symbol Segment | 1 | Indication of the presence of an LDPC extra symbol segment:<br>Set to 1 if an LDPC extra symbol segment is present.<br>Set to 0 otherwise. |
| B12 | STBC | 1 | In an HE MU PPDU where each RU includes no more than 1 user:<br>Set to 1 to indicate all RUs are STBC encoded in the payload.<br>Set to 0 to indicate all RUs are not STBC encoded in the payload.<br><br>STBC does not apply to the HE-SIG-B field. |
| B13–B14 | Pre-FEC Padding Factor | 2 | Indicates the pre-FEC padding factor:<br>Set to 0 to indicate a pre-FEC padding factor of 4.<br>Set to 1 to indicate a pre-FEC padding factor of 1.<br>Set to 2 to indicate a pre-FEC padding factor of 2.<br>Set to 3 to indicate a pre-FEC padding factor of 3. |
| B15 | PE Disambiguity | 1 | Indicates PE disambiguity as defined in 27.3.13 (Packet extension). |
| B16–B19 | CRC | 4 | CRC for bits 0-41 of the HE-SIG-A field (see 27.3.11.7.3 ((CRC computation)).<br>Bits 0-41 of the HE-SIG-A field correspond to bits 0-25 of the HE-SIG-A1 subfield followed by bits 0–15 of the HE-SIG-A2 subfield. |
| B20–B25 | Tail | 6 | Used to terminate the trellis of the convolutional decoder. Set to 0. |

It is optional for an HE STA to receive a preamble punctured HE MU PPDU with the Bandwidth field in the HE-SIG-A field in the range(#3482) 4 to 7. An HE STA indicates that it is capable of receiving a preamble punctured HE MU PPDU with the Bandwidth field of the HE-SIG-A field in the range(#3482) 4 to 7 using the Punctured Preamble Rx subfield in the HE PHY Capabilities Information field in the HE Capabilities element (see 9.4.2.247 (HE Capabilities element(11ax))).

The HE-SIG-A field for an HE TB PPDU contains the fields listed in Table 27-22 (HE-SIG-A field of an HE TB PPDU(11ax)).


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**Table 27-22—HE-SIG-A field of an HE TB PPDU(11ax)**

| Bit | Field | Number of bits | Description |
|---|---|---|---|
| **HE-SIG-A1 of the HE-SIG-A field** | | | |
| B0 | Format | 1 | Differentiate an HE SU PPDU and HE ER SU PPDU from an HE TB PPDU:<br>Set to 0 for an HE TB PPDU. |
| B1–B6 | BSS Color | 6 | An identifier of the BSS.<br><br>Set TXVECTOR parameter BSS_COLOR. |
| B7–B10 | Spatial Reuse 1 | 4 | Indicates whether specific spatial reuse modes are allowed in a subband of the PPDU during the transmission of this PPDU, and if PSR spatial reuse is allowed, indicates a value that is used to determine a limit on the transmit power of the PSRT PPDU.<br><br>If the Bandwidth field indicates 20 MHz, 40 MHz, or 80 MHz, then this Spatial Reuse field applies to the first 20 MHz subband.<br><br>If the Bandwidth field indicates 160/80+80 MHz, then this Spatial Reuse field applies to the first 40 MHz subband of the 160 MHz operating band.<br><br>Set to a value from Table 27-24 (Spatial Reuse field encoding for an HE TB PPDU(11ax)) for an HE TB PPDU (see 26.11.6 (SPATIAL_REUSE) and 26.10 (HE spatial reuse operation(#2389))).<br><br>See the first value in the TXVECTOR parameter SPATIAL_REUSE. |
| B11–B14 | Spatial Reuse 2 | 4 | Indicates whether specific spatial reuse modes are allowed in a subband of the PPDU during the transmission of this PPDU, and if PSR spatial reuse is allowed, indicates a value that is used to determine a limit on the transmit power of the PSRT PPDU.<br><br>If the Bandwidth field indicates 40 MHz or 80 MHz:<br>This Spatial Reuse field applies to the second 20 MHz subband.<br>If the STA operating channel width is 20 MHz, then this field is set to the same value as the Spatial Reuse 1 field.<br>If the STA operating channel width is 40 MHz in the 2.4 GHz band, this field is set to the same value as the Spatial Reuse 1 field.<br><br>If the Bandwidth field indicates 160/80+80 MHz, then this Spatial Reuse field applies to the second 40 MHz subband of the 160 MHz operating band.<br><br>Set to a value from Table 27-24 (Spatial Reuse field encoding for an HE TB PPDU(11ax)) for an HE TB PPDU (see 26.11.6 (SPATIAL_REUSE) and 26.10 (HE spatial reuse operation(#2389))).<br><br>See the second value in the TXVECTOR parameter SPATIAL_REUSE, if present. |

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**Table 27-22—HE-SIG-A field of an HE TB PPDU(11ax) *(continued)***

| Bit | Field | Number of bits | Description |
|---|---|---|---|
| B15–B18 | Spatial Reuse 3 | 4 | Indicates whether specific spatial reuse modes are allowed in a subband of the PPDU during the transmission of this PPDU, and if PSR spatial reuse is allowed, indicates a value that is used to determine a limit on the transmit power of the PSRT PPDU.<br><br>If the Bandwidth field indicates 80 MHz:<br>This Spatial Reuse field applies to the third 20 MHz subband.<br>If the STA operating channel width is 20 MHz or 40 MHz, this field is set to the same value as the Spatial Reuse 1 field.<br><br>If the Bandwidth field indicates 160/80+80 MHz:<br>This Spatial Reuse field applies to the third 40 MHz subband of the 160 MHz operating band.<br>If the STA operating channel width is 80+80 MHz, this field is set to the same value as the Spatial Reuse 1 field.<br><br>Set to a value from Table 27-24 (Spatial Reuse field encoding for an HE TB PPDU(11ax)) for an HE TB PPDU (see 26.11.6 (SPATIAL_REUSE) and 26.10 (HE spatial reuse operation(#2389))).<br><br>See the third value in the TXVECTOR parameter SPATIAL_REUSE, if present. |
| B19–B22 | Spatial Reuse 4 | 4 | Indicates whether specific spatial reuse modes are allowed in a subband of the PPDU during the transmission of this PPDU, and if PSR spatial reuse is allowed, indicates a value that is used to determine a limit on the transmit power of the PSRT PPDU.<br><br>If the Bandwidth field indicates 80 MHz:<br>This Spatial Reuse field applies to the fourth 20 MHz subband.<br>If the STA operating channel width is 20 MHz, then this field is set to the same value as the Spatial Reuse 1 field.<br>If the STA operating channel width is 40 MHz, then this field is set to the same value as the Spatial Reuse 2 field.<br><br>If the Bandwidth field indicates 160/80+80 MHz:<br>This Spatial Reuse field applies to the fourth 40 MHz subband of the 160 MHz operating band.<br>If the STA operating channel width is 80+80 MHz, then this field is set to same value as the Spatial Reuse 2 field.<br><br>Set to a value from Table 27-24 (Spatial Reuse field encoding for an HE TB PPDU(11ax)) for an HE TB PPDU (see 26.11.6 (SPATIAL_REUSE) and 26.10 (HE spatial reuse operation(#2389))).<br><br>See the fourth value in the TXVECTOR parameter SPATIAL_REUSE, if present. |
| B23 | Reserved | 1 | Reserved and set to 1.<br><br>NOTE—Unlike other Reserved fields in the HE-SIG-A field of the HE TB PPDU, B23 does not have a corresponding bit in the Trigger frame. |
| B24–B25 | Bandwidth | 2 | Set to 0 for 20 MHz.<br>Set to 1 for 40 MHz.<br>Set to 2 for 80 MHz.<br>Set to 3 for 160 MHz and 80+80 MHz. |


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**Table 27-22—HE-SIG-A field of an HE TB PPDU(11ax) *(continued)***

| Bit | Field | Number of bits | Description |
|---|---|---|---|
| **HE-SIG-A2 of the HE-SIG-A field** | | | |
| B0–B6 | TXOP | 7 | Set to 127 to indicate no duration information.<br><br>Set to a value less than 127 to indicate the closest minimum bound on the duration information for NAV setting and protection of the TXOP as follows:<br>If B0 is 0, the TXOP duration indicated is B1-B6, in units of 8 μs.<br>If B0 is 1, the TXOP duration indicated is B1-B6, in units of 128 μs, plus 512 μs.<br><br>See TXVECTOR parameter TXOP_DURATION. |
| B7–B15 | Reserved | 9 | Reserved and set to value indicated in the UL HE-SIG-A2 Reserved subfield in the Trigger frame. |
| B16–B19 | CRC | 4 | CRC of bits 0–41 of the HE-SIG-A field. See 27.3.11.7.3 ((CRC computation).<br>Bits 0–41 of the HE-SIG-A field correspond to bits 0–25 of the HE-SIG-A1 subfield followed by bits 0–15 of the HE-SIG-A2 subfield. |
| B20–B25 | Tail | 6 | Used to terminate the trellis of the convolutional decoder. Set to 0. |

The four Spatial Reuse fields, 1, 2, 3, and 4, are arranged in increasing order of frequency and correspond to the following:

- For 20 MHz, one Spatial Reuse field corresponding to the entire 20 MHz (the other 3 Spatial Reuse fields indicate the same value). The Spatial Reuse fields apply to only the 20 MHz used for the transmission.
- For 40 MHz, two Spatial Reuse fields with the Spatial Reuse 3 field identical in value to the Spatial Reuse 1 field and the Spatial Reuse 4 field identical in value to the Spatial Reuse 2 field. Each pair of Spatial Reuse fields applies to only the corresponding 20 MHz used for the transmission.
- For 80 MHz, four Spatial Reuse fields, one for each 20 MHz subchannel.
  - For an OFDMA transmission of a given BW, each of the Spatial Reuse fields that corresponds to a 20 MHz subband is also applicable to the 242-tone RU that is most closely aligned in frequency (in the tone plan for that BW) with the aforementioned 20 MHz subband. The correspondence from an Spatial Reuse field to a 242-tone RU also holds for any RU within the 242-tone RU. The above also implies that a 20 MHz OBSS STA uses the Spatial Reuse field corresponding to its 20 MHz channel; a 40 MHz OBSS STA located on the lower frequency half of the 80 MHz BSS uses Spatial Reuse 1 field and Spatial Reuse 2 field values; and a 40 MHz OBSS STA located on the upper frequency half of the 80 MHz BSS uses Spatial Reuse 3 field and Spatial Reuse 4 field values.
- For 160 MHz and 80+80 MHz, four Spatial Reuse fields, one for each 40 MHz subchannel.
  - For an OFDMA transmission of a given BW, each of the Spatial Reuse fields that corresponds to a 40 MHz subband is also applicable to the 484-tone RU that is most closely aligned in frequency (in the tone-plan of that BW) with the aforementioned 40 MHz subband. The correspondence from an Spatial Reuse field to a 484-tone RU also holds for any RU within the 484-tone RU.

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Table 27-23 (Spatial Reuse field encoding for an HE SU PPDU, HE ER SU PPDU, and HE MU PPDU(11ax)) defines the encoding for the Spatial Reuse field for an HE SU PPDU, HE ER SU PPDU, and HE MU PPDU.

**Table 27-23—Spatial Reuse field encoding for an HE SU PPDU, HE ER SU PPDU, and HE MU PPDU(11ax)**

| Value | Meaning |
|---|---|
| 0 | PSR_DISALLOW |
| 1–12 | Reserved |
| 13 | SR_RESTRICTED |
| 14 | SR_DELAYED |
| 15 | PSR_AND_NON_SRG_OBSS_PD_PROHIBITED |

Table 27-24 (Spatial Reuse field encoding for an HE TB PPDU(11ax)) defines the encoding for the Spatial Reuse 1, Spatial Reuse 2, Spatial Reuse 3, and Spatial Reuse 4 fields for an HE TB PPDU.

**Table 27-24—Spatial Reuse field encoding for an HE TB PPDU(11ax)**

| Value | Meaning |
|---|---|
| 0 | PSR_DISALLOW |
| 1 | PSR = –80(#3435) |
| 2 | PSR = –74(#3435) |
| 3 | PSR = –68(#3435) |
| 4 | PSR = –62(#3435) |
| 5 | PSR = –56(#3435) |
| 6 | PSR = –50(#3435) |
| 7 | PSR = –47(#3435) |
| 8 | PSR = –44(#3435) |
| 9 | PSR = –41(#3435) |
| 10 | PSR = –38(#3435) |
| 11 | PSR = –35(#3435) |
| 12 | PSR = –32(#3435) |
| 13 | PSR = –29(#3435) |
| 14 | PSR ≥ –26(#3435) |
| 15 | PSR_AND_NON_SRG_OBSS_PD_PROHIBITED |


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NOTE—The unit for PSR in the Meaning column of Table 27-24 (Spatial Reuse field encoding for an HE TB PPDU(11ax)) is 10log10(mW$^2$)(#3425)

### 27.3.11.7.3 (CRC computation

The CRC computation defined in this subclause applies to the HE-SIG-A field, the Common field of the HE-SIG-B field, and the User Block field of the HE-SIG-B field.

The CRC is calculated over bits 0 to 41 of the HE-SIG-A field and over bits 0 to $L$ of the HE-SIG-B field ($L = x$ for each Common field where $x = N \times 8$ if the Center 26-tone RU field is present and $x = N \times 8 - 1$ otherwise; $L = 20$ for an User Block field that contains one User field; and $L = 41$ for an User Block field that contains two User fields). Bits 0 to 41 of the HE-SIG-A field correspond to bits 0–25 of the HE-SIG-A1 subfield followed by bits 0–15 of the HE-SIG-A2 subfield. Refer to Table 27-25 (Common field(11ax)) for $N$ and the conditions under which the Center 26-tone RU field is present.

The value of the CRC field shall be the 1s complement of

$$crc(D) = (M(D) + I(D))D^8 mod\ G(D)$$

where

$$M(D) = \sum_{i=0}^{L} m_{L-i} D^i$$

$$I(D) = \sum_{i=L-7}^{L} D^i$$

$G(D)$ is defined in 19.3.9.4.4 (CRC calculation for HT-SIG)

$$crc(D) = c_0 D^7 + c_1 D^6 + \ldots + c_6 D + c_7$$

$m_L$ is the serial input shown in Figure 27-24 (CRC calculation(11ax))

The CRC field is transmitted from $c_4$ to $c_7$ with $c_7$ first.

Figure 27-24 (CRC calculation(11ax)) shows the operation of the CRC. First, the shift register is reset to all 1s. The bits are then passed through the XOR operation at the input. When the last bit has entered, the output is generated by shifting the bits out of the shift register, $c_7$ first, through an inverter.

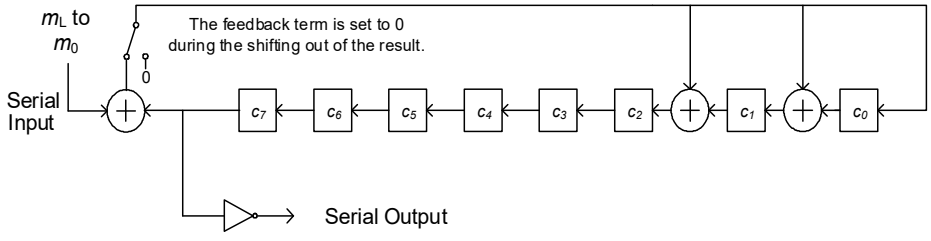


**Figure 27-24—CRC calculation(11ax)**

As an example, if bits $\{m_0 \ldots m_{41}\}$ are given by {1 1 0 1 1 1 0 0 0 0 0 0 0 1 0 0 0 0 0 0 1 1 0 0 0 0 0 0 0 0 0 0 0 1 0 0 1 1 0 1 0}, the output bits $\{B_7 \ldots B_4\}$, where $B_7$ is output first, are {0 1 1 1}.

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### 27.3.11.7.4 Encoding and modulation

For an HE SU PPDU, HE MU PPDU, and HE TB PPDU, the HE-SIG-A field is composed of two subfields, HE-SIG-A1 and HE-SIG-A2, each containing 26 data bits. (#1054)These two subfields are sent as two OFDM symbols: HE-SIG-A-sym-1 and HE-SIG-A-sym-2. The HE-SIG-A-sym-1 OFDM symbol is transmitted before the HE-SIG-A-sym-2 OFDM symbol. The data bits of the HE-SIG-A OFTDM symbols shall be BCC encoded at rate $R = 1/2$, be interleaved, be mapped to a BPSK constellation, and have pilots inserted following the steps described in 17.3.5.6 (Convolutional encoder), 27.3.12.8 (BCC interleavers), 17.3.5.8 (Subcarrier modulation mapping), and 17.3.5.9 (Pilot subcarriers), respectively. The constellation mappings of the HE-SIG-A field in an HE SU PPDU, HE MU PPDU, and HE TB PPDU are shown in Figure 27-25 (Data subcarrier constellation of HE-SIG-A symbols(#1054)(#2267)(11ax)). The first half and second half of the stream of 104 complex numbers generated by these steps (before pilot insertion) are divided into two groups of 52 complex numbers, where the first 52 complex numbers form the first OFDM symbol of the HE-SIG-A field, (#1054)HE-SIG-A-sym-1, and the second 52 complex numbers form the second OFDM symbol of the HE-SIG-A field, (#1054)HE-SIG-A-sym-2, respectively.

If the TXVECTOR parameter BEAM_CHANGE is 1 or not present, the time domain waveform for the HE-SIG-A field of an HE SU PPDU, HE MU PPDU, and HE TB PPDU, transmitted on frequency segment $i_{Seg}$ and transmit chain $i_{TX}$, shall be as specified in Equation (27-16).

$$r_{\text{HE-SIG-A}}^{(i_{Seg} i_{TX})}(t) = \frac{1}{\sqrt{N_{TX} \cdot N_{\text{HE-SIG-A}}^{\text{Tone}} \cdot \frac{|\Omega_{20\text{MHz}}|}{N_{20\text{MHz}}}}} \sum_{n=0}^{1} w_{T_{SYML}}(t - nT_{SYML}) \quad (27\text{-}16)$$

$$\sum_{i_{BW} \in \Omega_{20\text{MHz}}} \sum_{k=-28}^{28} \eta_{\text{HE-SIG-A},k} \left( \begin{array}{l} \Upsilon_{(k - K_{\text{Shift}}(i_{BW})),\,\text{BW}}(D_{k,n,20} + p_{n+2} P_k) \\ \cdot \exp(j2\pi(k - K_{\text{Shift}}(i_{\text{BW}}))\Delta_{F,\,\text{Pre-HE}}(t - nT_{SYML} - T_{GI,\,\text{Pre-HE}} - T_{CS}^{i_{TX}})) \end{array} \right)$$

where

$T_{SYML}$ is given in Table 27-13 (Timing-related constants(11ax))

$K_{\text{Shift}}(i) = (N_{20\text{MHz}} - 1 - 2i) \times 32$ (M118)

$$D_{k,n,20} = \begin{cases} 0, k = 0, \pm 7, \pm 21 \\ d_{M_{20}^r(k),n}, \text{otherwise} \end{cases}$$

$$M_{20}^r(k) = \begin{cases} k + 28, -28 \le k \le -22 \\ k + 27, -20 \le k \le -8 \\ k + 26, -6 \le k \le -1 \\ k + 25, 1 \le k \le 6 \\ k + 24, 8 \le k \le 20 \\ k + 23, 22 \le k \le 28 \end{cases}$$

$$\eta_{\text{HE-SIG-A},k} = \begin{cases} \left[\frac{1}{\sqrt{2}}, 1\right], \text{ for an HE TB PPDU} \\ 1, \text{ otherwise} \end{cases}$$

$P_k$ and $p_n$ are defined in 17.3.5.10 (OFDM modulation)



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$N_{\text{HE-SIG-A}}^{\text{Tone}}$ is defined in Table 27-17 (Number of modulated subcarriers and guard interval duration values for HE PPDU fields(11ax))

$T_{CS}^{i_{TX}}$ represents the cyclic shift for transmit chain $i_{TX}$ with a value given in 27.3.11.2.1 (Cyclic shift for pre-HE modulated fields)

If the TXVECTOR parameter BEAM_CHANGE is 0, the time domain waveform of the HE-SIG-A field shall be as given by Equation (27-17).

$$r_{\text{HE-SIG-A}}^{(i_{Seg}, i_{TX})}(t) = \frac{1}{\sqrt{N_{STS} \cdot N_{\text{HE-SIG-A}}^{\text{Tone}} \cdot \frac{|\Omega_{20\text{MHz}}|}{N_{20\text{MHz}}}}} \sum_{n=0}^{1} w_{T_{SYML}}(t - nT_{SYML}) \quad (27\text{-}17)$$

$$\sum_{i_{BW}=0}^{N_{20\text{MHz}}-1} \sum_{k=-28}^{28} \sum_{m=1}^{N_{STS}} \left( \left[ Q_{4(k-K_{\text{Shift}}(i_{BW}))}^{(i_{Seg})} \right]_{i_{TX}, m} \left[ A_{\text{HE-LTF}}^{4(k-K_{\text{Shift}}(i_{BW}))} \right]_{m, 1} (D_{k, n, 20} + p_{n+2} P_k) \cdot \exp(j2\pi(k - K_{\text{Shift}}(i_{\text{BW}}))\Delta_{F, \text{Pre-HE}}(t - nT_{SYML} - T_{\text{GI, Pre-HE}} - T_{CS, HE}(m))) \right)$$

where

$T_{CS, \text{HE}}(m)$ represents the cyclic shift for space-time stream $m$ as defined in 27.3.11.2.2 (Cyclic shift for HE modulated fields)

$Q_k^{(i_{Seg})}$ is defined in 27.3.10 (Mathematical description of signals)

$A_{\text{HE-LTF}}^{k}$ is defined in Equation (27-55)

For an HE ER SU PPDU, the HE-SIG-A field is composed of (#1054)two subfields, HE-SIG-A1 and HE-SIG-A2, each containing 26 data bits. These two subfields are sent as four OFDM symbols: HE-SIG-A-sym-1, HE-SIG-A-sym-1-R, HE-SIG-A-sym-2, and HE-SIG-A-sym-2-R. These four OFDM symbols are transmitted sequentially from HE-SIG-A-sym-1 to HE-SIG-A-sym-2-R. The data bits of the HE-SIG-A1 and HE-SIG-A2 subfields shall be BCC encoded at rate $R = 1/2$, be interleaved, be mapped to a BPSK constellation, and have pilots inserted. (#1054)The HE-SIG-A-sym-1-R OFDM symbol is calculated from the same encoded bits as the HE-SIG-A-sym-1 subfield, and the encoded bits shall be mapped to a QBPSK constellation without interleaving and have pilots inserted. The constellation mappings of the HE-SIG-A field in an HE ER SU PPDU are shown in Figure 27-25 (Data subcarrier constellation of HE-SIG-A symbols(#1054)(#2267)(11ax)). (#1054)The QBPSK constellation on the HE-SIG-A-sym-1-R OFDM symbol is used to differentiate between an HE ER SU PPDU and an HE MU PPDU when $m = 1$ in Equation (27-11). The HE-SIG-A-sym-2-R OFDM symbol is calculated using the same encoded bits as the HE-SIG-A-sym-2 OFDM symbol, and the encoded bits shall be mapped to a BPSK constellation without interleaving and have pilots inserted. BCC encoding, data interleaving, constellation mapping, and pilot

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insertion follow the steps described in 17.3.5.6, 27.3.12.8 (BCC interleavers), 17.3.5.8 (Subcarrier modulation mapping), and 17.3.5.9 (Pilot subcarriers), respectively.

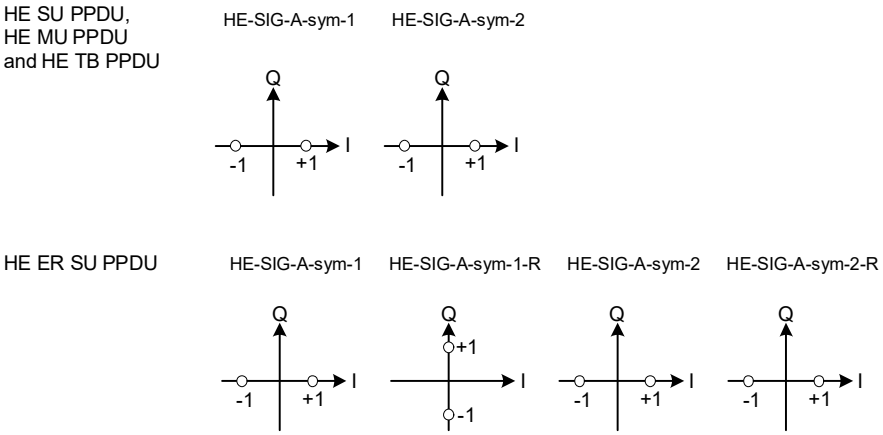


**Figure 27-25—Data subcarrier constellation of HE-SIG-A symbols(#1054)(#2267)(11ax)**

If the TXVECTOR parameter BEAM_CHANGE is 1 or not present, the time domain waveform for the HE-SIG-A field in an HE ER SU PPDU shall be as specified in Equation (27-18).

$$r_{\text{HE-SIG-A}}^{(i_{Seg},\, i_{TX})}(t) = \frac{1}{\sqrt{N_{TX} \cdot N_{\text{HE-SIG-A}}^{\text{Tone}} \cdot \frac{|\Omega_{20\text{MHz}}|}{N_{20\text{MHz}}}}} \sum_{n=0}^{3} w_{T_{\text{SYML}}}(t - nT_{SYML}) \sum_{k=-28}^{28} (R_n D_{k,n,20} + p_{n+2} P_k) \cdot \exp(j2\pi k \cdot \Delta_{F,\,\text{Pre-HE}}(t - nT_{SYML} - T_{GI,\,\text{Pre-HE}} - T_{CS}^{i_{TX}})) \quad (27\text{-}18)$$

where

$R_n$ is a phase rotation vector defined as [1, $j$, 1, 1]

If the TXVECTOR parameter BEAM_CHANGE is 0, the time domain waveform for the HE-SIG-A field in an HE ER SU PPDU shall be as specified in Equation (27-19).

$$r_{\text{HE-SIG-A}}^{(i_{Seg},\, i_{TX})}(t) = \frac{1}{\sqrt{N_{STS} \cdot N_{\text{HE-SIG-A}}^{\text{Tone}} \cdot \frac{|\Omega_{20\text{MHz}}|}{N_{20\text{MHz}}}}} \sum_{n=0}^{3} w_{T_{SYML}}(t - nT_{SYML}) \sum_{k=-28}^{28} \sum_{m=1}^{N_{STS}} \left( \left[ Q_{4k}^{(i_{Seg})} \right]_{i_{TX},\, m} \left[ A_{\text{HE-LTF}}^{4k} \right]_{m,\,1} (R_n D_{k,n,20} + p_{n+2} P_k) \cdot \exp(j2\pi k \cdot \Delta_{F,\,\text{Pre-HE}}(t - nT_{SYML} - T_{\text{GI,\,Pre-HE}} - T_{CS,\,HE}(m))) \right) \quad (27\text{-}19)$$



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### 27.3.11.8 HE-SIG-B field

#### 27.3.11.8.1 General

The HE-SIG-B field provides the necessary signaling, including the OFDMA and DL MU-MIMO resource allocation information, to allow the STAs to look up the corresponding resources to be used in the HE modulated fields of the PPDU. The integer fields of the HE-SIG-B field are transmitted in unsigned binary format, LSB first, where the LSB is in the lowest numbered bit position.

Dynamic split is defined as the split of User fields across HE-SIG-B content channels according to the Common field in each HE-SIG-B content channel and used when the HE-SIG-B Compression field in the HE-SIG-A field is set to 0.

Equitable split is defined as the split of User fields across HE-SIG-B content channels used when the HE-SIG-B Compression field in the HE-SIG-A field is set to 1.

#### 27.3.11.8.2 HE-SIG-B content channels

The HE-SIG-B field of a 20 MHz HE MU PPDU contains one HE-SIG-B content channel. The HE-SIG-B field of an HE MU PPDU that is 40 MHz or wider contains two HE-SIG-B content channels.

The HE-SIG-B content channel format is shown in Figure 27-26 (HE-SIG-B content channel format(11ax)). The HE-SIG-B content channel consists of a Common field, if present, followed by a User Specific field.

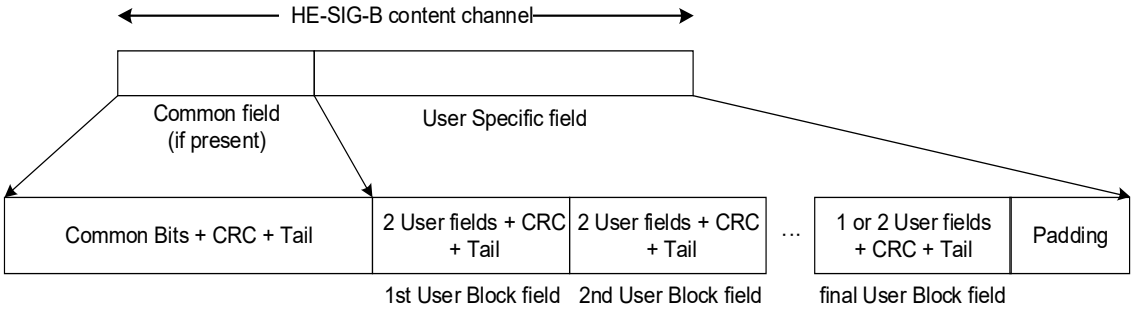


**Figure 27-26—HE-SIG-B content channel format(11ax)**

If the HE-SIG-B Compression field in the HE-SIG-A field of an HE MU PPDU is 1 (indicating full-bandwidth MU-MIMO transmission), then the Common field is not present, and the HE-SIG-B content channel consists of only the User Specific field. If the HE-SIG-B Compression field in the HE-SIG-A field of an HE MU PPDU is 0, the Common field is present in the HE-SIG-B content channel.

The Common field of an HE-SIG-B content channel contains information regarding the resource unit allocation such as the RU assignment to be used in the HE modulated fields of the PPDU, the RUs allocated for MU-MIMO, and the number of users in MU-MIMO allocations. The Common field is defined in 27.3.11.8.3 (Common field).

The union of the User Specific fields in the HE-SIG-B content channels contains information for all users in the PPDU on how to decode their payload. As shown in Figure 27-26 (HE-SIG-B content channel format(11ax)), the User Specific field is organized into User Block fields that in turn contain User fields. See 27.3.11.8.4 (User Specific field) for a description of the contents of the User Specific field.

See Annex Z for HE-SIG-B content examples.

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### 27.3.11.8.3 Common field

This subclause is not applicable if the HE-SIG-B Compression field in the HE-SIG-A field of an HE MU PPDU is 1.

The Common field format is defined in Table 27-25 (Common field(11ax)).

**Table 27-25—Common field(11ax)**

| Subfield | Number of subfields | Number of bits per subfield | Description |
|---|---|---|---|
| RU Allocation | N | 8 | *N* RU Allocation subfields are present in an HE-SIG-B content channel, where<br>*N* = 1 if the Bandwidth field in the HE-SIG-A field is 0 or 1 (indicating a 20 MHz or 40 MHz HE MU PPDU)<br>*N* = 2 if the Bandwidth field in the HE-SIG-A field is 2, 4, or 5 (indicating an 80 MHz HE MU PPDU)<br>*N* = 4 if the Bandwidth field in the HE-SIG-A field is 3, 6, or 7 (indicates a 160 MHz or 80+80 MHz HE MU PPDU)<br><br>Each RU Allocation subfield in an HE-SIG-B content channel corresponding to a 20 MHz frequency subchannel indicates the RU assignment, including the size of the RU(s) and their placement in the frequency domain, to be used in the HE modulated fields of the HE MU PPDU in the frequency domain and indicates information needed to compute the number of users allocated to each RU, where the subcarrier indices of the RU(s) meet the conditions in Table 27-26 (RUs associated with each RU Allocation subfield for each HE-SIG-B content channel and PPDU bandwidth(11ax)). |
| Center 26-tone RU | 0 or 1 | 1 | The Center 26-tone RU field is present if the Bandwidth field in the HE-SIG-A field indicates a bandwidth greater than 40 MHz and not present otherwise.<br><br>If the Bandwidth field in the HE-SIG-A field is 2, 4, or 5 (indicating 80 MHz):<br>Set to 1 to indicate that a user is allocated to the center 26-tone RU (see Figure 27-7 (RU locations in an 80 MHz HE PPDU(11ax))) and that its User field is present in HE-SIG-B content channel 1; otherwise, set to 0. The same value is applied to both HE-SIG-B content channels.<br><br>If the Bandwidth field in the HE-SIG-A field is 3, 6, or 7 (indicating 160 MHz or 80+80 MHz):<br>For HE-SIG-B content channel 1, set to 1 to indicate that a user is allocated to the center 26-tone RU of the lower frequency 80 MHz; otherwise, set to 0.<br>For HE-SIG-B content channel 2, set to 1 to indicate that a user is allocated to the center 26-tone RU of the higher frequency 80 MHz; otherwise, set to 0. |
| CRC | 1 | 4 | The CRC is calculated over bits 0 to $N \times 8$ if the Bandwidth field in the HE-SIG-A field indicates a bandwidth greater than 40 MHz, and bits 0 to $N \times 8 - 1$ otherwise. See 27.3.11.7.3 ((CRC computation). |
| Tail | 1 | 6 | Used to terminate the trellis of the convolutional decoder. Set to 0. |


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A 996-tone RU is referred to by two consecutive RU Allocation subfields per HE-SIG-B content channel, for both HE-SIG-B content channels. The two consecutive RU Allocation subfields per HE-SIG-B content channel are labeled the first RU Allocation subfield and the second RU Allocation subfield. A 484-tone RU is referred to by a single RU Allocation subfield per HE-SIG-B content channel, for both HE-SIG-B content channels. Smaller RUs are referred to by a single RU Allocation subfield in a single HE-SIG-B content channel. If a Common field is present in a 160 MHz or 80+80 MHz PPDU, a 2×996 tone RU is not permitted and cannot be indicated by the RU allocation subfield.

For an RU that is referred to by a first or only RU Allocation subfield in an HE-SIG-B content channel, the RU Allocation subfield encodes the number of User fields per RU contributed to the User Specific field in the same HE-SIG-B content channel as the RU Allocation subfield. This number is labeled $N_{user}(r, c)$ for RU $r$ and HE-SIG-B content channel $c$ as described in Table 27-27 (RU Allocation subfield(11ax)).

For an RU that is referred to by two RU Allocation subfields in an HE-SIG-B content channel (i.e., a 996-tone RU in a 160 MHz or 80+80 MHz PPDU), the second RU Allocation subfield in the HE-SIG-B content channel encodes zero additional User fields per RU contributed to the User Specific field in the same HE-SIG-B content channel as the RU Allocation subfield.

In an HE MU PPDU, an RU that is not allocated to a user can be indicated as follows:

— The Center 26-tone RU subfield in the Common field of the HE-SIG-B field is set to 0 (see Table 27-25 (Common field(11ax))).

— The RU Allocation subfield in the Common field of the HE-SIG-B field is set to a value between 16 and 31 or between 96 and 113 (see Table 27-27 (RU Allocation subfield(11ax))).

— Both RU Allocation subfields at the same position in each Common field of the two HE-SIG-B content channels are set to 114 (see Table 27-27 (RU Allocation subfield(11ax))).

— The STA-ID subfield in the User field of the HE-SIG-B field is set to 2046 (see 26.11.1 (STA_ID) and 27.3.11.8.4 (User Specific field)).

The subcarriers in the HE modulated fields of a PPDU that correspond to an unallocated RU shall not be modulated.

If an RU is an unallocated RU, zero users are allocated to it. Otherwise, the number of users allocated to RU $r$ is determined from the RU size and $N_{user}(r, c)$ as follows:

— If RU $r$ is a 26-tone or 52-tone RU, then one user is allocated to the RU.

— If RU $r$ is a 106-tone or 242-tone RU, then the number of users allocated to the RU is $N_{user}(r, c)$.

— If RU $r$ is a 484-tone or larger RU, then the number of users allocated to the RU equals the number of User fields for the RU summed across both HE-SIG-B content channels, i.e., $N_{user}(r, 1) + N_{user}(r, 2)$.

NOTE 1—The exact dynamic split of User fields between the two content channels, $N_{user}(r, 1)$ and $N_{user}(r, 2)$, is not specified and might be used to reduce any disparity in the number of User fields between content channels.

NOTE 2—If the number of users per RU is greater than one, then the users in the RU are multiplexed using MU-MIMO.

For a 996-tone RU, for each HE-SIG-B content channel, the first 8-bit RU Allocation subfield referring to the RU may use values in the range 208–215 ($11010y_2y_1y_0$ in binary representation) as in Table 27-27 (RU Allocation subfield(11ax)) with $y_2y_1y_0$ indicating the number of User fields signaled in the corresponding content channel, while the second 8-bit RU Allocation subfield referring to the RU shall be set to 115 (01110011 in binary representation).

NOTE 3—Although there are two RU Allocation subfields per HE-SIG-B content channel for the users of a 996-tone RU, each user is described by only one User field, which is located in one HE-SIG-B content channel.

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As defined in Table 27-25 (Common field(11ax)) and Table 27-26 (RUs associated with each RU Allocation subfield for each HE-SIG-B content channel and PPDU bandwidth(11ax)), the Center 26-tone RU field carries the same value in both HE-SIG-B content channels. The User field that corresponds to the center 26-tone RU is carried in HE-SIG-B content channel 1.

**Table 27-26—RUs associated with each RU Allocation subfield for each HE-SIG-B content channel and PPDU bandwidth(11ax)**

| PPDU bandwidth | RU Allocation subfield and Center 26-tone RU subfield (if present) | RUs in the subcarrier range, or overlapping with the subcarrier range if the RU is larger than a 242-tone RU |
|---|---|---|
| 20 MHz | The RU Allocation subfield in a single HE-SIG-B content channel | [–122:122] |
| 40 MHz | The RU Allocation subfield in HE-SIG-B content channel 1 | [–244:–3] |
| | The RU Allocation subfield in HE-SIG-B content channel 2 | [3:244] |
| 80 MHz | The first RU Allocation subfield in HE-SIG-B content channel 1 | [–500:–259] |
| | The first RU Allocation subfield in HE-SIG-B content channel 2 | [–258:–17] |
| | Center 26-tone RU subfield in HE-SIG-B content channel 1 and 2 | [–16:–4, 4:16] |
| | The second RU Allocation subfield in HE-SIG-B content channel 1 | [17:258] |
| | The second RU Allocation subfield in HE-SIG-B content channel 2 | [259:500] |


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**Table 27-26—RUs associated with each RU Allocation subfield for each HE-SIG-B content channel and PPDU bandwidth(11ax)**

| PPDU bandwidth | RU Allocation subfield and Center 26-tone RU subfield (if present) | RUs in the subcarrier range, or overlapping with the subcarrier range if the RU is larger than a 242-tone RU |
|---|---|---|
| 160 MHz or 80+80 MHz | The first RU Allocation subfield in HE-SIG-B content channel 1 | [–1012:–771] |
| | The first RU Allocation subfield in HE-SIG-B content channel 2 | [–770:–529] |
| | Center 26-tone RU subfield for lower frequency 80 MHz in HE-SIG-B content channel 1 | [–528:–516, –508:–496] |
| | The second RU Allocation subfield in HE-SIG-B content channel 1 | [–495:–254] |
| | The second RU Allocation subfield in HE-SIG-B content channel 2 | [–253:–12] |
| | The third RU Allocation subfield in HE-SIG-B content channel 1 | [12:253] |
| | The third RU Allocation subfield in HE-SIG-B content channel 2 | [254:495] |
| | Center 26-tone RU subfield for higher frequency 80 MHz in HE-SIG-B content channel 2 | [496:508, 516:528] |
| | The fourth RU Allocation subfield in HE-SIG-B content channel 1 | [529:770] |
| | The fourth RU Allocation subfield in HE-SIG-B content channel 2 | [771:1012] |

The mapping from the 8-bit RU Allocation subfield to the RU assignment and the number of User fields per RU contributed to the User Specific field in the same HE-SIG-B content channel as the RU Allocation subfield are defined in Table 27-27 (RU Allocation subfield(11ax)).

**Table 27-27—RU Allocation subfield(11ax)**

| RU Allocation subfield (B7 B6 B5 B4 B3 B2 B1 B0) | #1 | #2 | #3 | #4 | #5 | #6 | #7 | #8 | #9 | Number of entries |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 (00000000) | 26 | 26 | 26 | 26 | 26 | 26 | 26 | 26 | 26 | 1 |
| 1 (00000001) | 26 | 26 | 26 | 26 | 26 | 26 | 26 | 52 | | 1 |
| 2 (00000010) | 26 | 26 | 26 | 26 | 26 | 52 | | 26 | 26 | 1 |
| 3 (00000011) | 26 | 26 | 26 | 26 | 26 | 52 | | 52 | | 1 |
| 4 (00000100) | 26 | 26 | 52 | | 26 | 26 | 26 | 26 | 26 | 1 |
| 5 (00000101) | 26 | 26 | 52 | | 26 | 26 | 26 | 52 | | 1 |
| 6 (00000110) | 26 | 26 | 52 | | 26 | 52 | | 26 | 26 | 1 |

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**Table 27-27—RU Allocation subfield(11ax)**

| RU Allocation subfield (B7 B6 B5 B4 B3 B2 B1 B0) | #1 | #2 | #3 | #4 | #5 | #6 | #7 | #8 | #9 | Number of entries |
|---|---|---|---|---|---|---|---|---|---|---|
| 7 (00000111) | 26 | 26 | 52 | | 26 | 52 | | 52 | | 1 |
| 8 (00001000) | 52 | | 26 | 26 | 26 | 26 | 26 | 26 | 26 | 1 |
| 9 (00001001) | 52 | | 26 | 26 | 26 | 26 | 26 | 52 | | 1 |
| 10 (00001010) | 52 | | 26 | 26 | 26 | 52 | | 26 | 26 | 1 |
| 11 (00001011) | 52 | | 26 | 26 | 26 | 52 | | 52 | | 1 |
| 12 (00001100) | 52 | | 52 | | 26 | 26 | 26 | 26 | 26 | 1 |
| 13 (00001101) | 52 | | 52 | | 26 | 26 | 26 | 52 | | 1 |
| 14 (00001110) | 52 | | 52 | | 26 | 52 | | 26 | 26 | 1 |
| 15 (00001111) | 52 | | 52 | | 26 | 52 | | 52 | | 1 |
| 16-23 ($00010y_2y_1y_0$) | 52 | | 52 | | — | 106 | | | | 8 |
| 24-31 ($00011y_2y_1y_0$) | 106 | | | | — | 52 | | 52 | | 8 |
| 32-39 ($00100y_2y_1y_0$) | 26 | 26 | 26 | 26 | 26 | 106 | | | | 8 |
| 40-47 ($00101y_2y_1y_0$) | 26 | 26 | 52 | | 26 | 106 | | | | 8 |
| 48-55 ($00110y_2y_1y_0$) | 52 | | 26 | 26 | 26 | 106 | | | | 8 |
| 56-63 ($00111y_2y_1y_0$) | 52 | | 52 | | 26 | 106 | | | | 8 |
| 64-71 ($01000y_2y_1y_0$) | 106 | | | | 26 | 26 | 26 | 26 | 26 | 8 |
| (#2366)72-79 ($01001y_2y_1y_0$) | 106 | | | | 26 | 26 | 26 | 52 | | 8 |
| 80-87 ($01010y_2y_1y_0$) | 106 | | | | 26 | 52 | | 26 | 26 | 8 |
| 88-95 ($01011y_2y_1y_0$) | 106 | | | | 26 | 52 | | 52 | | 8 |
| 96-111 ($0110y_1y_0z_1z_0$) | 106 | | | | — | 106 | | | | 16 |
| 112 (01110000) | 52 | | 52 | | — | 52 | | 52 | | 1 |
| 113 (01110001) | 242-tone RU empty (with zero users) | | | | | | | | | 1 |
| 114 (01110010) | 484-tone RU; contributes zero User fields to the User Specific field in the same HE-SIG-B content channel as this RU Allocation subfield | | | | | | | | | 1 |
| 115 (01110011) | 996-tone RU; contributes zero User fields to the User Specific field in the same HE-SIG-B content channel as this RU Allocation subfield | | | | | | | | | 1 |



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**Table 27-27—RU Allocation subfield(11ax)**

| RU Allocation subfield (B7 B6 B5 B4 B3 B2 B1 B0) | #1 | #2 | #3 | #4 | #5 | #6 | #7 | #8 | #9 | Number of entries |
|---|---|---|---|---|---|---|---|---|---|---|
| 116-119 ($011101x_1x_0$) | Reserved | | | | | | | | | 4 |
| 120-127 ($01111y_2y_1y_0$) | Reserved | | | | | | | | | 8 |
| 128-191 ($10y_2y_1y_0z_2z_1z_0$) | 106 | | | | 26 | 106 | | | | 64 |
| 192-199 ($11000y_2y_1y_0$) | 242 | | | | | | | | | 8 |
| 200-207 ($11001y_2y_1y_0$) | 484 | | | | | | | | | 8 |
| 208-215 ($11010y_2y_1y_0$) | 996 | | | | | | | | | 8 |
| 216-223 ($11011y_2y_1y_0$) | Reserved | | | | | | | | | 8 |
| 224-255 ($111x_4x_3x_2x_1x_0$) | Reserved | | | | | | | | | 32 |

If signaling RUs of size greater than 242 subcarriers, $y_2y_1y_0$ = 000–111 indicates the number of User fields in the HE-SIG-B content channel that contains the corresponding 8-bit RU Allocation subfield. Otherwise, $y_2y_1y_0$ = 000–111 indicates the number of users multiplexed in the 106-tone RU, 242-tone RU or the lower frequency 106-tone RU if there are two 106-tone RUs and one 26-tone RU is assigned between two 106-tone RUs. The binary vector $y_2y_1y_0$ indicates $N_{user}(r, c) = 2^2 \times y_2 + 2^1 \times y_1 + y_0 + 1$ users multiplexed in the RU.

$z_2z_1z_0$ = 000–111 indicates the number of users multiplexed in the higher frequency 106-tone RU if there are two 106-tone RUs and one 26-tone RU is assigned between two 106-tone RUs. The binary vector $z_2z_1z_0$ indicates $N_{user}(r, c) = 2^2 \times z_2 + 2^1 \times z_1 + z_0 + 1$ users multiplexed in the RU.

Similarly, $y_1y_0$ = 00–11 indicates the number of users multiplexed in the lower frequency 106-tone RU. The binary vector $y_1y_0$ indicates $N_{user}(r, c) = 2^1 \times y_1 + y_0 + 1$ users multiplexed in the RU.

Similarly, $z_1z_0$ = 00–11 indicates the number of users multiplexed in the higher frequency 106-tone RU. The binary vector $z_1z_0$ indicates $N_{user}(r, c) = 2^1 \times z_1 + z_0 + 1$ users multiplexed in the RU.

#1 to #9 (from left to the right) is ordered in increasing order of the absolute frequency.

$x_1x_0$ = 00–11, $x_4x_3x_2x_1x_0$ = 00000–11111.

'-' means no user in that RU, i.e., $N_{user}(r, c) = 0$.

For RU $r$ that is a 106-tone or larger RU, $N_{user}(r, c)$ is indicated by the letters (such as $y_2y_1y_0$ or $z_2z_1z_0$) in the RU allocation subfield above if the letters are present in the RU allocation subfield; otherwise $N_{user}(r, c) = 0$.

For RU $r$ that is a 26-tone or 52-tone RU, $N_{user}(r, c) = 1$.

If a single RU in a 40 MHz PPDU overlaps the subcarrier ranges [–244:–3] and [3:244], the corresponding RU Allocation subfields in the respective content channels shall both refer to the same RU.

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If a single RU in an 80 MHz PPDU overlaps more than one of the subcarrier ranges [–500:–259], [–258:–17], [17:258] or [259:500], the corresponding RU Allocation subfields in the respective content channels shall all refer to the same RU.

If a single RU in a 160 MHz or 80+80 MHz PPDU overlaps more than one of the subcarrier ranges [–1012:–771], [–770:–529], [–495:–254], [–253:–12], [12:253], [254:495], [529:770] or [771:1012], the corresponding RU Allocation subfields in the respective content channels shall all refer to the same RU.

In Table 27-27 (RU Allocation subfield(11ax)), the (#4177)Number of entries column refers to the number of RU Allocation subfield values that refer to the same RU assignment to be used in the frequency domain but differ in the number of User fields per RU. The number of User fields per RU indicated by the RU Allocation subfields and the Center 26-tone RU subfield of an HE-SIG-B content channel indicate the number of User fields in the User Specific field of the HE-SIG-B content channel.

For an MU-MIMO allocation of RU size greater than 242 subcarriers, the dynamic split of User fields between HE-SIG-B content channel 1 and HE-SIG-B content channel 2 is decided by the AP (on a per case basis) and signaled by the AP using the RU Allocation subfields in each HE-SIG-B content channel. See Annex Z for examples.

The pre-HE modulated fields (see Figure 27-23 (Timing boundaries for HE PPDU fields if midamble is not present(11ax))) are not transmitted in 20 MHz subchannels in which the preamble is punctured (see 27.3.7 (HE modulation and coding schemes (HE-MCSs))).

If the Bandwidth field in the HE-SIG-A field of an HE MU PPDU is 4, 5, 6 or 7, then one or more 20 MHz subchannels of the preamble are punctured, as defined in Table 27-21 (HE-SIG-A field of an HE MU PPDU(11ax)). If two adjacent 20 MHz subchannels that constitute a 40 MHz subchannel in which a 484-tone RU is located are punctured, then B7–B0 of the RU Allocation subfields corresponding to the two 20 MHz subchannels shall both be set to 113 (242-tone RU is empty) or shall both be set to 114 (see Table 27-27 (RU Allocation subfield(11ax))) to indicate that the preamble is punctured in both the 20 MHz subchannels. Each punctured 20 MHz subchannel that does not have B7–B0 of its corresponding RU Allocation subfield set to 114 shall have B7–B0 of its RU Allocation subfield set to 113.

The center 26-tone RU in a preamble punctured 80 MHz, 160 MHz, or 80+80 MHz HE MU PPDU shall not be allocated to a user if either of the two 20 MHz subchannels that the center 26-tone RU straddles have the preamble punctured.

#### 27.3.11.8.4 User Specific field

The User Specific field of an HE-SIG-B content channel consists of zero or more User Block fields followed by padding (if present) as shown in Figure 27-26 (HE-SIG-B content channel format(11ax)). Each non-final User Block field is made up of two User fields that contain information for two STAs that is used to decode their payloads. The final User Block field contains information for one or two users depending on the number of users in the HE-SIG-B content channel. If the HE-SIG-B Compression field in the HE-SIG-A field of an HE MU PPDU is 0, then the number of User fields is indicated by the RU Allocation subfields and the Center 26-tone RU subfield in the same HE-SIG-B content channel. If the HE-SIG-B Compression field in the HE-SIG-A field of an HE MU PPDU is 1, then the number of users is indicated by the Number Of HE-SIG-B Symbols Or MU-MIMO Users field in the HE-SIG-A field.

If the HE-SIG-B Compression field in the HE-SIG-A field of an HE MU PPDU is 1 (indicating full-bandwidth MU-MIMO transmission) and the Number Of HE-SIG-B Symbols Or MU-MIMO Users field in the HE-SIG-A field of an HE MU PPDU is 0 (indicating 1 user), then the User Specific field in the HE-SIG-B field consists of a single User Block field containing one User field for a non-MU-MIMO allocation as shown in Table 27-29 (User field format for non-MU-MIMO allocation(11ax)).


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The User Block field is defined in Table 27-28 (User Block field(11ax)).

**Table 27-28—User Block field(11ax)**

| Field | Number of fields | Number of bits per field | Description |
|---|---|---|---|
| User field | N | 21 | *N* User fields are present, where<br>*N* = 1 if it is the final User Block field, and if there is only one user in the final User Block field.<br>*N* = 2 otherwise.<br><br>The User field format for a non-MU-MIMO allocation is defined in Table 27-29 (User field format for non-MU-MIMO allocation(11ax)). The User field format for a MU-MIMO allocation is defined in Table 27-30 (User field format for MU-MIMO allocation(11ax)). |
| CRC | 1 | 4 | The CRC is calculated over bits 0 to 20 for a User Block field that contains one User field and bits 0 to 41 for a User Block field that contains two User fields. See 27.3.11.7.3 ((CRC computation). |
| Tail | 1 | 6 | Used to terminate the trellis of the convolutional decoder. Set to 0. |

If the HE-SIG-B Compression field in the HE-SIG-A field of an HE MU PPDU is 0, then for an MU-MIMO allocation of RU size greater than 242 subcarriers, the AP performs a dynamic split of the User fields between HE-SIG-B content channel 1 and HE-SIG-B content channel 2 as described in 27.3.11.8.3 (Common field).

If the HE-SIG-B Compression field in the HE-SIG-A field of an HE MU PPDU is 1, for bandwidths larger than 20 MHz, the AP performs an equitable split of the User fields between two HE-SIG-B content channels, i.e., User field $k$ of a $K$ user MU-MIMO PPDU is carried in HE-SIG-B content channel $c$, where $c$ is defined in Equation (27-20).

$$c = \begin{cases} 1, & \text{if } k \in 1, \ldots, \lceil K/2 \rceil \\ 2, & \text{if } (k \in \lceil K/2 \rceil + 1, \ldots, K) \end{cases} \quad (27\text{-}20)$$

Since a single STA is not required to decode the data for more than one user (see 26.5.1.2 (RU addressing in an HE MU PPDU)), the signaling that enables a STA to decode its data is carried in only one User field.

The ordering of User fields in the User Specific field in an HE-SIG-B content channel is determined using the following three-step procedure:

a) If the HE-SIG-B Compression field in the HE-SIG-A field of an HE MU PPDU is 1, this first step is bypassed. Otherwise, the User fields in the User Specific field of an HE-SIG-B content channel are grouped into sets of User fields, where each set comprises the User fields indicated by one RU Allocation subfield or the Center 26-tone RU. These sets shall be ordered as follows:
   1) If the Bandwidth field in the HE-SIG-A field is 0 or 1, then there is only one set; therefore, the need for ordering in this first step does not arise.
   2) If the Bandwidth field in the HE-SIG-A field is 2, 4, or 5, then the set of User fields indicated by the first RU Allocation subfield is followed by the set of the User fields indicated by the second RU Allocation subfield; in turn, if the center 26-tone RU is assigned, then its User field is appended as the last User field to HE-SIG-B content channel 1 only.

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3) If the Bandwidth field in the HE-SIG-A field is 3, 6, or 7, then the set of User fields indicated by the first RU Allocation subfield is followed by the set of the User fields indicated by the second RU Allocation subfield; in turn these are followed by the set of the User fields indicated by the third RU Allocation subfield and then by the set of the User fields indicated by the fourth RU Allocation subfield. If the center 26-tone RU that spans subcarriers [–528:–516, –508:–496] is assigned, then its User field is appended to HE-SIG-B content channel 1. If the center 26-tone RU that spans subcarriers [496:508, 516:528] is assigned, then its User field is appended as the last User field to HE-SIG-B content channel 2.

b) If the HE-SIG-B Compression field in the HE-SIG-A field of an HE MU PPDU is 1, then this second step is bypassed. Otherwise, each subset of User fields indicated by an RU Allocation subfield shall be ordered by increasing frequency of RU, i.e., #1 to #9 in Table 27-27 (RU Allocation subfield(11ax)).

c) Without regard to the value of the HE-SIG-B Compression field, the ordering of User fields in the same RU shall follow the user ordering in Table 27-31 (Spatial Configuration subfield encoding(11ax)).

In this way, RU Allocation subfields, Center 26-tone RU fields (if present), and the position of a user's User field in the User Specific field of an HE-SIG-B content channel indicate the user's RU assignment.

If the Bandwidth field in the HE-SIG-A field of an HE MU PPDU (see Table 27-21 (HE-SIG-A field of an HE MU PPDU(11ax))) is 4 or 5 (preamble is punctured), the content of HE-SIG-B content channels 1 and 2 shall be constructed as described above for an 80 MHz PPDU without preamble puncturing.

If the Bandwidth field in the HE-SIG-A field of an HE MU PPDU is 6 or 7 (preamble is punctured), the content of HE-SIG-B content channels 1 and 2 shall be constructed as described above for an 160 MHz PPDU without preamble puncturing.

An example for the mapping of the 8-bit RU Allocation subfield and the position of the User field to a user's data is illustrated in Figure 27-27 (Example of the mapping of 8-bit RU Allocation subfield and the position of User field to user's assignment for one 20 MHz channel(11ax)). The RU Allocation subfield indicates an arrangement of one 106-tone RU followed by five 26-tone RUs and indicates that the 106-tone RU contains three User fields, i.e., the 106-tone RU supports multiplexing of three users using MU-MIMO. The 8 User fields in the User Specific field thus map to the 6 RUs, with the first three User fields indicating MU-MIMO allocations in the first 106-tone RU followed by User fields corresponding to the each of the five 26-tone RUs.

The contents of the User field differ depending on whether the field addresses a user in a non-MU-MIMO allocation in an RU or a user in an MU-MIMO allocation in an RU. Irrespective of whether the allocation is for a user in a non-MU-MIMO or an MU-MIMO allocation, the size of the User field is the same.

The User field format for a non-MU-MIMO allocation is defined in Table 27-29 (User field format for non-MU-MIMO allocation(11ax)).


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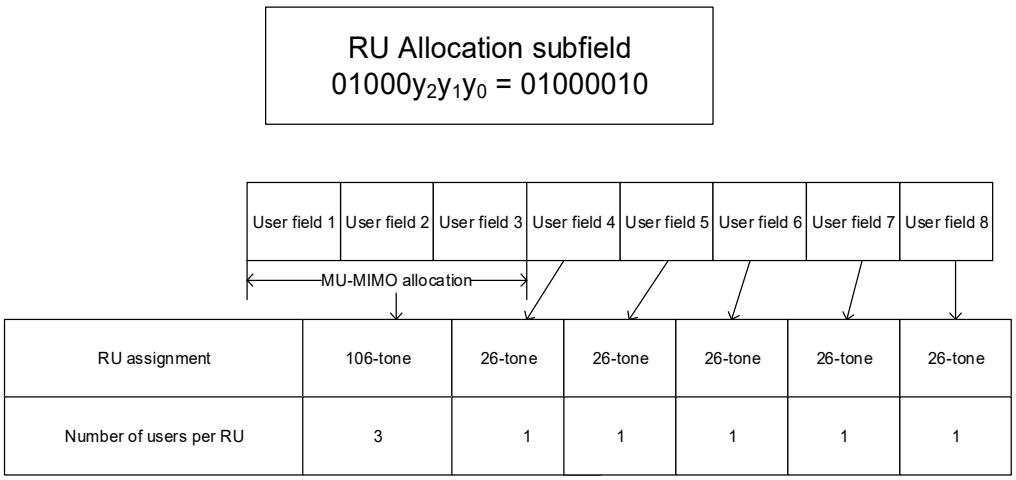


**Figure 27-27—Example of the mapping of 8-bit RU Allocation subfield and the position of User field to user's assignment for one 20 MHz channel(11ax)**

**Table 27-29—User field format for non-MU-MIMO allocation(11ax)**

| Bit | Subfield | Number of bits | Description |
|---|---|---|---|
| B0–B10 | STA-ID | 11 | Set to a value of the TXVECTOR parameter STA_ID (see 26.11.1 (STA_ID)). |
| B11–B13 | NSTS | 3 | If the STA-ID subfield is not 2046, indicates the number of space-time streams and is set to the number of space-time streams minus 1.<br><br>Set to an arbitrary value if the STA-ID subfield is 2046. |
| B14 | Beamformed | 1 | If the STA-ID subfield is not 2046, used in transmit beamforming:<br>Set to 1 if a beamforming steering matrix is applied to the waveform in a non-MU-MIMO allocation.<br>Set to 0 otherwise.<br><br>Set to an arbitrary value if the STA-ID subfield is 2046. |
| B15–B18 | HE-MCS | 4 | If the STA-ID subfield is not 2046, indicates the modulation and coding scheme:<br>Set to *n* for HE-MCS *n*, where *n* = 0, 1, 2, …, 11.<br>Values 12-15 are reserved.<br><br>Set to an arbitrary value if the STA-ID subfield is 2046. |
| B19 | DCM | 1 | If the STA-ID subfield is not 2046, indicates whether DCM is used:<br>Set to 1 to indicate that the payload of the corresponding user of the HE MU PPDU is modulated with DCM for the HE-MCS.<br>Set to 0 to indicate that the payload of the corresponding user of the PPDU is not modulated with DCM for the HE-MCS.<br><br>Set to an arbitrary value if the STA-ID subfield is 2046. |
| B20 | Coding | 1 | If the STA-ID subfield is not 2046, indicates whether BCC or LDPC is used:<br>Set to 0 for BCC.<br>Set to 1 for LDPC.<br><br>Set to an arbitrary value if the STA-ID subfield is 2046. |

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The User field format for an MU-MIMO allocation is defined in Table 27-30 (User field format for MU-MIMO allocation(11ax)).

**Table 27-30—User field format for MU-MIMO allocation(11ax)**

| Bit | Subfield | Number of bits | Description |
|---|---|---|---|
| B0–B10 | STA-ID | 11 | Set to a value indicated from TXVECTOR parameter STA_ID (see 26.11.1 (STA_ID)). |
| B11–B14 | Spatial Configuration | 4 | If the STA-ID subfield is not 2046, indicates the number of spatial streams for a user in an MU-MIMO allocation (see Table 27-31 (Spatial Configuration subfield encoding(11ax))).<br><br>Set to an arbitrary value if the STA-ID subfield is 2046. |
| B15–B18 | HE-MCS | 4 | If the STA-ID subfield is not 2046, indicates the modulation and coding scheme:<br>Set to *n* for HE-MCS *n*, where *n* = 0, 1, 2, …, 11.<br>Values 12-15 are reserved.<br><br>Set to an arbitrary value if the STA-ID subfield is 2046. |
| B19 | Reserved | 1 | If the STA-ID subfield is not 2046, reserved and set to 0.<br><br>Set to an arbitrary value if the STA-ID subfield is 2046. |
| B20 | Coding | 1 | If the STA-ID subfield is not 2046, indicates whether BCC or LDPC is used:<br>Set to 0 for BCC.<br>Set to 1 for LDPC.<br><br>Set to an arbitrary value if the STA-ID subfield is 2046. |

A User field for an MU-MIMO allocation includes a 4-bit Spatial Configuration subfield that indicates the number of spatial streams for each user and the total number of spatial streams in the MU-MIMO allocation. The subfield shown in Table 27-31 (Spatial Configuration subfield encoding(11ax)) is constructed by using the entries corresponding to the value of number of users ($N_{user}$) multiplexed using MU-MIMO in an RU.

If the HE-SIG-B Compression field in the HE-SIG-A field is 0 and MU-MIMO is used in an RU of size less than or equal to 242 subcarriers, the number of users ($N_{user}$) in an MU-MIMO allocation is equal to the number of User fields per RU signaled for the RU in the associated RU Allocation subfield of the Common field in the same HE-SIG-B content channel.

If the HE-SIG-B Compression field in the HE-SIG-A field is 0 and MU-MIMO is used in RUs of size greater than 242 subcarriers, the AP performs a dynamic split of the User fields corresponding to the same MU-MIMO allocations as described in 27.3.11.8.3 (Common field) into two HE-SIG-B content channels, and the number of users ($N_{user}$) is computed as the sum of the number of User fields indicated for the RU by the 8-bit RU Allocation subfield in each HE-SIG-B content channel.

If the HE-SIG-B Compression field in the HE-SIG-A field is 1, then the number of users, $N_{user}$, is signaled by the Number Of HE-SIG-B Symbols Or MU-MIMO Users field in the HE-SIG-A field, and the AP performs an equitable split of the User fields following Equation (27-20).


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**Table 27-31—Spatial Configuration subfield encoding(11ax)**

| $N_{user}$ | B3…B0 | $N_{STS}$ [1] | $N_{STS}$ [2] | $N_{STS}$ [3] | $N_{STS}$ [4] | $N_{STS}$ [5] | $N_{STS}$ [6] | $N_{STS}$ [7] | $N_{STS}$ [8] | Total $N_{STS}$ | Number of entries |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | 0000–0011 | 1–4 | 1 | | | | | | | 2–5 | 10 |
| | 0100–0110 | 2–4 | 2 | | | | | | | 4–6 | |
| | 0111–1000 | 3–4 | 3 | | | | | | | 6–7 | |
| | 1001 | 4 | 4 | | | | | | | 8 | |
| 3 | 0000–0011 | 1–4 | 1 | 1 | | | | | | 3–6 | 13 |
| | 0100–0110 | 2–4 | 2 | 1 | | | | | | 5–7 | |
| | 0111–1000 | 3–4 | 3 | 1 | | | | | | 7–8 | |
| | 1001–1011 | 2–4 | 2 | 2 | | | | | | 6–8 | |
| | 1100 | 3 | 3 | 2 | | | | | | 8 | |
| 4 | 0000–0011 | 1–4 | 1 | 1 | 1 | | | | | 4–7 | 11 |
| | 0100–0110 | 2–4 | 2 | 1 | 1 | | | | | 6–8 | |
| | 0111 | 3 | 3 | 1 | 1 | | | | | 8 | |
| | 1000–1001 | 2–3 | 2 | 2 | 1 | | | | | 7–8 | |
| | 1010 | 2 | 2 | 2 | 2 | | | | | 8 | |
| 5 | 0000–0011 | 1–4 | 1 | 1 | 1 | 1 | | | | 5–8 | 7 |
| | 0100–0101 | 2–3 | 2 | 1 | 1 | 1 | | | | 7–8 | |
| | 0110 | 2 | 2 | 2 | 1 | 1 | | | | 8 | |
| 6 | 0000–0010 | 1–3 | 1 | 1 | 1 | 1 | 1 | | | 6–8 | 4 |
| | 0011 | 2 | 2 | 1 | 1 | 1 | 1 | | | 8 | |
| 7 | 0000–0001 | 1–2 | 1 | 1 | 1 | 1 | 1 | 1 | | 7–8 | 2 |
| 8 | 0000 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 8 | 1 |

The User field positions within an RU are defined to be logically continuous: the last User field corresponding to an RU in HE-SIG-B content channel 1 is immediately followed by the first User field corresponding to the same RU in HE-SIG-B content channel 2.

For a given value of $N_{user}$, the four bits of the Spatial Configuration subfield are used as follows: A STA with a STA-ID that matches the 11-bit ID signaled in the User field for an MU-MIMO allocation derives the number of spatial streams allocated to it using the row corresponding to the signaled 4-bit Spatial Configuration subfield and the column corresponding to the User field position in the User Specific field. The starting stream index for the user is computed by summing the $N_{STS}$ in the columns prior to the column indicated by the user's User field position.

The user ordering identified by the column headers $N_{STS}[s]$, $s = 1, 2, 3, \ldots$ in Table 27-31 (Spatial Configuration subfield encoding(11ax)) shall be the same as the user index $u$, $u = 0, 1, 2, \ldots$ in Equation (27-38), Equation (27-59), and Equation (27-108), i.e., $u = s - 1$.

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The total number of spatial streams (total $N_{STS}$) is computed by summing all columns for the row signaled by the Spatial Configuration field and is indicated in the (#4177)Total $N_{STS}$ column of Table 27-31 (Spatial Configuration subfield encoding(11ax)).

### 27.3.11.8.5 Encoding and modulation

The bits in the Common field of each HE-SIG-B content channel shall be BCC encoded at rate $R$ = 1/2.

In the User Specific field, each User Block field of each HE-SIG-B content channel shall be BCC encoded at rate $R$ = 1/2. If the number of User fields in an HE-SIG-B content channel is odd, the CRC and tail bits are added immediately after the last User field; there is only one User field in the last User Block field (see Table 27-28 (User Block field(11ax)). Padding bits are appended immediately after the tail bits corresponding to the final User Block field in each HE-SIG-B content channel to round up to the next multiple of number of data bits per HE-SIG-B OFDM symbol. The padding bits may be set to any value. Further padding bits are appended to each HE-SIG-B content channel so that the number of OFDM symbols after encoding and modulation in different 20 MHz bands ends at the same OFDM symbol. For both the Common field and User Block field, the information bits, tail bits, and padding bits (if present) are BCC encoded at rate $R$ = 1/2 using the encoder described in 17.3.5.6 (Convolutional encoder). If the coding rate of the HE-SIG-B-MCS is not equal to 1/2, the convolutional encoder output bits for each field are concatenated, and then the concatenated bit streams are punctured as described in 17.3.5.6 (Convolutional encoder).

The coded bits are interleaved as in 27.3.12.8 (BCC interleavers). (#3413)The interleaved bits are mapped to constellation points from the (#1051)HE-SIG-B-MCS field in the HE-SIG-A field following the steps described in 17.3.5.8 (Subcarrier modulation mapping) if the HE-SIG-B field in the HE-SIG-A field is 0, and 27.3.12.15 (Dual carrier modulation) if the HE-SIG-B DCM field in the HE-SIG-A field is 1. $N_{SD}$ is 52 if the HE-SIG-B DCM field in the HE-SIG-A field is 0. $N_{SD}$ is 26 if the HE-SIG-B DCM field in the HE-SIG-A field is 1. Pilots are then inserted as described in 17.3.5.9 (Pilot subcarriers).

The guard interval used for the HE-SIG-B field shall be 0.8 μs.

If the HE-SIG-B Compression field in the HE-SIG-A field is 0, then the number of OFDM symbols in the HE-SIG-B field, denoted by $N_{SYM,\text{HE-SIG-B}}$, shall be signaled by the Number Of HE-SIG-B Symbols Or MU-MIMO Users field in the HE-SIG-A field of an HE MU PPDU (see 27.3.11.7.2 (Content)).

If the HE-SIG-B Compression field in the HE-SIG-A field is 1, then the number of OFDM symbols in the HE-SIG-B field is calculated based on the number of User fields in the HE-SIG-B content channel, the HE-MCS of the HE-SIG-B field, whether DCM is applied to the HE-SIG-B field, and the bandwidth of HE MU PPDU, all of which are indicated by the Number Of HE-SIG-B Symbols Or MU-MIMO Users field, HE-SIG-B-MCS field, HE-SIG-B DCM field, and Bandwidth field, respectively, in the HE-SIG-A field of an HE MU PPDU (see 27.3.11.7.2 (Content)).

For the HE-SIG-B content channel $c$ ($c$ = 1 or 2), denote the complex number assigned to the $k^{\text{th}}$ data subcarrier of the $n^{\text{th}}$ symbol by $d_{k,n,c}$. The time domain waveform for the HE-SIG-B field, transmitted on frequency segment $i_{Seg}$ and transmit chain $i_{TX}$, is given by Equation (27-21).


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$$r_{\text{HE-SIG-B}}^{(i_{Seg},\, i_{TX})}(t) = \frac{1}{\sqrt{N_{TX} \cdot N_{\text{HE-SIG-B}}^{\text{Tone}} \cdot \frac{|\Omega_{20\text{MHz}}|}{N_{20\text{MHz}}}}} \sum_{n=0}^{N_{SYM,\,\text{HE-SIG\_B}}-1} w_{T_{\text{HE-SIG-B}}}(t - nT_{SYML}) \quad (27\text{-}21)$$

$$\sum_{i_{BW} \in \Omega_{20\text{MHz}}} \sum_{k=-28}^{28} \left( \begin{array}{l} \Upsilon_{(k - K_{\text{Shift}}(i_{BW})),\,\text{BW}} \left( \Gamma_{M_{20}^{r}(k)} D_{k,\,n,\,i_{BW}}^{i_{Seg}} + p_{n+4} P_k \right) \\ \cdot \exp(j2\pi(k - K_{\text{Shift}}(i_{\text{BW}}))\Delta_{F,\,\text{Pre-HE}}(t - nT_{SYML} - T_{GI,\,\text{Pre-HE}} - T_{CS}^{i_{TX}})) \end{array} \right)$$

where

$\Gamma_{M_{20}^{r}(k)}$ is the phase rotation value for HE-SIG-B field PAPR reduction. If the HE-SIG-B field is modulated with HE-SIG-B-MCS 0 and DCM=1, then $\Gamma_{M_{20}^{r}(k)} = 1$. For all other modulation schemes of the HE-SIG-B field,

$$\Gamma_{M_{20}^{r}(k)} = \begin{cases} 1 & 0 \le M_{20}^{r}(k) < 26 \\ (-1)^{M_{20}^{r}(k)} & 26 \le M_{20}^{r}(k) < 52 \end{cases}$$

$N_{\text{HE-SIG-B}}^{Tone}$ is given in Table 27-17 (Number of modulated subcarriers and guard interval duration values for HE PPDU fields(11ax))

$K_{\text{Shift}}(i)$ is defined in 21.3.8.2.4 (L-SIG definition)

$$D_{k,\,n,\,i_{BW}}^{i_{Seg}} = \begin{cases} 0, k = 0, \pm 7, \pm 21 \\ d_{M_{20}^{r}(k),\,n,\,(i_{BW} mod\, 2)+1}, \text{otherwise} \end{cases}$$

$$M_{20}^{r}(k) = \begin{cases} k + 28, -28 \le k \le -22 \\ k + 27, -20 \le k \le -8 \\ k + 26, -6 \le k \le -1 \\ k + 25, 1 \le k \le 6 \\ k + 24, 8 \le k \le 20 \\ k + 23, 22 \le k \le 28 \end{cases}$$

$P_k$ and $p_n$ are defined in 17.3.5.10 (OFDM modulation)

$N_{SYM,\,\text{HE-SIG-B}}$ is the number of OFDM symbols in the HE-SIG-B field

From Equation (27-21) and 27.3.11.8.2 (HE-SIG-B content channels), a 20 MHz PPDU contains one HE-SIG-B content channel as shown in Figure 27-28 (HE-SIG-B content channel for a 20 MHz PPDU(11ax)).

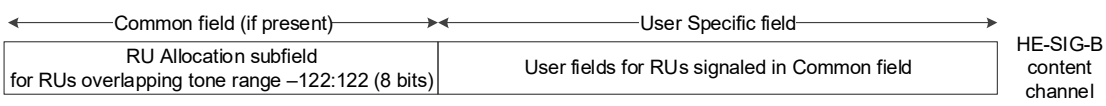


**Figure 27-28—HE-SIG-B content channel for a 20 MHz PPDU(11ax)**

From Equation (27-21) and 27.3.11.8.2 (HE-SIG-B content channels), a 40 MHz PPDU contains two HE-SIG-B content channels, each occupying a 20 MHz frequency segment as shown in Figure 27-29 (HE-SIG-

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B content channel for a 40 MHz PPDU(11ax)). HE-SIG-B content channel 1 occupies the 20 MHz frequency subchannel that is lower in frequency. HE-SIG-B content channel 2 occupies the 20 MHz frequency subchannel that is upper in frequency.

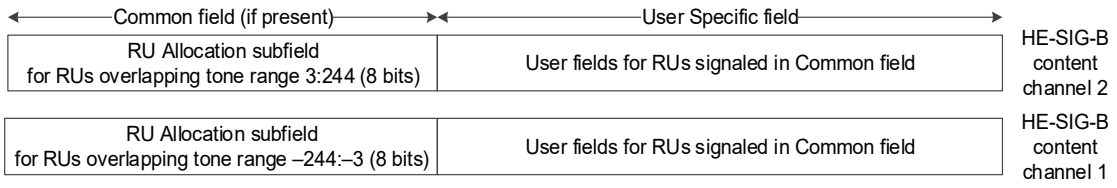


**Figure 27-29—HE-SIG-B content channel for a 40 MHz PPDU(11ax)**

From Equation (27-21) and 27.3.11.8.2 (HE-SIG-B content channels), an 80 MHz PPDU contains two HE-SIG-B content channels, each of which are duplicated once as shown in Figure 27-30 (HE-SIG-B content channels and their duplication in an 80 MHz PPDU(11ax)). HE-SIG-B content channel 1 occupies the 20 MHz frequency subchannel that is lowest in frequency and is duplicated on the 20 MHz frequency segment that is third lowest in frequency. HE-SIG-B content channel 2 occupies the 20 MHz frequency segment that is second lowest in frequency and is duplicated on the 20 MHz frequency subchannel that is highest in frequency.

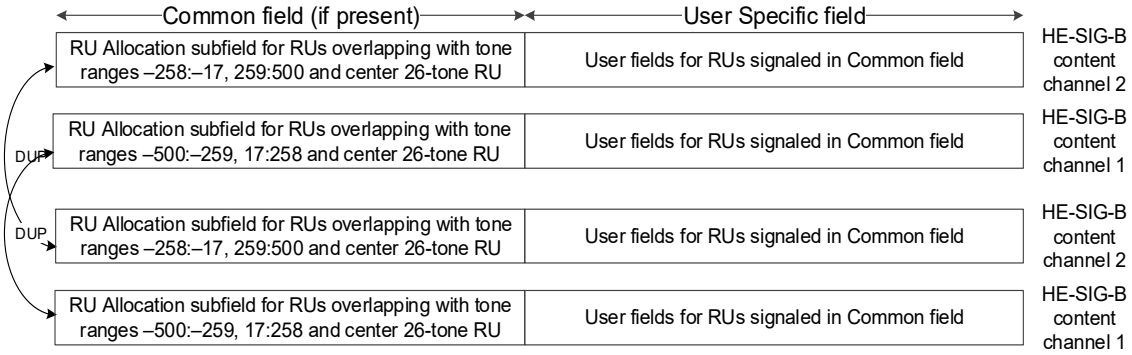


**Figure 27-30—HE-SIG-B content channels and their duplication in an 80 MHz PPDU(11ax)**

From Equation (27-21) and 27.3.11.8.2 (HE-SIG-B content channels), a 160 MHz PPDU contains two HE-SIG-B content channels, each of which are duplicated four times as shown in Figure 27-31 (HE-SIG-B content channels and their duplication in a 160 MHz PPDU(11ax)). HE-SIG-B content channel 1 occupies the 20 MHz frequency subchannel that is lowest in frequency and is duplicated on the 20 MHz frequency subchannels that are third, fifth, and seventh lowest in frequency. HE-SIG-B content channel 2 occupies the


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20 MHz frequency subchannel that is second lowest in frequency and is duplicated on the 20 MHz frequency subchannels that are fourth, sixth, and eighth lowest in frequency.

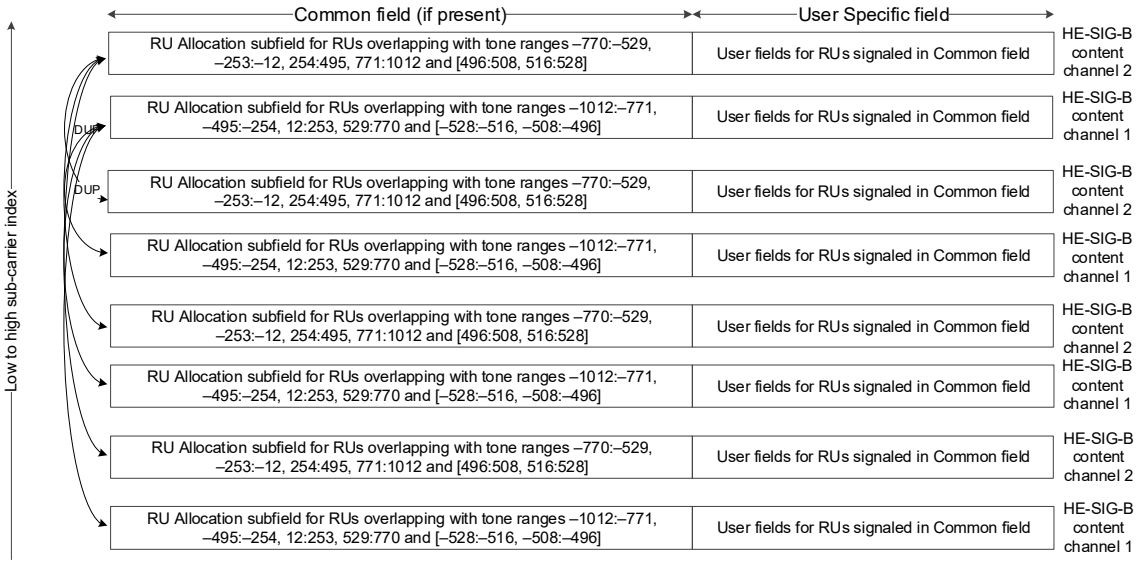


**Figure 27-31—HE-SIG-B content channels and their duplication in a 160 MHz PPDU(11ax)**

If the Bandwidth field in the HE-SIG-A field of an HE MU PPDU (see Table 27-21 (HE-SIG-A field of an HE MU PPDU(11ax))) is 4 or 5 (preamble is punctured), the mapping of the HE-SIG-B content channels to 20 MHz segments shall be the same as for an 80 MHz PPDU (see Figure 27-30 (HE-SIG-B content channels and their duplication in an 80 MHz PPDU(11ax))), with the exception that punctured 20 MHz channels shall be excluded.

If the Bandwidth field in the HE-SIG-A field of an HE MU PPDU (see Table 27-21 (HE-SIG-A field of an HE MU PPDU(11ax))) is 6 or 7 (preamble is punctured), the mapping of the HE-SIG-B content channels to 20 MHz segments shall be the same as for an 160 MHz PPDU (see Figure 27-31 (HE-SIG-B content channels and their duplication in a 160 MHz PPDU(11ax))), with the exception that punctured 20 MHz channels shall be excluded.

### 27.3.11.9 HE-STF field

The main purpose of the HE-STF field is to improve automatic gain control estimation in a MIMO transmission. The duration of the HE-STF field for HE PPDUs that are not HE TB PPDUs is $T_{\text{HE-STF-NT}}$ (periodicity of 0.8 μs with 5 periods as given in Table 27-13 (Timing-related constants(11ax))), and the duration of the HE-STF field for an HE TB PPDU is $T_{\text{HE-STF-T}}$ (periodicity of 1.6 μs with 5 periods as given in Table 27-13 (Timing-related constants(11ax))).

For the HE-STF field, the $M$ sequence is defined by Equation (27-22).

$$M = \{-1, -1, -1, 1, 1, 1, -1, 1, 1, 1, -1, 1, 1, -1, 1\} \quad (27\text{-}22)$$

The HE-STF field is constructed by mapping the $M$ sequence(s) multiplied by $(1+j)/\sqrt{2}$ or $(-1-j)/\sqrt{2}$ to each 242-tone RU. For a transmission bandwidth greater than 40 MHz, $(1+j)/\sqrt{2}$ or $(-1-j)/\sqrt{2}$ is assigned to subcarrier indices that are inside the center 26-tone RUs.

For a 20 MHz transmission, the frequency domain sequence for HE PPDUs that are not HE TB PPDUs is given by Equation (27-23).

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$$HES_{-112:16:112} = \{M\} \cdot (1+j)/\sqrt{2}$$
The value of the HE-STF sequence at null tone index 0 is $HES_0 = 0$ (27-23)

where $HES_{a:b:c}$ means coefficients of the HE-STF on every $b$ subcarrier indices from $a$ to $c$ subcarrier indices and coefficients on other subcarrier indices are set to zero.

For a 40 MHz transmission, the frequency domain sequence for HE PPDUs that are not HE TB PPDUs is given by Equation (27-24).

$$HES_{-240:16:240} = \{M, 0, -M\} \cdot (1+j)/\sqrt{2} \quad (27\text{-}24)$$

For an 80 MHz transmission, the frequency domain sequence for HE PPDUs that are not HE TB PPDUs is given by Equation (27-25).

$$HES_{-496:16:496} = \{M, 1, -M, 0, -M, 1, -M\} \cdot (1+j)/\sqrt{2} \quad (27\text{-}25)$$

For a 160 MHz transmission, the frequency domain sequence for HE PPDUs that are not HE TB PPDUs is given by Equation (27-26).

$$HES_{-1008:16:1008} = \{M, 1, -M, 0, -M, 1, -M, 0, -M, -1, M, 0, -M, 1, -M\} \cdot (1+j)/\sqrt{2} \quad (27\text{-}26)$$

For an 80+80 MHz transmission, the lower 80 MHz segment for HE PPDUs that are not HE TB PPDUs shall use the HE-STF pattern for the 80 MHz defined in Equation (27-25).

For an 80+80 MHz transmission, the frequency domain sequence of the upper 80 MHz segment for HE PPDUs that are not HE TB PPDUs is given by Equation (27-27).

$$HES_{-496:16:496} = \{-M, -1, M, 0, -M, 1, -M\} \cdot (1+j)/\sqrt{2} \quad (27\text{-}27)$$

For a 20 MHz transmission, the frequency domain sequence for HE TB PPDUs is given by Equation (27-28).

$$HES_{-120:8:120} = \{M, 0, -M\} \cdot (1+j)/\sqrt{2} \quad (27\text{-}28)$$

For an HE TB feedback NDP in 20 MHz channel width, the frequency domain sequence is given by Equation (27-29).

$$HES^{\text{TB NDP}}_{-120:8:120} = HES_{-120:8:120} \quad (27\text{-}29)$$

For a 40 MHz transmission, the frequency domain sequence for HE TB PPDUs is given by Equation (27-30).

$$HES_{-248:8:248} = \{M, -1, -M, 0, M, -1, M\} \cdot (1+j)/\sqrt{2}$$
The value of the HE-STF sequence at edge tone indices ±248 is $HES_{\pm 248} = 0$ (27-30)

For an HE TB feedback NDP in 40 MHz channel width, the frequency domain sequence is given by Equation (27-31).


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$$
\begin{aligned}
HES_{-248:8:-8}^{\text{TB NDP}} &= \{M, -1, -M\} \cdot (1+j)/\sqrt{2}, \text{ if RU\_TONE\_SET\_INDEX} \le 18 \\
HES_{8:8:248}^{\text{TB NDP}} &= \{M, -1, M\} \cdot (1+j)/\sqrt{2}, \text{ if RU\_TONE\_SET\_INDEX} > 18 \\
HES_{\pm 248}^{\text{TB NDP}} &= 0
\end{aligned}
\tag{27-31}
$$

For an 80 MHz transmission, the frequency domain sequence for HE TB PPDUs is given by Equation (27-32).

$$
\begin{aligned}
&HES_{-504:8:504} = \{M, -1, M, -1, -M, -1, M, 0, -M, 1, M, 1, -M, 1, -M\} \cdot (1+j)/\sqrt{2} \\
&\text{The value of the HE-STF sequence at edge tone indices } \pm 504 \text{ is } HES_{\pm 504} = 0
\end{aligned}
\tag{27-32}
$$

For an HE TB feedback NDP in 80 MHz channel width, the frequency domain sequence is given by Equation (27-33).

$$
\begin{aligned}
HES_{-504:8:-264}^{\text{TB NDP}} &= \{M, -1, M\} \cdot (1+j)/\sqrt{2}, \text{ if RU\_TONE\_SET\_INDEX} \le 18 \\
HES_{-248:8:-8}^{\text{TB NDP}} &= \{-M, -1, M\} \cdot (1+j)/\sqrt{2}, \text{ if } 18 < \text{RU\_TONE\_SET\_INDEX} \le 36 \\
HES_{8:8:248}^{\text{TB NDP}} &= \{-M, 1, M\} \cdot (1+j)/\sqrt{2}, \text{ if } 36 < \text{RU\_TONE\_SET\_INDEX} \le 54 \\
HES_{264:8:504}^{\text{TB NDP}} &= \{-M, 1, -M\} \cdot (1+j)/\sqrt{2}, \text{ if } 54 < \text{RU\_TONE\_SET\_INDEX} \le 72 \\
HES_{\pm 504}^{\text{TB NDP}} &= 0
\end{aligned}
\tag{27-33}
$$

For a 160 MHz transmission, the frequency domain sequence for HE TB PPDUs is given by Equation (27-34).

$$
\begin{aligned}
&HES_{-1016:8:1016} = \{M, -1, M, -1, -M, -1, M, 0, -M, 1, M, 1, -M, 1, -M, 0 \\
&\qquad -M, 1, -M, 1, M, 1, -M, 0, -M, 1, M, 1, -M, 1, -M\} \cdot (1+j)/\sqrt{2} \\
&\text{The value of the HE-STF sequence at edge tone indices } \pm 8 \text{ and } \pm 1016 \text{ is } HES_{\pm 8} = 0, HES_{\pm 1016} = 0
\end{aligned}
\tag{27-34}
$$

For an HE TB feedback NDP in 160 MHz channel width, the frequency domain sequence is given by Equation (27-35).

$$
\begin{aligned}
HES_{-1016:8:-776}^{\text{TB NDP}} &= \{M, -1, M\} \cdot (1+j)/\sqrt{2}, \text{ if RU\_TONE\_SET\_INDEX} \le 18 \\
HES_{-760:8:-520}^{\text{TB NDP}} &= \{-M, -1, M\} \cdot (1+j)/\sqrt{2}, \text{ if } 18 < \text{RU\_TONE\_SET\_INDEX} \le 36 \\
HES_{-504:8:-264}^{\text{TB NDP}} &= \{-M, 1, M\} \cdot (1+j)/\sqrt{2}, \text{ if } 36 < \text{RU\_TONE\_SET\_INDEX} \le 54 \\
HES_{-248:8:-8}^{\text{TB NDP}} &= \{-M, 1, -M\} \cdot (1+j)/\sqrt{2}, \text{ if } 54 < \text{RU\_TONE\_SET\_INDEX} \le 72 \\
HES_{8:8:248}^{\text{TB NDP}} &= \{-M, 1, -M\} \cdot (1+j)/\sqrt{2}, \text{ if } 72 < \text{RU\_TONE\_SET\_INDEX} \le 90 \\
HES_{264:8:504}^{\text{TB NDP}} &= \{M, 1, -M\} \cdot (1+j)/\sqrt{2}, \text{ if } 90 < \text{RU\_TONE\_SET\_INDEX} \le 108 \\
HES_{520:8:760}^{\text{TB NDP}} &= \{-M, 1, M\} \cdot (1+j)/\sqrt{2}, \text{ if } 108 < \text{RU\_TONE\_SET\_INDEX} \le 126 \\
HES_{776:8:1016}^{\text{TB NDP}} &= \{-M, 1, -M\} \cdot (1+j)/\sqrt{2}, \text{ if } 126 < \text{RU\_TONE\_SET\_INDEX} \le 144 \\
HES_{\pm 8}^{\text{TB NDP}} &= HES_{\pm 1016}^{\text{TB NDP}} = 0
\end{aligned}
\tag{27-35}
$$

For an 80+80 MHz transmission, the lower 80 MHz segment for HE TB PPDUs shall use the HE-STF pattern for the 80 MHz defined in Equation (27-32).

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For an 80+80 MHz transmission, the frequency domain sequence of the upper 80 MHz segment for HE TB PPDUs is given by Equation (27-36).

$$HES_{-504:8:504} = \{-M, 1, -M, 1, M, 1, -M, 0, -M, 1, M, 1, -M, 1, -M\} \cdot (1+j)/\sqrt{2}$$
The value of the HE-STF sequence at edge tone indices ±504 is $HES_{\pm 504} = 0$ (27-36)

For an HE TB feedback NDP in the lower 80 MHz segment of an 80+80 MHz channel width, the frequency domain sequence is given by Equation (27-33).

For an HE TB feedback NDP in the upper 80 MHz segment of an 80+80 MHz channel width, the frequency domain sequence is given by Equation (27-37).

$$\begin{aligned}
HES^{\text{TB NDP}}_{-504:8:-264} &= \{-M, 1, -M\} \cdot (1+j)/\sqrt{2}, \text{ if RU_TONE_SET_INDEX} \le 90 \\
HES^{\text{TB NDP}}_{-248:8:-8} &= \{M, 1, -M\} \cdot (1+j)/\sqrt{2}, \text{ if } 90 < \text{RU_TONE_SET_INDEX} \le 108 \\
HES^{\text{TB NDP}}_{8:8:248} &= \{-M, 1, M\} \cdot (1+j)/\sqrt{2}, \text{ if } 108 < \text{RU_TONE_SET_INDEX} \le 126 \\
HES^{\text{TB NDP}}_{264:8:504} &= \{-M, 1, -M\} \cdot (1+j)/\sqrt{2}, \text{ if } 126 < \text{RU_TONE_SET_INDEX} \le 144 \\
HES^{\text{TB NDP}}_{\pm 504} &= 0
\end{aligned} \quad (27\text{-}37)$$

If a 20 MHz operating non-AP STA sends an HE TB feedback NDP report response (see 26.5.7 (NDP feedback report procedure)) on a channel width greater than 20 MHz, the HE-STF subcarrier that overlaps the DC subcarrier of the 20 MHz operating non-AP STA is not transmitted.

For an OFDMA transmission, the coefficients in Equation (27-23) to Equation (27-36) are set to zero if those values correspond to subcarrier indices that fall within RUs that have no users assigned to them.

The time domain representation of the signal for an HE PPDU that is not an HE TB PPDU on frequency segment $i_{Seg}$ and transmit chain $i_{TX}$ shall be as specified in Equation (27-38).

$$r^{(i_{Seg}, i_{TX})}_{\text{HE-STF}}(t) = w_{T_{\text{HE-STF-NT}}}(t) \cdot \sum_{r=0}^{N_{RU}-1} \frac{\alpha_r \beta_r}{\sqrt{N_{STS,r,total}}} \sum_{k \in K_r} \eta_{\text{HE-STF},k} \sum_{u=0}^{N_{user,r}-1} \sum_{m=1}^{N_{STS,r,u}} \left( \left[ Q_k^{(i_{Seg})} \right]_{i_{TX}, M_{r,u}+m} HES_k \cdot \exp(j2\pi k \Delta_{F,\text{HE}}(t - T_{CS,HE}(M_{r,u}+m))) \right) \quad (27\text{-}38)$$

where

$\alpha_r$ is defined in 27.3.10 (Mathematical description of signals)

$\eta_{\text{HE-STF},k}$ is an HE PPDU format-dependent scaling factor as defined by

$$\eta_{\text{HE-STF},k} = \begin{cases} \sqrt{2}, & \text{for an HE ER SU PPDU} \\ 1, & \text{otherwise} \end{cases}$$

$\beta_r$ is the per-RU power normalization factor as defined by

$$\beta_r = \left( \sqrt{\frac{|K_r|}{|K_r^{\text{HE-STF}}|}} \right) \Big/ \left( \sqrt{\sum_{r=0}^{N_{RU}-1} \alpha_r^2 |K_r|} \right)$$

$|K_r|$ is the cardinality of the set of subcarriers $K_r$ as defined in 27.3.10 (Mathematical description of signals)


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$K_r^{\text{HE-STF}}$ is the set of subcarriers that have nonzero values within $K_r$ in the HE-STF field

$T_{CS,\text{HE}}(M_{r,u}+m)$ represents the cyclic shift for space-time stream $M_{r,u}+m$ as defined in 27.3.11.2.2 (Cyclic shift for HE modulated fields)

$Q_k^{(i_{Seg})}$ is defined in 27.3.10 (Mathematical description of signals)

$w_{T_{\text{HE-STF-NT}}}$ is the windowing function for HE-STF field in the non-HE TB PPDU

$\left|K_r^{\text{HE-STF}}\right|$ is the cardinality of the set of subcarriers $K_r^{\text{HE-STF}}$

$N_{RU}$, $N_{STS,r,total}$, $N_{user,r}$, and $N_{STS,r,u}$ are defined in Table 27-16 (Frequently used parameters(11ax))

The time domain representation of the signal for an HE TB PPDU transmitted by user $u$ in the $r^{\text{th}}$ RU on frequency segment $i_{Seg}$ and transmit chain $i_{TX}$ shall be as specified in Equation (27-39)(#1053).

$$r_{\text{HE-STF},r,u}^{(i_{Seg},i_{TX})}(t) = \frac{1}{\sqrt{\Gamma_r^{\text{HE-STF}} N_{STS,r,u}}} w_{T_{\text{HE-STF-T}}}(t) \sum_{k\in K_r}\sum_{m=1}^{N_{STS,r,u}} \left( \left[ Q_{k,u}^{(i_{Seg})} \right]_{i_{TX},m} HES_k \cdot \exp(j2\pi k\Delta_{F,\text{HE}}(t - T_{CS,HE}(M_{r,u}+m))) \right) \quad (27\text{-}39)$$

where

$w_{T_{\text{HE-STF-T}}}$ is the windowing function for HE-STF field in the HE TB PPDU

$Q_{k,u}^{(i_{Seg})}$ is defined in 27.3.10 (Mathematical description of signals)

$HES_k$ is the HE-STF sequence for HE TB PPDU applied on subcarrier $k$. For an HE TB feedback NDP, replace $HES_k$ with $HES_k^{\text{TB\_NDP}}$ in Equation (27-39).

$M_{r,u}$ is given by the TXVECTOR parameter STARTING_STS_NUM

It is recommended that the spatial mapping matrix applied to HE-STF and beyond be chosen such that it preserves the smoothness of the physical channel, achieved by limiting the variation of each element's real and imaginary values in the spatial mapping matrix across successive tones within one RU.

### 27.3.11.10 HE-LTF field

The HE-LTF field provides a means for the receiver to estimate the MIMO channel between the set of constellation mapper outputs (or, if STBC is applied, the STBC encoder outputs) and the receive chains. In an HE SU PPDU and HE ER SU PPDU, the transmitter provides training for $N_{STS}$ space-time streams (spatial mapper inputs) used for the transmission of the PSDU. In an HE MU PPDU, the transmitter provides training for $N_{STS,r,total}$ space-time streams used for the transmission of the PSDU(s) in the $r^{\text{th}}$ RU. In an HE TB PPDU, the transmitter of user $u$ in the $r^{\text{th}}$ RU provides training for $N_{STS,r,u}$ space-time streams used for the transmission of the PSDU. For each subcarrier in the $r^{\text{th}}$ RU, the MIMO channel that can be estimated is an $N_{RX} \times N_{STS,r,total}$ matrix. An HE transmission has a preamble that contains HE-LTF symbols, where the data tones of each HE-LTF symbol are multiplied by entries belonging to a matrix $P_{\text{HE-LTF}}$, to enable channel estimation at the receiver. When single stream pilot is used in HE-LTF, the pilot subcarriers of each HE-LTF symbol are multiplied by the entries of a matrix $R_{\text{HE-LTF}}$ defined below to allow receivers to track phase and/or frequency offset during MIMO channel estimation using the HE-LTF. Single stream pilots shall be used in the HE-LTF field for SU, DL, and UL OFDMA, DL MU-MIMO, and partial-bandwidth UL

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MU-MIMO transmissions. Single stream pilots shall be used in the HE-LTF field for a full-bandwidth UL MU-MIMO transmission if single stream pilot HE-LTF mode is selected.

In an HE SU PPDU, HE ER SU PPDU, and HE MU PPDU with a single RU (the RU having an MU-MIMO allocation or an SU allocation), the number of HE-LTF symbols, $N_{\text{HE-LTF}}$, is a function of the total number of space-time streams, $N_{STS}$, as shown in Table 21-13 (Number of VHT-LTFs required for different numbers of space-time streams) in 21.3.8.3.5 (VHT-LTF definition) with $N_{VHT\text{-}LTF}$ replaced by $N_{HE\text{-}LTF}$ and with $N_{STS,total}$ replaced by $N_{STS}$. In an HE MU PPDU, $N_{\text{HE-LTF}}$ is indicated in the HE-SIG-A field. In an HE MU PPDU with more than one RU, $N_{\text{HE-LTF}}$ may take a value 1, 2, 4, 6, or 8 that is greater than or equal to the maximum value of the initial number of HE-LTF symbols for each RU, where the initial number of HE-LTF symbols is calculated as a function of $N_{STS,r,total}$ (where $r$ is the index of the RU) based on Table 21-13 (Number of VHT-LTFs required for different numbers of space-time streams) in 21.3.8.3.5 (VHT-LTF definition) with $N_{VHT\text{-}LTF}$ replaced by $N_{HE\text{-}LTF}$.

NOTE—An AP might use the HE MU PPDU With More Than One RU Rx Max N_HE-LTF subfield in the PHY Capabilities Information field in the HE Capabilities element received from a non-AP STA for OFDMA scheduling and selecting an appropriate $N_{\text{HE-LTF}}$ for an OFDMA transmission.

In an HE TB PPDU, $N_{\text{HE-LTF}}$ is indicated in the Trigger frame that triggers the transmission of the PPDU. In a non-OFDMA HE TB PPDU, the number of HE-LTF symbols, $N_{HE\text{-}LTF}$, is a function of the total number of space-time streams, $N_{STS}$, as shown in Table 21-13 (Number of VHT-LTFs required for different numbers of space-time streams) in 21.3.8.3.5 (VHT-LTF definition) with $N_{VHT\text{-}LTF}$ replaced by $N_{HE\text{-}LTF}$. For an OFDMA HE TB PPDU, $N_{HE\text{-}LTF}$ may be 1, 2, 4, 6, or 8 that is greater than or equal to the maximum value of the initial number of HE-LTF symbols for each RU $r$, which is calculated as a function of $N_{STS,r,total}$, separately based on Table 21-13 (Number of VHT-LTFs required for different numbers of space-time streams) in 21.3.8.3.5 (VHT-LTF definition) with $N_{VHT\text{-}LTF}$ replaced by $N_{HE\text{-}LTF}$.

An HE PPDU supports 3 HE-LTF types: 1x HE-LTF, 2x HE-LTF, and 4x HE-LTF. Table 27-32 (HE-LTF type and GI duration combinations for various HE PPDU formats(11ax)) defines whether a particular HE-LTF type and GI duration combination is mandatory, conditional mandatory, or optional for each HE PPDU format.

In an HE SU PPDU, HE MU PPDU, and HE ER SU PPDU, the combination of HE-LTF type and GI duration is indicated in HE-SIG-A field. In an HE TB PPDU, the combination of HE-LTF type and GI duration is indicated in the Trigger frame that triggers the transmission of the PPDU. If an HE PPDU is an HE sounding NDP, the combinations of HE-LTF types and GI durations are listed in 27.3.17 (HE sounding NDP). If an HE PPDU is an HE TB feedback NDP, the combinations of types and GI durations are listed in 27.3.18 (HE TB feedback NDP).

The duration of each HE-LTF symbol excluding GI is $T_{\text{HE-LTF}}$, defined in Equation (27-40).

$$T_{\text{HE-LTF}} = \begin{cases} T_{\text{HE-LTF-1X}}, \text{ if 1x HE-LTF} \\ T_{\text{HE-LTF-2X}}, \text{ if 2x HE-LTF} \\ T_{\text{HE-LTF-4X}}, \text{ if 4x HE-LTF} \end{cases} \quad (27\text{-}40)$$

where $T_{\text{HE-LTF-1X}}$, $T_{\text{HE-LTF-2X}}$, and $T_{\text{HE-LTF-4X}}$ are defined in Table 27-13 (Timing-related constants(11ax)).


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**Table 27-32—HE-LTF type and GI duration combinations for various HE PPDU formats(11ax)**

| HE-LTF type and GI duration combination | HE SU PPDU | HE MU PPDU | HE ER SU PPDU | HE TB PPDU | HE sounding NDP | HE TB feedback NDP |
|---|---|---|---|---|---|---|
| 1x HE-LTF 0.8 µs GI | O | N/A | O | N/A | N/A | N/A |
| 1x HE-LTF 1.6 µs GI | N/A | N/A | N/A | CM3 | N/A | N/A |
| 2x HE-LTF 0.8 µs GI | M | M | M | N/A | M | N/A |
| 2x HE-LTF 1.6 µs GI | M | M | M | M | M | N/A |
| 4x HE-LTF 0.8 µs GI | CM1 | CM2 | O | N/A | N/A | N/A |
| 4x HE-LTF 3.2 µs GI | M | M | M | M | O | M |

Legend
M = mandatory.
CM1 = Mandatory if the STA supports 4x HE-LTF 0.8 µs GI for HE ER SU PPDU. Otherwise, optional.
CM2 = For an AP, mandatory for transmission if the AP supports 4x HE-LTF 0.8 µs GI for HE ER SU PPDU. For a non-AP STA, mandatory for reception if the non-AP STA supports 4x HE-LTF 0.8 µs GI for HE ER SU PPDU. Otherwise, optional.
CM3 = Mandatory for full-bandwidth UL MU-MIMO if the STA supports UL MU-MIMO. Otherwise, not supported. N/A for partial-bandwidth UL MU-MIMO or UL OFDMA.
O = optional.
N/A = not supported by the PPDU format.

If a STA does not support transmission or reception of a particular PPDU format, then the M/CM/O designation is not applicable for the transmission or reception, respectively, of that PPDU format.

In a 20 MHz transmission, the 1x HE-LTF sequence transmitted on subcarriers [–122: 122] is given by Equation (27-41).

$$\begin{aligned} HELTF_{-122,122} = \{&0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1,\\ &0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -\\ &1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0,\\ &-1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, 0, 0, 0, 0,\\ &-1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0,\\ &0, -1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, -1, 0,\\ &0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1,\\ &0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0\} \end{aligned} \tag{27-41}$$

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In a 20 MHz transmission, the 2x HE-LTF sequence transmitted on subcarriers [–122: 122] is given by Equation (27-42).

$$
\begin{aligned}
&HELTF_{-122,122} = \\
&\{-1, 0, -1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, \\
&-1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, +1, 0, \\
&-1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, \\
&+1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, \\
&+1, 0, +1, 0, -1, 0, -1, 0, +1, 0, 0, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, \\
&+1, 0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, +1, 0, \\
&+1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, \\
&-1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, \\
&-1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, +1\}
\end{aligned}
\tag{27-42}
$$

In a 20 MHz transmission, the 4x HE-LTF sequence transmitted on subcarriers [–122: 122] is given by Equation (27-43).

$$
\begin{aligned}
&HELTF_{-122,122} = \\
&\{-1, -1, +1, -1, +1, -1, +1, +1, +1, -1, +1, +1, +1, -1, -1, +1, -1, -1, -1, -1, -1, +1, +1, \\
&-1, -1, -1, -1, +1, +1, -1, +1, -1, +1, +1, +1, +1, -1, +1, -1, -1, +1, +1, -1, +1, +1, +1, \\
&+1, -1, -1, +1, -1, -1, -1, +1, +1, +1, +1, -1, +1, +1, -1, -1, -1, -1, +1, -1, -1, +1, +1, \\
&-1, +1, -1, -1, -1, -1, +1, -1, +1, -1, -1, -1, -1, -1, -1, +1, +1, -1, -1, -1, -1, -1, +1, -\\
&1, -1, +1, +1, +1, -1, +1, +1, +1, -1, +1, -1, +1, -1, -1, -1, -1, -1, +1, +1, +1, -1, -1, -\\
&1, +1, -1, +1, +1, +1, 0, 0, 0, -1, +1, -1, +1, -1, +1, +1, -1, +1, +1, +1, -1, -1, +1, -1, -\\
&1, +1, -1, +1, -1, +1, +1, +1, -1, +1, +1, +1, -1, -1, +1, -1, -1, -1, -1, -1, +1, +1, -1, -\\
&1, -1, -1, -1, -1, +1, -1, +1, -1, -1, -1, -1, +1, -1, +1, +1, -1, -1, +1, -1, -1, -1, -1, +1, \\
&+1, -1, +1, +1, +1, +1, +1, +1, +1, -1, +1, +1, -1, -1, -1, -1, +1, -1, -1, +1, +1, -1, +1, \\
&-1, -1, -1, -1, +1, -1, +1, -1, -1, +1, +1, +1, +1, -1, -1, +1, +1, +1, +1, +1, -1, +1, +1, \\
&-1, -1, -1, +1, -1, -1, -1, +1, -1, +1, -1, +1, +1\}
\end{aligned}
\tag{27-43}
$$

In a 40 MHz transmission, the 1x HE-LTF sequence transmitted on subcarriers [–244: 244] is given by Equation (27-44).

$$
\begin{aligned}
&HELTF_{-244,244} = \\
&\{+1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, \\
&0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, \\
&0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, \\
&0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -\\
&1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, \\
&-1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, \\
&0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, \\
&0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, 0, 0, 0, 0, +1, 0, \\
&0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, \\
&0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -\\
&1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, \\
&-1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, \\
&0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, \\
&0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, \\
&0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, \\
&+1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1\}
\end{aligned}
\tag{27-44}
$$


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In a 40 MHz transmission, the 2x HE-LTF sequence transmitted on subcarriers [–244: 244] is given by Equation (27-45).

$HELTF_{-244,244}$ =

{+1, 0, –1, 0, –1, 0, –1, 0, –1, 0, –1, 0, +1, 0, +1, 0, –1, 0, –1, 0, +1, 0, –1, 0, +1, 0, –1, 0,
–1, 0, –1, 0, –1, 0, –1, 0, –1, 0, +1, 0, +1, 0, +1, 0, +1, 0, –1, 0, +1, 0, –1, 0, +1, 0, +1, 0,
–1, 0, –1, 0, –1, 0, –1, 0, –1, 0, +1, 0, +1, 0, –1, 0, –1, 0, +1, 0, –1, 0, +1, 0, –1, 0, +1, 0,
+1, 0, +1, 0, +1, 0, +1, 0, –1, 0, –1, 0, –1, 0, –1, 0, +1, 0, –1, 0, +1, 0, –1, 0, +1, 0, +1, 0,
+1, 0, +1, 0, +1, 0, –1, 0, +1, 0, –1, 0, –1, 0, +1, 0, –1, 0, +1, 0, –1, 0, –1, 0, +1, 0, +1, 0,
+1, 0, +1, 0, +1, 0, –1, 0, –1, 0, +1, 0, +1, 0, –1, 0, +1, 0, –1, 0, +1, 0, +1, 0, +1, 0, +1, 0,
+1, 0, +1, 0, –1, 0, –1, 0, –1, 0, –1, 0, +1, 0, –1, 0, +1, 0, –1, 0, –1, 0, –1, 0, –1, 0, –1, 0,
–1, 0, –1, 0, +1, 0, +1, 0, –1, 0, –1, 0, +1, 0, –1, 0, +1, 0, –1, 0, +1, 0, +1, 0, +1, 0, +1, 0,
+1, 0, –1, 0, –1, 0, –1, 0, –1, 0, +1, 0, –1, 0, +1, 0, –1, 0, 0, 0, 0, 0, 0, 0, –1, 0, –1, 0, –1, (27-45)
0, –1, 0, –1, 0, +1, 0, +1, 0, –1, 0, –1, 0, +1, 0, –1, 0, +1, 0, –1, 0, –1, 0, –1, 0, –1, 0, –1,
0, –1, 0, +1, 0, –1, 0, +1, 0, +1, 0, –1, 0, +1, 0, –1, 0, +1, 0, +1, 0, +1, 0, +1, 0, +1, 0, +1,
0, +1, 0, –1, 0, –1, 0, +1, 0, +1, 0, –1, 0, +1, 0, –1, 0, +1, 0, –1, 0, –1, 0, –1, 0, –1, 0, –1,
0, +1, 0, –1, 0, +1, 0, +1, 0, –1, 0, +1, 0, –1, 0, +1, 0, +1, 0, +1, 0, +1, 0, +1, 0, +1, 0, +1,
0, –1, 0, –1, 0, +1, 0, +1, 0, –1, 0, +1, 0, –1, 0, +1, 0, –1, 0, –1, 0, –1, 0, –1, 0, –1, 0, +1,
0, +1, 0, –1, 0, –1, 0, +1, 0, –1, 0, +1, 0, –1, 0, –1, 0, –1, 0, –1, 0, –1, 0, –1, 0, –1, 0, +1, 0, –1,
0, +1, 0, +1, 0, –1, 0, +1, 0, –1, 0, +1, 0, +1, 0, –1, 0, –1, 0, –1, 0, –1, 0, –1, 0, –1, 0, +1, 0, +1,
0, –1, 0, –1, 0, +1, 0, –1, 0, +1, 0, –1, 0, +1, 0, +1, 0, +1, 0, +1, 0, +1, 0, +1, 0, –1, 0, +1, 0, –1,
0, –1, 0, +1, 0, –1, 0, +1, 0, –1, 0, +1}

In a 40 MHz transmission, the 4x HE-LTF sequence transmitted on subcarriers [–244: 244] is given by Equation (27-46).

$HELTF_{-244,244}$ =

{+1, –1, –1, –1, –1, +1, –1, –1, +1, +1, –1, +1, –1, +1, –1, +1, +1, –1, +1, –1, –1, –1, +1,
+1, –1, –1, –1, –1, –1, –1, –1, +1, –1, –1, +1, +1, –1, +1, –1, –1, –1, –1, –1, +1, –1, +1,
+1, +1, –1, –1, +1, +1, +1, –1, –1, +1, +1, +1, +1, –1, +1, +1, –1, –1, +1, –1, +1, –1, +1,
–1, –1, +1, –1, +1, +1, +1, –1, –1, +1, +1, +1, –1, –1, –1, –1, +1, –1, –1, +1, +1, –1, +1,
–1, –1, –1, –1, –1, +1, –1, +1, +1, +1, –1, –1, +1, +1, +1, +1, +1, +1, +1, +1, –1, +1, +1,
–1, –1, +1, –1, +1, +1, +1, +1, +1, –1, +1, –1, –1, –1, +1, +1, –1, –1, –1, –1, –1, –1, –1, –
1, +1, –1, –1, +1, +1, –1, +1, –1, +1, –1, +1, +1, –1, +1, –1, –1, –1, +1, +1, –1, –1, –1, –
1, –1, –1, –1, +1, –1, –1, +1, +1, –1, +1, –1, –1, –1, –1, –1, +1, –1, +1, +1, +1, –1, –1,
+1, +1, +1, –1, –1, –1, –1, –1, –1, +1, –1, –1, +1, +1, –1, +1, –1, +1, –1, +1, +1, –1, +1,
–1, –1, –1, +1, +1, –1, –1, –1, +1, +1, +1, +1, –1, +1, +1, –1, –1, +1, –1, +1, +1, +1, +1,
+1, –1, +1, –1, –1, –1, +1, +1, –1, –1, –1, +1, 0, 0, 0, 0, 0, –1, +1, +1, +1, +1, –1, +1, +1, (27-46)
–1, –1, +1, –1, +1, –1, +1, –1, –1, +1, –1, +1, +1, +1, –1, –1, +1, +1, +1, +1, +1, +1, +1,
–1, +1, +1, –1, –1, +1, –1, +1, +1, +1, +1, +1, –1, +1, –1, –1, –1, +1, +1, –1, –1, –1, +1,
+1, –1, –1, –1, –1, +1, –1, –1, +1, +1, –1, +1, –1, +1, –1, +1, +1, –1, +1, –1, –1, –1, +1,
+1, –1, –1, –1, +1, +1, +1, +1, –1, +1, +1, –1, –1, +1, –1, +1, +1, +1, +1, +1, –1, +1, –1,
–1, –1, +1, +1, –1, –1, –1, +1, –1, –1, –1, –1, +1, –1, –1, +1, +1, –1, +1, –1, +1, –1, +1,
+1, –1, +1, –1, –1, –1, +1, +1, –1, –1, –1, +1, –1, –1, –1, –1, +1, –1, –1, +1, +1, –1, +1, –
1, +1, –1, +1, +1, –1, +1, –1, –1, –1, +1, +1, –1, –1, –1, –1, –1, –1, –1, +1, –1, –1, +1,
+1, –1, +1, –1, –1, –1, –1, –1, +1, –1, +1, +1, +1, –1, –1, +1, +1, +1, –1, +1, –1, –1, –1,
–1, +1, –1, –1, +1, +1, –1, +1, –1, +1, –1, +1, +1, –1, +1, –1, –1, –1, +1, +1, –1, –1, –1,
+1, +1, +1, +1, –1, +1, +1, –1, –1, +1, –1, +1, +1, +1, +1, +1, –1, +1, –1, –1, –1, +1, +1,
–1, –1, –1, –1}

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In an 80 MHz transmission, the 1x HE-LTF sequence transmitted on subcarriers [–500: 500] is given by Equation (27-47).

$$
\begin{aligned}
&HELTF_{-500,500} = \\
&\{-1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, \\
&0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, \\
&0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, \\
&0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, – \\
&1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, \\
&+1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, \\
&0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, \\
&0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, \\
&0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, – \\
&1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, \\
&+1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, \\
&0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, \\
&0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, \\
&0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, – \\
&1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, \\
&–1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, \\
&0, 0, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, \\
&0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, \\
&0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, \\
&0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, \\
&+1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, \\
&0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, \\
&0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, \\
&0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, \\
&+1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, \\
&0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, \\
&0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, -1, \\
&0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, \\
&0, 0, 0, +1\}
\end{aligned}
\tag{27-47}
$$


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In an 80 MHz transmission, the 2x HE-LTF sequence transmitted on subcarriers [–500: 500] is given by Equation (27-48).

$$
\begin{aligned}
&HELTF_{-500,500} = \\
&\{+1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, +1, 0, -1, 0, -1, 0, -1,\\
&0, +1, 0, -1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1,\\
&0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1,\\
&0, -1, 0, +1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1,\\
&0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1,\\
&0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1,\\
&0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, +1, 0, -1,\\
&0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1,\\
&0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1,\\
&0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, -1, 0, +1,\\
&0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, +1, 0, +1, 0, +1,\\
&0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1,\\
&0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1,\\
&0, -1, 0, +1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1,\\
&0, -1, 0, +1, 0, +1, 0, +1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, +1, 0, +1, 0, 0, 0, 0, 0, 0, 0,\\
&+1, 0, -1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, +1, 0, +1, 0, +1, 0,\\
&-1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0,\\
&+1, 0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0,\\
&+1, 0, -1, 0, +1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, -1, 0, -1, 0,\\
&+1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0,\\
&+1, 0, -1, 0, -1, 0, -1, 0, +1, 0, +1, 0, +1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0,\\
&+1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, +1, 0, +1, 0,\\
&+1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0,\\
&-1, 0, -1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0,\\
&-1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0,\\
&-1, 0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0,\\
&-1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, -1, 0, -1, 0,\\
&-1, 0, -1, 0, +1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, -1, 0,\\
&+1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1\}
\end{aligned}
\tag{27-48}
$$

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In an 80 MHz transmission, the 4x HE-LTF sequence transmitted on subcarriers [–500: 500] is given by Equation (27-49).

$$
\begin{aligned}
HELTF_{-500,500} = \\
&\{+1, +1, -1, +1, -1, +1, -1, -1, -1, +1, -1, -1, -1, +1, +1, -1, +1, +1, +1, +1, +1, -1, -1, \\
&+1, +1, +1, +1, -1, +1, -1, +1, -1, -1, +1, +1, -1, +1, +1, +1, -1, -1, +1, -1, -1, -1, -1, \\
&+1, +1, +1, -1, -1, -1, -1, -1, -1, +1, +1, +1, +1, +1, +1, -1, +1, +1, +1, -1, +1, +1, -1, \\
&-1, -1, +1, -1, +1, -1, -1, +1, +1, -1, +1, -1, +1, +1, +1, +1, +1, -1, -1, +1, +1, +1, -1, \\
&+1, +1, -1, -1, -1, +1, -1, +1, +1, -1, +1, +1, -1, +1, -1, -1, +1, +1, +1, +1, -1, -1, +1, \\
&+1, +1, +1, +1, -1, +1, +1, -1, -1, -1, +1, -1, -1, -1, +1, -1, +1, -1, +1, +1, -1, +1, -1, \\
&+1, -1, +1, +1, +1, -1, +1, +1, +1, -1, -1, +1, -1, -1, -1, -1, -1, +1, +1, -1, -1, -1, -1, \\
&+1, -1, +1, -1, +1, +1, -1, -1, +1, -1, -1, -1, +1, +1, -1, +1, +1, +1, +1, -1, -1, -1, +1, \\
&+1, +1, +1, -1, +1, +1, +1, +1, +1, +1, +1, -1, +1, +1, +1, -1, +1, +1, -1, -1, -1, +1, -1, \\
&+1, -1, -1, +1, +1, -1, +1, -1, +1, +1, +1, +1, +1, -1, -1, +1, +1, +1, -1, +1, +1, -1, -1, \\
&-1, +1, -1, +1, +1, -1, +1, +1, -1, +1, -1, -1, +1, -1, +1, -1, +1, -1, +1, +1, +1, -1, +1, \\
&+1, +1, -1, -1, +1, -1, -1, -1, -1, -1, +1, +1, -1, -1, -1, -1, +1, -1, +1, -1, +1, +1, -1, \\
&+1, -1, -1, -1, -1, -1, +1, +1, -1, -1, -1, +1, -1, -1, +1, +1, +1, -1, +1, -1, -1, +1, -1, \\
&+1, -1, -1, -1, +1, -1, -1, -1, +1, -1, -1, +1, +1, +1, -1, +1, -1, -1, +1, -1, +1, -1, -1, \\
&+1, -1, -1, -1, -1, -1, -1, +1, +1, -1, -1, -1, -1, +1, -1, +1, -1, +1, +1, -1, -1, +1, -1, \\
&+1, +1, +1, -1, +1, +1, +1, +1, +1, -1, -1, -1, +1, +1, +1, +1, -1, -1, +1, +1, +1, +1, +1, \\
&+1, +1, -1, -1, +1, +1, +1, -1, +1, +1, -1, -1, -1, +1, -1, +1, +1, -1, +1, +1, -1, +1, -1, \\
&-1, -1, +1, -1, +1, -1, -1, -1, -1, +1, +1, +1, -1, -1, +1, 0, 0, 0, 0, 0, +1, -1, -1, -1, -1, \\
&-1, -1, +1, -1, +1, +1, -1, -1, +1, +1, -1, +1, -1, +1, +1, -1, -1, +1, -1, +1, -1, -1, -1, \\
&+1, +1, -1, +1, +1, +1, -1, +1, +1, +1, +1, +1, +1, +1, -1, +1, -1, -1, +1, -1, -1, +1, -1, \\
&+1, +1, +1, -1, -1, +1, -1, -1, -1, +1, +1, -1, -1, -1, -1, -1, +1, -1, -1, -1, -1, -1, +1, \\
&+1, -1, -1, -1, -1, -1, +1, -1, -1, +1, +1, +1, -1, +1, +1, +1, -1, +1, -1, +1, -1, -1, -1, \\
&-1, -1, +1, +1, +1, -1, -1, -1, -1, +1, -1, -1, +1, +1, +1, -1, +1, +1, -1, -1, +1, -1, +1, \\
&-1, -1, -1, -1, -1, -1, -1, +1, +1, -1, -1, -1, +1, -1, -1, +1, +1, +1, -1, +1, -1, -1, +1, - \\
&1, -1, +1, -1, +1, +1, +1, -1, +1, -1, -1, +1, +1, -1, +1, -1, +1, +1, -1, -1, +1, -1, +1, - \\
&1, -1, +1, -1, -1, -1, -1, -1, -1, -1, +1, -1, +1, +1, -1, +1, +1, -1, +1, -1, -1, -1, +1, \\
&+1, -1, +1, +1, +1, -1, -1, +1, +1, +1, +1, +1, -1, +1, -1, -1, -1, -1, +1, +1, -1, -1, -1, \\
&-1, -1, +1, -1, -1, +1, +1, +1, -1, +1, +1, +1, -1, +1, -1, +1, -1, -1, -1, -1, -1, +1, +1, \\
&+1, -1, -1, -1, -1, +1, -1, -1, +1, +1, +1, -1, +1, +1, -1, -1, +1, -1, +1, -1, +1, +1, +1, \\
&-1, +1, -1, -1, +1, +1, -1, +1, -1, +1, +1, +1, -1, -1, +1, -1, -1, -1, -1, -1, -1, +1, +1, \\
&+1, -1, -1, -1, +1, -1, -1, +1, +1, -1, +1, -1, +1, -1, -1, -1, -1, -1, -1, +1, +1, -1, -1, - \\
&1, +1, -1, -1, +1, +1, +1, -1, +1, -1, -1, +1, -1, -1, +1, -1, +1, -1, +1, -1, +1, -1, -1, \\
&+1, +1, -1, +1, -1, +1, +1, +1, -1, -1, +1, -1, -1, -1, +1, -1, -1, -1, -1, -1, -1, -1, +1, - \\
&1, +1, +1, -1, +1, +1, -1, +1, -1, -1, -1, +1, +1, -1, +1, +1, +1, +1, -1, +1, +1, +1, +1, \\
&+1, -1, +1, -1, -1, -1, -1, +1, +1, -1, -1, -1, -1, -1, +1, -1, -1, +1, +1, +1, -1, +1, +1, \\
&+1, -1, +1, -1, +1, -1, -1, -1, -1, -1, +1, +1, +1, -1, -1, -1, -1, +1, -1, -1, +1, +1, +1, \\
&-1, +1, +1, -1, -1, +1, -1, +1, -1, +1\}
\end{aligned}
\tag{27-49}
$$



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In a 160 MHz transmission using a 1x HE-LTF, the 1x HE-LTF sequence is given by Equation (27-50).

$$HELTF_{-1012,1012} = \{LTF_{80\mathrm{MHz_lower_1x}}, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, LTF_{80\mathrm{MHz_upper_1x}}\} \quad (27\text{-}50)$$

where

$LTF_{80\mathrm{MHz_lower_1x}} = \{LTF_{80\mathrm{MHz_left_1x}}, 0, LTF_{80\mathrm{MHz_right_1x}}\}$ shall be used in the lower 80 MHz frequency segment

$LTF_{80\mathrm{MHz_upper_1x}} = \{LTF_{80\mathrm{MHz_left_1x}}, 0, -LTF_{80\mathrm{MHz_right_1x}}\}$ shall be used in the upper 80 MHz frequency segment

$LTF_{80\mathrm{MHz_left_1x}}$ = {–1, 0, 0, 0, –1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, –1, 0, 0, 0, –1, 0, 0, 0, –1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, –1, 0, 0, 0, –1, 0, 0, 0, +1, 0, 0, 0, –1, 0, 0, 0, +1, 0, 0, 0, –1, 0, 0, 0, –1, 0, 0, 0, –1, 0, 0, 0, –1, 0, 0, 0, –1, 0, 0, 0, –1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, –1, 0, 0, 0, –1, 0, 0, 0, +1, 0, 0, 0, –1, 0, 0, 0, +1, 0, 0, 0, –1, 0, 0, 0, –1, 0, 0, 0, –1, 0, 0, 0, –1, 0, 0, 0, –1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, –1, 0, 0, 0, –1, 0, 0, 0, +1, 0, 0, 0, –1, 0, 0, 0, +1, 0, 0, 0, –1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, –1, 0, 0, 0, –1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, –1, 0, 0, 0, +1, 0, 0, 0, –1, 0, 0, 0, +1, 0, 0, 0, –1, 0, 0, 0, –1, 0, 0, 0, –1, 0, 0, 0, –1, 0, 0, 0, +1, 0, 0, 0, –1, 0, 0, 0, –1, 0, 0, 0, –1, 0, 0, 0, –1, 0, 0, 0, –1, 0, 0, 0, –1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, –1, 0, 0, 0, –1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, –1, 0, 0, 0, +1, 0, 0, 0, –1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, –1, 0, 0, 0, –1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, –1, 0, 0, 0, +1, 0, 0, 0, –1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, –1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, –1, 0, 0, 0, –1, 0, 0, 0, +1, 0, 0, 0, –1, 0, 0, 0, +1, 0, 0, 0, –1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, –1, 0, 0, 0, –1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, –1, 0, 0, 0, +1, 0, 0, 0, –1, 0, 0, 0, +1, 0, 0, 0, –1, 0, 0, 0, –1, 0, 0, 0, –1, 0, 0, 0, –1, 0, 0, 0, –1, 0, 0, 0, +1, 0, 0, 0, –1, 0, 0, 0, +1, 0, 0, 0, –1, 0, 0, 0, –1, 0, 0, 0}

$LTF_{80\mathrm{MHz_right_1x}}$ = {0, 0, 0, –1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, –1, 0, 0, 0, –1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, –1, 0, 0, 0, –1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, –1, 0, 0, 0, +1, 0, 0, 0, –1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, –1, 0, 0, 0, –1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, –1, 0, 0, 0, +1, 0, 0, 0, –1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, –1, 0, 0, 0, –1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, –1, 0, 0, 0, +1, 0, 0, 0, –1, 0, 0, 0, +1, 0, 0, 0, –1, 0, 0, 0, –1, 0, 0, 0, –1, 0, 0, 0, –1, 0, 0, 0, –1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, –1, 0, 0, 0, –1, 0, 0, 0, +1, 0, 0, 0, –1, 0, 0, 0, +1, 0, 0, 0, –1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, –1, 0, 0, 0, +1, 0, 0, 0, –1, 0, 0, 0, –1, 0, 0, 0, +1, 0, 0, 0, –1, 0, 0, 0, –1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, –1, 0, 0, 0, –1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, –1, 0, 0, 0, +1, 0, 0, 0, –1, 0, 0, 0, +1, 0, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, –1, 0, 0, 0, –1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, –1, 0, 0, 0, +1, 0, 0, 0, –1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, –1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, –1, 0, 0, 0, –1, 0, 0, 0, +1, 0, 0, 0, –1, 0, 0, 0, +1, 0, 0, 0, –1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, –1, 0, 0, 0, –1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, –1, 0, 0, 0, +1, 0, 0, 0, –1, 0, 0, 0, +1, 0, 0, 0, –1, 0, 0, 0, –1, 0, 0, 0, –1, 0, 0, 0, –1, 0, 0, 0, +1, 0, 0, 0, –1, 0, 0, 0, +1, 0, 0, 0, –1, 0, 0, 0, –1, 0, 0, 0, –1, 0, 0, 0, +1, 0, 0, 0, +1}

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In a 160 MHz transmission using a 2x HE-LTF, the 2x HE-LTF sequence is given by Equation (27-51).

$$HELTF_{-1012,1012} = \{LTF_{80\text{MHz_lower_2x}}, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, LTF_{80\text{MHz_upper_2x}}\} \tag{27-51}$$

where

$LTF_{80\text{MHz_lower_2x}} = \{LTF_{80\text{MHz_part1_2x}}, LTF_{80\text{MHz_part2_2x}}, LTF_{80\text{MHz_part3_2x}}, LTF_{80\text{MHz_part4_2x}}, LTF_{80\text{MHz_part5_2x}}\}$ shall be used in the lower 80 MHz frequency subblock

$LTF_{80\text{MHz_upper_2x}} = \{LTF_{80\text{MHz_part1_2x}}, -LTF_{80\text{MHz_part2_2x}}, LTF_{80\text{MHz_part3_2x}}, LTF_{80\text{MHz_part4_2x}}, -LTF_{80\text{MHz_part5_2x}}\}$ shall be used in the upper 80 MHz frequency subblock

$$LTF_{80\text{MHz_part1_2x}} = \{+1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0\}$$

$$LTF_{80\text{MHz_part2_2x}} = \{+1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, +1, 0, +1, 0\}$$

$$LTF_{80\text{MHz_part3_2x}} = \{+1, 0, -1, 0, -1, 0, -1, 0, +1, 0, +1, 0, +1, 0, 0, 0, 0, 0, 0, 0, +1, 0, -1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1\}$$

$$LTF_{80\text{MHz_part4_2x}} = \{0, -1, 0, -1, 0, -1, 0, +1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, +1, 0, +1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1\}$$

$$LTF_{80\text{MHz_part5_2x}} = \{0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1\}$$


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In a 160 MHz transmission using a 4x HE-LTF, the 4x HE-LTF sequence is given by Equation (27-52).

$$HELTF_{-1012,1012} = \{LTF_{80\text{MHz\_lower\_4x}}, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, LTF_{80\text{MHz\_upper\_4x}}\} \quad (27\text{-}52)$$

where

$LTF_{80\text{MHz\_lower\_4x}} = \{LTF_{80\text{MHz\_left\_4x}}, 0, LTF_{80\text{MHz\_right\_4x}}\}$ shall be used in the lower 80 MHz frequency segment

$LTF_{80\text{MHz\_upper\_4x}} = \{LTF_{80\text{MHz\_left\_4x}}, 0, -LTF_{80\text{MHz\_right\_4x}}\}$ shall be used in the upper 80 MHz frequency segment

$LTF_{80\text{MHz\_left\_4x}} = \{+1, +1, -1, +1, -1, +1, -1, -1, -1, +1, -1, -1, -1, +1, +1, -1, +1, +1, +1, +1, +1, -1,$
$-1, +1, +1, +1, +1, -1, +1, -1, +1, -1, -1, +1, +1, -1, +1, +1, +1, -1, -1, +1, -1, -1, -1, -1, +1,$
$+1, +1, -1, -1, -1, -1, -1, -1, +1, +1, +1, +1, +1, +1, -1, +1, +1, +1, -1, +1, +1, -1, -1, -1, +1,$
$-1, +1, -1, -1, +1, +1, -1, +1, -1, +1, +1, +1, +1, +1, -1, -1, +1, +1, +1, -1, +1, +1, -1, -1, -1,$
$+1, -1, +1, +1, -1, +1, +1, -1, +1, -1, -1, +1, +1, +1, +1, -1, -1, +1, +1, +1, +1, +1, -1, +1, +1,$
$-1, -1, -1, +1, -1, -1, -1, +1, -1, +1, -1, +1, +1, -1, +1, -1, +1, -1, +1, +1, +1, -1, +1, +1, +1,$
$-1, -1, +1, -1, -1, -1, -1, -1, +1, +1, -1, -1, -1, -1, +1, -1, +1, -1, +1, +1, -1, -1, +1, -1, -1,$
$-1, +1, +1, -1, +1, +1, +1, +1, -1, -1, -1, +1, +1, +1, +1, -1, +1, +1, +1, +1, +1, +1, +1, -1, +1,$
$+1, +1, -1, +1, +1, -1, -1, -1, +1, -1, +1, -1, -1, +1, +1, -1, +1, -1, +1, +1, +1, +1, +1, -1, -1,$
$+1, +1, +1, -1, +1, +1, -1, -1, -1, +1, -1, +1, +1, -1, +1, +1, -1, +1, -1, -1, +1, -1, +1, -1, +1,$
$-1, +1, +1, +1, -1, +1, +1, +1, -1, -1, +1, -1, -1, -1, -1, -1, +1, +1, -1, -1, -1, -1, +1, -1, +1,$
$-1, +1, +1, -1, -1, +1, -1, -1, -1, +1, +1, -1, +1, +1, +1, +1, -1, -1, -1, +1, +1, +1, +1, -1, +1,$
$-1, -1, -1, -1, -1, -1, +1, -1, -1, -1, +1, -1, -1, +1, +1, +1, -1, +1, -1, +1, +1, -1, -1, +1, -1,$
$+1, -1, -1, -1, -1, -1, +1, +1, -1, -1, -1, +1, -1, -1, +1, +1, +1, -1, +1, -1, -1, +1, -1, -1, +1,$
$-1, +1, +1, +1, +1, +1, +1, -1, -1, +1, +1, +1, +1, +1, -1, +1, +1, -1, -1, -1, +1, -1, -1, -1, +1,$
$-1, +1, -1, +1, +1, -1, +1, -1, +1, -1, +1, +1, +1, -1, +1, +1, +1, -1, -1, +1, -1, -1, -1, -1, -1,$
$+1, +1, -1, -1, -1, -1, +1, -1, +1, -1, +1, +1, -1, -1, +1, -1, -1, -1, +1, +1, -1, +1, +1, +1, +1,$
$-1, -1, -1, +1, +1, +1, +1, -1, -1, +1, +1, +1, +1, +1, +1, -1, +1, +1, +1, -1, +1, +1, -1, -1, -$
$1, +1, -1, +1, -1, -1, +1, +1, -1, +1, -1, +1, +1, +1, +1, +1, -1, -1, +1, +1, +1, -1, +1, +1, -1,$
$-1, -1, +1, -1, +1, +1, -1, +1, +1, -1, +1, -1, -1, -1, +1, -1, +1, -1, -1, -1, -1, +1, +1, +1, -1,$
$-1, +1, 0, 0\}$

$LTF_{80\text{MHz\_right\_4x}} = \{0, 0, +1, -1, -1, -1, -1, -1, -1, +1, -1, +1, +1, -1, -1, +1, +1, -1, +1, -1, +1, +1, -$
$1, -1, +1, -1, +1, -1, -1, -1, +1, +1, -1, +1, +1, +1, -1, +1, +1, +1, +1, +1, +1, +1, -1, +1, -1,$
$-1, +1, -1, -1, +1, -1, +1, +1, +1, -1, -1, +1, -1, -1, -1, +1, +1, -1, -1, -1, -1, -1, +1, -1, -1,$
$-1, -1, -1, +1, +1, -1, -1, -1, -1, -1, +1, -1, -1, +1, +1, +1, -1, +1, +1, +1, -1, +1, -1, +1, -1,$
$-1, -1, -1, -1, +1, +1, +1, -1, -1, -1, -1, +1, -1, -1, +1, +1, +1, -1, +1, +1, -1, -1, +1, -1, +1,$
$-1, -1, -1, -1, -1, -1, -1, +1, +1, -1, -1, -1, +1, -1, -1, +1, +1, +1, -1, +1, -1, -1, +1, -1, -1,$
$+1, -1, +1, +1, +1, -1, +1, -1, -1, +1, +1, -1, +1, -1, +1, +1, +1, -1, -1, +1, -1, -1, -1, +1, -1,$
$-1, -1, -1, -1, -1, -1, +1, -1, +1, +1, -1, +1, +1, -1, +1, -1, -1, -1, +1, +1, -1, +1, +1, +1, -1,$
$-1, +1, +1, +1, +1, +1, -1, +1, -1, -1, -1, -1, +1, +1, -1, -1, -1, -1, -1, +1, -1, -1, +1, +1, +1,$
$-1, +1, +1, +1, -1, +1, -1, +1, -1, -1, -1, -1, -1, +1, +1, +1, -1, -1, -1, -1, +1, -1, -1, +1, +1,$
$+1, -1, +1, +1, -1, -1, +1, -1, +1, -1, +1, +1, +1, -1, +1, -1, -1, +1, +1, -1, +1, -1, +1, +1, +1,$
$-1, -1, +1, -1, -1, -1, +1, -1, -1, -1, -1, -1, -1, -1, +1, -1, +1, +1, -1, +1, +1, -1, +1, -1, -1,$
$-1, +1, +1, -1, +1, +1, +1, -1, -1, +1, +1, +1, +1, +1, -1, +1, +1, +1, +1, +1, -1, -1, +1, +1, +1,$
$+1, +1, -1, +1, +1, -1, -1, -1, +1, -1, -1, -1, +1, -1, +1, -1, +1, +1, +1, +1, +1, -1, -1, -1, +1,$
$+1, +1, +1, -1, +1, +1, -1, -1, -1, +1, -1, -1, +1, +1, -1, +1, -1, +1, -1, -1, -1, -1, -1, -1, +1,$
$+1, -1, -1, -1, +1, -1, -1, +1, +1, +1, -1, +1, -1, -1, +1, -1, +1, -1, +1, -1, +1, -1, +1, -1, +1, -1,$
$-1, +1, +1, -1, +1, -1, +1, +1, +1, -1, -1, +1, -1, -1, -1, +1, -1, -1, -1, -1, -1, -1, -1, +1, -1,$
$+1, +1, -1, +1, +1, -1, +1, -1, -1, -1, +1, +1, -1, +1, +1, +1, -1, -1, +1, +1, +1, +1, +1, -1, +1,$
$-1, -1, -1, -1, +1, +1, -1, -1, -1, -1, -1, +1, -1, -1, +1, +1, +1, -1, +1, +1, +1, -1, +1, -1, +1,$
$-1, -1, -1, -1, -1, +1, +1, +1, -1, -1, -1, -1, +1, -1, -1, +1, +1, +1, -1, +1, +1, -1, -1, +1, -1,$
$+1, -1, +1\}$

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For an 80+80 MHz transmission using a 1x HE-LTF, the lower 80 MHz frequency segment shall use the 80 MHz 1x HE-LTF sequence, $HELTF_{-500,500} = LTF_{80\text{MHz\_lower\_1x}}$, and the upper 80 MHz frequency segment shall use the 80 MHz 1x HE-LTF sequence, $HELTF_{-500,500} = LTF_{80\text{MHz\_upper\_1x}}$.

For an 80+80 MHz transmission using a 2x HE-LTF, the lower 80 MHz frequency segment shall use the 80 MHz 2x HE-LTF sequence, $HELTF_{-500,500} = LTF_{80\text{MHz\_lower\_2x}}$, and the upper 80 MHz frequency segment shall use the 80 MHz 2x HE-LTF sequence, $HELTF_{-500,500} = LTF_{80\text{MHz\_upper\_2x}}$.

For an 80+80 MHz transmission using a 4x HE-LTF, the lower 80 MHz frequency segment shall use the 80 MHz 4x HE-LTF sequence, $HELTF_{-500,500} = LTF_{80\text{MHz\_lower\_4x}}$, and the upper 80 MHz frequency segment shall use the 80 MHz 4x HE-LTF sequence, $HELTF_{-500,500} = LTF_{80\text{MHz\_upper\_4x}}$.

For an OFDMA transmission, the values of HE-LTF sequence [defined in Equation (27-41) to Equation (27-56)] are set to zero if they are assigned to subcarriers within RUs that are not allocated to any user (see 27.3.10 (Mathematical description of signals)).

In (#2318)a UL MU-MIMO transmission using the HE masked HE-LTF sequence mode, the HE-LTF sequence per frequency subblock is generated by masking the nonzero elements in the common HE-LTF sequence repeatedly with a distinct orthogonal code as defined by Equation (27-53).

$$HELTF^{\text{Mask}}_{k,u,m} = HELTF_k \cdot \left[P_{8\times 8}\right]_{M_{r,u}+m,\left(\left(\left\lceil \frac{k}{N_{\text{HE-LTF-Type}}} \right\rceil - 1\right) \bmod 8\right)+1} \tag{27-53}$$

where

$HELTF_k$ is the value of the common HE-LTF sequence on subcarrier $k$ generated by one of the equations from Equation (27-41) to Equation (27-52) depending on the bandwidth and the HE-LTF type (excluding the 1x HE-LTF, which shall not be masked)

$\left[P_{8\times 8}\right]$ is defined in Equation (21-45)

$M_{r,u} + m$ is the row index of the $\left[P_{8\times 8}\right]$ corresponding to spatial time stream $m$ of user $u$ in the $r^{\text{th}}$ RU

$$N_{\text{HE-LTF-Type}} = \begin{cases} 2, \text{ for 2x HE-LTF} \\ 1, \text{ for 4x HE-LTF} \end{cases}$$

In the HE TB feedback NDP, neither HE single stream pilot HE-LTF mode nor HE masked HE-LTF sequence mode is applied to the HE-LTF sequence. Only 4x HE-LTF shall be used in the HE TB feedback NDP. The 4x HE-LTF sequence is generated by Equation (27-54).

$$HELTF^{\text{TB\_NDP}}_{k,u} = \begin{cases} HELTF_k, \text{ if } k \in K_{\text{tone\_NDP}_u} \\ 0, \text{ otherwise} \end{cases} \tag{27-54}$$

where

$HELTF_k$ is the value of the common HE-LTF sequence on subcarrier $k$ generated by one of the 4x HE-LTF equations [Equation (27-43), Equation (27-46), Equation (27-49), Equation (27-52)] according to the channel bandwidth

$K_{\text{tone\_NDP}u}$ is the set of subcarrier indices for user $u$ and is defined in Table 27-33 (HE-LTF subcarrier mapping for the HE TB feedback NDP(11ax)) according to the RU_TONE_SET_INDEX and FEEDBACK_STATUS


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**Table 27-33—HE-LTF subcarrier mapping for the HE TB feedback NDP(11ax)**

| RU_TONE_SET_INDEX | 80 MHz | | 40 MHz | | 20 MHz | |
|---|---|---|---|---|---|---|
| | $K_{tone\_NDP\mu}$ if FEEDBACK_STATUS is 1 | $K_{tone\_NDP\mu}$ if FEEDBACK_STATUS is 0 | $K_{tone\_NDP\mu}$ if FEEDBACK_STATUS is 1 | $K_{tone\_NDP\mu}$ if FEEDBACK_STATUS is 0 | $K_{tone\_NDP\mu}$ if FEEDBACK_STATUS is 1 | $K_{tone\_NDP\mu}$ if FEEDBACK_STATUS is 0 |
| 1 | Use 20 MHz FEEDBACK_STATUS = 1 Subcarrier Indices – 384 | Use 20 MHz FEEDBACK_STATUS = 0 Subcarrier Indices – 384 | Use 20 MHz FEEDBACK_STATUS = 1 Subcarrier Indices – 128 | Use 20 MHz FEEDBACK_STATUS = 0 Subcarrier Indices – 128 | –113, –77, –41, 6, 42, 78 | –112, –76, –40, 7, 43, 79 |
| 2 | | | | | –111, –75, –39, 8, 44, 80 | –110, –74, –38, 9, 45, 81 |
| 3 | | | | | –109, –73, –37, 10, 46, 82 | –108, –72, –36, 11, 47, 83 |
| 4 | | | | | –107, –71, –35, 12, 48, 84 | –106, –70, –34, 13, 49, 85 |
| 5 | | | | | –105, –69, –33, 14, 50, 86 | –104, –68, –32, 15, 51, 87 |
| 6 | | | | | –103, –67, –31, 16, 52, 88 | –102, –66, –30, 17, 53, 89 |
| 7 | | | | | –101, –65, –29, 18, 54, 90 | –100, –64, –28, 19, 55, 91 |
| 8 | | | | | –99, –63, –27, 20, 56, 92 | –98, –62, –26, 21, 57, 93 |
| 9 | | | | | –97, –61, –25, 22, 58, 94 | –96, –60, –24, 23, 59, 95 |
| 10 | | | | | –95, –59, –23, 24, 60, 96 | –94, –58, –22, 25, 61, 97 |
| 11 | | | | | –93, –57, –21, 26, 62, 98 | –92, –56, –20, 27, 63, 99 |
| 12 | | | | | –91, –55, –19, 28, 64, 100 | –90, –54, –18, 29, 65, 101 |
| 13 | | | | | –89, –53, –17, 30, 66, 102 | –88, –52, –16, 31, 67, 103 |
| 14 | | | | | –87, –51, –15, 32, 68, 104 | –86, –50, –14, 33, 69, 105 |
| 15 | | | | | –85, –49, –13, 34, 70, 106 | –84, –48, –12, 35, 71, 107 |
| 16 | | | | | –83, –47, –11, 36, 72, 108 | –82, –46, –10, 37, 73, 109 |
| 17 | | | | | –81, –45, –9, 38, 74, 110 | –80, –44, –8, 39, 75, 111 |
| 18 | | | | | –79, –43, –7, 40, 76, 112 | –78, –42, –6, 41, 77, 113 |

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**Table 27-33—HE-LTF subcarrier mapping for the HE TB feedback NDP(11ax) *(continued)***

| RU_TONE_SET_INDEX | 80 MHz | | 40 MHz | | 20 MHz | |
|---|---|---|---|---|---|---|
| | $K_{\text{tone\_NDP}u}$ if FEEDBACK_STATUS is 1 | $K_{\text{tone\_NDP}u}$ if FEEDBACK_STATUS is 0 | $K_{\text{tone\_NDP}u}$ if FEEDBACK_STATUS is 1 | $K_{\text{tone\_NDP}u}$ if FEEDBACK_STATUS is 0 | $K_{\text{tone\_NDP}u}$ if FEEDBACK_STATUS is 1 | $K_{\text{tone\_NDP}u}$ if FEEDBACK_STATUS is 0 |
| 19–36 | Use 20 MHz FEEDBACK_STATUS = 1 Subcarrier Indices – 128 | Use 20 MHz FEEDBACK_STATUS = 0 Subcarrier Indices – 128 | Use 20 MHz FEEDBACK_STATUS = 1 Subcarrier Indices + 128 | Use 20 MHz FEEDBACK_STATUS = 0 Subcarrier Indices + 128 | | |
| 37–54 | Use 20 MHz FEEDBACK_STATUS = 1 Subcarrier Indices + 128 | Use 20 MHz FEEDBACK_STATUS = 0 Subcarrier Indices + 128 | | | | |
| 55–72 | Use 20 MHz FEEDBACK_STATUS = 1 Subcarrier Indices + 384 | Use 20 MHz FEEDBACK_STATUS = 0 Subcarrier Indices + 384 | | | | |
| The RU_TONE_SET_INDEX for 80+80 MHz and 160 MHz shall use the 80 MHz RU_TONE_SET_INDEX definition for the lower and upper 80 MHz. The RU_TONE_SET_INDEX values 1–72 are mapped to the lower 80 MHz, and the RU_TONE_SET_INDEX values 73–144 are mapped to the upper 80 MHz. | | | | | | |

The generation of the time domain HE-LTF symbols per frequency segment in an HE SU PPDU, HE MU PPDU, and HE ER SU PPDU is shown in Figure 27-32 (Generation of HE-LTF symbols per frequency segment in an HE SU PPDU, HE MU PPDU, and HE ER SU PPDU(11ax)) where $A^{k}_{\text{HE-LTF}}$ is given by Equation (27-55).

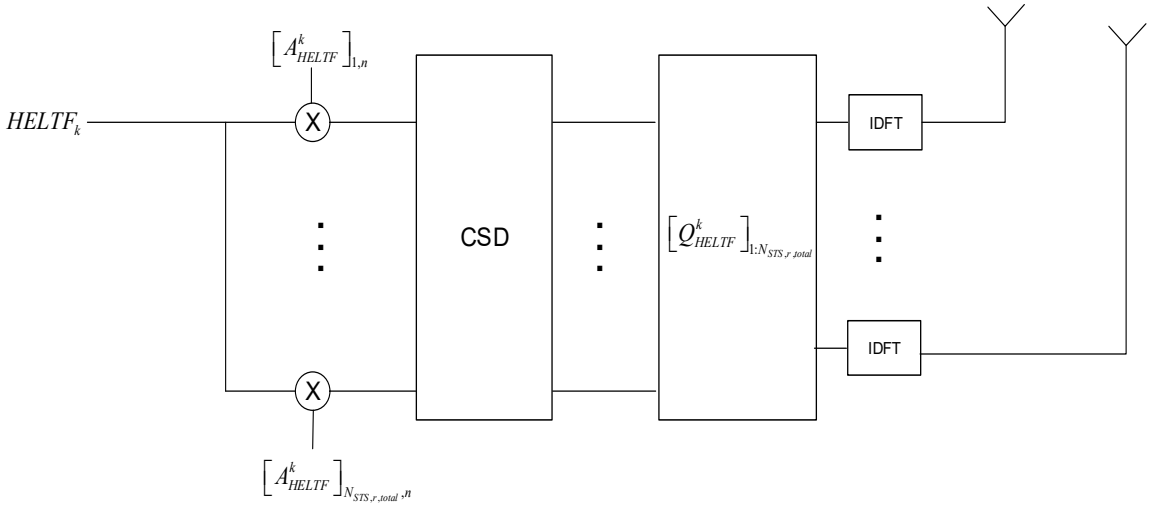


**Figure 27-32—Generation of HE-LTF symbols per frequency segment in an HE SU PPDU, HE MU PPDU, and HE ER SU PPDU(11ax)**


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The generation of the time domain HE-LTF symbols per frequency segment in an HE TB PPDU is shown in Figure 27-33 (Generation of HE-LTF symbols per frequency segment in an HE TB PPDU for user u on RU r(11ax)).

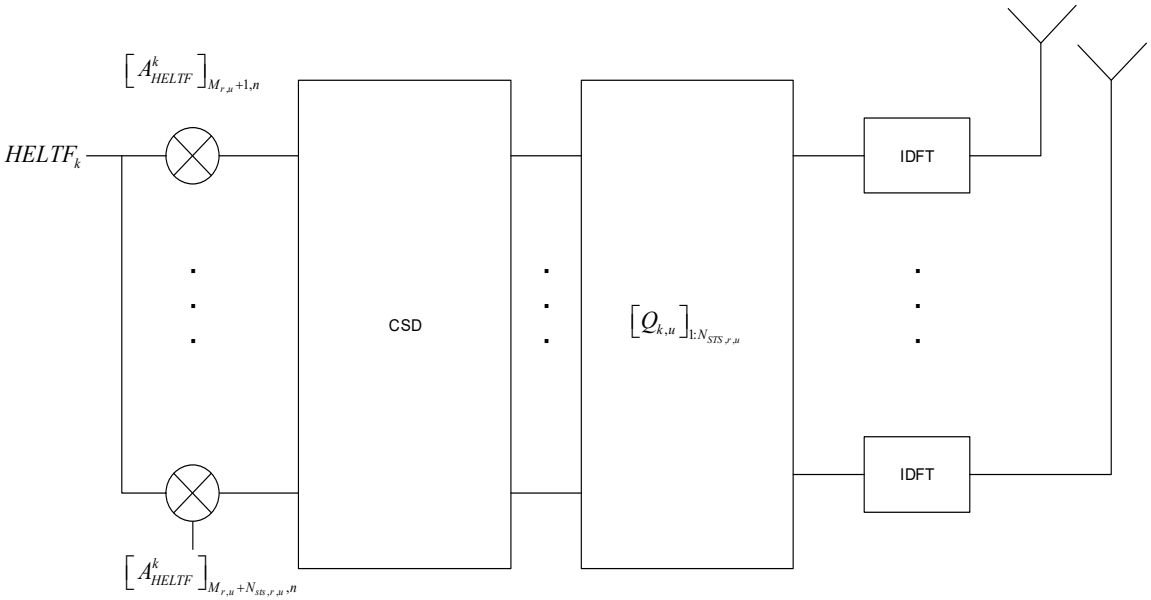


**Figure 27-33—Generation of HE-LTF symbols per frequency segment in an HE TB PPDU for user *u* on RU *r*(11ax)**

The generation of the time domain symbol of a 1x HE-LTF is equivalent to modulating every 4 subcarriers in an OFDM symbol of 12.8 μs excluding GI and then transmitting only the first 1/4 of the OFDM symbol in the time domain, as shown in Figure 27-34 (Generation of 1x HE-LTF symbols per frequency segment(11ax)).

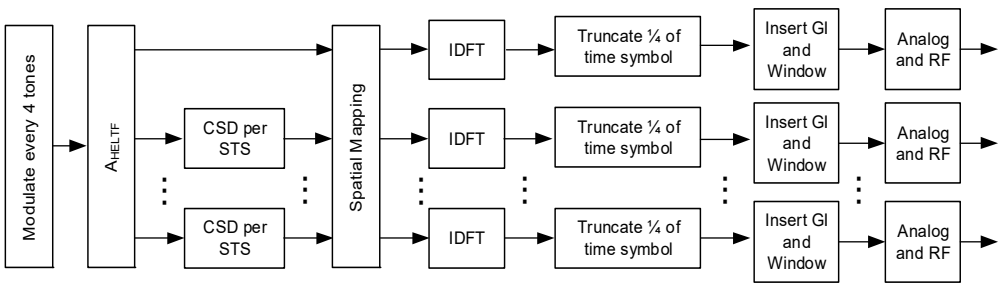


**Figure 27-34—Generation of 1x HE-LTF symbols per frequency segment(11ax)**

The generation of the time domain symbol of a 2x HE-LTF is equivalent to modulating every other subcarrier in an OFDM symbol of 12.8 μs excluding GI and then transmitting only the first half of the

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OFDM symbol in time domain, as shown in Figure 27-35 (Generation of 2x HE-LTF symbols per frequency segment(11ax)).

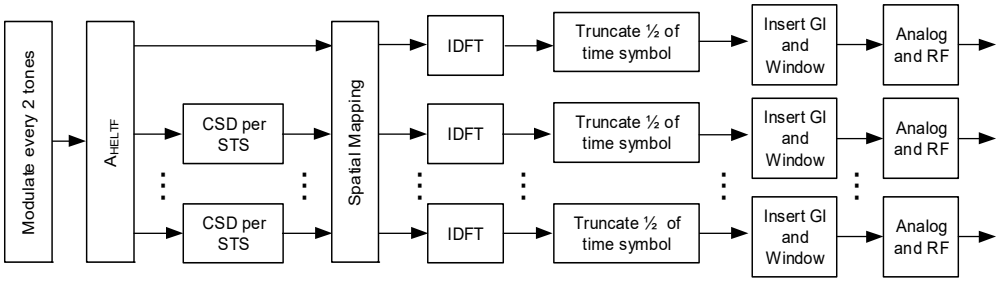


**Figure 27-35—Generation of 2x HE-LTF symbols per frequency segment(11ax)**

$A^{k}_{\text{HE-LTF}}$ is given by Equation (27-55).

$$A^{k}_{\text{HE-LTF}} = \begin{cases} R_{\text{HE-LTF}}, \text{ if } k \in K_{\text{Pilot}} \text{ and HE single stream pilot HE-LTF mode is used} \\ P_{\text{HE-LTF}}, \text{ otherwise} \end{cases} \quad (27\text{-}55)$$

where

$K_{\text{Pilot}}$ is the set of subcarrier indices for the pilot subcarriers as defined in 27.3.2.4 (Pilot subcarriers)

$R_{\text{HE-LTF}}$ is a $N_{\text{HE-LTF}} \times N_{\text{HE-LTF}}$ matrix whose elements are defined in Equation (27-56)

$$\left[R_{\text{HE-LTF}}\right]_{m,n} = \left[P_{\text{HE-LTF}}\right]_{1,n},\ 1 \le m, n \le N_{\text{HE-LTF}} \quad (27\text{-}56)$$

$P_{\text{HE-LTF}}$ is defined in Equation (27-57)

$$P_{\text{HE-LTF}} = \begin{cases} P_{4\times 4}, N_{\text{HE-LTF}} = 1, 2, 4 \\ P_{6\times 6}, N_{\text{HE-LTF}} = 6 \\ P_{8\times 8}, N_{\text{HE-LTF}} = 8 \end{cases} \quad (27\text{-}57)$$

where $P_{4\times 4}$ is defined in Equation (19-27), $P_{6\times 6}$ is defined in Equation (21-44), and $P_{8\times 8}$ is defined in Equation (21-45)

If the 1x HE-LTF is used for non-OFDMA UL MU-MIMO, the HE no pilot HE-LTF mode is used.

In an HE SU PPDU, HE MU PPDU, and HE ER SU PPDU, the time domain representation of the waveform, transmitted on frequency segment $i_{Seg}$ and transmit chain $i_{TX}$, shall be as described by Equation (27-58)(#1053)(#4404).

$$r^{(i_{Seg}, i_{TX})}_{\text{HE-LTF}}(t) = \frac{1}{\sqrt{\sum_{r=0}^{N_{RU}-1} \alpha_r^2 |K_r|}} \sum_{n=0}^{N_{\text{HE-LTF}}-1} w_{T_{\text{HE-LTF-SYM}}}(t - nT_{\text{HE-LTF-SYM}}) \sum_{r=0}^{N_{RU}-1} \frac{\alpha_r \sqrt{|K_r|}}{\sqrt{N_{STS,r,total}\Gamma_r^{\text{HE-LTF}}}} \quad (27\text{-}58)$$

$$\sum_{k \in K_r} \eta_{\text{HE-LTF},k} \sum_{u=0}^{N_{user,r}-1} \sum_{m=1}^{N_{STS,r,u}} \left( \begin{array}{l} \left[Q_k^{(i_{Seg})}\right]_{i_{TX},(M_{r,u}+m)} \left[A^{k}_{\text{HE-LTF}}\right]_{(M_{r,u}+m),(n+1)} HELTF''_{k,u,m} \\ \cdot \exp(j2\pi k \Delta_{F,\text{HE}}(t - nT_{\text{HE-LTF-SYM}} - T_{GI,\text{HE-LTF}} - T_{CS,\text{HE}}(M_{r,u}+m))) \end{array} \right)$$



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In an HE TB PPDU, the time domain representation of the waveform of user $u$ in the $r^{\text{th}}$ RU, transmitted on frequency segment $i_{Seg}$ and transmit chain $i_{TX}$, shall be as described by Equation (27-59)(#1053).

$$r_{\text{HE-LTF},r,u}^{(i_{Seg},i_{TX})}(t) = \frac{1}{\sqrt{N_{STS,r,u}\Gamma_r^{\text{HE-LTF}}}} \sum_{n=0}^{N_{\text{HE-LTF}}-1} w_{T_{\text{HE-LTF}}}(t - nT_{\text{HE-LTF}}) \sum_{k\in K_r}\sum_{m=1}^{N_{STS,r,u}} \left( \begin{array}{c} \left[Q_{k,u}^{(i_{Seg})}\right]_{i_{TX},m} \left[A_{\text{HE-LTF}}^{k}\right]_{(M_{r,u}+m),(n+1)} HELTF''_{k,u,m} \\ \cdot \exp(j2\pi k\Delta_{F,\text{HE}}(t - nT_{\text{HE-LTF-SYM}} - T_{GI,\text{HE-LTF}} - T_{CS,\text{HE}}(M_{r,u}+m))) \end{array} \right) \quad (27\text{-}59)$$

In Equation (27-58) and Equation (27-59), the following notations are used:

$N_{user,r}$ is the number of HE MU PPDU recipients (see Table 27-16 (Frequently used parameters(11ax))) in RU $r$

$HELTF''_{k,u,m}$ is the HE-LTF sequence applied on subcarrier $k$ for spatial stream $m$ of user $u$

$$HELTF''_{k,u,m} = \begin{cases} HELTF_{k,u,m}^{\text{Mask}}, \text{ if HE masked HE-LTF sequence mode is used} \\ HELTF_{k,u}^{\text{TB\_NDP}}, \text{ for an HE TB feedback NDP} \\ HELTF_k, \text{ otherwise} \end{cases}$$

$\alpha_r$ is defined in 27.3.10 (Mathematical description of signals)

$\eta_{\text{HE-LTF},k}$ is an HE PPDU format-dependent scaling factor, defined by

$$\eta_{\text{HE-LTF},k} = \begin{cases} \sqrt{2}, \text{ for an HE ER SU PPDU} \\ 1, \text{ otherwise} \end{cases}$$

$N_{\text{HE-LTF}}$ is the number of OFDM symbols in the HE-LTF field

$T_{CS,\text{HE}}(M_{r,u}+m)$ represents the cyclic shift for space-time stream $M_{r,u}+m$ as defined in 27.3.11.2.2 (Cyclic shift for HE modulated fields)

$Q_k^{(i_{Seg})}$ and $Q_{k,u}^{(i_{Seg})}$ are defined in 27.3.10 (Mathematical description of signals)

$A_{\text{HE-LTF}}^{k}$ is defined in Equation (27-55)

$M_{r,u}$ is given in Table 27-16 (Frequently used parameters(11ax)) for HE SU PPDU, HE ER SU PPDU, and HE MU PPDU. For an HE TB PPDU it is given by the TXVECTOR parameter STARTING_STS_NUM.

$K_r$ is the set of subcarrier indices for the tones in the RU $r$ as defined in 27.3.10 (Mathematical description of signals)

$|K_r|$ and $\Gamma_r^{\text{HE-LTF}}$ (#1053)are defined after Equation (27-5)

other variables are defined after Equation (27-1), Equation (27-3), Equation (27-4), Equation (27-6), Equation (27-8), Equation (27-12), and Equation (27-40)

### 27.3.12 Data field

#### 27.3.12.1 General

The number of OFDM symbols in the Data field is determined by the LENGTH field in the L-SIG field (#4181)(see Equation (27-11)), the preamble duration, and the settings of the GI+HE-LTF Size, Pre-FEC Padding Factor, and PE Disambiguity fields in the HE-SIG-A field (see 27.3.11.7 (HE-SIG-A field)) for an

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HE SU PPDU, HE ER SU PPDU, and HE MU PPDU or in the soliciting Triggering frame for an HE TB PPDU. Data field OFDM symbols in an HE PPDU shall use a DFT period of 12.8 μs and subcarrier spacing of 78.125 kHz. An HE STA shall support Data field OFDM symbols in an HE PPDU with guard interval durations of 0.8 μs, 1.6 μs, and 3.2 μs. HE PPDUs shall have HE single stream pilot in the Data field. In UL MU-MIMO transmissions, all streams use the same pilot sequence.

If BCC encoding is used, the Data field shall consist of the SERVICE field, the PSDU, the pre-FEC PHY padding bits, the tail bits, and the post-FEC padding bits. If LDPC encoding is used, the Data field shall consist of the SERVICE field, the PSDU, the pre-FEC PHY padding bits, and the post-FEC padding bits. No tail bits are present if LDPC encoding is used.

The Data field of the HE PPDU contains data for one or more users.

### 27.3.12.2 Pre-FEC padding process

A two-step padding process is applied to an HE PPDU. A pre-FEC padding process including both pre-FEC MAC and pre-FEC PHY padding is applied before conducting FEC coding, and a post-FEC PHY padding process is applied on the FEC encoded bits.

Four pre-FEC padding boundaries partition the last one (in the case of non-STBC) or two (in the case of STBC) OFDM symbols of an HE PPDU into four symbol segments. The pre-FEC padding may pad toward one of the four possible boundaries. The four pre-FEC padding boundaries are represented by a pre-FEC padding factor parameter.

Figure 27-36 (HE PPDU padding process in the last OFDM symbol (non-STBC) if a = 1(11ax)) illustrates these four possible symbol segments in the last OFDM symbol of a non-STBC case, and the general padding process assuming the desired pre-FEC padding boundary, represented by the pre-FEC padding factor, is 1.

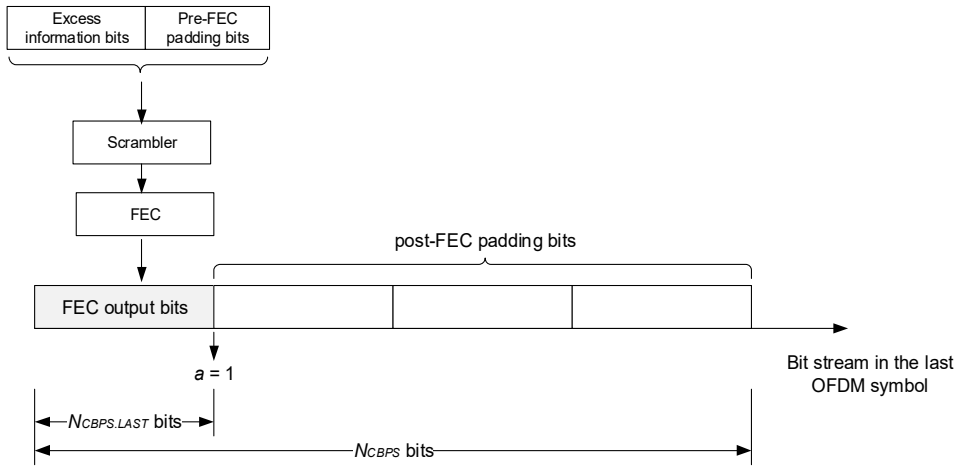


**Figure 27-36—HE PPDU padding process in the last OFDM symbol (non-STBC) if *a* = 1(11ax)**

(M74)Figure 27-37 (HE PPDU padding process in the last two OFDM symbols (STBC) if a = 1(M74)) illustrates these four possible symbol segments in the last two OFDM symbols of an STBC case, and the general padding process assuming the desired pre-FEC padding boundary, represented by the pre-FEC padding factor, is 1. The FEC output bits are modulated into the last two OFDM symbols toward the pre-FEC padding boundary by STBC encoding, then the post-FEC padding bits are modulated into the last two


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OFDM symbols after the pre-FEC padding boundary by STBC encoding. The last two OFDM symbols have the same pre-FEC padding boundary.

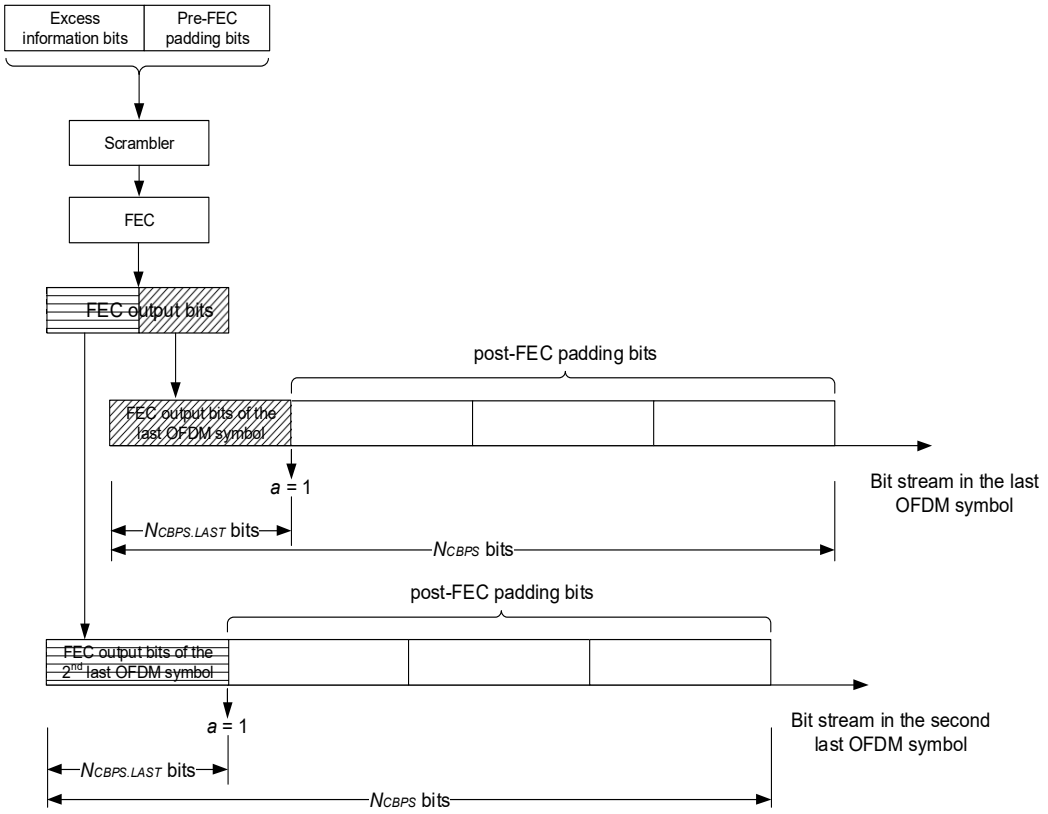


**Figure 27-37—HE PPDU padding process in the last two OFDM symbols (STBC) if a = 1(M74)**

The pre-FEC padding process is described in this subclause, and the encoding and post-FEC padding process are described in 27.3.12.5 (Coding). While this subclause describes the pre-FEC padding processing of an SU transmission, its extension to MU transmission is described in 27.3.12.5.4 (Encoding process for an HE MU PPDU) and 27.3.12.5.5 (Encoding process for an HE TB PPDU).

In an HE SU PPDU and HE ER SU PPDU transmission, the transmitter first computes the number of bits left in the last OFDM symbol (non-STBC) or in the last two OFDM symbols (STBC)(M74) based on Equation (27-60).(M118)

$$N_{Excess} = mod(8 \times \text{APEP\_LENGTH} + N_{Tail} + N_{service}, m_{STBC} \cdot N_{DBPS}) \quad (27\text{-}60)$$

where

$m_{STBC}$ is 2 if STBC is used, and 1 otherwise

APEP_LENGTH is the TXVECTOR parameter APEP_LENGTH

$N_{Tail}$ is the number of tail bits per encoder as defined in Table 27-13 (Timing-related constants(11ax))

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$N_{service}$ is the number of bits in the SERVICE field as defined in Table 27-13 (Timing-related constants(11ax))

$N_{DBPS}$ is the number of data bits per symbol

Based on $N_{Excess}$, compute the initial number of symbol segments in the last OFDM symbol (non-STBC) or in the last two OFDM symbols (STBC)(M74), initial pre-FEC padding factor value or $a_{init}$, as shown in Equation (27-61).

$$a_{init} = \begin{cases} 4, & \text{if } N_{Excess} = 0 \\ \min\left(\left\lceil \dfrac{N_{Excess}}{m_{STBC} \cdot N_{DBPS,short}} \right\rceil, 4\right), & \text{otherwise} \end{cases} \quad (27\text{-}61)$$

where

$N_{DBPS,short} = N_{CBPS,short} \cdot R$, where $R$ is the coding rate and $N_{CBPS,short} = N_{SD,short} \cdot N_{SS} \cdot N_{BPSCS}$

The parameter $N_{SD,short}$ values for different RU sizes are as shown in Table 27-34 (NSD,short values(11ax)).

**Table 27-34—$N_{SD,short}$ values(11ax)**

| RU size | $N_{SD,short}$ | |
|---|---|---|
| | DCM = 0 | DCM = 1 |
| 26-tone | 6 | 2 |
| 52-tone | 12 | 6 |
| 106-tone | 24 | 12 |
| 242-tone | 60 | 30 |
| 484-tone | 120 | 60 |
| 996-tone | 240 | 120 |
| 2×996-tone | 492 | 246 |

Given the $a_{init}$ values, the initial number of data bits per symbol and the initial number of coded bits per symbol in the last OFDM symbol (non-STBC) or in the last two OFDM symbols (STBC)(M74) are defined in Equation (27-62).

$$N_{DBPS,last,init} = \begin{cases} a_{init} N_{DBPS,short}, & \text{if } a_{init} < 4 \\ N_{DBPS}, & \text{if } a_{init} = 4 \end{cases}$$

$$N_{CBPS,last,init} = \begin{cases} a_{init} N_{CBPS,short}, & \text{if } a_{init} < 4 \\ N_{CBPS}, & \text{if } a_{init} = 4 \end{cases} \quad (27\text{-}62)$$

For an HE SU PPDU and HE ER SU PPDU, the number of pre-FEC pad bits is calculated using Equation (27-63).(M118)



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$$N_{PAD,\text{ Pre-FEC}} = (N_{SYM.init} - m_{STBC})N_{DBPS} + m_{STBC}N_{DBPS,last,init} - 8 \times \text{APEP\_LENGTH} - N_{Tail} - N_{service} \quad (27\text{-}63)$$

where $N_{SYM,init}$ is the initial number of data OFDM symbols with BCC or LDPC encoding in an HE SU PPDU or HE ER SU PPDU as defined by Equation (27-64).(M118)

$$N_{SYM,init} = m_{STBC} \cdot \left\lceil \frac{8 \times \text{APEP\_LENGTH} + N_{Tail} + N_{service}}{m_{STBC}N_{DBPS}} \right\rceil \quad (27\text{-}64)$$

Among the pre-FEC padding bits, the MAC delivers a PSDU that fills the available octets in the Data field of the HE PPDU (see A-MPDU padding for HE PPDUs in 26.6.2.2 (A-MPDU padding in an HE SU PPDU, HE ER SU PPDU, and HE MU PPDU) and 26.6.2.3 (A-MPDU padding in an HE TB PPDU)), toward the desired initial pre-FEC padding boundary, represented by $a_{init}$ value, in the last OFDM symbol (non-STBC) or in the last two OFDM symbols (STBC)(M74). The number of pre-FEC pad bits added by the MAC is(M118) a multiple of 8. The PHY then determines the number of remaining pad bits to add and appends them to the PSDU. The number of pre-FEC pad bits added by PHY is(M118) 0 to 7. The procedure is defined in Equation (27-65).(M118)

$$N_{PAD,\text{ Pre-FEC,MAC}} = \left\lfloor \frac{N_{PAD,\text{ Pre-FEC}}}{8} \right\rfloor \times 8$$
$$N_{PAD,\text{ Pre-FEC,PHY}} = N_{PAD,\text{ Pre-FEC}} \bmod 8 \quad (27\text{-}65)$$

### 27.3.12.3 SERVICE field

The SERVICE field of HE PPDU is shown in Table 27-35 (SERVICE field(11ax)).

**Table 27-35—SERVICE field(11ax)**

| Bits | Field | Description |
|---|---|---|
| B0–B6 | Scrambler Initialization | Set to 0 |
| B7–B15 | Reserved | Set to 0 |

### 27.3.12.4 Scrambler

The SERVICE field, PSDU, and pre-FEC PHY padding of the Data field shall be scrambled by the scrambler defined in 17.3.5.5 (PHY DATA scrambler and descrambler). The Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) (#602)TXVECTOR parameters CH_BANDWIDTH_IN_NON_HT, DYN_BANDWIDTH_IN_NON_HT, and SCRAMBLER_INITIAL_VALUE are not present; therefore, the first 7 bits of the scrambling sequence are set to a 7-bit nonzero pseudorandom integer. A different nonzero pseudorandom value may be used for each user in an HE MU PPDU.

### 27.3.12.5 Coding

The Data field shall be encoded using either the binary convolutional code (BCC) defined in 27.3.12.5.1 (BCC coding and puncturing) or the low-density parity check (LDPC) code defined in 27.3.12.5.2 (LDPC coding). The coding type is selected by the Coding field in the HE-SIG-A field in an HE SU PPDU or HE ER SU PPDU, by the Coding field in the HE-SIG-B field per user subfield(s) in an HE MU PPDU, or by the UL FEC Coding Type subfield in the User Info field in the corresponding Trigger frame in an HE TB

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PPDU, as defined in 27.3.11.7 (HE-SIG-A field), 27.3.11.8 (HE-SIG-B field), and 9.3.1.22 (Trigger frame format(11ax)), respectively.

When conducting BCC FEC encoding for an HE PPDU, the number of encoders is always 1.

LDPC is the only FEC coding scheme in the HE PPDU Data field for a 484-, 996-, and 2×996-tone RU. LDPC is the only FEC coding scheme in the HE PPDU Data field for HE-MCSs 10 and 11. Support for BCC coding is limited to less than or equal to four spatial streams and HE-MCSs 0 to 9 (per user in the case of MU-MIMO) and is mandatory (for both transmit and receive) for RU sizes less than or equal to a 242-tone RU. The LDPC Coding In Payload subfield in the HE Capabilities element indicates support for the transmission and reception of the LDPC encoded PPDUs. Support for LDPC coding (for both transmit and receive) is mandatory for HE STAs declaring support for at least one of HE 40/80/160/80+80 SU PPDU bandwidths, for HE STAs declaring support for more than 4 spatial streams, or for HE STAs declaring support for HE-MCSs 10 and 11, according to the LDPC Coding In Payload subfield in the HE Capabilities element as defined in 9.4.2.247 (HE Capabilities element(11ax)). Otherwise, support of LDPC coding for either transmit or receive is optional.

#### 27.3.12.5.1 BCC coding and puncturing

The information bits and pre-FEC padding bits of user $u$ are encoded by a rate $R = 1/2$ convolutional encoder defined in 17.3.5.6 (Convolutional encoder). After encoding, the encoded data is punctured by the method defined in 17.3.5.6 (Convolutional encoder) (except for rate 5/6) to achieve the rate selected by the modulation and coding scheme. When rate 5/6 coding is selected, the puncturing scheme is(M118) the same as described in 19.3.11.6 (BCC coding and puncturing).

If DCM is used with BPSK modulation in a 106-tone or 242-tone RU with $N_{SS} = 1$, then after every $2 \times N_{DBPS}$ coded bits, one padding bit is added. The padding bit may be set to any value.

For an HE SU PPDU and HE ER SU PPDU with BCC encoding,

$$N_{SYM} = N_{SYM,init} \tag{27-66}$$

and

$$a = a_{init} \tag{27-67}$$

where

$N_{SYM,init}$ is defined in Equation (27-64)
$a_{init}$ is defined in Equation (27-61)
$a$ is the pre-FEC padding factor

The number of data bits per symbol in the last OFDM symbol(s) of an HE SU PPDU or HE ER SU PPDU is $N_{DBPS,last} = N_{DBPS,last,init}$, where $N_{DBPS,last,init}$ is defined in Equation (27-62).

The number of coded bits per symbol in the last OFDM symbol(s) of an HE SU PPDU or HE ER SU PPDU is $N_{CBPS,last} = N_{CBPS,last,init}$, where $N_{CBPS,last,init}$ is defined in Equation (27-62).

#### 27.3.12.5.2 LDPC coding

For an HE SU PPDU or HE ER SU PPDU using LDPC coding on the Data field, the LDPC coding process described in 19.3.11.7 (LDPC codes) shall be used with the following modifications:


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First, all bits in the Data field including the scrambled SERVICE, PSDU, and pre-FEC pad bits are encoded. Thus, $N_{pld}$ for HE PPDUs shall be computed using Equation (27-68) instead of Equation (19-35).

$$N_{pld} = (N_{SYM,init} - m_{STBC})N_{DBPS} + m_{STBC}N_{DBPS,last,init} \quad (27\text{-}68)$$

where $N_{SYM,init}$ is defined in Equation (27-64).

$N_{avbits}$ shall be computed using Equation (27-69) instead of Equation (19-36).

$$N_{avbits} = (N_{SYM,init} - m_{STBC}) \cdot N_{CBPS} + m_{STBC} \cdot N_{CBPS,last,init} \quad (27\text{-}69)$$

In addition, in step d) of the LDPC encoding process in 19.3.11.7.5 (LDPC PPDU encoding process), if the following condition is met:

$(N_{punc} > 0.1 \times N_{CW} \times L_{LDPC} \times (1-R))$ AND $\left(N_{shrt} < 1.2 \times N_{punc} \times \frac{R}{1-R}\right)$ is true OR if

$N_{punc} > 0.3 \times N_{CW} \times L_{LDPC} \times (1-R)$ is true,

then the LDPC Extra Symbol Segment field of the HE-SIG-A field shall be set to 1, $N_{avbits}$ shall be increased according to the Equation (27-70) instead of Equation (19-39), and $N_{punc}$ shall be recomputed as in Equation (19-40):

$$N_{avbits} = \begin{cases} N_{avbits} + m_{STBC} \cdot (N_{CBPS} - 3N_{CBPS,short}), & \text{if } a_{init} = 3 \\ N_{avbits} + m_{STBC} \cdot N_{CBPS,short}, & \text{otherwise} \end{cases} \quad (27\text{-}70)$$

and then compute the pre-FEC padding factor $a$ and $N_{SYM}$ using Equation (27-71).

$$\begin{cases} N_{SYM} = N_{SYM,init} + m_{STBC} \text{ and } a = 1, & \text{if } a_{init} = 4 \\ N_{SYM} = N_{SYM,init} \text{ and } a = a_{init} + 1, & \text{otherwise} \end{cases} \quad (27\text{-}71)$$

If in step d) of the LDPC encoding process in 19.3.11.7.5 (LDPC PPDU encoding process), the above mentioned condition is not met, then the LDPC Extra Symbol Segment field in the HE-SIG-A field shall be set to 0, and

$$\begin{aligned} N_{SYM} &= N_{SYM,init} \\ a &= a_{init} \end{aligned} \quad (27\text{-}72)$$

Using the pre-FEC padding factor $a$, compute $N_{CBPS}$ of the last symbol using Equation (27-73).

$$N_{CBPS,last} = \begin{cases} a \cdot N_{CBPS,short}, & \text{if } a < 4 \\ N_{CBPS}, & \text{if } a = 4 \end{cases} \quad (27\text{-}73)$$

The number of data bits of the last symbol is calculated as $N_{DBPS,last} = N_{DBPS,last,init}$.

LDPC coding used in HE MU PPDUs shall also follow the definitions in 19.3.11.7 (LDPC codes). Refer to 27.3.12.5.4 (Encoding process for an HE MU PPDU) for a description of the LDPC encoding process for HE MU PPDUs.

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#### 27.3.12.5.3 Post-FEC padding

The number of post-FEC padding bits in each of the last $m_{STBC}$ symbols is computed by using Equation (27-74).

$$N_{PAD,Post\text{-}FEC} = N_{CBPS} - N_{CBPS,last} \tag{27-74}$$

The last $m_{STBC}$ symbols shall consist of $N_{CBPS,last}$ bits from the FEC output followed by $N_{PAD,Post\text{-}FEC}$ post-FEC padding bits. The values of the post-FEC padding bits are not specified and are determined by the implementation.

#### 27.3.12.5.4 Encoding process for an HE MU PPDU

For an HE MU PPDU, all the users shall use a common pre-FEC padding factor value and a common $N_{SYM}$ value. The padding process is described as follows:

First compute initial pre-FEC padding factor value, $a_{init,u}$, for each user $u$ using Equation (27-61) and the initial number of OFDM symbols, $N_{SYM,init,u}$, for each user $u$ using Equation (27-64). Among all the users, derive the user index with the longest encoded (#1065)duration, as in Equation (27-75).

$$u_{\max} = \arg\max_{u=0}^{N_{user,total}-1}\left(N_{SYM,init,u} - m_{STBC} + \frac{m_{STBC}a_{init,u}}{4}\right) \tag{27-75}$$

where

$\arg\max f(x) := \{x | x \in [0, N_{user,total} - 1] \wedge \forall y \in [0, N_{user,total} - 1]; f(y) \le f(x)\}$

$m_{STBC}$ is the common STBC setting among all the users, as described in 27.3.11.7 (HE-SIG-A field)

Then the common $a_{init}$ and $N_{SYM,init}$ values among all the users are derived by Equation (27-76).

$$\begin{aligned} N_{SYM,init} &= N_{SYM,init,u_{\max}} \\ a_{init} &= a_{init,u_{\max}} \end{aligned} \tag{27-76}$$

Calculate each user's initial number of coded bits in its last symbol as in Equation (27-77).

$$\begin{aligned} N_{DBPS,last,init,u} &= \begin{cases} a_{init}N_{DBPS,short,u}, \text{ if } a_{init} < 4 \\ N_{DBPS,u}, \text{ if } a_{init} = 4 \end{cases} \\ N_{CBPS,last,init,u} &= \begin{cases} a_{init}N_{CBPS,short,u}, \text{ if } a_{init} < 4 \\ N_{CBPS,u}, \text{ if } a_{init} = 4 \end{cases} \end{aligned} \tag{27-77}$$

For each user with LDPC encoding, the number of pre-FEC padding bits is computed as in Equation (27-78).

$$\begin{aligned} N_{PAD,\text{Pre-FEC},u} = {} & (N_{SYM,init} - m_{STBC})N_{DBPS,u} + m_{STBC}N_{DBPS,last,init,u} \\ & - 8 \cdot \text{APEP\_LENGTH}_u - N_{service} \end{aligned} \tag{27-78}$$



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For each user with LDPC encoding, the parameters $N_{pld,u}$ and $N_{avbits,u}$ are computed using Equation (27-79) and Equation (27-80), respectively.

$$N_{pld,u} = (N_{SYM,init} - m_{STBC})N_{DBPS,u} + m_{STBC}N_{DBPS,last,init,u} \quad (27\text{-}79)$$

$$N_{avbits,u} = (N_{SYM,init} - m_{STBC})N_{CBPS,u} + m_{STBC}N_{CBPS,last,init,u} \quad (27\text{-}80)$$

For each user with LDPC encoding, continue the LDPC encoding process in 19.3.11.7.5 (LDPC PPDU encoding process) starting with the parameters $N_{pld,u}$ and $N_{avbits,u}$. If there is at least one user with LDPC encoding for which step d) of the LDPC encoding process in 19.3.11.7.5 (LDPC PPDU encoding process) meets the following condition:

$(N_{punc,u} > 0.1 \times N_{CW,u} \times L_{LDPC,u} \times (1 - R_u))$ AND $\left(N_{shrt,u} < 1.2 \times N_{punc,u} \times \frac{R_u}{1 - R_u}\right)$ is true OR if $N_{punc,u} > 0.3 \times N_{CW,u} \times L_{LDPC,u} \times (1 - R_u)$ is true,

where $N_{punc,u}$, $N_{CW,u}$, $L_{LDPC,u}$, and $N_{shrt,u}$ are the LDPC encoding parameters for user $u$, as defined in 19.3.11.7.5 (LDPC PPDU encoding process), and $R_u$ is the coding rate of user $u$.

Then the LDPC Extra Symbol Segment field in the HE-SIG-A field shall be set to 1, and all the users with LDPC encoding shall increment $N_{avbits}$ and recompute $N_{punc}$ using Equation (27-81) and Equation (27-82) once.

$$N_{avbits,u} = \begin{cases} N_{avbits,u} + m_{STBC} \cdot (N_{CBPS,u} - 3N_{CBPS,short,u}), & \text{if } a_{init} = 3 \\ N_{avbits,u} + m_{STBC} \cdot N_{CBPS,short,u}, & \text{otherwise} \end{cases} \quad (27\text{-}81)$$

$$N_{punc,u} = \max(0, (N_{CW,u} \times L_{LDPC,u}) - N_{avbits,u} - N_{shrt,u}) \quad (27\text{-}82)$$

Update the common pre-FEC padding factor and $N_{SYM}$ values for all users using Equation (27-83).

$$\begin{cases} N_{SYM} = N_{SYM,init} + m_{STBC} \text{ and } a = 1, & \text{if } a_{init} = 4 \\ N_{SYM} = N_{SYM,init} \text{ and } a = a_{init} + 1, & \text{otherwise} \end{cases} \quad (27\text{-}83)$$

If none of the users with LDPC encoding in step d) of 19.3.11.7.5 (LDPC PPDU encoding process) meet the condition that $(N_{punc,u} > 0.1 \times N_{CW,u} \times L_{LDPC,u} \times (1 - R_u))$ and $\left(N_{shrt,u} < 1.2 \times N_{punc,u} \times \frac{R_u}{1 - R_u}\right)$ are true or $N_{punc,u} > 0.3 \times N_{CW,u} \times L_{LDPC,u} \times (1 - R_u)$ is true, or if all the users in the HE MU PPDU are BCC encoded, then the LDPC Extra Symbol Segment field in the HE-SIG-A field shall be set to 0, and the common pre-FEC padding factor and $N_{SYM}$ values for all users shall be updated by Equation (27-84).

$$a = a_{init}, N_{SYM} = N_{SYM,init} \quad (27\text{-}84)$$

For the users with LDPC encoding, $N_{DBPS,last,u} = N_{DBPS,last,init,u}$.

For the users with BCC encoding, update the $N_{DBPS}$ of the last symbol as

$$N_{DBPS,last,u} = \begin{cases} a \cdot N_{DBPS,short,u}, \text{ if } a < 4 \\ N_{DBPS,u}, \text{ if } a = 4 \end{cases} \quad (27\text{-}85)$$

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For each user with either LDPC or BCC encoding, update the $N_{CBPS}$ of the last symbol as

$$N_{CBPS,\,last,\,u} = \begin{cases} a \cdot N_{CBPS,\,short,\,u}, \text{ if } a < 4 \\ N_{CBPS,\,u}, \text{ if } a = 4 \end{cases}$$

For the users with BCC encoding, the number of pre-FEC padding bits is shown in Equation (27-86).

$$N_{PAD,\,\text{Pre-FEC},\,u} = (N_{SYM} - m_{STBC})N_{DBPS,\,u} + m_{STBC}N_{DBPS,\,last,\,u} - 8 \cdot \text{APEP\_LENGTH}_u - N_{Tail} - N_{service} \quad (27\text{-}86)$$

For each user with either LDPC or BCC encoding, the number of post-FEC padding bits in each of the last $m_{STBC}$ symbol(s) is computed as in Equation (27-87).

$$N_{PAD,\,\text{Post-FEC},\,u} = N_{CBPS,\,u} - N_{CBPS,\,last,\,u} \quad (27\text{-}87)$$

Among the pre-FEC padding bits, the MAC delivers a PSDU that fills the available octets in the Data field of the HE PPDU, toward the desired initial pre-FEC padding boundary represented by $a_{init}$ for users encoded by LDPC and the pre-FEC padding boundary represented by $a$ for users encoded by BCC, in the last OFDM symbol(s). The PHY then determines the number of pad bits to add and appends them to the PSDU. The number of pre-FEC pad bits added by PHY is(M118) 0 to 7. The procedure is defined in Equation (27-88) and Equation (27-89).

$$N_{PAD,\,\text{Pre-FEC},\,MAC,\,u} = 8 \cdot \left\lfloor \frac{N_{PAD,\,\text{Pre-FEC},\,u}}{8} \right\rfloor \quad (27\text{-}88)$$

$$N_{PAD,\,\text{Pre-FEC},\,PHY,\,u} = N_{PAD,\,\text{Pre-FEC},\,u} \bmod 8 \quad (27\text{-}89)$$

#### 27.3.12.5.5 Encoding process for an HE TB PPDU

For an HE TB PPDU sent in response to a Trigger frame, the AP indicates the UL Length, GI And HE-LTF Type, Number Of HE-LTF Symbols And Midamble Periodicity, Pre-FEC Padding Factor, UL STBC, LDPC Extra Symbol Segment, PE Disambiguity, and Doppler fields in the Trigger frame. The common values $T_{PE}$ and $N_{SYM}$ are derived by non-AP STAs as shown in Equation (27-114) and Equation (27-115) (in 27.3.13 (Packet extension)). The AP should set the LDPC Extra Symbol Segment field in the Common Info field of the Trigger frame to 1 if the calculations described in the LDPC encoding process indicate the need for an LDPC extra symbol segment for any STA solicited by the AP for HE TB PPDU transmission using LDPC.

NOTE—The AP might set the LDPC Extra Symbol Segment field to 1 regardless of these calculations. The AP might select a value for the Pre-FEC Padding Factor field that differs from that derived from the calculations described in the BCC or LDPC encoding process.

For an HE TB PPDU sent in response to a frame containing a TRS Control subfield, the parameters used to derive the common values $T_{PE}$ and $N_{SYM}$ are described in 26.5.2.3.4 (TXVECTOR parameters for HE TB PPDU response to TRS Control subfield).

For an HE TB PPDU with BCC encoding, follow the HE SU PPDU padding and encoding process introduced in 27.3.12.2 (Pre-FEC padding process), 27.3.12.5.1 (BCC coding and puncturing), and 27.3.12.5.3 (Post-FEC padding) with initial parameters as follows:

— If the TXVECTOR parameter TRIGGER_METHOD is TRIGGER_FRAME, the initial parameters are $N_{SYM,init} = N_{SYM}$ and $a_{init} = a$, where $a$ is the TXVECTOR parameter PRE_FEC_PADDING_FACTOR and $N_{SYM}$ is the common number of data OFDM symbols derived from the UL Length, Number Of HE-LTF Symbols And Midamble Periodicity, and Doppler subfields of the Common Info field in the Trigger frame.


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— If the TXVECTOR parameter TRIGGER_METHOD is TRS, the initial parameters are $N_{SYM,init} = F_{VAL} + 1$ and $a_{init} = 4$, where $F_{VAL}$ is the value of the UL Data Symbols subfield of the TRS Control subfield.

For an HE TB PPDU with LDPC encoding, follow the HE SU PPDU padding and encoding process introduced in 27.3.12.2 (Pre-FEC padding process), 27.3.12.5.2 (LDPC coding), and 27.3.12.5.3 (Post-FEC padding), with the following exceptions:

— If the TXVECTOR parameter TRIGGER_METHOD is TRIGGER_FRAME and the LDPC Extra Symbol Segment field in the Trigger frame is 1, set the initial parameters following Equation (27-90).

$$\begin{cases} a_{init} = 4 \text{ and } N_{SYM,\,init} = N_{SYM} - m_{STBC}, & \text{if } a = 1 \\ a_{init} = a - 1 \text{ and } N_{SYM,\,init} = N_{SYM}, & \text{otherwise} \end{cases} \tag{27-90}$$

where $m_{STBC}$ is 2 if the Trigger frame indicates STBC and 1 otherwise. Then continue with the LDPC encoding process in 27.3.12.5.2 (LDPC coding), during which $N_{avbits}$ is always incremented as in Equation (27-70) and $N_{punc}$ is always recomputed as in Equation (19-40).

— If the TXVECTOR parameter TRIGGER_METHOD is TRIGGER_FRAME and the LDPC Extra Symbol Segment field in the Trigger frame is 0, then set the initial parameters to $N_{SYM,init} = N_{SYM}$, and $a_{init} = a$. Then continue with the LDPC encoding process as in 27.3.12.5.2 (LDPC coding), during which $N_{avbits}$ and $N_{punc}$ are not changed and $a = a_{init}$.

— If the TXVECTOR parameter TRIGGER_METHOD is TRS, then the parameter LDPC_EXTRA_SYMBOL is 1, and the initial parameters are set to $N_{SYM,init} = F_{VAL} + 1$ and $a_{init} = 3$, where $F_{VAL}$ is the value of the UL Data Symbols subfield of the TRS Control subfield. Then continue with the LDPC encoding process as in 27.3.12.5.2 (LDPC coding), during which $N_{avbits}$ is always incremented as in Equation (27-70) and $N_{punc}$ is always recomputed as in Equation (19-40).

### 27.3.12.6 Stream parser

After scrambling, coding, puncturing, and post-FEC padding, the data bits are processed in groups of $N_{CBPS}$ bits. Each of these groups is rearranged into $N_{SS}$ blocks of $N_{CBPSS}$ bits ($N_{SS,u}$ blocks of $N_{CBPSS,u}$ bits in the case of an HE MU transmission). This operation is referred to as *stream parsing* and is described in this subclause.

The description is given in terms of an SU transmission. For MU transmissions, the rearrangements are carried out in the same way per user.

The number of bits assigned to a single axis (real or imaginary) in a constellation point in a spatial stream is denoted by Equation (27-91).

$$s = max(1, \frac{N_{BPSCS}}{2}) \tag{27-91}$$

The sum of these over all streams is $S = N_{SS} \cdot s$.

Consecutive blocks of $s$ bits are assigned to different spatial streams in a round robin fashion.

For the $N_{CBPS}$ bits of each OFDM symbol, $S$ bits from the output of the encoder are divided among all spatial streams, $s$ bits per stream.

NOTE—For all RU sizes the coded bits per OFDM symbol are always evenly allocated to $N_{SS}$ spatial streams.

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The following equations are an equivalent description to the above procedure. Bit $i$ at the output of the encoder is assigned to input bit $k$ of spatial stream $i_{SS}$ where

$$i = (i_{SS} - 1)s + S \cdot \left\lfloor \frac{k}{s} \right\rfloor + (k \bmod s)$$

$$i_{SS} = 1, 2, \ldots, N_{SS}$$

$$i = 0, 1, \ldots, N_{CBPS} - 1$$

$$k = 0, 1, \ldots, N_{CBPSS} - 1$$

### 27.3.12.7 Segment parser

The description in this subclause is for an SU transmission. For an MU transmissions, the rearrangements are carried out in the same way but per user.

For a 20 MHz, 40 MHz, 80 MHz, 160 MHz, and 80+80 MHz transmission with a 26-, 52-, 106-, 242-, 484-, or 996-tone RU, the segment parser is bypassed and the output bits are as specified in Equation (27-92).

$$y_{k,l} = x_k \tag{27-92}$$

where

$x_k$ is bit $k$ of a block of $N_{CBPSS}$ bits, $k = 0$ to $N_{CBPSS} - 1$

$l$ is the frequency subblock index and $l = 0$ for a 26-, 52-, 106-, 242-, 484-, and 996-tone RU

$y_{k,l}$ is bit $k$ of the frequency subblock $l$

For a 160 MHz and 80+80 MHz transmission with a 2×996-tone RU, the output bits of each stream parser are first divided into blocks of $N_{CBPSS}$ bits ($N_{CBPSS,u}$ bits in the case of an MU transmission). Then, each block is further divided into two frequency subblocks of $N_{CBPSS}/2$ bits as shown in Equation (27-93).

$$y_{k,l} = x_m \tag{27-93}$$

$$m = 2s \cdot \left\lfloor \frac{k}{s} \right\rfloor + l \cdot s + (k \bmod s), \quad k = 0, 1, \ldots, \frac{N_{CBPSS}}{2} - 1 \tag{27-94}$$

where

$x_m$ is bit $m$ of a block of $N_{CBPSS}$ bits and $m = 0, \ldots, N_{CBPSS} - 1$

$l$ is the frequency subblock index and $l = 0, 1$

$y_{k,l}$ is bit $k$ of the frequency subblock $l$

$s$ is defined in Equation (27-91)

### 27.3.12.8 BCC interleavers

For ease of explanation, the operation of the interleaver is described only for the SU case. For user $u$ of an MU transmission, the interleaver operates in the same way on the output bits for the user from the stream parser by replacing $N_{SS}$, $N_{CBPSS}$, $N_{CBPS}$, and $N_{BPSCS}$ with $N_{SS,u}$, $N_{CBPSS,u}$, $N_{CBPS,u}$ and $N_{BPSCS,u}$, respectively. That is, the operation of the interleaver is the same as if the transmission were an SU one, consisting of bits from only that user.

The BCC interleaver operation is specified in 21.3.10.8 (BCC interleaver). The interleaver parameters, $N_{COL}$, $N_{ROW}$, and $N_{ROT}$, for the Data field depend on the RU size and whether or not DCM is used and are defined in the (#4177)RU size column of Table 27-36 (BCC interleaver parameters(11ax)).


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**Table 27-36—BCC interleaver parameters(11ax)**

| DCM | Parameter | RU size (tones) | | | | HE-SIG-A/ HE-SIG-B (tones) |
|---|---|---|---|---|---|---|
| | | 26 | 52 | 106 | 242 | 56 |
| Not used | $N_{COL}$ | 8 | 16 | 17 | 26 | 13 |
| | $N_{ROW}$ | $3 \times N_{BPSCS}$ | $3 \times N_{BPSCS}$ | $6 \times N_{BPSCS}$ | $9 \times N_{BPSCS}$ | $4 \times N_{BPSCS}$ |
| | $N_{ROT}$ | 2 | 11 | 29 | 58 | — |
| Used | $N_{COL}$ | 4 | 8 | 17 | 13 | 13 |
| | $N_{ROW}$ | $3 \times N_{BPSCS}$ | $3 \times N_{BPSCS}$ | $3 \times N_{BPSCS}$ | $9 \times N_{BPSCS}$ | $2 \times N_{BPSCS}$ |
| | $N_{ROT}$ | 2 | 2 | 11 | 29 | — |

The interleaver parameters, $N_{COL}$ and $N_{ROW}$, for the HE-SIG-A and HE-SIG-B fields are defined in the (#4177)HE-SIG-A/HE-SIG-B column of Table 27-36 (BCC interleaver parameters(11ax)).

NOTE—DCM is not used on the HE-SIG-A field.

### 27.3.12.9 Constellation mapping

The mapping between the input bits of the constellation mapper and complex constellation points for BPSK, QPSK, 16-QAM, 64-QAM, and 256-QAM is defined in 21.3.10.9 (Constellation mapping).

For 1024-QAM, the mapping of the bits at the output of the stream parser or segment parser (if present) to the complex constellation points is defined in Figure 27-38 (Constellation bit encoding for 1024-QAM (1st quadrant)(11ax)), Figure 27-39 (Constellation bit encoding for 1024-QAM (2nd quadrant)(11ax)),

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Figure 27-40 (Constellation bit encoding for 1024-QAM (3rd quadrant)(11ax)), and Figure 27-41 (Constellation bit encoding for 1024-QAM (4th quadrant)(11ax)).

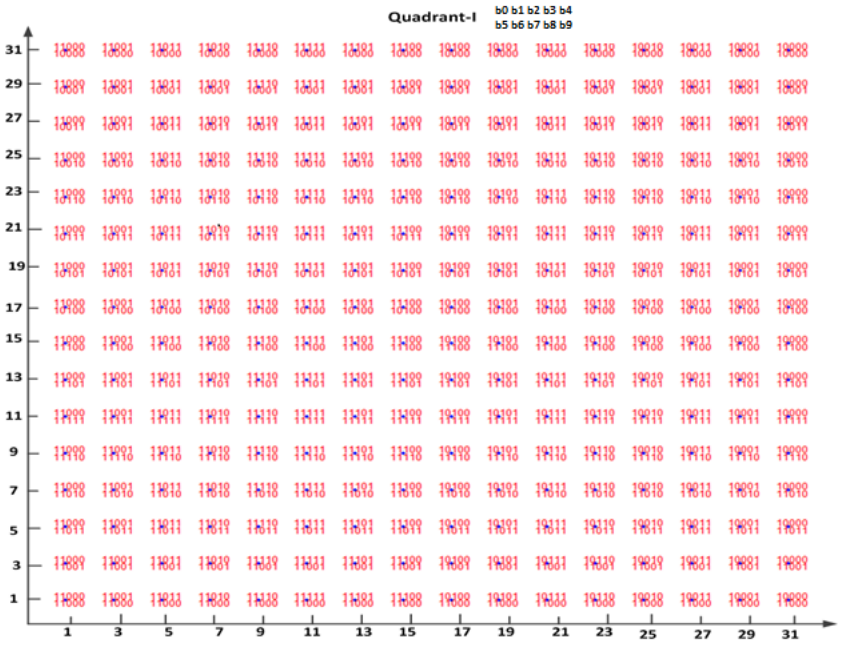


**Figure 27-38—Constellation bit encoding for 1024-QAM (1st quadrant)(11ax)**

**Figure 27-39—Constellation bit encoding for 1024-QAM (2nd quadrant)(11ax)**



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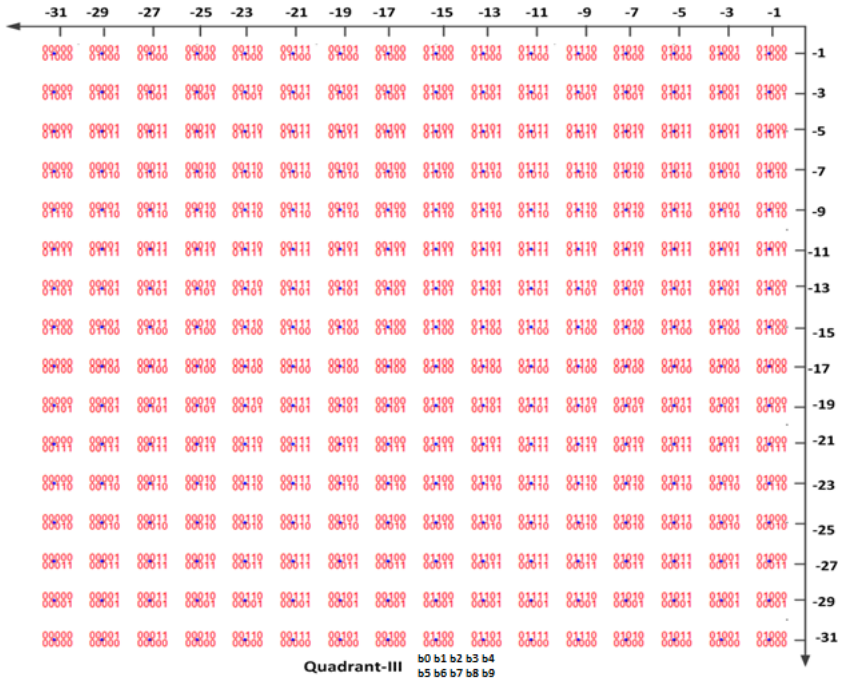


**Figure 27-40—Constellation bit encoding for 1024-QAM (3rd quadrant)(11ax)**

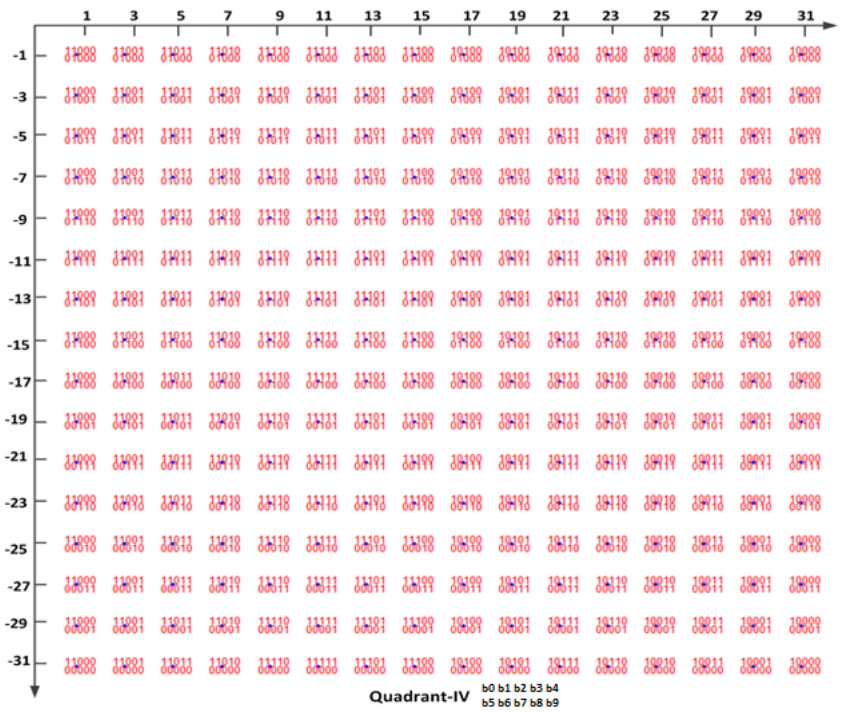


**Figure 27-41—Constellation bit encoding for 1024-QAM (4th quadrant)(11ax)**

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The bit string convention in Figure 27-38 (Constellation bit encoding for 1024-QAM (1st quadrant)(11ax)), Figure 27-39 (Constellation bit encoding for 1024-QAM (2nd quadrant)(11ax)), Figure 27-40 (Constellation bit encoding for 1024-QAM (3rd quadrant)(11ax)), and Figure 27-41 (Constellation bit encoding for 1024-QAM (4th quadrant)(11ax)) follows the bit string convention outlined in 17.3.5.8 (Subcarrier modulation mapping).

The normalization factor $K_{mod}$ for 1024 QAM is $1/\sqrt{682}$.

DCM is an optional modulation scheme for the HE-SIG-B and Data fields. DCM can be applied to an HE SU PPDU and an HE ER SU PPDU. In an HE MU PPDU or HE TB PPDU, DCM can be applied to an RU containing data for one user but cannot be applied to an RU containing data for more than one user.

DCM is applicable to only HE-MCSs 0, 1, 3, and 4. DCM is applicable to only $N_{SS} = 1$ or $N_{SS} = 2$ (in the case of single-user RU in an HE MU PPDU, $N_{SS,r,u} = 1$ or $N_{SS,r,u} = 2$). DCM is not applicable with MU-MIMO or with STBC.

If DCM is employed, bit sequences are mapped to a pair of symbols $(d'_k, d'_{q(k)})$ where to exploit frequency diversity for a 996-tone or smaller RU, $k$ is in the range(#3482) $0 \le k \le N_{SD} - 1$ and $q(k)$ is in the range(#3482) $N_{SD} \le q(k) \le 2N_{SD} - 1$ and, for a 2×996-tone RU, $k$ is in the range(#3482) $0 \le k \le N_{SD}/2 - 1$ and $q(k)$ is in the range(#3482) $N_{SD}/2 \le q(k) \le N_{SD} - 1$. To maximize the frequency diversity, the indices of a pair of DCM subcarriers $(k, q(k))$ are given by $q(k) = k + N_{SD}$ for a 996-tone or smaller RU. To reduce the implementation complexity, the indices of a pair of DCM subcarriers $(k, q(k))$ are given by $q(k) = k + N_{SD}/2$ for a 2×996-tone RU. The $N_{SD}$ here refers to the $N_{SD}$ with DCM = 1, which is half the value of $N_{SD}$ with DCM = 0.

Let $N_{80seg,ru} = 1$ for a 996-tone RU or smaller and $N_{80seg,ru} = 2$ for a 2×996-tone RU.

For BPSK modulation with DCM, the input stream is broken into groups of $N_{CBPS}/N_{80seg,ru}$ or $N_{CBPS,u}/N_{80seg,ru}$ bits $(B_0, B_1, \ldots, B_{N_{CBPS,u}/N_{80seg,ru}-1})$. Each bit $B_k$ is BPSK modulated to a sample $d'_k$. This generates the samples for the lower half of the data subcarriers (#1048)generated by the group. For the upper half of the data subcarriers generated by the group, the samples are generated as $d'_{k+N_{SD}/N_{80seg,ru}} = d'_k \times e^{j(k+N_{SD}/N_{80seg,ru})\pi}$, $k = 0, 1, \ldots, N_{SD}/N_{80seg,ru} - 1$. The $N_{SD}$ here refers to the $N_{SD}$ with DCM = 1, which is half the value of $N_{SD}$ with DCM = 0.

For QPSK modulation with DCM, the input stream is broken into groups of $N_{CBPS}/N_{80seg,ru}$ or $N_{CBPS,u}/N_{80seg,ru}$ bits $(B_0, B_1, \ldots, B_{N_{CBPS,u}/N_{80seg,ru}-1})$. Each pair of bits $(B_{2k}, B_{2k+1})$ is QPSK modulated to a symbol $d'_k$. (#1049)This generates the constellation points for the lower half of the data subcarriers generated by the group. For the upper half of the data subcarriers generated by the group, $d'_{k+N_{SD}/N_{80seg,ru}} = conj(d'_k)$, where $conj()$ represents the complex conjugate operation. The $N_{SD}$ here refers to the $N_{SD}$ with DCM = 1, which is half the value of $N_{SD}$ with DCM = 0.

For 16-QAM modulation with DCM, the input stream is broken into groups of $N_{CBPS}/N_{80seg,ru}$ or $N_{CBPS,u}/N_{80seg,ru}$ bits $(B_0, B_1, \ldots, B_{N_{CBPS,u}/N_{80seg,ru}-1})$. A group of 4 bits $(B_{4k}, B_{4k+1}, B_{4k+2}, B_{4k+3})$ is 16-QAM modulated to a sample $d'_k$ as described in 17.3.5.8 (Subcarrier modulation mapping). This is the sample on subcarrier $k$ in the lower half (#1048)of the data subcarriers generated by the group. In the upper half of the data subcarriers generated by the group, the sample $d'_{k+N_{SD}/N_{80seg,ru}}$ on subcarrier $k + N_{SD}/N_{80seg,ru}$ is


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obtained by 16-QAM modulating a permutation of the bits ($B_{4k}$, $B_{4k+1}$, $B_{4k+2}$, $B_{4k+3}$). Specifically, $d'_{k+N_{SD}/N_{80seg,ru}}$ is obtained by applying the 16-QAM modulation procedure in 17.3.5.8 (Subcarrier modulation mapping) to the bit group ($B_{4k+1}$, $B_{4k}$, $B_{4k+3}$, $B_{4k+2}$). The $N_{SD}$ here refers to the $N_{SD}$ with DCM = 1, which is half the value of $N_{SD}$ with DCM = 0.

### 27.3.12.10 LDPC tone mapper

The LDPC tone mapping shall be performed on all LDPC encoded streams mapped in an RU as described in this subclause. LDPC tone mapping shall not be performed on streams that are encoded using BCC. If DCM is applied to LDPC encoded streams, $D_{TM\_DCM}$ shall be applied on both the lower half data subcarriers in an RU and the upper half data subcarriers of the RU. The LDPC tone mapping distance parameters $D_{TM}$ and $D_{TM\_DCM}$ are constant for each RU size, and the values for different RU sizes are given in Table 27-37 (LDPC tone mapping distance for each RU size(11ax)).

**Table 27-37—LDPC tone mapping distance for each RU size(11ax)**

| Parameter | RU size (tones) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 26 | 52 | 106 | 242 | 484 | 996 | 2×996 |
| $D_{TM}$ | 1 | 3 | 6 | 9 | 12 | 20 | 20 |
| $D_{TM\_DCM}$ | 1 | 1 | 3 | 9 | 9 | 14 | 14 |

NOTE 1—The LDPC tone mapping parameters $D_{TM}$ and $D_{TM\_DCM}$ are applied for each frequency subblock, $l = 0$ and $l = 1$.

For an HE PPDU without DCM, the LDPC tone mapping for the LDPC encoded stream for user $u$ in the $r^{th}$ RU is done by permuting the stream of complex numbers generated by the constellation mappers (see 27.3.12.9 (Constellation mapping)) as defined by Equation (27-95).

$$d''_{t(k),i,n,l,r,u} = d'_{k,i,n,l,r,u} \tag{27-95}$$

where

$$k = \begin{cases} 0, 1, \ldots, N_{SD} - 1 \text{ for a 26-, 52-, 106-, 242-, 484- and 996-tone RU} \\ 0, 1, \ldots, N_{SD}/2 - 1 \text{ for a 2×996-tone RU} \end{cases}$$

$i = 1, \ldots, N_{SS,r,u}$

$n = 0, 1, \ldots, N_{SYM} - 1$

$$l = \begin{cases} 0 \text{ for a 26-, 52-, 106-, 242-, 484- and 996-tone RU} \\ 0, 1 \text{ for a 2×996-tone RU} \end{cases}$$

$u = 0, \ldots, N_{user,r} - 1$

$r = 0, \ldots, N_{RU} - 1$

$N_{SD}$ is the number of data tones in the $r^{th}$ RU

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$$t(k) = \begin{cases} D_{TM}\left(k \bmod \frac{N_{SD}}{D_{TM}}\right) + \left\lfloor \frac{k \cdot D_{TM}}{N_{SD}} \right\rfloor, & \text{for a 26-, 52-, 106-, 242-, 484- and 996-tone RU} \\ D_{TM}\left(k \bmod \frac{N_{SD}/2}{D_{TM}}\right) + \left\lfloor \frac{k \cdot D_{TM}}{N_{SD}/2} \right\rfloor, & \text{for a 2×996-tone RU} \end{cases}$$

For an HE PPDU with DCM applied to the Data field, the LDPC tone mapping for the LDPC encoded stream corresponding to user $u$ in the $r^{\text{th}}$ RU is done by permuting the stream of complex numbers generated by the constellation mappers (see 27.3.12.9 (Constellation mapping)) as defined by Equation (27-96).

$$d''_{t(k),\,i,\,n,\,l,\,r,\,u} = d'_{k,\,i,\,n,\,l,\,r,\,u} \tag{27-96}$$

where

$$k = \begin{cases} 0, 1, \ldots, 2N_{SD} - 1 & \text{for a 26-, 52-, 106-, 242-, 484- and 996-tone RU} \\ 0, 1, \ldots, N_{SD} - 1 & \text{for a 2×996-tone RU} \end{cases}$$

$i = 1, \ldots, N_{SS,\,r,\,u}$

$n = 0, 1, \ldots, N_{SYM} - 1$

$$l = \begin{cases} 0 & \text{for a 26-, 52-, 106-, 242-, 484- and 996-tone RU} \\ 0, 1 & \text{for a 2×996-tone RU} \end{cases}$$

$u = 0, \ldots, N_{user,\,r} - 1$

$r = 0, \ldots, N_{RU} - 1$

$N_{SD}$ is the number of data tones in the $r^{\text{th}}$ RU if DCM is applied

$t(k)$ is as follows:

For a 26-, 52-, 106-, 242-, 484-, and 996-tone RU:

$$t(k) = \begin{cases} D_{TM\_DCM}\left(k \bmod \frac{N_{SD}}{D_{TM\_DCM}}\right) + \left\lfloor \frac{k \cdot D_{TM\_DCM}}{N_{SD}} \right\rfloor, & \text{for } k < N_{SD} \\ D_{TM\_DCM}\left((k - N_{SD}) \bmod \frac{N_{SD}}{D_{TM\_DCM}}\right) + \left\lfloor \frac{(k - N_{SD}) \cdot D_{TM\_DCM}}{N_{SD}} \right\rfloor + N_{SD}, & \text{for } k \geq N_{SD} \end{cases}$$

For a 2×996-tone RU:

$$t(k) = \begin{cases} D_{TM\_DCM}\left(k \bmod \frac{N_{SD}/2}{D_{TM\_DCM}}\right) + \left\lfloor \frac{k \cdot D_{TM\_DCM}}{N_{SD}/2} \right\rfloor, & \text{for } 0 \leq k < N_{SD}/2 \\ D_{TM\_DCM}\left((k - N_{SD}/2) \bmod \frac{N_{SD}/2}{D_{TM\_DCM}}\right) + \left\lfloor \frac{(k - N_{SD}/2) \cdot D_{TM\_DCM}}{N_{SD}/2} \right\rfloor + N_{SD}/2, & \text{for } N_{SD}/2 \leq k < N_{SD} \end{cases}$$

$D_{TM\_DCM}$

is the LDPC tone mapping distance for the $r^{\text{th}}$ RU if DCM is applied

NOTE 2—LDPC tone mapper for a 26-, 52-, 106-, 242-, 484-, and 996-tone RU is defined as one segment. LDPC tone mapping is performed separately for the upper and lower 80 MHz frequency subblocks of a 2×996-tone RU as indicated by the frequency subblock index l.

Since LDPC tone mapping is not performed on BCC coded streams, for BCC coded spatial streams, Equation (27-97) applies.


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$$d''_{k,i,n,l,r,u} = d'_{k,i,n,l,r,u} \quad (27\text{-}97)$$

where

$k = 0, 1, \ldots, N_{SD} - 1$ for a 26-, 52-, 106-, and 242-tone RU

$i = 1, \ldots, N_{SS,r,u}$

$n = 0, 1, \ldots, N_{SYM} - 1$

$l = 0$ for a 26-, 52-, 106-, and 242-tone RU

$u = 0, \ldots, N_{user,r} - 1$

$r = 0, \ldots, N_{RU} - 1$

### 27.3.12.11 Segment deparser

For a 26-, 52-, 106-, 242-, 484-, and 996-tone RU, the segment deparsing is not performed, and $d^{(i_{Seg})}_{k,i,n,r,u}$ is specified in Equation (27-98).

$$d^{(i_{Seg})}_{k,i,n,r,u} = d''_{k,i,n,0,r,u}, \quad \text{if } 0 \le k \le N_{SD} - 1, i_{Seg} = 0 \quad (27\text{-}98)$$

For a 2×996-tone RU in a 160 MHz HE PPDU, the two frequency subblocks at the output of the LDPC tone mapper are combined into one frequency segment as specified in Equation (27-99).

$$d^{(i_{Seg})}_{k,i,n,r,u} = \begin{cases} d''_{k,i,n,0,r,u}, & \text{if } 0 \le k \le \frac{N_{SD}}{2} - 1 \\ d''_{k-\frac{N_{SD}}{2},i,n,l,r,u}, & \text{if } \frac{N_{SD}}{2} \le k \le N_{SD} - 1 \end{cases}, i_{Seg} = 0 \quad (27\text{-}99)$$

For a 2×996-tone RU in an 80+80 MHz HE PPDU, the segment deparsing is not performed, and $d^{(i_{Seg})}_{k,i,n,r,u}$ is specified in Equation (27-100).

$$d^{(i_{Seg})}_{k,i,n,r,u} = d''_{k,i,n,i_{Seg},r,u}, \quad \text{if } 0 \le k \le N_{SD} - 1, i_{Seg} = 0, 1 \quad (27\text{-}100)$$

NOTE—As per Table 21-7 (Center frequency of the portion of the PPDU transmitted in frequency segment iSeg), $f_c^{(0)}$ is always less than $f_c^{(1)}$ in the case of an 80+80 MHz HE PPDU. Hence, $d''_{k,i,n,0,r,u}$ (frequency subblock 0) is always transmitted in the frequency segment lower in frequency, while $d''_{k,i,n,1,r,u}$ (frequency subblock 1) is always transmitted in the frequency segment higher in frequency.

### 27.3.12.12 Space-time block coding

For an HE PPDU, STBC is applied with only 1 spatial stream and only if DCM is not applied. Its application is indicated by the STBC field in the HE-SIG-A field. In an HE MU PPDU, STBC coding is used in all RUs or not used in any of the RUs. If any RU in an HE MU PPDU uses DL MU-MIMO, STBC shall not be used in any RU in the HE MU PPDU.

The STBC encoding process is described in 21.3.10.9.4 (Space-time block coding), with $N_{SS,0} = 1$ and $N_{STS,0} = 2$.

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### 27.3.12.13 Pilot subcarriers

For a user transmitting on the $i^{th}$ 26-tone RU in a given PPDU BW, two pilot subcarriers shall be inserted in subcarriers $k \in K_{R26_i}$, where $K_{R26_i}$ is given by the $i^{th}$ pilot index set in the row of given PPDU BW of Table 27-38 (Pilot indices for a 26-tone RU(11ax)).

**Table 27-38—Pilot indices for a 26-tone RU(11ax)**

| PPDU BW | $K_{R26_i}$ |
|---|---|
| 20 MHz, $i$ = 1:9 | {−116, −102}, {−90, −76}, {−62, −48}, {−36, −22}, {−10, 10}, {22, 36}, {48, 62}, {76, 90}, {102, 116} |
| 40 MHz, $i$ = 1:18 | {−238, −224}, {−212, −198}, {−184, −170}, {−158, −144}, {−130, −116}, {−104, −90}, {−78, −64}, {−50, −36}, {−24, −10}, {10, 24}, {36, 50}, {64, 78}, {90, 104}, {116, 130}, {144, 158}, {170, 184}, {198, 212}, {224, 238} |
| 80 MHz, $i$ = 1:37 | {−494, −480}, {−468, −454}, {−440, −426}, {−414, −400}, {−386, −372}, {−360, −346}, {−334, −320}, {−306, −292}, {−280, −266}, {−252, −238}, {−226, −212}, {−198, −184}, {−172, −158}, {−144, −130}, {−118, 104}, {−92, −78}, {−64, −50}, {−38, −24}, {−10, 10}, {24, 38}, {50, 64}, {78, 92}, {104, 118}, {130, 144}, {158, 172}, {184, 198}, {212, 226}, {238, 252}, {266, 280}, {292, 306}, {320, 334}, {346, 360}, {372, 386}, {400, 414}, {426, 440}, {454, 468}, {480, 494} |
| 160 MHz, $i$ = 1:74 | {pilot subcarrier indices in 80 MHz −512, pilot subcarrier indices in 80 MHz +512} |

The pilot mapping $P_n^k$ for the subcarrier $k$ for symbol $n$ shall be as specified in Equation (27-101).

$$P_n^{k \in K_{R26_i}} = \{\Psi_{n \bmod 2}, \Psi_{(n+1) \bmod 2}\}$$
$$P_n^{k \notin K_{R26_i}} = 0 \quad (27\text{-}101)$$

where

$\Psi_m$ is defined in Table 27-39 (The 2 pilot values for a 26−tone RU(11ax))

**Table 27-39—The 2 pilot values for a 26–tone RU(11ax)**

| $\Psi_0$ | $\Psi_1$ |
|---|---|
| 1 | −1 |

For a user transmitting on the $i^{th}$ 52-tone RU in a given PPDU BW, four pilot subcarriers shall be inserted in subcarriers $k \in K_{R52_i}$, where $K_{R52_i}$ is given by the $i^{th}$ pilot index set in the row of given PPDU BW of Table 27-40 (Pilot indices for 52-tone RU transmission(11ax)).

**Table 27-40—Pilot indices for 52-tone RU transmission(11ax)**

| PPDU BW | $K_{R52_i}$ |
|---|---|
| 20 MHz, $i$ = 1:4 | {−116, −102, −90, −76}, {−62, −48, −36, −22}, {22, 36, 48, 62}, {76, 90, 102, 116} |


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**Table 27-40—Pilot indices for 52-tone RU transmission(11ax) *(continued)***

| | |
|---|---|
| 40 MHz, $i$ = 1:8 | {−238, −224, −212, −198}, {−184, −170, −158, −144}, {−104, −90, −78, −64}, {−50, −36, −24, −10}, {10, 24, 36, 50}, {64, 78, 90, 104}, {144, 158, 170, 184}, {198, 212, 224, 238} |
| 80 MHz, $i$ = 1:16 | {−494, −480, −468, −454}, {−440, −426, −414, −400}, {−360, −346, −334, −320}, {−306, −292, −280, −266}, {−252, −238, −226, −212}, {−198, −184, −172, −158}, {−118, −104, −92, −78}, {−64, −50, −38, −24}, {24, 38, 50, 64}, {78, 92, 104, 118}, {158, 172, 184, 198}, {212, 226, 238, 252}, {266, 280, 292, 306}, {320, 334, 346, 360}, {400, 414, 426, 440}, {454, 468, 480, 494} |
| 160 MHz, $i$ = 1:32 | {pilot subcarrier indices in 80 MHz −512, pilot subcarrier indices in 80 MHz +512} |

The pilot mapping $P_n^k$ for the subcarrier $k$ for symbol $n$ shall be as specified in Equation (27-102).

$$P_n^{K_{R52_i}} = \{\Psi_{n \bmod 4}, \Psi_{(n+1) \bmod 4}, \Psi_{(n+2) \bmod 4}, \Psi_{(n+3) \bmod 4}\}$$
$$P_n^{k \notin K_{R52_i}} = 0 \quad (27\text{-}102)$$

where

$\Psi_m$ is defined in Table 27-41 (The 4 pilot values in a 52- and 106-tone RU(11ax))

**Table 27-41—The 4 pilot values in a 52- and 106-tone RU(11ax)**

| $\Psi_0$ | $\Psi_1$ | $\Psi_2$ | $\Psi_3$ |
|---|---|---|---|
| 1 | 1 | 1 | –1 |

For a user transmitting on the $i^{\text{th}}$ 106-tone RU in a given PPDU BW, four pilot subcarriers shall be inserted at subcarriers $k \in K_{R106_i}$, where $K_{R106_i}$ is given by the $i^{\text{th}}$ pilot index set in the row of given PPDU BW of Table 27-42 (Pilot indices for 106-tone RU transmission(11ax)).

**Table 27-42—Pilot indices for 106-tone RU transmission(11ax)**

| PPDU BW | $K_{R106_i}$ |
|---|---|
| 20 MHz, $i$ = 1:2 | {−116, −90, −48, −22}, {22, 48, 90, 116} |
| 40 MHz, $i$ = 1:4 | {−238, −212, −170, −144}, {−104, −78, −36, −10}, {10, 36, 78, 104}, {144, 170, 212, 238} |
| 80 MHz, $i$ = 1:8 | {−494, −468, −426, −400}, {−360, −334, −292, −266}, {−252, −226, −184, −158}, {−118, −92, −50, −24}, {24, 50, 92, 118}, {158, 184, 226, 252}, {266, 292, 334, 360}, {400, 426, 468, 494} |
| 160 MHz, $i$ = 1:16 | {pilot subcarrier indices in 80 MHz −512, pilot subcarrier indices in 80 MHz +512} |

The pilot mapping $P_n^k$ for the subcarrier $k$ for symbol $n$ shall be as specified in Equation (27-103).

$$P_n^{K_{R106_i}} = \{\Psi_{n \bmod 4}, \Psi_{(n+1) \bmod 4}, \Psi_{(n+2) \bmod 4}, \Psi_{(n+3) \bmod 4}\}$$
$$P_n^{k \notin K_{R106_i}} = 0 \quad (27\text{-}103)$$

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where

$\Psi_m$ is defined in Table 27-41 (The 4 pilot values in a 52- and 106-tone RU(11ax))

For a user transmitting on the $i^{th}$ 242-tone RU in a given PPDU BW, 8 pilot subcarriers shall be inserted in subcarriers $k \in K_{R242_i}$, where $K_{R242_i}$ is given by the $i^{th}$ pilot index set in the row of given PPDU BW of Table 27-43 (Pilot indices for 242-tone RU transmission(11ax)).

**Table 27-43—Pilot indices for 242-tone RU transmission(11ax)**

| PPDU BW | $K_{R242_i}$ |
|---|---|
| 20 MHz, $i$ = 1 | {−116, −90, −48, −22, 22, 48, 90, 116} |
| 40 MHz, $i$ = 1:2 | {−238, −212, −170, −144, −104, −78, −36, −10}, {10, 36, 78, 104, 144, 170, 212, 238} |
| 80 MHz, $i$ = 1:4 | {−494, −468, −426, −400, −360, −334, −292, −266}, {−252, −226, −184, −158, −118, −92, −50, −24}, {24, 50, 92, 118, 158, 184, 226, 252}, {266, 292, 334, 360, 400, 426, 468, 494} |
| 160 MHz, $i$ = 1:8 | {pilot subcarrier indices in 80 MHz −512, pilot subcarrier indices in 80 MHz +512} |

The pilot mapping $P_n^k$ for the subcarrier $k$ for symbol $n$ shall be as specified in Equation (27-104).

$$P_n^{K_{R242_i}} = \{\Psi_{n \bmod 8}, \Psi_{(n+1) \bmod 8}, \Psi_{(n+2) \bmod 8}, \Psi_{(n+3) \bmod 8}, \Psi_{(n+4) \bmod 8}, \Psi_{(n+5) \bmod 8}, \Psi_{(n+6) \bmod 8}, \Psi_{(n+7) \bmod 8}\} \quad (27\text{-}104)$$

$$P_n^{k \notin K_{R242_i}} = 0$$

where

$\Psi_m$ is defined in Table 27-44 (The 8 pilot values in a 242-tone RU(11ax))

**Table 27-44—The 8 pilot values in a 242-tone RU(11ax)**

| $\Psi_0$ | $\Psi_1$ | $\Psi_2$ | $\Psi_3$ | $\Psi_4$ | $\Psi_5$ | $\Psi_6$ | $\Psi_7$ |
|---|---|---|---|---|---|---|---|
| 1 | 1 | 1 | –1 | –1 | 1 | 1 | 1 |

For a user transmitting on the $i^{th}$ 484-tone RU in a given PPDU BW, 16 pilot subcarriers shall be inserted in subcarriers $k \in K_{R484_i}$, where $K_{R484_i}$ is given by the $i^{th}$ pilot index set in the row of given PPDU BW of Table 27-45 (Pilot indices for 484-tone RU transmission(11ax)).

**Table 27-45—Pilot indices for 484-tone RU transmission(11ax)**

| PPDU BW | $K_{R484_i}$ |
|---|---|
| 40 MHz, $i$ = 1 | {−238, −212, −170, −144, −104, −78, −36, −10, 10, 36, 78, 104, 144, 170, 212, 238} |
| 80 MHz, $i$ = 1:2 | {−494, −468, −426, −400, −360, −334, −292, −266, −252, −226, −184, −158, −118, −92, −50, −24}, {24, 50, 92, 118, 158, 184, 226, 252, 266, 292, 334, 360, 400, 426, 468, 494} |
| 160 MHz, $i$ = 1:4 | {pilot subcarrier indices in 80 MHz −512, pilot subcarrier indices in 80 MHz +512} |


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The pilot mapping $P_n^k$ for the subcarrier $k$ for symbol $n$ shall be as specified in Equation (27-105).

$$\begin{aligned} P_n^{K_{R484_i}} = \{ & \Psi_{n \bmod 8}, \Psi_{(n+1) \bmod 8}, \Psi_{(n+2) \bmod 8}, \Psi_{(n+3) \bmod 8}, \\ & \Psi_{(n+4) \bmod 8}, \Psi_{(n+5) \bmod 8}, \Psi_{(n+6) \bmod 8}, \Psi_{(n+7) \bmod 8}, \\ & \Psi_{(n+8) \bmod 8}, \Psi_{(n+9) \bmod 8}, \Psi_{(n+10) \bmod 8}, \Psi_{(n+11) \bmod 8}, \\ & \Psi_{(n+12) \bmod 8}, \Psi_{(n+13) \bmod 8}, \Psi_{(n+14) \bmod 8}, \Psi_{(n+15) \bmod 8} \} \\ P_n^{k \notin K_{R484_i}} = 0 & \end{aligned} \quad (27\text{-}105)$$

where

$\Psi_m$ is defined in Table 27-44 (The 8 pilot values in a 242-tone RU(11ax))

For a user transmitting on the $i^{\text{th}}$ 996-tone RU in a given PPDU BW, 16 pilot subcarriers shall be inserted in subcarriers $k \in K_{R996_i}$, where $K_{R996_i}$ is given by the $i^{\text{th}}$ pilot index set in the row of given PPDU BW of Table 27-46 (Pilot indices for 996-tone RU transmission(11ax)).

**Table 27-46—Pilot indices for 996-tone RU transmission(11ax)**

| PPDU BW | $K_{R996_i}$ |
|---|---|
| 80 MHz, $i$ = 1 | {−468, −400, −334, −266, −226, −158, −92, −24, 24, 92, 158, 226, 266, 334, 400, 468} |
| 160 MHz, $i$ = 1:2 | {for $i$ = 1 pilot subcarrier indices in 80 MHz −512, for $i$ = 2 pilot subcarrier indices in 80 MHz +512} |

The pilot mapping $P_n^k$ for the subcarrier $k$ for symbol $n$ shall be as specified in Equation (27-106).

$$\begin{aligned} P_n^{K_{R996_i}} = \{ & \Psi_{n \bmod 8}, \Psi_{(n+1) \bmod 8}, \Psi_{(n+2) \bmod 8}, \Psi_{(n+3) \bmod 8}, \\ & \Psi_{(n+4) \bmod 8}, \Psi_{(n+5) \bmod 8}, \Psi_{(n+6) \bmod 8}, \Psi_{(n+7) \bmod 8}, \\ & \Psi_{(n+8) \bmod 8}, \Psi_{(n+9) \bmod 8}, \Psi_{(n+10) \bmod 8}, \Psi_{(n+11) \bmod 8}, \\ & \Psi_{(n+12) \bmod 8}, \Psi_{(n+13) \bmod 8}, \Psi_{(n+14) \bmod 8}, \Psi_{(n+15) \bmod 8} \} \\ P_n^{k \notin K_{R996_i}} = 0 & \end{aligned} \quad (27\text{-}106)$$

where

$\Psi_m$ is defined in Table 27-44 (The 8 pilot values in a 242-tone RU(11ax))

For a 160 MHz transmission (equivalently two 996-tone RU transmissions), the 80 MHz (equivalently 996-tone RU) pilot mapping is replicated in the two 80 MHz subchannels of the 160 MHz transmission. Specifically, 32 pilot subcarriers shall be inserted in subcarriers $k \in K_{\text{R2×996}_i}$, where $K_{\text{R2×996}_i}$ is given by {–980, –912, –846, –778, –738, –670, –604, –536, –488, –420, –354, –286, –246, –178, –112, –44, 44, 112, 178, 246, 286, 354, 420, 488, 536, 604, 670, 738, 778, 846, 912, 980}. The pilot mapping $P_n^k$ for the subcarrier $k$ for symbol $n$ shall be as specified in Equation (27-107).

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$$
\begin{aligned}
P_n^{K_{R2\times996_i}} = \{&\Psi_{n \bmod 8}, \Psi_{(n+1) \bmod 8}, \Psi_{(n+2) \bmod 8}, \Psi_{(n+3) \bmod 8},\\
&\Psi_{(n+4) \bmod 8}, \Psi_{(n+5) \bmod 8}, \Psi_{(n+6) \bmod 8}, \Psi_{(n+7) \bmod 8},\\
&\Psi_{(n+8) \bmod 8}, \Psi_{(n+9) \bmod 8}, \Psi_{(n+10) \bmod 8}, \Psi_{(n+11) \bmod 8},\\
&\Psi_{(n+12) \bmod 8}, \Psi_{(n+13) \bmod 8}, \Psi_{(n+14) \bmod 8}, \Psi_{(n+15) \bmod 8},\\
&\Psi_{n \bmod 8}, \Psi_{(n+1) \bmod 8}, \Psi_{(n+2) \bmod 8}, \Psi_{(n+3) \bmod 8},\\
&\Psi_{(n+4) \bmod 8}, \Psi_{(n+5) \bmod 8}, \Psi_{(n+6) \bmod 8}, \Psi_{(n+7) \bmod 8},\\
&\Psi_{(n+8) \bmod 8}, \Psi_{(n+9) \bmod 8}, \Psi_{(n+10) \bmod 8}, \Psi_{(n+11) \bmod 8},\\
&\Psi_{(n+12) \bmod 8}, \Psi_{(n+13) \bmod 8}, \Psi_{(n+14) \bmod 8}, \Psi_{(n+15) \bmod 8}\}
\end{aligned}
\tag{27-107}
$$

$$
P_n^{k \notin K_{R2\times996_i}} = 0
$$

where

$\Psi_m$ is defined in Table 27-44 (The 8 pilot values in a 242-tone RU(11ax))

For a noncontiguous 80+80 MHz transmission, each frequency segment shall follow the 80 MHz pilot subcarrier allocation and values defined for 996-tone RU in 80 MHz transmission as specified in Equation (27-106).

The pilot mapping described in this subclause shall be copied to all space-time streams before the space-time stream cyclic shifts are applied.

### 27.3.12.14 OFDM modulation

If midambles are not present, the time domain waveform of the Data field of an HE PPDU that is not an HE TB PPDU for transmit chain $i_{TX}$, where $1 \le i_{TX} \le N_{TX}$, and frequency segment $i_{Seg}$ shall be as defined in Equation (27-108).

$$
\begin{aligned}
r_{\text{HE-Data}}^{(i_{Seg} i_{TX})}(t) = &\frac{1}{\sqrt{\sum_{r=0}^{N_{RU}-1} \alpha_r^2 |K_r|}} \sum_{n=0}^{N_{SYM}-1} w_{T_{\text{HE-Data}}}(t - nT_{SYM}) \sum_{r=0}^{N_{RU}-1} \frac{\alpha_r}{\sqrt{N_{STS,\,r,\,total}}}\\
&\sum_{k \in K_r} \sum_{u=0}^{N_{user,\,r}-1} \sum_{m=1}^{N_{STS,\,r,\,u}} \left( \left[ Q_k^{(i_{Seg})} \right]_{i_{TX},\,(M_{r,\,u}+m)} (\tilde{D}_{k,\,m,\,n,\,r}^{(i_{Seg},\,u)} + p_{n+2+N_{\text{HE-SIG-A}}+N_{\text{HE-SIG-B}}} P_n^k) \right.\\
&\left. \cdot \exp(j2\pi k \Delta_{F,\,\text{HE}}(t - nT_{SYM} - T_{GI,\,Data} - T_{CS,\,\text{HE}}(M_{r,\,u}+m))) \right)
\end{aligned}
\tag{27-108}
$$

where

| | |
|---|---|
| $T_{SYM}$ | is defined in Table 27-13 (Timing-related constants(11ax)) |
| $p_n$ | is defined in 17.3.5.10 (OFDM modulation) |
| $P_n^k$ | can be selected from Equation (27-101) to Equation (27-107) defined in 27.3.12.13 (Pilot subcarriers), depending on the corresponding RU size |
| $T_{CS,\,\text{HE}}(M_{r,\,u}+m)$ | represents the cyclic shift for space-time stream $M_{r,u}+m$ as defined in 27.3.11.2.2 (Cyclic shift for HE modulated fields) |
| $T_{GI,\,Data}$ | is the guard interval duration as defined in Table 27-13 (Timing-related constants(11ax)) |


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$\tilde{D}_{k,m,n,r}^{(i_{Seg},u)}$ is the transmitted constellation for user $u$ in the $r^{\text{th}}$ RU at subcarrier $k$, space-time stream $m$, and Data field OFDM symbol $n$ and is defined by Equation (27-109)

$$\tilde{D}_{k,m,n,r}^{(i_{Seg},u)} = \begin{cases} 0, k \in K_{\text{Pilot}} \\ \tilde{d}_{M_r(k),m,n,r,u}^{(i_{Seg})}, \text{otherwise} \end{cases} \quad (27\text{-}109)$$

where

$K_{\text{Pilot}}$ is the set of pilot subcarrier indices for the Data field OFDM symbols as defined in 27.3.12.13 (Pilot subcarriers)

$M_r(k)$ is defined in Equation (27-110)

$$M_r(k) = k - K_{r,\min} - \left|\{k' : K_{r,\min} \le k' < k\} \cap K_{\text{Pilot}}\right| \quad (27\text{-}110)$$

where

$K_{r,min}$ is the minimum value of the set $K_r$

$|\Phi|$ is the cardinality of a set $\Phi$

NOTE—$M_r(k)$ translates a subcarrier index ($k \in K_r$) into the index of data symbols in a transmission over RU $r$ ($0 \le M_r(k) \le N_{SD}$). The subcarrier index $k$ for the data subcarrier is first offset by the minimum value of subcarrier index $K_{r,min}$ (for the lower edge subcarrier) in this RU and then subtracted by the number of pilot subcarriers falling in between the data subcarrier and the edge subcarrier.

In a noncontiguous 80+80 MHz transmission, each frequency segment shall follow the 80 MHz HE subcarrier mapping as specified in 27.3.10 (Mathematical description of signals).

If midambles are not present, the time domain waveform of the Data field of an HE TB PPDU for user $u$ in the $r^{\text{th}}$ RU from transmit chain $i_{TX}$, where $1 \le i_{TX} \le N_{TX}$, shall be as defined in Equation (27-111).

$$r_{\text{HE-Data},r,u}^{(i_{Seg}i_{TX})}(t) = \frac{1}{\sqrt{|K_r|}} \sum_{n=0}^{N_{SYM}-1} w_{T_{\text{HE-Data}}}(t - nT_{SYM}) \frac{1}{\sqrt{N_{STS,r,u}}} \sum_{k \in K_r} \sum_{m=1}^{N_{STS,r,u}} \left( \left[ Q_{k,u}^{(i_{Seg})} \right]_{i_{TX},m} (\tilde{D}_{k,m,n,r}^{(i_{Seg},u)} + p_{n+4} P_n^k) \cdot \exp(j2\pi k \Delta_{F,\text{HE}}(t - nT_{SYM} - T_{GI,Data} - T_{CS,HE}(M_{r,u} + m))) \right) \quad (27\text{-}111)$$

where

$Q_{k,u}^{(i_{Seg})}$ is defined in 27.3.10 (Mathematical description of signals)

$M_{r,u}$ is given by the TXVECTOR parameter STARTING_STS_NUM

### 27.3.12.15 Dual carrier modulation

DCM modulates the same information on a pair of subcarriers. DCM is an optional modulation scheme for the HE-SIG-B and Data fields. DCM is applicable to only HE-MCSs and HE-SIG-B-MCSs with indices 0, 1, 3, and 4.

The constellation mapper for DCM is defined in 27.3.12.9 (Constellation mapping). The LDPC tone mapper for DCM is defined in 27.3.12.10 (LDPC tone mapper). The BCC interleaver for DCM is defined in 27.3.12.8 (BCC interleavers).

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### 27.3.12.16 Midambles

An HE STA may include midambles in an HE PPDU transmission in fast varying channels, i.e., channels with high Doppler, to facilitate channel estimation update during the PPDU. Midambles are inserted only if $N_{STS} \leq 4$. The recipient might use the midambles to compensate the channel estimation if it is varying fast in channels with high Doppler.

If the Doppler field of the HE-SIG-A field is 1 in an HE SU PPDU, HE ER SU PPDU, or HE MU PPDU or if the Doppler subfield in the Common Info field in the Trigger frame preceding an HE TB PPDU is 1, then midambles are present in the Data field of the HE PPDU every $M_{MA}$ OFDM symbols, where $M_{MA}$ is either 10 or 20 as indicated by the NSTS And Midamble Periodicity field in the HE-SIG-A field (see 27.3.11.7 (HE-SIG-A field)) or by the Number Of HE-LTF Symbols And Midamble Periodicity subfield in the Common Info field in the Trigger frame (see 9.3.1.22 (Trigger frame format(11ax))).

Each midamble is the same as the HE-LTF field(s) in the preamble of the same PPDU as defined in 27.3.11.10 (HE-LTF field), as shown in Figure 27-42 (HE PPDU with midamble(11ax)).

An HE STA shall not transmit an HE MU PPDU with midambles if there is MU-MIMO on any RU.

The scrambling and encoding process of the bits in the Data field OFDM symbols is identical for transmissions with or without midamble.

If present, the number of midamble periods, $N_{MA}$, in a PPDU is calculated using Equation (27-112).

$$N_{MA} = max\left(0, \left\lceil \frac{N_{SYM} - 1}{M_{MA}} \right\rceil - 1\right) \quad (27\text{-}112)$$

where $N_{SYM}$ is as defined in 27.3.12.5 (Coding).

As shown in Figure 27-42 (HE PPDU with midamble(11ax)), the first midamble is inserted immediately after the $M_{MA}{}^{th}$ OFDM symbol in the Data field, and a midamble is not inserted after the last data OFDM symbol if mod($N_{SYM}$, $M_{MA}$) = 0. At the end of an HE PPDU, if mod($N_{SYM}$, $M_{MA}$) = 1, there is also no midamble inserted before the last OFDM symbol, as shown in Figure 27-43 (Midamble at the end of an HE PPDU(11ax)).

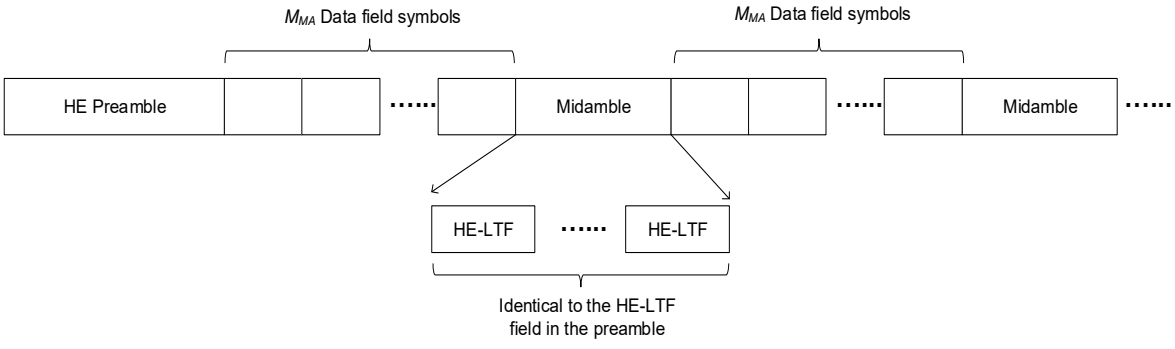


**Figure 27-42—HE PPDU with midamble(11ax)**


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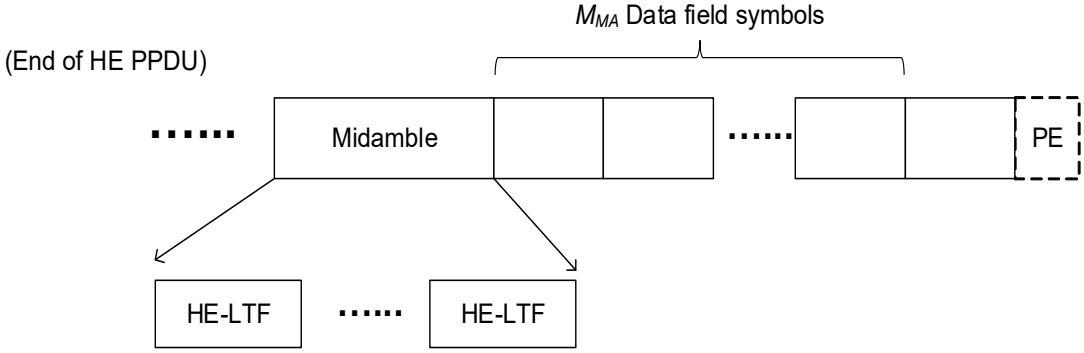


**Figure 27-43—Midamble at the end of an HE PPDU(11ax)**

In an HE SU PPDU, HE ER SU PPDU, or HE MU PPDU, if the Doppler field of the HE-SIG-A field is 1 and $N_{SYM} \leq M_{MA} + 1$, there is no midamble present in the current PPDU. In this case, the Doppler field setting to 1 indicates that the current channel between the transmitter and the recipient is with high channel Doppler and the transmitter recommends to the recipient that midamble may be used for the PPDUs of the reverse link.

### 27.3.13 Packet extension

A PE field of duration 0 μs, 4 μs, 8 μs, 12 μs, or 16 μs is present in an HE PPDU. The PE field provides additional receive processing time at the end of the HE PPDU. The PE field, if present, shall be transmitted with the same average power as the Data field and shall not cause significant power leakage outside of the spectrum used by the Data field. Other than that, its content is arbitrary. In an OFDMA HE PPDU, the spectrum used by the Data field for the purpose of packet extension is commensurate with the locations and sizes of the occupied RUs, not the PPDU bandwidth. For example, the Data field of an OFDMA HE PPDU using a 26-tone RU would have a spectrum that is approximately 2 MHz wide.

The duration of the PE field for an HE SU PPDU, HE ER SU PPDU, or HE MU PPDU is determined by both the pre-FEC padding factor value in the last OFDM symbol(s) of the Data field and the TXVECTOR parameter NOMINAL_PACKET_PADDING.

For an HE SU or HE ER SU PPDU, the nominal $T_{PE}$ value ($T_{PE,nominal}$) is given by Table 27-47 (Nominal TPE values(11ax)). In this case, $a$ in Table 27-47 (Nominal TPE values(11ax)) is given by Equation (27-71) or Equation (27-72).

For an HE MU PPDU, the nominal $T_{PE}$ value ($T_{PE,nominal}$) is given by Equation (27-113).

$$T_{PE,nominal} = \max_u T_{PE,nominal,u} \quad (27\text{-}113)$$

where

$T_{PE,nominal,u}$ is the nominal $T_{PE}$ value for user $u$ and is also given by Table 27-47 (Nominal TPE values(11ax))

$\max_u f(u)$ is the maximum value of $f(u)$ over all values of $u$

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In this case, *a* in Table 27-47 (Nominal TPE values(11ax)) is given by Equation (27-83) or Equation (27-84).

**Table 27-47—Nominal $T_{PE}$ values(11ax)**

| *a* | TXVECTOR parameter NOMINAL_PACKET_PADDING (HE SU PPDU or HE ER SU PPDU) or NOMINAL_PACKET_PADDING[*u*] (HE MU PPDU) | | |
|---|---|---|---|
| | **0 µs** | **8 µs** | **16 µs** |
| 1 | 0 µs | 0 µs | 4 µs |
| 2 | 0 µs | 0 µs | 8 µs |
| 3 | 0 µs | 4 µs | 12 µs |
| 4 | 0 µs | 8 µs | 16 µs |

The duration of the PE field, $T_{PE}$, may take a value of 0, 4, 8, 12, or 16 µs. $T_{PE}$ for an HE SU, HE ER SU, or HE MU PPDU shall not be less than $T_{PE,nominal}$. $T_{PE}$ for an HE SU, HE ER SU, or HE MU PPDU should be equal to $T_{PE,nominal}$ to minimize the packet extension overhead. Figure 27-44 (PE field duration of an HE SU PPDU or HE ER SU PPDU without midambles if TXVECTOR parameter NOMINAL_PACKET_PADDING is 8 µs and TPE = TPE,nominal(11ax)) and Figure 27-45 (PE field duration of an HE SU PPDU or HE ER SU PPDU without midambles if TXVECTOR parameter NOMINAL_PACKET_PADDING is 16 µs and TPE = TPE,nominal(11ax)) show examples of the PE field duration in an HE SU PPDU or HE ER SU PPDU without midambles if the TXVECTOR parameter NOMINAL_PACKET_PADDING is 8 µs and 16 µs, respectively, and $T_{PE} = T_{PE,nominal}$. STBC is not used in these examples.

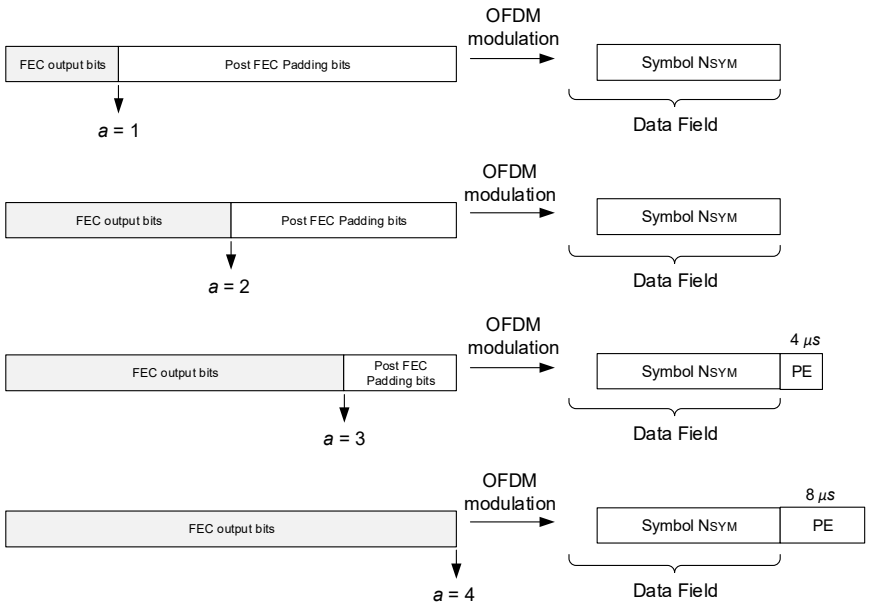


**Figure 27-44—PE field duration of an HE SU PPDU or HE ER SU PPDU without midambles if TXVECTOR parameter NOMINAL_PACKET_PADDING is 8 µs and $T_{PE} = T_{PE,nominal}$(11ax)**


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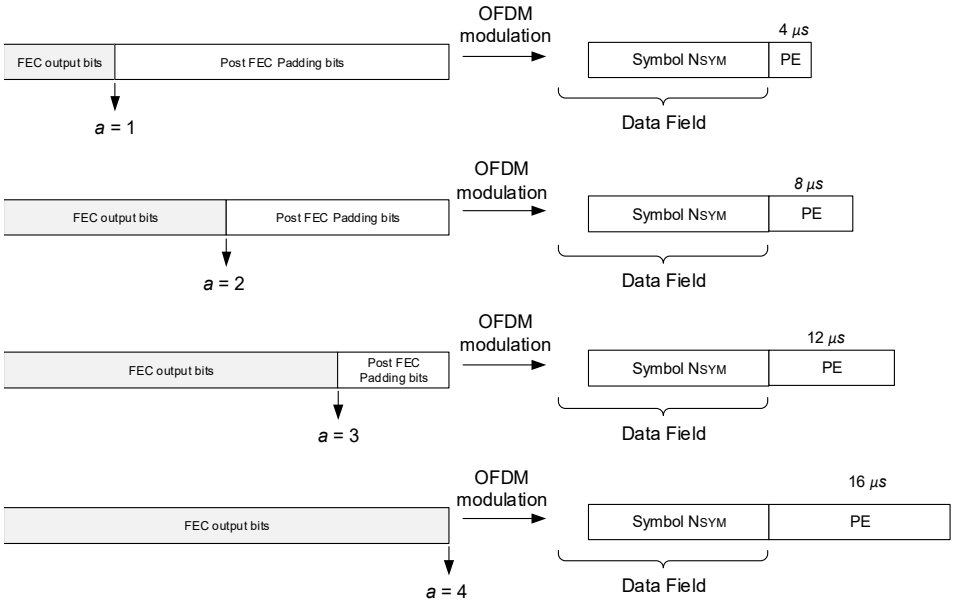


**Figure 27-45—PE field duration of an HE SU PPDU or HE ER SU PPDU without midambles if TXVECTOR parameter NOMINAL_PACKET_PADDING is 16 µs and $T_{PE} = T_{PE,nominal}$(11ax)**

$T_{PE}$ for an HE sounding NDP is 4 µs.

If transmitting an HE TB PPDU for which the TXVECTOR parameter TRIGGER_METHOD is TRIGGER_FRAME, each transmitter of an HE TB PPDU shall append a PE field with a duration $T_{PE}$ calculated using Equation (27-114), except for an HE TB feedback NDP (see 27.3.4 (HE PPDU formats)), which has $T_{PE} = 0$.

$$T_{PE} = \left\lfloor \frac{\left(\frac{\text{LENGTH} + m + 3}{3} \times 4 - T_{\text{HE-PREAMBLE}}\right) - N_{SYM} T_{SYM} - N_{MA} N_{\text{HE-LTF}} T_{\text{HE-LTF-SYM}}}{4} \right\rfloor \times 4 \quad (27\text{-}114)$$

where

$m = 2$ for an HE TB PPDU

LENGTH is the value indicated by the UL Length subfield in the Common Info field in the Trigger frame

$T_{\text{HE-PREAMBLE}}$ is the value for an HE TB PPDU in Equation (27-121)

$T_{\text{HE-STF-T}}$, $T_{\text{HE-LTF-SYM}}$, $T_{\text{RL-SIG}}$, and $T_{\text{HE-SIG-A}}$ are defined in Table 27-13 (Timing-related constants(11ax))

$N_{MA}$ is the number of midamble periods in the current PPDU

$$N_{SYM} = \left\lfloor \left(\frac{\text{LENGTH} + m + 3}{3} \times 4 - T_{\text{HE-PREAMBLE}} - N_{MA} N_{\text{HE-LTF}} T_{\text{HE-LTF-SYM}}\right) / T_{SYM} \right\rfloor - b_{\text{PE-Disambiguity}} \quad (27\text{-}115)$$

$b_{\text{PE-Disambiguity}}$ is the value of the TXVECTOR parameter HE_TB_PE_DISAMBIGUITY

There are multiple methods for computing $N_{MA}$ for an HE TB PPDU that yield the same result; one example is as follows. The duration of one midamble period is defined in Equation (27-116).

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$$T_{MA} = M_{MA} T_{SYM} + N_{\text{HE-LTF}} T_{\text{HE-LTF-SYM}} \quad (27\text{-}116)$$

where $M_{MA}$ is the midamble periodicity indicated by the Number of HE-LTF Symbols And Midamble Periodicity subfield of the Common Info field in the Trigger frame. Equation (27-117) for computing $N_{MA}$ can be used instead of Equation (27-112).

$$N_{MA} = \begin{cases} 0, \text{ if Doppler} = 0 \\ max\left(0, \left\lfloor \left( \frac{LENGTH + 3 + m}{3} \times 4 - T_{\text{HE-PREAMBLE}} - (b_{\text{PE-Diambiguity}} + 2) \cdot T_{SYM} \right) / T_{MA} \right\rfloor \right), \text{ if Doppler} = 1 \end{cases} \quad (27\text{-}117)$$

where Doppler is indicated by the Doppler subfield of the Common Info field of the Trigger frame.

If transmitting an HE TB PPDU for which the TXVECTOR parameter TRIGGER_METHOD is TRS, each transmitter of the HE TB PPDU shall append a PE field with the duration $T_{PE}$ equal to the value specified in the TXVECTOR parameter DEFAULT_PE_DURATION.

The PE Disambiguity field of the HE-SIG-A field for an HE SU, HE ER SU (see Table 27-19 (HE-SIG-A field of an HE SU PPDU and HE ER SU PPDU(11ax))), or HE MU PPDU (see Table 27-21 (HE-SIG-A field of an HE MU PPDU(11ax))) shall be set to 1 if the condition in Equation (27-118) is met; otherwise, it shall be set to 0.

The PE Disambiguity subfield in the Common Info field of the Trigger frame (see Table 9-51 (Pre-FEC Padding Factor and PE Disambiguity subfields(11ax))) shall be set to 1 if the condition in Equation (27-118) is met for the HE TB PPDU solicited by the Trigger frame. Otherwise, it shall be set to 0.

$$T_{PE} + 4 \times \left( \left\lceil \frac{\text{TXTIME} - SignalExtension - 20}{4} \right\rceil - \left( \frac{\text{TXTIME} - SignalExtension - 20}{4} \right) \right) \geq T_{SYM} \quad (27\text{-}118)$$

where

| | |
|---|---|
| $T_{PE}$ | is the PE field duration |
| $T_{SYM}$ | is the symbol duration of the Data field as defined in 27.3.9 (Timing-related parameters) |
| TXTIME | is defined in 27.4.3 (TXTIME and PSDU_LENGTH calculation) (in μs) |
| *SignalExtension* | is 0 μs if TXVECTOR parameter NO_SIG_EXTN is true and is aSignalExtension as defined in Table 27-61 (HE PHY characteristics(11ax)) if TXVECTOR parameter NO_SIG_EXTN is false |

The receiver computes $N_{SYM}$, $T_{PE}$, and $N_{MA}$ using Equation (27-119), Equation (27-120), and Equation (27-122), respectively.

$$N_{SYM} = \left\lfloor \left( \frac{\text{L\_LENGTH} + m + 3}{3} \times 4 - T_{\text{HE-PREAMBLE}} - N_{MA} N_{\text{HE-LTF}} T_{\text{HE-LTF-SYM}} \right) / T_{SYM} \right\rfloor - b_{\text{PE-Disambiguity}} \quad (27\text{-}119)$$

$$T_{PE} = \left\lfloor \frac{\left( \frac{\text{L\_LENGTH} + m + 3}{3} \times 4 - T_{\text{HE-PREAMBLE}} \right) - N_{SYM} T_{SYM} - N_{MA} N_{\text{HE-LTF}} T_{\text{HE-LTF-SYM}}}{4} \right\rfloor \times 4 \quad (27\text{-}120)$$

where


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L_LENGTH is the value indicated by the LENGTH field of the L-SIG field

$$T_{\text{HE-PREAMBLE}} = \begin{cases} T_{\text{RL-SIG}} + T_{\text{HE-SIG-A}} + T_{\text{HE-STF-T}} + N_{\text{HE-LTF}} T_{\text{HE-LTF-SYM}}, \text{ for an HE TB PPDU} \\ T_{\text{RL-SIG}} + T_{\text{HE-SIG-A}} + T_{\text{HE-STF-NT}} + N_{\text{HE-LTF}} T_{\text{HE-LTF-SYM}}, \text{ for an HE SU PPDU} \\ T_{\text{RL-SIG}} + T_{\text{HE-SIG-A}} + N_{\text{HE-SIG-B}} T_{\text{HE-SIG-B}} + T_{\text{HE-STF-NT}} + N_{\text{HE-LTF}} T_{\text{HE-LTF-SYM}}, \text{ for an HE MU PPDU} \\ T_{\text{RL-SIG}} + T_{\text{HE-SIG-A-R}} + T_{\text{HE-STF-NT}} + N_{\text{HE-LTF}} T_{\text{HE-LTF-SYM}}, \text{ for an HE ER SU PPDU} \end{cases} \quad (27\text{-}121)$$

where

$T_{\text{RL-SIG}}$, $T_{\text{HE-STF-T}}$, $T_{\text{HE-STF-NT}}$, $T_{\text{HE-LTF-SYM}}$, $T_{\text{HE-SIG-A}}$, $T_{\text{HE-SIG-A-R}}$, and $T_{\text{HE-SIG-B}}$ are defined in Table 27-13 (Timing-related constants(11ax))

$N_{\text{HE-SIG-B}}$ and $N_{\text{HE-LTF}}$ are defined in Table 27-16 (Frequently used parameters(11ax))

$b_{\text{PE-Disambiguity}}$ is the value indicated by the PE Disambiguity subfield of the HE-SIG-A field for an HE SU, HE ER SU, or HE MU PPDU or the value indicated by the PE Disambiguity subfield in the Common Info field in the Trigger frame (see Table 9-51 (Pre-FEC Padding Factor and PE Disambiguity subfields(11ax))) for an HE TB PPDU

$N_{MA}$ may be computed by multiple methods that yield the same result, one example of which is given in Equation (27-122)

$$N_{MA} = \begin{cases} 0, \text{ if Doppler} = 0 \\ max\left(0, \left\lfloor \left( \frac{\text{L\_LENGTH} + 3 + m}{3} \times 4 - T_{\text{HE-PREAMBLE}} - (b_{\text{PE-Diambiguity}} + 2) \cdot T_{SYM} \right) / T_{MA} \right\rfloor\right), \text{ if Doppler} = 1 \end{cases} \quad (27\text{-}122)$$

where

$T_{MA}$ is defined in Equation (27-116), except that $M_{MA}$ is the midamble periodicity indicated by the NSTS And Midamble Periodicity subfield of the HE-SIG-A field in an HE SU PPDU and HE ER SU PPDU or by the Number Of HE-LTF Symbols And Midamble Periodicity subfield of the HE-SIG-A field in an HE MU PPDU

Doppler is indicated by the Doppler field of HE-SIG-A field

### 27.3.14 Non-HT duplicate transmission

If the TXVECTOR parameter FORMAT is NON_HT and the TXVECTOR parameter NON_HT_MODULATION is NON_HT_DUP_OFDM, the transmitted PPDU is a non-HT duplicate. Non-HT duplicate transmission is used to transmit to non-HT STAs, HT STAs, VHT STAs, and HE STAs that may be present in a part of a 40 MHz, 80 MHz, or 160 MHz channel (see Table 21-2 (Interpretation of FORMAT, NON_HT_MODULATION, CH_BANDWIDTH, and CH_OFFSET parameters)). The RL-SIG, HE-SIG-A, HE-SIG-B, HE-STF, HE-LTF, and PE fields are not transmitted.

The L-STF and L-LTF fields shall be transmitted in the same way as in the HE transmission. The L-SIG field shall be transmitted in the same way as in the HE transmission, with the following exceptions:

— The Rate and Length fields shall follow 17.3.4 (SIGNAL field)

— The four additional subcarriers at indices ± 27 and ± 28 are not modulated (no energy)

NOTE—The L-STF, L-LTF, and L-SIG fields are not transmitted in 20 MHz subchannels in which the preamble is punctured (see 27.3.7 (HE modulation and coding schemes (HE-MCSs))).

In a 40 MHz non-HT duplicate transmission, the Data field shall be as defined by Equation (19-61).

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For 80 MHz and 160 MHz non-HT duplicate transmissions, the Data field shall be as defined by Equation (27-123).

$$r^{i_{TX}}_{\text{non-HT},\,BW}(t) = \frac{N_{20\text{MHz}}}{\sqrt{N^{\text{Tone}}_{\text{NON\_HT\_DUP\_OFDM-Data}} \cdot |\Omega_{20\text{MHz}}|}} \sum_{n=0}^{N_{SYM}-1} w_{T_{SYM}}(t - nT_{SYM}) \tag{27-123}$$

$$\cdot \sum_{i_{BW}=0}^{N_{20\text{MHz}}-1} \left( \begin{array}{c} (1 - \text{INACTIVE\_SUBCHANNELS}[i_{BW}]) \sum_{k=-26}^{26} \Upsilon_{(k-K_{\text{Shift}}(i_{BW})),\,BW}(D_{k,n} + p_{n+1}P_k) \\ \cdot \exp(j2\pi(k - K_{\text{Shift}}(i_{BW}))\Delta_F(t - nT_{SYM} - T_{GI} - T^{i_{TX}}_{\text{CS}})) \end{array} \right)$$

where

$N_{20\text{MHz}}$ and $K_{Shift}(i)$
: are defined in 21.3.8.2.4 (L-SIG definition)

$P_k$ and $P_n$
: are defined in 17.3.5.10 (OFDM modulation)

$D_{k,n}$
: is defined in Equation (21-26)

$\Upsilon_{k,\,BW}$
: is defined in Equation (21-16) and Equation (21-17)

$T^{i_{TX}}_{CS}$
: represents the cyclic shift for transmit chain $i_{TX}$ with a value given in Table 21-10

$N^{\text{Tone}}_{\text{NON\_HT\_DUP\_OFDM-Data}}$
: has the value given in Table 27-17 (Number of modulated subcarriers and guard interval duration values for HE PPDU fields(11ax))

INACTIVE_SUBCHANNELS[$x$]
: is bit $x$ of the TXVECTOR parameter INACTIVE_SUBCHANNELS, if present, and is 0 otherwise.

$|\Omega_{20\text{MHz}}|$
: is equal to the number of bits with value 0 in the TXVECTOR parameter INACTIVE_SUBCHANNELS, if present, and is equal to $N_{20\text{MHz}}$ otherwise

In a noncontiguous 80+80 MHz non-HT duplicate transmission, data transmission in each frequency segment shall be as defined for an 80 MHz non-HT duplicate transmission in Equation (27-123).

For each non-HT duplicate PPDU transmission that is a preamble punctured PPDU, each punctured 20 MHz subchannel is indicated as punctured by including the value of 113 (01110001 in binary representation) in the 8 bits of the TXVECTOR parameter RU_ALLOCATION corresponding to the 242-tone RU that is most closely aligned with the punctured 20 MHz subchannel. Each 20 MHz subchannel that is not punctured is indicated as such by including the value of 192 (11000000 in binary representation) in the 8 bits of the TXVECTOR parameter RU_ALLOCATION corresponding to the 242-tone RU that is most closely aligned with that 20 MHz subchannel.

### 27.3.15 Transmit requirements for PPDUs sent in response to a triggering frame

#### 27.3.15.1 Introduction

An AP may solicit simultaneous HE TB PPDU transmissions or simultaneous non-HT or non-HT duplicate PPDU transmissions from multiple non-AP STAs using a triggering frame. Since there are multiple transmitters, (M118)precorrection of transmission time, frequency, sampling symbol clock, and power (in the case of an HE TB PPDU) by the non-AP STAs is necessary to mitigate synchronization and interference issues at the AP. Frequency and sampling clock (M118)precorrections are needed to prevent inter-carrier interference. Power (M118)precorrection is necessary to control interference between HE TB PPDU


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transmissions from the non-AP STAs. An AP may solicit simultaneous HE TB PPDU transmissions from both Class A and Class B devices. A non-AP STA that supports HE TB PPDU transmission shall support power (M118)precorrection as described in 27.3.15.2 (Power precorrection(M118)) and shall meet the (M118)precorrection accuracy requirements described in 27.3.15.3 (Precorrection accuracy requirements(M118)).

### 27.3.15.2 Power precorrection(M118)

A STA transmits an HE TB PPDU at the STA's maximum transmit power for the assigned HE-MCS if the UL Target Receive Power subfield of the User Info field in the Trigger frame that solicits the HE TB PPDU or the UL Target Receive Power subfield of the TRS Control field of the frame that solicits a response in an HE TB PPDU indicates that the maximum transmit power be used.

Otherwise, the STA calculates the transmit power, $Tx_{pwr}^{STA}$, of the HE TB PPDU for the assigned HE-MCS using Equation (27-124).

$$Tx_{pwr}^{STA} = PL_{DL} + TargetRx_{pwr} \quad (27\text{-}124)$$

where

$PL_{DL}$ is the DL pathloss

$TargetRx_{pwr}$ is the expected receive signal power, in units of dBm, as indicated by the UL Target Receive Power subfield in the User Info field in the Trigger frame or by the UL Target Receive Power subfield in the TRS control field

The STA computes $PL_{DL}$ using Equation (27-125).

$$PL_{DL} = Tx_{pwr}^{AP} - Rx_{pwr} \quad (27\text{-}125)$$

where

$Tx_{pwr}^{AP}$ is the AP's transmit power, in units of dBm/20 MHz, as indicated by the AP Tx Power subfield of the Common Info field in the Trigger frame, the encoding of which is specified in 9.3.1.22 (Trigger frame format(11ax)), or the AP Tx Power subfield of the TRS Control field, the encoding of which is specified in 9.2.4.7.1 (TRS Control).

$Rx_{pwr}$ is the receive signal power, in units of dBm/20 MHz, at the antenna connector of the STA of the triggering PPDU. $Rx_{pwr}$ is an average of the receive signal power over the antennas on which the average $PL_{DL}$ is being computed. If the triggering PPDU is a HT-mixed, VHT or HE PPDU, then the receive signal power is measured from the fields prior to the HT-STF, VHT-STF, or HE-STF, respectively.

NOTE 1—$Tx_{pwr}^{AP}$ and $Rx_{pwr}$ are in units of dBm/20 MHz, while $Tx_{pwr}^{STA}$ and $TargetRx_{pwr}$ are in units of dBm.

A STA that applies beamforming (BF) in the UL should take the BF gain into account when calculating the transmit power needed to meet the target RSSI.

NOTE 2—An AP could account for its beamforming gain in $Tx_{pwr}^{AP}$ or $Target_{RSSI}$ if the triggering PPDU used beamforming.

The transmit power of the HE TB PPDU is further subject to a STA's minimum and maximum transmit power limit due to hardware capability, regulatory requirements, local maximum transmit power levels (see 11.7.5 (Specification of regulatory and local maximum transmit power levels)), and non-IEEE-802.11 in-device coexistence requirements.

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A STA includes its UL power headroom in the HE TB PPDU following the rules defined in 26.5.2.3 (Non-AP STA behavior for UL MU operation).

### 27.3.15.3 Precorrection accuracy requirements(M118)

A STA that transmits an HE TB PPDU shall support per chain max($P$–32, –10) dBm as the minimum transmit power, where $P$ is the maximum power, in dBm, that the STA can transmit at the antenna connector of that chain using HE-MCS 0 while meeting the transmit EVM and spectral mask requirements.

A STA transmitting using HE-MCS 7 or lower, at or above the minimum power but below $P_{max,MCS7}$, shall meet the EVM requirements for HE-MCS 7 even if the HE-MCS used for the transmission is lower than HE-MCS 7, where $P_{max,MCS7}$ is the maximum transmit power supported by the STA for HE-MCS 7 in an HE TB PPDU.

A STA that transmits an HE TB PPDU shall support the absolute and relative transmit power requirements and the RSSI measurement accuracy requirements defined in Table 27-48 (Transmit power and RSSI measurement accuracy(11ax)).

**Table 27-48—Transmit power and RSSI measurement accuracy(11ax)**

| Parameter | Minimum requirement | | Comments |
|---|---|---|---|
| | Class A | Class B | |
| Absolute transmit power accuracy | ± 3 dB | ± 9 dB | Accuracy of achieving a specified transmit power. |
| RSSI measurement accuracy | ± 3 dB | ± 5 dB | The difference between the RSSI and the received power.<br><br>Requirements are valid from minimum receive to maximum receive input power. |
| Relative transmit power accuracy | N/A | ± 3 dB | Accuracy of achieving a change in transmit power for consecutive HE TB PPDU.<br><br>The relative transmit power accuracy is applicable only to Class B devices. |

The absolute transmit power accuracy is applicable for the entire range of transmit power that the STA is intending to use for the current band of operation. The RSSI accuracy requirements shall be applied to receive signal level range from –82 dBm to –20 dBm in the 2.4 GHz band and from –82 dBm to –30 dBm in the 5 GHz and 6 GHz bands. The requirements are for nominal (room) temperature conditions. The RSSI shall be measured during the reception of the non-HE portion of the HE PPDU preamble.

A STA compensates for carrier frequency offset (CFO) error and symbol clock error with respect to the corresponding triggering PPDU when transmitting the following types of PPDUs:

— HE TB PPDU

— Non-HT or non-HT duplicate PPDU with the TXVECTOR parameter TRIGGER_RESPONDING set to true

NOTE 1—The MU-RTS Trigger frame solicits transmission of a non-HT or non-HT duplicate PPDU and not an HE TB PPDU. The non-HT or non-HT duplicate PPDU transmitted as a response to an MU-RTS Trigger frame carries a CTS frame.


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(#1070)NOTE 2—The PHY can compensate the HE TB PPDU autonomously of the MAC by applying frequency error measurement from the last PPDU received prior to the transmission of the HE TB PPDU, since that is the corresponding triggering PPDU.

After compensation, the absolute value of residual CFO error with respect to the corresponding triggering PPDU shall not exceed the following levels when measured at the 10% point of the complementary cumulative distribution function (CCDF) of CFO errors in AWGN at a received power of –60 dBm in the primary 20 MHz:

— 350 Hz for the data subcarriers of an HE TB PPDU
— 2 kHz for a non-HT PPDU or non-HT duplicate PPDU

The residual CFO error measurement on an HE TB PPDU shall be made after the HE-SIG-A field. The residual CFO error measurement on the non-HT or non-HT duplicate PPDU shall be made after the L-STF field. The symbol clock error shall be compensated by the same ppm amount as the CFO error.

A STA that transmits an HE TB PPDU, non-HT PPDU, or non-HT duplicate PPDU in response to a triggering PPDU shall ensure that the transmission start time of the HE TB PPDU, non-HT PPDU, or non-HT duplicate PPDU is within ± 0.4 μs + 16 μs from the end, at the STA's transmit antenna connector, of the last OFDM symbol of the triggering PPDU (if it contains no PE field) or of the PE field of the triggering PPDU (if the PE field is present).

NOTE 2—This end instant is before any signal extension; therefore, this is equivalent to HE TB PPDU transmission within 0.4 μs of SIFS after the end of the triggering PPDU including signal extension.

### 27.3.16 SU-MIMO and DL MU-MIMO beamforming

#### 27.3.16.1 General

SU-MIMO and DL MU-MIMO beamforming are techniques used by a STA with multiple antennas (the beamformer) to steer signals using knowledge of the channel to improve throughput. With SU-MIMO beamforming, all space-time streams in the transmitted signal are intended for reception at a single STA in an RU. With DL MU-MIMO beamforming, disjoint subsets of the space-time streams are intended for reception at different STAs in an RU of size greater than or equal to 106 tones.

For SU-MIMO and DL MU-MIMO beamforming in RU $r$, the receive signal vector in subcarrier $k$ (where subcarrier $k$ is one of the subcarriers in RU $r$, $K_r$ is the set of used subcarrier indices in RU $r$, and $k \in K_r$) at beamformee $u$, $\boldsymbol{y}_{k,u} = [y_{k,0}, y_{k,1}, \ldots, y_{k,N_{RX_u}-1}]^T$, is shown in Equation (27-126), where $\boldsymbol{x}_k = [\boldsymbol{x}_{k,0}^T, \boldsymbol{x}_{k,1}^T, \ldots, \boldsymbol{x}_{k,N_{user,r}-1}^T]^T$ denotes the transmit signal vector in subcarrier $k$ for all $N_{user,r}$ beamformees, with $\boldsymbol{x}_{k,u} = [x_{k,0}, x_{k,1}, \ldots, x_{k,N_{STS,r,u}-1}]^T$ being the transmit signal for beamformee $u$.

$$\boldsymbol{y}_{k,u} = \boldsymbol{H}_{k,u} \times [Q_{k,0}, Q_{k,1}, \ldots, Q_{k,N_{user,r}-1}] \times \boldsymbol{x}_k + \boldsymbol{n} \quad (27\text{-}126)$$

where

$\boldsymbol{H}_{k,u}$ is the channel matrix from the beamformer to beamformee $u$ in subcarrier $k$ with dimensions $N_{RX_u} \times N_{TX}$

$N_{RX_u}$ is the number of receive antennas at beamformee $u$

$Q_{k,u}$ is a steering matrix for beamformee $u$ in subcarrier $k$ with dimensions $N_{TX} \times N_{STS,r,u}$

$N_{user,r}$ is the number of HE MU PPDU recipients (see Table 27-16 (Frequently used parameters(11ax))) in RU $r$

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***n*** is a vector of additive noise and may include interference

The DL MU-MIMO steering matrix $Q_k = [Q_{k,0}, Q_{k,1}, \ldots, Q_{k,N_{user,r}-1}]$ can be determined by the beamformer using the beamforming feedback for subcarrier $k$ from beamformee $u$, where $u = 0, 1, \ldots, N_{user,r} - 1$. The feedback report format is described in 9.4.1.63 (HE Compressed Beamforming Report field(11ax)) and 9.4.1.64 (HE MU Exclusive Beamforming Report field(11ax)). The steering matrix that is computed (or updated) using new beamforming feedback from some or all of participating beamformees might replace the existing steering matrix $Q_k$ for the next DL MU-MIMO data transmission.

For SU-MIMO beamforming, the steering matrix $Q_k$ can be determined from the beamforming feedback matrix $V_k$ that is sent back to the beamformer by the beamformee using the compressed beamforming feedback matrix format as defined in 19.3.12.3.6 (Compressed beamforming feedback matrix). The feedback report format is described in 9.4.1.63 (HE Compressed Beamforming Report field(11ax)).

### 27.3.16.2 Beamforming feedback matrix *V*

Upon receipt of an HE sounding NDP, the beamformee computes a set of matrices for feedback to the beamformer as described in 21.3.11.2 (Beamforming Feedback Matrix V). The eligible beamformees shall remove the space-time stream CSD in Table 21-11 (Cyclic shift values for the VHT modulated fields of a PPDU) from the measured channel before computing a set of matrices for feedback to the beamformer.

The beamforming feedback matrix, $V_{k,u}$, found by the beamformee $u$ for subcarrier $k$ in RU $r$ shall be compressed in the form of angles using the method described in 19.3.12.3.6 (Compressed beamforming feedback matrix). The angles, $\phi(k,u)$ and $\psi(k,u)$, are quantized according to Table 9-92 (Quantization of angles) with (#1297)$b_\phi$ and $b_\psi$ defined by the Codebook Information field of the HE MIMO Control field (see 9.4.1.62 (HE MIMO Control field(11ax))). The compressed beamforming feedback matrix as defined in 19.3.12.3.6 (Compressed beamforming feedback matrix) is the only Clause 27 (High-efficiency (HE) PHY specification(11ax)) beamforming feedback matrix defined.

The beamformee shall generate the beamforming feedback matrices with the number of rows ($Nr$) equal to the $N_{STS}$ of the HE sounding NDP.

After receiving the angle information, $\phi(k,u)$ and $\psi(k,u)$, the beamformer reconstructs $V_{k,u}$ using Equation (19-79). For SU-MIMO beamforming, the beamformer uses the $V_{k,0}$ matrix to determine the steering matrix $Q_k$. For DL MU-MIMO beamforming, the beamformer may calculate a steering matrix $Q_k = [Q_{k,0}, Q_{k,1}, \ldots, Q_{k,N_{user,r}-1}]$ using $V_{k,u}$ and $\Delta SNR_{k,u}$ ($0 \le u \le N_{user,r}-1$) in order to (#2250)suppress crosstalk between transmissions to participating beamformees. The method used by the beamformer to calculate the steering matrix $Q_k$ is implementation specific.

### 27.3.16.3 CQI feedback

If the HE NDP Announcement frame requests CQI feedback, then upon receipt of the HE sounding NDP, the beamformee computes CQI feedback as described in 9.4.1.65 (HE CQI Report field(11ax)). The CQI feedback, $CQI_{s,r,u}$, for beamformee $u$ in RU $r$ for space-time stream $s$ shall be estimated using the method described in 9.4.1.65 (HE CQI Report field(11ax)). The CQI values to be fed back are derived from quantized SNRs according toTable 9-129 (Average SNR of RU index k for space-time stream i subfield(11ax)). The beamformee shall transmit the CQI feedback for space-time stream 1, …, $Nc$ for each of the RU indices for which the CQI report is being requested by the beamformer. The beamformer may use the CQI feedback to determine the best range of RUs for a compressed beamforming/CQI report or for RU assignment during a subsequent MU transmissions. The actual use is implementation specific.


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### 27.3.17 HE sounding NDP

The HE sounding NDP is a variant of the HE SU PPDU. The format of an HE sounding NDP is defined in Figure 27-46 (HE sounding NDP format(11ax)).

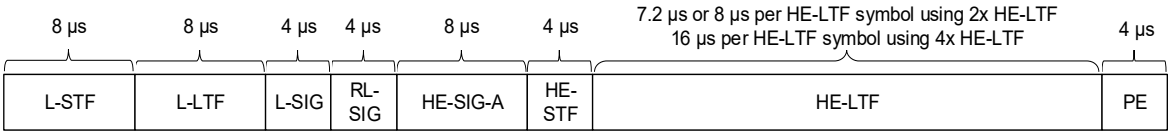


**Figure 27-46—HE sounding NDP format(11ax)**

NOTE—The number of HE-LTF symbols in the HE sounding NDP is indicated in the NSTS And Midamble Periodicity field in the HE-SIG-A field.

The HE sounding NDP has the following properties:

— Uses the HE SU PPDU format but without the Data field

— Has a PE field that is 4 µs in duration

The HE sounding NDP overlapping the 242-tone RUs corresponding to bits with a value of 1 in the bitmap of the TXVECTOR parameter INACTIVE_SUBCHANNELS or overlapping a punctured center 26-tone RU of an HE sounding NDP is punctured. The center 26-tone RU of the HE sounding NDP is punctured if either one of the adjacent 242-tone RUs is punctured.

It is mandatory to support the 2x HE-LTF with 0.8 µs GI and 2x HE-LTF with 1.6 µs GI. It is optional to support the 4x HE-LTF with 3.2 µs GI. The other combinations of HE-LTF type and GI duration are disallowed.

If the Beamformed field in the HE-SIG-A field of an HE sounding NDP is 1, then the receiver of the HE sounding NDP should not perform channel smoothing when generating the compressed beamforming feedback report.

### 27.3.18 HE TB feedback NDP

The HE TB feedback NDP is used to carry the NDP feedback report information as introduced in 26.5.7 (NDP feedback report procedure). The PPDU structure of an HE TB feedback NDP is shown in Figure 27-47 (HE TB feedback NDP format(11ax)).

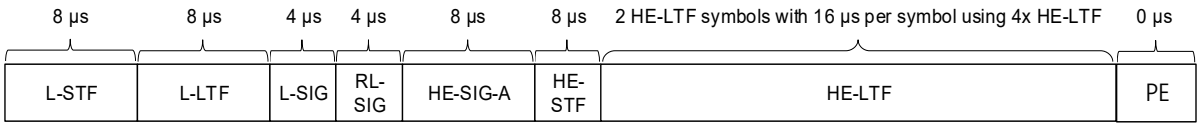


**Figure 27-47—HE TB feedback NDP format(11ax)**

The HE TB feedback NDP has the following properties:

— Uses the HE TB PPDU format but without the Data field.

— The PE field has a duration of 0 µs.

— Has two 4x HE-LTF symbols.

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— 4x HE-LTF with 3.2 µs GI is the only HE-LTF type and GI duration combination for the HE-LTF.

— The generation of HE-LTF symbols for the HE TB feedback NDP is defined in 27.3.11.10 (HE-LTF field).

— The HE-STF and the pre-HE modulated fields are transmitted only on the 20 MHz channel where the STA is assigned.

### 27.3.19 HE Ranging NDP and HE TB Ranging NDP(11az)

This subclause describes the HE Ranging NDP and HE TB Ranging NDP.

#### 27.3.19.1 HE Ranging NDP(11az)

The format of an HE Ranging NDP is shown in Figure 27-48 (HE Ranging NDP format(11az)).

**Figure 27-48—HE Ranging NDP format(11az)**

The HE Ranging NDP has the following properties:

— Uses the HE SU PPDU format but without the Data field.

— The L-STF and L-LTF fields in an HE Ranging NDP are the same as the L-STF and L-LTF fields in an HE SU PPDU. The subfields in L-SIG, RL-SIG and HE-SIG-A have the same bit assignments and definitions as the subfields in a HE SU PPDU unless specified otherwise.

— The HE-STF field in an HE Ranging NDP is the same as the HE-STF field in an HE SU PPDU.

— Uses HE-LTFs or secure HE-LTFs when the TXVECTOR parameter SECURE_LTF_FLAG is equal to 0 or 1, respectively.

— Secure HE-LTFs use randomized HE-LTF sequences, pseudorandom and deterministic per stream phase rotation and, when the TXVECTOR parameter TX_WINDOW_FLAG is equal to 1, a frequency domain flat top window is used instead of the frequency domain rectangular window; see 27.3.20.6 (Construction of secure HE-LTF symbols(11az)).

— Uses HE-LTF repetitions, if indicated in the TXVECTOR parameter LTF_REP by values larger than one.

— The HE-LTF field consists of one or more (#8096)HE-LTF user blocks; each HE-LTF user block contains one or more (#8096)HE-LTF repetition blocks, where the number of (#8096)HE-LTF repetition blocks is equal to LTF_REP. An (#8096)HE-LTF repetition block in an (#8096)HE-LTF user block comprises one or more HE-LTF symbols, NHE-LTF, calculated using the number of space-time streams NUM_STS for this user, as defined in Table 21-13 (Number of VHT-LTFs required for different numbers of space-time streams).

— When the TXVECTOR parameter SECURE_LTF_FLAG is equal to 0, the number of (#8096)HE-LTF user blocks is equal to 1, and the same (#8096)HE-LTF user block is applied to all users. When the TXVECTOR parameter SECURE_LTF_FLAG is equal to 1, an (#8096)HE-LTF user block contains all HE-LTF symbols for one user, and the number of (#8096)HE-LTF user blocks in the HE-LTF field is equal to the number of Users, NUM_USERS, and each (#8096)HE-LTF user block contains all the HE-LTF symbols for one user.

— No beamforming steering matrix is applied to the waveform. The Beamformed field in HE- SIG-A of an HE Ranging NDP is always set to 0.


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— (#7022)(#7016)For HE-STFs and HE-LTFs, if $N_{STS} = N_{TX}$, the spatial mapping matrix $Q$ shall be a permutation matrix with $N_{TX}$ rows and $N_{TX}$ columns; if $N_{STS} < N_{TX}$, $Q$ shall be a $P \times D$ matrix where $P$ is a permutation matrix with $N_{TX}$ rows and $N_{TX}$ columns and $D$ is a matrix with $N_{TX}$ rows and $N_{STS}$ columns where the first $N_{STS}$ rows make up an identity matrix and the remaining rows make up a zero matrix.

— Has a Packet Extension (PE) field that is 4 µs in duration. No energy is transmitted during the first 1.6 µs of the PE field if the HE-LTF field is using the secure HE-LTF, similar to no energy being transmitted during the GI of HE-LTF symbols.

— For decoding the HE-LTF fields, a PHY-RXLTFSEQUENCE.request primitive issued from the MAC provides the LTF_REP, LTF_NSTS, and LTF_OFFSET parameters, which are not encoded in the HE-SIG-A, but included in the preceding Ranging NDP Announcement frame. The LTF_OFFSET parameter indicates the number of secure HE-LTF symbols to skip for receiving the corresponding user's (#8096)HE-LTF user block.

— When the TXVECTOR parameter NUM_USERS is greater than 1, the TXVECTOR parameter NUM_STS[1] is used to encode the NSTS And Mid-amble Periodicity field of the HE-SIG-A1. Otherwise, the TXVECTOR parameter NUM_STS is used to encode the NSTS And Mid-amble Periodicity field of the HE-SIG-A1.

— The only supported mode is 2x HE-LTF with 1.6 µs GI. The other combinations of HE-LTF modes and GI duration are disallowed. No energy is transmitted during the GI of the HE-LTF symbols when secure HE-LTF are used, which is referred to as a zero-power GI.

— The number of HE-LTF symbols in the HE-LTF field in an HE Ranging NDP depends on the number of space-time streams NUM_STS, the number of HE-LTF repetitions, LTF-REP, and when secure HE-LTFs are used, the number of users NUM_USERS.

NOTE 1—See examples in Figure 27-49 (An example of HE-LTFs in an HE Ranging NDP with NUM_USERS = 1, NUM_STS = 2, and N_LTF_REP = 2(11az)(#8096)) and Figure 27-50 (An example of secure HE-LTFs with NUM_USERS = 2, NUM_STS = [2,1], and LTF_REP = [2,2](11az)(#8096)).

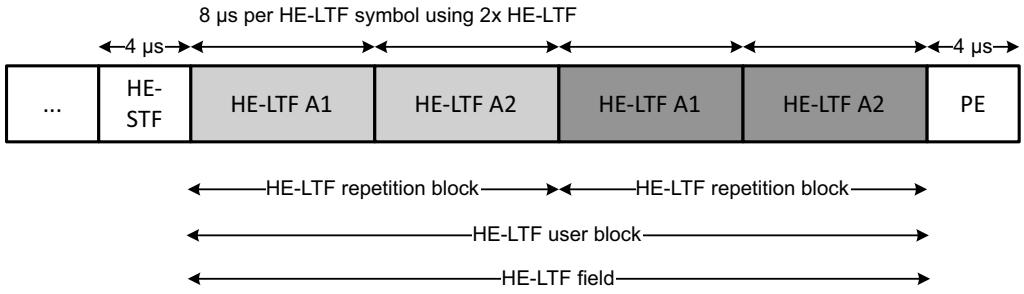


**Figure 27-49—An example of HE-LTFs in an HE Ranging NDP with NUM_USERS = 1, NUM_STS = 2, and N_LTF_REP = 2(11az)(#8096)**

When the TXVECTOR parameter SECURE_LTF_FLAG is equal to 0, HE-LTFs as defined in 27.3.11.10 (HE-LTF field) are used in the HE Ranging NDP. There is a single (#8096)HE-LTF user block in an HE-LTF field, and the total number of HE-LTF symbols in the HE-LTF field is the product of the number of symbols in an (#8096)HE-LTF repetition block, NHE-LTF, and the number of HE-LTF repetitions, given in LTF_REP.

The construction of the HE-LTFs in an HE Ranging NDP is done by repeating the steps in 27.3.6.9 (Construction of HE-LTF field) LTF_REP times, that is, a value of LTF_REP equal to 1 indicates a single (#8096)HE-LTF repetition block, and a value of LTF_REP greater than 1 indicates the use of repetitions,

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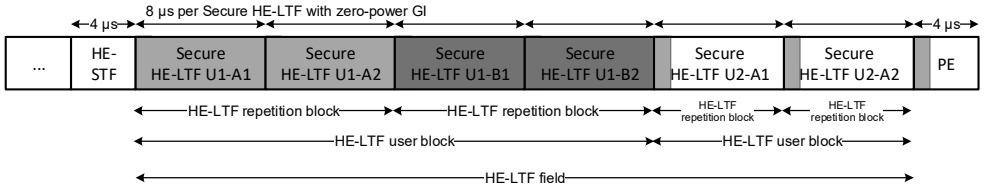


**Figure 27-50—An example of secure HE-LTFs with NUM_USERS = 2, NUM_STS = [2,1], and LTF_REP = [2,2](11az)(#8096)**

that is, multiple (#8096)HE-LTF repetition blocks are included in an (#8096)HE-LTF user block. If the TXVECTOR parameter SECURE_LTF_FLAG is set to 0, the TXVECTOR parameter NUM_USERS is not present, which is then assumed to be 1, and all the HE-LTF symbols belong to a single (#8096)HE-LTF user block.

When the TXVECTOR parameter SECURE_LTF_FLAG is equal to 1, secure HE-LTFs as defined in 27.3.20.6 (Construction of secure HE-LTF symbols(11az)), are used and the Packet Extension field will be partially replaced by a zero power GI in its first 1.6 µs, see Figure 27-51 (HE Ranging NDP format with secure HE-LTFs(11az)). For the secure HE-LTF symbol or Packet Extension field with zero power GI, the time domain signal has zero power during the period of the GI. The TXVECTOR parameters LTF_KEY, NUM_STS, and LTF_REP will be in array form with NUM_USERS entries. The repetitions of the HE-LTF symbols are repetitions of the (#8096)HE-LTF repetition block. The randomized HE-LTF sequences are different in each of the (#8096)HE-LTF repetition blocks. The total number of HE-LTF symbols in an (#8096)HE-LTF user block is the product of the number of symbols in an (#8096)HE-LTF repetition block, NHE-LTF, and the number of HE-LTF repetitions given in LTF_REP.

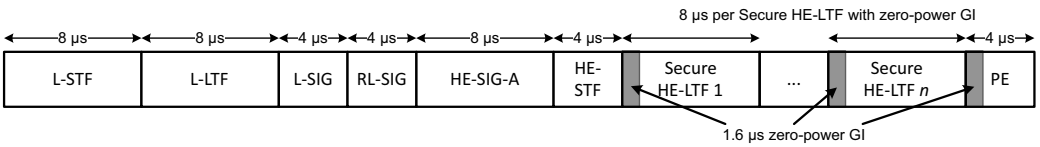


**Figure 27-51—HE Ranging NDP format with secure HE-LTFs(11az)**

For secure HE-LTF transmissions, the number of HE-LTF repetitions given in LTF_REP shall be greater than 1, and there are a minimum of two (#8096)HE-LTF repetition blocks in each (#8096)HE-LTF user block.

NOTE 2—The intended receiver of the Secure HE-LTFs can use implementation specific methods to detect the occurrence of an attack. It can explore the HE-LTF repetitions to check the consistency of the channel estimation or the signal to interference ratio (SIR) drop from impact of an attack. Please see Annex AE for more details on SIR drop due to attack.

The secure HE-LTFs of each (#8096)HE-LTF user block are concatenated one after another and form the HE-LTF field of an HE Ranging NDP; the total number of HE-LTF symbols in an HE-LTF field shall not exceed a maximum of 64 secure HE-LTF symbols over all users, all space-time streams. and number of HE-LTF repetitions.

(#7021)In each (#8096)HE-LTF user block within the HE-LTF field, the number of transmitted space-time streams (#8095)is indicated in NUM_STS for the corresponding (#8096)HE-LTF user block and may vary from one (#8096)HE-LTF user block to another. Within the HE-STF Field, the number of transmitted space-


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time streams should match the first (#8096)HE-LTF user block. In the pre-HE modulated fields, the number of transmitted space-time streams used shall be no less than the minimum number of transmitted space-time streams used in the HE modulated fields. The sum of the Tx power across all transmitted space-time streams shall remain constant throughout the entire HE Ranging NDP PPDU.

### 27.3.19.2 HE TB Ranging NDP(11az)

The format of an HE TB Ranging NDP is shown in Figure 27-52 (HE TB Ranging NDP format(11az)).

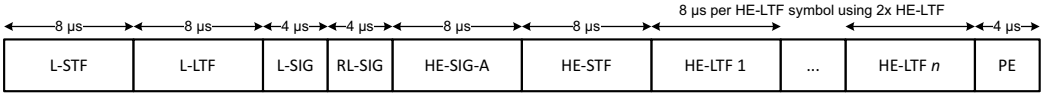


**Figure 27-52—HE TB Ranging NDP format(11az)**

The HE TB Ranging NDP has the following properties:

- Uses the HE TB PPDU format but without the Data field.
- The HE-STF field in HE TB Ranging NDP is the same as the HE-STF field in a HE TB PPDU.
- Uses HE-LTFs or secure HE-LTFs when the TXVECTOR parameter SECURE_LTF_FLAG is equal to 0 or 1, respectively.
- Secure HE-LTFs use randomized HE-LTF sequences, pseudorandom and deterministic per stream phase rotation and, when the TXVECTOR parameter TX_WINDOW_FLAG is equal to 1, a frequency domain flat top window is used instead of the frequency domain rectangular window; see 27.3.20.6 (Construction of secure HE-LTF symbols(11az)).
- Uses HE-LTF repetitions, if indicated in the TXVECTOR parameter LTF_REP by values larger than one.
- The HE-LTF field of an HE TB Ranging NDP consists of a single (#8096)HE-LTF user block. The (#8096)HE-LTF user block contains one or more (#8096)HE-LTF repetition blocks, and the number of (#8096)HE-LTF repetition blocks is equal to LTF_REP. Each (#8096)HE-LTF repetition block in the (#8096)HE-LTF user block comprises one or more HE-LTF symbols, $N_{HE\text{-}LTF}$ specified in the Common Info field within the Sounding Ranging Trigger frame.
- Has a Packet Extension (PE) field that is 4 µs in duration. No energy is transmitted during the first 1.6 µs of the PE field if the HE-LTF field is using the secure HE-LTF, similar to no energy being transmitted during the GI of HE-LTF symbols.
- No beamforming steering matrix is applied to the waveform.
- (#7023)(#7017)For transmission of HE-LTFs, i.if $N_{STS} = N_{TX}$, the spatial mapping matrix $Q$ shall be a permutation matrix with $N_{TX}$ rows and $N_{TX}$ columns; if $N_{STS} < N_{TX}$, $Q$ shall be a $P \times D$ matrix where $P$ is a permutation matrix with $N_{TX}$ rows and $N_{TX}$ columns and $D$ is a matrix with $N_{TX}$ rows and $N_{STS}$ columns where the first $N_{STS}$ rows make up an identity matrix and the remaining rows make up a zero matrix.
- The only supported mode is the 2x HE-LTF with 1.6 µs GI(#7221). The other combinations of HE-LTF modes and GI duration are disallowed.

The number of HE-LTF symbols in an HE TB Ranging NDP is the product of the number of HE-LTF symbols in an (#8096)HE-LTF repetition block, $N_{HE\text{-}LTF}$, and the number of HE-LTF repetitions, given in LTF_REP. A value of LTF_REP equal to 1 indicates no repetition, that is, a single (#8096)HE-LTF repetition block is included in an (#8096)HE-LTF user block, and a value of LTF_REP greater than 1 indicates the use of repetitions, that is, multiple (#8096)HE-LTF repetition blocks are included in the

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(#8096)HE-LTF user block. The sum of Tx power shall remain constant throughout the entire HE TB Ranging NDP PPDU.

When the TXVECTOR parameter SECURE_LTF_FLAG is equal to 0, HE-LTFs as defined in 27.3.11.10 (HE-LTF field) are used in each (#8096)HE-LTF repetition block.

When the TXVECTOR parameter SECURE_LTF_FLAG is equal to 1, secure HE-LTFs as defined in 27.3.20 (HE-LTF field using secure HE-LTF(11az)) are used in the (#8096)HE-LTF repetition blocks, and the Packet Extension field will be partially replaced by a zero power GI in its first 1.6 µs; see Figure 27-53 (HE TB Ranging NDP with secure HE-LTFs(11az)). The repetitions of the HE-LTF symbols form the (#8096)HE-LTF repetition blocks. The randomized HE-LTF sequences are different in each (#8096)HE-LTF repetition block.

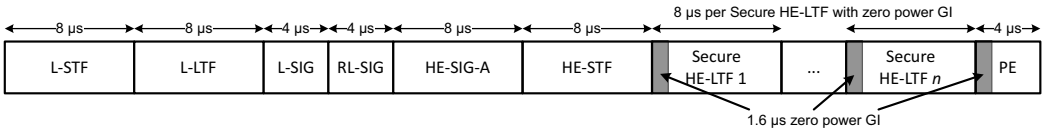


**Figure 27-53—HE TB Ranging NDP with secure HE-LTFs(11az)**

### 27.3.20 HE-LTF field using secure HE-LTF(11az)

#### 27.3.20.1 Introduction(11az)

The HE-LTF field using secure HE-LTF is similar to the HE-LTF field, see 27.3.11.10 (HE-LTF field), the main differences are as follows:

- The HE-LTF sequence is replaced by the randomized LTF sequence described in 27.3.20.2 (Generation of a randomized secure HE-LTF sequence(11az)).
- The conventional GI is replaced by a zero power GI.
- There are no single stream pilot subcarriers in the secure HE-LTFs, all subcarriers are mapped using the $P_{HE\text{-}LTF}$ matrix.
- No CSD is applied to the space-time streams.
- Each spatial stream has a per stream pseudorandom and deterministic phase rotation applied to all the subcarriers.
- A frequency domain flat top window is applied to the secure HE-LTF when configured.
- Only 2x HE-LTF and 1.6 µs GI is supported.
- (#7018)No beamforming is applied. If $N_{STS} = N_{TX}$, the spatial mapping matrix $Q$ is a permutation matrix with $N_{TX}$ rows and $N_{TX}$ columns. If $N_{STS} < N_{TX}$, $Q$ is a $P \times D$ matrix where $P$ is a permutation matrix with $N_{TX}$ rows and $N_{TX}$ columns and $D$ is a matrix with $N_{TX}$ rows and $N_{STS}$ columns where the first $N_{STS}$ rows make up an identity matrix and the remaining rows make up a zero matrix.

#### 27.3.20.2 Generation of a randomized secure HE-LTF sequence(11az)

The secure HE-LTF sequence is constructed using pseudorandom 64-QAM modulation. Pseudorandom octets defined in 11.21.6.4.5.4 (Overview of secure HE-LTF octet stream generation(11az)) are used in the construction of the pseudorandom 64-QAM values.

The first seven pseudorandom octets ($Octet_0$–$Octet_6$) in the secure NDP are used for per stream phase rotations see 27.3.20.3 (Pseudorandom and deterministic per spatial stream phase rotations(11az)).


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(#7094)NOTE—Each octet that is used for per stream phase rotation is mapped so that B7 is the most significant bit and B0 is the least significant bit.

Starting with $Octet_7$, these pseudorandom octets are used for construction of pseudorandom 64-QAM values in the secure HE-LTF sequences.

### 27.3.20.2.1 Randomized LTF sequence for 20 MHz secure NDP(11az)

There are 122 nonzero entries in the 20 MHz secure 2x HE-LTF sequence. This subclause describes the mapping of pseudorandom octets to the nonzero entries of the 20 MHz secure 2x HE-LTF sequence, and then the construction of the 64-QAM values for each nonzero entry of the secure HE-LTF sequence.

The indices of the nonzero entries of the 20 MHz secure 2x HE-LTF sequence are those of the nonzero entries in Equation (27-42). The indices for the nonzero entries are provided in Equation (27-127).

$$NZ_{20\,\mathrm{MHz}} = \{-122, -120, -118, -116, -114, -112, -110, -108, -106, -104, -102, -100, -98, -96, -94, -92, -90, -88, -86, -84, -82, -80, -78, -76, -74, -72, -70, -68, -66, -64, -62, -60, -58, -56, -54, -52, -50, -48, -46, -44, -42, -40, -38, -36, -34, -32, -30, -28, -26, -24, -22, -20, -18, -16, -14, -12, -10, -8, -6, -4, -2, 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30, 32, 34, 36, 38, 40, 42, 44, 46, 48, 50, 52, 54, 56, 58, 60, 62, 64, 66, 68, 70, 72, 74, 76, 78, 80, 82, 84, 86, 88, 90, 92, 94, 96, 98, 100, 102, 104, 106, 108, 110, 112, 114, 116, 118, 120, 122\} \quad (27\text{-}127)$$

There are up to 64 secure HE-LTF sequences in an NDP. For notational convenience we indicate the LTF sequence number with the integer $n$, which is an integer between 1 and 64. Since each secure HE-LTF sequence is used to generate each of the LTF symbols, $n$ also indicates the LTF symbol number. Table 27-49 (Pseudorandom octet index for each nonzero subcarrier index in the nth 20 MHz secure HE-LTF sequence(11az)) provides the pseudorandom octet index for each nonzero subcarrier index in the $n$th 20 MHz secure HE-LTF sequence.

**Table 27-49—Pseudorandom octet index for each nonzero subcarrier index in the *n*th 20 MHz secure HE-LTF sequence(11az)**

| Secure HE-LTF tone index | Pseudorandom octet index |
|---|---|
| –122 | $7 + (n - 1) \times 122$ |
| –120 | $8 + (n - 1) \times 122$ |
| –118 | $9 + (n - 1) \times 122$ |
| ⋮ | ⋮ |
| –4 | $66 + (n - 1) \times 122$ |
| –2 | $67 + (n - 1) \times 122$ |
| 2 | $68 + (n - 1) \times 122$ |
| 4 | $69 + (n - 1) \times 122$ |
| ⋮ | ⋮ |
| 118 | $126 + (n - 1) \times 122$ |
| 120 | $127 + (n - 1) \times 122$ |
| 122 | $128 + (n - 1) \times 122$ |

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All entries in the 20 MHz secure HE-LTF sequence other than the entries with indices defined in Equation (27-127) shall be set to 0.

The six least significant bits ($B_0$, $B_1$, $B_2$, $B_3$, $B_4$, $B_5$) of an octet are used in the construction of the 64-QAM value, as specified in Table 17-18 (64-QAM encoding table).

#### 27.3.20.2.2 Randomized LTF sequence for 40 MHz secure NDP(11az)

There are 242 nonzero entries in the 40 MHz secure 2x HE-LTF sequence. This subclause describes the mapping of pseudorandom octets to the nonzero entries of the 40 MHz secure 2x HE-LTF sequence, and then the construction of the 64-QAM values for each nonzero entry of the secure HE-LTF sequence.

The indices of the nonzero entries of the 40 MHz secure 2x HE-LTF sequence are those of the nonzero entries in Equation (27-45). The indices for the nonzero entries are provided in Equation (27-128).

$$NZ_{40\text{ MHz}} = \{-244, -242, -240, -238, -236, -234, -232, -230, -228, -226, -224, -222, -220, -218, -216, -214, -212, -210, -208, -206, -204, -202, -200, -198, -196, -194, -192, -190, -188, -186, -184, -182, -180, -178, -176, -174, -172, -170, -168, -166, -164, -162, -160, -158, -156, -154, -152, -150, -148, -146, -144, -142, -140, -138, -136, -134, -132, -130, -128, -126, -124, -122, -120, -118, -116, -114, -112, -110, -108, -106, -104, -102, -100, -98, -96, -94, -92, -90, -88, -86, -84, -82, -80, -78, -76, -74, -72, -70, -68, -66, -64, -62, -60, -58, -56, -54, -52, -50, -48, -46, -44, -42, -40, -38, -36, -34, -32, -30, -28, -26, -24, -22, -20, -18, -16, -14, -12, -10, -8, -6, -4, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30, 32, 34, 36, 38, 40, 42, 44, 46, 48, 50, 52, 54, 56, 58, 60, 62, 64, 66, 68, 70, 72, 74, 76, 78, 80, 82, 84, 86, 88, 90, 92, 94, 96, 98, 100, 102, 104, 106, 108, 110, 112, 114, 116, 118, 120, 122, 124, 126, 128, 130, 132, 134, 136, 138, 140, 142, 144, 146, 148, 150, 152, 154, 156, 158, 160, 162, 164, 166, 168, 170, 172, 174, 176, 178, 180, 182, 184, 186, 188, 190, 192, 194, 196, 198, 200, 202, 204, 206, 208, 210, 212, 214, 216, 218, 220, 222, 224, 226, 228, 230, 232, 234, 236, 238, 240, 242, 244\} \quad (27\text{-}128)$$

There are up to 64 secure HE-LTF sequences in an NDP. For notational convenience we indicate the LTF sequence number with the integer $n$, which is an integer between 1 and 64. Since each secure HE-LTF sequence is used to generate each of the LTF symbols, $n$ also indicates the LTF symbol number. Table 27-50 (Pseudorandom octet index for each nonzero subcarrier index in the nth 40 MHz secure HE-LTF sequence(11az)) provides the pseudorandom octet index for each nonzero subcarrier index in the $n$th 40 MHz secure HE-LTF sequence.

**Table 27-50—Pseudorandom octet index for each nonzero subcarrier index in the *n*th 40 MHz secure HE-LTF sequence(11az)**

| Secure HE-LTF tone index | Pseudorandom octet index |
|---|---|
| –244 | $7 + (n - 1) \times 242$ |
| –242 | $8 + (n - 1) \times 242$ |
| –240 | $9 + (n - 1) \times 242$ |
| ⋮ | ⋮ |
| –6 | $126 + (n - 1) \times 242$ |
| –4 | $127 + (n - 1) \times 242$ |


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**Table 27-50—Pseudorandom octet index for each nonzero subcarrier index in the *n*th 40 MHz secure HE-LTF sequence(11az) *(continued)***

| Secure HE-LTF tone index | Pseudorandom octet index |
|---|---|
| 4 | $128 + (n - 1) \times 242$ |
| 6 | $129 + (n - 1) \times 242$ |
| ⋮ | ⋮ |
| 240 | $246 + (n - 1) \times 242$ |
| 242 | $247 + (n - 1) \times 242$ |
| 244 | $248 + (n - 1) \times 242$ |

All entries in the 40 MHz secure HE-LTF sequence other than the entries with indices defined in Equation (27-128) shall be set to 0.

The six least significant bits ($B_0$, $B_1$, $B_2$, $B_3$, $B_4$, $B_5$) of an octet are used in the construction of the 64-QAM value, as specified in Table 17-18 (64-QAM encoding table).

#### 27.3.20.2.3 Randomized LTF sequence for 80 MHz secure NDP(11az)

There are 498 nonzero entries in the 80 MHz secure 2x HE-LTF sequence. This subclause describes the mapping of pseudorandom octets to the nonzero entries of the 80 MHz secure 2x HE-LTF sequence, and then the construction of the 64-QAM values for each nonzero entry of the secure HE-LTF sequence.

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The indices of the nonzero entries of the 80 MHz secure 2x HE-LTF sequence are those of the nonzero entries in Equation (27-48). The indices for the nonzero entries are provided in Equation (27-129).

$NZ_{80\ \mathrm{MHz}}$ = {–500, –498, –496, –494, –492, –490, –488, –486, –484, –482, –480, –478, –476, –474, –472, –470, –468, –466, –464, –462, –460, –458, –456, –454, –452, –450, –448, –446, –444, –442, –440, –438, –436, –434, –432, –430, –428, –426, –424, –422, –420, –418, –416, –414, –412, –410, –408, –406, –404, –402, –400, –398, –396, –394, –392, –390, –388, –386, –384, –382, –380, –378, –376, –374, –372, –370, –368, –366, –364, –362, –360, –358, –356, –354, –352, –350, –348, –346, –344, –342, –340, –338, –336, –334, –332, –330, –328, –326, –324, –322, –320, –318, –316, –314, –312, –310, –308, –306, –304, –302, –300, –298, –296, –294, –292, –290, –288, –286, –284, –282, –280, –278, –276, –274, –272, –270, –268, –266, –264, –262, –260, –258, –256, –254, –252, –250, –248, –246, –244, –242, –240, –238, –236, –234, –232, –230, –228, –226, –224, –222, –220, –218, –216, –214, –212, –210, –208, –206, –204, –202, –200, –198, –196, –194, –192, –190, –188, –186, –184, –182, –180, –178, –176, –174, –172, –170, –168, –166, –164, –162, –160, –158, –156, –154, –152, –150, –148, –146, –144, –142, –140, –138, –136, –134, –132, –130, –128, –126, –124, –122, –120, –118, –116, –114, –112, –110, –108, –106, –104, –102, –100, –98, –96, –94, –92, –90, –88, –86, –84, –82, –80, –78, –76, –74, –72, –70, –68, –66, –64, –62, –60, –58, –56, –54, –52, –50, –48, –46, –44, –42, –40, –38, –36, –34, –32, –30, –28, –26, –24, –22, –20, –18, –16, –14, –12, –10, –8, –6, –4, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30, 32, 34, 36, 38, 40, 42, 44, 46, 48, 50, 52, 54, 56, 58, 60, 62, 64, 66, 68, 70, 72, 74, 76, 78, 80, 82, 84, 86, 88, 90, 92, 94, 96, 98, 100, 102, 104, 106, 108, 110, 112, 114, 116, 118, 120, 122, 124, 126, 128, 130, 132, 134, 136, 138, 140, 142, 144, 146, 148, 150, 152, 154, 156, 158, 160, 162, 164, 166, 168, 170, 172, 174, 176, 178, 180, 182, 184, 186, 188, 190, 192, 194, 196, 198, 200, 202, 204, 206, 208, 210, 212, 214, 216, 218, 220, 222, 224, 226, 228, 230, 232, 234, 236, 238, 240, 242, 244, 246, 248, 250, 252, 254, 256, 258, 260, 262, 264, 266, 268, 270, 272, 274, 276, 278, 280, 282, 284, 286, 288, 290, 292, 294, 296, 298, 300, 302, 304, 306, 308, 310, 312, 314, 316, 318, 320, 322, 324, 326, 328, 330, 332, 334, 336, 338, 340, 342, 344, 346, 348, 350, 352, 354, 356, 358, 360, 362, 364, 366, 368, 370, 372, 374, 376, 378, 380, 382, 384, 386, 388, 390, 392, 394, 396, 398, 400, 402, 404, 406, 408, 410, 412, 414, 416, 418, 420, 422, 424, 426, 428, 430, 432, 434, 436, 438, 440, 442, 444, 446, 448, 450, 452, 454, 456, 458, 460, 462, 464, 466, 468, 470, 472, 474, 476, 478, 480, 482, 484, 486, 488, 490, 492, 494, 496, 498, 500} (27-129)

There are up to 64 secure HE-LTF sequences in an NDP. For notational convenience we indicate the LTF sequence number with the integer *n*, which is an integer between 1 and 64. Since each secure HE-LTF sequence is used to generate each of the LTF symbols, *n* also indicates the LTF symbol number. Table 27-51 (Pseudorandom octet index for each nonzero subcarrier index in the nth 80 MHz secure HE-LTF sequence(11az)) provides the pseudorandom octet index for each nonzero subcarrier index in the *n*th 80 MHz secure HE-LTF sequence.

All entries in the 80 MHz secure HE-LTF sequence other than the entries with indices defined in Equation (27-129) shall be set to 0.

The six least significant bits ($B_0$, $B_1$, $B_2$, $B_3$, $B_4$, $B_5$) of an octet are used in the construction of the 64-QAM value, as specified in Table 17-18 (64-QAM encoding table).


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**Table 27-51—Pseudorandom octet index for each nonzero subcarrier index in the *n*th 80 MHz secure HE-LTF sequence(11az)**

| Secure HE-LTF tone index | Pseudorandom octet index |
|---|---|
| –500 | $7 + (n - 1) \times 498$ |
| –498 | $8 + (n - 1) \times 498$ |
| –496 | $9 + (n - 1) \times 498$ |
| ⋮ | ⋮ |
| –6 | $254 + (n - 1) \times 498$ |
| –4 | $255 + (n - 1) \times 498$ |
| 4 | $256 + (n - 1) \times 498$ |
| 6 | $257 + (n - 1) \times 498$ |
| ⋮ | ⋮ |
| 496 | $502 + (n - 1) \times 498$ |
| 498 | $503 + (n - 1) \times 498$ |
| 500 | $504 + (n - 1) \times 498$ |

### 27.3.20.2.4 Randomized LTF sequence for the 160 MHz secure NDP and for the 80+80 MHz secure NDP(11az)

This subclause describes the mapping of pseudorandom octets to the nonzero entries of either the 160 MHz secure 2x HE-LTF sequence, or the 80+80 MHz secure 2x LTF sequence, and then the construction of the 64-QAM values for each nonzero entry of the secure HE-LTF sequence.

The construction of either the 160 MHz secure HE-LTF sequence, or the 80+80 MHz secure HE-LTF sequence, uses a segment parser to divide the pseudorandom octets between the sequence for the lower 80 MHz segment and the sequence for the upper 80 MHz segment. Figure 27-54 (Segment parser distributing pseudorandom octets to the sequences for the lower and upper 80 MHz segments in either the 160 MHz secure HE-LTF, or the 80+80 MHz secure HE-LTF sequence(11az)) illustrates the segment parser

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distribution of pseudorandom octets between the sequence for the lower 80 MHz segment and the sequence for the upper 80 MHz segment.

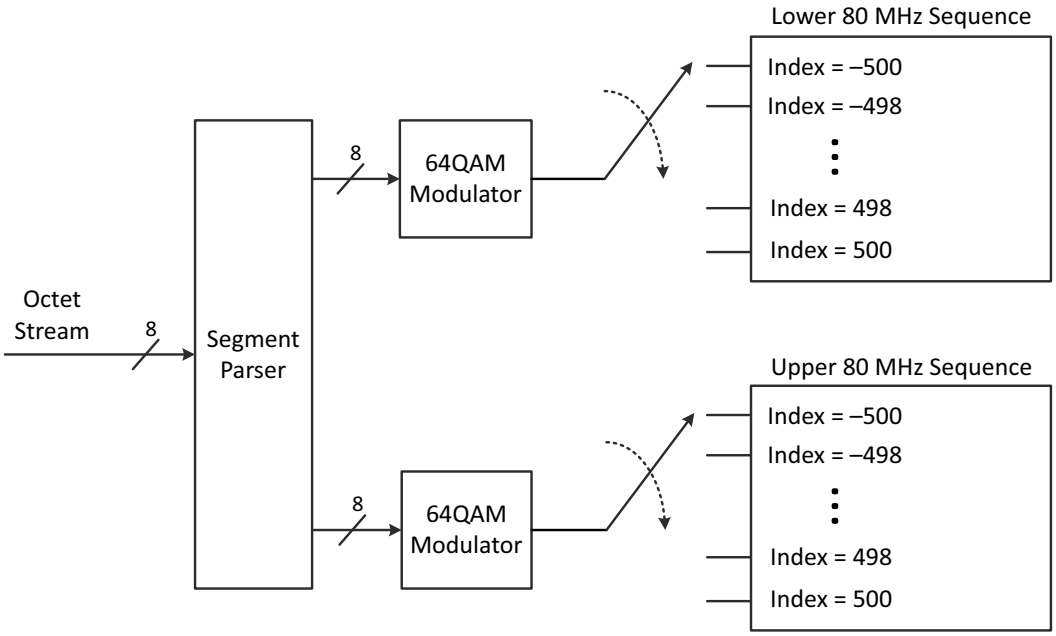


**Figure 27-54—Segment parser distributing pseudorandom octets to the sequences for the lower and upper 80 MHz segments in either the 160 MHz secure HE-LTF, or the 80+80 MHz secure HE-LTF sequence(11az)**

There are up to 64 secure HE-LTF sequences in an NDP. For notational convenience we indicate the LTF sequence number with the integer *n*, which is an integer between 1 and 64. Since each secure HE-LTF sequence is used to generate each of the LTF symbols, *n* also indicates the LTF symbol number. Table 27-52 (Pseudorandom octet index for each nonzero subcarrier index in the nth pair of lower and upper 80 MHz segments(11az)) provides the pseudorandom octet index for each nonzero subcarrier index for the *n*th pair of lower and upper 80 MHz segments.

**Table 27-52—Pseudorandom octet index for each nonzero subcarrier index in the *n*th pair of lower and upper 80 MHz segments(11az)**

| 80 MHz Segment | Secure HE-LTF tone index | Pseudorandom octet index |
|---|---|---|
| Lower | –500 | $7 + (n - 1) \times 996$ |
| Upper | –500 | $8 + (n - 1) \times 996$ |
| Lower | –498 | $9 + (n - 1) \times 996$ |
| Upper | –498 | $10 + (n - 1) \times 996$ |
| Lower | –496 | $11 + (n - 1) \times 996$ |
| Upper | –496 | $12 + (n - 1) \times 996$ |
| ⋮ | ⋮ | ⋮ |
| Lower | –6 | $501 + (n - 1) \times 996$ |


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**Table 27-52—Pseudorandom octet index for each nonzero subcarrier index in the *n*th pair of lower and upper 80 MHz segments(11az) *(continued)***

| 80 MHz Segment | Secure HE-LTF tone index | Pseudorandom octet index |
|---|---|---|
| Upper | –6 | $502 + (n - 1) \times 996$ |
| Lower | –4 | $503 + (n - 1) \times 996$ |
| Upper | –4 | $504 + (n - 1) \times 996$ |
| Lower | 4 | $505 + (n - 1) \times 996$ |
| Upper | 4 | $506 + (n - 1) \times 996$ |
| Lower | 6 | $507 + (n - 1) \times 996$ |
| Upper | 6 | $508 + (n - 1) \times 996$ |
| ⋮ | ⋮ | ⋮ |
| Lower | 496 | $997 + (n - 1) \times 996$ |
| Upper | 496 | $998 + (n - 1) \times 996$ |
| Lower | 498 | $999 + (n - 1) \times 996$ |
| Upper | 489 | $1000 + (n - 1) \times 996$ |
| Lower | 500 | $1001 + (n - 1) \times 996$ |
| Upper | 500 | $1002 + (n - 1) \times 996$ |

All entries in the 160 MHz secure HE-LTF sequence, or the 80+80 secure HE-LTF sequence, other than the nonzero entries shall be set to 0.

The six least significant bits ($B_0$, $B_1$, $B_2$, $B_3$, $B_4$, $B_5$) of an octet are used in the construction of the 64-QAM value, as specified in Table 17-15.

### 27.3.20.3 Pseudorandom and deterministic per spatial stream phase rotations(11az)

In each repetition of the secure HE-LTF symbols, each spatial stream has a phase rotation applied to all the subcarriers. The same phase rotation is applied to all subcarriers. The phase rotation can vary in different repetitions of the secure HE-LTF symbols.

The phase rotation for a given spatial stream consists of two components: a pseudorandom phase rotation and a deterministic phase rotation. For each spatial stream, the pseudorandom phase rotation is the same for all the repetitions of HE-LTF symbols within the secure NDP. As specified in 11.21.6.4.5.4 (Overview of secure HE-LTF octet stream generation(11az)), a stream of pseudorandom octets are provided by the AES-128 CTR Mode. The first seven pseudorandom octets are used in the construction of the pseudorandom phase rotations.

The deterministic phase rotation is a function of the repetition number within the secure NDP and the spatial stream number.

The total phase rotation applied to spatial stream $s$ within repetition $r$ is given by Equation (27-130).

$$\Theta_{r,s} = \alpha_s + \beta_{r,s} \quad (27\text{-}130)$$

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In Equation (27-130) the term $\alpha_s$ is the pseudorandom phase rotation that is the same for the entire secure NDP and the term $\beta_{r,s}$ is the deterministic phase rotation that depends on the rotation value *r*.

The pseudorandom phase $\alpha_s$ is constructed using one of the pseudorandom octets defined in 11.21.6.4.5.4 (Overview of secure HE-LTF octet stream generation(11az)). The index of spatial streams, *s*, is a number between one and eight. For $s = 1$ the phase rotation is zero: $\alpha_1 = 0$. The first octet ($Octet_0$) is used to construct $\alpha_2$, the second octet ($Octet_1$) is used to construct $\alpha_3$. Table 27-53 (Pseudorandom octets for generating per stream pseudorandom phase rotations(11az)) provides a summary of pseudorandom octets used in construction of each of the pseudorandom phase rotations.

**Table 27-53—Pseudorandom octets for generating per stream pseudorandom phase rotations(11az)**

| Pseudorandom octet | Spatial stream pseudorandom phase rotations |
|---|---|
| $Octet_0$ | $\alpha_2$ |
| $Octet_1$ | $\alpha_3$ |
| $Octet_2$ | $\alpha_4$ |
| $Octet_3$ | $\alpha_5$ |
| $Octet_4$ | $\alpha_6$ |
| $Octet_5$ | $\alpha_7$ |
| $Octet_6$ | $\alpha_8$ |

For STAs with fewer than eight spatial streams, not all of the pseudorandom octets up to $Octet_6$ are used.

The three most significant bits of the pseudorandom octet are used to construct the pseudorandom phase rotation. The integer *k* in Equation (27-131) is derived from the three MSBs of the pseudorandom octet.

$$k = (4 \times B_5) + (2 \times B_6) + B_7 \quad (27\text{-}131)$$

Equation (27-132) specifies the pseudorandom phase rotation as a function of the integer *k*.

$$\alpha_s = k \times \frac{\pi}{4} \quad (27\text{-}132)$$

The deterministic phase rotation $\beta_{r,s}$, which depends on both the spatial stream number *s* and the repetition number *r*, is provided in Table 27-54 (Deterministic phase rotation βr,s (radians)(11az)).

The steps in the process of the construction of the secure HE-LTF, including the application of the spatial stream phase rotation, are described in 27.3.20.6 (Construction of secure HE-LTF symbols(11az)).

### 27.3.20.4 Frequency domain windowing in HE-LTF field using secure HE-LTF(11az)

In an HE Ranging NDP or HE TB Ranging NDP using secure HE-LTF a frequency domain windowing function $w_{FD}(k)$ is applied to the subcarriers modulated with the secure HE-LTF sequence $X^m_{k,n}$ .


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**Table 27-54—Deterministic phase rotation $\beta_{r,s}$ (radians)(11az)**

| | $s=1$ | $s=2$ | $s=3$ | $s=4$ | $s=5$ | $s=6$ | $s=7$ | $s=8$ |
|---|---|---|---|---|---|---|---|---|
| $r=1$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| $r=2$ | 0 | $\frac{2\pi}{4}$ | $\frac{3\pi}{4}$ | $\frac{5\pi}{4}$ | $\frac{4\pi}{4}$ | $\frac{6\pi}{4}$ | $\frac{7\pi}{4}$ | $\frac{\pi}{4}$ |
| $r=3$ | 0 | $\frac{3\pi}{4}$ | $\frac{5\pi}{4}$ | $\frac{\pi}{4}$ | $\frac{4\pi}{4}$ | $\frac{7\pi}{4}$ | $\frac{2\pi}{4}$ | $\frac{6\pi}{4}$ |
| $r=4$ | 0 | $\frac{7\pi}{4}$ | $\frac{6\pi}{4}$ | $\frac{4\pi}{4}$ | $\frac{\pi}{4}$ | $\frac{5\pi}{4}$ | $\frac{3\pi}{4}$ | $\frac{2\pi}{4}$ |
| $r=5$ | 0 | $\frac{\pi}{4}$ | $\frac{4\pi}{4}$ | $\frac{6\pi}{4}$ | $\frac{7\pi}{4}$ | $\frac{5\pi}{4}$ | $\frac{3\pi}{4}$ | $\frac{2\pi}{4}$ |
| $r=6$ | 0 | $\frac{6\pi}{4}$ | $\frac{\pi}{4}$ | $\frac{2\pi}{4}$ | $\frac{7\pi}{4}$ | $\frac{4\pi}{4}$ | $\frac{5\pi}{4}$ | $\frac{3\pi}{4}$ |
| $r=7$ | 0 | $\frac{4\pi}{4}$ | $\frac{7\pi}{4}$ | $\frac{3\pi}{4}$ | $\frac{2\pi}{4}$ | $\frac{\pi}{4}$ | $\frac{5\pi}{4}$ | $\frac{6\pi}{4}$ |
| $r=8$ | 0 | $\frac{5\pi}{4}$ | $\frac{2\pi}{4}$ | $\frac{7\pi}{4}$ | $\frac{\pi}{4}$ | $\frac{4\pi}{4}$ | $\frac{6\pi}{4}$ | $\frac{3\pi}{4}$ |

There are two frequency domain windowing functions defined, the rectangle window $w_{FD}(k) = 1$ and the flat top window defined by Equation (27-133) and Equation (27-134).

$$w_{FD}(k) = \sum_{n=-10}^{10} p(n)\exp\left(\frac{-j\pi kn}{N_{FD}}\right), \quad \text{where } k \in K_s \tag{27-133}$$

$$N_{FD} = \begin{cases} 512 & \text{for 20 MHz} \\ 1024 & \text{for 40 MHz} \\ 2048 & \text{for 80 MHz} \\ 4096 & \text{for 160 MHz} \end{cases} \tag{27-134}$$

where

$K_s = NZ_{BW}$ is the set of nonzero subcarriers for a given bandwidth defined in 27.3.20.2 (Generation of a randomized secure HE-LTF sequence(11az))

$p(n)$ is the impulse response given by Equation (27-135)

$$p(n) = \sum_{m=0}^{4} a_m \cos\left(\frac{2m\pi(n+10)}{N_{WinFT}}\right) \quad \text{where } n = -10, \ldots, 10 \tag{27-135}$$

where

$a_0 = 0.21557895$

$a_1 = -0.41663158$

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$a_2 = 0.277263158$
$a_3 = -0.083578947$
$a_4 = 0.006947368$
$N_{WinFT} = 20$

The $w_{FD}(k)$ shall be normalized to have unit RMS power.

### 27.3.20.5 Mathematical description of HE-LTF field using secure HE-LTF(11az)

In an HE Ranging NDP or HE TB Ranging NDP using secure HE-LTF, the time domain representation of the waveform of user $u$, transmitted on frequency segment $i_{Seg}$, and transmit chain $i_{TX}$ shall be as described by Equation (27-136).

$$r_{\text{HE-LTF},u}^{(i_{Seg},i_{TX})}(t) = \frac{1}{\sqrt{|K_s|N_{STS,u}}} \sum_{r=0}^{N_{rep,u}-1} \sum_{n=0}^{N_{\text{HE-LTF},u}-1} w_{T_{\text{HE-LTF}}}(t-(n+rN_{\text{HE-LTF,u}})T_{\text{HE-LTF-SYM}} - T_{\text{GI,HE-LTF}}) \times \sum_{k\in K_s} \sum_{m=1}^{N_{STS,u}} \left( \begin{array}{l} [Q]_{i_{TX},m}[P_{\text{HE-LTF}}]_{m,(n+1)} w_{FD}(k) X^{u}_{k,(n+rN_{\text{HE-LTF},u})} \exp(j\Theta^{u}_{r+1,m}) \\ \exp(j2\pi k\Delta_{F,\text{HE}}(t-(n+rN_{\text{HE-LTF,u}})T_{\text{HE-LTF-SYM}} - T_{\text{GI,HE-LTF}})) \end{array} \right) \quad (27\text{-}136)$$

where

$K_s = NZ_{BW}$ is the set of nonzero subcarriers for a given bandwidth defined in 27.3.20.2 (Generation of a randomized secure HE-LTF sequence(11az))

$N_{STS,u}$ is the number of spatial streams for user $u$

$N_{rep,u}$ is the number of HE-LTF repetitions for user $u$

$N_{\text{HE-LTF,u}}$ is the number of HE-LTF symbols $N_{\text{HE-LTF}}$ in one (#8096)HE-LTF repetition block of user $u$

$w_{T_{\text{HE-LTF}}}(t)$ is the zero power GI windowing function, that avoids cyclic extension of the signal outside of $[0, T_{\text{HE-LTF}}]$

$T_{\text{HE-LTF}}$ is always set to $T_{\text{HE-LTF-2X}} = 6.4$ µs

$T_{\text{GI,HE-LTF}}$ is always set to 1.6 µs, accordingly $T_{\text{HE-LTF-SYM}} = 8.0$ µs

$Q$ is an identity matrix, that is, $Q = I_{N_{TX}}$

$P_{\text{HE-LTF}}$ is defined in Equation (27-57)

$w_{FD}(k)$ is the frequency domain windowing function

$X^{u}_{k,(n+rN_{\text{HE-LTF},u})}$ is the $k$th subcarrier of the 64-QAM modulated $(n+rN_{\text{HE-LTF,u}})$ secure HE-LTF sequence for user $u$

$\Theta^{u}_{r+1,m}$ is the total phase rotation applied to spatial stream $m$ within repetition $r+1$ for user $u$, defined in (#8067)Equation (27-130)

The time domain representation of the waveform including all users, transmitted on frequency segment $i_{Seg}$, and transmit chain $i_{TX}$ shall be as described by Equation (27-137).


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$$r_{\text{HE-LTF}}^{(i_{Seg}, i_{TX})}(t) \sum_{u=1}^{N_u} r_{\text{HE-LTF},u}^{(i_{Seg}, i_{TX})}(t - T_{\text{HE-LTF},u}) \quad (27\text{-}137)$$

where

$N_u$ is the total number of users (NUM_USERS)

$T_{\text{HE-LTF,u}}$ is the start time of the secure HE-LTF symbols for user $u$ as defined by Equation (27-138) and Equation (27-139)

$$T_{\text{HE-LTF},u} = \sum_{k=1}^{u-1} N_{rep,k} N_{\text{HE-LTF},k} T_{\text{HE-LTF-SYM}} \quad (27\text{-}138)$$

$$T_{\text{HE-LTF},1} = 0 \quad (27\text{-}139)$$

### 27.3.20.6 Construction of secure HE-LTF symbols(11az)

The construction of the $n$th secure HE-LTF symbol is achieved as follows:

a) Sequence generation: Construct the $n$th randomized HE-LTF sequence $X_{k,r,n}^{u}$ in the frequency domain over the bandwidth indicated by CH_BANDWIDTH as described in 27.3.20.2 (Generation of a randomized secure HE-LTF sequence(11az)).

b) Apply frequency domain window function $w_{FD}(k)$ to all the tones of the secure HE-LTF sequence. The frequency domain window can be the Rectangular window or flat top window, when the TXVECTOR parameter TX_WINDOW_FLAG is equal to 0 or 1, respectively.

c) Apply the $P_{\text{HE-LTF}}$ matrix to all tones of the secure HE-LTF sequence.

d) Apply per spatial stream phase rotation: Generate the pseudorandom phase rotation for each spatial stream. Apply the pseudorandom phase rotation along with the deterministic phase rotation to the spatial streams as described in 27.3.20.3 (Pseudorandom and deterministic per spatial stream phase rotations(11az)).

e) Apply a zero CSD on each space-time stream, which is equivalent to no CSD per space-time stream.

f) (#7020)If $N_{STS} = N_{TX}$, the spatial mapping matrix $Q$ is a permutation matrix with $N_{TX}$ rows and $N_{TX}$ columns. If $N_{STS} < N_{TX}$, $Q$ is a $P \times D$ matrix where $P$ is a permutation matrix with $N_{TX}$ rows and $N_{TX}$ columns and $D$ is a matrix with $N_{TX}$ rows and $N_{STS}$ columns where the first $N_{STS}$ rows make up an identity matrix and the remaining rows make up a zero matrix.

g) IDFT: Compute the inverse discrete Fourier transform.

h) Insert zero power GI: Prepend values of zero, of length indicated by the TXVECTOR parameter GI_TYPE.

i) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit. Refer to 27.3.10 (Mathematical description of signals).

The generation of the time domain secure HE-LTF symbol per repetition for repetition $r$, symbol $n$, and tone index $k$ is shown in Figure 27-55 (Generation of secure HE-LTF symbols per repetition in a HE Ranging NDP PPDU(11az)).

## 27.3.21 Transmit specification

### 27.3.21.1 Transmit spectral mask

The bandwidth of the spectral mask applied to an HE SU PPDU, an HE TB PPDU, and an HE MU PPDU with the Bandwidth field of the HE-SIG-A field equal to 0, 1, 2, or 3 shall be determined by the bandwidth

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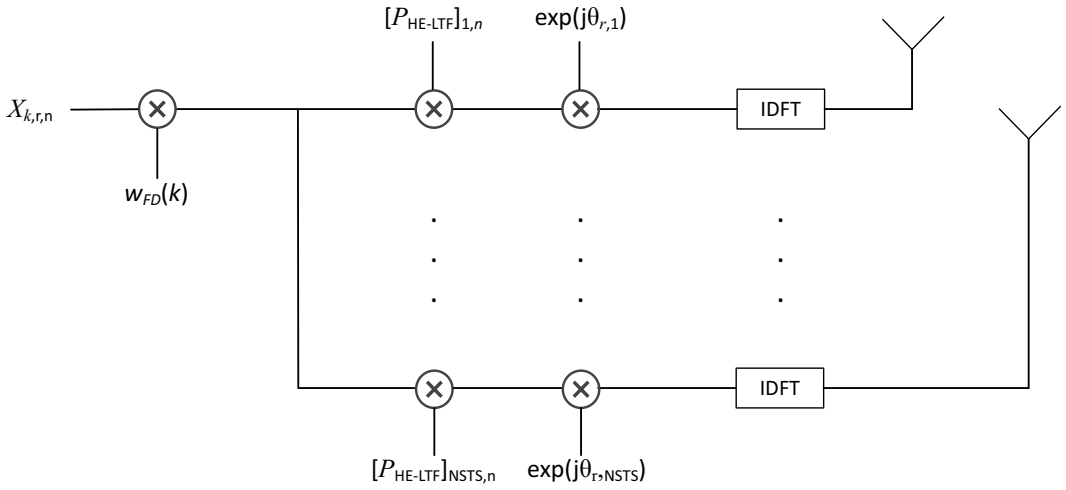


**Figure 27-55—Generation of secure HE-LTF symbols per repetition in a HE Ranging NDP PPDU(11az)**

indicated in the Bandwidth field of the HE-SIG-A field. The bandwidth of the spectral mask applied to an HE ER SU PPDU is 20 MHz. The bandwidth of the spectral mask applied to an HE MU PPDU with the Bandwidth field of the HE-SIG-A field equal to 4 or 5 is 80 MHz. The bandwidth of the spectral mask applied to an HE MU PPDU with the Bandwidth field of the HE-SIG-A field equal to 6 or 7 is 160 MHz. All HE PPDU formats shall be compliant with the transmit spectral mask described in 27.3.21 (Transmit specification).

NOTE 1—In the presence of additional regulatory restrictions, the device has to meet both the regulatory requirements and the mask defined in this subclause.

NOTE 2—Transmit spectral mask figures in this subclause are not drawn to scale.

NOTE 3—For rules regarding transmit center frequency leakage levels, see 27.3.21.4.2 (Transmit center frequency leakage). The spectral mask requirements in this subclause do not apply to the RF LO.

(#1471)The overall transmit spectral mask is constructed using two components. First, an interim spectral mask is constructed whose mask level is determined relative to the maximum spectral density of the signal. Second, an absolute transmit spectral limit is computed based on the mask bandwidth. The overall transmit spectral mask is then constructed by taking the higher of the interim transmit spectral mask and the absolute transmit spectral limit at each frequency offset.


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For a 20 MHz mask PPDU of HE format, the interim transmit spectral mask shall have a 0 dBr (dB relative to the maximum spectral density of the signal) bandwidth of 19.5 MHz, –20 dBr at 10.5 MHz frequency offset, –28 dBr at 20 MHz frequency offset, and –40 dBr at 30 MHz frequency offset and above. The interim transmit spectral mask for frequency offsets between 9.75 MHz and 10.5 MHz, 10.5 MHz and 20 MHz, and 20 MHz and 30 MHz shall be linearly interpolated in dB domain from the requirements for 9.75 MHz, 10.5 MHz, 20 MHz, and 30 MHz frequency offsets. The transmit spectrum shall not exceed the maximum of the interim transmit spectral mask and –53 dBm/MHz at any frequency offset in the 2.4 GHz band. The transmit spectrum shall not exceed the maximum of the interim transmit spectral mask and –39 dBm/MHz at any frequency offset in the 5 GHz and 6 GHz bands(M25). Figure 27-56 (Example transmit spectral mask for a 20 MHz mask PPDU(11ax)) shows an example of the resulting overall spectral mask when the –40 dBr spectrum level is above –53 dBm/MHz in the 2.4 GHz band or when the –40 dBr spectrum level is above –39 dBm/MHz in the 5 GHz and 6 GHz bands(M25).

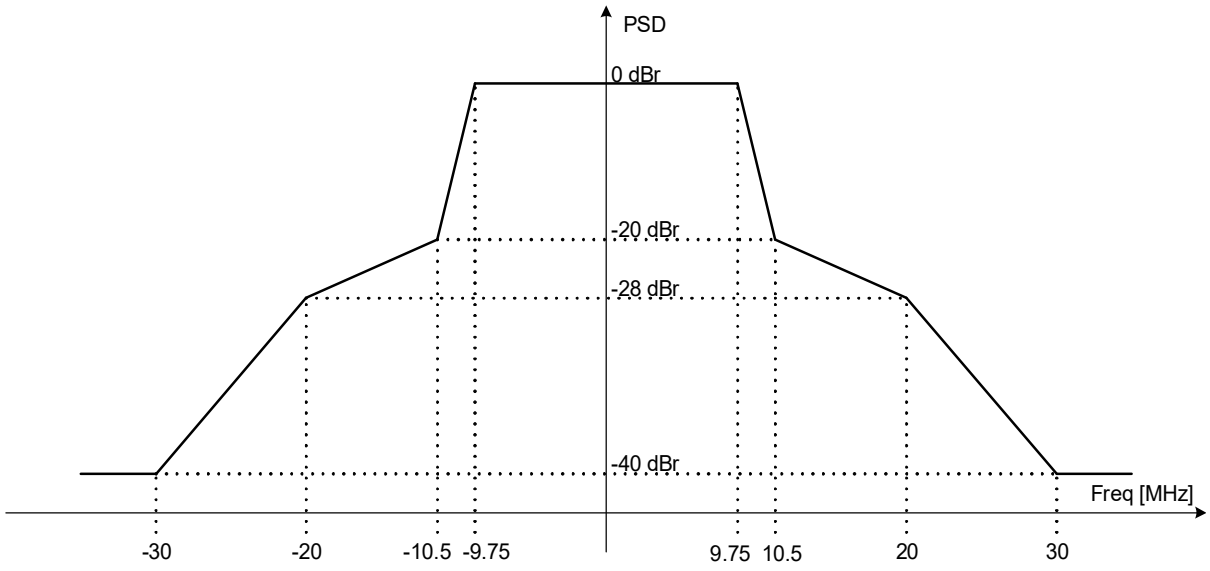


**Figure 27-56—Example transmit spectral mask for a 20 MHz mask PPDU(11ax)**

For a 40 MHz mask PPDU of HE format, the interim transmit spectral mask shall have a 0 dBr bandwidth of 39 MHz, –20 dBr at 20.5 MHz frequency offset, –28 dBr at 40 MHz frequency offset, and –40 dBr at 60 MHz frequency offset and above. The interim transmit spectral mask for frequency offsets between 19.5 MHz and 20.5 MHz, 20.5 MHz and 40 MHz, and 40 MHz and 60 MHz shall be linearly interpolated in dB domain from the requirements for 19.5 MHz, 20.5 MHz, 40 MHz, and 60 MHz frequency offsets. The transmit spectrum shall not exceed the maximum of the interim transmit spectral mask and –56 dBm/MHz at any frequency offset greater than 19.5 MHz in the 2.4 GHz band. The transmit spectrum shall not exceed the maximum of the interim transmit spectral mask and –39 dBm/MHz at any frequency offset in the 5 GHz and 6 GHz bands.(M25) Figure 27-57 (Example transmit spectral mask for a 40 MHz mask PPDU(11ax)) shows an example of the resulting overall spectral mask when the –40 dBr spectrum level is above –56 dBm/MHz in the 2.4 GHz band or when the –40 dBr spectrum level is above –39 dBm/MHz in the 5 GHz and 6 GHz bands.(M25)

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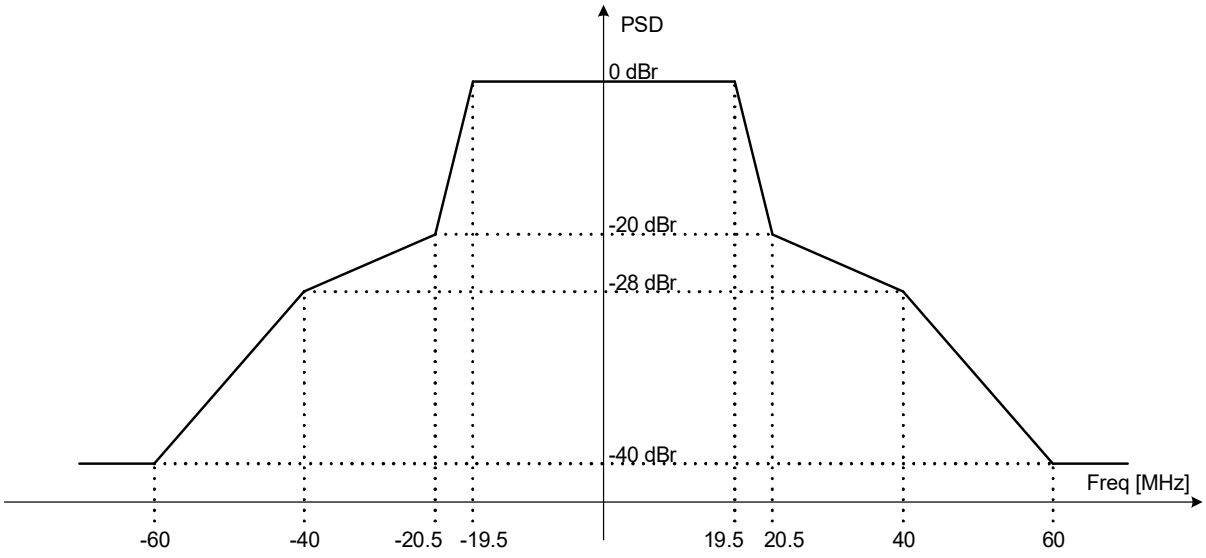


**Figure 27-57—Example transmit spectral mask for a 40 MHz mask PPDU(11ax)**

For an 80 MHz mask PPDU of HE format, the interim transmit spectral mask shall have a 0 dBr bandwidth of 79 MHz, –20 dBr at 40.5 MHz frequency offset, –28 dBr at 80 MHz frequency offset, and –40 dBr at 120 MHz frequency offset and above. The interim transmit spectral mask for frequency offsets between 39.5 MHz and 40.5 MHz, 40.5 MHz and 80 MHz, and 80 MHz and 120 MHz shall be linearly interpolated in dB domain from the requirements for 39.5 MHz, 40.5 MHz, 80 MHz, and 120 MHz frequency offsets. The transmit spectrum shall not exceed the maximum of the interim transmit spectrum mask and –39 dBm/MHz(M25) at any frequency offset. Figure 27-58 (Example transmit spectral mask for an 80 MHz mask PPDU(11ax)) shows an example of the resulting overall spectral mask when the –40 dBr spectrum level is above –39 dBm/MHz(M25).

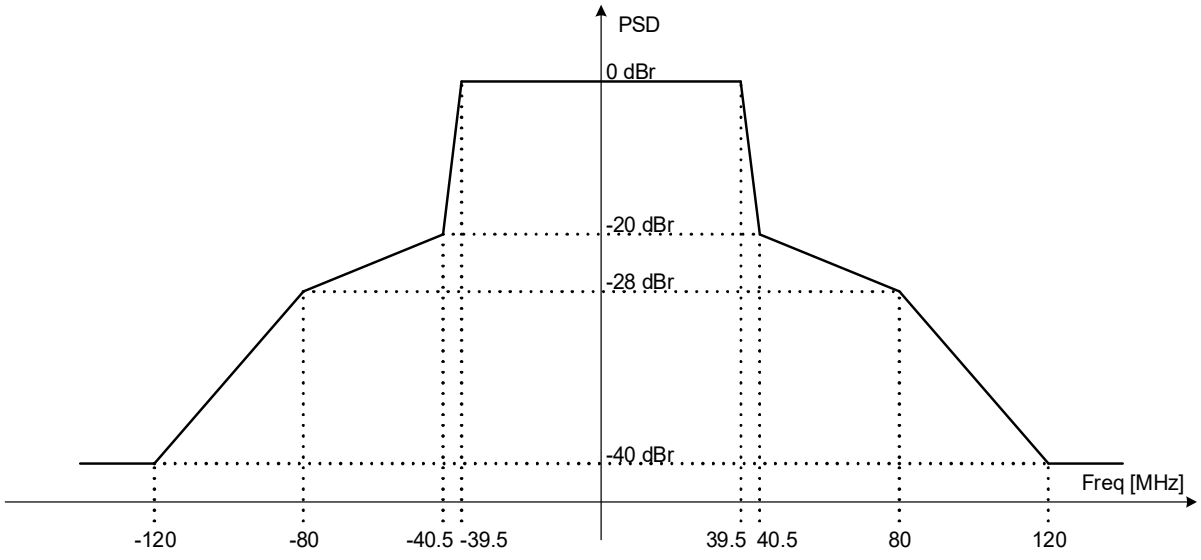


**Figure 27-58—Example transmit spectral mask for an 80 MHz mask PPDU(11ax)**


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For a 160 MHz mask PPDU of HE format, the interim transmit spectral mask shall have a 0 dBr bandwidth of 159 MHz, –20 dBr at 80.5 MHz frequency offset, –28 dBr at 160 MHz frequency offset, and –40 dBr at 240 MHz frequency offset and above. The interim transmit spectral mask for frequency offsets between 79.5 MHz and 80.5 MHz, 80.5 MHz and 160 MHz, and 160 MHz and 240 MHz shall be linearly interpolated in dB domain from the requirements for 79.5 MHz, 80.5 MHz, 160 MHz, and 240 MHz frequency offsets. The transmit spectrum shall not exceed the maximum of the interim transmit spectrum mask and –39(M25) dBm/MHz at any frequency offset. Figure 27-59 (Example transmit spectral mask for a 160 MHz mask PPDU(11ax)) shows an example of the resulting overall spectral mask when the –40 dBr spectrum level is above –39 dBm/MHz(M25).

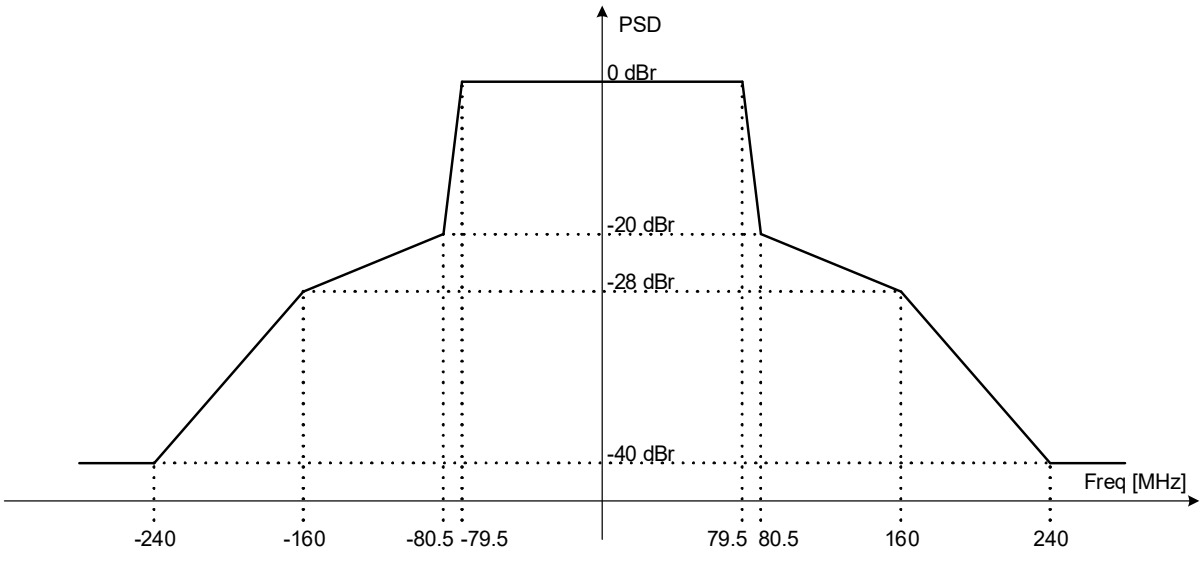


**Figure 27-59—Example transmit spectral mask for a 160 MHz mask PPDU(11ax)**

For an 80+80 MHz mask PPDU of HE format, the overall transmit spectral mask is constructed in the following manner. First, the 80 MHz interim spectral mask is placed on each of the two 80 MHz segments. For each frequency at which either of the 80 MHz interim spectral mask has a value equal to 0 dBr, then 0 dBr shall be taken as the overall interim spectral mask value. Then, for each frequency at which both of the 80 MHz interim spectral masks have values greater than –40 dBr and less than –20 dBr, the sum of the two interim mask values (summed in linear domain) shall be taken as the overall interim spectral mask value. Next, for each frequency at which neither of the two 80 MHz interim masks has a value greater than or equal to –20 dBr, the higher value of the two interim masks shall be taken as the overall interim spectral mask value. Finally, for any frequency region where the overall interim spectral mask value has not been defined yet, linear interpolation (in dB domain) between the nearest two frequency points with the overall interim spectral mask value defined shall be used to define the overall interim spectral mask value. The transmit spectrum shall not exceed the maximum of the overall interim transmit spectrum mask and –39 dBm/MHz(M25) at any frequency offset. Figure 27-60 (Example transmit spectral mask for an 80+80 MHz mask PPDU(11ax)) shows an example of a transmit spectral mask for a noncontiguous transmission using two 80 MHz channels where the center frequency of the two 80 MHz channels are separated by 160 MHz and the –40 dBr spectrum level is above –39 dBm/MHz(M25).

Different center frequency separation between the two 80 MHz frequency segments of the spectral mask and different peak levels of each 80 MHz frequency segment of the spectral mask are possible. In such cases, a similar procedure in determining the spectral mask as in Figure 27-60 (Example transmit spectral mask for an 80+80 MHz mask PPDU(11ax)) is followed.

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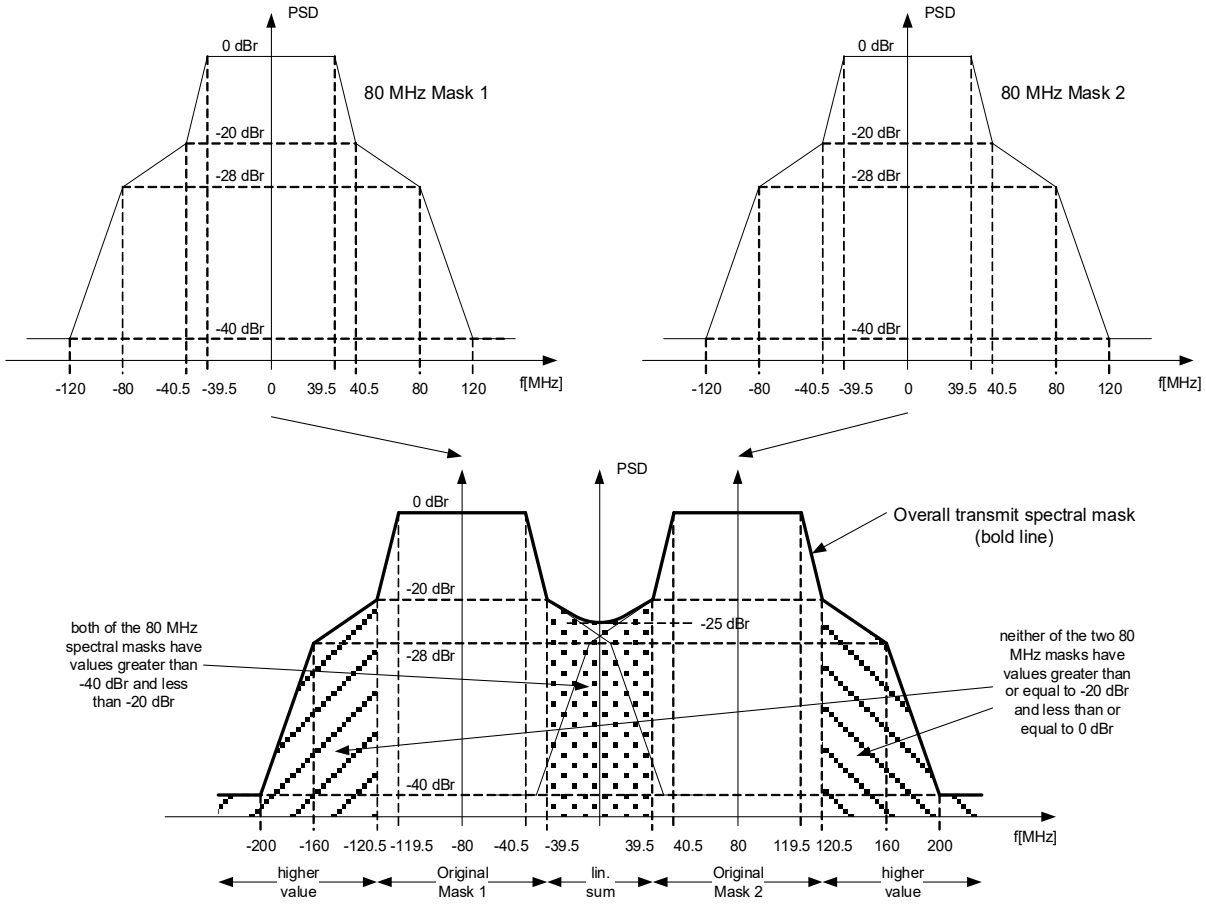


**Figure 27-60—Example transmit spectral mask for an 80+80 MHz mask PPDU(11ax)**

The transmit spectral mask for noncontiguous transmissions using two nonadjacent 80 MHz channels is applicable only in regulatory domains that allow for such transmissions.

Measurements shall be made using a 100 kHz resolution bandwidth and a 7.5 kHz video bandwidth.

For preamble puncture, the signal leakage to the preamble punctured channel from the occupied subchannels shall be less than or equal to –20 dBr starting 0.5 MHz from the boundary of the preamble punctured channel. Denote the number of 20 MHz punctured channels by *N*.

An example transmit spectral mask for an *N*×20 MHz preamble punctured channel with transmission on the both the upper and lower subchannels is shown in Figure 27-61 (Example transmit spectral mask for the N×20 MHz preamble punctured channel with transmissions on both upper and lower subchannels(11ax)), where the X axis in the plot is centered in the middle of the punctured subbands.


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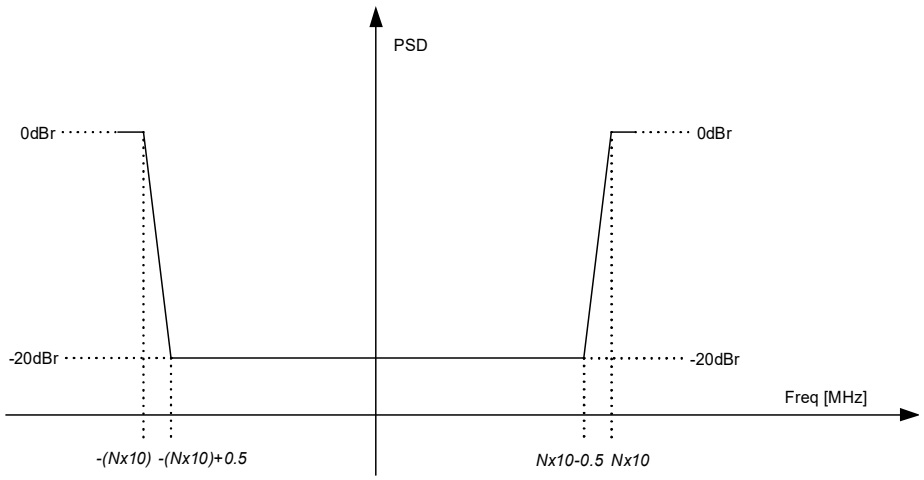


**Figure 27-61—Example transmit spectral mask for the *N*×20 MHz preamble punctured channel with transmissions on both upper and lower subchannels(11ax)**

An example transmit spectral mask for an 80 MHz HE PPDU with the highest 20 MHz subchannel punctured is shown in Figure 27-62 (Example transmit spectral mask for an 80 MHz HE PPDU with the highest 20 MHz subchannel punctured(11ax)).

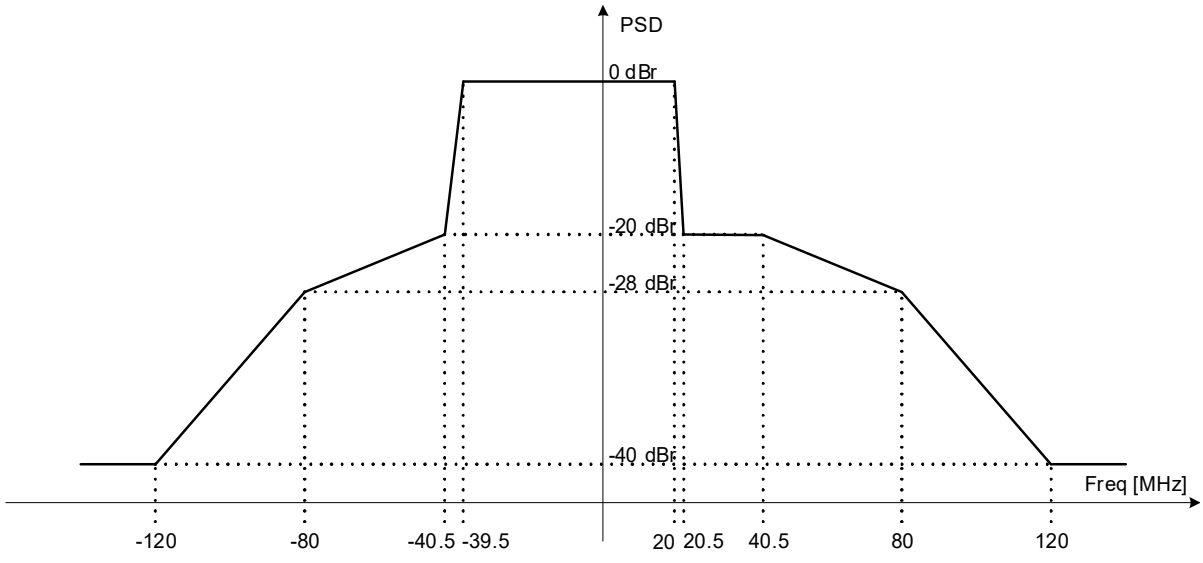


**Figure 27-62—Example transmit spectral mask for an 80 MHz HE PPDU with the highest 20 MHz subchannel punctured(11ax)**

### 27.3.21.2 Spectral flatness

Spectral flatness measurements shall be conducted using BPSK modulated HE PPDUs. The HE PPDUs shall be demodulated using the following (or equivalent) procedure:

a) Start of PPDU shall be detected.

b) Transition from L-STF to L-LTF shall be detected, and fine timing shall be established.

c) Coarse and fine frequency offsets shall be estimated.

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d) Symbols in a PPDU shall be manipulated to account for both frequency error and sampling offset drift.

e) For each HE-LTF symbol, transform the symbol into subcarrier received values, estimate the phase from the pilot subcarriers, and compensate the subcarrier values according to the estimated phase.

f) For each of the data OFDM symbols, transform the symbol into subcarrier received values.

The spectral flatness test shall be performed over at least 20 HE PPDUs. The PPDUs under test shall be at least 16 data OFDM symbols long.

Evaluate spectral flatness using the subcarrier received values or the magnitude of the channel estimation of the occupied subcarriers of the transmission HE PPDUs. Nonoccupied subcarriers of the transmitted HE PPDUs shall be ignored during averaging and testing. Resource unit power boosting and beamforming should not be used when measuring spectral flatness.

Let $E_{i,avg}$ denote the magnitude of the channel estimation on subcarrier $i$ or the average constellation energy of a BPSK modulated subcarrier $i$ in an HE data symbol. In a contiguous HE transmission having a bandwidth listed in Table 27-55 (Maximum transmit spectral flatness deviations(11ax)), $E_{i,avg}$ of each of the subcarriers with indices listed as tested subcarrier indices shall not deviate by more than the specified maximum deviation in Table 27-55 (Maximum transmit spectral flatness deviations(11ax)) from the average of $E_{i,avg}$ over subcarrier indices listed as averaging subcarrier indices. Averaging of $E_{i,avg}$ is done in the linear domain.

**Table 27-55—Maximum transmit spectral flatness deviations(11ax)**

| Bandwidth of transmission (MHz) | Averaging subcarrier indices (inclusive) | Tested subcarrier indices (inclusive) | Maximum deviation (dB) |
|---|---|---|---|
| 20 | –84 to –2 and +2 to +84 | –84 to –2 and +2 to +84 | ± 4 |
| | | –122 to –85 and +85 to +122 | +4/–6 |
| 40 | –168 to –3 and +3 to +168 | –168 to –3 and +3 to +168 | ± 4 |
| | | –244 to –169 and +169 to +244 | +4/–6 |
| 80 | –344 to –3 and +3 to +344 | –344 to –3 and +3 to +344 | ± 4 |
| | | –500 to –345 and +345 to +500 | +4/–6 |
| 160 | –696 to –515, –509 to –166, +166 to +509, and +515 to +696 | –696 to –515, –509 to –166, +166 to +509, and +515 to +696 | ± 4 |
| | | –1012 to –697, –165 to –12, +12 to +165, and +697 to +1012 | +4/–6 |

In an 80+80 MHz transmission, each segment shall meet the spectral flatness requirement for an 80 MHz transmission.

For the spectral flatness test, the transmitting STA shall be configured to use a spatial mapping matrix $Q_k$ (see 27.3.12.14 (OFDM modulation)) with flat frequency response. Each output port under test of the transmitting STA shall be connected through a cable to one input port of the testing instrumentation. The requirements shall apply to 20 MHz, 40 MHz, 80 MHz, and 160 MHz contiguous transmissions as well as 80+80 MHz transmissions.


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#### 27.3.21.3 Transmit center frequency and symbol clock frequency tolerance

Transmit center frequency and the symbol clock frequency for all transmit antennas and frequency segments shall be derived from the same reference oscillator. The symbol clock frequency and transmit center frequency tolerance shall be ± 20 ppm in the 5 GHz and 6 GHz bands and ± 25 ppm in the 2.4 GHz band. HE TB PPDU format is subject to additional requirements as defined in 27.3.15 (Transmit requirements for PPDUs sent in response to a triggering frame).

Transmit signals with TXVECTOR parameter CH_BANDWIDTH set to CBW160 or CBW80+80 may be generated using two separate RF LOs, one for each of the lower and upper 80 MHz frequency portions.

NOTE—The signal phase of the two 80 MHz frequency portions might not be correlated.

#### 27.3.21.4 Modulation accuracy

##### 27.3.21.4.1 Introduction to modulation accuracy tests

Transmit modulation accuracy specifications are described in 27.3.21.4.2 (Transmit center frequency leakage) and 27.3.21.4.3 (Transmitter constellation error). The test method is described in 27.3.21.4.4 (Transmitter modulation accuracy (EVM) test).

##### 27.3.21.4.2 Transmit center frequency leakage

For an 80+80 MHz transmission where the RF LO falls outside both frequency segments, the RF LO shall meet the spectral mask requirements as defined in 27.3.21.1 (Transmit spectral mask). Otherwise, the power measured at the location of the RF LO using resolution BW 78.125 kHz shall not exceed the maximum of –32 dB relative to the total transmit power and –20 dBm, or equivalently max($P$ – 32, –20), where $P$ is the transmit power per antenna in dBm. The transmit center frequency leakage is specified per antenna.

##### 27.3.21.4.3 Transmitter constellation error

The relative constellation RMS error in the test, calculated by first averaging over subcarriers, frequency segments, HE PPDUs, and spatial streams (#4181)(see Equation (27-140)) as described in 27.3.21.4.4 (Transmitter modulation accuracy (EVM) test) shall not exceed a data-rate-dependent value according to Table 27-56 (Allowed relative constellation error versus constellation size and coding rate(11ax)). The number of spatial streams under test shall be equal to the number of utilized transmitting STA antenna (output) ports and also equal to the number of utilized testing instrumentation input ports. In the test, $N_{SS} = N_{STS}$ (no STBC), and no beamforming steering matrix shall be used. Each output port of the transmitting STA shall be connected through a cable to one input port of the testing instrumentation. The

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requirements shall apply to 20 MHz, 40 MHz, 80 MHz, and 160 MHz contiguous transmissions as well as 80+80 MHz noncontiguous transmissions.

**Table 27-56—Allowed relative constellation error versus constellation size and coding rate(11ax)**

| Modulation | | Coding rate | Relative constellation error in an HE SU PPDU, HE ER SU PPDU, and HE MU PPDU (dB) | Relative constellation error in an HE TB PPDU when transmit power is larger than maximum power of HE-MCS 7 (dB) | Relative constellation error in an HE TB PPDU when transmit power is less than or equal to maximum power of HE-MCS 7 (dB) |
|---|---|---|---|---|---|
| Without DCM | With DCM | | | | |
| N/A | BPSK | 1/2 | –5 | –13 | –27 |
| BPSK | QPSK | 1/2 | –5 | –13 | –27 |
| QPSK | 16-QAM | 1/2 | –10 | –13 | –27 |
| QPSK | 16-QAM | 3/4 | –13 | –13 | –27 |
| 16-QAM | N/A | 1/2 | –16 | –16 | –27 |
| 16-QAM | N/A | 3/4 | –19 | –19 | –27 |
| 64-QAM | N/A | 2/3 | –22 | –22 | –27 |
| 64-QAM | N/A | 3/4 | –25 | –25 | –27 |
| 64-QAM | N/A | 5/6 | –27 | –27 | –27 |
| 256-QAM | N/A | 3/4 | –30 | –30 | –30 |
| 256-QAM | N/A | 5/6 | –32 | –32 | –32 |
| 1024-QAM | N/A | 3/4 | –35/–32 | –35/–32 | –35/–32 |
| 1024-QAM | N/A | 5/6 | –35/–32 | –35/–32 | –35/–32 |

NOTE—The maximum power of HE-MCS 7 can be measured by setting the (#4405)UL Target Receive Power subfield as defined in Table 9-54 (UL Target Receive Power subfield in Trigger frame(11ax)) in the Trigger frame to 127 for the RU for which the EVM test is conducted.

For 1024-QAM, the relative constellation error shall meet either one of the following requirements:

— The relative constellation error shall be less than or equal to –35 dB if amplitude drift compensation is disabled in the test equipment.

— The relative constellation error shall be less than or equal to –35 dB with amplitude drift compensation enabled in the test equipment, and the relative constellation error shall be less than or equal to –32 dB with amplitude drift compensation disabled in the test equipment.

For all other constellations, the relative constellation error shall be less than or equal to the values in Table 27-56 (Allowed relative constellation error versus constellation size and coding rate(11ax)) regardless of whether amplitude drift compensation is enabled in the test equipment.


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#### 27.3.21.4.4 Transmitter modulation accuracy (EVM) test

The transmit modulation accuracy test shall be performed by instrumentation capable of converting the transmitted signals into a stream of complex samples at a sampling rate greater than or equal to the bandwidth of the signal being transmitted, except that for a noncontiguous transmissions each frequency segment may be tested independently.

In this case, transmit modulation accuracy of each segment shall meet the required value in Table 27-56 (Allowed relative constellation error versus constellation size and coding rate(11ax)) using only the occupied data subcarriers within the corresponding segment. For HE TB PPDU transmission, two sets of EVM requirements are defined in Table 27-56 (Allowed relative constellation error versus constellation size and coding rate(11ax)) for different transmission power levels to assist AP in better managing the interference among multiple STAs responding to a Trigger frame.

LO leakage that can potentially show up at the center frequency of the HE PPDU tone plan and within ± 3 neighboring subcarriers shall be excluded from the computation of the transmitter modulation accuracy test. The potential LO leakage subcarriers for 20 MHz operating devices are the center of primary 20 MHz of the HE PPDU tone plan and ± 3 subcarriers of it. The potential LO leakage subcarriers for 40 MHz operating devices are the center of the primary 40 MHz of the PPDU tone plan and ± 3 subcarriers. The potential LO leakage subcarriers for 80 MHz operating devices are the center of the primary 80 MHz of the PPDU tone plan and ± 3 subcarriers of it. The potential LO leakage tones for 160 MHz operating devices are the center of the 160 MHz of the PPDU tone plan and ± 3 subcarriers of it. The potential LO leakage tones for 80+80 MHz operating devices exist outside the PPDU bandwidth and should not affect the transmitter modulation accuracy test. For 40 MHz capable devices that transmit 20 MHz, the potential LO leakage subcarriers exist outside the PPDU bandwidth and should not affect the transmitter modulation accuracy test. For 80 MHz capable devices that transmit 20 MHz or 40 MHz PPDU, the potential LO leakage subcarriers exist outside the PPDU bandwidth and should not affect the transmitter modulation accuracy test. For 160 or 80+80 MHz capable devices that transmit 20 MHz or 40 MHz PPDU or 80 MHz PPDU, the potential LO leakage subcarriers exist outside the PPDU bandwidth and should not affect the transmitter modulation accuracy test.

The instrument shall have sufficient accuracy in terms of I/Q branch amplitude and phase balance, DC offsets, phase noise, and analog-to-digital quantization noise. A possible embodiment of such a setup is converting the signals to a low IF frequency with a microwave synthesizer, sampling the signal with a digital oscilloscope, and decomposing it digitally into quadrature components. The sampled signal shall be processed in a manner similar to an actual receiver using the following or equivalent procedure:

a) Start of PPDU shall be detected.
b) Transition from L-STF to L-LTF shall be detected, and fine timing shall be established.
c) Coarse and fine frequency offsets shall be estimated.
d) Symbols in a PPDU shall be derotated according to estimated frequency offset. Sampling offset drift shall be also compensated.
e) For each HE-LTF symbol, transform the symbol into subcarrier received values, estimate the phase from the pilot subcarriers, and derotate the subcarrier values according to the estimated phase.
f) Estimate the complex channel response coefficient for each of the subcarriers and each of the transmit streams. If midambles are present in the Data field of the PPDU, the channel response coefficients shall be based upon the most recently received midamble symbols.
g) For each of the data OFDM symbols, transform the symbol into subcarrier received values, estimate the phase from the pilot subcarriers, compensate the subcarrier values according to the estimated phase, group the results from all of the receiver chains in each subcarrier to a vector, and multiply the vector by a zero-forcing equalization matrix generated from the estimated channel.

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h) For each data-carrying subcarrier in each spatial stream of RU under test, find the closest constellation point, and compute the Euclidean distance from it. If midambles are present in the Data field of the PPDU, the midamble symbols shall not be used to compute the Euclidean distance.

i) Compute the average across PPDUs of the RMS of all errors per PPDU as given by Equation (27-140).

$$Error_{RMS} = \frac{1}{N_f}\sum_{i_f=1}^{N_f}\sqrt{\frac{\sum_{i_s=1}^{N_{SYM}}\sum_{i_{ss}=1}^{N_{SS}}\sum_{i_{sc}=1}^{N_{SD}}\left(I_e(i_f,i_s,i_{ss},i_{sc})-I_0(i_f,i_s,i_{ss},i_{sc})\right)^2+\left(Q_e(i_f,i_s,i_{ss},i_{sc})-Q_0(i_f,i_s,i_{ss},i_{sc})\right)^2}{N_{SYM}N_{SS}N_{SD}P_0}} \quad (27\text{-}140)$$

where

$I_0(i_f, i_s, i_{ss}, i_{sc})$ $Q_0(i_f, i_s, i_{ss}, i_{sc})$
: denotes the ideal symbol point in the complex plane in data subcarrier $i_{sc}$ of the RU under test, spatial stream $i_{ss}$, and OFDM symbol $i_s$ of (#1065)PPDU $i_f$

$I_e(i_f, i_s, i_{ss}, i_{sc})$ $Q_e(i_f, i_s, i_{ss}, i_{sc})$
: denotes the equalized observed symbol point in the complex plane of the data subcarrier $i_{sc}$ of the RU under test, spatial stream $i_{ss}$, and OFDM symbol $i_s$ of (#1065)PPDU $i_f$

$P_0$ is the average power of constellation

$N_f$ is the number of tested (#1065)PPDUs

$N_{SD}$ is the number of data tones of the occupied RU. For an 80+80 MHz transmission, $N_{SD}$ is the total number of data subcarriers in both 80 MHz frequency segments.

$N_{SS}$ is the number of spatial streams of the data (#1065)OFDM symbols

$N_{SYM}$ is the number of data OFDM symbols

The test shall be performed over at least 20 PPDUs [$N_f$ as defined in Equation (27-140)]. If the occupied RU has 26 tones, the PPDUs under test shall be at least 32 data OFDM symbols long. For occupied RUs that have more than 26 tones, the PPDUs under test shall be at least 16 data OFDM symbols long. Random data shall be used for the symbols.

For an HE TB PPDU with an RU smaller than a 2×996-tone RU, additional transmit modulation accuracy test for the unoccupied subcarriers of the PPDU shall be performed. The transmit modulation accuracy of unoccupied subcarriers of the PPDU test shall be performed by instrumentation capable of converting the transmitted signals into a stream of complex samples at a sampling rate greater than or equal to the bandwidth of the signal being transmitted, except that for noncontiguous transmissions, only the frequency segment with occupied subcarriers is tested. The transmit modulation accuracy of unoccupied subcarriers of the PPDU shall meet the relative constellation error staircase mask specified in Equation (27-144) for each modulation and coding rate using the unoccupied subcarriers within the corresponding segment.

The instrument shall have sufficient accuracy in terms of I/Q branch amplitude and phase balance, DC offsets, phase noise, and analog-to-digital quantization noise. A possible embodiment of such a setup is converting the signals to a low IF frequency with a microwave synthesizer, sampling the signal with a digital oscilloscope and decomposing it digitally into quadrature components. The sampled signal shall be processed in a manner similar to an actual receiver, according to the following steps, or equivalent procedure:

a) Start of PPDU shall be detected.

b) Transition from L-STF to L-LTF shall be detected, and fine timing shall be established.

c) Coarse and fine frequency offsets shall be estimated.


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d) Symbols in a PPDU shall be derotated according to estimated frequency offset. Sampling offset drift shall be also compensated.

e) For each of the data OFDM symbols, transform the symbol into subcarrier received values, and estimate the power of each subcarrier.

f) Compute the average unoccupied subcarrier error vector magnitude for each unoccupied 26-tone RU and average across PPDUs of the RMS of all errors per PPDU as given by Equation (27-141).

$$UnusedToneError_{RMS}(k) = \frac{1}{N_f}\sum_{i_f=1}^{N_f}\sqrt{\frac{\sum_{i_s=1}^{N_{SYM}}\sum_{i_{sc}\in\Omega_k}(I_u(i_f,i_s,i_{sc}))^2+(Q_u(i_f,i_s,i_{sc}))^2}{N_{SYM}\cdot 26\cdot P_S}} \quad (27\text{-}141)$$

where

$I_u(i_f, i_s, i_{sc})$ $Q_u(i_f, i_s, i_{sc})$
: denotes unequalized observed symbol point in the complex plane in subcarrier $i_{sc}$ of the unoccupied 26-tone RU and OFDM symbol $i_s$ of (#1065)PPDU $i_f$

$\Omega_k$
: is a set of subcarriers for $k^{th}$ 26-tone RU as defined in Table 27-8 (Data and pilot subcarrier indices for RUs in a 20 MHz HE PPDU and in a non-OFDMA 20 MHz HE PPDU(11ax)), Table 27-9 (Data and pilot subcarrier indices for RUs in a 40 MHz HE PPDU and in a non-OFDMA 40 MHz HE PPDU(11ax)), and Table 27-10 (Data and pilot subcarrier indices for RUs in an 80 MHz HE PPDU and in a non-OFDMA 80 MHz HE PPDU(11ax))

$P_S$
: is the average data subcarrier power of the occupied RU under test and is given by Equation (27-142)

$$P_S = \frac{1}{N_{SYM}N_{SD}}\sum_{i_s=1}^{N_{SYM}}\sum_{i_{sc}=1}^{N_{SD}}(I_u(i_f,i_s,i_{SC}))^2+(Q_u(i_f,i_s,i_{SC}))^2 \quad (27\text{-}142)$$

$N_f$
: is the number of tested (#1065)PPDUs

$N_{SYM}$
: is the number of data OFDM symbols

$N_{SD}$
: is the number of data subcarriers in the occupied RU

g) For all HE-MCSs, for an occupied RU bandwidth of $r$ in units of a 26-tone RU as defined by Equation (27-143),

$$r = \begin{cases} 1, \text{ if 26-tone RU} \\ 2, \text{ if 52-tone RU} \\ 4, \text{ if 106-tone RU} \\ 9, \text{ if 242-tone RU} \\ 18, \text{ if 484-tone RU} \\ 37, \text{ if 996-tone RU} \end{cases} \quad (27\text{-}143)$$

The average unused subcarrier error vector magnitude for each unoccupied 26-tone RU as calculated in step f) shall meet the staircase mask requirement in Equation (27-144) and Equation (27-145), where $m$ defines the gap in the units of 26-tone RU to the occupied RU from either side with $m = \pm 1$ being the adjacent 26-tone RUs.

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$$UnusedToneError(i_{RU26,\,start}+m) \le \begin{cases} max(\varepsilon-2,-35\text{ dB}), & \text{if } -r \le m \le -1 \\ max(\varepsilon-12,-35\text{ dB}), & \text{if } -2r \le m \le -r-1 \\ max(\varepsilon-22,-35\text{ dB}), & \text{if } -3r \le m \le -2r-1 \\ -35\text{ dB}, & \text{otherwise} \end{cases} \quad (27\text{-}144)$$

The valid range for $m$ for Equation (27-144) is as follows:

$-i_{RU26,\,start}+1 \le m \le -1$ for a 20 MHz, 40 MHz, 80 MHz, or 160 MHz PPDU

$-i_{RU26,\,start}+1 \le m \le -1$ for an 80+80 MHz PPDU and $i_{RU26,\,start} \le 37$

$-i_{RU26,\,start}+38 \le m \le -1$ for an 80+80 MHz PPDU and $i_{RU26,\,start} > 37$

$$UnusedToneError(i_{RU26,\,end}+m) \le \begin{cases} max(\varepsilon-2,-35\text{ dB}), & \text{if } 1 \le m \le r \\ max(\varepsilon-12,-35\text{ dB}), & \text{if } r+1 \le m \le 2r \\ max(\varepsilon-22,-35\text{ dB}), & \text{if } 2r+1 \le m \le 3r \\ -35\text{ dB}, & \text{otherwise} \end{cases} \quad (27\text{-}145)$$

The valid range for $m$ for Equation (27-145) is as follows:

$1 \le m \le N_{RU26}-i_{RU26,\,end}$ for a 20 MHz, 40 MHz, 80 MHz, or 160 MHz PPDU

$1 \le m \le 37-i_{RU26,\,end}$ for an 80+80 MHz PPDU and $i_{RU26,\,start} \le 37$

$1 \le m \le 74-i_{RU26,\,end}$ for an 80+80 MHz PPDU and $i_{RU26,\,start} > 37$

where

$i_{RU26,start}$ is equal to $i_{RU}$ if the occupied RU is a 26-tone RU and is defined in Table 27-57 (iRU26,start for RUs other than a 26-tone RU(11ax)) for other RU sizes

**Table 27-57—$i_{RU26,start}$ for RUs other than a 26-tone RU(11ax)**

| $i_{RU}$ | 52-tone RU | 106-tone RU | 242-tone RU | 484-tone RU | 996-tone RU |
|---|---|---|---|---|---|
| 1 | 1 | 1 | 1 | 1 | 1 |
| 2 | 3 | 6 | 10 | 20 | 38 |
| 3 | 6 | 10 | 20 | 38 | |
| 4 | 8 | 15 | 29 | 57 | |
| 5 | 10 | 20 | 38 | | |
| 6 | 12 | 25 | 47 | | |
| 7 | 15 | 29 | 57 | | |
| 8 | 17 | 34 | 66 | | |
| 9 | 20 | 38 | | | |
| 10 | 22 | 43 | | | |
| 11 | 25 | 47 | | | |
| 12 | 27 | 52 | | | |
| 13 | 29 | 57 | | | |


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**Table 27-57—$i_{RU26,start}$ for RUs other than a 26-tone RU(11ax) *(continued)***

| $i_{RU}$ | 52-tone RU | 106-tone RU | 242-tone RU | 484-tone RU | 996-tone RU |
|---|---|---|---|---|---|
| 14 | 31 | 62 | | | |
| 15 | 34 | 66 | | | |
| 16 | 36 | 71 | | | |
| 17 | 38 | | | | |
| 18 | 40 | | | | |
| 19 | 43 | | | | |
| 20 | 45 | | | | |
| 21 | 47 | | | | |
| 22 | 49 | | | | |
| 23 | 52 | | | | |
| 24 | 54 | | | | |
| 25 | 57 | | | | |
| 26 | 59 | | | | |
| 27 | 62 | | | | |
| 28 | 64 | | | | |
| 29 | 66 | | | | |
| 30 | 68 | | | | |
| 31 | 71 | | | | |
| 32 | 73 | | | | |

$i_{RU26,end}$ is equal to $i_{RU26,start} + r - 1$

$i_{RU}$ is the index of the occupied RU

$N_{RU26}$ is the maximum number of 26-tone RUs for the given bandwidth of the HE TB PPDU as defined in Table 27-16 (Frequently used parameters(11ax))

ε is the relative constellation error requirement for an occupied RU of an HE TB PPDU as defined in Table 27-56 (Allowed relative constellation error versus constellation size and coding rate(11ax))

NOTE—For an 80+80 MHz PPDU the unused subcarrier error is measured only in the 80 MHz segment in which the occupied RU is located. This leads to the different valid range for *m* in Equation (27-144) and Equation (27-145) for the 80+80 MHz PPDU.

The test shall be performed over at least 20 PPDUs [$N_f$ as defined in Equation (27-140)]. The PPDUs under test shall be at least 16 data OFDM symbols long. The unequalized observed symbol of potential LO leakage subcarrier locations shall be treated as zero during unoccupied subcarriers transmit modulation accuracy test. Random data shall be used for the symbols.

### 27.3.21.5 Time of departure accuracy(11az)

(#8056)The RMS accuracy of the time of departure provided in TIME_OF_DEPARTURE shall be less than or equal to 80 ns.

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The time of departure accuracy test evaluates TIME_OF_DEPARTURE against aTxPHYTxStartRMS and aTxPHYTxStartRMS against TIME_OF_DEPARTURE_ACCURACY_TEST_THRESH as defined in Annex P with the following test parameters:

— MULTICHANNEL_SAMPLING_RATE is:

$20\times10^6\left(1+\left\lceil\frac{f_H-f_L}{20\text{ MHz}}\right\rceil\right)$ sample/s, for a CH_BANDWIDTH parameter equal to CBW20

$40\times10^6\left(1+\left\lceil\frac{f_H-f_L}{40\text{ MHz}}\right\rceil\right)$ sample/s, for a CH_BANDWIDTH parameter equal to CBW40

$80\times10^6\left(1+\left\lceil\frac{f_H-f_L}{80\text{ MHz}}\right\rceil\right)$ sample/s, for a CH_BANDWIDTH parameter equal to CBW80

$160\times10^6\left(1+\left\lceil\frac{f_H-f_L}{160\text{ MHz}}\right\rceil\right)$ sample/s, for a CH_BANDWIDTH parameter equal to CBW160 or CBW80+80

where

| | |
|---|---|
| $f_H$ | is the nominal center frequency in Hz of the highest channel in the channel set |
| $f_L$ | is the nominal center frequency in Hz of the lowest channel in the channel set |
| the channel set | is the set of channels upon which frames providing measurements are transmitted, the channel set comprises channels uniformly spaced across |

— FIRST_TRANSITION_FIELD is L-STF

— SECOND_TRANSITION_FIELD is L-LTF

— TRAINING_FIELD is L-LTF windowed in a manner which should approximate the windowing described in 17.3.2.5 (Mathematical conventions in the signal descriptions) with TTR = 100 ns

— TIME_OF_DEPARTURE_ACCURACY_TEST_THRESH is 80 ns

NOTE—The indicated windowing applies to the time of departure accuracy test equipment, and not the transmitter or receiver.

### 27.3.22 Receiver specification

#### 27.3.22.1 General

For receiver minimum input sensitivity, adjacent channel rejection, nonadjacent channel rejection, receiver maximum input level, and CCA sensitivity requirements described in this subclause, the input levels are measured at the transmit antenna connector and are referenced as the average power per receive antenna. (#2091)For tests in 27.3.22.2 (Receiver minimum input level sensitivity(#256)), 27.3.22.3 (Adjacent channel rejection), and 27.3.22.4 (Nonadjacent channel rejection), the number of spatial streams under test shall be equal to the number of utilized transmitting STA antenna (output) ports and also equal to the number of utilized (#1768)receiving STA antenna (input) ports. (#2091)Except where otherwise noted, each output port of the transmitting STA shall be connected through a cable to one input port of the (#1768)receiving STA.

NOTE—Additional test requirements and/or test methods may be needed to meet regulatory requirements.

The requirements on receiver minimum input sensitivity in 27.3.22.2 (Receiver minimum input level sensitivity(#256)), adjacent channel rejection in 27.3.22.3 (Adjacent channel rejection), and nonadjacent


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channel rejection in 27.3.22.4 (Nonadjacent channel rejection) apply to PPDUs that meet all the following conditions:

— STBC is not used.
— 0.8 μs GI is used.
— If the PPDU bandwidth is 20 MHz and the HE-MCS is less than 10, then BCC is used. Otherwise, LDPC is used.
— The PPDU is an HE SU PPDU.

### 27.3.22.2 Receiver minimum input level sensitivity(#256)

The (#1065)PER shall be less than 10% for a PSDU with the rate-dependent input levels listed in Table 27-58 (Receiver minimum input level sensitivity(11ax)). The PSDU length shall be 2048 octets for BPSK modulation with DCM or 4096 octets for all other modulations.

**Table 27-58—Receiver minimum input level sensitivity(11ax)**

| Modulation | | Rate (*R*) | Minimum sensitivity (20 MHz PPDU) (dBm) | Minimum sensitivity (40 MHz PPDU) (dBm) | Minimum sensitivity (80 MHz PPDU) (dBm) | Minimum sensitivity (160 MHz or 80+80 MHz PPDU) (dBm) |
|---|---|---|---|---|---|---|
| Without DCM | With DCM | | | | | |
| N/A | BPSK | 1/2 | –82 | –79 | –76 | –73 |
| BPSK | QPSK | 1/2 | –82 | –79 | –76 | –73 |
| QPSK | 16-QAM | 1/2 | –79 | –76 | –73 | –70 |
| QPSK | 16-QAM | 3/4 | –77 | –74 | –71 | –68 |
| 16-QAM | N/A | 1/2 | –74 | –71 | –68 | –65 |
| 16-QAM | N/A | 3/4 | –70 | –67 | –64 | –61 |
| 64-QAM | N/A | 2/3 | –66 | –63 | –60 | –57 |
| 64-QAM | N/A | 3/4 | –65 | –62 | –59 | –56 |
| 64-QAM | N/A | 5/6 | –64 | –61 | –58 | –55 |
| 256-QAM | N/A | 3/4 | –59 | –56 | –53 | –50 |
| 256-QAM | N/A | 5/6 | –57 | –54 | –51 | –48 |
| 1024-QAM | N/A | 3/4 | –54 | –51 | –48 | –45 |
| 1024-QAM | N/A | 5/6 | –52 | –49 | –46 | –43 |

### 27.3.22.3 Adjacent channel rejection

Adjacent channel rejection for *W* MHz (where *W* is 20, 40, 80, or 160) shall be measured by setting the desired signal's strength 3 dB above the rate-dependent sensitivity specified in Table 27-58 (Receiver minimum input level sensitivity(11ax)) and raising the power of the interfering signal of W MHz bandwidth until 10% PER is caused for a PSDU length of 2048 octets for BPSK modulation with DCM or 4096 octets for all other modulations. The difference in power between the signals in the interfering channel and the desired channel is the corresponding adjacent channel rejection. The center frequency of the adjacent channel shall be placed *W* MHz away from the center frequency of the desired signal.

Adjacent channel rejection for 80+80 MHz channels shall be measured by setting the desired signal's strength 3 dB above the rate-dependent sensitivity specified in Table 27-58 (Receiver minimum input level sensitivity(11ax)). Then, an interfering signal of 80 MHz bandwidth is introduced, where the center

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frequency of the interfering signal is placed 80 MHz away from the center frequency of the frequency segment lower in the frequency of the desired signal. The power of interfering signal is raised until 10% PER is caused for a PSDU length of 2048 octets for BPSK modulation with DCM or 4096 octets for all other modulations. Let $\Delta P_1$ be the difference between the interfering and desired signal. Next, the interfering signal of 80 MHz bandwidth is moved to the frequency where the center frequency of the interfering signal is 80 MHz away from the center frequency of the frequency segment higher in frequency of the desired signal. The power of the interfering is raised until 10% PER is caused for a PSDU length of 2048 octets for BPSK modulation with DCM or 4096 octets for all other modulations. Let $\Delta P_2$ be the power difference between the interfering and desired signal. The smaller value between $\Delta P_1$ and $\Delta P_2$ is the corresponding adjacent channel rejection.

The interfering signal in the adjacent channel shall be a signal compliant with the HE PHY, unsynchronized with the signal in the channel under test, and shall have a minimum duty cycle of 50%. The corresponding rejection shall be no less than specified in Table 27-59 (Minimum required adjacent and nonadjacent channel rejection levels(11ax)).

**Table 27-59—Minimum required adjacent and nonadjacent channel rejection levels(11ax)**

| Modulation | | Rate (*R*) | Adjacent channel rejection (dB) | | Nonadjacent channel rejection (dB) | |
|---|---|---|---|---|---|---|
| Without DCM | With DCM | | 20/40/80/ 160 MHz channel (#7214) | 80+80 MHz channel | 20/40/80/ 160 MHz channel (#7214) | 80+80 MHz channel |
| N/A | BPSK | 1/2 | 16 | 13 | 32 | 29 |
| BPSK | QPSK | 1/2 | 16 | 13 | 32 | 29 |
| QPSK | 16-QAM | 1/2 | 13 | 10 | 29 | 26 |
| QPSK | 16-QAM | 3/4 | 11 | 8 | 27 | 24 |
| 16-QAM | N/A | 1/2 | 8 | 5 | 24 | 21 |
| 16-QAM | N/A | 3/4 | 4 | 1 | 20 | 17 |
| 64-QAM | N/A | 2/3 | 0 | –3 | 16 | 13 |
| 64-QAM | N/A | 3/4 | –1 | –4 | 15 | 12 |
| 64-QAM | N/A | 5/6 | –2 | –5 | 14 | 11 |
| 256-QAM | N/A | 3/4 | –7 | –10 | 9 | 6 |
| 256-QAM | N/A | 5/6 | –9 | –12 | 7 | 4 |
| 1024-QAM | N/A | 3/4 | –12 | –15 | 4 | 1 |
| 1024-QAM | N/A | 5/6 | –14 | –17 | 2 | –1 |

The measurement of adjacent channel rejection for 160 MHz operation in regulatory domain is required only if such a frequency band plan is permitted in the regulatory domain.

### 27.3.22.4 Nonadjacent channel rejection

Nonadjacent channel rejection for *W* MHz channels (where *W* is 20, 40, 80, or 160) shall be measured by setting the desired signal's strength 3 dB above the rate-dependent sensitivity specified in Table 27-58


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(Receiver minimum input level sensitivity(11ax)) and (#1027)increasing the power of the interfering signal of $W$ MHz bandwidth until a 10% PER occurs for a PSDU length of 2048 octets for BPSK modulation with DCM or 4096 octets for all other modulations. The difference in power between the signals in the interfering channel and the desired channel is the corresponding nonadjacent channel rejection. The nonadjacent channel rejection shall be met with any nonadjacent channels located at least $2\times W$ MHz away from the center frequency of the desired signal.

Nonadjacent channel rejection for 80+80 MHz channels shall be measured by setting the desired signal's strength 3 dB above the rate-dependent sensitivity specified in Table 27-58 (Receiver minimum input level sensitivity(11ax)). Then, an interfering signal of 80 MHz bandwidth is introduced, where the center frequency of the interfering signal is placed at least 160 MHz away from the center frequency of the frequency segment lower in the frequency of the desired signal. The center frequency of the interfering signal shall also be at least 160 MHz away from the center frequency of the frequency segment higher in frequency of the desired signal. (#1027)The power of the interfering signal is increased until 10% PER is caused for a PSDU length of 2048 octets for BPSK modulation with DCM or 4096 octets for all other modulations. (#1027)Let $\Delta P_1$ be the difference in power between the interfering and desired signal. Next, the interfering signal of 80 MHz bandwidth is moved to the frequency where the center frequency of the interfering signal is at least 160 MHz away from the center frequency of the frequency segment higher in frequency of the desired signal. The center frequency of the interfering signal shall also be at least 160 MHz away from the center frequency of the frequency segment lower in frequency of the desired signal. (#1027)The power of the interfering signal is increased until 10% PER is caused for a PSDU length of 2048 octets for BPSK modulation with DCM or 4096 octets for all other modulations. (#1027)Let $\Delta P_2$ be the difference in power between the interfering and desired signal. The smaller value between $\Delta P_1$ and $\Delta P_2$ is the corresponding nonadjacent channel rejection.

The interfering signal in the nonadjacent channel shall be a signal compliant with the HE PHY, unsynchronized with the signal in the channel under test, and shall have a minimum duty cycle of 50%. The corresponding rejection shall be no less than specified in Table 27-59 (Minimum required adjacent and nonadjacent channel rejection levels(11ax)).

The measurement of nonadjacent channel rejection for 160 MHz operation in regulatory domain is required only if such a frequency band plan is permitted in the regulatory domain.

#### 27.3.22.5 Receiver maximum input level

The receiver shall provide a maximum PER of 10% at a PSDU length of 2048 octets for BPSK modulation with DCM or 4096 octets for all other modulations, for a maximum input level of –30 dBm in the 5 GHz and 6 GHz bands and –20 dBm in the 2.4 GHz band, measured at each antenna for any baseband HE modulation.

#### 27.3.22.6 CCA sensitivity

##### 27.3.22.6.1 General

The thresholds in 27.3.22.6 (CCA sensitivity) are compared with the signal level at each receiving antenna.

##### 27.3.22.6.2 CCA sensitivity for operating classes requiring CCA-OCSED(#2365)

For the operating classes requiring CCA-Operating Class Specific Energy Detect (CCA-OCSED), the PHY shall indicate a medium busy condition if CCA-OCSED detects a channel busy condition. For improved spectrum sharing, CCA-OCSED is required in some bands. The behavior class indicating CCA-OCSED is given in Table D-2 (Behavior limits). The operating classes requiring the corresponding CCA-OCSED behavior class are given in E.1 (Country information and operating classes). The PHY of a STA that is operating within an operating class that requires CCA-OCSED shall operate with CCA-OCSED.

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CCA-OCSED for a STA that is attempting a non-preamble puncturing transmission shall detect a channel busy condition if the received signal strength exceeds the CCA-OCSED threshold as given by dot11OFDMEDThreshold for the primary 20 MHz channel, dot11OFDMEDThreshold for the secondary 20 MHz channel (if present), dot11OFDMEDThreshold + 3 dB for the secondary 40 MHz channel (if present), and dot11OFDMEDThreshold + 6 dB for the secondary 80 MHz channel (if present). The CCA-OCSED thresholds for the operating classes requiring CCA-OCSED are subject to the criteria in D.2.5 (CCA-OCSED threshold(#2365)).

CCA-OCSED for a STA that is attempting a preamble puncturing transmission shall detect a channel busy condition if the received signal strength exceeds the CCA-OCSED threshold as given by dot11OFDMEDThreshold for the primary 20 MHz channel and dot11OFDMEDThreshold for each nonprimary 20 MHz subchannel. The CCA-OCSED thresholds for the operating classes requiring CCA-OCSED are subject to the criteria in D.2.5 (CCA-OCSED threshold(#2365)).

For the HE TB PPDU transmission, for each of 20 MHz sub-channels that require CCA, CCA-OCSED shall detect a channel busy condition if the received signal strength exceeds the CCA-OCSED threshold as given by dot11OFDMEDThreshold. The CCA-OCSED thresholds for the operating classes requiring CCA-OCSED are subject to the criteria in D.2.5 (CCA-OCSED threshold(#2365)).

For transmissions that carry a frame that includes a BQR Control subfield (see 9.2.4.7 (Control subfield variants of an A-Control subfield(11ax))), CCA-OCSED shall detect a channel busy condition if the received signal strength exceeds the CCA-OCSED threshold as given by dot11OFDMEDThreshold for primary 20 MHz channel and dot11OFDMEDThreshold for each nonprimary 20 MHz channel (if present). The CCA-OCSED thresholds for the operating classes requiring CCA-OCSED are subject to the criteria in D.2.5 (CCA-OCSED threshold(#2365)).

NOTE—The requirement to detect a channel busy condition as stated in 27.3.22.6.3 (CCA sensitivity for the primary 20 MHz channel) and 27.3.22.6.4 (CCA sensitivity for signals not occupying the primary 20 MHz channel) is a mandatory energy detect requirement on all Clause 27 (High-efficiency (HE) PHY specification(11ax))receivers. Support for CCA-OCSED is an additional requirement that relates specifically to the sensitivities described in D.2.5 (CCA-OCSED threshold(#2365)).

### 27.3.22.6.3 CCA sensitivity for the primary 20 MHz channel

An HE STA with a *W* MHz operating channel width shall detect, with > 90% probability, the start of a PPDU that occupies at least the primary 20 MHz channel in an otherwise idle *W* MHz channel width and issue a PHY-CCA.indication with the STATUS parameter set to BUSY within a period of aCCATime (see 21.4.4 (VHT PHY)) if one of the following conditions is met:

- The start of a non-HT PPDU as defined in 17.3.10.6 (CCA requirements) if operating in the 5 GHz or 6 GHz band and 18.4.6 (CCA performance) if operating in the 2.4 GHz band.
- The start of an HT PPDU as defined in 19.3.19.6 (CCA sensitivity).
- The start of a non-HT duplicate, VHT or HE PPDU for which the power measured within the primary 20 MHz channel is at or above –82 dBm.

The channel-list parameter is present and set to {primary} if the operating channel width is greater than 20 MHz. The CCA signal shall be held busy (not issue a PHY-CCA.indication primitive with the STATUS parameter set to IDLE) for the duration of the PPDU, unless it receives a (#1871)PHY-CCARESET.request primitive before the end of the PPDU, for instance, during spatial reuse operation as described in 26.10 (HE spatial reuse operation(#2389)).

The receiver shall issue a PHY-CCA.indication primitive with the STATUS parameter set to BUSY for (#1229)any signal at or above –62 dBm in the primary 20 MHz channel within a period of aCCATime after the signal arrives at the receiver's antenna(s). If the operating channel width is greater than 20 MHz, then the


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channel-list parameter is present and shall be set to {primary}. Following the indication and while the threshold continues to be exceeded, the receiver shall not issue a PHY-CCA.indication primitive with the STATUS parameter set to IDLE or with a change in the channel-list parameter.

#### 27.3.22.6.4 CCA sensitivity for signals not occupying the primary 20 MHz channel

The PHY shall issue a PHY-CCA.indication primitive with the STATUS parameter set to BUSY and with the channel-list parameter set to {secondary} if the conditions for issuing a PHY-CCA.indication primitive with the STATUS parameter set to BUSY as defined in 27.3.22.6.3 (CCA sensitivity for the primary 20 MHz channel) are not present and at least one of the following conditions is present in an otherwise idle 40 MHz, 80 MHz, 160 MHz, or 80+80 MHz operating channel width:

— Any signal within the secondary 20 MHz channel at or above a threshold of –62 dBm within a period of aCCATime after the signal arrives at the receiver's antenna(s).

— A 20 MHz (#2095)non-HT, HT-mixed format, HT-greenfield format, VHT or HE PPDU is detected in the secondary 20 MHz channel at or above max(–72 dBm, $OBSS\_PD_{level}$) with > 90% probability within a period aCCAMidTime (see 27.4.4 (HE PHY)).

Following the indication and while the threshold continues to be exceeded, the receiver shall not issue a PHY-CCA.indication primitive with the STATUS parameter set to IDLE or with the STATUS parameter set to BUSY and the channel-list parameter set to {secondary40} or {secondary80}.

The PHY shall issue a PHY-CCA.indication primitive with the STATUS parameter set to BUSY and the channel-list parameter set to {secondary40} if the conditions for issuing a PHY-CCA.indication with the STATUS parameter set to BUSY as defined in 27.3.22.6.3 (CCA sensitivity for the primary 20 MHz channel) and above are not present and at least one of the following conditions is present in an otherwise idle 80 MHz, 160 MHz, or 80+80 MHz operating channel width:

— Any signal within the secondary 40 MHz channel at or above a threshold of –59 dBm within a period of aCCATime after the signal arrives at the receiver's antenna(s).

— A 40 MHz (#2095)non-HT duplicate, HT-mixed format, HT-greenfield format, VHT or HE PPDU is detected in the secondary 40 MHz channel at or above max(–72 dBm, $OBSS\_PD_{level}$ + 3 dB) with > 90% probability within a period aCCAMidTime (see 27.4.4 (HE PHY)).

— A 20 MHz (#2095)non-HT, HT-mixed format, HT-greenfield format, VHT or HE PPDU is detected in any 20 MHz subchannel of the secondary 40 MHz channel at or above max(–72 dBm, $OBSS\_PD_{level}$) with > 90% probability within a period aCCAMidTime.

Following the indication and while the threshold continues to be exceeded, the receiver shall not issue a PHY-CCA.indication primitive with the STATUS parameter set to IDLE or with the STATUS parameter set to BUSY and the channel-list parameter set to {secondary80}.

The PHY shall issue a PHY-CCA.indication primitive with the STATUS parameter set to BUSY and the channel-list parameter set to {secondary80} if the conditions for issuing a PHY-CCA.indication primitive with the STATUS parameter set to BUSY as defined in 27.3.22.6.3 (CCA sensitivity for the primary 20 MHz channel) and above are not present and at least one of the following conditions is present in an otherwise idle 160 MHz or 80+80 MHz operating channel width:

— Any signal within the secondary 80 MHz channel at or above –56 dBm.

— An 80 MHz non-HT duplicate, VHT or HE PPDU is detected in the secondary 80 MHz channel at or above max(–69 dBm, $OBSS\_PD_{level}$ + 6 dB) with > 90% probability within a period aCCAMidTime (see 27.4.4 (HE PHY)).

— A 40 MHz (#2095)non-HT duplicate, HT-mixed format, HT-greenfield format, VHT or HE PPDU is detected in any 40 MHz subchannel of the secondary 80 MHz channel at or above max(–72 dBm, $OBSS\_PD_{level}$ + 3 dB) with > 90% probability within a period aCCAMidTime.

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— A 20 MHz (#2095)non-HT, HT-mixed format, HT-greenfield format, VHT or HE PPDU is detected in any 20 MHz subchannel of the secondary 80 MHz channel at or above max(–72 dBm, $OBSS\_PD_{level}$) with > 90% probability within a period aCCAMidTime.

$OBSS\_PD_{level}$ is defined in 26.10.2.4 (Adjustment of OBSS PD and transmit power) and applied in the equations to define the detection level in this subclause if an HE STA has ignored a 40 MHz, 80 MHz, 160 MHz, or 80+80 MHz inter-BSS PPDU following the procedure in 26.10.2.2 (General operation with non-SRG OBSS PD level) or 26.10.2.3 (General operation with SRG OBSS PD level). It is applied to any secondary channels within the PPDU bandwidth of the inter-BSS PPDU and during the RXTIME of the inter-BSS PPDU. Otherwise, $OBSS\_PD_{level}$ is not applied in the equations to define the detection level in this subclause.

#### 27.3.22.6.5 Per 20 MHz CCA sensitivity

If the operating channel width is greater than 20 MHz and the PHY issues a PHY-CCA.indication primitive, the PHY shall set the per20bitmap to indicate the busy/idle status of each 20 MHz subchannel. A 20 MHz subchannel is busy if at least one of the following conditions is present in an otherwise idle 40 MHz, 80 MHz, 80+80 MHz, or 160 MHz channel:

— A signal is present on the 20 MHz subchannel at or above a threshold of –62 dBm at the receiver's antenna(s). The PHY shall indicate that the 20 MHz subchannel is busy a period aCCATime after the signal starts and shall continue to indicate the 20 MHz subchannel is busy while the threshold continues to be exceeded.

— The 20 MHz subchannel is in a channel on which an 80 MHz non-HT duplicate, VHT or HE PPDU at or above max(–69 dBm, $OBSS\_PD_{level}$ + 6 dB) at the receiver's antenna(s) is present. The PHY shall indicate that the 20 MHz subchannel is busy with > 90% probability within a period aCCAMidTime (see 27.4.4 (HE PHY)).

— The 20 MHz subchannel is in a channel on which a 40 MHz (#2095)non-HT duplicate, HT-mixed format, HT-greenfield format, VHT or HE PPDU at or above max(–72 dBm, $OBSS\_PD_{level}$ + 3 dB) at the receiver's antenna(s) is present. The PHY shall indicate that the 20 MHz subchannel is busy with > 90% probability within a period aCCAMidTime (see 27.4.4 (HE PHY)).

— A 20 MHz (#2095)non-HT, HT-mixed format, HT-greenfield format, VHT, or HE PPDU at or above max(–72 dBm, $OBSS\_PD_{level}$) at the receiver's antenna(s) is present on the 20 MHz subchannel. The PHY shall indicate that the 20 MHz subchannel is busy with > 90% probability within a period aCCAMidTime (see 27.4.4 (HE PHY)).

NOTE—Following the receipt of a Trigger frame with the CS Required subfield in the Common Info field set to 1, the HE PHY is required to only detect a signal at the –62 dBm threshold since the other conditions require more time than is available before the response is expected.

$OBSS\_PD_{level}$ is defined in 26.10.2.4 (Adjustment of OBSS PD and transmit power) and applied in the equations to define the detection level in this subclause if an HE STA has ignored a 40 MHz, 80 MHz, 160 MHz, or 80+80 MHz inter-BSS PPDU following the procedure in 26.10.2.2 (General operation with non-SRG OBSS PD level) or 26.10.2.3 (General operation with SRG OBSS PD level). It is applied to any secondary channels within the PPDU bandwidth of the inter-BSS PPDU and during the RXTIME of the inter-BSS PPDU. Otherwise, $OBSS\_PD_{level}$ is not applied in the equations to define the detection level in this subclause.

#### 27.3.22.7 Received channel power indicator (RCPI) measurement(#2011)

The RCPI is a measure of the received RF power in the selected channel for a received PPDU. This parameter shall be a measurement by the PHY of the received RF power in the channel measured over the HE-STF or HE-LTF field of the received PPDU. If the RCPI is measured for an HE ER SU PPDU, then


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(#3473)the reported RCPI value is 3 dB less than the measured power over the HE-STF or HE-LTF field. The received power shall be the average of the power in all active receive chains.

NOTE—The HE-STF and HE-LTF fields in an HE ER SU PPDU have 3 dB higher power than the Data field, hence the reported RCPI value is subtracting 3 dB from the measured power.

RCPI shall equal the received RF power in dBm within an accuracy of ± 5 dB (95% confidence interval) within the specified dynamic range of the receiver.

### 27.3.23 HE transmit procedure

There are five options for the transmit PHY procedure. The first four options, for which typical transmit procedures are shown in Figure 27-63 (PHY transmit procedure for an HE SU PPDU(#1054)(11ax)(#213)), Figure 27-64 (PHY transmit procedure for an HE ER SU PPDU(#1054)(11ax)(#213)), Figure 27-65 (PHY transmit procedure for an HE MU PPDU(#1054)(11ax)(#213)), and Figure 27-66 (PHY transmit procedure for an HE TB PPDU(#1054)(11ax)(#213)), are selected if the FORMAT field of the PHY-TXSTART.request(TXVECTOR) primitive is equal to HE_SU, HE_MU, HE_ER_SU, or HE_TB, respectively. These transmit procedures do not describe the operation of optional features, such as DCM.

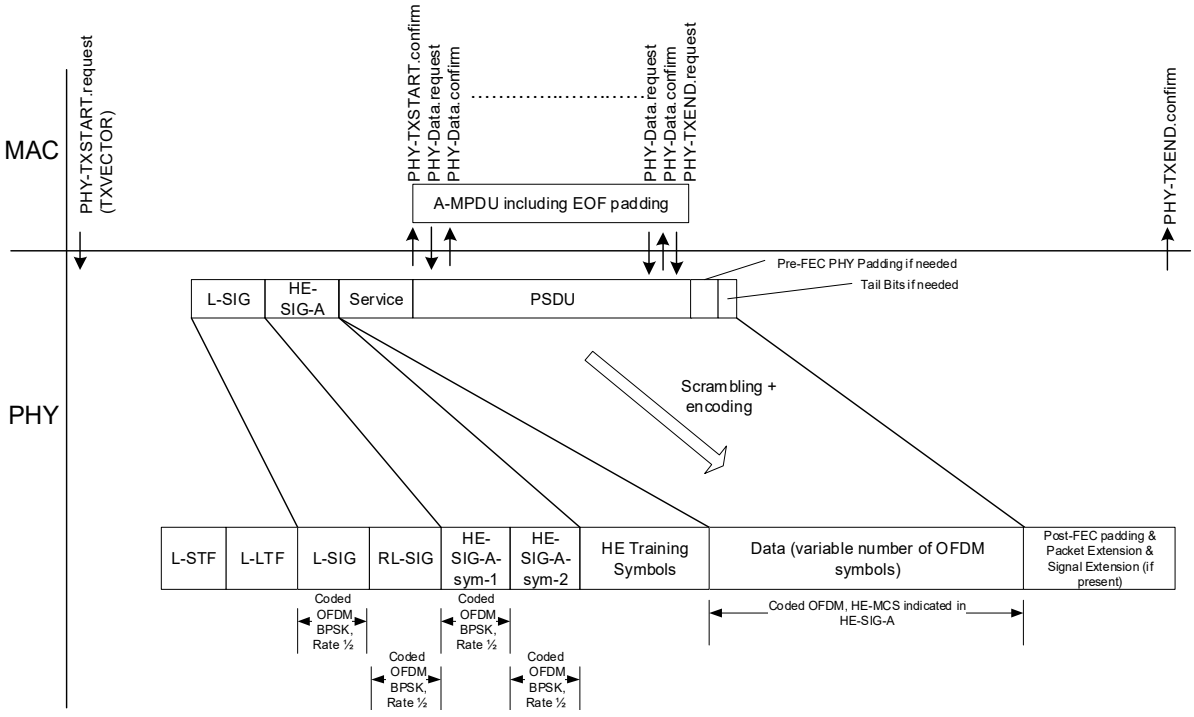


**Figure 27-63—PHY transmit procedure for an HE SU PPDU(#1054)(11ax)(#213)**

The fifth option is to follow the transmit procedure in Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) or Clause 18 (Extended Rate PHY (ERP) specification) if the FORMAT parameter of the PHYTXSTART.request(TXVECTOR) primitive is NON_HT as follows:

— If the FORMAT parameter is NON_HT and the NON_HT_MODULATION parameter is OFDM, then the transmit procedure defined in Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) is followed.

— If the FORMAT parameter is NON_HT and the NON_HT_MODULATION parameter is NON_HT_DUP_OFDM, then the transmit procedure defined in Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) is followed, except that the signal is generated

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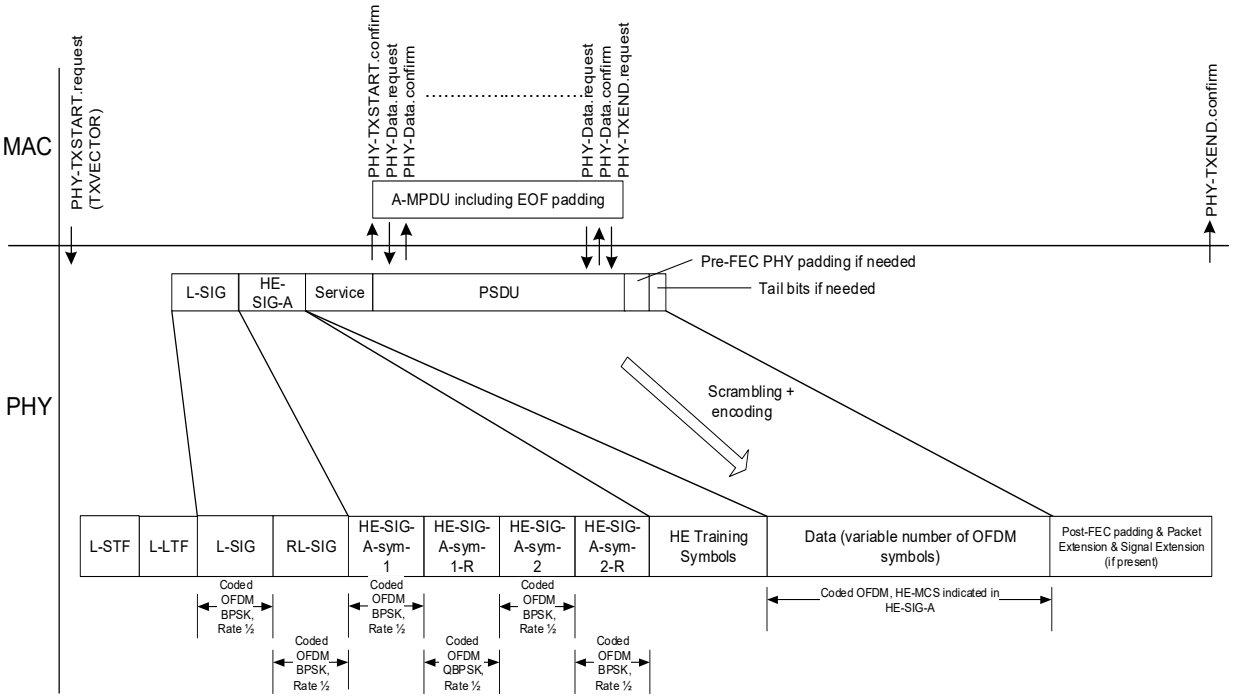


**Figure 27-64—PHY transmit procedure for an HE ER SU PPDU(#1054)(11ax)(#213)**

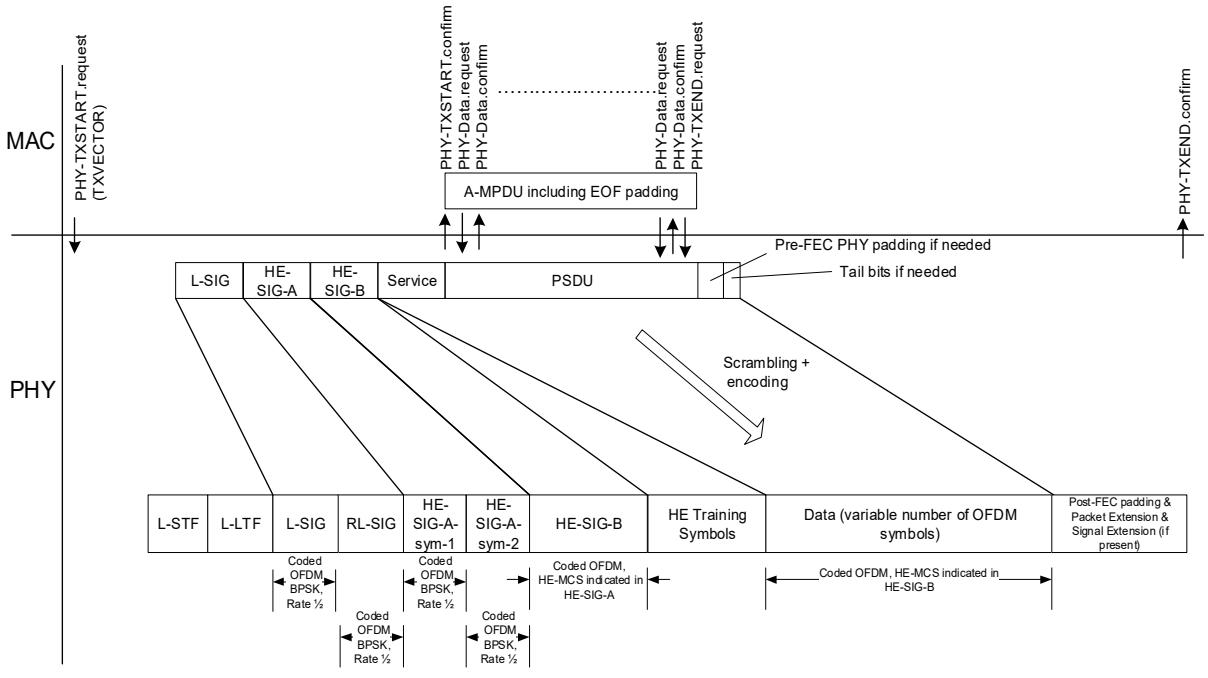


**Figure 27-65—PHY transmit procedure for an HE MU PPDU(#1054)(11ax)(#213)**

simultaneously on each of the 20 MHz channels identified by the CH_BANDWIDTH parameter as defined in 27.3.11 (HE preamble) and 27.3.14 (Non-HT duplicate transmission).



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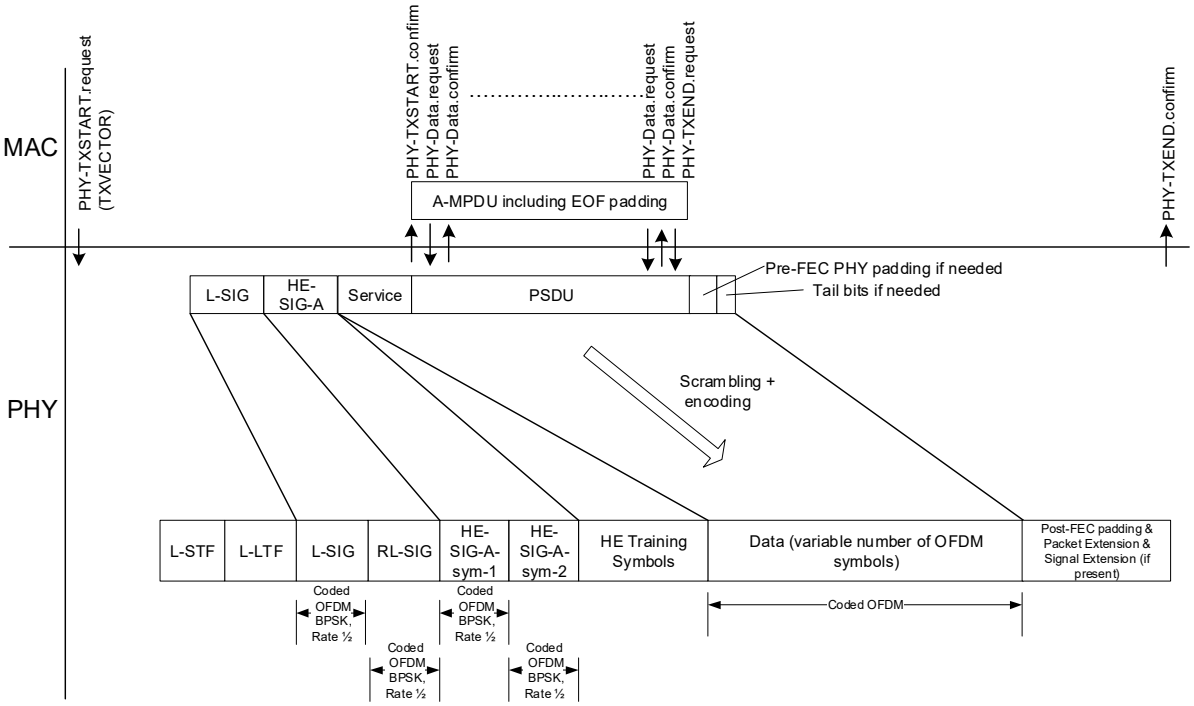


**Figure 27-66—PHY transmit procedure for an HE TB PPDU(#1054)(11ax)(#213)**

— If the FORMAT parameter is NON_HT, the CH_BANDWIDTH parameter is NON_HT_CBW20, and the NON_HT_MODULATION parameter is not OFDM, then the transmit procedure defined in Clause 18 (Extended Rate PHY (ERP) specification) is followed.

NOTE 1—For an HE MU PPDU, the A-MPDU is per user in the MAC sublayer, and the HE Training Symbols and Data fields are per user in the PHY in Figure 27-65 (PHY transmit procedure for an HE MU PPDU(#1054)(11ax)(#213)), with the number of HE Training Symbols depending on the maximum total number of space-time streams across all RUs.

NOTE 2—The transmit procedure for (#2095)non-HT, HT-mixed, HT-greenfield, and VHT format are specified in 27.2.7 (Support for non-HT, HT, and VHT formats).

In all options, in order to transmit data, the MAC generates a PHY-TXSTART.request primitive, which causes the PHY entity to enter the transmit state. Further, the PHY is set to operate at the appropriate frequency through station management via the PLME, as specified in 27.4 (HE PLME). Other transmit parameters, such as HE-MCS, coding types, and transmit power, are set via the PHY-SAP using the PHYTXSTART.request(TXVECTOR) primitive, as described in 27.2.2 (TXVECTOR and RXVECTOR parameters). After transmitting a PPDU that carries a Trigger frame, the MAC sublayer issues a PHY-TRIGGER.request with a TRIGVECTOR parameter that provides the PHY entity with the information needed to demodulate the expected HE TB PPDU response. The remainder of this subclause applies to the first four options.

The PHY indicates the state of the primary channel and other channels (if any) via the PHY-CCA.indication primitive (see 21.3.18.5 (CCA sensitivity) and 8.3.5.12 (PHY-CCA.indication)). Transmission of the PPDU shall be initiated by the PHY after receiving the PHY-TXSTART.request(TXVECTOR) primitive. The TXVECTOR parameters for the PHY-TXSTART.request primitive are specified in Table 27-1 (TXVECTOR and RXVECTOR parameters(#12)(11ax)).

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(11az)Transmission of the PHY preamble may start if TIME_OF_DEPARTURE_REQUESTED is false and shall start immediately if TIME_OF_DEPARTURE_REQUESTED is true, based on the parameters passed in the PHY-TXSTART.request primitive.

(11az)If all of the following conditions are met:

— If dot11TODImplemented and dot11TODActivated are true or if dot11TimingMsmtActivated is true

— The TXVECTOR parameter TIME_OF_DEPARTURE_REQUESTED is true

then the PHY shall issue a PHY-TXSTART.confirm(TXSTATUS) primitive to the MAC, forwarding the TIME_OF_DEPARTURE corresponding to the time when the first frame energy is sent by the transmitting port and TIME_OF_DEPARTURE_ClockRate parameter within the TXSTATUS vector. If dot11TimingMsmtActivated is true, then the PHY shall forward the value of TX_START_OF_FRAME_OFFSET in the TXSTATUS vector.

After the PHY preamble transmission is started, the PHY entity immediately initiates data scrambling and data encoding. The encoding method for the Data field is based on the FEC_CODING, CH_BANDWIDTH, NUM_STS, STBC, MCS, and NUM_USERS parameters of the TXVECTOR, as described in 27.3.4 (HE PPDU formats).

The SERVICE field and PSDU are encoded as described in 27.3.5 (Transmitter block diagram). The data shall be exchanged between the MAC and the PHY through a series of PHY-DATA.request(DATA) primitives issued by the MAC and PHY-DATA.confirm primitives issued by the PHY. PHY padding bits are appended to the PSDU to make the number of bits in the coded PSDU an integral multiple of the number of coded bits per OFDM symbol.

Transmission can be prematurely terminated by the MAC through the PHY-TXEND.request primitive. PSDU transmission is terminated by receiving a PHY-TXEND.request primitive. Each PHY-TXEND.request primitive is acknowledged with a PHY-TXEND.confirm primitive from the PHY.

A packet extension and/or a signal extension may be present in the PPDU. The PHY-TXEND.confirm primitive is generated at the latest of the actual ending time of the PPDU, the end of the packet extension if present, and the end of the signal extension if present.

In the PHY, the GI with GI duration indicated in GI_TYPE parameter of the TXVECTOR is inserted in every data OFDM symbol as a countermeasure against delay spread.

Once the PPDU transmission is completed, the PHY entity enters the receive state.

A typical state machine implementation for the transmission of an HE PPDU without midambles is shown in Figure 27-67 (PHY transmit state machine for an HE PPDU without midambles(11ax)(#1054)(). Request


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(.request) and confirmation (.confirm) primitives are issued once per state as shown. This state machine does not describe the operation of optional features, such as DCM.

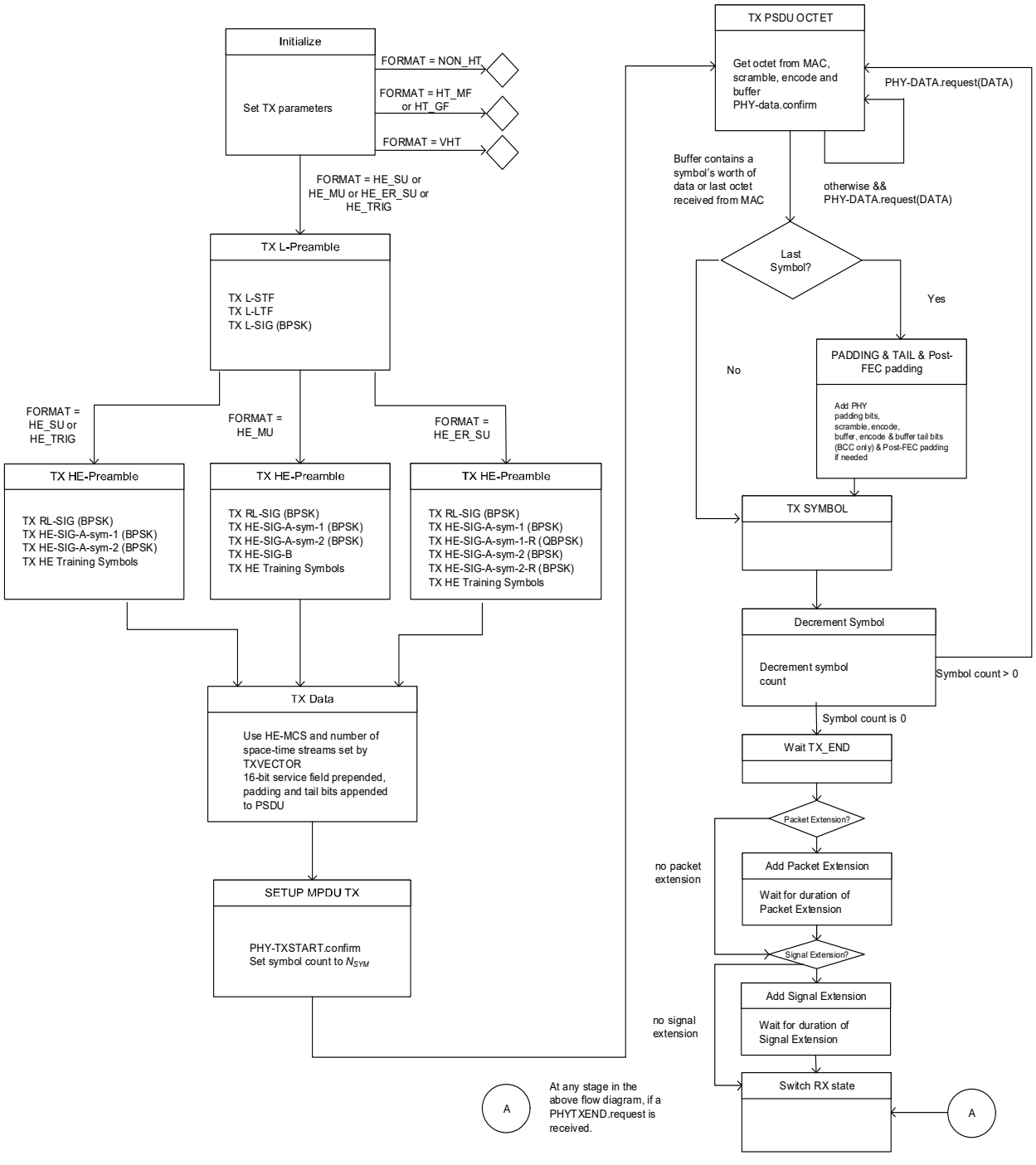


**Figure 27-67—PHY transmit state machine for an HE PPDU without midambles(11ax)(#1054)(**

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### 27.3.24 HE receive procedure

Typical PHY receive procedures are shown in Figure 27-68 (PHY receive procedure for an HE SU PPDU(#4202)(#3038)(#1054)(11ax)(#1058)(#3480)(#4122)), Figure 27-69 (PHY receive procedure for an HE ER SU PPDU(#4202)(#3038)(#1054)(11ax)(#1058)(#3480)(#4122)), Figure 27-70 (PHY receive procedure for an HE MU PPDU((11ax)#3038)(#1054)(11ax)(#1058)(#3480)(#4122)), and Figure 27-71 (PHY receive procedure for an HE TB PPDU(#4202)(#3038)(11ax)(#1058)(#3480)(#4122)), respectively.

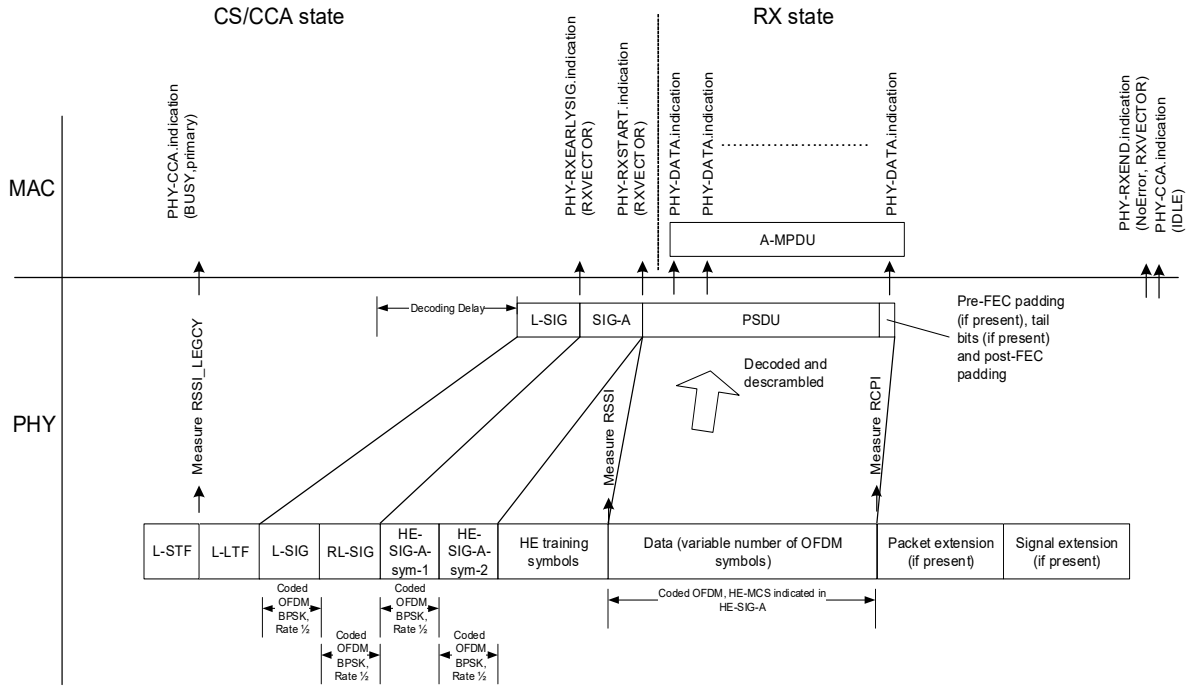


**Figure 27-68—PHY receive procedure for an HE SU PPDU(#4202)(#3038)(#1054)(11ax)(#1058)(#3480)(#4122)**


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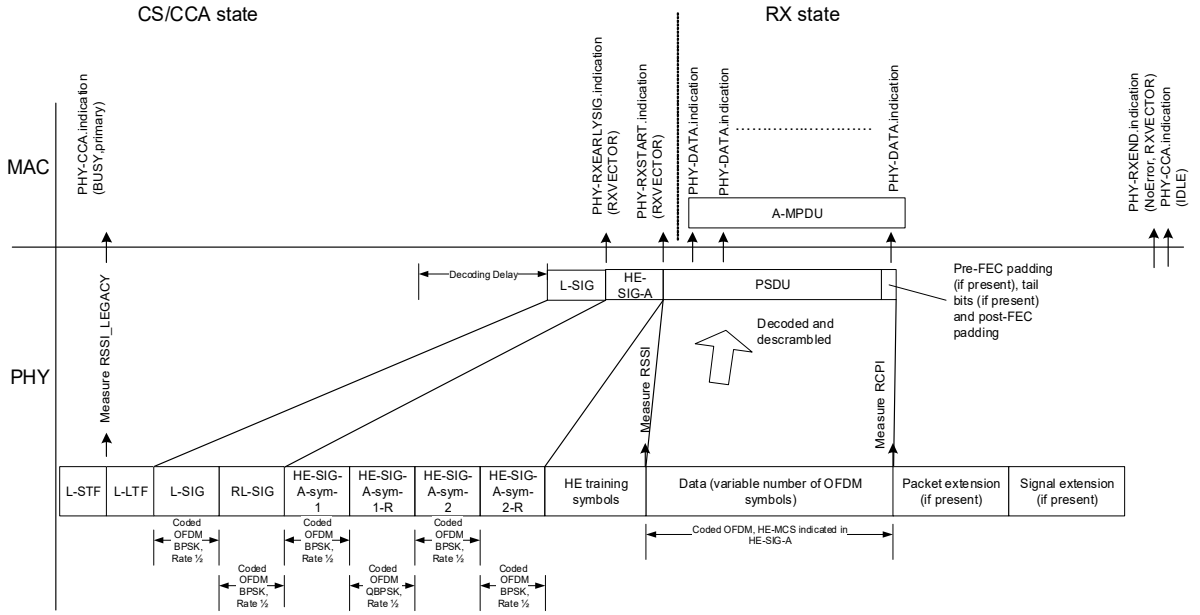


**Figure 27-69—PHY receive procedure for an HE ER SU PPDU(#4202)(#3038)(#1054)(11ax)(#1058)(#3480)(#4122)**

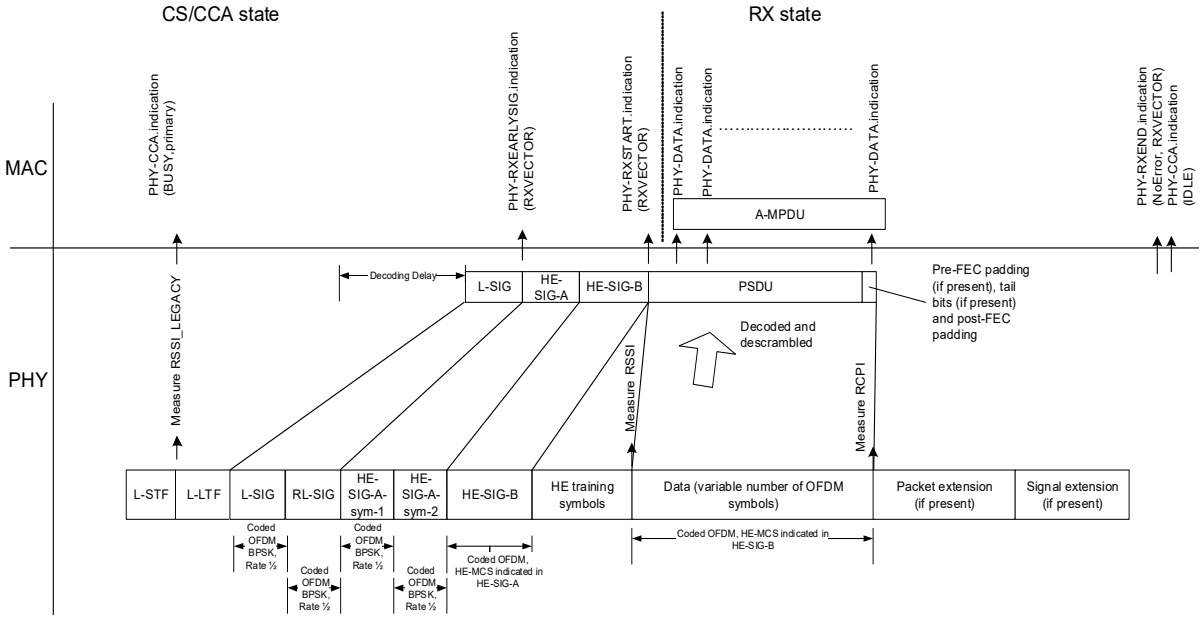


**Figure 27-70—PHY receive procedure for an HE MU PPDU((11ax)#3038)(#1054)(11ax)(#1058)(#3480)(#4122)**

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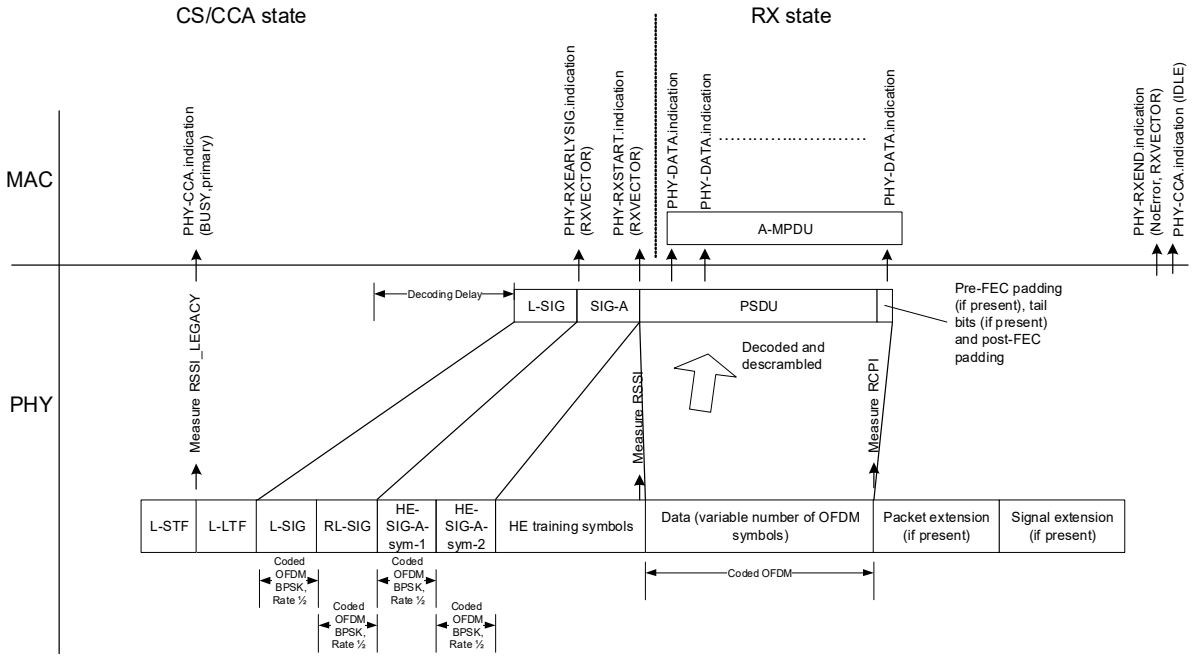


**Figure 27-71—PHY receive procedure for an HE TB PPDU(#4202)(#3038)(11ax)(#1058)(#3480)(#4122)**



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A typical state machine implementation of the receive PHY is given in Figure 27-72 (PHY receive state

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machine if midambles are not present(#3038)(#1590)(11ax)(#6467)).

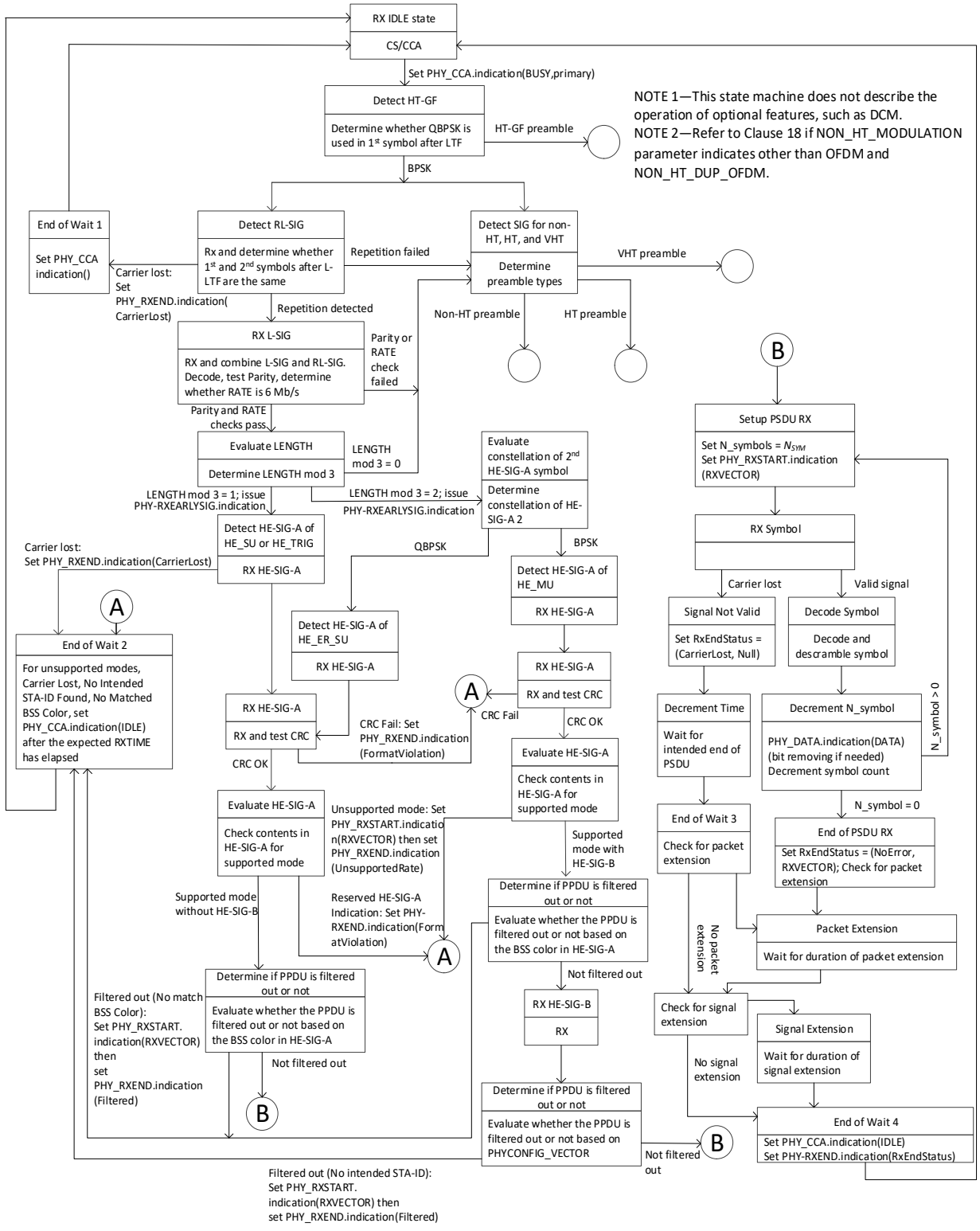


**Figure 27-72—PHY receive state machine if midambles are not present(#3038)(#1590)(11ax)(#6467)**



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This receive procedure and state machine do not describe the operation of optional features, such as DCM(11az), HE Ranging NDP, and HE TB Ranging NDP. If the detected format indicates a non-HT PPDU, refer to the receive procedure and state machine in Clause 15 (DSSS PHY specification for the 2.4 GHz band designated for ISM applications), Clause 16 (High rate direct sequence spread spectrum (HR/DSSS) PHY specification), Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification), and Clause 18 (Extended Rate PHY (ERP) specification). If the detected format indicates an HT PPDU format, refer to the receive procedure and state machine in Clause 19 (High Throughput (HT) PHY specification(#2297)). If the detected format indicates a VHT PPDU format, refer to the receive procedure and state machine in Clause 21 (Very high throughput (VHT) PHY specification). Through station management (via the PLME), the PHY is set to the appropriate frequency, as specified in 27.4 (HE PLME). The PHY has also been configured with BSS identification information and STA identification information (i.e., BSS color value and STA-ID in the BSS) so that it can receive data intended for the STA in the specific cell. Other receive parameters, such as RSSI and indicated DATARATE, may be accessed via the PHY-SAP.

Upon receiving the transmitted PHY preamble in a greater than or equal to 20 MHz BSS, the PHY measures a receive signal strength. This activity is indicated by the PHY to the MAC via a PHY-CCA.indication primitive. A PHY-CCA.indication(BUSY, channel-list) primitive is also issued as an initial indication of reception of a signal as specified in 27.3.22.6 (CCA sensitivity). The channel-list parameter of the PHY-CCA.indication primitive is absent when the operating channel width is 20 MHz. The channel-list parameter is present when the operating channel width is 40 MHz, 80 MHz, 160 MHz, or 80+80 MHz.

The PHY shall not issue a (#3038)PHY-RXEARLYSIG.indication nor a PHY-RXSTART.indication primitive in response to a PPDU that does not overlap the primary channel, unless the PHY at an AP receives the HE TB PPDU solicited by the AP. For the HE TB PPDU solicited by the AP, the PHY shall issue both a (#3038)PHY-RXEARLYSIG.indication and a PHY-RXSTART.indication primitive for a PPDU received in the primary or at the secondary 20 MHz channel, the secondary 40 MHz channel, or the secondary 80 MHz channel.

The PHY includes the measured RSSI and RSSI_LEGACY value in the PHY-RXSTART.indication(RXVECTOR) primitive issued to the MAC.

After the PHY-CCA.indication(BUSY, channel-list) primitive is issued, the PHY entity shall begin receiving the training symbols and searching for the preambles for non-HT, HT, VHT, and HE PPDUs, respectively. If the constellation used in the first symbol after the first long training field is QBPSK, the PHY entity shall continue to detect the received signal using the receive procedure for (#2095)HT-greenfield format depicted in Clause 19 (High Throughput (HT) PHY specification(#2297)). Otherwise, for detecting the HE preamble, the PHY entity shall search for L-SIG and RL-SIG fields in order to set the duration of the PPDU(#2056). If an RL-SIG field is detected, the PHY entity should check the parity bit and RATE fields in the L-SIG and RL-SIG fields. If either the check of the parity bit is invalid or the RATE field is not set to 6 Mb/s in non-HT, (#3038)no PHY-RXEARLYSIG.indication or PHY-RXSTART.indication primitive is issued. If the check of the parity bit is valid and the RATE field indicates 6 Mb/s in non-HT but the LENGTH field value in the L-SIG field is a multiple of 3, (#3038)no PHY-RXEARLYSIG.indication or PHY-RXSTART.indication primitive is issued. In both cases, the PHY should continue to detect the received signal using non-HT, HT, and VHT receive procedure in Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification), Clause 19 (High Throughput (HT) PHY specification(#2297)), and Clause 21 (Very high throughput (VHT) PHY specification), respectively.

If a valid parity bit and the RATE with 6 Mb/s in non-HT are indicated in the L-SIG and RL-SIG fields and the LENGTH field value in the L-SIG and RL-SIG fields meets the condition that the remainder is 1 after LENGTH divided by 3, the PHY entity (#3038)shall issue a PHY-RXEARLYSIG.indication primitive and should begin receiving the sequence of HE-SIG-A, HE-STF, and HE-LTF fields for the HE SU PPDU and HE TB PPDU as shown in Figure 27-68 (PHY receive procedure for an HE SU PPDU(#4202)(#3038)(#1054)(11ax)(#1058)(#3480)(#4122)) and Figure 27-71 (PHY receive procedure for

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an HE TB PPDU(#4202)(#3038)(11ax)(#1058)(#3480)(#4122)), respectively. After the RL-SIG field, the PHY entity shall receive two symbols of the HE-SIG-A field immediately followed by HE-STF.

The PHY entity shall check CRC of the HE-SIG-A field. If the CRC check is valid, the PHY entity shall report the TXOP and BSS color, check the Format field, and continue to receive HE-STF. The PHY entity shall report to the MAC entity the predicted duration of the TXOP in the HE-SIG-A field.

The PHY entity shall check the BSS color in the HE-SIG-A field. If the BSS color does not contain an intended value (#4386)(i.e., the color value is not contained in the PHYCONFIG_VECTOR parameter BSS_COLOR_LIST), the PHY entity shall issue a PHY-RXSTART.indication(RXVECTOR) and then issue a PHY-RXEND.indication(Filtered).

The PHY entity shall check the Format field in the HE-SIG-A field. If the Format field indicates an HE SU PPDU, the PHY entity shall receive HE-STF for 4 μs after the HE-SIG-A field. If the Format field indicates an HE TB PPDU, the PHY entity shall receive HE-STF for 8 μs after the HE-SIG-A field.

If the HE-SIG-A field indicates a valid CRC and a reserved HE-SIG-A indication is not indicated, for all supported modes and unsupported modes, the PHY entity shall maintain the PHY-CCA.indication(BUSY, channellist) primitive for the predicted duration of the transmitted PPDU, as defined by RXTIME in Equation (27-146), unless it receives a PHY-CCARESET.request primitive before the end of the PPDU, for instance, during spatial reuse operation as described in 26.10 (HE spatial reuse operation(#2389)). If the HE-SIG-A field indicates an unsupported mode, the PHY shall issue a PHY-RXEND.indication(UnsupportedRate) primitive.

If the HE-SIG-A field indicates a reserved HE-SIG-A indication, the PHY shall issue the error condition PHY-RXEND.indication(FormatViolation) primitive and maintain the PHY-CCA.indication(BUSY, channellist) primitive for the predicted duration of the transmitted PPDU derived from the LENGTH field in the L-SIG field, as defined in Equation (27-147), unless it receives a PHY-CCARESET.request primitive before the end of the PPDU, for instance, during spatial reuse operation as described in 26.10 (HE spatial reuse operation(#2389)). A reserved HE-SIG-A indication is defined as an HE-SIG-A field with Reserved bits equal to 0 or any other HE-SIG-A field bit combinations that do not correspond to modes of PHY operation defined in Clause 27 (High-efficiency (HE) PHY specification(11ax)).

If the HE-SIG-A field indicates an invalid CRC, the PHY shall issue the error condition PHY-RXEND.indication(FormatViolation) primitive and maintain the PHY-CCA.indication(BUSY, channellist) primitive for the predicted duration of the transmitted PPDU derived from the LENGTH field in the L-SIG field as defined in Equation (27-147).

If a valid parity bit of the L-SIG and RL-SIG fields is indicated and the LENGTH field value in the L-SIG and RL-SIG fields meets the condition that the remainder is 2 after LENGTH divided by 3, the PHY entity should detect the signal constellations in the second symbol after the RL-SIG field. If the constellation is QBPSK, the PHY entity shall continue receiving the sequence of HE-SIG-A, HE-STF, and HE-LTF fields for an HE ER SU PPDU shown in Figure 27-69 (PHY receive procedure for an HE ER SU PPDU(#4202)(#3038)(#1054)(11ax)(#1058)(#3480)(#4122)). After the RL-SIG field, the PHY entity shall receive four symbols of HE-SIG-A immediately followed by HE-STF.

The PHY entity shall check the CRC of the HE-SIG-A field. If the CRC is valid, the PHY entity shall report TXOP and BSS color and continue to receive the HE-STF. The PHY entity shall report to the MAC entity the predicted duration of the TXOP in the HE-SIG-A field.

The PHY entity shall check the BSS color in the HE-SIG-A field. If the BSS color does not contain an intended value (#4386)(i.e., the color value is not contained in the PHYCONFIG_VECTOR parameter BSS_COLOR_LIST), the PHY entity shall issue a PHY-RXSTART.indication(RXVECTOR) and then issue a PHY-RXEND.indication(Filtered).


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The PHY entity shall receive the HE-STF for 4 μs after the HE-SIG-A field.

If the HE-SIG-A field indicates a valid CRC and a reserved HE-SIG-A indication is not indicated, for all supported mode and unsupported modes, the PHY entity shall maintain the PHY-CCA.indication(BUSY, channellist) primitive for the predicted duration of the transmitted PPDU, as defined by RXTIME in Equation (27-146), unless it receives a PHY-CCARESET.request primitive before the end of the PPDU, for instance, during spatial reuse operation as described in 26.10 (HE spatial reuse operation(#2389)).

If the HE-SIG-A field indicates an unsupported mode, the PHY shall issue a PHY-RXEND.indication(UnsupportedRate) primitive.

If the HE-SIG-A field indicates a reserved HE-SIG-A indication, the PHY shall issue the error condition PHY-RXEND.indication(FormatViolation) primitive and maintain the PHY-CCA.indication(BUSY, channellist) primitive for the predicted duration of the transmitted PPDU derived from the LENGTH field in the L-SIG field, as defined in Equation (27-147), unless it receives a PHY-CCARESET.request primitive before the end of the PPDU, for instance, during spatial reuse operation as described in 26.10 (HE spatial reuse operation(#2389)). A reserved HE-SIG-A indication is defined as an HE-SIG-A field with Reserved bits equal to 0 or any other HE-SIG-A field bit combinations that do not correspond to modes of PHY operation defined in Clause 27 (High-efficiency (HE) PHY specification(11ax)).

If the HE-SIG-A field indicates an invalid CRC, the PHY shall issue the error condition PHY-RXEND.indication(FormatViolation) primitive and maintain the PHY-CCA.indication(BUSY, channellist) primitive for the predicted duration of the transmitted PPDU derived from the LENGTH field in the L-SIG field, as defined in Equation (27-147), unless it receives a PHY-CCARESET.request primitive before the end of the PPDU, for instance, during spatial reuse operation as described in 26.10 (HE spatial reuse operation(#2389)).

If a STA receives an HE TB PPDU and the TRIGVECTOR parameters are not present in its PHY entity, the STA shall use Equation (27-147) to calculate the predicted duration of the HE TB PPDU.

If a valid parity bit of the L-SIG and RL-SIG fields is indicated and the LENGTH field value in the L-SIG and RL-SIG fields meets the condition that the remainder is 2 after LENGTH divided by 3, the PHY entity should detect the signal constellations in the second symbol after the RL-SIG field. If the constellation is BPSK, the PHY entity shall continue receiving the sequence of HE-SIG-A, HE-SIG-B, HE-STF, and HE-LTF fields for an HE MU PPDU shown in Figure 27-70 (PHY receive procedure for an HE MU PPDU((11ax)#3038)(#1054)(11ax)(#1058)(#3480)(#4122)). After the RL-SIG field, the PHY entity shall receive two symbols of the HE-SIG-A field immediately followed by the HE-SIG-B field.

The PHY entity shall check CRC of the HE-SIG-A field. If the CRC check is valid, the PHY entity shall report TXOP and BSS color and continue to receive the HE-SIG-B field. The PHY entity shall report to the MAC entity the predicted duration of the TXOP in the HE-SIG-A field.

The PHY entity shall check the BSS color in the HE-SIG-A field. If the BSS color does not contain an intended value (#4386)(i.e., the color value is not contained in the PHYCONFIG_VECTOR parameter BSS_COLOR_LIST), the PHY entity shall issue a PHY-RXSTART.indication(RXVECTOR) and then issue a PHY-RXEND.indication(Filtered).

After the HE-SIG-A field, the PHY entity shall receive the HE-SIG-B field for the number of symbols predicted from the HE-SIG-A field. If the Common field is present in the HE-SIG-B field, the PHY entity shall check the CRC of the Common field. If the CRC in the Common field is valid or the Common field is not present, the PHY entity shall search for intended STA-ID in each User Specific subfield with a valid CRC. If no CRC is valid or no intended STA-ID is detected, the PHY entity shall issue a PHY-RXSTART.indication(RXVECTOR) and then issue a PHY-RXEND.indication(Filtered). If a complete

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allocation of an intended STA-ID is detected in block with valid CRC, the PHY entity shall continue receiving HE-STF for 4 μs after the HE-SIG-B field for the detected and intended STA.

If the HE-SIG-A field indicates a valid CRC and a reserved HE-SIG-A indication is not indicated, for all supported modes and unsupported modes, the PHY entity shall maintain the PHY-CCA.indication(BUSY, channellist) primitive for the predicted duration of the transmitted PPDU, as defined by RXTIME in Equation (27-146), unless it receives a PHY-CCARESET.request primitive before the end of the PPDU, for instance, during spatial reuse operation as described in 26.10 (HE spatial reuse operation(#2389)).

If the HE-SIG-A field indicates an unsupported mode, the PHY shall issue a PHY-RXEND.indication(UnsupportedRate) primitive.

If the HE-SIG-A field indicates a reserved HE-SIG-A indication, the PHY shall issue the error condition PHY-RXEND.indication(FormatViolation) primitive and maintain the PHY-CCA.indication(BUSY, channellist) primitive for the predicted duration of the transmitted PPDU derived from the LENGTH field in the L-SIG field, as defined in Equation (27-147), unless it receives a PHY-CCARESET.request primitive before the end of the PPDU, for instance, during spatial reuse operation as described in 26.10 (HE spatial reuse operation(#2389)). A reserved HE-SIG-A indication is defined as an HE-SIG-A field with Reserved bits equal to 0 or any other HE-SIG-A field bit combinations that do not correspond to modes of PHY operation defined in Clause 27 (High-efficiency (HE) PHY specification(11ax)).

If the HE-SIG-A field indicates an invalid CRC, the PHY shall issue the error condition PHY-RXEND.indication(FormatViolation) primitive and maintain the PHY-CCA.indication(BUSY, channellist) primitive for the predicted duration of the transmitted PPDU derived from the LENGTH field in the L-SIG field, as defined in Equation (27-147), unless it receives a PHY-CCARESET.request primitive before the end of the PPDU, for instance, during spatial reuse operation as described in 26.10 (HE spatial reuse operation(#2389)).

If signal loss occurs during reception prior to completion of the PSDU reception, the error condition PHY-RXEND.indication(CarrierLost) shall be reported to the MAC. After waiting for the end of the PPDU as determined by Equation (27-146), the PHY shall set the PHY-CCA.indication(IDLE)(#4122) primitive and return to the RX IDLE state.

(27-146)

$$\text{RXTIME}(\mu\text{s}) = 20 + T_{\text{HE\_PREAMBLE}} + N_{SYM}T_{SYM} + N_{MA}N_{\text{HE-LTF}}T_{\text{HE-LTF-SYM}} + T_{PE} + SignalExtension$$

where

$T_{\text{HE-PREAMBLE}}$, $N_{SYM}$, $T_{PE}$, and $N_{MA}$
: are defined in Equation (27-119), Equation (27-120), Equation (27-121), and Equation (27-122), respectively

*SignalExtension*
: is defined in Table 27-61 (HE PHY characteristics(11ax))

$$\text{RXTIME}(\mu\text{s}) = \left\lceil \frac{\text{LENGTH} + 3}{3} \right\rceil \cdot 4 + 20 + SignalExtension \quad (27\text{-}147)$$

where

LENGTH
: is the LENGTH field in the L-SIG field

*SignalExtension*
: is defined in Table 27-61 (HE PHY characteristics(11ax))



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Except in an HE sounding NDP and HE TB feedback NDP, a Data field follows the HE-STF and HE-LTF fields. The number of symbols in the Data field and the packet extension duration are computed from Equation (27-119) and Equation (27-120), respectively.

The received PSDU bits are assembled into octets, decoded, and presented to the MAC using a series of PHY-DATA.indication(DATA) primitive exchanges. Any final bits that cannot be assembled into a complete octet are considered pad bits and discarded. After the reception of the final bit of the last PSDU octet, and possible padding and tail bits, the PHY entity shall check whether packet extension and/or signal extension is applied. If packet extension and/or signal extension is applied, the PHY entity shall wait until the packet extension and/or signal extension expires before returning to the RX IDLE state, as shown in Figure 27-72 (PHY receive state machine if midambles are not present(#3038)(#1590)(11ax)(#6467)).

### 27.3.25 Channel numbering

#### 27.3.25.1 General

The STA may operate in the 2.4 GHz band, 5 GHz band, or 6 GHz band. The set of valid operating channel numbers by regulatory domain is defined in Annex E. Channel allocation for each band is defined in the following subclauses:

— In 19.3.15.2 (Channel allocation in the 2.4 GHz band) for the 2.4 GHz band
— In 19.3.15.3 (Channel allocation in the 5 GHz band) for the 5 GHz band
— In 27.3.25.2 (Channel allocation in the 6 GHz band) for the 6 GHz band

#### 27.3.25.2 Channel allocation in the 6 GHz band

Channel center frequencies are defined at every integer multiple of 5 MHz above the channel starting frequency. The relationship between center frequency and channel number is given in Equation (27-148).

$$\text{Channel center frequency} = \text{Channel starting frequency} + 5 \times n_{ch} \text{ (MHz)} \quad (27\text{-}148)$$

where

$n_{ch}$ = 1, …, 233

Channel starting frequency is defined as dot11ChannelStartingFactor × 500 kHz

For example, a channel center frequency of 5.955 GHz is indicated by dot11ChannelStartingFactor = 11 900 and $n_{ch}$ = 1. A channel center frequency of 5.935 GHz is indicated by dot11ChannelStartingFactor = 11 850 and $n_{ch}$ = 2.

### 27.3.26 Regulatory requirements

Wireless LANs (WLANs) implemented in accordance with this standard are subject to equipment certification and operating requirements established by regional and national regulatory administrations. The PHY specification establishes minimum technical requirements for interoperability, based upon established regulations at the time this standard was issued. These regulations are subject to revision or may be superseded. Requirements that are subject to local geographic regulations are annotated within the PHY specification. Regulatory requirements that do not affect interoperability are not addressed in this standard. Implementers are referred to the regulatory sources in Annex D for further information. Operation in countries within defined regulatory domains might be subject to additional or alternative national regulations.

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## 27.4 HE PLME

### 27.4.1 PLME SAP sublayer management primitives(#6321)

Table 27-60 (HE PHY MIB attributes(11ax)) lists the MIB attributes that may be accessed by the PHY entities and the intralayer of higher level LMEs. These attributes are accessed via the PLME-GET, PLME-SET, PLME-RESET, and PLME-CHARACTERISTICS primitives defined in 6.7 (PLME SAP interface).

### 27.4.2 PHY MIB

HE PHY MIB attributes are defined in Annex C with specific values defined in Table 27-60 (HE PHY MIB attributes(11ax)). The (#4177)Operational semantics column in Table 27-60 (HE PHY MIB attributes(11ax)) contains two types: static and dynamic.

— Static MIB attributes are fixed and cannot be modified for a given PHY implementation.

— Dynamic MIB attributes are interpreted according to the MAX-ACCESS field of the MIB attribute. If MAX-ACCESS is equal to read-only, the MIB attribute value may be updated by the PLME and read from the MIB attribute by management entities. if MAX-ACCESS is equal to read-write, the MIB attribute may be read and written by management entities(#1071).

**Table 27-60—HE PHY MIB attributes(11ax)**

| Managed object | Default value/ range | Operational semantics |
|---|---|---|
| **dot11PHYOperationTable** | | |
| dot11PHYType | (#3245)he(14) | Static |
| **dot11PHYTxPowerTable** | | |
| dot11NumberSupportedPowerLevelsImplemented | Implementation dependent | Static |
| dot11TxPowerLevel1 | Implementation dependent | Static |
| dot11TxPowerLevel2 | Implementation dependent | Static |
| dot11TxPowerLevel3 | Implementation dependent | Static |
| dot11TxPowerLevel4 | Implementation dependent | Static |
| dot11TxPowerLevel5 | Implementation dependent | Static |
| dot11TxPowerLevel6 | Implementation dependent | Static |
| dot11TxPowerLevel7 | Implementation dependent | Static |
| dot11TxPowerLevel8 | Implementation dependent | Static |
| dot11CurrentTxPowerLevel | Implementation dependent | Static |


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**Table 27-60—HE PHY MIB attributes(11ax) *(continued)***

| Managed object | Default value/ range | Operational semantics |
|---|---|---|
| dot11TxPowerLevelExtended | Implementation dependent | Static |
| dot11CurrentTxPowerLevelExtended | Implementation dependent | Static |
| **dot11PHYOFDMTable** | | |
| dot11TwentyMHzOperationImplemented | false/Boolean | Static |
| dot11ChannelStartingFactor | Implementation dependent | Dynamic |
| **dot11PHYHTTable** | | |
| dot11CurrentPrimaryChannel | Implementation dependent | Dynamic |
| dot11CurrentSecondaryChannel | Implementation dependent | Dynamic |
| dot11FortyMHzOperationImplemented | false/Boolean | Static |
| dot11FortyMHzOperationActivated | false/Boolean | Dynamic |
| dot11NumberOfSpatialStreamsImplemented | Implementation dependent | Static |
| dot11NumberOfSpatialStreamsActivated | Implementation dependent | Dynamic |
| dot11HTGreenfieldOptionImplemented | false/Boolean | Static |
| dot11HTGreenfieldOptionActivated | false/Boolean | Dynamic |
| dot11ShortGIOptionInTwentyImplemented | false/Boolean | Static |
| dot11ShortGIOptionInTwentyActivated | false/Boolean | Dynamic |
| dot11ShortGIOptionInFortyImplemented | false/Boolean | Static |
| dot11ShortGIOptionInFortyActivated | false/Boolean | Dynamic |
| dot11LDPCCodingOptionImplemented | false/Boolean | Static |
| dot11LDPCCodingOptionActivated | false/Boolean | Dynamic |
| dot11TxSTBCOptionImplemented | false/Boolean | Static |
| dot11TxSTBCOptionActivated | false/Boolean | Dynamic |
| dot11RxSTBCOptionImplemented | false/Boolean | Static |
| dot11RxSTBCOptionActivated | false/Boolean | Dynamic |
| dot11BeamFormingOptionImplemented | false/Boolean | Static |
| dot11BeamFormingOptionActivated | false/Boolean | Dynamic |
| **dot11PHYVHTTable** | | |
| dot11CurrentChannelWidth | Implementation dependent | Dynamic |

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**Table 27-60—HE PHY MIB attributes(11ax) *(continued)***

| Managed object | Default value/ range | Operational semantics |
|---|---|---|
| dot11CurrentChannelCenterFrequencyIndex0 | Implementation dependent | Dynamic |
| dot11CurrentChannelCenterFrequencyIndex1 | Implementation dependent | Dynamic |
| dot11VHTChannelWidthOptionImplemented | Implementation dependent | Static |
| dot11EightyMHzOperationImplemented | false/Boolean | Static |
| dot11EightyMHzOperationActivated | false/Boolean | Dynamic |
| dot11VHTShortGIOptionIn80Implemented | false/Boolean | Static |
| dot11VHTShortGIOptionIn80Activated | false/Boolean | Dynamic |
| dot11VHTShortGIOptionIn160and80p80Implemented | false/Boolean | Static |
| dot11VHTShortGIOptionIn160and80p80Activated | false/Boolean | Dynamic |
| dot11VHTLDPCCodingOptionImplemented | false/Boolean | Static |
| dot11VHTLDPCCodingOptionActivated | false/Boolean | Dynamic |
| dot11VHTTxSTBCOptionImplemented | false/Boolean | Static |
| dot11VHTTxSTBCOptionActivated | false/Boolean | Dynamic |
| dot11VHTRxSTBCOptionImplemented | false/Boolean | Static |
| dot11VHTRxSTBCOptionActivated | false/Boolean | Dynamic |
| dot11VHTMaxNTxChainsImplemented | Implementation dependent | Static |
| dot11VHTMaxNTxChainsActivated | Implementation dependent | Dynamic |
| **dot11TransmitBeamformingConfigTable** | | |
| dot11ReceiveStaggerSoundingOptionImplemented | false/Boolean | Static |
| dot11TransmitStaggerSoundingOptionImplemented | false/Boolean | Static |
| dot11ReceiveNDPOptionImplemented | false/Boolean | Static |
| dot11TransmitNDPOptionImplemented | false/Boolean | Static |
| dot11ImplicitTransmitBeamformingOptionImplemented | false/Boolean | Static |
| dot11CalibrationOptionImplemented | Implementation dependent | Static |
| dot11ExplicitCSITransmitBeamformingOptionImplemented | false/Boolean | Static |
| dot11ExplicitNonCompressedBeamformingMatrixOptionImplemented | false/Boolean | Static |
| dot11ExplicitTransmitBeamformingCSIFeedbackOptionImplemented | Implementation dependent | Static |
| dot11ExplicitNoncompressedBeamformingFeedbackOptionImplemented | Implementation dependent | Static |


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**Table 27-60—HE PHY MIB attributes(11ax) *(continued)***

| Managed object | Default value/ range | Operational semantics |
|---|---|---|
| dot11ExplicitCompressedBeamformingFeedbackOptionImplemented | Implementation dependent | Static |
| dot11NumberBeamFormingCSISupportAntenna | Implementation dependent | Static |
| dot11NumberNonCompressedBeamformingMatrixSupportAntenna | Implementation dependent | Static |
| dot11NumberCompressedBeamformingMatrixSupportAntenna | Implementation dependent | Static |
| **dot11VHTTransmitBeamformingConfigTable** | | |
| dot11VHTSUBeamformeeOptionImplemented | false/Boolean | Static |
| dot11VHTSUBeamformerOptionImplemented | false/Boolean | Static |
| dot11VHTMUBeamformeeOptionImplemented | false/Boolean | Static |
| dot11VHTMUBeamformerOptionImplemented | false/Boolean | Static |
| dot11VHTNumberSoundingDimensions | Implementation dependent | Static |
| dot11VHTBeamformeeNTxSupport | Implementation dependent | Static |
| (#4284)dot11VHTMaxNstsTotal | Implementation dependent | Static |
| **dot11PHYHETable** | | |
| dot11HECurrentChannelWidthSet | Implementation dependent | Dynamic |
| dot11HEPuncturedPreambleRxImplemented | Implementation dependent | Static |
| dot11HEPuncturedSoundingOptionImplemented | Implementation dependent | Static |
| dot11HEDeviceClass | Implementation dependent | Static |
| dot11HELDPCCodingInPayloadImplemented | false/Boolean | Static |
| dot11HESUPPDUwith1xHELTFand0point8GIlmplemented | false/Boolean | Static |
| dot11HESUPPDUandHEMUPPDUwith4xHELTFand0point8GIlmplemented | false/Boolean | Static |
| dot11HEERSUPPDUwith4xHELTFand0point8GIImplemented | false/Boolean | Static |
| dot11HEERSUPPDUwith1xHELTFand0point8GIImplemented | false/Boolean | Static |
| dot11HEMidambleRxMaxNSTS | false/Boolean | Dynamic |
| dot11HENDPwith4xHELTFand3point2GIImplemented | false/Boolean | Static |
| dot11HESTBCTxLessThanOrEqualTo80Implemented | false/Boolean | Static |
| dot11HESTBCRxLessThanOrEqualTo80Implemented | false/Boolean | Static |

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**Table 27-60—HE PHY MIB attributes(11ax) *(continued)***

| Managed object | Default value/ range | Operational semantics |
|---|---|---|
| dot11HESTBCTxGreaterThan80Implemented | false/Boolean | Static |
| dot11HESTBCRxGreaterThan80Implemented | false/Boolean | Static |
| dot11HEDopplerTxImplemented | false/Boolean | Static |
| dot11HEDopplerRxImplemented | false/Boolean | Static |
| dot11HEDCMImplemented | Implementation dependent | Static |
| dot11HEFullBWULMUMIMOImplemented | false/Boolean | Static |
| dot11HEPartialBWULMUMIMOImplemented | false/Boolean | Static |
| dot11HEPartialBWDLMUMIMOImplemented | false/Boolean | Static |
| dot11HEULMUPayloadImplemented | false/Boolean | Static |
| dot11HEPSRbasedSRSupportImplemented | false/Boolean | Static |
| dot11HEPowerBoostFactorImplemented | false/Boolean | Static |
| dot11HEPartialBWERSUPayloadImplemented | false/Boolean | Static |
| (#1072)dot11HEChannelWidthOptionImplemented | Implementation dependent | Static |
| **dot11HETransmitBeamformingConfigTable** | | |
| dot11HESUBeamformerOptionImplemented | false/Boolean | Static |
| dot11HESUBeamformeeOptionImplemented | false/Boolean | Static |
| dot11HEMUBeamformerOptionImplemented | false/Boolean | Static |
| dot11HEBeamformeeSTSSupportLessThanOrEqualTo80 | Implementation dependent | Static |
| dot11HEBeamformeeSTSSupportGreaterThan80 | Implementation dependent | Static |
| dot11HENumberSoundingDimensionsLessThanOrEqualTo80 | Implementation dependent | Static |
| dot11HENumberSoundingDimensionsGreaterThan80 | Implementation dependent | Static |
| dot11HENG16SUFeedbackSupport | false/Boolean | Static |
| dot11HENG16MUFeedbackSupport | false/Boolean | Static |
| dot11HECodebookSizePhi4Psi2SUFeedbackSupport | false/Boolean | Static |
| dot11HECodebookSizePhi7Psi5MUFeedbackSupport | false/Boolean | Static |
| dot11HETriggeredSUBeamformingFeedbackImplemented | false/Boolean | Static |
| dot11HETriggeredMUBeamformingFeedbackImplemented | false/Boolean | Static |
| dot11HETriggeredCQIFeedbackSupportImplemented | false/Boolean | Static |


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### 27.4.3 TXTIME and PSDU_LENGTH calculation

The value of the TXTIME parameter returned by the PLME-TXTIME.confirm primitive shall be calculated for an HE PPDU using Equation (27-149).

$$\text{TXTIME} = 20 + T_{\text{HE-PREAMBLE}} + N_{SYM}T_{SYM} + N_{MA}N_{\text{HE-LTF}}T_{\text{HE-LTF-SYM}} + T_{PE} + SignalExtension \quad (27\text{-}149)$$

where

$T_{\text{HE-PREAMBLE}}$ is defined as in Equation (27-121)

$T_{SYM}$ is the symbol duration of the Data field as defined in 27.3.9 (Timing-related parameters)(#2332)

*SignalExtension* takes the value of aSignalExtension as defined in Table 27-61 (HE PHY characteristics(11ax))

For an HE sounding NDP and HE TB feedback NDP, there is no Data field and $N_{SYM} = 0$.

(11az)For an HE TB Ranging NDP, TXTIME is defined by Equation (27-150).

$$\text{TXTIME} = 40 + T_{\text{HE-PREAMBLE}} + 8N_{\text{LTF-REP}}N_{\text{HE-LTF}} + T_{PE} + SignalExtension \quad (27\text{-}150)$$

where

$N_{\text{LTF-REP}}$ is given by the TXVECTOR parameter LTF_REP

$N_{\text{HE-LTF}}$ is given in Table 27-15 (Subcarrier allocation related constants for RUs in an OFDMA HE PPDU(11ax))

(11az)NOTE 1—The value 40 corresponds to the duration of L-STF, L-LTF, L-SIG, RL-SIG, HE-SIG-A, and HE-STF in µs. $T_{PE}$ is 4 µs in an HE TB Ranging NDP (see 27.3.19.2 (HE TB Ranging NDP(11az))).

(11az)For an HE Ranging NDP with the TXVECTOR parameter SECURE_LTF_FLAG equal to 0 or SECURE_LTF_FLAG equal to 1 and the TXVECTOR parameter NUM_USERS is equal to 1, TXTIME is defined by Equation (27-151).

$$\text{TXTIME} = 36 + 8N_{\text{LTF-REP}}N_{\text{HE-LTF}} + T_{PE} + SignalExtension \quad (27\text{-}151)$$

(11az)NOTE 2—The value 36 corresponds to the duration of L-STF, L-LTF, L-SIG, RL-SIG, HE-SIG-A, and HE-STF in µs. $T_{PE}$ is 4 µs in an HE Ranging NDP (see 27.3.19.1 (HE Ranging NDP(11az))).

(11az)For an HE Ranging NDP with the TXVECTOR parameter SECURE_LTF_FLAG equal to 1 and the TXVECTOR parameter NUM_USERS greater than 1, TXTIME is defined by Equation (27-152).

$$\text{TXTIME} = 36 + \sum_{n=1}^{\text{NUM\_USERS}} 8N_{\text{LTF\_REP}}(n)N_{\text{HE-LTF}}(n) + T_{PE} + SignalExtension \quad (27\text{-}152)$$

(11az)NOTE 3—The value 36 corresponds to the duration of L-STF, L-LTF, L-SIG, RL-SIG, HE-SIG-A, and HE-STF in µs. $T_{PE}$ is 4 µs in an HE Ranging NDP (see 27.3.19.1 (HE Ranging NDP(11az))).

For an HE SU PPDU and HE ER SU PPDU using BCC encoding, the total number of data OFDM symbols, $N_{SYM}$, is given by Equation (27-66).

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For an HE SU PPDU and HE ER SU PPDU using LDPC encoding, the total number of data OFDM symbols, $N_{SYM}$, is given in 27.3.12.5.2 (LDPC coding).

For an HE MU PPDU (including both MU-MIMO and OFDMA), the total number of data OFDM symbols, $N_{SYM}$, is given in 27.3.12.5.4 (Encoding process for an HE MU PPDU).

For an HE TB PPDU, the total number of data OFDM symbols, $N_{SYM}$, is given in 27.3.12.5.5 (Encoding process for an HE TB PPDU).

$T_{PE}$ is given in 27.3.13 (Packet extension).

$N_{MA}$ is the number of midambles. It is given by Equation (27-117) for an HE TB PPDU and by Equation (27-112) for an HE SU PPDU, HE ER SU PPDU, and HE MU PPDU if the TXVECTOR value DOPPLER is 1, and is 0 otherwise.

$N_{HE\text{-}LTF}$ and $T_{HE\text{-}LTF}$ are given in 27.3.9 (Timing-related parameters).

The value of the PSDU_LENGTH parameter returned in the PLME-TXTIME.confirm primitive for an HE SU PPDU, HE ER SU PPDU, and HE TB PPDU is calculated using Equation (27-153).

$$\text{PSDU\_LENGTH} = \left\lfloor \frac{(N_{SYM,init} - m_{STBC})N_{DBPS} + m_{STBC}N_{DBPS,last,init} - N_{service} - N_{tail}}{8} \right\rfloor \quad (27\text{-}153)$$

where

$N_{SYM,init}$ is given by Equation (27-64) for BCC encoding, by Equation (27-64) for LDPC encoding for an HE SU PPDU and HE ER SU PPDU, and in 27.3.12.5.5 (Encoding process for an HE TB PPDU) for an HE TB PPDU

$m_{STBC}$ is 2 when STBC is used, and 1 otherwise

$N_{DBPS}$ is given in 27.5 (Parameters for HE-MCSs)

$N_{DBPS,last,init}$ is given by Equation (27-62)

The value of the PSDU_LENGTH parameter for user $u$ returned in the PLME-TXTIME.confirm primitive for an HE MU PPDU is calculated using Equation (27-154) and Equation (27-155) for users using BCC and LDPC, respectively.

$$\text{PSDU\_LENGTH}_u = \left\lfloor \frac{(N_{SYM} - m_{STBC})N_{DBPS,u} + m_{STBC}N_{DBPS,last,u} - N_{service} - N_{tail}}{8} \right\rfloor \quad (27\text{-}154)$$

$$\text{PSDU\_LENGTH}_u = \left\lfloor \frac{(N_{SYM,init} - m_{STBC})N_{DBPS,u} + m_{STBC}N_{DBPS,last,init,u} - N_{service}}{8} \right\rfloor \quad (27\text{-}155)$$

where

$N_{SYM,init}$ is given by Equation (27-76)

$N_{DBPS,u}$ is given in Table 27-16 (Frequently used parameters(11ax))

$N_{DBPS,last,u}$ is given by Equation (27-85)

$N_{DBPS,last,init,u}$ is given by Equation (27-77)


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For an HE SU PPDU, HE ER SU PPDU, and HE TB PPDU, the value of the PSDU_LENGTH parameter returned in the RXVECTOR is calculated using Equation (27-156).

$$\text{PSDU\_LENGTH} = \left\lfloor \frac{(N_{SYM,RX} - m_{STBC})N_{DBPS} + m_{STBC}N_{DBPS,last,RX} - N_{service} - N_{tail}}{8} \right\rfloor \quad (27\text{-}156)$$

where

$N_{SYM,RX}$ is given by Equation (27-157)

$$N_{SYM,RX} = \begin{cases} N_{SYM} - m_{STBC}, & \text{if the Coding field is 1, the LDPC Extra Symbol Segment field is 1, and the Pre-FEC Padding Factor field is 1 in HE-SIG-A} \\ N_{SYM}, & \text{otherwise} \end{cases} \quad (27\text{-}157)$$

where

$N_{SYM}$ is given by Equation (27-119)

$m_{STBC}$ is 1 if the STBC field in the HE-SIG-A field is 0 and 2 if the STBC field is 1

$N_{DBPS,last,RX}$ is given by Equation (27-158)

$$N_{DBPS,last,RX} = \begin{cases} N_{DBPS}, & \text{if } a_{RX} = 4 \\ a_{RX} \cdot N_{SD,short} \cdot N_{SS} \cdot N_{BPSCS} \cdot R, & \text{otherwise} \end{cases} \quad (27\text{-}158)$$

where

$a_{RX}$ is given by Equation (27-159)

$N_{SD,short}$ is defined in Table 27-34 (NSD,short values(11ax))

$N_{SS}$, $N_{BPSCS}$, and $R$ are defined in Table 27-16 (Frequently used parameters(11ax))

$$a_{RX} = \begin{cases} 4, & \text{if } a = 1, \text{ the Coding field is 1 and the LDPC Extra Symbol Segment field is 1 in HE-SIG-A} \\ a - 1, & \text{if } a > 1, \text{ the Coding field is 1 and the LDPC Extra Symbol Segment field is 1 in HE-SIG-A} \\ a, & \text{otherwise} \end{cases} \quad (27\text{-}159)$$

where

$a$ is the pre-FEC padding factor (ranging from 1 to 4) indicated in the HE-SIG-A field

$N_{DBPS}$ is defined in Table 27-16 (Frequently used parameters(11ax))

$N_{service}$ and $N_{tail}$ are defined in Table 27-13 (Timing-related constants(11ax))

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For an HE MU PPDU, the value of the RXVECTOR parameter PSDU_LENGTH returned for user $u$ is calculated using Equation (27-160).

$$\text{PSDU\_LENGTH}_u = \left\lfloor \frac{(N_{SYM,RX,u} - m_{STBC})N_{DBPS,u} + m_{STBC}N_{DBPS,last,RX,u} - N_{service} - N_{tail,u}}{8} \right\rfloor \quad (27\text{-}160)$$

where

$N_{SYM,RX,u}$ is given by Equation (27-161)

$$N_{SYM,RX,u} = \begin{cases} N_{SYM} - m_{STBC}, & \text{if } a = 1, \text{ the Coding field is 1 in the User field of the HE-SIG-B field corresponding to user u and LDPC Extra Symbol Segment field is 1 in HE-SIG-A field} \\ N_{SYM}, & \text{othewise} \end{cases} \quad (27\text{-}161)$$

where

$N_{SYM}$ is given by Equation (27-119)

$m_{STBC}$ is 1 if the STBC field in the HE-SIG-A field is 0 and 2 if the STBC field is 1

$N_{DBPS,last,RX,u}$ is given by Equation (27-162)

$$N_{DBPS,last,RX,u} = \begin{cases} N_{DBPS,u}, & \text{if } a_{RX,u} = 4 \\ a_{RX,u} \cdot N_{SD,short,u} \cdot N_{SS,u} \cdot N_{BPSCS,u} \cdot R_u, & \text{otherwise} \end{cases} \quad (27\text{-}162)$$

where

$a_{RX,u}$ is given by Equation (27-163)

$N_{SD,short,u}$ is $N_{SD,short}$ defined in Table 27-34 (NSD,short values(11ax)) for user $u$

$N_{SS,u}$, $N_{BPSCS,u}$, and $R_u$ are defined in Table 27-16 (Frequently used parameters(11ax))

$$a_{RX,u} = \begin{cases} 4, & \text{if } a = 1, \text{ Coding field is 1 in User field of HE-SIG-B field corresponding to the user } u \text{ and LDPC Extra Symbol Segment field is 1 in HE-SIG-A} \\ a - 1, & \text{if } a > 1, \text{ the Coding field is 1 in User field of HE-SIG-B field corresponding to the user } u \text{ and LDPC Extra Symbol Segment field is 1 in HE-SIG-A field} \\ a, & \text{otherwise} \end{cases} \quad (27\text{-}163)$$

where

$a$ is the pre-FEC padding factor (ranging from 1 to 4) indicated in the HE-SIG-A field

$N_{DBPS,u}$ is defined in Table 27-16 (Frequently used parameters(11ax))

$N_{service}$ and $N_{tail}$ are defined in Table 27-13 (Timing-related constants(11ax))

The value of the PSDU_LENGTH parameter returned in the PLME-TXTIME.confirm primitive for an HE sounding NDP is 0.



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### 27.4.4 HE PHY

(#2123)The HE PHY characteristics, provided through the PLME-CHARACTERISTICS service primitive, are shown in Table 19-25 (HT PHY characteristics) unless otherwise listed in Table 27-61 (HE PHY characteristics(11ax)). The definitions for these characteristics are given in 6.7.4 (PLME-CHARACTERISTICS.confirm).

**Table 27-61—HE PHY characteristics(11ax)**

| Characteristic | Value |
|---|---|
| aTxPHYDelay | Implementation dependent |
| aRxPHYDelay | Implementation dependent |
| aSignalExtension | 0 μs if operating in the 5 GHz or 6 GHz band<br>6 μs if operating in the 2.4 GHz band |
| aSlotTime | If operating in the 2.4 GHz band:<br>If dot11OperatingClassesRequired is false, long = 20 μs<br>If dot11OperatingClassesRequired is true, long = 20 μs plus any coverage-class-dependent aAirPropagationTime (see Table 9-95)<br>If dot11OperatingClassesRequired is false, short = 9 μs<br>If dot11OperatingClassesRequired is true, short = 9 μs plus any coverage-class-dependent aAirPropagationTime (see Table 9-95)<br>If operating in the 5 GHz or 6 GHz band:<br>If dot11OperatingClassesRequired is false, 9 μs<br>If dot11OperatingClassesRequired is true, 9 μs plus any coverage-class-dependent aAirPropagationTime (see Table 9-95) |
| aSIFSTime | 10 μs if operating in the 2.4 GHz band<br>16 μs if operating in the 5 GHz or 6 GHz band |
| aCCAMidTime | 25 μs |
| aPPDUMaxTime | 5.484 ms |
| aPSDUMaxLength | 6 500 631 octets (see NOTE) |
| aRxPHYStartDelay | (#3038)24 μs |

NOTE—This is the maximum length in octets for an HE SU PPDU with a bandwidth of 160 MHz or 80+80 MHz using 2×996 RU, HE-MCS 11, 8 spatial streams, 0.8 μs GI duration, 1x HE-LTF, LDPC coding, 0 μs duration of the PE field, pre-FEC padding factor value of 4, and limited by 398 possible Data field OFDM symbols in aPPDUMaxTime. This is the maximum PSDU length an HE PHY could support assuming no restrictions in MAC. See (#2369)10.12.2 (A-MPDU length limit rules) and (#3335)9.2.4.8.1 (General) for additional restrictions on the maximum number of octets the MAC could support.

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## 27.5 Parameters for HE-MCSs

### 27.5.1 General

The rate-dependent parameters for 26-tone RU, 52-tone RU, 106-tone RU, 242-tone RU, and non-OFDMA 20 MHz; 484-tone RU and non-OFDMA 40 MHz; 996-tone RU and non-OFDMA 80 MHz; 2×996-tone RU and non-OFDMA 160 MHz and 80+80 MHz ($N_{SS}$ = 1, …, 8) are provided in 27.5.2 (HE-MCSs for 26-tone RU) through 27.5.8 (HE-MCSs for 2×996-tone RU). Support for HE-MCS 8, 9, 10, and 11 is optional in all cases.

HE-MCSs are defined for both SU transmission and for user $u$ of the $r^{th}$ RU of an MU transmission. In the case of HE-MCSs for MU transmissions, the parameters, $N_{SS}$, $R$, $N_{BPSCS}$, $N_{CBPS}$, and $N_{DBPS}$ are replaced with $N_{SS,u}$, $R_u$, $N_{BPSCS,u}$, $N_{CBPS,u}$, and $N_{DBPS,u}$, respectively.

$N_{DBPS}$ is an integer and shall be computed as follows $N_{DBPS} = \lfloor N_{CBPS} \times R \rfloor$ (#2380), where $R$ is the coding rate.

### 27.5.2 HE-MCSs for 26-tone RU

The rate-dependent parameters for the 26-tone RU are provided in Table 27-62 (HE-MCSs for 26-tone RU, NSS = 1(11ax)) through Table 27-69 (HE-MCSs for 26-tone RU, NSS = 8(11ax)).

**Table 27-62—HE-MCSs for 26-tone RU, $N_{SS}$ = 1(11ax)**

| HE-MCS Index | DCM | Modulation | $R$ | $N_{BPSCS}$ | $N_{SD}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 0.8 µs GI | 1.6 µs GI | 3.2 µs GI |
| 0 | 1 | BPSK | 1/2 | 1 | 12 | 12 | 6 | 0.4 | 0.4 | 0.4 |
| | 0 | | 1/2 | | 24 | 24 | 12 | 0.9 | 0.8 | 0.8 |
| 1 | 1 | QPSK | 1/2 | 2 | 12 | 24 | 12 | 0.9 | 0.8 | 0.8 |
| | 0 | | 1/2 | | 24 | 48 | 24 | 1.8 | 1.7 | 1.5 |
| 2 | N/A | | 3/4 | | 24 | 48 | 36 | 2.6 | 2.5 | 2.3 |
| 3 | 1 | 16-QAM | 1/2 | 4 | 12 | 48 | 24 | 1.8 | 1.7 | 1.5 |
| | 0 | | 1/2 | | 24 | 96 | 48 | 3.5 | 3.3 | 3.0 |
| 4 | 1 | | 3/4 | | 12 | 48 | 36 | 2.6 | 2.5 | 2.3 |
| | 0 | | 3/4 | | 24 | 96 | 72 | 5.3 | 5.0 | 4.5 |
| 5 | N/A | 64-QAM | 2/3 | 6 | 24 | 144 | 96 | 7.1 | 6.7 | 6.0 |
| 6 | | | 3/4 | | | | 108 | 7.9 | 7.5 | 6.8 |
| 7 | | | 5/6 | | | | 120 | 8.8 | 8.3 | 7.5 |
| 8 | | 256-QAM | 3/4 | 8 | | 192 | 144 | 10.6 | 10.0 | 9.0 |
| 9 | | | 5/6 | | | | 160 | 11.8 | 11.1 | 10.0 |
| 10 | | 1024-QAM | 3/4 | 10 | | 240 | 180 | 13.2 | 12.5 | 11.3 |
| 11 | | | 5/6 | | | | 200 | 14.7 | 13.9 | 12.5 |



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**Table 27-63—HE-MCSs for 26-tone RU, $N_{SS}$ = 2(11ax)**

| HE-MCS Index | DCM | Modulation | $R$ | $N_{BPSCS}$ | $N_{SD}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 0.8 µs GI | 1.6 µs GI | 3.2 µs GI |
| 0 | 1 | BPSK | 1/2 | 1 | 12 | 24 | 12 | 0.9 | 0.8 | 0.8 |
| | 0 | | 1/2 | | 24 | 48 | 24 | 1.8 | 1.7 | 1.5 |
| 1 | 1 | QPSK | 1/2 | 2 | 12 | 48 | 24 | 1.8 | 1.7 | 1.5 |
| | 0 | | 1/2 | | 24 | 96 | 48 | 3.5 | 3.3 | 3.0 |
| 2 | N/A | | 3/4 | | 24 | 96 | 72 | 5.3 | 5.0 | 4.5 |
| 3 | 1 | 16-QAM | 1/2 | 4 | 12 | 96 | 48 | 3.5 | 3.3 | 3.0 |
| | 0 | | 1/2 | | 24 | 192 | 96 | 7.1 | 6.7 | 6.0 |
| 4 | 1 | | 3/4 | | 12 | 96 | 72 | 5.3 | 5.0 | 4.5 |
| | 0 | | 3/4 | | 24 | 192 | 144 | 10.6 | 10.0 | 9.0 |
| 5 | N/A | 64-QAM | 2/3 | 6 | 24 | 288 | 192 | 14.1 | 13.3 | 12.0 |
| 6 | | | 3/4 | | | | 216 | 15.9 | 15.0 | 13.5 |
| 7 | | | 5/6 | | | | 240 | 17.6 | 16.7 | 15.0 |
| 8 | | 256-QAM | 3/4 | 8 | | 384 | 288 | 21.2 | 20.0 | 18.0 |
| 9 | | | 5/6 | | | | 320 | 23.5 | 22.2 | 20.0 |
| 10 | | 1024-QAM | 3/4 | 10 | | 480 | 360 | 26.5 | 25.0 | 22.5 |
| 11 | | | 5/6 | | | | 400 | 29.4 | 27.8 | 25.0 |

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**Table 27-64—HE-MCSs for 26-tone RU, $N_{SS}$ = 3(11ax)**

| HE-MCS Index | DCM | Modulation | $R$ | $N_{BPSCS}$ | $N_{SD}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 0.8 µs GI | 1.6 µs GI | 3.2 µs GI |
| 0 | N/A | BPSK | 1/2 | 1 | 24 | 72 | 36 | 2.6 | 2.5 | 2.3 |
| 1 | | QPSK | 1/2 | 2 | | 144 | 72 | 5.3 | 5.0 | 4.5 |
| 2 | | | 3/4 | | | | 108 | 7.9 | 7.5 | 6.8 |
| 3 | | 16-QAM | 1/2 | 4 | | 288 | 144 | 10.6 | 10.0 | 9.0 |
| 4 | | | 3/4 | | | | 216 | 15.9 | 15.0 | 13.5 |
| 5 | | 64-QAM | 2/3 | 6 | | 432 | 288 | 21.2 | 20.0 | 18.0 |
| 6 | | | 3/4 | | | | 324 | 23.8 | 22.5 | 20.3 |
| 7 | | | 5/6 | | | | 360 | 26.5 | 25.0 | 22.5 |
| 8 | | 256-QAM | 3/4 | 8 | | 576 | 432 | 31.8 | 30.0 | 27.0 |
| 9 | | | 5/6 | | | | 480 | 35.3 | 33.3 | 30.0 |
| 10 | | 1024-QAM | 3/4 | 10 | | 720 | 540 | 39.7 | 37.5 | 33.8 |
| 11 | | | 5/6 | | | | 600 | 44.1 | 41.7 | 37.5 |

**Table 27-65—HE-MCSs for 26-tone RU, $N_{SS}$ = 4(11ax)**

| HE-MCS Index | DCM | Modulation | $R$ | $N_{BPSCS}$ | $N_{SD}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 0.8 µs GI | 1.6 µs GI | 3.2 µs GI |
| 0 | N/A | BPSK | 1/2 | 1 | 24 | 96 | 48 | 3.5 | 3.3 | 3.0 |
| 1 | | QPSK | 1/2 | 2 | | 192 | 96 | 7.1 | 6.7 | 6.0 |
| 2 | | | 3/4 | | | | 144 | 10.6 | 10.0 | 9.0 |
| 3 | | 16-QAM | 1/2 | 4 | | 384 | 192 | 14.1 | 13.3 | 12.0 |
| 4 | | | 3/4 | | | | 288 | 21.2 | 20.0 | 18.0 |
| 5 | | 64-QAM | 2/3 | 6 | | 576 | 384 | 28.2 | 26.7 | 24.0 |
| 6 | | | 3/4 | | | | 432 | 31.8 | 30.0 | 27.0 |
| 7 | | | 5/6 | | | | 480 | 35.3 | 33.3 | 30.0 |
| 8 | | 256-QAM | 3/4 | 8 | | 768 | 576 | 42.4 | 40.0 | 36.0 |
| 9 | | | 5/6 | | | | 640 | 47.1 | 44.4 | 40.0 |
| 10 | | 1024-QAM | 3/4 | 10 | | 960 | 720 | 52.9 | 50.0 | 45.0 |
| 11 | | | 5/6 | | | | 800 | 58.8 | 55.6 | 50.0 |



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**Table 27-66—HE-MCSs for 26-tone RU, $N_{SS}$ = 5(11ax)**

| HE-MCS Index | DCM | Modulation | $R$ | $N_{BPSCS}$ | $N_{SD}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 0.8 µs GI | 1.6 µs GI | 3.2 µs GI |
| 0 | N/A | BPSK | 1/2 | 1 | 24 | 120 | 60 | 4.4 | 4.2 | 3.8 |
| 1 | | QPSK | 1/2 | 2 | | 240 | 120 | 8.8 | 8.3 | 7.5 |
| 2 | | | 3/4 | | | | 180 | 13.2 | 12.5 | 11.3 |
| 3 | | 16-QAM | 1/2 | 4 | | 480 | 240 | 17.6 | 16.7 | 15.0 |
| 4 | | | 3/4 | | | | 360 | 26.5 | 25.0 | 22.5 |
| 5 | | 64-QAM | 2/3 | 6 | | 720 | 480 | 35.3 | 33.3 | 30.0 |
| 6 | | | 3/4 | | | | 540 | 39.7 | 37.5 | 33.8 |
| 7 | | | 5/6 | | | | 600 | 44.1 | 41.7 | 37.5 |
| 8 | | 256-QAM | 3/4 | 8 | | 960 | 720 | 52.9 | 50.0 | 45.0 |
| 9 | | | 5/6 | | | | 800 | 58.8 | 55.6 | 50.0 |
| 10 | | 1024-QAM | 3/4 | 10 | | 1 200 | 900 | 66.2 | 62.5 | 56.3 |
| 11 | | | 5/6 | | | | 1 000 | 73.5 | 69.4 | 62.5 |

**Table 27-67—HE-MCSs for 26-tone RU, $N_{SS}$ = 6(11ax)**

| HE-MCS Index | DCM | Modulation | $R$ | $N_{BPSCS}$ | $N_{SD}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 0.8 µs GI | 1.6 µs GI | 3.2 µs GI |
| 0 | N/A | BPSK | 1/2 | 1 | 24 | 144 | 72 | 5.3 | 5.0 | 4.5 |
| 1 | | QPSK | 1/2 | 2 | | 288 | 144 | 10.6 | 10.0 | 9.0 |
| 2 | | | 3/4 | | | | 216 | 15.9 | 15.0 | 13.5 |
| 3 | | 16-QAM | 1/2 | 4 | | 576 | 288 | 21.2 | 20.0 | 18.0 |
| 4 | | | 3/4 | | | | 432 | 31.8 | 30.0 | 27.0 |
| 5 | | 64-QAM | 2/3 | 6 | | 864 | 576 | 42.4 | 40.0 | 36.0 |
| 6 | | | 3/4 | | | | 648 | 47.6 | 45.0 | 40.5 |
| 7 | | | 5/6 | | | | 720 | 52.9 | 50.0 | 45.0 |
| 8 | | 256-QAM | 3/4 | 8 | | 1 152 | 864 | 63.5 | 60.0 | 54.0 |
| 9 | | | 5/6 | | | | 960 | 70.6 | 66.7 | 60.0 |
| 10 | | 1024-QAM | 3/4 | 10 | | 1 440 | 1 080 | 79.4 | 75.0 | 67.5 |
| 11 | | | 5/6 | | | | 1 200 | 88.2 | 83.3 | 75.0 |

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**Table 27-68—HE-MCSs for 26-tone RU, $N_{SS}$ = 7(11ax)**

| HE-MCS Index | DCM | Modulation | $R$ | $N_{BPSCS}$ | $N_{SD}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 0.8 µs GI | 1.6 µs GI | 3.2 µs GI |
| 0 | N/A | BPSK | 1/2 | 1 | 24 | 168 | 84 | 6.2 | 5.8 | 5.3 |
| 1 | | QPSK | 1/2 | 2 | | 336 | 168 | 12.4 | 11.7 | 10.5 |
| 2 | | | 3/4 | | | | 252 | 18.5 | 17.5 | 15.8 |
| 3 | | 16-QAM | 1/2 | 4 | | 672 | 336 | 24.7 | 23.3 | 21.0 |
| 4 | | | 3/4 | | | | 504 | 37.1 | 35.0 | 31.5 |
| 5 | | 64-QAM | 2/3 | 6 | | 1 008 | 672 | 49.4 | 46.7 | 42.0 |
| 6 | | | 3/4 | | | | 756 | 55.6 | 52.5 | 47.3 |
| 7 | | | 5/6 | | | | 840 | 61.8 | 58.3 | 52.5 |
| 8 | | 256-QAM | 3/4 | 8 | | 1 344 | 1 008 | 74.1 | 70.0 | 63.0 |
| 9 | | | 5/6 | | | | 1 120 | 82.4 | 77.8 | 70.0 |
| 10 | | 1024-QAM | 3/4 | 10 | | 1 680 | 1 260 | 92.6 | 87.5 | 78.8 |
| 11 | | | 5/6 | | | | 1 400 | 102.9 | 97.2 | 87.5 |

**Table 27-69—HE-MCSs for 26-tone RU, $N_{SS}$ = 8(11ax)**

| HE-MCS Index | DCM | Modulation | $R$ | $N_{BPSCS}$ | $N_{SD}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 0.8 µs GI | 1.6 µs GI | 3.2 µs GI |
| 0 | N/A | BPSK | 1/2 | 1 | 24 | 192 | 96 | 7.1 | 6.7 | 6.0 |
| 1 | | QPSK | 1/2 | 2 | | 384 | 192 | 14.1 | 13.3 | 12.0 |
| 2 | | | 3/4 | | | | 288 | 21.2 | 20.0 | 18.0 |
| 3 | | 16-QAM | 1/2 | 4 | | 768 | 384 | 28.2 | 26.7 | 24.0 |
| 4 | | | 3/4 | | | | 576 | 42.4 | 40.0 | 36.0 |
| 5 | | 64-QAM | 2/3 | 6 | | 1 152 | 768 | 56.5 | 53.3 | 48.0 |
| 6 | | | 3/4 | | | | 864 | 63.5 | 60.0 | 54.0 |
| 7 | | | 5/6 | | | | 960 | 70.6 | 66.7 | 60.0 |
| 8 | | 256-QAM | 3/4 | 8 | | 1 536 | 1 152 | 84.7 | 80.0 | 72.0 |
| 9 | | | 5/6 | | | | 1 280 | 94.1 | 88.9 | 80.0 |
| 10 | | 1024-QAM | 3/4 | 10 | | 1 920 | 1 440 | 105.9 | 100.0 | 90.0 |
| 11 | | | 5/6 | | | | 1 600 | 117.6 | 111.1 | 100.0 |



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### 27.5.3 HE-MCSs for 52-tone RU

The rate-dependent parameters for the 52-tone RU are provided in Table 27-70 (HE-MCSs for 52-tone RU, NSS = 1(11ax)) through Table 27-77 (HE-MCSs for 52-tone RU, NSS = 8(11ax)).

**Table 27-70—HE-MCSs for 52-tone RU, $N_{SS}$ = 1(11ax)**

| HE-MCS Index | DCM | Modulation | $R$ | $N_{BPSCS}$ | $N_{SD}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 0.8 µs GI | 1.6 µs GI | 3.2 µs GI |
| 0 | 1 | BPSK | 1/2 | 1 | 24 | 24 | 12 | 0.9 | 0.8 | 0.8 |
| | 0 | | 1/2 | | 48 | 48 | 24 | 1.8 | 1.7 | 1.5 |
| 1 | 1 | QPSK | 1/2 | 2 | 24 | 48 | 24 | 1.8 | 1.7 | 1.5 |
| | 0 | | 1/2 | | 48 | 96 | 48 | 3.5 | 3.3 | 3.0 |
| 2 | N/A | | 3/4 | | 48 | 96 | 72 | 5.3 | 5.0 | 4.5 |
| 3 | 1 | 16-QAM | 1/2 | 4 | 24 | 96 | 48 | 3.5 | 3.3 | 3.0 |
| | 0 | | 1/2 | | 48 | 192 | 96 | 7.1 | 6.7 | 6.0 |
| 4 | 1 | | 3/4 | | 24 | 96 | 72 | 5.3 | 5.0 | 4.5 |
| | 0 | | 3/4 | | 48 | 192 | 144 | 10.6 | 10.0 | 9.0 |
| 5 | N/A | 64-QAM | 2/3 | 6 | 48 | 288 | 192 | 14.1 | 13.3 | 12.0 |
| 6 | | | 3/4 | | | | 216 | 15.9 | 15.0 | 13.5 |
| 7 | | | 5/6 | | | | 240 | 17.6 | 16.7 | 15.0 |
| 8 | | 256-QAM | 3/4 | 8 | | 384 | 288 | 21.2 | 20.0 | 18.0 |
| 9 | | | 5/6 | | | | 320 | 23.5 | 22.2 | 20.0 |
| 10 | | 1024-QAM | 3/4 | 10 | | 480 | 360 | 26.5 | 25.0 | 22.5 |
| 11 | | | 5/6 | | | | 400 | 29.4 | 27.8 | 25.0 |

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**Table 27-71—HE-MCSs for 52-tone RU, $N_{SS}$ = 2(11ax)**

| HE-MCS Index | DCM | Modulation | $R$ | $N_{BPSCS}$ | $N_{SD}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 0.8 µs GI | 1.6 µs GI | 3.2 µs GI |
| 0 | 1 | BPSK | 1/2 | 1 | 24 | 48 | 24 | 1.8 | 1.7 | 1.5 |
| | 0 | | 1/2 | | 48 | 96 | 48 | 3.5 | 3.3 | 3.0 |
| 1 | 1 | QPSK | 1/2 | 2 | 24 | 96 | 48 | 3.5 | 3.3 | 3.0 |
| | 0 | | 1/2 | | 48 | 192 | 96 | 7.1 | 6.7 | 6.0 |
| 2 | N/A | | 3/4 | | 48 | 192 | 144 | 10.6 | 10.0 | 9.0 |
| 3 | 1 | 16-QAM | 1/2 | 4 | 24 | 192 | 96 | 7.1 | 6.7 | 6.0 |
| | 0 | | 1/2 | | 48 | 384 | 192 | 14.1 | 13.3 | 12.0 |
| 4 | 1 | | 3/4 | | 24 | 192 | 144 | 10.6 | 10.0 | 9.0 |
| | 0 | | 3/4 | | 48 | 384 | 288 | 21.2 | 20.0 | 18.0 |
| 5 | N/A | 64-QAM | 2/3 | 6 | 48 | 576 | 384 | 28.2 | 26.7 | 24.0 |
| 6 | | | 3/4 | | | | 432 | 31.8 | 30.0 | 27.0 |
| 7 | | | 5/6 | | | | 480 | 35.3 | 33.3 | 30.0 |
| 8 | | 256-QAM | 3/4 | 8 | | 768 | 576 | 42.4 | 40.0 | 36.0 |
| 9 | | | 5/6 | | | | 640 | 47.1 | 44.4 | 40.0 |
| 10 | | 1024-QAM | 3/4 | 10 | | 960 | 720 | 52.9 | 50.0 | 45.0 |
| 11 | | | 5/6 | | | | 800 | 58.8 | 55.6 | 50.0 |



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**Table 27-72—HE-MCSs for 52-tone RU, $N_{SS}$ = 3(11ax)**

| HE-MCS Index | DCM | Modulation | $R$ | $N_{BPSCS}$ | $N_{SD}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 0.8 µs GI | 1.6 µs GI | 3.2 µs GI |
| 0 | N/A | BPSK | 1/2 | 1 | 48 | 144 | 72 | 5.3 | 5.0 | 4.5 |
| 1 | | QPSK | 1/2 | 2 | | 288 | 144 | 10.6 | 10.0 | 9.0 |
| 2 | | | 3/4 | | | | 216 | 15.9 | 15.0 | 13.5 |
| 3 | | 16-QAM | 1/2 | 4 | | 576 | 288 | 21.2 | 20.0 | 18.0 |
| 4 | | | 3/4 | | | | 432 | 31.8 | 30.0 | 27.0 |
| 5 | | 64-QAM | 2/3 | 6 | | 864 | 576 | 42.4 | 40.0 | 36.0 |
| 6 | | | 3/4 | | | | 648 | 47.6 | 45.0 | 40.5 |
| 7 | | | 5/6 | | | | 720 | 52.9 | 50.0 | 45.0 |
| 8 | | 256-QAM | 3/4 | 8 | | 1 152 | 864 | 63.5 | 60.0 | 54.0 |
| 9 | | | 5/6 | | | | 960 | 70.6 | 66.7 | 60.0 |
| 10 | | 1024-QAM | 3/4 | 10 | | 1 440 | 1 080 | 79.4 | 75.0 | 67.5 |
| 11 | | | 5/6 | | | | 1 200 | 88.2 | 83.3 | 75.0 |

**Table 27-73—HE-MCSs for 52-tone RU, $N_{SS}$ = 4(11ax)**

| HE-MCS Index | DCM | Modulation | $R$ | $N_{BPSCS}$ | $N_{SD}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 0.8 µs GI | 1.6 µs GI | 3.2 µs GI |
| 0 | N/A | BPSK | 1/2 | 1 | 48 | 192 | 96 | 7.1 | 6.7 | 6.0 |
| 1 | | QPSK | 1/2 | 2 | | 384 | 192 | 14.1 | 13.3 | 12.0 |
| 2 | | | 3/4 | | | | 288 | 21.2 | 20.0 | 18.0 |
| 3 | | 16-QAM | 1/2 | 4 | | 768 | 384 | 28.2 | 26.7 | 24.0 |
| 4 | | | 3/4 | | | | 576 | 42.4 | 40.0 | 36.0 |
| 5 | | 64-QAM | 2/3 | 6 | | 1 152 | 768 | 56.5 | 53.3 | 48.0 |
| 6 | | | 3/4 | | | | 864 | 63.5 | 60.0 | 54.0 |
| 7 | | | 5/6 | | | | 960 | 70.6 | 66.7 | 60.0 |
| 8 | | 256-QAM | 3/4 | 8 | | 1 536 | 1 152 | 84.7 | 80.0 | 72.0 |
| 9 | | | 5/6 | | | | 1 280 | 94.1 | 88.9 | 80.0 |
| 10 | | 1024-QAM | 3/4 | 10 | | 1 920 | 1 440 | 105.9 | 100.0 | 90.0 |
| 11 | | | 5/6 | | | | 1 600 | 117.6 | 111.1 | 100.0 |

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**Table 27-74—HE-MCSs for 52-tone RU, $N_{SS}$ = 5(11ax)**

| HE-MCS Index | DCM | Modulation | $R$ | $N_{BPSCS}$ | $N_{SD}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 0.8 µs GI | 1.6 µs GI | 3.2 µs GI |
| 0 | N/A | BPSK | 1/2 | 1 | 48 | 240 | 120 | 8.8 | 8.3 | 7.5 |
| 1 | | QPSK | 1/2 | 2 | | 480 | 240 | 17.6 | 16.7 | 15.0 |
| 2 | | | 3/4 | | | | 360 | 26.5 | 25.0 | 22.5 |
| 3 | | 16-QAM | 1/2 | 4 | | 960 | 480 | 35.3 | 33.3 | 30.0 |
| 4 | | | 3/4 | | | | 720 | 52.9 | 50.0 | 45.0 |
| 5 | | 64-QAM | 2/3 | 6 | | 1 440 | 960 | 70.6 | 66.7 | 60.0 |
| 6 | | | 3/4 | | | | 1080 | 79.4 | 75.0 | 67.5 |
| 7 | | | 5/6 | | | | 1 200 | 88.2 | 83.3 | 75.0 |
| 8 | | 256-QAM | 3/4 | 8 | | 1 920 | 1 440 | 105.9 | 100.0 | 90.0 |
| 9 | | | 5/6 | | | | 1 600 | 117.6 | 111.1 | 100.0 |
| 10 | | 1024-QAM | 3/4 | 10 | | 2 400 | 1 800 | 132.4 | 125.0 | 112.5 |
| 11 | | | 5/6 | | | | 2 000 | 147.1 | 138.9 | 125.0 |

**Table 27-75—HE-MCSs for 52-tone RU, $N_{SS}$ = 6(11ax)**

| HE-MCS Index | DCM | Modulation | $R$ | $N_{BPSCS}$ | $N_{SD}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 0.8 µs GI | 1.6 µs GI | 3.2 µs GI |
| 0 | N/A | BPSK | 1/2 | 1 | 48 | 288 | 144 | 10.6 | 10.0 | 9.0 |
| 1 | | QPSK | 1/2 | 2 | | 576 | 288 | 21.2 | 20.0 | 18.0 |
| 2 | | | 3/4 | | | | 432 | 31.8 | 30.0 | 27.0 |
| 3 | | 16-QAM | 1/2 | 4 | | 1 152 | 576 | 42.4 | 40.0 | 36.0 |
| 4 | | | 3/4 | | | | 864 | 63.5 | 60.0 | 54.0 |
| 5 | | 64-QAM | 2/3 | 6 | | 1 728 | 1 152 | 84.7 | 80.0 | 72.0 |
| 6 | | | 3/4 | | | | 1 296 | 95.3 | 90.0 | 81.0 |
| 7 | | | 5/6 | | | | 1 440 | 105.9 | 100.0 | 90.0 |
| 8 | | 256-QAM | 3/4 | 8 | | 2 304 | 1 728 | 127.1 | 120.0 | 108.0 |
| 9 | | | 5/6 | | | | 1 920 | 141.2 | 133.3 | 120.0 |
| 10 | | 1024-QAM | 3/4 | 10 | | 2 880 | 2 160 | 158.8 | 150.0 | 135.0 |
| 11 | | | 5/6 | | | | 2 400 | 176.5 | 166.7 | 150.0 |



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**Table 27-76—HE-MCSs for 52-tone RU, $N_{SS}$ = 7(11ax)**

| HE-MCS Index | DCM | Modulation | $R$ | $N_{BPSCS}$ | $N_{SD}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 0.8 µs GI | 1.6 µs GI | 3.2 µs GI |
| 0 | N/A | BPSK | 1/2 | 1 | 48 | 336 | 168 | 12.4 | 11.7 | 10.5 |
| 1 | | QPSK | 1/2 | 2 | | 672 | 336 | 24.7 | 23.3 | 21.0 |
| 2 | | | 3/4 | | | | 504 | 37.1 | 35.0 | 31.5 |
| 3 | | 16-QAM | 1/2 | 4 | | 1 344 | 672 | 49.4 | 46.7 | 42.0 |
| 4 | | | 3/4 | | | | 1 008 | 74.1 | 70.0 | 63.0 |
| 5 | | 64-QAM | 2/3 | 6 | | 2 016 | 1 344 | 98.8 | 93.3 | 84.0 |
| 6 | | | 3/4 | | | | 1 512 | 111.2 | 105.0 | 94.5 |
| 7 | | | 5/6 | | | | 1 680 | 123.5 | 116.7 | 105.0 |
| 8 | | 256-QAM | 3/4 | 8 | | 2 688 | 2 016 | 148.2 | 140.0 | 126.0 |
| 9 | | | 5/6 | | | | 2 240 | 164.7 | 155.6 | 140.0 |
| 10 | | 1024-QAM | 3/4 | 10 | | 3 360 | 2 520 | 185.3 | 175.0 | 157.5 |
| 11 | | | 5/6 | | | | 2 800 | 205.9 | 194.4 | 175.0 |

**Table 27-77—HE-MCSs for 52-tone RU, $N_{SS}$ = 8(11ax)**

| HE-MCS Index | DCM | Modulation | $R$ | $N_{BPSCS}$ | $N_{SD}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 0.8 µs GI | 1.6 µs GI | 3.2 µs GI |
| 0 | N/A | BPSK | 1/2 | 1 | 48 | 384 | 192 | 14.1 | 13.3 | 12.0 |
| 1 | | QPSK | 1/2 | 2 | | 768 | 384 | 28.2 | 26.7 | 24.0 |
| 2 | | | 3/4 | | | | 576 | 42.4 | 40.0 | 36.0 |
| 3 | | 16-QAM | 1/2 | 4 | | 1 536 | 768 | 56.5 | 53.3 | 48.0 |
| 4 | | | 3/4 | | | | 1 152 | 84.7 | 80.0 | 72.0 |
| 5 | | 64-QAM | 2/3 | 6 | | 2 304 | 1 536 | 112.9 | 106.7 | 96.0 |
| 6 | | | 3/4 | | | | 1 728 | 127.1 | 120.0 | 108.0 |
| 7 | | | 5/6 | | | | 1 920 | 141.2 | 133.3 | 120.0 |
| 8 | | 256-QAM | 3/4 | 8 | | 3 072 | 2 304 | 169.4 | 160.0 | 144.0 |
| 9 | | | 5/6 | | | | 2 560 | 188.2 | 177.8 | 160.0 |
| 10 | | 1024-QAM | 3/4 | 10 | | 3 840 | 2 880 | 211.8 | 200.0 | 180.0 |
| 11 | | | 5/6 | | | | 3 200 | 235.3 | 222.2 | 200.0 |

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### 27.5.4 HE-MCSs for 106-tone RU

The rate-dependent parameters for the 106-tone RU are provided in Table 27-78 (HE-MCSs for 106-tone RU, NSS = 1(11ax)) through Table 27-85 (HE-MCSs for 106-tone RU, NSS = 8(11ax)).

**Table 27-78—HE-MCSs for 106-tone RU, $N_{SS}$ = 1(11ax)**

| HE-MCS Index | DCM | Modulation | $R$ | $N_{BPSCS}$ | $N_{SD}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 0.8 µs GI | 1.6 µs GI | 3.2 µs GI |
| 0 | 1 | BPSK | 1/2 | 1 | 51 | 51 | 25 | 1.8 | 1.7 | 1.6 |
| | 0 | | 1/2 | | 102 | 102 | 51 | 3.8 | 3.5 | 3.2 |
| 1 | 1 | QPSK | 1/2 | 2 | 51 | 102 | 51 | 3.8 | 3.5 | 3.2 |
| | 0 | | 1/2 | | 102 | 204 | 102 | 7.5 | 7.1 | 6.4 |
| 2 | N/A | | 3/4 | | 102 | 204 | 153 | 11.3 | 10.6 | 9.6 |
| 3 | 1 | 16-QAM | 1/2 | 4 | 51 | 204 | 102 | 7.5 | 7.1 | 6.4 |
| | 0 | | 1/2 | | 102 | 408 | 204 | 15.0 | 14.2 | 12.8 |
| 4 | 1 | | 3/4 | | 51 | 204 | 153 | 11.3 | 10.6 | 9.6 |
| | 0 | | 3/4 | | 102 | 408 | 306 | 22.5 | 21.3 | 19.1 |
| 5 | N/A | 64-QAM | 2/3 | 6 | 102 | 612 | 408 | 30.0 | 28.3 | 25.5 |
| 6 | | | 3/4 | | | | 459 | 33.8 | 31.9 | 28.7 |
| 7 | | | 5/6 | | | | 510 | 37.5 | 35.4 | 31.9 |
| 8 | | 256-QAM | 3/4 | 8 | | 816 | 612 | 45.0 | 42.5 | 38.3 |
| 9 | | | 5/6 | | | | 680 | 50.0 | 47.2 | 42.5 |
| 10 | | 1024-QAM | 3/4 | 10 | | 1 020 | 765 | 56.3 | 53.1 | 47.8 |
| 11 | | | 5/6 | | | | 850 | 62.5 | 59.0 | 53.1 |


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**Table 27-79—HE-MCSs for 106-tone RU, $N_{SS}$ = 2(11ax)**

| HE-MCS Index | DCM | Modulation | $R$ | $N_{BPSCS}$ | $N_{SD}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 0.8 µs GI | 1.6 µs GI | 3.2 µs GI |
| 0 | 1 | BPSK | 1/2 | 1 | 51 | 102 | 51 | 3.8 | 3.5 | 3.2 |
| | 0 | | 1/2 | | 102 | 204 | 102 | 7.5 | 7.1 | 6.4 |
| 1 | 1 | QPSK | 1/2 | 2 | 51 | 204 | 102 | 7.5 | 7.1 | 6.4 |
| | 0 | | 1/2 | | 102 | 408 | 204 | 15.0 | 14.2 | 12.8 |
| 2 | N/A | | 3/4 | | 102 | 408 | 306 | 22.5 | 21.3 | 19.1 |
| 3 | 1 | 16-QAM | 1/2 | 4 | 51 | 408 | 204 | 15.0 | 14.2 | 12.8 |
| | 0 | | 1/2 | | 102 | 816 | 408 | 30.0 | 28.3 | 25.5 |
| 4 | 1 | | 3/4 | | 51 | 408 | 306 | 22.5 | 21.3 | 19.1 |
| | 0 | | 3/4 | | 102 | 816 | 612 | 45.0 | 42.5 | 38.3 |
| 5 | N/A | 64-QAM | 2/3 | 6 | 102 | 1 224 | 816 | 60.0 | 56.7 | 51.0 |
| 6 | | | 3/4 | | | | 918 | 67.5 | 63.8 | 57.4 |
| 7 | | | 5/6 | | | | 1 020 | 75.0 | 70.8 | 63.8 |
| 8 | | 256-QAM | 3/4 | 8 | | 1 632 | 1 224 | 90.0 | 85.0 | 76.5 |
| 9 | | | 5/6 | | | | 1 360 | 100.0 | 94.4 | 85.0 |
| 10 | | 1024-QAM | 3/4 | 10 | | 2 040 | 1 530 | 112.5 | 106.3 | 95.6 |
| 11 | | | 5/6 | | | | 1 700 | 125.0 | 118.1 | 106.3 |

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**Table 27-80—HE-MCSs for 106-tone RU, $N_{SS}$ = 3(11ax)**

| HE-MCS Index | DCM | Modulation | $R$ | $N_{BPSCS}$ | $N_{SD}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 0.8 µs GI | 1.6 µs GI | 3.2 µs GI |
| 0 | N/A | BPSK | 1/2 | 1 | 102 | 306 | 153 | 11.3 | 10.6 | 9.6 |
| 1 | | QPSK | 1/2 | 2 | | 612 | 306 | 22.5 | 21.3 | 19.1 |
| 2 | | | 3/4 | | | | 459 | 33.8 | 31.9 | 28.7 |
| 3 | | 16-QAM | 1/2 | 4 | | 1 224 | 612 | 45.0 | 42.5 | 38.3 |
| 4 | | | 3/4 | | | | 918 | 67.5 | 63.8 | 57.4 |
| 5 | | 64-QAM | 2/3 | 6 | | 1 836 | 1 224 | 90.0 | 85.0 | 76.5 |
| 6 | | | 3/4 | | | | 1 377 | 101.3 | 95.6 | 86.1 |
| 7 | | | 5/6 | | | | 1 530 | 112.5 | 106.3 | 95.6 |
| 8 | | 256-QAM | 3/4 | 8 | | 2 448 | 1 836 | 135.0 | 127.5 | 114.8 |
| 9 | | | 5/6 | | | | 2 040 | 150.0 | 141.7 | 127.5 |
| 10 | | 1024-QAM | 3/4 | 10 | | 3 060 | 2 295 | 168.8 | 159.4 | 143.4 |
| 11 | | | 5/6 | | | | 2 550 | 187.5 | 177.1 | 159.4 |

**Table 27-81—HE-MCSs for 106-tone RU, $N_{SS}$ = 4(11ax)**

| HE-MCS Index | DCM | Modulation | $R$ | $N_{BPSCS}$ | $N_{SD}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 0.8 µs GI | 1.6 µs GI | 3.2 µs GI |
| 0 | N/A | BPSK | 1/2 | 1 | 102 | 408 | 204 | 15.0 | 14.2 | 12.8 |
| 1 | | QPSK | 1/2 | 2 | | 816 | 408 | 30.0 | 28.3 | 25.5 |
| 2 | | | 3/4 | | | | 612 | 45.0 | 42.5 | 38.3 |
| 3 | | 16-QAM | 1/2 | 4 | | 1 632 | 816 | 60.0 | 56.7 | 51.0 |
| 4 | | | 3/4 | | | | 1 224 | 90.0 | 85.0 | 76.5 |
| 5 | | 64-QAM | 2/3 | 6 | | 2 448 | 1 632 | 120.0 | 113.3 | 102.0 |
| 6 | | | 3/4 | | | | 1 836 | 135.0 | 127.5 | 114.8 |
| 7 | | | 5/6 | | | | 2 040 | 150.0 | 141.7 | 127.5 |
| 8 | | 256-QAM | 3/4 | 8 | | 3 264 | 2 448 | 180.0 | 170.0 | 153.0 |
| 9 | | | 5/6 | | | | 2 720 | 200.0 | 188.9 | 170.0 |
| 10 | | 1024-QAM | 3/4 | 10 | | 4 080 | 3 060 | 225.0 | 212.5 | 191.3 |
| 11 | | | 5/6 | | | | 3 400 | 250.0 | 236.1 | 212.5 |



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**Table 27-82—HE-MCSs for 106-tone RU, $N_{SS}$ = 5(11ax)**

| HE-MCS Index | DCM | Modulation | $R$ | $N_{BPSCS}$ | $N_{SD}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 0.8 µs GI | 1.6 µs GI | 3.2 µs GI |
| 0 | N/A | BPSK | 1/2 | 1 | 102 | 510 | 255 | 18.8 | 17.7 | 15.9 |
| 1 | | QPSK | 1/2 | 2 | | 1 020 | 510 | 37.5 | 35.4 | 31.9 |
| 2 | | | 3/4 | | | | 765 | 56.3 | 53.1 | 47.8 |
| 3 | | 16-QAM | 1/2 | 4 | | 2 040 | 1 020 | 75.0 | 70.8 | 63.8 |
| 4 | | | 3/4 | | | | 1 530 | 112.5 | 106.3 | 95.6 |
| 5 | | 64-QAM | 2/3 | 6 | | 3 060 | 2 040 | 150.0 | 141.7 | 127.5 |
| 6 | | | 3/4 | | | | 2 295 | 168.8 | 159.4 | 143.4 |
| 7 | | | 5/6 | | | | 2 550 | 187.5 | 177.1 | 159.4 |
| 8 | | 256-QAM | 3/4 | 8 | | 4 080 | 3 060 | 225.0 | 212.5 | 191.3 |
| 9 | | | 5/6 | | | | 3 400 | 250.0 | 236.1 | 212.5 |
| 10 | | 1024-QAM | 3/4 | 10 | | 5 100 | 3 825 | 281.3 | 265.6 | 239.1 |
| 11 | | | 5/6 | | | | 4 250 | 312.5 | 295.1 | 265.6 |

**Table 27-83—HE-MCSs for 106-tone RU, $N_{SS}$ = 6(11ax)**

| HE-MCS Index | DCM | Modulation | $R$ | $N_{BPSCS}$ | $N_{SD}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 0.8 µs GI | 1.6 µs GI | 3.2 µs GI |
| 0 | N/A | BPSK | 1/2 | 1 | 102 | 612 | 306 | 22.5 | 21.3 | 19.1 |
| 1 | | QPSK | 1/2 | 2 | | 1 224 | 612 | 45.0 | 42.5 | 38.3 |
| 2 | | | 3/4 | | | | 918 | 67.5 | 63.8 | 57.4 |
| 3 | | 16-QAM | 1/2 | 4 | | 2 448 | 1 224 | 90.0 | 85.0 | 76.5 |
| 4 | | | 3/4 | | | | 1 836 | 135.0 | 127.5 | 114.8 |
| 5 | | 64-QAM | 2/3 | 6 | | 3 672 | 2 448 | 180.0 | 170.0 | 153.0 |
| 6 | | | 3/4 | | | | 2 754 | 202.5 | 191.3 | 172.1 |
| 7 | | | 5/6 | | | | 3 060 | 225.0 | 212.5 | 191.3 |
| 8 | | 256-QAM | 3/4 | 8 | | 4 896 | 3 672 | 270.0 | 255.0 | 229.5 |
| 9 | | | 5/6 | | | | 4 080 | 300.0 | 283.3 | 255.0 |
| 10 | | 1024-QAM | 3/4 | 10 | | 6 120 | 4 590 | 337.5 | 318.8 | 286.9 |
| 11 | | | 5/6 | | | | 5 100 | 375.0 | 354.2 | 318.8 |

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**Table 27-84—HE-MCSs for 106-tone RU, $N_{SS}$ = 7(11ax)**

| HE-MCS Index | DCM | Modulation | $R$ | $N_{BPSCS}$ | $N_{SD}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 0.8 µs GI | 1.6 µs GI | 3.2 µs GI |
| 0 | N/A | BPSK | 1/2 | 1 | 102 | 714 | 357 | 26.3 | 24.8 | 22.3 |
| 1 | | QPSK | 1/2 | 2 | | 1 428 | 714 | 52.5 | 49.6 | 44.6 |
| 2 | | | 3/4 | | | | 1 071 | 78.8 | 74.4 | 66.9 |
| 3 | | 16-QAM | 1/2 | 4 | | 2 856 | 1 428 | 105.0 | 99.2 | 89.3 |
| 4 | | | 3/4 | | | | 2 142 | 157.5 | 148.8 | 133.9 |
| 5 | | 64-QAM | 2/3 | 6 | | 4 284 | 2 856 | 210.0 | 198.3 | 178.5 |
| 6 | | | 3/4 | | | | 3 213 | 236.3 | 223.1 | 200.8 |
| 7 | | | 5/6 | | | | 3 570 | 262.5 | 247.9 | 223.1 |
| 8 | | 256-QAM | 3/4 | 8 | | 5 712 | 4 284 | 315.0 | 297.5 | 267.8 |
| 9 | | | 5/6 | | | | 4 760 | 350.0 | 330.6 | 297.5 |
| 10 | | 1024-QAM | 3/4 | 10 | | 7 140 | 5 355 | 393.8 | 371.9 | 334.7 |
| 11 | | | 5/6 | | | | 5 950 | 437.5 | 413.2 | 371.9 |

**Table 27-85—HE-MCSs for 106-tone RU, $N_{SS}$ = 8(11ax)**

| HE-MCS Index | DCM | Modulation | $R$ | $N_{BPSCS}$ | $N_{SD}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 0.8 µs GI | 1.6 µs GI | 3.2 µs GI |
| 0 | N/A | BPSK | 1/2 | 1 | 102 | 816 | 408 | 30.0 | 28.3 | 25.5 |
| 1 | | QPSK | 1/2 | 2 | | 1 632 | 816 | 60.0 | 56.7 | 51.0 |
| 2 | | | 3/4 | | | | 1 224 | 90.0 | 85.0 | 76.5 |
| 3 | | 16-QAM | 1/2 | 4 | | 3 264 | 1 632 | 120.0 | 113.3 | 102.0 |
| 4 | | | 3/4 | | | | 2 448 | 180.0 | 170.0 | 153.0 |
| 5 | | 64-QAM | 2/3 | 6 | | 4 896 | 3 264 | 240.0 | 226.7 | 204.0 |
| 6 | | | 3/4 | | | | 3 672 | 270.0 | 255.0 | 229.5 |
| 7 | | | 5/6 | | | | 4 080 | 300.0 | 283.3 | 255.0 |
| 8 | | 256-QAM | 3/4 | 8 | | 6 528 | 4 896 | 360.0 | 340.0 | 306.0 |
| 9 | | | 5/6 | | | | 5 440 | 400.0 | 377.8 | 340.0 |
| 10 | | 1024-QAM | 3/4 | 10 | | 8 160 | 6 120 | 450.0 | 425.0 | 382.5 |
| 11 | | | 5/6 | | | | 6 800 | 500.0 | 472.2 | 425.0 |


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### 27.5.5 HE-MCSs for 242-tone RU

The rate-dependent parameters for the 242-tone RU are provided in Table 27-86 (HE-MCSs for 242-tone RU, NSS = 1(11ax)) through Table 27-93 (HE-MCSs for 242-tone RU, NSS = 8(11ax)).

**Table 27-86—HE-MCSs for 242-tone RU, $N_{SS}$ = 1(11ax)**

| HE-MCS Index | DCM | Modulation | *R* | $N_{BPSCS}$ | $N_{SD}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 0.8 µs GI | 1.6 µs GI | 3.2 µs GI |
| 0 | 1 | BPSK | 1/2 | 1 | 117 | 117 | 58 | 4.3 | 4.0 | 3.6 |
| | 0 | | 1/2 | | 234 | 234 | 117 | 8.6 | 8.1 | 7.3 |
| 1 | 1 | QPSK | 1/2 | 2 | 117 | 234 | 117 | 8.6 | 8.1 | 7.3 |
| | 0 | | 1/2 | | 234 | 468 | 234 | 17.2 | 16.3 | 14.6 |
| 2 | N/A | | 3/4 | | 234 | 468 | 351 | 25.8 | 24.4 | 21.9 |
| 3 | 1 | 16-QAM | 1/2 | 4 | 117 | 468 | 234 | 17.2 | 16.3 | 14.6 |
| | 0 | | 1/2 | | 234 | 936 | 468 | 34.4 | 32.5 | 29.3 |
| 4 | 1 | | 3/4 | | 117 | 468 | 351 | 25.8 | 24.4 | 21.9 |
| | 0 | | 3/4 | | 234 | 936 | 702 | 51.6 | 48.8 | 43.9 |
| 5 | N/A | 64-QAM | 2/3 | 6 | 234 | 1 404 | 936 | 68.8 | 65.0 | 58.5 |
| 6 | | | 3/4 | | | | 1 053 | 77.4 | 73.1 | 65.8 |
| 7 | | | 5/6 | | | | 1 170 | 86.0 | 81.3 | 73.1 |
| 8 | | 256-QAM | 3/4 | 8 | | 1 872 | 1 404 | 103.2 | 97.5 | 87.8 |
| 9 | | | 5/6 | | | | 1 560 | 114.7 | 108.3 | 97.5 |
| 10 | | 1024-QAM | 3/4 | 10 | | 2 340 | 1 755 | 129.0 | 121.9 | 109.7 |
| 11 | | | 5/6 | | | | 1 950 | 143.4 | 135.4 | 121.9 |

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**Table 27-87—HE-MCSs for 242-tone RU, $N_{SS}$ = 2(11ax)**

| HE-MCS Index | DCM | Modulation | $R$ | $N_{BPSCS}$ | $N_{SD}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 0.8 µs GI | 1.6 µs GI | 3.2 µs GI |
| 0 | 1 | BPSK | 1/2 | 1 | 117 | 234 | 117 | 8.6 | 8.1 | 7.3 |
| | 0 | | 1/2 | | 234 | 468 | 234 | 17.2 | 16.3 | 14.6 |
| 1 | 1 | QPSK | 1/2 | 2 | 117 | 468 | 234 | 17.2 | 16.3 | 14.6 |
| | 0 | | 1/2 | | 234 | 936 | 468 | 34.4 | 32.5 | 29.3 |
| 2 | N/A | | 3/4 | | 234 | 936 | 702 | 51.6 | 48.8 | 43.9 |
| 3 | 1 | 16-QAM | 1/2 | 4 | 117 | 936 | 468 | 34.4 | 32.5 | 29.3 |
| | 0 | | 1/2 | | 234 | 1 872 | 936 | 68.8 | 65.0 | 58.5 |
| 4 | 1 | | 3/4 | | 117 | 936 | 702 | 51.6 | 48.8 | 43.9 |
| | 0 | | 3/4 | | 234 | 1 872 | 1 404 | 103.2 | 97.5 | 87.8 |
| 5 | N/A | 64-QAM | 2/3 | 6 | 234 | 2 808 | 1 872 | 137.6 | 130.0 | 117.0 |
| 6 | | | 3/4 | | | | 2 106 | 154.9 | 146.3 | 131.6 |
| 7 | | | 5/6 | | | | 2 340 | 172.1 | 162.5 | 146.3 |
| 8 | | 256-QAM | 3/4 | 8 | | 3 744 | 2 808 | 206.5 | 195.0 | 175.5 |
| 9 | | | 5/6 | | | | 3 120 | 229.4 | 216.7 | 195.0 |
| 10 | | 1024-QAM | 3/4 | 10 | | 4 680 | 3 510 | 258.1 | 243.8 | 219.4 |
| 11 | | | 5/6 | | | | 3 900 | 286.8 | 270.8 | 243.8 |



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**Table 27-88—HE-MCSs for 242-tone RU, $N_{SS}$ = 3(11ax)**

| HE-MCS Index | DCM | Modulation | R | $N_{BPSCS}$ | $N_{SD}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 0.8 µs GI | 1.6 µs GI | 3.2 µs GI |
| 0 | N/A | BPSK | 1/2 | 1 | 234 | 702 | 351 | 25.8 | 24.4 | 21.9 |
| 1 | | QPSK | 1/2 | 2 | | 1 404 | 702 | 51.6 | 48.8 | 43.9 |
| 2 | | | 3/4 | | | | 1 053 | 77.4 | 73.1 | 65.8 |
| 3 | | 16-QAM | 1/2 | 4 | | 2 808 | 1 404 | 103.2 | 97.5 | 87.8 |
| 4 | | | 3/4 | | | | 2 106 | 154.9 | 146.3 | 131.6 |
| 5 | | 64-QAM | 2/3 | 6 | | 4 212 | 2 808 | 206.5 | 195.0 | 175.5 |
| 6 | | | 3/4 | | | | 3 159 | 232.3 | 219.4 | 197.4 |
| 7 | | | 5/6 | | | | 3 510 | 258.1 | 243.8 | 219.4 |
| 8 | | 256-QAM | 3/4 | 8 | | 5 616 | 4 212 | 309.7 | 292.5 | 263.3 |
| 9 | | | 5/6 | | | | 4 680 | 344.1 | 325.0 | 292.5 |
| 10 | | 1024-QAM | 3/4 | 10 | | 7 020 | 5 265 | 387.1 | 365.6 | 329.1 |
| 11 | | | 5/6 | | | | 5 850 | 430.1 | 406.3 | 365.6 |

**Table 27-89—HE-MCSs for 242-tone RU, $N_{SS}$ = 4(11ax)**

| HE-MCS Index | DCM | Modulation | R | $N_{BPSCS}$ | $N_{SD}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 0.8 µs GI | 1.6 µs GI | 3.2 µs GI |
| 0 | N/A | BPSK | 1/2 | 1 | 234 | 936 | 468 | 34.4 | 32.5 | 29.3 |
| 1 | | QPSK | 1/2 | 2 | | 1 872 | 936 | 68.8 | 65.0 | 58.5 |
| 2 | | | 3/4 | | | | 1 404 | 103.2 | 97.5 | 87.8 |
| 3 | | 16-QAM | 1/2 | 4 | | 3 744 | 1 872 | 137.6 | 130.0 | 117.0 |
| 4 | | | 3/4 | | | | 2 808 | 206.5 | 195.0 | 175.5 |
| 5 | | 64-QAM | 2/3 | 6 | | 5 616 | 3 744 | 275.3 | 260.0 | 234.0 |
| 6 | | | 3/4 | | | | 4 212 | 309.7 | 292.5 | 263.3 |
| 7 | | | 5/6 | | | | 4 680 | 344.1 | 325.0 | 292.5 |
| 8 | | 256-QAM | 3/4 | 8 | | 7 488 | 5 616 | 412.9 | 390.0 | 351.0 |
| 9 | | | 5/6 | | | | 6 240 | 458.8 | 433.3 | 390.0 |
| 10 | | 1024-QAM | 3/4 | 10 | | 9 360 | 7 020 | 516.2 | 487.5 | 438.8 |
| 11 | | | 5/6 | | | | 7 800 | 573.5 | 541.7 | 487.5 |

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**Table 27-90—HE-MCSs for 242-tone RU, $N_{SS}$ = 5(11ax)**

| HE-MCS Index | DCM | Modulation | $R$ | $N_{BPSCS}$ | $N_{SD}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 0.8 µs GI | 1.6 µs GI | 3.2 µs GI |
| 0 | N/A | BPSK | 1/2 | 1 | 234 | 1 170 | 585 | 43.0 | 40.6 | 36.6 |
| 1 | | QPSK | 1/2 | 2 | | 2 340 | 1 170 | 86.0 | 81.3 | 73.1 |
| 2 | | | 3/4 | | | | 1 755 | 129.0 | 121.9 | 109.7 |
| 3 | | 16-QAM | 1/2 | 4 | | 4 680 | 2 340 | 172.1 | 162.5 | 146.3 |
| 4 | | | 3/4 | | | | 3 510 | 258.1 | 243.8 | 219.4 |
| 5 | | 64-QAM | 2/3 | 6 | | 7 020 | 4 680 | 344.1 | 325.0 | 292.5 |
| 6 | | | 3/4 | | | | 5 265 | 387.1 | 365.6 | 329.1 |
| 7 | | | 5/6 | | | | 5 850 | 430.1 | 406.3 | 365.6 |
| 8 | | 256-QAM | 3/4 | 8 | | 9 360 | 7 020 | 516.2 | 487.5 | 438.8 |
| 9 | | | 5/6 | | | | 7 800 | 573.5 | 541.7 | 487.5 |
| 10 | | 1024-QAM | 3/4 | 10 | | 11 700 | 8 775 | 645.2 | 609.4 | 548.4 |
| 11 | | | 5/6 | | | | 9 750 | 716.9 | 677.1 | 609.4 |

**Table 27-91—HE-MCSs for 242-tone RU, $N_{SS}$ = 6(11ax)**

| HE-MCS Index | DCM | Modulation | $R$ | $N_{BPSCS}$ | $N_{SD}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 0.8 µs GI | 1.6 µs GI | 3.2 µs GI |
| 0 | N/A | BPSK | 1/2 | 1 | 234 | 1 404 | 702 | 51.6 | 48.8 | 43.9 |
| 1 | | QPSK | 1/2 | 2 | | 2 808 | 1 404 | 103.2 | 97.5 | 87.8 |
| 2 | | | 3/4 | | | | 2 106 | 154.9 | 146.3 | 131.6 |
| 3 | | 16-QAM | 1/2 | 4 | | 5 616 | 2 808 | 206.5 | 195.0 | 175.5 |
| 4 | | | 3/4 | | | | 4 212 | 309.7 | 292.5 | 263.3 |
| 5 | | 64-QAM | 2/3 | 6 | | 8 424 | 5 616 | 412.9 | 390.0 | 351.0 |
| 6 | | | 3/4 | | | | 6 318 | 464.6 | 438.8 | 394.9 |
| 7 | | | 5/6 | | | | 7 020 | 516.2 | 487.5 | 438.8 |
| 8 | | 256-QAM | 3/4 | 8 | | 11 232 | 8 424 | 619.4 | 585.0 | 526.5 |
| 9 | | | 5/6 | | | | 9 360 | 688.2 | 650.0 | 585.0 |
| 10 | | 1024-QAM | 3/4 | 10 | | 14 040 | 10 530 | 774.3 | 731.3 | 658.1 |
| 11 | | | 5/6 | | | | 11 700 | 860.3 | 812.5 | 731.3 |



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**Table 27-92—HE-MCSs for 242-tone RU, $N_{SS}$ = 7(11ax)**

| HE-MCS Index | DCM | Modulation | R | $N_{BPSCS}$ | $N_{SD}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 0.8 µs GI | 1.6 µs GI | 3.2 µs GI |
| 0 | N/A | BPSK | 1/2 | 1 | 234 | 1 638 | 819 | 60.2 | 56.9 | 51.2 |
| 1 | | QPSK | 1/2 | 2 | | 3 276 | 1 638 | 120.4 | 113.8 | 102.4 |
| 2 | | | 3/4 | | | | 2 457 | 180.7 | 170.6 | 153.6 |
| 3 | | 16-QAM | 1/2 | 4 | | 6 552 | 3 276 | 240.9 | 227.5 | 204.8 |
| 4 | | | 3/4 | | | | 4 914 | 361.3 | 341.3 | 307.1 |
| 5 | | 64-QAM | 2/3 | 6 | | 9 828 | 6 552 | 481.8 | 455.0 | 409.5 |
| 6 | | | 3/4 | | | | 7 371 | 542.0 | 511.9 | 460.7 |
| 7 | | | 5/6 | | | | 8 190 | 602.2 | 568.8 | 511.9 |
| 8 | | 256-QAM | 3/4 | 8 | | 13 104 | 9 828 | 722.6 | 682.5 | 614.3 |
| 9 | | | 5/6 | | | | 10 920 | 802.9 | 758.3 | 682.5 |
| 10 | | 1024-QAM | 3/4 | 10 | | 16 380 | 12 285 | 903.3 | 853.1 | 767.8 |
| 11 | | | 5/6 | | | | 13 650 | 1 003.7 | 947.9 | 853.1 |

**Table 27-93—HE-MCSs for 242-tone RU, $N_{SS}$ = 8(11ax)**

| HE-MCS Index | DCM | Modulation | R | $N_{BPSCS}$ | $N_{SD}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 0.8 µs GI | 1.6 µs GI | 3.2 µs GI |
| 0 | N/A | BPSK | 1/2 | 1 | 234 | 1 872 | 936 | 68.8 | 65.0 | 58.5 |
| 1 | | QPSK | 1/2 | 2 | | 3 744 | 1 872 | 137.6 | 130.0 | 117.0 |
| 2 | | | 3/4 | | | | 2 808 | 206.5 | 195.0 | 175.5 |
| 3 | | 16-QAM | 1/2 | 4 | | 7 488 | 3 744 | 275.3 | 260.0 | 234.0 |
| 4 | | | 3/4 | | | | 5 616 | 412.9 | 390.0 | 351.0 |
| 5 | | 64-QAM | 2/3 | 6 | | 11 232 | 7 488 | 550.6 | 520.0 | 468.0 |
| 6 | | | 3/4 | | | | 8 424 | 619.4 | 585.0 | 526.5 |
| 7 | | | 5/6 | | | | 9 360 | 688.2 | 650.0 | 585.0 |
| 8 | | 256-QAM | 3/4 | 8 | | 14 976 | 11 232 | 825.9 | 780.0 | 702.0 |
| 9 | | | 5/6 | | | | 12 480 | 917.6 | 866.7 | 780.0 |
| 10 | | 1024-QAM | 3/4 | 10 | | 18 720 | 14 040 | 1 032.4 | 975.0 | 877.5 |
| 11 | | | 5/6 | | | | 15 600 | 1 147.1 | 1 083.3 | 975.0 |

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### 27.5.6 HE-MCSs for 484-tone RU

The rate-dependent parameters for the 484-tone RU are provided in Table 27-94 (HE-MCSs for 484-tone RU, NSS = 1(11ax)) through Table 27-101 (HE-MCSs for 484-tone RU, NSS = 8(11ax)).

**Table 27-94—HE-MCSs for 484-tone RU, $N_{SS}$ = 1(11ax)**

| HE-MCS Index | DCM | Modulation | *R* | $N_{BPSCS}$ | $N_{SD}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 0.8 µs GI | 1.6 µs GI | 3.2 µs GI |
| 0 | 1 | BPSK | 1/2 | 1 | 234 | 234 | 117 | 8.6 | 8.1 | 7.3 |
| | 0 | | 1/2 | | 468 | 468 | 234 | 17.2 | 16.3 | 14.6 |
| 1 | 1 | QPSK | 1/2 | 2 | 234 | 468 | 234 | 17.2 | 16.3 | 14.6 |
| | 0 | | 1/2 | | 468 | 936 | 468 | 34.4 | 32.5 | 29.3 |
| 2 | N/A | | 3/4 | | 468 | 936 | 702 | 51.6 | 48.8 | 43.9 |
| 3 | 1 | 16-QAM | 1/2 | 4 | 234 | 936 | 468 | 34.4 | 32.5 | 29.3 |
| | 0 | | 1/2 | | 468 | 1 872 | 936 | 68.8 | 65.0 | 58.5 |
| 4 | 1 | | 3/4 | | 234 | 936 | 702 | 51.6 | 48.8 | 43.9 |
| | 0 | | 3/4 | | 468 | 1 872 | 1 404 | 103.2 | 97.5 | 87.8 |
| 5 | N/A | 64-QAM | 2/3 | 6 | 468 | 2 808 | 1 872 | 137.6 | 130.0 | 117.0 |
| 6 | | | 3/4 | | | | 2 106 | 154.9 | 146.3 | 131.6 |
| 7 | | | 5/6 | | | | 2 340 | 172.1 | 162.5 | 146.3 |
| 8 | | 256-QAM | 3/4 | 8 | | 3 744 | 2 808 | 206.5 | 195.0 | 175.5 |
| 9 | | | 5/6 | | | | 3 120 | 229.4 | 216.7 | 195.0 |
| 10 | | 1024-QAM | 3/4 | 10 | | 4 680 | 3 510 | 258.1 | 243.8 | 219.4 |
| 11 | | | 5/6 | | | | 3 900 | 286.8 | 270.8 | 243.8 |


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**Table 27-95—HE-MCSs for 484-tone RU, $N_{SS}$ = 2(11ax)**

| HE-MCS Index | DCM | Modulation | $R$ | $N_{BPSCS}$ | $N_{SD}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 0.8 µs GI | 1.6 µs GI | 3.2 µs GI |
| 0 | 1 | BPSK | 1/2 | 1 | 234 | 468 | 234 | 17.2 | 16.3 | 14.6 |
| | 0 | | 1/2 | | 468 | 936 | 468 | 34.4 | 32.5 | 29.3 |
| 1 | 1 | QPSK | 1/2 | 2 | 234 | 936 | 468 | 34.4 | 32.5 | 29.3 |
| | 0 | | 1/2 | | 468 | 1 872 | 936 | 68.8 | 65.0 | 58.5 |
| 2 | N/A | | 3/4 | | 468 | 1 872 | 1 404 | 103.2 | 97.5 | 87.8 |
| 3 | 1 | 16-QAM | 1/2 | 4 | 234 | 1 872 | 936 | 68.8 | 65.0 | 58.5 |
| | 0 | | 1/2 | | 468 | 3 744 | 1 872 | 137.6 | 130.0 | 117.0 |
| 4 | 1 | | 3/4 | | 234 | 1 872 | 1 404 | 103.2 | 97.5 | 87.8 |
| | 0 | | 3/4 | | 468 | 3 744 | 2 808 | 206.5 | 195.0 | 175.5 |
| 5 | N/A | 64-QAM | 2/3 | 6 | 468 | 5 616 | 3 744 | 275.3 | 260.0 | 234.0 |
| 6 | | | 3/4 | | | | 4 212 | 309.7 | 292.5 | 263.3 |
| 7 | | | 5/6 | | | | 4 680 | 344.1 | 325.0 | 292.5 |
| 8 | | 256-QAM | 3/4 | 8 | | 7 488 | 5 616 | 412.9 | 390.0 | 351.0 |
| 9 | | | 5/6 | | | | 6 240 | 458.8 | 433.3 | 390.0 |
| 10 | | 1024-QAM | 3/4 | 10 | | 9 360 | 7 020 | 516.2 | 487.5 | 438.8 |
| 11 | | | 5/6 | | | | 7 800 | 573.5 | 541.7 | 487.5 |

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**Table 27-96—HE-MCSs for 484-tone RU, $N_{SS}$ = 3(11ax)**

| HE-MCS Index | DCM | Modulation | $R$ | $N_{BPSCS}$ | $N_{SD}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 0.8 µs GI | 1.6 µs GI | 3.2 µs GI |
| 0 | N/A | BPSK | 1/2 | 1 | 468 | 1 404 | 702 | 51.6 | 48.8 | 43.9 |
| 1 | | QPSK | 1/2 | 2 | | 2 808 | 1 404 | 103.2 | 97.5 | 87.8 |
| 2 | | | 3/4 | | | | 2 106 | 154.9 | 146.3 | 131.6 |
| 3 | | 16-QAM | 1/2 | 4 | | 5 616 | 2 808 | 206.5 | 195.0 | 175.5 |
| 4 | | | 3/4 | | | | 4 212 | 309.7 | 292.5 | 263.3 |
| 5 | | 64-QAM | 2/3 | 6 | | 8 424 | 5 616 | 412.9 | 390.0 | 351.0 |
| 6 | | | 3/4 | | | | 6 318 | 464.6 | 438.8 | 394.9 |
| 7 | | | 5/6 | | | | 7 020 | 516.2 | 487.5 | 438.8 |
| 8 | | 256-QAM | 3/4 | 8 | | 11 232 | 8 424 | 619.4 | 585.0 | 526.5 |
| 9 | | | 5/6 | | | | 9 360 | 688.2 | 650.0 | 585.0 |
| 10 | | 1024-QAM | 3/4 | 10 | | 14 040 | 10 530 | 774.3 | 731.3 | 658.1 |
| 11 | | | 5/6 | | | | 11 700 | 860.3 | 812.5 | 731.3 |

**Table 27-97—HE-MCSs for 484-tone RU, $N_{SS}$ = 4(11ax)**

| HE-MCS Index | DCM | Modulation | $R$ | $N_{BPSCS}$ | $N_{SD}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 0.8 µs GI | 1.6 µs GI | 3.2 µs GI |
| 0 | N/A | BPSK | 1/2 | 1 | 468 | 1 872 | 936 | 68.8 | 65.0 | 58.5 |
| 1 | | QPSK | 1/2 | 2 | | 3 744 | 1 872 | 137.6 | 130.0 | 117.0 |
| 2 | | | 3/4 | | | | 2 808 | 206.5 | 195.0 | 175.5 |
| 3 | | 16-QAM | 1/2 | 4 | | 7 488 | 3 744 | 275.3 | 260.0 | 234.0 |
| 4 | | | 3/4 | | | | 5 616 | 412.9 | 390.0 | 351.0 |
| 5 | | 64-QAM | 2/3 | 6 | | 11 232 | 7 488 | 550.6 | 520.0 | 468.0 |
| 6 | | | 3/4 | | | | 8 424 | 619.4 | 585.0 | 526.5 |
| 7 | | | 5/6 | | | | 9 360 | 688.2 | 650.0 | 585.0 |
| 8 | | 256-QAM | 3/4 | 8 | | 14 976 | 11 232 | 825.9 | 780.0 | 702.0 |
| 9 | | | 5/6 | | | | 12 480 | 917.6 | 866.7 | 780.0 |
| 10 | | 1024-QAM | 3/4 | 10 | | 18 720 | 14 040 | 1 032.4 | 975.0 | 877.5 |
| 11 | | | 5/6 | | | | 15 600 | 1 147.1 | 1 083.3 | 975.0 |



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**Table 27-98—HE-MCSs for 484-tone RU, $N_{SS}$ = 5(11ax)**

| HE-MCS Index | DCM | Modulation | $R$ | $N_{BPSCS}$ | $N_{SD}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 0.8 µs GI | 1.6 µs GI | 3.2 µs GI |
| 0 | N/A | BPSK | 1/2 | 1 | 468 | 2 340 | 1 170 | 86.0 | 81.3 | 73.1 |
| 1 | | QPSK | 1/2 | 2 | | 4 680 | 2 340 | 172.1 | 162.5 | 146.3 |
| 2 | | | 3/4 | | | | 3 510 | 258.1 | 243.8 | 219.4 |
| 3 | | 16-QAM | 1/2 | 4 | | 9 360 | 4 680 | 344.1 | 325.0 | 292.5 |
| 4 | | | 3/4 | | | | 7 020 | 516.2 | 487.5 | 438.8 |
| 5 | | 64-QAM | 2/3 | 6 | | 14 040 | 9 360 | 688.2 | 650.0 | 585.0 |
| 6 | | | 3/4 | | | | 10 530 | 774.3 | 731.3 | 658.1 |
| 7 | | | 5/6 | | | | 11 700 | 860.3 | 812.5 | 731.3 |
| 8 | | 256-QAM | 3/4 | 8 | | 18 720 | 14 040 | 1 032.4 | 975.0 | 877.5 |
| 9 | | | 5/6 | | | | 15 600 | 1 147.1 | 1 083.3 | 975.0 |
| 10 | | 1024-QAM | 3/4 | 10 | | 23 400 | 17 550 | 1 290.4 | 1 218.8 | 1 096.9 |
| 11 | | | 5/6 | | | | 19 500 | 1 433.8 | 1 354.2 | 1 218.8 |

**Table 27-99—HE-MCSs for 484-tone RU, $N_{SS}$ = 6(11ax)**

| HE-MCS Index | DCM | Modulation | $R$ | $N_{BPSCS}$ | $N_{SD}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 0.8 µs GI | 1.6 µs GI | 3.2 µs GI |
| 0 | N/A | BPSK | 1/2 | 1 | 468 | 2 808 | 1404 | 103.2 | 97.5 | 87.8 |
| 1 | | QPSK | 1/2 | 2 | | 5 616 | 2808 | 206.5 | 195.0 | 175.5 |
| 2 | | | 3/4 | | | | 4212 | 309.7 | 292.5 | 263.3 |
| 3 | | 16-QAM | 1/2 | 4 | | 11 232 | 5616 | 412.9 | 390.0 | 351.0 |
| 4 | | | 3/4 | | | | 8424 | 619.4 | 585.0 | 526.5 |
| 5 | | 64-QAM | 2/3 | 6 | | 16 848 | 11 232 | 825.9 | 780.0 | 702.0 |
| 6 | | | 3/4 | | | | 12 636 | 929.1 | 877.5 | 789.8 |
| 7 | | | 5/6 | | | | 14 040 | 1 032.4 | 975.0 | 877.5 |
| 8 | | 256-QAM | 3/4 | 8 | | 22 464 | 16 848 | 1 238.8 | 1 170.0 | 1 053.0 |
| 9 | | | 5/6 | | | | 18 720 | 1 376.5 | 1 300.0 | 1 170.0 |
| 10 | | 1024-QAM | 3/4 | 10 | | 28 080 | 21 060 | 1 548.5 | 1 462.5 | 1 316.3 |
| 11 | | | 5/6 | | | | 23 400 | 1 720.6 | 1 625.0 | 1 462.5 |

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**Table 27-100—HE-MCSs for 484-tone RU, $N_{SS}$ = 7(11ax)**

| HE-MCS Index | DCM | Modulation | $R$ | $N_{BPSCS}$ | $N_{SD}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 0.8 µs GI | 1.6 µs GI | 3.2 µs GI |
| 0 | N/A | BPSK | 1/2 | 1 | 468 | 3 276 | 1 638 | 120.4 | 113.8 | 102.4 |
| 1 | | QPSK | 1/2 | 2 | | 6 552 | 3 276 | 240.9 | 227.5 | 204.8 |
| 2 | | | 3/4 | | | | 4 914 | 361.3 | 341.3 | 307.1 |
| 3 | | 16-QAM | 1/2 | 4 | | 13 104 | 6 552 | 481.8 | 455.0 | 409.5 |
| 4 | | | 3/4 | | | | 9 828 | 722.6 | 682.5 | 614.3 |
| 5 | | 64-QAM | 2/3 | 6 | | 19 656 | 13 104 | 963.5 | 910.0 | 819.0 |
| 6 | | | 3/4 | | | | 14 742 | 1 084.0 | 1 023.8 | 921.4 |
| 7 | | | 5/6 | | | | 16 380 | 1 204.4 | 1 137.5 | 1 023.8 |
| 8 | | 256-QAM | 3/4 | 8 | | 26 208 | 19 656 | 1 445.3 | 1 365.0 | 1 228.5 |
| 9 | | | 5/6 | | | | 21 840 | 1 605.9 | 1 516.7 | 1 365.0 |
| 10 | | 1024-QAM | 3/4 | 10 | | 32 760 | 24 570 | 1 806.6 | 1 706.3 | 1 535.6 |
| 11 | | | 5/6 | | | | 27 300 | 2 007.4 | 1 895.8 | 1 706.3 |

**Table 27-101—HE-MCSs for 484-tone RU, $N_{SS}$ = 8(11ax)**

| HE-MCS Index | DCM | Modulation | $R$ | $N_{BPSCS}$ | $N_{SD}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 0.8 µs GI | 1.6 µs GI | 3.2 µs GI |
| 0 | N/A | BPSK | 1/2 | 1 | 468 | 3 744 | 1 872 | 137.6 | 130.0 | 117.0 |
| 1 | | QPSK | 1/2 | 2 | | 7 488 | 3 744 | 275.3 | 260.0 | 234.0 |
| 2 | | | 3/4 | | | | 5 616 | 412.9 | 390.0 | 351.0 |
| 3 | | 16-QAM | 1/2 | 4 | | 14 976 | 7 488 | 550.6 | 520.0 | 468.0 |
| 4 | | | 3/4 | | | | 11 232 | 825.9 | 780.0 | 702.0 |
| 5 | | 64-QAM | 2/3 | 6 | | 22 464 | 14 976 | 1 101.2 | 1 040.0 | 936.0 |
| 6 | | | 3/4 | | | | 16 848 | 1 238.8 | 1 170.0 | 1 053.0 |
| 7 | | | 5/6 | | | | 18 720 | 1 376.5 | 1 300.0 | 1 170.0 |
| 8 | | 256-QAM | 3/4 | 8 | | 29 952 | 22 464 | 1 651.8 | 1 560.0 | 1 404.0 |
| 9 | | | 5/6 | | | | 24 960 | 1 835.3 | 1 733.3 | 1 560.0 |
| 10 | | 1024-QAM | 3/4 | 10 | | 37 440 | 28 080 | 2 064.7 | 1 950.0 | 1 755.0 |
| 11 | | | 5/6 | | | | 31 200 | 2 294.1 | 2 166.7 | 1 950.0 |



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### 27.5.7 HE-MCSs for 996-tone RU

The rate-dependent parameters for the 996-tone RU are provided in Table 27-102 (HE-MCSs for 996-tone RU, NSS = 1(11ax)) through Table 27-109 (HE-MCSs for 996-tone RU, NSS = 8(11ax)).

**Table 27-102—HE-MCSs for 996-tone RU, $N_{SS}$ = 1(11ax)**

| HE-MCS Index | DCM | Modulation | *R* | $N_{BPSCS}$ | $N_{SD}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 0.8 µs GI | 1.6 µs GI | 3.2 µs GI |
| 0 | 1 | BPSK | 1/2 | 1 | 490 | 490 | 245 | 18.0 | 17.0 | 15.3 |
| | 0 | | 1/2 | | 980 | 980 | 490 | 36.0 | 34.0 | 30.6 |
| 1 | 1 | QPSK | 1/2 | 2 | 490 | 980 | 490 | 36.0 | 34.0 | 30.6 |
| | 0 | | 1/2 | | 980 | 1960 | 980 | 72.1 | 68.1 | 61.3 |
| 2 | N/A | | 3/4 | | 980 | 1960 | 1 470 | 108.1 | 102.1 | 91.9 |
| 3 | 1 | 16-QAM | 1/2 | 4 | 490 | 1960 | 980 | 72.1 | 68.1 | 61.3 |
| | 0 | | 1/2 | | 980 | 3920 | 1 960 | 144.1 | 136.1 | 122.5 |
| 4 | 1 | | 3/4 | | 490 | 1960 | 1 470 | 108.1 | 102.1 | 91.9 |
| | 0 | | 3/4 | | 980 | 3920 | 2 940 | 216.2 | 204.2 | 183.8 |
| 5 | N/A | 64-QAM | 2/3 | 6 | 980 | 5 880 | 3 920 | 288.2 | 272.2 | 245.0 |
| 6 | | | 3/4 | | | | 4 410 | 324.3 | 306.3 | 275.6 |
| 7 | | | 5/6 | | | | 4 900 | 360.3 | 340.3 | 306.3 |
| 8 | | 256-QAM | 3/4 | 8 | | 7 840 | 5 880 | 432.4 | 408.3 | 367.5 |
| 9 | | | 5/6 | | | | 6 533 | 480.4 | 453.7 | 408.3 |
| 10 | | 1024-QAM | 3/4 | 10 | | 9 800 | 7 350 | 540.4 | 510.4 | 459.4 |
| 11 | | | 5/6 | | | | 8 166 | 600.4 | 567.1 | 510.4 |

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**Table 27-103—HE-MCSs for 996-tone RU, $N_{SS}$ = 2(11ax)**

| HE-MCS Index | DCM | Modulation | $R$ | $N_{BPSCS}$ | $N_{SD}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 0.8 µs GI | 1.6 µs GI | 3.2 µs GI |
| 0 | 1 | BPSK | 1/2 | 1 | 490 | 980 | 490 | 36.0 | 34.0 | 30.6 |
| | 0 | | 1/2 | | 980 | 1 960 | 980 | 72.1 | 68.1 | 61.3 |
| 1 | 1 | QPSK | 1/2 | 2 | 490 | 1 960 | 980 | 72.1 | 68.1 | 61.3 |
| | 0 | | 1/2 | | 980 | 3 920 | 1 960 | 144.1 | 136.1 | 122.5 |
| 2 | N/A | | 3/4 | | 980 | 3 920 | 2 940 | 216.2 | 204.2 | 183.8 |
| 3 | 1 | 16-QAM | 1/2 | 4 | 490 | 3 920 | 1 960 | 144.1 | 136.1 | 122.5 |
| | 0 | | 1/2 | | 980 | 7 840 | 3 920 | 288.2 | 272.2 | 245.0 |
| 4 | 1 | | 3/4 | | 490 | 3 920 | 2 940 | 216.2 | 204.2 | 183.8 |
| | 0 | | 3/4 | | 980 | 7 840 | 5 880 | 432.4 | 408.3 | 367.5 |
| 5 | N/A | 64-QAM | 2/3 | 6 | 980 | 11 760 | 7 840 | 576.5 | 544.4 | 490.0 |
| 6 | | | 3/4 | | | | 8 820 | 648.5 | 612.5 | 551.3 |
| 7 | | | 5/6 | | | | 9 800 | 720.6 | 680.6 | 612.5 |
| 8 | | 256-QAM | 3/4 | 8 | | 15 680 | 11 760 | 864.7 | 816.7 | 735.0 |
| 9 | | | 5/6 | | | | 13 066 | 960.7 | 907.4 | 816.6 |
| 10 | | 1024-QAM | 3/4 | 10 | | 19 600 | 14 700 | 1 080.9 | 1 020.8 | 918.8 |
| 11 | | | 5/6 | | | | 16 333 | 1 201.0 | 1 134.2 | 1 020.8 |



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**Table 27-104—HE-MCSs for 996-tone RU, $N_{SS}$ = 3(11ax)**

| HE-MCS Index | DCM | Modulation | $R$ | $N_{BPSCS}$ | $N_{SD}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 0.8 µs GI | 1.6 µs GI | 3.2 µs GI |
| 0 | N/A | BPSK | 1/2 | 1 | 980 | 2 940 | 1 470 | 108.1 | 102.1 | 91.9 |
| 1 | | QPSK | 1/2 | 2 | | 5 880 | 2 940 | 216.2 | 204.2 | 183.8 |
| 2 | | | 3/4 | | | | 4 410 | 324.3 | 306.3 | 275.6 |
| 3 | | 16-QAM | 1/2 | 4 | | 11 760 | 5 880 | 432.4 | 408.3 | 367.5 |
| 4 | | | 3/4 | | | | 8 820 | 648.5 | 612.5 | 551.3 |
| 5 | | 64-QAM | 2/3 | 6 | | 17 640 | 11 760 | 864.7 | 816.7 | 735.0 |
| 6 | | | 3/4 | | | | 13 230 | 972.8 | 918.8 | 826.9 |
| 7 | | | 5/6 | | | | 14 700 | 1 080.9 | 1 020.8 | 918.8 |
| 8 | | 256-QAM | 3/4 | 8 | | 23 520 | 17 640 | 1 297.1 | 1 225.0 | 1 102.5 |
| 9 | | | 5/6 | | | | 19 600 | 1 441.2 | 1 361.1 | 1 225.0 |
| 10 | | 1024-QAM | 3/4 | 10 | | 29 400 | 22 050 | 1 621.3 | 1 531.3 | 1 378.1 |
| 11 | | | 5/6 | | | | 24 500 | 1 801.5 | 1 701.4 | 1 531.3 |

**Table 27-105—HE-MCSs for 996-tone RU, $N_{SS}$ = 4(11ax)**

| HE-MCS Index | DCM | Modulation | $R$ | $N_{BPSCS}$ | $N_{SD}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 0.8 µs GI | 1.6 µs GI | 3.2 µs GI |
| 0 | N/A | BPSK | 1/2 | 1 | 980 | 3 920 | 1 960 | 144.1 | 136.1 | 122.5 |
| 1 | | QPSK | 1/2 | 2 | | 7 840 | 3 920 | 288.2 | 272.2 | 245.0 |
| 2 | | | 3/4 | | | | 5 880 | 432.4 | 408.3 | 367.5 |
| 3 | | 16-QAM | 1/2 | 4 | | 15 680 | 7 840 | 576.5 | 544.4 | 490.0 |
| 4 | | | 3/4 | | | | 11 760 | 864.7 | 816.7 | 735.0 |
| 5 | | 64-QAM | 2/3 | 6 | | 23 520 | 15 680 | 1 152.9 | 1 088.9 | 980.0 |
| 6 | | | 3/4 | | | | 17 640 | 1 297.1 | 1 225.0 | 1 102.5 |
| 7 | | | 5/6 | | | | 19 600 | 1 441.2 | 1 361.1 | 1 225.0 |
| 8 | | 256-QAM | 3/4 | 8 | | 31 360 | 23 520 | 1 729.4 | 1 633.3 | 1 470.0 |
| 9 | | | 5/6 | | | | 26 133 | 1 921.5 | 1 814.8 | 1 633.3 |
| 10 | | 1024-QAM | 3/4 | 10 | | 39 200 | 29 400 | 2 161.8 | 2 041.7 | 1 837.5 |
| 11 | | | 5/6 | | | | 32 666 | 2 401.9 | 2 268.5 | 2 041.6 |

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**Table 27-106—HE-MCSs for 996-tone RU, $N_{SS}$ = 5(11ax)**

| HE-MCS Index | DCM | Modulation | R | $N_{BPSCS}$ | $N_{SD}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 0.8 µs GI | 1.6 µs GI | 3.2 µs GI |
| 0 | N/A | BPSK | 1/2 | 1 | 980 | 4 900 | 2 450 | 180.1 | 170.1 | 153.1 |
| 1 | | QPSK | 1/2 | 2 | | 9 800 | 4 900 | 360.3 | 340.3 | 306.3 |
| 2 | | | 3/4 | | | | 7 350 | 540.4 | 510.4 | 459.4 |
| 3 | | 16-QAM | 1/2 | 4 | | 19 600 | 9 800 | 720.6 | 680.6 | 612.5 |
| 4 | | | 3/4 | | | | 14 700 | 1 080.9 | 1 020.8 | 918.8 |
| 5 | | 64-QAM | 2/3 | 6 | | 29 400 | 19 600 | 1 441.2 | 1 361.1 | 1 225.0 |
| 6 | | | 3/4 | | | | 22 050 | 1 621.3 | 1 531.3 | 1 378.1 |
| 7 | | | 5/6 | | | | 24 500 | 1 801.5 | 1 701.4 | 1 531.3 |
| 8 | | 256-QAM | 3/4 | 8 | | 39 200 | 29 400 | 2 161.8 | 2 041.7 | 1 837.5 |
| 9 | | | 5/6 | | | | 32 666 | 2 401.9 | 2 268.5 | 2 041.6 |
| 10 | | 1024-QAM | 3/4 | 10 | | 49 000 | 36 750 | 2 702.2 | 2 552.1 | 2 296.9 |
| 11 | | | 5/6 | | | | 40 833 | 3 002.4 | 2 835.6 | 2 552.1 |

**Table 27-107—HE-MCSs for 996-tone RU, $N_{SS}$ = 6(11ax)**

| HE-MCS Index | DCM | Modulation | R | $N_{BPSCS}$ | $N_{SD}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 0.8 µs GI | 1.6 µs GI | 3.2 µs GI |
| 0 | N/A | BPSK | 1/2 | 1 | 980 | 5 880 | 2 940 | 216.2 | 204.2 | 183.8 |
| 1 | | QPSK | 1/2 | 2 | | 11 760 | 5 880 | 432.4 | 408.3 | 367.5 |
| 2 | | | 3/4 | | | | 8 820 | 648.5 | 612.5 | 551.3 |
| 3 | | 16-QAM | 1/2 | 4 | | 23 520 | 11 760 | 864.7 | 816.7 | 735.0 |
| 4 | | | 3/4 | | | | 17 640 | 1 297.1 | 1 225.0 | 1 102.5 |
| 5 | | 64-QAM | 2/3 | 6 | | 35 280 | 23 520 | 1 729.4 | 1 633.3 | 1 470.0 |
| 6 | | | 3/4 | | | | 26 460 | 1 945.6 | 1 837.5 | 1 653.8 |
| 7 | | | 5/6 | | | | 29 400 | 2 161.8 | 2 041.7 | 1 837.5 |
| 8 | | 256-QAM | 3/4 | 8 | | 47 040 | 35 280 | 2 594.1 | 2 450.0 | 2 205.0 |
| 9 | | | 5/6 | | | | 39 200 | 2 882.4 | 2 722.2 | 2 450.0 |
| 10 | | 1024-QAM | 3/4 | 10 | | 58 800 | 44 100 | 3 242.6 | 3 062.5 | 2 756.3 |
| 11 | | | 5/6 | | | | 49 000 | 3 602.9 | 3 402.8 | 3 062.5 |



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**Table 27-108—HE-MCSs for 996-tone RU, $N_{SS}$ = 7(11ax)**

| HE-MCS Index | DCM | Modulation | $R$ | $N_{BPSCS}$ | $N_{SD}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 0.8 µs GI | 1.6 µs GI | 3.2 µs GI |
| 0 | N/A | BPSK | 1/2 | 1 | 980 | 6 860 | 3 430 | 252.2 | 238.2 | 214.4 |
| 1 | | QPSK | 1/2 | 2 | | 13 720 | 6 860 | 504.4 | 476.4 | 428.8 |
| 2 | | | 3/4 | | | | 10 290 | 756.6 | 714.6 | 643.1 |
| 3 | | 16-QAM | 1/2 | 4 | | 27 440 | 13 720 | 1 008.8 | 952.8 | 857.5 |
| 4 | | | 3/4 | | | | 20 580 | 1 513.2 | 1 429.2 | 1 286.3 |
| 5 | | 64-QAM | 2/3 | 6 | | 41 160 | 27 440 | 2 017.6 | 1 905.6 | 1 715.0 |
| 6 | | | 3/4 | | | | 30 870 | 2 269.9 | 2 143.8 | 1 929.4 |
| 7 | | | 5/6 | | | | 34 300 | 2 522.1 | 2 381.9 | 2 143.8 |
| 8 | | 256-QAM | 3/4 | 8 | | 54 880 | 41 160 | 3 026.5 | 2 858.3 | 2 572.5 |
| 9 | | | 5/6 | | | | 45 733 | 3 362.7 | 3 175.9 | 2 858.3 |
| 10 | | 1024-QAM | 3/4 | 10 | | 68 600 | 51 450 | 3 783.1 | 3 572.9 | 3 215.6 |
| 11 | | | 5/6 | | | | 57 166 | 4 203.4 | 3 969.9 | 3 572.9 |

**Table 27-109—HE-MCSs for 996-tone RU, $N_{SS}$ = 8(11ax)**

| HE-MCS Index | DCM | Modulation | $R$ | $N_{BPSCS}$ | $N_{SD}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 0.8 µs GI | 1.6 µs GI | 3.2 µs GI |
| 0 | N/A | BPSK | 1/2 | 1 | 980 | 7 840 | 3 920 | 288.2 | 272.2 | 245.0 |
| 1 | | QPSK | 1/2 | 2 | | 15 680 | 7 840 | 576.5 | 544.4 | 490.0 |
| 2 | | | 3/4 | | | | 11 760 | 864.7 | 816.7 | 735.0 |
| 3 | | 16-QAM | 1/2 | 4 | | 31 360 | 15 680 | 1 152.9 | 1 088.9 | 980.0 |
| 4 | | | 3/4 | | | | 23 520 | 1 729.4 | 1 633.3 | 1 470.0 |
| 5 | | 64-QAM | 2/3 | 6 | | 47 040 | 31 360 | 2 305.9 | 2 177.8 | 1 960.0 |
| 6 | | | 3/4 | | | | 35 280 | 2 594.1 | 2 450.0 | 2 205.0 |
| 7 | | | 5/6 | | | | 39 200 | 2 882.4 | 2 722.2 | 2 450.0 |
| 8 | | 256-QAM | 3/4 | 8 | | 62 720 | 47 040 | 3 458.8 | 3 266.7 | 2 940.0 |
| 9 | | | 5/6 | | | | 52 266 | 3 843.1 | 3 629.6 | 3 266.6 |
| 10 | | 1024-QAM | 3/4 | 10 | | 78 400 | 58 800 | 4 323.5 | 4 083.3 | 3 675.0 |
| 11 | | | 5/6 | | | | 65 333 | 4 803.9 | 4 537.0 | 4 083.3 |

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### 27.5.8 HE-MCSs for 2×996-tone RU

The rate-dependent parameters for 2×996-tone RU are provided in Table 27-110 (HE-MCSs for 2×996-tone RU, NSS = 1(11ax)) through Table 27-117 (HE-MCSs for 2×996-tone RU, NSS = 8(11ax)).

**Table 27-110—HE-MCSs for 2×996-tone RU, $N_{SS}$ = 1(11ax)**

| HE-MCS Index | DCM | Modulation | *R* | $N_{BPSCS}$ | $N_{SD}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 0.8 µs GI | 1.6 µs GI | 3.2 µs GI |
| 0 | 1 | BPSK | 1/2 | 1 | 980 | 980 | 490 | 36.0 | 34.0 | 30.6 |
| | 0 | | 1/2 | | 1 960 | 1 960 | 980 | 72.1 | 68.1 | 61.3 |
| 1 | 1 | QPSK | 1/2 | 2 | 980 | 1 960 | 980 | 72.1 | 68.1 | 61.3 |
| | 0 | | 1/2 | | 1 960 | 3 920 | 1 960 | 144.1 | 136.1 | 122.5 |
| 2 | N/A | | 3/4 | | 1 960 | 3 920 | 2 940 | 216.2 | 204.2 | 183.8 |
| 3 | 1 | 16-QAM | 1/2 | 4 | 980 | 3 920 | 1 960 | 144.1 | 136.1 | 122.5 |
| | 0 | | 1/2 | | 1 960 | 7 840 | 3 920 | 288.2 | 272.2 | 245.0 |
| 4 | 1 | | 3/4 | | 980 | 3 920 | 2 940 | 216.2 | 204.2 | 183.8 |
| | 0 | | 3/4 | | 1 960 | 7 840 | 5 880 | 432.4 | 408.3 | 367.5 |
| 5 | N/A | 64-QAM | 2/3 | 6 | 1 960 | 11 760 | 7 840 | 576.5 | 544.4 | 490.0 |
| 6 | | | 3/4 | | | | 8 820 | 648.5 | 612.5 | 551.3 |
| 7 | | | 5/6 | | | | 9 800 | 720.6 | 680.6 | 612.5 |
| 8 | | 256-QAM | 3/4 | 8 | | 15 680 | 11 760 | 864.7 | 816.7 | 735.0 |
| 9 | | | 5/6 | | | | 13 066 | 960.7 | 907.4 | 816.6 |
| 10 | | 1024-QAM | 3/4 | 10 | | 19 600 | 14 700 | 1 080.9 | 1 020.8 | 918.8 |
| 11 | | | 5/6 | | | | 16 333 | 1 201.0 | 1 134.2 | 1 020.8 |


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**Table 27-111—HE-MCSs for 2×996-tone RU, $N_{SS}$ = 2(11ax)**

| HE-MCS Index | DCM | Modulation | $R$ | $N_{BPSCS}$ | $N_{SD}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 0.8 µs GI | 1.6 µs GI | 3.2 µs GI |
| 0 | 1 | BPSK | 1/2 | 1 | 980 | 1 960 | 980 | 72.1 | 68.1 | 61.3 |
| | 0 | | 1/2 | | 1 960 | 3 920 | 1 960 | 144.1 | 136.1 | 122.5 |
| 1 | 1 | QPSK | 1/2 | 2 | 980 | 3 920 | 1 960 | 144.1 | 136.1 | 122.5 |
| | 0 | | 1/2 | | 1 960 | 7 840 | 3 920 | 288.2 | 272.2 | 245.0 |
| 2 | N/A | | 3/4 | | 1 960 | 7 840 | 5 880 | 432.4 | 408.3 | 367.5 |
| 3 | 1 | 16-QAM | 1/2 | 4 | 980 | 7 840 | 3 920 | 288.2 | 272.2 | 245.0 |
| | 0 | | 1/2 | | 1 960 | 15 680 | 7 840 | 576.5 | 544.4 | 490.0 |
| 4 | 1 | | 3/4 | | 980 | 7 840 | 5 880 | 432.4 | 408.3 | 367.5 |
| | 0 | | 3/4 | | 1 960 | 15 680 | 11 760 | 864.7 | 816.7 | 735.0 |
| 5 | N/A | 64-QAM | 2/3 | 6 | 1 960 | 23 520 | 15 680 | 1 152.9 | 1 088.9 | 980.0 |
| 6 | | | 3/4 | | | | 17 640 | 1 297.1 | 1 225.0 | 1 102.5 |
| 7 | | | 5/6 | | | | 19 600 | 1 441.2 | 1 361.1 | 1 225.0 |
| 8 | | 256-QAM | 3/4 | 8 | | 31 360 | 23 520 | 1 729.4 | 1 633.3 | 1 470.0 |
| 9 | | | 5/6 | | | | 26 133 | 1 921.5 | 1 814.8 | 1 633.3 |
| 10 | | 1024-QAM | 3/4 | 10 | | 39 200 | 29 400 | 2 161.8 | 2 041.7 | 1 837.5 |
| 11 | | | 5/6 | | | | 32 666 | 2 401.9 | 2 268.5 | 2 041.6 |

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**Table 27-112—HE-MCSs for 2×996-tone RU, $N_{SS}$ = 3(11ax)**

| HE-MCS Index | DCM | Modulation | R | $N_{BPSCS}$ | $N_{SD}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 0.8 µs GI | 1.6 µs GI | 3.2 µs GI |
| 0 | N/A | BPSK | 1/2 | 1 | 1 960 | 5 880 | 2 940 | 216.2 | 204.2 | 183.8 |
| 1 | | QPSK | 1/2 | 2 | | 11 760 | 5 880 | 432.4 | 408.3 | 367.5 |
| 2 | | | 3/4 | | | | 8 820 | 648.5 | 612.5 | 551.3 |
| 3 | | 16-QAM | 1/2 | 4 | | 23 520 | 11 760 | 864.7 | 816.7 | 735.0 |
| 4 | | | 3/4 | | | | 17 640 | 1 297.1 | 1 225.0 | 1 102.5 |
| 5 | | 64-QAM | 2/3 | 6 | | 35 280 | 23 520 | 1 729.4 | 1 633.3 | 1 470.0 |
| 6 | | | 3/4 | | | | 26 460 | 1 945.6 | 1 837.5 | 1 653.8 |
| 7 | | | 5/6 | | | | 29 400 | 2 161.8 | 2 041.7 | 1 837.5 |
| 8 | | 256-QAM | 3/4 | 8 | | 47 040 | 35 280 | 2 594.1 | 2 450.0 | 2 205.0 |
| 9 | | | 5/6 | | | | 39 200 | 2 882.4 | 2 722.2 | 2 450.0 |
| 10 | | 1024-QAM | 3/4 | 10 | | 58 800 | 44 100 | 3 242.6 | 3 062.5 | 2 756.3 |
| 11 | | | 5/6 | | | | 49 000 | 3 602.9 | 3 402.8 | 3 062.5 |

**Table 27-113—HE-MCSs for 2×996-tone RU, $N_{SS}$ = 4(11ax)**

| HE-MCS Index | DCM | Modulation | R | $N_{BPSCS}$ | $N_{SD}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 0.8 µs GI | 1.6 µs GI | 3.2 µs GI |
| 0 | N/A | BPSK | 1/2 | 1 | 1 960 | 7 840 | 3 920 | 288.2 | 272.2 | 245.0 |
| 1 | | QPSK | 1/2 | 2 | | 15 680 | 7 840 | 576.5 | 544.4 | 490.0 |
| 2 | | | 3/4 | | | | 11 760 | 864.7 | 816.7 | 735.0 |
| 3 | | 16-QAM | 1/2 | 4 | | 31 360 | 15 680 | 1 152.9 | 1 088.9 | 980.0 |
| 4 | | | 3/4 | | | | 23 520 | 1 729.4 | 1 633.3 | 1 470.0 |
| 5 | | 64-QAM | 2/3 | 6 | | 47 040 | 31 360 | 2 305.9 | 2 177.8 | 1 960.0 |
| 6 | | | 3/4 | | | | 35 280 | 2 594.1 | 2 450.0 | 2 205.0 |
| 7 | | | 5/6 | | | | 39 200 | 2 882.4 | 2 722.2 | 2 450.0 |
| 8 | | 256-QAM | 3/4 | 8 | | 62 720 | 47 040 | 3 458.8 | 3 266.7 | 2 940.0 |
| 9 | | | 5/6 | | | | 52 266 | 3 843.1 | 3 629.6 | 3 266.6 |
| 10 | | 1024-QAM | 3/4 | 10 | | 78 400 | 58 800 | 4 323.5 | 4 083.3 | 3 675.0 |
| 11 | | | 5/6 | | | | 65 333 | 4 803.9 | 4 537.0 | 4 083.3 |



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**Table 27-114—HE-MCSs for 2×996-tone RU, $N_{SS}$ = 5(11ax)**

| HE-MCS Index | DCM | Modulation | R | $N_{BPSCS}$ | $N_{SD}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 0.8 µs GI | 1.6 µs GI | 3.2 µs GI |
| 0 | N/A | BPSK | 1/2 | 1 | 1 960 | 9 800 | 4 900 | 360.3 | 340.3 | 306.3 |
| 1 | | QPSK | 1/2 | 2 | | 19 600 | 9 800 | 720.6 | 680.6 | 612.5 |
| 2 | | | 3/4 | | | | 14 700 | 1 080.9 | 1 020.8 | 918.8 |
| 3 | | 16-QAM | 1/2 | 4 | | 39 200 | 19 600 | 1 441.2 | 1 361.1 | 1 225.0 |
| 4 | | | 3/4 | | | | 29 400 | 2 161.8 | 2 041.7 | 1 837.5 |
| 5 | | 64-QAM | 2/3 | 6 | | 58 800 | 39 200 | 2 882.4 | 2 722.2 | 2 450.0 |
| 6 | | | 3/4 | | | | 44 100 | 3 242.6 | 3 062.5 | 2 756.3 |
| 7 | | | 5/6 | | | | 49 000 | 3 602.9 | 3 402.8 | 3 062.5 |
| 8 | | 256-QAM | 3/4 | 8 | | 78 400 | 58 800 | 4 323.5 | 4 083.3 | 3 675.0 |
| 9 | | | 5/6 | | | | 65 333 | 4 803.9 | 4 537.0 | 4 083.3 |
| 10 | | 1024-QAM | 3/4 | 10 | | 98 000 | 73 500 | 5 404.4 | 5 104.2 | 4 593.8 |
| 11 | | | 5/6 | | | | 81 666 | 6 004.9 | 5 671.3 | 5 104.1 |

**Table 27-115—HE-MCSs for 2×996-tone RU, $N_{SS}$ = 6(11ax)**

| HE-MCS Index | DCM | Modulation | R | $N_{BPSCS}$ | $N_{SD}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 0.8 µs GI | 1.6 µs GI | 3.2 µs GI |
| 0 | N/A | BPSK | 1/2 | 1 | 1 960 | 11 760 | 5 880 | 432.4 | 408.3 | 367.5 |
| 1 | | QPSK | 1/2 | 2 | | 23 520 | 11 760 | 864.7 | 816.7 | 735.0 |
| 2 | | | 3/4 | | | | 17 640 | 1 297.1 | 1 225.0 | 1 102.5 |
| 3 | | 16-QAM | 1/2 | 4 | | 47 040 | 23 520 | 1 729.4 | 1 633.3 | 1 470.0 |
| 4 | | | 3/4 | | | | 35 280 | 2 594.1 | 2 450.0 | 2 205.0 |
| 5 | | 64-QAM | 2/3 | 6 | | 70 560 | 47 040 | 3 458.8 | 3 266.7 | 2 940.0 |
| 6 | | | 3/4 | | | | 52 920 | 3 891.2 | 3 675.0 | 3 307.5 |
| 7 | | | 5/6 | | | | 58 800 | 4 323.5 | 4 083.3 | 3 675.0 |
| 8 | | 256-QAM | 3/4 | 8 | | 94 080 | 70 560 | 5 188.2 | 4 900.0 | 4 410.0 |
| 9 | | | 5/6 | | | | 78 400 | 5 764.7 | 5 444.4 | 4 900.0 |
| 10 | | 1024-QAM | 3/4 | 10 | | 11 7600 | 88 200 | 6 485.3 | 6 125.0 | 5 512.5 |
| 11 | | | 5/6 | | | | 98 000 | 7 205.9 | 6 805.6 | 6 125.0 |

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**Table 27-116—HE-MCSs for 2×996-tone RU, $N_{SS}$ = 7(11ax)**

| HE-MCS Index | DCM | Modulation | R | $N_{BPSCS}$ | $N_{SD}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 0.8 µs GI | 1.6 µs GI | 3.2 µs GI |
| 0 | N/A | BPSK | 1/2 | 1 | 1 960 | 13 720 | 6 860 | 504.4 | 476.4 | 428.8 |
| 1 | | QPSK | 1/2 | 2 | | 27 440 | 13 720 | 1 008.8 | 952.8 | 857.5 |
| 2 | | | 3/4 | | | | 20 580 | 1 513.2 | 1 429.2 | 1 286.3 |
| 3 | | 16-QAM | 1/2 | 4 | | 54 880 | 27 440 | 2 017.6 | 1 905.6 | 1 715.0 |
| 4 | | | 3/4 | | | | 41 160 | 3 026.5 | 2 858.3 | 2 572.5 |
| 5 | | 64-QAM | 2/3 | 6 | | 82 320 | 54 880 | 4 035.3 | 3 811.1 | 3 430.0 |
| 6 | | | 3/4 | | | | 61 740 | 4 539.7 | 4 287.5 | 3 858.8 |
| 7 | | | 5/6 | | | | 68 600 | 5 044.1 | 4 763.9 | 4 287.5 |
| 8 | | 256-QAM | 3/4 | 8 | | 109 760 | 82 320 | 6 052.9 | 5 716.7 | 5 145.0 |
| 9 | | | 5/6 | | | | 91 466 | 6 725.4 | 6 351.8 | 5 716.6 |
| 10 | | 1024-QAM | 3/4 | 10 | | 137 200 | 102 900 | 7 566.2 | 7 145.8 | 6 431.3 |
| 11 | | | 5/6 | | | | 114 333 | 8 406.8 | 7 939.8 | 7 145.8 |

**Table 27-117—HE-MCSs for 2×996-tone RU, $N_{SS}$ = 8(11ax)**

| HE-MCS Index | DCM | Modulation | R | $N_{BPSCS}$ | $N_{SD}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 0.8 µs GI | 1.6 µs GI | 3.2 µs GI |
| 0 | N/A | BPSK | 1/2 | 1 | 1 960 | 15 680 | 7 840 | 576.5 | 544.4 | 490.0 |
| 1 | | QPSK | 1/2 | 2 | | 31 360 | 15 680 | 1 152.9 | 1 088.9 | 980.0 |
| 2 | | | 3/4 | | | | 23 520 | 1 729.4 | 1 633.3 | 1 470.0 |
| 3 | | 16-QAM | 1/2 | 4 | | 62 720 | 31 360 | 2 305.9 | 2 177.8 | 1 960.0 |
| 4 | | | 3/4 | | | | 47 040 | 3 458.8 | 3 266.7 | 2 940.0 |
| 5 | | 64-QAM | 2/3 | 6 | | 94 080 | 62 720 | 4 611.8 | 4 355.6 | 3 920.0 |
| 6 | | | 3/4 | | | | 70 560 | 5 188.2 | 4 900.0 | 4 410.0 |
| 7 | | | 5/6 | | | | 78 400 | 5 764.7 | 5 444.4 | 4 900.0 |
| 8 | | 256-QAM | 3/4 | 8 | | 125 440 | 94 080 | 6 917.6 | 6 533.3 | 5 880.0 |
| 9 | | | 5/6 | | | | 104 533 | 7 686.3 | 7 259.2 | 6 533.3 |
| 10 | | 1024-QAM | 3/4 | 10 | | 156 800 | 117 600 | 8 647.1 | 8 166.7 | 7 350.0 |
| 11 | | | 5/6 | | | | 130 666 | 9 607.8 | 9 074.0 | 8 166.6 |


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## 27.6 Parameters for HE-SIG-B-MCSs

The HE-SIG-B-MCSs, defined in Table 27-118 (HE-SIG-B-MCSs(11ax)), are used for the HE-SIG-B field transmission in the HE MU PPDU.

**Table 27-118—HE-SIG-B-MCSs(11ax)**

| HE-SIG-B-MCS Index | DCM | Modulation | *R* | $N_{BPSCS}$ | $N_{SD}$ | $N_{CBPS}$ | $N_{DBPS}$ | HE-SIG-B rate (Mb/s) |
|---|---|---|---|---|---|---|---|---|
| 0 | 1 | BPSK | 1/2 | 1 | 26 | 26 | 13 | 3.3 |
| | 0 | | 1/2 | | 52 | 52 | 26 | 6.6 |
| 1 | 1 | QPSK | 1/2 | 2 | 26 | 52 | 26 | 6.6 |
| | 0 | | 1/2 | | 52 | 104 | 52 | 13.2 |
| 2 | N/A | | 3/4 | | 52 | 104 | 78 | 19.5 |
| 3 | 1 | 16-QAM | 1/2 | 4 | 26 | 104 | 52 | 13.2 |
| | 0 | | 1/2 | | 52 | 208 | 104 | 26.0 |
| 4 | 1 | | 3/4 | | 26 | 104 | 78 | 19.5 |
| | 0 | | 3/4 | | 52 | 208 | 156 | 39.0 |
| 5 | N/A | 64-QAM | 2/3 | 6 | 52 | 312 | 208 | 52.0 |

NOTE—The parameters $N_{SD}$, $N_{CBPS}$ and $N_{DBPS}$ are used for the HE-SIG-B field transmission in each 20 MHz subchannel.

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# 28. Enhanced directional multi-gigabit (EDMG) PHY specification(11ay)

## 28.1 Introduction

### 28.1.1 Introduction to EDMG PHY

This clause specifies the PHY entity for the enhanced directional multi-gigabit (EDMG) control, single carrier (SC) and orthogonal frequency division multiplexing (OFDM) modes.

The EDMG PHY is based on the DMG PHY defined in Clause 20 (Directional multi-gigabit (DMG) PHY specification). In addition to the requirements in this clause, an EDMG STA shall support(#546) transmitting and receiving PPDUs that are compliant with the mandatory PHY specifications defined in Clause 20 (Directional multi-gigabit (DMG) PHY specification).

The EDMG PHY adds support for multiple space-time streams, downlink multi-user (MU) transmissions and PPDU transmissions with multiple channel widths, including 4.32 GHz, 6.48 GHz, 8.64 GHz, 2.16+2.16 GHz, and 4.32+4.32 GHz. The channels making up a 2.16+2.16 GHz and 4.32+4.32 GHz PPDU transmission may be contiguous or noncontiguous. The maximum number of spatial streams per STA is eight. An MU PPDU transmission supports up to eight STAs. For 2.16+2.16 GHz and 4.32+4.32 GHz transmissions, the maximum number of spatial streams in each 2.16 GHz channel and 4.32 GHz channel, respectively, is four.

An EDMG STA shall support the following features:

- EDMG format (transmit and receive)
- 2.16 GHz PPDU using EDMG control mode MCS 0 and (#8160)EDMG SC mode MCSs 1 to 5 and 7 to 10 (transmit and receive)
- 4.32 GHz PPDU using EDMG control mode MCS 0 and (#8160)EDMG SC mode MCSs 1 to 5 and 7 to 10 (transmit and receive)
- Single spatial stream (transmit and receive) in all channel widths that the EDMG STA supports
- Normal GI type
- 2.16 GHz PPDU using non-EDMG control mode MCS 0 and (#8160)EDMG SC mode MCSs 1 to 4 (transmit and receive)
- 4.32 GHz PPDU using non-EDMG duplicate control mode MCS 0 and (#8160)EDMG SC mode MCSs 1 to 4 (transmit and receive)

An EDMG STA may support the following features:

- 2.16 GHz PPDU using EDMG SC mode MCSs 6 and 11 to 21 and (#8160)EDMG OFDM mode all MCSs (transmit and receive)
- 4.32 GHz PPDU using EDMG SC mode MCSs 6 and 11 to 21 and (#8160)EDMG OFDM mode all MCSs (transmit and receive)
- Two or more spatial streams using EDMG SC and OFDM modes (transmit and receive)
- EDMG MU PPDUs using EDMG SC and OFDM modes (transmit and receive)
- 2.16+2.16 GHz PPDU using EDMG control mode MCS 0, (#8160)EDMG SC and OFDM modes all MCSs (transmit and receive)
- 4.32+4.32 GHz PPDU using EDMG control mode MCS 0, (#8160)EDMG SC and OFDM modes all MCSs (transmit and receive)
- 6.48 GHz PPDU using EDMG control mode MCS 0, (#8160)EDMG SC and OFDM modes all MCSs (transmit and receive)

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- 8.64 GHz PPDU using EDMG control mode MCS 0, (#8160)EDMG SC and OFDM modes all MCSs (transmit and receive)
- 2.16+2.16 GHz PPDU using non-EDMG duplicate control mode MCS 0 and (#8160)EDMG SC mode all MCSs (transmit and receive)
- 4.32+4.32 GHz PPDU using non-EDMG duplicate control mode MCS 0 and (#8160)EDMG SC mode all MCSs (transmit and receive)
- 6.48 GHz PPDU using non-EDMG duplicate control mode MCS 0 and (#8160)EDMG SC mode all MCSs (transmit and receive)
- 8.64 GHz PPDU using non-EDMG duplicate control mode MCS 0 and (#8160)EDMG SC mode all MCSs (transmit and receive)
- Short GI type, long GI type, or both
- SU A-PPDU (transmit and receive)
- STBC (transmit and receive)
- DCM π/2-BPSK using EDMG SC mode (transmit and receive)
- π/2-64-NUC using EDMG SC mode (transmit and receive)
- π/2-8-PSK using EDMG SC mode (transmit and receive)
- (11az)2.16 GHz, 4.32 GHz, 6.48 GHz, and 8.64 GHz EDMG secure ranging PPDU using EDMG SC mode (transmit and receive)

### 28.1.2 Scope

The services provided to the MAC by the EDMG PHY consist of the following protocol functions:

- A function that defines a method of mapping the PSDUs into a framing format (PPDU) suitable for sending and receiving PSDUs between two or more STAs.
- A function that defines the characteristics and method of transmitting and receiving data through a wireless medium between two or more STAs. Depending on the PPDU format, these STAs support a mixture of EDMG and Clause 20 (Directional multi-gigabit (DMG) PHY specification) PHYs.

### 28.1.3 EDMG PHY functions

#### 28.1.3.1 General

The EDMG PHY contains two functional entities: the PHY function and the physical layer management function (i.e., the PLME). These functions are described in detail in 28.4 (EDMG and non-EDMG control mode), 28.5 (EDMG and non-EDMG SC mode), and 28.6 (EDMG OFDM mode).

The EDMG PHY service is provided to the MAC through the PHY service primitives defined in Clause 8 (PHY service specification). The EDMG PHY service interface is described in 28.2 (EDMG PHY service interface).

#### 28.1.3.2 PHY management entity (PLME)

The PLME performs management of the local PHY functions in conjunction with the MLME.

#### 28.1.3.3 Service specification method

The models represented by figures and state diagrams are intended to be illustrations of the functions provided. It is important to distinguish between a model and a real implementation. The models are optimized for simplicity and clarity of presentation, but do not necessarily reflect any particular implementation.


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The service of a layer is the set of capabilities that it offers to a user in the next higher layer. Abstract services are specified here by describing the service primitives and parameters that characterize each service. This definition is independent of any particular implementation.

### 28.1.4 PPDU formats

The structure of the PPDU transmitted by an EDMG STA is determined by the TXVECTOR parameters as defined in Table 28-1 (TXVECTOR and RXVECTOR parameters(11ay)) (in 28.2.2 (TXVECTOR and RXVECTOR parameters)).

For an EDMG STA, the FORMAT parameter determines the overall structure of the PPDU and includes the following:

— Non-EDMG format (NON_EDMG) based on Clause 20 (Directional multi-gigabit (DMG) PHY specification).

— EDMG format (EDMG). PPDUs of this format contain a preamble compatible with Clause 20 (Directional multi-gigabit (DMG) PHY specification)STAs. The non-EDMG portion of the EDMG format preamble (the parts of EDMG preamble preceding the EDMG-Header-A field) is defined so that it can be decoded by these STAs. An EDMG PPDU can be further categorized as an EDMG SU PPDU or an EDMG MU PPDU. An EDMG SU PPDU shall not contain the EDMG-Header-B field. An EDMG MU PPDU shall contain the EDMG-Header-B field.

## 28.2 EDMG PHY service interface

### 28.2.1 General

The PHY provides an interface to the MAC through an extension of the generic PHY service interface defined in 8.3.4 (Basic service and options). The interface includes TXVECTOR, RXVECTOR, and PHYCONFIG_VECTOR.

The TXVECTOR supplies the PHY with per-PPDU transmit parameters. Using the RXVECTOR, the PHY informs the MAC of the received PPDU parameters. Using the PHYCONFIG_VECTOR, the MAC configures the PHY for operation, independent of frame transmission or reception.

### 28.2.2 TXVECTOR and RXVECTOR parameters

The parameters in Table 28-1 (TXVECTOR and RXVECTOR parameters(11ay)) are defined as part of the TXVECTOR parameter list in the PHY-TXSTART.request primitive and/or as part of the RXVECTOR parameter list in the PHY-RXSTART.indication primitive.

The $N_{CB}$ parameter represents the number of contiguous (i.e., bonded) 2.16 GHz channels used for a transmission. The value of the CH_BANDWIDTH and CHANNEL_AGGREGATION parameters in the TXVECTOR and RXVECTOR define the value of the $N_{CB}$ parameter in the EDMG PHY definition throughout this clause as follows:

(#3312)NOTE 1—Between 1 and 4 bits are set in the CH_BANDWIDTH parameter.

— If the CH_BANDWIDTH parameter has (#3312)exactly one bit equal to 1 (#2349)(e.g., “01000000”), then $N_{CB}$ is set to 1.

(#3312)NOTE 2—The CHANNEL_AGGREGATION parameter is ignored in this case.

— (#3312)If the CH_BANDWIDTH parameter has exactly two bits equal to 1, then:

  — (#3312)If the two bits are noncontiguous (e.g., “01001000”), then $N_{CB}$ is set to 1.

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(#3312)NOTE 3—The CHANNEL_AGGREGATION parameter is ignored in this case.

— (#3312)If the two bits are contiguous (e.g., "01100000"), then if the CHANNEL_AGGREGATION parameter is (M118)equal to (#4167)AGGREGATED, $N_{CB}$ is set to 1, otherwise $N_{CB}$ is set to 2.

— If the CH_BANDWIDTH parameter has (#3312)exactly three bits equal to 1 (e.g., "00111000"), then $N_{CB}$ is set to 3.

(#3312)NOTE 4—The three bits are necessarily contiguous in this case. The CHANNEL_AGGREGATION parameter is ignored in this case.

— If the CH_BANDWIDTH parameter has (#3312)exactly four bits equal to 1 (e.g., "01111000"), then if the CHANNEL_AGGREGATION parameter is (M118)equal to (#4167)AGGREGATED, $N_{CB}$ is set to 2, otherwise $N_{CB}$ is set to 4.

(#3312)NOTE 5—The four bits are necessarily contiguous in this case.

The parameter TIME_OF_DEPARTURE_REQUESTED is common for both NON_EDMG and EDMG formats. The parameter RX_START_OF_FRAME_OFFSET is common for both NON_EDMG and EDMG formats.

**Table 28-1—TXVECTOR and RXVECTOR parameters(11ay)**

| Parameter | Condition | Value | TXVECTOR | RXVECTOR |
|---|---|---|---|---|
| FORMAT | | Determines the format of the PPDU.<br><br>Enumerated type:<br>NON_EDMG indicates Clause 20 or non-EDMG duplicate format. In this case, the modulation is determined by the NON_EDMG_MODULATION parameter.<br>EDMG indicates EDMG format. In this case, the modulation is determined by the EDMG_MODULATION parameter. | Y | Y |
| NON_EDMG_MODULATION | FORMAT is NON_EDMG. | In TXVECTOR, indicates the format type of the transmitted non-EDMG PPDU.<br>In RXVECTOR, indicates the estimated format type of the received non-EDMG PPDU.<br><br>Enumerated type:<br>DMG_C_MODE indicates Clause 20 control mode format.<br>DMG_SC_MODE indicates Clause 20 SC mode format.<br>NON_EDMG_DUP_C_MODE indicates non-EDMG duplicate format of the Clause 20 control mode format.<br>NON_EDMG_DUP_SC_MODE indicates non-EDMG duplicate format of the Clause 20 SC mode format. | Y | Y |


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**Table 28-1—TXVECTOR and RXVECTOR parameters(11ay) *(continued)***

| Parameter | Condition | Value | TXVECTOR | RXVECTOR |
|---|---|---|---|---|
| L_LENGTH | FORMAT is NON_EDMG. | See LENGTH entry in Table 20-1 (TXVECTOR and RXVECTOR parameters). | Y | Y |
| L_MCS | FORMAT is NON_EDMG. | See MCS entry in Table 20-1 (TXVECTOR and RXVECTOR parameters). | Y | Y |
| L_ADD_PPDU | FORMAT is NON_EDMG. | See ADD-PPDU entry in Table 20-1 (TXVECTOR and RXVECTOR parameters). | Y | Y |
| L_PPDU_ TYPE | FORMAT is NON_EDMG. | See PPDU_TYPE entry in Table 20-1 (TXVECTOR and RXVECTOR parameters). | Y | Y |
| L_TRN_LEN | FORMAT is NON_EDMG. | See TRN-LEN entry in Table 20-1 (TXVECTOR and RXVECTOR parameters). | Y | Y |
| L_ AGGREGATION | FORMAT is NON_EDMG. | See AGGREGATION entry in Table 20-1 (TXVECTOR and RXVECTOR parameters). | Y | Y |
| L_ RSSI | FORMAT is NON_EDMG. | See RSSI entry in Table 20-1 (TXVECTOR and RXVECTOR parameters). | N | Y |
| L_ SNR | FORMAT is NON_EDMG. | See SNR entry in Table 20-1 (TXVECTOR and RXVECTOR parameters). | N | Y |
| L_ RCPI | FORMAT is NON_EDMG. | See RCPI entry in Table 20-1 (TXVECTOR and RXVECTOR parameters). | N | Y |

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**Table 28-1—TXVECTOR and RXVECTOR parameters(11ay) *(continued)***

| Parameter | Condition | Value | TXVECTOR | RXVECTOR |
|---|---|---|---|---|
| L_ANT_CONFIG | FORMAT is NON_EDMG. | See ANT_CONFIG entry in Table 20-1 (TXVECTOR and RXVECTOR parameters). | Y | N |
| L_CHAN_MEASUREMENT | FORMAT is NON_EDMG. | See CHAN_MEASUREMENT entry in Table 20-1 (TXVECTOR and RXVECTOR parameters). | N | Y |
| L_BEAM_TRACKING_REQUEST | FORMAT is NON_EDMG. | See BEAM_TRACKING_REQUEST entry in Table 20-1 (TXVECTOR and RXVECTOR parameters). | Y | Y |
| L_LAST_RSSI | FORMAT is NON_EDMG. | See LAST_RSSI entry in Table 20-1 (TXVECTOR and RXVECTOR parameters). | Y | Y |
| L_TURNAROUND | FORMAT is NON_EDMG. | See TURNAROUND entry in Table 20-1 (TXVECTOR and RXVECTOR parameters). | Y | Y |
| RX_START_OF_FRAME_OFFSET | | 0 to $2^{32}-1$. An estimate of the offset (in (#7198)100 ps units) from the point in time at which the start of the preamble corresponding to the incoming frame arrived at the receive antenna connector to the point in time at which this primitive is issued to the MAC. | N | See NOTE 3 |



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**Table 28-1—TXVECTOR and RXVECTOR parameters(11ay) *(continued)***

| Parameter | Condition | Value | TXVECTOR | RXVECTOR |
|---|---|---|---|---|
| EDMG_MODULATION | FORMAT is EDMG. | Indicates the EDMG modulation type.<br><br>Enumerated type:<br>EDMG_C_MODE indicates EDMG control mode (28.4 (EDMG and non-EDMG control mode)).<br>EDMG_SC_MODE indicates EDMG SC mode (28.5 (EDMG and non-EDMG SC mode)).<br>EDMG_OFDM_MODE indicates EDMG OFDM mode (28.6 (EDMG OFDM mode)). | Y | Y |
| EDMG_MCS | FORMAT is EDMG. | In the TXVECTOR, indicates the modulation and coding scheme applied for the transmission of the PPDU. In the RXVECTOR, indicates the modulation and coding scheme of the received PPDU. Values are integers in the range 0 to 21.<br>— If EDMG_MODULATION is EDMG_C_MODE, valid EDMG_MCS value is 0.<br>— If EDMG_MODULATION is EDMG_SC_MODE, valid EDMG_MCS values are 1 to 21.<br>— If EDMG_MODULATION is EDMG_OFDM_MODE, valid EDMG_MCS values are 1 to 20. | SU+ MU | Y |
| EDMG_LENGTH | FORMAT is EDMG. | Indicates the length of the PSDU in octets in the range(#3482) 14 to 1023 for the Control mode and 1 to 4 194 303 for the EDMG SC and OFDM modes. This value is used by the PHY to determine the number of octet transfers that occur between the MAC and the PHY. | MU | Y |
| LDPC_CW_TYPE | FORMAT is EDMG. | Indicates the LDPC codeword type in terms of code word length.<br><br>Enumerated type:<br>SHORT: LDPC codeword length 672, 624, 504, or 468.<br>LONG: LDPC codeword length 1344, 1248, 1008, or 936. | MU | Y |

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**Table 28-1—TXVECTOR and RXVECTOR parameters(11ay) *(continued)***

| Parameter | Condition | Value | TXVECTOR | RXVECTOR |
|---|---|---|---|---|
| LDPC_SUPERIMPOSED | FORMAT is EDMG. | Indicates whether punctured or superimposed LDPC code is used for code rate 7/8 encoding.<br>0 indicates that punctured LDPC code is applied as described in 20.5.3.2.3 (Encoding) and 28.5.9.4.3 (LDPC encoding).<br>1 indicates that superimposed LDPC code is applied as described in 28.5.9.4.3 (LDPC encoding).<br><br>If the EDMG_MCS parameter is 13 and the PSK_APPLIED parameter is PSK_APPLIED, then this parameter indicates the 7/8 code employed in the encoding procedure with codeword shortening to achieve the effective code rate of 5/6 as defined in 28.5.9.4.3 (LDPC encoding). | MU | Y |
| STBC | FORMAT is EDMG. | Indicates whether STBC is used.<br>0 indicates no STBC ($N_{STS} = N_{SS}$ in the Data field).<br>1 indicates STBC is used ($N_{STS} = 2 \times N_{SS}$ and $N_{SS}$ in the Data field). | MU | Y |
| DCM_BPSK | FORMAT is EDMG, EDMG_MODULATION is EDMG_SC_MODE, CHANNEL_AGGREGATION is (#4167)AGGREGATED, STBC is 0, NUM_STS is 2. | Indicates whether DCM BPSK modulation is applied.<br><br>Enumerated type:<br>DCM_BPSK_Not_Applied indicates that DCM π/2-BPSK is not applied.<br>DCM_BPSK_Applied indicates that DCM π/2-BPSK is applied and that $N_{SS} = N_{STS} = 2$. | Y | Y |
| | FORMAT is EDMG, EDMG_MODULATION is EDMG_OFDM_MODE, STBC is 0, NUM_STS is 2. | Enumerated type:<br>DCM_BPSK_Not_Applied indicates that Dual Stream DCM BPSK is not applied.<br>DCM_BPSK_Applied indicates that Dual Stream DCM BPSK is applied and that $N_{SS} = N_{STS} = 2$. | Y | Y |
| NUC_MOD | FORMAT is EDMG, EDMG_MODULATION is EDMG_SC_MODE. | Indicates whether NUC modulation is applied.<br><br>Enumerated type:<br>NUCNotApplied indicates that NUC modulation is not applied.<br>NUCApplied indicates that NUC modulation is applied. | MU | Y |
| PSK_APPLIED | FORMAT is EDMG, EDMG_MODULATION is EDMG_SC_MODE. | Indicates if π/2-8-PSK is applied for MCS 12 or MCS 13.<br><br>Enumerated Type:<br>PSK_APPLIED indicates that π/2-8-PSK is applied.<br>PSK_NOT_APPLIED indicates that π/2-8-PSK is not applied. | MU | Y |


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**Table 28-1—TXVECTOR and RXVECTOR parameters(11ay) *(continued)***

| Parameter | Condition | Value | TXVECTOR | RXVECTOR |
|---|---|---|---|---|
| PHASE_HOPPING | FORMAT is EDMG, EDMG_MODULATION is EDMG_OFDM_MODE. | Indicates whether phase hopping modulation is applied when $N_{STS} = N_{SS} = 2$.<br><br>Enumerated type:<br>PH_NOT_APPLIED indicates that phase hopping modulation is not applied.<br>PH_APPLIED indicates that phase hopping modulation is applied. | Y | Y |
| OPEN_LOOP_PC | FORMAT is EDMG, EDMG_MODULATION is EDMG_OFDM_MODE. | Indicates whether open loop precoding is applied when $N_{STS} = N_{SS} = 2$.<br><br>Enumerated type:<br>OL_NOT_APPLIED indicates that open loop precoding is not applied.<br>OL_APPLIED indicates that open loop precoding is applied. | Y | Y |
| NUM_STS | FORMAT is EDMG, STBC is 0. | Indicates the number of space-time streams.<br><br>Value is an integer in the range 1 to 8 for an SU PPDU. For an MU PPDU, values are integers in the range 1 to 2 per user in the TXVECTOR, and 0 to 2 per user in the RXVECTOR.<br><br>The sum of NUM_STS over all users is in the range(#3482) 1 to 8. | MU | Y |
| | FORMAT is EDMG, STBC is 1. | Indicates the number of space-time streams. The value of this parameter shall be an even number.<br><br>Value is an even integer in the range 2 to 8 for an SU PPDU. For an MU PPDU, the value is 2 for each user in the TXVECTOR, and 0 or 2 for each user in the RXVECTOR.<br><br>The sum of NUM_STS over all users is in the range(#3482) 1 to 8. | MU | Y |
| NUM_USERS | FORMAT is EDMG. | Indicates the number of users with nonzero space-time streams.<br><br>Integer: range 1 to 8. Range restrictions apply for SU PPDU or MU PPDU if at least one user employs STBC. | Y | N |
| MU_AID | FORMAT is EDMG. | Indicates the AID of each intended recipient addressed in an MU PPDU. | MU | O |

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**Table 28-1—TXVECTOR and RXVECTOR parameters(11ay) *(continued)***

| Parameter | Condition | Value | TXVECTOR | RXVECTOR |
|---|---|---|---|---|
| EDMG_PPDU_TYPE | FORMAT is EDMG, EDMG_TRN_LEN > 0. | Enumerated type:<br>EDMG-TRN-R indicates either a PPDU whose Data field is followed by one or more TRN subfields, all of which are transmitted with the same AWV, or a PPDU that is requesting TRN subfields to be appended to a future response PPDU, all of which are transmitted with the same AWV.<br>EDMG-TRN-T indicates a PPDU whose Data field is followed by a TRN field. As defined in 28.9.2.2 (EDMG BRP PPDU), the transmitter may change the AWV at the beginning of each set of *N* TRN subfields present in the last *M* TRN subfields of each TRN-Unit in the TRN field.<br>EDMG-TRN-R/T indicates a PPDU whose Data field is followed by one or more TRN subfields. The transmitter sends a number of consecutive TRN-Units in which the same AWV is used in the transmission of the last *M* TRN subfields of each TRN-Unit. | Y | Y |
| EDMG_TRN_LEN | FORMAT is EDMG. | Indicates the number of TRN-Units in the TRN field of a PPDU or, as defined in 10.41.7 (Beam tracking), a requested number of TRN-Units for receive beam tracking. Values are in the range 0 to 255 (see 28.9.2.2.5 (TRN field definition)). | Y | Y |
| RX_TRN_PER_TX_TRN | FORMAT is EDMG, EDMG_PPDU_TYPE is EDMG-TRN-R/T, EDMG_TRN_LEN > 0. | Indicates the number of consecutive TRN-Units in which the same AWV is used in the transmission of the last EDMG_TRN_M TRN subfields of each TRN-Unit. Values are in the range 2 to 255, and divisors of the value of EDMG_TRN_LEN including EDMG_TRN_LEN but excluding 1. | Y | Y |
| EDMG_TRN_P | FORMAT is EDMG, EDMG_PPDU_TYPE is EDMG-TRN-T or EDMG-TRN-R/T. | Indicates the number of TRN subfields at the beginning of a TRN-Unit that are transmitted with the same AWV. Values are in the range 0 to 3. | Y | Y |


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**Table 28-1—TXVECTOR and RXVECTOR parameters(11ay) *(continued)***

| Parameter | Condition | Value | TXVECTOR | RXVECTOR |
|---|---|---|---|---|
| EDMG_TRN_M | FORMAT is EDMG, EDMG_PPDU_TYPE is EDMG-TRN-T or EDMG-TRN-R/T. | If EDMG_PPDU_TYPE is EDMG-TRN-T or EDMG-TRN-R/T, indicates the number of TRN subfields in a TRN-Unit that may be used for transmit training, as defined in 28.9.2.2 (EDMG BRP PPDU). Values are in the range 0 to 15. The parameter is reserved if TRN-LEN is 0. The parameter is reserved if EDMG_PPDU_TYPE is EDMG-TRN-R. | Y | Y |
| EDMG_TRN_N | FORMAT is EDMG, EDMG_PPDU_TYPE is EDMG-TRN-T. | Indicates the number of consecutive TRN subfields within the EDMG TRN-Unit M of a TRN-Unit that are transmitted using the same AWV. Values are in the range 0 to 3. | Y | Y |
| TRN_SEQ_LENGTH | FORMAT is EDMG. | Indicates the length of the Golay sequence to be used to transmit the TRN subfields present in the TRN field of the PPDU.<br><br>Enumerated type:<br>Normal: The Golay sequence has a length of $128 \times N_{CB}$.<br>Long: The Golay sequence has a length of $256 \times N_{CB}$.<br>Short: The Golay sequence has a length of $64 \times N_{CB}$.<br><br>$N_{CB}$ represents the integer number of contiguous 2.16 GHz channels over which the TRN subfield is transmitted and $1 \leq N_{CB} \leq 4$. | Y | Y |
| TRN_RX_PATTERN | FORMAT is EDMG, EDMG_PPDU_TYPE is EDMG-TRN-T or EDMG-TRN-R/T. | Indicates the receive antenna pattern to be used when measuring TRN-Units present in a received PPDU.<br><br>Enumerated type:<br>QUASI_OMNI indicates that quasi-omni AWV should be used.<br>DIRECTIONAL indicates that directed AWV should be used. | Y | Y |
| EDMG_BEAM_TRACKING_REQUEST | FORMAT is EDMG. | This parameter indicates whether beam tracking (see 10.41.7 (Beam tracking)) is requested.<br><br>Enumerated type:<br>BEAM-TRACKING-REQUESTED<br>BEAM-TRACKING-NOT-REQUESTED | Y | Y |

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**Table 28-1—TXVECTOR and RXVECTOR parameters(11ay) *(continued)***

| Parameter | Condition | Value | TXVECTOR | RXVECTOR |
|---|---|---|---|---|
| EDMG_BEAM_TRACKING_TYPE | FORMAT is EDMG. | This parameter indicates if analog beam tracking or baseband beam tracking is requested.<br><br>Enumerated type:<br>Analog Beam Tracking<br>Baseband Beam Tracking | Y | Y |
| EDMG_BRP_MIN_SC_BLOCKS | FORMAT is EDMG, EDMG_TRN_LEN > 0. | Indicates the minimum duration of the Data field in units of SC IDFT/DFT period. | Y | N |
| SCRAMBLER_INIT_SETTING | FORMAT is EDMG. | Indicates that the PPDU is an EDMG control mode PPDU carrying the EDMG-Header-A.<br><br>Enumerated type:<br>EDMG-Header-A | Y | Y |
| | FORMAT is NON_EDMG. | Indicates the configuration of the Scrambler Initialization field of a control mode PPDU.<br><br>Enumerated type:<br>Channel_BW<br>CONTROL_TRAILER | Y | Y |
| CT_TYPE | SCRAMBLER_INIT_SETTING is CONTROL_TRAILER. | Indicates the content of the control trailer:<br><br>Enumerated type:<br>CTS_DTS<br>GRANT_RTS_CTS2self<br>SPR<br>SSW_FEEDBACK<br>BLOCK_ACK<br>ACK | Y | Y |



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**Table 28-1—TXVECTOR and RXVECTOR parameters(11ay) *(continued)***

| Parameter | Condition | Value | TXVECTOR | RXVECTOR |
|---|---|---|---|---|
| CH_BANDWIDTH | FORMAT is EDMG. | In the TXVECTOR, indicates the set of channels on which the PPDU is transmitted and the value of the BW field in the EDMG Header-A. In the RXVECTOR, indicates the value of the BW field in the EDMG Header-A of a received PPDU.<br><br>This parameter is a bitmap. Valid values for this parameter and the CHANNEL_AGGREGATION parameter are indicated in Table 28-21 (2.16 GHz, 4.32 GHz, 6.48 GHz, and 8.64 GHz channels used by an EDMG STA(11ay)), Table 28-22 (2.16+2.16 GHz channel used by an EDMG STA(11ay)), and Table 28-23 (4.32+4.32 GHz channel used by an EDMG STA(11ay)). | Y | Y |
| | FORMAT is NON_EDMG. | In the TXVECTOR, indicates the set of channels on which the PPDU is transmitted. In the RXVECTOR, indicates the estimated set of channels on which PPDU was received.<br><br>This parameter is a bitmap. Valid values for this parameter and the CHANNEL_AGGREGATION parameter are indicated in Table 28-21 (2.16 GHz, 4.32 GHz, 6.48 GHz, and 8.64 GHz channels used by an EDMG STA(11ay)), Table 28-22 (2.16+2.16 GHz channel used by an EDMG STA(11ay)), and Table 28-23 (4.32+4.32 GHz channel used by an EDMG STA(11ay)). | Y | Y |
| CH_BANDWIDTH_SIGNALING | FORMAT is NON_EDMG, NON_EDMG_MODULATION is NON_EDMG_DUP_C_MODE. | Indicates the value of the Scrambler Initialization field, as defined in Table 28-6 (Definition of Scrambler Initialization field when transmitted using the control mode and the Turnaround field is 1(11ay)), of the PPDU transmitted in NON_EDMG_DUP_C_MODE. | O | Y |
| CHANNEL_AGGREGATION | FORMAT is EDMG. | Indicates the transmission and reception type of the PPDU in case the number of bits equal to 1 in the CH_BANDWIDTH parameter is greater than 1.<br><br>Enumerated type:<br>(#4167)AGGREGATED<br>(#4167)NOT_AGGREGATED | Y | Y |
| EDMG_ADD_PPDU | FORMAT is EDMG. | Enumerated type:<br>ADD-PPDU indicates that this EDMG PPDU is immediately followed by another EDMG PPDU with no IFS or preamble on the subsequent EDMG PPDU.<br>NO-ADD-PPDU indicates no additional EDMG PPDU follows this EDMG PPDU. | Y | Y |

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**Table 28-1—TXVECTOR and RXVECTOR parameters(11ay) *(continued)***

| Parameter | Condition | Value | TXVECTOR | RXVECTOR |
|---|---|---|---|---|
| NUM_TX_CHAINS | | The value of this field indicates the number of transmit chains used in the transmission of the PPDU.<br><br>Integer: range 1 to 8. | Y | Y |
| DMG_TRN | FORMAT is EDMG, NUM_TX_CHAINS = 1, $N_{CB}$ = 1. | Indicates the configuration of the DMG TRN field (see Table 28-12 (EDMG-Header-A field structure and definition for an SU PPDU(11ay))). Possible values are 0 and 1.<br><br>When set to 1, indicates that the TRN field appended to this PPDU has the structure of a DMG training field containing an AGC training field and a TRN field as defined in 20.9.2.2.2 (BRP PPDU structure). In this case, the RX_TRN_PER_TX_TRN, EDMG_TRN_P, EDMG_TRN_M, EDMG_TRN_N and TRN_SEQ_LENGTH parameters are reserved. The EDMG_TRN_LEN parameter has a value greater than 0 and less than 32. | Y | Y |
| TIME_OF_DEPARTURE_REQUESTED | | Enumerated type:<br>True indicates that the MAC entity requests that the PHY entity measures and reports time of departure parameters corresponding to the time when the first frame energy is sent by the transmitting port. False indicates that the MAC entity requests that the PHY entity neither measures nor reports time of departure parameters. | O | N |
| RSSI | FORMAT is EDMG. | The allowed values for the RSSI parameter are in the range 0 through 255. This parameter is a measure by the PHY of the power observed at the input of the antennas plus the antenna gain, or equivalent antenna gain for a phased array antenna, used to receive the current PPDU.<br><br>The RSSI shall be measured during the reception of the L-STF or EDMG-STF field. RSSI is intended to be used in a relative manner, and it shall be a monotonically increasing function of the received power with equidistant step equal to 0.25 dB. | N | Y |
| RCPI | FORMAT is EDMG. | Is a measure of the received RF power (in dBm) measured over the preamble (#3475)of the current PPDU. Refer to 28.3.9.2 (Received channel power indicator (RCPI) measurement). | N | Y |


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**Table 28-1—TXVECTOR and RXVECTOR parameters(11ay) *(continued)***

| Parameter | Condition | Value | TXVECTOR | RXVECTOR |
|---|---|---|---|---|
| FIRST_PATH_TRAINING | FORMAT is EDMG. | When set to 1, indicates that the TRN field appended to this PPDU, if any, is used for first path beamforming training. Set to 0 otherwise. | Y | Y |
| DUAL_POL_TRAINING | FORMAT is EDMG. | When set to 1, indicates that the TRN subfields in the TRN field appended to this PPDU have different polarizations for the same AWV. When set to 0, indicates that the TRN field appended to this PPDU does not change polarization. | Y | Y |
| GI_TYPE | FORMAT is EDMG. | Indicates the length of the guard interval.<br><br>Enumerated type:<br>SHORT<br>NORMAL<br>LONG | Y | Y |
| PRIMARY_CHANNEL | FORMAT is EDMG. | Indicates the primary channel number for the transmission. Values are 1 to 8. | Y | Y |
| BEAMFORMED | FORMAT is EDMG or FORMAT is NON_EDMG and NON_EDMG_MODULATION is NON_EDMG_DUP_SC_MODE. | Enumerated type:<br>Beamformed<br>Not_Beamformed<br><br>If set to Beamformed, indicates that digital beamforming is applied. Set to Not_Beamformed otherwise. | Y | Y |
| CSD_APPLIED | BEAMFORMED is Not_Beamformed. | Enumerated type:<br>CSD_Applied<br>CSD_Not_Applied<br><br>If set to CSD_Applied, indicates that CSD is applied over different transmit chains. Set to CSD_Not_Applied otherwise. | Y | Y |
| TRN_AGGREGATION | FORMAT is EDMG and EDMG_TRN_LEN > 0. | Enumerated type:<br>WidebandTRN: The BW field specifies that the TRN field of the PPDU is appended on a 2.16 GHz, 4.32 GHz, 6.48 GHz, or 8.64 GHz channel.<br>AggregationTRN: The BW field specifies that the TRN field is transmitted over a 2.16+2.16 GHz or 4.32+4.32 GHz channel. | Y | Y |

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**Table 28-1—TXVECTOR and RXVECTOR parameters(11ay) *(continued)***

| Parameter | Condition | Value | TXVECTOR | RXVECTOR |
|---|---|---|---|---|
| NEXT_TX_SISO | SCRAMBLER_INIT_SETTING is CONTROL_TRAILER. | Indicates whether the following transmission from this STA is performed with a single DMG antenna or multiple DMG antennas.<br><br>Enumerated type:<br>NextTxSingleAntenna<br>NextTxMultiAntenna | Y | Y |
| MU_MIMO_NEXT | SCRAMBLER_INIT_SETTING is CONTROL_TRAILER. | Indicates whether the following transmission from this STA is performed in MU-MIMO.<br><br>Enumerated type:<br>NextMUMIMO<br>NextNotMUMIMO | Y | Y |
| HBF_TRAINING | SCRAMBLER_INIT_SETTING is CONTROL_TRAILER. | Indicates whether the following transmission from this STA is for hybrid beamforming training.<br><br>Enumerated type:<br>NextHBF<br>NextNotHBF | Y | Y |
| TX_SECTOR_CONFIG_INDEX | SCRAMBLER_INIT_SETTING is CONTROL_TRAILER. | An integer identifying the TX sector combination index.<br><br>Integer: range 0 to 63. | Y | Y |
| EDMG_GROUP_ID | MU_MIMO_NEXT is NextMUMIMO. | Indicates the identification of the MU-MIMO group of STAs that are involved in the following MU-MIMO transmission.<br><br>Integer: range 0 to 255. | Y | Y |
| MU_MIMO_TX_CONFIG_TYPE | MU_MIMO_NEXT is NextMUMIMO. | Indicates whether the MIMO phase of MU-MIMO beamforming training consisted of a nonreciprocal MIMO phase or a reciprocal MIMO phase.<br><br>Enumerated type:<br>Non_reciprocal_MU_MIMO_BF<br>Reciprocal_MU_MIMO_BF | Y | Y |


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**Table 28-1—TXVECTOR and RXVECTOR parameters(11ay) *(continued)***

| Parameter | Condition | Value | TXVECTOR | RXVECTOR |
|---|---|---|---|---|
| MU_MIMO_TX_CONFIG_INDEX | MU_MIMO_NEXT is NextMUMIMO. | An integer identifying the MU-MIMO configuration.<br><br>Integer: range 0 to 7. | Y | Y |
| IS_CHANNEL_NUMBER | SCRAMBLER_INIT_SETTING is CONTROL_TRAILER. | Indicates whether the value in the BW_IN_CT parameter represents a channel width or a channel number.<br><br>Enumerated type:<br>ChannelWidth<br>ChannelNumber | Y | Y |
| BW_IN_CT | SCRAMBLER_INIT_SETTING is CONTROL_TRAILER. | If the IS_CHANNEL_NUMBER is ChannelWidth, indicates a channel width. In this case, the format of this parameter is the same as the CH_BANDWIDTH parameter.<br><br>Otherwise, indicates a channel number. In this case, the format of this parameter is the same as the PRIMARY_CHANNEL parameter. | Y | Y |
| STREAM_FBCK | SCRAMBLER_INIT_SETTING is CONTROL_TRAILER. | Contains up to 8 pairs of spatial stream feedback. Each pair spatial stream feedback comprises an SNR and an RSSI and is defined as follows:<br>— STREAM_SNR: as defined in Table 28-39 (Control trailer definition when CT_TYPE is SSW_FEEDBACK, BLOCK_ACK, or ACK(11ay)).<br>— STREAM_RSSI: as defined in Table 28-39 (Control trailer definition when CT_TYPE is SSW_FEEDBACK, BLOCK_ACK, or ACK(11ay)). | Y | Y |
| NUM_SECTORS_MSB | SCRAMBLER_INIT_SETTING is CONTROL_TRAILER, CT_TYPE is GRANT_RTS_CTS2self. | Indicates the value of the Total Number of Sectors MSB field in the control trailer of a Grant or Grant Ack frame.<br><br>Integer: range 0 to 15. | Y | Y |
| NUM_ANT_MSB | SCRAMBLER_INIT_SETTING is CONTROL_TRAILER, CT_TYPE is GRANT_RTS_CTS2self. | Indicates the value of the Number of RX DMG Antennas MSB field in the control trailer of a Grant or Grant Ack frame. | Y | Y |

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**Table 28-1—TXVECTOR and RXVECTOR parameters(11ay) *(continued)***

| Parameter | Condition | Value | TXVECTOR | RXVECTOR |
|---|---|---|---|---|
| NUM_SECTORS | SCRAMBLER_INIT_SETTING is CONTROL_TRAILER, CT_TYPE is SPR. | Indicates the value of the Total Number of Sectors field in the control trailer of an SPR frame. | Y | Y |
| NUM_ANT | SCRAMBLER_INIT_SETTING is CONTROL_TRAILER, CT_TYPE is SPR. | Indicates the value of the Number of RX DMG Antennas field in the control trailer of an SPR frame. | Y | Y |
| SSSW_DIR | FORMAT is NON_EDMG, NON_EDMG_MODULATION is DMG_C_MODE, L_LENGTH is 6. | Indicates the direction of the transmission of a Short SSW PPDU.<br><br>Enumerated type:<br>Initiator indicates the frame is transmitted by the initiator.<br>Responder indicates the frame is transmitted by the responder. | Y | Y |
| SSSW_ADD_MODE | SSSW_DIR is Initiator. | Indicates the interpretation of the destination AID.<br><br>Enumerated type:<br>IndividualAddr: The destination AID field contains an individual address.<br>GroupAddr: The destination AID field contains a group address. | Y | Y |
| SSSW_SOURCE_AID | FORMAT is NON_EDMG, NON_EDMG_MODULATION is DMG_C_MODE, L_LENGTH is 6. | When the SSSW_DIR is set to Initiator, contains the AID of the STA that transmits the Short SSW PPDU, except if the transmitting STA is a PCP or an AP in which case this field contains the BSS AID or the transmitting STA is not associated to intended recipient in which case this field contains a random value in the range 0 to 255.<br><br>When the SSSW_DIR is set to Responder, contains the AID of the STA that transmits the Short SSW PPDU, except if the transmitting STA is a PCP or an AP in which case this field contains the BSS AID or the transmitting STA is not associated to the intended recipient in which case this field contains the value contained in the Source AID field in the received Short SSW PPDU during the preceding ISS. | Y | Y |


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**Table 28-1—TXVECTOR and RXVECTOR parameters(11ay) *(continued)***

| Parameter | Condition | Value | TXVECTOR | RXVECTOR |
|---|---|---|---|---|
| SSSW_DESTINATION_AID | FORMAT is NON_EDMG, NON_EDMG_ MODULATION is DMG_C_MODE, L_LENGTH is 6. | When the SSSW_DIR is set to Initiator, contains the AID of the STA addressed by the Short SSW PPDU, except if the addressed STA is a PCP or an AP in which case this field contains the BSS AID or the transmitting STA is not associated to the intended recipient in which case this field contains a random value in the range 0 to 255.<br><br>When the SSSW_DIR is set to Responder, contains the AID of the STA that transmits the Short SSW PPDU, except if the transmitting STA is a PCP or an AP in which case this field contains the BSS AID or the transmitting STA is not associated to the intended recipient in which case this field contains the value contained in the Destination AID field in the received Short SSW PPDU during the preceding ISS. | Y | Y |
| SSSW_CDOWN | FORMAT is NON_EDMG, NON_EDMG_ MODULATION is DMG_C_MODE, L_LENGTH is 6. | A down counter indicating the number of remaining Short SSW PPDU transmissions and LBIFSs to the end of the TXSS/RXSS across all DMG antennas. This parameter is set to 0 in the last Short SSW PPDU transmission. | Y | Y |
| SSSW_RF_CHAIN_ID | FORMAT is NON_EDMG, NON_EDMG_ MODULATION is DMG_C_MODE, L_LENGTH is 6. | Identifies the transmit chain currently being used for the transmission. Can take the values in the range 1 to 8. | Y | Y |
| SSSW_BSSID | SSSW_DIR is Initiator, SSSW_ADD_MODE is IndividualAddr. | Contains the BSSID of the BSS. | Y | Y |
| SSSW_UNASSOCIATED | SSSW_DIR is Initiator, SSSW_ADD_MODE is IndividualAddr. | Indicates whether the transmitting STA is associated to the intended recipient.<br><br>Enumerated type:<br>Associated: if the transmitting STA is associated to the intended recipient.<br>Unassociated: if the transmitting STA is not associated to the intended recipient. | Y | Y |

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**Table 28-1—TXVECTOR and RXVECTOR parameters(11ay) *(continued)***

| Parameter | Condition | Value | TXVECTOR | RXVECTOR |
|---|---|---|---|---|
| SSSW_SISO_FEEDBACK_DURATION | SSSW_DIR is Initiator. | Specifies the duration, in microseconds, of the SISO Feedback subphase that starts following the Short SSW PPDU transmission with CDOWN field equal to 0. | Y | Y |
| SSSW_FEEDBACK | SSSW_DIR is Responder. | Contains the value of the CDOWN field of the Short SSW PPDU that was received with the best quality in the immediately preceding sector sweep. The determination of which PPDU was received with the best quality is implementation dependent. | Y | Y |
| EXPANSION_MAT | FORMAT is EDMG and EXPANSION_MAT_TYPE is COMPRESSED_SV. | Contains a set of compressed digital beamforming feedback matrices as defined in 9.4.2.283 (Digital BF Feedback element(11ay)). The number of elements depends on the number of subcarriers, the number of spatial streams and the number of transmit chains. | Y | N |
| | FORMAT is EDMG and EXPANSION_MAT_TYPE is NON_COMPRESSED_SV. | Contains a set of noncompressed beamforming feedback matrices as defined in 9.4.2.283 (Digital BF Feedback element(11ay)). The number of complex elements depends on the number of feedback taps per element of the SC feedback matrix, the number of columns, and the number of rows in each matrix. | Y | N |
| | FORMAT is EDMG and EXPANSION_MAT_TYPE is CSI_MATRICES. | Contains a set of CSI matrices as defined in 9.4.2.267 (EDMG Channel Measurement Feedback element(11ay)). The number of complex elements depends on the number of feedback taps per element of the SC feedback matrix, the number of columns, and the number of rows in each matrix. | Y | N |
| | Otherwise | Not present | N | N |
| EXPANSION_MAT_TYPE | EXPANSION_MAT is present. | Enumerated type:<br>COMPRESSED_SV indicates that EXPANSION_MAT is a set of compressed beamforming feedback matrices.<br>NON_COMPRESSED_SV indicates that EXPANSION_MAT is a set of noncompressed beamforming feedback matrices.<br>CSI_MATRICES indicates that EXPANSION_MAT is a set of channel state matrices. | Y | N |


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**Table 28-1—TXVECTOR and RXVECTOR parameters(11ay) *(continued)***

| Parameter | Condition | Value | TXVECTOR | RXVECTOR |
|---|---|---|---|---|
| CHANNEL_MEASUREMENT | FORMAT is EDMG. | Channel measurement, including real and imaginary parts, based on measurements performed on received TRN field. | N | Y |
| SCRAMBLER_RESET | FORMAT is EDMG or FORMAT is NON_EDMG. | Indicates that the scrambler has to be reset before the start of the PPDU.<br><br>Enumerated Type:<br>RESET_SCRAMBLER: The scrambler has to be reset.<br>NO_SCRAMBLER_RESET: The scrambler does not have to be reset. | Y | N |
| SECURED_TRN(11az) | FORMAT is EDMG, EDMG_MODULATION is EDMG_SC_MODE, NUM_USERS is 1, NUM_STS is 1. | Indicates whether the TRN field, if present in the PPDU, contains Secure TRN sequences.<br><br>Enumerated type:<br>SECURED_TRN<br>NON_SECURED_TRN | Y | Y |
| | Otherwise. | Not present. | N | N |
| SECURED_TRN SEQUENCES(11az) | FORMAT is EDMG, EDMG_MODULATION is EDMG_SC_MODE, NUM_USERS is 1, NUM_STS is 1. | Provides the secure TRN sequences used in the EDMG secure ranging PPDU. | Y | N |
| | Otherwise. | Not present. | N | N |
| FIRST_PATH_AWV_TR (11az) | FORMAT is EDMG, EDMG_MODULATION is EDMG_SC_MODE, NUM_USERS is 1, NUM_STS is 1. | Enumerated Type<br>FIRST_PATH_AWV_ON_TRN<br>BEST_PATH_AWV_ON_TRN<br>Indicates whether the TRN field of the PPDU is transmitted using the first path AWV or the best path AWV. | Y | N |
| | Otherwise. | Not present. | N | N |

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**Table 28-1—TXVECTOR and RXVECTOR parameters(11ay) *(continued)***

| Parameter | Condition | Value | TXVECTOR | RXVECTOR |
|---|---|---|---|---|
| NOTE 1—In the (#4177)TXVECTOR and RXVECTOR columns, the following apply: Y = Present; N = Not present: O = Optional; SU = indicates that the parameter is present for each spatial stream. Those parameters are conceptually supplied as an array of values indexed by values 0 to NUM_STS – 1 if STBC is not applied or indexed by 0 to (NUM_STS/2 – 1) if STBC is applied; MU = indicates that the parameter is present once for an EDMG SU PPDU and present per user for an EDMG MU PPDU. Parameters specified to be present per user are conceptually supplied as an array of values indexed by values 0 to NUM_USERS – 1; SU+MU = indicates that the parameter is present for each spatial stream and each user. Those parameters are conceptually supplied as a two dimensional array of values indexed by values 0 to NUM_STS – 1 if STBC is not applied or 0 to (NUM_STS/2 – 1) if STBC is applied by 0 to NUM_USERS – 1.<br>NOTE 2—If the condition specified in the "Condition" is not satisfied, the parameter is not present in either the TXVECTOR or RXVECTOR.<br>NOTE 3—"Y" if dot11TimingMsmtActivated is true; otherwise, "N". | | | | |

### 28.2.3 PHYCONFIG_VECTOR parameters

The PHYCONFIG_VECTOR carried in a PHY-CONFIG.request primitive for an EDMG PHY contains a CHANNEL_WIDTH parameter, which identifies the operating channel width and takes one of the values 2.16 GHz, 4.32 GHz, 6.48 GHz, 8.64 GHz, 2.16+2.16 GHz, or 4.32+4.32 GHz. The PHY shall set dot11EDMGCurrentChannelWidth to the value of this parameter.

The PHYCONFIG_VECTOR carried in a PHY-CONFIG.request primitive for an EDMG PHY contains a CHANNEL_CENTER_CHANNEL_NUMBER_0(#6420) parameter, which identifies the center frequency of the 2.16 GHz, 4.32 GHz, 6.48 GHz, and 8.64 GHz channel. For 2.16+2.16 GHz channel configuration, it identifies the center frequency of the primary channel. For 4.32+4.32 GHz channel configuration, it identifies the center frequency of the 4.32 GHz channel containing the primary 2.16 GHz channel. The PHY shall set dot11EDMGCurrentChannelCenterFrequencyIndex0 to the value of this parameter defined in the range 1 to 15 (see Table 28-20 (Parameters that specify a channel used by an EDMG STA(11ay))).

The PHYCONFIG_VECTOR carried in a PHY-CONFIG.request primitive for an EDMG PHY contains a CHANNEL_CENTER_CHANNEL_NUMBER_1(#6420) parameter, which for 2.16+2.16 GHz channel configuration identifies the center frequency of the secondary channel. For 4.32+4.32 GHz channel configuration, it identifies the center frequency of the 4.32 GHz channel that contains the secondary 2.16 GHz channels only. The PHY shall set dot11EDMGCurrentChannelCenterFrequencyIndex1 to the value of this parameter defined in the range 1 to 15 (see Table 28-20 (Parameters that specify a channel used by an EDMG STA(11ay))).

The PHYCONFIG_VECTOR carried in a PHY-CONFIG.request primitive for an EDMG PHY contains an OPERATING_CHANNEL parameter, which identifies the operating or primary 2.16 GHz channel. The PHY shall set dot11EDMGCurrentPrimaryChannel to the value of this parameter defined in the range 1 to 15 (see Table 28-20 (Parameters that specify a channel used by an EDMG STA(11ay))).


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The PHYCONFIG_VECTOR carried in a PHY-CONFIG.request primitive for an EDMG PHY contains a set of up to 8 RX_CHAIN_ID_ASSIGNMENT parameters, each taking values from the set {DMG_ANT1, DMG_ANT2, DMG_ANT3, DMG_ANT4, DMG_ANT5, DMG_ANT6, DMG_ANT7, DMG_ANT8}.

The valid channel configurations for an EDMG STA and configuration rules are defined in 28.3.4 (Channelization).

### 28.2.4 Support for NON_EDMG formats

#### 28.2.4.1 General

An EDMG STA logically encompasses Clause 20 (Directional multi-gigabit (DMG) PHY specification) and Clause 28 (Enhanced directional multi-gigabit (EDMG) PHY specification(11ay)) PHYs. The MAC interfaces to the PHY via the Clause 28 (Enhanced directional multi-gigabit (EDMG) PHY specification(11ay)) PHY service interface, which in turn interacts with Clause 20 (Directional multi-gigabit (DMG) PHY specification) PHY service interface. The EDMG PHY TXVECTOR and RXVECTOR defined in 28.2.2 (TXVECTOR and RXVECTOR parameters) structurally include all fields of the DMG TXVECTOR and RXVECTOR accordingly defined in 20.2.2 (TXVECTOR and RXVECTOR parameters). The EDMG PHY TXSTATUS vector is identical to the TXSTATUS vector defined for DMG PHY in 20.2.3 (PHYCONFIG_VECTOR parameters). The EDMG PHYCONFIG_VECTOR defined in 28.2.3 (PHYCONFIG_VECTOR parameters) structurally includes all fields of the DMG PHYCONFIG_VECTOR.

#### 28.2.4.2 EDMG STA PHY entity configuration for transmission

Figure 28-1 (EDMG STA PHY interaction on transmit for various PPDU formats(11ay)) shows an EDMG STA PHY SAP interactions on transmit for different PPDU formats.

The selection of the PHY type is based on the FORMAT parameter included into the TXVECTOR and transferred from MAC to PHY entity using PHY-TXSTART.request(TXVECTOR) primitive.

If the FORMAT parameter is (M118)equal to EDMG, then Clause 28 (Enhanced directional multi-gigabit (EDMG) PHY specification(11ay)) PHY entity is used for transmission. The transmission mode is selected based on the TXVECTOR EDMG_MODULATION parameter and it can be set to EDMG_C_MODE for the EDMG control mode (28.4 (EDMG and non-EDMG control mode)), EDMG_SC_MODE for the EDMG SC mode (28.5 (EDMG and non-EDMG SC mode)), and EDMG_OFDM for EDMG OFDM mode (28.6 (EDMG OFDM mode)).

If the FORMAT parameter is (M118)equal to NON_EDMG and the TXVECTOR NON_EDMG_MODULATION parameter is (M118)equal to either NON_EDMG_DUP_C_MODE or NON_EDMG_DUP_SC_MODE, then Clause 28 (Enhanced directional multi-gigabit (EDMG) PHY specification(11ay)) PHY entity is used for transmission. If NON_EDMG_MODULATION parameter is (M118)equal to the NON_EDMG_DUP_C_MODE, then the non-EDMG control mode transmission defined in 28.4.7.2 (Non-EDMG PPDU transmission) is selected. If NON_EDMG_MODULATION parameter is (M118)equal to the NON_EDMG_DUP_SC_MODE, then the non-EDMG SC mode defined in 28.5.10.3 (Non-EDMG PPDU transmission) is selected.

If the FORMAT parameter is (M118)equal to NON_EDMG and NON_EDMG_MODULATION is (M118)equal to either DMG_C_MODE or DMG_SC_MODE, then Clause 20 (Directional multi-gigabit (DMG) PHY specification) PHY entity is used for transmission. The TXVECTOR content is filtered out while transferring to the Clause 20 (Directional multi-gigabit (DMG) PHY specification) PHY entity to keep the DMG fields only to define the TXVECTOR in accordance with DMG PHY SAP interface (see 20.2.2 (TXVECTOR and RXVECTOR parameters)). If NON_EDMG_MODULATION is (M118)equal to the DMG_C_MODE, then the DMG control mode defined in 20.4 (DMG control mode) is selected. If

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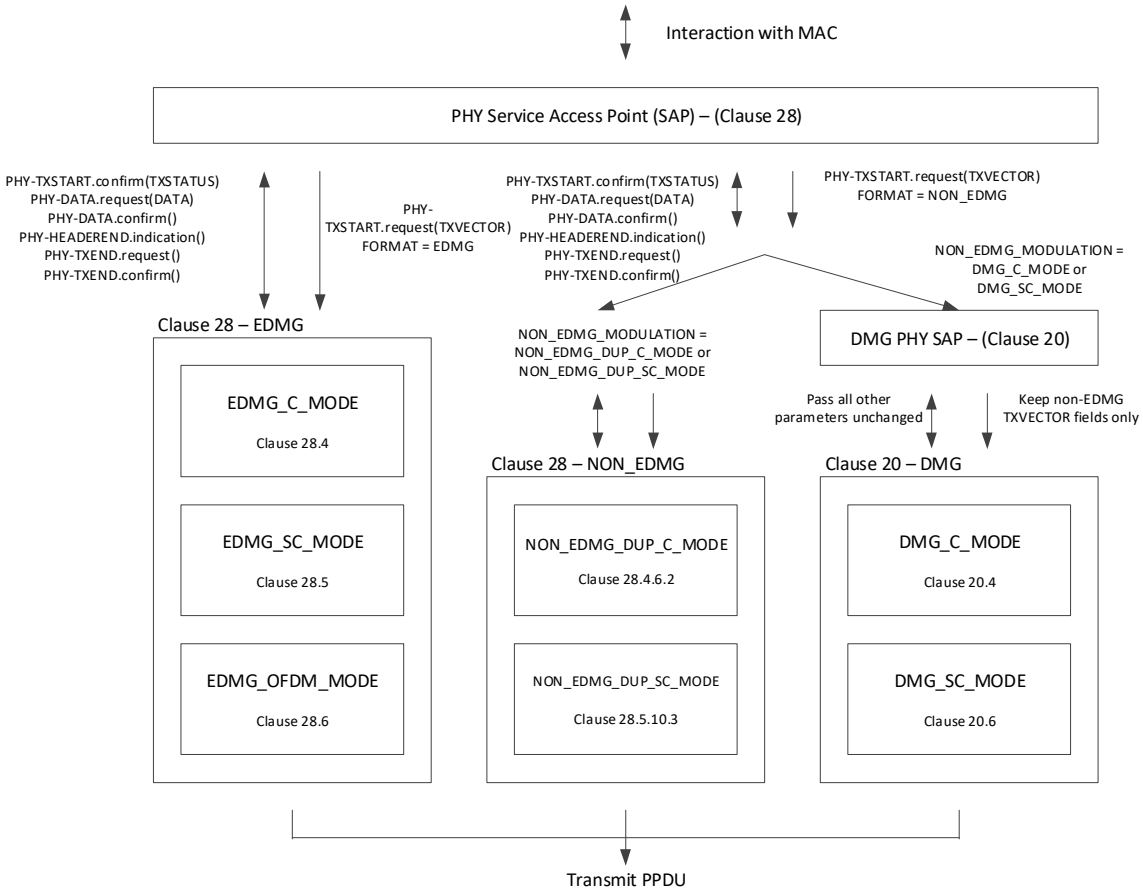


**Figure 28-1—EDMG STA PHY interaction on transmit for various PPDU formats(11ay)**

NON_EDMG_MODULATION is (M118)equal to the DMG_SC_MODE, then the DMG SC mode defined in 20.6 (DMG low-power SC mode) is selected.

### 28.2.4.3 EDMG STA PHY entity configuration for reception

Figure 28-2 (EDMG STA PHY interaction on receive for various PPDU formats(11ay)) shows an EDMG


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STA PHY SAP interactions on receive for different PPDU formats.

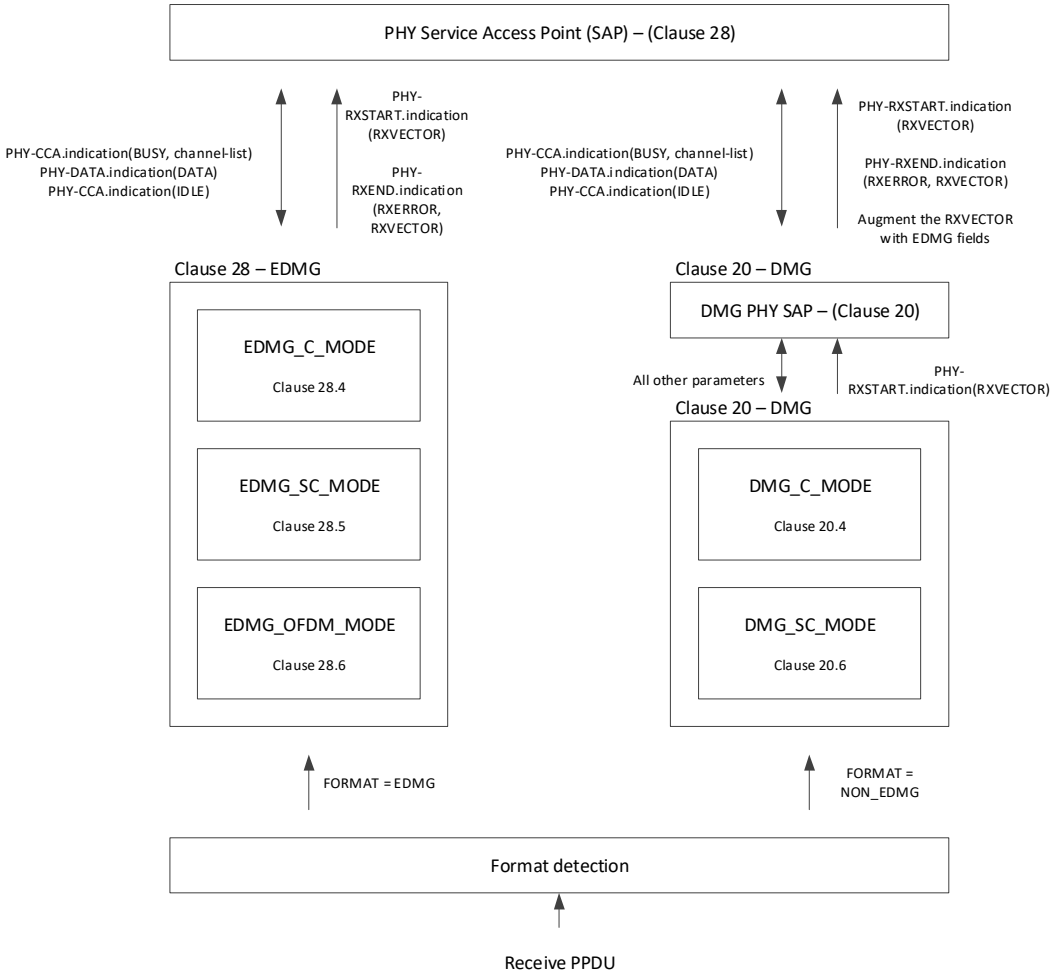


**Figure 28-2—EDMG STA PHY interaction on receive for various PPDU formats(11ay)**

The selection of the PHY type at the reception is based on the FORMAT detection. For a control mode PPDU, if bits 22 and 23 of the L-Header are both 1, the Scrambler Initialization field B0 is 0, B1 is 1, B2 and B3 are reserved, and the Turnaround field is 0, then the FORMAT parameter is set to the EDMG. Otherwise, the FORMAT parameter is set to the NON_EDMG.

For an(#1424) (#8160)EDMG SC and an (#8160)EDMG OFDM mode PPDU, if bit 46 of the L-Header is 1, then the FORMAT parameter is set to the EDMG. Otherwise, the FORMAT parameter is set to the NON_EDMG.

If the FORMAT is EDMG, then Clause 28 (Enhanced directional multi-gigabit (EDMG) PHY specification(11ay)) PHY entity is used for reception. If the FORMAT is EDMG and the PHY entity detects the Gb Golay sequence in the L-STF field, then the EDMG_MODULATION parameter is set to the EDMG_C_MODE. If the FORMAT is EDMG and the PHY entity detects the Ga Golay sequence in the L-STF field and the IsSC field of L-Header is(M118) 1, then the EDMG_MODULATION parameter is set to the EDMG_SC_MODE. If the FORMAT is EDMG and the PHY entity detects the Ga Golay sequence in the L-STF field and the IsSC field of L-Header is(M118) 0, then the EDMG_MODULATION parameter is set to the EDMG_OFDM_MODE.

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If the FORMAT is NON_EDMG, then Clause 20 PHY entity is used for reception. If the FORMAT is NON_EDMG and PHY entity detects the Gb Golay sequence in the L-STF field, then the NON_EDMG_MODULATION parameter is set to the DMG_C_MODE. If the FORMAT is NON_EDMG and the PHY entity detects the Ga Golay sequence in the L-STF field, then the NON_EDMG_MODULATION parameter is set to the DMG_SC_MODE. The RXVECTOR content is augmented with the EDMG fields to define the RXVECTOR in accordance with EDMG PHY SAP interface (see 28.2.2 (TXVECTOR and RXVECTOR parameters)). The augmented RXVECTOR is passed to the EDMG PHY SAP interface.

The EDMG STA performs the non-EDMG PPDU detection and reception in the primary 2.16 GHz channel only.

#### 28.2.4.4 EDMG STA PHY entity channel bandwidth configuration

Figure 28-3 (EDMG STA PHY interaction on channel bandwidth configuration for Clause 28 (Enhanced directional multi-gigabit (EDMG) PHY specification) and Clause 20 PHYs(11ay)) shows an EDMG STA PHY SAP operating channel bandwidth configuration using the PHYCONFIG_VECTOR parameters.

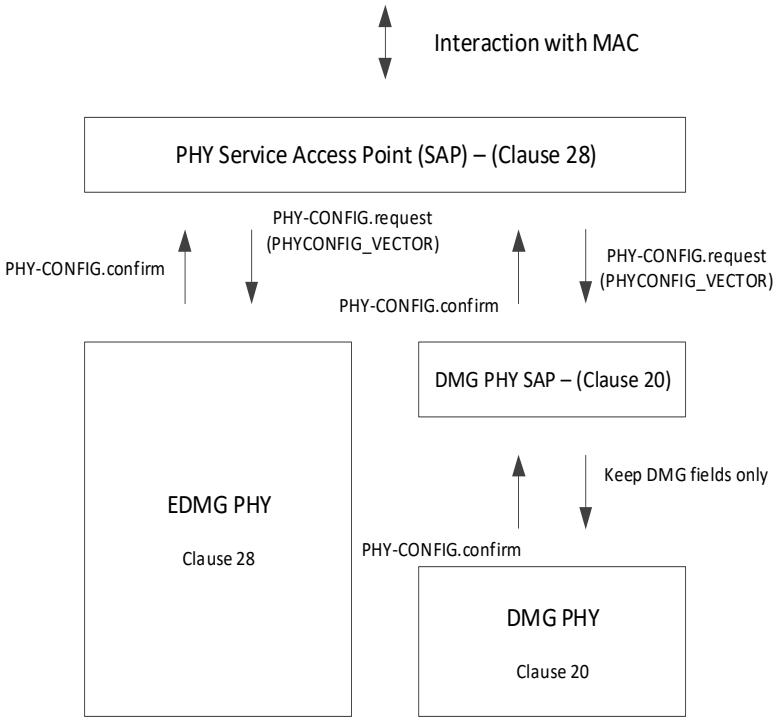


**Figure 28-3—EDMG STA PHY interaction on channel bandwidth configuration for Clause 28 (Enhanced directional multi-gigabit (EDMG) PHY specification) and Clause 20 PHYs(11ay)**

The EDMG STA PHY entity configuration is performed using the PHYCONFIG_VECTOR parameters defined in 28.2.3 (PHYCONFIG_VECTOR parameters). The configuration of the Clause 28 (Enhanced directional multi-gigabit (EDMG) PHY specification(11ay)) PHY entity shall follow the rules defined in 28.3.4 (Channelization) for the configuration of the following PLME MIB parameters:

— dot11EDMGCurrentChannelWidth
— dot11ChannelCenterFrequencyIndex
— dot11EDMGCurrentChannelCenterFrequencyIndex0


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— dot11EDMGCurrentChannelCenterFrequencyIndex1
— dot11EDMGCurrentPrimaryChannel

The configuration of Clause 20 (Directional multi-gigabit (DMG) PHY specification) PHY entity by an EDMG STA is performed by setting the OPERATING_CHANNEL parameter, which identifies the operating or primary 2.16 GHz channel. The PHY shall set dot11EDMGCurrentPrimaryChannel to the value of this parameter defined in the range 1 to 15 (see Table 28-20 (Parameters that specify a channel used by an EDMG STA(11ay))). The configuration of OPERATING_CHANNEL parameter (dot11EDMGCurrentPrimaryChannel) shall follow the rules defined in 28.3.4 (Channelization). All other parameters of the EDMG PHYCONFIG_VECTOR are filtered out while transferring to the Clause 20 (Directional multi-gigabit (DMG) PHY specification) PHY entity to keep the DMG fields only to define the PHYCONFIG_VECTOR in accordance with the DMG PHY SAP interface.

#### 28.2.4.5 EDMG STA PHY CCA

The EDMG STA shall follow the CCA requirements defined in 28.3.8 (CCA sensitivity) for both Clause 28 (Enhanced directional multi-gigabit (EDMG) PHY specification(11ay)) and Clause 20 (Directional multi-gigabit (DMG) PHY specification) PHY entities.

### 28.2.5 TXSTATUS parameters

The parameters listed in Table 20-2 (TXSTATUS parameters) (in 28.3.1 (Introduction)) are defined as part of the TXSTATUS parameter list in the PHY-TXSTART.confirm(TXSTATUS) primitive.

## 28.3 Common parameters

### 28.3.1 Introduction

Subclauses 28.4 (EDMG and non-EDMG control mode), 28.5 (EDMG and non-EDMG SC mode), and 28.6 (EDMG OFDM mode) provide a procedure for converting PSDUs to PPDUs. During transmission, the PSDU is processed (i.e., scrambled, coded and modulated) and appended to the PHY preamble to create the PPDU. At the receiver, the PHY preamble is processed to aid in demodulation and delivery of the PSDU.

Two preamble formats are defined. For EDMG format operation, the preamble has a non-EDMG portion and an EDMG portion. The non-EDMG portion of the EDMG format preamble enables detection of the PPDU and acquisition of carrier frequency and timing by both non-EDMG and EDMG STAs. To be decodable by non-EDMG and EDMG STAs compliant with Clause 20 (Directional multi-gigabit (DMG) PHY specification), the following applies:

— If the Short Training field and Channel Estimation field of the non-EDMG portion indicate a control mode transmission, the non-EDMG portion of the EDMG format preamble includes the Header field defined in Clause 20 (Directional multi-gigabit (DMG) PHY specification) for the (#8160)DMG control mode (see 20.4 (DMG control mode)).
— In all other cases, the non-EDMG portion of the EDMG format preamble includes the Header field defined in Clause 20 (Directional multi-gigabit (DMG) PHY specification) for the (#8160)DMG SC mode (see 20.6 (DMG low-power SC mode)).

The EDMG portion of the EDMG format preamble enables estimation of the channel to support demodulation of the PSDU transmitted over 2.16 GHz, 4.32 GHz, 6.48 GHz, 8.64 GHz, 2.16+2.16 GHz, and 4.32+4.32 GHz channels with single and multiple spatial streams. The EDMG portion of the EDMG format preamble includes the EDMG-Header-A field and may include EDMG-Header-B field.

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Table 28-2 (Frequently used parameters(11ay)) defines the symbol notations used throughout this clause.

**Table 28-2—Frequently used parameters(11ay)**

| Symbol | Explanation |
|---|---|
| $i_{SS}$ | Spatial stream number. |
| $N_{SS}$ | Total number of spatial streams. |
| $N_{SS\,i_{user}}$ | Total number of spatial streams for $i_{user}^{th}$ user. |
| $i_{STS}$ | Space-time stream number. |
| $N_{STS}$ | Total number of space-time streams. |
| $N_{STS\,i_{user}}$ | Total number of space-time streams for $i_{user}^{th}$ user. |
| $i_{STS\,i_{user}}$ | Space-time stream number for $i_{user}^{th}$ user. |
| $i_{user}$ | User number. |
| $N_{user}$ | Total number of users. |
| $i_{TX}$ | Transmit chain number. |
| $N_{TX}$ | Total number of transmit chains. |
| $N_{up}$ | Upsampling factor. |
| $N_{CB}$ | Number of contiguous 2.16 GHz channels, $N_{CB}$ = 1 for 2.16 GHz and 2.16+2.16 GHz, $N_{CB}$ = 2 for 4.32 GHz and 4.32+4.32 GHz, $N_{CB}$ = 3 for 6.48 GHz, and $N_{CB}$ = 4 for 8.64 GHz channel. |
| $i_{PPDU}$ | PPDU number aggregated into the EDMG A-PPDU. |
| $N_{PPDU}$ | Total number of PPDUs aggregated into the EDMG A-PPDU. |
| $h_{SCCB}$ | Shaping filter impulse response defined at the $N_{up} \times F_c$ sampling rate, where $F_c$ is defined in 28.5.2.2 (Timing-related parameters). |
| $Q$ | Spatial mapping matrix of size $N_{TX}$ by $N_{STS}$, independent of subcarrier index. |
| $Q_{non-EDMG}$ | Spatial mapping matrix of size $N_{TX}$ by $N_{STS}$, applied to a non-EDMG PPDU transmission and independent of subcarrier index. |
| $Q_{pre-EDMG}$ | Spatial mapping matrix of size $N_{TX}$ by $N_{STS}$, applied to the pre-EDMG fields of an EDMG PPDU transmission and independent of subcarrier index. |
| $Q_{EDMG}$ | Spatial mapping matrix of size $N_{TX}$ by $N_{STS}$, applied to the EDMG fields of an EDMG PPDU transmission and independent of subcarrier index. |
| $Q_k$ | Spatial mapping matrix of size $N_{TX}$ by $N_{STS}$, defined for $k^{th}$ subcarrier. |
| $Q_{EDMG\,k}$ | Spatial mapping matrix of size $N_{TX}$ by $N_{STS}$, applied to the EDMG fields of an EDMG PPDU transmission and defined for the $k^{th}$ subcarrier. |
| $Length_{i_{user}}$ | PSDU length in octets for $i_{user}^{th}$ user. |
| $L_{CW}$ | LDPC codeword length in bits, it can be equal to 468, 504, 624, 672, 936, 1008, 1248, and 1344. |
| $L_{CW\,i_{user}}$ | LDPC codeword length for the $i_{user}^{th}$ user. |
| $L_{CWD}$ | Number of systematic data bits per LDPC codeword. |


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**Table 28-2—Frequently used parameters(11ay) *(continued)***

| Symbol | Explanation |
|---|---|
| $L_{CWP}$ | Number of parity bits per LDPC codeword. |
| $R_{i_{user}}$ | LDPC code rate for the $i_{user}^{th}$ user and can be equal to1/2, 5/8, 2/3, 3/4, 13/16, 5/6, 7/8. |
| $\rho_{i_{user}}$ | Repetition factor for $i_{user}^{th}$ user; is equal to 2 for MCS 1 and equal to 1 for all other MCSs, applied for EDMG SC mode only. |
| $N_{CW\ i_{user}}$ | Total number of LDPC codewords for the $i_{user}^{th}$ user. |
| $N_{DATA\_PAD i_{user}}$ | Number of pad bits for $i_{user}^{th}$ user to get integer number of LDPC codewords. |
| $N_{BLKS\ i_{user}}$ | Total number of SC symbol blocks for the $i_{user}^{th}$ user, applied for EDMG SC mode only. |
| $N_{SYMS\ i_{user}}$ | Total number of OFDM symbols for $i_{user}^{th}$ user, applied for EDMG OFDM mode only. |
| $N_{BLKS\,\min}$ | Minimum number of total SC symbol blocks for a PPDU carrying a BRP frame transmission, applied for EDMG SC mode only. |
| $N_{SYMS\,\min}$ | Minimum number of total OFDM symbols for PPDU carrying a BRP frame transmission, applied for EDMG OFDM mode only. |
| $N_{BLK\_PAD i_{user}}$ | Number of pad bits for the $i_{user}^{th}$ user to reach an integer number of SC symbol blocks, applied for EDMG SC mode only. |
| $N_{SYM\_PAD i_{user}}$ | Number of pad bits for the $i_{user}^{th}$ user to get integer number of OFDM symbols, applied for EDMG OFDM mode only. |
| $N_{CBPB}$ | Total number of coded bits per SC symbol block, applied for EDMG SC mode only. |
| $N_{CBPS}$ | Number of coded bits per symbol (constellation point) for EDMG SC mode and per OFDM symbol for EDMG OFDM mode. |
| $N_{CBPS\ i_{user}\ i_{SS}}$ | Number of coded bits per symbol (constellation point) for the $i_{user}^{th}$ user and $i_{SS}^{th}$ spatial stream, applied for EDMG SC mode only. |
| $N_{SPB}$ | Total number of symbols (constellation points) per SC symbol block, applied for EDMG SC mode only. |
| $N_{BPSC}$ | Number of coded bits per constellation point, applied for EDMG OFDM mode only. |
| $N_{BPSC\ i_{user}\ i_{SS}}$ | Number of coded bits per constellation point for the $i_{user}^{th}$ user and $i_{SS}^{th}$ spatial stream, applied for EDMG OFDM mode only. |
| $N_{BLKS\,\max}$ | Maximum total number of SC symbol blocks over all users, applied for EDMG SC mode only. |
| $N_{SYMS\,\max}$ | Maximum total number of OFDM symbols over all users, applied for EDMG OFDM mode only. |
| $N_{PAD\_BLKS\ i_{user}}$ | The number of pad SC symbol blocks for the $i_{user}^{th}$ user that is required to align PPDUs over different users in time, applied for EDMG SC mode only. |
| $N_{PAD\_SYMS\ i_{user}}$ | The number of pad OFDM symbols for the $i_{user}^{th}$ user required to align PPDUs over different users in time, applied for EDMG OFDM mode only. |
| $N_{BLKSspoof}$ | Number of SC symbol blocks for the last PPDU in an EDMG A-PPDU to reach the spoofing EDMG A-PPDU duration, applied for EDMG SC mode only. |
| $N_{SYMSspoof}$ | Number of OFDM symbols for the last PPDU in an EDMG A-PPDU to reach the spoofing EDMG A-PPDU duration, applied for EDMG OFDM mode only. |

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### 28.3.2 EDMG PPDU format

#### 28.3.2.1 General

A single PPDU format is defined for all EDMG PHYs: the EDMG PPDU format. Figure 28-4 (EDMG PPDU format(11ay)) shows the EDMG PPDU format and all possible fields. Not all fields are transmitted in an EDMG PPDU. Fields are included depending on whether the PPDU is an SU PPDU, an MU PPDU, or a part of an A-PPDU.

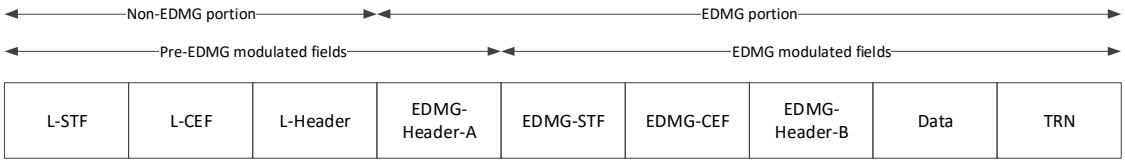


**Figure 28-4—EDMG PPDU format(11ay)**

The fields of the EDMG PPDU format are summarized in Table 28-3 (Fields of the EDMG PPDU(11ay)).

**Table 28-3—Fields of the EDMG PPDU(11ay)**

| Field | Description |
|---|---|
| L-STF | Non-EDMG Short Training field |
| L-CEF | Non-EDMG Channel Estimation field |
| L-Header | Non-EDMG Header field |
| EDMG-Header-A | EDMG Header A field |
| EDMG-STF | EDMG Short Training field |
| EDMG-CEF | EDMG Channel Estimation field |
| EDMG-Header-B | EDMG Header B field |
| Data | The Data field carries the PSDU(s) |
| TRN | Training sequence field |

(11az)NOTE—For EDMG secure ranging PPDU, the TRN field contains secure TRN sequences.

The EDMG-Header-A, EDMG-STF, EDMG-CEF, and EDMG-Header-B fields exist only in EDMG PPDUs.


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Table 28-4 (Data field content based on the values of B46 and B37 in the L-Header field(11ay)) describes the content of the Data field of a PPDU depending on values of specific bits in the L-Header.

**Table 28-4—Data field content based on the values of B46 and B37 in the L-Header field(11ay)**

| B46 | B37 | Data field content |
|---|---|---|
| 0 | 0 | DMG MPDU |
| 0 | 1 | DMG A-MPDU |
| 1 | 0 | EDMG MPDU |
| 1 | 1 | EDMG A-MPDU |

### 28.3.2.2 EDMG A-PPDU format

An EDMG A-PPDU is defined as a concatenation of EDMG PPDUs defined in 28.3.2.1 (General). An EDMG A-PPDU shall be transmitted to a single user and shall not be transmitted to multiple users. Figure 28-5 (EDMG A-PPDU format(11ay)) shows the EDMG A-PPDU format and all possible fields. The first PPDU of an EDMG A-PPDU includes L-STF, L-CEF, L-Header, EDMG-Header-A, EDMG-STF, EDMG-CEF, and Data fields, and each subsequent PPDU includes EDMG-Header-A and Data fields only. The TRN field, if present, is appended only once at the end of an EDMG A-PPDU. Not all fields are transmitted in an EDMG A-PPDU. Fields are included depending on the values of $N_{CB}$ and $N_{STS}$. The EDMG-Header-A field preceding a Data field defines the parameters of the PSDU transmitted in the Data field.

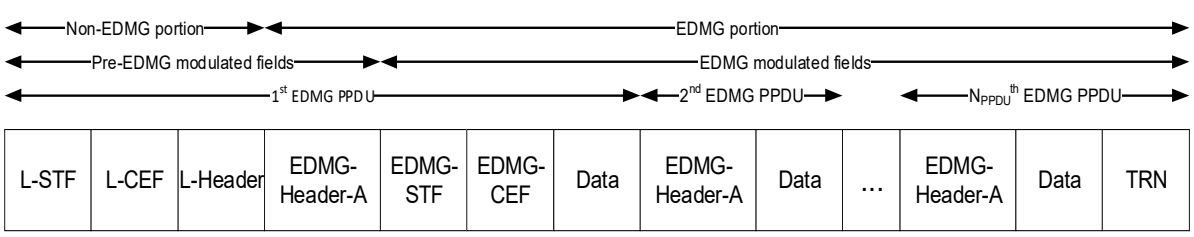


**Figure 28-5—EDMG A-PPDU format(11ay)**

### 28.3.3 EDMG preamble

#### 28.3.3.1 General

This subclause defines the EDMG format preamble, which includes a non-EDMG portion and an EDMG portion.

For a single PPDU transmission, the fields of the non-EDMG portion of the EDMG format preamble and the EDMG-Header-A field of the EDMG portion of the EDMG format preamble form the pre-EDMG modulated fields. The subsequent fields in the PPDU are referred to as EDMG modulated fields (see Figure 28-4 (EDMG PPDU format(11ay))).

For an EDMG A-PPDU transmission, the fields of the non-EDMG portion of the EDMG format preamble and the EDMG-Header-A field of the EDMG portion of the EDMG format preamble of the first EDMG

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PPDU form the pre-EDMG modulated fields, and subsequent fields in the EDMG A-PPDU are referred to as EDMG modulated fields (see Figure 28-5 (EDMG A-PPDU format(11ay))).

For 4.32 GHz, 6.48 GHz and 8.64 GHz EDMG PPDU transmissions, the pre-EDMG modulated fields shall be transmitted using the non-EDMG duplicate format (28.5.10.4.4.2 (Pre-EDMG modulated fields transmission)).

The pre-EDMG modulated fields when transmitted on each secondary channel shall have a relative delay with respect to the corresponding fields transmitted over the primary channel that is between zero (inclusive) and $T_c$ (inclusive), where $T_c$ is defined in Table 28-47 (EDMG SC mode timing-related parameters(11ay)). The relative delay applicable to each secondary channel transmission may be different from each other, so long as it follows this rule.

#### 28.3.3.2 Non-EDMG portion of EDMG format preamble

##### 28.3.3.2.1 General

The non-EDMG portion of the EDMG format preamble includes the L-STF, L-CEF and L-Header fields. These fields are defined at the DMG SC chip rate $F_c$ in 20.4.3.1.2 (Short Training field), 20.3.6.2 (Short Training field), 20.3.6.3 (Channel Estimation field), 20.4.3.2 (Header), and 20.5.3.1 (Header).

##### 28.3.3.2.2 L-STF definition

(#2351)For an EDMG control mode PPDU, the L-STF is the same as the Short Training field used by DMG Control PPDUs defined in 20.4.3.1.2 (Short Training field). For other types of EDMG PPDUs, the L-STF is the same as the Short Training field used by DMG SC PPDUs defined in 20.3.6.2 (Short Training field).

##### 28.3.3.2.3 L-CEF definition

The L-CEF for all types of EDMG PPDUs is the same as the Channel Estimation field used by DMG SC PPDUs defined in 20.3.6.3 (Channel Estimation field).

##### 28.3.3.2.4 L-Header definition

###### 28.3.3.2.4.1 General

For EDMG and non-EDMG PPDUs, spoofing error is defined as the difference between the PPDU duration calculated based on L-Header and the actual PPDU duration.

The structure of the L-Header field is defined as follows:

— For an EDMG control mode PPDU and a non-EDMG control mode PPDU transmitted with the control trailer or carrying bandwidth signaling information, the L-Header field is the same as the DMG control mode header field (see Table 20-11 (DMG control mode header fields)) except that the reserved bits 22 and 23 shall be both set to 1. In this case, the combination of the Turnaround field and the Scrambler Initialization field in the L-Header indicates the transmission mode:
  — If Turnaround field is 0, then the interpretation of the Scrambler Initialization field is defined in Table 28-5 (Definition of Scrambler Initialization field when transmitted using the control mode and the Turnaround field is 0(11ay)).
  — If Turnaround field is 1 and the PPDU contains an RTS, a DMG CTS, a DMG DTS, or a CF-End frame, then the interpretation of the Scrambler Initialization field is defined in Table 28-6 (Definition of Scrambler Initialization field when transmitted using the control mode and the Turnaround field is 1(11ay)) and indicates the channel bandwidth of the PPDU (corresponds to


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the TXVECTOR parameter SCRAMBLER_INIT_SETTING equal to Channel_BW). Otherwise, the Scrambler Initialization field is reserved.

— For an EDMG control mode PPDU and a non-EDMG control mode PPDU, the Length field and the Training Length field shall be set so that the spoofing error is non-negative and less than or equal to 150 ns, except for PPDU durations between 347.56 μs and 347.93 μs and between 349.10 μs and 350.76 μs where the maximum spoofing error shall be 0.37 μs and 1.66 μs, respectively.

— For an EDMG SC mode PPDU or an EDMG OFDM mode PPDU, the L-Header field is the same as the DMG SC mode PHY header (see Table 20-13 (DMG SC mode header fields)) with the following changes:

  — The reserved bit 46 shall be set to 1 to indicate the presence of the EDMG-Header-A field. This implies that the PPDU is an EDMG PPDU.
  — The Last RSSI field shall be redefined as shown in Table 28-7 (Definition of bit allocation of Last RSSI field when transmitted using the EDMG SC or EDMG OFDM mode(11ay)).
  — The 5 LSBs of the Length field shall be redefined as shown in Table 28-8 (Definition of the 5 LSBs of the Length field when transmitted using the EDMG SC or EDMG OFDM mode). Moreover, the remaining bits of the Length field together with the values of the Training Length field and of the MCS field shall be set so that the spoofing error is smaller than one SC symbol block ($512 \times T_c$) and non-negative.
  — The Additional PPDU field and the Beam Tracking Request field shall both be set to 0.

— For an EDMG SC mode A-PPDU or an EDMG OFDM mode A-PPDU, the definition of the L-Header field is the same as for the EDMG SC mode PPDU and the EDMG OFDM mode PPDU defined above with the following change:

  — If the actual A-PPDU duration is unknown at the point in time of L-Header transmission, the remaining bits of the Length field shall be set such that the PPDU duration calculated based on the L-Header shall be within the range of the actual PPDU duration of the first PPDU in the A-PPDU to the smaller of aPPDUMaxTime and remaining TXOP duration. Padding shall be applied such that the spoofing error requirements are fulfilled. The padding for EDMG SC mode A-PPDU is defined in 28.5.9.4.3 (LDPC encoding). The padding for EDMG OFDM mode A-PPDU is defined in 28.6.9.2.3 (LDPC encoding).

— For a non-EDMG SC mode PPDU that has the TXVECTOR parameter NON_EDMG_MODULATION equal to NON_EDMG_DUP_SC_MODE, the L-Header field is the same as the DMG SC mode PHY header (see Table 20-13 (DMG SC mode header fields)) with the following changes:

  — The Additional PPDU field shall be set to 0.

**Table 28-5—Definition of Scrambler Initialization field when transmitted using the control mode and the Turnaround field is 0(11ay)**

| Scrambler Initialization field | | | | Definition |
|---|---|---|---|---|
| B0 | B1 | B2 | B3 | |
| 0 | 0 | R | R | Corresponds to the TXVECTOR parameter SCRAMBLER_INIT_SETTING equal to CONTROL_TRAILER.<br><br>Indicates the presence of the control trailer in the PPDU. The content of the control trailer depends on the type of frame contained in the PPDU (see 28.3.7 (Control trailer)). |

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**Table 28-5—Definition of Scrambler Initialization field when transmitted using the control mode and the Turnaround field is 0(11ay)**

| Scrambler Initialization field | | | | Definition |
|---|---|---|---|---|
| B0 | B1 | B2 | B3 | |
| 0 | 1 | R | R | Corresponds to the TXVECTOR parameter SCRAMBLER_INIT_SETTING equal to EDMG-Header-A.<br><br>Indicates the presence of the EDMG-Header-A field. This implies that the PPDU is an EDMG control mode PPDU. |
| 1 | 0 | R | R | Reserved |
| 1 | 1 | R | R | Reserved |
| NOTE—"R" indicates that this bit field is reserved. | | | | |

**Table 28-6—Definition of Scrambler Initialization field when transmitted using the control mode and the Turnaround field is 1(11ay)**

| Scrambler Initialization field | | | | Requested channel bandwidth | 2.16 GHz channel number(s) making up the requested channelization |
|---|---|---|---|---|---|
| B0 | B1 | B2 | B3 | | |
| 0 | 0 | 0 | 0 | 2.16 GHz | Any one of 1, 2, 3, 4, 5, 6, 7, 8 |
| 1 | 0 | 0 | 0 | 4.32 GHz or 2.16+2.16 GHz | Any one of (1 and 2), (3 and 4), (5 and 6), or (7 and 8) |
| 0 | 1 | 0 | 0 | 4.32 GHz or 2.16+2.16 GHz | Any one of (2 and 3), (4 and 5), or (1 and 6) |
| 1 | 1 | 0 | 0 | 6.48 GHz | (1–3) or (4–6) |
| 0 | 0 | 1 | 0 | 6.48 GHz | (2–4) or (5–7) |
| 1 | 0 | 1 | 0 | 6.48 GHz | (3–5) or (6–8) |
| 0 | 1 | 1 | 0 | 8.64 GHz or 4.32+4.32 GHz | 1–4 |
| 1 | 1 | 1 | 0 | 8.64 GHz or 4.32+4.32 GHz | 2–5 |
| 0 | 0 | 0 | 1 | 8.64 GHz or 4.32+4.32 GHz | 3–6 |
| 1 | 0 | 0 | 1 | 2.16+2.16 GHz | (1 and 3) or (4 and 6) |
| 0 | 1 | 0 | 1 | 2.16+2.16 GHz | (2 and 4) or (3 and 5) |
| 1 | 1 | 0 | 1 | 2.16+2.16 GHz | Any one of (1 and 4), (2 and 5), or (3 and 6) |
| 0 | 0 | 1 | 1 | 2.16+2.16 GHz | Any one of (1 and 5), (2 and 6), (3 and 7), or (4 and 8) |
| 1 | 0 | 1 | 1 | 4.32+4.32 GHz | 1–2 and 4–5 |
| 0 | 1 | 1 | 1 | 4.32+4.32 GHz | 2–3 and 5–6 |


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**Table 28-6—Definition of Scrambler Initialization field when transmitted using the control mode and the Turnaround field is 1(11ay) *(continued)***

| Scrambler Initialization field | | | | Requested channel bandwidth | 2.16 GHz channel number(s) making up the requested channelization |
|---|---|---|---|---|---|
| B0 | B1 | B2 | B3 | | |
| 1 | 1 | 1 | 1 | 4.32+4.32 GHz | 3–4 and 6–7 |

**Table 28-7—Definition of bit allocation of Last RSSI field when transmitted using the EDMG SC or EDMG OFDM mode(11ay)**

| Bit number | Field name | Definition |
|---|---|---|
| B0 | IsSC | If set to 1, this field indicates that the PSDU is modulated using SC (see 28.5 (EDMG and non-EDMG SC mode)). Otherwise, if set to 0, this field indicates that the PSDU is modulated using OFDM (see 28.6 (EDMG OFDM mode)). If modulated using SC, the PPDU is termed as EDMG SC (mode) PPDU. If modulated using OFDM, the PPDU is termed as EDMG OFDM (mode) PPDU. |
| B1 | IsSISO | If set to 1, this field indicates that the PPDU is a single space-time stream PPDU. Otherwise, the PPDU encodes more than one space-time stream. |
| B2–B3 | GI Length | This field indicates the type of GI used in the PPDU and is set as follows: set to 0 for short GI, set to 1 for normal GI, and set to 2 for long GI. Value of 3 is reserved. |

**Table 28-8—Definition of the 5 LSBs of the Length field when transmitted using the EDMG SC or EDMG OFDM mode**

| Bit number | Field name | Definition |
|---|---|---|
| B0–B4 | Compressed BW | The Compressed BW field indicates the bandwidth over which the PPDU is transmitted. Possible values for this field are defined in Table 28-9 (Compressed BW field definition). Values not listed in Table 28-9 (Compressed BW field definition) are reserved. |

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**Table 28-9—Compressed BW field definition**

| Bandwidth of PPDU | 2.16 GHz channel number(s) over which PPDU is transmitted | | | | | | | | Compressed BW field value |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | |
| 2.16 GHz | x | — | — | — | — | — | — | — | 0 |
| | — | x | — | — | — | — | — | — | |
| | — | — | x | — | — | — | — | — | |
| | — | — | — | x | — | — | — | — | |
| | — | — | — | — | x | — | — | — | |
| | — | — | — | — | — | x | — | — | |
| | — | — | — | — | — | — | x | — | |
| | — | — | — | — | — | — | — | x | |
| 4.32 GHz or 2.16+2.16 GHz | x | x | — | — | — | — | — | — | 1 |
| | — | — | x | x | — | — | — | — | |
| | — | — | — | — | x | x | — | — | |
| | — | — | — | — | — | — | x | x | |
| 4.32 GHz or 2.16+2.16 GHz | — | x | x | — | — | — | — | — | 2 |
| | — | — | — | x | x | — | — | — | |
| | — | — | — | — | — | x | x | — | |
| | x | — | — | — | — | — | — | x | |
| 6.48 GHz | x | x | x | — | — | — | — | — | 3 |
| | — | — | — | x | x | x | — | — | |
| 6.48 GHz | — | x | x | x | — | — | — | — | 4 |
| | — | — | — | — | x | x | x | — | |
| 6.48 GHz | — | — | x | x | x | — | — | — | 5 |
| | — | — | — | — | — | x | x | x | |
| 8.64 GHz or 4.32+4.32 GHz | x | x | x | x | — | — | — | — | 6 |
| | — | — | — | — | x | x | x | x | |
| 8.64 GHz or 4.32+4.32 GHz | — | x | x | x | x | — | — | — | 7 |
| 8.64 GHz or 4.32+4.32 GHz | — | — | x | x | x | x | — | — | 8 |
| 8.64 GHz or 4.32+4.32 GHz | — | — | — | x | x | x | x | — | 9 |



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**Table 28-9—Compressed BW field definition *(continued)***

| Bandwidth of PPDU | 2.16 GHz channel number(s) over which PPDU is transmitted | | | | | | | | Compressed BW field value |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | |
| 2.16+2.16 GHz | x | — | x | — | — | — | — | — | 10 |
| | — | x | — | x | — | — | — | — | |
| | — | — | — | — | x | — | x | — | |
| | — | — | — | — | — | x | — | x | |
| 2.16+2.16 GHz | — | — | x | — | x | — | — | — | 11 |
| | — | — | — | x | — | x | — | — | |
| 2.16+2.16 GHz | x | — | — | x | — | — | — | — | 12 |
| | — | x | — | — | x | — | — | — | |
| | — | — | x | — | — | x | — | — | |
| 2.16+2.16 GHz | — | — | — | x | — | — | x | — | 13 |
| | — | — | — | — | x | — | — | x | |
| 2.16+2.16 GHz | x | — | — | — | x | — | — | — | 14 |
| | — | x | — | — | — | x | — | — | |
| | — | — | x | — | — | — | x | — | |
| | — | — | — | x | — | — | — | x | |
| 4.32+4.32 GHz | x | x | — | x | x | — | — | — | 15 |
| 4.32+4.32 GHz | — | x | x | — | x | x | — | — | 16 |
| 4.32+4.32 GHz | — | — | x | x | — | x | x | — | 17 |
| 4.32+4.32 GHz | — | — | — | x | x | — | x | x | 18 |
| 4.32+4.32 GHz | x | x | — | — | x | x | — | — | 19 |
| | — | — | x | x | — | — | x | x | |
| 4.32+4.32 GHz | — | x | x | — | — | x | x | — | 20 |

Legend: “x” indicates that the channel is used; “—” indicates that the channel is not used.

### 28.3.3.2.4.2 Example of spoofing algorithm for EDMG SC PPDUs

The following is an informative algorithm for calculating the value of the Length field (referred to in this subclause as Length), the Training Length field, and the MCS field (referred to in this subclause as Base MCS) used in items a), b), c), d), and e) in the L-Header of an EDMG SC mode PPDU.

a) The tentative number of SC symbol blocks, $N_{BLKS}'$, is calculated as $N_{BLKS}' = \left\lceil \frac{TXTIME - \left(T_{L-STF} + T_{L-CEF} + T_{L-Header}\right) - \left(64 \times T_c\right)}{512 \times T_c} \right\rceil$ where *TXTIME* is defined in 28.12.3 (TXTIME calculation) and $T_{L\text{-}STF}$, $T_{L\text{-}CEF}$, and $T_{L\text{-}Header}$ are defined in 28.5.10.4.4.2 (Pre-EDMG modulated fields transmission).

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b) The Base MCS field in the L-Header is set to the value such that the following conditions are met:

1) $N_{BLKS}' \le \left\lceil \left(2^{18}-1\right) \times 8 / \left( N_{CBPB} \times \frac{R}{\rho} \right) \right\rceil - 1$ where $N_{CBPB}$, $R$, and $\rho$ are the parameters chosen based on the value of the Base MCS field as described in 20.5.3 (Transmission). If this condition is fulfilled, the Length to be calculated in steps d) and e) does not exceed the maximum value of the Length field in the L-Header, $2^{18} - 1$.

2) If $N_{BLKS}'$ mod 3 = 1 and $N_{BLKS}' < 38$, the Base MCS field should be set to the value that is greater than 5 to apply algorithm in step c).

c) One of the combinations of the parameters $N_{BLKS}$ and $N_{TRN}$, which denote, respectively, the number of SC symbol blocks and the Training Length in a DMG SC mode PPDU with the spoofed TXTIME of the EDMG PPDU, is calculated as follows:

**If** the Base MCS > 5 (π/2-QPSK, π/2-16-QAM and π/2- 64-QAM) **then**

$N_{BLKS} = N_{BLKS}'$

$N_{TRN} = 0$

**Endif**

**If** the Base MCS ≤ 5 (π/2-BPSK) **then**

**If** $N_{BLKS}' \bmod 3 \neq 1$ **then**

$N_{BLKS} = N_{BLKS}'$

$N_{TRN} = 0$

**else if** $N_{BLKS}' \geq 38$ **then**

$N_{TRN} = 2$

**If** $0 < \frac{TXTIME - \left(T_{L-STF} + T_{L-CE} + T_{L-Header}\right) - \left(64 \times T_c\right)}{T_c} \bmod 512 \leq 256$ **then**

$N_{BLKS} = N_{BLKS}' - 20$

**else**

$N_{BLKS} = N_{BLKS}' - 19$

**endif**

**endif**

**endif**

d) The maximum *Length* value that fulfills the requirement for the spoofing error specified in 28.3.3.2.4.1 (General), $Length_{max}$, is calculated as $Length_{max} = \left\lfloor \left\lfloor N_{BLKS} \cdot \frac{N_{CBPB}}{L_{CW}} \right\rfloor \cdot \frac{L_{CW}}{8} \cdot \frac{R}{\rho} \right\rfloor$, where $L_{CW}$ is the parameter defined in 20.5.3.2.3 (Encoding), and the value is chosen based on the value of the Base MCS field as described in 20.5.3 (Transmission).


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e) The spoofed values of the Length and Training Length fields of the EDMG PPDU are calculated as follows:

$$Length = \begin{cases} \left\lfloor \frac{Length_{max}}{32} \right\rfloor \cdot 32 + compressed\_bw, \text{ if } Length_{max} \bmod 32 \geq compressed\_bw \\ \left( \left\lfloor \frac{Length_{max}}{32} \right\rfloor - 1 \right) \cdot 32 + compressed\_bw, \text{ otherwise} \end{cases}$$

$$Training\ Length = N_{TRN}$$

where

*compressed_bw* is the value of the Compressed BW field in the L-Header as described in 28.3.3.2.4.1 (General)

When the Base MCS field is equal to 1, the calculated length might not satisfy the requirement for the spoofing error defined in 28.3.3.2.4.1 (General). In that case, the Base MCS field shall be set to a value different from 1, and the Length and the Training Length fields shall be calculated by repeating steps c) to e).

### 28.3.3.3 EDMG portion of EDMG format preamble

#### 28.3.3.3.1 General

The EDMG portion of the EDMG format preamble includes the EDMG-Header-A, EDMG-STF, EDMG-CEF and EDMG-Header-B fields. The EDMG-Header-A field is defined at the DMG SC chip rate $F_c$. The EDMG-STF, EDMG-CEF and EDMG-Header-B fields are not always transmitted as part of an EDMG PPDU transmission.

#### 28.3.3.3.2 EDMG-Header-A definition

##### 28.3.3.3.2.1 General

The EDMG-Header-A field carries information required to demodulate EDMG PPDUs. The definition of the EDMG-Header-A is the same for an EDMG SC mode and an EDMG OFDM mode PPDU, but is different from the definition for an EDMG control mode PPDU.

Reserved bits in the EDMG-Header-A field shall be set to 0 by the transmitter and shall be ignored by the receiver.

##### 28.3.3.3.2.2 Definition for EDMG control mode PPDU

The contents of the EDMG-Header-A field are partitioned between the first and second LDPC codeword of an EDMG control mode PPDU as shown in Figure 28-6 (Structure of EDMG-Header-A in an EDMG control mode PPDU(11ay)). The contents included in the first LDPC codeword are referred to as the EDMG-Header-$A_1$ subfield, which is defined in Table 28-10 (EDMG-Header-A1 subfield definition(11ay)). The contents included in the second LDPC codeword are referred to as the EDMG-Header-$A_2$ subfield, which is defined in Table 28-11 (EDMG-Header-A2 subfield definition(11ay)).

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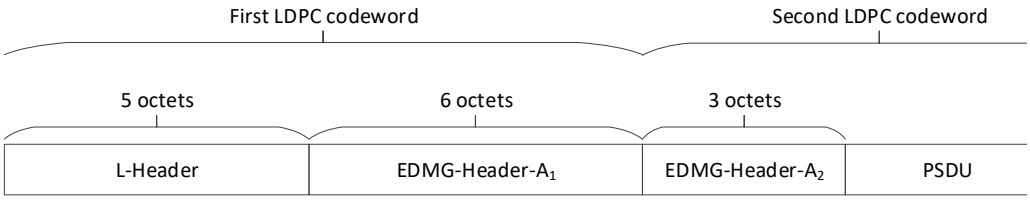


**Figure 28-6—Structure of EDMG-Header-A in an EDMG control mode PPDU(11ay)**

**Table 28-10—EDMG-Header-$A_1$ subfield definition(11ay)**

| Field | Number of bits | Start bit | Description |
|---|---|---|---|
| BW | 8 | 0 | See Table 28-12 (EDMG-Header-A field structure and definition for an SU PPDU(11ay)) (in 28.3.3.3.2.3 (Definition for EDMG SC mode and EDMG OFDM mode PPDUs)). |
| Primary Channel Number | 3 | 8 | See Table 28-12 (EDMG-Header-A field structure and definition for an SU PPDU(11ay)). |
| PSDU Length | 10 | 11 | Length of the PSDU field in octets in the range 14 to 1023. |
| EDMG TRN Length | 8 | 21 | See Table 28-12 (EDMG-Header-A field structure and definition for an SU PPDU(11ay)). |
| RX TRN-Units per Each TX TRN-Unit | 8 | 29 | See Table 28-12 (EDMG-Header-A field structure and definition for an SU PPDU(11ay)). |
| EDMG TRN-Unit P | 2 | 37 | See Table 28-12 (EDMG-Header-A field structure and definition for an SU PPDU(11ay)). |
| EDMG TRN-Unit M | 4 | 39 | See Table 28-12 (EDMG-Header-A field structure and definition for an SU PPDU(11ay)). |
| EDMG TRN-Unit N | 2 | 43 | See Table 28-12 (EDMG-Header-A field structure and definition for an SU PPDU(11ay)). |
| TRN Subfield Sequence Length | 2 | 45 | See Table 28-12 (EDMG-Header-A field structure and definition for an SU PPDU(11ay)). |
| TRN-Unit RX Pattern | 1 | 47 | See Table 28-12 (EDMG-Header-A field structure and definition for an SU PPDU(11ay)). |

For 2.16+2.16 GHz and 4.32+4.32 GHz PPDU transmission, the total number of transmit chains, $N_{TX}$, is an even number. For 2.16+2.16 GHz PPDU transmission, the first $N_{TX}/2$ transmit chains are used for transmission on the primary channel and the second $N_{TX}/2$ transmit chains are used for transmission on the secondary channel. For 4.32+4.32 GHz PPDU transmission, the first $N_{TX}/2$ transmit chains are used for transmission on the primary and secondary channels and the second $N_{TX}/2$ transmit chains are used for transmission on the secondary1 and secondary2 channels. See also 28.3.3.4.2 (Channel aggregation).

The knowledge of the number of transmit chains to receive the preamble and Data fields of a PPDU is not required, because the data is duplicated over all transmit chains with CSD. The knowledge of the number of transmit chains is needed to perform beamforming training using TRN units included in the TRN field of a


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**Table 28-11—EDMG-Header-A$_2$ subfield definition(11ay)**

| Field | Number of bits | Start bit | Description |
|---|---|---|---|
| TRN Aggregation | 1 | 0 | Corresponds to the TXVECTOR parameter TRN_AGGREGATION.<br><br>If this field set to 0, the BW field specifies that the TRN field of the PPDU is appended on a 2.16 GHz, 4.32 GHz, 6.48 GHz, or 8.64 GHz channel. If this field set to 1, the BW field specifies that the TRN field is transmitted over a 2.16+2.16 GHz or 4.32+4.32 GHz channel.<br><br>This field is reserved if the value of the EDMG TRN Length field is 0. |
| Number of Transmit Chains | 3 | 1 | See Table 28-12 (EDMG-Header-A field structure and definition for an SU PPDU(11ay)). |
| DMG TRN | 1 | 4 | See Table 28-12 (EDMG-Header-A field structure and definition for an SU PPDU(11ay)). |
| First Path Training | 1 | 5 | See Table 28-13 (EDMG-MCS field definition when the Number of SS field is 0(11ay)) (in 28.3.3.3.2.3 (Definition for EDMG SC mode and EDMG OFDM mode PPDUs)). |
| Dual Polarization TRN Training | 1 | 6 | See Table 28-13 (EDMG-MCS field definition when the Number of SS field is 0(11ay)). |
| Reserved | 1 | 7 | Set to 0 by the transmitter and ignored by the receiver. |
| CRC | 16 | 8 | Header Check sequence. Calculation of the header check sequence is defined in 20.3.7 (HCS calculation for headers of DMG control mode and DMG SC mode). |

PPDU. The TRN units are defined using orthogonal sequences and allow channel estimation between $N_{TX}$ transmit chains and $N_{RX}$ receive chains. The receiver needs to know the number of TRN units (corresponding to $N_{TX}$ chains) that were transmitted in order to perform channel measurements. Based on this information, the receiver can run the appropriate number of correlators for each receive chain.

#### 28.3.3.3.2.3 Definition for EDMG SC mode and EDMG OFDM mode PPDUs

The EDMG-Header-A field has a fixed size of two DMG SC symbol blocks (see Clause 20 (Directional multi-gigabit (DMG) PHY specification)) comprising 112 data bits followed by a 16 bit CRC.

Two types of EDMG-Header-A structures are defined, namely, one for EDMG SU PPDU and one for EDMG MU PPDU. The type of EDMG-Header-A structure used in an EDMG PPDU is indicated by the value of the SU/MU Format field.

The structure of the EDMG-Header-A field for an EDMG SU PPDU is shown in Table 28-12 (EDMG-Header-A field structure and definition for an SU PPDU(11ay)). The structure of the EDMG-Header-A field for an EDMG MU PPDU is shown in Table 28-17 (EDMG-Header-A field structure and definition for an MU PPDU(11ay)).

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For multiple stream transmission, each spatial stream has an identical bandwidth configuration as defined in the EDMG-Header-A.

For 2.16+2.16 GHz and 4.32+4.32 GHz PPDU transmission, the total number of transmit chains, $N_{TX}$, is an even number. For 2.16+2.16 GHz PPDU transmission, the first $N_{TX}/2$ transmit chains are used for transmission on the primary channel and the second $N_{TX}/2$ transmit chains are used for transmission on the secondary channel. For 4.32+4.32 GHz PPDU transmission, the first $N_{TX}/2$ transmit chains are used for transmission on the primary and secondary channels and the second $N_{TX}/2$ transmit chains are used for transmission on the secondary1 and secondary2 channels. See also 28.3.3.4.2 (Channel aggregation).

For an EDMG A-PPDU, the following apply:

— The SU/MU Format field shall be set to 0 for all EDMG PPDUs comprising the EDMG A-PPDU.

— The PSDU Length and EDMG-MCS fields may be set to different values for EDMG PPDUs comprising the EDMG A-PPDU.

— The Additional EDMG PPDU field shall be set to 1 for all EDMG PPDUs, except for the last EDMG PPDU where it shall be set to 0.

— The EDMG TRN Length field shall be set to 0 for all EDMG PPDUs, except for the last EDMG PPDU where it may be set to a nonzero value.

— The RX TRN-Units per Each TX TRN-Unit, EDMG TRN-Unit P, EDMG TRN-Unit M, EDMG TRN-Unit N, TRN Subfield Sequence Length, TRN-Unit RX Pattern, EDMG Beam Tracking Request, EDMG Beam Tracking Request Type, DMG TRN, First Path Training and Dual Polarization TRN Training fields are reserved for all EDMG PPDUs, except the last EDMG PPDU. For the last EDMG PPDU in the EDMG A-PPDU, the values of these fields may be set based on the TRN field parameters and EDMG TRN Length field value.

— The Channel Aggregation, BW, Primary Channel Number, Beamformed, Short/Long LDPC, STBC Applied, Number of SS, Number of Transmit Chains, and NUC Applied fields shall have the same value for all EDMG PPDUs comprising the EDMG A-PPDU.

— The DCM BPSK Applied field shall have the same value for all EDMG PPDUs comprising the EDMG A-PPDU. The conditions on DCM BPSK modulation usage shall be met as defined in 28.5.9.5.3 (Dual carrier modulation (DCM) π/2-BPSK) and 28.6.9.3.4 (Dual Stream DCM BPSK modulation) for the EDMG SC and EDMG OFDM modes, respectively. If conditions are not met, then the DCM BPSK Applied field is reserved for all EDMG PPDUs comprising the EDMG A-PPDU.

— The Phase Hopping and Open Loop Precoding fields shall have the same value for all EDMG PPDUs comprising the (#8160)EDMG OFDM A-PPDU. The conditions on phase hopping modulation usage shall be met as defined in 28.6.9.3.8 (Phase hopping modulation). If conditions are not met, the Phase Hopping and Open Loop Precoding fields are reserved for all EDMG PPDUs comprising the EDMG A-PPDU.

— The Superimposed Code Applied field shall have the same value for all EDMG PPDUs comprising the EDMG A-PPDU. The receiver shall ignore the Superimposed Code Applied field if the EDMG-MCS field does not indicate the LDPC code rate-7/8.

— The π/2-8-PSK Applied field shall have the same value for all EDMG PPDUs comprising the EDMG A-PPDU. The receiver shall ignore the π/2-8-PSK Applied field if the EDMG-MCS field does not indicate EDMG-MCS 12 or 13.

— The Reserved field is reserved for all EDMG PPDUs comprising the EDMG A-PPDU.


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— The CRC field is computed based on the EDMG-Header-A content for a given EDMG PPDU and may have different values for EDMG PPDUs comprising the EDMG A-PPDU.

**Table 28-12—EDMG-Header-A field structure and definition for an SU PPDU(11ay)**

| Field | Number of bits | Start bit | Description |
|---|---|---|---|
| SU/MU Format | 1 | 0 | Generated from the NUM_USERS parameter in the TXVECTOR. Indicates whether the PPDU is an SU PPDU or an MU PPDU. Set to 0 to indicate an SU PPDU and set to 1 otherwise. |
| Channel Aggregation | 1 | 1 | Generated from the CHANNEL_AGGREGATION parameter in the TXVECTOR. Set to 0 if the parameter is equal to (#4167)NOT_AGGREGATED. Set to 1 if the parameter is equal to (#4167)AGGREGATED. |
| BW | 8 | 2 | A bitmap as indicated by the CH_BANDWIDTH parameter in the TXVECTOR that indicates the 2.16 GHz channel(s) over which the PPDU is transmitted on. If a bit is set to 1, it indicates that the corresponding channel is used for the PPDU transmission; otherwise, if the bit is set to 0, the channel is not used. Bit 0 corresponds to channel 1, bit 1 corresponds to channel 2, and so on. |
| Primary Channel Number | 3 | 10 | Corresponds to the TXVECTOR parameter PRIMARY_CHANNEL. Contains the primary 2.16 GHz channel number of the BSS minus one. |
| Beamformed | 1 | 13 | Corresponds to the TXVECTOR parameter BEAMFORMED. Set to 1 to indicate that digital beamforming is applied. Set to 0 otherwise. |
| Short/Long LDPC | 1 | 14 | Corresponds to the TXVECTOR parameter LDPC_CW_LENGTH. Indicates the LDPC codeword length used in the PSDU. Set to 0 for LDPC codeword of length 672, 624, 504, or 468. Set to 1 for LDPC codeword of length 1344, 1248, 1008, or 936. |
| STBC Applied | 1 | 15 | Corresponds to the TXVECTOR parameter STBC. If set to 1, indicates that STBC was applied at the transmitter. Otherwise, set to 0.<br><br>If set to 1, the DCM BPSK Applied and the Phase Hopping fields shall be set to 0. |
| PSDU Length | 22 | 16 | Length of the PSDU field in octets. |
| Number of SS | 3 | 38 | Generated from the TXVECTOR parameters NUM_STS and STBC. The value of this field plus one indicates the number of SSs transmitted in the PPDU. |

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**Table 28-12—EDMG-Header-A field structure and definition for an SU PPDU(11ay)**

| Field | Number of bits | Start bit | Description |
|---|---|---|---|
| EDMG-MCS | 21 | 41 | Generated from TXVECTOR parameter EDMG_MCS. If the Number of SS field is 0, the EDMG-MCS field is as defined in Table 28-13 (EDMG-MCS field definition when the Number of SS field is 0(11ay)). Otherwise, the EDMG-MCS field is as defined in Table 28-14 (EDMG-MCS field definition when the Number of SS field is greater than 0(11ay)). |
| DCM BPSK Applied | 1 | 62 | Corresponds to the TXVECTOR parameter DCM_BPSK. If set to 1 and the PSDU is encoded using the EDMG SC mode, it indicates that DCM π/2-BPSK modulation defined in 28.5.9.5.3 (Dual carrier modulation (DCM) π/2-BPSK) was applied at the transmitter.<br><br>If set to 1 and the PSDU is encoded using the EDMG OFDM mode with two spatial streams, it indicates that Dual Stream DCM BPSK modulation defined in 28.6.9.3.4 (Dual Stream DCM BPSK modulation) was applied at the transmitter.<br><br>If set to 1, the STBC Applied and the Phase Hopping fields shall be set to 0.<br><br>In all other cases, this field is set to 0. |
| NUC Applied | 1 | 63 | Corresponds to the TXVECTOR parameter NUC_MOD. If this field is set to 1, π/2-64-NUC is applied at the transmitter for all MCSs indicated within the EDMG-MCS field, if supported. If a Differential EDMG-MCS indicated within the EDMG-MCS field does not support π/2-64-NUC, then π/2-64-QAM uniform constellation is applied for this particular MCS.<br><br>If set to 0, π/2-64-QAM uniform constellation is applied for all MCSs signaled in the EDMG-MCS field. |
| EDMG TRN Length | 8 | 64 | Corresponds to the TXVECTOR parameter EDMG_TRN_LEN. Indicates the number of TRN-Units present in the TRN field of the PPDU or, as defined in 10.41.7 (Beam tracking), a requested number of TRN-Units for receive beam tracking. |
| RX TRN-Units per Each TX TRN-Unit | 8 | 72 | Corresponds to TXVECTOR parameter RX_TRN_PER_TX_TRN. This field is reserved if the value of the EDMG TRN Length field is 0. Otherwise, the value of this field plus one indicates the number of consecutive TRN-Units in the TRN field for which the transmitter remains with the same transmit AWV (see 28.9.2.2.5 (TRN field definition)). |


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**Table 28-12—EDMG-Header-A field structure and definition for an SU PPDU(11ay)**

| Field | Number of bits | Start bit | Description |
|---|---|---|---|
| EDMG TRN-Unit P | 2 | 80 | Corresponds to TXVECTOR parameter EDMG_TRN_P. For EDMG BRP-TX and EDMG BRP-RX/TX PPDUs, the value of this field describes the number of TRN subfields in a TRN-Unit that are transmitted using the same AWV used in the transmission of the preamble and Data fields, except for the case when the DMG antenna used in the transmission of the PPDU changes at the beginning of the TRN field, as defined in 28.9.2.2.5 (TRN field definition). Possible values for this field are as follows:<br>0 indicates zero TRN subfields.<br>1 indicates one TRN subfield.<br>2 indicates two TRN subfields.<br>3 indicates four TRN subfields.<br><br>For EDMG BRP-RX PPDUs, this field is reserved. |
| EDMG TRN-Unit M | 4 | 82 | Corresponds to TXVECTOR parameter EDMG_TRN_M. For EDMG BRP-TX PPDUs, as defined in 28.9.2.2 (EDMG BRP PPDU), the transmitter may change the AWV at the beginning of each set of *N* TRN subfields present in the last *M* TRN subfields of each TRN-Unit in the TRN field, where *M* is the value of this field plus one and the value of *N* is indicated by the TXVECTOR parameter EDMG_TRN_N. For EDMG BRP-RX/TX PPDUs, the value of this field plus one indicates the number of TRN subfields in a TRN-Unit transmitted with the same AWV following a possible AWV change, as defined in 28.9.2.2.5 (TRN field definition).<br><br>For EDMG BRP-RX PPDUs, this field is reserved. For EDMG BRP-TX PPDUs transmitted with EDMG Beam Tracking Request Type field set to 1, this field is reserved. |
| EDMG TRN-Unit N | 2 | 86 | Corresponds to TXVECTOR parameter EDMG_TRN_N. For EDMG BRP-TX PPDUs, the value of this field indicates the number of consecutive TRN subfields within EDMG TRN-Unit M that are transmitted using the same AWV, as defined in 28.9.2.2.5 (TRN field definition). Possible values for this field are as follows:<br>0 indicates one TRN subfield.<br>1 indicates two TRN subfields.<br>2 indicates three TRN subfields if EDMG TRN-Unit M is equal to 2, 5, 8, 11 or 14; indicates eight TRN subfields if EDMG TRN-Unit M is equal to 7 or 15.<br>3 indicates four TRN subfields.<br><br>For EDMG BRP-RX and EDMG BRP-RX/TX PPDUs, this field is reserved. For EDMG BRP-TX PPDUs transmitted with EDMG Beam Tracking Request Type field set to 1, this field is reserved. |

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**Table 28-12—EDMG-Header-A field structure and definition for an SU PPDU(11ay)**

| Field | Number of bits | Start bit | Description |
|---|---|---|---|
| TRN Subfield Sequence Length | 2 | 88 | Corresponds to TXVECTOR parameter TRN_SEQ_LENGTH.<br><br>For an EDMG SC mode PPDU, this field is reserved if the value of the EDMG TRN Length field is 0. Otherwise, this field indicates the length of the Golay sequence used to transmit the TRN subfields present in the TRN field of the PPDU and is set as follows:<br>— Set to 0 to indicate normal sequence length of $128 \times N_{CB}$.<br>— Set to 1 to indicate long sequence length of $256 \times N_{CB}$.<br>— Set to 2 to indicate short sequence length of $64 \times N_{CB}$.<br>— Value of 3 is reserved.<br><br>$N_{CB}$ is defined in Table 28-2 (Frequently used parameters(11ay)) and, in this case, represents the integer number of contiguous 2.16 GHz channels over which the TRN subfield is transmitted.<br><br>For an EDMG OFDM mode PPDU, this field is reserved if the value of the EDMG TRN Length field is 0. Otherwise, this field indicates the number of basic TRN subfield repetitions used to transmit the TRN subfields present in the TRN field of the PPDU and is set as follows:<br>— Set to 0 to indicate normal TRN subfield composed of 2 repetitions of the basic TRN subfield.<br>— Set to 1 to indicate long TRN subfield composed of 4 repetitions of the basic TRN subfield.<br>— Set to 2 to indicate short TRN subfield composed of 1 repetition of the basic TRN subfield.<br>— Value of 3 is reserved. |
| TRN-Unit RX Pattern | 1 | 90 | Corresponds to TXVECTOR parameter TRN_RX_PATTERN. If set to 1 in a BRP-TX PPDU, indicates that the measurements of the TRN-Units is to be done using a quasi-omni antenna pattern. Otherwise, if set to 0 in a BRP-TX PPDU, indicates that the measurements of the TRN-Units is to be done using a directional AWV receive antenna configuration. For all other cases, this field is reserved. |
| EDMG Beam Tracking Request | 1 | 91 | Corresponds to the TXVECTOR parameter EDMG_BEAM_TRACKING_REQUEST.<br><br>Set to 1 to indicate the need for beam tracking (10.41.7 (Beam tracking)); otherwise, set to 0.<br><br>The EDMG Beam Tracking Request field is reserved when the EDMG TRN Length field is 0. |


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**Table 28-12—EDMG-Header-A field structure and definition for an SU PPDU(11ay)**

| Field | Number of bits | Start bit | Description |
|---|---|---|---|
| EDMG Beam Tracking Request Type | 1 | 92 | Corresponds to the TXVECTOR parameter EDMG_BEAM_TRACKING_TYPE.<br><br>Set to 0 to indicate analog beam tracking (10.41.7 (Beam tracking)); set to 1 to indicate baseband beam tracking (10.41.7 (Beam tracking)).<br><br>This field is reserved when the EDMG Beam Tracking Request field is reserved or 0. |
| Phase Hopping | 1 | 93 | Corresponds to TXVECTOR parameter PHASE_HOPPING. If set to 1 in an EDMG OFDM mode PPDU, this field indicates that phase hopping modulation (see 28.6.9.3.8 (Phase hopping modulation)) is used. Otherwise, this field is set to 0.<br><br>If set to 1, the STBC Applied and the DCM BPSK Applied fields shall be set to 0.<br><br>This field is reserved in an EDMG SC mode PPDU, or if the transmitter or receiver do not support phase hopping. |
| Open Loop Precoding | 1 | 94 | Corresponds to TXVECTOR parameter OPEN_LOOP_PC. If the Phase Hopping field is set to 1, this field indicates if open loop precoding is used. If this field is 1, open loop precoding (see 28.6.9.3.8 (Phase hopping modulation)) is used. Otherwise, open loop precoding is not used. If the Phase Hopping field is reserved, this field is also reserved. |
| Additional EDMG PPDU | 1 | 95 | Corresponds to TXVECTOR parameter EDMG-ADD-PPDU. A value of 1 indicates that this EDMG PPDU is immediately followed by another EDMG PPDU with no IFS or preamble in between the PPDUs. A value of 0 indicates that no additional EDMG PPDU follows this EDMG PPDU. |

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**Table 28-12—EDMG-Header-A field structure and definition for an SU PPDU(11ay)**

| Field | Number of bits | Start bit | Description |
|---|---|---|---|
| Superimposed Code Applied | 1 | 96 | Corresponds to TXVECTOR parameter LDPC_SUPERIMPOSED. If the LDPC code rate is 7/8 and this field is set to 0, it indicates puncturing code with codeword length 624 or 1248 is applied (see 28.5.9.4.3 (LDPC encoding) and 28.6.9.2.3 (LDPC encoding)).<br><br>If the LDPC code rate is 7/8 and this field is set to 1, it indicates that superimposed code with codeword length 672 or 1344 is applied (see 28.3.6.2 (Rate-7/8 LDPC code matrix H = 84 rows x 672 columns, Z = 42) and 28.3.6.7 (Rate-7/8 LDPC code matrix H = 168 rows x 1344 columns, Z = 42)).<br><br>If the EDMG-MCS field indicates a value of 13 and the π/2-8-PSK Applied field is 1, then this field indicates the 7/8 code employed in the encoding procedure with codeword shortening to achieve the effective code rate of 5/6 as defined in 28.5.9.4.3 (LDPC encoding).<br><br>In all other cases, this field is reserved. |
| π/2-8-PSK Applied | 1 | 97 | Corresponds to TXVECTOR parameter PSK_APPLIED. If this field is set to 1, π/2-8-PSK with corresponding LDPC shortening code with rates 2/3 or 5/6 is applied at the transmitter for MCS 12 or 13, respectively, as indicated within the EDMG-MCS field.<br><br>If set to 0, π/2-16-QAM constellation with regular LDPC code with rates 1/2 or 5/8 is applied at the transmitter for MCS 12 or 13, respectively, as indicated in the EDMG-MCS field. |
| Number of Transmit Chains | 3 | 98 | Corresponds to TXVECTOR parameter NUM_TX_CHAINS. The value of this field plus 1 indicates the number of transmit chains used in the transmission of the PPDU. The value of the field plus 1 also indicates the total number of orthogonal sequences in a TRN field (see 28.9.2.2.5 (TRN field definition)). This field is reserved when the EDMG TRN Length field is 0, or when the EDMG Beam Tracking Request field is 1 and the PPDU is an EDMG BRP-RX PPDU. |
| DMG TRN | 1 | 101 | Corresponds to TXVECTOR parameter DMG_TRN. When set to 1, indicates that the TRN field appended to this PPDU has the structure of a DMG training field containing an AGC training field and a TRN field as defined in 20.9.2.2.2 (BRP PPDU structure). In this case, the RX TRN-Units per Each TX TRN-Unit, the EDMG TRN-Unit P, the EDMG TRN-Unit M, the EDMG TRN-Unit N, and the TRN Subfield Sequence Length fields are reserved. This field is reserved when the EDMG TRN Length field is equal to 0. |


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**Table 28-12—EDMG-Header-A field structure and definition for an SU PPDU(11ay)**

| Field | Number of bits | Start bit | Description |
|---|---|---|---|
| Reserved | 10 | 102 | Set to 0 by the transmitter and ignored by the receiver. |
| CRC | 16 | 112 | Header Check sequence. Calculation of the header check sequence is defined in 20.3.7 (HCS calculation for headers of DMG control mode and DMG SC mode). |

**Table 28-13—EDMG-MCS field definition when the Number of SS field is 0(11ay)**

| Subfield | Number of bits | Start bit | Description |
|---|---|---|---|
| Base MCS | 5 | 0 | Indicates the index of the modulation and coding scheme that is used to define the modulation and coding scheme of the spatial stream. |
| First Path Training | 1 | 5 | Corresponds to the TXVECTOR parameter FIRST_PATH_TRAINING. When set to 1, indicates that the TRN field appended to this PPDU is used for first path beamforming training (see 10.41.10.6 (First path beamforming training)). Set to 0 otherwise. This field is reserved when the EDMG TRN Length field is equal to 0. |
| Dual Polarization TRN Training | 1 | 6 | Corresponds to the TXVECTOR parameter DUAL_POL_TRAINING. If set to 1, indicates that the TRN subfields appended to this PPDU have different polarization for the same AWV (see 28.9.2.2.5 (TRN field definition)). If set to 0, indicates that the TRN field appended to this PPDU does not change polarization. |
| (11az)Secure TRN | 1 | 7 | Corresponds to the TXVECTOR parameter SECURED_TRN. When set to 1 (TXVECTOR parameter SECURED_TRN equals SECURED_TRN), indicates that the TRN field contains secure TRN sequences specified in 28.9.3.5 (TRN field definition with Secure TRN subfields(11az)). Otherwise, (TXVECTOR parameter SECURED_TRN equals NON_SECURED_TRN) the TRN field uses the format specified in 28.9.2.2.5 (TRN field definition). This field is reserved when the EDMG TRN Length field is equal to 0. |
| (11az)First Path AWV TRN | 1 | 8 | When set to 1, indicates that the TRN field is transmitted (and shall be received) using the first path AWV antenna setting. Otherwise the TRN field is transmitted and shall be received using the best path AWV antenna setting. |
| Reserved | 14 | (11az)9 | |

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**Table 28-14—EDMG-MCS field definition when the Number of SS field is greater than 0(11ay)**

| Subfield | Number of bits | Start bit | Description |
|---|---|---|---|
| Base MCS | 5 | 0 | Indicates the lowest index of the modulation and coding scheme that is used to define the modulation and coding scheme of the spatial streams. |
| Differential EDMG-MCS1 | 2 | 5 | Generated from TXVECTOR parameter EDMG_MCS.<br><br>Each Differential EDMG-MCSi subfield, $1 \le i \le 8$, defines the modulation and coding scheme for spatial stream $i$, respectively. All spatial streams have the same code rate and repetition factor defined by the Base MCS subfield. A Differential EDMG-MCSi subfield is reserved if spatial stream $i$ is not defined.<br><br>The rules for setting each Differential EDMG-MCS subfield are defined in Table 28-15 (Rules for differential EDMG-MCS signaling for the EDMG SC mode(11ay)) and Table 28-16 (Rules for differential EDMG-MCS signaling for the EDMG OFDM mode(11ay)) for the EDMG SC and the EDMG OFDM modes, respectively. Each Differential EDMG-MCS subfield indicates a possible modulation change relative to one defined by the Base MCS subfield. |
| Differential EDMG-MCS2 | 2 | 7 | |
| Differential EDMG-MCS3 | 2 | 9 | |
| Differential EDMG-MCS4 | 2 | 11 | |
| Differential EDMG-MCS5 | 2 | 13 | |
| Differential EDMG-MCS6 | 2 | 15 | |
| Differential EDMG-MCS7 | 2 | 17 | |
| Differential EDMG-MCS8 | 2 | 19 | |

**Table 28-15—Rules for differential EDMG-MCS signaling for the EDMG SC mode(11ay)**

| Base MCS modulation type | Differential EDMG-MCS = 0 | Differential EDMG-MCS = 1 | Differential EDMG-MCS = 2 | Differential EDMG-MCS = 3 |
|---|---|---|---|---|
| π/2-BPSK with repetition factor 2 | π/2-BPSK | N/A | N/A | N/A |
| π/2-BPSK with repetition factor 1 | π/2-BPSK | π/2-QPSK | π/2-16-QAM | π/2-64-QAM or π/2-64-NUC |
| π/2-QPSK | π/2-QPSK | π/2-16-QAM | π/2-64-QAM or π/2-64-NUC | N/A |
| π/2-8-PSK | π/2-8-PSK | N/A | N/A | N/A |
| DCM π/2-BPSK | DCM π/2-BPSK | N/A | N/A | N/A |
| π/2-16-QAM | π/2-16-QAM | π/2-64-QAM or π/2-64-NUC | N/A | N/A |
| π/2-64-QAM | π/2-64-QAM | N/A | N/A | N/A |
| π/2-64-NUC | π/2-64-NUC | N/A | N/A | N/A |


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**Table 28-15—Rules for differential EDMG-MCS signaling for the EDMG SC mode(11ay)**

| Base MCS modulation type | Differential EDMG-MCS = 0 | Differential EDMG-MCS = 1 | Differential EDMG-MCS = 2 | Differential EDMG-MCS = 3 |
|---|---|---|---|---|
| NOTE 1—The π/2-64-QAM or π/2-64-NUC modulation type is selected based on the NUC Applied field in the EDMG-Header-A.<br>NOTE 2—An "N/A" entry denotes a disallowed mode of transmission.<br>NOTE 3—The DCM π/2-BPSK modulation type is selected by setting the Base MCS modulation type to π/2-BPSK and the DCM BPSK Applied field to 1 in the EDMG-Header-A. This type of modulation can only be applied to SU PPDUs. | | | | |

**Table 28-16—Rules for differential EDMG-MCS signaling for the EDMG OFDM mode(11ay)**

| Base MCS modulation type | Differential EDMG-MCS = 0 | Differential EDMG-MCS = 1 | Differential EDMG-MCS = 2 | Differential EDMG-MCS = 3 |
|---|---|---|---|---|
| DCM BPSK | DCM BPSK | DCM QPSK | 16-QAM | 64-QAM |
| DCM QPSK | DCM QPSK | 16-QAM | 64-QAM | N/A |
| 16-QAM | 16-QAM | 64-QAM | N/A | N/A |
| 64-QAM | 64-QAM | N/A | N/A | N/A |
| NOTE—An "N/A" entry denotes a disallowed mode of transmission. | | | | |

**Table 28-17—EDMG-Header-A field structure and definition for an MU PPDU(11ay)**

| Field | Number of bits | Start bit | Description |
|---|---|---|---|
| SU/MU Format | 1 | 0 | See Table 28-12 (EDMG-Header-A field structure and definition for an SU PPDU(11ay)). |
| Channel Aggregation | 1 | 1 | See Table 28-12 (EDMG-Header-A field structure and definition for an SU PPDU(11ay)). |
| BW | 8 | 2 | See Table 28-12 (EDMG-Header-A field structure and definition for an SU PPDU(11ay)). |
| Primary Channel Number | 3 | 10 | See Table 28-12 (EDMG-Header-A field structure and definition for an SU PPDU(11ay)). |
| SS Descriptor Set 0 | 9 | 13 | Describes the SS assignment to the first STA addressed within the MU PPDU. This field is formatted as described in Table 28-18 (SS Descriptor Set field(11ay)). |
| SS Descriptor Set 1 | 9 | 22 | Describes the SS assignment to the first STA addressed within the MU PPDU. This field is formatted as described in Table 28-18 (SS Descriptor Set field(11ay)). |
| SS Descriptor Set 2 | 9 | 31 | Describes the SS assignment to the first STA addressed within the MU PPDU. This field is formatted as described in Table 28-18 (SS Descriptor Set field(11ay)). |

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**Table 28-17—EDMG-Header-A field structure and definition for an MU PPDU(11ay)**

| Field | Number of bits | Start bit | Description |
|---|---|---|---|
| SS Descriptor Set 3 | 9 | 40 | Describes the SS assignment to the first STA addressed within the MU PPDU. This field is formatted as described in Table 28-18 (SS Descriptor Set field(11ay)). |
| SS Descriptor Set 4 | 9 | 49 | Describes the SS assignment to the first STA addressed within the MU PPDU. This field is formatted as described in Table 28-18 (SS Descriptor Set field(11ay)). |
| SS Descriptor Set 5 | 9 | 58 | Describes the SS assignment to the first STA addressed within the MU PPDU. This field is formatted as described in Table 28-18 (SS Descriptor Set field(11ay)). |
| SS Descriptor Set 6 | 9 | 67 | Describes the SS assignment to the first STA addressed within the MU PPDU. This field is formatted as described in Table 28-18 (SS Descriptor Set field(11ay)). |
| SS Descriptor Set 7 | 9 | 76 | Describes the SS assignment to the first STA addressed within the MU PPDU. This field is formatted as described in Table 28-18 (SS Descriptor Set field(11ay)). |
| EDMG TRN Length | 8 | 85 | See Table 28-12 (EDMG-Header-A field structure and definition for an SU PPDU(11ay)). |
| RX TRN-Units per Each TX TRN-Unit | 8 | 93 | See Table 28-12 (EDMG-Header-A field structure and definition for an SU PPDU(11ay)). |
| EDMG TRN-Unit P | 2 | 101 | See Table 28-12 (EDMG-Header-A field structure and definition for an SU PPDU(11ay)). |
| EDMG TRN-Unit M | 4 | 103 | See Table 28-12 (EDMG-Header-A field structure and definition for an SU PPDU(11ay)). |
| EDMG TRN-Unit N | 2 | 107 | See Table 28-12 (EDMG-Header-A field structure and definition for an SU PPDU(11ay)). |
| TRN Subfield Sequence Length | 2 | 109 | See Table 28-12 (EDMG-Header-A field structure and definition for an SU PPDU(11ay)). |
| Reserved | 1 | 111 | |
| CRC | 16 | 112 | Header Check sequence. Calculation of the header check sequence is defined in 20.3.7 (HCS calculation for headers of DMG control mode and DMG SC mode). |

The SS Descriptor Set field is defined in Table 28-18 (SS Descriptor Set field(11ay)).

**Table 28-18—SS Descriptor Set field(11ay)**

| | AID | Number of SS |
|---|---|---|
| Bits | 8 | 1 |



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The AID subfield indicates the AID of a STA addressed by an MPDU contained within the MU PPDU and corresponds to TXVECTOR parameter MU_AID. The AID of a STA shall not appear more than once across all SS Descriptor Set fields included in the EDMG-Header-A. The SS Descriptor Set field is reserved if the value of the AID subfield is 0.

The value of the Number of SS subfield plus one indicates the number of SSs transmitted to the STA indicated by the AID subfield. This subfield value is generated from the TXVECTOR parameters NUM_STS and STBC. SSs are assigned sequentially across all STAs addressed by the MU PPDU.

#### 28.3.3.3.2.4 Encoding and modulation

For an EDMG SC mode PPDU or an EDMG OFDM mode PPDU, the EDMG-Header-A field is encoded and modulated using two SC blocks of 448 chips with 64 guard symbols. The bits are scrambled and encoded as follows:

- The input 112 header bits are appended with 16 HCS bits calculated as defined in 20.3.7.
- The resulting 128 bits (including CRC) are scrambled as described in 20.3.9, starting from the first bit using a continuation of the scrambler bit sequence from the L-Header.
- The scrambled bits are divided into two parts $\mathbf{b1} = \left(B_1, B_2, ..., B_{64}\right)$ and $\mathbf{b2} = \left(B_{65}, B_{66}, ..., B_{128}\right)$ of 64 bits each. Each part is encoded taking the following steps:
  - For each data word $\mathbf{b} = \mathbf{b1}$ or $\mathbf{b} = \mathbf{b2}$, append 440 zero bits $\mathbf{0} = \left(0_1, 0_2, ..., 0_{440}\right)$ and generate 168 parity bits $\mathbf{p} = \left(p_1, p_2, ..., p_{168}\right)$ to create a codeword $\mathbf{c} = \left(\mathbf{b}, \mathbf{0}, \mathbf{p}\right)$, such that $\mathbf{H} \cdot \left(\mathbf{c}\right)^T = \mathbf{0}$, parity bits are computed applying $L_{CW}$ = 672, $R$ = 3/4 LDPC matrix defined in 20.5.3.2.3.2 (Parity check matrices).
  - Remove zero-valued bits and discard (puncture) the last 8 parity bits to create a codeword $\mathbf{cs1} = \left(b_1, b_2, ..., b_{64}, p_1, p_2, ..., p_{160}\right)$ of length 224 bits.
  - Remove zero-valued bits and discard (puncture) the second to last 8 parity bits to create a codeword $\mathbf{cs2} = \left(b_1, b_2, ..., b_{64}, p_1, p_2, ..., p_{152}, p_{161}, p_{162}, ..., p_{168}\right)$ of length 224 bits and then XOR with a PN sequence that is generated from the LFSR used for data scrambling defined in 20.3.9 (Scrambler). The LFSR is initialized to the all 1s vector.
  - Concatenate **cs1** and **cs2** to create the output codeword $\mathbf{cs} = \left(\mathbf{cs1}, \mathbf{cs2}\right)$ of length 448 bits.
- The resulting codewords **cs** for **b1** and **b2** of 448 bits each are then modulated applying π/2-BPSK modulation as defined in 20.5.3.2.4.2 (π/2-BPSK modulation). This creates two SC data blocks EDMG-Header-$A_1$ and EDMG-Header-$A_2$, respectively.
- Each of the resulting two SC data blocks is prepended with 64 guard symbols to create SC symbol blocks. The second SC data block, EDMG-Header-$A_2$, is appended with the appropriate number of guard symbols as described in 28.5.9.2 (Symbol blocking and guard insertion).

The EDMG-Header-A encoding and modulation for an EDMG SC mode and an EDMG OFDM mode A-PPDU is defined in 28.5.7 (Encoding of EDMG-Header-A for EDMG A-PPDU transmission) and 28.6.7 (Encoding of EDMG-Header-A for EDMG A-PPDU transmission), respectively.

The EDMG-Header-A encoding and modulation for an EDMG control mode PPDU is defined in 28.4.5 (EDMG portion of the EDMG control mode PPDU).

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#### 28.3.3.3.3 EDMG-STF definition

For EDMG SC mode PPDU transmissions, the EDMG-STF field is defined in 28.5.4 (EDMG-STF definition). For EDMG OFDM mode PPDU transmissions, the EDMG-STF field is defined in 28.6.4 (EDMG-STF definition). The EDMG-STF field is not present in EDMG control mode PPDUs.

#### 28.3.3.3.4 EDMG-CEF definition

For EDMG SC mode PPDU transmissions, the EDMG-CEF field is defined in 28.5.5 (EDMG-CEF definition). For EDMG OFDM mode PPDU transmissions, the EDMG-CEF field is defined in 28.6.5 (EDMG-CEF definition). The EDMG-CEF field is not present in EDMG control mode PPDUs.

#### 28.3.3.3.5 EDMG-Header-B definition

##### 28.3.3.3.5.1 General

The EDMG-Header-B is transmitted only in EDMG MU PPDUs and on a per STA basis. The EDMG-Header-B field is defined in Table 28-19 (EDMG-Header-B field structure and definition(11ay)).

**Table 28-19—EDMG-Header-B field structure and definition(11ay)**

| Field | Number of bits | Start bit | Description |
|---|---|---|---|
| Scrambler Seed | 7 | 0 | |
| PSDU Length | 22 | 7 | Length of the PSDU field in octets in the range 1 to 4 194 303. |
| Base MCS | 5 | 29 | Generated from TXVECTOR parameter EDMG_MCS. Indicates the lowest index of the modulation and coding scheme that is used to define the modulation and coding scheme of the spatial streams. |
| Differential EDMG-MCS | 2 | 34 | Generated from TXVECTOR parameter EDMG_MCS.<br><br>The Base MCS field defines the modulation and coding scheme for the spatial stream 1.<br><br>The Differential EDMG-MCS field defines a possible modulation level change for the spatial stream 2 relative to the modulation level of spatial stream 1. The rules for setting the Differential EDMG-MCS field are defined in Table 28-15 (Rules for differential EDMG-MCS signaling for the EDMG SC mode(11ay)) and Table 28-16 (Rules for differential EDMG-MCS signaling for the EDMG OFDM mode(11ay)) for the EDMG SC and the EDMG OFDM modes, respectively.<br><br>All spatial streams have the same code rate defined by the Base MCS field.<br><br>If the number of spatial streams is 1 (per user), then the Differential EDMG-MCS field is reserved. |


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**Table 28-19—EDMG-Header-B field structure and definition(11ay) *(continued)***

| Field | Number of bits | Start bit | Description |
|---|---|---|---|
| Superimposed Code Applied | 1 | 36 | See Table 28-12 (EDMG-Header-A field structure and definition for an SU PPDU(11ay)). |
| Short/Long LDPC | 1 | 37 | See Table 28-12 (EDMG-Header-A field structure and definition for an SU PPDU(11ay)). |
| STBC Applied | 1 | 38 | See Table 28-12 (EDMG-Header-A field structure and definition for an SU PPDU(11ay)). |
| NUC Applied | 1 | 39 | Corresponds to the TXVECTOR parameter NUC_MOD. If this field is set to 1, π/2-64-NUC is applied at the transmitter for the MCSs indicated by the Base MCS and Differential EDMG-MCS fields, if supported. If an indicated MCS does not support π/2-64-NUC, then π/2-64-QAM uniform constellation is applied for this particular MCS.<br><br>If set to 0, π/2-64-QAM uniform constellation is applied for MCSs signaled in the Base MCS and Differential EDMG-MCS fields. |
| π/2-8-PSK Applied | 1 | 40 | See Table 28-12 (EDMG-Header-A field structure and definition for an SU PPDU(11ay)). |
| Spoofing Error Length Indicator | 1 | 41 | If set to 0 in an EDMG OFDM PPDU, indicates that the spoofing error, defined as the difference between the PPDU duration calculated based on L-Header and the actual PPDU duration, is smaller than $T_{OFDM\text{-}SYM}$, where $T_{OFDM\text{-}SYM} = T_{DFT} + T_{GI}$, $T_{DFT}$ is the OFDM IDFT/DFT period and $T_{GI}$ is the guard interval duration, which is determined by bits B2 and B3 of the Last RSSI field within the L-Header of the PPDU. Otherwise, if set to 1 in an EDMG OFDM PPDU, indicates that the spoofing error is greater than or equal to $T_{OFDM\text{-}SYM}$. For an EDMG SC PPDU, this field is reserved. |
| Beamformed | 1 | 42 | See Table 28-12 (EDMG-Header-A field structure and definition for an SU PPDU(11ay)). |
| Number of Transmit Chains | 3 | 43 | See Table 28-12 (EDMG-Header-A field structure and definition for an SU PPDU(11ay)). |
| Reserved | 2 | 46 | |
| CRC | 16 | 48 | Header Check sequence. Calculation of the header check sequence is defined in 20.3.7 (HCS calculation for headers of DMG control mode and DMG SC mode). |

The value of the Spoofing Error Length Indicator subfield within all EDMG-Header-B fields present in an EDMG MU PPDU shall be the same.

Reserved bits in the EDMG-Header-B field shall be set to 0 by the transmitter and shall be ignored by the receiver.

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#### 28.3.3.3.5.2 Transmission

The encoding of EDMG-Header-B in an EDMG SC mode PPDU is specified in 28.5.6 (Encoding of EDMG-Header-B). The encoding of EDMG-Header-B in an EDMG OFDM mode PPDU is specified in 28.6.6 (Encoding of EDMG-Header-B).

### 28.3.3.4 Mathematical description of signals

#### 28.3.3.4.1 General

The transmitted signal is described in complex baseband signal notation. The actual transmitted signal in the $i_{TX}$ transmit chain is related to the complex baseband signal $r^{i_{TX}}(t)$ by the following relation:

$$r_{RF}^{i_{TX}}(t) = Re\left\{ r_{PPDU}^{i_{TX}}(t) \exp\left( j2\pi f_c(t) \right) \right\}$$

where

$f_c$ is the carrier center frequency

The transmitted signal is generated by modulating the complex baseband signal, which consists of the fields defined in 28.3.2.1 (General) and 28.3.2.2 (EDMG A-PPDU format). The waveform $r_{PPDU}^{i_{TX}}(nT_c)$ is defined for various control and (#8160)EDMG SC mode PPDU formats in 28.4.7.2 (Non-EDMG PPDU transmission), 28.4.7.3 (EDMG PPDU transmission), 28.5.3.3.1 (Pre-EDMG modulated fields of PPDU transmission), 28.5.3.3.2 (EDMG modulated fields of SU PPDU transmission), and 28.5.3.3.3 (EDMG modulated fields of MU PPDU transmission). The waveform $r_{PPDU}^{i_{TX}}(nT_s)$ is defined in 28.6.10.3 (EDMG SU PPDU transmission) and 28.6.10.4 (EDMG MU PPDU transmission) for (#8160)EDMG OFDM mode PPDU formats.

#### 28.3.3.4.2 Channel aggregation

For a PPDU with TXVECTOR parameter CHANNEL_AGGREGATION set to (#4167)AGGREGATED, the following shall apply:

— The number of transmit chains $N_{TX}$ is even.

— The lower half $N_{TX}/2$ transmit chains (i.e., those with lower indices) are used in the primary channel for a 2.16+2.16 GHz PPDU transmission, or in the primary and secondary channels for a 4.32+4.32 GHz PPDU transmission.

— The upper half $N_{TX}/2$ transmit chains (i.e., those with higher indices) are used in the secondary channel for a 2.16+2.16 GHz PPDU transmission, or in the secondary1 and secondary2 channels for a 4.32+4.32 GHz PPDU transmission.

In this case, the transmitted signal is as follows:

$$r_{RF}^{i_{TX}}(t) = \begin{cases} Re\left\{ r_{PPDU}^{i_{TX}}(t) \exp\left( j2\pi f_{c_p}(t) \right) \right\} & i_{TX} \le \dfrac{N_{TX}}{2} \\ Re\left\{ r_{PPDU}^{i_{TX}}(t) \exp\left( j2\pi f_{c_s}(t) \right) \right\} & i_{TX} > \dfrac{N_{TX}}{2} \end{cases}$$

where

$f_{c_p}$ is the carrier center frequency of the primary channel for a 2.16+2.16 GHz PPDU transmission, or of the primary and secondary channels for a 4.32+4.32 GHz PPDU transmission


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$f_{c_s}$ is the carrier center frequency of the secondary channel for a 2.16+2.16 GHz PPDU transmission, or of the secondary1 and secondary2 channels for a 4.32+4.32 GHz PPDU transmission

### 28.3.4 Channelization

A channel used by an EDMG STA is specified by the four PLME MIB fields defined in Table 28-20 (Parameters that specify a channel used by an EDMG STA(11ay)).

**Table 28-20—Parameters that specify a channel used by an EDMG STA(11ay)**

| Field | Meaning |
|---|---|
| dot11EDMGCurrentChannelWidth | Channel width. Possible values represent 2.16 GHz, 4.32 GHz, 6.48 GHz, 8.64 GHz, 2.16+2.16 GHz, and 4.32+4.32 GHz. |
| dot11EDMGCurrentChannelCenterFrequencyIndex0 | For a 2.16 GHz, 4.32 GHz, 6.48 GHz, and 8.64 GHz channel, denotes the channel center frequency.<br><br>For a 2.16+2.16 GHz channel, denotes the center frequency of the primary channel.<br><br>For a 4.32+4.32 GHz channel, denotes the center frequency of the 4.32 GHz channel containing the primary 2.16 GHz channel.<br><br>Value range is 1 to 15(#4032). |
| dot11EDMGCurrentChannelCenterFrequencyIndex1 | For a 2.16+2.16 GHz channel, denotes the center frequency of the secondary channel.<br><br>For a 4.32+4.32 GHz channel, denotes the center frequency of the 4.32 GHz channel that contains the secondary 2.16 GHz channels only.<br><br>For a 2.16 GHz, 4.32 GHz, 6.48 GHz, and 8.64 GHz channel, it is undefined.<br><br>Value range is 1 to 15. |
| dot11EDMGCurrentPrimaryChannel | Denotes the location of the primary 2.16 GHz channel. Value range is 1 to 15. |

The channelization used by (#4033)an EDMG STA is shown in Figure 28-7 (Channelization used by EDMG STAs(#4034)(11ay)).

(#4033)An EDMG STA can use any of the channels shown in Figure 28-7 (Channelization used by EDMG STAs(#4034)(11ay)). The channel number is shown in the center of the trapezoid defining the particular channel location.

The support of the 2.16 GHz channel number 2, and the 4.32 GHz channel number 10 with channel number 2 as a primary channel is mandatory. The support of other channels is optional.

Table 28-21 (2.16 GHz, 4.32 GHz, 6.48 GHz, and 8.64 GHz channels used by an EDMG STA(11ay)) defines the valid configurations for 2.16 GHz, 4.32 GHz, 6.48 GHz, and 8.64 GHz channels. Table 28-22 (2.16+2.16 GHz channel used by an EDMG STA(11ay)) defines the valid configurations for 2.16+2.16 GHz

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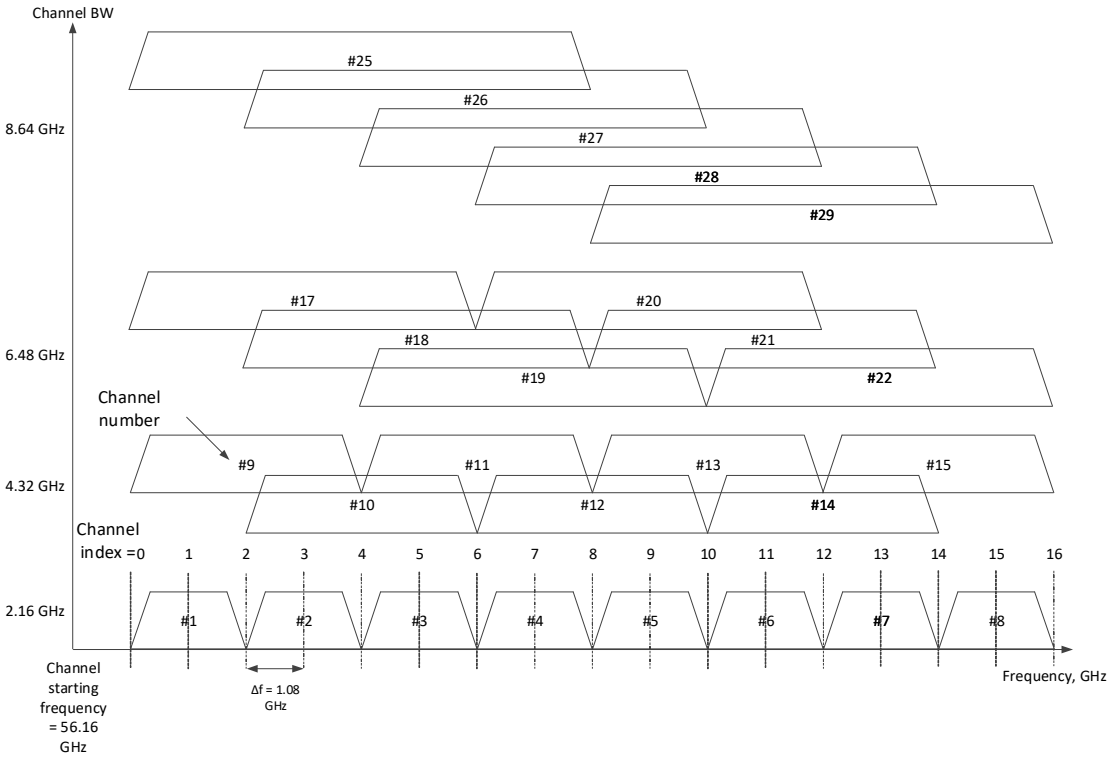


**Figure 28-7—Channelization used by EDMG STAs(#4034)(11ay)**

channel. Table 28-23 (4.32+4.32 GHz channel used by an EDMG STA(11ay)) defines the valid configurations for 4.32+4.32 GHz channel.

(#4034)dot11CurrentChannelCenterFrequencyIndex0 and dot11CurrentChannelCenterFrequencyIndex1 columns in Table 28-21 (2.16 GHz, 4.32 GHz, 6.48 GHz, and 8.64 GHz channels used by an EDMG STA(11ay)), Table 28-22 (2.16+2.16 GHz channel used by an EDMG STA(11ay)), and Table 28-23 (4.32+4.32 GHz channel used by an EDMG STA(11ay)) provide the channel index. The definition of the channel index and channel number is shown in Figure 28-7 (Channelization used by EDMG STAs(#4034)(11ay)). The channel index is defined in the range 0 to 16 and (#4035)is indicated as Channel Idx in the figure. The increment of the channel index by 1 corresponds to the frequency step equal to the half of channel spacing $\Delta f$ = 1.08 GHz depicted in the horizontal axis corresponding to the frequency in GHz.

The current center frequency for the channel containing the primary 2.16 GHz channel is defined as follows:

*Channel center frequency0* [GHz] = (*Channel starting frequency* + $\Delta f$) + $\Delta f$ × *dot11EDMGCurrentChannelCenterFrequencyIndex0*

where

*Channel starting frequency* is given by the operating class (see Annex E)

For 2.16+2.16 GHz and 4.32+4.32 GHz channel configurations, the current center frequency for the channel containing the secondary 2.16 GHz channels only is defined as follows:

*Channel center frequency1* [GHz] = (*Channel starting frequency* + $\Delta f$) + $\Delta f$ × *dot11EDMGCurrentChannelCenterFrequencyIndex1*


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For 4.32 GHz, 6.48 GHz, and 8.64 GHz channels, the dot11EDMGCurrentChannelCenterFrequencyIndex1 is not defined and is marked as N/A in Table 28-21 (2.16 GHz, 4.32 GHz, 6.48 GHz, and 8.64 GHz channels used by an EDMG STA(11ay)).

The center frequency of the primary 2.16 GHz channel is given as follows:

*Primary 2.16 GHz channel center frequency* [GHz] = (*Channel starting frequency* + $\Delta f$) + $\Delta f$ × *dot11EDMGCurrentPrimaryChannel*

The circumstances in which a channel can be used in a regulatory domain is determined by local regulatory rules and any additional rules prescribed by this standard.

### 28.3.5 Transmit mask

NOTE 1—In the presence of additional regulatory restrictions, the device has to meet both the regulatory requirements and the mask defined in this subclause.

NOTE 2—Transmit spectral mask figures in this subclause are not drawn to scale.

NOTE 3—For rules regarding TX center frequency leakage levels, see 28.3.9.4 (Transmit center frequency leakage). The spectral mask requirements in this subclause do not apply to the RF LO leakage and its harmonics.

An EDMG PPDU transmission shall comply with the TX masks defined in this subclause. An EDMG PPDU transmission that partially occupies a channel shall comply with the TX mask defined for the wider channel. For example, a 2.16 GHz PPDU transmission that partially occupies a 4.32 GHz channel shall not exceed the 4.32 GHz channel mask.

A 2.16 GHz PPDU of EDMG and non-EDMG format shall adhere to the transmit spectrum mask shown in Figure 20-1 (Transmit mask).

For a 4.32 GHz mask PPDU or a 2.16+2.16 GHz mask PPDU spanning adjacent channels, the transmit spectral mask shall have a 0 dBr bandwidth of 4.04 GHz, –17 dBr at 2.40 GHz frequency offset, –22 dBr at 5.40 GHz frequency offset, and –30 dBr at 6.12 GHz frequency offset and above. The transmit spectral mask for frequency offsets in between 2.02 and 2.40 GHz, 2.40 and 5.40 GHz, and 5.40 and 6.12 GHz shall be linearly interpolated in decibels from the requirements for 2.02 GHz, 2.40 GHz, 5.40 GHz, and 6.12 GHz frequency offsets. Figure 28-8 (Example transmit spectral mask for a 4.32 GHz mask PPDU(11ay)) shows an example of the resulting overall spectral mask.

For a 6.48 GHz mask PPDU, the transmit spectral mask shall have a 0 dBr bandwidth of 6.20 GHz, –17 dBr at 3.60 GHz frequency offset, –22 dBr at 8.10 GHz frequency offset, and –30 dBr at 9.18 GHz frequency offset and above. The transmit spectral mask for frequency offsets in between 3.10 and 3.60 GHz, 3.60 and 8.10 GHz, and 8.10 and 9.18 GHz shall be linearly interpolated in decibels from the requirements for 3.10 GHz, 3.60 GHz, 8.10 GHz, and 9.18 GHz frequency offsets. Figure 28-9 (Example transmit spectral mask for a 6.48 GHz mask PPDU(11ay))shows an example of the resulting overall spectral mask.

For an 8.64 GHz mask PPDU or a 4.32+4.32 GHz mask PPDU spanning adjacent channels, the transmit spectral mask shall have a 0 dBr bandwidth of 8.36 GHz, –17 dBr at 4.80 GHz frequency offset, –22 dBr at 10.80 GHz frequency offset, and –30 dBr at 12.24 GHz frequency offset and above. The transmit spectral mask for frequency offsets in between 4.18 and 4.80 GHz, 4.80 and 10.80 GHz, and 10.80 and 12.24 GHz shall be linearly interpolated in decibels from the requirements for 4.18 GHz, 4.80 GHz, 10.80 GHz, and 12.24 GHz frequency offsets. Figure 28-10 (Example transmit spectral mask for an 8.64 GHz mask PPDU(11ay)) shows an example of the resulting overall spectral mask.

For 2.16+2.16 GHz or 4.32+4.32 GHz mask PPDUs spanning non-adjacent channels, the overall transmit spectral mask is constructed in the following manner. First, the 2.16 (or 4.32) GHz spectral mask is placed

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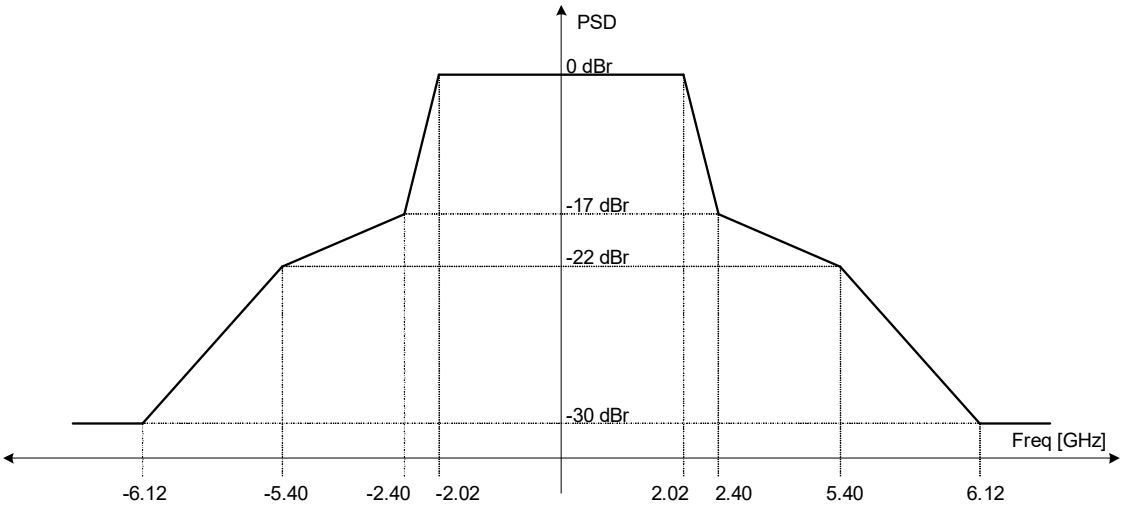


**Figure 28-8—Example transmit spectral mask for a 4.32 GHz mask PPDU(11ay)**

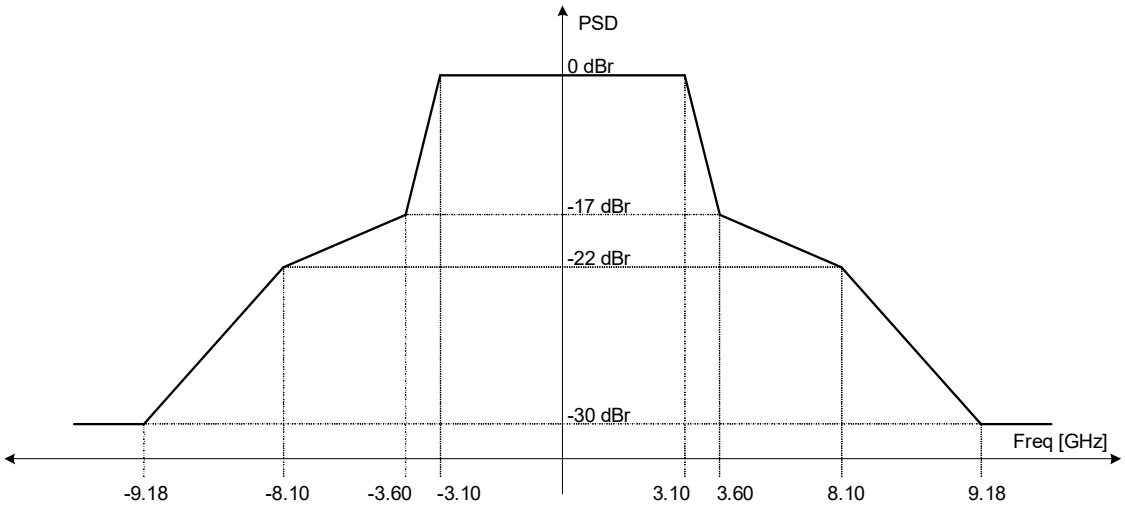


**Figure 28-9—Example transmit spectral mask for a 6.48 GHz mask PPDU(11ay)**

on each of the two 2.16 (or 4.32) GHz segments. Then, for each frequency at which both of the 2.16 (or 4.32) GHz spectral masks have values greater than –30 dBr and less than –17 dBr, the sum of the two mask values (summed in power) shall be taken as the overall spectral mask value. Next, for each frequency at which neither of the two 2.16 (or 4.32) GHz masks have values greater than or equal to –17 dBr and less than or equal to 0 dBr, the higher value of the two masks shall be taken as the overall spectral value.


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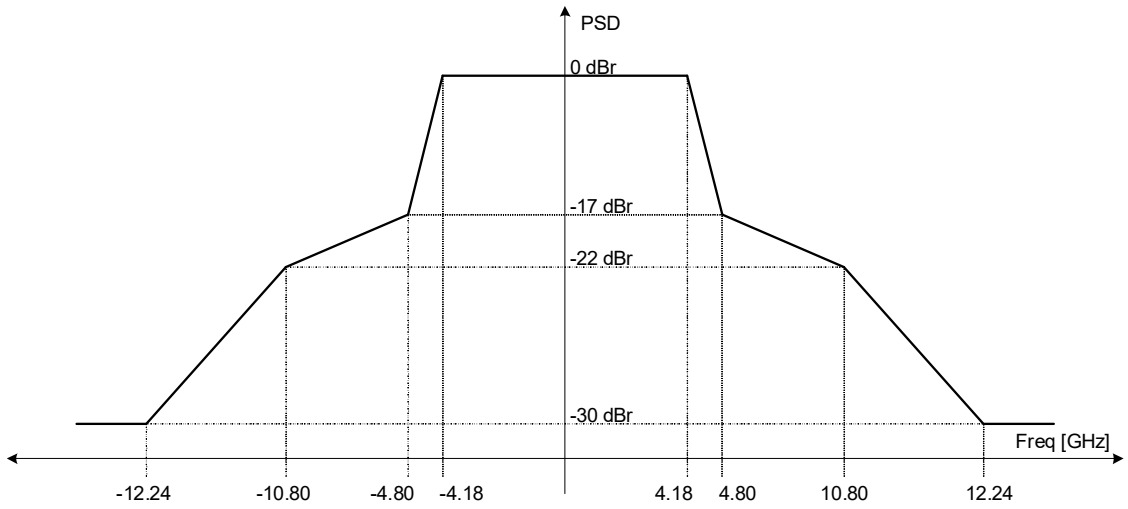


**Figure 28-10—Example transmit spectral mask for an 8.64 GHz mask PPDU(11ay)**

Finally, for any frequency region where the mask value has not been defined yet, linear interpolation (in decibels) between the nearest two frequency points with the spectral mask value defined shall be used to define the spectral mask value.

Different center frequency separation between the two 2.16 GHz frequency segments of the spectral mask as well as different peak levels of each 2.16 GHz frequency segment of the spectral mask are possible, in which case a similar procedure in determining the spectral mask as in Figure 28-11 (Example transmit spectral mask for a 2.16+2.16 GHz mask PPDU(11ay)) is followed.

The transmit spectral mask for noncontiguous transmissions using two nonadjacent channels is applicable only in regulatory domains that allow for such transmissions.

Measurements shall be made using a 1 MHz resolution bandwidth and a 300 kHz video bandwidth.

### 28.3.6 LDPC parity matrices

#### 28.3.6.1 General

The EDMG PHY shall support the LDPC parity matrices specified in 20.3.8 (Common LDPC parity matrices) and may support the additional matrices described in this subclause.

The EDMG PHY defines an additional rate-7/8 LDPC code matrix for a codeword of size equal to 672 bits, which is the same codeword size used in the DMG PHY. The definition of this LDPC code matrix follows the approach specified in 20.3.8 (Common LDPC parity matrices).

In addition, the EDMG PHY also defines an LDPC codeword of size equal to 1344 bits through the use of lifting matrices. A lifting matrix acts on the code matrix to generate a larger matrix as follows:

— A nonblank ‘0’ element in the lifting matrix acts on the $Z \times Z$ cyclic permutation matrix $P_i$ in the code matrix (at the same location) to create the $2Z \times 2Z$ matrix:

— A nonblank ‘1’ element in the lifting matrix acts on the $Z \times Z$ cyclic permutation matrix $P_i$ in the code matrix (at the same location) to create the $2Z \times 2Z$ matrix:

— A blank entry in the lifting matrix acts on the blank entry in the code matrix representing the $Z \times Z$ zero matrix (at the same location) to create the blank entry representing the $2Z \times 2Z$ zero matrix:

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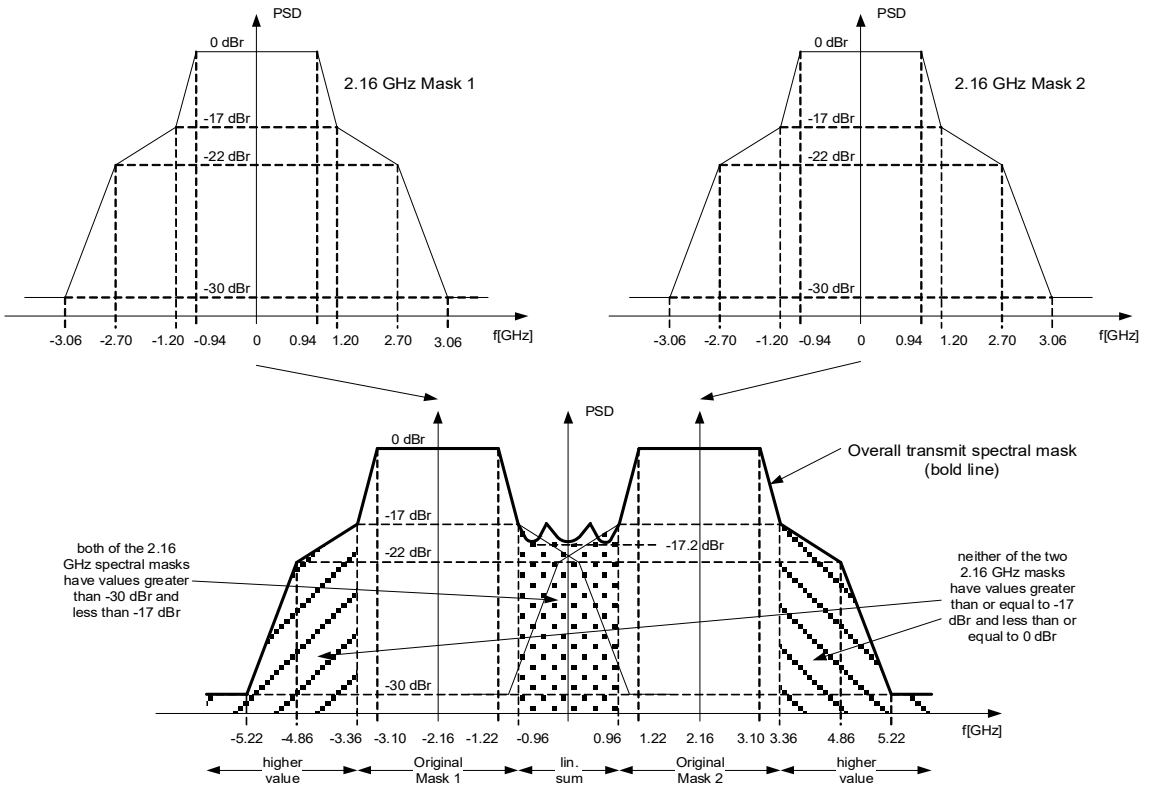


**Figure 28-11—Example transmit spectral mask for a 2.16+2.16 GHz mask PPDU(11ay)**

NOTE—Each element *i* in the matrices represents the cyclic permutation matrix $P_i$, and a blank entry represents the zero matrix of size $Z \times Z$. The cyclic permutation matrix $P_i$ is defined in 20.3.8 (Common LDPC parity matrices).

### 28.3.6.2 Rate-7/8 LDPC code matrix H = 84 rows x 672 columns, *Z* = 42

The rate-7/8 LDPC code matrix with codeword length 672 is defined in Table 28-24 (Rate 7/8 LDPC code matrix(11ay)). It is derived using the rate-3/4 LDPC code matrix specified in Table 20-8 (Rate 3/4 LDPC code matrix (Each nonblank element i in the table is the cyclic permutation matrix Pi of size Z × Z; blank


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**Table 28-21—2.16 GHz, 4.32 GHz, 6.48 GHz, and 8.64 GHz channels used by an EDMG STA(11ay)**

| Channel number(#4034) | TXVECTOR | | | PLME MIB variables (PHYCONFIG_VECTOR) | | | |
|---|---|---|---|---|---|---|---|
| | CH_BANDWIDTH [LSB...MSB] | CHANNEL_AGGREGATION | PRIMARY_CHANNEL | dot11 Current Channel Width | dot11 Current Channel Center Frequency Index0 | dot11 Current Primary Channel | dot11 Current Channel Center Frequency Index1 |
| 1 | 10000000 | NOT_AGGREGATED(#4167) | 1 | 2.16 GHz | 1 | 1 | N/A |
| 2 | 01000000 | | 2 | | 3 | 3 | |
| 3 | 00100000 | | 3 | | 5 | 5 | |
| 4 | 00010000 | | 4 | | 7 | 7 | |
| 5 | 00001000 | | 5 | | 9 | 9 | |
| 6 | 00000100 | | 6 | | 11 | 11 | |
| 7 | 00000010 | | 7 | | 13 | 13 | |
| 8 | 00000001 | | 8 | | 15 | 15 | |
| 9 | 11000000 | | 1 | 4.32 GHz | 2 | 1 | |
| 10 | | | 2 | | | 3 | |
| 11 | 01100000 | | 2 | | 4 | 3 | |
| 12 | | | 3 | | | 5 | |
| 13 | 00110000 | | 3 | | 6 | 5 | |
| 14 | | | 4 | | | 7 | |
| 15 | 00011000 | | 4 | | 8 | 7 | |
| 16 | | | 5 | | | 9 | |
| 17 | 00001100 | | 5 | | 10 | 9 | |
| 18 | | | 6 | | | 11 | |
| 19 | 00000110 | | 6 | | 12 | 11 | |
| 20 | | | 7 | | | 13 | |
| 21 | 00000011 | | 7 | | 14 | 13 | |
| 22 | | | 8 | | | 15 | |

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**Table 28-21—2.16 GHz, 4.32 GHz, 6.48 GHz, and 8.64 GHz channels used by an EDMG STA(11ay) *(continued)***

| Channel number(#4034) | TXVECTOR | | | PLME MIB variables (PHYCONFIG_VECTOR) | | | |
|---|---|---|---|---|---|---|---|
| | CH_BANDWIDTH [LSB…MSB] | CHANNEL_AGGREGATION | PRIMARY_CHANNEL | dot11 Current Channel Width | dot11 Current Channel Center Frequency Index0 | dot11 Current Primary Channel | dot11 Current Channel Center Frequency Index1 |
| 23 | 11100000 | NOT_AGGREGATED(#4167) | 1 | 6.48 GHz | 3 | 1 | N/A |
| 24 | | | 2 | | | 3 | |
| 25 | | | 3 | | | 5 | |
| 26 | 01110000 | | 2 | | 5 | 3 | |
| 27 | | | 3 | | | 5 | |
| 28 | | | 4 | | | 7 | |
| 29 | 00111000 | | 3 | | 7 | 5 | |
| 30 | | | 4 | | | 7 | |
| 31 | | | 5 | | | 9 | |
| 32 | 00011100 | | 4 | | 9 | 7 | |
| 33 | | | 5 | | | 9 | |
| 34 | | | 6 | | | 11 | |
| 35 | 00001110 | | 5 | | 11 | 9 | |
| 36 | | | 6 | | | 11 | |
| 37 | | | 7 | | | 13 | |
| 38 | 00000111 | | 6 | | 13 | 11 | |
| 39 | | | 7 | | | 13 | |
| 40 | | | 8 | | | 15 | |



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**Table 28-21—2.16 GHz, 4.32 GHz, 6.48 GHz, and 8.64 GHz channels used by an EDMG STA(11ay) *(continued)***

| Channel number(#4034) | TXVECTOR | | | PLME MIB variables (PHYCONFIG_VECTOR) | | | |
|---|---|---|---|---|---|---|---|
| | CH_BANDWIDTH [LSB...MSB] | CHANNEL_AGGREGATION | PRIMARY_CHANNEL | dot11 Current Channel Width | dot11 Current Channel Center Frequency Index0 | dot11 Current Primary Channel | dot11 Current Channel Center Frequency Index1 |
| 41 | 11110000 | NOT_AGGREGATED(#4167) | 1 | 8.64 GHz | 4 | 1 | N/A |
| 42 | | | 2 | | | 3 | |
| 43 | | | 3 | | | 5 | |
| 44 | | | 4 | | | 7 | |
| 45 | 01111000 | | 2 | | 6 | 3 | |
| 46 | | | 3 | | | 5 | |
| 47 | | | 4 | | | 7 | |
| 48 | | | 5 | | | 9 | |
| 49 | 00111100 | | 3 | | 8 | 5 | |
| 50 | | | 4 | | | 7 | |
| 51 | | | 5 | | | 9 | |
| 52 | | | 6 | | | 11 | |
| 53 | 00011110 | | 4 | | 10 | 7 | |
| 54 | | | 5 | | | 9 | |
| 55 | | | 6 | | | 11 | |
| 56 | | | 7 | | | 13 | |
| 57 | 00001111 | | 5 | | 12 | 9 | |
| 58 | | | 6 | | | 11 | |
| 59 | | | 7 | | | 13 | |
| 60 | | | 8 | | | 15 | |

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**Table 28-22—2.16+2.16 GHz channel used by an EDMG STA(11ay)**

| Channel number(#4034) | TXVECTOR | | | PLME MIB variables (PHYCONFIG_VECTOR) | | | |
|---|---|---|---|---|---|---|---|
| | CH_BANDWIDTH [LSB...MSB] | CHANNEL_AGGREGATION | PRIMARY_CHANNEL | dot11 Current Channel Width | dot11 Current Channel Center Frequency Index0 | dot11 Current Primary Channel | dot11 Current Channel Center Frequency Index1 |
| 61 | 11000000 | AGGREGATED(#4167) | 1 | 2.16+2.16 GHz | 1 | 1 | 3 |
| 62 | 10100000 | | 1 | | | | 5 |
| 63 | 10010000 | | 1 | | | | 7 |
| 64 | 10001000 | | 1 | | | | 9 |
| 65 | 10000100 | | 1 | | | | 11(#6) |
| 66 | 10000010 | | 1 | | | | 13 |
| 67 | 10000001 | | 1 | | | | 15 |
| 68 | 11000000 | | 2 | | 3 | 3 | 1 |
| 69 | 01100000 | | 2 | | | | 5 |
| 70 | 01010000 | | 2 | | | | 7 |
| 71 | 01001000 | | 2 | | | | 9 |
| 72 | 01000100 | | 2 | | | | 11 |
| 73 | 01000010 | | 2 | | | | 13 |
| 74 | 01000001 | | 2 | | | | 15 |
| 75 | 10100000 | | 3 | | 5 | 5 | 1 |
| 76 | 01100000 | | 3 | | | | 3 |
| 77 | 00110000 | | 3 | | | | 7 |
| 78 | 00101000 | | 3 | | | | 9 |
| 79 | 00100100 | | 3 | | | | 11 |
| 80 | 00100010 | | 3 | | | | 13 |
| 81 | 00100001 | | 3 | | | | 15 |



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**Table 28-22—2.16+2.16 GHz channel used by an EDMG STA(11ay) *(continued)***

| Channel number(#4034) | TXVECTOR | | | PLME MIB variables (PHYCONFIG_VECTOR) | | | |
|---|---|---|---|---|---|---|---|
| | CH_BANDWIDTH [LSB...MSB] | CHANNEL_AGGREGATION | PRIMARY_CHANNEL | dot11 Current Channel Width | dot11 Current Channel Center Frequency Index0 | dot11 Current Primary Channel | dot11 Current Channel Center Frequency Index1 |
| 82 | 10010000 | AGGREGATED(#4167) | 4 | 2.16+2.16 GHz *(continued)* | 7 | 7 | 1 |
| 83 | 01010000 | | 4 | | | | 3 |
| 84 | 00110000 | | 4 | | | | 5 |
| 85 | 00011000 | | 4 | | | | 9 |
| 86 | 00010100 | | 4 | | | | 11 |
| 87 | 00010010 | | 4 | | | | 13 |
| 88 | 00010001 | | 4 | | | | 15 |
| 89 | 10001000 | | 5 | | 9 | 9 | 1 |
| 90 | 01001000 | | 5 | | | | 3 |
| 91 | 00101000 | | 5 | | | | 5 |
| 92 | 00011000 | | 5 | | | | 7 |
| 93 | 00001100 | | 5 | | | | 11 |
| 94 | 00001010 | | 5 | | | | 13 |
| 95 | 00001001 | | 5 | | | | 15 |
| 96 | 10000100 | | 6 | | 11 | 11 | 1 |
| 97 | 01000100 | | 6 | | | | 3 |
| 98 | 00100100 | | 6 | | | | 5 |
| 99 | 00010100 | | 6 | | | | 7 |
| 100 | 00001100 | | 6 | | | | 9 |
| 101 | 00000110 | | 6 | | | | 13 |
| 102 | 00000011 | | 6 | | | | 15 |

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**Table 28-22—2.16+2.16 GHz channel used by an EDMG STA(11ay) *(continued)***

| Channel number(#4034) | TXVECTOR | | | PLME MIB variables (PHYCONFIG_VECTOR) | | | |
|---|---|---|---|---|---|---|---|
| | CH_BANDWIDTH [LSB...MSB] | CHANNEL_AGGREGATION | PRIMARY_CHANNEL | dot11 Current Channel Width | dot11 Current Channel Center Frequency Index0 | dot11 Current Primary Channel | dot11 Current Channel Center Frequency Index1 |
| 103 | 10000010 | AGGREGATED(#4167) | 7 | 2.16+2.16 GHz *(continued)* | 13 | 13 | 1 |
| 104 | 01000010 | | 7 | | | | 3 |
| 105 | 00100010 | | 7 | | | | 5 |
| 106 | 00010010 | | 7 | | | | 7 |
| 107 | 00001010 | | 7 | | | | 9 |
| 108 | 00000110 | | 7 | | | | 11 |
| 109 | 00000011 | | 7 | | | | 15 |
| 110 | 10000001 | | 8 | | 15 | 15 | 1 |
| 111 | 01000001 | | 8 | | | | 3 |
| 112 | 00100001 | | 8 | | | | 5 |
| 113 | 00010001 | | 8 | | | | 7 |
| 114 | 00001001 | | 8 | | | | 9 |
| 115 | 00000101 | | 8 | | | | 11 |
| 116 | 00000011 | | 8 | | | | 13 |



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**Table 28-23—4.32+4.32 GHz channel used by an EDMG STA(11ay)**

| Channel number(#4034) | TXVECTOR | | | PLME MIB variables (PHYCONFIG_VECTOR) | | | |
|---|---|---|---|---|---|---|---|
| | CH_BANDWIDTH [LSB...MSB] | CHANNEL_AGGREGATION | PRIMARY_CHANNEL | dot11 Current Channel Width | dot11 Current Channel Center Frequency Index0 | dot11 Current Primary Channel | dot11 Current Channel Center Frequency Index1 |
| 117 | 11110000 | AGGREGATED(#4167) | 1 | 4.32+4.32 GHz | 2 | 1 | 6 |
| 118 | | | 2 | | | 3 | |
| 119 | 11011000 | | 1 | | | 1 | 8 |
| 120 | | | 2 | | | 3 | |
| 121 | 11001100 | | 1 | | | 1 | 10 |
| 122 | | | 2 | | | 3 | |
| 123 | 11000110 | | 1 | | | 1 | 12 |
| 124 | | | 2 | | | 3 | |
| 125 | 11000011 | | 1 | | | 1 | 14 |
| 126 | | | 2 | | | 3 | |
| 127 | 01111000 | | 2 | | 4 | 3 | 8 |
| 128 | | | 3 | | | 5 | |
| 129 | 01101100 | | 2 | | | 3 | 10 |
| 130 | | | 3 | | | 5 | |
| 131 | 01100110 | | 2 | | | 3 | 12 |
| 132 | | | 3 | | | 5 | |
| 133 | 01100011 | | 2 | | | 3 | 14 |
| 134 | | | 3 | | | 5 | |

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**Table 28-23—4.32+4.32 GHz channel used by an EDMG STA(11ay) *(continued)***

| Channel number(#4034) | TXVECTOR | | | PLME MIB variables (PHYCONFIG_VECTOR) | | | |
|---|---|---|---|---|---|---|---|
| | CH_BANDWIDTH [LSB...MSB] | CHANNEL_AGGREGATION | PRIMARY_CHANNEL | dot11 Current Channel Width | dot11 Current Channel Center Frequency Index0 | dot11 Current Primary Channel | dot11 Current Channel Center Frequency Index1 |
| 135 | 11110000 | AGGREGATED(#4167) | 3 | 4.32+4.32 GHz *(continued)* | 6 | 5 | 2 |
| 136 | | | 4 | | | 7 | |
| 137 | 00111100 | | 3 | | | 5 | 10 |
| 138 | | | 4 | | | 7 | |
| 139 | 00110110 | | 3 | | | 5 | 12 |
| 140 | | | 4 | | | 7 | |
| 141 | 00110011 | | 3 | | | 5 | 14 |
| 142 | | | 4 | | | 7 | |
| 143 | 11011000 | | 4 | | 8 | 7 | 2 |
| 144 | | | 5 | | | 9 | |
| 145 | 01111000 | | 4 | | | 7 | 4 |
| 146 | | | 5 | | | 9 | |
| 147 | 00011110 | | 4 | | | 7 | 12 |
| 148 | | | 5 | | | 9 | |
| 149 | 00011011 | | 4 | | | 7 | 14 |
| 150 | | | 5 | | | 9 | |
| 151 | 11001100 | | 5 | | 10 | 9 | 2 |
| 152 | | | 6 | | | 11 | |
| 153 | 01101100 | | 5 | | | 9 | 4 |
| 154 | | | 6 | | | 11 | |
| 155 | 00111100 | | 5 | | | 9 | 6 |
| 156 | | | 6 | | | 11 | |
| 157 | 00001111 | | 5 | | | 9 | 14 |
| 158 | | | 6 | | | 11 | |



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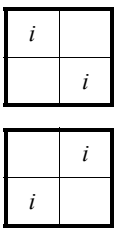
**Table 28-23—4.32+4.32 GHz channel used by an EDMG STA(11ay) *(continued)***

| Channel number(#4034) | TXVECTOR | | | PLME MIB variables (PHYCONFIG_VECTOR) | | | |
|---|---|---|---|---|---|---|---|
| | CH_BANDWIDTH [LSB...MSB] | CHANNEL_AGGREGATION | PRIMARY_CHANNEL | dot11 Current Channel Width | dot11 Current Channel Center Frequency Index0 | dot11 Current Primary Channel | dot11 Current Channel Center Frequency Index1 |
| 159 | 11000110 | AGGREGATED(#4167) | 6 | 4.32+4.32 GHz *(continued)* | 12 | 11 | 2 |
| 160 | | | 7 | | | 13 | |
| 161 | 01100110 | | 6 | | | 11 | 4 |
| 162 | | | 7 | | | 13 | |
| 163 | 00110110 | | 6 | | | 11 | 6 |
| 164 | | | 7 | | | 13 | |
| 165 | 00011110 | | 6 | | | 11 | 8 |
| 166 | | | 7 | | | 13 | |
| 167 | 11000011 | | 7 | | 14 | 13 | 2 |
| 168 | | | 8 | | | 15 | |
| 169 | 01100011 | | 7 | | | 13 | 4 |
| 170 | | | 8 | | | 15 | |
| 171 | 00110011 | | 7 | | | 13 | 6 |
| 172 | | | 8 | | | 15 | |
| 173 | 00011011 | | 7 | | | 13 | 8 |
| 174 | | | 8 | | | 15 | |
| 175 | 00001111 | | 7 | | | 13 | 10 |
| 176 | | | 8 | | | 15 | |

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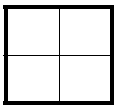

entries represent the zero matrix of size Z × Z)) by rows 1 and 3, 2 and 4 modulo-2 addition of the original rate-3/4 LDPC matrix.

**Table 28-24—Rate 7/8 LDPC code matrix(11ay)**

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 37⊕35 | 31⊕19 | 18⊕41 | 23⊕22 | 11⊕40 | 21⊕41 | 6⊕39 | 20⊕6 | 32⊕28 | 9⊕18 | 12⊕17 | 29⊕3 | 28 | 0 | 13 | |
| 25⊕29 | 22⊕30 | 4⊕0 | 34⊕8 | 31⊕33 | 3⊕22 | 14⊕17 | 15⊕4 | 4⊕27 | 28 | 14⊕20 | 18⊕27 | 13⊕24 | 13⊕23 | 22 | 24 |

NOTE—Each nonblank element $i$ or $i \oplus j$ is the cyclic permutation matrix $P_i$ of size $Z \times Z$ or the modulo-2 addition of the cyclic permutation matrices $P_i$ and $P_j$ of size $Z \times Z$ (denoted by $P_i \oplus P_j$), respectively; blank entries represent the zero matrix of size $Z \times Z$.

### 28.3.6.3 Rate-1/2 LDPC code matrix H = 672 rows x 1344 columns, *Z* = 42

The rate-1/2 LDPC code matrix with codeword length 1344 is defined in Table 28-25 (Rate-1/2 LDPC code matrix(11ay)). It is derived using rate-1/2 LDPC code matrix specified in Table 20-6 (Rate 1/2 LDPC code matrix (Each nonblank element i in the table is the cyclic permutation matrix Pi of size Z × Z; blank entries represent the zero matrix of size Z × Z)) by application of the lifting matrix specified in Table 28-26 (Rate-1/2 lifting matrix(11ay)).

**Table 28-25—Rate-1/2 LDPC code matrix(11ay)**

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 40 | | | | | 38 | | | 13 | | | | | 5 | | | 18 | | | | | | | | | | | | | | |
| | 40 | | | 38 | | | | | 13 | | | 5 | | | | | 18 | | | | | | | | | | | | | |
| 34 | | | | 35 | | | | | 27 | | | | | | 30 | 2 | | 1 | | | | | | | | | | | | |
| | 34 | | | | 35 | | | 27 | | | | | | 30 | | | 2 | | 1 | | | | | | | | | | | |
| | | 36 | | | | | 31 | | | 7 | | | | | 34 | | | | 10 | 41 | | | | | | | | | | |
| | | | 36 | | | 31 | | | | | 7 | | | 34 | | | | 10 | | | 41 | | | | | | | | | |
| | | | 27 | | | | 18 | | | | 12 | 20 | | | | | | | | 15 | | 6 | | | | | | | | |
| | | 27 | | | | 18 | | | | 12 | | | 20 | | | | | | | | 15 | | 6 | | | | | | | |
| 35 | | | | | 41 | | | | 40 | | | 39 | | | | 28 | | | | | | | 3 | 28 | | | | | | |
| | 35 | | | 41 | | | | 40 | | | | | 39 | | | | 28 | | | | | 3 | | | 28 | | | | | |
| | 29 | | | | 0 | | | | | | 22 | | | 4 | | | | | 28 | | | | 27 | | | 23 | | | | |
| 29 | | | | 0 | | | | | | 22 | | | | | 4 | | | 28 | | | | 27 | | | | | 23 | | | |
| | | 31 | | | | 23 | | | | | 21 | | | 20 | | | | | | 12 | | | | | | | 0 | 13 | | |
| | | | 31 | | | | 23 | | | 21 | | | | | 20 | | | | | | 12 | | | | | 0 | | | 13 | |
| | | 22 | | | | | 34 | 31 | | | | 14 | | | | 4 | | | | | | | | | 13 | | | 22 | | 24 | |
| | | | 22 | | | 34 | | | 31 | | | | 14 | | | | 4 | | | | | | | 13 | | | | 22 | | 24 |



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NOTE—Each nonblank element $i$ in the table is the cyclic permutation matrix $P_i$ of size $Z \times Z$; blank entries represent the zero matrix of size $Z \times Z$.

**Table 28-26—Rate-1/2 lifting matrix(11ay)**

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | | 1 | | 0 | | 1 | | 0 | | | | | | | |
| 0 | | 0 | | 1 | | | 1 | 0 | 0 | | | | | | |
| | 0 | | 1 | | 0 | | 1 | | 1 | 0 | | | | | |
| | 1 | | 1 | | 1 | 0 | | | | 0 | 0 | | | | |
| 0 | | 1 | | 1 | | 0 | | 0 | | | 1 | 0 | | | |
| 1 | | 1 | | | 1 | | 0 | | 1 | | 1 | | 0 | | |
| | 0 | | 0 | | 1 | | 0 | | | 0 | | | 1 | 0 | |
| | 0 | | 1 | 0 | | 0 | | 0 | | | | 1 | | 0 | 0 |

### 28.3.6.4 Rate-5/8 LDPC code matrix H = 504 rows x 1344 columns, *Z* = 42

The rate-5/8 LDPC code matrix with codeword length 1344 is defined in Table 28-27 (Rate-5/8 LDPC code matrix(11ay)). It is derived using rate-5/8 LDPC code matrix specified in Table 20-7 by application of the lifting matrix specified in Table 28-28 (Rate-5/8 lifting matrix(11ay)).

**Table 28-27—Rate-5/8 LDPC code matrix(11ay)**

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 20 | | 36 | | | 34 | | 31 | 20 | | 7 | | | 41 | | 34 | | | | 10 | 41 | | | | | | | | | | |
| | 20 | | 36 | 34 | | 31 | | | 20 | | 7 | 41 | | 34 | | | | 10 | | | 41 | | | | | | | | | |
| 30 | | | 27 | | | | 18 | | | | 12 | 20 | | 14 | | | 2 | | 25 | 15 | | 6 | | | | | | | | |
| | 30 | 27 | | | | 18 | | | | 12 | | | 20 | | 14 | 2 | | 25 | | | 15 | | 6 | | | | | | | |
| 35 | | | | | 41 | | | | 40 | | | 39 | | | | 28 | | | | | | 3 | 28 | | | | | | | |
| | 35 | | | 41 | | | | 40 | | | | | 39 | | | | 28 | | | | | 3 | | | 28 | | | | | |
| | 29 | | | | 0 | | | | | | 22 | | | 4 | | | | | 28 | | | | 27 | | 24 | 23 | | | | |
| 29 | | | | 0 | | | | | | 22 | | | | | 4 | | | 28 | | | | 27 | | 24 | | | 23 | | | |
| | | 31 | | | | 23 | | | | | 21 | | | 20 | | | | 9 | | 12 | | | | | | | 0 | 13 | | |
| | | | 31 | | | | 23 | | | 21 | | | | | 20 | | | | 9 | | 12 | | | | | 0 | | | 13 | | |
| | | 22 | | | | | 34 | 31 | | | | 14 | | | | 4 | | | | | | | | | | | | 22 | | 24 | |
| | | | 22 | | | 34 | | | 31 | | | | 14 | | | | 4 | | | | | | | | | | | | 22 | | 24 |

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NOTE—Each nonblank element *i* in the table is the cyclic permutation matrix $P_i$ of size $Z \times Z$; blank entries represent the zero matrix of size $Z \times Z$.

**Table 28-28—Rate-5/8 lifting matrix(11ay)**

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | | 1 | 0 | | | | | |
| 0 | 1 | | 1 | | 1 | 0 | 0 | 1 | 1 | 0 | 0 | | | | |
| 0 | | 1 | | 1 | | 0 | | 0 | | | 1 | 0 | | | |
| 1 | | 1 | | | 1 | | 0 | | 1 | | 1 | 1 | 0 | | |
| | 0 | | 0 | | 1 | | 0 | | 0 | 0 | | | 1 | 0 | |
| | 0 | | 1 | 0 | | 0 | | 0 | | | | | | 0 | 0 |

### 28.3.6.5 Rate-3/4 LDPC code matrix H = 336 rows x 1344 columns, *Z* = 42

The rate-3/4 LDPC code matrix with codeword length 1344 is defined in Table 28-29 (Rate-3/4 LDPC code matrix(11ay)). It is derived using rate-3/4 LDPC code matrix specified in Table 20-8 (Rate 3/4 LDPC code matrix (Each nonblank element i in the table is the cyclic permutation matrix Pi of size Z × Z; blank entries represent the zero matrix of size Z × Z)) by application of the lifting matrix specified in Table 28-30 (Rate-3/4 lifting matrix(11ay)).

**Table 28-29—Rate-3/4 LDPC code matrix(11ay)**

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 35 | | 19 | | | 41 | | 22 | | 40 | 41 | | 39 | | | 6 | 28 | | 18 | | | 17 | | 3 | 28 | | | | | | |
| | 35 | | 19 | 41 | | 22 | | 40 | | | 41 | | 39 | 6 | | | 28 | | 18 | 17 | | 3 | | | 28 | | | | | |
| | 29 | 30 | | | 0 | | 8 | | 33 | | 22 | 17 | | 4 | | | 27 | | 28 | 20 | | | 27 | | 24 | 23 | | | | |
| 29 | | | 30 | 0 | | 8 | | 33 | | 22 | | | 17 | | 4 | 27 | | 28 | | | 20 | 27 | | 24 | | | 23 | | | |
| 37 | | 31 | | 18 | | 23 | | 11 | | | 21 | 6 | | 20 | | 32 | | 9 | | 12 | | | 29 | | | | 0 | 13 | | |
| | 37 | | 31 | | 18 | | 23 | | 11 | 21 | | | 6 | | 20 | | 32 | | 9 | | 12 | 29 | | | | 0 | | | 13 | |
| | 25 | 22 | | | 4 | | 34 | 31 | | | 3 | 14 | | | 15 | 4 | | | | | 14 | 18 | | | 13 | 13 | | 22 | | 24 | |
| 25 | | | 22 | 4 | | 34 | | | 31 | 3 | | | 14 | 15 | | | 4 | | | 14 | | | 18 | 13 | | | 13 | | 22 | | 24 |

NOTE—Each nonblank element *i* in the table is the cyclic permutation matrix $P_i$ of size $Z \times Z$; blank entries represent the zero matrix of size $Z \times Z$.

**Table 28-30—Rate-3/4 lifting matrix(11ay)**

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | | | |
| 1 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | | |
| 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | | 1 | 0 | |
| 1 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | | 1 | 0 | 1 | 0 | 0 | 0 |


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### 28.3.6.6 Rate-13/16 LDPC code matrix H = 252 rows x 1344 columns, *Z* = 42

The rate-13/16 LDPC code matrix with codeword length 1344 is defined in Table 28-31 (Rate-13/16 LDPC code matrix(11ay)). It is derived using rate-13/16 LDPC code matrix specified in Table 20-9 (Rate 13/16 LDPC code matrix (Each nonblank element i in the table is the cyclic permutation matrix Pi of size Z × Z; blank entries represent the zero matrix of size Z × Z)) by application of the lifting matrix specified in Table 28-32 (Rate-13/16 lifting matrix(11ay)).

**Table 28-31—Rate-13/16 LDPC code matrix(11ay)**

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 29 | 30 | | | 0 | | 8 | | 33 | | 22 | 17 | | 4 | | | 27 | | 28 | 20 | | | 27 | | 24 | 23 | | | | | |
| 29 | | | 30 | 0 | | 8 | | 33 | | 22 | | | 17 | | 4 | 27 | | 28 | | | 20 | 27 | | 24 | | | 23 | | | | |
| 37 | | 31 | | 18 | | 23 | | 11 | | | 21 | 6 | | 20 | | 32 | | 9 | | 12 | | | 29 | | 10 | | 0 | 13 | | | |
| | 37 | | 31 | | 18 | | 23 | | 11 | 21 | | | 6 | | 20 | | 32 | | 9 | | 12 | 29 | | 10 | | 0 | | | 13 | | |
| | 25 | 22 | | | 4 | | 34 | 31 | | | 3 | 14 | | | 15 | 4 | | 2 | | | 14 | 18 | | | 13 | 13 | | 22 | | 24 | |
| 25 | | | 22 | 4 | | 34 | | | 31 | 3 | | | 14 | 15 | | | 4 | | 2 | 14 | | | 18 | 13 | | | 13 | | 22 | | 24 |

NOTE—Each nonblank element *i* in the table is the cyclic permutation matrix $P_i$ of size $Z \times Z$; blank entries represent the zero matrix of size $Z \times Z$.

**Table 28-32—Rate-13/16 lifting matrix(11ay)**

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | | |
| 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | |
| 1 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 |

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### 28.3.6.7 Rate-7/8 LDPC code matrix H = 168 rows x 1344 columns, *Z* = 42

The rate-7/8 LDPC code matrix with codeword length 1344 is defined in Table 28-33 (Rate-7/8 LDPC code matrix(11ay)). This code matrix is derived using rate-3/4 LDPC code matrix specified in Table 20-8 (Rate 3/4 LDPC code matrix (Each nonblank element i in the table is the cyclic permutation matrix Pi of size Z × Z; blank entries represent the zero matrix of size Z × Z)) by applying two steps. In the first step, the lifting matrix in Table 28-34 (Rate-7/8 lifting matrix(11ay)) is applied to the rate-3/4 LDPC code matrix. In the second step, rows 1 and 5, 2 and 6, 3 and 7, and 4 and 8 modulo-2 addition of the lifted matrix is performed to produce the resulting rate-7/8 LDPC code matrix specified in Table 28-33 (Rate-7/8 LDPC code matrix(11ay)).

**Table 28-33—Rate-7/8 LDPC code matrix(11ay)**

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 37 | 35 | 31 | 19 | 41 | 18 | 22 | 23 | 40 | 11 | 41 | 21 | 39 | 6 | 20 | 6 | 32 | 28 | 18 | 9 | 12 | 17 | 3 | 29 | 28 | | 0 | | | 13 | | |
| 35 | 37 | 19 | 31 | 18 | 41 | 23 | 22 | 11 | 40 | 21 | 41 | 6 | 39 | 6 | 20 | 28 | 32 | 9 | 18 | 17 | 12 | 29 | 3 | | 28 | | 0 | 13 | | | |
| 25 | 29 | 30 | 22 | 0 | 4 | 34 | 8 | 31 | 33 | 3 | 22 | 14 | 17 | 15 | 4 | 4 | 27 | | 28 | 14 | 20 | 27 | 18 | 13 | 24 | 13 | 23 | 22 | | 24 | |
| 29 | 25 | 22 | 30 | 4 | 0 | 8 | 34 | 33 | 31 | 22 | 3 | 17 | 14 | 4 | 15 | 27 | 4 | 28 | | 20 | 14 | 18 | 27 | 24 | 13 | 23 | 13 | | 22 | | 24 |

NOTE—Each nonblank element *i* in the table is the cyclic permutation matrix $P_i$ of size $Z \times Z$; blank entries represent the zero matrix of size $Z \times Z$.

**Table 28-34—Rate-7/8 lifting matrix(11ay)**

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | | | |
| 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | | |
| 0 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | | 0 | 1 | |
| 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 1 | 0 | 0 | 0 | 0 |

### 28.3.7 Control trailer

If the TXVECTOR parameter SCRAMBLER_INIT_SETTING is (M118)equal to CONTROL_TRAILER for a non-EDMG control mode PPDU, a control trailer shall be inserted in the PPDU immediately following the Data field of the PPDU. The control trailer is one LDPC codeword with 18 data octets and 21 parity octets. The control trailer is added after the Data field of a non-EDMG control mode PPDU, using and continuing the control mode modulation and encoding. The scrambler is used to generate the control trailer and its initial state is the final state of the scrambler from the Data field of the PPDU.

To indicate the presence of a control trailer in a non-EDMG control mode PPDU, the Scrambler Initialization field in the L-Header shall be set as indicated in Table 28-5 (Definition of Scrambler Initialization field when transmitted using the control mode and the Turnaround field is 0(11ay)) and the value of the Training Length field in the L-Header shall be incremented by 2 to account for the presence of the control trailer. If the value of the Training Length field is equal to 2, the control trailer takes the place of the AGC and TRN fields following the Data field. If the value of the Training Length field is greater than 2, the AGC and TRN fields are appended after the control trailer.

The format of the control trailer depends on the value of the TXVECTOR parameter CT_TYPE. Each control trailer starts with a CT Format Type field, whose value depends on the value of the CT_TYPE parameter as shown in Table 28-35 (CT Format Type field value(11ay)). Table 28-36 (Control trailer


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definition when CT_TYPE is CTS_DTS(11ay)) defines the control trailer format when the CT_TYPE parameter is equal to CTS_DTS. Table 28-37 (Control trailer definition when CT_TYPE is GRANT_RTS_CTS2self(11ay)) defines the control trailer format when the CT_TYPE parameter is equal to GRANT_RTS_CTS2self. Table 28-38 (Control trailer definition when CT_TYPE is SPR(11ay)) defines the control trailer format when the CT_TYPE parameter is equal to SPR. Table 28-39 (Control trailer definition when CT_TYPE is SSW_FEEDBACK, BLOCK_ACK, or ACK(11ay)) defines the control trailer format when the CT_TYPE parameter is equal to SSW_FEEDBACK, BLOCK_ACK or ACK.

**Table 28-35—CT Format Type field value(11ay)**

| CT_TYPE parameter value | CT Format Type field value |
|---|---|
| CTS_DTS | 0 |
| GRANT_RTS_CTS2self | 1 |
| SPR | 2 |
| SSW_FEEDBACK, BLOCK_ACK or ACK | 3 |
| Reserved | 4–15 |

**Table 28-36—Control trailer definition when CT_TYPE is CTS_DTS(11ay)**

| Field | Number of bits | Start bit | Description |
|---|---|---|---|
| CT Format Type | 4 | 0 | Indicates the format of the control trailer. This field takes the value defined in Table 28-35 (CT Format Type field value(11ay)) for CT_TYPE = CTS_DTS. |
| Channel Aggregation | 1 | 4 | See Table 28-12 (EDMG-Header-A field structure and definition for an SU PPDU(11ay)). |
| BW | 8 | 5 | See Table 28-12 (EDMG-Header-A field structure and definition for an SU PPDU(11ay)). |
| Primary Channel Number | 3 | 13 | See Table 28-12 (EDMG-Header-A field structure and definition for an SU PPDU(11ay)). |
| SISO/MIMO | 1 | 16 | Corresponds to the TXVECTOR parameter NEXT_TX_SISO. Set to 0 to indicate that the following transmission from this STA is performed with a single antenna. Set to 1 to indicate that the following transmission from this STA is performed with multiple antennas. |
| SU/MU MIMO | 1 | 17 | Corresponds to the TXVECTOR parameter MU_MIMO_NEXT. Set to 0 to indicate SU-MIMO, and set to 1 to indicate MU-MIMO. Reserved when the SISO/ MIMO field is(M118) 0. |
| EDMG Group ID | 8 | 18 | Corresponds to the TXVECTOR parameter EDMG_GROUP_ID. This field indicates the group of STAs that are involved in the following MU-MIMO transmission. Reserved when the SU/MU MIMO field is(M118) 0. |

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**Table 28-36—Control trailer definition when CT_TYPE is CTS_DTS(11ay) *(continued)***

| Field | Number of bits | Start bit | Description |
|---|---|---|---|
| TX Sector Combination Index | 6 | 26 | Indicates the TX sector combination (as defined in 9.4.2.267 (EDMG Channel Measurement Feedback element(11ay))) and the corresponding RX AWVs to be used in the SU-MIMO transmission from the EDMG STA transmitting the CTS to the EDMG STA that transmitted the RTS. Reserved if the SISO/MIMO field is(M118) 0, if the SU/MU MIMO field is(M118) 1 or if the control trailer is sent with a DMG DTS frame. |
| HBF | 1 | 32 | Corresponds to the TXVECTOR parameter HBF_TRAINING. Set to 0 to indicate that the following transmission from this STA is not hybrid beamforming training. Set to 1 to indicate that the following transmission from this STA is hybrid beamforming training. Reserved when the SISO/MIMO field is 0. |
| Reserved | 95 | 33 | Set to 0 by the transmitter and ignored by the receiver. |
| CTCS | 16 | 128 | Control Trailer Check Sequence (CTCS) is a CRC-16 computed over the content of the control trailer. The CRC-16 is computed as defined in 20.3.7 (HCS calculation for headers of DMG control mode and DMG SC mode). |

**Table 28-37—Control trailer definition when CT_TYPE is GRANT_RTS_CTS2self(11ay)**

| Field | Number of bits | Start bit | Description |
|---|---|---|---|
| CT Format Type | 4 | 0 | Indicates the format of the control trailer. This field takes the value defined in Table 28-35 (CT Format Type field value(11ay)) for CT_TYPE = GRANT_RTS_CTS2self. |
| Channel Aggregation | 1 | 4 | See Table 28-12 (EDMG-Header-A field structure and definition for an SU PPDU(11ay)). |
| BW | 8 | 5 | See Table 28-12 (EDMG-Header-A field structure and definition for an SU PPDU(11ay)). |
| Primary Channel Number | 3 | 13 | See Table 28-12 (EDMG-Header-A field structure and definition for an SU PPDU(11ay)). |
| SISO/MIMO | 1 | 16 | See Table 28-36 (Control trailer definition when CT_TYPE is CTS_DTS(11ay)). |
| SU/MU MIMO | 1 | 17 | See Table 28-36 (Control trailer definition when CT_TYPE is CTS_DTS(11ay)). |
| TX Sector Combination Index | 6 | 18 | Indicates the TX sector combination (as defined in 9.4.2.267 (EDMG Channel Measurement Feedback element(11ay))) and the corresponding RX AWVs to be used in the following SU-MIMO transmission. Reserved if the SISO/MIMO field is 0 or the SU/MU MIMO field is 1. |
| EDMG Group ID | 8 | 24 | See Table 28-36 (Control trailer definition when CT_TYPE is CTS_DTS(11ay)). |


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**Table 28-37—Control trailer definition when CT_TYPE is GRANT_RTS_CTS2self(11ay)**

| Field | Number of bits | Start bit | Description |
|---|---|---|---|
| MU-MIMO Transmission Configuration Type | 1 | 32 | Corresponds to the TXVECTOR parameter MU_MIMO_TX_CONFIG_TYPE. Set to 1 to indicate that the MU-MIMO transmission configuration was obtained from the reciprocal MU-MIMO BF training; set to 0 to indicate that the MU-MIMO transmission configuration was obtained from the nonreciprocal MU-MIMO BF training. Reserved if the SISO/MIMO field is 0 or the SU/MU MIMO field is 0. |
| MU-MIMO Transmission Configuration Index | 3 | 33 | Corresponds to the TXVECTOR parameter MU_MIMO_TX_CONFIG_INDEX. Indicates the MU-MIMO transmission configuration (as defined in 9.4.2.275 (MIMO Selection Control element(11ay))) to be used in the following MU-MIMO transmission. Reserved if the SISO/MIMO field is 0 or the SU/MU MIMO field is 0. |
| Total Number of Sectors MSB | 4 | 36 | This field is prepended to the Total Number of Sectors subfield in the BF Control field to form a single 11-bit field indicating the total number of sectors the initiator or the responder uses during an SLS. This field is reserved and set to 0 when the PPDU does not carry a Grant or Grant Ack frame with the Beamforming Training field equal to 1. |
| Number of RX DMG Antennas MSB | 1 | 40 | This field is prepended to the Number of RX DMG Antennas subfield in the BF Control field to form a single 3-bit field indicating the total number of repetitions of the TXSS that the initiator or the responder uses during the SLS. This field is reserved and set to 0 when the PPDU does not carry a Grant or Grant Ack frame with the Beamforming Training field equal to 1. |
| HBF | 1 | 41 | See Table 28-36 (Control trailer definition when CT_TYPE is CTS_DTS(11ay)). |
| Reserved | 86 | 42 | Set to 0 by the transmitter and ignored by the receiver. |
| CTCS | 16 | 128 | Control Trailer Check Sequence (CTCS) is a CRC-16 computed over the content of the control trailer. The CRC-16 is computed as defined in 20.3.7 (HCS calculation for headers of DMG control mode and DMG SC mode). |

**Table 28-38—Control trailer definition when CT_TYPE is SPR(11ay)**

| Field | Number of bits | Start bit | Description |
|---|---|---|---|
| CT Format Type | 4 | 0 | Indicates the format of the control trailer. This field takes the value defined in Table 28-35 (CT Format Type field value(11ay)) for CT_TYPE = SPR. |
| Channel Aggregation | 1 | 4 | See Table 28-12 (EDMG-Header-A field structure and definition for an SU PPDU(11ay)). |

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**Table 28-38—Control trailer definition when CT_TYPE is SPR(11ay) *(continued)***

| Field | Number of bits | Start bit | Description |
|---|---|---|---|
| BW | 8 | 5 | Corresponds to the TXVECTOR parameter BW_IN_CT. Indicates the requested channel width or channel number of the allocation.<br><br>If the Is Channel Number field is(M118) 1, the BW field indicates the requested channel number for the allocation per the channel numbers defined in Annex E.<br><br>If the Is Channel Number field is(M118) 0, the BW field indicates a channel width using the bitmap format of the BW field defined in Table 28-12 (EDMG-Header-A field structure and definition for an SU PPDU(11ay)). In this case, the channel width can be allocated on any channel number. |
| Primary Channel Number | 3 | 13 | See Table 28-12 (EDMG-Header-A field structure and definition for an SU PPDU(11ay)). |
| Is Channel Number | 1 | 16 | Corresponds to the TXVECTOR parameter IS_CHANNEL_NUMBER. Indicates whether the value in the BW subfield represents a channel width or a channel number (see 11.4.12.3 (Asynchronous allocations)). |
| Total Number of Sectors | 11 | 17 | Corresponds to the TXVECTOR parameter NUM_SECTORS. This field indicates the total number of sectors the initiator or the unsolicited RSS responder uses during an SLS. This field is reserved and set to 0 when the PPDU does not carry an SPR frame with the Beamforming Training field equal to 1. |
| Number of RX DMG Antennas | 3 | 28 | Corresponds to the TXVECTOR parameter NUM_ANT. This field indicates the total number of repetitions of the TXSS that the responder uses during the SLS. This field is reserved and set to 0 when the PPDU does not carry an SPR frame with the Beamforming Training field equal to 1. |
| Reserved | 97 | 31 | Set to 0 by the transmitter and ignored by the receiver. |
| CTCS | 16 | 128 | Control Trailer Check Sequence (CTCS) is a CRC-16 computed over the content of the control trailer. The CRC-16 is computed as defined in 20.3.7 (HCS calculation for headers of DMG control mode and DMG SC mode). |


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**Table 28-39—Control trailer definition when CT_TYPE is SSW_FEEDBACK, BLOCK_ACK, or ACK(11ay)**

| Field | Number of bits | Start bit | Description |
|---|---|---|---|
| CT Format Type | 4 | 0 | Indicates the format of the control trailer. This field takes the value defined in Table 28-35 (CT Format Type field value(11ay)) for CT_TYPE = SSW_FEEDBACK, BLOCK_ACK or ACK. |
| Number of reported Streams | 3 | 4 | Indicates the total number of reported streams minus one. This value should match the Number of SS field in the PHY header of the PPDU to which this Control frame is responding. |
| Stream 1 SNR | 4 | 7 | Range 0 to 30 dB in 2 dB steps. |
| Stream 1 RSSI | 3 | 11 | Range –70 dBm to –42 dBm in 4 dB steps. |
| Stream 2 SNR | 4 | 14 | Range 0 to 30 dB in 2 dB steps.<br>If unused, these bits are reserved. |
| Stream 2 RSSI | 3 | 18 | Range –70 dBm to –42 dBm in 4 dB steps.<br>If unused, these bits are reserved. |
| Stream 3 SNR | 4 | 21 | Range 0 to 30 dB in 2 dB steps.<br>If unused, these bits are reserved. |
| Stream 3 RSSI | 3 | 25 | Range –70 dBm to –42 dBm in 4 dB steps.<br>If unused, these bits are reserved. |
| Stream 4 SNR | 4 | 28 | Range 0 to 30 dB in 2 dB steps.<br>If unused, these bits are reserved. |
| Stream 4 RSSI | 3 | 32 | Range –70 dBm to –42 dBm in 4 dB steps.<br>If unused, these bits are reserved. |

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**Table 28-39—Control trailer definition when CT_TYPE is SSW_FEEDBACK, BLOCK_ACK, or ACK(11ay) *(continued)***

| Field | Number of bits | Start bit | Description |
|---|---|---|---|
| Stream 5 SNR | 4 | 35 | Range 0 to 30 dB in 2 dB steps.<br>If unused, these bits are reserved. |
| Stream 5 RSSI | 3 | 39 | Range –70 dBm to –42 dBm in 4 dB steps.<br>If unused, these bits are reserved. |
| Stream 6 SNR | 4 | 42 | Range 0 to 30 dB in 2 dB steps.<br>If unused, these bits are reserved. |
| Stream 6 RSSI | 3 | 46 | Range –70 dBm to –42 dBm in 4 dB steps.<br>If unused, these bits are reserved. |
| Stream 7 SNR | 4 | 49 | Range 0 to 30 dB in 2 dB steps.<br>If unused, these bits are reserved. |
| Stream 7 RSSI | 3 | 53 | Range –70 dBm to –42 dBm in 4 dB steps.<br>If unused, these bits are reserved. |
| Stream 8 SNR | 4 | 56 | Range 0 to 30 dB in 2 dB steps.<br>If unused, these bits are reserved. |
| Stream 8 RSSI | 3 | 60 | Range –70 dBm to –42 dBm in 4 dB steps.<br>If unused, these bits are reserved. |
| Reserved | 65 | 63 | Set to 0 by the transmitter and ignored by the receiver. |
| CTCS | 16 | 128 | Contains the CRC-16 computed over the content of the control trailer. This field is computed as defined in 20.3.7 (HCS calculation for headers of DMG control mode and DMG SC mode). |

### 28.3.8 CCA sensitivity

The start of a valid 2.16 GHz EDMG PPDU and of a valid 2.16 GHz non-EDMG PPDU at a receive power level greater than the minimum sensitivity for a 2.16 GHz SC PPDU using MCS 1 shall cause the receiver to issue a PHY-CCA.indication(BUSY) primitive with a probability > 90% within aCCAtime. The PHY-CCA.indication(BUSY) primitive shall be maintained for the duration of the PPDU. The receiver shall issue the PHY-CCA.indication(BUSY) primitive for any signal 20 dB above the minimum sensitivity for a 2.16 GHz PPDU using SC MCS 1 for at least aDMGCCAEDDetectTime.

For a receiver using a 4.32 GHz, 6.48 GHz, 8.64 GHz, 2.16+2.16 GHz, or 4.32+4.32 GHz channel, the start of a valid EDMG PPDU and of a valid non-EDMG PPDU at a receive power level greater than the minimum sensitivity for a 2.16 GHz SC PPDU using MCS 1 at the primary channel shall cause the receiver to issue a PHY-CCA.indication(BUSY) primitive with a probability > 90% within aCCAtime. The PHY-CCA.indication(BUSY) primitive shall be maintained for the duration of the PPDU. The receiver shall issue the PHY-CCA.indication(BUSY, primary/secondary/secondary1/secondary2) primitive for any signal 20 dB above the minimum sensitivity for a 2.16 GHz PPDU using SC MCS 1 at any of the channels (primary/secondary/secondary1/secondary2) the receiver is open to receive in for at least aDMGCCAEDDetectTime.

A receiver that has more than one active RX chain shall issue PHY-CCA.indication(BUSY, RX-Antenna-ID, primary/secondary/secondary1/secondary2) primitive if the condition above applies to any DMG antenna connected to an active receive chain.


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### 28.3.9 Common requirements

#### 28.3.9.1 Introduction

This subclause describes common requirement to all EDMG and non-EDMG modes, specifically EDMG and non-EDMG control mode, EDMG and non-EDMG SC mode, and EDMG OFDM mode.

#### 28.3.9.2 Received channel power indicator (RCPI) measurement

The RCPI is a measure of the received RF power (in dBm) in the selected channel as measured at the DMG antenna output, including the antenna gain that is used to receive the PPDU. This parameter shall be measured by the PHY over the preamble (#3475)of the received PPDU, that is, L-STF or L-CEF, or both, or, if present, EDMG-STF or EDMG-CEF. The measurement shall be done over the same bandwidth as the PSDU of the PPDU. When multiple RF chains are used to receive the PPDU, RCPI is measured per each RF chain.

(#2011)The RCPI for each RF chain shall be equal to the received RF power in dBm at each RF chain with an accuracy of ± 5 dB with 95% confidence interval within the specified dynamic range of the receiver. The relative error between RCPI measurements made per RF chain within a one(#1155) second interval should be less than ± 1 dB.

#### 28.3.9.3 Transmit center frequency and symbol clock frequency tolerance

The requirements defined in 20.3.3.2 (Center frequency tolerance) for the center frequency tolerance and center frequency convergence and in 20.3.3.3 (Symbol clock tolerance) for the symbol clock tolerance apply for all EDMG and non-EDMG modes. The transmit center frequency and the symbol clock frequency for all transmit chains and channels shall be derived from the same reference oscillator. Transmit signals with TXVECTOR parameter CHANNEL_AGGREGATION set to (#4167)AGGREGATED may be generated using two separate RF LOs, one for each channel, with the constraint that all RF LOs shall be locked to a common source.

#### 28.3.9.4 Transmit center frequency leakage

The transmit center frequency leakage is specified per transmit chain.

For transmissions with TXVECTOR parameter CHANNEL_AGGREGATION set to (#4167)NOT_AGGREGATED, the transmitter center frequency leakage shall not exceed –23 dB relative to the transmit power per transmit chain regardless of the relationship between the RF LO and center of the transmitted PPDU BW. Equivalently, for the EDMG OFDM mode, the transmitter center frequency leakage shall not exceed $P + 2.5 - 10\log10(N_{SD} + N_{SP})$ (#3360) measured over a subcarrier spacing bandwidth regardless of the relationship between the RF LO and center of the transmitted PPDU bandwidth, where $P$ is the transmit power per transmit chain in dBm and $N_{SD}$ and $N_{SP}$ are defined in Table 28-62 (EDMG OFDM mode timing related parameters1(11ay)).

For transmissions with TXVECTOR parameter CHANNEL_AGGREGATION set to (#4167)AGGREGATED, the transmitter center frequency leakage shall meet the following requirements for all EDMG and non-EDMG formats:

— When the RF LO falls within one of the two frequency segments, the transmitter center frequency leakage requirement is the same as the one for transmissions with TXVECTOR parameter CHANNEL_AGGREGATION set to (#4167)NOT_AGGREGATED.

— When the RF LO falls outside both frequency segments, the RF LO shall follow the spectral mask requirements as defined in 28.3.5 (Transmit mask).

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#### 28.3.9.5 Transmit rampup and rampdown

The requirements defined in 20.3.3.5 (Transmit rampup and rampdown) for transmit power on ramp and power down ramp apply for all EDMG and non-EDMG modes.

#### 28.3.9.6 Antenna setting

Antenna setting shall remain constant for the transmission of the entire PPDU, except for the case of transmission of EDMG BRP-TX PPDUs, EDMG BRP-RX/TX PPDUs and, when transmitted during a SISO BRP TXSS (see 10.41.10.5 (BRP transmit sector sweep (BRP TXSS))), EDMG BRP-RX PPDUs. In these cases, the antenna setting shall remain constant for the transmission of all fields up to the TRN field. The transmission of the TRN field is defined in 28.9.2.2.5 (TRN field definition).

#### 28.3.9.7 Maximum input requirement

The requirement defined in 20.3.3.7 (Maximum input requirement) for the receiver maximum input level apply for all EDMG and non-EDMG modes.

#### 28.3.9.8 Receiver minimum input level sensitivity(#256)

For the EDMG control mode and non-EDMG control mode, the PER shall be less than 5% for a PSDU length of 256 octets and with the input level listed in Table 28-40 (Receiver minimum input level sensitivity for the EDMG and non-EDMG control mode(11ay)) defined at the antenna connector(s). If the TXVECTOR parameter NON_EDMG_MODULATION is (M118)equal to NON_EDMG_DUP_SC_MODE, the minimum sensitivity listed in Table 28-40 (Receiver minimum input level sensitivity for the EDMG and non-EDMG control mode(11ay)) shall be met in the reception of each 2.16 GHz channel.

For the non-EDMG SC mode, EDMG SC mode, and EDMG OFDM mode, the PER shall be less than 1% for a PSDU length of 4096 octets with the MCS and mode dependent input levels listed in Table 28-41 (Receiver minimum input level sensitivity for the EDMG and non-EDMG SC mode(11ay)) through Table 28-45 (Receiver minimum input level sensitivity for the EDMG OFDM mode(11ay)) defined at the antenna connector(s).

When an EDMG STA has multiple DMG RX antennas, each DMG antenna shall be tested in SISO non-STBC mode, using a spatial expansion matrix that directs the single spatial stream to the tested DMG antenna. All other DMG antennas shall be covered with absorptive material. If covering a DMG antenna with absorptive material is not possible, the STA shall disable all DMG antennas besides the one being tested.

For transmissions with TXVECTOR parameter CHANNEL_AGGREGATION set to (#4167)AGGREGATED, the minimum sensitivity listed in Table 28-41 (Receiver minimum input level sensitivity for the EDMG and non-EDMG SC mode(11ay)) through Table 28-45 (Receiver minimum input level sensitivity for the EDMG OFDM mode(11ay)) (values corresponding to 2.16 GHz PPDU or 4.32+4.32 GHz PPDU) shall be met in the reception of each channel. For transmissions with TXVECTOR parameter NON_EDMG_MODULATION set to NON_EDMG_DUP_SC_MODE, the minimum sensitivity listed in Table 28-41 (Receiver minimum input level sensitivity for the EDMG and non-EDMG SC mode(11ay)) through Table 28-45 (Receiver minimum input level sensitivity for the EDMG OFDM mode(11ay)) (values corresponding to 2.16 GHz PPDU) shall be met in the reception of each channel.

NOTE—For RF power measurements performed over the air, the input level has to be corrected to compensate for the antenna gain in the implementation. The gain of the antenna is the maximum estimated gain by the manufacturer. In the


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case of the phased array antenna, the gain of the phased array antenna is the maximum sum of estimated element gain minus 3 dB implementation loss.(#4046)

**Table 28-40—Receiver minimum input level sensitivity for the EDMG and non-EDMG control mode(11ay)**

| MCS | Minimum sensitivity (dBm) |
|---|---|
| 0 | –78 |

**Table 28-41—Receiver minimum input level sensitivity for the EDMG and non-EDMG SC mode(11ay)**

| MCS | Minimum sensitivity (2.16 GHz PPDU or 2.16+2.16 GHz PPDU) (dBm) | Minimum sensitivity (4.32 GHz PPDU or 4.32+4.32 GHz PPDU) (dBm) | Minimum sensitivity (6.48 GHz PPDU) (dBm) | Minimum sensitivity (8.64 GHz PPDU) (dBm) |
|---|---|---|---|---|
| 1 | –68 | –65 | –63 | –62 |
| 2 | –66 | –63 | –61 | –60 |
| 3 | –65 | –62 | –60 | –59 |
| 4 | –64 | –61 | –59 | –58 |
| 5 | –62 | –59 | –57 | –56 |
| 6 | –61 | –58 | –56 | –55 |
| 7 | –63 | –60 | –58 | –57 |
| 8 | –62 | –59 | –57 | –56 |
| 9 | –61 | –58 | –56 | –55 |
| 10 | –59 | –56 | –54 | –53 |
| 11 | –57 | –54 | –52 | –51 |
| 12 | –55 | –52 | –50 | –49 |
| 13 | –54 | –51 | –49 | –48 |
| 14 | –53 | –50 | –48 | –47 |
| 15 | –51 | –48 | –46 | –45 |
| 16 | –50 | –47 | –45 | –44 |
| 17 | –49 | –46 | –44 | –43 |
| 18 | –48 | –45 | –43 | –42 |
| 19 | –46 | –43 | –41 | –40 |
| 20 | –45 | –42 | –40 | –39 |
| 21 | –44 | –41 | –39 | –38 |

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**Table 28-42—Receiver minimum input level sensitivity for the EDMG SC mode if the π/2-8-PSK Applied field is 1(11ay)**

| MCS | Minimum sensitivity (2.16 GHz PPDU or 2.16+2.16 GHz PPDU) (dBm) | Minimum sensitivity (4.32 GHz PPDU or 4.32+4.32 GHz PPDU) (dBm) | Minimum sensitivity (6.48 GHz PPDU) (dBm) | Minimum sensitivity (8.64 GHz PPDU) (dBm) |
|---|---|---|---|---|
| 12 | –56 | –53 | –51 | –50 |
| 13 | –54 | –51 | –49 | –48 |

**Table 28-43—Receiver minimum input level sensitivity for the EDMG SC mode if the π/2-64-NUC Applied field is 1(11ay)**

| MCS | Minimum sensitivity (2.16 GHz PPDU or 2.16+2.16 GHz PPDU) (dBm) | Minimum sensitivity (4.32 GHz PPDU or 4.32+4.32 GHz PPDU) (dBm) | Minimum sensitivity (6.48 GHz PPDU) (dBm) | Minimum sensitivity (8.64 GHz PPDU) (dBm) |
|---|---|---|---|---|
| 17 | –49 | –46 | –44 | –43 |
| 18 | –48 | –45 | –43 | –42 |
| 19 | –46 | –43 | –41 | –40 |
| 20 | –45 | –42 | –40 | –39 |
| 21 | –44 | –41 | –39 | –38 |

**Table 28-44—Receiver minimum input level sensitivity for the EDMG SC mode if the DCM π/2-BPSK Applied field is 1(11ay)**

| MCS | Minimum sensitivity (2.16 GHz PPDU or 2.16+2.16 GHz PPDU) (dBm) | Minimum sensitivity (4.32 GHz PPDU or 4.32+4.32 GHz PPDU) (dBm) | Minimum sensitivity (6.48 GHz PPDU) (dBm) | Minimum sensitivity (8.64 GHz PPDU) (dBm) |
|---|---|---|---|---|
| 2 | –66 | –63 | –61 | –60 |
| 3 | –65 | –62 | –60 | –59 |
| 4 | –64 | –61 | –59 | –58 |
| 5 | –62 | –59 | –57 | –56 |
| 6 | –61 | –58 | –56 | –55 |

The receiver sensitivity for the EDMG OFDM mode if the DCM BPSK Applied field is 1 and the number of spatial streams is 2 is the same one defined in Table 28-45 (Receiver minimum input level sensitivity for the EDMG OFDM mode(11ay)) for the coding scheme used (MCSs 1 to 5). Similarly, the receiver sensitivity


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**Table 28-45—Receiver minimum input level sensitivity for the EDMG OFDM mode(11ay)**

| MCS | Minimum sensitivity (2.16 GHz PPDU or 2.16+2.16 GHz PPDU) (dBm) | Minimum sensitivity (4.32 GHz PPDU or 4.32+4.32 GHz PPDU) (dBm) | Minimum sensitivity (6.48 GHz PPDU) (dBm) | Minimum sensitivity (8.64 GHz PPDU) (dBm) |
|---|---|---|---|---|
| 1 | –66 | –63 | –61 | –60 |
| 2 | –64 | –61 | –59 | –58 |
| 3 | –63 | –60 | –58 | –57 |
| 4 | –61 | –58 | –56 | –55 |
| 5 | –60 | –57 | –55 | –54 |
| 6 | –63 | –60 | –58 | –57 |
| 7 | –62 | –59 | –57 | –56 |
| 8 | –61 | –57 | –55 | –54 |
| 9 | –59 | –55 | –53 | –52 |
| 10 | –58 | –54 | –52 | –51 |
| 11 | –58 | –54 | –52 | –51 |
| 12 | –57 | –52 | –50 | –49 |
| 13 | –56 | –50 | –48 | –47 |
| 14 | –55 | –48 | –46 | –45 |
| 15 | –54 | –47 | –45 | –44 |
| 16 | –52 | –49 | –47 | –46 |
| 17 | –51 | –47 | –45 | –44 |
| 18 | –50 | –45 | –43 | –42 |
| 19 | –48 | –43 | –41 | –40 |
| 20 | –46 | –41 | –39 | –38 |

for the EDMG OFDM mode if the Phase Hopping field in the EDMG-Header-A is equal to 1 and the number of spatial streams is 2 is the same one defined in Table 28-45 (Receiver minimum input level sensitivity for the EDMG OFDM mode(11ay)) for the coding scheme used (MCSs 1 to 20).

### 28.3.9.9 Spectral flatness test for the EDMG OFDM mode

Spectral flatness measurements shall be conducted using DCM BPSK modulated EDMG OFDM PPDUs only while transmitting OFDM symbols. See 28.6.11.1.1 (Transmit modulation accuracy (EVM) test and requirements) for the demodulation procedure and the number of PPDUs and OFDM symbols to be used for testing. Spectral flatness shall be evaluated using the subcarrier received values or the magnitude of channel estimates obtained with the EDMG-CEF field.

Let $E_{i,avg}$ denote the magnitude of the channel estimation on subcarrier $i$ or the average constellation energy of a DCM BPSK modulated subcarrier $i$. In an EDMG OFDM PPDU having TXVECTOR parameter CH_BANDWIDTH listed in Table 28-46 (Maximum transmit spectral flatness deviations(11ay)), $E_{i,avg}$ of each of the subcarriers with indices listed as tested subcarrier indices shall not deviate by more than the

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specified maximum deviation in Table 28-46 (Maximum transmit spectral flatness deviations(11ay)) from the average of $E_{i,avg}$ over subcarrier indices listed as averaging subcarrier indices. Averaging of $E_{i,avg}$ is done in the linear domain.

**Table 28-46—Maximum transmit spectral flatness deviations(11ay)**

| TXVECTOR parameter CH_BANDWIDTH (CHANNEL_AGGREGATION = (#4167)NOT_AGGREGATED) | Average subcarrier indices (inclusive) | Tested subcarrier indices (inclusive) | Maximum deviation (dB) |
|---|---|---|---|
| One bit set to 1 | –146 to –2 and 2 to 146 | –146 to –2 and 2 to 146 | ± 2 |
| | | –177 to –147 and 147 to 177 | +2/–4 |
| Two bits set to 1 | –355 to –2 and 2 to 355 | –325 to –2 and 2 to 325 | ± 2 |
| | | –386 to –326 and 326 to 386 | +2/–4 |
| Three bits set to 1 | –565 to –2 and 2 to 565 | –505 to –2 and 2 to 505 | ± 2 |
| | | –596 to –506 and 506 to 596 | +2/–4 |
| Four bits set to 1 | –774 to –2 and 2 to 774 | –684 to –2 and 2 to 684 | ± 2 |
| | | –805 to –685 and 685 to 805 | +2/–4 |

For transmit signals with TXVECTOR parameter CHANNEL_AGGREGATION set to (#4167)AGGREGATED and CH_BANDWIDTH parameter with two bits set to 1, each frequency segment shall meet the spectral flatness requirement for a transmission with TXVECTOR parameter CH_BANDWIDTH with one bit set to 1. For transmit signals with TXVECTOR parameter CHANNEL_AGGREGATION set to (#4167)AGGREGATED and CH_BANDWIDTH parameter with four bits set to 1, each frequency segment shall meet the spectral flatness requirement for a transmission with TXVECTOR parameter CH_BANDWIDTH with two bits set to 1.

For the spectral flatness test, the transmitting STA shall be configured to use a spatial mapping matrix $Q_k$ (see 28.6.10 (PPDU transmission)) with flat frequency response. Each output port under test of the transmitting STA shall be connected through a cable to one input port of the testing instrumentation.

### 28.3.9.10 Receiver co-channel interference (CCI) resilience

Co-channel interference resilience is defined as the ability of a STA to correctly receive an intended PPDU in the presence of an interfering transmission on the same channel and overlapping in time.

In the presence of CCI originating from a DMG PPDU transmission, a DMG STA operating in a TDD SP should decode an intended PPDU as long as all of the following conditions hold:

— The RCPI of the intended PPDU is at least 3 dB above actual receiver sensitivity.
— The RCPI of the CCI is at least 6 dB below the RCPI of the intended PPDU.
— The intended PPDU has sufficient signal to noise plus interference ratio to be decodable.


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NOTE—An intended PPDU is a PPDU that contains at least one MPDU with the RA field set to the MAC address of the receiving STA.

In addition, a DMG STA operating in a TDD SP may abort a PPDU reception (see 8.3.5.17 (PHY-ABORT.request(11ay))) at the trailing boundary of any TDD slot after which the STA is scheduled to receive from a different transmitting STA.

## 28.4 EDMG and non-EDMG control mode

### 28.4.1 General

Transmission and reception of 2.16 GHz PPDU using EDMG and non-EDMG control mode and 4.32 GHz PPDU using EDMG duplicate and non-EDMG duplicate control mode is mandatory.

Transmission and reception of a 2.16+2.16 GHz PPDU using EDMG and non-EDMG control mode is optional. Transmission and reception of a 6.48 GHz PPDU, 8.64 GHz PPDU, and 4.32+4.32 GHz PPDU using EDMG duplicate and non-EDMG duplicate control mode is optional.

The transmission block diagrams for non-EDMG and EDMG control modes are illustrated in 28.4.2.2 (Non-EDMG PPDU transmission) and 28.4.2.3 (EDMG PPDU transmission), respectively. The PPDU format, non-EDMG portion and EDMG portion of the EDMG control mode PPDU are defined in 28.4.3 (PPDU format), 28.4.4 (Non-EDMG portion of the EDMG control mode PPDU), and 28.4.5 (EDMG portion of the EDMG control mode PPDU), respectively.

The non-EDMG and EDMG PPDU transmissions are defined in 28.4.7.2 (Non-EDMG PPDU transmission) and 28.4.7.3 (EDMG PPDU transmission), respectively.

The non-EDMG control trailer encoding and modulation is defined in 28.4.6 (Non-EDMG control trailer encoding and modulation).

The non-EDMG and EDMG control mode PPDUs are transmitted using MCS 0 and EDMG-MCS 0 modulation and coding schemes, respectively.

The performance requirements are defined in 28.4.8 (Performance requirements).

### 28.4.2 Transmitter block diagram

#### 28.4.2.1 General

EDMG and non-EDMG control mode PPDU transmissions may be generated using a transmitter consisting of the following blocks:

- Scrambler scrambles the data to reduce the probability of long sequences of 0s and 1s; see 28.4.5.2.2 (Scrambler).
- LDPC encoder encodes the data to enable error correction; see 28.4.5.2.3 (Encoder).
- Constellation mapper maps the sequence of bits to constellation points; see 28.4.5.2.4 (Modulation and spreading).
- Spreader spreads out a single constellation point to 32 chips applying the Ga Golay sequence of length 32; see 28.4.5.2.4 (Modulation and spreading).
- Golay builder builds π/2-BPSK modulated Ga and Gb Golay sequences comprising the L-STF, L-CEF, and TRN units; see 28.10 (Golay sequences).
- Cyclic shift diversity (CSD) prevents the signal from unintentional beamforming. CSD is specified per transmitter chain for EDMG and non-EDMG duplicate PPDU transmissions.

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— Pulse shaping performs convolution of constellation points with shape filter impulse response with possible sampling rate change. For duplicate transmissions, pulse shaping may include a relative time delay between the primary and secondary channels. The exact definition of shape filter impulse response is implementation dependent.

### 28.4.2.2 Non-EDMG PPDU transmission

Figure 28-12 (Control mode transmitter block diagram for a non-EDMG PPDU transmission(11ay)) shows the transmitter blocks used to generate a non-EDMG PPDU. The L-STF, L-CEF, and TRN units of the PPDU are generated using the Golay builder block. The L-Header and Data fields of the PPDU are generated using the scrambler, LDPC encoder, constellation mapper, and spreader. The encoded and modulated bit stream is mapped to $N_{TX}$ transmit chains applying spatial expansion with relative cyclic shift over the chains as defined in 28.4.7.2 (Non-EDMG PPDU transmission).

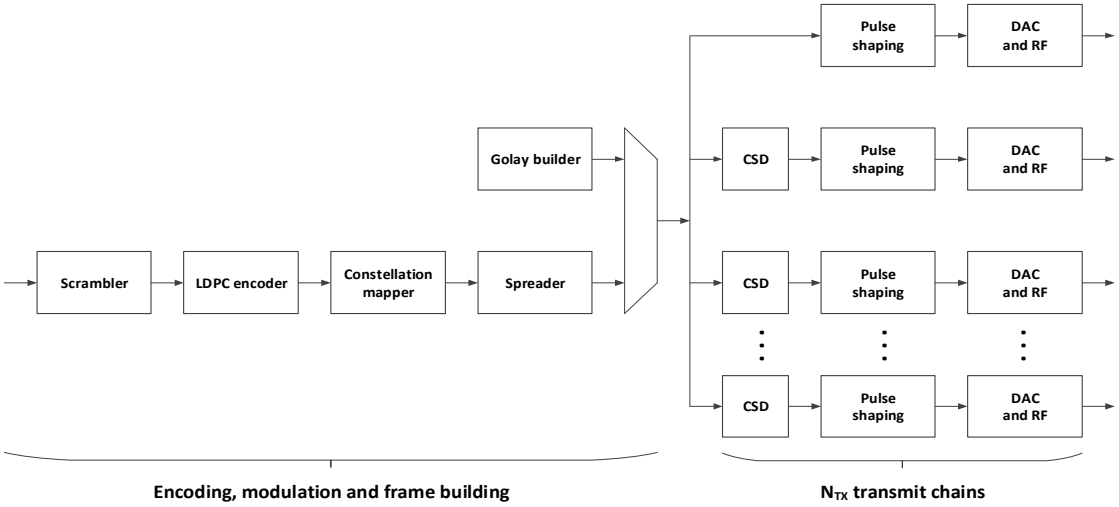


**Figure 28-12—Control mode transmitter block diagram for a non-EDMG PPDU transmission(11ay)**

### 28.4.2.3 EDMG PPDU transmission

Figure 28-13 (Control mode transmitter block diagram for an EDMG PPDU transmission(11ay)) shows the transmitter blocks used to generate an EDMG PPDU. The L-STF, L-CEF, and TRN units of the PPDU are generated using the Golay builder block. The L-Header, EDMG-Header-A, and Data fields of PPDU are generated using the scrambler, LDPC encoder, constellation mapper, and spreader. The encoded and modulated bit stream is mapped to the $N_{TX}$ transmit chains applying spatial expansion with relative cyclic shift over the transmit chains as defined in 28.4.7.3 (EDMG PPDU transmission). The cyclic shift is not applied to TRN units included in the TRN field and each transmit chain transmits its own TRN field as defined in 28.9.2.2.6 (TRN subfield definition for EDMG SC PPDUs and EDMG control mode PPDUs).

## 28.4.3 PPDU format

An EDMG control mode PPDU shall contain the L-STF, L-CEF, L-Header, and EDMG-Header-A fields, but shall not contain the EDMG-STF, EDMG-CEF or EDMG-Header-B fields.

An EDMG control mode PPDU may contain a TRN field as defined in 28.9.2.2.5 (TRN field definition).


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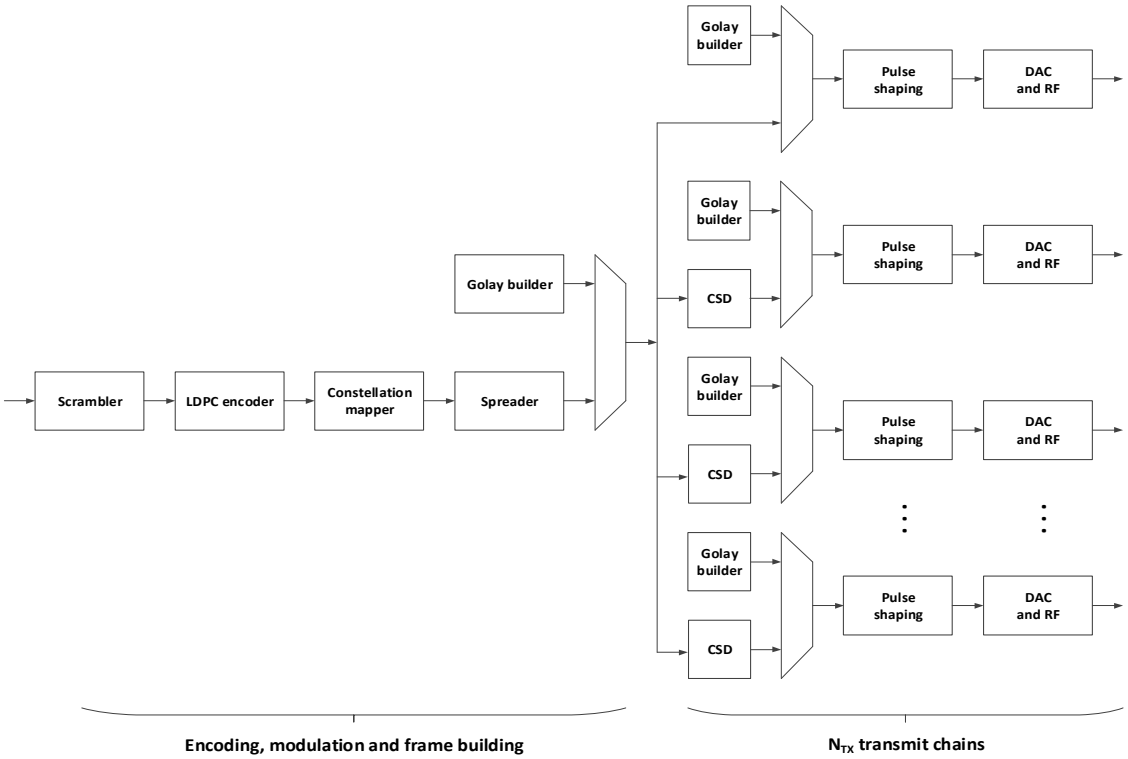


**Figure 28-13—Control mode transmitter block diagram for an EDMG PPDU transmission(11ay)**

An EDMG control mode PPDU may contain the DMG AGC and TRN fields defined in 20.9.2.2.5 (AGC field) and 20.9.2.2.6 (TRN field), respectively, indicated by the DMG TRN field in the EDMG-Header-A. In this case, the TRN field defined in 28.9.2.2.5 (TRN field definition) shall not be transmitted.

A non-EDMG PPDU format shall be as defined in 20.4.2 (PPDU format).

### 28.4.4 Non-EDMG portion of the EDMG control mode PPDU

The non-EDMG portion of the EDMG control mode PPDU is composed of the L-STF, the L-CEF, and the L-Header. These fields are defined at the DMG SC chip rate $F_c$ and transmitted in the EDMG control mode for 2.16 GHz and 2.16+2.16 GHz channels, and in the EDMG duplicate control mode for 4.32 GHz, 6.48 GHz, 8.64 GHz, and 4.32+4.32 GHz channels as defined in 28.4.7.3.2 (EDMG preamble and Data field transmission over a 2.16 GHz and 2.16+2.16 GHz channel) and 28.4.7.3.3 (EDMG duplicate preamble and Data field transmission over a 4.32 GHz, 6.48 GHz, 8.64 GHz, and 4.32+4.32 GHz channel).

The L-STF, L-CEF and L-Header fields of an EDMG control mode PPDU are defined in 28.3.3.2.2 (L-STF definition), 28.3.3.2.3 (L-CEF definition), and 28.3.3.2.4 (L-Header definition), respectively.

### 28.4.5 EDMG portion of the EDMG control mode PPDU

#### 28.4.5.1 General

The EDMG portion of the EDMG control mode PPDU is composed of the EDMG-Header-A field, the Data field, and the TRN field.

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The EDMG-Header-A and the Data fields are defined at the DMG SC chip rate $F_c$ and transmitted in the EDMG control mode for 2.16 GHz and 2.16+2.16 GHz channels, and in the EDMG duplicate control mode for 4.32 GHz, 6.48 GHz, 8.64 GHz, and 4.32+4.32 GHz channels as defined in 28.4.7.3.2 (EDMG preamble and Data field transmission over a 2.16 GHz and 2.16+2.16 GHz channel) and 28.4.7.3.3 (EDMG duplicate preamble and Data field transmission over a 4.32 GHz, 6.48 GHz, 8.64 GHz, and 4.32+4.32 GHz channel).

The TRN field, if present, is transmitted at the EDMG SC chip rate $F_{c\ EDMG}$ as defined in 28.4.7.3.4 (TRN field transmission over a 2.16 GHz, 4.32 GHz, 6.48 GHz, 8.64 GHz, 2.16+2.16 GHz, and 4.32+4.32 GHz channel)

The EDMG control mode PPDU transmission with TRN field is defined in 28.4.7.3.5 (EDMG PPDU transmission with TRN field transmission over a 2.16 GHz, 4.32 GHz, 6.48 GHz, 8.64 GHz, 2.16+2.16 GHz, and 4.32+4.32 GHz channel).

The case of an EDMG control mode PPDU transmission with DMG AGC and TRN fields is defined in 28.4.7.3.6 (EDMG PPDU transmission with DMG AGC and TRN fields over a 2.16 GHz channel).

### 28.4.5.2 Data field

#### 28.4.5.2.1 General

The Data field contains the PSDU. The PSDU shall be scrambled, encoded, modulated and spread as described in the following subclauses.

#### 28.4.5.2.2 Scrambler

The operation of the scrambler is defined in 20.3.9 (Scrambler). Bits x1, x2, x3, x4 of the scrambler shift register shall be initialized using the bits in the scrambler initialization bits from the L-Header and bits x5, x6, x7 shall be set to 1. The L-Header is scrambled starting from bit 5. The scrambling of the EDMG-Header-A shall continue the scrambling of the L-Header with no reset. The scrambling of the Data field shall continue the scrambling of the EDMG-Header-A with no reset.

#### 28.4.5.2.3 Encoder

The L-Header, EDMG-Header-A, and Data field are encoded using an effective LDPC code rate less than or equal to 1/2, generated from the data PHY rate 3/4 LDPC parity check matrix, with shortening. The maximum number of data bits in each LDPC codeword is $L_{CWD} = 168$. The following steps are used for the encoding:

— $L_{L\text{-}Header} = 5$ is the length of L-Header in octets. $L_{EDMG\text{-}Header\text{-}A1} = 6$ is the length of EDMG-Header-$A_1$ subfield in octets. Therefore, the total number of bits in the first LDPC codeword is $L_{DPFCW} = (L_{L\text{-}Header} + L_{EDMG\text{-}Header\text{-}A1}) \times 8 = 88$ bits.

— $L_{EDMG\text{-}Header\text{-}A2} = 3$ is the length of EDMG-Header-$A_2$ subfield in octets. The EDMG-Header-$A_2$ subfield is transmitted in the second LDPC codeword.

— The number of LDPC codewords is $N_{CW} = 1 + \left\lceil \frac{(Length + L_{EDMG-Header-A2}) \times 8}{L_{CWD}} \right\rceil$, where Length is the value of the PSDU Length subfield in the EDMG-Header-A field.

— The number of bits in the second and, if present, any subsequent LDPC codeword except the last one is $L_{DPCW} = \left\lceil \frac{(Length + L_{EDMG-Header-A2}) \times 8}{N_{CW} - 1} \right\rceil$.

— The number of bits in the last LDPC codeword is $L_{DPLCW} = (Length + L_{EDMG\text{-}Header\text{-}A2}) \times 8 - (N_{CW} - 2) \times L_{DPCW}$.


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NOTE—For example, if Length is 128 octets, then $N_{CW} = 8$, $L_{DPCW} = 150$, and $L_{DPLCW} = 148$. In the first LDPC block, the $L_{DPFCW} = 88$ bits consist of 40 bits from the L-Header field along with 48 bits from the EDMG-Header-$A_1$ subfield. In the second LDPC block, the $L_{DPCW} = 150$ bits consist of 24 bits from the EDMG-Header-$A_2$ subfield along with 126 data bits.

#### 28.4.5.2.4 Modulation and spreading

The scrambled and coded bit stream shall be converted into a stream of complex constellation points by using the procedure defined in 20.4.3.3.4 (Modulation). The constellation points shall then be spread using the sequence $Ga^3_2(n)$, as defined in 20.4.3.3.5 (Spreading).

### 28.4.6 Non-EDMG control trailer encoding and modulation

If a control trailer is present in a transmitted PPDU (see 28.3.7 (Control trailer)), the control trailer has a length of 18 data octets. The control trailer continues scrambling of the Data field with no seed reset as defined in 20.4.3.3.2 (Scrambler). The control trailer is encoded using the rate 3/4 LDPC parity check matrix defined in 20.3.8.4 (Rate 3/4 LDPC code matrix H = 168 rows x 672 columns, Z = 42) with shortening to achieve the effective LDPC code rate of 6/13.

The encoding procedure includes the following steps:

— The input 144 data bits (18 octets) are padded with 360 0s to get an LDPC codeword length of 504 bits.
— Compute the 168 parity bits applying the rate-3/4 LDPC parity check matrix.
— Discard the padded 360 zero bits and form the output LDPC codeword of length 312 bits.

The control trailer LDPC codeword continues the DBPSK modulation as defined in 20.4.3.3.4 (Modulation) and then applies the spreading as defined in 20.4.3.3.5 (Spreading).

### 28.4.7 PPDU transmission

#### 28.4.7.1 General

This subclause defines the waveform for a control mode PPDU transmitted using the non-EDMG format and EDMG format over a 2.16 GHz, 4.32 GHz, 6.48 GHz, 8.64 GHz, 2.16+2.16 GHz, and 4.32+4.32 GHz channel using $N_{TX}$ transmit chains. The non-EDMG PPDU transmission shall be as defined in 28.4.7.2 (Non-EDMG PPDU transmission). The EDMG PPDU transmission shall be as defined in 28.4.7.3 (EDMG PPDU transmission).

#### 28.4.7.2 Non-EDMG PPDU transmission

##### 28.4.7.2.1 Non-EDMG PPDU transmission over a 2.16 GHz and 2.16+2.16 GHz channel

The non-EDMG control mode PPDU waveform shall be defined at the DMG SC chip rate $F_c$ and include the following modulated fields:

$$r_{non\text{-}EDMG}\left(nT_c\right) = r_{L\text{-}STF}\left(nT_c\right) + r_{L\text{-}CEF}\left(nT_c - t_{L\text{-}CEF}\right) + r_{L\text{-}Header}\left(nT_c - t_{L\text{-}Header}\right)$$
$$+ r_{Data}\left(nT_c - t_{Data}\right) + r_{AGC\ \ TRN}\left(nT_c - t_{AGC\ \ TRN}\right)$$

where

$t_{L\text{-}CEF} = T_{L\text{-}STF}$ is the duration of the L-STF field of the PPDU

$t_{L\text{-}Header} = t_{L\text{-}CEF} + T_{L\text{-}CEF}$ is the total duration of the L-STF and L-CEF fields of the PPDU

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$t_{Data} = t_{L\text{-}Header} + T_{L\text{-}Header}$ is the total duration of the L-STF, L-CEF, and L-Header fields of the PPDU

$t_{AGC\ TRN} = t_{Data} + T_{Data}$ is the total duration of the L-STF, L-CEF, L-Header, and Data fields of the PPDU

In the non-EDMG control mode PPDU waveform, the AGC and TRN fields may be present in a 2.16 GHz non-EDMG PPDU transmission and shall not be present in a 4.32 GHz, 6.48 GHz, 8.64 GHz, 2.16+2.16 GHz, or 4.32+4.32 GHz non-EDMG PPDU transmission.

In a 2.16 GHz non-EDMG PPDU transmission, a control trailer can be present in place of the AGC and TRN fields (see 28.3.7 (Control trailer)).

In a 4.32 GHz, 6.48 GHz, 8.64 GHz 2.16+2.16 GHz, or 4.32+4.32 GHz non-EDMG PPDU transmission, the Training Length field in the L-Header of the non-EDMG PPDU shall not have a value that is different from 0 or 2. If the Training Length field is equal to 2, a control trailer is present in place of the AGC and TRN fields as defined in 28.3.7 (Control trailer).

Unless specified, the chip index $n$ is defined in the range [0, $N_{Field}$ − 1], where $N_{Field}$ defines the total number of samples for a given signal field. The definition of the L-STF, L-CEF, and L-Header fields is provided in 28.3.3.2.2 (L-STF definition), 28.3.3.2.3 (L-CEF definition), and 28.3.3.2.4 (L-Header definition), respectively. The definition of the AGC and TRN fields is provided in 20.9.2.2.5 (AGC field) and 20.9.2.2.6 (TRN field), respectively. The L-Header and Data fields encoding and modulation is provided in 20.4.3.2.3 (Header encoding and modulation) and 20.4.3.3 (Data field), respectively.

To transmit a non-EDMG waveform using multiple transmit chains, a spatial expansion with cyclic shift diversity (CSD) is applied. The non-EDMG PPDU waveform for the $i_{TX}^{\text{th}}$ transmit chain includes a CSD, $T_{SC}^{i_{TX}}$, that is dependent on the particular transmit chain number. The cyclic shift, $T_{SC}^{i_{TX}}$, is defined in SC chip units as $(i_{TX} - 1) \times N_c \times T_c$, where $N_c$ is equal to 4 chips and $T_c$ is a chip time duration.

$$r_{non\text{-}EDMG}^{i_{TX}\ (1)}(nT_c) = \begin{cases} r_{non\text{-}EDMG}\left(nT_c + T_{SC}^{i_{TX}}\right), & n = 0,1,...,N-1-T_{SC}^{i_{TX}}/T_c \\ r_{non\text{-}EDMG}\left(nT_c - \left(NT_c - T_{SC}^{i_{TX}}\right)\right), & n = N - T_{SC}^{i_{TX}}/T_c,...,N-1 \end{cases}, \quad 1 \le i_{TX} \le N_{TX}$$

where

$N$ is the total number of chips in the non-EDMG PPDU waveform $r_{non\text{-}EDMG}$

$T_c$ is the chip time duration

The non-EDMG PPDU waveform for $i_{TX}^{\text{th}}$ transmit chain is obtained by upsampling and filtering and then appropriate carrier frequency shift of the $r_{non-EDMG}^{i_{TX}\ (1)}(nT_c)$ waveform, if required. The upsampling procedure is applied using a factor of $N_{up}$. The filtering procedure is performed with a pulse shaping filter, $h_{SC\ CB}$, defined at the $N_{up} \times F_c$ sampling rate as follows(#1150):

$$r_{non\text{-}EDMG}^{i_{TX}(2)}\left(n\frac{T_c}{N_{up}}\right) = \begin{cases} r_{non\text{-}EDMG}^{i_{TX}(1)}\left(n\frac{T_c}{N_{up}}\right), & n=0,\ N_{up},\ 2\times N_{up} \\ 0, & otherwise \end{cases}$$

$$r_{non\text{-}EDMG}^{i_{TX}(3)}\left(n\frac{T_c}{N_{up}}\right) = \sum_{k=0}^{K-1} r_{non\text{-}EDMG}^{i_{TX}(2)}\left((n-k)\frac{T_c}{N_{up}}\right) h_{SC\ CB}(k),\ n=0,\ 1,\ \ldots$$



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$$r_{non\text{-}EDMG}^{i_{TX}(4)}\left(n\frac{T_c}{N_{up}}\right) = r_{non\text{-}EDMG}^{i_{TX}(3)}\left(\left(n+\frac{K-1}{2}\right)\frac{T_c}{N_{up}}\right), n=0, 1, \ldots$$

where

$K$ is the length of $h_{SC\,CB}$ in samples

$$r_{non\text{-}EDMG}^{i_{TX}\,(2)}\left(n\frac{T_c}{N_{up}}\right) = 0, \text{ for } n < 0 \text{ and } n \geq N \times N_{up}$$

$N$ is the total number of chips in the non-EDMG PPDU waveform $r_{non\text{-}EDMG}^{i_{TX}\,(1)}$

$T_c$ is the chip time duration

The pulse shaping filter impulse response, $h_{SC\,CB}$, and the $N_{up}$ parameter definition are implementation dependent.

The non-EDMG PPDU waveform for the $i_{TX}^{\text{th}}$ transmit chain with transmission over a 2.16 GHz or 2.16+2.16 GHz channel shall be defined as follows:

$$r_{PPDU}^{i_{TX}}\left(n\frac{T_c}{N_{up}}\right) = r_{non\text{-}EDMG}^{i_{TX}\,(4)}\left(n\frac{T_c}{N_{up}}\right), 1 \leq i_{TX} \leq N_{TX}$$

For a 2.16+2.16 GHz PPDU transmission, the total number of transmit chains, $N_{TX}$, shall be an even number. The first $N_{TX}/2$ transmit chains shall be used for transmission on the primary channel and the second $N_{TX}/2$ transmit chains shall be used for transmission on the secondary channel (see 28.3.4 (Channelization)).

#### 28.4.7.2.2 Non-EDMG duplicate PPDU transmission over a 4.32 GHz, 6.48 GHz, 8.64 GHz, and 4.32+4.32 GHz channel

The non-EDMG PPDU waveform for the $i_{TX}^{\text{th}}$ transmit chain with duplicate transmission over a 4.32 GHz or 4.32+4.32 GHz channel shall be defined as follows:

$$r_{PPDU}^{i_{TX}}\left(n\frac{T_c}{N_{up}}\right) = r_{non\text{-}EDMG}^{i_{TX}\,(4)}\left(n\frac{T_c}{N_{up}}+\Delta t_1\right)\cdot\frac{1}{\sqrt{2}}\exp\left(-j2\pi\left(\frac{\Delta F}{2}\right)\left(\frac{T_c}{N_{up}}\right)n\right)$$

$$+r_{non\text{-}EDMG}^{i_{TX}\,(4)}\left(n\frac{T_c}{N_{up}}+\Delta t_2\right)\cdot\frac{1}{\sqrt{2}}\exp\left(+j2\pi\left(\frac{\Delta F}{2}\right)\left(\frac{T_c}{N_{up}}\right)n\right), 1 \leq i_{TX} \leq N_{TX}$$

where

$\Delta F$ defines the channel spacing and is equal to 2.16 GHz

$\Delta t_1$ and $\Delta t_2$ are in the range $[0, T_c]$

$\Delta t_i$ equal to 0 corresponds to the primary channel

For 4.32+4.32 GHz transmission, the total number of transmit chains, $N_{TX}$, shall be an even number. The first $N_{TX}/2$ transmit chains shall be used for transmission on the primary and secondary channels and the second $N_{TX}/2$ transmit chains shall be used for transmission on the secondary1 and secondary2 channels (see 28.3.4 (Channelization)).

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The non-EDMG PPDU waveform for the $i_{TX}^{\text{th}}$ transmit chain with duplicate transmission over a 6.48 GHz channel shall be defined as follows:

$$r_{PPDU}^{i_{TX}}\left(n\frac{T_c}{N_{up}}\right) = r_{non\text{-}EDMG}^{i_{TX}\ (4)}\left(n\frac{T_c}{N_{up}}+\Delta t_1\right)\cdot\frac{1}{\sqrt{3}}\exp\left(-j2\pi\Delta F\left(\frac{T_c}{N_{up}}\right)n\right)$$
$$+r_{non\text{-}EDMG}^{i_{TX}\ (4)}\left(n\frac{T_c}{N_{up}}+\Delta t_2\right)\cdot\frac{1}{\sqrt{3}}$$
$$+r_{non\text{-}EDMG}^{i_{TX}\ (4)}\left(n\frac{T_c}{N_{up}}+\Delta t_3\right)\cdot\frac{1}{\sqrt{3}}\exp\left(+j2\pi\Delta F\left(\frac{T_c}{N_{up}}\right)n\right), 1\le i_{TX}\le N_{TX}$$

where

| | |
|---|---|
| $\Delta t_1$, $\Delta t_2$, and $\Delta t_3$ | are in the range $[0, T_c]$ |
| $\Delta t_i$ equal to 0 | corresponds to the primary channel |

The non-EDMG PPDU waveform for the $i_{TX}^{\text{th}}$ transmit chain with duplicate transmission over an 8.64 GHz channel shall be defined as follows:

$$r_{PPDU}^{i_{TX}}\left(n\frac{T_c}{N_{up}}\right) = r_{non\text{-}EDMG}^{i_{TX}\ (4)}\left(n\frac{T_c}{N_{up}}+\Delta t_1\right)\cdot\frac{1}{\sqrt{4}}\exp\left(-j2\pi\left(\frac{3\Delta F}{2}\right)\left(\frac{T_c}{N_{up}}\right)n\right)$$
$$+r_{non\text{-}EDMG}^{i_{TX}\ (4)}\left(n\frac{T_c}{N_{up}}+\Delta t_2\right)\cdot\frac{1}{\sqrt{4}}\exp\left(-j2\pi\left(\frac{\Delta F}{2}\right)\left(\frac{T_c}{N_{up}}\right)n\right)$$
$$+r_{non\text{-}EDMG}^{i_{TX}\ (4)}\left(n\frac{T_c}{N_{up}}+\Delta t_3\right)\cdot\frac{1}{\sqrt{4}}\exp\left(+j2\pi\left(\frac{\Delta F}{2}\right)\left(\frac{T_c}{N_{up}}\right)n\right)$$
$$+r_{non\text{-}EDMG}^{i_{TX}\ (4)}\left(n\frac{T_c}{N_{up}}+\Delta t_4\right)\cdot\frac{1}{\sqrt{4}}\exp\left(+j2\pi\left(\frac{3\Delta F}{2}\right)\left(\frac{T_c}{N_{up}}\right)n\right), 1\le i_{TX}\le N_{TX}$$

where

| | |
|---|---|
| $\Delta t_1$, $\Delta t_2$, $\Delta t_3$, and $\Delta t_4$ | are in the range $[0, T_c]$ |
| $\Delta t_i$ equal to 0 | corresponds to the primary channel |

### 28.4.7.3 EDMG PPDU transmission

#### 28.4.7.3.1 General

The EDMG control mode PPDU is composed of a preamble, a Data field and a TRN field. The total number of transmit chains, $N_{TX}$, used for transmission shall be constant over the different fields of EDMG PPDU.

For the case of DMG AGC and TRN fields transmission over a 2.16 GHz channel, indicated by the DMG TRN field in the EDMG-Header-A, the EDMG control mode PPDU is composed of a preamble, a Data field, and DMG AGC and TRN fields.


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#### 28.4.7.3.2 EDMG preamble and Data field transmission over a 2.16 GHz and 2.16+2.16 GHz channel

The preamble and Data fields shall be defined at the DMG SC chip rate $F_c$ and include the following modulated fields:

$$r_{EDMG\text{-}Pream,\,Data}\left(nT_c\right) = r_{L\text{-}STF}\left(nT_c\right) + r_{L\text{-}CEF}\left(nT_c - t_{L\text{-}CEF}\right) + r_{L\text{-}Header}\left(nT_c - t_{L\text{-}Header}\right)$$
$$+ r_{EDMG\text{-}Header\text{-}A}\left(nT_c - t_{EDMG\text{-}Header\text{-}A}\right) + r_{Data}\left(nT_c - t_{Data}\right)$$

where

$t_{L\text{-}CEF} = T_{L\text{-}STF}$ is the duration of the L-STF field of the PPDU

$t_{L\text{-}Header} = t_{L\text{-}CEF} + T_{L\text{-}CEF}$ is the total duration of the L-STF and L-CEF fields of the PPDU

$t_{EDMG\text{-}Header\text{-}A} = t_{L\text{-}Header} + T_{L\text{-}Header}$ is the total duration of L-STF, L-CEF, and L-Header fields of the PPDU

$t_{Data} = t_{EDMG\text{-}Header\text{-}A} + T_{EDMG\text{-}Header\text{-}A}$ is the total duration of the L-STF, L-CEF, L-Header, and EDMG-Header-A fields of the PPDU

The definition of the L-STF, L-CEF, and L-Header fields is provided in 28.3.3.2.2 (L-STF definition), 28.3.3.2.3 (L-CEF definition), and 28.3.3.2.4 (L-Header definition), respectively. The definition of EDMG-Header-A is provided in 28.3.3.3.2.2 (Definition for EDMG control mode PPDU) and 28.3.3.3.2.4 (Encoding and modulation). The definition of the Data field is provided in 28.4.5.2 (Data field).

To transmit the preamble and Data fields using multiple transmit chains, a spatial expansion with cyclic shift diversity (CSD) is applied. The preamble and Data fields of the PPDU waveform for the $i_{TX}^{\text{th}}$ transmit chain includes a cyclic shift, $T_{SC}^{i_{TX}}$, dependent on the particular transmit chain number. The cyclic shift, $T_{SC}^{i_{TX}}$, is defined in SC chip units as $(i_{TX} - 1) \times N_c \times T_c$, where $N_c$ is equal to 4 chips and $T_c$ is a chip time duration.

$$r_{EDMG\text{-}Pream,\,Data}^{i_{TX}\,(1)}\left(nT_c\right) = \begin{cases} r_{EDMG\text{-}Pream,\,Data}\left(nT_c + T_{SC}^{i_{TX}}\right), & n = 0,1,\ldots,N-1-T_{SC}^{i_{TX}}/T_c \\ r_{EDMG\text{-}Pream,\,Data}\left(nT_c - \left(NT_c - T_{SC}^{i_{TX}}\right)\right), & n = N - T_{SC}^{i_{TX}}/T_c,\ldots,N-1 \end{cases}, \quad 1 \le i_{TX} \le N_{TX}$$

where

$N$ is the total number of chips in the EDMG preamble and Data fields $r_{EDMG\text{-}Pream,\,Data}$ of the EDMG PPDU waveform

$T_c$ is a chip time duration

The EDMG PPDU waveform for the $i_{TX}^{\text{th}}$ transmit chain is obtained by upsampling and filtering and then appropriate carrier frequency shift of the $r_{EDMG\text{-}Pream,\,Data}^{i_{TX}\,(1)}\left(nT_c\right)$ waveform, if required. The upsampling procedure is applied using a factor of $N_{up}$. The filtering procedure is performed with a pulse shaping filter, $h_{SC\,CB}$, defined at the $N_{up} \times F_c$ sampling rate as follows(#1151):

$$r_{EDMG\text{-}Pream,\,Data}^{i_{TX}(2)}\left(n\frac{T_c}{N_{up}}\right) = \begin{cases} r_{EDMG\text{-}Pream,\,Data}^{i_{TX}(1)}\left(n\frac{T_c}{N_{up}}\right), & n=0, N_{up}, 2\times N_{up} \\ 0, & otherwise \end{cases}$$

$$r_{EDMG\text{-}Pream,\,Data}^{i_{TX}(3)}\left(n\frac{T_c}{N_{up}}\right) = \sum_{k=0}^{K-1} r_{EDMG\text{-}Pream,\,Data}^{i_{TX}(2)}\left((n-k)\frac{T_c}{N_{up}}\right) h_{SC\,CB}(k),\ n=0,\,1,\,\ldots$$

$$r_{EDMG\text{-}Pream,\,Data}^{i_{TX}(4)}\left(n\frac{T_c}{N_{up}}\right) = r_{EDMG\text{-}Pream,\,Data}^{i_{TX}(3)}\left(\left(n+\frac{K-1}{2}\right)\frac{T_c}{N_{up}}\right),\ n=0,\,1,\,\ldots$$

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where

$K$ is the length of $h_{SC\,CB}$ in samples

$r^{i_{TX}\,(2)}_{EDMG\text{-}Pream,\,Data}\left(n\frac{T_c}{N_{up}}\right)=0,$ for $n<0$ and $n\geq N\times N_{up}$

$N$ is the total number of chips in the EDMG preamble and Data fields $r^{i_{TX}\,(1)}_{EDMG\text{-}Pream,\,Data}$ of the EDMG PPDU waveform

$T_c$ is a chip time duration

The pulse shaping filter impulse response, $h_{SC\,CB}$, and $N_{up}$ parameter definition is implementation dependent.

The preamble and Data fields of the EDMG PPDU waveform for the $i_{TX}^{\text{th}}$ transmit chain with transmission over a 2.16 GHz or 2.16+2.16 GHz channel shall be defined as follows:

$$r^{i_{TX}}_{EDMG-Pream,\,Data}\left(n\frac{T_c}{N_{up}}\right)=r^{i_{TX}\,(4)}_{EDMG-Pream,\,Data}\left(n\frac{T_c}{N_{up}}\right),1\leq i_{TX}\leq N_{TX}$$

For a 2.16+2.16 GHz PPDU transmission, the total number of transmit chains, $N_{TX}$, shall be an even number. The first $N_{TX}/2$ transmit chains shall be used for transmission on the primary channel and the second $N_{TX}/2$ transmit chains shall be used for transmission on the secondary channel (see 28.3.4 (Channelization)).

#### 28.4.7.3.3 EDMG duplicate preamble and Data field transmission over a 4.32 GHz, 6.48 GHz, 8.64 GHz, and 4.32+4.32 GHz channel

The preamble and Data fields of the EDMG PPDU waveform for the $i_{TX}^{\text{th}}$ transmit chain with duplicate transmission over a 4.32 GHz or 4.32+4.32 GHz channel shall be defined as follows:

$$r^{i_{TX}}_{EDMG-Pream,\,Data}\left(n\frac{T_c}{N_{up}}\right)=r^{i_{TX}\,(4)}_{EDMG-Pream,\,Data}\left(n\frac{T_c}{N_{up}}+\Delta t_1\right)\cdot\frac{1}{\sqrt{2}}\exp\left(-j2\pi\left(\frac{\Delta F}{2}\right)\left(\frac{T_c}{N_{up}}\right)n\right)$$

$$+r^{i_{TX}\,(4)}_{EDMG-Pream,\,Data}\left(n\frac{T_c}{N_{up}}+\Delta t_2\right)\cdot\frac{1}{\sqrt{2}}\exp\left(+j2\pi\left(\frac{\Delta F}{2}\right)\left(\frac{T_c}{N_{up}}\right)n\right),1\leq i_{TX}\leq N_{TX}$$

where

$\Delta F$ defines the channel spacing and is equal to 2.16 GHz

$\Delta t_1$ and $\Delta t_2$ are in the range [0, $T_c$]

$\Delta t_i$ equal to 0 corresponds to the primary channel

For 4.32+4.32 GHz transmission, the total number of transmit chains, $N_{TX}$, shall be an even number. The first $N_{TX}/2$ transmit chains shall be used for transmission on the primary and secondary channels and the second $N_{TX}/2$ transmit chains shall be used for transmission on the secondary1 and secondary2 channels (see 28.3.4 (Channelization)).

The preamble and Data fields of the EDMG PPDU waveform for the $i_{TX}^{\text{th}}$ transmit chain with duplicate transmission over a 6.48 GHz channel shall be defined as follows:


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$$r^{i_{TX}}_{EDMG-Pream,\,Data}\left(n\frac{T_c}{N_{up}}\right)=r^{i_{TX}\,(4)}_{EDMG-Pream,\,Data}\left(n\frac{T_c}{N_{up}}+\Delta t_1\right)\cdot\frac{1}{\sqrt{3}}\exp\left(-j2\pi\Delta F\left(\frac{T_c}{N_{up}}\right)n\right)$$

$$+r^{i_{TX}\,(4)}_{EDMG-Pream,\,Data}\left(n\frac{T_c}{N_{up}}+\Delta t_2\right)\cdot\frac{1}{\sqrt{3}}$$

$$+r^{i_{TX}\,(4)}_{EDMG-Pream,\,Data}\left(n\frac{T_c}{N_{up}}+\Delta t_3\right)\cdot\frac{1}{\sqrt{3}}\exp\left(+j2\pi\Delta F\left(\frac{T_c}{N_{up}}\right)n\right),1\le i_{TX}\le N_{TX}$$

where

$\Delta t_1$, $\Delta t_2$, and $\Delta t_3$ are in the range [0, $T_c$]

$\Delta t_i$ equal to 0 corresponds to the primary channel

The preamble and Data fields of the EDMG PPDU waveform for the $i_{TX}^{\text{th}}$ transmit chain with duplicate transmission over an 8.64 GHz channel shall be defined as follows:

$$r^{i_{TX}}_{EDMG-Pream,\,Data}\left(n\frac{T_c}{N_{up}}\right)=r^{i_{TX}\,(4)}_{EDMG-Pream,\,Data}\left(n\frac{T_c}{N_{up}}+\Delta t_1\right)\cdot\frac{1}{\sqrt{4}}\exp\left(-j2\pi\left(\frac{3\Delta F}{2}\right)\left(\frac{T_c}{N_{up}}\right)n\right)$$

$$+r^{i_{TX}\,(4)}_{EDMG-Pream,\,Data}\left(n\frac{T_c}{N_{up}}+\Delta t_2\right)\cdot\frac{1}{\sqrt{4}}\exp\left(-j2\pi\left(\frac{\Delta F}{2}\right)\left(\frac{T_c}{N_{up}}\right)n\right)$$

$$+r^{i_{TX}\,(4)}_{EDMG-Pream,\,Data}\left(n\frac{T_c}{N_{up}}+\Delta t_3\right)\cdot\frac{1}{\sqrt{4}}\exp\left(+j2\pi\left(\frac{\Delta F}{2}\right)\left(\frac{T_c}{N_{up}}\right)n\right)$$

$$+r^{i_{TX}\,(4)}_{EDMG-Pream,\,Data}\left(n\frac{T_c}{N_{up}}+\Delta t_4\right)\cdot\frac{1}{\sqrt{4}}\exp\left(+j2\pi\left(\frac{3\Delta F}{2}\right)\left(\frac{T_c}{N_{up}}\right)n\right),1\le i_{TX}\le N_{TX}$$

where

$\Delta t_1$, $\Delta t_2$, $\Delta t_3$, and $\Delta t_4$ are in the range [0, $T_c$]

$\Delta t_i$ equal to 0 corresponds to the primary channel

#### 28.4.7.3.4 TRN field transmission over a 2.16 GHz, 4.32 GHz, 6.48 GHz, 8.64 GHz, 2.16+2.16 GHz, and 4.32+4.32 GHz channel

The TRN field, $r^{i_{TX}\,(1)}_{TRN}\left(n\frac{T_c}{N_{CB}}\right)$, shall be defined at the EDMG SC chip rate $F_{c\ EDMG}$ per $i_{TX}^{\text{th}}$ transmit chain as defined in 28.9.2.2.6 (TRN subfield definition for EDMG SC PPDUs and EDMG control mode PPDUs). The TRN field is defined using $N_{TX}$ orthogonal waveforms and transmitted over the entire channel bandwidth.

The TRN field is filtered and resampled with conversion rate ratio $N_{up}/N_{CB}$. For example, the resampling procedure for the ratio $N_{up}/N_{CB}$ equal to 3/2 can be defined as follows:

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$$r_{TRN}^{i_{TX}}{}^{(2)}\left(n\frac{T_c}{3N_{CB}}\right)=\begin{cases} r_{TRN}^{i_{TX}}{}^{(1)}\left(n\frac{T_c}{3N_{CB}}\right), n=0,3,6... \\ 0 \quad \text{otherwise} \end{cases}$$

$$r_{TRN}^{i_{TX}}{}^{(3)}\left(n\frac{T_c}{3N_{CB}}\right)=\sum_{k=0}^{K-1} r_{TRN}^{i_{TX}}{}^{(2)}\left((n-k)\frac{T_c}{3N_{CB}}\right)h_{SC\,CB}(k), n=0,1,...$$

$$r_{TRN}^{i_{TX}}\left(n\frac{2T_c}{3N_{CB}}\right)=r_{TRN}^{i_{TX}}{}^{(3)}\left(\left(2n+\frac{K-1}{2}\right)\frac{T_c}{3N_{CB}}\right), n=0,1,...$$

where

$K$ is the length of $h_{SC\,CB}$ in samples

$r_{TRN}^{i_{TX}}{}^{(2)}\left(n\frac{T_c}{3N_{CB}}\right)=0,$ for $n<0$ and $n\geq N\times 3$

$N$ is the total number of chips in the TRN field $r_{TRN}^{i_{TX}}{}^{(1)}$

$T_c/N_{CB}$ is the chip time duration

### 28.4.7.3.5 EDMG PPDU transmission with TRN field transmission over a 2.16 GHz, 4.32 GHz, 6.48 GHz, 8.64 GHz, 2.16+2.16 GHz, and 4.32+4.32 GHz channel

The EDMG control mode PPDU waveform for the $i_{TX}^{\text{th}}$ transmit chain concatenates the preamble and Data fields defined in 28.4.7.3.2 (EDMG preamble and Data field transmission over a 2.16 GHz and 2.16+2.16 GHz channel) and 28.4.7.3.3 (EDMG duplicate preamble and Data field transmission over a 4.32 GHz, 6.48 GHz, 8.64 GHz, and 4.32+4.32 GHz channel) with the TRN field defined in 28.4.7.3.4 (TRN field transmission over a 2.16 GHz, 4.32 GHz, 6.48 GHz, 8.64 GHz, 2.16+2.16 GHz, and 4.32+4.32 GHz channel) and shall be defined as follows:

$$r_{PPDU}^{i_{TX}}\left(n\frac{T_c}{N_{up}}\right)=r_{EDMG\text{-}Pream,\,Data}^{i_{TX}}\left(n\frac{T_c}{N_{up}}\right)+r_{TRN}^{i_{TX}}\left(n\frac{T_c}{N_{up}}-t_{TRN}\right), 1\leq i_{TX}\leq N_{TX}$$

where

$t_{TRN}=t_{Data}+T_{Data}$ is the total duration of the L-STF, L-CEF, L-Header, EDMG-Header-A, and Data fields of the PPDU

### 28.4.7.3.6 EDMG PPDU transmission with DMG AGC and TRN fields over a 2.16 GHz channel

For the case of DMG AGC and TRN fields transmission over a 2.16 GHz channel, indicated by the DMG TRN field in the EDMG-Header-A, the EDMG control mode PPDU is composed of a preamble, a Data field and DMG AGC and TRN fields.

The EDMG control mode PPDU shall be defined at the DMG SC chip rate $F_c$ and include the following modulated fields:

$$r_{EDMG\text{-}PPDU}(nT_c)=r_{L\text{-}STF}(nT_c)+r_{L\text{-}CEF}(nT_c-t_{L\text{-}CEF})+r_{L\text{-}Header}(nT_c-t_{L\text{-}Header})$$
$$+r_{EDMG\text{-}Header\text{-}A}(nT_c-t_{EDMG\text{-}Header\text{-}A})+r_{Data}(nT_c-t_{Data})+r_{AGC\ TRN}(nT_c-t_{AGC\ TRN})$$

where


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| | |
|---|---|
| $t_{L\text{-}CEF} = T_{L\text{-}STF}$ | is the duration of the L-STF field of the PPDU |
| $t_{L\text{-}Header} = t_{L\text{-}CEF} + T_{L\text{-}CEF}$ | is the total duration of the L-STF and L-CEF fields of the PPDU |
| $t_{EDMG\text{-}Header\text{-}A} = t_{L\text{-}Header} + T_{L\text{-}Header}$ | is the total duration of L-STF, L-CEF, and L-Header fields of the PPDU |
| $t_{Data} = t_{EDMG\text{-}Header\text{-}A} + T_{EDMG\text{-}Header\text{-}A}$ | is the total duration of the L-STF, L-CEF, L-Header, and EDMG-Header-A fields of the PPDU |
| $t_{AGC\ TRN} = t_{Data} + T_{Data}$ | is the total duration of the L-STF, L-CEF, L-Header, EDMG-Header-A, and Data fields of the PPDU |

The definition of the L-STF, L-CEF, and L-Header fields is provided in 28.3.3.2.2 (L-STF definition), 28.3.3.2.3 (L-CEF definition), and 28.3.3.2.4 (L-Header definition), respectively. The definition of EDMG-Header-A is provided in 28.3.3.3.2.2 (Definition for EDMG control mode PPDU) and 28.3.3.3.2.4 (Encoding and modulation). The definition of the Data field is provided in 28.4.5.2 (Data field). The definition of the DMG AGC and TRN fields is provided in 20.9.2.2.5 (AGC field) and 20.9.2.2.6 (TRN field), respectively.

To transmit an EDMG PPDU using multiple transmit chains, a spatial expansion with cyclic shift diversity (CSD) is applied. The EDMG PPDU waveform for the $i_{TX}^{\text{th}}$ transmit chain includes a cyclic shift, $T_{SC}^{i_{TX}}$, dependent on the particular transmit chain number. The cyclic shift, $T_{SC}^{i_{TX}}$, is defined in SC chip units as $(i_{TX}-1) \times N_c \times T_c$, where $N_c$ is equal to 4 chips and $T_c$ is a chip time duration.

$$r_{EDMG\text{-}PPDU}^{i_{TX}\,(1)}\left(nT_c\right) = \begin{cases} r_{EDMG\text{-}PPDU}\left(nT_c + T_{SC}^{i_{TX}}\right), & n = 0,1,\ldots,N-1-T_{SC}^{i_{TX}}/T_c \\ r_{EDMG\text{-}PPDU}\left(nT_c - \left(NT_c - T_{SC}^{i_{TX}}\right)\right), & n = N - T_{SC}^{i_{TX}}/T_c,\ldots,N-1 \end{cases}, \quad 1 \le i_{TX} \le N_{TX}$$

where

$N$ is the total number of chips in the EDMG PPDU waveform $r_{EDMG\text{-}PPDU}$

$T_c$ is a chip time duration

The EDMG PPDU waveform for the $i_{TX}^{\text{th}}$ transmit chain is obtained by upsampling and filtering. The upsampling procedure is applied using a factor of $N_{up}$. The filtering procedure is performed with a pulse shaping filter, $h_{SC\,CB}$, defined at the $N_{up} \times F_c$ sampling rate as follows:

$$r_{EDMG\text{-}PPDU}^{i_{TX}\,(2)}\left(n\frac{T_c}{N_{up}}\right) = \begin{cases} r_{EDMG\text{-}PPDU}^{i_{TX}\,(1)}\left(n\frac{T_c}{N_{up}}\right), & n = 0, N_{up}, 2*N_{up}\ldots \\ 0 & \text{otherwise} \end{cases}$$

$$r_{EDMG\text{-}PPDU}^{i_{TX}\,(3)}\left(n\frac{T_c}{N_{up}}\right) = \sum_{k=0}^{K-1} r_{EDMG\text{-}PPDU}^{i_{TX}\,(2)}\left(\left(n-k\right)\frac{T_c}{N_{up}}\right) h_{SC\,CB}\left(k\right), n = 0,1,\ldots$$

$$r_{PPDU}^{i_{TX}}\left(n\frac{T_c}{N_{up}}\right) = r_{EDMG\text{-}PPDU}^{i_{TX}\,(3)}\left(\left(n+\frac{K-1}{2}\right)\frac{T_c}{N_{up}}\right), n = 0,1,\ldots$$

where

$K$ is the length of $h_{SC\,CB}$ in samples

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$$r^{i_{TX}\,(2)}_{EDMG\text{-}PPDU}\left(n\frac{T_c}{N_{up}}\right)=0,\ \text{for}\ n<0\ \text{and}\ n\geq N\times N_{up}$$

$N$ is the total number of chips in the EDMG PPDU waveform $r^{i_{TX}\,(1)}_{EDMG\text{-}PPDU}$

$T_c$ is a chip time duration

The pulse shaping filter impulse response, $h_{SC\,CB}$, and the $N_{up}$ parameter definition are implementation dependent.

### 28.4.8 Performance requirements

The transmit EVM performance requirement of EDMG and non-EDMG control mode PPDUs shall be the same as that of DMG control mode PPDUs defined in 20.4.4.1.2 (Transmit EVM).

In the transmit EVM accuracy test, each transmit chain of the transmitting STA shall be connected through a cable to one input port of the testing instrumentation. If the TXVECTOR parameter CH_BANDWIDTH has more than one bit set to 1, the duplicate transmission in the two or more 2.16 GHz channels may be tested independently. In this case, the transmit EVM accuracy of each 2.16 GHz channel shall meet the required value defined in 20.4.4.1.2 (Transmit EVM) using only the signal within the corresponding channel.

Receive requirement of EDMG and non-EDMG control mode PPDUs are defined in 28.3.8 (CCA sensitivity).

## 28.5 EDMG and non-EDMG SC mode

### 28.5.1 General

Transmission and reception of the following modes are mandatory:

— 2.16 GHz SU PPDU using the EDMG SC mode MCSs 1 to 5 and 7 to 10 with single spatial stream
— 2.16 GHz PPDU using the non-EDMG SC mode MCSs 1 to 4
— 4.32 GHz SU PPDU using the EDMG SC mode MCSs 1 to 5 and 7 to 10 with single spatial stream
— 4.32 GHz PPDU using the non-EDMG duplicate SC mode MCSs 1 to 4

Transmission and reception of all other modes are optional.

### 28.5.2 Signal parameters

#### 28.5.2.1 General

This subclause defines the main EDMG SC signal parameters for 2.16 GHz ($N_{CB}$ = 1), 4.32 GHz ($N_{CB}$ = 2), 6.48 GHz ($N_{CB}$ = 3), 8.64 GHz ($N_{CB}$ = 4), 2.16+2.16 GHz ($N_{CB}$ = 1), and 4.32+4.32 GHz ($N_{CB}$ = 2) PPDU transmissions.


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### 28.5.2.2 Timing-related parameters

Table 28-47 (EDMG SC mode timing-related parameters(11ay)) provides a summary of the EDMG SC mode timing-related parameters.

**Table 28-47—EDMG SC mode timing-related parameters(11ay)**

| Parameter | Value | | | |
|---|---|---|---|---|
| | $N_{CB} = 1$ | $N_{CB} = 2$ | $N_{CB} = 3$ | $N_{CB} = 4$ |
| $N_{SPB}$: number of symbols per SC symbol block for short GI length | 480 | 960 | 1440 | 1920 |
| $N_{SPB}$: number of symbols per SC symbol block for normal GI length | 448 | 896 | 1344 | 1792 |
| $N_{SPB}$: number of symbols per SC symbol block for long GI length | 384 | 768 | 1152 | 1536 |
| $N_{GI\ short}$: short guard interval length | 32 | 64 | 96 | 128 |
| $N_{GI\ normal}$: normal guard interval length | 64 | 128 | 192 | 256 |
| $N_{GI\ long}$: long guard interval length | 128 | 256 | 384 | 512 |
| $F_c$: DMG SC chip rate | 1.76 GHz | 1.76 GHz | 1.76 GHz | 1.76 GHz |
| $F_{c\ EDMG}$: EDMG SC chip rate | 1.76 GHz | 3.52 GHz | 5.28 GHz | 7.04 GHz |
| $T_c$: DMG SC chip time duration | 0.57 ns | 0.57 ns | 0.57 ns | 0.57 ns |
| $T_{c\ EDMG}$: EDMG SC chip time duration | 0.57 ns | 0.28 ns | 0.19 ns | 0.14 ns |
| $N_{DFT}$: DFT size | 512 | 1024 | 1536 | 2048 |
| $T_{DFT}$: SC IDFT/DFT period | 0.291 µs | 0.291 µs | 0.291 µs | 0.291 µs |
| $T_{GI\ short}$: short guard interval duration | 18.18 ns | 18.18 ns | 18.18 ns | 18.18 ns |
| $T_{GI\ normal}$: normal guard interval duration | 36.36 ns | 36.36 ns | 36.36 ns | 36.36 ns |
| $T_{GI\ long}$: long guard interval duration | 72.72 ns | 72.72 ns | 72.72 ns | 72.72 ns |

NOTE 1—The non-EDMG and pre-EDMG modulated fields are defined at the DMG SC chip rate $F_c$ and the corresponding chip time duration $T_c$. The EDMG modulated fields are defined at the EDMG SC chip rate $F_{c\ EDMG} = F_c \times N_{CB}$ and the corresponding chip time duration $T_{c\ EDMG} = T_c/N_{CB}$.

NOTE 2—The values given for parameters $N_{GI\ short}$, $N_{GI\ normal}$, and $N_{GI\ long}$ correspond to the number of elements in the GI for each GI length and $N_{CB}$ value.

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### 28.5.3 Transmitter block diagram

#### 28.5.3.1 General

EDMG and non-EDMG SC PPDU transmissions can be generated using a transmitter consisting of the following blocks:

- Scrambler scrambles the data to reduce the probability of long sequences of 0s and 1s; see 28.5.9.3 (Scrambler).
- LDPC encoder encodes the data to enable error correction. It pads the data with 0s to get an integer number of codewords and SC symbol blocks; see 28.5.9.4 (Encoding).
- Stream parser divides the output of the LDPC encoder into the groups of bits that are sent to different mapping devices. The sequence of the bits sent to different mapping devices is called a spatial stream; see 28.5.9.4 (Encoding).
- Constellation mapper and π/2-rotation block map the sequence of bits in each spatial stream to constellation points (complex numbers); see 28.5.9.5 (Modulation mapping).
- Interleaver performs interleaving inside an(#1424) SC symbol block; see 28.5.9.5.5 (Block interleaver).
- STBC encoder spreads constellation points from $N_{SS}$ spatial streams into $N_{STS}$ space-time streams using a space-time block code. (#8160)EDMG SC mode defines STBC schemes with $N_{STS} = 2 \times N_{SS}$; see 28.5.9.5.4 (Space-time block coding (STBC)).
- GI insertion prepends the SC symbol block with guard interval defined as a π/2-BPSK modulated Golay sequence; see 28.5.9.2 (Symbol blocking and guard insertion)
- Preamble builder builds π/2-BPSK modulated Ga and Gb Golay sequences comprising the L-STF, L-CEF, EDMG-STF, and EDMG-CEF fields; see 28.10 (Golay sequences).
- Spatial mapper maps space-time streams to transmit chains. This may include one of the following, see 28.5.10.2 (Spatial mapping):
  - Direct mapping: constellation points from each space-time stream are mapped directly to the transmit chains.
  - Indirect mapping: constellation points from each space-time stream are mapped to each transmit chain.
  - Digital beamforming: each vector of constellation points from all of the space-time streams is multiplied by a matrix of steering vectors to produce the input to the transmit chains.
- Cyclic shift diversity (CSD) prevents the signal transmission from unintentional beamforming. A cyclic shift is specified per transmitter chain for non-EDMG duplicate PPDU transmission; see 28.5.3.2 (Non-EDMG PPDU transmission) and 28.5.3.3.1 (Pre-EDMG modulated fields of PPDU transmission).
- Pulse shaping performs convolution of constellation points with shape filter impulse response with possible sampling rate change. For duplicate channel transmission, pulse shaping may include a relative time delay between the primary and secondary channels. The exact definition of shape filter impulse response is beyond the scope of this standard and is implementation specific.


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#### 28.5.3.2 Non-EDMG PPDU transmission

Figure 28-14 (Transmitter block diagram for non-EDMG PPDU transmission(11ay)) shows the transmitter blocks used to generate the non-EDMG PPDU. The L-STF, L-CEF fields and TRN units of PPDU are generated using Golay builder block. The L-Header and data part of PPDU are generated using scrambler, LDPC encoder, constellation mapper, and GI insertion blocks. A single spatial stream is mapped to the $N_{TX}$ transmit chains applying relative cyclic shift over the chains as defined in 28.5.9 (Data field).

#### 28.5.3.3 EDMG PPDU transmission

##### 28.5.3.3.1 Pre-EDMG modulated fields of PPDU transmission

Figure 28-14 (Transmitter block diagram for non-EDMG PPDU transmission(11ay)) shows the transmitter blocks used to generate the pre-EDMG modulated fields of the EDMG PPDU preamble. The L-STF and L-CEF fields are generated using Golay builder block. The L-Header and EDMG-Header-A are generated using scrambler, LDPC encoder, constellation mapper, and GI insertion blocks. A single spatial stream is mapped to the $N_{TX}$ transmit chains applying relative cyclic shift over the chains as defined in 28.5.10 (PPDU transmission).

##### 28.5.3.3.2 EDMG modulated fields of SU PPDU transmission

Figure 28-15 (Transmitter block diagram for the EDMG modulated fields of an SU PPDU transmission(11ay)) shows the transmitter blocks used to generate the EDMG modulated fields of an SU PPDU. The EDMG-STF and EDMG-CEF fields are generated using the Preamble builder block. The TRN field is generated using TRN builder block. (#2350)The EDMG-Header-A field in the PPDU starting from the second PPDU in the EDMG A-PPDU and Data field of the PPDU are generated using the scrambler, LDPC encoder, constellation mapper, interleaver, and GI insertion blocks. If STBC encoder is applied, then $N_{SS}$ spatial streams are mapped to $2 \times N_{SS}$ space-time streams as defined in 28.5.9.5.4 (Space-time block coding (STBC)). The $N_{STS}$ space-time streams are further mapped to $N_{TX}$ transmit chains, where $N_{STS} \leq N_{TX}$.

NOTE—Interleaver is applied to π/2-64-QAM and π/2-64-NUC modulations only. π/2-rotation is applied to the 64-QAM and 64-NUC symbols at the output of the interleaver block.

##### 28.5.3.3.3 EDMG modulated fields of MU PPDU transmission

Figure 28-16 (Transmitter block diagram for the EDMG modulated fields of an MU PPDU transmission(11ay)) shows the transmitter blocks used to generate the EDMG modulated fields of an MU PPDU. The EDMG-STF and EDMG-CEF fields are generated using the Preamble builder block. The TRN field is generated using TRN builder block. The EDMG-Header-B and Data field of the PPDU are generated using scrambler, LDPC encoder, constellation mapper, interleaver, and GI insertion blocks. The PPDU encoding uses seed value defined in the EDMG-Header-B and has independent flows per user. The EDMG-Header-B encoding is defined in 28.5.6 (Encoding of EDMG-Header-B). The space-time streams mapping is defined in 28.5.9.4.4 (MU PPDU padding and space-time streams mapping). The total number of space-time streams per user shall be less than or equal to 2. If STBC encoder is applied, then a single spatial stream is mapped to two space-time streams as defined in 28.5.9.5.4 (Space-time block coding (STBC)). The $N_{STS}$ space-time streams are further mapped to $N_{TX}$ transmit chains, where $N_{STS} \leq N_{TX}$.

NOTE—Interleaver is applied to π/2-64-QAM and π/2-64-NUC modulations only. π/2-rotation is applied to the 64-QAM and 64-NUC symbols at the output of the interleaver block.

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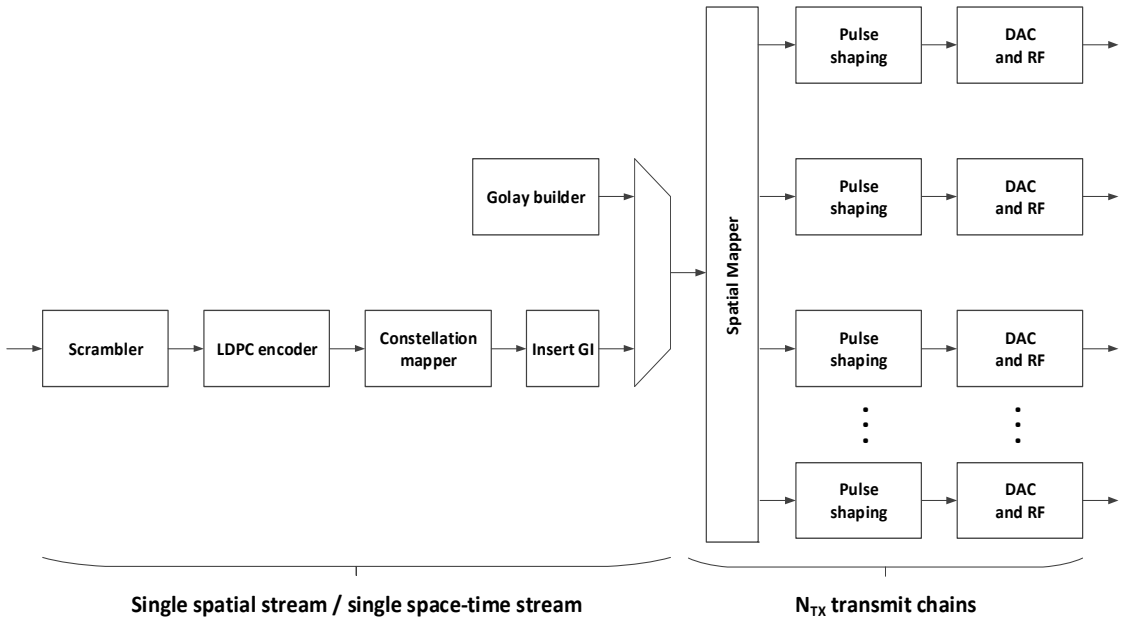


**Figure 28-14—Transmitter block diagram for non-EDMG PPDU transmission(11ay)**

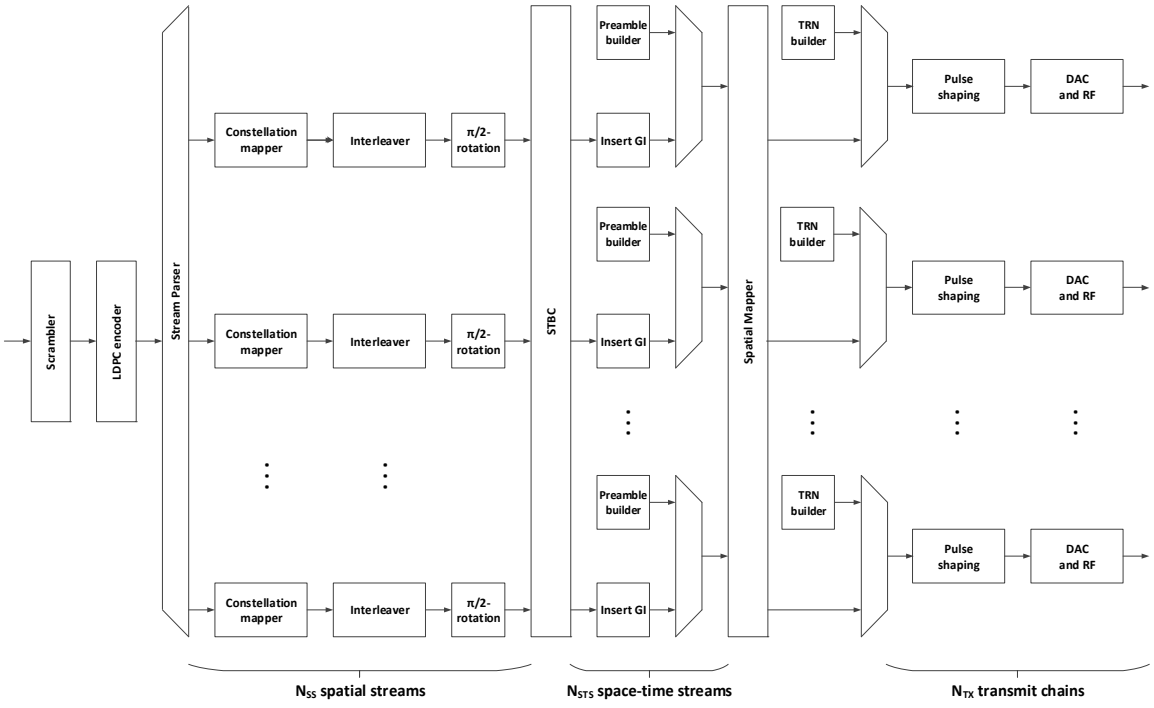


**Figure 28-15—Transmitter block diagram for the EDMG modulated fields of an SU PPDU transmission(11ay)**



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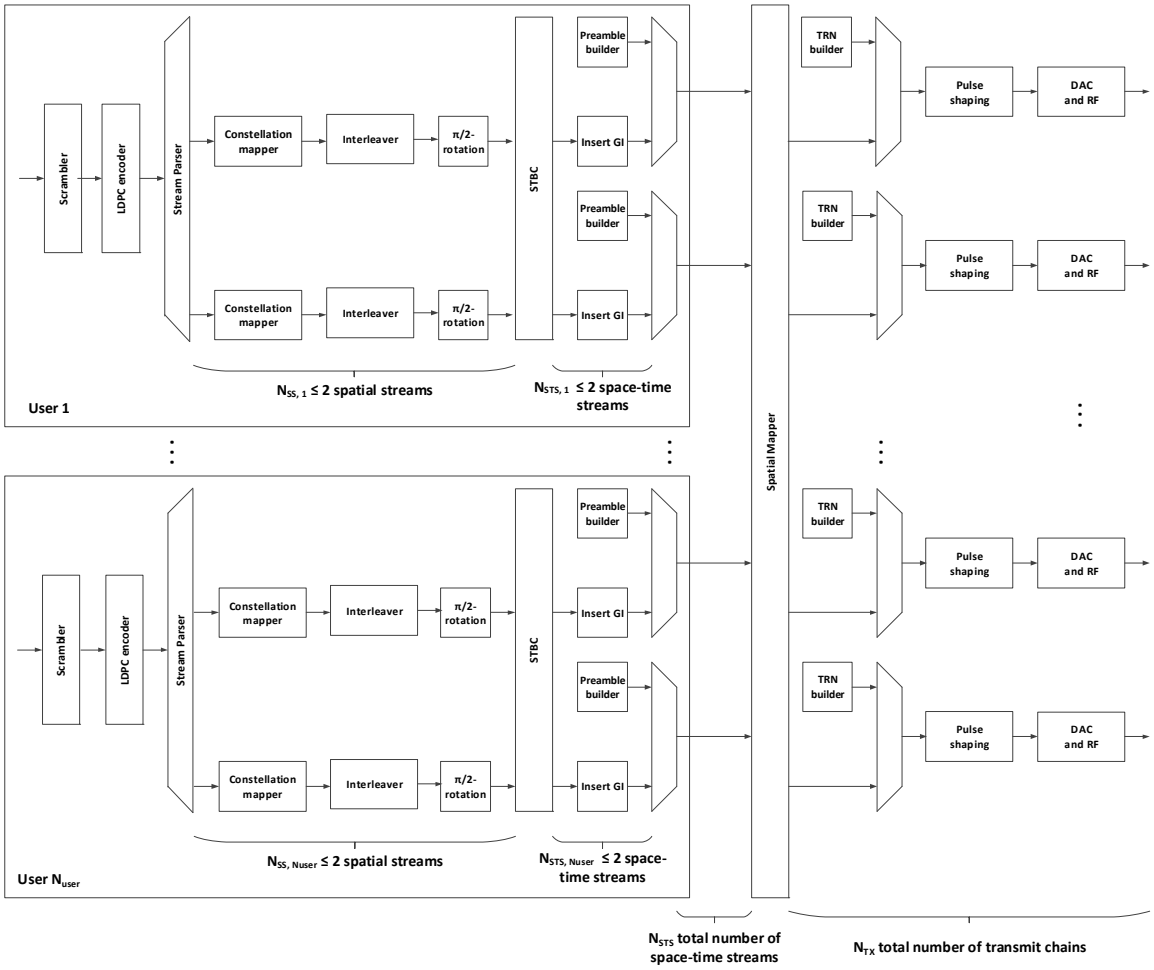


**Figure 28-16—Transmitter block diagram for the EDMG modulated fields of an MU PPDU transmission(11ay)**

### 28.5.4 EDMG-STF definition

#### 28.5.4.1 General

The structure of the EDMG-STF field depends on the number of contiguous 2.16 GHz channels over which an EDMG PPDU is transmitted and the index $i_{STS}$ of the $i_{STS}^{th}$ space-time stream.

For single space-time stream EDMG PPDU transmissions using the EDMG SC mode over a single 2.16 GHz channel, the EDMG-STF field is not present.

For EDMG SC transmissions, the EDMG-STF field shall be modulated using π/2-BPSK.

The Golay sequences used in the definition of the EDMG-STF are found in 28.10 (Golay sequences).

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#### 28.5.4.2 Definition

The EDMG-STF field transmit waveform in time domain shall be defined at the EDMG SC chip rate $F_{c\ EDMG}$ and chip time duration $T_{c\ EDMG}$. The EDMG-STF field for the $i_{TX}^{\text{th}}$ transmit chain is defined as follows:

$$r_{EDMG\text{-}STF}^{i_{TX}}\left(q\frac{T_c}{N_{CB}}\right)=\frac{1}{\sqrt{N_{STS}}}\sum_{i_{STS}=1}^{N_{STS}}\left[Q_{EDMG}\right]_{i_{TX},i_{STS}}r_{STF}^{i_{STS}}\left(q\frac{T_c}{N_{CB}}\right)$$

where

$N_{STS}$ is a total number of space-time streams

$r_{STF}^{i_{STS}}\left(q\frac{T_c}{N_{CB}}\right)$ is the short training field definition for $i_{STS}^{\text{th}}$ space-time stream

$Q_{EDMG}$ is a spatial mapping matrix

$[\ ]_{m,n}$ is a matrix element from $m^{\text{th}}$ row and $n^{\text{th}}$ column

For spatial expansion, $N_{STS} = 1 \le N_{TX}$, the spatial mapping matrix $Q$ is defined as the column vector composed of all 1s of size $N_{TX}$ by 1. The spatial expansion is performed by application of CSD over different transmit chains as defined in 28.5.10 (PPDU transmission).

The EDMG-STF field is composed of 18 repetitions of $Ga_{128\times N_{CB}}^{i_{STS}}$ followed by one with inverse sign $-Ga_{128\times N_{CB}}^{i_{STS}}$. The waveform for the EDMG-STF field, $r_{STF}^{i_{STS}}\left(qT_c\right)$, is defined as follows:

$$r_{STF}^{i_{STS}}\left(q\frac{T_c}{N_{CB}}\right)=\left(\sum_{n=1}^{18}Ga_{128\times N_{CB}}^{i_{STS}}\left(q-128\times(n-1)\times N_{CB}\right)-Ga_{128\times N_{CB}}^{i_{STS}}\left(q-128\times 18\times N_{CB}\right)\right)$$

Note that sequence $Ga_{128\times N_{CB}}^{i_{STS}}\left(n\right)$ is defined for $0 \le n \le 128 \times N_{CB} - 1$. For other values of $n$, $Ga_{128\times N_{CB}}^{i_{STS}}\left(n\right)$ is set to 0.

### 28.5.5 EDMG-CEF definition

#### 28.5.5.1 General

The structure of the EDMG-CEF field depends on the number of contiguous 2.16 GHz channels over which an EDMG PPDU is transmitted and the number, $i_{STS}$, of space-time streams.

For single space-time stream EDMG PPDU transmissions using the EDMG SC mode over a single 2.16 GHz channel, the EDMG-CEF field is not present.

For EDMG SC transmissions, the EDMG-CEF field shall be modulated using π/2-BPSK.

The pairs of Golay complementary sequences ($Ga^{iSTS}{}_{128}$, $Gb^{iSTS}{}_{128}$), ($Ga^{iSTS}{}_{256}$, $Gb^{iSTS}{}_{256}$), ($Ga^{iSTS}{}_{384}$, $Gb^{iSTS}{}_{384}$) and ($Ga^{iSTS}{}_{512}$, $Gb^{iSTS}{}_{512}$) used in the definition of the EDMG-CEF field for different space-time streams are specified in 28.10 (Golay sequences).


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### 28.5.5.2 Definition

The EDMG-CEF field transmit waveform in time domain shall be defined at the EDMG SC chip rate $F_{c\ EDMG}$ and chip time duration $T_{c\ EDMG}$. The EDMG-CEF field is composed of $N_{EDMG\text{-}CEF}^{N_{STS}}$ subfields for the $i_{TX}^{\text{th}}$ transmit chain is defined as follows:

$$r_{EDMG\text{-}CEF}^{i_{TX}}\left(q\frac{T_c}{N_{CB}}\right)=\frac{1}{\sqrt{N_{STS}}}\sum_{n=1}^{N_{EDMG\text{-}CEF}^{N_{STS}}}\sum_{i_{STS}=1}^{N_{STS}}\left[Q_{EDMG}\right]_{i_{TX},i_{STS}}\left[P_{EDMG\text{-}CEF}\right]_{i_{STS},n}r_{CE,m}^{i_{STS}}\left(q\frac{T_c}{N_{CB}}-nT_{EDMG\text{-}CEF,m}\right),$$

$m=1$ *for* $n=1$; $m=2$ *for* $n>1$

$T_{EDMG\text{-}CEF,1}=1152\times T_c$ , $T_{EDMG\text{-}CEF,2}=1280\times T_c$

where

| | |
|---|---|
| $N_{EDMG\text{-}CEF}^{N_{STS}}$ | is the total number of EDMG-CEF subfields, where index *n* defines a subfield number |
| $N_{STS}$ | is a total number of space-time streams |
| $r_{CE,m}^{i_{STS}}\left(q\frac{T_c}{N_{CB}}\right)$ | is a channel estimation field definition for the $i_{STS}^{\text{th}}$ space-time stream, where $m$ = 1 for $n$ = 1 and $m$ = 2 for $n$ > 1 |
| $T_{EDMG\text{-}CEF}$ | is the EDMG-CEF subfield duration |
| $P_{EDMG\text{-}CEF}$ | is an EDMG-CEF mapping matrix |
| $Q_{EDMG}$ | is a spatial mapping matrix |
| $[\ ]_{m,n}$ | is a matrix element from $m^{\text{th}}$ row and $n^{\text{th}}$ column |

For spatial expansion, $N_{STS} = 1 \le N_{TX}$, the spatial mapping matrix $Q$ is defined as the column vector composed of all 1s of size $N_{TX}$ by 1. The spatial expansion is performed by application of CSD over different transmit chains as defined in 28.5.10 (PPDU transmission).

The waveform for the channel estimation subfield, $r_{CE,1}^{i_{STS}}\left(q\frac{T_c}{N_{CB}}\right)$, is defined as follows:

$$r_{CE,1}^{i_{STS}}\left(q\frac{T_c}{N_{CB}}\right)=\left(Gu_{512\times N_{CB}}^{i_{STS}}\left(q\right)+Gv_{512\times N_{CB}}^{i_{STS}}\left(q-512\times N_{CB}\right)-Gb_{128\times N_{CB}}^{i_{STS}}\left(q-1024\times N_{CB}\right)\right)$$

$$\cdot\exp\left(j\left(\pi/2\right)q\right),q=0,1,...,1152\times N_{CB}-1$$

The waveform for the channel estimation subfield, $r_{CE,2}^{i_{STS}}\left(q\frac{T_c}{N_{CB}}\right)$, is defined as follows:

$$r_{CE,2}^{i_{STS}}\left(q\frac{T_c}{N_{CB}}\right)=\left(-Ga_{128\times N_{CB}}^{i_{STS}}\left(q\right)+Gu_{512\times N_{CB}}^{i_{STS}}\left(q-128\times N_{CB}\right)+Gv_{512\times N_{CB}}^{i_{STS}}\left(q-640\times N_{CB}\right)\right.$$

$$\left.-Gb_{128\times N_{CB}}^{i_{STS}}\left(q-1152\times N_{CB}\right)\right)\cdot\exp\left(j\left(\pi/2\right)q\right),q=0,1,...,1280\times N_{CB}-1$$

Note that sequences $Ga_{128\times N_{CB}}^{i_{STS}}\left(n\right)$ and $Gb_{128\times N_{CB}}^{i_{STS}}\left(n\right)$, $i_{STS}$ = 1, 2, …, 8, are defined for $0 \le n \le 128 \times N_{CB} - 1$. For other values of $n$, $Ga_{128\times N_{CB}}^{i_{STS}}\left(n\right)$ and $Gb_{128\times N_{CB}}^{i_{STS}}\left(n\right)$ are set to 0.

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The sequences $Gu^{i_{STS}}_{512\times N_{CB}}(n)$ and $Gv^{i_{STS}}_{512\times N_{CB}}(n)$ are defined as follows:

$$Gu^{i_{STS}}_{512\times N_{CB}} = \left[ -Gb^{i_{STS}}_{128\times N_{CB}} \quad -Ga^{i_{STS}}_{128\times N_{CB}} \quad +Gb^{i_{STS}}_{128\times N_{CB}} \quad -Ga^{i_{STS}}_{128\times N_{CB}} \right], \text{ for } i_{STS} = 1, 2, 3, 4, 5, 6, 7, 8$$

$$Gv^{i_{STS}}_{512\times N_{CB}} = \left[ -Gb^{i_{STS}}_{128\times N_{CB}} \quad +Ga^{i_{STS}}_{128\times N_{CB}} \quad -Gb^{i_{STS}}_{128\times N_{CB}} \quad -Ga^{i_{STS}}_{128\times N_{CB}} \right], \text{ for } i_{STS} = 1, 2, 3, 4, 5, 6, 7, 8$$

Note that sequences $Gu^{i_{STS}}_{512\times N_{CB}}(n)$ and $Gv^{i_{STS}}_{512\times N_{CB}}(n)$ are defined for $0 \le n \le 512 \times N_{CB} - 1$. For other values of $n$, $Gu^{i_{STS}}_{512\times N_{CB}}(n)$ and $Gv^{i_{STS}}_{512\times N_{CB}}(n)$ are set to 0.

The EDMG-CEF mapping matrix for $N_{STS} = 1, 2$ is defined as follows:

$$P_{EDMG-CEF} = \begin{bmatrix} +1 \\ +1 \end{bmatrix},\ N^{N_{STS}}_{EDMG-CEF} = 1$$

The EDMG-CEF mapping matrix for $N_{STS} = 3, 4$ is defined as follows:

$$P_{EDMG-CEF} = \begin{bmatrix} +1 & +1 \\ +1 & +1 \\ +1 & -1 \\ +1 & -1 \end{bmatrix},\ N^{N_{STS}}_{EDMG-CEF} = 2$$

The EDMG-CEF mapping matrix for $N_{STS} = 5, 6, 7,$ and 8 is defined as follows:

$$P_{EDMG-CEF} = \begin{bmatrix} +1 & +1 & +1 & +1 \\ +1 & +1 & +1 & +1 \\ +1 & -1 & +1 & -1 \\ +1 & -1 & +1 & -1 \\ +1 & +1 & -1 & -1 \\ +1 & +1 & -1 & -1 \\ +1 & -1 & -1 & +1 \\ +1 & -1 & -1 & +1 \end{bmatrix},\ N^{N_{STS}}_{EDMG-CEF} = 4$$

### 28.5.6 Encoding of EDMG-Header-B

The EDMG-Header-B for the $i_{user}$th user shall be encoded as follows:

— The input 64 bits of the EDMG-Header-B, $\mathbf{b} = (b_1, b_2, ..., b_{64})$, are scrambled with the PN sequence described in 20.3.9 (Scrambler), starting from the eighth bit to create the $\mathbf{bq} = (bq_1, bq_2, ..., bq_{64})$ sequence. The scrambler seed value is initialized by the first seven bits of the EDMG-Header-B.

— The LDPC codeword of length 672 bits is created by concatenating the 440 0s to the scrambled header bits $\mathbf{bq} = (bq_1, bq_2, ..., bq_{64})$ and then computing 168 parity bits $\mathbf{p} = (p_1, p_2, ..., p_{168})$ using the LDPC matrix with $R$ = 3/4 and $L_{CW}$ = 672 defined in 20.3.8.4 (Rate 3/4 LDPC code matrix H = 168 rows x 672 columns, Z = 42). The LDPC codeword is defined as $(bq_1, bq_2, ..., bq_{64}, 0_1, 0_2, ..., 0_{440}, p_1, p_2, ..., p_{168})$.


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- The zero padded bits are discarded and the output codeword is defined as $\mathbf{c} = (\mathbf{c}_1, \mathbf{c}_2)$, where
  - $\mathbf{c}_1 = (bq_1, bq_2, ..., bq_{64}, p_1, p_2, ..., p_{160})$
  - $\mathbf{c}_2 = (bq_1, bq_2, ..., bq_{64}, p_1, p_2, ..., p_{152}, p_{161}, p_{162}, ..., p_{168})$
- For a PPDU transmitted over a $N_{CB}$ × 2.16 GHz channel, where $1 \le N_{CB} \le 4$, the data block is defined as a repetition of codeword **c** by $N_{CB}$ times:
  - **cb** = **c** for $N_{CB} = 1$
  - **cb** = (**c**, **c**) for $N_{CB} = 2$
  - **cb** = (**c**, **c**, **c**) for $N_{CB} = 3$
  - **cb** = (**c**, **c**, **c**, **c**) for $N_{CB} = 4$
- For a PPDU transmitted using $N_{STS}$ ($N_{STS}$ = 1, 2) space-time streams, the data block **cb** is repeated $N_{STS}$ times. Then, the $N_{STS}$ data blocks are scrambled continuously with the PN sequence defined in 28.5.9.3.2 (Scrambler for EDMG-Header-A in SU EDMG A-PPDU, EDMG-Header-B, and EDMG SC MCS1 coded bits) without seed reset. The initial seed value is equal to all 1s $(1_1, 1_2, ..., 1_7)$. The scrambling starts at the 225th bit and ends at the $(N_{STS} \times 448 \times N_{CB})^{th}$ bit. The first scrambled **cb** block is mapped to the first space-time stream and the second scrambled **cb** block to the second space-time stream.

The SC data blocks shall be modulated using π/2-BPSK modulation as defined in 20.5.3.2.4 (Modulation mapping). Each SC data block is prepended with a guard interval as defined in 28.5.9.2 (Symbol blocking and guard insertion).

The EDMG-Header-B field is transmitted by applying EDMG transmission format defined in 28.5.9.5.2 (Transmission in EDMG format).

### 28.5.7 Encoding of EDMG-Header-A for EDMG A-PPDU transmission

The EDMG-Header-A field in the first EDMG PPDU in an EDMG SC mode A-PPDU (i.e., $i_{PPDU} = 1$, where $i_{PPDU}$ represents the index of the PPDU into the EDMG A-PPDU) is encoded and modulated as specified in 28.3.3.3.2.4 (Encoding and modulation).

For the $i_{PPDU}^{th}$ EDMG PPDU in the EDMG SC mode A-PPDU, $i_{PPDU} > 1$, the EDMG-Header-A field shall be encoded and modulated as follows:

- The input 112 header bits are appended with 16 HCS bits calculated as defined in 20.3.7 (HCS calculation for headers of DMG control mode and DMG SC mode).
- The resulting 128 bits including CRC, **b** = ($b_1$, $b_2$,…, $b_{128}$), are scrambled with the PN sequence as described in 20.3.9 (Scrambler), starting from the first bit using a continuation of the scrambler bit sequence from the Data field of preceding EDMG PPDU in the EDMG SC mode A-PPDU to create the **bq** = ($bq_1$, $bq_2$,…, $bq_{128}$) sequence.
- The scrambled header bits, **bq**, are divided into two parts **bq1** = ($bq_1$, $bq_2$,…, $bq_{64}$) and **bq2** = ($bq_{65}$, $bq_{66}$,…, $bq_{128}$) of 64 bits each.
- Two LDPC codewords of length 672 bits each are created by concatenating the 440 0s to each part, **bq1** and **bq2**, and then computing 168 parity bits **p1** = ($p1_1$, $p1_2$,…, $p1_{168}$) and **p2** = ($p2_1$, $p2_2$,…, $p2_{168}$) for **bq1** and **bq2**, respectively, using the LDPC matrix with $R$ = 3/4 and $L_{CW}$ = 672 defined in 20.3.8.4 (Rate 3/4 LDPC code matrix H = 168 rows x 672 columns, Z = 42). The LDPC codewords are defined as follows:
  - **cw1** = ($bq_1$, $bq_2$,…, $bq_{64}$, $0_1$, $0_2$,…, $0_{440}$, $p1_1$, $p1_2$,…, $p1_{168}$)
  - **cw2** = ($bq_{65}$, $bq_{66}$,…, $bq_{128}$, $0_1$, $0_2$,…, $0_{440}$, $p2_1$, $p2_2$,…, $p2_{168}$)

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- The padded 0s are discarded and two output codewords are defined as **c1** = ($c1_1$, $c1_2$) and **c2** = ($c2_1$, $c2_2$), where
  - **c1$_1$** = ($bq_1$, $bq_2$,…, $bq_{64}$, $p1_1$, $p1_2$,…, $p1_{160}$)
  - **c1$_2$** = ($bq_1$, $bq_2$,…, $bq_{64}$, $p1_1$, $p1_2$,…, $p1_{152}$, $p1_{161}$, $p1_{162}$,…, $p1_{168}$)
  - **c2$_1$** = ($bq_{65}$, $bq_{66}$,…, $bq_{128}$, $p2_1$, $p2_2$,…, $p2_{160}$)
  - **c2$_2$** = ($bq_{65}$, $bq_{66}$,…, $bq_{128}$, $p2_1$, $p2_2$,…, $p2_{152}$, $p2_{161}$, $p2_{162}$,…, $p2_{168}$)
- For a PPDU transmitted over an $N_{CB}$ × 2.16 GHz channel, where $1 \le N_{CB} \le 4$, the data blocks are defined as a repetition of codeword **c1** and **c2** by $N_{CB}$ times:
  - **cb1** = c1, **cb2** = c2 for $N_{CB} = 1$
  - **cb1** = (c1, c1), **cb2** = (c2, c2) for $N_{CB} = 2$
  - **cb1** = (c1, c1, c1), **cb2** = (c2, c2, c2) for $N_{CB} = 3$
  - **cb1** = (c1, c1, c1, c1), **cb2** = (c2, c2, c2, c2) for $N_{CB} = 4$
- For a PPDU transmitted using $N_{STS}$ ($N_{STS}$ = 1, 2, …, 8) space-time streams, the data blocks **cb1** and **cb2** are concatenated as **cb** = (**cb1**, **cb2**) and the data block **cb** is repeated $N_{STS}$ times. Then, the $N_{STS}$ data blocks **cb** are scrambled continuously with the PN sequence defined in 28.5.9.3.2 (Scrambler for EDMG-Header-A in SU EDMG A-PPDU, EDMG-Header-B, and EDMG SC MCS1 coded bits) without seed reset. The initial seed value is equal to all 1s ($1_1$, $1_2$,…, $1_7$). The scrambling starts at the 225$^{th}$ bit and ends at the ($N_{STS} \times 896 \times N_{CB}$)$^{th}$ bit. The first scrambled **cb** block is mapped to the first space-time stream and the second scrambled **cb** block to the second space-time stream, and so on.

The data blocks shall be modulated using π/2-BPSK modulation as defined in 20.5.3.2.4 (Modulation mapping). Each of the modulated data blocks **cb1** and **cb2** is prepended with 64 × $N_{CB}$ guard symbols, and the data block **cb2** is appended with appropriate number of guard symbols as described in 28.5.9.2.3 (SU A-PPDU transmission).

The EDMG-Header-A field for $i_{PPDU} > 1$ is transmitted by applying the EDMG transmission format defined in 28.5.9.5.2 (Transmission in EDMG format).

### 28.5.8 Modulation and coding scheme (MCS)

The MCS is a value that determines the modulation and coding. For an EDMG PPDU, the MCS value is carried in the EDMG-Header-A field and in the EDMG-Header-B field. The data rate provided by an MCS depends on the guard interval length, the number of spatial streams, $N_{SS}$ ($1 \le N_{SS} \le 8$), and the number of contiguous 2.16 GHz channels, $N_{CB}$ ($1 \le N_{CB} \le 4$), that make up the signal bandwidth of an EDMG PPDU.

The set of MCSs for an EDMG SC mode PPDU are defined in Table 28-48 (EDMG-MCSs for the EDMG SC mode(11ay)), where $N_{CB}$ is as defined above. If the π/2-8-PSK Applied field in the EDMG-Header-A of an SU PPDU is 1, then MCS 12 and 13 shall use π/2-8-PSK modulation as indicated inTable 28-49 (EDMG-MCSs 12 and 13 for the EDMG SC mode if the π/2-8-PSK Applied field is 1(11ay)). If the π/2-64-NUC Applied field in the EDMG-Header-A or in the EDMG-Header-B is 1, then MCS 17 through 21 shall use π/2-64-NUC modulation as indicated in Table 28-50 (EDMG-MCSs 17 to 21 for the EDMG SC mode if the π/2-64-NUC Applied field is 1(11ay)). If the DCM BPSK Applied field in the EDMG-Header-A of an SU PPDU is 1, then MCS 2 through 6 shall use DCM BPSK modulation as indicated in Table 28-51 (EDMG-MCSs 2 to 6 for the EDMG SC mode if the DCM BPSK Applied field is 1(11ay)).

For a given type of guard interval used in the transmission of an EDMG SC mode PPDU, the total transmission data rate, ρ, provided by the PPDU is defined as follows:

$$\rho = \sum_{i_{ss}=1}^{N_{ss}} Data\_rate_{i_{ss}}$$

where


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$N_{SS}$ is as defined above

$Data\_rate_{i_{ss}}$ is the data rate provided by the MCS of spatial stream $i_{ss}$ as defined in Table 28-48 (EDMG-MCSs for the EDMG SC mode(11ay))

Transmit and receive support for MCSs 1 to 5 and 7 to 10 are mandatory. Other MCSs are optional. MCS (#4136)indices exceeding the largest MCS index defined in Table 28-48 (EDMG-MCSs for the EDMG SC mode(11ay)) are reserved.

NOTE 1—The LDPC code with rate 7/8 can use a superimposed or puncturing code selected by the Superimposed Code Applied field defined in the EDMG-Header-A or EDMG-Header-B, as appropriate. The encoding procedure for both cases is described in 28.5.9.4.3 (LDPC encoding).

NOTE 2—The LDPC code with rate 2/3 is generated by employing the original LDPC code with rate 3/4 and applying the codeword shortening procedure to achieve the effective code rate. The LDPC code with rate 5/6 is generated by employing the original LDPC code with rate 7/8 and applying the codeword shortening procedure to achieve the effective code rate. Therefore, similar to the LDPC code with rate 7/8, the LDPC code with rate 5/6 is obtained by using a superimposed or puncturing code selected by the Superimposed Code Applied field defined in the EDMG-Header-A or EDMG-Header-B, as appropriate. The encoding procedure for both cases is described in 28.5.9.4.3 (LDPC encoding).

**Table 28-48—EDMG-MCSs for the EDMG SC mode(11ay)**

| EDMG-MCS index | Modulation | $N_{CBPS}$ | Repetition | Code rate | Data rate per spatial stream (Mb/s) | | |
|---|---|---|---|---|---|---|---|
| | | | | | Normal GI | Short GI | Long GI |
| 1 | π/2-BPSK | 1 | 2 | 1/2 | $N_{CB}$×385.00 | $N_{CB}$×412.50 | $N_{CB}$×330.00 |
| 2 | π/2-BPSK | 1 | 1 | 1/2 | $N_{CB}$×770.00 | $N_{CB}$×825.00 | $N_{CB}$×660.00 |
| 3 | π/2-BPSK | 1 | 1 | 5/8 | $N_{CB}$×962.50 | $N_{CB}$×1031.25 | $N_{CB}$×825.00 |
| 4 | π/2-BPSK | 1 | 1 | 3/4 | $N_{CB}$×1155.00 | $N_{CB}$×1237.50 | $N_{CB}$×990.00 |
| 5 | π/2-BPSK | 1 | 1 | 13/16 | $N_{CB}$×1251.25 | $N_{CB}$×1340.63 | $N_{CB}$×1072.50 |
| 6 | π/2-BPSK | 1 | 1 | 7/8 | $N_{CB}$×1347.50 | $N_{CB}$×1443.75 | $N_{CB}$×1155.00 |
| 7 | π/2-QPSK | 2 | 1 | 1/2 | $N_{CB}$×1540.00 | $N_{CB}$×1650.00 | $N_{CB}$×1320.00 |
| 8 | π/2-QPSK | 2 | 1 | 5/8 | $N_{CB}$×1925.00 | $N_{CB}$×2062.50 | $N_{CB}$×1650.00 |
| 9 | π/2-QPSK | 2 | 1 | 3/4 | $N_{CB}$×2310.00 | $N_{CB}$×2475.00 | $N_{CB}$×1980.00 |
| 10 | π/2-QPSK | 2 | 1 | 13/16 | $N_{CB}$×2502.50 | $N_{CB}$×2681.25 | $N_{CB}$×2145.00 |
| 11 | π/2-QPSK | 2 | 1 | 7/8 | $N_{CB}$×2695.00 | $N_{CB}$×2887.50 | $N_{CB}$×2310.00 |
| 12 | π/2-16-QAM | 4 | 1 | 1/2 | $N_{CB}$×3080.00 | $N_{CB}$×3300.00 | $N_{CB}$×2640.00 |
| 13 | π/2-16-QAM | 4 | 1 | 5/8 | $N_{CB}$×3850.00 | $N_{CB}$×4125.00 | $N_{CB}$×3300.00 |
| 14 | π/2-16-QAM | 4 | 1 | 3/4 | $N_{CB}$×4620.00 | $N_{CB}$×4950.00 | $N_{CB}$×3960.00 |
| 15 | π/2-16-QAM | 4 | 1 | 13/16 | $N_{CB}$×5005.00 | $N_{CB}$×5362.50 | $N_{CB}$×4290.00 |
| 16 | π/2-16-QAM | 4 | 1 | 7/8 | $N_{CB}$×5390.00 | $N_{CB}$×5775.00 | $N_{CB}$×4620.00 |
| 17 | π/2-64-QAM | 6 | 1 | 1/2 | $N_{CB}$×4620.00 | $N_{CB}$×4950.00 | $N_{CB}$×3960.00 |
| 18 | π/2-64-QAM | 6 | 1 | 5/8 | $N_{CB}$×5775.00 | $N_{CB}$×6187.50 | $N_{CB}$×4950.00 |
| 19 | π/2-64-QAM | 6 | 1 | 3/4 | $N_{CB}$×6930.00 | $N_{CB}$×7425.00 | $N_{CB}$×5940.00 |

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**Table 28-48—EDMG-MCSs for the EDMG SC mode(11ay) *(continued)***

| EDMG-MCS index | Modulation | $N_{CBPS}$ | Repetition | Code rate | Data rate per spatial stream (Mb/s) | | |
|---|---|---|---|---|---|---|---|
| | | | | | Normal GI | Short GI | Long GI |
| 20 | π/2-64-QAM | 6 | 1 | 13/16 | $N_{CB}$×7507.50 | $N_{CB}$×8043.75 | $N_{CB}$×6435.00 |
| 21 | π/2-64-QAM | 6 | 1 | 7/8 | $N_{CB}$×8085.00 | $N_{CB}$×8662.50 | $N_{CB}$×6930.00 |

**Table 28-49—EDMG-MCSs 12 and 13 for the EDMG SC mode if the π/2-8-PSK Applied field is 1(11ay)**

| EDMG-MCS index | Modulation | $N_{CBPS}$ | Repetition | Code rate | Data rate per spatial stream (Mb/s) | | |
|---|---|---|---|---|---|---|---|
| | | | | | Normal GI | Short GI | Long GI |
| 12 | π/2-8-PSK | 3 | 1 | 2/3 | $N_{CB}$×3080.00 | $N_{CB}$×3300.00 | $N_{CB}$×2640.00 |
| 13 | π/2-8-PSK | 3 | 1 | 5/6 | $N_{CB}$×3850.00 | $N_{CB}$×4125.00 | $N_{CB}$×3300.00 |

**Table 28-50—EDMG-MCSs 17 to 21 for the EDMG SC mode if the π/2-64-NUC Applied field is 1(11ay)**

| EDMG-MCS index | Modulation | $N_{CBPS}$ | Repetition | Code rate | Data rate per spatial stream (Mb/s) | | |
|---|---|---|---|---|---|---|---|
| | | | | | Normal GI | Short GI | Long GI |
| 17 | π/2-64-NUC | 6 | 1 | 1/2 | $N_{CB}$×4620.00 | $N_{CB}$×4950.00 | $N_{CB}$×3960.00 |
| 18 | π/2-64-NUC | 6 | 1 | 5/8 | $N_{CB}$×5775.00 | $N_{CB}$×6187.50 | $N_{CB}$×4950.00 |
| 19 | π/2-64-NUC | 6 | 1 | 3/4 | $N_{CB}$×6930.00 | $N_{CB}$×7425.00 | $N_{CB}$×5940.00 |
| 20 | π/2-64-NUC | 6 | 1 | 13/16 | $N_{CB}$×7507.50 | $N_{CB}$×8043.75 | $N_{CB}$×6435.00 |
| 21 | π/2-64-NUC | 6 | 1 | 7/8 | $N_{CB}$×8085.00 | $N_{CB}$×8662.50 | $N_{CB}$×6930.00 |

**Table 28-51—EDMG-MCSs 2 to 6 for the EDMG SC mode if the DCM BPSK Applied field is 1(11ay)**

| EDMG-MCS index | Modulation | $N_{CBPS}$ | Repetition | Code rate | Data rate per spatial stream (Mb/s) | | |
|---|---|---|---|---|---|---|---|
| | | | | | Normal GI | Short GI | Long GI |
| 2 | DCM π/2-BPSK | 1 | 1 | 1/2 | $N_{CB}$×770.00 | $N_{CB}$×825.00 | $N_{CB}$×660.00 |
| 3 | DCM π/2-BPSK | 1 | 1 | 5/8 | $N_{CB}$×962.50 | $N_{CB}$×1031.25 | $N_{CB}$×825.00 |
| 4 | DCM π/2-BPSK | 1 | 1 | 3/4 | $N_{CB}$×1155.00 | $N_{CB}$×1237.50 | $N_{CB}$×990.00 |
| 5 | DCM π/2-BPSK | 1 | 1 | 13/16 | $N_{CB}$×1251.25 | $N_{CB}$×1340.63 | $N_{CB}$×1072.50 |
| 6 | DCM π/2-BPSK | 1 | 1 | 7/8 | $N_{CB}$×1347.50 | $N_{CB}$×1443.75 | $N_{CB}$×1155.00 |


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### 28.5.9 Data field

#### 28.5.9.1 Guard interval definition

Three types of GIs are defined: short, normal and long. An EDMG STA shall support the normal GI for each combination of channel bandwidth and number of spatial streams supported by the EDMG STA. All GI sequences are defined at the $N_{CB} \times F_c$ sampling rate, where $N_{CB}$ is the integer number of 2.16 GHz channels that make up the channel bandwidth and $1 \leq N_{CB} \leq 4$.

The following GI nomenclature is used: $GI^{iSTS}{}_N$ and $GIe^{iSTS}{}_N$. Here, $i_{STS}$ represents the space-time stream number, and $N$ represents the sequence length.

The GIs definitions utilize $GI^{iSTS}{}_{64}$ and $GIe^{iSTS}{}_{\mathrm{N}}$. $GI^{iSTS}{}_{64}$ shall be equal to $+Ga^{iSTS}{}_{64}$ for all cases. However, the definition of $GIe^{iSTS}{}_N$ depends on the value of $N_{CB}$. Table 28-52 (GIe definition for 2.16 GHz or 2.16+2.16 GHz (NCB = 1) channel(11ay)), Table 28-53 (GIe definition for 4.32 GHz or 4.32+4.32 GHz (NCB = 2) channel(11ay)), Table 28-54 (GIe definition for 6.48 GHz (NCB = 3) channel(11ay)), and Table 28-55 (GIe definition for 8.64 GHz (NCB = 4) channel(11ay)) define $GIe^{iSTS}{}_N$ for $N_{CB} = 1$, $N_{CB} = 2$, $N_{CB} = 3$, and $N_{CB} = 4$, respectively.

**Table 28-52—*GIe* definition for 2.16 GHz or 2.16+2.16 GHz ($N_{CB}$ = 1) channel(11ay)**

| Space-time stream number ($i_{STS}$) | Short GI | Normal GI | Long GI |
|---|---|---|---|
| 1 | $GIe^1{}_{32} = -Gc^1{}_{32}$ | $GIe^1{}_{64} = +Ga^1{}_{64}$ | $GIe^1{}_{128} = -Gc^1{}_{128}$ |
| 2 | $GIe^2{}_{32} = -Gc^2{}_{32}$ | $GIe^2{}_{64} = +Ga^2{}_{64}$ | $GIe^2{}_{128} = -Gc^2{}_{128}$ |
| 3 | $GIe^3{}_{32} = -Gc^3{}_{32}$ | $GIe^3{}_{64} = +Ga^3{}_{64}$ | $GIe^3{}_{128} = -Gc^3{}_{128}$ |
| 4 | $GIe^4{}_{32} = -Gc^4{}_{32}$ | $GIe^4{}_{64} = +Ga^4{}_{64}$ | $GIe^4{}_{128} = -Gc^4{}_{128}$ |
| 5 | $GIe^5{}_{32} = -Gc^5{}_{32}$ | $GIe^5{}_{64} = +Ga^5{}_{64}$ | $GIe^5{}_{128} = -Gc^5{}_{128}$ |
| 6 | $GIe^6{}_{32} = -Gc^6{}_{32}$ | $GIe^6{}_{64} = +Ga^6{}_{64}$ | $GIe^6{}_{128} = -Gc^6{}_{128}$ |
| 7 | $GIe^7{}_{32} = -Gc^7{}_{32}$ | $GIe^7{}_{64} = +Ga^7{}_{64}$ | $GIe^7{}_{128} = -Gc^7{}_{128}$ |
| 8 | $GIe^8{}_{32} = -Gc^8{}_{32}$ | $GIe^8{}_{64} = +Ga^8{}_{64}$ | $GIe^8{}_{128} = -Gc^8{}_{128}$ |

**Table 28-53—*GIe* definition for 4.32 GHz or 4.32+4.32 GHz ($N_{CB}$ = 2) channel(11ay)**

| Space-time stream number ($i_{STS}$) | Short GI | Normal GI | Long GI |
|---|---|---|---|
| 1 | $GIe^1{}_{64} = -Gc^1{}_{64}$ | $GIe^1{}_{128} = +Ga^1{}_{128}$ | $GIe^1{}_{256} = +Ga^1{}_{256}$ |
| 2 | $GIe^2{}_{64} = -Gc^2{}_{64}$ | $GIe^2{}_{128} = +Ga^2{}_{128}$ | $GIe^2{}_{256} = +Ga^2{}_{256}$ |
| 3 | $GIe^3{}_{64} = +Gc^3{}_{64}$ | $GIe^3{}_{128} = +Ga^3{}_{128}$ | $GIe^3{}_{256} = +Ga^3{}_{256}$ |
| 4 | $GIe^4{}_{64} = +Gc^4{}_{64}$ | $GIe^4{}_{128} = +Ga^4{}_{128}$ | $GIe^4{}_{256} = +Ga^4{}_{256}$ |
| 5 | $GIe^5{}_{64} = +Gc^5{}_{64}$ | $GIe^5{}_{128} = +Ga^5{}_{128}$ | $GIe^5{}_{256} = +Ga^5{}_{256}$ |
| 6 | $GIe^6{}_{64} = +Gc^6{}_{64}$ | $GIe^6{}_{128} = +Ga^6{}_{128}$ | $GIe^6{}_{256} = +Ga^6{}_{256}$ |
| 7 | $GIe^7{}_{64} = -Gc^7{}_{64}$ | $GIe^7{}_{128} = +Ga^7{}_{128}$ | $GIe^7{}_{256} = +Ga^7{}_{256}$ |

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**Table 28-53—*GIe* definition for 4.32 GHz or 4.32+4.32 GHz ($N_{CB}$ = 2) channel(11ay)**

| Space-time stream number ($i_{STS}$) | Short GI | Normal GI | Long GI |
|---|---|---|---|
| 8 | $GIe^8_{64} = -Gc^8_{64}$ | $GIe^8_{128} = +Ga^8_{128}$ | $GIe^8_{256} = +Ga^8_{256}$ |

**Table 28-54—*GIe* definition for 6.48 GHz ($N_{CB}$ = 3) channel(11ay)**

| Space-time stream number ($i_{STS}$) | Short GI | Normal GI | Long GI |
|---|---|---|---|
| 1 | $GIe^1 96 = +Ga^1_{96}$ | $GIe^1_{192} = +Ga^1_{192}$ | $GIe^1_{384} = +Ga^1_{384}$ |
| 2 | $GIe^2_{96} = +Ga^2_{96}$ | $GIe^2_{192} = +Ga^2_{192}$ | $GIe^2_{384} = +Ga^2_{384}$ |
| 3 | $GIe^3_{96} = +Ga^3_{96}$ | $GIe^3_{192} = +Ga^3_{192}$ | $GIe^3_{384} = +Ga^3_{384}$ |
| 4 | $GIe^4_{96} = +Ga^4_{96}$ | $GIe^4_{192} = +Ga^4_{192}$ | $GIe^4_{384} = +Ga^4_{384}$ |
| 5 | $GIe^5_{96} = +Ga^5_{96}$ | $GIe^5_{192} = +Ga^5_{192}$ | $GIe^5_{384} = +Ga^5_{384}$ |
| 6 | $GIe^6_{96} = +Ga^6_{96}$ | $GIe^6_{192} = +Ga^6_{192}$ | $GIe^6_{384} = +Ga^6_{384}$ |
| 7 | $GIe^7_{96} = +Ga^7_{96}$ | $GIe^7_{192} = +Ga^7_{192}$ | $GIe^7_{384} = +Ga^7_{384}$ |
| 8 | $GIe^8_{96} = +Ga^8_{96}$ | $GIe^8_{192} = +Ga^8_{192}$ | $GIe^8_{384} = +Ga^8_{384}$ |

**Table 28-55—*GIe* definition for 8.64 GHz ($N_{CB}$ = 4) channel(11ay)**

| Space-time stream number ($i_{STS}$) | Short GI | Normal GI | Long GI |
|---|---|---|---|
| 1 | $GIe^1_{128} = +Ga^1_{128}$ | $GIe^1_{256} = +Ga^1_{256}$ | $GIe^1_{512} = +Ga^1_{512}$ |
| 2 | $GIe^2_{128} = +Ga^2_{128}$ | $GIe^2_{256} = +Ga^2_{256}$ | $GIe^2_{512} = +Ga^2_{512}$ |
| 3 | $GIe^3_{128} = -Ga^3_{128}$ | $GIe^3_{256} = +Ga^3_{256}$ | $GIe^3_{512} = +Ga^3_{512}$ |
| 4 | $GIe^4_{128} = -Ga^4_{128}$ | $GIe^4_{256} = +Ga^4_{256}$ | $GIe^4_{512} = +Ga^4_{512}$ |
| 5 | $GIe^5_{128} = -Ga^5_{128}$ | $GIe^5_{256} = +Ga^5_{256}$ | $GIe^5_{512} = +Ga^5_{512}$ |
| 6 | $GIe^6_{128} = -Ga^6_{128}$ | $GIe^6_{256} = +Ga^6_{256}$ | $GIe^6_{512} = +Ga^6_{512}$ |
| 7 | $GIe^7_{128} = -Ga^7_{128}$ | $GIe^7_{256} = +Ga^7_{256}$ | $GIe^7_{512} = +Ga^7_{512}$ |
| 8 | $GIe^8_{128} = -Ga^8_{128}$ | $GIe^8_{256} = +Ga^8_{256}$ | $GIe^8_{512} = +Ga^8_{512}$ |

### 28.5.9.2 Symbol blocking and guard insertion

#### 28.5.9.2.1 General

This subclause defines the symbol blocking and guard interval structure for each type of EDMG SC mode PPDU. The GIs used to define symbol blocking structure for the pre-EDMG modulated fields, EDMG-Header-B and Data field are defined in 28.5.9.1 (Guard interval definition).


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The SU PPDU symbol blocking and guard interval structure shall be as defined in 28.5.9.2.2 (SU PPDU transmission). The SU A-PPDU symbol blocking and guard interval structure shall be as defined in 28.5.9.2.3 (SU A-PPDU transmission).

The MU PPDU symbol blocking and guard interval structure shall be as defined in 28.5.9.2.4 (MU PPDU transmission).

### 28.5.9.2.2 SU PPDU transmission

#### 28.5.9.2.2.1 General

This subclause defines an SU PPDU transmission over a 2.16 GHz, 4.32 GHz, 6.48 GHz, 8.64 GHz, 2.16+2.16 GHz, or 4.32+4.32 GHz channel with one or more space-time streams.

The SU PPDU structure for a 2.16 GHz PPDU transmission and a single space-time stream transmission ($N_{STS}$ = 1) is defined in 28.5.9.2.2.2 (SU PPDU transmission over a 2.16 GHz or a 2.16+2.16 GHz channel with NSTS = 1). The SU PPDU structure for a 2.16 GHz or a 2.16+2.16 GHz PPDU transmission with more than one space-time streams ($N_{STS}$ > 1) and 4.32 GHz, 6.48 GHz, 8.64 GHz, or 4.32+4.32 GHz PPDU transmissions with one or more space-time streams ($N_{STS}$ ≥ 1) is defined in 28.5.9.2.2.3 (SU PPDU transmission over a 2.16 GHz or 2.16+2.16 GHz channel with NSTS > 1 and over a 4.32 GHz, 6.48 GHz, 8.64 GHz, or 4.32+4.32 GHz channel with NSTS ≥ 1).

#### 28.5.9.2.2.2 SU PPDU transmission over a 2.16 GHz or a 2.16+2.16 GHz channel with $N_{STS}$ = 1

An SU PPDU transmitted over a 2.16 GHz or a 2.16+2.16 GHz channel with a single space-time stream ($N_{STS}$ = 1) shall be defined at the DMG SC chip rate $F_c$. The PPDU of this type does not include the EDMG-STF and EDMG-CEF fields and the symbol blocking structure defined for the Data field continues the symbol blocking structure of the pre-EDMG modulated fields.

The EDMG SC mode SU PPDU symbol blocking structure for the short, normal and long GI shall be as shown in Figure 28-17 (SU PPDU structure: 2.16 GHz or 2.16+2.16 GHz channel, NSTS = 1, short GI(11ay)), Figure 28-18 (SU PPDU structure: 2.16 GHz or 2.16+2.16 GHz channel, NSTS = 1, normal GI(11ay)), and Figure 28-19 (SU PPDU structure: 2.16 GHz or 2.16+2.16 GHz channel, NSTS = 1, long GI(11ay)), respectively. An EDMG STA shall support the SU PPDU structure with normal GI as shown in Figure 28-18 (SU PPDU structure: 2.16 GHz or 2.16+2.16 GHz channel, NSTS = 1, normal GI(11ay)).

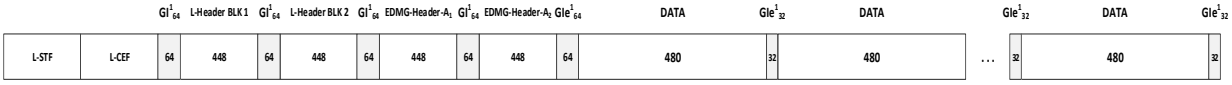


**Figure 28-17—SU PPDU structure: 2.16 GHz or 2.16+2.16 GHz channel, $N_{STS}$ = 1, short GI(11ay)**

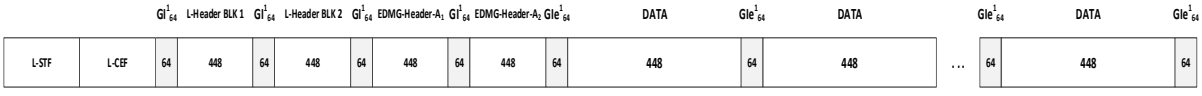


**Figure 28-18—SU PPDU structure: 2.16 GHz or 2.16+2.16 GHz channel, $N_{STS}$ = 1, normal GI(11ay)**

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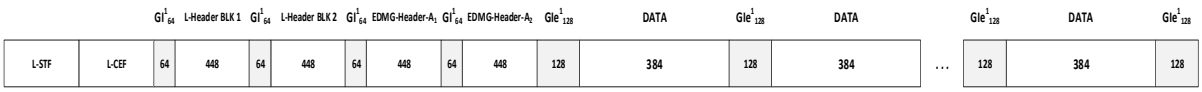


**Figure 28-19—SU PPDU structure: 2.16 GHz or 2.16+2.16 GHz channel, $N_{STS}$ = 1, long GI(11ay)**

The single space-time stream of an SU PPDU may be mapped to $N_{TX} \geq 1$ transmit chains applying direct, indirect spatial mapping or digital beamforming as defined in 28.5.10.4.2 (EDMG PPDU transmission over a 2.16 GHz or 2.16+2.16 GHz channel with NSTS = 1). The single space-time stream may be mapped to $N_{TX} \geq 1$ transmit chains applying spatial expansion as defined in 28.5.10.4.4 (EDMG PPDU transmission over a 2.16 GHz or 2.16+2.16 GHz channel with NSTS > 1 and 4.32 GHz, 6.48 GHz, 8.64 GHz or 4.32+4.32 GHz channel with NSTS ≥ 1).

A TRN field per transmit chain (see 28.9.2.2.6 (TRN subfield definition for EDMG SC PPDUs and EDMG control mode PPDUs)) may be appended to an SU PPDU.

(11az)A Secure TRN field (see 28.9.3.5 (TRN field definition with Secure TRN subfields(11az))) shall be appended to an SU PPDU for EDMG secure ranging PPDU.

### 28.5.9.2.2.3 SU PPDU transmission over a 2.16 GHz or 2.16+2.16 GHz channel with $N_{STS}$ > 1 and over a 4.32 GHz, 6.48 GHz, 8.64 GHz, or 4.32+4.32 GHz channel with $N_{STS}$ ≥ 1

An SU PPDU transmitted over a 2.16 GHz or 2.16+2.16 GHz channel with more than one space-time stream ($N_{STS} > 1$) and an SU PPDU transmission over a 4.32 GHz, 6.48 GHz, 8.64 GHz, or 4.32+4.32 GHz channel with one or more space-time streams ($N_{STS} \geq 1$) shall have a sampling rate of $N_{CB} \times F_c$.

A PPDU of this type includes the EDMG-STF and EDMG-CEF fields separating the symbol blocking structure of the Data field and pre-EDMG modulated fields.

The symbol blocking structure for pre-EDMG modulated fields transmitted over a 2.16 GHz or 2.16+2.16 GHz channel shall be defined at the DMG SC chip rate $F_c$ as shown in Figure 28-20 (SU PPDU structure: pre-EDMG modulated fields symbol blocking, 2.16 GHz or 2.16+2.16 GHz channel(11ay)).

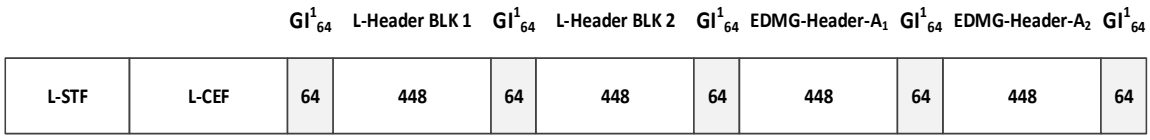


**Figure 28-20—SU PPDU structure: pre-EDMG modulated fields symbol blocking, 2.16 GHz or 2.16+2.16 GHz channel(11ay)**

To transmit pre-EDMG modulated fields over a 4.32 GHz, 6.48 GHz, 8.64 GHz, or 4.32+4.32 GHz channel, the duplicate format defined in 28.5.10.4.4 (EDMG PPDU transmission over a 2.16 GHz or 2.16+2.16 GHz channel with NSTS > 1 and 4.32 GHz, 6.48 GHz, 8.64 GHz or 4.32+4.32 GHz channel with NSTS ≥ 1) shall be used.

To transmit pre-EDMG modulated fields using $N_{TX} > 1$ transmit chains, the format using cyclic shift diversity (CSD) defined in 28.5.10.4.4 (EDMG PPDU transmission over a 2.16 GHz or 2.16+2.16 GHz channel with NSTS > 1 and 4.32 GHz, 6.48 GHz, 8.64 GHz or 4.32+4.32 GHz channel with NSTS ≥ 1) shall be used.


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The symbol blocking structure for the Data field of an SU PPDU for the short, normal and long GI shall be as shown in Figure 28-21 (SU PPDU structure: Data field symbol blocking, (2.16 GHz or 2.16+2.16 GHz, NSTS > 1) or (4.32 GHz, 6.48 GHz, 8.64 GHz or 4.32+4.32 GHz, NSTS ≥ 1), short GI(11ay)), Figure 28-22 (SU PPDU structure: Data field symbol blocking, (2.16 GHz or 2.16+2.16 GHz, NSTS > 1) or (4.32 GHz, 6.48 GHz, 8.64 GHz or 4.32+4.32 GHz, NSTS ≥ 1), normal GI(11ay)), and Figure 28-23 (SU PPDU structure: Data field symbol blocking, (2.16 GHz or 2.16+2.16 GHz, NSTS > 1) or (4.32 GHz, 6.48 GHz, 8.64 GHz or 4.32+4.32 GHz, NSTS ≥ 1), long GI(11ay)), respectively.

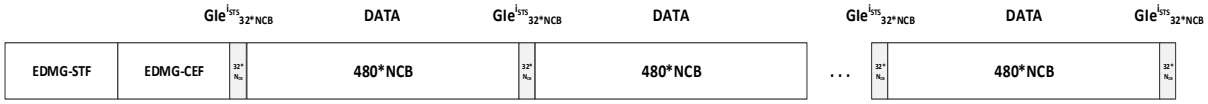


**Figure 28-21—SU PPDU structure: Data field symbol blocking, (2.16 GHz or 2.16+2.16 GHz, $N_{STS}$ > 1) or (4.32 GHz, 6.48 GHz, 8.64 GHz or 4.32+4.32 GHz, $N_{STS}$ ≥ 1), short GI(11ay)**

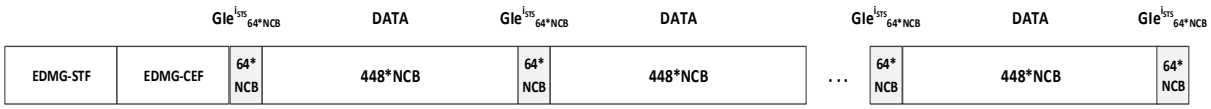


**Figure 28-22—SU PPDU structure: Data field symbol blocking, (2.16 GHz or 2.16+2.16 GHz, $N_{STS}$ > 1) or (4.32 GHz, 6.48 GHz, 8.64 GHz or 4.32+4.32 GHz, $N_{STS}$ ≥ 1), normal GI(11ay)**

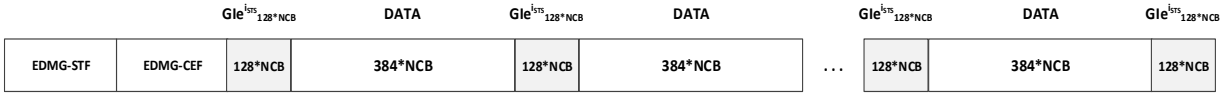


**Figure 28-23—SU PPDU structure: Data field symbol blocking, (2.16 GHz or 2.16+2.16 GHz, $N_{STS}$ > 1) or (4.32 GHz, 6.48 GHz, 8.64 GHz or 4.32+4.32 GHz, $N_{STS}$ ≥ 1), long GI(11ay)**

The $N_{STS}$ space-time streams of an SU PPDU may be mapped to $N_{TX}$ ($N_{STS} \leq N_{TX}$) transmit chains applying direct, indirect spatial mapping or digital beamforming as defined in 28.5.10.4.2 (EDMG PPDU transmission over a 2.16 GHz or 2.16+2.16 GHz channel with NSTS = 1). The single space-time stream may be mapped to $N_{TX} \geq 1$ transmit chains applying spatial expansion as defined in 28.5.10.4.4 (EDMG PPDU transmission over a 2.16 GHz or 2.16+2.16 GHz channel with NSTS > 1 and 4.32 GHz, 6.48 GHz, 8.64 GHz or 4.32+4.32 GHz channel with NSTS ≥ 1).

A TRN field per transmit chain (see 28.9.2.2.6 (TRN subfield definition for EDMG SC PPDUs and EDMG control mode PPDUs)) may be appended to an SU PPDU.

### 28.5.9.2.3 SU A-PPDU transmission

The SU PPDU structures for EDMG A-PPDU transmission described in this subclause cover all the combination of channel bandwidth and number of spatial streams.

The SU PPDU structures for the first EDMG PPDU (i.e., $i_{PPDU} = 1$) within the EDMG A-PPDU are as shown in Figure 28-17 (SU PPDU structure: 2.16 GHz or 2.16+2.16 GHz channel, NSTS = 1, short GI(11ay)) through Figure 28-23 (SU PPDU structure: Data field symbol blocking, (2.16 GHz or 2.16+2.16 GHz, NSTS > 1) or (4.32 GHz, 6.48 GHz, 8.64 GHz or 4.32+4.32 GHz, NSTS ≥ 1), long GI(11ay)). The SU PPDU structure for the EDMG PPDUs following the first EDMG PPDU (i.e., $2 \leq i_{PPDU} \leq N_{PPDU}$) when using the short GI, normal GI and long GI shall be as shown in Figure 28-24 (SU PPDU structure: EDMG A-PPDU, 2 ≤ iPPDU ≤ NPPDU, short GI(11ay)), Figure 28-25 (SU PPDU structure: EDMG A-PPDU, 2 ≤

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iPPDU ≤ NPPDU, normal GI(11ay)), and Figure 28-26 (SU PPDU structure: EDMG A-PPDU, 2 ≤ iPPDU ≤ NPPDU, long GI(11ay)), respectively. The final block transmitted of each EDMG PPDU within the EDMG A-PPDU is followed by the same GI as the Data field regardless of the value of the Additional EDMG PPDU field within the EDMG-Header-A.

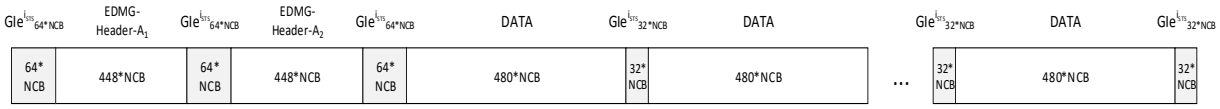


**Figure 28-24—SU PPDU structure: EDMG A-PPDU, 2 ≤ $i_{PPDU}$ ≤ $N_{PPDU}$, short GI(11ay)**

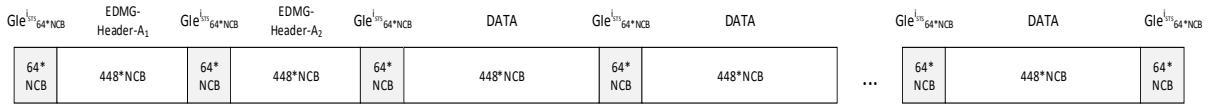


**Figure 28-25—SU PPDU structure: EDMG A-PPDU, 2 ≤ $i_{PPDU}$ ≤ $N_{PPDU}$, normal GI(11ay)**

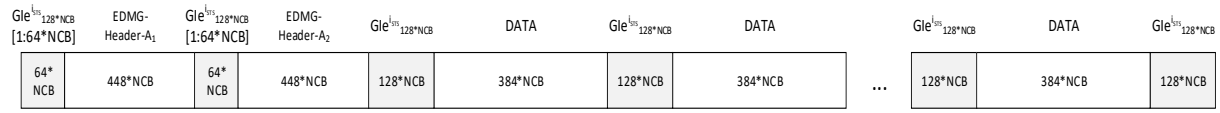


**Figure 28-26—SU PPDU structure: EDMG A-PPDU, 2 ≤ $i_{PPDU}$ ≤ $N_{PPDU}$, long GI(11ay)**

### 28.5.9.2.4 MU PPDU transmission

#### 28.5.9.2.4.1 General

This subclause defines an MU PPDU transmission over a 2.16 GHz, 4.32 GHz, 6.48 GHz, 8.64 GHz, 2.16+2.16 GHz, or 4.32+4.32 GHz channel with more than one space-time stream ($N_{STS} > 1$) transmitted to two or more users ($N_{user} > 1$).

An MU PPDU transmission shall be as defined in 28.5.9.2.4.2 (MU PPDU transmission).

#### 28.5.9.2.4.2 MU PPDU transmission

As opposed to an SU PPDU, an MU PPDU includes the EDMG-Header-B. Similar to an SU PPDU transmission, the EDMG-Header-B and data symbol blocking structure is separated from the pre-EDMG modulated fields' symbol blocking structure by the EDMG-STF and EDMG-CEF fields.

The symbol blocking structure for pre-EDMG modulated fields transmitted over a 2.16 GHz or 2.16+2.16 GHz channel shall be defined at the DMG SC chip rate $F_c$ as shown in Figure 28-20 (SU PPDU structure: pre-EDMG modulated fields symbol blocking, 2.16 GHz or 2.16+2.16 GHz channel(11ay)).

To transmit pre-EDMG modulated fields over a 4.32 GHz, 6.48 GHz, 8.64 GHz, or 4.32+4.32 GHz channel, the duplicate format defined in 28.5.10.4.4 (EDMG PPDU transmission over a 2.16 GHz or 2.16+2.16 GHz channel with NSTS > 1 and 4.32 GHz, 6.48 GHz, 8.64 GHz or 4.32+4.32 GHz channel with NSTS ≥ 1) shall be used.


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To transmit pre-EDMG modulated fields using $N_{TX} > 1$ transmit chains, the format using cyclic shift diversity (CSD) defined in 28.5.10.4.4 (EDMG PPDU transmission over a 2.16 GHz or 2.16+2.16 GHz channel with NSTS > 1 and 4.32 GHz, 6.48 GHz, 8.64 GHz or 4.32+4.32 GHz channel with NSTS ≥ 1) shall be used.

The symbol blocking structure for the EDMG-Header-B and Data field of an MU PPDU for the short, normal and long GI shall be as shown in Figure 28-27 (MU PPDU structure: EDMG-Header-B and Data field symbol blocking, (2.16 GHz, 4.32 GHz, 6.48 GHz, 8.64 GHz, 2.16+2.16 GHz or 4.32+4.32 GHz, NSTS > 1), short GI(11ay)), Figure 28-28 (MU PPDU structure: EDMG-Header-B and Data field symbol blocking, (2.16 GHz, 4.32 GHz, 6.48 GHz, 8.64 GHz, 2.16+2.16 GHz or 4.32+4.32 GHz, NSTS > 1), normal GI(11ay)), and Figure 28-29 (MU PPDU structure: EDMG-Header-B and Data field symbol blocking, (2.16 GHz, 4.32 GHz, 6.48 GHz, 8.64 GHz, 2.16+2.16 GHz or 4.32+4.32 GHz, NSTS > 1), long GI(11ay)), respectively.

**Figure 28-27—MU PPDU structure: EDMG-Header-B and Data field symbol blocking, (2.16 GHz, 4.32 GHz, 6.48 GHz, 8.64 GHz, 2.16+2.16 GHz or 4.32+4.32 GHz, $N_{STS}$ > 1), short GI(11ay)**

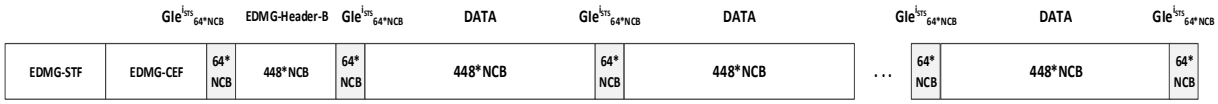


**Figure 28-28—MU PPDU structure: EDMG-Header-B and Data field symbol blocking, (2.16 GHz, 4.32 GHz, 6.48 GHz, 8.64 GHz, 2.16+2.16 GHz or 4.32+4.32 GHz, $N_{STS}$ > 1), normal GI(11ay)**

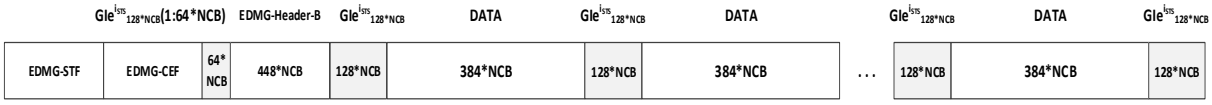


**Figure 28-29—MU PPDU structure: EDMG-Header-B and Data field symbol blocking, (2.16 GHz, 4.32 GHz, 6.48 GHz, 8.64 GHz, 2.16+2.16 GHz or 4.32+4.32 GHz, $N_{STS}$ > 1), long GI(11ay)**

The $N_{STS}$ space-time streams of an MU PPDU may be mapped to $N_{TX}$ ($N_{STS} \leq N_{TX}$) transmit chains applying direct, indirect spatial mapping or digital beamforming as defined in 28.5.10.4.2 (EDMG PPDU transmission over a 2.16 GHz or 2.16+2.16 GHz channel with NSTS = 1).

A TRN field per transmit chain (see 28.9.2.2.6 (TRN subfield definition for EDMG SC PPDUs and EDMG control mode PPDUs)) may be appended to an MU PPDU.

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### 28.5.9.3 Scrambler

#### 28.5.9.3.1 Scrambler for the Data field, L-Header, EDMG-Header-A, and EDMG-Header-B data bits and non-EDMG SC MCS1 coded bits

The Data field, L-Header, EDMG-Header-A, and EDMG-Header-B data bits and non-EDMG SC MCS1 coded bits (see 20.5.3.2.3 (Encoding)) shall be scrambled applying scrambler defined in 20.3.9 (Scrambler).

The scrambling of the Data field of an SU PPDU continues the scrambling of the L-Header and the EDMG-Header-A fields. The initial seed value is defined in the L-Header field.

The scrambling of the Data field of an MU PPDU is performed on a per user basis and continues the scrambling of the EDMG-Header-B field with reset of the seed value. The initial seed value is defined in the EDMG-Header-B field on a per user basis.

For an SU EDMG A-PPDU, the initial seed value is defined in the L-Header field and the scrambling of the $i_{PPDU}{}^{\text{th}}$ PPDU continues the scrambling of $(i_{PPDU}-1)^{\text{th}}$ PPDU with no seed reset.

For non-EDMG SC MCS1 with codeword length equal to 672 bits, the 168 repeated systematic bits shall be scrambled in turn starting from bit 1 and ending with bit 168 (see 20.5.3.2.3 (Encoding)). For each codeword, the transmitter shall reload the seed value to all 1s (bits $x_1$ through $x_7$).

#### 28.5.9.3.2 Scrambler for EDMG-Header-A in SU EDMG A-PPDU, EDMG-Header-B, and EDMG SC MCS1 coded bits

The EDMG Header-A transmitted in an SU EDMG A-PPDU (excluding the first PPDU) coded bits, EDMG-Header-B coded bits, and repeated systematic part of an LDPC codeword using EDMG SC MCS1 encoding shall be scrambled by XORing each bit in turn with a length 127 periodic sequence generated by polynomial $S(x)=x^7+x+1$. The generation of the sequence and the XOR operation are shown in Figure 28-30 (EDMG-Header-A in SU EDMG A-PPDU, EDMG-Header-B, and EDMG SC MCS1 coded bits sequence scrambler(11ay)). Each data or header bit is XORed with the scrambler output $(x_1 \oplus x_7)$ and the scrambler content is shifted once. The 127-bit sequence generated repeatedly by the scrambler shall be (leftmost used first), 01010100 11001110 11101001 01100011 01111011 01011011 00100100 01110000 10111110 01010111 00110100 01001111 00010100 00110000 01000000 1111111, when the all 1s (bits $x_1$ through $x_7$) initial state is used.

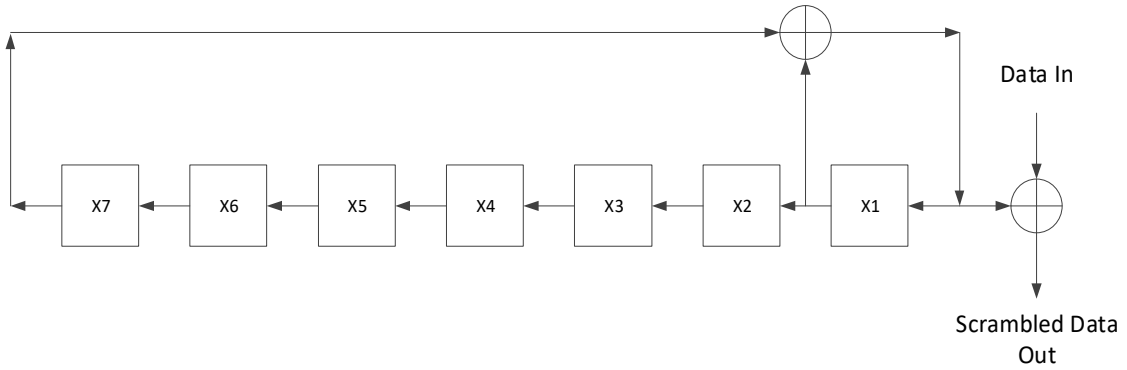


**Figure 28-30—EDMG-Header-A in SU EDMG A-PPDU, EDMG-Header-B, and EDMG SC MCS1 coded bits sequence scrambler(11ay)**

For an EDMG-Header-A of an SU EDMG A-PPDU (excluding the first PPDU) using the EDMG SC mode, the scrambling of the coded bits starts at the 225th bit and ends at the $(N_{STS} \times 896 \times N_{CB})^{\text{th}}$ bit (see 28.5.7


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(Encoding of EDMG-Header-A for EDMG A-PPDU transmission)). The initial seed value is equal to all 1s (bits $x_1$ through $x_7$).

For an EDMG-Header-A of an SU EDMG A-PPDU (excluding the first PPDU) using the EDMG OFDM mode, the scrambling of the coded bits starts at the 225th bit and ends at the $(N_{STS} \times 4 \times N_{SD})^{th}$ bit (see 28.6.7 (Encoding of EDMG-Header-A for EDMG A-PPDU transmission)). The initial seed value is equal to all 1s (bits $x_1$ through $x_7$).

In an MU PPDU transmission using the EDMG SC mode, the scrambling of the EDMG-Header-B coded bits starts at the 225th bit and ends at the $(N_{STS} \times 448 \times N_{CB})^{th}$ bit (see 28.5.6 (Encoding of EDMG-Header-B)). The initial seed value is equal to all 1s (bits $x_1$ through $x_7$).

In an MU PPDU transmission using the EDMG OFDM mode, the scrambling of the EDMG-Header-B coded bits starts at the 225th bit and ends at the $(N_{STS} \times 2 \times N_{SD})^{th}$ bit (see 28.6.6 (Encoding of EDMG-Header-B)). The initial seed value is equal to all 1s (bits $x_1$ through $x_7$).

For EDMG SC MCS1 with codeword length equal to 672 bits, the 168 repeated systematic bits shall be scrambled in turn starting from bit 1 and ending with bit 168. For EDMG SC MCS1 scrambling and codeword length equal to 1344 bits, the 336 repeated systematic bits shall be scrambled in turn starting from bit 1 and ending with bit 336. For each codeword, the transmitter shall reload the seed value to all 1s (bits $x_1$ through $x_7$).

#### 28.5.9.4 Encoding

##### 28.5.9.4.1 General

An EDMG SC mode PSDU is encoded by a systematic LDPC block code. Each data word of $L_{CWD}$ information bits is concatenated with $L_{CWP}$ parity bits to create a codeword of total length $L_{CW} = L_{CWD} + L_{CWP}$ bits. The EDMG LDPC encoding can employ the codeword lengths $L_{CW}$ = 468, 504, 624, 672, 936, 1008, 1248, and 1344 and code rates $R$ = 1/2, 5/8, 2/3, 3/4, 13/16, 5/6, and 7/8. The set of code rates is defined in Table 28-56 (LDPC code rates(11ay)).

**Table 28-56—LDPC code rates(11ay)**

| Code rate | Codeword size ($L_{CW}$) | | Number of data bits ($L_{CWD}$) | |
|---|---|---|---|---|
| | Short | Long | Short | Long |
| 1/2 | 672 | 1344 | 336 | 672 |
| 5/8 | 672 | 1344 | 420 | 840 |
| 2/3 | 504 | 1008 | 336 | 672 |
| 3/4 | 672 | 1344 | 504 | 1008 |
| 13/16 | 672 | 1344 | 546 | 1092 |
| 5/6 | 468 or 504 | 936 or 1008 | 390 or 420 | 780 or 840 |
| 7/8 | 624 or 672 | 1248 or 1344 | 546 or 588 | 1092 or 1176 |

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The LDPC encoding with codeword length $L_{CW}$ = 672 and 1344 is performed by solving the linear system of equations $\mathbf{H}\cdot\left(\mathbf{c}^{(m)}\right)^{T}=\mathbf{0}$ defined by the parity matrix H of size $L_{CWP}$ by $L_{CW}$, where $\mathbf{c}^{(m)}=\left(\mathbf{b}^{(m)},\mathbf{p}^{(m)}\right)$ defines the $m^{\text{th}}$ LDPC codeword, $\mathbf{b}^{(m)}=\left(b_1^{(m)},b_2^{(m)},...,b_{L_{CWD}}^{(m)}\right)$ defines the $m^{\text{th}}$ data word, and $\mathbf{p}^{(m)}=\left(p_1^{(m)},p_2^{(m)},...,p_{L_{CWP}}^{(m)}\right)$ defines parity bits for $m^{\text{th}}$ LDPC codeword.

The LDPC encoding with codeword length $L_{CW}$ = 624 and 1248 employs the matrices H with $L_{CW}$ = 672 and 1344 for code rate $R$ = 13/16, and then applies a puncturing procedure to get to a desired code rate $R$ = 7/8. For $L_{CW}$ = 624, first 48 parity bits are discarded; for $L_{CW}$ = 1248, first 96 parity bits are discarded.

The LDPC encoding for code rate 2/3 with codeword length $L_{CW}$ = 504 and 1008 employs the matrices H with $L_{CW}$ = 672 and 1344 for code rate $R$ = 3/4, and then applies a shortening procedure to get to a desired code rate $R$ = 2/3. For $L_{CW}$ = 504, 168, 0s are appended to 336 data bits before encoding; for $L_{CW}$ = 1008, 336, 0s are appended to 672 data bits before encoding. After encoding the zero bits are discarded and not transmitted.

The LDPC encoding for code rate 5/6 with codeword length $L_{CW}$ = 504 and 1008 employs the matrices H with $L_{CW}$ = 672 and 1344 for code rate $R$ = 7/8. For $L_{CW}$ = 504, 168, 0s are appended to 420 data bits before encoding; for $L_{CW}$ = 1008, 336, 0s are appended to 840 data bits before encoding. After encoding, the zero bits are discarded and not transmitted.

The LDPC encoding for code rate 5/6 with codeword length $L_{CW}$ = 468 and 936 employs the matrices H with $L_{CW}$ = 672 and 1344 for code rate $R$ = 13/16. For $L_{CW}$ = 468, 156, 0s are appended to 390 data bits before encoding; for $L_{CW}$ = 936, 312, 0s are appended to 780 data bits before encoding. After encoding, the zero bits are discarded; for $L_{CW}$ = 468, the first 48 parity bits are discarded (punctured); for $L_{CW}$ = 936, the first 96 parity bits are discarded and not transmitted.

Table 28-57 (Values of NCBPB for different types of GI(11ay)) defines the number of coded bits per SC symbol block, $N_{CBPB}$, for different types of GI.

**Table 28-57—Values of $N_{CBPB}$ for different types of GI(11ay)**

| Symbol mapping | Short GI | Normal GI | Long GI |
|---|---|---|---|
| π/2-BPSK | 480 | 448 | 384 |
| π/2-QPSK | 960 | 896 | 768 |
| π/2-8-PSK | 1440 | 1344 | 1152 |
| π/2-16-QAM | 1920 | 1792 | 1536 |
| π/2-64-QAM/π/2-64-NUC | 2880 | 2688 | 2304 |

Table 28-47 (EDMG SC mode timing-related parameters(11ay)) defines the number of symbols (constellation points) per SC symbol block, $N_{SPB}$, for different types of GI.

### 28.5.9.4.2 Parity check matrices

See 28.3.6 (LDPC parity matrices).


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#### 28.5.9.4.3 LDPC encoding

This subclause defines the PSDU encoding process for an SU PPDU and the PSDU per user basis encoding for an MU PPDU. The LDPC encoding may employ codeword lengths $L_{CW}$ = 468, 504, 624, 672, 936, 1008, 1248, or 1344 and code rates $R$ = 1/2, 5/8, 2/3, 3/4, 13/16, 5/6 or 7/8.

The LDPC encoding process for the $i_{user}^{\text{th}}$ user shall be as follows:

a) Compute the number of data pad bits, $N_{DATA\_PAD\,i_{user}}$, using the number of LDPC codewords, $N_{CW\,i_{user}}$, as follows:

$$N_{CW\,i_{user}} = \left\lceil \frac{Length_{i_{user}} \cdot 8}{L_{CW\,i_{user}} \cdot \frac{R_{i_{user}}}{\rho_{i_{user}}}} \right\rceil$$

$$N_{DATA\_PAD\,i_{user}} = N_{CW\,i_{user}} \cdot L_{CW\,i_{user}} \cdot \left( \frac{R_{i_{user}}}{\rho_{i_{user}}} \right) - Length_{i_{user}} \cdot 8$$

The scrambled PSDU is concatenated with $N_{DATA\_PAD\,i_{user}}$ zero bits. They are scrambled using the continuation of the scrambler sequence that scrambled the PSDU input bits.

b) Convert the scrambled PSDU bits to LDPC codewords as follows:

1) If $\rho$ = 1 and $L_{CW}$ = 672 or 1344, $R$ = 1/2, 5/8, 3/4, 13/16, or 7/8:

i) The output stream of scrambler is broken into the blocks of length $L_{CWD} = L_{CW} \times R$ bits such that the $m^{\text{th}}$ data word is $\mathbf{b}^{(m)} = \left( b_1^{(m)}, b_2^{(m)}, ..., b_{L_{CWD}}^{(m)} \right), m \le N_{CW\,i_{user}}$.

ii) To each data word, parity bits $\mathbf{p}^{(m)} = \left( p_1^{(m)}, p_2^{(m)}, ..., p_{L_{CWP}}^{(m)} \right), L_{CWP} = L_{CW} - L_{CWD}$, are added to create the codeword $\mathbf{c}^{(m)} = \left( \mathbf{b}^{(m)}, \mathbf{p}^{(m)} \right), m \le N_{CW\,i_{user}}$ such that $\mathbf{H} \cdot \left( \mathbf{c}^{(m)} \right)^T = \mathbf{0}$.

2) If $\rho$ = 1 and $L_{CW}$ = 624, $R$ = 7/8:

i) The output stream of scrambler is broken into the blocks of length 546 bits such that the $m^{\text{th}}$ data word is $\mathbf{b}^{(m)} = \left( b_1^{(m)}, b_2^{(m)}, ..., b_{546}^{(m)} \right), m \le N_{CW\,i_{user}}$.

ii) To each data word, parity bits $\mathbf{p}^{(m)} = \left( p_1^{(m)}, p_2^{(m)}, ..., p_{126}^{(m)} \right)$ are added to create the codeword $\mathbf{c}^{(m)} = \left( \mathbf{b}^{(m)}, \mathbf{p}^{(m)} \right), m \le N_{CW\,i_{user}}$ such that $\mathbf{H} \cdot \left( \mathbf{c}^{(m)} \right)^T = \mathbf{0}$, parity bits are computed applying $L_{CW}$ = 672, $R$ = 13/16 LDPC matrix.

iii) Finally, the first 48 parity bits are discarded (punctured) to create the output codeword $\mathbf{c}^{(m)} = \left( b_1^{(m)}, b_2^{(m)}, ...., b_{546}^{(m)}, p_{49}^{(m)}, p_{50}^{(m)}, ..., p_{126}^{(m)} \right), m \le N_{CW\,i_{user}}$ (#515).

3) If $\rho$ = 1 and $L_{CW}$ = 1248, $R$ = 7/8:

i) The output stream of scrambler is broken into the blocks of length 1092 bits such that the $m^{\text{th}}$ data word is $\mathbf{b}^{(m)} = \left( b_1^{(m)}, b_2^{(m)}, ..., b_{1092}^{(m)} \right), m \le N_{CW\,i_{user}}$.

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ii) To each data word, parity bits $\mathbf{p}^{(m)} = \left(p_1^{(m)}, p_2^{(m)}, ..., p_{252}^{(m)}\right)$ are added to create the codeword $\mathbf{c}^{(m)} = \left(\mathbf{b}^{(m)}, \mathbf{p}^{(m)}\right), m \le N_{CW\,i_{user}}$ such that $\mathbf{H} \cdot \left(\mathbf{c}^{(m)}\right)^T = \mathbf{0}$, parity bits are computed applying $L_{CW} = 1344$, $R = 13/16$ LDPC matrix.

iii) Finally, the first 96 parity bits are discarded (punctured) to create the output codeword $\mathrm{c}^{(m)} = (b_1^{(m)}, b_2^{(m)}, ..., b_{1092}^{(m)}, p_{97}^{(m)}, p_{98}^{(m)}, ..., p_{252}^{(m)}), m \le N_{CW\,i_{user}}$ (#515).

4) If $\rho = 2$ and $L_{CW} = 672$, $R = 1/2$:

i) The output stream of scrambler is broken into the blocks of length 168 bits such that the $m^{\text{th}}$ data word is $\mathbf{b}^{(m)} = \left(b_1^{(m)}, b_2^{(m)}, ..., b_{168}^{(m)}\right), m \le N_{CW\,i_{user}}$.

ii) To each data word, zero bits $\mathbf{0}^{(m)} = \left(0_1^{(m)}, 0_2^{(m)}, ..., 0_{168}^{(m)}\right)$ and parity bits $\mathbf{p}^{(m)} = \left(p_1^{(m)}, p_2^{(m)}, ..., p_{336}^{(m)}\right)$ are added to create the codeword $\mathbf{c}^{(m)} = \left(\mathbf{b}^{(m)}, \mathbf{0}^{(m)}, \mathbf{p}^{(m)}\right), m \le N_{CW\,i_{user}}$ such that $\mathbf{H} \cdot \left(\mathbf{c}^{(m)}\right)^T = \mathbf{0}$.

iii) Finally, the zero bits are replaced with word $\mathbf{b}^{(m)}$ repetition XORed by PN sequence that is generated from the LFSR used for MCS 1 scrambling as defined in 28.5.9.3.2 (Scrambler for EDMG-Header-A in SU EDMG A-PPDU, EDMG-Header-B, and EDMG SC MCS1 coded bits). The LFSR is initialized to all 1s initial seed value and reinitialized to the same seed after every codeword.

5) If $\rho = 2$ and $L_{CW} = 1344$, $R = 1/2$:

i) The output stream of scrambler is broken into the blocks of length 336 bits such that the $m^{\text{th}}$ data word is $\mathbf{b}^{(m)} = \left(b_1^{(m)}, b_2^{(m)}, ..., b_{336}^{(m)}\right), m \le N_{CW\,i_{user}}$.

ii) To each data word, zero bits $\mathbf{0}^{(m)} = \left(0_1^{(m)}, 0_2^{(m)}, ..., 0_{336}^{(m)}\right)$ and parity bits $\mathbf{p}^{(m)} = \left(p_1^{(m)}, p_2^{(m)}, ..., p_{672}^{(m)}\right)$ are added to create the codeword $\mathbf{c}^{(m)} = \left(\mathbf{b}^{(m)}, \mathbf{0}^{(m)}, \mathbf{p}^{(m)}\right), m \le N_{CW\,i_{user}}$ such that $\mathbf{H} \cdot \left(\mathbf{c}^{(m)}\right)^T = \mathbf{0}$.

iii) Finally, the zero bits are replaced with word $\mathbf{b}^{(m)}$ repetition XORed by PN sequence that is generated from the LFSR used for MCS 1 scrambling as defined in 28.5.9.3.2 (Scrambler for EDMG-Header-A in SU EDMG A-PPDU, EDMG-Header-B, and EDMG SC MCS1 coded bits). The LFSR is initialized to all 1s initial seed value and reinitialized to the same seed after every codeword.

6) If $\rho = 1$ and $L_{CW} = 504$, $R = 2/3$:

i) The output stream of scrambler is broken into the blocks of length 336 bits such that the $m^{\text{th}}$ data word is $\mathbf{b}^{(m)} = \left(b_1^{(m)}, b_2^{(m)}, ..., b_{336}^{(m)}\right), m \le N_{CW\,i_{user}}$.

ii) To each data word, zero bits $\mathbf{0}^{(m)} = \left(0_1^{(m)}, 0_2^{(m)}, ..., 0_{168}^{(m)}\right)$ and parity bits $\mathbf{p}^{(m)} = \left(p_1^{(m)}, p_2^{(m)}, ..., p_{168}^{(m)}\right)$ are added to create the codeword $\mathbf{c}^{(m)} = \left(\mathbf{b}^{(m)}, \mathbf{0}^{(m)}, \mathbf{p}^{(m)}\right), m \le N_{CW\,i_{user}}$ such that $\mathbf{H} \cdot \left(\mathbf{c}^{(m)}\right)^T = \mathbf{0}$, parity bits are computed applying $L_{CW} = 672$, $R = 3/4$ LDPC matrix.



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iii) Finally, the zero bits are discarded to create the output codeword $\mathbf{c}^{(m)} = \left(\mathbf{b}^{(m)}, \mathbf{p}^{(m)}\right), m \le N_{CW\,i_{user}}$.

7) If $\rho = 1$ and $L_{CW} = 1008$, $R = 2/3$:

i) The output stream of scrambler is broken into the blocks of length 672 bits such that the $m^{\text{th}}$ data word is $\mathbf{b}^{(m)} = \left(b_1^{(m)}, b_2^{(m)}, ..., b_{672}^{(m)}\right), m \le N_{CW\,i_{user}}$.

ii) To each data word, zero bits $\mathbf{0}^{(m)} = \left(0_1^{(m)}, 0_2^{(m)}, ..., 0_{336}^{(m)}\right)$ and parity bits $\mathbf{p}^{(m)} = \left(p_1^{(m)}, p_2^{(m)}, ..., p_{336}^{(m)}\right)$ are added to create the codeword $\mathbf{c}^{(m)} = \left(\mathbf{b}^{(m)}, \mathbf{0}^{(m)}, \mathbf{p}^{(m)}\right), m \le N_{CW\,i_{user}}$ such that $\mathbf{H} \cdot \left(\mathbf{c}^{(m)}\right)^T = \mathbf{0}$, parity bits are computed applying $L_{CW} = 1344$, $R = 3/4$ LDPC matrix.

iii) Finally, the zero bits are discarded to create the output codeword $\mathbf{c}^{(m)} = \left(\mathbf{b}^{(m)}, \mathbf{p}^{(m)}\right), m \le N_{CW\,i_{user}}$.

8) If $\rho = 1$ and $L_{CW} = 504$, $R = 5/6$:

i) The output stream of scrambler is broken into the blocks of length 420 bits such that the $m^{\text{th}}$ data word is $\mathbf{b}^{(m)} = \left(b_1^{(m)}, b_2^{(m)}, ..., b_{420}^{(m)}\right), m \le N_{CW\,i_{user}}$.

ii) To each data word, zero bits $\mathbf{0}^{(m)} = \left(0_1^{(m)}, 0_2^{(m)}, ..., 0_{168}^{(m)}\right)$ and parity bits $\mathbf{p}^{(m)} = \left(p_1^{(m)}, p_2^{(m)}, ..., p_{84}^{(m)}\right)$ are added to create the codeword $\mathbf{c}^{(m)} = \left(\mathbf{b}^{(m)}, \mathbf{0}^{(m)}, \mathbf{p}^{(m)}\right), m \le N_{CW\,i_{user}}$ such that $\mathbf{H} \cdot \left(\mathbf{c}^{(m)}\right)^T = \mathbf{0}$, parity bits are computed applying for $L_{CW} = 672$, $R = 7/8$ LDPC matrix.

iii) Finally, the zero bits are discarded to create the output codeword $\mathbf{c}^{(m)} = \left(\mathbf{b}^{(m)}, \mathbf{p}^{(m)}\right), m \le N_{CW\,i_{user}}$.

9) If $\rho = 1$ and $L_{CW} = 1008$, $R = 5/6$:

i) The output stream of scrambler is broken into the blocks of length 840 bits such that the $m^{\text{th}}$ data word is $\mathbf{b}^{(m)} = \left(b_1^{(m)}, b_2^{(m)}, ..., b_{840}^{(m)}\right), m \le N_{CW\,i_{user}}$.

ii) To each data word, zero bits $\mathbf{0}^{(m)} = \left(0_1^{(m)}, 0_2^{(m)}, ..., 0_{336}^{(m)}\right)$ and parity bits $\mathbf{p}^{(m)} = \left(p_1^{(m)}, p_2^{(m)}, ..., p_{168}^{(m)}\right)$ are added to create the codeword $\mathbf{c}^{(m)} = \left(\mathbf{b}^{(m)}, \mathbf{0}^{(m)}, \mathbf{p}^{(m)}\right), m \le N_{CW\,i_{user}}$ such that $\mathbf{H} \cdot \left(\mathbf{c}^{(m)}\right)^T = \mathbf{0}$, parity bits are computed applying $L_{CW} = 1344$, $R = 7/8$ LDPC matrix.

iii) Finally, the zero bits are discarded to create the output codeword $\mathbf{c}^{(m)} = \left(\mathbf{b}^{(m)}, \mathbf{p}^{(m)}\right), m \le N_{CW\,i_{user}}$.

10) If $\rho = 1$ and $L_{CW} = 468$, $R = 5/6$:

i) The output stream of scrambler is broken into the blocks of length 390 bits such that the $m^{\text{th}}$ data word is $\mathbf{b}^{(m)} = \left(b_1^{(m)}, b_2^{(m)}, ..., b_{390}^{(m)}\right), m \le N_{CW\,i_{user}}$.

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ii) To each data word, zero bits $\mathbf{0}^{(m)} = \left(0_1^{(m)}, 0_2^{(m)}, ..., 0_{156}^{(m)}\right)$ and parity bits $\mathbf{p}^{(m)} = \left(p_1^{(m)}, p_2^{(m)}, ..., p_{126}^{(m)}\right)$ are added to create the codeword $\mathbf{c}^{(m)} = \left(\mathbf{b}^{(m)}, \mathbf{0}^{(m)}, \mathbf{p}^{(m)}\right), m \le N_{CW\,i_{user}}$ such that $\mathbf{H} \cdot \left(\mathbf{c}^{(m)}\right)^T = \mathbf{0}$, parity bits are computed applying $L_{CW} = 672$, $R = 13/16$ LDPC matrix.

iii) Finally, the zero bits are discarded and the first 48 parity bits are discarded (punctured) to create the output codeword $\mathrm{c}^{(m)} = (b_1^{(m)}, b_2^{(m)}, ..., b_{390}^{(m)}, p_{49}^{(m)}, p_{50}^{(m)}, ..., p_{126}^{(m)}), m \le N_{CW\,i_{user}}$ (#515).

11) If $\rho = 1$ and $L_{CW} = 936$, $R = 5/6$:

i) The output stream of scrambler is broken into the blocks of length 780 bits such that the $m^{\text{th}}$ data word is $\mathbf{b}^{(m)} = \left(b_1^{(m)}, b_2^{(m)}, ..., b_{780}^{(m)}\right), m \le N_{CW\,i_{user}}$.

ii) To each data word, zero bits $\mathbf{0}^{(m)} = \left(0_1^{(m)}, 0_2^{(m)}, ..., 0_{312}^{(m)}\right)$ and parity bits $\mathbf{p}^{(m)} = \left(p_1^{(m)}, p_2^{(m)}, ..., p_{252}^{(m)}\right)$ are added to create the codeword $\mathbf{c}^{(m)} = \left(\mathbf{b}^{(m)}, \mathbf{0}^{(m)}, \mathbf{p}^{(m)}\right), m \le N_{CW\,i_{user}}$ such that $\mathbf{H} \cdot \left(\mathbf{c}^{(m)}\right)^T = \mathbf{0}$, parity bits are computed applying $L_{CW} = 1344$, $R = 13/16$ LDPC matrix.

iii) Finally, the zero bits are discarded and the first 96 parity bits are discarded (punctured) to create the output codeword $\mathrm{c}^{(m)} = (b_1^{(m)}, b_2^{(m)}, ..., b_{780}^{(m)}, p_{97}^{(m)}, p_{98}^{(m)}, ..., p_{252}^{(m)}), m \le N_{CW\,i_{user}}$ (#515).

c) Concatenate LDPC codewords one after the other to create the coded bits stream $\left(\mathbf{c}^{(1)}, \mathbf{c}^{(2)}, ..., \mathbf{c}^{\left(N_{CW\,i_{user}}\right)}\right)$.

d) Compute the number of coded pad bits, $N_{BLK\_PAD\,i_{user}}$, using the number of SC symbol blocks, $N_{BLKS\,i_{user}}$, as follows:

$$N_{BLKS\,i_{user}} = \left\lceil \frac{N_{CW\,i_{user}} \cdot L_{CW\,i_{user}}}{N_{SPB} \cdot \sum_{i_{SS}=1}^{N_{SS\,i_{user}}} N_{CBPS\,i_{user}\,i_{ss}}} \right\rceil$$

If (BRP PPDU) and $N_{BLKS\,i_{user}} < N_{BLKS\,\min}$, then $N_{BLKS\,i_{user}} = N_{BLKS\,\min}$.

If last PPDU in A-PPDU, then $N_{BLKS\,i_{user}} = N_{BLKSspoof}$.

If STBC applied and $N_{BLKS\,i_{user}}$ is odd, then $N_{BLKS\,i_{user}} = N_{BLKS\,i_{user}} + 1$.

$$N_{BLK\_PAD\,i_{user}} = N_{BLKS\,i_{user}} \cdot N_{SPB} \cdot \sum_{i_{SS}=1}^{N_{SS\,i_{user}}} N_{CBPS\,i_{user}\,i_{SS}} - N_{CW\,i_{user}} \cdot L_{CW\,i_{user}}$$

Concatenate coded bits with $N_{BLK\_PAD\,i_{user}}$ zero bits. They are scrambled using the continuation of the scrambler sequence that scrambled the PSDU bits and data pad bits in step a).

e) Distribute the encoded and padded bits over the $N_{SS\,i_{user}}$ spatial streams on a group basis with the number of $N_{CBPS\,i_{user}\,i_{ss}}$ bits in a group. The first group of bits goes to the first spatial stream, the second group of bits goes to the second spatial stream, and so on. The procedure is repeated when


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the maximum number of spatial streams, $N_{SS\,i_{user}}$, is reached. The procedure ends when all PSDU encoded bits, including $N_{BLK\_PAD\,i_{user}}$ pad bits, are distributed over the $N_{SS\,i_{user}}$ spatial streams.

For each user, if STBC coding is applied, then $N_{SS\,i_{user}}$ spatial streams are mapped to $N_{STS\,i_{user}} = 2N_{SS\,i_{user}}$ space-time streams as defined in 28.5.9.5.4 (Space-time block coding (STBC)). Otherwise, a one-to-one mapping of $N_{SS\,i_{user}}$ spatial streams to $N_{STS\,i_{user}}$ space-time streams shall be applied.

NOTE—For a PPDU carrying a BRP frame, the value of $N_{BLKS\,\min}$ is specified in 28.9.2.2.4 (EDMG BRP PPDU duration).

#### 28.5.9.4.4 MU PPDU padding and space-time streams mapping

For an MU PPDU transmission, all user PPDUs shall be aligned in time. If necessary, PSDUs within the MU PPDU shall be padded according to the following steps:

a) Compute the maximum number of SC symbol blocks over all users $N_{BLKS\,\max} = \max_{i_{user}}\left(N_{BLKS\,i_{user}}\right)$ for $i_{user} = 1, 2, \ldots, N_{user}$.

b) Update the number of SC symbol blocks at step e) in 28.5.9.4.3 (LDPC encoding) as $N_{BLKS\,i_{user}} = N_{BLKS\,\max}$ for $i_{user} = 1, 2, \ldots, N_{user}$. Update the number of pad bits for the $i_{user}^{\text{th}}$ user accordingly.

c) The number of pad SC symbol blocks for the MU PPDU transmission for the $i_{user}^{\text{th}}$ user is defined as $N_{PAD\_BLKS\,i_{user}} = N_{BLKS\,\max} - N_{BLKS\,i_{user}}$.

The number of pad blocks $N_{PAD\_BLKS\,i_{user}}$ takes into account the MU PPDU padding only and does not include the regular padding described in 28.5.9.4.3 (LDPC encoding).

The space-time stream index per user, $i_{STS\,i_{user}}$, is mapped to the space-time stream index over all users, $i_{STS}$, as follows:

$$i_{STS}\left(i_{user}, i_{STS\,i_{user}}\right) = \sum_{m=0}^{i_{user}-1} Num_m + i_{STS\,i_{user}},\ 1 \le i_{STS\,i_{user}} \le N_{STS\,i_{user}},\ 1 \le i_{user} \le N_{user}$$

$$Num_m = N_{STS\,m} \text{ for } m > 0 \text{ and } Num_m = 0 \text{ otherwise}$$

NOTE—$i_{STS}$ is a function of $i_{user}$ and $i_{STS\,i_{user}}$ indices. However, to simplify the notation, this dependence is not indicated explicitly in other equations.

#### 28.5.9.4.5 SU A-PPDU padding

For the last PPDU in an EDMG A-PPDU, $N_{BLKSspoof}$ shall be set, at step d) in 28.5.9.4.3 (LDPC encoding), so that the spoofing error is non-negative and smaller than one SC symbol block (i.e., $T_{DFT}$, defined in Table 28-47 (EDMG SC mode timing-related parameters(11ay)). If the last PPDU in an EDMG A-PPDU contains a BRP frame, $N_{BLKSspoof}$ shall be equal to or greater than $N_{BLKS\,\min}$. $N_{BLKSspoof}$ is calculated as follows:

$$T_{Data\,\max}^{(N_{PPDU})} = TXTIME_{spoof} - \left(T_{L\text{-}STF} + T_{L\text{-}CEF} + T_{L\text{-}Header} + N_{PPDU} \cdot T_{EDMG\text{-}Header\text{-}A} + T_{EDMG\text{-}STF} + T_{EDMG\text{-}CEF} + \sum_{i_{PPDU}=1}^{N_{PPDU}-1} T_{Data}^{(i_{PPDU})} + T_{TRN}\right)$$

$$N_{BLKSspoof} = \left\lfloor \frac{T_{Data\,\max}^{(N_{PPDU})}}{T_{DFT}} \right\rfloor$$

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where

$i_{STS}$ is the space-time stream number and $1 \le i_{STS} \le 8$

$TXTIME_{spoof}$ is the spoofed PPDU duration calculated based on L-Header

$T_{L\text{-}STF}$, $T_{L\text{-}CEF}$, $T_{L\text{-}Header}$, $T_{EDMG\text{-}STF}$, $T_{EDMG\text{-}CEF}$, $T_{EDMG\text{-}Header\text{-}A}$, and $T_{TRN}$ are the durations of the L-STF, L-CEF, L-Header, EDMG-STF, EDMG-CEF, EDMG-Header-A, and TRN fields as defined in 28.12.3.3 (TXTIME calculation for EDMG SC mode)

$T_{DFT}$ is defined in Table 28-47 (EDMG SC mode timing-related parameters(11ay))

$T_{Data}^{(i_{PPDU})}$, for $i_{PPDU}$=1, …, $N_{PPDU}$ – 1, is the duration of the Data field of the $i_{PPDU}^{\text{th}}$ PPDU, except for the last PPDU, as defined in 28.12.3.3 (TXTIME calculation for EDMG SC mode)

$T_{Data\,\max}^{(N_{PPDU})}$ is the maximum duration of the last PPDU that fulfills the spoofing error requirement

For an EDMG A-PPDU transmission, the spoofed values of the L-Header fields and the duration of the PPDUs except the last PPDU shall be determined so that $N_{BLKSspoof}$ is equal to or greater than $N_{BLKS\,\min}$.

### 28.5.9.5 Modulation mapping

#### 28.5.9.5.1 General

The coded and padded bit stream is converted into a stream of complex constellation points, following the rules defined in 20.5.3.2.4 (Modulation mapping) for π/2-BPSK, π/2-QPSK, π/2-16-QAM, and π/2-64-QAM. The π/2-64-NUC nonuniform constellation (NUC) modulation is defined in 28.5.9.5.6 (π/2-64-NUC nonuniform constellation modulation). For π/2-8-PSK, follow the rules defined in 28.5.9.5.7 (π/2-8-PSK modulation).

#### 28.5.9.5.2 Transmission in EDMG format

The EDMG data transmit waveform for $i_{TX}^{\text{th}}$ transmit chain in time domain shall be defined at the EDMG SC chip rate $F_{c\,EDMG}$ as follows:

$$r_{Data}^{i_{TX}}\left(q\frac{T_c}{N_{CB}}\right)=\frac{1}{\sqrt{N_{STS}}}\sum_{n=0}^{N_{EDMG\text{-}DATA}-1}\sum_{i_{STS}=1}^{N_{STS}}\left[Q_{EDMG}\right]_{i_{TX},i_{STS}}d\left(i_{STS},n\right)\delta\left(\left(n-q\right)\frac{T_c}{N_{CB}}\right)$$

where

$N_{EDMG\text{-}DATA}$ is the total number of chips

$N_{STS}$ is the total number of space-time streams

$Q_{EDMG}$ is a spatial mapping matrix independent of the $n^{\text{th}}$ chip time index that is described in 28.5.10.2 (Spatial mapping)

$[\ ]_{m,n}$ is a matrix element from $m^{\text{th}}$ row and $n^{\text{th}}$ column

$d(i_{STS}, n)$ is the data sequence, it includes data payload symbols as well as the guard interval symbols

$\delta\left(\left(n-q\right)\frac{T_c}{N_{CB}}\right)$ is the delta function, which is equal to 1 if $n = q$, and is equal to 0 otherwise

$q$ is a time sample index


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#### 28.5.9.5.3 Dual carrier modulation (DCM) π/2-BPSK

A frequency domain diversity scheme based on DCM π/2-BPSK may be applied to an EDMG PPDU transmission over 2.16+2.16 GHz or 4.32+4.32 GHz channels. An EDMG STA shall only apply DCM π/2-BPSK to an EDMG PPDU transmitted to a peer EDMG STA if the DCM π/2-BPSK Supported field in the peer STA's EDMG Capabilities element is 1.

The DCM π/2-BPSK modulation is applied to an EDMG PPDU if, in the EDMG-Header-A, the BW field indicates a bandwidth configuration 2.16+2.16 GHz or 4.32+4.32 GHz, the Channel Aggregation field is set to 1, the Number of SS field indicates 2 spatial streams, and the DCM BPSK Applied field is set to 1. The value of the Differential EDMG-MCS1 and Differential EDMG-MCS2 fields in the EDMG-Header-A shall be the same. The resulting EDMG-MCS index shall be in the range from 2 to 6 as defined in Table 28-51 (EDMG-MCSs 2 to 6 for the EDMG SC mode if the DCM BPSK Applied field is 1(11ay)).

The DCM π/2-BPSK modulation is defined as follows:

— After LDPC encoding, the bit stream of the first spatial stream ($i_{SS}$ = 1) and the second spatial stream ($i_{SS}$ = 2) is broken into two groups of $N_{CBPB} \times N_{CB}$ bits as $\left(c_0^{(i_{SS}=1,q)}, c_1^{(i_{SS}=1,q)}, \ldots, c_{N_{CBPB}\times N_{CB}-1}^{(i_{SS}=1,q)}\right)$ and $\left(c_0^{(i_{SS}=2,q)}, c_1^{(i_{SS}=2,q)}, \ldots, c_{N_{CBPB}\times N_{CB}-1}^{(i_{SS}=2,q)}\right)$, respectively, where $q$ denotes the SC symbol block number and $q$ =0, 1, …, $N_{BLKS}$ − 1(#515). $N_{CBPB}$ is defined as in Table 28-57 (Values of NCBPB for different types of GI(11ay)) for the π/2-BPSK case, $N_{CB}$ = 1 for a 2.16+2.16 GHz channel and $N_{CB}$ = 2 for a 4.32+4.32 GHz channel.

— Each pair of bits $\left(c_k^{(i_{SS}=1,q)}, c_k^{(i_{SS}=2,q)}\right)$ of the $q^{\text{th}}$ SC data block, $k$ = 0, 1, $N_{CBPB} \times N_{CB}$ − 1, is converted into a pair of constellation points $d_k^{(i_{SS}=1,q)} == \frac{1}{\sqrt{2}}\left(\left(2\times c_k^{(i_{SS}=1,q)} - 1\right) + j\left(2\times c_k^{(i_{SS}=2,q)} - 1\right)\right)e^{j\pi k/2}$ and $d_k^{(i_{SS}=2,q)} == \frac{1}{\sqrt{2}}\left(\left(2\times c_k^{(i_{SS}=1,q)} - 1\right) - j\left(2\times c_k^{(i_{SS}=2,q)} - 1\right)\right)e^{j\pi k/2}$.

— Finally, the $q^{\text{th}}$ SC data block of the first spatial stream $d_k^{(i_{SS}=1,q)}$, $k$ = 0, 1, …, $N_{CBPB} \times N_{CB}$ − 1, is assigned to the channel containing the primary 2.16 GHz channel and the second spatial stream $d_k^{(i_{SS}=2,q)}$, $k$ = 0, 1, …, $N_{CBPB} \times N_{CB}$ − 1, is assigned to the channel that does not contain the primary channel.

The DCM π/2-BPSK modulation uses the same symbol blocking structure as for an SU PPDU defined in 28.5.9.2.2.3 (SU PPDU transmission over a 2.16 GHz or 2.16+2.16 GHz channel with NSTS > 1 and over a 4.32 GHz, 6.48 GHz, 8.64 GHz, or 4.32+4.32 GHz channel with NSTS ≥ 1).

#### 28.5.9.5.4 Space-time block coding (STBC)

An EDMG STA shall only apply STBC to an EDMG PPDU transmitted to a peer EDMG STA if the STBC Type field in the peer STA's EDMG Capabilities element is nonzero.

STBC performs mapping of $N_{SS}$ spatial streams to $2 \times N_{SS}$ space-time streams. STBC is applied to an EDMG PPDU if, in the EDMG-Header-A of the PPDU, the STBC field is equal to 1. The number of STBC modulated spatial streams $N_{SS}$ is given by the Number of SS field in the EDMG-Header-A. $N_{SS}$ shall not exceed four for an SU PPDU and one per user for an MU PPDU.

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The mapping of each spatial stream, $i_{SS} = 1, \ldots, N_{SS}$, includes the following steps:

— The input encoded bits stream of spatial stream $i_{SS}$ is broken into groups of $N_{CBPB\ i_{SS}} \times N_{CB}$ bits, $\left( c_0^{(i_{SS},q)}, c_1^{(i_{SS},q)}, \ldots, c_{N_{CBPB\ i_{SS}} \times N_{CB}-1}^{(i_{SS},q)} \right)$, where $q$ denotes the group number. The STBC applies the encoding procedure defined in 28.5.9.4.3 (LDPC encoding). The padding procedure requires that the total number of groups of $N_{CBPB\ i_{SS}} \times N_{CB}$ bits shall be an even number.

— Each group of bits $\left( c_{N_{CBPS\ i_{SS}} \cdot k}^{(i_{SS},q)}, c_{N_{CBPS\ i_{SS}} \cdot k+1}^{(i_{SS},q)}, \ldots, c_{N_{CBPS\ i_{SS}} \cdot k+N_{CBPS\ i_{SS}}-1}^{(i_{SS},q)} \right)$, $k = 0, 1, \ldots, N_{SPB} - 1$, is converted to the constellation point $d_k^{(i_{SS},q)}$ following the rules defined in 20.5.3.2.4 (Modulation mapping), 28.5.9.5.6 (π/2-64-NUC nonuniform constellation modulation), and 28.5.9.5.7 (π/2-8-PSK modulation).

— STBC operates with symbol blocks $d^{(i_{SS},q)} = \left( d_0^{(i_{SS},q)}, d_1^{(i_{SS},q)}, \ldots, d_{N_{SPB}-1}^{(i_{SS},q)} \right)$, $q = 0, 1, \ldots, N_{BLKS} - 1$, and with blocks with reversed symbols order $d_{inv}^{(i_{SS},q)} = \left( d_{N_{SPB}-1}^{(i_{SS},q)}, d_{N_{SPB}-2}^{(i_{SS},q)}, \ldots, d_0^{(i_{SS},q)} \right)$ of spatial stream $i_{SS}$ and assigns these blocks to two space-time streams.

— The modulated data symbols for the odd space-time stream are defined as follows:

$$s^{(i_{STS}=2\times i_{SS}-1)} = \left( d^{(i_{SS},0)}, d^{(i_{SS},1)}, d^{(i_{SS},2)}, d^{(i_{SS},3)}, \ldots, d^{(i_{SS},N_{BLKS}-2)}, d^{(i_{SS},N_{BLKS}-1)} \right)$$

— The modulated data symbols for the even space-time stream are defined as follows:

$$s^{(i_{STS}=2\times i_{SS})} = \left( \begin{array}{l} -conj\left( d_{inv}^{(i_{SS},1)} \right), conj\left( d_{inv}^{(i_{SS},0)} \right), -conj\left( d_{inv}^{(i_{SS},3)} \right), conj\left( d_{inv}^{(i_{SS},2)} \right), \ldots \\ \ldots, -conj\left( d_{inv}^{(i_{SS},N_{BLKS}-1)} \right), conj\left( d_{inv}^{(i_{SS},N_{BLKS}-2)} \right) \end{array} \right)$$

— STBC uses the same symbol blocking structure for an SU PPDU and an MU PPDU defined in 28.5.9.2.2.3 (SU PPDU transmission over a 2.16 GHz or 2.16+2.16 GHz channel with NSTS > 1 and over a 4.32 GHz, 6.48 GHz, 8.64 GHz, or 4.32+4.32 GHz channel with NSTS ≥ 1) and 28.5.9.2.4 (MU PPDU transmission), respectively.

### 28.5.9.5.5 Block interleaver

The block interleaver is defined for π/2-64-QAM and π/2-64-NUC modulations. The block interleaver performs modulated complex symbols interleaving inside an(#1424) SC symbol block and its parameters depend on the $N_{SPB}$, $N_{CB}$, $N_{SS\ i_{user}}$, $L_{CW\ i_{user}}$, and $N_{CBPS\ i_{user}\ i_{SS}}$ parameters.

The input to the interleaver for the $i^{\text{th}}$ spatial stream is an(#1424) SC symbol block $d_{in}^{(i_{SS},q)}$ of length $N_{SPB}$ and composed of 64-QAM or 64-NUC symbols (before application of π/2-rotation) $d_{in}^{(i_{SS},q)} = \left( d_0^{(i_{SS},q)}, d_1^{(i_{SS},q)}, \ldots, d_{N_{SPB}-1}^{(i_{SS},q)} \right)$, where $q$ denotes the SC symbol block number, $q = 0, 1, \ldots, N_{BLKS\ i_{user}} - 1$.


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The output of the interleaver for the $i^{\text{th}}$ spatial stream is a permuted SC symbol block $d_{out}^{(i_{SS},q)}$ of length $N_{SPB}$ and defined as $d_{out}^{(i_{SS},q)} = \left( d_{idx(0)}^{(i_{SS},q)}, d_{idx(1)}^{(i_{SS},q)}, \ldots, d_{idx(N_{SPB}-1)}^{(i_{SS},q)} \right)$, where *idx*() defines the array of permutation (#4136)indices.

The array of permutation (#4136)indices, *idx*(), is constructed as follows:

Let $x = \left( N_{SPB} \times \sum_{i_{SS}=1}^{N_{SS\,i_{user}}} N_{CBPS\,i_{user}\,i_{SS}} \right) / L_{CW\,i_{user}}$.

Moreover, for each $x$, let $N_x = \begin{cases} 2 \times N_{CB}, & \text{if } x \le 3 \times N_{CB} \\ 4 \times N_{CB}, & \text{if } 3 \times N_{CB} < x \le 6 \times N_{CB} \\ 8 \times N_{CB}, & \text{if } 6 \times N_{CB} < x \le 12 \times N_{CB} \\ 16 \times N_{CB}, & \text{if } 12 \times N_{CB} < x \le 24 \times N_{CB} \\ 32 \times N_{CB}, & \text{if } 24 \times N_{CB} < x \end{cases}$ and $N_y = N_{SPB} / N_x$.

Then, $idx\left(j \times N_x + i\right) = N_y \times i + j$, where $i = 0, 1, \ldots, N_x - 1$ and $j = 0, 1, \ldots, N_y - 1$.

The symbols of the output interleaver SC symbol block are then rotated by π/2 as defined in 20.5.3.2.4.5 (π/2-16-QAM modulation) and 28.5.9.5.6 (π/2-64-NUC nonuniform constellation modulation) to produce the π/2-64-QAM and π/2-64-NUC constellation points, respectively.

### 28.5.9.5.6 π/2-64-NUC nonuniform constellation modulation

An EDMG STA shall only apply nonuniform constellation (NUC) to an EDMG PPDU transmitted to a peer EDMG STA if the NUC RX Supported field in the peer STA's EDMG Capabilities element is nonzero.

In π/2-64-NUC NUC modulation, the input bit stream is grouped in sets of 6 bits and mapped according to the following equation:

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$$\tilde{s}_k = \left(1-2c_{6k}\right)\begin{pmatrix}(1-c_{6k+2})(1-c_{6k+3})(1-c_{6k+4})(1-c_{6k+5})1.0997+(1-c_{6k+2})(1-c_{6k+3})(1-c_{6k+4})c_{6k+5}0.1440\\+(1-c_{6k+2})(1-c_{6k+3})c_{6k+4}(1-c_{6k+5})0.7484+(1-c_{6k+2})(1-c_{6k+3})c_{6k+4}c_{6k+5}0.4369\\+(1-c_{6k+2})c_{6k+3}(1-c_{6k+4})(1-c_{6k+5})1.0414+(1-c_{6k+2})c_{6k+3}(1-c_{6k+4})c_{6k+5}0.1414+(1-c_{6k+2})c_{6k+3}c_{6k+4}(1-c_{6k+5})0.7230\\+(1-c_{6k+2})c_{6k+3}c_{6k+4}c_{6k+5}0.4272+c_{6k+2}(1-c_{6k+3})(1-c_{6k+4})(1-c_{6k+5})1.0691+c_{6k+2}(1-c_{6k+3})(1-c_{6k+4})c_{6k+5}0.1426\\+c_{6k+2}(1-c_{6k+3})c_{6k+4}(1-c_{6k+5})0.7360+c_{6k+2}(1-c_{6k+3})c_{6k+4}c_{6k+5}0.4351+c_{6k+2}c_{6k+3}(1-c_{6k+4})(1-c_{6k+5})1.4058\\+c_{6k+2}c_{6k+3}(1-c_{6k+4})c_{6k+5}0.1695+c_{6k+2}c_{6k+3}c_{6k+4}(1-c_{6k+5})0.5981+c_{6k+2}c_{6k+3}c_{6k+4}c_{6k+5}0.2236\end{pmatrix}$$

$$+j\left(2c_{6k+1}-1\right)\begin{pmatrix}(1-c_{6k+2})(1-c_{6k+3})(1-c_{6k+4})(1-c_{6k+5})0.5419+(1-c_{6k+2})(1-c_{6k+3})(1-c_{6k+4})c_{6k+5}0.4167\\+(1-c_{6k+2})(1-c_{6k+3})c_{6k+4}(1-c_{6k+5})0.4663+(1-c_{6k+2})(1-c_{6k+3})c_{6k+4}c_{6k+5}0.4317\\+(1-c_{6k+2})c_{6k+3}(1-c_{6k+4})(1-c_{6k+5})0.1712+(1-c_{6k+2})c_{6k+3}(1-c_{6k+4})c_{6k+5}0.1379+(1-c_{6k+2})c_{6k+3}c_{6k+4}(1-c_{6k+5})0.1517\\+(1-c_{6k+2})c_{6k+3}c_{6k+4}c_{6k+5}0.1421+c_{6k+2}(1-c_{6k+3})(1-c_{6k+4})(1-c_{6k+5})0.9443+c_{6k+2}(1-c_{6k+3})(1-c_{6k+4})c_{6k+5}0.7102\\+c_{6k+2}(1-c_{6k+3})c_{6k+4}(1-c_{6k+5})0.8042+c_{6k+2}(1-c_{6k+3})c_{6k+4}c_{6k+5}0.7394+c_{6k+2}c_{6k+3}(1-c_{6k+4})(1-c_{6k+5})0.2115\\+c_{6k+2}c_{6k+3}(1-c_{6k+4})c_{6k+5}1.0298+c_{6k+2}c_{6k+3}c_{6k+4}(1-c_{6k+5})1.1597+c_{6k+2}c_{6k+3}c_{6k+4}c_{6k+5}1.3784\end{pmatrix}$$



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Each output symbol is then rotated according to the equation $s_k = \tilde{s}_k \cdot e^{\frac{j\pi k}{2}}$. The constellation bit encoding for the 64-NUC is depicted in Figure 28-31 (64-NUC nonuniform constellation bit encoding(11ay)).

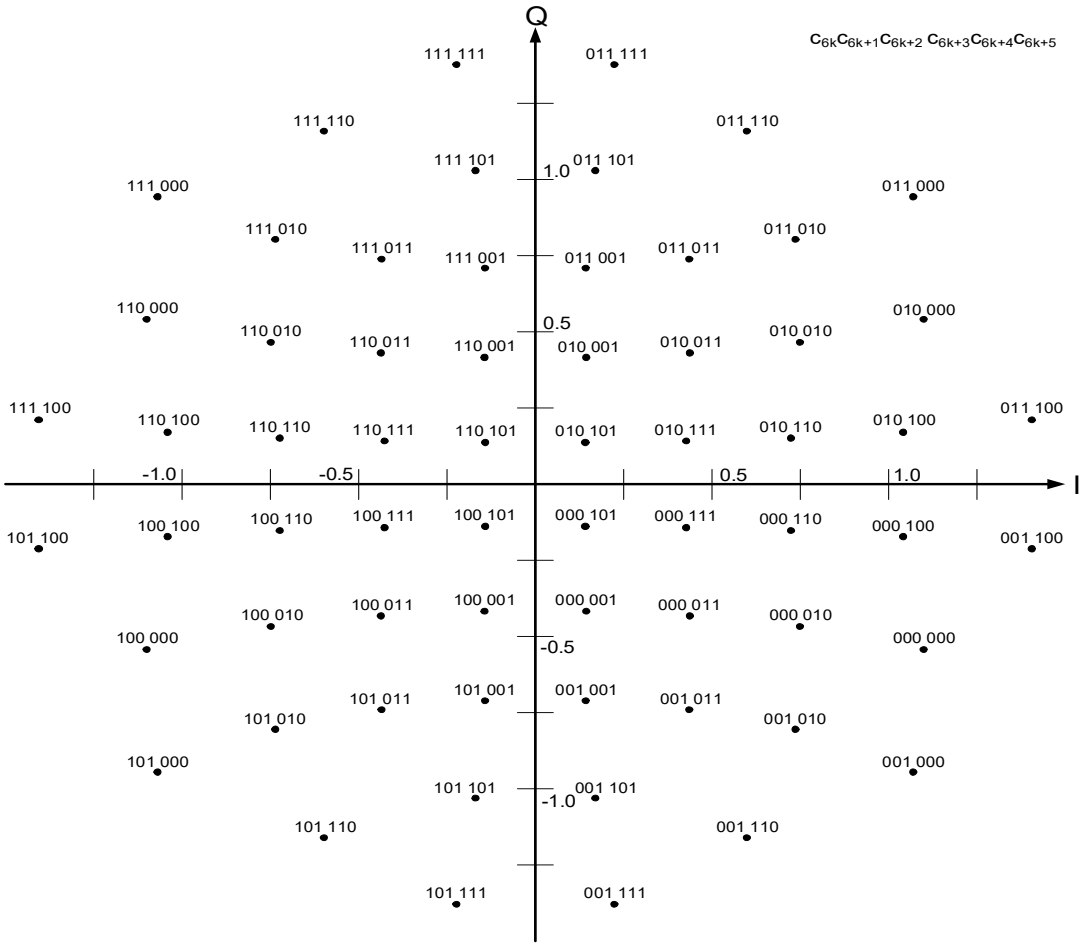


**Figure 28-31—64-NUC nonuniform constellation bit encoding(11ay)**

NOTE—The π/2-64-NUC is quadrant symmetric and has an average power of one.

### 28.5.9.5.7 π/2-8-PSK modulation

An EDMG STA shall only apply π/2-8-PSK modulation to an EDMG PPDU transmitted to a peer EDMG STA if the π/2-8-PSK Supported field in the peer STA's EDMG Capabilities element is nonzero.

In π/2-8-PSK modulation, the input stream is grouped into sets of 3 bits and mapped according to the following equation:

$$\tilde{s}_k = \exp\left( j\frac{\pi}{4}\left(c_{3k} - 3c_{3k+1} - c_{3k+2} - 2c_{3k}c_{3k+1} + 2c_{3k+1}c_{3k+2} + 2c_{3k}c_{3k+2} + 4c_{3k}c_{3k+1}c_{3k+2} + 4\right)\right)$$

where

$k$ is the symbol output index, $k = 0, 1, \ldots$.

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Each output symbol is then rotated according to the equation $s_k = \tilde{s}_k \cdot e^{j \cdot \pi \cdot k/2}$. The constellation bit encoding for 8-PSK is depicted in Figure 28-32 (8-PSK constellation bit encoding(11ay)).

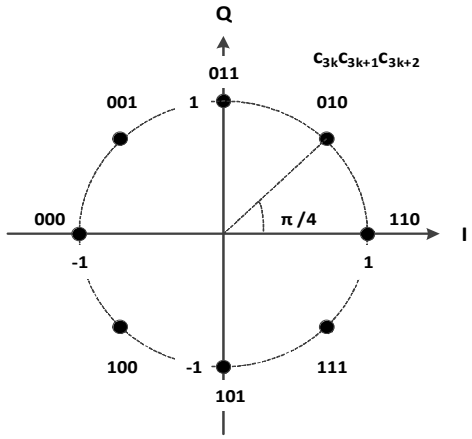


**Figure 28-32—8-PSK constellation bit encoding(11ay)**

### 28.5.10 PPDU transmission

#### 28.5.10.1 General

This subclause defines the waveform for the EDMG SC mode and the non-EDMG PPDU transmission over a 2.16 GHz, 4.32 GHz, 6.48 GHz, 8.64 GHz, 2.16+2.16 GHz, or 4.32+4.32 GHz channel using $N_{TX}$ transmit chains.

The definition of the spatial mapping methods is provided in 28.5.10.2 (Spatial mapping). The non-EDMG PPDU transmission shall be as defined in 28.5.10.3 (Non-EDMG PPDU transmission). The EDMG SU PPDU transmission shall be as defined in 28.5.10.4 (EDMG SU PPDU transmission). The EDMG MU PPDU transmission shall be as defined in 28.5.10.5 (EDMG MU PPDU transmission).

#### 28.5.10.2 Spatial mapping

Spatial mapping defines the method of $N_{STS}$ space-time streams to $N_{TX}$ transmit chains mapping, where $N_{STS} \leq N_{TX}$, which may be implemented by means of a spatial mapping matrix $Q$ of size $N_{TX}$ by $N_{STS}$ and by cyclic shift diversity (CSD), if applied. The spatial mapping matrix $Q$ is independent of the chip time index or subcarrier index and is constant in time.

This standard defines four basic mappings for the EDMG PHY, namely, direct mapping, indirect mapping, digital beamforming and spatial expansion. Provided below are examples of spatial mapping methods and $Q$ matrices that might be used in different cases.

- Direct mapping, $N_{STS} = N_{TX}$: the spatial mapping matrix $Q$ is a square diagonal complex value matrix of size $N_{TX}$ that might be defined as follows:
  - $[Q]_{i,i} = 1, i = 1, 2, ..., N_{TX}$, the identity matrix
  - $[Q]_{i,i} = \exp\left(j 2\pi \phi_i\right), i = 1, 2, ..., N_{TX}$, exponential matrix
- Indirect mapping, $N_{STS} = N_{TX}$: the spatial mapping matrix $Q$ is a square matrix of size $N_{TX}$ composed of complex values that might be defined as follows:
  - Normalized discrete Fourier matrix


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- Normalized Hadamard matrix
- Normalized direct mapping diagonal matrix with permutated rows and/or columns

— Digital beamforming, $N_{STS} \leq N_{TX}$: the spatial mapping matrix $Q$ is a rectangular matrix of size $N_{TX}$ by $N_{STS}$ composed of complex values that might be defined based on some knowledge of the channel.

— Spatial expansion, $N_{STS} = 1 < N_{TX}$: the spatial expansion is performed by multiplication by matrix $Q$, which is defined as a column vector of size $N_{TX}$ by 1 and composed of all 1s, and application of CSD over different transmit chains. The CSD is applied to the fields of PPDU with the exception of the TRN field. This enables duplication of the transmission of PPDU fields over the $N_{TX}$ transmit chains and avoids unintentional beamforming that exists with a coherent signal transmission. The spatial expansion technique is not applied to the TRN field, which is transmitted using an orthogonal sequence set.

— Channel aggregation, in this case $N_{TX}$ is an even number: the transmit chains 1 through $N_{TX}/2$ are assigned to the primary or primary and secondary channels and transmit chains $N_{TX}/2 + 1$ are assigned to the secondary or secondary1 and secondary2 channels. The mapping of space-time streams to the transmit chains is defined by the spatial mapping matrix $Q$, which is implementation specific.

The spatial mapping matrix $Q$ may be different for the pre-EDMG and EDMG modulated fields, except for the case of an EDMG SU PPDU transmitted over a 2.16 GHz or a 2.16+2.16 GHz channel with single space-time stream ($i_{STS} = 1$). The spatial mapping matrix $Q$ shall be normalized to have the same average power per transmit chain for pre-EDMG and EDMG modulated fields.

### 28.5.10.3 Non-EDMG PPDU transmission

#### 28.5.10.3.1 Non-EDMG PPDU transmission over a 2.16 GHz or 2.16+2.16 GHz channel

The non-EDMG PPDU waveform shall be defined at the DMG SC chip rate $F_c$ and include the following modulated fields:

$$r_{non\text{-}EDMG}(nT_c) = r_{L\text{-}STF}(nT_c) + r_{L\text{-}CEF}(nT_c - t_{L\text{-}CEF}) + r_{L\text{-}Header}(nT_c - t_{L\text{-}Header}) + r_{Data}(nT_c - t_{Data}) + r_{AGC\ TRN}(nT_c - t_{AGC\ TRN})$$

where

$t_{L\text{-}CEF} = T_{L\text{-}STF}$ is the duration of the L-STF field of the PPDU

$t_{L\text{-}Header} = t_{L\text{-}CEF} + T_{L\text{-}CEF}$ is the total duration of the L-STF and L-CEF fields of the PPDU

$t_{Data} = t_{L\text{-}Header} + T_{L\text{-}Header}$ is the total duration of the L-STF, L-CEF, and L-Header fields of the PPDU

$t_{AGC\ TRN} = t_{Data} + T_{Data}$ is the total duration of the L-STF, L-CEF, L-Header, and Data fields of the PPDU

In the non-EDMG duplicate PPDU waveform, the AGC and TRN fields may be present in a 2.16 GHz non-EDMG PPDU transmission and shall not be present in a 4.32 GHz, 6.48 GHz, 8.64 GHz, 2.16+2.16 GHz, or 4.32+4.32 GHz non-EDMG PPDU transmission.

Unless specified, the chip index $n$ is defined in the range [0, $N_{Field} - 1$], where $N_{Field}$ defines the total number of samples for a given signal field. The definition of the L-STF, L-CEF, and L-Header fields is provided in 28.3.3.2.2 (L-STF definition), 28.3.3.2.3 (L-CEF definition), and 28.3.3.2.4 (L-Header definition), respectively. The definition of the AGC and TRN fields is provided in 20.9.2.2.5 (AGC field)

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and 20.9.2.2.6 (TRN field), respectively. The L-Header and Data fields encoding and modulation is provided in 20.5.3.1.4 (Header encoding and modulation) and 20.5.3.2 (Data field), respectively.

The non-EDMG PPDU waveform for the $i_{TX}^{\text{th}}$ transmit chain shall be defined as follows:

$$r_{non\text{-}EDMG}^{i_{TX}(1)}\left(nT_c\right) = \left[Q_{non\text{-}EDMG}\right]_{i_{TX},1} \cdot r_{non\text{-}EDMG}\left(nT_c\right), 1 \le i_{TX} \le N_{TX}$$

where

$Q_{non\text{-}EDMG}$ is a spatial mapping matrix

$[\ ]_{m,n}$ is a matrix element from $m^{\text{th}}$ row and $n^{\text{th}}$ column

For spatial expansion, the non-EDMG waveform for the $i_{TX}^{\text{th}}$ transmit chain includes a cyclic shift, $T_{SC}^{i_{TX}}$, dependent on the particular transmit chain number. The cyclic shift, $T_{SC}^{i_{TX}}$, is defined in SC chip units as $(i_{TX}-1) \times N_c \times T_c$, where $N_c$ is equal to 4 chips and $T_c$ is a chip time duration.

$$r_{non\text{-}EDMG}^{i_{TX}(1)}\left(nT_c\right) = \begin{cases} r_{non\text{-}EDMG}^{i_{TX}(1)}\left(nT_c + T_{SC}^{i_{TX}}\right), & n = 0,1,\ldots,N-1-T_{SC}^{i_{TX}}/T_c \\ r_{non\text{-}EDMG}^{i_{TX}(1)}\left(nT_c - \left(NT_c - T_{SC}^{i_{TX}}\right)\right), & n = N-T_{SC}^{i_{TX}}/T_c,\ldots,N-1 \end{cases}, \quad 1 \le i_{TX} \le N_{TX}$$

where

$N$ is the total number of chips in the non-EDMG PPDU waveform

The non-EDMG waveform for the $i_{TX}^{\text{th}}$ transmit chain is obtained by upsampling and filtering and then appropriate carrier frequency shift of the $r_{non\text{-}EDMG}^{i_{TX}(1)}\left(nT_c\right)$ waveform, if required. The upsampling procedure is applied using a factor of $N_{up}$. The filtering procedure is performed with a pulse shaping filter, $h_{SC\,CB}$, defined at the $N_{up} \times F_c$ sampling rate as follows(#1152):

$$r_{non\text{-}EDMG}^{i_{TX}(2)}\left(n\frac{T_c}{N_{up}}\right) = \begin{cases} r_{non\text{-}EDMG}^{i_{TX}(1)}\left(n\frac{T_c}{N_{up}}\right), & n=0, N_{up}, 2\times N_{up} \\ 0, & otherwise \end{cases}$$

$$r_{non\text{-}EDMG}^{i_{TX}(3)}\left(n\frac{T_c}{N_{up}}\right) = \sum_{k=0}^{K-1} r_{non\text{-}EDMG}^{i_{TX}(2)}\left((n-k)\frac{T_c}{N_{up}}\right) h_{SC\,CB}(k),\ n=0,\ 1,\ \ldots$$

$$r_{non\text{-}EDMG}^{i_{TX}(4)}\left(n\frac{T_c}{N_{up}}\right) = r_{non\text{-}EDMG}^{i_{TX}(3)}\left(\left(n+\frac{K-1}{2}\right)\frac{T_c}{N_{up}}\right),\ n=0,\ 1,\ \ldots$$

where

$K$ is the length of $h_{SC\,CB}$ in samples

$r_{non\text{-}EDMG}^{i_{TX}(2)}\left(n\frac{T_c}{N_{up}}\right) = 0$, for $n < 0$ and $n \ge N \times N_{up}$

$N$ is the total number of chips in the non-EDMG PPDU waveform

The non-EDMG waveform for the $i_{TX}^{\text{th}}$ transmit chain when transmitted over a 2.16 GHz or 2.16+2.16 GHz channel shall be defined as follows:


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$$r_{PPDU}^{i_{TX}}\left(n\frac{T_c}{N_{up}}\right)=r_{non\text{-}EDMG}^{i_{TX}(4)}\left(n\frac{T_c}{N_{up}}\right),1\le i_{TX}\le N_{TX}$$

For a 2.16+2.16 GHz transmission, the total number of transmit chains, $N_{TX}$, shall be an even number. The first $N_{TX}/2$ transmit chains shall be used for transmission on the primary channel and the second $N_{TX}/2$ transmit chains shall be used for transmission on the secondary channel (see 28.3.4 (Channelization)).

#### 28.5.10.3.2 Non-EDMG duplicate PPDU transmission over a 4.32 GHz, 6.48 GHz, 8.64 GHz, or 4.32+4.32 GHz channel

The non-EDMG waveform for the $i_{TX}^{\text{th}}$ transmit chain when transmitted using duplicate transmission over a 4.32 GHz or 4.32+4.32 GHz channel shall be defined as follows:

$$r_{PPDU}^{i_{TX}}\left(n\frac{T_c}{N_{up}}\right)=r_{non\text{-}EDMG}^{i_{TX}(4)}\left(n\frac{T_c}{N_{up}}+\Delta t_1\right)\cdot\frac{1}{\sqrt{2}}\exp\left(-j2\pi\left(\frac{\Delta F}{2}\right)\left(\frac{T_c}{N_{up}}\right)n\right)+r_{non\text{-}EDMG}^{i_{TX}(4)}\left(n\frac{T_c}{N_{up}}+\Delta t_2\right)$$
$$\cdot\frac{1}{\sqrt{2}}\exp\left(+j2\pi\left(\frac{\Delta F}{2}\right)\left(\frac{T_c}{N_{up}}\right)n\right),1\le i_{TX}\le N_{TX}$$

where

| | |
|---|---|
| $\Delta F$ | defines the channel spacing and is equal to 2.16 GHz |
| $\Delta t_1$ and $\Delta t_2$ | are in the range [0, $T_c$] |
| $\Delta t_i$ equal to 0 | corresponds to the primary channel |

For 4.32+4.32 GHz transmission, the total number of transmit chains, $N_{TX}$, shall be an even number. The first $N_{TX}/2$ transmit chains shall be used for transmission on the primary and secondary channels and the second $N_{TX}/2$ transmit chains shall be used for transmission on the secondary1 and secondary2 channels (see 28.3.4 (Channelization)).

The non-EDMG waveform for the $i_{TX}^{\text{th}}$ transmit chain when transmitted using duplicate transmission over a 6.48 GHz channel shall be defined as follows:

$$r_{PPDU}^{i_{TX}}\left(n\frac{T_c}{N_{up}}\right)=r_{non\text{-}EDMG}^{i_{TX}(4)}\left(n\frac{T_c}{N_{up}}+\Delta t_1\right)\cdot\frac{1}{\sqrt{3}}\exp\left(-j2\pi\Delta F\left(\frac{T_c}{N_{up}}\right)n\right)+r_{non\text{-}EDMG}^{i_{TX}(4)}\left(n\frac{T_c}{N_{up}}+\Delta t_2\right)$$
$$\cdot\frac{1}{\sqrt{3}}+r_{non\text{-}EDMG}^{i_{TX}(4)}\left(n\frac{T_c}{N_{up}}+\Delta t_3\right)\cdot\frac{1}{\sqrt{3}}\exp\left(+j2\pi\Delta F\left(\frac{T_c}{N_{up}}\right)n\right),1\le i_{TX}\le N_{TX}$$

where

| | |
|---|---|
| $\Delta t_1$, $\Delta t_2$, and $\Delta t_3$ | are in the range [0, $T_c$] |
| $\Delta t_i$ equal to 0 | corresponds to the primary channel |

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The non-EDMG waveform for the $i_{TX}^{\text{th}}$ transmit chain when transmitted using duplicate transmission over an 8.64 GHz channel shall be defined as follows:

$$r_{PPDU}^{i_{TX}}\left(n\frac{T_c}{N_{up}}\right) = r_{non\text{-}EDMG}^{i_{TX}(4)}\left(n\frac{T_c}{N_{up}}+\Delta t_1\right) \cdot\frac{1}{\sqrt{4}}\exp\left(-j2\pi\left(\frac{3\Delta F}{2}\right)\left(\frac{T_c}{N_{up}}\right)n\right) + r_{non\text{-}EDMG}^{i_{TX}(4)}\left(n\frac{T_c}{N_{up}}+\Delta t_2\right) \cdot\frac{1}{\sqrt{4}}\exp\left(-j2\pi\left(\frac{\Delta F}{2}\right)\left(\frac{T_c}{N_{up}}\right)n\right) + r_{non\text{-}EDMG}^{i_{TX}(4)}\left(n\frac{T_c}{N_{up}}+\Delta t_3\right) \cdot\frac{1}{\sqrt{4}}\exp\left(+j2\pi\left(\frac{\Delta F}{2}\right)\left(\frac{T_c}{N_{up}}\right)n\right) + r_{non\text{-}EDMG}^{i_{TX}(4)}\left(n\frac{T_c}{N_{up}}+\Delta t_2\right) \cdot\frac{1}{\sqrt{4}}\exp\left(+j2\pi\left(\frac{3\Delta F}{2}\right)\left(\frac{T_c}{N_{up}}\right)n\right), 1 \le i_{TX} \le N_{TX}$$

where

| | |
|---|---|
| $\Delta t_1$, $\Delta t_2$, $\Delta t_3$, and $\Delta t_4$ | are in the range [0, $T_c$] |
| $\Delta t_i$ equal to 0 | corresponds to the primary channel |

The definition of the pulse shaping filter impulse response, $h_{SC\,CB}$, and the $N_{up}$ parameter are implementation dependent.

### 28.5.10.4 EDMG SU PPDU transmission

#### 28.5.10.4.1 General

An EDMG SC mode SU PPDU transmitted over a 2.16 GHz, 4.32 GHz, 6.48 GHz, 8.64 GHz, 2.16+2.16 GHz, or 4.32+4.32 GHz channel with single and multiple space-time streams ($i_{STS} \ge 1$) is composed of pre-EDMG modulated fields, EDMG preamble, Data field and TRN field. The EDMG preamble and TRN field might not be present in a transmitted SU PPDU depending on particular transmission parameters. The total number of transmit chains, $N_{TX}$, shall be constant over the different fields of a transmitted EDMG SU PPDU.

#### 28.5.10.4.2 EDMG PPDU transmission over a 2.16 GHz or 2.16+2.16 GHz channel with $N_{STS}$ = 1

An EDMG SC mode SU PPDU transmitted over a 2.16 GHz or 2.16+2.16 GHz channel with single space-time stream ($N_{STS}$ = 1) is composed of pre-EDMG, Data, and TRN fields.

For a single PPDU transmission, the pre-EDMG and Data fields include the following modulated fields:

$$r_{pre\text{-}EDMG,\,Data}\left(nT_c\right) = r_{L\text{-}STF}\left(nT_c\right) + r_{L\text{-}CEF}\left(nT_c - t_{L\text{-}CEF}\right) + r_{L\text{-}Header}\left(nT_c - t_{L\text{-}Header}\right) + r_{EDMG\text{-}Header\text{-}A}\left(nT_c - t_{EDMG\text{-}Header\text{-}A}\right) + r_{Data}\left(nT_c - t_{Data}\right)$$


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where

$t_{L\text{-}CEF} = T_{L\text{-}STF}$ is the duration of the L-STF field of the PPDU

$t_{L\text{-}Header} = t_{L\text{-}CEF} + T_{L\text{-}CEF}$ is the total duration of the L-STF and L-CEF fields of the PPDU

$t_{EDMG\text{-}Header\text{-}A} = t_{L\text{-}Header} + T_{L\text{-}Header}$ is the total duration of the L-STF, L-CEF, and L-Header fields of the PPDU

$t_{Data} = t_{EDMG\text{-}Header\text{-}A} + T_{EDMG\text{-}Header\text{-}A}$ is the total duration of the L-STF, L-CEF, L-Header, and EDMG-Header-A fields of the PPDU

The definition of the L-STF, L-CEF, and L-Header fields is provided in 28.3.3.2.2 (L-STF definition), 28.3.3.2.3 (L-CEF definition), and 28.3.3.2.4 (L-Header definition), respectively.

For an EDMG A-PPDU transmission of $N_{PPDU}$ PPDUs, the pre-EDMG, the EDMG modulated field of the EDMG preamble, and Data fields include the following modulated fields:

$$r_{pre\text{-}EDMG,\,Data}\left(nT_c\right) = r_{L\text{-}STF}\left(nT_c\right) + r_{L\text{-}CEF}\left(nT_c - t_{L\text{-}CEF}\right) + r_{L\text{-}Header}\left(nT_c - t_{L\text{-}Header}\right)$$
$$+ r_{EDMG\text{-}Header\text{-}A_1}\left(nT_c - t_{EDMG\text{-}Header\text{-}A_1}\right) + r_{Data_1}\left(nT_c - t_{Data_1}\right)$$
$$+ r_{EDMG\text{-}Header\text{-}A_2}\left(nT_c - t_{EDMG\text{-}Header\text{-}A_2}\right) + r_{Data_2}\left(nT_c - t_{Data_2}\right)$$
$$+ \ldots$$
$$+ r_{EDMG\text{-}Header\text{-}A_{N_{PPDU}}}\left(nT_c - t_{EDMG\text{-}Header\text{-}A_{N_{PPDU}}}\right) + r_{Data_{N_{PPDU}}}\left(nT_c - t_{Data_{N_{PPDU}}}\right)$$

where

$t_{L\text{-}CEF} = T_{L\text{-}STF}$ is the duration of L-STF field of the PPDU

$t_{L\text{-}Header} = t_{L\text{-}CEF} + T_{L\text{-}CEF}$ is the total duration of L-STF and L-CEF fields of the PPDU

$t_{EDMG\text{-}Header\text{-}A_1} = t_{L\text{-}Header} + T_{L\text{-}Header}$ is the total duration of L-STF, L-CEF, and L-Header fields of the PPDU

$t_{Data_1} = t_{EDMG\text{-}Header\text{-}A_1} + T_{EDMG\text{-}Header\text{-}A_1}$ is the total duration of L-STF, L-CEF, L-Header, and EDMG-Header-$A_1$ fields of the PPDU

$t_{EDMG\text{-}Header\text{-}A_2} = t_{Data_1} + T_{Data_1}$ is the total duration of L-STF, L-CEF, L-Header, EDMG-Header-$A_1$, and $Data_1$ fields of the PPDU

$t_{Data_2} = t_{EDMG\text{-}Header\text{-}A_2} + T_{EDMG\text{-}Header\text{-}A_2}$ is the total duration of L-STF, L-CEF, L-Header, EDMG-Header-$A_1$, $Data_1$, and EDMG-Header-$A_2$ fields of the PPDU

…

$t_{EDMG\text{-}Header\text{-}A_{N_{PPDU}}} = t_{Data_{N_{PPDU}-1}} + T_{Data_{N_{PPDU}-1}}$ is the total duration of L-STF, L-CEF, L-Header, EDMG-Header-$A_1$, $Data_1$, EDMG-Header-$A_2$, $Data_2$, …, and $Data_{NPPDU–1}$ fields of the PPDU

$t_{Data_{N_{PPDU}}} = t_{EDMG\text{-}Header\text{-}A_{N_{PPDU}}} + T_{EDMG\text{-}Header\text{-}A_{N_{PPDU}}}$ is the total duration of L-STF, L-CEF, L-Header, EDMG-Header-$A_1$, $Data_1$, EDMG-Header-$A_2$, $Data_2$, …, $Data_{NPPDU–1}$, and EDMG-Header-$A_{NPPDU}$ fields of the PPDU

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The PPDU waveform of the pre-EDMG and Data fields for the $i_{TX}^{\text{th}}$ transmit chain shall be defined as follows:

$$r_{pre\text{-}EDMG,\,Data}^{i_{TX}}\left(nT_c\right)=\left[Q_{EDMG}\right]_{i_{TX},1}\cdot r_{pre\text{-}EDMG,\,Data}\left(nT_c\right),1\le i_{TX}\le N_{TX}$$

where

$Q_{EDMG}$ is a spatial mapping matrix

$[\ ]_{m,n}$ is a matrix element from $m^{\text{th}}$ row and $n^{\text{th}}$ column

For spatial expansion, the PPDU waveform of the pre-EDMG and Data fields for the $i_{TX}^{\text{th}}$ transmit chain includes a cyclic shift, $T_{SC}^{i_{TX}}$, dependent on the particular transmit chain number. The cyclic shift, $T_{SC}^{i_{TX}}$, is defined in SC chip units as $(i_{TX}-1)\times N_c\times T_c$, where $N_c$ is equal to 4 chips and $T_c$ is a chip time duration.

$$r_{pre\text{-}EDMG,\,Data}^{i_{TX}}\left(nT_c\right)=\begin{cases}r_{pre\text{-}EDMG,\,Data}^{i_{TX}}\left(nT_c+T_{SC}^{i_{TX}}\right), & n=0,1,...,N-1-T_{SC}^{i_{TX}}/T_c\\ r_{pre\text{-}EDMG,\,Data}^{i_{TX}}\left(nT_c-\left(NT_c-T_{SC}^{i_{TX}}\right)\right), & n=N-T_{SC}^{i_{TX}}/T_c,...,N-1\end{cases},\quad 1\le i_{TX}\le N_{TX}$$

where

$N$ is the total number of chips in the pre-EDMG and Data fields of the EDMG PPDU

The TRN field, $r_{TRN}^{i_{TX}}\left(nT_c\right)$, shall be defined at the DMG SC chip rate $F_c$ per $i_{TX}^{\text{th}}$ transmit chain as defined in 28.9.2.2.6 (TRN subfield definition for EDMG SC PPDUs and EDMG control mode PPDUs).

The resulting SU PPDU waveform for a 2.16 GHz or 2.16+2.16 GHz channel and single space-time stream ($N_{STS}$ = 1) for the $i_{TX}^{\text{th}}$ transmit chain concatenates the preamble and Data fields with the TRN field and shall be defined as follows:

$$r_{EDMG}^{i_{TX}\,(1)}\left(nT_c\right)=r_{pre\text{-}EDMG,\,Data}^{i_{TX}}\left(nT_c\right)+r_{TRN}^{i_{TX}}\left(nT_c-t_{TRN}\right),1\le i_{TX}\le N_{TX}$$

where

$t_{TRN}=t_{Data}+T_{Data}$ is the total duration of the L-STF, L-CEF, L-Header, EDMG-Header-A, and Data fields of the PPDU

For a 2.16+2.16 GHz transmission, the total number of transmit chains, $N_{TX}$, shall be an even number. The first $N_{TX}/2$ transmit chains shall be used for transmission on the primary channel and the second $N_{TX}/2$ transmit chains shall be used for transmission on the secondary channel (see 28.3.4 (Channelization)).

The filtering procedure is performed with a pulse shaping filter, $h_{SC\,CB}$, defined at the $N_{up}\times F_c$ sampling rate as follows:

$$r_{EDMG}^{i_{TX}\,(2)}\left(n\frac{T_c}{N_{up}}\right)=\begin{cases}r_{EDMG}^{i_{TX}\,(1)}\left(n\frac{T_c}{N_{up}}\right), & n=0,N_{up},2*N_{up}...\\ 0 & \text{otherwise}\end{cases}$$

$$r_{EDMG}^{i_{TX}\,(3)}\left(n\frac{T_c}{N_{up}}\right)=\sum_{k=0}^{K-1}r_{EDMG}^{i_{TX}\,(2)}\left(\left(n-k\right)\frac{T_c}{N_{up}}\right)h_{SC\,CB}\left(k\right),n=0,1,...$$

$$r_{EDMG}^{i_{TX}}\left(n\frac{T_c}{N_{up}}\right)=r_{EDMG}^{i_{TX}\,(3)}\left(\left(n+\frac{K-1}{2}\right)\frac{T_c}{N_{up}}\right),n=0,1,...$$


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where

$K$ is the length of $h_{SC\,CB}$ in samples

$$r_{EDMG}^{i_{TX}(2)}\left(n\frac{T_c}{N_{up}}\right)=0, \text{for } n<0 \text{ and } n\geq N\times N_{up}$$

$N$ is the total number of chips in the EDMG PPDU

The definition of the pulse shaping filter impulse response, $h_{SC\,CB}$, and the $N_{up}$ parameter are implementation dependent.

### 28.5.10.4.3 EDMG PPDU transmission with DMG AGC and TRN fields over a 2.16 GHz channel with $N_{STS}$ = 1

For the case of DMG AGC and TRN field transmission over a 2.16 GHz channel, indicated by the DMG TRN field in the EDMG-Header-A, the EDMG SU PPDU is transmitted with a single space-time stream and composed of pre-EDMG, Data, DMG AGC and TRN fields.

For a single PPDU transmission, the pre-EDMG, Data, AGC, and TRN fields include the following modulated fields:

$$r_{pre\text{-}EDMG,\,Data,AGC\ TRN}\left(nT_c\right)=r_{L\text{-}STF}\left(nT_c\right)+r_{L\text{-}CEF}\left(nT_c-t_{L\text{-}CEF}\right)+r_{L\text{-}Header}\left(nT_c-t_{L\text{-}Header}\right)$$
$$+r_{EDMG\text{-}Header\text{-}A}\left(nT_c-t_{EDMG\text{-}Header\text{-}A}\right)+r_{Data}\left(nT_c-t_{Data}\right)+r_{AGC\ TRN}\left(nT_c-t_{AGC\ TRN}\right)$$

where

$t_{L\text{-}CEF}=T_{L\text{-}STF}$ is the duration of the L-STF field of the PPDU

$t_{L\text{-}Header}=t_{L\text{-}CEF}+T_{L\text{-}CEF}$ is the total duration of the L-STF and L-CEF fields of the PPDU

$t_{EDMG\text{-}Header\text{-}A}=t_{L\text{-}Header}+T_{L\text{-}Header}$ is the total duration of the L-STF, L-CEF, and L-Header fields of the PPDU

$t_{Data}=t_{EDMG\text{-}Header\text{-}A}+T_{EDMG\text{-}Header\text{-}A}$ is the total duration of the L-STF, L-CEF, L-Header, and EDMG-Header-A fields of the PPDU

$t_{AGC\ TRN}=t_{Data}+T_{Data}$ is the total duration of the L-STF, L-CEF, L-Header, EDMG-Header-A, and Data fields of the PPDU

The definition of the L-STF, L-CEF, and L-Header fields is provided in 28.3.3.2.2 (L-STF definition), 28.3.3.2.3 (L-CEF definition), and 28.3.3.2.4 (L-Header definition) respectively. The definition of the AGC and TRN fields is provided in 20.9.2.2.5 (AGC field) and 20.9.2.2.6 (TRN field), respectively.

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For an EDMG A-PPDU transmission of $N_{PPDU}$ PPDUs, the pre-EDMG, the EDMG modulated field of the EDMG preamble, Data AGC and TRN fields include the following modulated fields:

$$r_{pre\text{-}EDMG,\,Data,\,AGC\ TRN}\left(nT_c\right) = r_{L\text{-}STF}\left(nT_c\right) + r_{L\text{-}CEF}\left(nT_c - t_{L\text{-}CEF}\right) + r_{L\text{-}Header}\left(nT_c - t_{L\text{-}Header}\right)$$
$$+ r_{EDMG\text{-}Header\text{-}A_1}\left(nT_c - t_{EDMG\text{-}Header\text{-}A_1}\right) + r_{Data_1}\left(nT_c - t_{Data_1}\right)$$
$$+ r_{EDMG\text{-}Header\text{-}A_2}\left(nT_c - t_{EDMG\text{-}Header\text{-}A_2}\right) + r_{Data_2}\left(nT_c - t_{Data_2}\right)$$
$$+ \ldots$$
$$+ r_{EDMG\text{-}Header\text{-}A_{N_{PPDU}}}\left(nT_c - t_{EDMG\text{-}Header\text{-}A_{N_{PPDU}}}\right) + r_{Data_{N_{PPDU}}}\left(nT_c - t_{Data_{N_{PPDU}}}\right)$$
$$+ r_{AGC\ TRN}\left(nT_c - t_{AGC\ TRN}\right)$$

where

$t_{L\text{-}CEF} = T_{L\text{-}STF}$ is the duration of L-STF field of the PPDU

$t_{L\text{-}Header} = t_{L\text{-}CEF} + T_{L\text{-}CEF}$ is the total duration of L-STF and L-CEF fields of the PPDU

$t_{EDMG\text{-}Header\text{-}A_1} = t_{L\text{-}Header} + T_{L\text{-}Header}$ is the total duration of L-STF, L-CEF, and L-Header fields of the PPDU

$t_{Data_1} = t_{EDMG\text{-}Header\text{-}A_1} + T_{EDMG\text{-}Header\text{-}A_1}$ is the total duration of L-STF, L-CEF, L-Header, and EDMG-Header-$A_1$ fields of the PPDU

$t_{EDMG\text{-}Header\text{-}A_2} = t_{Data_1} + T_{Data_1}$ is the total duration of L-STF, L-CEF, L-Header, EDMG-Header-$A_1$, and $Data_1$ fields of the PPDU

$t_{Data_2} = t_{EDMG\text{-}Header\text{-}A_2} + T_{EDMG\text{-}Header\text{-}A_2}$ is the total duration of L-STF, L-CEF, L-Header, EDMG-Header-$A_1$, $Data_1$, and EDMG-Header-$A_2$ fields of the PPDU

$t_{EDMG\text{-}Header\text{-}A_{N_{PPDU}}} = t_{Data_{N_{PPDU}-1}} + T_{Data_{N_{PPDU}-1}}$ is the total duration of L-STF, L-CEF, L-Header, EDMG-Header-$A_1$, $Data_1$, EDMG-Header-$A_2$, $Data_2$, …, and $Data_{NPPDU}$–1 fields of the PPDU

$t_{Data_{N_{PPDU}}} = t_{EDMG\text{-}Header\text{-}A_{N_{PPDU}}} + T_{EDMG\text{-}Header\text{-}A_{N_{PPDU}}}$ is the total duration of L-STF, L-CEF, L-Header, EDMG-Header-$A_1$, $Data_1$, EDMG-Header-$A_2$, $Data_2$, …, $Data_{NPPDU}$–1, and EDMG-Header-$A_{NPPDU}$ fields of the PPDU

$t_{AGC\ TRN} = t_{Data_{N_{PPDU}}} + T_{Data_{N_{PPDU}}}$ is the total duration of L-STF, L-CEF, L-Header, EDMG-Header-$A_1$, $Data_1$, EDMG-Header-$A_2$, $Data_2$, …, $Data_{NPPDU}$–1, EDMG-Header-$A_{NPPDU}$, and $Data_{NPPDU}$ fields of the PPDU

The EDMG PPDU waveform for the $i_{TX}^{\text{th}}$ transmit chain shall be defined as follows:

$$r_{EDMG,}^{i_{TX}(1)}\left(nT_c\right) = \left[Q_{EDMG}\right]_{i_{TX},1} \cdot r_{pre-EDMG,\,Data,\,AGC\ TRN}\left(nT_c\right), 1 \le i_{TX} \le N_{TX}$$

where

$Q_{EDMG}$ is a spatial mapping matrix

$[\ ]_{m,n}$ is a matrix element from $m^{\text{th}}$ row and $n^{\text{th}}$ column


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For spatial expansion, the EDMG PPDU waveform for the $i_{TX}^{\text{th}}$ transmit chain includes a cyclic shift, $T_{SC}^{i_{TX}}$, dependent on the particular transmit chain number. The cyclic shift, $T_{SC}^{i_{TX}}$, is defined in SC chip units as $(i_{TX} - 1) \times N_c \times T_c$, where $N_c$ is equal to 4 chips and $T_c$ is a chip time duration:

$$r_{EDMG}^{i_{TX}(1)}(nT_c) = \begin{cases} r_{pre\text{-}EDMG,\,Data,\,AGC\ TRN}^{i_{TX}(1)}\left(nT_c + T_{SC}^{i_{TX}}\right), & n = 0,1,\ldots,N-1-T_{SC}^{i_{TX}}/T_c \\ r_{pre\text{-}EDMG,\,Data,\,AGC\ TRN}^{i_{TX}(1)}\left(nT_c - \left(NT_c - T_{SC}^{i_{TX}}\right)\right), & n = N - T_{SC}^{i_{TX}}/T_c,\ldots,N-1 \end{cases}, \quad 1 \le i_{TX} \le N_{TX}$$

where

$N$ is the total number of chips in the pre-EDMG, Data, AGC, and TRN fields

The filtering procedure is performed with a pulse shaping filter, $h_{SC\,CB}$, defined at the $N_{up} \times F_c$ sampling rate as follows:

$$r_{EDMG}^{i_{TX}(2)}\left(n\frac{T_c}{N_{up}}\right) = \begin{cases} r_{EDMG}^{i_{TX}(1)}\left(n\frac{T_c}{N_{up}}\right), n = 0, N_{up}, 2*N_{up}\ldots \\ 0 \qquad \text{otherwise} \end{cases}$$

$$r_{EDMG}^{i_{TX}(3)}\left(n\frac{T_c}{N_{up}}\right) = \sum_{k=0}^{K-1} r_{EDMG}^{i_{TX}(2)}\left((n-k)\frac{T_c}{N_{up}}\right) h_{SC\,CB}(k), n = 0,1,\ldots$$

$$r_{EDMG}^{i_{TX}}\left(n\frac{T_c}{N_{up}}\right) = r_{EDMG}^{i_{TX}(3)}\left(\left(n + \frac{K-1}{2}\right)\frac{T_c}{N_{up}}\right), n = 0,1,\ldots$$

where

$K$ is the length of $h_{SC\,CB}$ in samples

$r_{non\text{-}EDMG}^{i_{TX}(2)}\left(n\frac{T_c}{N_{up}}\right) = 0$, for $n < 0$ and $n \ge N \times N_{up}$

$N$ is the total number of chips in the EDMG PPDU waveform

The definition of the pulse shaping filter impulse response, $h_{SC\,CB}$, and the $N_{up}$ parameter are implementation dependent.

#### 28.5.10.4.4 EDMG PPDU transmission over a 2.16 GHz or 2.16+2.16 GHz channel with $N_{STS} > 1$ and 4.32 GHz, 6.48 GHz, 8.64 GHz or 4.32+4.32 GHz channel with $N_{STS} \ge 1$

##### 28.5.10.4.4.1 General

An EDMG SC mode SU PPDU transmitted over a 2.16 GHz or 2.16+2.16 GHz channel with more than one stream ($N_{STS} > 1$) or over a 4.32 GHz, 6.48 GHz, 8.64 GHz, or 4.32+4.32 GHz channels with one or more space-time streams ($N_{STS} \ge 1$) is composed of pre-EDMG modulated fields, EDMG preamble, Data field and TRN field. The total number of transmit chains, $N_{TX}$, shall be constant over the different fields of the EDMG SU PPDU.

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#### 28.5.10.4.4.2 Pre-EDMG modulated fields transmission

The pre-EDMG modulated fields of the PPDU includes the following modulated fields:

$$r_{pre\text{-}EDMG}\left(nT_c\right) = r_{L\text{-}STF}\left(nT_c\right) + r_{L\text{-}CEF}\left(nT_c - t_{L\text{-}CEF}\right) + r_{L\text{-}Header}\left(nT_c - t_{L\text{-}Header}\right)$$
$$+ r_{EDMG\text{-}Header\text{-}A}\left(nT_c - t_{EDMG\text{-}Header\text{-}A}\right)$$

where

$t_{L\text{-}CEF} = T_{L\text{-}STF}$ is the duration of the L-STF field of the PPDU

$t_{L\text{-}Header} = t_{L\text{-}CEF} + T_{L\text{-}CEF}$ is the total duration of the L-STF and L-CEF fields of the PPDU

$t_{EDMG\text{-}Header\text{-}A} = t_{L\text{-}Header} + T_{L\text{-}Header}$ is the total duration of the L-STF, L-CEF, and L-Header fields of the PPDU

The definition of the L-STF, L-CEF, and L-Header fields is provided in 28.3.3.2.2 (L-STF definition), 28.3.3.2.3 (L-CEF definition), and 28.3.3.2.4 (L-Header definition), respectively.

The PPDU waveform of the pre-EDMG modulated fields for the $i_{TX}^{\text{th}}$ transmit chain shall be defined as follows:

$$r_{pre\text{-}EDMG}^{i_{TX}}{}^{(1)}\left(nT_c\right) = \left[Q_{pre\text{-}EDMG}\right]_{i_{TX},1} \cdot r_{pre\text{-}EDMG}\left(nT_c\right), 1 \le i_{TX} \le N_{TX}$$

where

$Q_{pre\text{-}EDMG}$ is a spatial mapping matrix

$[\ ]_{m,n}$ is a matrix element from $m^{\text{th}}$ row and $n^{\text{th}}$ column

For spatial expansion, the PPDU waveform of the pre-EDMG modulated fields for the $i_{TX}^{\text{th}}$ transmit chain includes a cyclic shift, $T_{SC}^{i_{TX}}$, dependent on the particular transmit chain number. The cyclic shift, $T_{SC}^{i_{TX}}$, is defined in SC chip units as $(i_{TX} - 1) \times N_c \times T_c$, where $N_c$ is equal to 4 chips and $T_c$ is a chip time duration.

$$r_{pre\text{-}EDMG}^{i_{TX}}{}^{(1)}\left(nT_c\right) = \begin{cases} r_{pre\text{-}EDMG}^{i_{TX}}{}^{(1)}\left(nT_c + T_{SC}^{i_{TX}}\right), & n = 0,1,\ldots,N-1-T_{SC}^{i_{TX}}/T_c \\ r_{pre\text{-}EDMG}^{i_{TX}}{}^{(1)}\left(nT_c - \left(NT_c - T_{SC}^{i_{TX}}\right)\right), & n = N - T_{SC}^{i_{TX}}/T_c,\ldots,N-1 \end{cases}, \quad 1 \le i_{TX} \le N_{TX}$$

where

$N$ is the total number of chips in the pre-EDMG field of the EDMG PPDU waveform

The waveform for the pre-EDMG modulated fields for $i_{TX}^{\text{th}}$ transmit chain is obtained by upsampling and filtering and then appropriate carrier frequency shift of the $r_{pre-EDMG}^{i_{TX}}{}^{(1)}\left(nT_c\right)$ waveform, if required. The upsampling procedure is applied using a factor of $N_{up}$. The filtering procedure is performed with a pulse shaping filter, $h_{SC\,CB}$, defined at the $N_{up} \times F_c$ sampling rate as follows:


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$$r_{pre-EDMG}^{i_{TX}\ (2)}\left(n\frac{T_c}{N_{up}}\right)=\begin{cases} r_{pre-EDMG}^{i_{TX}\ (1)}\left(n\frac{T_c}{N_{up}}\right), n=0,N_{up},2*N_{up}... \\ 0 \qquad\qquad otherwise \end{cases}$$

$$r_{pre-EDMG}^{i_{TX}\ (3)}\left(n\frac{T_c}{N_{up}}\right)=\sum_{k=0}^{K-1} r_{pre-EDMG}^{i_{TX}\ (2)}\left((n-k)\frac{T_c}{N_{up}}\right)h_{SC\,CB}(k), n=0,1,...$$

$$r_{pre-EDMG}^{i_{TX}\ (4)}\left(n\frac{T_c}{N_{up}}\right)=r_{pre-EDMG}^{i_{TX}\ (3)}\left(\left(n+\frac{K-1}{2}\right)\frac{T_c}{N_{up}}\right), n=0,1,...$$

where

$K$ is the length of $h_{SC\,CB}$ in samples

$$r_{pre\text{-}EDMG}^{i_{TX}\ (2)}\left(n\frac{T_c}{N_{up}}\right)=0, \text{ for } n<0 \text{ and } n\geq N\times N_{up}$$

$N$ is the total number of chips in the pre-EDMG field of the EDMG PPDU

The waveform of the pre-EDMG modulated fields for the $i_{TX}^{\text{th}}$ transmit chain when transmitted over a 2.16 GHz or 2.16+2.16 GHz channel shall be defined as follows:

$$r_{pre-EDMG}^{i_{TX}}\left(n\frac{T_c}{N_{up}}\right)=r_{pre-EDMG}^{i_{TX}\ (4)}\left(n\frac{T_c}{N_{up}}\right), 1\leq i_{TX}\leq N_{TX}$$

For a 2.16+2.16 GHz transmission, the total number of transmit chains, $N_{TX}$, shall be an even number. The first $N_{TX}/2$ transmit chains shall be used for transmission on the primary channel and the second $N_{TX}/2$ transmit chains shall be used for transmission on the secondary channel (see 28.3.4 (Channelization)).

The waveform of the pre-EDMG modulated fields for the $i_{TX}^{\text{th}}$ transmit chain when transmitted using duplicate transmission over a 4.32 GHz or 4.32+4.32 GHz channel shall be defined as follows:

$$r_{pre\text{-}EDMG}^{i_{TX}}\left(n\frac{T_c}{N_{up}}\right)=r_{pre\text{-}EDMG}^{i_{TX}\ (4)}\left(n\frac{T_c}{N_{up}}+\Delta t_1\right)\cdot\frac{1}{\sqrt{2}}\exp\left(-j2\pi\left(\frac{\Delta F}{2}\right)\left(\frac{T_c}{N_{up}}\right)n\right)$$

$$+r_{pre\text{-}EDMG}^{i_{TX}\ (4)}\left(n\frac{T_c}{N_{up}}+\Delta t_2\right)\cdot\frac{1}{\sqrt{2}}\exp\left(+j2\pi\left(\frac{\Delta F}{2}\right)\left(\frac{T_c}{N_{up}}\right)n\right), 1\leq i_{TX}\leq N_{TX}$$

where

| | |
|---|---|
| $\Delta F$ | defines the channel spacing and is equal to 2.16 GHz |
| $\Delta t_1$ and $\Delta t_2$ | are in the range [0, $T_c$] |
| $\Delta t_i$ equal to 0 | corresponds to the primary channel |

For a 4.32+4.32 GHz transmission, the total number of transmit chains, $N_{TX}$, shall be an even number. The first $N_{TX}/2$ transmit chains shall be used for transmission on the primary and secondary channels and the second $N_{TX}/2$ transmit chains shall be used for transmission on the secondary1 and secondary2 channels (see 28.3.4 (Channelization)).

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The waveform of the pre-EDMG modulated fields for the $i_{TX}^{\text{th}}$ transmit chain when transmitted using duplicate transmission over a 6.48 GHz channel shall be defined as follows:

$$r_{pre\text{-}EDMG}^{i_{TX}}\left(n\frac{T_c}{N_{up}}\right) = r_{pre\text{-}EDMG}^{i_{TX}\ (4)}\left(n\frac{T_c}{N_{up}}+\Delta t_1\right)\cdot\frac{1}{\sqrt{3}}\exp\left(-j2\pi\Delta F\left(\frac{T_c}{N_{up}}\right)n\right)$$
$$+r_{pre\text{-}EDMG}^{i_{TX}\ (4)}\left(n\frac{T_c}{N_{up}}+\Delta t_2\right)\cdot\frac{1}{\sqrt{3}}$$
$$+r_{pre\text{-}EDMG}^{i_{TX}\ (4)}\left(n\frac{T_c}{N_{up}}+\Delta t_3\right)\cdot\frac{1}{\sqrt{3}}\exp\left(+j2\pi\Delta F\left(\frac{T_c}{N_{up}}\right)n\right), 1\le i_{TX}\le N_{TX}$$

where

$\Delta t_1$, $\Delta t_2$, and $\Delta t_3$ are in the range [0, $T_c$]
$\Delta t_i$ equal to 0 corresponds to the primary channel

The waveform of the pre-EDMG modulated fields for the $i_{TX}^{\text{th}}$ transmit chain when transmitted using duplicate transmission over an 8.64 GHz channel shall be defined as follows:

$$r_{pre\text{-}EDMG}^{i_{TX}}\left(n\frac{T_c}{N_{up}}\right) = r_{pre\text{-}EDMG}^{i_{TX}\ (4)}\left(n\frac{T_c}{N_{up}}+\Delta t_1\right)\cdot\frac{1}{\sqrt{4}}\exp\left(-j2\pi\left(\frac{3\Delta F}{2}\right)\left(\frac{T_c}{N_{up}}\right)n\right)$$
$$+r_{pre\text{-}EDMG}^{i_{TX}\ (4)}\left(n\frac{T_c}{N_{up}}+\Delta t_2\right)\cdot\frac{1}{\sqrt{4}}\exp\left(-j2\pi\left(\frac{\Delta F}{2}\right)\left(\frac{T_c}{N_{up}}\right)n\right)$$
$$+r_{pre\text{-}EDMG}^{i_{TX}\ (4)}\left(n\frac{T_c}{N_{up}}+\Delta t_3\right)\cdot\frac{1}{\sqrt{4}}\exp\left(+j2\pi\left(\frac{\Delta F}{2}\right)\left(\frac{T_c}{N_{up}}\right)n\right)$$
$$+r_{pre\text{-}EDMG}^{i_{TX}\ (4)}\left(n\frac{T_c}{N_{up}}+\Delta t_4\right)\cdot\frac{1}{\sqrt{4}}\exp\left(+j2\pi\left(\frac{3\Delta F}{2}\right)\left(\frac{T_c}{N_{up}}\right)n\right), 1\le i_{TX}\le N_{TX}$$

where

$\Delta t_1$, $\Delta t_2$, $\Delta t_3$, and $\Delta t_4$ are in the range [0, $T_c$]
$\Delta t_i$ equal to 0 corresponds to the primary channel

The definition of the pulse shaping filter impulse response, $h_{SC\,CB}$, and the $N_{up}$ parameter are implementation dependent.

#### 28.5.10.4.4.3 EDMG preamble and Data field transmission

For a single PPDU transmission, the EDMG modulated field of the EDMG preamble and Data field of an SU PPDU is defined for the $i_{TX}^{\text{th}}$ transmit chain at the EDMG SC chip rate $F_{c\ EDMG}$ and includes the following modulated fields:


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$$r^{i_{TX}}_{EDMG\text{-}Pream,\,Data}\left(n\frac{T_c}{N_{CB}}\right)=r^{i_{TX}}_{EDMG\text{-}STF}\left(n\frac{T_c}{N_{CB}}\right)+r^{i_{TX}}_{EDMG\text{-}CEF}\left(n\frac{T_c}{N_{CB}}-t_{EDMG\text{-}CEF}\right)$$
$$+r^{i_{TX}}_{Data}\left(n\frac{T_c}{N_{CB}}-t_{Data}\right),\ 1\le i_{TX}\le N_{TX}$$

where

$t_{EDMG\text{-}CEF}=T_{EDMG\text{-}STF}$ is the duration of the EDMG-STF field of the PPDU

$t_{Data}=t_{EDMG\text{-}CEF}+T_{EDMG-CEF}$ is the total duration of the EDMG-STF and EDMG-CEF fields of the PPDU

The EDMG-STF, EDMG-CEF, and Data field transmission is defined in 28.5.4 (EDMG-STF definition), 28.5.5 (EDMG-CEF definition), and 28.5.9.5.2 (Transmission in EDMG format), respectively.

For an EDMG A-PPDU transmission of $N_{PPDU}$ PPDUs, the EDMG modulated field of the EDMG preamble and Data field of an SU PPDU is defined for $i_{TX}^{th}$ transmit chain at the $F_{c\ EDMG}$ and includes the following modulated fields:

$$r^{i_{TX}}_{EDMG\text{-}Pream,\,Data}\left(n\frac{T_c}{N_{CB}}\right)=r^{i_{TX}}_{EDMG\text{-}STF}\left(n\frac{T_c}{N_{CB}}\right)+r^{i_{TX}}_{EDMG\text{-}CEF}\left(n\frac{T_c}{N_{CB}}-t_{EDMG\text{-}CEF}\right)$$
$$+r^{i_{TX}}_{Data_1}\left(n\frac{T_c}{N_{CB}}-t_{Data_1}\right)$$
$$+r^{i_{TX}}_{EDMG\text{-}Header\text{-}A_2}\left(n\frac{T_c}{N_{CB}}-t_{EDMG\text{-}Header\text{-}A_2}\right)+r^{i_{TX}}_{Data_2}\left(n\frac{T_c}{N_{CB}}-t_{Data_2}\right)$$
$$+\ldots$$
$$+r^{i_{TX}}_{EDMG\text{-}Header\text{-}A_{N_{PPDU}}}\left(n\frac{T_c}{N_{CB}}-t_{EDMG\text{-}Header\text{-}A_{N_{PPDU}}}\right)+r^{i_{TX}}_{Data_{N_{PPDU}}}\left(n\frac{T_c}{N_{CB}}-t_{Data_{N_{PPDU}}}\right),\ 1\le i_{TX}\le N_{TX}$$

where

$t_{EDMG\text{-}CEF}=T_{EDMG\text{-}STF}$ is the duration of the EDMG-STF field of the PPDU

$t_{Data_1}=t_{EDMG\text{-}CEF}+T_{EDMG\text{-}CEF}$ is the total duration of the EDMG-STF and EDMG-CEF fields of the PPDU

$t_{EDMG\text{-}Header\text{-}A_2}=t_{Data_1}+T_{Data_1}$ is the total duration of the EDMG-STF, EDMG-CEF, and $Data_1$ fields of the PPDU

$t_{Data_2}=t_{EDMG\text{-}Header\text{-}A_2}+T_{EDMG\text{-}Header\text{-}A_2}$ is the total duration of the EDMG-STF, EDMG-CEF, $Data_1$, and EDMG-Header-$A_2$ fields of the PPDU

…

$t_{EDMG\text{-}Header\text{-}A_{N_{PPDU}}}=t_{Data_{N_{PPDU}-1}}+T_{Data_{N_{PPDU}-1}}$ is the total duration of the EDMG-STF, EDMG-CEF, $Data_1$, EDMG-Header-$A_2$, $Data_2$, …, and $Data_{NPPDU-1}$ fields of the PPDU

$t_{Data_{N_{PPDU}}}=t_{EDMG\text{-}Header-A_{N_{PPDU}}}+T_{EDMG\text{-}Header-A_{N_{PPDU}}}$ is the total duration of the EDMG-STF, EDMG-CEF, $Data_1$, EDMG-Header-$A_2$, $Data_2$, …, $Data_{NPPDU-1}$, and EDMG-Header-$A_{NPPDU}$ fields of the PPDU

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The EDMG-STF, EDMG-CEF, Data, and EDMG-Header-A field transmission is defined in 28.5.4 (EDMG-STF definition), 28.5.5 (EDMG-CEF definition), 28.5.9.5.2 (Transmission in EDMG format), and 28.5.7 (Encoding of EDMG-Header-A for EDMG A-PPDU transmission), respectively.

For spatial expansion, the PPDU waveform of the EDMG preamble and Data field for the $i_{TX}^{\text{th}}$ transmit chain includes a cyclic shift, $T_{SC}^{i_{TX}}$, dependent on the particular transmit chain number. The cyclic shift, $T_{SC}^{i_{TX}}$, is defined in SC chip units as $(i_{TX}-1) \times N_c \times T_c$, where $N_c$ is equal to 4 chips and $T_c$ is a chip time duration.

$$r_{EDMG\text{-}Pream,\,Data}^{i_{TX}}\left(n\frac{T_c}{N_{CB}}\right) =$$

$$= \begin{cases} r_{EDMG\text{-}Pream,\,Data}^{i_{TX}}\left(n\left(\frac{T_c}{N_{CB}}\right)+T_{SC}^{i_{TX}}\right), & n = 0,1,...,N-1-T_{SC}^{i_{TX}}/\left(T_c/N_{CB}\right) \\ r_{EDMG\text{-}Pream,\,Data}^{i_{TX}}\left(n\left(\frac{T_c}{N_{CB}}\right)-\left(N\left(\frac{T_c}{N_{CB}}\right)-T_{SC}^{i_{TX}}\right)\right), & n = N-T_{SC}^{i_{TX}}/\left(T_c/N_{CB}\right),...,N-1 \end{cases}, \quad 1 \le i_{TX} \le N_{TX}$$

where

$N$ is the total number of chips in the EDMG preamble and Data fields of the EDMG PPDU

#### 28.5.10.4.4.4 TRN field transmission

The TRN field, $r_{TRN}^{i_{TX}}\left(n\frac{T_c}{N_{CB}}\right)$, shall be defined at the EDMG SC chip rate $F_{c\ EDMG}$ per $i_{TX}^{\text{th}}$ transmit chain as defined in 28.9.2.2.6 (TRN subfield definition for EDMG SC PPDUs and EDMG control mode PPDUs).

#### 28.5.10.4.4.5 Filtering procedure

The EDMG preamble, Data field, and TRN field for the $i_{TX}^{\text{th}}$ transmit chain are defined as follows:

$$r_{EDMG\text{-}Pream,\,Data,\,TRN}^{i_{TX}\,(1)}\left(n\frac{T_c}{N_{CB}}\right) = r_{EDMG\text{-}Pream,\,Data}^{i_{TX}}\left(n\frac{T_c}{N_{CB}}\right)$$

$$+ r_{TRN}^{i_{TX}}\left(n\frac{T_c}{N_{CB}} - t_{TRN}\right), 1 \le i_{TX} \le N_{TX}$$

where

$t_{TRN} = t_{Data} + T_{Data}$ is the total duration of the EDMG-STF, EDMG-CEF, and Data fields of the PPDU

The EDMG preamble, Data field, and TRN field are filtered and resampled with a conversion rate ratio $N_{up}/N_{CB}$. For example, the resampling procedure for a ratio $N_{up}/N_{CB}$ equal to 3/2 can be defined as follows:


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$$r^{i_{TX}\ (2)}_{EDMG\text{-}Pream,\ Data,\ TRN}\left(n\frac{T_c}{3N_{CB}}\right)=\begin{cases} r^{i_{TX}\ (1)}_{EDMG\text{-}Pream,\ Data,\ TRN}\left(n\frac{T_c}{3N_{CB}}\right), n=0,3,6... \\ 0 \quad \text{otherwise} \end{cases}$$

$$r^{i_{TX}\ (3)}_{EDMG\text{-}Pream,\ Data,\ TRN}\left(n\frac{T_c}{3N_{CB}}\right)=\sum_{k=0}^{K-1} r^{i_{TX}\ (2)}_{EDMG\text{-}Pream,\ Data,\ TRN}\left((n-k)\frac{T_c}{3N_{CB}}\right)h_{SC\,CB}(k), n=0,1,...$$

$$r^{i_{TX}}_{EDMG\text{-}Pream,\ Data,\ TRN}\left(n\frac{2T_c}{3N_{CB}}\right)=r^{i_{TX}\ (3)}_{EDMG\text{-}Pream,\ Data,\ TRN}\left(\left(2n+\frac{K-1}{2}\right)\frac{T_c}{3N_{CB}}\right), n=0,1,...$$

where

$K$ is the length of $h_{SC\,CB}$ in samples

$$r^{i_{TX}\ (2)}_{EDMG\text{-}Pream,Data,TRN}\left(n\frac{T_c}{3N_{CB}}\right)=0, \text{ for } n<0 \text{ and } n\geq N\times 3$$

$N$ is the total number of chips in the EDMG preamble, Data field, and TRN field of the EDMG PPDU

The EDMG SC mode SU PPDU waveform for the $i_{TX}^{\text{th}}$ transmit chain concatenates the pre-EDMG modulated fields, EDMG preamble, Data field, and TRN field and shall be defined as follows:

$$r^{i_{TX}}_{PPDU}\left(n\frac{T_c}{N_{up}}\right)=r^{i_{TX}}_{pre\text{-}EDMG}\left(n\frac{T_c}{N_{up}}\right)+r^{i_{TX}}_{EDMG\text{-}Pream,\ Data,\ TRN}\left(n\frac{T_c}{N_{up}}-t_{EDMG\text{-}STF}\right), 1\leq i_{TX}\leq N_{TX}$$

where

$t_{EDMG\text{-}STF}=t_{EDMG\text{-}Header\text{-}A}+T_{EDMG\text{-}Header\text{-}A}$ is the total duration of the L-STF, L-CEF, L-Header, and EDMG-Header-A fields of the PPDU

The definition of the pulse shaping filter impulse response, $h_{SC\,CB}$, and the $N_{up}$ parameter are implementation dependent.

### 28.5.10.5 EDMG MU PPDU transmission

#### 28.5.10.5.1 General

The EDMG SC mode MU PPDU transmitted over a 2.16 GHz, 4.32 GHz, 6.48 GHz, 8.64 GHz, 2.16+2.16 GHz, or 4.32+4.32 GHz channel with multiple space-time streams ($N_{STS}$ > 1) for two or more users ($N_{user}$ > 1) is composed of pre-EDMG modulated fields, EDMG preamble, EDMG-Header-B field, Data field and TRN field. The TRN field might not be present in a transmitted MU PPDU depending on particular transmission parameters. The total number of transmit chains, $N_{TX}$, shall be constant over the different fields of a transmitted EDMG MU PPDU.

#### 28.5.10.5.2 Pre-EDMG modulated fields transmission

The pre-EDMG modulated fields of the PPDU shall be transmitted as specified in 28.5.10.4.4.2 (Pre-EDMG modulated fields transmission).

#### 28.5.10.5.3 EDMG preamble, EDMG-Header-B, and Data field transmission

The EDMG preamble, EDMG-Header-B and Data field of an EDMG MU PPDU is defined for $i_{TX}^{\text{th}}$ transmit chain at the EDMG SC chip rate $F_{c\,EDMG}$ and includes the following modulated fields:

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$$r^{i_{TX}}_{EDMG\text{-}Pream,\ EDMG\text{-}Header\text{-}B,\ Data}\left(n\frac{T_c}{N_{CB}}\right)=r^{i_{TX}}_{EDMG\text{-}STF}\left(n\frac{T_c}{N_{CB}}\right)+r^{i_{TX}}_{EDMG\text{-}CEF}\left(n\frac{T_c}{N_{CB}}-t_{EDMG\text{-}CEF}\right)$$
$$+r^{i_{TX}}_{EDMG\text{-}Header\text{-}B}\left(n\frac{T_c}{N_{CB}}-t_{EDMG\text{-}Header\text{-}B}\right)+r^{i_{TX}}_{Data}\left(n\frac{T_c}{N_{CB}}-t_{Data}\right),\ 1\le i_{TX}\le N_{TX}$$

where

$t_{EDMG\text{-}CEF}=T_{EDMG\text{-}STF}$ is the duration of the EDMG-STF field of the PPDU

$t_{EDMG\text{-}Header\text{-}B}=t_{EDMG\text{-}CEF}+T_{EDMG\text{-}CEF}$ is the total duration of the EDMG-STF and EDMG-CEF fields of the PPDU

$t_{Data}=t_{EDMG\text{-}Header\text{-}B}+T_{EDMG\text{-}Header\text{-}B}$ is the total duration of the EDMG-STF, EDMG-CEF, and EDMG-Header-B fields of the PPDU

The EDMG-STF, EDMG-CEF, Data, and EDMG-Header-B field transmission is defined in 28.5.4 (EDMG-STF definition), 28.5.5 (EDMG-CEF definition), 28.5.9.5.2 (Transmission in EDMG format), and 28.5.6 (Encoding of EDMG-Header-B), respectively.

#### 28.5.10.5.4 TRN field transmission

The TRN field, $r^{i_{TX}}_{TRN}\left(n\frac{T_c}{N_{CB}}\right)$, shall be defined at the EDMG SC chip rate $F_{c\ EDMG}$ per $i_{TX}^{\text{th}}$ transmit chain as defined in 28.9.2.2.6 (TRN subfield definition for EDMG SC PPDUs and EDMG control mode PPDUs).

#### 28.5.10.5.5 Filtering procedure

The EDMG preamble, EDMG-Header-B, Data field, and TRN field for the $i_{TX}^{\text{th}}$ transmit chain are defined as follows:

$$r^{i_{TX}\,(1)}_{EDMG\text{-}Pream,\ EDMG\text{-}Header\text{-}B,\ Data,\ TRN}\left(n\frac{T_c}{N_{CB}}\right)=r^{i_{TX}}_{EDMG\text{-}Pream,\ EDMG\text{-}Header\text{-}B,\ Data}\left(n\frac{T_c}{N_{CB}}\right)$$
$$+r^{i_{TX}}_{TRN}\left(n\frac{T_c}{N_{CB}}-t_{TRN}\right),\ 1\le i_{TX}\le N_{TX}$$

where

$t_{TRN}=t_{Data}+T_{Data}$ is the total duration of the EDMG-STF, EDMG-CEF, EDMG-Header-B, and Data fields of the PPDU

The EDMG preamble, EDMG-Header-B, Data field and TRN field are filtered and resampled with a conversion rate ratio $N_{up}/N_{CB}$. For example, the resampling procedure for a ratio $N_{up}/N_{CB}$ equal to 3/2 can be defined as follows:


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$$r^{i_{TX}\ (2)}_{EDMG\text{-}Pream,\ Header\text{-}B,\ Data,\ TRN}\left(n\frac{T_c}{3N_{CB}}\right)=\begin{cases} r^{i_{TX}\ (1)}_{EDMG\text{-}Pream,\ EDMG\text{-}Header\text{-}B,\ Data,\ TRN}\left(n\frac{T_c}{3N_{CB}}\right), n=0,3,6... \\ 0 \quad \text{otherwise} \end{cases}$$

$$r^{i_{TX}\ (3)}_{EDMG\text{-}Pream,\ Header\text{-}B,\ Data,\ TRN}\left(n\frac{T_c}{3N_{CB}}\right)=\sum_{k=0}^{K-1} r^{i_{TX}\ (2)}_{EDMG\text{-}Pream,\ Header\text{-}B,\ Data,\ TRN}\left((n-k)\frac{T_c}{3N_{CB}}\right)h_{SC\,CB}(k), n=0,1,...$$

$$r^{i_{TX}}_{EDMG\text{-}Pream,\ Header\text{-}B,\ Data,\ TRN}\left(n\frac{2T_c}{3N_{CB}}\right)=r^{i_{TX}\ (3)}_{EDMG\text{-}Pream,\ Header\text{-}B,\ Data,\ TRN}\left(\left(2n+\frac{K-1}{2}\right)\frac{T_c}{3N_{CB}}\right), n=0,1,...$$

where

$K$ is the length of $h_{SC\,CB}$ in samples

$$r^{i_{TX}\ (2)}_{EDMG\text{-}Pream,Header\text{-}B,Data,TRN}\left(n\frac{T_c}{3N_{CB}}\right)=0, \text{ for } n<0 \text{ and } n\geq N\times 3$$

$N$ is the total number of chips in the EDMG preamble, EDMG-Header-B, Data, and TRN fields of the EDMG PPDU

The EDMG SC mode MU PPDU waveform for the $i_{TX}^{\text{th}}$ transmit chain concatenates the pre-EDMG modulated fields, EDMG preamble, EDMG-Header-B, Data field, and TRN field and shall be defined as follows:

$$r^{i_{TX}}_{PPDU}\left(n\frac{T_c}{N_{up}}\right)=r^{i_{TX}}_{pre\text{-}EDMG}\left(n\frac{T_c}{N_{up}}\right)+r^{i_{TX}}_{EDMG\text{-}Pream,\ Header\text{-}B,\ Data,\ TRN}\left(n\frac{T_c}{N_{up}}-t_{EDMG\text{-}STF}\right), 1\leq i_{TX}\leq N_{TX}$$

where

$t_{EDMG\text{-}STF}=t_{EDMG\text{-}Header\text{-}A}+T_{EDMG\text{-}Header\text{-}A}$ is the total duration of the L-STF, L-CEF, L-Header, and EDMG-Header-A fields of the PPDU

The definition of the pulse shaping filter impulse response, $h_{SC\,CB}$, and the $N_{up}$ parameter are implementation dependent.

### 28.5.11 Performance requirements

#### 28.5.11.1 Transmit requirements

##### 28.5.11.1.1 Transmit modulation accuracy (EVM) test and requirements

This subclause specifies the EVM test and corresponding requirements for the following:

— PPDUs transmitted with the TXVECTOR parameter EDMG_MODULATION equal to EDMG_SC_MODE and with TXVECTOR parameters CH_BANDWIDTH and CHANNEL_AGGREGATION equal to any valid combination indicated in Table 28-21 (2.16 GHz, 4.32 GHz, 6.48 GHz, and 8.64 GHz channels used by an EDMG STA(11ay)), Table 28-22 (2.16+2.16 GHz channel used by an EDMG STA(11ay)), or Table 28-23 (4.32+4.32 GHz channel used by an EDMG STA(11ay)).

— PPDUs transmitted with the TXVECTOR parameter NON_EDMG_MODULATION equal to NON_EDMG_DUP_SC_MODE and with TXVECTOR parameter CH_BANDWIDTH with at least 2 bits equal one.

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The transmit modulation accuracy test shall be performed by instrumentation capable of converting the transmitted signals into a stream of complex samples at sampling rate greater than or equal to the SC chip rate, with the following exceptions:

— If the TXVECTOR parameter NON_EDMG_MODULATION is (M118)equal to NON_EDMG_DUP_SC_MODE, the transmission in the two or more 2.16 GHz channels may be tested independently.

— If the TXVECTOR parameter CHANNEL_AGGREGATION is (M118)equal to (#4167)AGGREGATED, the transmission in the two (adjacent or non-adjacent) 2.16 GHz channels or 4.32 GHz channels may be tested independently.

In the two cases indicated above, transmit modulation accuracy of each 2.16 GHz channel (when NON_EDMG_MODULATION is (M118)equal to NON_EDMG_DUP_SC_MODE or when CHANNEL_AGGREGATION is (M118)equal to (#4167)AGGREGATED) or of each 4.32 GHz channel (when CHANNEL_AGGREGATION is (M118)equal to (#4167)AGGREGATED) shall meet the required value in Table 28-58 (EDMG-MCSs for the EDMG SC mode(11ay)) through Table 28-61 (EDMG-MCSs 2 to 6 for the EDMG SC mode if the DCM π/2-BPSK Applied field is 1(11ay)) using only the signal within the corresponding channel.

If the TXVECTOR parameter EDMG_MODULATION is (M118)equal to EDMG_SC_MODE, the TXVECTOR parameters NUM_STS and NUM_TX_CHAINS shall be equal, and the value of both parameters shall be equal to the number of utilized testing instrumentation input ports or antennas, if ports are not available on the STA under test. In the test, $N_{SS} = N_{STS}$ (no STBC) shall be used. If the TXVECTOR parameter NUM_STS is (M118)equal to a value greater than 1, the two or more space-time streams shall have the same modulation type. The identity matrix should be used as the expansion matrix. (#3445)Each port or antenna connected to a transmit chain of the transmitting STA shall be assigned to a port or antenna of the testing instrumentation in a way that makes signal coupling between the different transmit signal paths negligible.

The instrumentation used in the transmit EVM accuracy test shall have sufficient accuracy in terms of I/Q arm amplitude and phase balance, DC offsets, phase noise, and analog-to-digital quantization noise, so as not to mask or degrade the true EVM measurement. A possible embodiment of such a setup is converting the signals to a low IF frequency with a microwave synthesizer, sampling the signal with a digital oscilloscope and decomposing it digitally into quadrature components. The sampled signal shall be processed in a manner similar to an actual receiver, according to the following steps, or equivalent procedure:

— Detect the start of the PPDU.

— Establish fine timing.

— Estimate the coarse and fine frequency offsets.

— De-rotate the frame according to the estimated frequency offset.

— Estimate the complex channel impulse response for each of the transmit chains using the EDMG-CEF field, if present. If not, channel estimation is performed using the L-CEF field.

— For each SC symbol block, estimate time-dependent phase variations using guard interval symbols (for example, by interpolating the phase between the prefix and postfix GI samples), and de-rotate the corresponding symbol samples accordingly.

— For each SC symbol block, perform demodulation and apply a minimum mean square error equalization matrix generated from the channel estimate. Group the demodulated symbols from each SC symbol block, and combine the demodulated data from each spatial stream into a vector.

— For each element of the vector, find the closest constellation point and compute the Euclidian distance from it.

— Compute the average relative constellation RMS error (EVM) across PPDUs according to the formula:


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$$EVM = 20\log_{10}\left(\frac{1}{N_f}\sum_{f=1}^{N_f}\sqrt{\frac{\sum_{n=0}^{N_{BLKS}-1}\sum_{j=1}^{N_{ss}}\sum_{k=0}^{N_{SPB}-1}\left(I(f,n,j,k)-I^{*}(f,n,j,k)-I_0(f,j)\right)^2+\left(Q(f,n,j,k)-Q^{*}(f,n,j,k)-Q_0(f,j)\right)^2}{N_{BLKS}\times N_{SS}\times N_{SPB}\times P_0}}\right)$$

where

$N_f$ is the number of frames for the measurement

$N_{BLKS}$ is the number of SC symbol blocks within each frame

$N_{SS}$ is the number of spatial streams of each frame

$N_{SPB}$ is the number of data modulated symbols per SC symbol block

$P_0$ is the average power of the constellation

$I(f,n,j,k)$ and $Q(f,n,j,k)$ denote the observed symbol point in the complex plane for the $k^{th}$ symbol of the $n^{th}$ SC symbol block and $j^{th}$ spatial stream within the $f^{th}$ frame

$I^{*}(f,n,j,k)$ and $Q^{*}(f,n,j,k)$ denote the ideal symbol point in the complex plane for the $k^{th}$ symbol of the $n^{th}$ SC symbol block and $j^{th}$ spatial stream within the $f^{th}$ frame

$I_0(f,j)$ and $Q_0(f,j)$ are the complex DC term chosen to minimize the EVM, which may be dependent on the frame index ($f$) and spatial stream index ($j$)

The total number of symbols used in the test is equal to $N_f \times N_{BLKS} \times N_{SS} \times N_{SPB}$ with the constraint that $N_{BLKS}$ shall be at least 20 and that $N_f$ shall be at least 20. Random data shall be used for the symbols and frames.

The test equipment shall use a root-raised cosine filter with roll-off factor of 0.25 for the pulse shaping filter when conducting EVM measurements.

The transmit pulse shaping filter impulse response is implementation specific.

The EVM shall not exceed an MCS dependent value provided in Table 28-58 (EDMG-MCSs for the EDMG SC mode(11ay)) through Table 28-61 (EDMG-MCSs 2 to 6 for the EDMG SC mode if the DCM π/2-BPSK Applied field is 1(11ay)).

Transmit requirements of PPDUs transmitted with TXVECTOR parameter NON_EDMG_MODULATION equal to DMG_SC_MODE are defined in 20.5.4 (Performance requirements).

**Table 28-58—EDMG-MCSs for the EDMG SC mode(11ay)**

| MCS | EVM value (dB) |
|---|---|
| 1 | –6 |
| 2 | –7 |
| 3 | –9 |
| 4 | –10 |
| 5 | –12 |

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**Table 28-58—EDMG-MCSs for the EDMG SC mode(11ay) *(continued)***

| MCS | EVM value (dB) |
|---|---|
| 6 | –13 |
| 7 | –11 |
| 8 | –12 |
| 9 | –13 |
| 10 | –15 |
| 11 | –16 |
| 12 | –19 |
| 13 | –20 |
| 14 | –21 |
| 15 | –22 |
| 16 | –23 |
| 17 | –24 |
| 18 | –25 |
| 19 | –27 |
| 20 | –28 |
| 21 | –29 |

**Table 28-59—EDMG-MCSs 12 and 13 for the EDMG SC mode if the π/2-8-PSK Applied field is 1(11ay)**

| MCS | EVM value (dB) |
|---|---|
| 12 | –17 |
| 13 | –20 |

**Table 28-60—EDMG-MCSs 17 to 21 for the EDMG SC mode if the π/2-64-NUC Applied field is 1(11ay)**

| MCS | EVM value (dB) |
|---|---|
| 17 | –24 |
| 18 | –25 |


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**Table 28-60—EDMG-MCSs 17 to 21 for the EDMG SC mode if the π/2-64-NUC Applied field is 1(11ay)**

| MCS | EVM value (dB) |
|---|---|
| 19 | –27 |
| 20 | –28 |
| 21 | –29 |

**Table 28-61—EDMG-MCSs 2 to 6 for the EDMG SC mode if the DCM π/2-BPSK Applied field is 1(11ay)**

| MCS | EVM value (dB) |
|---|---|
| 2 | –7 |
| 3 | –9 |
| 4 | –10 |
| 5 | –12 |
| 6 | –13 |

#### 28.5.11.1.2 Time of Departure accuracy

(#8057)The RMS accuracy of the time of departure provided in TIME_OF_DEPARTURE shall be less than or equal to 80 ns.

The Time of Departure accuracy test evaluates TIME_OF_DEPARTURE against aTxPHYTxStartRMS and aTxPHYTxStartRMS against TIME_OF_DEPARTURE_ACCURACY_TEST_THRESH as defined in Annex P with the following test parameters:

- MULTICHANNEL_SAMPLING_RATE is set to aDMGChipRate.
- FIRST_TRANSITION_FIELD is L-STF of the waveform transmitted in the primary channel.
- SECOND_TRANSITION_FIELD is L-CEF of the waveform transmitted in the primary channel.
- TRAINING_FIELD is L-CEF of the waveform transmitted in the primary channel.
- TIME_OF_DEPARTURE_ACCURACY_TEST_THRESH is set to aDMGTimeOfDepartureAccuracyThresh.

### 28.5.11.2 Receive requirements

CCA sensitivity requirements are defined in 28.3.8 (CCA sensitivity).

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## 28.6 EDMG OFDM mode

### 28.6.1 General

Transmission and reception of 2.16 GHz PPDU, 4.32 GHz PPDU, 6.48 GHz PPDU, 8.64 GHz PPDU, 2.16+2.16 GHz PPDU, and 4.32+4.32 GHz PPDU using the EDMG OFDM mode are optional. This applies to SU and MU PPDUs with one or more spatial streams.

### 28.6.2 OFDM signal parameters

#### 28.6.2.1 General

This subclause defines main EDMG OFDM signal parameters for 2.16 GHz ($N_{CB}$ = 1), 4.32 GHz ($N_{CB}$ = 2), 6.48 GHz ($N_{CB}$ = 3), 8.64 GHz ($N_{CB}$ = 4), 2.16+2.16 GHz ($N_{CB}$ = 1), and 4.32+4.32 GHz ($N_{CB}$ = 2) transmissions.

#### 28.6.2.2 Timing related parameters

Table 28-62 (EDMG OFDM mode timing related parameters1(11ay)) provides a summary of the timing related parameters of the EDMG OFDM mode.

**Table 28-62—EDMG OFDM mode timing related parameters1(11ay)**

| Parameter | Value | | | |
|---|---|---|---|---|
| | $N_{CB}$ = 1 | $N_{CB}$ = 2 | $N_{CB}$ = 3 | $N_{CB}$ = 4 |
| $N_{SD}$: Number of data subcarriers | 336 | 734 | 1134 | 1532 |
| $N_{SP}$: Number of pilot subcarriers | 16 | 36 | 56 | 76 |
| $N_{DC}$: Number of DC subcarriers | 3 | 3 | 3 | 3 |
| $N_{ST}$: Total number of subcarriers | 355 | 773 | 1193 | 1611 |
| $N_{SR}$: Number of subcarriers occupying half of the overall bandwidth | 177 | 386 | 596 | 805 |
| $N_{GI\ short}$: short guard interval length | 48 | 96 | 144 | 192 |
| $N_{GI\ normal}$: normal guard interval length | 96 | 192 | 288 | 384 |
| $N_{GI\ long}$: long guard interval length | 192 | 384 | 576 | 768 |
| $\Delta_F$: Subcarrier frequency spacing | 5.15625 MHz | 5.15625 MHz | 5.15625 MHz | 5.15625 MHz |
| $F_s$: EDMG OFDM sample rate | 2.64 GHz | 5.28 GHz | 7.92 GHz | 10.56 GHz |
| $T_s$: EDMG OFDM sample time duration | 0.38 ns | 0.19 ns | 0.13 ns | 0.09 ns |
| $N_{DFT}$: DFT size | 512 | 1024 | 1536 | 2048 |
| $T_{DFT}$: OFDM IDFT/DFT period | 0.194 µs | 0.194 µs | 0.194 µs | 0.194 µs |
| $T_{GI\ short}$: short guard interval duration | 18.18 ns | 18.18 ns | 18.18 ns | 18.18 ns |
| $T_{GI\ normal}$: normal guard interval duration | 36.36 ns | 36.36 ns | 36.36 ns | 36.36 ns |
| $T_{GI\ long}$: long guard interval duration | 72.72 ns | 72.72 ns | 72.72 ns | 72.72 ns |


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NOTE—The values given for parameters $N_{GI\ short}$, $N_{GI\ normal}$, and $N_{GI\ long}$ correspond to the number of elements in the GI for each GI length and $N_{CB}$ value.

The pre-EDMG modulated fields are defined at the DMG SC chip rate $F_c$ and the corresponding chip time duration $T_c$ (see Table 28-47 (EDMG SC mode timing-related parameters(11ay))). Then, the resampling procedure is applied with 3/2 sample rate conversion ratio to achieve the effective sample rate of $(3/2) \times f_c$ and sample time duration of $(2/3) \times 1/f_c$.

The EDMG modulated fields are defined at the EDMG OFDM sample rate $F_s = 2.64 \times N_{CB}$ GHz and the corresponding sample time duration $T_s = 1 / (2.64 \times N_{CB})$ ns.

### 28.6.2.3 DC relative shift to carrier frequency

The DC relative frequency shift is applied in digital domain to the EDMG-STF, EDMG-CEF, Data, and TRN fields of an EDMG OFDM mode PPDU. The DC relative shift is frequency channel dependent, and denoted as $(f_{DC} - f_c)$, where $f_c$ is the center frequency of the carrier and $f_{DC}$ is the DC subcarrier frequency. $f_{DC}$ and the DC relative shift are defined in Table 28-63 (DC relative shift to carrier frequency(11ay)).

NOTE—By applying the DC relative shift, each of the subcarrier frequencies for any channel numbers can be denoted as $64.8 + \Delta_F \times n$ GHz, where $n$ is an integer. This makes the space between DC subcarrier frequencies of any two channels an integer multiple of the OFDM subcarrier spacing, and the subcarrier frequencies for 4.32 GHz or wider channels are aligned with the subcarriers in 2.16 GHz channels. In all cases, the relative shift between the DC subcarrier frequency and the center frequency of the carrier does not exceed half of the subcarrier spacing.

**Table 28-63—DC relative shift to carrier frequency(11ay)**

| Number of contiguous 2.16 GHz channels ($N_{CB}$) | Channel number | Center frequency of the carrier, $f_c$ (GHz) | DC subcarrier frequency, $f_{DC}$ (GHz) | DC relative shift, $(f_{DC} - f_c)$ (MHz) |
|---|---|---|---|---|
| 1 | 1 | 58.32 | $64.8 - \Delta_F \times 3 \times 419$ | –1.4063 |
| | 2 | 60.48 | $64.8 - \Delta_F \times 2 \times 419$ | –0.9375 |
| | 3 | 62.64 | $64.8 - \Delta_F \times 419$ | –0.4688 |
| | 4 | 64.8 | 64.8 | 0 |
| | 5 | 66.96 | $64.8 + \Delta_F \times 419$ | 0.4688 |
| | 6 | 69.12 | $64.8 + \Delta_F \times 2 \times 419$ | 0.9375 |
| | 7 | 71.28 | $64.8 + \Delta_F \times 3 \times 419$ | 1.4063 |
| | 8 | 73.44 | $64.8 + \Delta_F \times 4 \times 419$ | 1.8750 |
| 2 | 9 | 59.4 | $64.8 - \Delta_F \times 1047$ | 1.4062 |
| | 10 | 61.56 | $64.8 - \Delta_F \times 628$ | 1.8750 |
| | 11 | 63.72 | $64.8 - \Delta_F \times 209$ | 2.3438 |
| | 12 | 65.88 | $64.8 + \Delta_F \times 209$ | –2.3437 |
| | 13 | 68.04 | $64.8 + \Delta_F \times 628$ | –1.8750 |
| | 14 | 70.2 | $64.8 + \Delta_F \times 1047$ | –1.4063 |
| | 15 | 72.36 | $64.8 + \Delta_F \times 1466$ | –0.9375 |

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**Table 28-63—DC relative shift to carrier frequency(11ay)**

| Number of contiguous 2.16 GHz channels ($N_{CB}$) | Channel number | Center frequency of the carrier, $f_c$ (GHz) | DC subcarrier frequency, $f_{DC}$ (GHz) | DC relative shift, ($f_{DC} - f_c$) (MHz) |
|---|---|---|---|---|
| 3 | 17 | 60.48 | $64.8 - \Delta_F \times 2 \times 419$ | –0.9375 |
| | 18 | 62.64 | $64.8 - \Delta_F \times 419$ | –0.4688 |
| | 19 | 64.8 | 64.8 | 0 |
| | 20 | 66.96 | $64.8 + \Delta_F \times 419$ | 0.4688 |
| | 21 | 69.12 | $64.8 + \Delta_F \times 2 \times 419$ | 0.9375 |
| | 22 | 71.28 | $64.8 + \Delta_F \times 3 \times 419$ | 1.4063 |
| 4 | 25 | 61.56 | $64.8 - \Delta_F \times 628$ | 1.8750 |
| | 26 | 63.72 | $64.8 - \Delta_F \times 209$ | 2.3438 |
| | 27 | 65.88 | $64.8 + \Delta_F \times 209$ | –2.3437 |
| | 28 | 68.04 | $64.8 + \Delta_F \times 628$ | –1.8750 |
| | 29 | 70.2 | $64.8 + \Delta_F \times 1047$ | –1.4063 |

### 28.6.2.4 Pilot tones

Pilot tones $M_p(k)$ are frequency channel dependent and defined in Table 28-64 (Pilot tones definition(11ay)).

**Table 28-64—Pilot tones definition(11ay)**

| Number of contiguous 2.16 GHz channels ($N_{CB}$) | Channel number | Pilot tones – $M_p(k)$ |
|---|---|---|
| 1 | 1 | [–162, –140, –118, –96, –74, –52, –30, –8, 14, 36, 58, 80, 102, 124, 146, 168] |
| | 2 | [–163, –141, –119, –97, –75, –53, –31, –9, 13, 35, 57, 79, 101, 123, 145, 167] |
| | 3 | [–164, –142, –120, –98, –76, –54, –32, –10, 12, 34, 56, 78, 100, 122, 144, 166] |
| | 4 | [–165, –143, –121, –99, –77, –55, –33, –11, 11, 33, 55, 77, 99, 121, 143, 165] |
| | 5 | [–166, –144, –122, –100, –78, –56, –34, –12, 10, 32, 54, 76, 98, 120, 142, 164] |
| | 6 | [–167, –145, –123, –101, –79, –57, –35, –13, 9, 31, 53, 75, 97, 119, 141, 163] |
| | 7 | [–168, –146, –124, –102, –80, –58, –36, –14, 8, 30, 52, 74, 96, 118, 140, 162] |
| | 8 | [–169, –147, –125, –103, –81, –59, –37, –15, 7, 29, 51, 73, 95, 117, 139, 161] |


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**Table 28-64—Pilot tones definition(11ay) *(continued)***

| Number of contiguous 2.16 GHz channels ($N_{CB}$) | Channel number | Pilot tones – $M_p(k)$ |
|---|---|---|
| 2 | 9 | [–372, –350, –328, –306, –284, –262, –240, –218, –196, –174, –152, –130, –108, –86, –64, –42, –20, –3, 7, 24, 46, 68, 90, 112, 134, 156, 178, 200, 222, 244, 266, 288, 310, 332, 354, 376] |
| | 10 | [–373, –351, –329, –307, –285, –263, –241, –219, –197, –175, –153, –131, –109, –87, –65, –43, –21, –4, 6, 23, 45, 67, 89, 111, 133, 155, 177, 199, 221, 243, 265, 287, 309, 331, 353, 375] |
| | 11 | [–374, –352, –330, –308, –286, –264, –242, –220, –198, –176, –154, –132, –110, –88, –66, –44, –22, –5, 5, 22, 44, 66, 88, 110, 132, 154, 176, 198, 220, 242, 264, 286, 308, 330, 352, 374] |
| | 12 | [–374, –352, –330, –308, –286, –264, –242, –220, –198, –176, –154, –132, –110, –88, –66, –44, –22, –5, 5, 22, 44, 66, 88, 110, 132, 154, 176, 198, 220, 242, 264, 286, 308, 330, 352, 374] |
| | 13 | [–375, –353, –331, –309, –287, –265, –243, –221, –199, –177, –155, –133, –111, –89, –67, –45, –23, –6, 4, 21, 43, 65, 87, 109, 131, 153, 175, 197, 219, 241, 263, 285, 307, 329, 351, 373] |
| | 14 | [–376, –354, –332, –310, –288, –266, –244, –222, –200, –178, –156, –134, –112, –90, –68, –46, –24, –7, 3, 20, 42, 64, 86, 108, 130, 152, 174, 196, 218, 240, 262, 284, 306, 328, 350, 372] |
| | 15 | [–377, –355, –333, –311, –289, –267, –245, –223, –201, –179, –157, –135, –113, –91, –69, –47, –25, –8, 2, 19, 41, 63, 85, 107, 129, 151, 173, 195, 217, 239, 261, 283, 305, 327, 349, 371] |
| 3 | 17 | [–581, –559, –537, –515, –493, –471, –449, –427, –405, –383, –361, –339, –317, –295, –273, –251, –229, –212, –202, –185, –163, –141, –119, –97, –75, –53, –31, –9, 13, 35, 57, 79, 101, 123, 145, 167, 189, 206, 216, 233, 255, 277, 299, 321, 343, 365, 387, 409, 431, 453, 475, 497, 519, 541, 563, 585] |
| | 18 | [–582, –560, –538, –516, –494, –472, –450, –428, –406, –384, –362, –340, –318, –296, –274, –252, –230, –213, –203, –186, –164, –142, –120, –98, –76, –54, –32, –10, 12, 34, 56, 78, 100, 122, 144, 166, 188, 205, 215, 232, 254, 276, 298, 320, 342, 364, 386, 408, 430, 452, 474, 496, 518, 540, 562, 584] |
| | 19 | [–583, –561, –539, –517, –495, –473, –451, –429, –407, –385, –363, –341, –319, –297, –275, –253, –231, –214, –204, –187, –165, –143, –121, –99, –77, –55, –33, –11, 11, 33, 55, 77, 99, 121, 143, 165, 187, 204, 214, 231, 253, 275, 297, 319, 341, 363, 385, 407, 429, 451, 473, 495, 517, 539, 561, 583] |
| | 20 | [–584, –562, –540, –518, –496, –474, –452, –430, –408, –386, –364, –342, –320, –298, –276, –254, –232, –215, –205, –188, –166, –144, –122, –100, –78, –56, –34, –12, 10, 32, 54, 76, 98, 120, 142, 164, 186, 203, 213, 230, 252, 274, 296, 318, 340, 362, 384, 406, 428, 450, 472, 494, 516, 538, 560, 582] |
| | 21 | [–585, –563, –541, –519, –497, –475, –453, –431, –409, –387, –365, –343, –321, –299, –277, –255, –233, –216, –206, –189, –167, –145, –123, –101, –79, –57, –35, –13, 9, 31, 53, 75, 97, 119, 141, 163, 185, 202, 212, 229, 251, 273, 295, 317, 339, 361, 383, 405, 427, 449, 471, 493, 515, 537, 559, 581] |
| | 22 | [–586, –564, –542, –520, –498, –476, –454, –432, –410, –388, –366, –344, –322, –300, –278, –256, –234, –217, –207, –190, –168, –146, –124, –102, –80, –58, –36, –14, 8, 30, 52, 74, 96, 118, 140, 162, 184, 201, 211, 228, 250, 272, 294, 316, 338, 360, 382, 404, 426, 448, 470, 492, 514, 536, 558, 580] |

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**Table 28-64—Pilot tones definition(11ay) *(continued)***

| Number of contiguous 2.16 GHz channels ($N_{CB}$) | Channel number | Pilot tones – $M_p(k)$ |
|---|---|---|
| 4 | 25 | [–791, –769, –747, –725, –703, –681, –659, –637, –615, –593, –571, –549, –527, –505, –483, –461, –439, –422, –412, –395, –373, –351, –329, –307, –285, –263, –241, –219, –197, –175, –153, –131, –109, –87, –65, –43, –21, –4, 6, 23, 45, 67, 89, 111, 133, 155, 177, 199, 221, 243, 265, 287, 309, 331, 353, 375, 397, 414, 424, 441, 463, 485, 507, 529, 551, 573, 595, 617, 639, 661, 683, 705, 727, 749, 771, 793] |
| | 26 | [–792, –770, –748, –726, –704, –682, –660, –638, –616, –594, –572, –550, –528, –506, –484, –462, –440, –423, –413, –396, –374, –352, –330, –308, –286, –264, –242, –220, –198, –176, –154, –132, –110, –88, –66, –44, –22, –5, 5, 22, 44, 66, 88, 110, 132, 154, 176, 198, 220, 242, 264, 286, 308, 330, 352, 374, 396, 413, 423, 440, 462, 484, 506, 528, 550, 572, 594, 616, 638, 660, 682, 704, 726, 748, 770, 792] |
| | 27 | [–792, –770, –748, –726, –704, –682, –660, –638, –616, –594, –572, –550, –528, –506, –484, –462, –440, –423, –413, –396, –374, –352, –330, –308, –286, –264, –242, –220, –198, –176, –154, –132, –110, –88, –66, –44, –22, –5, 5, 22, 44, 66, 88, 110, 132, 154, 176, 198, 220, 242, 264, 286, 308, 330, 352, 374, 396, 413, 423, 440, 462, 484, 506, 528, 550, 572, 594, 616, 638, 660, 682, 704, 726, 748, 770, 792] |
| | 28 | [–793, –771, –749, –727, –705, –683, –661, –639, –617, –595, –573, –551, –529, –507, –485, –463, –441, –424, –414, –397, –375, –353, –331, –309, –287, –265, –243, –221, –199, –177, –155, –133, –111, –89, –67, –45, –23, –6, 4, 21, 43, 65, 87, 109, 131, 153, 175, 197, 219, 241, 263, 285, 307, 329, 351, 373, 395, 412, 422, 439, 461, 483, 505, 527, 549, 571, 593, 615, 637, 659, 681, 703, 725, 747, 769, 791] |
| | 29 | [–794, –772, –750, –728, –706, –684, –662, –640, –618, –596, –574, –552, –530, –508, –486, –464, –442, –425, –415, –398, –376, –354, –332, –310, –288, –266, –244, –222, –200, –178, –156, –134, –112, –90, –68, –46, –24, –7, 3, 20, 42, 64, 86, 108, 130, 152, 174, 196, 218, 240, 262, 284, 306, 328, 350, 372, 394, 411, 421, 438, 460, 482, 504, 526, 548, 570, 592, 614, 636, 658, 680, 702, 724, 746, 768, 790] |


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### 28.6.2.5 Data tones

Data tones $M_d(k)$ are frequency channel dependent and defined in Table 28-65 (Data tones definition(11ay)). In the table, the notation $m$:$n$ denotes an array of integer values starting with $m$ (inclusive) and ending with $n$ (inclusive), and with a step equal to 1.

**Table 28-65—Data tones definition(11ay)**

| Number of contiguous 2.16 GHz channels ($N_{CB}$) | Channel number | Data tones – $M_d(k)$ |
|---|---|---|
| 1 | 1 | [–177:–163,–161:–141,–139:–119,–117:–97,–95:–75,–73:–53,–51:–31,–29:–9, –7:–2,2:13,15:35,37:57,59:79,81:101,103:123,125:145,147:167,169:177] |
| | 2 | [–177:–164,–162:–142,–140:–120,–118:–98,–96:–76,–74:–54,–52:–32,–30: –10,–8:–2,2:12,14:34,36:56,58:78,80:100,102:122,124:144,146:166,168:177] |
| | 3 | [–177:–165,–163:–143,–141:–121,–119:–99,–97:–77,–75:–55,–53:–33,–31: –11,–9:–2,2:11,13:33,35:55,57:77,79:99,101:121,123:143,145:165,167:177] |
| | 4 | [–177:–166,–164:–144,–142:–122,–120:–100,–98:–78,–76:–56,–54:–34,–32: –12,–10:–2,2:10,12:32,34:54,56:76,78:98,100:120,122:142,144:164,166:177] |
| | 5 | [–177:–167,–165:–145,–143:–123,–121:–101,–99:–79,–77:–57,–55:–35,–33: –13,–11:–2,2:9,11:31,33:53,55:75,77:97,99:119,121:141,143:163,165:177] |
| | 6 | [–177:–168,–166:–146,–144:–124,–122:–102,–100:–80,–78:–58,–56:–36,–34: –14,–12:–2,2:8,10:30,32:52,54:74,76:96,98:118,120:140,142:162,164:177] |
| | 7 | [–177:–169,–167:–147,–145:–125,–123:–103,–101:–81,–79:–59,–57:–37,–35: –15,–13:–2,2:7,9:29,31:51,53:73,75:95,97:117,119:139,141:161,163:177] |
| | 8 | [–177:–170,–168:–148,–146:–126,–124:–104,–102:–82,–80:–60,–58:–38,–36: –16,–14:–2,2:6,8:28,30:50,52:72,74:94,96:116,118:138,140:160,162:177] |

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**Table 28-65—Data tones definition(11ay) *(continued)***

| Number of contiguous 2.16 GHz channels ($N_{CB}$) | Channel number | Data tones – $M_d(k)$ |
|---|---|---|
| 2 | 9 | [–386:–373,–371:–351,–349:–329,–327:–307,–305:–285,–283:–263,–261:–241,–239:–219,–217:–197,–195:–175,–173:–153,–151:–131,–129:–109,–107:–87,–85:–65,–63:–43,–41:–21,–19:–4,–2,2:6,8:23,25:45,47:67,69:89,91:111,113:133,135:155,157:177,179:199,201:221,223:243,245:265,267:287,289:309,311:331,333:353,355:375,377:386] |
| | 10 | [–386:–374,–372:–352,–350:–330,–328:–308,–306:–286,–284:–264,–262:–242,–240:–220,–218:–198,–196:–176,–174:–154,–152:–132,–130:–110,–108:–88,–86:–66,–64:–44,–42:–22,–20:–5,–3:–2,2:5,7:22,24:44,46:66,68:88,90:110,112:132,134:154,156:176,178:198,200:220,222:242,244:264,266:286,288:308,310:330,332:352,354:374,376:386] |
| | 11 | [–386:–375,–373:–353,–351:–331,–329:–309,–307:–287,–285:–265,–263:–243,–241:–221,–219:–199,–197:–177,–175:–155,–153:–133,–131:–111,–109:–89,–87:–67,–65:–45,–43:–23,–21:–6,–4:–2,2:4,6:21,23:43,45:65,67:87,89:109,111:131,133:153,155:175,177:197,199:219,221:241,243:263,265:285,287:307,309:329,331:351,353:373,375:386] |
| | 12 | [–386:–375,–373:–353,–351:–331,–329:–309,–307:–287,–285:–265,–263:–243,–241:–221,–219:–199,–197:–177,–175:–155,–153:–133,–131:–111,–109:–89,–87:–67,–65:–45,–43:–23,–21:–6,–4:–2,2:4,6:21,23:43,45:65,67:87,89:109,111:131,133:153,155:175,177:197,199:219,221:241,243:263,265:285,287:307,309:329,331:351,353:373,375:386] |
| | 13 | [–386:–376,–374:–354,–352:–332,–330:–310,–308:–288,–286:–266,–264:–244,–242:–222,–220:–200,–198:–178,–176:–156,–154:–134,–132:–112,–110:–90,–88:–68,–66:–46,–44:–24,–22:–7,–5:–2,2:3,5:20,22:42,44:64,66:86,88:108,110:130,132:152,154:174,176:196,198:218,220:240,242:262,264:284,286:306,308:328,330:350,352:372,374:386] |
| | 14 | [–386:–377,–375:–355,–353:–333,–331:–311,–309:–289,–287:–267,–265:–245,–243:–223,–221:–201,–199:–179,–177:–157,–155:–135,–133:–113,–111:–91,–89:–69,–67:–47,–45:–25,–23:–8,–6:–2,2,4:19,21:41,43:63,65:85,87:107,109:129,131:151,153:173,175:195,197:217,219:239,241:261,263:283,285:305,307:327,329:349,351:371,373:386] |
| | 15 | [–386:–378,–376:–356,–354:–334,–332:–312,–310:–290,–288:–268,–266:–246,–244:–224,–222:–202,–200:–180,–178:–158,–156:–136,–134:–114,–112:–92,–90:–70,–68:–48,–46:–26,–24:–9,–7:–2,3:18,20:40,42:62,64:84,86:106,108:128,130:150,152:172,174:194,196:216,218:238,240:260,262:282,284:304,306:326,328:348,350:370,372:386] |


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**Table 28-65—Data tones definition(11ay) *(continued)***

| Number of contiguous 2.16 GHz channels ($N_{CB}$) | Channel number | Data tones – $M_d(k)$ |
|---|---|---|
| 3 | 17 | [–596:–582,–580:–560,–558:–538,–536:–516,–514:–494,–492:–472,–470:–450,–448:–428,–426:–406,–404:–384,–382:–362,–360:–340,–338:–318,–316:–296,–294:–274,–272:–252,–250:–230,–228:–213,–211:–203,–201:–186,–184:–164,–162:–142,–140:–120,–118:–98,–96:–76,–74:–54,–52:–32,–30:–10,–8:–2,2:12,14:34,36:56,58:78,80:100,102:122,124:144,146:166,168:188,190:205,207:215,217:232,234:254,256:276,278:298,300:320,322:342,344:364,366:386,388:408,410:430,432:452,454:474,476:496,498:518,520:540,542:562,564:584,586:596] |
| | 18 | [–596:–583,–581:–561,–559:–539,–537:–517,–515:–495,–493:–473,–471:–451,–449:–429,–427:–407,–405:–385,–383:–363,–361:–341,–339:–319,–317:–297,–295:–275,–273:–253,–251:–231,–229:–214,–212:–204,–202:–187,–185:–165,–163:–143,–141:–121,–119:–99,–97:–77,–75:–55,–53:–33,–31:–11,–9:–2,2:11,13:33,35:55,57:77,79:99,101:121,123:143,145:165,167:187,189:204,206:214,216:231,233:253,255:275,277:297,299:319,321:341,343:363,365:385,387:407,409:429,431:451,453:473,475:495,497:517,519:539,541:561,563:583,585:596] |
| | 19 | [–596:–584,–582:–562,–560:–540,–538:–518,–516:–496,–494:–474,–472:–452,–450:–430,–428:–408,–406:–386,–384:–364,–362:–342,–340:–320,–318:–298,–296:–276,–274:–254,–252:–232,–230:–215,–213:–205,–203:–188,–186:–166,–164:–144,–142:–122,–120:–100,–98:–78,–76:–56,–54:–34,–32:–12,–10:–2,2:10,12:32,34:54,56:76,78:98,100:120,122:142,144:164,166:186,188:203,205:213,215:230,232:252,254:274,276:296,298:318,320:340,342:362,364:384,386:406,408:428,430:450,452:472,474:494,496:516,518:538,540:560,562:582,584:596] |
| | 20 | [–596:–585,–583:–563,–561:–541,–539:–519,–517:–497,–495:–475,–473:–453,–451:–431,–429:–409,–407:–387,–385:–365,–363:–343,–341:–321,–319:–299,–297:–277,–275:–255,–253:–233,–231:–216,–214:–206,–204:–189,–187:–167,–165:–145,–143:–123,–121:–101,–99:–79,–77:–57,–55:–35,–33:–13,–11:–2,2:9,11:31,33:53,55:75,77:97,99:119,121:141,143:163,165:185,187:202,204:212,214:229,231:251,253:273,275:295,297:317,319:339,341:361,363:383,385:405,407:427,429:449,451:471,473:493,495:515,517:537,539:559,561:581,583:596] |
| | 21 | [–596:–586,–584:–564,–562:–542,–540:–520,–518:–498,–496:–476,–474:–454,–452:–432,–430:–410,–408:–388,–386:–366,–364:–344,–342:–322,–320:–300,–298:–278,–276:–256,–254:–234,–232:–217,–215:–207,–205:–190,–188:–168,–166:–146,–144:–124,–122:–102,–100:–80,–78:–58,–56:–36,–34:–14,–12:–2,2:8,10:30,32:52,54:74,76:96,98:118,120:140,142:162,164:184,186:201,203:211,213:228,230:250,252:272,274:294,296:316,318:338,340:360,362:382,384:404,406:426,428:448,450:470,472:492,494:514,516:536,538:558,560:580,582:596] |
| | 22 | [–596:–587,–585:–565,–563:–543,–541:–521,–519:–499,–497:–477,–475:–455,–453:–433,–431:–411,–409:–389,–387:–367,–365:–345,–343:–323,–321:–301,–299:–279,–277:–257,–255:–235,–233:–218,–216:–208,–206:–191,–189:–169,–167:–147,–145:–125,–123:–103,–101:–81,–79:–59,–57:–37,–35:–15,–13:–2,2:7,9:29,31:51,53:73,75:95,97:117,119:139,141:161,163:183,185:200,202:210,212:227,229:249,251:271,273:293,295:315,317:337,339:359,361:381,383:403,405:425,427:447,449:469,471:491,493:513,515:535,537:557,559:579,581:596] |

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**Table 28-65—Data tones definition(11ay) *(continued)***

| Number of contiguous 2.16 GHz channels ($N_{CB}$) | Channel number | Data tones – $M_d(k)$ |
|---|---|---|
| 4 | 25 | [–805:–792,–790:–770,–768:–748,–746:–726,–724:–704,–702:–682,–680:<br>–660,–658:–638,–636:–616,–614:–594,–592:–572,–570:–550,–548:–528,<br>–526:–506,–504:–484,–482:–462,–460:–440,–438:–423,–421:–413,–411:<br>–396,–394:–374,–372:–352,–350:–330,–328:–308,–306:–286,–284:–264,<br>–262:–242,–240:–220,–218:–198,–196:–176,–174:–154,–152:–132,–130:<br>–110,–108:–88,–86:–66,–64:–44,–42:–22,–20:–5,–3:–2,2:5,7:22,24:44,46:66,<br>68:88,90:110,112:132,134:154,156:176,178:198,200:220,222:242,244:264,266:<br>286,288:308,310:330,332:352,354:374,376:396,398:413,415:423,425:440,442:<br>462,464:484,486:506,508:528,530:550,552:572,574:594,596:616,618:638,640:<br>660,662:682,684:704,706:726,728:748,750:770,772:792,794:805] |
| | 26 | [–805:–793,–791:–771,–769:–749,–747:–727,–725:–705,–703:–683,–681:<br>–661,–659:–639,–637:–617,–615:–595,–593:–573,–571:–551,–549:–529,<br>–527:–507,–505:–485,–483:–463,–461:–441,–439:–424,–422:–414,–412:<br>–397,–395:–375,–373:–353,–351:–331,–329:–309,–307:–287,–285:–265,<br>–263:–243,–241:–221,–219:–199,–197:–177,–175:–155,–153:–133,–131:<br>–111,–109:–89,–87:–67,–65:–45,–43:–23,–21:–6,–4:–2,2:4,6:21,23:43,45:65,<br>67:87,89:109,111:131,133:153,155:175,177:197,199:219,221:241,243:263,265:<br>285,287:307,309:329,331:351,353:373,375:395,397:412,414:422,424:439,441:<br>461,463:483,485:505,507:527,529:549,551:571,573:593,595:615,617:637,639:<br>659,661:681,683:703,705:725,727:747,749:769,771:791,793:805] |
| | 27 | [–805:–793,–791:–771,–769:–749,–747:–727,–725:–705,–703:–683,–681:<br>–661,–659:–639,–637:–617,–615:–595,–593:–573,–571:–551,–549:–529,<br>–527:–507,–505:–485,–483:–463,–461:–441,–439:–424,–422:–414,–412:<br>–397,–395:–375,–373:–353,–351:–331,–329:–309,–307:–287,–285:–265,<br>–263:–243,–241:–221,–219:–199,–197:–177,–175:–155,–153:–133,–131:<br>–111,–109:–89,–87:–67,–65:–45,–43:–23,–21:–6,–4:–2,2:4,6:21,23:43,45:65,<br>67:87,89:109,111:131,133:153,155:175,177:197,199:219,221:241,243:263,265:<br>285,287:307,309:329,331:351,353:373,375:395,397:412,414:422,424:439,441:<br>461,463:483,485:505,507:527,529:549,551:571,573:593,595:615,617:637,639:<br>659,661:681,683:703,705:725,727:747,749:769,771:791,793:805] |
| | 28 | [–805:–794,–792:–772,–770:–750,–748:–728,–726:–706,–704:–684,–682:<br>–662,–660:–640,–638:–618,–616:–596,–594:–574,–572:–552,–550:–530,<br>–528:–508,–506:–486,–484:–464,–462:–442,–440:–425,–423:–415,–413:<br>–398,–396:–376,–374:–354,–352:–332,–330:–310,–308:–288,–286:–266,<br>–264:–244,–242:–222,–220:–200,–198:–178,–176:–156,–154:–134,–132:<br>–112,–110:–90,–88:–68,–66:–46,–44:–24,–22:–7,–5:–2,2:3,5:20,22:42,44:64,<br>66:86,88:108,110:130,132:152,154:174,176:196,198:218,220:240,242:262,264:<br>284,286:306,308:328,330:350,352:372,374:394,396:411,413:421,423:438,440:<br>460,462:482,484:504,506:526,528:548,550:570,572:592,594:614,616:636,638:<br>658,660:680,682:702,704:724,726:746,748:768,770:790,792:805] |
| | 29 | [–805:–795,–793:–773,–771:–751,–749:–729,–727:–707,–705:–685,–683:<br>–663,–661:–641,–639:–619,–617:–597,–595:–575,–573:–553,–551:–531,<br>–529:–509,–507:–487,–485:–465,–463:–443,–441:–426,–424:–416,–414:<br>–399,–397:–377,–375:–355,–353:–333,–331:–311,–309:–289,–287:–267,<br>–265:–245,–243:–223,–221:–201,–199:–179,–177:–157,–155:–135,–133:<br>–113,–111:–91,–89:–69,–67:–47,–45:–25,–23:–8,–6:–2,2,4:19,21:41,43:63,<br>65:85,87:107,109:129,131:151,153:173,175:195,197:217,219:239,241:261,263:<br>283,285:305,307:327,329:349,351:371,373:393,395:410,412:420,422:437,439:<br>459,461:481,483:503,505:525,527:547,549:569,571:591,593:613,615:635,637:<br>657,659:679,681:701,703:723,725:745,747:767,769:789,791:805] |



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### 28.6.2.6 Pilot sequences

The pilot sequence $P(i_{STS}, n, k)$ is created by inserting a sequence of 0s corresponding to tones $-N_{SR}$ to $N_{SR}$. The pilots are then inserted at the tone (#4136)indices $M_p(k)$ defined in 28.6.2.4 (Pilot tones), which are frequency channel and bandwidth dependent, but independent of the space-time stream or OFDM symbol number as follows:

$$P\left(i_{STS}, n, M_p(k)\right) = P_{N_{SP}}\left(i_{STS}, n, k\right), k = 0,1,\ldots,N_{SP}-1$$

The pilot value $P_{N_{SP}}\left(i_{STS}, n, k\right)$ depends on the $i_{STS}^{\text{th}}$ space-time stream number, $n^{\text{th}}$ OFDM symbol, and $k^{\text{th}}$ subcarrier index and defined as follows:

$$P_{N_{SP}}\left(i_{STS}, n, k\right) = W\left(i_{STS}, n \bmod N_{STS}\right) \times \left(2 \times p(n) - 1\right) \times P_{N_{SP}}\left(i_{STS}, k\right)$$

where

| | |
|---|---|
| $P_{N_{SP}}\left(i_{STS}, k\right)$ | defines the pilot for $i_{STS}^{\text{th}}$ space-time stream and $k^{\text{th}}$ subcarrier |
| $W(i_{STS}, n) \times (2 \times p(n) - 1)$ | defines a common phase shift (over subcarriers) for the $i_{STS}^{\text{th}}$ space-time stream and $n^{\text{th}}$ OFDM symbol, $p(n)$ defines a bit coming from the scrambler defined in 28.6.9.1 (Scrambler) with shift register x1, x2,…, x7 initialized to all 1s at the zeroth (i.e., $n = 0$) OFDM symbol |
| $N_{STS}$ | defines the total number of space-time streams |

The common phase shift is composed as a product of deterministic shift $W(i_{STS}, n)$ repeated with period $N_{STS}$ over the time and random shift defined by $(2 \times p(n) - 1)$, which is scrambler output dependent. The random component depends on the $n^{\text{th}}$ OFDM symbol number only and does not depend on the particular $i_{STS}^{\text{th}}$ space-time stream number.

The pilot sequence $P_{N_{SP}}\left(i_{STS}, :\right)$ for a given number of contiguous channel bandwidth, $N_{CB}$, is defined in Table 28-66 (Pilot sequence () definition(11ay)).

**Table 28-66—Pilot sequence ($P_{N_{SP}}$) definition(11ay)**

| $N_{CB}$ | $P_{N_{SP}}\left(i_{STS}, :\right)$ |
|---|---|
| 1 | $P_{16}(i_{STS},:)$ |
| 2 | $P_{36}(i_{STS},:) = [P_{12}(i_{STS},:), P_{12}(i_{STS},:), P_{12}(i_{STS},:)]$ |
| 3 | $P_{56}(i_{STS},:) = [P_{16}(i_{STS},:), P_{12}(i_{STS},:), P_{12}(i_{STS},:), P_{16}(i_{STS},:)]$ |
| 4 | $P_{76}(i_{STS},:) = [P_{16}(i_{STS},:), P_{16}(i_{STS},:), P_{12}(i_{STS},:), P_{16}(i_{STS},:), P_{16}(i_{STS},:)]$ |

The pilot sequences $P_{16}(i_{STS},:)$ and $P_{12}(i_{STS},:)$ are defined in Table 28-67 (Pilot sequence (P16 and P12) definition(11ay)) .

The deterministic component of common phase shift, $W(i_{STS}, n)$, is defined as follows:

$$W\left(i_{STS}, n\right) = \exp\left(-j\frac{2\pi}{N_{STS}} \cdot \left(i_{STS} - 1\right) \cdot n\right), i_{STS} = 1,2,\ldots,N_{STS}; n = 0,1,\ldots,N_{SYM}-1$$

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**Table 28-67—Pilot sequence ($P_{16}$ and $P_{12}$) definition(11ay)**

| $i_{STS}$ | $P_{16}(i_{STS},:)$ | $P_{12}(i_{STS},:)$ |
|---|---|---|
| 1 | [+1 +1 +1 –1 +1 +1 –1 +1 +1 +1 +1 –1 –1 –1 +1 –1] | [–1 +1 –1 +1 +1 –1 –1 –1 –1 –1 +1 +1] |
| 2 | [–1 –1 –1 +1 –1 –1 +1 –1 +1 +1 +1 –1 –1 –1 +1 –1] | [+1 –1 +1 +1 –1 –1 –1 –1 –1 +1 +1 –1] |
| 3 | [–1 –1 –1 +1 +1 +1 –1 +1 –1 –1 –1 +1 –1 –1 +1 –1] | [–1 +1 +1 –1 –1 –1 –1 –1 +1 +1 –1 +1] |
| 4 | [+1 +1 +1 –1 –1 –1 +1 –1 –1 –1 –1 +1 –1 –1 +1 –1] | [+1 +1 –1 –1 –1 –1 –1 +1 +1 –1 +1 –1] |
| 5 | [–1 –1 +1 –1 –1 –1 –1 +1 –1 –1 +1 –1 +1 +1 +1 –1] | [+1 –1 –1 –1 +1 –1 –1 +1 –1 +1 –1 +1] |
| 6 | [+1 +1 –1 +1 +1 +1 +1 –1 –1 –1 +1 –1 +1 +1 +1 –1] | [–1 –1 +1 –1 –1 –1 +1 +1 –1 –1 +1 +1] |
| 7 | [+1 +1 –1 +1 –1 –1 –1 +1 +1 +1 –1 +1 +1 +1 +1 –1] | [–1 –1 –1 +1 –1 +1 –1 +1 +1 +1 +1 +1] |
| 8 | [–1 –1 +1 –1 +1 +1 +1 –1 +1 +1 –1 +1 +1 +1 +1 –1] | [–1 –1 –1 –1 +1 –1 +1 –1 +1 +1 +1 –1] |

where

$N_{SYM}$ is the total number of OFDM symbols

### 28.6.3 Transmitter block diagram

#### 28.6.3.1 General

An EDMG OFDM PPDU transmission may be generated using a transmitter consisting of the following blocks:

a) Scrambler scrambles the data to reduce the probability of long sequences of 0s and 1s; see 28.6.9.1 (Scrambler).

b) LDPC encoder encodes the data to enable error correction. Data is padded with 0s to get an integer number of codewords and OFDM symbols; see 28.6.9.2 (Encoding).

c) Stream parser divides the output of the LDPC encoder into the groups of bits that are sent to different mapping devices. The sequence of the bits sent to different mapping devices is called a spatial stream; see 28.6.9.2 (Encoding).

d) Constellation mapper maps the sequence of bits in each spatial stream to constellation points (complex numbers); see 28.6.9.3 (Modulation mapping).

e) Interleaver performs interleaving inside an OFDM symbol; see 28.6.9.3.9 (Interleaver).

f) STBC encoder spreads constellation points from $N_{SS}$ spatial streams into $N_{STS}$ space-time streams using a space-time block code. (#8160)EDMG OFDM mode defines STBC schemes with $N_{STS} = 2 \times N_{SS}$; see 28.6.9.3.10 (Space-time block coding).

g) Preamble builder builds symbols of EDMG-STF and EDMG-CEF fields in frequency domain; see 28.6.4 (EDMG-STF definition) and 28.6.5 (EDMG-CEF definition).

h) TRN builder builds symbols of TRN field; see 28.9.2.2.5 (TRN field definition).

i) Spatial mapper maps space-time streams to transmit chains. The spatial mapping is applied per subcarrier basis and may include one of the following (see 28.6.10.2 (Spatial mapping)):

   1) Direct mapping: constellation points from each space-time stream are mapped directly to the transmit chains.

   2) Indirect mapping: constellation points from each space-time stream are mapped to each transmit chain.

   3) Digital beamforming: each vector of constellation points from all of the space-time streams is multiplied by a matrix of steering vectors to produce the input to the transmit chains.


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j) Cyclic shift (CSD) insertion prevents the transmission from unintentional beamforming. A cyclic shift is specified per transmitter chain for pre-EDMG portion of PPDU transmission; see 28.5.3.3.1 (Pre-EDMG modulated fields of PPDU transmission).

k) IDFT applies Inverse Discrete Fourier Transform to the input block of subcarriers.

l) GI insertion and windowing prepends the OFDM symbol with a guard interval defined as a cyclic extension of the OFDM symbol in time domain and applies a window function; see 28.6.9.3 (Modulation mapping).

### 28.6.3.2 EDMG PPDU transmission

#### 28.6.3.2.1 Pre-EDMG modulated fields of PPDU transmission

See 28.5.3.3.1 (Pre-EDMG modulated fields of PPDU transmission).

#### 28.6.3.2.2 EDMG modulated fields of SU PPDU transmission

Figure 28-33 (Transmitter block diagram for the EDMG modulated fields of an SU PPDU transmission(11ay)) shows the transmitter blocks used to generate the EDMG modulated fields of an SU PPDU. The EDMG-STF and EDMG-CEF fields are generated using the preamble builder, IDFT, and GI insertion blocks. The TRN field is generated using the TRN builder, IDFT, and GI insertion blocks. (#2350)The EDMG-Header-A field in the PPDU starting from the second PPDU in the EDMG A-PPDU and Data field of the PPDU are generated using the scrambler, the LDPC encoder, the constellation mapper, the interleaver, IDFT, and GI insertion blocks. If the STBC encoder is applied, then $N_{SS}$ spatial streams are mapped to $2 \times N_{SS}$ space-time streams as defined in 28.6.9.3.10 (Space-time block coding). The $N_{STS}$ space-time streams are further mapped to $N_{TX}$ transmit chains, where $N_{STS} \leq N_{TX}$.

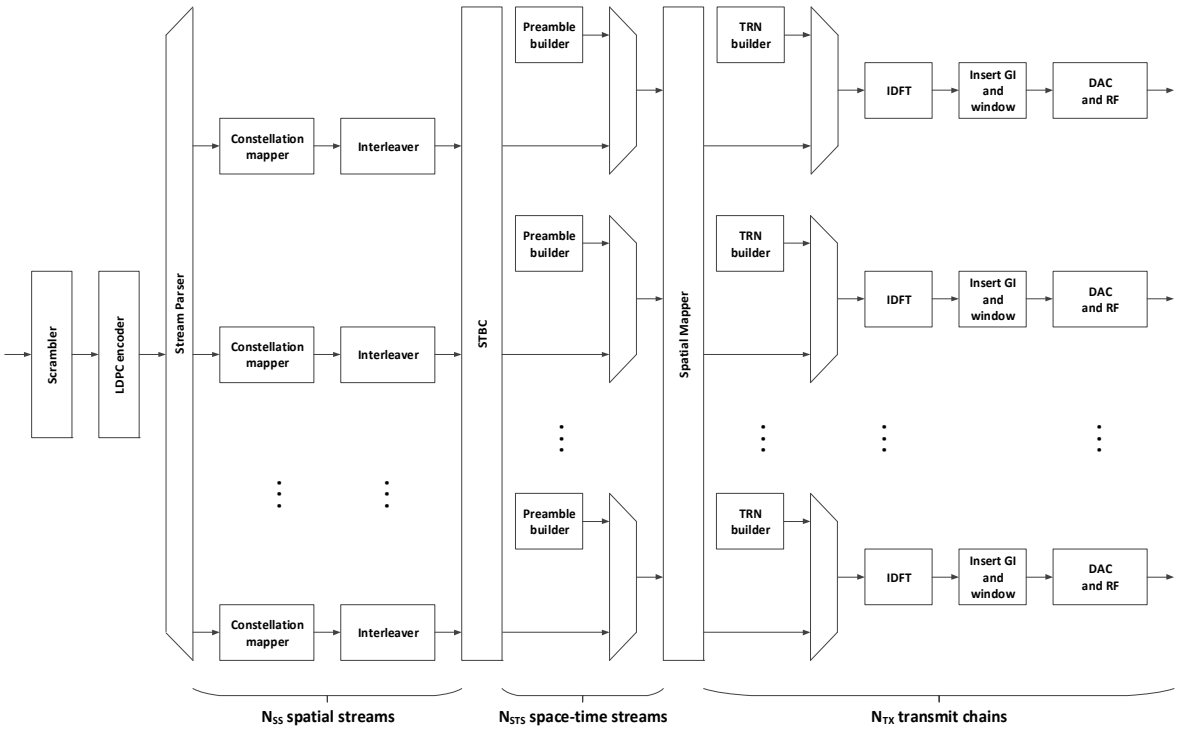


**Figure 28-33—Transmitter block diagram for the EDMG modulated fields of an SU PPDU transmission(11ay)**

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NOTE—The interleaver is applied to 16-QAM and 64-QAM modulations only.

### 28.6.3.2.3 EDMG modulated fields of MU PPDU transmission

Figure 28-34 (Transmitter block diagram for the EDMG modulated fields of an MU PPDU transmission(11ay)) shows the transmitter blocks used to generate the EDMG modulated fields of an MU PPDU. The EDMG-STF and EDMG-CEF fields are generated using the preamble builder, IDFT, and GI insertion blocks. The TRN field is generated using the TRN builder, IDFT, and GI insertion blocks. The EDMG-Header-B and Data fields are generated using the scrambler, the LDPC encoder, the constellation mapper, the interleaver, IDFT, and GI insertion blocks. The PPDU encoding uses the seed value defined in the EDMG-Header-B and has an independent flow per user. However, the transmitter keeps a common space-time stream enumeration over all users. If the STBC encoder is applied, then a single spatial stream is mapped to two space-time streams as defined in 28.6.9.3.10 (Space-time block coding). The $N_{STS}$ space-time streams are further mapped to $N_{TX}$ transmit chains, where $N_{STS} \leq N_{TX}$.

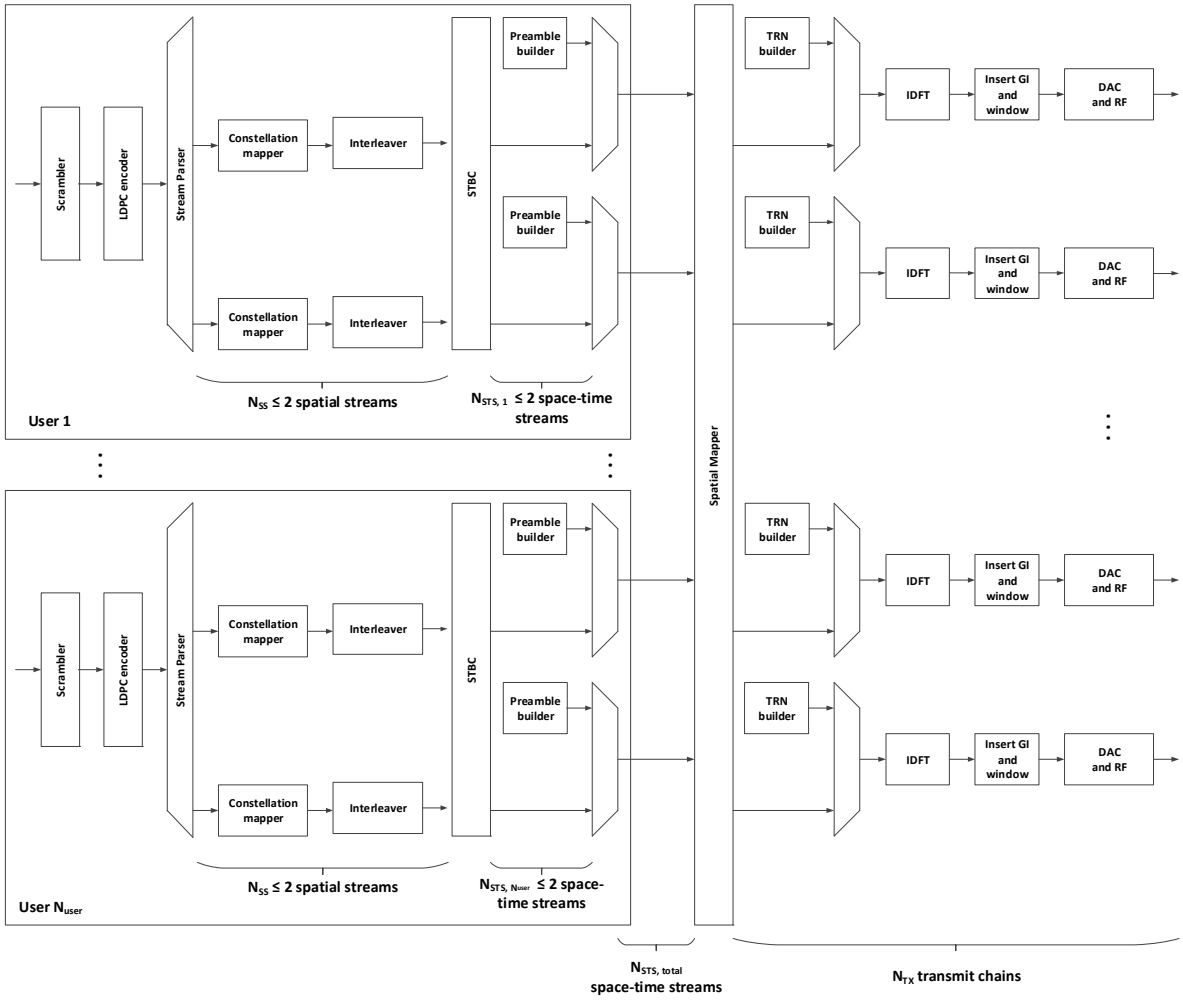


**Figure 28-34—Transmitter block diagram for the EDMG modulated fields of an MU PPDU transmission(11ay)**

NOTE—The interleaver is applied to 16-QAM and 64-QAM modulations only.


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### 28.6.4 EDMG-STF definition

#### 28.6.4.1 General

The EDMG-STF field has a fixed time duration independent on the number of space-time streams. The structure of the EDMG-STF field depends on the number of contiguous 2.16 GHz channels over which an EDMG PPDU is transmitted and the space-time stream number $i_{STS}$, where $1 \le i_{STS} \le 8$.

$EDMGS^{i_{STS}}_{left,N}$ and $EDMGS^{i_{STS}}_{right,N}$, the sequences of length $N$ used in the definition of the EDMG-STF field for different space-time streams, are defined in 28.11.1 (EDMG-STF sequence).

#### 28.6.4.2 Definition

For EDMG OFDM transmissions using a single 2.16 GHz channel, the frequency sequence used to construct the EDMG-STF field for the $i_{STS}$th space-time stream is given as follows:

$$EDMG\text{-}STF^{i_{STS}}_{-177,177} = \{EDMGS^{i_{STS}}_{left,176}, 0, 0, 0, EDMGS^{i_{STS}}_{right,176}\}$$

For EDMG OFDM transmissions using a single 4.32 GHz channel, the frequency sequence used to construct the EDMG-STF field for the $i_{STS}$th space-time stream is given as follows:

$$EDMG\text{-}STF^{i_{STS}}_{-386,386} = \{EDMGS^{i_{STS}}_{left,385}, 0, 0, 0, EDMGS^{i_{STS}}_{right,385}\}$$

For EDMG OFDM transmissions using a single 6.48 GHz channel, the frequency sequence used to construct the EDMG-STF field for the $i_{STS}$th space-time stream is given as follows:

$$EDMG\text{-}STF^{i_{STS}}_{-596,596} = \{EDMGS^{i_{STS}}_{left,595}, 0, 0, 0, EDMGS^{i_{STS}}_{right,595}\}$$

For EDMG OFDM transmissions using a single 8.64 GHz channel, the frequency sequence used to construct the EDMG-STF field for the $i_{STS}$th space-time stream is given as follows:

$$EDMG\text{-}STF^{i_{STS}}_{-805,805} = \{EDMGS^{i_{STS}}_{left,804}, 0, 0, 0, EDMGS^{i_{STS}}_{right,804}\}$$

The EDMG-STF field transmit waveform in time domain shall be defined at the OFDM sampling rate $F_s$ and sample time duration $T_s$ as follows:

$$r^{i_{TX}}_{EDMG\text{-}STF}(qT_s) = \frac{1}{\sqrt{N_{STS} \cdot N^{Tone}_{EDMG\text{-}STF}}} w(qT_s)$$

$$\cdot \sum_{k=-N_{SR}}^{N_{SR}} \sum_{i_{STS}=1}^{N_{STS}} \left[Q_{EDMG\,k}\right]_{i_{TX},i_{STS}} EDMG\text{-}STF^{i_{STS}}_{k} \exp\left(j2\pi k\Delta_F (qT_s)\right)$$

where

$N^{Tone}_{EDMG\text{-}STF}$ is 88 192 296 and 400 for $N_{CB}$ = 1, 2, 3, and 4, respectively

$N_{STS}$ is the total number of space-time streams

$Q_{EDMG\,k}$ is the spatial mapping matrix per $k$th subcarrier

$[\ ]_{m,n}$ is a matrix element from $m$th row and $n$th column

$w(qT_s)$ is a window function applied to smooth the transitions between consecutive OFDM symbols and its definition is implementation dependent

$q$ is the time sample index, $q = 0, 1, \ldots, 30 \times (N_{DFT}/4) - 1$

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The fact that only spectral lines of $EDMG\text{-}STF_k^{i_{STS}}$ with indices that are a multiple of four have nonzero amplitude results in a periodicity of $T_{DFT}/4 = 48.48$ ns. The interval TEDMG-STF is equal to thirty 48.48 ns periods (i.e., 1.455 μs).

### 28.6.5 EDMG-CEF definition

#### 28.6.5.1 General

The structure of the EDMG-CEF field depends on the number of contiguous 2.16 GHz channels over which an EDMG PPDU is transmitted and the space-time stream number, $i_{STS}$.

$Seq_{left,N}^{i_{STS}}$ and $Seq_{right,N}^{i_{STS}}$, the sequences of length $N$ used in the definition of the EDMG-CEF field for different space-time streams, are defined in 28.11.2 (EDMG-CEF sequence).

#### 28.6.5.2 Definition

For an EDMG PPDU transmission using the EDMG OFDM mode over a 2.16 GHz channel, the EDMG-CEF sequence is defined in frequency domain for the $i^{th}$ space-time stream as follows:

$$EDMG\text{-}CEF_{-177,177}^{i_{STS}} = \{ Seq_{left,176}^{i_{STS}}, 0, 0, 0, Seq_{right,176}^{i_{STS}} \}$$

For an EDMG PPDU transmission using the EDMG OFDM mode over a 4.32 GHz channel, the EDMG-CEF sequence is defined in frequency domain for the $i^{th}$ space-time stream as follows:

$$EDMG\text{-}CEF_{-386,386}^{i_{STS}} = \{ Seq_{left,385}^{i_{STS}}, 0, 0, 0, Seq_{right,385}^{i_{STS}} \}$$

For an EDMG PPDU transmission using the EDMG OFDM mode over a 6.48 GHz channel, the EDMG-CEF sequence is defined in frequency domain for the $i^{th}$ space-time stream as follows:

$$EDMG\text{-}CEF_{-596,596}^{i_{STS}} = \{ Seq_{left,595}^{i_{STS}}, 0, 0, 0, Seq_{right,595}^{i_{STS}} \}$$

For an EDMG PPDU transmission using the EDMG OFDM mode over an 8.64 GHz channel, the EDMG-CEF sequence is defined in frequency domain for the $i^{th}$ space-time stream as follows:

$$EDMG\text{-}CEF_{-805,805}^{i_{STS}} = \{ Seq_{left,804}^{i_{STS}}, 0, 0, 0, Seq_{right,804}^{i_{STS}} \}$$

The EDMG-CEF field transmit waveform in time domain shall be defined at the OFDM sampling rate $F_s$ and sample time duration $T_s$ as follows:

$$r_{EDMG\text{-}CEF}^{i_{TX}}\left(qT_s\right) = \frac{1}{\sqrt{N_{STS} \cdot N_{EDMG\text{-}CEF}^{Tone}}} \sum_{n=0}^{N_{EDMG-CEF}^{N_{STS}}-1} w\left(qT_s - nT_{SYM}\right)$$

$$\cdot \sum_{k=-N_{SR}}^{N_{SR}} \sum_{i_{STS}=1}^{N_{STS}} \left[ Q_{EDMG\,k} \right]_{i_{TX},i_{STS}} \left[ P_{EDMG\text{-}CEF} \right]_{i_{STS},n} EDMG\text{-}CEF_k^{i_{STS}} \exp\left( j2\pi k\Delta_F \left( qT_s - nT_{SYM} - T_{GI\,long} \right) \right)$$

where

$N_{EDMG\text{-}CEF}^{Tone} = N_{ST} - N_{DC}$ is the total number of active tones

$N_{STS}$ is the total number of space-time streams

$T_{SYM} = T_{DFT} + T_{GI\,long}$ is the OFDM symbol duration in time domain

$T_{GI\,long}$ is the long guard interval time duration


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| | |
|---|---|
| $Q_{EDMG\,k}$ | is the spatial mapping matrix per $k^{\text{th}}$ subcarrier |
| $P_{EDMG\text{-}CEF}$ | is the EDMG-CEF mapping matrix defined below |
| $N_{EDMG\text{-}CEF}^{N_{STS}}$ | is the number of OFDM symbols in the EDMG-CEF for a given total number of space-time streams $N_{STS}$ defined below |
| $[\ ]_{m,n}$ | is a matrix element from $m^{\text{th}}$ row and $n^{\text{th}}$ column |
| $w(qT_s)$ | is the window function applied to smooth the transitions between consecutive OFDM symbols and its definition is implementation dependent |
| $q$ | is the time sample index, $q = 0,1,...,\left(N_{DFT} + N_{GI\,long}\right) \times N_{EDMG\text{-}CEF}^{N_{STS}} - 1$ |

The EDMG-CEF mapping matrix for $N_{STS} = 1$ is defined as follows:

$$P_{EDMG\text{-}CEF} = \begin{bmatrix} +1 & -1 \end{bmatrix},\ N_{EDMG\text{-}CEF}^{N_{STS}} = 2$$

The EDMG-CEF mapping matrix for $N_{STS} = 2$ is defined as follows:

$$P_{EDMG\text{-}CEF} = \begin{bmatrix} +1 & -1 \\ +1 & +1 \end{bmatrix},\ N_{EDMG\text{-}CEF}^{N_{STS}} = 2$$

The EDMG-CEF mapping matrix for $N_{STS} = 3$ is defined as follows:

$$P_{EDMG\text{-}CEF} = \begin{bmatrix} +1 & -1 & +1 \\ +1 & -w_3^1 & w_3^2 \\ +1 & -w_3^2 & w_3^4 \end{bmatrix},\ w_3 = \exp\left(-j2\pi/3\right),\ N_{EDMG\text{-}CEF}^{N_{STS}} = 3$$

The EDMG-CEF mapping matrix for $N_{STS} = 4$ is defined as follows:

$$P_{EDMG\text{-}CEF} = P_{4x4} = \begin{bmatrix} +1 & -1 & +1 & +1 \\ +1 & +1 & -1 & +1 \\ +1 & +1 & +1 & -1 \\ -1 & +1 & +1 & +1 \end{bmatrix},\ N_{EDMG\text{-}CEF}^{N_{STS}} = 4$$

The EDMG-CEF mapping matrix for $N_{STS} = 5$ or 6 is defined as follows:

$$P_{EDMG\text{-}CEF} = \begin{bmatrix} +1 & -1 & +1 & +1 & +1 & -1 \\ +1 & -w_6^1 & w_6^2 & w_6^3 & w_6^4 & -w_6^5 \\ +1 & -w_6^2 & w_6^4 & w_6^6 & w_6^8 & -w_6^{10} \\ +1 & -w_6^3 & w_6^6 & w_6^9 & w_6^{12} & -w_6^{15} \\ +1 & -w_6^4 & w_6^8 & w_6^{12} & w_6^{16} & -w_6^{20} \\ +1 & -w_6^5 & w_6^{10} & w_6^{15} & w_6^{20} & -w_6^{25} \end{bmatrix},\ w_6 = \exp\left(-j2\pi/6\right),\ N_{EDMG\text{-}CEF}^{N_{STS}} = 6$$

The EDMG-CEF mapping matrix for $N_{STS} = 7$ or 8 is defined as follows:

$$P_{EDMG\text{-}CEF} = \begin{bmatrix} P_{4x4} & P_{4x4} \\ P_{4x4} & -P_{4x4} \end{bmatrix},\ N_{EDMG\text{-}CEF}^{N_{STS}} = 8$$

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### 28.6.6 Encoding of EDMG-Header-B

The EDMG-Header-B for the $i_{user}^{th}$ shall be encoded as follows:

— The input 64 bits of the EDMG-Header-B, $\mathbf{b} = (b_1, b_2, ..., b_{64})$, are scrambled with the PN sequence described in 20.3.9 (Scrambler), starting from the eighth bit to create the $\mathbf{bq} = (bq_1, bq_2, ..., bq_{64})$ sequence. The scrambler seed value is initialized by the first seven bits of the EDMG-Header-B.

— The LDPC codeword of length 672 bits is created by concatenating the 440 0s to the scrambled header bits $\mathbf{bq} = (bq_1, bq_2, ..., bq_{64})$ and then computing 168 parity bits $\mathbf{p} = (p_1, p_2, ..., p_{168})$ using the LDPC matrix with $R$ = 3/4 and $L_{CW}$ = 672 defined in 20.3.8.4 (Rate 3/4 LDPC code matrix H = 168 rows x 672 columns, Z = 42). The LDPC codeword is defined as $(bq_1, bq_2, ..., bq_{64}, 0_1, 0_2, ..., 0_{440}, p_1, p_2, ..., p_{168})$.

— The zero padded bits are discarded and the output codeword is defined as $\mathbf{c} = (\mathbf{c}_1, \mathbf{c}_2, \mathbf{c}_3)$, where

  — $\mathbf{c}_1 = (bq_1, bq_2, ..., bq_{64}, p_9, p_{10}, ..., p_{168})$

  — $\mathbf{c}_2 = (bq_1, bq_2, ..., bq_{64}, p_1, p_2, ..., p_{84}, p_{93}, p_{94}, ..., p_{168})$

  — $\mathbf{c}_3 = (bq_1, bq_2, ..., bq_{64}, p_1, p_2, ..., p_{160})$

— For a PPDU transmitted over a $N_{CB}$ × 2.16 GHz channel, where $1 \le N_{CB} \le 4$, the data block is defined as a repetition of codeword **c** bits as follows:

  — **cb** = **c** for $N_{CB}$ = 1

  — **cb** = (**c**, **c**, $\mathbf{c_{1:124}}$) for $N_{CB}$ = 2

  — **cb** = (**c**, **c**, **c**, $\mathbf{c_{1:252}}$) for $N_{CB}$ = 3

  — **cb** = (**c**, **c**, **c**, **c**, $\mathbf{c_{1:376}}$) for $N_{CB}$ = 4

— For a PPDU transmitted using $N_{STS}$ ($N_{STS}$ = 1, 2) space-time streams, the data block **cb** is repeated $N_{STS}$ times. Then the $N_{STS}$ data blocks are scrambled continuously with PN sequence defined in 28.5.9.3.2 (Scrambler for EDMG-Header-A in SU EDMG A-PPDU, EDMG-Header-B, and EDMG SC MCS1 coded bits) without seed reset. The initial seed value is equal to all 1s $(1_1, 1_2, ..., 1_7)$. The scrambling starts at the 225$^{th}$ bit and ends at the $(N_{STS} \times 2 \times N_{SD})^{th}$ bit. The first scrambled **cb** block is mapped to the first space-time stream and the second scrambled **cb** block to the second space-time stream.

In the description above, the $\mathbf{c_{1:}}_{\boldsymbol{m}}$ notation defines an array of vector **c** elements, starting from the first bit (inclusive) and ending at the $m^{th}$ bit (inclusive).

The data blocks shall be modulated using DCM QPSK modulation. The EDMG-Header-B shall use the OFDM modulation as defined for the Data field of the PPDU (see 28.6.9.3 (Modulation mapping)).

### 28.6.7 Encoding of EDMG-Header-A for EDMG A-PPDU transmission

The EDMG-Header-A field in the first EDMG PPDU in an EDMG OFDM mode A-PPDU (i.e., $i_{PPDU}$ = 1, where $i_{PPDU}$ represents the index of the PPDU into the EDMG A-PPDU) is encoded and modulated as specified in 28.3.3.3.2.4 (Encoding and modulation).

For the $i_{PPDU}^{th}$ EDMG PPDU in the EDMG SC mode A-PPDU, $i_{PPDU}$ > 1, the EDMG-Header-A field shall be encoded and modulated using two OFDM symbols. The encoding and modulation shall be as follows:

— The input 112 header bits are appended with 16 HCS bits calculated as defined in 20.3.7 (HCS calculation for headers of DMG control mode and DMG SC mode).

— The resulting 128 bits including CRC, **b** = ($b_1$, $b_2$,…, $b_{128}$), are scrambled with the PN sequence as described in 20.3.9 (Scrambler), starting from the first bit using a continuation of the scrambler bit


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sequence from the Data field of preceding EDMG PPDU in the EDMG OFDM mode A-PPDU to create the **bq** = ($bq_1$, $bq_2$,…, $bq_{128}$) sequence.

— The scrambled header bits, **bq**, are divided into two parts **bq1** = ($bq_1$, $bq_2$,…, $bq_{64}$) and **bq2** = ($bq_{65}$, $bq_{66}$,…, $bq_{128}$) of 64 bits each.

— Two LDPC codewords of length 672 bits each are created by concatenating the 440 0s to each part, **bq1** and **bq2**, and then computing 168 parity bits **p1** = ($p1_1$, $p1_2$,…, $p1_{168}$) and **p2** = ($p2_1$, $p2_2$,…, $p2_{168}$) for **bq1** and **bq2**, respectively, using the LDPC matrix with $R$ = 3/4 and $L_{CW}$ = 672 defined in 20.3.8.4 (Rate 3/4 LDPC code matrix H = 168 rows x 672 columns, Z = 42). The LDPC codewords are defined as follows:

  — **cw1** = ($bq_1$, $bq_2$,…, $bq_{64}$, $0_1$, $0_2$,…, $0_{440}$, $p1_1$, $p1_2$,…, $p1_{168}$)
  — **cw2** = ($bq_{65}$, $bq_{66}$,…, $bq_{128}$, $0_1$, $0_2$,…, $0_{440}$, $p2_1$, $p2_2$,…, $p2_{168}$)

— The padded 0s are discarded and two output codewords are defined as **c1** = ($c1_1$, $c1_2$, $c1_3$) and **c2** = ($c2_1$, $c2_2$, $c2_3$), where

  — $\mathbf{c1_1}$ = ($bq_1$, $bq_2$,…, $bq_{64}$, $p1_9$, $p1_{10}$,…, $p1_{168}$)
  — $\mathbf{c1_2}$ = ($bq_1$, $bq_2$,…, $bq_{64}$, $p1_1$, $p1_2$,…, $p1_{84}$, $p1_{93}$, $p1_{94}$,…, $p1_{168}$)
  — $\mathbf{c1_3}$ = ($bq_1$, $bq_2$,…, $bq_{64}$, $p1_1$, $p1_2$,…, $p1_{160}$)
  — $\mathbf{c2_1}$ = ($bq_{65}$, $bq_{66}$,…, $bq_{128}$, $p2_9$, $p2_{10}$,…, $p2_{168}$)
  — $\mathbf{c2_2}$ = ($bq_{65}$, $bq_{66}$,…, $bq_{128}$, $p2_1$, $p2_2$,…, $p2_{84}$, $p2_{93}$, $p2_{94}$,…, $p2_{168}$)
  — $\mathbf{c2_3}$ = ($bq_{65}$, $bq_{66}$,…, $bq_{128}$, $p2_1$, $p2_2$,…, $p2_{160}$)

— For a PPDU transmitted over an $N_{CB}$ × 2.16 GHz channel, where $1 \le N_{CB} \le 4$, the data blocks are defined as a repetition of codeword **c1** and **c2** as follows:

  — **cb1** = $c1$, **cb2** = $c2$ for $N_{CB}$ = 1
  — **cb1** = ($c1$, $c1$, $c1_{1:124}$), **cb2** = ($c2$, $c2$, $c2_{1:124}$) for $N_{CB}$ = 2
  — **cb1** = ($c1$, $c1$, $c1$, $c1_{1:252}$), **cb2** = ($c2$, $c2$, $c2$, $c2_{1:252}$) for $N_{CB}$ = 3
  — **cb1** = ($c1$, $c1$, $c1$, $c1$, $c1_{1:376}$), **cb2** = ($c2$, $c2$, $c2$, $c2$, $c2_{1:376}$) for $N_{CB}$ = 4

— For a PPDU transmitted using $N_{STS}$ ($N_{STS}$ = 1, 2, …, 8) space-time streams, the data blocks **cb1** and **cb2** are concatenated as **cb** = (**cb1**, **cb2**) and the data block **cb** is repeated $N_{STS}$ times. Then, the $N_{STS}$ data blocks **cb** are scrambled continuously with the PN sequence defined in 28.5.9.3.2 (Scrambler for EDMG-Header-A in SU EDMG A-PPDU, EDMG-Header-B, and EDMG SC MCS1 coded bits)without seed reset. The initial seed value is equal to all 1s ($1_1$, $1_2$,…, $1_7$). The scrambling starts at the 225$^{th}$ bit and ends at the ($N_{STS}$ × 4 × $N_{SD}$)$^{th}$ bit. The first scrambled **cb** block is mapped to the first space-time stream and the second scrambled **cb** block to the second space-time stream, and so on.

In the above description, the $\mathbf{c1_{1:}}_{\boldsymbol{m}}$ and $\mathbf{c2_{1:}}_{\boldsymbol{m}}$ notations define an array of vector **c1** and **c2** elements starting from the first bit (inclusive) and ending at the $m^{th}$ bit (inclusive).

The data blocks shall be modulated using DCM QPSK modulation. The EDMG-Header-A field shall use an OFDM modulation as defined for the Data field of the PPDU in 28.6.9.3 (Modulation mapping).

### 28.6.8 Modulation and coding scheme (MCS)

The MCS is a value that determines modulation and coding. For an EDMG PPDU, the MCS value is carried in the EDMG-Header-A field and in the EDMG-Header-B field. The data rate provided by an MCS depends on the guard interval length, the number of spatial streams, $N_{SS}$ ($1 \le N_{SS} \le 8$), and the number of $N_{SD}$ data subcarriers defined per OFDM symbol.

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Table 28-68 (EDMG-MCSs for the EDMG OFDM mode(11ay)) defines the set of MCSs for an EDMG OFDM mode PPDU. MCS (#4136)indicess exceeding the largest MCS index defined in Table 28-68 (EDMG-MCSs for the EDMG OFDM mode(11ay)) are reserved.

**Table 28-68—EDMG-MCSs for the EDMG OFDM mode(11ay)**

| EDMG-MCS index | Modulation | NBPSC | Code rate |
|---|---|---|---|
| 1 | DCM BPSK | 1 | 1/2 |
| 2 | DCM BPSK | 1 | 5/8 |
| 3 | DCM BPSK | 1 | 3/4 |
| 4 | DCM BPSK | 1 | 13/16 |
| 5 | DCM BPSK | 1 | 7/8 |
| 6 | DCM QPSK | 2 | 1/2 |
| 7 | DCM QPSK | 2 | 5/8 |
| 8 | DCM QPSK | 2 | 3/4 |
| 9 | DCM QPSK | 2 | 13/16 |
| 10 | DCM QPSK | 2 | 7/8 |
| 11 | 16-QAM | 4 | 1/2 |
| 12 | 16-QAM | 4 | 5/8 |
| 13 | 16-QAM | 4 | 3/4 |
| 14 | 16-QAM | 4 | 13/16 |
| 15 | 16-QAM | 4 | 7/8 |
| 16 | 64-QAM | 6 | 1/2 |
| 17 | 64-QAM | 6 | 5/8 |
| 18 | 64-QAM | 6 | 3/4 |
| 19 | 64-QAM | 6 | 13/16 |
| 20 | 64-QAM | 6 | 7/8 |

For a given type of guard interval used in the transmission of an EDMG OFDM mode PPDU, the total transmission data rate, ρ, provided by the PPDU is defined as follows:

$$\rho = \sum_{i_{SS}=1}^{N_{SS}} Data\_rate_{i_{SS}}$$

where

$N_{SS}$ is as defined in this subclause

$Data\_rate_{i_{SS}}$ is the data rate provided by the MCS of spatial stream $i_{SS}$ as defined in Table 28-69 (Data rate for the EDMG OFDM mode with NSD = 336, 734(11ay)) and Table 28-70 (Data rate for the EDMG OFDM mode with NSD = 1134, 1532(11ay))



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Table 28-69 (Data rate for the EDMG OFDM mode with NSD = 336, 734(11ay)) and Table 28-70 (Data rate for the EDMG OFDM mode with NSD = 1134, 1532(11ay)) define the data rate for a given number of data subcarriers, $N_{SD}$, and guard interval type.

**Table 28-69—Data rate for the EDMG OFDM mode with $N_{SD}$ = 336, 734(11ay)**

| MCS | Data rate per spatial stream (Mb/s) | | | | | |
|---|---|---|---|---|---|---|
| | $N_{SD}$ = 336 | | | $N_{SD}$ = 734 | | |
| | Normal GI | Short GI | Long GI | Normal GI | Short GI | Long GI |
| 1 | 729.47 | 792.00 | 630.00 | 1593.55 | 1730.14 | 1376.25 |
| 2 | 911.84 | 990.00 | 787.50 | 1991.94 | 2162.68 | 1720.31 |
| 3 | 1094.21 | 1188.00 | 945.00 | 2390.33 | 2595.21 | 2064.38 |
| 4 | 1185.39 | 1287.00 | 1023.75 | 2589.52 | 2811.48 | 2236.41 |
| 5 | 1276.58 | 1386.00 | 1102.50 | 2788.72 | 3027.75 | 2408.44 |
| 6 | 1458.95 | 1584.00 | 1260.00 | 3187.11 | 3460.29 | 2752.50 |
| 7 | 1823.68 | 1980.00 | 1575.00 | 3983.88 | 4325.36 | 3440.63 |
| 8 | 2188.42 | 2376.00 | 1890.00 | 4780.66 | 5190.43 | 4128.75 |
| 9 | 2370.79 | 2574.00 | 2047.50 | 5179.05 | 5622.96 | 4472.81 |
| 10 | 2553.16 | 2772.00 | 2205.00 | 5577.43 | 6055.50 | 4816.88 |
| 11 | 2917.89 | 3168.00 | 2520.00 | 6374.21 | 6920.57 | 5505.00 |
| 12 | 3647.37 | 3960.00 | 3150.00 | 7967.76 | 8650.71 | 6881.25 |
| 13 | 4376.84 | 4752.00 | 3780.00 | 9561.32 | 10 380.86 | 8257.50 |
| 14 | 4741.58 | 5148.00 | 4095.00 | 10 358.09 | 11 245.93 | 8945.63 |
| 15 | 5106.32 | 5544.00 | 4410.00 | 11 154.87 | 12 111.00 | 9633.75 |
| 16 | 4376.84 | 4752.00 | 3780.00 | 9561.32 | 10 380.86 | 8257.50 |
| 17 | 5471.05 | 5940.00 | 4725.00 | 11 951.64 | 12 976.07 | 10 321.88 |
| 18 | 6565.26 | 7128.00 | 5670.00 | 14 341.97 | 15 571.29 | 12 386.25 |
| 19 | 7112.37 | 7722.00 | 6142.50 | 15 537.14 | 16 868.89 | 13 418.44 |
| 20 | 7659.47 | 8316.00 | 6615.00 | 16 732.30 | 18 166.50 | 14 450.63 |

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**Table 28-70—Data rate for the EDMG OFDM mode with $N_{SD}$ = 1134, 1532(11ay)**

| MCS | Data rate per spatial stream (Mb/s) | | | | | |
|---|---|---|---|---|---|---|
| | $N_{SD}$ = 1134 | | | $N_{SD}$ = 1532 | | |
| | Normal GI | Short GI | Long GI | Normal GI | Short GI | Long GI |
| 1 | 2461.97 | 2673.00 | 2126.25 | 3326.05 | 3611.14 | 2872.50 |
| 2 | 3077.47 | 3341.25 | 2657.81 | 4157.57 | 4513.93 | 3590.63 |
| 3 | 3692.96 | 4009.50 | 3189.38 | 4989.08 | 5416.71 | 4308.75 |
| 4 | 4000.71 | 4343.63 | 3455.16 | 5404.84 | 5868.11 | 4667.81 |
| 5 | 4308.45 | 4677.75 | 3720.94 | 5820.59 | 6319.50 | 5026.88 |
| 6 | 4923.95 | 5346.00 | 4252.50 | 6652.11 | 7222.29 | 5745.00 |
| 7 | 6154.93 | 6682.50 | 5315.63 | 8315.13 | 9027.86 | 7181.25 |
| 8 | 7385.92 | 8019.00 | 6378.75 | 9978.16 | 10 833.43 | 8617.50 |
| 9 | 8001.41 | 8687.25 | 6910.31 | 10 809.67 | 11 736.21 | 9335.63 |
| 10 | 8616.91 | 9355.50 | 7441.88 | 11 641.18 | 12 639.00 | 10 053.75 |
| 11 | 9847.89 | 10 692.00 | 8505.00 | 13 304.21 | 14 444.57 | 11 490.00 |
| 12 | 12 309.87 | 13 365.00 | 10 631.25 | 16 630.26 | 18 055.71 | 14 362.50 |
| 13 | 14 771.84 | 16 038.00 | 12 757.50 | 19 956.32 | 21 666.86 | 17 235.00 |
| 14 | 16 002.83 | 17 374.50 | 13 820.63 | 21 619.34 | 23 472.43 | 18 671.25 |
| 15 | 17 233.82 | 18 711.00 | 14 883.75 | 23 282.37 | 25 278.00 | 20 107.50 |
| 16 | 14 771.84 | 16 038.00 | 12 757.50 | 19 956.32 | 21 666.86 | 17 235.00 |
| 17 | 18 464.80 | 20 047.50 | 15 946.88 | 24 945.39 | 27 083.57 | 21 543.75 |
| 18 | 22 157.76 | 24 057.00 | 19 136.25 | 29 934.47 | 32 500.29 | 25 852.50 |
| 19 | 24 004.24 | 26 061.75 | 20 730.94 | 32 429.01 | 35 208.64 | 28 006.88 |
| 20 | 25 850.72 | 28 066.50 | 22 325.63 | 34 923.55 | 37 917.00 | 30 161.25 |


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### 28.6.9 Data field

#### 28.6.9.1 Scrambler

The operation of the scrambler applied for the data bits is defined in 20.3.9 (Scrambler). The scrambling of an SU PSDU continues the scrambling of L-Header and EDMG-Header-A. The initial seed value is defined in the L-Header.

The scrambling of an MU PSDU is performed on a per user basis and continues the scrambling of EDMG-Header-B with reset of the seed value. The initial seed value is defined in the EDMG-Header-B on a per user basis.

#### 28.6.9.2 Encoding

##### 28.6.9.2.1 General

An EDMG OFDM PSDU is encoded by a systematic LDPC block code. Each data word of $L_{CWD}$ information bits is concatenated with $L_{CWP}$ parity bits to create a codeword of length $L_{CW} = L_{CWD} + L_{CWP}$ bits. The EDMG LDPC encoding can employ the codeword lengths $L_{CW}$ = 624, 672, 1248, and 1344 and code rates $R$ = 1/2, 5/8, 3/4, 13/16, and 7/8.

Table 28-71 (LDPC code rates(11ay)) provides a summary of LDPC code rates.

**Table 28-71—LDPC code rates(11ay)**

| Code rate | Codeword length ($L_{CW}$) | | Number of data bits ($L_{CWD}$) | |
|---|---|---|---|---|
| | Short | Long | Short | Long |
| 1/2 | 672 | 1344 | 336 | 672 |
| 5/8 | 672 | 1344 | 420 | 840 |
| 3/4 | 672 | 1344 | 504 | 1008 |
| 13/16 | 672 | 1344 | 546 | 1092 |
| 7/8 | 624 or 672 | 1248 or 1344 | 546 or 588 | 1092 or 1176 |

The LDPC encoding with codeword length $L_{CW}$ = 672 and 1344 is performed by solving the linear system of equations $\mathbf{H} \cdot \left(\mathbf{c}^{(m)}\right)^T = \mathbf{0}$ defined by the parity matrix H of size $L_{CWP}$ by $L_{CW}$, where $\mathbf{c}^{(m)} = \left(\mathbf{b}^{(m)}, \mathbf{p}^{(m)}\right)$ defines the $m^{\text{th}}$ LDPC codeword, $\mathbf{b}^{(m)} = \left(b_1^{(m)}, b_2^{(m)}, ..., b_{L_{CWD}}^{(m)}\right)$ defines the data bits of the $m^{\text{th}}$ LDPC codeword (or data word), and $\mathbf{p}^{(m)} = \left(p_1^{(m)}, p_2^{(m)}, ..., p_{L_{CWP}}^{(m)}\right)$ defines parity bits for $m^{\text{th}}$ LDPC codeword.

The LDPC encoding with codeword length $L_{CW}$ = 624 and 1248 employs the matrices H with $L_{CW}$ = 672 and 1344 for code rate $R$ = 13/16 and then applies puncturing procedure to get a desired code rate $R$ = 7/8. For $L_{CW}$ = 624, the first 48 parity bits are discarded; and for $L_{CW}$ = 1248, the first 96 parity bits are discarded.

Table 28-72 (Values of NCBPS for different modulation types and number of data subcarriers(11ay)) defines the number of coded bits per OFDM symbol, $N_{CBPS}$, for different modulation types and number of data subcarriers, $N_{SD}$.

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**Table 28-72—Values of $N_{CBPS}$ for different modulation types and number of data subcarriers(11ay)**

| Symbol mapping | $N_{SD}$ = 336 | $N_{SD}$ = 734 | $N_{SD}$ = 1134 | $N_{SD}$ = 1532 |
|---|---|---|---|---|
| DCM BPSK | 336 | 734 | 1134 | 1532 |
| DCM QPSK | 672 | 1468 | 2268 | 3064 |
| 16-QAM | 1344 | 2936 | 4536 | 6128 |
| 64-QAM | 2016 | 4404 | 6804 | 9192 |

#### 28.6.9.2.2 Parity check matrices

See 28.3.6 (LDPC parity matrices).

#### 28.6.9.2.3 LDPC encoding

This subclause defines the EDMG SU PSDU and EDMG MU PSDU per user basis LDPC encoding. The LDPC encoding can employ the codeword lengths $L_{CW}$ = 624, 672, 1248, and 1344 and code rates $R$ = 1/2, 5/8, 3/4, 13/16, and 7/8.

The LDPC encoding process for the $i_{user}$th user includes the following steps:

a) Compute the number of data pad bits, $N_{DATA\_PAD\,i_{user}}$, using the number of LDPC codewords, $N_{CW\,i_{user}}$, as follows:

$$N_{CW\ i_{user}} = \left\lceil \frac{Length_{i_{user}} \cdot 8}{L_{CW\ i_{user}} \cdot R_{i_{user}}} \right\rceil$$

$$N_{DATA\_PAD\ i_{user}} = N_{CW\ i_{user}} \cdot L_{CW\ i_{user}} \cdot R_{i_{user}} - Length_{i_{user}} \cdot 8$$

The scrambled PSDU is concatenated with $N_{DATA\_PAD\,i_{user}}$ zero bits. They are scrambled using the continuation of the scrambler sequence that scrambled the PSDU input bits.

b) Convert the scrambled PSDU bits to LDPC codewords as follows:

1) If $L_{CW}$ = 672 or 1344, $R$ = 1/2, 5/8, 3/4, 13/16, or 7/8:

i) The output stream of scrambler is broken into the blocks of length $L_{CWD} = L_{CW} \times R$ bits such that the $m$th data word is $\mathbf{b}^{(m)} = \left(b_1^{(m)}, b_2^{(m)}, ..., b_{L_{CWD}}^{(m)}\right), m \le N_{CW\,i_{user}}$.

ii) To each data word, parity bits $\mathbf{p}^{(m)} = \left(p_1^{(m)}, p_2^{(m)}, ..., p_{L_{CWP}}^{(m)}\right)$, $L_{CWP} = L_{CW} - L_{CWD}$, are added to create the codeword $\mathbf{c}^{(m)} = \left(\mathbf{b}^{(m)}, \mathbf{p}^{(m)}\right), m \le N_{CW\,i_{user}}$ such that $\mathbf{H} \cdot \left(\mathbf{c}^{(m)}\right)^T = \mathbf{0}$.

2) If $L_{CW}$ = 624, $R$ = 7/8:

i) The output stream of scrambler is broken into the blocks of length 546 bits such that the $m$th data word is $\mathbf{b}^{(m)} = \left(b_1^{(m)}, b_2^{(m)}, ..., b_{546}^{(m)}\right), m \le N_{CW\,i_{user}}$.



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ii) To each data word, parity bits $\mathbf{p}^{(m)} = \left(p_1^{(m)}, p_2^{(m)}, ..., p_{126}^{(m)}\right)$ are added to create the codeword $\mathbf{c}^{(m)} = \left(\mathbf{b}^{(m)}, \mathbf{p}^{(m)}\right), m \le N_{CW\,i_{user}}$ such that $\mathbf{H} \cdot \left(\mathbf{c}^{(m)}\right)^T = \mathbf{0}$; parity bits are computed applying the $L_{CW} = 672$, $R = 13/16$ LDPC matrix.

iii) Finally, the first 48 parity bits are discarded (punctured) to create the output codeword $\mathrm{c}^{(m)} = (b_1^{(m)}, b_2^{(m)}, \ldots, b_{546}^{(m)}, p_{49}^{(m)}, p_{50}^{(m)}, \ldots, p_{126}^{(m)}), m \le N_{CW\,i_{user}}$ (#515).

3) If $L_{CW} = 1248$, $R = 7/8$:

i) The output stream of scrambler is broken into the blocks of length 1092 bits such that the $m^{\text{th}}$ data word is $\mathbf{b}^{(m)} = \left(b_1^{(m)}, b_2^{(m)}, ..., b_{1092}^{(m)}\right), m \le N_{CW\,i_{user}}$.

ii) To each data word, parity bits $\mathbf{p}^{(m)} = \left(p_1^{(m)}, p_2^{(m)}, ..., p_{252}^{(m)}\right)$ are added to create the codeword $\mathbf{c}^{(m)} = \left(\mathbf{b}^{(m)}, \mathbf{p}^{(m)}\right), m \le N_{CW\,i_{user}}$ such that $\mathbf{H} \cdot \left(\mathbf{c}^{(m)}\right)^T = \mathbf{0}$; parity bits are computed applying the $L_{CW} = 1344$, $R = 13/16$ LDPC matrix.

iii) Finally, the first 96 parity bits are discarded (punctured) to create the output codeword $\mathrm{c}^{(m)} = (b_1^{(m)}, b_2^{(m)}, \ldots, b_{1092}^{(m)}, p_{97}^{(m)}, p_{98}^{(m)}, \ldots, p_{252}^{(m)}), m \le N_{CW\,i_{user}}$ (#515).

c) For each spatial stream concatenate LDPC codewords one after the other to create the coded bit stream $\left(\mathbf{c}^{(1)}, \mathbf{c}^{(2)}, ..., \mathbf{c}^{\left(N_{CW\,i_{user}}\right)}\right)$.

d) Compute the number of coded pad bits, $N_{SYM\_PAD\,i_{user}}$, using the number of OFDM symbols, $N_{SYMS\,i_{user}}$, as follows:

$$N_{SYMS\,i_{user}} = \left\lceil \frac{N_{CW\,i_{user}} \cdot L_{CW\,i_{user}}}{N_{SD} \cdot \sum_{i_{SS}=1}^{N_{SS\,i_{user}}} N_{BPSC\,i_{user}\,i_{SS}}} \right\rceil$$

If (BRP PPDU) and $N_{SYMS\,i_{user}} < N_{SYMS\,\min}$, then $N_{SYMS\,i_{user}} = N_{SYMS\,\min}$.

If last PPDU in A-PPDU, then $N_{SYMS\,i_{user}} = N_{SYMSspoof}$.

If STBC applied and $N_{SYMS\,i_{user}}$ is odd, then $N_{SYMS\,i_{user}} = N_{SYMS\,i_{user}} + 1$.

$$N_{SYM\_PAD\,i_{user}} = N_{SYMS\,i_{user}} \cdot N_{SD} \cdot \sum_{i_{SS}=1}^{N_{SS\,i_{user}}} N_{BPSC\,i_{user}\,i_{SS}} - N_{CW\,i_{user}} \cdot L_{CW\,i_{user}}$$

e) For an MU PPDU transmission, update the number of OFDM symbols $N_{SYMS\,i_{user}}$ as described in 28.6.9.2.4 (MU PPDU padding and space-time streams mapping), then update the number of pad bits $N_{SYM\_PAD\,i_{user}}$ as described in step d) using updated number of OFDM symbols $N_{SYMS\,i_{user}}$.

f) Concatenate coded bits with $N_{SYM\_PAD\,i_{user}}$ zero bits. They are scrambled using the continuation of the scrambler sequence that scrambled the PSDU input bits and data pad bits in step a).

g) Distribute the encoded and padded bits over the $N_{SS\,i_{user}}$ spatial streams on a group basis with the number of $N_{CBPS\,i_{user}\,i_{ss}}$ bits in a group. The first group of bits goes to the first spatial stream, the

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second group of bits goes to the second spatial stream, and so on. The procedure is repeated when the maximum number of spatial streams, $N_{SS\,i_{user}}$, is reached. The procedure ends when all PSDU encoded bits, including $N_{SYM\_PAD\,i_{user}}$ pad bits, are distributed over the $N_{SS\,i_{user}}$ spatial streams.

For each user, if STBC coding is applied, then $N_{SS\,i_{user}}$ space-time streams are mapped to $N_{STS\,i_{user}} = 2N_{SS\,i_{user}}$ space-time streams as defined in 28.6.9.3.10 (Space-time block coding). Otherwise, a one-to-one mapping of $N_{SS\,i_{user}}$ spatial streams to $N_{STS\,i_{user}}$ space-time streams shall be applied.

NOTE—For a PPDU carrying a BRP frame, the value of $N_{SYMS\,\min}$ is specified in 28.9.2.2.4 (EDMG BRP PPDU duration).

### 28.6.9.2.4 MU PPDU padding and space-time streams mapping

For an MU PPDU transmission, all user PPDUs shall be aligned in time. If necessary, user PSDUs shall be padded according to the following steps:

— Compute the maximum number of OFDM symbols over all users $N_{SYMS\,\max} = \max_{i_{user}}\left(N_{SYMS\,i_{user}}\right)$ for $i_{user} = 1, 2, \ldots, N_{user}$.

— Update the number of OFDM symbols at step e) in 28.6.9.2.3 (LDPC encoding) as $N_{SYMS\,i_{user}} = N_{SYMS\,\max}$ for $i_{user} = 1, 2, \ldots, N_{user}$. Update the number of pad bits for the $i_{user}^{\text{th}}$ user, $N_{SYM\_PAD\,i_{user}}$, accordingly.

— The number of pad OFDM symbols for the MU PPDU transmission for the $i_{user}^{\text{th}}$ user is defined as $N_{PAD\_SYMS\,i_{user}} = N_{SYMS\,\max} - N_{SYMS\,i_{user}}$.

The number of pad symbols $N_{PAD\_SYMS\,i_{user}}$ takes into account MU PPDU padding only and does not include the regular padding described in 28.6.9.2.3 (LDPC encoding).

A receiver can compute the number of pad OFDM symbols, $N_{PAD\_SYMS\,i_{user}}$, using the overall PPDU time duration computed using the MCS and PSDU Length fields defined in the L-Header, MCS, and PSDU Length fields defined in EDMG-Header-B, and TRN field duration defined in the EDMG-Header-A.

— For a nonzero spoofing error and if the spoofing error duration is shorter than one OFDM symbol duration ($T_{SYM} = T_{DFT} + T_{GI}$), the fractional part of OFDM symbol is discarded.

— For a nonzero spoofing error and if the spoofing error duration is longer than or equal to an OFDM symbol duration, then one OFDM symbol and possible fractional part of OFDM symbol are discarded; this is signaled by the Spoofing Error Length Indicator field in the EDMG-Header-B.

This procedure also allows a receiver to determine the beginning of a TRN field if one is present in a received MU PPDU.

The space-time stream index per user, $i_{STS\,i_{user}}$, is mapped to the space-time stream index over all users, $i_{STS}$, as follows:

$$i_{STS}\left(i_{user}, i_{STS\,i_{user}}\right) = \sum_{m=0}^{i_{user}-1} Num_m + i_{STS\,i_{user}},\ 1 \le i_{STS\,i_{user}} \le N_{STS\,i_{user}},\ 1 \le i_{user} \le N_{user}$$

$$Num_m = N_{STS\,m} \text{ for } m > 0 \text{ and } Num_m = 0 \text{ otherwise}$$

NOTE—$i_{STS}$ is a function of $i_{user}$ and $i_{STS\,i_{user}}$ indices. However, to simplify notations, this dependence is not indicated explicitly in other equations.


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#### 28.6.9.2.5 SU A-PPDU padding

For the last PPDU in an EDMG A-PPDU, $N_{SYMSspoof}$ shall be set, at step d) in 28.6.9.2.3 (LDPC encoding), so that the spoofing error is non-negative and smaller than one SC symbol block (i.e., $T_{DFT}$, defined in Table 28-47 (EDMG SC mode timing-related parameters(11ay))). If the last PPDU in an EDMG A-PPDU contains a BRP frame, $N_{SYMSspoof}$ shall be equal to or greater than $N_{SYMS\,\min}$ and set so that the spoofing error is smaller than one OFDM symbol duration (i.e., $T_{SYM} = T_{DFT} + T_{GI}$, where $T_{DFT}$ and $T_{GI}$ are defined in Table 28-62 (EDMG OFDM mode timing related parameters1(11ay))) to enable the receiver to determine the start of the TRN field. $N_{SYMSspoof}$ is calculated as follows:

$$T_{Data\,\max}^{(N_{PPDU})} = TXTIME_{spoof} - \Big(T_{L\text{-}STF} + T_{L\text{-}CEF} + T_{L\text{-}Header} + T_{EDMG\text{-}Header\text{-}A} + T_{EDMG\text{-}STF} + T_{EDMG\text{-}CEF} + \left(N_{PPDU} - 1\right) T_{EDMG\text{-}Header\text{-}A}^{(OFDM)} + \sum_{i_{PPDU}=1}^{N_{PPDU}-1} T_{Data}^{(i_{PPDU})} + T_{TRN}\Big)$$

$$N_{SYMSspoof} = \left\lfloor \frac{T_{Data\,\max}^{(N_{PPDU})}}{T_{SYM}} \right\rfloor$$

where

$TXTIME_{spoof}$ is the spoofed PPDU duration calculated based on L-Header

$T_{L\text{-}STF}$, $T_{L\text{-}CEF}$, $T_{L\text{-}Header}$, $T_{EDMG\text{-}STF}$, $T_{EDMG\text{-}CEF}$, $T_{EDMG\text{-}Header\text{-}A}$, and $T_{TRN}$ are the durations of the L-STF, L-CEF, L-Header, EDMG-STF, EDMG-CEF, EDMG-Header-A, and TRN fields as defined in 28.12.3.4 (TXTIME calculation for EDMG OFDM mode)

$T_{SYM} = T_{DFT} + T_{GI}$ where $T_{DFT}$ and $T_{GI}$ are defined in Table 28-62 (EDMG OFDM mode timing related parameters1(11ay)); $T_{GI}$ can be equal to $T_{GI\,short}$, $T_{GI\,normal}$, or $T_{GI\,long}$

$T_{EDMG\text{-}Header\text{-}A}^{(OFDM)}$ is the duration of the EDMG-Header-A of the second to the last PPDU using OFDM modulation (see 28.6.7 (Encoding of EDMG-Header-A for EDMG A-PPDU transmission))

$T_{Data}^{(i_{PPDU})}$, for $i_{PPDU} = 1, \ldots, N_{PPDU} - 1$, is the duration of the (#404)Data field of $i_{PPDU}^{\text{th}}$ PPDU, except for the last PPDU, as defined in 28.12.3.4 (TXTIME calculation for EDMG OFDM mode)

$T_{Data\,\max}^{(N_{PPDU})}$ is the maximum duration of the last PPDU that fulfills the spoofing error requirement

For an EDMG A-PPDU transmission, the spoofed values of the L-Header fields and the duration of the PPDUs except the last PPDU shall be determined so that $N_{SYMSspoof}$ is equal to or greater than $N_{SYMS\,\min}$.

NOTE—The EDMG Header-A field in the first PPDU is modulated with (#8160)EDMG SC mode while the EDMG Header-A fields in the following PPDUs are modulated with (#8160)EDMG OFDM mode as described in 28.6.7 (Encoding of EDMG-Header-A for EDMG A-PPDU transmission). The duration of the fields might be different from that of the field in the first PPDU.

### 28.6.9.3 Modulation mapping

#### 28.6.9.3.1 General

This subclause defines the OFDM transmission for the data part of a PPDU over 2.16 GHz, 4.32 GHz, 6.48 GHz, and 8.64 GHz channels with $i_{STS} = 1, 2, 3, 4, 5, 6, 7$, or 8.

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The coded and padded bit stream is converted into a stream of complex constellation points, following the rules defined in this subclause for BPSK, Dual Stream DCM BPSK, DCM QPSK, 16-QAM, 64-QAM, and phase hopping modulations.

The DCM BPSK, Dual Stream DCM BPSK, and DCM QPSK modulations use the tone pairing mechanism to extract channel frequency diversity as defined in 28.6.9.3.3 (DCM BPSK modulation), 28.6.9.3.4 (Dual Stream DCM BPSK modulation), and 28.6.9.3.5 (DCM QPSK modulation), respectively. The 16-QAM and 64-QAM modulations use the interleaver defined in 28.6.9.3.9 (Interleaver).

### 28.6.9.3.2 Transmission in EDMG format

The EDMG data transmit waveform for $i_{TX}^{\text{th}}$ transmit chain in time domain shall be defined at the OFDM sampling rate $F_s$ as follows:

$$r_{Data}^{i_{TX}}\left(qT_s\right) = \frac{1}{\sqrt{N_{STS} \cdot N_{EDMG\text{-}DATA}^{Tone}}} \sum_{n=0}^{N_{SYM}-1} w_{T_{SYM}}\left(qT_s - nT_{SYM}\right)$$

$$\cdot \sum_{k=-N_{SR}}^{N_{SR}} \sum_{i_{STS}=1}^{N_{STS}} \left[Q_{EDMG\,k}\right]_{i_{TX},i_{STS}} \left(D\left(i_{STS},n,k\right) + P\left(i_{STS},n,k\right)\right) \exp\left(j2\pi k\Delta_F\left(qT_s - nT_{SYM} - T_{GI}\right)\right)$$

where

$N_{EDMG\text{-}DATA}^{Tone} = N_{SD} + N_{SP}$ is the total number of active tones

$N_{STS}$ is the total number of space-time streams

$T_{SYM} = T_{DFT} + T_{GI}$ is the OFDM symbol duration in time domain

$T_{GI}$ is the guard interval duration

$Q_{EDMG\,k}$ is the spatial mapping matrix per $k^{\text{th}}$ subcarrier

$[\ ]_{m,n}$ is a matrix element from $m^{\text{th}}$ row and $n^{\text{th}}$ column

$w_{T_{SYM}}\left(qT_s\right)$ is a window function applied to smooth the transitions between consecutive OFDM symbols and its definition is implementation specific

$D\left(i_{STS},n,k\right)$ is the data sequence, it is defined by inserting 0s from $-N_{SR}$ to $N_{SR}$, and then inserting data at the $M_d(k)$ tones defined in 28.6.2.5 (Data tones), $D(i_{STS}, n, M_d(k)) = d(i_{STS}, n, k)$, for $k = 0, 1, \ldots, N_{SD} - 1$

$P\left(i_{STS},n,k\right)$ is the pilot sequence defined in 28.6.2.6 (Pilot sequences)

$q$ is a time sample index

NOTE—For EDMG-Header-B transmission, the zeroth OFDM symbol corresponds to the EDMG-Header-B, $n = 0$, and the numbering of OFDM symbols for the data part starts from $n = 1$.

### 28.6.9.3.3 DCM BPSK modulation

The input encoded bits belonging to the $i_{SS}^{\text{th}}$ spatial stream are broken into the groups of $N_{CBPS}$ bits, $\left(c_0^{(q)}, c_1^{(q)}, \ldots, c_{N_{CBPS}-1}^{(q)}\right)$, where $q$ denotes the group number. Each pair of bits $\left(c_{2k}^{(q)}, c_{2k+1}^{(q)}\right)$, $k = 0, 1, \ldots, N_{SD}/2 - 1$, is converted into the pair of complex points $\left(d\left(i_{SS},q,k\right), d\left(i_{SS},q,P\left(k\right)\right)\right)$. The modulation is performed in two steps:

— First, two BPSK points are modulated as $x_{2k}^{(q)} = \left(2 \times c_{2k}^{(q)} - 1\right)$, $x_{2k+1}^{(q)} = \left(2 \times c_{2k+1}^{(q)} - 1\right)$.


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— Second, two BPSK points $\left(x_{2k}^{(q)}, x_{2k+1}^{(q)}\right)$ are converted to two QPSK points $\left(d\left(i_{SS}, q, k\right), d\left(i_{SS}, q, P(k)\right)\right)$ by multiplication on mapping matrix $W$ as follows:

$$\begin{bmatrix} d\left(i_{SS}, q, k\right) \\ d\left(i_{SS}, q, P(k)\right) \end{bmatrix} = W \cdot \begin{bmatrix} x_{2k}^{(q)} \\ x_{2k+1}^{(q)} \end{bmatrix}, W = \frac{1}{\sqrt{2}} \begin{bmatrix} 1 & j \\ 1 & -j \end{bmatrix}$$

where the tone pairing index $P(k)$ is defined as $P(k) = k + N_{SD}/2$ in the range $N_{SD}/2$ to $N_{SD} - 1$. The $q^{\text{th}}$ modulated data block of the $i_{SS}{}^{\text{th}}$ spatial stream is mapped to $N_{SD}$ data subcarriers of the $q^{\text{th}}$ OFDM symbol of the $i_{SS}{}^{\text{th}}$ spatial stream.

#### 28.6.9.3.4 Dual Stream DCM BPSK modulation

Dual Stream DCM BPSK modulation is applied if the number of spatial streams, $N_{SS}$, is equal to 2 and the DCM BPSK Applied field in EDMG-Header-A is set to 1.

The input encoded bits of $i_{SS}{}^{\text{th}}$ spatial stream are broken into the groups of $N_{CBPS}$ bits, $\left(c_0^{(i_{SS},q)}, c_1^{(i_{SS},q)}, ..., c_{N_{CBPS}-1}^{(i_{SS},q)}\right)$, where $q$ denotes the group number. Each pair of bits $\left(c_{2k}^{(i_{SS},q)}, c_{2k+1}^{(i_{SS},q)}\right)$, $k = 0, 1, \ldots, N_{SD}/2 - 1$, is converted into the complex point $d\left(i_{SS}, q, k\right)$.

For 2.16 GHz, 4.32 GHz, 6.48 GHz, and 8.64 GHz channel configurations, the modulation is performed as follows:

$$d\left(i_{SS}=1, q, k\right) = \frac{1}{\sqrt{2}}\left(\left(2 \times c_{2k}^{(i_{SS}=1,q)} - 1\right) + j\left(2 \times c_{2k+1}^{(i_{SS}=1,q)} - 1\right)\right)$$

$$d\left(i_{SS}=1, q, P(k)\right) = \frac{1}{\sqrt{2}}\left(\left(2 \times c_{2k}^{(i_{SS}=2,q)} - 1\right) - j\left(2 \times c_{2k+1}^{(i_{SS}=2,q)} - 1\right)\right)$$

$$d\left(i_{SS}=2, q, k\right) = \frac{1}{\sqrt{2}}\left(\left(2 \times c_{2k}^{(i_{SS}=2,q)} - 1\right) + j\left(2 \times c_{2k+1}^{(i_{SS}=2,q)} - 1\right)\right)$$

$$d\left(i_{SS}=2, q, P(k)\right) = \frac{1}{\sqrt{2}}\left(\left(2 \times c_{2k}^{(i_{SS}=1,q)} - 1\right) - j\left(2 \times c_{2k+1}^{(i_{SS}=1,q)} - 1\right)\right)$$

where the tone pairing index $P(k)$ is defined as $P(k) = k + N_{SD}/2$ in the range $N_{SD}/2$ to $N_{SD} - 1$. The $q^{\text{th}}$ modulated data block of the $i_{SS}{}^{\text{th}}$ spatial stream is mapped to $N_{SD}$ data subcarriers of the $q^{\text{th}}$ OFDM symbol of the $i_{SS}{}^{\text{th}}$ spatial stream.

For 2.16+2.16 GHz and 4.32+4.32 GHz channel configurations, the modulation is performed as follows:

$$d\left(i_{SS}=1, q, k\right) = \frac{1}{\sqrt{2}}\left(\left(2 \times c_{2k}^{(i_{SS}=1,q)} - 1\right) + j\left(2 \times c_{2k+1}^{(i_{SS}=1,q)} - 1\right)\right)$$

$$d\left(i_{SS}=1, q, P(k)\right) = \frac{1}{\sqrt{2}}\left(\left(2 \times c_{2k}^{(i_{SS}=2,q)} - 1\right) + j\left(2 \times c_{2k+1}^{(i_{SS}=2,q)} - 1\right)\right)$$

$$d\left(i_{SS}=2, q, k\right) = \frac{1}{\sqrt{2}}\left(\left(2 \times c_{2k}^{(i_{SS}=1,q)} - 1\right) - j\left(2 \times c_{2k+1}^{(i_{SS}=1,q)} - 1\right)\right)$$

$$d\left(i_{SS}=2, q, P(k)\right) = \frac{1}{\sqrt{2}}\left(\left(2 \times c_{2k}^{(i_{SS}=2,q)} - 1\right) - j\left(2 \times c_{2k+1}^{(i_{SS}=2,q)} - 1\right)\right)$$

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where the tone pairing index $P(k)$ is defined as $P(k) = k + N_{SD}/2$ in the range $N_{SD}/2$ to $N_{SD} - 1$. The $q^{th}$ modulated data block of the $i_{SS}^{th}$ spatial stream is mapped to $N_{SD}$ data subcarriers of the $q^{th}$ OFDM symbol of the $i_{SS}^{th}$ spatial stream.

#### 28.6.9.3.5 DCM QPSK modulation

The input encoded bits of the $i_{SS}^{th}$ spatial stream are broken into the groups of $N_{CBPS}$ bits, $\left(c_0^{(q)}, c_1^{(q)}, ..., c_{N_{CBPS}-1}^{(q)}\right)$, where $q$ denotes the group number. Each four bits $\left(c_{4k}^{(q)}, c_{4k+1}^{(q)}, c_{4k+2}^{(q)}, c_{4k+3}^{(q)}\right)$, $k = 0, 1, \ldots, N_{SD}/2 - 1$, are converted into the pair of complex points $\left(d\left(i_{SS}, q, k\right), d\left(i_{SS}, q, P\left(k\right)\right)\right)$. The modulation is performed in two steps:

— First, two QPSK points are modulated as $x_{2k}^{(q)} = \frac{1}{\sqrt{2}}\left(\left(2 \times c_{4k}^{(q)} - 1\right) + j\left(2 \times c_{4k+2}^{(q)} - 1\right)\right)$, $x_{2k+1}^{(q)} = \frac{1}{\sqrt{2}}\left(\left(2 \times c_{4k+1}^{(q)} - 1\right) + j\left(2 \times c_{4k+3}^{(q)} - 1\right)\right)$.

— Second, two QPSK points $\left(x_{2k}^{(q)}, x_{2k+1}^{(q)}\right)$ are converted to two 16-QAM points $\left(d\left(i_{SS}, q, k\right), d\left(i_{SS}, q, P\left(k\right)\right)\right)$ by multiplication on mapping matrix $W$ as follows:

$$\begin{bmatrix} d\left(i_{SS}, q, k\right) \\ d\left(i_{SS}, q, P\left(k\right)\right) \end{bmatrix} = W \cdot \begin{bmatrix} x_{2k}^{(q)} \\ x_{2k+1}^{(q)} \end{bmatrix}, \; W = \frac{1}{\sqrt{5}} \begin{bmatrix} 1 & 2 \\ -2 & 1 \end{bmatrix}$$

where the tone pairing index $P(k)$ is defined as $P(k) = k + N_{SD}/2$ in the range $N_{SD}/2$ to $N_{SD} - 1$. The $q^{th}$ modulated data block of the $i_{SS}^{th}$ spatial stream is mapped to $N_{SD}$ data subcarriers of the $q^{th}$ OFDM symbol of the $i_{SS}^{th}$ spatial stream.

#### 28.6.9.3.6 16-QAM modulation

The input encoded bits of the $i_{SS}^{th}$ spatial stream are broken into the groups of $N_{CBPS}$ bits, $\left(c_0^{(q)}, c_1^{(q)}, ..., c_{N_{CBPS}-1}^{(q)}\right)$, where $q$ denotes the group number. Each four bits $\left(c_{4k}^{(q)}, c_{4k+1}^{(q)}, c_{4k+2}^{(q)}, c_{4k+3}^{(q)}\right)$, $k = 0, 1, \ldots, N_{SD} - 1$, are converted into the single constellation point $d\left(i_{SS}, q, k\right)$. The modulation is performed as follows:

$$d\left(i_{SS}, q, k\right) = \frac{1}{\sqrt{10}}\left(\left(2 \times \left(2c_{4k}^{(q)} - 1\right) - \left(2c_{4k}^{(q)} - 1\right) \times \left(2c_{4k+1}^{(q)} - 1\right)\right)\right.$$
$$\left. + j\left(2 \times \left(2c_{4k+2}^{(q)} - 1\right) - \left(2c_{4k+2}^{(q)} - 1\right) \times \left(2c_{4k+3}^{(q)} - 1\right)\right)\right)$$

The $q^{th}$ modulated data block of the $i_{SS}^{th}$ spatial stream is mapped to $N_{SD}$ data subcarriers of the $q^{th}$ OFDM symbol of the $i_{SS}^{th}$ spatial stream.

#### 28.6.9.3.7 64-QAM modulation

The input encoded bits of the $i_{SS}^{th}$ spatial stream are broken into the groups of $N_{CBPS}$ bits, $\left(c_0^{(q)}, c_1^{(q)}, ..., c_{N_{CBPS}-1}^{(q)}\right)$, where $q$ denotes the group number. Each six bits $\left(c_{6k}^{(q)}, c_{6k+1}^{(q)}, c_{6k+2}^{(q)}, c_{6k+3}^{(q)}, c_{6k+4}^{(q)}, c_{6k+5}^{(q)}\right)$, $k = 0, 1, \ldots, N_{SD} - 1$, are converted into the single constellation point $d\left(i_{SS}, q, k\right)$. The modulation is performed as follows:


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$$d\left(i_{SS},q,k\right)=\frac{1}{\sqrt{42}}\left(\left(4\times\left(2c_{6k}^{(q)}-1\right)-2\times\left(2c_{6k}^{(q)}-1\right)\times\left(2c_{6k+1}^{(q)}-1\right)+\left(2c_{6k}^{(q)}-1\right)\times\left(2c_{6k+1}^{(q)}-1\right)\times\left(2c_{6k+2}^{(q)}-1\right)\right)\right.$$
$$\left.+j\left(4\times\left(2c_{6k+3}^{(q)}-1\right)-2\times\left(2c_{6k+3}^{(q)}-1\right)\times\left(2c_{6k+4}^{(q)}-1\right)+\left(2c_{6k+3}^{(q)}-1\right)\times\left(2c_{6k+4}^{(q)}-1\right)\times\left(2c_{6k+5}^{(q)}-1\right)\right)\right)$$

The $q^{\text{th}}$ modulated data block of the $i_{SS}{}^{\text{th}}$ spatial stream is mapped to $N_{SD}$ data subcarriers of the $q^{\text{th}}$ OFDM symbol of the $i_{SS}{}^{\text{th}}$ spatial stream.

#### 28.6.9.3.8 Phase hopping modulation

The phase hopping modulation is applied if the number of spatial streams is equal to two (i.e., $N_{SS}$ = 2) and the Phase Hopping field in the EDMG-Header-A is equal to 1.

The phase hopping modulation shall use the (BPSK, BPSK), (QPSK, QPSK), (QPSK, 16-QAM), (16-QAM, QPSK), (16-QAM, 16-QAM), or (64-QAM, 64-QAM) modulations for the first and the second spatial streams accordingly.

For each modulation type, the encoded bits of $i_{SS}{}^{\text{th}}$ spatial stream are broken into groups of $N_{CBPSi_{SS}}$ bits, $\left(c_0^{\left(i_{SS},q\right)},c_1^{\left(i_{SS},q\right)},...,c_{N_{CBPSi_{SS}}-1}^{\left(i_{SS},q\right)}\right)$, where $q$ denotes the group number.

For (BPSK, BPSK) configuration, the modulation is performed in two steps:

— First, BPSK points are modulated as $x_k^{\left(i_{SS},q\right)}=\left(2\times c_k^{\left(i_{SS},q\right)}-1\right)$, $i_{SS}=1,2$, $k$ = 0, 1, …, $N_{SD}$ − 1.

— Second, two BPSK points $\left(x_k^{\left(i_{SS}=1,q\right)},x_k^{\left(i_{SS}=2,q\right)}\right)$ are converted to two modulation points $\left(d\left(i_{SS}=1,q,k\right),d\left(i_{SS}=2,q,k\right)\right)$ by multiplication with mapping matrix $Q$ and phase hopping matrix $W(k)$ as follows:

$$\begin{bmatrix}d\left(i_{SS}=1,q,k\right)\\d\left(i_{SS}=2,q,k\right)\end{bmatrix}=W\left(k\right)\cdot Q\cdot\begin{bmatrix}x_k^{\left(i_{SS}=1,q\right)}\\x_k^{\left(i_{SS}=2,q\right)}\end{bmatrix}$$

If the Open Loop Precoding field in the EDMG-Header-A is equal to 1, then matrix $Q$ is defined as $Q=\frac{1}{\sqrt{2}}\begin{bmatrix}1 & j\\1 & -j\end{bmatrix}$. Otherwise, it is defined as an identity matrix.

For (QPSK, QPSK) configuration, the modulation is performed in two steps:

— First, QPSK points are modulated as $x_k^{\left(i_{SS},q\right)}=\frac{1}{\sqrt{2}}\left(\left(2\times c_{2k}^{\left(i_{SS},q\right)}-1\right)+j\left(2\times c_{2k+1}^{\left(i_{SS},q\right)}-1\right)\right)$, $i_{SS}=1,2$, $k$ = 0, 1, …, $N_{SD}$ − 1.

— Second, two QPSK points $\left(x_k^{\left(i_{SS}=1,q\right)},x_k^{\left(i_{SS}=2,q\right)}\right)$ are converted to two modulation points $\left(d\left(i_{SS}=1,q,k\right),d\left(i_{SS}=2,q,k\right)\right)$ by multiplication with mapping matrix $Q$ and phase hopping matrix $W(k)$ as follows:

$$\begin{bmatrix}d\left(i_{SS}=1,q,k\right)\\d\left(i_{SS}=2,q,k\right)\end{bmatrix}=W\left(k\right)\cdot Q\cdot\begin{bmatrix}x_k^{\left(i_{SS}=1,q\right)}\\x_k^{\left(i_{SS}=2,q\right)}\end{bmatrix}$$

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If the Open Loop Precoding field in the EDMG-Header-A is equal to 1, then matrix $Q$ is defined as $Q = \frac{1}{\sqrt{2}}\begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix}$. Otherwise, it is defined as an identity matrix.

For (QPSK, 16-QAM) and (16-QAM, QPSK) configuration, the modulation is performed in two steps:

— First QPSK and 16-QAM points are modulated as follows:

  — QPSK points are modulated as $x_k^{(i_{SS},q)} = \frac{1}{\sqrt{2}}\left(\left(2 \times c_{2k}^{(i_{SS},q)} - 1\right) + j\left(2 \times c_{2k+1}^{(i_{SS},q)} - 1\right)\right)$.

  — 16-QAM points are modulated as defined in 28.6.9.3.6 (16-QAM modulation).

— Second, two (QPSK, 16-QAM) or (16-QAM, QPSK) points $\left(x_k^{(i_{SS}=1,q)}, x_k^{(i_{SS}=2,q)}\right)$ are converted to two modulation points $\left(d\left(i_{SS}=1,q,k\right), d\left(i_{SS}=2,q,k\right)\right)$ by multiplication with mapping matrix $Q$ and phase hopping matrix $W(k)$ as follows:

$$\begin{bmatrix} d\left(i_{SS}=1,q,k\right) \\ d\left(i_{SS}=2,q,k\right) \end{bmatrix} = W\left(k\right) \cdot Q \cdot \begin{bmatrix} x_k^{(i_{SS}=1,q)} \\ x_k^{(i_{SS}=2,q)} \end{bmatrix}$$

If the Open Loop Precoding field in the EDMG-Header-A is equal to 1 and the modulation configuration is (QPSK, 16-QAM), then matrix $Q$ is defined as $Q = \frac{1}{\sqrt{2}}\begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix} \cdot \begin{bmatrix} \sqrt{2/3} & 0 \\ 0 & \sqrt{4/3} \end{bmatrix}$. Otherwise, it is defined as an identity matrix.

If the Open Loop Precoding field in the EDMG-Header-A is equal to 1 and the modulation configuration is (16-QAM, QPSK), then matrix $Q$ is defined as $Q = \frac{1}{\sqrt{2}}\begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix} \cdot \begin{bmatrix} \sqrt{4/3} & 0 \\ 0 & \sqrt{2/3} \end{bmatrix}$. Otherwise, it is defined as an identity matrix.

For (16-QAM, 16-QAM) and (64-QAM, 64-QAM) configurations, the modulation is performed in two steps:

— First, 16-QAM or 64-QAM points are modulated as defined in 28.6.9.3.6 (16-QAM modulation) or 28.6.9.3.7 (64-QAM modulation), respectively.

— Second, two 16-QAM or 64-QAM points $\left(x_k^{(i_{SS}=1,q)}, x_k^{(i_{SS}=2,q)}\right)$ are converted to two modulation points $\left(d\left(i_{SS}=1,q,k\right), d\left(i_{SS}=2,q,k\right)\right)$ by multiplication with mapping matrix $Q$ and phase hopping matrix $W(k)$ as follows:

$$\begin{bmatrix} d\left(i_{SS}=1,q,k\right) \\ d\left(i_{SS}=2,q,k\right) \end{bmatrix} = W\left(k\right) \cdot Q \cdot \begin{bmatrix} x_k^{(i_{SS}=1,q)} \\ x_k^{(i_{SS}=2,q)} \end{bmatrix}$$

If the Open Loop Precoding field in the EDMG-Header-A is equal to 1, then matrix $Q$ is defined as $Q = \frac{1}{\sqrt{2}}\begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix}$. Otherwise, it is defined as an identity matrix.


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The phase hopping matrix $W(k)$ depends on $k$ and is defined as follows:

$$W(k)=\begin{bmatrix}1 & 0\\ 0 & e^{j\phi(y(k))}\end{bmatrix},\ \phi(y(k))=\frac{3\pi\cdot y(k)}{4}$$

where

$y(k)$ is initialized to the value 0 at $(x_k^{(i_{SS}=1,q)}, x_k^{(i_{SS}=2,q)})$ including a first bit of the LDPC codeword; otherwise, $y(k)$ is incremented by 1 for every $(x_k^{(i_{SS}=1,q)}, x_k^{(i_{SS}=2,q)})$ inside the LDPC codeword

#### 28.6.9.3.9 Interleaver

This subclause defines a symbol interleaver for 16-QAM and 64-QAM modulations. The interleaver performs modulated complex symbols interleaving inside an OFDM symbol and its parameters depend on the $N_{SD}$, $N_{CB}$, $N_{SS\,i_{user}}$, $L_{CW\,i_{user}}$, and $N_{BPSC\,i_{user}\,i_{SS}}$ parameters.

The input to the interleaver for the $i_{SS}^{\text{th}}$ spatial stream is an OFDM data block $d_{in}^{(i_{SS},q)}$ of length $N_{SD}$ composed of 16-QAM or 64-QAM symbols $d_{in}^{(i_{SS},q)}=\left(d_0^{(i_{SS},q)}, d_1^{(i_{SS},q)}, ..., d_{N_{SD}-1}^{(i_{SS},q)}, 0_0, 0_1, ..., 0_{N_p-1}\right)$, where $q$ denotes the OFDM symbol number and $q = 0, 1, \ldots, N_{SYM} - 1$.

The interleaving is performed inside the block of length $N_{SD} + N_p$, where $N_p$ is equal to 0, 34, 18, and 4 for $N_{CB}$ equal to 1, 2, 3, and 4, respectively.

The output of the interleaver scheme for the $i_{SS}^{\text{th}}$ spatial stream is a permutated OFDM data block of length $N_{SD}$ and defined as $d_{out}^{(i_{SS},q)}=\left(d_{idx(0)}^{(i_{SS},q)}, d_{idx(1)}^{(i_{SS},q)}, ..., d_{idx\left(\left(N_{SD}+N_p\right)-1\right)}^{(i_{SS},q)}\right)$, where $idx()$ defines the array of permutation (#4136)indices.

The array of permutation (#4136)indices, $idx()$, is constructed as follows:

Let $x=\left(\left(N_{SD}+N_p\right)\times\sum_{i_{SS}=1}^{N_{SS\,i_{user}}} N_{BPSC\,i_{user}\,i_{SS}}\right)/L_{CW\,i_{user}}$.

Moreover, for each $x$, let $N_x=\begin{cases}2\times N_{CB} & \text{if } x<2.5\times N_{CB}\\ 3\times N_{CB} & \text{if } 2.5\times N_{CB}\le x<3.5\times N_{CB}\\ 4\times N_{CB} & \text{if } 3.5\times N_{CB}\le x<5\times N_{CB}\\ 6\times N_{CB} & \text{if } 5\times N_{CB}\le x<7\times N_{CB}\\ 8\times N_{CB} & \text{if } 7\times N_{CB}\le x<10\times N_{CB}\\ 12\times N_{CB} & \text{if } 10\times N_{CB}\le x<14\times N_{CB}\\ 16\times N_{CB} & \text{if } 14\times N_{CB}\le x<20\times N_{CB}\\ 24\times N_{CB} & \text{if } x\ge 20\times N_{CB}\end{cases}$ and $N_y = (N_{SD} + N_p)/N_x$.

Then, $idx\left(j\times N_x+i\right)=N_y\times i+j$, where $i = 0, 1, \ldots, N_x - 1$ and $j = 0, 1, \ldots, N_y - 1$.

After permutation, the padded 0s at the first step are discarded (punctured) to form the output array of length $N_{SD}$.

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#### 28.6.9.3.10 Space-time block coding

An EDMG STA shall only apply STBC to an EDMG PPDU transmitted to a peer EDMG STA if the STBC Type field in the peer STA's EDMG Capabilities element is nonzero.

The space-time block coding (STBC) for the EDMG OFDM mode maps $N_{SS}$ spatial streams to $2 \times N_{SS}$ space-time streams. STBC is applied to an EDMG PPDU if, in the EDMG-Header-A of the PPDU, the STBC field is equal to 1. The number of STBC modulated spatial streams $N_{SS}$ is given by Number of SS field in the EDMG-Header-A. $N_{SS}$ shall not exceed four for an SU PPDU and one per user for an MU PPDU.

The mapping of each spatial stream, $i_{SS} = 1, \ldots, N_{SS}$, includes the following steps for the data subcarriers mapping:

a) The input bits of spatial stream $i_{SS}$ are broken into the groups of $N_{CBPS}(i_{SS})$ bits, $\left(c_0^{(q)}, c_1^{(q)}, ..., c_{N_{CBPS}(i_{SS})-1}^{(q)}\right)$, where $q$ denotes the group number. The STBC applies the encoding procedure defined in 28.6.8 (Modulation and coding scheme (MCS)). The padding procedure requires that the total number of groups of $N_{CBPS}(i_{SS})$ bits shall be an even number.

b) Each group of bits $\left(c_{N_{BPSC}(i_{SS})\cdot k}^{(q)}, c_{N_{BPSC}(i_{SS})\cdot k+1}^{(q)}, ..., c_{N_{BPSC}(i_{SS})\cdot k+N_{BPSC}(i_{SS})-1}^{(q)}\right)$, $k = 0, 1, \ldots, N_{SD} - 1$ is converted to the constellation point $d\left(i_{SS}, q, k\right)$, $q = 0, 1, \ldots, N_{SYM} - 1$, following the rules defined in 28.6.9.3.3 (DCM BPSK modulation), 28.6.9.3.5 (DCM QPSK modulation), 28.6.9.3.6 (16-QAM modulation), and 28.6.9.3.7 (64-QAM modulation).

c) The modulated data sequence $D(i_{STS} = 2 \times i_{SS} - 1, n, k)$ for the odd space-time stream is defined by inserting 0s from $-N_{SR}$ to $N_{SR}$ and then inserting data at tones $M_d(k)$ defined in 28.6.2.5 (Data tones) as follows:

$$D\left(i_{STS} = 2i_{SS} - 1, 2n, M_d\left(k\right)\right) = d\left(i_{SS}, 2n, k\right),$$
$$D\left(i_{STS} = 2i_{SS} - 1, 2n+1, M_d\left(k\right)\right) = d\left(i_{SS}, 2n+1, k\right), k = 0, 1, \ldots, N_{SD} - 1$$

d) The modulated data sequence $D(i_{STS} = 2 \times i_{SS}, n, k)$ for the even space-time stream is defined by inserting 0s from $-N_{SR}$ to $N_{SR}$ and then inserting data at tones $M_d(k)$ defined in 28.6.2.5 (Data tones) as follows:

$$D\left(i_{STS} = 2i_{SS}, 2n, M_d\left(k\right)\right) = -conj\left(d\left(i_{SS}, 2n+1, k\right)\right),$$
$$D\left(i_{STS} = 2i_{SS}, 2n+1, M_d\left(k\right)\right) = conj\left(d\left(i_{SS}, 2n, k\right)\right), k = 0, 1, \ldots, N_{SD} - 1$$

e) The modulated pilot sequence $P(i_{STS} = 2 \times i_{SS} - 1, n, k)$ for the odd space-time stream is defined by inserting 0s from $-N_{SR}$ to $N_{SR}$ and then inserting pilots at tones $M_p(k)$ defined in 28.6.2.4 (Pilot tones) as follows:

$$P\left(i_{STS} = 2i_{SS} - 1, 2n, M_p\left(k\right)\right) = P_{N_{SP}}\left(i_{STS} = 2i_{SS} - 1, k\right) \cdot \left(2p\left(2n\right) - 1\right),$$
$$P\left(i_{STS} = 2i_{SS} - 1, 2n+1, M_p\left(k\right)\right) = P_{N_{SP}}\left(i_{STS} = 2i_{SS}, k\right) \cdot \left(2p\left(2n+1\right) - 1\right), k = 0, 1, \ldots, N_{SP} - 1$$

f) The modulated pilot sequence $P(i_{STS} = 2 \times i_{SS}, n, k)$ for the even space-time stream is defined by inserting 0s from $-N_{SR}$ to $N_{SR}$ and then inserting pilots at tones $M_p(k)$ defined in 28.6.2.4 (Pilot tones) as follows:

$$P\left(i_{STS} = 2i_{SS}, 2n, M_p\left(k\right)\right) = -P_{N_{SP}}\left(i_{STS} = 2i_{SS}, k\right) \cdot \left(2p\left(2n\right) - 1\right),$$
$$P\left(i_{STS} = 2i_{SS}, 2n+1, M_p\left(k\right)\right) = P_{N_{SP}}\left(i_{STS} = 2i_{SS} - 1, k\right) \cdot \left(2p\left(2n+1\right) - 1\right), k = 0, 1, \ldots, N_{SP} - 1$$


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In the above procedure, index $n$ = 0, 1, …, $N_{SYM}$ / 2 – 1, pilot sequences $P_{N_{SP}}\left(i_{STS} = 2 \times i_{SS} - 1, k\right)$ and $P_{N_{SP}}\left(i_{STS} = 2 \times i_{SS}, k\right)$ are defined in 28.6.2.6 (Pilot sequences) and $p(n)$ defines a bit coming from the scrambler defined in 28.6.9.1 (Scrambler) with shift register $x_1$, $x_2$,…, $x_7$ initialized to all 1s for the $n$ = 0 OFDM symbol.

### 28.6.10 PPDU transmission

#### 28.6.10.1 General

This subclause defines the waveform for an EDMG OFDM mode PPDU transmission over a 2.16 GHz, 4.32 GHz, 6.48 GHz, 8.64 GHz, 2.16+2.16 GHz, or 4.32+4.32 GHz channel using $N_{TX}$ transmit chains.

The spatial mapping methods are defined in 28.6.10.2 (Spatial mapping). The EDMG SU PPDU transmission shall be as defined in 28.6.10.3 (EDMG SU PPDU transmission). The EDMG MU PPDU transmission shall be as defined in 28.6.10.4 (EDMG MU PPDU transmission).

#### 28.6.10.2 Spatial mapping

Spatial mapping defines the method of $N_{STS}$ space-time streams to $N_{TX}$ transmit chains mapping, where $N_{STS} \leq N_{TX}$. This may be implemented by means of spatial mapping matrix $Q_k$ of size $N_{TX}$ by $N_{STS}$ defined per subcarrier basis and cyclic shift diversity (CSD), if applied.

The standard defines four basic mappings, including direct mapping, indirect mapping, digital beamforming, and spatial expansion. Examples of spatial mapping methods and $Q_k$ matrices that might be used in different cases are as follows:

- Direct mapping, $N_{STS} = N_{TX}$: spatial mapping matrix $Q_k$ is a square diagonal complex value matrix of size $N_{TX}$ that might be defined as follows:
  - $\left[Q_k\right]_{i,i} = 1, i = 1, 2, ..., N_{TX}$, the identity matrix
  - $\left[Q_k\right]_{i,i} = \exp\left(j 2\pi\phi_i\right), i = 1, 2, ..., N_{TX}$, the exponential matrix
- Indirect mapping, $N_{STS} = N_{TX}$: spatial mapping matrix $Q_k$ is a square matrix of size $N_{TX}$ composed of complex values that might be defined as follows:
  - Normalized discrete Fourier matrix
  - Normalized Hadamard matrix
  - Normalized direct mapping diagonal matrix with permuted rows and/or columns
- Digital beamforming, $N_{STS} \leq N_{TX}$: spatial mapping matrix $Q_k$ is a rectangular matrix of size $N_{TX}$ by $N_{STS}$ composed of complex values that might be defined based on the knowledge of the channel.
- Spatial expansion, $N_{STS} = 1 < N_{TX}$: spatial expansion that might be applied to the pre-EDMG fields is performed by multiplication by matrix $Q$, which is defined as a column vector of size $N_{TX}$ by 1 and composed of all 1s and application of CSD over different transmit chains. The cyclic shift is applied to the number of consecutive fields in the PPDU. This allows duplication of the PPDU fields transmission over the $N_{TX}$ transmit chains and avoids unintentional beamforming existing with a coherent signal transmission.
- Channel aggregation, in this case $N_{TX}$ is an even number: the transmit chains 1 through $N_{TX}$/2 are assigned to the primary or primary and secondary channels and transmit chains $N_{TX}$/2 + 1 are assigned to the secondary or secondary1 and secondary2 channels. The mapping of space-time streams to the transmit chains is defined by the spatial mapping matrix $Q_k$, which is implementation specific.

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### 28.6.10.3 EDMG SU PPDU transmission

#### 28.6.10.3.1 General

An EDMG OFDM mode SU PPDU transmitted over a 2.16 GHz, 4.32 GHz, 6.48 GHz, 8.64 GHz, 2.16+2.16 GHz, or 4.32+4.32 GHz channel with single and multiple space-time streams ($1 \le i_{STS} \le N_{STS}$) is composed of pre-EDMG, EDMG preamble, Data field and TRN field.

The pre-EDMG modulated fields of the EDMG PPDU includes the L-STF, L-CEF, L-Header, and EDMG-Header-A and shall be transmitted using SC modulation as defined in 28.5.10.4.4.2 (Pre-EDMG modulated fields transmission). The EDMG-STF, EDMG-CEF, Data field, and TRN field shall be transmitted using OFDM modulation as defined in 28.6.4 (EDMG-STF definition), 28.6.5 (EDMG-CEF definition), 28.6.9 (Data field), and 28.9.2.2.5 (TRN field definition), respectively.

The total number of transmit chains, $N_{TX}$, shall be constant over the different fields of a transmitted EDMG SU PPDU.

#### 28.6.10.3.2 Pre-EDMG modulated fields transmission

See 28.5.10.4.4.2 (Pre-EDMG modulated fields transmission). The upsampling factor shall be equal to $N_{up} = (3/2) \times N_{CB}$.

#### 28.6.10.3.3 EDMG preamble, Data field, and TRN field transmission

For a single PPDU transmission, the EDMG modulated field of the EDMG preamble, Data field, and TRN field of an SU PPDU is defined for the $i_{TX}^{\text{th}}$ transmit chain at the $F_s$ sampling rate and sample time duration $T_s$ and includes the following modulated fields:

$$r_{EDMG\text{-}Pream,\,Data,\,TRN}^{i_{TX}}\left(nT_s\right) = r_{EDMG\text{-}STF}^{i_{TX}}\left(nT_s\right) + r_{EDMG\text{-}CEF}^{i_{TX}}\left(nT_s - t_{EDMG\text{-}CEF}\right)$$
$$+ r_{Data}^{i_{TX}}\left(nT_s - t_{Data}\right) + r_{TRN}^{i_{TX}}\left(nT_s - t_{TRN}\right), 1 \le i_{TX} \le N_{TX}$$

where

| | |
|---|---|
| $t_{EDMG\text{-}CEF} = T_{EDMG\text{-}STF}$ | is the duration of the EDMG-STF field of the PPDU |
| $t_{Data} = t_{EDMG\text{-}CEF} + T_{EDMG\text{-}CEF}$ | is the total duration of the EDMG-STF and the EDMG-CEF fields of the PPDU |
| $t_{TRN} = t_{Data} + T_{Data}$ | is the total duration of the EDMG-STF, the EDMG-CEF, and Data fields of the PPDU |

For an EDMG A-PPDU transmission of $N_{PPDU}$ PPDUs, the EDMG modulated field of the EDMG preamble, Data field, and TRN field of an SU PPDU is defined for $i_{TX}^{\text{th}}$ transmit chain at the $F_s$ sampling rate, sample time duration $T_s$ and includes the following modulated fields:


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$$r^{i_{TX}}_{EDMG\text{-}Pream,\,Data,\,TRN}\left(nT_s\right) = r^{i_{TX}}_{EDMG\text{-}STF}\left(nT_s\right) + r^{i_{TX}}_{EDMG\text{-}CEF}\left(nT_s - t_{EDMG\text{-}CEF}\right)$$
$$+ r^{i_{TX}}_{Data_1}\left(nT_s - t_{Data_1}\right)$$
$$+ r^{i_{TX}}_{EDMG\text{-}Header\text{-}A_2}\left(nT_s - t_{EDMG\text{-}Header\text{-}A_2}\right) + r^{i_{TX}}_{Data_2}\left(nT_s - t_{Data_2}\right)$$
$$+ \ldots$$
$$+ r^{i_{TX}}_{EDMG\text{-}Header\text{-}A_{N_{PPDU}}}\left(nT_s - t_{EDMG\text{-}Header\text{-}A_{N_{PPDU}}}\right) + r^{i_{TX}}_{Data_{N_{PPDU}}}\left(nT_s - t_{Data_{vN_{PPDU}}}\right)$$
$$+ r^{i_{TX}}_{TRN}\left(nT_s - t_{TRN}\right), 1 \le i_{TX} \le N_{TX}$$

where

$t_{EDMG\text{-}CEF} = T_{EDMG\text{-}STF}$ is the duration of the EDMG-STF field of the PPDU

$t_{DATA_1} = t_{EDMG\text{-}CEF} + T_{EDMG\text{-}CEF}$ is the total duration of the EDMG-STF and EDMG-CEF fields of the PPDU

$t_{EDMG\text{-}Header\text{-}A_2} = t_{Data_1} + T_{Data_1}$ is the total duration of the EDMG-STF, EDMG-CEF, and $Data_1$ fields of the PPDU

$t_{Data_2} = t_{EDMG\text{-}Header\text{-}A_2} + T_{EDMG\text{-}Header\text{-}A_2}$ is the total duration of the EDMG-STF, EDMG-CEF, $Data_1$, and EDMG-Header-$A_2$ fields of the PPDU

…

$t_{EDMG\text{-}Header\text{-}A_{N_{PPDU}}} = t_{Data_{N_{PPDU}-1}} + T_{Data_{N_{PPDU}-1}}$ is the total duration of the EDMG-STF, EDMG-CEF, $Data_1$, EDMG-Header-$A_2$, $Data_2$, …, and $Data_{NPPDU-1}$ fields of the PPDU

$t_{Data_{N_{PPDU}}} = t_{EDMG\text{-}Header\text{-}A_{N_{PPDU}}} + T_{EDMG\text{-}Header\text{-}A_{N_{PPDU}}}$ is the total duration of the EDMG-STF, EDMG-CEF, $Data_1$, EDMG-Header-$A_2$, $Data_2$, …, $Data_{NPPDU-1}$, and EDMG-Header-$A_{NPPDU}$ fields of the PPDU

$t_{TRN} = t_{Data_{N_{PPDU}}} + T_{Data_{N_{PPDU}}}$ is the total duration of the EDMG-STF, EDMG-CEF, $Data_1$, EDMG-Header-$A_2$, $Data_2$, …, $Data_{NPPDU-1}$, EDMG-Header-$A_{NPPDU}$, and $Data_{NPPDU}$ fields of the PPDU

The EDMG OFDM mode SU PPDU waveform for the $i_{TX}^{th}$ transmit chain concatenates the pre-EDMG, EDMG preamble, Data field and TRN field, with DC relative shift applied to the EDMG modulated fields as described in 28.6.2.3 (DC relative shift to carrier frequency), and shall be defined as follows:

$$r^{i_{TX}}_{PPDU}\left(nT_s\right) = r^{i_{TX}}_{pre\text{-}EDMG}\left(nT_s\right) + r^{i_{TX}}_{EDMG\text{-}Pream,\,Data,\,TRN}\left(nT_s - t_{EDMG}\right)\cdot e^{j2\pi\left(f_{DC}-f_c\right)\cdot nT_s}, 1 \le i_{TX} \le N_{TX}$$

where

$t_{EDMG} = T_{pre\text{-}EDMG}$ is the total duration of the L-STF, the L-CEF, the L-Header, and the EDMG-Header-A fields of the PPDU

$f_c$ is the center frequency of the carrier

$f_{DC}$ is the DC subcarrier frequency defined in 28.6.2.3 (DC relative shift to carrier frequency)

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The definition of the pulse shaping filter impulse response, $h_{SC\,CB}$, used for the transmission of the pre-EDMG modulated fields is implementation specific and beyond the scope of this standard.

### 28.6.10.4 EDMG MU PPDU transmission

#### 28.6.10.4.1 General

An EDMG OFDM mode MU PPDU transmission over a 2.16 GHz, 4.32 GHz, 6.48 GHz, 8.64 GHz, or 2.16+2.16 GHz channel with single and multiple space-time streams ($1 \le i_{STS} \le N_{STS}$) is composed of pre-EDMG, EDMG preamble, Data field and TRN field.

The pre-EDMG modulated fields of the PPDU includes the L-STF, L-CEF, L-Header, and EDMG-Header-A and shall be transmitted using SC modulation as defined in 28.5.10.4.4.2 (Pre-EDMG modulated fields transmission). The EDMG-STF, EDMG-CEF, EDMG-Header-B, Data field, and TRN field shall be transmitted using OFDM modulation as defined in 28.6.4 (EDMG-STF definition), 28.6.5 (EDMG-CEF definition), 28.6.6 (Encoding of EDMG-Header-B), 28.6.9 (Data field), and 28.9.2.2.5 (TRN field definition), respectively.

The total number of transmit chains, $N_{TX}$, shall be constant over the different fields of a transmitted EDMG MU PPDU.

#### 28.6.10.4.2 Pre-EDMG modulated fields transmission

See 28.5.10.4.4.2 (Pre-EDMG modulated fields transmission). The upsampling factor shall be equal to $N_{up} = (3/2) \times N_{CB}$.

#### 28.6.10.4.3 EDMG preamble, Data field, and TRN field transmission

The EDMG preamble, Data field, and TRN field of an MU PPDU is defined for the $i_{TX}^{\text{th}}$ transmit chain at the $F_s$ sampling rate and sample time duration $T_s$ and includes the following modulated fields:

$$r^{i_{TX}}_{EDMG\text{-}Pream,\,Data,\,TRN}\left(nT_s\right) = r^{i_{TX}}_{EDMG\text{-}STF}\left(nT_s\right) + r^{i_{TX}}_{EDMG\text{-}CEF}\left(nT_s - t_{EDMG\text{-}CEF}\right)$$
$$+ r^{i_{TX}}_{EDMG\text{-}Header\text{-}B}\left(nT_s - t_{EDMG\text{-}Header\text{-}B}\right) + r^{i_{TX}}_{Data}\left(nT_s - t_{Data}\right) + r^{i_{TX}}_{TRN}\left(nT_s - t_{TRN}\right), 1 \le i_{TX} \le N_{TX}$$

where

$t_{EDMG\text{-}CEF} = T_{EDMG\text{-}STF}$ is the duration of the EDMG-STF field of the PPDU

$t_{EDMG\text{-}Header\text{-}B} = t_{EDMG\text{-}CEF} + T_{EDMG\text{-}CEF}$ is the total duration of the EDMG-STF and EDMG-CEF fields of the PPDU

$t_{Data} = t_{EDMG\text{-}Header\text{-}B} + T_{EDMG\text{-}Header\text{-}B}$ is the total duration of the EDMG-STF, EDMG-CEF, and EDMG-Header-B fields of the PPDU

$t_{TRN} = t_{Data} + T_{Data}$ is the total duration of the EDMG-STF, EDMG-CEF, EDMG-Header-B, and Data fields of the PPDU

The Data field of an MU PPDU shall be modulated using $N_{SYM\,i_{user}}$ OFDM symbols for the $i_{user}^{\text{th}}$ user as defined in 28.6.9 (Data field).

The EDMG OFDM mode MU PPDU waveform for the $i_{TX}^{\text{th}}$ transmit chain concatenates the pre-EDMG, EDMG preamble, Data field and TRN field, with DC relative shift applied to the EDMG modulated fields as described in 28.6.2.3 (DC relative shift to carrier frequency), and shall be defined as follows:

$$r^{i_{TX}}_{PPDU}\left(nT_s\right) = r^{i_{TX}}_{pre\text{-}EDMG}\left(nT_s\right) + r^{i_{TX}}_{EDMG\text{-}Pream,\,Data,\,TRN}\left(nT_s - t_{EDMG}\right) \cdot e^{j2\pi\left(f_{DC} - f_c\right)\cdot nT_s}, 1 \le i_{TX} \le N_{TX}$$


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where

| | |
|---|---|
| $t_{EDMG} = T_{pre\text{-}EDMG}$ | is the total duration of the L-STF, the L-CEF, the L-Header, and the EDMG-Header-A fields of the PPDU |
| $f_c$ | is the center frequency of the carrier |
| $f_{DC}$ | is the DC subcarrier frequency defined in 28.6.2.3 (DC relative shift to carrier frequency) |

The definition of the pulse shaping filter impulse response, $h_{SC\ CB}$, used for the transmission of the pre-EDMG modulated fields is implementation specific and beyond the scope of this standard.

### 28.6.11 Performance requirements

### 28.6.11.1 Transmit requirements

#### 28.6.11.1.1 Transmit modulation accuracy (EVM) test and requirements

This subclause specifies the EVM test and corresponding requirements for PPDUs transmitted with the TXVECTOR parameter EDMG_MODULATION equal to EDMG_OFDM_MODE and TXVECTOR parameters CH_BANDWIDTH and CHANNEL_AGGREGATION equal to any valid combination indicated in Table 28-21 (2.16 GHz, 4.32 GHz, 6.48 GHz, and 8.64 GHz channels used by an EDMG STA(11ay)), Table 28-22 (2.16+2.16 GHz channel used by an EDMG STA(11ay)), or Table 28-23 (4.32+4.32 GHz channel used by an EDMG STA(11ay)).

The transmit modulation accuracy test shall be performed by instrumentation capable of converting the transmitted signals into a stream of complex samples at sampling rate greater than or equal to the OFDM sampling rate $F_s$. The TXVECTOR parameters NUM_STS and NUM_TX_CHAINS shall be equal, and the value of both parameters shall be equal to the number of utilized testing instrumentation input ports or antennas. (#3445)Each port or antenna connected to a transmit chain of the transmitting STA shall be assigned to a port or antenna of the testing instrumentation in a way that makes signal coupling between the different transmit signal paths negligible. In the test, $N_{SS} = N_{STS}$ (i.e., no STBC) shall be used. If the TXVECTOR parameter NUM_STS is(M118) greater than 1, the two or more space-time streams shall have the same modulation type.

The instrumentation used shall have sufficient accuracy in terms of I/Q arm amplitude and phase balance, DC offsets, phase noise, and analog-to-digital quantization noise, so as not to mask or degrade the true EVM measurement. A possible embodiment of such a setup is converting the signals to a low IF frequency with a microwave synthesizer, sampling the signal with a digital oscilloscope and decomposing it digitally into quadrature components. The sampled signal shall be processed in a manner similar to an actual receiver, according to the following steps, or equivalent procedure:

- Detect the start of the PPDU.
- Establish fine timing.
- Estimate coarse and fine frequency offsets.
- De-rotate the symbols in the PPDU according to the estimated frequency offset.
- Estimate the complex channel for each of the subcarriers and each of the spatial streams using the EDMG-CEF field.
- For each of the OFDM symbols: transform the symbol into subcarrier received values, estimate the phase from the pilot subcarriers, de-rotate the subcarrier values according to the estimated phase, group the results from all RF chains in each subcarrier to a vector, and multiply the vector by an equalization matrix generated from the estimated channel.
- For each data-carrying subcarrier and each spatial stream, find the closest constellation point and compute the Euclidean distance from it.

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— Compute the average relative constellation RMS error (EVM) across PPDUs according to the formula:

$$EVM = 20\log_{10}\left(\frac{1}{N_f}\sum_{f=1}^{N_f}\sqrt{\frac{\sum_{n=0}^{N_{SYMS}-1}\sum_{j=1}^{N_{SS}}\sum_{k\in M_d(k)}\left(I(f,n,j,k)-I^*(f,n,j,k)\right)^2+\left(Q(f,n,j,k)-Q^*(f,n,j,k)\right)^2}{N_{SYMS}\times N_{SS}\times N_{SD}\times P_0}}\right)$$

where

$N_f$ is the number of frames for the measurement

$N_{SYMS}$ is the number of OFDM symbols

$N_{SS}$ is the number of spatial streams

$M_d(k)$ is set of data subcarriers defined in 28.6.2.5 (Data tones)

$N_{SD}$ is the number of data subcarriers

$P_0$ is the average power of the constellation

$I(f,n,j,k)$ and $Q(f,n,j,k)$
denote the observed symbol point in the complex plane for the $k^{th}$ subcarrier of the $n^{th}$ OFDM symbol and $j^{th}$ spatial stream within the $f^{th}$ frame

$I^*(f,n,j,k)$ and $Q^*(f,n,j,k)$
denote the ideal symbol point in the complex plane for the $k^{th}$ subcarrier of the $n^{th}$ OFDM symbol and $j^{th}$ spatial stream within the $f^{th}$ frame

The total number of symbol points used in the test, which is equal to $N_f \times N_{SYMS} \times N_{SS} \times N_{SD}$, shall be at least 1000, with the constraint that $N_{SYMS}$ shall be at least 16 and that $N_f$ shall be at least 20. Random data shall be used for the symbols and frames.

The EVM shall not exceed an MCS dependent value provided in Table 28-73 (EVM requirement for the EDMG OFDM mode(11ay)). If the TXVECTOR parameter CHANNEL_AGGREGATION is(M118) equal to (#4167)AGGREGATED, the transmission in the two 2.16 GHz channels or 4.32 GHz channels may be tested independently. In this case, the transmit modulation accuracy of each 2.16 GHz channel or of each 4.32 GHz channel shall meet the required value in Table 28-73 (EVM requirement for the EDMG OFDM mode(11ay)).

**Table 28-73—EVM requirement for the EDMG OFDM mode(11ay)**

| MCS | EVM value (dB) |
|---|---|
| 1 | –7 |
| 2 | –9 |
| 3 | –10 |
| 4 | –12 |
| 5 | –13 |
| 6 | –10 |
| 7 | –11 |
| 8 | –12 |


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**Table 28-73—EVM requirement for the EDMG OFDM mode(11ay) *(continued)***

| MCS | EVM value (dB) |
|---|---|
| 9 | –14 |
| 10 | –15 |
| 11 | –15 |
| 12 | –16 |
| 13 | –17 |
| 14 | –18 |
| 15 | –19 |
| 16 | –21 |
| 17 | –22 |
| 18 | –23 |
| 19 | –25 |
| 20 | –27 |

#### 28.6.11.1.2 Time of Departure accuracy

(#8058)The RMS accuracy of the time of departure provided in TIME_OF_DEPARTURE shall be less than or equal to 80 ns.

The Time of Departure accuracy test evaluates TIME_OF_DEPARTURE against aTxPHYTxStartRMS and aTxPHYTxStartRMS against TIME_OF_DEPARTURE_ACCURACY_TEST_THRESH as defined in Annex P with the following test parameters:

- MULTICHANNEL_SAMPLING_RATE is set to aDMGChipRate.
- FIRST_TRANSITION_FIELD is L-STF of the waveform transmitted in the primary channel.
- SECOND_TRANSITION_FIELD is L-CEF of the waveform transmitted in the primary channel.
- TRAINING_FIELD is L-CEF of the waveform transmitted in the primary channel.
- TIME_OF_DEPARTURE_ACCURACY_TEST_THRESH is set to aDMGTimeOfDepartureAccuracyThresh.

### 28.6.11.2 Receive requirements

CCA sensitivity requirements are defined in 28.3.8 (CCA sensitivity).

## 28.7 EDMG transmit procedure

This subclause defines the PHY transmit procedure for EDMG and non-EDMG duplicate format. The format selection is performed based on the FORMAT parameter of the PHY-TXSTART.request(TXVECTOR) primitive.

There are two paths for the transmit PHY procedure:

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- The first path is selected if the FORMAT parameter is EDMG. In this case, the modulation is defined by EDMG_MODULATION parameter. If EDMG_MODULATION parameter is set to EDMG_C_MODE, EDMG_SC_MODE, or EDMG_OFDM_MODE, then it indicates EDMG control mode, EDMG SC mode, or EDMG OFDM mode defined in 28.4 (EDMG and non-EDMG control mode), 28.5 (EDMG and non-EDMG SC mode), and 28.6 (EDMG OFDM mode), respectively. An example of the EDMG PHY transmit procedure provided in this subclause does not include optional features like EDMG A-PPDU, SU with multiple space-time streams, STBC, Dual Stream DCM BPSK, DCM π/2-BPSK and MU transmission.
- The second path is selected if the FORMAT parameter is non-EDMG. In this case, the modulation is defined by NON_EDMG_MODULATION parameter. If NON_EDMG_MODULATION is set to DMG_C_MODE or DMG_SC_MODE, then it indicates (#8160)DMG control mode or (#8160)DMG SC mode defined in Clause 20 (Directional multi-gigabit (DMG) PHY specification), respectively. If NON_EDMG_MODULATION is set to NON_EDMG_DUP_C_MODE or NON_EDMG_DUP_SC_MODE, then it indicates non-EDMG duplicate control mode or non-EDMG duplicate SC mode defined in 28.4 (EDMG and non-EDMG control mode) and 28.5 (EDMG and non-EDMG SC mode), respectively.

In both paths, in order to transmit data, the MAC generates a PHY-TXSTART.request primitive, which causes the PHY entity to enter the transmit state. Further, the PHY is set to operate at the appropriate frequency through station management via the PLME as specified in EDMG PLME. Other transmit parameters, such as EDMG-MCS, PSDU Length, and others are set via the PHY SAP using the PHY-TXSTART.request(TXVECTOR) primitive, as described in 28.2 (EDMG PHY service interface).

The PHY indicates the state of the 2.16 GHz primary channel and any secondary channels, including 2.16 GHz Secondary, 2.16 GHz secondary1, and 2.16 GHz secondary2 via a PHY-CCA.indication primitive as defined in 8.3.5.12 (PHY-CCA.indication). Transmission of the PPDU shall be initiated by the PHY after receiving the PHY-TXSTART.request(TXVECTOR) primitive. The TXVECTOR parameters for the PHY-TXSTART.request primitive are specified in 28.2.2 (TXVECTOR and RXVECTOR parameters) (Table 28-1 (TXVECTOR and RXVECTOR parameters(11ay))).

Figure 28-35 (PHY transmit procedure for the control mode(11ay)) shows PHY transmit procedure for EDMG_C_MODE mode with schematic diagram of primitives exchange between the MAC and PHY layers through PHY SAP interface. Figure 28-36 (PHY transmit procedure for the SU EDMG SC and OFDM modes(11ay)(#8160))shows PHY transmit procedure for SU PPDU format for EDMG_SC_MODE or EDMG_OFDM_MODE. The fields of the PPDU highlighted by dotted line might not be present for some particular parameters configuration.

The EDMG-STF and EDMG-CEF fields are not transmitted if EDMG_MODULATION parameter is set to EDMG_C_MODE.

The EDMG-STF and EDMG-CEF fields are not transmitted if the number of bits set to 1 in the CH_BANDWIDTH parameter is equal to 1, EDMG_MODULATION parameter is set to EDMG_SC_MODE, the number of space-time streams NUM_STS is set to 1, and STBC is set to 0 (#4181)(see 28.2.2 (TXVECTOR and RXVECTOR parameters) (Table 28-1 (TXVECTOR and RXVECTOR parameters(11ay)))).

The TRN field is not transmitted if EDMG_TRN_LEN is 0 (#4181)(see 28.2.2 (TXVECTOR and RXVECTOR parameters) (Table 28-1 (TXVECTOR and RXVECTOR parameters(11ay)))) or, as defined in 10.12.7 (Setting the EOF/Tag(11ax) field of the MPDU delimiter), if EDMG_TRN_LEN is (M118)greater than 0, BEAM_TRACKING_REQUEST is set to 0, EDMG_BEAM_TRACKING_REQUEST is set to 1, and EDMG_PPDU_TYPE is set to EDMG-TRN-R. It may also not be transmitted if EDMG_TRN_LEN > 0 and beam tracking request was initiated (see 28.9 (EDMG beamforming)).


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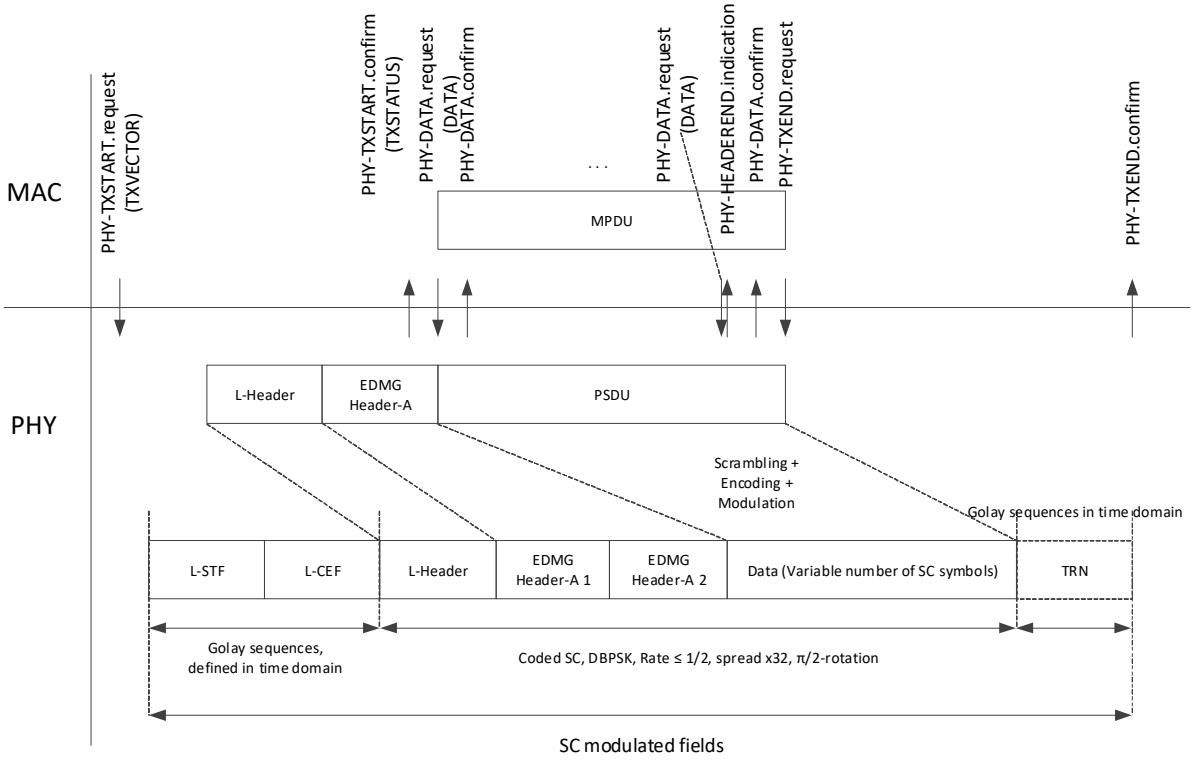


**Figure 28-35—PHY transmit procedure for the control mode(11ay)**

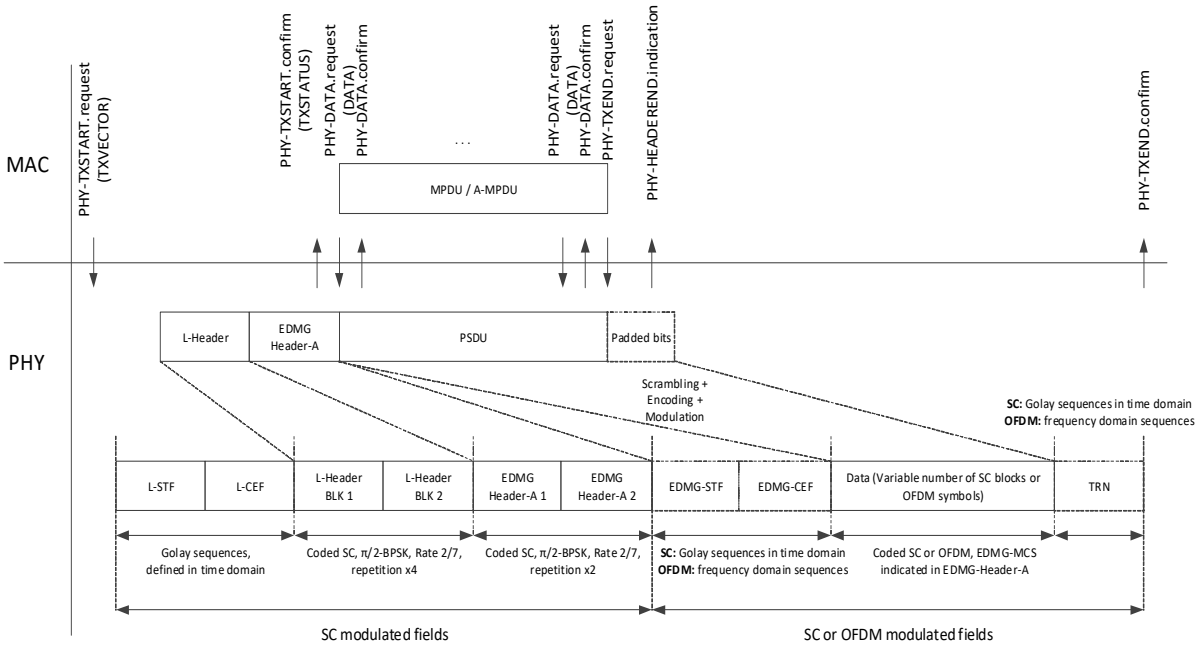


**Figure 28-36—PHY transmit procedure for the SU EDMG SC and OFDM modes(11ay)(#8160)**

NOTE 1—This procedure does not describe the operation of optional features, such as A-PPDU, SU multiple space-time streams, STBC, DCM BPSK, DCM π/2-BPSK, and MU transmission.

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The PHY entity performs TXVECTOR parsing to extract the transmission parameters and build up the L-Header and EDMG-Header-A bit content. It computes CRC per each header separately.

If the EDMG_MODULATION parameter is(M118) equal to EDMG_C_MODE, all fields are transmitted using SC modulation. The L-STF and L-CEF fields are transmitted using π/2-BPSK modulated Golay complementary sequences defined in time domain as specified in 20.4.3.1.2 (Short Training field) and 20.4.3.1.3 (Channel Estimation field), respectively. The L-Header, EDMG-Header-A composed of two parts EDMG-Header-$A_1$ and EDMG-Header-$A_2$, and data (PSDU) are transmitted by applying scrambling, LDPC code with effective rate less or equal to 1/2, DBPSK modulation, 32× spreading applying Golay sequences, and π/2-rotation as defined in 28.4.5.2 (Data field). The TRN field is transmitted using π/2-BPSK modulated Golay complementary sequences in time domain as defined in 28.9.2.2.5 (TRN field definition).

If the EDMG_MODULATION parameter is(M118) equal to EDMG_SC_MODE or EDMG_OFDM_MODE, the L-STF, L-CEF, L-Header, and EDMG-Header-A are transmitted using SC modulation. The rest of the frame, including EDMG-STF, EDMG-CEF, Data (PSDU), and TRN field can be transmitted using SC or OFDM modulation.

The L-STF and L-CEF fields are transmitted using π/2-BPSK modulated Golay complementary sequences defined in time domain as specified in 28.3.3.2.2 (L-STF definition) and 28.3.3.2.3 (L-CEF definition), respectively. The L-Header is transmitted by applying LDPC code with effective rate 2/7, π/2-BPSK modulation, and codeword repetition 4× times. The transmission of L-Header occupies two SC symbol blocks. The EDMG-Header-A is transmitted by applying the LDPC code with effective rate 2/7, π/2-BPSK modulation, and codeword repetition 2× times. It is composed of two parts: EDMG-Header-$A_1$ and EDMG-Header-$A_2$. The transmission of EDMG-Header-A occupies two SC symbol blocks.

The SC symbol blocks used for the L-Header and EDMG-Header-A transmission are prepended with Guard Intervals (GIs). The extra GI is inserted at the end of EDMG-Header-$A_2$ block. This creates the blocking structure when each SC symbol block is surrounded by two GIs. The GI is defined using π/2-BPSK modulated Golay sequence in time domain as specified in 28.5.9.1 (Guard interval definition).

If the EDMG_MODULATION parameter is(M118) equal to EDMG_SC_MODE, the EDMG-STF and EDMG-CEF are defined using π/2-BPSK modulated Golay complementary sequences in time domain as specified in 28.6.4 (EDMG-STF definition) and 28.6.5 (EDMG-CEF definition), respectively. The data (PSDU) is padded and scrambled to get an integer number of LDPC codewords and SC symbol blocks and then encoded as defined in 28.5.9.4 (Encoding). The encoded bits are modulated as defined in 28.5.9.5 (Modulation mapping). The modulated symbols are grouped into the SC symbol blocks and prepended with GIs as defined in 28.5.9.2 (Symbol blocking and guard insertion). The extra GI is inserted at the end of last SC symbol block. This creates the blocking structure when each SC symbol block is surrounded by two GIs. The GI is defined using π/2-BPSK modulated Golay sequence in time domain as specified in 28.5.9.1 (Guard interval definition). The TRN field is defined using π/2-BPSK modulated Golay complementary sequences in time domain as specified in 28.9.2.2.5 (TRN field definition).

If the EDMG_MODULATION parameter is(M118) equal to EDMG_OFDM_MODE, the EDMG-STF and EDMG-CEF are defined using 4-PSK modulated sequences in frequency domain as specified in EDMG-STF definition and EDMG-CEF definition, respectively. The data (PSDU) is padded and scrambled to get an integer number of LDPC codewords and OFDM symbols and then encoded as defined in 28.6.9.2 (Encoding). The encoded bits are modulated as defined in 28.6.9.3 (Modulation mapping). The modulated symbols are grouped into the OFDM data blocks, supplemented with pilots and converted to time domain applying IDFT. The OFDM symbol in time domain is prepended with GI, which is in fact a cyclic extension of OFDM symbol.


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Transmission of the PHY preamble may start if TIME_OF_DEPARTURE_REQUESTED is false, and shall start immediately if TIME_OF_DEPARTURE_REQUESTED is true, based on the parameters passed in the PHY-TXSTART.request primitive.

The PHY layer shall issue a PHY-TXSTART.confirm primitive to the MAC in response to the PHY-TXSTART.request(TXVECTOR) primitive when it is ready to receive an MPDU/A-MPDU from the MAC (#6268). The receipt of this primitive by the MAC entity causes the MAC to start the transfer of data octets.

The PHY-TXSTART.confirm(TXSTATUS) primitive shall contain the TXSTATUS vector defined in Table 20-2 (TXSTATUS parameters), if the conditions below are met:

— If dot11TODImplemented and dot11TODActivated are both true or dot11TimingMsmtActivated is true; and the parameter TIME_OF_DEPARTURE_REQUESTED in the TXVECTOR specified in the PHY-TXSTART.request is true, then the PHY shall include the TIME_OF_DEPARTURE corresponding to the time when the first frame energy is sent by the transmitting port and TIME_OF_DEPARTURE_ClockRate parameters in the TXSTATUS vector (see Table 20-2 (TXSTATUS parameters)).

— If dot11TimingMsmtActivated is true, then the PHY shall include TX_START_OF_FRAME_OFFSET in the TXSTATUS vector (see Table 20-2 (TXSTATUS parameters)).

Once a PHY-TXSTART.confirm primitive is issued, the MAC initiates data (MPDU octets) exchange with the PHY entity. The data shall be exchanged between the MAC and the PHY through a series of PHY-DATA.request(DATA) primitives issued by the MAC, and PHY-DATA.confirm primitives issued by the PHY.

If TIME_OF_DEPARTURE_REQUESTED is true, the PHY entity shall generate the PHY-TXHEADEREND.indication primitive at the end of transmission of the last symbol containing the PHY EDMG-Header-A for an SU PPDU and the last symbol containing the PHY EDMG-Header-B for an MU PPDU. The receipt of this primitive by the MAC entity causes the MAC to record the time when this primitive is received.

Transmission can be prematurely terminated by the MAC through the PHY-TXEND.request primitive. The PSDU transmission is terminated by receiving a PHY-TXEND.request primitive. Each PHY-TXEND.request primitive is acknowledged with a PHY-TXEND.confirm primitive from the PHY. In an SU transmission, normal termination occurs after the transmission and confirmation of the last PSDU octet.

Once the PPDU transmission is completed the PHY entity issues PHY-TXEND.confirm primitive and enters the receive state.

A typical transmit state machine for an SU transmission with NUM_STS = 1 and no TRN field is shown in Figure 28-37 (PHY transmit state machine for SU transmission (NUM_STS = 1 and no TRN field)(11ay)).

NOTE 2—PSDU encoding and modulation can be started in parallel with preamble transmission and depends on the particular hardware pipeline implementation.

## 28.8 EDMG receive procedure

This subclause defines the PHY receive procedure for the EDMG format. The receive procedure for the non-EDMG duplicate format is defined in 20.9 (Beamforming).

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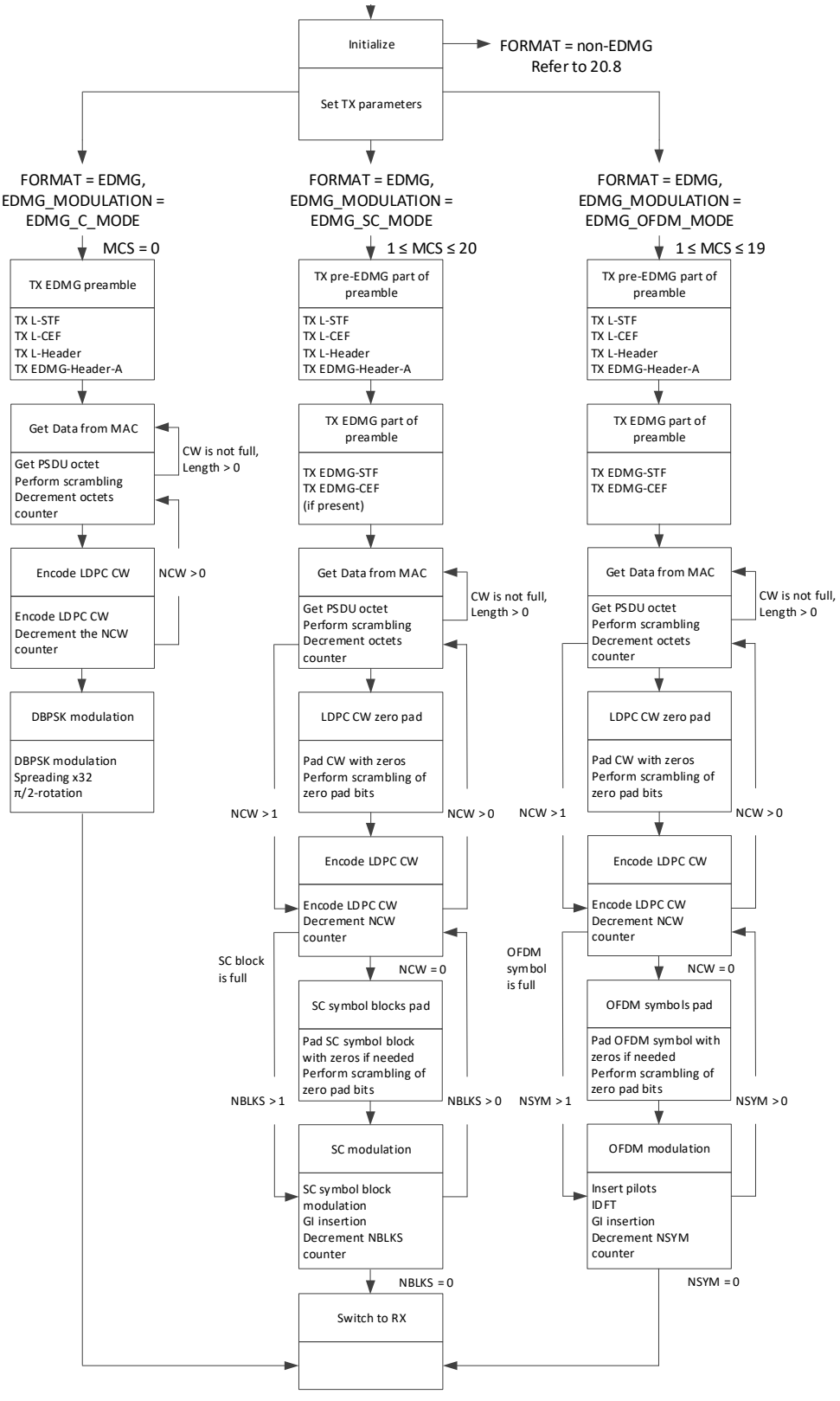


**Figure 28-37—PHY transmit state machine for SU transmission (NUM_STS = 1 and no TRN field)(11ay)**



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Figure 28-38 (PHY receive procedure for the EDMG control mode(11ay)) shows the PHY receive procedure for the EDMG_C_MODE mode with a schematic diagram of primitives exchange between the MAC and PHY layers through PHY SAP interface. Figure 28-39 (PHY receive procedure for the SU EDMG SC and SU EDMG OFDM modes(11ay)) shows the PHY receive procedure for an SU PPDU format for the EDMG_SC_MODE or the EDMG_OFDM_MODE. The fields of the PPDU highlighted by dotted line might not be present for some particular parameters configuration.

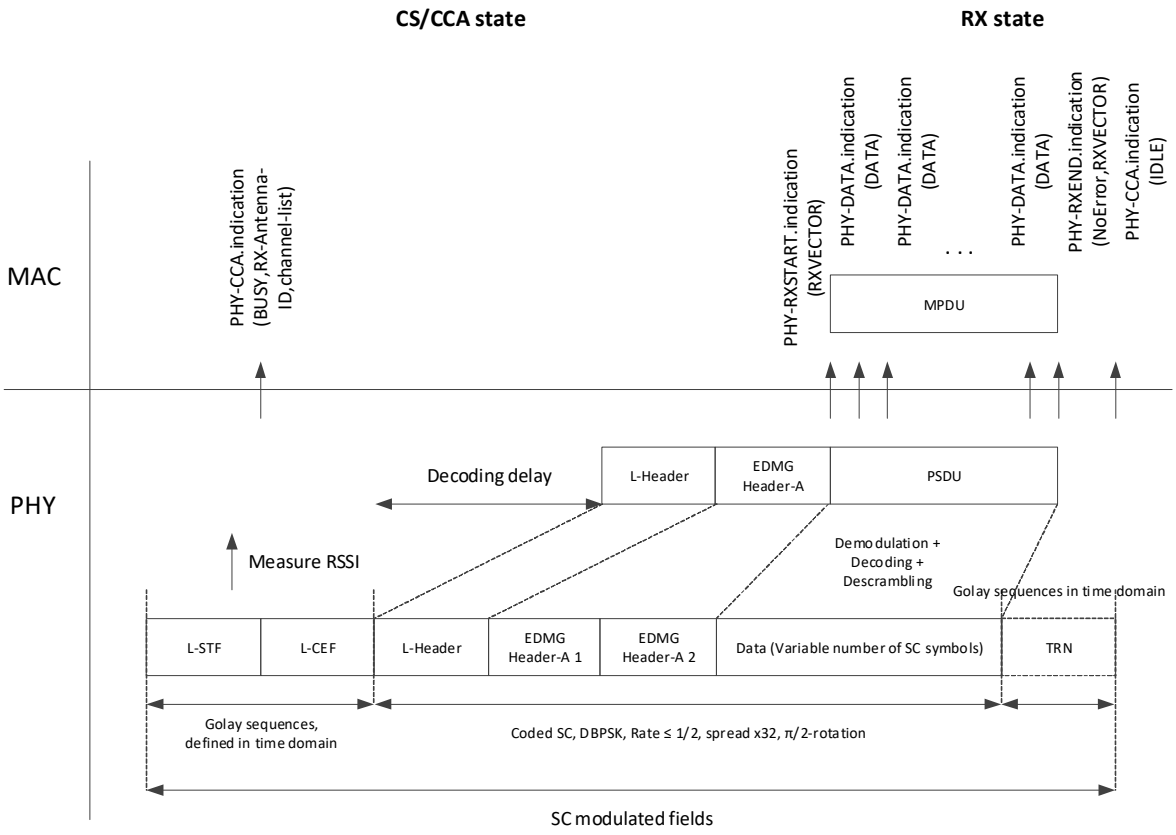


**Figure 28-38—PHY receive procedure for the EDMG control mode(11ay)**

NOTE—This procedure does not describe the operation of optional features, such as A-PPDU, SU multiple space-time streams, STBC, DCM BPSK, DCM π/2-BPSK, and MU reception.

Upon receiving the transmitted PHY preamble over the primary 2.16 GHz channel, the PHY measures a receive signal strength. The PHY indicates this activity to the MAC by issuing a PHY-CCA.indication primitive. A PHY-CCA.indication(BUSY, RX-Antenna-ID, channel-list) primitive is also issued as an initial indication of reception of a signal as defined in 8.3.5.12 (PHY-CCA.indication). The channel-list parameter of the CCA-PHY.indication primitive is absent when the operating channel width is 2.16 GHz. The channel-list parameter is present and includes the element primary when operating channel width is 4.32 GHz, 6.48 GHz, 8.64 GHz, 2.16+2.16 GHz, or 4.32+4.32 GHz. The RX-Antenna-ID parameter is present if the PHY entity has more than one active RX chain and the CCA sensitivity condition defined in 28.3.8 (CCA sensitivity) applies to any DMG antenna connected to an active receive chain.

The PHY includes the most recently measured RSSI value in the PHY-RXSTART.indication(RXVECTOR) primitive issued to the MAC.

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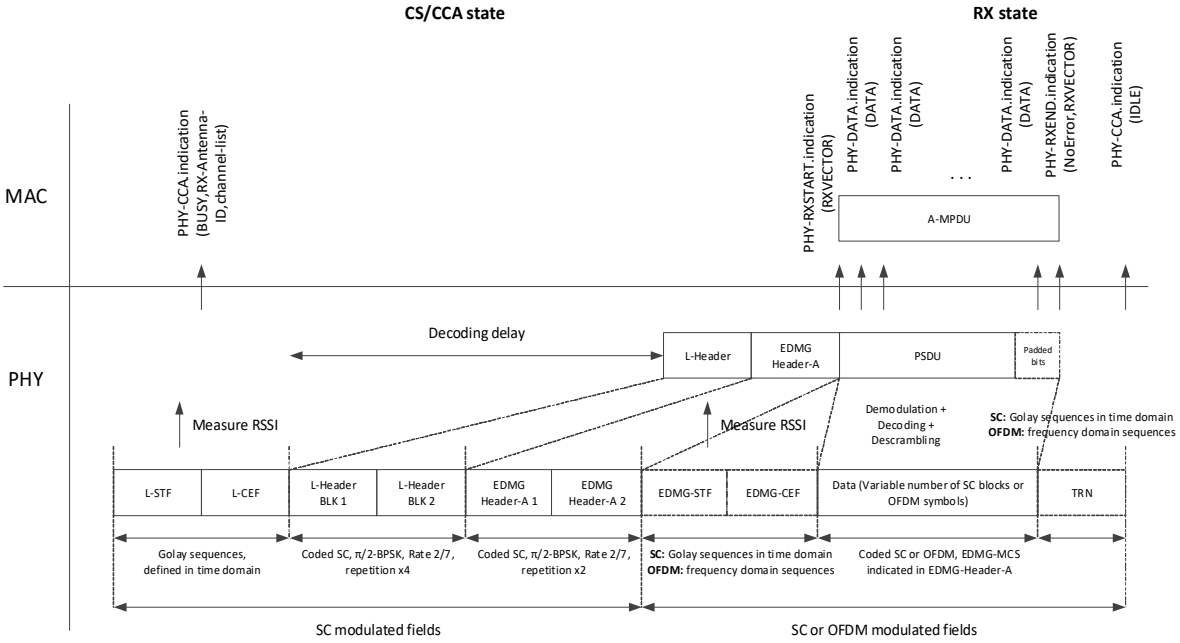


**Figure 28-39—PHY receive procedure for the SU EDMG SC and SU EDMG OFDM modes(11ay)**

After the PHY-CCA.indication(BUSY, channel-list) primitive is issued, the PHY entity shall continue receiving the pre-EDMG part of the PPDU, including L-STF, L-CEF, L-Header, and EDMG-Header-A fields.

For an EDMG control mode PPDU, the L-Header contains the channel bandwidth indication field, the EDMG-Header-A indication field that indicates that the PPDU is an EDMG control mode PPDU, and the control trailer indication field as defined in 28.3.3.2.4 (L-Header definition) (Table 28-5 (Definition of Scrambler Initialization field when transmitted using the control mode and the Turnaround field is 0(11ay)) and Table 28-6 (Definition of Scrambler Initialization field when transmitted using the control mode and the Turnaround field is 1(11ay))).

For an EDMG SC or EDMG OFDM mode PPDU, the L-Header contains the IsSC field indicating the EDMG SC or EDMG OFDM modulation type, the IsSISO field indicating the single or multiple spatial streams transmission, the GI length field indicating the type of GI used for the data (PSDU) transmission, and the compressed bandwidth indication as defined in 28.3.3.2.4 (L-Header definition) (Table 28-7 (Definition of bit allocation of Last RSSI field when transmitted using the EDMG SC or EDMG OFDM mode(11ay)), Table 28-8 (Definition of the 5 LSBs of the Length field when transmitted using the EDMG SC or EDMG OFDM mode), and Table 28-9 (Compressed BW field definition)).

If the check of the L-Header CRC bits is not valid, a PHY-RXSTART.indication primitive is not issued, and instead the PHY shall issue the error condition PHY-RXEND.indication(FormatViolation) primitive. If a check of the L-Header CRC bits is valid, the EDMG PHY shall maintain the PHY-CCA.indication(BUSY, channel-list) primitive for the predicted duration of the transmitted PPDU, as defined by RXTIME parameter, for all supported modes, unsupported modes, and invalid EDMG-Header-A CRC.

If the check of the EDMG-Header-A CRC bits is not valid, a PHY-RXSTART.indication primitive is not issued, and instead the PHY shall issue the error condition PHY-RXEND.indication(FormatViolation)


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primitive. For an EDMG STA, if the EDMG-Header-A indicates an unsupported mode, the PHY shall issue a PHY-RXEND.indication(UnsupportedRate) primitive.

After receiving a valid L-Header and EDMG-Header-A indicating a supported mode, the PHY entity shall begin reception of the EDMG portion of the PPDU. For an EDMG STA and EDMG control mode PPDU, the EDMG portion of the PPDU includes the data (PSDU) and possible TRN field as defined in 28.4 (EDMG and non-EDMG control mode).

For an EDMG STA and EDMG SC mode PPDU, if the SU/MU Format field in the EDMG-Header-A indicates an SU PPDU, the Number of SS field indicates a single spatial stream, the STBC Applied field is 0, and the BW field indicates a single 2.16 GHz channel, then the EDMG part of the frame includes data (PSDU) and possibly a TRN field.

For an EDMG STA and EDMG SC mode PPDU, if the SU/MU Format field in the EDMG-Header-A indicates an SU PPDU and the Number of SS field indicates multiple spatial streams, or STBC Applied field is 1, or the BW field indicates 4.32 GHz, 6.48 GHz, 8.64 GHz, 2.16+2.16 GHz, or 4.32+4.32 GHz channel, then the EDMG part of the frame includes EDMG-STF, EDMG-CEF, data (PSDU), and possibly a TRN field as defined in 28.5 (EDMG and non-EDMG SC mode).

For an EDMG STA and EDMG OFDM mode PPDU, if the SU/MU Format field in the EDMG-Header-A indicates an SU PPDU, then the EDMG part of the frame includes EDMG-STF, EDMG-CEF, data (PSDU), and possibly a TRN field as defined in 28.6 (EDMG OFDM mode).

For an EDMG STA and EDMG SC or OFDM mode PPDU, if the SU/MU Format field in the EDMG-Header-A indicates an MU PPDU, then the EDMG part of the frame includes EDMG-STF, EDMG-CEF, EDMG-Header-B, data (PSDU), and possibly a TRN field as defined in 28.5 (EDMG and non-EDMG SC mode) and 28.6 (EDMG OFDM mode).

If an MU PPDU is indicated in the EDMG-Header-A, the EDMG STA verifies the AIDs included into the SS descriptors. If there is no match between the STA's AID and one included in any of the SS descriptors, then PHY shall issue a PHY-RXEND.indication(Filtered) primitive. If AID verification is successful, then the STA continues with EDMG-Header-B decoding.

If the check of the EDMG-Header-B CRC bits is not valid, a PHY-RXSTART.indication primitive is not issued, and instead the PHY shall issue the error condition PHY-RXEND.indication(FormatViolation) primitive. For an EDMG STA, if the EDMG-Header-B indicates an unsupported mode, the PHY shall issue a PHY-RXEND.indication(UnsupportedRate) primitive.

For successful decoding of the L-Header, the EDMG-Header-A, and the EDMG-Header-B (for MU only), the PHY shall issue a PHY-RXSTART.indication(RXVECTOR) primitive to the MAC containing the RXVECTOR parameters as defined in 28.2.2 (TXVECTOR and RXVECTOR parameters) (Table 28-1 (TXVECTOR and RXVECTOR parameters(11ay))).

After successful decoding of the header fields, the PHY performs decoding of the PSDU and initiates the series of PHY-DATA.indication(DATA) primitive exchanges. The decoded PSDU bits are assembled into octets and any pad bits added at the stage of encoding are discarded. If the PSDU decoding is successful, then the PHY shall issue the PHY-RXEND.indication(NoError, RXVECTOR) primitive.

If signal loss occurs during reception prior to completion of the PPDU reception, the error condition shall be reported to the MAC using a PHY-RXEND.indication(CarrierLost) primitive. After waiting for the intended end of the PPDU as determined by the RXTIME parameter, including possibly a TRN field, the PHY shall generate a PHY-CCA.indication(IDLE) primitive and return to the IDLE state. If the decoding of the L-Header is unsuccessful, then the RXTIME parameter cannot be determined. In this case, the PHY-CCA(BUSY) shall be maintained as long as the detected energy is 20 dB above the minimum sensitivity for

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a 2.16 GHz PPDU using the SC MCS 1. The PHY entity shall switch to the IDLE state immediately after the energy drops below the specified threshold.

A typical receive state machine for an SU PPDU reception with NUM_STS = 1 and no TRN field is shown in Figure 28-40 (PHY receive state machine for an SU PPDU reception (NUM_STS = 1, no TRN field)(11ay)).

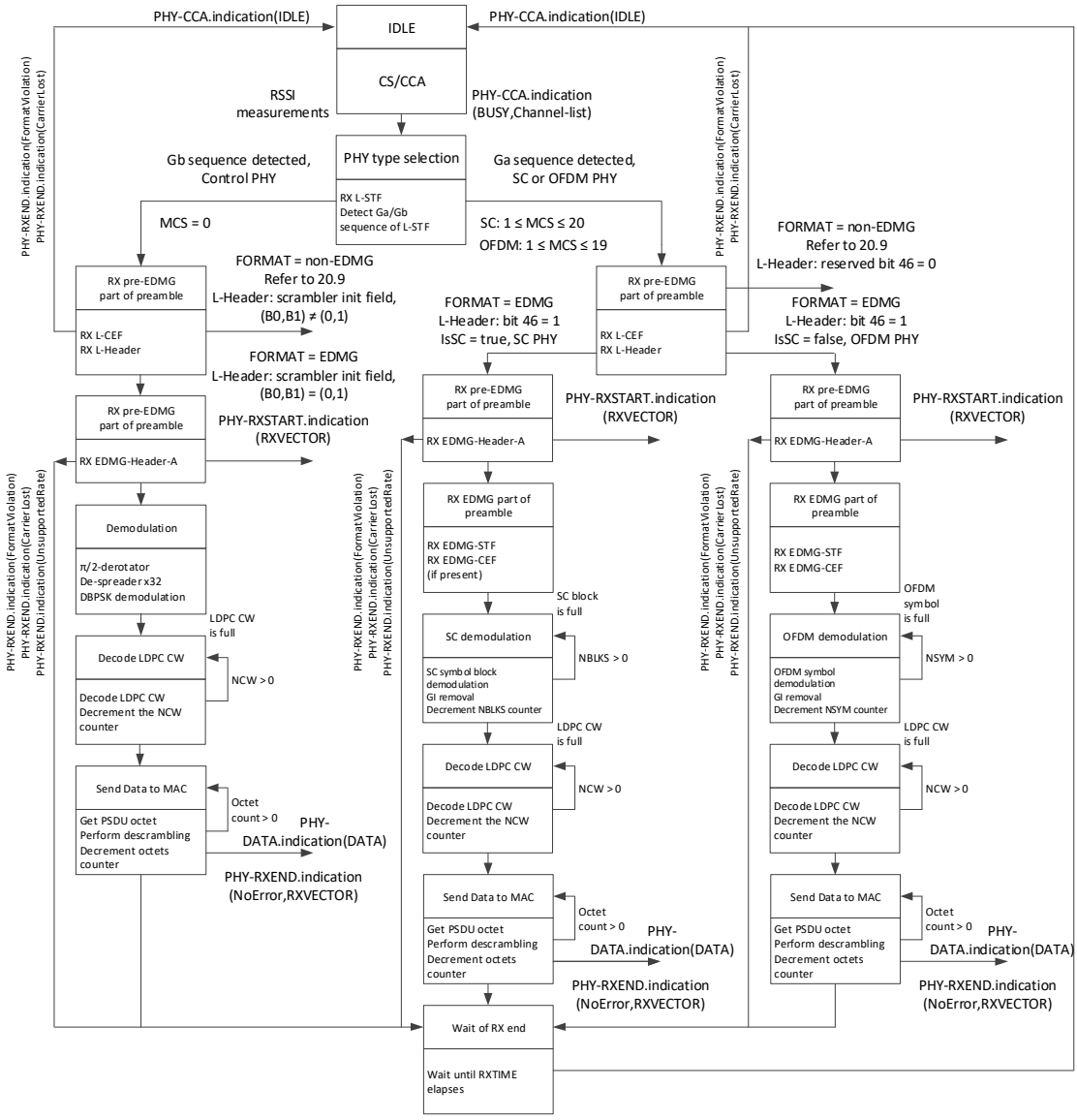


**Figure 28-40—PHY receive state machine for an SU PPDU reception (NUM_STS = 1, no TRN field)(11ay)**

For an EDMG STA and EDMG and non-EDMG control mode PPDUs, the RXTIME parameter shall be computed using the Length and Training Length fields defined in the (#6409)L-Header field (see Table 20-11 (DMG control mode header fields)). The minimum value for the Length field is equal to 14 octets, with the exception for the Short SSW PPDU where the minimum value for the Length field is equal to 6 octets, and the Training Length (*TRN_LEN*) can be equal to 0. In the latter case, the TRN field is not appended to the PPDU.


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The RXTIME parameter shall be defined in microseconds as follows:

$$RXTIME\ (\mu s) = T_{L\text{-}STF} + T_{L\text{-}CEF} + T_{L\text{-}Header+Data} + T_{TRN}$$

where

$T_{L\text{-}STF}$ = 6400 × aDMGChipTimeDuration ~ 3.63 μs

$T_{L\text{-}CEF}$ = 1152 × aDMGChipTimeDuration ~ 0.65 μs

$T_{L\text{-}Header+Data}$ = ((*Length* + $L_{L\text{-}Header}$) × 8 + 168 × $N_{CW}$) × 32 × aDMGChipTimeDuration μs

$$N_{CW} = 1 + \left\lceil \frac{(Length - 6) \times 8}{168} \right\rceil$$

$L_{L\text{-}Header}$ = 5

$T_{TRN}$ = (4992 × *TRN_LEN*) × aDMGChipTimeDuration μs

For an EDMG and non-EDMG PPDU transmission, the RXTIME computation using the above equation shall cause a spoofing error less than or equal to 0.15 μs, except for PPDU durations between 347.56 μs and 347.93 μs and between 349.10 μs and 350.76 μs where the maximum spoofing error can be 0.37 μs and 1.66 μs, respectively, as defined in 28.3.3.2.4.1 (General). Spoofing error is defined as the difference between the PPDU duration calculated based on the L-Header and the actual PPDU duration.

For an EDMG STA and EDMG and non-EDMG SC mode PPDUs, the RXTIME parameter shall be computed using the Base MCS, Length, Extended SC MCS Indication, and Training Length fields of the L-Header (see Table 20-13 (DMG SC mode header fields)).

The RXTIME parameter shall be defined in microseconds as follows:

$$RXTIME\ (\mu s) = T_{L\text{-}STF} + T_{L\text{-}CEF} + T_{L\text{-}Header} + T_{Data} + T_{TRN}$$

where

$T_{L\text{-}STF}$ = 2176 × aDMGChipTimeDuration ~ 1.24 μs

$T_{L\text{-}CEF}$ = 1152 × aDMGChipTimeDuration ~ 0.65 μs

$T_{L\text{-}Header}$ = 1024 × aDMGChipTimeDuration μs ~ 0.58 μs

$T_{Data}$ = ($N_{BLKS}$ × 512 + 64) × aDMGChipTimeDuration μs

$T_{TRN}$ = (4992 × *TRN_LEN*) × aDMGChipTimeDuration μs

The number of SC symbol blocks, $N_{BLKS}$, shall be as defined in 20.5.3.2.3.3 (LDPC encoding process).

For a DMG A-PPDU reception (i.e., Additional PPDU field is equal to 1), the RXTIME parameter shall be updated every time when receiving the next L-Header field. For an EDMG A-PPDU, the RXTIME parameter predicts the reception time for the entire EDMG A-PPDU. In both cases, the TRN field can be appended only once at the very end of the A-PPDU.

For an EDMG and non-EDMG PPDU transmission, the RXTIME computation using the above equation shall cause a spoofing error less than one SC symbol block, i.e., 512×aDMGChipTimeDuration as defined in 28.3.3.2.4.1 (General). Spoofing error is defined as the difference between the PPDU duration calculated based on the L-Header and the actual PPDU duration.

Optionally, an EDMG STA can estimate more accurately the actual RXTIME parameter for an EDMG PPDU by using the fields within the EDMG-Header-A.

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## 28.9 EDMG beamforming

### 28.9.1 Short SSW PPDU

#### 28.9.1.1 General

A Short SSW PPDU is a DMG control mode PPDU (see 20.4 (DMG control mode)) that has the Length field in the PHY header equal to 6 and the PPDU Type subfield within the Short SSW Payload field equal to 0.

The contents of the Short SSW Payload field, which consists of 6 octets and shall be transmitted following the PHY header, depend on whether the Short SSW PPDU is transmitted as part of an I-TXSS or R-TXSS, and whether it is used for MU-MIMO beamforming training.

The Short SSW Payload field of a Short SSW PPDU that is transmitted as part of an I-TXSS for SISO beamforming training is shown in Figure 28-41 (Short SSW Payload field when the Direction field is 0 (I-TXSS) and Addressing Mode field is 0(11ay)). The Short SSW Payload field of a Short SSW PPDU that is transmitted as part of an I-TXSS for MU-MIMO beamforming training is shown in Figure 28-42 (Short SSW Payload field when the Direction field is 0 (I-TXSS) and Addressing Mode field is 1(11ay)). The Short SSW Payload field of a Short SSW PPDU that is transmitted as part of an R-TXSS is shown in Figure 28-43 (Short SSW Payload field when the Direction field is 1 (R-TXSS)(11ay)). The subfields of the Short SSW Payload field are defined in Table 28-74 (Short SSW Payload field definition(11ay)).

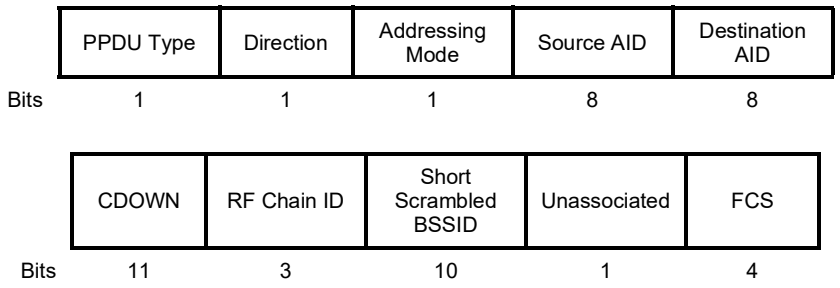


**Figure 28-41—Short SSW Payload field when the Direction field is 0 (I-TXSS) and Addressing Mode field is 0(11ay)**

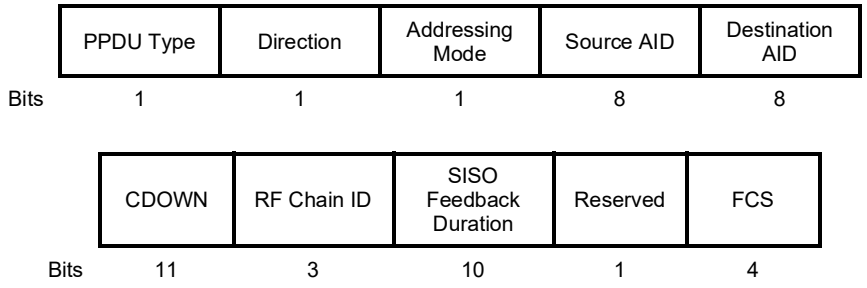


**Figure 28-42—Short SSW Payload field when the Direction field is 0 (I-TXSS) and Addressing Mode field is 1(11ay)**


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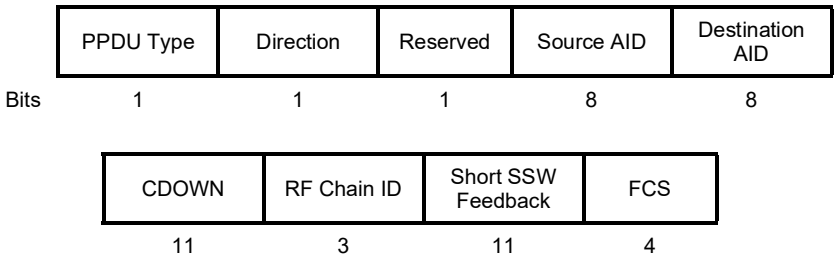


**Figure 28-43—Short SSW Payload field when the Direction field is 1 (R-TXSS)(11ay)**

**Table 28-74—Short SSW Payload field definition(11ay)**

| Subfield | Definition |
|---|---|
| PPDU Type | Indicates the type of the PPDU. Possible values:<br>0: Short SSW<br>1: Reserved |
| Direction | Corresponds to TXVECTOR parameter SSSW_DIR. Indicates the direction of the transmission. The Direction field is set to 0 to indicate that the frame is transmitted by the beamforming initiator and set to 1 to indicate that the frame is transmitted by the beamforming responder. |
| Addressing Mode | Corresponds to TXVECTOR parameter SSSW_ADD_MODE. If set to 0, this indicates that the Destination AID field contains an individual address. Otherwise, the Destination AID field contains a group address.<br><br>For an individual address, the SISO beamforming training is used. Otherwise, the MU-MIMO beamforming training is used. |
| Source AID | Corresponds to TXVECTOR parameter SSSW_SOURCE_AID. In an ISS, contains the AID of the STA that transmits the Short SSW PPDU, except if the transmitting STA is a PCP or an AP in which case this field contains the BSS AID (see 9.4.2.265 (EDMG Operation element(11ay))) or the transmitting STA is not associated to intended recipient in which case this field contains a random value (#6119)in the range 0 to 255.<br><br>In an RSS, contains the AID of the STA that transmits the Short SSW PPDU, except if the transmitting STA is a PCP or an AP in which case this field contains the BSS AID (see 9.4.2.265 (EDMG Operation element(11ay))) or the transmitting STA is not associated to the intended recipient in which case this field contains the value contained in the Source AID field in the received Short SSW PPDU during the preceding ISS. |
| Destination AID | Corresponds to TXVECTOR parameter SSSW_DESTINATION_AID. In an ISS, contains the AID of the STA addressed by the Short SSW PPDU, except if the addressed STA is a PCP or an AP in which case this field contains the BSS AID (see 9.4.2.265 (EDMG Operation element(11ay))) or the transmitting STA is not associated to the intended recipient in which case this field contains a random value in the range(#3482) 0 to 255.<br><br>In an RSS, contains the AID of the STA that transmits the Short SSW PPDU, except if the transmitting STA is a PCP or an AP in which case this field contains the BSS AID (see 9.4.2.265 (EDMG Operation element(11ay))) or the transmitting STA is not associated to the intended recipient in which case this field contains the value contained in the Destination AID field in the received Short SSW PPDU during the preceding ISS. |

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**Table 28-74—Short SSW Payload field definition(11ay) *(continued)***

| Subfield | Definition |
|---|---|
| CDOWN | Corresponds to TXVECTOR parameter SSSW_CDOWN. A down counter indicating the number of remaining Short SSW PPDU transmissions and LBIFSs to the end of the TXSS/RXSS across all antennas. This field is set to 0 in the last Short SSW PPDU transmission. |
| RF Chain ID | Corresponds to TXVECTOR parameter SSSW_RF_CHAIN_ID. The content of this field is set to the value of the RF_CHAIN_ID parameter minus one. Identifies the transmit chain currently being used for the transmission. |
| Short Scrambled BSSID | Derived from the TXVECTOR parameter SSSW_BSSID. The content of this field is defined in 28.9.1.2 (Short Scrambled BSSID subfield definition). |
| Unassociated | Corresponds to TXVECTOR parameter SSSW_UNASSOCIATED. Indicates whether the transmitting STA is associated to the intended recipient. This field is set to 1 if the transmitting STA is not associated to the intended recipient. Otherwise, it is set to 0. |
| SISO Feedback Duration | Corresponds to TXVECTOR parameter SSSW_SISO_FEEDBACK_DURATION. Specifies the duration, in microseconds, of the SISO Feedback subphase that starts following the Short SSW PPDU transmission with CDOWN field equal to 0. |
| Short SSW Feedback | Corresponds to TXVECTOR parameter SSSW_FEEDBACK. In an RSS, contains the value of the CDOWN field of the Short SSW PPDU that was received with the best quality in the immediately preceding sector sweep. The determination of which PPDU was received with the best quality is implementation dependent. |
| FCS | The four MSBs of the FCS. The FCS is calculated as defined in 9.2.4.8 (Frame Body field). |

### 28.9.1.2 Short Scrambled BSSID subfield definition

The process for generating the Short Scrambled BSSID subfield is depicted in Figure 28-44 (Generation of Short Scrambled BSSID subfield(11ay)).

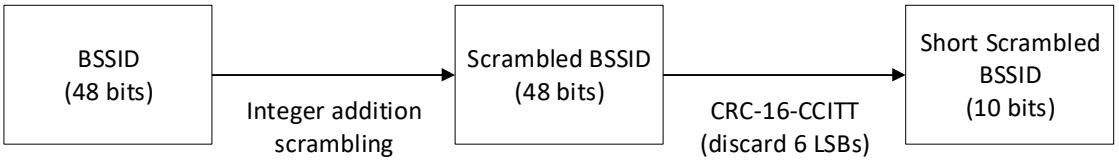


**Figure 28-44—Generation of Short Scrambled BSSID subfield(11ay)**

The process starts by using the BSSID to generate the scrambled BSSID. The BSSID is divided into three words, $word_i$ ($0 \le i \le 2$), of 16 bits each, where $word_0$ is the 16 MSB of the BSSID and $word_2$ is the 16 LSB of the BSSID. For each $word_i$, a $scrambled\_word_i$ is created (#4031)as follows:

$$scrambled\_word_i = (word_i + scramble\_pattern) \bmod 2^{16}$$

where

$word_i$ is the corresponding 16 bit word from the BSSID

$scramble\_pattern$ is $((0x5795 \times seed\_value) \bmod 2^{15})$, where $seed\_value$ is the value of the Scrambler Initialization field in the L-Header of the PPDU carrying the Short SSW PPDU


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The scrambled BSSID is generated by the consecutive concatenation of $scrambled\_word_0$, $scrambled\_word_1$, and $scrambled\_word_2$.

Finally, the Short Scrambled BSSID subfield is generated by taking the 10 MSBs of CRC-16-CCITT computed over the scrambled BSSID. The CRC-16 is computed as defined in 20.3.7 (HCS calculation for headers of DMG control mode and DMG SC mode).

#### 28.9.1.3 Short SSW Payload field example

This subclause describes an example configuration of a Short SSW Payload field using the following configuration as input:

- BSSID = 0B-25-4D-00-B8-6A
- L-Header:
  - Scrambler Initialization = 1
- Short SSW Payload field:
  - PPDU Type = 0
  - Direction = 0
  - Addressing Mode = 0
  - Source AID = 0x15
  - Destination AID = 1
  - CDOWN = 0x3F
  - RF Chain ID = 3
  - Short Scrambled BSSID = 0x02D
  - Unassociated = 0
  - FCS = 0xE

Using the above configuration, the Short SSW Payload field encoding using the convention in 9.2.2 (Conventions) is as follows: 00010101 00010000 00011111 10000011 01011010 00000111.

### 28.9.2 Beam refinement

#### 28.9.2.1 General

An EDMG STA shall support the beam refinement procedure and PPDUs defined in 20.9.2 (Beamforming PPDU format(#14)) in addition to the mechanisms described in this subclause.

An EDMG PPDU shall not include a TRN field

- If the EDMG TRN Length field is equal to 0; or
- If the EDMG TRN Length field is greater than 0, the Beam Tracking Request field is equal to 0, the EDMG Beam Tracking Request field is equal to 1, the PPDU Type field is equal to 0, and the RX TRN-Units per Each TX TRN-Unit field is equal to 0. As defined in 10.41.7 (Beam tracking), this configuration corresponds to a request for receive beam tracking.

#### 28.9.2.2 EDMG BRP PPDU

##### 28.9.2.2.1 General

An EDMG BRP PPDU is an EDMG PPDUs that contains a TRN field and enable antenna configuration training for transmission and/or reception. There are three types of EDMG BRP PPDUs: EDMG BRP-RX PPDUs, EDMG BRP-TX PPDUs, and EDMG BRP-RX/TX PPDUs:

- EDMG BRP-RX PPDU are used for receive AWV training. All TRN subfields of an EDMG BRP-RX PPDU are transmitted with the same AWV.

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— EDMG BRP-TX PPDU are used for transmit AWV training. The transmitter may change the AWV at the beginning of each set of *N* TRN subfields present in the last *M* TRN subfields of each TRN-Unit present in the TRN field. The transmitter may transmit all TRN subfields of a TRN field with the same AWV. The receiver performs measurements during the reception of the EDMG BRP-TX PPDU and sends feedback to the STA that transmitted the PPDU.

— EDMG BRP-RX/TX PPDUs are used for simultaneous training of the transmitter's transmit AWV and the receiver's receive AWV. To enable simultaneous receive and transmit training using the same EDMG BRP-RX/TX PPDU, different from an EDMG BRP-TX PPDU, the transmitter sends a number of consecutive TRN-Units in which the last *M* TRN subfields of each TRN-Unit are transmitted with the same AWV configuration.

NOTE—An EDMG BRP PPDU does not necessarily have to include a BRP frame in the PSDU.

#### 28.9.2.2.2 EDMG BRP PPDU structure

The EDMG_TRN_LEN parameter in the TVXVECTOR of an EDMG BRP PPDU shall be greater than 0.

As defined in 28.9.2.2.6 (TRN subfield definition for EDMG SC PPDUs and EDMG control mode PPDUs) for EDMG SC PPDUs and EDMG control mode PPDUs, and in 28.9.2.2.7 (TRN subfield definition for EDMG OFDM PPDUs) for EDMG OFDM PPDUs, if beam refinement is performed on a 4.32 GHz, 6.48 GHz, or 8.64 GHz channel, the TRN field in EDMG BRP PPDUs sent as part of beam refinement shall occupy 2, 3, or 4 contiguous 2.16 GHz channels, respectively. Also, if beam refinement is performed on a 2.16+2.16 GHz or 4.32+4.32 GHz channel, the TRN field in EDMG BRP PPDUs sent as part of beam refinement shall occupy one or two contiguous 2.16 GHz channels, respectively, for each of the two aggregated channels.

#### 28.9.2.2.3 EDMG BRP PPDU Header field(#6409)

The PPDU Type field within the L-Header together with the indication that the PPDU is an EDMG PPDU as defined in28.3.3.2.4 (L-Header definition) are used to indicate that a PPDU is an EDMG BRP PPDU. In the EDMG-Header-A of an EDMG PPDU, as defined in Table 28-12 (EDMG-Header-A field structure and definition for an SU PPDU(11ay)), the fields EDMG TRN Length, RX TRN-Units per Each TX TRN-Unit, the EDMG TRN-Unit P, EDMG TRN-Unit M and EDMG TRN-Unit N are used to indicate the length of the training field, the EDMG BRP-RX/TX PPDU configuration, the number of TRN subfields in a TRN-Unit that are used for channel estimation, the number of TRN subfields in a TRN-Unit that are used for beamforming training, and the number of consecutive TRN subfields within EDMG TRN-Unit M that are transmitted using the same AWV, respectively.

An EDMG STA that has the DMG TRN RX Only Capable subfield in its EDMG Capabilities element equal to 0 shall support the following transmit and receive configurations of the EDMG TRN-Unit P, EDMG TRN-Unit M and EDMG TRN-Unit N fields in a PPDU:

— EDMG TRN-Unit P = 2, EDMG TRN-Unit M = 5 and EDMG TRN-Unit N = 2

— EDMG TRN-Unit P = 2, EDMG TRN-Unit M = 7 and EDMG TRN-Unit N = 0

— EDMG TRN-Unit P = 0, EDMG TRN-Unit M = 2, 5, 8, 11, and 14, and EDMG TRN-Unit N = 2

— EDMG TRN-Unit P = 0, EDMG TRN-Unit M = 0 through 15, and EDMG TRN-Unit N = 0

All other configurations are optionally supported by an EDMG STA. In all cases, the value of the EDMG TRN-Unit M field plus one shall be an integer multiple of the value indicated in the EDMG TRN-Unit N field.

A value of 0 in the PPDU Type field, a value of 0 in the Beam Tracking Request field, a value of 0 in the EDMG Beam Tracking Request field, a value of 0 in the RX TRN-Units per Each TX TRN-Unit field, and a value greater than 0 in the EDMG TRN Length field indicate an EDMG BRP-RX PPDU.


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A value of 1 in the PPDU Type field, a value of 0 in the Beam Tracking Request field, a value of 0 in the RX TRN-Units per Each TX TRN-Unit field, and a value greater than 0 in the EDMG TRN Length field indicate an EDMG BRP-TX PPDU.

A value of 1 in the PPDU Type field, a value of 0 in the Beam Tracking Request field, a value greater than 0 in the RX TRN-Units per Each TX TRN-Unit field, and a value greater than 0 in the EDMG TRN Length field indicate an EDMG BRP-RX/TX PPDU.

A value in the EDMG TRN Length field of an EDMG BRP-RX PPDU shall be equal to the value of the L-RX field requested by the intended receiver of the EDMG BRP-RX PPDU in the last received EDMG BRP Request element (see 9.4.2.269 (EDMG BRP Request element(11ay))). A value in the RX TRN-Units per Each TX TRN-Unit field of an EDMG BRP-RX/TX PPDU shall be equal to the value of the L-TX-RX field requested by the intended receiver of the EDMG BRP-RX/TX PPDU in the last received EDMG BRP Request element (see 9.4.2.269 (EDMG BRP Request element(11ay))).

When the DMG TRN field is equal to 1 in an EDMG PPDU that has the EDMG TRN Length field greater than 0, the TRN field appended to the PPDU has the structure of a DMG training field containing an AGC training field and a TRN field as defined in 20.9.2.2.2 (BRP PPDU structure). In this case, the value of the EDMG TRN Length field is smaller than 32 and only one bit is set to 1 in the BW field.

#### 28.9.2.2.4 EDMG BRP PPDU duration

The minimum duration of the Data field of an EDMG BRP PPDU sent in EDMG SC mode or in EDMG OFDM mode is specified by the TXVECTOR parameter EDMG_BRP_MIN_SC_BLOCKS.

If the BRP PPDU is sent in EDMG SC mode, the number of the minimum SC symbol blocks, $N_{BLKS\,\min}$ (see 28.5.9.4.3 (LDPC encoding)), shall be equal to the value of the TXVECTOR parameter EDMG_BRP_MIN_SC_BLOCKS. If necessary, the Data field of the EDMG BRP PPDU shall be extended by extra zero padding to generate the required number of EDMG SC blocks.

If the BRP PPDU is sent in EDMG OFDM mode, the number of the minimum OFDM symbol blocks, $N_{SYMS\,\min}$ (see 28.6.9.2.3 (LDPC encoding)), is defined as follows:

$$N_{SYMS\,\min} = \left\lceil N_{SCBLKS\,\min} \cdot \frac{T_{DFT}^{(SC)}}{T_{DFT}^{(OFDM)} + T_{GI}^{(OFDM)}} \right\rceil$$

where

$N_{SCBLKS\,\min}$ is the value of the TXVECTOR parameter EDMG_BRP_MIN_SC_BLOCKS

$T_{DFT}^{(SC)}$ is the SC IDFT/DFT period defined in 28.5.2.2 (Timing-related parameters)

$T_{DFT}^{(OFDM)}$ is the OFDM IDFT/DFT period defined in 28.6.2.2 (Timing related parameters)

$T_{GI}^{(OFDM)}$ is the guard interval duration of the EDMG PPDU

If necessary, the Data field of the EDMG BRP PPDU shall be extended by extra zero padding to generate the required number of EDMG OFDM symbols.

The value of the PSDU Length field within the EDMG-Header-A of an EDMG BRP PPDU sent in EDMG control mode shall be greater than or equal to 19.

NOTE—The above requirement can be met by, for example, including a BRP frame in the PSDU.

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#### 28.9.2.2.5 TRN field definition

The TRN field enables transmit and receive AWV training by EDMG STAs. The TRN field has the same form for all EDMG PHY modes (EDMG control, EDMG SC, and EDMG OFDM). The TRN field structure of EDMG BRP-TX PPDUs, of EDMG BRP-RX/TX PPDUs, and of EDMG BRP-RX PPDUs are shown in Figure 28-45 (TRN field structure of EDMG BRP-TX PPDUs(11ay)), Figure 28-46 (TRN field structure of EDMG BRP-RX/TX PPDUs(11ay)), and Figure 28-47 (TRN field structure of EDMG BRP-RX PPDUs(11ay)), respectively.

The total number of TRN-Units present in the TRN field of an EDMG PPDU is equal to the value of the EDMG TRN Length field contained in the EDMG-Header-A field of the PPDU.

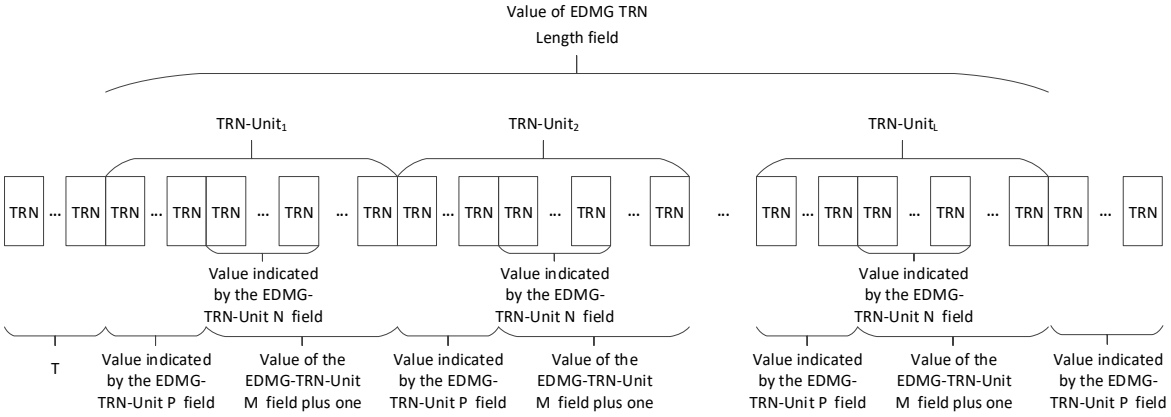


**Figure 28-45—TRN field structure of EDMG BRP-TX PPDUs(11ay)**

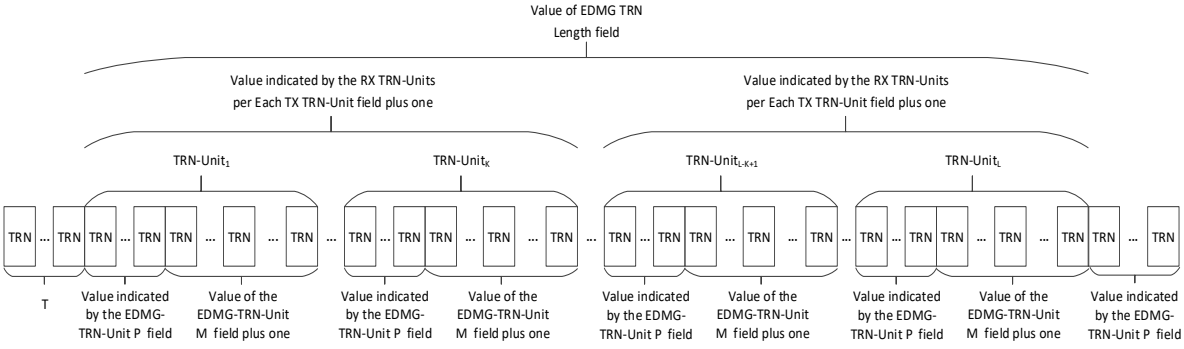


**Figure 28-46—TRN field structure of EDMG BRP-RX/TX PPDUs(11ay)**


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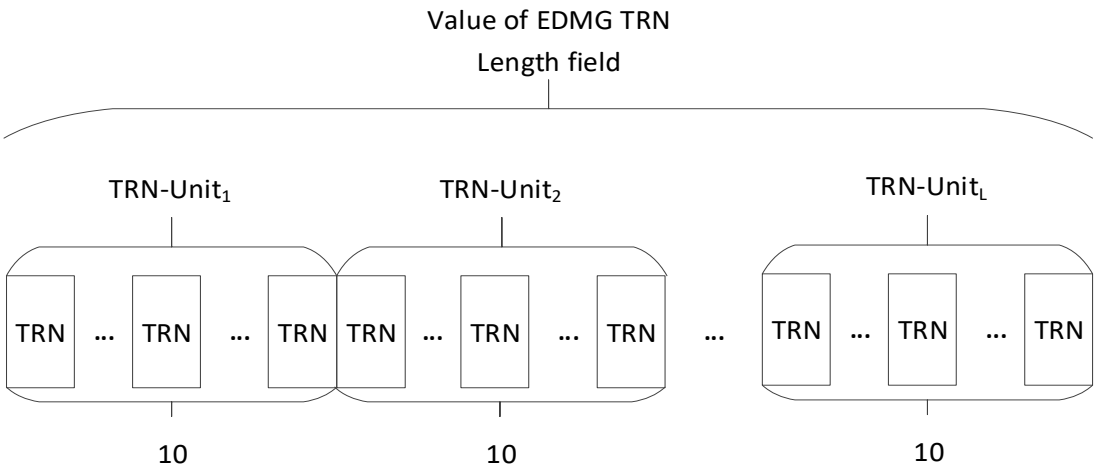


**Figure 28-47—TRN field structure of EDMG BRP-RX PPDUs(11ay)**

For EDMG BRP-TX and EDMG BRP-RX/TX PPDUs, each TRN-Unit comprises *P* plus *M* repetitions of the TRN subfield defined in 28.9.2.2.6 (TRN subfield definition for EDMG SC PPDUs and EDMG control mode PPDUs), where *P* is the value indicated by the EDMG TRN-Unit P field and *M* is the value of the EDMG TRN-Unit M field in the EDMG-Header-A plus one. The first *P* TRN subfields of each TRN-Unit shall be transmitted using the same AWV as the preamble and Data fields of the PPDU, except for the case when the DMG antenna used in the transmission of an EDMG BRP-TX PPDU changes at the beginning of the TRN field, as described in 10.41.10.5.2 (BRP TXSS configuration) for the BRP TXSS procedure. In this particular case, the AWV used in the transmission of the first *P* TRN subfields of each TRN-Unit is selected in an implementation dependent manner and should be the same for all TRN-Units.

For EDMG BRP-TX PPDUs, the transmitter may change the AWV at the beginning of each set of *N* TRN subfields present in the last *M* TRN subfields of each TRN-Unit in the TRN field, where *N* is the value indicated by the EDMG TRN-Unit N field within the EDMG-Header-A. The *N* consecutive TRN subfields that comprise each set of *N* TRN subfields shall be transmitted with the same AWV. For EDMG BRP-RX/TX PPDUs, the transmitter may change AWV once at the beginning of the last *M* TRN subfields of each TRN-Unit with the constraint that the same AWV configuration shall be used in the transmission of *R* TRN-Units, where *R* is the value of the RX TRN-Units per Each TX TRN-Unit field in the EDMG-Header-A plus one. Any transmit signal transients that occur due to TX AWV configuration changes at the beginning of a TRN subfield shall settle within $64 \times T_c$ from the beginning of the TRN subfield.

In an EDMG BRP-RX PPDU, all TRN subfields of all TRN-Units shall be transmitted using the same AWV as the preamble and (#404)Data fields of the PPDU. Moreover, each TRN-Unit shall have 10 TRN subfields.

The transmission of the TRN field starts with *T* repetitions of the TRN subfield, which should be transmitted with the same AWV that is used for the transmission of the first *P* TRN subfields of each TRN-Unit. The *T* repetitions of the TRN subfield at the beginning of the TRN field are defined to provide a transition interval between the processing of the data and TRN fields. As such, the *T* repetitions of the TRN subfield shall not be used for AWV training and shall not be used to compute channel measurement feedback. For EDMG BRP-TX PPDUs and EDMG BRP-RX/TX PPDUs, *T* is determined by the value of the TRN Subfield Sequence Length field in EDMG-Header-A of the PPDU. If the TRN Subfield Sequence Length field is 0, *T* shall be equal to 2. If the TRN Subfield Sequence Length field is 1, *T* shall be equal to 1. If the TRN Subfield Sequence Length field is 2, *T* shall be equal to 4. For EDMG BRP-RX PPDUs or if the value of the EDMG TRN Length field contained in the EDMG-Header-A is 0, *T* shall be equal to 0.

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NOTE 1—The duration of *T* repetitions of the TRN subfield is the same for all values of the TRN Subfield Sequence Length field in the EDMG-Header-A.

In EDMG BRP-TX and EDMG BRP-RX/TX PPDUs, following the transmission of all TRN-Units as indicated by the value of the EDMG TRN Length field, there are *P* repetitions of the TRN subfield, which shall be transmitted with the same AWV that is used for the transmission of the preamble and Data fields of the PPDU containing the TRN field, except for the case when the DMG antenna used in the transmission of an EDMG BRP-TX PPDU changes at the beginning of the TRN field, as described in 10.41.10.5.2 (BRP TXSS configuration) for the BRP TXSS procedure. In this particular case, the AWV used in the transmission of the *P* repetitions of the TRN subfield is selected in an implementation dependent manner.

In an EDMG BRP-TX PPDU that has the value of the EDMG TRN-Unit N field in the EDMG-Header-A equal to 0, the EDMG TRN Length field in the EDMG-Header-A shall be less than or equal to 2040/*M*, where *M* is the value of the EDMG TRN-Unit M field in the EDMG-Header-A of the PPDU plus one.

The concept of AWV feedback ID is defined to indicate TRN subfields transmitted with the same AWV in the feedback of measurements made with EDMG BRP-TX and EDMG BRP-RX/TX PPDUs. For EDMG BRP-TX and EDMG BRP-RX/TX PPDUs, a TRN subfield with index *i* is defined as the $(i + 1)^{th}$ TRN subfield transmitted in the TRN field of the PPDU, where $i = 0, 1, \ldots, (M \times L) - 1$, *M* is the value of the EDMG TRN-Unit M field in the EDMG-Header-A plus one, and *L* is the value of the EDMG TRN Length field in the EDMG-Header-A. The *P* TRN subfields at the start of each TRN-Unit transmitted with the same AWV are not indexed, where *P* is the value indicated by the EDMG TRN-Unit P field in the EDMG-Header-A of the PPDU.

An AWV feedback ID of value a indicates the TRN subfields transmitted with the $(a + 1)^{th}$ AWV used in the transmission of the TRN field. For EDMG BRP-TX PPDUs in which the value of the EDMG TRN-Unit N field in the EDMG-Header-A is greater than 0, a TRN subfield with index *i* shall have AWV feedback ID equal to the following:

$$a = \lfloor i / N \rfloor$$

where

*N* is the number of consecutive TRN subfields within a TRN-Unit that are transmitted with the same AWV configuration, which can be equal to 1, 2, 3, 4, or 8, as indicated by the EDMG TRN-Unit M and EDMG TRN-Unit N fields in the EDMG-Header-A

For EDMG BRP-TX PPDUs in which the value of the EDMG TRN-Unit N field in the EDMG-Header-A is greater than 0, $a = 0, 1, \ldots, (M \times L)/N - 1$.

For EDMG BRP-TX PPDUs in which the value of the EDMG TRN-Unit N field in the EDMG-Header-A is equal to 0, $a = i$ and $a = 0, 1, \ldots, (M \times L) - 1$. For EDMG BRP-RX/TX PPDUs, a TRN subfield with index *i* shall have AWV feedback ID a equal to the following:

$$a = \lfloor i / (C \times M) \rfloor$$

where

*M* is as defined above
*N* is as defined above
*C* is the value of the RX TRN-Units per Each TX TRN-Unit field in the EDMG-Header-A
*L* is as defined above

For EDMG BRP-RX/TX PPDUs, $a = 0, 1, \ldots, L/C - 1$.


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NOTE 2—When processing the TRN field of an EDMG BRP PPDU, the repeated transmission of TRN subfields with the same AWV, which could be obtained by setting the EDMG TRN-Unit P field and/or EDMG TRN-Unit N field in the EDMG-Header-A to values greater than 0, can be used for AGC.

If the Dual Polarization TRN Training field is 1 and the value *N* indicated by the EDMG TRN-Unit N field in the EDMG-Header-A of an EDMG BRP-RX, EDMG BRP-TX or EDMG BRP-RX/TX PPDU is even, the transmitter changes the antenna polarization at the end of each group of *N*/2 TRN subfields, in the last *M* subfields in each TRN unit, where *M* is the value of EDMG TRN-Unit M plus one. The antenna polarization change shall be done while keeping the same AWV. The antenna polarization change should take no more time than the settling time for the change of an AWV.

The receiver shall also switch polarization at the end of each *k* TRN subfields within the last *M* subfields in each TRN unit, where *k* is *N*/2, *M* is the value of EDMG TRN-Unit M plus one, and *N* is the value indicated by the EDMG TRN-Unit N field in the EDMG-Header-A of the received PPDU.

#### 28.9.2.2.6 TRN subfield definition for EDMG SC PPDUs and EDMG control mode PPDUs

The TRN subfield shall consist of $N_{TX}$ orthogonal waveforms, where $N_{TX}$ is the total number of transmit chains used in the transmission of the EDMG PPDU. The total number of transmit chains is indicated by the value of the TXVECTOR or RXVECTOR parameter NUM_TX_CHAINS.

The basic SC TRN subfield waveform for the $i_{TX}^{\text{th}}$ transmit chain in time domain shall be defined at the EDMG SC chip rate $F_{c\,EDMG}$ and chip time duration $T_c/N_{CB}$ as follows:

$$r_{TRN\_BASIC}^{i_{TX}}\left(q\frac{T_c}{N_{CB}}\right)=\left(Ga_{TRN\_BL\times N_{CB}}^{i_{TX}}\left(q\right)-Gb_{TRN\_BL\times N_{CB}}^{i_{TX}}\left(q-TRN\_BL\times N_{CB}\right)\right.$$
$$+Ga_{TRN\_BL\times N_{CB}}^{i_{TX}}\left(q-2\times TRN\_BL\times N_{CB}\right)+Gb_{TRN\_BL\times N_{CB}}^{i_{TX}}\left(q-3\times TRN\_BL\times N_{CB}\right)$$
$$\left.+Ga_{TRN\_BL\times N_{CB}}^{i_{TX}}\left(q-4\times TRN\_BL\times N_{CB}\right)-Gb_{TRN\_BL\times N_{CB}}^{i_{TX}}\left(q-5\times TRN\_BL\times N_{CB}\right)\right)$$

Sequences $Ga_{TRN\_BL\times N_{CB}}^{i_{TX}}\left(n\right)$ and $Gb_{TRN\_BL\times N_{CB}}^{i_{TX}}\left(n\right)$, $i_{TX}$ = 1, 2, …, 8, are defined for $0 \le n \le TRN\_BL \times N_{CB} - 1$. For other values of *n*, $Ga_{TRN\_BL\times N_{CB}}^{i_{TX}}\left(n\right)$ and $Gb_{TRN\_BL\times N_{CB}}^{i_{TX}}\left(n\right)$ are set to 0.

If the $TRN\_BL \times N_{CB}$ length is equal to 64 ($TRN\_BL$ = 64 and $N_{CB}$ = 1), then the basic TRN subfield waveform for the $i_{TX}^{\text{th}}$ transmit chain in time domain shall be defined at the DMG SC chip rate $F_c$ and chip time duration $T_c$ as follows:

$$r_{TRN\_BASIC}^{i_{TX}}\left(qT_c\right)=\left(Gc_{64}^{i_{TX}}\left(q\right)-Gd_{64}^{i_{TX}}\left(q-64\right)\right.$$
$$+Gc_{64}^{i_{TX}}\left(q-2\times 64\right)+Gd_{64}^{i_{TX}}\left(q-3\times 64\right)$$
$$\left.+Gc_{64}^{i_{TX}}\left(q-4\times 64\right)-Gd_{64}^{i_{TX}}\left(q-5\times 64\right)\right)$$

Sequences $Gc_{64}^{i_{TX}}\left(n\right)$ and $Gd_{64}^{i_{TX}}\left(n\right)$, $i_{TX}$ = 1, 2, …, 8, are defined for $0 \le n \le 63$. For other values of *n*, $Gc_{64}^{i_{TX}}\left(n\right)$ and $Gd_{64}^{i_{TX}}\left(n\right)$ are set to 0.

*TRN_BL* represents the length of the Golay sequence used in the TRN subfield and depends on the value of the TRN Subfield Sequence Length field in the EDMG-Header-A of the PPDU. If the TRN Subfield

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Sequence Length field is 0, *TRN_BL* is equal to 128. If the TRN Subfield Sequence Length field is 1, *TRN_BL* is equal to 256. If the TRN Subfield Sequence Length field is 2, *TRN_BL* is equal to 64.

Moreover, $N_{CB}$ = 1 for a 2.16 GHz or a 2.16+2.16 GHz channel, $N_{CB}$ = 2 for a 4.32 GHz or a 4.32+4.32 GHz channel, $N_{CB}$ = 3 for a 6.48 GHz channel, and $N_{CB}$ = 4 for an 8.64 GHz channel.

An EDMG STA shall support Golay sequences of length 128 and 256 (i.e., *TRN_BL* equal to 128 and $N_{CB}$ equal to 1 or 2). Other lengths are optional and support is indicated in the STA's EDMG Capabilities element.

The pairs of Golay complementary sequences ($Gc^i_{64}$, $Gd^i_{64}$), ($Ga^i_{128}$, $Gb^i_{128}$), ($Ga^i_{192}$, $Gb^i_{192}$), ($Ga^i_{256}$, $Gb^i_{256}$), ($Ga^i_{384}$, $Gb^i_{384}$), ($Ga^i_{512}$, $Gb^i_{512}$), ($Ga^i_{768}$, $Gb^i_{768}$), and ($Ga^i_{1024}$, $Gb^i_{1024}$) are defined in 28.10 (Golay sequences). These sequences shall be transmitted using π/2-BPSK modulation.

The TRN subfield waveform for the $i_{TX}^{\text{th}}$ transmit chain is defined as follows:

$$r^{i_{TX}}_{TRN\_SUBFIELD}\left(q\frac{T_c}{N_{CB}}\right)=\sum_{n=1}^{N^{TX}_{TRN}}\left[P_{TRN}\right]_{i_{TX},n} r^{i_{TX}}_{TRN\_BASIC}\left(q\frac{T_c}{N_{CB}}-(n-1)\times T_{BASIC}\right)$$

where

$P_{TRN}$ is the TRN mapping matrix

$N^{N_{TX}}_{TRN}$ is the number of SC TRN basic subfields in a TRN subfield for the given total number of transmit chains $N_{TX}$

$[\ ]_{m,n}$ is a matrix element from $m^{\text{th}}$ row and $n^{\text{th}}$ column

$T_{BASIC}$ is the duration of the basic TRN subfield

$q$ is a chip time index, $q = 0,1,...,TRN\_BL \times N_{CB} \times 6 \times N^{TX}_{TRN} - 1$

The TRN mapping matrix used in the TRN subfield definition for a 2.16 GHz, 4.32 GHz, 6.48 GHz, and 8.64 GHz PPDU transmission is defined as follows:

— The TRN mapping matrix for $N_{TX}$ = 1, 2 is defined as follows:

$$P_{TRN}=\begin{bmatrix}+1\\+1\end{bmatrix},\ N^{N_{TX}}_{TRN}=1$$

— The TRN mapping matrix for $N_{TX}$ = 3, 4 is defined as follows:

$$P_{TRN}=\begin{bmatrix}+1 & +1\\ +1 & +1\\ +1 & -1\\ +1 & -1\end{bmatrix},\ N^{N_{TX}}_{TRN}=2$$

— The TRN mapping matrix for $N_{TX}$ = 5, 6, 7, and 8 is defined as follows:


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$$P_{TRN} = \begin{bmatrix} +1 & +1 & +1 & +1 \\ +1 & +1 & +1 & +1 \\ +1 & -1 & +1 & -1 \\ +1 & -1 & +1 & -1 \\ +1 & +1 & -1 & -1 \\ +1 & +1 & -1 & -1 \\ +1 & -1 & -1 & +1 \\ +1 & -1 & -1 & +1 \end{bmatrix}, \; N_{TRN}^{N_{TX}} = 4$$

The TRN mapping matrix used in the TRN subfield definition for a 2.16+2.16 GHz and a 4.32+4.32 GHz PPDU transmission is defined as follows:

— The TRN mapping matrix for $N_{TX}$ = 2, 4 is defined as follows:

$$P_{TRN} = \begin{bmatrix} +1 \\ +1 \\ +1 \\ +1 \end{bmatrix}, \; N_{TRN}^{N_{TX}} = 1$$

— The TRN mapping matrix for $N_{TX}$ = 6, 8 is defined as follows:

$$P_{TRN} = \begin{bmatrix} +1 & +1 \\ +1 & +1 \\ +1 & -1 \\ +1 & -1 \\ +1 & +1 \\ +1 & +1 \\ +1 & -1 \\ +1 & -1 \end{bmatrix}, \; N_{TRN}^{N_{TX}} = 2$$

The TRN field waveform for the $i_{TX}^{\text{th}}$ transmit chain in an EDMG control PPDU or EDMG SC PPDU is defined as follows:

$$r_{TRN}^{i_{TX}}\left(q\frac{T_c}{N_{CB}}\right) = \sum_{n=1}^{N_{SUBFIELD}} r_{TRN\_SUBFIELD}^{i_{TX}}\left(q\frac{T_c}{N_{CB}} - (n-1)\times T_{SUBFIELD}\right)$$

where

$r_{TRN\_SUBFIELD}^{i_{TX}}\left(q\frac{T_c}{N_{CB}}\right)$ is the TRN subfield waveform defined in this subclause

$T_{SUBFIELD}$ is the time duration of the TRN subfield

$N_{SUBFIELD}$ is the total number of TRN subfields transmitted in the TRN field

$q$ is a chip time index, $q = 0,1,\ldots, N_{SUBFIELD} \times TRN\_BL \times N_{CB} \times 6 \times N_{TRN}^{TX} - 1$

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#### 28.9.2.2.7 TRN subfield definition for EDMG OFDM PPDUs

For EDMG PPDU transmissions using the EDMG OFDM mode over a 2.16 GHz or 2.16+2.16 GHz channel, the OFDM *TRN_BASIC* sequence is defined in frequency domain for the $i_{TX}^{th}$ transmit chain as follows:

— $TRN\_BASIC^{iTX}_{-177,\,177} = [Seq^{iTX}_{left,\,176}, 0, 0, 0, Seq^{iTX}_{right,\,176}]$, for $i_{TX}$=1, 2, 3, 4, 5, 6, 7, 8

For EDMG PPDU transmissions using the EDMG OFDM mode over a 4.32 GHz or 4.32+4.32 GHz channel, the OFDM *TRN_BASIC* sequence is defined in frequency domain for the $i_{TX}^{th}$ transmit chain as follows:

— $TRN\_BASIC^{iTX}_{-386,\,386} = [Seq^{iTX}_{left,\,385}, 0, 0, 0, Seq^{iTX}_{right,\,385}]$, for $i_{TX}$=1, 2, 3, 4, 5, 6, 7, 8

For EDMG PPDU transmissions using the EDMG OFDM mode over a 6.48 GHz channel, the OFDM *TRN_BASIC* sequence is defined in frequency domain for the $i_{TX}^{th}$ transmit chain as follows:

— $TRN\_BASIC^{iTX}_{-596,\,596} = [Seq^{iTX}_{left,\,595}, 0, 0, 0, Seq^{iTX}_{right,\,595}]$, for $i_{TX}$=1, 2, 3, 4, 5, 6, 7, 8

For EDMG PPDU transmissions using the EDMG OFDM mode over an 8.64 GHz channel, the OFDM *TRN_BASIC* sequence is defined in frequency domain for the $i_{TX}^{th}$ transmit chain as follows:

— $TRN\_BASIC^{iTX}_{-805,\,805} = [Seq^{iTX}_{left,\,804}, 0, 0, 0, Seq^{iTX}_{right,\,804}]$, for $i_{TX}$=1, 2, 3, 4, 5, 6, 7, 8

The basic OFDM TRN subfield waveform for the $i_{TX}^{th}$ transmit chain in time domain shall be defined at the OFDM sampling rate $F_s$ and sample time duration $T_s$ as follows:

$$r^{i_{TX}}_{TRN\_BASIC}\left(qT_s\right) = \sum_{n=1}^{N^{N_{TX}}_{TRN}} r^{n,i_{TX}}_{TRN}\left(qT_s - (n-1)\cdot\left(T_{DFT} + T_{GI\ long}\right)\right)$$

where

$$r^{n,i_{TX}}_{TRN}\left(qT_s\right) = \frac{1}{\sqrt{N^{Tone}_{TRN}}} w\left(qT_s\right)$$

$$\cdot \sum_{k=-N_{SR}}^{N_{SR}} \left[P_{TRN}\right]_{i_{TX},n} TRN\_BASIC^{i_{TX}}_{k} \exp\left(j2\pi k\Delta_F\left(qT_s - T_{GI\ long}\right)\right), 1 \le n \le N^{N_{TX}}_{TRN}$$

$N^{Tone}_{TRN} = N_{ST} - N_{DC}$ is the total number of active tones

$P_{TRN}$ is the TRN mapping matrix (see below)

$N^{N_{TX}}_{TRN}$ is the number of OFDM symbols in a TRN subfield for the given total number of transmit chains $N_{TX}$ (see below)

$[\ ]_{m,n}$ is a matrix element from $m^{th}$ row and $n^{th}$ column

$w(qT_s)$ is window function applied to smooth the transitions between consecutive OFDM symbols and its definition is implementation specific

$q$ is a time sample index

The TRN subfield waveform for the $i_{TX}^{th}$ transmit chain is defined as follows:

$$r^{i_{TX}}_{TRN\_SUBFIELD}\left(qT_S\right) = \sum_{n=1}^{N_{SEQ\_LEN}} r^{i_{TX}}_{TRN\_BASIC}\left(qT_s - (n-1)\cdot T_{BASIC}\right)$$



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where

| | |
|---|---|
| $r_{TRN\_BASIC}^{i_{TX}}(qT_S)$ | is the basic TRN subfield waveform for the $i_{TX}^{\text{th}}$ transmit chain |
| $T_{BASIC}$ | is the duration of the basic TRN subfield |
| $N_{SEQ\_LEN}$ | shall be set to 2 if the value of the TXVECTOR parameter TRN_SEQ_LENGTH of the PPDU is equal to Normal; or to 1 if TRN_SEQ_LENGTH is equal to Short; or to 4 if TRN_SEQ_LENGTH is equal to Long |
| $q$ | is a time sample index |

The TRN field transmit waveform for $i_{TX}^{\text{th}}$ transmit chain in an EDMG OFDM PPDU is defined as follows:

$$r_{TRN}^{i_{TX}}(qT_s) = \sum_{n=1}^{N_{SUBFIELD}} r_{TRN\_SUBFIELD}^{i_{TX}}(qT_s - (n-1)\times T_{SUBFIELD})$$

where

| | |
|---|---|
| $r_{TRN\_SUBFIELD}^{i_{TX}}(qT_s)$ | is the TRN subfield waveform defined in this subclause |
| $T_{SUBFIELD}$ | is the time duration of the TRN subfield |
| $N_{SUBFIELD}$ | is the total number of TRN subfields transmitted in the TRN field |
| $q$ | is a sample time index, $q = 0,1,...,N_{SUBFIELD}\times(N_{DFT}+N_{GI\,long})\times N_{TRN}^{N_{TX}}\times N_{SEQ\_LEN}-1$ |

If the Maximum OFDM MCS subfield in a STA's EDMG Capabilities element is greater than 0, the STA shall support 2 repetitions of the basic TRN subfield. Other repetitions are optional and support is indicated in the STA's EDMG Capabilities element.

The OFDM TRN mapping matrix for $N_{TX} = 1$ is defined as follows:

$$P_{TRN} = [+1 \quad -1],\ N_{TRN}^{N_{TX}} = 2$$

The OFDM TRN mapping matrix for $N_{TX} = 2$ is defined as follows:

$$P_{TRN} = \begin{bmatrix} +1 & -1 \\ +1 & +1 \end{bmatrix},\ N_{TRN}^{N_{TX}} = 2$$

The OFDM TRN mapping matrix for $N_{TX} = 3$ is defined as follows:

$$P_{TRN} = \begin{bmatrix} +1 & -1 & +1 \\ +1 & -w_3^1 & w_3^2 \\ +1 & -w_3^2 & w_3^4 \end{bmatrix},\ w_3 = \exp(-j2\pi/3),\ N_{TRN}^{N_{TX}} = 3$$

The OFDM TRN mapping matrix for $N_{TX} = 4$ is defined as follows:

$$P_{TRN} = P_{4x4} = \begin{bmatrix} +1 & -1 & +1 & +1 \\ +1 & +1 & -1 & +1 \\ +1 & +1 & +1 & -1 \\ -1 & +1 & +1 & +1 \end{bmatrix},\ N_{TRN}^{N_{TX}} = 4$$

The OFDM TRN mapping matrix for $N_{TX} = 5, 6$ is defined as follows:

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$$P_{TRN} = \begin{bmatrix} +1 & -1 & +1 & +1 & +1 & -1 \\ +1 & -w_6^1 & w_6^2 & w_6^3 & w_6^4 & -w_6^5 \\ +1 & -w_6^2 & w_6^4 & w_6^6 & w_6^8 & -w_6^{10} \\ +1 & -w_6^3 & w_6^6 & w_6^9 & w_6^{12} & -w_6^{15} \\ +1 & -w_6^4 & w_6^8 & w_6^{12} & w_6^{16} & -w_6^{20} \\ +1 & -w_6^5 & w_6^{10} & w_6^{15} & w_6^{20} & -w_6^{25} \end{bmatrix}, \; w_6 = \exp(-j2\pi/6), \; N_{TRN}^{N_{TX}} = 6$$

The OFDM TRN mapping matrix for $N_{TX}$ = 7, 8 is defined as follows:

$$P_{TRN} = \begin{bmatrix} P_{4x4} & P_{4x4} \\ P_{4x4} & -P_{4x4} \end{bmatrix}, \; N_{TRN}^{N_{TX}} = 8$$

For 2.16+2.16 GHz and 4.32+4.32 GHz PPDU transmission, the OFDM TRN mapping matrix for each channel is determined by the number of transmit chains per channel, which is half of the total number of transmit chains.

If the number of transmit chains per channel is 1 ($N_{TX}$ = 2), the OFDM TRN mapping matrix for each channel is defined as follows:

$$P_{TRN} = \begin{bmatrix} +1 & -1 \end{bmatrix}, \; N_{TRN}^{N_{TX}} = 2$$

If the number of transmit chains per channel is 2 ($N_{TX}$ = 4), the OFDM TRN mapping matrix for each channel is defined as follows:

$$P_{TRN} = \begin{bmatrix} +1 & -1 \\ +1 & +1 \end{bmatrix}, \; N_{TRN}^{N_{TX}} = 2$$

If the number of transmit chains per channel is 3 ($N_{TX}$ = 6), the OFDM TRN mapping matrix for each channel is defined as follows:

$$P_{TRN} = \begin{bmatrix} +1 & -1 & +1 \\ +1 & -w_3^1 & w_3^2 \\ +1 & -w_3^2 & w_3^4 \end{bmatrix}, \; w_3 = \exp(-j2\pi/3), \; N_{TRN}^{N_{TX}} = 3$$

If the number of transmit chains per channel is 4 ($N_{TX}$ = 8), the OFDM TRN mapping matrix for each channel is defined as follows:

$$P_{TRN} = P_{4x4} = \begin{bmatrix} +1 & -1 & +1 & +1 \\ +1 & +1 & -1 & +1 \\ +1 & +1 & +1 & -1 \\ -1 & +1 & +1 & +1 \end{bmatrix}, \; N_{TRN}^{N_{TX}} = 4$$

$TRN\_BASIC^{i_{TX}}$ for the first $N_{TX}/2$ transmit chains shall be correspond to the transmit chain number $i_{TX}$ = 1, …, $N_{TX}/2$ and $TRN\_BASIC^{i_{TX}}$ for the second $N_{TX}/2$ transmit chains shall be correspond to the transmit chain number $i_{TX} = N_{TX}/2 + 1$, …, $N_{TX}$.


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#### 28.9.2.2.8 Channel measurement

The autocorrelation properties of the Golay sequence used in the TRN field allow for the estimation of the impulse response of the channel between transmitter and receiver. When the channel measurement is performed using an EDMG BRP-TX PPDU, the receiver should determine the channel tap with largest magnitude using the first *P* TRN subfields of the first TRN-Unit of the PPDU, where *P* is the number of TRN subfields indicated in the EDMG TRN-Unit P field within the EDMG-Header-A of the PPDU. The receiver then selects the set of taps that is measured around the tap with the largest magnitude, according to dot11ChanMeasFBCKNtaps. It can select a contiguous set of taps or select a noncontiguous set of taps, and include the delays of the selected taps in the Tap Delay field of the Channel Measurement Feedback element. The receiver then measures the amplitude of the corresponding channel taps in each of the last *M* TRN subfields of all TRN-Units in the PPDU if *N* is equal to 0, where *M* and *N* are the number of TRN subfields indicated in the EDMG TRN-Unit M field and in the EDMG TRN-Unit N field within the EDMG-Header-A of the PPDU, respectively. If *N* is greater than 0, one set of amplitudes are obtained for each group of *N* consecutive TRN subfields that have the same AWV feedback ID, as defined in 28.9.2.2.5 (TRN field definition). The in-phase and quadrature components of the selected taps measured using the $k^{th}$ TRN subfield (if *N* is equal to 0) or $k^{th}$ group of *N* consecutive TRN subfields that have the same AWV feedback ID (if *N* is greater than 0) included in the Channel Measurement *k* subfield of the Channel Measurement field within the Channel Measurement Feedback element. As defined in 9.4.2.135 (Channel Measurement Feedback element), the in-phase and quadrature values in the Channel Measurement field are normalized with respect to the tap with largest magnitude over all measurements made using the TRN field of the EDMG BRP-TX PPDU.

### 28.9.3 EDMG secure ranging PPDU(11az)

#### 28.9.3.1 General(11az)

EDMG secure ranging PPDUs are used for secure RTT measurement. The EDMG secure ranging PPDU is defined for single space-time stream ($i_{STS} = 1$) PPDUs only.

#### 28.9.3.2 EDMG secure ranging PPDU structure(11az)

An EDMG secure ranging PPDU shall be composed of a non-EDMG portion containing an L-STF, an L-CEF, and L-Header, and of an EDMG portion containing an EDMG-Header-A, a Data field, and a TRN field that contains Secure TRN subfields only. An EDMG secure ranging PPDU may include an EDMG-STF and an EDMG-CEF.

If beam refinement has been performed on a 4.32 GHz, 6.48 GHz, or 8.64 GHz channel, the Secure TRN subfields in the TRN field of EDMG secure ranging PPDUs shall be transmitted over the entire signal bandwidth of the channel.

#### 28.9.3.3 EDMG secure ranging PPDU header fields(11az)

An EDMG secure ranging PPDU is indicated by setting the Secure TRN field to 1 in EDMG-Header A.

#### 28.9.3.4 EDMG secure ranging PPDU duration(11az)

The duration of an EDMG secure ranging PPDU follows the same calculation procedure as an EDMG SU PPDU with TRN field appended as described in 28.9.2.2.4 (EDMG BRP PPDU duration). Each Secure TRN subfield is of the same duration as each TRN subfield as described in 28.9.3.6 (Secure TRN subfield definition for EDMG secure ranging PPDU(11az)).

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#### 28.9.3.5 TRN field definition with Secure TRN subfields(11az)

The Secure TRN subfields enable secure ranging measurements by an EDMG STA.

##### 28.9.3.5.1 TRN field structure with Secure TRN subfields(11az)

The TRN field structure containing the Secure TRN subfields in EDMG secure ranging PPDU is shown in Figure 28-45 (TRN field structure of EDMG BRP-TX PPDUs(11ay)). The header fields related to TRN should be set according to the Table 28-75 (EDMG-A header fields setting for secure DMG TRNs(11az)).

**Table 28-75—EDMG-A header fields setting for secure DMG TRNs(11az)**

| Header field | Value |
|---|---|
| PPDU Type | 1 |
| EDMG Beam Tracking Request | 0 |
| EDMG TRN Length | 1 |
| RX TRN-Units per Each TX TRN-Unit | 0 |
| EDMG TRN-Unit P | 0 |
| EDMG TRN-Unit M | 3 |
| EDMG TRN-Unit N | 3 |
| TRN Subfield Sequence Length | 0 |

EDMG secure ranging PPDUs are EDMG BRP-TX PPDUs. In such PPDUs, all TRN subfields of all TRN-Units shall be transmitted using the same AWV as the preamble and data field of the PPDU. The EDMG TRN-Unit M field in the EDMG-A header shall be set to 3 so that each TRN-Unit shall have 4 secure TRN subfields that contain Secure TRN sequences.

#### 28.9.3.6 Secure TRN subfield definition for EDMG secure ranging PPDU(11az)

An EDMG secure ranging PPDU transmission over a 2.16 GHz, 4.32 GHz, 6.48 GHz, and 8.64 GHz channel is defined at the NCB × 1.76 GHz chip rate. The symbol blocking structure for the normal GI is as shown in Figure 28-48 (DMG secure ranging TRN subfield structure over 2.16 GHz, 4.32 GHz, 6.48 GHz, and 8.64 GHz channel(11az)). An EDMG STA that supports secure TRN shall support the TRN field structure with normal GI as shown in Figure 28-48 (DMG secure ranging TRN subfield structure over 2.16 GHz, 4.32 GHz, 6.48 GHz, and 8.64 GHz channel(11az)).

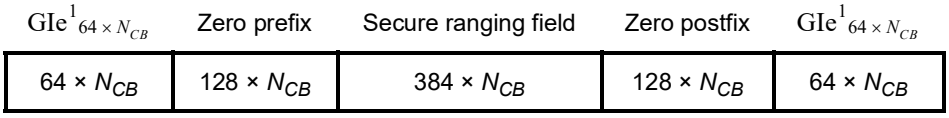


**Figure 28-48—DMG secure ranging TRN subfield structure over 2.16 GHz, 4.32 GHz, 6.48 GHz, and 8.64 GHz channel(11az)**

An EDMG secure ranging PPDU shall have a single spatial stream ($i_{STS}$ = 1) mapped to a single transmit chain ($i_{TX}$ = 1) as defined in 28.5.10.2 (Spatial mapping). The single transmit chain is chosen by the first path beamforming training procedure in 10.41.10.6 (First path beamforming training). All fields of EDMG


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secure ranging PPDU shall be transmitted with the same single transmit chain and AWV chosen by the first path beamforming training procedure.

As shown in Figure 28-48 (DMG secure ranging TRN subfield structure over 2.16 GHz, 4.32 GHz, 6.48 GHz, and 8.64 GHz channel(11az)), each secure TRN subfield shall consist of five consecutive segments:

1) GI: The $GI^{1}_{64 \times N_{CB}}$ as defined in 28.5.9.1 (Guard interval definition).
2) Zero prefix: A prefix of $128 \times N_{CB}$ zero channel symbols.
3) Secure Ranging field: A secure ranging waveform composed of $384 \times N_{CB}$ π/2-BPSK modulated channel symbols. The modulated symbols are based on bit sequences of length $384 \times N_{CB}$ which are taken from the binary pseudorandom sequence SECURE_TRN_SEQUENCE in the TXVECTOR parameters as defined in Table 28-1 (TXVECTOR and RXVECTOR parameters(11ay)). Each group of $384 \times N_{CB}$ bits is taken consecutively without overlap from the sequence. The constellation mapper maps the sequence of bits to constellation points; see 20.5.3.2.4.2 (π/2-BPSK modulation).
4) Zero postfix: A postfix of $128 \times N_{CB}$ zero channel symbols.
5) GI: The $GI^{1}_{64 \times N_{CB}}$ as defined in 28.5.9.1 (Guard interval definition).

The overall length of each Secure TRN subfield is the same as each TRN subfield defined in 28.9.2.2.6 (TRN subfield definition for EDMG SC PPDUs and EDMG control mode PPDUs).

#### 28.9.3.7 Transmission of an EDMG secure ranging PPDU(11az)

Transmission of an EDMG secure ranging PPDU follows the same procedure as EDMG SU PPDU transmission in 28.5.10.4 (EDMG SU PPDU transmission) with the TRN field containing secure TRN sequences.

## 28.10 Golay sequences

### 28.10.1 General

The EDMG PHY uses the pairs of complementary sequences defined in 20.11 (DMG PLME) and defines new sequences. The use of each sequence depends on the transmitted channel bandwidth, number of transmitted space-time streams or transmit chains and the field of the PPDU.

### 28.10.2 Sequences of length 32, 64, 128, 256, 512, and 1024

Golay sequences of length 32, 64, 128, 256, 512, and 1024 are generated using the procedure and notation specified in 20.11 (DMG PLME). The $i^{th}$ index defines the space-time stream or the transmit chain number.

The value of the $D_K$ vector for each of the EDMG sequences are as follows:

— For $Gc^{i}_{32}$ and $Gd^{i}_{32}$: $D_K$ = [2 1 4 8 16]
— For $Ga^{i}_{64}$ and $Gb^{i}_{64}$: $D_K$ = [2 1 4 8 16 32]
— For $Gc^{i}_{64}$ and $Gd^{i}_{64}$: $D_K$ = [1 8 2 4 16 32]
— For $Ga^{i}_{128}$ and $Gb^{i}_{128}$: $D_K$ = [1 8 2 4 16 32 64]
— For $Gc^{i}_{128}$ and $Gd^{i}_{128}$: $D_K$ = [2 1 4 8 16 32 64]
— For $Ga^{i}_{256}$ and $Gb^{i}_{256}$: $D_K$ = [1 8 2 4 16 32 64 128]
— For $Ga^{i}_{512}$ and $Gb^{i}_{512}$: $D_K$ = [1 8 2 4 16 32 64 128 256]
— For $Ga^{i}_{1024}$ and $Gb^{i}_{1024}$: $D_K$ = [1 8 2 4 16 32 64 128 256 512]

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NOTE 1—The sequences $Gc^i_{32}$, $Gd^i_{32}$, $Gc^i_{64}$, $Gd^i_{64}$, $Gc^i_{128}$, $Gd^i_{128}$ are different from the corresponding $Ga^i_{32}$, $Gb^i_{32}$, $Ga^i_{64}$, $Gb^i_{64}$, $Ga^i_{128}$, $Gb^i_{128}$ sequences defined in 20.11 for the DMG PHY.

NOTE 2—For $i$ = 1, the sequences $Ga^i_{64}$ and $Gb^i_{64}$ are equal to the corresponding $Ga_{64}$ and $Gb_{64}$ sequences defined in 20.11 (DMG PLME) for the DMG PHY. Similarly, for $i$ = 1, the sequences $Ga^i_{128}$ and $Gb^i_{128}$ are equal to the corresponding $Ga_{128}$ and $Gb_{128}$ sequences defined in 20.11 (DMG PLME) for the DMG PHY.

As opposed to the $D_K$ vector, the value of the $W_K$ vector depends on the space-time stream number or transmit chain number used to define the Golay pair ($Ga^i_N$, $Gb^i_N$). Table 28-76 (WK vector value to generate Golay sequences of length 32, 64, and 128(11ay)) shows the value of the $W_K$ vector defined for each space-time stream or transmit chain and sequence lengths of 32, 64, and 128. Table 28-77 (WK vector value to generate Golay sequences of length 256, 512, and 1024(11ay)) shows the value of the $W_K$ vector defined for each space-time stream or transmit chain and sequence lengths of 256, 512, and 1024.

**Table 28-76—$W_K$ vector value to generate Golay sequences of length 32, 64, and 128(11ay)**

| Space-time stream/ transmit chain number | $W_K$ for $Gc^i_{32}$ and $Gd^i_{32}$ | $W_K$ for $Ga^i_{64}$ and $Gb^i_{64}$ | $W_K$ for $Gc^i_{64}$ and $Gd^i_{64}$ | $W_K$ for $Ga^i_{128}$ and $Gb^i_{128}$ | $W_K$ for $Gc^i_{128}$ and $Gd^i_{128}$ |
|---|---|---|---|---|---|
| 1 | [+1,+1,–1,–1, +1] | [+1,+1,–1,–1, +1,–1] | [–1,–1,–1,–1, +1,–1] | [–1,–1,–1,–1, +1,–1,–1] | [+1,+1,–1,–1, +1,+1,+1] |
| 2 | [–1,+1,–1,–1, +1] | [–1,+1,–1,–1, +1,–1] | [+1,–1,–1,–1, +1,–1] | [+1,–1,–1,–1, +1,–1,–1] | [–1,+1,–1,–1, +1,+1,+1] |
| 3 | [–1,–1,–1,–1, –1] | [–1,–1,–1,–1, –1,–1] | [–1,–1,–1,+1, –1,–1] | [–1,–1,–1,+1, –1,–1,+1] | [–1,–1,–1,–1, –1,+1,+1] |
| 4 | [+1,–1,–1,–1, –1] | [+1,–1,–1,–1, –1,–1] | [+1,–1,–1,+1, –1,–1] | [+1,–1,–1,+1, –1,–1,+1] | [+1,–1,–1,–1, –1,+1,+1] |
| 5 | [–1,–1,–1,–1, +1] | [–1,–1,–1,–1, +1,–1] | [–1,–1,–1,+1, –1,+1] | [–1,–1,–1,+1, –1,+1,+1] | [–1,–1,–1,–1, +1,+1,+1] |
| 6 | [+1,–1,–1,–1, +1] | [+1,–1,–1,–1, +1,–1] | [+1,–1,–1,+1, –1,+1] | [+1,–1,–1,+1, –1,+1,+1] | [+1,–1,–1,–1, +1,+1,+1] |
| 7 | [–1,–1,–1,+1, –1] | [–1,–1,–1,+1, –1,–1] | [–1,–1,–1,+1, +1,+1] | [–1,–1,–1,+1, +1,+1,–1] | [–1,–1,–1,+1, –1,+1,+1] |
| 8 | [+1,–1,–1,+1, –1] | [+1,–1,–1,+1, –1,–1] | [+1,–1,–1,+1, +1,+1] | [+1,–1,–1,+1, +1,+1,–1] | [+1,–1,–1,+1, –1,+1,+1] |

**Table 28-77—$W_K$ vector value to generate Golay sequences of length 256, 512, and 1024(11ay)**

| Space-time stream/ transmit chain number | $W_K$ for $Ga^i_{256}$ and $Gb^i_{256}$ | $W_K$ for $Ga^i_{512}$ and $Gb^i_{512}$ | $W_K$ for $Ga^i_{1024}$ and $Gb^i_{1024}$ |
|---|---|---|---|
| 1 | [–1,–1,–1,–1,+1,–1,–1,+1] | [–1,–1,–1,–1,+1,–1,–1,+1, +1] | [–1,–1,–1,–1,+1,–1,–1,+1, +1,+1] |
| 2 | [+1,–1,–1,–1,+1,–1,–1,+1] | [+1,–1,–1,–1,+1,–1,–1,+1, +1] | [+1,–1,–1,–1,+1,–1,–1,+1, +1,+1] |



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**Table 28-77—$W_K$ vector value to generate Golay sequences of length 256, 512, and 1024(11ay)**

| Space-time stream/ transmit chain number | $W_K$ for $Ga^i_{256}$ and $Gb^i_{256}$ | $W_K$ for $Ga^i_{512}$ and $Gb^i_{512}$ | $W_K$ for $Ga^i_{1024}$ and $Gb^i_{1024}$ |
|---|---|---|---|
| 3 | [–1,–1,–1,+1,–1,–1,+1,–1] | [–1,–1,–1,+1,–1,–1,+1,–1, +1] | [–1,–1,–1,+1,–1,–1,+1,–1, +1,+1] |
| 4 | [+1,–1,–1,+1,–1,–1,+1,–1] | [+1,–1,–1,+1,–1,–1,+1,–1, +1] | [+1,–1,–1,+1,–1,–1,+1,–1, +1,+1] |
| 5 | [–1,–1,–1,+1,–1,+1,+1,–1] | [–1,–1,–1,+1,–1,+1,+1,–1, +1] | [–1,–1,–1,+1,–1,+1,+1,–1, +1,+1] |
| 6 | [+1,–1,–1,+1,–1,+1,+1,–1] | [+1,–1,–1,+1,–1,+1,+1,–1, +1] | [+1,–1,–1,+1,–1,+1,+1,–1, +1,+1] |
| 7 | [–1,–1,–1,+1,+1,+1,–1,–1] | [–1,–1,–1,+1,+1,+1,–1,–1, +1] | [–1,–1,–1,+1,+1,+1,–1,–1, +1,+1] |
| 8 | [+1,–1,–1,+1,+1,+1,–1,–1] | [+1,–1,–1,+1,+1,+1,–1,–1, +1] | [+1,–1,–1,+1,+1,+1,–1,–1, +1,+1] |

The sequences are defined from Table 28-78 (The sequence Gci32(n)(11ay)) through Table 28-93 (The sequence Gbi1024(n)(11ay)). The sequences in the tables are normative; the description above is informative.

**Table 28-78—The sequence $Gc^i_{32}(n)$(11ay)**

| |
|---|
| The sequence $Gc^1_{32}(n)$, to be transmitted from left to right, up to down |
| +1 +1 –1 +1 –1 +1 +1 +1 –1 –1 +1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 –1 –1 –1 –1 +1 –1 –1 +1 +1 +1 |
| The sequence $Gc^2_{32}(n)$, to be transmitted from left to right, up to down |
| +1 +1 +1 –1 –1 +1 –1 –1 –1 –1 –1 +1 –1 +1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 –1 –1 +1 –1 +1 –1 –1 |
| The sequence $Gc^3_{32}(n)$, to be transmitted from left to right, up to down |
| +1 –1 +1 +1 –1 –1 –1 +1 –1 +1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 –1 –1 +1 +1 –1 +1 +1 +1 +1 +1 –1 |
| The sequence $Gc^4_{32}(n)$, to be transmitted from left to right, up to down |
| +1 –1 –1 –1 –1 –1 +1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 –1 –1 –1 –1 +1 –1 +1 –1 –1 –1 +1 +1 –1 +1 |
| The sequence $Gc^5_{32}(n)$, to be transmitted from left to right, up to down |
| +1 –1 +1 +1 –1 –1 –1 +1 –1 +1 –1 –1 –1 –1 –1 +1 –1 +1 –1 –1 +1 +1 +1 –1 –1 +1 –1 –1 –1 –1 –1 +1 |
| The sequence $Gc^6_{32}(n)$, to be transmitted from left to right, up to down |
| +1 –1 –1 –1 –1 –1 +1 –1 –1 +1 +1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 –1 +1 –1 +1 +1 +1 –1 –1 +1 –1 |
| The sequence $Gc^7_{32}(n)$, to be transmitted from left to right, up to down |
| +1 –1 +1 +1 –1 –1 –1 +1 +1 –1 +1 +1 +1 +1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 –1 +1 –1 –1 –1 –1 –1 +1 |
| The sequence $Gc^8_{32}(n)$, to be transmitted from left to right, up to down |
| +1 –1 –1 –1 –1 –1 +1 –1 +1 –1 –1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 +1 –1 –1 +1 +1 +1 –1 –1 +1 –1 |

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**Table 28-79—The sequence $Gd^{i}_{32}(n)$(11ay)**

| |
|---|
| The sequence $Gd^{1}_{32}(n)$, to be transmitted from left to right, up to down |
| –1 –1 +1 –1 +1 –1 –1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 +1 –1 +1 –1 –1 –1 –1 –1 +1 –1 –1 +1 +1 +1 |
| The sequence $Gd^{2}_{32}(n)$, to be transmitted from left to right, up to down |
| –1 –1 –1 +1 +1 –1 +1 +1 +1 +1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 –1 +1 +1 –1 –1 –1 +1 –1 +1 –1 –1 |
| The sequence $Gd^{3}_{32}(n)$, to be transmitted from left to right, up to down |
| –1 +1 –1 –1 +1 +1 +1 –1 +1 –1 +1 +1 +1 +1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 –1 +1 +1 +1 +1 +1 –1 |
| The sequence $Gd^{4}_{32}(n)$, to be transmitted from left to right, up to down |
| –1 +1 +1 +1 +1 +1 –1 +1 +1 –1 –1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 +1 –1 +1 –1 –1 –1 +1 +1 –1 +1 |
| The sequence $Gd^{5}_{32}(n)$, to be transmitted from left to right, up to down |
| –1 +1 –1 –1 +1 +1 +1 –1 +1 –1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 +1 +1 –1 –1 +1 –1 –1 –1 –1 –1 +1 |
| The sequence $Gd^{6}_{32}(n)$, to be transmitted from left to right, up to down |
| –1 +1 +1 +1 +1 +1 –1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 +1 +1 +1 +1 –1 +1 –1 +1 +1 +1 –1 –1 +1 –1 |
| The sequence $Gd^{7}_{32}(n)$, to be transmitted from left to right, up to down |
| –1 +1 –1 –1 +1 +1 +1 –1 –1 +1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 –1 +1 –1 –1 –1 –1 –1 +1 |
| The sequence $Gd^{8}_{32}(n)$, to be transmitted from left to right, up to down |
| –1 +1 +1 +1 +1 +1 –1 +1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 –1 –1 –1 –1 +1 –1 –1 +1 +1 +1 –1 –1 +1 –1 |


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**Table 28-80—The sequence $Ga^{i}_{64}(n)$(11ay)**

| |
|---|
| The sequence $Ga^{1}_{64}(n)$, to be transmitted from left to right, up to down |
| –1 –1 +1 –1 +1 –1 –1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 +1 –1 +1 –1 –1 –1 –1 –1 +1 –1 –1 +1 +1 +1 +1 –1 –1 +1 –1 +1 –1 –1 –1 +1 +1 –1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 +1 +1 +1 +1 –1 +1 +1 –1 –1 –1 |
| The sequence $Ga^{2}_{64}(n)$, to be transmitted from left to right, up to down |
| –1 –1 –1 +1 +1 –1 +1 +1 +1 +1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 –1 +1 +1 –1 –1 –1 +1 –1 +1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 +1 +1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 +1 +1 –1 +1 –1 +1 +1 |
| The sequence $Ga^{3}_{64}(n)$, to be transmitted from left to right, up to down |
| –1 +1 –1 –1 +1 +1 +1 –1 +1 –1 +1 +1 +1 +1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 –1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 +1 +1 –1 +1 –1 –1 +1 +1 +1 +1 –1 –1 +1 –1 –1 –1 –1 –1 +1 |
| The sequence $Ga^{4}_{64}(n)$, to be transmitted from left to right, up to down |
| –1 +1 +1 +1 +1 +1 –1 +1 +1 –1 –1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 +1 –1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 +1 +1 +1 +1 +1 –1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 +1 +1 +1 –1 +1 –1 +1 +1 +1 –1 –1 +1 –1 |
| The sequence $Ga^{5}_{64}(n)$, to be transmitted from left to right, up to down |
| –1 +1 –1 –1 +1 +1 +1 –1 +1 –1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 +1 +1 –1 –1 +1 –1 –1 –1 –1 –1 +1 –1 +1 –1 –1 +1 +1 +1 –1 +1 –1 +1 +1 +1 +1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 –1 +1 +1 +1 +1 +1 –1 |
| The sequence $Ga^{6}_{64}(n)$, to be transmitted from left to right, up to down |
| –1 +1 +1 +1 +1 +1 –1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 +1 +1 +1 +1 –1 +1 –1 +1 +1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 –1 +1 +1 –1 –1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 +1 –1 +1 –1 –1 –1 +1 +1 –1 +1 |
| The sequence $Ga^{7}_{64}(n)$, to be transmitted from left to right, up to down |
| –1 +1 –1 –1 +1 +1 +1 –1 –1 +1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 –1 –1 +1 –1 +1 –1 –1 –1 –1 +1 –1 +1 –1 –1 +1 +1 +1 –1 –1 +1 –1 –1 –1 –1 –1 +1 –1 +1 –1 –1 +1 +1 +1 –1 +1 –1 +1 +1 +1 +1 +1 –1 |
| The sequence $Ga^{8}_{64}(n)$, to be transmitted from left to right, up to down |
| –1 +1 +1 +1 +1 +1 –1 +1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 –1 –1 –1 –1 +1 –1 –1 +1 +1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 –1 +1 –1 +1 +1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 –1 +1 +1 –1 –1 –1 +1 +1 –1 +1 |

**Table 28-81—The sequence $Gb^{i}_{64}(n)$(11ay)**

| |
|---|
| The sequence $Gb^{1}_{64}(n)$, to be transmitted from left to right, up to down |
| +1 +1 –1 +1 –1 +1 +1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 –1 +1 –1 +1 +1 +1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 –1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 +1 +1 +1 +1 –1 +1 +1 –1 –1 –1 |
| The sequence $Gb^{2}_{64}(n)$, to be transmitted from left to right, up to down |
| +1 +1 +1 –1 –1 +1 –1 –1 –1 –1 –1 +1 –1 +1 –1 –1 +1 +1 +1 –1 –1 +1 –1 –1 +1 +1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 –1 +1 +1 +1 +1 +1 –1 +1 –1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 +1 +1 –1 +1 –1 +1 +1 |
| The sequence $Gb^{3}_{64}(n)$, to be transmitted from left to right, up to down |
| +1 –1 +1 +1 –1 –1 –1 +1 –1 +1 –1 –1 –1 –1 –1 +1 –1 +1 –1 –1 +1 +1 +1 –1 –1 +1 –1 –1 –1 –1 –1 +1 –1 +1 –1 –1 +1 +1 +1 –1 +1 –1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 +1 +1 –1 –1 +1 –1 –1 –1 –1 –1 +1 |
| The sequence $Gb^{4}_{64}(n)$, to be transmitted from left to right, up to down |
| +1 –1 –1 –1 –1 –1 +1 –1 –1 +1 +1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 –1 +1 –1 +1 +1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 –1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 +1 +1 +1 +1 –1 +1 –1 +1 +1 +1 –1 –1 +1 –1 |

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**Table 28-81—The sequence $Gb^{i}_{64}(n)$(11ay) *(continued)***

| |
|---|
| The sequence $Gb^{5}_{64}(n)$, to be transmitted from left to right, up to down |
| +1 –1 +1 +1 –1 –1 –1 +1 –1 +1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 –1 –1 +1 +1 –1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 +1 +1 –1 +1 –1 +1 +1 +1 +1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 –1 +1 +1 +1 +1 +1 –1 |
| The sequence $Gb^{6}_{64}(n)$, to be transmitted from left to right, up to down |
| +1 –1 –1 –1 –1 –1 +1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 –1 –1 –1 –1 +1 –1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 +1 +1 +1 +1 –1 +1 +1 –1 –1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 +1 –1 +1 –1 –1 –1 +1 +1 –1 +1 |
| The sequence $Gb^{7}_{64}(n)$, to be transmitted from left to right, up to down |
| +1 –1 +1 +1 –1 –1 –1 +1 +1 –1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 +1 +1 –1 +1 –1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 +1 +1 –1 –1 +1 –1 –1 –1 –1 –1 +1 –1 +1 –1 –1 +1 +1 +1 –1 +1 –1 +1 +1 +1 +1 +1 –1 |
| The sequence $Gb^{8}_{64}(n)$, to be transmitted from left to right, up to down |
| +1 –1 –1 –1 –1 –1 +1 –1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 +1 +1 +1 +1 –1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 +1 +1 +1 +1 –1 +1 –1 +1 +1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 –1 +1 +1 –1 –1 –1 +1 +1 –1 +1 |

**Table 28-82—The sequence $Gc^{i}_{128}(n)$(11ay)**

| |
|---|
| The sequence $Gc^{1}_{128}(n)$, to be transmitted from left to right, up to down |
| +1 +1 –1 +1 –1 +1 +1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 –1 +1 –1 +1 +1 +1 +1 +1 –1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 +1 +1 –1 –1 +1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 –1 –1 –1 –1 +1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 +1 –1 +1 –1 –1 –1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 –1 +1 –1 +1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 –1 +1 –1 –1 +1 +1 +1 |
| The sequence $Gc^{2}_{128}(n)$, to be transmitted from left to right, up to down |
| +1 +1 +1 –1 –1 +1 –1 –1 –1 –1 –1 +1 –1 +1 –1 –1 +1 +1 +1 –1 –1 +1 –1 –1 +1 +1 +1 –1 +1 –1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 –1 –1 –1 +1 –1 +1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 –1 –1 +1 –1 +1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 –1 +1 –1 –1 –1 –1 –1 +1 –1 +1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 +1 –1 –1 +1 –1 –1 |
| The sequence $Gc^{3}_{128}(n)$, to be transmitted from left to right, up to down |
| +1 –1 +1 +1 –1 –1 –1 +1 –1 +1 –1 –1 –1 –1 –1 +1 –1 +1 –1 –1 +1 +1 +1 –1 –1 +1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 –1 –1 +1 –1 +1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 –1 –1 +1 +1 –1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 +1 –1 +1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 –1 –1 +1 +1 –1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 –1 –1 –1 +1 –1 –1 +1 +1 +1 –1 –1 –1 +1 –1 +1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 +1 –1 +1 –1 –1 –1 +1 +1 –1 +1 +1 +1 +1 +1 –1 |
| The sequence $Gc^{4}_{128}(n)$, to be transmitted from left to right, up to down |
| +1 –1 –1 –1 –1 –1 +1 –1 –1 +1 +1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 –1 +1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 –1 –1 –1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 –1 +1 –1 +1 –1 –1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 +1 –1 +1 –1 +1 +1 +1 +1 +1 –1 +1 +1 –1 –1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 +1 –1 +1 –1 –1 –1 –1 –1 +1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 –1 –1 –1 –1 +1 –1 +1 –1 –1 –1 –1 –1 +1 –1 +1 –1 –1 +1 +1 –1 +1 |
| The sequence $Gc^{5}_{128}(n)$, to be transmitted from left to right, up to down |
| +1 –1 +1 +1 –1 –1 –1 +1 –1 +1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 –1 –1 +1 +1 –1 +1 +1 +1 +1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 –1 +1 –1 –1 –1 –1 –1 +1 –1 +1 –1 –1 –1 –1 –1 +1 –1 +1 –1 –1 +1 +1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 +1 +1 –1 –1 +1 –1 –1 –1 –1 –1 +1 –1 +1 –1 –1 +1 +1 +1 –1 +1 –1 –1 –1 –1 –1 +1 –1 +1 –1 –1 –1 –1 –1 +1 –1 –1 +1 –1 +1 –1 –1 –1 –1 –1 +1 –1 +1 –1 –1 –1 –1 –1 +1 –1 +1 –1 –1 –1 –1 –1 +1 |



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**Table 28-82—The sequence $Gc^{i}_{128}(n)$(11ay) *(continued)***

| The sequence $Gc^{6}_{128}(n)$, to be transmitted from left to right, up to down |
|---|
| +1 –1 –1 –1 –1 –1 +1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 –1 –1 –1 –1 +1 –1 +1 –1 –1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 +1 –1 –1 +1 +1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 –1 +1 –1 +1 +1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 –1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 +1 +1 +1 +1 –1 +1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 –1 –1 –1 –1 +1 –1 –1 +1 +1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 –1 +1 –1 +1 +1 +1 –1 –1 +1 –1 |
| The sequence $Gc^{7}_{128}(n)$, to be transmitted from left to right, up to down |
| +1 –1 +1 +1 –1 –1 –1 +1 +1 –1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 +1 +1 –1 +1 –1 +1 +1 +1 +1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 –1 +1 +1 +1 +1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 –1 +1 –1 –1 –1 –1 –1 +1 –1 +1 –1 –1 +1 +1 +1 –1 –1 +1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 +1 +1 +1 +1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 –1 +1 –1 –1 –1 –1 –1 +1 |
| The sequence $Gc^{8}_{128}(n)$, to be transmitted from left to right, up to down |
| +1 –1 –1 –1 –1 –1 +1 –1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 +1 +1 +1 +1 –1 +1 +1 –1 –1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 +1 –1 –1 +1 –1 +1 –1 –1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 +1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 –1 –1 –1 –1 +1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 –1 –1 –1 –1 +1 –1 +1 –1 –1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 +1 –1 –1 +1 +1 +1 –1 –1 +1 –1 |

**Table 28-83—The sequence $Gd^{i}_{128}(n)$(11ay)**

| The sequence $Gd^{1}_{128}(n)$, to be transmitted from left to right, up to down |
|---|
| –1 –1 +1 –1 +1 –1 –1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 +1 –1 +1 –1 –1 –1 –1 –1 +1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 –1 –1 +1 +1 –1 +1 +1 –1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 +1 –1 +1 –1 +1 +1 +1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 +1 –1 +1 –1 –1 –1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 –1 +1 –1 +1 +1 +1 –1 –1 +1 –1 –1 +1 +1 +1 –1 –1 –1 –1 –1 +1 –1 +1 –1 –1 –1 –1 –1 +1 –1 –1 +1 +1 +1 |
| The sequence $Gd^{2}_{128}(n)$, to be transmitted from left to right, up to down |
| –1 –1 –1 +1 +1 –1 +1 +1 +1 +1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 –1 +1 +1 –1 –1 –1 +1 –1 +1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 +1 +1 +1 –1 +1 –1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 +1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 –1 +1 +1 +1 +1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 +1 –1 –1 –1 –1 –1 –1 +1 –1 +1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 –1 –1 +1 –1 +1 –1 –1 |
| The sequence $Gd^{3}_{128}(n)$, to be transmitted from left to right, up to down |
| –1 +1 –1 –1 +1 +1 +1 –1 +1 –1 +1 +1 +1 +1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 –1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 +1 +1 –1 +1 –1 +1 +1 +1 +1 +1 –1 +1 –1 +1 +1 –1 –1 –1 –1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 +1 +1 +1 +1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 –1 +1 +1 +1 +1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 –1 +1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 –1 –1 +1 +1 –1 +1 +1 +1 +1 +1 –1 |
| The sequence $Gd^{4}_{128}(n)$, to be transmitted from left to right, up to down |
| –1 +1 +1 +1 +1 +1 –1 +1 +1 –1 –1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 +1 –1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 +1 +1 +1 +1 –1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 +1 +1 +1 +1 –1 +1 –1 +1 +1 +1 –1 –1 +1 –1 –1 +1 +1 +1 –1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1 –1 –1 –1 –1 +1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 –1 –1 +1 +1 –1 +1 +1 +1 +1 +1 –1 |
| The sequence $Gd^{5}_{128}(n)$, to be transmitted from left to right, up to down |
| –1 +1 –1 –1 +1 +1 +1 –1 +1 –1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 +1 +1 –1 –1 +1 –1 –1 –1 –1 –1 +1 –1 +1 –1 –1 +1 +1 –1 +1 –1 +1 +1 +1 +1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 –1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 +1 +1 –1 –1 +1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 –1 –1 +1 –1 +1 –1 –1 –1 –1 –1 +1 –1 –1 +1 –1 +1 –1 –1 –1 –1 –1 +1 –1 –1 +1 –1 –1 –1 –1 –1 +1 |

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**Table 28-83—The sequence $Gd^{i}_{128}(n)$(11ay) *(continued)***

| The sequence $Gd^{6}_{128}(n)$, to be transmitted from left to right, up to down |
|---|
| –1 +1 +1 +1 +1 +1 –1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 +1 +1 +1 +1 –1 +1 –1 +1 +1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 –1 +1 +1 –1 –1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 +1 –1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 +1 +1 +1 +1 –1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 +1 +1 +1 +1 –1 +1 –1 +1 +1 –1 –1 –1 –1 –1 +1 –1 –1 +1 +1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 +1 –1 –1 +1 –1 |
| The sequence $Gd^{7}_{128}(n)$, to be transmitted from left to right, up to down |
| –1 +1 –1 –1 +1 +1 +1 –1 –1 +1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 –1 –1 +1 –1 +1 –1 –1 –1 –1 –1 +1 –1 +1 –1 –1 +1 +1 +1 –1 –1 +1 –1 –1 –1 –1 –1 +1 –1 +1 –1 –1 +1 +1 +1 –1 +1 –1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 +1 +1 –1 –1 +1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 –1 –1 +1 –1 +1 –1 –1 –1 –1 –1 +1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 –1 +1 –1 –1 –1 –1 –1 +1 |
| The sequence $Gd^{8}_{128}(n)$, to be transmitted from left to right, up to down |
| –1 +1 +1 +1 +1 +1 –1 +1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 –1 –1 –1 –1 +1 –1 –1 +1 +1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 –1 +1 –1 +1 +1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 –1 +1 +1 –1 –1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 +1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 –1 –1 –1 –1 +1 –1 +1 –1 –1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 +1 –1 –1 +1 +1 +1 –1 –1 +1 –1 |

**Table 28-84—The sequence $Gc^{i}_{64}(n)$(11ay)**

| The sequence $Gc^{1}_{64}(n)$, to be transmitted from left to right, up to down |
|---|
| –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 |
| The sequence $Gc^{2}_{64}(n)$, to be transmitted from left to right, up to down |
| –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 |
| The sequence $Gc^{3}_{64}(n)$, to be transmitted from left to right, up to down |
| –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 +1 +1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 |
| The sequence $Gc^{4}_{64}(n)$, to be transmitted from left to right, up to down |
| –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 –1 +1 +1 +1 +1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 |
| The sequence $Gc^{5}_{64}(n)$, to be transmitted from left to right, up to down |
| –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 +1 +1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 |
| The sequence $Gc^{6}_{64}(n)$, to be transmitted from left to right, up to down |
| –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 |
| The sequence $Gc^{7}_{64}(n)$, to be transmitted from left to right, up to down |
| –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 |
| The sequence $Gc^{8}_{64}(n)$, to be transmitted from left to right, up to down |
| –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 |



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**Table 28-85—The sequence $Gd^{i}_{64}(n)$(11ay)**

| |
|---|
| The sequence $Gd^{1}_{64}(n)$, to be transmitted from left to right, up to down |
| +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 |
| The sequence $Gd^{2}_{64}(n)$, to be transmitted from left to right, up to down |
| +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 –1 +1 +1 |
| The sequence $Gd^{3}64(n)$, to be transmitted from left to right, up to down |
| +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 |
| The sequence $Gd^{4}_{64}(n)$, to be transmitted from left to right, up to down |
| +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 |
| The sequence $Gd^{5}_{64}(n)$, to be transmitted from left to right, up to down |
| +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 |
| The sequence $Gd^{6}_{64}(n)$, to be transmitted from left to right, up to down |
| +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 |
| The sequence $Gd^{7}_{64}(n)$, to be transmitted from left to right, up to down |
| +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 |
| The sequence $Gd^{8}_{64}(n)$, to be transmitted from left to right, up to down |
| +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 |

**Table 28-86—The sequence $Ga^{i}_{128}(n)$(11ay)**

| |
|---|
| The sequence $Ga^{1}_{128}(n)$, to be transmitted from left to right, up to down |
| +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 |
| The sequence $Ga^{2}_{128}(n)$, to be transmitted from left to right, up to down |
| +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 |
| The sequence $Ga^{3}_{128}(n)$, to be transmitted from left to right, up to down |
| +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –

**Table 28-86—The sequence $Ga^{i}_{128}(n)$(11ay) *(continued)***

| The sequence $Ga^{4}_{128}(n)$, to be transmitted from left to right, up to down |
|---|
| +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 |
| The sequence $Ga^{5}_{128}(n)$, to be transmitted from left to right, up to down |
| +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 –1 +1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 |
| The sequence $Ga^{6}_{128}(n)$, to be transmitted from left to right, up to down |
| +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 –1 –1 –1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 |
| The sequence $Ga^{7}_{128}(n)$, to be transmitted from left to right, up to down |
| +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 |
| The sequence $Ga^{8}_{128}(n)$, to be transmitted from left to right, up to down |
| +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 |

**Table 28-87—The sequence $Gb^{i}_{128}(n)$(11ay)**

| The sequence $Gb^{1}_{128}(n)$, to be transmitted from left to right, up to down |
|---|
| –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 +1 +1 –1 –1 –1 –1 –1 –1 +1 –1 +1 –1 –1 +1 –1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 –1 –1 –1 –1 +1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 |
| The sequence $Gb^{2}_{128}(n)$, to be transmitted from left to right, up to down |
| –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 |
| The sequence $Gb^{3}_{128}(n)$, to be transmitted from left to right, up to down |
| –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 –1 –1 –1 –1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 |



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**Table 28-87—The sequence $Gb^{i}_{128}(n)$(11ay) *(continued)***

| The sequence $Gb^{4}_{128}(n)$, to be transmitted from left to right, up to down |
|---|
| –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 |
| The sequence $Gb^{5}_{128}(n)$, to be transmitted from left to right, up to down |
| –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 –1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 –1 –1 +1 –1 +1 –1 –1 +1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 –1 +1 –1 +1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 |
| The sequence $Gb^{6}_{128}(n)$, to be transmitted from left to right, up to down |
| –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 |
| The sequence $Gb^{7}_{128}(n)$, to be transmitted from left to right, up to down |
| –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 –1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 –1 –1 +1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 |
| The sequence $Gb^{8}_{128}(n)$, to be transmitted from left to right, up to down |
| –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 |

**Table 28-88—The sequence $Ga^{i}_{256}(n)$(11ay)**

| The sequence $Ga^{1}_{256}(n)$, to be transmitted from left to right, up to down |
|---|
| –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 –1 –1 +1 –1 +1 –1 –1 +1 +1 +1 –1 –1 –1 –1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 –1 –1 |
| The sequence $Ga^{2}_{256}(n)$, to be transmitted from left to right, up to down |
| –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 |

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**Table 28-88—The sequence $Ga^{i}_{256}(n)$(11ay) *(continued)***

| The sequence $Ga^{3}_{256}(n)$, to be transmitted from left to right, up to down |
|---|
| –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 +1 +1 –1 –1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 +1 +1 –1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 |
| The sequence $Ga^{4}_{256}(n)$, to be transmitted from left to right, up to down |
| –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 |
| The sequence $Ga^{5}_{256}(n)$, to be transmitted from left to right, up to down |
| –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 +1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 |
| The sequence $Ga^{6}_{256}(n)$, to be transmitted from left to right, up to down |
| –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 +1 –1 +1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 |
| The sequence $Ga^{7}_{256}(n)$, to be transmitted from left to right, up to down |
| –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 +1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –

**Table 28-89—The sequence $Gb^{i}_{256}(n)$(11ay)**

| |
|---|
| The sequence $Gb^{1}_{256}(n)$, to be transmitted from left to right, up to down |
| +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 –1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 |
| The sequence $Gb^{2}_{256}(n)$, to be transmitted from left to right, up to down |
| +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 –1 |
| The sequence $Gb^{3}_{256}(n)$, to be transmitted from left to right, up to down |
| +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 +1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 –1 |
| The sequence $Gb^{4}_{256}(n)$, to be transmitted from left to right, up to down |
| +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 |
| The sequence $Gb^{5}_{256}(n)$, to be transmitted from left to right, up to down |
| +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 –1 +1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 +1 –1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 +1 –1 –1 +1 +1 –1 |

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**Table 28-89—The sequence $Gb^{i}_{256}(n)$(11ay) *(continued)***

| The sequence $Gb^{6}_{256}(n)$, to be transmitted from left to right, up to down |
|---|
| +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 +1 +1 –1 –1 +1 +1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 +1 +1 +1 +1 +1 –1 –1 +1 +1 |
| The sequence $Gb^{7}_{256}(n)$, to be transmitted from left to right, up to down |
| +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 –1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 +1 +1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 +1 –1 –1 +1 –1 |
| The sequence $Gb^{8}_{256}(n)$, to be transmitted from left to right, up to down |
| +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 –1 +1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 +1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 –1 +1 –1 +1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 – 1 +1 +1 |

**Table 28-90—The sequence $Ga^{i}_{512}(n)$(11ay)**

| The sequence $Ga^{1}_{512}(n)$, to be transmitted from left to right, up to down |
|---|
| +1 +1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 +1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 +1 +1 –1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 –1 –1 +1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 +1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 –1 +1 –1 +1 –1 –1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 –1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 –1 –1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 –1 +1 –

**Table 28-90—The sequence $Ga^{i}_{512}(n)$(11ay) *(continued)***

| The sequence $Ga^{2}_{512}(n)$, to be transmitted from left to right, up to down |
|---|
| +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1<br>–1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 +1 –1 +1<br>+1 +1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1<br>–1 +1 +1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1<br>–1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1<br>–1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 +1 –1 +1 –1 –1<br>–1 –1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 +1<br>–1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 +1 –1<br>–1 +1 –1 +1 –1 +1 –1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 –1 +1<br>–1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1<br>–1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1<br>–1 –1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 +1 –1<br>–1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 +1<br>–1 –1 –1 –1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 –1<br>+1 +1 –1 –1 |
| The sequence $Ga^{3}_{512}(n)$, to be transmitted from left to right, up to down |
| +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 –1 –1 +1 +1<br>–1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 +1 +1<br>–1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 +1 –1 +1<br>–1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 +1<br>+1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 +1 –1 +1 –1 –1 –1<br>–1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 +1 –1 –1 –1 +1 +1 +1 +1 +1 +1<br>–1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1<br>–1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 +1 +1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1<br>–1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1<br>–1 –1 +1 –1 +1 –1 +1 –1 –1 +1 +1 +1 –1 –1 –1 +1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1<br>–1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 +1 –1 +1 –1 –1 +1<br>+1 +1 –1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 +1 –1 –1<br>–1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 +1 +1 +1 +1<br>+1 –1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1<br>+1 –1 –1 +1 |
| The sequence $Ga^{4}_{512}(n)$, to be transmitted from left to right, up to down |
| +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 –1 +1 +1 –1<br>–1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 –1 +1 –1<br>–1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1<br>–1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1<br>+1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 –1 +1<br>–1 +1 –1 –1 +1 –1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 +1 +1<br>+1 –1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 +1 +1 +1 +1<br>–1 –1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1<br>–1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1<br>–1 +1 +1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1<br>+1 +1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1<br>–1 –1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 +1 –1<br>–1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 +1<br>–1 +1 +1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1<br>–1 +1 +1 –1 –1 |

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**Table 28-90—The sequence $Ga^{i}_{512}(n)$(11ay) *(continued)***

| |
|---|
| The sequence $Ga^{5}_{512}(n)$, to be transmitted from left to right, up to down |
| +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1<br>+1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 +1 +1<br>–1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1<br>+1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1<br>+1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1<br>+1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 +1 +1 +1 +1 +1<br>–1 +1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1<br>+1 –1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1<br>+1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 –1<br>–1 +1 –1 +1 –1 +1 –1 –1 +1 +1 +1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1<br>–1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 +1<br>+1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1<br>+1 +1 +1 –1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1<br>+1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1<br>+1 –1 |
| The sequence $Ga^{6}_{512}(n)$, to be transmitted from left to right, up to down |
| +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1<br>+1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 +1 –1<br>–1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1<br>+1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1<br>+1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 –1 +1 +1 –1<br>+1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 +1 –1<br>+1 +1 +1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1<br>–1 –1 +1 +1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1<br>–1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 –1 +1 +1 –1<br>–1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 +1 –1<br>–1 –1 –1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1<br>+1 –1 –1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 –1 +1<br>+1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1<br>+1 –1 +1 +1 +1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1<br>+1 +1 –1 –1 +1 +1 |
| The sequence $Ga^{7}_{512}(n)$, to be transmitted from left to right, up to down |
| +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1<br>+1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 –1 –1<br>+1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1<br>–1 +1 +1 –1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1<br>–1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 +1 +1 –1 –1<br>–1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 +1 +1<br>–1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1<br>+1 +1 –1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 –1<br>–1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1<br>+1 +1 –1 +1 –1 +1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1<br>–1 +1 –1 –1 +1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1<br>–1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 +1 +1 –1 –1<br>–1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 +1 +1<br>–1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1<br>+1 +1 –1 |


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This is an unapproved IEEE Standards Draft, subject to change.

**Table 28-90—The sequence $Ga^{i}_{512}(n)$(11ay) *(continued)***

| The sequence $Ga^{8}_{512}(n)$, to be transmitted from left to right, up to down |
|---|
| +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 –1 +1 –1 –1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 –1 +1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 –1 +1 +1 |

**Table 28-91—The sequence $Gb^{i}_{512}(n)$(11ay)**

| The sequence $Gb^{1}_{512}(n)$, to be transmitted from left to right, up to down |
|---|
| –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 +1 +1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 +1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 –1 |
| The sequence $Gb^{2}_{512}(n)$, to be transmitted from left to right, up to down |
| –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 –1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 –1 –1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +

### Table 28-91—The sequence $Gb^i_{512}(n)$(11ay) *(continued)*

| The sequence $Gb^3_{512}(n)$, to be transmitted from left to right, up to down |
|---|
| –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1<br>+1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 +1<br>–1 +1 –1 +1 –1 –1 +1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1<br>–1 –1 +1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1<br>–1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1<br>+1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1<br>–1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1<br>+1 –1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1<br>–1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1<br>–1 –1 +1 –1 +1 –1 +1 –1 –1 +1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1<br>–1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1<br>+1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 +1 +1 –1 –1<br>–1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 +1 +1 +1 +1<br>+1 –1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1<br>+1 –1 –1 +1 |
| The sequence $Gb^4_{512}(n)$, to be transmitted from left to right, up to down |
| –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1<br>+1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 +1<br>+1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1<br>+1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1<br>+1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1<br>+1 –1 +1 +1 +1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1<br>–1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1<br>+1 +1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1<br>–1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1<br>–1 +1 +1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1<br>+1 +1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1<br>–1 –1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 +1 –1<br>–1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 +1<br>–1 +1 +1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1<br>–1 +1 +1 –1 –1 |
| The sequence $Gb^5_{512}(n)$, to be transmitted from left to right, up to down |
| –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1<br>–1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 –1 –1 +1<br>–1 +1 –1 +1 –1 –1 +1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1<br>+1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1<br>+1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1<br>–1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1<br>+1 –1 –1 +1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1<br>–1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1<br>–1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 –1 –1 +1<br>–1 +1 –1 +1 –1 –1 +1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1<br>+1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 +1 +1<br>–1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1<br>+1 +1 –1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1<br>–1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 |



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**Table 28-91—The sequence $Gb^{i}_{512}(n)$(11ay) *(continued)***

| The sequence $Gb^{6}_{512}(n)$, to be transmitted from left to right, up to down |
|---|
| –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1<br>–1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 –1 +1<br>+1 +1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1<br>–1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1<br>–1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 +1 –1 –1 +1<br>–1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 –1 –1 +1 –1 +1 +1<br>–1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1<br>+1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1<br>+1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1<br>–1 +1 +1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1<br>–1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1<br>–1 –1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 –1 +1 +1<br>–1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 +1<br>–1 +1 +1 +1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1 –1 +1 +1 +1<br>+1 –1 –1 +1 +1 |
| The sequence $Gb^{7}_{512}(n)$, to be transmitted from left to right, up to down |
| –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 –1 –1 +1 +1<br>–1 –1 –1 –1 +1 –1 +1 –1 +1 –1 +1 –1 –1 +1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 +1 +1<br>–1 +1 –1 +1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1<br>–1 –1 +1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 +1<br>+1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 –1 –1 +1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1<br>–1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1<br>+1 –1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1<br>+1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1<br>+1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1<br>–1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 –1<br>–1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 +1<br>+1 –1 –1 +1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 –1<br>–1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 –1<br>–1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1<br>+1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 –1 +1 +1 +1 –1 –1<br>–1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 +1 +1 +1<br>–1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 –1 –1<br>+1 +1 –1 |
| The sequence $Gb^{8}_{512}(n)$, to be transmitted from left to right, up to down |
| –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 –1 +1 +1 –1<br>–1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 +1 –1<br>–1 –1 –1 –1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1<br>+1 –1 –1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1<br>–1 –1 +1 –1 +1 –1 +1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 +1 +1 –1 –1<br>–1 +1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 +1 +1<br>–1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1<br>+1 +1 –1 |

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## Table 28-92—The sequence $Ga^{i}_{1024}(n)$(11ay)

| The sequence $Ga^{1}_{1024}(n)$, to be transmitted from left to right, up to down |
|---|
| –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 +1 +1 –1 –1 |
| –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 +1 +1 –1 –1 –1 –1 –1 –1 |
| –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 |
| +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 |
| –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 |
| –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 –1 –1 +1 |
| –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 |
| +1 +1 –1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 +1 |
| +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 +1 +1 –1 –1 –1 |
| –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 |
| –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 +1 +1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 |
| –1 +1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 +1 +1 |
| –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 |
| +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 |
| –1 +1 –1 –1 +1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 |
| –1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 |
| +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 |
| +1 +1 –1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 |
| +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 |
| –1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 |
| –1 +1 +1 +1 –1 +1 –1 +1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 |
| –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 |
| –1 +1 –1 –1 +1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 +1 –1 –1 –1 –1 +1 –1 –1 |
| –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 +1 –1 +1 –1 +1 –1 –1 +1 +1 +1 –1 –1 –1 –1 –1 –1 |
| –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 |
| –1 +1 +1 –1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 –1 –1 +1 |
| +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 |
| –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 |



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**Table 28-92—The sequence $Ga^{i}_{1024}(n)$(11ay) *(continued)***

| The sequence $Ga^{2}_{1024}(n)$, to be transmitted from left to right, up to down |
|---|
| –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1<br>–1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 –1 +1 –1 +1<br>–1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1<br>+1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 –1<br>+1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1<br>+1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 –1 +1 +1<br>+1 +1 +1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1<br>–1 +1 +1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 +1<br>–1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 –1 +1<br>–1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1<br>–1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1<br>–1 –1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 +1 –1<br>–1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1<br>–1 –1 –1 –1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1<br>+1 +1 –1 –1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 +1 +1<br>–1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 –1 –1 +1 +1<br>+1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 +1<br>–1 –1 –1 –1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1<br>+1 +1 –1 –1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 +1 +1<br>–1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 –1 +1<br>+1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1<br>+1 +1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1<br>+1 –1 –1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 +1<br>–1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1<br>–1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1<br>+1 +1 +1 –1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1<br>–1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1<br>+1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1<br>+1 –1 +1 –1 –1 –1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 +1<br>+1 +1 +1 +1 +1 –1 –1 |

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### Table 28-92—The sequence $Ga^{i}_{1024}(n)$(11ay) *(continued)*

| The sequence $Ga^{3}_{1024}(n)$, to be transmitted from left to right, up to down |
|---|
| –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 |
| +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 +1 |
| –1 +1 –1 +1 –1 –1 +1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 |
| –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1 |
| –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 |
| +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 |
| –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 |
| +1 –1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 |
| –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 |
| –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 |
| –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 |
| +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 +1 +1 –1 –1 |
| –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 +1 +1 +1 +1 |
| +1 –1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 |
| +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 |
| –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 |
| +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 +1 +1 +1 |
| –1 +1 –1 +1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 |
| –1 –1 +1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 +1 |
| +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 +1 |
| +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 |
| +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 |
| –1 –1 +1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 |
| –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 |
| –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 –1 –1 +1 |
| –1 +1 –1 +1 –1 –1 +1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 |
| +1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 |
| +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 |
| –1 –1 +1 –1 +1 +1 –1 –1 +1 |


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**Table 28-92—The sequence $Ga^{i}_{1024}(n)$(11ay) *(continued)***

| The sequence $Ga^{4}_{1024}(n)$, to be transmitted from left to right, up to down |
|---|
| –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1<br>+1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 +1<br>+1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1<br>+1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1<br>+1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1<br>+1 –1 +1 +1 +1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 –1 +1 –1 –1<br>–1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1<br>+1 +1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1<br>–1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1<br>–1 +1 +1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1<br>+1 +1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1<br>–1 –1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 –1 +1 +1 +1 –1<br>–1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 +1<br>–1 +1 +1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1<br>–1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1<br>–1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 –1 +1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1<br>+1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 –1 +1 –1<br>–1 –1 –1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1<br>+1 –1 –1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 +1<br>–1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1<br>–1 +1 –1 +1 +1 +1 +1 –1 –1 +1 –1 +1 –1 –1 +1 –1 –1 –1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1<br>–1 –1 –1 +1 +1 –1 –1 +1 –1 –1 –1 –1 –1 –1 –1 –

**Table 28-92—The sequence $Ga^{i}_{1024}(n)$(11ay) *(continued)***

| The sequence $Ga^{5}_{1024}(n)$, to be transmitted from left to right, up to down |
|---|
| –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 +1 +1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1<br>–1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 –1 –1 +1<br>–1 +1 –1 +1 –1 –1 +1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1<br>+1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1<br>+1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1<br>–1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1<br>+1 –1 –1 +1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 –1 +1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1<br>–1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1<br>–1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 –1 –1 +1<br>–1 +1 –1 +1 –1 –1 +1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1<br>+1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 +1 +1<br>–1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1<br>+1 +1 –1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1<br>–1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 +1 –1 +1 –1 –1 +1 +1<br>–1 +1 +1 –1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 +1 +1 –1<br>–1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 +1 –1<br>+1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 +1 +1 +1 +1 +1<br>–1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 –1 +1 +1<br>+1 +1 –1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1<br>+1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 +1 +1 +1 +1 +1<br>–1 +1 –1 –1 +1 –1 –1 +1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1<br>+1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1<br>+1 +1 +1 –1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 +1 +1 +1 +1 –1<br>+1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1<br>+1 –1 |



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**Table 28-92—The sequence $Ga^{i}_{1024}(n)$(11ay) *(continued)***

| The sequence $Ga^{6}_{1024}(n)$, to be transmitted from left to right, up to down |
|---|
| –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1<br>–1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 –1 +1<br>+1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1<br>–1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 +1 +1<br>–1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 +1 +1 +1 –1 –1 +1<br>–1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 –1 +1 –1 +1<br>–1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1<br>+1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1<br>+1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1<br>–1 +1 +1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1<br>–1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1<br>–1 –1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 –1 +1 +1<br>–1 +1 –1 +1 –1 +1 +1 +1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 –1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 –1 –1 +1<br>–1 +1 +1 +1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1<br>+1 –1 –1 +1 +1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1<br>+1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1<br>+1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 –1 +1<br>+1 +1 +1 +1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1<br>+1 +1 –1 –1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 –1 –1<br>–1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1<br>+1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1<br>+1 +1 +1 +1 +1 –1 –1 +1 –1 +1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1<br>+1 –1 –1 +1 +1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1<br>+1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1<br>+1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 –1 +1<br>+1 +1 +1 +1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1<br>+1 +1 –1 –1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 –1 –1<br>–1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1<br>+1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1<br>+1 +1 +1 +1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 –1 –1 +1<br>+1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1<br>+1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1<br>+1 –1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 |

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**Table 28-92—The sequence $Ga^{i}_{1024}(n)$(11ay) *(continued)***

| The sequence $Ga^{7}_{1024}(n)$, to be transmitted from left to right, up to down |
|---|
| –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 –1 –1 +1 +1<br>–1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 +1 +1<br>–1 +1 –1 +1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1<br>–1 –1 +1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 +1<br>+1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 +1<br>+1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1<br>+1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 +1 –1 –1 +1 +1 +1 –1 –1 –1 +1 –1 +1 +1<br>–1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 –1<br>–1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1<br>+1 +1 –1 +1 –1 +1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1<br>–1 +1 –1 –1 +1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1<br>–1 –1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 +1 +1 –1 –1<br>–1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 +1 +1<br>–1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1<br>+1 +1 –1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1<br>+1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1<br>–1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 +1 +1 +1 –1<br>+1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1<br>–1 –1 +1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 +1<br>+1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1<br>+1 +1 +1 –1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 –1<br>+1 –1 –1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1<br>–1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1 +1 –1<br>+1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 +1<br>–1 –1 +1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 +1<br>+1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1<br>+1 +1 +1 –1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 –1<br>+1 –1 +1 –1 –1 +1 –1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1<br>+1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1<br>+1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 +1 +1 +1 +1 +1<br>–1 +1 –1 –1 +1 +1 –1 |



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**Table 28-92—The sequence $Ga^{i}_{1024}(n)$(11ay) *(continued)***

| The sequence $Ga^{8}_{1024}(n)$, to be transmitted from left to right, up to down |
|---|
| –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 +1 +1 +1 +1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 +1 –1 –1 +1 –1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 +1 +1 +1 –1 –1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 –1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 –1 –1 –1 –1 –1 –

**Table 28-93—The sequence $Gb^{i}_{1024}(n)$(11ay)**

| The sequence $Gb^{1}_{1024}(n)$, to be transmitted from left to right, up to down |
|---|
| +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1<br>+1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 +1 +1 +1 +1<br>+1 –1 +1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1<br>–1 +1 +1 –1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1<br>+1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1<br>+1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 +1 +1<br>–1 +1 –1 +1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 +1<br>–1 –1 +1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1<br>–1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 +1<br>+1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 +1 +1<br>–1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1<br>+1 +1 –1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1<br>–1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1<br>–1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 +1 +1 +1 –1<br>+1 –1 +1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1<br>+1 +1 –1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1<br>–1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1<br>+1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1<br>+1 –1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1<br>+1 +1 –1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1<br>+1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1<br>–1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 –1 –1 +1<br>–1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1<br>–1 –1 +1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 +1<br>+1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 +1 +1 –1 –1 –1<br>–1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 +1 +1 +1 +1 +1<br>–1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1<br>–1 –1 +1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1<br>–1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 |



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**Table 28-93—The sequence $Gb^{i}_{1024}(n)$(11ay) *(continued)***

| The sequence $Gb^{2}_{1024}(n)$, to be transmitted from left to right, up to down |
|---|
| +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1<br>–1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 +1 –1 +1<br>+1 +1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1<br>–1 +1 +1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1<br>–1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1<br>–1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 +1 –1 –1<br>–1 –1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 +1 +1<br>–1 –1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1<br>–1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 +1<br>–1 +1 +1 +1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1<br>+1 –1 –1 +1 +1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1<br>+1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1<br>–1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 –1<br>+1 +1 +1 +1 +1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1<br>–1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1<br>–1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1<br>+1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1<br>–1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 –1<br>+1 +1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1<br>+1 –1 –1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 +1<br>–1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1<br>–1 +1 –1 –1 –1 –1 –1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1<br>+1 +1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 –1 +1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 +1 +1 +1 –1 –1 +1 +1 +1<br>–1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1<br>–1 +1 –1 –1 –1 –1 –1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1<br>+1 +1 +1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1<br>–1 –1 –1 +1 +1 –1 –1 +1 –1 –1 –1 –1 –1 –1 –1 –

**Table 28-93—The sequence $Gb^{i}_{1024}(n)$(11ay) *(continued)***

| The sequence $Gb^{3}_{1024}(n)$, to be transmitted from left to right, up to down |
|---|
| +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 –1 –1 +1 +1<br>–1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 +1 +1 +1<br>–1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1<br>–1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 +1<br>+1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 +1 +1 –1 –1 –1<br>–1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 +1 +1 +1 +1 +1<br>–1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1<br>–1 –1 +1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 –1<br>–1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1<br>+1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 +1 +1 +1 –1<br>+1 –1 +1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1<br>+1 +1 –1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1<br>–1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 +1 +1 –1 –1 –1<br>–1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 +1 +1<br>–1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1<br>+1 +1 –1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 +1<br>+1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1<br>+1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 +1<br>–1 +1 –1 +1 –1 –1 +1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1<br>+1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1<br>+1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1<br>–1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1<br>+1 –1 –1 +1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1<br>–1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1<br>–1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 –1 –1 +1<br>–1 +1 –1 +1 –1 –1 +1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1<br>+1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1<br>+1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1<br>–1 –1 +1 –1 +1 +1 –1 –1 +1 |


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This is an unapproved IEEE Standards Draft, subject to change.

**Table 28-93—The sequence $Gb^{i}_{1024}(n)$(11ay) *(continued)***

| The sequence $Gb^{4}_{1024}(n)$, to be transmitted from left to right, up to down |
|---|
| +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 –1 +1 +1 –1 |
| –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 –1 +1 –1 |
| –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 |
| –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 |
| +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 +1 –1 –1 +1 |
| –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 +1 –1 +1 |
| +1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 |
| –1 –1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 –1 +1 +1 |
| –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 –1 +1 |
| –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 |
| –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 |
| –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 –1 +1 +1 –1 |
| +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 –1 +1 –1 +1 |
| –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 |
| –1 –1 +1 +1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 |
| –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 |
| +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 –1 +1 –1 |
| –1 –1 –1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 –1 |
| –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 +1 –1 –1 –1 –1 |
| –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 |
| –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 –1 +1 +1 –1 |
| +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 –1 +1 –1 +1 |
| –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 |
| –1 –1 +1 +1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 |
| –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 |
| +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 –1 +1 –1 |
| –1 –1 –1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 +1 |
| +1 –1 –1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 +1 |
| –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 |
| –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 –1 |
| –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 +1 |
| –1 –1 +1 +1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 |
| –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 |
| +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 –1 +1 –1 |
| –1 –1 –1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 +1 |
| +1 –1 –1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 +1 |
| –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 |
| –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 –1 |
| –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 +1 |
| –1 –1 +1 +1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 |
| –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 |
| +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 –1 +1 –1 |
| –1 –1 –1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 +1 |
| +1 –1 –1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 +1 |
| –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 |
| –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 |
| –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 +1 |
| –1 –1 +1 +1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 |
| –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 |
| +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 –1 +1 –1 |
| –1 –1 –1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 +1 |
| +1 –1 –1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 +1 |
| –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 |
| –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 –

**Table 28-93—The sequence $Gb^{i}_{1024}(n)$(11ay) *(continued)***

| The sequence $Gb^{5}_{1024}(n)$, to be transmitted from left to right, up to down |
|---|
| +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1<br>+1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 +1 +1<br>–1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1<br>+1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1<br>+1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1<br>+1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 +1 +1 +1 +1 +1<br>–1 +1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 +1<br>+1 –1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 +1 +1<br>–1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1<br>+1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1<br>+1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1<br>+1 –1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 +1 +1<br>–1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 +1 +1 –1 –1 –1 –1<br>–1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1<br>–1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1<br>+1 –1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1<br>–1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1<br>–1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1<br>–1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1<br>+1 –1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1<br>–1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1<br>–1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 –1 –1 –1 +1<br>–1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1<br>–1 –1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 +1 +1<br>+1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 +1<br>+1 –1 +1 –1 –1 +1 +1 –1 |



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**Table 28-93—The sequence $Gb^{i}_{1024}(n)$(11ay) *(continued)***

| The sequence $Gb^{6}_{1024}(n)$, to be transmitted from left to right, up to down |
|---|
| +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1<br>+1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 +1 –1<br>–1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1<br>+1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 –1 –1<br>+1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 –1 –1 –1 +1 +1 –1<br>+1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 +1 –1<br>+1 +1 +1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1 –1 +1 +1 +1<br>–1 –1 +1 +1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1<br>+1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1<br>–1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 –1 +1 +1<br>+1 +1 +1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1<br>–1 +1 +1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 +1 +1 +1<br>–1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 –1 +1<br>–1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1<br>–1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1<br>+1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1<br>+1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1<br>+1 +1 +1 +1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 +1 +1 +1<br>+1 +1 –1 –1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 –1 –1<br>–1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1<br>+1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1<br>+1 +1 +1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 –1 –1<br>+1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 –1 –1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1<br>+1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1<br>+1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1<br>+1 +1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 –1 +1 –1 +1 –1 –1 +1 –1 +1 +1<br>–1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1<br>+1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 +1<br>+1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1<br>+1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 –1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1<br>+1 –1 +1 +1 +1 +1 –1 –1 +1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 –1 –1<br>+1 –1 +1 +1 –1 –1 +1 –1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1<br>+1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1<br>+1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 –1 –1 +1 –1 +1 –1 –1 –1 –1 –1 –1 +1 +1<br>+1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 +1<br>+1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1<br>+1 +1 –1 –1 –1 +1 +1 –1 +1 –1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1<br>–1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1<br>+1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 +1<br>+1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1<br>+1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1<br>+1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1<br>+1 –1 +1 +1 +1 +1 –1 –1 +1 +1 |

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**Table 28-93—The sequence $Gb^{i}_{1024}(n)$(11ay) *(continued)***

| The sequence $Gb^{7}_{1024}(n)$, to be transmitted from left to right, up to down |
|---|
| +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 |
| +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 –1 –1 |
| +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 |
| –1 +1 +1 –1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 |
| –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 +1 +1 –1 –1 |
| –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 +1 +1 |
| –1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 |
| +1 +1 –1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 |
| +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 |
| –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 +1 +1 +1 –1 |
| +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 |
| +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1 |
| –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 +1 +1 –1 –1 –1 |
| –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 |
| –1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 |
| –1 +1 +1 +1 –1 –1 +1 +1 +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 –1 –1 |
| +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 +1 |
| +1 +1 –1 +1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 –1 –1 |
| +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 |
| –1 +1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 |
| +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 +1 –1 +1 –1 –1 +1 +1 |
| +1 +1 –1 +1 –1 –1 +1 +1 –1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 |
| +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 |
| –1 +1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 |
| +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 +1 –1 +1 –1 –1 +1 +1 |
| +1 +1 –1 +1 –1 –1 –1 –1 +1 –1 +1 –1 –1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 |
| –1 +1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 |
| +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 +1 –1 +1 –1 –1 +1 +1 |
| +1 +1 –1 +1 –1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 |
| +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 |
| –1 +1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 |
| +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 +1 –1 +1 –1 –1 +1 +1 |
| +1 +1 –1 +1 –1 –1 –1 –1 +1 –1 +1 –1 –1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 |
| +1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 |
| –1 +1 +1 +1 –1 –1 –1 –1 –1 –1 –1 +1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 –1 –1 –1 +1 –1 +1 –1 +1 –1 –1 +1 –1 –1 +1 |
| +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 +1 –1 +1 +1 –1 –1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 +1 –1 +1 –1 –1 +1 +1 |
| +1 +1 –1 +1 –1 –1 +1 –1 +1 +1 –1 –1 –1 +1 +1 +1 +1 +1 +1 +1 –1 +1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 –

**Table 28-93—The sequence $Gb^{i}_{1024}(n)$(11ay) *(continued)***

| The sequence $Gb^{8}_{1024}(n)$, to be transmitted from left to right, up to down |
|---|
| +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1<br>–1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 –1 +1 +1<br>+1 +1 +1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1<br>–1 +1 +1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 –1<br>+1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 –1<br>+1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1<br>+1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1<br>–1 +1 +1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1<br>–1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1<br>–1 +1 +1 +1 +1 +1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1<br>–1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1<br>+1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1<br>–1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 –1 –1 –1 –1 –1 –1 +1 –1 –1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1<br>–1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1<br>+1 –1 –1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 +1 +1 –1 –1 +1<br>–1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1<br>–1 +1 +1 +1 +1 +1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 +1 +1 –1 +1 –1 –1 –1 +1 –1 –1 –1<br>–1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1<br>–1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 +1 –1<br>–1 +1 –1 +1 –1 +1 –1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1<br>+1 –1 +1 +1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1<br>+1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 –1 –1<br>+1 +1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 +1 –1<br>–1 +1 +1 –1 +1 –1 –1 –1 –1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1<br>–1 +1 +1 +1 +1 +1 +1 +1 –1 –1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1<br>+1 +1 +1 +1 –1 –1 –1 +1 +1 –1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1<br>–1 –1 +1 –1 –1 +1 –1 +1 –1 +1 –1 –1 –1 –1 +1 +1 –1 –1 –1 +1 +1 –1 –1 +1 –1 +1 +1 +1 +1 +1 +1 +1 –1 –1 –1 +1 +1<br>–1 +1 +1 –1 +1 –1 +1 +1 +1 +1 –1 –1 +1 +1 +1 –1 –1 +1 +1 –1 +1 –1 +1 –1 –1 –1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 –1 +1<br>–1 +1 +1 +1 +1 –1 –1 +1 +1 |

### 28.10.3 Sequences of length 96, 192, 384, and 768

The Golay sequences of length 96, 192, 384, and 768 use a quadri-phase complex Golay complementary pair and are generated using the following recursive procedure, where $i$ is the index of the space-time stream or transmit chain number:

- $Ga_3 = [+1, +1, -1]$
- $Gb_3 = [+1, +j, +1]$
- If ($i$ = 1, 3, 5, or 7), then $(A^i_0(n), B^i_0(n)) = (+Ga_3(2 - n), +Gb_3(2 - n))$. Otherwise, if ($i$ = 2, 4, 6, or 8), then $(A^i_0(n), B^i_0(n)) = (+\text{conj}(Gb_3(n)), -\text{conj}(Ga_3(n)))$
- $A^i_k(n) = W^i_k A^i_{k-1}(n) + B^i_{k-1}(n - D_k)$
- $B^i_k(n) = W^i_k A^i_{k-1}(n) - B^i_{k-1}(n - D_k)$

In the paragraph above, $A^i_k(n)$ and $B^i_k(n)$ are zero for $n < 0$ and for $n > 3 \times 2k$.

Starting with $k = 1$ and making 5, 6, 7, and 8 iterations, corresponding sequences of length 96, 192, 384, and 768 are obtained.

The Golay sequences are defined as follows, where $i$ is the space-time stream or transmit chain number and $1 \le i \le 8$:

- $Ga^i_{96}(n) = \text{conj}(A^i_5(95 - n))$ and $Gb^i_{96} = \text{conj}(B^i_5(95 - n))$
- $Ga^i_{192}(n) = \text{conj}(A^i_6(191 - n))$ and $Gb^i_{192} = \text{conj}(B^i_6(191 - n))$

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— $Ga^i_{384}(n) = \text{conj}(A^i_7(383 - n))$ and $Gb^i_{384} = \text{conj}(B^i_7(383 - n))$
— $Ga^i_{768}(n) = \text{conj}(A^i_8(767 - n))$ and $Gb^i_{768} = \text{conj}(B^i_8(767 - n))$

The value of the $D_K$ vector for each of the sequences are defined as follows, where $i$ is the space-time stream or transmit chain number and $1 \le i \le 8$:

— For $Ga^i_{96}$ and $Gb^i_{96}$: $D_K$ = [3 24 6 12 48].
— For $Ga^i_{192}$ and $Gb^i_{192}$: $D_K$ = [3 24 6 12 48 96].
— For $Ga^i_{384}$ and $Gb^i_{384}$: $D_K$ = [3 24 6 12 48 96 192].
— For $Ga^i_{768}$ and $Ga^i_{768}$: $D_K$ = [3 24 6 12 48 96 192 384].

As opposed to the $D_K$ vector, the value of the $W^i_k$ vector depends on the space-time stream or transmit chain number used to define the Golay pair ($Ga^i_{96}$, $Gb^i_{96}$), ($Ga^i_{192}$, $Gb^i_{192}$), ($Ga^i_{384}$, $Gb^i_{384}$), and ($Ga^i_{768}$, $Ga^i_{768}$). Table 28-94 (WiK vector value to generate Golay sequences of length 96, 192, 384, and 768(11ay)) shows the value of the $W^i_k$ vector defined for each space-time stream or transmit chain.

**Table 28-94—$W^i_K$ vector value to generate Golay sequences of length 96, 192, 384, and 768(11ay)**

| Space-time stream/ transmit chain number ($i$) | $W^i_K$ for $Ga^i_{96}$ and $Gb^i_{96}$ | $W^i_K$ for $Ga^i_{192}$ and $Gb^i_{192}$ | $W^i_K$ for $Ga^i_{384}$ and $Gb^i_{384}$ | $W^i_K$ for $Ga^i_{768}$ and $Ga^i_{768}$ |
|---|---|---|---|---|
| 1 | [–1,–1,–1,–1,+1] | [–1,–1,–1,–1,+1,+1] | [–1,–1,–1,–1,+1,–1, –1] | [–1,–1,–1,–1,+1,–1, –1,+1] |
| 2 | | | | |
| 3 | [–1,–1,–1,+1,–1] | [–1,–1,–1,+1,–1,+1] | [–1,–1,–1,+1,–1,–1, +1] | [–1,–1,–1,+1,–1,–1, +1, +1] |
| 4 | | | | |
| 5 | [–1,–1,+1,–1,–1] | [–1,–1,+1,–1,–1,+1] | [–1,–1,–1,+1,–1,+1, +1] | [–1,–1,–1,+1,–1,+1, +1, +1] |
| 6 | | | | |
| 7 | [–1,–1,+1,+1,–1] | [–1,–1,+1,+1,–1,+1] | [–1,–1,–1,+1,+1,+1, –1] | [–1,–1,–1,+1,+1,+1, –1, +1] |
| 8 | | | | |

The sequence $Ga_{96}(n) = \text{conj}(A_5(95 - n))$ and the sequence $Gb_{96}(n) = \text{conj}(B_5(95 - n))$, $n = 0, 1, \ldots, 95$.

The sequence $Ga_{192}(n) = \text{conj}(A_6(191 - n))$ and the sequence $Gb_{192}(n) = \text{conj}(B_6(191 - n))$, $n = 0, 1, \ldots, 191$.

The sequence $Ga_{384}(n) = \text{conj}(A_7(383 - n))$ and the sequence $Gb_{384}(n) = \text{conj}(B_7(383 - n))$, $n = 0, 1, \ldots, 383$.

The sequence $Ga_{768}(n) = \text{conj}(A_8(767 - n))$ and the sequence $Gb_{768}(n) = \text{conj}(B_8(767 - n))$, $n = 0, 1, \ldots, 767$.

The sequences are defined from Table 28-95 (The sequence Gai96(n)(11ay)) through Table 28-102 (The sequence Gbi768(n)(11ay)). The sequences in the tables are normative; the description above is informative.


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**Table 28-95—The sequence $Ga^{i}_{96}(n)$(11ay)**

| |
|---|
| The sequence $Ga^{1}_{96}(n)$, to be transmitted from left to right, up to down |
| +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 |
| The sequence $Ga^{2}_{96}(n)$, to be transmitted from left to right, up to down |
| +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 |
| The sequence $Ga^{3}_{96}(n)$, to be transmitted from left to right, up to down |
| +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 |
| The sequence $Ga^{4}_{96}(n)$, to be transmitted from left to right, up to down |
| +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 –1 –1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 |
| The sequence $Ga^{5}_{96}(n)$, to be transmitted from left to right, up to down |
| +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 +1 +1 –1 +1 –j +1 –1 –1 +1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 |
| The sequence $Ga^{6}_{96}(n)$, to be transmitted from left to right, up to down |
| +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 +1 +j +1 +1 –1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 |
| The sequence $Ga^{7}_{96}(n)$, to be transmitted from left to right, up to down |
| +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j +1 –1 +1 +1 –1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 |
| The sequence $Ga^{8}_{96}(n)$, to be transmitted from left to right, up to down |
| +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 |

**Table 28-96—The sequence $Gb^{i}_{96}(n)$(11ay)**

| |
|---|
| The sequence $Gb^{1}_{96}(n)$, to be transmitted from left to right, up to down |
| –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 |
| The sequence $Gb^{2}_{96}(n)$, to be transmitted from left to right, up to down |
| –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 |

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**Table 28-96—The sequence $Gb^{i}_{96}(n)$(11ay) *(continued)***

| |
|---|
| The sequence $Gb^{3}_{96}(n)$, to be transmitted from left to right, up to down |
| –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 |
| The sequence $Gb^{4}_{96}(n)$, to be transmitted from left to right, up to down |
| –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –1 –j –1 +1 –1 –1 –1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 |
| The sequence $Gb^{5}_{96}(n)$, to be transmitted from left to right, up to down |
| –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 |
| The sequence $Gb^{6}_{96}(n)$, to be transmitted from left to right, up to down |
| –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 |
| The sequence $Gb^{7}_{96}(n)$, to be transmitted from left to right, up to down |
| –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 |
| The sequence $Gb^{8}_{96}(n)$, to be transmitted from left to right, up to down |
| –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 |

**Table 28-97—The sequence $Ga^{i}_{192}(n)$(11ay)**

| |
|---|
| The sequence $Ga^{1}_{192}(n)$, to be transmitted from left to right, up to down |
| –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 –1 +1 +1 –j +1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 |
| The sequence $Ga^{2}_{192}(n)$, to be transmitted from left to right, up to down |
| –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 –1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 |



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**Table 28-97—The sequence $Ga^i_{192}(n)$(11ay) *(continued)***

| The sequence $Ga^3_{192}(n)$, to be transmitted from left to right, up to down |
|---|
| –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 |
| The sequence $Ga^4_{192}(n)$, to be transmitted from left to right, up to down |
| –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 |
| The sequence $Ga^5_{192}(n)$, to be transmitted from left to right, up to down |
| –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 |
| The sequence $Ga^6_{192}(n)$, to be transmitted from left to right, up to down |
| –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 |
| The sequence $Ga^7_{192}(n)$, to be transmitted from left to right, up to down |
| –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 |
| The sequence $Ga^8_{192}(n)$, to be transmitted from left to right, up to down |
| –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 |

**Table 28-98—The sequence $Gb^{i}_{192}(n)$(11ay)**

| |
|---|
| The sequence $Gb^{1}_{192}(n)$, to be transmitted from left to right, up to down |
| +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –<br>j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1<br>+1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –<br>1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 –1 –1 +1<br>+1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 –1 +j<br>–1 +1 +1 –1 |
| The sequence $Gb^{2}_{192}(n)$, to be transmitted from left to right, up to down |
| +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –<br>1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1<br>+1 +j +1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –<br>j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 –1 +1 +1 –1 –j –1<br>+1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 –1 +1<br>+1 +1 +j +1 |
| The sequence $Gb^{3}_{192}(n)$, to be transmitted from left to right, up to down |
| +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j<br>–1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 +1 –j +1 –<br>1 –1 +1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1<br>–1 +1 –j +1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 +1 –j +1 +1 +1 –1 –<br>1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j<br>–1 +1 +1 –1 |
| The sequence $Gb^{4}_{192}(n)$, to be transmitted from left to right, up to down |
| +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 –1<br>+1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 +1 –1 –<br>1 –1 –j –1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1<br>+j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 +1 –1 –1 +1 +j<br>+1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 –<br>1 +1 +1 +1 +j +1 |
| The sequence $Gb^{5}_{192}(n)$, to be transmitted from left to right, up to down |
| +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 +1 –<br>j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 +1 –j +1<br>–1 –1 +1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –<br>1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 +1 +1 –<br>1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 –1<br>+j –1 +1 +1 –1 |
| The sequence $Gb^{6}_{192}(n)$, to be transmitted from left to right, up to down |
| +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 +1 –<br>1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 +1 –1 –1<br>–1 –j –1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –<br>j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 +1 +j +1<br>+1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 –1<br>+1 +1 +1 +j +1 |
| The sequence $Gb^{7}_{192}(n)$, to be transmitted from left to right, up to down |
| +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j<br>–1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 +1 –j +1 –<br>1 –1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1<br>–1 –1 +j –1 –1 –1 +1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 +1 +1 –1 +1<br>–j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1<br>–1 –1 +1 |



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**Table 28-98—The sequence $Gb^{i}_{192}(n)$(11ay) *(continued)***

| The sequence $Gb^{8}_{192}(n)$, to be transmitted from left to right, up to down |
|---|
| +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 |

**Table 28-99—The sequence $Ga^{i}_{384}(n)$(11ay)**

| The sequence $Ga^{1}_{384}(n)$, to be transmitted from left to right, up to down |
|---|
| +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 |
| The sequence $Ga^{2}_{384}(n)$, to be transmitted from left to right, up to down |
| +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 +j +1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 |
| The sequence $Ga^{3}_{384}(n)$, to be transmitted from left to right, up to down |
| +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 |


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**Table 28-99—The sequence $Ga^{i}_{384}(n)$(11ay) *(continued)***

| The sequence $Ga^{4}_{384}(n)$, to be transmitted from left to right, up to down |
|---|
| +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 –1<br>+1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 +1 –1 –<br>1 –1 –j –1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1<br>–j –1 –1 +1 +1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 –1 +1 +1 –1 –j –1<br>+1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 +1 –<br>1 –1 –1 –j –1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1<br>–1 –j –1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –<br>j –1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1<br>–1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 –1 +1<br>+1 –1 –j –1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1<br>+j +1 +1 –1 –1 –1 –j –1 |
| The sequence $Ga^{5}_{384}(n)$, to be transmitted from left to right, up to down |
| +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j<br>–1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 +1 –j +1 –<br>1 –1 +1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1<br>–1 +1 –j +1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 +1 –j +1 +1 +1 –1 –<br>1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j<br>–1 +1 +1 –1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 –<br>1 –1 +1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1<br>+1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1<br>+1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 +1 –<br>j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1<br>–1 –1 +1 –1 +j –1 +1 +1 –1 |
| The sequence $Ga^{6}_{384}(n)$, to be transmitted from left to right, up to down |
| +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 –1<br>+1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 +1 –1 –<br>1 –1 –j –1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1<br>+j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 +1 –1 –1 +1 +j<br>+1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 –<br>1 +1 +1 +1 +j +1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1<br>–1 –1 –j –1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 –<br>1 –j –1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j<br>–1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1<br>+1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –<br>1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 |
| The sequence $Ga^{7}_{384}(n)$, to be transmitted from left to right, up to down |
| +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j<br>–1 +1 +1 –1 +1 –j +1 –1 –1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 +1<br>+1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –<br>1 +1 –j +1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j –1 –1 –1 +1 +1<br>–j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 +1 –j +1<br>–1 –1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1<br>+1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1<br>–1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 –1 +j<br>–1 –1 –1 +1 –1 +j –1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 +1 –j +1 +1<br>+1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1<br>–1 +j –1 +1 +1 –1 |


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### Table 28-99—The sequence $Ga^i_{384}(n)$(11ay) *(continued)*

| The sequence $Ga^8_{384}(n)$, to be transmitted from left to right, up to down |
|---|
| +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 |

### Table 28-100—The sequence $Gb^i_{384}(n)$(11ay)

| The sequence $Gb^1_{384}(n)$, to be transmitted from left to right, up to down |
|---|
| –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 |
| The sequence $Gb^2_{384}(n)$, to be transmitted from left to right, up to down |
| –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 |
| The sequence $Gb^3_{384}(n)$, to be transmitted from left to right, up to down |
| –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 |



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**Table 28-100—The sequence $Gb^{i}_{384}(n)$(11ay) (continued)**

| |
|---|
| The sequence $Gb^{4}_{384}(n)$, to be transmitted from left to right, up to down |
| –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1<br>–1 –1 –j –1 –1 +1 +1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 +1<br>+j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j<br>+1 +1 –1 –1 +1 +j +1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 +1 –1 –1 +1 +j +1<br>–1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 –1 +1<br>+1 +1 +j +1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 –<br>1 –j –1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j<br>–1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 –<br>1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 –1 +1<br>+1 –1 –j –1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1<br>+j +1 +1 –1 –1 –1 –j –1 |
| The sequence $Gb^{5}_{384}(n)$, to be transmitted from left to right, up to down |
| –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –<br>j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1<br>+1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –<br>1 +1 –1 +j –1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 –1 –1 +1<br>+1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 +1 –<br>j +1 –1 –1 +1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1<br>–1 –1 +1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –<br>1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1<br>+1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 +1 –<br>j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1<br>–1 –1 +1 –1 +j –1 +1 +1 –1 |
| The sequence $Gb^{6}_{384}(n)$, to be transmitted from left to right, up to down |
| –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1<br>–1 –1 –j –1 –1 +1 +1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 +1<br>+j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –<br>1 –1 +1 +1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 –1 +1 +1 –1 –j –1 +1<br>–1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 +1 –1 –<br>1 –1 –j –1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1<br>–j –1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1<br>–1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 +1<br>–1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 +1 –1<br>–1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –<br>1 –j –1 –1 +1 +1 +1 +j +1 |
| The sequence $Gb^{7}_{384}(n)$, to be transmitted from left to right, up to down |
| –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –<br>j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 +1 –j +1<br>–1 –1 +1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –<br>1 +1 –1 +j –1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 +1 –j +1 +1 +1 –1<br>–1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j<br>–1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1<br>+1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –<br>1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1<br>–1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 +1 –<br>j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1<br>–1 –1 +1 –1 +j –1 +1 +1 –1 |

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### Table 28-100—The sequence $Gb^{i}_{384}(n)$(11ay) *(continued)*

| The sequence $Gb^{8}_{384}(n)$, to be transmitted from left to right, up to down |
|---|
| –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1<br>–1 –1 –j –1 –1 +1 +1 +1 +j +1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 +1 –1 –1 –<br>1 –j –1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j<br>–1 –1 +1 +1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 +1 –1 –1 +1 +j +1 –<br>1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 –1 +1<br>+1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 +1 +j +1 –1 +1 +1<br>+1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –<br>j –1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1<br>–1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 +1 –1<br>–1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –<br>1 –j –1 –1 +1 +1 +1 +j +1 |

### Table 28-101—The sequence $Ga^{i}_{768}(n)$(11ay)

| The sequence $Ga^{1}_{768}(n)$, to be transmitted from left to right, up to down |
|---|
| –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 –1 +j<br>–1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 +1 –j +1 –<br>1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1<br>+1 –1 +j –1 –1 –1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 –1 –1 +1 +1<br>–j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 –1 +j –<br>1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 +1<br>+1 –1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –<br>1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1<br>+j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 –1 +j –<br>1 –1 –1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 –1<br>–1 +1 –1 +j –1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 +1 +1 –<br>1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 +1<br>–j +1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j –1 –1 –1 +1 +1 –j +1<br>+1 +1 –1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –<br>1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –<br>1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1<br>+j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 +1 –j +1<br>+1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 +1 –j +1 +1<br>+1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1<br>–1 +j –1 +1 +1 –1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –<br>j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 |

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**Table 28-101—The sequence $Ga^{i}_{768}(n)$(11ay) *(continued)***

| The sequence $Ga^{2}_{768}(n)$, to be transmitted from left to right, up to down |
|---|
| –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 –1 +1<br>+1 +1 +j +1 +1 –1 –1 –1 –j –1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 +1 –1 –1 –<br>1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j<br>–1 –1 +1 +1 –1 –j –1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 –1 +1 +1 –1 –j –1<br>+1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 –1 +1<br>+1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 +1 +j +1 –1 +1 +1<br>+1 +j +1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1<br>+j +1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –<br>1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 –1<br>+1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1<br>–1 –j –1 –1 +1 +1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 +1 +j<br>+1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1<br>+1 –1 –1 +1 +j +1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 –1 +1 +1 –1 –j –1 +1<br>–1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 +1 –1 –<br>1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1<br>+j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –<br>1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 +1<br>–1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 +1 –1<br>–1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –<br>1 –j –1 –1 +1 +1 +1 +j +1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 +1 –1 –1 –1 –j<br>–1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 |
| The sequence $Ga^{3}_{768}(n)$, to be transmitted from left to right, up to down |
| –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –<br>j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1<br>+1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 +1 –j +1 +1<br>+1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 +1 –j +1 +1 +1 –<br>1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1<br>+j –1 +1 +1 –1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1<br>–1 –1 +1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –<br>1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1<br>–1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 –1 +j<br>–1 –1 –1 +1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 –1 +j –1<br>+1 +1 –1 +1 –j +1 –1 –1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 +1<br>+1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –<br>1 +1 –j +1 +1 +1 –1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j –1 –1 –1 +1 +1<br>–j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 –1 +j –<br>1 +1 +1 –1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 +1 –j +1 –1 –1 +1 +1 –j +1 –<br>1 –1 +1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1<br>+1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –<br>1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 –1 +j<br>–1 –1 –1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 –<br>1 –1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 +1 –j +1 –1 –1<br>+1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 |


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### Table 28-101—The sequence $Ga^{i}_{768}(n)$(11ay) *(continued)*

| |
|---|
| The sequence $Ga^{4}_{768}(n)$, to be transmitted from left to right, up to down |
| –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1<br>–1 –1 –j –1 –1 +1 +1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 +1<br>+j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j<br>+1 +1 –1 –1 +1 +j +1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 +1 –1 –1 +1 +j +1<br>–1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 –1 +1<br>+1 +1 +j +1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 –<br>1 –j –1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j<br>–1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 –<br>1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 –1 +1<br>+1 –1 –j –1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1<br>+j +1 +1 –1 –1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 +1 +j +1<br>–1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 +1 –<br>1 –1 +1 +j +1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 –1 +1 +1 –1 –j –1 +1 –1 –1<br>+1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j<br>+1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 –<br>1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 +1 –1<br>–1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –<br>1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 –1 +1 +1 –1 –j<br>–1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 –1<br>+1 +1 +1 +j +1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 +1 –1 –1 –1 –j –1 +1 –1 –<br>1 –1 –j –1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 |
| The sequence $Ga^{5}_{768}(n)$, to be transmitted from left to right, up to down |
| –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –<br>j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1<br>+1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –<br>1 +1 –1 +j –1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 –1 –1 +1<br>+1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 +1 –<br>j +1 –1 –1 +1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1<br>–1 –1 +1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –<br>1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1<br>+1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 +1 –<br>j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1<br>–1 –1 +1 –1 +j –1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 +1<br>+1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –<br>1 +1 –j +1 +1 +1 –1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 +1 –j +1 +1 +1 –1 –1<br>+j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1<br>–1 –1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1<br>–1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 +1<br>–j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –<br>1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 +1 –j +1 +1<br>+1 –1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –<br>1 +1 –j +1 –1 –1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 +1 +1 –1 –1<br>+j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 |

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**Table 28-101—The sequence $Ga^{i}_{768}(n)$(11ay) *(continued)***

| The sequence $Ga^{6}_{768}(n)$, to be transmitted from left to right, up to down |
|---|
| –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1<br>–1 –1 –j –1 –1 +1 +1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 +1<br>+j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –<br>1 –1 +1 +1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 –1 +1 +1 –1 –j –1 +1<br>–1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 +1 –1 –<br>1 –1 –j –1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1<br>–j –1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1<br>–1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 +1<br>–1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 +1 –1<br>–1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –<br>1 –j –1 –1 +1 +1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 +1 +j<br>+1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1<br>+1 –1 –1 +1 +j +1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 +1<br>+1 –1 –j –1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1<br>–1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j<br>+1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 +1<br>–1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1<br>–1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 +1 –1 –1 +1 +j<br>+1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1<br>+1 –1 –1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 +1 +j +1 –1 +1<br>+1 +1 +j +1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 |
| The sequence $Ga^{7}_{768}(n)$, to be transmitted from left to right, up to down |
| –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –<br>j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 +1 –j +1<br>–1 –1 +1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –<br>1 +1 –1 +j –1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 +1 –j +1 +1 +1 –1<br>–1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j<br>–1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1<br>+1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –<br>1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1<br>–1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 +1 –<br>j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1<br>–1 –1 +1 –1 +j –1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 +1<br>+1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1<br>–1 +j –1 –1 –1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j<br>–1 –1 –1 +1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –<br>1 –1 +1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1<br>+1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 –<br>1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j<br>–1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 –<br>1 –1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1<br>+1 –1 +j –1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 +1 +1 –1 –<br>1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 |



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### Table 28-101—The sequence $Ga^{i}_{768}(n)$(11ay) *(continued)*

| The sequence $Ga^{8}_{768}(n)$, to be transmitted from left to right, up to down |
|---|
| –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1<br>–1 –1 –j –1 –1 +1 +1 +1 +j +1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 +1 –1 –1 –<br>1 –j –1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j<br>–1 –1 +1 +1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 +1 –1 –1 +1 +j +1 –<br>1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 –1 +1<br>+1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 +1 +j +1 –1 +1 +1<br>+1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –<br>j –1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1<br>–1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 +1 –1<br>–1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –<br>1 –j –1 –1 +1 +1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 +1 +j<br>+1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –<br>1 +1 +1 –1 –j –1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1<br>+1 –1 –j –1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1<br>–1 –j –1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –<br>j –1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1<br>–1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1<br>+1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 –1 +1<br>+1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1<br>–j –1 –1 +1 +1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 +1 +j +1<br>–1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 |

### Table 28-102—The sequence $Gb^{i}_{768}(n)$(11ay)

| The sequence $Gb^{1}_{768}(n)$, to be transmitted from left to right, up to down |
|---|
| +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –<br>j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1<br>+1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 +1 –j +1 +1<br>+1 –1 +1 –j +1 +1 +1 –1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 +1 –j +1 +1 +1 –<br>1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1<br>–j +1 –1 –1 +1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 +1 –j +1 –1 –1 +1 +1 –j +1<br>–1 –1 +1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –<br>1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1<br>+1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 +1 –<br>j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1<br>+1 +1 –1 +1 –j +1 –1 –1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 +1 +1<br>–1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1<br>+1 –j +1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j –1 –1 –1 +1 +1 –<br>j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 +1 –j +1<br>–1 –1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1<br>+1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1<br>–1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 +1 –<br>j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 +1 –j +1<br>+1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –<br>1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 +1 –j +1 –1 –1 +1<br>+1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 |

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**Table 28-102—The sequence $Gb^{i}_{768}(n)$(11ay) *(continued)***

| |
|---|
| The sequence $Gb^2{}_{768}(n)$, to be transmitted from left to right, up to down |
| +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –<br>1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1<br>+1 +j +1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1<br>+j +1 +1 –1 –1 +1 +j +1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 +1 –1 –1 +1 +j +1<br>–1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1<br>–1 –1 –1 –j –1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 +1 –1 –1 –1 –j –1 +1 –1 –<br>1 –1 –j –1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1<br>–j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1<br>+1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 +1 –<br>1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 –1 +1 +1<br>+1 +j +1 +1 –1 –1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 +1 +j<br>+1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1<br>+1 –1 –1 +1 +j +1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 –1 +1 +1 –1 –j –1 +1<br>–1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 +1 –1 –<br>1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1<br>+j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –<br>1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 +1<br>–1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 +1 –1<br>–1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –<br>1 –j –1 –1 +1 +1 +1 +j +1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 +1 –1 –1 –1 –j<br>–1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 |
| The sequence $Gb^3{}_{768}(n)$, to be transmitted from left to right, up to down |
| +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j<br>–1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 +1 –j +1 –<br>1 –1 +1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1<br>+1 –1 +j –1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 –1 –1 +1 +1<br>–j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 +1 –j +1<br>–1 –1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1<br>+1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –<br>1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 +1<br>–j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 +1 –j +1<br>+1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –<br>1 +1 –1 +j –1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 +1 +1 –<br>1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 +1<br>–j +1 +1 +1 –1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j –1 –1 –1 +1 +1 –j +1<br>+1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1<br>–1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 –<br>1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 +1 –j<br>+1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –<br>1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 –1 –1<br>+1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 –<br>1 +j –1 +1 +1 –1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 +1 –j +1 –1 –1 +1 +1 –j<br>+1 –1 –1 +1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 |



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**Table 28-102—The sequence $Gb^{i}_{768}(n)$(11ay) *(continued)***

| The sequence $Gb^4_{768}(n)$, to be transmitted from left to right, up to down |
|---|
| +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 –1<br>+1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 +1 –1 –<br>1 –1 –j –1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1<br>–j –1 –1 +1 +1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 –1 +1 +1 –1 –j –1<br>+1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 +1 –<br>1 –1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 +1 +j +1 –1 +1 +1<br>+1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1<br>+j +1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1<br>+1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 +1<br>–1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –<br>1 –1 –j –1 –1 +1 +1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 +1<br>+j +1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j<br>+1 +1 –1 –1 +1 +j +1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 –1 +1 +1 –1 –j –1 +1<br>–1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 –1 +1 +1<br>+1 +j +1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –<br>j –1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1<br>+1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1<br>+1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 –1 +1 +1 –<br>1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –<br>1 –1 +1 +1 +1 +j +1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 +1 –1 –1 –1 –j –1 +1<br>–1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 |
| The sequence $Gb^5_{768}(n)$, to be transmitted from left to right, up to down |
| +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j<br>–1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 +1 –j +1 –<br>1 –1 +1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1<br>–1 +1 –j +1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 +1 –j +1 +1 +1 –1 –<br>1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j<br>–1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1<br>+1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 +1 –j +1 +1<br>+1 –1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –<br>1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 –1<br>+j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 –1 +j –<br>1 +1 +1 –1 +1 –j +1 –1 –1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 +1<br>+1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –<br>1 +1 –j +1 +1 +1 –1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 +1 –j +1 +1 +1 –1 –1<br>+j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1<br>–1 –1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1<br>–1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 +1<br>–j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –<br>1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 +1 –j +1 +1<br>+1 –1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –<br>1 +1 –j +1 –1 –1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 +1 +1 –1 –1<br>+j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 |



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### Table 28-102—The sequence $Gb^i_{768}(n)$(11ay) *(continued)*

| The sequence $Gb^6_{768}(n)$, to be transmitted from left to right, up to down |
|---|
| +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 –1<br>+1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 +1 –1 –<br>1 –1 –j –1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1<br>+j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 +1 –1 –1 +1 +j<br>+1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 –<br>1 +1 +1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 +1 +j +1 –1 +1<br>+1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 +1 –1 –1<br>+1 +j +1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j<br>+1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 –1<br>+1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 –1 +1 +1<br>+1 +j +1 +1 –1 –1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 +1<br>+j +1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j<br>+1 +1 –1 –1 +1 +j +1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 +1 –1 –1 +1 +j +1 –<br>1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –<br>1 –1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 +1 +j +1 –1 +1 +1<br>+1 +j +1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –<br>j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –<br>1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 +1 –<br>1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 –1 +1 +1<br>+1 +j +1 +1 –1 –1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 +1 +j<br>+1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 |
| The sequence $Gb^7_{768}(n)$, to be transmitted from left to right, up to down |
| +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j<br>–1 +1 +1 –1 +1 –j +1 –1 –1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 +1<br>+1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –<br>1 +1 –j +1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j –1 –1 –1 +1 +1<br>–j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 +1 –j +1<br>–1 –1 +1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –<br>1 +1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –<br>1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 +1<br>–j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j –<br>1 –1 –1 +1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 –1 +j –1 +1<br>+1 –1 +1 –j +1 –1 –1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 +1 +1 –<br>1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1<br>+j –1 –1 –1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –<br>1 –1 –1 +1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1<br>–1 +1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1<br>+1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 +1 –j +1 +1 +1 –1 +1 –j +1 +1 +1 –1 –<br>1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j<br>–1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 –1 +j –1 –<br>1 –1 +1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1 +1 +1 –j +1 –1 –1<br>+1 –1 +j –1 +1 +1 –1 +1 –j +1 +1 +1 –1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 –1 –1 +1 –1 +j –1 +1 +1 –1 –<br>1 +j –1 +1 +1 –1 +1 –j +1 –1 –1 +1 –1 +j –1 +1 +1 –1 |


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**Table 28-102—The sequence $Gb^{i}_{768}(n)$(11ay) *(continued)***

| The sequence $Gb^{8}_{768}(n)$, to be transmitted from left to right, up to down |
|---|
| +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 –1<br>+1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1<br>+1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1<br>+j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 –1 +1 +1 –1 –j –<br>1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 +1<br>–1 –1 –1 –j –1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1<br>–1 –j –1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j<br>+1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 +1<br>–1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 –1 +1<br>+1 –1 –j –1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1<br>+j +1 +1 –1 –1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 +1 +j +1<br>–1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1<br>+1 +1 –1 –j –1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1<br>+1 –1 –j –1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1<br>–1 –j –1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –<br>j –1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 +1 –1 –1 +1 +j +1 +1 –1 –1 +1 +j +1<br>–1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1<br>+1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 +1 +j +1 –1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 –1 +1<br>+1 –1 –j –1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1 –j –1 +1 –1 –1 –1<br>–j –1 –1 +1 +1 +1 +j +1 +1 –1 –1 +1 +j +1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 –1 –j –1 –1 +1 +1 +1 +j +1<br>–1 +1 +1 +1 +j +1 +1 –1 –1 –1 –j –1 –1 +1 +1 +1 +j +1 |

## 28.11 OFDM sequences

### 28.11.1 EDMG-STF sequence

#### 28.11.1.1 General

For transmissions over a 2.16 GHz (or 2.16+2.16 GHz), 4.32 GHz (or 4.32+4.32 GHz), 6.48 GHz, and 8.64 GHz channel, the EDMG OFDM mode uses the pairs of $EDMGS^{i_{STS}}_{left,N}$ and $EDMGS^{i_{STS}}_{right,N}$ sequences ($i_{STS}$ = 1, 2, …, 8) with length $N$ = 176, 385, 595, and 804, respectively, to define the EDMG-STF field in frequency domain.

#### 28.11.1.2 Sequence definition

The sequence pairs $EDMGS^{i_{STS}}_{left,N}$ and $EDMGS^{i_{STS}}_{right,N}$ of length $N$ = 176, 385, 595, and 804 use {±1, ±$j$} symbols alphabet and are defined in Table 28-103 (The sequence (11ay)) through Table 28-110 (The sequence (11ay)).

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**Table 28-103—The sequence $EDMGS^{i_{STS}}_{left,176}(n)$ (11ay)**

| |
|---|
| The sequence $EDMGS^{1}_{left,176}(n)$, to be transmitted from left to right, up to down |
| 0 +1 0 0 0 +j 0 0 0 +j 0 0 0 –1 0 0 0 –j 0 0 0 +j 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 –j 0 0 0 –j 0 0 0 –j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +j 0 0 0 –1 0 0 0 –j 0 0 0 +j 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 +j 0 0 0 +j 0 0 0 +j 0 0 0 –1 0 0 0 –1 0 0 |
| The sequence $EDMGS^{2}_{left,176}(n)$, to be transmitted from left to right, up to down |
| 0 –1 0 0 0 –j 0 0 0 –j 0 0 0 +1 0 0 0 +j 0 0 0 –j 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 +j 0 0 0 +j 0 0 0 +j 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +j 0 0 0 –1 0 0 0 –j 0 0 0 +j 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 +j 0 0 0 +j 0 0 0 +j 0 0 0 –1 0 0 0 –1 0 0 |
| The sequence $EDMGS^{3}_{left,176}(n)$, to be transmitted from left to right, up to down |
| 0 +j 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 +j 0 0 0 –j 0 0 0 –1 0 0 0 +j 0 0 0 –j 0 0 0 +j 0 0 0 –j 0 0 0 –1 0 0 0 +j 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +j 0 0 0 +1 0 0 0 +j 0 0 0 +j 0 0 0 –1 0 0 0 –j 0 0 0 +j 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 +j 0 0 0 +j 0 0 0 +j 0 0 0 –1 0 0 0 –1 0 0 |
| The sequence $EDMGS^{4}_{left,176}(n)$, to be transmitted from left to right, up to down |
| 0 –j 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 –j 0 0 0 +j 0 0 0 +1 0 0 0 –j 0 0 0 +j 0 0 0 –j 0 0 0 +j 0 0 0 +1 0 0 0 –j 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –j 0 0 0 +1 0 0 0 +j 0 0 0 +j 0 0 0 –1 0 0 0 –j 0 0 0 +j 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 +j 0 0 0 +j 0 0 0 +j 0 0 0 –1 0 0 0 –1 0 0 |
| The sequence $EDMGS^{5}_{left,176}(n)$, to be transmitted from left to right, up to down |
| 0 +1 0 0 0 +j 0 0 0 +j 0 0 0 –1 0 0 0 –j 0 0 0 +j 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 –j 0 0 0 –j 0 0 0 –j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +j 0 0 0 –1 0 0 0 –j 0 0 0 +j 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 +j 0 0 0 +j 0 0 0 +j 0 0 0 –1 0 0 0 –1 0 0 |
| The sequence $EDMGS^{6}_{left,176}(n)$, to be transmitted from left to right, up to down |
| 0 –1 0 0 0 –j 0 0 0 –j 0 0 0 +1 0 0 0 +j 0 0 0 –j 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 +j 0 0 0 +j 0 0 0 +j 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +j 0 0 0 –1 0 0 0 –j 0 0 0 +j 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 +j 0 0 0 +j 0 0 0 +j 0 0 0 –1 0 0 0 –1 0 0 |
| The sequence $EDMGS^{7}_{left,176}(n)$, to be transmitted from left to right, up to down |
| 0 +j 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 +j 0 0 0 –j 0 0 0 –1 0 0 0 +j 0 0 0 –j 0 0 0 +j 0 0 0 –j 0 0 0 –1 0 0 0 +j 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +j 0 0 0 +1 0 0 0 +j 0 0 0 +j 0 0 0 –1 0 0 0 –j 0 0 0 +j 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 +j 0 0 0 +j 0 0 0 +j 0 0 0 –1 0 0 0 –1 0 0 |
| The sequence $EDMGS^{8}_{left,176}(n)$, to be transmitted from left to right, up to down |
| 0 –j 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 –j 0 0 0 +j 0 0 0 +1 0 0 0 –j 0 0 0 +j 0 0 0 –j 0 0 0 +j 0 0 0 +1 0 0 0 –j 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –j 0 0 0 +1 0 0 0 +j 0 0 0 +j 0 0 0 –1 0 0 0 –j 0 0 0 +j 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 +j 0 0 0 +j 0 0 0 +j 0 0 0 –1 0 0 0 –1 0 0 |



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**Table 28-104—The sequence $EDMGS^{i_{STS}}_{right,176}(n)$ (11ay)**

| |
|---|
| The sequence $EDMGS^{1}_{right,176}(n)$, to be transmitted from left to right, up to down |
| 0 0 +1 0 0 0 +j 0 0 0 +j 0 0 0 –1 0 0 0 –j 0 0 0 +j 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 –j 0 0 0 –j 0 0 0 –j 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –j 0 0 0 +1 0 0 0 +j 0 0 0 –j 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 –j 0 0 0 –j 0 0 0 –j 0 0 0 +1 0 0 0 +1 0 |
| The sequence $EDMGS^{2}_{right,176}(n)$, to be transmitted from left to right, up to down |
| 0 0 –1 0 0 0 –j 0 0 0 –j 0 0 0 +1 0 0 0 +j 0 0 0 –j 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 +j 0 0 0 +j 0 0 0 +j 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –j 0 0 0 +1 0 0 0 +j 0 0 0 –j 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 –j 0 0 0 –j 0 0 0 –j 0 0 0 +1 0 0 0 +1 0 |
| The sequence $EDMGS^{3}_{right,176}(n)$, to be transmitted from left to right, up to down |
| 0 0 +j 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 +j 0 0 0 –j 0 0 0 –1 0 0 0 +j 0 0 0 –j 0 0 0 +j 0 0 0 –j 0 0 0 –1 0 0 0 +j 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +j 0 0 0 –1 0 0 0 –j 0 0 0 –j 0 0 0 +1 0 0 0 +j 0 0 0 –j 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 –j 0 0 0 –j 0 0 0 –j 0 0 0 +1 0 0 0 +1 0 |
| The sequence $EDMGS^{4}_{right,176}(n)$, to be transmitted from left to right, up to down |
| 0 0 –j 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 –j 0 0 0 +j 0 0 0 +1 0 0 0 –j 0 0 0 +j 0 0 0 –j 0 0 0 +j 0 0 0 +1 0 0 0 –j 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –j 0 0 0 –1 0 0 0 –j 0 0 0 –j 0 0 0 +1 0 0 0 +j 0 0 0 –j 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 –j 0 0 0 –j 0 0 0 –j 0 0 0 +1 0 0 0 +1 0 |
| The sequence $EDMGS^{5}_{right,176}(n)$, to be transmitted from left to right, up to down |
| 0 0 –1 0 0 0 –j 0 0 0 –j 0 0 0 +1 0 0 0 +j 0 0 0 –j 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 +j 0 0 0 +j 0 0 0 +j 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +j 0 0 0 –1 0 0 0 –j 0 0 0 +j 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +j 0 0 0 +j 0 0 0 +j 0 0 0 –1 0 0 0 –1 0 |
| The sequence $EDMGS^{6}_{right,176}(n)$, to be transmitted from left to right, up to down |
| 0 0 +1 0 0 0 +j 0 0 0 +j 0 0 0 –1 0 0 0 –j 0 0 0 +j 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 –j 0 0 0 –j 0 0 0 –j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +j 0 0 0 –1 0 0 0 –j 0 0 0 +j 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 +j 0 0 0 +j 0 0 0 +j 0 0 0 –1 0 0 0 –1 0 |
| The sequence $EDMGS^{7}_{right,176}(n)$, to be transmitted from left to right, up to down |
| 0 0 –j 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 –j 0 0 0 +j 0 0 0 +1 0 0 0 –j 0 0 0 +j 0 0 0 –j 0 0 0 +j 0 0 0 +1 0 0 0 –j 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –j 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 +j 0 0 0 +j 0 0 0 +j 0 0 0 –1 0 0 0 –1 0 |
| The sequence $EDMGS^{8}_{right,176}(n)$, to be transmitted from left to right, up to down |
| 0 0 +j 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 +j 0 0 0 –j 0 0 0 –1 0 0 0 +j 0 0 0 –j 0 0 0 +j 0 0 0 –j 0 0 0 –1 0 0 0 +j 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +j 0 0 0 –1 0 0 0 +j 0 0 0 –1 0 0 0 –j 0 0 0 +j 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 +j 0 0 0 +j 0 0 0 +j 0 0 0 –1 0 0 0 –1 0 |

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**Table 28-105—The sequence $EDMGS^{i_{STS}}_{left,385}(n)$ (11ay)**

| |
|---|
| The sequence $EDMGS^{1}_{left,385}(n)$, to be transmitted from left to right, up to down |
| 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 |
| The sequence $EDMGS^{2}_{left,385}(n)$, to be transmitted from left to right, up to down |
| 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 |
| The sequence $EDMGS^{3}_{left,385}(n)$, to be transmitted from left to right, up to down |
| 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 |
| The sequence $EDMGS^{4}_{left,385}(n)$, to be transmitted from left to right, up to down |
| 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 |
| The sequence $EDMGS^{5}_{left,385}(n)$, to be transmitted from left to right, up to down |
| 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 |



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**Table 28-105—The sequence $EDMGS^{i_{STS}}_{left,385}(n)$ (11ay) *(continued)***

| The sequence $EDMGS^{6}_{left,385}(n)$, to be transmitted from left to right, up to down |
|---|
| 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 |
| The sequence $EDMGS^{7}_{left,385}(n)$, to be transmitted from left to right, up to down |
| 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 |
| The sequence $EDMGS^{8}_{left,385}(n)$, to be transmitted from left to right, up to down |
| 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 |

**Table 28-106—The sequence $EDMGS^{i_{STS}}_{right,385}(n)$ (11ay)**

| The sequence $EDMGS^{1}_{right,385}(n)$, to be transmitted from left to right, up to down |
|---|
| 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +

**Table 28-106—The sequence $EDMGS^{i_{STS}}_{right,385}(n)$ (11ay) *(continued)***

| The sequence $EDMGS^{3}_{right,385}(n)$, to be transmitted from left to right, up to down |
|---|
| 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 |
| The sequence $EDMGS^{4}_{right,385}(n)$, to be transmitted from left to right, up to down |
| 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 |
| The sequence $EDMGS^{5}_{right,385}(n)$, to be transmitted from left to right, up to down |
| 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 |
| The sequence $EDMGS^{6}_{right,385}(n)$, to be transmitted from left to right, up to down |
| 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 |
| The sequence $EDMGS^{7}_{right,385}(n)$, to be transmitted from left to right, up to down |
| 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –

**Table 28-106—The sequence $EDMGS^{i_{STS}}_{right,385}(n)$ (11ay) *(continued)***

| The sequence $EDMGS^{8}_{right,385}(n)$, to be transmitted from left to right, up to down |
|---|
| 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 |

**Table 28-107—The sequence $EDMGS^{i_{STS}}_{left,595}(n)$ (11ay)**

| The sequence $EDMGS^{1}_{left,595}(n)$, to be transmitted from left to right, up to down |
|---|
| 0 0 0 0 –j 0 0 0 +j 0 0 0 –j 0 0 0 –j 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 |
| The sequence $EDMGS^{2}_{left,595}(n)$, to be transmitted from left to right, up to down |
| 0 0 0 0 –j 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 |
| The sequence $EDMGS^{3}_{left,595}(n)$, to be transmitted from left to right, up to down |
| 0 0 0 0 +1 0 0 0 –j 0 0 0 +1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j

**Table 28-107—The sequence $EDMGS^{i_{STS}}_{left,595}(n)$ (11ay) *(continued)***

| The sequence $EDMGS^{4}_{left,595}(n)$, to be transmitted from left to right, up to down |
|---|
| 0 0 0 0 +j 0 0 0 –j 0 0 0 –j 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0<br>0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0<br>0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –<br>1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0<br>0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0<br>0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –<br>1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0<br>0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0<br>+1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –1<br>0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0<br>0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0<br>+j 0 0 0 +1 0 0 |
| The sequence $EDMGS^{5}_{left,595}(n)$, to be transmitted from left to right, up to down |
| 0 0 0 0 +1 0 0 0 –j 0 0 0 –1 0 0 0 –j 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0<br>0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0<br>–j 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1<br>0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0<br>0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –<br>1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0<br>0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0<br>–1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1<br>0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0<br>0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0<br>+1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j<br>0 0 0 +1 0 0 |
| The sequence $EDMGS^{6}_{left,595}(n)$, to be transmitted from left to right, up to down |
| 0 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0<br>0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0<br>–j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0<br>0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0<br>–1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1<br>0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0<br>0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1<br>0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0<br>0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –<br>1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1<br>0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0<br>0 +1 0 0 |
| The sequence $EDMGS^{7}_{left,595}(n)$, to be transmitted from left to right, up to down |
| 0 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –1<br>0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0<br>0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0<br>+1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1<br>0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0<br>0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0<br>+1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j<br>0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0<br>0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –<br>1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0<br>0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0<br>+j 0 0 0 +1 0 0 |



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**Table 28-107—The sequence $EDMGS^{i_{STS}}_{left,595}(n)$ (11ay) *(continued)***

| |
|---|
| The sequence $EDMGS^{8}_{left,595}(n)$, to be transmitted from left to right, up to down |
| 0 0 0 0 –j 0 0 0 –j 0 0 0 +j 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0<br>0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –<br>j 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0<br>0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0<br>+1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 +1<br>0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0<br>0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0<br>+1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1<br>0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0<br>0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –<br>1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0<br>0 0 +1 0 0 |

**Table 28-108—The sequence $EDMGS^{i_{STS}}_{right,595}(n)$ (11ay)**

| |
|---|
| The sequence $EDMGS^{1}_{right,595}(n)$, to be transmitted from left to right, up to down |
| 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0<br>+1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1<br>0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0<br>0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +j 0 0 0 +j 0 0 0 –j 0 0 0 +j 0 0 0 –1 0 0 0 +j<br>0 0 0 +j 0 0 0 +j 0 0 0 –j 0 0 0 –j 0 0 0 +1 0 0 0 –j 0 0 0 +j 0 0 0 +j 0 0 0 –j 0 0 0 +j 0 0 0 –1 0 0 0 +j 0 0 0 –j 0 0 0 –j<br>0 0 0 +j 0 0 0 +j 0 0 0 –1 0 0 0 +j 0 0 0 –j 0 0 0 –j 0 0 0 +j 0 0 0 –j 0 0 0 +1 0 0 0 –j 0 0 0 –j 0 0 0 –j 0 0 0 +j 0 0 0 +j<br>0 0 0 –1 0 0 0 +j 0 0 0 +j 0 0 0 +j 0 0 0 –j 0 0 0 +j 0 0 0 –1 0 0 0 +j 0 0 0 –j 0 0 0 –j 0 0 0 +j 0 0 0 +j 0 0 0 –1 0 0 0 +j<br>0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0<br>0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0<br>+1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1<br>0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –j 0 0 0 –j 0 0 0 –j 0 0 0 +j 0 0 0 0 |
| The sequence $EDMGS^{2}_{right,595}(n)$, to be transmitted from left to right, up to down |
| 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0<br>+1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –1<br>0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0<br>0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –j 0 0 0 –j 0 0 0 +j 0 0 0 –j 0 0 0 +1 0 0 0 –j<br>0 0 0 –j 0 0 0 –j 0 0 0 +j 0 0 0 +j 0 0 0 –1 0 0 0 +j 0 0 0 +j 0 0 0 +j 0 0 0 –j 0 0 0 +j 0 0 0 –1 0 0 0 +j 0 0 0 –j 0 0 0 –j<br>0 0 0 +j 0 0 0 +j 0 0 0 –1 0 0 0 +j 0 0 0 +j 0 0 0 +j 0 0 0 –j 0 0 0 +j 0 0 0 –1 0 0 0 +j 0 0 0 +j 0 0 0 +j 0 0 0 –j 0 0 0 –<br>j 0 0 0 +1 0 0 0 –j 0 0 0 +j 0 0 0 +j 0 0 0 –j 0 0 0 +j 0 0 0 –1 0 0 0 +j 0 0 0 –j 0 0 0 –j 0 0 0 +j 0 0 0 +j 0 0 0 –1 0 0 0<br>+j 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1<br>0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0<br>0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0<br>+1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –j 0 0 0 –1 0 0 0 +j 0 0 0 –1 0 0 0 0 |
| The sequence $EDMGS^{3}_{right,595}(n)$, to be transmitted from left to right, up to down |
| 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0<br>–1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –1<br>0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0<br>0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –j 0 0 0 –j 0 0 0 +j 0 0 0 –j 0 0 0 +1 0 0 0 –j 0<br>0 0 +j 0 0 0 +j 0 0 0 –j 0 0 0 –j 0 0 0 +1 0 0 0 –j 0 0 0 –j 0 0 0 –j 0 0 0 +j 0 0 0 –j 0 0 0 +1 0 0 0 –j 0 0 0 –j 0 0 0 –j 0<br>0 0 +j 0 0 0 +j 0 0 0 –1 0 0 0 +j 0 0 0 +j 0 0 0 +j 0 0 0 –j 0 0 0 +j 0 0 0 –1 0 0 0 +j 0 0 0 –j 0 0 0 –j 0 0 0 +j 0 0 0 +j 0<br>0 0 –1 0 0 0 +j 0 0 0 –j 0 0 0 –j 0 0 0 +j 0 0 0 –j 0 0 0 +1 0 0 0 –j 0 0 0 –j 0 0 0 –j 0 0 0 +j 0 0 0 +j 0 0 0 –1 0 0 0 +j 0<br>0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0<br>–1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –1<br>0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0<br>0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 0 |


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**Table 28-108—The sequence $EDMGS^{i_{STS}}_{right,595}(n)$ (11ay) *(continued)***

| |
|---|
| The sequence $EDMGS^{4}_{right,595}(n)$, to be transmitted from left to right, up to down |
| 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0<br>0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –<br>1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0<br>0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +j 0 0 0 +j 0 0 0 –j 0 0 0 +j 0 0 0 –1 0 0 0 +j<br>0 0 0 –j 0 0 0 –j 0 0 0 +j 0 0 0 +j 0 0 0 –1 0 0 0 +j 0 0 0 +j 0 0 0 +j 0 0 0 –j 0 0 0 +j 0 0 0 –1 0 0 0 +j 0 0 0 +j 0 0 0 +j<br>0 0 0 –j 0 0 0 –j 0 0 0 +1 0 0 0 –j 0 0 0 +j 0 0 0 +j 0 0 0 –j 0 0 0 +j 0 0 0 –1 0 0 0 +j 0 0 0 –j 0 0 0 –j 0 0 0 +j 0 0 0 +j<br>0 0 0 –1 0 0 0 +j 0 0 0 –j 0 0 0 –j 0 0 0 +j 0 0 0 –j 0 0 0 +1 0 0 0 –j 0 0 0 –j 0 0 0 –j 0 0 0 +j 0 0 0 +j 0 0 0 –1 0 0 0 +j<br>0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0<br>0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0<br>–1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1<br>0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –j 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 0 |
| The sequence $EDMGS^{5}_{right,595}(n)$, to be transmitted from left to right, up to down |
| 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0<br>+1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1<br>0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0<br>0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +j 0 0 0 +j 0 0 0 –j 0 0 0 –j 0 0 0 +1 0 0 0 –j<br>0 0 0 +j 0 0 0 +j 0 0 0 –j 0 0 0 +j 0 0 0 –1 0 0 0 +j 0 0 0 +j 0 0 0 +j 0 0 0 –j 0 0 0 –j 0 0 0 +1 0 0 0 –j 0 0 0 –j 0 0 0 –j<br>0 0 0 +j 0 0 0 –j 0 0 0 +1 0 0 0 –j 0 0 0 +j 0 0 0 +j 0 0 0 –j 0 0 0 –j 0 0 0 +1 0 0 0 –j 0 0 0 +j 0 0 0 +j 0 0 0 –j 0 0 0 +j<br>0 0 0 –1 0 0 0 +j 0 0 0 –j 0 0 0 –j 0 0 0 +j 0 0 0 +j 0 0 0 –1 0 0 0 +j 0 0 0 +j 0 0 0 +j 0 0 0 –j 0 0 0 +j 0 0 0 –1 0 0 0 +j<br>0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0<br>0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –<br>1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0<br>0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 +1 0 0 0 –j 0 0 0 0 |
| The sequence $EDMGS^{6}_{right,595}(n)$, to be transmitted from left to right, up to down |
| 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0<br>–1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 +1<br>0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0<br>0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –j 0 0 0 –j 0 0 0 +j 0 0 0 +j 0 0 0 –1 0 0 0 +j<br>0 0 0 +j 0 0 0 +j 0 0 0 –j 0 0 0 +j 0 0 0 –1 0 0 0 +j 0 0 0 –j 0 0 0 –j 0 0 0 +j 0 0 0 +j 0 0 0 –1 0 0 0 +j 0 0 0 –j 0 0 0 –j<br>0 0 0 +j 0 0 0 –j 0 0 0 +1 0 0 0 –j 0 0 0 –j 0 0 0 –j 0 0 0 +j 0 0 0 +j 0 0 0 –1 0 0 0 +j 0 0 0 +j 0 0 0 +j 0 0 0 –j 0 0 0 +j<br>0 0 0 –1 0 0 0 +j 0 0 0 +j 0 0 0 +j 0 0 0 –j 0 0 0 –j 0 0 0 +1 0 0 0 –j 0 0 0 +j 0 0 0 +j 0 0 0 –j 0 0 0 +j 0 0 0 –1 0 0 0 +j<br>0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0<br>0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0<br>+1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –<br>1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 0 |
| The sequence $EDMGS^{7}_{right,595}(n)$, to be transmitted from left to right, up to down |
| 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0<br>0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –<br>1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0<br>0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –j 0 0 0 –j 0 0 0 +j 0 0 0 +j 0 0 0 –1 0 0 0 +j<br>0 0 0 +j 0 0 0 +j 0 0 0 –j 0 0 0 +j 0 0 0 –1 0 0 0 +j 0 0 0 +j 0 0 0 +j 0 0 0 –j 0 0 0 –j 0 0 0 +1 0 0 0 –j 0 0 0 +j 0 0 0 +j<br>0 0 0 –j 0 0 0 +j 0 0 0 –1 0 0 0 +j 0 0 0 +j 0 0 0 +j 0 0 0 –j 0 0 0 –j 0 0 0 +1 0 0 0 –j 0 0 0 –j 0 0 0 –j 0 0 0 +j 0 0 0 –j<br>0 0 0 +1 0 0 0 –j 0 0 0 +j 0 0 0 +j 0 0 0 –j 0 0 0 –j 0 0 0 +1 0 0 0 –j 0 0 0 +j 0 0 0 +j 0 0 0 –j 0 0 0 +j 0 0 0 –1 0 0 0 +j<br>0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0<br>0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0<br>–1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1<br>0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 0 |



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**Table 28-108—The sequence $EDMGS^{i_{STS}}_{right,595}(n)$ (11ay) *(continued)***

| The sequence $EDMGS^{8}_{right,595}(n)$, to be transmitted from left to right, up to down |
|---|
| 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +j 0 0 0 +j 0 0 0 –j 0 0 0 –j 0 0 0 +1 0 0 0 –j 0 0 0 –j 0 0 0 –j 0 0 0 +j 0 0 0 –j 0 0 0 +1 0 0 0 –j 0 0 0 –j 0 0 0 –j 0 0 0 –j 0 0 0 +j 0 0 0 +j 0 0 0 –1 0 0 0 +j 0 0 0 –j 0 0 0 –j 0 0 0 +j 0 0 0 –j 0 0 0 +1 0 0 0 –j 0 0 0 +j 0 0 0 +j 0 0 0 –j 0 0 0 +j 0 0 0 –j 0 0 0 +1 0 0 0 –j 0 0 0 –j 0 0 0 +j 0 0 0 –j 0 0 0 +j 0 0 0 –j 0 0 0 +1 0 0 0 –j 0 0 0 +j 0 0 0 –j 0 0 0 +j 0 0 0 –j 0 0 0 +1 0 0 0 –j 0 0 0 +j 0 0 0 –j 0 0 0 +j 0 0 0 –j 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –1 0 0 0 +1 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 –j 0 0 0 +1 0 0 0 –j 0 0 0 +1 0 0 0 0 |

**Table 28-109—The sequence $EDMGS^{i_{STS}}_{left,804}(n)$ (11ay)**

| The sequence $EDMGS^{1}_{left,804}(n)$, to be transmitted from left to right, up to down |
|---|
| 0 0 0 0 0 –1 0 0 0 –1 0 0 0 +j 0 0 0 –j 0 0 0 +j 0 0 0 –1 0 0 0 +j 0 0 0 +j 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 +j 0 0 0 –j 0 0 0 +j 0 0 0 +1 0 0 0 –j 0 0 0 –j 0 0 0 +1 0 0 0 +j 0 0 0 –1 0 0 0 –1 0 0 0 +j 0 0 0 –j 0 0 0 +j 0 0 0 –1 0 0 0 +j 0 0 0 +j 0 0 0 –1 0 0 0 –j 0 0 0 +1 0 0 0 –j 0 0 0 –j 0 0 0 +1 0 0 0 +1 0 0 0 –j 0 0 0 +j 0 0 0 –j 0 0 0 –1 0 0 0 +j 0 0 0 –j 0 0 0 –1 0 0 0 +j 0 0 0 +j 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 +j 0 0 0 –j 0 0 0 +j 0 0 0 –1 0 0 0 +j 0 0 0 +j 0 0 0 –1 0 0 0 +j 0 0 0 –j 0 0 0 +1 0 0 0 –j 0 0 0 –j 0 0 0 +1 0 0 0 +j 0 0 0 –1 0 0 0 –1 0 0 0 +j 0 0 0 –j 0 0 0 –j 0 0 0 +j 0 0 0 –j 0 0 0 –1 0 0 0 +j 0 0 0 –j 0 0 0 +1 0 0 0 –j 0 0 0 –j 0 0 0 +1 0 0 0 +j 0 0 0 –1 0 0 0 –j 0 0 0 +1 0 0 0 +1 0 0 0 –j 0 0 0 +j 0 0 0 +j 0 0 0 –j 0 0 0 +1 0 0 0 –j 0 0 0 –j 0 0 0 –1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 –1 0 0 0 –j 0 0 0 –j 0 0 0 +1 0 0 0 +j 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 +j 0 0 0 –1 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 –1 0 0 0 –j 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 –1 0 0 0 –

**Table 28-109—The sequence $EDMGS^{i_{STS}}_{left,804}(n)$ (11ay) *(continued)***

| |
|---|
| The sequence $EDMGS^{3}_{left,804}(n)$, to be transmitted from left to right, up to down |
| 0 0 0 0 0 +1 0 0 0 +1 0 0 0 –j 0 0 0 +j 0 0 0 –j 0 0 0 +1 0 0 0 –j 0 0 0 –j 0 0 0 +1 0 0 0 +j 0 0 0 –1 0 0 0 –1 0 0 0 +j 0<br>0 0 –j 0 0 0 +j 0 0 0 +1 0 0 0 –j 0 0 0 –j 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 –j 0 0 0 +j 0 0 0 –j 0 0 0 +1 0 0 0 –j<br>0 0 0 –j 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 –j 0 0 0 +j 0 0 0 –j 0 0 0 –1 0 0 0 +j 0 0 0 +j 0 0 0 –1 0 0 0 –j 0 0 0<br>+1 0 0 0 +1 0 0 0 –j 0 0 0 +j 0 0 0 –j 0 0 0 +1 0 0 0 –j 0 0 0 –j 0 0 0 +1 0 0 0 +j 0 0 0 –1 0 0 0 –1 0 0 0 +j 0 0 0 –j 0 0<br>0 +j 0 0 0 +1 0 0 0 –j 0 0 0 –j 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 –j 0 0 0 +j 0 0 0 –j 0 0 0 +1 0 0 0 –j 0 0 0 –j 0<br>0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 –j 0 0 0 +j 0 0 0 –j 0 0 0 –1 0 0 0 +j 0 0 0 +j 0 0 0 –1 0 0 0 –j 0 0 0 –j 0 0 0 –j<br>0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 +1 0 0 0 +j 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0<br>0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 +1 0 0 0 –j 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –j 0<br>0 0 +1 0 0 0 –j 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 –1 0 0 0 +j 0 0 0 +j 0 0 0<br>+1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 –1 0 0 0 –j 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 +j 0<br>0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 –1 0 0 0 +j 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0<br>–1 0 0 0 +j 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 +1 0 0 0 –j 0 0 0 –j 0 0 0 –1 0<br>0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 +1 0 0 0 +j 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 –j 0 0 0<br>–1 0 0 0 –1 0 0 0 –j 0 0 0 +1 0 0 0 –j 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 +1 0<br>0 0 –j 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 –1 0 0 |
| The sequence $EDMGS^{4}_{left,804}(n)$, to be transmitted from left to right, up to down |
| 0 0 0 0 0 –1 0 0 0 –1 0 0 0 +j 0 0 0 –j 0 0 0 +j 0 0 0 –1 0 0 0 +j 0 0 0 +j 0 0 0 –1 0 0 0 –j 0 0 0 +1 0 0 0 +1 0 0 0 –j 0<br>0 0 +j 0 0 0 –j 0 0 0 –1 0 0 0 +j 0 0 0 +j 0 0 0 –1 0 0 0 –j 0 0 0 +1 0 0 0 +1 0 0 0 –j 0 0 0 +j 0 0 0 –j 0 0 0 +1 0 0 0 –j<br>0 0 0 –j 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 –j 0 0 0 +j 0 0 0 –j 0 0 0 –1 0 0 0 +j 0 0 0 +j 0 0 0 –1 0 0 0 –j 0 0 0<br>–1 0 0 0 –1 0 0 0 +j 0 0 0 –j 0 0 0 +j 0 0 0 –1 0 0 0 +j 0 0 0 +j 0 0 0 –1 0 0 0 –j 0 0 0 +1 0 0 0 +1 0 0 0 –j 0 0 0 +j 0 0<br>0 –j 0 0 0 –1 0 0 0 +j 0 0 0 +j 0 0 0 –1 0 0 0 –j 0 0 0 +1 0 0 0 +1 0 0 0 –j 0 0 0 +j 0 0 0 –j 0 0 0 +1 0 0 0 –j 0 0 0 –j 0<br>0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 –j 0 0 0 +j 0 0 0 –j 0 0 0 –1 0 0 0 +j 0 0 0 +j 0 0 0 –1 0 0 0 –j 0 0 0 +j 0 0 0 +j<br>0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 –1 0 0 0 –j 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0<br>0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 –1 0 0 0 –j 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –j<br>0 0 0 +1 0 0 0 –j 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 –1 0 0 0 –j 0 0 0 –j 0 0 0<br>–1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 +1 0 0 0 +j 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 –j 0<br>0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 +1 0 0 0 +j 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0<br>–1 0 0 0 +j 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 +1 0 0 0 +j 0 0 0 +j 0 0 0 +1 0<br>0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 –1 0 0 0 –j 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 +j 0 0 0<br>+1 0 0 0 +1 0 0 0 +j 0 0 0 –1 0 0 0 –j 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 +1 0<br>0 0 –j 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 –1 0 0 |
| The sequence $EDMGS^{5}_{left,804}(n)$, to be transmitted from left to right, up to down |
| 0 0 0 0 0 +1 0 0 0 +1 0 0 0 –j 0 0 0 +j 0 0 0 –j 0 0 0 –1 0 0 0 +j 0 0 0 +j 0 0 0 –1 0 0 0 –j 0 0 0 +1 0 0 0 +1 0 0 0 –j 0<br>0 0 +j 0 0 0 –j 0 0 0 +1 0 0 0 –j 0 0 0 –j 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 –j 0 0 0 +j 0 0 0 –j 0 0 0 –1 0 0 0 +j<br>0 0 0 +j 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 +j 0 0 0 –j 0 0 0 +j 0 0 0 –1 0 0 0 +j 0 0 0 +j 0 0 0 –1 0 0 0 –j 0 0 0<br>+1 0 0 0 +1 0 0 0 –j 0 0 0 +j 0 0 0 –j 0 0 0 –1 0 0 0 +j 0 0 0 +j 0 0 0 –1 0 0 0 –j 0 0 0 +1 0 0 0 +1 0 0 0 –j 0 0 0 +j 0 0<br>0 –j 0 0 0 +1 0 0 0 –j 0 0 0 –j 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 –j 0 0 0 +j 0 0 0 –j 0 0 0 –1 0 0 0 +j 0 0 0 +j 0<br>0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 +j 0 0 0 –j 0 0 0 +j 0 0 0 –1 0 0 0 +j 0 0 0 +j 0 0 0 –1 0 0 0 –j 0 0 0 –j 0 0 0 –j<br>0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 –1 0 0 0 –j 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0<br>0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 +1 0 0 0 –j 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +j<br>0 0 0 –1 0 0 0 +j 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 –1 0 0 0 +j 0 0 0 +j 0 0 0<br>+1 0 0 0 –1 0 0 0 +1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 +1 0 0 0 +j 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0<br>0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 –1 0 0 0 +j 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0<br>+1 0 0 0 –j 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 +1 0 0 0 –j 0 0 0 –j 0 0 0 –1 0 0<br>0 +1 0 0 0 –1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 –1 0 0 0 –j 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1<br>0 0 0 –1 0 0 0 –j 0 0 0 +1 0 0 0 –j 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 –1 0 0 0<br>+j 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 –1 0 0 |


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**Table 28-109—The sequence $EDMGS^{i_{STS}}_{left,804}(n)$ (11ay) *(continued)***

| |
|---|
| The sequence $EDMGS^{6}_{left,804}(n)$, to be transmitted from left to right, up to down |
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**Table 28-110—The sequence $EDMGS^{i_{STS}}_{right,804}(n)$ (11ay)**

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| The sequence $EDMGS^{1}_{right,804}(n)$, to be transmitted from left to right, up to down |
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**Table 28-110—The sequence $EDMGS^{i_{STS}}_{right,804}(n)$ (11ay) *(continued)***

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| The sequence $EDMGS^{4}_{right,804}(n)$, to be transmitted from left to right, up to down |
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| The sequence $EDMGS^{5}_{right,804}(n)$, to be transmitted from left to right, up to down |
| 0 0 +1 0 0 0 +1 0 0 0 –j 0 0 0 +j 0 0 0 –j 0 0 0 –1 0 0 0 +j 0 0 0 +j 0 0 0 –1 0 0 0 –j 0 0 0 +1 0 0 0 +1 0 0 0 –j 0 0 0 +j<br>0 0 0 –j 0 0 0 +1 0 0 0 –j 0 0 0 –j 0 0 0 +1 0 0 0 +j 0 0 0 –1 0 0 0 –1 0 0 0 +j 0 0 0 –j 0 0 0 +j 0 0 0 +1 0 0 0 –j 0 0 0 –<br>j 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 –j 0 0 0 +j 0 0 0 –j 0 0 0 +1 0 0 0 –j 0 0 0 –j 0 0 0 +1 0 0 0 +j 0 0 0 –j 0 0 0<br>–j 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 –1 0 0 0 –j 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 –1 0<br>0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 +1 0 0 0 +j 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –<br>j 0 0 0 +1 0 0 0 –j 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 +1 0 0 0 –j 0 0 0 –j 0 0<br>0 –1 0 0 0 +1 0 0 0 –1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 –1 0 0 0 –j 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j<br>0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 +1 0 0 0 +j 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0<br>+1 0 0 0 –j 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –j 0<br>0 0 +j 0 0 0 –j 0 0 0 –1 0 0 0 +j 0 0 0 +j 0 0 0 –1 0 0 0 –j 0 0 0 +1 0 0 0 +1 0 0 0 –j 0 0 0 +j 0 0 0 –j 0 0 0 +1 0 0 0 –j<br>0 0 0 –j 0 0 0 +1 0 0 0 +j 0 0 0 –1 0 0 0 –1 0 0 0 +j 0 0 0 –j 0 0 0 +j 0 0 0 +1 0 0 0 –j 0 0 0 –j 0 0 0 +1 0 0 0 +j 0 0 0<br>+1 0 0 0 +1 0 0 0 –j 0 0 0 +j 0 0 0 –j 0 0 0 +1 0 0 0 –j 0 0 0 –j 0 0 0 +1 0 0 0 +j 0 0 0 +j 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0<br>0 +1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 +1 0 0 0 +j 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1<br>0 0 0 +j 0 0 0 –1 0 0 0 –j 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 –1 0 0 0 +j 0 0 0<br>+j 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 –1 0 0 0 0 0 |
| The sequence $EDMGS^{6}_{right,804}(n)$, to be transmitted from left to right, up to down |
| 0 0 –1 0 0 0 –1 0 0 0 +j 0 0 0 –j 0 0 0 +j 0 0 0 +1 0 0 0 –j 0 0 0 –j 0 0 0 +1 0 0 0 +j 0 0 0 –1 0 0 0 –1 0 0 0 +j 0 0 0 –j<br>0 0 0 +j 0 0 0 –1 0 0 0 +j 0 0 0 +j 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 +j 0 0 0 –j 0 0 0 +j 0 0 0 +1 0 0 0 –j 0 0 0 –<br>j 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 –j 0 0 0 +j 0 0 0 –j 0 0 0 +1 0 0 0 –j 0 0 0 –j 0 0 0 +1 0 0 0 +j 0 0 0 +j 0 0 0<br>+j 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 +1 0 0 0 +j 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 +1 0<br>0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 –1 0 0 0 +j 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0<br>–j 0 0 0 +1 0 0 0 –j 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 +1 0 0 0 +j 0 0 0 +j 0 0<br>0 +1 0 0 0 –1 0 0 0 +1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 +1 0 0 0 +j 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j<br>0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 –1 0 0 0 +j 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0<br>+1 0 0 0 –j 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +j 0<br>0 0 –j 0 0 0 +j 0 0 0 +1 0 0 0 –j 0 0 0 –j 0 0 0 +1 0 0 0 +j 0 0 0 –1 0 0 0 –1 0 0 0 +j 0 0 0 –j 0 0 0 +j 0 0 0 –1 0 0 0 +j<br>0 0 0 +j 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 +j 0 0 0 –j 0 0 0 +j 0 0 0 +1 0 0 0 –j 0 0 0 –j 0 0 0 +1 0 0 0 +j 0 0 0<br>+1 0 0 0 +1 0 0 0 –j 0 0 0 +j 0 0 0 –j 0 0 0 +1 0 0 0 –j 0 0 0 –j 0 0 0 +1 0 0 0 +j 0 0 0 –j 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0<br>0 –1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 –1 0 0 0 –j 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1<br>0 0 0 –j 0 0 0 +1 0 0 0 –j 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 –1 0 0 0 +j 0 0 0<br>+j 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 –1 0 0 0 0 0 |

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**Table 28-110—The sequence $EDMGS^{i_{STS}}_{right,804}(n)$ (11ay) *(continued)***

| |
|---|
| The sequence $EDMGS^{7}_{right,804}(n)$, to be transmitted from left to right, up to down |
| 0 0 –1 0 0 0 –1 0 0 0 +j 0 0 0 –j 0 0 0 +j 0 0 0 +1 0 0 0 –j 0 0 0 –j 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 –j 0 0 0 +j<br>0 0 0 –j 0 0 0 +1 0 0 0 –j 0 0 0 –j 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 –j 0 0 0 +j 0 0 0 –j 0 0 0 –1 0 0 0 +j 0 0 0<br>+j 0 0 0 –1 0 0 0 –j 0 0 0 +1 0 0 0 +1 0 0 0 –j 0 0 0 +j 0 0 0 –j 0 0 0 +1 0 0 0 –j 0 0 0 –j 0 0 0 +1 0 0 0 +j 0 0 0 +j 0 0<br>0 +j 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 +1 0 0 0 –j 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 –1<br>0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 +1 0 0 0 –j 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0<br>+j 0 0 0 –1 0 0 0 –j 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 +1 0 0 0 +j 0 0 0 +j 0 0<br>0 +1 0 0 0 –1 0 0 0 +1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 +1 0 0 0 –j 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j<br>0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 +1 0 0 0 –j 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0<br>–1 0 0 0 –j 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 +1 0 0 0 –1 0 0 0 –1 0 0 0 +j 0<br>0 0 –j 0 0 0 +j 0 0 0 +1 0 0 0 –j 0 0 0 –j 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 –j 0 0 0 +j 0 0 0 –j 0 0 0 +1 0 0 0 –j<br>0 0 0 –j 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 –j 0 0 0 +j 0 0 0 –j 0 0 0 –1 0 0 0 +j 0 0 0 +j 0 0 0 –1 0 0 0 –j 0 0 0<br>+1 0 0 0 +1 0 0 0 –j 0 0 0 +j 0 0 0 –j 0 0 0 +1 0 0 0 –j 0 0 0 –j 0 0 0 +1 0 0 0 +j 0 0 0 –j 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0<br>0 –1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 –1 0 0 0 +j 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1<br>0 0 0 +j 0 0 0 –1 0 0 0 +j 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 +1 0 0 0 +j 0 0 0<br>+j 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 –1 0 0 0 0 0 |
| The sequence $EDMGS^{8}_{right,804}(n)$, to be transmitted from left to right, up to down |
| 0 0 +1 0 0 0 +1 0 0 0 –j 0 0 0 +j 0 0 0 –j 0 0 0 –1 0 0 0 +j 0 0 0 +j 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 +j 0 0 0 –j<br>0 0 0 +j 0 0 0 –1 0 0 0 +j 0 0 0 +j 0 0 0 –1 0 0 0 –j 0 0 0 +1 0 0 0 +1 0 0 0 –j 0 0 0 +j 0 0 0 –j 0 0 0 –1 0 0 0 +j 0 0 0<br>+j 0 0 0 –1 0 0 0 –j 0 0 0 +1 0 0 0 +1 0 0 0 –j 0 0 0 +j 0 0 0 –j 0 0 0 +1 0 0 0 –j 0 0 0 –j 0 0 0 +1 0 0 0 +j 0 0 0 –j 0 0<br>0 –j 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 –1 0 0 0 +j 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 +1<br>0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 –1 0 0 0 –j 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0<br>0 +j 0 0 0 –1 0 0 0 –j 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 +1 0 0 0 –j 0 0 0 –j 0<br>0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 –1 0 0 0 +j 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0<br>+j 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 –1 0 0 0 –j 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +j 0<br>0 0 –1 0 0 0 –j 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 +1 0 0 0 +1 0 0 0 +1 0 0 0 –<br>j 0 0 0 +j 0 0 0 –j 0 0 0 –1 0 0 0 +j 0 0 0 +j 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 +j 0 0 0 –j 0 0 0 +j 0 0 0 –1 0 0 0<br>+j 0 0 0 +j 0 0 0 –1 0 0 0 –j 0 0 0 +1 0 0 0 +1 0 0 0 –j 0 0 0 +j 0 0 0 –j 0 0 0 –1 0 0 0 +j 0 0 0 +j 0 0 0 –1 0 0 0 –j 0 0<br>0 +1 0 0 0 +1 0 0 0 –j 0 0 0 +j 0 0 0 –j 0 0 0 +1 0 0 0 –j 0 0 0 –j 0 0 0 +1 0 0 0 +j 0 0 0 +j 0 0 0 +j 0 0 0 +1 0 0 0 –1 0<br>0 0 +1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 +1 0 0 0 –j 0 0 0 –j 0 0 0 –1 0 0 0 +1 0 0 0 –1 0 0 0 –j 0 0 0 –1 0 0 0 –<br>1 0 0 0 –j 0 0 0 +1 0 0 0 +j 0 0 0 +j 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 –j 0 0 0 –1 0 0 0 –1 0 0 0 –j 0 0 0 +1 0 0 0 +j 0 0<br>0 +j 0 0 0 +1 0 0 0 –1 0 0 0 +1 0 0 0 +j 0 0 0 +1 0 0 0 +1 0 0 0 +j 0 0 0 –1 0 0 0 0 0 |

## 28.11.2 EDMG-CEF sequence

### 28.11.2.1 General

For transmissions over a 2.16 GHz (or 2.16+2.16 GHz), 4.32 GHz (or 4.32+4.32 GHz), 6.48 GHz, and 8.64 GHz channel, the EDMG OFDM mode uses the pairs of $Seq^{i}_{left,N}$ and $Seq^{i}_{right,N}$ sequences of length $N$ = 176, 385, 595, and 804, respectively, to define the EDMG-CEF field in frequency domain. The $i^{th}$ index defines the space-time stream or the transmit chain number.

### 28.11.2.2 Sequences definition

The sequence pairs $Seq^{i}_{left,N}$ and $Seq^{i}_{right,N}$ of length $N$ = 176, 385, 595, and 804 use {±1, ±*j*} symbols alphabet and are defined in Table 28-111 (The sequence Seqileft,176(k)(11ay)) through Table 28-118 (The sequence Seqiright,804(k)(11ay)).


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**Table 28-111—The sequence $Seq^{i}_{left,176}(k)$(11ay)**

| |
|---|
| The sequence $Seq^{1}_{left,176}(k)$, to be transmitted from left to right, up to down |
| –1 –j –j +1 +j –j +1 –1 +1 –j –1 +1 –1 +1 –j –1 –1 +j +j +j –1 –1 +1 +j +j –1 –j +j –1 +1 –1 +j +1 +1 –1 +1 –j –1 –1 +j +j +j –1 –1 +j –1 –1 –j +1 –1 –j +j –j –1 +j –j +j –j –1 +j +j +1 +1 +1 +j +j +j –1 –1 –j +1 –1 –j +j –j –1 +j +j –j +j +1 –j –j –1 –1 –1 –j –j +j –1 –1 –j +1 –1 –j +j –j –1 +j –j +j –j –1 +j +j +1 +1 +1 +j +j –j +1 +1 +j –1 +1 +j –j +j +1 –j –j +j –j –1 +j +j +1 +1 +1 +j +j –1 –j –j +1 +j –j +1 –1 +1 –j –1 +1 –1 +1 –j –1 –1 +j +j +j –1 –1 –1 –j –j +1 +j –j +1 –1 +1 –j –1 –1 +1 –1 +j +1 +1 –j –j –j +1 +1 |
| The sequence $Seq^{2}_{left,176}(k)$, to be transmitted from left to right, up to down |
| +1 –j –j –1 +j –j –1 +1 –1 –j +1 +1 –j –j –1 +j –j –1 +1 –1 –j +1 +j +1 +1 –j –1 +1 –j +j –j +1 +j –j –1 –1 +j +1 –1 +j –j +j –1 –j +1 –1 +1 +j –1 –1 –j –j –j –1 –1 +1 –1 +1 +j –1 –1 –j –j –j –1 –1 +j –j +j –1 –j –j +1 +1 +1 –j –j –j +j –j +1 +j +j –1 –1 –1 +j +j +j +1 +1 –j –1 +1 –j +j –j +1 +j –j –1 –1 +j +1 –1 +j –j +j –1 –j –1 +j +j +1 –j +j +1 –1 +1 +j –1 –1 +j +j +1 –j +j +1 –1 +1 +j –1 –j +j –j +1 +j +j –1 –1 –1 +j +j +j –j +j –1 –j –j +1 +1 +1 –j –j +1 –1 +1 +j –1 –1 –j –j –j –1 –1 +1 –1 +1 +j –1 –1 –j –j –j –1 –1 |
| The sequence $Seq^{3}_{left,176}(k)$, to be transmitted from left to right, up to down |
| +1 +1 +j +j +j +1 +1 –j –1 +1 –1 +1 +1 +j +j +j +1 +1 –j –1 +1 –1 +j +j –1 –1 –1 +j +j +1 –j +j –j –j –j +1 +1 +1 –j –j –1 +j –j +j +j +j –1 –1 –1 +j +j +1 –j +j –j +j +j –1 –1 +j +j +1 –j +j –j +1 +1 +j +j +j +1 +1 –j –1 +1 –1 –1 –1 –j –j –j –1 –1 +j +1 –1 +1 –j –1 +j –j +j –1 +1 +j –1 –1 –j +j +1 –j +j –j +1 –1 –j +1 +1 +j +1 –j –1 +1 –1 –j +j –1 –j –j +1 +1 –j –1 +1 –1 –j +j –1 –j –j +1 –1 +j +1 –1 +1 +j –j +1 +j +j –1 –j –1 +j –j +j –1 +1 +j –1 –1 –j –j –1 +j –j +j –1 +1 +j –1 –1 –j |
| The sequence $Seq^{4}_{left,176}(k)$, to be transmitted from left to right, up to down |
| –1 +j +j +1 –j +j +1 –1 +1 +j –1 –j –1 –1 +j +1 –1 +j –j +j –1 –j +j –j +j –1 –j –j +1 +1 +1 –j –j –1 +1 –1 –j +1 +1 +j +j +j +1 +1 –1 +j +j +1 –j +j +1 –1 +1 +j –1 –j –1 –1 +j +1 –1 +j –j +j –1 –j –j +j –j +1 +j +j –1 –1 –1 +j +j +1 –1 +1 +j –1 –j –j –j +1 –1 +j +1 –j –j +1 –1 +j +1 –1 +1 +j –j +1 +j +j –1 –j –1 +j –j +j –1 –j –j +j –j +1 +j +j –1 –1 –1 +j +j –1 +1 –1 –j +1 +1 +j –j +1 +j +j +1 –j +j –1 +1 –j +j +1 +1 –j +1 –j +j –j +1 +j –j +j –j +1 +j +j –1 –1 –1 +j +j –1 +1 –1 –j +1 +1 +j +j +j +1 +1 |
| The sequence $Seq^{5}_{left,176}(k)$, to be transmitted from left to right, up to down |
| +1 –1 +1 –j –1 –1 +j +j +j –1 –1 +1 +j +j –1 –j +j –1 +1 –1 +j +1 +1 –1 +1 –j –1 –1 +j +j +j –1 –1 +1 +j +j –1 –j +j –1 +1 –1 +j +1 +j –j +j +1 –j –j –1 –1 –1 –j –j +j –1 –1 –j +1 –1 –j +j –j –1 +j –j +j –j –1 +j +j +1 +1 +1 +j +j –j +1 +1 +j –1 +1 +j –j +j +1 –j –j +j –j –1 –1 +j +j +1 –1 –j +1 –1 –j +j –j –1 +j +j –j +j +1 –1 –j –j +1 +1 –j –j –1 –1 –1 –j –j –j +1 +1 –j –1 +1 +j –j –1 +1 –j –1 –1 +j –1 –1 +1 –j –1 –1 +1 –j –1 –1 +j +j +j –1 –1 –1 –j –j +1 +j –j +1 –1 +1 –j –1 |
| The sequence $Seq^{6}_{left,176}(k)$, to be transmitted from left to right, up to down |
| +1 +j –1 +1 –1 +j –j –1 +j +j +1 –1 –j +1 –1 +1 –j +j +1 –j –j –1 +j –1 –j +j –j –1 +1 –j –1 –1 +j –j +1 +j –j +j +1 –1 +j +1 +1 –j +j +j +1 +1 +1 +j +j –1 –j +j –j +j +j +1 +1 +1 +j +j –1 –j +j –j +j +1 –1 –1 +j +j +j –1 –1 –j +1 –1 +1 +j –1 –j +j –j –1 +1 +j –1 +1 –1 +j –j –1 +j +j +1 –1 –1 +j +1 –1 +1 +j –j –1 +j +j +1 –1 +1 –j –1 +j +j +1 +1 +1 +j +j –1 –j +j –j –1 –1 –j +1 +j +j –j –1 –1 –1 –j –j +1 +j –j +1 –1 +1 –j +1 +j +j +j –1 –1 –1 –j –j –j –1 –1 –1 –j –j +1 +j –j +j |
| The sequence $Seq^{7}_{left,176}(k)$, to be transmitted from left to right, up to down |
| –j –1 +j –j +j –1 +1 +j –1 –1 –j +j +j –1 –1 –1 +j +j +1 –j +j –j +1 –j –1 +1 –1 –j +j –1 –j –j +1 –1 –1 –j –j –j –1 –1 +j +1 –1 +1 +1 –j –1 +1 –1 –j +j –1 –j –j +1 –1 –1 –j –j –j –1 –1 +j +1 –1 +1 –j –1 +j –j +j –1 +1 +j –1 –1 –j +j +j –1 –1 –1 +j +j +1 –j +j –j +1 –j –1 +1 –j –1 +j –j +j +1 –1 +1 +j –j +1 +1 +j +j +1 –j –j +1 +1 +j +j +j –1 –1 –1 +j +j +1 –j +j –j +1 –j –1 +1 –j +1 –j +j –1 –1 –1 –j –j –j –1 –1 +j +1 –1 +1 +j –j +1 +j +j +j –1 –j +j –j –1 –1 –j –j +1 +j –j +j –1 –1 –1 –j –j –j –1 –1 +j +1 –1 +1 |
| The sequence $Seq^{8}_{left,176}(k)$, to be transmitted from left to right, up to down |
| +1 –1 +1 +j –1 –1 –j –j –j –1 –1 +j –j +j –1 –j –j +1 +1 +1 –j –j –j +j –j +1 +j +j –1 –1 –1 +j +j +1 –1 +1 +j –1 –1 –j –j –j –1 –1 +1 –1 +1 +j –1 –1 –j –j –j –1 –1 +j +1 –1 +1 +j –1 –1 –j –j –j –1 –1 +j +1 +1 –j –1 +1 –j +j –1 +1 –j –1 –1 +j +j +1 –j +j +1 –1 +1 +j –1 –1 –j –j –j –1 –1 +j +1 –j +j –j +1 –j –1 +1 –j +1 +1 –j –1 –1 +j –j +1 –1 +1 –j –1 –1 –j +1 –1 +j –j +j –1 –j –1 –1 –j +1 –1 +j –j +j –1 –j |

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**Table 28-112—The sequence $Seq^{i}_{right,176}(k)$(11ay)**

| |
|---|
| The sequence $Seq^{1}_{right,176}(k)$, to be transmitted from left to right, up to down |
| –1 –j –j +1 +j –j +1 –1 +1 –j –1 +1 –1 +1 –j –1 –1 +j +j +j –1 –1 +1 +j +j –1 –j +j –1 +1 –1 +j +1 +1 –1 +1 –j –1 –1 +j +j +j –1 –1 +j –1 –1 –j +1 –1 –j +j –j –1 +j –j +j –j –1 +j +j +1 +1 +1 +j +j +j –1 –1 –j +1 –1 –j +j –j –1 +j +j –j +j +1 –j –j –1 –1 –1 –j –j –j +1 +1 +j –1 +1 +j –j +j +1 –j +j –j +j +1 –j –j –1 –1 –1 –j –j +j –1 –1 –j +1 –1 –j +j –j –1 +j +j –j +j +1 –j –j –1 –1 –1 –j –j +1 +j +j –1 –j +1 –1 +j +1 –1 +1 –1 +j +1 +1 –j –j –j +1 +1 +1 +j +j –1 –j +j –1 +1 –1 +j +1 +1 –j –j –1 –1 –j –j +1 +j +j –1 –1 –1 +j +1 +1 –1 +1 –j –1 –1 +j +j +j –1 –1 |
| The sequence $Seq^{2}_{right,176}(k)$, to be transmitted from left to right, up to down |
| –1 +j +j +1 –j +j +1 –1 +1 +j –1 –1 +j +j +1 –j +j +1 –1 +1 +j –1 +j +1 +1 –j –1 +1 –j +j –j +1 +j –j –1 –1 +j +1 –1 +j –j +j –1 –j –1 +1 –1 –j +1 +1 +j +j +j +1 +1 –1 +1 –1 –j +1 +1 +j +j +j +1 +1 +j –j +j –1 –j –j +1 +1 +1 –j –j –j +j –j +1 +j +j –1 –1 –1 +j +j –j –1 –1 +j +1 –1 +j –j +j –1 –j +j +1 +1 –j –1 +1 –j +j –j +1 +j –1 +j +j +1 –j +j +1 –1 +1 +j –1 –1 +j +j +1 –j +j +1 –1 +1 +j –1 +j –j +j –1 –j –j +1 +1 +1 –j –j –j +j –j –1 –1 +1 –1 +1 +j –1 –1 –j –j –j –1 –1 |
| The sequence $Seq^{3}_{right,176}(k)$, to be transmitted from left to right, up to down |
| –1 –1 –j –j –j –1 –1 +j +1 –1 +1 –1 –1 –j –j –j –1 –1 +j +1 –1 +1 –j –j +1 +1 +1 –j –j –1 +j –j +j +j +j –1 –1 –1 +j +j +1 –j +j –j +j +j –1 –1 –1 +j +j +1 –j +j –j +j +j –1 –1 –1 +j +j +1 –j +j –j +j +1 +1 +j +j +j +1 +1 –j –1 +1 –1 –1 –1 –j –j –j –1 –1 +j +1 –1 +1 +j +1 –j +j –j +1 –1 –j +1 +1 +j –j –1 +j –j +j –1 +1 +j –1 –1 –j –1 +j +1 –1 +1 +j –j +1 +j +j –1 +1 –j –1 +1 –1 –j +j –1 –j –j +1 –1 +j +1 –1 +1 +j –j +1 +j +j –1 –j –1 +j –j +j –1 +1 +j –1 –1 –j –j –j –1 +j –j +j –1 +1 +j –1 –1 –j |
| The sequence $Seq^{4}_{right,176}(k)$, to be transmitted from left to right, up to down |
| +1 –j –j –1 +j –j –1 +1 –1 –j +1 –j –1 –1 +j +1 –1 +j –j +j –1 –j –j +j –j +1 +j +j –1 –1 –1 +j +j –1 +1 –1 –j +1 +1 +j +j +j +1 +1 +1 –j –j –1 +j –j –1 +1 –1 –j +1 –j –1 –1 +j +1 –1 +j –j +j –1 –j +j –j +j –1 –j –j +1 +1 +1 –j –j +1 –1 +1 +j –1 –1 –j –j –j –1 –1 +j +j +1 –j +j –1 –1 +j –1 +j –j +j –1 –j +j –j +1 +1 –j –1 +j –j +j –1 –j +j –j +j –1 –j –j +1 +1 +1 –j –j –1 +1 –1 –j +1 +1 +j +j +j +1 +1 +1 –j –j –1 +j –j +j +1 –j –j –1 +1 –1 –j +1 +j +1 +1 –j –1 +1 –j +j –j +1 +j +j –j +j –1 –j –j +1 +1 +1 –j –j –1 +1 –1 –j +1 +1 +j +j +j +1 +1 |
| The sequence $Seq^{5}_{right,176}(k)$, to be transmitted from left to right, up to down |
| –1 +1 –1 +j +1 +1 –j –j –j +1 +1 –1 –j –j +1 +j –j +1 –1 +1 –j –1 –1 +1 –1 +j +1 +1 –j –j –j +1 +1 –1 –j –j +1 +j –j +1 –1 +1 –j –1 +j –j +j +1 –j –j –1 –1 –1 –j –j +j –1 –1 –j +1 –1 –j +j –j –1 +j –j +j –j –1 +j +j +1 +1 +1 +j +j –j +1 +1 +j –1 +1 +j –j +j +1 –j +j –j +j +1 –j –j –1 –1 –1 –j –j –j +1 +1 +j –1 +1 +j –j +j +1 –j +j –j –1 +j +j +1 +1 +1 +j +j +j –1 –1 –j +1 –1 –j +j –j –1 +j +1 –1 +1 +j –j +1 +j +j –1 +1 –j –1 +1 –1 +1 –j –1 –1 +j +j +j –1 –1 –1 –j –j +1 +j –j +1 –1 +1 –j –1 |
| The sequence $Seq^{6}_{right,176}(k)$, to be transmitted from left to right, up to down |
| –1 –j +1 –1 +1 –j +j +1 –j –j –1 +1 +j –1 +1 –1 +j –j –1 +j +j +1 +j –1 –j +j –j –1 +1 –j –1 –1 +j –j +1 +j –j +j +1 –1 +j +1 +1 –j –j –j –1 –1 –1 –j –j +1 +j –j +j –j –j –1 –1 –1 –j –j +1 +j –j +j –1 –1 +j +j +j –1 –1 –j +1 –1 +1 –1 –1 +j +j +j –1 –1 –j +1 –1 +1 –j +1 +j –j +j +1 –1 +j +1 +1 –j –j +1 +j –j +1 –1 +j –j +1 –1 +j –j +j –1 +j +j +1 +1 +j –1 +1 –1 +j –j –1 +j +j +1 +1 +1 –j –j –1 +j –j +j –1 –1 +j –1 +j –j –j –j –1 –1 –1 –j –j +1 +j –j +1 –1 +j –j |
| The sequence $Seq^{7}_{right,176}(k)$, to be transmitted from left to right, up to down |
| +j +1 –j +j –j +1 –1 –j +1 +1 +j –j –j +1 +1 +1 –j –j –1 +j –j +j –1 +j +1 –1 +1 +j –j +1 +j +j –1 +1 +1 +j +j +j +1 +1 –j –1 +1 –1 +1 –j –1 +1 –1 –j +j –1 –j –j +1 –1 –1 –j –j –j –1 –1 +j +1 –1 +1 –j –1 +j –j +j –1 +1 +j –1 –1 –1 +j +j +1 –j +j –j –1 +j +1 –1 +1 +j –j +1 +j +j –1 –1 –j +1 –1 +1 +j –j +1 +j +j +j –1 –1 –1 +j +j +1 –j +j –j +j +1 –j +j –j +1 –1 –j +1 +1 +j +j +j –1 –1 –1 +j +j +1 –j +j –j +j +1 –1 +1 +j –j +1 +j +j –1 –1 –1 –j –j –j –1 –1 +j +1 –1 +1 |
| The sequence $Seq^{8}_{right,176}(k)$, to be transmitted from left to right, up to down |
| –1 +1 –1 –j +1 +1 +j +j +j +1 +1 +j –j +j –1 –j –j +1 +1 +1 –j –j +j –j +j –1 –j –j +1 +1 +1 –j –j +1 –1 +1 +j –1 –1 –j –j –j –1 –1 +1 –1 –1 +1 –j +1 +1 +j +j +j +1 +1 +j –j +j –j +1 +j +j +j –1 –1 –1 +j +j +1 –1 +1 +j –1 –1 –j –j –j –1 –1 –j –1 –1 +j +1 –1 +j –j +j –1 –j –j –1 –1 +j +1 –1 +j –j +j –1 –j +1 –j –j –1 +j –j –1 +1 –1 –j +1 –1 +j +j +1 –j –j +1 –1 +j –j +j –1 –j +1 –1 +1 +j –1 –j –1 –1 +j +1 –1 +j –j +j –1 –j |



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**Table 28-113—The sequence $Seq^{i}_{left,385}(k)$(11ay)**

| |
|---|
| The sequence $Seq^{1}_{left,385}(k)$, to be transmitted from left to right, up to down |
| –1 –1 +j –1 +1 +1 –1 +j +1 +j +j +j –j –j –1 –j +j +j –j +1 –j +1 +1 +1 –1 –1 +j –1 +1 +1 –1 +j +1 +j +j +j –j +j +1 +j<br>–j –j +j –1 +j –1 –1 –1 +1 +1 –j +1 –1 –1 +1 –j –1 –j –j –j +j +j +1 +j –j –j +j –1 +j –1 –1 –1 +1 –1 +j –1 +1 +1 –1 +j<br>+1 +j +j +j –j +j +1 +j –j –j +j –1 +j –1 –1 –1 +1 –1 +j –1 +1 +1 –1 +j +1 +j +j +j –j –j –1 –j +j +j –j +1 –j +1 +1 +1<br>–1 –1 +j –1 +1 +1 –1 +j +1 +j +j +j –j +j +1 +j –j –j +j –1 +j –1 –1 –1 +1 –1 +j –1 +1 +1 –1 +j +1 +j +j +j –j –j –1 –<br>j +j +j –j +1 –j +1 +1 +1 –1 +1 –j +1 –1 –1 +1 –j –1 –j –j –j +j –j –1 –j +j +j –j +1 –j +1 +1 +1 –1 –j –1 –j +j +j –j –<br>1 +j –1 –1 –1 +1 +1 –j +1 –1 –1 +1 +j +1 +j +j +j –j –j –1 –j +j +j –j –1 +j –1 –1 –1 +1 –1 +j –1 +1 +1 –1 –j –1 –j –j<br>–j +j +j +1 +j –j –j +j +1 –j +1 +1 +1 –1 –1 +j –1 +1 +1 –1 –j –1 –j –j –j +j –j –1 –j +j +j –j –1 +j –1 –1 –1 +1 –1 +j<br>–1 +1 +1 –1 –j –1 –j –j –j +j +j +1 +j –j –j +j +1 –j +1 +1 +1 –1 –1 +j –1 +1 +1 –1 –j –1 –j –j –j +j +j +1 +j –j –j +j<br>+1 –j +1 +1 +1 –1 +1 –j +1 –1 –1 +1 +j +1 +j +j +j –j +j +1 +j –j –j +j +1 –j +1 +1 +1 –1 –1 +j –1 +1 +1 –1 –j –1 –j<br>–j –j +j –j –1 –j +j +j –j –1 +j –1 –1 –1 +1 –1 +j –1 +1 +1 –1 –j –1 –j –j –j +j |
| The sequence $Seq^{2}_{left,385}(k)$, to be transmitted from left to right, up to down |
| –j +1 –1 –1 –1 +j –1 –j +j +j +j +1 +j +j –j –j +j +1 +j –1 +1 +1 –1 +j –1 –1 +1 +1 +1 –j +1 +j –j –j –j –1 –j –j +j +j<br>–j –1 –j +1 –1 –1 +1 –j +1 +1 –1 –1 –1 +j –1 –j +j +j +j +1 +j +j –j –j +j +1 +j –1 +1 +1 –1 +j –1 +1 –1 –1 –1 +j –1<br>–j +j +j +j +1 +j +j –j –j +j +1 +j –1 +1 +1 –1 +j –1 +1 –1 –1 –1 +j –1 –j +j +j +j +1 +j +j –j –j +j +1 +j –1 +1 +1 –1<br>+j –1 +1 –1 –1 –1 +j –1 –j +j +j +j +1 +j +j –j –j +j +1 +j –1 +1 +1 –1 +j –1 +1 –1 –1 –1 +j –1 –j +j +j +j +1 +j +j –j<br>–j +j +1 +j –1 +1 +1 –1 +j –1 –1 +1 +1 +1 –j +1 +j –j –j –j –1 –j –j +j +j –j –1 –j +1 –1 –1 +1 –j +1 +j –j –j –j –1 –j<br>–1 +1 +1 +1 –j +1 –1 +1 +1 –1 +j –1 +j –j –j +j +1 +j –j +j +j +j +1 +j +1 –1 –1 –1 +j –1 +1 –1 –1 +1 –j +1 –j +j +j<br>–j –1 –j +j –j –j –j –1 –j –1 +1 +1 +1 –j +1 –1 +1 +1 –1 +j –1 +j –j –j +j +1 +j +j –j –j –j –1 –j –1 +1 +1 +1 –j +1 –1<br>+1 +1 –1 +j –1 +j –j –j +j +1 +j –j +j +j +j +1 +j +1 –1 –1 –1 +j –1 +1 –1 –1 +1 –j +1 –j +j +j –j –1 –j –j +j +j +j +1<br>+j +1 –1 –1 –1 +j –1 +1 –1 –1 +1 –j +1 –j +j +j –j –1 –j –j +j +j +j +1 +j +1 –1 –1 –1 +j –1 +1 –1 –1 +1 –j +1 –j +j +j<br>–j –1 –j +j –j –j –j –1 –j –1 +1 +1 +1 –j +1 –1 +1 +1 –1 +j –1 +j –j –j +j +1 +j |
| The sequence $Seq^{3}_{left,385}(k)$, to be transmitted from left to right, up to down |
| +1 –1 +j –1 +1 –j +1 +j +1 +j –j –1 –j +1 –j +1 –1 +j –1 +j +1 +j –j –1 –j +1 –j +1 –1 +j –1 +j +1 +j –j –1 –j –1 +j –<br>1 +1 –j +1 +j +1 +j –j –1 –j +1 +1 –1 –1 –1 +1 –j –j +j +j +j –j +1 +1 –1 –1 –1 +1 +j +j –j –j –j +j –1 –1 +1 +1 +1 –1<br>–j –j +j +j +j –j –1 –1 +1 +1 +1 –1 +j +j –j –j –j +j +j +1 +j –j –1 –j +1 –j +1 –1 +j –1 –j –1 –j +j +1 +j +1 –j +1 –1 +j<br>–1 +j +1 +j –j –1 –j –1 +j –1 +1 –j +1 –j –1 –j +j +1 +j –1 +j –1 +1 –j +1 –j –j +j +j +j –j –1 –1 +1 +1 +1 –1 –j –j +j<br>+j +j –j +1 +1 –1 –1 –1 +1 –j –j +j +j +j –j +1 +1 –1 –1 –1 +1 –j –j +j +j +j –j –1 –1 +1 +1 +1 –1 +j +1 +j +j +1 +j +1<br>–j +1 +1 –j +1 –j –1 –j –j –1 –j +1 –j +1 +1 –j +1 –j –1 –j –j –1 –j +1 –j +1 +1 –j +1 +j +1 +j +j +1 +j +1 –j +1 +1 –j<br>+1 –j –j +j –j –j +j –1 –1 +1 –1 –1 +1 –j –j +j –j –j +j +1 +1 –1 +1 +1 –1 +j +j –j +j +j –j –1 –1 +1 –1 –1 +1 +j +j –j<br>+j +j –j +1 +1 –1 +1 +1 –1 –1 +j –1 –1 +j –1 +j +1 +j +j +1 +j +1 –j +1 +1 –j +1 +j +1 +j +j +1 +j –1 +j –1 –1 +j –1<br>–j –1 –j –j –1 –j +1 –j +1 +1 –j +1 –j –1 –j –j –1 –j +1 +1 –1 +1 +1 –1 –j –j +j –j –j +j +1 +1 –1 +1 +1 –1 +j +j –j +j<br>+j –j +1 +1 –1 +1 +1 –1 +j +j –j +j +j –j +1 +1 –1 +1 +1 –1 –j –j +j –j –j +j |
| The sequence $Seq^{4}_{left,385}(k)$, to be transmitted from left to right, up to down |
| –1 –1 +j –1 +j +1 +j +1 +1 –1 –j –j +j –j –1 –j +1 –j +1 +j +j –j –1 –1 +1 +1 –j +1 –j –1 –j –1 –1 +1 +j +j –j +j +1 +j<br>–1 +j –1 –j –j +j +1 +1 –1 –j –1 –j –1 +j –1 –j –j +j –1 –1 +1 +1 –j +1 +j +1 +j +1 +1 –1 +j +j –j +j +1 +j +1 –j +1 +j<br>+j –j +1 +1 –1 –1 +j –1 –j –1 –j –1 –1 +1 –j –j +j –1 +j –1 +j +1 +j +1 +1 –1 –j –j +j –j –1 –j +1 –j +1 +j +j –j –1 –1<br>+1 –1 +j –1 +j +1 +j +1 +1 –1 –j –j +j –j –1 –j +1 –j +1 +j +j –j –1 –1 +1 +j +1 +j +1 –j +1 +j +j –j +1 +1 –1 –1 +j –<br>1 –j –1 –j –1 –1 +1 –j –j +j +j +1 +j +1 –j +1 +j +j –j +1 +1 –1 –1 +j –1 –j –1 –j –1 –1 +1 –j –j +j +j +1 +j –1 +j –1 –<br>j –j +j +1 +1 –1 –1 +j –1 +j +1 +j +1 +1 –1 –j –j +j +j +1 +j –1 +j –1 –j –j +j +1 +1 –1 –1 +j –1 +j +1 +j +1 +1 –1 –j<br>–j +j –1 +j –1 –j –1 –j –1 –1 +1 –j –j +j –j –1 –j –1 +j –1 –j –j +j –1 –1 +1 –1 +j –1 –j –1 –j –1 –1 +1 –j –j +j –j –1 –<br>j –1 +j –1 –j –j +j –1 –1 +1 +j +1 +j –1 +j –1 –j –j +j +1 +1 –1 –1 +j –1 +j +1 +j +1 +1 –1 –j –j +j –j –1 –j +1 –j +1<br>+j +j –j –1 –1 +1 +1 –j +1 –j –1 –j –1 –1 +1 +j +j –j +1 –j +1 +j +1 +j +1 +1 –1 +j +j –j +j +1 +j +1 –j +1 +j +j –j +1<br>+1 –1 –1 +j –1 –j –1 –j –1 –1 +1 –j –j +j –j –1 –j –1 +j –1 –j –j +j –1 –1 +1 |

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**Table 28-113—The sequence $Seq^{i}_{left,385}(k)$(11ay) *(continued)***

| |
|---|
| The sequence $Seq^{5}_{left,385}(k)$, to be transmitted from left to right, up to down |
| –j –1 +1 +1 –1 +1 +1 +j –j –j +j –j –j –j +j +j +j –j –j –1 +1 +1 +1 –1 –1 –1 +1 +1 +1 –1 –1 +j –j –j –j +j +j –j +j +j<br>–j +j +j –1 +1 +1 –1 +1 +1 +1 –1 –1 +1 –1 –1 +j –j –j +j –j –j +j –j –j –j +j +j –1 +1 +1 +1 –1 –1 +1 –1 –1 –1 +1 +1<br>+j –j –j –j +j +j +j –j –j +j –j –j –1 +1 +1 –1 +1 +1 –j +j +j –j +j +j +1 –1 –1 +1 –1 –1 +1 –1 –1 –1 +1 +1 +j –j –j –j<br>+j +j +j –j –j –j +j +j –1 +1 +1 +1 –1 –1 –1 +1 +1 –1 +1 +1 –j +j +j –j +j +j +j –j –j +j –j –j +1 –1 –1 +1 –1 –1 –1 +1<br>+1 +1 –1 –1 +j –j –j –j +j +j –j +j +j +j –j –j –1 +1 +1 +1 –1 –1 +1 –1 –1 +1 –1 –1 –j +j +j –j +j +j +1 –j +1 +1 –j +1<br>–j –1 –j –j –1 –j +j +1 +j –j –1 –j +1 –j +1 –1 +j –1 +1 –j +1 –1 +j –1 –j –1 –j +j +1 +j +j +1 +j +j +1 +j +1 –j +1 +1<br>–j +1 +1 –j +1 +1 –j +1 +j +1 +j +j +1 +j +j +1 +j –j –1 –j –1 +j –1 +1 –j +1 +1 –j +1 –1 +j –1 +j +1 +j –j –1 –j +j +1<br>+j +j +1 +j –1 +j –1 –1 +j –1 +j +1 +j +j +1 +j –1 +j –1 –1 +j –1 –1 +j –1 +1 –j +1 –j –1 –j +j +1 +j –j –1 –j +j +1 +j<br>+1 –j +1 –1 +j –1 +1 –j +1 +1 –j +1 +j +1 +j +j +1 +j +j +1 +j +j +1 +j +1 –j +1 +1 –j +1 –1 +j –1 +1 –j +1 +j +1 +j<br>–j –1 –j –j –1 –j +j +1 +j –1 +j –1 +1 –j +1 +1 –j +1 +1 –j +1 –j –1 –j –j –1 –j |
| The sequence $Seq^{6}_{left,385}(k)$, to be transmitted from left to right, up to down |
| +j –1 +j –1 +j +1 +j –1 +j –1 +j +1 +j –j –1 –j –1 +j –1 –j –1 –j –1 +j –1 –1 +j –1 –j –1 –j –1 +j –1 –j –1 –j +j +1 +j –<br>1 +j –1 +j +1 +j –1 +j –1 –j –1 –j –1 +j –1 +j +1 +j +1 –j +1 +1 –j +1 –j –1 –j –1 +j –1 +j +1 +j –j –1 –j +1 –j +1 +j<br>+1 +j –1 +j –1 –1 +j –1 –j –1 –j +1 –j +1 +j +1 +j –j +j +j –1 +1 +1 –j +j +j –1 +1 +1 +1 –1 –1 –j +j +j +1 –1 –1 –j +j<br>+j –j +j +j +1 –1 –1 –j +j +j +1 –1 –1 –1 +1 +1 –j +j +j –1 +1 +1 –j +j +j –1 +1 +1 +j –j –j +1 –1 –1 –j +j +j –j +j +j<br>–1 +1 +1 +j –j –j +1 –1 –1 –1 +1 +1 –j +j +j +1 –1 –1 +j –j –j +j –j –j –1 +1 +1 –j +j +j +1 –1 –1 +1 –j +1 +j +1 +j –<br>1 +j –1 –j –1 –j +j +1 +j –1 +j –1 –j –1 –j +1 –j +1 +1 –j +1 –j –1 –j –1 +j –1 +j +1 +j –j –1 –j –1 +j –1 +j +1 +j +1 –<br>j +1 +j +1 +j –1 +j –1 +j +1 +j –1 +j –1 –1 +j –1 –j –1 –j –1 +j –1 –j –1 –j +j +1 +j +1 –j +1 +j +1 +j +1 –j +1 +1 –j<br>+1 –j –1 –j +1 –j +1 –j –1 –j +j –j –j –1 +1 +1 –j +j +j +1 –1 –1 –1 +1 +1 –j +j +j +1 –1 –1 +j –j –j +j –j –j +1 –1 –1<br>–j +j +j –1 +1 +1 +1 –1 –1 –j +j +j –1 +1 +1 +j –j –j +1 –1 –1 +j –j –j +1 –1 –1 +j –j –j +j –j –j –1 +1 +1 +j –j –j –1<br>+1 +1 +1 –1 –1 –j +j +j +1 –1 –1 –j +j +j –j +j +j –1 +1 +1 –j +j +j –1 +1 +1 |
| The sequence $Seq^{7}_{left,385}(k)$, to be transmitted from left to right, up to down |
| –1 +1 –1 –1 +j –j –j +1 –1 –1 +j –j –j +1 –1 –1 –j +j +j +1 –1 –1 –j +j +j +j +1 +j –1 +j –1 +j +1 +j –1 +j –1 +j +1 +j<br>+1 –j +1 +j +1 +j +1 –j +1 +j –j –j –1 +1 +1 –j +j +j +1 –1 –1 +j –j –j +1 –1 –1 –j +j +j –1 +1 +1 +1 –j +1 +j +1 +j –<br>1 +j –1 –j –1 –j +1 –j +1 –j –1 –j –1 +j –1 +j +1 +j –1 +1 +1 +j –j –j –1 +1 +1 +j –j –j –1 +1 +1 –j +j +j –1 +1 +1 –j<br>+j +j –j –1 –j –1 +j –1 –j –1 –j –1 +j –1 –j –1 –j +1 –j +1 –j –1 –j +1 –j +1 –j +j +j –1 +1 +1 +j –j –j +1 –1 –1 –j +j +j<br>+1 –1 –1 +j –j –j –1 +1 +1 –1 +j –1 +j +1 +j +1 –j +1 –j –1 –j –1 +j –1 –j –1 –j +1 –j +1 +j +1 +j +j –j –j –1 +1 +1 –<br>j +j +j +1 –1 –1 –j +j +j –1 +1 +1 +j –j –j +1 –1 –1 –1 +j –1 –j –1 –j +1 –j +1 +j +1 +j +1 –j +1 –j –1 –j –1 +j –1 +j<br>+1 +j –1 +1 +1 –j +j +j –1 +1 +1 –j +j +j +1 –1 –1 –j +j +j +1 –1 –1 –j +j +j +j +1 +j –1 +j –1 +j +1 +j –1 +j –1 –j –<br>1 –j –1 +j –1 –j –1 –j –1 +j –1 –j +j +j –1 +1 +1 +j –j –j +1 –1 –1 +j –j –j –1 +1 +1 –j +j +j +1 –1 –1 +1 –j +1 –j –1 –<br>j –1 +j –1 +j +1 +j –1 +j –1 –j –1 –j +1 –j +1 +j +1 +j +1 –1 –1 –j +j +j +1 –1 –1 –j +j +j –1 +1 +1 –j +j +j –1 +1 +1<br>–j +j +j –j –1 –j –1 +j –1 –j –1 –j –1 +j –1 +j +1 +j –1 +j –1 +j +1 +j –1 +j –1 |
| The sequence $Seq^{8}_{left,385}(k)$, to be transmitted from left to right, up to down |
| +1 +1 –j +1 –j –1 –j +1 –j +1 +j +1 +j –1 +1 +1 +j –j –j –1 +1 +1 –j +j +j –1 +j –1 –j –1 –j –1 +j –1 +j +1 +j +1 –1 –<br>1 +j –j –j +1 –1 –1 –j +j +j –1 +j –1 +j +1 +j –1 +j –1 –j –1 –j +1 –1 –1 –j +j +j +1 –1 –1 +j –j –j +1 –j +1 +j +1 +j +1<br>–j +1 –j –1 –j –1 +1 +1 –j +j +j –1 +1 +1 +j –j –j –1 +j –1 +j +1 +j +1 –j +1 +j +1 +j –1 +1 +1 +j –j –j +1 –1 –1 +j –<br>j –j +1 –j +1 +j +1 +j –1 +j –1 +j +1 +j +1 –1 –1 +j –j –j –1 +1 +1 +j –j –j +1 –j +1 –j –1 –j –1 +j –1 –j –1 –j +1 –1 –<br>1 –j +j +j –1 +1 +1 –j +j +j –1 +j –1 –j –1 –j +1 –j +1 –j –1 –j –1 +1 +1 –j +j +j +1 –1 –1 –j +j +j –j –1 –j –1 +j –1 –<br>j –1 –j +1 –j +1 +j –j –j +1 –1 –1 +j –j –j –1 +1 +1 –j –1 –j +1 –j +1 –j –1 –j –1 +j –1 +j –j –j –1 +1 +1 +j –j –j +1 –<br>1 –1 –j –1 –j –1 +j –1 –j –1 –j +1 –j +1 +j –j –j +1 –1 –1 +j –j –j –1 +1 +1 –j –1 –j +1 –j +1 –j –1 –j –1 +j –1 +j –j –j<br>–1 +1 +1 +j –j –j +1 –1 –1 +j +1 +j +1 –j +1 –j –1 –j +1 –j +1 +j –j –j +1 –1 –1 –j +j +j +1 –1 –1 +j +1 +j –1 +j –1 –<br>j –1 –j –1 +j –1 +j –j –j –1 +1 +1 –j +j +j –1 +1 +1 +j +1 +j +1 –j +1 –j –1 –j +1 –j +1 +j –j –j +1 –1 –1 –j +j +j +1 –<br>1 –1 +j +1 +j –1 +j –1 –j –1 –j –1 +j –1 +j –j –j –1 +1 +1 –j +j +j –1 +1 +1 |



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This is an unapproved IEEE Standards Draft, subject to change.

**Table 28-114—The sequence $Seq^{i}_{right,385}(k)$(11ay)**

| |
|---|
| The sequence $Seq^{1}_{right,385}(k)$, to be transmitted from left to right, up to down |
| +1 –j +1 –1 –1 +1 –j –1 –j –j –j +j +j +1 +j –j –j +j –1 +j –1 –1 –1 +1 +1 –j +1 –1 –1 +1 –j –1 –j –j –j +j –j –1 –j +j<br>+j –j +1 –j +1 +1 +1 –1 –1 +j –1 +1 +1 –1 +j +1 +j +j +j –j –j –1 –j +j +j –j +1 –j +1 +1 +1 –1 +1 –j +1 –1 –1 +1 –j –<br>1 –j –j –j +j –j –1 –j +j +j –j +1 –j +1 +1 +1 –1 +1 –j +1 –1 –1 +1 –j –1 –j –j –j +j +j +1 +j –j –j +j –1 +j –1 –1 –1 +1<br>+1 –j +1 –1 –1 +1 –j –1 –j –j –j +j –j –1 –j +j +j –j +1 –j +1 +1 +1 –1 +1 –j +1 –1 –1 +1 –j –1 –j –j –j +j +j +1 +j –j<br>–j +j –1 +j –1 –1 –1 +1 –1 +j –1 +1 +1 –1 +j +1 +j +j +j –j +j +1 +j –j –j +j –1 +j –1 –1 –1 +1 –j –1 –j +j +j –j –1 +j<br>–1 –1 –1 +1 +1 –j +1 –1 –1 +1 +j +1 +j +j +j –j –j –1 –j +j +j –j –1 +j –1 –1 –1 +1 –1 +j –1 +1 +1 –1 –j –1 –j –j –j +j<br>+j +1 +j –j –j +j +1 –j +1 +1 +1 –1 –1 +j –1 +1 +1 –1 –j –1 –j –j –j +j –j –1 –j +j +j –j –1 +j –1 –1 –1 +1 –1 +j –1 +1<br>+1 –1 –j –1 –j –j –j +j +j +1 +j –j –j +j +1 –j +1 +1 +1 –1 –1 +j –1 +1 +1 –1 –j –1 –j –j –j +j +j +1 +j –j –j +j +1 –j<br>+1 +1 +1 –1 +1 –j +1 –1 –1 +1 +j +1 +j +j +j –j +j +1 +j –j –j +j +1 –j +1 +1 +1 –1 –1 +j –1 +1 +1 –1 –j –1 –j –j –j<br>+j –j –1 –j +j +j –j –1 +j –1 –1 –1 +1 –1 +j –1 +1 +1 –1 –j –1 –j –j –j +j +j |
| The sequence $Seq^{2}_{right,385}(k)$, to be transmitted from left to right, up to down |
| –1 +1 +1 +1 –j +1 +j –j –j –j –1 –j –j +j +j –j –1 –j +1 –1 –1 +1 –j +1 +1 –1 –1 –1 +j –1 –j +j +j +j +1 +j +j –j –j +j<br>+1 +j –1 +1 +1 –1 +j –1 +1 –1 –1 –1 +j –1 –j +j +j +j +1 +j +j –j –j +j +1 +j –1 +1 +1 –1 +j –1 +1 –1 –1 –1 +j –1 –j<br>+j +j +j +1 +j +j –j –j +j +1 +j –1 +1 +1 –1 +j –1 –1 +1 +1 +1 –j +1 +j –j –j –j –1 –j –j +j +j –j –1 –j +1 –1 –1 +1 –j<br>+1 –1 +1 +1 +1 –j +1 +j –j –j –j –1 –j –j +j +j –j –1 –j +1 –1 –1 +1 –j +1 +1 –1 –1 –1 +j –1 –j +j +j +j +1 +j +j –j –j<br>+j +1 +j –1 +1 +1 –1 +j –1 –1 +1 +1 +1 –j +1 +j –j –j –j –1 –j –j +j +j –j –1 –j +1 –1 –1 +1 –j +1 –j +j +j +j +1 +j +1<br>–1 –1 –1 +j –1 +1 –1 –1 +1 –j +1 –j +j +j –j –1 –j +j –j –j –j –1 –j –1 +1 +1 +1 –j +1 –1 +1 +1 –1 +j –1 +j –j –j +j +1<br>+j +j –j –j –j –1 –j –1 +1 +1 +1 –j +1 –1 +1 +1 –1 +j –1 +j –j –j +j +1 +j +j –j –j –j –1 –j –1 +1 +1 +1 –j +1 –1 +1 +1<br>–1 +j –1 +j –j –j +j +1 +j +j –j –j –j –1 –j –1 +1 +1 +1 –j +1 –1 +1 +1 –1 +j –1 +j –j –j +j +1 +j +j –j –j –j –1 –j –1 +1<br>+1 +1 –j +1 –1 +1 +1 –1 +j –1 +j –j –j +j +1 +j –j +j +j +j +1 +j +1 –1 –1 –1 +j –1 +1 –1 –1 +1 –j +1 –j +j +j –j –1 –<br>j +j –j –j –j –1 –j –1 +1 +1 +1 –j +1 –1 +1 +1 –1 +j –1 +j –j –j +j +1 +j –j |
| The sequence $Seq^{3}_{right,385}(k)$, to be transmitted from left to right, up to down |
| +1 –j +1 +1 –j +1 –j –1 –j –j –1 –j –1 +j –1 –1 +j –1 –j –1 –j –j –1 –j –1 +j –1 –1 +j –1 –j –1 –j –j –1 –j +1 –j +1 +1<br>–j +1 –j –1 –j –j –1 –j –1 –1 +1 –1 –1 +1 +j +j –j +j +j –j –1 –1 +1 –1 –1 +1 –j –j +j –j –j +j +1 +1 –1 +1 +1 –1 +j +j<br>–j +j +j –j +1 +1 –1 +1 +1 –1 –j –j +j –j –j +j –j –1 –j –j –1 –j –1 +j –1 –1 +j –1 +j +1 +j +j +1 +j –1 +j –1 –1 +j –1 –<br>j –1 –j –j –1 –j +1 –j +1 +1 –j +1 +j +1 +j +j +1 +j +1 –j +1 +1 –j +1 +j +j –j +j +j –j +1 +1 –1 +1 +1 –1 +j +j –j +j<br>+j –j –1 –1 +1 –1 –1 +1 +j +j –j +j +j –j –1 –1 +1 –1 –1 +1 +j +j –j +j +j –j +1 +1 –1 +1 +1 –1 –j –1 –j +j +1 +j –1 +j<br>–1 +1 –j +1 +j +1 +j –j –1 –j –1 +j –1 +1 –j +1 +j +1 +j –j –1 –j –1 +j –1 +1 –j +1 –j –1 –j +j +1 +j –1 +j –1 +1 –j +1<br>+j +j –j –j –j +j +1 +1 –1 –1 –1 +1 +j +j –j –j –j +j –1 –1 +1 +1 +1 –1 –j –j +j +j +j –j +1 +1 –1 –1 –1 +1 –j –j +j +j<br>+j –j –1 –1 +1 +1 +1 –1 +1 –j +1 –1 +j –1 –j –1 –j +j +1 +j –1 +j –1 +1 –j +1 –j –1 –j +j +1 +j +1 –j +1 –1 +j –1 +j<br>+1 +j –j –1 –j –1 +j –1 +1 –j +1 +j +1 +j –j –1 –j –1 –1 +1 +1 +1 –1 +j +j –j –j –j +j –1 –1 +1 +1 +1 –1 –j –j +j +j +j<br>–j –1 –1 +1 +1 +1 –1 –j –j +j +j +j –j –1 –1 +1 +1 +1 –1 +j +j –j –j –j +j +j |
| The sequence $Seq^{4}_{right,385}(k)$, to be transmitted from left to right, up to down |
| +1 –j +1 –j –1 –j –1 –1 +1 +j +j –j –j –1 –j +1 –j +1 +j +j –j –1 –1 +1 –1 +j –1 +j +1 +j +1 +1 –1 –j –j +j +j +1 +j –1<br>+j –1 –j –j +j +1 +1 –1 +j +1 +j +1 –j +1 +j +j –j +1 +1 –1 +1 –j +1 +j +1 +j +1 +1 –1 +j +j –j –j –1 –j –1 +j –1 –j –j<br>+j –1 –1 +1 –1 +j –1 –j –1 –j –1 –1 +1 –j –j +j +1 –j +1 –j –1 –j –1 –1 +1 +j +j –j –j –1 –j +1 –j +1 +j +j –j –1 –1 +1<br>+1 –j +1 –j –1 –j –1 –1 +1 +j +j –j –j –1 –j +1 –j +1 +j +j –j –1 –1 +1 –j –1 –j –1 +j –1 –j –j +j –1 –1 +1 –1 +j –1 –j<br>–1 –j –1 –1 +1 –j –j +j –j –1 –j –1 +j –1 –j –j +j –1 –1 +1 –1 +j –1 –j –1 –j –1 –1 +1 –j –j +j –j –1 –j +1 –j +1 +j +j –<br>j –1 –1 +1 –1 +j –1 +j +1 +j +1 +1 –1 –j –j +j –j –1 –j +1 –j +1 +j +j –j –1 –1 +1 –1 +j –1 +j +1 +j +1 +1 –1 –j –j +j<br>+1 –j +1 +j +1 +j +1 +1 –1 +j +j –j –j –1 –j –1 +j –1 –j –j +j –1 –1 +1 +1 –j +1 +j +1 +j +1 +1 –1 +j +j –j –j –1 –j –1<br>+j –1 –j –j +j –1 –1 +1 –j –1 –j +1 –j +1 +j +j –j –1 –1 +1 –1 +j –1 +j +1 +j +1 +1 –1 –j –j +j +j +1 +j –1 +j –1 –j –j<br>+j +1 +1 –1 +1 –j +1 –j –1 –j –1 –1 +1 +j +j –j –1 +j –1 –j –1 –j –1 –1 +1 –j –j +j +j +1 +j +1 –j +1 +j +j –j +1 +1 –<br>1 +1 –j +1 +j +1 +j +1 +1 –1 +j +j –j –j –1 –j –1 +j –1 –j –j +j –1 –1 +1 –j |

**Table 28-114—The sequence $Seq^{i}_{right,385}(k)$(11ay) *(continued)***

| |
|---|
| The sequence $Seq^{5}_{right,385}(k)$, to be transmitted from left to right, up to down |
| +1 –1 –1 +1 –1 –1 –j +j +j –j +j +j –j +j +j +j –j –j –1 +1 +1 +1 –1 –1 +1 –1 –1 –1 +1 +1 –j +j +j +j –j –j –j +j +j –j<br>+j +j –1 +1 +1 –1 +1 +1 –1 +1 +1 –1 +1 +1 –j +j +j –j +j +j +j –j –j –j +j +j –1 +1 +1 +1 –1 –1 –1 +1 +1 +1 –1 –1 –j<br>+j +j +j –j –j +j –j –j +j –j –j –1 +1 +1 –1 +1 +1 +j –j –j +j –j –j –1 +1 +1 –1 +1 +1 +1 –1 –1 –1 +1 +1 +j –j –j –j +j<br>+j –j +j +j +j –j –j +1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 +1 –j +j +j –j +j +j –j +j +j –j +j +j –1 +1 +1 –1 +1 +1 –1 +1 +1<br>+1 –1 –1 +j –j –j –j +j +j +j –j –j –j +j +j +1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 –1 –j +j +j –j +j +j –1 +j –1 –1 +j –1 +j<br>+1 +j +j +1 +j +j +1 +j –j –1 –j +1 –j +1 –1 +j –1 –1 +j –1 +1 –j +1 +j +1 +j –j –1 –j +j +1 +j +j +1 +j +1 –j +1 +1 –<br>j +1 –1 +j –1 –1 +j –1 –j –1 –j –j –1 –j +j +1 +j –j –1 –j –1 +j –1 +1 –j +1 –1 +j –1 +1 –j +1 –j –1 –j +j +1 +j +j +1 +j<br>+j +1 +j –1 +j –1 –1 +j –1 –j –1 –j –j –1 –j +1 –j +1 +1 –j +1 –1 +j –1 +1 –j +1 –j –1 –j +j +1 +j +j +1 +j –j –1 –j –1<br>+j –1 +1 –j +1 +1 –j +1 +1 –j +1 +j +1 +j +j +1 +j –j –1 –j –j –1 –j –1 +j –1 –1 +j –1 –1 +j –1 +1 –j +1 +j +1 +j –j –<br>1 –j +j +1 +j –j –1 –j +1 –j +1 –1 +j –1 +1 –j +1 +1 –j +1 –j –1 –j –j –1 –j –j |
| The sequence $Seq^{6}_{right,385}(k)$, to be transmitted from left to right, up to down |
| +1 –j +1 –j –1 –j +1 –j +1 –j –1 –j –j –1 –j –1 +j –1 –j –1 –j –1 +j –1 +1 –j +1 +j +1 +j +1 –j +1 +j +1 +j +j +1 +j –1<br>+j –1 +j +1 +j –1 +j –1 +j +1 +j +1 –j +1 –j –1 –j –1 +j –1 +1 –j +1 –j –1 –j –1 +j –1 +j +1 +j +j +1 +j –1 +j –1 –j –1<br>–j +1 –j +1 –1 +j –1 –j –1 –j +1 –j +1 +j +1 +j +j –j –j +1 –1 –1 +j –j –j +1 –1 –1 +1 –1 –1 –j +j +j +1 –1 –1 –j +j +j<br>+j –j –j –1 +1 +1 +j –j –j –1 +1 +1 –1 +1 +1 –j +j +j –1 +1 +1 –j +j +j +1 –1 –1 –j +j +j –1 +1 +1 +j –j –j –j +j +j –1<br>+1 +1 +j –j –j +1 –1 –1 +1 –1 –1 +j –j –j –1 +1 +1 –j +j +j +j –j –j –1 +1 +1 –j +j +j +1 –1 –1 –1 +j –1 –j –1 –j +1 –<br>j +1 +j +1 +j +j +1 +j –1 +j –1 –j –1 –j +1 –j +1 –1 +j –1 +j +1 +j +1 –j +1 –j –1 –j –j –1 –j –1 +j –1 +j +1 +j +1 –j<br>+1 –j –1 –j +1 –j +1 –j –1 –j +1 –j +1 –1 +j –1 –j –1 –j –1 +j –1 –j –1 –j –j –1 –j –1 +j –1 –j –1 –j –1 +j –1 +1 –j +1<br>–j –1 –j +1 –j +1 –j –1 –j –j +j +j +1 –1 –1 +j –j –j –1 +1 +1 –1 +1 +1 –j +j +j +1 –1 –1 +j –j –j –j +j +j –1 +1 +1 +j<br>–j –j +1 –1 –1 +1 –1 –1 –j +j +j –1 +1 +1 +j –j –j –1 +1 +1 –j +j +j –1 +1 +1 –j +j +j +j –j –j –1 +1 +1 +j –j –j –1 +1<br>+1 –1 +1 +1 +j –j –j –1 +1 +1 +j –j –j –j +j +j –1 +1 +1 –j +j +j –1 +1 +1 –j |
| The sequence $Seq^{7}_{right,385}(k)$, to be transmitted from left to right, up to down |
| –1 +1 +1 –j +j +j –1 +1 +1 –j +j +j –1 +1 +1 +j –j –j –1 +1 +1 +j –j –j –j –1 –j +1 –j +1 –j –1 –j +1 –j +1 –j –1 –j –1<br>+j –1 –j –1 –j –1 +j –1 –j +j +j +1 –1 –1 +j –j –j –1 +1 +1 –j +j +j –1 +1 +1 +j –j –j +1 –1 –1 –1 +j –1 –j –1 –j +1 –j<br>+1 +j +1 +j –1 +j –1 +j +1 +j +1 –j +1 –j –1 –j –1 +1 +1 +j –j –j –1 +1 +1 +j –j –j –1 +1 +1 –j +j +j –1 +1 +1 –j +j +j<br>–j –1 –j –1 +j –1 –j –1 –j –1 +j –1 –j –1 –j +1 –j +1 –j –1 –j +1 –j +1 –j +j +j –1 +1 +1 +j –j –j +1 –1 –1 –j +j +j +1 –<br>1 –1 +j –j –j –1 +1 +1 –1 +j –1 +j +1 +j +1 –j +1 –j –1 –j –1 +j –1 –j –1 –j +1 –j +1 +j +1 +j –j +j +j +1 –1 –1 +j –j –<br>j –1 +1 +1 +j –j –j +1 –1 –1 –j +j +j –1 +1 +1 +1 –j +1 +j +1 +j –1 +j –1 –j –1 –j –1 +j –1 +j +1 +j +1 –j +1 –j –1 –j<br>+1 –1 –1 +j –j –j +1 –1 –1 +j –j –j –1 +1 +1 +j –j –j –1 +1 +1 +j –j –j –j –1 –j +1 –j +1 –j –1 –j +1 –j +1 +j +1 +j +1<br>–j +1 +j +1 +j +1 –j +1 –j +j +j –1 +1 +1 +j –j –j +1 –1 –1 +j –j –j –1 +1 +1 –j +j +j +1 –1 –1 +1 –j +1 –j –1 –j –1 +j<br>–1 +j +1 +j –1 +j –1 –j –1 –j +1 –j +1 +j +1 +j +1 –1 –1 –j +j +j +1 –1 –1 –j +j +j –1 +1 +1 –j +j +j –1 +1 +1 –j +j +j<br>–j –1 –j –1 +j –1 –j –1 –j –1 +j –1 +j +1 +j –1 +j –1 +j +1 +j –1 +j –1 +1 |
| The sequence $Seq^{8}_{right,385}(k)$, to be transmitted from left to right, up to down |
| –1 +j –1 +j +1 +j –1 +j –1 –j –1 –j +1 –1 –1 –j +j +j +1 –1 –1 +j –j –j +1 –j +1 +j +1 +j +1 –j +1 –j –1 –j –1 +1 +1 –<br>j +j +j –1 +1 +1 +j –j –j –1 +j –1 +j +1 +j –1 +j –1 –j –1 –j +1 –1 –1 –j +j +j +1 –1 –1 +j –j –j +1 –j +1 +j +1 +j +1 –<br>j +1 –j –1 –j –1 +1 +1 –j +j +j –1 +1 +1 +j –j –j +1 –j +1 –j –1 –j –1 +j –1 –j –1 –j +1 –1 –1 –j +j +j –1 +1 +1 –j +j +j<br>–1 +j –1 –j –1 –j +1 –j +1 –j –1 –j –1 +1 +1 –j +j +j +1 –1 –1 –j +j +j +1 –j +1 –j –1 –j –1 +j –1 –j –1 –j +1 –1 –1 –j<br>+j +j –1 +1 +1 –j +j +j –1 +j –1 –j –1 –j +1 –j +1 –j –1 –j –1 +1 +1 –j +j +j +1 –1 –1 –j +j +j +j +1 +j +1 –j +1 +j +1<br>+j –1 +j –1 –j +j +j –1 +1 +1 –j +j +j +1 –1 –1 +j +1 +j –1 +j –1 +j +1 +j +1 –j +1 –j +j +j +1 –1 –1 –j +j +j –1 +1 +1<br>–j –1 –j –1 +j –1 –j –1 –j +1 –j +1 +j –j –j +1 –1 –1 +j –j –j –1 +1 +1 –j –1 –j +1 –j +1 –j –1 –j –1 +j –1 +j –j –j –1<br>+1 +1 +j –j –j +1 –1 –1 –j –1 –j –1 +j –1 +j +1 +j –1 +j –1 –j +j +j –1 +1 +1 +j –j –j –1 +1 +1 –j –1 –j +1 –j +1 +j +1<br>+j +1 –j +1 –j +j +j +1 –1 –1 +j –j –j +1 –1 –1 +j +1 +j +1 –j +1 –j –1 –j +1 –j +1 +j –j –j +1 –1 –1 –j +j +j +1 –1 –1<br>+j +1 +j –1 +j –1 –j –1 –j –1 +j –1 +j –j –j –1 +1 +1 –j +j +j –1 +1 +1 +1 |



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## Table 28-115—The sequence $Seq^{i}_{left,595}(k)$(11ay)

| |
|---|
| The sequence $Seq^{1}_{left,595}(k)$, to be transmitted from left to right, up to down |
| +j +1 –1 +j +1 +j –j –1 –1 +j +j –1 –1 +1 +1 +1 –j –j –1 +1 –j +1 –1 –1 +1 –j –1 –j –j –j +j +j +1 +j –j –j +j –1 +j –1<br>–1 –1 +1 +1 –j +1 –1 –1 +1 –j –1 –j –j –j +j –j –1 –j +j +j –j +1 –j +1 +1 +1 –1 –1 +j –1 +1 +1 –1 +j +1 +j +j +j –j –<br>j –1 –j +j +j –j +1 –j +1 +1 +1 –1 +1 –j +1 –1 –1 +1 –j –1 –j –j –j +j –j –1 –j +j +j –j +1 –j +1 +1 +1 –1 –j –1 –j +j +j<br>–j –1 +j –1 –1 –1 +1 +1 –j +1 –1 –1 +1 +j +1 +j +j +j –j –j –1 –j +j +j –j –1 +j –1 –1 –1 +1 –1 +j –1 +1 +1 –1 –j –1 –<br>j –j –j +j –j –1 –j +j +j –j –1 +j –1 –1 –1 +1 +1 –j +1 –1 –1 +1 +j +1 +j +j +j –j +j +1 +j –j –j +j +1 –j +1 +1 +1 –1 +1<br>–j +1 –1 –1 +1 +j +1 +j +j +j –j +1 –j +1 –1 –1 +1 –j –1 –j –j –j +j +j +1 +j –j –j +j –1 +j –1 –1 –1 +1 +1 –j +1 –1 –1<br>+1 –j –1 –j –j –j +j –j –1 –j +j +j –j +1 –j +1 +1 +1 –1 –1 +j –1 +1 +1 –1 +j +1 +j +j +j –j –j –1 –j +j +j –j +1 –j +1<br>+1 +1 –1 +1 –j +1 –1 –1 +1 –j –1 –j –j –j +j –j –1 –j +j +j –j +1 –j +1 +1 +1 –1 –j –1 –j +j +j –j –1 +j –1 –1 –1 +1 +1<br>–j +1 –1 –1 +1 +j +1 +j +j +j –j –j –1 –j +j +j –j –1 +j –1 –1 –1 +1 –1 +j –1 +1 +1 –1 –j –1 –j –j –j +j –j –1 –j +j +j –<br>j –1 +j –1 –1 –1 +1 +1 –j +1 –1 –1 +1 +j +1 +j +j +j –j +j +1 +j –j –j +j +1 –j +1 +1 +1 –1 +1 –j +1 –1 –1 +1 +j +1 +j<br>+j +j –j –1 +j –1 +1 +1 –1 +j +1 +j +j +j –j –j –1 –j +j +j –j +1 –j +1 +1 +1 –1 –1 +j –1 +1 +1 –1 +j +1 +j +j +j –j +j<br>+1 +j –j –j +j –1 +j –1 –1 –1 +1 +1 –j +1 –1 –1 +1 –j –1 –j –j –j +j +j +1 +j –j –j +j –1 +j –1 –1 –1 +1 –1 +j –1 +1 +1<br>–1 +j +1 +j +j +j –j +j +1 +j –j –j +j –1 +j –1 –1 –1 +1 +j +1 +j –j –j +j +1 –j +1 +1 +1 –1 –1 +j –1 +1 +1 –1 –j –1 –<br>j –j –j +j +j +1 +j –j –j +j +1 –j +1 +1 +1 –1 +1 –j +1 –1 –1 +1 +j +1 +j +j +j –j +j +1 +j –j –j +j +1 –j +1 +1 +1 –1 –<br>1 +j –1 +1 +1 –1 –j –1 –j –j –j +j –j –1 –j +j +j –j –1 +j –1 –1 –1 +1 –1 +j –1 +1 +1 –1 –j –1 –j –j –j +j |
| The sequence $Seq^{2}_{left,595}(k)$, to be transmitted from left to right, up to down |
| –1 +1 –j +1 –j –1 +j +j +j –1 –1 +1 –1 –1 +j +1 +j –j –1 +1 –j +1 –1 +j –1 +1 –j +1 +1 –j +1 +1 –j +1 –1 +j –1 –1 +j<br>–1 –1 +j –1 –j –1 –j +j +1 +j –j –1 –j –j –1 –j +j +1 +j –j –1 –j –j –1 –j –j –1 –j –1 +j –1 +1 –j +1 –1 +j –1 –1 +j –1 –<br>1 +j –1 +1 –j +1 +1 –j +1 +1 –j +1 –j –1 –j +j +1 +j –j –1 –j –j –1 –j +j +1 +j –j –1 –j –j –1 –j –j –1 –j +j +j –j –j –j +j<br>+j +j –j +j +j –j +j +j –j –j –j +j –j –j +j –j –j +j +1 +1 –1 –1 –1 +1 +1 +1 –1 +1 +1 –1 –1 –1 +1 +1 +1 –1 +1 +1 –1 +1<br>+1 –1 +j +j –j –j –j +j +j +j –j +j +j –j +j +j –j –j –j +j –j –j +j –j –j +j –1 –1 +1 +1 +1 –1 –1 –1 +1 –1 –1 +1 +1 +1 –<br>1 –1 –1 +1 –1 –1 +1 –1 –1 +1 +1 –j +1 –1 +j –1 +1 –j +1 +1 –j +1 +1 –j +1 –1 +j –1 –1 +j –1 –1 +j –1 –j –1 –j +j +1<br>+j –j –1 –j –j –1 –j +j +1 +j –j –1 –j –j –1 –j –j –1 –j –1 +j –1 +1 –j +1 –1 +j –1 –1 +j –1 –1 +j –1 +1 –j +1 +1 –j +1<br>+1 –j +1 –j –1 –j +j +1 +j –j –1 –j –j –1 –j +j +1 +j –j –1 –j –j –1 –j –j –1 –j +j +j –j –j –j +j +j +j –j +j +j –j +j +j –j<br>–j –j +j –j –j +j –j –j +j +1 +1 –1 –1 –1 +1 +1 +1 –1 +1 +1 –1 –1 –1 +1 +1 +1 –1 +1 +1 –1 +1 +1 –1 +j +j –j –j –j +j<br>+j +j –j +j +j –j +j +j –j –j –j +j –j –j +j –j –j +j –1 –1 +1 +1 +1 –1 –1 –1 +1 –1 –1 +1 +1 +1 –1 –1 –1 +1 –1 –1 +1 –<br>1 –1 +1 –1 +j –1 +1 –j +1 –1 +j –1 –1 +j –1 –1 +j –1 +1 –j +1 +1 –j +1 +1 –j +1 +j +1 +j –j –1 –j +j +1 +j +j +1 +j –<br>j –1 –j +j +1 +j +j +1 +j +j +1 +j +1 –j +1 –1 +j –1 +1 –j +1 +1 –j +1 +1 –j +1 –1 +j –1 –1 +j –1 –1 +j –1 +j +1 +j –j<br>–1 –j +j +1 +j +j +1 +j –j –1 –j +j +1 +j +j +1 +j +j +1 +j –j –j +j +j +j –j –j –j +j –j –j +j –j –j +j +j +j –j +j +j –j +j<br>+j –j –1 –1 +1 +1 +1 –1 –1 –1 +1 –1 –1 +1 +1 +1 –1 –1 –1 +1 –1 –1 +1 –1 –1 +1 –j –j +j +j +j –j –j –j +j –j –j +j –j<br>–j +j +j +j –j +j +j –j +j +j –j +1 +1 –1 –1 –1 +1 +1 +1 –1 +1 +1 –1 –1 –1 +1 +1 +1 –1 +1 +1 –1 +1 +1 –1 |
| The sequence $Seq^{3}_{left,595}(k)$, to be transmitted from left to right, up to down |
| –j –j –j –j –j +j –j +1 –j –j –j +j +j +j +1 –1 +j –1 +1 +1 –j +1 +j +1 +j +1 –j +1 –j –1 –j –j –1 –j –1 +j –1 –j –1 –j +1<br>–j +1 –1 +j –1 –j –1 –j –1 +j –1 +j +1 +j –j –1 –j –1 +j –1 –j –1 –j +1 –j +1 –1 –1 +1 –j –j +j –1 –1 +1 +j +j –j +j +j –<br>j +1 +1 –1 +j +j –j –1 –1 +1 –1 –1 +1 –j –j +j –1 –1 +1 +j +j –j –j –j +j –1 –1 +1 –j –j +j +1 +1 –1 +j +1 +j –1 +j –1<br>–j –1 –j –1 +j –1 +1 –j +1 –j –1 –j –1 +j –1 –j –1 –j –j –1 –j +1 –j +1 +j +1 +j +1 –j +1 +1 –j +1 –j –1 –j –1 +j –1 –j<br>–1 –j –j –j +j +1 +1 –1 +j +j –j +1 +1 –1 –1 –1 +1 +j +j –j +1 +1 –1 +j +j –j –j –j +j +1 +1 –1 +j +j –j +1 +1 –1 +1 +1<br>–1 –j –j +j –1 –1 +1 –j –j +j +j +1 +j –1 +j –1 +j +1 +j +1 –j +1 +1 –j +1 –j –1 –j +1 –j +1 +j +1 +j –j –1 –j +1 –j +1<br>–j –1 –j –1 +j –1 +1 –j +1 –j –1 –j +1 –j +1 +j +1 +j –j –j +j +1 +1 –1 –j –j +j –1 –1 +1 –1 –1 +1 +j +j –j –1 –1 +1 –j<br>–j +j –j –j +j +1 +1 –1 –j –j +j –1 –1 +1 +1 +1 –1 –j –j +j +1 +1 –1 +j +j –j –1 +j –1 –j –1 –j +1 –j +1 –j –1 –j +j +1<br>+j +1 –j +1 –j –1 –j +1 –j +1 +1 –j +1 +j +1 +j –1 +j –1 +j +1 +j +j +1 +j +1 –j +1 –j –1 –j +1 –j +1 +1 +1 –1 +j +j –<br>j –1 –1 +1 +j +j –j –j –j +j –1 –1 +1 +j +j –j –1 –1 +1 +1 +1 –1 +j +j –j –1 –1 +1 +j +j –j +j +j –j +1 +1 –1 –j –j +j +1<br>+1 –1 +1 –j +1 +j +1 +j +1 –j +1 –j –1 –j –j –1 –j –1 +j –1 –j –1 –j +1 –j +1 –1 +j –1 –j –1 –j –1 +j –1 +j +1 +j –j –1<br>–j –1 +j –1 –j –1 –j +1 –j +1 –1 –1 +1 –j –j +j –1 –1 +1 +j +j –j +j +j –j +1 +1 –1 +j +j –j –1 –1 +1 –1 –1 +1 –j –j +j<br>–1 –1 +1 +j +j –j –j –j +j –1 –1 +1 –j –j +j +1 +1 –1 +j +1 +j –1 +j –1 –j –1 –j –1 +j –1 +1 –j +1 –j –1 –j –1 +j –1 –j<br>–1 –j –j –1 –j +1 –j +1 +j +1 +j +1 –j +1 +1 –j +1 –j –1 –j –1 +j –1 –j –1 –j –j –j +j +1 +1 –1 +j +j –j +1 +1 –1 –1 –1<br>+1 +j +j –j +1 +1 –1 +j +j –j –j –j +j +1 +1 –1 +j +j –j +1 +1 –1 +1 +1 –1 –j –j +j –1 –1 +1 –j –j +j |

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### Table 28-115—The sequence $Seq^{i}_{left,595}(k)$(11ay) *(continued)*

| |
|---|
| The sequence $Seq^{4}_{left,595}(k)$, to be transmitted from left to right, up to down |
| +1 +1 +1 –1 –j –1 +1 –1 –j –1 –j –j –1 –j +j +1 +j –1 +1 +1 –j +1 +j +1 +j +j +1 +j +1 –j +1 +1 +1 –1 +j +j –j +j +j –<br>j +1 +1 –1 +j +1 +j +1 –j +1 –1 +j –1 –j –1 –j –j –j +j –1 –1 +1 +1 +1 –1 +j +j –j –1 +j –1 –j –1 –j –j –1 –j –1 +j –1 –<br>1 –1 +1 –j –j +j –j –j +j –1 –1 +1 –j –1 –j –1 +j –1 +1 –j +1 +j +1 +j +j +j –j +1 +1 –1 –1 –1 +1 –j –j +j +1 –j +1 +j<br>+1 +j –j –1 –j –1 +j –1 +1 +1 –1 +j +j –j –j –j +j –1 –1 +1 +j +1 +j +1 –j +1 +1 –j +1 +j +1 +j –j –j +j –1 –1 +1 –1 –<br>1 +1 –j –j +j +1 –j +1 +j +1 +j –j –1 –j –1 +j –1 +1 +1 –1 +j +j –j –j –j +j –1 –1 +1 +j +1 +j +1 –j +1 +1 –j +1 +j +1<br>+j –j –j +j –1 –1 +1 –1 –1 +1 –j –j +j +j +1 +j –1 +j –1 –1 +j –1 +j +1 +j +j +j –j –1 –1 +1 –1 –1 +1 +j +j –j –1 +j –1<br>+j +1 +j –j –1 –j +1 –j +1 +1 +1 –1 –j –j +j +j +j –j –1 –1 +1 –j –1 –j +1 –j +1 +1 –j +1 –j –1 –j –j –j +j +1 +1 –1 +1<br>+1 –1 –j –j +j +1 –j +1 –j –1 –j +j +1 +j –1 +j –1 –1 –1 +1 +j +j –j –j –j +j +1 +1 –1 +j +1 +j –1 +j –1 +1 –j +1 –j –1<br>–j +j +j –j –1 –1 +1 +1 +1 –1 –j –j +j –1 +j –1 +j +1 +j +j +1 +j –1 +j –1 +1 +1 –1 –j –j +j –j –j +j +1 +1 –1 +j +1 +j<br>–1 +j –1 +1 –j +1 –j –1 –j +j +j –j –1 –1 +1 +1 +1 –1 –j –j +j –1 +j –1 +j +1 +j +j +1 +j –1 +j –1 +1 +1 –1 –j –j +j –j<br>–j +j +1 +1 –1 +1 –j +1 +j +1 +j +j +1 +j +1 –j +1 +1 +1 –1 +j +j –j +j +j –j +1 +1 –1 +j +1 +j +1 –j +1 –1 +j –1 –j –<br>1 –j –j –j +j –1 –1 +1 +1 +1 –1 +j +j –j –1 +j –1 –j –1 –j –j –1 –j –1 +j –1 –1 –1 +1 –j –j +j –j –j +j –1 –1 +1 –j –1 –j<br>–1 +j –1 +1 –j +1 +j +1 +j +j +j –j +1 +1 –1 –1 –1 +1 –j –j +j +1 –j +1 +j +1 +j –j –1 –j –1 +j –1 +1 +1 –1 +j +j –j –<br>j –j +j –1 –1 +1 +j +1 +j +1 –j +1 +1 –j +1 +j +1 +j –j –j +j –1 –1 +1 –1 –1 +1 –j –j +j +1 –j +1 +j +1 +j –j –1 –j –1<br>+j –1 +1 +1 –1 +j +j –j –j –j +j –1 –1 +1 +j +1 +j +1 –j +1 +1 –j +1 +j +1 +j –j –j +j –1 –1 +1 –1 –1 +1 –j –j +j |
| The sequence $Seq^{5}_{left,595}(k)$, to be transmitted from left to right, up to down |
| +1 –j +1 –1 +1 –j –j –1 –j +j –1 +j +1 +1 +j +1 –j +1 +1 +1 –1 –1 +1 –1 –1 +1 –1 –1 –1 +1 +1 +j –j –j +j –j –j +j –j<br>–j –j +j +j –j –1 –j –j –1 –j +j +1 +j –j –1 –j +1 –j +1 +1 –j +1 –1 +j –1 +1 –j +1 –j +j +j –j +j +j –j +j +j +j –j –j –1<br>+1 +1 –1 +1 +1 –1 +1 +1 +1 –1 –1 –1 +j –1 –1 +j –1 +1 –j +1 –1 +j –1 +j +1 +j +j +1 +j –j –1 –j +j +1 +j –1 +1 +1<br>+1 –1 –1 –1 +1 +1 –1 +1 +1 –j +j +j +j –j –j –j +j +j –j +j +j +j +1 +j –j –1 –j –j –1 –j –j –1 –j –1 +j –1 +1 –j +1 +1 –<br>j +1 +1 –j +1 –j +j +j +j –j –j –j +j +j –j +j +j –1 +1 +1 +1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +j –1 +1 –j +1 +1 –j +1 +1 –<br>j +1 +j +1 +j –j –1 –j –j –1 –j –j –1 –j +j –j –j +j –j –j +j –j –j –j +j +j –1 +1 +1 –1 +1 +1 –1 +1 +1 +1 –1 –1 +1 –j +1<br>+1 –j +1 –1 +j –1 +1 –j +1 +j +1 +j +j +1 +j –j –1 –j +j +1 +j +1 –1 –1 +1 –1 –1 +1 –1 –1 –1 +1 +1 –j +j +j –j +j +j<br>–j +j +j +j –j –j –j –1 –j –j –1 –j +j +1 +j –j –1 –j –1 +j –1 –1 +j –1 +1 –j +1 –1 +j –1 –j +j +j +j –j –j –j +j +j –j +j +j<br>+1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 –1 –1 +j –1 +1 –j +1 +1 –j +1 +1 –j +1 –j –1 –j +j +1 +j +j +1 +j +j +1 +j +1 –1 –<br>1 –1 +1 +1 +1 –1 –1 +1 –1 –1 –j +j +j +j –j –j –j +j +j –j +j +j –j –1 –j +j +1 +j +j +1 +j +j +1 +j –1 +j –1 +1 –j +1 +1<br>–j +1 +1 –j +1 +1 –1 –1 +1 –1 –1 +1 –1 –1 –1 +1 +1 +j –j –j +j –j –j +j –j –j –j +j +j –j –1 –j –j –1 –j +j +1 +j –j –1 –<br>j +1 –j +1 +1 –j +1 –1 +j –1 +1 –j +1 –j +j +j –j +j +j –j +j +j +j –j –j –1 +1 +1 –1 +1 +1 –1 +1 +1 +1 –1 –1 –1 +j –1<br>–1 +j –1 +1 –j +1 –1 +j –1 +j +1 +j +j +1 +j –j –1 –j +j +1 +j –1 +1 +1 +1 –1 –1 –1 +1 +1 –1 +1 +1 –j +j +j +j –j –j<br>–j +j +j –j +j +j +j +1 +j –j –1 –j –j –1 –j –j –1 –j –1 +j –1 +1 –j +1 +1 –j +1 +1 –j +1 –j +j +j +j –j –j –j +j +j –j +j +j<br>–1 +1 +1 +1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +j –1 +1 –j +1 +1 –j +1 +1 –j +1 +j +1 +j –j –1 –j –j –1 –j –j –1 –j |
| The sequence $Seq^{6}_{left,595}(k)$, to be transmitted from left to right, up to down |
| +1 –j +1 +1 –j +j +1 –1 –j +j –j –1 +j +j +1 –1 +1 +1 –1 +1 –1 –1 –j +j +j –1 +j –1 +j +1 +j –j +j +j –1 +1 +1 +j +1<br>+j +1 –j +1 +1 –1 –1 –j +j +j –1 +j –1 +j +1 +j +j –j –j +1 –1 –1 –j –1 –j –1 +j –1 +j –j –j –1 +1 +1 –j –1 –j +1 –j +1<br>–1 +1 +1 –j +j +j +1 –j +1 +j +1 +j +j –j –j –1 +1 +1 –j –1 –j +1 –j +1 +1 –1 –1 +j –j –j –1 +j –1 –j –1 –j –1 +1 +1 –<br>j +j +j –1 +j –1 –j –1 –j +j –j –j –1 +1 +1 +j +1 +j –1 +j –1 –1 +1 +1 –j +j +j –1 +j –1 –j –1 –j –j +j +j +1 –1 –1 –j –<br>1 –j +1 –j +1 –j +j +j –1 +1 +1 –j –1 –j –1 +j –1 +1 –1 –1 –j +j +j +1 –j +1 –j –1 –j –j +j +j –1 +1 +1 –j –1 –j –1 +j –<br>1 –1 +1 +1 +j –j –j –1 +j –1 +j +1 +j +j –j –j +1 –1 –1 –j –1 –j –1 +j –1 +1 –1 –1 –j +j +j –1 +j –1 +j +1 +j +j –j –j +1<br>–1 –1 –j –1 –j –1 +j –1 –1 +1 +1 +j –j –j +1 –j +1 –j –1 –j –1 +1 +1 –j +j +j +1 –j +1 +j +1 +j –j +j +j +1 –1 –1 +j +1<br>+j –1 +j –1 –1 +1 +1 –j +j +j +1 –j +1 +j +1 +j +j –j –j –1 +1 +1 –j –1 –j +1 –j +1 –j +j +j +1 –1 –1 –j –1 –j +1 –j +1<br>–1 +1 +1 –j +j +j –1 +j –1 –j –1 –j –j +j +j +1 –1 –1 –j –1 –j +1 –j +1 +1 –1 –1 +j –j –j +1 –j +1 +j +1 +j +1 –1 –1 –<br>j +j +j +1 –j +1 –j –1 –j +j –j –j +1 –1 –1 +j +1 +j +1 –j +1 +1 –1 –1 –j +j +j +1 –j +1 –j –1 –j –j +j +j –1 +1 +1 –j –<br>1 –j –1 +j –1 +1 –1 –1 –j +j +j –1 +j –1 +j +1 +j –j +j +j –1 +1 +1 +j +1 +j +1 –j +1 +1 –1 –1 –j +j +j –1 +j –1 +j +1<br>+j +j –j –j +1 –1 –1 –j –1 –j –1 +j –1 +j –j –j –1 +1 +1 –j –1 –j +1 –j +1 –1 +1 +1 –j +j +j +1 –j +1 +j +1 +j +j –j –j –<br>1 +1 +1 –j –1 –j +1 –j +1 +1 –1 –1 +j –j –j –1 +j –1 –j –1 –j –1 +1 +1 –j +j +j –1 +j –1 –j –1 –j +j –j –j –1 +1 +1 +j<br>+1 +j –1 +j –1 –1 +1 +1 –j +j +j –1 +j –1 –j –1 –j –j +j +j +1 –1 –1 –j –1 –j +1 –j +1 –j +j +j –1 +1 +1 –j –1 –j –1 +j<br>–1 +1 –1 –1 –j +j +j +1 –j +1 –j –1 –j –j +j +j –1 +1 +1 –j –1 –j –1 +j –1 –1 +1 +1 +j –j –j –1 +j –1 +j +1 +j |



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### Table 28-115—The sequence $Seq^{i}_{left,595}(k)$(11ay) *(continued)*

| The sequence $Seq^{7}_{left,595}(k)$, to be transmitted from left to right, up to down |
|---|
| +j –j +j –1 –1 +1 +j +1 –1 –j +j –j –j –j –j –1 +1 +1 +1 +1 –1 –1 –1 +1 +1 –j +j +j +j –j –j +j –j –j +j –j –j +1 –1 –1<br>+1 –1 –1 –j +j +j +j –j –j +1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 –1 +j –j –j +j –j –j +j –j –j –j +j +j –1 +1 +1 +1 –1 –1 +1<br>–1 –1 +1 –1 –1 +j –j –j +j –j –j +1 –1 –1 –1 +1 +1 –j +j +j +j –j –j –j +j +j –j +j +j –1 +1 +1 –1 +1 +1 +1 –j +1 +1 –j<br>+1 –j –1 –j –j –1 –j +j +1 +j –j –1 –j +1 –j +1 –1 +j –1 –j –1 –j –j –1 –j +1 –j +1 +1 –j +1 +1 –j +1 –1 +j –1 +j +1 +j<br>–j –1 –j +j +1 +j +j +1 +j –1 +j –1 –1 +j –1 +1 –j +1 –1 +j –1 +j +1 +j –j –1 –j +1 –j +1 +1 –j +1 –j –1 –j –j –1 –j –j<br>–1 –j +j +1 +j –1 +j –1 +1 –j +1 +1 –1 –1 –1 +1 +1 –j +j +j +j –j –j +j –j –j +j –j –j +1 –1 –1 +1 –1 –1 –j +j +j +j –j –<br>j +1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 –1 +j –j –j +j –j –j +j –j –j –j +j +j –1 +1 +1 +1 –1 –1 +1 –1 –1 +1 –1 –1 +j –j –<br>j +j –j –j +1 –1 –1 –1 +1 +1 –j +j +j +j –j –j –j +j +j –j +j +j –1 +1 +1 –1 +1 +1 +1 –j +1 +1 –j +1 –j –1 –j –j –1 –j +j<br>+1 +j –j –1 –j +1 –j +1 –1 +j –1 –j –1 –j –j –1 –j +1 –j +1 +1 –j +1 +1 –j +1 –1 +j –1 +j +1 +j –j –1 –j +j +1 +j +j +1<br>+j –1 +j –1 –1 +j –1 +1 –j +1 –1 +j –1 +j +1 +j –j –1 –j +1 –j +1 +1 –j +1 –j –1 –j –j –1 –j –j –1 –j +j +1 +j –1 +j –1<br>+1 –j +1 –1 +1 +1 +1 –1 –1 +j –j –j –j +j +j –j +j +j –j +j +j –1 +1 +1 –1 +1 +1 +j –j –j –j +j +j –1 +1 +1 +1 –1 –1 –<br>1 +1 +1 –1 +1 +1 –j +j +j –j +j +j –j +j +j +j –j –j +1 –1 –1 –1 +1 +1 –1 +1 +1 –1 +1 +1 –j +j +j –j +j +j –1 +1 +1 +1<br>–1 –1 +j –j –j –j +j +j +j –j –j +j –j –j +1 –1 –1 +1 –1 –1 –1 +j –1 –1 +j –1 +j +1 +j +j +1 +j –j –1 –j +j +1 +j –1 +j –<br>1 +1 –j +1 +j +1 +j +j +1 +j –1 +j –1 –1 +j –1 –1 +j –1 +1 –j +1 –j –1 –j +j +1 +j –j –1 –j –j –1 –j +1 –j +1 +1 –j +1<br>–1 +j –1 +1 –j +1 –j –1 –j +j +1 +j –1 +j –1 –1 +j –1 +j +1 +j +j +1 +j +j +1 +j –j –1 –j +1 –j +1 –1 +j –1 |
| The sequence $Seq^{8}_{left,595}(k)$, to be transmitted from left to right, up to down |
| –1 +j +j +1 +1 –1 –j +j –j –1 –j +j –1 +j –j +j –1 +j +1 +1 –1 –1 –1 +1 +1 +j –j –j –j +j +j –1 +j –1 –1 +j –1 –j –1 –j<br>–j –1 –j –j +j +j +j –j –j –1 +1 +1 +1 –1 –1 +j +1 +j +j +1 +j +1 –j +1 +1 –j +1 –j +j +j –j +j +j –1 +1 +1 –1 +1 +1 +j<br>+1 +j –j –1 –j +1 –j +1 –1 +j –1 –1 +1 +1 –1 +1 +1 –j +j +j –j +j +j +1 –j +1 –1 +j –1 +j +1 +j –j –1 –j +1 –1 –1 –1<br>+1 +1 +j –j –j –j +j +j –1 +j –1 –1 +j –1 –j –1 –j –j –1 –j +j –j –j –j +j +j +1 –1 –1 –1 +1 +1 –j –1 –j –j –1 –j –1 +j –<br>1 –1 +j –1 –j +j +j –j +j +j –1 +1 +1 –1 +1 +1 +j +1 +j –j –1 –j +1 –j +1 –1 +j –1 +1 –1 –1 +1 –1 –1 +j –j –j +j –j –j<br>–1 +j –1 +1 –j +1 –j –1 –j +j +1 +j +1 –1 –1 –1 +1 +1 +j –j –j –j +j +j –1 +j –1 –1 +j –1 –j –1 –j –j –1 –j –j +j +j +j –<br>j –j –1 +1 +1 +1 –1 –1 +j +1 +j +j +1 +j +1 –j +1 +1 –j +1 –j +j +j –j +j +j –1 +1 +1 –1 +1 +1 +j +1 +j –j –1 –j +1 –j<br>+1 –1 +j –1 –1 +1 +1 –1 +1 +1 –j +j +j –j +j +j +1 –j +1 –1 +j –1 +j +1 +j –j –1 –j +1 –1 –1 –1 +1 +1 +j –j –j –j +j +j<br>–1 +j –1 –1 +j –1 –j –1 –j –j –1 –j +j –j –j –j +j +j +1 –1 –1 –1 +1 +1 –j –1 –j –j –1 –j –1 +j –1 –1 +j –1 –j +j +j –j +j<br>+j –1 +1 +1 –1 +1 +1 +j +1 +j –j –1 –j +1 –j +1 –1 +j –1 +1 –1 –1 +1 –1 –1 +j –j –j +j –j –j –1 +j –1 +1 –j +1 –j –1 –<br>j +j +1 +j –1 +1 +1 +1 –1 –1 –j +j +j +j –j –j +1 –j +1 +1 –j +1 +j +1 +j +j +1 +j +j –j –j –j +j +j +1 –1 –1 –1 +1 +1<br>–j –1 –j –j –1 –j –1 +j –1 –1 +j –1 +j –j –j +j –j –j +1 –1 –1 +1 –1 –1 –j –1 –j +j +1 +j –1 +j –1 +1 –j +1 +1 –1 –1 +1<br>–1 –1 +j –j –j +j –j –j –1 +j –1 +1 –j +1 –j –1 –j +j +1 +j –1 +1 +1 +1 –1 –1 –j +j +j +j –j –j +1 –j +1 +1 –j +1 +j +1<br>+j +j +1 +j –j +j +j +j –j –j –1 +1 +1 +1 –1 –1 +j +1 +j +j +1 +j +1 –j +1 +1 –j +1 +j –j –j +j –j –j +1 –1 –1 +1 –1 –1<br>–j –1 –j +j +1 +j –1 +j –1 +1 –j +1 –1 +1 +1 –1 +1 +1 –j +j +j –j +j +j +1 –j +1 –1 +j –1 +j +1 +j –j –1 –j |



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**Table 28-116—The sequence $Seq^{i}_{right,595}(k)$(11ay)**

| |
|---|
| The sequence $Seq^{1}_{right,595}(k)$, to be transmitted from left to right, up to down |
| –j –1 –j +j +j –j –1 +j –1 –1 –1 +1 +1 –j +1 –1 –1 +1 +j +1 +j +j +j –j –j –1 –j +j +j –j –1 +j –1 –1 –1 +1 –1 +j –1 +1<br>+1 –1 –j –1 –j –j –j +j +j +1 +j –j –j +j +1 –j +1 +1 +1 –1 –1 +j –1 +1 +1 –1 –j –1 –j –j –j +j –j –1 –j +j +j –j –1 +j –<br>1 –1 –1 +1 –1 +j –1 +1 +1 –1 –j –1 –j –j –j +j +1 –j +1 –1 –1 +1 –j –1 –j –j –j +j +j +1 +j –j –j +j –1 +j –1 –1 –1 +1<br>+1 –j +1 –1 –1 +1 –j –1 –j –j –j +j –j –1 –j +j +j –j +1 –j +1 +1 +1 –1 +1 –j +1 –1 –1 +1 –j –1 –j –j –j +j +j +1 +j –j<br>–j +j –1 +j –1 –1 –1 +1 –1 +j –1 +1 +1 –1 +j +1 +j +j +j –j +j +1 +j –j –j +j –1 +j –1 –1 –1 +1 +1 –j +1 –1 –1 +1 –j –<br>1 –j –j –j +j +j +1 +j –j –j +j –1 +j –1 –1 –1 +1 +1 –j +1 –1 –1 +1 –j –1 –j –j –j +j –j –1 –j +j +j –j +1 –j +1 +1 +1 –1<br>–1 +j –1 +1 +1 –1 +j +1 +j +j +j –j –j –1 –j +j +j –j +1 –j +1 +1 +1 –1 +1 –j +1 –1 –1 +1 –j –1 –j –j –j +j –j –1 –j +j<br>+j –j +1 –j +1 +1 +1 –1 +j +1 +j –j –j +j +1 –j +1 +1 +1 –1 –1 +j –1 +1 +1 –1 –j –1 –j –j –j +j +j +1 +j –j –j +j +1 –j<br>+1 +1 +1 –1 +1 –j +1 –1 –1 +1 +j +1 +j +j +j –j +j +1 +j –j –j +j +1 –j +1 +1 +1 –1 –1 +j –1 +1 +1 –1 –j –1 –j –j –j<br>+j –j –1 –j +j +j –j –1 +j –1 –1 –1 +1 –1 +j –1 +1 +1 –1 –j –1 –j –j –j +j –j –1 –j +j +j –j –1 +j –1 –1 –1 +1 +1 –j +1<br>–1 –1 +1 +j +1 +j +j +j –j –j –1 –j +j +j –j –1 +j –1 –1 –1 +1 –1 +j –1 +1 +1 –1 –j –1 –j –j –j +j +j +1 +j –j –j +j +1 –<br>j +1 +1 +1 –1 –1 +j –1 +1 +1 –1 –j –1 –j –j –j +j –j –1 –j +j +j –j –1 +j –1 –1 –1 +1 –1 +j –1 +1 +1 –1 –j –1 –j –j –j<br>+j +1 –j +1 –1 –1 +1 –j –1 –j –j –j +j +j +1 +j –j –j +j –1 +j –1 –1 –1 +1 +1 –j +1 –1 –1 +1 –j –1 –j –j –j +j –j –1 –j<br>+j +j –j +1 –j +1 +1 +1 –1 +1 –j +1 –1 –1 +1 –j –1 –j –j –j +j +j +1 +j –j –j +j –1 +j –1 –1 –1 +1 –1 +j –1 +1 +1 –1 +j<br>+1 +j +j +j –j +j +1 +j –j –j +j –1 +j –1 –1 –1 +1 –1 +1 +j +j –1 +1 +1 +j –j +j –1 +j +1 +1 +j +1 +j –1 –j |
| The sequence $Seq^{2}_{right,595}(k)$, to be transmitted from left to right, up to down |
| –j –1 –j –j –1 –j –j –1 –j +j +1 +j –j –1 –j –j –1 –j +j +1 +j –j –1 –j –1 +j –1 –1 +j –1 –1 +j –1 +1 –j +1 +1 –j +1 +1 –<br>j +1 –1 +j –1 +1 –j +1 +j +1 +j +j +1 +j +j +1 +j –j –1 –j +j +1 +j +j +1 +j –j –1 –j +j +1 +j –1 +j –1 –1 +j –1 –1 +j –<br>1 +1 –j +1 +1 –j +1 +1 –j +1 –1 +j –1 +1 –j +1 +1 +1 –1 +1 +1 –1 +1 +1 –1 –1 –1 +1 +1 +1 –1 +1 +1 –1 –1 –1 +1 +1<br>+1 –1 –j –j +j –j –j +j –j –j +j +j +j –j +j +j –j +j +j –j –j –j +j +j +j –j +1 +1 –1 +1 +1 –1 +1 +1 –1 –1 –1 +1 +1 +1 –<br>1 +1 +1 –1 –1 –1 +1 +1 +1 –1 +j +j –j +j +j –j +j +j –j –j –j +j –j –j +j –j –j +j +j +j –j –j –j +j +1 –j +1 +1 –j +1 +1<br>–j +1 –1 +j –1 +1 –j +1 +1 –j +1 –1 +j –1 +1 –j +1 –j –1 –j –j –1 –j –j –1 –j +j +1 +j +j +1 +j +j +1 +j –j –1 –j +j +1<br>+j –1 +j –1 –1 +j –1 –1 +j –1 +1 –j +1 –1 +j –1 –1 +j –1 +1 –j +1 –1 +j –1 –j –1 –j –j –1 –j –j –1 –j +j +1 +j +j +1 +j<br>+j +1 +j –j –1 –j +j +1 +j +j +j –j +j +j –j +j +j –j –j –j +j +j +j –j +j +j –j –j –j +j +j +j –j +1 +1 –1 +1 +1 –1 +1 +1 –<br>1 –1 –1 +1 –1 –1 +1 –1 –1 +1 +1 +1 –1 –1 –1 +1 +j +j –j +j +j –j +j +j –j –j –j +j +j +j –j +j +j –j –j –j +j +j +j –j –1<br>–1 +1 –1 –1 +1 –1 –1 +1 +1 +1 –1 +1 +1 –1 +1 +1 –1 –1 –1 +1 +1 +1 –1 –j –1 –j –j –1 –j –j –1 –j +j +1 +j –j –1 –j –<br>j –1 –j +j +1 +j –j –1 –j –1 +j –1 –1 +j –1 –1 +j –1 +1 –j +1 +1 –j +1 +1 –j +1 –1 +j –1 +1 –j +1 +j +1 +j +j +1 +j +j<br>+1 +j –j –1 –j +j +1 +j +j +1 +j –j –1 –j +j +1 +j –1 +j –1 –1 +j –1 –1 +j –1 +1 –j +1 +1 –j +1 +1 –j +1 –1 +j –1 +1 –<br>j +1 +1 +1 –1 +1 +1 –1 +1 +1 –1 –1 –1 +1 +1 +1 –1 +1 +1 –1 –1 –1 +1 +1 +1 –1 –j –j +j –j –j +j –j –j +j +j +j –j +j<br>+j –j +j +j –j –j –j +j +j +j –j +1 +1 –1 +1 +1 –1 +1 +1 –1 –1 –1 +1 +1 +1 –1 +1 +1 –1 –1 –1 +1 +1 +1 –1 +j +j –j +j<br>+j –j +j +j –j –j –j +j –j –j +j –j –j +j +j +j –j –j –j +j –1 –j +j –1 +1 –1 –1 +j –1 +j –j –1 +1 +1 –1 +1 –j –j +1 |
| The sequence $Seq^{3}_{right,595}(k)$, to be transmitted from left to right, up to down |
| +1 –j +1 +j +1 +j +1 –j +1 –j –1 –j –j –1 –j –1 +j –1 –j –1 –j +1 –j +1 –1 +j –1 –j –1 –j –1 +j –1 +j +1 +j –j –1 –j –1<br>+j –1 –j –1 –j +1 –j +1 –1 –1 +1 –j –j +j –1 –1 +1 +j +j –j +j +j –j +1 +1 –1 +j +j –j –1 –1 +1 –1 –1 +1 –j –j +j –1 –1<br>+1 +j +j –j –j –j +j –1 –1 +1 –j –j +j +1 +1 –1 –j –1 –j +1 –j +1 +j +1 +j +1 –j +1 –1 +j –1 +j +1 +j +1 –j +1 +j +1 +j<br>+j +1 +j –1 +j –1 –j –1 –j –1 +j –1 –1 +j –1 +j +1 +j +1 –j +1 +j +1 +j +j +j –j –1 –1 +1 –j –j +j –1 –1 +1 +1 +1 –1 –<br>j –j +j –1 –1 +1 –j –j +j +j +j –j –1 –1 +1 –j –j +j –1 –1 +1 –1 –1 +1 +j +j –j +1 +1 –1 +j +j –j –1 +j –1 –j –1 –j –1 +j<br>–1 +j +1 +j +j +1 +j +1 –j +1 +j +1 +j –1 +j –1 +1 –j +1 +j +1 +j +1 –j +1 –j –1 –j +j +1 +j +1 –j +1 +j +1 +j –1 +j –<br>1 +1 +1 –1 +j +j –j +1 +1 –1 –j –j +j –j –j +j –1 –1 +1 –j –j +j +1 +1 –1 +1 +1 –1 +j +j –j +1 +1 –1 –j –j +j +j +j –j<br>+1 +1 –1 +j +j –j –1 –1 +1 +j +1 +j –1 +j –1 –j –1 –j –1 +j –1 +1 –j +1 –j –1 –j –1 +j –1 –j –1 –j –j –1 –j +1 –j +1 +j<br>+1 +j +1 –j +1 +1 –j +1 –j –1 –j –1 +j –1 –j –1 –j –j –j +j +1 +1 –1 +j +j –j +1 +1 –1 –1 –1 +1 +j +j –j +1 +1 –1 +j +j<br>–j –j –j +j +1 +1 –1 +j +j –j +1 +1 –1 +1 +1 –1 –j –j +j –1 –1 +1 –j –j +j –1 +j –1 –j –1 –j –1 +j –1 +j +1 +j +j +1 +j<br>+1 –j +1 +j +1 +j –1 +j –1 +1 –j +1 +j +1 +j +1 –j +1 –j –1 –j +j +1 +j +1 –j +1 +j +1 +j –1 +j –1 +1 +1 –1 +j +j –j<br>+1 +1 –1 –j –j +j –j –j +j –1 –1 +1 –j –j +j +1 +1 –1 +1 +1 –1 +j +j –j +1 +1 –1 –j –j +j +j +j –j +1 +1 –1 +j +j –j –1<br>–1 +1 +j +1 +j –1 +j –1 –j –1 –j –1 +j –1 +1 –j +1 –j –1 –j –1 +j –1 –j –1 –j –j –1 –j +1 –j +1 +j +1 +j +1 –j +1 +1 –j<br>+1 –j –1 –j –1 +j –1 –j –1 –j –j –j +j +1 +1 –1 +j +j –j +1 +1 –1 –1 –1 +1 +j +j –j +1 +1 –1 +j +j –j –j –j +j +1 +1 –1<br>+j +j –j +1 +1 –1 +1 +1 –1 –j –j +j –1 –1 +1 –j –j +j –j –j +j +1 –1 –1 –j +j –j +j –1 +j +1 +1 +1 –1 +1 –1 –j |



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### Table 28-116—The sequence $Seq^{i}_{right,595}(k)$(11ay) *(continued)*

| |
|---|
| The sequence $Seq^{4}_{right,595}(k)$, to be transmitted from left to right, up to down |
| +1 –j +1 +j +1 +j +j +1 +j +1 –j +1 +1 +1 –1 +j +j –j +j +j –j +1 +1 –1 +j +1 +j +1 –j +1 –1 +j –1 –j –1 –j –j –j +j –1<br>–1 +1 +1 +1 –1 +j +j –j +1 –j +1 +j +1 +j +j +1 +j +1 –j +1 +1 +1 –1 +j +j –j +j +j –j +1 +1 –1 +j +1 +j +1 –j +1 –1<br>+j –1 –j –1 –j –j –j +j –1 –1 +1 +1 +1 –1 +j +j –j +1 –j +1 +j +1 +j –j –1 –j –1 +j –1 +1 +1 –1 +j +j –j –j –j +j –1 –1<br>+1 +j +1 +j +1 –j +1 +1 –j +1 +j +1 +j –j –j +j –1 –1 +1 –1 –1 +1 –j –j +j –1 +j –1 –j –1 –j +j +1 +j +1 –j +1 –1 –1 +1<br>–j –j +j +j +j –j +1 +1 –1 –j –1 –j –1 +j –1 –1 +j –1 –j –1 –j +j +j –j +1 +1 –1 +1 +1 –1 +j +j –j –1 +j –1 –j –1 –j –j –<br>1 –j –1 +j –1 –1 –1 +1 –j –j +j –j –j +j –1 –1 +1 –j –1 –j –1 +j –1 +1 –j +1 +j +1 +j +j +j –j +1 +1 –1 –1 –1 +1 –j –j<br>+j –1 +j –1 –j –1 –j –j –1 –j –1 +j –1 –1 –1 +1 –j –j +j –j –j +j –1 –1 +1 –j –1 –j –1 +j –1 +1 –j +1 +j +1 +j +j +j –j +1<br>+1 –1 –1 –1 +1 –j –j +j –1 +j –1 –j –1 –j +j +1 +j +1 –j +1 –1 –1 +1 –j –j +j +j +j –j +1 +1 –1 –j –1 –j –1 +j –1 –1 +j<br>–1 –j –1 –j +j +j –j +1 +1 –1 +1 +1 –1 +j +j –j +1 –j +1 +j +1 +j –j –1 –j –1 +j –1 +1 +1 –1 +j +j –j –j –j +j –1 –1 +1<br>+j +1 +j +1 –j +1 +1 –j +1 +j +1 +j –j –j +j –1 –1 +1 –1 –1 +1 –j –j +j –1 +j –1 –j –1 –j –j –1 –j –1 +j –1 –1 –1 +1 –j<br>–j +j –j –j +j –1 –1 +1 –j –1 –j –1 +j –1 +1 –j +1 +j +1 +j +j +j –j +1 +1 –1 –1 –1 +1 –j –j +j –1 +j –1 –j –1 –j –j –1 –<br>j –1 +j –1 –1 –1 +1 –j –j +j –j –j +j –1 –1 +1 –j –1 –j –1 +j –1 +1 –j +1 +j +1 +j +j +j –j +1 +1 –1 –1 –1 +1 –j –j +j –<br>1 +j –1 –j –1 –j +j +1 +j +1 –j +1 –1 –1 +1 –j –j +j +j +j –j +1 +1 –1 –j –1 –j –1 +j –1 –1 +j –1 –j –1 –j +j +j –j +1 +1<br>–1 +1 +1 –1 +j +j –j +1 –j +1 +j +1 +j –j –1 –j –1 +j –1 +1 +1 –1 +j +j –j –j –j +j –1 –1 +1 +j +1 +j +1 –j +1 +1 –j +1<br>+j +1 +j –j –j +j –1 –1 +1 –1 –1 +1 –j –j +j –j –1 +j +1 +j –1 +1 +1 +j +1 –j –j +1 +1 +1 +j +1 –1 –1 |
| The sequence $Seq^{5}_{right,595}(k)$, to be transmitted from left to right, up to down |
| +1 –1 –1 +1 –1 –1 +1 –1 –1 –1 +1 +1 –j +j +j –j +j +j –j +j +j +j –j –j –j –1 –j –j –1 –j +j +1 +j –j –1 –j –1 +j –1 –1<br>+j –1 +1 –j +1 –1 +j –1 –j +j +j –j +j +j –j +j +j +j –j –j +1 –1 –1 +1 –1 –1 +1 –1 –1 –1 +1 +1 –1 +j –1 –1 +j –1 +1 –<br>j +1 –1 +j –1 –j –1 –j –j –1 –j +j +1 +j –j –1 –j –1 +1 +1 +1 –1 –1 –1 +1 +1 –1 +1 +1 +j –j –j –j +j +j +j –j –j +j –j –<br>j +j +1 +j –j –1 –j –j –1 –j –j –1 –j +1 –j +1 –1 +j –1 –1 +j –1 –1 +j –1 –j +j +j +j –j –j –j +j +j –j +j +j +1 –1 –1 –1<br>+1 +1 +1 –1 –1 +1 –1 –1 –1 +j –1 +1 –j +1 +1 –j +1 +1 –j +1 –j –1 –j +j +1 +j +j +1 +j +j +1 +j –1 +1 +1 –1 +1 +1 –<br>1 +1 +1 +1 –1 –1 +j –j –j +j –j –j +j –j –j –j +j +j +j +1 +j +j +1 +j –j –1 –j +j +1 +j +1 –j +1 +1 –j +1 –1 +j –1 +1 –j<br>+1 +j –j –j +j –j –j +j –j –j –j +j +j –1 +1 +1 –1 +1 +1 –1 +1 +1 +1 –1 –1 +1 –j +1 +1 –j +1 –1 +j –1 +1 –j +1 +j +1<br>+j +j +1 +j –j –1 –j +j +1 +j +1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 –1 –j +j +j +j –j –j –j +j +j –j +j +j –j –1 –j +j +1 +j<br>+j +1 +j +j +1 +j –1 +j –1 +1 –j +1 +1 –j +1 +1 –j +1 +j –j –j –j +j +j +j –j –j +j –j –j –1 +1 +1 +1 –1 –1 –1 +1 +1 –<br>1 +1 +1 +1 –j +1 –1 +j –1 –1 +j –1 –1 +j –1 +j +1 +j –j –1 –j –j –1 –j –j –1 –j –1 +1 +1 –1 +1 +1 –1 +1 +1 +1 –1 –1<br>+j –j –j +j –j –j +j –j –j –j +j +j +j +1 +j +j +1 +j –j –1 –j +j +1 +j +1 –j +1 +1 –j +1 –1 +j –1 +1 –j +1 +j –j –j +j –j –<br>j +j –j –j –j +j +j –1 +1 +1 –1 +1 +1 –1 +1 +1 +1 –1 –1 +1 –j +1 +1 –j +1 –1 +j –1 +1 –j +1 +j +1 +j +j +1 +j –j –1 –<br>j +j +1 +j +1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 –1 –j +j +j +j –j –j –j +j +j –j +j +j –j –1 –j +j +1 +j +j +1 +j +j +1 +j –<br>1 +j –1 +1 –j +1 +1 –j +1 +1 –j +1 +j –j –j –j +j +j +j –j –j +j –j –j –1 +1 +1 +1 –1 –1 –1 +1 +1 –1 +1 +1 +1 –j +1 –<br>1 +j –1 –1 +j –1 –1 +j –1 +j +1 +j –j –1 –j –j –1 –j –j –1 –j –1 –j +1 –j –1 +1 +j –j +1 +j –1 –j +1 +1 +1 –j +j +j +j |
| The sequence $Seq^{6}_{right,595}(k)$, to be transmitted from left to right, up to down |
| +1 –1 –1 –j +j +j –1 +j –1 +j +1 +j –j +j +j –1 +1 +1 +j +1 +j +1 –j +1 –1 +1 +1 +j –j –j +1 –j +1 –j –1 –j –j +j +j –1<br>+1 +1 +j +1 +j +1 –j +1 +j –j –j –1 +1 +1 –j –1 –j +1 –j +1 –1 +1 +1 –j +j +j +1 –j +1 +j +1 +j –j +j +j +1 –1 –1 +j<br>+1 +j –1 +j –1 –1 +1 +1 –j +j +j +1 –j +1 +j +1 +j –1 +1 +1 –j +j +j –1 +j –1 –j –1 –j +j –j –j –1 +1 +1 +j +1 +j –1 +j<br>–1 +1 –1 –1 +j –j –j +1 –j +1 +j +1 +j +j –j –j –1 +1 +1 +j +1 +j –1 +j –1 –j +j +j –1 +1 +1 –j –1 –j –1 +j –1 +1 –1 –<br>1 –j +j +j +1 –j +1 –j –1 –j +j –j –j +1 –1 –1 +j +1 +j +1 –j +1 +1 –1 –1 –j +j +j +1 –j +1 –j –1 –j –1 +1 +1 +j –j –j +1<br>–j +1 –j –1 –j +j –j –j +1 –1 –1 –j –1 –j –1 +j –1 +1 –1 –1 –j +j +j –1 +j –1 +j +1 +j +j –j –j +1 –1 –1 –j –1 –j –1 +j –<br>1 –j +j +j +1 –1 –1 +j +1 +j –1 +j –1 +1 –1 –1 +j –j –j –1 +j –1 –j –1 –j +j –j –j –1 +1 +1 –j –1 –j +1 –j +1 +1 –1 –1<br>+j –j –j –1 +j –1 –j –1 –j +1 –1 –1 +j –j –j +1 –j +1 +j +1 +j –j +j +j +1 –1 –1 –j –1 –j +1 –j +1 –1 +1 +1 –j +j +j –1<br>+j –1 –j –1 –j –j +j +j +1 –1 –1 –j –1 –j +1 –j +1 +j –j –j +1 –1 –1 +j +1 +j +1 –j +1 –1 +1 +1 +j –j –j –1 +j –1 +j +1<br>+j –j +j +j –1 +1 +1 –j –1 –j –1 +j –1 –1 +1 +1 +j –j –j –1 +j –1 +j +1 +j –1 +1 +1 +j –j –j +1 –j +1 –j –1 –j +j –j –j<br>+1 –1 –1 –j –1 –j –1 +j –1 +1 –1 –1 –j +j +j –1 +j –1 +j +1 +j +j –j –j +1 –1 –1 –j –1 –j –1 +j –1 –j +j +j +1 –1 –1 +j<br>+1 +j –1 +j –1 +1 –1 –1 +j –j –j –1 +j –1 –j –1 –j +j –j –j –1 +1 +1 –j –1 –j +1 –j +1 +1 –1 –1 +j –j –j –1 +j –1 –j –1<br>–j +1 –1 –1 +j –j –j +1 –j +1 +j +1 +j –j +j +j +1 –1 –1 –j –1 –j +1 –j +1 –1 +1 +1 –j +j +j –1 +j –1 –j –1 –j –j +j +j<br>+1 –1 –1 –j –1 –j +1 –j +1 +j –j –j +1 –1 –1 +j +1 +j +1 –j +1 –1 +1 +1 +j –j –j –1 +j –1 +j +1 +j –j +j +j –1 +1 +1 –<br>j –1 –j –1 +j –1 –1 +1 +1 +j –j –j –1 +j –1 +j +1 +j +1 +1 +1 +j +j –1 +j +1 –j +1 +j –1 +1 +1 +1 +j –j +j +j |

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**Table 28-116—The sequence $Seq^{i}_{right,595}(k)$(11ay) *(continued)***

| |
|---|
| The sequence $Seq^{7}_{right,595}(k)$, to be transmitted from left to right, up to down |
| –j +j +j +j –j –j –1 +1 +1 +1 –1 –1 +1 –1 –1 +1 –1 –1 –j +j +j –j +j +j +1 –1 –1 –1 +1 +1 +j –j –j –j +j +j +j –j –j +j –j –j –1 +1 +1 –1 +1 +1 +1 –1 –1 –1 +1 +1 +j –j –j –j +j +j –j +j +j –j +j +j +1 –1 –1 +1 –1 –1 +j –j –j –j +j +j +1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 –1 –j +j +j –j +j +j –j –1 –j –j –1 –j –1 +j –1 –1 +j –1 +1 –j +1 –1 +j –1 –j –1 –j +j +1 +j +1 +1 –j +1 +j +1 +j +j +1 +j +j +1 +j –j –1 –j –1 +j –1 +1 –j +1 +1 –j +1 +1 –j +1 +j +1 +j +j +1 +j –j –1 –j +j +1 +j +1 –j +1 –1 +j –1 +j +1 +j +j +1 +j +1 –j +1 +1 –j +1 +1 –j +1 –1 +j –1 –j –1 –j +j +1 +j +j +1 –1 –1 –1 +1 +1 –j +j +j +j –j –j +j –j –j +j –j –j +1 –1 –1 +1 –1 –1 +j –j –j –j +j +j –1 +1 +1 +1 –1 –1 +j –j –j –j +j +j +1 –1 –1 +1 –1 –1 –j +j +j –j +j +j +1 –1 –1 +1 –1 –1 +j –1 +1 –j +1 –j –1 –j +j +1 +j +j +1 +j –j –1 –j –j +1 –1 –1 +1 –1 –1 +1 –j +1 +1 –j +1 –j –1 –j +j +1 +j +j +1 +j –1 +j –1 –1 +j –1 –1 +j –1 +1 –j +1 –j –1 –j +j +1 +j +j +1 +j –1 +j –1 –1 +j –1 –1 +j –1 +1 –j +1 –j –1 –j +j +1 +j +j +1 +j –1 –j –1 +j –1 –1 +j –1 +1 +j +j –1 –j +1 –j –1 +j –1 +1 –j +1 –j –1 –j +j +j +j –j –j –1 +1 +1 +1 –1 –1 +1 –1 –1 –j +j +j –j +j +1 –1 –1 –1 +1 +1 +j –j –j –j +j +j –j +j –j –j –1 +1 +1 –1 +1 +1 +1 –1 –1 –1 +1 +1 +j –j –j –j +j +j –j +j +j –j +j +j –1 –1 –1 +1 +1 +j –j –j –j +j +j +1 –1 –1 –1 +1 +1 +1 –1 –1 +1 –1 –1 –j +j +j –j +j –j –1 –j –j –1 –j –1 +j –1 –1 +j –1 +1 –j +1 –j –1 –j –1 +j –1 +j –1 –1 +j –1 +j –1 +j –1 +j +j –1 –j –1 –j +1 +j –1 +j –1 +j +1 –j +1 +1 –j +1 +1 –j +1 +j +1 +j +j +1 +j +j +1 +j –j –1 –j –1 +j –1 +1 –j +1 +1 –j +1 +1 –j +1 +j +1 +j +j +1 +j –j +1 +1 –j +1 +1 –j +1 +1 –j +1 –1 +j –1 –j –1 –j +j +1 +j +j +1 +j +1 –j +1 +1 –j +1 +1 –j +1 –1 +j –1 –j –1 –j +j +1 +j +j +1 +j –1 –1 –1 +1 +1 +j –j –j –j +j +j –j +j +j –j +j +1 –1 –1 +1 –1 –1 –j +j +j –j +j +1 –1 –1 –1 +1 +1 +j –j –j –j +j +j –j +j +j –j +j +1 –1 –1 +1 –1 –1 +j –j –j –j +j +j –j –1 –j –j –1 –j –1 +j –1 –1 +j –1 +1 –j +1 –j –1 –j –1 +j –1 +j –1 –1 +j –1 +j –1 +j –1 +j +j –1 –j –1 –j +1 +j –1 +j –1 +j +1 –j +1 +1 –j +1 +1 –j +1 +j +1 +j +j +1 +j +j +1 +j –j –1 –j –1 +j –1 +1 –j +1 +1 –j +1 +1 –j +1 +j +1 +j +j +1 +j –j –1 –j –1 +j –1 +1 –j +1 +1 –j +1 +1 –j +1 +j +1 +j +j +1 +j –j +1 +1 –j +1 +1 –j +1 +1 –j +1 –1 +j –1 –j –1 –j +j +1 +j +j +1 +j –j +1 +1 –j +1 +1 –j +1 –1 +j –1 –j –1 –j +j +1 +j +j +1 +j –1 –1 –1 +1 +1 +j –j –j –j +j +j –j +j +j –j +j +1 –1 –1 +1 –1 –1 +j –j –j –j +j +j –j +j +j –j +j +1 –1 –1 +1 –1 –1 +j –j –j –j +j +j –j +j +j –j +j +1 –1 –1 +1 –1 –1 –j –j –j –j +j +j –j +j +j –j –1 –j –j –1 –j –1 +j –1 –1 +j –1 +1 –j +1 –j –1 –j –1 +j –1 +j –1 –1 +j –1 +j –1 +j –1 +j +j –1 –j –1 –j +1 +j –1 +j –1 +j +1 –j +1 +1 –j +1 +1 –j +1 +j +1 +j +j +1 +j +j +1 +j –j –1 –j –1 +j –1 +1 –j +1 +1 –j +1 +1 –j +1 +j +1 +j +j +1 +j –j +1 +1 –j +1 +1 –j +1 +1 –j +1 –1 +j –1 –j –1 –j +j +1 +j +j +1 +j –j +1 +1 –j +1 +1 –j +1 –1 +j –1 –j –1 –j +j +1 +j +j +1 +j –1 –1 –1 +1 +1 +j –j –j –j +j +j –j +j +j –j +j +1 –1 –1 +1 –1 –1 +j –j –j –j +j +j –j +j +j –j +j +1 –1 –1 +1 –1 –1 –

**Table 28-117—The sequence $Seq^{i}_{left,804}(k)$(11ay)**

| The sequence $Seq^{1}_{left,804}(k)$, to be transmitted from left to right, up to down |
|---|
| –j +j +1 –1 +j –1 –j –j –1 +j –j +j +1 +1 +1 +j –1 –1 +j –1 +1 –1 +j +j –1 –j +1 +1 –j –1 +1 –1 +j +j –j +1 +j +j +1 +j<br>–j +j +1 +1 +j –1 –j –j –1 +j –j +j +1 +1 +1 +j –1 –1 +j –1 +1 –1 +j +j +1 +j –1 –1 +j +1 –1 +1 –j –j +j –1 –j –j –1 –j<br>+j –j –1 –1 –j +1 +j +j +1 –j +j –j –1 –1 –1 –j +1 +1 –j +1 –1 +1 –j –j +1 +j –1 –1 +j +1 –1 +1 –j –j +j –1 –j –j –1 –j<br>+j –j –1 –1 +j –1 –j –j –1 +j –j +j +1 +1 +1 +j –1 –1 +j –1 +1 –1 +j +j +1 +j –1 –1 +j +1 –1 +1 –j –j +j –1 –j –j –1 –j<br>+j –j –1 –1 +j –1 –j –j –1 +j –j +j +1 +1 +1 +j –1 –1 +j –1 +1 –1 +j +j –1 –j +1 +1 –j –1 +1 –1 +j +j –j +1 +j +j +1 +j<br>–j +j +1 +1 +j –1 –j –j –1 +j –j +j +1 +1 +1 +j –1 –1 +j –1 +1 –1 +j +j +1 +j –1 –1 +j +1 –1 +1 –j –j +j –1 –j –j –1 –j<br>+j –j –1 –1 –j +1 +j +j +1 –j +j –j –1 –1 –1 –j +1 +1 –j +1 –1 +1 –j –j +1 +j –1 –1 +j +1 –1 +1 –j –j +j –1 –j –j –1 –j<br>+j –j –1 –1 +j –1 –j –j –1 +j –j +j +1 +1 +1 +j –1 –1 +j –1 +1 –1 +j +j +1 +j –1 –1 +j +1 –1 +1 –j –j +j –1 –j –j –1 –j<br>+j –j –1 –1 +1 +j –1 –1 +j +1 –1 +1 –j –j –j +1 +j +j +1 +j –j +j +1 +1 +j –1 –j –j –1 +j –j +j +1 +1 –1 –j +1 +1 –j +1<br>–1 +1 –j –j +1 +j –1 –1 +j +1 –1 +1 –j –j –j +1 +j +j +1 +j –j +j +1 +1 –j +1 +j +j +1 –j +j –j –1 –1 +1 +j –1 –1 +j –1<br>+1 –1 +j +j –1 –j +1 +1 –j –1 +1 –1 +j +j +j –1 –j –j –1 –j +j –j –1 –1 –j +1 +j +j +1 –j +j –j –1 –1 +1 +j –1 –1 +j –1<br>+1 –1 +j +j +1 +j –1 –1 +j +1 –1 +1 –j –j –j +1 +j +j +1 +j –j +j +1 +1 –j +1 +j +j +1 –j +j –j –1 –1 +1 +j –1 –1 +j –<br>1 +1 –1 +j +j –1 –j +1 +1 –j –1 +1 –1 +j +j +j –1 –j –j –1 –j +j –j –1 –1 –j +1 +j +j +1 –j +j –j –1 –1 +1 +j –1 –1 +j –<br>1 +1 –1 +j +j –1 –j +1 +1 –j –1 +1 –1 +j +j +j –1 –j –j –1 –j +j –j –1 –1 +j –1 –j –j –1 +j –j +j +1 +1 –1 –j +1 +1 –j<br>+1 –1 +1 –j –j +1 +j –1 –1 +j +1 –1 +1 –j –j –j +1 +j +j +1 +j –j +j +1 +1 +j –1 –j –j –1 +j –j +j +1 +1 –1 –j +1 +1 –<br>j +1 –1 +1 –j –j –1 –j +1 +1 –j –1 +1 –1 +j +j +j –1 –j –j –1 –j +j –j –1 –1 +j –1 –j –j –1 +j –j +j +1 +1 –1 –j +1 +1 –<br>j +1 –1 +1 –j –j +1 +j –1 –1 +j +1 –1 +1 –j –j –j +1 +j +j +1 +j –j +j +1 +1 +j –1 –j –j –1 +j –j +j +1 +1 –1 –j +1 +1<br>–j +1 –1 +1 –j –j +1 +j –1 –1 +j +1 –1 +1 –j –j –j +1 +j +j +1 +j –j +j +1 +1 –j +1 +j +j +1 –j +j –j –1 –1 +1 +j –1 –1<br>+j –1 +1 –1 +j +j –1 –j +1 +1 –j –1 +1 –1 +j +j +j –1 –j –j –1 –j +j –j –1 –1 –j +1 +j +j +1 –j +j –j –1 –1 +1 +j –1 –1<br>+j –1 +1 –1 +j +j +1 +j –1 –1 +j +1 –1 +1 –j –j –j +1 +j +j +1 +j –j +j +1 +1 –j +1 +j +j +1 –j +j –j –1 –1 +1 +j –1 –<br>1 +j –1 +1 –1 +j +j |
| The sequence $Seq^{2}_{left,804}(k)$, to be transmitted from left to right, up to down |
| +1 –1 –1 +1 +j –1 –j –j –1 +j –1 –j –j –1 +1 +j –1 –1 +j +1 +j –1 –1 +j –j +1 +j +j +1 –j +1 +j +j +1 +1 +j –1 –1 +j +1<br>+j –1 –1 +j +j –1 –j –j –1 –j +1 +j +j +1 –1 –j +1 +1 –j +1 +j –1 –1 +j –j +1 +j +j +1 +j –1 –j –j –1 –1 –j +1 +1 –j +1<br>+j –1 –1 +j +1 –1 +1 –j –j +1 –1 +1 –j –j –j +j –j –1 –1 –j +j –j –1 –1 +1 –1 +1 –j –j +1 –1 +1 –j –j +j –j +j +1 +1 +j<br>–j +j +1 +1 +1 –1 +1 –j –j –1 +1 –1 +j +j +j –j +j +1 +1 –j +j –j –1 –1 +1 –1 +1 –j –j –1 +1 –1 +j +j –j +j –j –1 –1 +j<br>–j +j +1 +1 +j –1 –j –j –1 +j –1 –j –j –1 +1 +j –1 –1 +j +1 +j –1 –1 +j –j +1 +j +j +1 –j +1 +j +j +1 +1 +j –1 –1 +j +1<br>+j –1 –1 +j +j –1 –j –j –1 –j +1 +j +j +1 –1 –j +1 +1 –j +1 +j –1 –1 +j –j +1 +j +j +1 +j –1 –j –j –1 –1 –j +1 +1 –j +1<br>+j –1 –1 +j +1 –1 +1 –j –j +1 –1 +1 –j –j –j +j –j –1 –1 –j +j –j –1 –1 +1 –1 +1 –j –j +1 –1 +1 –j –j +j –j +j +1 +1 +j<br>–j +j +1 +1 +1 –1 +1 –j –j –1 +1 –1 +j +j +j –j +j +1 +1 –j +j –j –1 –1 +1 –1 +1 –j –j –1 +1 –1 +j +j –j +j –j –1 –1 +j<br>–j +j +1 +1 +1 +j –1 –1 +j +1 +j –1 –1 +j –j +1 +j +j +1 –j +1 +j +j +1 –1 –j +1 +1 –j –1 –j +1 +1 –j –j +1 +j +j +1 –<br>j +1 +j +j +1 +1 +j –1 –1 +j –1 –j +1 +1 –j +j –1 –j –j –1 –j +1 +j +j +1 –1 –j +1 +1 –j +1 +j –1 –1 +j +j –1 –j –j –1 –<br>j +1 +j +j +1 –j +j –j –1 –1 –j +j –j –1 –1 –1 +1 –1 +j +j –1 +1 –1 +j +j –j +j –j –1 –1 –j +j –j –1 –1 +1 –1 +1 –j –j +1<br>–1 +1 –j –j –j +j –j –1 –1 +j –j +j +1 +1 +1 –1 +1 –j –j –1 +1 –1 +j +j –j +j –j –1 –1 +j –j +j +1 +1 –1 +1 –1 +j +j +1<br>–1 +1 –j –j –1 –j +1 +1 –j –1 –j +1 +1 –j +j –1 –j –j –1 +j –1 –j –j –1 +1 +j –1 –1 +j +1 +j –1 –1 +j +j –1 –j –j –1 +j<br>–1 –j –j –1 –1 –j +1 +1 –j +1 +j –1 –1 +j –j +1 +j +j +1 +j –1 –j –j –1 +1 +j –1 –1 +j –1 –j +1 +1 –j –j +1 +j +j +1 +j<br>–1 –j –j –1 +j –j +j +1 +1 +j –j +j +1 +1 +1 –1 +1 –j –j +1 –1 +1 –j –j +j –j +j +1 +1 +j –j +j +1 +1 –1 +1 –1 +j +j –<br>1 +1 –1 +j +j +j –j +j +1 +1 –j +j –j –1 –1 –1 +1 –1 +j +j +1 –1 +1 –j –j +j –j +j +1 +1 –j +j –j –1 –1 +1 –1 +1 –j –j –<br>1 +1 –1 +j +j +1 +j –1 –1 +j +1 +j –1 –1 +j –j +1 +j +j +1 –j +1 +j +j +1 –1 –j +1 +1 –j –1 –j +1 +1 –j –j +1 +j +j +1<br>–j +1 +j +j +1 +1 +j –1 –1 +j –1 –j +1 +1 –j +j –1 –j –j –1 –j +1 +j +j +1 –1 –j +1 +1 –j +1 +j –1 –1 +j +j –1 –j –j –1<br>–j +1 +j +j +1 –j +j –j –1 –1 –j +j –j –1 –1 –1 +1 –1 +j +j –1 +1 –1 +j +j –j +j –j –1 –1 –j +j –j –1 –1 +1 –1 +1 –j –j<br>+1 –1 +1 –j –j –j +j –j –1 –1 +j –j +j +1 +1 +1 –1 +1 –j –j –1 +1 –1 +j +j –j +j –j –1 –1 +j –j +j +1 +1 –1 +1 –1 +j +j<br>+1 –1 +1 –j –j |

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This is an unapproved IEEE Standards Draft, subject to change.

**Table 28-117—The sequence $Seq^{i}_{left,804}(k)$(11ay) *(continued)***

| The sequence $Seq^{3}_{left,804}(k)$, to be transmitted from left to right, up to down |
|---|
| –j –1 –1 –1 +j –1 –j –j –1 +j –j +j +1 +1 –1 –j +1 +1 –j –1 +1 –1 +j +j –j +1 +j +j +1 +j –j +j +1 +1 +1 +j –1 –1 +j –1 +1 –1 +j +j +1 +j –1 –1 +j +1 –1 +1 –j –j –j +1 +j +j +1 –j +j –j –1 –1 +1 +j –1 –1 +j –1 +1 –1 +j +j –j +1 +j +j +1 +j –j +j +1 +1 +j –1 –j –j –1 +j –j +j +1 +1 +1 +j –1 –1 +j +1 –1 +1 –j –j –j +1 +j +j +1 +j –j +j +1 +1 –1 –j +1 +1 –j +1 –1 +1 –j –j +1 +j –1 –1 +j +1 –1 +1 –j –j +j –1 –j –j –1 +j –j +j +1 +1 +1 +j –1 –1 +j –1 +1 –1 +j +j +j –1 –j –j –1 –j +j –j –1 –1 –j +1 +j +j +1 –j +j –j –1 –1 +1 +j –1 –1 +j +1 –1 +1 –j –j +j –1 –j –j –1 –j +j –j –1 –1 –1 –j +1 +1 –j +1 –1 +1 –j –j –1 –j +1 +1 –j –1 +1 –1 +j +j +j –1 –j –j –1 +j –j +j +1 +1 –1 –j +1 +1 –j +1 –1 +1 –j –j +j –1 –j –j –1 –j +j –j –1 –1 –j +1 +j +j +1 –j +j –j –1 –1 –1 –j +1 +1 –j –1 +1 –1 +j +j +j –1 –j –j –1 –j +j –j –1 –1 +1 +j –1 –1 +j –1 +1 –1 +j +j –1 –j +1 +1 –j –1 +1 –1 +j +j –j +1 +j +j +1 –j +j –j –1 –1 –1 –j +1 +1 –j +1 –1 +1 –j –j –j +1 +j +j +1 +j –j +j +1 +1 +j –1 –j –j –1 +j –j +j +1 +1 –1 –j +1 +1 –j –1 +1 –1 +j +j –j +1 +j +j +1 +j –j +j +1 +1 +1 +j –1 –1 +j –1 +1 –1 +j +j +1 +j –1 –1 +j +1 –1 +1 –j –j –j +1 +j +j +1 –j +j –j –1 –1 +1 +j –1 –1 +j –1 +1 –1 +j +j –j +1 +j +j +1 +j –j +j +1 +1 +j –1 –j –j –1 +j –j +j +1 +1 +1 +j –1 –1 +j +1 –1 +1 –j –j –j +1 +j +j +1 +j –j +j +1 +1 –1 –j +1 +1 –j +1 –1 +1 –j –j +1 +j –1 –1 +j +1 –1 +1 –j –j +j –1 –j –j –1 +j –j +j +1 +1 +1 +j –1 –1 +j –1 +1 –1 +j +j +j –1 –j –j –1 –j +j –j –1 –1 –1 –j +1 +1 –j –1 +1 –1 +j +j –j +1 +j +j +1 –j +j –j –1 –1 +1 +j –1 –1 +j –1 +1 –1 +j +j +j –1 –j –j –1 –j +j –j –1 –1 +j –1 –j –j –1 +j –j +j +1 +1 +1 +j –1 –1 +j +1 –1 +1 –j –j +j –1 –j –j –1 –j +j –j –1 –1 +1 +j –1 –1 +j –1 +1 –1 +j +j –1 –j +1 +1 –j –1 +1 –1 +j +j +j –1 –j –j –1 +j –j +j +1 +1 +1 +j –1 –1 +j –1 +1 –1 +j +j –j +1 +j +j +1 +j –j +j +1 +1 +j –1 –j –j –1 +j –j +j +1 +1 –1 –j +1 +1 –j –1 +1 –1 +j +j +j –1 –j –j –1 –j +j –j –1 –1 –1 –j +1 +1 –j +1 –1 +1 –j –j –1 –j +1 +1 –j –1 +1 –1 +j +j –j +1 +j +j +1 –j +j –j –1 –1 +1 +j –1 –1 +j –1 +1 –1 +j +j +j –1 –j –j –1 –j +j –j –1 –1 +j –1 –j –j –1 +j –j +j +1 +1 +1 +j –1 –1 +j +1 –1 +1 –j –j +j –1 –j –j –1 –j +j –j –1 –1 +1 +j –1 –1 +j –1 +1 –1 +j +j –1 –j +1 +1 –j –1 +1 –1 +j +j +j –1 –j –j –1 +j –j +j +1 +1 +1 +j –1 –1 +j –1 +1 –1 +j +j –j +1 +j +j +1 +j –j +j +1 +1 +j –1 –j –j –1 +j –j +j +1 +1 –1 –j +1 +1 –j –1 +1 –1 +j +j +j –1 –j –j –1 –j +j –j –1 –1 –1 –j +1 +1 –j +1 –1 +1 –j –j |
| The sequence $Seq^{4}_{left,804}(k)$, to be transmitted from left to right, up to down |
| +1 +j +j –j +j –1 –j –j –1 +j –1 –j –j –1 –j +j –j –1 –1 –j +j –j –1 –1 –1 –j +1 +1 –j –1 –j +1 +1 –j +1 –1 +1 –j –j +1 –1 +1 –j –j –1 –j +1 +1 –j +1 +j –1 –1 +j +1 –1 +1 –j –j –1 +1 –1 +j +j +j –1 –j –j –1 –j +1 +j +j +1 –j +j –j –1 –1 +j –j +j +1 +1 –1 –j +1 +1 –j –1 –j +1 +1 –j –1 +1 –1 +j +j –1 +1 –1 +j +j +j –1 –j –j –1 +j –1 –j –j –1 +j –j +j +1 +1 +j –j +j +1 +1 –j +1 +j +j +1 +j –1 –j –j –1 –j +j –j –1 –1 +j –j +j +1 +1 +1 +j –1 –1 +j –1 –j +1 +1 –j +1 –1 +1 –j –j –1 +1 –1 +j +j –j +1 +j +j +1 –j +1 +j +j +1 +j –j +j +1 +1 +j –j +j +1 +1 +1 +j –1 –1 +j +1 +j –1 –1 +j –1 +1 –1 +j +j –1 +1 –1 +j +j +1 +j –1 –1 +j –1 –j +1 +1 –j –1 +1 –1 +j +j +1 –1 +1 –j –j –j +1 +j +j +1 +j –1 –j –j –1 +j –j +j +1 +1 –j +j –j –1 –1 +1 +j –1 –1 +j +1 +j –1 –1 +j +1 –1 +1 –j –j +1 –1 +1 –j –j –j +1 +j +j +1 –j +1 +j +j +1 –j +j –j –1 –1 –j +j –j –1 –1 +j –1 –j –j –1 –j +1 +j +j +1 +j –j +j +1 +1 –j +j –j –1 –1 –1 –j +1 +1 –j +1 +j –1 –1 +j –1 +1 –1 +j +j +1 –1 +1 –j –j +j –1 –j –j –1 +j –1 –j –j –1 –j +j –j –1 –1 –j +j –j –1 –1 –1 –j +1 +1 –j –1 –j +1 +1 –j +1 –1 +1 –j –j +1 –1 +1 –j –j –1 –j +1 +1 –j +1 +j –1 –1 +j +1 –1 +1 –j –j –1 +1 –1 +j +j +j –1 –j –j –1 –j +1 +j +j +1 –j +j –j –1 –1 +j –j +j +1 +1 –1 –j +1 +1 –j –1 –j +1 +1 –j –1 +1 –1 +j +j –1 +1 –1 +j +j +j –1 –j –j –1 +j –1 –j –j –1 +j –j +j +1 +1 +j –j +j +1 +1 –j +1 +j +j +1 +j –1 –j –j –1 –j +j –j –1 –1 +j –j +j +1 +1 +1 +j –1 –1 +j –1 –j +1 +1 –j +1 –1 +1 –j –j –1 +1 –1 +j +j –1 –j +1 +1 –j –1 –j +1 +1 –j +1 –1 +1 –j –j +1 –1 +1 –j –j –j +1 +j +j +1 –j +1 +j +j +1 +j –j +j +1 +1 +j –j +j +1 +1 –j +1 +j +j +1 +j –1 –j –j –1 +j –j +j +1 +1 –j +j –j –1 –1 –1 –j +1 +1 –j +1 +j –1 –1 +j +1 –1 +1 –j –j –1 +1 –1 +j +j –j +1 +j +j +1 –j +1 +j +j +1 –j +j –j –1 –1 –j +j –j –1 –1 –1 –j +1 +1 –j –1 –j +1 +1 –j –1 +1 –1 +j +j –1 +1 –1 +j +j +1 +j –1 –1 +j –1 –j +1 +1 –j +1 –1 +1 –j –j –1 +1 –1 +j +j +j –1 –j –j –1 –j +1 +j +j +1 +j –j +j +1 +1 –j +j –j –1 –1 –1 –j +1 +1 –j –1 –j +1 +1 –j +1 –1 +1 –j –j +1 –1 +1 –j –j –j +1 +j +j +1 –j +1 +j +j +1 +j –j +j +1 +1 +j –j +j +1 +1 –j +1 +j +j +1 +j –1 –j –j –1 +j –j +j +1 +1 –j +j –j –1 –1 –1 –j +1 +1 –j +1 +j –1 –1 +j +1 –1 +1 –j –j –1 +1 –1 +j +j –j +1 +j +j +1 –j +1 +j +j +1 –j +j –j –1 –1 –j +j –j –1 –1 –1 –j +1 +1 –j –1 –j +1 +1 –j –1 +1 –1 +j +j –1 +1 –1 +j +j +1 +j –1 –1 +j –1 –j +1 +1 –j +1 –1 +1 –j –j –1 +1 –1 +j +j +j –1 –j –j –1 –j +1 +j +j +1 +j –j +j +1 +1 –j +j –j –1 –1 |



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**Table 28-117—The sequence $Seq^{i}_{left,804}(k)$(11ay) *(continued)***

| |
|---|
| The sequence $Seq^{5}_{left,804}(k)$, to be transmitted from left to right, up to down |
| –j –j +1 –j –1 –1 –j +j –j –1 –1 –j +j –j +1 +1 +j –j +j –1 –1 –j +j –j –j +1 +1 –j –1 –j +1 +1 –j –1 +j –1 –1 +j +1 –j +1<br>+1 –j –1 –1 –1 –j +j –j +1 +1 +j –j +j +1 +1 +j –j +j +1 +1 +j –j +j +j –1 –1 +j +1 –j +1 +1 –j –1 –j +1 +1 –j –1 –j +1<br>+1 –j –1 +j +j –1 +1 –1 +j +j –1 +1 –1 +j +j –1 +1 –1 –j –j +1 –1 +1 –1 –j –j –1 +j –1 –j –j –1 +j –1 –j –j –1 +j +1 +j<br>+j +1 –j +j +j –1 +1 –1 –j –j +1 –1 +1 +j +j –1 +1 –1 +j +j –1 +1 –1 +1 +j +j +1 –j –1 –j –j –1 +j +1 +j +j +1 –j +1 +j<br>+j +1 –j –1 –1 –j +j –j –1 –1 –j +j –j +1 +1 +j –j +j –1 –1 –j +j –j –j +1 +1 –j –1 –j +1 +1 –j –1 +j –1 –1 +j +1 –j +1<br>+1 –j –1 –1 –1 –j +j –j +1 +1 +j –j +j +1 +1 +j –j +j +1 +1 +j –j +j +j –1 –1 +j +1 –j +1 +1 –j –1 –j +1 +1 –j –1 –j +1<br>+1 –j –1 +j +j –1 +1 –1 +j +j –1 +1 –1 +j +j –1 +1 –1 –j –j +1 –1 +1 –1 –j –j –1 +j –1 –j –j –1 +j –1 –j –j –1 +j +1 +j<br>+j +1 –j +j +j –1 +1 –1 –j –j +1 –1 +1 +j +j –1 +1 –1 +j +j –1 +1 –1 +1 +j +j +1 –j –1 –j –j –1 +j +1 +j +j +1 –j +1 +j<br>+j +1 –j +j +j –1 +1 –1 +j +j –1 +1 –1 –j –j +1 –1 +1 +j +j –1 +1 –1 –1 –j –j –1 +j –1 –j –j –1 +j +1 +j +j +1 –j –1 –j<br>–j –1 +j +j +j –1 +1 –1 –j –j +1 –1 +1 –j –j +1 –1 +1 –j –j +1 –1 +1 +1 +j +j +1 –j –1 –j –j –1 +j –1 –j –j –1 +j –1 –j<br>–j –1 +j +1 +1 +j –j +j +1 +1 +j –j +j +1 +1 +j –j +j –1 –1 –j +j –j +j –1 –1 +j +1 +j –1 –1 +j +1 +j –1 –1 +j +1 –j +1<br>+1 –j –1 +1 +1 +j –j +j –1 –1 –j +j –j +1 +1 +j –j +j +1 +1 +j –j +j –j +1 +1 –j –1 +j –1 –1 +j +1 –j +1 +1 –j –1 –j +1<br>+1 –j –1 –j –j +1 –1 +1 –j –j +1 –1 +1 +j +j –1 +1 –1 –j –j +1 –1 +1 +1 +j +j +1 –j +1 +j +j +1 –j –1 –j –j –1 +j +1 +j<br>+j +1 –j –j –j +1 –1 +1 +j +j –1 +1 –1 +j +j –1 +1 –1 +j +j –1 +1 –1 –1 –j –j –1 +j +1 +j +j +1 –j +1 +j +j +1 –j +1 +j<br>+j +1 –j –1 –1 –j +j –j –1 –1 –j +j –j –1 –1 –j +j –j +1 +1 +j –j +j –j +1 +1 –j –1 –j +1 +1 –j –1 –j +1 +1 –j –1 +j –1 –<br>1 +j +1 –1 –1 –j +j –j +1 +1 +j –j +j –1 –1 –j +j –j –1 –1 –j +j –j +j –1 –1 +j +1 –j +1 +1 –j –1 +j –1 –1 +j +1 +j –1 –<br>1 +j +1 +j +j –1 +1 –1 +j +j –1 +1 –1 –j –j +1 –1 +1 +j +j –1 +1 –1 –1 –j –j –1 +j –1 –j –j –1 +j +1 +j +j +1 –j –1 –j<br>–j –1 +j +j +j –1 +1 –1 –j –j +1 –1 +1 –j –j +1 –1 +1 –j –j +1 –1 +1 +1 +j +j +1 –j –1 –j –j –1 +j –1 –j –j –1 +j –1 –j<br>–j –1 +j +1 +1 +j –j +j +1 +1 +j –j +j +1 +1 +j –j +j –1 –1 –j +j –j +j –1 –1 +j +1 +j –1 –1 +j +1 +j –1 –1 +j +1 –j +1<br>+1 –j –1 +1 +1 +j –j +j –1 –1 –j +j –j +1 +1 +j –j +j +1 +1 +j –j +j –j +1 +1 –j –1 +j –1 –1 +j +1 –j +1 +1 –j –1 –j +1<br>+1 –j –1 |
| The sequence $Seq^{6}_{left,804}(k)$, to be transmitted from left to right, up to down |
| +j +j +1 –1 +1 +j +j +1 –j –j +1 +1 –j –1 –1 –j –j –1 +j –j +1 +1 –j –1 –j +1 +1 –j –1 –1 –j –j –1 +j +j –1 –1 +j +1 –1<br>–j –j –1 +j +1 +1 +j –j +j –j –j +1 –1 +1 +1 +1 +j –j +j +j +j –1 +1 –1 –j –j +1 –1 +1 –1 –1 –j +j –j –j –j +1 –1 +1 +1<br>+1 +j –j +j +j –1 –1 +j +1 –1 –j –j –1 +j –j +1 +1 –j –1 –1 –j –j –1 +j –1 –j –j –1 +j –j +1 +1 –j –1 +1 +j +j +1 –j –j<br>+1 +1 –j –1 +j +j –1 +1 –1 –1 –1 –j +j –j +j +j –1 +1 –1 +1 +1 +j –j +j –1 –1 –j +j –j –j –j +1 –1 +1 –1 –1 –j +j –j +j<br>+j –1 +1 –1 +1 +j +j +1 –j –j +1 +1 –j –1 –1 –j –j –1 +j –j +1 +1 –j –1 –j +1 +1 –j –1 –1 –j –j –1 +j +j –1 –1 +j +1 –<br>1 –j –j –1 +j +1 +1 +j –j +j –j –j +1 –1 +1 +1 +1 +j –j +j +j +j –1 +1 –1 –j –j +1 –1 +1 –1 –1 –j +j –j –j –j +1 –1 +1<br>+1 +1 +j –j +j +j –1 –1 +j +1 –1 –j –j –1 +j –j +1 +1 –j –1 –1 –j –j –1 +j –1 –j –j –1 +j –j +1 +1 –j –1 +1 +j +j +1 –j<br>–j +1 +1 –j –1 +j +j –1 +1 –1 –1 –1 –j +j –j +j +j –1 +1 –1 +1 +1 +j –j +j –1 –1 –j +j –j –j –j +1 –1 +1 –1 –1 –j +j –j<br>+j +j –1 +1 –1 –j +1 +1 –j –1 –1 –j –j –1 +j +j –1 –1 +j +1 –1 –j –j –1 +j –1 –j –j –1 +j +j –1 –1 +j +1 +1 +j +j +1 –j<br>+j –1 –1 +j +1 –j –j +1 –1 +1 –1 –1 –j +j –j –j –j +1 –1 +1 +1 +1 +j –j +j –1 –1 –j +j –j +j +j –1 +1 –1 –1 –1 –j +j –j<br>–j –j +1 –1 +1 +1 +j +j +1 –j +j –1 –1 +j +1 –1 –j –j –1 +j +j –1 –1 +j +1 +j –1 –1 +j +1 –1 –j –j –1 +j –j +1 +1 –j –1<br>–1 –j –j –1 +j +1 +1 +j –j +j +j +j –1 +1 –1 +1 +1 +j –j +j –j –j +1 –1 +1 +j +j –1 +1 –1 –1 –1 –j +j –j +j +j –1 +1 –1<br>+1 +1 +j –j +j +j –1 –1 +j +1 +1 +j +j +1 –j –j +1 +1 –j –1 +1 +j +j +1 –j +1 +j +j +1 –j –j +1 +1 –j –1 –1 –j –j –1 +j<br>–j +1 +1 –j –1 +j +j –1 +1 –1 +1 +1 +j –j +j +j +j –1 +1 –1 –1 –1 –j +j –j +1 +1 +j –j +j –j –j +1 –1 +1 +1 +1 +j –j +j<br>+j +j –1 +1 –1 –1 –j –j –1 +j –j +1 +1 –j –1 +1 +j +j +1 –j –j +1 +1 –j –1 –j +1 +1 –j –1 +1 +j +j +1 –j +j –1 –1 +j +1<br>+1 +j +j +1 –j –1 –1 –j +j –j –j –j +1 –1 +1 –1 –1 –j +j –j +j +j –1 +1 –1 –j –j +1 –1 +1 +1 +1 +j –j +j –j –j +1 –1 +1<br>–1 –1 –j +j –j –j +1 +1 –j –1 –1 –j –j –1 +j +j –1 –1 +j +1 –1 –j –j –1 +j –1 –j –j –1 +j +j –1 –1 +j +1 +1 +j +j +1 –j<br>+j –1 –1 +j +1 –j –j +1 –1 +1 –1 –1 –j +j –j –j –j +1 –1 +1 +1 +1 +j –j +j –1 –1 –j +j –j +j +j –1 +1 –1 –1 –1 –j +j –j<br>–j –j +1 –1 +1 +1 +j +j +1 –j +j –1 –1 +j +1 –1 –j –j –1 +j +j –1 –1 +j +1 +j –1 –1 +j +1 –1 –j –j –1 +j –j +1 +1 –j –1<br>–1 –j –j –1 +j +1 +1 +j –j +j +j +j –1 +1 –1 +1 +1 +j –j +j –j –j +1 –1 +1 +j +j –1 +1 –1 –1 –1 –j +j –j +j +j –1 +1 –1<br>+1 +1 +j –j +j |


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### Table 28-117—The sequence $Seq^{i}_{left,804}(k)$ (11ay) *(continued)*

| The sequence $Seq^{7}_{left,804}(k)$, to be transmitted from left to right, up to down |
|---|
| +j –j –1 –1 –1 –1 –j +j –j +1 +1 +j –j +j +1 +j +j +1 –j +1 +j +j +1 –j –j –j +1 –1 +1 +j +j –1 +1 –1 +j –1 –1 +j +1 +j<br>–1 –1 +j +1 +j +j –1 +1 –1 –j –j +1 –1 +1 –j +1 +1 –j –1 –j +1 +1 –j –1 +1 +1 +j –j +j –1 –1 –j +j –j –1 –j –j –1 +j –<br>1 –j –j –1 +j –j –j +1 –1 +1 –j –j +1 –1 +1 +j –1 –1 +j +1 –j +1 +1 –j –1 –1 –1 –j +j –j –1 –1 –j +j –j +1 +j +j +1 –j –<br>1 –j –j –1 +j –1 –1 –j +j –j –1 –1 –j +j –j +1 +j +j +1 –j –1 –j –j –1 +j –j –j +1 –1 +1 –j –j +1 –1 +1 +j –1 –1 +j +1 –j<br>+1 +1 –j –1 +1 +1 +j –j +j –1 –1 –j +j –j –1 –j –j –1 +j –1 –j –j –1 +j +j +j –1 +1 –1 –j –j +1 –1 +1 –j +1 +1 –j –1 –j<br>+1 +1 –j –1 –j –j +1 –1 +1 +j +j –1 +1 –1 +j –1 –1 +j +1 +j –1 –1 +j +1 –1 –1 –j +j –j +1 +1 +j –j +j +1 +j +j +1 –j<br>+1 +j +j +1 –j +j +j –1 +1 –1 +j +j –1 +1 –1 –j +1 +1 –j –1 +j –1 –1 +j +1 +1 +1 +j –j +j +1 +1 +j –j +j –1 –j –j –1 +j<br>+1 +j +j +1 –j +1 +1 +j –j +j +1 +1 +j –j +j –1 –j –j –1 +j +1 +j +j +1 –j +j +j –1 +1 –1 +j +j –1 +1 –1 –j +1 +1 –j –1<br>+j –1 –1 +j +1 –1 –1 –j +j –j +1 +1 +j –j +j +1 +j +j +1 –j +1 +j +j +1 –j –j –j +1 –1 +1 +j +j –1 +1 –1 +j –1 –1 +j +1<br>+j –1 –1 +j +1 +j +j –1 +1 –1 –j –j +1 –1 +1 –j +1 +1 –j –1 –j +1 +1 –j –1 +1 +1 +j –j +j –1 –1 –j +j –j –1 –j –j –1 +j<br>–1 –j –j –1 +j –j –j +1 –1 +1 –j –j +1 –1 +1 +j –1 –1 +j +1 –j +1 +1 –j –1 –1 –1 –j +j –j –1 –1 –j +j –j +1 +j +j +1 –j<br>–1 –j –j –1 +j –1 –1 –j +j –j –1 –1 –j +j –j +1 +j +j +1 –j –1 –j –j –1 +j –j –j +1 –1 +1 –j –j +1 –1 +1 +j –1 –1 +j +1 –<br>j +1 +1 –j –1 –j –j +1 –1 +1 +j +j –1 +1 –1 +j –1 –1 +j +1 +j –1 –1 +j +1 +1 +1 +j –j +j –1 –1 –j +j –j –1 –j –j –1 +j<br>–1 –j –j –1 +j –1 –1 –j +j –j +1 +1 +j –j +j +1 +j +j +1 –j +1 +j +j +1 –j +j +j –1 +1 –1 –j –j +1 –1 +1 –j +1 +1 –j –1<br>–j +1 +1 –j –1 +1 +1 +j –j +j +1 +1 +j –j +j –1 –j –j –1 +j +1 +j +j +1 –j –j –j +1 –1 +1 –j –j +1 –1 +1 +j –1 –1 +j +1<br>–j +1 +1 –j –1 –j –j +1 –1 +1 –j –j +1 –1 +1 +j –1 –1 +j +1 –j +1 +1 –j –1 +1 +1 +j –j +j +1 +1 +j –j +j –1 –j –j –1 +j<br>+1 +j +j +1 –j –j –j +1 –1 +1 +j +j –1 +1 –1 +j –1 –1 +j +1 +j –1 –1 +j +1 +1 +1 +j –j +j –1 –1 –j +j –j –1 –j –j –1 +j<br>–1 –j –j –1 +j –1 –1 –j +j –j +1 +1 +j –j +j +1 +j +j +1 –j +1 +j +j +1 –j +j +j –1 +1 –1 –j –j +1 –1 +1 –j +1 +1 –j –1<br>–j +1 +1 –j –1 +1 +1 +j –j +j +1 +1 +j –j +j –1 –j –j –1 +j +1 +j +j +1 –j –j –j +1 –1 +1 –j –j +1 –1 +1 +j –1 –1 +j +1<br>–j +1 +1 –j –1 –j –j +1 –1 +1 –j –j +1 –1 +1 +j –1 –1 +j +1 –j +1 +1 –j –1 +1 +1 +j –j +j +1 +1 +j –j +j –1 –j –j –1 +j<br>+1 +j +j +1 –j |
| The sequence $Seq^{8}_{left,804}(k)$, to be transmitted from left to right, up to down |
| –1 +j +1 –1 –j –j +1 –1 +1 –1 –1 –j +j –j –1 –1 –j +j –j +j +j –1 +1 –1 –j +1 +1 –j –1 –1 –j –j –1 +j –1 –j –j –1 +j +j<br>–1 –1 +j +1 +1 +1 +j –j +j +j +j –1 +1 –1 +j +j –1 +1 –1 –1 –1 –j +j –j +1 +j +j +1 –j +j –1 –1 +j +1 +j –1 –1 +j +1 –<br>1 –j –j –1 +j +j +j –1 +1 –1 –1 –1 –j +j –j +1 +1 +j –j +j +j +j –1 +1 –1 –j +1 +1 –j –1 +1 +j +j +1 –j –1 –j –j –1 +j –<br>j +1 +1 –j –1 –1 –1 –j +j –j +j +j –1 +1 –1 –j –j +1 –1 +1 –1 –1 –j +j –j +1 +j +j +1 –j –j +1 +1 –j –1 +j –1 –1 +j +1<br>+1 +j +j +1 –j +j +j –1 +1 –1 +1 +1 +j –j +j +1 +1 +j –j +j –j –j +1 –1 +1 +j –1 –1 +j +1 +1 +j +j +1 –j +1 +j +j +1 –<br>j –j +1 +1 –j –1 –1 –1 –j +j –j –j –j +1 –1 +1 –j –j +1 –1 +1 +1 +1 +j –j +j –1 –j –j –1 +j –j +1 +1 –j –1 –j +1 +1 –j –<br>1 +1 +j +j +1 –j –j –j +1 –1 +1 +1 +1 +j –j +j –1 –1 –j +j –j –j –j +1 –1 +1 +j –1 –1 +j +1 –1 –j –j –1 +j +1 +j +j +1<br>–j +j –1 –1 +j +1 +1 +1 +j –j +j –j –j +1 –1 +1 +j +j –1 +1 –1 +1 +1 +j –j +j –1 –j –j –1 +j +j –1 –1 +j +1 –j +1 +1 –<br>j –1 –1 –j –j –1 +j –j –j +1 –1 +1 –1 –1 –j +j –j –1 –1 –j +j –j +j +j –1 +1 –1 –j +1 +1 –j –1 –1 –j –j –1 +j –1 –j –j –1<br>+j +j –1 –1 +j +1 +1 +1 +j –j +j +j +j –1 +1 –1 +j +j –1 +1 –1 –1 –1 –j +j –j +1 +j +j +1 –j +j –1 –1 +j +1 +j –1 –1 +j<br>+1 –1 –j –j –1 +j +j +j –1 +1 –1 –1 –1 –j +j –j +1 +1 +j –j +j +j +j –1 +1 –1 –j +1 +1 –j –1 +1 +j +j +1 –j –1 –j –j –1<br>+j –j +1 +1 –j –1 –1 –1 –j +j –j +j +j –1 +1 –1 –j –j +1 –1 +1 –1 –1 –j +j –j +1 +j +j +1 –j –j +1 +1 –j –1 +j –1 –1 +j<br>+1 +1 +j +j +1 –j +1 +1 +j –j +j –j –j +1 –1 +1 –j –j +1 –1 +1 –1 –1 –j +j –j +1 +j +j +1 –j –j +1 +1 –j –1 –j +1 +1 –<br>j –1 –1 –j –j –1 +j +j +j –1 +1 –1 –1 –1 –j +j –j –1 –1 –j +j –j –j –j +1 –1 +1 +j –1 –1 +j +1 –1 –j –j –1 +j –1 –j –j –1<br>+j –j +1 +1 –j –1 –1 –1 –j +j –j –j –j +1 –1 +1 +j +j –1 +1 –1 –1 –1 –j +j –j +1 +j +j +1 –j +j –1 –1 +j +1 –j +1 +1 –j<br>–1 +1 +j +j +1 –j –j –j +1 –1 +1 –1 –1 –j +j –j +1 +1 +j –j +j –j –j +1 –1 +1 +j –1 –1 +j +1 +1 +j +j +1 –j –1 –j –j –1<br>+j +j –1 –1 +j +1 +1 +1 +j –j +j –j –j +1 –1 +1 –j –j +1 –1 +1 –1 –1 –j +j –j +1 +j +j +1 –j –j +1 +1 –j –1 –j +1 +1 –<br>j –1 –1 –j –j –1 +j +j +j –1 +1 –1 –1 –1 –j +j –j –1 –1 –j +j –j –j –j +1 –1 +1 +j –1 –1 +j +1 –1 –j –j –1 +j –1 –j –j –1<br>+j –j +1 +1 –j –1 –1 –1 –j +j –j –j –j +1 –1 +1 +j +j –1 +1 –1 –1 –1 –j +j –j +1 +j +j +1 –j +j –1 –1 +j +1 –j +1 +1 –j<br>–1 +1 +j +j +1 –j –j –j +1 –1 +1 –1 –1 –j +j –j +1 +1 +j –j +j –j –j +1 –1 +1 +j –1 –1 +j +1 +1 +j +j +1 –j –1 –j –j –1<br>+j +j –1 –1 +j +1 |



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## Table 28-118—The sequence $Seq^{i}_{right,804}(k)$(11ay)

| |
|---|
| The sequence $Seq^{1}_{right,804}(k)$, to be transmitted from left to right, up to down |
| –j +1 +j +j +1 –j +j –j –1 –1 –1 –j +1 +1 –j +1 –1 +1 –j –j +1 +j –1 –1 +j +1 –1 +1 –j –j +j –1 –j –j –1 –j +j –j –1 –1<br>–j +1 +j +j +1 –j +j –j –1 –1 –1 –j +1 +1 –j +1 –1 +1 –j –j –1 –j +1 +1 –j –1 +1 –1 +j +j –j +1 +j +j +1 +j –j +j +1 +1<br>–j +1 +j +j +1 –j +j –j –1 –1 –1 –j +1 +1 –j +1 –1 +1 –j –j +1 +j –1 –1 +j +1 –1 +1 –j –j +j –1 –j –j –1 –j +j –j –1 –1<br>+j –1 –j –j –1 +j –j +j +1 +1 +1 +j –1 –1 +j –1 +1 –1 +j +j +1 +j –1 –1 +j +1 –1 +1 –j –j +j –1 –j –j –1 –j +j –j –1 –1<br>–1 –j +1 +1 –j –1 +1 –1 +j +j +j –1 –j –j –1 –j +j –j –1 –1 –j +1 +j +j +1 –j +j –j –1 –1 +1 +j –1 –1 +j –1 +1 –1 +j +j<br>–1 –j +1 +1 –j –1 +1 –1 +j +j +j –1 –j –j –1 –j +j –j –1 –1 +j –1 –j –j –1 +j –j +j +1 +1 –1 –j +1 +1 –j +1 –1 +1 –j –j<br>–1 –j +1 +1 –j –1 +1 –1 +j +j +j –1 –j –j –1 –j +j –j –1 –1 –j +1 +j +j +1 –j +j –j –1 –1 +1 +j –1 –1 +j –1 +1 –1 +j +j<br>+1 +j –1 –1 +j +1 –1 +1 –j –j –j +1 +j +j +1 +j –j +j +1 +1 –j +1 +j +j +1 –j +j –j –1 –1 +1 +j –1 –1 +j –1 +1 –1 +j +j<br>–1 –j +1 +1 –j –1 +1 –1 +j +j +j –1 –j –j –1 –j +j –j –1 –1 –j +1 +j +j +1 –j +j –j –1 –1 +1 +j –1 –1 +j –1 +1 –1 +j +j<br>–1 –j +1 +1 –j –1 +1 –1 +j +j +j –1 –j –j –1 –j +j –j –1 –1 +j –1 –j –j –1 +j –j +j +1 +1 –1 –j +1 +1 –j +1 –1 +1 –j –j<br>–1 –j +1 +1 –j –1 +1 –1 +j +j +j –1 –j –j –1 –j +j –j –1 –1 –j +1 +j +j +1 –j +j –j –1 –1 +1 +j –1 –1 +j –1 +1 –1 +j +j<br>+1 +j –1 –1 +j +1 –1 +1 –j –j –j +1 +j +j +1 +j –j +j +1 +1 –j +1 +j +j +1 –j +j –j –1 –1 +1 +j –1 –1 +j –1 +1 –1 +j +j<br>–j +1 +j +j +1 –j +j –j –1 –1 –1 –j +1 +1 –j +1 –1 +1 –j –j +1 +j –1 –1 +j +1 –1 +1 –j –j +j –1 –j –j –1 –j +j –j –1 –1<br>–j +1 +j +j +1 –j +j –j –1 –1 –1 –j +1 +1 –j +1 –1 +1 –j –j –1 –j +1 +1 –j –1 +1 –1 +j +j –j +1 +j +j +1 +j –j +j +1 +1<br>–j +1 +j +j +1 –j +j –j –1 –1 –1 –j +1 +1 –j +1 –1 +1 –j –j +1 +j –1 –1 +j +1 –1 +1 –j –j +j –1 –j –j –1 –j +j –j –1 –1<br>+j –1 –j –j –1 +j –j +j +1 +1 +1 +j –1 –1 +j –1 +1 –1 +j +j +1 +j –1 –1 +j +1 –1 +1 –j –j +j –1 –j –j –1 –j +j –j –1 –1<br>+1 +j –1 –1 +j +1 –1 +1 –j –j –j +1 +j +j +1 +j –j +j +1 +1 +j –1 –j –j –1 +j –j +j +1 +1 –1 –j +1 +1 –j +1 –1 +1 –j –<br>j +1 +j –1 –1 +j +1 –1 +1 –j –j –j +1 +j +j +1 +j –j +j +1 +1 –j +1 +j +j +1 –j +j –j –1 –1 +1 +j –1 –1 +j –1 +1 –1 +j<br>+j +1 +j –1 –1 +j +1 –1 +1 –j –j –j +1 +j +j +1 +j –j +j +1 +1 +j –1 –j –j –1 +j –j +j +1 +1 –1 –j +1 +1 –j +1 –1 +1 –<br>j –j –1 –j +1 +1 –j –1 +1 –1 +j +j +j –1 –j –j –1 –j +j –j –1 –1 +j –1 –j –j –1 +j –j +j +1 +1 –1 –j +1 +1 –j +1 –1 +1 –<br>j –j +1 +1 +j –1 |
| The sequence $Seq^{2}_{right,804}(k)$, to be transmitted from left to right, up to down |
| –j +1 +j +j +1 +j –1 –j –j –1 –1 –j +1 +1 –j +1 +j –1 –1 +j +j –1 –j –j –1 –j +1 +j +j +1 –1 –j +1 +1 –j +1 +j –1 –1 +j<br>–j +1 +j +j +1 –j +1 +j +j +1 +1 +j –1 –1 +j +1 +j –1 –1 +j +j –1 –j –j –1 +j –1 –j –j –1 +1 +j –1 –1 +j +1 +j –1 –1 +j<br>–1 +1 –1 +j +j +1 –1 +1 –j –j +j –j +j +1 +1 –j +j –j –1 –1 –1 +1 –1 +j +j +1 –1 +1 –j –j –j +j –j –1 –1 +j –j +j +1 +1<br>–1 +1 –1 +j +j –1 +1 –1 +j +j –j +j –j –1 –1 –j +j –j –1 –1 –1 +1 –1 +j +j –1 +1 –1 +j +j +j –j +j +1 +1 +j –j +j +1 +1<br>–1 –j +1 +1 –j +1 +j –1 –1 +j +j –1 –j –j –1 –j +1 +j +j +1 +1 +j –1 –1 +j –1 –j +1 +1 –j +j –1 –j –j –1 –j +1 +j +j +1<br>–1 –j +1 +1 –j –1 –j +1 +1 –j –j +1 +j +j +1 –j +1 +j +j +1 +1 +j –1 –1 +j +1 +j –1 –1 +j –j +1 +j +j +1 –j +1 +j +j +1<br>+j –j +j +1 +1 –j +j –j –1 –1 +1 –1 +1 –j –j –1 +1 –1 +j +j +j –j +j +1 +1 –j +j –j –1 –1 –1 +1 –1 +j +j +1 –1 +1 –j –j<br>+j –j +j +1 +1 +j –j +j +1 +1 –1 +1 –1 +j +j –1 +1 –1 +j +j +j –j +j +1 +1 +j –j +j +1 +1 +1 –1 +1 –j –j +1 –1 +1 –j –<br>j –1 –j +1 +1 –j +1 +j –1 –1 +j +j –1 –j –j –1 –j +1 +j +j +1 +1 +j –1 –1 +j –1 –j +1 +1 –j +j –1 –j –j –1 –j +1 +j +j +1<br>–1 –j +1 +1 –j –1 –j +1 +1 –j –j +1 +j +j +1 –j +1 +j +j +1 +1 +j –1 –1 +j +1 +j –1 –1 +j –j +1 +j +j +1 –j +1 +j +j +1<br>+j –j +j +1 +1 –j +j –j –1 –1 +1 –1 +1 –j –j –1 +1 –1 +j +j +j –j +j +1 +1 –j +j –j –1 –1 –1 +1 –1 +j +j +1 –1 +1 –j –j<br>+j –j +j +1 +1 +j –j +j +1 +1 –1 +1 –1 +j +j –1 +1 –1 +j +j +j –j +j +1 +1 +j –j +j +1 +1 +1 –1 +1 –j –j +1 –1 +1 –j –<br>j –j +1 +j +j +1 +j –1 –j –j –1 –1 –j +1 +1 –j +1 +j –1 –1 +j +j –1 –j –j –1 –j +1 +j +j +1 –1 –j +1 +1 –j +1 +j –1 –1<br>+j –j +1 +j +j +1 –j +1 +j +j +1 +1 +j –1 –1 +j +1 +j –1 –1 +j +j –1 –j –j –1 +j –1 –j –j –1 +1 +j –1 –1 +j +1 +j –1 –1<br>+j –1 +1 –1 +j +j +1 –1 +1 –j –j +j –j +j +1 +1 –j +j –j –1 –1 –1 +1 –1 +j +j +1 –1 +1 –j –j –j +j –j –1 –1 +j –j +j +1<br>+1 –1 +1 –1 +j +j –1 +1 –1 +j +j –j +j –j –1 –1 –j +j –j –1 –1 –1 +1 –1 +j +j –1 +1 –1 +j +j +j –j +j +1 +1 +j –j +j +1<br>+1 +1 +j –1 –1 +j –1 –j +1 +1 –j –j +1 +j +j +1 +j –1 –j –j –1 –1 –j +1 +1 –j +1 +j –1 –1 +j –j +1 +j +j +1 +j –1 –j –<br>j –1 +1 +j –1 –1 +j +1 +j –1 –1 +j +j –1 –j –j –1 +j –1 –j –j –1 –1 –j +1 +1 –j –1 –j +1 +1 –j +j –1 –j –j –1 +j –1 –j –<br>j –1 –j +j –j –1 –1 +j –j +j +1 +1 –1 +1 –1 +j +j +1 –1 +1 –j –j –j +j –j –1 –1 +j –j +j +1 +1 +1 –1 +1 –j –j –1 +1 –1<br>+j +j –j +j –j –1 –1 –j +j –j –1 –1 +1 –1 +1 –j –j +1 –1 +1 –j –j –j +j –j –1 –1 –j +j –j –1 –1 –1 +1 –1 +j +j –1 +1 –1<br>+j +j +j +j +j –j |

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**Table 28-118—The sequence $Seq^{i}_{right,804}(k)$(11ay) *(continued)***

| The sequence $Seq^{3}_{right,804}(k)$, to be transmitted from left to right, up to down |
|---|
| +1 +j –1 –1 +j +1 –1 +1 –j –j +j –1 –j –j –1 +j –j +j +1 +1 –1 –j +1 +1 –j +1 –1 +1 –j –j –j +1 +j +j +1 +j –j +j +1 +1<br>–j +1 +j +j +1 –j +j –j –1 –1 –1 –j +1 +1 –j –1 +1 –1 +j +j –j +1 +j +j +1 +j –j +j +1 +1 –1 –j +1 +1 –j +1 –1 +1 –j –<br>j –1 –j +1 +1 –j –1 +1 –1 +j +j +j –1 –j –j –1 +j –j +j +1 +1 +1 +j –1 –1 +j –1 +1 –1 +j +j –j +1 +j +j +1 +j –j +j +1<br>+1 +j –1 –j –j –1 +j –j +j +1 +1 –1 –j +1 +1 –j –1 +1 –1 +j +j +j –1 –j –j –1 –j +j –j –1 –1 –1 –j +1 +1 –j +1 –1 +1 –j<br>–j –j +1 +j +j +1 –j +j –j –1 –1 +1 +j –1 –1 +j +1 –1 +1 –j –j +j –1 –j –j –1 –j +j –j –1 –1 –1 –j +1 +1 –j +1 –1 +1 –j<br>–j –1 –j +1 +1 –j –1 +1 –1 +j +j +j –1 –j –j –1 +j –j +j +1 +1 –1 –j +1 +1 –j +1 –1 +1 –j –j +j –1 –j –j –1 –j +j –j –1 –<br>1 +j –1 –j –j –1 +j –j +j +1 +1 +1 +j –1 –1 +j +1 –1 +1 –j –j –j +1 +j +j +1 +j –j +j +1 +1 –1 –j +1 +1 –j +1 –1 +1 –j<br>–j +1 +j –1 –1 +j +1 –1 +1 –j –j +j –1 –j –j –1 +j –j +j +1 +1 +1 +j –1 –1 +j –1 +1 –1 +j +j +j –1 –j –j –1 –j +j –j –1<br>–1 –1 –j +1 +1 –j –1 +1 –1 +j +j –j +1 +j +j +1 –j +j –j –1 –1 +1 +j –1 –1 +j –1 +1 –1 +j +j +j –1 –j –j –1 –j +j –j –1<br>–1 +j –1 –j –j –1 +j –j +j +1 +1 +1 +j –1 –1 +j +1 –1 +1 –j –j +j –1 –j –j –1 –j +j –j –1 –1 +1 +j –1 –1 +j –1 +1 –1 +j<br>+j +1 +j –1 –1 +j +1 –1 +1 –j –j –j +1 +j +j +1 –j +j –j –1 –1 –1 –j +1 +1 –j +1 –1 +1 –j –j +j –1 –j –j –1 –j +j –j –1<br>–1 –j +1 +j +j +1 –j +j –j –1 –1 +1 +j –1 –1 +j +1 –1 +1 –j –j –j +1 +j +j +1 +j –j +j +1 +1 +1 +j –1 –1 +j –1 +1 –1 +j<br>+j –1 –j +1 +1 –j –1 +1 –1 +j +j –j +1 +j +j +1 –j +j –j –1 –1 +1 +j –1 –1 +j –1 +1 –1 +j +j +j –1 –j –j –1 –j +j –j –1<br>–1 +j –1 –j –j –1 +j –j +j +1 +1 +1 +j –1 –1 +j +1 –1 +1 –j –j +j –1 –j –j –1 –j +j –j –1 –1 +1 +j –1 –1 +j –1 +1 –1 +j<br>+j +1 +j –1 –1 +j +1 –1 +1 –j –j –j +1 +j +j +1 –j +j –j –1 –1 –1 –j +1 +1 –j +1 –1 +1 –j –j +j –1 –j –j –1 –j +j –j –1<br>–1 –j +1 +j +j +1 –j +j –j –1 –1 +1 +j –1 –1 +j +1 –1 +1 –j –j –j +1 +j +j +1 +j –j +j +1 +1 +1 +j –1 –1 +j –1 +1 –1 +j<br>+j –j +1 +j +j +1 –j +j –j –1 –1 +1 +j –1 –1 +j +1 –1 +1 –j –j +j –1 –j –j –1 –j +j –j –1 –1 –1 –j +1 +1 –j +1 –1 +1 –j<br>–j –1 –j +1 +1 –j –1 +1 –1 +j +j +j –1 –j –j –1 +j –j +j +1 +1 –1 –j +1 +1 –j +1 –1 +1 –j –j +j –1 –j –j –1 –j +j –j –1 –<br>1 +j –1 –j –j –1 +j –j +j +1 +1 +1 +j –1 –1 +j +1 –1 +1 –j –j –j +1 +j +j +1 +j –j +j +1 +1 –1 –j +1 +1 –j +1 –1 +1 –j<br>–j +1 +j –1 –1 +j +1 –1 +1 –j –j +j –1 –j –j –1 +j –j +j +1 +1 +1 +j –1 –1 +j –1 +1 –1 +j +j +j –1 –j –j –1 –j +j –j –1<br>–1 –1 +1 –1 –j |
| The sequence $Seq^{4}_{right,804}(k)$, to be transmitted from left to right, up to down |
| +1 +j –1 –1 +j –1 –j +1 +1 –j –1 +1 –1 +j +j +1 –1 +1 –j –j +j –1 –j –j –1 –j +1 +j +j +1 –j +j –j –1 –1 +j –j +j +1 +1<br>+j –1 –j –j –1 +j –1 –j –j –1 –j +j –j –1 –1 –j +j –j –1 –1 +1 +j –1 –1 +j +1 +j –1 –1 +j –1 +1 –1 +j +j –1 +1 –1 +j +j<br>+j –1 –j –j –1 –j +1 +j +j +1 +j –j +j +1 +1 –j +j –j –1 –1 +1 +j –1 –1 +j –1 –j +1 +1 –j +1 –1 +1 –j –j –1 +1 –1 +j +j<br>–1 –j +1 +1 –j –1 –j +1 +1 –j –1 +1 –1 +j +j –1 +1 –1 +j +j –j +1 +j +j +1 –j +1 +j +j +1 –j +j –j –1 –1 –j +j –j –1 –1<br>–j +1 +j +j +1 +j –1 –j –j –1 +j –j +j +1 +1 –j +j –j –1 –1 +1 +j –1 –1 +j –1 –j +1 +1 –j –1 +1 –1 +j +j +1 –1 +1 –j –j<br>+1 +j –1 –1 +j +1 +j –1 –1 +j –1 +1 –1 +j +j –1 +1 –1 +j +j –j +1 +j +j +1 –j +1 +j +j +1 +j –j +j +1 +1 +j –j +j +1 +1<br>+1 +j –1 –1 +j –1 –j +1 +1 –j +1 –1 +1 –j –j –1 +1 –1 +j +j –j +1 +j +j +1 +j –1 –j –j –1 –j +j –j –1 –1 +j –j +j +1 +1<br>+j –1 –j –j –1 +j –1 –j –j –1 +j –j +j +1 +1 +j –j +j +1 +1 –1 –j +1 +1 –j –1 –j +1 +1 –j –1 +1 –1 +j +j –1 +1 –1 +j +j<br>–1 –j +1 +1 –j +1 +j –1 –1 +j +1 –1 +1 –j –j –1 +1 –1 +j +j –j +1 +j +j +1 +j –1 –j –j –1 +j –j +j +1 +1 –j +j –j –1 –1<br>–j +1 +j +j +1 –j +1 +j +j +1 +j –j +j +1 +1 +j –j +j +1 +1 –1 –j +1 +1 –j –1 –j +1 +1 –j +1 –1 +1 –j –j +1 –1 +1 –j –<br>j –j +1 +j +j +1 +j –1 –j –j –1 –j +j –j –1 –1 +j –j +j +1 +1 –1 –j +1 +1 –j +1 +j –1 –1 +j –1 +1 –1 +j +j +1 –1 +1 –j –<br>j +1 +j –1 –1 +j +1 +j –1 –1 +j +1 –1 +1 –j –j +1 –1 +1 –j –j +j –1 –j –j –1 +j –1 –j –j –1 +j –j +j +1 +1 +j –j +j +1 +1<br>–1 –j +1 +1 –j +1 +j –1 –1 +j +1 –1 +1 –j –j –1 +1 –1 +j +j –j +1 +j +j +1 +j –1 –j –j –1 +j –j +j +1 +1 –j +j –j –1 –1<br>–j +1 +j +j +1 –j +1 +j +j +1 +j –j +j +1 +1 +j –j +j +1 +1 –1 –j +1 +1 –j –1 –j +1 +1 –j +1 –1 +1 –j –j +1 –1 +1 –j –<br>j –j +1 +j +j +1 +j –1 –j –j –1 –j +j –j –1 –1 +j –j +j +1 +1 –1 –j +1 +1 –j +1 +j –1 –1 +j –1 +1 –1 +j +j +1 –1 +1 –j –<br>j +1 +j –1 –1 +j +1 +j –1 –1 +j +1 –1 +1 –j –j +1 –1 +1 –j –j +j –1 –j –j –1 +j –1 –j –j –1 +j –j +j +1 +1 +j –j +j +1 +1<br>–j +1 +j +j +1 +j –1 –j –j –1 +j –j +j +1 +1 –j +j –j –1 –1 +1 +j –1 –1 +j –1 –j +1 +1 –j –1 +1 –1 +j +j +1 –1 +1 –j –j<br>+1 +j –1 –1 +j +1 +j –1 –1 +j –1 +1 –1 +j +j –1 +1 –1 +j +j –j +1 +j +j +1 –j +1 +j +j +1 +j –j +j +1 +1 +j –j +j +1 +1<br>+1 +j –1 –1 +j –1 –j +1 +1 –j +1 –1 +1 –j –j –1 +1 –1 +j +j –j +1 +j +j +1 +j –1 –j –j –1 –j +j –j –1 –1 +j –j +j +1 +1<br>+j –1 –j –j –1 +j –1 –j –j –1 +j –j +j +1 +1 +j –j +j +1 +1 –1 –j +1 +1 –j –1 –j +1 +1 –j –1 +1 –1 +j +j –1 +1 –1 +j +j<br>+1 +1 –1 –j |



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**Table 28-118—The sequence $Seq^{i}_{right,804}(k)$(11ay) *(continued)***

| |
|---|
| The sequence $Seq^{5}_{right,804}(k)$, to be transmitted from left to right, up to down |
| +1 +1 +j –j +j +1 +1 +j –j +j –1 –1 –j +j –j +1 +1 +j –j +j +j –1 –1 +j +1 +j –1 –1 +j +1 –j +1 +1 –j –1 +j –1 –1 +j +1<br>+1 +1 +j –j +j –1 –1 –j +j –j –1 –1 –j +j –j –1 –1 –j +j –j –j +1 +1 –j –1 +j –1 –1 +j +1 +j –1 –1 +j +1 +j –1 –1 +j +1<br>+j +j –1 +1 –1 +j +j –1 +1 –1 +j +j –1 +1 –1 –j –j +1 –1 +1 –1 –j –j –1 +j –1 –j –j –1 +j –1 –j –j –1 +j +1 +j +j +1 –j<br>+j +j –1 +1 –1 –j –j +1 –1 +1 +j +j –1 +1 –1 +j +j –1 +1 –1 +1 +j +j +1 –j –1 –j –j –1 +j +1 +j +j +1 –j +1 +j +j +1 –<br>j –j –j +1 –1 +1 –j –j +1 –1 +1 +j +j –1 +1 –1 –j –j +1 –1 +1 +1 +j +j +1 –j +1 +j +j +1 –j –1 –j –j –1 +j +1 +j +j +1<br>–j –j –j +1 –1 +1 +j +j –1 +1 –1 +j +j –1 +1 –1 +j +j –1 +1 –1 –1 –j –j –1 +j +1 +j +j +1 –j +1 +j +j +1 –j +1 +j +j +1<br>–j +1 +1 +j –j +j +1 +1 +j –j +j +1 +1 +j –j +j –1 –1 –j +j –j +j –1 –1 +j +1 +j –1 –1 +j +1 +j –1 –1 +j +1 –j +1 +1 –j<br>–1 +1 +1 +j –j +j –1 –1 –j +j –j +1 +1 +j –j +j +1 +1 +j –j +j –j +1 +1 –j –1 +j –1 –1 +j +1 –j +1 +1 –j –1 –j +1 +1 –<br>j –1 –j –j +1 –1 +1 –j –j +1 –1 +1 +j +j –1 +1 –1 –j –j +1 –1 +1 +1 +j +j +1 –j +1 +j +j +1 –j –1 –j –j –1 +j +1 +j +j<br>+1 –j –j –j +1 –1 +1 +j +j –1 +1 –1 +j +j –1 +1 –1 +j +j –1 +1 –1 –1 –j –j –1 +j +1 +j +j +1 –j +1 +j +j +1 –j +1 +j +j<br>+1 –j +1 +1 +j –j +j +1 +1 +j –j +j +1 +1 +j –j +j –1 –1 –j +j –j +j –1 –1 +j +1 +j –1 –1 +j +1 +j –1 –1 +j +1 –j +1 +1<br>–j –1 +1 +1 +j –j +j –1 –1 –j +j –j +1 +1 +j –j +j +1 +1 +j –j +j –j +1 +1 –j –1 +j –1 –1 +j +1 –j +1 +1 –j –1 –j +1 +1<br>–j –1 +1 +1 +j –j +j +1 +1 +j –j +j –1 –1 –j +j –j +1 +1 +j –j +j +j –1 –1 +j +1 +j –1 –1 +j +1 –j +1 +1 –j –1 +j –1 –1<br>+j +1 +1 +1 +j –j +j –1 –1 –j +j –j –1 –1 –j +j –j –1 –1 –j +j –j –j +1 +1 –j –1 +j –1 –1 +j +1 +j –1 –1 +j +1 +j –1 –1<br>+j +1 +j +j –1 +1 –1 +j +j –1 +1 –1 +j +j –1 +1 –1 –j –j +1 –1 +1 –1 –j –j –1 +j –1 –j –j –1 +j –1 –j –j –1 +j +1 +j +j<br>+1 –j +j +j –1 +1 –1 –j –j +1 –1 +1 +j +j –1 +1 –1 +j +j –1 +1 –1 +1 +j +j +1 –j –1 –j –j –1 +j +1 +j +j +1 –j +1 +j +j<br>+1 –j +j +j –1 +1 –1 +j +j –1 +1 –1 –j –j +1 –1 +1 +j +j –1 +1 –1 –1 –j –j –1 +j –1 –j –j –1 +j +1 +j +j +1 –j –1 –j –j<br>–1 +j +j +j –1 +1 –1 –j –j +1 –1 +1 –j –j +1 –1 +1 –j –j +1 –1 +1 +1 +j +j +1 –j –1 –j –j –1 +j –1 –j –j –1 +j –1 –j –j<br>–1 +j –1 –1 –j +j –j –1 –1 –j +j –j –1 –1 –j +j –j +1 +1 +j –j +j –j +1 +1 –j –1 –j +1 +1 –j –1 –j +1 +1 –j –1 +j –1 –1<br>+j +1 –1 –1 –j +j –j +1 +1 +j –j +j –1 –1 –j +j –j –1 –1 –j +j –j +j –1 –1 +j +1 –j +1 +1 –j –1 +j –1 –1 +j +1 +j –1 –1<br>+j +1 +j –1 +1 +1 |
| The sequence $Seq^{6}_{right,804}(k)$, to be transmitted from left to right, up to down |
| –1 –j –j –1 +j +j –1 –1 +j +1 +1 +j +j +1 –j +j –1 –1 +j +1 –j +1 +1 –j –1 –1 –j –j –1 +j +j –1 –1 +j +1 –1 –j –j –1 +j<br>–1 –1 –j +j –j +j +j –1 +1 –1 –1 –1 –j +j –j –j –j +1 –1 +1 –j –j +1 –1 +1 –1 –1 –j +j –j –j –j +1 –1 +1 +1 +1 +j –j +j<br>–j +1 +1 –j –1 +1 +j +j +1 –j +j –1 –1 +j +1 +1 +j +j +1 –j –1 –j –j –1 +j –j +1 +1 –j –1 +1 +j +j +1 –j –j +1 +1 –j –1<br>–j –j +1 –1 +1 +1 +1 +j –j +j –j –j +1 –1 +1 –1 –1 –j +j –j –1 –1 –j +j –j –j –j +1 –1 +1 –1 –1 –j +j –j +j +j –1 +1 –1<br>+j –1 –1 +j +1 +1 +j +j +1 –j –j +1 +1 –j –1 +1 +j +j +1 –j –1 –j –j –1 +j +j –1 –1 +j +1 +1 +j +j +1 –j +j –1 –1 +j +1<br>+j +j –1 +1 –1 +1 +1 +j –j +j +j +j –1 +1 –1 –1 –1 –j +j –j –1 –1 –j +j –j +j +j –1 +1 –1 –1 –1 –j +j –j –j –j +1 –1 +1<br>–1 –j –j –1 +j –j +1 +1 –j –1 +1 +j +j +1 –j –j +1 +1 –j –1 +j –1 –1 +j +1 –1 –j –j –1 +j –j +1 +1 –j –1 –1 –j –j –1 +j<br>–1 –1 –j +j –j –j –j +1 –1 +1 –1 –1 –j +j –j +j +j –1 +1 –1 +j +j –1 +1 –1 –1 –1 –j +j –j +j +j –1 +1 –1 +1 +1 +j –j +j<br>+j –1 –1 +j +1 +1 +j +j +1 –j –j +1 +1 –j –1 +1 +j +j +1 –j –1 –j –j –1 +j +j –1 –1 +j +1 +1 +j +j +1 –j +j –1 –1 +j +1<br>+j +j –1 +1 –1 +1 +1 +j –j +j +j +j –1 +1 –1 –1 –1 –j +j –j –1 –1 –j +j –j +j +j –1 +1 –1 –1 –1 –j +j –j –j –j +1 –1 +1<br>–1 –j –j –1 +j –j +1 +1 –j –1 +1 +j +j +1 –j –j +1 +1 –j –1 +j –1 –1 +j +1 –1 –j –j –1 +j –j +1 +1 –j –1 –1 –j –j –1 +j<br>–1 –1 –j +j –j –j –j +1 –1 +1 –1 –1 –j +j –j +j +j –1 +1 –1 +j +j –1 +1 –1 –1 –1 –j +j –j +j +j –1 +1 –1 +1 +1 +j –j +j<br>–1 –j –j –1 +j +j –1 –1 +j +1 +1 +j +j +1 –j +j –1 –1 +j +1 –j +1 +1 –j –1 –1 –j –j –1 +j +j –1 –1 +j +1 –1 –j –j –1 +j<br>–1 –1 –j +j –j +j +j –1 +1 –1 –1 –1 –j +j –j –j –j +1 –1 +1 –j –j +1 –1 +1 –1 –1 –j +j –j –j –j +1 –1 +1 +1 +1 +j –j +j<br>–j +1 +1 –j –1 +1 +j +j +1 –j +j –1 –1 +j +1 +1 +j +j +1 –j –1 –j –j –1 +j –j +1 +1 –j –1 +1 +j +j +1 –j –j +1 +1 –j –1<br>–j –j +1 –1 +1 +1 +1 +j –j +j –j –j +1 –1 +1 –1 –1 –j +j –j –1 –1 –j +j –j –j –j +1 –1 +1 –1 –1 –j +j –j +j +j –1 +1 –1<br>–j +1 +1 –j –1 –1 –j –j –1 +j +j –1 –1 +j +1 –1 –j –j –1 +j +1 +j +j +1 –j –j +1 +1 –j –1 –1 –j –j –1 +j –j +1 +1 –j –1<br>–j –j +1 –1 +1 –1 –1 –j +j –j –j –j +1 –1 +1 +1 +1 +j –j +j +1 +1 +j –j +j –j –j +1 –1 +1 +1 +1 +j –j +j +j +j –1 +1 –1<br>+1 +j +j +1 –j +j –1 –1 +j +1 –1 –j –j –1 +j +j –1 –1 +j +1 –j +1 +1 –j –1 +1 +j +j +1 –j +j –1 –1 +j +1 +1 +j +j +1 –<br>j +1 +1 +j –j +j +j +j –1 +1 –1 +1 +1 +j –j +j –j –j +1 –1 +1 –j –j +1 –1 +1 +1 +1 +j –j +j –j –j +1 –1 +1 –1 –1 –j +j<br>–j –1 –j +1 +1 |

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**Table 28-118—The sequence $Seq^{i}_{right,804}(k)$<u>(11ay)</u> *(continued)***

| The sequence $Seq^{7}_{right,804}(k)$, to be transmitted from left to right, up to down |
|---|
| +j +j –1 +1 –1 –j –j +1 –1 +1 –j +1 +1 –j –1 –j +1 +1 –j –1 –1 –1 –j +j –j +1 +1 +j –j +j +1 +j +j +1 –j +1 +j +j +1 –j –1 –1 –j +j –j +1 +1 +j –j +j +1 +j +j +1 –j +1 +j +j +1 –j +j +j –1 +1 –1 –j –j +1 –1 +1 –j +1 +1 –j –1 –j +1 +1 –j –1 –1 –1 –j +j –j –1 –1 –j +j –j +1 +j +j +1 –j –1 –j –j –1 +j +j +j –1 +1 –1 +j +j –1 +1 –1 –j +1 +1 –j –1 +j –1 –1 +j +1 –j –j +1 –1 +1 –j –j +1 –1 +1 +j –1 –1 +j +1 –j +1 +1 –j –1 +1 +1 +j –j +j +1 +1 +j –j +j –1 –j –j –1 +j +1 +j +j +1 –j +1 +1 +j –j +j –1 –1 –j +j –j –1 –j –j –1 +j –1 –j –j –1 +j +j +j –1 +1 –1 –j –j +1 –1 +1 –j +1 +1 –j –1 –j +1 +1 –j –1 +j +j –1 +1 –1 –j –j +1 –1 +1 –j +1 +1 –j –1 –j +1 +1 –j –1 +1 +1 +j –j +j –1 –1 –j +j –j –1 –j –j –1 +j –1 –j –j –1 +j +j +j –1 +1 –1 +j +j –1 +1 –1 –j +1 +1 –j –1 +j –1 –1 +j +1 +1 +1 +j –j +j +1 +1 +j –j +j –1 –j –j –1 +j +1 +j +j +1 –j –1 –1 –j +j –j –1 –1 –j +j –j +1 +j +j +1 –j –1 –j –j –1 +j –j –j +1 –1 +1 –j –j +1 –1 +1 +j –1 –1 +j +1 –j +1 +1 –j –1 –j –j +1 –1 +1 +j +j –1 +1 –1 +j –1 –1 +j +1 +j –1 –1 +j +1 +1 +1 +j –j +j –1 –1 –j +j –j –1 –j –j –1 +j –1 –j –j –1 +j +1 +1 +j –j +j –1 –1 –j +j –j –1 –j –j –1 +j –1 –j –j –1 +j –j –j +1 –1 +1 +j +j –1 +1 –1 +j –1 –1 +j +1 +j –1 –1 +j +1 +1 +1 +j –j +j +1 +1 +j –j +j –1 –j –j –1 +j +1 +j +j +1 –j –j –j +1 –1 +1 –j –j +1 –1 +1 +j –1 –1 +j +1 –j +1 +1 –j –1 +j +j –1 +1 –1 +j +j –1 +1 –1 –j +1 +1 –j –1 +j –1 –1 +j +1 –1 –1 –j +j –j –1 –1 –j +j –j +1 +j +j +1 –j –1 –j –j –1 +j –j –j +1 –1 +1 +j +j –1 +1 –1 +j –1 –1 +j +1 +j –1 –1 +j +1 +1 +1 +j –j +j –1 –1 –j +j –j –1 –j –j –1 +j –1 –j –j –1 +j +1 +1 +j –j +j –1 –1 –j +j –j –1 –j –j –1 +j –1 –j –j –1 +j –j –j +1 –1 +1 +j +j –1 +1 –1 +j –1 –1 +j +1 +j –1 –1 +j +1 +1 +1 +j –j +j +1 +1 +j –j +j –1 –j –j –1 +j +1 +j +j +1 –j –j –j +1 –1 +1 –j –j +1 –1 +1 +j –1 –1 +j +1 –j +1 +1 –j –1 +j +j –1 +1 –1 +j +j –1 +1 –1 –j +1 +1 –j –1 +j –1 –1 +j +1 –1 –1 –j +j –j –1 –1 –j +j –j +1 +j +j +1 –j –1 –j –j –1 +j +1 +1 +j –j +j –1 –1 –j +j –j –1 –j –j –1 +j –1 –j –j –1 +j +j +j –1 +1 –1 –j –j +1 –1 +1 –j +1 +1 –j –1 –j +1 +1 –j –1 +j +j –1 +1 –1 –j –j +1 –1 +1 –j +1 +1 –j –1 –j +1 +1 –j –1 +1 +1 +j –j +j –1 –1 –j +j –j –1 –j –j –1 +j –1 –j –j –1 +j +j +j –1 +1 –1 +j +j –1 +1 –1 –j +1 +1 –j –1 +j –1 –1 +j +1 +1 +1 +j –j +j +1 +1 +j –j +j –1 –j –j –1 +j +1 +j +j +1 –j –1 –1 –j +j –j –1 –1 –j +j –j +1 +j +j +1 –j –1 –j –j –1 +j –j –j +1 –1 +1 –j –j +1 –1 +1 +j –1 –1 +j +1 –j +1 +1 –j –1 +j –j –1 –j |
| The sequence $Seq^{8}_{right,804}(k)$, to be transmitted from left to right, up to down |
| +1 +1 +j –j +j –j –j +1 –1 +1 +j +j –1 +1 –1 +1 +1 +j –j +j +1 +j +j +1 –j –j +1 +1 –j –1 +j –1 –1 +j +1 +1 +j +j +1 –j +j +j –1 +1 –1 –1 –1 –j +j –j +1 +1 +j –j +j +j +j –1 +1 –1 +j –1 –1 +j +1 –1 –j –j –1 +j +1 +j +j +1 –j +j –1 –1 +j +1 –1 –1 –j +j –j –j –j +1 –1 +1 –j –j +1 –1 +1 +1 +1 +j –j +j +1 +j +j +1 –j +j –1 –1 +j +1 +j –1 –1 +j +1 –1 –j –j –1 +j –j –j +1 –1 +1 –1 –1 –j +j –j –1 –1 –j +j –j +j +j –1 +1 –1 +j –1 –1 +j +1 +1 +j +j +1 –j +1 +j +j +1 –j –j +1 +1 –j –1 –j –j +1 –1 +1 –1 –1 –j +j –j +1 +1 +j –j +j –j –j +1 –1 +1 –j +1 +1 –j –1 –1 –j –j –1 +j +1 +j +j +1 –j –j +1 +1 –j –1 +1 +1 +j –j +j +j +j –1 +1 –1 –j –j +1 –1 +1 +1 +1 +j –j +j +1 +j +j +1 –j +j –1 –1 +j +1 –j +1 +1 –j –1 +1 +j +j +1 –j +j +j –1 +1 –1 –1 –1 –j +j –j –1 –1 –j +j –j –j –j +1 –1 +1 –j +1 +1 –j –1 +1 +j +j +1 –j +1 +j +j +1 –j +j –1 –1 +j +1 –1 –1 –j +j –j +j +j –1 +1 –1 +j +j –1 +1 –1 +1 +1 +j –j +j +1 +j +j +1 –j –j +1 +1 –j –1 –j +1 +1 –j –1 –1 –j –j –1 +j –1 –1 –j +j –j +j +j –1 +1 –1 –j –j +1 –1 +1 –1 –1 –j +j –j –1 –j –j –1 +j +j –1 –1 +j +1 –j +1 +1 –j –1 –1 –j –j –1 +j –j –j +1 –1 +1 +1 +1 +j –j +j –1 –1 –j +j –j –j –j +1 –1 +1 –j +1 +1 –j –1 +1 +j +j +1 –j –1 –j –j –1 +j –j +1 +1 –j –1 +1 +1 +j –j +j +j +j –1 +1 –1 +j +j –1 +1 –1 –1 –1 –j +j –j –1 –j –j –1 +j –j +1 +1 –j –1 –j +1 +1 –j –1 +1 +j +j +1 –j +j +j –1 +1 –1 +1 +1 +j –j +j +1 +1 +j –j +j –j –j +1 –1 +1 –j +1 +1 –j –1 –1 –j –j –1 +j –1 –j –j –1 +j +j –1 –1 +j +1 –1 –1 –j +j –j +j +j –1 +1 –1 –j –j +1 –1 +1 –1 –1 –j +j –j –1 –j –j –1 +j +j –1 –1 +j +1 –j +1 +1 –j –1 –1 –j –j –1 +j –j –j +1 –1 +1 +1 +1 +j –j +j –1 –1 –j +j –j –j –j +1 –1 +1 –j +1 +1 –j –1 +1 +j +j +1 –j –1 –j –j –1 +j –j +1 +1 –j –1 +1 +1 +j –j +j +j +j –1 +1 –1 +j +j –1 +1 –1 –1 –1 –j +j –j –1 –j –j –1 +j –j +1 +1 –j –1 –j +1 +1 –j –1 +1 +j +j +1 –j +j +j –1 +1 –1 +1 +1 +j –j +j +1 +1 +j –j +j –j –j +1 –1 +1 –j +1 +1 –j –1 –1 –j –j –1 +j –1 –j –j –1 +j +j –1 –1 +j +1 –j –j +1 –1 +1 –1 –1 –j +j –j +1 +1 +j –j +j –j –j +1 –1 +1 –j +1 +1 –j –1 –1 –j –j –1 +j +1 +j +j +1 –j –j +1 +1 –j –1 +1 +1 +j –j +j +j +j –1 +1 –1 –j –j +1 –1 +1 +1 +1 +j –j +j +1 +j +j +1 –j +j –1 –1 +j +1 –j +1 +1 –j –1 +1 +j +j +1 –j +j +j –1 +1 –1 –1 –1 –j +j –j –1 –1 –j +j –j –j –j +1 –1 +1 –j +1 +1 –j –1 +1 +j +j +1 –j +1 +j +j +1 –j +j –1 –1 +j +1 –1 –1 –j +j –j +j +j –1 +1 –1 +j +j –1 +1 –1 +1 +1 +j –j +j +1 +j +j +1 –j –j +1 +1 –j –1 –j +1 +1 –j –1 –1 –j –j –1 +j –1 –1 +j –1 |

## 28.12 EDMG PLME

### 28.12.1 PLME SAP sublayer management primitives<u>(#6321)</u>

Table 28-119 (EDMG PHY MIB attribute default values(11ay)) lists the MIB attributes that may be accessed by the PHY entities and the intra-layer of higher level LMEs. These attributes are accessed via the


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PLME-GET, PLME-SET, PLME-RESET, and PLME-CHARACTERISTICS primitives defined in 6.7 (PLME SAP interface).

**Table 28-119—EDMG PHY MIB attribute default values(11ay)**

| Managed object | Default range/value | Operational semantics |
|---|---|---|
| dot11PHYOperationTable | | |
| dot11PHYType | EDMG | Static |
| dot11PHYEDMGTable | | |
| | | |

### 28.12.2 PHY MIB

All EDMG PHY MIB attributes are defined in Annex C, with specific values defined in Table 28-119 (EDMG PHY MIB attribute default values(11ay)). The (#4177)Operational semantics column in Table 28-119 (EDMG PHY MIB attribute default values(11ay)) contains two types: static and dynamic. Static MIB attributes are fixed and cannot be modified for a given PHY implementation. Dynamic MIB attributes can be modified by some management entity.

### 28.12.3 TXTIME calculation

#### 28.12.3.1 General

This subclause defines the TXTIME parameter calculation for (#8160)EDMG control, SC, and OFDM modes of an EDMG STA PHY entity. The TXTIME parameter is returned from the PHY to the MAC entity using the PLME-TXTIME.confirm primitive issued in response to a PLME-TXTIME.request(TXVECTOR) primitive. The TXTIME represents the time, in microseconds, required to transmit PPDU configured using the indicated TXVECTOR parameters.

#### 28.12.3.2 TXTIME calculation for EDMG control mode

If the FORMAT parameter of TXVECTOR is EDMG, then the modulation is defined by the EDMG_MODULATION parameter. If the EDMG_MODULATION parameter is(M118) to EDMG_C_MODE, the TXTIME parameter shall be defined in microseconds as follows:

$$TXTIME\left(\mu s\right) = T_{L\text{-}STF} + T_{L\text{-}CEF} + T_{L\text{-}Header+EDMG\text{-}Header\text{-}A+Data} + T_{TRN}$$

where

$T_{L\text{-}STF} = 6400 \times \text{aDMGChipTimeDuration} \approx 3.63\ \mu s$

$T_{L\text{-}CEF} = 1152 \times \text{aDMGChipTimeDuration} \approx 0.65\ \mu s$

$$T_{L\text{-}Header+EDMG\text{-}Header\text{-}A+Data} = \left(\left(Length + L_{L\text{-}Header} + L_{EDMG\text{-}Header\text{-}A}\right)\times 8 + 168 \times N_{CW}\right) \times 32 \times \text{aDMGChipTimeDuration}\ \mu s$$

$$N_{CW} = 1 + \left\lceil \frac{\left(Length + L_{EDMG-Header-A2}\right)\times 8}{168} \right\rceil$$

$L_{L-Header} = 5$ octets

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$L_{EDMG-Header-A}$ = 9 octets

$L_{EDMG-Header-A2}$ = 3 octets

The parameter Length (EDMG_LENGTH in TXVECTOR) indicates the number of data octets in the PSDU and ranges from 14 to 1023.

If the CH_BANDWIDTH parameter has a single bit set to 1, the number of space-time streams NUM_STS is equal to 1, and DMG-TRN parameter is equal to 1, then the TRN field duration is defined as follows:

$$T_{TRN} = \left(4992 \times EDMG\_TRN\_LEN\right) \times \text{aDMGChipTimeDuration}\,\mu\text{s}$$

The EDMG_TRN_LEN parameter indicates the length of the training field in the range 0 to 31.

For other values of the CH_BANDWIDTH parameter, the TRN field duration is defined as follows:

$$T_{TRN} = \Big(L_T + \left(L_{TRN\text{-}Unit\text{-}P} + L_{TRN\text{-}Unit\text{-}M}\right) \times TRN\_BASIC\_LENGTH \times EDMG\_TRN\_LEN + L_{TRN\text{-}Unit\text{-}P} \times TRN\_BASIC\_LENGTH\Big) \times \text{aDMGChipTimeDuration}\,\mu\text{s}$$

where

$TRN\_BASIC\_LENGTH = 6 \times TRN\_BL \times N_{TRN}^{N_{TX}}$

If EDMG_TRN_LEN > 0, EDMG-TRN-T or EDMG-TRN-R/T, then $L_T = 6 \times 256 \times N_{TRN}^{N_{TX}}$, $L_{TRN\text{-}Unit\text{-}P}$ = 0, 1, 2, or 4, and $L_{TRN\text{-}Unit\text{-}M}$ = 1, 2, ..., or 16

If EDMG_TRN_LEN > 0, EDMG-TRN-R, then $L_T$ = 0, $L_{TRN\text{-}Unit\text{-}P}$ = 0, and $L_{TRN\text{-}Unit\text{-}M}$ = 10

If EDMG_TRN_LEN = 0, then $L_T$ = 0, $L_{TRN\text{-}Unit\text{-}P}$ = 0, and $L_{TRN\text{-}Unit\text{-}M}$ = 0

If the TRN_SEQ_LENGTH parameter is equal to NORMAL, then *TRN_BL* is set to 128. If the TRN_SEQ_LENGTH parameter is equal to LONG, then *TRN_BL* is set to 256. If the TRN_SEQ_LENGTH parameter is equal to SHORT, then *TRN_BL* is set to 64.

If the CHANNEL_AGGREGATION parameter is equal to (#4167)AGGREGATED and the NUM_TX_CHAINS parameter is equal to 2 or 4, then $N_{TRN}^{N_{TX}}$ is set to 1. If the CHANNEL_AGGREGATION parameter is equal to (#4167)AGGREGATED and the NUM_TX_CHAINS parameter is equal to 6 or 8, then $N_{TRN}^{N_{TX}}$ is set to 2.

If the CHANNEL_AGGREGATION parameter is equal to (#4167)NOT_AGGREGATED and the NUM_TX_CHAINS parameter is equal to 1 or 2, then $N_{TRN}^{N_{TX}}$ is set to 1. If the CHANNEL_AGGREGATION parameter is equal to (#4167)NOT_AGGREGATED and the NUM_TX_CHAINS parameter is equal to 3 or 4, then $N_{TRN}^{N_{TX}}$ is set to 2. If the CHANNEL_AGGREGATION parameter is equal to (#4167)NOT_AGGREGATED and the NUM_TX_CHAINS parameter is equal to 5, 6, 7, or 8, then $N_{TRN}^{N_{TX}}$ is set to 4.

If the EDMG_TRN_LEN parameter is greater than 0 and the EDMG_PPDU_TYPE parameter is equal to EDMG-TRN-T or EDMG-TRN-R/T, then $L_T = 6 \times 256 \times N_{TRN}^{N_{TX}}$, $L_{TRN\text{-}Unit\text{-}P}$ = 0, 1, 2, or 4, and $L_{TRN\text{-}Unit\text{-}M}$ = 1, 2, ..., or 16.

If the EDMG_TRN_LEN parameter is greater than 0 and the EDMG_PPDU_TYPE parameter is equal to EDMG-TRN-R, then $L_T$ = 0, $L_{TRN\text{-}Unit\text{-}P}$ = 0, and $L_{TRN\text{-}Unit\text{-}M}$ = 10.

If the EDMG_TRN_LEN parameter is equal to 0, then $L_T$ = 0, $L_{TRN\text{-}Unit\text{-}P}$ = 0, and $L_{TRN\text{-}Unit\text{-}M}$ = 0.


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The EDMG_TRN_LEN parameter indicates the length of the training field in the range 0 to 255.

#### 28.12.3.3 TXTIME calculation for EDMG SC mode

If the EDMG_MODULATION parameter is set to EDMG_SC_MODE, the TXTIME parameter shall be defined in microseconds as follows:

$$TXTIME(\mu s) = T_{L\text{-}STF} + T_{L\text{-}CEF} + T_{L\text{-}Header} + T_{EDMG\text{-}Header\text{-}A} + T_{EDMG\text{-}STF} + T_{EDMG\text{-}CEF} + T_{EDMG\text{-}Header\text{-}B} + T_{Data} + T_{TRN}$$

where

$T_{L\text{-}STF} = 2176 \times \text{aDMGChipTimeDuration} \approx 1.24\ \mu s$

$T_{L\text{-}CEF} = 1152 \times \text{aDMGChipTimeDuration} \approx 0.65\ \mu s$

$T_{L\text{-}Header} = 1024 \times \text{aDMGChipTimeDuration} \approx 0.58\ \mu s$

If EDMG_ADD_PPDU = NO-ADD-PPDU, NUM_USERS = 1, CH_BANDWIDTH has a single bit set to 1, and NUM_STS = 1, then $T_{EDMG\text{-}Header\text{-}A} = 1024 \times \text{aDMGChipTimeDuration} \approx 0.58\ \mu s$

If EDMG_ADD_PPDU = NO-ADD-PPDU, NUM_USERS ≥ 1, CH_BANDWIDTH has more than 1 bit set to 1 and/or NUM_STS ≠ 1, then $T_{EDMG\text{-}Header\text{-}A} = 1088 \times \text{aDMGChipTimeDuration} \approx 0.62\ \mu s$

If EDMG_ADD_PPDU = ADD-PPDU, $i_{PPDU}$ = 1, CH_BANDWIDTH has a single bit set to 1, and NUM_STS = 1, then $T_{EDMG\text{-}Header\text{-}A} = 1024 \times \text{aDMGChipTimeDuration} \approx 0.58\ \mu s$

If EDMG_ADD_PPDU = ADD-PPDU, $i_{PPDU}$ = 1, CH_BANDWIDTH has more than 1 bit set to 1 and/or NUM_STS ≠ 1, then $T_{EDMG\text{-}Header\text{-}A} = 1088 \times \text{aDMGChipTimeDuration} \approx 0.62\ \mu s$

If EDMG_ADD_PPDU = ADD-PPDU, $i_{PPDU} > 1$, then $T_{EDMG\text{-}Header\text{-}A} = 1024 \times \text{aDMGChipTimeDuration} \approx 0.58\ \mu s$

If NUM_USERS = 1, CH_BANDWIDTH has a single bit set to 1, and NUM_STS = 1, then $T_{EDMG\text{-}STF}$ = 0 and $T_{EDMG\text{-}CEF}$ = 0

If NUM_USERS ≥ 1, CH_BANDWIDTH has more than 1 bit set to 1 and/or NUM_STS ≠ 1, then $T_{EDMG\text{-}STF} = 2432 \times \text{aDMGChipTimeDuration} \approx 1.38\ \mu s$ and $T_{EDMG-CEF} = \left(1152 + 1280 \times \left(N_{EDMG-CEF}^{N_{STS}} - 1\right)\right) / \left(1.76 \times 10^3\right)$

If NUM_USERS = 1, then $T_{EDMG\text{-}Header\text{-}B} = 0$

If NUM_USERS > 1, then $T_{EDMG\text{-}Header\text{-}B} = 512 \times \text{aDMGChipTimeDuration} \approx 0.29\ \mu s$

$T_{Data} = \left(N_{BLKS} \times 512 + N_{GI}\right) \times \text{aDMGChipTimeDuration}\ \mu s$

If the NUM_USERS parameter is equal to 1, the CH_BANDWIDTH parameter has a single bit set to 1, and the NUM_STS parameter is equal to 1, then the EDMG-STF and EDMG-CEF fields are not transmitted and $T_{EDMG\text{-}STF}$ = 0 and $T_{EDMG\text{-}CEF}$ = 0.

If the NUM_USERS parameter is greater than or equal to 1 and the CH_BANDWIDTH parameter has more than 1 bit set to 1 and/or the NUM_STS parameter is not equal to 1, then the EDMG-STF and EDMG-CEF fields are transmitted with a time duration specified above.

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If the NUM_USERS parameter is equal to 1, then the EDMG-Header-B is not transmitted and TEDMG-Header-B = 0. If the NUM_USERS is equal to a value greater than 1, then the EDMG-Header-B is transmitted with a time duration specified above.

If the NUM_STS parameter is equal to 1 or 2, then the $N_{EDMG-CEF}^{N_{STS}}$ parameter is set to 1. If the NUM_STS parameter is equal to 3 or 4, then the $N_{EDMG-CEF}^{N_{STS}}$ parameter is set to 2. If the NUM_STS parameter is equal to 5, 6, 7, or 8, then the $N_{EDMG-CEF}^{N_{STS}}$ parameter is set to 4.

The number of SC symbol blocks, $N_{BLKS}$, depends on the EDMG_LENGTH, MCS and other parameters in the TXVECTOR and shall be as defined in 28.5.9.4 (Encoding).

If the EDMG_ADD_PPDU parameter is equal to NO-ADD-PPDU, the NUM_USERS parameter is equal to 1, the CH_BANDWIDTH parameter has a single bit set to 1, and the NUM_STS is equal to 1, then

— If the GI_TYPE parameter is equal to SHORT, $N_{GI} = 64$.
— If the GI_TYPE is equal to NORMAL, $N_{GI} = 64$.
— If the GI_TYPE is equal to LONG, $N_{GI} = 128$.

If the EDMG_ADD_PPDU parameter is equal to NO-ADD-PPDU, the NUM_USERS parameter is equal to 1, the CH_BANDWIDTH parameter has more than 1 bit set to 1 and/or the NUM_STS parameter is not equal to 1, then

— If the GI_TYPE parameter is equal to SHORT, $N_{GI} = 32$.
— If the GI_TYPE is equal to NORMAL, $N_{GI} = 64$.
— If the GI_TYPE is equal to LONG, $N_{GI} = 128$.

If the EDMG_ADD_PPDU parameter is equal to NO-ADD-PPDU and the NUM_USERS parameter is greater than 1, then

— If the GI_TYPE parameter is equal to SHORT, $N_{GI} = 64$.
— If the GI_TYPE is equal to NORMAL, $N_{GI} = 64$.
— If the GI_TYPE is equal to LONG, $N_{GI} = 128$.

If the EDMG_ADD_PPDU parameter is equal to ADD-PPDU, $i_{PPDU}$ is equal to 1, the CH_BANDWIDTH parameter has a single bit set to 1, and the NUM_STS is equal to 1, then

— If the GI_TYPE parameter is equal to SHORT, $N_{GI} = 64$.
— If the GI_TYPE is equal to NORMAL, $N_{GI} = 64$.
— If the GI_TYPE is equal to LONG, $N_{GI} = 128$.

If the EDMG_ADD_PPDU parameter is equal to ADD-PPDU, $i_{PPDU}$ is equal to 1, the CH_BANDWIDTH parameter has more than 1 bit set to 1 and/or the NUM_STS parameter is not equal to 1, then

— If the GI_TYPE parameter is equal to SHORT, $N_{GI} = 32$.
— If the GI_TYPE is equal to NORMAL, $N_{GI} = 64$.
— If the GI_TYPE is equal to LONG, $N_{GI} = 128$.

If the EDMG_ADD_PPDU parameter is equal to ADD-PPDU and $i_{PPDU}$ is greater than 1, then

— If the GI_TYPE parameter is equal to SHORT, $N_{GI} = 64$.
— If the GI_TYPE is equal to NORMAL, $N_{GI} = 64$.
— If the GI_TYPE is equal to LONG, $N_{GI} = 128$.

The TRN field duration shall be as defined in 28.12.3.2 (TXTIME calculation for EDMG control mode).


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If the L_BEAM_TRACKING_REQUEST parameter is equal to BEAM-TRACKING-NOT-REQUESTED, the L_PPDU_TYPE parameter is equal to TRN-R, the EDMG_BEAM_TRACKING_REQUEST parameter is equal to Beam_Tracking_Requested, the EDMG_PPDU_TYPE parameter is equal to EDMG-TRN-R, and the EDMG_TRN_LEN parameter is greater than 0, then $L_T = 0$, $L_{TRN\text{-}Unit\text{-}P} = 0$, and $L_{TRN\text{-}Unit\text{-}M} = 0$.

If the EDMG_ADD_PPDU parameter is equal to ADD-PPDU, then the TXTIME parameter shall be updated every time a PLME-TXTIME.request(TXVECTOR) primitive is received for each consecutive PPDU. The TXTIME shall be increased by the duration of ($T_{EDMG\text{-}Header\text{-}A} + T_{Data}$) every time the PHY entity receives a new PPDU transmitted as a part of the A-PPDU.

If present in an A-PPDU, the TRN field shall be appended only once at the last PPDU of the A-PPDU.

#### 28.12.3.4 TXTIME calculation for EDMG OFDM mode

If the EDMG_MODULATION parameter is equal to EDMG_OFDM_MODE, the TXTIME parameter shall be defined in microseconds as follows:

$$TXTIME(\mu s) = T_{L\text{-}STF} + T_{L\text{-}CEF} + T_{L\text{-}Header} + T_{EDMG\text{-}Header\text{-}A} + T_{EDMG\text{-}STF} + T_{EDMG\text{-}CEF} + T_{EDMG\text{-}Header\text{-}B} + T_{Data} + T_{TRN}$$

where

$T_{L\text{-}STF} = 2176 \times \text{aDMGChipTimeDuration} \approx 1.24\ \mu s$

$T_{L\text{-}CEF} = 1152 \times \text{aDMGChipTimeDuration} \approx 0.65\ \mu s$

$T_{L\text{-}Header} = 1024 \times \text{aDMGChipTimeDuration} \approx 0.58\ \mu s$

If EDMG_ADD_PPDU is equal to NO-ADD-PPDU, then $T_{EDMG\text{-}Header\text{-}A} = 1088 \times \text{aDMGChipTimeDuration} \approx 0.62\ \mu s$

If EDMG_ADD_PPDU is equal to ADD-PPDU and $i_{PPDU}$ = 1, then $T_{EDMG\text{-}Header\text{-}A} = 1088 \times \text{aDMGChipTimeDuration} \approx 0.62\ \mu s$

$T_{EDMG\text{-}CEF} = \left(704 \times N_{EDMG\text{-}CEF}^{N_{STS}}\right) \times \text{aDMGSampleTimeDuration}\ \mu s$

If NUM_USERS = 1, then $T_{EDMG\text{-}Header\text{-}B} = 0$

If NUM_USERS > 1, then $T_{EDMG\text{-}Header\text{-}B} = \left(512 + N_{GI}\right) \times \text{aDMGSampleTimeDuration}\ \mu s$

$T_{Data} = \left(N_{SYMS} \times (512 + N_{GI})\right) \times \text{aDMGSampleTimeDuration}\ \mu s$

$$T_{TRN} = \Big(L_T + \left(L_{TRN\text{-}Unit\text{-}P} + L_{TRN\text{-}Unit\text{-}M}\right) \times TRN\_BASIC\_LENGTH \times EDMG\_TRN\_LEN + L_{TRN\text{-}Unit\text{-}P} \times TRN\_BASIC\_LENGTH\Big) \times \text{aDMGSampleTimeDuration}\ \mu s$$

$TRN\_BASIC\_LENGTH = TRN\_BL \times N_{TRN}^{N_{TX}}$

If EDMG_TRN_LEN > 0, EDMG-TRN-T or EDMG-TRN-R/T, then $L_T = 4 \times 704 \times N_{TRN}^{N_{TX}}$, $L_{TRN\text{-}Unit\text{-}P}$ = 0, 1, 2, or 4, and $L_{TRN\text{-}Unit\text{-}M}$ = 1, 2, ..., or 16

If EDMG_TRN_LEN > 0 and EDMG-TRN-R, then $L_T = 0$, $L_{TRN\text{-}Unit\text{-}P} = 0$, and $L_{TRN\text{-}Unit\text{-}M} = 10$

If EDMG_TRN_LEN = 0, then $L_T = 0$, $L_{TRN\text{-}Unit\text{-}P} = 0$, and $L_{TRN\text{-}Unit\text{-}M} = 0$

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If the NUM_STS parameter is equal to 1 or 2, then the $N_{EDMG\text{-}CEF}^{N_{STS}}$ parameter is set to 2. If the NUM_STS parameter is equal to 3, then the $N_{EDMG\text{-}CEF}^{N_{STS}}$ parameter is set to 3. If the NUM_STS parameter is equal to 4, then the $N_{EDMG\text{-}CEF}^{N_{STS}}$ parameter is set to 4. If the NUM_STS parameter is equal to 5 or 6, then the $N_{EDMG\text{-}CEF}^{N_{STS}}$ parameter is set to 6. If the NUM_STS parameter is equal to 7 or 8, then the $N_{EDMG\text{-}CEF}^{N_{STS}}$ parameter is set to 8.

If the NUM_USERS parameter is equal to 1, then the EDMG-Header-B is not transmitted and $T_{EDMG\text{-}Header\text{-}B} = 0$. If the NUM_USERS parameter is equal to a value greater than 1, then the EDMG-Header-B is transmitted with time a duration specified above.

If the GI_TYPE parameter is equal to SHORT, $N_{GI} = 48$. If the GI_TYPE parameter is equal to NORMAL, $N_{GI} = 96$. If the GI_TYPE parameter is equal to LONG, $N_{GI} = 192$.

The number of OFDM symbols, $N_{SYMS}$, depends on the EDMG_LENGTH, MCS and other parameters in the TXVECTOR and shall be as defined in 28.6.9.2 (Encoding).

If the TRN_SEQ_LENGTH parameter is equal to NORMAL, then *TRN_BL* is set to $2 \times 704$. If the TRN_SEQ_LENGTH parameter is equal to LONG, then *TRN_BL* is set to $4 \times 704$. If the TRN_SEQ_LENGTH parameter is equal to SHORT, then *TRN_BL* is set to 704.

If the NUM_TX_CHAINS parameter is equal to 1 or 2, then $N_{TRN}^{N_{TX}}$ is set to 2. If the NUM_TX_CHAINS parameter is equal to 3, then $N_{TRN}^{N_{TX}}$ is set to 3. If the NUM_TX_CHAINS parameter is equal to 4, then $N_{TRN}^{N_{TX}}$ is set to 4. If the NUM_TX_CHAINS parameter is equal to 5 or 6, then $N_{TRN}^{N_{TX}}$ is set to 6. If the NUM_TX_CHAINS parameter is equal to 7 or 8, then $N_{TRN}^{N_{TX}}$ is set to 8.

If the EDMG_TRN_LEN parameter is greater than 0 and the EDMG_PPDU_TYPE parameter is equal to EDMG-TRN-T or EDMG-TRN-R/T, then $L_T = 4 \times 704 \times N_{TRN}^{N_{TX}}$, $L_{TRN\text{-}Unit\text{-}P} = 0$, 1, 2, or 4, and $L_{TRN\text{-}Unit\text{-}M} =$ 1, 2, ..., or 16.

If the EDMG_TRN_LEN parameter is greater than 0 and the EDMG_PPDU_TYPE parameter is equal to EDMG-TRN-R, then $L_T = 0$, $L_{TRN\text{-}Unit\text{-}P} = 0$, and $L_{TRN\text{-}Unit\text{-}M} = 10$.

If the EDMG_TRN_LEN parameter is equal to 0, then $L_T = 0$, $L_{TRN\text{-}Unit\text{-}P} = 0$, and $L_{TRN\text{-}Unit\text{-}M} = 0$.

If the L_BEAM_TRACKING_REQUEST parameter is equal to BEAM-TRACKING-NOT-REQUESTED, the L_PPDU_TYPE parameter is equal to TRN-R, the EDMG_BEAM_TRACKING_REQUEST parameter is equal to Beam_Tracking_Requested, the EDMG_PPDU_TYPE parameter is equal to EDMG-TRN-R, and the EDMG_TRN_LEN parameter is greater than 0, then $L_T = 0$, $L_{TRN\text{-}Unit\text{-}P} = 0$, and $L_{TRN\text{-}Unit\text{-}M} = 0$.

If the EDMG_ADD_PPDU parameter is equal to ADD-PPDU, then the TXTIME parameter shall be updated every time a PLME-TXTIME.request(TXVECTOR) is received for each consecutive PPDU. The TXTIME shall be increased by the duration of ($T_{EDMG\text{-}Header\text{-}A} + T_{Data}$) every time the PHY entity receives a new PPDU to be transmitted as a part of the A-PPDU.

The duration of the EDMG-Header-A starting from the second PPDU aggregated in an A-PPDU is defined in microseconds as follows:

$$T_{EDMG\text{-}Header\text{-}A} = \left(1024 + 2 \times N_{GI}\right) \times \text{aDMGSampleTimeDuration } \mu\text{s}$$

where

$N_{GI}$ depends on the GI_TYPE parameter as defined above

If present in an A-PPDU, the TRN field shall be appended only once at the last PPDU of the A-PPDU.


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### 28.12.3.5 TXTIME calculation for non-EDMG control mode

If the FORMAT parameter of the TXVECTOR is NON_EDMG, then the modulation is defined by the NON_EDMG_MODULATION parameter. If the NON_EDMG_MODULATION parameter is equal to DMG_C_MODE or NON_EDMG_DUP_C_MODE, then the TXTIME parameter shall be defined in microseconds as follows:

$$TXTIME(\mu s) = T_{L\text{-}STF} + T_{L\text{-}CEF} + T_{L\text{-}Header+Data} + T_{TRN}$$

where

$T_{L\text{-}STF} = 6400 \times \text{aDMGChipTimeDuration} \approx 3.63\ \mu s$

$T_{L\text{-}CEF} = 1152 \times \text{aDMGChipTimeDuration} \approx 0.65\ \mu s$

$T_{L\text{-}Header+Data} = \left(\left(Length + L_{L\text{-}Header}\right) \times 8 + 168 \times N_{CW}\right) \times 32 \times \text{aDMGChipTimeDuration}\ \mu s$

$N_{CW} = 1 + \left\lceil \frac{(Length - 6) \times 8}{168} \right\rceil$

$L_{L\text{-}Header} = 5$ octets

$T_{TRN} = \left(4992 \times TRN\_LEN\right) \times \text{aDMGChipTimeDuration}\ \mu s$

The parameter Length (LENGTH parameter in the TXVECTOR) indicates the number of data octets in the PSDU in the range 14 to 1023. The TRN_LEN parameter indicates the length of the training field in the range 0 to 16.

### 28.12.3.6 TXTIME calculation for non-EDMG SC mode

If the NON_EDMG_MODULATION parameter is equal to DMG_SC_MODE or NON_EDMG_DUP_SC_MODE, the TXTIME parameter shall be defined in microseconds as follows:

$$TXTIME(\mu s) = T_{L\text{-}STF} + T_{L\text{-}CEF} + T_{L\text{-}Header} + T_{Data} + T_{GI} + T_{TRN}$$

where

$T_{L\text{-}STF} = 2176 \times \text{aDMGChipTimeDuration} \approx 1.24\ \mu s$

$T_{L\text{-}CEF} = 1152 \times \text{aDMGChipTimeDuration} \approx 0.65\ \mu s$

$T_{L\text{-}Header} = 1024 \times \text{aDMGChipTimeDuration} \approx 0.58\ \mu s$

$T_{Data} = \left(N_{BLKS} \times 512\right) \times \text{aDMGChipTimeDuration}\ \mu s$

$T_{GI} = 64 \times \text{aDMGChipTimeDuration} \approx 0.036\ \mu s$

$T_{TRN} = \left(4992 \times TRN\_LEN\right) \times \text{aDMGChipTimeDuration}\ \mu s$

The number of SC symbol blocks, $N_{BLKS}$, depends on the LENGTH and MCS parameters in the TXVECTOR and shall be as defined in 20.5.3.2.3.3 (LDPC encoding process).

The LENGTH parameter indicates the number of data octets in the PSDU in the range 1 to 262143.

The MCS parameter indicates the modulation type and coding scheme used in the transmission of the PPDU. For an(#1424)(#8160) EDMG SC mode transmission, the MCS parameter is in the range 1 to 12, with possible extension to 9.1, 12.1, 12.2, 12.3, 12.4, 12.5, and 12.6 MCS subset.

The TRN_LEN parameter indicates the length of the training field in the range 0 to 16.

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If the L_BEAM_TRACKING_REQUEST is equal to BEAM-TRACKING-REQUESTED, the L_PPDU_TYPE parameter is equal to TRN-R, and the L_TRN_LEN parameter is greater than 0, then $T_{TRN} = 0$.

If the ADD_PPDU parameter is equal to ADD-PPDU, then the TXTIME parameter shall be updated every time a PLME-TXTIME.request(TXVECTOR) primitive is received for each consecutive PPDU. The TXTIME shall be increased by a duration of (TL-Header + TData) every time the PHY entity receives a new PPDU to be transmitted as a part of the A-PPDU.

If present in an A-PPDU, the TRN field shall be appended only once at the last PPDU of the A-PPDU.

### 28.12.4 EDMG PHY characteristics

(#2123)The EDMG PHY characteristics, provided through the PLME-CHARACTERISTICS service primitive, are shown in Table 20-30 unless otherwise listed in Table 28-120 (EDMG PHY characteristics(11ay)). The definitions for these characteristics are given in 6.7.4 (PLME-CHARACTERISTICS.confirm).

**Table 28-120—EDMG PHY characteristics(11ay)**

| PHY parameter | Value |
|---|---|
| aTxPHYDelay | Implementation dependent |
| aRxPHYDelay | Implementation dependent |
| aCCATime | Implementation dependent |
| aDMGChipRate | 1760 MHz |
| aDMGTimeOfDepartureAccuracyThresh | 0.5 ns |
| aDMGChipTimeDuration | 1/1760 μs |
| aDMGSampleTimeDuration | 1/2640 μs |
| aDMGCCAEDDetectTime | 4 μs |


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# 29. Wake-Up Radio (WUR) MAC specification(11ba)

## 29.1 Introduction

A WUR STA has dot11WUROptionImplemented equal to true.

A WUR STA supports the MAC and MLME functions defined in this clause in addition to the MAC functions defined in Clause 10 (MAC sublayer functional description), the MLME functions defined in Clause 11 (MLME), the security functions defined in Clause 12 (Security). When the WUR STA is an HE STA, the WUR STA supports the HE MAC functions defined in Clause 26 (High-efficiency (HE) MAC specification(11ax)). Where the functional specifications in this clause conflict with (#2284)Clause 10 (MAC sublayer functional description), Clause 11 (MLME), Clause 12 (Security), or Clause 26 (High-efficiency (HE) MAC specification(11ax)), this clause takes precedence.

A WUR AP that transmits a WUR PPDU shall include a WUR frame in the WUR PPDU as defined in 30.3.2 (WUR Basic PPDU format) or 30.3.3 (WUR FDMA PPDU format).

## 29.2 WUR channel, WUR primary channel, and WUR discovery channel

A WUR primary channel of a WUR AP is the channel in which the WUR AP transmits WUR Beacon frames (see 29.6.2 (WUR Beacon frame generation)). The WUR primary channel is indicated in the WUR Operating Class and the WUR Channel subfields in the WUR Operation element contained in a Beacon, Association Response, Reassociation Response, or Probe Response frame transmitted by the WUR AP.

A WUR channel of a WUR AP is the channel in which the WUR AP transmits WUR Short Wake-up frames, WUR Wake-up frames, and WUR Vendor Specific frames to an associated WUR non-AP STA.

When the WUR FDMA operation is used, the WUR channel may be different from the WUR primary channel (see 29.11 (WUR FDMA operation)). Otherwise, the WUR channel is equal to the WUR primary channel.

A WUR AP shall not set the WUR Operating Class subfield in the WUR Operation element it transmits to an operating class for which the behavior limits set, listed in Annex E, includes the DFS_50_100_Behavior (see 30.1 (Introduction)).

A WUR AP shall not set the WUR Discovery Operating Class field in the WUR Discovery element it transmits to an operating class for which the behavior limits set, listed in Annex E, includes the DFS_50_100_Behavior (see 30.1 (Introduction)).

A WUR channel and a WUR primary channel should be in the same band as the primary channel of the BSS.

NOTE—Transmissions in a WUR channel and a WUR primary channel that are in the same band as the primary channel of the BSS provide similar range.

A WUR discovery channel of a WUR AP is a channel in which the WUR AP transmits WUR Discovery frames. The WUR discovery channel may be indicated in a WUR Discovery element in Beacon and Probe Response frames (see 29.12 (WUR discovery)). WUR discovery channel may be different from the WUR channel and the WUR primary channel.

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## 29.3 Channel access

Before transmitting a WUR frame, a WUR AP shall contend for the medium as defined in 10.23.3 (HCF controlled channel access (HCCA))) and 10.3.2 (Procedures common to the DCF and EDCAF):

- The WUR AP may use any AC for sending a WUR frame.
- The WUR AP should initiate a TXOP that contains one or more WUR frames with a frame that sets NAV for the duration of the TXOP (see 10.3.2.15 (NAV distribution)).
- A WUR AP that sent one or more WUR frames using the EDCAF of a particular AC shall not update the CW and the retry counters for that AC as a result of the WUR frame transmission.
- A WUR AP that supports the WUR FDMA operation is defined in 29.11.1 (WUR FDMA channel access).

If the WUR primary channel is the same as the primary channel of the BSS, the WUR AP shall use the EDCAF that is also used for transmitting non-WUR frames on the primary channel of the BSS (e.g. using the CCA on the primary channel of the BSS).

If the WUR primary channel is different from the BSS primary channel, the WUR AP shall use a separate EDCAF that uses the CCA on the WUR primary channel.

After moving to a new WUR channel (see 29.11 (WUR FDMA operation)), the WUR AP shall perform CCA until a frame is detected by which it can set its NAV, or until a period of time indicated by the NAVSyncDelay parameter in the most recent MLME-START.request primitive has transpired.

NOTE—When the WUR Channel Offset subfield is equal to 0, the WUR Channel is the same as the WUR primary channel, i.e., the WUR Short Wake-up frame, the WUR Wake-up frame, the WUR Vendor Specific frame, and the WUR Beacon frame are transmitted on the same channel. Otherwise, the WUR Channel can be different from the WUR primary channel (see 29.11 (WUR FDMA operation)).

## 29.4 Discarding a WUR frame

If the PHY of a WUR non-AP STA issues a PHY-RXSTART.indication due to a WUR PPDU reception, then the MAC sublayer of the WUR non-AP STA should discard a WUR frame contained in the WUR PPDU once the WUR frame satisfies any of the following:

- The Type subfield of a WUR frame with a value that is not supported by the WUR non-AP STA
- The Frame Body Present subfield of a WUR frame with a value that is not supported by the WUR non-AP STA
- The Protected subfield of a WUR frame with a value that is not supported by the WUR non-AP STA
- The ID subfield of a WUR frame with a value that is not maintained by the WUR non-AP STA (see 29.5.1 (General))
- A STA Info field of a VL WUR Wake-up frame where the WUR ID field of the STA Info field is greater than the WUR ID assigned to the WUR non-AP STA and none of the WUR ID field in the previous STA Info fields contains the WUR ID assigned to the WUR non-AP STA (see 29.9.3 (WUR AP operation))
- The last STA Info field of a VL WUR Wake-up frame where the WUR ID field of the STA Info field is less than the WUR ID assigned to the WUR non-AP STA (see 29.9.4 (WUR non-AP STA operation))

NOTE 1—A WUR non-AP STA (#1414)that receives a WUR frame that does not satisfy the above conditions follows other rules, which depend on the type of the received WUR frame (see Clause 29).

NOTE 2—A WUR non-AP STA that encounters a field or a subfield that is reserved ignores that field as described in 9.2.2.


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## 29.5 Setting the identifiers of WUR frames

### 29.5.1 General

The ID field of WUR frames contains an identifier (ID) that is selected from the identifier's space, which consists of all integer values between 0 and 4095 (see 9.9.2.2.2 (ID field)).

A WUR AP that maintains a list of multiple IDs shall ensure that each ID that is included in a transmitted WUR frame is either a transmitter ID (see 29.5.3 (Transmitter ID)), a WUR group ID (see 29.5.4 (WUR Group ID)), a WUR ID (see 29.5.5 (WUR ID)), a nontransmitter ID (see 29.5.6 (Nontransmitter ID)) or a portion of the (#8042)OUI or CID (see 9.9.3.4 (WUR Vendor Specific frame format)).

NOTE—A WUR AP might dynamically change the identifiers used within the BSS(#3314) sporadically and randomly to provide a certain degree of security and privacy.

A WUR non-AP STA (#1414)that is in WUR mode or in WUR mode suspend maintains a list of multiple IDs. A WUR non-AP STA is configured to receive one or more WUR frames that contain any of these IDs when the WUR power state of the WUR non-AP STA is in the WUR awake state.

The list of IDs maintained by the WUR non-AP STA includes:

- A WUR ID for WUR Short Wake-up frames and individually addressed FL WUR Wake-up frames.
- A transmitter ID for WUR Beacon, WUR Discovery frames, and for broadcast WUR Wake-up frames sent by the AP corresponding to the transmitted BSSID.
- A nontransmitter ID for broadcast WUR Wake up frames sent by the AP corresponding to the non-transmitted BSSID.
- A set containing zero or more instances of 12 LSBs of an (#8042)OUI or CID for WUR Vendor Specific frames.
- A set containing zero or more instances of a group ID for group addressed FL WUR frames and for VL WUR Wake-up frames.

### 29.5.2 Compressed BSSID

The compressed BSSID is used by a WUR STA to obtain several of the identifiers defined in the remaining subclauses.

The compressed BSSID is equal to the 32-bit CRC calculated over the BSSID contained in Beacon frames transmitted by the WUR AP if dot11MultiBSSIDImplemented is false or calculated over the transmitted BSSID of the multiple BSSID set (see 11.1.3.8 (Multiple BSSID procedure)) if dot11MultiBSSIDImplemented is true (calculation is performed as defined in 9.2.4.8 (Frame Body field) where the BSSID is the *calculation fields*).

### 29.5.3 Transmitter ID

A transmitter ID identifies the WUR AP transmitting the WUR frame.

A WUR Wake-up frame is a broadcast WUR Wake-up frame if the WUR Wake-up frame has a transmitter ID in the ID field. The broadcast WUR Wake-up frame is addressed to all the WUR non-AP STAs that are associated with the WUR AP if dot11MultiBSSIDImplemented is false or addressed to all the WUR non-AP STAs that are associated with the AP corresponding to the transmitted BSSID if dot11MultiBSSIDImplemented is true.

WUR Beacon frames and WUR Discovery frames sent by a WUR AP shall have a transmitter ID in the ID field.

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NOTE—WUR non-AP STAs associated to a nontransmitted BSSID are identified by the nontransmitter ID (see 29.5.6 (Nontransmitter ID)). These WUR non-AP STAs associated with the AP corresponding to a nontransmitted BSSID in a multiple BSSID set are expected to receive WUR Beacons and WUR Discovery frames sent with the a transmitter ID in the ID field and are not expected to receive other types of WUR frames sent with a transmitter ID in the ID field.

A WUR AP shall use the 12 LSBs of the compressed BSSID as the transmitter ID of WUR frames it transmits.

### 29.5.4 WUR Group ID

A WUR group ID identifies a group of one or more WUR non-AP STAs and is selected from a WUR group ID space, which is a subset of consecutive values obtained from the identifier's space. A FL WUR Wake-up frame with WUR group ID in the ID field is defined as a group addressed WUR frame that is addressed to all the WUR non-AP STAs identified by that WUR group ID. A VL WUR Wake-up frame is a group addressed WUR frame that is addressed to all the WUR non-AP STAs that are identified by the WUR IDs included in the Frame Body field and belong to the group identified by the WUR group ID indicated in the ID field.

A WUR AP shall randomly select the starting value of the WUR group ID space from the identifier's space before the WUR AP starts to assign any WUR group ID(s) to any WUR non-AP STA. All WUR group IDs shall not match any of the assigned WUR IDs, transmitter ID, and nontransmitter IDs (if any).

A WUR AP may assign one or more WUR group IDs to a WUR non-AP STA if the WUR non-AP STA has set the WUR Group IDs Support field of the WUR Capabilities element it transmits to a nonzero value and may assign a single WUR group ID to the WUR non-AP STA if the WUR non-AP STA has set the WUR Group IDs Support subfield of the WUR Capabilities element to 0 and has set VL WUR Frame Support subfield of the WUR Capabilities element to 1; otherwise the WUR AP shall not assign a WUR group ID to the WUR non-AP STA.

A WUR AP shall indicate the WUR group IDs assigned to a WUR non-AP STA in the WUR Group ID List subfield of the WUR Parameters field of the WUR Mode element that is sent to the WUR non-AP STA. The difference between the largest WUR group ID and the lowest WUR group ID assigned by the WUR AP to a WUR non-AP STA shall not exceed the value indicated in the WUR Group IDs Support field of the WUR Capabilities element sent by the WUR non-AP STA, where the comparison performed between the two WUR group IDs is circular modulo 4096.

A WUR non-AP STA that has indicated support for WUR group IDs shall obtain the assigned WUR group IDs from the WUR Group ID List subfield of the WUR Parameters field in the most recent WUR Mode element received from the WUR AP if the Action Type field in the most recently received WUR Mode element is equal to "Enter WUR Mode Response" or "Enter WUR Mode Suspend Response" and the WUR Mode Response Status field is equal to "Accept". Otherwise, the WUR non-AP STA shall not obtain the assigned WUR group IDs from the WUR Group ID List subfield of the WUR Parameters field in the most recent WUR Mode element received from the WUR AP.

### 29.5.5 WUR ID

A WUR ID identifies the WUR non-AP STA that is the intended recipient of the WUR frame. A WUR frame with a WUR ID in the ID field is defined as an individually addressed WUR frame that is addressed to the WUR non-AP STA identified by that WUR ID.

A WUR AP shall assign to each WUR non-AP STA a WUR ID that uniquely identifies the WUR non-AP STA within the BSS of the WUR AP if dot11MultiBSSIDImplemented is false. A WUR AP shall assign to each WUR non-AP STA a WUR ID that uniquely identifies the WUR non-AP STA within BSSs of the Multiple BSSID set that the WUR AP is a member if dot11MultiBSSIDImplemented is true. The WUR AP shall either select the WUR ID randomly from the identifier's space or calculate the WUR ID as *AID* +


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*transmitter ID*, where *AID* is the association identifier of the WUR non-AP STA, *transmitter ID* is the transmitter ID of the WUR AP as defined in 29.5.3 (Transmitter ID) and the addition performed between the two identifiers is circular modulo $2^{12}$. The WUR AP shall verify that the selected or calculated WUR ID is not any of WUR Group ID, the transmitter ID of the WUR AP, or any nontransmitter ID (if any). The WUR AP shall indicate the WUR ID assigned to a WUR non-AP STA in the WUR ID field of the WUR Mode element it sends to the WUR non-AP STA.

A WUR non-AP STA shall obtain the WUR ID from the WUR ID field of the most recent WUR Mode element received from the WUR AP.

### 29.5.6 Nontransmitter ID

A nontransmitter ID identifies a nontransmitted BSSID from the multiple BSSID set (see 11.1.3.8 (Multiple BSSID procedure)).

A WUR Wake-up frame is a broadcast WUR Wake-up frame if the WUR Wake-up frame has a nontransmitter ID in the ID field. The WUR Wake-up frame is addressed to all the WUR non-AP STAs that are associated with the AP corresponding to a nontransmitted BSSID in a multiple BSSID set.

A WUR AP that operates a multiple BSSID set containing a nontransmitted BSSID and a WUR non-AP STA that is a member of a BSS corresponding to a nontransmitted BSSID shall calculate the nontransmitter ID as k + transmitter ID, where k is equal to the BSSID index field corresponding to that BSS (see 9.4.2.72 (Multiple BSSID-Index element) for the nontransmitted BSSID, the transmitter ID is defined in 29.5.3 (Transmitter ID), and the addition performed between the two identifiers is circular modulo $2^{12}$.

## 29.6 Synchronization using WUR Beacon frame

### 29.6.1 General

A WUR non-AP STA that is in WUR mode expects to receive WUR Beacon frames every dot11WURBeaconPeriod and expects to receive WUR Beacon frames within WUR duty cycle service periods negotiated with the WUR AP if the WUR AP has accepted to transmit keep-alive WUR frames (see 29.8.2 (WUR mode setup).

NOTE 1—A WUR STA's TSF timer has the same TSF timer accuracy requirement, which is accurate to within ±100 ppm, defined in 11.1.3.9 (TSF timer accuracy) for a non-DMG STA.

If a WUR non-AP STA (#1414)that is in WUR mode and doze state (see 11.2.1 (General)) does not receive WUR Beacon frames for a time period, the WUR non-AP STA should perform WUR scanning (see 29.12 (WUR discovery)) or transition to awake state (see 11.2.1 (General)). The methods by which the WUR non-AP STA determines the exact value of the time period are implementation specific and out of scope of this standard.

NOTE 2—If a WUR non-AP STA does not perform any action while not receiving WUR Beacon frames for a time period, the WUR non-AP STA might not discover that it is already out of range of the WUR AP sending the WUR Beacon frames.

A WUR AP sending a WUR Beacon frame shall set the Type Dependent Control field of the WUR Beacon frame to the TSF timer [5:16] of the WUR AP's TSF timer at the time that the start of the (#4055)(#4370)first WUR On-Off Keying (OOK) symbol containing the first bit of the Type Dependent Control field is transmitted by the PHY plus the WUR AP's delays through its local PHY from the MAC-PHY interface to its interface with the WM.

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### 29.6.2 WUR Beacon frame generation

A WUR AP shall define the timing for the WUR operations by transmitting WUR Beacon frames according to dot11WURBeaconPeriod and the Offset Of TWBTT subfield of the WUR Operation element that the WUR AP transmits. This defines a series of target WUR beacon transmission times exactly dot11WURBeaconPeriod TUs apart. Additionally, the WUR AP may transmit WUR Beacon frames as keep-alive WUR frames during WUR duty cycle service periods negotiated with a WUR non-AP STA (see 29.8.3 (WUR power management operation for a WUR AP)).

NOTE 1—The method to determine the value of dot11WURBeaconPeriod is implementation specific and might be chosen based on the considerations of overhead, timing correction requirement, and other implementation specific reasons.

If dot11MultiBSSIDImplemented is true, among all BSS in a multiple BSSID set (see 11.10.14 (Multiple BSSID set)), the WUR AP with BSSID equal to transmitted BSSID in a multiple BSSID set transmits WUR Beacon frames, and other WUR APs with BSSID not equal to transmitted BSSID in the multiple BSSID set shall not transmit WUR Beacon frames.

At each target WUR beacon transmission time, the WUR AP shall schedule a WUR Beacon frame on the WUR primary channel indicated by the WUR Operating Class and WUR Channel subfields in the WUR Operation element if all the following conditions are met:

- dot11MultiBSSIDImplemented is false or dot11MultiBSSIDImplemented is true, and the BSSID of the WUR AP is equal to transmitted BSSID in a multiple BSSID set
- None of the following conditions are met:
  - There are no WUR non-AP STAs associated with the WUR AP if dot11MultiBSSIDImplemented is false.
  - There are no WUR non-AP STAs associated with any WUR APs in the multiple BSSID set if dot11MultiBSSIDImplemented is true.
  - The WUR AP does not provide WUR power management service to any associated WUR non-AP STA (see 29.8 (WUR power management procedure)).
  - All associated WUR non-AP STAs are in Active mode.

If the WUR AP schedules a WUR Beacon frame, the WUR Beacon frame shall be the next frame for transmission according to the medium access rules specified in 10 (MAC sublayer functional description) unless a Beacon frame is scheduled for transmission as defined in 11.1.3.2 (Beacon generation in non-DMG infrastructure networks) in which case the Beacon frame is the next frame for transmission and the WUR Beacon frame is the next frame for transmission after transmitting the Beacon frame and non-GCR-SP group addressed (#3814)BUs if the Beacon frame is a (#1000)DTIM beacon (see 11.2.3.1 (General)).

NOTE 2—To achieve this requirement of scheduling a WUR Beacon frame, the WUR AP suspends any pending transmissions until the WUR Beacon frame has been transmitted.

A WUR AP shall indicate the WUR beacon period in the WUR Operation element that the WUR AP transmits. A WUR non-AP STA shall adopt that WUR beacon period when joining the BSS, i.e., the WUR non-AP STA shall set the dot11WURBeaconPeriod to the WUR Beacon Period subfield of the received WUR Operation element.

NOTE 3—Though the transmission of a WUR Beacon frame might be delayed because of CSMA deferrals, subsequent WUR Beacon frames are scheduled at the undelayed nominal WUR beacon period.

If dot11MultiBSSIDImplemented is false, a WUR AP shall transmit a WUR Beacon frame with a data rate that is supported by all WUR non-AP STAs that have negotiated WUR power management service (see 29.8 (WUR power management procedure)).


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If dot11MultiBSSIDImplemented is true, the WUR AP with BSSID equal to the transmitted BSSID in a multiple BSSID set (see 11.10.14 (Multiple BSSID set)) shall transmit a WUR Beacon frame with a data rate that is supported by all WUR non-AP STAs that have negotiated WUR power management service to any members in the multiple BSSID set (see 29.8 (WUR power management procedure)).

### 29.6.3 Maintaining TSF timer synchronization with WUR Beacon frame

Upon receiving a WUR Beacon frame with a valid FCS and transmitter ID that matches the transmitter ID of the WUR AP to which a WUR non-AP STA is associated if dot11MultiBSSIDImplemented is false or the transmitter ID of the WUR AP corresponding to the transmitted BSSID of the multiple BSSID set, where the WUR AP to which a WUR non-AP STA is associated is a member, if dot11MultiBSSIDImplemented is true (see 29.5.3 (Transmitter ID)), the WUR non-AP STA shall update its TSF timer according to the algorithm described below.

The received partial TSF timestamp, obtained from the Type Dependent Control field of the WUR Beacon frame, is adjusted to consider the WUR non-AP STA's delay as shown below:

— Create a temporary timestamp by concatenating the received partial TSF timestamp with 5 bits containing an implementation specific value that represents the assumed value of bit position 0 to 4 of the temporary timestamp.

— Add an amount equal to the receiving WUR non-AP STA's delay through its local PHY components plus the time since the first bit of the Partial TSF field was received at the MAC/PHY interface to the temporary timestamp.

— The adjusted value of the received partial TSF timestamp is set as the value of bit position 5 to 16 of the temporary timestamp.

If the most significant bit (MSB) of the adjusted value of the received partial TSF timestamp is not equal to the bit 16 of the local TSF timer, then the value of bits 17 to 63 of the local TSF timer shall be adjusted to account for roll over as follows:

— The value shall be increased by one unit (modulo $2^{47}$) if LT[5:16] > AT and LT[5:16] > ((AT+ $2^{11}$) (modulo $2^{12}$)).

— The value shall be decreased by one unit (modulo $2^{47}$) if LT[5:16] < AT and LT[5:16] < ((AT – $2^{11}$) (modulo $2^{12}$)).

where AT is the adjusted value of the received partial TSF timestamp and LT[5:16] is the value of bits 5 to 16 of the local TSF timer.

The bits 5 to 16 of the WUR non-AP STA's local TSF timer shall be set to the adjusted value of the received partial TSF timestamp.

## 29.7 WUR duty cycle operation

WUR duty cycle operation identifies the required amount of time that the WUR power state of a WUR non-AP STA utilizing WUR mode needs to be in the WUR awake state after the WUR non-AP STA enters the doze state (see 11.2.1 (General) and 29.8 (WUR power management procedure)). An illustration of state transition diagram of WUR power state is shown in Figure 29-1 (State transition diagram of WUR power state of a WUR non-AP STA in WUR mode(11ba)). WUR duty cycle operation also allows a WUR AP to manage WUR activity in the BSS by scheduling a WUR non-AP STA to receive WUR frames at different times.

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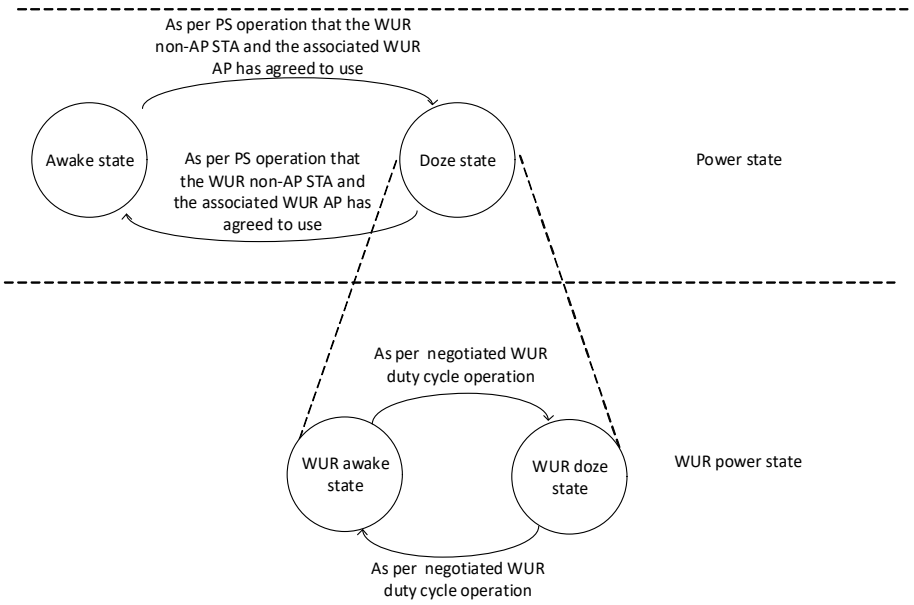


**Figure 29-1—State transition diagram of WUR power state of a WUR non-AP STA in WUR mode(11ba)**

A WUR AP shall support WUR duty cycle operation.

A WUR non-AP STA establishes WUR duty cycle operation with the WUR AP to which it is associated through WUR mode setup as described in 29.8.2 (WUR mode setup).

WUR duty cycle operation is determined by the following parameters: start point, WUR duty cycle service period, and duty cycle period (see Figure 29-2 (WUR Duty Cycle(11ba))).

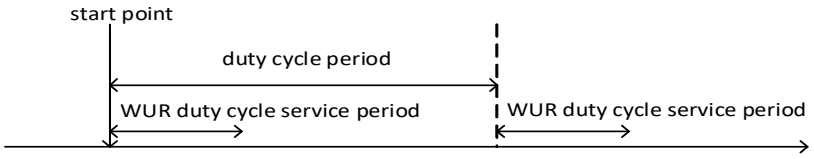


**Figure 29-2—WUR Duty Cycle(11ba)**

The start point indicates the start time of a WUR duty cycle service period. For any WUR duty cycle service period, the start time of the next WUR duty cycle service period is equal to the start time of the WUR duty cycle service period plus the duty cycle period.

A WUR AP indicates the minimum wake-up duration in the Minimum Wake-up Duration subfield of the WUR Operation element and the duty cycle period unit in the Duty Cycle Period Units subfield of the WUR Operation element.


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In the response frame sent by the WUR AP during a WUR mode setup (see 29.8.2 (WUR mode setup)), the WUR Duty Cycle Start Time present subfield of the WUR Parameters Control field in the WUR Mode element within the response frame shall be set to 1 if the WUR Mode Response Status field of the carrying WUR Mode element within a response frame is equal to "Accept," and the WUR duty cycle service period indicated in the WUR Duty Cycle Service Period subfield of the WUR Parameters field in the WUR Mode element within the request frame is smaller than the duty cycle period indicated in the Duty Cycle Period subfield of the WUR Parameters field in the WUR Mode element within the request frame. Otherwise, the WUR Duty Cycle Start Time present subfield of the WUR Parameters Control field in the WUR Mode element within the response frame shall be set to 0.

In the request frame sent by the WUR non-AP STA during a WUR mode setup (see 29.8.2 (WUR mode setup)), the WUR Duty Cycle Start Time present subfield of the WUR Parameters Control field in the WUR Mode element within the request frame shall be set to 0.

After a WUR non-AP STA establishes WUR duty cycle operation with a WUR AP through WUR mode setup as described in 29.8.2 (WUR mode setup):

— the duty cycle period is indicated in the Duty Cycle Period subfield of the WUR Parameters field in the WUR Mode element transmitted by the WUR non-AP STA.
— the WUR duty cycle service period is indicated in the WUR Duty Cycle Service Period subfield of the WUR Parameters field in the WUR Mode element transmitted by the WUR non-AP STA.
— the start point is indicated in the WUR Duty Cycle Start Time subfield of the WUR Parameters field in the WUR Mode element transmitted by the WUR AP.

A WUR non-AP STA shall set the WUR Duty Cycle Service Period subfield of the WUR Parameters field in the WUR Mode element to indicate a duration that is larger than or equal to the duration indicated by the Minimum Wake-up Duration subfield in the most recently received WUR Operation element from the associated WUR AP.

A WUR non-AP STA shall set the WUR Duty Cycle Service Period subfield of the WUR Parameters field in a WUR Mode element to indicate a duration that is smaller than or equal to the duty cycle period indicated in the Duty Cycle Period subfield of the WUR parameters field in the WUR Mode element.

If a WUR non-AP STA is in WUR mode, and the WUR non-AP STA is in the doze state (see 11.2.1 (General)), the WUR power state of the WUR non-AP STA shall be in the WUR awake state within the WUR duty cycle service period of a WUR duty cycle period.

## 29.8 WUR power management procedure

### 29.8.1 General

A WUR AP may provide WUR power management service to its associated WUR non-AP STAs as defined in 29.8.2 (WUR mode setup), 29.8.3 (WUR power management operation for a WUR AP), 29.8.4 (WUR power management operation for a WUR non-AP STA), and 29.9 (Wake-up operation).

A WUR non-AP STA is in WUR mode or WUR mode suspend while using WUR power management service provided by a WUR AP.

A WUR STA shall follow the power management procedure defined in 11.2.3 (Power management in a non-DMG infrastructure network) except that some of the rules are relaxed as defined in 29.8.3 (WUR power management operation for a WUR AP) and 29.8.4 (WUR power management operation for a WUR non-AP STA).

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### 29.8.2 WUR mode setup

To use the WUR power management service, a WUR non-AP STA initiates a successful frame exchanges with its associated WUR AP. Table 29-1 (Settings for WUR mode setup frame exchange - Request and Response(11ba)) defines the frames used in the WUR mode setup frame exchange and the status after the exchange. These frames contain the WUR Mode elements necessary to define the WUR power management service in WUR Mode Setup frames or (Re)Association Request/Response frames with a WUR AP. Table 29-1 (Settings for WUR mode setup frame exchange - Request and Response(11ba)) and Table 29-2 (WUR Mode Setup frame or WUR Mode Teardown frame transmission(11ba)) define the frames used in the WUR Mode Setup frame and WUR Mode Teardown frame exchanges.

**Table 29-1—Settings for WUR mode setup frame exchange - Request and Response(11ba)**

| Request frame: Action Type field of the WUR Mode element within a request frame transmitted from a WUR non-AP STA to a WUR AP | Response frame: Action Type field of the WUR Mode element within a response frame transmitted from a WUR AP to a WUR non-AP STA | Response frame: WUR Mode Response Status field of the WUR Mode element within a response frame transmitted from a WUR AP to a WUR non-AP STA | Status after the completion of the successful frame transmission |
|---|---|---|---|
| Enter WUR Mode Request | Enter WUR Mode Response | Accept | The WUR non-AP STA enters WUR mode. |
| Enter WUR Mode Suspend Request | Enter WUR Mode Suspend Response | Accept | The WUR non-AP STA enters WUR mode suspend. |
| Enter WUR Mode Request | Enter WUR Mode Response | Denied | WUR power management service is not provided by the WUR AP to the WUR non-AP STA at this time. |
| Enter WUR Mode Suspend Request | Enter WUR Mode Suspend Response | Denied | WUR power management service is not provided by the WUR AP to the WUR non-AP STA at this time. |

NOTE 1—If WUR power management service is not provided by the WUR AP to the WUR non-AP STA, the WUR non-AP STA is not in WUR mode or WUR mode suspend.

NOTE 2—The definition of WUR mode and WUR mode suspend is described in 29.8.4 (WUR power management operation for a WUR non-AP STA) and 29.9 (Wake-up operation).


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**Table 29-2—WUR Mode Setup frame or WUR Mode Teardown frame transmission(11ba)**

| Frame type carrying the WUR Mode element (and Action Type field of the WUR Mode element) transmitted from a WUR non-AP STA to a WUR AP | Frame type carrying the WUR Mode element (and Action Type field of the WUR Mode element) transmitted from a WUR AP to a WUR non-AP STA | Status after the completion of the exchange |
|---|---|---|
| WUR Mode Setup frame (Action Type = Enter WUR Mode) | N/A | The WUR non-AP STA enters WUR mode from WUR mode suspend. |
| WUR Mode Setup frame (Action Type = Enter WUR Mode Suspend) | N/A | The WUR non-AP STA enters WUR mode suspend from WUR mode. |
| N/A | WUR Mode Setup frame (Action Type = Enter WUR Mode Response) | The WUR non-AP STA that is in WUR mode updates the WUR Parameters. |
| N/A | WUR Mode Setup frame (Action Type = Enter WUR Mode Suspend Response) | The WUR non-AP STA that is in WUR mode suspend updates the WUR Parameters. |
| WUR Mode Teardown frame | N/A | The WUR non-AP STA tears down WUR power management service. |
| N/A | WUR Mode Teardown frame | The WUR AP tears down WUR power management service. |

NOTE 3—See 9.4.2.292 (WUR Mode element(11ba)) for the definition of Action Type field in WUR Mode element.

A request frame in Table 29-1 (Settings for WUR mode setup frame exchange - Request and Response(11ba)) is successfully transmitted from a WUR non-AP STA to a WUR AP if an Ack frame is received by the WUR non-AP STA for the request frame.

A response frame in Table 29-1 (Settings for WUR mode setup frame exchange - Request and Response(11ba)) is successfully transmitted from a WUR AP to a WUR non-AP STA if an Ack frame is received by the WUR AP for the response frame.

If the WUR AP denies the WUR mode setup, the WUR Mode Response Status field in the corresponding WUR Mode element shall be set to one of the values with meaning “Denied” shown in Table 9-408 (WUR Mode Response Status Definition(11ba)).

If the WUR AP accepts the request for WUR mode setup with the WUR Parameters field in the WUR Mode Setup frame, the WUR Mode Response Status field in the corresponding WUR Mode element is set to “Accept”. If the WUR non-AP STA receives the WUR Mode element, which contains WUR Mode Response Status field equal to “Accept”, WUR power management service is negotiated between the WUR non-AP STA and the WUR AP with WUR parameters, which are indicated in the WUR Mode elements.

After a WUR non-AP STA has negotiated WUR power management service with a WUR AP, the WUR non-AP STA may switch from WUR mode to WUR mode suspend by initiating and completing a successful frame exchange exchange(#109), which includes a WUR Mode Setup frame with Action Type field of the

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carrying WUR Mode element equal to “Enter WUR Mode Suspend” from the WUR non-AP STA and an Ack frame from the WUR AP as described in Table 29-2 (WUR Mode Setup frame or WUR Mode Tear-down frame transmission(11ba)).

After a WUR non-AP STA has negotiated WUR power management service with a WUR AP, the WUR non-AP STA may switch from WUR mode suspend to WUR mode by initiating and completing a successful frame exchange sequence(#109), which includes a WUR Mode Setup frame with Action Type field of the carrying WUR Mode element equal to “Enter WUR Mode” from the WUR non-AP STA and an Ack frame from the WUR AP as described in Table 29-2 (WUR Mode Setup frame or WUR Mode Teardown frame transmission(11ba)).

The Action Type field in the WUR Mode element of the WUR Mode Setup frame sent by the WUR non-AP STA in this frame exchange sequence(#109) indicates the status that the WUR non-AP STA shall adopt upon successful completion of the frame exchange sequence(#109).

A WUR non-AP STA may indicate in the WUR Mode element its recommendation on which WUR channel to assign for itself if the WUR FDMA Support subfield in the WUR Capabilities element sent by the WUR non-AP STA is equal to 1; otherwise, the WUR non-AP STA shall not recommend a WUR channel. The WUR non-AP STA may indicate in the WUR Mode element its recommendation on which data rate (LDR or HDR) to use for WUR Short Wake-up frames or individually or group addressed WUR Wake-up frames transmitted to the WUR non-AP STA if the 20 MHz WUR PPDU with HDR Support subfield in the WUR Capabilities element sent by the WUR non-AP STA is equal to 1; otherwise, the WUR non-AP STA shall not recommend a WUR data rate and shall set the Recommended WUR Short Wake-up Frame or WUR Wake-up Frame Rate field to 0 if a Proposed WUR Parameter subfield is included in the WUR Parameter field in a WUR Mode element it transmits. The WUR non-AP STA should avoid repeatedly renegotiating WUR power management with the same proposed WUR parameters in the WUR Mode element for the remainder of the association if the WUR AP (#6147)does not use the recommended value(s) from the WUR non-AP STA.

A WUR non-AP STA may set the Requested Keep-Alive WUR Frame field to 1 in the WUR Mode element to request the WUR AP to generate a keep-alive WUR frame during the WUR duty cycle service periods that are negotiated with the WUR non-AP STA.

A WUR AP may assign the WUR channel to WUR non-AP STAs or select the data rate of the transmitted WUR PPDU based on the values contained in the Proposed WUR Parameters subfields received from these WUR non-AP STAs.

After a WUR non-AP STA has negotiated WUR power management service with a WUR AP, the WUR AP may update the WUR parameters with the WUR non-AP STA in WUR mode by initiating and completing a successful frame exchange sequence(#109), which includes an unsolicited WUR Mode Setup frame with the Action Type in WUR Mode element equal to “Enter WUR Mode Response” from the WUR AP and an Ack frame from the WUR non-AP STA as described in Table 29-2 (WUR Mode Setup frame or WUR Mode Teardown frame transmission(11ba)).

After a WUR non-AP STA has negotiated WUR power management service with a WUR AP, the WUR AP may update the WUR parameters with the WUR non-AP STA in WUR mode suspend by initiating and completing a successful frame exchange sequence(#109), which includes an unsolicited WUR Mode Setup frame with the Action Type in WUR Mode element equal to “Enter WUR Mode Suspend Response” from the WUR AP and an Ack frame from the WUR non-AP STA as described in Table 29-2 (WUR Mode Setup frame or WUR Mode Teardown frame transmission(11ba)).

The WUR non-AP STA that sent the Ack frame in response to the unsolicited WUR Mode Setup frame shall update the WUR parameters to the parameters included in the received WUR Mode Setup frame. The WUR


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non-AP STA may teardown WUR operation as described below if the WUR non-AP STA (#6147)does not intend to use the parameters.

After a WUR non-AP STA negotiates WUR power management service with a WUR AP, the WUR non-AP STA may tear down WUR power management service by initiating and completing a successful frame exchange sequence(#109), which includes a WUR Mode Teardown frame from the WUR non-AP STA and an Ack frame from the WUR AP as described in Table 29-2 (WUR Mode Setup frame or WUR Mode Teardown frame transmission(11ba)).

After a WUR non-AP STA negotiates WUR power management service with a WUR AP, the WUR AP may tear down WUR power management service by initiating and completing a successful frame exchange sequence(#109), which includes a WUR Mode Teardown frame from the WUR AP and an Ack frame from the WUR non-AP STA as described in Table 29-2 (WUR Mode Setup frame or WUR Mode Teardown frame transmission(11ba)).

A WUR STA that successfully finishes WUR mode setup shall operate as defined in 29.8.3 (WUR power management operation for a WUR AP), 29.8.4 (WUR power management operation for a WUR non-AP STA), and 29.9 (Wake-up operation).

### 29.8.3 WUR power management operation for a WUR AP

For each WUR non-AP STA that requests WUR power management service from an associated WUR AP, the WUR AP shall maintain a WUR status that indicates whether the WUR non-AP STA is in WUR mode or WUR mode suspend.

If a WUR non-AP STA is in WUR mode, then:

- The negotiated WUR parameters between the WUR AP and the WUR non-AP STA are maintained by the WUR AP.
- The WUR AP shall schedule for transmission a WUR Wake-up frame or a WUR Short Wake-up frame for the WUR non-AP STA during a WUR duty cycle service period that is negotiated with the WUR non-AP STA to notify the WUR non-AP STA that the WUR AP intends to have operation with the WUR non-AP STA as described in 29.9.3 (WUR AP operation) and 29.9.4 (WUR non-AP STA operation) if the WUR non-AP STA is in the doze state (see 11.2.1 (General)). The WUR Short Wake-up frame or the WUR Wake-up frame classifies as a keep-alive WUR frame for a WUR non-AP STA that has requested the transmission of keep-alive WUR frames during WUR mode setup.
- The WUR AP shall schedule for transmission a WUR Beacon frame during a WUR duty cycle service period that is negotiated with the WUR non-AP STA as a keep-alive WUR frame if the WUR AP does not schedule for transmission a WUR Short Wake-up frame or a WUR Wake-up frame for the WUR non-AP STA during that WUR duty cycle service period and the WUR non-AP STA has requested the transmission of keep-alive WUR frames during a successful WUR mode setup (see 29.8.2 (WUR mode setup)).
- The negotiated service periods between the WUR AP and the WUR non-AP STA for the WUR non-AP STA's schedule are suspended, i.e., the WUR non-AP STA is not required to be in the awake state (see 11.2.1 (General)) during the negotiated service period:
  - After the WUR AP transmits a WUR Short Wake-up frame or a WUR Wake-up frame addressed to the WUR non-AP STA with an indication of individually addressed buffered BU(s), the WUR AP expects that the WUR non-AP STA is in the awake state (see 11.2.1 (General)) at the earliest service period, which has end time larger than the received time of the frame plus the transition delay indicated by the WUR non-AP STA in the WUR Capabilities elements, following the PS operation (e.g., individual TWT) agreed between the WUR AP and the WUR non-AP STA.
  - The parameters of the negotiated service period for the WUR non-AP STA's schedule between the WUR AP and the WUR non-AP STA are maintained by the WUR AP.

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— The WUR AP shall follow the wake-up operation defined in 29.9 (Wake-up operation).

NOTE 1—The WUR non-AP STA might not wake up at the exact start time of the earliest service period.

NOTE 2—A WUR AP can generate keep-alive WUR frames, which are WUR beacon frames, in the WUR primary channel, and a WUR AP cannot generate keep-alive WUR frames, which are WUR beacon frames, in a WUR channel that is not the WUR primary channel. Hence, the AP can assign these WUR non-AP STAs in the WUR primary channel to enable generation of the keep-alive WUR frames, and the AP cannot assign these WUR non-AP STAs in a WUR channel that is not the WUR primary channel to enable the keep-alive operation.

NOTE 3—If the WUR non-AP STA is in power save mode, then the WUR AP still buffer individually addressed BUs (see 11.2.3.1 (General)) as described in 29.1 (Introduction) and deliver them in designated time as described in 29.9.3 (WUR AP operation) and 29.9.4 (WUR non-AP STA operation).

If a WUR non-AP STA is in WUR mode suspend, then the negotiated WUR parameters between the WUR AP and the WUR non-AP STA are maintained by the WUR AP.

NOTE 4—A WUR non-AP STA in WUR mode suspend does not need to follow the WUR duty cycle service period agreed between the WUR AP and the WUR non-AP STA.

### 29.8.4 WUR power management operation for a WUR non-AP STA

In addition to the two power states defined in 11.2.1 (General) that differentiate the functionality of being able to receive or not being able to receive non-WUR frames, two WUR power states are defined to differentiate the functionality of being able to receive or not being able to receive WUR frames.

The WUR power state of a WUR non-AP STA can be in one of two WUR power states:

— WUR awake: the WUR non-AP STA is able to receive WUR frames.

— WUR doze: the WUR non-AP STA is not able to receive WUR frames.

NOTE 1—A WUR non-AP STA can be in the awake or doze state as defined in 11.2.1 (General) while in the power save mode regardless of whether the WUR non-AP STA has negotiated WUR power management service to be in WUR mode or WUR mode suspend. A WUR non-AP STA can be in active mode or power save (PS) mode as defined in 11.2.3.2 (Non-AP STA power management modes) regardless of whether the WUR non-AP STA has negotiated WUR power management service to be in WUR mode or WUR mode suspend. The change of power management mode and the change of negotiated WUR power management service to be in WUR mode or WUR mode suspend are independent.

If a WUR non-AP STA is in WUR mode, then:

— The negotiated WUR parameters between the WUR AP and the WUR non-AP STA are maintained by the WUR non-AP STA.

— If the WUR non-AP STA is considered by the WUR AP to be in the doze state (see 11.2.1 (General)), the WUR power state of the WUR non-AP STA shall be in the WUR awake state during the WUR duty cycle service period agreed between WUR AP and WUR non-AP STA. Otherwise, the WUR power state of the WUR non-AP STA may be in the WUR doze state.

— The WUR power state of the WUR non-AP STA may be in the WUR doze state after the WUR non-AP STA completes a successful frame exchange sequence(#109) with the WUR AP, and the frame exchange sequence(#109) informs the WUR AP that the WUR non-AP STA is in the awake state (see 11.2.1 (General)).

— The WUR non-AP STA may (M118)wake up to receive Beacon frame if the WUR non-AP STA is in PS mode (see 11.2.3.1 (General)).

— The negotiated service periods between WUR AP and WUR non-AP STA for the WUR non-AP STA's schedule are suspended, and the WUR non-AP STA may be in the doze state (see 11.2.1 (General)) during the negotiated service periods until the schedule is resumed as described below:

  — After the WUR non-AP STA receives a WUR Short Wake-up frame or a WUR Wake-up frame addressed to it from the WUR AP with an indication of individually addressed BU(s), the WUR


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non-AP STA shall be in the awake state (see 11.2.1 (General)) at the earliest service period, which has end time larger than the received time of the frame plus the transition delay indicated by the WUR non-AP STA in the WUR Capabilities element, following the PS operation (e.g., individual TWT) agreed between the WUR AP and the WUR non-AP STA.

— The parameters of the negotiated service period for the WUR non-AP STA's schedule between the WUR AP and the WUR non-AP STA are maintained by the WUR non-AP STA.

— The WUR non-AP STA shall follow the wake-up operation defined in 29.9 (Wake-up operation).

NOTE 2—The WUR duty cycle service period agreed between WUR AP and WUR non-AP STA can be that the WUR power state of the WUR non-AP STA is always in the WUR awake state.

NOTE 3—Examples of the negotiated service period between WUR AP and WUR non-AP STA for the WUR non-AP STA's schedule include individual TWT and schedule for WNM sleep mode.

NOTE 4—The WUR power state of a WUR non-AP STA is implementation specific if the WUR non-AP STA is in the awake state (see 11.2.1 (General)).

NOTE 5—The WUR non-AP STA might not wake up at the exact start time of the earliest service period.

If a WUR non-AP STA is in WUR mode suspend, then:

— The WUR power state of the WUR non-AP STA may be in the WUR doze state.

— The negotiated WUR parameters between the WUR AP and the WUR non-AP STA are maintained by the WUR non-AP STA.

NOTE 6—If a WUR non-AP STA is in WUR mode suspend, the negotiated service period between WUR AP and WUR non-AP STA for the WUR non-AP STA's schedule is active.

## 29.9 Wake-up operation

### 29.9.1 General

A WUR AP may send a WUR Wake-up frame or a WUR Short Wake-up frame (see 29.9.2 (WUR Short Wake-up frame operation)) to an associated WUR non-AP STA as described in 29.9 (Wake-up operation) and 29.8.3 (WUR power management operation for a WUR AP) to notify the WUR non-AP STA that the WUR AP intends to have operation with the WUR non-AP STA as described in 29.9.3 (WUR AP operation) and 29.9.4 (WUR non-AP STA operation).

A WUR AP shall not send a WUR Short Wake-up frame or a WUR Wake-up frame or a WUR Vendor Specific frame with HDR to associated WUR non-AP STA(s) that does not support HDR as indicated by the 20 MHz WUR PPDU with HDR Support subfield in the WUR Capabilities element sent by the WUR non-AP STA(s).

If a WUR AP and an associated WUR non-AP STA support traffic filtering service (TFS) as specified in 11.22.12, then the WUR AP and the WUR non-AP STA may use the traffic filter established according to the traffic filtering agreement between the WUR AP and the associated WUR non-AP STA sets to control the WUR Short Wake-up frame or the WUR Wake-up frame transmission as described in 29.9.3 (WUR AP operation).

A WUR AP may transmit a WUR Wake-up frame to an associated WUR non-AP STA to indicate that individually addressed BU(s) are available for the non-AP STA. The WUR Wake-up frame shall satisfy any of the conditions below:

— The ID field of the WUR Wake-up frame contains a WUR ID that identifies the WUR non-AP STA.

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- If the WUR Wake-up frame is FL WUR Wake-up frame, the ID field of the WUR Wake-up frame contains a WUR group ID that identifies a group of WUR non-AP STAs that include the WUR non-AP STA.
- If the WUR Wake-up frame is VL WUR Wake-up frame, the ID field of the WUR Wake-up frame contains a WUR group ID that identifies a group of WUR non-AP STAs that include the WUR non-AP STAs, and one of the identifiers in the Frame Body field identifies the WUR non-AP STA (see 9.9.3.2 (WUR Wake-up frame format)).

A WUR AP may transmit a WUR Short Wake-up frame to an associated WUR non-AP STA to indicate that individually addressed BU(s) are available for the non-AP STA.

A WUR AP may transmit a broadcast WUR Wake-up frame (see 29.5.3 (Transmitter ID) and 29.5.6 (Nontransmitter ID)) with the Group Addressed BU subfield of the Miscellaneous subfield equal to 1 to indicate that group addressed BU(s) of the WUR AP (see 11.2.3.4 (TIM types)) are available for all the associated WUR non-AP STA(s).

A WUR AP may transmit a broadcast WUR Wake-up frame (see 29.5.3 (Transmitter ID) and 29.5.6 (Nontransmitter ID)) to associated WUR non-AP STA(s) to indicate that a critical update to the BSS parameters of the WUR AP has occurred for the associated WUR non-AP STA (see 29.9.3 (WUR AP operation)). The critical update is indicated in the Counter subfield of the Type Dependent Control field.

### 29.9.2 WUR Short Wake-up frame operation

When a WUR non-AP STA and its WUR AP both set WUR Short Wake-up Frame Support subfield to 1 in their WUR Capabilities Information field (indicating support WUR Short Wake-up frames):

- The WUR AP may transmit WUR Short Wake-up frames instead of WUR Wake-up frames to the WUR non-AP STA. WUR Wake-up frames and WUR Short Wake-up frames may be used interchangeably in this case according to the rules outlined in this subclause.
- The WUR non-AP STA shall act on received WUR Short Wake-up frames with a matching WUR ID and FCS in the same way it acts on received WUR Wake-up frames with a matching WUR ID and FCS according to the rules outlined in this subclause.

Otherwise, a WUR AP shall not transmit WUR Short Wake-up frames to a WUR non-AP STA and the WUR non-AP STA shall (#3683)discard received WUR Short Wake-up frames with a matching WUR ID and FCS.

When a WUR AP transmits WUR Short Wake-up frames to a WUR non-AP STA and the WUR AP has a secure association with the non-AP STA, the following rules apply:

- The WUR AP shall select the WUR non-AP STA's WUR ID randomly.
- The WUR AP shall configure a new random WUR ID at the WUR non-AP STA when the WUR AP receives one or more frames from the WUR non-AP STA, but not a WUR Wake-up Indication frame with a WUR Wake-up Indication field indicating UNSOLICITED_WAKEUP.
  - When the WUR AP receives one or more frames from the WUR non-AP STA, but not a WUR Wake-up Indication frame with a WUR Wake-up Indication field indicating UNSOLICITED_WAKEUP from the WUR non-AP STA and the WUR AP did not transmit a prior WUR Short Wake-up frame to the WUR non-AP STA, the WUR AP should invoke a timeout before configuring a new WUR ID at the WUR non-AP STA. During this time, the WUR AP uses WUR Wake-up frames to wake up the WUR non-AP STA, using the current WUR ID. The WUR AP should double this interval upon each consecutive unsolicited wake-up event in which no WUR Wake-up Indication frame with a WUR Wake-up Indication field indicating UNSOLICITED_WAKEUP is received.


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- The WUR AP should not retransmit a WUR Short Wake-up frame. The WUR AP may retransmit a WUR Wake-up frame instead.
- The WUR non-AP STA shall (#3683)discard received WUR Short Wake-up frames with a matching WUR ID and FCS after the WUR non-AP STA received a WUR Short Wake-up frame with a matching WUR ID and FCS, until a new WUR ID has been configured at the WUR non-AP STA by the WUR AP.
- The WUR non-AP STA may transmit a WUR Wake-up Indication frame with a WUR Wake-up Indication field indicating UNSOLICITED_WAKEUP as the first frame when it wakes up without receiving a prior WUR Short Wake-up frame or WUR Wake-up frame so that the WUR AP does not configure a new WUR ID at the WUR non-AP STA.

NOTE 1—On a secure link with dot11RSNAProtectedManagementFramesActivated equal to false, the new WUR ID might still be overheard. Therefore, for full protection, dot11RSNAProtectedManagementFramesActivated needs to be true.

NOTE 2—On a secure link, the WUR ID is changed by the WUR AP after each use in a WUR Short Wake-up frame or after an unsolicited wake-up not indicating UNSOLICITED_WAKEUP. In case of an unsolicited wake-up not indicating UNSOLICITED_WAKEUP, the WUR AP invokes an increasing timeout before configuring a new WUR ID, to avoid that repeated false positive WUR Short Wake-up frames cause the battery at the WUR non-AP STA to drain (like in the event that an adversary repeatedly plays out all WUR IDs). After an unsolicited wake-up not indicating UNSOLICITED_WAKEUP, the WUR non-AP STA might not respond to WUR Short Wake-up frames, and the WUR AP uses regular secure WUR Wake-up frames to wake up the WUR non-AP STA, using the current WUR ID, until the timeout expired and a new WUR ID has been configured.

### 29.9.3 WUR AP operation

A WUR AP that transmits a WUR Short Wake-up frame or a WUR Wake-up frame to a WUR non-AP STA that indicates the availability of individually addressed BU(s) shall follow the PS operation defined in 11.2 (Power management) and 26.8 (TWT operation) that the WUR AP and the WUR non-AP STA has agreed to use (e.g., active mode and PS mode change, U-APSD, TWT, etc.), to deliver individually addressed BU(s) to the WUR non-AP STA and follow the timing information (e.g., the next service period) that is provided along with the agreed PS operation.

NOTE 1—As described in 29.3 (Channel access), a WUR AP can transmit multiple WUR Wake-up frames in a TXOP (see 10.23.2.8 (Multiple frame exchange sequences in an EDCA TXOP(#109))).

If the WUR AP schedules a transmission that is not a WUR PPDU to the WUR non-AP STA, the WUR AP shall verify that either of the conditions below is met:

- The transition delay indicated by the WUR non-AP STA in the WUR Capabilities elements following the most recent transmitted WUR Short Wake-up frame or WUR Wake-up frame intended to the WUR non-AP STA has expired.
- The WUR non-AP STA has indicated that it is in the awake state (see 11.2.1 (General)) by transmitting a frame to the WUR AP.

NOTE 2—The frames scheduled by the WUR AP to be delivered are not limited to individually addressed BU(s).

NOTE 3—The WUR non-AP STA indicates that it is in the awake state by transmitting a frame to the WUR AP and following the PS operation after receiving a WUR Wake-up frame addressed to it with an indication of individually addressed BU(s) (see 29.9.4 (WUR non-AP STA operation)).

A WUR AP that generates a VL WUR Wake-up frame with two or more STA Info fields shall order the STA Info fields in the Frame Body field so that the WUR IDs appear in increasing order. The WUR AP shall not include the WUR ID of a WUR non-AP STA that does not support reception of VL WUR frames. (see 9.4.2.290 (WUR Capabilities element(11ba))).

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NOTE 4—Inclusion of the STA Info fields in a VL WUR Wake-up frame in increasing order allows a WUR STA to stop processing the WUR frame once the STA locates a User Info field that contains the WUR ID of the STA or a WUR ID that is greater than the WUR ID of the STA.

A WUR AP that transmits a broadcast WUR Wake-up frame to a WUR non-AP STA that indicates the availability of group addressed BU(s) shall follow the PS operation that the WUR AP and the WUR non-AP STA has agreed to use (e.g., DTIM, FMS, etc.), to deliver group addressed BU(s) to the WUR non-AP STA and follow the timing information (e.g., the next DTIM TBTT) that is provided along with the agreed PS operation.

If the WUR AP schedules a transmission of group addressed BU(s) to the WUR non-AP STA(s), the WUR AP shall verify that the following condition is met:

— The maximum transition delay following the most recently transmitted WUR Wake-up frame indicating buffered group addressed BU(s) has expired. The maximum transition delay is defined as the maximum value of the transition delay values in the WUR Capabilities elements indicated by all the WUR non-AP STAs that are not in the awake state (see 11.2.1 (General)), have negotiated WUR power management service with the WUR AP, and are in WUR mode.

A WUR AP that sends a WUR Wake-up frame to the WUR non-AP STA(s) may send a frame (for example, a Trigger frame) to solicit response frames from one or more WUR non-AP STAs that support the reception of the frame.

If a traffic filtering agreement is established for a WUR non-AP STA in WUR mode, the WUR non-AP STA is in doze state (see 11.2.1 (General)), and Bit 1 of the TFS Action Code field is equal to 1, then the WUR AP should transmit a WUR Wake-up frame to the WUR non-AP STA if the WUR AP receives an individually addressed BU destined to the WUR non-AP STA that matches the traffic filter set.

If a traffic filtering agreement is established for a WUR non-AP STA in WUR mode, the WUR non-AP STA is in doze state (see 11.2.1 (General)), and Bit 1 of the TFS Action Code field is equal to 0, then the WUR AP should not transmit a WUR Wake-up frame to the WUR non-AP STA if the WUR AP receives an individually addressed BU destined to the WUR non-AP STA that matches the traffic filter set.

A WUR AP shall maintain (#3116)a BSS parameter update counter. The WUR AP shall increase (#3116)the BSS parameter update counter if a critical update occurs to any of the elements inside the Beacon frame. The following events shall be classified as a critical update:

— Inclusion of a Channel Switch announce element
— Inclusion of an Extended Channel Switch announce element
— Inclusion of a Wide Bandwidth Channel Switch element
— Inclusion of an Operating Mode Notification element
— Modification of the EDCA parameters
— Modification of the HT Operation element
— Modification of the VHT Operation element
— Modification of the HE Operation element
— Modification of the DSSS Parameter Set
— Inclusion of a Channel Switch Wrapper element

NOTE 5—The list of elements for critical update advertised by a broadcast WUR Wake-up frame aligns with the list of elements for critical update advertised in Check Beacon field in the TIM frame(s) (see 11.2.3.14 (TIM Broadcast)).

The WUR AP shall include the current value of (#3116)the BSS parameter update counter in the WUR Parameter field in the WUR Operation element. The WUR AP shall include a WUR Operation element in


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the WUR Mode Setup frames if (#3116)the Counter subfield in the WUR Operation element has been recently updated.

The WUR AP shall include the current value of the (#3116)BSS parameter update counter in the Counter subfield of the Type Dependent Control field in all transmitted broadcast WUR Wake-up frames.

A WUR AP may classify other changes in the Beacon frame as critical updates, which may include modification of the RSNE (see 9.4.2.23 (RSNE)) or those that are described in 11.2.3.5 (Power management with APSD).

After a WUR AP sends a WUR Short Wake-up frame or a WUR Wake-up frame with the ID field equal to a WUR ID that identifies a WUR non-AP STA, the WUR AP waits for a timeout interval that is larger than the transition delay indicated by the WUR non-AP STA in the WUR Capabilities elements:

— If the WUR AP receives any transmission from the WUR non-AP STA within the timeout interval, then the WUR Short Wake-up frame or the WUR Wake-up frame transmission is successful.

— Otherwise, the WUR Short Wake-up frame or the WUR Wake-up frame transmission fails, and the WUR AP may retransmit the WUR Wake-up frame to the WUR non-AP STA.

The methods by which a WUR AP determines the exact value of the timeout interval and determines the number of retries after the transmission of individually addressed WUR Wake-up frame fails are implementation specific and out of scope of this standard.

NOTE 6—The WUR AP might take into account the wake up timing information (e.g., the next service period) that is provided along with the agreed PS operation to determine the value of the timeout interval.

NOTE 7—A WUR AP might disassociate a WUR non-AP STA by following the operation based on BSS max idle period (see 11.21.13 (BSS max idle period management).

### 29.9.4 WUR non-AP STA operation

A WUR non-AP STA that receives a WUR Short Wake-up frame or a WUR Wake-up frame addressed to it with an indication of individually addressed BU(s) (see 29.9.1 (General)) shall follow the PS operation defined in 11.2 (Power management) and 26.8 (TWT operation) that the associated WUR AP and the WUR non-AP STA has agreed to use (e.g., power management mode change, U-APSD, TWT, etc.), to retrieve individually addressed BU(s) and follow the wake up timing information (e.g., the next service period) that is provided along with the agreed PS operation. In this case, the WUR non-AP STA may be in the doze state (see 11.2.1 (General)) until the time indicated by the wake up timing information (e.g., the next service period) that is provided along with the agreed PS operation.

NOTE 1—For example, rule b), c), and d) in 11.2.3.7 (Receive operation for STAs in PS mode) describes one operation for a WUR non-AP STA to retrieve individually addressed BU(s) using PS-Poll or U-APSD.

NOTE 2—To use both PS-Poll and U-APSD, the WUR non-AP STA can set all ACs as delivery-enabled as defined in 11.2.3.7 (Receive operation for STAs in PS mode).

NOTE 3—The WUR non-AP STA might follow the procedures in 11.2.3.2 (Non-AP STA power management modes) to change the power management mode to active mode.

A WUR non-AP STA that receives a WUR Wake-up frame with an indication of buffered group addressed BU(s) (see 29.9.1 (General)) shall follow the PS operation that the associated WUR AP and the WUR non-AP STA has agreed to use (e.g., DTIM, FMS, etc.) to receive group addressed BU(s) and follow the wake up timing information (e.g., the next DTIM TBTT) that is provided along with the agreed PS operation. In this case, the WUR non-AP STA may be in the doze state (see 11.2.1 (General)) until the time indicated by the wake up timing information (e.g., the next DTIM TBTT) that is provided along with the agreed PS operation.

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NOTE 4—For example, rule e) in 11.2.3.7 (Receive operation for STAs in PS mode) describes one operation for a WUR non-AP STA to receive group addressed frame.

A WUR non-AP STA shall maintain (#3116)a BSS parameter update counter. The WUR non-AP STA shall update (#3116)its BSS parameter update counter to the Counter subfield contained in the latest WUR Operation element received from the WUR AP with which it is associated. A WUR non-AP STA that receives the Counter subfield of the Type Dependent Control field in a broadcast WUR Wake-up frame that contains a value that is different from (#3116)its BSS parameter update counter shall follow the procedure defined in 11.2.3.14 (TIM Broadcast) to attempt to receive the Beacon information. In this case, the WUR non-AP STA may be in the doze state) until the time indicated by the next TBTT.

## 29.10 WUR frame protection

### 29.10.1 General

WUR frame protection cannot be applied until the PTKSA (see 12.6.1.1.6 (PTKSA)) and WIGTKSA (12.6.1.1.12 (WIGTKSA(11ba))) have been established.

WUR frame protection is enabled when dot11RSNAWURFrameProtectionActivated is true, and is disabled otherwise. When WUR frame protection is enabled at a WUR AP, the WUR AP shall advertise such capability by setting to 1 the Protected WUR Frame Support subfield of the RSNXE in its Beacon and Probe Response frames. When WUR frame protection is enabled at a WUR non-AP STA, the WUR non-AP STA shall indicate such capability by setting to 1 the Protected WUR Frame Support subfield of the RSNXE in its (Re)Association Request frames.

WUR frame protection is negotiated between a WUR AP and a WUR non-AP STA if the following conditions are met:

- Management frame protection is negotiated
- Both parties set the Protected WUR Frame Support subfield to 1 in their respective RSNXEs in the (re)association procedure
- It is successfully verified that the WUR Frame Protection Support subfield is equal to 1 in the Extended RSN Capabilities field in the RSNXE received during the 4-way handshake, FT 4-way handshake, FT fast BSS transition protocol, or (re)association procedure of FILS authentication.

Otherwise, WUR frame protection is not negotiated.

WUR Short Wake-up frames are not protected.

If WUR frame protection is negotiated between a WUR AP and a WUR non-AP STA, the WUR AP shall protect all individually addressed WUR Wake-up frames that are transmitted to the WUR non-AP STA; otherwise the WUR AP shall not transmit a protected individually addressed WUR Wake-up frame to the WUR non-AP STA.

If a WUR non-AP STA negotiated WUR frame protection for an association, it shall discard any unprotected WUR Wake-up frames received from the WUR AP associated. If the WUR non-AP STA did not negotiate WUR frame protection for an association, it shall discard any protected WUR Wake-up frames received from the WUR AP.

The WUR AP may transmit a protected WUR Wake-up frame addressed to more than one WUR non-AP STAs if WUR frame protection is negotiated with, and the WIGTK has been transported to, any WUR non-AP STAs that are being addressed. The WUR AP may transmit an unprotected WUR Wake-up frame addressed to more than one WUR non-AP STAs if WUR frame protection is not negotiated with or the WIGTK has not been transported to, any WUR non-AP STAs that are being addressed. The WUR AP shall


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not transmit a protected broadcast or group addressed WUR Wake-up frame to a WUR non-AP STA if all the WUR non-AP STAs that are being addressed have not negotiated WUR frame protection with the WUR AP.

NOTE—If the WUR non-AP STAs associated with a WUR AP consist of both WUR non-AP STAs that negotiated WUR frame protection and WUR non-AP STAs that did not negotiated WUR frame protection, the WUR AP can transmit a protected broadcast WUR Wake-up frame and an unprotected broadcast WUR Wake-up frame, in order to wake up all associated WUR non-AP STAs. If a WUR AP assigns a group ID to both WUR non-AP STAs that negotiated WUR frame protection and WUR non-AP STAs that did not negotiated WUR frame protection, the WUR AP can transmit a protected group addressed WUR Wake-up frame and an unprotected group addressed WUR Wake-up frame, both containing that group ID, in order to wake up that group of WUR non-AP STAs.

The WUR AP shall not transmit a protected individually addressed WUR Wake-up frame to the WUR non-AP STA until the WTK is installed at the WUR non-AP STA, and should not transmit a protected broadcast or group addressed WUR Wake-up frame until the WIGTK is installed at all WUR non-AP STAs with which the WUR AP has negotiated WUR frame protection.

A WUR AP that installs the WTK for a WUR non-AP STA (see 12.7.6 (4-way handshake)) shall use the WTK to protect all subsequent individually addressed WUR Wake-up frames transmitted to the WUR non-AP STA. A WUR AP that installs the WIGTK (see 12.7.6 (4-way handshake) or 12.7.7 (Group key handshake)) shall use the WIGTK to protect all subsequent protected broadcast or group addressed WUR Wake-up frames.

A WUR non-AP STA that installs WTK (see 12.7.6 (4-way handshake)) shall use the WTK to process all subsequently received protected individually addressed WUR Wake-up frames. The WUR non-AP STA shall discard any protected WUR frames received before the WTK is installed. A WUR non-AP STA shall identify the appropriate WIGTK and associated state based on the Key ID subfield of the received protected broadcast or group addressed FL WUR Wake-up frames. If no such WIGTK exists, the WUR non-AP STA shall silently (#3683)discard the frame and terminate BIP processing for this reception. A WUR non-AP STA shall use the latest installed WIGTK to process all subsequently received protected group addressed VL WUR Wake-up frame.

A WUR AP shall set the Protected subfield of the Frame Control field of transmitted WUR Wake-up frames to 1 if the WUR frame is protected; otherwise the WUR AP shall set the Protected subfield of the Frame Control field of the WUR frame to 0.

A WUR STA with dot11RSNAWURFrameProtectionActivated equal to true shall set dot11RSNAProtectedManagementFramesActivated to true.

A WUR AP that transmits a protected WUR Wake-up frame shall protect the WUR Wake-up frame using the BIP protocol as defined in 12.5.3 (Broadcast/multicast integrity protocol (BIP)) except that:

- The WUR AP shall use BIP-CMAC-128 to provide data integrity and replay protection and shall use an integrity key to compute the MIC of the WUR Wake-up frame, which is defined below:
  - Broadcast and group addressed WUR Wake-up frames shall be protected using a WIGTK that is negotiated as defined in 12.7.7 (Group key handshake) Individually addressed WUR Wake-up frames shall be protected using a WTK that is negotiated as defined in 12.7.6 (4-way handshake).
- The CMAC output for BIP-CMAC-128 shall be truncated to 16 bits: MIC = Truncate-16 (CMAC Output). The MIC shall be included in the FCS field of the protected WUR Wake-up frame.
- The AAD shall have a length of 40 bits consisting of the following:
- the Frame Control, and the ID field, which are obtained from the WUR Wake-up frame,
- the Counter field, which is obtained from the Type Dependent Control field of the WUR Wake-up frame if it is broadcast; otherwise it is reserved, and

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— the Embedded BSSID field, which is equal to the 16 MSBs of the compressed BSSID (see 29.5.2 (Compressed BSSID).

The AAD is as shown in Figure 29-3 (AAD construction for WUR frames(11ba)).

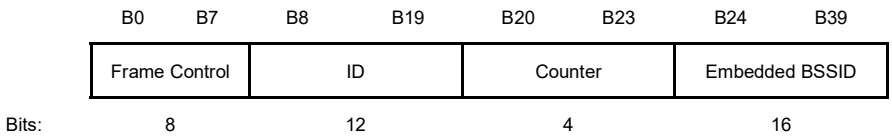


**Figure 29-3—AAD construction for WUR frames(11ba)**

### 29.10.2 Protected WUR frame transmission

A WUR AP that sends a protected WUR frame shall follow the rules in 12.5.3.5 (BIP transmission) except that the WUR AP shall:

— Select the appropriate integrity key associated to protected WUR frames (see 29.10 (WUR frame protection)), (#3493)key ID that is equal to the corresponding WIGTK or WTK (#3493)key ID, a WUR PN that is generated and partially included in the WUR frame as defined in 29.10.4.1 (Generation of the PN by a WUR AP). If the Miscellaneous subfield is present in the protected WUR Wake-up frame, the Key ID subfield is set to the value representing the corresponding WIGTK (see 9.9.3.2 (WUR Wake-up frame format)).

— Construct the AAD as defined in Figure 29-3 (AAD construction for WUR frames(11ba)).

— Compute an integrity value over the concatenation of AAD, the Frame Body field (if present), and the WUR PN, and insert the 16-bit truncated output, which is the MIC, into the FCS field of the WUR frame. The integrity value is computed using AES-128-CMAC.

— Transmit the protected WUR frame.

A WUR AP that sends a protected group addressed VL WUR Wake-up frame should include WUR ID(s) of the WUR non-AP STA(s) that have already been provided with the WIGTK used to protect the group addressed VL WUR Wake-up frame and should not include WUR ID(s) of the WUR non-AP STA(s) that have not been provided with the WIGTK used to protect the group addressed VL WUR Wake-up frame.

If the most recently transmitted WUR Operation element has the Common PN subfield equal to 1, in order not to reuse the same WIPN for protection of group addressed or broadcast WUR frames with the same WIGTK, a WUR AP shall not transmit more than one protected group addressed or broadcast WUR frames that have different contents in a WUR FDMA PPDU.

NOTE—Since the reuse of a PN with the same temporal key voids the security guarantees, such cases need to be avoided. However, repeating the same protected (#1293)group addressed or broadcast WUR frames in a WUR FDMA PPDU does not void the security guarantees, and therefore, is allowed.

### 29.10.3 Protected WUR frame reception

A WUR non-AP STA with WUR frame protection negotiated that receives a protected WUR Wake-up frame shall follow the rules in 12.5.3.6 (BIP reception) except that the WUR non-AP STA shall:

— Use the appropriate integrity key associated to protected WUR Wake-up frames (see 29.10 (WUR frame protection)), and associated state based on (#3493)key ID equal to the corresponding WIGTK or WTK (#3493)key ID.

— Perform replay protection on the received WUR Wake-up frame as defined in 12.5.3.4 (BIP replay counters and packet numbers(#3573)) except that the WUR non-AP STA shall construct the PN locally as defined in 29.10.4.2 (Construction of the PN by a WUR non-AP STA), and the WUR non-


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AP STA shall maintain a separate replay counters (RC) for each WIGTK and WTK when the most recently received WUR Operation element has the Common PN subfield equal to 0. The WUR non-AP STA shall initialize the replay counter to the initial value of the corresponding PN prior to any update due to WUR Wake-up frames. The WUR non-AP STA shall also initialize the replay counter to the initial value of the corresponding PN when it resets the WIGTK or WTK. If PN is less than or equal to corresponding *RC* then the WUR non-AP STA shall discard the WUR Wake-up frame, increment its internal dot11RSNAStatsCMACWURReplays counter by 1, and terminate BIP processing for this reception.

— Construct the AAD as defined in Figure 29-3 (AAD construction for WUR frames(11ba)).

— Extract and save the received MIC value from the FCS field of the WUR Wake-up frame and compute a verifier over the concatenation of AAD, Frame Body field (if present), and the locally constructed PN. If the result does not match the received MIC value, then the receiver shall discard the frame, increment its internal MIC error counter by 1, and terminate BIP processing for this reception.

— Update the *RC* for the integrity key associated to protected WUR Wake-up frames identified by (#3493)key ID equal to the corresponding WIGTK or WTK (#3493)key ID with the corresponding PN.

— If the Common PN subfield is equal to 1, update the local TSF timer as follows:

  — The received partial TSF timestamp, obtained from the Sequence Number subfield of the Type Dependent Control field of the WUR Wake-up frame, is adjusted to consider the WUR non-AP STA's delay as shown below:

    — Create a temporary timestamp by concatenating the received partial TSF timestamp with 9 bits containing an implementation specific value that represents the assumed value of bit position 0 to 8 of temporary timestamp;

    — Add an amount equal to the receiving WUR non-AP STA's delay through its local PHY components plus the time since the first bit of the Partial TSF field was received at the MAC/PHY interface to the temporary timestamp

    — The adjusted value of the received partial TSF timestamp is set as the value of bit position 9 to 16 of the temporary timestamp.

  — If the most significant bit (MSB) of the adjusted value of the received partial TSF timestamp is not equal to the bit 16 of the local TSF timer then the value of bits 17 to 63 of the local TSF timer shall be adjusted to account for roll over as follows:

    — The value shall be increased by one unit (modulo $2^{47}$) if LT [9:16] > AT and LT [9:16] > ((AT + $2^7$) (modulo $2^8$))

    — The value shall be decreased by one unit (modulo $2^{47}$) if LT [9:16] < AT and LT [9:16] < ((AT–$2^7$) (modulo $2^8$))

      where AT is the adjusted value of the received partial TSF timestamp and LT [9:16] is the value of bits 9 to 16 of the local TSF timer

  — The bits 9 to 16 of the WUR non-AP STA's local TSF timer shall be set to the adjusted value of the received partial TSF timestamp.

— If the Common PN subfield is equal to 0, update the local WIPN or WTPN to the locally constructed PN used to receive the WUR frame (see 29.10.4.2 (Construction of the PN by a WUR non-AP STA))

NOTE 1—Before the adjusted value of the received partial TSF timestamp is set as the value of bit position 9 to 16 of the temporary timestamp, the temporary timestamp might be further compensated for a clock drift offset between the WUR AP and the WUR non-AP STA, which is determined by multiplying the estimated clock drift by the time between receiving the latest TSF from the WUR AP and the time at which the WUR frame is received from the WUR AP, where the estimated clock draft is determined based on two or more received TSF values from the WUR AP and comparing these to the internal TSF at the WUR non-AP STA.

NOTE 2—When the most recently received WUR Operation element has the Common PN subfield equal to 1, a single common replay counter is maintained for both WIGTK and WTK.

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### 29.10.4 Generation and construction of PN for WUR frames

The PN for WIGTK is defined as WIPN and the PN for WTK is defined as WTPN. When the Common PN subfield in the WUR Operation element sent by the WUR AP is equal to 1 then WIPN and WTPN are derived in the same way and are equal.

#### 29.10.4.1 Generation of the PN by a WUR AP

A WUR AP that intends to transmit protected WUR frames shall set the Common PN subfield in the WUR Operation element it transmits to 0 if it intends to maintain separate PN counters for each WIGTK and WTK and shall set the Common PN subfield to 1 if it intends to maintain a common PN for all protected WUR frames generated within its BSS.

The WUR AP that intends to transmit a protected WUR frame shall construct the PN as follows:

- If the Common PN subfield is equal to 1:
  - PN = PN0||PN1||PN2||PN3||PN4||PN5 = TSF timer [9: 56], where the TSF timer is obtained as defined in 29.6.1 (General).
  - The PN shall never repeat for protected WUR frames generated using the same WIGTK or WTK
  - The WUR AP shall include PN0, i.e., the PPN, which is equal to its TSF timer [9: 16], in the Sequence Number subfield of the Type Dependent Control field of the WUR Wake-up frame
- If the Common PN subfield is equal to 0:
  - PN = PN0||PN1||PN2||PN3||PN4||PN5, where PN shall be incremented by one for each transmitted WUR frame using the same WIGTK or WTK.
  - The PN shall never repeat for protected WUR frames generated using the same WIGTK or WTK
  - If the WUR Wake-up frame is not broadcast,
    - PPN = PN0||PN1[0:3]. The WUR AP shall include PN0 (i.e., the 8 LSBs of the PPN) in the Sequence Number subfield of the Type Dependent Control field of the WUR Wake-up frame. The AP shall include PN1[0:3] (i.e., the 4 MSBs of the PPN) in the Counter subfield of the Type Dependent field of the WUR Wake-up frame.
  - If the WUR Wake-up frame is broadcast:
    - PPN = PN0. The WUR AP shall include PN0 (i.e., the PPN) in the Sequence Number subfield of the Type Dependent Control field of the WUR Wake-up frame.

If the most recently transmitted WUR Operation element has the Common PN subfield equal to 0, the local WTPN at the WUR AP is initialized to 0 and the local WIPN at the WUR AP is initialized to the WIPN provided in the WIGTK KDE (Figure 12-50 (WIGTK KDE format(#3493)(11ba))) when the corresponding integrity key (WTK or WIGTK) is set in the MAC (see 12.7.6 (4-way handshake) and 12.7.7 (Group key handshake)).

If the most recently transmitted WUR Operation element has the Common PN subfield equal to 1, the local WTPN and WIPN at the WUR AP, which are the same in this case, are initialized to the value of the local TSF timer [9: 56] when the corresponding integrity key (WTK or WIGTK) is set in the MAC (see 12.7.6 (4-way handshake) and 12.7.7 (Group key handshake)).

#### 29.10.4.2 Construction of the PN by a WUR non-AP STA

The full PN is not present in protected WUR frames, depending on the Common PN subfield of the most recently received WUR Operation element, and is constructed locally at the WUR non-AP STA as follows:

- If the Common PN subfield is equal to 1, the PN is obtained as follows:
  - PN0 is set as the Sequence Number subfield of the Type Dependent Control field of the WUR Wake-up frame
  - BPN is set as the value of bits 17 to 56 of the local TSF timer


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- If the most significant bit (MSB) of the PN0 is not equal to the bit 16 of the local TSF timer then the value BPN shall be adjusted to account for roll over as follows:
  - The value shall be increased by one unit (modulo $2^{40}$) if LT[9:16] > PN0 and LT[9:16] > ((PN0 + $2^7$) (modulo $2^8$))
  - The value shall be decreased by one unit (modulo $2^{40}$) if LT[9:16] < PN0 and LT[9:16] < ((PN0 – $2^7$) (modulo $2^8$)), where LT[9:16] is the value of bits 9 to 16 of the local TSF timer
- The PN=PN0||BPN where PN1||PN2||PN3||PN4||PN5 = BPN

- If the Common PN subfield is equal to 0, the PN is obtained as follows:
  - If the WUR Wake-up frame is not broadcast:
    - The PN is obtained as PPN||BPN, where PPN is equal to the Type Dependent Control field of the received WUR frame, and BPN is retrieved from the locally stored PN at the receiver for the corresponding WIGTK or WTK.
    - PN0||PN1[0:3] = PPN, and PN1[4:7]||PN2||PN3||PN4||PN5 = BPN.
  - If the WUR Wake-up frame is broadcast:
    - The PN is obtained as PPN||BPN, where the PPN is equal to the Sequence Number subfield of the Type Dependent Control field of the received WUR frame, and BPN is retrieved from the locally stored PN at the receiver for the corresponding WIGTK or WTK.
    - PN0 = PPN, and PN1||PN2||PN3||PN4||PN5 = BPN.
  - The portion of the computed PN corresponding to the BPN shall be incremented by 1 to account for roll over when the PPN in the received WUR frame is less than the portion of the locally stored PN corresponding to the PPN.

If the most recently received WUR Operation element has the Common PN subfield equal to 0, the locally stored WTPN at the WUR non-AP STA is initialized to 0 and the local WIPN at the WUR non-AP STA is initialized to the WIPN provided in the WIGTK KDE (Figure 12-47a) when the corresponding integrity key (WTK or WIGTK) is set in the MAC (see 12.7.6 (4-way handshake) and 12.7.7 (Group key handshake)).

If the most recently received WUR Operation element has the Common PN subfield equal to 1, the locally stored WTPN and WIPN, which are the same in this case, at the WUR non-AP STA is initialized to the value of the local TSF timer [9: 56] when the corresponding integrity key (WTK or WIGTK) is set in the MAC (see 12.7.6 (4-way handshake) and 12.7.7 (Group key handshake)).

If the most recently received WUR Operation element has the Common PN subfield equal to 0, the WTPN or WIPN may be updated explicitly through (#4173)a secure WUR mode setup request/response frame exchange as described in 29.10.4.3 (WUR PN update procedure).

### 29.10.4.3 WUR PN update procedure

The WUR PN update procedure(M118) enables a WUR AP and a WUR non-AP with WUR frame protection negotiated with the WUR AP to update the locally stored PN at the WUR non-AP STA.

If the most recently transmitted WUR Operation element has the Common PN subfield equal to 0, a WUR AP may indicate the PN maintained by the WUR AP to a WUR non-AP by including one or more WUR PN Update elements in the WUR Mode Setup frame with the Action Type in WUR Mode element equal to "Enter WUR Mode Response."

If the most recently received WUR Operation element has the Common PN subfield equal to 0, a WUR non-AP STA that receives a WUR Mode Setup frame that includes a WUR PN Update element shall update the locally stored PN value corresponding to the (#3493)key ID indicated in the Key Info field to the received PN value.

A WUR non-AP STA may request a PN update by sending a WUR Mode Setup frame with Action Type field of the carrying WUR Mode element equal to "Enter WUR Mode Request" and includes a WUR PN

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Update element that indicates a (#3493)key ID corresponding to a integrity key currently used by the WUR non-AP STA and optionally includes the corresponding locally stored PN.

If the most recently transmitted WUR Operation element has the Common PN subfield equal to 0, a WUR AP that receives a WUR Mode Setup frame with Action Type field of the carrying WUR Mode element equal to "Enter WUR Mode Request" and that includes a WUR PN Update element shall respond with a WUR Mode Setup frame with Action Type field of the carrying WUR Mode element equal to "Enter WUR Mode Response" and includes a WUR PN Update element indicating the PN maintained by the WUR AP corresponding to the requested (#3493)key ID if any of the following conditions apply:

— The WUR non-AP STA has negotiated WUR power management service with the WUR AP
— The WUR non-AP STA has not negotiated WUR power management service with the WUR AP and the WUR AP accepts the negotiation

All optional subfields of the WUR Parameters field in the WUR Mode element may be omitted.

## 29.11 WUR FDMA operation

When dot11WURFDMAChannelSwitchImplemented is true, a WUR non-AP STA shall set the WUR FDMA Support subfield of the WUR Capabilities Information field of the WUR Capabilities element that it transmits to a WUR AP to 1. Otherwise, it shall set the WUR FDMA Support subfield to 0.

If a WUR AP receives from a WUR non-AP STA a WUR Capabilities element of which the WUR FDMA Support subfield of the WUR Capabilities Information field is equal to 0, the WUR AP shall set the WUR Channel Offset subfield of the WUR Parameters field of the WUR Mode element that it transmits to the WUR non-AP STA to 0.

If a WUR AP receives from a WUR non-AP STA a WUR Capabilities element of which the WUR FDMA Channel Switching subfield of the WUR Capabilities Information field is equal to 1, the WUR AP may set the WUR Channel Offset subfield of the WUR Parameters field of the WUR Mode element that it transmits to a nonzero value as defined in Table 9-409 (Subfields of WUR Parameters field from WUR AP(11ba)), subject to the following constraints:

— The negotiated WUR duty cycle service period does not overlap with the target WUR beacon transmission times at which the WUR AP schedules transmission of WUR Beacon frames, except for the case when the value indicated in the WUR Duty Cycle Service Period subfield of the WUR Parameters field in the WUR Mode element received from the WUR non-AP STA is equal to the value indicated in the Duty Cycle Period subfield
— The WUR AP shall not transmit in the WUR secondary channel and WUR secondary 40 MHz channel any WUR frame addressed to the WUR non-AP STA for aPPDUMaxTime defined in Table 30-13 (WUR PPDU Time and Length Characteristics(11ba)) from the target WUR beacon transmission times.

If dot11WURFDMAChannelSwitchImplemented of a WUR non-AP STA is equal to false, the WUR channel of the WUR non-AP STA shall be same as the channel on which the WUR Beacon frames are transmitted.

The WUR channel of a WUR non-AP STA with dot11WURFDMAChannelSwitchImplemented equal to true is defined by the WUR Channel Offset subfield of the WUR Parameters field of the WUR Mode element that it receives from its associated WUR AP.

NOTE—A WUR non-AP STA might indicate its recommendation in the WUR Mode element on which WUR channel to assign for the WUR non-AP STA (see 29.8.2 (WUR mode setup)).


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### 29.11.1 WUR FDMA channel access

A WUR AP may send multiple WUR Wake-up frames in a WUR FDMA PPDU.

If a WUR AP intends to transmit a WUR FDMA PPDU (as defined in 10.23.2.4 (Obtaining an EDCA TXOP) and 29.3 (Channel access)), the WUR AP shall perform exactly one of the following actions:

a) Transmit a 40 MHz WUR FDMA PPDU in the WUR primary 40 MHz channel if the following conditions are met:
   1) The WUR secondary channel was idle during an interval of PIFS immediately preceding the start of the TXOP.
   2) The WUR AP schedules at least one WUR frame transmission on each of 20 MHz subchannels of the WUR primary 40 MHz channel.

b) Transmit an 80 MHz WUR FDMA PPDU on the WUR 80 MHz channel if the following conditions are met:
   1) Both the WUR secondary channel and the WUR secondary 40 MHz channel were idle during an interval of PIFS immediately preceding the start of the TXOP.
   2) The WUR AP schedules at least one WUR frame transmission on each of 20 MHz subchannels of the WUR 80 MHz channel.

c) Transmit an 80 MHz subchannel punctured WUR FDMA PPDU on the WUR 80 MHz channel if the following conditions are met:
   1) At least one of the 20 MHz subchannels of the WUR secondary channel and the WUR secondary 40 MHz channel were idle during an interval of PIFS immediately preceding the start of the TXOP.
   2) The WUR AP schedules at least one WUR frame transmission on each of 20 MHz subchannels of the WUR 80 MHz channel, except when the subchannel was not idle or the WUR AP does not have a pending WUR frame intended for WUR non-AP STAs listening on that subchannel.

In any of the above actions, if the WUR AP does not have a pending WUR frame intended for WUR non-AP STAs on the WUR primary channel, then the WUR AP shall transmit a WUR frame on the WUR primary channel, which may be any WUR frame that does not cause a WUR non-AP STA to transition to awake state(#6038) on the primary channel.

## 29.12 WUR discovery

A WUR AP with dot11WURDiscoveryImplemented equal to true shall periodically schedule WUR Discovery frames on the WUR AP's WUR discovery channel for transmission to assist WUR non-AP STAs in WUR AP discovery. The WUR AP may transmit a WUR Discovery element in Beacon and Probe Response frames to indicate the WUR discovery channel used by the WUR AP to transmit WUR Discovery frames. The WUR AP may include a WUR Discovery element in a Probe Response frame that is transmitted in response to a Probe Request frame that contains a WUR Capability element. The WUR AP's WUR discovery channel may be indicated in the transmitted WUR Discovery elements by the WUR Discovery Operating Class and WUR Discovery Channel fields in the WUR AP Information subfield in which the Transmitting WUR AP subfield is equal to 1. WUR Discovery frames shall be scheduled for transmission by the WUR AP with a periodicity as indicated in the WUR Discovery Period field in the WUR AP Parameters subfield of the WUR Discovery element in which the Transmitting WUR AP subfield is equal to 1.

NOTE 1—Though the transmission of a WUR Discovery frame might be delayed because of CSMA deferrals, subsequent WUR Discovery frames are scheduled at the undelayed nominal WUR Discover Period value indicated in the WUR AP Parameters subfield.

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The WUR discovery channel(s) that are used to transmit the WUR Discovery frames should be selected from channel 1 in the 2.4 GHz frequency band and channel 40, 44, 149 and 153 in the 5 GHz frequency band as specified in Table E-4 in Annex E.

NOTE 2—The purpose of the above recommendation is to encourage adoption of a common set of WUR discovery channels that are available in most of the regulatory domains to reduce WUR scanning latency.

A WUR AP with dot11WURNeighborDiscoveryImplemented equal to true may transmit a WUR Discovery element in Beacon and Probe Response frames to advertise the WUR discovery channel(s) used by neighboring WUR APs. The WUR AP may include a WUR Discovery element in a Probe Response frame that is transmitted in response to a Probe Request frame that contains a WUR Capability element. A WUR AP may use the WUR Discovery elements transmitted by neighboring WUR APs to compile the WUR discovery channel(s) used by the neighboring WUR APs. A WUR AP should include a single WUR AP Information subfield for a WUR discovery channel in a WUR Discovery element.

A WUR non-AP STA with dot11WURDiscoveryImplemented equal to true may perform WUR scanning to discover WUR APs. Upon receipt of the MLME-WURDISCOVERY.request primitive, the WUR non-AP STA performs WUR scanning according to the parameters given in the primitive. The WURDiscoveryChannelList parameter indicates the WUR discovery channel(s) to be scanned. The WUR non-AP STA shall scan a WUR discovery channel for a period of time no less than MinChannelTime. The MaxChannelTime parameter indicates the maximum time (in TU) to spend on each WUR discovery channel within the WURDiscoverChannelList parameter when scanning for WUR Discovery frames. The Transmitter ID parameter, if present in the primitive, indicates the Transmitter ID of the WUR AP to be discovered. The CompressedBSSID_MSB parameter, if present in the primitive, indicates the 12 MSBs of the compressed BSSID of the WUR AP to be discovered. The Compressed SSID parameter, if present in the primitive, indicates the 16 LSBs of the (#7151)short SSID of the WUR AP to be discovered, as defined in 9.4.2.169.3 (Calculating the short SSID). When none of the Transmitter ID, CompressedBSSID_MSB, and Compressed SSID parameters are present in the MLME-WURDISCOVERY.request primitive, the WUR non-AP STA scans for WUR Discovery frames from any WUR APs. After scanning one WUR discovery channel, the WUR non-AP STA initiates scanning in another WUR discovery channel if at least one WUR discovery channel within the WURDiscoveryChannelList parameter has not yet been scanned. When the WUR non-AP STA has completed scanning all indicated WUR discovery channels, it returns the scan results via an MLME-WURDISCOVERY.confirm primitive.

NOTE 3—A WUR non-AP STA might perform WUR scanning at any time except during any active WUR duty cycle service period agreed between the WUR non-AP STA and the WUR AP.

A WUR non-AP STA with dot11WURDiscoveryImplemented equal to true receiving the WUR Discovery element may use the information of the WUR discovery channels to schedule WUR scanning. The WUR non-AP STA may limit the WUR scanning to the WUR discovery channels listed in the WUR Discovery element.


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# 30. Wake-Up Radio (WUR) PHY specification(11ba)

## 30.1 Introduction

Clause 30 (Wake-Up Radio (WUR) PHY specification(11ba)) specifies the PHY entity for (#3066)(#3067)wake-up radio (WUR) systems. In addition to the requirements in Clause 30 (Wake-Up Radio (WUR) PHY specification(11ba)), a WUR STA that supports WUR PHY specification shall support(#546) transmitting and receiving PPDUs that are compliant with the mandatory requirements of the following PHY specifications:

— Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) if a WUR STA is a non-HT STA
— Clause 19 (High Throughput (HT) PHY specification(#2297)) if a WUR STA is an HT STA
— Clause 21 (Very high throughput (VHT) PHY specification) if a WUR STA is a VHT STA
— Clause 27 (High-efficiency (HE) PHY specification(11ax)) if a WUR STA is an HE STA

The transmission and reception of WUR PPDUs is defined in the 2.4 GHz and 5 GHz bands. The transmission of 40 MHz WUR FDMA PPDUs is defined in the 2.4 GHz and 5 GHz bands and the transmission of 80 MHz WUR FDMA PPDUs is defined in the 5 GHz band.

A WUR AP shall support(#546) transmitting a WUR Basic PPDU.

A WUR non-AP STA shall support(#546) receiving a WUR Basic PPDU.

NOTE—The capability to transmit a WUR PPDU by a WUR non-AP STA is implementation specific and is out of scope of the standard.

The WUR PHY is based on the PHY defined in Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification)(#3065).

The WUR PHY provides support for data rates of 62.5 kb/s and 250 kb/s. WUR low data rate (LDR) indicates 62.5 kb/s, and WUR high data rate (HDR) indicates 250 kb/s.

The WUR PHY provides support for WUR encoding, which shall be applied to all data rates for the WUR-Data field.

The WUR PHY provides support for 20 MHz and optionally 40 MHz and 80 MHz contiguous channel widths depending on the frequency band and capability. For the channel width equal to 80 MHz, the WUR PHY may support subchannel puncturing transmission where one or more of the non-primary WUR 20 MHz channels are zeroed out.

(#4055)(#4370)The WUR PHY uses on-off keying (OOK) modulation for (#1128)WUR-Sync and WUR-Data fields. The WUR OOK modulation may be generated by using the multicarrier on-off keying (MC-OOK) modulation technique with (#3771)a signal constructed from multiple subcarriers. When MC-OOK is used to generate the WUR OOK signal MC-OOK should use 13 contiguous subcarriers, centered within a 20 MHz channel, with a subcarrier spacing of 312.5 kHz and the center subcarrier (#1131)being null. The subcarrier coefficients may take values from the BPSK, QPSK, 16-QAM, 64-QAM, or 256-QAM (#3069)constellations.

A WUR AP shall support the following features:

— Transmission of a WUR Basic PPDU with 20 MHz channel width, WUR LDR, and single stream.

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— Transmission of a WUR Basic PPDU with 20 MHz channel width, WUR HDR, and single stream.

A WUR non-AP STA shall support the following features:

— Reception of a WUR Basic PPDU with 20 MHz channel width, WUR LDR, and single stream.

A WUR AP may support the following features:

— Transmission of a WUR FDMA PPDU with 40 MHz and 80 MHz contiguous channel widths.

— Transmission of a WUR FDMA PPDU with subchannel puncturing for 80 MHz.

A WUR non-AP STA may support the following features:

— Reception of a WUR Basic PPDU with 20 MHz channel width, WUR HDR, and single stream.

— Reception of a WUR Beacon frame in one channel at one time and a WUR Short Wake-up frame or a WUR Wake-up frame or a WUR Vendor Specific frame in a different channel at a different time (see 29.11 (WUR FDMA operation)).

A WUR AP shall not transmit a WUR PPDU in an operating class for which the behavior limits set listed in Annex E includes the DFS_50_100_Behavior.

## 30.2 WUR PHY service interface

### 30.2.1 Introduction

The WUR PHY provides an interface to the WUR MAC. The interface includes TXVECTOR, RXVECTOR and PHY-CONFIG_VECTOR.

Using the TXVECTOR, the MAC supplies the PHY with per PPDU transmit parameters. Using the RXVECTOR, the PHY informs the MAC of the received PPDU parameters. Using the PHY-CONFIG_VECTOR, the MAC configures the PHY for operation, independent of frame transmission or reception.


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### 30.2.2 TXVECTOR and RXVECTOR parameters

The parameters in Table 30-1 (TXVECTOR and RXVECTOR parameters(11ba)) are defined as part of the TXVECTOR parameter list in the PHY-TXSTART.request primitive and/or as part of the RXVECTOR parameter list in the PHY-RXSTART.indication and PHY_RXEND.indication primitives.

**Table 30-1—TXVECTOR and RXVECTOR parameters(11ba)**

| Parameter | Condition | Value | TXVECTOR | RXVECTOR |
|---|---|---|---|---|
| FORMAT | | Determines the format of the PPDU.<br>Enumerated type:<br>— WUR_BASIC indicates WUR Basic PPDU format in TXVECTOR.<br>— WUR_FDMA indicates WUR FDMA PPDU format in TXVECTOR.<br>— WUR indicates WUR PPDU format in RXVECTOR. | Y | Y |
| L_LENGTH | FORMAT is WUR_BASIC | Indicates the value used to set the LENGTH field in L-SIG field(#4145).<br><br>NOTE—The length field of the L-SIG field(#4145) in WUR Basic PPDU is defined in Equation (30-16) using the TXTIME | Y | N |
| | FORMAT is WUR_FDMA | Indicates the value used to set the LENGTH field in L-SIG field(#4145).<br><br>NOTE—The length field of the L-SIG field(#4145) in WUR FDMA PPDU is defined in Equation (30-16) using the TXTIME value defined by Equation (30-17). | | |
| L_DATARATE | FORMAT is WUR_BASIC or WUR_FDMA | Indicates the value used to set the RATE field in L-SIG field(#4145).<br><br>NOTE—The rate field in the L-SIG field in WUR Basic PPDU and WUR FDMA PPDU is set to value representing 6Mb/s in the 20 MHz channel spacing column of Table 17-6 (Contents of the SIGNAL field). | Y | N |

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**Table 30-1—TXVECTOR and RXVECTOR parameters(11ba) *(continued)***

| Parameter | Condition | Value | TXVECTOR | RXVECTOR |
|---|---|---|---|---|
| CH_BANDWIDTH | FORMAT is WUR_BASIC or WUR_FDMA | Indicates whether the PPDU is transmitted using 20 MHz or 40 MHz or 80 MHz channel width.<br>Enumerated type:<br>— WUR_CBW_20 for 20 MHz.<br>— WUR_CBW_40 for 40 MHz.<br>— WUR_CBW_80 for 80 MHz.<br>— WUR_CBW_PUNC80-PRI for subchannel puncturing in 80 MHz, where in the preamble the secondary 20 MHz is punctured.<br>— WUR_CBW_PUNC80-SEC for subchannel puncturing in 80 MHz, where in the preamble one of the two 20 MHz subchannels in secondary 40 MHz is punctured.<br>— WUR_CBW_PUNC80-PRI-SEC-1 for subchannel puncturing in 80 MHz, where in the preamble the secondary 20 MHz and the lower 20 MHz subchannel in secondary 40 MHz is punctured.<br>— WUR_CBW_PUNC80-PRI-SEC-2 for subchannel puncturing in 80 MHz, where in the preamble the secondary 20 MHz and the higher 20 MHz subchannel in secondary 40 MHz is punctured. | Y | N |
| WUR_DATARATE | FORMAT is WUR_BASIC or WUR_FDMA | Determines the transmission rate of the WUR Basic PPDU and WUR FDMA PPDU.<br>Enumerated type:<br>— WUR_LDR indicates the data rate 62.5 kb/s.<br>— WUR_HDR indicates the data rate 250 kb/s. | MU | Y |
| PSDU_LENGTH | FORMAT is WUR_BASIC or WUR_FDMA | Indicates the number of octets in the (#6182)WUR PPDU in the range(#3482) 0 to aPSDUMaxLength octets. | MU | N |
| RSSI | FORMAT is WUR_BASIC or WUR_FDMA | The allowed values for the RSSI parameter are in the range 0 to 255 inclusive. This parameter is a (#1132)measurement by the PHY of the power observed at the antennas used to receive the current WUR PPDU. RSSI shall be measured during the reception of the WUR-Sync. RSSI is intended to be used in a relative manner, and it is a monotonically increasing function of the received power. | N | Y |



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**Table 30-1—TXVECTOR and RXVECTOR parameters(11ba) *(continued)***

| Parameter | Condition | Value | TXVECTOR | RXVECTOR |
|---|---|---|---|---|
| WUR_CH_OFFSET | FORMAT is WUR_BASIC or WUR_FDMA | Determines the WUR channel.<br><br>Enumerated type:<br>— 0 indicates the WUR Short Wake-up frame or the WUR Wake-up frame or the WUR Vendor Specific frame is to be transmitted in the WUR primary channel.<br>— 1 indicates the WUR Short Wake-up frame or the WUR Wake-up frame or the WUR Vendor Specific frame is to be transmitted in first higher frequency 20 MHz channel relative to the WUR primary channel.<br>— 2 indicates the WUR Short Wake-up frame or the WUR Wake-up frame or the WUR Vendor Specific frame is to be transmitted in first lower frequency 20 MHz channel relative to the WUR primary channel.<br>— 3 indicates the WUR Short Wake-up frame or the WUR Wake-up frame or the WUR Vendor Specific frame is to be transmitted in second higher frequency 20 MHz channel relative to the WUR primary channel.<br>— 4 indicates the WUR Short Wake-up frame or the WUR Wake-up frame or the WUR Vendor Specific frame is to be transmitted in second lower frequency 20 MHz channel relative to the WUR primary channel.<br>— 5 indicates the WUR Short Wake-up frame or the WUR Wake-up frame or the WUR Vendor Specific frame is to be transmitted in third higher frequency 20 MHz channel relative to the WUR primary channel.<br>— 6 indicates the WUR Short Wake-up frame or the WUR Wake-up frame or the WUR Vendor Specific frame is to be transmitted in third lower frequency 20 MHz channel relative to the WUR primary channel. | MU | N |

NOTE 1—In the (#4177)TXVECTOR column, the following apply:

— "Y" means that the parameter is present.
— "N" means that the parameter is not present.
— "MU" means that the parameter is present for WUR Basic PPDU and is present per user for WUR FDMA PPDU.

NOTE 2—In the (#4177)RXVECTOR column, the following apply:

— "Y" means that the parameter is present for WUR Basic PPDU.
— "N" means that the parameter is not present.

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### 30.2.3 PHY-CONFIG_VECTOR parameters

The PHY-CONFIG_VECTOR carried in a PHY-CONFIG.request primitive for a WUR PHY contains an OPERATING_CHANNEL parameter, which identifies the operating channel. The PHY shall set dot11CurrentFrequency to this parameter.

## 30.3 WUR PHY

### 30.3.1 Introduction

This subclause provides the procedure by which PSDUs are converted to and from transmissions on the wireless medium.

During transmission, a single PSDU (in the WUR Basic PPDU case) or multiple PSDUs (in the WUR FDMA PPDU case) are processed and appended to the WUR PHY preamble including L-STF, L-LTF, L-SIG, BPSK-Mark1, BPSK-Mark2, and WUR-Sync field to create the WUR PPDU. At the receivers, the L-STF, L-LTF, L-SIG fields(#4145) are accordingly processed to aid in protection of the WUR-Sync and the PSDU. The WUR-Sync field is accordingly processed to aid in the detection, demodulation, and delivery of the PSDU.

### 30.3.2 WUR Basic PPDU format

The WUR Basic PPDU format is defined for the 20 MHz channel bandwidth. Figure 30-1 (WUR Basic PPDU format(11ba)) shows the WUR Basic PPDU format.

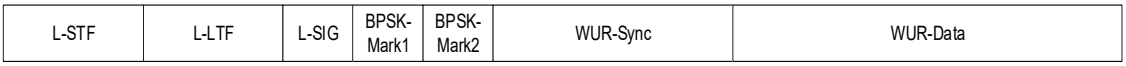


**Figure 30-1—WUR Basic PPDU format(11ba)**

The fields of the WUR Basic PPDU format are summarized in Table 30-2 (Fields of the WUR Basic PPDU(11ba)).

**Table 30-2—Fields of the WUR Basic PPDU(11ba)**

| Field | Description |
|---|---|
| L-STF | Non-HT Short Training field (see 21.3.4.2 (Construction of L-STF)) |
| L-LTF | Non-HT Long Training field (see 21.3.4.3 (Construction of the L-LTF)) |
| L-SIG | Non-HT SIGNAL field (see 21.3.4.4 (Construction of L-SIG) and 21.3.8.2.4 (L-SIG definition) |
| BPSK-Mark1 | A BPSK modulated OFDM symbol (see 30.3.9.2.4 (BPSK-Mark1 definition)) |
| BPSK-Mark2 | A BPSK modulated OFDM symbol (see 30.3.9.2.5 (BPSK-Mark2 definition)) |
| WUR-Sync | WUR Synchronization field (see 30.3.9.3 (WUR-Sync field)) |
| WUR-Data | WUR Data field carrying the PSDU (see 30.3.10 (WUR-Data field)) |


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The WUR-Sync field is either 64 μs or 128 μs long, which is determined by the rate of the WUR-Data field.

### 30.3.3 WUR FDMA PPDU format

The examples of WUR FDMA PPDUs with 40 MHz and 80 MHz channel bandwidths are illustrated in Figure 30-2 (An example of a WUR FDMA PPDU for 40 MHz channel widths(#7174)(11ba)(#7214)) and Figure 30-3 (An example of a WUR FDMA PPDU for 80 MHz channel widths(#7174)(11ba)(#7214)), respectively.

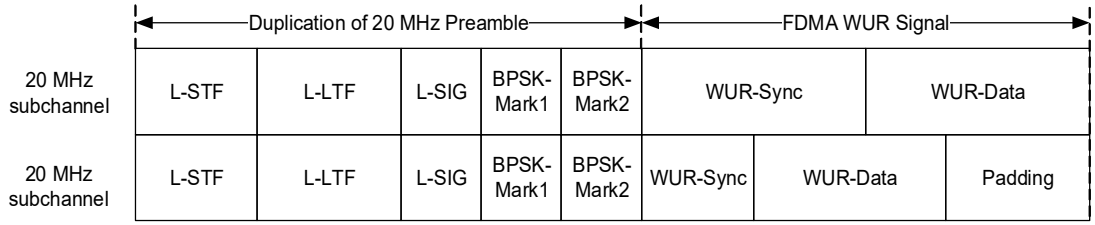


**Figure 30-2—An example of a WUR FDMA PPDU for 40 MHz channel widths(#7174)(11ba)(#7214)**

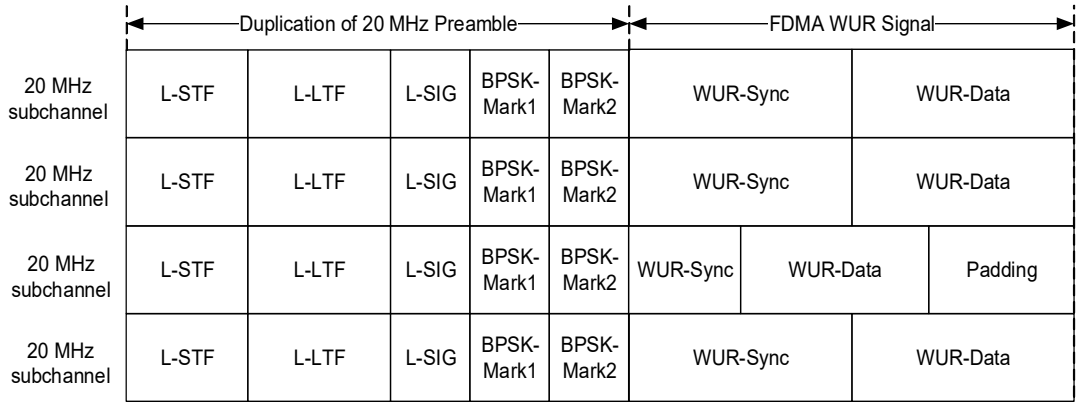


**Figure 30-3—An example of a WUR FDMA PPDU for 80 MHz channel widths(#7174)(11ba)(#7214)**

For the WUR FDMA PPDUs with 40 MHz and 80 MHz channel bandwidth, different WUR-Sync field according to the rate of the WUR-Data field may be applied to each 20 MHz subchannel.

The preamble of the WUR FDMA PPDU with 40 MHz or 80 MHz channel bandwidth before the WUR-Sync field is the duplication of 20 MHz preamble, which is composed of L-STF, L-LTF, L-SIG, BPSK-Mark1, and BPSK-Mark2 fields. In each 20 MHz subchannel with duplicated 20 MHz preamble, one WUR signal centered in the 20 MHz subchannel is transmitted following the 20 MHz preamble.

In FDMA transmission, the WUR transmission on each nonpunctured 20 MHz subchannel has equal duration of transmission, and if the duration of WUR transmission on any of the nonpunctured 20 MHz subchannels is shorter than the length indicated by the LENGTH field described in 30.4.1 (TXTIME and PSDU length calculation), then padding is used such that WUR transmissions on each nonpunctured 20 MHz subchannel always have the length indicated by the LENGTH field in the L-SIG field(#4145).

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### 30.3.4 Transmitter block diagram

The WUR-Sync field generation uses (#1135)an On waveform generator (On-WG) and an Off waveform generator (Off-WG).

The WUR-Data field generation uses the On-WG, the Off-WG, and WUR encoder.

Figure 30-4 (An example of a WUR signal generator for the WUR-Sync field(11ba)), Figure 30-5 (An example of a WUR signal generator for the WUR-Data field(11ba)), and 30.3.4.1 (WUR Basic PPDU waveform generation for WUR-Sync field and WUR-Data field with WUR HDR) through 30.3.4.4 (Symbol Randomizer and Per-transmit chain Cyclic Shift) show an example of transmitter block diagram for the WUR-Sync field and the WUR-Data field. The actual waveform generation of these fields is implementation dependent. The waveform generation for L-STF, L-LTF, L-SIG, BPSK-Mark1, and BPSK-Mark2 fields is described in 30.3.5 (Overview of the PPDU encoding process).

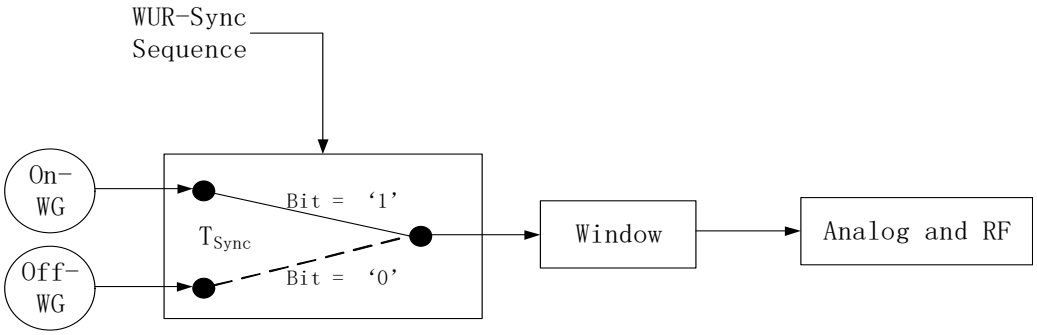


**Figure 30-4—An example of a WUR signal generator for the WUR-Sync field(11ba)**

In Figure 30-4 (An example of a WUR signal generator for the WUR-Sync field(11ba)), the WUR-Sync sequence is used to switch between the On-WG and the Off-WG. An example of an On-WG and an Off-WG for the WUR-Sync field is given in 30.3.4.1 (WUR Basic PPDU waveform generation for WUR-Sync field and WUR-Data field with WUR HDR). The corresponding mathematical description of the On-WG for the WUR-Sync field is described as SymHDROn in 30.3.8 (Mathematical description of signals).

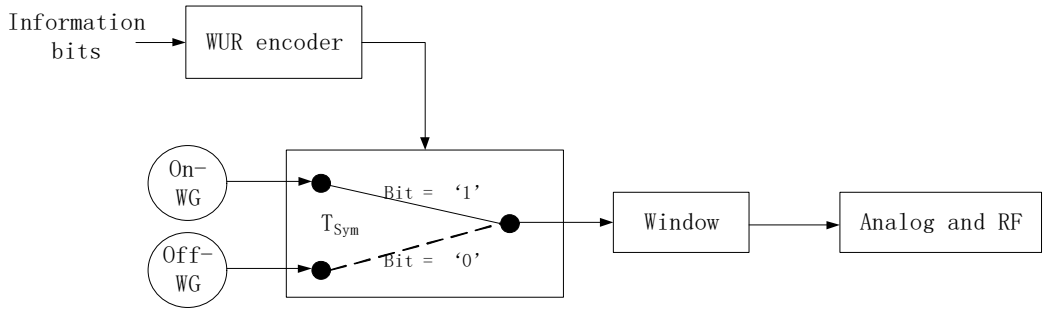


**Figure 30-5—An example of a WUR signal generator for the WUR-Data field(11ba)**

An example of a WUR signal generator for the WUR-Data field is shown in Figure 30-5 (An example of a WUR signal generator for the WUR-Data field(11ba)). The information bits are mapped to coded bits by a WUR encoder. Each coded bit is then used to switch between the On-WG and the Off-WG. An example of


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an On/Off-WG for the WUR-Data field with WUR HDR and WUR-Data field with WUR LDR are given in 30.3.4.1 (WUR Basic PPDU waveform generation for WUR-Sync field and WUR-Data field with WUR HDR) and 30.3.4.2 (WUR Basic PPDU waveform generation for WUR-Data field with WUR LDR), respectively. The corresponding mathematical descriptions of the On-WG for the WUR-Data field with WUR HDR and WUR-Data field with WUR LDR are described as SymHDROn and SymLDROn, respectively, in 30.3.8 (Mathematical description of signals).

NOTE—The waveform generators are different for different data rates(#1136).

### 30.3.4.1 WUR Basic PPDU waveform generation for WUR-Sync field and WUR-Data field with WUR HDR

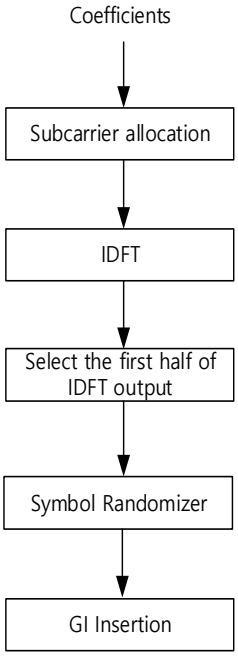


**Figure 30-6—An example of an On-WG for the WUR-Sync and WUR-Data fields with WUR HDR(11ba)**

(#4055)(#4370)For a single 20 MHz WUR channel the 2 µs (#7174)WUR OOK On symbol shall have a 2 µs duration. The 2 µs (#7174)WUR OOK On symbol may be constructed using MC-OOK with the On-WG using (#1137)the center 13 subcarriers of a 64-point IDFT, sampling at 20 MHz as follows:

- The six subcarriers with subcarrier indices $k = (-6, -4, -2, 2, 4, 6)$ are used with nonzero input. Other subcarriers are null.
- The coefficients of the nonzero subcarriers are selected from the symbols of any of the following constellations: BPSK, QPSK, 16-QAM, 64-QAM, and 256-QAM.
- The first 32 values of the 64-point IDFT output are selected.
- Those 32 values are processed by the Symbol Randomizer as described in 30.3.4.4 (Symbol Randomizer and Per-transmit chain Cyclic Shift).
- The last 8 samples of those 32 samples are prepended to the 32 samples generating 40 samples.(#4370)(#4055) This step corresponds to the GI Insertion in Figure 30-6 (An example of an On-WG for the WUR-Sync and WUR-Data fields with WUR HDR(11ba)).

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For a single 20 MHz WUR channel the 2 µs (#7174)WUR OOK Off symbol shall have a 2 µs duration. The 2 µs (#7174)WUR OOK Off symbol may be constructed using MC-OOK with the Off-Waveform Generator (Off-WG) as zero for 2 µs.(#4055)(#4370)

(#6340)(#4055)For 2 µs (#7174)WUR OOK On and Off symbols, the PPDU correlation test is defined in 30.3.12.5 (Correlation test on (#4370)(#4055)WUR OOK symbols).

### 30.3.4.2 WUR Basic PPDU waveform generation for WUR-Data field with WUR LDR

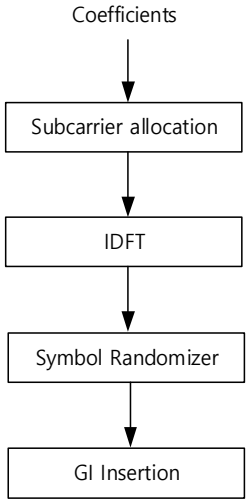


**Figure 30-7—An example of an On-WG for the WUR-Data fields with WUR LDR(11ba)**

(#4055)(#4370)For a single 20 MHz WUR channel the 4 µs (#7174)WUR OOK On symbol shall have a 4 µs duration. The 4 µs (#7174)WUR OOK On symbol may be constructed using MC-OOK with the On-WG using (#1139)the center 13 subcarriers of a 64-point IDFT, sampling at 20 MHz as follows:

- The 12 subcarriers with subcarrier indices $k = (-6, -5, \ldots -1, 1, 2, \ldots 6)$ are used with nonzero input. Other subcarriers are null.
- The coefficients of the nonzero subcarriers are selected from the symbols of any of the following constellations: BPSK, QPSK, 16-QAM, 64-QAM, and 256-QAM.
- The 64 values from the 64-point IDFT are processed by the Symbol Randomizer as described in 30.3.4.4 (Symbol Randomizer and Per-transmit chain Cyclic Shift).
- The last 16 values of the 64-point IDFT output are prepended to the 64 samples generating 80 samples(#4370)(#4055). This step corresponds to the GI Insertion in Figure 30-7 (An example of an On-WG for the WUR-Data fields with WUR LDR(11ba)).

(#4055)(#4370)For a single 20 MHz WUR channel the 4 µs duration (#7174)WUR OOK Off symbol may be constructed using MC-OOK with the Off-Waveform Generator (Off-WG) as zero for 4 µs.

(#6340)(#4055)(#4370)For 4 µs (#7174)WUR OOK On and Off symbols, the PPDU correlation test is defined in 30.3.12.5 (Correlation test on (#4370)(#4055)WUR OOK symbols).


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### 30.3.4.3 WUR FDMA PPDU WUR-Data field waveform generation

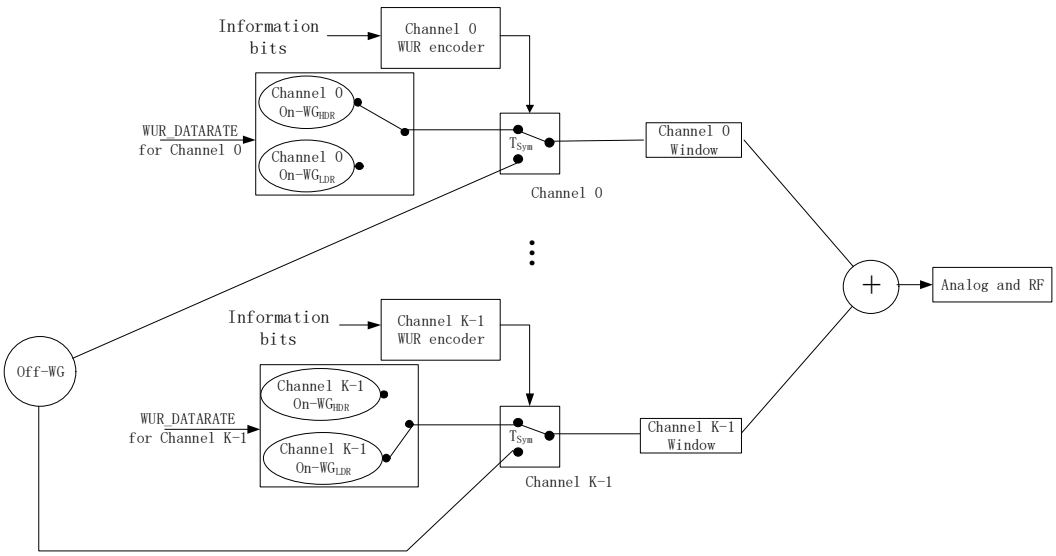


**Figure 30-8—An example of a WUR-Data field signal generator for the FDMA transmission(11ba)**

(#4055)(#4370)(#7174)The WUR OOK On symbol for the 20 MHz WUR waveform shall be generated according to 30.3.4.1 (WUR Basic PPDU waveform generation for WUR-Sync field and WUR-Data field with WUR HDR) or 30.3.4.2 (WUR Basic PPDU waveform generation for WUR-Data field with WUR LDR) depending on WUR_DATARATE. The 40 MHz or 80 MHz WUR FDMA PPDU should be generated by multiplexing multiple 20 MHz WUR waveforms in the corresponding channel as shown in Figure 30-8 (An example of a WUR-Data field signal generator for the FDMA transmission(11ba)).

### 30.3.4.4 Symbol Randomizer and Per-transmit chain Cyclic Shift

The spectral lines in the WUR PPDU spectrum are removed by the symbol randomizer.

The Symbol Randomizer, shown in Figure 30-9 (Symbol Randomizer(11ba)), uses a linear feedback shift register (LFSR) with a generator polynomial $G(z) = z^{-7} + z^{-4} + 1$ to generate a sequence of pseudo random bits. The state of the LFSR is first updated at the end of the first symbol in the WUR-Sync field.

The seventh bit of LFSR state is converted to an integer *m*, with a value of either plus or minus one. A logical zero bit is converted to plus one and a logical one bit is converted to minus one. The input waveform is then multiplied by either plus or minus one, based on the logical bit.

Three of the bits from the LFSR are converted to an integer value between zero and seven, indicated by *n* in Figure 30-9 (Symbol Randomizer(11ba)). In Figure 30-9 (Symbol Randomizer(11ba)), b0 is the least significant bit (LSB) of the integer *n*, while b2 is the most significant bit of the integer *n*. This integer is used to lookup a cyclic shift value, from a cyclic shift lookup table, which shows cyclic shift values corresponding to the integer *n*. The pseudorandom cyclic shift values according to the cyclic shift integer *n* are given in Table 30-6 (Values of pseudorandom cyclic shift with cyclic shift index *n* for the WUR-Sync field and WUR-Data field with WUR HDR(11ba)) for the WUR-Sync field and the WUR-Data field with WUR HDR and in Table 30-7 (Values of pseudorandom cyclic shift with cyclic shift index *n* for the WUR-Data field with WUR LDR(11ba)) for the WUR-Data field with WUR LDR.

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The cyclic shift value, obtained from the lookup table, is applied to the input waveform.

Then the per-transmit chain cyclic shift is applied to the input waveform. Example values of such cyclic shift diversity are provided in Annex AC.

The symbol randomizer is used for both the WUR-Sync field and the WUR-Data field. The state of the LFSR is updated every $T_{Sync}$ during the WUR-Sync field and updated every $T_{Sym}$ during the WUR-Data field.

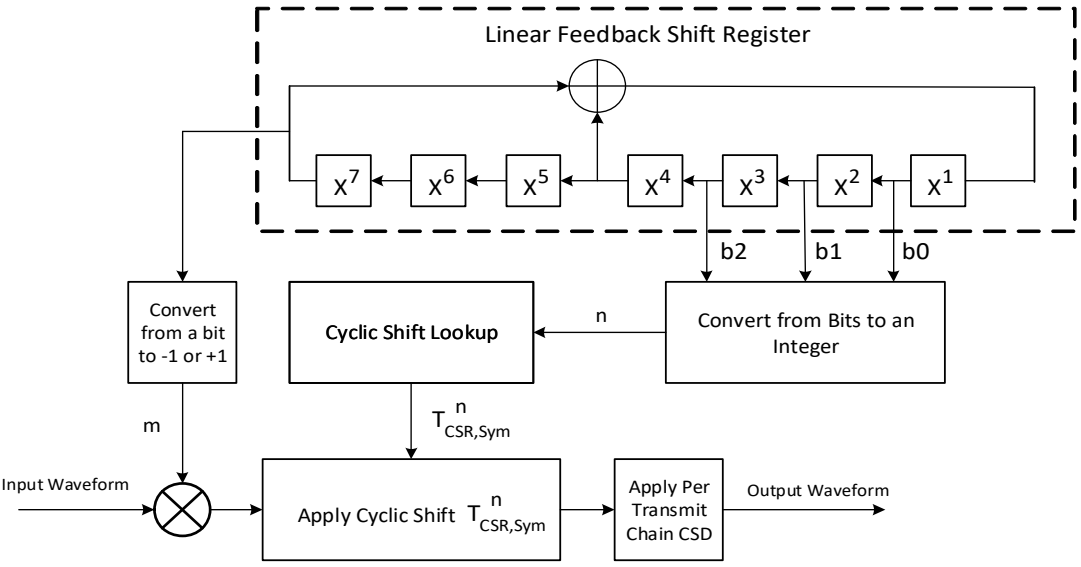


**Figure 30-9—Symbol Randomizer(11ba)**

### 30.3.5 Overview of the PPDU encoding process

#### 30.3.5.1 General

This subclause provides an overview of the WUR PPDU encoding process.

#### 30.3.5.2 Construction of the L-STF

Construct the L-STF field as defined in 30.3.9.2.1 (L-STF definition) with the following highlights:

a) Determine the channel bandwidth from the TXVECTOR parameter CH_BANDWIDTH.

b) Sequence generation: Generate the L-STF sequence over the CH_BANDWIDTH as described in 30.3.9.2.1 (L-STF definition).

c) Phase rotation: Apply appropriate phase rotation for each 20 MHz subchannel as described in 21.3.7.4 (Transmitted signal) and 21.3.7.5 (Definition of tone rotation).

d) IDFT: Compute the inverse discrete Fourier transform.

e) CSD: Apply CSD for each transmit chain as described in 21.3.8.2.1 (Cyclic shift for pre-VHT modulated fields).

f) Insert GI and apply windowing: Prepend a GI (LONG_GI) and apply windowing as described in 21.3.7.4 (Transmitted signal).


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g) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit. Refer to 21.3.7.4 (Transmitted signal) for details.

#### 30.3.5.3 Construction of the L-LTF

Construct the L-LTF field as defined in 30.3.9.2.2 (L-LTF definition) with the following highlights:

a) Determine the CH_BANDWIDTH from the TXVECTOR.

b) Sequence generation: Generate the L-LTF sequence over the CH_BANDWIDTH as described in 30.3.9.2.2 (L-LTF definition).

c) Phase rotation: Apply appropriate phase rotation for each 20 MHz subchannel as described in 21.3.7.4 (Transmitted signal) and 21.3.7.5 (Definition of tone rotation).

d) IDFT: Compute the inverse discrete Fourier transform.

e) CSD: Apply CSD for each transmit chain as described in 21.3.8.2.1 (Cyclic shift for pre-VHT modulated fields).

f) Insert GI and apply windowing: Prepend a GI (2 x LONG_GI) and apply windowing as described in 21.3.7.4 (Transmitted signal).

g) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit. Refer to 21.3.7.4 (Transmitted signal) and 21.3.8 (VHT preamble) for details.

#### 30.3.5.4 Construction of the L-SIG field(#4145)

Construct the L-SIG field as defined in 30.3.9.2.3 (L-SIG field definition(#4145)) with the following highlights:

a) In a WUR PPDU, set the RATE subfield in the SIGNAL field to 6 Mb/s. Set the Length, Parity, and Tail bits in the SIGNAL field as described in 30.3.9.2.3 (L-SIG field definition(#4145)).

b) BCC encoder: Encode the L-SIG field by a convolutional encoder at the rate of R=1/2 as described in 21.3.10.5.3 (BCC coding and puncturing).

c) BCC interleaver: Interleave as described in 21.3.10.8 (BCC interleaver).

d) Constellation Mapper: BPSK modulate as described in 21.3.10.9 (Constellation mapping).

e) Pilot insertion: Insert pilots as described in 21.3.10.10 (Pilot subcarriers).

f) Duplication and phase rotation: Duplicate the L-SIG field over the occupied 20 MHz subchannel of the CH_BANDWIDTH. Apply appropriate phase rotation for each 20 MHz subchannel as described in 21.3.7.4 (Transmitted signal) and 21.3.7.5 (Definition of tone rotation).

g) IDFT: Compute the inverse discrete Fourier transform.

h) CSD: Apply CSD for each transmit chain as described in 21.3.7.4 (Transmitted signal).

i) Insert GI and apply windowing: Prepend a GI (LONG_GI) and apply windowing as described in 21.3.7.4 (Transmitted signal).

j) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit. Refer to 21.3.7.4 (Transmitted signal) and 21.3.8 (VHT preamble) for details.

#### 30.3.5.5 Construction of the BPSK-Mark1

Construct the BPSK-Mark1 field as derived from the L-SIG field as defined in 30.3.9.2.4 (BPSK-Mark1 definition) with the following highlights:

a) In a WUR PPDU, set the BPSK-Mark1 field as described in 30.3.9.2.4 (BPSK-Mark1 definition).

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b) BCC encoder: Encode the BPSK-Mark1 field by a convolutional encoder at the rate of R=1/2 as described in 21.3.10.5.3 (BCC coding and puncturing).

c) BCC interleaver: Interleave as described in 21.3.10.8 (BCC interleaver).

d) Exclusive OR (XOR) each of the output bits of the BCC interleaver with 1.

e) Constellation Mapper: BPSK modulate as described in 21.3.10.9 (Constellation mapping).

f) Pilot insertion: Insert pilots as described in 21.3.10.10 (Pilot subcarriers).

g) Duplication and phase rotation: Duplicate the BPSK-Mark1 field over each occupied 20 MHz of the CH_BANDWIDTH. Apply appropriate phase rotation for each 20 MHz subchannel as described in 21.3.7.4 (Transmitted signal) and 21.3.7.5 (Definition of tone rotation).

h) IDFT: Compute the inverse discrete Fourier transform.

i) CSD: Apply CSD for each transmit chain as described in 21.3.8.2.1 (Cyclic shift for pre-VHT modulated fields).

j) Insert GI and apply windowing: Prepend a GI (LONG_GI) and apply windowing as described in 21.3.7.4 (Transmitted signal).

k) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit. Refer to 21.3.7.4 (Transmitted signal) and 21.3.8 (VHT preamble) for details.

#### 30.3.5.6 Construction of the BPSK-Mark2

Construct the BPSK-Mark2 field as derived from the L-SIG field as defined in 30.3.9.2.5 (BPSK-Mark2 definition) with the following highlights:

a) In a WUR PPDU, set the BPSK-Mark2 field as described in 30.3.9.2.5 (BPSK-Mark2 definition).

b) BCC encoder: Encode the BPSK-Mark2 field by a convolutional encoder at the rate of R=1/2 as described in 21.3.10.5.3 (BCC coding and puncturing).

c) BCC interleaver: Interleave as described in 21.3.10.8 (BCC interleaver).

d) Exclusive OR (XOR) each of the output bits of the BCC interleaver with 1.

e) Constellation Mapper: BPSK modulate as described in 21.3.10.9 (Constellation mapping).

f) Pilot insertion: Insert pilots as described in 21.3.10.10 (Pilot subcarriers).

g) Duplication and phase rotation: Duplicate the BPSK-Mark2 field over each occupied 20 MHz of the CH_BANDWIDTH. Apply appropriate phase rotation for each 20 MHz subchannel as described in 21.3.7.4 (Transmitted signal) and 21.3.7.5 (Definition of tone rotation).

h) IDFT: Compute the inverse discrete Fourier transform.

i) CSD: Apply CSD for each transmit chain and frequency segment as described in 21.3.8.2.1 (Cyclic shift for pre-VHT modulated fields).

j) Insert GI and apply windowing: Prepend a GI (LONG_GI) and apply windowing as described in 21.3.7.4 (Transmitted signal).

k) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit. Refer to 21.3.7.4 (Transmitted signal) and 21.3.8 (VHT preamble) for details.

#### 30.3.5.7 Construction of the WUR-Sync for a single 20 MHz channel

Construct the WUR-Sync field for a single 20 MHz channel defined in 30.3.9.3 (WUR-Sync field) as follows:

a) Set the WUR_DATARATE from the TXVECTOR.

b) WUR-Sync sequence generation: Generate the Sync-bit sequence according to the WUR_DATARATE as described in 30.3.9.3 (WUR-Sync field).


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c) Waveform generation: Generate the (#4055)(#4370)WUR OOK waveform by using either On-WG or Off-WG according to the WUR-Sync. The samples in Off-WG (#3073)shall have zero energy. WUR-Sync bit duration $T_{Sync}$ is 2 µs. Symbol randomization and per-transmit-chain CSD is applied within the waveform generation step.

d) Windowing: Apply windowing.

e) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit.

#### 30.3.5.8 Construction of the WUR-Data for a single 20 MHz channel

Construct the WUR-Data waveform as follows:

a) Information bits are encoded using a WUR encoder as described in 30.3.10 (WUR-Data field).

b) The output of WUR encoder determines whether to take samples from On-WG or Off-WG. Each symbol duration, $T_{Sym}=T_{SYM\text{-}HDR}$ is 2 µs for WUR HDR, and $T_{Sym}=T_{SYM\text{-}LDR}$ is 4 µs for WUR LDR.

c) Apply the windowing.

d) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal based on the center frequency of the desired channel.

#### 30.3.5.9 Construction of the WUR-Sync and WUR-Data for the FDMA transmission

Construct the WUR-Sync and WUR-Data waveform for the FDMA transmission as follows:

a) Determine the WUR_DATARATE from the TXVECTOR for each 20 MHz subchannel.

b) WUR-Sync sequence generation and WUR encoder for each 20 MHz subchannel: Generate the WUR-Sync sequence according to the WUR_DATARATE as described in 30.3.9.3 (WUR-Sync field) and WUR encoded bits, which follow the WUR-Sync sequence according to the input bits as described in 30.3.10 (WUR-Data field) for each 20 MHz subchannel.

c) Waveform generation for the WUR-Sync field: Generate the (#4055)WUR OOK waveform for the WUR-Sync field by using either On-WG or Off-WG according to the WUR-Sync bit for each 20 MHz subchannel. The samples in Off-WG (#3073)shall have zero energy. Each WUR-Sync bit duration, $T_{Sync}$ is 2 µs.

d) Waveform generation for the WUR-Data field: The output of the $k^{th}$ WUR encoder determines whether to sample from the $k^{th}$ On-WG or from the Off-WG, depending on the encoded bit of the corresponding 20 MHz subchannel, where k, $0 \le k \le K-1$ , is the index of the 20 MHz subchannel. The samples in Off-WG (#3073)shall have zero energy. Each symbol duration, $T_{Sym}=T_{SYM\text{-}HDR}$ is 2 µs for WUR HDR, and $T_{Sym}=T_{SYM\text{-}LDR}$ is 4 µs for WUR LDR.

e) Append the padding on nonpunctured 20 MHz subchannel: If the duration of WUR transmission on any nonpunctured 20 MHz subchannel is shorter than the indicated L_LENGTH as described in 30.4.1 (TXTIME and PSDU length calculation), generate the padding according to 30.3.11 (WUR Padding field for a WUR FDMA PPDU) to align the length indicated by the LENGTH field in the L-SIG field(#4145), and the padding is not applied to the punctured 20 MHz subchannel.

f) Windowing: Apply windowing for each 20 MHz subchannel.

g) The outputs per 20 MHz subchannel are added across the 20 MHz subchannels, sample by sample, after applying appropriate subchannel frequency offset.

h) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit.

### 30.3.6 WUR data rates

The WUR data rate represents the data rate used in the WUR-Data field of the WUR PPDU. There are two data rates: 62.5 kb/s and 250 kb/s, respectively, which are denoted as WUR LDR and WUR HDR. WUR

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LDR and WUR HDR are distinguished by the predefined sequence in the WUR-Sync field. Rate-dependent parameters are shown in Table 30-14 (WUR PPDU data rates(11ba)).WUR encoding is applied to both WUR data rates.(#4370)(#4055)

### 30.3.7 Timing related parameters

Table 30-3 (Timing-related constants(11ba)) defines the timing-related parameters for WUR PPDU formats.

Table 30-4 (Frequently used parameters(11ba)) defines parameters used frequently in Clause 30 (Wake-Up Radio (WUR) PHY specification(11ba)).

**Table 30-3— Timing-related constants(11ba)**

| Parameter | Value | Description |
|---|---|---|
| $\Delta_{F,\ \mathrm{WUR}}$ | 312.5 kHz | Subcarrier frequency spacing for WUR PPDU when MC-OOK is used(#4370)(#4055) |
| $T_{DFT,WUR}$ | 3.2 µs | IDFT/DFT period for the WUR PPDU when MC-OOK is used(#4370)(#4055) |
| $T_{GI,WUR}$ | 0.8 µs for 4 µs duration (#4370)(#4055)WUR OOK symbols; 0.4 µs for 2 µs duration (#4370)(#4055)WUR OOK symbols | Guard interval duration for the WUR PPDU when MC-OOK is used(#4370)(#4055) |
| $T_{GI,2}$ | 1.6 µs | Guard interval duration for the L-LTF field when MC-OOK is used(#4370)(#4055) |
| $T_{Sym\text{-}LDR}$ | 4 µs | Duration of (#4370)(#4055)WUR LDR OOK symbol in WUR-Data field |
| $T_{Sym\text{-}HDR}$ | 2 µs | Duration of (#4370)(#4055)WUR HDR OOK symbol in WUR-Data field |
| $T_{Sym}$ | $T_{Sym\text{-}LDR}$ or $T_{Sym\text{-}HDR}$ depending on WUR data rate | Duration of (#4370)(#4055)WUR OOK symbol in WUR-Data field |
| $T_{Sync}$ | 2 µs | Duration of (#4370)(#4055)WUR OOK symbol in WUR-Sync field |
| $T_{L\text{-}STF}$ | 8 µs = 10 × $T_{DFT,WUR}$ /4 | Non-HT Short Training field duration |
| $T_{L\text{-}LTF}$ | 8 µs = 2 × $T_{DFT,WUR}$ + $T_{GI,L\text{-}LTF}$ | Non-HT Long Training field duration |
| $T_{L\text{-}SIG}$ | 4 µs | Non-HT SIGNAL field duration |
| $T_{BPSK\text{-}Mark1}$ | 4 µs | BPSK-Mark1 field duration |
| $T_{BPSK\text{-}Mark2}$ | 4 µs | BPSK-Mark2 field duration |
| $T_{WUR\text{-}Sync\text{-}LDR}$ | 128 µs | WUR-Sync field duration for WUR LDR |
| $T_{WUR\text{-}Sync\text{-}HDR}$ | 64 µs | WUR-Sync field duration for WUR HDR |
| $T_{WUR\text{-}Sync}$ | $T_{WUR\text{-}Sync\text{-}LDR}$ or $T_{WUR\text{-}Sync\text{-}HDR}$ depending on WUR data rate | WUR-Sync field duration for WUR PPDU |


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**Table 30-4— Frequently used parameters(11ba)**

| Symbol | Explanation |
|---|---|
| $N_{SPDB}$ | Number of (#4370)(#4055)WUR OOK symbols per information data bit.<br>For WUR LDR, $N_{SPDB}$=4.<br>For WUR HDR, $N_{SPDB}$=2. |
| $N_{TX}$ | Number of transmit chains |
| $N_{WUR\text{-}Sync}$ | Number of (#4370)(#4055)WUR OOK symbols in the WUR-Sync field.<br>For WUR LDR, $N_{WUR\text{-}Sync}$=64.<br>For WUR HDR, $N_{WUR\text{-}Sync}$=32. |

### 30.3.8 Mathematical description of signals

The transmitted signal is described in complex baseband signal notation. The actual transmitted signal on transmit chain $i_{TX}$, $r_{RF}^{(i_{TX})}(t)$, is related to the complex baseband signal by the relation shown in Equation (30-1).

$$r_{RF}^{(i_{TX})}(t) = Re(r_{WUR-Basic-PPDU}^{(i_{TX})}(t)\exp(j2\pi f_c t)) \quad (30\text{-}1)$$

where

$Re(\ldots)$ represents the real part of a complex variable

$f_c$ is the center frequency

$r_{WUR-Basic-PPDU}^{(i_{TX})}(t)$ is the baseband WUR signal on transmit chain $i_{TX}$

The transmitted RF signal is obtained by up-converting the complex baseband signal, which consists of several fields. The timing boundaries for the various fields are shown in Figure 30-10 (Timing boundaries for the WUR Basic PPDU fields(11ba)) where $N_{WUR\text{-}Sync}$ is the number of (#4370)(#4055)WUR OOK symbols in the WUR-Sync field and is defined in Table 30-4 (Frequently used parameters(11ba)).

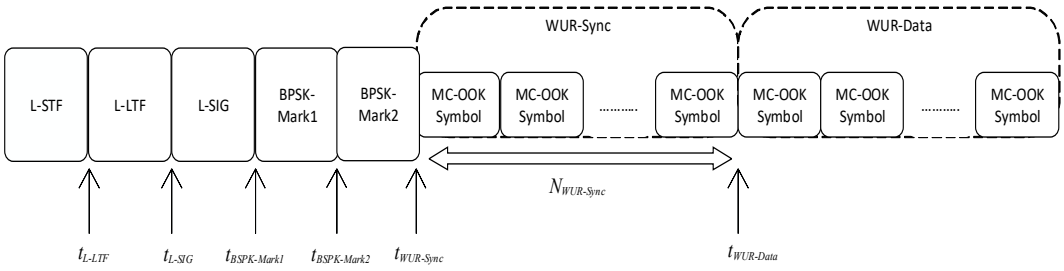


**Figure 30-10—Timing boundaries for the WUR Basic PPDU fields(11ba)**

The time offset, $t_{Field}$, determines the starting time of the corresponding field relative to the start of L-STF ($t = 0$).

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The baseband signal is constructed by the concatenation of several fields as shown in Figure 30-10 (Timing boundaries for the WUR Basic PPDU fields(11ba)). It shall be as shown in Equation (30-2):

$$
\begin{aligned}
r^{(i_{TX})}_{WUR-Basic-PPDU}(t) \;=\; & r^{(i_{TX})}_{L-STF}(t) + r^{(i_{TX})}_{L-LTF}(t - t_{L-LTF}) + r^{(i_{TX})}_{L-SIG}(t - t_{L-SIG}) \\
& + r^{(i_{TX})}_{BPSK-Mark1}(t - t_{BPSK-Mark1}) + r^{(i_{TX})}_{BPSK-Mark2}(t - t_{BPSK-Mark2}) \;+ \\
& r^{(i_{TX})}_{WUR-Sync}(t - t_{WUR-Sync}) + r^{(i_{TX})}_{WUR-Data}(t - t_{WUR-Data}), \\
& 0 \le t \le T_{WUR-Basic-PPDU}
\end{aligned}
\tag{30-2}
$$

The timing offset values for various fields are given below:

$t_{L\text{-}LTF} = T_{L\text{-}STF}$

$t_{L\text{-}SIG} = t_{L\text{-}LTF} + T_{L\text{-}LTF}$

$t_{BSPK\text{-}Mark1} = t_{L\text{-}SIG} + T_{L\text{-}SIG}$

$t_{BSPK\text{-}Mark2} = t_{BPSK\text{-}Mark1} + T_{BPSK\text{-}Mark1}$

$t_{WUR\text{-}Sync} = t_{BSPK\text{-}Mark2} + T_{BSPK\text{-}Mark2}$

$t_{WUR\text{-}Data} = t_{WUR\text{-}Sync} + T_{WUR\text{-}Sync}$

$T_{WUR\text{-}Basic\text{-}PPDU} = t_{WUR\text{-}Data} + T_{WUR\text{-}Data}$

where $T_{Field}$ is the duration of the field, $T_{WUR\text{-}Sync}$ is the duration of WUR-Sync field, as defined in Table 30-3 (Timing-related constants(11ba)). $T_{WUR\text{-}Data}$ is the duration of WUR-Data field, with $T_{WUR\text{-}Data} = N_{sym} \times T_{sym,}$ where $N_{sym}$ is the number of (#4370)(#4055)WUR OOK symbols in the WUR-Data field, as given in Equation (30-14).

The duration of different fields of the WUR Basic PPDU are provided in Table 30-3 (Timing-related constants(11ba)).

For the L-STF, L-LTF, L-SIG, BPSK-Mark1, and BPSK-Mark2 fields, the baseband signal is constructed as described in 30.3.9.2 (Non-WUR portion of WUR PHY preamble).

The WUR-Sync and WUR-Data fields comprises of (#4370)(#4055)WUR OOK symbols as described in 30.3.9.3 (WUR-Sync field) and 30.3.10 (WUR-Data field), respectively. For the (#4370)(#4055)(#7174)WUR OOK On symbols in the WUR-Sync field (WUR-Sync On symbols) and the (#4370)(#4055)(#7174)WUR OOK On symbols in the WUR-Data field (SymLDROn and SymHDROn), the baseband signal (#4370)(#4055)may be obtained by the MC-OOK (#4370)(#4055)modulation technique of taking the Inverse Discrete Fourier Transform (IDFT) of a set of subcarrier coefficients, which is described by Equation (30-3). This general representation holds for WUR-Sync and WUR-Data fields, and the field specific parameters are provided in Table 30-5 (Field specific parameter values for the (#4370)(#4055)WUR OOK symbols in WUR-Sync and WUR-Data fields(11ba)).

$$
r^{(i_{TX})}_{Field}(t) \;=\; \frac{\sqrt{2}}{\sqrt{N^{Tone}_{Field} N_{TX}}} w_{T_{Field}}(t) m \sum_{k=-6}^{6} X_{Field}(k) \exp\left(j 2\pi k \Delta_{F,\,\mathrm{WUR}} (t - T_{GI,\,WUR} - T^{i_{TX}}_{CS,\,Field} - T^{n}_{CSR,\,Field})\right) \tag{30-3}
$$



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where

$\sqrt{2}$ is the scaling factor to compensate for 50% duty cycle from (#4370)(#4055)WUR OOK.

$N_{TX}$ is the number of transmit chains as defined in Table 30-4 (Frequently used parameters(11ba)).

$w_{T_{Field}}(t)$ is a windowing function of duration T used to control spectral leakage. Refer to 17.3.2.5 (Mathematical conventions in the signal descriptions) for a discussion of windowing functions.

*m* and *n* are described in 30.3.4.4 (Symbol Randomizer and Per-transmit chain Cyclic Shift). These parameter values may vary across (#4370)(#4055)WUR OOK symbols within the field.

$\Delta_{F,\,\mathrm{WUR}}$ is the subcarrier frequency spacing and is given in Table 30-3 (Timing-related constants(11ba)).

$T_{GI,\,WUR}$ is the length of cyclic prefix.

$T_{CS,\,Field}^{i_{TX}}$ is the cyclic shift applied to the signal from transmit chain $i_{TX}$, and equals either $T_{CS}^{HDR}$ or $T_{CS}^{LDR}$, as given in Table 30-5 (Field specific parameter values for the (#4370)(#4055)WUR OOK symbols in WUR-Sync and WUR-Data fields(11ba)). $T_{CS}^{HDR}$ and $T_{CS}^{LDR}$ are implementation dependent, and example values are given in Table AC-3 (Recommended CSD values for the WUR-Sync field and WUR-Data field with WUR HDR(11ba) using MC-OOK modulation(#4370)(#4055)) and Table AC-4 (Recommended CSD values for the WUR-Data field with WUR LDR using MC-OOK modulation(#4370)(11ba)).

$T_{CSR,\,Field}^{n}$ is the pseudorandom cyclic shift with cyclic shift index *n* described in 30.3.4.4 (Symbol Randomizer and Per-transmit chain Cyclic Shift). Its values are specified in Table 30-6 (Values of pseudorandom cyclic shift with cyclic shift index *n* for the WUR-Sync field and WUR-Data field with WUR HDR(11ba)) and Table 30-7 (Values of pseudorandom cyclic shift with cyclic shift index *n* for the WUR-Data field with WUR LDR(11ba)).

$\{X_{Field}(k), -6 \le k \le 6\}$ are the field specific subcarrier coefficients, and equals either $S^{HDR}$ or $S^{LDR}$, as given in Table 30-5 (Field specific parameter values for the (#4370)(#4055)WUR OOK symbols in WUR-Sync and WUR-Data fields(11ba)). $S^{HDR}$ and $S^{LDR}$ are implementation dependent sequences, and example values for these sequences are given in Table AC-1 (Example Values for the Sequence $S^{HDR}$ used for the Construction of the 2 μs duration WUR OOK On symbol(#7174)(11ba) using MC-OOK modulation(#4370)(#4055)) and Table AC-2 (Example Values for the Sequence $S^{LDR}$ used for the Construction of the 4 μs duration WUR OOK On symbol(#7174)(11ba) using MC-OOK modulation(#4370)(#4055))

$N_{Field}^{Tone}$ is a tone scaling factor.

For the (#4370)(#4055)(#7174)WUR OOK Off symbols in the WUR-Sync and WUR-Data fields, $r_{Field}^{(i_{TX})}(t) = 0$.

NOTE—The expression in Equation (30-3) is provided for a single 20 MHz WUR channel.

Table 30-6 (Values of pseudorandom cyclic shift with cyclic shift index *n* for the WUR-Sync field and WUR-Data field with WUR HDR(11ba)) provides, for each value of the index *n*, the cyclic shift values, $T_{CSR,\,Sym}^{n}$, for the WUR-Sync field and the WUR-Data field with WUR HDR.

Table 30-7 (Values of pseudorandom cyclic shift with cyclic shift index *n* for the WUR-Data field with WUR LDR(11ba)) provides, for each value of the index *n*, the cyclic shift values, $T_{CSR,\,Sym}^{n}$, for the LDR WUR-Data field.

Table 30-8 (The states of the LFSR, the values of the bits b2, b1, b0, the value of *n*, and the pseudorandom cyclic shift with cyclic shift index *n* for the first seven (#4730)(#4055)WUR OOK symbols in the WUR-Sync field(11ba)) provides the values of the LFSR, the three bits (b2, b1, b0), the index value *n*, and the time delay value of $T_{CSR,\,Sym}^{n}$ for the first seven states of the LFSR.

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**Table 30-5—Field specific parameter values for the (#4370)(#4055)WUR OOK symbols in WUR-Sync and WUR-Data fields(11ba)**

| Parameter | WUR-Sync field | WUR-Data field | |
|---|---|---|---|
| | | SymLDROn | SymHDROn |
| $N_{Field}^{Tone}$ | 6 | 12 | 6 |
| $T_{Field}$ | 2 μs | 4 μs | 2 μs |
| $T_{GI,WUR}$ | 0.4 μs | 0.8 μs | 0.4 μs |
| $\{X_{Field}(k), -6 \le k \le 6\}$ | $S^{HDR}$ | $S^{LDR}$ | $S^{HDR}$ |
| $\left\{T_{CS,Field}^{i_{TX}}, 1 \le i_{TX} \le N_{TX}\right\}$ | $T_{CS}^{HDR}$ | $T_{CS}^{LDR}$ | $T_{CS}^{HDR}$ |
| $\{T_{CSR,Field}^{n}, 0 \le n \le 7\}$ | Table 30-6 (Values of pseudorandom cyclic shift with cyclic shift index *n* for the WUR-Sync field and WUR-Data field with WUR HDR(11ba)) | Table 30-7 (Values of pseudorandom cyclic shift with cyclic shift index *n* for the WUR-Data field with WUR LDR(11ba)) | Table 30-6 (Values of pseudorandom cyclic shift with cyclic shift index *n* for the WUR-Sync field and WUR-Data field with WUR HDR(11ba)) |

**Table 30-6—Values of pseudorandom cyclic shift with cyclic shift index *n* for the WUR-Sync field and WUR-Data field with WUR HDR(11ba)**

| *n* | $T_{CSR,Sym}^{n}$ (ns) |
|---|---|
| 0 | 0 |
| 1 | –200 |
| 2 | –400 |
| 3 | –600 |
| 4 | –800 |
| 5 | –1000 |
| 6 | –1200 |
| 7 | –1400 |

### 30.3.9 WUR preamble

#### 30.3.9.1 Introduction

The WUR PHY supports two data rates for the WUR-Data field: (i) 62.5 kb/s, which is denoted as WUR LDR. (ii) 250 kb/s, which is denoted as WUR HDR.

The data rate of the WUR-Data field of a WUR PPDU is indicated by the WUR-Sync field. There is no explicit field in a WUR PPDU to indicate the data rate. To indicate WUR LDR for the WUR-Data field of a WUR PPDU, a repeated sequence ([*W W*]) is transmitted. Here, *W* is a 32-bit sequence and 64 μs long as defined in Equation (30-9). To indicate WUR HDR for the WUR-Data field of a WUR PPDU, a bitwise complement of the sequence *W* is transmitted.


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**Table 30-7—Values of pseudorandom cyclic shift with cyclic shift index *n* for the WUR-Data field with WUR LDR(11ba)**

| *n* | $T^{n}_{CSR,\,Sym}$ (ns) |
|---|---|
| 0 | 0 |
| 1 | –400 |
| 2 | –800 |
| 3 | –1200 |
| 4 | –1600 |
| 5 | –2000 |
| 6 | –2400 |
| 7 | –2800 |

**Table 30-8—The states of the LFSR, the values of the bits b2, b1, b0, the value of n, and the pseudorandom cyclic shift with cyclic shift index n for the first seven (#4730)(#4055)WUR OOK symbols in the WUR-Sync field(11ba)**

| Time Step | LFSR X7...X1 | b2 b1 b0 | Index *n* | $T^{n}_{CSR,\,Sym}$ (ns) |
|---|---|---|---|---|
| 1 | 1 1 1 1 1 1 1 | 1 1 1 | 7 | –1400 |
| 2 | 1 1 1 1 1 1 0 | 1 1 0 | 6 | –1200 |
| 3 | 1 1 1 1 1 0 0 | 1 0 0 | 4 | –800 |
| 4 | 1 1 1 1 0 0 0 | 0 0 0 | 0 | 0 |
| 5 | 1 1 1 0 0 0 0 | 0 0 0 | 0 | 0 |
| 6 | 1 1 0 0 0 0 1 | 0 0 1 | 1 | –200 |
| 7 | 1 0 0 0 0 1 1 | 0 1 1 | 3 | –600 |

### 30.3.9.2 Non-WUR portion of WUR PHY preamble

The Non-WUR portion of the WUR PHY preamble consists of five fields: L-STF, L-LTF, L-SIG, BPSK-Mark1, and BPSK-Mark2.

#### 30.3.9.2.1 L-STF definition

The time domain representation of the L-STF field, transmitted on transmit chain $i_{TX}$, shall be as specified in Equation (30-4).

$$r^{(i_{TX})}_{L-STF}(t) = \frac{1}{\sqrt{N^{Tone}_{L-STF}N_{TX}}} w_{T_{L-STF}}(t) \sum_{i_{BW}\in\Omega_{20MHz}} \sum_{k=-26}^{26} (\Upsilon_{(k-K_{shift}(i_{BW})),\,BW} S_{k,\,20} \exp(j2\pi(k-K_{shift}(i_{BW}))\Delta_f(t-T^{i_{TX}}_{CS}))) \quad (30\text{-}4)$$

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where

$N_{L-STF}^{Tone}$ has the value given in Table 21-8 (Tone scaling factor and guard interval duration values for PHY fields).

$T_{CS}^{i_{TX}}$ represents the cyclic shift for transmitter chain $i_{TX}$ with a value given in Table 21-10 (Cyclic shift values for L-STF, L-LTF, L-SIG, and VHT-SIG-A fields of the PPDU).

$\Omega_{20MHz}$ is the set of 20 MHz subchannels that are occupied.

$i_{BW}$ is the index of 20 MHz subchannels, $0 \le i_{BW} \le N_{20MHz}$, and $N_{20MHz}$ is the number of 20 MHz subchannels in the bandwidth indicated by dot11CurrentChannelWidth.

$S_{k,20}$ is defined as $S_{-26,26}$ in Equation (19-8).

$\Upsilon_{k,BW}$ is defined by Equation (21-14), Equation (21-15), and Equation (21-16).

$K_{shift}(i) = 32 \times (N_{20MHz} - 1 - 2i)$.

$\Delta_f$ is the subcarrier frequency spacing given in Table 21-5 (Timing-related constants).

#### 30.3.9.2.2 L-LTF definition

The time domain representation of the L-LTF field, transmitted on transmit chain $i_{TX}$, shall be as specified in Equation (30-5).

$$r_{L-LTF}^{(i_{TX})}(t) = \frac{1}{\sqrt{N_{L-LTF}^{Tone} N_{TX}}} w_{T_{L-LTF}}(t) \sum_{i_{BW} \in \Omega_{20MHz}} \sum_{k=-26}^{26} (\Upsilon_{(k-K_{shift}(i_{BW})),BW} L_{k,20} \exp(j2\pi(k - K_{shift}(i_{BW}))\Delta_f(t - T_{GI,2} - T_{CS}^{i_{TX}}))) \quad (30\text{-}5)$$

where

$N_{L-LTF}^{Tone}$ has the value given in Table 21-8 (Tone scaling factor and guard interval duration values for PHY fields).

$L_{k,20}$ is defined as $L_{-26,26}$ in Equation (17-8).

$T_{GI,2}$ is the GI duration for L-LTF defined in Table 21-5 (Timing-related constants).

Other variables are defined below Equation (30-4).

#### 30.3.9.2.3 L-SIG field definition(#4145)

The L-SIG field is used to communicate rate and length information. The structure of the L-SIG field is defined in Figure 17-5 (SIGNAL field bit assignment).

In a WUR PPDU, the RATE field shall be set to the value representing 6 Mb/s in the 20 MHz channel spacing column of Table 17-6 (Contents of the SIGNAL field).

The LENGTH field shall be set to the value given by Equation (21-24). The value of TXTIME is described in 30.4.1 (TXTIME and PSDU length calculation).

The LSB of the binary expression of the Length value shall be mapped to B5.

The Reserved (R) field shall be set to 0.

The Parity (P) field has the even parity of bits 0–16.

The SIGNAL TAIL field shall be set to 0.


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The L-SIG field shall be encoded, interleaved, and mapped following the steps described in 17.3.5.6 (Convolutional encoder), 17.3.5.7 (Data interleaving), and 17.3.5.8 (Subcarrier modulation mapping). The stream of 48 complex numbers generated by these steps is denoted by $d_k$, $k = 0, \ldots, 47$. Pilots shall be inserted as described in 17.3.5.9 (Pilot subcarriers).

The time domain representation of the L-SIG field, transmitted on transmit chain $i_{TX}$, shall be as specified in Equation (30-6).

$$r_{L-SIG}^{(i_{TX})}(t) = \frac{1}{\sqrt{N_{L-SIG}^{Tone} N_{TX}}} w_{T_{L-SIG}}(t) \sum_{i_{BW} \in \Omega_{20MHz}} \sum_{k=-26}^{26} (\Upsilon_{(k-K_{shift}(i_{BW})),\,BW}(D_{k,20} + p_0 P_k) \exp(j2\pi(k - K_{shift}(i_{BW}))\Delta_f(t - T_{GI} - T_{CS}^{i_{TX}}))) \quad (30\text{-}6)$$

where

$N_{L-SIG}^{Tone}$ has the value given in Table 21-8 (Tone scaling factor and guard interval duration values for PHY fields).

$$D_{k,20} = \begin{cases} 0, k = 0, \pm 7, \pm 21 \\ d_{M_{20}^{r}(k)}, otherwise \end{cases}$$

$$M_{20}^{r}(k) = \begin{cases} k+26, -26 \le k \le -22 \\ k+25, -20 \le k \le -8 \\ k+24, -6 \le k \le -1 \\ k+23, 1 \le k \le 6 \\ k+22, 8 \le k \le 20 \\ k+21, 22 \le k \le 26 \end{cases}.$$

$p_0$ is the first pilot value in the sequence defined in 17.3.5.10 (OFDM modulation).

$P_k$ is defined in 17.3.5.10 (OFDM modulation).

$T_{GI}$ is the GI duration defined in Table 21-5 (Timing-related constants).

Other variables are defined below Equation (30-4).

#### 30.3.9.2.4 BPSK-Mark1 definition

The BPSK-Mark1 field is derived from the L-SIG field and is used to spoof HT STAs from false PPDU format detection.

The time domain waveform of the BPSK-Mark1 field, transmitted on transmit chain $i_{TX}$, shall be as specified in Equation (30-7).

$$r_{BPSK-Mark1}^{(i_{TX})}(t) = \frac{1}{\sqrt{N_{L-SIG}^{Tone} N_{TX}}} w_{T_{BPSK-Mark1}}(t) \sum_{i_{BW} \in \Omega_{20MHz}} \sum_{k=-26}^{26} (\Upsilon_{(k-K_{shift}(i_{BW})),\,BW}(-D_{k,20} + p_1 P_k) \exp(j2\pi(k - K_{shift}(i_{BW}))\Delta_f(t - T_{GI} - T_{CS}^{i_{TX}}))) \quad (30\text{-}7)$$

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where

$p_1$ is the second pilot value in the sequence defined in 17.3.5.10 (OFDM modulation).

Other variables are defined below Equation (30-4) and Equation (30-6).

#### 30.3.9.2.5 BPSK-Mark2 definition

The BPSK-Mark2 field is derived from the L-SIG field and is used to spoof VHT STAs from false PPDU format detection.

The time domain waveform of the BPSK-Mark2 field, transmitted on transmit chain $i_{TX}$, shall be as specified in Equation (30-8).

$$r_{BPSK-Mark2}^{(i_{TX})}(t) = \frac{1}{\sqrt{N_{L-SIG}^{Tone} N_{TX}}} w_{T_{BPSK-Mark2}}(t) \sum_{i_{BW} \in \Omega_{20MHz}} \sum_{k=-26}^{26} (\Upsilon_{(k-K_{shift}(i_{BW})),BW}(-D_{k,20} + p_2 P_k) \exp(j2\pi(k - K_{shift}(i_{BW}))\Delta_f(t - T_{GI} - T_{CS}^{i_{TX}}))) \quad (30\text{-}8)$$

where

$p_2$ is the third pilot value in the sequence defined in 17.3.5.10 (OFDM modulation).

Other variables are defined below Equation (30-4) and Equation (30-6).

### 30.3.9.3 WUR-Sync field

#### 30.3.9.3.1 Introduction

The structure of the WUR-Sync field depends on the data rate of the WUR-Data field. For WUR LDR, the duration of the WUR-Sync field is 128 µs. For WUR HDR, the duration of the WUR-Sync field is 64 µs. The WUR-Sync field is used by the receiver for PPDU detection, symbol timing recovery and determination of the data rate.

#### 30.3.9.3.2 Cyclic Shift for WUR-Sync field

(#4370)(#4055)A cyclic shift should be applied to the WUR-Sync field when multi-antenna WUR OOK signals are transmitted to minimize unintentional beamforming.

(#4370)(#4055)When MC-OOK is used to generate the WUR OOK symbols the recommended cycle shift diversity (CSD) values for the WUR-Sync field, which is constructed from 2 µs duration WUR OOK symbols, are provided in Annex AC.

#### 30.3.9.3.3 WUR-Sync field for WUR LDR

For WUR LDR, the WUR-Sync field shall be constructed as a (#4370)(#4055)WUR OOK signal. The WUR-Sync sequence is constructed by concatenating two copies of the 32-bit sequence $W$, where each bit in the sequence is mapped to a (#4370)(#4055)WUR OOK symbol of duration 2 µs, and $W$ is defined in Equation (30-9).

$$W = [1\ 0\ 1\ 0\ 0\ 1\ 0\ 0\ 1\ 0\ 1\ 1\ 1\ 0\ 1\ 1\ 0\ 0\ 0\ 1\ 0\ 1\ 1\ 1\ 0\ 0\ 1\ 1\ 1\ 0\ 0\ 0] \quad (30\text{-}9)$$

This WUR-Sync sequence is used to construct the WUR-Sync field waveform as shown in Figure 30-4.



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#### 30.3.9.3.4 WUR-Sync field for WUR HDR

For WUR HDR, the WUR-Sync field shall be constructed as a (#4370)(#4055)WUR OOK signal. The WUR-Sync sequence is constructed as the bitwise complement of the 32-bit sequence $W$, where each bit in the sequence is mapped to a (#4370)(#4055)WUR OOK symbol of duration 2 μs, and $W$ is defined in Equation (30-9). This bitwise complement sequence is defined in Equation (30-10).

$$\overline{W} = \left[0\ 1\ 0\ 1\ 1\ 0\ 1\ 1\ 0\ 1\ 0\ 0\ 0\ 1\ 0\ 0\ 1\ 1\ 1\ 0\ 1\ 0\ 0\ 0\ 1\ 1\ 0\ 0\ 0\ 1\ 1\ 1\right] \quad (30\text{-}10)$$

This Sync-bit sequence is used to construct the WUR-Sync field waveform as shown in Figure 30-4 (An example of a WUR signal generator for the WUR-Sync field(11ba)).

### 30.3.10 WUR-Data field

#### 30.3.10.1 Cyclic Shift for WUR-Data field

(#4370)(#4055)A cyclic shift should be applied to the WUR-Data field when multi-antenna WUR OOK signals are transmitted to minimize unintentional beamforming.

(#4370)(#4055)When MC-OOK is used to generate the WUR OOK symbols the recommended cycle shift diversity (CSD) values for the WUR-Data field with WUR LDR, which is constructed from 4 μs duration (#4370)(#4055)WUR OOK symbols, are provided in Annex AC.

(#4370)(#4055)When MC-OOK is used to generate the WUR OOK symbols the recommended cycle shift diversity (CSD) values for the WUR-Data field with WUR HDR, which is constructed from 2 μs duration (#4370)(#4055)WUR OOK symbols, are provided in Annex AC.

#### 30.3.10.2 WUR-Data field for WUR LDR and WUR HDR

The WUR-Data field shall be encoded by WUR encoding. Encoded bits corresponding to each input bit are shown in Table 30-9 (WUR encoded bits for WUR LDR(11ba)) and Table 30-10 (WUR encoded bits for WUR HDR(11ba)) for WUR LDR and WUR HDR, respectively.

**Table 30-9—WUR encoded bits for WUR LDR(11ba)**

| Input bit | Encoded bits |
|---|---|
| 0 | 1010 |
| 1 | 0101 |

**Table 30-10—WUR encoded bits for WUR HDR(11ba)**

| Input bit | Encoded bits |
|---|---|
| 0 | 10 |
| 1 | 01 |

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The encoded binary data shall be modulated (#3070)so that encoded bits 0 and 1 shall be represented by Off and (#7174)On symbols, respectively. The duration of the (#4370)(#4055)WUR OOK symbol corresponding to each encoded bit is dependent on WUR data rate: 4 µs for WUR LDR and 2 µs for WUR HDR.

For WUR LDR, 4 µs duration (#4370)(#4055)(#7174)WUR OOK Off and On symbols are denoted as SymLDROff and SymLDROn, respectively. For WUR HDR, 2 µs duration (#4370)(#4055)(#7174)WUR OOK Off and On symbols are denoted as SymHDROff and SymHDROn, respectively.

SymLDROn and SymHDROn should be generated (#3279)using 13 contiguous subcarriers, centered within a 20 MHz channel, with a subcarrier spacing of 312.5 kHz and the center subcarrier being null. The subcarrier coefficients may take values from the BPSK, QPSK, 16-QAM, 64-QAM, or 256-QAM constellations(M95).

When a single 20 MHz WUR channel is used for transmission of a WUR Basic PPDU, SymHDROn and SymLDROn are described in 30.3.8 (Mathematical description of signals). The generation of SymHDROn and SymLDROn is described in 30.3.4.1 (WUR Basic PPDU waveform generation for WUR-Sync field and WUR-Data field with WUR HDR) and 30.3.4.2 (WUR Basic PPDU waveform generation for WUR-Data field with WUR LDR), respectively.

For a FDMA transmission, the (#4370)(#4055)WUR OOK waveform generation is described in 30.3.4.3 (WUR FDMA PPDU WUR-Data field waveform generation).

### 30.3.11 WUR Padding field for a WUR FDMA PPDU

For a WUR FDMA PPDU, if padding is needed on any 20 MHz subchannels, the padding waveform shall be generated by repeating the (#4370)(#4055)WUR OOK waveform of WUR HDR information bit 1 as described in Table 30-14 (WUR PPDU data rates(11ba)). The symbol randomizer as described in 30.3.4.4 (Symbol Randomizer and Per-transmit chain Cyclic Shift) should be used in the padding field continued from the WUR-Data field. The state of the LSFR is updated every $T_{Sym-HDR}$ during the padding field.

For a nonpunctured WUR FDMA 20 MHz subchannel, $i_{BW}$, the number of padding WUR HDR bits is calculated as:

$$N_{pad,\,i_{BW}} = \frac{\max\limits_{j_{BW} \in \Omega_{20MHz}} \left\{ T_{WUR-Sync,\,j_{BW}} + T_{Sym,\,j_{BW}} \times N_{Sym,\,j_{BW}} \right\} - \left( T_{WUR-Sync,\,i_{BW}} + T_{Sym,\,i_{BW}} \times N_{Sym,\,i_{BW}} \right)}{4} \quad (30\text{-}11)$$

where

$T_{WUR-Sync,\,i_{BW}}$ and $T_{Sym,\,i_{BW}}$ denote $T_{WUR-Sync}$ and $T_{Sym}$ for 20 MHz subchannel $i_{BW}$, respectively. $T_{WUR-Sync}$ and $T_{Sym}$ are defined in Table 30-3 (Timing-related constants(11ba)).

$N_{Sym,\,i_{BW}}$ is the number of (#4370)(#4055)WUR OOK symbols in the WUR-Data field for 20 MHz subchannel. It is a function of the length of WUR MAC frame in the WUR-Data field (WUR_MPDU_LENGTH) for 20 MHz subchannel $i_{BW}$ and $N_{SPDB}$ as defined in Equation (30-14).

### 30.3.12 WUR transmit specification

#### 30.3.12.1 Transmit spectrum mask

For operation using 20 MHz channel spacing, the transmitted spectrum of the L-STF, L-LTF, L-SIG, BPSK-Mark1, and BSPK-Mark2 fields shall have a 0 dBr (dB relative to the maximum spectral density of the signal) bandwidth not exceeding 18 MHz, –20 dBr at 11 MHz frequency offset, –28 dBr at 20 MHz


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frequency offset, and the maximum of –40 dBr and –53 dBm/MHz at 30 MHz frequency offset and above. The transmitted spectral density of the L-STF, L-LTF, L-SIG, BPSK-Mark1, and BPSK-Mark2 fields of the transmitted signal shall fall within the spectral mask, as shown in Figure 17-13 (Transmit spectrum mask for 20 MHz transmission).

NOTE 1—In the presence of additional regulatory restrictions, the device has to meet both the regulatory requirements and the mask defined in this subclause.

NOTE 2—Transmit spectral mask in Figure 17-13 (Transmit spectrum mask for 20 MHz transmission) is not drawn to scale.

NOTE 3—For rules regarding TX center frequency leakage levels, the power measured at the center of transmission BW using resolution BW 312.5 kHz cannot exceed *P*-17.5, where *P* is the transmit power per antenna in dBm during transmission of the L-SIG field.

For operation using 20 MHz channel spacing, the transmitted spectrum of the WUR-Sync and WUR-Data fields shall have a 0 dBr (dB relative to the maximum spectral density of the signal) bandwidth not exceeding 4.5 MHz, –15 dBr at 3.5 MHz frequency offset, –20 dBr at 11 MHz frequency offset, –28 dBr at 20 MHz frequency offset, and the maximum of –40 dBr and –53 dBm/MHz at 30 MHz frequency offset and above.

The transmitted spectral density of the WUR-Sync and WUR-Data fields of the transmitted signal shall fall within the spectral mask, as shown in Figure 30-11 (Transmit spectrum mask for WUR-Sync and WUR-Data fields of WUR Basic PPDU transmission(11ba)).

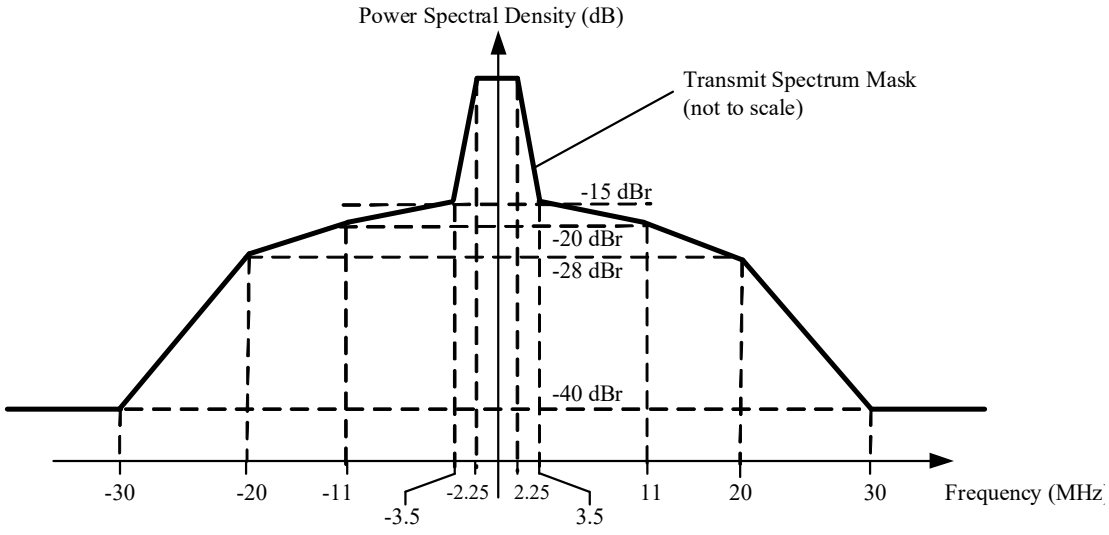


**Figure 30-11—Transmit spectrum mask for WUR-Sync and WUR-Data fields of WUR Basic PPDU transmission(11ba)**

For a WUR FDMA PPDU, the spectrum mask within each 20 MHz subchannel is the same as the spectrum mask of 20 MHz WUR Basic PPDU as defined above. The spectrum outside the WUR FDMA PPDU channel bandwidth is the same as spectrum mask of 40 MHz or 80 MHz as defined in 21.3.17.1 (Transmit spectrum mask).

For a 40 MHz mask WUR FDMA PPDU, the transmitted spectrum of the L-STF, L-LTF, L-SIG, BPSK-Mark1, and BPSK-Mark2 fields shall have a 0 dBr (dB relative to the maximum spectral density of the

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signal) bandwidth not exceeding 38 MHz, –20 dBr at 21 MHz frequency offset, –28 dBr at 40 MHz frequency offset, and the maximum of –40 dBr and –56 dBm/MHz at 60 MHz frequency offset and above. The transmitted spectral density of the L-STF, L-LTF, L-SIG, BPSK-Mark1, and BPSK-Mark2 fields of the transmitted signal shall fall within the spectral mask, as shown in Figure 21-30 (Example transmit spectral mask for 40 MHz mask PPDU).

For a 40 MHz mask WUR FDMA PPDU, the transmitted spectrum of the WUR-Sync and WUR-Data fields within each 20 MHz subchannel shall have a 0 dBr (dB relative to the maximum spectral density of the signal) bandwidth not exceeding 4.5 MHz from the center of the 20 MHz subchannel, –15 dBr at 3.5 MHz, and –20 dBr at 11 MHz frequency offset from the center of the 20 MHz subchannel. The transmitted spectrum of the WUR-Sync and WUR-Data fields shall have –28 dBr at 40 MHz frequency offset, and the maximum of –40 dBr and –56 dBm/MHz at 60 MHz frequency offset and above. The transmitted spectral density of the WUR-Sync and WUR-Data fields of the transmitted signal shall fall within the spectral mask, as shown in Figure 30-12 (Transmit spectrum mask for WUR-Sync and WUR-Data fields of 40 MHz WUR FDMA PPDU transmission(11ba)).

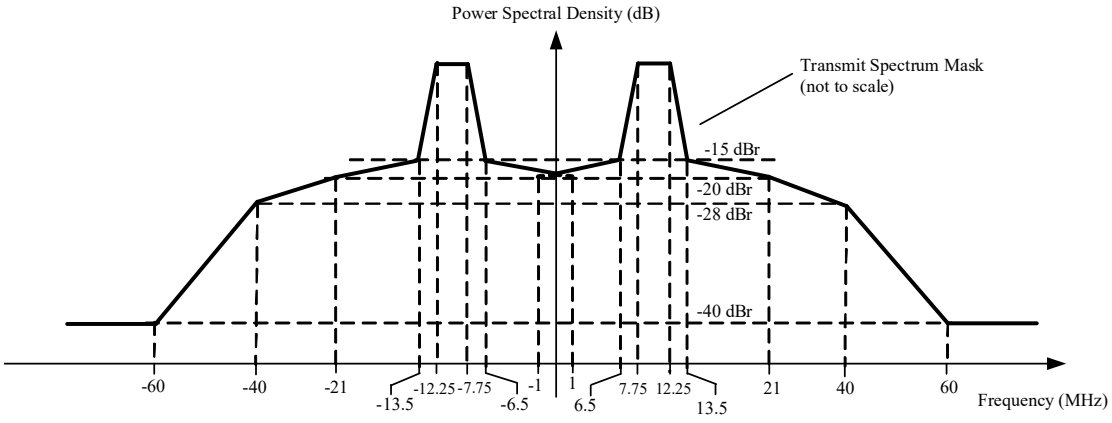


**Figure 30-12—Transmit spectrum mask for WUR-Sync and WUR-Data fields of 40 MHz WUR FDMA PPDU transmission(11ba)**

For a 80 MHz mask WUR FDMA PPDU, the transmitted spectrum of the L-STF, L-LTF, L-SIG, BPSK-Mark1, and BPSK-Mark2 fields shall have a 0 dBr (dB relative to the maximum spectral density of the signal) bandwidth not exceeding 78 MHz, –20 dBr at 41 MHz frequency offset, –28 dBr at 80 MHz frequency offset, and the maximum of –40 dBr and –59 dBm/MHz at 120 MHz frequency offset and above. The transmitted spectral density of the L-STF, L-LTF, L-SIG, BPSK-Mark1, and BPSK-Mark2 fields of the transmitted signal shall fall within the spectral mask, as shown in Figure 21-31 (Example transmit spectral mask for 80 MHz mask PPDU).

For an 80 MHz mask WUR FDMA PPDU, the transmitted spectrum of the WUR-Sync and WUR-Data fields within each 20 MHz subchannel shall have a 0 dBr (dB relative to the maximum spectral density of the signal) bandwidth not exceeding 4.5 MHz from the center of the 20 MHz subchannel, –15 dBr at 3.5 MHz, –20 dBr at 11 MHz frequency offset from the center of the 20 MHz subchannel. The transmitted spectrum of the WUR-Sync and WUR-Data fields shall have –28 dBr at 80 MHz frequency offset, and the maximum of –40 dBr and –59 dBm/MHz at 120 MHz frequency offset and above. The transmitted spectral density of the WUR-Sync and WUR-Data fields of the transmitted signal shall fall within the spectral mask,


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as shown in Figure 30-13 (Transmit spectrum mask for WUR-Sync and WUR-Data fields of 80 MHz WUR FDMA PPDU transmission(11ba)).

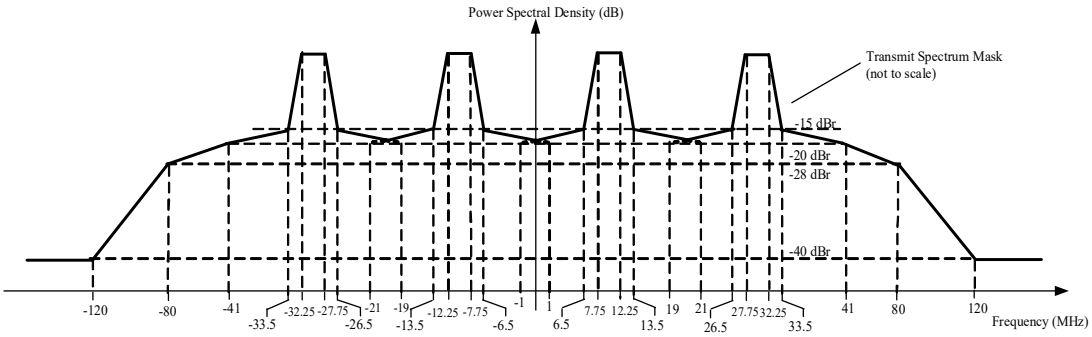


**Figure 30-13—Transmit spectrum mask for WUR-Sync and WUR-Data fields of 80 MHz WUR FDMA PPDU transmission(11ba)**

### 30.3.12.2 Spectral flatness

The spectral flatness is measured by comparing the power in any contiguous 1 MHz segment within the center 4 MHz of the 20 MHz channel to the total transmitted power in the center 4 MHz.

The transmitted power is measured in the manner described in 5.4.3.2.1 of [B10] for equipment with continuous and noncontinuous transmissions.

Let $P_{4MHz}$ indicate the total power in the center 4 MHz. The average power over a 1 MHz segment, within the center 4 MHz, is given by, $P_{ave} = P_{4MHz} - 6$ dB. The requirement is that the power in any 1 MHz segment, within the center 4 MHz, is (#6119)in the range [$P_{ave} - 6$ dB, $P_{ave} + 3$ dB].

For FDMA transmission, this applies to each 20 MHz channel.

### 30.3.12.3 Transmit center frequency and symbol clock frequency tolerance

The symbol clock frequency and transmit center frequency tolerance shall be ±20 ppm maximum. The transmit center frequency and the symbol clock frequency for all transmit antennas and frequency segments shall be derived from the same reference oscillator.

### 30.3.12.4 Transmit On and Off symbols power ratio(#7174)

For each input bit of the WUR-Data field transmitted at WUR HDR, the ratio between the averaged power of the (#7174)On symbol and the averaged power of the (#7174)Off symbol of the transmit signal in the WUR-Data field shall be at least 20 dB.

For each input bit of the WUR-Data field transmitted at WUR LDR, the ratio between the averaged power over (#7174)On symbols and the averaged power over (#7174)Off symbols of the transmit signal in the WUR-Data field shall be at least 20 dB.

For the WUR-Sync field transmission, the ratio between the averaged power over all (#7174)On symbols and the averaged power over all (#7174)Off symbols in the WUR-Sync field shall be at least 20 dB.

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For FDMA transmission, the above requirement on the transmit (#7174)On and Off symbols power ratio applies to each 20 MHz channel.

### 30.3.12.5 Correlation test on (#4370)(#4055)WUR OOK symbols

An autocorrelation metric indicative of that used for L-STF detection in non-WUR receivers is defined. The correlation metric is given in Equation (30-12),

$$C(n)=\left|\left(\frac{N}{N-1}\right)\frac{\sum_{k=0}^{M(N-1)-1} x(n+k)x^{*}(n+k+M)}{\sum_{k=0}^{MN-1}|x(n+k)|^{2}}\right| \quad (30\text{-}12)$$

where $M$ = 16, which is the number of samples in an 800 ns time period, sampled at 20 MHz, and $N$=6, which is the number of 800 ns time periods over which the correlation metric is calculated.

This metric is calculated over the WUR-Sync and WUR-Data fields, at a sampling rate of 20 MHz using the (#4370)(#4055)WUR OOK symbols. Hence, the value of $n$ spans from the beginning of the WUR-Sync field to the end of the WUR-Data field. The PPDU should be tested for both the WUR LDR and WUR HDR with a 6-byte data field of random data. The maximum value of the correlation metric should be less than 0.4.

### 30.3.13 WUR receiver specification

The input levels are measured at the antenna connectors and are referenced as the average power per receive antenna.

### 30.3.13.1 Receiver minimum input sensitivity

The packet error ratio (PER) shall be less than 10% for a PSDU length of 6 octets with the rate-dependent input levels listed in Table 30-11 (Receiver minimum input level sensitivity(11ba)).

**Table 30-11—Receiver minimum input level sensitivity(11ba)**

| Modulation | Minimum sensitivity (dBm) |
|---|---|
| WUR LDR | –82 |
| WUR HDR | –77 |

### 30.3.13.2 Adjacent channel rejection

Adjacent channel rejection shall be measured by setting the desired signal's strength 3 dB above the rate dependent sensitivity specified in Table 30-11 (Receiver minimum input level sensitivity(11ba)) and raising the power of the interfering signal of 20 MHz bandwidth until 10% PER is caused for a WUR PSDU length of 6 octets. The power difference between the interfering and desired channel is the corresponding adjacent channel rejection. The center frequency of the adjacent channel shall be placed 20 MHz away from the center frequency of the desired signal.


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The interfering signal in the adjacent channel shall be a conformant OFDM signal, unsynchronized with the signal in the channel under test, and shall have a minimum duty cycle of 50%. The interfering signal shall be derived from a separate signal source. For a conforming OFDM PHY, the corresponding rejection shall be no less than specified in Table 30-12 (Minimum required adjacent and nonadjacent channel rejection levels(11ba)).

**Table 30-12—Minimum required adjacent and nonadjacent channel rejection levels(11ba)**

| Modulation | Adjacent channel rejection (dB) | Nonadjacent channel rejection (dB) |
|---|---|---|
| WUR LDR | 16 | 32 |
| WUR HDR | 11 | 27 |

### 30.3.13.3 Nonadjacent channel rejection

Nonadjacent channel rejection shall be measured by setting the desired signal's strength 3 dB above the rate dependent sensitivity specified in Table 30-11 (Receiver minimum input level sensitivity(11ba)) and raising the power of the interfering signal of 20 MHz bandwidth until 10% PER is caused for a WUR PSDU length of 6 octets. The power difference between the interfering and desired channel is the corresponding nonadjacent channel rejection. The center frequency of the nonadjacent channel shall be placed 40 MHz away from the center frequency of the desired signal.

The interfering signal in the nonadjacent channel shall be a conformant OFDM signal, unsynchronized with the signal in the channel under test, and shall have a minimum duty cycle of 50%. The interfering signal shall be derived from a separate signal source. For a conforming OFDM PHY, the corresponding rejection shall be no less than specified in Table 30-12 (Minimum required adjacent and nonadjacent channel rejection levels(11ba)).

### 30.3.13.4 Receiver maximum input level

The receiver shall provide a maximum PER of 10% at a WUR PSDU length of 6 octets, for a maximum input level of -30 dBm in 5 GHz band and –20 dBm in 2.4 GHz band, measured at each antenna for any baseband WUR modulation.

### 30.3.13.5 CCA sensitivity

The CCA sensitivity shall follow each CCA sensitivity specification for the attached non-WUR PHY as defined in 17.3.10.6 (CCA requirements) for OFDM, 19.3.19.6 (CCA sensitivity) for HT, 21.3.18.5 (CCA sensitivity) for VHT and 27.3.22.6 (CCA sensitivity) for HE depending on the Capabilities Element.

### 30.3.14 WUR transmit procedure

There are two options for the PHY transmit procedure: single channel and FDMA. The typical transmit procedures are shown in Figure 30-14 (PHY transmit procedure for a WUR Basic PPDU(11ba)) and Figure 30-15 (PHY transmit procedure for a WUR FDMA PPDU(11ba)). The first option is selected if the TXVECTOR CH_BANDWIDTH parameter is equal to WUR_CBW_20.

The second option is for the optional FDMA to transmit at a wider bandwidth if the TXVECTOR CH_BANDWIDTH parameter is not equal to WUR_CBW_20 (see Table 30-1 (TXVECTOR and RXVEC-

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TOR parameters(11ba))). In this option WUR PPDU is simultaneously generated and transmitted on each of the 20 MHz channels.

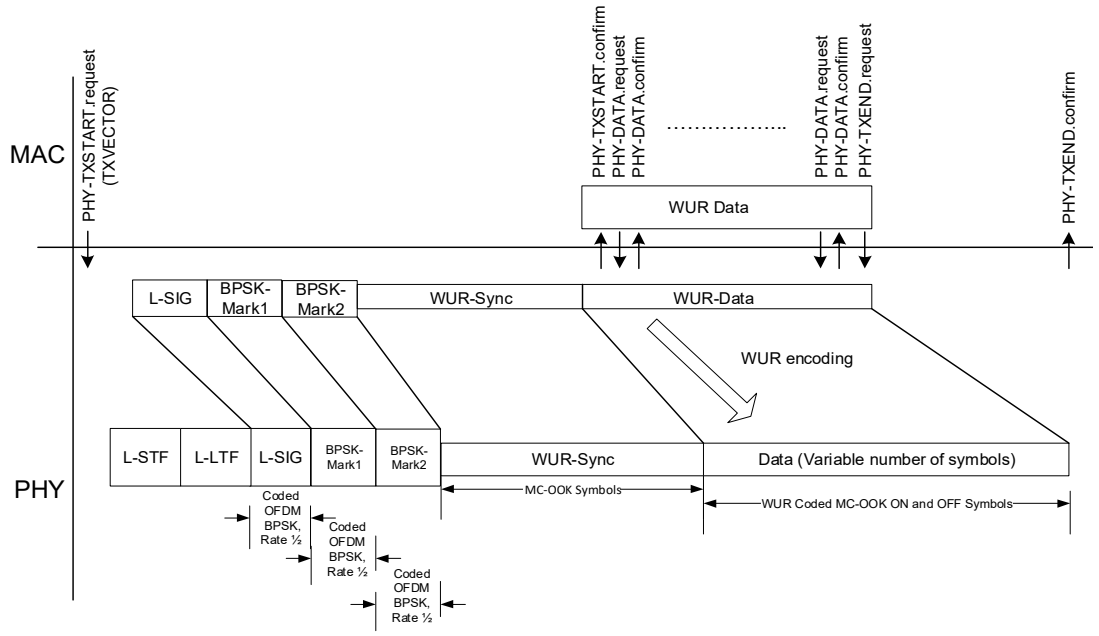


**Figure 30-14—PHY transmit procedure for a WUR Basic PPDU(11ba)**

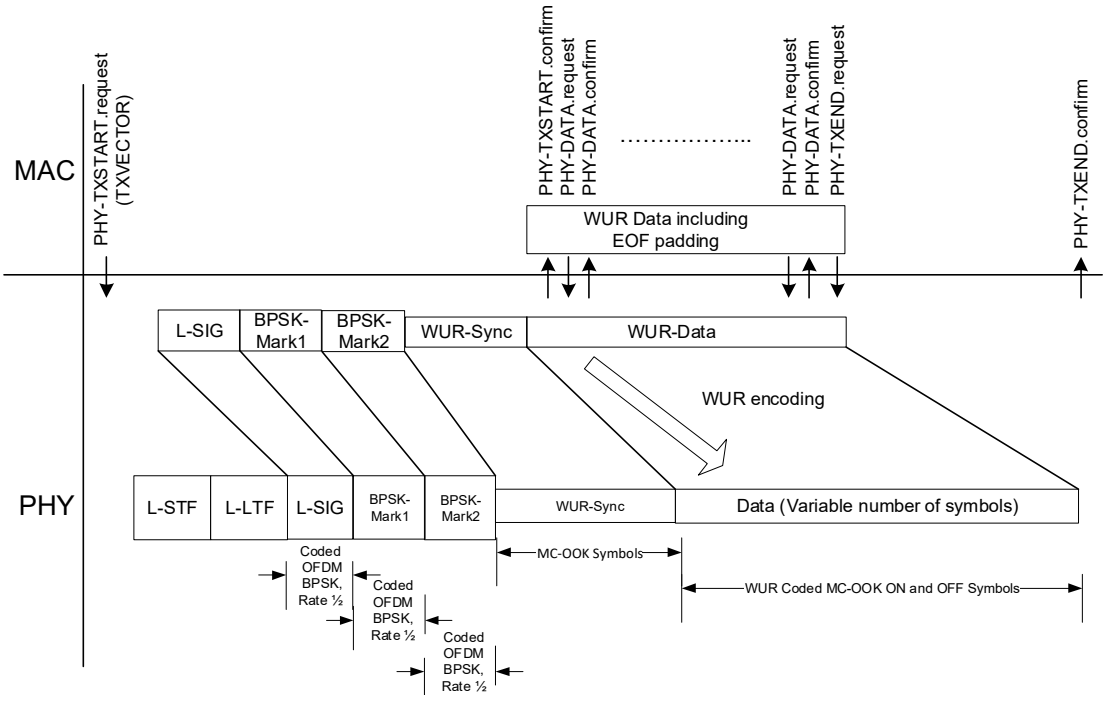


**Figure 30-15—PHY transmit procedure for a WUR FDMA PPDU(11ba)**


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For both options, in order to transmit data, the MAC generates a PHY-TXSTART.request primitive, which causes the PHY entity to enter the transmit state. Further, the PHY is set to operate at the appropriate frequency through station management via the PLME, as specified in 30.4 (WUR PLME). Other transmit parameters, such as transmit power, are set via the PHY-SAP using the PHY-TXSTART.request(TXVECTOR) primitive, as described in 30.2.2 (TXVECTOR and RXVECTOR parameters).

The PHY indicates the state of the primary channel and other channels for FDMA case via the PHY-CCA.indication primitive (see 30.3.13.5 (CCA sensitivity) and 8.3.5.12 (PHY-CCA.indication)). Transmission of the PPDU shall be initiated by the PHY after receiving the PHY-TXSTART.request(TXVECTOR) primitive. The TXVECTOR elements for the PHY-TXSTART.request primitive are specified in Table 30-1 (TXVECTOR and RXVECTOR parameters(11ba)).

After the PHY L-STF, L-LTF and L-SIG field (#4145)transmission are started, the PHY entity immediately initiates BPSK-Mark1 transmission and performs any required scrambling and data encoding if needed as defined by parameters of the TXVECTOR, as described in 30.2.2 (TXVECTOR and RXVECTOR parameters). After the BPSK-Mark1 transmission the PHY entity immediately initiates BPSK-Mark2 transmission and performs any required scrambling and data encoding if needed as defined by parameters of the TXVECTOR, as described in 30.2.2 (TXVECTOR and RXVECTOR parameters). After BPSK-Mark2 transmission is started, the PHY entity initiates transmission of WUR-Sync field according to the data rate defined in TXVECTOR. The Sync transmission is followed by WUR encoding of WUR-Data field as described in 30.3.4 (Transmitter block diagram). The data shall be exchanged between the MAC and the PHY through a series of PHY-DATA.request(DATA) primitives issued by the MAC, and PHY-DATA.confirm primitives issued by the PHY. In FDMA case, PHY padding bits are appended, as needed, to each 20 MHz channel to make the length of the PPDU equal to the Length indicated in L-SIG field(#4145).

A transmission may be prematurely terminated by the MAC through the PHY-TXEND.request primitive.

A WUR transmission is terminated by receiving a PHY-TXEND.request primitive. Each PHY-TXEND.request primitive is acknowledged with a PHY-TXEND.confirm primitive from the PHY. In a single channel WUR transmission, normal termination occurs after the transmission of the final bit of the last WUR octet indicated by $N_{octet}$, which is defined as the WUR MPDU LENGTH in octets. The maximum value of the parameter is given in 30.4.2 (Table of time and length characteristics). In WUR FDMA transmission, normal termination occurs after the transmission of the final bit of the last WUR octet indicated by $N_{max\_octet}$, which is defined as the maximum of WUR MPDU LENGTH in octets, over the 20 MHz channels. For a single channel WUR, $N_{max\_octet} = N_{octet}$.

When the WUR transmission is completed, the PHY entity enters the receive state.

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A typical state machine implementation of the transmit PHY for a WUR transmission is provided in Figure 30-16 (PHY transmit state machine(11ba)(#7214)). Request (.request) and confirmation (.confirm) primitives are issued once per state as shown.

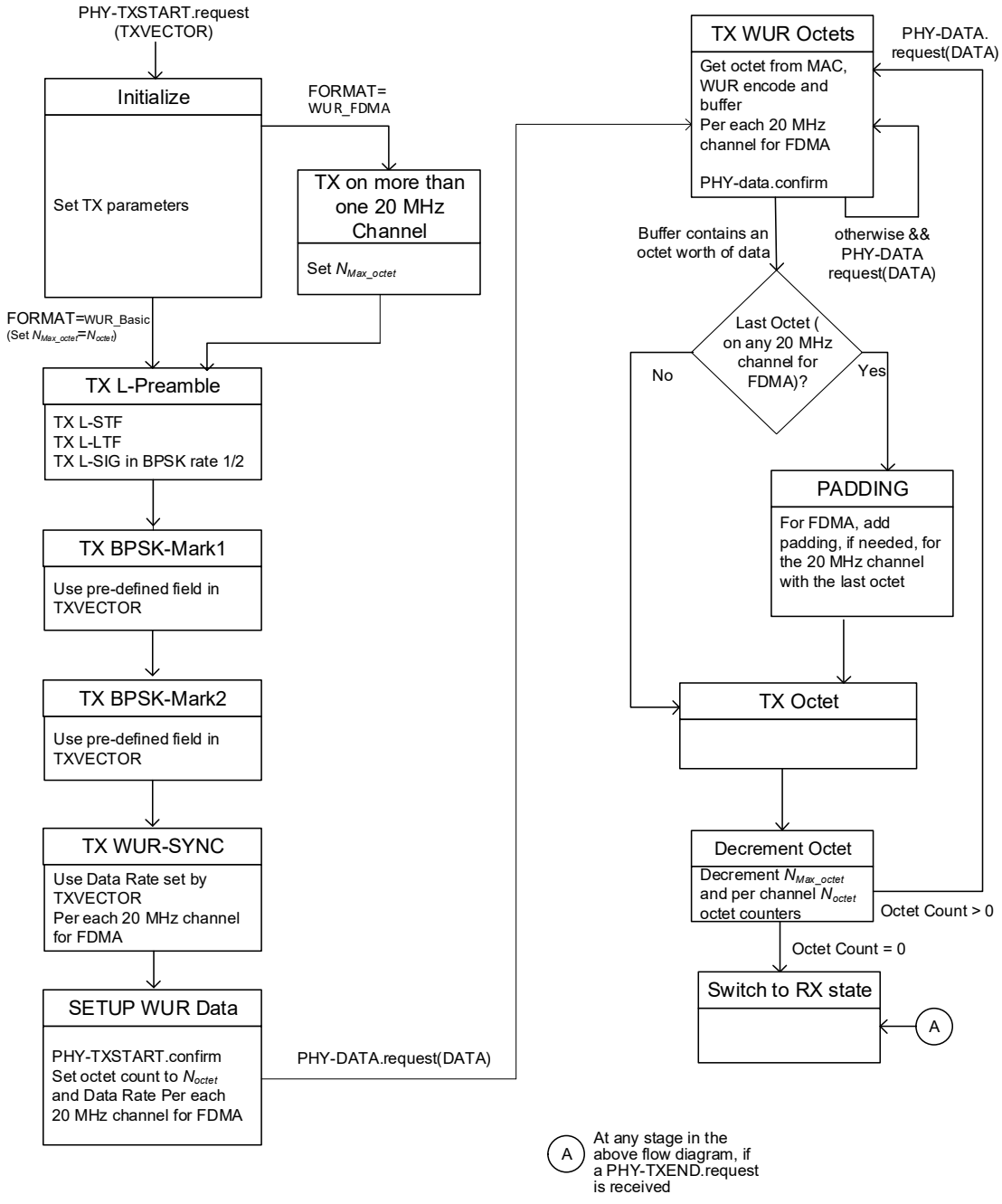


**Figure 30-16—PHY transmit state machine(11ba)(#7214)**



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### 30.3.15 WUR receive procedure

A typical PHY receive procedure is shown for WUR_Basic format in Figure 30-17 (PHY receive procedure for WUR Basic PPDU(11ba)(#3480)). A typical state machine implementation of the receive PHY is given in Figure 30-18 (PHY receive state machine(11ba)). The PHY is set to operate at the appropriate frequency through station management via the PLME, as specified in 30.4 (WUR PLME). The receive parameters, such as RSSI, may be accessed via the PHY-SAP.

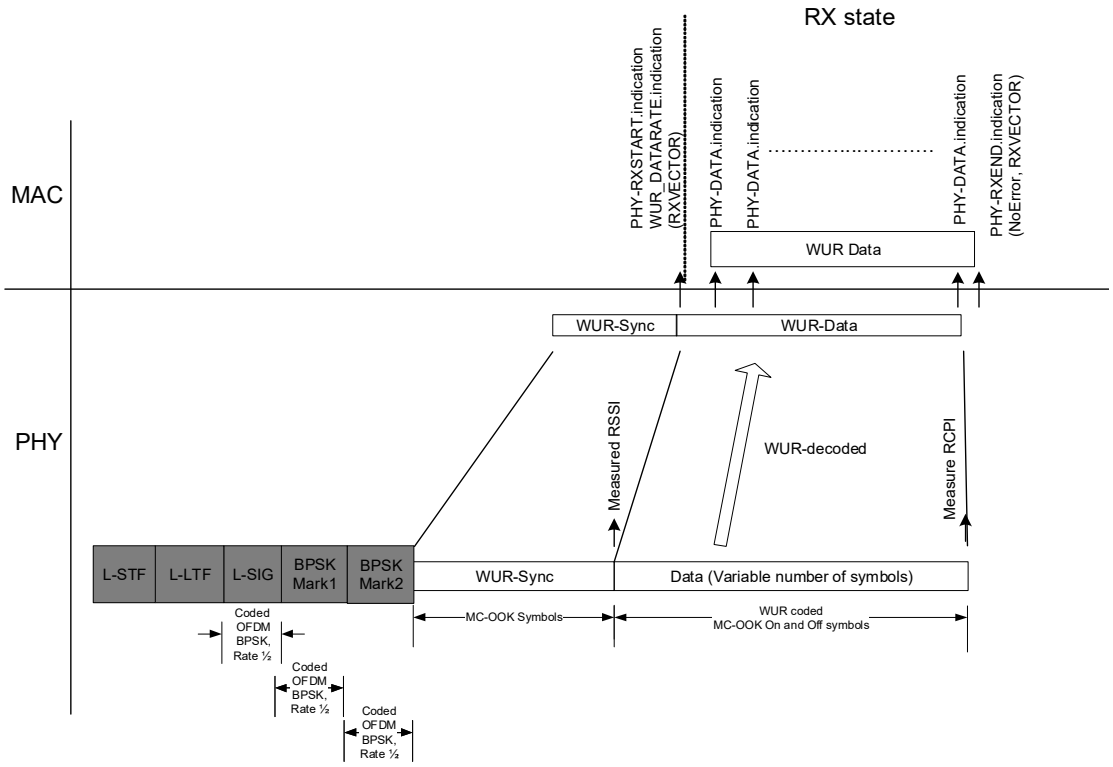


**Figure 30-17—PHY receive procedure for WUR Basic PPDU(11ba)(#3480)**

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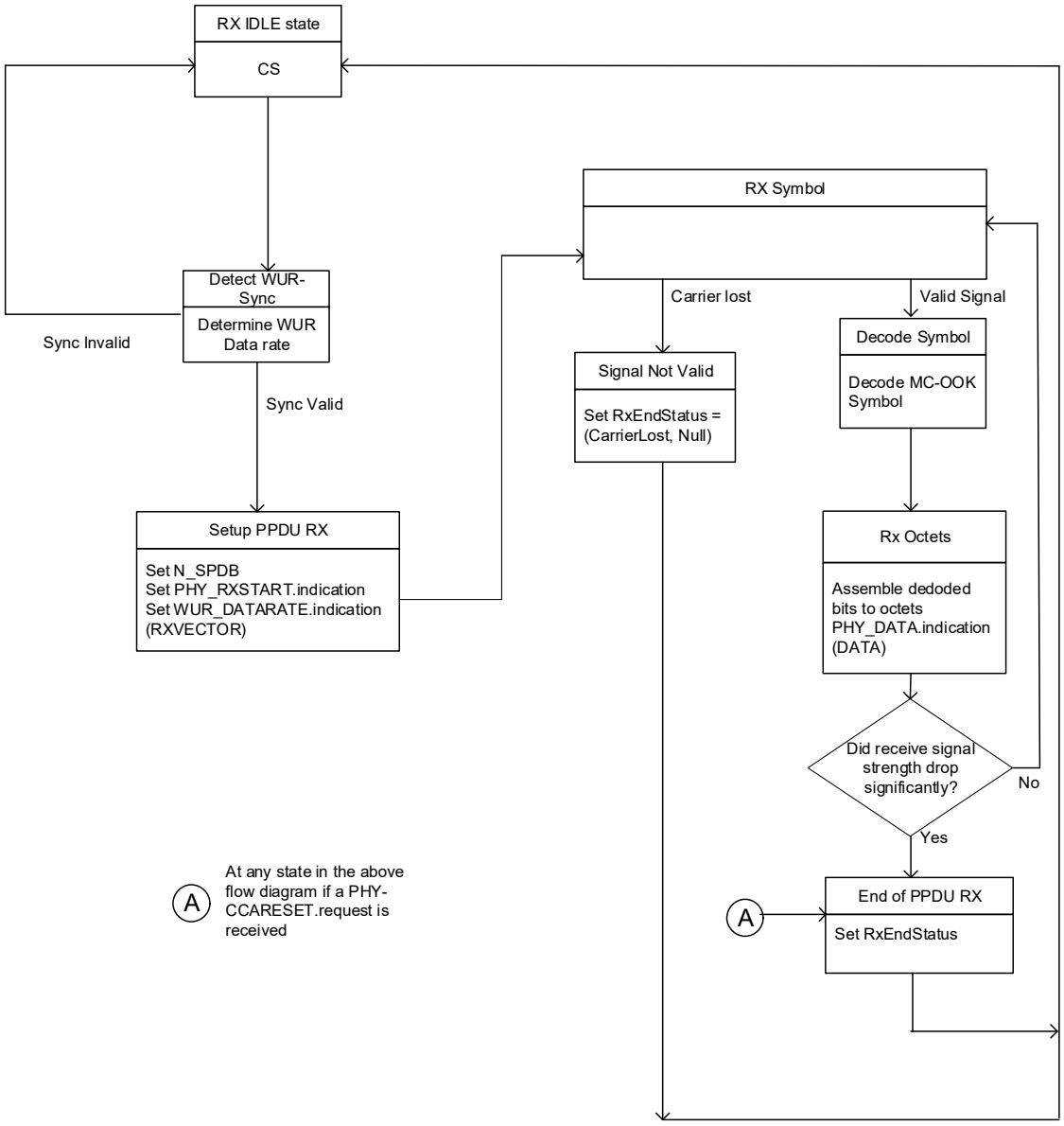


**Figure 30-18—PHY receive state machine(11ba)**

The PHY measures a receive signal strength and searches for a valid WUR-Sync sequence, in order to acquire WUR Basic PPDU, to determine the WUR data rate and the start of the WUR-Data field. If a valid WUR-Sync sequence is detected, WUR PHY issues PHY-RXSTART.indication primitive along with the WUR_DATARATE.indication. If the WUR-Sync sequence detection fails, a PHY-RXSTART.indication primitive is not issued, and WUR PHY goes back to RX IDLE state. RSSI measurement is made during the reception of the WUR-Sync field. Based on the WUR data rate, the PHY sets the $N_{SPDB}$ parameter as given in Table 30-4 (Frequently used parameters(11ba)).

The PHY entity shall begin receiving the (#4370)(#4055)WUR OOK symbols in the WUR-Data field. If signal loss occurs during reception, prior to completion of the PPDU reception, the error condition PHY-RXEND.indication (CarrierLost) shall be reported to the MAC. The received PPDU bits are decoded, assembled into octets and presented to the MAC using a series of PHY-DATA.indication (DATA) primitive


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exchanges. Any remaining bits, which could not be assembled into a complete octet are discarded. RCPI measurement is made during the reception of the (#2011)WUR-Sync field as described in 19.3.19.7 (Received channel power indicator (RCPI) measurement). Since the WUR PHY is not aware of the end of the WUR PPDU, the PHY shall keep decoding until receive signal strength drops significantly. Alternatively, the WUR MAC may also indicate the end of WUR PPDU to PHY by means of PHY-CCARESET.request primitive. On termination, the WUR PHY enters the RX IDLE state. If the WUR PHY terminates due to reduction of the receive signal strength, a PHY-RXEND.indication (NoError) primitive shall be issued. If it terminates due to PHY-CCARESET.request, a PHY-RXEND.indication (MAC Request) primitive shall be issued.

## 30.4 WUR PLME

### 30.4.1 TXTIME and PSDU length calculation

For a WUR Basic PPDU, the value of the TXTIME parameter shall be calculated as follows:

$$\text{TXTIME} = T_{L-STF} + T_{L-LTF} + T_{L-SIG} + T_{BPSK-Mark1} + T_{BPSK-Mark2} + T_{WUR-Sync} + T_{Sym} \times N_{Sym} \quad (30\text{-}13)$$

where

$T_{L\text{-}STF}$, $T_{L\text{-}LTF}$, $T_{L\text{-}SIG}$, $T_{BSPK\text{-}Mark1}$, $T_{BSPK\text{-}Mark2}$, $T_{WUR\text{-}Sync}$, and $T_{Sym}$ are defined in Table 30-3 (Timing-related constants(11ba)), and $N_{Sym}$ is the number of (#4370)(#4055)WUR OOK symbols in the WUR-Data field.

The number of (#4370)(#4055)WUR OOK symbols is a function of the length of WUR MAC frame in the WUR-Data field (WUR_MPDU_LENGTH) and $N_{SPDB}$ and is calculated as follows:

$$N_{Sym} = 8 \times \text{WUR\_MPDU\_LENGTH} \times N_{SPDB} \quad (30\text{-}14)$$

where

$N_{SPDB}$ is defined in Table 30-4 (Frequently used parameters(11ba))

The value of the PSDU_LENGTH parameter is calculated as follows:

$$\text{PSDU\_LENGTH} = \text{WUR\_MPDU\_LENGTH} \quad (30\text{-}15)$$

In a WUR PPDU, the RATE field of L-SIG field(#4145) shall be set to the value representing 6 Mb/s in the 20 MHz channel spacing column of Table 17-6 (Contents of the SIGNAL field). The Length field set in the L-SIG (L_LENGTH) is calculated as follows:

$$\text{L\_LENGTH} = \frac{\text{TXTIME} - 20}{4} \times 3 - 3 \quad (30\text{-}16)$$

For the FDMA transmission, the value of the TXTIME and PSDU_LENGTH for each WUR transmission in a 20 MHz subchannel shall be calculated according to the longest WUR transmissions among all 20 MHz subchannels.

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The value of the TXTIME parameter for a WUR FDMA transmission shall be calculated as follows:

$$\text{TXTIME} = T_{L-STF} + T_{L-LTF} + T_{L-SIG} + T_{BPSK-Mark1} + T_{BPSK-Mark2} + \max_{i_{BW} \in \Omega_{20MHz}} \left\{ T_{WUR-Sync, i_{BW}} + T_{Sym, i_{BW}} \times N_{Sym, i_{BW}} \right\} \quad (30\text{-}17)$$

### 30.4.2 Table of time and length characteristics

**Table 30-13—WUR PPDU Time and Length Characteristics(11ba)**

| Characteristics | Value |
|---|---|
| aCCAMidTime | 25 μs |
| aPPDUMaxTime | 2972 μs |
| aPSDUMaxLength | 22 octets (see NOTE 1) |
| aRxPHYStartDelay | 92 μs (see NOTE 2) |
| NOTE 1—This is the maximum length in octets for a WUR Basic PPDU with WUR LDR.<br>NOTE 2—This value arises from the time to the end of the WUR-Sync field with WUR HDR. | |

## 30.5 Parameters for WUR Data Rates

The rate-dependent parameters for 62.5 kb/s and 250 kb/s are given in Table 30-14 (WUR PPDU data rates(11ba)). WUR encoding shall be used for all the data rates for the WUR-Data field of a WUR PPDU.

**Table 30-14—WUR PPDU data rates(11ba)**

| Data rate | Modulation | Symbol structure | | Equivalent information bit duration | $N_{SPDB}$ | Data rate (kb/s) |
|---|---|---|---|---|---|---|
| WUR LDR | (#4370)(#4055)WUR OOK | Information 0 | [SymLDROn, SymLDROff, SymLDROn, SymLDROff] | 16 μs | 4 | 62.5 |
| | | Information 1 | [SymLDROff, SymLDROn, SymLDROff, SymLDROn] | | | |
| WUR HDR | (#4370)(#4055)WUR OOK | Information 0 | [SymHDROn, SymHDROff] | 4 μs | 2 | 250 |
| | | Information 1 | [SymHDROff, SymHDROn] | | | |


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# 31. Next Generation V2X (NGV) MAC specification(11bd)

## 31.1 Introduction

An NGV STA supports the MAC and MLME functions defined in 31.2 (Operation in the 5.9 GHz band) in addition to the MAC functions defined in Clause 10 (MAC sublayer functional description) and the MLME functions defined in Clause 11 (MLME) for STAs communicating Data frames OCB.

If dot11DMGOCBActivated is true, a DMG STA shall support the features defined in 31.3 (Operation in the 60 GHz band), the MAC functions defined in Clause 10 (MAC sublayer functional description), and the MLME functions defined in Clause 11 (MLME) for DMG or EDMG STAs communicating Data frames OCB.

## 31.2 Operation in the 5.9 GHz band

### 31.2.1 Coexistence with non-NGV STAs

In order to enable coexistence and interoperability with non-NGV STAs, if dot11NGVOptionImplemented is true then dot11OCBActivated shall be true. Moreover, the non-NGV PPDUs transmitted by NGV STAs carry an indication that informs the receiving NGV STAs that the transmitter is an NGV STA. This indication is carried in the Duration/ID field of the MAC header.

NOTE 1—An NGV STA that wishes to communicate OCB with one or more neighboring non-NGV STAs is recommended to use the non-NGV PPDU format.

When an NGV STA transmits an Ack frame solicited by an individually addressed Management or QoS Data frame in a non-NGV PPDU and the Duration field value specified in 9.2.5.7 (Setting for other response frames) is 0, the Duration/ID field in the Ack frame shall be set to 2. When an NGV STA transmits an individually addressed Management or QoS Data frame in a non-NGV PPDU as the last frame of a TXOP, the Duration/ID field of the Management or QoS Data frame shall be set to the sum of 4, SIFS, and the transmission time of the responding Ack frame as defined in 10.6 (Multirate support).

NOTE 2—An NGV STA can transmit either a non-NGV PPDU or an NGV PPDU. The value of the Duration field carried in a non-NGV PPDU indicates to a receiving NGV STA whether the transmitter is an NGV STA or a non-NGV STA.

When an NGV STA transmits a group addressed frame in a non-NGV PPDU, the Duration/ID field in the group addressed frame shall be set to 2.

An NGV STA determines that a received non-NGV PPDU was transmitted by an NGV STA if the non-NGV PPDU contains one of the following frames:

- An Ack or BlockAck frame with Duration/ID field equal to 2.
- An individually addressed frame with Duration/ID field equal to the sum of 4, SIFS, and the transmission time of the responding Ack or BlockAck frame as defined in 10.6 (Multirate support).
- A group addressed frame with Duration/ID field equal to 2.

### 31.2.2 Channel access and transmission methods for 20 MHz OCB transmission

An NGV 20 MHz channel consists of two contiguous 10 MHz channels: the OCB primary channel and the OCB secondary channel.

The OCB primary channel is designated by the primary channel parameter of the radio environment vector in the MA-UNITDATA.request primitive (see 5.2.4 (MA-UNITDATA.request)).

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An NGV STA transmitting a 20 MHz NGV PPDU or 20 MHz non-NGV duplicate PPDU shall contend for the medium using EDCA as defined in 10.2.3.2 (HCF contention based channel access (EDCA)) and 10.3.2 based on the medium sensing results of two contiguous 10 MHz channels, OCB primary channel and OCB secondary channel in an NGV 20 MHz channel. An NGV STA performing 20 MHz channel access determines that the 20 MHz medium is idle if all of the following conditions are met:

— The CS mechanism (see 10.3.2.1) indicates that the OCB primary channel is idle.

— The PHY-CCA.indication primitive indicates that the OCB secondary channel is idle.

— The virtual CS mechanism (see 10.3.2.1 (CS mechanism)) indicates that the OCB secondary channel is idle, if dot11VirtualCSonOCBSecondaryImplemented is true.

Otherwise, the NGV STA performing 20 MHz channel access determines that the 20 MHz medium is busy.

NOTE—An NGV STA transmitting a 20 MHz NGV PPDU or 20 MHz non-NGV duplicate PPDU follows rules defined in 31.2.2 (Channel access and transmission methods for 20 MHz OCB transmission) and does not follow rules defined in 11.15.9 (STA CCA sensing in a 20/40 MHz BSS).

If either the medium of the OCB primary channel or the OCB secondary channel is determined to be busy, an NGV STA shall invoke the random backoff procedure as described in 10.23.2.2 (EDCA backoff procedure).

When the random backoff procedure is invoked, an NGV STA transmitting a 20 MHz NGV PPDU or 20 MHz non-NGV duplicate PPDU shall perform as described in 10.23.2.4, with the exception of the definition of the slot boundaries. In this subclause, the slot boundaries are defined as follows:

a) Following AIFSN[AC] × aSlotTime – aRxTxTurnaroundTime of idle medium on the 20 MHz channel after a SIFS(#6587) (not necessarily idle medium during the SIFS) after the last busy medium on the antenna that was the result of reception of a frame with a correct FCS.

b) Following EIFS – DIFS + AIFSN[AC] × aSlotTime + aSIFSTime – aRxTxTurnaroundTime of idle medium on the 20 MHz channel after the last indicated busy medium as determined by the physical CS mechanism that was the result of a frame reception that has resulted in FCS error, or of a frame reception that has resulted in a PHY-RXEND.indication (RXERROR) primitive where the value of RXERROR is not NoError.

c) When any other EDCAF at this STA transmitted a frame requiring immediate acknowledgment, the earlier of:

   1) The end of the AckTimeout interval timed from the PHY-TXEND.confirm primitive, followed by AIFSN[AC] × aSlotTime + aSIFSTime – aRxTxTurnaroundTime of idle medium on the 20 MHz channel.

   2) The end of the first AIFSN[AC] × aSlotTime – aRxTxTurnaroundTime of idle medium on the 20 MHz channel after a SIFS(#6587) (not necessarily medium idle during the SIFS, the start of the SIFS implied by the length in the PHY header of the previous frame) when a PHY-RXEND.indication primitive occurs as specified in 10.3.2.11 (Acknowledgment procedure).

d) Following AIFSN[AC] × aSlotTime – aRxTxTurnaroundTime of idle medium on the 20 MHz channel after a SIFS(#6587) (not necessarily medium idle during the SIFS) after the last busy medium on the antenna that was the result of transmission of a frame for any EDCAF and that did not require an acknowledgment and after the expiration of the TXNAV timer if nonzero.

e) Following AIFSN[AC] × aSlotTime + aSIFSTime – aRxTxTurnaroundTime of idle medium on the 20 MHz channel after the last indicated busy medium as indicated by the CS mechanism on the OCB primary channel that is not covered by a) to d).

f) Following EIFS – DIFS + AIFSN[AC] × aSlotTime + aSIFSTime – aRxTxTurnaroundTime of idle medium on the 20 MHz channel after the last indicated busy medium as indicated by the CCA mechanism on the OCB secondary channel that is not covered by a) to d), when the duration of channel busy is not known.


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g) Following AIFSN[AC] × aSlotTime + aSIFSTime – aRxTxTurnaroundTime of idle medium on the 20 MHz channel after the last indicated busy medium as indicated by the CS mechanism on the OCB secondary channel that is not covered by a) to d), when the duration of channel busy is known.

h) Following aSlotTime of idle medium on the 20 MHz channel, which occurs immediately after any of these conditions, a) to g), is met for the EDCAF.

If an NGV STA is unable to transmit a 20 MHz NGV PPDU or 20 MHz non-NGV duplicate PPDU because the medium of the OCB secondary channel is busy and the fallback enabled member of the radio environment request vector so allows, the STA may instead use the medium access procedure to transmit a 10 MHz PPDU on the OCB primary channel. The medium of the OCB secondary channel is busy if a PHY-CCA.indication(BUSY, {secondary}) primitive occurs or the virtual CS indicates that the medium is busy on the OCB secondary channel, if dot11VirtualCSonOCBSecondaryImplemented is true.

### 31.2.3 A-MSDU operation, A-MPDU operation, and BA operation

NGV STA frame aggregation parameters are fixed and are defined in this clause. This provides the ability to transmit an A-MPDU and an A-MSDU outside the context of a BSS (OCB). An NGV STA may transmit an A-MPDU or A-MSDU and shall support the reception of an A-MSDU or A-MPDU with aggregation parameters as defined in this clause.

An NGV STA shall support receiving an MPDU of length equal to or less than the maximum NGV MPDU length in Table 31-1 (Maximum NGV MPDU length(11bd)). An NGV STA shall not transmit an MPDU with a length greater than the maximum NGV MPDU length shown in Table 31-1 (Maximum NGV MPDU length(11bd)).

**Table 31-1—Maximum NGV MPDU length(11bd)**

| NGV-MCS | 1SS 10 MHz (octets) | 2SS 10 MHz (octets) | 1SS 20 MHz (octets) | 2SS 20 MHz (octets) |
|---|---|---|---|---|
| 0 | 4524 | 7991 | 7991 | 7991 |
| 1 | 7991 | 7991 | 7991 | 7991 |
| 2 | 7991 | 7991 | 7991 | 7991 |
| 3 | 7991 | 7991 | 7991 | 7991 |
| 4 | 7991 | 7991 | 7991 | 7991 |
| 5 | 7991 | 7991 | 7991 | 7991 |
| 6 | 7991 | 7991 | 7991 | 7991 |
| 7 | 7991 | 7991 | 7991 | 7991 |
| 8 | 7991 | 7991 | 7991 | 7991 |
| 9 | N/A | N/A | 7991 | 7991 |
| 15 | 2192 | 4524 | 4386 | 7991 |

NOTE 1—The maximum MPDU length is determined based on a maximum PPDU duration of 10 968 μs.

NOTE 2—The maximum PPDU duration may be reduced by regulatory authorities in some regulatory domains. If the maximum PPDU duration is less than 10 968 μs, the maximum MPDU length may be limited to a lower value for some MCSs.

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An NGV STA shall transmit adjacent MPDUs in an A-MPDU with a minimum of 2 μs between the MPDUs.

An NGV STA shall support block ack and does so without exchanging capabilities or creating a block ack agreement. An NGV STA shall have the following block ack configuration:

- A-MSDU is supported
- Block ack policy is HT-immediate block ack
- No timeout
- The number of buffers available is 32
- Each buffer is capable of holding 7935 octets (the maximum size of an A-MSDU)
- The block ack frame is a Compressed BlockAck frame (see 9.3.1.8.1 (Overview) and 9.3.1.8.2 (Compressed BlockAck variant)).

### 31.2.4 NON_NGV_10 repetition transmission

The NON_NGV_10 repetition transmission mode supports OCB broadcast service to both NGV STAs and non-NGV STAs with improved frame reception reliability.

This mode allows an NGV STA to repeat one NON_NGV_10 PPDU, defined in 32.1.4 (PPDU Formats), multiple times with a time gap of SIFS between every two transmissions.

For a group addressed MPDU containing only group addressed MPDUs, the number of repetitions of the NON_NGV_10 PPDU is decided by a higher layer and indicated by the number of repetitions element of the radio environment request vector (5.2.4 (MA-UNITDATA.request)) in the MAC SAP.Otherwise, the number of repetitions of the NON_NGV_10 PPDU is fixed to 0 by the MAC.The MAC sets the number of repetitions, N_PPDU_REP, via the PHY service interface using the PHY-TXSTART.request(TXVECTOR) primitive, as described in Table 32-1 (TXVECTOR and RXVECTOR parameters(11bd)).

NOTE—The Duration setting of the Duration/ID field in NON_NGV_10 repetition transmission does not follow the rules in 9.2.5 (Duration/ID field (QoS STA)). An NGV STA that transmits the frames in NON_NGV_10 repetition transmission mode follows the rules in 10.23.2.9 (TXOP limits).

### 31.2.5 Non-NGV duplication operation

A 20 MHz NGV STA may transmit RTS frames in non-NGV duplicate PPDUs to protect a 20 MHz NGV PPDU.

A 20 MHz NGV STA that is addressed by an RTS frame in a non-NGV or non-NGV duplicate PPDU that has a bandwidth signaling TA and that has the RXVECTOR parameter DYN_BANDWIDTH_IN_NON_NGV equal to Static behaves as follows:

- If the NAV indicates idle and CCA indicates idle for the secondary 10 MHz channel when the RTS frame's RXVECTOR parameter CH_BANDWIDTH_IN_NON_NGV is equal to CBW20, then the STA shall respond with a CTS frame carried in a non-NGV duplicate PPDU after a SIFS. The CTS frame's TXVECTOR parameters CH_BANDWIDTH and CH_BANDWIDTH_IN_NON_NGV shall be set to CBW20.
- If the NAV indicates idle when the RTS frame's RXVECTOR parameter CH_BANDWIDTH_IN_NON_NGV is equal to CBW10, then the STA shall respond with a CTS frame carried in a non-NGV PPDU after a SIFS. The CTS frame's TXVECTOR parameters CH_BANDWIDTH and CH_BANDWIDTH_IN_NON_NGV shall be set to CBW10.
- Otherwise, the STA shall not respond with a CTS frame.


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A 20 MHz NGV STA that is addressed by an RTS frame in a non-NGV or non-NGV duplicate PPDU that has a bandwidth signaling TA and that has the RXVECTOR parameter DYN_BANDWIDTH_IN_NON_NGV equal to Dynamic behaves as follows:

— If the NAV indicates idle and the CCA indicates idle for the secondary 10 MHz channel when the RTS frame's RXVECTOR parameter CH_BANDWIDTH_IN_NON_NGV is equal to CBW20, then the 20 MHz NGV STA shall respond with a CTS frame in a non-NGV duplicate PPDU after a SIFS. The CTS frame's TXVECTOR parameters CH_BANDWIDTH and CH_BANDWIDTH_IN_NON_NGV shall be set to CBW20.

— If the NAV indicates idle and the CCA indicates busy for the secondary 10 MHz channel when the RTS frame's RXVECTOR parameter CH_BANDWIDTH_IN_NON_NGV is equal to CBW20, then the 20 MHz NGV STA shall respond with a CTS frame in a non-NGV PPDU after a SIFS. The CTS frame's TXVECTOR parameters CH_BANDWIDTH and CH_BANDWIDTH_IN_NON_NGV shall be set to CBW10.

— If the NAV indicates idle when the RTS frame's RXVECTOR parameter CH_BANDWIDTH_IN_NON_NGV is equal to CBW10, then the 20 MHz NGV STA shall respond with a CTS frame in a non-NGV PPDU after a SIFS. The CTS frame's TXVECTOR parameters CH_BANDWIDTH and CH_BANDWIDTH_IN_NON_NGV shall be set to CBW10.

— Otherwise, the STA shall not respond with a CTS frame.

If a 20 MHz NGV STA receives a frame that solicits a response and is carried in a 20 MHz NGV PPDU, it should transmit the response in a 20 MHz non-NGV duplicate PPDU.

## 31.3 Operation in the 60 GHz band

### 31.3.1 DMG beamforming outside the context of a BSS

A DMG STA with dot11DMGOCBActivated equal to true may transmit DMG Beacon frames as described in 10.42.4 outside the context of a BSS. The DMG STA shall set the Discovery Mode field and OCB subfield in the Clustering Control field to 1 in each of the DMG Beacon frames when the STA performs beamforming training with the DMG Beacon frame outside of the context of a BSS.The STA may set all the bits in the A-BFT Responder Address subfield to 1 in a DMG Beacon frame to allow any STAs to transmit SSW or Short SSW frames during A-BFT that follows the BTI in which the DMG Beacon frame is transmitted, or set the A-BFT Responder Address subfield to an individual address to indicate the STA that is allowed to transmit during the A-BFT. A DMG OCB element is optionally present in a DMG Beacon frame to indicate the STA transmitting the DMG Beacon frame supports optional features used during communication outside the context of a BSS.

When a DMG STA with dot11DMGOCBActivated equal to true receives a DMG beacon frame with the OCB subfield equal to 1, the STA may perform beamforming training as described in 10.42.5.When the DMG STA transmits SSW frames during the A-BFT after a BTI in which the STA received a DMG beacon frame with the OCB subfield equal to 1, the STA shall set the OCB subfield to 1 in the SSW frames transmitted during the A-BFT.

If a responder DMG STA that receives a DMG beacon frame with the OCB subfield equal to 1 has successfully completed an SLS or a BRP with the initiator STA that transmitted the DMG Beacon frame recently, the responder STA should not transmit SSW frames during the A-BFT following the BTI to avoid collisions during the A-BFT.

A DMG STA with dot11DMGOCBActivated equal to true may transmit SSW frames as described in 10.42.6 outside the context of a BSS. The DMG STA shall set the OCB subfield to 1 in the SSW frames during beamforming training outside of the context of a BSS.

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A DMG STA with dot11DMGOCBActivated equal to true shall support Beamformed link maintenance procedure as described in 11.27.1.1 (General(11ay)).

## 31.4 NGV ranging

An NGV STA may support NGV ranging. NGV ranging is a subset of (#7065)FTM functionalities defined in 11.21.6 (FTM procedure(#7065)); the supported functionalities are as follows:

- (#7065)FTM procedures, including FTM procedure negotiation and FTM session termination for non-TB ranging as defined in 11.21.6.3 (FTM procedure negotiation(11az)) and in 11.21.6.6 (FTM session termination(11az)), with the modifications specified in this subclause.
- Non-TB ranging as described in 11.21.6.4.4 (Non-TB ranging measurement exchange(11az)) with the modifications specified in this subclause. PHY security is not specified for NGV STAs.
- NGV STAs may support differential distance computation as detailed in Annex P.3.

Additionally, if an NGV STA is co-located with a STA that supports (#7065)FTM functionalities as defined in 11.21.6 (FTM procedure(#7065)), it may support (#7065)FTM procedure outside the 5.9 GHz frequency band.

The capability discovery for whether an NGV STA supports ranging as specified in this subclause is out of the scope of IEEE Std 802.11 and is expected to be conducted by higher layers. The higher layer exchanges are over the 5.9 GHz frequency band. The higher layer negotiations are expected to identify the following:

- Whether an NGV STA supports non-TB ranging in the 5.9 GHz band.
- Whether an NGV STA is co-located with a STA that supports ranging on IEEE 802.11 bands outside the 5.9 GHz band and if so the type of ranging: non-TB ranging and/or EDCA based ranging (see 11.21.6.1.1 (EDCA based Ranging and TB ranging overview) and 11.21.6.1.2 (Non-TB ranging overview)).
- For an NGV STA co-located with a STA that supports ranging on 802.11 bands outside the 5.9 GHz band, whether the co-located STA supports PASN, and if so, the contents of the PASN Parameters element, or alternatively the security context required for exchange of protected frames.
- The channel number for ranging exchanges between peer STAs.
- Role of STA: ISTA or RSTA.
- LMR Feedback policy.

NOTE—The channel number is not limited to the 5.9 GHz band.

The (#7065)FTM procedure negotiation is performed by an NGV STA as specified in 11.21.6.3 (FTM procedure negotiation(11az)) with the following differences:

- For ranging in the 5.9 GHz band, in the Ranging Parameters element included in the IFTMR frame:
  - Status indication subfield and Value subfield are reserved.
  - Max R2I STS > 80 MHz subfield is reserved.
  - Max I2R STS > 80 MHz subfield is reserved.
  - BSS Color Information subfield is reserved.
- For ranging in the 5.9 GHz band, a non-TB ranging measurement exchange is used by NGV STAs as defined in 11.21.6.4.4 (Non-TB ranging measurement exchange(11az)) with the following changes:
  - An NGV ranging NDP is transmitted instead of an HE ranging NDP.
  - A Ranging NDP Announcement frame (9.3.1.19 (VHT/HE/Ranging NDP Announcement frame format(11ax)(11az))) is transmitted. The following differences in the subfields of the STA Info fields of the Ranging NDP Announcement frame apply compared to 9.3.1.19 (VHT/HE/Ranging NDP Announcement frame format(11ax)(11az)):


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- LTF Offset is set to 0.
- R2I N_STS subfield is set to the number of spatial streams of the R2I NGV ranging NDP minus 1.
- R2I Rep subfield is set to 0 if the NGV-LTF in the R2I NGV ranging NDP is not repeated and is set to 1 if the NGV-LTF in the R2I NGV ranging NDP is repeated.
- I2R N_STS subfield is set to the number of spatial streams of the I2R NGV ranging NDP minus 1.
- I2R Rep subfield is set to 0 if the NGV-LTF in the I2R NGV ranging NDP is not repeated and is set to 1 if the NGV-LTF in the I2R NGV ranging NDP is repeated.
- The I2R N_STS and I2R Rep subfields are used to indicate the following I2R NGV ranging NDP's NGV-LTF configuration, 32.3.16 (NGV ranging NDP), while the R2I N_STS and R2I Rep subfields indicate the NGV-LTF configuration of the R2I NGV ranging NDP sent in response by the RSTA, see 11.21.6.4.4 (Non-TB ranging measurement exchange(11az)).
- When the TXVECTOR parameter CH_BANDWIDTH is CBW10, the I2R NDP Tx Power subfield indicates the combined average power per 10 MHz bandwidth referenced to the antenna connector, of all antennas used to transmit the following I2R NDP.

For ranging on IEEE Std 802.11 bands outside the 5.9 GHz band, whether PASN is required is indicated by higher layers. Two STAs co-located with NGV STAs may establish PASN authentication if so indicated by higher layers using the procedures as defined in 12.13 (Preassociation security negotiation) with the following change: the exchanges between ISTA and RSTA are done by two STAs each co-located with an NGV STA. Alternatively, the security association between the two STAs may be established by higher layer exchanges in the 5.9 GHz band.

## 31.5 NGV MAC data service

An NGV STA shall follow the rules in 10.2.7 (Fragmentation/defragmentation overview) and the additional rules as defined in this subclause.

When a member in radio environment request vector represents "selection within MAC sublayer", the NGV STA shall select the related member value by itself. Otherwise the following rules shall be applied:

- When transmitting an MPDU that encapsulates an MSDU, an NGV STA shall use the PPDU format indicated by the PPDU format member of the radio environment request vector related to the MSDU.
- When transmitting an MPDU that encapsulates an MSDU, an NGV STA shall use the data rate/ NGV-MCS indicated by the data rate/NGV-MCS member of the radio environment request vector related to the MSDU in the initial transmission of the MPDU. In the retransmission of the MPDU, the data rate/NGV-MCS shall be no more than data rate/NGV-MCS indicated by the data rate/NGV-MCS member of the radio environment request vector related to the MSDU.
- When transmitting an MPDU that encapsulates an MSDU, an NGV STA shall use the number of spatial streams indicated by the number of spatial streams member of the radio environment request vector related to the MSDU in the initial transmission of the MPDU. In the retransmission of the MPDU, the number of spatial streams shall be no more than the number of spatial streams indicated by the number of spatial streams member of the radio environment request vector related to the MSDU.
- An NGV STA shall transmit a frame that encapsulates an MSDU in an A-MPDU if the permitted aggregation member of the radio environment request vector related to the MSDU is equal to 1. Otherwise the NGV STA shall not aggregate the frame in an A-MPDU.

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- An NGV STA shall set the lifetime of an MSDU to the value of expiry time member of the radio environment request vector related to the MSDU.
- An NGV STA shall transmit an MPDU that encapsulates an MSDU in the channel defined by the channel member, primary channel member, and channel width member of the radio environment request vector related to the MSDU with the following exception:
  - If the channel width indicates 20 MHz channel width and the fallback enabled parameter indicates 1, the channel can be 10 MHz channel.
- An NGV STA shall transmit an MPDU that encapsulates an MSDU with the transmit power indicated by the transmit power spectral density member of the radio environment request vector related to the MSDU.

NOTE—The higher layer sets the parameters in the radio environment request vector based on the NGV STA's capabilities.

When reporting a received MSDU to a higher layer, an NGV STA shall report the radio environment status vector of the received MSDU as defined in 5.2.5 (MA-UNITDATA.indication).

## 31.6 Radio environment measurement

An NGV STA provides periodic reports on the radio environment.

If requested by a higher layer, an NGV STA with dot11RadioEnvironmentMeasurementPeriod not equal to 0 shall measure the channel busy percentage and report the measurement results to a higher layer as defined in (#7082)6.5.27 (NGV radio environment measurement(11bd)(#7082)).

If requested by a higher layer, an NGV STA with dot11StationMeasurementPeriod not equal to 0 shall measure the number of neighboring STAs (non-NGV STAs and NGV-STAs) and the number of neighboring NGV STAs, and report these measurement results to a higher layer as defined in 6.5.27 (NGV radio environment measurement(11bd)(#7082)).

An NGV STA with both dot11StationMeasurementPeriod and dot11RadioEnvironmentMeasurementPeriod not equal to 0 shall start a STA measurement period at the same time as a radio environment measurement period.


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# 32. Next Generation V2X (NGV) PHY specification(11bd)

## 32.1 Introduction

### 32.1.1 Introduction to NGV PHY

Clause 32 (Next Generation V2X (NGV) PHY specification(11bd)) specifies the PHY entity for an NGV orthogonal frequency division multiplexing (OFDM) system. In addition to the requirements in Clause 32 (Next Generation V2X (NGV) PHY specification(11bd)), an NGV STA shall be capable of transmitting and receiving 10 MHz PPDUs specified in Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification).

The NGV PHY is mainly based on the VHT PHY defined in Clause 21 (Very high throughput (VHT) PHY specification), which in turn is based on the HT PHY defined in Clause 19 (High Throughput (HT) PHY specification(#2297)), which in turn is further based on the OFDM PHY defined in Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification). The NGV PHY preamble structure, BPSK-dual carrier modulation (DCM), and midamble structure are based on the HE PHY defined in Clause 27 (High-efficiency (HE) PHY specification(11ax)).

The NGV PHY provides support for both 10 MHz and contiguous 20 MHz channel widths. The NGV PHY data subcarrier frequency spacing is a half of VHT PHY and HT PHY subcarrier frequency spacing defined in Clause 21 (Very high throughput (VHT) PHY specification) and Clause 19 (High Throughput (HT) PHY specification(#2297)), respectively.

The NGV PHY data subcarriers are modulated using binary phase shift keying (BPSK), BPSK-DCM, quadrature phase shift keying (QPSK), 16-quadrature amplitude modulation (16-QAM), 64-QAM, and 256-QAM. The NGV PHY preamble is encoded by a convolutional encoder and the NGV PHY data payload is encoded by an LDPC encoder. STBC is not employed.

The NGV PHY supports the regulatory requirements in 32.3.15 (Regulatory requirements).

An NGV STA shall support the following features:

- Single spatial stream
- NGV-MCS 0 to 9 and NGV-MCS 15
- Three LTF formats: NGV-LTF-1x, NGV-LTF-2x, and NGV-LTF-2x-Repeat
- LDPC coding (transmit and receive)
- Midamble periodicity of 4, 8, 16 OFDM symbols
- 10 MHz NGV PPDU
- NON_NGV_10 PPDU and repetitive NON_NGV_10 PPDU
- Transmit spectrum mask C2 when transmitting a 20 MHz NGV PPDU or 20 MHz non-NGV duplicate PPDU, if 20 MHz NGV PPDU is supported
- Transmit spectrum mask A, B, C, or D when transmitting a 10 MHz NGV PPDU, if the STA belongs to transmit power class A, B, C, or D, respectively

An NGV STA may support the following features:

- Transmission and reception of SU MIMO with two spatial streams
- NGV ranging NDP for NGV ranging as described in 31.4 (NGV ranging)
- 20 MHz NGV PPDU or 20 MHz non-NGV duplicate PPDU

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### 32.1.2 Scope

The services provided to the MAC by the NGV PHY consist of the following protocol functions:

a) A function that maps the PSDU received from the MAC into a PPDU for transmission to one or more receiving STAs.

b) A function that defines the characteristics and method of transmitting and receiving data through a wireless medium between two or more STAs. Depending on the PPDU format, these STAs support a mixture of NGV and Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) PHYs.

### 32.1.3 NGV PHY functions

#### 32.1.3.1 General

The NGV PHY contains two functional entities: the PHY function, and the physical layer management function (via the PLME). These functions are described in detail in 32.3 (NGV PHY) and 32.4 (NGV PLME), respectively. The NGV PHY service is provided to the MAC through the PHY service primitives defined in Clause 8 (PHY service specification). The NGV PHY service interface is described in 32.2 (NGV PHY service interface).

#### 32.1.3.2 PHY layer management entity (PLME)

The PLME performs management of the local PHY functions in conjunction with the MLME.

#### 32.1.3.3 Service specification method

The models represented by figures and state diagrams are intended to be illustrations of the functions provided. It is important to distinguish between a model and a real implementation. The models are optimized for simplicity and clarity of presentation.

The service of a layer is the set of capabilities that it offers to a user in the next higher layer. Abstract services are specified here by describing the service primitives and parameters that characterize each service. This definition is independent of any particular implementation.

### 32.1.4 PPDU Formats

The structure of the PPDU transmitted by an NGV STA is determined by the TXVECTOR parameters as defined in Table 32-1 (TXVECTOR and RXVECTOR parameters(11bd)).

In an NGV STA the FORMAT parameter determines the overall structure of the PPDU and can take one of the following values:

— Non-NGV format of 10 MHz bandwidth (NON_NGV_10), for the PPDU format as specified in Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) for 10 MHz channel spacing including non-NGV duplicate format.

— NGV format (NGV), for the PPDU format as specified in Clause 32 (Next Generation V2X (NGV) PHY specification(11bd)).

NOTE—Required support for these formats is defined in 17.1 (Introduction) and 32.1.1 (Introduction to NGV PHY).


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## 32.2 NGV PHY service interface

### 32.2.1 Introduction

The PHY provides an interface to the MAC through an extension of the generic PHY service interface defined in 8.3.4 (Basic service and options). The interface includes TXVECTOR, RXVECTOR, and PHYCONFIG_VECTOR.

The MAC uses the TXVECTOR to supply the PHY with per-PPDU transmit parameters. The PHY uses the RXVECTOR to inform the MAC of the received PPDU parameters. The MAC uses the PHYCONFIG_VECTOR to configure the PHY for operation that is independent of frame transmission or reception.

### 32.2.2 TXVECTOR and RXVECTOR

The parameters in Table 32-1 (TXVECTOR and RXVECTOR parameters(11bd)) are defined as part of the TXVECTOR parameter list in the PHY-TXSTART.request primitive and/or as part of the RXVECTOR parameter list in the PHY-RXSTART.indication primitives.

**Table 32-1—TXVECTOR and RXVECTOR parameters(11bd)**

| Parameter | Condition | Value | TXVECTOR | RXVECTOR |
|---|---|---|---|---|
| FORMAT | | Determines the format of the PPDU.<br>Enumerated type:<br>NON_NGV_10 indicates the PPDU format for 10 MHz channel spacing as defined in Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) or non-NGV duplicate PPDU format as defined in 32.3.9.10 (Non-NGV duplicate transmission).<br>NGV indicates NGV PPDU format as defined in Clause 32 (Next Generation V2X (NGV) PHY specification(11bd)). | Y | Y |
| L_LENGTH | FORMAT is NGV | Not present.<br>NOTE—The value of the Length field of the L-SIG in an NGV PPDU is calculated as in Equation (32-8). | N | N |
| | Otherwise | Indicates the length of the PSDU in octets in the range 1 to 4095. The value is used by the PHY to determine the number of octet transfers that occur between the MAC and the PHY. | Y | Y |
| L_DATARATE | FORMAT is NGV | Not present.<br>NOTE—The RATE field in the L-SIG field in an NGV PPDU is set to the value representing 3 Mb/s in the 10 MHz channel spacing column of Table 17-6 (Contents of the SIGNAL field). | N | N |
| | Otherwise | Indicates the rate, in Mb/s, used to transmit the PSDU.<br>See corresponding entry in Table 17-1 (TXVECTOR parameters) and Table 17-2 (RXVECTOR parameters). | Y | Y |

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**Table 32-1—TXVECTOR and RXVECTOR parameters(11bd) *(continued)***

| Parameter | Condition | Value | TXVECTOR | RXVECTOR |
|---|---|---|---|---|
| SERVICE | FORMAT is NGV | Not present. | N | N |
| | Otherwise | Scrambler initialization, null. | Y | N |
| TXPWR_LEVEL_INDEX | FORMAT is NGV | The allowed values for the TXPWR_LEVEL_INDEX parameter are in the range 1 to *N*/2, where *N* is the number of octets in dot11TxPowerLevelExtended. This parameter is used to indicate the available transmit output power levels defined in dot11TxPowerLevelExtended that shall be used for the current transmission. | Y | N |
| | Otherwise | 1–8<br><br>Refer to 17.2.2 (TXVECTOR parameters(#1369)) for the definition of TXPWR_LEVEL_INDEX. | Y | N |
| RSSI | FORMAT is NGV | The allowed values for the RSSI parameter are in the range 0 to 255. This parameter is a measure by the PHY of the power observed at the antenna connector used to receive the current PPDU measured during the reception of the NGV-LTF field. RSSI is intended to be used in a relative manner, and it shall be a monotonically increasing function of the received power. | N | Y |
| | Otherwise | 0–RSSI maximum.<br><br>See 17.2.3 (RXVECTOR parameters(#1369)) for the definition of RSSI. | N | Y |
| NGV-MCS | FORMAT is NGV | Indicates the modulation and coding scheme used in the transmission of the PPDU.<br>Integer in the range:<br>0 to 8 and 15 for 10 MHz PPDU.<br>0 to 9 and 15 for 20 MHz PPDU.<br><br>NOTE—Set to 0 for NGV ranging NDP. See 32.3.16 (NGV ranging NDP) | Y | Y |
| | Otherwise | Not present. | N | N |
| CH_BANDWIDTH | FORMAT is NGV | Indicates the channel width of the transmitted PPDU.<br><br>Enumerated type:<br>CBW10 for 10 MHz.<br>CBW20 for 20 MHz. | Y | Y |
| | Otherwise | Not present. | N | N |


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**Table 32-1—TXVECTOR and RXVECTOR parameters(11bd) *(continued)***

| Parameter | Condition | Value | TXVECTOR | RXVECTOR |
|---|---|---|---|---|
| N_TX | FORMAT is NGV | Indicates the number of transmit chains. | Y | N |
| | Otherwise | Not present. | N | N |
| MIDAMBLE_PERIODICITY | FORMAT is NGV | Indicates the midamble periodicity in the Data field.<br><br>Integer values:<br>Set to 0 to indicate the midamble periodicity of 4 OFDM symbols.<br>Set to 1 to indicate the midamble periodicity of 8 OFDM symbols.<br>Set to 2 to indicate the midamble periodicity of 16 OFDM symbols.<br>Other values are reserved. | Y | Y |
| | Otherwise | Not present. | N | N |
| NGV_LTF_TYPE | FORMAT is NGV | Indicates the type of NGV-LTF.<br><br>Set to 0 to indicate NGV-LTF-2x is used in the transmitted PPDU.<br>Set to 1 to indicate NGV-LTF-1x is used in the transmitted PPDU.<br><br>NOTE—When NGV-MCS 15 is indicated in 10 MHz, Repeated NGV-LTF-2x is used in the transmitted PPDU. See 32.3.8.10 (NGV-LTF definition). | Y | Y |
| | Otherwise | Not present. | N | N |
| N_PPDU_REP | FORMAT is NGV | Not present. | N | N |
| | FORMAT is NON_NGV_10 | Indicates the number of repetitive transmissions of NON_NGV_10 PPDU after the initial transmission. The allowed values are in the range 0 to 3. | Y | Y |
| NUM_SS | FORMAT is NGV | Indicates the number of spatial streams.<br>The allowed value:<br>Set to 0 to indicate the number of spatial streams is one.<br>Set to 1 to indicate the number of spatial streams is two | Y | Y |
| | Otherwise | Not present. | N | N |

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**Table 32-1—TXVECTOR and RXVECTOR parameters(11bd) *(continued)***

| Parameter | Condition | Value | TXVECTOR | RXVECTOR |
|---|---|---|---|---|
| NON_NGV_MODULATION | FORMAT is NON_NGV_10 | In the TXVECTOR, indicates the format of the transmitted non-NGV PPDU.<br><br>In the RXVECTOR, indicates the estimated format of the received non-NGV PPDU.<br><br>Enumerated type:<br>OFDM indicates Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) format.<br><br>NON_NGV_10_DUP_OFDM indicates non-NGV duplicate PPDU format. | Y | Y |
| | Otherwise | Not present. | N | N |
| APEP_LENGTH | FORMAT is NGV | If 0, indicates an NGV ranging NDP.<br>Otherwise, indicates the number of octets in the range 1 to aPSDUMaxLength in the A-MPDU pre-EOF padding (see Table 32-20 (NGV PHY characteristics(11bd))) that is carried in the PSDU. | Y | N |
| | Otherwise | Not present. | N | N |
| PSDU_LENGTH | FORMAT is NGV | Indicates the number of octets in the range 0 to aPSDUMaxLength octets (see Table 32-20 (NGV PHY characteristics(11bd))) in the NGV PSDU. The value of 0 indicates an NGV ranging NDP. | N | Y |
| | Otherwise | Not present. | N | N |
| DYN_BANDWIDTH_IN_NON_NGV | FORMAT is NON_NGV_10 | In the TXVECTOR, if present, indicates whether the transmitter is capable of Static or Dynamic bandwidth operation.<br><br>In the RXVECTOR, if valid, indicates whether the transmitter is capable of Static or Dynamic bandwidth operation.<br><br>Enumerated type:<br>Static if the transmitter is capable of Static bandwidth operation.<br><br>Dynamic if the transmitter is capable of Dynamic bandwidth operation.<br><br>NOTE—In the RXVECTOR, the validity of this parameter is determined by the MAC based on the contents of the received MPDU. | O | Y |
| | Otherwise | Not present. | N | N |



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**Table 32-1—TXVECTOR and RXVECTOR parameters(11bd) *(continued)***

| Parameter | Condition | Value | TXVECTOR | RXVECTOR |
|---|---|---|---|---|
| CH_BANDWIDTH_IN_NON_NGV | FORMAT is NON_NGV_10 | In the TXVECTOR, if present, indicates the channel width of the transmitted PPDU, which is signaled via the scrambling sequence.<br><br>In the RXVECTOR, if valid, indicates the channel width of the received PPDU, which is signaled via the scrambling sequence.<br><br>Enumerated type:<br>CBW10, CBW20.<br><br>NOTE—In the RXVECTOR, the validity of this parameter is determined by the MAC based on the contents of the currently received MPDU (e.g., RTS) or the previous MPDU in an exchange (e.g., RTS preceding a CTS). | O | Y |
| | Otherwise | Not present. | N | N |
| TIME_OF_DEPARTURE_REQUESTED | Enumerated type:<br>true indicates that the MAC entity requests that the PHY entity measures and reports time of departure parameters corresponding to the time when the first frame energy is sent by the transmitting port. false indicates that the MAC entity requests that the PHY entity neither measures nor reports time of departure parameters. | | O | N |
| LTF_REP | FORMAT is NGV and APEP_LENGTH is 0 | Indicates the number of repetitions of the NGV-LTF symbols. Set to the number of repetitions. | O | N |
| | Otherwise | Not present. | N | N |

NOTE—In the "TXVECTOR" and "RXVECTOR" columns, the following apply:
Y = Present;
N = Not present;
O = Optional.

### 32.2.3 PHY CONFIG_VECTOR

The PHYCONFIG_VECTOR carried in a PHY-CONFIG.request primitive for the NGV PHY contains an OPERATING_CHANNEL parameter, which identifies the operating or primary channel. The PHY shall set dot11CurrentPrimaryChannel to the value of parameter OPERATING_CHANNEL.

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The PHYCONFIG_VECTOR carried in a PHY-CONFIG.request primitive for the NGV PHY contains a SECONDARY_CHANNEL_OFFSET parameter, which takes one of the following values:

— SECONDARY_CHANNEL_NONE if no secondary channel is present; in this case the PHY shall set dot11CurrentSecondaryChannel to 0.

— SECONDARY_CHANNEL_ABOVE if the channel number of the secondary channel is greater than the channel number of the primary channel; in this case the PHY shall set dot11CurrentSecondaryChannel to dot11CurrentPrimaryChannel + 2.

— SECONDARY_CHANNEL_BELOW if the channel number of the secondary channel is smaller than the channel number of the primary channel; in this case the PHY shall set dot11CurrentSecondaryChannel to dot11CurrentPrimaryChannel – 2.

### 32.2.4 Effects of CH_BANDWIDTH parameter on PPDU format

Table 32-2 (Interpretation of FORMAT, NON_NGV_MODULATION, and CH_BANDWIDTH parameters(11bd)) shows the valid combinations of the FORMAT, NON_NGV_MODULATION, and CH_BANDWIDTH parameters and the corresponding PPDU format.

**Table 32-2— Interpretation of FORMAT, NON_NGV_MODULATION, and CH_BANDWIDTH parameters(11bd)**

| FORMAT | NON_NGV_MODULATION | CH_BANDWIDTH | PPDU format |
|---|---|---|---|
| NGV | N/A | CBW10 | The STA transmits an NGV PPDU of 10 MHz bandwidth. |
| NGV | N/A | CBW20 | The STA transmits an NGV PPDU of 20 MHz bandwidth. |
| NON_NGV_10 | OFDM | N/A | The STA transmits a non-NGV PPDU of 10 MHz bandwidth. |
| NON_NGV_10 | NON_NGV_10_DUP_OFDM | N/A | The STA transmits a NON_NGV_10 PPDU with NON_NGV_MODULATION set to NON_NGV_10_DUP_OFDM using two adjacent 10 MHz channels as defined in 32.3.9.10 (Non-NGV duplicate transmission). The 10 MHz channel higher in frequency is rotated +90º relative to the 10 MHz channel lower in frequency as defined in Equation (32-5). |

### 32.2.5 Support for NON_NGV format

#### 32.2.5.1 General

An NGV STA logically contains Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) and Clause 32 (Next Generation V2X (NGV) PHY specification(11bd)) PHYs. The MAC interfaces to the PHYs via the Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) and Clause 32 (Next Generation V2X (NGV) PHY specification(11bd)) PHY service interfaces as shown in Figure 32-1 (PHY interaction on transmit for various PPDU formats(11bd)), Figure 32-2 (PHY interaction on receive for various PPDU formats(11bd)), and Clause 32 (Next Generation V2X (NGV) PHY specification(11bd)).


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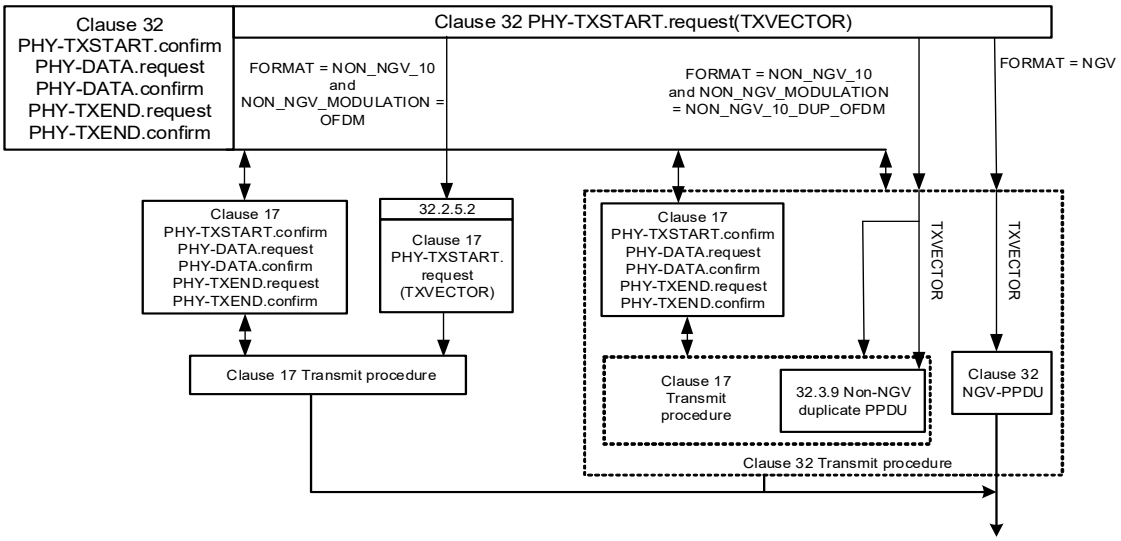


**Figure 32-1—PHY interaction on transmit for various PPDU formats(11bd)**

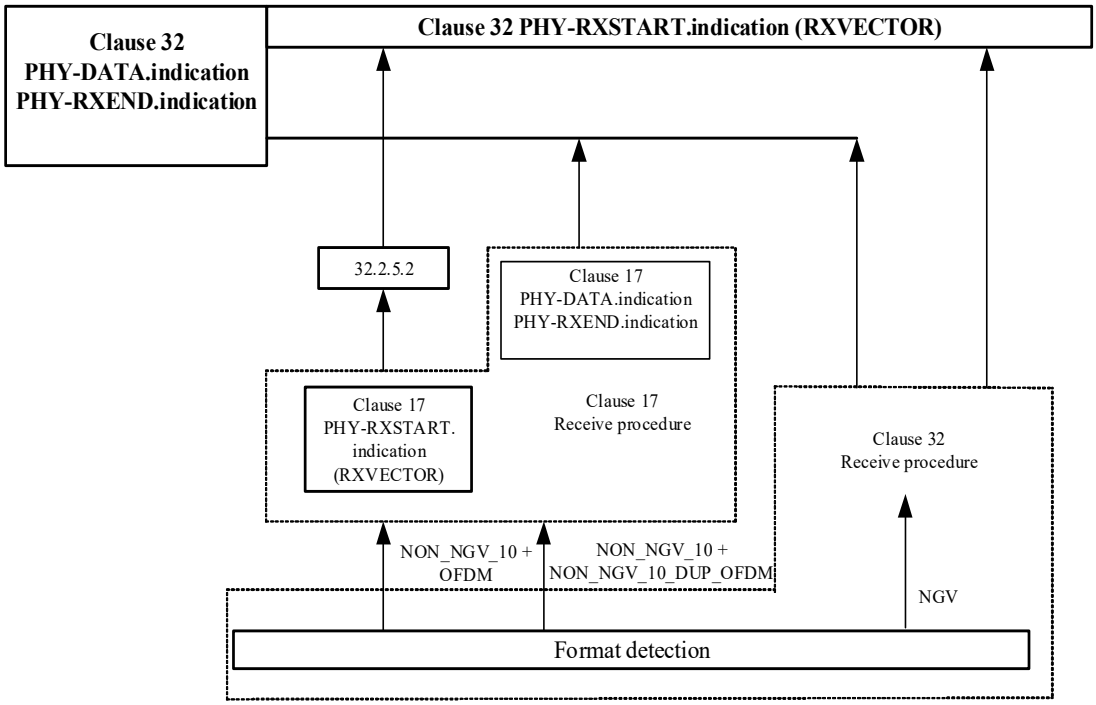


**Figure 32-2—PHY interaction on receive for various PPDU formats(11bd)**

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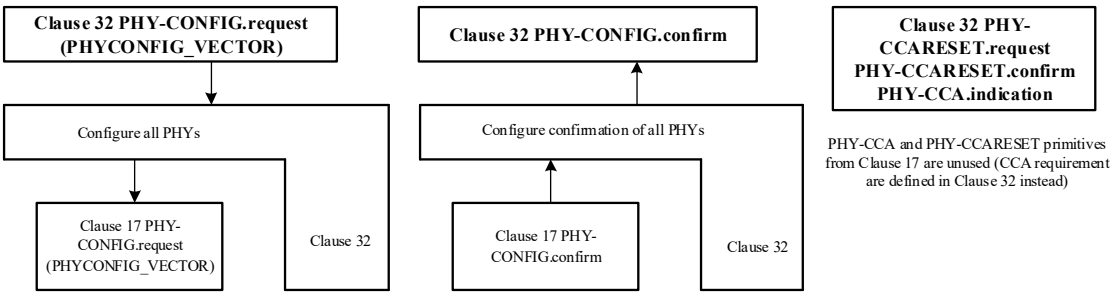


**Figure 32-3—PHY-CONFIG and CCA interaction with Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) and Clause 32 (Next Generation V2X (NGV) PHY specification(11bd))(11bd)**

When a PHY-TXSTART.request(TXVECTOR) primitive with the FORMAT parameter equal to NON_NGV_10 is issued, the behavior of the NGV PHY is defined in Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) with additional requirements described in the following subclauses:

— 32.3.11.1 (Transmit spectrum mask) instead of 17.3.9.3 (Transmit spectrum mask)

— 32.3.11.4.2 (Transmitter center frequency leakage) instead of 17.3.9.7.2 (Transmitter center frequency leakage)

where the Clause 32 (Next Generation V2X (NGV) PHY specification(11bd)) TXVECTOR parameters in Table 32-1 (TXVECTOR and RXVECTOR parameters(11bd)) are mapped to Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) TXVECTOR parameters in Table 17-1 (TXVECTOR parameters) according to Table 32-3 (Mapping of the NGV PHY parameters for non-NGV operation(11bd)).

When the NGV PHY receives a Clause 32 (Next Generation V2X (NGV) PHY specification(11bd)) PHY-CONFIG.request(PHYCONFIG_VECTOR) primitive, the NGV PHY shall, for the purpose of OFDM PPDU transmission and reception, behave as if it were a Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) PHY that had received a PHY-CONFIG.request(PHYCONFIG_VECTOR) primitive but with the SECONDARY_CHANNEL_OFFSET parameter discarded from PHYCONFIG_VECTOR.

As defined in 32.3.14 (NGV receive procedure), once a PPDU is received and detected as a non-NGV PPDU, the behavior of the NGV PHY is defined in Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification). The RXVECTOR parameters from the Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) PHY-RXSTART.indication primitive are mapped to the Clause 32 (Next Generation V2X (NGV) PHY specification(11bd)) RXVECTOR parameters as defined in Table 32-3 (Mapping of the NGV PHY parameters for non-NGV operation(11bd)). NGV PHY parameters not listed in the table are not present.


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**Table 32-3—Mapping of the NGV PHY parameters for non-NGV operation(11bd)**

| NGV parameters | 5.9 GHz operation defined by Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) | Parameter list |
|---|---|---|
| L_LENGTH | L_LENGTH | TXVECTOR/RXVECTOR |
| L_DATARATE | L_DATARATE | TXVECTOR/RXVECTOR |
| TXPWR_LEVEL_INDEX | TXPWR_LEVEL_INDEX | TXVECTOR |
| RSSI | RSSI | RXVECTOR |
| SERVICE | SERVICE | TXVECTOR/RXVECTOR |
| OPERATING_CHANNEL | OPERATING_CHANNEL | PHYCONFIG_VECTOR |
| SECONDARY_CHANNEL_OFFSET | Discarded | PHYCONFIG_VECTOR |

### 32.2.5.2 Repetition transmission of NON_NGV_10 PPDU

NGV STA shall support NON_NGV_10 PPDU repetition transmission mode. When a PHY-TXSTART.request(TXVECTOR) primitive with the FORMAT parameter equal to NON_NGV_10 and N_PPDU_REP being nonzero, the NON_NGV_10 repetition transmission mode shall be used by the PHY layer.

In this mode, the NON_NGV_10 PPDU is transmitted 1 + N_PPDU_REP times in sequence, where N_PPDU_REP is the number of repetitions following the first transmission, and N_PPDU_REP is indicated through TXVECTOR.

The time separation between every two repeated transmissions is indicated by parameter *aSIFSTime* (see Table 32-20 (NGV PHY characteristics(11bd))), as illustrated in Figure 32-4 (Example of NON_NGV_10 repetition transmission with N_PPDU_REP = 2(11bd)).

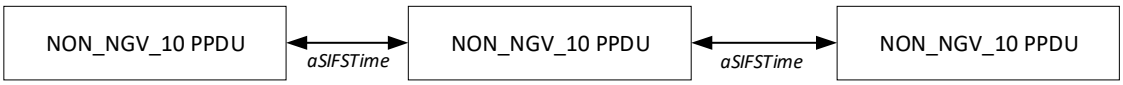


**Figure 32-4—Example of NON_NGV_10 repetition transmission with N_PPDU_REP = 2(11bd)**

NOTE—All the following N_PPDU_REP repetition PPDUs use the same scrambler as the first NON_NGV_10 PPDU.

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#### 32.2.5.3 TXSTATUS parameters

The parameters listed in Table 32-4 (TXSTATUS parameters(11bd)) are defined as part of the TXSTATUS parameter list in the PHY-TXSTART.confirm(TXSTATUS) service primitive.

**Table 32-4—TXSTATUS parameters(11bd)**

| Parameter | Value |
|---|---|
| TIME_OF_DEPARTURE | 0 to $2^{32}$ – 1. The locally measured time when the first frame energy is sent by the transmitting port, in units equal to 1/ TIME_OF_DEPARTURE_ClockRate. This parameter is present only if TIME_OF_DEPARTURE_REQUESTED is true in the corresponding request. |
| TIME_OF_DEPARTURE_ClockRate | 0 to $2^{16}$ – 1. The clock rate, in units of MHz, is used to generate the TIME_OF_DEPARTURE value. This parameter is present only if TIME_OF_DEPARTURE_REQUESTED is true in the corresponding request. |
| TX_START_OF_FRAME_OFFSET | 0 to $2^{32}$ – 1. An estimate of the offset (in 10 ns(#7198) units) from the point in time at which the start of the preamble corresponding to the frame was transmitted at the transmit antenna connector to the point in time at which this primitive is issued to the MAC. |

## 32.3 NGV PHY

### 32.3.1 Introduction

This subclause provides the procedure by which PSDUs are converted to and from transmissions on the wireless medium.

During transmission, a single PSDU is processed and appended to the NGV PHY preamble including L-STF, L-LTF, L-SIG, RL-SIG, NGV-SIG, RNGV-SIG, NGV-STF, and NGV-LTF fields to create the NGV PPDU. At the receivers, the PHY preamble is processed to aid in the detection, demodulation, and delivery of the PSDU.

### 32.3.2 NGV PPDU format

A single PPDU format is defined for this PHY: the NGV PPDU format. The format of NGV PPDU is defined in Figure 32-5 (NGV PPDU format(11bd)).

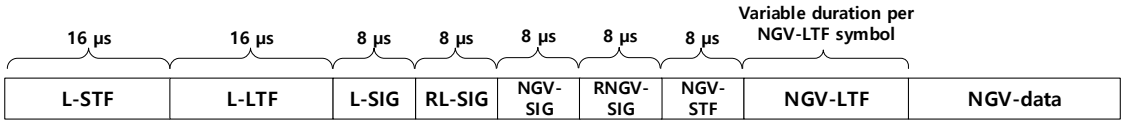


**Figure 32-5—NGV PPDU format(11bd)**


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The fields of the NGV PPDU format are summarized in Table 32-5 (Fields of the NGV PPDU(11bd)).

**Table 32-5—Fields of the NGV PPDU(11bd)**

| Field | Description |
|---|---|
| L-STF | Non-HT Short Training field |
| L-LTF | Non-HT Long Training field |
| L-SIG | Non-HT SIGNAL field |
| RL-SIG | Repeated Non-HT SIGNAL field |
| NGV-SIG | NGV Signal field |
| RNGV-SIG | Repeated NGV Signal field |
| NGV-STF | NGV Short Training field |
| NGV-LTF | NGV Long Training field |
| Data | The Data field carrying the PSDU(s) |

The RL-SIG, NGV-SIG, RNGV-SIG, NGV-STF, and NGV-LTF fields are present only in NGV PPDU formats. The RNGV-SIG field is equal to NGV-SIG field. The fields present in a non-NGV PPDU are the L-STF, L-LTF, L-SIG, and Data fields. The number of symbols in the NGV-LTF field, $N_{\text{NGV-LTF}}$, can be 1, 2, or 4 and is determined by the total number of spatial streams being transmitted in the NGV PPDU and whether the NGV-LTF is repeated in NGV ranging NDP (see Table 32-11 (Number of NGV-LTFs required for different numbers of spatial streams(11bd))).

### 32.3.3 Transmitter block diagram

The generation of each field in an NGV PPDU uses many of the following blocks:

a) PHY padding
b) Scrambler
c) FEC (BCC or LDPC) encoders
d) Stream parser
e) BCC interleaver
f) Constellation mapper
g) Pilot insertion
h) Replication over two 10 MHz channels (for BW = 20 MHz)
i) CSD per spatial stream insertion
j) Spatial mapper
k) IDFT
l) CSD per chain insertion
m) GI insertion
n) Windowing

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Figure 32-6 (Transmitter block diagram for the L-SIG, RL-SIG, NGV-SIG, and RNGV-SIG fields for an NGV PPDU(11bd)) and Figure 32-7 (Transmitter block diagram for the Data field of an NGV transmission(11bd)) show example transmitter block diagrams. The actual structure of the transmitter is implementation dependent.

In particular, Figure 32-6 (Transmitter block diagram for the L-SIG, RL-SIG, NGV-SIG, and RNGV-SIG fields for an NGV PPDU(11bd)) shows the transmit process for the L-SIG, RL-SIG, NGV-SIG, and RNGV-SIG fields of an NGV PPDU. The BCC encoder and interleaver are not used when generating the L-STF and L-LTF fields. The same BCC interleaver is applied to both the NGV-SIG field and the RNGV-SIG field such that the baseband signals of the NGV-SIG field symbol and the RNGV-SIG field symbol are exactly the same.

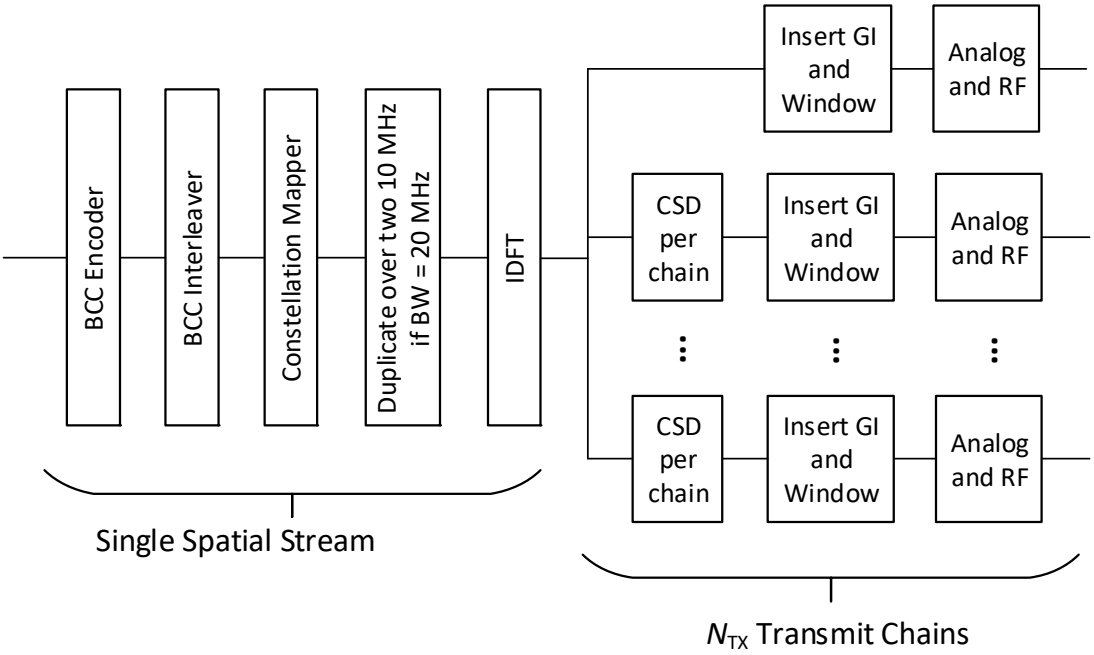


**Figure 32-6—Transmitter block diagram for the L-SIG, RL-SIG, NGV-SIG, and RNGV-SIG fields for an NGV PPDU(11bd)**

Figure 32-7 (Transmitter block diagram for the Data field of an NGV transmission(11bd)) shows the transmitter blocks used to generate the Data field of an NGV transmission. The BPSK-DCM tone mapping,


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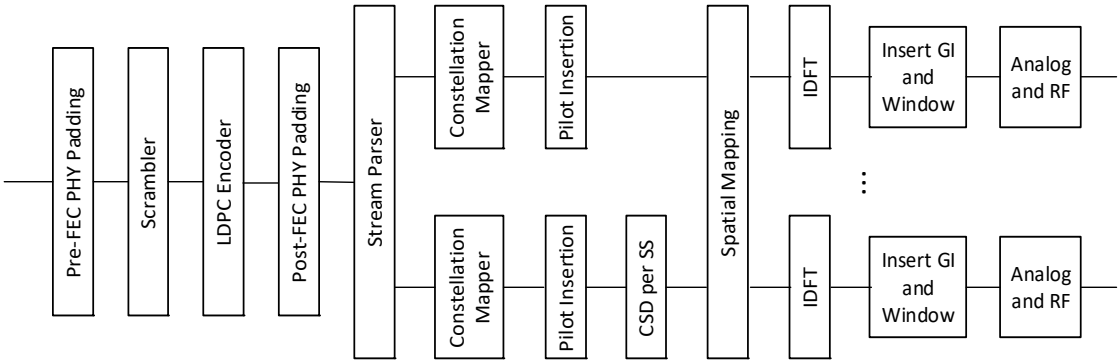
which is part of the constellation mapper block, is applied only if BPSK-DCM is indicated by NGV-MCS field value 15 in NGV-SIG field.




NOTE—Transmission with two spatial streams is optional.

**Figure 32-7—Transmitter block diagram for the Data field of an NGV transmission(11bd)**

### 32.3.4 Overview of the PPDU encoding process

#### 32.3.4.1 General

This subclause provides an overview of the NGV PPDU encoding process.

#### 32.3.4.2 Construction of L-STF

Construct the L-STF field as defined in 32.3.8.3 (L-STF definition) with the following highlights:

a) Determine the CH_BANDWIDTH from the TXVECTOR.

b) Sequence generation: Generate the L-STF sequence over the CH_BANDWIDTH as described in 32.3.8.3 (L-STF definition).

c) Phase rotation: Apply appropriate phase rotation for each 10 MHz subchannel as described in 32.3.7.3 (Transmitted signal) and 32.3.7.4 (Definition of tone rotation).

d) IDFT: Compute the inverse discrete Fourier transform.

e) CSD: Apply CSD for each transmit chain as described in 32.3.8.2.1 (Cyclic shift for pre-NGV modulated fields).

f) Insert GI and apply windowing: Prepend a GI and apply windowing as described in 32.3.7.3 (Transmitted signal).

Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit. Refer to 32.3.7.3 (Transmitted signal) and 32.3.8 (NGV preamble) for details.

#### 32.3.4.3 Construction of the L-LTF

Construct the L-LTF field as defined in 32.3.8.4 (L-LTF definition) with the following highlights:

a) Determine the CH_BANDWIDTH from the TXVECTOR.

b) Sequence generation: Generate the L-LTF sequence over the CH_BANDWIDTH as described in 32.3.8.4 (L-LTF definition).

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c) Phase rotation: Apply appropriate phase rotation for each 10 MHz subchannel as described in 32.3.7.3 (Transmitted signal) and 32.3.7.4 (Definition of tone rotation).

d) IDFT: Compute the inverse discrete Fourier transform.

e) CSD: Apply CSD for each transmit chain as described in 32.3.8.2.1 (Cyclic shift for pre-NGV modulated fields).

f) Insert GI and apply windowing: Prepend a GI and apply windowing as described in 32.3.7.3 (Transmitted signal).

g) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit. Refer to 32.3.7.3 (Transmitted signal) and 32.3.8 (NGV preamble) for details.

#### 32.3.4.4 Construction of the L-SIG and RL-SIG

Construct the L-SIG field as the SIGNAL field defined in 32.3.8.5 (L-SIG definition) with the following highlights:

a) In an NGV PPDU set the RATE subfield in the SIGNAL field to 3 Mb/s in the 10 MHz channel spacing column of Table 17-6 (Contents of the SIGNAL field). Set the Length, Parity, and Tail bits in the SIGNAL field as described in 32.3.8.5 (L-SIG definition).

b) BCC encoder: Encode the SIGNAL field by a convolutional encoder at the rate of R=1/2 as described in 17.3.5.6 (Convolutional encoder).

c) BCC interleaver: Interleave as described in 17.3.5.7 (Data interleaving).

d) Constellation Mapper: BPSK modulate as described in 17.3.5.8 (Subcarrier modulation mapping).

e) Pilot insertion: Insert pilots as described in 17.3.5.9 (Pilot subcarriers).

f) Duplication and phase rotation: Duplicate the L-SIG field over each 10 MHz of the CH_BANDWIDTH. Apply appropriate phase rotation for each 10 MHz subchannel as described in 32.3.7.3 (Transmitted signal) and 32.3.7.4 (Definition of tone rotation).

g) IDFT: Compute the inverse discrete Fourier transform.

h) CSD: Apply CSD for each transmit chain as described in 32.3.8.2.1 (Cyclic shift for pre-NGV modulated fields).

i) Insert GI and apply windowing: Prepend a GI and apply windowing as described in 32.3.7.3 (Transmitted signal).

j) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit. Refer to 32.3.7.3 (Transmitted signal) and 32.3.8 (NGV preamble) for details.

Construct the RL-SIG field as the repeat SIGNAL field defined in 32.3.8.6 (RL-SIG definition) with the same process as for the L-SIG field.

#### 32.3.4.5 Construction of the NGV-SIG and RNGV-SIG

The NGV-SIG field consists of one symbol as defined in 32.3.8.7 (NGV-SIG definition) and is constructed as follows:

a) Obtain the NGV-SIG field values from the TXVECTOR entries of NGV-MCS, CH_BANDWIDTH, MIDAMBLE_PERIODICITY, NGV_LTF_TYPE, NUM_SS, and LTF_REP. Add the reserved bits, append the calculated CRC, then append the tail bits as shown in 32.3.8.7 (NGV-SIG definition). This results in 24 uncoded bits.

b) BCC encoder: Encode the data by a convolutional encoder at the rate of R=1/2 as described in 17.3.5.6 (Convolutional encoder).

c) BCC interleaver: Interleave as described in 17.3.5.7 (Data interleaving).


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d) Constellation Mapper: BPSK modulate the 48 interleaved bits as described in 17.3.5.8 (Subcarrier modulation mapping) to form the NGV-SIG symbol.

e) Pilot insertion: Insert pilots as described in 17.3.5.9 (Pilot subcarriers).

f) Duplication and phase rotation: Duplicate NGV-SIG over each 10 MHz of the CH_BANDWIDTH. Apply appropriate phase rotation for each 10 MHz subchannel as described in 32.3.7.3 (Transmitted signal) and 32.3.7.4 (Definition of tone rotation).

g) IDFT: Compute the inverse discrete Fourier transform.

h) CSD: Apply CSD for each transmit chain as described in 32.3.8.2.1 (Cyclic shift for pre-NGV modulated fields).

i) Insert GI and apply windowing: Prepend a GI and apply windowing as described in 32.3.7.3 (Transmitted signal).

j) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit. Refer to 32.3.7.3 (Transmitted signal) and 32.3.8 (NGV preamble) for details.

Construct the RNGV-SIG field as the repeat NGV-SIG field defined in 32.3.8.8 (RNGV-SIG definition) with the same process as for the NGV-SIG field.

#### 32.3.4.6 Construction of NGV-STF

The NGV-STF field is defined in 32.3.8.9 (NGV-STF definition) and is constructed as follows:

a) Sequence generation: Generate the NGV-STF in the frequency domain over the bandwidth indicated by CH_BANDWIDTH as described in 32.3.8.9 (NGV-STF definition).

b) Phase rotation: Apply appropriate phase rotation for each 10 MHz subchannel as described in 32.3.7.3 (Transmitted signal) and 32.3.7.4 (Definition of tone rotation).

c) CSD: Apply CSD for each spatial stream as described in 32.3.8.2.2 (Cyclic shift for NGV modulated fields).

d) Spatial mapping: Apply the $Q$ matrix as described in 32.3.9.8.1 (Transmission in NGV format).

e) IDFT: Compute the inverse discrete Fourier transform.

f) Insert GI and apply windowing: Prepend a GI and apply windowing as described in 32.3.7.3 (Transmitted signal).

g) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit. Refer to 32.3.7.3 (Transmitted signal) and 32.3.8 (NGV preamble) for details.

#### 32.3.4.7 Construction of NGV-LTF

The NGV-LTF field is defined in 32.3.8.10 (NGV-LTF definition) and constructed as follows:

a) Sequence generation: Generate the NGV-LTF sequence in the frequency domain over the CH_BANDWIDTH as described in 32.3.8.10 (NGV-LTF definition).

b) Phase rotation: Apply appropriate phase rotation for each 10 MHz subchannel as described in 32.3.7.3 (Transmitted signal) and 32.3.7.4 (Definition of tone rotation).

c) $A_{NGV\text{-}LTF}$ matrix mapping: Apply the $P_{NGV\text{-}LTF}$ matrix to the data tones of the NGV-LTF sequence and apply the $R_{NGV\text{-}LTF}$ matrix to the pilot tones as described in 32.3.8.10 (NGV-LTF definition).

d) CSD: Apply CSD for each spatial stream as described in 32.3.8.2.2 (Cyclic shift for NGV modulated fields).

e) Spatial mapping: Apply the $Q$ matrix as described in 32.3.9.8.1 (Transmission in NGV format).

f) IDFT: Compute the inverse discrete Fourier transform.

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g) Insert GI and apply windowing: Prepend a GI and apply windowing as described in 32.3.7.3 (Transmitted signal).

h) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit. Refer to 32.3.7.3 (Transmitted signal) and 32.3.8 (NGV preamble) for details.

#### 32.3.4.8 Construction of the Data field in an NGV PPDU

The construction of the Data field in an NGV PPDU proceeds as follows:

a) Construct the SERVICE field as described in 32.3.9.2 (SERVICE field) and append the PSDU to the SERVICE field.

b) PHY padding: Append the PHY pad bits to the PSDU. There are no tail bits.

c) Scrambler: Scramble the PHY padded data.

d) LDPC encoder: The scrambled bits are encoded using the LDPC code with the APEP_LENGTH in the TXVECTOR as described in 32.3.9.4 (Coding).

e) Stream parser: The output of the LDPC encoder is rearranged into blocks as described in 32.3.9.5 (Stream parser).

f) Phase rotation: Apply appropriate phase rotation for each 10 MHz subchannel as described in 32.3.7.3 (Transmitted signal) and 32.3.7.4 (Definition of tone rotation).

g) CSD: Apply CSD for each spatial stream as described in 32.3.8.2.2 (Cyclic shift for NGV modulated fields).

h) Spatial mapping: Apply the $Q$ matrix as described in 32.3.9.8.1 (Transmission in NGV format).

i) IDFT: Compute the inverse discrete Fourier transform.

j) Insert GI and apply windowing: Prepend a GI and apply windowing as described in 32.3.7.3 (Transmitted signal).

k) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit. Refer to 32.3.7.3 (Transmitted signal) and 32.3.8 (NGV preamble) for details.

### 32.3.5 NGV modulation and coding schemes

The NGV-MCS is a value that determines the modulation and coding used in the Data field of the PPDU. It is a compact representation that is carried in the NGV-SIG field and RNGV-SIG field for NGV PPDUs. Rate dependent parameters for the full set of NGV-MCSs are shown in Table 32-21 (NGV-MCSs for 10 MHz, NSS = 1(11bd)) to Table 32-24 (NGV-MCSs for 20 MHz, NSS = 2(11bd)). These tables give rate-dependent parameters for NGV-MCSs with indices $n$, where $n$ = 0, ..., 15, with number of spatial streams from 1 to 2 and bandwidth options of 10 MHz and 20 MHz. Equal modulation is applied to all streams.

The use of BPSK-DCM on the Data field of an NGV PPDU is indicated as NGV-MCS 15 in NGV-SIG field.


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### 32.3.6 Timing related parameters

Table 32-6 (Timing related constants(11bd)) defines the timing related parameters.

**Table 32-6—Timing related constants(11bd)**

| Parameter | CBW10 | CBW20 | Description |
|---|---|---|---|
| $N_{SD}$ | 52 | 108 | Number of data subcarriers |
| $N_{SP}$ | 4 | 6 | Number of pilot subcarriers |
| $N_{ST}$ | 56 | 114 | Total number of subcarriers<br>See NOTE |
| $N_{SR}$ | 28 | 58 | Highest data subcarrier index |
| $\Delta_F$ | 156.25 kHz | | Subcarrier frequency spacing |
| $T_{DFT}$ | 6.4 μs | | IDFT/DFT period |
| $T_{GI}$ | 1.6 μs = $T_{DFT}$/4 | | Guard interval duration |
| $T_{GI2}$ | 3.2 μs | | Double guard interval |
| $T_{SYM}$ | 8 μs = $T_{DFT}$ + $T_{GI}$ = 1.25×$T_{DFT}$ | | Symbol interval |
| $T_{\text{L-STF}}$ | 16 μs = 10 × $T_{DFT}$/4 | | Non-HT Short Training field duration |
| $T_{\text{L-LTF}}$ | 16 μs = 2 × $T_{DFT}$ + $T_{GI2}$ | | Non-HT Long Training field duration |
| $T_{\text{L-SIG}}$ | 8 μs | | Non-HT SIGNAL field duration |
| $T_{\text{RL-SIG}}$ | 8 μs | | Repeated Non-HT SIGNAL field duration |
| $T_{\text{NGV-SIG}}$ | 8 μs | | NGV SIGNAL field duration |
| $T_{\text{RNGV-SIG}}$ | 8 μs | | Repeated NGV SIGNAL field duration |
| $T_{\text{NGV-STF}}$ | 8 μs | | NGV Short Training field duration |
| $T_{\text{NGV-LTF-2X}}$ | 8 μs | | Duration of each NGV-LTF-2x symbol |
| $T_{\text{NGV-LTF-1X}}$ | 4.8 μs | | Duration of each NGV-LTF-1x symbol |
| $T_{\text{NGV-LTF-2X-Repeat}}$ | 14.4 μs | | Duration of each repeated NGV-LTF-2x symbol |
| $T_{\text{NGV-LTF}}$ | $T_{\text{NGV-LTF-2X}}$ , $T_{\text{NGV-LTF-1X}}$ or $T_{\text{NGV-LTF-2X-Repeat}}$ depending on the LTF format used | | Duration of each OFDM symbol in NGV-LTF field |
| $N_{service}$ | 16 | | Number of bits in the SERVICE field |
| $N_{tail}$ | 6 | | Number of tail bits per BCC encoder |
| NOTE —$N_{ST} = N_{SD} + N_{SP}$ | | | |

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Table 32-7 (Frequently used parameters(11bd)) defines parameters used frequently in Clause 32 (Next Generation V2X (NGV) PHY specification(11bd)).

**Table 32-7—Frequently used parameters(11bd)**

| Symbol | Explanation |
|---|---|
| $N_{CBPS}$ | Number of coded bits per symbol |
| $N_{CBPSS}$ | Number of coded bits per symbol per spatial stream |
| $N_{DBPS}$ | Number of data bits per symbol |
| $N_{BPSCS}$ | Number of coded bits per subcarrier per spatial stream |
| $N_{RX}$ | Number of receive chains |
| $N_{SS}$ | Number of spatial streams |
| $N_{TX}$ | Number of transmit chains |
| $N_{\text{NGV-LTF}}$ | Number of NGV-LTF symbols |
| $R$ | $R$ is the coding rate |

### 32.3.7 Mathematical description of signals

#### 32.3.7.1 Notation

For a description of the conventions used for the mathematical description of the signals, see 17.3.2.5 (Mathematical conventions in the signal descriptions), and 21.3.7.1 (Notation).

#### 32.3.7.2 Subcarrier indices in use

For a 10 MHz non-NGV PPDU, the signal is transmitted on subcarriers –26 to –1 and 1 to 26, with 0 being the center (DC) subcarrier. See 17.3.2.6 (Discrete time implementation considerations).

For a 10 MHz NGV PPDU transmission, the 10 MHz is divided into 64 subcarriers. The signal is transmitted on subcarriers –28 to –1 and 1 to 28, with 0 being the center (DC) subcarrier.

For a 20 MHz NGV PPDU transmission, the 20 MHz is divided into 128 subcarriers. The signal is transmitted on subcarriers –58 to –2 and 2 to 58.

#### 32.3.7.3 Transmitted signal

The transmitted signal is described in complex baseband signal notation. The actual transmitted signal is related to the complex baseband signal by the relation shown in Equation (32-1).

$$r_{RF}^{i_{TX}} = \text{Re}\{r_{PPDU}^{i_{TX}}(t) \exp(j2\pi f_c t)\}, \quad i_{TX} = 1, \ldots, N_{TX} \tag{32-1}$$

where

$r_{PPDU}^{i_{TX}}(t)$ represents the complex baseband signal of transmit chain $i_{TX}$


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$f_c$ represents the center frequency of the PPDU

The transmitted RF signal is derived by upconverting the complex baseband signal, which consists of several fields. The timing boundaries for the various fields are shown in Figure 32-8 (Timing boundaries for NGV PPDU fields(11bd)), where $N_{\text{NGV-LTF}}$ is the number of NGV-LTF symbols as defined in Table 32-11 (Number of NGV-LTFs required for different numbers of spatial streams(11bd)).

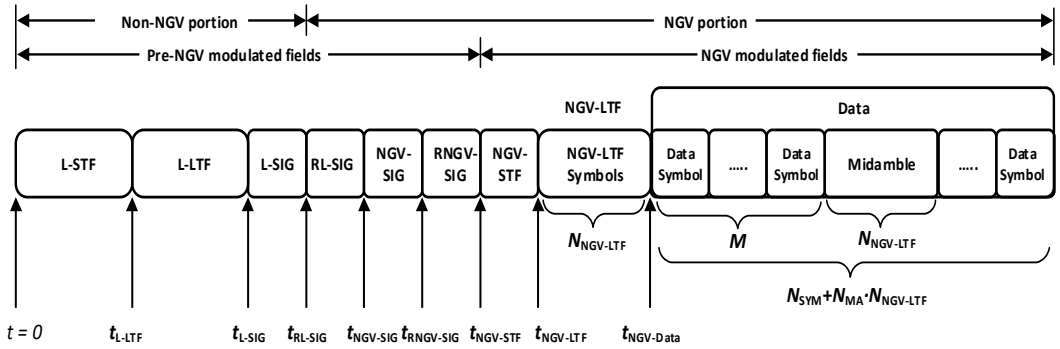


**Figure 32-8—Timing boundaries for NGV PPDU fields(11bd)**

The time offset, $t_{Field}$, determines the starting time of the corresponding field relative to the start of L-STF ($t = 0$).

The signal transmitted on transmit chain $i_{TX}$ shall be as shown in Equation (32-2).

$$\begin{aligned} r_{PPDU}^{i_{TX}}(t) = {} & r_{L\text{-}STF}^{i_{TX}}(t) + r_{L\text{-}LTF}^{i_{TX}}(t - t_{L\text{-}LTF}) \\ & + r_{L\text{-}SIG}^{i_{TX}}(t - t_{L\text{-}SIG}) + r_{RL\text{-}SIG}^{i_{TX}}(t - t_{RL\text{-}SIG}) + r_{NGV\text{-}SIG}^{i_{TX}}(t - t_{NGV\text{-}SIG}) \\ & + r_{RNGV\text{-}SIG}^{i_{TX}}(t - t_{RNGV\text{-}SIG}) + r_{NGV\text{-}STF}^{i_{TX}}(t - t_{NGV\text{-}STF}) + r_{NGV\text{-}LTF}^{i_{TX}}(t - t_{NGV\text{-}LTF}) \\ & + r_{NGV\text{-}Data}^{i_{TX}}(t - t_{NGV\text{-}Data}) \end{aligned} \tag{32-2}$$

where

$$1 \le i_{TX} \le N_{TX}$$

$$t_{L\text{-}LTF} = T_{L\text{-}STF}$$

$$t_{L\text{-}SIG} = t_{L\text{-}LTF} + T_{L\text{-}LTF}$$

$$t_{RL\text{-}SIG} = t_{L\text{-}SIG} + T_{L\text{-}SIG}$$

$$t_{NGV\text{-}SIG} = t_{RL\text{-}SIG} + T_{RL\text{-}SIG}$$

$$t_{RNGV\text{-}SIG} = t_{NGV\text{-}SIG} + T_{NGV\text{-}SIG}$$

$$t_{NGV\text{-}STF} = t_{RNGV\text{-}SIG} + T_{RNGV\text{-}SIG}$$

$$t_{NGV\text{-}LTF} = t_{NGV\text{-}STF} + T_{NGV\text{-}STF}$$

$$t_{NGV\text{-}Data} = t_{NGV\text{-}LTF} + N_{NGV\text{-}LTF} \cdot T_{NGV\text{-}LTF} \cdot$$

Each field, $r_{Field}^{i_{TX}}(t)$, is defined as the summation of one or more subfields, where each subfield is defined to be an inverse discrete Fourier transform as specified in Equation (32-3).

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$$r_{Subfield}^{i_{TX}}(t) = \frac{1}{\sqrt{N_{\text{Field}}^{\text{Tone}} \times N_{Norm}}} w_{T_{Subfield}}(t)\eta_{Field} \sum_{k=-N_{SR}}^{N_{SR}} \sum_{m=1}^{N_{SS}} [Q_k]_{i_{TX},m} \Upsilon_{k,BW} X_k^m \exp(j2\pi k\Delta_F(t - T_{GI,Field} - T_{CS,NGV}(m))) \quad (32\text{-}3)$$

This general representation holds for all subfields. The total power of the time domain NGV modulated field signals summed over all transmit chains should not exceed the total power of the time domain pre-NGV modulated field signals summed over all transmit chains. For notational simplicity, the parameter BW is omitted from some bandwidth dependent terms.

In Equation (32-3), the following notations are used:

$N_{Field}^{\text{Tone}}$ Table 32-8 (Tone scaling factor and guard interval duration values for PHY fields(11bd)) summarizes the various values of $N_{Field}^{\text{Tone}}$ as a function of bandwidth.

$N_{Norm}$ For pre-NGV modulated fields, $N_{Norm} = N_{TX}$. For NGV modulated fields $N_{Norm} = N_{SS}$, where $N_{SS}$ is given in Table 32-7 (Frequently used parameters(11bd)).

$w_{T_{Subfield}}(t)$ is a windowing function. An example function, $w_{T_{Subfield}}(t)$, is given in 17.3.2.5 (Mathematical conventions in the signal descriptions). $T_{Subfield}$ is $T_{L\text{-}STF}$ for L-STF, $T_{L\text{-}LTF}$ for L-LTF, $T_{L\text{-}SIG}$ for L-SIG, $T_{RL\text{-}SIG}$ for RL-SIG, $T_{NGV\text{-}SIG}$ for NGV-SIG, $T_{RNGV\text{-}SIG}$ for RNGV-SIG, $T_{NGV\text{-}STF}$ for NGV-STF, $T_{NGV\text{-}LTF}$ for NGV-LTF symbol and midamble symbol, and $T_{SYM}$ for Data symbol.

$Q_k$ is the spatial mapping matrix for the subcarrier $k$. For pre-NGV modulated fields, $Q_k$ is a column vector with $N_{TX}$ elements with element $i_{TX}$ being $e^{-j2\pi k\Delta_F T_{CS}^{i_{TX}}}$, where $T_{CS}^{i_{TX}}$ represents the cyclic shift for transmitter chain $i_{TX}$ whose values are given in Table 21-10 (Cyclic shift values for L-STF, L-LTF, L-SIG, and VHT-SIG-A fields of the PPDU). For NGV modulated fields, $Q_k$ is a matrix with $N_{TX}$ rows and $N_{SS}$ columns as further described in 32.3.9.8.1 (Transmission in NGV format).

$\Upsilon_{k,BW}$ is defined in 32.3.7.4 (Definition of tone rotation).

$\Delta_F$ is the subcarrier frequency spacing given in Table 32-6 (Timing related constants(11bd)).

$X_k^m$ is the frequency domain symbol in subcarrier $k$ of spatial stream $m$. Some of the $X_k^m$ within $-N_{SR} \le k \le N_{SR}$ have a value of 0. Examples of such cases include the DC tones, guard tones on each side of the transmit spectrum, as well as the unmodulated tones of L-STF and NGV-STF fields.

NOTE—The multiplication matrices $A_{NGV\text{-}LTF}^k$ and $P_{NGV\text{-}LTF}$ are included in the calculation of $X_k^m$ for the NGV-LTF field.

$T_{GI,Field}$ is the guard interval duration used for each OFDM symbol in the field. For L-STF and NGV-STF, $T_{GI,Field} = T_{GI}$ but it can be omitted from Equation (32-3) due to the periodic property of L-STF and NGV-STF over every 1.6 µs. For the L-SIG, RL-SIG, NGV-SIG, RNGV-SIG, NGV-LTF, and Data fields, $T_{GI,Field}$ is defined in the "Guard interval duration" column of Table 32-8 (Tone scaling factor and guard interval duration values for PHY fields(11bd)).


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$T_{CS,NGV}(m)$ For pre-NGV modulated fields, $T_{CS,NGV}(m) = 0$. For NGV modulated fields, $T_{CS,NGV}(m)$ represents the cyclic shift per spatial stream, whose value is given in 21.3.8.3.2 (Cyclic shift for VHT modulated fields), where the row for $N_{STS,total} = 1$ corresponds to $N_{SS} = 1$ and the row for $N_{STS,total} = 2$ corresponds to $N_{SS} = 2$.

$\eta_{Field}$ is the power scale factor of a given field within an OFDM symbol for NGV PPDU. For the L-STF and L-LTF fields, $\eta_{Field}$ is $\sqrt{2}$ when NGV-MCS 0 or NGV-MCS 15 and one spatial stream is used for data field in 10 MHz NGV PPDU; otherwise it is 1. For other fields of NGV PPDU, $\eta_{Field} = 1$.

**Table 32-8—Tone scaling factor and guard interval duration values for PHY fields(11bd)**

| Field | $N_{Field}^{Tone}$ | | Guard interval duration |
|---|---|---|---|
| | 10 MHz | 20 MHz | |
| L-STF | 12 | 24 | — |
| L-LTF | 52 | 104 | $T_{GI2}$ |
| L-SIG | 52 | 104 | $T_{GI}$ |
| RL-SIG | 52 | 104 | $T_{GI}$ |
| NGV-SIG | 52 | 104 | $T_{GI}$ |
| RNGV-SIG | 52 | 104 | $T_{GI}$ |
| NGV-STF | 12 | 24 | — |
| NGV-LTF-1x | 28 | 58 | $T_{GI}$ |
| NGV-LTF-2x | 56 | 114 | $T_{GI}$ |
| NGV-LTF-2x-Repeat | 56 | 114 | $T_{GI}$ |
| Data | 56 | 114 | $T_{GI}$ |
| NON_NGV_10_DUP_OFDM-Data | — | 104 | $T_{GI}$ |

### 32.3.7.4 Definition of tone rotation

The function $\Upsilon_{k,BW}$ is used to represent a rotation of the tones. The value of $BW$ in $\Upsilon_{k,BW}$ is determined by the TXVECTOR parameter CH_BANDWIDTH as defined in Table 32-9 (CH_BANDWIDTH(11bd)).

**Table 32-9—CH_BANDWIDTH(11bd)**

| CH_BANDWIDTH | $\Upsilon_{k,BW}$ |
|---|---|
| CBW10 | $\Upsilon_{k,10}$ |
| CBW20 | $\Upsilon_{k,20}$ |

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For a 10 MHz NGV PPDU transmission:

$$\Upsilon_{k,10} = 1 \tag{32-4}$$

For a 20 MHz NGV PPDU transmission:

$$\Upsilon_{k,20} = \begin{cases} 1, & k < 0 \\ j, & k \geq 0 \end{cases} \tag{32-5}$$

### 32.3.8 NGV preamble

#### 32.3.8.1 Introduction

An NGV preamble is defined to carry the required information to operate in a system with multiple transmit and multiple receive antennas. To maintain compatibility with non-NGV STAs, specific non-NGV fields are defined that can be received by non-NGV STAs compliant with Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification). The non-NGV fields are followed by NGV fields specific to NGV STAs.

#### 32.3.8.2 Cyclic shift

##### 32.3.8.2.1 Cyclic shift for pre-NGV modulated fields

The cyclic shift value $N_{CS}^{i_{TX}}$ for the L-STF, L-LTF, L-SIG, RL-SIG, NGV-SIG, and RNGV-SIG fields of the PPDU for transmit chain $i_{TX}$ out of a total of $N_{TX}$ are defined in Table 21-10 (Cyclic shift values for L-STF, L-LTF, L-SIG, and VHT-SIG-A fields of the PPDU).

##### 32.3.8.2.2 Cyclic shift for NGV modulated fields

The cyclic shift values defined in this subclause apply to the NGV-STF, NGV-LTF, and Data fields of the NGV PPDU.

Throughout the NGV modulated fields of the preamble, cyclic shifts are applied to prevent unintended beamforming when correlated signals are transmitted in multiple spatial streams. The same cyclic shift is also applied to these streams during the transmission of the Data field of the NGV PPDU. The cyclic shift value for the NGV modulated fields for spatial stream *m* out of $N_{SS}$, the number of spatial streams, is shown in Table 21-11 (Cyclic shift values for the VHT modulated fields of a PPDU) where the values in the row for $N_{STS} = m$ is used.

#### 32.3.8.3 L-STF definition

The frequency domain sequence of the L-STF field for a 10 MHz or 20 MHz transmission is defined by Equation (19-8) and Equation (19-9), respectively, in 19.3.9.3.3 (L-STF definition).

The time domain representation of the signal on transmit chain $i_{TX}$ shall be as specified in Equation (32-6).


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$$r_{L\text{-}STF}^{(i_{TX})}(t) = \frac{1}{\sqrt{N_{TX} \times N_{L\text{-}STF}^{Tone}}} w_{T_{L\text{-}STF}}(t) \eta_{L-STF} \sum_{i_{BW}=0}^{N_{10\,\mathrm{MHz}}-1} \sum_{k=-26}^{26} (\gamma_{(k-K_{shift}(i_{BW})),\,BW} S_{k,\,10} \times \exp(j2\pi(k-K_{shift}(i_{BW}))\Delta_F(t-T_{CS}^{i_{TX}}))) \quad (32\text{-}6)$$

where

$\eta_{L-STF}$ is the modulation dependent power scaling factor for the L-STF field with the following value:

$$\eta_{L-STF} = \begin{cases} \sqrt{2}, & \text{when NGV-MCS 0 or NGV-MCS 15 and one spatial stream is used on Data field for 10 MHz transmission} \\ 1, & \text{otherwise} \end{cases}$$

$$N_{10\,\mathrm{MHz}} = \begin{cases} 1, & \text{If CH\_BANDWIDTH is CBW10} \\ 2, & \text{If CH\_BANDWIDTH is CBW20} \end{cases}$$

$K_{shift}(i) = (N_{10\,\mathrm{MHz}} - 1 - 2i) \times 32$

$T_{CS}^{(i_{TX})}$ represents the cyclic shift for transmit chain $i_{TX}$ with a value given in 32.3.8.2.1 (Cyclic shift for pre-NGV modulated fields)

$\gamma_{k,\,BW}$ is defined in Equation (32-4) and Equation (32-5)

$N_{L\text{-}STF}^{Tone}$ has the value given in Table 32-8 (Tone scaling factor and guard interval duration values for PHY fields(11bd))

$S_{k,\,10}$ is defined as $S_{-26,\,26}$ in Equation (19-8)

### 32.3.8.4 L-LTF definition

For a 10 MHz or 20 MHz transmission, the L-LTF pattern in the NGV preamble is defined by Equation (19-11) and Equation (19-12) in 19.3.9.3.4 (L-LTF definition), respectively.

The time domain representation of the signal on transmit chain $i_{TX}$ shall be as defined in Equation (32-7).

$$r_{L\text{-}LTF}^{(i_{TX})}(t) = \frac{1}{\sqrt{N_{TX} \times N_{L\text{-}LTF}^{Tone}}} w_{T_{L\text{-}LTF}}(t) \eta_{L-LTF} \sum_{i_{BW}=0}^{N_{10\,\mathrm{MHz}}-1} \sum_{k=-26}^{26} (\gamma_{(k-K_{shift}(i_{BW})),\,BW} L_{k,\,10} \times \exp(j2\pi(k-K_{shift}(i_{BW}))\Delta_F(t-T_{CS}^{i_{TX}}))) \quad (32\text{-}7)$$

where

$\eta_{L-LTF}$ is a modulation dependent scaling factor for the L-LTF field with the same value as $\eta_{L-STF}$

$T_{CS}^{(i_{TX})}$ represents the cyclic shift for transmit chain $i_{TX}$ with a value given in 32.3.8.2.1 (Cyclic shift for pre-NGV modulated fields)

$\gamma_{k,\,BW}$ is defined in Equation (32-4) and Equation (32-5)

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$N_{L\text{-}LTF}^{Tone}$ has the value given in Table 32-8 (Tone scaling factor and guard interval duration values for PHY fields(11bd))

$N_{10\,\mathrm{MHz}}$ is defined in 32.3.8.3 (L-STF definition)

$K_{shift}(i) = (N_{10\,\mathrm{MHz}} - 1 - 2i) \times 32$

$L_{k,\,10}$ is defined as $L_{-26,\,26}$ in Equation (19-11)

### 32.3.8.5 L-SIG definition

The L-SIG field is used to communicate rate and length information. The structure of the L-SIG field is defined in Figure 17-5 (SIGNAL field bit assignment).

In an NGV PPDU, the RATE field shall be set to the value representing 3 Mb/s in the 10 MHz channel spacing column of Table 17-6 (Contents of the SIGNAL field). In a non-NGV duplicate PPDU, the RATE field is defined in 17.3.4.2 (RATE field) using the L_DATARATE parameter in the TXVECTOR.

The Length field shall be set to the value given by Equation (32-8).

$$\text{Length} = \frac{\text{TXTIME} - 40}{8} \times 3 - 3 \tag{32-8}$$

where

TXTIME (in μs) is defined in 32.4.3 (TXTIME and PSDU_LENGTH calculation).

The LSB of the binary expression of the value of the Length field shall be mapped to B5. In a non-NGV duplicate PPDU, the LENGTH field is defined in 17.3.4.3 (PHY LENGTH field) using the L_LENGTH parameter in the TXVECTOR.

The Reserved (R) field shall be set to 0.

The Parity (P) field has the even parity of bits 0–16.

The SIGNAL TAIL field shall be set to 0.

The L-SIG field shall be encoded, interleaved, and mapped following the steps described in 17.3.5.6 (Convolutional encoder), 17.3.5.7 (Data interleaving), and 17.3.5.8 (Subcarrier modulation mapping). The stream of 48 complex numbers generated by these steps is denoted by $d_k$, $k = 0, \ldots, 47$ and are mapped to subcarriers [–26, 26]. Pilots shall be inserted as described in 17.3.5.9 (Pilot subcarriers).

The time domain waveform of the L-SIG field shall be as given by Equation (32-9).

$$r_{L\text{-}SIG}^{(i_{TX})}(t) = \frac{1}{\sqrt{N_{TX} \times N_{L\text{-SIG}}^{Tone}}} w_{\mathrm{T}_{L\text{-}SIG}}(t) \sum_{i_{BW}=0}^{N_{10\,\mathrm{MHz}}-1} \sum_{k=-26}^{26} \gamma_{(k - K_{shift}(i_{BW})),\,BW}(D_{k,\,10} + p_0 P_k) \times \exp(j2\pi(k - K_{shift}(i_{BW}))\Delta_F(t - T_{GI} - T_{CS}^{i_{TX}})) \tag{32-9}$$



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where

$N_{10\,\mathrm{MHz}}$ is defined in 32.3.8.3 (L-STF definition)

$K_{shift}(i) = (N_{10\,\mathrm{MHz}} - 1 - 2i) \times 32$

$$D_{k,\,10} = \begin{cases} 0,\ k = 0, \pm 7, \pm 21 \\ d_{M_{10}^{r}(k)},\ \text{otherwise} \end{cases}$$

$$M_{10}^{r}(k) = \begin{cases} k + 26, & -26 \le k \le -22 \\ k + 25, & -20 \le k \le -8 \\ k + 24, & -6 \le k \le -1 \\ k + 23, & 1 \le k \le 6 \\ k + 22, & 8 \le k \le 20 \\ k + 21, & 22 \le k \le 26 \end{cases} \tag{32-10}$$

$P_k$ is defined in 17.3.5.10 (OFDM modulation)

$p_0$ is the first pilot value in the sequence defined in 17.3.5.10 (OFDM modulation)

$N_{L\text{-}SIG}^{Tone}$ has the value given in Table 32-8 (Tone scaling factor and guard interval duration values for PHY fields(11bd))

$\gamma_{k,BW}$ is defined in Equation (32-4) and Equation (32-5)

$T_{CS}^{i_{TX}}$ represents the cyclic shift for transmit chain $i_{TX}$ with a value given in 32.3.8.2.1 (Cyclic shift for pre-NGV modulated fields)

NOTE—$M_{10}^{r}(k)$ is a "reverse" function of the $M(k)$ defined in 17.3.5.10 (OFDM modulation).

### 32.3.8.6 RL-SIG definition

The RL-SIG field is a repeat of the L-SIG field and is used to differentiate an NGV PPDU from a non-NGV PPDU. RL-SIG field shall be modulated the same as L-SIG field.

The time domain waveform of the RL-SIG field shall be as given by Equation (32-11).

$$r_{RL\text{-}SIG}^{(i_{TX})}(t) = \frac{1}{\sqrt{N_{TX} \times N_{RL\text{-}\mathrm{SIG}}^{Tone}}} w_{\mathrm{T}_{L\text{-}SIG}}(t) \sum_{i_{BW}=0}^{N_{10\,\mathrm{MHz}}-1} \sum_{k=-26}^{26} \gamma_{(k - K_{shift}(i_{BW})),\,BW} (D_{k,\,10} + p_1 P_k) \times \exp(j2\pi(k - K_{shift}(i_{BW}))\Delta_F(t - T_{GI} - T_{CS}^{i_{TX}})) \tag{32-11}$$

where

$N_{RL\text{-}\mathrm{SIG}}^{Tone}$ has the value given in Table 32-8 (Tone scaling factor and guard interval duration values for PHY fields(11bd)).

$p_1$ is the second pilot value in the sequence defined in 17.3.5.10 (OFDM modulation)

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### 32.3.8.7 NGV-SIG definition

The NGV-SIG field carries information required to interpret NGV PPDUs. The NGV-SIG field contains the fields listed in Table 32-10 (Fields in the NGV-SIG field(11bd)).

**Table 32-10—Fields in the NGV-SIG field(11bd)**

| Bit | Field | Number of bits | Description |
|---|---|---|---|
| B0–B1 | PHY Version | 2 | Set to 0 for NGV PHY. Values 1–3 are reserved. |
| B2 | Bandwidth | 1 | Set to 0 for 10 MHz, and set to 1 for 20 MHz. |
| B3–B6 | NGV-MCS | 4 | For 10 MHz PPDU, set to *n* for NGV-MCS *n*, where $n = 0, 1, 2, \ldots, 8$, and 15. Value 9 is not valid and values 10–14 are reserved.<br>For 20 MHz PPDU, set to *n* for NGV-MCS *n*, where $n = 0, 1, 2, \ldots, 9$, and 15. MCS 10–14 are reserved. |
| B7 | $N_{SS}$ | 1 | Set to 0 for one spatial stream, and set to 1 for two spatial streams. |
| B8–B9 | Midamble Periodicity | 2 | Set to 0 for 4 symbols.<br>Set to 1 for 8 symbols.<br>Set to 2 for 16 symbols.<br>Value 3 is reserved. |
| B10 | LTF Format | 1 | Set to 0 for NGV-LTF-2x.<br>Set to 1 for NGV-LTF-1x.<br><br>NOTE—If NGV-LTF-2x-Repeat is used (see 32.3.8.10 (NGV-LTF definition)) with B2 set to 0, B3–B6 set to 15 and B7 set to 0, this field is reserved and set to 1. |
| B11 | LDPC Extra OFDM Symbol | 1 | Set to 1 if the LPDC PPDU encoding process results in an extra OFDM symbol as described in 21.3.10.5.4 (LDPC coding).<br>Set to 0 otherwise. |
| B12 | LTF Repetition | 1 | Set to 1 for NGV ranging NDP with NGV-LTF repetition.<br>Set to 0 otherwise. |
| B13 | Reserved | 1 | Reserved and set to 1. |
| B14–B17 | CRC | 4 | CRC is calculated as in 27.3.11.7.3 ((CRC computation) with $L = 13$. |
| B18–B23 | Tail | 6 | Used to terminate the trellis of the convolutional decoder.<br>Set to 0. |

The NGV-SIG field is composed of one OFDM symbol, containing 24 data bits, as shown in Table 32-10 (Fields in the NGV-SIG field(11bd)). NGV-SIG is transmitted before RNGV-SIG. The NGV-SIG symbol shall be BCC encoded at rate, R = 1/2, be interleaved, be mapped to a BPSK constellation, and have pilots inserted following the steps described in 17.3.5.6 (Convolutional encoder), 17.3.5.7 (Data interleaving), 17.3.5.8 (Subcarrier modulation mapping), and 17.3.5.9 (Pilot subcarriers). The stream of 48 complex numbers generated by these steps (before pilot insertion) is denoted by $d_k, k = 0,\ldots,47$.


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The time domain waveform for the NGV-SIG field in an NGV PPDU shall be as specified in Equation (32-12).

$$r_{NGV\text{-}SIG}^{(i_{TX})}(t) = \frac{1}{\sqrt{N_{TX} \times N_{NGV\text{-}SIG}^{Tone}}} w_{T_{NGV\text{-}SIG}}(t) \sum_{i_{BW}=0}^{N_{10\,\mathrm{MHz}}-1} \sum_{k=-26}^{26} \gamma_{(k-K_{shift}(i_{BW})),BW}(D_{k,10} + p_2 P_k) \times \exp(j2\pi(k - K_{shift}(i_{BW}))\Delta_F(t - T_{GI} - T_{CS}^{i_{TX}})) \quad (32\text{-}12)$$

where

$N_{10\,\mathrm{MHz}}$ and $K_{shift}(i)$ are defined in 32.3.8.5 (L-SIG definition)

$$D_{k,10} = \begin{cases} 0, & k = 0, \pm 7, \pm 21 \\ d_{M_{10}^r(k)}, & \text{otherwise} \end{cases}$$

$M_{10}^r(k)$ is defined in Equation (32-10)

$P_k$ and $p_2$ are defined in 17.3.5.10 (OFDM modulation)

$N_{NGV\text{-}SIG}^{Tone}$ has the value given in Table 32-8 (Tone scaling factor and guard interval duration values for PHY fields(11bd))

$\Upsilon_{k,BW}$ is defined in Equation (32-4) and Equation (32-5)

$T_{CS}^{i_{TX}}$ represents the cyclic shift for transmit chain $i_{TX}$ with a value given in 32.3.8.2.1 (Cyclic shift for pre-NGV modulated fields)

NOTE—In NGV PPDUs, the NGV-SIG is transmitted with the same number of subcarriers and the same cyclic shifts as the preceding non-NGV portion of the preamble.

### 32.3.8.8 RNGV-SIG definition

The RNGV-SIG field is a repeat of the NGV-SIG field and is configured identically to the NGV-SIG.

The time domain waveform of the RNGV-SIG field shall be as given by Equation (32-13).

$$r_{RNGV\text{-}SIG}^{(i_{TX})}(t) = \frac{1}{\sqrt{N_{TX} \times N_{RNGV\text{-}SIG}^{Tone}}} w_{T_{RNGV\text{-}SIG}}(t) \sum_{i_{BW}=0}^{N_{10\,\mathrm{MHz}}-1} \sum_{k=-26}^{26} \gamma_{(k-K_{shift}(i_{BW})),BW}(D_{k,10} + p_3 P_k) \times \exp(j2\pi(k - K_{shift}(i_{BW}))\Delta_F(t - T_{GI} - T_{CS}^{i_{TX}})) \quad (32\text{-}13)$$

where

$N_{RNGV\text{-}SIG}^{Tone}$ has the value given in Table 32-8 (Tone scaling factor and guard interval duration values for PHY fields(11bd))

$p_3$ is the fourth pilot value in the sequence defined in 17.3.5.10 (OFDM modulation)

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### 32.3.8.9 NGV-STF definition

The main purpose of the NGV-STF field is to improve automatic gain control estimation in a MIMO transmission. The duration of the NGV-STF field is 8 μs. The frequency domain sequence used to construct the NGV-STF field in a 10 MHz transmission is identical to the VHT-STF field for 20 MHz transmission. In a 20 MHz transmission, the NGV-STF field is constructed by using the frequency domain sequence for the VHT-STF field of 40 MHz transmission and applying appropriate phase rotations per 10 MHz subchannel.

For a 10 MHz transmission, the frequency domain sequence is given by Equation (32-14).

$$NGVS_{-28,28} = VHTS_{-28,28} \tag{32-14}$$

where $VHTS_{-28,28}$ is defined in Equation (21-29).

For a 20 MHz transmission, the frequency domain sequence is given by Equation (32-15).

$$NGVS_{-58,58} = VHTS_{-58,58} \tag{32-15}$$

where $VHTS_{-58,58}$ is defined in Equation (21-30).

NOTE—Equation (32-14) and Equation (32-15) do not show the phase rotation per 10 MHz subchannel.

The time domain representation of the signal on transmit chain $i_{TX}$ shall be as specified in Equation (32-16).

$$r_{NGV\text{-}STF}^{(i_{TX})}(t) = \frac{1}{\sqrt{N_{SS} \times N_{NGV\text{-}STF}^{Tone}}} w_{T_{NGV\text{-}STF}}(t) \sum_{k=-N_{SR}}^{N_{SR}} \sum_{m=1}^{N_{SS}} [Q_k]_{i_{TX},m} \gamma_{k,BW} NGVS_k \times \exp(j2\pi k\Delta_F(t - T_{CS,NGV}(m))) \tag{32-16}$$

where

$N_{NGV\text{-}STF}^{Tone}$ has the value given in Table 32-8 (Tone scaling factor and guard interval duration values for PHY fields(11bd))

$T_{CS,NGV}(m)$ is given in 32.3.8.2.2 (Cyclic shift for NGV modulated fields)

$Q_k$ is defined in 32.3.7.3 (Transmitted signal)

$\gamma_{k,BW}$ is defined in defined in Equation (32-4) and Equation (32-5)

### 32.3.8.10 NGV-LTF definition

The NGV-LTF field provides means for the receiver to estimate the MIMO channel between the set of constellation mapper outputs and the receive chains. The transmitter provides training for $N_{SS}$ spatial streams (spatial mapper inputs) used for the transmission of the PSDU(s). For each tone, the MIMO channel that can be estimated is an $N_{RX} \times N_{SS}$ matrix. An NGV transmission has a preamble that contains NGV-LTF symbols, where the data tones of each NGV-LTF symbol are multiplied by entries belonging to a matrix $P_{NGV\text{-}LTF}$, to enable channel estimation at the receiver. The pilot tones of each NGV-LTF symbol are multiplied by the entries of a matrix $R_{NGV\text{-}LTF}$ defined in the following text. The multiplication of the pilot tones in the NGV-LTF symbol by the $R_{NGV\text{-}LTF}$ matrix instead of the $P_{NGV\text{-}LTF}$ matrix allows receivers to track phase and frequency offset during MIMO channel estimation using the NGV-LTF. The number of


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NGV-LTF symbols, $N_{NGV\text{-}LTF}$, is a function of the number of spatial streams, $N_{SS}$, as shown in Table 32-11 (Number of NGV-LTFs required for different numbers of spatial streams(11bd)) and LTF_REP as shown in 32.3.16 (NGV ranging NDP). As a result the NGV-LTF field consists of one, two, or four symbols.

**Table 32-11—Number of NGV-LTFs required for different numbers of spatial streams(11bd)**

| $N_{SS}$ | $N_{NGV\text{-}LTF}$ |
|---|---|
| 1 | 1 × (LTF_REP + 1) |
| 2 | 2 × (LTF_REP + 1) |

An NGV PPDU supports three NGV-LTF formats: NGV-LTF-1x, NGV-LTF-2x, and NGV-LTF-2x-Repeat. NGV-LTF-2x is the default LTF format; NGV-LTF-1x is used for high efficiency transmission of one spatial stream and NGV-LTF-2x-Repeat is used for extended range transmissions. (#7220)A transmitter shall use the NGV-LTF-2x-Repeat format if the NGV Data field of a 10 MHz NGV PPDU is modulated with BPSK-DCM and one spatial stream; the transmitter shall use the NGV-LTF-2x format if the NGV Data field is modulated with two spatial streams; the transmitter shall use the NGV-LTF-2x format for an NGV ranging NDP; otherwise, the transmitter (#8147)shall choose either NGV-LTF-2x or NGV-LTF-1x format. The NGV-LTF format of NGV-LTF-1x or NGV-LTF-2x is signaled by B10 in NGV-SIG field. The NGV-LTF-2x-Repeat format is signaled by the combination of B2 set to 0, B3–B6 set to 15 and B7 set to 0 in NGV-SIG field, and B10 is Reserved and set to 1. The duration of each NGV-LTF symbol is $T_{NGV\text{-}LTF}$, defined in Equation (32-17).

$$T_{\text{NGV-LTF}} = \begin{cases} T_{\text{NGV-LTF-1X}}, & \text{if NGV-LTF-1x} \\ T_{\text{NGV-LTF-2X}}, & \text{if NGV-LTF-2x} \\ T_{\text{NGV-LTF-2X-Repeat}}, & \text{if NGV-LTF-2x-Repeat} \end{cases} \quad (32\text{-}17)$$

Let $LTF_{left}$ and $LTF_{right}$ be the sequences defined in Equation (32-18) and Equation (32-19), respectively.

$$LTF_{left} = \{1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 1\} \quad (32\text{-}18)$$

$$LTF_{right} = \{1, -1, -1, 1, 1, -1, 1, -1, 1, -1, -1, -1, -1, -1, 1, 1, -1, -1, 1, -1, 1, -1, 1, 1, 1, 1, 1\} \quad (32\text{-}19)$$

NOTE 1— $LTF_{left}$ is identical to the leftmost 26 elements of Equation (17-8), and $LTF_{right}$ is identical to the rightmost 26 elements of Equation (17-8).

In a 10 MHz transmission, the NGV-LTF-1x sequence transmitted is given by Equation (32-20).

$$NGV\text{-}LTF_{-28,28} = \{1, 0, 1, 0, -1, 0, 1, 0, -1, 0, -1, 0, 1, 0, 1, 0, 1, 0, 1, 0, -1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 0, 0, -1, 0, 1, 0, -1, 0, -1, 0, -1, 0, -1, 0, -1, 0, 1, 0, -1, 0, -1, 0, -1, 0, 1, 0, 1, 0, -1\} \quad (32\text{-}20)$$

In a 10 MHz transmission, the NGV-LTF-2x sequence transmitted is given by Equation (32-21).

$$\begin{aligned} NGV\text{-}LTF_{-28,28} &= \{1, 1, LTF_{left}, 0, LTF_{right}, -1, -1\} \\ &= VHT\text{-}LTF_{-28,28} \end{aligned} \quad (32\text{-}21)$$

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where

$VHT\text{-}LTF_{-28,28}$ is defined in Equation (21-36).

In a 20 MHz transmission, the NGV-LTF-1x sequence transmitted is given by Equation (32-22).

$$NGV\text{-}LTF_{-58,58} = \{1, 0, -1, 0, 1, 0, -1, 0, -1, 0, 1, 0, 1, 0, 1, 0, -1, 0, 1, 0, 1, 0,$$
$$1, 0, 1, 0, 1, 0, -1, 0, 1, 0, -1, 0, -1, 0, -1, 0, -1, 0, -1, 0, 1, 0, -1, 0, -1, 0, -1, 0,$$
$$1, 0, 1, 0, -1, 0, 1, 0, 0, 0, -1, 0, 1, 0, 1, 0, -1, 0, 1, 0, -1, 0, -1, 0, 1, 0, 1, 0, 1, 0,$$
$$-1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, -1, 0, 1, 0, -1, 0, -1, 0, -1, 0, -1, 0, -1, 0, 1, 0, -1,$$
$$0, -1, 0, -1, 0, 1, 0, 1\} \quad (32\text{-}22)$$

In a 20 MHz transmission, the NGV-LTF-2x sequence transmitted is given by Equation (32-23).

$$NGV\text{-}LTF_{-58,58} = \{LTF_{left}, 1, LTF_{right}, -1, -1, -1, 1, 0, 0, 0, -1, 1, 1, -1, LTF_{left}, 1, LTF_{right}\} \quad (32\text{-}23)$$
$$= VHT\text{-}LTF_{-58,58}$$

where

$VHT\text{-}LTF_{-58,58}$ is defined in Equation (21-37).

NOTE 2—Equation (32-20), Equation (32-21), Equation (32-22), and Equation (32-23) do not show the phase rotation per 10 MHz subchannel.

The generation of the time domain NGV-LTF symbols is shown in Figure 32-9 (Generation of NGV-LTF symbols(11bd)).

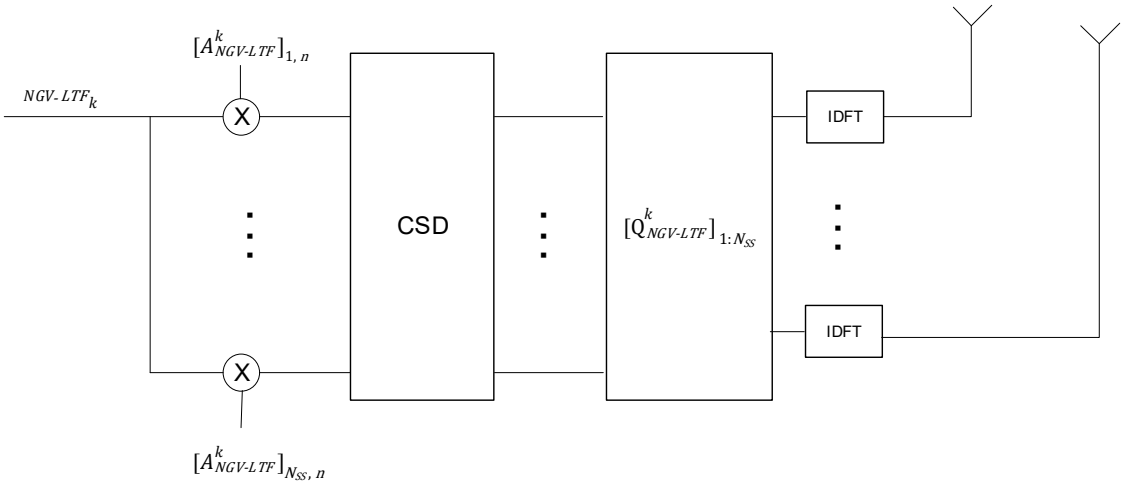


**Figure 32-9—Generation of NGV-LTF symbols(11bd)**


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The generation of a time domain symbol of NGV-LTF-1x is equivalent to modulating every other tone in an OFDM symbol of 6.4 μs excluding GI, and then only transmit the first half of the OFDM symbol in the time domain, as shown in Figure 32-10 (Generation of NGV-LTF-1x symbols(11bd)).

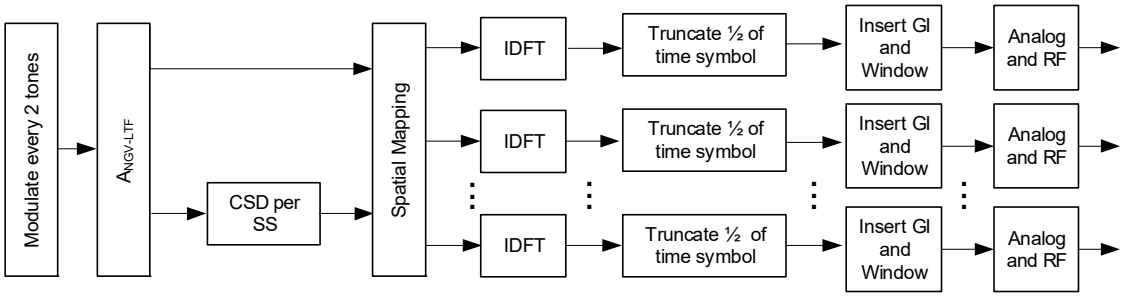


**Figure 32-10—Generation of NGV-LTF-1x symbols(11bd)**

NGV-LTF-2x-Repeat is constructed by repeating the time domain symbol of NGV-LTF-2x excluding GI and preappend one cyclic prefix of duration 1.6 μs.The generation of a time domain symbol of NGV-LTF-2x-Repeat is equivalent to modulating every tone in an OFDM symbol of 6.4 μs excluding GI, and then the OFDM symbol is repeated in the time domain, as shown in Figure 32-11 (Generation of NGV-LTF-2x-Repeat symbols(11bd)).

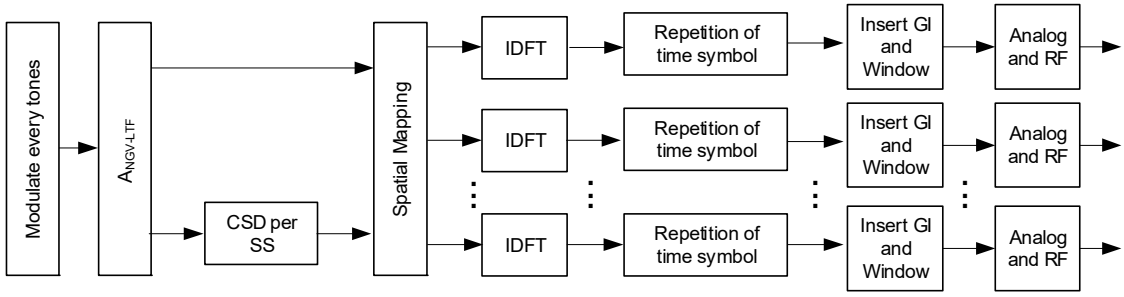


**Figure 32-11—Generation of NGV-LTF-2x-Repeat symbols(11bd)**

$A^k_{NGV\text{-}LTF}$ is given by Equation (32-24).

$$A^k_{NGV\text{-}LTF} = \begin{cases} R_{NGV\text{-}LTF}, \text{ if } k \in K_{pilot} \\ P_{NGV\text{-}LTF}, \text{ otherwise} \end{cases} \quad (32\text{-}24)$$

where

$K_{pilot}$ is the set of subcarrier indices for the pilot tones:

For a 10 MHz transmission, $K_{pilot} = \{\pm 8, \pm 22\}$

For a 20 MHz transmission, $K_{pilot} = \{\pm 12, \pm 26, \pm 54\}$

$R_{NGV\text{-}LTF}$ is an $N_{SS} \times N_{NGV\text{-}LTF}$ matrix whose elements are defined in Equation (32-25) and Equation (32-26)

$$[R_{NGV\text{-}LTF}]_{m,n} = [P_{NGV\text{-}LTF}]_{1,n}, \ 1 \le n \le N_{NGV\text{-}LTF}, \ 1 \le m \le N_{SS} \quad (32\text{-}25)$$

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$$P_{NGV\text{-}LTF} = [P_{2\times 2} P_{2\times 2}] \tag{32-26}$$

where

$P_{2\times 2} = P_{4\times 4\{1:2\}\{1:2\}}$ is a submatrix of $P_{4\times 4}$ with elements of the first two rows and two columns of $P_{4\times 4}$, which is defined in Equation (19-27)

The time domain representation of the waveform transmitted on transmit chain $i_{TX}$ shall be as described by Equation (32-27).

$$\begin{aligned} r_{NGV\text{-}LTF}^{(i_{TX})}(t) = {} & \frac{1}{\sqrt{N_{SS} \times N_{NGV\text{-}LTF}^{Tone}}} \sum_{n=0}^{N_{NGV\text{-}LTF}-1} w_{\mathrm{T}_{NGV\text{-}LTF}}(t - nT_{NGV\text{-}LTF}) \\ & \times \sum_{k=-N_{SR}}^{N_{SR}} \sum_{m=1}^{N_{SS}} [Q_k]_{i_{TX},m} \gamma_{k,BW} [A_{NGV\text{-}LTF}^{k}]_{m,(n+1)} NGV\text{-}LTF_k \\ & \times \exp(j2\pi k\Delta_F(t - nT_{NGV\text{-}LTF} - T_{GI} - T_{CS,NGV}(m))) \end{aligned} \tag{32-27}$$

where

| | |
|---|---|
| $N_{NGV\text{-}LTF}^{Tone}$ | has the value given in Table 32-8 (Tone scaling factor and guard interval duration values for PHY fields(11bd)) |
| $T_{CS,NGV}(m)$ | is given in 32.3.8.2.2 (Cyclic shift for NGV modulated fields) |
| $Q_k$ | is defined in 32.3.7.3 (Transmitted signal) |
| $\gamma_{k,BW}$ | is defined in Equation (32-4) and Equation (32-5) |
| $A_{NGV\text{-}LTF}^{k}$ | is defined in Equation (32-24) |

### 32.3.9 Data field

#### 32.3.9.1 General

The number of OFDM symbols in the Data field is determined by the Length field in L-SIG (see Equation (32-8)), the preamble duration, and the setting of the NGV-LTF and Midamble field in NGV-SIG (see 32.3.8 (NGV preamble)).

For LDPC encoding, the Data field shall consist of the SERVICE field, the PSDU, and the PHY pad bits. The padding flow is as follows. The MAC delivers a PSDU that fills the available octets in the Data field of the PPDU. The PHY determines the number of pad bits to add and appends them to the PSDU. The number of pad bits added always is 0 to 7. The PHY padding bits are calculated using Equation (32-28).

$$N_{PAD} = N_{SYM,init} N_{DBPS} - 8 \times \mathrm{PSDU\_LENGTH} - N_{service} \tag{32-28}$$

where

| | |
|---|---|
| PSDU_LENGTH | is defined in 32.4.3 (TXTIME and PSDU_LENGTH calculation) |
| $N_{SYM,init}$ | is given by Equation (21-62) with $m_{STBC} = 1$ |


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#### 32.3.9.2 SERVICE field

The SERVICE field is as shown in Table 32-12 (SERVICE field(11bd)).

**Table 32-12—SERVICE field(11bd)**

| Bits | Field | **Description** |
|---|---|---|
| B0–B6 | Scrambler Initialization | Set to 0 |
| B7–B15 | Reserved | Set to 0 |

#### 32.3.9.3 Scrambler

The SERVICE, PSDU, and PHY pad parts of the Data field shall be scrambled by the scrambler defined in 17.3.5.5 (PHY DATA scrambler and descrambler). The Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) TXVECTOR parameters CH_BANDWIDTH_IN_NON_HT and DYN_BANDWIDTH_IN_NON_HT are not present; therefore, the initial state of the scrambler is set to a pseudorandom nonzero seed.

#### 32.3.9.4 Coding

The Data field of an NGV PPDU shall be encoded using LDPC coding. The LDPC code and encoding process shall follow as described in 21.3.10.5.4 (LDPC coding)for a VHT SU PPDU with parameter $m_{STBC}$ set to 1 and the LDPC Extra Symbol field setting in NGV-SIG.

#### 32.3.9.5 Stream parser

After coding and puncturing, the data bit streams at the output of the FEC encoder are processed in groups of $N_{CBPS}$ bits. Each of these groups is rearranged into $N_{SS}$ blocks of $N_{CBPSS}$ bits. This operation is referred to as stream parsing and is described in 21.3.10.6 (Stream parser) for a SU transmission.

#### 32.3.9.6 Constellation mapping

The mapping between bits at the output of the stream parser and complex constellation points for BPSK, QPSK, 16-QAM, and 64-QAM follows the rules defined in 17.3.5.8 (Subcarrier modulation mapping) and 256-QAM follows the rules defined in 21.3.10.9 (Constellation mapping).

The streams of complex numbers out of constellation mapping are denoted as shown in Equation (32-29).

$$d_{k,m,n}, \quad 0 \le k \le N_{SD} - 1; \;\; 1 \le m \le N_{SS}; \;\; 0 \le n \le N_{SYM} - 1 \tag{32-29}$$

For NGV data portion modulated with NGV-MCS 15, the input stream is broken into groups of $N_{CBPS}$ bits $(B_0, B_1, \ldots, B_{N_{CBPS}-1})$. Each bit $B_k$ is BPSK modulated to a sample $d_k$. This generates the samples for the lower half of the data subcarriers as $d_{k,1,n} = d_k$. For the upper half of the subcarriers, the samples are generated as $d_{k+N_{SD},1,n} = d_{k,1,n} \times e^{j(k+N_{SD})\pi}$, with $k = 0, 1, \ldots, N_{SD} - 1$. The $N_{SD}$ here refers to the $N_{SD}$ for NGV-MCS 15, which is half the value of $N_{SD}$ for NGV-MCS 0.

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#### 32.3.9.7 Pilot subcarriers

In a 10 MHz transmission, four pilot tones shall be inserted in subcarriers $k = \{-22, -8, 8, 22\}$. The pilot mapping $P_n^k$ for subcarrier $k$ for symbol $n$ shall be as specified in Equation (32-30).

$$\begin{aligned} P_n^{\{-22,\,-8,\,8,\,22\}} &= \{\Psi^{(1)}_{1,\,n \bmod 4} \;, \Psi^{(1)}_{1,\,(n+1) \bmod 4} \;, \Psi^{(1)}_{1,\,(n+2) \bmod 4} \;, \Psi^{(1)}_{1,\,(n+3) \bmod 4} \;\} \\ P_n^{k \neq \{-22,\,-8,\,8,\,22\}} &= 0 \end{aligned} \tag{32-30}$$

where

$\Psi^{(1)}_{1,m}$ is given by the $N_{STS} = 1$ row of Table 19-19 (Pilot values for 20 MHz transmission)

In a 20 MHz transmission, six pilot tones shall be inserted in subcarriers $k = \{-54, -26, -12, 12, 26, 54\}$. The pilot mapping $P_n^k$ for subcarrier $k$ for symbol $n$ shall be as specified in Equation (32-31).

$$\begin{aligned} P_n^{\{-54,\,-26,\,-12,\,12,\,26,\,54\}} &= \{\Psi^{(1)}_{1,\,n \bmod 6} \;, \Psi^{(1)}_{1,\,(n+1) \bmod 6} \;, \ldots, \Psi^{(1)}_{1,\,(n+5) \bmod 6} \;\} \\ P_n^{k \neq \{-54,\,-26,\,-12,\,12,\,26,\,54\}} &= 0 \end{aligned} \tag{32-31}$$

where

$\Psi^{(1)}_{1,m}$ is given by the $N_{STS} = 1$ row of Table 19-20 (Pilots values for 40 MHz transmission (excluding MCS 32))

The above pilot mapping shall be copied to all spatial streams before the spatial stream cyclic shifts are applied.

The pilot subcarrier locations in the NGV-LTF field for NGV-LTF-1x, NGV-LTF-2x, and NGV-LTF-2x-Repeat are the same as the pilot subcarrier locations in the Data field.

#### 32.3.9.8 OFDM modulation

##### 32.3.9.8.1 Transmission in NGV format

The time domain waveform of the Data field of an NGV PPDU from transmit chain $i_{TX}$, $1 \le i_{TX} \le N_{TX}$ shall be as defined in Equation (32-32) and Equation (32-33).

$$\begin{aligned} r^{(i_{TX})}_{NGV\text{-Data}}(t) = \sum_{n=0}^{N_{SYM}-1} & w_{T_{\text{SYM}}}\left(t - nT_{SYM} - \left\lfloor \frac{n}{M} \right\rfloor T_{MA}\right) q_n r^{(i_{TX})}_{NGV\text{-Data},n}\left(t - \left\lfloor \frac{n}{M} \right\rfloor T_{MA}\right) + \\ & \sum_{i_{MA}=0}^{N_{MA}-1} p_{i_{MA}} r^{(i_{TX})}_{NGV\text{-}LTF}(t - (i_{MA}+1)M \cdot T_{SYM} - i_{MA}T_{MA}) \end{aligned} \tag{32-32}$$

$$\begin{aligned} r^{(i_{TX})}_{NGV\text{-Data},n}(t) = \frac{1}{\sqrt{N^{Tone}_{NGV\text{-}Data}\;\; N_{SS}}} \sum_{k=-N_{SR}}^{N_{SR}} \sum_{m=1}^{N_{SS}} \Big( & \left[Q_k\right]_{i_{TX},\,m} \Upsilon_{k,BW} (D_{k,\,m,\,n,\,BW} + p_{n+4} P_n^k) \\ & \times \exp(j2\pi k \Delta_F (t - nT_{SYM} - T_{GI,\,Data} - T_{CS,\,NGV}(m))) \Big) \end{aligned} \tag{32-33}$$

where



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| | |
|---|---|
| $r^{(i_{TX})}_{NGV\text{-Data},n}(t)$ | is the $n^{th}$ OFDM data symbol in the Data field, $0 \le n < N_{SYM} - 1$ |
| $M$ | is the midamble periodicity defined in 32.3.9.9 (Midambles) |
| $r^{(i_{TX})}_{NGV\text{-}LTF}(t)$ | is defined in Equation (32-27) |
| $T_{MA} = T_{NGV\text{-}LTF} N_{NGV\text{-}LTF}$ | is the duration of one midamble |
| $p_n$ | is defined in 17.3.5.10 (OFDM modulation) |

$$q_n = \begin{cases} 1, & \text{for } n < M \\ p_{\left\lfloor \frac{n-M}{M} \right\rfloor}, & \text{for } n \ge M \end{cases}$$

| | |
|---|---|
| $i_{MA}$ | is the index for the midambles, $0 \le i_{MA} \le N_{MA} - 1$ |
| $P^k_n$ | is defined in 32.3.9.7 (Pilot subcarriers) |
| $\Upsilon_{k,\,BW}$ | is defined in Equation (32-4) and Equation (32-5) |
| $D_{k,\,m,\,n,\,BW}$ | is the transmitted constellation at subcarrier $k$, spatial stream $m$, and Data field OFDM symbol $n$ and is defined in Equation (32-34) and Equation (32-35) |
| $N^{Tone}_{NGV\text{-}Data}$ | has the value given in Table 32-8 (Tone scaling factor and guard interval duration values for PHY fields(11bd)) |
| $T_{CS,\,NGV}(n)$ | is defined in Table 21-11 (Cyclic shift values for the VHT modulated fields of a PPDU) |
| $T_{GI,\,Data}$ | is the guard interval duration. $T_{GI,\,Data} = T_{GI}$ |

In a 10 MHz NGV PPDU transmission:

$$D_{k,\,m,\,n,\,10} = \begin{cases} 0, & k = 0, \pm 8, \pm 22 \\ d_{M^r_{10}(k),\,m,\,n}, & \text{otherwise} \end{cases} \tag{32-34}$$

where

$$M^r_{10}(k) = \begin{cases} k + 28, & -28 \le k \le -23 \\ k + 27, & -21 \le k \le -9 \\ k + 26, & -7 \le k \le -1 \\ k + 25, & 1 \le k \le 7 \\ k + 24, & 9 \le k \le 21 \\ k + 23, & 23 \le k \le 28 \end{cases}$$

In a 20 MHz NGV PPDU transmission:

$$D_{k,\,m,\,n,\,20} = \begin{cases} 0, & k = 0, \pm 12, \pm 26, \pm 54 \\ d_{M^r_{20}(k),\,m,\,n}, & \text{otherwise} \end{cases} \tag{32-35}$$

where

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$$M^{r}_{20}(k) = \begin{cases} k+58, & -58 \le k \le -55 \\ k+57, & -53 \le k \le -27 \\ k+56, & -25 \le k \le -13 \\ k+55, & -11 \le k \le -2 \\ k+52, & 2 \le k \le 11 \\ k+51, & 13 \le k \le 25 \\ k+50, & 27 \le k \le 53 \\ k+49, & 55 \le k \le 58 \end{cases}$$

$Q_k$ is a spatial mapping/steering matrix with $N_{TX}$ rows and $N_{SS}$ columns for subcarrier $k$. $Q_k$ may be frequency dependent. Refer to the examples of $Q_k$ listed in 19.3.11.11.2 (Spatial mapping) for examples of $Q_k$ that could be used for NGV PPDU.

NOTE—Implementations are not restricted to the spatial mapping matrix examples listed in 19.3.11.11.2 (Spatial mapping) and the number of transmit chains $N_{TX}$ could be more than one. The beamforming steering matrices are implementation specific.

### 32.3.9.9 Midambles

An NGV STA shall include midambles in an NGV PPDU transmission when the number of midamble periods, $N_{MA}$, is greater than zero in accordance with Equation (32-36). Midambles facilitate updating of the channel estimate during the NGV PPDU reception.

Midambles are present in the Data field of the NGV PPDU every $M$ OFDM symbols, where $M$ is either 4, 8, or 16 as indicated by the Midamble Periodicity field in the NGV-SIG field (see Table 32-10 (Fields in the NGV-SIG field(11bd))).

The Midamble field shall use the same format as the NGV-LTF field of the same PPDU, which format is signalled in the NGV-SIG field. The generation of midamble is defined in 32.3.8.10 (NGV-LTF definition).

The midambles and succeeding Data field OFDM symbols shall be randomized to prevent the generation of spectral lines in the NGV PPDU spectrum. The $n$th midamble and $M$ Data field OFDM symbols following immediately after the $n$th midamble shall be multiplied by $p_n$, $n = 0, \ldots, N_{MA} - 1$, where $p_n$ is defined in 17.3.5.10 (OFDM modulation). The midamble and the randomization procedure in an NGV PPDU are shown in Figure 32-12 (NGV PPDU with midamble and randomization procedure(11bd)).

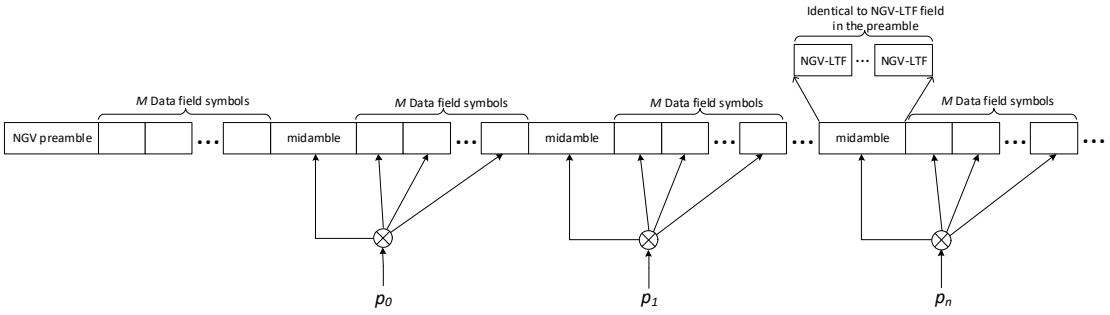


**Figure 32-12—NGV PPDU with midamble and randomization procedure(11bd)**

If present, the number of midamble periods, $N_{MA}$, in a PPDU is calculated using Equation (32-36).


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$$N_{MA} = \left\lfloor \frac{N_{SYM} - 1}{M} \right\rfloor \quad (32\text{-}36)$$

where $N_{SYM}$ is the total number of data symbols in the Data field, is given in 21.3.10.5.4 (LDPC coding), and computed using Equation (19-41) in step d) of 19.3.11.7.5 (LDPC PPDU encoding process).

As shown in Figure 32-12 (NGV PPDU with midamble and randomization procedure(11bd)), the first midamble is inserted immediately after the *M*th OFDM symbol in the Data field, and a midamble is not inserted after the last data OFDM symbol if mod ($N_{SYM}$, $M$) = 0.

### 32.3.9.10 Non-NGV duplicate transmission

When the TXVECTOR parameter FORMAT is NON_NGV_10 and the TXVECTOR parameter NON_NGV_MODULATION is NON_NGV_10_DUP_OFDM, the transmitted PPDU is a non-NGV duplicate. Non-NGV duplicate transmission is used to transmit to STAs that support non-NGV OFDM and may be present in a part of a 20 MHz channel (see Table 32-2 (Interpretation of FORMAT, NON_NGV_MODULATION, and CH_BANDWIDTH parameters(11bd))). The RL-SIG, NGV-SIG, RNGV-SIG, NGV-STF, and NGV-LTF fields are not transmitted. The L-STF, L-LTF, and L-SIG fields shall be transmitted in the same way as in the NGV transmission, except that the L-SIG field's Rate and Length fields shall be as defined in 17.3.4 (SIGNAL field). The Data field shall be as defined in Equation (32-37).

NOTE—For L-STF and L-LTF fields, the power scale factor is 1 in 20 MHz non-NGV duplicate PPDU.

$$r^{(i_{TX})}_{\text{Non-NGV-Data}}(t) = \frac{1}{\sqrt{N_{TX} N^{Tone}_{\text{NON\_NGV\_10\_DUP\_OFDM-Data}}}} \sum_{n=0}^{N_{SYM}-1} w_{T_{\text{SYM}}}(t - nT_{SYM}) \quad (32\text{-}37)$$

$$\times \sum_{k=-26}^{26} (D_{k,n} + p_{n+1}P_k)(\exp(j2\pi(k-32)\Delta_F(t - nT_{SYM} - T_{GI} - T^{i_{TX}}_{CS}))$$

$$+ j \times \exp(j2\pi(k+32)\Delta_F(t - nT_{SYM} - T_{GI} - T^{i_{TX}}_{CS})))$$

where

$P_k$ and $p_n$ are defined in 17.3.5.10 (OFDM modulation)

$$D_{k,n} = \begin{cases} 0, & k = 0, \pm 7, \pm 21 \\ d_{M^r_{10}(k),1,n}, & \text{otherwise} \end{cases} \quad (32\text{-}38)$$

$M^r_{10}(k)$ is defined in Equation (32-10)

$T^{i_{TX}}_{CS}$ represents the cyclic shift of the transmit chain $i_{TX}$ and is defined in 32.3.8.2.1 (Cyclic shift for pre-NGV modulated fields)

$N^{Tone}_{\text{NON\_NGV\_10\_DUP\_OFDM-Data}}$ has the value given in Table 32-8 (Tone scaling factor and guard interval duration values for PHY fields(11bd))

## 32.3.10 SU-MIMO

SU-MIMO is defined for an NGV transmitter to transmit two spatial streams to an NGV receiver to improve throughput.

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An NGV transmitter equipped with more than one antenna may use the SU-MIMO technique to transmit an NGV PPDU with two spatial streams. The choice of number of spatial streams is described in 31.5 (NGV MAC data service).

The steering matrix $Q_k$, defined in 32.3.7.3 (Transmitted signal), used by the transmitter is implementation specific.

NOTE—The channel in the vehicular environment is fast-varying, so a SU-MIMO transmitter cannot obtain accurate channel information through sounding. Therefore, there is no explicit sounding protocol defined for an NGV transmitter to obtain the channel information prior to the transmission.

### 32.3.11 Transmit specification

#### 32.3.11.1 Transmit spectrum mask

The transmit spectrum mask by regulatory domain is defined in Annex D and Annex E.

For any STA transmitting a 10 MHz NGV PPDU, the transmit spectrum mask is defined in 17.3.9.3 (Transmit spectrum mask).

For any STA using 20 MHz channel spacing and transmitting a 20 MHz NGV PPDU or 20 MHz non-NGV duplicate PPDU, the transmitted spectral density shall have a 0 dBr bandwidth not exceeding 19 MHz and shall not exceed the spectrum mask created using the permitted power spectral density levels listed in Table 32-13 (Spectrum mask data for 20 MHz channel spacing(11bd)).

The transmission of a 20 MHz NGV PPDU or 20 MHz non-NGV duplicate PPDU shall meet transmit spectrum mask C2 regardless of the transmit power class to which the STA belongs.

NOTE 1—In the presence of additional regulatory restrictions, the device needs to meet both the regulatory requirements and the mask defined in this subclause.

NOTE 2—For rules regarding TX center frequency leakage levels, see 32.3.11.4.2 (Transmitter center frequency leakage). The spectral mask requirements in this subclause do not apply to the RF LO.

**Table 32-13—Spectrum mask data for 20 MHz channel spacing(11bd)**

| STA transmit power class | Permitted power spectral density, dBr | | | | |
|---|---|---|---|---|---|
| | ± 9.5 MHz offset (±f1) | ± 10.0 MHz offset (±f2) | ± 10.5 MHz offset (±f3) | ± 15 MHz offset (±f4) | ± 25 MHz offset (±f5) |
| Any Class | 0 | –26 | –32 | –40 | –50 |

#### 32.3.11.2 Spectral flatness

Spectral flatness measurements shall be conducted using BPSK modulated PPDUs. Demodulate the PPDUs according to the following (or equivalent) procedure:

a) Start of PPDU shall be detected.
b) Transition from L-STF to L-LTF shall be detected and fine timing shall be established.
c) Coarse and fine frequency offsets shall be estimated.
d) Symbols in a PPDU shall be derotated according to estimated frequency offset.


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e) For each NGV-LTF symbol, transform the symbol into subcarrier received values, estimate the phase from the pilot subcarriers, and derotate the subcarrier values according to the estimated phase.

f) For each of the data OFDM symbols: transform the symbol into subcarrier received values.

The spectral flatness test shall be performed over at least 20 PPDUs. The PPDUs under test shall be at least 16 data OFDM symbols long.

Evaluate spectral flatness using the subcarrier received values or the magnitude of the channel estimation.

Let $E_{i,avg}$ denote the magnitude of the channel estimation on subcarrier $i$ or the average constellation energy of a BPSK modulated subcarrier $i$ in an NGV data symbol.

For the spectral flatness test, the transmitting STA shall be configured to use a spatial mapping matrix $Q_k$ (see 32.3.9.8 (OFDM modulation)) with flat frequency response. Each output port under test of the transmitting STA shall be connected through a cable to one input port of the testing instrumentation. The requirements are defined in Table 32-14 (Maximum transmit spectral flatness deviations(11bd)) and apply to both 10 MHz and 20 MHz transmissions.

**Table 32-14—Maximum transmit spectral flatness deviations(11bd)**

| Format | Bandwidth of transmission (MHz) | Average subcarrier indices (inclusive) | Tested subcarrier indices (inclusive) | Maximum deviation (dB) |
|---|---|---|---|---|
| NGV | 10 | –16 to –1 and +1 to +16 | –16 to –1 and +1 to +16 | ±4 |
| | | | –28 to –17 and +17 to +28 | +4/–6 |
| | 20 | –42 to –2 and +2 to +42 | –42 to –2 and +2 to +42 | ±4 |
| | | | –58 to –43 and +43 to +58 | +4/–6 |

### 32.3.11.3 Transmit center frequency and symbol clock frequency tolerance

The symbol clock frequency and transmit center frequency tolerance shall be ±20 ppm maximum. The transmit center frequency and the symbol clock frequency for all transmit antennas and frequency segments shall be derived from the same reference oscillator.

### 32.3.11.4 Modulation accuracy

#### 32.3.11.4.1 Introduction to modulation accuracy tests

Transmit modulation accuracy specifications are described in 32.3.11.4.2 (Transmitter center frequency leakage) and 32.3.11.4.3 (Transmitter constellation error). The test method is described in 32.3.11.4.4 (Transmitter modulation accuracy (EVM) test).

#### 32.3.11.4.2 Transmitter center frequency leakage

TX LO leakage shall meet the following requirements for all bandwidths:

— When the RF LO is in the center of the transmitted PPDU BW, the power measured at the center of transmission BW using resolution BW 156.25 kHz shall not exceed the average power per subcarrier of the transmitted PPDU, or equivalently, $(P - 10\log(N_{ST}))$, where $P$ is the transmit power per antenna in dBm, and $N_{ST}$ is defined in Table 32-6 (Timing related constants(11bd)).

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— When the RF LO is not at the center of the transmitted PPDU BW, the power measured at the location of the RF LO using resolution BW 156.25 kHz shall not exceed the maximum of –32 dB relative to the total transmit power and –20 dBm, or equivalently $\max(P-32,-20)$, where $P$ is the transmit power per antenna in dBm.

The transmit center frequency leakage is specified per antenna.

#### 32.3.11.4.3 Transmitter constellation error

The relative constellation RMS error, calculated by first averaging over subcarriers, NGV PPDUs, and spatial streams (see Equation (19-89)) shall not exceed a data-rate dependent value according to Table 32-15 (Allowed relative constellation error versus constellation size and coding rate(11bd)). The number of spatial streams under test shall be equal to the number of utilized transmitting STA antenna (output) ports and also equal to the number of utilized testing instrumentation input ports. In the test, $N_{SS} = N_{STS}$ (no STBC) shall be used and no beamforming steering matrix shall be used. Each output port of the transmitting STA shall be connected through a cable to one input port of the testing instrumentation. The requirements apply to both 10 MHz and 20 MHz transmissions.

#### 32.3.11.4.4 Transmitter modulation accuracy (EVM) test

The transmit modulation accuracy test shall be performed by instrumentation capable of converting the transmitted signals into a stream of complex samples at a sampling rate greater than or equal to the bandwidth of the signal being transmitted.

In this case, transmit modulation accuracy shall meet the required value in Table 32-15 (Allowed relative constellation error versus constellation size and coding rate(11bd)) using only the subcarriers within the channel width.

**Table 32-15—Allowed relative constellation error versus constellation size and coding rate(11bd)**

| Modulation | Coding rate | Relative constellation error (dB) |
|---|---|---|
| BPSK-DCM | 1/2 | –5 |
| BPSK | 1/2 | –5 |
| QPSK | 1/2 | –10 |
| QPSK | 3/4 | –13 |
| 16-QAM | 1/2 | –16 |
| 16-QAM | 3/4 | –19 |
| 64-QAM | 2/3 | –22 |
| 64-QAM | 3/4 | –25 |
| 64-QAM | 5/6 | –27 |
| 256-QAM | 3/4 | –30 |
| 256-QAM | 5/6 | –32 |


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The instrument shall have sufficient accuracy in terms of I/Q arm amplitude and phase balance, DC offsets, phase noise, and analog to digital quantization noise. A possible embodiment of such a setup is converting the signals to a low IF frequency with a microwave synthesizer, sampling the signal with a digital oscilloscope and decomposing it digitally into quadrature components. The sampled signal shall be processed in a manner similar to an actual receiver, according to the following steps, or equivalent procedure:

a) Start of PPDU shall be detected.

b) Transition from L-STF to L-LTF shall be detected and fine timing shall be established.

c) Coarse and fine frequency offsets shall be estimated.

d) Symbols in a PPDU shall be derotated according to estimated frequency offset.

e) For each NGV-LTF symbol, transform the symbol into subcarrier received values, estimate the phase from the pilot subcarriers, and derotate the subcarrier values according to the estimated phase.

f) Estimate the complex channel response coefficient for each of the subcarriers and each of the transmit streams. If midambles are present in the Data field of the PPDU, the channel response coefficients shall be based upon the most recently received midamble symbols.

g) For each of the data OFDM symbols: transform the symbol into subcarrier received values, estimate the phase from the pilot subcarriers, derotate the subcarrier values according to the estimated phase, group the results from all of the receiver chains in each subcarrier to a vector, and multiply the vector by a zero-forcing equalization matrix generated from the estimated channel.

h) For each data-carrying subcarrier in each spatial stream, find the closest constellation point and compute the Euclidean distance from it. If midambles are present in the Data field of the PPDU, the midamble symbols shall not be used to compute the Euclidean distance.

i) Compute the average across PPDUs of the RMS of all errors per PPDU as given by Equation (19-89).

The test shall be performed over at least 20 PPDUs [$N_f$ as defined in Equation (19-89)]. The PPDUs under test shall be at least 16 data OFDM symbols long. Random data shall be used for the symbols.

#### 32.3.11.4.5 Time of departure accuracy

The time of departure accuracy test evaluates TIME_OF_DEPARTURE against aTxPHYTxStartRMS and aTxPHYTxStartRMS against TIME_OF_DEPARTURE_ACCURACY_TEST_THRESH as defined in Annex P with the following test parameters:

— MULTICHANNEL_SAMPLING_RATE is:

$10 \times 10^6 \left(1 + \left\lceil \frac{f_H - f_L}{10\ \text{MHz}} \right\rceil\right)$ sample/s, for a CH_BANDWIDTH parameter equal to CBW10

$20 \times 10^6 \left(1 + \left\lceil \frac{f_H - f_L}{10\ \text{MHz}} \right\rceil\right)$ sample/s, for a CH_BANDWIDTH parameter equal to CBW20

where

$f_H$ is the nominal center frequency in Hz of the highest channel in the channel set

$f_L$ is the nominal center frequency in Hz of the lowest channel in the channel set. The channel set is the set of channels used for transmitting measurement frames, the channel set comprises channels uniformly spaced across $f_H - f_L \leq 50$ MHz.

— FIRST_TRANSITION_FIELD is L-STF.

— SECOND_TRANSITION_FIELD is L-LTF.

— TRAINING_FIELD is the long symbols windowed in a manner that should approximate the windowing described in 17.3.2.5 (Mathematical conventions in the signal descriptions) with $T_{TR}$ = 100 ns for 20 MHz channel spacing, $T_{TR}$ = 200 ns for 10 MHz channel spacing.

— TIME_OF_DEPARTURE_ACCURACY_TEST_THRESH is 80 ns.

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NOTE—The indicated windowing applies to the time of departure accuracy test equipment, and not the transmitter or receiver.

### 32.3.12 Receiver specification

#### 32.3.12.1 General

For receiver minimum input sensitivity, adjacent channel rejection, nonadjacent channel rejection, receiver maximum input level, and CCA sensitivity requirements described in this subclause, the input levels are measured at the antenna connector and are referenced as the average power per receive antenna. The number of spatial streams under test shall be equal to the number of utilized transmitting STA antenna (output) ports and also equal to the number of utilized device under test input ports. Each output port of the transmitting STA shall be connected through a cable to one input port of the device under test.

The requirements on receiver minimum input sensitivity in 32.3.12.2 (Receiver minimum input sensitivity), adjacent channel rejection in 32.3.12.3 (Adjacent channel rejection), and nonadjacent channel rejection in 32.3.12.4 (Nonadjacent channel rejection) apply to NGV PPDUs. NGV-LTF-2x-Repeat format is used if the NGV PPDUs are modulated with NGV-MCS 15 and $N_{SS} = 1$ in 10 MHz, otherwise, NGV-LTF-2x format is used.

NOTE—Similar receiver minimum input sensitivity requirements, adjacent channel rejection requirements, and nonadjacent channel rejection requirements are defined for VHT PPDUs specified in 21.3.18 (VHT receiver specification).

#### 32.3.12.2 Receiver minimum input sensitivity

The packet error ratio (PER) shall be less than 10% for a PSDU with the rate dependent input levels listed in Table 32-16 (Receiver minimum input level sensitivity(11bd)). The PSDU length shall be 2048 octets for BPSK-DCM or 4096 octets for all other modulations.

**Table 32-16—Receiver minimum input level sensitivity(11bd)**

| Modulation | Rate (R) | Minimum sensitivity (10 MHz PPDU) (dBm) | Minimum sensitivity (20 MHz PPDU) (dBm) |
|---|---|---|---|
| BPSK-DCM | 1/2 | –88 | –82 |
| BPSK | 1/2 | –85 | –82 |
| QPSK | 1/2 | –82 | –79 |
| QPSK | 3/4 | –80 | –77 |
| 16-QAM | 1/2 | –77 | –74 |
| 16-QAM | 3/4 | –73 | –70 |
| 64-QAM | 2/3 | –69 | –66 |
| 64-QAM | 3/4 | –68 | –65 |
| 64-QAM | 5/6 | –67 | –64 |
| 256-QAM | 3/4 | –62 | –59 |
| 256-QAM | 5/6 | N/A | –57 |


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### 32.3.12.3 Adjacent channel rejection

Adjacent channel rejection for *W* MHz channels (where *W* is 10 or 20) shall be measured by setting the desired signal's strength 3 dB above the rate-dependent sensitivity specified in 32.3.12.2 (Receiver minimum input sensitivity) and raising the power of the interfering signal of *W* MHz bandwidth until 10% PER is caused for a PSDU length of 2048 octets for BPSK-DCM or 4096 octets for all other modulations. The difference in power between the signals in the interfering channel and the desired channel is the corresponding adjacent channel rejection. The center frequency of the adjacent channel shall be placed *W* MHz away from the center frequency of the desired signal.

The interfering signal in the adjacent channel shall be a signal compliant with the NGV PHY, unsynchronized with the signal in the channel under test, and shall have a minimum duty cycle of 50%. The corresponding rejection shall be no less than specified in Table 32-17 (Minimum required adjacent and nonadjacent channel rejection level(11bd)).

**Table 32-17—Minimum required adjacent and nonadjacent channel rejection level(11bd)**

| Modulation | Rate (R) | Adjacent channel rejection (dB) (10 MHz/20 MHz PPDU) | Nonadjacent channel rejection (dB) (10 MHz/20 MHz PPDU) |
|---|---|---|---|
| BPSK-DCM | 1/2 | 19 (10 MHz), 16 (20 MHz) | 35 (10 MHz), 32 (20 MHz) |
| BPSK | 1/2 | 16 | 32 |
| QPSK | 1/2 | 13 | 29 |
| QPSK | 3/4 | 11 | 27 |
| 16-QAM | 1/2 | 8 | 24 |
| 16-QAM | 3/4 | 4 | 20 |
| 64-QAM | 2/3 | 0 | 16 |
| 64-QAM | 3/4 | –1 | 15 |
| 64-QAM | 5/6 | –2 | 14 |
| 256-QAM | 3/4 | –7 | 9 |
| 256-QAM | 5/6 | –9 | 7 |
| NOTE—The values defined for 256-QAM with 5/6 coding rate only apply to 20 MHz channel. | | | |

An optional enhanced performance specification is provided for systems requiring improved immunity to out-of-channel interfering emissions. If a STA has dot11ACRType equal to 2, the adjacent channel rejection shall be no less than specified in Table 32-18 (Optional enhanced minimum required adjacent and nonadjacent channel rejection level(11bd)). The interfering signal in the adjacent channel shall be a signal compliant with the NGV PHY, using class C transmit mask for 10 MHz channel and C2 transmit mask for 20 MHz channel (see D.2.2 (Transmit power levels)), unsynchronized with the signal in the channel under test. The corresponding minimum receiver sensitivities for each modulation and coding rate are the same as in Table 32-16 (Receiver minimum input level sensitivity(11bd)).

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**Table 32-18—Optional enhanced minimum required adjacent and nonadjacent channel rejection level(11bd)**

| Modulation | Rate (R) | Adjacent channel rejection (dB) (10 MHz/20 MHz PPDU) | Nonadjacent channel rejection (dB) (10 MHz/20 MHz PPDU) |
|---|---|---|---|
| BPSK-DCM | 1/2 | 31 (10 MHz), 28 (20 MHz) | 45 (10 MHz), 42 (20 MHz) |
| BPSK | 1/2 | 28 | 42 |
| QPSK | 1/2 | 25 | 39 |
| QPSK | 3/4 | 23 | 37 |
| 16-QAM | 1/2 | 20 | 34 |
| 16-QAM | 3/4 | 16 | 30 |
| 64-QAM | 2/3 | 12 | 26 |
| 64-QAM | 3/4 | 11 | 25 |
| 64-QAM | 5/6 | 10 | 24 |
| 256-QAM | 3/4 | 5 | 19 |
| 256-QAM | 5/6 | 3 | 17 |
| NOTE—The values defined for 256-QAM with 5/6 coding rate only apply to 20 MHz channel. | | | |

### 32.3.12.4 Nonadjacent channel rejection

Nonadjacent channel rejection for *W* MHz channels (where *W* is 10 or 20) shall be measured by setting the desired signal's strength 3 dB above the rate-dependent sensitivity specified in Table 32-16 (Receiver minimum input level sensitivity(11bd)), and raising the power of the interfering signal of *W* MHz bandwidth until a 10% PER occurs for a PSDU length of 2048 octets for BPSK-DCM or 4096 octets for all other modulations. The difference in power between the signals in the interfering channel and the desired channel is the corresponding nonadjacent channel rejection. The nonadjacent channel rejection shall be met with any nonadjacent channels located at least 2 × *W* MHz away from the center frequency of the desired signal.

The interfering signal in the nonadjacent channel shall be a signal compliant with the NGV PHY, unsynchronized with the signal in the channel under test, and shall have a minimum duty cycle of 50%. The corresponding rejection shall be no less than specified in Table 32-17 (Minimum required adjacent and nonadjacent channel rejection level(11bd)).

An optional enhanced performance specification is provided for systems requiring improved immunity to out-of-channel interfering emissions. If a STA has dot11ACRType equal to 2, the nonadjacent channel rejection shall be no less than specified in Table 32-18 (Optional enhanced minimum required adjacent and nonadjacent channel rejection level(11bd)). The interfering signal in the nonadjacent channel shall be a signal compliant with the NGV PHY, using class C transmit mask for 10 MHz channel and C2 transmit mask for 20 MHz channel (see D.2.2 (Transmit power levels)), unsynchronized with the signal in the channel under test. The corresponding minimum receiver sensitivities for each modulation and coding rate are the same as in Table 32-16 (Receiver minimum input level sensitivity(11bd)).


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#### 32.3.12.5 Receiver maximum input level

The receiver shall provide a maximum PER of 10% at a PSDU length of 2048 octets for BPSK-DCM or 4096 octets for all other modulations, for a maximum input level of –30 dBm, measured at each antenna connector for any baseband NGV modulation.

#### 32.3.12.6 CCA sensitivity

##### 32.3.12.6.1 General

The thresholds in this subclause are compared with the signal level at each receiving antenna.

##### 32.3.12.6.2 CCA sensitivity for signals occupying the primary 10 MHz channel

An NGV STA with a *W* MHz operating channel width shall detect, with > 90% probability, the start of a PPDU that occupies at least the primary 10 MHz channel in an otherwise idle *W* MHz operating channel width, and issue a PHY CCA.indication(BUSY, {primary}) primitive within a period of aCCATime (see 17.4.4 (OFDM PHY)) if one of the following conditions is met:

— The start of a NON_NGV_10 PPDU as defined in 17.3.10.6 (CCA requirements).

— The start of a 20 MHz non-NGV duplicate or NGV PPDU for which the power measured within the primary 10 MHz channel is above –85 dBm.

The CCA signal shall be held busy (PHY-CCA.indication(BUSY, {primary}) primitive) for the duration of the PPDU.

The receiver shall issue a PHY-CCA.indication(BUSY, {primary}) primitive for any signal that exceeds a threshold of –65 dBm in the primary 10 MHz channel within a period of aCCATime after the signal arrives at the receiver's antenna(s); then the receiver shall not issue a PHY-CCA.indication(BUSY, {secondary}), or PHYCCA.indication(IDLE) primitive while the threshold continues to be exceeded.

##### 32.3.12.6.3 CCA sensitivity for signals not occupying the primary 10 MHz channel

The PHY shall issue a PHY-CCA.indication(BUSY, {secondary}) primitive if the conditions for issuing a PHY-CCA.indication(BUSY, {primary}) primitive are not present and one of the following conditions are present in an otherwise idle 20 MHz operating channel width:

— Any signal within the secondary 10 MHz channel at or above a threshold of –65 dBm within a period of aCCATime after the signal arrives at the receiver's antenna(s); then the PHY shall not issue a PHY-CCA.indication(IDLE) primitive while the threshold continues to be exceeded.

— A 10 MHz NON_NGV, or NGV PPDU detected in the secondary 10 MHz channel at or above –85 dBm with > 90% probability within a period aCCAMidTime (see 32.4.4 (NGV PHY)).

#### 32.3.13 NGV transmit procedure

There are two paths for the transmit PHY procedure:

— The first path, for which typical transmit procedures are shown in Figure 32-13 (PHY transmit procedure for NGV transmission(11bd)), is selected if the FORMAT parameter of the PHY-TXSTART.request(TXVECTOR) primitive is NGV. These transmit procedures do not describe the operation of optional features, such as SU-MIMO.

— The second path is selected if the FORMAT parameter of the PHY-TXSTART.request(TXVECTOR) primitive is NON_NGV_10. Transmit parameter N_PPDU_REP is set via the PHY service interface using the PHY-TXSTART.request(TXVECTOR) primitive, as

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described in Table 32-1 (TXVECTOR and RXVECTOR parameters(11bd)) to indicate the number of repetitions of NON_NGV_10 PPDU transmission.

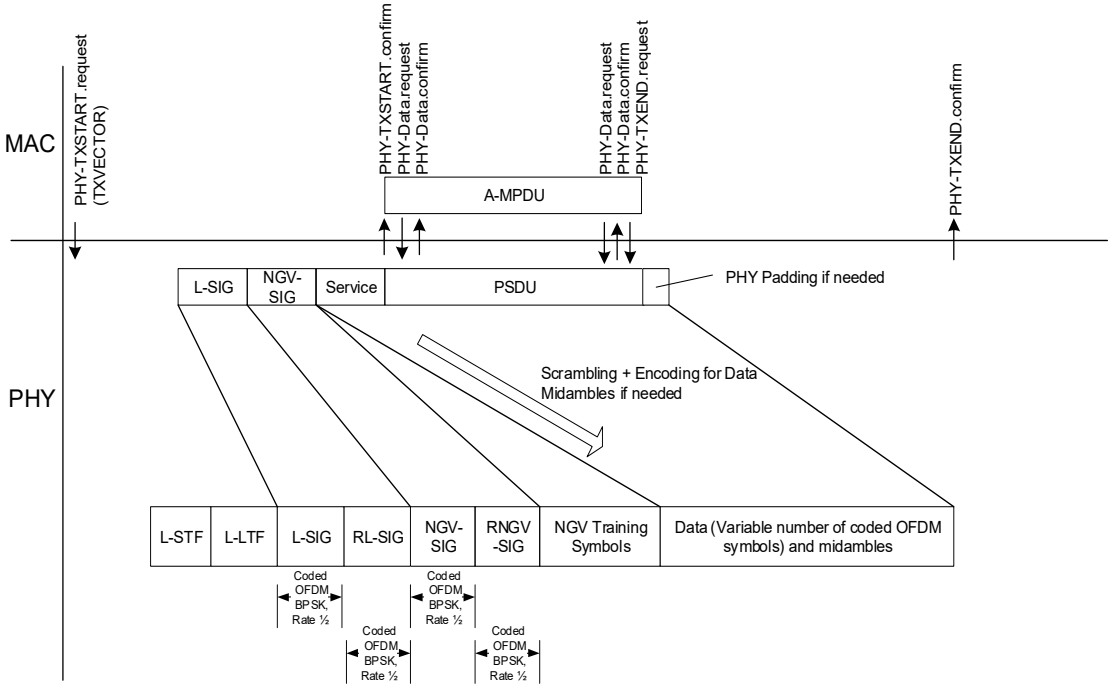


**Figure 32-13—PHY transmit procedure for NGV transmission(11bd)**

In the second path, the transmission follows the transmit procedure in Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) except that the signal referred to in Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) is instead generated with the Duration/ID field to report transmitter is an NGV STA as defined in 31.2.1 (Coexistence with non-NGV STAs). If N_PPDU_REP is nonzero, the first NON_NGV_10 PPDU may be stored in the memory, and the same PPDU is transmitted N_PPDU_REP times after the initial transmission, with each repetition occurring after a SIFS following the previous NON_NGV_10 PPDU transmission.

In both paths, in order to transmit data, the MAC generates a PHY-TXSTART.request primitive, that causes the PHY entity to enter the transmit state. Further, the PHY is set to operate at the appropriate frequency through station management via PLME, as specified in 32.4 (NGV PLME). Other transmit parameters, such as NGV-MCS, Coding types, and transmit power, are set via the PHY SAP using the PHY-TXSTART.request(TXVECTOR) primitive, as described in Table 32-1 (TXVECTOR and RXVECTOR parameters(11bd)). The remainder of the clause applies to the first path.

Transmission of the PPDU shall be initiated by the PHY after receiving the PHY-TXSTART.request(TXVECTOR) primitive. The TXVECTOR parameters for the PHY-TXSTART.request primitive are specified in Table 32-1 (TXVECTOR and RXVECTOR parameters(11bd)).

Transmission of the PHY preamble shall start immediately provided that TIME_OF_DEPARTURE_REQUESTED is true, based on the parameters passed in the PHY-TXSTART.request primitive.

After the PHY preamble transmission is started, the PHY entity immediately initiates data scrambling and data encoding. The encoding method for the Data field is based on the CH_BANDWIDTH, NUM_SS, and NGV-MCS parameters of the TXVECTOR, as described in 32.3.2 (NGV PPDU format).


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The SERVICE field and PSDU are scrambled and encoded as described in 32.3.3 (Transmitter block diagram). The data shall be exchanged between the MAC and the PHY through a series of PHY-DATA.request(DATA) primitives issued by the MAC, and PHY-DATA.confirm primitives issued by the PHY. PHY padding bits are appended to the PSDU to make the number of bits in the coded SERVICE field and PSDU an integer multiple of the number of coded bits per OFDM symbol. Midambles are inserted every *M* OFDM symbols if present, where *M* is indicated by the Midamble Periodicity field in the NGV-SIG field.

Transmission can be prematurely terminated by the MAC through the PHY-TXEND.request primitive. PSDU transmission is terminated by receiving a PHY-TXEND.request primitive. Each PHY-TXEND.request primitive is acknowledged with a PHY-TXEND.confirm primitive from the PHY. Normal termination occurs after the transmission of the final bit of the last PSDU octet, according to the number of OFDM symbols indicated by $N_{SYM}$ (see 21.3.10.5.4 (LDPC coding)).

In the PHY, the GI is inserted in every data OFDM symbol as a countermeasure against delay spread.

When the PPDU transmission is completed the PHY entity enters the receive state.

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A typical state machine implementation of the transmit PHY is provided in Figure 32-14 (PHY transmit state machine(11bd)). Request (.request) and confirmation (.confirm) primitives are issued as shown. This state machine does not describe the operation of optional features, such as SU-MIMO.

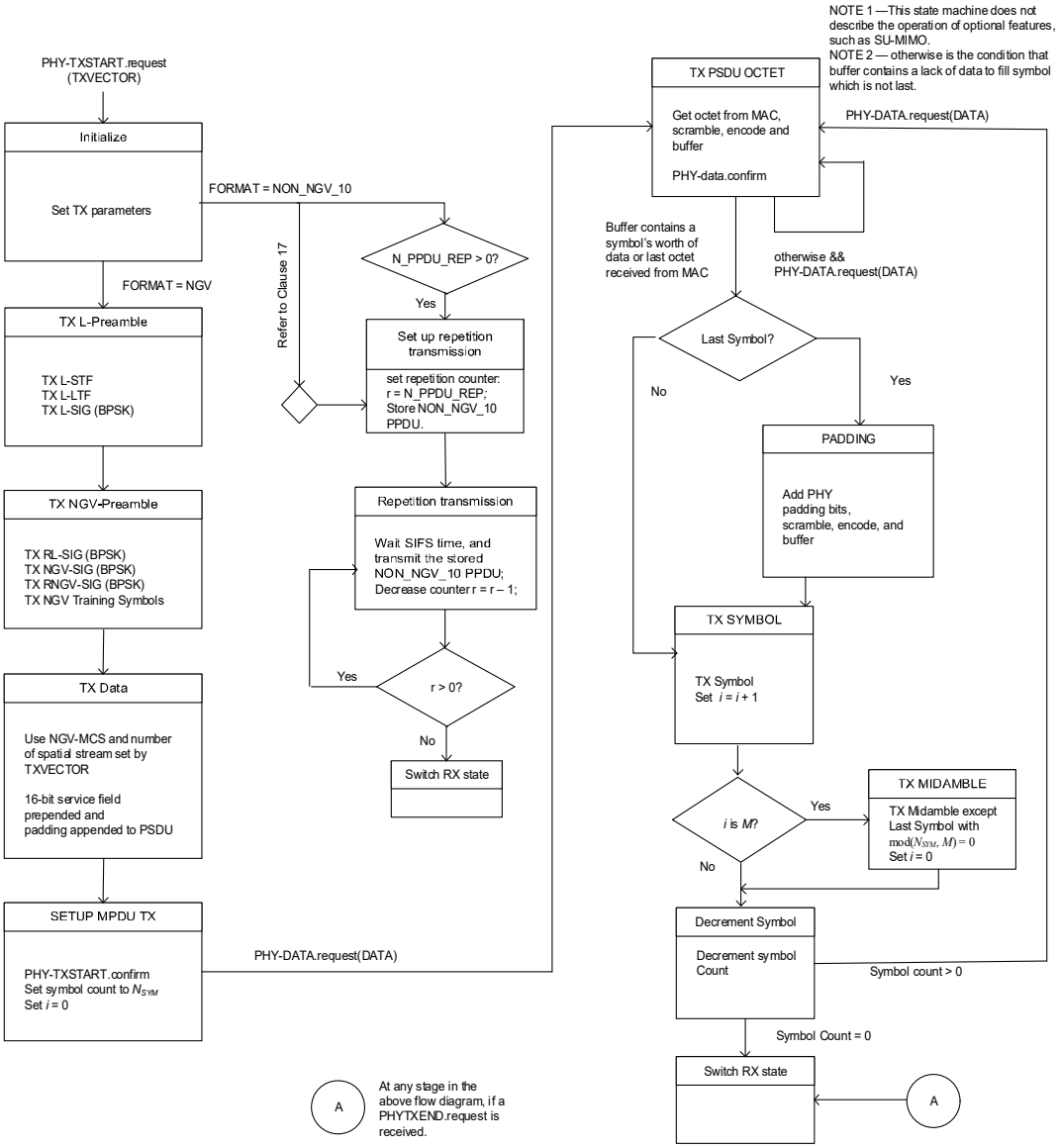


**Figure 32-14—PHY transmit state machine(11bd)**

### 32.3.14 NGV receive procedure

A typical PHY receive procedure is shown in Figure 32-15 (PHY receive procedure for NGV transmission(11bd)) for NGV format. A typical state machine implementation of the receive PHY is given in Figure 32-16 (PHY receive state machine(11bd)). This receive procedure and state machine do not describe the operation of optional features, such as SU-MIMO. If the detected format indicates a NON_NGV_10 PPDU:

— If combined detection of NON_NGV_10 PPDU with repetition is not considered, refer to the receive procedure and state machine in Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification).


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— Else the receiver checks whether the currently received PPDU is qualified as a repetition of previously received NON_NGV_10 PPDU. The repetition may be determined by checking whether the gap between the time of arrival of the currently detected PPDU and the ending time of the previously received NON_NGV_10 PPDU is SIFS or not. Other repetition detection techniques may be exploited to improve the detection reliability.

  — If the current reception is not a repetition, refer to the receive procedure and state machine in Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) to decode the PPDU, and overwrite the memory with current PPDU for potential combining with next repetition.

  — Else, the receiver may combine the currently received PPDU with the previously stored NON_NGV_10 PPDU and decode the combined PPDU according to the receive procedure and state machine in Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification). Update the memory with combined PPDU for potential reception of more repetitions.

Further, through station management (via the PLME) the PHY is set to the appropriate frequency, as specified in 32.4 (NGV PLME). Receive parameters, such as RSSI and indicated DATARATE, may be accessed via the PHY SAP.

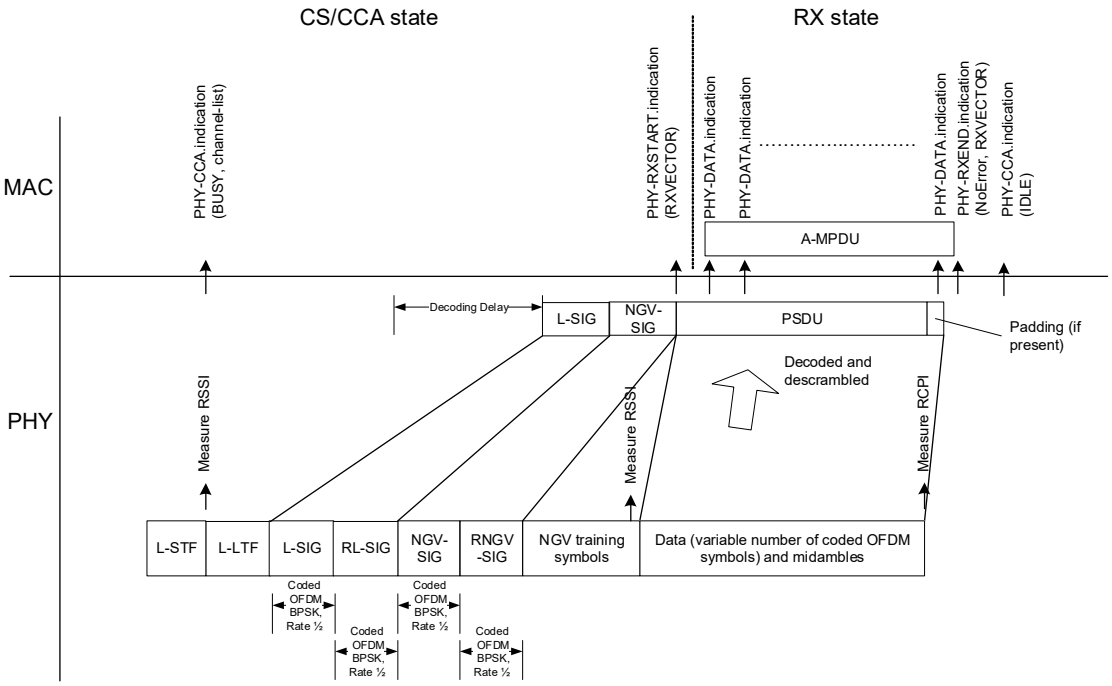


**Figure 32-15—PHY receive procedure for NGV transmission(11bd)**

Upon receiving the transmitted PHY preamble in a greater than or equal to 10 MHz channel, the PHY measures a receive signal strength. This activity is indicated by the PHY to the MAC via a PHY-CCA.indication primitive. A PHY-CCA.indication(BUSY, channel-list) primitive is also issued as an initial indication of reception of a signal as specified in 32.3.12.6 (CCA sensitivity). The channel-list parameter of the PHY-CCA.indication primitive is absent when the operating channel width is 10 MHz. The channel-list parameter is present when the operating channel width is 20 MHz.

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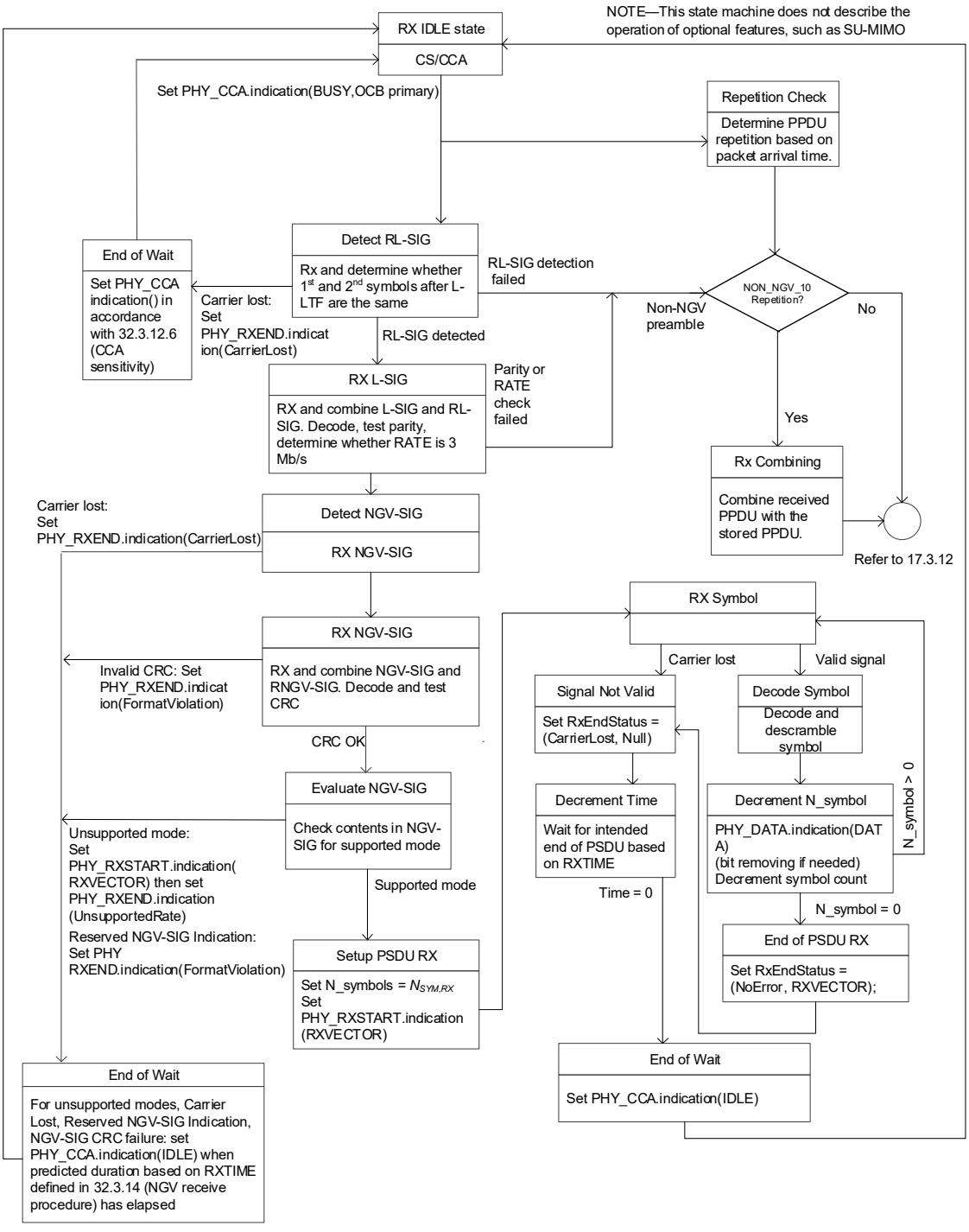


**Figure 32-16—PHY receive state machine(11bd)**

The PHY shall not issue a PHY-RXSTART.indication primitive in response to a PPDU that does not overlap the OCB primary 10 MHz channel.


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The PHY includes the most recently measured RSSI value in the PHY-RXSTART.indication(RXVECTOR) primitive issued to the MAC.

After the PHY-CCA.indication(BUSY, channel-list) primitive is issued, the PHY entity shall begin receiving the training symbols and searching for the preambles for non-NGV and NGV PPDUs. For detecting the NGV preamble, the PHY entity shall search for L-SIG and RL-SIG in order to set the maximum duration of the data stream. If RL-SIG is detected, the PHY entity should check the parity bit and RATE fields in L-SIG and RL-SIG. If RL-SIG detection fails, the check of the parity bit is invalid, or the RATE field is not equal to 3 Mb/s, a PHY-RXSTART.indication primitive is not issued, and instead the PHY should continue to detect the received signal using NON_NGV_10 Repetition check. If a valid parity bit and the RATE with 3 Mb/s are indicated in L-SIG and RL-SIG, the NGV PHY shall maintain the PHY-CCA.indication(BUSY, channel-list) primitive for the predicted duration of the transmitted PPDU, as defined by RXTIME in Equation (32-41), for all supported modes, unsupported modes, Reserved NGV-SIG Indication, and invalid SIG CRC. Reserved NGV-SIG Indication is defined as an NGV-SIG with the Reserved bits equal to 0 or any other NGV-SIG field bit combinations that do not correspond to modes of PHY operation defined in Clause 32 (Next Generation V2X (NGV) PHY specification(11bd)). If the NGV-SIG indicates an unsupported mode, the PHY shall issue a PHY-RXEND.indication(UnsupportedRate) primitive. If the NGV-SIG indicates an invalid CRC or Reserved NGV-SIG indication, the PHY shall issue the error condition PHY-RXEND.inidcation(FormatViolation).primitive.

After receiving a valid L-SIG, RL-SIG, NGV-SIG, and RNGV-SIG indicating a supported mode, the PHY entity shall begin receiving the NGV training symbols.

The PHY entity shall check the PHY Version in the NGV-SIG field. If the PHY Version does not contain an intended value with 0 for NGV PHY in Table 32-10 (Fields in the NGV-SIG field(11bd)), the PHY entity shall issue a PHY-RXSTART.indication(RXVECTOR) and then issue a PHY-RXEND.indication(Filtered).

Following training fields, the Data field shall be received. The number of symbols in the Data field is determined by Equation (32-39).

$$N_{SYM,\,RX} = \begin{cases} N'_{SYM,\,RX}, & \text{if LDPC Extra Symbol = 0} \\ N'_{SYM,\,RX} - 1, & \text{if LDPC Extra Symbol = 1} \end{cases} \tag{32-39}$$

where

LDPC Extra Symbol is a field in the NGV-SIG field (see Table 32-10 (Fields in the NGV-SIG field(11bd))).

$$N'_{SYM,RX} = \left\lfloor \left( \frac{(\text{L\_LENGTH} + 3) \times 8}{3} - T_{NGV\text{-}PREAMBLE} - N_{MA,\,RX} \times N_{NGV\text{-}LTF} \times T_{NGV\text{-}LTF} \right) / T_{SYM} \right\rfloor$$

where

L_LENGTH is the LENGTH field in L-SIG

$T_{NGV\text{-}PREAMBLE} = T_{RL\text{-}SIG} + T_{NGV\text{-}SIG} + T_{RNGV\text{-}SIG} + T_{NGV\text{-}STF} + N_{NGV\text{-}LTF} \times T_{NGV\text{-}LTF}$

$T_{RL\text{-}SIG}$, $T_{NGV\text{-}SIG}$, $T_{RNGV\text{-}SIG}$, $T_{NGV\text{-}STF}$, and $T_{NGV\text{-}LTF}$, are defined in Table 32-6 (Timing related constants(11bd))

$N_{NGV\text{-}LTF}$ is defined in Table 32-7 (Frequently used parameters(11bd))

$N_{MA,\,RX}$ may be computed by multiple methods that get the same results, an example method is provided in Equation (32-40)

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$$N_{MA,RX} = \left\lfloor \frac{\frac{(\text{L\_LENGTH} + 3) \times 8}{3} - T_{NGV\text{-}PREAMBLE} - T_{SYM}}{N_{NGV\text{-}LTF} \times T_{NGV\text{-}LTF} + M \times T_{SYM}} \right\rfloor \quad (32\text{-}40)$$

where $M$ is the midamble periodicity as defined in Table 32-10 (Fields in the NGV-SIG field(11bd)).

If signal loss occurs during reception prior to completion of the PSDU reception, the error condition shall be reported to the MAC using a PHY-RXEND.indication(CarrierLost) primitive. After waiting for the intended end of the PSDU as determined by Equation (32-41), the PHY shall generate a PHY-CCA.indication(IDLE) primitive and return to RX IDLE state.

$$\text{RXTIME} = \left\lceil \frac{(\text{L\_LENGTH} + 3)}{3} \right\rceil \times 8 + 40 \quad (32\text{-}41)$$

The received PSDU bits are assembled into octets, decoded, and presented to the MAC using a series of PHY-DATA.indication(DATA) primitive exchanges. Any final bits that cannot be assembled into a complete octet are considered pad bits and discarded. After the reception of the final bit of the last PSDU octet, and possible padding, the receiver shall be returned to the RX IDLE state, as shown in Figure 32-16 (PHY receive state machine(11bd)). A PHY-RXEND.indication(NoError) primitive shall be issued on entry to the RX IDLE state.

### 32.3.15 Regulatory requirements

Wireless LANs (WLANs) implemented in accordance with this standard are subject to equipment certification and operating requirements established by regional and national regulatory administrations. The PHY specification establishes minimum technical requirements for interoperability, based upon established regulations at the time this standard was issued. These regulations are subject to revision or may be superseded. Requirements that are subject to local geographic regulations are annotated within the PHY specification. Regulatory requirements that do not affect interoperability are not addressed in this standard. Implementers are referred to the regulatory sources in Annex D for further information. Operation in countries within defined regulatory domains might be subject to additional or alternative national regulations.

### 32.3.16 NGV ranging NDP

The NGV ranging NDP is a variant of NGV PPDU but without the Data field. The format of an NGV ranging NDP is shown in Figure 32-17 (NGV ranging NDP format(11bd)).

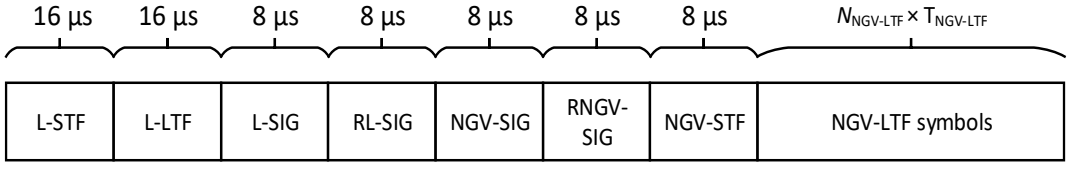


**Figure 32-17—NGV ranging NDP format(11bd)**

The NGV ranging NDP has the following properties:

— The TXVECTOR parameter NUM_SS is used to encode the NSS field of the NGV-SIG and RNGV-SIG.

— The TXVECTOR parameter LTF_REP indicates the number of repetitions of the NGV-LTF symbols.

— The TXVECTOR parameter NGV-MCS shall be set to 0.


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In an NGV ranging NDP, the NGV-LTF symbol format shall be NGV-LTF-2x.

The number of NGV-LTF symbols in an NGV ranging NDP is the product of the TXVECTOR parameter NUM_SS and (LTF_REP + 1), see Table 32-11 (Number of NGV-LTFs required for different numbers of spatial streams(11bd)).The number of LTF repetitions equals LTF_REP. When LTF repetition is used, LTF_REP is 1. Otherwise, LTF_REP is 0.

The construction of the NGV-LTFs in an NGV ranging NDP is done by performing the steps in 32.3.4.7 (Construction of NGV-LTF) LTF_REP + 1 times. An example of NGV_LTF with two spatial streams and one LTF repetition is shown in Figure 32-18 (Example of NGV-LTF with NSS = 2 and LTF_REP = 1(11bd)).

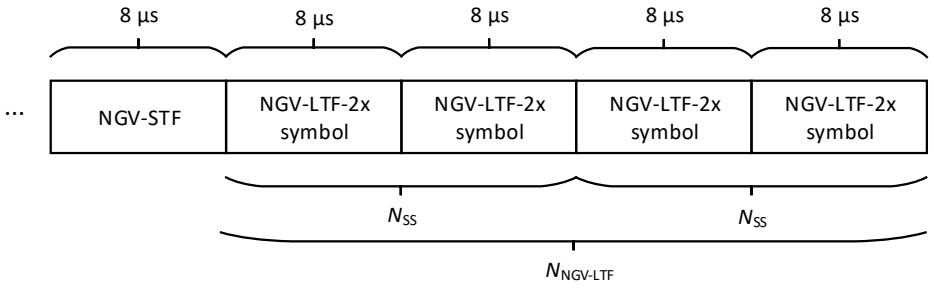


**Figure 32-18—Example of NGV-LTF with $N_{SS}$ = 2 and LTF_REP = 1(11bd)**

## 32.4 NGV PLME

### 32.4.1 PLME-SAP

Table 32-19 (NGV PHY MIB attributes(11bd)) lists the MIB attributes that may be accessed by the PHY entities and the intralayer of higher level LMEs. These attributes are accessed via the PLME-GET, PLME-SET, PLME-RESET, and PLME-CHARACTERISTICS primitives defined in 6.5 (MLME SAP primitives(#1114)).

**Table 32-19—NGV PHY MIB attributes(11bd)**

| Managed object | Default value/range | Operational semantics |
|---|---|---|
| dot11PHYOperationTable | | |
| dot11PHYType | ngv | Static |
| dot11PHYTxPowerTable | | |
| dot11NumberSupportedPowerLevelsImplemented | Implementation dependent | Static |
| dot11TxPowerLevel1 | Implementation dependent | Static |
| dot11TxPowerLevel2 | Implementation dependent | Static |
| dot11TxPowerLevel3 | Implementation dependent | Static |
| dot11TxPowerLevel4 | Implementation dependent | Static |
| dot11TxPowerLevel5 | Implementation dependent | Static |

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**Table 32-19—NGV PHY MIB attributes(11bd) *(continued)***

| Managed object | Default value/range | Operational semantics |
|---|---|---|
| dot11TxPowerLevel6 | Implementation dependent | Static |
| dot11TxPowerLevel7 | Implementation dependent | Static |
| dot11TxPowerLevel8 | Implementation dependent | Static |
| dot11CurrentTxPowerLevel | Implementation dependent | Static |
| dot11TxPowerLevelExtended | Implementation dependent | Static |
| dot11PHYNGVTable | | |
| dot11CurrentChannelWidth | Implementation dependent | Dynamic |
| dot11CurrentPrimaryChannel | Implementation dependent | Dynamic |
| dot11CurrentSecondaryChannel | Implementation dependent | Dynamic |
| dot11NGVDYN20MAllowed | Implementation dependent | Static |

### 32.4.2 PHY MIB

NGV PHY MIB attributes are defined in C.3 (MIB detail) with specific values defined in Table 32-19 (NGV PHY MIB attributes(11bd)). The "Operational semantics" column in Table 32-19 (NGV PHY MIB attributes(11bd)) contains two types: Static and Dynamic.

— Static MIB attributes are fixed and cannot be modified for a given PHY implementation.

— Dynamic MIB attributes are interpreted according to the MAX-ACCESS field of the MIB attribute. When MAX-ACCESS is read-only, the MIB attribute value may be updated by the PLME and read from the MIB attribute by management entities. When MAX-ACCESS is read-write, the MIB attribute may be read and written by management entities but shall not be updated by the PLME.

### 32.4.3 TXTIME and PSDU_LENGTH calculation

The value of the TXTIME parameter returned by the PLME-TXTIME.confirm primitive shall be calculated for an NGV PPDU using Equation (32-42).

$$\begin{aligned}\text{TXTIME} = {} & 40 + T_{RL\text{-}SIG} + T_{NGV\text{-}SIG} + T_{RNGV\text{-}SIG} + T_{NGV\text{-}STF} + N_{SYM} \times T_{SYM} + \\ & 8 \times \left\lceil \frac{N_{NGV\text{-}LTF} \times T_{NGV\text{-}LTF} + N_{MA} \times N_{NGV\text{-}LTF} \times T_{NGV\text{-}LTF}}{8} \right\rceil \end{aligned} \tag{32-42}$$

where

$T_{RL\text{-}SIG}$, $T_{NGV\text{-}SIG}$, $T_{RNGV\text{-}SIG}$, $T_{NGV\text{-}STF}$, and $T_{SYM}$ are defined in Table 32-6 (Timing related constants(11bd))

$N_{NGV\text{-}LTF}$ is defined in Table 32-7 (Frequently used parameters(11bd))

$N_{MA}$ is defined in 32.3.9.9 (Midambles)

For an NGV PPDU using LDPC encoding, the total number of data symbols in the Data field, $N_{SYM}$, is given in 21.3.10.5.4 (LDPC coding) and computed using Equation (19-41) in step d) of 19.3.11.7.5 (LDPC PPDU encoding process).


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The value of the PSDU_LENGTH parameter returned in the PLME-TXTIME.confirm primitive for an NGV SU PPDU using LDPC encoding is calculated using Equation (32-43).

$$\text{PSDU\_LENGTH} = \left\lfloor \frac{N_{SYM,init} N_{DBPS} - N_{service}}{8} \right\rfloor \quad (32\text{-}43)$$

where

$N_{SYM,init}$ is given by Equation (21-62) with $m_{STBC} = 1$.

### 32.4.4 NGV PHY

The static NGV PHY characteristics, provided through the PLME-CHARACTERISTICS service primitive, shall be as shown in Table 17-24 (OFDM PHY characteristics) with 10 MHz channel spacing unless otherwise listed in Table 32-20 (NGV PHY characteristics(11bd)). The definitions for these characteristics are given in 6.5.4 (Synchronization).

**Table 32-20—NGV PHY characteristics(11bd)**

| Characteristics | Value |
|---|---|
| aSlotTime | If dot11OperatingClassesRequired is false, 13 μs.<br>If dot11OperatingClassesRequired is true, 13 μs plus any coverage-class-dependent aAirPropagationTime (see Table 9-95 (Venue group codes and descriptions)). |
| aSIFSTime | 32 μs |
| aCCAMidTime | 45 μs |
| aPPDUMaxTime | 10.968 ms |
| aPSDUMaxLength | 244 800 octets (see NOTE 1) |
| aRxPHYStartDelay | 64 μs (see NOTE 2) |

NOTE 1—This is the maximum length in octets for an NGV PPDU with a bandwidth of 20 MHz, NGV-MCS 9, and two spatial streams, and limited by 1360 possible data symbols in aPPDUMaxTime. This is the maximum PSDU length an NGV PHY could support assuming no restrictions in MAC. See 10.3.2 (Procedures common to the DCF and EDCAF) and 9.2.4.7.1 (TRS Control) for additional restrictions on the maximum number of octets the MAC could support.

NOTE 2—This value arises from the time to the end of RNGV-SIG (see Figure 32-5 (NGV PPDU format(11bd))).

## 32.5 Parameters for NGV-MCSs

The rate-dependent parameters for 10 MHz and 20 MHz are given in Table 32-21 (NGV-MCSs for 10 MHz, NSS = 1(11bd)) to Table 32-24 (NGV-MCSs for 20 MHz, NSS = 2(11bd)).

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**Table 32-21—NGV-MCSs for 10 MHz, $N_{SS}$ = 1(11bd)**

| NGV-MCS index | Modulation | *R* | $N_{BPSCS}$ | $N_{SD}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) 1.6 µs GI NGV-LTF-2x |
|---|---|---|---|---|---|---|---|
| 0 | BPSK | 1/2 | 1 | 52 | 52 | 26 | 3.3 |
| 1 | QPSK | 1/2 | 2 | 52 | 104 | 52 | 6.5 |
| 2 | QPSK | 3/4 | 2 | 52 | 104 | 78 | 9.8 |
| 3 | 16-QAM | 1/2 | 4 | 52 | 208 | 104 | 13.0 |
| 4 | 16-QAM | 3/4 | 4 | 52 | 208 | 156 | 19.5 |
| 5 | 64-QAM | 2/3 | 6 | 52 | 312 | 208 | 26.0 |
| 6 | 64-QAM | 3/4 | 6 | 52 | 312 | 234 | 29.3 |
| 7 | 64-QAM | 5/6 | 6 | 52 | 312 | 260 | 32.5 |
| 8 | 256-QAM | 3/4 | 8 | 52 | 416 | 312 | 39.0 |
| 9 | Not valid | | | | | | |
| 10–14 | Reserved | | | | | | |
| 15 | BPSK-DCM | 1/2 | 1 | 26 | 26 | 13 | 1.6 |

**Table 32-22—NGV-MCSs for 10 MHz, $N_{SS}$ = 2(11bd)**

| NGV-MCS index | Modulation | *R* | $N_{BPSCS}$ | $N_{SD}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) 1.6 µs GI NGV-LTF-2x |
|---|---|---|---|---|---|---|---|
| 0 | BPSK | 1/2 | 1 | 52 | 104 | 52 | 6.5 |
| 1 | QPSK | 1/2 | 2 | 52 | 208 | 104 | 13.0 |
| 2 | QPSK | 3/4 | 2 | 52 | 208 | 156 | 19.5 |
| 3 | 16-QAM | 1/2 | 4 | 52 | 416 | 208 | 26.0 |
| 4 | 16-QAM | 3/4 | 4 | 52 | 416 | 312 | 39.0 |
| 5 | 64-QAM | 2/3 | 6 | 52 | 624 | 416 | 52.0 |
| 6 | 64-QAM | 3/4 | 6 | 52 | 624 | 468 | 58.5 |
| 7 | 64-QAM | 5/6 | 6 | 52 | 624 | 520 | 65.0 |
| 8 | 256-QAM | 3/4 | 8 | 52 | 832 | 624 | 78.0 |
| 9 | Not valid | | | | | | |
| 10–15 | Reserved | | | | | | |


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**Table 32-23—NGV-MCSs for 20 MHz, $N_{SS}$ = 1(11bd)**

| NGV-MCS index | Modulation | *R* | $N_{BPSCS}$ | $N_{SD}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) 1.6 µs GI NGV-LTF-2x |
|---|---|---|---|---|---|---|---|
| 0 | BPSK | 1/2 | 1 | 108 | 108 | 54 | 6.8 |
| 1 | QPSK | 1/2 | 2 | 108 | 216 | 108 | 13.5 |
| 2 | QPSK | 3/4 | 2 | 108 | 216 | 162 | 20.3 |
| 3 | 16-QAM | 1/2 | 4 | 108 | 432 | 216 | 27.0 |
| 4 | 16-QAM | 3/4 | 4 | 108 | 432 | 324 | 40.5 |
| 5 | 64-QAM | 2/3 | 6 | 108 | 648 | 432 | 54.0 |
| 6 | 64-QAM | 3/4 | 6 | 108 | 648 | 486 | 60.8 |
| 7 | 64-QAM | 5/6 | 6 | 108 | 648 | 540 | 67.5 |
| 8 | 256-QAM | 3/4 | 8 | 108 | 864 | 648 | 81.0 |
| 9 | 256-QAM | 5/6 | 8 | 108 | 864 | 720 | 90.0 |
| 10–14 | Reserved | | | | | | |
| 15 | BPSK-DCM | 1/2 | 1 | 54 | 54 | 27 | 3.4 |

**Table 32-24—NGV-MCSs for 20 MHz, $N_{SS}$ = 2(11bd)**

| NGV-MCS index | Modulation | *R* | $N_{BPSCS}$ | $N_{SD}$ | $N_{CBPS}$ | $N_{DBPS}$ | Data rate (Mb/s) 1.6 µs GI NGV-LTF-2x |
|---|---|---|---|---|---|---|---|
| 0 | BPSK | 1/2 | 1 | 108 | 216 | 108 | 13.5 |
| 1 | QPSK | 1/2 | 2 | 108 | 432 | 216 | 27.0 |
| 2 | QPSK | 3/4 | 2 | 108 | 432 | 324 | 40.5 |
| 3 | 16-QAM | 1/2 | 4 | 108 | 864 | 432 | 54.0 |
| 4 | 16-QAM | 3/4 | 4 | 108 | 864 | 648 | 81.0 |
| 5 | 64-QAM | 2/3 | 6 | 108 | 1296 | 864 | 106.0 |
| 6 | 64-QAM | 3/4 | 6 | 108 | 1296 | 972 | 121.5 |
| 7 | 64-QAM | 5/6 | 6 | 108 | 1296 | 1080 | 135.0 |
| 8 | 256-QAM | 3/4 | 8 | 108 | 1728 | 1296 | 162.0 |
| 9 | 256-QAM | 5/6 | 8 | 108 | 1728 | 1440 | 180.0 |
| 10–15 | Reserved | | | | | | |

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# 33. Light communication (LC) MAC and PHY specification(11bb)

## 33.1 LC MAC specification

### 33.1.1 Introduction

An LC STA supports the MAC functions defined in Clause 10 (MAC sublayer functional description), the MLME functions defined in Clause 11 (MLME), and the security functions defined in Clause 12 (Security).

### 33.1.2 LC MAC

An LC STA with HT support shall follow HT MAC procedures and requirements with an LC PHY. An LC STA with VHT support shall follow VHT MAC procedures and requirements with an LC PHY. An LC STA with HE support shall follow HE MAC procedures and requirements with an LC PHY.

## 33.2 LC PHY specification

### 33.2.1 General

This subclause specifies the PHY entity for a light communications (LC) orthogonal frequency division multiplexing (OFDM) system with an intensity modulation and direct detection (IM/DD) optical interface.

An LC PHY provides one of three levels of support: HT, VHT, or HE.

An LC PHY with HT support conforms to the requirements for an HT PHY as defined in Clause 19 (High Throughput (HT) PHY specification(#2297)) except where the requirements in 33.2 (LC PHY specification) supersede those requirements.

An LC PHY with VHT support conforms to the requirements for a VHT PHY as defined in Clause 21 (Very high throughput (VHT) PHY specification) except where the requirements in 33.2 (LC PHY specification) supersede those requirements.

An LC PHY with HE support conforms to the requirements for an HE PHY as defined in Clause 27 (High-efficiency (HE) PHY specification(11ax)) except for the requirements in 33.2 (LC PHY specification) that supersede those requirements.

### 33.2.2 LC PHY service interface

The LC PHY service is provided to the MAC through the PHY service primitive described in Clause 8 (PHY service specification).

### 33.2.3 LC PHY

#### 33.2.3.1 Introduction

The procedure by which an LC PHY converts a PSDU into a PPDU is defined in 19.3 (HT PHY), 21.3 (VHT PHY), and 27.3 (HE PHY) for an LC PHY with HT, VHT and HE support, respectively, except for the differences described in the remainder of 33.2.3 (LC PHY).

For the requirements in 21.3 (VHT PHY) and 27.3 (HE PHY), the term *frequency segment* applies to the LC IF signal.

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### 33.2.3.2 Transmitter block diagram

The transmitter block diagrams in 19.3.3 (Transmitter block diagram), 21.3.3 (Transmitter block diagram), and 27.3.5 (Transmitter block diagram) show an Analog and RF block that is described as upconverting the complex baseband waveform associated with each transmit chain to an RF signal.

In the LC PHY, the complex baseband waveform associated with each transmit chain is instead upconverted to an LC IF signal, either directly or by up/down conversion. A DC bias is added to the LC IF signal which is then fed into an optical front end (OFE). The OFE converts the DC biased LC IF signal into an intensity modulated optical signal.

In comparison to an RF channel, which is characterized by multipath propagation, the LC channel is relatively transparent with a dominant LOS component usually 10s of decibels stronger than non-line-of-sight components.

In some implementations, the complex baseband waveform is upconverted directly to an LC IF signal as shown in Figure 33-1 (Direct conversion LC TX(11bb)(M148)). In this example, the LC PHY TX/RX are HT/VHT/HE PHY TX/RX where the RF antennas are replaced by LC optical antennas.

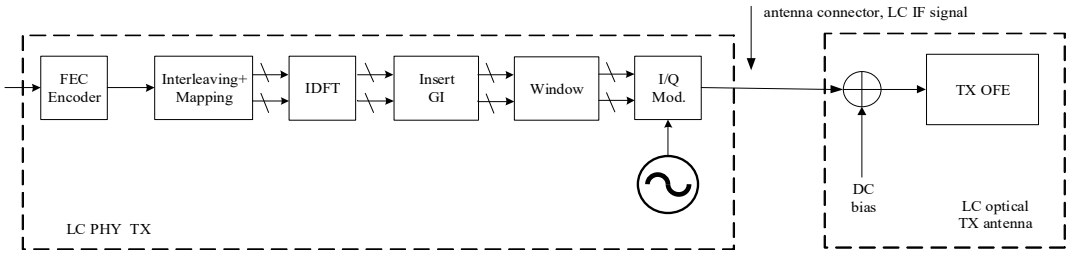


**Figure 33-1—Direct conversion LC TX(11bb)(M148)**

In some implementations, the complex baseband waveform might first be upconverted to an RF signal and then downconverted to the LC IF signal as shown in Figure 33-2 (Up/down conversion LC TX(11bb)(M148)). The downconversion is defined to have unity gain.

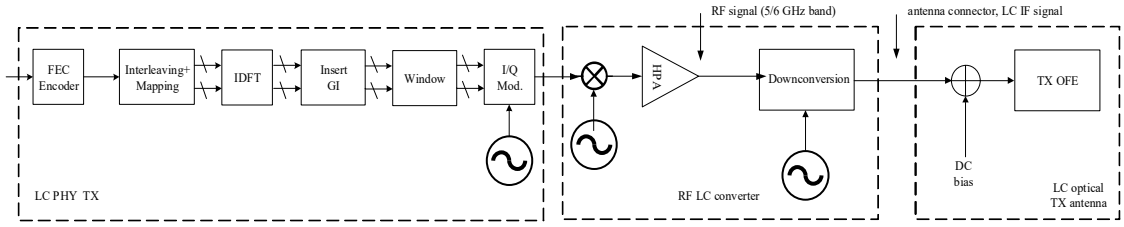


**Figure 33-2—Up/down conversion LC TX(11bb)(M148)**

In this example, the RF signal from the HPA, which is in the frequency range 5 GHz to 6 GHz, is downconverted such that the center frequency aligns with the LC IF channel frequency defined in 33.2.3.4 (Channel numbering). The reference clock of the local oscillator for the downconversion at the LC optical TX antenna is the same as in the LC PHY TX.


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A DC bias is added to the LC IF signal before the signal is fed to the transmitting OFE because the current through an SSL device can only be positive, as illustrated in Figure 33-3 (Operation of an SSL device with DC bias(11bb)(M148)).

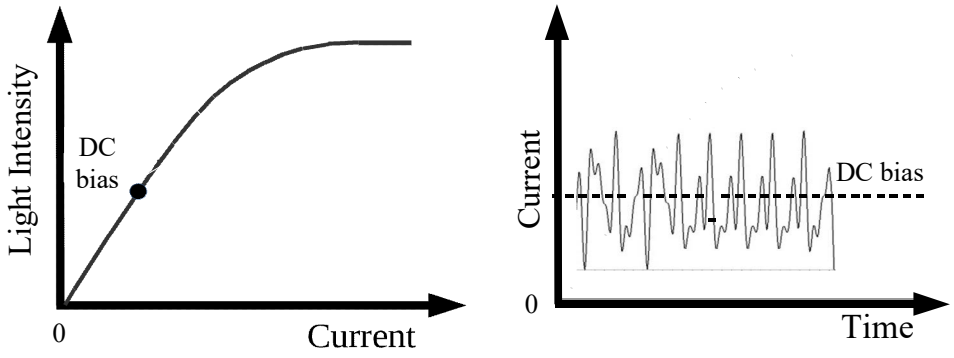


**Figure 33-3—Operation of an SSL device with DC bias(11bb)(M148)**

An LC PHY supports the use of multiple transmit chains and multiple receive chains. An example of the LC PHY TX connected to multiple LC optical TX antennas is shown in Figure 33-4 (Connecting the LC PHY TX to multiple optical TX antennas(11bb)).

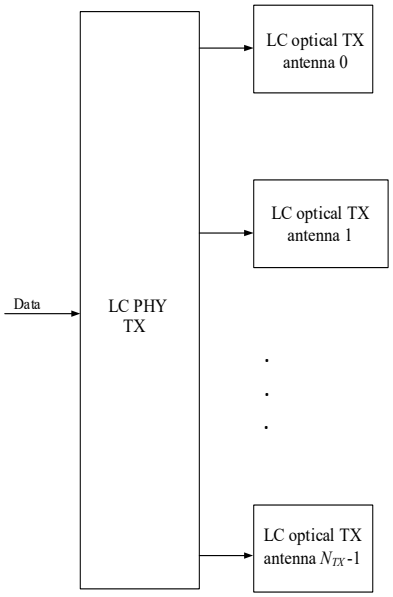


**Figure 33-4—Connecting the LC PHY TX to multiple optical TX antennas(11bb)**

### 33.2.3.3 Mathematical description of signals

The LC IF signal is described by Equation (19-1), Equation (21-11), and Equation (27-1) for an LC PHY with HT, VHT or HE support, respectively, where $f_c$ is the LC IF.

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#### 33.2.3.4 Channel numbering

In systems using light communications, the frequency segment refers to the LC IF signal.

LC IF channel center frequencies are defined at integer multiples of 5 MHz above the LC IF channel starting frequency. The relationship between LC IF channel center frequency and channel number $n_{ch}$ is given in Equation (33-1).

$$\text{LC IF channel center frequency} = \text{LC IF channel starting frequency} + 5 \times n_{ch} \text{ (MHz)}, \quad (33\text{-}1)$$

where

$n_{ch} = 1,\ldots, 64$ is the channel number or channel center frequency index

LC IF channel starting is defined in Annex E.

Equation (33-1) and the LC IF channel starting frequencies defined in Annex E divide the LC IF spectrum into two segments: frequencies in the range 16 MHz to 176 MHz that map from the 5 GHz band and frequencies in the range 176 MHz to 336 MHz that map from the 6 GHz band as shown in Table 33-1 (RF to LC IF mapping for channels in the 5 GHz and 6 GHz bands(11bb))(M148).

A channel number or channel center frequency index from the 5 GHz band shall not be greater than 64. A channel number or center frequency index from the 6 GHz band shall not be greater than 29.


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**Table 33-1—RF to LC IF mapping for channels in the 5 GHz and 6 GHz bands(11bb)**

| | | | | Channel width | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Channel number** | **RF frequency band** | **RF center frequency (MHz)** | **LC IF center frequency (MHz)** | **20 MHz** | **40 MHz PrimaryChannel LowerBehaviour** | **40 MHz PrimaryChannel UpperBehaviour** | **40 MHz** | **80 MHz / 80+80 MHz** | **160 MHz** |
| 34 | 5 GHz | 5170 | 16 | Channel number 36 16 MHz–36 MHz | Channel number 36 16 MHz–56 MHz | Channel number 40 16 MHz–56 MHz | NA | Channel center frequency index 42 16 MHz–96 MHz | Channel center frequency index 50 16 MHz–176 MHz |
| 36 | | 5180 | 26 | | | | | | |
| 38 | | 5190 | 36 | Channel number 40 36 MHz–56 MHz | | | | | |
| 40 | | 5200 | 46 | | | | | | |
| 42 | | 5210 | 56 | Channel number 44 56 MHz–76 MHz | Channel number 44 56 MHz–96 MHz | Channel number 48 56 MHz–96 MHz | | | |
| 44 | | 5220 | 66 | | | | | | |
| 46 | | 5230 | 76 | Channel number 48 76 MHz–96 MHz | | | | | |
| 48 | | 5240 | 86 | | | | | | |
| 50 | | 5250 | 96 | Channel number 52 96 MHz–116 MHz(#M148) | Channel number 52 96 MHz–136 MHz | Channel number 56 96 MHz–136 MHz | | Channel center frequency index 58 96 MHz–176 MHz | |
| 52 | | 5260 | 106 | | | | | | |
| 54 | | 5270 | 116 | Channel number 56 116 MHz–136 MHz | | | | | |
| 56 | | 5280 | 126 | | | | | | |
| 58 | | 5290 | 136 | Channel number 60 136 MHz–156 MHz | Channel number 60 136 MHz–176 MHz | Channel number 64 136 MHz–176 MHz | | | |
| 60 | | 5300 | 146 | | | | | | |
| 62 | | 5310 | 156 | Channel number 64 156 MHz–176 MHz | | | | | |
| 64 | | 5320 | 166 | | | | | | |

**Table 33-1—RF to LC IF mapping for channels in the 5 GHz and 6 GHz bands(11bb) *(continued)***

| | | | | Channel width | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Channel number** | **RF frequency band** | **RF center frequency (MHz)** | **LC IF center frequency (MHz)** | **20 MHz** | **40 MHz PrimaryChannel LowerBehaviour** | **40 MHz PrimaryChannel UpperBehaviour** | **40 MHz** | **80 MHz / 80+80 MHz** | **160 MHz** |
| | 6 GHz | | 176 | Channel number 1 176 MHz–196 MHz | NA | | Channel center frequency index 3 176 MHz–216 MHz | Channel center frequency index 7 176 MHz–256 MHz | Channel center frequency index 15 176 MHz–336 MHz |
| 1 | | 5955 | 186 | | | | | | |
| 3 | | 5965 | 196 | Channel number 5 196 MHz–216 MHz | | | | | |
| 5 | | 5975 | 206 | | | | | | |
| 7 | | 5985 | 216 | Channel number 9 216 MHz–236 MHz | | | Channel center frequency index 11 216 MHz–256 MHz | | |
| 9 | | 5995 | 226 | | | | | | |
| 11 | | 6005 | 236 | Channel number 13 236 MHz-256 MHz | | | | | |
| 13 | | 6015 | 246 | | | | | | |
| 15 | | 6025 | 256 | Channel number 17 256 MHz–276 MHz | | | Channel center frequency index 19 256 MHz–296 MHz | Channel center frequency index 23 256 MHz–336 MHz | |
| 17 | | 6035 | 266 | | | | | | |
| 19 | | 6045 | 276 | Channel number 21 276 MHz–296 MHz | | | | | |
| 21 | | 6055 | 286 | | | | | | |
| 23 | | 6065 | 296 | Channel number 25 296 MHz–316 MHz | | | Channel center frequency index 27 296 MHz–336 MHz | | |
| 25 | | 6075 | 306 | | | | | | |
| 27 | | 6085 | 316 | Channel number 29 316 MHz–336 MHz | | | | | |
| 29 | | 6095 | 326 | | | | | | |

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### 33.2.3.5 Multiple transmit chains and multiple receive chains

#### 33.2.3.5.1 General

The LC PHY may use multiple transmit chains and multiple receive chains to support spatial multiplexing and/or wavelength division multiplexing.

In an LC PHY that implements RF up/downconversion and has multiple transmit chains, the RF downconverters shall be synchronized to a common reference clock. In an LC PHY that implements RF up/downconversion and has multiple receive chains, the RF upconverters shall be synchronized to a common reference clock.

For an LC PHY with multiple optical TX antennas and HT support, the LC PHY TX shall use the procedures defined in 19.3 (HT PHY), where $N_{TX}$ transmit chains in the HT PHY shall be connected to $N_{TX}$ LC optical TX antennas.

For an LC PHY with multiple optical TX antennas and VHT support, the LC PHY TX shall use the procedures defined in 21.3 (VHT PHY), where $N_{TX}$ transmit chains in the VHT PHY shall be connected to $N_{TX}$ LC optical TX antennas.

For an LC PHY with multiple optical TX antennas and HE support, the LC PHY TX shall use the procedures defined in 27.3 (HE PHY), where $N_{TX}$ transmit chains in the HE PHY shall be connected to $N_{TX}$ LC optical TX antennas.

#### 33.2.3.5.2 Spatial multiplexing

Spatial multiplexing is supported when LC optical RX antennas and LC optical TX antennas are positioned such that light transmitted by an LC optical TX antenna incident on an LC optical RX antenna is at least partially isolated from the light transmitted by another LC optical TX antenna that is incident on another LC optical RX antenna. The isolation might be achieved by directing the light at the optical TX antenna or capturing light from a particular direction at the optical RX antenna. The isolation might also be achieved by spatially separating the LC optical TX antennas and/or LC optical RX antennas. This principle is illustrated in Figure 33-5 (Spatial multiplexing with an LC PHY(11bb)(M148)).

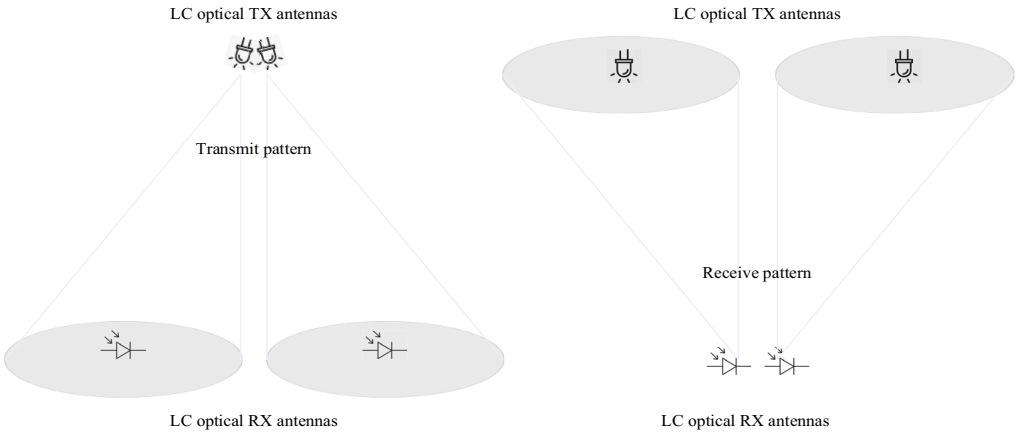


**Figure 33-5—Spatial multiplexing with an LC PHY(11bb)(M148)**

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#### 33.2.3.5.3 Wavelength-division multiplexing

Wavelength division multiplexing is supported when the wavelength of the light transmitted by one LC optical TX antenna is different from the wavelength of the light transmitted by another LC optical TX antenna and, correspondingly, one LC optical RX antenna is sensitive to the light of the first wavelength but not the second wavelength and another LC optical RX antenna is sensitive to the light of the second wavelength but not the first wavelength. This principle is illustrated in Figure 33-6 (Wavelength division multiplexing with an LC PHY(11bb)(M148)).

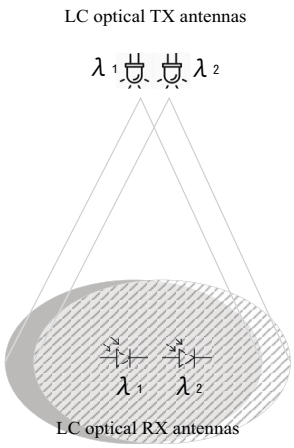


**Figure 33-6—Wavelength division multiplexing with an LC PHY(11bb)(M148)**

For example, with two transmit chains, one operating at 950 nm and the other at 850 nm, a shortpass dicroic beam splitter with a cut-off wavelength of 900 nm can be used in front of both receive chains. The wavelength of the first transmit chain is longer than the cut-off wavelength. It is reflected and detected by the first receive chain. The wavelength of the second transmit chain is shorter than the cut-off wavelength. It passes through and is detected by the second receive chain.

An LC STA with a single transmit chain is interoperable with an LC STA with multiple transmit and multiple receive chains operating in wavelength division multiplexing mode. The sum of transmitted and reflected signals from a dicroic beamsplitter is approximately the same, independent of the wavelength.

For example, a first LC STA with a single optical antenna supports a single stream. This stream can be detected by both receive chains of a second LC STA with two optical antennas by combining their signals. In the reverse link direction, both transmit chains of the second LC STA are used to transmit a single stream which can be detected by the single receive chain of the first LC STA.

Note that when using LEDs with different wavelengths, their optical spectra might be wider and cause residual crosstalk at a receive chain. The crosstalk might be minimized by using multiple-transmit multiple-receive antenna processing.

In the above description, if the LC optical TX antennas are in one LC STA and the LC optical RX antennas are in another LC STA the arrangement supports SU-MIMO. If the LC optical antennas (TX or RX) at one


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end are in the same LC STA but the LC optical antennas (RX or TX) at the other end are in different LC STAs then the arrangement supports MU-MIMO.

An LC optical RX antenna shall be sensitive to light in one of the following wavelength ranges:

— 800 nm to 900 nm
— 900 nm to 1000 nm
— 800 nm to 1000 nm

An LC PHY shall have at least one receive chain with an LC optical RX antenna sensitive to light in the 800 nm to 1000 nm range or at least two receive chains with one receive chain with an LC optical RX antenna sensitive to light in the 800 nm to 900 nm range and the other receive chain with an LC optical RX antenna sensitive to light in the 900 nm to 1000 nm range.

The maximum number of spatial streams supported by an LC PHY using wavelength division multiplexing is 2.

#### 33.2.3.6 Receive specification

The minimum receive sensitivity of an LC PHY shall be –15 $dBm_{opt}$ measured as the average incident optical power in the range 800 to 1000 nm at the LC optical RX antennas.

#### 33.2.3.7 CCA for LC

##### 33.2.3.7.1 CCA requirements

The CCA requirements for the LC PHY apply to the LC IF signal as measured at the antenna connector.

The CCA requirements for the HT PHY in 19.3.19.6 (CCA sensitivity) to detect a channel busy condition are applicable to the LC PHY with HT support.

The CCA requirements for the VHT PHY in 21.3.18.5 (CCA sensitivity) to detect a channel busy condition are applicable to the LC PHY with VHT support.

The CCA requirements for the HE PHY in 27.2.7 (Support for non-HT, HT, and VHT formats) and 27.3.22 (Receiver specification) to detect a channel busy condition are applicable to LC PHY with HE support.

##### 33.2.3.7.2 LC repetition

An LC STA transmission is directional, hence a non-AP LC STA might not be able to receive signals from peer non-AP LC STAs. LC repetition is an optional feature in an LC AP that effectively extends the area covered by a transmission from a non-AP LC STA to include the area covered by the LC AP. LC repetition together with other mechanisms, such as the RTS/CTS mechanism defined in 10.3 (DCF), might reduce collisions in an LC BSS.

An LC AP may transmit at the TX OFE a repeat of the signal it receives at the RX OFE. The delay between the received signal and the repeated signal shall be less than 1 μs.

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Figure 33-7 (An example of channel access with LC repetition(11bb)) illustrates an example of channel access with the LC repetition mechanism.

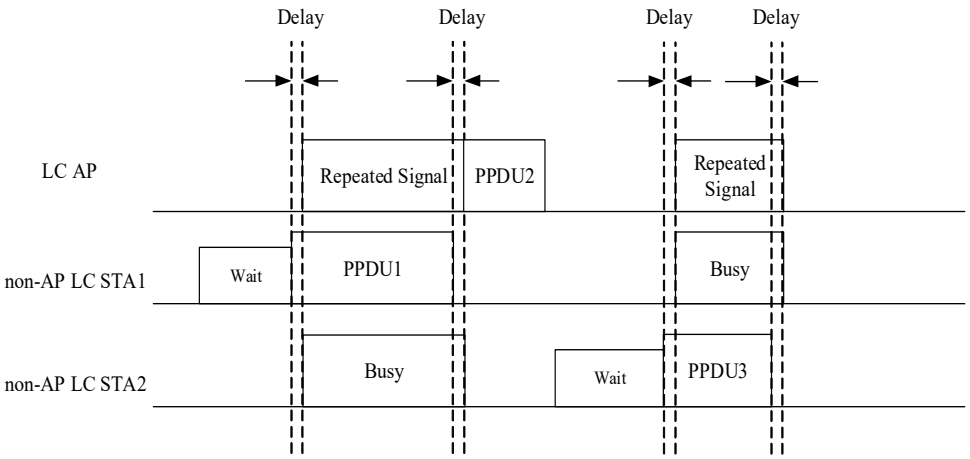


**Figure 33-7—An example of channel access with LC repetition(11bb)**

The LC AP receives PPDU1 from non-AP LC STA1 and repeats the signal to non-AP LC STAs in its coverage area. The non-AP LC STA2 then detects a channel busy condition on receiving the repeated signal. After retransmitting PPDU1, the LC AP sends PPDU2 to non-AP LC STA1 in response to PPDU1. Non-AP LC STA2 sends PPDU3 to the LC AP after it detects an idle channel condition. The LC AP repeats the signal and, as a result, non-AP LC STA1 finds the channel busy.

#### 33.2.3.8 Regulatory requirements

Wireless LANs (WLANs) implemented in accordance with this standard are subject to equipment certification and operating requirements established by regional and national regulatory administrations. The PHY specification establishes minimum technical requirements for interoperability, based upon established regulations at the time this standard was issued. These regulations are subject to revision or may be superseded. Requirements that are subject to local geographic regulations are annotated within the PHY specification. Regulatory requirements that do not affect interoperability are not addressed in this standard.

Implementers are referred to the regulatory sources in Annex D and to IEC 60825-1 (or its relevant latest version) for further information.


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# 34. Enhanced broadcast services MAC specification(#7051)(11bc)

## 34.1 Overview

### 34.1.1 Introduction

This clause describes EBCS procedures that are used for EBCS STAs. EBCS procedures are supported both where there is an association between the transmitter(s) and the receiver(s) in an infrastructure BSS and in cases where there is no association between transmitter(s) and receiver(s).

The EBCS procedures include the EBCS DL procedure and the EBCS UL procedure. With the EBCS DL procedure EBCS Data frames are broadcast by an EBCS AP to one or more EBCS receivers (see 34.3 (EBCS DL procedures)). With the EBCS UL procedure EBCS Data frames are broadcast by an EBCS non-AP STA to one or more EBCS relaying STAs, for subsequent delivery to a specified destination (see 34.4 (EBCS UL procedure)). The EBCS procedures are not supported for MBSS or GLK.

NOTE—EBCS DL and EBCS UL do not operate with DMG, CDMG, and EDMG.

## 34.2 EBCS addressing

EBCS Data frames shall use an EBCS content MAC address in the Address 1 field in the MAC header. EBCS UL frames shall use an EBCS content MAC address in the Address 3 field in the MAC header. EBCS Info frames shall use an EBCS info MAC address in the Address 3 field in the MAC header. Both the EBCS content MAC address and EBCS info MAC address are multicast addresses with the first three octets set to 01-0F-AC, and the remaining octets generated depending on the type of stream and the content ID.

The EBCS info MAC address used for EBCS Info frames shall be set to 01-0F-AC-*xx*-*yy*-00, where octets *xx*-*yy* are set to the EBCS AP group ID or 00-00 when the EBCS AP does not belong to any EBCS AP group.

The EBCS content MAC address for EBCS UL or EBCS Data frames shall be set to 01-0F-AC-*xx*-*yy*-*zz*.

For EBCS Data frames, the assigned content ID and the configured EBCS AP group ID are encoded into the Address fields in the MAC header by the EBCS traffic stream mapper as follows:(#7110)

— octet *zz* is set by the EBCS traffic stream mapper to the content ID
— octets *xx*-*yy* are set by the EBCS traffic stream mapper to the EBCS AP group ID or 00-00 when the EBCS AP does not belong to an EBCS AP group.

NOTE 1—The EBCS DL traffic stream might originate from another STA in the ESS or from a device outside the ESS, through a portal.(#7110)

For EBCS UL frames,

— octets *xx*, *yy* and *zz* are populated by the EBCS non-AP STA to a set of provisioned values that corresponds to the UL traffic stream.

NOTE 2—Although the octets *xx* and *yy* for EBCS DL traffic are expected to be set to a combination of values that are unique to the coverage area where the content is being broadcast, the uniqueness of the octets *xx* and *yy* is not guaranteed. It is recommended that the octets *xx*, *yy*, and *zz* for EBCS UL traffic be provisioned in EBCS non-AP STAs to values that are unique for each UL traffic stream. EBCS UL and EBCS Data frames can be differentiated because the EBCS UL frame is a management frame while the EBCS Data frame is a Data frame.

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## 34.3 EBCS DL procedures

### 34.3.1 General

The EBCS DL procedure allows an EBCS AP to distribute multicast content to both associated and unassociated EBCS receivers with data origin authenticity.

The frame sequence of the EBCS DL procedure is shown in Figure 34-1 (EBCS DL frame sequence(11bc)).

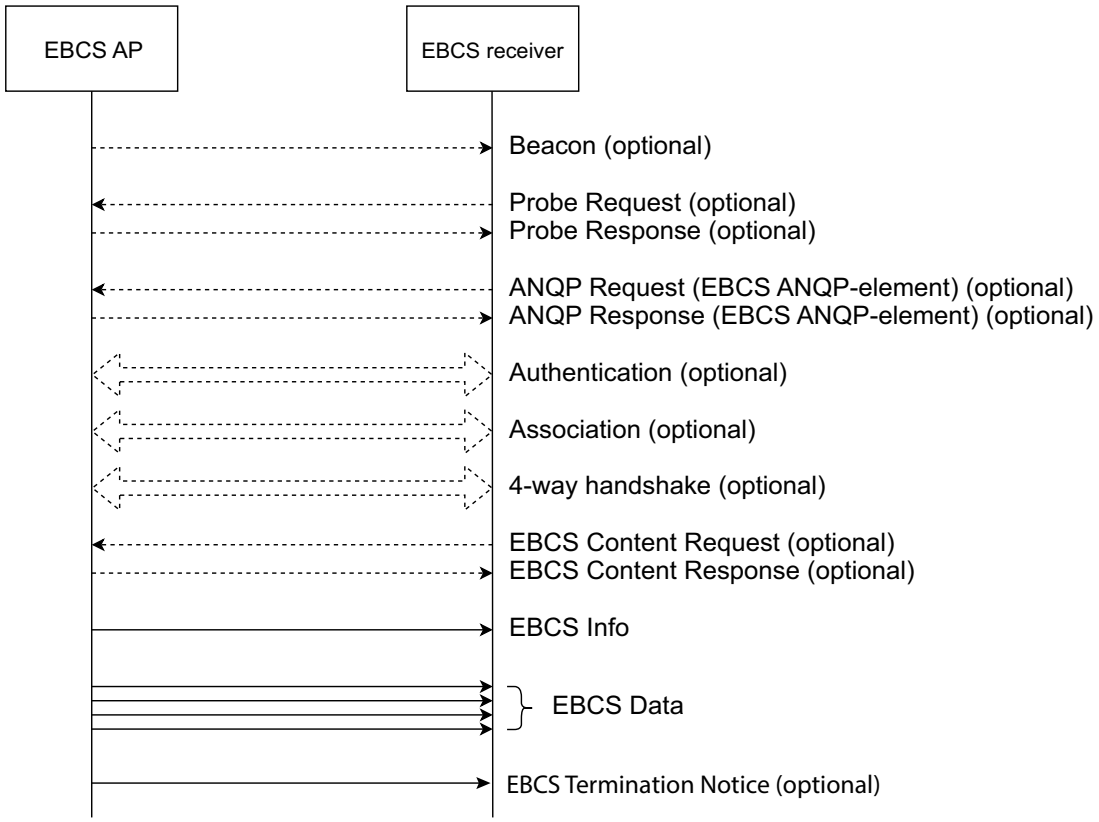


**Figure 34-1—EBCS DL frame sequence(11bc)**

NOTE—An EBCS AP might transmit EBCS Info frames and EBCS Data frames that contain the same Frame Body field multiple times consecutively to increase redundancy.

Beacon, S1G Beacon, Probe Request/Response/PV1 Probe Response, and ANQP Request/Response frames are optional. Authentication, Association Request/Response, and EBCS Content Request Response frames and the 4-way handshake depend on the requirements and status of the desired EBCS traffic streams.

The usage of these frames is described in the following subclauses:

- Beacon, S1G Beacon, Probe Request/Response/PV1 Probe Response, FILS Discovery: 34.3.2 (EBCS DL procedure at an EBCS AP) and 34.3.3 (EBCS DL procedure at an EBCS receiver)
- ANQP Request/Response: 11.22.3.3.17 (Enhanced broadcast services procedures(11bc)) and 34.3.8 (EBCS negotiation for unassociated STAs)
- EBCS Content Request/Response: 34.3.7 (EBCS negotiation for associated STAs)
- EBCS Termination Notice: 34.3.9 (EBCS termination notice and extension negotiation)


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### 34.3.2 EBCS DL procedure at an EBCS AP

EBCS DL procedure is enabled in an EBCS AP if the length of the dot11EBCSTrafficStreamTable is greater than 0. The EBCS traffic streams to be transmitted are specified in dot11EBCSTrafficStreamTable. The EBCS traffic streams are handled differently from other traffic. An EBCS content ID and EBCS content MAC address shall be assigned by the EBCS traffic stream mapper to identify each different traffic stream of content. Each content ID shall be unique in the EBCS AP group if the EBCS AP belongs to an EBCS AP group, otherwise each content ID shall be unique in the EBCS certificate group. If an EBCS AP does not belong to either an EBCS certificate group or an EBCS AP group, each content ID shall be unique in the EBCS AP. The content ID shall be nonzero.

NOTE 1—The content ID is contained in the EBCS content MAC address. To avoid conflict between the EBCS content MAC address and the EBCS info MAC address, the content ID is not set to 0.

An EBCS AP that has enabled EBCS DL may use an AP certificate. An EBCS AP using an AP certificate shall belong to an EBCS certificate group, otherwise it shall not belong to an EBCS certificate group. An EBCS AP that has enabled EBCS DL may belong to an EBCS AP group. An EBCS AP group is a subgroup in an EBCS certificate group. Each EBCS AP group is identified by a 2 octet EBCS AP group ID in the range of 00-01 to 7F-FF indicated in dot11EBCSAPGroupID.

NOTE 2—The EBCS AP group ID that is encoded in the EBCS content MAC address (Address 1 field in MAC header) helps EBCS receivers to filter undesired frames. If the EBCS AP group ID is unique, then the EBCS receiver can omit the corresponding Address 1 filter and hence avoid performing unnecessary authentication steps.

When an EBCS AP is an HE AP or S1G AP:

— The BSS color of EBCS Info frames shall be 0.

— The BSS color of EBCS Data frames shall be 0 if association is not required to consume EBCS traffic streams, otherwise the BSS color of EBCS Data frames shall be the same as that indicated in the HE Operation element in the most recent Beacon frame.

An EBCS AP, which is an S1G AP, may advertise its EBCS capabilities in the EBCS Support field in the Extended Capabilities element in S1G Beacon frames and PV1 Probe Response frames. An EBCS AP, which is an S1G AP, shall advertise its EBCS capabilities in the EBCS Support field in the Extended Capabilities element in Probe Response frames.

An EBCS AP, which is not an S1G AP, shall advertise its EBCS capabilities in the EBCS Support field in the Extended Capabilities element in Beacon frames and Probe Response frames. An EBCS AP that has EBCS DL enabled shall transmit EBCS Info frames periodically. The interval between two consecutive EBCS Info frames is specified by dot11EBCSInfoInterval. An EBCS AP shall advertise the timing of the next EBCS Info frame transmission in the EBCS Info Frame TX Countdown field in the EBCS Parameters element and shall not signal an upcoming EBCS Info frame via the TIM element (#8039)or the EBCS TIM element. An EBCS AP shall advertise the certificate group in Beacon frames using the Compressed Certificate Group ID field in the EBCS parameters element if the EBCS AP belongs to an EBCS certificate group. An EBCS AP shall advertise the EBCS AP group by the EBCS Group ID field in the EBCS Parameters element in Beacon frames if the EBCS AP belongs to an EBCS AP group. The EBCS Info frame shall be transmitted among the set of group addressed frames transmitted immediately after the Beacon frame identified by the EBCS Info Frame TX Countdown field set equal to 1 in the EBCS Parameters element. Details of EBCS Info frame generation are described in 34.3.4 (EBCS Info frame generation and usage).

(#8039)NOTE 3—An EBCS AP might provide the timing of the next EBCS Info frame transmission for a reported AP by including a TBTT Information field (corresponding to the reported AP) carrying the EBCS Info Frame TX Countdown field within a Reduced Neighbor Report element.

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In the MAC, MSDUs with a non-null EBCS content ID in the MA-UNITDATA.request shall bypass IEEE 802.1X filtering. If the destination address in the MA-UNITDATA.request is an EBCS content MAC address, the MAC shall process the request as an EBCS content request, otherwise the MAC shall process the request as a non-EBCS request. For an MA-UNITDATA.request for EBCS content, the MAC shall use one of the following three frame authentication mechanisms according to the content ID that is encoded in the EBCS content MAC address (34.2 (EBCS addressing)).

— PKFA (12.15.2 (EBCS public key frame authentication (PKFA)))
— HCFA (12.15.3 (EBCS hash chain frame authentication (HCFA)))
— HLSA (12.15.4 (No frame authentication with mandatory higher layer source authentication (HLSA)))

EBCS traffic streams are carried by EBCS Data frames. The EBCS AP shall set the RA of the EBCS Data frame to the EBCS content MAC address, the TA to its BSSID, and the SA to the group address assigned to the EBCS traffic stream by the EBCS DL content server. If the EBCS Data frame contains an IPv4 multicast packet or an IPv6 multicast packet, the SA shall be mapped according to IETF RFC 1112 or IETF RFC 2464, respectively.

If dot11EBCSTrafficStreamPHYType is not 255, an EBCS AP shall generate a PHY-TXSTART.request primitive with the transmission rate information specified by the dot11EBCSTrafficStreamPHYType and dot11EBCSTrafficStreamTxRate for each MPDU according to the EBCS content ID. If dot11EBCSTrafficStreamPHYType is 255, the AP shall select a transmission rate following the rules specified in 10.6.5.4 (Rate selection for other group addressed Data and Management frames).

NOTE 4—Rate selection for each EBCS traffic stream provides flexibility of operation. For example, one stream that provides a video streaming service can use HE for high throughput. Another stream that provides a directory of the venue can use HT to cover a large area.

When dot11EBCSTrafficStreamBufferableActivated for an EBCS traffic stream is true, an EBCS AP shall buffer the EBCS Data frames for that EBCS traffic stream and shall signal buffered EBCS Data frames via the EBCS TIM field or the EBCS TIM element (see 9.4.2.314 (EBCS TIM element(11bc))) instead of the TIM element. The EBCS AP shall transmit the buffered EBCS Data frames after transmitting the EBCS Info frame or the Beacon frame that contains the EBCS TIM field or the EBCS TIM element indicating the EBCS traffic stream. The EBCS AP shall set the More Data subfield in the Frame Control field in the EBCS Data frame to 1 if more EBCS Data frames of the same EBCS traffic stream are buffered at the AP, otherwise the More Data subfield shall be set to 0.

When dot11EBCSTrafficStreamBufferableActivated for an EBCS traffic stream is false, an EBCS AP shall not buffer the EBCS Data frames and shall transmit the EBCS Data frames that contain the EBCS traffic stream as soon as possible and shall not signal via the EBCS TIM element or the TIM element.

An EBCS AP shall transmit the EBCS TIM element in Beacon frames or S1G Beacon frames if dot11EBCSTIMInBeaconActivated is true, in addition to EBCS Info frames.

NOTE 5—The TIM element has only 1 bit for signaling buffered group addressed frames and so cannot differentiate between different streams of traffic. If an EBCS AP were to use the TIM element, an associated non-AP STA that does not subscribe to any EBCS traffic stream would stay awake for the EBCS traffic streams. This would cause unnecessary power consumption at the STA. Similarly, using a TIM element would cause an unassociated non-AP STA that subscribes to an EBCS traffic stream to stay awake for any non-EBCS group addressed traffic.

### 34.3.3 EBCS DL procedure at an EBCS receiver

An EBCS receiver discovers an EBCS capable AP by receiving any of the following:

— a Beacon frame, an S1G Beacon frame, a Probe Response frame or a PV1 Probe Response frame with the EBCS Support field in the Extended Capability element equal to 1


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- an EBCS Info frame
- an ANQP Response frame that includes the EBCS ANQP-element
- a FILS Discovery frame that includes an EBCS Parameters element

In case of PKFA or HCFA, an EBCS receiver shall use the content of received EBCS Info frames to validate the source of an EBCS traffic stream as describe in 12.15.2 (EBCS public key frame authentication (PKFA)) or 12.15.3 (EBCS hash chain frame authentication (HCFA)). An EBCS receiver is able to know when the next EBCS Info frame is transmitted by inspecting the EBCS Info Frame TX Countdown field in the EBCS Parameters element in Beacon frames, S1G Beacon frames, PV1 Probe Response frames, and Probe Response frames, FILS Discovery frames or the Enhanced Broadcast Services ANQP-element in ANQP Response frames. An EBCS receiver may select the EBCS traffic streams to receive and consume. Details of the usage of the EBCS Info frame is described in 34.3.4 (EBCS Info frame generation and usage). An EBCS receiver may need to request or register for one or more EBCS traffic streams by transmitting to an EBCS AP an EBCS Content Request frame or a frame containing an EBCS Content Request ANQP-element (see 34.3.7 (EBCS negotiation for associated STAs) and 34.3.8 (EBCS negotiation for unassociated STAs)).

NOTE 1—An EBCS receiver might be able to receive EBCS content without transmitting any frames.

The SME of an EBCS receiver shall maintain the dot11EBCSTrafficStreamEntry entries in the dot11EBCSTrafficStreamTable table that corresponds to the Content Information subfields in the Content Information List field in the EBCS Info frame. The SME selects one or more EBCS traffic streams to receive, then sets its dot11EBCSTrafficStreamActivated accordingly and configures the EBCS filter in its MAC to pass through the EBCS Data frames that have the EBCS content MAC address corresponding to the selected EBCS traffic streams as the DA and to filter other EBCS data frames. If the HLP payload destination address is an IPv4 address or an IPv6 address, the SA is assumed to be mapped according to IETF RFC 1112 and IETF RFC 2464, respectively.

An EBCS receiver shall authenticate all EBCS Info frames and EBCS Data frames by the authentication mechanism specified in the EBCS Info Authentication Algorithm subfield in the EBCS Info Control field for the EBCS Info frame and the Content Authentication Algorithm subfield in the Content Information field for the EBCS Data frames, in the EBCS Info frame. Details of frame authentication procedures are described in 12.15 (Frame authentication for EBCS(11bc)).

An MSDU contained in an authenticated EBCS Data frame shall be forwarded to a higher layer via the EBCS filter. The EBCS filter shall be configured by the SME to filter out the undesired MSDUs if they do not have the corresponding EBCS content MAC address and the corresponding EBCS content ID. An EBCS traffic stream shall pass through the IEEE 802.1X Controlled Port even if the IEEE 802.1X Controlled Port is blocked (e.g., because the STA is not associated), and generate MA-UNITDATA.indication with the SA of the EBCS Data frame as the destination address and the TA of the EBCS Data frame as the source address.

An EBCS receiver may receive and consume an EBCS traffic stream that is transmitted by multiple EBCS APs. An EBCS receiver shall identify an EBCS traffic stream by its content ID and the BSSID of the EBCS AP, and optionally by its AP certificate and its AP group ID.

NOTE 2—The EBCS filter does not provide duplicate detection for EBCS traffic streams transmitted from multiple APs. Duplicate detection can be provided in a higher layer.

### 34.3.4 EBCS Info frame generation and usage

An EBCS AP that is not in a multiple BSSID set shall transmit an EBCS Info frame every dot11EBCSInfoInterval beacon periods with the Address 1 field set to the broadcast address, the Address 2 field set to the transmitting AP's MAC address, and the Address 3 field set to the EBCS info MAC address. In a multiple BSSID set, only the AP corresponding to the transmitted BSSID may have EBCS DL enabled

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and, if enabled, shall transmit an EBCS Info frame, with the Address 1 field set to the broadcast address, the Address 2 field set to the transmitted BSSID, and the Address 3 field set to the EBCS info MAC address every dot11EBCSInfoInterval beacon periods. The other APs in the multiple BSSID set shall not transmit EBCS Info frames. In a cohosted BSSID set, at most one AP may have EBCS DL enabled and, if enabled, shall transmit an EBCS Info frame every dot11EBCSInfoInterval beacon periods. The other APs in the cohosted BSSID set shall not have EBCS DL enabled and shall not transmit an EBCS Info frame.

The EBCS Info Sequence Number subfield in the first EBCS Info frame shall be set to a random number and shall be incremented by 1 for each subsequent EBCS Info frame transmission. If the field value overflows, it shall be set to 0.

If any of the EBCS traffic streams made available by a single AP do not use HLSA as the content authentication algorithm, then the EBCS Info Authentication Algorithm field in the EBCS Info frame that it transmits shall not indicate None (see Table 9-507 (EBCS Info Authentication Algorithm field(11bc))); otherwise it may indicate None.

If the EBCS Info Authentication Algorithm field value is not None nor Prenegotiated, the EBCS Info frame shall contain the certificate of the AP that is signed by the certificate of the CA or an intermediate certificate. If the certificate is signed by an intermediate certificate, the certificate of the AP shall contain the full certificate chain to the certificate of the CA.

If dot11EBCSInfoPHYType is not 255, an EBCS AP shall generate a PHY-TXSTART.request primitive with the transmission rate information specified by the dot11EBCSInfoPHYType and dot11EBCSInfoTxRate for EBCS Info frames. If dot11EBCSInfoPHYType is 255, the AP shall select a transmission rate following the rules specified in 10.6.5.4 (Rate selection for other group addressed Data and Management frames).

On reception of an EBCS Info frame, an EBCS receiver shall check the integrity of the EBCS Info frame as described in 12.15.2 (EBCS public key frame authentication (PKFA)) if the EBCS Info Authentication Algorithm subfield in the EBCS Info frame does not indicate None.

If the integrity of the EBCS Info frame is verified, the EBCS receiver shall process each Content Information field according to the value of the Content Authentication Algorithm subfield:

The following processes are common in all authentication algorithms:

— The EBCS receiver shall cache the values of the Content Information List field.
— The EBCS receiver shall notify the SME of the cached information (see 6.3.129.3).

In the PKFA case,

— If the Vendor Specific Data subfield is present in the Content Information field, the EBCS receiver shall forward the MSDU in the Vendor Specific Data subfield to a higher layer and shall cache the certificate in the EBCS Info frame to authenticate PFKA MPDUs.

An EBCS STA may filter traffic based on the value carried in the Address 3 field of a received frame to determine that the frame is an EBCS Info frame.

In the HCFA case,

— The EBCS receiver shall cache the HCFA base key in the Content Information field.
— If instant authenticators are present in the content information, the EBCS receiver shall cache them.
— If HCFA base keys from a previous period are present in the Content Information field, the EBCS receiver shall authenticate the EBCS data frames of the previous HCFA period.


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### 34.3.5 EBCS Info frame fragmentation

An EBCS Info frame may be fragmented into multiple MMPDUs. The length of each fragment shall be an even number of octets, except for the last fragment, which may have an odd length. The length of a fragment shall not be larger than dot11FragmentationThreshold.

An EBCS info frame is fragmented as follows:

1) Construct an unfragmented EBCS Info frame.
2) Select a fragment length such that the Fragment Hash Values field, the Certificate field, and the Signature field will fit in the first fragment.
3) Determine the number of fragments, *n,* and set the Number of Fragments subfield to *n*–1.
4) Insert space for *n*–1 Fragment Hash Values fields into the EBCS Info frame.
5) Divide the EBCS Info frame after the Fragment Hash Values field into fragments.
6) Set the Fragment Index subfield from 0 to *n*–1 for successive fragments.
7) Calculate the hash value of each fragment (see 12.15.2.1 (Signature of an EBCS Info frame)) except the first one and set the corresponding Fragment Hash Values field(s).
8) Calculate the signature value (see 12.15.2.1 (Signature of an EBCS Info frame)) and set the Signature field in the first fragment.
9) Transmit the fragments in order of the value of Fragment Index field. EBCS data frames shall not be transmitted before all of the fragments are transmitted.

The EBCS Info frame fragmentation is shown in Figure 34-2 (EBCS Info frame fragmentation(11bc)).

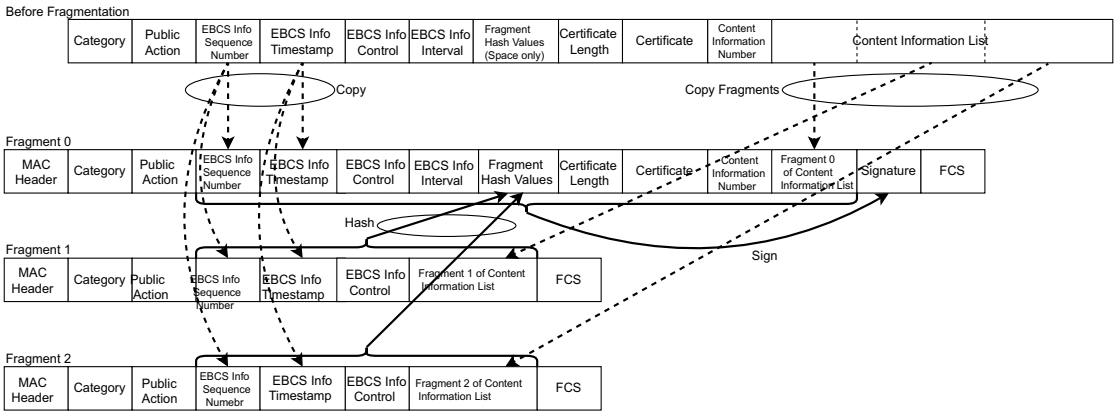


**Figure 34-2—EBCS Info frame fragmentation(11bc)**

### 34.3.6 EBCS Info frame defragmentation

The EBCS Info frame defragmentation procedure is described in 12.15.2.2 (Authentication of an EBCS Info frame).

### 34.3.7 EBCS negotiation for associated STAs

To request one or more EBCS traffic streams provided by an EBCS AP, with which an EBCS non-AP STA is associated, the STA shall transmit an EBCS Content Request frame to the EBCS AP. To request one or more EBCS traffic streams that an EBCS AP has indicated require association, an unassociated EBCS non-AP STA shall associate with the EBCS AP and subsequently transmit an EBCS Content Request frame. A request for one or more EBCS traffic streams that does not require association may also be included in the

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same EBCS Content Request frame. When requesting an EBCS traffic stream using an EBCS Content Request frame, an EBCS non-AP STA may request an EBCS traffic stream with a certain time to termination as indicated in the Requested Time To Termination field included in the EBCS Content Request frame. In addition, the STA may indicate the MAC address of the AP it is currently receiving the service from, using the Broadcaster MAC Address subfield. The non-AP STA may include in the Broadcaster MAC Address subfield in the EBCS Content Request frame the MAC address of the AP currently serving the EBCS traffic stream, which may differ from the AP receiving the request. This information may be used to distribute the EBCS load transmitted by different EBCS APs in a certain area.

An EBCS STA that receives an EBCS Content Request Info subfield shall determine the presence of fields(s) based on the corresponding presence bits in the EBCS Content Request Info Control subfield.

NOTE 1—An EBCS receiving STA determines the end of the EBCS Content Request Info subfield based on the EBCS Content Request Info Length field and skips fields that it cannot decode.

After receiving an EBCS Content Request frame from an associated EBCS non-AP STA, an EBCS AP shall respond with an EBCS Content Response frame. The status of the request for the EBCS traffic stream identified by a content ID is indicated by the EBCS Content Request Status subfield in the EBCS Content Response Info subfield containing the same content ID. If the EBCS AP indicates in the EBCS Content Response frame that the request for an EBCS traffic stream is successful, it may include a Time To Termination field to indicate the time to termination for the EBCS traffic stream. It may also include EBCS SP duration and the EBCS SP interval for the EBCS traffic stream in the EBCS Content Response frame.

An EBCS STA that receives an EBCS Content Response Info field shall determine the presence of fields(s) based on the corresponding presence bits in the EBCS Content Request Info Control subfield.

NOTE 2—An EBCS receiving STA determines the end of the EBCS Content Request Info subfield based on the EBCS Content Request Info Length field and skips fields that it cannot decode.

An EBCS non-AP STA that receives an EBCS Content Response frame may negotiate for the extension of an EBCS traffic stream if the EBCS traffic stream indicated in one of the EBCS Content Response Info subfields terminates earlier than desired. The EBCS STA may negotiate the extension of the EBCS traffic stream by transmitting another EBCS Content Request frame to its associated AP by including a desired value in the Requested Time To Termination subfield in the EBCS Content Request Info subfield whose Content ID subfield corresponds to the EBCS traffic stream.

An EBCS non-AP STA that received an EBCS Termination Notice frame may negotiate for the extension of an EBCS traffic stream using an EBCS Content Request frame if the EBCS traffic stream indicated in one of the EBCS Termination Info subfields terminates earlier than desired and the Negotiation Method indicated in the same EBCS Termination Info subfield is set to 1 or 2. The EBCS STA may negotiate the extension of the EBCS traffic stream by transmitting an EBCS Content Request frame to its associated AP by including a desired value in the Requested Time To Termination subfield in the EBCS Content Request Info subfield whose Content ID subfield corresponds to the EBCS traffic stream.

NOTE 3—Which values of a received Time To Termination subfield are considered desirable is determined by the receiving EBCS non-AP STA and is beyond the scope of this standard.

NOTE 4—The EBCS transmitter of an EBCS traffic stream has the authority to determine the time to termination of the EBCS traffic stream.

### 34.3.8 EBCS negotiation for unassociated STAs

An unassociated EBCS STA may transmit an EBCS Content Request ANQP-element to an EBCS AP to register for one or more EBCS traffic streams when that AP has indicated that association is not required for those streams. When registering for an EBCS traffic stream using an EBCS Content Request ANQP-


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element, an EBCS STA may request a specific time to termination using the Requested Time To Termination subfield and may indicate the MAC address of the AP it is currently receiving the service from using the Broadcaster MAC Address subfield. The Broadcaster MAC Address subfield allows the non-AP STA to provide the MAC address of the AP currently serving the EBCS traffic stream, which might not be the same as the one receiving the request. This information might be used to distribute the EBCS load transmitted by different EBCS APs in a certain area.

After receiving an EBCS Content Request ANQP-element from an unassociated EBCS STA, an EBCS AP shall respond with EBCS Content Response ANQP-element indicating the acceptance or rejection of the request to start transmitting each EBCS traffic stream indicated in the EBCS Content Request ANQP-element. If the EBCS AP accepts a request for an EBCS traffic stream, it may include a Time To Termination subfield in the EBCS ANQP-element to indicate the time to termination for the EBCS traffic stream.

An unassociated EBCS STA that received an EBCS Termination Notice frame may negotiate for the extension of an EBCS traffic stream using an EBCS Content Request ANQP-element if the EBCS traffic stream indicated in one of the EBCS Termination Info subfields terminates earlier than desired and the Negotiation Method indicated in the same EBCS Termination Info subfield is set to 2. The EBCS STA may negotiate the extension of the EBCS traffic stream by transmitting an EBCS Content Request ANQP-element to the EBCS AP from which the EBCS Termination Notice frame is received by including a desired value in the Requested Time To Termination subfield in the EBCS Content Request Info subfield whose Content ID subfield corresponds to the EBCS traffic stream.

NOTE—The EBCS AP has the authority to determine the time to termination of the EBCS traffic stream. ANQP-elements received from unassociated STAs are not protected and hence the EBCS AP might exercise caution in accepting certain requested durations. An EBCS AP evaluates certain criteria before responding to the EBCS service request from an unassociated STA from which it receives an EBCS Content Request ANQP-element. Such criteria might include, but are not limited to, limiting the time duration and/or frequency of EBCS traffic stream requests. The evaluation of the criteria might be based on local policies installed at the EBCS AP, which is out of scope of this standard.

An EBCS STA that has registered for an EBCS traffic stream using an EBCS Content Request ANQP-element may deregister for the EBCS traffic stream when it no longer consumes the traffic stream. In order to deregister, the EBCS STA shall send a frame containing an EBCS Content Request ANQP-element to the EBCS AP that is transmitting the EBCS traffic stream. The Broadcast Action bit in the EBSCS Content Request Info Control subfield in the EBCS Content Request Info subfield containing the content ID of the EBCS traffic stream for which the EBCS STA attempts to deregister shall be set to 0.

An EBCS STA may combine registering for one or more EBCS traffic streams and deregistering for one or more EBCS traffic streams by sending one frame that contains one EBCS Content Request ANQP-element, in which one or more EBCS Content Request Info subfields contain a Broadcast Action bit set to 1 and one or more EBCS Content Request Info subfields containing a Broadcast Action bit set to 0.

After receiving an EBCS Content Request ANQP-element from an unassociated EBCS STA that registered for one or more EBCS traffic streams, with the Broadcast Action bit set to 0 in an EBCS Content Request Info subfield for one or more EBCS traffic streams, an EBCS AP shall respond with an EBCS Content Response ANQP-element with the EBCS Content Request Status bit set to 1 in the EBCS Content Response Info subfield containing the content ID for the traffic stream for which the EBCS STA is requesting deregistration.

The EBCS AP, after receiving an EBCS Content Request ANQP-element from an unassociated EBCS STA that registered for one or more EBCS traffic streams, with the Broadcast Action bit set to 0 in an EBCS Content Request Info subfield for one or more EBCS traffic streams, may terminate the transmission of the EBCS traffic streams. The EBCS AP shall follow the EBCS termination notice procedure (see 34.3.9 (EBCS

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termination notice and extension negotiation)) prior to termination the transmission of the EBCS traffic streams.

### 34.3.9 EBCS termination notice and extension negotiation

The EBCS termination notice procedure allows a STA that is a broadcaster of EBCS traffic streams to indicate that one or more of the EBCS traffic streams that it is broadcasting is to be terminated. In EBCS DL, a broadcaster of one or more EBCS traffic streams is an EBCS AP.

An EBCS STA shall start to transmit EBCS Termination Notice frames if one or more EBCS that it is transmitting will terminate within an interval that is equal to or shorter than dot11EBCSTerminationNoticeTime, if the STA is not periodically transmitting a schedule for the EBCS traffic stream that is to be terminated. If the EBCS STA starts to transmit EBCS Termination Notice frames, the STA shall transmit the EBCS Termination Notice frames with a period that is larger than dot11EBCSTerminationNoticeMinimumInterval and smaller than dot11EBCSTerminationNoticeMaximumInterval.

The EBCS STA transmitting an EBCS Termination Notice frame shall indicate in the Time To Termination subfield in an EBCS Termination Info subfield the number of TBTTs before the EBCS traffic stream identified by the content ID contained in the Content ID subfield in the same EBCS Termination Info subfield terminates.

The EBCS STA transmitting an EBCS Termination Notice frame shall indicate in the Negotiation Method subfield in an EBCS Termination Info subfield the negotiation method that a STA should use to negotiate for the extension of the EBCS traffic stream identified by the content ID contained in the Content ID subfield in the same EBCS Termination Info subfield. The EBCS STA transmitting an EBCS Termination Notice frame may indicate in the Negotiation Address subfield in an EBCS Termination Info subfield the address associated with the negotiation method indicated in the Negotiation Method subfield in the same EBCS Termination Info subfield that a STA should use to negotiate for the extension of the EBCS traffic stream identified by the content ID contained in the Content ID subfield in the same EBCS Termination Info subfield.

After transmitting an EBCS Termination Notice frame, an EBCS STA shall transmit an EBCS Termination Notice frame with an updated value in the Time To Termination subfield in an EBCS Termination Info subfield if the EBCS traffic stream identified by the content ID in the Content ID subfield in the same EBCS Termination Info subfield has been negotiated to have a new time to termination value. If the negotiated duration for the EBCS traffic stream is longer than the maximum time to termination value, the transmitting STA shall set the Time To Termination subfield to 65 535.

An EBCS STA that receives an EBCS Termination Notice frame shall negotiate for the extension of an EBCS traffic stream if the EBCS traffic stream indicated in one of the EBCS Termination Info subfields terminates earlier than desired. If the EBCS STA negotiates the extension of the EBCS traffic stream, it shall use the negotiation method indicated in the Negotiation Method subfield in the EBCS Termination Info subfield (see 34.3.7 (EBCS negotiation for associated STAs) and 34.3.8 (EBCS negotiation for unassociated STAs)).

An EBCS STA that receives an EBCS Termination Info subfield shall determine the presence of fields(s) based on the corresponding presence bits in the EBCS Termination Info Control subfield.

NOTE 1—An EBCS receiving STA determines the end of the EBCS Termination Info subfield based on the EBCS Termination Info Length field and skips fields that it cannot decode.

An EBCS STA shall not transmit an EBCS Content Request frame or a frame containing an EBCS Content Request ANQP-element requesting an EBCS traffic stream if the STA receives an EBCS Termination


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Notice frame with an acceptable time to termination value contained in the EBCS Termination Info subfield containing the content ID of the EBCS traffic stream.

NOTE 2—Whether a value in a received Time To Termination subfield is considered acceptable is determined by the receiving STA and is beyond the scope of this standard.

## 34.4 EBCS UL procedure

### 34.4.1 General

The EBCS UL procedure allows a non-AP STA to transmit an EBCS UL frame containing an HLP payload that is intended to be relayed by one or more EBCS relaying STAs to a destination specified in the frame. EBCS UL does not use Data frames and the EBCS DL Filtering block in Figure 5-1 (MAC data plane architecture (#7109)(#4149)(#1001)(11ay)(#3186)(#3185)(#4172)(#4192)(11bc)) does not apply.

NOTE—The relaying service is best effort with no guarantee that the HLP payload will be delivered to the specified destination.

### 34.4.2 EBCS UL procedure at an EBCS relaying STA

An EBCS relaying STA provides access to a relaying service (via its affiliated EBCS proxy) in which the HLP payload carried in an EBCS UL frame received from an EBCS non-AP STA is relayed to a destination specified in the frame (see 4.5.12.3 (EBCS relaying service) and 34.4.4 (EBCS UL procedure at an EBCS proxy)).

NOTE 1—An EBCS relaying STA can be an AP that has established its own infrastructure BSS or a STA that provides a relaying service without establishing an infrastructure BSS.

NOTE 2—An EBCS AP that relays an HLP payload to the specified destination via its EBCS proxy can be in an unassociated state with the non-AP STA that transmitted the EBCS UL frame carrying the HLP payload.

An EBCS relaying STA shall have dot11EBCSRelayingServiceImplemented equal to true. Otherwise, dot11EBCSRelayingServiceImplemented shall not be true. Among all APs in a multiple BSSID set, only the AP corresponding to the transmitted BSSID may be affiliated with an EBCS proxy. Among all APs in a cohosted BSSID set, only one AP may be affiliated with an EBCS proxy.

An EBCS relaying STA may filter traffic based on the EBCS content MAC address carried in the Address 3 field of a received frame to determine that the frame is an EBCS UL frame. An EBCS relaying STA may further filter traffic based on the value carried in the Address 1 field of a received EBCS UL frame.

NOTE 3—An EBCS relaying STA that is affiliated with an EBCS proxy can ignore an EBCS UL frame whose Address 3 field does not match the one or more EBCS content MAC addresses that can be based on the relationship between the EBCS proxy and one or more destinations. Furthermore, an EBCS relaying STA can be configured to ignore EBCS UL frames based on the value carried in the Address 1 field.

### 34.4.3 EBCS UL procedure at an EBCS non-AP STA

An EBCS non-AP STA may transmit an EBCS UL frame without receiving a Beacon frame, S1G Beacon frame, PV1 Probe Response frame, or a Probe Response frame with the EBCS Relaying Supported field of the Extended Capabilities element set to 1. The address fields are defined in 9.3.3.1 (Format of (PV0) Management frames) where the Address 1 field of the frame shall be set to a group address. The EBCS content MAC address is formatted as described in 34.2 (EBCS addressing).

NOTE—The group address value of the Address 1 field can be either set to a broadcast address or a multicast address to differentiate different types of EBCS UL traffic belonging to the same UL traffic stream. For example, an EBCS non-AP STA could transmit different EBCS UL frames, each carrying a different EBCS UL traffic and having the Address 1

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field set to a different group address value. The Address 3 field is set to the EBCS content MAC address, which is unique to the UL traffic stream (see 34.2 (EBCS addressing)).

An EBCS non-AP STA should include its certificate in an EBCS UL frame to allow the EBCS proxy to authenticate the EBCS non-AP STA (see 12.15.2.6 (Authentication of an EBCS UL frame)).

When an EBCS non-AP STA has time information, the Frame Tx Time field shall indicate the time when the EBCS UL frame is queued for transmission.

NOTE—How an EBCS non-AP STA, that transmits an EBCS UL frame while in an unassociated state, obtains time information is out of scope of this standard.

An EBCS non-AP STA should include the Frame Count field in an EBCS UL frame that it transmits to reduce the possibility of a successful replay attack. When the STA provides a frame count, the Frame Count field shall carry a value that is equal to 1 in the first EBCS UL frame that the STA transmits and shall be incremented for each subsequent transmission of an EBCS UL frame.

The Frame Signature field, if present in the EBCS UL frame, shall be computed as defined in 12.15.2.5 (Signature of the EBCS UL frame).

### 34.4.4 EBCS UL procedure at an EBCS proxy

An EBCS proxy evaluates various criteria such as the ones described in 12.15.2.6 (Authentication of an EBCS UL frame) to decide whether to relay the HLP payload to the specified destination. An EBCS proxy may limit the amount or frequency of payloads that are relayed to the specified destination. An EBCS proxy may embed additional information before relaying the HLP payload to the specified destination. The evaluation of criteria, the decision to limit the amount or frequency of relaying, and the decision to embed additional information can be based on local policies or based on a relationship established with the specified destination.

NOTE 1—The establishment of such a relationship is out of scope of this standard.

NOTE 2—An EBCS proxy can decide to not relay the HLP payload for any reason such as not having a relationship with the specified destination or the implemented criteria for relaying not being satisfied.

An EBCS proxy that decides to relay an HLP payload shall generate and transmit one or more IP packets carrying the HLP payload addressed to the specified destination.


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# Annex A

(informative)

# Bibliography

Bibliographical references are resources that provide additional or helpful material but do not need to be understood or used to implement this standard. Reference to these resources is made for informational use only. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) at the time of publication of this standard applies, (#4283)and as adapted per Structure of Management Information Version 2 (SMIv2) specified in IETF RFC 2578.

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# Annex B

(normative)

# Protocol Implementation Conformance Statement (PICS) proforma

***Editor's Note: Any <year> below will be replaced by the year of publication by the IEEE SA publication.***

## B.1 Introduction

The supplier of a protocol implementation that is claimed to comply with IEEE Std 802.11-<year>(#1147) shall complete the following protocol implementation conformance statement (PICS) proforma.

A completed PICS proforma is the PICS for the implementation in question. The PICS is a statement of which capabilities and options of the protocol have been implemented. This annex might not be compatible with operation in any Regulatory Domain or describe combinations of usable features in any Regulatory Domain. The PICS has a number of uses, including use:

a) By the protocol implementer, as a checklist to reduce the risk of failure to comply with the standard through oversight;

b) By the supplier and acquirer, or potential acquirer, of the implementation, as a detailed indication of the capabilities of the implementation, stated relative to the common basis for understanding provided by the standard PICS proforma;

c) By the user, or potential user, of the implementation, as a basis for initially checking the possibility of interworking with another implementation (note that, while interworking is not guaranteed, failure to interwork can often be predicted from incompatible PICS proformas);

d) By a protocol tester, as the basis for selecting appropriate tests against which to assess the claim for compliance of the implementation.

## B.2 Abbreviations and special symbols

### B.2.1 Symbols for Status column

M mandatory
O optional
O.<n> optional — Support of at least one of the group of options labeled by the same numeral <n> is required. The scope of the group of options is limited to a single table (i.e., subclause) within the PICS.
pred: predicate identification

### B.2.2 General abbreviations for Item and Support columns

N/A not applicable
AD address function
AVT audio video transport
CDMG-M China directional multi-gigabit (CDMG) medium access control (MAC) features
CDMG-P China directional multi-gigabit (CDMG) physical layer (PHY) features


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| | |
|---|---|
| CMMG-M | China Millimeter-wave multi-gigabit (CMMG) medium access control (MAC) features |
| CMMG-P | China Millimeter-wave multi-gigabit (CMMG) physical layer (PHY) features |
| CF | implementation under test (IUT) configuration |
| DMG-M | directional multi-gigabit (DMG) medium access control (MAC) features |
| DMG-P | directional multi-gigabit (DMG) physical layer (PHY) features |
| DS | direct sequence |
| DSE | dynamic station enablement |
| EDMG-M | enhanced directional multi-gigabit (EDMG) medium access control (MAC) features(M118) |
| EDMG-P | enhanced directional multi-gigabit (EDMG) physical layer (PHY) features(M118) |
| ERP | extended rate physical layer (PHY) |
| FILS | fast initial link setup |
| FR | frame reception |
| FS | frame exchange sequence |
| FT | frame transmission |
| HRDS | high rate direct sequence |
| HEM | high-efficiency (HE) medium access control (MAC) features(M118) |
| HEP | high-efficiency (HE) physical layer (PHY) features(M118) |
| HTM | (#2297)high throughput (HT) medium access control (MAC) features |
| HTP | (#2297)high throughput (HT) physical layer (PHY) features |
| HWM | hybrid wireless mesh protocol (HWMP) path selection protocol capability |
| IW | interworking with external networks |
| LC | Light communication(11bb) |
| MD | multidomain |
| MP | mesh protocol |
| NGV | Next Generation V2X(11bd) |
| OC | operating classes |
| OF | orthogonal frequency division multiplexing (OFDM) |
| PAD | preassociation discovery |
| PC | protocol capability |
| QB | quality-of-service (QoS) base functionality |
| QD | quality-of-service (QoS) enhanced distributed channel access (EDCA) |
| QMF | quality-of-service Management frame |
| QP | quality-of-service (QoS) hybrid coordination function (HCF) controlled channel access (HCCA) |
| RL | S1G Relay features |
| RM | radio management |
| SIGM | Sub 1 GHz (S1G) medium access control (MAC) features |
| SIGP | Sub 1 GHz (S1G) physical layer (PHY) features |
| SM | spectrum management |
| TDD-M | time division duplex (TDD) medium access control (MAC) features(M118) |
| TDLS | tunneled direct link(#1356) setup |
| TVHTM | television very high throughput medium access control (MAC) features |
| TVHTP | television very high throughput physical layer (PHY) features |
| TVWS | television white spaces |
| VHTM | Very high throughput MAC |
| VHTP | Very high throughput PHY |
| WNM | wireless network management |
| WURM | wake up radio (WUR) medium access control (MAC) features(M118) |
| WURP | wake up radio (WUR) physical layer (PHY) features(M118) |

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## B.3 Instructions for completing the PICS proforma

### B.3.1 General structure of the PICS proforma

The first parts of the PICS proforma, Implementation identification and Protocol summary, are to be completed as indicated with the information necessary to identify fully both the supplier and the implementation.

The main part of the PICS proforma is a fixed questionnaire, divided into subclauses, each containing a number of individual items. Answers to the questionnaire items are to be provided in the rightmost column, either by simply marking an answer to indicate a restricted choice (usually Yes or No) or by entering a value or a set or a range of values. (Note that there are some items where two or more choices from a set of possible answers may apply. All relevant choices are to be marked in these cases.)

Each item is identified by an item reference in the first column. The second column contains the question to be answered. The third column contains the reference or references to the material that specifies the item in the main body of this standard. The remaining columns record the status of each item, i.e., whether support is mandatory, optional, or conditional, and provide the space for the answers (see also B.3.4 (Conditional status)). Marking an item as supported is to be interpreted as a statement that all relevant requirements of the subclauses and normative annexes, cited in the References column for the item, are met by the implementation.

A supplier may also provide, or be required to provide, further information, categorized as either Additional Information or Exception Information. When present, each kind of further information is to be provided in a further subclause of items labeled A<*I*> or X<*I*>, respectively, for cross-referencing purposes, where <*I*> is any unambiguous identification for the item (e.g., simply a numeral). There are no other restrictions on its format or presentation.

A completed PICS proforma, including any Additional Information and Exception Information, is the PICS for the implementation in question.

NOTE—Where an implementation is capable of being configured in more than one way, a single PICS might be able to describe all such configurations. However, the supplier has the choice of providing more than one PICS, each covering some subset of the implementation's capabilities, if this makes for easier and clearer presentation of the information.

### B.3.2 Additional information

Items of Additional Information allow a supplier to provide further information intended to assist in the interpretation of the PICS. It is not intended or expected that a large quantity of information will be supplied, and a PICS can be considered complete without any such information. Examples of such Additional Information might be an outline of the ways in which an (single) implementation can be set up to operate in a variety of environments and configurations, or information about aspects of the implementation that are outside the scope of this standard but have a bearing upon the answers to some items.

References to items of Additional Information may be entered next to any answer in the questionnaire, and may be included in items of Exception Information.

### B.3.3 Exception information

It may happen occasionally that a supplier wishes to answer an item with mandatory status (after any conditions have been applied) in a way that conflicts with the indicated requirement. No preprinted answer is found in the Support column for this. Instead, the supplier shall write the missing answer into the Support


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column, together with an X<*I*> reference to an item of Exception Information, and shall provide the appropriate rationale in the Exception Information item itself.

An implementation for which an Exception Information item is required in this way does not comply with this standard.

NOTE—A possible reason for the situation described above is that a defect in this standard has been reported, a correction for which is expected to change the requirement not met by the implementation.

### B.3.4 Conditional status

The PICS proforma contains a number of conditional items. These are items for which both the applicability of the item itself, and its status if it does apply, mandatory or optional, are dependent upon whether certain other items are supported.

Where a group of items is subject to the same condition for applicability, a separate preliminary question about the condition appears at the head of the group, with an instruction to skip to a later point in the questionnaire if the N/A answer is selected. Otherwise, individual conditional items are indicated by a conditional symbol in the Status column.

A conditional symbol is of the form "<pred>:<S>" or "O" (or "O.<n>"), where "<pred>" is a predicate as described below, and "<S>" is one of the status symbols "M" or "O" (or "O.<n>").

If the value of a predicate is true, the conditional symbol is applicable, and yields the status given by S. If any applicable conditional symbol yields mandatory status, the conditional item has mandatory status. Otherwise, if any applicable conditional symbol [including one of the form "O" (or "O.<n>")] yields optional status, the conditional item has optional status. In either case, the support column is to be completed in the usual way. If no conditional symbol is applicable, the conditional item is not relevant and the N/A answer is to be marked.

A predicate is one of the following:

a) An item-reference for an item in the PICS proforma: the value of the predicate is true if the item is marked as supported and is false otherwise.

b) An expression constructed by combining item-references using the boolean operators (in decreasing order of precedence) "NOT", "AND", and "OR", with or without the use of parenthetical groupings: the value of the predicate is true if the expression evaluates to true and is false otherwise.

NOTE—If optional feature F1 requires features F2 and F3, this can be represented in the PICS in one of two ways:
— The status for conditional items F2 and F3 is "F1:M" and the status for conditional item F1 is "O", or
— The status for conditional item F1 is "F2 AND F3:O".

If feature F1 is required if feature F2 or F3 is supported, and is optional otherwise, this can be represented in the PICS in one way:
— The status for conditional item F1 is "F2 OR F3:M" and "O".

If feature F1 is required if feature F2 or F3 is supported, and is not relevant otherwise, this can be represented in the PICS in one way:
— The status for conditional item F1 is "F2 OR F3:M".

If feature F1 is required if feature F2 is supported, is optional if feature F3 is supported, and is not relevant otherwise, this can be represented in the PICS in one way:
— The status for conditional item F1 is "F2:M" and "F3:O".

Conditional symbols can be given in any order.

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Each item referenced in a predicate, or in a preliminary question for grouped conditional items, is indicated by an asterisk in the Item column.

## B.4 PICS proforma—IEEE Std 802.11-2020[58]

### B.4.1 Implementation identification

| | |
|---|---|
| Supplier | |
| Contact point for queries about the PICS | |
| Implementation Name(s) and Version(s) | |
| Other information necessary for full identification, e.g., name(s) and version(s) of the machines and/or operating system(s), system names | |

NOTE 1—Only the first three items are required for all implementations. Other information might be completed as appropriate in meeting the requirement for full identification.

NOTE 2—The terms Name and Version need to be interpreted appropriately to correspond with a supplier's terminology (e.g., Type, Series, Model).

### B.4.2 Protocol summary

| | | | | |
|---|---|---|---|---|
| Identification of protocol standard | IEEE Std 802.11-2020 | | | |
| Identification of amendments and corrigenda to this PICS proforma that have been completed as part of this PICS | Amd. | : | Corr. | : |
| | Amd. | : | Corr. | : |
| Have any exception items been required? (See B.3.3 (Exception information); the answer Yes means that the implementation does not comply with IEEE Std 802.11-2020.) | Yes ☐ No ☐ | | | |

[58] *Copyright release for PICS proforma:* Users of this standard may freely reproduce the PICS proforma in this annex so that it can be used for its intended purpose and may further publish the completed PICS.


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| | |
|---|---|
| Date of statement (yyyy-mm-dd) | |

## B.4.3 IUT configuration

| Item | IUT configuration | References | Status | Support |
|---|---|---|---|---|
| | What is the configuration of the IUT? | | | |
| * CFAP | Access point (AP) | 4.3 (Components of the IEEE 802.11 architecture) | O.1 | Yes ☐ No ☐ |
| * CFIndepSTA | Independent station (neither an AP, nor a mesh STA, nor a STA operating outside the context of a BSS) | 4.3 (Components of the IEEE 802.11 architecture) | O.1 | Yes ☐ No ☐ |
| *CFSTAofAP | Operation in an infrastructure BSS | 4.3 (Components of the IEEE 802.11 architecture) | CFIndepSTA: M | Yes ☐ No ☐ N/A ☐ |
| *CFIBSS | Operation in an independent BSS (IBSS) | 4.3 (Components of the IEEE 802.11 architecture) | CFIndepSTA: O | Yes ☐ No ☐ N/A ☐ |
| *CFPBSS | Operation in a PBSS | 4.3.3 (Personal BSS (PBSS)) | CFIndepSTA AND CFDMG:M CFDMG:O.7 (11ay)CFEDMG:M | |
| *CFPCP | Operation as a PCP | 4.3.3 (Personal BSS (PBSS)) | CFPBSS:M | Yes ☐ No ☐ |
| *CFPBSSnotPCP | Operation *not* as a PCP | 4.3.3 (Personal BSS (PBSS)) | CFPBSS:M | Yes ☐ No ☐ |
| NOTE—See CFMBSS for mesh STA and CFOCB for OCB operation. | | | | |
| * CFDSSS (#2285) | Direct sequence spread spectrum (DSSS) PHY for the 2.4 GHz band | — | O.2 CFHRDSSS: M | Yes ☐ No ☐ |

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## B.4.3 IUT configuration *(continued)*

| Item | IUT configuration | References | Status | Support |
|---|---|---|---|---|
| * CFOFDM | Orthogonal frequency division multiplexing (OFDM) PHY | — | O.2 CFHT5G:M CFTVHT:M CFS1G:M CFHE:M(11ax) (CFWUR AND NOT CFAP):O (CFWUR AND CFAP):M (#4116)(11ba)(#1184) | Yes ☐ No ☐ |
| * CFHRDSSS | High rate direct sequence spread spectrum (HR/DSSS) PHY | — | O.2 CFERP:M | Yes ☐ No ☐ |
| * CFMD | Multidomain operation capability implemented | 10.22 (Operation across regulatory domains) | O | Yes ☐ No ☐ |
| * CFERP | Extended Rate PHY (ERP) | Clause 18 (Extended Rate PHY (ERP) specification) | O.2 (#266)CFHT2G4:M | Yes ☐ No ☐ |
| * CFSM | Spectrum management | 9.4.1.4 (Capability Information field), 11.7 (TPC procedures), 11.8 (DFS procedures) | O | Yes ☐ No ☐ |
| *CFOC | Operating classes capability implemented | 9.4.2.8 (Request element), 17.3.8.4.2 (Channel numbering), 17.3.8.6 (Slot time), 17.4.2 (OFDM PHY MIB) Annex D, Annex E | O | Yes ☐ No ☐ N/A ☐ |


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## B.4.3 IUT configuration *(continued)*

| Item | IUT configuration | References | Status | Support |
|---|---|---|---|---|
| * CFQoS | Quality of service (QoS) | 10.23 (HCF), 10.25 (Block acknowledgment (block ack)), 4.3.13 (High Throughput (HT) STA(#2297)), 4.3.24.3 (Mesh STA) | O<br><br>CFHT OR CFMBSS OR CFQMF OR CFAVT:M<br><br>CFDMG:M<br><br>CFTVHT:M<br><br>CFS1G:M | Yes ☐ No ☐ N/A ☐ |
| * CFRM | Radio Measurement | 9.4.1.4 (Capability Information field), 11.10 (Radio measurement procedures) | (CFMD AND CFOC):O | Yes ☐ No ☐ N/A ☐ |
| *CFInfraSTA | Infrastructure mode | 4.3.4 (STA membership in a BSS is dynamic) | CFAP OR CFSTAofAP:M<br>CFDMG:O.7<br><br>(11ay)CFEDMG:M | Yes ☐ No ☐ N/A ☐ |
| *CF3G6 | 3.65–3.70 GHz band in the United States and its territories(#296) | 9.4.2.50 (DSE Registered Location element), 11.11 (DSE procedures), 17.3.6 (CCA), 17.3.10.6 (CCA requirements), Annex D, Annex E | CFOFDM AND CFMD AND CFSM AND CFOC:O | Yes ☐ No ☐ N/A ☐ |
| *CFHT | (#2297)High Throughput (HT) PHY | 9.4.2.54 (HT Capabilities element) | O.2<br>CFVHT:M | Yes ☐ No ☐ |
| * CFHT2G4 | HT operation in 2.4 GHz band | Clause 19 (High Throughput (HT) PHY specification(#2297)) | CFHT:O.6<br>CFHE2G4:M(11ax)(#7038) | Yes ☐ No ☐ N/A ☐ |

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## B.4.3 IUT configuration *(continued)*

| Item | IUT configuration | References | Status | Support |
|---|---|---|---|---|
| * CFHT5G | HT operation in 5 GHz band | Clause 19 (High Throughput (HT) PHY specification(#2297)) | CFHT:O.6 CFVHT:M | Yes ☐ No ☐ N/A ☐ |
| *CF5G9 | 5.9 GHz band | Annex E | CFOFDM:O | Yes ☐ No ☐ N/A ☐ |
| *CFTDLS | Tunneled direct link(#1356) setup supported | 11.20 (Tunneled direct link setup(#1356)) | O | Yes ☐ No ☐ N/A ☐ |
| *CFWNM | Wireless network management (WNM) | 4.3.22 (Wireless network management)(#2286) | ((CFMD AND CFOC AND CFRM):O | Yes ☐ No ☐ N/A ☐ |
| *CFIW | Interworking with external networks service | 9.4.2.25 (Extended Capabilities element) | O | Yes ☐ No ☐ |
| *CFMBSS | Operation in a mesh BSS (MBSS) | 4.3.24 (Mesh BSS) | (NOT CFDMG) AND (NOT CFS1G):O.1 | Yes ☐ No ☐ N/A ☐ |
| * CFS1G | Sub 1 GHz (S1G) features | 9.4.2.199 (S1G Capabilities element) | O.2 | Yes ☐ No ☐ N/A ☐ |
| * CFS1GRelay | S1G relay | 10.53 (S1G relay operation) | (CFAP AND CFIndepSTA): O | Yes ☐ No ☐ N/A ☐ |
| *CFQMF | QoS management frame (QMF) policy | 11.24 (Quality-of-service Management frame (QMF)) | O | Yes ☐ No ☐ N/A ☐ |
| *CFAVT (M118) | Robust audio/video transport (AVT) | 4.3.27 (Robust audio video (AV) streaming) | O | Yes ☐ No ☐ |
| *CFDMG | Directional multi-gigabit (DMG) PHY | 9.4.2.126 (DMG Capabilities element) | O.2 (#6012)CFCMMG:M CFCDMG:M (11ay)CFEDMG:M CFTDD:M (11bd)CFNGV60:M | Yes ☐ No ☐ |



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## B.4.3 IUT configuration *(continued)*

| Item | IUT configuration | References | Status | Support |
|---|---|---|---|---|
| *CFMBO | Multi-band operation | 9.6.20 (FST Action frame details), 11.30 (Spatial sharing and interference mitigation for DMG STAs) | At least two of CFDSSS, CFOFDM, CF3G6, CF5G9, CFDMG:O | Yes ☐ No ☐ N/A ☐ |
| *CFVHT | Very High Throughput (VHT) features | 9.4.2.156 (VHT Capabilities element) | O.2 CFHE5G:M(11ax)(#1185) | Yes ☐ No ☐ |
| *CFTVHT | TVWS Operation | Annex D, Annex E | O | Yes ☐ No ☐ |
| *CFOCB | Operation outside the context of a BSS (OCB) | 11.18 (STAs communicating Data frames outside the context of a BSS) | O.1 CF5G9:M (11bd)CFNGV:M CFNGV60:M | Yes ☐ No ☐ |
| *CFESM | Extended spectrum management | 10.22.3 (Operation with operating classes) | O CFVHT OR CFTVHT:M | Yes ☐ No ☐ |
| (11ax) *CFHE | High-efficiency (HE) operation | 9.4.2.247 (HE Capabilities element(11ax)) | O CFHE20:M CFHE80:M | Yes ☐ No ☐ |
| (11ax) *CFHE2G4 | HE operation in the 2.4 GHz band | Clause 27 (High-efficiency (HE) PHY specification(11ax)) | (#6576)CFHE:O.8 | Yes ☐ No ☐ |
| (11ax)*CFHE5G | HE operation in the 5 GHz band | Clause 27 (High-efficiency (HE) PHY specification(11ax)) | (#6576)CFHE:O.8 | Yes ☐ No ☐ |
| (11ax)*CFHE6G | HE operation in the 6 GHz band | Clause 27 (High-efficiency (HE) PHY specification(11ax)) | (#6576)CFHE:O.8 | Yes ☐ No ☐ |

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## B.4.3 IUT configuration *(continued)*

| Item | IUT configuration | References | Status | Support |
|---|---|---|---|---|
| (11ax)*CFHE20 | HE operation as a 20 MHz-only non-AP HE STA | Clause 27 (High-efficiency (HE) PHY specification(11ax)) | CFIndepSTA AND CFHE:O (#1186) | Yes ☐ No ☐ |
| (11ax)*CFHE80 | HE operation with capability of 80 MHz or wider channel width | Clause 27 (High-efficiency (HE) PHY specification(11ax)) | CFAP AND (CFHE5G OR CFHE6G): M(#1186)<br><br>CFIndepSTA AND (CFHE5G OR CFHE6G) AND (NOT CFHE20):M (#1186) | Yes ☐ No ☐ |
| (11ax)(M118)*CF2G4n6G | An AP that operates in the 2.4 GHz band and that is in the same (#2210)colocated AP set as one or more 6 GHz APs | 11.53 (Out-of-band discovery of a 6 GHz BSS(11ax)) | CFAP AND CFDSSS:O | Yes ☐ No ☐ N/A ☐ |
| (11ax)(M118)*CF5Gn6G | An AP that operates in the 5 GHz band and that is in the same (#2210)colocated AP set as one or more 6 GHz APs | 11.53 (Out-of-band discovery of a 6 GHz BSS(11ax)) | CFAP AND CFOFDM:O | Yes ☐ No ☐ N/A ☐ |
| *CFFILS | Fast Initial Link Setup (FILS) | 11.45 (Fast Initial Link Setup (FILS) procedures) | O | Yes ☐ No ☐ |
| *CFCDMG | China directional multi-gigabit (CDMG) PHY | 9.4.2.218 (CDMG Capabilities element) | (#6012)O.2 | Yes ☐ No ☐ |
| *CFCMMG | China Millimeter-wave multi-gigabit (CMMG) PHY | 9.4.2.228 (CMMG Capabilities element) | (#6012)O.2 | Yes ☐ No ☐ |
| *CFGLK | GLK enabled STA | 11.50 (GLK operation) | (NOT CFOCB):O | Yes ☐ No ☐ N/A ☐ |
| CFGLK.1 | GLK-GCR | 11.21.16.4 (GLK-GCR) | CFGLK:O | Yes ☐ No ☐ N/A ☐ |
| (M118)*CFPAD | Preassociation discovery | 11.23 (Preassociation discovery (PAD) procedures) | O | Yes ☐ No ☐ N/A ☐ |


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## B.4.3 IUT configuration *(continued)*

| Item | IUT configuration | References | Status | Support |
|---|---|---|---|---|
| (11ay)*CFEDMG | Enhanced directional multi-gigabit (EDMG) PHY | 9.4.2.264 (EDMG Capabilities element(11ay)) | (#6012)O.2 (11bd)CFNGV60:O | Yes ☐ No ☐ |
| (11ay)*CFTDD | Time division duplex (TDD) features | 9.4.2.126 (DMG Capabilities element) | CFDMG:O CFEDMG:O | Yes ☐ No ☐ |
| (11ba)*CFWUR | Wake-up Radio features | 9.4.2.290 (WUR Capabilities element(11ba)) | O | Yes ☐ No ☐ N/A ☐ |
| (11ba)(M118)CFWUR2G4 | WUR operation in the 2.4 GHz band | Clause 30 (Wake-Up Radio (WUR) PHY specification(11ba)) | CFWUR:O | Yes ☐ No ☐ N/A ☐ |
| (11ba)(M118)CFWUR5G | WUR operation in the 5 GHz band | Clause 30 (Wake-Up Radio (WUR) PHY specification(11ba)) | CFWUR:O | Yes ☐ No ☐ N/A ☐ |
| (11az)CFRSTA | FTMRSTA operation | 11.21.6 (FTM procedure(#7065)) | WNM23:O | Yes ☐ No ☐ N/A ☐ |
| (11az)CFISTA | FTM ISTA operation | 11.21.6 (FTM procedure(#7065)) | WNM23:O | Yes ☐ No ☐ N/A ☐ |
| (11az)CFPLISTA | FTM passive TB ranging ISTA | 11.21.6.4.8 (Measurement exchange in passive TB ranging mode(11az)) | WNM23:O | Yes ☐ No ☐ N/A ☐ |
| (11az)CFPLRSTA | FTM passive TB ranging RSTA | 11.21.6.4.8 (Measurement exchange in passive TB ranging mode(11az)) | WNM23:O | Yes ☐ No ☐ N/A ☐ |

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## B.4.3 IUT configuration *(continued)*

| Item | IUT configuration | References | Status | Support |
|---|---|---|---|---|
| (11az)CFPLPSTA | FTM passive STA | 11.21.6.4.8 (Measurement exchange in passive TB ranging mode(11az)) | WNM23:O | Yes ☐ No ☐ N/A ☐ |
| (11az)CFTB | Support for FTM TB sounding | 11.21.6.4.3 (TB ranging measurement exchange(11az)) | CFHE:O | Yes ☐ No ☐ N/A ☐ |
| (11az)*CFNTB | Support for FTM non-TB sounding | 11.21.6.4.4 (Non-TB ranging measurement exchange(11az)) | CFHE:O (11bd)CFNGV:O | Yes ☐ No ☐ N/A ☐ |
| (11az)CFPTB | Support for Passive Sounding | 11.21.6.4.8 (Measurement exchange in passive TB ranging mode(11az)) | CFHE:O | Yes ☐ No ☐ N/A ☐ |
| (11az)CFPASN | Support for PASN | 12.13 (Preassociation security negotiation(11az)) | PC34:O | Yes ☐ No ☐ N/A ☐ |
| (11az)CFPSEC | Support for PHY security, ability to transmit and receive secure HE-LTF waveforms for TB and non-TB operation | 11.21.6.4.5 (Secure HE-LTF in the TB and non-TB ranging measurement exchange protocol(11az)) | PC34:O CFHE:O | Yes ☐ No ☐ N/A ☐ |
| *CFNGV | Next generation V2X (NGV) operation in the 5.9 GHz band | 31.2 (Operation in the 5.9 GHz band) | O | Yes ☐ No ☐ |
| *CFNGV60 | Next generation V2X (NGV) operation in the 60 GHz band | 31.3 (Operation in the 60 GHz band) | O | Yes ☐ No ☐ |


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### B.4.3 IUT configuration *(continued)*

| Item | IUT configuration | References | Status | Support |
|---|---|---|---|---|
| * CFLC (11bb) | Light communications | 4.3.34 (Light communication (LC) STA(11bb)) | O | Yes ☐ No ☐ N/A ☐ |
| *CFEBCS (11bc) | Enhanced Broadcast Services | Clause 34 (Enhanced broadcast services MAC specification(#7051) (11bc)) | O | Yes ☐ No ☐ |
| *CFSTARX-Only(11bc) | Enhanced Broadcast Services receive only | 34.3.3 (EBCS DL procedure at an EBCS receiver) | O | Yes ☐ No ☐ |

## B.4.4 MAC protocol

### B.4.4.1 MAC protocol capabilities

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| | Are the following MAC protocol capabilities supported? | | | |
| (M118)*PC1 | Authentication service | 4.5.4.2 (Authentication), 4.5.4.3 (Deauthentication), 11.18 (STAs communicating Data frames outside the context of a BSS), 12.2 (Framework) | CFInfraSTA AND (#4138)NOT CFDMG:M CFIBSS OR CFDMG:M | Yes ☐ No ☐ N/A ☐ |
| PC1.1 | Authentication state | 11.3 (STA authentication and association) | PC1:M | Yes ☐ No ☐ |
| PC1.2 | Open System authentication | 12.2.2 (Security methods) | PC1 AND (#4138)NOT CFDMG:M | Yes ☐ No ☐(#3056) |
| PC2 | Reserved(#3056) | | | |
| PC3 | Distributed coordination function (DCF) | 10.2 (MAC architecture), 10.3 (DCF) | M | Yes ☐ No ☐ |
| PC3.1 | Network allocation vector (NAV) function | 10.3.2.1 (CS mechanism), 10.3.4 (DCF access procedure) | M | Yes ☐ No ☐ |

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### B.4.4.1 MAC protocol capabilities *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| PC3.2 | Interframe space usage and timing | 10.3.2.3 (IFS), 10.3.4 (DCF access procedure), 10.3.7 (DCF timing relations) | M | Yes ☐ No ☐ |
| PC3.3 | (M118)Random backoff function | 10.3.3 (Random backoff procedure) | M | Yes ☐ No ☐ |
| PC3.4 | (M118)DCF access procedure | 10.3.4.2 (Basic access), 10.3.4.5 (Control of the channel) | M | Yes ☐ No ☐ |
| PC3.5 | (M118)Random backoff procedure | 10.3.4.3 (Backoff procedure for DCF) | M | Yes ☐ No ☐ |
| PC3.6 | Recovery procedures and retransmit limits | 10.3.4.4 (Recovery procedures and retransmit limits) | M | Yes ☐ No ☐ |
| PC3.7 | Request to send (RTS)/clear to send (CTS) procedure | 10.3.2.4 (Setting and resetting the NAV), 10.3.2.6 (RTS/CTS with fragmentation), 10.3.2.9 (CTS and DMG CTS procedure) | M | Yes ☐ No ☐ |
| PC3.8 | Individually addressed MAC protocol data unit (MPDU) transfer | 10.3.5 (Individually addressed MPDU transfer procedure) | M | Yes ☐ No ☐ |
| PC3.9 | Group addressed MPDU transfer | 10.3.6 (Group addressed MPDU transfer procedure) | M | Yes ☐ No ☐ |
| PC3.10 | MAC-level acknowledgment | 10.3.2.2 (MAC-level acknowledgments), 10.3.2.11 (Acknowledgment procedure) | M | Yes ☐ No ☐ |
| PC3.11 | Duplicate detection and recovery | 10.3.2.14 (Duplicate detection and recovery) | M | Yes ☐ No ☐ |
| PC3.12 | Dynamic EIFS | 10.3.7 (DCF timing relations) | O | Yes ☐ No ☐ |
| (M118)PC4 | *Reserved* | | | |
| (M118)PC5 | *Reserved* | | | |


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### B.4.4.1 MAC protocol capabilities *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| PC6 | Fragmentation | 10.3 (DCF), 10.4 (MSDU, (11ax)A-MSDU, and MMPDU fragmentation) | M | Yes ☐ No ☐ |
| PC7 | Defragmentation | 10.3 (DCF), 10.5 (MSDU, (11ax)A-MSDU, and MMPDU defragmentation) | M | Yes ☐ No ☐ |
| PC8 | MAC data service | 10.2.8 (MAC data service), 10.7 (MSDU transmission restrictions) | M | Yes ☐ No ☐ |
| PC8.1 | ReorderableGroupAddressed service class | 10.7 (MSDU transmission restrictions) | M | Yes ☐ No ☐ |
| PC9 | Multirate support | 10.6 (Multirate support) | M | Yes ☐ No ☐ |
| PC9.1 | Rate selection using Rx Supported VHT-MCS and NSS Set / Tx Supported VHT-MCS and NSS Set | 10.6.13.1 (Rx Supported VHT-MCS and NSS Set), 10.6.13.2 (Tx Supported VHT-MCS and NSS Set) | CFVHT:M CFTVHT:M | Yes ☐ No ☐ N/A ☐ |
| PC9.2 | Rate selection constraints for VHT PPDUs | 10.6.13.3 (Additional rate selection constraints for VHT PPDUs) | CFVHT:O CFTVHT:O | Yes ☐ No ☐ N/A ☐ |
| * PC10 | Multiple outstanding MAC service data unit (MSDU) support | 10.7 (MSDU transmission restrictions) | O | Yes ☐ No ☐ |
| PC10.1 | Multiple outstanding MSDU transmission restrictions | 10.7 (MSDU transmission restrictions) | PC10:M | Yes ☐ No ☐ N/A ☐ |
| PC11 | Timing synchronization function (TSF) | 11.1 (Synchronization) | CFAP OR CFIndepSTA:M | Yes ☐ No ☐ |
| PC11.1 | Timing in an infrastructure network | 11.1.2.1 (TSF for an infrastructure BSS or a PBSS), 11.1.5 (Adjusting STA timers) | CFInfraSTA:M | Yes ☐ No ☐ N/A ☐ |
| PC11.2 | Timing in an independent basic service set (IBSS) | 11.1.2.2 (TSF for an IBSS), 11.1.5 (Adjusting STA timers) | CFIBSS:M | Yes ☐ No ☐ N/A ☐ |
| PC11.3 | Beacon generation function | 11.1.3 (Maintaining synchronization) | CFAP OR CFIBSS OR CFPCP:M | Yes ☐ No ☐ |

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### B.4.4.1 MAC protocol capabilities *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| PC11.4 | TSF synchronization and accuracy | 11.1.2 (Basic approach), 11.1.3 (Maintaining synchronization) | CFAP OR CFIndepSTA: M | Yes ☐ No ☐ N/A ☐ |
| PC11.5 | Infrastructure basic service set (BSS) initialization | 11.1.4 (Acquiring synchronization, scanning) | CFAP:M | Yes ☐ No ☐ N/A ☐ |
| PC11.6 | IBSS initialization | 11.1.4 (Acquiring synchronization, scanning) | CFIBSS:M | Yes ☐ No ☐ N/A ☐ |
| PC11.7 | Passive scanning | 11.1.4 (Acquiring synchronization, scanning) | (CFSTAofAP OR CFIBSS OR CFPBSSnotPCP):O.1 | Yes ☐ No ☐ N/A ☐ |
| PC11.8 | Active scanning | 11.1.4 (Acquiring synchronization, scanning) | (CFSTAofAP OR CFIBSS OR CFPBSSnotPCP):O.1 | Yes ☐ No ☐ N/A ☐ |
| PC11.9 | Probe response | 11.1.4 (Acquiring synchronization, scanning) | (NOT CFOCB):M | Yes ☐ No ☐ N/A ☐ |
| (M118)PC12 | Infrastructure power management | 11.2.3 (Power management in a non-DMG infrastructure network) | CFInfraSTA AND (#4138)NOT CFDMG:M | Yes ☐ No ☐ N/A ☐ |
| PC12.1 | STA power management modes | 11.2.3.2 (Non-AP STA power management modes), 11.2.3.7 (Receive operation for STAs in PS mode) | (CFSTAofAP (#4138)OR CFIBSS):M | Yes ☐ No ☐ N/A ☐ |
| PC12.2 | Traffic indication map (TIM) transmission | 11.2.3.3 (AP TIM transmissions), 11.2.3.4 (TIM types) | CFAP:M | Yes ☐ No ☐ N/A ☐ |
| PC12.3 | AP function | 11.2.3.6 (AP operation) | CFAP:M | Yes ☐ No ☐ N/A ☐ |
| PC12.4 | Reserved | | | |
| PC12.5 | Non-AP STA receive function | 11.2.3.7 (Receive operation for STAs in PS mode) | CFSTAofAP: M | Yes ☐ No ☐ N/A ☐ |
| PC12.6 | Reserved | | | |


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### B.4.4.1 MAC protocol capabilities *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| PC12.7 | Aging function | 11.2.3.10 (AP aging function) | CFAP:M | Yes ☐ No ☐ N/A ☐ |
| PC13 | IBSS power management. This capability is deprecated. | 11.2.4 (Power management in an IBSS) | CFIBSS:M | Yes ☐ No ☐ N/A ☐ |
| PC13.1 | Initialization of power management | 11.2.4.3 (Initialization of power management within an IBSS) | CFIBSS:M | Yes ☐ No ☐ N/A ☐ |
| PC13.2 | STA power state transitions | 11.2.4.4 (STA power state transitions) | CFIBSS:M | Yes ☐ No ☐ N/A ☐ |
| PC13.3 | Announcement traffic indication message (ATIM) and frame transmission | 11.2.4.4 (STA power state transitions) f (If the STA has not transmitted an ATIM frame and does not receive either an individually addressed ATIM frame containing the STA's individual address, or a group addressed ATIM frame during the ATIM window, the STA may return to the doze state following the end | CFIBSS:M | Yes ☐ No ☐ N/A ☐ |
| *PC14 | (Re)Association | 4.5 (Overview of the services), 11.3 (STA authentication and association), 11.3.5 (Association, reassociation, and disassociation), | CFInfraSTA OR CFPCP:M CFPBSSnotPCP:O | Yes ☐ No ☐ N/A ☐ |
| PC14.1 | Association state | 11.3.5 (Association, reassociation, and disassociation) | PC14:M | Yes ☐ No ☐ N/A ☐ |
| PC14.2 | STA association procedure | 11.3.5.2 (Non-AP and non-PCP STA association initiation procedures) | CFSTAofAP:M CFPBSSnotPCP:O | Yes ☐ No ☐ N/A ☐ |

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### B.4.4.1 MAC protocol capabilities *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| PC14.3 | AP association procedure | 11.3.5.3 (AP or PCP association receipt procedures) | CFAP OR CFPCP:M | Yes ☐ No ☐ N/A ☐ |
| PC14.4 | STA reassociation procedure | 11.3.5.4 (Non-AP and non-PCP STA reassociation initiation procedures) | CFSTAofAP:M CFPBSSnotPCP:O | Yes ☐ No ☐ N/A ☐ |
| PC14.5 | AP reassociation procedure | 11.3.5.5 (AP or PCP reassociation receipt procedures) | CFAP OR CFPCP:M | Yes ☐ No ☐ N/A ☐ |
| PC15 | Management information base (MIB) | Annex C | M | Yes ☐ No ☐ |
| PC15.1 | dot11SMTbase, dot11SmtAuthenticationAlgorithms | Annex C | M | Yes ☐ No ☐ |
| PC15.2 (#4074) | *Reserved* | | | |
| PC15.3 | dot11MACbase, dot11CountersGroup6(#3263), dot11GroupAddressesTable | Annex C | M | Yes ☐ No ☐ |
| (M118)PC15.4 | dot11MACStatistics | Annex C | O | Yes ☐ No ☐ |
| PC15.5 | dot11ResourceTypeID | Annex C | M | Yes ☐ No ☐ |
| PC16 | Set dot11ShortPreambleOptionImplemented to 1 | 9.4.1.4 (Capability Information field) | CFERP:M | Yes ☐ No ☐ N/A ☐ |
| PC17 | *Reserved* | | | |
| PC18 | *Reserved* | | | |
| PC19 | *Reserved* | | | |
| PC20 | Set Short Slot Time subfield as described in reference | 9.4.1.4 (Capability Information field) | CFERP:M | Yes ☐ No ☐ N/A ☐ |
| PC21 | Monitor each received Short Time Slot subfield and take action as described in reference. | 9.4.1.4 (Capability Information field) | CFERP:M | Yes ☐ No ☐ N/A ☐ |
| PC22 | Transmit the ERP element in each transmitted Beacon or Probe Response frame in the format and with content as described in reference | 9.4.1.4 (Capability Information field) | CFERP:M | Yes ☐ No ☐ N/A ☐ |


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### B.4.4.1 MAC protocol capabilities *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| PC23 | Receive the ERP element and employ a protection mechanism when required prior to transmitting information using ERP-OFDM modulation | 9.4.1.4 (Capability Information field) | CFERP:M | Yes ☐ No ☐ N/A ☐ |
| PC24 | Determine the value of aCWmin based on the characteristic rate set as described in the reference | 10.3.9 (Determination of PLME aCWmin characteristics) | CFERP:M | Yes ☐ No ☐ N/A ☐ |
| PC25 | Transmit control response frames at the largest basic rates less than equal to the rate received and with the same PHY options or use the highest mandatory rate if no basic rate meets the above criterion | 10.6 (Multirate support) | CFERP:M | Yes ☐ No ☐ N/A ☐ |
| PC26 | Transmit group addressed frames at a rate contained in the BSSBasicRateSet parameter | 10.6 (Multirate support) | CFERP:M | Yes ☐ No ☐ N/A ☐ |
| PC27 | Transmit individually addressed frames at any supported rate selected by a rate switching mechanism as long as it is supported by the destination STA | 10.6 (Multirate support) | CFERP:M | Yes ☐ No ☐ N/A ☐ |
| PC28 | *Reserved* | | | |
| PC29 | Use ERP element to control use of protection mechanism as described in the reference | 10.27 (Protection mechanisms) | CFERP:M | Yes ☐ No ☐ N/A ☐ |
| PC30 | Updated NAV is long enough to cover frame and any response | 10.27 (Protection mechanisms) | CFERP:M | Yes ☐ No ☐ N/A ☐ |
| PC31 | Support transmission of CTS-to-self sequence as described in the references | 10.3.2.15 (NAV distribution) | CFERP:O CFTVHT:O | Yes ☐ No ☐ N/A ☐ |
| PC32 | Support reception of CTS-to-self sequence as described in the references | 10.3.2.15 (NAV distribution) | CFERP:M CFTVHT:M | Yes ☐ No ☐ N/A ☐ |
| PC33 | Update NAV | 10.27 (Protection mechanisms) | CFERP:M | Yes ☐ No ☐ N/A ☐ |

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### B.4.4.1 MAC protocol capabilities *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| * PC34 | Robust security network association (RSNA) | 9.3.2.1 (Format of Data frames), 9.4.1.4 (Capability Information field), 4.5.4.4 (Data confidentiality), 11.3.4 (Authentication and deauthentication), 11.3.5 (Association, reassociation, and disassociation), 12.5.2 (CTR with CBC-MAC protocol (CCMP)) | O | Yes ☐ No ☐ |
| (M118)*PC34.1 | RSNE | 9.4.2.23 (RSNE) | PC34:M | Yes ☐ No ☐ N/A ☐ |
| PC34.1.1 | Group data cipher suite(#6020) | 9.4.2.23 (RSNE) | PC34.1:M | Yes ☐ No ☐ N/A ☐ |
| PC34.1.2 | Pairwise cipher suite list | 9.4.2.23 (RSNE) | PC34.1:M | Yes ☐ No ☐ N/A ☐ |
| (M118)*PC34.1.2.1 | (#1912)Counter Mode with cipher-block chaining message authentication code protocol (CCMP) data confidentiality protocol using CCMP-128 | 12.5.2 (CTR with CBC-MAC protocol (CCMP)) | PC34:M | Yes ☐ No ☐ N/A ☐ |
| PC34.1.2.1.1 | CCMP cryptographic encapsulation procedure using CCMP-128 | 12.5.2.3 (CCMP cryptographic encapsulation) | PC34.1.2.1:M | Yes ☐ No ☐ N/A ☐ |
| PC34.1.2.1.2 | CCMP decapsulation procedure using CCMP-128 | 12.5.2.4 (CCMP decapsulation) | PC34.1.2.1:M | Yes ☐ No ☐ N/A ☐ |
| (M118)*PC34.1.2.2 | Temporal key integrity protocol (TKIP) data confidentiality protocol. This capability is (#1643)obsolete (applicable only to systems that are backward compatible). | 12.5.2 (CTR with CBC-MAC protocol (CCMP)) | PC34:O | Yes ☐ No ☐ N/A ☐ |
| PC34.1.2.2.1 | TKIP cryptographic encapsulation procedure | 12.3.4.1.2 (TKIP cryptographic encapsulation) | PC34.1.2.2:M | Yes ☐ No ☐ N/A ☐ |
| PC34.1.2.2.2 | TKIP decapsulation procedure | 12.3.4.1.3 (TKIP decapsulation) | PC34.1.2.2:M | Yes ☐ No ☐ N/A ☐ |
| PC34.1.2.2.3 | TKIP countermeasures | 12.3.4.4 (TKIP countermeasures procedures) | PC34.1.2.2:M | Yes ☐ No ☐ N/A ☐ |


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### B.4.4.1 MAC protocol capabilities *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| PC34.1.2.2.4 | TKIP security services management | 12.3.4.3 (TKIP MIC) | PC34.1.2.2:M | Yes ☐ No ☐ N/A ☐ |
| PC34.1.2.3 | (#1912)Galois/Counter Mode protocol (GCMP) | 12.5.4 (GCM protocol (GCMP)) | (CFDMG (#4138)AND PC34):M | Yes ☐ No ☐ N/A ☐ |
| *PC34.1.3 | Authentication key management (AKM) suite list | 9.4.2.23 (RSNE), 12.5.1 (Overview) | PC34.1:M | Yes ☐ No ☐ N/A ☐ |
| PC34.1.3.1 | IEEE 802.1X-defined/RSNA key management | 9.4.2.23 (RSNE) | PC34.1:M | Yes ☐ No ☐ N/A ☐ |
| PC34.1.3.2 | Preshared key (PSK)/ RSNA key management | 9.4.2.23 (RSNE) | PC34.1:M | Yes ☐ No ☐ N/A ☐ |
| PC34.1.3.3 | RSNA key management | 12.7 (Keys and key distribution) | PC34.1:M | Yes ☐ No ☐ N/A ☐ |
| PC34.1.3.3.1 | Key hierarchy | 12.7 (Keys and key distribution), 12.8 (Mapping EAPOL keys to IEEE 802.11 keys) | PC34.1:M | Yes ☐ No ☐ N/A ☐ |
| PC34.1.3.3.1.1 | Pairwise key hierarchy | 12.7.1.3 (Pairwise key hierarchy) | PC34.1:M | Yes ☐ No ☐ N/A ☐ |
| PC34.1.3.3.1.2 | Group key hierarchy | 12.7.1.4 (Group key hierarchy) | PC34.1:M | Yes ☐ No ☐ N/A ☐ |
| PC34.1.3.3.2 | 4-way handshake | 12.7.6 (4-way handshake) | PC34.1:M | Yes ☐ No ☐ N/A ☐ |
| PC34.1.3.3.3 | Group key handshake | 12.7.7 (Group key handshake) | PC34.1:M | Yes ☐ No ☐ N/A ☐ |
| PC34.1.4 | RSN capabilities | 9.4.2.23 (RSNE), 12.2.3 (RSNA STA capabilities) | PC34.1:M | Yes ☐ No ☐ N/A ☐ |
| PC34.1.5 | RSNA preauthentication | 12.6.8.2 (Preauthentication and RSNA key management) | PC34.1:O | Yes ☐ No ☐ N/A ☐ |
| PC34.1.6 | RSNA security association management | 12.6 (RSNA security association management) | PC34.1:M | Yes ☐ No ☐ N/A ☐ |
| PC34.1.7 | RSNA pairwise master key security association (PMKSA) caching | 12.6.1 (Security associations), 12.6.8.3 (Cached PMKSAs and RSNA key management) | PC34.1:M | Yes ☐ No ☐ N/A ☐ |

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### B.4.4.1 MAC protocol capabilities *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| PC34.1.8 | RSNA extended service set (ESS) | 12.6.8 (RSNA establishment in an infrastructure BSS(#1084)), 12.6.12 (RSNA key management in an infrastructure BSS) | (PC34.1 (#4138)AND CFAP):M | Yes ☐ No ☐ N/A ☐ |
| PC34.1.9 | RSNA IBSS | 12.6.4 (RSNA policy selection in an IBSS), 12.6.9 (RSNA authentication in an IBSS), 12.6.13 (RSNA key management in an IBSS) | (PC34.1 (#4138)AND CFIBSS):O | Yes ☐ No ☐ N/A ☐ |
| *PC34.1.10 | Management frame protection | 9.2.4.1.10 (+HTC subfield), 9.4.1.11 (Action field), 9.4.2.23.4 (RSN capabilities), 9.6.3 (QoS Action frame details)(#3056), 12.3.4.1.2 (TKIP cryptographic encapsulation), 12.3.4.1.3 (TKIP decapsulation), 12.3.4.2 (TKIP MPDU formats), 12.5.2.3.3 (Construct AAD), 12.5.2.3.7 (CCM originator processing), 12.5.2.4.2 (CCM recipient processing), 12.5.2.4.4 (PN and replay detection)(#4175), 12.5.4.4.4 (PN and replay detection), 12.6.3 (RSNA policy selection in an infrastructure BSS) | PC34:O | Yes ☐ No ☐ N/A ☐ |


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### B.4.4.1 MAC protocol capabilities *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| *PC34.1.10.1 | BIP | Clause 11 (MLME), 12.5.3 (Broadcast/ multicast integrity protocol (BIP)) | PC34.1.10:M | Yes ☐ No ☐ N/A ☐ |
| PC34.1.10.1.1 | MME(#1517) | 9.4.2.53 (MME(#1517)) | PC34.1.10.1: M | Yes ☐ No ☐ N/A ☐ |
| PC 34.1.10.1.2 | Beacon protection | 11.52 (Beacon protection procedures(#8133)); 12.6.21 (Protection of Beacon frames) | PC34.1.10.1 AND (CFAP OR CFSTAofAP) :O(#3304) | Yes ☐ No ☐ N/A ☐ |
| PC 34.1.10.1.2.1 | BIP compact encapsulation(#6054) | 12.5.3 (Broadcast/ multicast integrity protocol (BIP)) | PC 34.1.10.1.2 AND CFS1G: O | Yes ☐ No ☐ N/A ☐ |
| PC 34.1.10.1.2.2 | MIC element(#6054) | 9.4.2.117 (MIC element) | PC 34.1.10.1.2.1: M | Yes ☐ No ☐ N/A ☐ |
| PC34.1.11 | AKM: IEEE 802.1X authentication with SHA-256 PRF | 9.4.2.23 (RSNE), 12.7 (Keys and key distribution) | PC34:O | Yes ☐ No ☐ N/A ☐ |
| PC34.1.12 | AKM: PSK with SHA-256 PRF | 9.4.2.23 (RSNE), 12.7 (Keys and key distribution) | PC34:O | Yes ☐ No ☐ N/A ☐ |
| PC34.1.13 | RSNA rekeying | 12.6.19 (RSNA rekeying) | PC34:O | Yes ☐ No ☐ N/A ☐ |
| PC34.1.14 | Multi-band RSNA | 12.6.20 (Multi-band RSNA) | CFMBO AND PC34:M | Yes ☐ No ☐ N/A ☐ |
| PC34.1.15(#6020) | Group management cipher suite | 9.4.2.23 (RSNE) | PC34.1:O | Yes ☐ No ☐ N/A ☐ |
| *PC35 | Fast basic service set (BSS) transition (FT) | Clause 13 (Fast BSS transition) | CFInfraSTA: O | Yes ☐ No ☐ N/A ☐ |
| PC35.1 | (#1776)MDE | 9.4.2.45 (MDE(#1776)) | PC35:M | Yes ☐ No ☐ N/A ☐ |
| PC35.2 | (#1776)FTE | 9.4.2.46 (FTE(#1776)) | PC35 AND PC34:M | Yes ☐ No ☐ N/A ☐ |
| PC35.3 | (#1776)TIE | 9.4.2.47 (TIE(#1776)) | PC35:M | Yes ☐ No ☐ N/A ☐ |
| PC35.4 | Fast basic service set (BSS) Transition (FT) authentication algorithm | 9.4.1.1 (Authentication Algorithm Number field) | PC35:M | Yes ☐ No ☐ N/A ☐ |
| PC35.5 | Fast basic service set (BSS) Transition (FT) Action frames | 9.6.8 (FT Action frame details) | PC35:M | Yes ☐ No ☐ N/A ☐ |

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### B.4.4.1 MAC protocol capabilities *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| PC35.6 | Fast basic service set (BSS) Transition (FT) key management based on IEEE Std 802.1X | 9.4.2.23 (RSNE), 12.7.1.6 (FT key hierarchy) | PC35 AND PC34:M | Yes ☐ No ☐ N/A ☐ |
| PC35.7 | Fast basic service set (BSS) Transition (FT) key management based on preshared keys (PSKs) | 9.4.2.23 (RSNE), 12.7.1.6 (FT key hierarchy) | PC35 AND PC34:M | Yes ☐ No ☐ N/A ☐ |
| PC35.8 | Fast basic service set (BSS) Transition (FT) key hierarchy | 12.7.1.6 (FT key hierarchy) | PC35 AND PC34:M | Yes ☐ No ☐ N/A ☐ |
| PC35.9 | FT initial mobility domain association | 13.4 (FT initial mobility domain association) | PC35 AND PC34:M | Yes ☐ No ☐ N/A ☐ |
| PC35.10 | Fast Basic Service Set (BSS) Transition (FT) Protocol | 13.5 (FT protocol) | PC35:M | Yes ☐ No ☐ N/A ☐ |
| PC35.10.1 | Fast Basic Service Set (BSS) Transition (FT) Protocol in robust security network (RSN) | 13.5.2 (Over-the-air FT protocol authentication in an RSN), 13.5.3 (Over-the-DS FT protocol in an RSN), 13.7.1 (FT reassociation in an RSN) | PC35 AND PC34:M | Yes ☐ No ☐ N/A ☐ |
| PC35.10.2 | Fast Basic Service Set (BSS) Transition (FT) Protocol in nonrobust security network (non-RSN) | 13.5.4 (Over-the-air FT protocol in a non-RSN), 13.5.5 (Over-the-DS FT protocol in a non-RSN), 13.7.2 (FT reassociation in a non-RSN) | PC35:M | Yes ☐ No ☐ N/A ☐ |
| *PC35.11 | Fast Basic Service Set (BSS) transition (FT) resource request protocol | 13.6 (FT resource request protocol) | PC35:O | Yes ☐ No ☐ N/A ☐ |
| PC35.11.1 | (M118)Resource request protocol over the air | 13.6.2 (Over-the-air fast BSS transition with resource request) | PC35.11:M | Yes ☐ No ☐ N/A ☐ |
| PC35.11.2 | (M118)Resource request protocol over the distribution system (DS) | 13.6.3 (Over-the-DS fast BSS transition with resource request), 13.10 (Remote request broker (RRB) communication) | PC35.11:M | Yes ☐ No ☐ N/A ☐ |
| PC35.12 | QoS procedures for fast basic service set (BSS) transition | 13.11 (Resource request procedures) | (CFQoS AND PC35 (#4138)OR CFDMG AND PC35):M | Yes ☐ No ☐ N/A ☐ |


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### B.4.4.1 MAC protocol capabilities *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| *PC35.13 | (#1776)RDE | 9.4.2.48 (RDE(#1776)), 13.11 (Resource request procedures) | PC35:M | Yes ☐ No ☐ N/A ☐ |
| PC35.13.1 | (M118)Resource request procedures at the (#4237)FTO | 13.11.3.1 (FTO procedures) | PC35.13:M | Yes ☐ No ☐ N/A ☐ |
| PC35.13.2 | (M118)Resource request procedures at the target access point (AP) | 13.11.3.2 (AP procedures) | PC35.13:M | Yes ☐ No ☐ N/A ☐ |
| *PC35.14 | (M118)Remote request procedures at the current access point (AP) | 13.10 (Remote request broker (RRB) communication) | PC35:M | Yes ☐ No ☐ N/A ☐ |
| PC35.14.1 | Remote Request/Response frame support | 13.10.3 (Remote Request/ Response frame definition) | PC35.14:O | Yes ☐ No ☐ N/A ☐ |
| PC35.14.2 | Vendor-specific remote request broker (RRB) mechanism | 13.10.3 (Remote Request/ Response frame definition) | PC35.14:O | Yes ☐ No ☐ N/A ☐ |
| PC36 | (M118)SA Query procedure | 9.6.9 (SA Query Action frame details), 11.13 (SA Query procedures) | PC34.1.10:M | Yes ☐ No ☐ N/A ☐ |
| PC37(#3263) | *Reserved* | | | |
| PC38 | dot11OCBActivated is false when STA is a BSS member | 11.18 (STAs communicating Data frames outside the context of a BSS) | (CFSTAofAP OR CFIBSS):M | Yes ☐ No ☐ N/A ☐ |
| (M118)*PC39 | Simultaneous authentication of equals (SAE) | 12.4 (Authentication using a password) | CFMBSS:M | Yes ☐ No ☐ N/A ☐ |
| *PC40 | Multi-band Operation | 11.31 (Multi-band operation) | CFMBO:M (#4115) | Yes ☐ No ☐ N/A ☐ |

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### B.4.4.1 MAC protocol capabilities *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| *PC40.1 | FST Setup | 9.4.2.137 (Multi-band element), 9.4.2.149 (Quiet Period Response element), 9.4.2.150 (BeamLink Maintenance element), 9.6.20.2 (FST Setup Request frame format), 9.6.20.3 (FST Setup Response frame format), 9.6.20.5 (FST Ack Request frame format), 9.6.20.6 (FST Ack Response frame format), 11.31.3.1 (General), 11.31.3.2 (Transitioning between states) | PC40:M | Yes ☐ No ☐ N/A ☐ |
| PC40.2 | FST TS switching | 9.4.2.28 (TSPEC element), 9.4.2.140 (PCP Handover element), 9.6.3.2.2 (DMG ADDTS Request frame variant), 9.6.3.3.2 (DMG ADDTS Response frame variant), 9.6.3.4 (DELTS frame format), 9.6.4.2 (ADDBA Request frame format), 9.6.4.3 (ADDBA Response frame format), 9.6.4.4 (DELBA frame format), 11.31.3.3 (FST TS switching) | PC40.1:M | Yes ☐ No ☐ N/A ☐ |
| PC40.3 | FST Teardown | | | |
| PC40.3.1 | Transmission of FST Teardown | 9.6.20.4 (FST Teardown frame format), 11.31.4 (FST teardown) | PC40.1:O | Yes ☐ No ☐ N/A ☐ |


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### B.4.4.1 MAC protocol capabilities *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| PC40.3.2 | Reception of FST Teardown | 9.6.20.4 (FST Teardown frame format), 11.31.4 (FST teardown) | PC40.1:M | Yes ☐ No ☐ N/A ☐ |
| (11ay)PC40.4 | (M118)Multi-band discovery assistance | 9.4.2.287 (DMG Discovery Assistance element(11ay)), 11.31.7 (Multi-band discovery assistance procedure(11ay)) | (CFDMG AND PC40.1): O | Yes ☐ No ☐ N/A ☐ |
| PC41 | MMSL cluster operation | 11.32 (MMSL cluster operation) | O | Yes ☐ No ☐ N/A ☐ |
| PC42 | Quieting adjacent BSS operation | 11.35 (Quieting adjacent DMG BSSs) | O | Yes ☐ No ☐ N/A ☐ |
| PC43 | Beacon RSSI | 11.43 (Beacon RSSI) | O | Yes ☐ No ☐ N/A ☐ |
| PC44 | Estimated throughput | 11.44 (Estimated throughput) | O | Yes ☐ No ☐ N/A ☐ |

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### B.4.4.1 MAC protocol capabilities *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| (M118)*PC45 | (M118)Operating channel information validation | 9.4.2.23 (RSNE), 12.7.6 (4-way handshake), 12.7.7 (Group key handshake), 14.6 (Authenticated mesh peering exchange (AMPE)), 11.2.3.15 (WNM sleep mode), 9.6.9 (SA Query Action frame details), 13.7 (FT reassociation), 13.8 (FT authentication sequence), 12.11.2.6.2 ((Re)Association Request for FILS key confirmation), 12.11.2.6.3 ((Re)Association Response for FILS key confirmation), 11.9.3.2 (Selecting and advertising a new channel in an infrastructure BSS), 12.7.2 (EAPOL-Key frames), 9.4.2.46 (FTE(#1776)) | PC34:O | Yes ☐ No ☐ |
| PC45.1 | (M118)OCI element | 9.4.2.235 (OCI element) | PC45:M | Yes ☐ No ☐ N/A ☐ |
| PC45.2 | OCI KDE | 12.7.2 (EAPOL-Key frames) | PC45:M | Yes ☐ No ☐ N/A ☐ |
| PC45.3 | (#6386)OCI subelement | 9.4.2.46 (FTE(#1776)) | PC45:M | Yes ☐ No ☐ N/A ☐ |
| (11ax)PC46 | Dynamic fragmentation | 10.3 (DCF), 10.4 (MSDU, (11ax)A-MSDU, and MMPDU fragmentation) | | |
| (11ax)PC46.1 | Dynamic fragmentation level 1 | 26.3.2.2 (Level 1 dynamic fragmentation) | | |
| (11ax)PC46.1.1 | Dynamic fragmentation level 1 MSDU/MMPDU transmission | 26.3.2.2 (Level 1 dynamic fragmentation) | CFHE:O | Yes ☐ No ☐ |


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### B.4.4.1 MAC protocol capabilities *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| (11ax)PC46.1.2 | Dynamic fragmentation level 1 MSDU/MMPDU reception | 26.3.2.2 (Level 1 dynamic fragmentation) | CFHE:O | Yes ☐ No ☐ |
| (11ax)PC46.2 | Dynamic fragmentation level 2 | 26.3.2.3 (Level 2 dynamic fragmentation) | | |
| (11ax)PC46.2.1 | Dynamic fragmentation level 2 MSDU/MMPDU transmission | 26.3.2.3 (Level 2 dynamic fragmentation) | CFHE:O | Yes ☐ No ☐ |
| (11ax)PC46.2.2 | Dynamic fragmentation level 2 MSDU/MMPDU reception | 26.3.2.3 (Level 2 dynamic fragmentation) | CFHE:O | Yes ☐ No ☐ |
| (#2287)(11ax) PC46.3 | Dynamic fragmentation level 3 | 26.3.2.4 (Level 3 dynamic fragmentation) | | |
| (11ax)PC46.3.1 | Dynamic fragmentation level 3 MSDU/MMPDU transmission | 26.3.2.4 (Level 3 dynamic fragmentation) | CFHE:O | Yes ☐ No ☐ |
| (11ax)PC46.3.2 | Dynamic fragmentation level 3 MSDU/MMPDU reception | 26.3.2.4 (Level 3 dynamic fragmentation) | CFHE:O | Yes ☐ No ☐ |
| (11az)PC47 | Support for TB ranging sounding exchange sequence | 11.21.6.4.3 (TB ranging measurement exchange(11az)) | CFTB:M | Yes ☐ No ☐ N/A ☐ |
| (11az)PC48 | Support for non-TB ranging sounding exchange sequence | 11.21.6.4.4 (Non-TB ranging measurement exchange(11az)) | CFNTB:M | Yes ☐ No ☐ N/A ☐ |
| (11az)PC49 | Support for passive TB ranging sounding exchange sequence | 11.21.6.4.8 (Measurement exchange in passive TB ranging mode(11az)) | CFPTB:M | Yes ☐ No ☐ N/A ☐ |

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### B.4.4.2 MAC frames

| Item | MAC frame | References | Status | Support |
|---|---|---|---|---|
| | Is transmission of the following MAC frames supported? | Clause 9 (Frame formats) | | |
| FT1 | Association Request | Clause 9 (Frame formats) | CFSTAofAP:M CFPBSSnotPCP:O | Yes ☐ No ☐ N/A ☐ |
| FT2 | Association Response | Clause 9 (Frame formats) | (CFAP OR CFPCP):M | Yes ☐ No ☐ N/A ☐ |
| FT3 | Reassociation Request | Clause 9 (Frame formats) | CFSTAofAP:M CFPBSSnotPCP:O | Yes ☐ No ☐ N/A ☐ |
| FT4 | Reassociation Response | Clause 9 (Frame formats) | (CFAP OR CFPCP):M | Yes ☐ No ☐ N/A ☐ |
| FT5 | Probe Request | Clause 9 (Frame formats) | (CFSTAofAP ((#4138-Ed)OR CFIBSS OR CFPBSSnotPCP OR CFMBSS):M | Yes ☐ No ☐ N/A ☐ |
| FT6 | Probe Response | Clause 9 (Frame formats) | (CFAP OR CFIBSS OR CFPCP OR CFMBSS):M | Yes ☐ No ☐ N/A ☐ |
| FT7 | Beacon | Clause 9 (Frame formats) | (CFAP OR CFIBSS OR CFMBSS) AND ((#4138)NOT CFDMG AND (NOT CFS1G)):M | Yes ☐ No ☐ N/A ☐ |
| FT8 | ATIM | Clause 9 (Frame formats) | CFIBSS:M | Yes ☐ No ☐ N/A ☐ |
| FT9 | Disassociation | Clause 9 (Frame formats) | CFInfraSTA:M CFPBSS:O | Yes ☐ No ☐ N/A ☐ |
| FT10 | Authentication | Clause 9 (Frame formats) | CFInfraSTA:M CFIBSS OR CFPBSS:O | Yes ☐ No ☐ N/A ☐ |
| FT11 | Deauthentication | Clause 9 (Frame formats) | (NOT CFOCB):M (#4138)NOT CFDMG:M | Yes ☐ No ☐ N/A ☐ |
| FT12 | Power save (PS)-Poll | Clause 9 (Frame formats) | (#4138)NOT CFDMG AND CFSTAofAP:M | Yes ☐ No ☐ N/A ☐ |
| FT13 | RTS | Clause 9 (Frame formats) | M | Yes ☐ No ☐ |


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### B.4.4.2 MAC frames *(continued)*

| Item | MAC frame | References | Status | Support |
|---|---|---|---|---|
| FT14 | CTS | Clause 9 (Frame formats) | (#4138)NOT CFDMG AND NOT CFS1G):M (CFS1G AND VHTM3.1):O | Yes ☐ No ☐ |
| FT15 | Acknowledgment (Ack) | Clause 9 (Frame formats) | NOT CFS1G:M CFS1G AND VHTM3.1 OR S1GM28):O | Yes ☐ No ☐ |
| FT16 | CF-End | Clause 9 (Frame formats) | NOT CFOCB:O (#3795) | Yes ☐ No ☐ N/A ☐ |
| FT17 | *Reserved* | | | |
| FT18 | Data | Clause 9 (Frame formats) | (#4138)NOT CFDMG:M | Yes ☐ No ☐ |
| FT19 | *Reserved* | | | |
| FT20 | *Reserved* | | | |
| FT21 | *Reserved* | | | |
| FT22 | Null | Clause 9 (Frame formats) | (#4138)NOT CFDMG:M | Yes ☐ No ☐ |
| FT23 | *Reserved* | | | |
| FT24 | *Reserved* | | | |
| FT25 | *Reserved* | | | |
| FT26 | (M118)Timing advertisement frame | Clause 9 (Frame formats) | O | Yes ☐ No ☐ |
| FT27 | QoS Data | Clause 9 (Frame formats) | CFQoS:M | Yes ☐ No ☐ N/A ☐ |
| FT28 | QoS Null | Clause 9 (Frame formats) | CFQoS:M | Yes ☐ No ☐ N/A ☐ |
| FT29 | BlockAckReq | Clause 9 (Frame formats) | CFDMG:M CFQoS:O | Yes ☐ No ☐ N/A ☐ |
| FT30 | BlockAck | Clause 9 (Frame formats) | CFDMG:M CFQoS:O CFHT:M | Yes ☐ No ☐ N/A ☐ |
| FT31 | Poll | Clause 9 (Frame formats) | CFDMG:M | Yes ☐ No ☐ N/A ☐ |
| FT32 | SPR | Clause 9 (Frame formats) | CFDMG:M | Yes ☐ No ☐ N/A ☐ |
| FT33 | Grant | Clause 9 (Frame formats) | CFDMG:M | Yes ☐ No ☐ N/A ☐ |

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### B.4.4.2 MAC frames *(continued)*

| Item | MAC frame | References | Status | Support |
|---|---|---|---|---|
| FT34 | DMG CTS | Clause 9 (Frame formats) | CFDMG:M | Yes ☐ No ☐ N/A ☐ |
| FT35 | DMG DTS | Clause 9 (Frame formats) | CFDMG:M | Yes ☐ No ☐ N/A ☐ |
| FT36 | SSW | Clause 9 (Frame formats) | CFDMG:M | Yes ☐ No ☐ N/A ☐ |
| FT37 | SSW-Feedback | Clause 9 (Frame formats) | CFDMG:M | Yes ☐ No ☐ N/A ☐ |
| FT38 | SSW-Ack | Clause 9 (Frame formats) | CFDMG:M | Yes ☐ No ☐ N/A ☐ |
| FT39 | DMG Beacon | Clause 9 (Frame formats) | CFDMG:M | Yes ☐ No ☐ N/A ☐ |
| FT40 | VHT NDP Announcement | Clause 9 (Frame formats) | VHTM4.1:M TVHTM4.1:M | Yes ☐ No ☐ N/A ☐ |
| FT41 | Beamforming Report Poll | Clause 9 (Frame formats) | VHTM4.1:O VHTM4.3:M TVHTM4.1:O TVHTM4.3:M | Yes ☐ No ☐ N/A ☐ |
| FT42 | Transmission of Operating Mode Notification frame and Operating Mode Notification element | 9.6.22.4 (Operating Mode Notification frame format), 9.4.2.164 (Operating Mode Notification element), 11.40 (Notification of operating mode changes) | O | Yes ☐ No ☐ N/A ☐ |
| FT43 | TACK | Clause 9 (Frame formats) | S1GM6.2:M (CFS1G AND NOT S1GM6):O | Yes ☐ No ☐ N/A ☐ |
| FT44 | S1G Beacon | Clause 9 (Frame formats) | ((CFAP OR CFIBSS) AND CFS1G):M | Yes ☐ No ☐ N/A ☐ |
| (M118)*FT45 | PV1(M118) | 9.8 (MAC frame format for PV1 frames) | CFS1G:O | Yes ☐ No ☐ N/A ☐ |


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### B.4.4.2 MAC frames *(continued)*

| Item | MAC frame | References | Status | Support |
|---|---|---|---|---|
| FT45.1 | STACK(M118) | 9.8 (MAC frame format for PV1 frames)(#2288) | (S1GM6.2: OR S1GM6.1):M | Yes ☐ No ☐ N/A ☐ |
| FT45.2 | BAT(M118) | 9.8 (MAC frame format for PV1 frames)(#2288) | (S1GM6.2 AND QB4.1):M | Yes ☐ No ☐ N/A ☐ |
| FT45.3 | PV1 Action(M118) | 9.8 (MAC frame format for PV1 frames)(#2288) | CFS1G:O | Yes ☐ No ☐ N/A ☐ |
| FT45.4 | PV1 Action No Ack(M118) | 9.8 (MAC frame format for PV1 frames)(#2288) | CFS1G:O | Yes ☐ No ☐ N/A ☐ |
| FT45.5 | PV1 Probe Response(M118) | 9.8 (MAC frame format for PV1 frames)(#2288) | (CFAP AND CFS1G):O | Yes ☐ No ☐ N/A ☐ |
| FT45.6 | PV1 Data(M118) | 9.8 (MAC frame format for PV1 frames)(#2288) | CFS1G:O RL6:M S1GM13:M | Yes ☐ No ☐ N/A ☐ |
| FT45.7 | Resource Allocation | 9.8 (MAC frame format for PV1 frames)(#2288) | (CFAP AND S1GM22.5):O | Yes ☐ No ☐ N/A ☐ |
| (M118)*FT46 | NDP CMAC PPDUs | 23.3.12 (NDP CMAC PPDUs) | CFS1G: M | Yes ☐ No ☐ N/A ☐ |
| FT46.1 | NDP CTS | 23.3.12 (NDP CMAC PPDUs) | CFS1G: M | Yes ☐ No ☐ N/A ☐ |
| (M118)*FT46.2 | NDP PS-Poll | 23.3.12 (NDP CMAC PPDUs) | (CFIndepSTA AND CFS1G): O | Yes ☐ No ☐ N/A ☐ |

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### B.4.4.2 MAC frames *(continued)*

| Item | MAC frame | References | Status | Support |
|---|---|---|---|---|
| FT46.3 | NDP Ack | 23.3.12 (NDP CMAC PPDUs) | CFS1G: M | Yes ☐ No ☐ N/A ☐ |
| FT46.4 | NDP PS-Poll-Ack | 23.3.12 (NDP CMAC PPDUs) | (CFAP AND CFS1G AND FR47.2): M | Yes ☐ No ☐ N/A ☐ |
| FT46.5 | NDP BlockAck | 23.3.12 (NDP CMAC PPDUs) | (CFS1G AND HTM5.3): M | Yes ☐ No ☐ N/A ☐ |
| FT46.6 | NDP Beamforming Report Poll | 23.3.12 (NDP CMAC PPDUs) | CFS1G AND CFAP: O | Yes ☐ No ☐ N/A ☐ |
| FT46.7 | NDP Paging | 23.3.12 (NDP CMAC PPDUs) | S1GM6.11: M | Yes ☐ No ☐ N/A ☐ |
| FT46.8 | NDP Probe Request | 23.3.12 (NDP CMAC PPDUs) | (CFS1G AND CFIndepSTA AND S1GM4.5):M | Yes ☐ No ☐ N/A ☐ |
| FT46.9 | NDP CF-End | 23.3.12 (NDP CMAC PPDUs) | CFS1G:O | Yes ☐ No ☐ N/A ☐ |
| FT47 | Unprotected S1G Action(M118) | 9.6.24 (Unprotected S1G Action frame details) | CFS1G:M | Yes ☐ No ☐ N/A ☐ |
| FT47.1 | AID Switch Request(M118) | 9.6.24 (Unprotected S1G Action frame details) | (CFIndepSTA AND CFS1G AND (S1GM13 OR S1GM18)):M | Yes ☐ No ☐ N/A ☐ |
| FT47.2 | AID Switch Response(M118) | 9.6.24 (Unprotected S1G Action frame details) | (CFAP AND CFS1G AND (S1GM13 OR S1GM18)):M | Yes ☐ No ☐ N/A ☐ |
| FT47.3 | Sync Control(M118) | 9.6.24 (Unprotected S1G Action frame details) | (CFAP AND CFS1G AND S1GM8.2):M | Yes ☐ No ☐ N/A ☐ |


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### B.4.4.2 MAC frames *(continued)*

| Item | MAC frame | References | Status | Support |
|---|---|---|---|---|
| FT47.4 | STA Information Announcement(M118) | 9.6.24 (Unprotected S1G Action frame details) | (CFIndepSTA AND CFS1G AND S1GM18):M | Yes ☐ No ☐ N/A ☐ |
| FT47.5 | EDCA Parameter Set(M118) | 9.6.24 (Unprotected S1G Action frame details) | (CFAP AND CFS1G):O | Yes ☐ No ☐ N/A ☐ |
| FT47.6 | EL Operation(M118) | 9.6.24 (Unprotected S1G Action frame details) | (CFIndepSTA AND CFS1G AND S1GM21):M | Yes ☐ No ☐ N/A ☐ |
| FT47.7 | TWT Setup(M118) | 9.6.24 (Unprotected S1G Action frame details) | (CFS1G AND S1GM6.3):M | Yes ☐ No ☐ N/A ☐ |
| FT47.8 | TWT Teardown(M118) | 9.6.24 (Unprotected S1G Action frame details) | (CFS1G AND S1GM6.5):M | Yes ☐ No ☐ N/A ☐ |
| FT47.9 | Sectorized Group ID List(M118) | 9.6.24 (Unprotected S1G Action frame details) | (CFAP AND CFS1G AND S1GM11):M | Yes ☐ No ☐ N/A ☐ |
| FT47.10 | Sector ID feedback(M118) | 9.6.24 (Unprotected S1G Action frame details) | (CFIndepSTA AND CFS1G AND S1GM11):M | Yes ☐ No ☐ N/A ☐ |
| (M118)*FT47.11 | (M118)Header Compression frame as a request | | (CFS1G AND S1GM16):O | Yes ☐ No ☐ N/A ☐ |
| FT47.12 | Header Compression frame as a response | | CFS1G:M | Yes ☐ No ☐ N/A ☐ |
| FT47.13 | TWT Information(M118) | 9.6.24.12 (TWT Information frame format)(#2289) | (CFS1G AND S1GM6.1):O (CFS1G AND S1GM6.2):O | Yes ☐ No ☐ N/A ☐ |

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### B.4.4.2 MAC frames *(continued)*

| Item | MAC frame | References | Status | Support |
|---|---|---|---|---|
| FT48 | S1G Action(M118) | 9.6.25 (S1G Action frame details) | (RL1 OR S1GM6.13 OR S1GM30):M(#1276) | Yes ☐ No ☐ N/A ☐ |
| FT48.1 | Reachable Address Update(M118) | 9.6.25 (S1G Action frame details) | RL1:M | Yes ☐ No ☐ N/A ☐ |
| FT48.2 | Relay Activation Request(M118) | | RL1:O | Yes ☐ No ☐ N/A ☐ |
| FT48.3 | Relay Activation Response(M118) | | RL1:M | Yes ☐ No ☐ N/A ☐ |
| FT48.4 | Protected TWT Setup(M118) | 9.6.25 (S1G Action frame details) | S1GM6.13:M | Yes ☐ No ☐ N/A ☐ |
| FT48.5 | Protected TWT Teardown(M118) | 9.6.25 (S1G Action frame details) | S1GM6.13:M | Yes ☐ No ☐ N/A ☐ |
| FT48.6 | Protected TWT Information(M118) | 9.6.25 (S1G Action frame details) | S1GM6.13:M | Yes ☐ No ☐ N/A ☐ |
| FT48.7(#1276) | Protected AID Switch Request(M118) | 9.6.25 (S1G Action frame details) | S1GM30:M | Yes ☐ No ☐ N/A ☐ |
| FT48.8(#1276) | Protected AID Switch Response(M118) | 9.6.25 (S1G Action frame details) | S1GM30:M | Yes ☐ No ☐ N/A ☐ |
| FT48.9(#1276) | Protected Sync Control | 9.6.25 (S1G Action frame details) | S1GM30:M | Yes ☐ No ☐ N/A ☐ |
| FT48.10(#1276) | Protected STA Information Announcement | 9.6.25 (S1G Action frame details) | S1GM30:M | Yes ☐ No ☐ N/A ☐ |
| FT48.11(#1276) | Protected EDCA Parameter Set | 9.6.25 (S1G Action frame details) | S1GM30:M | Yes ☐ No ☐ N/A ☐ |
| FT48.12(#1276) | Protected EL Operation | 9.6.25 (S1G Action frame details) | S1GM30:M | Yes ☐ No ☐ N/A ☐ |



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### B.4.4.2 MAC frames *(continued)*

| Item | MAC frame | References | Status | Support |
|---|---|---|---|---|
| FT48.13(#1276) | Protected Sectorized Group ID List | 9.6.25 (S1G Action frame details) | S1GM30:M | Yes ☐ No ☐ N/A ☐ |
| FT48.14(#1276) | Protected Sector ID Feedback | 9.6.25 (S1G Action frame details) | S1GM30:M | Yes ☐ No ☐ N/A ☐ |
| FT49 | Flow Control Action(M118) | 9.6.26 (Flow Control Action frame details) | CFS1G:M | Yes ☐ No ☐ N/A ☐ |
| FT49.1 | Flow Suspension(M118) | 9.6.26 (Flow Control Action frame details) | (CFS1G AND S1GM17.1):M | Yes ☐ No ☐ N/A ☐ |
| FT49.2 | Flow Resumption(M118) | 9.6.26 (Flow Control Action frame details) | (CFS1G AND S1GM17.1):O | Yes ☐ No ☐ N/A ☐ |
| FT50 | Control Response MCS Negotiation(M118) | 9.6.27 (Control Response MCS Negotiation Action frame details(#3175)) | CFS1G AND S1GM28:M | Yes ☐ No ☐ N/A ☐ |
| FT50.1 | Control Response MCS Negotiation Request | 9.6.27 (Control Response MCS Negotiation Action frame details(#3175)) | (CFS1G AND S1GM28):O | Yes ☐ No ☐ N/A ☐ |
| FT50.2 | Control Response MCS Negotiation Response | 9.6.27 (Control Response MCS Negotiation Action frame details(#3175)) | (CFS1G AND S1GM28):M | Yes ☐ No ☐ N/A ☐ |
| FT51 | LPD MSDU | 5.1.4 (MSDU format) | M | Yes ☐ No ☐ N/A |

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### B.4.4.2 MAC frames *(continued)*

| Item | MAC frame | References | Status | Support |
|---|---|---|---|---|
| (M118)*FT52 | EPD MSDU | 5.1.4 (MSDU format), 11.51 (EPD operation) | O | Yes ☐ No ☐ N/A |
| (11ax)FT53 | Trigger(M118) | 9.3.1.22 (Trigger frame format(11ax))(#2347) | (#2347) | (#2347) |
| FT53.1(#2347) | Basic Trigger(M118) | 9.3.1.22 (Trigger frame format(11ax)) | CFHE AND CFAP: M | Yes ☐ No ☐ N/A ☐ |
| FT53.2(#2347) | Beamforming Report Poll (BFRP)(M118) | 9.3.1.22 (Trigger frame format(11ax)) | CFHE AND CFAP AND HEP2.3.3: M | Yes ☐ No ☐ N/A ☐ |
| FT53.3(#2347) | MU-BAR(M118) | 9.3.1.22 (Trigger frame format(11ax)) | CFHE AND CFAP: O | Yes ☐ No ☐ N/A ☐ |
| FT53.4(#2347) | MU-RTS(M118) | 9.3.1.22 (Trigger frame format(11ax)) | CFHE AND CFAP: O | Yes ☐ No ☐ N/A ☐ |
| FT53.5(#2347) | Buffer Status Report Poll (BSRP)(M118) | 9.3.1.22 (Trigger frame format(11ax)) | CFHE AND CFAP: O | Yes ☐ No ☐ N/A ☐ |
| FT53.6(#2347) | GCR MU-BAR(M118) | 9.3.1.22 (Trigger frame format(11ax)) | CFHE AND CFAP: O | Yes ☐ No ☐ N/A ☐ |
| FT53.7(#2347) | Bandwidth Query Report Poll (BQRP)(M118) | 9.3.1.22 (Trigger frame format(11ax)) | CFHE AND CFAP: O | Yes ☐ No ☐ N/A ☐ |
| FT53.8(#2347) | NDP Feedback Report Poll (NFRP)(M118) | 9.3.1.22 (Trigger frame format(11ax)) | CFHE AND CFAP: O | Yes ☐ No ☐ N/A ☐ |
| (11ay)FT54 | Sector Ack | Clause 9 (Frame formats) | EDMG-M16.4:M | Yes ☐ No ☐ |


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### B.4.4.2 MAC frames *(continued)*

| Item | MAC frame | References | Status | Support |
|---|---|---|---|---|
| (11ay)FT55 | Block Ack Schedule | Clause 9 (Frame formats) | EDMG-M9.2:M | Yes ☐ No ☐ |
| (11ay)FT56 | TDD Beamforming | Clause 9 (Frame formats) | CFTDD:M | Yes ☐ No ☐ |
| (11ba)FT57 | WUR Beacon(M118) | 9.9.3.1 (WUR Beacon frame format) | (CFWUR (#4138)AND CFAP):M | Yes ☐ No ☐ N/A ☐ |
| (11ba)FT58 | Individually addressed and broadcast FL WUR Wake-up(M118) | 9.9.3.2 (WUR Wake-up frame format) | (CFWUR (#4138)AND CFAP):M | Yes ☐ No ☐ N/A ☐ |
| (11ba)FT59 | FL WUR Wake-up frame with a WUR group ID | 9.9.3.2 (WUR Wake-up frame format) | (CFWUR (#4138)AND CFAP):O | Yes ☐ No ☐ N/A ☐ |
| (11ba)FT60 | VL WUR Wake-up(M118) | 9.9.3.2 (WUR Wake-up frame format) | (CFWUR (#4138)AND CFAP):O | Yes ☐ No ☐ N/A ☐ |
| (11ba)FT61 | WUR Short Wake-up(M118) | 9.9.3.5 (WUR Short Wake-up frame format) | (CFWUR (#4138)AND CFAP):O | Yes ☐ No ☐ N/A ☐ |
| (11ba)FT62 | WUR Discovery(M118) | 9.9.3.3 (WUR Discovery frame format) | (CFWUR (#4138)AND CFAP):O | Yes ☐ No ☐ N/A ☐ |
| (11ba)FT63 | WUR Vendor Specific(M118) | 9.9.3.4 (WUR Vendor Specific frame format) | (CFWUR (#4138)AND CFAP):O | Yes ☐ No ☐ N/A ☐ |
| (11ba)FT64 | WUR Mode Setup(M118) | 9.6.33.2 (WUR Mode Setup frame format) | CFWUR:M | Yes ☐ No ☐ N/A ☐ |
| (11ba)FT65 | WUR Mode Teardown(M118) | 9.6.33.3 (WUR Mode Teardown frame format) | CFWUR:M | Yes ☐ No ☐ N/A ☐ |

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### B.4.4.2 MAC frames *(continued)*

| Item | MAC frame | References | Status | Support |
|---|---|---|---|---|
| (11az)FT66 | FTM Request | 11.21.6.3 (FTM procedure negotiation(11az)) | CFISTA:M (CFTB OR CFNTB):M | Yes ☐ No ☐ N/A ☐ |
| (11az)FT67 | FTM | 11.21.6.3 (FTM procedure negotiation(11az)) | CFRSTA:M (CFTB OR CFNTB OR CFPTB):M | Yes ☐ No ☐ N/A ☐ |
| (11az)FT68 | LMR | 9.6.7.49 (LMR frame format(11az)(#8216)), 11.21.6.4.3 (TB ranging measurement exchange(11az)), 11.21.6.4.4 (Non-TB ranging measurement exchange(11az)) | (CFRSTA OR CFISTA):M (CFTB OR CFNTB):M | Yes ☐ No ☐ N/A ☐ |
| (11az)FT69 | Transmission of TF type Ranging using FTM TB ranging operation | 9.3.1.22.10 (Ranging Trigger variant(11az)), 11.21.6.4.3 (TB ranging measurement exchange(11az)) | CFRSTA:M CFTB:M | Yes ☐ No ☐ N/A ☐ |
| (11az)FT70 | Transmission of Ranging NDP Announcement frame using FTM TB ranging operation | 9.3.1.22.10 (Ranging Trigger variant(11az)), 11.21.6.4.3 (TB ranging measurement exchange(11az)) | CFRSTA:M CFTB:M | Yes ☐ No ☐ N/A ☐ |


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### B.4.4.2 MAC frames *(continued)*

| Item | MAC frame | References | Status | Support |
|---|---|---|---|---|
| (11az)FT71 | Transmission of Ranging NDP Announcement frame using FTM non-TB ranging operation | 9.3.1.22.10 (Ranging Trigger variant(11az)), 11.21.6.4.4 (Non-TB ranging measurement exchange(11az)) | CFISTA:M CFNTB:M | Yes ☐ No ☐ N/A ☐ |
| (11az)FT72 | Transmission of TF subvariant Passive Sounding | 9.3.1.23.5 (Passive sounding subvariant) | (CFRSTA AND CFPTB): M | Yes ☐ No ☐ N/A ☐ |
| (11az)FT73 | Transmission of Ranging NDP Announcement frame | 9.3.1.19 (VHT/HE/ Ranging NDP Announcement frame format(11ax)(11az)) | (CFRSTA AND CFPTB): M | Yes ☐ No ☐ N/A ☐ |
| | Is reception of the following MAC frames supported? | Clause 9 (Frame formats) | | |
| *FR1 | Association Request | Clause 9 (Frame formats) | (CFAP OR CFPCP):M | Yes ☐ No ☐ N/A ☐ |
| *FR2 | Association Response | Clause 9 (Frame formats) | (CFSTAofAP1 OR CFPBSSnotPCP):M | Yes ☐ No ☐ N/A ☐ |
| FR3 | Reassociation Request | Clause 9 (Frame formats) | (CFAP OR CFPCP):M | Yes ☐ No ☐ N/A ☐ |
| FR4 | Reassociation Response | Clause 9 (Frame formats) | (CFSTAofAP OR CFPBSSnotPCP):M | Yes ☐ No ☐ N/A ☐ |
| FR5 | Probe Request | Clause 9 (Frame formats) | (CFAP OR CFIBSS OR CFPCP OR CFMBSS):M | Yes ☐ No ☐ N/A ☐ |

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### B.4.4.2 MAC frames *(continued)*

| Item | MAC frame | References | Status | Support |
|---|---|---|---|---|
| FR6 | Probe Response | Clause 9 (Frame formats) | (CFSTAofAP OR CFIBSS OR CFPBSSnotPCP OR CFMBSS):M | Yes ☐ No ☐ N/A ☐ |
| FR7 | Beacon | Clause 9 (Frame formats) | (NOT CFOCB AND (NOT CFS1G)):M (#4138)NOT CFDMG AND (NOT CFS1G)):M | Yes ☐ No ☐ N/A ☐ |
| FR8 | ATIM | Clause 9 (Frame formats) | (CFSTAofAP OR CFIBSS OR CFMBSS) AND (#4138)NOT CFDMG:M | Yes ☐ No ☐ N/A ☐ |
| FR9 | Disassociation | Clause 9 (Frame formats) | FR1 OR FR2:M | Yes ☐ No ☐ N/A ☐ |
| (M118)*FR10 | Authentication | Clause 9 (Frame formats) | CFAP AND (#4138)NOT CFDMG:M CFIBSS OR CFPBSS OR (CFAP AND CFDMG):O | Yes ☐ No ☐ N/A ☐ |
| FR11 | Deauthentication | Clause 9 (Frame formats) | FR10:M | Yes ☐ No ☐ N/A ☐ |
| FR12 | PS-Poll | Clause 9 (Frame formats) | CFAP:M | Yes ☐ No ☐ N/A ☐ |
| FR13 | RTS | Clause 9 (Frame formats) | M | Yes ☐ No ☐ |
| FR14 | CTS | Clause 9 (Frame formats) | (#4138)NOT CFDMG AND NOT CFS1G):M (CFS1G AND VHTM3.1):O | Yes ☐ No ☐ |
| FR15 | Ack | Clause 9 (Frame formats) | NOT CFS1G:M CFS1G AND VHTM3.1 OR S1GM28):O | Yes ☐ No ☐ |
| FR16 | CF-End | Clause 9 (Frame formats) | (NOT CFOCB):M | Yes ☐ No ☐ N/A ☐ |
| FR17 | *Reserved* | | | |



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### B.4.4.2 MAC frames *(continued)*

| Item | MAC frame | References | Status | Support |
|---|---|---|---|---|
| FR18 | Data | Clause 9 (Frame formats) | (#4138)NOT CFDMG:M | Yes ☐ No ☐ |
| FR19 | *Reserved* | | | |
| FR20 | *Reserved* | | | |
| FR21 | *Reserved* | | | |
| FR22 | Null | Clause 9 (Frame formats) | (#4138)NOT CFDMG:M | Yes ☐ No ☐ |
| FR23 | *Reserved* | | | |
| FR24 | *Reserved* | | | |
| FR25 | *Reserved* | | | |
| FR26 | Timing Advertisement frame | Clause 9 (Frame formats) | O | Yes ☐ No ☐ |
| FR27 | QoS Data | Clause 9 (Frame formats) | CFQoS:M | Yes ☐ No ☐ N/A ☐ |
| FR28 | QoS Null | Clause 9 (Frame formats) | CFQoS:M | Yes ☐ No ☐ N/A ☐ |
| FR29 | BlockAckReq | Clause 9 (Frame formats) | CFQoS:O HTM3.1:M | Yes ☐ No ☐ N/A ☐ |
| FR30 | BlockAck | Clause 9 (Frame formats) | CFQoS:O HTM3.5:M | Yes ☐ No ☐ N/A ☐ |
| FR31 | Poll | Clause 9 (Frame formats) | CFDMG:M | Yes ☐ No ☐ N/A ☐ |
| FR32 | SPR | Clause 9 (Frame formats) | CFDMG:M | Yes ☐ No ☐ N/A ☐ |
| FR33 | Grant | Clause 9 (Frame formats) | CFDMG:M | Yes ☐ No ☐ N/A ☐ |
| FR34 | DMG CTS | Clause 9 (Frame formats) | CFDMG:M | Yes ☐ No ☐ N/A ☐ |
| FR35 | DMG DTS | Clause 9 (Frame formats) | CFDMG:M | Yes ☐ No ☐ N/A ☐ |
| FR36 | *Reserved* | | | |
| FR37 | SSW | Clause 9 (Frame formats) | CFDMG:M | Yes ☐ No ☐ N/A ☐ |
| FR38 | SSW-Feedback | Clause 9 (Frame formats) | CFDMG:M | Yes ☐ No ☐ N/A ☐ |

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### B.4.4.2 MAC frames *(continued)*

| Item | MAC frame | References | Status | Support |
|---|---|---|---|---|
| FR39 | SSW-Ack | Clause 9 (Frame formats) | CFDMG:M | Yes ☐ No ☐ N/A ☐ |
| FR40 | DMG Beacon | Clause 9 (Frame formats) | (CFSTAofAP OR CFIBSS OR CFPBSS) AND CFDMG:M | Yes ☐ No ☐ N/A ☐ |
| FR41 | VHT NDP Announcement | Clause 9 (Frame formats) | VHTM4.2:M TVHTM4.2:M | Yes ☐ No ☐ N/A ☐ |
| FR42 | Beamforming Report Poll | Clause 9 (Frame formats) | VHTM4.2:O VHTM4.4:M TVHTM4.2:O TVHTM4.4:M | Yes ☐ No ☐ N/A ☐ |
| FR43 | Reception of Operating Mode Notification frame and Operating Mode Notification element | 9.6.22.4 (Operating Mode Notification frame format), 9.4.2.164 (Operating Mode Notification element), 11.40 (Notification of operating mode changes) | CFVHT:M CFTVHT:M | Yes ☐ No ☐ N/A ☐ |
| FR44 | TACK | Clause 9 (Frame formats) | (CFAP AND CFS1G):O (CFIndepSTA AND CFS1G AND S1GM7.3 OR S1GM6.1):M | Yes ☐ No ☐ N/A ☐ |
| FR45 | S1G Beacon | 9.3.4.3 (S1G Beacon frame format), 11.1.3 (Maintaining synchronization) (#3188) | CFS1G:M | Yes ☐ No ☐ N/A ☐ |
| (M118)*FR46 | PV1 frame | 9.8 (MAC frame format for PV1 frames)(#2288) | CFS1G:O | Yes ☐ No ☐ N/A ☐ |


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### B.4.4.2 MAC frames *(continued)*

| Item | MAC frame | References | Status | Support |
|---|---|---|---|---|
| FR46.1 | STACK frame | 9.8 (MAC frame format for PV1 frames)(#2288) | (CFS1G AND S1GM6.1):M | Yes ☐ No ☐ N/A ☐ |
| FR46.2 | BAT frame | 9.8 (MAC frame format for PV1 frames)(#2288) | (CFS1G AND S1GM6.1 AND QB4.1 OR):M | Yes ☐ No ☐ N/A ☐ |
| FR46.3 | PV1 Action frame | 9.8 (MAC frame format for PV1 frames)(#2288) | CFS1G AND (S1GM20.1 OR S1GM20.3 OR S1GM20.5):M CFS1G AND (S1GM20.2 OR S1GM20.5):O :O | Yes ☐ No ☐ N/A ☐ |
| FR46.4 | PV1 Action No Ack frame | 9.8 (MAC frame format for PV1 frames)(#2288) | CFS1G AND (S1GM20.1 OR S1GM20.3 OR S1GM20.5):M CFS1G AND (S1GM20.2 OR S1GM20.5):O | Yes ☐ No ☐ N/A ☐ |
| FR46.5 | PV1 Probe Response frame | 9.8 (MAC frame format for PV1 frames)(#2288) | CFS1G:O | Yes ☐ No ☐ N/A ☐ |
| FR46.6 | PV1 Data frame | 9.8 (MAC frame format for PV1 frames)(#2288) | CFS1G AND (S1GM20.1 OR S1GM20.3 OR S1GM20.4):M<br><br>CFS1G AND (S1GM20.2 OR S1GM20.5):O | Yes ☐ No ☐ N/A ☐ |
| FR46.7 | Resource Allocation | 9.8 (MAC frame format for PV1 frames)(#2288) | (CFIndepSTA AND CFS1G AND S1GM22.5):M | Yes ☐ No ☐ N/A ☐ |
| FR47 | NDP CMAC PPDUs | 23.3.12 (NDP CMAC PPDUs) | CFS1G:M | Yes ☐ No ☐ N/A ☐ |
| FR47.1 | NDP CTS | 23.3.12 (NDP CMAC PPDUs) | CFS1G:M | Yes ☐ No ☐ N/A ☐ |

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### B.4.4.2 MAC frames *(continued)*

| Item | MAC frame | References | Status | Support |
|---|---|---|---|---|
| FR47.2 | NDP PS-Poll | 23.3.12 (NDP CMAC PPDUs) | (CFAP AND CFS1G):O | Yes ☐ No ☐ N/A ☐ |
| FR47.3 | NDP ACK | 23.3.12 (NDP CMAC PPDUs) | CFS1G:M | Yes ☐ No ☐ N/A ☐ |
| FR47.4 | NDP PS-Poll-Ack | 23.3.12 (NDP CMAC PPDUs) | (CFIndepSTA AND CFS1G AND FT46.2):M | Yes ☐ No ☐ N/A ☐ |
| FR47.5 | NDP BlockAck | 23.3.12 (NDP CMAC PPDUs) | (CFS1G AND HTM5.3):M | Yes ☐ No ☐ N/A ☐ |
| FR47.6 | NDP Beamforming Report Poll | 23.3.12 (NDP CMAC PPDUs) | (CFIndepSTA AND CFS1G):O | Yes ☐ No ☐ N/A ☐ |
| FR47.7 | NDP Paging | 23.3.12 (NDP CMAC PPDUs) | (CFS1G AND S1GM6.9):M | Yes ☐ No ☐ N/A ☐ |
| FR47.8 | NDP Probe Request | 23.3.12 (NDP CMAC PPDUs) | (CFAP AND CFS1G):M | Yes ☐ No ☐ N/A ☐ |
| FR47.9 | NDP CF-End | 23.3.12 (NDP CMAC PPDUs) | (CFIndepSTA AND CFS1G):O | Yes ☐ No ☐ N/A ☐ |
| FR48 | Unprotected S1G Action frame | 9.6.24 (Unprotected S1G Action frame details) | CFS1G:M | Yes ☐ No ☐ N/A ☐ |
| FR48.1 | AID Switch Request frame | 9.6.24 (Unprotected S1G Action frame details) | (CFIndepSTA AND CFS1G AND (S1GM13 OR S1GM18)):M | Yes ☐ No ☐ N/A ☐ |
| FR48.2 | AID Switch Response frame | 9.6.24 (Unprotected S1G Action frame details) | (CFAP AND CFS1G OR (S1GM13 OR S1GM18)):M | Yes ☐ No ☐ N/A ☐ |


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### B.4.4.2 MAC frames *(continued)*

| Item | MAC frame | References | Status | Support |
|---|---|---|---|---|
| FR48.3 | Sync Control frame | 9.6.24 (Unprotected S1G Action frame details) | (CFIndepSTA AND CFS1G AND S1GM8.1):M | Yes ☐ No ☐ N/A ☐ |
| FR48.4 | STA Information Announcement frame | 9.6.24 (Unprotected S1G Action frame details) | (CFAP AND CFS1G AND S1GM18):M | Yes ☐ No ☐ N/A ☐ |
| FR48.5 | EDCA Parameter Set frame | 9.6.24 (Unprotected S1G Action frame details) | (CFIndepSTA AND CFS1G):M | Yes ☐ No ☐ N/A ☐ |
| FR48.6 | EL Operation frame | 9.6.24 (Unprotected S1G Action frame details) | (CFAP AND CFS1G AND S1GM21):M | Yes ☐ No ☐ N/A ☐ |
| FR48.7 | TWT Setup frame | 9.6.24 (Unprotected S1G Action frame details) | (CFS1G AND S1GM6.2):M | Yes ☐ No ☐ N/A ☐ |
| FR48.8 | TWT Teardown frame | 9.6.24 (Unprotected S1G Action frame details) | (CFS1G AND S1GM6.5):M | Yes ☐ No ☐ N/A ☐ |
| FR48.9 | Sectorized Group ID List frame | 9.6.24 (Unprotected S1G Action frame details) | (CFIndepSTA AND CFS1G AND S1GM11):M | Yes ☐ No ☐ N/A ☐ |
| FR48.10 | Sector ID feedback frame | 9.6.24 (Unprotected S1G Action frame details) | (CFAP AND CFS1G AND S1GM11):M | Yes ☐ No ☐ N/A ☐ |
| FR48.11 | Header Compression frame | | CFS1G: M | Yes ☐ No ☐ N/A ☐ |
| FR48.12 | Header Compression frame | | (CFS1G AND FT47.11):M | Yes ☐ No ☐ N/A ☐ |
| FR48.13 | TWT Information frame | | (CFS1G AND S1GM6):M | Yes ☐ No ☐ N/A ☐ |

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### B.4.4.2 MAC frames *(continued)*

| Item | MAC frame | References | Status | Support |
|---|---|---|---|---|
| FR49 | S1G Action frame | 9.6.25 (S1G Action frame details) | (CFAP AND CFS1G):O | Yes ☐ No ☐ N/A ☐ |
| FR49.1 | Reachable Address Update frame | 9.6.25 (S1G Action frame details) | RL1:M | Yes ☐ No ☐ N/A ☐ |
| FR49.2 | Relay Activation Request frame | 9.6.25 (S1G Action frame details) | RL1:M | Yes ☐ No ☐ N/A ☐ |
| FR49.3 | Relay Activation Response frame | 9.6.25 (S1G Action frame details) | RL1:M | Yes ☐ No ☐ N/A ☐ |
| FR49.4 | Protected TWT Setup frame | 9.6.25 (S1G Action frame details) | S1GM6.13:M | Yes ☐ No ☐ N/A ☐ |
| FR49.5 | Protected TWT Teardown frame | 9.6.25 (S1G Action frame details) | S1GM6.13:M | Yes ☐ No ☐ N/A ☐ |
| FR49.6 | Protected TWT Information frame | 9.6.25 (S1G Action frame details) | S1GM6.13:M | Yes ☐ No ☐ N/A ☐ |
| FR49.7(#1276) | Protected AID Switch Request frame | 9.6.25 (S1G Action frame details) | S1GM30:M | Yes ☐ No ☐ N/A ☐ |
| FR49.8(#1276) | Protected AID Switch Response frame | 9.6.25 (S1G Action frame details) | S1GM30:M | Yes ☐ No ☐ N/A ☐ |
| FR49.9(#1276) | Protected Sync Control | 9.6.25 (S1G Action frame details) | S1GM30:M | Yes ☐ No ☐ N/A ☐ |
| FR49.10(#1276) | Protected STA Information Announcement | 9.6.25 (S1G Action frame details) | S1GM30:M | Yes ☐ No ☐ N/A ☐ |
| FR49.11(#1276) | Protected EDCA Parameter Set | 9.6.25 (S1G Action frame details) | S1GM30:M | Yes ☐ No ☐ N/A ☐ |
| FR49.12(#1276) | Protected EL Operation | 9.6.25 (S1G Action frame details) | S1GM30:M | Yes ☐ No ☐ N/A ☐ |


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### B.4.4.2 MAC frames *(continued)*

| Item | MAC frame | References | Status | Support |
|---|---|---|---|---|
| FR49.13(#1276) | Protected Sectorized Group ID List | 9.6.25 (S1G Action frame details) | S1GM30:M | Yes ☐ No ☐ N/A ☐ |
| FR49.14(#1276) | Protected Sector ID Feedback | 9.6.25 (S1G Action frame details) | S1GM30:M | Yes ☐ No ☐ N/A ☐ |
| FR50 | Flow Control Action frame | 9.6.26(Flow Control Action frame details) | (CFIndepSTA AND CFS1G):O | Yes ☐ No ☐ N/A ☐ |
| FR50.1 | Flow Suspension frame | 9.6.26(Flow Control Action frame details) | (CFIndepSTA AND CFS1G AND S1GM17):M | Yes ☐ No ☐ N/A ☐ |
| FR50.2 | Flow Resumption frame | 9.6.26(Flow Control Action frame details) | (CFIndepSTA AND CFS1G AND S1GM17):M | Yes ☐ No ☐ N/A ☐ |
| FR51 | Control Response MCS Negotiation frame | 9.6.27 (Control Response MCS Negotiation Action frame details(#3175)) | CFS1G AND S1GM28:M | Yes ☐ No ☐ N/A ☐ |
| FR51.1 | Control Response MCS Negotiation Request frame | 9.6.27 (Control Response MCS Negotiation Action frame details(#3175)) | (CFS1G AND S1GM28):M | Yes ☐ No ☐ N/A ☐ |
| FR51.2 | Control Response MCS Negotiation Response frame | 9.6.27 (Control Response MCS Negotiation Action frame details(#3175)) | (CFS1G AND S1GM28):M | Yes ☐ No ☐ N/A ☐ |
| FR52 | LPD MSDU | 5.1.4 (MSDU format) | M | Yes ☐ No ☐ N/A ☐ |

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### B.4.4.2 MAC frames *(continued)*

| Item | MAC frame | References | Status | Support |
|---|---|---|---|---|
| FR53 | EPD MSDU | 5.1.4 (MSDU format), 11.51 (EPD operation) | FT52:M | Yes ☐ No ☐ N/A ☐ |
| (11ax)FR54 | Trigger frame | Clause 9 (Frame formats) | CFHE:O | Yes ☐ No ☐ N/A ☐ |


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### B.4.4.2 MAC frames *(continued)*

| Item | MAC frame | References | Status | Support |
|---|---|---|---|---|
| (11ay)FR55 | Sector Ack | Clause 9 (Frame formats) | EDMG-M16.4:M | Yes ☐ No ☐ |
| (11ay)FR56 | Block Ack Schedule | Clause 9 (Frame formats) | EDMG-M9.2:M | Yes ☐ No ☐ |
| (11ay)FR57 | TDD Beamforming | Clause 9 (Frame formats) | CFTDD:M | Yes ☐ No ☐ |
| (11ba)FR58 | WUR Beacon frame | 9.9.3.1 (WUR Beacon frame format) | (CFWUR AND CFSTAo-fAP):M | Yes ☐ No ☐ N/A ☐ |
| (11ba)FR59 | Individually addressed and broadcast FL WUR Wake-up frame | 9.9.3.2 (WUR Wake-up frame format) | (CFWUR AND CFSTAo-fAP):M | Yes ☐ No ☐ N/A ☐ |
| (11ba)FR60 | FL WUR Wake-up frame with a WUR group ID | 9.9.3.2 (WUR Wake-up frame format) | (CFWUR AND CFSTAo-fAP):O | Yes ☐ No ☐ N/A ☐ |
| (11ba)FR61 | VL WUR Wake-up frame | 9.9.3.2 (WUR Wake-up frame format) | (CFWUR AND CFSTAo-fAP):O | Yes ☐ No ☐ N/A ☐ |
| (11ba)FR62 | WUR Discovery frame | 9.9.3.3 (WUR Discovery frame format) | (CFWUR AND CFSTAo-fAP):O | Yes ☐ No ☐ N/A ☐ |
| (11ba)FR63 | WUR Vendor Specific frame | 9.9.3.4 (WUR Vendor Specific frame format) | (CFWUR AND CFSTAo-fAP):O | Yes ☐ No ☐ N/A ☐ |
| (11ba)FR64 | WUR Mode Setup frame | 9.6.33.2 (WUR Mode Setup frame format) | CFWUR:M | Yes ☐ No ☐ N/A ☐ |
| (11ba)FR65 | WUR Mode Teardown frame | 9.6.33.3 (WUR Mode Teardown frame format) | CFWUR:M | Yes ☐ No ☐ N/A ☐ |
| (11ba)FR66 | WUR Short Wake-up frame | 9.9.3.5 (WUR Short Wake-up frame format) | CFWUR:O | Yes ☐ No ☐ N/A ☐ |

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### B.4.4.2 MAC frames *(continued)*

| Item | MAC frame | References | Status | Support |
|---|---|---|---|---|
| (11az)FR67 | FTM Request | 11.21.6.3 (FTM procedure negotiation(11az)) | CFRSTA:M (CFTB OR CFNTB):M | Yes ☐ No ☐ N/A ☐ |
| (11az)FR68 | FTM | 11.21.6.3 (FTM procedure negotiation(11az)) | CFISTA:M (CFTB OR CFNTB):M | Yes ☐ No ☐ N/A ☐ |
| (11az)FR69 | LMR | 9.3.1.22.10 (Ranging Trigger variant(11az)), 11.21.6.4.3 (TB ranging measurement exchange(11az)) | (CFRSTA OR CFISTA):M (CFTB OR CFNTB ):M | Yes ☐ No ☐ N/A ☐ |
| (11az)FR70 | Receive of TF of type Ranging for TB ranging operation | 9.3.1.22.10 (Ranging Trigger variant(11az)), 11.21.6.4.3 (TB ranging measurement exchange(11az)) | CFISTA:M CFTB:M | Yes ☐ No ☐ N/A ☐ |
| (11az)FR71 | Receive of Ranging NDP Announcement frame for TB ranging operation | 9.3.1.22.10 (Ranging Trigger variant(11az)), 11.21.6.4.3 (TB ranging measurement exchange(11az)) | CFISTA:M CFTB:M | Yes ☐ No ☐ N/A ☐ |
| (11az)FR72 | Receive of Ranging NDP Announcement frame for non-TB ranging operation | 9.3.1.22.10 (Ranging Trigger variant(11az)), 11.21.6.4.4 (Non-TB ranging measurement exchange(11az)) | CFRSTA:M CFNTB:M | Yes ☐ No ☐ N/A ☐ |


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### B.4.4.2 MAC frames *(continued)*

| Item | MAC frame | References | Status | Support |
|---|---|---|---|---|
| (11az)FR73 | Reception of TF subvariant Passive Sounding | 9.3.1.23.5 (Passive sounding subvariant) | (CFISTA AND CFPTB):M CFPLPSTA:M | Yes ☐ No ☐ N/A ☐ |
| (11az)FR74 | Reception of Ranging NDP Announcement frame | 9.3.1.19 (VHT/HE/ Ranging NDP Announcement frame format(11ax )(11az)) | (CFISTA AND CFPTB):M CFPLPSTA:M | Yes ☐ No ☐ N/A ☐ |

### B.4.4.3 Frame exchange sequences

| Item | Frame exchange sequence | References | Status | Support |
|---|---|---|---|---|
| | Are the following frame exchange sequences supported? | | | |
| FS1 | Basic frame exchange sequences | 10.3.2.6 (RTS/CTS with fragmentation), 10.3.2.9 (CTS and DMG CTS procedure), 10.3.2.11 (Acknowledgment procedure), 10.3.5 (Individually addressed MPDU transfer procedure), 10.3.6 (Group addressed MPDU transfer procedure) | M | Yes ☐ No ☐ |

### B.4.4.4 MAC addressing functions

| Item | MAC Address function | References | Status | Support |
|---|---|---|---|---|
| | Are the following MAC Addressing functions supported? | | | |
| AD1 | STA universal individual IEEE 802 address | 9.2.4.3 (Address fields) | M | Yes ☐ No ☐ |
| AD2 | BSS identification (BSSID) generation | 9.2.4.3 (Address fields), 11.1.4 (Acquiring synchronization , scanning) | M | Yes ☐ No ☐ |

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### B.4.4.4 MAC addressing functions *(continued)*

| Item | MAC Address function | References | Status | Support |
|---|---|---|---|---|
| AD3 | Receiver address matching | 9.2.4.3 (Address fields), 9.3.2.1 (Format of Data frames) | M | Yes ☐ No ☐ |
| AD4 | Wildcard BSSID | 9.2.4.3.4 (BSSID field), 9.3.2 (Data frames) | CFOCB:M | Yes ☐ No ☐ N/A ☐ |
| AD5 | MAC and PHY operation resumes with appropriate MIB attributes in less than 2 TU | 11.18 (STAs communicating Data frames outside the context of a BSS) | CFOCB:M | Yes ☐ No ☐ N/A ☐ |
| AD6 | Group addressed mesh Data frame addressing (3 address frame) | 9.2.3 (General frame format), 9.2.4.1 (Frame Control field), 9.2.4.3 (Address fields), 9.3.5 (Frame addressing in an MBSS) | CFMBSS:M | Yes ☐ No ☐ N/A ☐ |
| AD7 | Individually addressed mesh Data frame addressing (4 address frame) | 9.2.3 (General frame format), 9.2.4.1 (Frame Control field), 9.2.4.3 (Address fields), 9.3.5 (Frame addressing in an MBSS) | CFMBSS:M | Yes ☐ No ☐ N/A ☐ |
| AD8 | Proxied group addressed mesh Data frame addressing (4 address frame) | 9.2.3 (General frame format), 9.2.4.1 (Frame Control field), 9.2.4.3 (Address fields), 9.2.4.8.3 (Mesh Control field), 9.3.5 (Frame addressing in an MBSS) | CFMBSS:M | Yes ☐ No ☐ N/A ☐ |


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### B.4.4.4 MAC addressing functions *(continued)*

| Item | MAC Address function | References | Status | Support |
|---|---|---|---|---|
| AD9 | Proxied individually addressed mesh Data frame addressing (6 address frame) | 9.2.3 (General frame format), 9.2.4.1 (Frame Control field), 9.2.4.3 (Address fields), 9.2.4.8.3 (Mesh Control field), 9.3.5 (Frame addressing in an MBSS) | CFMBSS:M | Yes ☐ No ☐ N/A ☐ |
| AD10 | Multihop Action frame addressing (4 address frame) | 9.2.3 (General frame format), 9.2.4.1 (Frame Control field), 9.2.4.3 (Address fields), 9.2.4.8.3 (Mesh Control field), 9.6.17 (Multihop Action frame details), 9.3.5 (Frame addressing in an MBSS) | CFMBSS:M | Yes ☐ No ☐ N/A ☐ |
| AD11 | TA filtering for mesh STA | 9.2.4.3 (Address fields), 9.3.2.1 (Format of Data frames), 9.3.5 (Frame addressing in an MBSS) | CFMBSS:M | Yes ☐ No ☐ N/A ☐ |
| (M118)* AD12 | Group addressed Data frame addressing (4 address frame) | 9.2.3 (General frame format), 9.2.4.1 (Frame Control field), 9.2.4.3 (Address fields) | CFS1GRelay: O<br>RL2:O<br>CFAP: O<br>CFIndepSTA: O | Yes ☐ No ☐ N/A ☐ |
| (M118)* AD13 | Individually addressed Data frame addressing (4 address frame) | 9.2.3 (General frame format), 9.2.4.1 (Frame Control field), 9.2.4.3 (Address fields) | CFS1GRelay: O<br>RL2:O<br>CFAP: O<br>CFIndepSTA: O | Yes ☐ No ☐ N/A ☐ |

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### B.4.4.4 MAC addressing functions *(continued)*

| Item | MAC Address function | References | Status | Support |
|---|---|---|---|---|
| (M118)* AD14 | Group addressed PV1 Data frame addressing (4 address frame) | 9.8 (MAC frame format for PV1 frames)(#2288), 10.53.4 (Addressing and forwarding of group addressed relay frames), 10.53.3 (Addressing and forwarding of individually addressed relay frames) | CFS1GRelay: O<br>RL2:O<br>CFS1G: O | Yes ☐ No ☐ N/A ☐ |
| (M118)* AD15 | Individually addressed PV1 Data frame addressing (4 address frame) | 9.8 (MAC frame format for PV1 frames)(#2288), 10.53.4 (Addressing and forwarding of group addressed relay frames), 10.53.3 (Addressing and forwarding of individually addressed relay frames) | CFS1GRelay: O<br>RL2:O<br>CFS1G: O | Yes ☐ No ☐ N/A ☐ |
| AD16 | Receive SYNRA | 10.65 (SYNRA filtering operation) | (CFGLK AND CFIndep-STA):M | Yes ☐ No ☐ N/A ☐ |
| AD17 | Transmit SYNRA | 10.65 (SYNRA filtering operation) | (CFGLK AND CFAP):O | Yes ☐ No ☐ N/A ☐ |

## B.4.5 Direct sequence PHY functions

| Item | PHY feature | References | Status | Support |
|---|---|---|---|---|
| | PHY layer(#4114) procedures | 15.3 (DSSS PHY) | | |
| DS1 | Preamble prepend on transmit (TX) | 15.3.1 (Overview) | M | Yes ☐ No ☐ |
| DS1.1 | PHY frame format | 15.3.2 (PPDU format), 15.3.3 (PHY field definitions) | M | Yes ☐ No ☐ |


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## B.4.5 Direct sequence PHY functions *(continued)*

| Item | PHY feature | References | Status | Support |
|---|---|---|---|---|
| DS1.2 | PHY integrity check generation | 15.3.3 (PHY field definitions), 15.3.3.7 (PHY CRC field) | M | Yes ☐ No ☐ |
| DS1.3 | TX rate change capability | (#1369)15.2.3 (RXVECTOR parameters(#1369)), 15.3.5 (PHY data modulation and modulation rate change) | M | Yes ☐ No ☐ |
| DS1.4 | Supported data rates | 15.1 (Overview), (#1369)15.2.3 (RXVECTOR parameters(#1369)) | M | Yes ☐ No ☐ |
| DS1.5 | Data whitener scrambler | 15.3.4 (PHY/ DSSS PHY data scrambler and descrambler) | M | Yes ☐ No ☐ |
| DS1.6 | Scrambler initialization | 15.3.4 (PHY/ DSSS PHY data scrambler and descrambler) | M | Yes ☐ No ☐ |
| DS2 | Preamble process on receive (RX) | 15.3.1 (Overview) | | |
| DS2.1 | PHY frame format | 15.3.2 (PPDU format), 15.3.3 (PHY field definitions) | M | Yes ☐ No ☐ |
| DS2.2 | PHY integrity check verify | 15.3.3 (PHY field definitions), 15.3.3.7 (PHY CRC field) | M | Yes ☐ No ☐ |
| DS2.3 | RX Rate change capability | (#1369)15.2.3 (RXVECTOR parameters(#1369)), 15.3.5 (PHY data modulation and modulation rate change) | M | Yes ☐ No ☐ |
| DS2.4 | Data whitener descrambler | 15.3.4 (PHY/ DSSS PHY data scrambler and descrambler) | M | Yes ☐ No ☐ |
| DS3 | Pseudonoise (PN) code sequence | 15.4.4.4 (Spreading sequence) | M | Yes ☐ No ☐ |
| DS4 | Chipping continue on power-down | 15.3.6 (Transmit PHY) | O | Yes ☐ No ☐ |

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## B.4.5 Direct sequence PHY functions *(continued)*

| Item | PHY feature | References | Status | Support |
|---|---|---|---|---|
| *DS5 | Operating channel capability | 15.3.6 (Transmit PHY), 15.4.4.3 (Channel Numbering of operating channels) | | |
| * DS5.1 | United States and its territories (FCC)(#7179) | 15.3.6 (Transmit PHY), 15.4.4.3 (Channel Numbering of operating channels) | DS5:O.1 | Yes ☐ No ☐ N/A ☐ |
| DS5.1.1 | Channel 1 | 15.3.6 (Transmit PHY), 15.4.4.3 (Channel Numbering of operating channels) | DS5.1:M | Yes ☐ No ☐ N/A ☐ |
| DS5.1.2 | Channel 2 | 15.3.6 (Transmit PHY), 15.4.4.3 (Channel Numbering of operating channels) | DS5.1:M | Yes ☐ No ☐ N/A ☐ |
| DS5.1.3 | Channel 3 | 15.3.6 (Transmit PHY), 15.4.4.3 (Channel Numbering of operating channels) | DS5.1:M | Yes ☐ No ☐ N/A ☐ |
| DS5.1.4 | Channel 4 | 15.3.6 (Transmit PHY), 15.4.4.3 (Channel Numbering of operating channels) | DS5.1:M | Yes ☐ No ☐ N/A ☐ |
| DS5.1.5 | Channel 5 | 15.3.6 (Transmit PHY), 15.4.4.3 (Channel Numbering of operating channels) | DS5.1:M | Yes ☐ No ☐ N/A ☐ |
| DS5.1.6 | Channel 6 | 15.3.6 (Transmit PHY), 15.4.4.3 (Channel Numbering of operating channels) | DS5.1:M | Yes ☐ No ☐ N/A ☐ |
| DS5.1.7 | Channel 7 | 15.3.6 (Transmit PHY), 15.4.4.3 (Channel Numbering of operating channels) | DS5.1:M | Yes ☐ No ☐ N/A ☐ |


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## B.4.5 Direct sequence PHY functions *(continued)*

| Item | PHY feature | References | Status | Support |
|---|---|---|---|---|
| DS5.1.8 | Channel 8 | 15.3.6 (Transmit PHY), 15.4.4.3 (Channel Numbering of operating channels) | DS5.1:M | Yes ☐ No ☐ N/A ☐ |
| DS5.1.9 | Channel 9 | 15.3.6 (Transmit PHY), 15.4.4.3 (Channel Numbering of operating channels) | DS5.1:M | Yes ☐ No ☐ N/A ☐ |
| DS5.1.10 | Channel 10 | 15.3.6 (Transmit PHY), 15.4.4.3 (Channel Numbering of operating channels) | DS5.1:M | Yes ☐ No ☐ N/A ☐ |
| DS5.1.11 | Channel 11 | 15.3.6 (Transmit PHY), 15.4.4.3 (Channel Numbering of operating channels) | DS5.1:M | Yes ☐ No ☐ N/A ☐ |
| * DS5.2 | Canada (IC) | 15.3.6 (Transmit PHY), 15.4.4.3 (Channel Numbering of operating channels) | DS5:O.1 | Yes ☐ No ☐ N/A ☐ |
| DS5.2.1 | Channel 1 | 15.3.6 (Transmit PHY), 15.4.4.3 (Channel Numbering of operating channels) | DS5.2:M | Yes ☐ No ☐ N/A ☐ |
| DS5.2.2 | Channel 2 | 15.3.6 (Transmit PHY), 15.4.4.3 (Channel Numbering of operating channels) | DS5.2:M | Yes ☐ No ☐ N/A ☐ |
| DS5.2.3 | Channel 3 | 15.3.6 (Transmit PHY), 15.4.4.3 (Channel Numbering of operating channels) | DS5.2:M | Yes ☐ No ☐ N/A ☐ |
| DS5.2.4 | Channel 4 | 15.3.6 (Transmit PHY), 15.4.4.3 (Channel Numbering of operating channels) | DS5.2:M | Yes ☐ No ☐ N/A ☐ |

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## B.4.5 Direct sequence PHY functions *(continued)*

| Item | PHY feature | References | Status | Support |
|---|---|---|---|---|
| DS5.2.5 | Channel 5 | 15.3.6 (Transmit PHY), 15.4.4.3 (Channel Numbering of operating channels) | DS5.2:M | Yes ☐ No ☐ N/A ☐ |
| DS5.2.6 | Channel 6 | 15.3.6 (Transmit PHY), 15.4.4.3 (Channel Numbering of operating channels) | DS5.2:M | Yes ☐ No ☐ N/A ☐ |
| DS5.2.7 | Channel 7 | 15.3.6 (Transmit PHY), 15.4.4.3 (Channel Numbering of operating channels) | DS5.2:M | Yes ☐ No ☐ N/A ☐ |
| DS5.2.8 | Channel 8 | 15.3.6 (Transmit PHY), 15.4.4.3 (Channel Numbering of operating channels) | DS5.2:M | Yes ☐ No ☐ N/A ☐ |
| DS5.2.9 | Channel 9 | 15.3.6 (Transmit PHY), 15.4.4.3 (Channel Numbering of operating channels) | DS5.2:M | Yes ☐ No ☐ N/A ☐ |
| DS5.2.10 | Channel 10 | 15.3.6 (Transmit PHY), 15.4.4.3 (Channel Numbering of operating channels) | DS5.2:M | Yes ☐ No ☐ N/A ☐ |
| DS5.2.11 | Channel 11 | 15.3.6 (Transmit PHY), 15.4.4.3 (Channel Numbering of operating channels) | DS5.2:M | Yes ☐ No ☐ N/A ☐ |
| * DS5.3 | Europe (ETSI) | 15.3.6 (Transmit PHY), 15.4.4.3 (Channel Numbering of operating channels) | DS5:O.1 | Yes ☐ No ☐ N/A ☐ |
| DS5.3.1 | Channel 1 | 15.3.6 (Transmit PHY), 15.4.4.3 (Channel Numbering of operating channels) | DS5.3:M | Yes ☐ No ☐ N/A ☐ |


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## B.4.5 Direct sequence PHY functions *(continued)*

| Item | PHY feature | References | Status | Support |
|---|---|---|---|---|
| DS5.3.2 | Channel 2 | 15.3.6 (Transmit PHY), 15.4.4.3 (Channel Numbering of operating channels) | DS5.3:M | Yes ☐ No ☐ N/A ☐ |
| DS5.3.3 | Channel 3 | 15.3.6 (Transmit PHY), 15.4.4.3 (Channel Numbering of operating channels) | DS5.3:M | Yes ☐ No ☐ N/A ☐ |
| DS5.3.4 | Channel 4 | 15.3.6 (Transmit PHY), 15.4.4.3 (Channel Numbering of operating channels) | DS5.3:M | Yes ☐ No ☐ N/A ☐ |
| DS5.3.5 | Channel 5 | 15.3.6 (Transmit PHY), 15.4.4.3 (Channel Numbering of operating channels) | DS5.3:M | Yes ☐ No ☐ N/A ☐ |
| DS5.3.6 | Channel 6 | 15.3.6 (Transmit PHY), 15.4.4.3 (Channel Numbering of operating channels) | DS5.3:M | Yes ☐ No ☐ N/A ☐ |
| DS5.3.7 | Channel 7 | 15.3.6 (Transmit PHY), 15.4.4.3 (Channel Numbering of operating channels) | DS5.3:M | Yes ☐ No ☐ N/A ☐ |
| DS5.3.8 | Channel 8 | 15.3.6 (Transmit PHY), 15.4.4.3 (Channel Numbering of operating channels) | DS5.3:M | Yes ☐ No ☐ N/A ☐ |
| DS5.3.9 | Channel 9 | 15.3.6 (Transmit PHY), 15.4.4.3 (Channel Numbering of operating channels) | DS5.3:M | Yes ☐ No ☐ N/A ☐ |
| DS5.3.10 | Channel 10 | 15.3.6 (Transmit PHY), 15.4.4.3 (Channel Numbering of operating channels) | DS5.3:M | Yes ☐ No ☐ N/A ☐ |

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## B.4.5 Direct sequence PHY functions *(continued)*

| Item | PHY feature | References | Status | Support |
|---|---|---|---|---|
| DS5.3.11 | Channel 11 | 15.3.6 (Transmit PHY), 15.4.4.3 (Channel Numbering of operating channels) | DS5.3:M | Yes ☐ No ☐ N/A ☐ |
| DS5.3.12 | Channel 12 | 15.3.6 (Transmit PHY), 15.4.4.3 (Channel Numbering of operating channels) | DS5.3:M | Yes ☐ No ☐ N/A ☐ |
| DS5.3.13 | Channel 13 | 15.3.6 (Transmit PHY), 15.4.4.3 (Channel Numbering of operating channels) | DS5.3:M | Yes ☐ No ☐ N/A ☐ |
| * DS5.4 | France | 15.3.6 (Transmit PHY), 15.4.4.3 (Channel Numbering of operating channels) | DS5:O.1 | Yes ☐ No ☐ N/A ☐ |
| DS5.4.1 | Channel 10 | 15.3.6 (Transmit PHY), 15.4.4.3 (Channel Numbering of operating channels) | DS5.4:M | Yes ☐ No ☐ N/A ☐ |
| DS5.4.2 | Channel 11 | 15.3.6 (Transmit PHY), 15.4.4.3 (Channel Numbering of operating channels) | DS5.4:M | Yes ☐ No ☐ N/A ☐ |
| DS5.4.3 | Channel 12 | 15.3.6 (Transmit PHY), 15.4.4.3 (Channel Numbering of operating channels) | DS5.4:M | Yes ☐ No ☐ N/A ☐ |
| DS5.4.4 | Channel 13 | 15.3.6 (Transmit PHY), 15.4.4.3 (Channel Numbering of operating channels) | DS5.4:M | Yes ☐ No ☐ N/A ☐ |
| * DS5.5 | Spain | 15.3.6 (Transmit PHY), 15.4.4.3 (Channel Numbering of operating channels) | DS5:O.1 | Yes ☐ No ☐ N/A ☐ |


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## B.4.5 Direct sequence PHY functions *(continued)*

| Item | PHY feature | References | Status | Support |
|---|---|---|---|---|
| DS5.5.1 | Channel 10 | 15.3.6 (Transmit PHY), 15.4.4.3 (Channel Numbering of operating channels) | DS5.5:M | Yes ☐ No ☐ N/A ☐ |
| DS5.5.2 | Channel 11 | 15.3.6 (Transmit PHY), 15.4.4.3 (Channel Numbering of operating channels) | DS5.5:M | Yes ☐ No ☐ N/A ☐ |
| (M118)DS5.6 | Japan | 15.3.6 (Transmit PHY), 15.4.4.3 (Channel Numbering of operating channels) | DS5:O.1 | Yes ☐ No ☐ N/A ☐ |
| * DS5.7 | China | 15.3.6 (Transmit PHY), 15.4.4.3 (Channel Numbering of operating channels) | DS5:O.1 | Yes ☐ No ☐ N/A ☐ |
| DS5.7.1 | Channel 1 | 15.3.6 (Transmit PHY), 15.4.4.3 (Channel Numbering of operating channels) | DS5.7:M | Yes ☐ No ☐ N/A ☐ |
| DS5.7.2 | Channel 2 | 15.3.6 (Transmit PHY), 15.4.4.3 (Channel Numbering of operating channels) | DS5.7:M | Yes ☐ No ☐ N/A ☐ |
| DS5.7.3 | Channel 3 | 15.3.6 (Transmit PHY), 15.4.4.3 (Channel Numbering of operating channels) | DS5.7:M | Yes ☐ No ☐ N/A ☐ |
| DS5.7.4 | Channel 4 | 15.3.6 (Transmit PHY), 15.4.4.3 (Channel Numbering of operating channels) | DS5.7:M | Yes ☐ No ☐ N/A ☐ |
| DS5.7.5 | Channel 5 | 15.3.6 (Transmit PHY), 15.4.4.3 (Channel Numbering of operating channels) | DS5.7:M | Yes ☐ No ☐ N/A ☐ |

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## B.4.5 Direct sequence PHY functions *(continued)*

| Item | PHY feature | References | Status | Support |
|---|---|---|---|---|
| DS5.7.6 | Channel 6 | 15.3.6 (Transmit PHY), 15.4.4.3 (Channel Numbering of operating channels) | DS5.7:M | Yes ☐ No ☐ N/A ☐ |
| DS5.7.7 | Channel 7 | 15.3.6 (Transmit PHY), 15.4.4.3 (Channel Numbering of operating channels) | DS5.7:M | Yes ☐ No ☐ N/A ☐ |
| DS5.7.8 | Channel 8 | 15.3.6 (Transmit PHY), 15.4.4.3 (Channel Numbering of operating channels) | DS5.7:M | Yes ☐ No ☐ N/A ☐ |
| DS5.7.9 | Channel 9 | 15.3.6 (Transmit PHY), 15.4.4.3 (Channel Numbering of operating channels) | DS5.7:M | Yes ☐ No ☐ N/A ☐ |
| DS5.7.10 | Channel 10 | 15.3.6 (Transmit PHY), 15.4.4.3 (Channel Numbering of operating channels) | DS5.7:M | Yes ☐ No ☐ N/A ☐ |
| DS5.7.11 | Channel 11 | 15.3.6 (Transmit PHY), 15.4.4.3 (Channel Numbering of operating channels) | DS5.7:M | Yes ☐ No ☐ N/A ☐ |
| DS5.7.12 | Channel 12 | 15.3.6 (Transmit PHY), 15.4.4.3 (Channel Numbering of operating channels) | DS5.7:M | Yes ☐ No ☐ N/A ☐ |
| DS5.7.13 | Channel 13 | 15.3.6 (Transmit PHY), 15.4.4.3 (Channel Numbering of operating channels) | DS5.7:M | Yes ☐ No ☐ N/A ☐ |
| * DS5.8 (#7179) | Mexico (IFT) | 15.3.6 (Transmit PHY), 15.4.4.3 (Channel Numbering of operating channels) | DS5:O.1 | Yes ☐ No ☐ N/A ☐ |


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## B.4.5 Direct sequence PHY functions *(continued)*

| Item | PHY feature | References | Status | Support |
|---|---|---|---|---|
| DS5.8.1 (#7179) | Channel 1 | 15.3.6 (Transmit PHY), 15.4.4.3 (Channel Numbering of operating channels) | DS5.8:M | Yes ☐ No ☐ N/A ☐ |
| DS5.8.2 (#7179) | Channel 2 | 15.3.6 (Transmit PHY), 15.4.4.3 (Channel Numbering of operating channels) | DS5.8:M | Yes ☐ No ☐ N/A ☐ |
| DS5.8.3 (#7179) | Channel 3 | 15.3.6 (Transmit PHY), 15.4.4.3 (Channel Numbering of operating channels) | DS5.8:M | Yes ☐ No ☐ N/A ☐ |
| DS5.8.4 (#7179) | Channel 4 | 15.3.6 (Transmit PHY), 15.4.4.3 (Channel Numbering of operating channels) | DS5.8:M | Yes ☐ No ☐ N/A ☐ |
| DS5.8.5 (#7179) | Channel 5 | 15.3.6 (Transmit PHY), 15.4.4.3 (Channel Numbering of operating channels) | DS5.8:M | Yes ☐ No ☐ N/A ☐ |
| DS5.8.6 (#7179) | Channel 6 | 15.3.6 (Transmit PHY), 15.4.4.3 (Channel Numbering of operating channels) | DS5.8:M | Yes ☐ No ☐ N/A ☐ |
| DS5.8.7 (#7179) | Channel 7 | 15.3.6 (Transmit PHY), 15.4.4.3 (Channel Numbering of operating channels) | DS5.8:M | Yes ☐ No ☐ N/A ☐ |
| DS5.8.8 (#7179) | Channel 8 | 15.3.6 (Transmit PHY), 15.4.4.3 (Channel Numbering of operating channels) | DS5.8:M | Yes ☐ No ☐ N/A ☐ |
| DS5.8.9 (#7179) | Channel 9 | 15.3.6 (Transmit PHY), 15.4.4.3 (Channel Numbering of operating channels) | DS5.8:M | Yes ☐ No ☐ N/A ☐ |

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## B.4.5 Direct sequence PHY functions *(continued)*

| Item | PHY feature | References | Status | Support |
|---|---|---|---|---|
| DS5.8.10 (#7179) | Channel 10 | 15.3.6 (Transmit PHY), 15.4.4.3 (Channel Numbering of operating channels) | DS5.8:M | Yes ☐ No ☐ N/A ☐ |
| DS5.8.11 (#7179) | Channel 11 | 15.3.6 (Transmit PHY), 15.4.4.3 (Channel Numbering of operating channels) | DS5.8:M | Yes ☐ No ☐ N/A ☐ |
| DS6 | Bits to symbol mapping | 15.4.4.5 (Modulation and channel data rates) | | |
| DS6.1 | 1 Mb/s | 15.4.4.5 (Modulation and channel data rates) | M | Yes ☐ No ☐ |
| DS6.2 | 2 Mb/s | 15.4.4.5 (Modulation and channel data rates) | M | Yes ☐ No ☐ |
| *DS7 | CCA functionality | 15.4.6.5 (CCA) | | |
| DS7.1 | (M118)Energy only (RSSI above threshold) | 15.4.6.5 (CCA) | DS7:O.2 | Yes ☐ No ☐ N/A ☐ |
| DS7.2 | IEEE 802.11 DSSS correlation | 15.4.6.5 (CCA) | DS7:O.2 | Yes ☐ No ☐ N/A ☐ |
| DS7.3 | Both methods | 15.4.6.5 (CCA) | DS7:O.2 | Yes ☐ No ☐ N/A ☐ |
| DS7.4 | Hold CCA busy for (#14)PPDU duration of a correctly received PPDU but carrier lost during reception of MPDU | 15.3.7 (Receive PHY) | M | Yes ☐ No ☐ |
| DS7.5 | Hold CCA busy for (#14)PPDU duration of a correctly received but out of specification PPDU | 15.3.7 (Receive PHY) | M | Yes ☐ No ☐ |
| DS8 | Transmit antenna selection | | O | Yes ☐ No ☐ |
| DS9 | Receive antenna diversity | (#1369)15.2.3 (RXVECTOR parameters(#1369)) | O | Yes ☐ No ☐ |
| *DS10 | Antenna connector availability | 15.4.4.10 (Transmit and receive antenna connector impedance) | O | Yes ☐ No ☐ |
| DS10.1 | 50 Ω impedance | 15.4.4.10 (Transmit and receive antenna connector impedance) | DS10:M | Yes ☐ No ☐ N/A ☐ |


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## B.4.5 Direct sequence PHY functions *(continued)*

| Item | PHY feature | References | Status | Support |
|---|---|---|---|---|
| *DS11 | Transmit power level support | 15.4.5.4 (Transmit power level control) | O | Yes ☐ No ☐ |
| DS11.1 | If greater than 100 mW capability | 15.4.5.4 (Transmit power level control) | DS11:M | Yes ☐ No ☐ N/A ☐ |
| DS12 | Spurious emissions compliance | 15.4.4.6 (Transmit and receive in-band and out-of-band spurious emissions) | M | Yes ☐ No ☐ |
| DS13 | TX-to-RX turnaround time | 15.4.4.7 (TX-to-RX turnaround time) | M | Yes ☐ No ☐ |
| DS14 | RX-to-TX turnaround time | 15.4.4.8 (RX-to-TX turnaround time) | M | Yes ☐ No ☐ |
| DS15 | Slot time | 15.4.4.9 (Slot time) | M | Yes ☐ No ☐ |
| DS16 | Energy detection (ED) reporting time | 15.4.4.9 (Slot time), 15.4.6.5 (CCA) | M | Yes ☐ No ☐ |
| DS17 | Minimum transmit power level | 15.4.5.3 (Minimum transmitted power level) | M | Yes ☐ No ☐ |
| DS18 | Transmit spectral mask compliance | 15.4.5.5 (Transmit spectrum mask) | M | Yes ☐ No ☐ |
| DS19 | Transmitted center frequency tolerance | 15.4.5.6 (Transmit center frequency tolerance) | M | Yes ☐ No ☐ |
| DS20 | Chip clock frequency tolerance | 15.4.5.7 (Chip clock frequency tolerance) | M | Yes ☐ No ☐ |
| DS21 | Transmit power-on ramp | 15.4.5.8 (Transmit power-on and power-down ramp) | M | Yes ☐ No ☐ |
| DS22 | Transmit power-down ramp | 15.4.5.8 (Transmit power-on and power-down ramp) | M | Yes ☐ No ☐ |
| DS23 | Radio frequency (RF) carrier suppression | 15.4.5.9 (RF carrier suppression) | M | Yes ☐ No ☐ |

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## B.4.5 Direct sequence PHY functions *(continued)*

| Item | PHY feature | References | Status | Support |
|---|---|---|---|---|
| DS24 | Transmit modulation accuracy | 15.4.5.10 (Transmit modulation accuracy) | M | Yes ☐ No ☐ |
| DS25 | Receiver minimum input level sensitivity | 15.4.6.2 (Receiver minimum input level sensitivity) | M | Yes ☐ No ☐ |
| DS26 | Receiver maximum input level | 15.4.6.3 (Receiver maximum input level) | M | Yes ☐ No ☐ |
| DS27 | Receiver adjacent channel rejection | 15.4.6.4 (Receiver adjacent channel rejection) | M | Yes ☐ No ☐ |
| DS28 | MIB | 15.4.2 (DSSS PHY MIB), Annex C | M | Yes ☐ No ☐ |
| DS28.1 | dot11PhyDSSSComplianceGroup, dot11PhyRegDomainsSupportGroup, and dot11PhyOperationComplianceGroup | 15.4.2 (DSSS PHY MIB) | M | Yes ☐ No ☐ |

## B.4.6 OFDM PHY functions

| Item | Feature | References | Status | Support |
|---|---|---|---|---|
| **OF1: OFDM PHY Specific Service Parameters** | | | | |
| OF1.1 | TXVECTOR parameter: LENGTH | (#1369)17.2.2 (TXVECTOR parameters(#1369)) | M | Yes ☐ No ☐ |
| OF1.2 | TXVECTOR parameter: DATARATE | (#1369)17.2.2 (TXVECTOR parameters(#1369)) | M | Yes ☐ No ☐ |
| OF1.2.1 | DATARATE = 6.0 Mb/s | (#1369)17.2.2 (TXVECTOR parameters(#1369)) | M | Yes ☐ No ☐ |


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## B.4.6 OFDM PHY functions *(continued)*

| Item | Feature | References | Status | Support |
|---|---|---|---|---|
| *OF1.2.2 | DATARATE = 9.0 Mb/s | (#1369)17.2.2 (TXVECTOR parameters(#1369)) | O | Yes ☐ No ☐ |
| OF1.2.3 | DATARATE = 12.0 Mb/s | (#1369)17.2.2 (TXVECTOR parameters(#1369)) | M | Yes ☐ No ☐ |
| *OF1.2.4 | DATARATE = 18.0 Mb/s | (#1369)17.2.2 (TXVECTOR parameters(#1369)) | O | Yes ☐ No ☐ |
| *OF1.2.5 | DATARATE = 24.0 Mb/s | (#1369)17.2.2 (TXVECTOR parameters(#1369)), Annex E | (NOT CF3G6):M CF3G6:O | Yes ☐ No ☐ |
| *OF1.2.6 | DATARATE = 36.0 Mb/s | (#1369)17.2.2 (TXVECTOR parameters(#1369)) | O | Yes ☐ No ☐ |
| *OF1.2.7 | DATARATE = 48.0 Mb/s | (#1369)17.2.2 (TXVECTOR parameters(#1369)) | O | Yes ☐ No ☐ |
| *OF1.2.8 | DATARATE = 54.0 Mb/s | (#1369)17.2.2 (TXVECTOR parameters(#1369)) | O | Yes ☐ No ☐ |
| OF1.3 | TXVECTOR parameter: SERVICE | (#1369)17.2.2 (TXVECTOR parameters(#1369)) | M | Yes ☐ No ☐ |
| OF1.4 | TXVECTOR parameter: TXPWR_LEVEL_INDEX | (#1369)17.2.2 (TXVECTOR parameters(#1369)) | M | Yes ☐ No ☐ |

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## B.4.6 OFDM PHY functions *(continued)*

| Item | Feature | References | Status | Support |
|---|---|---|---|---|
| OF1.5 | RXVECTOR parameter: LENGTH | (#1369)17.2.2 (TXVECTOR parameters(#1369)) | M | Yes ☐ No ☐ |
| OF1.6 | RXVECTOR parameter: RSSI | (#1369)17.2.3 (RXVECTOR parameters(#1369)) | M | Yes ☐ No ☐ |
| *OF1.7 | 10 MHz Channel spacing | (#1369)17.2.2 (TXVECTOR parameters(#1369)), 17.2.3 (RXVECTOR parameters(#1369)), Annex E | CFOC:O CF3G6 AND DSE2:M | Yes ☐ No ☐ N/A ☐ |
| *OF1.7.1 | DATARATE = 3 Mb/s (10 MHz channel spacing) | 17.2.2 (TXVECTOR parameters(#1369)), 17.2.3 (RXVECTOR parameters(#1369))(#1369) | CFOC AND OF1.7:M | Yes ☐ No ☐ N/A ☐ |
| *OF1.7.2 | DATARATE = 4.5 Mb/s (10 MHz channel spacing) | 17.2.2 (TXVECTOR parameters(#1369)), 17.2.3 (RXVECTOR parameters(#1369))(#1369) | CFOC AND OF1.7:O | Yes ☐ No ☐ N/A ☐ |
| *OF1.7.3 | DATARATE = 6 Mb/s (10 MHz channel spacing) | 17.2.2 (TXVECTOR parameters(#1369)), 17.2.3 (RXVECTOR parameters(#1369))(#1369) | CFOC AND OF1.7:M | Yes ☐ No ☐ N/A ☐ |


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## B.4.6 OFDM PHY functions *(continued)*

| Item | Feature | References | Status | Support |
|---|---|---|---|---|
| *OF1.7.4 | DATARATE = 9 Mb/s (10 MHz channel spacing) | 17.2.2 (TXVECTOR parameters(#1369)), 17.2.3 (RXVECTOR parameters(#1369))(#1369) | CFOC AND OF1.7:O | Yes ☐ No ☐ N/A ☐ |
| *OF1.7.5 | DATARATE = 12 Mb/s (10 MHz channel spacing) | 17.2.2 (TXVECTOR parameters(#1369)), 17.2.3 (RXVECTOR parameters(#1369))(#1369) | CFOC AND OF1.7:M | Yes ☐ No ☐ N/A ☐ |
| *OF1.7.6 | DATARATE = 18 Mb/s (10 MHz channel spacing) | 17.2.2 (TXVECTOR parameters(#1369)), 17.2.3 (RXVECTOR parameters(#1369))(#1369) | CFOC AND OF1.7:O | Yes ☐ No ☐ N/A ☐ |
| *OF1.7.7 | DATARATE = 24 Mb/s (10 MHz channel spacing) | 17.2.2 (TXVECTOR parameters(#1369)), 17.2.3 (RXVECTOR parameters(#1369))(#1369) | CFOC AND OF1.7:O | Yes ☐ No ☐ N/A ☐ |
| *OF1.7.8 | DATARATE = 27 Mb/s (10 MHz channel spacing) | 17.2.2 (TXVECTOR parameters(#1369)), 17.2.3 (RXVECTOR parameters(#1369))(#1369) | CFOC AND OF1.7:O | Yes ☐ No ☐ N/A ☐ |

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## B.4.6 OFDM PHY functions *(continued)*

| Item | Feature | References | Status | Support |
|---|---|---|---|---|
| *OF1.8 | 5 MHz Channel spacing | 17.2.2 (TXVECTOR parameters(#1369)), 17.2.3 (RXVECTOR parameters(#1369))(#1369), Annex E | CFOC:O CF3G6 AND DSE2:M CF3G6 AND DSE3:M | Yes ☐ No ☐ N/A ☐ |
| *OF1.8.1 | DATARATE = 1.5 Mb/s (5 MHz channel spacing) | 17.2.2 (TXVECTOR parameters(#1369)), 17.2.3 (RXVECTOR parameters(#1369))(#1369) | CFOC AND OF1.8:M | Yes ☐ No ☐ N/A ☐ |
| *OF1.8.2 | DATARATE = 2.25 Mb/s (5 MHz channel spacing) | 17.2.2 (TXVECTOR parameters(#1369)), 17.2.3 (RXVECTOR parameters(#1369))(#1369) | CFOC AND OF1.8:O | Yes ☐ No ☐ N/A ☐ |
| *OF1.8.3 | DATARATE = 3 Mb/s (5 MHz channel spacing) | 17.2.2 (TXVECTOR parameters(#1369)), 17.2.3 (RXVECTOR parameters(#1369))(#1369) | CFOC AND OF1.8:M | Yes ☐ No ☐ N/A ☐ |
| *OF1.8.4 | DATARATE = 4.5 Mb/s (5 MHz channel spacing) | 17.2.2 (TXVECTOR parameters(#1369)), 17.2.3 (RXVECTOR parameters(#1369))(#1369) | CFOC AND OF1.8:O | Yes ☐ No ☐ N/A ☐ |


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## B.4.6 OFDM PHY functions *(continued)*

| Item | Feature | References | Status | Support |
|---|---|---|---|---|
| *OF1.8.5 | DATARATE = 6 Mb/s (5 MHz channel spacing) | 17.2.2 (TXVECTOR parameters(#1369)), 17.2.3 (RXVECTOR parameters(#1369))(#1369) | CFOC AND OF1.8:M | Yes ☐ No ☐ N/A ☐ |
| *OF1.8.6 | DATARATE = 9 Mb/s (5 MHz channel spacing) | 17.2.2 (TXVECTOR parameters(#1369)), 17.2.3 (RXVECTOR parameters(#1369))(#1369) | CFOC AND OF1.8:O | Yes ☐ No ☐ N/A ☐ |
| *OF1.8.7 | DATARATE = 12 Mb/s (5 MHz channel spacing) | 17.2.2 (TXVECTOR parameters(#1369)), 17.2.3 (RXVECTOR parameters(#1369))(#1369) | CFOC AND OF1.8:O | Yes ☐ No ☐ N/A ☐ |
| *OF1.8.8 | DATARATE = 13.5 Mb/s (5 MHz channel spacing) | 17.2.2 (TXVECTOR parameters(#1369)), 17.2.3 (RXVECTOR parameters(#1369))(#1369) | CFOC AND OF1.8:O | Yes ☐ No ☐ N/A ☐ |
| **OF2: OFDM PHY Layer(#4114)** | | | | |
| OF2.1 | RATE-dependent parameters | 17.3.2.3 (Modulation-dependent parameters) | M | Yes ☐ No ☐ |
| OF2.2 | (M118)Timing-related parameters | 17.3.2.4 (Timing-related parameters) | M | Yes ☐ No ☐ |

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## B.4.6 OFDM PHY functions *(continued)*

| Item | Feature | References | Status | Support |
|---|---|---|---|---|
| OF2.3 | PHY preamble: SYNC | 17.3.3 (PHY preamble (SYNC)) | M | Yes ☐ No ☐ |
| OF2.4 | PHY header: SIGNAL | 17.3.4 (SIGNAL field) | M | Yes ☐ No ☐ |
| OF2.5 | PHY header: LENGTH | 17.3.4.2 (RATE field) | M | Yes ☐ No ☐ |
| OF2.6 | PHY header: RATE | 17.3.4.3 (PHY LENGTH field) | M | Yes ☐ No ☐ |
| OF2.7 | PHY header: parity, reserve | 17.3.4.4 (Parity (P), Reserved (R), and SIGNAL TAIL fields) | M | Yes ☐ No ☐ |
| OF2.8 | PHY header: SIGNAL TAIL | 17.3.4.4 (Parity (P), Reserved (R), and SIGNAL TAIL fields) | M | Yes ☐ No ☐ |
| OF2.9 | PHY header: SERVICE | 17.3.5.2 (SERVICE field) | M | Yes ☐ No ☐ |
| OF2.10 | PHY protocol data unit (PPDU): TAIL | 17.3.5.3 (PPDU TAIL field) | M | Yes ☐ No ☐ |
| OF2.11 | PPDU: PAD | 17.3.5.4 (Pad bits (PAD)) | M | Yes ☐ No ☐ |
| OF2.12 | PHY/OFDM PHY data scrambler and descrambler | 17.3.5.5 (PHY DATA scrambler and descrambler) | M | Yes ☐ No ☐ |
| OF2.13 | Convolutional encoder | 17.3.5.6 (Convolutional encoder) | M | Yes ☐ No ☐ |
| OF2.13.1 | Rate R = 1/2 | 17.3.5.6 (Convolutional encoder) | M | Yes ☐ No ☐ |


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## B.4.6 OFDM PHY functions *(continued)*

| Item | Feature | References | Status | Support |
|---|---|---|---|---|
| OF2.13.2 | Punctured coding R = 2/3 | 17.3.5.6 (Convolutional encoder) | OF1.2.7:M | Yes ☐ No ☐ N/A ☐ |
| OF2.13.3 | Punctured coding R = 3/4 | 17.3.5.6 (Convolutional encoder) | OF1.2.2 OR OF1.2.4 OR OF1.2.6 OR OF1.2.8:M | Yes ☐ No ☐ N/A ☐ |
| OF2.14 | Data interleaving | 17.3.5.7 (Data interleaving) | M | Yes ☐ No ☐ |
| OF2.15 | Subcarrier modulation mapping | 17.3.5.8 (Subcarrier modulation mapping) | M | Yes ☐ No ☐ |
| OF2.15.1 | Binary phase shift keying (BPSK) | 17.3.5.8 (Subcarrier modulation mapping) | M | Yes ☐ No ☐ |
| OF2.15.2 | Quadrature phase shift keying (QPSK) | 17.3.5.8 (Subcarrier modulation mapping) | M | Yes ☐ No ☐ |
| OF2.15.3 | 16-quadrature amplitude modulation (QAM) | 17.3.5.8 (Subcarrier modulation mapping) | M | Yes ☐ No ☐ |
| OF2.15.4 | 64-QAM | 17.3.5.8 (Subcarrier modulation mapping) | OF1.2.7 OR OF1.2.8:M | Yes ☐ No ☐ N/A ☐ |
| OF2.16 | Pilot subcarriers | 17.3.5.9 (Pilot subcarriers) | M | Yes ☐ No ☐ |
| OF2.17 | OFDM modulation | 17.3.5.6 (Convolutional encoder) | M | Yes ☐ No ☐ |
| OF2.18 | (#14)PPDU duration calculation | | M | Yes ☐ No ☐ |
| OF2.19 | CCA | | | |
| OF2.19.1 | CCA: RSSI | 17.3.6 (CCA) | M | Yes ☐ No ☐ |
| OF2.19.2 | CCA: indication to MAC sublayer | 17.3.6 (CCA) | M | Yes ☐ No ☐ |

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## B.4.6 OFDM PHY functions *(continued)*

| Item | Feature | References | Status | Support |
|---|---|---|---|---|
| *OF2.19.3 | (#2365)CCA-OCSED functionality | 17.3.10.6.2 (CCA requirements for operating classes requiring CCA-OCSED(#2365)) | CF3G6:M | Yes ☐ No ☐ N/A ☐ |
| OF2.19.3.1 | CCA-OCSED energy above dot11OFDMEDThreshold | 17.3.10.6.2 (CCA requirements for operating classes requiring CCA-OCSED(#2365)) | OF2.19.3: M | Yes ☐ No ☐ N/A ☐ |
| OF2.19.3.2 | Hold CCA busy for (#14)PPDU duration of a correctly received PPDU, but carrier lost during reception of MPDU | 17.3.10.6 (CCA requirements) | OF2.19.3: M | Yes ☐ No ☐ N/A ☐ |
| OF2.20 | PHY data modulation and modulation rate change | 17.3.7 (PHY data modulation and modulation rate change) | M | Yes ☐ No ☐ |
| OF2.21 | Modulation-dependent parameters (10 MHz channel spacing) | 17.3.2.3 (Modulation-dependent parameters) | CFOC AND OF1.7:M | Yes ☐ No ☐ N/A ☐ |
| OF2.22 | Timing-related parameters (10 MHz channel spacing) | 17.3.2.4 (Timing-related parameters) | CFOC AND OF1.7:M | Yes ☐ No ☐ N/A ☐ |
| OF2.23 | PHY header: RATE (10 MHz channel spacing) | 17.3.4.2 (RATE field) | CFOC AND OF1.7:M | Yes ☐ No ☐ N/A ☐ |
| OF2.24 | Modulation-dependent parameters (5 MHz channel spacing) | 17.3.2.3 (Modulation-dependent parameters) | CFOC AND OF1.8:M | Yes ☐ No ☐ N/A ☐ |
| OF2.25 | Timing-related parameters (5 MHz channel spacing) | 17.3.2.4 (Timing-related parameters) | CFOC AND OF1.8:M | Yes ☐ No ☐ N/A ☐ |
| OF2.26 | PHY header: RATE (5 MHz channel spacing) | 17.3.4.2 (RATE field) | CFOC AND OF1.8:M | Yes ☐ No ☐ N/A ☐ |


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## B.4.6 OFDM PHY functions *(continued)*

| Item | Feature | References | Status | Support |
|---|---|---|---|---|
| **OF3: PDM Operating Specification General** | | | | |
| OF3.1 | Occupied channel bandwidth | | | |
| OF3.1.1 | 20 MHz channel spacing | 17.3.8.2 (Outline description) | M | Yes ☐ No ☐ |
| OF3.1.2 | 10 MHz channel spacing | 17.3.8.2 (Outline description) | CFOC AND OF1.7:M | Yes ☐ No ☐ N/A ☐ |
| OF3.1.3 | 5 MHz channel spacing | 17.3.8.2 (Outline description) | CFOC AND OF1.8:M | Yes ☐ No ☐ N/A ☐ |
| OF3.2 | Operating frequency range | 17.3.8.4.1 (Operating frequency range) | | |
| *OF3.2.1 | 4.9 GHz band | Annex E | CFOC:O | Yes ☐ No ☐ N/A ☐ |
| *OF3.2.2 | (#4147)5 GHz band | Annex E | CFOC:M | Yes ☐ No ☐ N/A ☐ |
| OF3.2.3 | 5.15–5.25 GHz band | 17.3.8.4 (Operating channel frequencies) | O.1 | Yes ☐ No ☐ |
| OF3.2.4 | 5.25–5.35 GHz band | 17.3.8.4 (Operating channel frequencies) | O.1 | Yes ☐ No ☐ |
| *OF3.2.5 | 5.47–5.725 GHz band | Annex E | CFSM:M | Yes ☐ No ☐ N/A ☐ |
| OF3.2.6 | 5.725–5.85 GHz band | 17.3.8.4 (Operating channel frequencies) | O.1 | Yes ☐ No ☐ |
| *OF3.2.7 | 3.65–3.70 GHz band | Annex D, Annex E | CF3G6:M | Yes ☐ No ☐ N/A ☐ |
| OF3.2.8 | 5.9 GHz band | Annex E | CF5G9:M | Yes ☐ No ☐ N/A ☐ |
| OF3.3 | Channelization | | | |
| OF3.3.1 | 5.15–5.25 GHz (20 MHz channel spacing) | Annex E | O.1 | Yes ☐ No ☐ |
| OF3.3.2 | 5.25–5.35 GHz (20 MHz channel spacing) | Annex E | O.1 | Yes ☐ No ☐ |
| OF3.3.3 | 5.725–5.825 GHz (20 MHz channel spacing) | Annex E | O.1 | Yes ☐ No ☐ |
| OF3.3.4 | 5.15–5.25 GHz band in Japan (20 MHz channel spacing) | Annex E | CFOC:M | Yes ☐ No ☐ N/A ☐ |
| OF3.3.5 | 5.47–5.725 GHz (20 MHz channel spacing) | Annex E | CFSM AND OF3.2.5:M | Yes ☐ No ☐ N/A ☐ |

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## B.4.6 OFDM PHY functions *(continued)*

| Item | Feature | References | Status | Support |
|---|---|---|---|---|
| OF3.3.6 | 5.725–5.85 GHz (20 MHz channel spacing) | Annex E | O.1 | Yes ☐ No ☐ |
| OF3.3.7 | 4.9 GHz band (20 MHz channel spacing) | Annex E | CFOC AND OF3.2.1:M | Yes ☐ No ☐ N/A ☐ |
| OF3.3.8 | (#4147)5 GHz band (20 MHz channel spacing) | Annex E | CFOC AND OF3.2.2:M | Yes ☐ No ☐ N/A ☐ |
| OF3.3.9 | 4.9 GHz band (10 MHz channel spacing) | Annex E | CFOC AND OF3.2.1 AND OF1.7:M | Yes ☐ No ☐ N/A ☐ |
| OF3.3.10 | (#4147)5 GHz band (10 MHz channel spacing) | Annex E | CFOC AND OF3.2.2 AND OF1.7:M | Yes ☐ No ☐ N/A ☐ |
| OF3.3.11 | 4.9 GHz band (5 MHz channel spacing) | Annex E | CFOC AND OF3.2.1 AND OF1.8:M | Yes ☐ No ☐ N/A ☐ |
| OF3.3.12 | (#4147)5 GHz band (5 MHz channel spacing) | Annex E | CFOC AND OF3.2.2 AND OF1.8:M | Yes ☐ No ☐ N/A ☐ |
| OF3.3.13 | 3.65–3.70 GHz (20 MHz channel spacing) | Annex E | CF3G6 AND OF3.2.7:M | Yes ☐ No ☐ N/A ☐ |
| OF3.3.14 | 3.65–3.70 GHz (10 MHz channel spacing) | Annex E | CF3G6 AND OF3.2.7 AND OF1.7:M | Yes ☐ No ☐ N/A ☐ |
| OF3.3.15 | 3.65–3.70 GHz (5 MHz channel spacing) | Annex E | CF3G6 AND OF3.2.7 AND OF1.8:M | Yes ☐ No ☐ N/A ☐ |
| OF3.3.16 | 5.9 GHz band (10 MHz channel spacing) | Annex E | CF5G9:O | Yes ☐ No ☐ N/A ☐ |
| OF3.3.17 | 5.9 GHz band (20 MHz channel spacing) | Annex E | CF5G9:O | Yes ☐ No ☐ N/A ☐ |
| OF3.3.18 | 5.9 GHz band (5 MHz channel spacing) | Annex E | CF5G9:O | Yes ☐ No ☐ N/A ☐ |
| OF3.4 | Number of operating channels | Annex E | M | Yes ☐ No ☐ |
| OF3.5 | Operating channel frequencies | Annex E | M | Yes ☐ No ☐ |
| OF3.6 | Transmit and receive in band and out of band spurious emission | Annex E | M | Yes ☐ No ☐ |


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## B.4.6 OFDM PHY functions *(continued)*

| Item | Feature | References | Status | Support |
|---|---|---|---|---|
| OF3.6.1 | Interference-limited areas, 4.9 GHz band (20 MHz channel spacing) | Annex E | CFOC AND OF3.2.1:M | Yes ☐ No ☐ N/A ☐ |
| OF3.6.2 | Interference-limited areas, (#4147)5 GHz band (20 MHz channel spacing) | Annex E | CFOC AND OF3.2.2:M | Yes ☐ No ☐ N/A ☐ |
| OF3.6.3 | Interference-limited areas, 4.9 GHz band (10 MHz channel spacing) | Annex E | CFOC AND OF3.2.1 AND OF1.7:O | Yes ☐ No ☐ N/A ☐ |
| OF3.6.4 | Interference-limited areas, (#4147)5 GHz band (10 MHz channel spacing) | Annex E | CFOC AND OF3.2.2 AND OF1.7:O | Yes ☐ No ☐ N/A ☐ |
| OF3.6.5 | Interference-limited areas, 4.9 GHz band (5 MHz channel spacing) | Annex E | CFOC AND OF3.2.1 AND OF1.8:O | Yes ☐ No ☐ N/A ☐ |
| OF3.6.6 | Interference-limited areas, (#4147)5 GHz band (5 MHz channel spacing) | Annex E | CFOC AND OF3.2.2 AND OF1.8:O | Yes ☐ No ☐ N/A ☐ |
| OF3.7 | *Reserved* | | | |
| OF3.8 | Slot time | 17.3.8.6 (Slot time) | M | Yes ☐ No ☐ |
| OF3.8.1 | Slot time (20 MHz channel spacing) | 17.3.8.6 (Slot time) | CFOC AND OC2:M | Yes ☐ No ☐ N/A ☐ |
| OF3.8.2 | Slot time (10 MHz channel spacing) | 17.3.8.6 (Slot time) | CFOC AND OC3 AND OF1.7:M | Yes ☐ No ☐ N/A ☐ |
| OF3.8.3 | Slot time (5 MHz channel spacing) | 17.3.8.6 (Slot time) | CFOC AND OC4 AND OF1.8:M | Yes ☐ No ☐ N/A ☐ |
| OF3.9 | Transmit and receive antenna connector impedance | 17.3.8.7 (Transmit and receive impedance at the antenna connector) | M | Yes ☐ No ☐ |
| **OF4: PHY Transmit Specification** | | | | |
| OF4.1 | Transmit power levels | | M | Yes ☐ No ☐ |

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## B.4.6 OFDM PHY functions *(continued)*

| Item | Feature | References | Status | Support |
|---|---|---|---|---|
| OF4.1.1 | Power level (5.15–5.25 GHz) | 17.3.9.2 (Transmit power levels) | OF3.3.1:M | Yes ☐ No ☐ N/A ☐ |
| OF4.1.2 | Power level (5.25–5.35 GHz) | 17.3.9.2 (Transmit power levels) | OF3.3.2:M | Yes ☐ No ☐ N/A ☐ |
| OF4.1.3 | Power level (5.725–5.825 GHz) | 17.3.9.2 (Transmit power levels) | OF3.3.3:M | Yes ☐ No ☐ N/A ☐ |
| *OF4.1.4 | Power Level (5.850–5.925 GHz), Class A | D.2.2 (Transmit power levels) | CF5G9:M | Yes ☐ No ☐ N/A ☐ |
| *OF4.1.5 | Power Level (5.850–5.925 GHz), Class B | D.2.2 (Transmit power levels) | CF5G9:O | Yes ☐ No ☐ N/A ☐ |
| *OF4.1.6 | Power Level (5.850–5.925 GHz), Class C | D.2.2 (Transmit power levels) | CF5G9:O | Yes ☐ No ☐ N/A ☐ |
| *OF4.1.7 | Power Level (5.850–5.925 GHz), Class D | D.2.2 (Transmit power levels) | CF5G9:O | Yes ☐ No ☐ N/A ☐ |
| OF4.2 | Spectrum mask | 17.3.9.3 (Transmit spectrum mask) | M | Yes ☐ No ☐ |
| OF4.3 | Spurious | 17.3.9.4 (Transmission spurious) | M | Yes ☐ No ☐ |
| OF4.4 | Center frequency tolerance | 17.3.9.5 (Transmit center frequency tolerance) | M | Yes ☐ No ☐ |
| OF4.5 | Clock frequency tolerance | 17.3.9.6 (Symbol clock frequency tolerance) | M | Yes ☐ No ☐ |
| OF4.6 | Modulation accuracy | | | Yes ☐ No ☐ |
| OF4.6.1 | Center frequency leakage | 17.3.9.7.2 (Transmitter center frequency leakage) | M | Yes ☐ No ☐ |


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## B.4.6 OFDM PHY functions *(continued)*

| Item | Feature | References | Status | Support |
|---|---|---|---|---|
| OF4.6.2 | Spectral flatness | 17.3.9.7.3 (Transmitter spectral flatness) | M | Yes ☐ No ☐ |
| OF4.6.3 | Transmitter constellation error < –5 dB | 17.3.9.7.4 (Transmitter constellation error) | M | Yes ☐ No ☐ |
| OF4.6.4 | Transmitter constellation error < –8 dB | 17.3.9.7.4 (Transmitter constellation error) | OF1.2.2:M | Yes ☐ No ☐ N/A ☐ |
| OF4.6.5 | Transmitter constellation error < –10 dB | 17.3.9.7.4 (Transmitter constellation error) | M | Yes ☐ No ☐ |
| OF4.6.6 | Transmitter constellation error < –13 dB | 17.3.9.7.4 (Transmitter constellation error) | OF1.2.4:M | Yes ☐ No ☐ N/A ☐ |
| OF4.6.7 | Transmitter constellation error < –16 dB | 17.3.9.7.4 (Transmitter constellation error) | M | Yes ☐ No ☐ |
| OF4.6.8 | Transmitter constellation error < –19 dB | 17.3.9.7.4 (Transmitter constellation error) | OF1.2.6:M | Yes ☐ No ☐ N/A ☐ |
| OF4.6.9 | Transmitter constellation error < –22 dB | 17.3.9.7.4 (Transmitter constellation error) | OF1.2.7:M | Yes ☐ No ☐ N/A ☐ |
| OF4.6.10 | Transmitter constellation error < –25 dB | 17.3.9.7.4 (Transmitter constellation error) | OF1.2.8:M | Yes ☐ No ☐ N/A ☐ |
| OF4.7 | Power level, 4.9 GHz band (20 MHz channel spacing) | 17.3.9.2 (Transmit power levels) | CFOC AND OF3.12.1: M | Yes ☐ No ☐ N/A ☐ |
| OF4.8 | Power level, (#4147)5 GHz band (20 MHz channel spacing) | 17.3.9.2 (Transmit power levels) | CFOC AND OF3.12.2: M | Yes ☐ No ☐ N/A ☐ |

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## B.4.6 OFDM PHY functions *(continued)*

| Item | Feature | References | Status | Support |
|---|---|---|---|---|
| OF4.9 | Power level, 5.47–5.725 GHz band | 17.3.9.2 (Transmit power levels) | CFOC AND OF3.12.3: M | Yes ☐ No ☐ N/A ☐ |
| OF4.10 | Power level, 4.9 GHz band (10 MHz channel spacing) | 17.3.9.2 (Transmit power levels) | CFOC AND OF3.12.1 AND OF1.7:M | Yes ☐ No ☐ N/A ☐ |
| OF4.11 | Power level, (#4147)5 GHz band (10 MHz channel spacing) | 17.3.9.2 (Transmit power levels) | CFOC AND OF3.12.2 AND OF1.7:M | Yes ☐ No ☐ N/A ☐ |
| OF4.12 | Power level, 4.9 GHz band (5 MHz channel spacing) | 17.3.9.2 (Transmit power levels) | CFOC AND OF3.12.1 AND OF1.8:M | Yes ☐ No ☐ N/A ☐ |
| OF4.13 | Power level, (#4147)5 GHz band (5 MHz channel spacing) | 17.3.9.2 (Transmit power levels) | CFOC AND OF3.12.2 AND OF1.8:M | Yes ☐ No ☐ N/A ☐ |
| OF4.13.1 | Power level, 3.65–3.70 GHz (20 MHz channel spacing) | Annex E | CF3G6 AND OF3.2.7:M | Yes ☐ No ☐ N/A ☐ |
| OF4.13.2 | Power level, 3.65–3.70 GHz (10 MHz channel spacing) | Annex E | CF3G6 AND OF3.2.7 AND OF1.7:M | Yes ☐ No ☐ N/A ☐ |
| OF4.13.3 | Power level, 3.65–3.70 GHz (5 MHz channel spacing) | Annex E | CF3G6 AND OF3.2.7 AND OF1.8:M | Yes ☐ No ☐ N/A ☐ |
| OF4.14 | Spectrum mask (20 MHz channel spacing) | 17.3.9.3 (Transmit spectrum mask) | CFOC:M | Yes ☐ No ☐ N/A ☐ |
| OF4.15 | Spectrum mask (10 MHz channel spacing) | 17.3.9.3 (Transmit spectrum mask) | CFOC AND OF1.7:M | Yes ☐ No ☐ N/A ☐ |
| OF4.15.1 | Spectrum mask, Class A (10 MHz channel spacing) | D.2.3 (Transmit spectrum mask) | OF4.1.4:M | Yes ☐ No ☐ N/A ☐ |
| OF4.15.2 | Spectrum mask, Class B (10 MHz channel spacing) | D.2.3 (Transmit spectrum mask) | OF4.1.5:M | Yes ☐ No ☐ N/A ☐ |


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## B.4.6 OFDM PHY functions *(continued)*

| Item | Feature | References | Status | Support |
|---|---|---|---|---|
| OF4.15.3 | Spectrum mask, Class C (10 MHz channel spacing) | D.2.3 (Transmit spectrum mask) | OF4.1.6:M | Yes ☐ No ☐ N/A ☐ |
| OF4.15.4 | Spectrum mask, Class D (10 MHz channel spacing) | D.2.3 (Transmit spectrum mask) | OF4.1.7:M | Yes ☐ No ☐ N/A ☐ |
| OF4.16 | Spectrum mask (5 MHz channel spacing) | 17.3.9.3 (Transmit spectrum mask) | CFOC AND OF1.8:M | Yes ☐ No ☐ N/A ☐ |
| (#2290)OF4.17 | Transmitter constellation error (10 MHz channel spacing) | | | |
| OF4.17.1 | Transmitter constellation error < –5 dB (10 MHz channel spacing) | 17.3.9.7.4 (Transmitter constellation error) | CFOC AND OF1.7.1:M | Yes ☐ No ☐ N/A ☐ |
| OF4.17.2 | Transmitter constellation error < –8 dB (10 MHz channel spacing) | 17.3.9.7.4 (Transmitter constellation error) | CFOC AND OF1.7.2:M | Yes ☐ No ☐ N/A ☐ |
| OF4.17.3 | Transmitter constellation error < –10 dB (10 MHz channel spacing) | 17.3.9.7.4 (Transmitter constellation error) | CFOC AND OF1.7.3:M | Yes ☐ No ☐ N/A ☐ |
| OF4.17.4 | Transmitter constellation error < –13 dB (10 MHz channel spacing) | 17.3.9.7.4 (Transmitter constellation error) | CFOC AND OF1.7.4:M | Yes ☐ No ☐ N/A ☐ |
| OF4.17.5 | Transmitter constellation error < –16 dB (10 MHz channel spacing) | 17.3.9.7.4 (Transmitter constellation error) | CFOC AND OF1.7.5:M | Yes ☐ No ☐ N/A ☐ |
| OF4.17.6 | Transmitter constellation error < –19 dB (10 MHz channel spacing) | 17.3.9.7.4 (Transmitter constellation error) | CFOC AND OF1.7.6:M | Yes ☐ No ☐ N/A ☐ |
| OF4.17.7 | Transmitter constellation error < –22 dB (10 MHz channel spacing) | 17.3.9.7.4 (Transmitter constellation error) | CFOC AND OF1.7.7:M | Yes ☐ No ☐ N/A ☐ |
| OF4.17.8 | Transmitter constellation error < –25 dB (10 MHz channel spacing) | 17.3.9.7.4 (Transmitter constellation error) | CFOC AND OF1.7.8:M | Yes ☐ No ☐ N/A ☐ |

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## B.4.6 OFDM PHY functions *(continued)*

| Item | Feature | References | Status | Support |
|---|---|---|---|---|
| OF4.18 | Transmitter constellation error (5 MHz channel spacing) | | | |
| OF4.18.1 | Transmitter constellation error < –5 dB (5 MHz channel spacing) | 17.3.9.7.4 (Transmitter constellation error) | CFOC AND OF1.8.1:M | Yes ☐ No ☐ N/A ☐ |
| OF4.18.2 | Transmitter constellation error < –8 dB (5 MHz channel spacing) | 17.3.9.7.4 (Transmitter constellation error) | CFOC AND OF1.8.2:M | Yes ☐ No ☐ N/A ☐ |
| OF4.18.3 | Transmitter constellation error < –10 dB (5 MHz channel spacing) | 17.3.9.7.4 (Transmitter constellation error) | CFOC AND OF1.8.3:M | Yes ☐ No ☐ N/A ☐ |
| OF4.18.4 | Transmitter constellation error < –13 dB (5 MHz channel spacing) | 17.3.9.7.4 (Transmitter constellation error) | CFOC AND OF1.8.4:M | Yes ☐ No ☐ N/A ☐ |
| OF4.18.5 | Transmitter constellation error < –16 dB (5 MHz channel spacing) | 17.3.9.7.4 (Transmitter constellation error) | CFOC AND OF1.8.5:M | Yes ☐ No ☐ N/A ☐ |
| OF4.18.6 | Transmitter constellation error < –19 dB (5 MHz channel spacing) | 17.3.9.7.4 (Transmitter constellation error) | CFOC AND OF1.8.6:M | Yes ☐ No ☐ N/A ☐ |
| OF4.18.7 | Transmitter constellation error < –22 dB (5 MHz channel spacing) | 17.3.9.7.4 (Transmitter constellation error) | CFOC AND OF1.8.7:M | Yes ☐ No ☐ N/A ☐ |
| OF4.18.8 | Transmitter constellation error < –25 dB (5 MHz channel spacing) | 17.3.9.7.4 (Transmitter constellation error) | CFOC AND OF1.8.8:M | Yes ☐ No ☐ N/A ☐ |
| **OF5: PHY Receiver Specifications** | | | | |
| OF5.1 | Minimum input level sensitivity at packet error ratio (PER) = 10% with 1000 octet (#14)PSDU | | | |
| OF5.1.1 | –82 dBm for 6 Mb/s | 17.3.10.2 (Receiver minimum input level sensitivity(#256)) | M | Yes ☐ No ☐ |


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## B.4.6 OFDM PHY functions *(continued)*

| Item | Feature | References | Status | Support |
|---|---|---|---|---|
| OF5.1.2 | –81 dBm for 9 Mb/s | 17.3.10.2 (Receiver minimum input level sensitivity( #256)) | OF1.2.2:M | Yes ☐ No ☐ N/A ☐ |
| OF5.1.3 | –79 dBm for 12 Mb/s | 17.3.10.2 (Receiver minimum input level sensitivity( #256)) | M | Yes ☐ No ☐ |
| OF5.1.4 | –77 dBm for 18 Mb/s | 17.3.10.2 (Receiver minimum input level sensitivity( #256)) | OF1.2.4:M | Yes ☐ No ☐ N/A ☐ |
| OF5.1.5 | –74 dBm for 24 Mb/s | 17.3.10.2 (Receiver minimum input level sensitivity( #256)) | M | Yes ☐ No ☐ |
| OF5.1.6 | –70 dBm for 36 Mb/s | 17.3.10.2 (Receiver minimum input level sensitivity( #256)) | OF1.2.6:M | Yes ☐ No ☐ N/A ☐ |
| OF5.1.7 | –66 dBm for 48 Mb/s | 17.3.10.2 (Receiver minimum input level sensitivity( #256)) | OF1.2.7:M | Yes ☐ No ☐ N/A ☐ |
| OF5.1.8 | –65 dBm for 54 Mb/s | 17.3.10.2 (Receiver minimum input level sensitivity( #256)) | OF1.2.8:M | Yes ☐ No ☐ N/A ☐ |
| OF5.2 | Adjacent channel rejection | 17.3.10.3 (Adjacent channel rejection) | M | Yes ☐ No ☐ |
| OF5.2.1 | Optional adjacent channel rejection | 17.3.10.3 (Adjacent channel rejection) | O | Yes ☐ No ☐ |
| OF5.3 | Nonadjacent channel rejection | 17.3.10.4 (Nonadjacent channel rejection) | M | Yes ☐ No ☐ |

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## B.4.6 OFDM PHY functions *(continued)*

| Item | Feature | References | Status | Support |
|---|---|---|---|---|
| OF5.3.1 | Optional nonadjacent channel rejection | 17.3.10.4 (Nonadjacent channel rejection) | O | Yes ☐ No ☐ |
| OF5.4 | Maximum input level | 17.3.10.5 (Receiver maximum input level) | M | Yes ☐ No ☐ |
| OF5.5 | CCA sensitivity | 17.3.10.6 (CCA requirements) | M | Yes ☐ No ☐ |
| OF5.6 | Maximum input level sensitivity at packet error ratio (PER) = 10% with 1000 octet (#14)PSDUs (10 MHz channel spacing) | | | |
| OF5.6.1 | –85 dBm for 3 Mb/s (10 MHz channel spacing) | 17.3.10.2 (Receiver minimum input level sensitivity(#256)) | CFOC AND OF1.7.1:M | Yes ☐ No ☐ N/A ☐ |
| OF5.6.2 | –84 dBm for 4.5 Mb/s (10 MHz channel spacing) | 17.3.10.2 (Receiver minimum input level sensitivity(#256)) | CFOC AND OF1.7.2:M | Yes ☐ No ☐ N/A ☐ |
| OF5.6.3 | –82 dBm for 6 Mb/s (10 MHz channel spacing) | 17.3.10.2 (Receiver minimum input level sensitivity(#256)) | CFOC AND OF1.7.3:M | Yes ☐ No ☐ N/A ☐ |
| OF5.6.4 | –80 dBm for 9 Mb/s (10 MHz channel spacing) | 17.3.10.2 (Receiver minimum input level sensitivity(#256)) | CFOC AND OF1.7.4:M | Yes ☐ No ☐ N/A ☐ |
| OF5.6.5 | –77 dBm for 12 Mb/s (10 MHz channel spacing) | 17.3.10.2 (Receiver minimum input level sensitivity(#256)) | CFOC AND OF1.7.5:M | Yes ☐ No ☐ N/A ☐ |
| OF5.6.6 | –73 dBm for 18 Mb/s (10 MHz channel spacing) | 17.3.10.2 (Receiver minimum input level sensitivity(#256)) | CFOC AND OF1.7.6:M | Yes ☐ No ☐ N/A ☐ |


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## B.4.6 OFDM PHY functions *(continued)*

| Item | Feature | References | Status | Support |
|---|---|---|---|---|
| OF5.6.7 | –69 dBm for 24 Mb/s<br>(10 MHz channel spacing) | 17.3.10.2 (Receiver minimum input level sensitivity(#256)) | CFOC AND OF1.7.7:M | Yes ☐ No ☐ N/A ☐ |
| OF5.6.8 | –68 dBm for 27 Mb/s<br>(10 MHz channel spacing) | 17.3.10.2 (Receiver minimum input level sensitivity(#256)) | CFOC AND OF1.7.8:M | Yes ☐ No ☐ N/A ☐ |
| OF5.7 | Adjacent channel rejection<br>(10 MHz channel spacing) | 17.3.10.3 (Adjacent channel rejection) | CFOC AND OF1.7:M | Yes ☐ No ☐ N/A ☐ |
| OF5.8 | Nonadjacent channel rejection<br>(10 MHz channel spacing) | 17.3.10.4 (Nonadjacent channel rejection) | CFOC AND OF1.7:M | Yes ☐ No ☐ N/A ☐ |
| OF5.9 | Maximum input level<br>(10 MHz channel spacing) | 17.3.10.5 (Receiver maximum input level) | CFOC AND OF1.7:M | Yes ☐ No ☐ N/A ☐ |
| OF5.10 | CCA sensitivity<br>(10 MHz channel spacing) | 17.3.10.6 (CCA requirements) | CFOC AND OF1.7:M | Yes ☐ No ☐ N/A ☐ |
| OF5.11 | Maximum input level sensitivity at packet error ratio (PER) = 10% with 1000 octet (#14)PSDUs (5 MHz channel spacing) | | | |
| OF5.11.1 | –85 dBm for 3 Mb/s<br>(5 MHz channel spacing) | 17.3.10.2 (Receiver minimum input level sensitivity(#256)) | CFOC AND OF1.8.1:M | Yes ☐ No ☐ N/A ☐ |
| OF5.11.2 | –84 dBm for 4.5 Mb/s<br>(5 MHz channel spacing) | 17.3.10.2 (Receiver minimum input level sensitivity(#256)) | CFOC AND OF1.8.2:M | Yes ☐ No ☐ N/A ☐ |
| OF5.11.3 | –82 dBm for 6 Mb/s<br>(5 MHz channel spacing) | 17.3.10.2 (Receiver minimum input level sensitivity(#256)) | CFOC AND OF1.8.3:M | Yes ☐ No ☐ N/A ☐ |

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## B.4.6 OFDM PHY functions *(continued)*

| Item | Feature | References | Status | Support |
|---|---|---|---|---|
| OF5.11.4 | –80 dBm for 9 Mb/s (5 MHz channel spacing) | 17.3.10.2 (Receiver minimum input level sensitivity( #256)) | CFOC AND OF1.8.4:M | Yes ☐ No ☐ N/A ☐ |
| OF5.11.5 | –77 dBm for 12 Mb/s (5 MHz channel spacing) | 17.3.10.2 (Receiver minimum input level sensitivity( #256)) | CFOC AND OF1.8.5:M | Yes ☐ No ☐ N/A ☐ |
| OF5.11.6 | –73 dBm for 18 Mb/s (5 MHz channel spacing) | 17.3.10.2 (Receiver minimum input level sensitivity( #256)) | CFOC AND OF1.8.6:M | Yes ☐ No ☐ N/A ☐ |
| OF5.11.7 | –69 dBm for 24 Mb/s (5 MHz channel spacing) | 17.3.10.2 (Receiver minimum input level sensitivity( #256)) | CFOC AND OF.1.8.7:M | Yes ☐ No ☐ N/A ☐ |
| OF5.11.8 | –68 dBm for 27 Mb/s (5 MHz channel spacing) | 17.3.10.2 (Receiver minimum input level sensitivity( #256)) | CFOC AND OF1.8.8:M | Yes ☐ No ☐ N/A ☐ |
| OF5.12 | Adjacent channel rejection (5 MHz channel spacing) | 17.3.10.3 (Adjacent channel rejection) | CFOC AND OF1.8:M | Yes ☐ No ☐ N/A ☐ |
| OF5.13 | Nonadjacent channel rejection (5 MHz channel spacing) | 17.3.10.4 (Nonadjacent channel rejection) | CFOC AND OF1.8:M | Yes ☐ No ☐ N/A ☐ |
| OF5.14 | Maximum input level (5 MHz channel spacing) | 17.3.10.5 (Receiver maximum input level) | CFOC AND OF1.8:M | Yes ☐ No ☐ N/A ☐ |
| OF5.15 | CCA sensitivity (5 MHz channel spacing) | 17.3.10.6 (CCA requirements) | CFOC AND OF1.8:M | Yes ☐ No ☐ N/A ☐ |
| **OF6: Transmit PHY** | | | | |
| OF6.1 | Transmit: transmit on MAC request | 17.3.11 (Transmit PHY) | M | Yes ☐ No ☐ |
| OF6.2 | Transmit: format and data encoding | 17.3.11 (Transmit PHY) | M | Yes ☐ No ☐ |


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## B.4.6 OFDM PHY functions *(continued)*

| Item | Feature | References | Status | Support |
|---|---|---|---|---|
| OF6.3 | Transmit: timing | 17.3.11 (Transmit PHY) | M | Yes ☐ No ☐ |
| **OF7: Receive PHY** | | | | |
| OF7.1 | Receive: receive and data decoding | 17.3.12 (Receive PHY) | M | Yes ☐ No ☐ |
| **OF8: PLME** | | | | |
| OF8.1 | PLME: support PLME SAP management primitives | 17.4.1 (PLME SAP layer management primitives(#6320)) | M | Yes ☐ No ☐ |
| OF8.2 | PLME: support PHY MIB | 17.4.2 (OFDM PHY MIB) | M | Yes ☐ No ☐ |
| OF8.3 | PLME: support PHY characteristics | 17.4.3 (OFDM TXTIME calculation) | M | Yes ☐ No ☐ |
| OF8.4 | PLME:support PHY characteristics (dot11ChannelStartingFactor) | 17.4.2 (OFDM PHY MIB) | CFOC:M | Yes ☐ No ☐ N/A ☐ |
| OF9 | *Reserved* | | | |

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## B.4.6 OFDM PHY functions *(continued)*

| Item | Feature | References | Status | Support |
|---|---|---|---|---|
| **OF10: Geographic Area Specific Requirements** | | | | |
| *OF10.1 | Geographic areas | 17.3.8.3 (Regulatory requirements), 17.3.8.4 (Operating channel frequencies), 17.3.8.5 (Transmit and receive in-band and out-of-band spurious emissions), 17.3.9.4 (Transmission spurious) | M | Yes ☐ No ☐ |
| OF10.2 | Regulatory domain extensions | 17.3.8.4.3 (Channelization), 17.3.8.5 (Transmit and receive in-band and out-of-band spurious emissions), 17.3.9.2 (Transmit power levels), 17.3.9.3 (Transmit spectrum mask), Annex E | CFOC:M | Yes ☐ No ☐ N/A ☐ |

## B.4.7 High rate, direct sequence PHY functions

| Item | PHY feature | References | Status | Support |
|---|---|---|---|---|
| | Are the following PHY features supported? | | | |
| HRDS1 | Long preamble and header procedures | 16.2 (HR/DSSS PHY) | M | Yes ☐ No ☐ |
| HRDS1.1 | Long direct sequence preamble prepended on TX | 16.2.1 (Overview) | M | Yes ☐ No ☐ |
| HRDS1.2 | Long PHY integrity check generation | 16.2.3 (PPDU field definitions) | M | Yes ☐ No ☐ |


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## B.4.7 High rate, direct sequence PHY functions *(continued)*

| Item | PHY feature | References | Status | Support |
|---|---|---|---|---|
| HRDS1.3 | TX rate change capability | 16.2.3.4 (Long PHY SIGNAL field) | M | Yes ☐ No ☐ |
| HRDS1.4 | Supported data rates | 16.1 (Overview), 16.2.3.4 (Long PHY SIGNAL field) | M | Yes ☐ No ☐ |
| HRDS1.5 | Data scrambler | 16.2.4 (PHY/HR/ DSSS PHY data scrambler and descrambler) | M | Yes ☐ No ☐ |
| HRDS1.6 | Scrambler initialization | 16.2.4 (PHY/HR/ DSSS PHY data scrambler and descrambler) | M | Yes ☐ No ☐ |
| HRDS2 | *Reserved* | | | |
| *HRDS3 | Short preamble and header procedures | 16.2 (HR/DSSS PHY) | O | Yes ☐ No ☐ |
| HRDS3.1 | Short preamble prepended on TX | 16.2.2 (PPDU format) | HRDS3:M | Yes ☐ No ☐ N/A ☐ |
| HRDS3.2 | Short header transmission | 16.2.3.9 (Short PHY synchronization (shortSYNC)), 16.2.3.10 (Short PHY SFD field (shortSFD)), 16.2.3.11 (Short PHY SIGNAL field (shortSIGNAL)), 16.2.3.12 (Short PHY SERVICE field (shortSERVICE)), 16.2.3.13 (Short PHY LENGTH field (shortLENGTH)), 16.2.3.14 (Short CRC-16 field (shortCRC)), 16.2.3.15 (Short PHY data modulation and modulation rate change) | HRDS3:M | Yes ☐ No ☐ N/A ☐ |
| HRDS4 | Long preamble process on RX | 16.2.6 (Receive PHY) | M | Yes ☐ No ☐ |
| HRDS4.1 | PHY format | 16.2.6 (Receive PHY) | M | Yes ☐ No ☐ |
| HRDS4.2 | PHY integrity check verify | 16.2.6 (Receive PHY) | M | Yes ☐ No ☐ |

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## B.4.7 High rate, direct sequence PHY functions *(continued)*

| Item | PHY feature | References | Status | Support |
|---|---|---|---|---|
| HRDS4.3 | RX Rate change capability | 16.2.6 (Receive PHY) | M | Yes ☐ No ☐ |
| HRDS4.4 | Data whitener descrambler | 16.2.6 (Receive PHY) | M | Yes ☐ No ☐ |
| *HRDS5 | Short preamble process on RX | 16.2.6 (Receive PHY) | HRDS3:M | Yes ☐ No ☐ N/A ☐ |
| HRDS5.1 | PHY format | 16.2.6 (Receive PHY) | HRDS5:M | Yes ☐ No ☐ N/A ☐ |
| HRDS5.2 | PHY integrity check verify | 16.2.6 (Receive PHY) | HRDS5:M | Yes ☐ No ☐ N/A ☐ |
| HRDS5.3 | RX rate change capability | 16.2.6 (Receive PHY) | HRDS5:M | Yes ☐ No ☐ N/A ☐ |
| HRDS5.4 | Data whitener descrambler | 16.2.6 (Receive PHY) | HRDS5:M | Yes ☐ No ☐ N/A ☐ |
| *HRDS6 | Operating channel capability | — | — | — |
| *HRDS6.1 | United States and its territories (FCC)(#7179) | 16.3.6.3 (Channel Numbering of operating channels) | HRDS6:O.3 | Yes ☐ No ☐ N/A ☐ |
| HRDS6.1.1 | Channel 1 | 16.3.6.3 (Channel Numbering of operating channels) | HRDS6.1:M | Yes ☐ No ☐ N/A ☐ |
| HRDS6.1.2 | Channel 2 | 16.3.6.3 (Channel Numbering of operating channels) | HRDS6.1:M | Yes ☐ No ☐ N/A ☐ |
| HRDS6.1.3 | Channel 3 | 16.3.6.3 (Channel Numbering of operating channels) | HRDS6.1:M | Yes ☐ No ☐ N/A ☐ |
| HRDS6.1.4 | Channel 4 | 16.3.6.3 (Channel Numbering of operating channels) | HRDS6.1:M | Yes ☐ No ☐ N/A ☐ |
| HRDS6.1.5 | Channel 5 | 16.3.6.3 (Channel Numbering of operating channels) | HRDS6.1:M | Yes ☐ No ☐ N/A ☐ |
| HRDS6.1.6 | Channel 6 | 16.3.6.3 (Channel Numbering of operating channels) | HRDS6.1:M | Yes ☐ No ☐ N/A ☐ |
| HRDS6.1.7 | Channel 7 | 16.3.6.3 (Channel Numbering of operating channels) | HRDS6.1:M | Yes ☐ No ☐ N/A ☐ |
| HRDS6.1.8 | Channel 8 | 16.3.6.3 (Channel Numbering of operating channels) | HRDS6.1:M | Yes ☐ No ☐ N/A ☐ |
| HRDS6.1.9 | Channel 9 | 16.3.6.3 (Channel Numbering of operating channels) | HRDS6.1:M | Yes ☐ No ☐ N/A ☐ |
| HRDS6.1.10 | Channel 10 | 16.3.6.3 (Channel Numbering of operating channels) | HRDS6.1:M | Yes ☐ No ☐ N/A ☐ |


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## B.4.7 High rate, direct sequence PHY functions *(continued)*

| Item | PHY feature | References | Status | Support |
|---|---|---|---|---|
| HRDS6.1.11 | Channel 11 | 16.3.6.3 (Channel Numbering of operating channels) | HRDS6.1:M | Yes ☐ No ☐ N/A ☐ |
| *HRDS6.2 | Canada (IC) | 16.3.6.3 (Channel Numbering of operating channels) | HRDS6:O.3 | Yes ☐ No ☐ N/A ☐ |
| HRDS6.2.1 | Channel 1 | 16.3.6.3 (Channel Numbering of operating channels) | HRDS6.2:M | Yes ☐ No ☐ N/A ☐ |
| HRDS6.2.2 | Channel 2 | 16.3.6.3 (Channel Numbering of operating channels) | HRDS6.2:M | Yes ☐ No ☐ N/A ☐ |
| HRDS6.2.3 | Channel 3 | 16.3.6.3 (Channel Numbering of operating channels) | HRDS6.2:M | Yes ☐ No ☐ N/A ☐ |
| HRDS6.2.4 | Channel 4 | 16.3.6.3 (Channel Numbering of operating channels) | HRDS6.2:M | Yes ☐ No ☐ N/A ☐ |
| HRDS6.2.5 | Channel 5 | 16.3.6.3 (Channel Numbering of operating channels) | HRDS6.2:M | Yes ☐ No ☐ N/A ☐ |
| HRDS6.2.6 | Channel 6 | 16.3.6.3 (Channel Numbering of operating channels) | HRDS6.2:M | Yes ☐ No ☐ N/A ☐ |
| HRDS6.2.7 | Channel 7 | 16.3.6.3 (Channel Numbering of operating channels) | HRDS6.2:M | Yes ☐ No ☐ N/A ☐ |
| HRDS6.2.8 | Channel 8 | 16.3.6.3 (Channel Numbering of operating channels) | HRDS6.2:M | Yes ☐ No ☐ N/A ☐ |
| HRDS6.2.9 | Channel 9 | 16.3.6.3 (Channel Numbering of operating channels) | HRDS6.2:M | Yes ☐ No ☐ N/A ☐ |
| HRDS6.2.10 | Channel 10 | 16.3.6.3 (Channel Numbering of operating channels) | HRDS6.2:M | Yes ☐ No ☐ N/A ☐ |
| HRDS6.2.11 | Channel 11 | 16.3.6.3 (Channel Numbering of operating channels) | HRDS6.2:M | Yes ☐ No ☐ N/A ☐ |
| *HRDS6.3 | Europe (ETSI) | 16.3.6.3 (Channel Numbering of operating channels) | HRDS6:O.3 | Yes ☐ No ☐ N/A ☐ |
| HRDS6.3.1 | Channel 1 | 16.3.6.3 (Channel Numbering of operating channels) | HRDS6.3:M | Yes ☐ No ☐ N/A ☐ |
| HRDS6.3.2 | Channel 2 | 16.3.6.3 (Channel Numbering of operating channels) | HRDS6.3:M | Yes ☐ No ☐ N/A ☐ |
| HRDS6.3.3 | Channel 3 | 16.3.6.3 (Channel Numbering of operating channels) | HRDS6.3:M | Yes ☐ No ☐ N/A ☐ |

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## B.4.7 High rate, direct sequence PHY functions *(continued)*

| Item | PHY feature | References | Status | Support |
|---|---|---|---|---|
| HRDS6.3.4 | Channel 4 | 16.3.6.3 (Channel Numbering of operating channels) | HRDS6.3:M | Yes ☐ No ☐ N/A ☐ |
| HRDS6.3.5 | Channel 5 | 16.3.6.3 (Channel Numbering of operating channels) | HRDS6.3:M | Yes ☐ No ☐ N/A ☐ |
| HRDS6.3.6 | Channel 6 | 16.3.6.3 (Channel Numbering of operating channels) | HRDS6.3:M | Yes ☐ No ☐ N/A ☐ |
| HRDS6.3.7 | Channel 7 | 16.3.6.3 (Channel Numbering of operating channels) | HRDS6.3:M | Yes ☐ No ☐ N/A ☐ |
| HRDS6.3.8 | Channel 8 | 16.3.6.3 (Channel Numbering of operating channels) | HRDS6.3:M | Yes ☐ No ☐ N/A ☐ |
| HRDS6.3.9 | Channel 9 | 16.3.6.3 (Channel Numbering of operating channels) | HRDS6.3:M | Yes ☐ No ☐ N/A ☐ |
| HRDS6.3.10 | Channel 10 | 16.3.6.3 (Channel Numbering of operating channels) | HRDS6.3:M | Yes ☐ No ☐ N/A ☐ |
| HRDS6.3.11 | Channel 11 | 16.3.6.3 (Channel Numbering of operating channels) | HRDS6.3:M | Yes ☐ No ☐ N/A ☐ |
| HRDS6.3.12 | Channel 12 | 16.3.6.3 (Channel Numbering of operating channels) | HRDS6.3:M | Yes ☐ No ☐ N/A ☐ |
| HRDS6.3.13 | Channel 13 | 16.3.6.3 (Channel Numbering of operating channels) | HRDS6.3:M | Yes ☐ No ☐ N/A ☐ |
| *HRDS6.4 | France | 16.3.6.3 (Channel Numbering of operating channels) | HRDS6:O.3 | Yes ☐ No ☐ N/A ☐ |
| HRDS6.4.1 | Channel 10 | 16.3.6.3 (Channel Numbering of operating channels) | HRDS6.4:M | Yes ☐ No ☐ N/A ☐ |
| HRDS6.4.2 | Channel 11 | 16.3.6.3 (Channel Numbering of operating channels) | HRDS6.4:M | Yes ☐ No ☐ N/A ☐ |
| HRDS6.4.3 | Channel 12 | 16.3.6.3 (Channel Numbering of operating channels) | HRDS6.4:M | Yes ☐ No ☐ N/A ☐ |
| HRDS6.4.4 | Channel 13 | 16.3.6.3 (Channel Numbering of operating channels) | HRDS6.4:M | Yes ☐ No ☐ N/A ☐ |
| *HRDS6.5 | Spain | 16.3.6.3 (Channel Numbering of operating channels) | HRDS6:O.3 | Yes ☐ No ☐ N/A ☐ |
| HRDS6.5.1 | Channel 10 | 16.3.6.3 (Channel Numbering of operating channels) | HRDS6.5:M | Yes ☐ No ☐ N/A ☐ |


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## B.4.7 High rate, direct sequence PHY functions *(continued)*

| Item | PHY feature | References | Status | Support |
|---|---|---|---|---|
| HRDS6.5.2 | Channel 11 | 16.3.6.3 (Channel Numbering of operating channels) | HRDS6.5:M | Yes ☐ No ☐ N/A ☐ |
| *HRDS6.6 | Japan | 16.3.6.3 (Channel Numbering of operating channels) | HRDS6:O.3 | Yes ☐ No ☐ N/A ☐ |
| HRDS6.6.1 | Channel 1 | 16.3.6.3 (Channel Numbering of operating channels) | HRDS6.6:M | Yes ☐ No ☐ N/A ☐ |
| HRDS6.6.2 | Channel 2 | 16.3.6.3 (Channel Numbering of operating channels) | HRDS6.6:M | Yes ☐ No ☐ N/A ☐ |
| HRDS6.6.3 | Channel 3 | 16.3.6.3 (Channel Numbering of operating channels) | HRDS6.6:M | Yes ☐ No ☐ N/A ☐ |
| HRDS6.6.4 | Channel 4 | 16.3.6.3 (Channel Numbering of operating channels) | HRDS6.6:M | Yes ☐ No ☐ N/A ☐ |
| HRDS6.6.5 | Channel 5 | 16.3.6.3 (Channel Numbering of operating channels) | HRDS6.6:M | Yes ☐ No ☐ N/A ☐ |
| HRDS6.6.6 | Channel 6 | 16.3.6.3 (Channel Numbering of operating channels) | HRDS6.6:M | Yes ☐ No ☐ N/A ☐ |
| HRDS6.6.7 | Channel 7 | 16.3.6.3 (Channel Numbering of operating channels) | HRDS6.6:M | Yes ☐ No ☐ N/A ☐ |
| HRDS6.6.8 | Channel 8 | 16.3.6.3 (Channel Numbering of operating channels) | HRDS6.6:M | Yes ☐ No ☐ N/A ☐ |
| HRDS6.6.9 | Channel 9 | 16.3.6.3 (Channel Numbering of operating channels) | HRDS6.6:M | Yes ☐ No ☐ N/A ☐ |
| HRDS6.6.10 | Channel 10 | 16.3.6.3 (Channel Numbering of operating channels) | HRDS6.6:M | Yes ☐ No ☐ N/A ☐ |
| HRDS6.6.11 | Channel 11 | 16.3.6.3 (Channel Numbering of operating channels) | HRDS6.6:M | Yes ☐ No ☐ N/A ☐ |
| HRDS6.6.12 | Channel 12 | 16.3.6.3 (Channel Numbering of operating channels) | HRDS6.6:M | Yes ☐ No ☐ N/A ☐ |
| HRDS6.6.13 | Channel 13 | 16.3.6.3 (Channel Numbering of operating channels) | HRDS6.6:M | Yes ☐ No ☐ N/A ☐ |
| HRDS6.6.14 | Channel 14 | 16.3.6.3 (Channel Numbering of operating channels) | HRDS6.6:M | Yes ☐ No ☐ N/A ☐ |
| *HRDS6.7 | China (Radio Administration The Radio Administration of P.R.China) | 16.3.6.3 (Channel Numbering of operating channels) | HRDS6:O.3 | Yes ☐ No ☐ N/A ☐ |

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## B.4.7 High rate, direct sequence PHY functions *(continued)*

| Item | PHY feature | References | Status | Support |
|---|---|---|---|---|
| HRDS6.7.1 | Channel 1 | 16.3.6.3 (Channel Numbering of operating channels) | HRDS6.7:M | Yes ☐ No ☐ N/A ☐ |
| HRDS6.7.2 | Channel 2 | 16.3.6.3 (Channel Numbering of operating channels) | HRDS6.7:M | Yes ☐ No ☐ N/A ☐ |
| HRDS6.7.3 | Channel 3 | 16.3.6.3 (Channel Numbering of operating channels) | HRDS6.7:M | Yes ☐ No ☐ N/A ☐ |
| HRDS6.7.4 | Channel 4 | 16.3.6.3 (Channel Numbering of operating channels) | HRDS6.7:M | Yes ☐ No ☐ N/A ☐ |
| HRDS6.7.5 | Channel 5 | 16.3.6.3 (Channel Numbering of operating channels) | HRDS6.7:M | Yes ☐ No ☐ N/A ☐ |
| HRDS6.7.6 | Channel 6 | 16.3.6.3 (Channel Numbering of operating channels) | HRDS6.7:M | Yes ☐ No ☐ N/A ☐ |
| HRDS6.7.7 | Channel 7 | 16.3.6.3 (Channel Numbering of operating channels) | HRDS6.7:M | Yes ☐ No ☐ N/A ☐ |
| HRDS6.7.8 | Channel 8 | 16.3.6.3 (Channel Numbering of operating channels) | HRDS6.7:M | Yes ☐ No ☐ N/A ☐ |
| HRDS6.7.9 | Channel 9 | 16.3.6.3 (Channel Numbering of operating channels) | HRDS6.7:M | Yes ☐ No ☐ N/A ☐ |
| HRDS6.7.10 | Channel 10 | 16.3.6.3 (Channel Numbering of operating channels) | HRDS6.7:M | Yes ☐ No ☐ N/A ☐ |
| HRDS6.7.11 | Channel 11 | 16.3.6.3 (Channel Numbering of operating channels) | HRDS6.7:M | Yes ☐ No ☐ N/A ☐ |
| HRDS6.7.12 | Channel 12 | 16.3.6.3 (Channel Numbering of operating channels) | HRDS6.7:M | Yes ☐ No ☐ N/A ☐ |
| HRDS6.7.13 | Channel 13 | 16.3.6.3 (Channel Numbering of operating channels) | HRDS6.7:M | Yes ☐ No ☐ N/A ☐ |
| *HRDS6.8 (#7179) | Mexico (IFT) | 16.3.6.3 (Channel Numbering of operating channels) | HRDS6:O.3 | Yes ☐ No ☐ N/A ☐ |
| HRDS6.8.1 (#7179) | Channel 1 | 16.3.6.3 (Channel Numbering of operating channels) | HRDS6.8:M | Yes ☐ No ☐ N/A ☐ |
| HRDS6.8.2 (#7179) | Channel 2 | 16.3.6.3 (Channel Numbering of operating channels) | HRDS6.8:M | Yes ☐ No ☐ N/A ☐ |
| HRDS6.8.3 (#7179) | Channel 3 | 16.3.6.3 (Channel Numbering of operating channels) | HRDS6.8:M | Yes ☐ No ☐ N/A ☐ |


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## B.4.7 High rate, direct sequence PHY functions *(continued)*

| Item | PHY feature | References | Status | Support |
|---|---|---|---|---|
| HRDS6.8.4 (#7179) | Channel 4 | 16.3.6.3 (Channel Numbering of operating channels) | HRDS6.8:M | Yes ☐ No ☐ N/A ☐ |
| HRDS6.8.5 (#7179) | Channel 5 | 16.3.6.3 (Channel Numbering of operating channels) | HRDS6.8:M | Yes ☐ No ☐ N/A ☐ |
| HRDS6.8.6 (#7179) | Channel 6 | 16.3.6.3 (Channel Numbering of operating channels) | HRDS6.8:M | Yes ☐ No ☐ N/A ☐ |
| HRDS6.8.7 (#7179) | Channel 7 | 16.3.6.3 (Channel Numbering of operating channels) | HRDS6.8:M | Yes ☐ No ☐ N/A ☐ |
| HRDS6.8.8 (#7179) | Channel 8 | 16.3.6.3 (Channel Numbering of operating channels) | HRDS6.8:M | Yes ☐ No ☐ N/A ☐ |
| HRDS6.8.9 (#7179) | Channel 9 | 16.3.6.3 (Channel Numbering of operating channels) | HRDS6.8:M | Yes ☐ No ☐ N/A ☐ |
| HRDS6.8.10 (#7179) | Channel 10 | 16.3.6.3 (Channel Numbering of operating channels) | HRDS6.8:M | Yes ☐ No ☐ N/A ☐ |
| HRDS6.8.11 (#7179) | Channel 11 | 16.3.6.3 (Channel Numbering of operating channels) | HRDS6.8:M | Yes ☐ No ☐ N/A ☐ |
| HRDS7 | *Reserved* | | | |
| HRDS8 | Complementary code keying (CCK) bits to symbol mapping | | | |
| HRDS8.1 | 5.5 Mb/s | 16.3.6.6 (Spreading sequences and modulation for CCK modulation at 5.5 Mb/s and 11 Mb/s) | M | Yes ☐ No ☐ |
| HRDS8.2 | 11 Mb/s | 16.3.6.6 (Spreading sequences and modulation for CCK modulation at 5.5 Mb/s and 11 Mb/s) | M | Yes ☐ No ☐ |
| HRDS9 | *Reserved* | | | |
| *HRDS10 | CCA functionality | 16.3.8.5 (CCA) | | |
| HRDS10.1 | CCA Mode 1, energy only (RSSI above threshold) | 16.3.8.5 (CCA) | HRDS10:O.4 | Yes ☐ No ☐ N/A ☐ |
| HRDS10.2 | CCA Mode 4, CS with timer | 16.3.8.5 (CCA) | HRDS10:O.4 | Yes ☐ No ☐ N/A ☐ |
| HRDS10.3 | CCA Mode 5, energy detect with high rate CS | 16.3.8.5 (CCA) | HRDS10:O.4 | Yes ☐ No ☐ N/A ☐ |
| HRDS10.4 | Hold CCA busy for packet duration of a correctly received PPDU, but carrier lost during reception of MPDU. | 16.2.6 (Receive PHY) | M | Yes ☐ No ☐ |

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## B.4.7 High rate, direct sequence PHY functions *(continued)*

| Item | PHY feature | References | Status | Support |
|---|---|---|---|---|
| HRDS10.5 | Hold CCA busy for packet duration of a correctly received, but out of spec, PPDU. | 16.2.6 (Receive PHY) | M | Yes ☐ No ☐ |
| HRDS11 | Transmit antenna selection | 16.3.5 (Vector descriptions) | O | Yes ☐ No ☐ |
| HRDS12 | Receive antenna diversity | 16.3.5 (Vector descriptions) | O | Yes ☐ No ☐ |
| *HRDS13 | Antenna connector availability | 16.3.6.11 (Transmit and receive impedance at the antenna connector) | O | Yes ☐ No ☐ |
| HRDS13.1 | If available (50 Ω impedance) | 16.3.6.11 (Transmit and receive impedance at the antenna connector) | HRDS13:M | Yes ☐ No ☐ N/A ☐ |
| *HRDS14 | Transmit power level support | 16.3.7.3 (Transmit power level control) | O | Yes ☐ No ☐ |
| HRDS14.1 | If greater than 100 mW capability | 16.3.7.3 (Transmit power level control) | HRDS14:M | Yes ☐ No ☐ N/A ☐ |
| HRDS15 | Spurious emissions compliance | 16.3.6.7 (Transmit and receive in-band and out-of-band spurious emissions) | M | Yes ☐ No ☐ |
| HRDS16 | TX-to-RX turnaround time | 16.3.6.8 (TX-to-RX turnaround time) | M | Yes ☐ No ☐ |
| HRDS17 | RX-to-TX turnaround time | 16.3.6.9 (RX-to-TX turnaround time) | M | Yes ☐ No ☐ |
| HRDS18 | Slot time | 16.3.6.10 (Slot time) | M | Yes ☐ No ☐ |
| HRDS19 | ED reporting time | 16.3.6.9 (RX-to-TX turnaround time), 16.3.8.5 (CCA) | M | Yes ☐ No ☐ |
| HRDS20 | Minimum transmit power level | 16.3.7.3 (Transmit power level control) | M | Yes ☐ No ☐ |
| HRDS21 | Transmit spectral mask compliance | 16.3.7.4 (Transmit spectrum mask) | M | Yes ☐ No ☐ |
| HRDS22 | Transmitted center frequency tolerance | 16.3.7.5 (Transmit center frequency tolerance) | M | Yes ☐ No ☐ |
| HRDS23 | Chip clock frequency tolerance | 16.3.7.6 (Chip clock frequency tolerance) | M | Yes ☐ No ☐ |
| HRDS24 | Transmit power-on ramp | 16.3.7.7 (Transmit power-on and power-down ramp) | M | Yes ☐ No ☐ |


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## B.4.7 High rate, direct sequence PHY functions *(continued)*

| Item | PHY feature | References | Status | Support |
|---|---|---|---|---|
| HRDS25 | Transmit power-down ramp | 16.3.7.7 (Transmit power-on and power-down ramp) | M | Yes ☐ No ☐ |
| HRDS26 | RF carrier suppression | 16.3.7.8 (RF carrier suppression) | M | Yes ☐ No ☐ |
| HRDS27 | Transmit modulation accuracy | 16.3.7.9 (Transmit modulation accuracy) | M | Yes ☐ No ☐ |
| HRDS28 | Receiver minimum input level sensitivity | 16.3.8.2 (Receiver minimum input level sensitivity) | M | Yes ☐ No ☐ |
| HRDS29 | Receiver maximum input level | 16.3.8.3 (Receiver maximum input level) | M | Yes ☐ No ☐ |
| HRDS30 | Receiver adjacent channel rejection | 16.3.8.4 (Receiver adjacent channel rejection) | M | Yes ☐ No ☐ |
| HRDS31 | MIB | 16.3.2 (HR/DSSS PHY MIB) | M | Yes ☐ No ☐ |
| HRDS31.1 | PHY object class | 16.3.3 (HR/DSSS PHY) | M | Yes ☐ No ☐ |

## B.4.8 Regulatory domain extensions

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| MD1 | Country element<br><br>Length<br>Country String<br>First Channel Number<br>Maximum Transmit Power Level<br>Number of Channels | 9.3.3.2 (Beacon frame format), 9.3.3.10 (Probe Response frame format), 9.4.2.7 (Country element) | CFMD:M | Yes ☐ No ☐ N/A ☐ |
| MD2 | Inclusion of the Request information in the Probe Request frame | 9.3.3.9 (Probe Request frame format) | CFMD:O | Yes ☐ No ☐ N/A ☐ |
| MD3 | *Reserved* | | | |
| MD4 | *Reserved* | | | |
| MD5 | Request mechanism | | | |

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## B.4.8 Regulatory domain extensions *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| MD5.1 | Request element<br><br>Format<br>Element ID<br>Order of the Requested Elemented IDs | 9.4.2.8 (Request element) | CFMD:M | Yes ☐ No ☐ N/A ☐ |
| MD5.2 | Extended Request element | 9.4.2.9 (Extended Request element) | CFMD:M | Yes ☐ No ☐ N/A ☐ |
| MD6 | Entering a Regulatory Domain<br>Lost Connectivity with its extended service set (ESS)<br>Passive Scanning to learn Beacon information<br>Transmit Probe Request | 10.22.2 (Operation upon entering a regulatory domain) | CFMD:M | Yes ☐ No ☐ N/A ☐ |
| MD7 | *Reserved* | | | |
| MD8 | (#3449)Beacon frame with country element | 11.1.4.4 (Initializing a BSS) | CFMD:M | Yes ☐ No ☐ N/A ☐ |
| MD9 | Actions to be taken upon the receipt of the Beacon frame | 11.1.4.5 (Synchronizing with a BSS) | CFMD:M | Yes ☐ No ☐ N/A ☐ |
| MD10 | *Reserved* | | | |
| MD11 | *Reserved* | | | |
| MD12 | Operating and Coverage classes | 9.4.2.7 (Country element) | OC1:M | Yes ☐ No ☐ N/A ☐ |
| MD13 | Reserved First Channel Number | 10.22.3 (Operation with operating classes) | CF3G6:M | Yes ☐ No ☐ N/A ☐ |
| MD14 | Reserved Operating Class | 10.22.3 (Operation with operating classes) | CF3G6:M | Yes ☐ No ☐ N/A ☐ |
| *MD15 | Operation with operating classes | 10.22.3 (Operation with operating classes) | CF3G6:M | Yes ☐ No ☐ N/A ☐ |


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### B.4.8 Regulatory domain extensions *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| MD15.1 | Multiple classes in Country element | 10.22.3 (Operation with operating classes) | MD15:M | Yes ☐ No ☐ N/A ☐ |
| MD15.2 | Multiple classes in (Re)Association Request and Response frames | 10.22.3 (Operation with operating classes) | MD15:M | Yes ☐ No ☐ N/A ☐ |

### B.4.9 ERP functions

| Item | PHY features | References | Status | Support |
|---|---|---|---|---|
| *ERP1 | Transmit and Receive ERP-DSSS data rates 1 and 2 Mb/s and ERP-CCK data rates 5.5 and 11 Mb/s | 18.3.2 (PPDU format) | CFERP:M | Yes ☐ No ☐ N/A ☐ |
| ERP1.1 | Transmit and receive ERP-OFDM data rates of 6, 12, and 24 Mb/s | 18.3.2 (PPDU format) | CFERP:M | Yes ☐ No ☐ N/A ☐ |
| ERP1.2 | Transmit and receive ERP-OFDM data rate of 9 Mb/s | 18.3.2 (PPDU format) | ERP1:O | Yes ☐ No ☐ N/A ☐ |
| ERP1.3 | Transmit and receive ERP-OFDM data rate of 18 Mb/s | 18.3.2 (PPDU format) | ERP1:O | Yes ☐ No ☐ N/A ☐ |
| ERP1.4 | Transmit and receive ERP-OFDM data rate of 36 Mb/s | 18.3.2 (PPDU format) | ERP1:O | Yes ☐ No ☐ N/A ☐ |
| ERP1.5 | Transmit and receive ERP-OFDM data rate of 48 Mb/s | 18.3.2 (PPDU format) | ERP1:O | Yes ☐ No ☐ N/A ☐ |
| ERP1.6 | Transmit and receive ERP-OFDM data rate of 54 Mb/s | 18.3.2 (PPDU format) | ERP1:O | Yes ☐ No ☐ N/A ☐ |
| ERP2 | *Reserved* | | | |
| ERP3 | *Reserved* | | | |
| ERP4 (#6009) | *Reserved* | | | |
| ERP5 | Able to transmit and receive long and short DSSS as well as OFDM preambles | 18.3.2 (PPDU format) | CFERP:M | Yes ☐ No ☐ N/A ☐ |

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## B.4.9 ERP functions *(continued)*

| Item | PHY features | References | Status | Support |
|---|---|---|---|---|
| ERP6 | Set SERVICE field bits for locked clocks, and length extension | 18.3.2.2 (Long preamble PPDU format) | CFERP:M | Yes ☐ No ☐ N/A ☐ |
| ERP7 | Set B1 and B4 of long and short preamble PPDU SERVICE field to 0 | 18.3.2.2 (Long preamble PPDU format) | CFERP:M | Yes ☐ No ☐ N/A ☐ |
| ERP8 | Set B2 to 1 in all long and short preamble PPDU SERVICE fields | 18.3.2.2 (Long preamble PPDU format) | CFERP:M | Yes ☐ No ☐ N/A ☐ |
| ERP9 | Set B7 of the long and short preamble PPDU SERVICE fields as described in the reference | 18.3.2.2 (Long preamble PPDU format), 18.3.2.3 (Short preamble PPDU format) | CFERP:M | Yes ☐ No ☐ N/A ☐ |
| ERP10 | Use Clause 15 (DSSS PHY specification for the 2.4 GHz band designated for ISM applications) (DSSS for 2.4 GHz band for ISM applications) or Clause 16 (High rate direct sequence spread spectrum (HR/DSSS) PHY specification) (HR/DSSS) rates when using protection mechanisms | 10.27 (Protection mechanisms) | CFERP:M | Yes ☐ No ☐ N/A ☐ |
| ERP11 | *Reserved* | | | |
| ERP12 | *Reserved* | | | |
| ERP13 | *Reserved* | | | |
| ERP14 | *Reserved* | | | |
| ERP15 | *Reserved* | | | |
| ERP16 | Add signal extension of 6 μs | 18.3.2.4 (ERP-OFDM PPDU format) | CFERP:M | Yes ☐ No ☐ N/A ☐ |
| ERP17 | Simultaneous CCA on long preamble Barker, short preamble Barker, and OFDM | 18.3.4 (CCA) | CFERP:M | Yes ☐ No ☐ N/A ☐ |


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## B.4.9 ERP functions *(continued)*

| Item | PHY features | References | Status | Support |
|---|---|---|---|---|
| ERP18 | CCA with energy detect above threshold and CS | 18.3.4 (CCA) | CFERP:M | Yes ☐ No ☐ N/A ☐ |
| ERP19 | *Reserved* | | | |
| ERP20 | Able to automatically detect format of long preamble Barker, short preamble Barker, and OFDM and receive appropriately | 18.3.6 (PHY receive procedure) | CFERP:M | Yes ☐ No ☐ N/A ☐ |
| ERP21 | Comply with local regulatory frequency allocation requirements | 18.4.2 (Regulatory requirements) | CFERP:M | Yes ☐ No ☐ N/A ☐ |
| ERP22 | Use frequency plan for 2.4 GHz | 18.4.3 (Operating channel frequencies) | CFERP:M | Yes ☐ No ☐ N/A ☐ |
| ERP23 | Comply with regulatory spurious emissions regulations | 18.4.4 (Transmit and receive in-band and out-of-band spurious emissions) | CFERP:M | Yes ☐ No ☐ N/A ☐ |
| ERP24 | Slot time requirements | 18.5.4 (ERP) | CFERP:M | Yes ☐ No ☐ N/A ☐ |
| ERP25 | Support short slot time | 18.5.4 (ERP) | CFERP:O | Yes ☐ No ☐ N/A ☐ |
| ERP26 | Use 10 μs short interframe space (SIFS) time | 18.4.6 (CCA performance) | CFERP:M | Yes ☐ No ☐ N/A ☐ |
| ERP27 | Comply with regulatory transmit power requirements | 18.4.7.2 (Transmit power levels) | CFERP:M | Yes ☐ No ☐ N/A ☐ |
| ERP28 | ± 25 ppm frequency tolerance | 18.4.7.4 (Transmit center frequency tolerance) | CFERP:M | Yes ☐ No ☐ N/A ☐ |
| ERP29 | Use locked clocks | 18.4.7.4 (Transmit center frequency tolerance), 18.4.7.5 (Symbol clock frequency tolerance) | CFERP:M | Yes ☐ No ☐ N/A ☐ |

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## B.4.9 ERP functions *(continued)*

| Item | PHY features | References | Status | Support |
|---|---|---|---|---|
| ERP30 | Tolerate input level of –20 dBm | 18.4.8.4 (Receive maximum input level capability) | CFERP:M | Yes ☐ No ☐ N/A ☐ |
| ERP31 | Use specified transmit mask | 18.5 (ERP PLME) | CFERP:M | Yes ☐ No ☐ N/A ☐ |
| ERP32 | Meet sensitivity for all supported data rates | 18.4.8.2 (Receiver minimum input level sensitivity) | CFERP:M | Yes ☐ No ☐ N/A ☐ |
| ERP33 | Reject adjacent channels as in 17.3.10.2 (Receiver minimum input level sensitivity(#256)) (Table 17-21 (Receiver performance requirements)) or in 16.3.8.4 (Receiver adjacent channel rejection) as appropriate | 18.4.8.3 (Adjacent channel rejection) | CFERP:M | Yes ☐ No ☐ N/A ☐ |
| ERP34 | *Reserved* | | | |
| ERP35 | *Reserved* | | | |
| ERP36 | *Reserved* | | | |
| ERP37 | *Reserved* | | | |
| ERP38 | *Reserved* | | | |
| ERP39 | Calculate ERP-OFDM TXTIME | 18.5.3.2 (ERP-OFDM TXTIME calculations) | CFERP:M | Yes ☐ No ☐ N/A ☐ |
| ERP40 | *Reserved* | | | |
| ERP41 | *Reserved* | | | |
| ERP42 | Revert to long slot time when establishing association with a long slot time STA | 9.4.1.4 (Capability Information field) | CFERP:M | Yes ☐ No ☐ N/A ☐ |
| ERP43 | Support TXVECTOR and RXVECTOR as described in reference | 10.3 (DCF) | CFERP:M | Yes ☐ No ☐ N/A ☐ |
| ERP44 | *Reserved* | | | |


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## B.4.10 Spectrum management extensions

| Item | IUT configuration | References | Status | Support |
|---|---|---|---|---|
| SM1 | Country, Power Constraint, and transmit power control (TPC) Report elements included in Beacon and Probe Response frames | 9.3.3.2 (Beacon frame format), 9.3.3.10 (Probe Response frame format), 9.4.2.7 (Country element), 9.4.2.10 (ERP element), 9.4.2.13 (Power Capability element) | CFSM:M | Yes ☐ No ☐ N/A ☐ |
| SM1.1 | Transmit Envelope element(s) in Beacon and Probe Response frames | 9.4.2.160 (Transmit Power Envelope element) | CFSM AND CFESM:M | Yes ☐ No ☐ N/A ☐ |
| SM2 | (#402)Spectrum Management Capability subfield in the Capability Information field | 9.4.1.4 (Capability Information field) | CFSM:M | Yes ☐ No ☐ N/A ☐ |
| SM3 | Power Capability and Supported Channels elements in (Re)Association Request and Response frames | 9.3.3.5 (Association Request frame format), 9.3.3.6 (Association Response frame format), 11.6.1 (Introduction) | CFSM:M NOT CFSM:O(#3510) | Yes ☐ No ☐ N/A ☐ |
| SM4 | Action frame protocol for spectrum management actions | 9.4.1.11 (Action field), 9.5.7 (EDMG BRP field(11ay)) | CFSM:M | Yes ☐ No ☐ N/A ☐ |
| SM4.1 | Measurement Request frame | 9.6.2.2 (Spectrum Measurement Request frame format) | CFSM:M | Yes ☐ No ☐ N/A ☐ |
| SM4.2 | Measurement Report frame | 9.6.2.3 (Spectrum Measurement Report frame format) | CFSM:M | Yes ☐ No ☐ N/A ☐ |
| SM4.3 | TPC Request frame | 9.6.2.4 (TPC Request frame format) | CFSM:M | Yes ☐ No ☐ N/A ☐ |
| SM4.4 | TPC Report frame | 9.6.2.5 (TPC Report frame format) | CFSM:M | Yes ☐ No ☐ N/A ☐ |

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## B.4.10 Spectrum management extensions *(continued)*

| Item | IUT configuration | References | Status | Support |
|---|---|---|---|---|
| SM4.5 | Channel Switch Announcement frame | 9.6.2.6 (Channel Switch Announcement frame format) | CFSM AND NOT CFDMG:M | Yes ☐ No ☐ N/A ☐ |
| SM5 | Measurement requests | | | |
| SM5.1 | Basic request | 9.4.2.19.2 (Basic request) | CFSM:M | Yes ☐ No ☐ N/A ☐ |
| SM5.2 | CCA request | 9.4.2.19.3 (CCA request (Clear channel access request)) | CFSM:O | Yes ☐ No ☐ N/A ☐ |
| SM5.3 | Receive power indication (RPI) histogram | 9.4.2.19.4 (RPI histogram request (Received power indicator histogram request)) | CFSM:O | Yes ☐ No ☐ N/A ☐ |
| SM5.4 | Enabling/disabling requests and reports | 9.4.2.19 (Measurement Request element) | CFSM:M | Yes ☐ No ☐ N/A ☐ |
| SM6 | Measurement reports | | | |
| SM6.1 | Basic report | 9.4.2.20.2 (Basic report) | CFSM:M | Yes ☐ No ☐ N/A ☐ |
| SM6.2 | CCA report | 9.4.2.20.3 (CCA report) | CFSM:O | Yes ☐ No ☐ N/A ☐ |
| SM6.3 | RPI histogram report | 9.4.2.20.4 (RPI histogram report) | CFSM:O | Yes ☐ No ☐ N/A ☐ |
| SM6.4 | Refusal to measure | 9.4.2.20 (Measurement Report element) | CFSM:M | Yes ☐ No ☐ N/A ☐ |
| SM7 | Quiet interval(#3797) | | | |
| SM7.1 | AP-defined Quiet interval | 9.3.3.2 (Beacon frame format), 9.3.3.10 (Probe Response frame format), 9.4.2.21 (Quiet element), 11.8.3 (Quieting channels for testing)(#3797) | (CFAP (#4138)AND CFSM):M | Yes ☐ No ☐ N/A ☐ |


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## B.4.10 Spectrum management extensions *(continued)*

| Item | IUT configuration | References | Status | Support |
|---|---|---|---|---|
| SM7.2 | STA-defined Quiet interval | 9.3.3.2 (Beacon frame format), 9.3.3.10 (Probe Response frame format), 9.4.2.21 (Quiet element), 11.8.3 (Quieting channels for testing)(#3797) | (CFSTAofAP (#4138)AND CFSM):M | Yes ☐ No ☐ N/A ☐ |
| SM7.3 | STA support for Quiet interval | 9.3.3.2 (Beacon frame format), 9.3.3.10 (Probe Response frame format), 9.4.2.21 (Quiet element), 11.8.3 (Quieting channels for testing)(#3797) | CFSM:M | Yes ☐ No ☐ N/A ☐ |
| SM8 | Association control based on spectrum management capability | 11.7 (TPC procedures), 11.8 (DFS procedures) | (CFAP (#4138)AND CFSM):M | Yes ☐ No ☐ N/A ☐ |
| SM9 | Association control based on transmit power capability | 11.7.2 (Association based on transmit power capability) | (CFAP (#4138)AND CFSM):M | Yes ☐ No ☐ N/A ☐ |
| SM10 | Maximum transmit power levels | | | |
| SM10.1 | AP determination and communication of local maximum transmit power level | 11.7.5 (Specification of regulatory and local maximum transmit power levels) | (CFAP AND CFSM):M | Yes ☐ No ☐ N/A ☐ |
| SM10.2 | STA determination and communication of local maximum transmit power level | 11.7.5 (Specification of regulatory and local maximum transmit power levels) | ((CFSTAofAP OR CFIBSS) AND CFSM):M | Yes ☐ No ☐ N/A ☐ |
| SM11 | Selection of transmit power | 11.7.6 (Transmit power selection) | CFSM:M | Yes ☐ No ☐ N/A ☐ |
| SM12 | Adaptation of transmit power | | | |
| SM12.1 | TPC report in Beacon and Probe Response frames | 11.7.7 (Transmit power adaptation) | CFSM:M | Yes ☐ No ☐ N/A ☐ |

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## B.4.10 Spectrum management extensions *(continued)*

| Item | IUT configuration | References | Status | Support |
|---|---|---|---|---|
| SM13.1 | Dynamic transmit power adaptation | 11.7.7 (Transmit power adaptation) | CFSM:O | Yes ☐ No ☐ N/A ☐ |
| SM13 | Testing channels for radar | 11.8.4 (Testing channels for radar) | CFSM:M | Yes ☐ No ☐ N/A ☐ |
| SM14 | Detecting and discontinuing operations after detection of radar | 11.8.5 (Discontinuing operations after detecting radar) | CFSM:M | Yes ☐ No ☐ N/A ☐ |
| SM15 | Requesting and reporting of measurements | 11.8.7 (Requesting and reporting of measurements) | CFSM:M | Yes ☐ No ☐ N/A ☐ |
| SM16 | Autonomous reporting of radar | 11.8.7 (Requesting and reporting of measurements) | CFSM:M | Yes ☐ No ☐ N/A ☐ |
| SM17 | (#1776)IBSS DFS element | 9.4.2.22 (IBSS DFS element) | (CFIBSS AND CFSM):M | Yes ☐ No ☐ N/A ☐ |
| SM18 | DFS owner function | 11.8.8 (Selecting and advertising a new channel) | (CFIBSS AND CFSM):M | Yes ☐ No ☐ N/A ☐ |
| SM19 | DFS owner recovery procedure | 11.8.8 (Selecting and advertising a new channel) | (CFIBSS AND CFSM):M | Yes ☐ No ☐ N/A ☐ |
| SM20 | Channel switching procedure | | | |
| SM20.1 | Transmission of channel switch announcement and channel switching procedure by an AP | 11.8.8 (Selecting and advertising a new channel) | (CFAP AND CFSM):M (#423)AND NOT CFDMG: M | Yes ☐ No ☐ N/A ☐ |
| SM20.2 | Transmission of channel switch announcement and channel switching procedure by a STA | 11.8.8 (Selecting and advertising a new channel) | (CFSTAofAP AND CFSM):M (#423)AND NOT CFDMG: M | Yes ☐ No ☐ N/A ☐ |
| SM20.3 | Reception of channel switch announcement and channel switching procedure by a STA | 11.8.8 (Selecting and advertising a new channel) | CFSM:M (#423)AND NOT CFDMG: M | Yes ☐ No ☐ N/A ☐ |
| SM20.4 | Transmission of Wide Bandwidth Channel Switch element in Channel Announcement frame and transmission of Wide Bandwidth Channel Switch subelement in Channel Switch Wrapper element in Beacon/ Probe Response frames, and associated channel switching procedure by an AP | 11.38.4 (Channel switching methods for a VHT BSS) | (CFAP AND CFSM AND CFESM):M (#423)AND NOT CFDMG: M | Yes ☐ No ☐ N/A ☐ |


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## B.4.10 Spectrum management extensions *(continued)*

| Item | IUT configuration | References | Status | Support |
|---|---|---|---|---|
| SM20.5 | Transmission of Wide Bandwidth Channel Switch element in Channel Announcement frame and transmission of Wide Bandwidth Channel Switch subelement in Channel Switch Wrapper element in Beacon/ Probe Response frames, and associated channel switching procedure by a STA. | 11.38.4 (Channel switching methods for a VHT BSS) | (CFIBSS AND CFSM AND CFESM):M (#423)AND NOT CFDMG: M | Yes ☐ No ☐ N/A ☐ |
| SM20.6 | Reception of Wide Bandwidth Channel Switch element in Channel Announcement frame and reception of Wide Bandwidth Channel Switch subelement in Channel Switch Wrapper element in Beacon/Probe Response frames, and associated channel switching procedure by a STA. | 11.38.4 (Channel switching methods for a VHT BSS) | (CFSM AND CFESM):M (#423)AND NOT CFDMG: M | Yes ☐ No ☐ N/A ☐ |
| SM20.7 | Transmission of New Transmit Power Envelope element in Channel Announcement frame and transmission of New Transmit Power Envelope subelement in Channel Switch Wrapper element in Beacon/ Probe Response frames, and associated channel switching procedure by an AP. | 11.38.4 (Channel switching methods for a VHT BSS) | (CFAP AND CFSM AND CFESM):M (#423)AND NOT CFDMG: M | Yes ☐ No ☐ N/A ☐ |
| SM20.8 | Transmission of New Transmit Power Envelope element in Channel Announcement frame and transmission of New Transmit Power Envelope subelement in Channel Switch Wrapper element in Beacon/ Probe Response frames, and associated channel switching procedure by a STA. | 11.38.4 (Channel switching methods for a VHT BSS) | (CFIBSS AND CFSM AND CFESM):M (#423)AND NOT CFDMG: M | Yes ☐ No ☐ N/A ☐ |
| SM20.9 | Reception of New Transmit Power Envelope element in Channel Announcement frame and reception of New Transmit Power Envelope subelement in Channel Switch Wrapper element in Beacon/Probe Response frames, and associated channel switching procedure by a STA. | 11.38.4 (Channel switching methods for a VHT BSS) | (CFSM AND CFESM):M (#423)AND NOT CFDMG: M | Yes ☐ No ☐ N/A ☐ |
| SM20.10 | Transmission of Future Channel Guidance element by a STA. | 11.8.10 (Future Channel Guidance operation) | CFSM:O (#423)AND NOT CFDMG: M | Yes ☐ No ☐ N/A ☐ |
| SM20.11 | Reception of Future Channel Guidance element procedure by a STA. | 11.8.10 (Future Channel Guidance operation) | CFSM:O (#423)AND NOT CFDMG: M | Yes ☐ No ☐ N/A ☐ |

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## B.4.11 Operating classes extensions

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| OC1 | Operating and coverage classes | 9.4.2.7 (Country element) | CFMD AND CFOC:M | Yes ☐ No ☐ N/A ☐ |
| OC2 | Operating and coverage classes (20 MHz channel spacing) | 9.4.2.7 (Country element), 17.3.8.6 (Slot time) | CFMD AND CFOC:M | Yes ☐ No ☐ N/A ☐ |
| OC3 | Operating and coverage classes (10 MHz channel spacing) | 9.4.2.7 (Country element), 17.3.8.6 (Slot time) | CFMD AND CFOC AND OF1.7:M | Yes ☐ No ☐ N/A ☐ |
| OC4 | Operating and coverage classes (5 MHz channel spacing) | 9.4.2.7 (Country element), 17.3.8.6 (Slot time) | CFMD AND CFOC AND OF1.8:M | Yes ☐ No ☐ N/A ☐ |
| OC5 | Coverage classes 0–31 | 10.22.5 (Operation with coverage classes) | CF3G6:M | Yes ☐ No ☐ N/A ☐ |
| OC5.1(M118) | Coverage class operation when not associated | 10.22.5 (Operation with coverage classes) | CF3G6:M | Yes ☐ No ☐ N/A ☐ |
| OC6 | Power level, equivalent maximum transmit power level and operating class | 10.22.5 (Operation with coverage classes) | CF3G6:M | Yes ☐ No ☐ N/A ☐ |
| OC6.1(M118) | Power level operation when not associated | 10.22.5 (Operation with coverage classes) | CF3G6:M | Yes ☐ No ☐ N/A ☐ |
| OC7 | Power level, different maximum transmit power level and operating class | 10.22.5 (Operation with coverage classes) | CF3G6:M | Yes ☐ No ☐ N/A ☐ |


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## B.4.11 Operating classes extensions *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| OC7.1(M118) | Power level operation when not associated | 10.22.5 (Operation with coverage classes) | CF3G6:M | Yes ☐ No ☐ N/A ☐ |
| OC8 | Operation with multiple country elements | — (When dot11OperatingClassesRequired is true, or where operating classes domain information is present and the STA parsing a Country element finds an invalid First Channel Number field or Operating Class field with a value that is reserved, the STA shall ignore the remainder of the Country element and shall parse any remaining management frame body for additional elements.) | OC1:O | Yes ☐ No ☐ N/A ☐ |

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## B.4.12 QoS base functionality

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| QB1 | QoS frame format | | | |
| QB1.1 | QoS frame format | 9.3.1.2 (RTS frame format)–9.3.1.4 (Ack frame format), 9.3.2.1 (Format of Data frames), 9.3.3.2 (Beacon frame format), 9.3.3.5 (Association Request frame format)–9.3.3.8 (Reassociation Response frame format), 9.3.3.10 (Probe Response frame format), 9.3.3.13 (Action frame format) | (#4138)NOT CFDMG AND CFQoS:M | Yes ☐ No ☐ N/A ☐ |
| QB1.2 | QoS frame format | 9.3.1.2 (RTS frame format), 9.3.1.4 (Ack frame format), 9.3.1.7 (BlockAckReq frame format), 9.3.1.8 (BlockAck frame format), 9.3.1.10 (Poll frame format)–9.3.1.18 (Grant Ack frame format), 9.3.2.1 (Format of Data frames), 9.3.4.2 (DMG Beacon), 9.3.3.5 (Association Request frame format)–9.3.3.8 (Reassociation Response frame format), 9.3.3.10 (Probe Response frame format), 9.3.3.13 (Action frame format) | CFDMG:M | Yes ☐ No ☐ N/A ☐ |
| QB2 | Per traffic identifier (TID) duplicate detection | 9.2.4.4 (Sequence Control field), 9.2.4.5 (QoS Control field), 10.3.2.14 (Duplicate detection and recovery) | CFQoS OR CFDMG:M | Yes ☐ No ☐ N/A ☐ |


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## B.4.12 QoS base functionality *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| QB3 | Decode of No Ack ack policy in QoS Data frames | 9.2.4.5.4 (Ack Policy Indicator subfield), 10.23.2.8 (Multiple frame exchange sequences in an EDCA TXOP(#109)), 10.23.2.12 (Retransmit procedures), 10.23.4.2 (Contention based admission control procedures), 10.23.4.3 (Controlled-access admission control) | CFQoS OR CFDMG:M | Yes ☐ No ☐ N/A ☐ |
| QB4 | Block acknowledgments (block ack) | | | |
| QB4.1 | Immediate block ack(#1332) | 9.3.1.7.1 (Overview), 9.3.1.8.1 (Overview), 9.6.4 (Block Ack Action frame details), 10.25 (Block acknowledgment (block ack)) (except 10.25.6 (HT-immediate block ack extensions)), 11.5 (Block ack operation) | CFQoS:O CFHT OR CFDMG OR CFTVHT:M | Yes ☐ No ☐ N/A ☐ |
| (M118) QB4.2 | *Reserved* | | | |
| QB4.3 | (11ay)Unsolicited block ack | (11ay)9.4.2.278 (Unsolicited Block Ack Extension element(11ay)), 10.25.10 (Unsolicited block ack extension(11ay)) | (11ay)CFQoS:O | (11ay)Yes ☐ No ☐ N/A ☐ |
| QB4.3.1 | Compressed Block Ack | 9.3.1.7.2 (Compressed BlockAckReq variant) | CFQoS:O CFHT OR CFDMG OR CFTVHT:M | Yes ☐ No ☐ N/A ☐ |
| QB4.3.2 | Extended Compressed Block Ack | 9.3.1.7.3 (Extended Compressed BlockAckReq variant) | CFDMG:O | Yes ☐ No ☐ N/A ☐ |

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## B.4.12 QoS base functionality *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| (11ay)QB4.3.3 | EDMG Compressed BlockAck | 9.3.1.8.7 (EDMG Compressed BlockAck variant(11ay)) | CFEDMG:M | Yes ☐ No ☐ N/A ☐ |
| QB4.4 | Reserved(#6599) | | | Yes ☐ No ☐ N/A ☐ |
| (11ay)QB4.4.1 | Reserved(#4251) | | | |
| (11ay)QB4.4.2 | EDMG Multi-TID BlockAck | 9.3.1.8.8 (EDMG Multi-TID BlockAck variant(11ay)) | CFEDMG:O | Yes ☐ No ☐ N/A ☐ |
| (11ax)QB4.5 | Multi-STA BlockAck | 9.3.1.8.6 (Multi-STA BlockAck variant(11ax)) | CFHE:M | Yes ☐ No ☐ N/A ☐ |
| (M118)* QB5 | Automatic power save delivery (APSD) | 9.6.3 (QoS Action frame details), 11.2.3 (Power management in a non-DMG infrastructure network) | (CFAP (#4138)AND CFQoS):O (CFIndepSTA (#4138)AND CFQoS):O | Yes ☐ No ☐ N/A ☐ |

## B.4.13 QoS enhanced distributed channel access (EDCA)

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| QD1 | Support for four transmit queues with a separate channel access entity associated with each | 10.2.3.2 (HCF contention based channel access (EDCA)), 10.23.2.1 (Reference model) | (#4138)NOT CFDMG AND CFQoS:M CFS1G AND S1GM20.5: M CFS1G AND S1GM20.4:O | Yes ☐ No ☐ N/A ☐ |
| QD2 | Per-channel access function differentiated channel access | 10.23.2.2 (EDCA backoff procedure), 10.23.2.4 (Obtaining an EDCA TXOP), 10.23.2.12 (Retransmit procedures) | (#4138)NOT CFDMG AND CFQoS:M | Yes ☐ No ☐ N/A ☐ |
| QD3 | Multiple frame exchange sequences in an ECDA TXOP support(#109) | 10.23.2.8 (Multiple frame exchange sequences in an EDCA TXOP(#109)) | CFQoS OR CFDMG OR CFS1G:O | Yes ☐ No ☐ N/A ☐ |
| QD4 | Maintenance of within-queue ordering, exhaustive retransmission when sending non-QoS Data frames | 10.23.2.12 (Retransmit procedures) | (CFQoS AND NOT CFS1G) OR CFDMG:M | Yes ☐ No ☐ N/A ☐ |


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## B.4.13 QoS enhanced distributed channel access (EDCA) *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| QD5 | Interpretation of admission control mandatory (ACM) subfield in EDCA Parameter Set element | 9.4.2.11 (Extended Supported Rates and BSS Membership Selectors element), 10.23.4.2 (Contention based admission control procedures) | (CFSTAofAP AND (CFQoS OR CFDMG)):M (CFPBSSnotPCP AND CFDMG): | Yes ☐ No ☐ N/A ☐ |
| (M118)*QD6 | Contention based admission control | 9.4.2.12 (Power Constraint element), 9.4.2.13 (Power Capability element), 9.6.3.2 (Basic and DMG ADDTS Request frame format)–9.6.3.4 (DELTS frame format), 10.23.4.2 (Contention based admission control procedures), 11.4 (TS operation) | (CFAP AND (CFQoS OR CFDMG)):O (CFSTAofAP AND (CFQoS OR CFDMG)):O (CFPCP AND CFDMG):O (CFPBSSnotPCP AND CFDMG):O | Yes ☐ No ☐ N/A ☐ |
| QD7 | Power management in an infrastructure BSS or in an IBSS | 11.2 (Power management) | (CFAP AND CFQoS):O (CFIndepSTA AND CFQoS):O | Yes ☐ No ☐ N/A ☐ |
| QD8 | Default EDCA parameters for communications outside context of BSS | 9.4.2.27 (EDCA Parameter Set element), 10.23.2.2 (EDCA backoff procedure) | CFOCB:M | Yes ☐ No ☐ N/A ☐ |
| QD9 | Duration/ID rules for QoS STA | 9.2.5 (Duration/ID field (QoS STA)) | CFQoS | Yes ☐ No ☐ N/A ☐ |
| QD10 | Mirrored Stream Classification Service (MSCS) | 9.6.18.6 (MSCS Request frame format), 9.6.18.7 (MSCS Response frame format), 11.25.3 (MSCS procedures) | CFQoS:O | Yes ☐ No ☐ N/A ☐ |

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## B.4.14 QoS hybrid coordination function (HCF) controlled channel access (HCCA)

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| QP1 | Traffic specification (TSPEC) and associated frame formats | 9.6.3 (QoS Action frame details) | (CFAP AND CFQoS):M (CFIndepSTA AND CFQoS):M | Yes ☐ No ☐ N/A ☐ |
| (M118)*QP2 | HCCA rules | 10.2.3.3 (HCF controlled channel access (HCCA)), 10.23.3 (HCF controlled channel access (HCCA)), 10.23.3.2 (HCCA procedure)–10.23.3.5 (HCCA transfer rules) | (CFAP AND CFQoS):M (CFIndepSTA AND CFQoS):M | Yes ☐ No ☐ N/A ☐ |
| QP3 | HCCA schedule generation and management | 10.23.4 (Admission control at the HC) | (CFAP AND CFQoS):M | Yes ☐ No ☐ N/A ☐ |
| QP4 | HCF frame exchange sequences | 10.23.2 (HCF contention based channel access (EDCA)) | (CFAP AND CFQoS):M (CFIndepSTA AND CFQoS):M | Yes ☐ No ☐ N/A ☐ |
| QP5 | Traffic stream (TS) management | 11.4 (TS operation) | (CFAP AND CFQoS):M (CFIndepSTA AND CFQoS):M | Yes ☐ No ☐ N/A ☐ |
| QP6 | Minimum TSPEC parameter set | 10.23.4 (Admission control at the HC) | (CFAP AND CFQoS):M (CFIndepSTA AND CFQoS):M | Yes ☐ No ☐ N/A ☐ |
| QP7 | Power management in an infrastructure BSS | 11.2.3.5 (Power management with APSD), 11.2.3.6 (AP operation), 11.2.3.6 (AP operation), 11.2.3.7 (Receive operation for STAs in PS mode), 11.2.3.7 (Receive operation for STAs in PS mode), 11.2.3.8 (Receive operation using APSD), 11.2.3.9 (STAs operating in the active mode) | (CFAP AND CFQoS):M (CFIndepSTA AND CFQoS):M | Yes ☐ No ☐ N/A ☐ |


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## B.4.15 Radio management extensions

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| | Are the following Radio Measurement capabilities supported? | | | |
| RM1 | (M118)Radio measurement capability | 9.4.1.4 (Capability Information field) | CFRM:M | Yes ☐ No ☐ N/A ☐ |
| RM2 | Action frame protocol for measurements | 9.5.7 (EDMG BRP field(11ay)) | CFRM:M | Yes ☐ No ☐ N/A ☐ |
| RM2.1 | Radio Measurement Request frame | 9.6.6.2 (Radio Measurement Request frame format) | CFRM:M | Yes ☐ No ☐ N/A ☐ |
| RM2.2 | Radio Measurement Report frame | 9.6.6.3 (Radio Measurement Report frame format) | CFRM:M | Yes ☐ No ☐ N/A ☐ |
| RM2.3 | Link Measurement Request frame | 9.6.6.4 (Link Measurement Request frame format) | CFRM:M | Yes ☐ No ☐ N/A ☐ |
| RM2.4 | Link Measurement Report frame | 9.6.6.5 (Link Measurement Report frame format) | CFRM:M | Yes ☐ No ☐ N/A ☐ |
| RM2.4.1 | Link Measurement Report frame | 9.6.6.5 (Link Measurement Report frame format) | (#4138)NOT CF DMG AND CFRM:M | Yes ☐ No ☐ N/A ☐ |
| RM2.4.2 | Link Measurement Report frame | 9.6.6.5 (Link Measurement Report frame format), 9.4.2.147 (Relay Transfer Parameter Set element), 9.4.2.148 (Quiet Period Request element), 10.41.9 (CDMG enhanced beam tracking) | CFDMG AND CFRM:M | Yes ☐ No ☐ N/A ☐ |
| RM2.5 | Neighbor Report Request | | | |
| RM2.5.1 | Generate and transmit Neighbor Report Request | 9.6.6.6 (Neighbor Report Request frame format) | (CFRM AND CFSTAofAP):M | Yes ☐ No ☐ N/A ☐ |
| RM2.5.2 | Receive and process Neighbor Report Request | 9.6.6.6 (Neighbor Report Request frame format) | (CFRM AND CFAP):M | Yes ☐ No ☐ N/A ☐ |
| RM2.6 | Neighbor Report Response | | | |

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## B.4.15 Radio management extensions *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| RM2.6.1 | Generate and transmit Neighbor Report Response | 9.4.2.35 (Neighbor Report element), 9.6.6.7 (Neighbor Report Response frame format) | (CFRM AND CFAP):M | Yes ☐ No ☐ N/A ☐ |
| RM2.6.2 | Receive and process Neighbor Report Response | 9.4.2.35 (Neighbor Report element), 9.6.6.7 (Neighbor Report Response frame format) | (CFRM AND CFSTAofAP):M | Yes ☐ No ☐ N/A ☐ |
| RM3 | General protocol for requesting and reporting of measurements | 9.4.2.19 (Measurement Request element), 9.4.2.20 (Measurement Report element), 11.10 (Radio measurement procedures), 11.10.6 (Requesting and reporting of measurements) | CFRM:M | Yes ☐ No ☐ N/A ☐ |
| RM3.1 | Parallel Measurements | 9.4.2.19 (Measurement Request element), 9.4.2.20 (Measurement Report element), 11.10.6 (Requesting and reporting of measurements) | CFRM:M | Yes ☐ No ☐ N/A ☐ |
| RM3.2 | Use of Enable, Request and Report subfields(#291) to enable/disable measurement requests and triggered autonomous reports Measurement Requests | 9.4.2.19 (Measurement Request element), 11.10.6 (Requesting and reporting of measurements), 11.10.8 (Triggered autonomous reporting) | CFRM:M | Yes ☐ No ☐ N/A ☐ |
| RM3.3 | Enable Autonomous Report | 9.4.2.19 (Measurement Request element), 11.10.8 (Triggered autonomous reporting) | CFRM:M | Yes ☐ No ☐ N/A ☐ |
| RM3.4 | Duration Mandatory | 9.4.2.19 (Measurement Request element), 11.10.4 (Measurement duration) | CFRM:M | Yes ☐ No ☐ N/A ☐ |
| RM3.5 | Incapable Indication | 9.4.2.20 (Measurement Report element) | CFRM:M | Yes ☐ No ☐ N/A ☐ |


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## B.4.15 Radio management extensions *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| RM3.6 | Refused Indication | 9.4.2.20 (Measurement Report element), 11.10.5 (Station responsibility for conducting measurements) | CFRM:M | Yes ☐ No ☐ N/A ☐ |
| RM3.7 | Repeated Measurement | 9.6.6.2 (Radio Measurement Request frame format), 11.10.7 (Repeated Measurement Request frames) | CFRM:M | Yes ☐ No ☐ N/A ☐ |
| RM3.8 | Measurement Pause | 9.4.2.19.12 (Measurement Pause request), 11.10.9.7 (Measurement pause) | CFRM:M | Yes ☐ No ☐ N/A ☐ |
| RM4 | Beacon Measurement Type | 11.10 (Radio measurement procedures), 11.10.9.1 (Beacon report) | CFRM:M | Yes ☐ No ☐ N/A ☐ |
| RM4.1 | Beacon request | 9.4.2.19.7 (Beacon request) | CFRM:M | Yes ☐ No ☐ N/A ☐ |
| RM4.2 | Passive Measurement mode | 9.4.2.19.7 (Beacon request), 11.10.9.1 (Beacon report) | CFRM:M | Yes ☐ No ☐ N/A ☐ |
| RM4.3 | Active Measurement mode | 9.4.2.19.7 (Beacon request), 11.10.9.1 (Beacon report) | CFRM:M | Yes ☐ No ☐ N/A ☐ |
| RM4.4 | Beacon table mode | 9.4.2.19.7 (Beacon request), 11.10.9.1 (Beacon report) | CFRM:M | Yes ☐ No ☐ N/A ☐ |
| RM4.5 | Reporting Conditions | 9.4.2.19.7 (Beacon request) | CFRM:O | Yes ☐ No ☐ N/A ☐ |
| RM4.6 | Beacon report | 9.4.2.19.7 (Beacon request) | CFRM:M | Yes ☐ No ☐ N/A ☐ |
| RM4.7 | Reporting Detail | 9.4.2.19.7 (Beacon request), 9.4.2.20.7 (Beacon report), 9.4.2.34 (AP Channel Report element) | CFRM:O | Yes ☐ No ☐ N/A ☐ |
| * RM5 | Frame Measurement Type | 11.10 (Radio measurement procedures), 11.10.9.2 (Frame report) | CFRM:O | Yes ☐ No ☐ N/A ☐ |
| RM5.1 | Frame request | 9.4.2.19.8 (Frame request) | (CFRM AND RM5):M | Yes ☐ No ☐ N/A ☐ |

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## B.4.15 Radio management extensions *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| RM5.2 | Frame report | 9.4.2.20.8 (Frame report) | (CFRM AND RM5):M | Yes ☐ No ☐ N/A ☐ |
| RM6 | Channel Load Measurement Type | 11.10 (Radio measurement procedures), 11.10.9.3 (Channel load report) | CFRM:M | Yes ☐ No ☐ N/A ☐ |
| RM6.1 | Channel Load request | 9.4.2.19.5 (Channel Load request) | CFRM:M | Yes ☐ No ☐ N/A ☐ |
| RM6.2 | Channel Load report | 9.4.2.20.5 (Channel Load report) | CFRM:M | Yes ☐ No ☐ N/A ☐ |
| RM7 | Noise Histogram Measurement Type | 11.10 (Radio measurement procedures), 11.10.9.4 (Noise Histogram report) | CFRM:M | Yes ☐ No ☐ N/A ☐ |
| RM7.1 | Noise Histogram request | 9.4.2.19.6 (Noise Histogram request) | CFRM:M | Yes ☐ No ☐ N/A ☐ |
| RM7.2 | Noise Histogram report | 9.4.2.20.6 (Noise Histogram report) | CFRM:M | Yes ☐ No ☐ N/A ☐ |
| RM8 | STA Statistics Measurement Type | 11.10 (Radio measurement procedures), 11.10.9.5 (STA Statistics report) | CFRM:M | Yes ☐ No ☐ N/A ☐ |
| RM8.1 | STA Statistics request | 9.4.2.19.9 (STA Statistics request) | CFRM:M | Yes ☐ No ☐ N/A ☐ |
| RM8.2 | STA Statistics report | 9.4.2.20.9 (STA Statistics report) | CFRM:M | Yes ☐ No ☐ N/A ☐ |
| RM9 | LCI Measurement Type | 11.10 (Radio measurement procedures), 11.10.9.6 (LCI report (Location configuration information report)) | CFRM:M | Yes ☐ No ☐ N/A ☐ |
| RM9.1 | LCI request | 9.4.2.19.10 (LCI request (Location configuration information request)) | CFRM:M | Yes ☐ No ☐ N/A ☐ |
| RM9.1.1 | Location Subject | 9.4.2.19.10 (LCI request (Location configuration information request)) | CFRM:M | Yes ☐ No ☐ N/A ☐ |
| RM9.1.1.1 | Location Subject third party | 9.4.2.19.10 (LCI request (Location configuration information request)) | CFRM:O | Yes ☐ No ☐ N/A ☐ |


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## B.4.15 Radio management extensions *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| RM9.2 | LCI report | 9.4.2.20.10 (LCI report (Location configuration information report)) | CFRM:M | Yes ☐ No ☐ N/A ☐ |
| RM9.3 | Azimuth | 11.10 (Radio measurement procedures), 11.10.9.6 (LCI report (Location configuration information report)) | CFRM:O | Yes ☐ No ☐ N/A ☐ |
| RM9.3.1 | Azimuth Request | 9.4.2.19.10 (LCI request (Location configuration information request)) | CFRM:O | Yes ☐ No ☐ N/A ☐ |
| RM9.3.2 | Azimuth Response | 9.4.2.20.10 (LCI report (Location configuration information report)) | CFRM:O | Yes ☐ No ☐ N/A ☐ |
| *RM10 | Transmit Stream/ Category Measurement Type | 11.10 (Radio measurement procedures), 11.10.9.8 (Transmit Stream/Category Measurement report) | (CFRM AND (CFQoS OR CFDMG)):O | Yes ☐ No ☐ N/A ☐ |
| RM10.1 | Transmit Stream/ Category Measurement request | 9.4.2.19.11 (Transmit Stream/ Category Measurement request) | RM10:M | Yes ☐ No ☐ N/A ☐ |
| RM10.2 | Transmit Stream/ Category Measurement report | 9.4.2.20.11 (Transmit Stream/ Category Measurement report) | RM10:M | Yes ☐ No ☐ N/A ☐ |
| RM10.3 | Triggered Transmit Stream/Category Measurement report | 9.4.2.20.11 (Transmit Stream/ Category Measurement report), 11.10.9.8 (Transmit Stream/ Category Measurement report) | RM10:O | Yes ☐ No ☐ N/A ☐ |
| RM11 | AP Channel report | 9.4.2.7 (Country element), 9.4.2.34 (AP Channel Report element) | (CFRM AND CFAP):M | Yes ☐ No ☐ N/A ☐ |
| RM11.1 | Generate and transmit AP Channel report | 9.3.3.2 (Beacon frame format), 9.3.3.10 (Probe Response frame format), 9.4.2.34 (AP Channel Report element) | (CFRM AND CFAP):M | Yes ☐ No ☐ N/A ☐ |

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## B.4.15 Radio management extensions *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| RM11.2 | Receive and process AP Channel report | 9.3.3.2 (Beacon frame format), 9.3.3.10 (Probe Response frame format), 9.4.2.34 (AP Channel Report element) | (CFRM AND CFSTAofAP):M | Yes ☐ No ☐ N/A ☐ |
| RM12 | Neighbor report procedure | 11.10 (Radio measurement procedures), 11.10.10 (Usage of the neighbor report) | CFRM:M | Yes ☐ No ☐ N/A ☐ |
| RM12.1 | Neighbor report procedure | 11.10.10.2 (Requesting a neighbor report), 11.10.10.3 (Responding to a neighbor report request) | CFRM:M | Yes ☐ No ☐ N/A ☐ |
| RM12.2 | TSF Offset in neighbor report | 9.4.2.35 (Neighbor Report element), 11.10.10.3 (Responding to a neighbor report request) | CFRM:O | Yes ☐ No ☐ N/A ☐ |
| RM13 | RCPI Measurement | | | |
| RM13.1 | RCPI Measurement for DSSS PHY at 2.4 GHz | 15.4.6.6 (Received channel power indicator (RCPI) measurement) | (CFRM AND CFDSSS):M | Yes ☐ No ☐ N/A ☐ |
| RM13.2 | RCPI Measurement for OFDM PHY at 5 GHz | (#1369)17.2.3 (RXVECTOR parameters(#1369)), 17.3.10.7 (Received channel power indicator (RCPI) measurement) | (CFRM AND CFOFDM): M | Yes ☐ No ☐ N/A ☐ |
| RM13.3 | RCPI Measurement for HR DSSS PHY at 2.4 GHz | 16.3.8.6 (Received channel power indicator (RCPI) measurement) | (CFRM AND CFHRDSSS):M | Yes ☐ No ☐ N/A ☐ |
| RM13.4 | RCPI Measurement for Extended Rate PHY at 2.4 GHz | 8.3.5.15 (PHY-RXEND.indication) | (CFRM AND CFERP):M | Yes ☐ No ☐ N/A ☐ |
| RM14 | RCPI Measurement during Active Scanning | | | |
| RM14.1 | Respond with RCPI element when requested | 11.1.4.3.2 (Active scanning procedure for a non-DMG STA) | (CFRM AND (CFQoS OR CFDMG) AND CFAP):M | Yes ☐ No ☐ N/A ☐ |


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## B.4.15 Radio management extensions *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| RM14.2 | Measurement of RCPI on Probe Request frames | 11.1.4.3.2 (Active scanning procedure for a non-DMG STA) | (CFRM AND (CFQoS OR CFDMG) AND CFAP):O | Yes ☐ No ☐ N/A ☐ |
| RM15 | RSNI Measurement | 9.4.2.39 (RSNI element) | (CFRM AND RM13):M | Yes ☐ No ☐ N/A ☐ |
| RM16 | TPC Information in Beacon and Probe Response frames | | | |
| RM16.1 | Country and TPC Report elements included in Beacon and Probe Response frames | 9.3.3.2 (Beacon frame format), 9.3.3.10 (Probe Response frame format), 9.4.2.7 (Country element), 9.4.2.15 (TPC Report element), 11.7 (TPC procedures) | CFRM:M | Yes ☐ No ☐ N/A ☐ |
| RM16.2 | Power Constraint element included in Beacon and Probe Response frames | 9.3.3.2 (Beacon frame format), 9.3.3.10 (Probe Response frame format), 9.4.2.12 (Power Constraint element) | CFRM:O | Yes ☐ No ☐ N/A ☐ |
| RM17 | Power Capability elements in (Re)Association Request and Response frames | 9.3.3.5 (Association Request frame format), 9.3.3.6 (Association Response frame format), 11.8.2 (Association based on supported channels) | CFRM:M | Yes ☐ No ☐ N/A ☐ |
| RM18 | Management Information Base | | | |
| RM18.1 | dot11RadioMeasurement | Annex C | (CFRM AND CFAP):M | Yes ☐ No ☐ N/A ☐ |
| RM18.2 | dot11SMTRMRequest | Annex C | (CFRM AND CFAP):O | Yes ☐ No ☐ N/A ☐ |
| RM18.3 | dot11SMTRMReport | Annex C | (CFRM AND CFAP):O | Yes ☐ No ☐ N/A ☐ |
| RM18.4 | dot11SMTRMConfig | Annex C | (CFRM AND CFAP):O | Yes ☐ No ☐ N/A ☐ |

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## B.4.15 Radio management extensions *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| RM19 | Measurement Pilot frame | 6.5.3.2 (MLME-SCAN.request), 9.4.1.18 (Measurement Pilot Interval field), 9.4.2.44 (Multiple BSSID element), 11.7 (TPC procedures), 11.10.14 (Multiple BSSID set), 11.10.5 (Station responsibility for conducting measurements) | CFRM:O | Yes ☐ No ☐ N/A ☐ |
| RM20 | BSS Average Access Delay elements included in Beacon and Probe Response frames | 9.3.3.2 (Beacon frame format), 9.3.3.10 (Probe Response frame format), 9.4.2.37 (BSS Average Access Delay element) | (CFAP AND CFRM):M | Yes ☐ No ☐ N/A ☐ |
| RM21 | Antenna elements included in Beacon and Probe Response frames | 9.3.3.2 (Beacon frame format), 9.3.3.10 (Probe Response frame format), 9.4.2.38 (Antenna element) | CFRM:M | Yes ☐ No ☐ N/A ☐ |
| RM22 | Measurement Pilot Transmission element and Multiple BSSID element, if required, included in Probe Response frame | 9.3.3.10 (Probe Response frame format), 9.4.2.40 (Measurement Pilot Transmission element), 9.4.2.44 (Multiple BSSID element) | CFRM:O | Yes ☐ No ☐ N/A ☐ |
| RM23 | Quiet interval | | | |
| RM23.1 | AP-defined Quiet Interval | 9.3.3.2 (Beacon frame format), 9.3.3.10 (Probe Response frame format), 9.4.2.21 (Quiet element), 11.8.3 (Quieting channels for testing) | (CFAP AND CFRM):M | Yes ☐ No ☐ N/A ☐ |
| RM23.2 | STA-defined Quiet Interval | 9.3.3.2 (Beacon frame format), 9.3.3.10 (Probe Response frame format), 9.4.2.21 (Quiet element), 11.8.3 (Quieting channels for testing) | (CFSTAofAP AND CFRM):M | Yes ☐ No ☐ N/A ☐ |


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## B.4.15 Radio management extensions *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| RM23.3 | STA support for Quiet Interval | 9.3.3.2 (Beacon frame format), 9.3.3.10 (Probe Response frame format), 9.4.2.21 (Quiet element), 11.8.3 (Quieting channels for testing) | CFRM:M | Yes ☐ No ☐ N/A ☐ |
| RM24 | BSS Available Admission Capacity | 9.4.2.41 (BSS Available Admission Capacity element) | (CFAP AND (CFQoS OR CFDMG) AND CFRM):M | Yes ☐ No ☐ N/A ☐ |
| RM25 | BSS AC Access Delay | 9.3.3.2 (Beacon frame format), 9.3.3.10 (Probe Response frame format), 9.4.2.42 (BSS AC Access Delay element) | (#4138)NOT CFDMG AND (CFAP AND CFQoS AND CFRM):M | Yes ☐ No ☐ N/A ☐ |
| RM26 | BSS AC Access Delay | 9.3.3.2 (Beacon frame format), 9.3.3.10 (Probe Response frame format), 9.4.2.42 (BSS AC Access Delay element) | CFDMG AND CFAP AND CFRM:M | Yes ☐ No ☐ N/A ☐ |
| RM27 | Directional channel quality measurement | 11.10 (Radio measurement procedures), 11.30 (Spatial sharing and interference mitigation for DMG STAs) | | |
| RM27.1 | Directional Channel Quality request | 8.4.2.23.16, 11.30 (Spatial sharing and interference mitigation for DMG STAs) | (CFRM AND DMG-M19):O | Yes ☐ No ☐ N/A ☐ |
| RM27.2 | Directional Channel Quality report | 8.4.2.24.15, 11.30 (Spatial sharing and interference mitigation for DMG STAs) | (CFRM AND DMG-M19):M | Yes ☐ No ☐ N/A ☐ |
| RM28 | Directional measurement type | 11.10 (Radio measurement procedures) | | |
| RM28.1 | Directional Measurement request | 9.4.2.19.17 (Directional Measurement request) | (CFRM AND CFDMG):O | Yes ☐ No ☐ N/A ☐ |
| RM28.2 | Directional Measurement report | 9.4.2.20.16 (Directional Measurement report) | (CFRM AND CFDMG):O | Yes ☐ No ☐ N/A ☐ |

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### B.4.15 Radio management extensions *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| RM29 | Directional statistics measurement type | 11.10 (Radio measurement procedures) | | |
| RM29.1 | Directional Statistics Measurement Type | 9.4.2.19.18 (Directional Statistics request) | (CFRM AND CFDMG):O | Yes ☐ No ☐ N/A ☐ |
| RM29.2 | Directional Statistics Measurement Type | 9.4.2.20.17 (Directional Statistics report) | (CFRM AND CFDMG):O | Yes ☐ No ☐ N/A ☐ |

### B.4.16 DSE functions

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| (M118)DSE1 | Fixed STA operation with RegLoc | 11.11.3 (Registered STA operation) | CF3G6:O.1 | Yes ☐ No ☐ N/A ☐ |
| *DSE2 | Enabling STA operation with RegLoc | 11.11.3 (Registered STA operation) | CF3G6:O.1 | Yes ☐ No ☐ N/A ☐ |
| DSE2.1 | Enabling STA creation of DSE service area | 11.11.4 (Enabling STA operation with DSE) | DSE2:M | Yes ☐ No ☐ N/A ☐ |
| DSE2.2 | Enabling STA operation with DSE | 11.11.3 (Registered STA operation) | DSE2:M | Yes ☐ No ☐ N/A ☐ |
| *DSE3 | Dependent STA operation with DSE | 11.11.5 (Dependent STA operation with DSE) | CF3G6:O.1 | Yes ☐ No ☐ N/A ☐ |
| DSE3.1 | Dependent STA enablement | 11.11.5 (Dependent STA operation with DSE) | DSE3:M | Yes ☐ No ☐ N/A ☐ |
| DSE3.2 | Dependent STA DSE time to enablement | 11.11.5 (Dependent STA operation with DSE) | DSE3:M | Yes ☐ No ☐ N/A ☐ |
| DSE3.3 | Dependent STA DSE time to not transmit | 11.11.5 (Dependent STA operation with DSE) | DSE3:M | Yes ☐ No ☐ N/A ☐ |


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## B.4.16 DSE functions *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| DSE3.4 | Dependent STA DSE Registered Location Announcement frame | 11.11.5 (Dependent STA operation with DSE) | DSE3:M | Yes ☐ No ☐ N/A ☐ |
| DSE3.5 | Dependent STA MLME-ASSOCIATE.response primitive DSE | 6.5.7.5 (MLME-ASSOCIATE.response) | DSE3:M | Yes ☐ No ☐ N/A ☐ |
| DSE3.6 | Dependent STA MLME-REASSOCIATE.response primitive DSE | 6.5.8.5 (MLME-REASSOCIATE.response) | DSE3:M | Yes ☐ No ☐ N/A ☐ |
| DSE4 | DSE request report procedure<br>Transmission of DSE measurement request by an AP<br>Transmission of DSE measurement report by a STA | 11.11.5 (Dependent STA operation with DSE)<br><br>11.11.5 (Dependent STA operation with DSE) | (CF3G6 AND CFAP):M<br><br>(CF3G6 AND CFSTAofAP):M | Yes ☐ No ☐ N/A ☐<br><br>Yes ☐ No ☐ N/A ☐ |
| DSE5 | STA association procedure<br>Transmission of Association Request frame with Supported Operating Classes element by a STA<br>Transmission of Association Response frame with Supported Operating Classes element by an AP | 10.22.3 (Operation with operating classes), 11.3.5.2 (Non-AP and non-PCP STA association initiation procedures), 11.3.5.3 (AP or PCP association receipt procedures) | (CF3G6 AND CFSTAofAP):M<br><br>(CF3G6 AND CFAP):M | Yes ☐ No ☐ N/A ☐<br><br>Yes ☐ No ☐ N/A ☐ |
| DSE6 | STA reassociation procedure<br>Transmission of Reassociation Request frame with Supported Operating Classes element by a STA<br>Transmission of Reassociation Response frame with Supported Operating Classes element by an AP | 11.3.5.4 (Non-AP and non-PCP STA reassociation initiation procedures), 11.3.5.5 (AP or PCP reassociation receipt procedures) | (CF3G6 AND CFSTAofAP):M<br><br>(CF3G6 AND CFAP):M | Yes ☐ No ☐ N/A ☐<br><br>Yes ☐ No ☐ N/A ☐ |

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## B.4.16 DSE functions *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| DSE7 | Probe request procedure Transmission of Probe Request frame with Supported Operating Classes element by a STA | 11.9.1 (General) | CF3G6 AND CFSTAofAP:M | Yes ☐ No ☐ N/A ☐ |
| DSE8 | Probe response procedure Transmission of Probe Response frame with Supported Operating Classes element by an AP | 11.9.1 (General) | CF3G6 AND CFAP:M | Yes ☐ No ☐ N/A ☐ |
| DSE9 | Extended channel switching procedure | 11.9.1 (General) | | |
| DSE9.1 | Transmission of extended channel switch announcement frame/element and extended channel switching procedure by an AP. | 11.9.3 (Selecting and advertising a new channel and/or operating class) | (CF3G6 AND CFAP):M (CFAP AND CFVHT):M (CFAP AND CFTVHT):M (#423)AND NOT CFDMG: M | Yes ☐ No ☐ N/A ☐ |
| DSE9.2 | Transmission of extended channel switch announcement frame/element and extended channel switching procedure by a STA. | 11.9.3 (Selecting and advertising a new channel and/or operating class) | (CF3G6 AND CFIBSS):M (CFIBSS AND CFVHT):M (CFIBSS AND CFTVHT):M (#423)AND NOT CFDMG: M | Yes ☐ No ☐ N/A ☐ |
| DSE9.3 | Reception of extended channel switch announcement frame/element and extended channel switching procedure by a STA. | 11.9.3 (Selecting and advertising a new channel and/or operating class) | CF3G6:M CFVHT:M CFTVHT:M (#423)AND NOT CFDMG: M | Yes ☐ No ☐ N/A ☐ |
| DSE9.4 | Transmission of Wide Bandwidth Channel Switch element in Extended Channel Announcement frame and transmission of Wide Bandwidth Channel Switch subelement in Channel Switch Wrapper element in Beacon/ Probe Response frames, and associated extended channel switching procedure by an AP. | 11.38.4 (Channel switching methods for a VHT BSS) | (CFAP AND CFESM):M (#423)AND NOT CFDMG: M | Yes ☐ No ☐ N/A ☐ |
| DSE9.5 | Transmission of Wide Bandwidth Channel Switch element in Extended Channel Announcement frame and transmission of Wide Bandwidth Channel Switch subelement in Channel Switch Wrapper element in Beacon/ Probe Response frames, and associated extended channel switching procedure by a STA. | 11.38.4 (Channel switching methods for a VHT BSS) | (CFIBSS AND CFESM):M (#423)AND NOT CFDMG: M | Yes ☐ No ☐ N/A ☐ |


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## B.4.16 DSE functions *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| DSE9.6 | Reception of Wide Bandwidth Channel Switch element in Extended Channel Announcement frame and reception of Wide Bandwidth Channel Switch subelement in Channel Switch Wrapper element in Beacon/Probe Response frames, and associated extended channel switching procedure by a STA. | 11.38.4 (Channel switching methods for a VHT BSS) | CFESM:M (#423)AND NOT CFDMG: M | Yes ☐ No ☐ N/A ☐ |
| DSE9.7 | Transmission of New Transmit Power Envelope element in Extended Channel Announcement frame and transmission of New Transmit Power Envelope subelement in Channel Switch Wrapper element in Beacon/ Probe Response frames, and associated extended channel switching procedure by an AP. | 11.38.4 (Channel switching methods for a VHT BSS) | (CFAP AND CFESM):M (#423)AND NOT CFDMG: M | Yes ☐ No ☐ N/A ☐ |
| DSE9.8 | Transmission of New Transmit Power Envelope element in Extended Channel Announcement frame and transmission of NewTransmit Power Envelope subelement in Channel Switch Wrapper element in Beacon/ Probe Response frames, and associated extended channel switching procedure by a STA. | 11.38.4 (Channel switching methods for a VHT BSS) | (CFIBSS AND CFESM):M (#423)AND NOT CFDMG: M | Yes ☐ No ☐ N/A ☐ |
| DSE9.9 | Reception of New Transmit Power Envelope element in Extended Channel Announcement frame and reception of New Transmit Power Envelope subelement in Channel Switch Wrapper element in Beacon/ Probe Response frames, and associated extended channel switching procedure by a STA. | 11.38.4 (Channel switching methods for a VHT BSS) | CFESM:M (#423)AND NOT CFDMG: M | Yes ☐ No ☐ N/A ☐ |
| DSE9.10 | Transmission of New Country element in Extended Channel Announcement frame and transmission of New Country subelement in Channel Switch Wrapper element in Beacon/Probe Response frames, and associated extended channel switching procedure by an AP. | 11.38.4 (Channel switching methods for a VHT BSS) | (CFAP AND CFESM):M (#423)AND NOT CFDMG: M | Yes ☐ No ☐ N/A ☐ |
| DSE9.11 | Transmission of New Country element in Extended Channel Announcement frame and transmission of New Country subelement in Channel Switch Wrapper element in Beacon/Probe Response frames, and associated extended channel switching procedure by a STA. | 11.38.4 (Channel switching methods for a VHT BSS) | (CFIBSS AND CFESM):M (#423)AND NOT CFDMG: M | Yes ☐ No ☐ N/A ☐ |

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## B.4.16 DSE functions *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| DSE9.12 | Reception of New Country element in Extended Channel Announcement frame and reception of New Country subelement in Channel Switch Wrapper element in Beacon/Probe Response frames, and associated extended channel switching procedure by a STA. | 11.38.4 (Channel switching methods for a VHT BSS) | CFESM:M | Yes ☐ No ☐ N/A ☐ |
| DSE10 | DSE power constraint procedure Transmission of DSE power constraint announcement by an enabling STA<br><br>Reception of DSE power constraint announcement by a dependent STA | 11.11.5 (Dependent STA operation with DSE)<br><br>11.11.5 (Dependent STA operation with DSE) | (CF3G6 AND CFAP):M<br><br>CF3G6:M | Yes ☐ No ☐ N/A ☐<br><br>Yes ☐ No ☐ N/A ☐ |

## B.4.17 High Throughput (HT) features(#2297)

### B.4.17.1 HT MAC features

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| | Are the following MAC protocol features supported? | | | |
| HTM1 | HT capabilities signaling | | | |
| HTM1.1 | HT Capabilities element | 9.4.2.54.1 (HT Capabilities element structure) | CFHT:M CFTVHT:M | Yes ☐ No ☐ N/A ☐ |
| HTM1.2 | Signaling of STA capabilities in Probe Request, (Re)Association Request frames | 9.3.3.5 (Association Request frame format), 9.3.3.7 (Reassociation Request frame format), 9.3.3.9 (Probe Request frame format), 9.4.2.54 (HT Capabilities element) | (CFHT AND CFIndepSTA): M (CFTVHT AND CFIndepSTA): M | Yes ☐ No ☐ N/A ☐ |


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### B.4.17.1 HT MAC features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| HTM1.3 | Signaling of STA and BSS capabilities in Beacon, Probe Response, (Re)Association Response frames | 9.3.3.2 (Beacon frame format), 9.3.3.6 (Association Response frame format), 9.3.3.8 (Reassociation Response frame format), 9.3.3.10 (Probe Response frame format), 9.4.2.54 (HT Capabilities element) | (CFHT AND CFAP):M (CFTVHT AND CFAP):M | Yes ☐ No ☐ N/A ☐ |
| HTM2 | Signaling of HT operation | 9.4.2.55 (HT Operation element) | (CFHT AND CFAP):M (CFTVHT AND CFAP):M | Yes ☐ No ☐ N/A ☐ |
| HTM3 | MPDU aggregation | | | |
| HTM3.1 | Reception of A-MPDU | 9.4.2.54.3 (A-MPDU Parameters field), 10.12.2 (A-MPDU length limit rules), 12.5 (RSNA confidentiality and integrity protocols) | (CFHT AND NOT CFS1G):M CFS1G: O | Yes ☐ No ☐ N/A ☐ |
| HTM3.2 | A-MPDU format | 9.7.1 (A-MPDU format) | (CFHT OR CFS1G):M | Yes ☐ No ☐ N/A ☐ |
| HTM3.3 | A-MPDU contents | 9.7.3 (A-MPDU contents) | (CFHT OR CFS1G):M | Yes ☐ No ☐ N/A ☐ |
| HTM3.4 | A-MPDU frame exchange sequences | 10.23.2.8 (Multiple frame exchange sequences in an EDCA TXOP(#109)) | (CFHT AND NOT CFS1G):M CFS1G: O | Yes ☐ No ☐ N/A ☐ |
| HTM3.5 | Transmission of A-MPDU | 9.4.2.54.3 (A-MPDU Parameters field), 12.5 (RSNA confidentiality and integrity protocols) | CFHT:O CFVHT:M CFS1G: O | Yes ☐ No ☐ N/A ☐ |
| HTM4 | MSDU aggregation | | | |

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### B.4.17.1 HT MAC features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| HTM4.1 | Reception of A-MSDUs | 9.2.4.5 (QoS Control field), 9.3.2.2 (Aggregate MSDU (A-MSDU) format) | (CFHT AND NOT CFS1G):M<br>CFS1G:O | Yes ☐ No ☐ N/A ☐ |
| HTM4.2 | A-MSDU format | 9.3.2.2 (Aggregate MSDU (A-MSDU) format) | (CFHT AND NOT CFS1G):M<br><br>CFS1GRelay AND ((NOT AD12) AND (NOT AD14)): M<br><br>CFS1GRelay AND ((NOT AD13) AND (NOT AD15)): M<br><br>RL2 AND ((NOT AD12) AND (NOT AD14)):M<br><br>RL2 AND ((NOT AD13) AND (NOT AD15)):M<br><br>CFS1GRelay AND (AD12 OR (AD14):O<br><br>CFS1GRelay AND (AD13 OR AD15): O<br><br>RL2 AND (AD12 OR AD14): O<br><br>RL2 AND (AD13 OR AD15): O | Yes ☐ No ☐ N/A ☐ |
| HTM4.3 | A-MSDU content | 9.3.2.2 (Aggregate MSDU (A-MSDU) format) | (CFHT AND NOT CFS1G):M | Yes ☐ No ☐ N/A ☐ |


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### B.4.17.1 HT MAC features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| (M118)*HTM 4.4 | Transmission of A-MSDUs | 9.2.4.5 (QoS Control field), 9.3.2.2 (Aggregate MSDU (A-MSDU) format) | CFHT:O CFS1G:O | Yes ☐ No ☐ N/A ☐ |
| HTM5 | Block Ack | | | |
| HTM5.1 | Block ack mechanism | 9.3.1.7 (BlockAckReq frame format), 9.3.1.8 (BlockAck frame format), 9.4.1.13 (Block Ack Parameter Set field), 10.25 (Block acknowledgment (block ack)), 11.15 (20/40 MHz BSS operation) | CFHT:M CFTVHT:M | Yes ☐ No ☐ N/A ☐ |
| HTM5.2 | Use of compressed bitmap between HT STAs | 9.3.1.8.2 (Compressed BlockAck variant), 10.25.5 (Selection of BlockAck and BlockAckReq variants) | CFHT:M CFTVHT:M | Yes ☐ No ☐ N/A ☐ |
| HTM5.3 | HT-immediate block ack extensions | 10.25.6 (HT-immediate block ack extensions) | (CFHT AND NOT CFS1G):M CFVHT:M CFS1G:O (CFS1G AND (S1GM20.2 OR S1GM20.3 OR S1GM20.5)): M | Yes ☐ No ☐ N/A ☐ |
| HTM5.4 | *Reserved* | | | |
| HTM5.5 | *Reserved(#3263)* | | | Yes ☐ No ☐ N/A ☐ |
| HTM6 | Protection mechanisms for different HT PHY options | | | |
| HTM6.1 | Protection of RIFS PPDUs in the presence of non-HT STAs | 10.27.3.3 (RIFS protection) | CFHT:M | Yes ☐ No ☐ N/A ☐ |
| HTM6.2 | Protection of RIFS PPDUs in an IBSS | 10.27.3.3 (RIFS protection) | CFHT:M | Yes ☐ No ☐ N/A ☐ |
| HTM6.3 | Protection of (#1367)(#2095)HT-greenfield format PPDUs in the presence of non-HT STAs | 10.27.3.1 (General) | HTP1.3:M | Yes ☐ No ☐ N/A ☐ |
| HTM6.4 | Protection of (#1367)(#2095)HT-greenfield format PPDUs in an IBSS | 10.27.3.1 (General) | CFHT:M | Yes ☐ No ☐ N/A ☐ |

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### B.4.17.1 HT MAC features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| HTM7 | Duration/ID rules for A-MPDU | 9.7.3 (A-MPDU contents) | CFHT:M | Yes ☐ No ☐ N/A ☐ |
| HTM8 | Truncation of TXOP as TXOP holder | 10.23.2.10 (Truncation of TXOP) | CFHT:O CFTVHT:O | Yes ☐ No ☐ N/A ☐ |
| HTM9 | Reception of +HTC frames | 9.2.4.1.10 (+HTC subfield), 9.4.2.54.5 (HT Extended Capabilities field), 10.8 (HT Control field operation) | CFHT:O CFTVHT:O | Yes ☐ No ☐ N/A ☐ |
| (M118)HTM10 | Reverse direction (RD) aggregation exchanges | 10.29 (Reverse direction protocol) | CFHT:O CFTVHT:O | Yes ☐ No ☐ N/A ☐ |
| HTM10.1 | Constraints regarding responses | 10.29.4 (Rules for RD responder) | HTM11:M | Yes ☐ No ☐ N/A ☐ |
| (M118)*HTM11 | Link adaptation | | | |
| HTM11.1 | Use of the HT Control field for link adaptation in immediate response exchange | 9.2.4.6 (HT Control field), 9.3.3.14 (Action No Ack frame format), 10.31.2 (Link adaptation using the HT variant HT Control field) | CFHT:O CFTVHT:O | Yes ☐ No ☐ N/A ☐ |
| HTM11.2 | Link adaptation using explicit feedback mechanism | 9.3.3.14 (Action No Ack frame format), 10.33.3 (Explicit feedback beamforming) | CFHT:O CFTVHT:O | Yes ☐ No ☐ N/A ☐ |
| HTM12 | Transmit beamforming | | | |
| *HTM12.1 | Transmission of beamformed PPDUs | 10.33 (Transmit beamforming) | CFHT:O | Yes ☐ No ☐ N/A ☐ |
| *HTM12.2 | Reception of beamformed PPDUs | 10.33 (Transmit beamforming) | CFHT:O | Yes ☐ No ☐ N/A ☐ |
| *HTM12.3 | Initiate transmit beamforming frame exchange sequence(#109) with implicit feedback | 10.33.2 (HT transmit beamforming with implicit feedback) | (M118)HTM12.1:O | Yes ☐ No ☐ N/A ☐ |
| HTM12.3.1 | Reception of sounding PPDUs | 10.33.2 (HT transmit beamforming with implicit feedback) | (M118)HTM12.3:M | Yes ☐ No ☐ N/A ☐ |


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### B.4.17.1 HT MAC features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| *HTM12.4 | Response to transmit beamforming frame exchange sequence(#109) with implicit feedback | 10.33.2 (HT transmit beamforming with implicit feedback) | (M118)HTM12.2:O | Yes ☐ No ☐ N/A ☐ |
| HTM12.4.1 | Transmission of sounding PPDUs | 10.33.2 (HT transmit beamforming with implicit feedback) | (M118)HTM12.4:M | Yes ☐ No ☐ N/A ☐ |
| *HTM12.5 | Initiate transmit beamforming frame exchange sequence(#109) with explicit feedback | 9.6.11.4 (CSI frame format), 10.33.3 (Explicit feedback beamforming) | (M118)HTM12.1:O | Yes ☐ No ☐ N/A ☐ |
| HTM12.5.1 | Transmission of sounding PPDUs | 10.33.3 (Explicit feedback beamforming) | (M118)HTM12.5:M | Yes ☐ No ☐ N/A ☐ |
| *HTM12.6 | Respond to transmit beamforming frame exchange sequence(#109) with explicit feedback | 10.33.3 (Explicit feedback beamforming) | (M118)HTM12.2:O | Yes ☐ No ☐ N/A ☐ |
| HTM12.6.1 | Transmission of Action No Ack +HTC frame including Action payload of type CSI | 9.6.11.4 (CSI frame format), 10.33.3 (Explicit feedback beamforming) | (M118)HTM12.6:O.1 | Yes ☐ No ☐ N/A ☐ |
| HTM12.6.2 | Transmission of Action No Ack +HTC frame including Action payload of type “Noncompressed beamforming” | 9.6.11.5 (Noncompressed Beamforming frame format), 10.33.3 (Explicit feedback beamforming) | (M118)HTM12.6:O.1 | Yes ☐ No ☐ N/A ☐ |
| HTM12.6.3 | Transmission of Action No Ack +HTC frame including Action payload of type “Compressed beamforming” | 9.6.11.6 (Compressed Beamforming frame format), 10.33.3 (Explicit feedback beamforming) | (M118)HTM12.6:O.1 | Yes ☐ No ☐ N/A ☐ |
| *HTM12.7 | Calibration procedure | 9.3.3.14 (Action No Ack frame format), 10.33.2.4 (Calibration) | (M118)HTM12:O | Yes ☐ No ☐ N/A ☐ |

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### B.4.17.1 HT MAC features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| HTM13 | Antenna selection (ASEL) | 9.2.4.6 (HT Control field), 9.4.2.54.7 (ASEL Capability field), 9.6.11.7 (Antenna Selection Indices Feedback frame format), 10.34 (Antenna selection (ASEL)) | CFHT:O | Yes ☐ No ☐ N/A ☐ |
| *HTM14 | Null data PPDU (NDP) | 10.35 (Null data PPDU (NDP) sounding) | CFHT:O | Yes ☐ No ☐ N/A ☐ |
| (M118)*HTM15 | Space-time block coding (STBC) support | | | |
| HTM15.1 | STBC beacon transmission<br><br>The use of the STBC beacon transmission mechanism is deprecated. | 11.1.3.2 (Beacon generation in non-DMG infrastructure networks) | HTP2.11:O | Yes ☐ No ☐ N/A ☐ |
| HTM15.2 | Dual CTS protection<br><br>The use of the dual CTS mechanism is obsolete. | 10.3.2.10 (Dual CTS protection) | HTP2.11 AND NOT CFS1G: O | Yes ☐ No ☐ N/A ☐ |
| HTM16 | SM power save support | | | |
| *HTM16.1 | AP support for non-AP STA dynamic and static SM power save mode | 11.2.6 (SM power save) | (CFHT AND CFAP):M (CFTVHT AND CFAP):M | Yes ☐ No ☐ N/A ☐ |
| *HTM16.2 | STA support for local dynamic and static SM power save mode | 11.2.6 (SM power save) | (CFHT AND CFIndepSTA):O (CFTVHT AND CFIndepSTA):O | Yes ☐ No ☐ N/A ☐ |
| HTM16.3 | Transmit SM power save state information using HT Capabilities element, or SM Power Save frame | 9.6.11.3 (SM Power Save frame format), 11.2.6 (SM power save) | (M118)HTM16.2:M | Yes ☐ No ☐ N/A ☐ |
| HTM16.4 | Receive SM power save state information and support frame exchanges with STAs in SM power save mode | 11.2.6 (SM power save) | (M118)HTM16.1:M | Yes ☐ No ☐ N/A ☐ |
| HTM17 | Mechanisms for coexistence of 20 MHz and 40 MHz channels | 11.15 (20/40 MHz BSS operation) | CFHT:M | Yes ☐ No ☐ N/A ☐ |



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### B.4.17.1 HT MAC features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| HTM18 | Channel selection methods for 20/40 MHz operation | 11.15.3 (Channel scanning and selection methods for 20/ 40 MHz operation) | (HTP2.3.4 AND CFAP):M | Yes ☐ No ☐ N/A ☐ |
| HTM19 | 20/40 MHz operation | 11.15 (20/40 MHz BSS operation) | HTP2.3.4:M | Yes ☐ No ☐ N/A ☐ |
| HTM20 | Management information base (MIB) | | | |
| HTM20.1 | dot11PhyHTComplianceGroup | Annex C | CFHT:M | Yes ☐ No ☐ N/A ☐ |
| HTM20.2 | dot11PhyMCSGroup | Annex C | CFHT:M | Yes ☐ No ☐ N/A ☐ |

### B.4.17.2 HT PHY features

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| | Are the following PHY protocol features supported? | | | |
| HTP1 | PHY operating modes | | | |
| HTP1.1 | Operation according to Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) (OFDM) and/or Clause 18 (Extended Rate PHY (ERP) specification) (ERP) | 19.1.4 (PPDU formats) | CFHT:M | Yes ☐ No ☐ N/A ☐ |
| HTP1.2 | HT-mixed format | 19.1.4 (PPDU formats) | CFHT:M | Yes ☐ No ☐ N/A ☐ |
| *HTP1.3 | (#1367)HT-greenfield format | 19.1.4 (PPDU formats) | CFHT:O | Yes ☐ No ☐ N/A ☐ |
| HTP2 | PHY frame format | | | |
| HTP2.1 | (#2095)HT-mixed format PPDU | 19.3.2 (PPDU format) | CFHT:M | Yes ☐ No ☐ N/A ☐ |
| HTP2.2 | (#2095)HT-greenfield format PPDU | 19.3.2 (PPDU format) | HTP1.3:M | Yes ☐ No ☐ N/A ☐ |

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### B.4.17.2 HT PHY features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| HTP2.3 | Modulation and coding schemes (MCS) | | | |
| HTP2.3.1 | MCS 0 to MCS 7 in 20 MHz with 800 ns guard interval (GI) | | | |
| HTP2.3.1.1 | Support for 20 MHz with 800 ns GI MCS index 0 | 19.3.5 (Modulation and coding scheme (MCS)), 19.5 (Parameters for HT-MCSs) | CFHT:M | Yes ☐ No ☐ N/A ☐ |
| HTP2.3.1.2 | Support for 20 MHz with 800 ns GI MCS index 1 | 19.3.5 (Modulation and coding scheme (MCS)), 19.5 (Parameters for HT-MCSs) | CFHT:M | Yes ☐ No ☐ N/A ☐ |
| HTP2.3.1.3 | Support for 20 MHz with 800 ns GI MCS index 2 | 19.3.5 (Modulation and coding scheme (MCS)), 19.5 (Parameters for HT-MCSs) | CFHT:M | Yes ☐ No ☐ N/A ☐ |
| HTP2.3.1.4 | Support for 20 MHz with 800 ns GI MCS index 3 | 19.3.5 (Modulation and coding scheme (MCS)), 19.5 (Parameters for HT-MCSs) | CFHT:M | Yes ☐ No ☐ N/A ☐ |
| HTP2.3.1.5 | Support for 20 MHz with 800 ns GI MCS index 4 | 19.3.5 (Modulation and coding scheme (MCS)), 19.5 (Parameters for HT-MCSs) | CFHT:M | Yes ☐ No ☐ N/A ☐ |
| HTP2.3.1.6 | Support for 20 MHz with 800 ns GI MCS index 5 | 19.3.5 (Modulation and coding scheme (MCS)), 19.5 (Parameters for HT-MCSs) | CFHT:M | Yes ☐ No ☐ N/A ☐ |
| HTP2.3.1.7 | Support for 20 MHz with 800 ns GI MCS index 6 | 19.3.5 (Modulation and coding scheme (MCS)), 19.5 (Parameters for HT-MCSs) | CFHT:M | Yes ☐ No ☐ N/A ☐ |


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### B.4.17.2 HT PHY features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| HTP2.3.1.8 | Support for 20 MHz with 800 ns GI MCS index 7 | 19.3.5 (Modulation and coding scheme (MCS)), 19.5 (Parameters for HT-MCSs) | CFHT:M | Yes ☐ No ☐ N/A ☐ |
| HTP2.3.2 | MCS 8 to MCS 15 in 20 MHz with 800 ns GI | | | |
| HTP2.3.2.1 | Support for 20 MHz with 800 ns GI MCS index 8 | 19.3.5 (Modulation and coding scheme (MCS)), 19.5 (Parameters for HT-MCSs) | (CFHT AND CFAP AND NOT CFVHT):M (CFVHT AND CFAP):O (CFHT AND NOT CFAP):O | Yes ☐ No ☐ N/A ☐ |
| HTP2.3.2.2 | Support for 20 MHz with 800 ns GI MCS index 9 | 19.3.5 (Modulation and coding scheme (MCS)), 19.5 (Parameters for HT-MCSs) | (CFHT AND CFAP AND NOT CFVHT):M (CFVHT AND CFAP):O (CFHT AND NOT CFAP):O | Yes ☐ No ☐ N/A ☐ |
| HTP2.3.2.3 | Support for 20 MHz with 800 ns GI MCS index 10 | 19.3.5 (Modulation and coding scheme (MCS)), 19.5 (Parameters for HT-MCSs) | (CFHT AND CFAP AND NOT CFVHT):M (CFVHT AND CFAP):O (CFHT AND NOT CFAP):O | Yes ☐ No ☐ N/A ☐ |
| HTP2.3.2.4 | Support for 20 MHz with 800 ns GI MCS index 11 | 19.3.5 (Modulation and coding scheme (MCS)), 19.5 (Parameters for HT-MCSs) | (CFHT AND CFAP AND NOT CFVHT):M (CFVHT AND CFAP):O (CFHT AND NOT CFAP):O | Yes ☐ No ☐ N/A ☐ |
| HTP2.3.2.5 | Support for 20 MHz with 800 ns GI MCS index 12 | 19.3.5 (Modulation and coding scheme (MCS)), 19.5 (Parameters for HT-MCSs) | (CFHT AND CFAP AND NOT CFVHT):M (CFVHT AND CFAP):O (CFHT AND NOT CFAP):O | Yes ☐ No ☐ N/A ☐ |

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### B.4.17.2 HT PHY features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| HTP2.3.2.6 | Support for 20 MHz with 800 ns GI MCS index 13 | 19.3.5 (Modulation and coding scheme (MCS)), 19.5 (Parameters for HT-MCSs) | (CFHT AND CFAP AND NOT CFVHT):M (CFVHT AND CFAP):O (CFHT AND NOT CFAP):O | Yes ☐ No ☐ N/A ☐ |
| HTP2.3.2.7 | Support for 20 MHz with 800 ns GI MCS index 14 | 19.3.5 (Modulation and coding scheme (MCS)), 19.5 (Parameters for HT-MCSs) | (CFHT AND CFAP AND NOT CFVHT):M (CFVHT AND CFAP):O (CFHT AND NOT CFAP):O | Yes ☐ No ☐ N/A ☐ |
| HTP2.3.2.8 | Support for 20 MHz with 800 ns GI MCS index 15 | 19.3.5 (Modulation and coding scheme (MCS)), 19.5 (Parameters for HT-MCSs) | (CFHT AND CFAP AND NOT CFVHT):M (CFVHT AND CFAP):O (CFHT AND NOT CFAP):O | Yes ☐ No ☐ N/A ☐ |
| HTP2.3.3 | Transmit and receive support for 400 ns GI | 19.3.5 (Modulation and coding scheme (MCS)), 19.5 (Parameters for HT-MCSs) | CFHT:O | Yes ☐ No ☐ N/A ☐ |
| *HTP2.3.4 | Operation at 40 MHz | 19.3.5 (Modulation and coding scheme (MCS)), 19.5 (Parameters for HT-MCSs) | CFHT:O | Yes ☐ No ☐ N/A ☐ |
| HTP2.3.5 | Support for MCS with indices 16 to 76 | | | |
| HTP2.3.5.1 | Support for MCS with index 16 | 19.3.5 (Modulation and coding scheme (MCS)), 19.5 (Parameters for HT-MCSs) | CFHT:O | Yes ☐ No ☐ N/A ☐ |
| HTP2.3.5.2 | Support for MCS with index 17 | 19.3.5 (Modulation and coding scheme (MCS)), 19.5 (Parameters for HT-MCSs) | CFHT:O | Yes ☐ No ☐ N/A ☐ |


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### B.4.17.2 HT PHY features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| HTP2.3.5.3 | Support for MCS with index 18 | 19.3.5 (Modulation and coding scheme (MCS)), 19.5 (Parameters for HT-MCSs) | CFHT:O | Yes ☐ No ☐ N/A ☐ |
| HTP2.3.5.4 | Support for MCS with index 19 | 19.3.5 (Modulation and coding scheme (MCS)), 19.5 (Parameters for HT-MCSs) | CFHT:O | Yes ☐ No ☐ N/A ☐ |
| HTP2.3.5.5 | Support for MCS with index 20 | 19.3.5 (Modulation and coding scheme (MCS)), 19.5 (Parameters for HT-MCSs) | CFHT:O | Yes ☐ No ☐ N/A ☐ |
| HTP2.3.5.6 | Support for MCS with index 21 | 19.3.5 (Modulation and coding scheme (MCS)), 19.5 (Parameters for HT-MCSs) | CFHT:O | Yes ☐ No ☐ N/A ☐ |
| HTP2.3.5.7 | Support for MCS with index 22 | 19.3.5 (Modulation and coding scheme (MCS)), 19.5 (Parameters for HT-MCSs) | CFHT:O | Yes ☐ No ☐ N/A ☐ |
| HTP2.3.5.8 | Support for MCS with index 23 | 19.3.5 (Modulation and coding scheme (MCS)), 19.5 (Parameters for HT-MCSs) | CFHT:O | Yes ☐ No ☐ N/A ☐ |
| HTP2.3.5.9 | Support for MCS with index 24 | 19.3.5 (Modulation and coding scheme (MCS)), 19.5 (Parameters for HT-MCSs) | CFHT:O | Yes ☐ No ☐ N/A ☐ |
| HTP2.3.5.10 | Support for MCS with index 25 | 19.3.5 (Modulation and coding scheme (MCS)), 19.5 (Parameters for HT-MCSs) | CFHT:O | Yes ☐ No ☐ N/A ☐ |

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### B.4.17.2 HT PHY features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| HTP2.3.5.11 | Support for MCS with index 26 | 19.3.5 (Modulation and coding scheme (MCS)), 19.5 (Parameters for HT-MCSs) | CFHT:O | Yes ☐ No ☐ N/A ☐ |
| HTP2.3.5.12 | Support for MCS with index 27 | 19.3.5 (Modulation and coding scheme (MCS)), 19.5 (Parameters for HT-MCSs) | CFHT:O | Yes ☐ No ☐ N/A ☐ |
| HTP2.3.5.13 | Support for MCS with index 28 | 19.3.5 (Modulation and coding scheme (MCS)), 19.5 (Parameters for HT-MCSs) | CFHT:O | Yes ☐ No ☐ N/A ☐ |
| HTP2.3.5.14 | Support for MCS with index 29 | 19.3.5 (Modulation and coding scheme (MCS)), 19.5 (Parameters for HT-MCSs) | CFHT:O | Yes ☐ No ☐ N/A ☐ |
| HTP2.3.5.15 | Support for MCS with index 30 | 19.3.5 (Modulation and coding scheme (MCS)), 19.5 (Parameters for HT-MCSs) | CFHT:O | Yes ☐ No ☐ N/A ☐ |
| HTP2.3.5.16 | Support for MCS with index 31 | 19.3.5 (Modulation and coding scheme (MCS)), 19.5 (Parameters for HT-MCSs) | CFHT:O | Yes ☐ No ☐ N/A ☐ |
| HTP2.3.5.17 | Support for MCS with index 32 The use of MCS with index 32 is deprecated. | 19.3.5 (Modulation and coding scheme (MCS)), 19.5 (Parameters for HT-MCSs) | CFHT:O | Yes ☐ No ☐ N/A ☐ |
| HTP2.3.5.18 | Support for MCS with index 33 | 19.3.5 (Modulation and coding scheme (MCS)), 19.5 (Parameters for HT-MCSs) | CFHT:O | Yes ☐ No ☐ N/A ☐ |


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### B.4.17.2 HT PHY features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| HTP2.3.5.19 | Support for MCS with index 34 | 19.3.5 (Modulation and coding scheme (MCS)), 19.5 (Parameters for HT-MCSs) | CFHT:O | Yes ☐ No ☐ N/A ☐ |
| HTP2.3.5.20 | Support for MCS with index 35 | 19.3.5 (Modulation and coding scheme (MCS)), 19.5 (Parameters for HT-MCSs) | CFHT:O | Yes ☐ No ☐ N/A ☐ |
| HTP2.3.5.21 | Support for MCS with index 36 | 19.3.5 (Modulation and coding scheme (MCS)), 19.5 (Parameters for HT-MCSs) | CFHT:O | Yes ☐ No ☐ N/A ☐ |
| HTP2.3.5.22 | Support for MCS with index 37 | 19.3.5 (Modulation and coding scheme (MCS)), 19.5 (Parameters for HT-MCSs) | CFHT:O | Yes ☐ No ☐ N/A ☐ |
| HTP2.3.5.23 | Support for MCS with index 38 | 19.3.5 (Modulation and coding scheme (MCS)), 19.5 (Parameters for HT-MCSs) | CFHT:O | Yes ☐ No ☐ N/A ☐ |
| HTP2.3.5.24 | Support for MCS with index 39 | 19.3.5 (Modulation and coding scheme (MCS)), 19.5 (Parameters for HT-MCSs) | CFHT:O | Yes ☐ No ☐ N/A ☐ |
| HTP2.3.5.25 | Support for MCS with index 40 | 19.3.5 (Modulation and coding scheme (MCS)), 19.5 (Parameters for HT-MCSs) | CFHT:O | Yes ☐ No ☐ N/A ☐ |
| HTP2.3.5.26 | Support for MCS with index 41 | 19.3.5 (Modulation and coding scheme (MCS)), 19.5 (Parameters for HT-MCSs) | CFHT:O | Yes ☐ No ☐ N/A ☐ |

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### B.4.17.2 HT PHY features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| HTP2.3.5.27 | Support for MCS with index 42 | 19.3.5 (Modulation and coding scheme (MCS)), 19.5 (Parameters for HT-MCSs) | CFHT:O | Yes ☐ No ☐ N/A ☐ |
| HTP2.3.5.28 | Support for MCS with index 43 | 19.3.5 (Modulation and coding scheme (MCS)), 19.5 (Parameters for HT-MCSs) | CFHT:O | Yes ☐ No ☐ N/A ☐ |
| HTP2.3.5.29 | Support for MCS with index 44 | 19.3.5 (Modulation and coding scheme (MCS)), 19.5 (Parameters for HT-MCSs) | CFHT:O | Yes ☐ No ☐ N/A ☐ |
| HTP2.3.5.30 | Support for MCS with index 45 | 19.3.5 (Modulation and coding scheme (MCS)), 19.5 (Parameters for HT-MCSs) | CFHT:O | Yes ☐ No ☐ N/A ☐ |
| HTP2.3.5.31 | Support for MCS with index 46 | 19.3.5 (Modulation and coding scheme (MCS)), 19.5 (Parameters for HT-MCSs) | CFHT:O | Yes ☐ No ☐ N/A ☐ |
| HTP2.3.5.32 | Support for MCS with index 47 | 19.3.5 (Modulation and coding scheme (MCS)), 19.5 (Parameters for HT-MCSs) | CFHT:O | Yes ☐ No ☐ N/A ☐ |
| HTP2.3.5.33 | Support for MCS with index 48 | 19.3.5 (Modulation and coding scheme (MCS)), 19.5 (Parameters for HT-MCSs) | CFHT:O | Yes ☐ No ☐ N/A ☐ |
| HTP2.3.5.34 | Support for MCS with index 49 | 19.3.5 (Modulation and coding scheme (MCS)), 19.5 (Parameters for HT-MCSs) | CFHT:O | Yes ☐ No ☐ N/A ☐ |


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### B.4.17.2 HT PHY features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| HTP2.3.5.35 | Support for MCS with index 50 | 19.3.5 (Modulation and coding scheme (MCS)), 19.5 (Parameters for HT-MCSs) | CFHT:O | Yes ☐ No ☐ N/A ☐ |
| HTP2.3.5.36 | Support for MCS with index 51 | 19.3.5 (Modulation and coding scheme (MCS)), 19.5 (Parameters for HT-MCSs) | CFHT:O | Yes ☐ No ☐ N/A ☐ |
| HTP2.3.5.37 | Support for MCS with index 52 | 19.3.5 (Modulation and coding scheme (MCS)), 19.5 (Parameters for HT-MCSs) | CFHT:O | Yes ☐ No ☐ N/A ☐ |
| HTP2.3.5.38 | Support for MCS with index 53 | 19.3.5 (Modulation and coding scheme (MCS)), 19.5 (Parameters for HT-MCSs) | CFHT:O | Yes ☐ No ☐ N/A ☐ |
| HTP2.3.5.39 | Support for MCS with index 54 | 19.3.5 (Modulation and coding scheme (MCS)), 19.5 (Parameters for HT-MCSs) | CFHT:O | Yes ☐ No ☐ N/A ☐ |
| HTP2.3.5.40 | Support for MCS with index 55 | 19.3.5 (Modulation and coding scheme (MCS)), 19.5 (Parameters for HT-MCSs) | CFHT:O | Yes ☐ No ☐ N/A ☐ |
| HTP2.3.5.41 | Support for MCS with index 56 | 19.3.5 (Modulation and coding scheme (MCS)), 19.5 (Parameters for HT-MCSs) | CFHT:O | Yes ☐ No ☐ N/A ☐ |
| HTP2.3.5.42 | Support for MCS with index 57 | 19.3.5 (Modulation and coding scheme (MCS)), 19.5 (Parameters for HT-MCSs) | CFHT:O | Yes ☐ No ☐ N/A ☐ |

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### B.4.17.2 HT PHY features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| HTP2.3.5.43 | Support for MCS with index 58 | 19.3.5 (Modulation and coding scheme (MCS)), 19.5 (Parameters for HT-MCSs) | CFHT:O | Yes ☐ No ☐ N/A ☐ |
| HTP2.3.5.44 | Support for MCS with index 59 | 19.3.5 (Modulation and coding scheme (MCS)), 19.5 (Parameters for HT-MCSs) | CFHT:O | Yes ☐ No ☐ N/A ☐ |
| HTP2.3.5.45 | Support for MCS with index 60 | 19.3.5 (Modulation and coding scheme (MCS)), 19.5 (Parameters for HT-MCSs) | CFHT:O | Yes ☐ No ☐ N/A ☐ |
| HTP2.3.5.46 | Support for MCS with index 61 | 19.3.5 (Modulation and coding scheme (MCS)), 19.5 (Parameters for HT-MCSs) | CFHT:O | Yes ☐ No ☐ N/A ☐ |
| HTP2.3.5.47 | Support for MCS with index 62 | 19.3.5 (Modulation and coding scheme (MCS)), 19.5 (Parameters for HT-MCSs) | CFHT:O | Yes ☐ No ☐ N/A ☐ |
| HTP2.3.5.48 | Support for MCS with index 63 | 19.3.5 (Modulation and coding scheme (MCS)), 19.5 (Parameters for HT-MCSs) | CFHT:O | Yes ☐ No ☐ N/A ☐ |
| HTP2.3.5.49 | Support for MCS with index 64 | 19.3.5 (Modulation and coding scheme (MCS)), 19.5 (Parameters for HT-MCSs) | CFHT:O | Yes ☐ No ☐ N/A ☐ |
| HTP2.3.5.50 | Support for MCS with index 65 | 19.3.5 (Modulation and coding scheme (MCS)), 19.5 (Parameters for HT-MCSs) | CFHT:O | Yes ☐ No ☐ N/A ☐ |


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### B.4.17.2 HT PHY features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| HTP2.3.5.51 | Support for MCS with index 66 | 19.3.5 (Modulation and coding scheme (MCS)), 19.5 (Parameters for HT-MCSs) | CFHT:O | Yes ☐ No ☐ N/A ☐ |
| HTP2.3.5.52 | Support for MCS with index 67 | 19.3.5 (Modulation and coding scheme (MCS)), 19.5 (Parameters for HT-MCSs) | CFHT:O | Yes ☐ No ☐ N/A ☐ |
| HTP2.3.5.53 | Support for MCS with index 68 | 19.3.5 (Modulation and coding scheme (MCS)), 19.5 (Parameters for HT-MCSs) | CFHT:O | Yes ☐ No ☐ N/A ☐ |
| HTP2.3.5.54 | Support for MCS with index 69 | 19.3.5 (Modulation and coding scheme (MCS)), 19.5 (Parameters for HT-MCSs) | CFHT:O | Yes ☐ No ☐ N/A ☐ |
| HTP2.3.5.55 | Support for MCS with index 70 | 19.3.5 (Modulation and coding scheme (MCS)), 19.5 (Parameters for HT-MCSs) | CFHT:O | Yes ☐ No ☐ N/A ☐ |
| HTP2.3.5.56 | Support for MCS with index 71 | 19.3.5 (Modulation and coding scheme (MCS)), 19.5 (Parameters for HT-MCSs) | CFHT:O | Yes ☐ No ☐ N/A ☐ |
| HTP2.3.5.57 | Support for MCS with index 72 | 19.3.5 (Modulation and coding scheme (MCS)), 19.5 (Parameters for HT-MCSs) | CFHT:O | Yes ☐ No ☐ N/A ☐ |
| HTP2.3.5.58 | Support for MCS with index 73 | 19.3.5 (Modulation and coding scheme (MCS)), 19.5 (Parameters for HT-MCSs) | CFHT:O | Yes ☐ No ☐ N/A ☐ |

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### B.4.17.2 HT PHY features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| HTP2.3.5.59 | Support for MCS with index 74 | 19.3.5 (Modulation and coding scheme (MCS)), 19.5 (Parameters for HT-MCSs) | CFHT:O | Yes ☐ No ☐ N/A ☐ |
| HTP2.3.5.60 | Support for MCS with index 75 | 19.3.5 (Modulation and coding scheme (MCS)), 19.5 (Parameters for HT-MCSs) | CFHT:O | Yes ☐ No ☐ N/A ☐ |
| HTP2.3.5.61 | Support for MCS with index 76 | 19.3.5 (Modulation and coding scheme (MCS)), 19.5 (Parameters for HT-MCSs) | CFHT:O | Yes ☐ No ☐ N/A ☐ |
| HTP2.4 | PHY timing parameters | | | |
| HTP2.4.1 | Values in non-HT 20 MHz channel | 19.3.6 (Timing-related parameters) | CFHT:M | Yes ☐ No ☐ N/A ☐ |
| HTP2.4.2 | Values in 20 MHz HT channel | 19.3.6 (Timing-related parameters) | CFHT:M | Yes ☐ No ☐ N/A ☐ |
| HTP2.4.3 | Values in 40 MHz channel | 19.3.6 (Timing-related parameters) | HTP2.3.4:M | Yes ☐ No ☐ N/A ☐ |
| HTP2.5 | HT Preamble field definition and coding | | | |
| HTP2.5.1 | HT-mixed format preamble | 19.3.9.2 (HT-mixed format preamble) | CFHT:M | Yes ☐ No ☐ N/A ☐ |
| HTP2.5.2 | HT-greenfield preamble | 19.3.9.5 (HT-greenfield format preamble) | HTP1.3:M | Yes ☐ No ☐ N/A ☐ |
| HTP2.5.3 | Extension HT Long Training fields (HT-ELTFs) | 19.3.9.4.6 (HT-LTF definition) | CFHT:O | Yes ☐ No ☐ N/A ☐ |
| HTP2.6 | HT Data field definition and coding | 19.3.11 (Data field) | CFHT:M | Yes ☐ No ☐ N/A ☐ |
| HTP2.6.1 | Use of LDPC codes | 19.3.11.7 (LDPC codes) | CFHT:O | Yes ☐ No ☐ N/A ☐ |
| HTP2.7 | Beamforming | 19.3.12 (Beamforming) | CFHT:O | Yes ☐ No ☐ N/A ☐ |
| HTP2.8 | Sounding PPDUs | | | |


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### B.4.17.2 HT PHY features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| HTP2.8.1 | HT preamble format for sounding PPDUs | 19.3.13 (HT Preamble format for sounding PPDUs) | CFHT:O | Yes ☐ No ☐ N/A ☐ |
| HTP2.8.2 | Sounding with an NDP | 19.3.13.2 (Sounding with an NDP(#2137)) | HTM15:O | Yes ☐ No ☐ N/A ☐ |
| HTP2.8.3 | Sounding PPDU for calibration | 19.3.13.3 (Sounding PPDU for calibration) | (M118)HTM12.7:M | Yes ☐ No ☐ N/A ☐ |
| HTP2.9 | Channel numbering and channelization | | | |
| HTP2.9.1 | Channel allocation for 20 MHz channels at 5 GHz | 17.3.8.4 (Operating channel frequencies) | CFHT:M | Yes ☐ No ☐ N/A ☐ |
| HTP2.9.2 | Channel allocation for 20 MHz channels at 2.4 GHz | 18.4.3 (Operating channel frequencies) | CFHT:M | Yes ☐ No ☐ N/A ☐ |
| HTP2.9.3 | Channel allocation for 40 MHz channels at 5 GHz | 19.3.15.3 (Channel allocation in the 5 GHz band) | HTP2.3.4:M | Yes ☐ No ☐ N/A ☐ |
| HTP2.9.4 | Channel allocation for 40 MHz channels at 2.4 GHz | 19.3.15.2 (Channel allocation in the 2.4 GHz band) | HTP2.3.4:M | Yes ☐ No ☐ N/A ☐ |
| HTP2.10 | PHY transmit specification | | | |
| HTP2.10.1 | PHY transmit specification for 20 MHz channel | 19.3.18 (PHY transmit specification) | CFHT:M | Yes ☐ No ☐ N/A ☐ |
| HTP2.10.2 | PHY transmit specification for 40 MHz channel | 19.3.18 (PHY transmit specification) | HTP2.3.4:M | Yes ☐ No ☐ N/A ☐ |
| *HTP2.11 | Space-time block coding (STBC) | 19.3.11.9.2 (Space-time block coding (STBC)) | CFHT:O | Yes ☐ No ☐ N/A ☐ |

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### B.4.17.2 HT PHY features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| HTP2.12 | PHY receive specification(#3797) | | | |
| HTP2.12.1 | PHY receive specification for 20 MHz channel | 19.3.19 (HT PHY receiver specification) | CFHT:M | Yes ☐ No ☐ N/A ☐ |
| HTP2.12.2 | PHY receive specification for 40 MHz channel | 19.3.19 (HT PHY receiver specification) | HTP2.3.4:M | Yes ☐ No ☐ N/A ☐ |
| HTP2.13 | PPDU reception with RIFS | 19.3.19.8 (Reduced interframe space (RIFS)) | CFHT:M | Yes ☐ No ☐ N/A ☐ |

## B.4.18 Tunneled direct link setup extensions(#1356)

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| TDLS1 | Tunneled direct link setup(#1356) | 9.6.12 (TDLS Action field formats), 11.20 (Tunneled direct link setup(#1356)) | CFIndepSTA AND CFTDLS:M | Yes ☐ No ☐ N/A ☐ |
| TDLS1.1 | TDLS setup | 9.4.2.60 (Link Identifier element), 9.6.12.2 (TDLS Setup Request Action field format), 9.6.12.3 (TDLS Setup Response Action field format), 9.6.12.4 (TDLS Setup Confirm Action field format), 11.20.4 (TDLS direct link establishment(#1356)) | CFIndepSTA AND CFTDLS:M | Yes ☐ No ☐ N/A ☐ |
| TDLS1.2 | TDLS teardown | 9.4.2.60 (Link Identifier element), 9.6.12.5 (TDLS Teardown Action field format), 11.20.5 (TDLS direct link teardown(#1356)) | CFIndepSTA AND CFTDLS:M | Yes ☐ No ☐ N/A ☐ |


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### B.4.18 Tunneled direct link setup extensions(#1356)

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| TDLS1.3 | TPK handshake | 12.7.8 (TDLS PeerKey (TPK) security protocol) | CFIndepSTA AND CFTDLS:M | Yes ☐ No ☐ N/A ☐ |
| TDLS1.4 | TDLS peer PSM | 9.4.2.60 (Link Identifier element), 9.4.2.61 (Wakeup Schedule element), 9.6.12.9 (TDLS Peer PSM Request Action field format), 9.6.12.10 (TDLS Peer PSM Response Action field format), 11.2.3.11 (TDLS peer power save mode) | CFIndepSTA AND CFTDLS:O | Yes ☐ No ☐ N/A ☐ |
| TDLS 1.5 | TPU | 9.4.2.60 (Link Identifier element), 9.4.2.63 (PTI Control element), 9.4.2.64 (TPU Buffer Status element), 9.6.12.6 (TDLS Peer Traffic Indication Action field format), 9.6.12.11 (TDLS Peer Traffic Response Action field format), 11.2.3.12 (TDLS peer U-APSD (TPU)) | CFIndepSTA AND CFTDLS:O | Yes ☐ No ☐ N/A ☐ |

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## B.4.18 Tunneled direct link setup extensions(#1356)

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| TDLS 1.6 | TDLS Channel Switching | 9.4.2.60 (Link Identifier element), 9.4.2.62 (Channel Switch Timing element), 9.6.12.7 (TDLS Channel Switch Request Action field format), 9.6.12.8 (TDLS Channel Switch Response Action field format), 11.20.6 (TDLS channel switching) | CFIndepSTA AND CFMD AND CFOC AND CFTDLS:O | Yes ☐ No ☐ N/A ☐ |
| TDLS1.7 | TDLS Discovery | 9.4.2.60 (Link Identifier element), 9.6.7.17 (TDLS Discovery Response frame format), 9.6.12.12 (TDLS Discovery Request Action field format), 11.20.3 (TDLS discovery(#197)) | CFIndepSTA AND CFMD AND CFOC AND CFTDLS:O | Yes ☐ No ☐ N/A ☐ |

## B.4.19 WNM extensions

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| WNM1 | Extended Capabilities element | 9.4.2.25 (Extended Capabilities element) | CFWNM:M | Yes ☐ No ☐ N/A ☐ |
| WNM2 | STA Statistics (Triggered) and Multicast Diagnostics | 11.10.8 (Triggered autonomous reporting) | CFWNM:M | Yes ☐ No ☐ N/A ☐ |
| WNM2.1 | Protocol for Triggered Measurements | 11.10.8 (Triggered autonomous reporting) | CFWNM:M | Yes ☐ No ☐ N/A ☐ |


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## B.4.19 WNM extensions *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| WNM2.2 | Triggered STA Statistics | 9.4.2.19.9 (STA Statistics request), 9.4.2.20.9 (STA Statistics report), 9.6.6.2 (Radio Measurement Request frame format), 9.6.6.3 (Radio Measurement Report frame format), 11.10.9.5 (STA Statistics report) | CFWNM:O | Yes ☐ No ☐ N/A ☐ |
| WNM2.3 | Multicast Diagnostics | 9.4.2.19.13 (Multicast Diagnostics request), 9.4.2.20.12 (Multicast Diagnostics report), 9.6.6.2 (Radio Measurement Request frame format), 9.6.6.3 (Radio Measurement Report frame format), 11.10.19 (Multicast diagnostic reporting) | CFWNM:M | Yes ☐ No ☐ N/A ☐ |
| WNM3 | Event | 11.21.2 (Event request and report procedures) | CFWNM:M | Yes ☐ No ☐ N/A ☐ |
| WNM3.1 | Event Request frame | 9.4.2.65 (Event Request element), 9.6.13.2 (Event Request frame format) | (CFWNM AND CFAP):M | Yes ☐ No ☐ N/A ☐ |
| WNM3.2 | Event Report frame | 9.4.2.66 (Event Report element), 9.6.13.3 (Event Report frame format) | (CFWNM AND CFIndepSTA):M | Yes ☐ No ☐ N/A ☐ |

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## B.4.19 WNM extensions *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| WNM4 | Diagnostic | 11.21.3 (Diagnostic request and report procedures) | CFWNM:M | Yes ☐ No ☐ N/A ☐ |
| WNM4.1 | Diagnostic Request frame | 9.4.2.67 (Diagnostic Request element), 9.6.13.4 (Diagnostic Request frame format) | (CFWNM AND CFAP):M | Yes ☐ No ☐ N/A ☐ |
| WNM4.2 | Diagnostic Report frame | 9.4.2.68 (Diagnostic Report element), 9.6.13.5 (Diagnostic Report frame format) | (CFWNM AND CFIndepSTA) :M | Yes ☐ No ☐ N/A ☐ |
| WNM4.3 | Configuration Profile Diagnostic Type | 9.4.2.68.3 (Configuration Profile report), 11.21.3.2 (Configuration Profile report) | CFWNM:M | Yes ☐ No ☐ N/A ☐ |
| WNM4.4 | Manufacturer Information STA Report Diagnostic Type | 9.4.2.68.2 (Manufacturer Information STA Report), 11.21.3.3 (Manufacturer information STA report) | CFWNM:M | Yes ☐ No ☐ N/A ☐ |
| WNM4.5 | Association Diagnostic Type | 9.4.2.67.2 (Association Diagnostic request), 9.4.2.68.4 (Association Diagnostic report), 11.21.3.4 (Association diagnostic) | CFWNM:M | Yes ☐ No ☐ N/A ☐ |


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## B.4.19 WNM extensions *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| WNM4.6 | IEEE 802.1X Authentication Diagnostic Type | 9.4.2.67.3 (IEEE 802.1X Authentication Diagnostic request), 9.4.2.68.5 (IEEE 802.1X Authentication Diagnostic report), 11.21.3.5 (IEEE 802.1X authentication diagnostic) | (CFWNM AND PC34):M | Yes ☐ No ☐ N/A ☐ |
| WNM5 | Location | 9.4.2.69 (Location Parameters element), 11.21.4 (Location track procedures) | CFWNM:M | Yes ☐ No ☐ N/A ☐ |
| WNM5.1 | Location Civic request/report | 11.10.9.9 (Location Civic report) | CFWNM:M | Yes ☐ No ☐ N/A ☐ |
| WNM5.2 | Location Identifier request/report | 11.10.9.10 (Location Identifier report) | CFWNM:M | Yes ☐ No ☐ N/A ☐ |
| WNM5.3 | Location Track Notification | 9.6.7.18 (Location Track Notification frame format), 11.21.4 (Location track procedures) | CFWNM:O | Yes ☐ No ☐ N/A ☐ |
| WNM5.3.1 | Time of Departure Notifications | 9.4.2.69 (Location Parameters element), 11.21.4 (Location track procedures) | CFWNM:O | Yes ☐ No ☐ N/A ☐ |
| WNM5.3.2 | Motion Detection Notifications | 9.4.2.69 (Location Parameters element), 11.21.4 (Location track procedures) | CFWNM:O | Yes ☐ No ☐ N/A ☐ |

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## B.4.19 WNM extensions *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| WNM5.4 | Location Configuration Request frame | 9.4.2.69 (Location Parameters element), 9.6.13.6 (Location Configuration Request frame format) | CFWNM:M | Yes ☐ No ☐ N/A ☐ |
| WNM5.4.1 | Normal Indication | 9.4.2.69 (Location Parameters element), 9.6.13.6 (Location Configuration Request frame format) | CFWNM:O | Yes ☐ No ☐ N/A ☐ |
| WNM5.4.2 | Motion Indication | 9.4.2.69 (Location Parameters element), 9.6.13.6 (Location Configuration Request frame format) | CFWNM:O | Yes ☐ No ☐ N/A ☐ |
| WNM5.5 | Location Configuration Response frame | 9.4.2.69 (Location Parameters element), 9.6.13.7 (Location Configuration Response frame format) | CFWNM:M | Yes ☐ No ☐ N/A ☐ |
| *WNM6 | Multiple BSSID Support | 11.1.3.8 (Multiple BSSID procedure), 11.1.4 (Acquiring synchronization, scanning), 11.10.14 (Multiple BSSID set) | CFWNM:O | Yes ☐ No ☐ N/A ☐ |
| WNM6.1 | Multiple BSSID element | 9.4.2.44 (Multiple BSSID element) | WNM6:M | Yes ☐ No ☐ N/A ☐ |
| WNM6.2 | Multiple BSSID-Index element | 9.4.2.72 (Multiple BSSID-Index element) | WNM6:M | Yes ☐ No ☐ N/A ☐ |


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## B.4.19 WNM extensions *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| WNM7 | BSS transition management | 11.21.7 (BSS transition management(#556)) | CFWNM:O | Yes ☐ No ☐ N/A ☐ |
| WNM7.1 | Neighbor Report element | 9.4.2.35 (Neighbor Report element) | (CFWNM AND CFAP):M | Yes ☐ No ☐ N/A ☐ |
| WNM7.2 | BSS Transition Management Query frame | 9.6.13.8 (BSS Transition Management Query frame format) | (CFWNM AND CFAP):M | Yes ☐ No ☐ N/A ☐ |
| WNM7.3 | BSS Transition Management Request frame | 9.6.13.9 (BSS Transition Management Request frame format) | (CFWNM AND CFIndepSTA):M | Yes ☐ No ☐ N/A ☐ |
| WNM7.4 | BSS Transition Management Response frame | 9.6.13.10 (BSS Transition Management Response frame format) | (CFWNM AND CFIndepSTA):M | Yes ☐ No ☐ N/A ☐ |
| *WNM8 | FMS | 11.2.3.13 (FMS power management) | CFWNM:O | Yes ☐ No ☐ N/A ☐ |
| WNM8.1 | FMS Request frame | 9.6.13.11 (FMS Request frame format) | (CFIndepSTA AND WNM8):M | Yes ☐ No ☐ N/A ☐ |
| WNM8.2 | FMS Response frame | 9.6.13.12 (FMS Response frame format) | (CFAP AND WNM8):M | Yes ☐ No ☐ N/A ☐ |
| WNM9 | Proxy ARP | 11.21.14 (Proxy ARP service) | CFWNM:O | Yes ☐ No ☐ N/A ☐ |
| *WNM10 | (#2210)Colocated Interference Reporting | 11.21.10 (QoS Traffic capability procedure) | CFWNM:O | Yes ☐ No ☐ N/A ☐ |
| WNM10.1 | (#2210)Colocated Interference Request frame | 9.6.13.13 ((#2210)Colocated Interference Request frame format) | WNM10:M | Yes ☐ No ☐ N/A ☐ |
| WNM10.2 | (#2210)Colocated Interference Report frame | 9.6.13.14 ((#2210)Colocated Interference Report frame format) | WNM10:M | Yes ☐ No ☐ N/A ☐ |

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## B.4.19 WNM extensions *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| *WNM11 | BSS max idle period | 11.21.13 (BSS max idle period management) | (CFWNM OR CFS1G):M | Yes ☐ No ☐ N/A ☐ |
| WNM11.1 | BSS Max Idle Period element | 9.4.2.77 (BSS Max Idle Period element) | WNM11:M | Yes ☐ No ☐ N/A ☐ |
| *WNM12 | TFS | 11.21.12 (TFS procedures) | CFWNM:O | Yes ☐ No ☐ N/A ☐ |
| WNM12.1 | TFS Request frame | 9.4.2.78 (TFS Request element), 9.6.13.15 (TFS Request frame format) | WNM12:M | Yes ☐ No ☐ N/A ☐ |
| WNM12.2 | TFS Response frame | 9.4.2.79 (TFS Response element), 9.6.13.16 (TFS Response frame format) | WNM12:M | Yes ☐ No ☐ N/A ☐ |
| WNM12.3 | TFS Notify frame | 9.6.13.17 (TFS Notify frame format) | (CFAP AND WNM12):M<br>(CFIndepSTA AND WNM12):O | Yes ☐ No ☐ N/A ☐ |
| *WNM13 | WNM sleep mode | 11.2.3.15 (WNM sleep mode) | WNM12:O | Yes ☐ No ☐ N/A ☐ |
| WNM13.1 | WNM Sleep Mode Request frame | 9.4.2.80 (WNM Sleep Mode element), 9.6.13.19 (WNM Sleep Mode Request frame format) | WNM13:M | Yes ☐ No ☐ N/A ☐ |
| WNM13.2 | WNM Sleep Mode Response frame | 9.4.2.80 (WNM Sleep Mode element), 9.6.13.20 (WNM Sleep Mode Response frame format) | WNM13:M | Yes ☐ No ☐ N/A ☐ |
| *WNM14 | TIM Broadcast | 11.2.3.14 (TIM Broadcast) | CFWNM:O | Yes ☐ No ☐ N/A ☐ |


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## B.4.19 WNM extensions *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| WNM14.1 | TIM Broadcast Request frame | 9.4.2.81 (TIM Broadcast Request element), 9.6.13.21 (TIM Broadcast Request frame format) | WNM14:M | Yes ☐ No ☐ N/A ☐ |
| WNM14.2 | TIM Broadcast Response frame | 9.4.2.82 (TIM Broadcast Response element), 9.6.13.22 (TIM Broadcast Response frame format) | WNM14:M | Yes ☐ No ☐ N/A ☐ |
| WNM14.3 | TIM frame | 9.6.14.2 (TIM frame format) | WNM14:M | Yes ☐ No ☐ N/A ☐ |
| *WNM15 | QoS Traffic Capability | 11.21.10 (QoS Traffic capability procedure) | (CFWNM AND CFIndepSTA) :O | Yes ☐ No ☐ N/A ☐ |
| WNM15.1 | QoS Traffic Capability element | 9.4.2.76 (QoS Traffic Capability element) | WNM15:M | Yes ☐ No ☐ N/A ☐ |
| WNM15.2 | QoS Traffic Capability Update frame | 9.6.13.23 (QoS Traffic Capability Update frame format) | WNM15:M | Yes ☐ No ☐ N/A ☐ |
| WNM16 | AC Station Count | 11.21.11 (AC Station Count) | (CFWNM AND CFIndepSTA) :O | Yes ☐ No ☐ N/A ☐ |
| (M118)*WNM17 | Timing Measurement | 11.21.5 (Timing measurement procedure) | CFWNM:O | Yes ☐ No ☐ N/A ☐ |
| WNM17.1 | Timing Measurement Request | 9.6.13.28 (Timing Measurement Request frame format) | WNM17:M | Yes ☐ No ☐ N/A ☐ |
| WNM17.2 | Timing Measurement | 9.6.14.3 (Timing Measurement frame format) | WNM17:M | Yes ☐ No ☐ N/A ☐ |
| *WNM18 | (#3311)Channel usage | 11.21.15 (Channel usage procedures) | CFWNM:O | Yes ☐ No ☐ N/A ☐ |

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## B.4.19 WNM extensions *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| WNM18.1 | Channel Usage Request frame | 9.4.2.84 (Channel Usage element), 9.6.13.24 (Channel Usage Request frame format) | WNM18:M | Yes ☐ No ☐ N/A ☐ |
| WNM18.2 | Channel Usage Response frame | 9.4.2.84 (Channel Usage element), 9.6.13.25 (Channel Usage Response frame format) | WNM18:M | Yes ☐ No ☐ N/A ☐ |
| *WNM19 | DMS | 11.21.16 (Group addressed transmission service) | (CFWNM AND CFHT):O (CFWNM AND CFTVHT):O | Yes ☐ No ☐ N/A ☐ |
| WNM19.1 | DMS Request frame | 9.4.2.86 (DMS Request element), 9.6.13.26 (DMS Request frame format) | WNM19:M | Yes ☐ No ☐ N/A ☐ |
| WNM19.2 | DMS Response frame | 9.4.2.87 (DMS Response element), 9.6.13.27 (DMS Response frame format) | WNM19:M | Yes ☐ No ☐ N/A ☐ |
| WNM20 | UTC TSF Offset | 9.4.2.59 (Time Advertisement element), 9.4.2.85 (Time Zone element), 11.19.3 (UTC TSF Offset procedures) | CFWNM:O | Yes ☐ No ☐ N/A ☐ |
| WNM21 | U-APSD coexistence | 9.4.2.89 (U-APSD Coexistence element), 11.2.3.5.2 (U-APSD coexistence) | CFWNM:O | Yes ☐ No ☐ N/A ☐ |


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## B.4.19 WNM extensions *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| (M118)*WNM 22 | WNM notification | 11.21.17 (WNM notification) | (CFWNM AND CFHT):O (CFWNM AND CFTVHT):O | Yes ☐ No ☐ N/A ☐ |
| WNM22.1 | WNM Notification Request frame | 9.6.13.29 (WNM Notification Request frame format) | (M118)WNM 22:M | Yes ☐ No ☐ N/A ☐ |
| WNM22.2 | WNM Notification Response frame | 9.6.13.30 (WNM Notification Response frame format) | (M118)WNM 22:M | Yes ☐ No ☐ N/A ☐ |
| (M118)*WNM 23 | FTM(#7065) | 11.21.6 (FTM procedure(#7065)) | CFWNM:O | Yes ☐ No ☐ N/A ☐ |
| WNM23.1 | (#7065)FTM request (including LCI and/or location civic request) | 9.6.7.32 (FTM(11az) Request frame format) | WNM23:M | Yes ☐ No ☐ N/A ☐ |
| WNM23.2 | (#7065)FTM (including LCI and/ or location civic report) | 9.6.7.33 (FTM(11az) frame format) | WNM23:M | Yes ☐ No ☐ N/A ☐ |
| WNM23.3 | Request neighbor LCI and/or civic locations within neighbor report request | 11.10.10.2 (Requesting a neighbor report) | (CFIndepSTA OR CFMBSS) AND WNM23:M | Yes ☐ No ☐ N/A ☐ |
| WNM23.4 | Report neighbor LCI and/or civic locations within neighbor report response | 11.10.10.2 (Requesting a neighbor report) | CFAP AND WNM23:M | Yes ☐ No ☐ N/A ☐ |
| WNM23.5 | Transmitter of (#7065)FTM Range request and receiver of (#7065)FTM Range report | 11.10.9.11 (FTM Range report(#7065)) | WNM23:M | Yes ☐ No ☐ N/A ☐ |
| WNM23.6 | Receiver of (#7065)FTM Range request and transmitter of (#7065)FTM Range report | 11.10.9.11 (FTM Range report(#7065)) | (CFIndepSTA OR CFMBSS) AND WNM23:M | Yes ☐ No ☐ N/A ☐ |

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## B.4.20 Interworking (IW) with external networks extensions

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| | Are the following Interworking with External Networks capabilities supported? | | | |
| (M118)*IW1 | Interworking capabilities and information(#2164) | 9.4.2.90 (Interworking element), 11.22.2 (Interworking capabilities and information) | CFIW:M | Yes ☐ No ☐ N/A ☐ |
| IW1.1 | Interworking element | 9.4.2.90 (Interworking element) | IW1:M | Yes ☐ No ☐ N/A ☐ |
| IW1.2 | Access network type | 9.4.2.90 (Interworking element) | IW1:M | Yes ☐ No ☐ N/A ☐ |
| IW1.3 | Venue type | 9.4.2.90 (Interworking element) | IW1:M | Yes ☐ No ☐ N/A ☐ |
| IW1.4 | HESSID | 9.4.2.90 (Interworking element) | IW1:M | Yes ☐ No ☐ N/A ☐ |
| (M118)*IW2 | Generic Advertisement Service | 11.22.3 (Interworking procedures: generic advertisement service (GAS)) | CFIW:M | Yes ☐ No ☐ N/A ☐ |
| IW2.1 | Advertisement Protocol element | 9.4.2.91 (Advertisement Protocol element) | IW2:M | Yes ☐ No ☐ N/A ☐ |
| *IW2.2 | GAS Protocol | 11.22.3.2 (GAS Protocol) | IW2:M | Yes ☐ No ☐ N/A ☐ |
| *IW2.2.1 | GAS frames | 9.6.7 (Public Action frame details(#3729)) | IW2:M | Yes ☐ No ☐ N/A ☐ |
| (M118)*IW2.2.2 | Access network query protocol | 9.4.5 (Access network query protocol (ANQP)-elements(M118)) | IW2.2:M | Yes ☐ No ☐ N/A ☐ |
| IW2.2.3 | Query List | 9.4.5.2 (Query List ANQP-element) | IW2.2.1:M | Yes ☐ No ☐ N/A ☐ |
| IW2.2.4 | Capability List | 9.4.5.3 (Capability List ANQP-element) | IW2.2.1:M | Yes ☐ No ☐ N/A ☐ |



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## B.4.20 Interworking (IW) with external networks extensions *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| IW2.2.5 | Venue Name | 9.4.5.4 (Venue Name ANQP-element) | IW2.2.1:O | Yes ☐ No ☐ N/A ☐ |
| IW2.2.6 | Emergency Call Number | 9.4.5.5 (Emergency Call Number ANQP-element) | IW2.2.1:O | Yes ☐ No ☐ N/A ☐ |
| IW2.2.7 | Network Authentication Type | 9.4.5.6 (Network Authentication Type ANQP-element) | IW2.2.1:O | Yes ☐ No ☐ N/A ☐ |
| IW2.2.8 | Roaming Consortium | 9.4.5.7 (Roaming Consortium ANQP-element) | IW2.2.1:O | Yes ☐ No ☐ N/A ☐ |
| IW2.2.9 | IP Address Type Availability | 9.4.5.9 (IP Address Type Availability ANQP-element) | IW2.2.1:O | Yes ☐ No ☐ N/A ☐ |
| IW2.2.10 | NAI Realm | 9.4.5.10 (NAI Realm ANQP-element) | IW2.2.1:O | Yes ☐ No ☐ N/A ☐ |
| IW2.2.11 | 3GPP Cellular Network | 9.4.5.11 (3GPP Cellular Network ANQP-element) | IW2.2.1:O | Yes ☐ No ☐ N/A ☐ |
| IW2.2.12 | AP Geospatial Location | 9.4.5.12 (AP Geospatial Location ANQP-element) | IW2.2.1:O | Yes ☐ No ☐ N/A ☐ |
| IW2.2.13 | AP Civic Location | 9.4.5.13 (AP Civic Location ANQP-element) | IW2.2.1:O | Yes ☐ No ☐ N/A ☐ |
| IW2.2.14 | AP Location Public Identifier URI/ FQDN | 9.4.5.14 (AP Location Public Identifier URI/ FQDN ANQP-element) | IW2.2.1:O | Yes ☐ No ☐ N/A ☐ |
| IW2.2.15 | Domain Name | 9.4.5.15 (Domain Name ANQP-element) | IW2.2.1:O | Yes ☐ No ☐ N/A ☐ |
| IW2.2.16 | Emergency Alert URI | 9.4.5.16 (Emergency Alert URI ANQP-element) | IW2.2.1:O | Yes ☐ No ☐ N/A ☐ |

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## B.4.20 Interworking (IW) with external networks extensions *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| IW2.2.17 | Emergency NAI | 9.4.5.17 (Emergency NAI ANQP-element) | IW2.2.1:O | Yes ☐ No ☐ N/A ☐ |
| IW2.2.18 | Vendor Specific | 9.4.5.8 (Vendor Specific ANQP-element) | IW2.2.1:O | Yes ☐ No ☐ N/A ☐ |
| IW2.2.19 | MIS Information Service | 9.4.2.91 (Advertisement Protocol element), 11.22.4 (Interworking procedures: IEEE 802.21 MIS support) | IW2:O | Yes ☐ No ☐ N/A ☐ |
| IW2.2.20 | MIS Event and Command Services Discovery | 9.4.2.91 (Advertisement Protocol element), 11.22.4 (Interworking procedures: IEEE 802.21 MIS support) | IW2.2:O | Yes ☐ No ☐ N/A ☐ |
| (M118)*IW2.2.21 | Emergency Alert System (EAS) | 9.4.2.91 (Advertisement Protocol element), 9.4.2.95 (Emergency Alert Identifier element) | IW2.2:O | Yes ☐ No ☐ N/A ☐ |
| IW2.2.22 | Advertisement Protocol ID, Vendor Specific | 9.4.2.91 (Advertisement Protocol element) | IW2.2:O | Yes ☐ No ☐ N/A ☐ |
| IW2.2.23 | TDLS Capability | 9.4.5.18 (TDLS Capability ANQP-element) | IW2.21:O | Yes ☐ No ☐ N/A ☐ |
| IW2.2.24 | Neighbor Report | 9.4.5.19 (Neighbor Report ANQP-element) | IW2.21:O | Yes ☐ No ☐ N/A ☐ |
| IW2.3 | GAS Initial Request frame | 9.6.7.12 (GAS Initial Request frame format) | IW2:M | Yes ☐ No ☐ N/A ☐ |
| IW2.4 | GAS Initial Response frame | 9.6.7.13 (GAS Initial Response frame format) | IW2:M | Yes ☐ No ☐ N/A ☐ |


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## B.4.20 Interworking (IW) with external networks extensions *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| IW2.5 | GAS Comeback Request frame | 9.6.7.14 (GAS Comeback Request frame format) | IW2:M | Yes ☐ No ☐ N/A ☐ |
| IW2.6 | GAS Comeback Response frame | 9.6.7.16 (GAS Comeback Response frame format) | IW2:M | Yes ☐ No ☐ N/A ☐ |
| IW2.7 | Group Addressed GAS Request frame | 9.6.7.14 (GAS Comeback Request frame format) | O | Yes ☐ No ☐ N/A ☐ |
| IW2.8 | Group Addressed GAS Response frame | 9.6.7.16 (GAS Comeback Response frame format) | O EBCS1:M(11bc) | Yes ☐ No ☐ N/A ☐ |
| IW2.9 | Retransmission of a query response fragment | 11.22.3.2.1 (General) | O | Yes ☐ No ☐ N/A ☐ |
| (M118)*IW3 | QoS Mapping from External Networks | 10.23.4.2 (Contention based admission control procedures), 10.23.4.3 (Controlled-access admission control), 11.22.9 (Interworking procedures: support for QoS mapping from external networks) | CFIW:O | Yes ☐ No ☐ N/A ☐ |
| IW3.1 | QoS Map element | 9.4.2.93 (QoS Map element) | IW3:M | Yes ☐ No ☐ N/A ☐ |
| IW3.2 | Transport of QoS Map | 11.22.9 (Interworking procedures: support for QoS mapping from external networks) | IW3:M | Yes ☐ No ☐ N/A ☐ |
| IW3.3 | QoS Map Configure | 9.6.3.6 (QoS Map Configure frame format) | IW3:M | Yes ☐ No ☐ N/A ☐ |

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## B.4.20 Interworking (IW) with external networks extensions *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| (M118)*IW4 | MIS Support | 6.4 (Table of MLME SAP interfaces(#1114)), 11.22.4 (Interworking procedures: IEEE 802.21 MIS support) | CFIW:O | Yes ☐ No ☐ N/A ☐ |
| IW4.1 | MAC state generic convergence function support | 6.4 (Table of MLME SAP interfaces(#1114)) | IW4:M | Yes ☐ No ☐ N/A ☐ |
| IW4.2 | Informational events | 6.6.5 (Convergence function informational events) | IW4:M | Yes ☐ No ☐ N/A ☐ |
| IW4.3 | ESS status reporting | 6.6.7 (ESS status reporting) | IW4:M | Yes ☐ No ☐ N/A ☐ |
| IW4.4 | Network configuration | 6.6.8 (Network configuration) | IW4:M | Yes ☐ No ☐ N/A ☐ |
| IW4.5 | Network events | 6.6.9 (Network events) | IW4:M | Yes ☐ No ☐ N/A ☐ |
| IW4.6 | Network command interface | 6.6.10 (Network command interface) | IW4:M | Yes ☐ No ☐ N/A ☐ |
| IW4.7 | Mobility management | 6.6.11 (MAC state SME SAP—mobility management) | IW4:M | Yes ☐ No ☐ N/A ☐ |
| IW4.8 | Network configuration | 6.6.8 (Network configuration) | IW4:M | Yes ☐ No ☐ N/A ☐ |
| IW5 | Extended channel switching enabled | 9.4.2.56 (20/40 BSS Intolerant Channel Report element), 11.1.4 (Acquiring synchronization, scanning) | (CF3G6 AND DSE9):M | Yes ☐ No ☐ N/A ☐ |
| IW6 | Expedited Bandwidth Request | 9.4.2.92 (Expedited Bandwidth Request element) | CFIW:O | Yes ☐ No ☐ N/A ☐ |
| IW7 | SSPN Interface | 11.22.5 (Interworking procedures: interactions with SSPN) | CFIW:O | Yes ☐ No ☐ N/A ☐ |


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## B.4.21 Mesh protocol capabilities

### B.4.21.1 General mesh support

| Item | Protocol capability | Reference | Status | Support |
|---|---|---|---|---|
| *MP1 | Support of mesh capability | 4.3.24 (Mesh BSS), 14.1 (General) | CFMBSS: M | Yes ☐ No ☐ N/A ☐ |
| MP1.1 | Mesh BSS scanning | 14.3.2 (Mesh identifier), 14.3.6 (Scanning mesh BSSs) | MP1:M | Yes ☐ No ☐ N/A ☐ |
| MP1.2 | Candidate peer mesh STA determination | 14.3.7 (Candidate peer mesh STA) | MP1:M | Yes ☐ No ☐ N/A ☐ |
| MP1.3 | Active mesh profile determination | 14.3.3 (Mesh profile), 14.3.4 (Mesh STA configuration) | MP1:M | Yes ☐ No ☐ N/A ☐ |
| MP1.4 | Establishing a mesh BSS | 14.3.8 (Establishing or becoming a member of a mesh BSS) | MP1:M | Yes ☐ No ☐ N/A ☐ |
| MP1.5 | Becoming a member of a mesh BSS | 14.3.8 (Establishing or becoming a member of a mesh BSS) | MP1:M | Yes ☐ No ☐ N/A ☐ |
| MP1.6 | Announcement of mesh profile and supplemental information for the mesh discovery | 14.3.3 (Mesh profile), 14.3.5 (Supplemental information for the mesh discovery) | MP1:M | Yes ☐ No ☐ N/A ☐ |
| *MP2 | Mesh peering management (MPM) framework | 14.4 (Mesh peering management (MPM)) | CFMBSS: M | Yes ☐ No ☐ N/A ☐ |
| *MP2.1 | Mesh peering management (MPM) protocol | 14.4 (Mesh peering management (MPM)) | MP2:M | Yes ☐ No ☐ N/A ☐ |
| MP2.1.1 | Processing of Mesh Peering Open frame | 14.4.6 (Mesh peering open) | MP2.1:M | Yes ☐ No ☐ N/A ☐ |
| MP2.1.2 | Processing of Mesh Peering Confirm frame | 14.4.7 (Mesh peering confirm) | MP2.1:M | Yes ☐ No ☐ N/A ☐ |
| MP2.1.3 | Processing of Mesh Peering Close frame | 14.4.8 (Mesh peering close) | MP2.1:M | Yes ☐ No ☐ N/A ☐ |
| MP2.1.4 | MPM finite state machine | 14.5 (Mesh peering management finite state machine (MPM FSM)) | MP2.1:M | Yes ☐ No ☐ N/A ☐ |
| *MP2.2 | Authenticated mesh peering exchange (AMPE) | 14.6 (Authenticated mesh peering exchange (AMPE)) | MP2:O | Yes ☐ No ☐ N/A ☐ |
| MP2.2.1 | Mesh authentication using SAE | 12.4 (Authentication using a password), 14.4.3 (Mesh authentication) | MP2.2:M | Yes ☐ No ☐ N/A ☐ |
| MP2.2.2 | Mesh authentication using IEEE Std 802.1X | 4.10 (IEEE Std 802.11 and IEEE Std 802.1X-2020(#3469)), 14.4.3 (Mesh authentication) | MP2.2:O | Yes ☐ No ☐ N/A ☐ |

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### B.4.21.1 General mesh support *(continued)*

| Item | Protocol capability | Reference | Status | Support |
|---|---|---|---|---|
| MP2.2.3 | Protected mesh peering management frame processing(M118) | 14.6.3 (Construction and processing AES-SIV-protected mesh peering Management frames), 14.6.3 (Construction and processing AES-SIV-protected mesh peering Management frames) | MP2.2:M | Yes ☐ No ☐ N/A ☐ |
| MP2.2.4 | Mesh pairwise master key security association (PMKSA) caching | 12.6.10 (RSNA authentication in an MBSS) | MP2.2:M | Yes ☐ No ☐ N/A ☐ |
| MP2.2.5 | AMPE finite state machine | 14.6.6 (AMPE finite state machine) | MP2.2:M | Yes ☐ No ☐ N/A ☐ |
| MP2.2.6 | MGTK distribution | 14.6.4 (Distribution of group keys in an MBSS(#1521)) | MP2.2:M | Yes ☐ No ☐ N/A ☐ |
| MP2.2.7 | MGTK update | 14.7 (Mesh group key handshake) | MP2.2:O | Yes ☐ No ☐ N/A ☐ |
| MP3 | Mesh STA beaconing | 14.14.3 (Beaconing) | CFMBSS:M | Yes ☐ No ☐ N/A ☐ |
| *MP4 | Mesh STA synchronization | 14.14.2 (Extensible synchronization framework) | CFMBSS:M | Yes ☐ No ☐ N/A ☐ |
| *MP4.1 | Neighbor offset synchronization method | 14.14.2 (Extensible synchronization framework) | MP4:M | Yes ☐ No ☐ N/A ☐ |
| MP4.1.1 | Calculation of TSF offset | 14.14.2.2.2 (Timing offset calculation) | MP4.1:M | Yes ☐ No ☐ N/A ☐ |
| MP4.1.2 | Clock drift adjustment | 14.14.2.2.3 (Clock drift adjustment) | MP4.1:M | Yes ☐ No ☐ N/A ☐ |
| *MP4.2 | Mesh beacon collision avoidance (MBCA) | 14.14.4 (Mesh beacon collision avoidance (MBCA)) | MP4:O | Yes ☐ No ☐ N/A ☐ |
| MP4.2.1 | Beacon timing advertisement | 14.14.4.2 (Beacon timing advertisement) | MP4.2:M | Yes ☐ No ☐ N/A ☐ |
| MP4.2.2 | TBTT selection | 14.14.4.3 (TBTT selection) | MP4.2:M | Yes ☐ No ☐ N/A ☐ |
| MP4.2.3 | TBTT adjustment | 14.14.4.4 (TBTT adjustment) | MP4.2:M | Yes ☐ No ☐ N/A ☐ |
| MP4.2.4 | Frame transmission across reported TBTT | 14.14.4.5 (Frame transmission across reported TBTT) | MP4.2:O | Yes ☐ No ☐ N/A ☐ |
| MP4.2.5 | Delayed beacon transmission | 14.14.4.6 (Delayed beacon transmissions) | MP4.2:O | Yes ☐ No ☐ N/A ☐ |
| *MP5 | MCCA | 10.24.3 (MCF controlled channel access (MCCA)) | CFMBSS:O | Yes ☐ No ☐ N/A ☐ |
| MP5.1 | (M118)MCCAOP advertisement | 10.24.3.7 (MCCAOP advertisement) | MP5:M | Yes ☐ No ☐ N/A ☐ |


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### B.4.21.1 General mesh support *(continued)*

| Item | Protocol capability | Reference | Status | Support |
|---|---|---|---|---|
| MP5.2 | (M118)Neighbor MCCAOP recognition | 10.24.3.4 (Neighborhood MCCAOP periods at a mesh STA), 10.24.3.5 (MCCA access fraction (MAF)) | MP5:M | Yes ☐ No ☐ N/A ☐ |
| MP5.3 | (M118)MCCAOP setup | 10.24.3.6 (MCCAOP setup procedure) | MP5:M | Yes ☐ No ☐ N/A ☐ |
| MP5.4 | Access during MCCAOPs | 10.24.3.9 (Access during MCCAOPs) | MP5:M | Yes ☐ No ☐ N/A ☐ |
| MP5.5 | MCCAOP teardown | 10.24.3.8 (MCCAOP teardown) | MP5:M | Yes ☐ No ☐ N/A ☐ |
| *MP6 | Intra mesh congestion control | 14.13 (Intra-mesh congestion control) | CFMBSS: O | Yes ☐ No ☐ N/A ☐ |
| MP6.1 | Local congestion monitoring and detection | 14.13 (Intra-mesh congestion control) | MP6:M | Yes ☐ No ☐ N/A ☐ |
| MP6.2 | Congestion control signaling | 14.13 (Intra-mesh congestion control) | MP6:M | Yes ☐ No ☐ N/A ☐ |
| MP6.3 | Local rate control | 14.13 (Intra-mesh congestion control) | MP6:M | Yes ☐ No ☐ N/A ☐ |
| *MP7 | MBSS channel switching procedure | 11.8.8 (Selecting and advertising a new channel), 11.9.3 (Selecting and advertising a new channel and/or operating class) | CFMBSS: M | Yes ☐ No ☐ N/A ☐ |
| MP7.1 | Transmission of channel switch advertisement | 11.8.8 (Selecting and advertising a new channel), 11.9.3 (Selecting and advertising a new channel and/or operating class) | MP7:M | Yes ☐ No ☐ N/A ☐ |
| MP7.2 | Propagation of channel switch advertisement | 11.8.8 (Selecting and advertising a new channel), 11.9.3 (Selecting and advertising a new channel and/or operating class) | MP7:M | Yes ☐ No ☐ N/A ☐ |
| *MP8 | Mesh power save operation (operation in light or deep sleep mode) | 14.15 (Power save in a mesh BSS) | CFMBSS: O | Yes ☐ No ☐ N/A ☐ |
| MP8.1 | Link-specific mesh power management mode setting | 14.15.2.2 (Peer-specific mesh power management modes), 14.15.8 (Operation in peer-specific and nonpeer mesh power management modes) | MP8:M | Yes ☐ No ☐ N/A ☐ |

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### B.4.21.1 General mesh support *(continued)*

| Item | Protocol capability | Reference | Status | Support |
|---|---|---|---|---|
| MP8.2 | Nonpeer mesh power management mode setting | 14.15.2.3 (Nonpeer mesh power management modes) | MP8:M | Yes ☐ No ☐ N/A ☐ |
| MP8.3 | Light sleep mode operation | 14.15.8.4 (Operation in light sleep mode for a mesh peering) | MP8:M | Yes ☐ No ☐ N/A ☐ |
| MP8.4 | Deep sleep mode operation | 14.15.8.5 (Operation in deep sleep mode for a mesh peering) | MP8:M | Yes ☐ No ☐ N/A ☐ |
| MP8.5 | STA power state transitions | 14.15.3 (Mesh power management mode indications and transitions) | MP8:M | Yes ☐ No ☐ N/A ☐ |
| MP8.6 | Mesh awake window operation | 14.15.6 (Mesh awake window) | MP8:M | Yes ☐ No ☐ N/A ☐ |
| *MP9 | Mesh power save support | 14.15 (Power save in a mesh BSS) | CFMBSS: M | Yes ☐ No ☐ N/A ☐ |
| MP9.1 | TIM transmission | 14.15.4 (TIM transmissions in an MBSS) | MP9:M | Yes ☐ No ☐ N/A ☐ |
| MP9.2 | Link-specific mesh power management modes determination | 14.15.2 (Mesh power management modes) | MP9:M | Yes ☐ No ☐ N/A ☐ |
| MP9.3 | Group addressed frame transmission | 14.15.7 (Power save support) | MP9:M | Yes ☐ No ☐ N/A ☐ |
| MP9.4 | Frame transmission to a mesh STA in light sleep mode | 14.15.7 (Power save support), 14.15.9 (Mesh peer service periods) | MP9:M | Yes ☐ No ☐ N/A ☐ |
| MP9.5 | Frame transmission to a mesh STA in deep sleep mode | 14.15.7 (Power save support), 14.15.9 (Mesh peer service periods) | MP9:M | Yes ☐ No ☐ N/A ☐ |
| *MP10 | Link metric computation | 14.10 (Path selection link metric) | CFMBSS: M | Yes ☐ No ☐ N/A ☐ |
| MP10.1 | Airtime link metric computation | (The extensibility framework allows the default link metric to be overridden by another path selection metric as specified in the mesh profile.) | MP10:M | Yes ☐ No ☐ N/A ☐ |
| MP10.2 | High PHY rate airtime link metric computation | 14.10.2 (Airtime link metric and high PHY rate airtime link metric) | MP10:O | Yes ☐ No ☐ N/A ☐ |
| *MP11 | Link metric reporting | 14.9.3 (Link metric reporting) | CFMBSS: M | Yes ☐ No ☐ N/A ☐ |
| MP11.1 | Autonomous link metric reporting | 14.9.3 (Link metric reporting) | MP11:O | Yes ☐ No ☐ N/A ☐ |


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### B.4.21.1 General mesh support *(continued)*

| Item | Protocol capability | Reference | Status | Support |
|---|---|---|---|---|
| MP11.2 | Link metric reporting upon request | 14.9.3 (Link metric reporting) | MP11:M | Yes ☐ No ☐ N/A ☐ |
| *MP12 | Proxy operation | 14.12.4 (Proxy information and proxy update) | CFMBSS: O | Yes ☐ No ☐ N/A ☐ |
| MP12.1 | Data forwarding at proxy mesh gate | 14.12.3 (Data forwarding at proxy mesh gates) | MP12:M | Yes ☐ No ☐ N/A ☐ |
| MP12.2 | Maintenance of proxy information | 14.12.4.2 (Proxy information) | CFMBSS: M | Yes ☐ No ☐ N/A ☐ |
| MP12.3 | Proxy update using Proxy Update and Proxy Update Confirmation frames | 14.12.4 (Proxy information and proxy update) | CFMBSS: M | Yes ☐ No ☐ N/A ☐ |
| MP12.4 | Proxy update using HWMP Mesh Path Selection frames | 14.11.9 (Path request (PREQ) mechanism), 14.11.10 (Path reply (PREP) mechanism), 14.11.11 (Path error (PERR) mechanism) | HWM1:M | Yes ☐ No ☐ N/A ☐ |
| *MP13 | Gate announcement | 14.12.2 (Gate announcement (GANN)) | CFMBSS: O | Yes ☐ No ☐ N/A ☐ |
| MP13.1 | GANN transmission | 14.12.2 (Gate announcement (GANN)) | MP13:O | Yes ☐ No ☐ N/A ☐ |
| MP13.2 | GANN reception and propagation | 14.12.2 (Gate announcement (GANN)) | CFMBSS: M | Yes ☐ No ☐ N/A ☐ |
| *MP14 | Mesh Control field handling | 9.2.4.8.3 (Mesh Control field) | CFMBSS: M | Yes ☐ No ☐ N/A ☐ |
| MP14.1 | Address Extension recognition | 9.2.4.8.3 (Mesh Control field), 9.3.5 (Frame addressing in an MBSS) | MP14:M | Yes ☐ No ☐ N/A ☐ |
| MP14.2 | Mesh TTL handling | 9.2.4.8.3 (Mesh Control field), 10.37.3 (Addressing and forwarding of individually addressed mesh Data frames), 10.37.4 (Addressing and forwarding of group addressed mesh Data frames), 10.37.5 (Addressing of Management frames and MMPDU forwarding) | MP14:M | Yes ☐ No ☐ N/A ☐ |

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### B.4.21.1 General mesh support *(continued)*

| Item | Protocol capability | Reference | Status | Support |
|---|---|---|---|---|
| MP14.3 | Mesh Sequence Number handling | 9.2.4.8.3 (Mesh Control field), 10.37.3 (Addressing and forwarding of individually addressed mesh Data frames), 10.37.4 (Addressing and forwarding of group addressed mesh Data frames), 10.37.5 (Addressing of Management frames and MMPDU forwarding), 10.37.6 (Detection of duplicate MSDUs/MMPDUs) | MP14:M | Yes ☐ No ☐ N/A ☐ |
| *MP15 | MSDU/MMPDU forwarding | 10.37 (Mesh forwarding framework) | CFMBSS: O | Yes ☐ No ☐ N/A ☐ |
| MP15.1 | Individually addressed MSDU forwarding | 10.37.3 (Addressing and forwarding of individually addressed mesh Data frames) | MP15:M | Yes ☐ No ☐ N/A ☐ |
| MP15.2 | Group addressed MSDU forwarding | 10.37.4 (Addressing and forwarding of group addressed mesh Data frames) | MP15:M | Yes ☐ No ☐ N/A ☐ |
| MP15.3 | MMPDU forwarding | 10.37.5 (Addressing of Management frames and MMPDU forwarding) | MP15:M | Yes ☐ No ☐ N/A ☐ |
| MP15.4 | Detection of duplicate MSDUs/ MMPDUs | 10.37.6 (Detection of duplicate MSDUs/ MMPDUs) | CFMBSS: M | Yes ☐ No ☐ N/A ☐ |
| MP15.5 | Treatment of unknown destination | 10.37.8 (MSDU forwarding and unknown destination) | CFMBSS: M | Yes ☐ No ☐ N/A ☐ |

### B.4.21.2 HWMP path selection protocol capabilities

| Item | Protocol capability | Reference | Status | Support |
|---|---|---|---|---|
| *HWM1 | Hybrid wireless mesh protocol (HWMP) | 14.11 (Hybrid wireless mesh protocol (HWMP)) | CFMBSS:M | Yes ☐ No ☐ N/A ☐ |
| *HWM1.1 | On-demand path selection | 14.11.3 (On-demand path selection mode) | HWM1:M | Yes ☐ No ☐ N/A ☐ |
| HWM1.1.1 | PREQ processing for on-demand path selection | 14.11.9 (Path request (PREQ) mechanism) | HWM1.1:M | Yes ☐ No ☐ N/A ☐ |


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### B.4.21.2 HWMP path selection protocol capabilities *(continued)*

| Item | Protocol capability | Reference | Status | Support |
|---|---|---|---|---|
| HWM1.1.2 | PREP processing for on-demand path selection | 14.11.10 (Path reply (PREP) mechanism) | HWM1.1:M | Yes ☐ No ☐ N/A ☐ |
| HWM1.1.3 | PERR processing for on-demand path selection | 14.11.11 (Path error (PERR) mechanism) | HWM1.1:M | Yes ☐ No ☐ N/A ☐ |
| *HWM1.2 | Proactive tree building | 14.11.4 (Proactive tree building mode) | HWM1:M | Yes ☐ No ☐ N/A ☐ |
| HWM1.2.1 | PREQ processing for proactive tree building | 14.11.9 (Path request (PREQ) mechanism) | HWM1.2:M | Yes ☐ No ☐ N/A ☐ |
| HWM1.2.2 | PREP processing for proactive tree building | 14.11.10 (Path reply (PREP) mechanism) | HWM1.2:M | Yes ☐ No ☐ N/A ☐ |
| HWM1.2.3 | PERR processing for proactive tree building | 14.11.11 (Path error (PERR) mechanism) | HWM1.2:M | Yes ☐ No ☐ N/A ☐ |
| HWM1.2.4 | RANN processing | 14.11.12 (Root announcement (RANN) mechanism) | HWM1.2:M | Yes ☐ No ☐ N/A ☐ |
| HWM2 | Maintenance of forwarding information | 10.37.2 (Forwarding information), 14.11.8.4 (Forwarding information) | MP15:M | Yes ☐ No ☐ N/A ☐ |

## B.4.22 QMF extensions

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| QMF1 | Extended Capabilities element | 9.4.2.25 (Extended Capabilities element) | CFQMF:M | Yes ☐ No ☐ N/A ☐ |
| QMF2 | Channel access procedures for QMFs | 10.2.3.2 (HCF contention based channel access (EDCA)) | CFQMF:M | Yes ☐ No ☐ N/A ☐ |
| QMF3 | Duplicate detection and recovery for QMFs | 10.3.2.14 (Duplicate detection and recovery) | CFQMF:M | Yes ☐ No ☐ N/A ☐ |
| QMF4 | QMF policy Configuration | 11.24.2 (QMF policy advertisement and configuration procedures) | CFQMF:M | Yes ☐ No ☐ N/A ☐ |

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## B.4.22 QMF extensions *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| QMF5 | Interpreting QMF priority | 11.24.3 (Interpreting QMF access categories) | CFQMF:M | Yes ☐ No ☐ N/A ☐ |
| QMF6 | CCMP cryptographic encapsulation for QMFs | 12.5.2.3 (CCMP cryptographic encapsulation) | (CFQMF AND PC34.1.10):M | Yes ☐ No ☐ N/A ☐ |

## B.4.23 RobustAVT extensions

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| AVT1 | Extended Capabilities element | 9.4.2.25 (Extended Capabilities element) | CFAVT:M | Yes ☐ No ☐ N/A ☐ |
| AVT2 | Groupcast with Retries (GCR) | 11.21.16.3.2 (GCR group membership procedures), 11.21.16.3.3 (GCR setup procedures), 11.21.16.3.4 (GCR operation), 11.21.16.3.5 (Concealment of GCR transmissions), 11.21.16.3.6 (GCR unsolicited retry) | (CFHT AND CFAVT AND WNM19):M (CFTVHT AND CFAVT AND WNM19):M | Yes ☐ No ☐ N/A ☐ |
| | | | (CFAP AND CFAVT AND WNM19 AND HTM4.4):M | Yes ☐ No ☐ N/A ☐ |
| AVT2.1 | Advanced GCR | 9.4.2.25 (Extended Capabilities element), 10.25.8 (GCR and GLK-GCR block ack), 11.21.16.3.7 (GCR block ack), 11.21.16.3.8 (GCR-SP) | (CFAVT AND QB5):O | Yes ☐ No ☐ N/A ☐ |
| AVT3 | Alternate EDCA transmit queues | 10.2.3.2 (HCF contention based channel access (EDCA)) | CFAVT AND CFHT:O | Yes ☐ No ☐ N/A ☐ |


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## B.4.23 RobustAVT extensions *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| (M118)*AVT 4 | Stream Classification Service (SCS) | 11.25.2 (SCS procedures) | CFAVT:O | Yes ☐ No ☐ N/A ☐ |
| AVT4.1 | SCS Request frame | 9.6.18.2 (SCS Request frame format) | AVT4:M | Yes ☐ No ☐ N/A ☐ |
| AVT4.2 | SCS Response frame | 9.6.18.3 (SCS Response frame format) | AVT4:M | Yes ☐ No ☐ N/A ☐ |
| AVT4.3 | Drop eligibility indicator (DEI) | 11.25.2 (SCS procedures) | (CFHT AND AVT4):M (CFTVHT AND AVT4):M | Yes ☐ No ☐ N/A ☐ |
| (M118)*ATV 5 | Overlapping Basic Service Set (OBSS) Management | 9.4.2.25 (Extended Capabilities element), 11.26 (Procedures to manage OBSS) | (CFAP AND (QP2 OR QD6) AND CFAVT):M | Yes ☐ No ☐ N/A ☐ |
| (M118)*ATV 5.1 | AP PeerKey | 12.10 (AP PeerKey support) | AVT5:O | Yes ☐ No ☐ N/A ☐ |
| (M118)*ATV 5.2<br>AVT5.2.1<br>AVT5.2.2<br>AVT5.2.3<br>AVT5.2.4 | QLoad Report<br>QLoad Report element<br>QLoad Request frame<br>QLoad Report frame<br>Protected QLoad Report | 11.26.2 (QLoad Report element)<br>9.4.2.121 (QLoad Report element)<br>9.6.7.20 (QLoad Request frame format)<br>9.6.7.21 (QLoad Report frame format)<br>9.6.7.21 (QLoad Report frame format) | AVT5:M<br>AVT5.2:M<br>AVT5.2:M<br>AVT5.2:M<br>(AVT5.2 AND AVT5.1):O | Yes ☐ No ☐ N/A ☐<br>Yes ☐ No ☐ N/A ☐<br>Yes ☐ No ☐ N/A ☐<br>Yes ☐ No ☐ N/A ☐<br>Yes ☐ No ☐ N/A ☐ |
| (M118)*AVT 5.3 | HCCA TXOP Update Count element | 9.4.2.122 (HCCA TXOP Update Count element) | (AVT5 AND QP2):O | Yes ☐ No ☐ N/A ☐ |
| AVT5.3.1 | HCCA TXOP Negotiation | 11.26.3 (HCCA TXOP negotiation) | AVT5.3:O | Yes ☐ No ☐ N/A ☐ |
| AVT5.3.2 | Protected HCCA TXOP Negotiation | 11.26.3 (HCCA TXOP negotiation) | (AVT5.3 AND ATV5.1):O | Yes ☐ No ☐ N/A ☐ |

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## B.4.23 RobustAVT extensions *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| AVT6 | GCR for Mesh | 9.4.2.25 (Extended Capabilities element), 10.25.8 (GCR and GLK-GCR block ack), 11.21.16.3.6 (GCR unsolicited retry), 11.21.16.3.7 (GCR block ack) | (WNM19 AND HTM4.4 AND CFHT AND CFAVT AND CFMBSS):O<br><br>(WNM19 AND HTM4.4 AND CFTVHT AND CFAVT (#4138)AND CFMBSS):O | Yes ☐ No ☐ N/A ☐ |

## B.4.24 DMG features

### B.4.24.1 DMG MAC features

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| | Are the following MAC protocol features supported? | | | |
| DMG-M1 | DMG capabilities signaling | | | |
| DMG-M1.1 | DMG Capabilities element | 9.4.2.126 (DMG Capabilities element) | CFDMG:M | Yes ☐ No ☐ N/A ☐ |
| DMG-M1.2 | Signaling of STA capabilities in Probe Request, (Re)Association Request frames | 9.3.3.5 (Association Request frame format), 9.3.3.7 (Reassociation Request frame format), 9.3.3.9 (Probe Request frame format), 9.4.2.126 (DMG Capabilities element) | (CFDMG AND (CFSTAofAP OR CFIBSS OR CFPBSSnotPCP)):M | Yes ☐ No ☐ N/A ☐ |


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### B.4.24.1 DMG MAC features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| DMG-M1.3 | Signaling of STA and BSS capabilities in DMG Beacon, Probe Response, (Re)Association Response frames | 9.3.3.6 (Association Response frame format), 9.3.3.8 (Reassociation Response frame format), 9.3.3.10 (Probe Response frame format), 9.3.4.2 (DMG Beacon), 9.4.2.126 (DMG Capabilities element) | (CFDMG AND (CFAP OR CFPCP)):M | Yes ☐ No ☐ N/A ☐ |
| DMG-M2 | Signaling of DMG operation | 9.4.2.127 (DMG Operation element) (#3062) | (CFDMG AND (CFAP OR CFPCP)):M | Yes ☐ No ☐ N/A ☐ |
| DMG-M3 | MSDU aggregation | | | |
| DMG-M3.1 | Reception of Basic A-MSDUs | 9.2.4.5 (QoS Control field), 9.3.2.2.2 (Basic A-MSDU subframe format) | CFDMG:M | Yes ☐ No ☐ N/A ☐ |
| DMG-M3.2 | Basic A-MSDU format | 9.3.2.2.2 (Basic A-MSDU subframe format) | CFDMG:M | Yes ☐ No ☐ N/A ☐ |
| DMG-M3.3 | Basic A-MSDU content | 9.3.2.2.2 (Basic A-MSDU subframe format) | CFDMG:M | Yes ☐ No ☐ N/A ☐ |
| DMG-M3.4 | Transmission of Basic A-MSDUs | 9.2.4.5 (QoS Control field), 9.3.2.2.2 (Basic A-MSDU subframe format) | CFDMG:O | Yes ☐ No ☐ N/A ☐ |

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### B.4.24.1 DMG MAC features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| *DMG-M3.5 | Reception of Short A-MSDU | 9.2.4.5 (QoS Control field), 9.3.2.2.2 (Basic A-MSDU subframe format) | CFDMG:O | Yes ☐ No ☐ N/A ☐ |
| DMG-M3.6 | Short A-MSDU format | 9.3.2.2.4 (Short A-MSDU subframe format) | (DMG-M3.5 OR DMG-M3.8):M | Yes ☐ No ☐ N/A ☐ |
| DMG-M3.7 | Short A-MSDU content | 9.3.2.2.4 (Short A-MSDU subframe format) | (DMG-M3.5 OR DMG-M3.8):M | Yes ☐ No ☐ N/A ☐ |
| *DMG-M3.8 | Transmission of Short A-MSDU | 9.2.4.5 (QoS Control field), 9.3.2.2.4 (Short A-MSDU subframe format) | CFDMG:O | Yes ☐ No ☐ N/A ☐ |
| DMG-M3.9 | Negotiation of Short A-MSDU usage | 9.4.2.28 (TSPEC element) | CFDMG:M | Yes ☐ No ☐ N/A ☐ |
| DMG-M4 | MPDU aggregation | | | |
| DMG-M4.1 | Reception of A-MPDU | 9.4.2.126.2 (DMG STA Capability Information field), 10.12.2 (A-MPDU length limit rules), 11.3 (STA authentication and association) | CFDMG:M | Yes ☐ No ☐ N/A ☐ |
| DMG-M4.2 | A-MPDU format | 9.7.1 (A-MPDU format) | CFDMG:M | Yes ☐ No ☐ N/A ☐ |
| DMG-M4.3 | A-MPDU content | 9.7.3 (A-MPDU contents) | CFDMG:M | Yes ☐ No ☐ N/A ☐ |


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### B.4.24.1 DMG MAC features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| DMG-M4.4 | Transmission of A-MPDU | 9.4.2.126.2 (DMG STA Capability Information field), 10.12.2 (A-MPDU length limit rules) | CFDMG:O | Yes ☐ No ☐ N/A ☐ |
| DMG-M5 | A-PPDU aggregation | 10.12 (A-MPDU operation)-10.14 (DMG A-PPDU and EDMG A-PPDU(11ay) operation) | | |
| *DMG-M5.1 | Reception of A-PPDU | 9.4.2.126.2 (DMG STA Capability Information field) | CFDMG:O | Yes ☐ No ☐ N/A ☐ |
| DMG-M5.2 | A-PPDU format | 20.5.2 (PPDU format), 20.5.2 (PPDU format) | (DMG-M5.1 OR DMG-M5.3):M | Yes ☐ No ☐ N/A ☐ |
| *DMG-M5.3 | Transmission of A-PPDU | 9.4.2.126.2 (DMG STA Capability Information field) | CFDMG:O | Yes ☐ No ☐ N/A ☐ |
| *DMG-M6 | Reverse direction aggregation exchanges | 9.4.2.126.2 (DMG STA Capability Information field), 10.29 (Reverse direction protocol) | CFDMG:O | Yes ☐ No ☐ N/A ☐ |
| DMG-M6.1 | Constraints regarding responses | 10.29.3 (Rules for RD initiator) | DMG-M6:M | Yes ☐ No ☐ N/A ☐ |
| (11ay)*DMG-M7 | DMG channel access | | | |
| DMG-M7.1 | ATI transmission | | | |
| DMG-M7.1.1 | (M118)Transmission of request | 10.38.3 (ATI transmission rules) | CFDMG AND (CFAP OR CFPCP):O | Yes ☐ No ☐ N/A ☐ |

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### B.4.24.1 DMG MAC features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| DMG-M7.1.2 | (M118)Reception of request | 10.38.3 (ATI transmission rules) | CFDMG AND (CFSTAofAP OR CFPBSSnotPCP):M | Yes ☐ No ☐ N/A ☐ |
| DMG-M7.1.3 | (M118)Transmission of response | 10.38.3 (ATI transmission rules) | CFDMG AND (CFSTAofAP OR CFPBSSnotPCP):M | Yes ☐ No ☐ N/A ☐ |
| DMG-M7.1.4 | (M118)Reception of response | 10.38.3 (ATI transmission rules) | CFDMG AND (CFAP OR CFPCP):M | Yes ☐ No ☐ N/A ☐ |
| DMG-M7.2 | DTI transmission | 10.38.4 (DTI transmission rules) | CFDMG:M | Yes ☐ No ☐ N/A ☐ |
| DMG-M7.3 | Time allocation | | | |
| *DMG-M7.3.1 | Service period (SP) allocation | 9.4.2.130 (Extended Schedule element), 9.4.2.132 (DMG TSPEC element), 9.4.2.136 (Awake Window element), 10.38.6.2 (Service period (SP) allocation) | CFDMG AND (CFAP OR CFPCP):O | Yes ☐ No ☐ N/A ☐ |
| *DMG-M7.3.2 | CBAP allocation | 9.4.2.130 (Extended Schedule element), 9.4.2.136 (Awake Window element), 10.38.6.2 (Service period (SP) allocation) | CFDMG AND (CFAP OR CFPCP):O | Yes ☐ No ☐ N/A ☐ |


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### B.4.24.1 DMG MAC features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| DMG-M7.3.3 | Interpretation of allocation | 9.4.2.130 (Extended Schedule element), 9.4.2.136 (Awake Window element), 10.38.5 (Contention based access period (CBAP) transmission rules), 10.38.6.2 (Service period (SP) allocation) | CFDMG AND (CFInfraSTA OR CFIBSS OR CFPCP OR CFPBSSnotPCP):M | Yes ☐ No ☐ N/A ☐ |
| *DMG-M7.4 | Contention based access period | 10.38.5 (Contention based access period (CBAP) transmission rules), 10.38.6.2 (Service period (SP) allocation) | CFDMG:M | Yes ☐ No ☐ N/A ☐ |
| DMG-M7.4.1 | Distributed coordination function (DCF) | | | |
| DMG-M7.4.1.1 | Network allocation vector (NAV) function | 10.3.2.2 (MAC-level acknowledgments), 10.3.4 (DCF access procedure), 10.38.10 (Updating multiple NAVs) | DMG-M7.4:M | Yes ☐ No ☐ N/A ☐ |
| DMG-M7.4.1.2 | Interframe space usage and timing | 10.3.2.4 (Setting and resetting the NAV), 10.3.4 (DCF access procedure), 10.3.7 (DCF timing relations) | DMG-M7.4:M | Yes ☐ No ☐ N/A ☐ |

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### B.4.24.1 DMG MAC features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| DMG-M7.4.1.3 | (M118)Random backoff function | 10.3.3 (Random backoff procedure) | DMG-M7.4:M | Yes ☐ No ☐ N/A ☐ |
| DMG-M7.4.1.4 | (M118)DCF access procedure | 10.3 (DCF), 10.3.4.2 (Basic access), 10.3.4.5 (Control of the channel) | DMG-M7.4:M | Yes ☐ No ☐ N/A ☐ |
| DMG-M7.4.1.5 | (M118)Random backoff procedure | 10.3 (DCF), 10.3.4.3 (Backoff procedure for DCF) | DMG-M7.4:M | Yes ☐ No ☐ N/A ☐ |
| DMG-M7.4.1.6 | Recovery procedures and retransmit limits | 10.3.4.4 (Recovery procedures and retransmit limits) | DMG-M7.4:M | Yes ☐ No ☐ N/A ☐ |
| DMG-M7.4.1.7 | Request to send (RTS)/DMG clear to send (DMG CTS) procedure | 10.3.2.6 (RTS/CTS with fragmentation), 10.3.2.9 (CTS and DMG CTS procedure), 10.3.2.10 (Dual CTS protection), 10.38.10 (Updating multiple NAVs) | DMG-M7.4:M | Yes ☐ No ☐ N/A ☐ |
| DMG-M7.4.1.8 | Individually addressed MAC protocol data unit (MPDU) transfer | 10.3.5 (Individually addressed MPDU transfer procedure) | DMG-M7.4:M | Yes ☐ No ☐ N/A ☐ |
| DMG-M7.4.1.9 | Group addressed MPDU transfer | 10.3.6 (Group addressed MPDU transfer procedure) | DMG-M7.4:M | Yes ☐ No ☐ N/A ☐ |


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### B.4.24.1 DMG MAC features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| DMG-M7.4.1.10 | MAC-level acknowledgment | 10.3.2.3 (IFS), 10.3.2.11 (Acknowledgment procedure) | DMG-M7.4:M | Yes ☐ No ☐ N/A ☐ |
| DMG-M7.4.1.11 | Duplicate detection and recovery | 10.3.2.14 (Duplicate detection and recovery) | DMG-M7.4:M | Yes ☐ No ☐ N/A ☐ |
| DMG-M7.4.2 | Enhanced DCF (EDCA) | | | |
| *DMG-M7.4.2.1 | Support for one transmit queue with AC_BE access category | 10.2.3.2 (HCF contention based channel access (EDCA)), 10.23.2.1 (Reference model) | DMG-M7.4:M | Yes ☐ No ☐ N/A ☐ |
| DMG-M7.4.2.2 | Support for four transmit queues with a separate channel access entity associated with each | 10.2.3.2 (HCF contention based channel access (EDCA)), 10.23.2.1 (Reference model) | DMG-M7.4.2.1:O | Yes ☐ No ☐ N/A ☐ |
| DMG-M7.4.2.3 | AC_BE access category and differentiated channel access | 10.23.2.2 (EDCA backoff procedure), 10.23.2.4 (Obtaining an EDCA TXOP), 10.23.2.12 (Retransmit procedures) | DMG-M7.4.2.1:M | Yes ☐ No ☐ N/A ☐ |
| DMG-M7.5 | Pseudo-static allocation | | | |

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### B.4.24.1 DMG MAC features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| DMG-M7.5.1 | Scheduling of pseudo-static allocation | 9.4.2.111 (PREQ element), 9.4.2.140 (PCP Handover element), 10.38.6.2 (Service period (SP) allocation), 10.38.6.5 (Guard time), 11.4.12.2 (Isochronous allocations) | DMG-M7.3.1:O | Yes ☐ No ☐ N/A ☐ |
| DMG-M7.5.2 | Operation within pseudo-static allocation | 9.4.2.138 (ADDBA Extension element), 9.4.2.140 (PCP Handover element), 10.38.6.2 (Service period (SP) allocation), 10.38.6.4 (Pseudo-static allocations) | CFDMG AND (CFAP OR CFSTAofAP OR CFPCP OR CFPBSSnotPCP):M | Yes ☐ No ☐ N/A ☐ |
| DMG-M7.6 | Guard time | 10.38.6.5 (Guard time) | DMG-M7.3.1:M | Yes ☐ No ☐ N/A ☐ |
| DMG-M7.7 | DMG protected period | | | |
| *DMG-M7.7.1 | Establishment of DMG protected period with RTS at source DMG STA | 10.38.6.6 (DMG and CMMG protected period) | DMG-M7.3.1:O | Yes ☐ No ☐ N/A ☐ |
| *DMG-M7.7.2 | Establishment of DMG protected period using a DMG CTS frame at destination DMG STA | 10.38.6.6 (DMG and CMMG protected period) | DMG-M7.3.1:M | Yes ☐ No ☐ N/A ☐ |
| DMG-M7.7.3 | Transmission of DMG DTS frame at destination DMG STA | 10.38.6.6 (DMG and CMMG protected period) | DMG-M7.7.2:O | Yes ☐ No ☐ N/A ☐ |


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### B.4.24.1 DMG MAC features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| DMG-M7.7.4 | Reception of DMG DTS frame at source DMG STA | 10.38.6.6 (DMG and CMMG protected period) | DMG-M7.7.1:M | Yes ☐ No ☐ N/A ☐ |
| DMG-M7.8 | Service period recovery | 10.38.6.7 (Service period recovery) | DMG-M7.3.1 AND (CFAP OR CFPCP):O | Yes ☐ No ☐ N/A ☐ |
| DMG-M7.9 | Dynamic allocation of service period | 10.38.7 (Dynamic allocation of service period) | | |
| DMG-M7.9.1 | Polling period (PP) | 9.4.2.141.3 (Rate Adaptation Control/ Extended TPC field(11ay)), 10.38.7.2 (Polling period (PP)) | | |
| DMG-M7.9.1.1 | Transmission of Poll | 9.3.1.10 (Poll frame format) | CFDMG AND (CFAP OR CFPCP):O | Yes ☐ No ☐ N/A ☐ |
| DMG-M7.9.1.2 | Reception of Poll | 9.3.1.10 (Poll frame format) | CFDMG AND (CFSTAofAP OR CFPBSSnotPCP):M | Yes ☐ No ☐ N/A ☐ |
| DMG-M7.9.1.3 | Transmission of SPR | 9.3.1.11 (SPR frame format(#4303)) | CFDMG AND (CFSTAofAP OR CFPBSSnotPCP):M | Yes ☐ No ☐ N/A ☐ |
| DMG-M7.9.1.4 | Reception of SPR | 9.3.1.11 (SPR frame format(#4303)) | CFDMG AND (CFAP OR CFPCP):M | Yes ☐ No ☐ N/A ☐ |
| DMG-M7.9.2 | Grant period (GP) | 10.38.7.3 (Grant period (GP)) | | |
| DMG-M7.9.2.1 | Transmission of Grant | 9.3.1.12 (Grant frame format) | CFDMG AND (CFAP OR CFPCP):O | Yes ☐ No ☐ N/A ☐ |

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### B.4.24.1 DMG MAC features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| DMG-M7.9.2.2 | Reception of Grant | 9.3.1.12 (Grant frame format) | CFDMG AND (CFSTAofAP OR CFPBSSnotPCP):M | Yes ☐ No ☐ N/A ☐ |
| DMG-M7.10 | Dynamic truncation of service period | 10.38.8 (Dynamic truncation of service period) | | |
| DMG-M7.10.1 | Transmission of CF-End | 9.3.1.15 (SSW frame format(#4303)) | CFDMG:O | Yes ☐ No ☐ N/A ☐ |
| DMG-M7.10.2 | Reception of CF-End | 9.3.1.15 (SSW frame format(#4303)) | CFDMG:M | Yes ☐ No ☐ N/A ☐ |
| DMG-M7.11 | Dynamic extension of service period | 10.38.9 (Dynamic extension of service period) | | |
| DMG-M7.11.1 | Transmission of SPR | 9.3.1.11 (SPR frame format(#4303)) | CFDMG AND (CFSTAofAP OR CFPBSSnotPCP):O | Yes ☐ No ☐ N/A ☐ |
| DMG-M7.11.2 | Reception of SPR | 9.3.1.11 (SPR frame format(#4303)) | CFDMG AND (CFAP OR CFPCP):M | Yes ☐ No ☐ N/A ☐ |
| DMG-M7.11.3 | Transmission of Grant | 9.3.1.12 (Grant frame format) | CFDMG AND (CFAP OR CFPCP):O | Yes ☐ No ☐ N/A ☐ |
| DMG-M7.11.4 | Reception of Grant | 9.3.1.12 (Grant frame format) | CFDMG AND (CFSTAofAP OR CFPBSSnotPCP):M | Yes ☐ No ☐ N/A ☐ |
| DMG-M7.12 | Isochronous and Asynchronous TS support | | | |


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### B.4.24.1 DMG MAC features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| DMG-M7.12.1 | Isochronous operation | 9.4.2.130 (Extended Schedule element), 9.4.2.132 (DMG TSPEC element), 9.4.2.136 (Awake Window element), 11.4.12.2 (Isochronous allocations) | DMG-M7.3.1 AND (CFInfraSTA OR CFPCP OR CFPBSSnotPCP):M | Yes ☐ No ☐ N/A ☐ |
| DMG-M7.12.2 | Asynchronous operation | 9.3.1.11 (SPR frame format(#4303)), 9.4.2.130 (Extended Schedule element), 9.4.2.132 (DMG TSPEC element), 9.4.2.136 (Awake Window element), 11.4.12.2 (Isochronous allocations) | DMG-M7.3.1 AND (CFInfraSTA OR CFPCP OR CFPBSSnotPCP):M | Yes ☐ No ☐ N/A ☐ |
| DMG-M8 | AP or PCP clustering | | | |
| DMG-M8.1 | S-AP in centralized AP or PCP cluster | 10.39 (DMG and CMMG AP or PCP clustering) | CFDMG:O | Yes ☐ No ☐ N/A ☐ |
| DMG-M8.2 | Except when centralized AP or PCP clusters on all channels supported by the AP or PCP in the operating class, join a centralized AP or PCP cluster or cease activity on channel | 10.39.2.2 (Centralized AP or PCP cluster formation) | CFDMG AND (CFAP OR CFPCP) AND NOT DMG-M8.1:M | Yes ☐ No ☐ N/A ☐ |
| DMG-M8.3 | Other AP or PCP clustering | 10.39 (DMG and CMMG AP or PCP clustering) | CFDMG:O | Yes ☐ No ☐ N/A ☐ |
| DMG-M9 | DMG beamforming | | | |

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### B.4.24.1 DMG MAC features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| DMG-M9.1 | Sector-level sweep | 10.41.2 (Sector-level sweep (SLS) phase), 10.41.6.2 (SLS phase execution) | CFDMG:M | Yes ☐ No ☐ N/A ☐ |
| DMG-M9.2 | Beamforming in BTI | 10.41.4 (Beamforming in BTI) | CFDMG:M | Yes ☐ No ☐ N/A ☐ |
| DMG-M9.3 | Beamforming in A-BFT | 10.41.5 (Beamforming in A-BFT) | CFDMG:M | Yes ☐ No ☐ N/A ☐ |
| DMG-M9.4 | BRP setup | 10.41.3.2 (BRP setup subphase) | CFDMG:M | Yes ☐ No ☐ N/A ☐ |
| DMG-M9.5 | MID | 10.41.6.3.3 (MIDC subphase with MID subphase only) | CFDMG:O | Yes ☐ No ☐ N/A ☐ |
| DMG-M9.6 | BC | 10.41.6.3.4 (MIDC subphase with BC subphase only) | CFDMG:O | Yes ☐ No ☐ N/A ☐ |
| DMG-M9.7 | BRP | | | |
| *DMG-M9.7.1 | BRP with BS-FBCK | 10.41.3 (Beam Refinement Protocol (BRP) phase), 10.41.6.4 (BRP phase execution) | CFDMG:M | Yes ☐ No ☐ N/A ☐ |
| DMG-M9.7.2 | BRP with channel measurement | 10.41.3 (Beam Refinement Protocol (BRP) phase), 10.41.6.4 (BRP phase execution) | DMG-M9.7.1:O | Yes ☐ No ☐ N/A ☐ |
| DMG-M9.8 | Beam tracking | 10.41.7 (Beam tracking) | CFDMG:M | Yes ☐ No ☐ N/A ☐ |


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### B.4.24.1 DMG MAC features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| DMG-M10 | DMG block ack with flow control | 9.4.2.126.2 (DMG STA Capability Information field), 10.41.9 (CDMG enhanced beam tracking) | CFDMG:O | Yes ☐ No ☐ N/A ☐ |
| DMG-M11 | DMG link adaptation | 10.41.9 (CDMG enhanced beam tracking) | CFDMG:O | Yes ☐ No ☐ N/A ☐ |
| DMG-M12 | Timing synchronization function (TSF) in a PBSS | | | |
| DMG-M12.1 | Timing in a PBSS | 11.1.2.1 (TSF for an infrastructure BSS or a PBSS), 11.1.5 (Adjusting STA timers) | CFPCP AND CFDMG:M | Yes ☐ No ☐ N/A ☐ |
| DMG-M12.2 | PBSS initialization | 11.1.4 (Acquiring synchronization, scanning) | CFPCP AND CFDMG:M | Yes ☐ No ☐ N/A ☐ |
| DMG-M13 | Power management | | | |
| DMG-M13.1 | STA power management without wakeup schedule | 11.2.7.2.2 (Non-AP and non-PCP STA operation without a wakeup schedule), 11.2.7.2.4 (Non-AP and non-PCP STA operation with or without a wakeup schedule) | CFDMG:M | Yes ☐ No ☐ N/A ☐ |

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### B.4.24.1 DMG MAC features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| DMG-M13.2 | STA power management with wakeup schedule | 9.4.2.137 (Multi-band element), 11.2.7.2.3 (Non-AP and non-PCP STA operation with a wakeup schedule), 11.2.7.2.4 (Non-AP and non-PCP STA operation with or without a wakeup schedule) | CFDMG:O | Yes ☐ No ☐ N/A ☐ |
| DMG-M13.3 | PCP power management | 9.4.2.137 (Multi-band element), 11.2.7.2.3 (Non-AP and non-PCP STA operation with a wakeup schedule) | CFDMG:O | Yes ☐ No ☐ N/A ☐ |
| DMG-M14 | Authentication and association | | | |
| DMG-M14.1 | Association state | 11.3.1 (State variables) | M | Yes ☐ No ☐ |
| DMG-M14.2 | STA association procedure | 11.3.5.2 (Non-AP and non-PCP STA association initiation procedures) | CFSTAofAP AND CFDMG:M CFPBSSnotPCP AND CFDMG:O | Yes ☐ No ☐ N/A ☐ |
| DMG-M14.3 | AP or PCP association procedure | 11.3.5.3 (AP or PCP association receipt procedures) | CFAP AND CFDMG:M CFPCP AND CFDMG:O | Yes ☐ No ☐ N/A ☐ |
| DMG-M14.4 | Communicating PBSS information | 11.3.7 (Communicating PBSS information) | (CFPCP OR CFPBSSnotPCP) AND CFDMG:M | Yes ☐ No ☐ N/A ☐ |
| DMG-M14.5 | SAE authentication | 12.4 (Authentication using a password) | (DMG-M14.2 OR DMG-M14.3) AND PC39:O | Yes ☐ No ☐ N/A ☐ |


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### B.4.24.1 DMG MAC features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| DMG-M14.6 | FT authentication | 13 (Fast BSS transition) | (DMG-M14.2 OR DMG-M14.3) AND PC35:O | Yes ☐ No ☐ N/A ☐ |
| DMG-M14.7 | FILS authentication | 12.11 (Authentication for FILS) | (DMG-M14.2 OR DMG-M14.3) AND FILS4:O | Yes ☐ No ☐ N/A ☐ |
| DMG-M15 | DMG beamformed link and BSS maintenance | | | |
| DMG-M15.1 | Beamformed link maintenance | | | |
| *DMG-M15.1.1 | Negotiation of dot11BeamLinkMaintenanceTime timer | 9.5.6 (Beamformed Link Maintenance field) | CFDMG:M | Yes ☐ No ☐ N/A ☐ |
| DMG-M15.1.2 | Beamformed link maintenance procedure | 11.27.1 (Beamformed link maintenance) | DMG-M15.1.1:O (11bd)NGVM1.2:M | Yes ☐ No ☐ N/A ☐ |
| DMG-M15.2 | PCP handover | 11.27.2 (PCP Handover) | CFDMG:O | Yes ☐ No ☐ N/A ☐ |
| DMG-M16 | (M118)DMG BSS peer and service discovery | 11.28 (DMG BSS peer and service discovery) | CFDMG:M | Yes ☐ No ☐ N/A ☐ |
| DMG-M17 | Changing DMG BSS parameters | 11.29 (Changing DMG BSS parameters) | CFDMG:O | Yes ☐ No ☐ N/A ☐ |
| *DMG-M18 | Spatial sharing and interference mitigation | 11.30 (Spatial sharing and interference mitigation for DMG STAs) | CFDMG:O | Yes ☐ No ☐ N/A ☐ |
| DMG-M19 | (M118)DMG coexistence with other DMG systems | 11.33 (DMG coexistence with non-IEEE-802.11 systems) | CFDMG:O | Yes ☐ No ☐ N/A ☐ |
| DMG-M20 | Traffic specification (TSPEC and DMG TSPEC) and associated frame formats | 9.6.3 (QoS Action frame details) | CFDMG:M | Yes ☐ No ☐ N/A ☐ |
| DMG-M21 | DMG frame formats | | | |
| DMG-M21.1 | DMG Action field | 9.6.19.1 (DMG Action field) | CFDMG:M | Yes ☐ No ☐ N/A ☐ |

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### B.4.24.1 DMG MAC features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| DMG-M21.2 | Announce frame | 9.6.21.2 (Announce frame format) | CFDMG:M | Yes ☐ No ☐ N/A ☐ |
| DMG-M21.3 | (M118)Power save configuration | 9.6.19.2 (Power Save Configuration Request frame format), 9.6.19.3 (Power Save Configuration Response frame format) | CFDMG:M | Yes ☐ No ☐ N/A ☐ |
| DMG-M21.4 | (M118)Information request/response | 9.6.19.4 (Information Request frame format), 9.6.19.5 (Information Response frame format) | CFDMG:M | Yes ☐ No ☐ N/A ☐ |
| DMG-M21.5 | BRP | 9.6.21.3 (BRP frame format) | CFDMG:M | Yes ☐ No ☐ N/A ☐ |
| DMG-M21.6 | Handover | 9.6.19.6 (Handover Request frame format), 9.6.19.7 (Handover Response frame format) | DMG-M15.2:M | Yes ☐ No ☐ N/A ☐ |
| DMG-M21.7 | DMG relay | 9.6.19.8 (Relay Search Request frame format)– 9.6.19.22 (ROC Response frame format) | DMG-M22:M | Yes ☐ No ☐ N/A ☐ |


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### B.4.24.1 DMG MAC features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| DMG-M22 | DMG relay | 10.44 (DMG relay operation), 11.34 (DMG relay procedures) | CFDMG:O | Yes ☐ No ☐ N/A ☐ |
| (11ay)DMG-M23 | Segmentation and Reassembly (SAR) | 10.69 (DMG segmentation and reassembly operation(11ay)) | CFDMG:O | Yes ☐ No ☐ N/A ☐ |

### B.4.24.2 DMG PHY features

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| | Are the following PHY protocol features supported? | | | |
| DMG-P1 | PHY operating modes | | | |
| DMG-P1.1 | Operation according to Clause 20 (Directional multi-gigabit (DMG) PHY specification) | 20 (Directional multi-gigabit (DMG) PHY specification) | CFDMG:M | Yes ☐ No ☐ N/A ☐ |
| DMG-P2 | PHY frame format | | | |
| *DMG-P2.1 | DMG control mode format | 20.4 (DMG control mode) | CFDMG:M | Yes ☐ No ☐ N/A ☐ |
| *DMG-P2.2 | DMG SC mode format | 20.5 (DMG SC mode) | CFDMG:M | Yes ☐ No ☐ N/A ☐ |
| *DMG-P2.3 | DMG low-power SC mode format. The DMG low-power SC mode is obsolete. Support for this mechanism might be removed in a later revision of the standard. | 20.6 (DMG low-power SC mode) | CFDMG:O | Yes ☐ No ☐ N/A ☐ |
| DMG-P2.4 | Modulation and coding schemes (MCS) | | | |
| (#2291)DMG-P2.4.1 | MCS 0 of DMG control mode | 20.4 (DMG control mode)(#2292) | DMG-P2.1:M | Yes ☐ No ☐ N/A ☐ |
| (#2291)DMG-P2.4.2 | MCS 1-12 of DMG SC mode | 20.5 (DMG SC mode)(#2292) | | |

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### B.4.24.2 DMG PHY features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| (#2291)DMG-P2.4.2.1 | MCS 1-4 | 20.5 (DMG SC mode)(#2292) | DMG-P2.2:M | Yes ☐ No ☐ N/A ☐ |
| (#2291)DMG-P2.4.2.2 | MCS 5-12 | 20.5 (DMG SC mode)(#2292) | DMG-P2.2:O | Yes ☐ No ☐ N/A ☐ |
| (#2291)DMG-P2.4.2.3 | π/2-8-PSK for MCS 10 and 11 | 20.5 (DMG SC mode)(#2292) | DMG-P2.2:O | Yes ☐ No ☐ N/A ☐ |
| (#2291)DMG-P2.4.3 | MCS 25-31 of DMG low-power SC mode (M118)The DMG low-power SC mode is obsolete. Support for this mechanism might be removed in a later revision of the standard. | 20.6 (DMG low-power SC mode)(#2292) | DMG-P2.3:M | Yes ☐ No ☐ N/A ☐ |
| (#2291)DMG-P2.5 | Common preamble format | 20.3.6 (Common preamble) | CFDMG:M | Yes ☐ No ☐ N/A ☐ |
| (#2291)DMG-P2.6 | Use of LDPC codes | 20.3.8 (Common LDPC parity matrices) | CFDMG:M | Yes ☐ No ☐ N/A ☐ |

## B.4.25 Very high throughput (VHT) features

### B.4.25.1 VHT MAC features

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| | Are the following MAC protocol features supported? | | | |
| VHTM1 | VHT capabilities signaling | | | |
| VHTM1.1 | VHT Capabilities element | 9.4.2.156.1 (VHT Capabilities element structure) | CFVHT:M | Yes ☐ No ☐ N/A ☐ |


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### B.4.25.1 VHT MAC features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| VHTM1.2 | Signaling of STA capabilities in Probe Request, (Re)Association Request frames | 9.3.3.5 (Association Request frame format), 9.3.3.7 (Reassociation Request frame format), 9.3.3.9 (Probe Request frame format), 9.4.2.156.1 (VHT Capabilities element structure) | (CFVHT AND CFIndepSTA): M (CFVHT AND CFMBSS):M | Yes ☐ No ☐ N/A ☐ |
| VHTM1.3 | Signaling of STA and BSS capabilities in Beacon, Probe Response, (Re)Association Response frames | 9.3.3.2 (Beacon frame format), 9.3.3.6 (Association Response frame format), 9.3.3.8 (Reassociation Response frame format), 9.3.3.10 (Probe Response frame format), 9.4.2.156 (VHT Capabilities element) | (CFVHT AND CFAP):M (CFVHT AND CFMBSS):M | Yes ☐ No ☐ N/A ☐ |
| VHTM2 | Signaling of VHT operation | 9.4.2.157 (VHT Operation element) | (CFVHT AND CFAP):M (CFVHT AND CFMBSS):M (CFVHT AND CFIBSS):M | Yes ☐ No ☐ N/A ☐ |
| VHTM3 | Link adaptation | | | |
| *VHTM3.1 | Use of the VHT variant HT Control field for link adaptation in immediate response exchange. | 9.2.4.6 (HT Control field), 9.3.3.14 (Action No Ack frame format), 10.31.3 (Link adaptation using the VHT variant HT Control field), 10.8 (HT Control field operation) | CFVHT:O, CFS1G:O | Yes ☐ No ☐ N/A ☐ |
| VHTM4 | Transmit beamforming | | | |

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### B.4.25.1 VHT MAC features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| *VHTM4.1 | SU Beamformer Capable | 9.4.2.156 (VHT Capabilities element) | CFVHT:O | Yes ☐ No ☐ N/A ☐ |
| *VHTM4.2 | SU Beamformee Capable | 9.4.2.156 (VHT Capabilities element) | CFVHT:O | Yes ☐ No ☐ N/A ☐ |
| *VHTM4.3 | MU Beamformer Capable | 9.4.2.156 (VHT Capabilities element) | CFAP AND VHTM4.1:O | Yes ☐ No ☐ N/A ☐ |
| *VHTM4.4 | MU Beamformee Capable | 9.4.2.156 (VHT Capabilities element) | CFIndepSTA AND VHTM4.2:O | Yes ☐ No ☐ N/A ☐ |
| VHTM4.5 | Transmission of null data PPDU | 10.35 (Null data PPDU (NDP) sounding) | VHTM4.1:M | Yes ☐ No ☐ N/A ☐ |
| VHTM4.6 | Reception of null data PPDU | 10.35 (Null data PPDU (NDP) sounding) | VHTM4.2:M | |
| VHTM5 | VHT Sounding Protocol | | | |
| VHTM5.1 | VHT sounding protocol as SU beamformer | 10.35.5 (VHT sounding protocol) | VHTM4.1:M | Yes ☐ No ☐ N/A ☐ |
| VHTM5.2 | VHT sounding protocol as SU beamformee | 10.35.5 (VHT sounding protocol) | VHTM4.2:M | Yes ☐ No ☐ N/A ☐ |
| VHTM5.3 | VHT sounding protocol as MU beamformer | 10.35.5 (VHT sounding protocol) | VHTM4.3:M | Yes ☐ No ☐ N/A ☐ |
| VHTM5.4 | VHT sounding protocol as MU beamformee | 10.35.5 (VHT sounding protocol) | VHTM4.4:M | Yes ☐ No ☐ N/A ☐ |
| VHTM6 | TXOP Sharing | | | |
| VHTM6.1 | Sharing of EDCA TXOP | 10.23.2.7 (Sharing an EDCA TXOP) | CFVHT:O | Yes ☐ No ☐ N/A ☐ |
| VHTM6.2 | Use of Primary and Secondary AC | 10.23.2.7 (Sharing an EDCA TXOP) | VHTM6.1:M | Yes ☐ No ☐ N/A ☐ |
| VHTM7 | VHT TXOP power saving | 11.2.3.16 (VHT TXOP power save) | CFVHT:O | Yes ☐ No ☐ N/A ☐ |
| VHTM8 | (M118)BSS operation | | | |


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### B.4.25.1 VHT MAC features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| VHTM8.1 | Use of primary 20 MHz, secondary 20 MHz, and secondary 40 MHz channels | 10.3.2.7 (VHT and S1G RTS procedure), 10.3.2.9 (CTS and DMG CTS procedure) | CFVHT:M | Yes ☐ No ☐ N/A ☐ |
| VHTM8.2 | Use of secondary 80 MHz channels for 160 MHz and 80+80 MHz | 11.38.1 (Basic VHT BSS functionality) | (VHTP3.4 OR VHTP3.5):M | Yes ☐ No ☐ N/A ☐ |
| VHTM8.3 | CCA on primary 20 MHz, secondary 20 MHz, and secondary 40 MHz channels | 11.38.5 (NAV assertion in a VHT BSS) | CFVHT:M | Yes ☐ No ☐ N/A ☐ |
| VHTM8.4 | CCA on secondary 80 MHz channels for 160 MHz and 80+80 MHz | 11.38.5 (NAV assertion in a VHT BSS) | (VHTP3.4 OR VHTP3.5):M | Yes ☐ No ☐ N/A ☐ |
| VHTM9 | Group ID | | | |
| VHTM9.1 | Transmission of Group ID Management frame | 9.6.22.3 (Group ID Management frame format) | VHTM4.3:M | Yes ☐ No ☐ N/A ☐ |
| VHTM9.2 | Reception of Group ID Management frame | 9.6.22.3 (Group ID Management frame format) | VHTM4.4:M | |
| VHTM10 | Bandwidth signaling | | | |
| VHTM10.1 | Support for non-HT bandwidth signaling and static operation | 10.3.2.7 (VHT and S1G RTS procedure) | CFVHT:M | Yes ☐ No ☐ N/A ☐ |
| VHTM10.2 | Support for non-HT bandwidth signaling and dynamic operation | 10.3.2.7 (VHT and S1G RTS procedure) | CFVHT:O | Yes ☐ No ☐ N/A ☐ |
| VHTM11 | S-MPDU format | 10.12.7 (Setting the EOF/Tag(11ax) field of the MPDU delimiter) | CFVHT:M CGS1G:M | Yes ☐ No ☐ N/A ☐ |
| VHTM12 | Partial AID in VHT PPDU | 10.19 (Group ID and partial AID in VHT and CMMG PPDUs) | CFVHT:M | Yes ☐ No ☐ N/A ☐ |
| VHTM13 | Extended BSS Load element | 9.4.2.158 (Extended BSS Load element) | CFVHT:O | Yes ☐ No ☐ N/A ☐ |
| VHTM13.1 | Transmission of the Extended BSS Load element | 9.4.2.158 (Extended BSS Load element) | CFAP AND CFVHT:O | Yes ☐ No ☐ N/A ☐ |
| VHTM14 | Quiet Channel element | | | |

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### B.4.25.1 VHT MAC features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| VHTM14.1 | Transmission of Quiet Channel element by an AP or mesh station in Beacon and Probe Response frames | 9.3.3.2 (Beacon frame format), 9.3.3.10 (Probe Response frame format), 9.4.2.163 (Quiet Channel element), 11.8.3 (Quieting channels for testing) | (CFAP OR CFMBSS) AND CFSM AND CFVHT AND VHTP3.4:O | Yes ☐ No ☐ N/A ☐ |
| VHTM14.2 | Transmission of Quiet Channel element by an independent station or mesh station in Beacon and Probe Response frames | 9.3.3.2 (Beacon frame format), 9.3.3.10 (Probe Response frame format), 9.4.2.163 (Quiet Channel element), 11.8.3 (Quieting channels for testing) | (CFIndepSTA OR CFMBSS) AND CFSM AND CFVHT AND VHTP3.4:O | Yes ☐ No ☐ N/A ☐ |
| VHTM14.3 | Reception of Quiet Channel element by an independent station or mesh station in Beacon and Probe Response frames | 9.3.3.2 (Beacon frame format), 9.3.3.10 (Probe Response frame format), 9.4.2.163 (Quiet Channel element), 11.8.3 (Quieting channels for testing) | (CFIndepSTA OR CFMBSS) AND CFSM AND CFVHT:M | Yes ☐ No ☐ N/A ☐ |
| VHTM15 | Space-time block coding (STBC) | | | |
| VHTM15.1 | STBC operation | 9.4.2.156 (VHT Capabilities element), 10.16 (STBC operation) | VHTP9:M | Yes ☐ No ☐ N/A ☐ |
| VHTM15.2 | Transmission of at least 2×1 STBC | 9.4.2.156.2 (VHT Capabilities Information field) | VHTP9:O.1 | Yes ☐ No ☐ N/A ☐ |
| VHTM15.3 | Reception of 1 STBC spatial stream | 9.4.2.156.2 (VHT Capabilities Information field) | VHTP9:O.1 | Yes ☐ No ☐ N/A ☐ |


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### B.4.25.1 VHT MAC features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| VHTM15.4 | Reception of 2 STBC spatial streams | 9.4.2.156.2 (VHT Capabilities Information field) | VHTM15.3:O | Yes ☐ No ☐ N/A ☐ |
| VHTM15.5 | Reception of 3 STBC spatial streams | 9.4.2.156.2 (VHT Capabilities Information field) | VHTM15.4:O | Yes ☐ No ☐ N/A ☐ |
| VHTM15.6 | Reception of 4 STBC spatial streams | 9.4.2.156.2 (VHT Capabilities Information field) | VHTM15.5:O | Yes ☐ No ☐ N/A ☐ |
| VHTM16 | Highest Supported Long GI Data Rate | | | |
| VHTM16.1 | Tx Highest Supported Long GI Data Rate | 9.4.2.156.3 (Supported VHT-MCS and NSS Set field) | CFVHT:M | Yes ☐ No ☐ N/A ☐ |
| VHTM16.2 | Rx Highest Supported Long GI Data Rate | 9.4.2.156.3 (Supported VHT-MCS and NSS Set field) | CFVHT:M | Yes ☐ No ☐ N/A ☐ |
| NOTE—Required support for MCS might be limited by the declaration of Tx and Rx Highest Supported Long GI Data Rates. | | | | |

### B.4.25.2 VHT PHY features

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| | Are the following PHY protocol features supported? | | | |
| VHTP1 | PHY operating modes | | | |
| VHTP1.1 | Operation according to Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) (OFDM) and/or Clause 19 (High Throughput (HT) PHY specification(#2297)) (high throughput) | 21.1.4 (PPDU formats) | CFVHT:M | Yes ☐ No ☐ N/A ☐ |
| VHTP2 | VHT format | 21.3.2 (VHT PPDU format) | CFVHT:M | Yes ☐ No ☐ N/A ☐ |
| VHTP3 | BSS bandwidth | | | |
| VHTP3.1 | 20 MHz operation | 11.38.1 (Basic VHT BSS functionality) | CFVHT:M | Yes ☐ No ☐ N/A ☐ |

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### B.4.25.2 VHT PHY features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| VHTP3.2 | 40 MHz operation | 11.38.1 (Basic VHT BSS functionality) | CFVHT:M | Yes ☐ No ☐ N/A ☐ |
| VHTP3.3 | 80 MHz operation | 11.38.1 (Basic VHT BSS functionality) | CFVHT:M | Yes ☐ No ☐ N/A ☐ |
| VHTP3.4 | 160 MHz operation | 11.38.1 (Basic VHT BSS functionality) | CFVHT:O VHTP3.5:M | Yes ☐ No ☐ N/A ☐ |
| VHTP3.5 | 80+80 MHz operation | 11.38.1 (Basic VHT BSS functionality) | CFVHT:O | Yes ☐ No ☐ N/A ☐ |
| VHTP4 | Bandwidth indication | 17.3.5.5 (PHY DATA scrambler and descrambler) | CFVHT:M | Yes ☐ No ☐ N/A ☐ |
| VHTP5 | PHY timing parameters | | | |
| VHTP5.1 | Values in 20 MHz channel | 21.3.6 (Timing-related parameters) | CFVHT:M | Yes ☐ No ☐ N/A ☐ |
| VHTP5.2 | Values in 40 MHz channel | 21.3.6 (Timing-related parameters) | CFVHT:M | Yes ☐ No ☐ N/A ☐ |
| VHTP5.3 | Values in 80 MHz channel | 21.3.6 (Timing-related parameters) | CFVHT:M | Yes ☐ No ☐ N/A ☐ |
| VHTP5.4 | Values in 160 MHz channel | 21.3.6 (Timing-related parameters) | VHTP3.4:M | Yes ☐ No ☐ N/A ☐ |
| VHTP5.5 | Values in 80+80 MHz channel | 21.3.6 (Timing-related parameters) | VHTP3.5:M | Yes ☐ No ☐ N/A ☐ |
| VHTP6 | VHT preamble | 21.3.8 (VHT preamble) | CFVHT:M | Yes ☐ No ☐ N/A ☐ |
| VHTP7 | Use of LDPC Code | 21.3.10.5.4 (LDPC coding) | CFVHT:O | Yes ☐ No ☐ N/A ☐ |
| VHTP8 | Modulation and coding schemes (MCS) | | | |
| VHTP8.1 | CBW20, CBW40, and CBW80 | 21.5 (Parameters for VHT-MCSs) | | |
| VHTP8.1.1 | VHT-MCS with Index 0-7 and $N_{SS} = 1$ | 21.5 (Parameters for VHT-MCSs) | CFVHT:M | Yes ☐ No ☐ N/A ☐ |
| VHTP8.1.2 | VHT-MCS with Index 0-8 and $N_{SS} = 1$ | 21.5 (Parameters for VHT-MCSs) | VHTP8.1.1:O | Yes ☐ No ☐ N/A ☐ |
| VHTP8.1.3 | VHT-MCS with Index 0-9 and $N_{SS} = 1$ | 21.5 (Parameters for VHT-MCSs) | VHTP8.1.2:O | Yes ☐ No ☐ N/A ☐ |


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### B.4.25.2 VHT PHY features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| VHTP8.1.4 | VHT-MCS with Index 0-7 and $N_{SS} = 2$ | 21.5 (Parameters for VHT-MCSs) | CFVHT:O | Yes ☐ No ☐ N/A ☐ |
| VHTP8.1.5 | VHT-MCS with Index 0-8 and $N_{SS} = 2$ | 21.5 (Parameters for VHT-MCSs) | VHTP8.1.4:O | Yes ☐ No ☐ N/A ☐ |
| VHTP8.1.6 | VHT-MCS with Index 0-9 and $N_{SS} = 2$ | 21.5 (Parameters for VHT-MCSs) | VHTP8.1.5:O | Yes ☐ No ☐ N/A ☐ |
| VHTP8.1.7 | VHT-MCS with Index 0-7 and $N_{SS} = 3$ | 21.5 (Parameters for VHT-MCSs) | CFVHT:O | Yes ☐ No ☐ N/A ☐ |
| VHTP8.1.8 | VHT-MCS with Index 0-8 and $N_{SS} = 3$ | 21.5 (Parameters for VHT-MCSs) | VHTP8.1.7:O | Yes ☐ No ☐ N/A ☐ |
| VHTP8.1.9 | VHT-MCS with Index 0-9 and $N_{SS} = 3$ | 21.5 (Parameters for VHT-MCSs) | VHTP8.1.7:O | Yes ☐ No ☐ N/A ☐ |
| VHTP8.1.10 | VHT-MCS with Index 0-7 and $N_{SS} = 4$ | 21.5 (Parameters for VHT-MCSs) | CFVHT:O | Yes ☐ No ☐ N/A ☐ |
| VHTP8.1.11 | VHT-MCS with Index 0-8 and $N_{SS} = 4$ | 21.5 (Parameters for VHT-MCSs) | VHTP8.1.10:O | Yes ☐ No ☐ N/A ☐ |
| VHTP8.1.12 | VHT-MCS with Index 0-9 and $N_{SS} = 4$ | 21.5 (Parameters for VHT-MCSs) | VHTP8.1.11:O | Yes ☐ No ☐ N/A ☐ |
| VHTP8.1.13 | VHT-MCS with Index 0-7 and $N_{SS} = 5$ | 21.5 (Parameters for VHT-MCSs) | CFVHT:O | Yes ☐ No ☐ N/A ☐ |
| VHTP8.1.14 | VHT-MCS with Index 0-8 and $N_{SS} = 5$ | 21.5 (Parameters for VHT-MCSs) | VHTP8.1.13:O | Yes ☐ No ☐ N/A ☐ |
| VHTP8.1.15 | VHT-MCS with Index 0-9 and $N_{SS} = 5$ | 21.5 (Parameters for VHT-MCSs) | VHTP8.1.14:O | Yes ☐ No ☐ N/A ☐ |
| VHTP8.1.16 | VHT-MCS with Index 0-7 and $N_{SS} = 6$ | 21.5 (Parameters for VHT-MCSs) | CFVHT:O | Yes ☐ No ☐ N/A ☐ |
| VHTP8.1.17 | VHT-MCS with Index 0-8 and $N_{SS} = 6$ | 21.5 (Parameters for VHT-MCSs) | VHTP8.1.16:O | Yes ☐ No ☐ N/A ☐ |
| VHTP8.1.18 | VHT-MCS with Index 0-9 and $N_{SS} = 6$ | 21.5 (Parameters for VHT-MCSs) | VHTP8.1.17:O | Yes ☐ No ☐ N/A ☐ |
| VHTP8.1.19 | VHT-MCS with Index 0-7 and $N_{SS} = 7$ | 21.5 (Parameters for VHT-MCSs) | CFVHT:O | Yes ☐ No ☐ N/A ☐ |
| VHTP8.1.20 | VHT-MCS with Index 0-8 and $N_{SS} = 7$ | 21.5 (Parameters for VHT-MCSs) | VHTP8.1.19:O | Yes ☐ No ☐ N/A ☐ |

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### B.4.25.2 VHT PHY features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| VHTP8.1.21 | VHT-MCS with Index 0-9 and $N_{SS} = 7$ | 21.5 (Parameters for VHT-MCSs) | VHTP8.1.20:O | Yes ☐ No ☐ N/A ☐ |
| VHTP8.1.22 | VHT-MCS with Index 0-7 and $N_{SS} = 8$ | 21.5 (Parameters for VHT-MCSs) | CFVHT:O | Yes ☐ No ☐ N/A ☐ |
| VHTP8.1.23 | VHT-MCS with Index 0-8 and $N_{SS} = 8$ | 21.5 (Parameters for VHT-MCSs) | VHTP8.1.22:O | Yes ☐ No ☐ N/A ☐ |
| VHTP8.1.24 | VHT-MCS with Index 0-9 and $N_{SS} = 8$ | 21.5 (Parameters for VHT-MCSs) | VHTP8.1.23:O | Yes ☐ No ☐ N/A ☐ |
| VHTP8.2 | CBW160 | 21.5 (Parameters for VHT-MCSs) | | |
| VHTP8.2.1 | VHT-MCS with Index 0-7 and $N_{SS} = 1$ | 21.5 (Parameters for VHT-MCSs) | VHTP3.4:M | Yes ☐ No ☐ N/A ☐ |
| VHTP8.2.2 | VHT-MCS with Index 0-8 and $N_{SS} = 1$ | 21.5 (Parameters for VHT-MCSs) | VHTP8.2.1:O | Yes ☐ No ☐ N/A ☐ |
| VHTP8.2.3 | VHT-MCS with Index 0-9 and $N_{SS} = 1$ | 21.5 (Parameters for VHT-MCSs) | VHTP8.2.2:O | Yes ☐ No ☐ N/A ☐ |
| VHTP8.2.4 | VHT-MCS with Index 0-7 and $N_{SS} = 2$ | 21.5 (Parameters for VHT-MCSs) | CFVHT:O | Yes ☐ No ☐ N/A ☐ |
| VHTP8.2.5 | VHT-MCS with Index 0-8 and $N_{SS} = 2$ | 21.5 (Parameters for VHT-MCSs) | VHTP8.2.4:O | Yes ☐ No ☐ N/A ☐ |
| VHTP8.2.6 | VHT-MCS with Index 0-9 and $N_{SS} = 2$ | 21.5 (Parameters for VHT-MCSs) | VHTP8.2.5:O | Yes ☐ No ☐ N/A ☐ |
| VHTP8.2.7 | VHT-MCS with Index 0-7 and $N_{SS} = 3$ | 21.5 (Parameters for VHT-MCSs) | CFVHT:O | Yes ☐ No ☐ N/A ☐ |
| VHTP8.2.8 | VHT-MCS with Index 0-8 and $N_{SS} = 3$ | 21.5 (Parameters for VHT-MCSs) | VHTP8.2.7:O | Yes ☐ No ☐ N/A ☐ |
| VHTP8.2.9 | VHT-MCS with Index 0-9 and $N_{SS} = 3$ | 21.5 (Parameters for VHT-MCSs) | VHTP8.2.8:O | Yes ☐ No ☐ N/A ☐ |
| VHTP8.2.10 | VHT-MCS with Index 0-7 and $N_{SS} = 4$ | 21.5 (Parameters for VHT-MCSs) | CFVHT:O | Yes ☐ No ☐ N/A ☐ |
| VHTP8.2.11 | VHT-MCS with Index 0-8 and $N_{SS} = 4$ | 21.5 (Parameters for VHT-MCSs) | VHTP8.2.10:O | Yes ☐ No ☐ N/A ☐ |
| VHTP8.2.12 | VHT-MCS with Index 0-9 and $N_{SS} = 4$ | 21.5 (Parameters for VHT-MCSs) | VHTP8.2.11:O | Yes ☐ No ☐ N/A ☐ |


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### B.4.25.2 VHT PHY features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| VHTP8.2.13 | VHT-MCS with Index 0-7 and $N_{SS} = 5$ | 21.5 (Parameters for VHT-MCSs) | CFVHT9:O | Yes ☐ No ☐ N/A ☐ |
| VHTP8.2.14 | VHT-MCS with Index 0-8 and $N_{SS} = 5$ | 21.5 (Parameters for VHT-MCSs) | VHTP8.2.13:O | Yes ☐ No ☐ N/A ☐ |
| VHTP8.2.15 | VHT-MCS with Index 0-9 and $N_{SS} = 5$ | 21.5 (Parameters for VHT-MCSs) | VHTP8.2.14:O | Yes ☐ No ☐ N/A ☐ |
| VHTP8.2.16 | VHT-MCS with Index 0-7 and $N_{SS} = 6$ | 21.5 (Parameters for VHT-MCSs) | CFVHT:O | Yes ☐ No ☐ N/A ☐ |
| VHTP8.2.17 | VHT-MCS with Index 0-8 and $N_{SS} = 6$ | 21.5 (Parameters for VHT-MCSs) | VHTP8.2.16:O | Yes ☐ No ☐ N/A ☐ |
| VHTP8.2.18 | VHT-MCS with Index 0-9 and $N_{SS} = 6$ | 21.5 (Parameters for VHT-MCSs) | VHTP8.2.17:O | Yes ☐ No ☐ N/A ☐ |
| VHTP8.2.19 | VHT-MCS with Index 0-7 and $N_{SS} = 7$ | 21.5 (Parameters for VHT-MCSs) | CFVHT:O | Yes ☐ No ☐ N/A ☐ |
| VHTP8.2.20 | VHT-MCS with Index 0-8 and $N_{SS} = 7$ | 21.5 (Parameters for VHT-MCSs) | VHTP8.2.19:O | Yes ☐ No ☐ N/A ☐ |
| VHTP8.2.21 | VHT-MCS with Index 0-9 and $N_{SS} = 7$ | 21.5 (Parameters for VHT-MCSs) | VHTP8.2.20:O | Yes ☐ No ☐ N/A ☐ |
| VHTP8.2.22 | VHT-MCS with Index 0-7 and $N_{SS} = 8$ | 21.5 (Parameters for VHT-MCSs) | CFVHT:O | Yes ☐ No ☐ N/A ☐ |
| VHTP8.2.23 | VHT-MCS with Index 0-8 and $N_{SS} = 8$ | 21.5 (Parameters for VHT-MCSs) | VHTP8.2.22:O | Yes ☐ No ☐ N/A ☐ |
| VHTP8.2.24 | VHT-MCS with Index 0-9 and $N_{SS} = 8$ | 21.5 (Parameters for VHT-MCSs) | VHTP8.2.23:O | Yes ☐ No ☐ N/A ☐ |
| VHTP8.3 | CBW80+80 | 21.5 (Parameters for VHT-MCSs) | | |
| VHTP8.3.1 | VHT-MCS with Index 0-7 and $N_{SS} = 1$ | 21.5 (Parameters for VHT-MCSs) | VHTP3.5:M | Yes ☐ No ☐ N/A ☐ |
| VHTP8.3.2 | VHT-MCS with Index 0-8 and $N_{SS} = 1$ | 21.5 (Parameters for VHT-MCSs) | VHTP8.3.1:O | Yes ☐ No ☐ N/A ☐ |
| VHTP8.3.3 | VHT-MCS with Index 0-9 and $N_{SS} = 1$ | 21.5 (Parameters for VHT-MCSs) | VHTP8.3.2:O | Yes ☐ No ☐ N/A ☐ |
| VHTP8.3.4 | VHT-MCS with Index 0-7 and $N_{SS} = 2$ | 21.5 (Parameters for VHT-MCSs) | CFVHT:O | Yes ☐ No ☐ N/A ☐ |

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### B.4.25.2 VHT PHY features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| VHTP8.3.5 | VHT-MCS with Index 0-8 and $N_{SS} = 2$ | 21.5 (Parameters for VHT-MCSs) | VHTP8.3.4:O | Yes ☐ No ☐ N/A ☐ |
| VHTP8.3.6 | VHT-MCS with Index 0-9 and $N_{SS} = 2$ | 21.5 (Parameters for VHT-MCSs) | VHTP8.3.5:O | Yes ☐ No ☐ N/A ☐ |
| VHTP8.3.7 | VHT-MCS with Index 0-7 and $N_{SS} = 3$ | 21.5 (Parameters for VHT-MCSs) | CFVHT:O | Yes ☐ No ☐ N/A ☐ |
| VHTP8.3.8 | VHT-MCS with Index 0-8 and $N_{SS} = 3$ | 21.5 (Parameters for VHT-MCSs) | VHTP8.3.7:O | Yes ☐ No ☐ N/A ☐ |
| VHTP8.3.9 | VHT-MCS with Index 0-9 and $N_{SS} = 3$ | 21.5 (Parameters for VHT-MCSs) | VHTP8.3.8:O | Yes ☐ No ☐ N/A ☐ |
| VHTP8.3.10 | VHT-MCS with Index 0-7 and $N_{SS} = 4$ | 21.5 (Parameters for VHT-MCSs) | CFVHT:O | Yes ☐ No ☐ N/A ☐ |
| VHTP8.3.11 | VHT-MCS with Index 0-8 and $N_{SS} = 4$ | 21.5 (Parameters for VHT-MCSs) | VHTP8.3.10:O | Yes ☐ No ☐ N/A ☐ |
| VHTP8.3.12 | VHT-MCS with Index 0-9 and $N_{SS} = 4$ | 21.5 (Parameters for VHT-MCSs) | VHTP8.3.11:O | Yes ☐ No ☐ N/A ☐ |
| VHTP8.3.13 | VHT-MCS with Index 0-7 and $N_{SS} = 5$ | 21.5 (Parameters for VHT-MCSs) | CFVHT:O | Yes ☐ No ☐ N/A ☐ |
| VHTP8.3.14 | VHT-MCS with Index 0-8 and $N_{SS} = 5$ | 21.5 (Parameters for VHT-MCSs) | VHTP8.3.13:O | Yes ☐ No ☐ N/A ☐ |
| VHTP8.3.15 | VHT-MCS with Index 0-9 and $N_{SS} = 5$ | 21.5 (Parameters for VHT-MCSs) | VHTP8.3.14:O | Yes ☐ No ☐ N/A ☐ |
| VHTP8.3.16 | VHT-MCS with Index 0-7 and $N_{SS} = 6$ | 21.5 (Parameters for VHT-MCSs) | CFVHT:O | Yes ☐ No ☐ N/A ☐ |
| VHTP8.3.17 | VHT-MCS with Index 0-8 and $N_{SS} = 6$ | 21.5 (Parameters for VHT-MCSs) | VHTP8.3.16:O | Yes ☐ No ☐ N/A ☐ |
| VHTP8.3.18 | VHT-MCS with Index 0-9 and $N_{SS} = 6$ | 21.5 (Parameters for VHT-MCSs) | VHTP8.3.17:O | Yes ☐ No ☐ N/A ☐ |
| VHTP8.3.19 | VHT-MCS with Index 0-7 and $N_{SS} = 7$ | 21.5 (Parameters for VHT-MCSs) | CFVHT:O | Yes ☐ No ☐ N/A ☐ |
| VHTP8.3.20 | VHT-MCS with Index 0-8 and $N_{SS} = 7$ | 21.5 (Parameters for VHT-MCSs) | VHTP8.3.19:O | Yes ☐ No ☐ N/A ☐ |
| VHTP8.3.21 | VHT-MCS with Index 0-9 and $N_{SS} = 7$ | 21.5 (Parameters for VHT-MCSs) | VHTP8.3.20:O | Yes ☐ No ☐ N/A ☐ |


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### B.4.25.2 VHT PHY features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| VHTP8.3.22 | VHT-MCS with Index 0-7 and $N_{SS} = 8$ | 21.5 (Parameters for VHT-MCSs) | CFVHT:O | Yes ☐ No ☐ N/A ☐ |
| VHTP8.3.23 | VHT-MCS with Index 0-8 and $N_{SS} = 8$ | 21.5 (Parameters for VHT-MCSs) | VHTP8.3.22:O | Yes ☐ No ☐ N/A ☐ |
| VHTP8.3.24 | VHT-MCS with Index 0-9 and $N_{SS} = 8$ | 21.5 (Parameters for VHT-MCSs) | VHTP8.3.23:O | Yes ☐ No ☐ N/A ☐ |
| VHTP8.4 | Transmit and receive support for 400 ns GI | 21.5 (Parameters for VHT-MCSs) | CFVHT:O | Yes ☐ No ☐ N/A ☐ |
| VHTP9 | Space-time block coding (STBC) | 21.3.10.9.4 (Space-time block coding) | CFVHT:O | Yes ☐ No ☐ N/A ☐ |
| VHTP10 | Non-HT duplicate format | 21.3.10.12 (Non-HT duplicate transmission) | CFVHT:M | Yes ☐ No ☐ N/A ☐ |

## B.4.26 TVWS functions

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| TVWS 1 | Fixed STA TVWS operation | 11.42 (Operation under the control of a GDB), Annex D, E.2.5 (TVWS band in the United States and its territories and Canada (54–698 MHz)(#296)) | CFTVHT:O | Yes ☐ No ☐ N/A ☐ |
| TVWS 2 | Master STA TVWS operation | 11.42 (Operation under the control of a GDB), 11.42.2 (GDD enabling STA operation), Annex D, E.2.5 (TVWS band in the United States and its territories and Canada (54–698 MHz)(#296)) | CFTVHT:O | Yes ☐ No ☐ N/A ☐ |
| *TVWS3 | Client STA TVWS operation | 11.42.3 (GDD dependent STA operation), Annex D, E.2.5 (TVWS band in the United States and its territories and Canada (54–698 MHz)(#296)) | CFTVHT:O | Yes ☐ No ☐ N/A ☐ |

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## B.4.26 TVWS functions

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| TVWS 3.1 | GDD dependent STA TVWS behavior | 11.42.3 (GDD dependent STA operation), Annex D, E.2.5 (TVWS band in the United States and its territories and Canada (54–698 MHz)(#296)) | WS3:M | Yes ☐ No ☐ N/A ☐ |
| TVWS 4 | Channel Availability Query | 9.4.5.2 (Query List ANQP-element), 9.6.7.25 (Channel Availability Query frame format), 11.42.4 (Channel availability query (CAQ) procedure) | CFTVHT:M | Yes ☐ No ☐ N/A ☐ |
| TVWS 5 | Channel Schedule Management | 9.4.5.3 (Capability List ANQP-element), 9.6.7.26 (Channel Schedule Management frame format), 11.42.5 (Channel schedule management (CSM) procedures) | CFTVHT:M | Yes ☐ No ☐ N/A ☐ |
| TVWS 6 | Contact Verification Signal | 9.6.7.27 (Contact Verification Signal frame format), 11.42.6 (Contact verification signal (CVS)) | CFTVHT:M | Yes ☐ No ☐ N/A ☐ |
| *TVWS 7 | Network Channel Control | 9.4.5.4 (Venue Name ANQP-element), 9.6.7.30 (Network Channel Control frame format), 11.42.7 (Network channel control (NCC) procedures) | CFTVHT:M | |
| TVWS 7.1 | NCC Requesting STA | 11.42.7.2 (NCC requesting STA) | CFTVHT:M | Yes ☐ No ☐ N/A ☐ |
| TVWS 7.2 | NCC Responding STA | 11.42.7.3 (NCC responding STA) | CFTVHT:O | Yes ☐ No ☐ N/A ☐ |
| TVWS 8 | White Space Map Announcement | 9.4.2.168 (White Space Map element), 9.6.7.31 (White Space Map Announcement frame format), 11.42.8 (White space map (WSM)) | CFTVHT:M | Yes ☐ No ☐ N/A ☐ |


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### B.4.26.1 TVHT MAC features

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| | Are the following MAC protocol features supported? | | | |
| TVHTM1 | TVHT Capabilities element | | | |
| TVHTM1.1 | VHT Capabilities element | 9.4.2.156.1 (VHT Capabilities element structure) | CFTVHT:O | Yes ☐ No ☐ N/A ☐ |
| TVHTM1.2 | Signaling of STA capabilities in Probe Request, (Re)Association Request frames | 9.3.3.5 (Association Request frame format), 9.3.3.7 (Reassociation Request frame format), 9.3.3.9 (Probe Request frame format), 9.4.2.156.1 (VHT Capabilities element structure) | (CFTVHT AND CFIndepSTA): O (CFTVHT AND CFMBSS):O | Yes ☐ No ☐ N/A ☐ |
| TVHTM1.3 | Signaling of STA and BSS capabilities in Beacon, Probe Response, (Re)Association Response frames | 9.3.3.2 (Beacon frame format), 9.3.3.6 (Association Response frame format), 9.3.3.8 (Reassociation Response frame format), 9.3.3.10 (Probe Response frame format), 9.4.2.156 (VHT Capabilities element) | (CFTVHT AND CFAP):O (CFTVHT AND CFMBSS):O | Yes ☐ No ☐ N/A ☐ |
| TVHTM2 | Signaling of VHT operation | 9.4.2.157 (VHT Operation element) | (CFTVHT AND CFAP):O (CFTVHT AND CFMBSS):O (CFTVHT AND CFIBSS):O | Yes ☐ No ☐ N/A ☐ |
| TVHTM3 | Link adaptation | | | |

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### B.4.26.1 TVHT MAC features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| TVHTM3.1 | Use of the VHT variant HT Control field for link adaptation in immediate response exchange | 9.2.4.6 (HT Control field), 9.3.3.14 (Action No Ack frame format), 10.29.3 (Rules for RD initiator) | CFTVHT:O | Yes ☐ No ☐ N/A ☐ |
| TVHTM4 | Transmit beamforming | | | |
| *TVHTM4.1 | SU Beamformer Capable | 9.4.2.156 (VHT Capabilities element) | CFTVHT:O | Yes ☐ No ☐ N/A ☐ |
| *TVHTM4.2 | SU Beamformee Capable | 9.4.2.156 (VHT Capabilities element) | CFTVHT:O | Yes ☐ No ☐ N/A ☐ |
| *TVHTM4.3 | MU Beamformer Capable | 9.4.2.156 (VHT Capabilities element) | CFAP AND TVHTM4.1:O | Yes ☐ No ☐ N/A ☐ |
| *TVHTM4.4 | MU Beamformee Capable | 9.4.2.156 (VHT Capabilities element) | CFIndepSTA AND TVHTM4.2:O | Yes ☐ No ☐ N/A ☐ |
| TVHTM4.5 | Transmission of null data PPDU | 10.31 (Link adaptation) | TVHTM4.1:M | Yes ☐ No ☐ N/A ☐ |
| TVHTM4.6 | Reception of null data PPDU | 10.31 (Link adaptation) | TVHTM4.2:M | Yes ☐ No ☐ N/A ☐ |
| TVHTM5 | VHT sounding protocol | | | |
| TVHTM5.1 | VHT sounding protocol as SU beamformer | 10.35.5 (VHT sounding protocol) | TVHTM4.1:M | Yes ☐ No ☐ N/A ☐ |
| TVHTM5.2 | VHT sounding protocol as SU beamformee | 10.35.5 (VHT sounding protocol) | TVHTM4.2:M | Yes ☐ No ☐ N/A ☐ |
| TVHTM5.3 | VHT sounding protocol as MU beamformer | 10.35.5 (VHT sounding protocol) | TVHTM4.3:M | Yes ☐ No ☐ N/A ☐ |
| TVHTM5.4 | VHT sounding protocol as MU beamformee | 10.35.5 (VHT sounding protocol) | TVHTM4.4:M | Yes ☐ No ☐ N/A ☐ |
| TVHTM6 | TXOP Sharing | | | |


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### B.4.26.1 TVHT MAC features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| TVHTM6.1 | Sharing of EDCA TXOP | 10.23.2.5 (EDCA channel access in a VHT or TVHT BSS)(#6585) | CFTVHT:O | Yes ☐ No ☐ N/A ☐ |
| TVHTM6.2 | Use of Primary and Secondary AC | 10.23.2.5 (EDCA channel access in a VHT or TVHT BSS)(#6585) | TVHTM6.1:M | Yes ☐ No ☐ N/A ☐ |
| TVHTM7 | VHT TXOP power saving | 11.2.3.16(VHT TXOP power save)(#6585) | CFTVHT:O | Yes ☐ No ☐ N/A ☐ |
| TVHTM8 | BSS Operation | | | |
| TVHTM8.1 | Use of primary TVHT_W, secondary TVHT_W, and secondary TVHT_2W channels | 11.41 (Basic TVHT BSS functionality) | CFTVHT:O | Yes ☐ No ☐ N/A ☐ |
| TVHTM8.2 | CCA on primary TVHT_W, secondary TVHT_W, and secondary TVHT_2W channels | 11.41 (Basic TVHT BSS functionality) | CFTVHT:O | Yes ☐ No ☐ N/A ☐ |
| TVHTM9 | Group ID | | | |
| TVHTM9.1 | Transmission of Group ID Management frame | 9.6.22.3 (Group ID Management frame format) | TVHTM4.3:M | Yes ☐ No ☐ N/A ☐ |
| TVHTM9.2 | Reception of Group ID Management frame | 9.6.22.3 (Group ID Management frame format) | TVHTM4.4:M | Yes ☐ No ☐ N/A ☐ |
| TVHTM10 | Bandwidth signaling | | | |
| TVHTM10.1 | Support for non-HT bandwidth signaling and static operation | 10.3.2.9 (CTS and DMG CTS procedure)(#6585) | CFTVHT:M | Yes ☐ No ☐ N/A ☐ |
| TVHTM10.2 | Support for non-HT bandwidth signaling and dynamic operation | 10.3.2.9 (CTS and DMG CTS procedure)(#6585) | CFTVHT:O | Yes ☐ No ☐ N/A ☐ |
| TVHTM11 | S-MPDU | 10.12.8 (Transport of S-MPDUs) | CFTVHT:M | Yes ☐ No ☐ N/A ☐ |
| TVHTM12 | Partial AID in VHT PPDU | 10.19 (Group ID and partial AID in VHT and CMMG PPDUs) | CFTVHT:M | Yes ☐ No ☐ N/A ☐ |

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### B.4.26.1 TVHT MAC features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| TVHTM13 | Extended BSS Load element | 9.4.2.158 (Extended BSS Load element) | CFTVHT:O | Yes ☐ No ☐ N/A ☐ |
| TVHTM13.1 | Transmission of the Extended BSS Load element | 9.4.2.158 (Extended BSS Load element) | CFAP AND CFTVHT:O | Yes ☐ No ☐ N/A ☐ |
| TVHTM14 | Quiet Channel element | | | |
| TVHTM14.1 | Transmission of Quiet Channel element by an AP or mesh STA in Beacon and Probe Response frames | 9.3.3.2 (Beacon frame format), 9.3.3.10 (Probe Response frame format), 9.4.2.163 (Quiet Channel element), 11.8.3 (Quieting channels for testing) | (CFAP OR CFMBSS) AND CFSM AND CFTVHT AND TVHTP3.4:O | Yes ☐ No ☐ N/A ☐ |
| TVHTM14.2 | Transmission of Quiet Channel element by an independent STA or mesh STA in Beacon and Probe Response frames | 9.3.3.2 (Beacon frame format), 9.3.3.10 (Probe Response frame format), 9.4.2.163 (Quiet Channel element), 11.8.3 (Quieting channels for testing) | (CFIndepSTA OR CFMBSS) AND CFSM AND CFTVHT AND TVHTP3.4:O | Yes ☐ No ☐ N/A ☐ |
| TVHTM14.3 | Reception of Quiet Channel element by an independent STA or mesh STA in Beacon and Probe Response frames | 9.3.3.2 (Beacon frame format), 9.3.3.10 (Probe Response frame format), 9.4.2.163 (Quiet Channel element), 11.8.3 (Quieting channels for testing) | (CFIndepSTA OR CFMBSS) AND CFSM AND CFTVHT:O | Yes ☐ No ☐ N/A ☐ |
| TVHTM15 | Space-time block coding (STBC) | | | |
| TVHTM15.1 | STBC operation | 9.4.2.156 (VHT Capabilities element), 10.14 (DMG A-PPDU and EDMG A-PPDU(11ay) operation) | TVHTP9:M | Yes ☐ No ☐ N/A ☐ |


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### B.4.26.1 TVHT MAC features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| TVHTM15.2 | Transmission of at least 2×1 STBC | 9.4.2.156 (VHT Capabilities element) | TVHTP9:O.1 | Yes ☐ No ☐ N/A ☐ |
| TVHTM15.3 | Reception of 1 STBC spatial stream | 9.4.2.156 (VHT Capabilities element) | TVHTP9:O.1 | Yes ☐ No ☐ N/A ☐ |
| TVHTM15.4 | Reception of 2 STBC spatial stream | 9.4.2.156 (VHT Capabilities element) | TVHTM15.3:O | Yes ☐ No ☐ N/A ☐ |
| TVHTM15.5 | Reception of 3 STBC spatial stream | 9.4.2.156 (VHT Capabilities element) | TVHTM15.4:O | Yes ☐ No ☐ N/A ☐ |
| TVHTM15.6 | Reception of 4 STBC spatial stream | 9.4.2.156 (VHT Capabilities element) | TVHTM15.5:O | Yes ☐ No ☐ N/A ☐ |
| TVHTM16 | Highest Supported Long GI Data Rate | | | |
| TVHTM16.1 | Tx Highest Supported Long GI Data Rate | 9.4.2.156.3 (Supported VHT-MCS and NSS Set field) | CFTVHT:O | Yes ☐ No ☐ N/A ☐ |
| TVHTM16.2 | Rx Highest Supported Long GI Data Rate | 9.4.2.156.3 (Supported VHT-MCS and NSS Set field) | CFTVHT:O | Yes ☐ No ☐ N/A ☐ |
| NOTE—Required support for MCS might be limited by the declaration of Tx and Rx Highest Supported Long GI Data Rates. | | | | |

### B.4.26.2 TVHT PHY features

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| | Are the following PHY protocol features supported? | | | |
| TVHTP1 | PHY operating modes | | | Yes ☐ No ☐ N/A ☐ |
| TVHTP2 | VHT format | 21.3.2 (VHT PPDU format) | CFTVHT:M | Yes ☐ No ☐ N/A ☐ |
| TVHTP3 | BSS bandwidth | | | |

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### B.4.26.2 TVHT PHY features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| TVHTP3.1 | TVHT_W operation | 11.41 (Basic TVHT BSS functionality) | CFTVHT:M | Yes ☐ No ☐ N/A ☐ |
| TVHTP3.2 | TVHT_2W operation | 11.41 (Basic TVHT BSS functionality) | CFTVHT:O | Yes ☐ No ☐ N/A ☐ |
| TVHTP3.3 | TVHT_W+W operation | 11.41 (Basic TVHT BSS functionality) | CFTVHT:O | Yes ☐ No ☐ N/A ☐ |
| TVHTP3.4 | TVHT_4W operation | 11.41 (Basic TVHT BSS functionality) | CFTVHT:O | Yes ☐ No ☐ N/A ☐ |
| TVHTP3.5 | TVHT_2W+2W operation | 11.41 (Basic TVHT BSS functionality) | CFTVHT:O | Yes ☐ No ☐ N/A ☐ |
| TVHTP4 | Bandwidth indication | 17.3.5.5 (PHY DATA scrambler and descrambler) | CFVHT:M | Yes ☐ No ☐ N/A ☐ |
| TVHTP5 | PHY timing parameters | | | |
| TVHTP5.1 | Values in 6 MHz channel | 22.3.6 (Timing-related parameters) | CFTVHT:M | Yes ☐ No ☐ N/A ☐ |
| TVHTP5.2 | Values in 7 MHz channel | 22.3.6 (Timing-related parameters) | CFTVHT:M | Yes ☐ No ☐ N/A ☐ |
| TVHTP5.3 | Values in 8 MHz channel | 22.3.6 (Timing-related parameters) | CFTVHT:M | Yes ☐ No ☐ N/A ☐ |
| TVHTP5.4 | Values in non-HT 6 MHz, 7 MHz, and 8 MHz channels | 22.2.4 (Support for NON_HT and HT formats) | CFTVHT:M | Yes ☐ No ☐ N/A ☐ |


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### B.4.26.2 TVHT PHY features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| TVHTP6 | TVHT preamble | 22.3.8 (TVHT preamble) | CFTVHT:M | Yes ☐ No ☐ N/A ☐ |
| TVHTP7 | Use of LDPC Code | 11.5.4 (Error recovery upon a peer failure), 21.3 (VHT PHY) | CFTVHT:O | Yes ☐ No ☐ N/A ☐ |
| TVHTP8 | Modulation and coding schemes (MCS) | | | |
| TVHTP8.1 | TVHT_MODE_1 | 22.5 (Parameters for TVHT-MCSs) | | |
| TVHTP8.1.1 | TVHT-MCS with Index 0-7 and $N_{SS} = 1$ | 22.5 (Parameters for TVHT-MCSs) | CFTVHT:M | Yes ☐ No ☐ N/A ☐ |
| TVHTP8.1.2 | TVHT-MCS with Index 0-8 and $N_{SS} = 1$ | 22.5 (Parameters for TVHT-MCSs) | TVHTP8.1.1:O | Yes ☐ No ☐ N/A ☐ |
| TVHTP8.1.3 | TVHT-MCS with Index 0-9 and $N_{SS} = 1$ | 22.5 (Parameters for TVHT-MCSs) | TVHTP8.1.2:O | Yes ☐ No ☐ N/A ☐ |
| TVHTP8.1.4 | TVHT-MCS with Index 0-7 and $N_{SS} = 2$ | 22.5 (Parameters for TVHT-MCSs) | CFTVHT:O | Yes ☐ No ☐ N/A ☐ |
| TVHTP8.1.5 | TVHT-MCS with Index 0-8 and $N_{SS} = 2$ | 22.5 (Parameters for TVHT-MCSs) | TVHTP8.1.4:O | Yes ☐ No ☐ N/A ☐ |
| TVHTP8.1.6 | TVHT-MCS with Index 0-9 and $N_{SS} = 2$ | 22.5 (Parameters for TVHT-MCSs) | TVHTP8.1.5:O | Yes ☐ No ☐ N/A ☐ |
| TVHTP8.1.7 | TVHT-MCS with Index 0-7 and $N_{SS} = 3$ | 22.5 (Parameters for TVHT-MCSs) | CFTVHT:O | Yes ☐ No ☐ N/A ☐ |
| TVHTP8.1.8 | TVHT-MCS with Index 0-8 and $N_{SS} = 3$ | 22.5 (Parameters for TVHT-MCSs) | TVHTP8.1.7:O | Yes ☐ No ☐ N/A ☐ |

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### B.4.26.2 TVHT PHY features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| TVHTP8.1.9 | TVHT-MCS with Index 0-9 and $N_{SS} = 3$ | 22.5 (Parameters for TVHT-MCSs) | TVHTP8.1.7:O | Yes ☐ No ☐ N/A ☐ |
| TVHTP8.1.10 | TVHT-MCS with Index 0-7 and $N_{SS} = 4$ | 22.5 (Parameters for TVHT-MCSs) | CFTVHT:O | Yes ☐ No ☐ N/A ☐ |
| TVHTP8.1.11 | TVHT-MCS with Index 0-8 and $N_{SS} = 4$ | 22.5 (Parameters for TVHT-MCSs) | TVHTP8.1.10: O | Yes ☐ No ☐ N/A ☐ |
| TVHTP8.1.12 | TVHT-MCS with Index 0-9 and $N_{SS} = 4$ | 22.5 (Parameters for TVHT-MCSs) | TVHTP8.1.11: O | Yes ☐ No ☐ N/A ☐ |
| TVHTP8.2 | TVHT_MODE_2C and TVHT_MODE_2N | 22.5 (Parameters for TVHT-MCSs) | | |
| TVHTP8.2.1 | TVHT-MCS with Index 0-7 and $N_{SS} = 1$ | 22.5 (Parameters for TVHT-MCSs) | (TVHTP3.2 AND TVHTP3.3):M | Yes ☐ No ☐ N/A ☐ |
| TVHTP8.2.2 | TVHT-MCS with Index 0-8 and $N_{SS} = 1$ | 22.5 (Parameters for TVHT-MCSs) | TVHTP8.2.1:O | Yes ☐ No ☐ N/A ☐ |
| TVHTP8.2.3 | TVHT-MCS with Index 0-9 and $N_{SS} = 1$ | 22.5 (Parameters for TVHT-MCSs) | TVHTP8.2.2:O | Yes ☐ No ☐ N/A ☐ |
| TVHTP8.2.4 | TVHT-MCS with Index 0-7 and $N_{SS} = 2$ | 22.5 (Parameters for TVHT-MCSs) | (TVHTP3.2 AND TVHTP3.3):O | Yes ☐ No ☐ N/A ☐ |
| TVHTP8.2.5 | TVHT-MCS with Index 0-8 and $N_{SS} = 2$ | 22.5 (Parameters for TVHT-MCSs) | TVHTP8.2.4:O | Yes ☐ No ☐ N/A ☐ |
| TVHTP8.2.6 | TVHT-MCS with Index 0-9 and $N_{SS} = 2$ | 22.5 (Parameters for TVHT-MCSs) | TVHTP8.2.5:O | Yes ☐ No ☐ N/A ☐ |
| TVHTP8.2.7 | TVHT-MCS with Index 0-7 and $N_{SS} = 3$ | 22.5 (Parameters for TVHT-MCSs) | (TVHTP3.2 AND TVHTP3.3):O | Yes ☐ No ☐ N/A ☐ |


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### B.4.26.2 TVHT PHY features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| TVHTP8.2.8 | TVHT-MCS with Index 0-8 and $N_{SS} = 3$ | 22.5 (Parameters for TVHT-MCSs) | TVHTP8.2.7:O | Yes ☐ No ☐ N/A ☐ |
| TVHTP8.2.9 | TVHT-MCS with Index 0-9 and $N_{SS} = 3$ | 22.5 (Parameters for TVHT-MCSs) | TVHTP8.2.8:O | Yes ☐ No ☐ N/A ☐ |
| TVHTP8.2.10 | TVHT-MCS with Index 0-7 and $N_{SS} = 4$ | 22.5 (Parameters for TVHT-MCSs) | (TVHTP3.2 AND TVHTP3.3):O | Yes ☐ No ☐ N/A ☐ |
| TVHTP8.2.11 | TVHT-MCS with Index 0-8 and $N_{SS} = 4$ | 22.5 (Parameters for TVHT-MCSs) | TVHTP8.2.10: O | Yes ☐ No ☐ N/A ☐ |
| TVHTP8.2.12 | TVHT-MCS with Index 0-9 and $N_{SS} = 4$ | 22.5 (Parameters for TVHT-MCSs) | TVHTP8.2.11: O | Yes ☐ No ☐ N/A ☐ |
| TVHTP8.3 | TVHT_MODE_4C and TVHT_MODE_4N | 22.5 (Parameters for TVHT-MCSs) | | |
| TVHTP8.3.1 | TVHT-MCS with Index 0-7 and $N_{SS} = 1$ | 22.5 (Parameters for TVHT-MCSs) | (TVHTP3.4 AND TVHTP3.5):M | Yes ☐ No ☐ N/A ☐ |
| TVHTP8.3.2 | TVHT-MCS with Index 0-8 and $N_{SS} = 1$ | 22.5 (Parameters for TVHT-MCSs) | TVHTP8.3.1:O | Yes ☐ No ☐ N/A ☐ |
| TVHTP8.3.3 | TVHT-MCS with Index 0-9 and $N_{SS} = 1$ | 22.5 (Parameters for TVHT-MCSs) | TVHTP8.3.2:O | Yes ☐ No ☐ N/A ☐ |
| TVHTP8.3.4 | TVHT-MCS with Index 0-7 and $N_{SS} = 2$ | 22.5 (Parameters for TVHT-MCSs) | (TVHTP3.4 AND TVHTP3.5):O | Yes ☐ No ☐ N/A ☐ |
| TVHTP8.3.5 | TVHT-MCS with Index 0-8 and $N_{SS} = 2$ | 22.5 (Parameters for TVHT-MCSs) | TVHTP8.3.4:O | Yes ☐ No ☐ N/A ☐ |
| TVHTP8.3.6 | TVHT-MCS with Index 0-9 and $N_{SS} = 2$ | 22.5 (Parameters for TVHT-MCSs) | TVHTP8.3.5:O | Yes ☐ No ☐ N/A ☐ |

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### B.4.26.2 TVHT PHY features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| TVHTP8.3.7 | TVHT-MCS with Index 0-7 and $N_{SS} = 3$ | 22.5 (Parameters for TVHT-MCSs) | (TVHTP3.4 AND TVHTP3.5):O | Yes ☐ No ☐ N/A ☐ |
| TVHTP8.3.8 | TVHT-MCS with Index 0-8 and $N_{SS} = 3$ | 22.5 (Parameters for TVHT-MCSs) | TVHTP8.3.7:O | Yes ☐ No ☐ N/A ☐ |
| TVHTP8.3.9 | TVHT-MCS with Index 0-9 and $N_{SS} = 3$ | 22.5 (Parameters for TVHT-MCSs) | TVHTP8.3.8:O | Yes ☐ No ☐ N/A ☐ |
| TVHTP8.3.10 | TVHT-MCS with Index 0-7 and $N_{SS} = 4$ | 22.5 (Parameters for TVHT-MCSs) | (TVHTP3.4 AND TVHTP3.5):O | Yes ☐ No ☐ N/A ☐ |
| TVHTP8.3.11 | TVHT-MCS with Index 0-8 and $N_{SS} = 4$ | 22.5 (Parameters for TVHT-MCSs) | TVHTP8.3.10: O | Yes ☐ No ☐ N/A ☐ |
| TVHTP8.3.12 | TVHT-MCS with Index 0-9 and $N_{SS} = 4$ | 22.5 (Parameters for TVHT-MCSs) | TVHTP8.3.11: O | Yes ☐ No ☐ N/A ☐ |
| TVHTP9 | Space-time block coding (STBC) | 22.3.10.9.4 (Space-time block coding) | CFTVHT:O | Yes ☐ No ☐ N/A ☐ |

## B.4.27 FILS features

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| FILS1.1 | FILS Discovery frame | 11.45.2 (FILS Discovery frame generation and usage) | (CFAP OR CFSTAofAP) AND CFFILS: M | Yes ☐ No ☐ N/A ☐ |
| FILS1.2 | FILS Discovery frame | 9.6.7.36 (FILS Discovery frame format) | (CFAP OR CFSTAofAP) AND CFFILS: M | Yes ☐ No ☐ N/A ☐ |
| FILS2.1 | DILS | 11.45.5 (DILS), 9.4.2.185 (DILS element) | CFFILS: O | Yes ☐ No ☐ N/A ☐ |
| * FILS3 | ANQP procedure for FILS | 9.4.5.24 (Query AP List ANQP-element) | (CFAP OR CFSTAofAP) AND CFIW AND CFFILS: M | Yes ☐ No ☐ N/A ☐ |
| FILS3.1 | Query AP List | 9.4.5.25 (AP List Response ANQP-element) | FILS3: M | Yes ☐ No ☐ N/A ☐ |


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## B.4.27 FILS features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| FILS3.2 (M118) | *Reserved* | | | |
| FILS3.3 | Common ANQP Group | 9.4.5.26 (CAG ANQP-element), 9.4.2.175 (CAG Number element) | FILS3: M | Yes ☐ No ☐ N/A ☐ |
| * FILS4 | FILS authentication | 12.11 (Authentication for FILS), 9.4 (Management and Extension frame body components), 9.4.2.177 (FILS Key Confirmation element), 9.4.2.178 (FILS Session element), 9.4.2.181 (FILS Indication element), 9.4.2.188 (FILS Nonce element) | (CFAP OR CFSTAofAP) AND CFFILS: M | Yes ☐ No ☐ N/A ☐ |
| FILS4.1 | FILS Shared Key authentication without PFS | 9.4.2.186 ((11az)Wrapped Data element), 12.11.2.3 (Key establishment with FILS Shared Key authentication) | FILS4: O.1 | Yes ☐ No ☐ N/A ☐ |
| FILS4.2 | FILS Shared Key authentication with PFS | 9.4.2.186 ((11az)Wrapped Data element), 12.11.2.3 (Key establishment with FILS Shared Key authentication) | FILS4: O | Yes ☐ No ☐ N/A ☐ |
| FILS4.3 | FILS Public Key authentication | 9.4.2.179 (FILS Public Key element), 9.4.2.187 (Fragment element), 12.11.2.4 (Key establishment with FILS Public Key authentication) | FILS4: O.1 | Yes ☐ No ☐ N/A ☐ |
| * FILS5 | Higher Layer Setup during (re)association procedure | 11.45.3 (Higher layer setup during (re)association procedure) | (CFAP OR CFSTAofAP) AND CFFILS: M | Yes ☐ No ☐ N/A ☐ |
| FILS5.1 | HLP Packet Encapsulation | 11.45.3.2 (Higher layer protocol encapsulation), 9.4.2.182 (FILS HLP Container element) | FILS5: M | Yes ☐ No ☐ N/A ☐ |
| FILS5.2 | FILS IP Address Configuration | 11.45.3.3 (FILS IP address configuration), 9.4.2.183 (FILS IP Address Assignment element) | FILS5: O | Yes ☐ No ☐ N/A ☐ |

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## B.4.27 FILS features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| * FILS6 | Scanning Enhancement | 11.1.4 (Acquiring synchronization, scanning) | (CFAP OR CFSTAofAP) AND CFFILS: M | Yes ☐ No ☐ N/A ☐ |
| FILS6.1 | Probe Request Reduction | 11.1.4.3.2 (Active scanning procedure for a non-DMG STA) | FILS6: M | Yes ☐ No ☐ N/A ☐ |
| FILS6.2 | Probe Response Reduction | 11.1.4.3.4 (Criteria for sending a response), 9.4.2.176 (FILS Request Parameters element(#2193)) | FILS6: M | Yes ☐ No ☐ N/A ☐ |
| FILS6.3 | OmitReplicateProbeResponses | 11.1.4.3.9 (Contents of a probe response) | FILS6: M | Yes ☐ No ☐ N/A ☐ |
| FILS6.4 | AP Configuration Sequence Number | 9.4.2.180 (AP Configuration Sequence Number (AP-CSN) element) | FILS6: O | Yes ☐ No ☐ N/A ☐ |
| FILS6.5 | Reduced Neighbor Report | 11.49 (Reduced neighbor report), 9.4.2.169 (Reduced Neighbor Report element) | FILS6: M | Yes ☐ No ☐ N/A ☐ |

## B.4.28 Sub 1 GHz (S1G) features

### B.4.28.1 S1G MAC features

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| | Are the following MAC protocol features supported? | | | |
| S1GM1 | S1G capabilities signaling | | CFS1G:M | Yes ☐ No ☐ N/A ☐ |
| S1GM1.1 | S1G Capabilities element | 9.4.2.199 (S1G Capabilities element) | CFS1G:M | Yes ☐ No ☐ N/A ☐ |
| S1GM1.2 | Signaling of S1G capabilities in Probe Request, (Re)Association Request frames | 9.4.2.199 (S1G Capabilities element), 9.3.3.5 (Association Request frame format), 9.3.3.7 (Reassociation Request frame format), 9.3.3.9 (Probe Request frame format) | (CFIndepSTA AND CFS1G):M | Yes ☐ No ☐ N/A ☐ |


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### B.4.28.1 S1G MAC features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| S1GM1.3 | Signaling of S1G capabilities in S1G Beacon, Probe Response, (Re)Association Response frames | 9.4.2.199 (S1G Capabilities element), 9.3.4.3 (S1G Beacon frame format), 9.3.3.6 (Association Response frame format), 9.3.3.8 (Reassociation Response frame format), 9.3.3.10 (Probe Response frame format) | (CFAP AND CFS1G):M | Yes ☐ No ☐ N/A ☐ |
| S1GM2 | S1G operation | | CFS1G:M | Yes ☐ No ☐ N/A ☐ |
| S1GM2.1 | S1G Operation element | 9.4.2.211 (S1G Operation element) | CFS1G:M | Yes ☐ No ☐ N/A ☐ |
| S1GM2.2 | Signaling of S1G operation in S1G Beacon, Probe Response | 9.4.2.211 (S1G Operation element), 9.3.4.3 (S1G Beacon frame format), 9.3.3.10 (Probe Response frame format) | ((CFAP OR CFIndepSTA.2) AND CFS1G):M | Yes ☐ No ☐ N/A ☐ |
| S1GM3 | MSDU aggregation | 10.11 (A-MSDU operation), 9.2.4.5 (QoS Control field), 9.8.3.2 (Address fields), 9.3.2.2.5 (Dynamic A-MSDU format) | CFS1G:O | Yes ☐ No ☐ N/A ☐ |
| S1GM3.1 | Transmission of Dynamic A-MSDU | | CFS1G:O (CFS1G AND HTM4.4):M | Yes ☐ No ☐ N/A ☐ |
| S1GM3.2 | Reception of Dynamic A-MSDU | | CFS1G:O (CFS1G AND HTM4.1):M | Yes ☐ No ☐ N/A ☐ |
| S1GM3.3 | Transmission of Dynamic A-MSDU in PV1 frame | | (CFS1G AND HTM4.4 AND FT45):M | Yes ☐ No ☐ N/A ☐ |
| S1GM3.4 | Reception of Dynamic A-MSDU in PV1 frame | | (CFS1G AND HTM4.1 AND FT46):M | Yes ☐ No ☐ N/A ☐ |
| S1GM3.5 | Reception of Dynamic A-MSDU | | (CFS1G AND (HTM4.1 OR HTM4.4 OR S1GM3.3 OR S1GM3.4)):M | Yes ☐ No ☐ N/A ☐ |
| S1GM4 | Timing synchronization function (TSF) | | CFS1G:M | Yes ☐ No ☐ N/A ☐ |

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### B.4.28.1 S1G MAC features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| S1GM4.1 | Generation of S1G Beacon | 11.1.3.10.2 (Generation of S1G Beacon frames) | (CFAP AND CFS1G): M | Yes ☐ No ☐ N/A ☐ |
| S1GM4.1.1 | S1G Beacon generation at TBTT | | (CFAP AND CFS1G): M | |
| S1GM4.1.2 | S1G Beacon generation at TSBTT | | (CFAP AND CFS1G): O | Yes ☐ No ☐ N/A ☐ |
| S1GM4.1.3 | S1G Beacon reception at TBTT | | (CFIndepSTA AND CFS1G): M | Yes ☐ No ☐ N/A ☐ |
| S1GM4.1.4 | S1G Beacon reception at TSBTT | | (CFIndepSTA AND CFS1G): M | Yes ☐ No ☐ N/A ☐ |
| S1GM4.2 | TSF timer accuracy with S1G Beacon | 11.1.3.10.3 (TSF timer accuracy with S1G Beacon frame) | CFS1G: M | Yes ☐ No ☐ N/A ☐ |
| S1GM4.3 | TSF timer accuracy with TACK, STACK, BAT, PV1 Probe Response frames | | CFS1G: O | Yes ☐ No ☐ N/A ☐ |
| S1GM4.4 | Signaling PV1 Probe Response Option element in Probe Request frame | | CFS1G: O | Yes ☐ No ☐ N/A ☐ |
| S1GM4.5 | Active scanning using NDP Probe Request frame | 11.1.4.3.6 (NDP Probing) | CFS1G: O | Yes ☐ No ☐ N/A ☐ |
| S1GM4.6 | Sending PV1 Probe Response frame | 11.1.4.3.7 (Active scanning using PV1 Probe Response), 11.1.4.3.6 (NDP Probing) | (CFAP AND CFS1G): O | Yes ☐ No ☐ N/A ☐ |
| S1GM5 | Reverse direction protocol | 10.29 (Reverse direction protocol) | CFS1G:O | Yes ☐ No ☐ N/A ☐ |
| S1GM5.1 | Initiation of RD protocol | | CFS1G:O | Yes ☐ No ☐ N/A ☐ |
| S1GM5.2 | Response to RD request | | CFS1G:O | Yes ☐ No ☐ N/A ☐ |
| *S1GM6 | Target wake time (TWT) operation | 10.46 (Target wake time (TWT)) | CFS1G:O | Yes ☐ No ☐ N/A ☐ |
| *S1GM6.1 | Assume the role of TWT requesting STA | 10.46.1 (TWT overview) | S1GM6:O.1 | Yes ☐ No ☐ N/A ☐ |
| *S1GM6.2 | Assume the role of TWT responding STA | 10.46.1 (TWT overview) | S1GM6:O.1 | Yes ☐ No ☐ N/A ☐ |
| S1GM6.3 | Request TWT Setup | 10.46.1 (TWT overview) | S1GM6.1:O | Yes ☐ No ☐ N/A ☐ |
| S1GM6.4 | Response to TWT Setup request | 10.46.1 (TWT overview) | S1GM6.2:M | Yes ☐ No ☐ N/A ☐ |


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### B.4.28.1 S1G MAC features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| S1GM6.5 | TWT Teardown | 10.46.8 (TWT teardown) | S1GM6:O | Yes ☐ No ☐ N/A ☐ |
| S1GM6.6 | TWT acknowledgment procedure | 10.46.2 (TWT acknowledg-ment proce-dure) | S1GM6:M | Yes ☐ No ☐ N/A ☐ |
| S1GM6.7 | Explicit TWT operation | 10.46.3 (Explicit TWT operation) | S1GM6:O.2 | Yes ☐ No ☐ N/A ☐ |
| S1GM6.8 | Implicit TWT operation | 10.46.4 (Implicit TWT operation) | S1GM6:O.2 | Yes ☐ No ☐ N/A ☐ |
| S1GM6.9 | Request NDP paging setup(#8182) | 10.46.6 (NDP paging setup) | S1GM6.1:O | Yes ☐ No ☐ N/A ☐ |
| S1GM6.10 | Accept the NDP paging setup request(#8182) | 10.46.6 (NDP paging setup) | S1GM6.2:O | Yes ☐ No ☐ N/A ☐ |
| S1GM6.11 | Schedule NDP Paging frame as the first frame in a TWT | | S1GM10:M | Yes ☐ No ☐ N/A ☐ |
| S1GM6.12 | TWT grouping | 10.46.5 (TWT grouping) | S1GM6:O | Yes ☐ No ☐ N/A ☐ |
| S1GM6.13 | Protected TWT Operations | 10.46.1 (TWT overview) | (PC 34.1.10 AND S1GM6):O | Yes ☐ No ☐ N/A ☐ |
| S1GM7 | Non-TIM operation | 10.47 (Non-TIM opera-tion) | (CFIndepSTA AND CFS1G):O (CFAP AND CFS1G AND (S1GM20.1 OR S1GM20.3)): M | Yes ☐ No ☐ N/A ☐ |
| S1GM7.1 | Request non-TIM Mode | 11.2.3.2 (Non-AP STA power man-agement modes) | (CFIndepSTA AND S1GM7):O | Yes ☐ No ☐ N/A ☐ |
| S1GM7.2 | Response to non-TIM Mode request | 11.2.3.2 (Non-AP STA power man-agement modes) | (CFAP AND S1GM7):M | Yes ☐ No ☐ N/A ☐ |
| S1GM7.3 | Request rescheduling of awake/ doze cycle | 10.47.2 (Reschedul-ing of awake/ doze cycle) | (CFIndepSTA AND S1GM7):O | Yes ☐ No ☐ N/A ☐ |
| S1GM7.4 | Reschedule awake/doze cycle of S1G STAs in non-TIM mode | 10.47.2 (Reschedul-ing of awake/ doze cycle) | (CFAP AND S1GM7):O | Yes ☐ No ☐ N/A ☐ |

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### B.4.28.1 S1G MAC features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| S1GM7.5 | Temporary PS Mode Switch to TIM mode | 10.47.2 (Rescheduling of awake/doze cycle) | (CFIndepSTA AND S1GM7):O | Yes ☐ No ☐ N/A ☐ |
| S1GM7.6 | Listen interval update procedure for S1G STAs in non-TIM mode | | S1GM7:O | Yes ☐ No ☐ N/A ☐ |
| S1GM7.7 | Resource protection for S1G STAs in non-TIM mode | 10.47.1 (Resource protection for S1G STAs in non-TIM mode) | (CFAP AND S1GM7):O | Yes ☐ No ☐ N/A ☐ |
| S1GM7.8 | Resource protection for S1G STAs in non-TIM mode using periodic RAW (PRAW) operation | 10.47.1.2 (Resource protection for S1G STAs in non-TIM mode using periodic RAW (PRAW) operation) | (CFAP AND S1GM7):O | Yes ☐ No ☐ N/A ☐ |
| S1GM8 | Sync frame operation | 10.48 (Sync frame operation) | CFS1G:O | Yes ☐ No ☐ N/A ☐ |
| S1GM8.1 | Request for a sync frame transmission | 10.48 (Sync frame operation) | (CFIndepSTA AND S1GM8):O | Yes ☐ No ☐ N/A ☐ |
| S1GM8.2 | Schedule a sync frame transmission | 10.48 (Sync frame operation) | (CFAP AND S1GM8):M | Yes ☐ No ☐ N/A ☐ |
| S1GM8.3 | Request for time slot protection | 10.48 (Sync frame operation) | (CFIndepSTA AND S1GM8):O | Yes ☐ No ☐ N/A ☐ |
| S1GM8.4 | Protect the time slot assigned to the STA that requested for time slot protection. | 10.48 (Sync frame operation) | (CFAP AND S1GM8):M | Yes ☐ No ☐ N/A ☐ |
| S1GM8.5 | Respond to sync frame | 10.48 (Sync frame operation) | (CFIndepSTA AND S1GM8):M | Yes ☐ No ☐ N/A ☐ |
| S1GM9 | Bidirectional TXOP | 10.49 (Bidirectional TXOP) | CFS1G:O | Yes ☐ No ☐ N/A ☐ |
| S1GM9.1 | Act as BDT Initiator | 10.49.2 (Rules for BDT) | S1GM9:O | Yes ☐ No ☐ N/A ☐ |
| S1GM9.2 | Act as BDT Responder | | S1GM9:M | Yes ☐ No ☐ N/A ☐ |
| S1GM10 | Subchannel Selective Transmission (SST) | 10.49 (Bidirectional TXOP) | CFS1G:O | Yes ☐ No ☐ N/A ☐ |
| S1GM11 | Sectorized beam operation | 10.52 (Sectorized beam operation) | CFS1G:O | Yes ☐ No ☐ N/A ☐ |


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### B.4.28.1 S1G MAC features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| S1GM11.1 | Support for Group Sectorization Operation | 10.52.3 (Group sectorization operation) | (CFAP AND S1GM11):O.3 (CFIndepSTA AND S1GM11):M | Yes ☐ No ☐ N/A ☐ |
| S1GM11.2 | Support for TXOP-based Sectorization Operation | 10.52.4 (TXOP-based sectorization operation) | (CFAP AND S1GM11):O.3 (CFIndepSTA AND S1GM11):M | Yes ☐ No ☐ N/A ☐ |
| S1GM11.3 | Transmission of S1G Sector Operation element with Sectorization Type field equal to 0 | 10.52.2 (Sector Capabilities Exchange) | (CFAP AND S1GM11.1):M | Yes ☐ No ☐ N/A ☐ |
| S1GM11.4 | Transmission of S1G Sector Operation element with Sectorization Type field equal to 1 | 10.52.2 (Sector Capabilities Exchange) | (CFAP AND S1GM11.2):M | Yes ☐ No ☐ N/A ☐ |
| S1GM11.5 | Sector training operation | 10.52.2 (Sector Capabilities Exchange) | S1GM11:O | Yes ☐ No ☐ N/A ☐ |
| S1GM11.6 | Send back Sector ID feedback to associated AP | 10.52.2 (Sector Capabilities Exchange) | (CFIndepSTA AND S1GM11):O | Yes ☐ No ☐ N/A ☐ |
| S1GM12 | 1 MHz Control Response Preamble Support | 10.6.6.6 (Channel Width selection for Control frames) | CFS1G: O | Yes ☐ No ☐ N/A ☐ |
| *S1GM13 | Group AID | 10.54 (Group AID) | CFS1G:O | Yes ☐ No ☐ N/A ☐ |
| S1GM14 | Traveling Pilot Operation | 10.55 (Traveling pilot operation) | CFS1G:O | Yes ☐ No ☐ N/A ☐ |
| S1GM15 | Bitmap Protection for NDP BlockAck frames | 10.56 (Bitmap protection for NDP BlockAck frames) | (CFS1G AND (FT47 OR FR 48)): M | Yes ☐ No ☐ N/A ☐ |
| S1GM16 | Header compression procedure | 10.57 (Generation of PV1 MPDUs and header compression procedure) | CFS1G:O | Yes ☐ No ☐ N/A ☐ |
| S1GM16.1 | Signaling Header Compression element in (Re)Association Request frames | 10.57 (Generation of PV1 MPDUs and header compression procedure) | (CFIndepSTA AND S1GM16):O | Yes ☐ No ☐ N/A ☐ |

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### B.4.28.1 S1G MAC features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| S1GM16.2 | Signaling Header Compression element in (Re)Association Response frames | 10.57 (Generation of PV1 MPDUs and header compression procedure) | (CFAP AND S1GM16):M | Yes ☐ No ☐ N/A ☐ |
| S1GM16.3 | Request header compression procedure | | S1GM16:O | Yes ☐ No ☐ N/A ☐ |
| S1GM16.4 | Store the optional fields indicated in the Header Compression frame request | | S1GM16:O | Yes ☐ No ☐ N/A ☐ |
| S1GM16.5 | Send back the Header Compression frame response | | CFS1G:M | Yes ☐ No ☐ N/A ☐ |
| S1GM17 | Flow control | 10.60 (S1G flow control) | CFS1G:M | Yes ☐ No ☐ N/A ☐ |
| S1GM17.1 | Request flow suspension/resumption | 10.60 (S1G flow control) | CFS1G:O | Yes ☐ No ☐ N/A ☐ |
| S1GM17.2 | Flow suspension in response to a(#375) Flow Suspension frame or NDP ACK frame | 10.60 (S1G flow control) | (CFIndepSTA AND CFS1G):M | Yes ☐ No ☐ N/A ☐ |
| S1GM17.3 | Flow suspension in response to a(#375) STACK or BAT or TACK frame | | (CFIndepSTA AND S1GM6.6):M | Yes ☐ No ☐ N/A ☐ |
| S1GM17.4 | Flow resumption upon receiving a Flow Resumption frame | | (CFIndepSTA AND CFS1G):O | Yes ☐ No ☐ N/A ☐ |
| *S1GM18 | Dynamic AID assignment operation | 10.20 (S1G dynamic AID assignment operation) | CFS1G:O | Yes ☐ No ☐ N/A ☐ |
| S1GM18.1 | Request AID switch | 10.20 (S1G dynamic AID assignment operation) | (CFIndepSTA AND S1GM18):O | Yes ☐ No ☐ N/A ☐ |
| S1GM18.2 | Respond to request for AID switch | 10.20 (S1G dynamic AID assignment operation) | (CFAP AND S1GM18):M | Yes ☐ No ☐ N/A ☐ |
| S1GM18.3 | Issue unsolicited AID switch instruction | 10.20 (S1G dynamic AID assignment operation) | (CFAP AND S1GM18):O | Yes ☐ No ☐ N/A ☐ |
| S1GM18.4 | Respond to unsolicited AID switch instruction | 10.20 (S1G dynamic AID assignment operation) | (CFIndepSTA AND S1GM18):O | Yes ☐ No ☐ N/A ☐ |


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### B.4.28.1 S1G MAC features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| S1GM19 | System information update procedure | 10.45.2 (System information update procedure) | CFS1G:M | Yes ☐ No ☐ N/A ☐ |
| S1GM19.1 | Update the Change Sequence field in S1G Beacon frame | | (CFAP AND CFS1G):M | Yes ☐ No ☐ N/A ☐ |
| S1GM19.2 | Respond to changes in the Change Sequence field in S1G Beacon frame | | (CFIndepSTA AND CFS1G):M | Yes ☐ No ☐ N/A ☐ |
| S1GM19.3 | Respond to probe request frames that contain the Change Sequence field | | (CFAP AND CFS1G):O | Yes ☐ No ☐ N/A ☐ |
| S1GM20 | STA types | 10.62 (S1G BSS type and STA type) | CFS1G:M | Yes ☐ No ☐ N/A ☐ |
| S1GM20.1 | Support for sensor STA | 10.62 (S1G BSS type and STA type) | (CFAP AND CFS1G):O.5 | Yes ☐ No ☐ N/A ☐ |
| S1GM20.2 | Support for non-sensor STA | 10.62 (S1G BSS type and STA type) | (CFAP AND CFS1G):O.5 | Yes ☐ No ☐ N/A ☐ |
| S1GM20.3 | Support for both sensor and non-sensor STA | 10.62 (S1G BSS type and STA type) | (CFAP AND CFS1G):O.5 | Yes ☐ No ☐ N/A ☐ |
| S1GM20.4 | Assume the role of sensor STA | 10.62 (S1G BSS type and STA type) | (CFIndepSTA AND CFS1G):O.6 | Yes ☐ No ☐ N/A ☐ |
| S1GM20.5 | Assume the role of non-sensor STA | 10.62 (S1G BSS type and STA type) | (CFIndepSTA AND CFS1G):O.6 | Yes ☐ No ☐ N/A ☐ |
| S1GM21 | Support for energy limited STAs | 11.46 (Support for energy limited STAs) | (CFAP AND CFS1G AND (S1GM20.1 OR S1GM20.3)):M (CFAP AND S1GM20.2):O (CFIndepSTA AND S1GM20.4):O | Yes ☐ No ☐ N/A ☐ |
| S1GM22 | S1G Channel Access | | CFS1G: M | Yes ☐ No ☐ N/A ☐ |
| S1GM22.1 | Response indication deferral (RID) function | 10.3.2.1 (CS mechanism), 10.3.2.4 (Setting and resetting the NAV), 10.3.2.5 (Setting and resetting the RID), 10.3.2.17 (Response Indication procedure) | CFS1G: M | Yes ☐ No ☐ N/A ☐ |

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### B.4.28.1 S1G MAC features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| S1GM22.2 | Dynamic bandwidth operation | 10.3.2.7 (VHT and S1G RTS procedure) | CFS1G: O | Yes ☐ No ☐ N/A ☐ |
| S1GM22.3 | Fragment BA | 10.3.2.12 (Fragment BA procedure) | CFS1G: O | Yes ☐ No ☐ N/A ☐ |
| S1GM22.4 | Support for at least one transmit queue with AC_BE access category | 10.2.3.2 (HCF contention based channel access (EDCA)), 10.23.2.1 (Reference model) | S1GM20.4: M | Yes ☐ No ☐ N/A ☐ |
| S1GM22.5 | Restricted Access Window (RAW) Operation | 10.23.5 (Restricted access window (RAW) operation) | CFS1G:O | Yes ☐ No ☐ N/A ☐ |
| S1GM22.5.1 | EDCA backoff procedure in generic RAW or triggering frame RAW | 10.23.5.5 (EDCA backoff procedure in generic RAW or triggering frame RAW) | (CFAP AND S1GM22.5):O (CFIndepSTA AND S1GM22.5):M | Yes ☐ No ☐ N/A ☐ |
| S1GM22.5.2 | Deferral for generic RAW, triggering RAW, sounding RAW and simplex RAW when RAW Type Options subfield indicates non-TIM RAW | | (CFIndepSTA AND S1GM7): O (CFIndepSTA AND CFS1G AND (NOT S1GM7)): M | |
| S1GM22.5.3 | Deferral for simplex RAW when RAW Type Options subfield does not indicate non-TIM RAW | | (CFIndepSTA AND CFS1G): O | |
| S1GM23 | Traffic indication map (TIM) | 11.2.3.3 (AP TIM transmis-sions), 11.2.3.4 (TIM types) | CFAP: M | Yes ☐ No ☐ N/A ☐ |
| S1GM23.1 | Encode partial virtual bitmap in Block Bitmap mode | 9.4.2.5 (TIM element) | (CFAP AND CFS1G): O.5 | Yes ☐ No ☐ N/A ☐ |
| S1GM23.1.1 | Encode partial virtual bitmap in Single AID mode | | (CFAP AND CFS1G): O.5 | Yes ☐ No ☐ N/A ☐ |
| S1GM23.1.2 | Encode partial virtual bitmap in OLB mode | | (CFAP AND CFS1G): O.5 | Yes ☐ No ☐ N/A ☐ |
| S1GM23.1.3 | Encode partial virtual bitmap in ADE mode | | (CFAP AND CFS1G): O | Yes ☐ No ☐ N/A ☐ |


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### B.4.28.1 S1G MAC features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| S1GM23.1.4 | Decode partial virtual bitmap encoded in Block Bitmap mode | | (CFIndepSTA AND CFS1G AND NOT S1GM7):M (CFIndepSTA AND S1GM7):O | Yes ☐ No ☐ N/A ☐ |
| S1GM23.1.5 | Decode partial virtual bitmap encoded in Single AID mode | | (CFIndepSTA AND CFS1G AND NOT S1GM7):M (CFIndepSTA AND S1GM7):O | Yes ☐ No ☐ N/A ☐ |
| S1GM23.1.6 | Decode partial virtual bitmap encoded in OLB mode | | (CFIndepSTA AND CFS1G AND NOT S1GM7):M (CFIndepSTA AND S1GM7):O | Yes ☐ No ☐ N/A ☐ |
| S1GM23.1.7 | Decode partial virtual bitmap encoded in ADE mode | | (CFIndepSTA AND CFS1G AND NOT S1GM7):O | Yes ☐ No ☐ N/A ☐ |
| S1GM23.2 | Page slicing | 10.50 (Page slicing) | (CFAP AND CFS1G): O (CFIndepSTA AND CFS1G):O | Yes ☐ No ☐ N/A ☐ |
| S1GM23.2.1 | Divide the TIM into page slices | | (CFAP AND S1GM23.2): O | Yes ☐ No ☐ N/A ☐ |
| S1GM23.2.2 | Decode the TIM divided into page slices | | (CFIndepSTA AND S1GM23.2):M | Yes ☐ No ☐ N/A ☐ |
| S1GM24 | AP power management | 11.2.3.17 (AP power management) | (CFAP AND CFS1G): O | Yes ☐ No ☐ N/A ☐ |
| S1GM25 | Association and reassociation | 11.3 (STA authentication and association) | CFS1G: M | Yes ☐ No ☐ N/A ☐ |
| S1GM25.1 | Service characteristic indication during association | 11.3.5.11 (Service characteristic indication during association) | (CFIndepSTA AND CFS1G AND PC14):O | Yes ☐ No ☐ N/A ☐ |
| S1GM25.2 | Authentication Control | 11.3.9 (Authentication control) | CFS1G: O | Yes ☐ No ☐ N/A ☐ |

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### B.4.28.1 S1G MAC features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| S1GM25.2.1 | Centralized authentication control | | (CFAP AND S1GM25.2): O.2 (CFIndepSTA AND S1GM25.2): O | Yes ☐ No ☐ N/A ☐ |
| S1GM25.2.2 | Distributed authentication control | | (CFAP AND S1GM25.2): O.2 (CFIndepSTA AND CFS1G): M | Yes ☐ No ☐ N/A ☐ |
| S1GM26 | Robust security network association (RSNA) | | O | Yes ☐ No ☐ |
| S1GM26.1 | PV1 CCMP MPDU format | 12.5.2.2 (CCMP MPDU format) | CFS1G AND (FT45 (#4138)OR FR46): M | Yes ☐ No ☐ N/A ☐ |
| S1GM26.2 | Local construction of CCMP header for PV1 MPDUs | 12.5.2.3.6 (Construct CCMP header for transmitted PV1 MPDUs(#7012)) | CFS1G AND FR46: M | Yes ☐ No ☐ N/A ☐ |
| S1GM26.3 | CCMP cryptographic encapsulation procedure for PV1 MPDUs | 12.5.2.3 (CCMP cryptographic encapsulation) | CFS1G AND FT45: M | Yes ☐ No ☐ N/A ☐ |
| S1GM26.4 | CCMP decapsulation procedure for PV1 MPDUs | 12.5.2.4 (CCMP decapsulation) | CFS1G AND FR46: M | Yes ☐ No ☐ N/A ☐ |
| S1GM27 | Asymmetric BA | 10.6.6.5.2 (Selection of a rate or MCS), 10.6.6.5.5 (MCS for asymmetric BA operation) | CFS1G: O | Yes ☐ No ☐ N/A ☐ |
| *S1GM28 | Control Response MCS Negotiation | 10.6.6.5.5 (MCS for asymmetric BA operation) | CFS1G: O | Yes ☐ No ☐ N/A ☐ |
| S1GM29 | OBSS Mitigation Support | 10.6.6.6 (Channel Width selection for Control frames) | CFS1G: O | Yes ☐ No ☐ N/A ☐ |
| *S1GM30(#1276) | Extended S1G Action Protection | 9.4.2.240 (RSNXE(#1776)) | CFS1G: O | Yes ☐ No ☐ N/A ☐ |


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### B.4.28.2 S1G PHY features

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| | Are the following PHY protocol features supported? | | | |
| S1GP1 | BSS bandwidth | | | |
| S1GP1.1 | 1 MHz operation | 10.45.1 (Basic S1G BSS functionality), 23.1.1 (Introduction to the S1G PHY) | CFS1G: M | Yes ☐ No ☐ N/A ☐ |
| S1GP1.2 | 2 MHz operation | 10.45.1 (Basic S1G BSS functionality), 23.1.1 (Introduction to the S1G PHY) | CFS1G: M | Yes ☐ No ☐ N/A ☐ |
| S1GP1.3 | 4 MHz operation | 10.45.1 (Basic S1G BSS functionality), 23.1.1 (Introduction to the S1G PHY) | CFS1G: O | Yes ☐ No ☐ N/A ☐ |
| S1GP1.4 | 8 MHz operation | 10.45.1 (Basic S1G BSS functionality), 23.1.1 (Introduction to the S1G PHY) | CFS1G: O | Yes ☐ No ☐ N/A ☐ |
| S1GP1.5 | 16 MHz operation | 10.45.1 (Basic S1G BSS functionality), 23.1.1 (Introduction to the S1G PHY) | CFS1G: O | Yes ☐ No ☐ N/A ☐ |
| S1GP2 | Coding scheme | | | |
| S1GP2.1 | Use of BCC code | 23.1.1 (Introduction to the S1G PHY), 23.3.4 (Overview of the PPDU encoding process) | CFS1G: M | Yes ☐ No ☐ N/A ☐ |
| S1GP2.2 | Use of STBC code | 23.1.1 (Introduction to the S1G PHY), 23.3.4 (Overview of the PPDU encoding process) | CFS1G: O | Yes ☐ No ☐ N/A ☐ |

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### B.4.28.2 S1G PHY features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| S1GP2.3 | Use of LDPC code | 23.1.1 (Introduction to the S1G PHY), 23.3.4 (Overview of the PPDU encoding process) | CFS1G: O | Yes ☐ No ☐ N/A ☐ |
| S1GP3 | Demodulation scheme | | | |
| S1GP3.1 | SIG-A of greater than or equal to 2 MHz long preamble format PPDU | 23.1.1 (Introduction to the S1G PHY), 23.3.4.2.3 (Construction of SIG-A) | CFS1G: M | Yes ☐ No ☐ N/A ☐ |
| S1GP4 | PHY timing parameters | | | |
| S1GP4.1 | Normal (long) guard interval | 23.1.1 (Introduction to the S1G PHY), 23.3.6 (Timing-related parameters) | CFS1G: M | Yes ☐ No ☐ N/A ☐ |
| S1GP4.2 | Short guard interval | 23.1.1 (Introduction to the S1G PHY), 23.3.6 (Timing-related parameters) | CFS1G: O | Yes ☐ No ☐ N/A ☐ |
| S1GP5 | Use of S1G beamforming | 23.1.1 (Introduction to the S1G PHY), 23.3.10 (SU-MIMO and (#3367)DL MU-MIMO Beamforming) | CFS1G: O | Yes ☐ No ☐ N/A ☐ |
| S1GP6 | PPDU format | | | |
| S1GP6.1 | 1 MHz short preamble format PPDU | 23.1.1 (Introduction to the S1G PHY), 23.3.2 (S1G PPDU format) | CFS1G: M | Yes ☐ No ☐ N/A ☐ |
| S1GP6.2 | 2 MHz short preamble format PPDU | 23.1.1 (Introduction to the S1G PHY), 23.3.2 (S1G PPDU format) | CFS1G: M | Yes ☐ No ☐ N/A ☐ |
| S1GP6.3 | Greater than 2 MHz short preamble format PPDU | 23.1.1 (Introduction to the S1G PHY), 23.3.2 (S1G PPDU format) | CFS1G: O | Yes ☐ No ☐ N/A ☐ |


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### B.4.28.2 S1G PHY features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| S1GP6.4 | Greater than or equal to 2 MHz long preamble format PPDU | 23.1.1 (Introduction to the S1G PHY), 23.3.2 (S1G PPDU format) | CFS1G AND S1GP1.1: O CFS1G AND S1GP1.2: O CFS1G AND S1GP1.3: M CFS1G AND S1GP1.4: M CFS1G AND S1GP1.5: M | Yes ☐ No ☐ N/A ☐ |
| S1GP6.5 | S1G 1 MHz duplicate PPDU | 23.3.9.12.1 (S1G 1 MHz duplicate transmission) | CFS1G: O | Yes ☐ No ☐ N/A ☐ |
| S1GP6.6 | S1G 2 MHz duplicate PPDU | 23.3.9.12.2 (S1G 2 MHz duplicate transmission) | CFS1G AND S1GP1.3: M CFS1G AND S1GP1.4: M CFS1G AND S1GP1.5: M | Yes ☐ No ☐ N/A ☐ |
| S1GP6.7 | Use of fixed pilots | 23.3.9.10 (Pilot subcarriers) | CFS1G: M | Yes ☐ No ☐ N/A ☐ |
| S1GP6.8 | Use of traveling pilots | 23.3.9.10 (Pilot subcarriers) | CFS1G: O | Yes ☐ No ☐ N/A ☐ |
| S1GP7 | | | | |
| S1GP7.1 | MCS 0, Nss = 1 | 23.1.1 (Introduction to the S1G PHY), 23.5 (Parameters for S1G-MCSs) | CFS1G: M | Yes ☐ No ☐ N/A ☐ |
| S1GP7.2 | MCS 0, Nss = 2 | 23.1.1 (Introduction to the S1G PHY), 23.5 (Parameters for S1G-MCSs) | CFS1G: O | Yes ☐ No ☐ N/A ☐ |
| S1GP7.3 | MCS 0, Nss = 3 | 23.1.1 (Introduction to the S1G PHY), 23.5 (Parameters for S1G-MCSs) | CFS1G: O | Yes ☐ No ☐ N/A ☐ |
| S1GP7.4 | MCS 0, Nss = 4 | 23.1.1 (Introduction to the S1G PHY), 23.5 (Parameters for S1G-MCSs) | CFS1G: O | Yes ☐ No ☐ N/A ☐ |

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### B.4.28.2 S1G PHY features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| S1GP7.5 | MCS 1, Nss = 1 | 23.1.1 (Introduction to the S1G PHY), 23.5 (Parameters for S1G-MCSs) | CFS1G: M | Yes ☐ No ☐ N/A ☐ |
| S1GP7.6 | MCS 1, Nss = 2 | 23.1.1 (Introduction to the S1G PHY), 23.5 (Parameters for S1G-MCSs) | CFS1G: O | Yes ☐ No ☐ N/A ☐ |
| S1GP7.7 | MCS 1, Nss = 3 | 23.1.1 (Introduction to the S1G PHY), 23.5 (Parameters for S1G-MCSs) | CFS1G: O | Yes ☐ No ☐ N/A ☐ |
| S1GP7.8 | MCS 1, Nss = 4 | 23.1.1 (Introduction to the S1G PHY), 23.5 (Parameters for S1G-MCSs) | CFS1G: O | Yes ☐ No ☐ N/A ☐ |
| S1GP7.9 | MCS 2, Nss = 1 | 23.1.1 (Introduction to the S1G PHY), 23.5 (Parameters for S1G-MCSs) | CFS1G: M | Yes ☐ No ☐ N/A ☐ |
| S1GP7.10 | MCS 2, Nss = 2 | 23.1.1 (Introduction to the S1G PHY), 23.5 (Parameters for S1G-MCSs) | CFS1G: O | Yes ☐ No ☐ N/A ☐ |
| S1GP7.11 | MCS 2, Nss = 3 | 23.1.1 (Introduction to the S1G PHY), 23.5 (Parameters for S1G-MCSs) | CFS1G: O | Yes ☐ No ☐ N/A ☐ |
| S1GP7.12 | MCS 2, Nss = 4 | 23.1.1 (Introduction to the S1G PHY), 23.5 (Parameters for S1G-MCSs) | CFS1G: O | Yes ☐ No ☐ N/A ☐ |
| S1GP7.13 | MCS 3, Nss = 1 | 23.1.1 (Introduction to the S1G PHY), 23.5 (Parameters for S1G-MCSs) | CFAP AND CFS1G: M CFIndepSTA AND CFS1G: O | Yes ☐ No ☐ N/A ☐ |


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### B.4.28.2 S1G PHY features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| S1GP7.14 | MCS 3, Nss = 2 | 23.1.1 (Introduction to the S1G PHY), 23.5 (Parameters for S1G-MCSs) | S1GP7.13: O CFIndepSTA AND CFS1G: O | Yes ☐ No ☐ N/A ☐ |
| S1GP7.15 | MCS 3, Nss = 3 | 23.1.1 (Introduction to the S1G PHY), 23.5 (Parameters for S1G-MCSs) | S1GP7.13: O CFIndepSTA AND CFS1G: O | Yes ☐ No ☐ N/A ☐ |
| S1GP7.16 | MCS 3, Nss = 4 | 23.1.1 (Introduction to the S1G PHY), 23.5 (Parameters for S1G-MCSs) | S1GP7.13: O CFIndepSTA AND CFS1G: O | Yes ☐ No ☐ N/A ☐ |
| S1GP7.17 | MCS 4, Nss = 1 | 23.1.1 (Introduction to the S1G PHY), 23.5 (Parameters for S1G-MCSs) | CFAP AND CFS1G: M CFIndepSTA AND CFS1G: O | Yes ☐ No ☐ N/A ☐ |
| S1GP7.18 | MCS 4, Nss = 2 | 23.1.1 (Introduction to the S1G PHY), 23.5 (Parameters for S1G-MCSs) | S1GP7.17: O CFIndepSTA AND CFS1G: O | Yes ☐ No ☐ N/A ☐ |
| S1GP7.19 | MCS 4, Nss = 3 | 23.1.1 (Introduction to the S1G PHY), 23.5 (Parameters for S1G-MCSs) | S1GP7.17: O CFIndepSTA AND CFS1G: O | Yes ☐ No ☐ N/A ☐ |
| S1GP7.20 | MCS 4, Nss = 4 | 23.1.1 (Introduction to the S1G PHY), 23.5 (Parameters for S1G-MCSs) | S1GP7.17: O CFIndepSTA AND CFS1G: O | Yes ☐ No ☐ N/A ☐ |
| S1GP7.21 | MCS 5, Nss = 1 | 23.1.1 (Introduction to the S1G PHY), 23.5 (Parameters for S1G-MCSs) | CFAP AND CFS1G: M CFIndepSTA AND CFS1G: O | Yes ☐ No ☐ N/A ☐ |
| S1GP7.22 | MCS 5, Nss = 2 | 23.1.1 (Introduction to the S1G PHY), 23.5 (Parameters for S1G-MCSs) | S1GP7.21: O CFIndepSTA AND CFS1G: O | Yes ☐ No ☐ N/A ☐ |

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### B.4.28.2 S1G PHY features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| S1GP7.23 | MCS 5, Nss = 3 | 23.1.1 (Introduction to the S1G PHY), 23.5 (Parameters for S1G-MCSs) | S1GP7.21: O CFIndepSTA AND CFS1G: O | Yes ☐ No ☐ N/A ☐ |
| S1GP7.24 | MCS 5, Nss = 4 | 23.1.1 (Introduction to the S1G PHY), 23.5 (Parameters for S1G-MCSs) | S1GP7.21: O CFIndepSTA AND CFS1G: O | Yes ☐ No ☐ N/A ☐ |
| S1GP7.25 | MCS 6, Nss = 1 | 23.1.1 (Introduction to the S1G PHY), 23.5 (Parameters for S1G-MCSs) | CFAP AND CFS1G: M CFIndepSTA AND CFS1G: O | Yes ☐ No ☐ N/A ☐ |
| S1GP7.26 | MCS 6, Nss = 2 | 23.1.1 (Introduction to the S1G PHY), 23.5 (Parameters for S1G-MCSs) | S1GP7.25: O CFIndepSTA AND CFS1G: O | Yes ☐ No ☐ N/A ☐ |
| S1GP7.27 | MCS 6, Nss = 3 | 23.1.1 (Introduction to the S1G PHY), 23.5 (Parameters for S1G-MCSs) | S1GP7.25: O CFIndepSTA AND CFS1G: O | Yes ☐ No ☐ N/A ☐ |
| S1GP7.28 | MCS 6, Nss = 4 | 23.1.1 (Introduction to the S1G PHY), 23.5 (Parameters for S1G-MCSs) | S1GP7.25: O CFIndepSTA AND CFS1G: O | Yes ☐ No ☐ N/A ☐ |
| S1GP7.29 | MCS 7, Nss = 1 | 23.1.1 (Introduction to the S1G PHY), 23.5 (Parameters for S1G-MCSs) | CFAP AND CFS1G: M CFIndepSTA AND CFS1G: O | Yes ☐ No ☐ N/A ☐ |
| S1GP7.30 | MCS 7, Nss = 2 | 23.1.1 (Introduction to the S1G PHY), 23.5 (Parameters for S1G-MCSs) | S1GP7.29: O CFIndepSTA AND CFS1G: O | Yes ☐ No ☐ N/A ☐ |
| S1GP7.31 | MCS 7, Nss = 3 | 23.1.1 (Introduction to the S1G PHY), 23.5 (Parameters for S1G-MCSs) | S1GP7.29: O CFIndepSTA AND CFS1G: O | Yes ☐ No ☐ N/A ☐ |


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### B.4.28.2 S1G PHY features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| S1GP7.32 | MCS 7, Nss = 4 | 23.1.1 (Introduction to the S1G PHY), 23.5 (Parameters for S1G-MCSs) | S1GP7.29: O CFIndepSTA AND CFS1G: O | Yes ☐ No ☐ N/A ☐ |
| S1GP7.33 | MCS 8, Nss = 1 | 23.1.1 (Introduction to the S1G PHY), 23.5 (Parameters for S1G-MCSs) | CFAP AND CFS1G: O CFIndepSTA AND CFS1G: O | Yes ☐ No ☐ N/A ☐ |
| S1GP7.34 | MCS 8, Nss = 2 | 23.1.1 (Introduction to the S1G PHY), 23.5 (Parameters for S1G-MCSs) | S1GP7.33: O CFIndepSTA AND CFS1G: O | Yes ☐ No ☐ N/A ☐ |
| S1GP7.35 | MCS 8, Nss = 3 | 23.1.1 (Introduction to the S1G PHY), 23.5 (Parameters for S1G-MCSs) | S1GP7.33: O CFIndepSTA AND CFS1G: O | Yes ☐ No ☐ N/A ☐ |
| S1GP7.36 | MCS 8, Nss = 4 | 23.1.1 (Introduction to the S1G PHY), 23.5 (Parameters for S1G-MCSs) | S1GP7.33: O CFIndepSTA AND CFS1G: O | Yes ☐ No ☐ N/A ☐ |
| S1GP7.37 | MCS 9, Nss = 1 | 23.1.1 (Introduction to the S1G PHY), 23.5 (Parameters for S1G-MCSs) | CFAP AND CFS1G AND (NOT S1GP1.2): O CFIndepSTA AND CFS1G: O | Yes ☐ No ☐ N/A ☐ |
| S1GP7.38 | MCS 9, Nss = 2 | 23.1.1 (Introduction to the S1G PHY), 23.5 (Parameters for S1G-MCSs) | CFAP AND CFS1G AND S1GP7.37 AND (NOT S1GP1.2): O CFIndepSTA AND CFS1G: O | Yes ☐ No ☐ N/A ☐ |
| S1GP7.39 | MCS 9, Nss = 3 | 23.1.1 (Introduction to the S1G PHY), 23.5 (Parameters for S1G-MCSs) | CFAP AND CFS1G AND S1GP7.37: O CFIndepSTA AND CFS1G: O | Yes ☐ No ☐ N/A ☐ |

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### B.4.28.2 S1G PHY features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| S1GP7.40 | MCS 9, Nss = 4 | 23.1.1 (Introduction to the S1G PHY), 23.5 (Parameters for S1G-MCSs) | CFAP AND CFS1G AND S1GP7.37 AND (NOT S1GP1.2): O CFIndepSTA AND CFS1G: O | Yes ☐ No ☐ N/A ☐ |
| S1GP7.41 | MCS 10, Nss = 1 | 23.1.1 (Introduction to the S1G PHY), 23.5 (Parameters for S1G-MCSs) | CFS1G: M | Yes ☐ No ☐ N/A ☐ |
| S1GP7.42(M102) | MCS 11, Nss = 1 | 23.1.1 (Introduction to the S1G PHY), 23.5 (Parameters for S1G-MCSs) | CFS1G: O | Yes ☐ No ☐ N/A ☐ |
| S1GP7.43(M102) | MCS 11, Nss = 2 | 23.1.1 (Introduction to the S1G PHY), 23.5 (Parameters for S1G-MCSs) | CFS1G: O | Yes ☐ No ☐ N/A ☐ |
| S1GP7.44(M102) | MCS 11, Nss = 3 | 23.1.1 (Introduction to the S1G PHY), 23.5 (Parameters for S1G-MCSs) | CFS1G: O | Yes ☐ No ☐ N/A ☐ |
| S1GP7.45(M102) | MCS 11, Nss = 4 | 23.1.1 (Introduction to the S1G PHY), 23.5 (Parameters for S1G-MCSs) | CFS1G: O | Yes ☐ No ☐ N/A ☐ |
| S1GP7.46(M102) | MCS 12, Nss = 1 | 23.1.1 (Introduction to the S1G PHY), 23.5 (Parameters for S1G-MCSs) | CFS1G: O | Yes ☐ No ☐ N/A ☐ |
| S1GP7.47(M102) | MCS 12, Nss = 2 | 23.1.1 (Introduction to the S1G PHY), 23.5 (Parameters for S1G-MCSs) | CFS1G: O | Yes ☐ No ☐ N/A ☐ |


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### B.4.28.2 S1G PHY features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| S1GP7.48(M102) | MCS 12, Nss = 3 | 23.1.1 (Introduction to the S1G PHY), 23.5 (Parameters for S1G-MCSs) | CFS1G: O | Yes ☐ No ☐ N/A ☐ |
| S1GP7.49(M102) | MCS 12, Nss = 4 | 23.1.1 (Introduction to the S1G PHY), 23.5 (Parameters for S1G-MCSs) | CFS1G: O | Yes ☐ No ☐ N/A ☐ |

## B.4.29 S1G relay features

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| (M118)*RL1 | S1G relay operation | 10.53 (S1G relay operation) | CFS1GRelay: M | Yes ☐ No ☐ N/A ☐ |
| (M118)*RL2 | (M118)S1G relay support | | CFAP: O | Yes ☐ No ☐ N/A ☐ |
| RL3 | S1G Relay element | | RL1 OR RL2:M | Yes ☐ No ☐ N/A ☐ |
| RL4 | Signaling of S1G Relay element in Probe Request, (Re)Association Request frames | | CFS1GRelay:M | Yes ☐ No ☐ N/A ☐ |
| RL5 | Signaling of S1G Relay element in S1G Beacon, Probe Response, PV1 Probe Response frames and (Re)Association Response frames | | (M118)RL2:M | Yes ☐ No ☐ N/A ☐ |
| (M118)*RL6 | TXOP sharing | 10.53.5 (Procedures of TXOP sharing for S1G relay operation) | (CFS1G AND RL1):O (CFS1G AND RL2):O (CFIndepSTA AND CFS1G):O | Yes ☐ No ☐ N/A ☐ |
| RL6.1 | Explicit Ack procedure | 10.53.2 (S1G relay operation) | RL6:O.4 | Yes ☐ No ☐ N/A ☐ |

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## B.4.29 S1G relay features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| RL6.2 | Implicit Ack procedure | 10.53.3 (Addressing and for-warding of individually addressed relay frames) | RL6:O.4 | Yes ☐ No ☐ N/A ☐ |
| RL7 | S1G relay discovery procedure | 10.53.6 (S1G relay discovery procedure), 11.1.4.3.5 (Active scanning for relay dis-covery) | (CFS1G AND RL1):O CFAP: O CFIndepSTA: O | Yes ☐ No ☐ N/A ☐ |

## B.4.30 CDMG features(#2293)

### B.4.30.1 CDMG MAC features

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| | Are the following MAC protocol features supported? | | | |
| CDMG-M1 | CDMG capabilities signaling | | | |
| CDMG-M1.1 | CDMG Capabilities element | 9.4.2.218 (CDMG Capabilities element) | CFCDMG:M | Yes ☐ No ☐ N/A ☐ |
| CDMG-M1.2 | Signaling of STA capabilities in Probe Request and (Re)Association Request frames | 9.3.3.5 (Association Request frame for-mat), 9.3.3.7 (Reassocia-tion Request frame format), 9.3.3.9 (Probe Request frame for-mat), 9.4.2.218 (CDMG Capabilities element) | (CFCDMG AND (CFSTAofAP OR CFIBSS OR CFPBSSnot PCP)):M | Yes ☐ No ☐ N/A ☐ |


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### B.4.30.1 CDMG MAC features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| CDMG-M1.3 | Signaling of STA and BSS capabilities in DMG Beacon, Probe Response, and (Re)Association Response frames | 9.3.3.6 (Association Response frame format), 9.3.3.8 (Reassociation Response frame format), 9.3.3.10 (Probe Response frame format), 9.3.4.2 (DMG Beacon), 9.4.2.218 (CDMG Capabilities element) | (CFCDMG AND (CFAP OR CFPCP)):M | Yes ☐ No ☐ N/A ☐ |
| CDMG-M2 | Dynamic bandwidth control | 9.3.4.2 (DMG Beacon), 10.63 (DBC mechanism for CDMG STAs) | CFCDMG:M | Yes ☐ No ☐ N/A ☐ |
| CDMG-M3 | Dynamic channel selection | 11.47 (DCS procedure for CDMG BSS), 9.6.7.37 (DCS Measurement Request frame format), 9.6.7.38 (DCS Measurement Response frame format), 9.6.7.39 (DCS Request frame format), 9.6.7.40 (DCS Response frame format) | CFCDMG:O | Yes ☐ No ☐ N/A ☐ |
| CDMG-M4 | Opportunistic transmissions | 9.4.1.7 (Reason Code field), 9.4.2.228 (CMMG Capabilities element), 10.38.11 (Opportunistic transmission in alternative channel for CDMG STAs) | CFCDMG:O | Yes ☐ No ☐ N/A ☐ |
| CDMG-M5 | Selection of candidate SPs for spatial sharing | 9.4.2.221 (SSW Report element), 11.30.1 (General), W.1 (Selection of candidate SPs for spatial sharing) | CFCDMG:O | Yes ☐ No ☐ N/A ☐ |
| CDMG-M6 | CDMG AP or PCP clustering | 10.39 (DMG and CMMG AP or PCP clustering) | CFCDMG:M | Yes ☐ No ☐ N/A ☐ |
| CDMG-M7 | CDMG protected period establishment and maintenance | 10.38.6.6.3 (CDMG protected period establishment and maintenance) | CFCDMG:M | Yes ☐ No ☐ N/A ☐ |

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### B.4.30.1 CDMG MAC features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| CDMG-M8 | Spatial sharing in a CDMG AP or PCP cluster | 10.40.6 (Spatial sharing in a CDMG AP or PCP cluster) | CFCDMG:M | Yes ☐ No ☐ N/A ☐ |
| CDMG-M9 | CDMG enhanced beam tracking | 10.41.9 (CDMG enhanced beam tracking), W.3 (Beam tracking and switching for enhanced beam tracking mechanism) | CFCDMG:O | Yes ☐ No ☐ N/A ☐ |
| CDMG-M10 | CDMG dynamic truncation of service period | 10.38.8.2 (CDMG dynamic truncation of service period) | CFCDMG:M | Yes ☐ No ☐ N/A ☐ |

### B.4.30.2 CDMG PHY features

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| | Are the following PHY protocol features supported? | | | |
| CDMG-P1 | PHY operating modes | | | |
| CDMG-P1.1 | Operation according to Clause 24 (China directional multi-gigabit (CDMG) PHY specification) | Clause 24 (China directional multi-gigabit (CDMG) PHY specification) | CFCDMG:M | Yes ☐ No ☐ N/A ☐ |
| CDMG-P2 | CDMG PHY frame format | | | |
| (M118)*CDMG-P2.1 | CDMG control mode format | 24.4 (CDMG control mode) | CFCDMG:M | Yes ☐ No ☐ N/A ☐ |
| (M118)*CDMG-P2.2 | CDMG SC mode format | 24.5 (CDMG SC mode) | CFCDMG:M | Yes ☐ No ☐ N/A ☐ |
| (M118)*CDMG-P2.3 | CDMG low-power SC mode format. The CDMG low-power SC mode is obsolete. Support for this mechanism might be removed in a later revision of the standard. | 24.6 (CDMG low-power SC mode) | CFCDMG:O | Yes ☐ No ☐ N/A ☐ |
| CDMG-P2.4 | Modulation and coding schemes (MCSs) | 24.4 (CDMG control mode)(#2294) | | Yes ☐ No ☐ N/A ☐ |
| CDMG-P2.4.1 | MCS 0 of CDMG control mode | 24.4 (CDMG control mode)(#2294) | CDMG-P2.1:M | Yes ☐ No ☐ N/A ☐ |
| CDMG-P2.4.2 | MCSs 1 to 16 of CDMG SC mode | 24.5 (CDMG SC mode)(#2294) | | Yes ☐ No ☐ N/A ☐ |
| CDMG-P2.4.2.1 | MCSs 1 to 9 | 24.5 (CDMG SC mode)(#2294) | CDMG-P2.2:M | Yes ☐ No ☐ N/A ☐ |


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### B.4.30.2 CDMG PHY features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| CDMG-P2.4.2.2 | MCSs 10 to 16 | 24.5 (CDMG SC mode)(#2294) | CDMG-P2.2:O | Yes ☐ No ☐ N/A ☐ |
| CDMG-P2.4.3 | MCSs 17 to 23 of CDMG low-power SC mode. The CDMG low-power SC mode is obsolete. Support for this mechanism might be removed in a later revision of the standard. | 24.6 (CDMG low-power SC mode) | CDMG-P2.3:M | Yes ☐ No ☐ N/A ☐ |
| CDMG-P2.5 | Common preamble format | 24.3 (Common parameters) | CFCDMG:M | Yes ☐ No ☐ N/A ☐ |
| CDMG-P2.6 | Enhanced mobile device support mode | 24.5 (CDMG SC mode) | CFCDMG:M | Yes ☐ No ☐ N/A ☐ |

## B.4.31 CMMG features

### B.4.31.1 CMMG PHY features

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| | Are the following PHY protocol features supported? | | | |
| CMMG-P1 | PHY operating modes | | | |
| CMMG-P1.1 | Operation according to Clause 25 (China millimeter-wave multi-gigabit (CMMG) PHY specification) | Clause 25 (China millimeter-wave multi-gigabit (CMMG) PHY specification) | CFCMMG:M | |

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### B.4.31.1 CMMG PHY features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| CMMG-P2 | PHY frame format | | | |
| (M118)*CMMG-P2.1 | CMMG control mode format | 25.4 (CMMG control mode) | CFCMMG:M | Yes ☐ No ☐ N/A ☐ |
| (M118)*CMMG-P2.2 | CMMG SC mode format | 25.5 (CMMG SC mode) | CFCMMG:M | Yes ☐ No ☐ N/A ☐ |
| (M118)*CMMG-P2.3 | CMMG OFDM mode format | 25.6 (CMMG OFDM mode) | CFCMMG:O | Yes ☐ No ☐ N/A ☐ |
| CMMG-P2.4 | Modulation and coding schemes (MCSs) | | | |
| CMMG-P2.4.1 | MCS 0 of CMMG control mode | 25.4 (CMMG control mode) | CMMG-P2.1:M | Yes ☐ No ☐ N/A ☐ |
| CMMG-P2.4.2 | MCSs 1 to 8 of CMMG SC mode | | | |
| CMMG-P2.4.2.1 | MCSs 1 to 3 | 25.5 (CMMG SC mode) | CMMG-P2.2:M | Yes ☐ No ☐ N/A ☐ |
| CMMG-P2.4.2.2 | MCSs 4 to 8 | 25.5 (CMMG SC mode) | CMMG-P2.2:O | Yes ☐ No ☐ N/A ☐ |
| CMMG-P2.4.3 | MCSs 9 to 16 of CMMG OFDM mode | 25.6 (CMMG OFDM mode) | CMMG-P2.3:M | Yes ☐ No ☐ N/A ☐ |


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### B.4.32 Preassociation discovery extensions

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| *PAD1 | Unsolicited PAD procedure | 11.23.2 (Unsolicited PAD procedure) | CFPAD:M | Yes ☐ No ☐ N/A ☐ |
| PAD1.1 | Service Hint element | 9.4.2.236 (Service Hint element) | PAD1:M | Yes ☐ No ☐ N/A ☐ |
| PAD1.2 | Service Hash element | 9.4.2.237 (Service Hash element) | PAD1:M | Yes ☐ No ☐ N/A ☐ |
| *PAD2 | Solicited PAD procedure | 11.23.3 (Solicited PAD procedure) | (CFPAD AND IW2.2.2):M | Yes ☐ No ☐ N/A ☐ |
| PAD2.1 | (M118)Service information request | 9.4.5.27 (Service Information Request ANQP-element) | PAD2:M | Yes ☐ No ☐ N/A ☐ |
| PAD2.2 | (M118)Service information response | 9.4.5.28 (Service Information Response ANQP-element) | PAD2:M | Yes ☐ No ☐ N/A ☐ |

### B.4.33 High-efficiency (HE) features(11ax)

#### B.4.33.1 HE MAC features

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| | Are the following MAC protocol features supported? | | | |
| HEM1 | HE capabilities signaling | | | |
| HEM1.1 | HE Capabilities element | 9.4.2.247 (HE Capabilities element(11ax)) | CFHE:M | Yes ☐ No ☐ N/A ☐ |

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### B.4.33.1 HE MAC features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| HEM1.2 | Signaling of STA capabilities in Probe Request, (Re)Association Request frames | 9.3.3.5 (Association Request frame format), 9.3.3.7 (Reassociation Request frame format), 9.3.3.9 (Probe Request frame format), 9.4.2.247 (HE Capabilities element(11ax)) | (CFHE AND CFIndepSTA): M | Yes ☐ No ☐ N/A ☐ |
| HEM1.3 | Signaling of HE STA capabilities and HE BSS capabilities in Beacon, Probe Response, (Re)Association Response frames | 9.3.3.2 (Beacon frame format), 9.3.3.6 (Association Response frame format), 9.3.3.8 (Reassociation Response frame format), 9.3.3.10 (Probe Response frame format), 9.4.2.247 (HE Capabilities element(11ax)) | (CFHE AND CFAP):M | Yes ☐ No ☐ N/A ☐ |
| HEM2 | Signaling of HE operation | 9.4.2.248 (HE Operation element(11ax)) | (CFHE AND CFAP):M | Yes ☐ No ☐ N/A ☐ |
| HEM3 | A-MPDU with multiple TIDs | 26.6.3 (Multi-TID A-MPDU and ack-enabled single-TID A-MPDU) | CFHE:O | Yes ☐ No ☐ N/A ☐ |
| HEM4 | HE variant HT Control | | | |
| HEM4.1 | UL MU Response Scheduling | 9.2.4.7.1 (TRS Control) | CFHE:O | Yes ☐ No ☐ N/A ☐ |
| HEM4.2 | Operating Mode | 9.2.4.7.2 (OM Control) | CFHE:O | Yes ☐ No ☐ N/A ☐ |
| HEM4.3 | HE Link Adaptation | 9.2.4.7.3 (HLA Control) | CFHE:O | Yes ☐ No ☐ N/A ☐ |
| HEM4.4 | Buffer Status Report | 9.2.4.7.4 (BSR Control) | CFHE:O | Yes ☐ No ☐ N/A ☐ |
| HEM4.5 | UL Power Headroom | 9.2.4.7.5 (UPH Control) | CFHE:M | Yes ☐ No ☐ N/A ☐ |
| HEM4.6 | BQR Control | 9.2.4.7.6 (BQR Control) | CFHE:O | Yes ☐ No ☐ N/A ☐ |
| HEM4.7 | CAS Control | 9.2.4.7.7 (CAS Control) | CFHE:O | Yes ☐ No ☐ N/A ☐ |
| HEM5 | Trigger frame | | | |


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### B.4.33.1 HE MAC features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| HEM5.1 | Basic Trigger frame | 9.3.1.22.2 (Basic Trigger frame format) | CFHE:M | Yes ☐ No ☐ N/A ☐ |
| HEM5.2 | BFRP Trigger frame | 9.3.1.22.3 (BFRP Trigger frame format) | CFHE:M | Yes ☐ No ☐ N/A ☐ |
| HEM5.3 | MU-BAR Trigger frame | 9.3.1.22.4 (MU-BAR Trigger frame format) | CFHE:O | Yes ☐ No ☐ N/A ☐ |
| HEM5.4 | MU-RTS Trigger frame transmission | 9.3.1.22.5 (MU-RTS Trigger frame format) | CFHE:O | Yes ☐ No ☐ N/A ☐ |
| HEM5.5 | MU-RTS Trigger frame reception | 9.3.1.22.5 (MU-RTS Trigger frame format) | CFHE:M | Yes ☐ No ☐ N/A ☐ |
| HEM5.6 | BSRP Trigger frame | 9.3.1.22.6 (BSRP Trigger frame format) | CFHE:O | Yes ☐ No ☐ N/A ☐ |
| HEM5.7 | GCR MU-BAR Trigger frame | 9.3.1.22.7 (GCR MU-BAR Trigger frame format) | CFHE:O | Yes ☐ No ☐ N/A ☐ |
| HEM5.8 | BQRP Trigger frame | 9.3.1.22.8 (BQRP Trigger frame format) | CFHE:O | Yes ☐ No ☐ N/A ☐ |
| HEM5.9 | NFRP Trigger frame | 9.3.1.22.9 (NFRP Trigger frame format) | CFHE:O | Yes ☐ No ☐ N/A ☐ |
| HEM6 | Transmit beamforming | | | |
| *HEM6.1 | SU beamformer capable if the supported maximum number of transmit spatial streams is less than 4 | 9.4.2.247 (HE Capabilities element(11ax)) | CFHE:O | Yes ☐ No ☐ N/A ☐ |
| *HEM6.2 | SU beamformer capable if the supported maximum number of transmit spatial streams is greater than or equal to 4 | 9.4.2.247 (HE Capabilities element(11ax)) | CFHE:M | Yes ☐ No ☐ N/A ☐ |
| *HEM6.3 | SU beamformee capable | 9.4.2.247 (HE Capabilities element(11ax)) | CFHE:O | Yes ☐ No ☐ N/A ☐ |
| *HEM6.4 | MU beamformer capable if the supported maximum number of transmit spatial streams is less than 4 | 9.4.2.247 (HE Capabilities element(11ax)) | CFAP AND (M118)HEM6.1:O | Yes ☐ No ☐ N/A ☐ |
| *HEM6.5 | MU beamformer capable if the supported maximum number of transmit spatial streams is greater than or equal to 4 | 9.4.2.247 (HE Capabilities element(11ax)) | CFAP AND (M118)HEM6.2:M | Yes ☐ No ☐ N/A ☐ |
| *HEM6.6 | MU beamformee capable | 9.4.2.247 (HE Capabilities element(11ax)) | CFIndepSTA AND VHTM7.2: O | Yes ☐ No ☐ N/A ☐ |

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### B.4.33.1 HE MAC features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| HEM6.7 | Transmission of an HE sounding NDP | 26.7 (HE sounding operation(#2388)) | HEM6.1:M HEM6.2:M | Yes ☐ No ☐ N/A ☐ |
| HEM6.8 | Reception of an HE sounding NDP | 26.7 (HE sounding operation(#2388)) | HEM6.3:M | Yes ☐ No ☐ N/A ☐ |
| *HEM6.9 | Transmission of Trigger frame | 26.7 (HE sounding operation(#2388)) | HEM6.1:O HEM6.2:O | Yes ☐ No ☐ N/A ☐ |
| HEM6.10 | Reception of Trigger frame | 26.7 (HE sounding operation(#2388)) | HEM6.9:M | Yes ☐ No ☐ N/A ☐ |
| HEM7 | Sounding protocol | | | |
| HEM7.1 | HE Sounding Protocol as SU beamformer | 26.7 (HE sounding operation(#2388)) | HEM6.1:M HEM6.2:M | Yes ☐ No ☐ N/A ☐ |
| HEM7.2 | HE Sounding Protocol as SU beamformee | 26.7 (HE sounding operation(#2388)) | HEM6.3:M | Yes ☐ No ☐ N/A ☐ |
| HEM7.3 | HE Sounding Protocol as MU beamformer | 26.7 (HE sounding operation(#2388)) | HEM6.4:M HEM6.5:M | Yes ☐ No ☐ N/A ☐ |
| HEM7.4 | HE Sounding Protocol as MU beamformee | 26.7 (HE sounding operation(#2388)) | HEM6.6:M | Yes ☐ No ☐ N/A ☐ |
| HEM8 | NAV update | 26.2.4 (Updating two NAVs) | | |
| HEM8.1 | Update basic NAV | 26.2.4 (Updating two NAVs) | CFHE:M | Yes ☐ No ☐ N/A ☐ |
| HEM8.2 | Update IntraBSS NAV | 26.2.4 (Updating two NAVs) | CFAP AND CFHE:O CFIndepSTA AND CFHE:M | Yes ☐ No ☐ N/A ☐ |
| HEM9 | OFDMA-based random access | 26.5.4 (UL OFDMA-based random access (UORA)) | CFHE:O | Yes ☐ No ☐ N/A ☐ |
| HEM10 | TWT operation | 26.8 (TWT operation) | CFHE:O | Yes ☐ No ☐ N/A ☐ |
| HEM11 | Quiet time period | | | |
| (M118)*HEM11.1 | Responding AP procedure | | CFAP AND CFHE:O | |


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### B.4.33.1 HE MAC features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| HEM11.1.1 | QTP AP capability | 26.17.5.1 (General) | HEM11.1:M | Yes ☐ No ☐ N/A ☐ |
| HEM11.1.2 | QTP responding AP procedure | 26.17.5.3 (Responding AP procedure) | HEM11.1:M | Yes ☐ No ☐ N/A ☐ |
| (M118)*HEM11.2 | Requesting STA procedure | | CFSTAof AP AND CFHE:O | |
| HEM11.2.1 | QTP non-AP STA capability | 26.17.5.1 (General) | HEM11.2:M | Yes ☐ No ☐ N/A ☐ |
| HEM11.2.2 | QTP requesting STA procedure | 26.17.5.2 (QTP Requesting STA procedure) | HEM11.2:M | Yes ☐ No ☐ N/A ☐ |
| HEM12 | HE BSS operation in the 6 GHz band | | | |
| HEM12.1 | Scanning in the 6 GHz band | 26.17.2.3 (Scanning in the 6 GHz band) | CFHE6G:O | Yes ☐ No ☐ N/A ☐ |
| HEM12.2 | Out of band discovery | 11.53 (Out-of-band discovery of a 6 GHz BSS(11ax)) | (CF2G4n6G OR CF5Gn6G):O | Yes ☐ No ☐ N/A ☐ |

### B.4.33.2 HE PHY features

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| | Are the following PHY protocol features supported? | | | |
| HEP1 | PHY operating modes | | | |
| HEP1.1 | Operation according to Clause 17, Clause 19, and/or Clause 21 | 27.1.1 (Introduction to the HE PHY) | CFHE5G AND (CFAP OR CFHE80):M | Yes ☐ No ☐ N/A ☐ |
| HEP1.2 | Operation according (#1187)to Clause 19 in the 5 GHz band | 27.1.1 (Introduction to the HE PHY) | CFHE5G AND CFHE20:M | Yes ☐ No ☐ N/A ☐ |
| HEP1.3 | Operation according (#1187)to Clause 19 in the 2.4 GHz band | 27.1.1 (Introduction to the HE PHY) | CFHE2G4:M | Yes ☐ No ☐ N/A ☐ |
| HEP1.4 | Operation according to Clause 17 in the 6 GHz band | 27.1.1 (Introduction to the HE PHY) | CFHE6G:M | Yes ☐ No ☐ N/A ☐ |
| HEP2 | HE PPDU format | 27.1.4 (PPDU formats) | | |
| *HEP2.1 | HE SU PPDU | 27.1.4 (PPDU formats) | CFHE:M | Yes ☐ No ☐ N/A ☐ |
| *HEP2.2 | HE ER SU PPDU | 27.1.4 (PPDU formats) | CFHE:M | Yes ☐ No ☐ N/A ☐ |

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### B.4.33.2 HE PHY features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| HEP2.3 | HE MU PPDU | 27.1.4 (PPDU formats) | | |
| *HEP2.3.1 | DL OFDMA Tx | 27.3.1.1 (MU transmission) | CFAP AND CFHE:M | Yes ☐ No ☐ N/A ☐ |
| *HEP2.3.2 | DL OFDMA Rx | 27.3.1.1 (MU transmission) | CFSTAofAP AND CFHE:M | Yes ☐ No ☐ N/A ☐ |
| *HEP2.3.3 | DL MU-MIMO Tx | 27.3.1.1 (MU transmission) | CFAP AND HEP9.1.10:M | Yes ☐ No ☐ N/A ☐ |
| *HEP2.3.4 | DL MU-MIMO Rx | 27.3.1.1 (MU transmission) | CFSTAofAP AND CFHE:M | Yes ☐ No ☐ N/A ☐ |
| *HEP2.3.5 | DL MU-MIMO within OFDMA Tx | 27.3.1.1 (MU transmission) | CFAP AND CFHE:O | Yes ☐ No ☐ N/A ☐ |
| *HEP2.3.6 | DL MU-MIMO within OFDMA Rx | 27.3.1.1 (MU transmission) | CFSTAofAP AND CFHE:O | Yes ☐ No ☐ N/A ☐ |
| HEP2.3.7 | Rx full BW with a single user using HE MU PPDU with compressed HE-SIG-B field | 26.15.2 (PPDU format selection) | CFHE:O | Yes ☐ No ☐ N/A ☐ |
| HEP2.3.8 | Rx full BW with a single user using HE MU PPDU with noncompressed HE-SIG-B field | 26.15.2 (PPDU format selection) | CFHE:O | Yes ☐ No ☐ N/A ☐ |
| HEP2.4 | HE TB PPDU | 27.1.4 (PPDU formats) | | |
| HEP2.4.1 | UL OFDMA Tx | 27.3.1.1 (MU transmission) | CFSTAofAP AND CFHE:M | Yes ☐ No ☐ N/A ☐ |
| HEP2.4.2 | UL OFDMA Rx | 27.3.1.1 (MU transmission) | CFAP AND CFHE:M | Yes ☐ No ☐ N/A ☐ |
| *HEP2.4.3 | UL MU-MIMO Tx | 27.3.1.1 (MU transmission) | CFSTAofAP AND CFHE:O | Yes ☐ No ☐ N/A ☐ |
| *HEP2.4.4 | UL MU-MIMO Rx | 27.3.1.1 (MU transmission) | CFAP AND CFHE:O | Yes ☐ No ☐ N/A ☐ |
| HEP2.4.5 | UL MU-MIMO within OFDMA Tx | 27.3.1.1 (MU transmission) | CFSTAofAP AND CFHE:O | Yes ☐ No ☐ N/A ☐ |
| HEP2.4.6 | UL MU-MIMO within OFDMA Rx | 27.3.1.1 (MU transmission) | CFAP AND CFHE:O | Yes ☐ No ☐ N/A ☐ |
| HEP3 | BSS bandwidth | | | |
| *HEP3.1 | 20 MHz operation | 26.17 (HE BSS operation) | CFHE:M | Yes ☐ No ☐ N/A ☐ |
| *HEP3.2 | 40 MHz operation | 26.17 (HE BSS operation) | CFHE80 AND (CFHE5G OR CFHE6G):M<br><br>CFHE2G4:O | Yes ☐ No ☐ N/A ☐ |
| *HEP3.3 | 80 MHz operation | 26.17 (HE BSS operation) | CFHE80 AND (CFHE5G OR CFHE6G):M | Yes ☐ No ☐ N/A ☐ |
| *HEP3.4 | 160 MHz operation | 26.17 (HE BSS operation) | CFHE80 AND (CFHE5G OR CFHE6G):O HEP3.5:M | Yes ☐ No ☐ N/A ☐ |


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### B.4.33.2 HE PHY features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| *HEP3.5 | 80+80 MHz operation | 26.17 (HE BSS operation) | CFHE80 AND (CFHE5G OR CFHE6G):O | Yes ☐ No ☐ N/A ☐ |
| HEP4 | PHY timing information | | | |
| HEP4.1 | Values in 20 MHz channel | 27.3.9 (Timing-related parameters) | CFHE:M | Yes ☐ No ☐ N/A ☐ |
| HEP4.2 | Values in 40 MHz channel | 27.3.9 (Timing-related parameters) | CFHE:M | Yes ☐ No ☐ N/A ☐ |
| HEP4.3 | Values in 80 MHz channel | 27.3.9 (Timing-related parameters) | CFHE:M | Yes ☐ No ☐ N/A ☐ |
| HEP4.4 | Values in 160 MHz channel | 27.3.9 (Timing-related parameters) | HEP3.4:M | Yes ☐ No ☐ N/A ☐ |
| HEP4.5 | Values in 80+80 MHz channel | 27.3.9 (Timing-related parameters) | HEP3.5:M | Yes ☐ No ☐ N/A ☐ |
| HEP5 | STBC | 27.3.12.12 (Space-time block coding) | CFHE:O | Yes ☐ No ☐ N/A ☐ |
| HEP6 | Tone allocation | | | |
| *HEP6.1 | 26-tone RU mapping | 27.3.2.2 (Resource unit, guard, and DC subcarriers), 27.3.2.3 (Null subcarriers), and 27.3.2.4 (Pilot subcarriers) | CFHE:M | Yes ☐ No ☐ N/A ☐ |
| *HEP6.2 | 52-tone RU mapping | 27.3.2.2 (Resource unit, guard, and DC subcarriers), 27.3.2.3 (Null subcarriers), and 27.3.2.4 (Pilot subcarriers) | CFHE:M | Yes ☐ No ☐ N/A ☐ |
| *HEP6.3 | 106-tone RU mapping | 27.3.2.2 (Resource unit, guard, and DC subcarriers), 27.3.2.3 (Null subcarriers), and 27.3.2.4 (Pilot subcarriers) | CFHE:M | Yes ☐ No ☐ N/A ☐ |

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### B.4.33.2 HE PHY features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| *HEP6.4 | 242-tone RU mapping | 27.3.2.2 (Resource unit, guard, and DC subcarriers), 27.3.2.3 (Null subcarriers), and 27.3.2.4 (Pilot subcarriers) | CFHE80:M CFHE20:O | Yes ☐ No ☐ N/A ☐ |
| *HEP6.5 | 484-tone RU mapping | 27.3.2.2 (Resource unit, guard, and DC subcarriers), 27.3.2.3 (Null subcarriers), and 27.3.2.4 (Pilot subcarriers) | CFHE80 AND HEP3.2:M | Yes ☐ No ☐ N/A ☐ |
| *HEP6.6 | 996-tone RU mapping | 27.3.2.2 (Resource unit, guard, and DC subcarriers), 27.3.2.3 (Null subcarriers), and 27.3.2.4 (Pilot subcarriers) | CFHE80 AND HEP3.3:M CFHE80 AND HEP3.4:M | Yes ☐ No ☐ N/A ☐ |
| *HEP6.7 | 2×996-tone RU mapping | 27.3.2.2 (Resource unit, guard, and DC subcarriers), 27.3.2.3 (Null subcarriers), and 27.3.2.4 (Pilot subcarriers) | CFHE80 AND HEP3.4:M | Yes ☐ No ☐ N/A ☐ |
| HEP7 | Coding | | | |
| HEP8.1 | BCC with 4 or fewer spatial streams | 27.3.12.5.1 (BCC coding and puncturing) | (HEP6.1 OR HEP6.2 OR HEP6.3 OR HEP6.4):M (HEP3.1 AND HEP2.1):M | Yes ☐ No ☐ N/A ☐ |
| HEP8.2 | LDPC with more than 4 spatial streams | 27.3.12.5.2 (LDPC coding) | CFHE80:M CFHE20:M | Yes ☐ No ☐ N/A ☐ |


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### B.4.33.2 HE PHY features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| HEP8.3 | LDPC with 4 or fewer spatial streams | 27.3.12.5.2 (LDPC coding) | (HEP6.5 OR HEP6.6 OR HEP6.7):M<br><br>((HEP3.2 OR HEP3.3 OR HEP3.4 OR HEP3.5) AND HEP2.1):M<br><br>(HEP6.1 OR HEP6.2 OR HEP6.3 OR HEP6.4):O<br><br>(HEP3.1 AND HEP2.1):O<br><br>CFHE20:O | Yes ☐ No ☐ N/A ☐ |
| HEP9 | Coding and modulation schemes | | | |
| HEP9.1 | For 26-, 52-, 106-, 242-, 484-, and 996-tone mapping | | | |
| *HEP9.1.1 | HE-MCS with Index 0-7 and $N_{SS} = 1$ | 27.5 (Parameters for HE-MCSs) | CFHE:M | Yes ☐ No ☐ N/A ☐ |
| *HEP9.1.2 | HE-MCS with Index 0-8 and $N_{SS} = 1$ | 27.5 (Parameters for HE-MCSs) | HEP9.1.1:O | Yes ☐ No ☐ N/A ☐ |
| HEP9.1.3 | HE-MCS with Index 0-9 and $N_{SS} = 1$ | 27.5 (Parameters for HE-MCSs) | HEP9.1.2:O | Yes ☐ No ☐ N/A ☐ |
| *HEP9.1.4 | HE-MCS with Index 0-7 and $N_{SS} = 2$ | 27.5 (Parameters for HE-MCSs) | CFHE:O | Yes ☐ No ☐ N/A ☐ |
| *HEP9.1.5 | HE-MCS with Index 0-8 and $N_{SS} = 2$ | 27.5 (Parameters for HE-MCSs) | HEP9.1.4:O | Yes ☐ No ☐ N/A ☐ |
| HEP9.1.6 | HE-MCS with Index 0-9 and $N_{SS} = 2$ | 27.5 (Parameters for HE-MCSs) | HEP9.1.5:O | Yes ☐ No ☐ N/A ☐ |
| *HEP9.1.7 | HE-MCS with Index 0-7 and $N_{SS} = 3$ | 27.5 (Parameters for HE-MCSs) | CFHE:O | Yes ☐ No ☐ N/A ☐ |
| *HEP9.1.8 | HE-MCS with Index 0-8 and $N_{SS} = 3$ | 27.5 (Parameters for HE-MCSs) | HEP9.1.7:O | Yes ☐ No ☐ N/A ☐ |
| HEP9.1.9 | HE-MCS with Index 0-9 and $N_{SS} = 3$ | 27.5 (Parameters for HE-MCSs) | HEP9.1.8:O | Yes ☐ No ☐ N/A ☐ |
| *HEP9.1.10 | HE-MCS with Index 0-7 and $N_{SS} = 4$ | 27.5 (Parameters for HE-MCSs) | CFHE:O | Yes ☐ No ☐ N/A ☐ |

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### B.4.33.2 HE PHY features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| *HEP9.1.11 | HE-MCS with Index 0-8 and $N_{SS} = 4$ | 27.5 (Parameters for HE-MCSs) | HEP9.1.10:O | Yes ☐ No ☐ N/A ☐ |
| HEP9.1.12 | HE-MCS with Index 0-9 and $N_{SS} = 4$ | 27.5 (Parameters for HE-MCSs) | HEP9.1.11:O | Yes ☐ No ☐ N/A ☐ |
| *HEP9.1.13 | HE-MCS with Index 0-7 and $N_{SS} = 5$ | 27.5 (Parameters for HE-MCSs) | CFHE:O | Yes ☐ No ☐ N/A ☐ |
| *HEP9.1.14 | HE-MCS with Index 0-8 and $N_{SS} = 5$ | 27.5 (Parameters for HE-MCSs) | HEP9.1.13:O | Yes ☐ No ☐ N/A ☐ |
| HEP9.1.15 | HE-MCS with Index 0-9 and $N_{SS} = 5$ | 27.5 (Parameters for HE-MCSs) | HEP9.1.14:O | Yes ☐ No ☐ N/A ☐ |
| *HEP9.1.16 | HE-MCS with Index 0-7 and $N_{SS} = 6$ | 27.5 (Parameters for HE-MCSs) | CFHE:O | Yes ☐ No ☐ N/A ☐ |
| *HEP9.1.17 | HE-MCS with Index 0-8 and $N_{SS} = 6$ | 27.5 (Parameters for HE-MCSs) | HEP9.1.16:O | Yes ☐ No ☐ N/A ☐ |
| HEP9.1.18 | HE-MCS with Index 0-9 and $N_{SS} = 6$ | 27.5 (Parameters for HE-MCSs) | HEP9.1.17:O | Yes ☐ No ☐ N/A ☐ |
| *HEP9.1.19 | HE-MCS with Index 0-7 and $N_{SS} = 7$ | 27.5 (Parameters for HE-MCSs) | CFHE:O | Yes ☐ No ☐ N/A ☐ |
| *HEP9.1.20 | HE-MCS with Index 0-8 and $N_{SS} = 7$ | 27.5 (Parameters for HE-MCSs) | HEP9.1.19:O | Yes ☐ No ☐ N/A ☐ |
| HEP9.1.21 | HE-MCS with Index 0-9 and $N_{SS} = 7$ | 27.5 (Parameters for HE-MCSs) | HEP9.1.20:O | Yes ☐ No ☐ N/A ☐ |
| *HEP9.1.22 | HE-MCS with Index 0-7 and $N_{SS} = 8$ | 27.5 (Parameters for HE-MCSs) | CFHE:O | Yes ☐ No ☐ N/A ☐ |
| *HEP9.1.23 | HE-MCS with Index 0-8 and $N_{SS} = 8$ | 27.5 (Parameters for HE-MCSs) | HEP9.1.22:O | Yes ☐ No ☐ N/A ☐ |
| HEP9.1.24 | HE-MCS with Index 0-9 and $N_{SS} = 8$ | 27.5 (Parameters for HE-MCSs) | HEP9.1.23:O | Yes ☐ No ☐ N/A ☐ |
| HEP9.2 | For 242-, 484-, and 996-tone plan | | | |
| *HEP9.2.1 | HE-MCS with Index 0-10 and $N_{SS} = 1$ | 27.5 (Parameters for HE-MCSs) | CFHE80:O | Yes ☐ No ☐ N/A ☐ |
| HEP9.2.2 | HE-MCS with Index 0-11 and $N_{SS} = 1$ | 27.5 (Parameters for HE-MCSs) | HEP9.2.1:O | Yes ☐ No ☐ N/A ☐ |


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### B.4.33.2 HE PHY features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| *HEP9.2.3 | HE-MCS with Index 0-10 and $N_{SS} = 2$ | 27.5 (Parameters for HE-MCSs) | CFHE80:O | Yes ☐ No ☐ N/A ☐ |
| HEP9.2.4 | HE-MCS with Index 0-11 and $N_{SS} = 2$ | 27.5 (Parameters for HE-MCSs) | HEP9.2.3:O | Yes ☐ No ☐ N/A ☐ |
| *HEP9.2.5 | HE-MCS with Index 0-10 and $N_{SS} = 3$ | 27.5 (Parameters for HE-MCSs) | CFHE80:O | Yes ☐ No ☐ N/A ☐ |
| HEP9.2.6 | HE-MCS with Index 0-11 and $N_{SS} = 3$ | 27.5 (Parameters for HE-MCSs) | HEP9.2.5:O | Yes ☐ No ☐ N/A ☐ |
| *HEP9.2.7 | HE-MCS with Index 0-10 and $N_{SS} = 4$ | 27.5 (Parameters for HE-MCSs) | CFHE80:O | Yes ☐ No ☐ N/A ☐ |
| HEP9.2.8 | HE-MCS with Index 0-11 and $N_{SS} = 4$ | 27.5 (Parameters for HE-MCSs) | HEP9.2.7:O | Yes ☐ No ☐ N/A ☐ |
| *HEP9.2.9 | HE-MCS with Index 0-10 and $N_{SS} = 5$ | 27.5 (Parameters for HE-MCSs) | CFHE80:O | Yes ☐ No ☐ N/A ☐ |
| HEP9.2.10 | HE-MCS with Index 0-11 and $N_{SS} = 5$ | 27.5 (Parameters for HE-MCSs) | HEP9.2.9:O | Yes ☐ No ☐ N/A ☐ |
| *HEP9.2.11 | HE-MCS with Index 0-10 and $N_{SS} = 6$ | 27.5 (Parameters for HE-MCSs) | CFHE80:O | Yes ☐ No ☐ N/A ☐ |
| HEP9.2.12 | HE-MCS with Index 0-11 and $N_{SS} = 6$ | 27.5 (Parameters for HE-MCSs) | HEP9.2.11:O | Yes ☐ No ☐ N/A ☐ |
| *HEP9.2.13 | HE-MCS with Index 0-10 and $N_{SS} = 7$ | 27.5 (Parameters for HE-MCSs) | CFHE80:O | Yes ☐ No ☐ N/A ☐ |
| HEP9.2.14 | HE-MCS with Index 0-11 and $N_{SS} = 7$ | 27.5 (Parameters for HE-MCSs) | HEP9.2.13:O | Yes ☐ No ☐ N/A ☐ |
| *HEP9.2.15 | HE-MCS with Index 0-10 and $N_{SS} = 8$ | 27.5 (Parameters for HE-MCSs) | CFHE80:O | Yes ☐ No ☐ N/A ☐ |
| HEP9.2.16 | HE-MCS with Index 0-11 and $N_{SS} = 8$ | 27.5 (Parameters for HE-MCSs) | HEP9.2.15:O | Yes ☐ No ☐ N/A ☐ |
| HEP10 | HE-LTF formats | 27.3.11.10 (HE-LTF field) | | |
| HEP10.1 | 2x HE-LTF and 0.8 μs GI | 27.3.11.10 (HE-LTF field) | CFHE:M | Yes ☐ No ☐ N/A ☐ |
| HEP10.2 | 2x HE-LTF and 1.6 μs GI | 27.3.11.10 (HE-LTF field) | CFHE:M | Yes ☐ No ☐ N/A ☐ |
| HEP10.3 | 4x HE-LTF and 3.2 μs GI | 27.3.11.10 (HE-LTF field) | CFHE:M | Yes ☐ No ☐ N/A ☐ |

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### B.4.33.2 HE PHY features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| HEP10.4 | 1x HE-LTF and 0.8 μs GI | 27.3.11.10 (HE-LTF field) | CFHE:O | Yes ☐ No ☐ N/A ☐ |
| HEP10.5 | 4x HE-LTF and 0.8 μs GI | 27.3.11.10 (HE-LTF field) | CFHE:O | Yes ☐ No ☐ N/A ☐ |
| HEP10.6 | 1x HE-LTF and 1.6 μs GI | 27.3.11.10 (HE-LTF field) | HEP2.4.3 OR HEP2.4.4:M | Yes ☐ No ☐ N/A ☐ |
| HEP11 | DCM | 27.3.12.9 (Constellation mapping) | CFHE:O | Yes ☐ No ☐ N/A ☐ |
| HEP12 | Preamble puncturing | 27.2.2 (TXVECTOR and RXVECTOR parameters) | CFHE:O | Yes ☐ No ☐ N/A ☐ |
| HEP13 | Sounding | | | |
| HEP13.1 | Punctured sounding operation | 26.7.2 (HE sounding protocol) | CFHE:O | Yes ☐ No ☐ N/A ☐ |
| HEP13.2 | NDP with 4x HE-LTF and 3.2 μs GI | 27.3.17 (HE sounding NDP) | CFHE:O | Yes ☐ No ☐ N/A ☐ |
| HEP13.3 | Ng = 16 SU feedback | 26.7.3 (Rules for HE sounding protocol sequences) | HEM6.3:O | Yes ☐ No ☐ N/A ☐ |
| HEP13.4 | Ng = 16 MU feedback | 26.7.3 (Rules for HE sounding protocol sequences) | HEM6.6:O | Yes ☐ No ☐ N/A ☐ |
| HEP13.5 | Codebook size ($\phi$, $\psi$) = {4, 2} SU feedback | 26.7.3 (Rules for HE sounding protocol sequences) | HEM6.3:O | Yes ☐ No ☐ N/A ☐ |
| HEP13.6 | Codebook size ($\phi$, $\psi$) = {7, 5} MU feedback | 26.7.3 (Rules for HE sounding protocol sequences) | HEM6.6:O | Yes ☐ No ☐ N/A ☐ |
| HEP13.7 | Triggered SU beamforming feedback | 26.7.3 (Rules for HE sounding protocol sequences) | CFSTAofAP AND HEM6.3:O<br><br>CFAP AND (HEM6.1 OR HEM6.2):O | Yes ☐ No ☐ N/A ☐ |


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### B.4.33.2 HE PHY features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| HEP13.8 | Triggered MU beamforming partial BW feedback | 26.7.3 (Rules for HE sounding protocol sequences) | CFSTAofAP AND HEM6.6:O<br><br>CFAP AND (HEM6.4 OR HEM6.5):O | Yes ☐ No ☐ N/A ☐ |
| HEP13.9 | Triggered CQI feedback | 26.7.3 (Rules for HE sounding protocol sequences) | CFSTAofAP AND HEM6.3:O<br><br>CFAP AND (HEM6.1 OR HEM6.2):O | Yes ☐ No ☐ N/A ☐ |
| HEP13.10 | Non-triggered CQI feedback | 26.7.3 (Rules for HE sounding protocol sequences) | CFSTAofAP AND HEM6.3:O<br><br>CFAP AND (HEM6.1 OR HEM6.2):O | Yes ☐ No ☐ N/A ☐ |
| HEP14 | Midambles | 27.3.12.16 (Midambles) | CFHE:O | Yes ☐ No ☐ N/A ☐ |
| HEP15 | HE-SIG-B field | 27.3.11.8 (HE-SIG-B field) | | |
| HEP15.1 | HE-MCSs 0 to 5 for the HE-SIG-B field | 27.3.11.8 (HE-SIG-B field) | CFHE:M | Yes ☐ No ☐ N/A ☐ |
| HEP15.2 | Greater than 16 HE-SIG-B OFDM symbols | 27.3.11.8 (HE-SIG-B field) | CFHE:O | Yes ☐ No ☐ N/A ☐ |
| HEP16 | Spatial reuse | | | |
| HEP16.1 | PSR-based SR support | 26.10.3 (PSR-based spatial reuse operation) | CFHE:O | Yes ☐ No ☐ N/A ☐ |
| HEP16.2 | OBSS PD-based spatial reuse operation | 26.10.2 (OBSS PD-based spatial reuse operation) | CFHE:O | Yes ☐ No ☐ N/A ☐ |

## B.4.34 Enhanced directional multi-gigabit (EDMG) features(11ay)

### B.4.34.1 EDMG MAC features

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| | Are the following MAC protocol features supported? | | | |
| EDMG-M1 | EDMG capabilities signaling | | | |
| EDMG-M1.1 | EDMG Capabilities element | 9.4.2.264 (EDMG Capabilities element(11ay)) | CFEDMG:M | Yes ☐ No ☐ N/A ☐ |

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### B.4.34.1 EDMG MAC features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| EDMG-M1.2 | Signaling of STA capabilities in Probe Request, (Re)Association Request frames | 9.3.3.5 (Association Request frame format), 9.3.3.7 (Reassociation Request frame format), 9.3.3.9 (Probe Request frame format), 9.4.2.264 (EDMG Capabilities element(11ay)) | (CFEDMG AND (CFSTAofAP OR CFIBSS OR CFPBSSnotPCP)):M | Yes ☐ No ☐ N/A ☐ |
| EDMG-M1.3 | Signaling of STA capabilities in Probe Response, (Re)Association Response frames | 9.3.3.6 (Association Response frame format), 9.3.3.8 (Reassociation Response frame format), 9.3.3.10 (Probe Response frame format), 9.4.2.264 (EDMG Capabilities element(11ay)) | (CFEDMG AND (CFAP OR CFPCP)):M | Yes ☐ No ☐ N/A ☐ |
| EDMG-M.2 | Signaling of EDMG Capabilities, EDMG Operation | 9.4.2.264 (EDMG Capabilities element(11ay)), 9.4.2.264.1 (General) | (CFEDMG AND (CFAP OR CFPCP)):M | Yes ☐ No ☐ N/A ☐ |
| EDMG-M3 | MPDU aggregation | | | |
| EDMG-M3.1 | Maximum A-MPDU Length Exponent | 9.4.2.264.1 (General) | CFEDMG: M | Yes ☐ No ☐ N/A ☐ |
| EDMG-M3.2 | Negotiation of window sizes: 64; 128; 256; 512; 1024 | 9.4.2.264.1 (General) | CFEDMG: M | Yes ☐ No ☐ N/A ☐ |
| EDMG-M3.3 | A-MPDU with multiple TIDs | 9.3.1.7.4 (Multi-TID BlockAckReq variant(#6599)), 9.3.1.8.8 (EDMG Multi-TID BlockAck variant(11ay)), 10.25.5 (Selection of BlockAck and BlockAckReq variants), 10.70 (EDMG A-MPDU with multiple TIDs(11ay)) | CFEDMG: O | Yes ☐ No ☐ N/A ☐ |
| EDMG-M4 | EDMG flow control | | | |


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### B.4.34.1 EDMG MAC features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| EDMG-M4.1 | Flow control operation | 10.25 (Block acknowledgment (block ack)) | CFEDMG:M | Yes ☐ No ☐ N/A ☐ |
| EDMG-M4.2 | EDMG Flow Control Extension Configuration element | | | |
| EDMG-M4.2.1 | RBUFCAP values: 0, FF | 9.4.2.276 (EDMG Flow Control Extension Configuration element(11ay)) | CFEDMG: M | Yes ☐ No ☐ N/A ☐ |
| EDMG-M4.2.2 | RBUFCAP values: 1 – FE | 9.4.2.276 (EDMG Flow Control Extension Configuration element(11ay)) | CFEDMG: O | Yes ☐ No ☐ N/A ☐ |
| EDMG-M4.2.3 | Recipient Memory Configuration subelement | 9.4.2.276 (EDMG Flow Control Extension Configuration element(11ay)) | CFEDMG:O | Yes ☐ No ☐ N/A ☐ |
| EDMG-M4.2.4 | Advanced Recipient Memory Length Exponent | 9.4.2.276 (EDMG Flow Control Extension Configuration element(11ay)) | CFEDMG:O | Yes ☐ No ☐ N/A ☐ |
| EDMG-M5 | EDMG spatial stream feedback | 10.42.4 (EDMG spatial stream feedback(11ay)) | EDMG-M9.1:O EDMG-M9.2:O | Yes ☐ No ☐ N/A ☐ |
| EDMG-M6 | Directional allocation | 10.38.12.3 (Directional allocation) | CFEDMG: O EDMG-M16.4:M | Yes ☐ No ☐ N/A ☐ |
| EDMG-M7 | EDMG AP or EDMG PCP distributed scheduling | 10.68 (EDMG AP or EDMG PCP distributed scheduling protocol operation(11ay)) | CFEDMG:O | Yes ☐ No ☐ N/A ☐ |
| EDMG-M8 | Use of multiple channels | | | |
| EDMG-M8.1 | CCA on the primary, secondary channels | 8.3.5.12 (PHY-CCA.indication) | CFEDMG: M | Yes ☐ No ☐ N/A ☐ |
| EDMG-M8.2 | CCA on secondary1 channels | 8.3.5.12 (PHY-CCA.indication), 9.4.2.264.5 (Supported Channels subelement) | EDMG-P2.3 OR EDMG-P2.6:M | Yes ☐ No ☐ N/A ☐ |

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### B.4.34.1 EDMG MAC features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| EDMG-M8.3 | CCA on secondary2 channels | 8.3.5.12 (PHY-CCA.indication), 9.4.2.264.5 (Supported Channels subelement) | EDMG-P2.4 OR EDMG-P2.6:M | Yes ☐ No ☐ N/A ☐ |
| (M118)EDMG-M8.4 | RTS, DMG CTS, DMG DTS, Ack, Block Ack duplicate transmission | 10.3.2 (Procedures common to the DCF and EDCAF) | CFEDMG: M | Yes ☐ No ☐ N/A ☐ |
| (M118)EDMG-M8.5 | RTS, DMG CTS, DMG DTS bandwidth signaling | 10.3.2 (Procedures common to the DCF and EDCAF), 10.38.12.2 (Channel access over multiple channels) | CFEDMG: M | Yes ☐ No ☐ N/A ☐ |
| EDMG-M9 | MIMO | | | |
| *EDMG-M9.1 | SU-MIMO capable | 9.4.2.264.2 (Beamforming Capability subelement), 10.38.12.4.2 (MIMO channel access rules) | CFEDMG: O | Yes ☐ No ☐ N/A ☐ |
| *EDMG-M9.2 | MU-MIMO capable | 9.4.2.264.2 (Beamforming Capability subelement) | CFEDMG: O | Yes ☐ No ☐ N/A ☐ |
| EDMG-M9.3 | SU-MIMO channel access | 10.38.12.4.2 (MIMO channel access rules), 10.38.12.4.4 (MU-MIMO channel access procedure) | EDMG-M9.1:M | Yes ☐ No ☐ N/A ☐ |
| EDMG-M9.4 | MU-MIMO channel access | 10.38.12.4.2 (MIMO channel access rules), 10.38.12.4.4 (MU-MIMO channel access procedure) | EDMG-M9.2:M | Yes ☐ No ☐ N/A ☐ |
| EDMG-M10 | EDMG A-PPDU format | 10.13 (PPDU duration constraint), 28.3.2.2 (EDMG A-PPDU format) | CFEDMG: O | Yes ☐ No ☐ N/A ☐ |


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### B.4.34.1 EDMG MAC features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| EDMG-M11 | EDMG phase hopping | 10.67 (EDMG phase hopping and open loop precoding operation(11ay)) | CFEDMG: O | Yes ☐ No ☐ N/A ☐ |
| EDMG-M12 | Unsolicited RSS | 10.41.6.2 (SLS phase execution) | CFEDMG: O | Yes ☐ No ☐ N/A ☐ |
| EDMG-M13 | EDMG Extended Schedule element | 9.4.2.266 (EDMG Extended Schedule element(11ay)) | (CFEDMG AND (CFSTAofAP OR CFIBSS OR CFPBSSnotPCP)):M | Yes ☐ No ☐ N/A ☐ |
| EDMG-M14 | EDMG power save enhancements | | | |
| EDMG-M14.1 | QoS Triggered unscheduled (QoS-TU) power save | 9.4.2.277 (QoS-TU element(#1776)(11ay)), 11.2.7.2 (Non-AP and non-PCP STA power management mode) | (CFEDMG AND (CFAP OR CFPCP)):M | Yes ☐ No ☐ N/A ☐ |
| EDMG-M14.2 | Spatial multiplexing power save | 11.2.7.2 (Non-AP and non-PCP STA power management mode) | EDMG-M9.1: M | Yes ☐ No ☐ N/A ☐ |
| EDMG-M14.3 | MU-MIMO power save | 11.2.7.5 (MU-MIMO power save(11ay)) | EDMG-M9.2: M | Yes ☐ No ☐ N/A ☐ |
| EDMG-M15 | Reverse direction protocol | | | |
| EDMG-M15.1 | Reverse direction for SU-SISO | 10.29 (Reverse direction protocol) | (CFEDMG AND DMG-M7): M | Yes ☐ No ☐ N/A ☐ |
| EDMG-M15.2 | Reverse direction for SU-MIMO | 10.29 (Reverse direction protocol) | (EDMG-M9.1 AND DMG-M7): M | Yes ☐ No ☐ N/A ☐ |
| EDMG-M15.3 | Reverse direction for MU-MIMO | 10.29.5 (Reverse direction for EDMG DL MU-MIMO(11ay)) | (EDMG-M9.2 AND DMG-M7): M | Yes ☐ No ☐ N/A ☐ |
| EDMG-M15.4 | Scheduled reverse direction | | EDMG-M15.3: M | Yes ☐ No ☐ N/A ☐ |
| EDMG-M16 | EDMG beamforming | | | |
| EDMG-M16.1 | SU-MIMO beamforming | 10.41.10.2.2 (SU-MIMO beamforming) | EDMG-M9.1: M | Yes ☐ No ☐ N/A ☐ |
| EDMG-M16.2 | MU-MIMO beamforming | 10.41.10.2.3 (MU-MIMO beamforming) | EDMG-M9.2: M | Yes ☐ No ☐ N/A ☐ |

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### B.4.34.1 EDMG MAC features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| EDMG-M16.3 | Hybrid beamforming | 10.41.10.2.4 (Hybrid beamforming for SU-MIMO and MU-MIMO) | CFEDMG:O | Yes ☐ No ☐ N/A ☐ |
| *EDMG-M16.4 | Beamforming for asymmetric links | 10.41.10.3 (Beamforming for asymmetric links) | CFEDMG:O | Yes ☐ No ☐ N/A ☐ |
| EDMG-M16.5 | Group beamforming | 10.41.10.4 (Group beamforming) | CFEDMG:O | Yes ☐ No ☐ N/A ☐ |
| EDMG-M16.6 | BRP transmit sector sweep | 10.41.10.5 (BRP transmit sector sweep (BRP TXSS)) | CFEDMG:M | Yes ☐ No ☐ N/A ☐ |
| EDMG-M16.7 | First path beamforming | 10.41.10.6 (First path beamforming training) | CFEDMG:O | Yes ☐ No ☐ N/A ☐ |
| EDMG-M16.8 | Partial sector level sweep | 10.41.6.4 (BRP phase execution), 11.27.1 (Beamformed link maintenance) | CFEDMG:O | Yes ☐ No ☐ N/A ☐ |
| *EDMG-M16.9 | DMG TRN RX only capable | 9.4.2.264 (EDMG Capabilities element(11ay)) | CFEDMG:O | Yes ☐ No ☐ N/A ☐ |
| EDMG-M16.10 | Dual polarization TRN beamforming training | 10.41.10.7 (Dual polarization TRN beamforming training) | CFEDMG:O | Yes ☐ No ☐ N/A ☐ |

### B.4.34.2 EDMG PHY features

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| | Are the following PHY protocol features supported? | | | |
| EDMG-P1 | PHY operating modes | | | |
| EDMG-P1.1 | Operation according to Clause 28(#1188) | Clause 28 (Enhanced directional multi-gigabit (EDMG) PHY specification(11ay)) | CFEDMG:M | Yes ☐ No ☐ N/A ☐ |


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### B.4.34.2 EDMG PHY features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| EDMG-P2 | Channel bandwidth | | | |
| EDMG-P2.1 | 2.16 GHz | 28.3.4 (Channelization) | CFEDMG:M | Yes ☐ No ☐ N/A ☐ |
| EDMG-P2.2 | 4.32 GHz | 28.3.4 (Channelization) | CFEDMG:M | Yes ☐ No ☐ N/A ☐ |
| *EDMG-P2.3 | 6.48 GHz | 28.3.4 (Channelization) | CFEDMG:O | Yes ☐ No ☐ N/A ☐ |
| *EDMG-P2.4 | 8.64 GHz | 28.3.4 (Channelization) | CFEDMG:O | Yes ☐ No ☐ N/A ☐ |
| EDMG-P2.5 | 2.16+2.16 GHz | 28.3.4 (Channelization) | CFEDMG:O | Yes ☐ No ☐ N/A ☐ |
| *EDMG-P2.6 | 4.32+4.32 GHz | 28.3.4 (Channelization) | CFEDMG:O | Yes ☐ No ☐ N/A ☐ |
| EDMG-P3 | Channelization | | | |
| EDMG-P3.1 | Channels 2 and 10 | 28.3.4 (Channelization) | CFEDMG:M | Yes ☐ No ☐ N/A ☐ |
| EDMG-P3.2 | Other channels | 28.3.4 (Channelization) | CFEDMG:O | Yes ☐ No ☐ N/A ☐ |
| EDMG-P4 | PHY capabilities | | | |
| EDMG-P4.1 | SU-SISO | 28.5.10.4.2 (EDMG PPDU transmission over a 2.16 GHz or 2.16+2.16 GHz channel with NSTS = 1), 28.5.10.4.3 (EDMG PPDU transmission with DMG AGC and TRN fields over a 2.16 GHz channel with NSTS = 1)(#2295) | CFEDMG:M | Yes ☐ No ☐ N/A ☐ |

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### B.4.34.2 EDMG PHY features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| EDMG-P4.2 | SU-MIMO | 28.5.10.4.4 (EDMG PPDU transmission over a 2.16 GHz or 2.16+2.16 GHz channel with NSTS > 1 and 4.32 GHz, 6.48 GHz, 8.64 GHz or 4.32+4.32 GHz channel with NSTS ≥ 1)(#2295) | EDMG-M9.1:M | Yes ☐ No ☐ N/A ☐ |
| EDMG-P4.3 | MU-MIMO | 28.5.10.5 (EDMG MU PPDU transmission)(#2295) | EDMG-M9.2:M | Yes ☐ No ☐ N/A ☐ |
| EDMG-P4.4 | (M118)Support of one spatial stream (transmit and receive) in all supported channel bandwidth configurations | 28.5.1 (General)(#2295) | CFEDMG:M | Yes ☐ No ☐ N/A ☐ |
| EDMG-P4.5 | Support of 2 through 8 spatial streams (transmit and receive) in all supported channel bandwidth configurations | | CFEDMG:O | Yes ☐ No ☐ N/A ☐ |
| EDMG-P5 | PHY frame format | | | |
| EDMG-P5.1 | EDMG preamble | 28.3.3 (EDMG preamble) | | |
| EDMG-P5.1.1 | Non-EDMG portion of EDMG preamble | 28.3.3.2 (Non-EDMG portion of EDMG format preamble) | | |
| EDMG-P5.1.1.1 | L-STF | 28.3.3.2.2 (L-STF definition) | CFEDMG:M | Yes ☐ No ☐ N/A ☐ |
| EDMG-P5.1.1.2 | L-CEF | 28.3.3.2.3 (L-CEF definition) | CFEDMG:M | Yes ☐ No ☐ N/A ☐ |
| EDMG-P5.1.1.3 | L-Header | 28.3.3.2.4 (L-Header definition) | CFEDMG:M | Yes ☐ No ☐ N/A ☐ |
| EDMG-P5.1.2 | EDMG portion of EDMG preamble | 28.3.3.3 (EDMG portion of EDMG format preamble) | | |
| EDMG-P5.1.2.1 | EDMG-Header-A | 28.3.3.3.2 (EDMG-Header-A definition) | CFEDMG:M | Yes ☐ No ☐ N/A ☐ |


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### B.4.34.2 EDMG PHY features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| EDMG-P5.1.2.2 | EDMG-STF | 28.3.3.3.3 (EDMG-STF definition) | EDMG-P2.2 OR EDMG-P2.3 OR EDMG-P2.4 OR EDMG-P2.6:M | Yes ☐ No ☐ N/A ☐ |
| EDMG-P5.1.2.3 | EDMG-CEF | 28.3.3.3.4 (EDMG-CEF definition) | EDMG-P2.2 OR EDMG-P2.3 OR EDMG-P2.4 OR EDMG-P2.6:M | Yes ☐ No ☐ N/A ☐ |
| EDMG-P5.1.2.4 | EDMG-Header-B | 28.3.3.3.5 (EDMG-Header-B definition) | EDMG-P4.3:M | Yes ☐ No ☐ N/A ☐ |
| EDMG-P5.2 | EDMG control mode PPDU | | | |
| EDMG-P5.2.1 | MCS 0 | 28.4 (EDMG and non-EDMG control mode) | CFEDMG:M | Yes ☐ No ☐ N/A ☐ |
| EDMG-P5.2.2 | Non-EDMG duplicate MCS 0 | 28.4.7.2 (Non-EDMG PPDU transmission) | EDMG-P2.2 OR EDMG-P2.3 OR EDMG-P2.4 OR EDMG-P2.5 OR EDMG-P2.6:M | Yes ☐ No ☐ N/A ☐ |
| EDMG-P5.2.3 | Control mode | 28.3.3.2.4 (L-Header definition) | | |
| EDMG-P5.2.3.1 | Control trailer | 28.3.7 (Control trailer), 10.38.12.5 (Control trailer) | CFEDMG:O (EDMG-M9.1 OR EDMG-M9.2):M | Yes ☐ No ☐ N/A ☐ |
| EDMG-P5.2.3.2 | EDMG-Header-A, MCS 0 | 28.3.3.3 (EDMG portion of EDMG format preamble) | CFEDMG:M | Yes ☐ No ☐ N/A ☐ |
| EDMG-P5.2.3.3 | Channel bandwidth signaling in L-Header | 28.3.3.2.4 (L-Header definition) | CFEDMG:M | Yes ☐ No ☐ N/A ☐ |
| EDMG-P5.3 | EDMG SC mode PPDU | 28.5 (EDMG and non-EDMG SC mode) | | |
| EDMG-P5.3.1 | MCSs | 28.5.8 (Modulation and coding scheme (MCS)) | | |
| EDMG-P5.3.1.1 | MCS 1–5, 7–10 | | CFEDMG:M | Yes ☐ No ☐ N/A ☐ |

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### B.4.34.2 EDMG PHY features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| EDMG-P5.3.1.2 | MCS 6, 11–21 | | CFEDMG:O | Yes ☐ No ☐ N/A ☐ |
| EDMG-P5.3.1.3 | (M118)π /2-8-PSK MCS 12, 13 | | CFEDMG:O | Yes ☐ No ☐ N/A ☐ |
| EDMG-P5.3.1.4 | (M118)NUC π /2-64-QAM MCS 17–21 | | CFEDMG:O | Yes ☐ No ☐ N/A ☐ |
| EDMG-P5.3.2 | Non-EDMG duplicate MCS | 28.5.10.3 (Non-EDMG PPDU transmission) | | |
| EDMG-P5.3.2.1 | MCS 1–4 | | CFEDMG:M | Yes ☐ No ☐ N/A ☐ |
| EDMG-P5.3.2.2 | Other MCSs | | CFEDMG:O | Yes ☐ No ☐ N/A ☐ |
| EDMG-P5.3.3 | Guard interval | 28.5.9.1 (Guard interval definition) | | |
| EDMG-P5.3.3.1 | Short | | CFEDMG:O | Yes ☐ No ☐ N/A ☐ |
| EDMG-P5.3.3.2 | Normal | | CFEDMG:M | Yes ☐ No ☐ N/A ☐ |
| EDMG-P5.3.3.3 | Long | | CFEDMG:O | Yes ☐ No ☐ N/A ☐ |
| EDMG-P5.3.4 | STBC | 28.5.9.5.4 (Space-time block coding (STBC)) | CFEDMG:O | Yes ☐ No ☐ N/A ☐ |
| EDMG-P5.4 | EDMG OFDM mode PPDU | 28.6 (EDMG OFDM mode) | EDMG-P1.1:O | Yes ☐ No ☐ N/A ☐ |
| EDMG-P5.4.1 | MCSs | 28.6.8 (Modulation and coding scheme (MCS))(#2296) | | |
| EDMG-P5.4.1.1 | MCS 1–20 | 28.6.9.3 (Modulation mapping)(#2296) | EDMG-P5.4:O | Yes ☐ No ☐ N/A ☐ |
| EDMG-P5.4.2 | Guard Interval | 28.6.2.2 (Timing related parameters) | | |
| EDMG-P5.4.2.1 | Short | | EDMG-P5.4:O | Yes ☐ No ☐ N/A ☐ |
| EDMG-P5.4.2.2 | Normal | | EDMG-P5.4:M | Yes ☐ No ☐ N/A ☐ |
| EDMG-P5.4.2.3 | Long | | EDMG-P5.4:O | Yes ☐ No ☐ N/A ☐ |
| EDMG-P5.4.3 | STBC | 28.6.9.3.10 (Space-time block coding) | EDMG-P5.4:O | Yes ☐ No ☐ N/A ☐ |


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### B.4.34.2 EDMG PHY features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| EDMG-P5.4.4 | Phase hopping | 28.6.9.3.8 (Phase hopping modulation) | | |
| EDMG-P5.4.4.1 | Open Loop Spatial Multiplexing | | EDMG-P5.4:O | Yes ☐ No ☐ N/A ☐ |
| EDMG-P5.4.4.2 | Phase hopping | | EDMG-P5.4:O | Yes ☐ No ☐ N/A ☐ |
| EDMG-P5.5 | EDMG A-PPDU | 28.3.2.2 (EDMG A-PPDU format) | EDMG-P5.3:O EDMG-P5.4:O | Yes ☐ No ☐ N/A ☐ |
| EDMG-P6 | EDMG beamforming | 28.9 (EDMG beamforming) | | |
| EDMG-P6.1 | Short SSW | 28.9.1 (Short SSW PPDU) | CFEDMG:M | Yes ☐ No ☐ N/A ☐ |
| EDMG-P6.2 | Beam refinement | 28.9.2 (Beam refinement) | | |
| EDMG-P6.2.1 | EDMG BRP PPDU (TRN fields) | 28.9.2.2 (EDMG BRP PPDU) | CFEDMG AND (NOT EDMG-M16.9):M | |
| EDMG-P6.2.1.1 | TRN P / TRN M / TRN N | 28.9.2.2.3 (EDMG BRP PPDU Header field(#6409)) | | |
| EDMG-P6.2.1.1.1 | P=2, M=5, N=2 | | EDMG-P6.2.1:M | Yes ☐ No ☐ N/A ☐ |
| EDMG-P6.2.1.1.2 | P=2, M=7, N=0 | | EDMG-P6.2.1:M | Yes ☐ No ☐ N/A ☐ |
| EDMG-P6.2.1.1.3 | P=0, M=2/5/8/11, N=2 | | EDMG-P6.2.1:M | Yes ☐ No ☐ N/A ☐ |
| EDMG-P6.2.1.1.4 | P=0, M=0-15, N=0 | | EDMG-P6.2.1:M | Yes ☐ No ☐ N/A ☐ |
| EDMG-P6.2.1.1.5 | All other valid combinations of P, M, N | | EDMG-P6.2.1:O | Yes ☐ No ☐ N/A ☐ |
| EDMG-P6.2.1.2 | TRN Subfield Sequence | 28.9.2.2.6 (TRN subfield definition for EDMG SC PPDUs and EDMG control mode PPDUs) | | |
| EDMG-P6.2.1.2.1 | $0 = 128 \times N_{CB}$ | | | |
| EDMG-P6.2.1.2.1.1 | $N_{CB} = 1$ or 2 | | CFEDMG:M | Yes ☐ No ☐ N/A ☐ |
| EDMG-P6.2.1.2.1.2 | $N_{CB} = 3$ or 4 | | CFEDMG:O | Yes ☐ No ☐ N/A ☐ |
| EDMG-P6.2.1.2.2 | $1 = 256 \times N_{CB}$ | | CFEDMG:O | Yes ☐ No ☐ N/A ☐ |

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### B.4.34.2 EDMG PHY features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| EDMG-P6.2.1.2.3 | 2 = 64×$N_{CB}$ | | CFEDMG:O | Yes ☐ No ☐ N/A ☐ |
| EDMG-P6.2.2 | Channel measurement | 28.9.2.2.8 (Channel measurement) | CFEDMG:O | Yes ☐ No ☐ N/A ☐ |
| EDMG-P6.2.3 | DMG AGC and TRN support over 2.16 GHz channel | | | |
| EDMG-P6.2.3.1 | Transmission | 20.9.2.2.2 (BRP PPDU structure) | CFEDMG:M | Yes ☐ No ☐ N/A ☐ |
| EDMG-P6.2.3.2 | Reception | 20.9.2.2.2 (BRP PPDU structure) | CFEDMG:O | Yes ☐ No ☐ N/A ☐ |
| EDMG-P7 | LDPC | | | |
| EDMG-P7.1 | Codeword = 672, *R* = 1/2, 5/8, 3/4, 13/16 | 20.3.8 (Common LDPC parity matrices) | EDMG-P5.3 OR EDMG-P5.4:M | Yes ☐ No ☐ N/A ☐ |
| EDMG-P7.2 | Codeword = 624, *R* = 7/8 punctured | 28.5.9.4.3 (LDPC encoding), 28.6.9.2.3 (LDPC encoding) | EDMG-P5.3 OR EDMG-P5.4:O EDMG-P7.3:M | Yes ☐ No ☐ N/A ☐ |
| EDMG-P7.3 | Codeword = 672, *R* = 7/8 superimposed | 28.3.6 (LDPC parity matrices) | EDMG-P5.3 OR EDMG-P5.4:O | Yes ☐ No ☐ N/A ☐ |
| EDMG-P7.4 | Codeword = 1344, *R* = 1/2, 5/8, 3/4, 13/16 | 28.3.6 (LDPC parity matrices) | EDMG-P5.3 OR EDMG-P5.4:O | Yes ☐ No ☐ N/A ☐ |
| EDMG-P7.5 | Codeword = 1248, *R* = 7/8 punctured | 28.5.9.4.3 (LDPC encoding), 28.6.9.2.3 (LDPC encoding) | EDMG-P5.3 OR EDMG-P5.4:O EDMG-P7.6:M | Yes ☐ No ☐ N/A ☐ |
| EDMG-P7.6 | Codeword = 1344, *R* = 7/8 superimposed | 28.3.6 (LDPC parity matrices) | EDMG-P5.3 OR EDMG-P5.4:O | Yes ☐ No ☐ N/A ☐ |


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## B.4.35 Time division duplex (TDD) features(11ay)

| Item | Protocol capability(#1189) | References | Status | Support |
|---|---|---|---|---|
| | Are the following TDD protocol features supported? | | | |
| TDD-M1 | TDD capabilities signaling | | | |
| TDD-M1.1 | DMG Capabilities element | 9.4.2.126 (DMG Capabilities element) | CFTDD:M | Yes ☐ No ☐ N/A ☐ |
| TDD-M1.2 | Signaling of STA capabilities in Probe Request, (Re)Association Request frames | 9.3.3.5 (Association Request frame format), 9.3.3.7 (Reassociation Request frame format), 9.3.3.9 (Probe Request frame format), 9.4.2.126 (DMG Capabilities element) | (CFTDD AND (CFSTAofAP OR CFIBSS OR CFPBSSnotPCP)):M | Yes ☐ No ☐ N/A ☐ |
| TDD-M1.3 | Signaling of STA capabilities in Probe Response, (Re)Association Response frames | 9.3.3.6 (Association Response frame format), 9.3.3.8 (Reassociation Response frame format), 9.3.3.10 (Probe Response frame format), 9.4.2.126 (DMG Capabilities element) | (CFTDD AND (CFAP OR CFPCP)):M | Yes ☐ No ☐ N/A ☐ |
| TDD-M.2 | TDD channel access | | | |
| TDD-M.2.1 | SP with TDD channel access | 10.38.6.2.1 (General(11ay)) 10.38.6.2.2 (SP with TDD channel access(11ay)), 9.4.2.280 (TDD Slot Structure element(11ay)), 9.4.2.281 (TDD Slot Schedule element(11ay)) | CFTDD:M | Yes ☐ No ☐ N/A ☐ |

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## B.4.35 Time division duplex (TDD) features(11ay) *(continued)*

| Item | Protocol capability(#1189) | References | Status | Support |
|---|---|---|---|---|
| TDD-M.2.2 | BlockAck procedure within a TDD SP | 10.25.6.5 (Generation and transmission of BlockAck frames by an HT STA, DMG STA, or S1G STA) | CFTDD:M | Yes ☐ No ☐ N/A ☐ |
| TDD-M.2.3 | Acknowledgment procedure within a TDD SP | 10.3.2.11 (Acknowledgment procedure) | CFTDD:M | Yes ☐ No ☐ N/A ☐ |
| TDD-M.2.4 | Beacon generation under TDD channel access | 11.1.3.3.4 (Beacon generation under TDD channel access(11ay)) | CFTDD:O | Yes ☐ No ☐ N/A ☐ |
| TDD-M.2.5 | Directional Transmit Activity Report frames transmission | 11.30.5 (Directional transmit activity report(11ay)) | CFTDD:M | Yes ☐ No ☐ N/A ☐ |
| TDD-M3 | MIMO | | | |
| *TDD-M3.1 | SU-MIMO capable | 9.4.2.264.2 (Beamforming Capability subelement) | CFTDD AND CFEDMG: O(#1190) | Yes ☐ No ☐ N/A ☐ |
| TDD-M3.2 | SU-MIMO channel access in a TDD slot(#1190) | 10.38.12.4.2 (MIMO channel access rules), 10.38.12.4.3 (SU-MIMO channel access procedure) | TDD-M3.1:M | Yes ☐ No ☐ N/A ☐ |
| TDD-M4 | TDD beamforming features | | | |
| TDD-M4.1 | TDD beamforming | 10.41.11 (TDD beamforming(11ay)) | CFTDD:M | Yes ☐ No ☐ N/A ☐ |
| TDD-M4.2 | SU-MIMO beamforming | 10.41.10.2.2 (SU-MIMO beamforming) | TDD-M3.1:M | Yes ☐ No ☐ N/A ☐ |


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## B.4.36 Wake-up Radio (WUR) features(11ba)

### B.4.36.1 WUR MAC features

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| | Are the following MAC protocol features supported? | | | |
| WURM1 | WUR capabilities signaling | | CFWUR:M | Yes ☐ No ☐ N/A ☐ |
| WURM1.1 | WUR Capabilities element | 9.4.2.290 (WUR Capabilities element(11ba)) | CFWUR:M | Yes ☐ No ☐ N/A ☐ |
| WURM1.2 | Signaling of STA capabilities in Probe Request, (Re)Association Request frames | 9.3.3.5 (Association Request frame format), 9.3.3.7 (Reassociation Request frame format), 9.3.3.9 (Probe Request frame format), 9.4.2.290 (WUR Capabilities element(11ba)) | (CFWUR AND CFSTAoffAP):M | Yes ☐ No ☐ N/A ☐ |
| WURM1.3 | Signaling of STA and BSS capabilities in Beacon, Probe Response, (Re)Association Response frames | 9.3.3.2 (Beacon frame format), 9.3.3.6 (Association Response frame format), 9.3.3.8 (Reassociation Response frame format), 9.3.3.10 (Probe Response frame format), 9.4.2.290 (WUR Capabilities element(11ba)) | (CFWUR AND CFAP):M | Yes ☐ No ☐ N/A ☐ |
| WURM2 | Signaling of WUR operation | 9.4.2.291 (WUR Operation element(11ba)) | (CFWUR AND CFAP):M | Yes ☐ No ☐ N/A ☐ |

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### B.4.36.1 WUR MAC features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| WURM2.1 | Signaling of WUR operation in Beacon, Probe Response, (Re)Association Response frames | 9.3.3.2 (Beacon frame format), 9.3.3.6 (Association Response frame format), 9.3.3.8 (Reassociation Response frame format), 9.3.3.10 (Probe Response frame format), 9.4.2.291 (WUR Operation element(11ba)) | (CFWUR AND CFAP):M | Yes ☐ No ☐ N/A ☐ |
| WURM3 | Signaling of WUR mode | 9.4.2.292 (WUR Mode element(11ba)) | CFWUR:M | |
| WURM3.1 | Signaling of WUR mode in WUR Mode Setup, WUR Mode Teardown | 9.6.33.2 (WUR Mode Setup frame format), 9.6.33.3 (WUR Mode Teardown frame format), 9.4.2.292 (WUR Mode element(11ba)) | CFWUR:M | Yes ☐ No ☐ N/A ☐ |
| WURM4 | WUR duty cycle operation | 29.7 (WUR duty cycle operation) | CFWUR:O | Yes ☐ No ☐ N/A ☐ |
| WURM5 | WUR mode setup in WUR power management procedure | 29.8.2 (WUR mode setup) | CFWUR:M | Yes ☐ No ☐ N/A ☐ |
| WURM6 | WUR non-AP STA operation in WUR power management procedure | 29.8.4 (WUR power management operation for a WUR non-AP STA) | (CFWUR AND CFSTAoFAP):M | Yes ☐ No ☐ N/A ☐ |
| WURM7 | WUR AP operation in WUR power management procedure | 29.9 (Wake-up operation) | (CFWUR AND CFAP):M | Yes ☐ No ☐ N/A ☐ |
| WURM8 | Wake-up operation | 29.9 (Wake-up operation) | CFWUR:M | Yes ☐ No ☐ N/A ☐ |
| WURM8.1 | Wake-up operation with a WUR Wake-up frame with a WUR group ID | 29.9 (Wake-up operation) | CFWUR:O | Yes ☐ No ☐ N/A ☐ |
| WURM9 | Protected WUR frames | 29.10 (WUR frame protection) | CFWUR:O | Yes ☐ No ☐ N/A ☐ |


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### B.4.36.1 WUR MAC features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| WURM9.1 | (M118)WUR PN update procedure | 9.4.2.294 (WUR PN Update element(11ba)), 29.10.4.3 (WUR PN update procedure) | (CFWUR (#4138)AND WURM9):O | Yes ☐ No ☐ N/A ☐ |
| WURM10 | WUR FDMA operation | 29.11 (WUR FDMA operation) | CFWUR:O | Yes ☐ No ☐ N/A ☐ |
| WURM11 | (M118)WUR discovery | 29.12 (WUR discovery) | CFWUR:O | Yes ☐ No ☐ N/A ☐ |
| WURM12 | WUR Short Wake-up frame operation | 29.9.2 (WUR Short Wake-up frame operation) | CFWUR:O | Yes ☐ No ☐ N/A ☐ |

### B.4.36.2 WUR PHY features

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| | Are the following PHY protocol features supported? | | | |
| WURP1 | PHY operating modes | | | |
| WURP1.1 | Operation according to Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) | 30.1 (Introduction) | CFWUR:M | Yes ☐ No ☐ N/A ☐ |
| WURP2 | WUR PPDU format | | | |
| WURP2.1 | WUR PPDU with 20 MHz channel width, WUR LDR, and single stream | 30.1 (Introduction), 30.3.2 (WUR Basic PPDU format) | CFWUR:M | Yes ☐ No ☐ N/A ☐ |
| WURP2.2 | WUR preamble | 30.3.9 (WUR preamble) | CFWUR:M | Yes ☐ No ☐ N/A ☐ |
| WURP2.3 | WUR-Data field | 30.3.10 (WUR-Data field) | CFWUR:M | Yes ☐ No ☐ N/A ☐ |
| WURP2.4 | WUR PPDU with WUR HDR | 30.1 (Introduction), 30.3.2 (WUR Basic PPDU format) | (CFWUR AND CFAP):M<br><br>(CFWUR AND CFSTAo-fAP):O | Yes ☐ No ☐ N/A ☐ |

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### B.4.36.2 WUR PHY features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| WURP3 | WUR FDMA PPDU | 30.1 (Introduction), 30.3.3 (WUR FDMA PPDU format) | CFWUR:O | Yes ☐ No ☐ N/A ☐ |
| WURP4 | WUR encoding for the Data field | 30.3.10.2 (WUR-Data field for WUR LDR and WUR HDR) | CFWUR:M | Yes ☐ No ☐ N/A ☐ |

## B.4.37 Enhanced positioning (Ranging) features(11az)

### B.4.37.1 EP MAC features

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| | Are the following MAC protocol features supported? | | | |
| EP7 | Passive TB ranging operation | | | |
| EP7.1 | Passive TB ranging sequence | 11.21.6.4.8 (Measurement exchange in passive TB ranging mode(11az)) | CFPTB:M CFHE:O | Yes ☐ No ☐ N/A ☐ |
| EPM1 | EP capability signaling | | | |
| EPM1.1 | EP FTM support advertisement | 11.21.6.2 (FTM capabilities), 11.21.6.3.1 (General) | (CFTB OR CFNTB):M | Yes ☐ No ☐ N/A ☐ |
| EPM1.2 | EP FTM capability negotiation | 11.21.6.3.1 (General) | (CFTB OR CFNTB):M | Yes ☐ No ☐ N/A ☐ |
| EPM1.3 | EP secured MAC operation negotiation | 12.13 (Preassociation security negotiation(11az)), 11.21.6.4.5 (Secure HE-LTF in the TB and non-TB ranging measurement exchange protocol(11az)) | CFPASN:M (CFTB OR CFNTB):M | Yes ☐ No ☐ N/A ☐ |
| EPM2 | TB ranging operation | | | |
| EPM2.1 | TB measurement sequence | 11.21.6.4.3 (TB ranging measurement exchange(11az)) | CFTB:M | Yes ☐ No ☐ N/A ☐ |


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### B.4.37.1 EP MAC features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| EPM2.2 | Protected LMR exchange in TB ranging exchange | 12.13 (Preassociation security negotiation(11az)), 11.21.6.4.5 (Secure HE-LTF in the TB and non-TB ranging measurement exchange protocol(11az)) | (CFTB AND CFPASN): M CFPSEC:M | Yes ☐ No ☐ N/A ☐ |
| EPM3 | MAC support of PHY security | | | |
| EPM3.1 | SAC exchange for TB operation | 12.13 (Preassociation security negotiation(11az)), 11.21.6.4.5 (Secure HE-LTF in the TB and non-TB ranging measurement exchange protocol(11az)) | CFTB:O CFPSEC:M | Yes ☐ No ☐ N/A ☐ |
| EPM4 | Non-TB ranging operation | | | |
| EPM4.1 | non-TB ranging exchange | 11.21.6.4.4 (Non-TB ranging measurement exchange(11az)) | CFNTB:M | Yes ☐ No ☐ N/A ☐ |
| EPM4.2 | Protected LMR exchange in non-TB ranging exchange | 12.13 (Preassociation security negotiation(11az)), 11.21.6.4.5 (Secure HE-LTF in the TB and non-TB ranging measurement exchange protocol(11az)) | (CFNTB AND CFPASN):M CFPSEC:M | Yes ☐ No ☐ N/A ☐ |
| EPM4.3 | SAC exchange for non-TB ranging operation | 12.13 (Preassociation security negotiation(11az)), 11.21.6.4.5 (Secure HE-LTF in the TB and non-TB ranging measurement exchange protocol(11az)) | CFNTB:O CFPSEC:M | Yes ☐ No ☐ N/A ☐ |
| EPM5 | EDMG/DMG operation | 11.21.6.4.2.2 (DMG general measurement exchange(11az)) | O | Yes ☐ No ☐ |

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### B.4.37.1 EP MAC features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| EPM5.1 | EDMG/DMG direction measurement as ISTA | 11.21.6.4.2.3 (DMG/EDMG AOA/AOD measurement exchange(11az)) | CFISTA: O | Yes ☐ No ☐ N/A ☐ |
| EPM5.2 | EDMG/DMG direction measurement as RSTA | 11.21.6.4.2.3 (DMG/EDMG AOA/AOD measurement exchange(11az)) | CFRSTA: O | Yes ☐ No ☐ N/A ☐ |
| EPM5.3 | EDMG FTM (#8113)with first arrival path as ISTA | 11.21.6.4.2.6 (DMG first path AWV for EDCA based ranging measurement exchange(11az)) | (CFISTA and EMDG-M16.7): M | Yes ☐ No ☐ N/A ☐ |
| EPM5.4 | EDMG FTM (#8113)with first arrival path as RSTA | 11.21.6.4.2.6 (DMG first path AWV for EDCA based ranging measurement exchange(11az)) | (CFRSTA and EMDG-M16.7): M | Yes ☐ No ☐ N/A ☐ |
| EPM5.5 | EDMG direction measurement with first arrival path as ISTA | 11.21.6.4.2.3 (DMG/EDMG AOA/AOD measurement exchange(11az)) | (CFISTA and EMDG-M16.7): O | Yes ☐ No ☐ N/A ☐ |
| EPM5.6 | EDMG direction measurement with first arrival path as RSTA | 11.21.6.4.2.3 (DMG/EDMG AOA/AOD measurement exchange(11az)) | (CFRSTA and EMDG-M16.7): O | Yes ☐ No ☐ N/A ☐ |
| EPM5.7 | EDMG LOS assessment as ISTA | 11.21.6.4.2.5 (DMG LOS assessment for EDCA based ranging measurement exchange(11az)) | (CFISTA and EMDG-M16.7 and EDMG-M16.10):O | Yes ☐ No ☐ N/A ☐ |
| EPM5.8 | EDMG LOS assessment as RSTA | 11.21.6.4.2.5 (DMG LOS assessment for EDCA based ranging measurement exchange(11az)) | (CFISTA and EMDG-M16.7 and EDMG-M16.10):O | Yes ☐ No ☐ N/A ☐ |
| EPM6 | Secure EDMG FTM operation | 11.21.6.4.8 (Measurement exchange in passive TB ranging mode(11az)) | (CFEDMG and (CFISTA or CFRSTA) and EPP4 and EPM1.3): | Yes ☐ No ☐ N/A ☐ |


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### B.4.37.2 EP PHY features

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| | Are the following PHY protocol features supported? | | | |
| EPP1 | EP TB and non-TB measurement exchange waveforms | 27.3 (HE PHY) | | |
| EPP1.1 | HE ranging NDP | 27.3.19.1 (HE Ranging NDP(11az)) | (CFTB OR CFNTB OR CFPTB):M | Yes ☐ No ☐ N/A ☐ |
| EPP1.2 | HE ranging NDP with secure HE-LTFs | 27.3.19.1 (HE Ranging NDP(11az)) | (CFTB OR CFNTB):M CFPASN:M CFPSEC:M | Yes ☐ No ☐ N/A ☐ |
| EPP1.3 | HE TB ranging NDP | 27.3.19.2 (HE TB Ranging NDP(11az)) | CFTB:M | Yes ☐ No ☐ N/A ☐ |
| EPP1.4 | HE TB ranging NDP with secure HE-LTFs | 27.3.19.2 (HE TB Ranging NDP(11az)) | CFPASN:M CFPSEC:M CFTB:M | Yes ☐ No ☐ N/A ☐ |
| EPP2 | MIMO operation | | | |

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### B.4.37.2 EP PHY features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| EPP2.1 | Multi transmit streams | 11.21.6.4.3 (TB ranging measurement exchange(11az)), 11.21.6.4.4 (Non-TB ranging measurement exchange(11az)) | (CFTB or CFNTB):M | Yes ☐ No ☐ N/A ☐ |
| EPP2.2 | Multi receive streams | 11.21.6.4.3 (TB ranging measurement exchange(11az)), 11.21.6.4.4 (Non-TB ranging measurement exchange(11az)) | (CFTB or CFNTB):M | Yes ☐ No ☐ N/A ☐ |
| EPP3 | EDMG frame formats | | | |
| EPP4 | Secure ranging EDMG TRN field | 28.9.3.5 (TRN field definition with Secure TRN subfields(11az)), 28.9.3.6 (Secure TRN subfield definition for EDMG secure ranging PPDU(11az)), 28.9.3.7 (Transmission of an EDMG secure ranging PPDU(11az)) | | Yes ☐ No ☐ N/A ☐ |

## B.4.38 NGV features(11bd)

### B.4.38.1 NGV MAC features

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| | Are the following MAC protocol features supported? | | | |
| NGVM1 | Operating band | | | |
| NGVM1.1 | NGV operation in the 5.9 GHz band | 31.2 (Operation in the 5.9 GHz band) | CFNGV:M | Yes ☐ No ☐ N/A ☐ |


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### B.4.38.1 NGV MAC features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| NGVM1.2 | NGV operation in the 60 GHz band | 31.3 (Operation in the 60 GHz band) | CFNGV60:M | Yes ☐ No ☐ N/A ☐ |
| NGVM2 | NGV fallback procedure | | | |
| NGVM2.1 | 20 MHz transmission fallback to 10 MHz | 31.2.2 (Channel access and transmission methods for 20 MHz OCB transmission) | CFNGV:O | Yes ☐ No ☐ N/A ☐ |
| NGVM3 | DMG operation | | | |
| NGVM3.1 | DMG OCB element | 9.4.2.310 (DMG OCB element(11bd)) | CFNGV60:M | Yes ☐ No ☐ N/A ☐ |
| NGVM3.2 | DMG beamforming outside the context of a BSS | 31.3.1 (DMG beamforming outside the context of a BSS) | CFNGV60:M | Yes ☐ No ☐ N/A ☐ |
| NGVM4 | NGV ranging | | | |
| NGVM4.1 | Support for NGV ranging | 31.4 (NGV ranging) | CFNGV:O | Yes ☐ No ☐ N/A ☐ |
| *NGVM4.2 | Support for NGV ranging in the 5.9 GHz frequency band | 31.4 (NGV ranging) | (CFNGV AND CFNTB):O | Yes ☐ No ☐ N/A ☐ |

### B.4.38.2 NGV PHY features

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| | Are the following PHY protocol features supported? | | | |
| NGVP1 | Operating bandwidth | | | |
| *NGVP1.1 | 10 MHz operation in the 5.9 GHz band | 32.5 (Parameters for NGV-MCSs) | CFNGV:M | Yes ☐ No ☐ N/A ☐ |
| *NGVP1.2 | 20 MHz operation in the 5.9 GHz band | 32.5 (Parameters for NGV-MCSs) | CFNGV:O | Yes ☐ No ☐ N/A ☐ |

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### B.4.38.2 NGV PHY features *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| NGVP2 | Modulation and coding schemes (MCS) | | | |
| NGVP2.1 | NGV-MCS with Index = 0–8, or 15 and 10 MHz and $N_{SS}$ = 1 | 32.5 (Parameters for NGV-MCSs) | NGVP1.1:M | Yes ☐ No ☐ N/A ☐ |
| NGVP2.2 | NGV-MCS with Index = 0–8 and 10 MHz and $N_{SS}$ = 2 | 32.5 (Parameters for NGV-MCSs) | NGVP1.1:O | Yes ☐ No ☐ N/A ☐ |
| NGVP2.3 | NGV-MCS with Index = 0–9, or 15 and 20 MHz and $N_{SS}$ = 1 | 32.5 (Parameters for NGV-MCSs) | NGVP1.2:M | Yes ☐ No ☐ N/A ☐ |
| NGVP2.4 | NGV-MCS with Index = 0–9 and 20 MHz and $N_{SS}$ = 2 | 32.5 (Parameters for NGV-MCSs) | NGVP1.2:O | Yes ☐ No ☐ N/A ☐ |
| NGVP3 | Transmit spectrum masks | | | |
| NGVP3.1 | Spectrum mask, Class A (10 MHz channel spacing) | D.2.3 (Transmit spectrum mask) | CFNGV:O | Yes ☐ No ☐ N/A ☐ |
| NGVP3.2 | Spectrum mask, Class B (10 MHz channel spacing) | D.2.3 (Transmit spectrum mask) | CFNGV:O | Yes ☐ No ☐ N/A ☐ |
| NGVP3.3 | Spectrum mask, Class C (10 MHz channel spacing) | D.2.3 (Transmit spectrum mask) | NGVP1.1:M | Yes ☐ No ☐ N/A ☐ |
| NGVP3.4 | Spectrum mask C2, Class C (20 MHz channel spacing) | D.2.3 (Transmit spectrum mask) | NGVP1.2:M | Yes ☐ No ☐ N/A ☐ |
| NGVP3.5 | Spectrum mask, Class D (10 MHz channel spacing) | D.2.3 (Transmit spectrum mask) | CFNGV:O | Yes ☐ No ☐ N/A ☐ |
| NGVP4 | NGV PPDU format | | | |
| NGVP4.1 | Midambles | 32.3 (NGV PHY) | CFNGV:M | Yes ☐ No ☐ N/A ☐ |
| NGVP4.2 | LDPC support | 32.3 (NGV PHY) | CFNGV:M | Yes ☐ No ☐ N/A ☐ |
| NGVP4.3 | NGV ranging NDP | 31.4 (NGV ranging) | NGVM4.2:M | Yes ☐ No ☐ N/A ☐ |


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### B.4.38.3 NGV extended MAC service features

| Item | Feature | References | Status | Support |
|---|---|---|---|---|
| | Are the following NGV extended MAC service features supported? | | | |
| NGVE1 | NGV extended MAC service features | | | |
| NGVE1.1 | NGV extended MAC service features-MLME; 5.9 GHz band (MLME-CANCELTX)(#7073) | 10.2.3.2 (HCF contention based channel access (EDCA)), 6.5.26 (Cancel transmissions of MSDUs(11bd)((#7067))(#7067) | | |
| NGVE1.2 | NGV extended MAC service features—MLME; DMG (MLME-DMG-OCB-START, MLME-DMG-OCB-STOP, MLME-OCB-DMGDISCOVERY, MLME-OCB-LINKSTATUS) | 11.1.4 (Acquiring synchronization, scanning), 11.27 (DMG beamformed link and BSS maintenance) | CFNGV60:M | Yes ☐ No ☐ N/A ☐ |

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## B.4.39 Light communications (LC) features(11bb)

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| | Are the following PHY protocol features supported? | | | |
| LCP1 | LC PHY level of support | | | |
| *LCP1.1 | LC PHY with HT support | 33.2.1 (General) | CFHT5G: O.1 | Yes □ No □ N/A □ |
| *LCP1.2 | LC PHY with VHT support | 33.2.1 (General) | CFVHT: O.1 | Yes □ No □ N/A □ |
| *LCP1.3 | LC PHY with HE support | 33.2.1 (General) | CFHE5G OR CFHE6G: O.1 | Yes □ No □ N/A □ |
| LCP3 | Channel numbering and channelization | 33.2.3.4 (Channel numbering) | | |
| LCP3.1 | 5 GHz band mapping | 33.2.3.4 (Channel numbering) | CFLC: O.2 | Yes □ No □ N/A □ |
| LCP3.2 | 6 GHz band mapping | 33.2.3.4 (Channel numbering) | CFLC: O.2 | Yes □ No □ N/A □ |
| LCP4 | Multiple transmit and receive chains | 33.2.3.5 (Multiple transmit chains and multiple receive chains) | | |
| LCP4.1 | More than one transmit chain | 33.2.3.5 (Multiple transmit chains and multiple receive chains) | CFLC: O | Yes □ No □ N/A □ |
| LCP4.2 | More than one receive chain | 33.2.3.5 (Multiple transmit chains and multiple receive chains) | CFLC: O | Yes □ No □ N/A □ |
| LCP5 | LC CCA requirements | 33.2.3.7.1 (CCA requirements) | CFLC: M | Yes □ No □ N/A □ |
| LCP6 | LC repetition mechanism | 33.2.3.7.2 (LC repetition) | CFLC: O | Yes □ No □ N/A □ |


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### B.4.39 Enhanced Broadcast Services (EBCS) features(11bc)

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| *EBCS1 | EBCS downlink procedure | 34.3 (EBCS DL procedures) | CFEBCS:O.1 CFSTARXOnly: M | Yes ☐ No ☐ N/A ☐ |
| EBCS1.1 | EBCS Info frame | 9.6.7.54 (EBCS Info frame format(11bc)) | EBCS1:M | Yes ☐ No ☐ N/A ☐ |
| *EBCS2 | EBCS uplink procedure | 34.4 (EBCS UL procedure) | CFEBCS:O.1 | Yes ☐ No ☐ N/A ☐ |
| EBCS2.1 | EBCS UL frame | 9.6.7.53 (EBCS UL frame format(11bc)) | EBCS2:M | Yes ☐ No ☐ N/A ☐ |
| *EBCS3 | Frame authentication for EBCS | 12.15 (Frame authentication for EBCS(11bc)) | CFEBCS:M | Yes ☐ No ☐ N/A ☐ |
| *EBCS3.1 | PKFA | 12.15.2 (EBCS public key frame authentication (PKFA)) | EBCS1 AND EBCS3:O.2 EBCS2 AND EBCS3:O.3 | Yes ☐ No ☐ N/A ☐ |
| EBCS3.1.1 | PKFA MPDU | 12.15.3 (EBCS hash chain frame authentication (HCFA)) | EBCS3.1: M | Yes ☐ No ☐ N/A ☐ |
| *EBCS3.2 | HCFA | 12.15.3 (EBCS hash chain frame authentication (HCFA)) | EBCS1 AND EBCS3: O.2 | Yes ☐ No ☐ N/A ☐ |
| EBCS3.2.1 | HCFA MPDU | 12.15.3.3 (HCFA MPDU) | EBCS3.2: M | Yes ☐ No ☐ N/A ☐ |
| EBCS3.3 | HLSA | 12.15.4 (No frame authentication with mandatory higher layer source authentication (HLSA)) | EBCS1 AND EBCS3: O.2 EBCS2 AND EBCS3: O.3 | Yes ☐ No ☐ N/A ☐ |

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## B.4.39 Enhanced Broadcast Services (EBCS) features(11bc) *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| EBCS3.4 | RSASSA-PSS | 12.15.2.1 (Signature of an EBCS Info frame), 12.15.2.2 (Authentication of an EBCS Info frame) | EBCS3:O | |
| EBCS3.5 | ECDSA | 12.15.2.1 (Signature of an EBCS Info frame), 12.15.2.2 (Authentication of an EBCS Info frame) | EBCS3:M | |
| *EBCS4 | EBCS DL negotiation procedures | 34.3.8 (EBCS negotiation for unassociated STAs), 34.3.7 (EBCS negotiation for associated STAs) | CFAP AND EBCS1: M CFSTAofAP AND EBCS1: M CFIndepSTA AND EBCS1:M | Yes ☐ No ☐ N/A ☐ |
| EBCS4.1 | EBCS Content Request frame | 9.6.35.2 (EBCS Content Request frame format) | EBCS4: M | Yes ☐ No ☐ N/A ☐ |
| EBCS4.2 | EBCS Content Response frame | 9.6.35.3 (EBCS Content Response frame format) | EBCS4: M | Yes ☐ No ☐ N/A ☐ |
| *EBCS5 | EBCS termination notice procedure | 34.3.9 (EBCS termination notice and extension negotiation) | CFAP AND CFE-BCS: M (CFSTAofAPOR CFIndepSTA)AND EBCS1: M | Yes ☐ No ☐ N/A ☐ |
| EBCS5.1 | EBCS Termination Notice frame | 9.6.7.55 (EBCS Termination Notice frame format(11bc)) | EBCS5: M | Yes ☐ No ☐ N/A ☐ |


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## B.4.39 Enhanced Broadcast Services (EBCS) features(11bc) *(continued)*

| Item | Protocol capability | References | Status | Support |
|---|---|---|---|---|
| EBCS6 | ANQP EBCS procedure | 11.22.3.3.17 (Enhanced broadcast services procedures(11bc)) | CFAP AND CFE-BCS: M (CFSTAofAPOR CFIndepSTA)AND CFE-BCS: O | Yes ☐ No ☐ N/A ☐ |
| EBCS7 | Transmission rate control for EBCS | 10.6.5.3 (Rate selection for EBCS Info, EBCS UL, and EBCS Data frames(11bc)) | (CFAP AND EBCS1) OR (CFSTAofAPOR CFIndepSTA)AND EBCS2: M | Yes ☐ No ☐ N/A ☐ |

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# Annex C

(normative)

# ASN.1 encoding of the MAC and PHY MIB

## C.1 General

The MIB for the current revision of IEEE Std 802.11 is available online at the following URL: http://www.ieee802.org/11/802.11mib.txt. The MAC and PHY MIBs are described in Abstract Syntax Notation One (ASN.1), defined in ISO/IEC 8824-1:1995, ISO/IEC 8824-2:1995, ISO/IEC 8824-3:1995 and ISO/IEC 8824-4:1995, (#4112)and as adapted per Structure of Management Information Version 2 (SMIv2) specified in IETF RFC 2578.

NOTE 1—An external management entity is a component that is beyond the scope of this standard. The SME is not an external management entity.

(#3504)NOTE 2—Certain MIB attributes for a TDLS STA only apply to the link with the AP.

***-- Editor Note: Any <year> below will be replaced by the year of publication by the IEEE SA publication editor.***

## C.2 Guidelines for IEEE 802.11 MIB authors/editors

The MIB may be compiled using the "smitools" package from the Institute of Operating Systems and Computer Networks at the Technical University of Braunschweig, Germany. These tools may be accessed online using the following URL: http://www.ibr.cs.tu-bs.de/bin/smitools.cgi.

Using this tool, the MIB should compile without generating warnings of severity 3 or lower.

Specific points that authors and editors should pay attention to:

- The MIB should compile as specified above prior to submission to IEEE SA RevCom.
- Use only the 7-bit US-ASCII character-set. In particular, use only straight single and double quotes.
- Do not use symbols such as <greek-mu> in units, instead spell out the units fully, i.e., "microseconds."
- Follow the guidelines for writing MIB modules in http://www.rfc-editor.org/rfc/rfc4181.txt (including any updates thereto).
- Pay attention to IETF recommendations on object types.
- When adding a lot of new objects, consider adding a new module.
- Consider seeking advice from an IETF MIB Doctor when creating significant new material. The IEEE has an arrangement with the IETF whereby the IEEE may ask for a MIB Advisor from the IETF MIB Doctors.
- When an object is deprecated, add a line to the Description indicating why (IETF convention).

## C.3 MIB detail

```
-- ****************************************************************
-- * IEEE 802.11 MIB
```


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```
-- ************************************************************************

IEEE802dot11-MIB DEFINITIONS ::= BEGIN

IMPORTS
   MODULE-IDENTITY, OBJECT-TYPE, NOTIFICATION-TYPE,
   Integer32, Counter32, Counter64, Unsigned32, TimeTicks, Gauge32
   FROM SNMPv2-SMI

   DisplayString , MacAddress, RowStatus, TruthValue,
   TEXTUAL-CONVENTION FROM SNMPv2-TC

   MODULE-COMPLIANCE, OBJECT-GROUP, NOTIFICATION-GROUP FROM SNMPv2-CONF

   ifIndex, InterfaceIndex FROM IF-MIB;

-- ************************************************************************
-- *  MODULE IDENTITY
-- ************************************************************************
```

***During publication, update the following datestamp to the date of publication using the format yyyymmdd0000Z.***

```
ieee802dot11 MODULE-IDENTITY
   LAST-UPDATED "202102290000Z"
   ORGANIZATION "IEEE Std 802.11"
   CONTACT-INFO(#8239)
      "Chair: Robert Stacey
      E-mail: rjstacey@ieee.org

      Editor: Emily Qi
      E-mail: emily.h.qi@intel.com"
   DESCRIPTION
      "The MIB module for IEEE 802.11 entities.
      iso(1).member-body(2).us(840).ieee802dot11(10036)"

   REVISION    "202103050000Z"
   DESCRIPTION "IEEE Std 802.11-<year>

      Note that not all objects within this MIB are referenced by a group, and
      not all groups are referenced by a MODULE-COMPLIANCE statement.   Some
      existing groups and the dot11Compliance MODULE-COMPLIANCE have been modi-
      fied since the previous revision of this standard."

   REVISION    "202102290000Z"
   DESCRIPTION "IEEE Std 802.11-2020

      Note that not all objects within this MIB are referenced by a group, and
      not all groups are referenced by a MODULE-COMPLIANCE statement.   Some
      existing groups and the dot11Compliance MODULE-COMPLIANCE have been
      modified since the previous revision of this standard."

   REVISION    "201612140000Z"
   DESCRIPTION "IEEE Std 802.11-2016.

      Note that not all objects within this MIB are referenced by a group, and
      not all groups are referenced by a MODULE-COMPLIANCE statement.   Some
      existing groups and the dot11Compliance MODULE-COMPLIANCE have been
      modified since the previous revision of this standard.

      Implementations should not claim compliance to dot11Compliance."


   ::= { us 10036 }

-- ************************************************************************
```

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```
-- *  Tree Definition
-- ************************************************************************

   member-body     OBJECT IDENTIFIER ::= { iso 2 }
   us              OBJECT IDENTIFIER ::= { member-body 840 }

-- ************************************************************************
-- *  Major sections
-- ************************************************************************

--  Station ManagemenT (SMT) Attributes
    --  DEFINED AS "The SMT object class provides the necessary support
    --  at the station to manage the processes in the station such that
    --  the station may work cooperatively as a part of an IEEE 802.11
    --  network."

   dot11smt OBJECT IDENTIFIER ::= { ieee802dot11 1 }
   --  dot11smt GROUPS
   --  dot11StationConfigTable                          ::= { dot11smt 1 }
   --  dot11AuthenticationAlgorithmsTable               ::= { dot11smt 2 }
   --  dot11WEPDefaultKeysTable                         ::= { dot11smt 3 }
   --  dot11WEPKeyMappingsTable                         ::= { dot11smt 4 }
   --  dot11PrivacyTable                                ::= { dot11smt 5 }
   --  dot11SMTnotification                             ::= { dot11smt 6 }
   --  dot11MultiDomainCapabilityTable                  ::= { dot11smt 7 }
   --  dot11SpectrumManagementTable                     ::= { dot11smt 8 }
   --  dot11RSNAConfigTable                             ::= { dot11smt 9 }
   --  dot11RSNAConfigPairwiseCiphersTable              ::= { dot11smt 10 }
   --  dot11RSNAConfigAuthenticationSuitesTable         ::= { dot11smt 11 }
   --  dot11RSNAStatsTable                              ::= { dot11smt 12 }
   --  dot11OperatingClassesTable                       ::= { dot11smt 13 }
   --  dot11RadioMeasurement                            ::= { dot11smt 14 }
   --  dot11FastBSSTransitionConfigTable                ::= { dot11smt 15 }
   --  dot11LCIDSETable                                 ::= { dot11smt 16 }
   --  dot11HTStationConfigTable                        ::= { dot11smt 17 }
   --  dot11WirelessMgmtOptionsTable                    ::= { dot11smt 18 }
   --  dot11LocationServicesNextIndex                   ::= { dot11smt 19 }
   --  dot11LocationServicesTable                       ::= { dot11smt 20 }
   --  dot11WirelessMGTEventTable                       ::= { dot11smt 21 }
   --  dot11WirelessNetworkManagement                   ::= { dot11smt 22 }
   --  dot11MeshSTAConfigTable                          ::= { dot11smt 23 }
   --  dot11MeshHWMPConfigTable                         ::= { dot11smt 24 }
   --  dot11RSNAConfigPasswordValueTable                ::= { dot11smt 25 }
   --  dot11RSNAConfigDLCGroupTable                     ::= { dot11smt 26 }
   --  dot11DMGSTAConfigTable                           ::= { dot11smt 27 }
   --  dot11AVOptionsTable                              ::= { dot11smt 28 }
   --  dot11AVConfigTable                               ::= { dot11smt 29 }
   --  dot11APCTable                                    ::= { dot11smt 30 }
   --  dot11VHTStationConfigTable                       ::= { dot11smt 31 }
   --  dot11TVHTStationConfigTable                      ::= { dot11smt 32 }
   --  dot11STALCITable                                 ::= { dot11smt 33 }
   --  dot11FILSConfigTable                             ::= { dot11smt 35 }
   --  dot11STALCIConfigTable                           ::= { dot11smt 36 }
   --  dot11STACivicLocationConfigTable                 ::= { dot11smt 37 }
   --  dot11CDMGSTAConfigTable                          ::= { dot11smt 39 }
   --  dot11CMMGSTAConfigTable                          ::= { dot11smt 40 }
   --  dot11GLKLinkMetricsTable                         ::= ( dot11smt 41 )
   --  (11ax)dot11HEStationConfigTable                  ::= { dot11smt 42 }
   --  (11ax)dot11PPEThresholdsMappingsTable            ::= { dot11smt 43 }
   --  (11ay)dot11EDMGSTAConfigTable                    ::= { dot11smt 44 }
   --  (11ba)dot11WURStationConfigTable                 ::= { dot11smt 45 }
   --  (11bc)dot11EBCSTrafficStreamTable               ::= { dot11smt 48 }

--  MAC Attributes
```


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```
     --  DEFINED AS "The MAC object class provides the necessary support
     --  for the access control, generation, and verification of frame
     --  check sequences (FCSs), and proper delivery of valid data to
     --  upper layers."

    dot11mac OBJECT IDENTIFIER ::= { ieee802dot11 2 }

--  MAC GROUPS
    --  dot11OperationTable                       ::= { dot11mac 1 }
    --  dot11CountersTable                        ::= { dot11mac 2 }
    --  dot11GroupAddressesTable                  ::= { dot11mac 3 }
    --  dot11EDCATable                            ::= { dot11mac 4 }
    --  dot11QAPEDCATable                         ::= { dot11mac 5 }
    --  dot11QosCountersTable                     ::= { dot11mac 6 }
    --  dot11ResourceInfoTable                    ::= { dot11mac 7 }
    --  dot11DMGOperationTable                    ::= { dot11mac 8 }
    --  dot11DMGCountersTable                     ::= { dot11mac 9 }
    --  dot11BSSStatisticsTable                   ::= { dot11mac 10 }
    --  dot11CDMGOperationTable                   ::= { dot11mac 11 }
    --  (11ay)dot11EDMGOperationTable             ::= { dot11mac 14 }
    --  (11ax)dot11MUEDCATable                    ::= { dot11mac 15 }

--  Resource Type ID
    dot11res          OBJECT IDENTIFIER ::= { ieee802dot11 3 }
    dot11resAttribute OBJECT IDENTIFIER ::= { dot11res 1 }

--  PHY Attributes
     --  DEFINED AS "The PHY object class provides the necessary support
     --  for required PHY operational information that may vary from PHY
     --  to PHY and from STA to STA to be communicated to upper layers."

    dot11phy OBJECT IDENTIFIER ::= { ieee802dot11 4 }

--  PHY GROUPS
    --  dot11PhyOperationTable                          ::= { dot11phy 1 }
    --  dot11PhyAntennaTable                            ::= { dot11phy 2 }
    --  dot11PhyTxPowerTable                            ::= { dot11phy 3 }
    --  (#23)dot11PhyFHSSTable                          ::= { dot11phy 4 }
    --  dot11PhyDSSSTable                               ::= { dot11phy 5 }
    --  (#23)dot11PhyIRTable                            ::= { dot11phy 6 }
    --  dot11RegDomainsSupportedTable                   ::= { dot11phy 7 }
    --  dot11AntennasListTable                          ::= { dot11phy 8 }
    --  dot11SupportedDataRatesTxTable                  ::= { dot11phy 9 }
    --  dot11SupportedDataRatesRxTable                  ::= { dot11phy 10 }
    --  dot11PhyOFDMTable                               ::= { dot11phy 11 }
    --  dot11PhyHRDSSSTable                             ::= { dot11phy 12 }
    --  dot11HoppingPatternTable                        ::= { dot11phy 13 }
    --  dot11PhyERPTable                                ::= { dot11phy 14 }
    --  dot11PhyHTTable                                 ::= { dot11phy 15 }
    --  dot11SupportedHTMCSTxTable                      ::= { dot11phy 16 }
    --  dot11SupportedHTMCSRxTable                      ::= { dot11phy 17 }
    --  dot11TransmitBeamformingConfigTable             ::= { dot11phy 18 }
    --  dot11PHYDMGTable                                ::= { dot11phy 19 }
    --  dot11DMGBeamformingConfigTable                  ::= { dot11phy 22 }
    --  (#23)dot11PhyVHTTable                           ::= { dot11phy 23 }
    --  (#23)dot11VHTTransmitBeamformingConfigTable     ::= { dot11phy 24 }
    --  (#23)dot11PhyTVHTTable                          ::= { dot11phy 25 }
    --  (#23)dot11TVHTTransmittedBeamformingConfigTable ::= { dot11phy 26 }
    --  (#23)dot11PhyS1GTable                           ::= { dot11phy 27 }
    --  (#23)dot11S1GTransmitBeamformingConfigTable     ::= { dot11phy 28 }
    --  dot11PHYCDMGTable                               ::= { dot11phy 29 }
    --  dot11PHYCMMGTable                               ::= { dot11phy 30 }
    --  (11ay)dot11PHYEDMGTable                         ::= { dot11phy 33 }
    --  (11ay)dot11EDMGBeamformingConfigTable           ::= { dot11phy 34 }
```

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```
-- ************************************************************************
-- *  Textual conventions for 802 definitions
-- ************************************************************************

WEPKeytype ::= TEXTUAL-CONVENTION
   STATUS      (#3056)deprecated
   DESCRIPTION "(#3056)Deprecated because WEP has been removed from (#6318)IEEE
      Std 802.11. Represents the type of WEP key."
   SYNTAX      OCTET STRING (SIZE (5))

TSFType ::= TEXTUAL-CONVENTION
   STATUS      current
   DESCRIPTION "Represents the type of TSF."
   SYNTAX      OCTET STRING (SIZE (8))

-- ************************************************************************
-- *  MIB attribute OBJECT-TYPE definitions follow
-- ************************************************************************

-- ************************************************************************
-- *  dot11StationConfig  TABLE
-- ************************************************************************

dot11StationConfigTable OBJECT-TYPE
   SYNTAX SEQUENCE OF Dot11StationConfigEntry
   MAX-ACCESS not-accessible
   STATUS current
   DESCRIPTION
      "Station Configuration attributes. In tabular form to allow for multiple
      instances on an agent."
   ::= { dot11smt 1 }

dot11StationConfigEntry OBJECT-TYPE
   SYNTAX Dot11StationConfigEntry
   MAX-ACCESS not-accessible
   STATUS current
   DESCRIPTION
      "An entry in the dot11StationConfigTable. It is possible for there to be
      multiple IEEE 802.11 interfaces on one agent, each with its unique MAC
      address. The relationship between an IEEE 802.11 interface and an
      interface in the context of the Internet-standard MIB is one-to-one. As
      such, the value of an ifIndex object instance can be directly used to
      identify corresponding instances of the objects defined herein.

      ifIndex - Each IEEE 802.11 interface is represented by an ifEntry.
      Interface tables in this MIB module are indexed by ifIndex."
   INDEX { ifIndex }
   ::= { dot11StationConfigTable 1 }

Dot11StationConfigEntry ::= SEQUENCE
   {
      dot11StationID                                    MacAddress,
      dot11MediumOccupancyLimit                         Unsigned32,
      dot11CFPollable                                   TruthValue,
      dot11CFPPeriod                                    Unsigned32,
      dot11CFPMaxDuration                               Unsigned32,
      dot11AuthenticationResponseTimeout                Unsigned32,
      dot11PrivacyOptionImplemented                     TruthValue,
      dot11PowerManagementMode                          INTEGER,
      dot11DesiredSSID                                  OCTET STRING,
      dot11DesiredBSSType                               INTEGER,
      dot11OperationalRateSet                           OCTET STRING,
```


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```
        dot11BeaconPeriod                                   Unsigned32,
        dot11DTIMPeriod                                     Unsigned32,
        dot11AssociationResponseTimeout                     Unsigned32,
        dot11DisassociateReason                             Unsigned32,
        dot11DisassociateStation                            MacAddress,
        dot11DeauthenticateReason                           Unsigned32,
        dot11DeauthenticateStation                          MacAddress,
        dot11AuthenticateFailStatus                         Unsigned32,
        dot11AuthenticateFailStation                        MacAddress,
        dot11MultiDomainCapabilityImplemented               TruthValue,
        dot11MultiDomainCapabilityActivated                 TruthValue,
        dot11CountryString                                  OCTET STRING,
        dot11SpectrumManagementImplemented                  TruthValue,
        dot11SpectrumManagementRequired                     TruthValue,
        dot11RSNAOptionImplemented                          TruthValue,
        dot11RSNAPreauthenticationImplemented               TruthValue,
        dot11OperatingClassesImplemented                    TruthValue,
        dot11OperatingClassesRequired                       TruthValue,
        dot11QosOptionImplemented                           TruthValue,
        dot11ImmediateBlockAckOptionImplemented             TruthValue,
        dot11DelayedBlockAckOptionImplemented               TruthValue,
        dot11DirectOptionImplemented                        TruthValue,
        dot11APSDOptionImplemented                          TruthValue,
        dot11QAckOptionImplemented                          TruthValue,
        dot11QBSSLoadImplemented                            TruthValue,
        dot11QueueRequestOptionImplemented                  TruthValue,
        dot11TXOPRequestOptionImplemented                   TruthValue,
        dot11MoreDataAckOptionImplemented                   TruthValue,
        dot11AssociateInNQBSS                               TruthValue,
        dot11DLSAllowedInQBSS                               TruthValue,
        dot11DLSAllowed                                     TruthValue,
        dot11AssociateStation                               MacAddress,
        dot11AssociateID                                    Unsigned32,
        dot11AssociateFailStation                           MacAddress,
        dot11AssociateFailStatus                            Unsigned32,
        dot11ReassociateStation                             MacAddress,
        dot11ReassociateID                                  Unsigned32,
        dot11ReassociateFailStation                         MacAddress,
        dot11ReassociateFailStatus                          Unsigned32,
        dot11RadioMeasurementImplemented                    TruthValue,
        dot11RadioMeasurementActivated                      TruthValue,
        dot11RMMeasurementNavSync                           Unsigned32,
        dot11RMMeasurementPilotPeriod                       Unsigned32,
        dot11RMLinkMeasurementActivated                     TruthValue,
        dot11RMNeighborReportActivated                      TruthValue,
        dot11RMParallelMeasurementsActivated                TruthValue,
        dot11RMRepeatedMeasurementsActivated                TruthValue,
        dot11RMBeaconPassiveMeasurementActivated            TruthValue,
        dot11RMBeaconActiveMeasurementActivated             TruthValue,
        dot11RMBeaconTableMeasurementActivated              TruthValue,
        dot11RMBeaconMeasurementReportingConditionsActivated  TruthValue,
        dot11RMFrameMeasurementActivated                    TruthValue,
        dot11RMChannelLoadMeasurementActivated              TruthValue,
        dot11RMNoiseHistogramMeasurementActivated           TruthValue,
        dot11RMStatisticsMeasurementActivated               TruthValue,
        dot11RMLCIMeasurementActivated                      TruthValue,
        dot11RMLCIAzimuthActivated                          TruthValue,
        dot11RMTransmitStreamCategoryMeasurementActivated   TruthValue,
        dot11RMTriggeredTransmitStreamCategoryMeasurementActivated
        TruthValue,
        dot11RMAPChannelReportActivated                     TruthValue,
        dot11RMMIBActivated                                 TruthValue,
        dot11RMMaxMeasurementDuration                       Unsigned32,
        dot11RMNonOperatingChannelMaxMeasurementDuration    Unsigned32,
```

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```
        dot11RMMeasurementPilotTransmissionInformationActivated
        TruthValue,
        dot11RMMeasurementPilotActivated                        Unsigned32,
        dot11RMNeighborReportTSFOffsetActivated                 TruthValue,
        dot11RMRCPIMeasurementActivated                         TruthValue,
        dot11RMRSNIMeasurementActivated                         TruthValue,
        dot11RMBSSAverageAccessDelayActivated                   TruthValue,
        dot11RMBSSAvailableAdmissionCapacityActivated           TruthValue,
        dot11RMAntennaInformationActivated                      TruthValue,
        dot11FastBSSTransitionImplemented                       TruthValue,
        dot11LCIDSEImplemented                                  TruthValue,
        dot11LCIDSERequired                                     TruthValue,
        dot11DSERequired                                        TruthValue,
        dot11ExtendedChannelSwitchActivated                     TruthValue,
        dot11RSNAProtectedManagementFramesActivated             TruthValue,
        dot11RSNAUnprotectedManagementFramesAllowed             TruthValue,
        dot11AssociationSAQueryMaximumTimeout                   Unsigned32,
        dot11AssociationSAQueryRetryTimeout                     Unsigned32,
        dot11HighThroughputOptionImplemented                    TruthValue,
        dot11RSNAPBACRequired                                   TruthValue,
        dot11PSMPOptionImplemented                              TruthValue,
        dot11TunneledDirectLinkSetupImplemented                 TruthValue,
        dot11TDLSPeerUAPSDBufferSTAActivated                    TruthValue,
        dot11TDLSPeerPSMActivated                               TruthValue,
        dot11TDLSPeerUAPSDIndicationWindow                      Unsigned32,
        dot11TDLSChannelSwitchingActivated                      TruthValue,
        dot11TDLSPeerSTAMissingAckRetryLimit                    Unsigned32,
        dot11TDLSResponseTimeout                                Unsigned32,
        dot11OCBActivated                                       TruthValue,
        dot11TDLSNavSync                                        Unsigned32,
        dot11TDLSDiscoveryRequestWindow                         Unsigned32,
        dot11TDLSACDeterminationInterval                        Unsigned32,
        dot11WirelessManagementImplemented                      TruthValue,
        dot11BssMaxIdlePeriod                                   Unsigned32,
        dot11BssMaxIdlePeriodOptions                            OCTET STRING,
        dot11TIMBroadcastInterval                               Unsigned32,
        dot11TIMBroadcastOffset                                 Integer32,
        dot11TIMBroadcastHighRateTIMRate                        Unsigned32,
        dot11TIMBroadcastLowRateTIMRate                         Unsigned32,
        dot11StatsMinTriggerTimeout                             Unsigned32,
        dot11RMCivicMeasurementActivated                        TruthValue,
        dot11RMIdentifierMeasurementActivated                   TruthValue,
        dot11TimeAdvertisementDTIMInterval                      Unsigned32,
        dot11TimeAdvertisementTimeError                         OCTET STRING,
        dot11TimeAdvertisementTimeValue                         OCTET STRING,
        dot11RM3rdPartyMeasurementActivated                     TruthValue,
        dot11InterworkingServiceImplemented                     TruthValue,
        dot11InterworkingServiceActivated                       TruthValue,
        dot11QosMapImplemented                                  TruthValue,
        dot11QosMapActivated                                    TruthValue,
        dot11EBRImplemented                                     TruthValue,
        dot11EBRActivated                                       TruthValue,
        dot11ESNetwork                                          TruthValue,
        dot11SSPNInterfaceImplemented                           TruthValue,
        dot11SSPNInterfaceActivated                             TruthValue,
        dot11HESSID                                             MacAddress,
        dot11EASImplemented                                     TruthValue,
        dot11EASActivated                                       TruthValue,
        dot11MSGCFImplemented                                   TruthValue,
        dot11MSGCFActivated                                     TruthValue,
        dot11MeshActivated                                      TruthValue,
        dot11RejectUnadmittedTraffic                            TruthValue,
        dot11BSSBroadcastNullCount                              Unsigned32,
        dot11QMFActivated                                       TruthValue,
```


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```
        dot11QMFReconfigurationActivated                        TruthValue,
        dot11QMFPolicyChangeTimeout                             Unsigned32,
        dot11RobustAVStreamingImplemented                       TruthValue,
        dot11MultibandImplemented                               TruthValue,
        dot11DynamicEIFSActivated                               TruthValue,
        dot11VHTOptionImplemented                               TruthValue,
        dot11OperatingModeNotificationImplemented               TruthValue,
        dot11TVHTOptionImplemented                              TruthValue,
        dot11ChannelScheduleManagementActivated                 TruthValue,
        dot11ContactVerificationSignalActivated                 TruthValue,
        dot11ContactVerificationSignalInterval                  Unsigned32,
        dot11NetworkChannelControlActivated                     TruthValue,
        dot11RLSSActivated                                      TruthValue,
        dot11WhiteSpaceMapActivated                             TruthValue,
        dot11WSSTAType                                          INTEGER,
        dot11GeolocationCapabilityActivated                     TruthValue,
        dot11GDDActivated                                       TruthValue,
        dot11GDDEnablementTimeLimit                             Unsigned32,
        dot11GDDEnablementFailHoldTime                          Unsigned32,
        dot11GDDEnablementValidityTimer                         Unsigned32,
        dot11MaxMSDULength                                      INTEGER,
        dot11ExtendedSpectrumManagementImplemented              TruthValue,
        dot11EstimatedServiceParametersInboundOptionImplementedTruthValue,
        dot11EstimatedServiceParametersOutboundOptionImplemented TruthValue,
        dot11VHTExtendedNSSBWCapable                            TruthValue,
        dot11FutureChannelGuidanceActivated                     TruthValue,
        dot11FILSActivated                                      TruthValue,
        dot11S1GOptionImplemented                               TruthValue,
        dot11RSNAOperatingChannelValidationActivated            TruthValue,
        dot11GLKImplemented                                     TruthValue,
        dot11GLKRequired                                        TruthValue,
        dot11EPDImplemented                                     TruthValue,
        dot11EPDRequired                                        TruthValue,
        dot11GLKLinkRateSamples                                 Unsigned32,
        dot11GLKLinkRateWindowSize                              Unsigned32,
        dot11GLKLinkRateWmin                                    Unsigned32,
        dot11GLKLinkRateWavg                                    Unsigned32,
        dot11GLKLinkRateWgeo                                    Unsigned32,
        dot11GLKLinkRateScaling                                 Unsigned32,
        dot11GLKLinkRateHysteresis                              Unsigned32,
        dot11GLKGCRImplemented                                  TruthValue,
        dot11SolicitedPADActivated                              TruthValue,
        dot11UnsolicitedPADActivated                            TruthValue,
        dot11MACPrivacyActivated                                TruthValue,
        dot11GASExtensionImplemented                            TruthValue,
        dot11LocallyAdministeredMACConfig                       Unsigned32,
        (11ba)dot11WUROptionImplemented                         TruthValue,
        dot11BeaconProtectionEnabled                            TruthValue,
        dot11MSCSActivated                                      TruthValue,
        dot11LocalMACAddressPolicyActivated                     TruthValue,
        dot11BSSMaxIdlePeriodIndicationByNonAPSTA                TruthValue,
        (11ax)dot11HEOptionImplemented                          TruthValue,
        (11ax)dot11OBSSNarrowBWRUinOFDMATolerated               TruthValue,
        (11ax)dot11HE6GOptionImplemented                        TruthValue,
        (11ax)dot11OCTOptionImplemented                         TruthValue,
        (11ax)dot11QTPOptionImplemented                         TruthValue,
        (11ax)dot11ColocatedRNRImplemented                      TruthValue,
        (11ay)dot11UnsolicitedBAActivated                       TruthValue,
        (11az)dot11PASNActivated                                TruthValue,
        (11az)dot11NoAuthPASNActivated                          TruthValue,
        (#6077)dot11ExtendedRegInfoSupport                      TruthValue,
        (11bd)dot11NONNGVRadioEnvironmentImplemented            TruthValue,
        (11bd)dot11NGVOptionImplemented                         TruthValue,
        (11bd)dot11RadioEnvironmentMeasurementPeriod            Unsigned32,
```

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```
        (11bd)dot11VirtualCSonOCBSecondaryImplemented          TruthValue,
        (11bd)dot11StationMeasurementPeriod                    Unsigned32,
        (11bb)dot11LCOptionImplemented                         TruthValue,
        (#6058)dot11GASQueryRequestFragmentationActivated      TruthValue,
        (11bc)dot11EBCSSupportActivated                        TruthValue,
        (11bc)dot11EBCSInfoInterval                            Unsigned32,
        (11bc)dot11EBCSHCFAKeyChangeInterval                   Unsigned32,
        (11bc)dot11EBCSHCFAHashDistance                        OCTET STRING,
        (11bc)dot11EBCSInfoPHYType                             Unsigned32,
        (11bc)dot11EBCSInfoTxRate                              OCTET STRING,
        (11bc)dot11EBCSTerminationNoticeTime                   Unsigned32,
        (11bc)dot11EBCSTerminationNoticeMinimumInterval        Unsigned32,
        (11bc)dot11EBCSTerminationNoticeMaximumInterval        Unsigned32,
        (11bc)dot11EBCSRelayingServiceImplemented              TruthValue,
        (11bc)dot11EBCSTIMInBeaconActivated                    TruthValue,
        (11bc)dot11EBCSAPGroupID                               OCTET STRING
}

dot11StationID OBJECT-TYPE
   SYNTAX MacAddress
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by the SME or external management entity.
      Changes take effect for the next MLME-START.request primitive.

      The purpose of dot11StationID is to allow a manager to identify a station
      for its own purposes. This attribute provides for that eventuality while
      keeping the true MAC address independent. Its syntax is MAC address, and
      the default value is the STA's assigned, unique MAC address."
   ::= { dot11StationConfigEntry 1 }

dot11MediumOccupancyLimit OBJECT-TYPE
   SYNTAX Unsigned32 (0..1000)
   UNITS "TUs"
   MAX-ACCESS read-write
   STATUS deprecated
   DESCRIPTION
      "Deprecated as the related feature has been removed from IEEE Std 802.11.
      This is a control variable.
      It is written by an external management entity.
      Changes take effect as soon as practical in the implementation."
   DEFVAL { 100 }
   ::= { dot11StationConfigEntry 2 }

dot11CFPollable OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-only
   STATUS deprecated
   DESCRIPTION
      "Deprecated as the related feature has been removed from IEEE Std 802.11.
      This is a capability variable.
      Its value is determined by (#3375)STA capabilities.

      When this attribute is true, it indicates that the STA is able to respond
      to a CF-Poll with a Data frame within a SIFS. This attribute is false if
      the STA is not able to respond to a CF-Poll with a Data frame within a
      SIFS."
   ::= { dot11StationConfigEntry 3 }

dot11CFPPeriod OBJECT-TYPE
   SYNTAX Unsigned32 (0..255)
   MAX-ACCESS read-only
```


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```
    STATUS deprecated
    DESCRIPTION
        "Deprecated as the related feature has been removed from IEEE Std 802.11.
        This is a status variable.
        In an AP, it is written by the MAC when it receives an MLME-START.request
        primitive.
        In a non-AP STA, it is written by the MAC when it receives an updated CF
        Parameter Set in a Beacon frame.

        The attribute describes the number of DTIM intervals between the start of
        CFPs. It is modified by MLME-START.request primitive."
    ::= { dot11StationConfigEntry 4 }

dot11CFPMaxDuration OBJECT-TYPE
    SYNTAX Unsigned32 (0..65535)
    UNITS "TUs"
    MAX-ACCESS read-only
    STATUS deprecated
    DESCRIPTION
        "Deprecated as the related feature has been removed from IEEE Std 802.11.
        This is a status variable.
        In an AP, it is written by the MAC when it receives an MLME-START.request
        primitive.
        In a non-AP STA, it is written by the MAC when it receives an updated CF
        Parameter Set in a Beacon frame.

        The attribute describes the maximum duration of the CFP that may be
        generated by the PCF. It is modified by MLME-START.request primitive."
    ::= { dot11StationConfigEntry 5 }


dot11AuthenticationResponseTimeout OBJECT-TYPE
    SYNTAX Unsigned32 (1..4294967295)
    MAX-ACCESS read-write
    STATUS deprecated
    DESCRIPTION
        "Deprecated, as redundant in purpose with the AuthenticateFailureTimeout
        parameter provided in an MLME-AUTHENTICATE.request.
        This is a control variable.
        It is written by an external management entity.
        Changes take effect for the next Authentication frame.

        This attribute specifies the number of time units (TUs) that a responding
        STA should wait for the next frame in the authentication sequence."
    ::= { dot11StationConfigEntry 6 }

dot11PrivacyOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS (#3056)deprecated
    DESCRIPTION
        "(#3056)Deprecated because WEP has been removed from (#6318)IEEE Std
        802.11
        This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the IEEE 802.11 WEP option is
        implemented."
    ::= { dot11StationConfigEntry 7 }

dot11PowerManagementMode OBJECT-TYPE
    SYNTAX INTEGER { active(1), powersave(2) }
    MAX-ACCESS read-only
    STATUS current
```

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```
    DESCRIPTION
        "This is a status variable.
        It is written by the MAC when an MLME-POWERMGT.request primitive is
        received.

        This attribute specifies the power management mode of the STA. When equal
        to active, it indicates that the station is not in power save (PS) mode.
        When equal to powersave, it indicates that the station is in power save
        mode. The power management mode is transmitted in all frames according to
        the rules in 9.2.4.1.8 (More Data subfield)."
    ::= { dot11StationConfigEntry 8 }

dot11DesiredSSID OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(0..32))
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect for the next MLME-SCAN.request primitive.

        This attribute reflects the service set identifier (SSID) used in the SSID
        parameter of the most recent MLME-SCAN.request primitive. This value may
        be modified by an external management entity and used by the local SME to
        make decisions about the Scanning process."
    ::= { dot11StationConfigEntry 9 }

dot11DesiredBSSType OBJECT-TYPE
    SYNTAX INTEGER { infrastructure(1), independent(2), any(3) }
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect for the next MLME-SCAN.request primitive.

        This attribute specifies the type of BSS the station uses when scanning
        for a BSS with which to synchronize. This value is used to filter Probe
        Response frames and Beacon frames. When equal to infrastructure, the
        station synchronizes only with a BSS in which the Capability Information
        field has the ESS subfield equal to 1. When equal to independent, the
        station synchronizes only with a BSS whose Capability Information field
        has the IBSS subfield equal to 1. When equal to any, the station may
        synchronize to either type of BSS."
    ::= { dot11StationConfigEntry 10 }

dot11OperationalRateSet OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(1..126))
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when joining or establishing a BSS.

        This attribute specifies the set of non-HT data rates at which the station
        is able to receive data. Each octet contains a value representing a rate.
        Each rate is within the range 2 to 127, corresponding to data rates in
        increments of 500 kb/s from 1 Mb/s to 63.5 Mb/s, and is supported (as
        indicated in the supported rates table) for receiving data. This value is
        reported in transmitted Beacon, Probe Request, Probe Response, Association
        Request, Association Response, Reassociation Request, and Reassociation
        Response frames, and is used to determine whether a BSS with which the
        station might synchronize is suitable. It is also used when starting a
        BSS, as specified in 6.5.4 (Synchronization)."
```


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```
    ::= { dot11StationConfigEntry 11 }

dot11BeaconPeriod OBJECT-TYPE
    SYNTAX Unsigned32 (1..65535)
    UNITS "TU"(#1724)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect for the next MLME-START.request primitive.

        For non-DMG STAs, this attribute specifies the time period(#1724) that a
        station uses for scheduling Beacon transmissions. For DMG STAs, this
        attribute specifies the time period(#1724) that a station uses for
        scheduling(11ay) TDD slots for DMG Beacon transmission or for scheduling
        BTI and/or ATI in the beacon interval. This value is transmitted in Beacon
        and Probe Response frames."
    ::= { dot11StationConfigEntry 12 }

dot11DTIMPeriod OBJECT-TYPE
    SYNTAX Unsigned32 (1..255)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect for the next MLME-START.request primitive.

        This attribute specifies the number of beacon intervals that elapse
        between transmission of Beacon frames containing a TIM element whose DTIM
        Count field is 0. This value is transmitted in the DTIM Period field of
        Beacon frames."
    ::= { dot11StationConfigEntry 13 }

dot11AssociationResponseTimeout OBJECT-TYPE
    SYNTAX Unsigned32 (1..4294967295)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute specifies the number of TU that a requesting STA should
        wait for a response to a transmitted (Re)Association Request frame."
    ::= { dot11StationConfigEntry 14 }

dot11DisassociateReason OBJECT-TYPE
    SYNTAX Unsigned32 (0..65535)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the MAC when a STA disassociates.

        This attribute holds the most recently transmitted Reason Code in a
        Disassociation frame. If no Disassociation frame has been transmitted, the
        value of this attribute is 0."
    ::= { dot11StationConfigEntry 15 }

dot11DisassociateStation OBJECT-TYPE
    SYNTAX MacAddress
    MAX-ACCESS read-only
```

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```
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the MAC when a STA disassociates.

        This attribute holds the MAC address from the Address 1 field of the most
        recently transmitted Disassociation frame. If no Disassociation frame has
        been transmitted, the value of this attribute is 0."
    ::= { dot11StationConfigEntry 16 }

dot11DeauthenticateReason OBJECT-TYPE
    SYNTAX Unsigned32 (0..65535)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the MAC when a STA deauthenticates.

        This attribute holds the most recently transmitted Reason Code in a
        Deauthentication frame. If no Deauthentication frame has been transmitted,
        the value of this attribute is 0."
    ::= { dot11StationConfigEntry 17 }

dot11DeauthenticateStation OBJECT-TYPE
    SYNTAX MacAddress
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the MAC when a STA deauthenticates.

        This attribute holds the MAC address from the Address 1 field of the most
        recently transmitted Deauthentication frame. If no Deauthentication frame
        has been transmitted, the value of this attribute is 0."
    ::= { dot11StationConfigEntry 18 }

dot11AuthenticateFailStatus OBJECT-TYPE
    SYNTAX Unsigned32 (0..65535)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the MAC when a STA fails to authenticate.

        This attribute holds the most recently transmitted Status Code field
        value(M118) in a failed Authentication frame. If no failed Authentication
        frame has been transmitted, the value of this attribute is 0."
    ::= { dot11StationConfigEntry 19 }

dot11AuthenticateFailStation OBJECT-TYPE
    SYNTAX MacAddress
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the MAC when a STA fails to authenticate.

        This attribute holds the MAC address from the Address 1 field of the most
        recently transmitted failed Authentication frame. If no failed
        Authentication frame has been transmitted, the value of this attribute is
        0."
    ::= { dot11StationConfigEntry 20 }

dot11MultiDomainCapabilityImplemented OBJECT-TYPE
```


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```
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the station implementation is
        capable of supporting multiple regulatory domains. The capability is
        disabled, otherwise."
    ::= { dot11StationConfigEntry 21 }

dot11MultiDomainCapabilityActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by the SME or external management entity.
        Changes take effect for the next MLME-START.request primitive.

        This attribute, when true, indicates that the capability of the station to
        operate in multiple regulatory domains is enabled."
    DEFVAL { false }
    ::= { dot11StationConfigEntry 22 }

dot11CountryString OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(3))
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by the SME.
        Changes take effect for the next MLME-START.request primitive.

        This attribute identifies the country or noncountry entity in which the
        station is operating. If it is a country, the first two octets of this
        string (#2053)are the two character country code as described in document
        ISO 3166-1. The third octet is one of the following:

        1. an ASCII space character, if the regulations under which the station is
        operating encompass all environments for the current frequency band in the
        country,

        2. an ASCII 'O' character, if the regulations under which the station is
        operating are for an outdoor environment only, or

        3. an ASCII 'I' character, if the regulations under which the station is
        operating are for an indoor environment only.

        4. an ASCII 'X' character, if the station is operating under a noncountry
        entity. (#2053)The first two octets of the noncountry entity are also
        ASCII 'X' characters.

        5. (#1863)the Operating Class table number currently in use, from the set
        of tables defined in Annex E, e.g., Table E-1 (Operating classes in the
        United States and its territories(#296)) is represented as x'01'."
    ::= { dot11StationConfigEntry 23 }

dot11SpectrumManagementImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
```

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```
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the station implementation is
        capable of supporting spectrum management. The capability is disabled
        otherwise."
    ::= { dot11StationConfigEntry 24 }


dot11SpectrumManagementRequired OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by the SME or external management entity.
        Changes take effect for the next MLME-START.request primitive.

        A STA uses the defined TPC and DFS procedures if this attribute is true;
        otherwise it does not use the defined TPC and DFS procedures."
    DEFVAL { false }
    ::= { dot11StationConfigEntry 25 }

dot11RSNAOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This variable indicates whether the entity is an RSNA STA."
    ::= { dot11StationConfigEntry 26 }

dot11RSNAPreauthenticationImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This variable indicates whether the entity supports RSNA
        preauthentication. This cannot be true unless dot11RSNAOptionImplemented
        is true."
    ::= { dot11StationConfigEntry 27 }

dot11OperatingClassesImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the station implementation is
        capable of supporting operating classes. The capability is disabled
        otherwise."
    ::= { dot11StationConfigEntry 28 }

dot11OperatingClassesRequired OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
```


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```
    DESCRIPTION
        "This is a control variable.
        It is written by the SME or external management entity.
        Changes take effect for the next MLME-START.request primitive.

        A STA uses the defined operating classes procedures if this attribute is
        true."
    DEFVAL { false }
    ::= { dot11StationConfigEntry 29 }

dot11QosOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the station implementation is
        capable of supporting QoS. The capability is disabled, otherwise."
    ::= { dot11StationConfigEntry 30}

dot11ImmediateBlockAckOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the station implementation is
        capable of supporting immediate block ack. The capability is disabled,
        otherwise."
    ::= { dot11StationConfigEntry 31}

dot11DelayedBlockAckOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS (#3441)deprecated
    DESCRIPTION
        "Deprecated as the related feature has been removed from IEEE Std 802.11.
        This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the station implementation is
        capable of supporting delayed block ack. The capability is disabled,
        otherwise."
    ::= { dot11StationConfigEntry 32 }

dot11DirectOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the station implementation is
        capable of sending and receiving frames from a non-AP STA in the BSS. The
        capability is disabled, otherwise."
    ::= { dot11StationConfigEntry 33 }

dot11APSDOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
```

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```
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute is available only at an AP. When true, this attribute
        indicates that the AP implementation is capable of delivering data and
        polls to stations using APSD."
    ::= { dot11StationConfigEntry 34 }

dot11QAckOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the station implementation is
        capable of interpreting the CF-Ack bit in a received frame with the Type
        subfield equal to Data even if the frame is not directed to the QoS
        station. The capability is disabled, otherwise. A STA is capable of
        interpreting the CF-Ack bit in a received Data frame if that station is
        the recipient of the Data frame, regardless of the value of this MIB
        attribute."
    ::= { dot11StationConfigEntry 35 }

dot11QBSSLoadImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute is available only at a QoS AP or PCP. This attribute, when
        true, indicates that the AP or PCP transmits the BSS Load element in
        Beacon frames (non-DMG non-S1G AP only) and Probe Response frames, and
        optionally in DMG Beacon frames (DMG AP or PCP only) and S1G Beacon frames
        (S1G AP only); optionally transmits the Extended BSS Load element in
        Beacon and Probe Response frames (VHT AP only); and optionally transmits
        the HE BSS Load element in Beacon and Probe Response frames (HE AP only).
        These elements are not transmitted, otherwise.(#3338)"
    ::= { dot11StationConfigEntry 36 }

dot11QueueRequestOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute is available only at an AP. This attribute, when true,
        indicates that the AP is capable of processing the Queue Size field in QoS
        Control field of QoS Data frames. The capability is disabled, otherwise."
    ::= { dot11StationConfigEntry 37 }

dot11TXOPRequestOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
```


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```
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute is available only at an AP. This attribute, when true,
        indicates that the AP is capable of processing the TXOP Duration requested
        field in QoS Control field of QoS Data frames. The capability is disabled,
        otherwise."
    ::= { dot11StationConfigEntry 38 }

dot11MoreDataAckOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the station implementation is
        capable of interpreting the More Data bit in the Ack frames. The
        capability is disabled, otherwise."
    ::= { dot11StationConfigEntry 39 }

dot11AssociateInNQBSS OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute, when true, indicates that the station may associate in a
        non-QoS BSS. When false, this attribute indicates that the station does
        not associate in a non-QoS BSS."
    DEFVAL { true }
    ::= { dot11StationConfigEntry 40 }

dot11DLSAllowedInQBSS OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS deprecated
    DESCRIPTION
        "Deprecated as the related feature has been removed from IEEE Std 802.11.
        This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute available at the AP, when true, indicates that STAs may set
        up DLS and communicate using DLS with other STAs in the BSS. When false,
        this attribute indicates that the stations do not set up DLS nor
        communicate with other STAs using DLS in the BSS."
    DEFVAL { true }
    ::= { dot11StationConfigEntry 41 }

dot11DLSAllowed OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS deprecated
    DESCRIPTION
        "Deprecated as the related feature has been removed from IEEE Std 802.11.
        This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.
```

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```
        This attribute available at non-AP STAs, when true, indicates that the STA
        may set up DLS or accept DLS Requests, and communicate with other STAs in
        the BSS using DLS. When false, this attribute indicates that the STA does
        not set up DLS nor accept DLS, nor communicate with other STAs in the BSS
        using DLS."
    DEFVAL { true }
    ::= { dot11StationConfigEntry 42}

dot11AssociateStation OBJECT-TYPE
    SYNTAX MacAddress
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the MAC when a STA associates.

        This attribute indicates the MAC address from the Address 1 field of the
        most recently transmitted Association Response frame. If no Association
        Response frame has been transmitted, the value of this attribute is 0."
    ::= { dot11StationConfigEntry 43 }

dot11AssociateID OBJECT-TYPE
    SYNTAX Unsigned32 (0..2007)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the MAC when a STA associates.

        This attribute indicates the Association ID from the most recently
        transmitted Association Response frame. If no Association Response frame
        has been transmitted, the value of this attribute is 0."
    ::= { dot11StationConfigEntry 44 }

dot11AssociateFailStation OBJECT-TYPE
    SYNTAX MacAddress
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the MAC when a STA fails to associate.

        This attribute indicates the MAC address from the Address 1 field of the
        most recently transmitted failed Association Response frame. If no failed
        Association Response frame has been transmitted, the value of this
        attribute is 0."
    ::= { dot11StationConfigEntry 45 }

dot11AssociateFailStatus OBJECT-TYPE
    SYNTAX Unsigned32 (0..65535)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the MAC when a STA fails to associate.

        This attribute indicates the most recently transmitted Status Code
        field(M118) in a failed Association Response frame. If no failed Associa-
        tion Response frame has been transmitted, the value of this attribute is
        0."
    ::= { dot11StationConfigEntry 46 }

dot11ReassociateStation OBJECT-TYPE
    SYNTAX MacAddress
```


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```
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the MAC when a STA reassociates.

        This attribute indicates the MAC address from the Address 1 field of the
        most recently transmitted Reassociation Response frame. If no
        Reassociation Response frame has been transmitted, the value of this
        attribute is 0."
    ::= { dot11StationConfigEntry 47 }

dot11ReassociateID OBJECT-TYPE
    SYNTAX Unsigned32 (0..2007)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the MAC when a STA reassociates.

        This attribute indicates the Association ID from the most recently
        transmitted Reassociation Response frame. If no Reassociation Response
        frame has been transmitted, the value of this attribute is 0."
    ::= { dot11StationConfigEntry 48 }

dot11ReassociateFailStation OBJECT-TYPE
    SYNTAX MacAddress
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the MAC when a STA fails to reassociate.

        This attribute indicates the MAC address from the Address 1 field of the
        most recently transmitted failed Reassociation Response frame. If no
        failed Reassociation Response frame has been transmitted, the value of
        this attribute is 0."
    ::= { dot11StationConfigEntry 49 }

dot11ReassociateFailStatus OBJECT-TYPE
    SYNTAX Unsigned32 (0..65535)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the MAC when a STA fails to reassociate.

        This attribute indicates the most recently transmitted Status Code
        field(M118) in a failed Reassociation Response frame. If no failed Reasso-
        ciation Response frame has been transmitted, the value of this attribute
        is 0."
    ::= { dot11StationConfigEntry 50 }

dot11RadioMeasurementImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the station implementation is
        capable of supporting Radio Measurement. Otherwise it is not capable of
        performing Radio Measurement."
```

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```
    ::= { dot11StationConfigEntry 51 }

dot11RadioMeasurementActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity when any of the MIB
        attributes listed in 9.4.2.43 (RM Enabled Capabilities element) is equal
        to true.
        Changes take effect with the next MLME-START.request primitive or MLME-
        JOIN.request primitive.

        This attribute, when true, indicates that one or more of the Radio
        Measurement Activated Capabilities MIB attributes, listed in 9.4.2.43 (RM
        Enabled Capabilities element), are equal to true. A STA may use the
        defined Radio Measurement procedures if this attribute is true."
    DEFVAL { false }
    ::= { dot11StationConfigEntry 52 }

dot11RMMeasurementNavSync OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        The value of ProbeDelay to be used when making a beacon type measurement
        with measurement mode active."
    ::= { dot11StationConfigEntry 53 }

dot11RMMeasurementPilotPeriod OBJECT-TYPE
    SYNTAX Unsigned32 (1..255)
    UNITS "TUs"(#1724)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute specifies the time period(#1724) that a station uses for
        scheduling Measurement Pilot frame transmissions. This value is
        transmitted in Measurement Pilot frames. The default period is 25% of
        dot11BeaconPeriod."
    ::= { dot11StationConfigEntry 54 }

dot11RMLinkMeasurementActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect for the next MLME-START.request primitive or MLME-
        JOIN.request primitive.

        This attribute, when true, indicates that dot11RadioMeasurementActivated
        is true and that the station capability for Link Measurement is enabled. A
        value of false indicates the station has no Link Measurement capability or
        that the capability is present but is disabled."
```


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```
    DEFVAL { false }
    ::= { dot11StationConfigEntry 55 }

dot11RMNeighborReportActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute, when true, indicates that dot11RadioMeasurementActivated
        is true and that the station capability for neighbor report is enabled.
        false indicates the station has no neighbor report capability or that the
        capability is present but is disabled."
    DEFVAL { false }
    ::= { dot11StationConfigEntry 56 }

dot11RMParallelMeasurementsActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect for the next MLME-START.request primitive or MLME-
        JOIN.request primitive.

        This attribute, when true, indicates that dot11RadioMeasurementActivated
        is true and that the station capability for Parallel Measurements is
        enabled. false indicates the station has no Parallel Measurements
        capability or that the capability is present but is disabled."
    DEFVAL { false }
    ::= { dot11StationConfigEntry 57 }

dot11RMRepeatedMeasurementsActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect for the next MLME-START.request primitive or MLME-
        JOIN.request primitive.

        This attribute, when true, indicates that dot11RadioMeasurementActivated
        is true and that the station capability for Repeated Measurements is
        enabled. false indicates the station has no Repeated Measurements
        capability or that the capability is present but is disabled."
    DEFVAL { false }
    ::= { dot11StationConfigEntry 58 }

dot11RMBeaconPassiveMeasurementActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect for the next MLME-START.request primitive or MLME-
        JOIN.request primitive.

        This attribute, when true, indicates that dot11RadioMeasurementActivated
```

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```
        is true and that the station capability for Beacon Passive Measurement is
        enabled. false indicates the station has no Beacon Passive Measurement
        capability or that the capability is present but is disabled."
    DEFVAL { false }
    ::= { dot11StationConfigEntry 59 }

dot11RMBeaconActiveMeasurementActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect for the next MLME-START.request primitive or MLME-
        JOIN.request primitive.

        This attribute, when true, indicates that dot11RadioMeasurementActivated
        is true and that the station capability for Beacon Active Measurement is
        enabled. false indicates the station has no Beacon Active Measurement
        capability or that the capability is present but is disabled."
    DEFVAL { false }
    ::= { dot11StationConfigEntry 60 }

dot11RMBeaconTableMeasurementActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect for the next MLME-START.request primitive or MLME-
        JOIN.request primitive.

        This attribute, when true, indicates that dot11RadioMeasurementActivated
        is true and that the station capability for Beacon Table Measurement is
        enabled. false indicates the station has no Beacon Table Measurement
        capability or that the capability is present but is disabled."
    DEFVAL { false }
    ::= { dot11StationConfigEntry 61 }

dot11RMBeaconMeasurementReportingConditionsActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect for the next MLME-START.request primitive or MLME-
        JOIN.request primitive.

        This attribute, when true, indicates that dot11RadioMeasurementActivated
        is true and that the station capability for Beacon Measurement Reporting
        Conditions is enabled. false indicates the station has no Beacon
        Measurement Reporting Conditions capability or that the capability is
        present but is disabled."
    DEFVAL { false }
    ::= { dot11StationConfigEntry 62 }

dot11RMFrameMeasurementActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
```


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```
        It is written by an external management entity.
        Changes take effect for the next MLME-START.request primitive or MLME-
        JOIN.request primitive.

        This attribute, when true, indicates that dot11RadioMeasurementActivated
        is true and that the station capability for Frame Measurement is enabled.
        false indicates the station has no Frame Measurement capability or that
        the capability is present but is disabled."
    DEFVAL { false }
    ::= { dot11StationConfigEntry 63 }

dot11RMChannelLoadMeasurementActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect for the next MLME-START.request primitive or MLME-
        JOIN.request primitive.

        This attribute, when true, indicates that dot11RadioMeasurementActivated
        is true and that the station capability for Channel Load Measurement is
        enabled. false indicates the station has no Channel Load Measurement
        capability or that the capability is present but is disabled."
    DEFVAL { false }
    ::= { dot11StationConfigEntry 64 }

dot11RMNoiseHistogramMeasurementActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect for the next MLME-START.request primitive or MLME-
        JOIN.request primitive.

        This attribute, when true, indicates that dot11RadioMeasurementActivated
        is true and that the station capability for Noise Histogram Measurement is
        enabled. false indicates the station has no Noise Histogram Measurement
        capability or that the capability is present but is disabled."
    DEFVAL { false }
    ::= { dot11StationConfigEntry 65 }

dot11RMStatisticsMeasurementActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute, when true, indicates that dot11RadioMeasurementActivated
        is true and that the station capability for Statistics Measurement is
        enabled. false indicates the station has no Statistics Measurement
        capability or that the capability is present but is disabled."
    DEFVAL { false }
    ::= { dot11StationConfigEntry 66 }

dot11RMLCIMeasurementActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
```

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```
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect for the next MLME-START.request primitive or MLME-
        JOIN.request primitive.

        This attribute, when true, indicates that dot11RadioMeasurementActivated
        is true and that the station capability for LCI Measurement is enabled.
        false indicates the station has no LCI Measurement capability or that the
        capability is present but is disabled."
    DEFVAL { false }
    ::= { dot11StationConfigEntry 67 }

dot11RMLCIAzimuthActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect for the next MLME-START.request primitive or MLME-
        JOIN.request primitive.

        This attribute, when true, indicates that dot11RadioMeasurementActivated
        is true and that the station capability for LCI Azimuth Measurement is
        enabled. false indicates the station has no LCI Azimuth Measurement
        capability or that the capability is present but is disabled."
    DEFVAL { false }
    ::= { dot11StationConfigEntry 68 }

dot11RMTransmitStreamCategoryMeasurementActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute, when true, indicates that dot11RadioMeasurementActivated
        is true and that the station capability for Transmit Stream/Category
        Measurement is enabled. false indicates the station has no Transmit
        Stream/Category Measurement capability or that the capability is present
        but is disabled."
    DEFVAL { false }
    ::= { dot11StationConfigEntry 69 }

dot11RMTriggeredTransmitStreamCategoryMeasurementActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute, when true, indicates that dot11RadioMeasurementActivated
        is true and that the station capability for Triggered Transmit Stream/
        Category Measurement is enabled. false indicates the station has no
        Triggered Transmit Stream/Category Measurement capability or that the
        capability is present but is disabled."
    DEFVAL { false }
    ::= { dot11StationConfigEntry 70 }
```


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```
dot11RMAPChannelReportActivated OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by an external management entity.
      Changes take effect for the next MLME-START.request primitive or MLME-
      JOIN.request primitive.

      This attribute, when true, indicates that dot11RadioMeasurementActivated
      is true and that the station capability for AP Channel Report is enabled.
      false indicates the station has no AP Channel Report capability or that
      the capability is present but is disabled."
   DEFVAL { false }
   ::= { dot11StationConfigEntry 71 }

dot11RMMIBActivated OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by an external management entity.
      Changes take effect as soon as practical in the implementation.

      This attribute, when true, indicates that dot11RadioMeasurementActivated
      is true and that the station capability for RM MIB is enabled. false
      indicates the station has no RM MIB capability or that the capability is
      present but is disabled. See RM MIB details."
   DEFVAL { false }
   ::= { dot11StationConfigEntry 72 }

dot11RMMaxMeasurementDuration OBJECT-TYPE
   SYNTAX Unsigned32 (0 .. 7)
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by an external management entity.
      Changes take effect as soon as practical in the implementation.

      This attribute indicates the maximum measurement duration for operating
      channel measurements, where
      Max Measurement Duration in TUs =
        (2 ^ (dot11RMMaxMeasurementDuration - 4)) * BeaconInterval

      Further details are provided in 11.10.4 (Measurement duration)"
   ::= { dot11StationConfigEntry 73 }

dot11RMNonOperatingChannelMaxMeasurementDuration OBJECT-TYPE
   SYNTAX Unsigned32 (0 .. 7)
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by an external management entity.
      Changes take effect for the next MLME-START.request primitive or MLME-
      JOIN.request primitive.

      This attribute indicates the maximum measurement duration for nonoperating
      channel measurements, where
```

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```
        Non-OpMax Measurement Duration in TUs =
          (2 ^ (dot11RMNonOperatingChannelMaxMeasurementDuration - 4))
          * BeaconInterval

        Further details are provided in 11.10.4 (Measurement duration)"
    ::= { dot11StationConfigEntry 74 }

dot11RMMeasurementPilotTransmissionInformationActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute, when true, indicates that dot11RadioMeasurementActivated
        is true and that the station capability for Measurement Pilot Transmission
        information is enabled. false indicates the station has no Measurement
        Pilot Transmission information capability or that the capability is
        present but is disabled."
    DEFVAL { false }
    ::= { dot11StationConfigEntry 75 }

dot11RMMeasurementPilotActivated OBJECT-TYPE
    SYNTAX Unsigned32 (0 .. 7)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute indicates the station capability for Measurement Pilot
        frame(#297). The value 0 indicates the station has no Measurement Pilot
        frame(#297) capability or that the capability is present but is disabled.
        Activated values 1-7 are defined in Table 11-14 (Measurement pilot acti-
        vated definition)."
    DEFVAL { 0 }
    ::= { dot11StationConfigEntry 76 }

dot11RMNeighborReportTSFOffsetActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute, when true, indicates that dot11RadioMeasurementActivated
        is true and that the station capability for Neighbor Report TSF Offset is
        enabled. false indicates the station has no Neighbor Report TSF Offset
        capability or that the capability is present but is disabled."
    DEFVAL { false }
    ::= { dot11StationConfigEntry 77 }

dot11RMRCPIMeasurementActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
```


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```
        Changes take effect for the next MLME-START.request primitive or MLME-
        JOIN.request primitive.

        This attribute, when true, indicates that dot11RadioMeasurementActivated
        is true and that the station capability for RCPI Measurement is enabled.
        false indicates the station has no RCPI Measurement capability or that the
        capability is present but is disabled."
    DEFVAL { false }
    ::= { dot11StationConfigEntry 78 }

dot11RMRSNIMeasurementActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute, when true, indicates that dot11RadioMeasurementActivated
        is true and that the station capability for RSNI Measurement is enabled.
        false indicates the station has no RSNI Measurement capability or that the
        capability is present but is disabled."
    DEFVAL { false }
    ::= { dot11StationConfigEntry 79 }

dot11RMBSSAverageAccessDelayActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect for the next MLME-START.request primitive or MLME-
        JOIN.request primitive.

        This attribute, when true, indicates that dot11RadioMeasurementActivated
        is true and that the station capability for BSS Average Access Delay is
        enabled. false indicates the station has no BSS Average Access Delay
        capability or that the capability is present but is disabled."
    DEFVAL { false }
    ::= { dot11StationConfigEntry 80 }

dot11RMBSSAvailableAdmissionCapacityActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect for the next MLME-START.request primitive or MLME-
        JOIN.request primitive.

        This attribute, when true, indicates that dot11RadioMeasurementActivated
        is true and that the station capability for BSS Available Admission
        Capacity is enabled. false indicates the station has no BSS Available
        Admission Capacity capability or that the capability is present but is
        disabled."
    DEFVAL { false }
    ::= { dot11StationConfigEntry 81 }

dot11RMAntennaInformationActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
```

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```
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect for the next MLME-START.request primitive or MLME-
        JOIN.request primitive.

        This attribute, when true, indicates that dot11RadioMeasurementActivated
        is true and that the station capability for Antenna information is
        enabled. false indicates the station has no Antenna information capability
        or that the capability is present but is disabled."
    DEFVAL { false }
    ::= { dot11StationConfigEntry 82 }

dot11FastBSSTransitionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This object indicates if the entity is fast BSS transition capable."
    ::= { dot11StationConfigEntry 83 }

dot11LCIDSEImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the station implementation is
        capable of supporting LCI DSE. The capability is disabled, otherwise."
    ::= { dot11StationConfigEntry 84 }

dot11LCIDSERequired OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by the SME.

        A STA uses the Dependent Station Enablement procedures if this attribute
        is true."
    DEFVAL { false }
    ::= { dot11StationConfigEntry 85 }

dot11DSERequired OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by the SME.

        This attribute, when true, indicates that the station operation is
        dependent on enablement from enabling STAs. This attribute, when false,
        indicates that the station operation does not depend on enablement from
        STAs."
    DEFVAL { false }
    ::= { dot11StationConfigEntry 86 }
```


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```
dot11ExtendedChannelSwitchActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by the SME when the (#4213)STA is initialized for operation
        in a band defined by an Operating Class.

        This attribute, when true, indicates that the capability of the station to
        perform extended channel switching is enabled."
    DEFVAL { false }
    ::= { dot11StationConfigEntry 87 }

--**********************************************************
--* Management frame protection MIBs
--**********************************************************
dot11RSNAProtectedManagementFramesActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This variable indicates whether this STA enables management frame
        protection."
    DEFVAL { false }
    ::= { dot11StationConfigEntry 88}

dot11RSNAUnprotectedManagementFramesAllowed OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This variable indicates whether this STA supports (#333)RSNA STAs that do
        not provide management frame protection."
    DEFVAL { true }
    ::= { dot11StationConfigEntry 89}

--**********************************************************
--* SA Query Procedure MIBs
--**********************************************************
dot11AssociationSAQueryMaximumTimeout OBJECT-TYPE
    SYNTAX Unsigned32 (1..4294967295)
    UNITS "TUs"(#1724)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute specifies the time period(#1724) that an AP can wait, from
        the scheduling of the first SA Query Request to allow association process
        to be started without starting additional SA Query procedure if a success-
        ful SA Query Response is not received."
    DEFVAL { 1000 }
```

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```
    ::= { dot11StationConfigEntry 90}

dot11AssociationSAQueryRetryTimeout OBJECT-TYPE
    SYNTAX Unsigned32 (1..4294967295)
    UNITS "TUs"(#1724)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute specifies the time period(#1724) that an AP waits between
        issuing two subsequent MLME-SA-QUERY.request primitive primitives."
    DEFVAL { 201 }
    ::= { dot11StationConfigEntry 91}

dot11HighThroughputOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute indicates whether the entity is HT capable."
    ::= { dot11StationConfigEntry 92}

dot11RSNAPBACRequired OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This variable indicates whether this STA requires the (#1405)protection of
        block ack agreements."
    DEFVAL { false }
    ::= { dot11StationConfigEntry 93}

dot11PSMPOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS Deprecated(#3263)
    DESCRIPTION
        "Deprecated as the related feature has been removed from the stan-
        dard.(#3263)
        This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the station implementation is
        capable of supporting PSMP."
    ::= { dot11StationConfigEntry 94 }

dot11TunneledDirectLinkSetupImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        This attribute, when true, indicates that the STA implementation is
        capable of supporting tunneled direct link(#1356) setup."
```


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```
    ::= { dot11StationConfigEntry 95 }

dot11TDLSPeerUAPSDBufferSTAActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        This attribute, when true, indicates that the STA implementation is
        capable of supporting TPU."
    ::= { dot11StationConfigEntry 96 }

dot11TDLSPeerPSMActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        This attribute, when true, indicates that the STA implementation is
        capable of supporting TDLS peer PSM."
    ::= { dot11StationConfigEntry 97 }

dot11TDLSPeerUAPSDIndicationWindow OBJECT-TYPE
    SYNTAX Unsigned32 (1..256)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control  variable.
        This attribute indicates the minimum interval in Beacon Intervals between
        successive Peer Traffic Indication frames."
    DEFVAL { 1 }
    ::= { dot11StationConfigEntry 98 }

dot11TDLSChannelSwitchingActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        This attribute, when true, indicates that the STA implementation is
        capable of supporting TDLS Channel Switching."
    ::= { dot11StationConfigEntry 99 }

dot11TDLSPeerSTAMissingAckRetryLimit OBJECT-TYPE
    SYNTAX Unsigned32 (1..100)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control  variable.
        This attribute indicates the number of times the TDLS STA may retry a
        frame for which it does not receive an Ack frame from TDLS peer STA in
        power save mode after the TDLS peer STA does not receive an Ack frame to
        an individually addressed MPDU sent with the EOSP subfield equal to 1 or
        to an individually addressed MPDU that initiated a channel switch."
    DEFVAL { 3 }
    ::= { dot11StationConfigEntry 100 }

dot11TDLSResponseTimeout OBJECT-TYPE
    SYNTAX Unsigned32 (1..255)
    UNITS "seconds"
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
```

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```
        This attribute indicates the amount of time the STA waits before timing
        out a TDLS setup request."
    DEFVAL { 5 }
    ::= { dot11StationConfigEntry 101 }

dot11OCBActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        A STA uses the defined outside the context of a BSS procedures if this
        attribute is true; otherwise it does not use them.(#7220)"
    DEFVAL { false }
    ::= { dot11StationConfigEntry 102 }

dot11TDLSNavSync OBJECT-TYPE
    SYNTAX Unsigned32 (1..65535)
    UNITS "microseconds"
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        This attribute indicates the amount of time the STA waits before
        transmitting on a new channel, in the absence of traffic on the channel
        that causes a CCA state to be created."
    DEFVAL { 1000 }
    ::= { dot11StationConfigEntry 103 }

dot11TDLSDiscoveryRequestWindow OBJECT-TYPE
    SYNTAX Unsigned32 (1..255)
    MAX-ACCESS read-write
    STATUS (#3441)deprecated(#1712)
    DESCRIPTION
        "Deprecated as the related feature has been removed from the stan-
        dard.(#1712) This is a control variable.
        This attribute indicates the minimum number of DTIM intervals between suc-
        cessive TDLS Discovery Request frames."
    DEFVAL { 2 }
    ::= { dot11StationConfigEntry 104 }

dot11TDLSACDeterminationInterval OBJECT-TYPE
    SYNTAX Unsigned32 (1..255)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control  variable.
        This attribute indicates the number of seconds during which the lowest AC
        of transmitted traffic is determined."
    DEFVAL { 1 }
    ::= { dot11StationConfigEntry 105 }

dot11WirelessManagementImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the station implementation is
        capable of supporting one or more wireless network management services."
    ::= { dot11StationConfigEntry 106}
```


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```
dot11BssMaxIdlePeriod OBJECT-TYPE
   SYNTAX Unsigned32 (1..65535)
   MAX-ACCESS read-write
   UNITS "1000 TUs"
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by an external management entity or the SME.
      Changes take effect as soon as practical in the implementation.

      At an AP, this attribute indicates that the time period that passes before
      an AP disassociates an inactive non-AP STA. This value may be overriden by
      the AP based on the non-AP STA indication, if any, in the (Re)Association
      Request frame. The (overriden, if needed) value is transmitted in the
      (Re)Association Response frame.

      At a non-AP STA, this attribute indicates the requested time before which
      the AP should not disassociate the inactive non-AP STA due to inactivity.
      This value might be transmitted in the (Re)Association Request frame."
   ::= { dot11StationConfigEntry 107}

dot11BssMaxIdlePeriodOptions OBJECT-TYPE
   SYNTAX OCTET STRING (SIZE(1))
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by an external management entity or the SME.
      Changes take effect as soon as practical in the implementation.

      This attribute indicates the options associated with the BSS max idle
      capability. This value is transmitted in the Association Response and
      Reassociation Response frames."
   ::= { dot11StationConfigEntry 108}

dot11TIMBroadcastInterval OBJECT-TYPE
   SYNTAX Unsigned32 (0..255)
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by an external management entity or the SME.
      Changes take effect as soon as practical in the implementation.

      This attribute indicates the number of beacon periods between TIM frame
      transmissions. A value of 0 disables TIM Broadcast for the requesting sta-
      tion."
   DEFVAL { 0 }
   ::= { dot11StationConfigEntry 109}

dot11TIMBroadcastOffset OBJECT-TYPE
   SYNTAX Integer32 (-214748364..214748363)
   UNITS "microseconds"
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by an external management entity or the SME.
      Changes take effect as soon as practical in the implementation.

      This attribute indicates the offset with a tolerance of +/- 4 microseconds
      relative to the TBTT for which a TIM frame is scheduled for transmission."
   DEFVAL { 0 }
   ::= { dot11StationConfigEntry 110}
```

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```
dot11TIMBroadcastHighRateTIMRate OBJECT-TYPE
   SYNTAX Unsigned32 (0..65535)
   UNITS "0.5 Mb/s"
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by an external management entity or the SME.
      Changes take effect as soon as practical in the implementation.

      This attribute indicates the rate used to transmit the high data rate
      TIM frame. A value of 0 indicates that the high data rate TIM frame is not
      transmitted."
   DEFVAL { 0 }
   ::= { dot11StationConfigEntry 111}

dot11TIMBroadcastLowRateTIMRate OBJECT-TYPE
   SYNTAX Unsigned32 (0..65535)
   UNITS "0.5 Mb/s"
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by an external management entity or the SME.
      Changes take effect as soon as practical in the implementation.

      This attribute indicates the rate used to transmit the low data rate
      TIM frame. A value of 0 indicates that the low data rate TIM frame is not
      transmitted."
   DEFVAL { 0 }
   ::= { dot11StationConfigEntry 112}

dot11StatsMinTriggerTimeout OBJECT-TYPE
   SYNTAX Unsigned32 (10..7200)
   UNITS "seconds"
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by an external management entity or the SME.
      Changes take effect as soon as practical in the implementation.

      This attribute indicates the minimum allowable value for Triggered
      Timeout. A Triggered STA Statistics report is generated by the STA after
      the timeout if none of the trigger conditions are satisfied."
   DEFVAL { 10 }
   ::= { dot11StationConfigEntry 113 }

dot11RMCivicMeasurementActivated OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by an external management entity or the SME.
      Changes take effect as soon as practical in the implementation.

      This attribute, when true, indicates that dot11RadioMeasurementActivated
      is true and that the station capability for Location Civic Measurement is
      enabled. false indicates the station has no Location Civic Measurement
      capability or that the capability is present but is disabled."
   DEFVAL { false }
   ::= { dot11StationConfigEntry 114 }
```


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```
dot11RMIdentifierMeasurementActivated OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by an external management entity or the SME.
      Changes take effect as soon as practical in the implementation.

      This attribute, when true, indicates that dot11RadioMeasurementActivated
      is true and that the station capability for location identifier
      measurement is enabled. false indicates the station has no Location
      Identifier Measurement capability or that the capability is present but is
      disabled."
   DEFVAL { false }
   ::= { dot11StationConfigEntry 115 }

dot11TimeAdvertisementDTIMInterval OBJECT-TYPE
   SYNTAX Unsigned32 (1..255)
   UNITS "DTIM intervals"(#4221)
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by an external management entity or the SME.
      Changes take effect as soon as practical in the implementation.

      This attribute indicates the interval (#4221)when the Time Advertisement
      element is included in Beacon frames."
   DEFVAL { 1 }
   ::= { dot11StationConfigEntry 116 }

dot11InterworkingServiceImplemented OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a capability variable.

      Its value is determined by (#3375)STA capabilities.

      This attribute when true, indicates the STA is capable of interworking
      with external networks. A STA setting this to true implements Interworking
      Service. When this is false, the STA does not implement Interworking
      Service."
   ::= { dot11StationConfigEntry 117 }

dot11InterworkingServiceActivated OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.

      It is written by an external management entity or the SME. Changes take
      effect as soon as practical in the implementation.

      This attribute when true, indicates the capability of the STA to interwork
      with external networks is enabled. The capability is disabled otherwise."
   DEFVAL { false }(#7210)
   ::= { dot11StationConfigEntry 118 }

dot11QosMapImplemented OBJECT-TYPE
```

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```
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.

        Its value is determined by (#3375)STA capabilities.

        This attribute available at STAs, when true, indicates the STA is capable
        of supporting the QoS Map procedures. When this is false, the STA does not
        implement QoS Map procedures."
    ::= { dot11StationConfigEntry 119 }

dot11QosMapActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.

        It is written by an external management entity or the SME. Changes take
        effect as soon as practical in the implementation.

        This attribute, when true, indicates the capability of the STA to support
        QoS Map procedures is enabled. The capability is disabled otherwise."
    DEFVAL { false }(#7210)
    ::= { dot11StationConfigEntry 120 }

dot11EBRImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.

        Its value is determined by (#3375)STA capabilities.

        This attribute available at STAs, when true, indicates the STA is capable
        of supporting Expedited Bandwidth Request procedures. When this is false,
        the STA does not implement Expedited Bandwidth Request procedures."
    ::= { dot11StationConfigEntry 121 }

dot11EBRActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.

        It is written by an external management entity or the SME. Changes take
        effect as soon as practical in the implementation.

        This attribute, when true, indicates the capability of the STA to support
        Expedited Bandwidth Request procedures is enabled. The capability is
        disabled otherwise."
    DEFVAL { false }(#7210)
    ::= { dot11StationConfigEntry 122 }

dot11ESNetwork OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
```


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```
        It is written by an external management entity or the SME. Changes take
        effect as soon as practical in the implementation.

        The emergency services access network type equal to true indicates that
        the BSS is used exclusively for the purposes of accessing emergency
        services. This object is not used by non-AP STAs."
    ::= { dot11StationConfigEntry 123 }

dot11SSPNInterfaceImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.

        Its value is determined by (#3375)STA capabilities.

        This attribute when true, indicates the AP is capable of SSPN Interface
        service. When this is false, the STA does not implement SSPN Interface
        Service. This object is not used by non-AP STAs."
    ::= { dot11StationConfigEntry 124 }

dot11SSPNInterfaceActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.

        It is written by an external management entity or the SME. Changes take
        effect as soon as practical in the implementation.

        This attribute, when true, indicates the capability of the AP to provide
        SSPN Interface service is enabled. The capability is disabled, otherwise."
    DEFVAL { false }(#7210)
    ::= { dot11StationConfigEntry 125 }

dot11HESSID OBJECT-TYPE
    SYNTAX MacAddress
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.

        It is written by an external management entity or the SME. Changes take
        effect for the next MLME-START.request primitive.

        This attribute is used by an AP and is the (#2047)HeSS(M12) identifier
        field, whose value is set to one of the BSSIDs in the HeSS(M12). It is
        required that the same value of HESSID be used for all BSSs in the
        HeSS(M12)."
    ::= { dot11StationConfigEntry 126 }

dot11EASImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.

        Its value is determined by (#3375)STA capabilities.

        This attribute when true, indicates the STA is capable of emergency alert
```

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```
        system notification with external networks. A STA setting this to true
        implements emergency alert system notification. When this is false, the
        STA does not implement emergency alert system notification."
    ::= { dot11StationConfigEntry 127 }

dot11EASActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.

        It is written by an external management entity or the SME. Changes take
        effect as soon as practical in the implementation.

        This attribute when true, indicates the STA is capable of supporting
        emergency alert system. The capability is disabled otherwise."
    DEFVAL { false }(#7210)
    ::= { dot11StationConfigEntry 128 }

dot11MSGCFImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.

        Its value is determined by (#3375)STA capabilities.

        This attribute when true, indicates the non-AP STA is capable of
        supporting the MSGCF procedures defined in 6.4 (Table of MLME SAP
        interfaces(#1114)). When false, the non-AP STA does not implement MSGCF
        procedures. This object is not used by APs."
    ::= { dot11StationConfigEntry 129 }

dot11MSGCFActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.

        It is written by an external management entity or the SME. Changes take
        effect as soon as practical in the implementation.

        This attribute, when true, indicates the capability of the non-AP STA to
        provide the MSGCF is enabled. The capability is disabled, otherwise."
    DEFVAL { false }(#7210)
    ::= { dot11StationConfigEntry 130 }

dot11TimeAdvertisementTimeError OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(5))
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        This attribute indicates the Time Error value as defined in the Time
        Advertisement element Time Error field when the Time Capabilities field is
        set to 2. This field is included in the Time Advertisement element in
        Beacon and Probe Response frames."
    DEFVAL { '0000000000'H }(#1342)
```


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```
    ::= { dot11StationConfigEntry 131 }

dot11TimeAdvertisementTimeValue OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(10))
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        This attribute indicates the TimeAdvertisement Time Value as defined in
        the Time Advertisement element Time Value field when the Time Capabilities
        field is set to 2. The format is defined in Table 9-232 (Time Value field
        format when Timing Capabilities is 2) and is included in the Time Adver-
        tisement element in Beacon and Probe Response frames."
    ::= { dot11StationConfigEntry 132 }

dot11RM3rdPartyMeasurementActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        This attribute, when true, indicates that dot11RadioMeasurementActivated
        is true and that the station capability for Third Party Location
        Measurement is enabled. false indicates the station has no Third Party
        Location Measurement capability or that the capability is present but is
        disabled."
    DEFVAL { false }
    ::= { dot11StationConfigEntry 133 }

dot11RejectUnadmittedTraffic OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect at the next MLME-START.request primitive or  MLME-
        JOIN.request primitive.

         This attribute when true indicates the STA rejects MA-UNITDATA.requests
        whose requested priority corresponds to an AC for which admission control
        is mandatory and for which there is not an admitted TSPEC."
    DEFVAL { false }
    ::= {dot11StationConfigEntry 134}

dot11BSSBroadcastNullCount OBJECT-TYPE
    SYNTAX Unsigned32 (1..64)
    MAX-ACCESS read-write
    STATUS deprecated
    DESCRIPTION
        "Deprecated because this attribute is not referenced in IEEE Std 802.11.
        This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute specifies the number of group addressed (QoS) Null frames
        an IBSS STA transmits before it changes power management modes."
    DEFVAL { 3 }
```

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```
    ::= {dot11StationConfigEntry 135}

dot11MeshActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        When this object is true, this indicates that the STA is a mesh STA.
        Configuration variables for mesh operation are found in the
        dot11MeshSTAConfigTable."
    ::= { dot11StationConfigEntry 136 }

dot11QMFActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by the SME or external management entity.
        In an AP changes take effect for the next MLME-START.request primitive. In
        a non-AP STA that is not associated and is not an IBSS STA, changes take
        effect as soon as practical in the implementation. In a non-AP STA that is
        associated, changes take effect at the end of the lifetime of the
        association. For a STA that is an IBSS STA, changes take effect for the
        next MLME-START.request primitive or MLME-JOIN.request primitive.
        This attribute indicates whether the entity is QMF enabled or disabled."
    DEFVAL { false }
    ::= { dot11StationConfigEntry 137 }

dot11QMFReconfigurationActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by the SME or external management entity.
        Changes take effect for the next MLME-START.request primitive or MLME-
        JOIN.request primitive.
        The purpose of dot11QMFReconfigurationActivated is to allow an SME to
        accept a QMF Policy Change request from another STA and respond with a QMF
        Policy frame."
    DEFVAL { false }
    ::= { dot11StationConfigEntry 138 }

dot11QMFPolicyChangeTimeout OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by the SME or external management entity.
        Changes take effect as soon as practical in the implementation.
        This attribute indicates the minimum number of TUs that a STA waits to
        receive a response to a QMF Policy Change request before declaring that
        the request has failed and also the number of TUs that a STA waits after
        it has received a rejection to a QMF Policy Change request before issuing
        a repeat QMF Policy Change request to the same destination STA."
    DEFVAL { 5000 }
    ::= { dot11StationConfigEntry 139 }
```


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```
dot11RobustAVStreamingImplemented OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a capability variable.
      Its value is determined by (#3375)STA capabilities.

      This attribute, when true, indicates that the station implementation
      supports robust AV streaming."
   ::= { dot11StationConfigEntry 140 }

dot11VHTOptionImplemented OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a capability variable.
      Its value is determined by (#3375)STA capabilities.

      This attribute indicates whether the entity is VHT capable."
   ::= { dot11StationConfigEntry 141}

dot11OperatingModeNotificationImplemented OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a capability variable.
      Its value is determined by (#3375)STA capabilities.

      This attribute indicates whether the entity is Operating Mode Notification
      Capable."
   ::= { dot11StationConfigEntry 142}

dot11TVHTOptionImplemented OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a capability variable.
      Its value is determined by (#3375)STA capabilities.
      This attribute indicates whether the entity is TVHT capable."
   ::= { dot11StationConfigEntry 143}

dot11MultibandImplemented OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a capability variable.
      Its value is determined by (#3375)STA capabilities.

      Multi-band Support Activated
      This attribute, when true, indicates that the STA is (#4105)contained
      within a logical device that supports operation over more than one fre-
      quency band or channel, and implements fast session transfer (FST)."
   ::= {  dot11StationConfigEntry 144 }

dot11ChannelScheduleManagementActivated OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
```

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```
        "This is a status variable.
        It is written by the SME when the (#4213)STA is initialized for
        operation in a band defined by an Operating Class.

        This attribute, when true, indicates that the STA implementation is
        capable of supporting Channel Schedule Management Announcement. The
        capability is disabled, otherwise."
    DEFVAL { false }
    ::= { dot11StationConfigEntry 145 }

dot11ContactVerificationSignalActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect for the next MLME-START.request primitive
        primitive.

        This attribute, when true, indicates that the system capability for
        contact verification signal is activated. false indicates that the STA has
        contact verification signal capability, but it is disabled."
    DEFVAL { false }
    ::= { dot11StationConfigEntry 146 }

dot11ContactVerificationSignalInterval OBJECT-TYPE
    SYNTAX Unsigned32 (1..255)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.

        dot11ContactVerificationSignalInterval indicates the maximum number of
        seconds that a GDD dependent STA may wait to receive the Contact
        Verification Signal frame before stopping operation in TVWS. Unless
        another value is mandated by regulatory authorities, the value is 60
        s(#7198)."
    DEFVAL { 60 }
    ::= { dot11StationConfigEntry 147 }

dot11NetworkChannelControlActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when the (#4213)STA is initialized for
        operation in a band defined by an Operating Class.

        This attribute, when true, indicates that the STA implementation is
        capable of supporting network channel control. The capability is disabled,
        otherwise."
    DEFVAL { false }
    ::= { dot11StationConfigEntry 148 }

dot11RLSSActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by the SME or an external management entity.
```


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```
        Changes take effect as soon as possible in the (#4213)STA.

        This attribute, when true, indicates that the RLQP capability is
        activated. The capability is disabled, otherwise."
    DEFVAL { false }
    ::= { dot11StationConfigEntry 149 }

dot11WhiteSpaceMapActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect for the next MLME-START.request
        primitive or MLME-JOIN.request primitive.

        This attribute, when true, indicates that the STA capability for white
        space map is activated. false indicates the STA has no white space map
        capability or that the capability is present but is disabled."
    DEFVAL { false }
    ::= { dot11StationConfigEntry 150 }

dot11WSSTAType OBJECT-TYPE
    SYNTAX INTEGER {gddap(1), gddnonapsta(2), gddfixedsta(3), reserved(4)}
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when the (#4213)STA is initialized for operation
        in a band that requires Geolocation Database Control.

        This attribute specifies the type of STA mode for the purpose of channel
        availability query requirements. This value is used to set the desired
        channel availability query request parameters in using GAS frames carrying
        Channel Availability Query element of RLQP. When set to gddap, the STA
        indicates that it operates as a personal/portable AP  after channel avail-
        ability query.
        When set to gddnonapsta, the STA indicates that it operates as a personal/
        portable non-AP STA after channel availability query. When set to
        gddfixedsta, the STA indicates that it operates as a fixed STA after
        channel availability query. When set to any other values, its use is
        reserved, and remains unspecified."
    ::= { dot11StationConfigEntry 151}

dot11GeolocationCapabilityActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME.
        Changes take effect as soon as practical in the implementation.

        This attribute, when true, indicates that the has obtained its (#4213)STA
        location information in geospatial coordinates for its position using its
        geolocation capability, as required for its device class, otherwise this
        is false."
    DEFVAL { false }
    ::= { dot11StationConfigEntry 152 }

dot11GDDActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
```

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```
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when the (#4213)STA is initialized for operation
        in a band that requires Geolocation Database Dependent behavior.

        This attribute, when true, indicates that the STA capability for operation
        with Geolocation Database Dependent behavior is activated. The capability
        is disabled, otherwise."
    DEFVAL { false }
    ::= { dot11StationConfigEntry 153 }

dot11GDDEnablementTimeLimit OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when the (#4213)STA is initialized.
        Changes take effect as soon as practical in the implementation.

        dot11GDDEnablementTimeLimit indicates the maximum number of seconds that a
        GDD dependent STA may transmit in a frequency band under the control of a
        geolocation database while attaining GDD enablement with a GDD enabling
        STA. Unless another value is mandated by regulatory authorities, the value
        is 32 s(#7198)."
    DEFVAL { 32 }
    ::= { dot11StationConfigEntry 155 }

dot11GDDEnablementFailHoldTime OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when the (#4213)STA is initialized.
        Changes take effect as soon as practical in the implementation.

        dot11GDDEnablementFailHoldTime indicates the number of seconds that a GDD
        dependent STA shall not transmit in a frequency band under control of a
        geolocation database when it fails to attain GDD enablement with an GDD
        enabling STA within dot11GDDEnablementTimeLimit seconds. Unless another
        value is mandated by regulatory authorities, the value is 512 s(#7198)."
    DEFVAL { 512 }
    ::= { dot11StationConfigEntry 156 }

dot11GDDEnablementValidityTimer OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-only
    STATUS deprecated
    DESCRIPTION
        "Deprecated as the related feature has been removed from IEEE Std 802.11.
        This is a status variable.
        It is written by the SME when the (#4213)STA is initialized.
        Changes take effect as soon as practical in the implementation.

        dot11GDDEnablementValidityTimer indicates the number of seconds that a GDD
        dependent STA remains in GDDEnabled state. Unless another value is
        mandated by regulatory authorities, the value is 60 s(#7198)."
    DEFVAL { 60 }
    ::= { dot11StationConfigEntry 157 }

dot11MaxMSDULength OBJECT-TYPE
    SYNTAX INTEGER { normal(2304), long(7920) }
```


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```
    UNITS "octets"
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.
        This attribute indicates the maximum supported MSDU size.
        This is 7920 octets for a DMG STA and 2304 octets for a non-DMG STA."
    ::= { dot11StationConfigEntry 162 }


dot11DynamicEIFSActivated OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect for the next MLME-START.request primitive or MLME-
        JOIN.request primitive.

        This attribute indicates whether the entity uses a dynamic value for EIFS
        based on properties of the PPDU that causes the EIFS, or a fixed value."
   ::= { dot11StationConfigEntry 158 }

dot11S1GOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute indicates whether the entity is S1G Capable."
    ::= { dot11StationConfigEntry 159 }

dot11FILSActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity or the SME. Changes
        take effect for the next MLME-START.request primitive or MLME-
        JOIN.request primitive.
        This attribute, when true, indicates that FILS is enabled."
    DEFVAL { false }(#7210)
    ::= { dot11StationConfigEntry 160 }

dot11ExtendedSpectrumManagementImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the non-VHT station
        implementation is capable of supporting extended spectrum management. The
        capability is disabled at the non-VHT station otherwise."
    ::= { dot11StationConfigEntry 161 }

dot11EstimatedServiceParametersInboundOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
```

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```
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.
        This attribute, when true, indicates that the IEEE 802.11 Estimated
        Service Parameters Inbound option is implemented."
    ::= { dot11StationConfigEntry 163 }

dot11VHTExtendedNSSBWCapable OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.
        This attribute, when true, indicates that the VHT extended NSS BW support
        option is implemented. dot11VHTExtendedNSSBWCapable is(#244) false when
        dot11VHTOptionImplemented is false."
    ::= { dot11StationConfigEntry 165 }

dot11FutureChannelGuidanceActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity or the SME. Changes take
        effect as soon as practical in the implementation.
        This attribute, when true, indicates the capability of the STA to support
        Future channel guidance procedures is enabled. The capability is disabled
        otherwise."
    DEFVAL { false }(#7210)
    ::= { dot11StationConfigEntry 166 }

dot11SolicitedPADActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity or the SME. Changes take
        effect as soon as practical in the implementation.
        This attribute when true, indicates that the capability of the STA to
        operate solicited PAD with external networks is enabled. The capability is
        disabled otherwise."
    DEFVAL { false }(#7210)
::= { dot11StationConfigEntry 167 }

dot11UnsolicitedPADActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity or the SME. Changes take
        effect as soon as practical in the implementation.
        This attribute when true, indicates that the capability of the STA to
        operate unsolicited PAD with external networks is enabled. The capability
        is disabled otherwise."
    DEFVAL { false }(#7210)
    ::= { dot11StationConfigEntry 168 }

dot11GLKImplemented OBJECT-TYPE
```


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```
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "When true, this attribute indicates a GLK capable STA. When false, it
        indicates a non-GLK capable STA. This is a capability variable."
    ::= { dot11StationConfigEntry 169 }

dot11GLKRequired OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "When true, this attribute indicates a STA that does(M118) not accept
        associations from or peer with a non-GLK capable STA. When false, it indi-
        cates a STA that (M118)peers with or accepts associations  from a non-GLK
        capable STA.
        This is a control variable.
        It is written by an external management entity. Changes take effect as
        soon as practical in the implementation."
    ::= { dot11StationConfigEntry 170 }

dot11EPDImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "When true, this attribute indicates a STA that supports the receipt and
        transmission of EPD MSDUs. When false, it indicates a STA that does not
        support EPD. This is a capability variable."
    ::= { dot11StationConfigEntry 171 }

dot11EPDRequired OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "When true, this attribute indicates a STA that (M118)only associates,
        direct links, or peers with a STA supporting EPD. When false, it indicates
        a STA that (M118)associates, direct links, or peers with a STA that does
        not support EPD.
        This is a control variable.
        It is written by an external management entity. Changes take effect as
        soon as practical in the implementation."
    ::= { dot11StationConfigEntry 172 }

dot11GLKLinkRateSamples OBJECT-TYPE
    SYNTAX Unsigned32 (2..257)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is the number of data bit rate sample windows in the array of such
        values used in the determination of the data rate metrics for general
        links.
        This is a control variable.
        It is written by an external management entity. Changes take effect as
        soon as practical in the implementation."
    DEFVAL { 8 }
    ::= { dot11StationConfigEntry 173 }

dot11GLKLinkRateWindowSize OBJECT-TYPE
    SYNTAX Unsigned32 (1..256)
    MAX-ACCESS read-only
    STATUS current
```

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```
    DESCRIPTION
        "The size of the data bit rate sample window duration in units of 16 TUs.
        This is a control variable.
        It is written by an external management entity. Changes take effect as
        soon as practical in the implementation."
    DEFVAL { 8 }
    ::= { dot11StationConfigEntry 174 }

dot11GLKLinkRateWmin OBJECT-TYPE
    SYNTAX Unsigned32 (0..255)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This value is the relative weight given to the minimum bit rate observed
        in the data rate sample windows on a general link or peering. A larger
        value means more weight or influence for the minimum observed bit rate.
        This is a control variable.
        It is written by an external management entity. Changes take effect as
        soon as practical in the implementation.
        It is used in the determination of the data rate metrics for general
        links."
    DEFVAL { 50 }
    ::= { dot11StationConfigEntry 175 }

dot11GLKLinkRateWavg OBJECT-TYPE
    SYNTAX Unsigned32 (0..255)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This value is the relative weight given to the arithmetic mean bit rate
        observed in the data rate sample windows on a general link or peering. A
        larger value means more weight or influence for the arithmetic mean
        observed bit rate.
        This is a control variable.
        It is written by an external management entity. Changes take effect as
        soon as practical in the implementation.
        It is used in the determination of the data rate metrics for general
        links."
    DEFVAL { 50 }
    ::= { dot11StationConfigEntry 176 }

dot11GLKLinkRateWgeo OBJECT-TYPE
    SYNTAX Unsigned32 (0..255)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This value is the relative weight given to the geometric mean of the bit
        rates observed in the data rate sample windows on a general link or peer-
        ing. A larger value means more weight or influence for the geometric mean
        of the observed bit rates.
        This is a control variable.
        It is written by an external management entity. Changes take effect as
        soon as practical in the implementation.
        It is used in the determination of the data rate metrics for general
        links."
    DEFVAL { 50 }
    ::= { dot11StationConfigEntry 177 }

dot11GLKLinkRateScaling OBJECT-TYPE
    SYNTAX Unsigned32 (1..256)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This value is used to scale the data rate reported appropriately depend-
```


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```
        ing on the use of that rate and how pessimistically data rates are being
        determined. A scaling of 16 would produce a data rate suitable for use in
        IEEE 802.1Q protocols with no pessimism.
        This is a control variable.
        It is written by an external management entity. Changes take effect as
        soon as practical in the implementation."
    DEFVAL { 10 }
    ::= { dot11StationConfigEntry 178 }

dot11GLKLinkRateHysteresis OBJECT-TYPE
    SYNTAX Unsigned32 (1..256)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This value is used to apply hysteresis to the data rate reported for a
        general link. If it contains 256, then any change in rate is immediately
        reported. The smaller its value, the larger the change that occurs before
        that change is reported.
        This is a control variable.
        It is written by an external management entity. Changes take effect as
        soon as practical in the implementation."
    DEFVAL { 200 }
    ::= { dot11StationConfigEntry 179 }

dot11GLKGCRImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "When true, this attribute indicates a GLK-GCR capable STA. When false,
        this attribute indicates a GLK capable STA that does not support GLK-GCR
        or a STA that is not GLK capable.
        This is a capability variable."
    ::= { dot11StationConfigEntry 180 }

dot11GASExtensionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable. Its value is determined by (#3375)STA
        capabilities. This attribute, when true, indicates that the STA is capable
        of operating in GAS extension in GAS frame exchanges. Otherwise, it is
        false."
::= { dot11StationConfigEntry 183 }

dot11MACPrivacyActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity or the SME. Changes take
        effect as soon as practical in the implementation. This attribute when
        true, indicates that the (#4023)non-AP STA enables MAC privacy
        considerations. Otherwise, the capability is disabled, and the STA's MAC
        address in unchanging."
    DEFVAL { false }(#7210)
    ::= { dot11StationConfigEntry 184 }

dot11LocallyAdministeredMACConfig OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-write
    STATUS current
```

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```
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity or the SME. Changes take
        effect as soon as practical in the implementation. This attribute identi-
        fies an addressing plan to use for when associating with the BSS.

        0: local addresses comply with the Structured Local Address Plan as
        defined in IEEE Std 802c-2017

        1: local addresses are constructed according to vendor-specific local
        address plan.")
    DEFVAL {0}
    ::= { dot11StationConfigEntry 185 }

(11ba)dot11WUROptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.
        This attribute, when true, indicates that the WUR feature is implemented
        and operational. This attribute, when false or not present, indicates that
        the WUR feature is not implemented or not operational."
::= { dot11StationConfigEntry 186 }

dot11EstimatedServiceParametersOutboundOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.
        This attribute, when true, indicates that the IEEE 802.11 Estimated
        Service Parameters Outbound option is implemented."
    ::= { dot11StationConfigEntry 191 }

dot11RSNAOperatingChannelValidationActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.
        This variable indicates whether this STA has enabled operating channel
        validation in an RSNA."
    DEFVAL { false }(#7210)
    ::= { dot11StationConfigEntry 192 }

dot11BeaconProtectionEnabled OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.
        This variable indicates whether beacon protection is enabled. If dot11Bea-
        conProtectionEnabled is true for an AP, beacon protection is enabled on
        transmission. If dot11BeaconProtectionEnabled is true for a non-AP STA and
        the STA receives a BIGTK from the AP with which it is associated,  beacon
        protection is enabled on reception.  Otherwise, beacon protection is dis-
        abled."
```


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```
    DEFVAL { false }(#7210)
    ::= { dot11StationConfigEntry 195 }

dot11MSCSActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by the MAC or an external management entity.
        Changes take effect as soon as practical in the implementation.
        This variable indicates whether support for Mirrored SCS is enabled on the
        STA."
    DEFVAL { false }(#7210)
    ::= { dot11StationConfigEntry 197 }

dot11LocalMACAddressPolicyActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity or the SME.

        Changes take effect as soon as practical in the implementation.
        This attribute, when true, indicates the presence of a local MAC address
        policy to be advertised."
    DEFVAL { false }(#7210)
    ::= { dot11StationConfigEntry 188 }

(11ax)dot11BSSMaxIdlePeriodIndicationByNonAPSTA OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        This attribute is only present for a non-S1G STA.

        This attribute, when true at a non-AP STA, indicates that the STA might
        include the BSS Max Idle Period element in (Re)Association Request frames.

        This attribute, when true at an AP, indicates that the AP might consider
        the value of the Max Idle Period subfield in the BSS Max Idle Period ele-
        ment in the (Re)Association Request frame in setting the Max Idle Period
        subfield in the BSS Max Idle Period element in the (Re)Association
        Response frame."
    ::= { dot11StationConfigEntry 200 }

(11ax)dot11HEOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute indicates whether the entity is HE Capable."
::= { dot11StationConfigEntry 181 }

(11ax)dot11OBSSNarrowBWRUinOFDMATolerated OBJECT-TYPE
    SYNTAX TruthValue
```

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```
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute indicates whether the AP STA is able to tolerate 26-tone RU
        UL OFDMA transmissions using HE TB PPDU from OBSS (not falsely classify
        the 26-tone RU UL OFDMA transmissions as radar pulses)."
::= { dot11StationConfigEntry 182 }

(11ax)dot11HE6GOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute indicates whether the entity is capable of operating in the
        6 GHz band."
::= { dot11StationConfigEntry 194 }

(11ax)dot11OCTOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the station implementation is
        capable of on-channel tunneling operation. The capability is disabled
        otherwise."
::= { dot11StationConfigEntry 187 }

(11ay)dot11UnsolicitedBAActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by the SME or external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute, when true, indicates that the station supports Unsolicited
        Block Ack Extension procedures."
    DEFVAL { false }
    ::= { dot11StationConfigEntry 189 }

(11ax)dot11QTPOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the QTP operation is implemented
        and operational. This attribute, when false or not present, indicates that
        the QTP operation is not implemented or not operational."
::= { dot11StationConfigEntry 198 }

(11ax)dot11ColocatedRNRImplemented OBJECT-TYPE
```



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```
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable. Its value is determined by (#3375)STA
        capabilities.

        This attribute, when true, indicates that the STA implementation is
        capable of transmitting or receiving a Reduced Neighbor Report element
        carrying information on APs that are in the same (#2210)colocated AP set
        as the reporting AP in Probe Response, Beacon and FILS Discovery frames.
        The capability is disabled otherwise."
    DEFVAL { false }
::= { dot11StationConfigEntry 199 }

(11az)dot11PASNActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable. It is written by an external management
        entity or the SME. Changes take effect for the next MLME-START.request
        primitive or MLME JOIN.request primitive. This attribute indicates whether
        or not PASN authentication is enabled."
    DEFVAL { false }(#7210)
    ::= { dot11StationConfigEntry 201 }

(11az)dot11NoAuthPASNActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable. It is written by an external management
        entity or the SME. Changes take effect for the next MLME-START.request
        primitive or MLME JOIN.request primitive. This attribute indicates whether
        or not PASN without mutual authentication is allowed."
    DEFVAL { false }(#7210)
    ::= { dot11StationConfigEntry 202 }

(#6077)dot11ExtendedRegInfoSupport OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by STA capabilities.

        This attribute, when true, indicates the non-AP STA interprets the
        Regulatory Info subfield of the 6 GHz Operation Information field of the
        HE Capability element per Table E-13 (Regulatory Info subfield
        interpretation by non-AP STAs with dot11ExtendedRegInfoSupport set to
        true(#6077)). Otherwise, the station implementation interprets the
        subfield per Table E-12 (Regulatory Info subfield interpretation by non-AP
        STAs with dot11ExtendedRegInfoSupport not set to true(#6077)(#600)). This
        object is not used by APs."
    ::= { dot11StationConfigEntry 233 }

(11bd)dot11NONNGVRadioEnvironmentImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable. Its value is determined by device
```

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```
        capabilities. A non-NGV STA supports the radio environment transmit vector
        and the radio environment status vector when this attribute is true."
    ::= { dot11StationConfigEntry 219 }

(11bd)dot11NGVOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable. Its value is determined by device
        capabilities. This attribute, when true, indicates that the STA supports
        NGV features. This STA also has dot11OCBActivated equal to true."
    ::= { dot11StationConfigEntry 203 }

(11bd)dot11RadioEnvironmentMeasurementPeriod OBJECT-TYPE
    SYNTAX Unsigned32 (0..1000)
    UNITS "milliseconds"
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable. It is written by an external management
        entity or the SME. Changes take effect as soon as practical in the
        implementations. This attribute indicates the amount of time an NGV STA
        conducts the radio measurement before reporting its radio environment.
        When equal to 0, measurements are not made."
    DEFVAL { 0 }
    ::= { dot11StationConfigEntry 204 }

(11bd)dot11VirtualCSonOCBSecondaryImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable. Its value is determined by device
        capabilities. This attribute, when true, indicates that virtual CS
        operation in the OCB secondary channel is implemented."
    ::= { dot11StationConfigEntry 220 }

(11bd)dot11StationMeasurementPeriod OBJECT-TYPE
    SYNTAX Unsigned32 (0..1000)
    UNITS "milliseconds"
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable. It is written by an external management
        entity or the SME. Changes take effect as soon as practical in the
        implementations. This attribute indicates the amount of time an NGV STA
        conducts the STA measurement before reporting its radio environment. When
        equal to 0, measurements are not made."
    DEFVAL { 0 }
    ::= { dot11StationConfigEntry 221 }

(11bb)dot11LCOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.Its value is determined by device
        capabilities.This attribute indicates whether the entity is LC capable."
    ::= { dot11StationConfigEntry 226 }


(#6058)dot11GASQueryRequestFragmentationActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
```



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```
    STATUS current
    DESCRIPTION
        "This is a control variable.

        It is written by an external management entity or the SME. Changes take
        effect as soon as practical in the implementation.
        This attribute when true, indicates the capability of the STA to fragment
        GAS query requests is enabled. The capability is disabled otherwise."
    DEFVAL { false }
    ::= { dot11StationConfigEntry 238 }

(11bc)dot11EBCSSupportActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity or the SME. Changes take
        effect as soon as practical in the implementation. This attribute when
        true, indicates that the capability of the STA to support EBCS is enabled.
        The capability is disabled otherwise."
    DEFVAL { false }(#7210)
::= { dot11StationConfigEntry 208 }

(11bc)dot11EBCSInfoInterval OBJECT-TYPE
    SYNTAX Unsigned32 (1..255)
    UNITS "100 milliseconds"
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
       "This is a control variable.
        It is written by an external management entity or the SME. Changes take
        effect as soon as practical in the implementation. This attribute indi-
        cates the interval of EBCS Info frames."
    DEFVAL {10}
::= { dot11StationConfigEntry 210 }

(11bc)dot11EBCSHCFAKeyChangeInterval OBJECT-TYPE
    SYNTAX Unsigned32 (1..255)
    UNITS "10 milliseconds"
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
       "This is a control variable.
        It is written by an external management entity or the SME. Changes take
        effect as soon as practical in the implementation. This attribute indi-
        cates the interval between EBCS HCFA key changes."
    DEFVAL {10}
::= { dot11StationConfigEntry 211 }

(11bc)dot11EBCSHCFAHashDistance OBJECT-TYPE
    SYNTAX OCTET STRING
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
       "This is a control variable.
        It is written by an external management entity or the SME. Changes take
        effect as soon as practical in the implementation. Each octet indicates
        the distance of an EBCS HCFA hash."
::= { dot11StationConfigEntry 212 }

(11bc)dot11EBCSInfoPHYType OBJECT-TYPE
    SYNTAX Unsigned32 (0..255)
    MAX-ACCESS read-write
```

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```
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity or the SME. Changes take
        effect as soon as practical in the implementation. This variable specifies
        the transmission PHY type of the EBCS Info frames encoded in the PHY Type
        subfield value in Table 9-438 (PHY Type subfield(11bc)). A value of 255
        indicates the PHY type is not specified."
    ::= { dot11StationConfigEntry 225 }

(11bc)dot11EBCSInfoTxRate OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(2..4))
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
       "This is a control variable.
        It is written by an external management entity or the SME. Changes take
        effect as soon as practical in the implementation. This attribute indi-
        cates the transmission rate of EBCS Info frames.
        This variable specifies the transmission rate of the EBCS Info frames
        encoded as in the TX Rate subfield in 9.4.5.30 (EBCS ANQP-element(11bc))."
    DEFVAL {'000C'H}
::= { dot11StationConfigEntry 213 }

(11bc)dot11EBCSTerminationNoticeTime OBJECT-TYPE
    SYNTAX Unsigned32 (1..65 535)
    UNITS "TBTTs"
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
       "This is a control variable.
        It is written by an external management entity or the SME. Changes take
        effect as soon as practical in the implementation. For an EBCS AP, this
        attribute specifies the time before the end of a broadcast EBCS at or
        after which the EBCS AP shall transmit EBCS Termination Notice frames
        regarding the EBCS."
    DEFVAL {100}
::= { dot11StationConfigEntry 215 }

(11bc)dot11EBCSTerminationNoticeMinimumInterval OBJECT-TYPE
    SYNTAX Unsigned32
    UNITS "milliseconds"
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
       "This is a control variable.
        It is written by an external management entity or the SME. Changes take
        effect as soon as practical in the implementation. For an EBCS AP, this
        attribute specifies the minimum interval between two consecutive EBCS Ter-
        mination Notice frames transmitted by the EBCS AP."
    DEFVAL {100}
::= { dot11StationConfigEntry 216 }

(11bc)dot11EBCSTerminationNoticeMaximumInterval OBJECT-TYPE
    SYNTAX Unsigned32
    UNITS "milliseconds"
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
       "This is a control variable.
        It is written by an external management entity or the SME. Changes take
        effect as soon as practical in the implementation. For an EBCS AP, this
        attribute specifies the maximum interval between two consecutive EBCS Ter-
        mination Notice frames transmitted by the EBCS AP."
```


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```
    DEFVAL {500}
    ::= { dot11StationConfigEntry 217 }

(11bc)dot11EBCSRelayingServiceImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by device capabilities. This attribute when true,
        indicates that the STA is an EBCS relaying STA.  The capability is dis-
        abled otherwise."
    ::= { dot11StationConfigEntry 218 }

(11bc)dot11EBCSTIMInBeaconActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity or the SME. Changes take
        effect as soon as practical in the implementation. This attribute when
        true, indicates that the EBCS TIM element is included in the Beacon frame
        or S1G Beacon frame."
    ::= { dot11StationConfigEntry 209 }

(11bc)dot11EBCSAPGroupID OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(2))
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity or the SME. Changes take
        effect as soon as practical in the implementation. This variable specifies
        the EBCS AP group ID. The range of value is 00-00 to 7F-FF. The value 00-
        00 means the AP does not belong to any EBCS AP group."
    DEFVAL {'0000'H}
    ::= { dot11StationConfigEntry 224 }

-- ****************************************************************
-- *    End of dot11StationConfig  TABLE
-- ****************************************************************

-- ****************************************************************
-- *    dot11AuthenticationAlgorithms  TABLE
-- ****************************************************************

dot11AuthenticationAlgorithmsTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11AuthenticationAlgorithmsEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "This (conceptual) table of attributes is a set of all of the
        authentication algorithms and whether they are activated."
    ::= { dot11smt 2 }

dot11AuthenticationAlgorithmsEntry OBJECT-TYPE
    SYNTAX Dot11AuthenticationAlgorithmsEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "An Entry (conceptual row) in the Authentication Algorithms Table.

        ifIndex - Each IEEE 802.11 interface is represented by an ifEntry.

```

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```
        Interface tables in this MIB module are indexed by ifIndex."
    INDEX { ifIndex,
    dot11AuthenticationAlgorithmIndex}
    ::= { dot11AuthenticationAlgorithmsTable  1 }

Dot11AuthenticationAlgorithmsEntry ::=
    SEQUENCE {
        dot11AuthenticationAlgorithmIndex                    Unsigned32,
        dot11AuthenticationAlgorithm                         INTEGER,
        dot11AuthenticationAlgorithmActivated                TruthValue }

dot11AuthenticationAlgorithmIndex OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "The auxiliary variable used to identify instances of the columnar objects
        in the Authentication Algorithms Table."
    ::= { dot11AuthenticationAlgorithmsEntry 1 }

dot11AuthenticationAlgorithm OBJECT-TYPE
    SYNTAX INTEGER {
        openSystem(1),
        sharedKey(2),
        fastBSSTransition(3),
        simultaneousAuthEquals(4),
        filsSharedKeyWithoutPFS(5),
        filsSharedKeyWithPFS(6),
        filsPublicKey(7)}
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute is the authentication algorithm described by this entry in
        the table. The following values can be used here
        Value = 1: Open system(#3056)
        Value = 3: Fast BSS transition (FT)
        Value = 4: Simultaneous authentication of equals (SAE)
        Value = 5: FILS Shared Key authentication without PFS
        Value = 6: FILS Shared Key authentication with PFS
        Value = 7: FILS Public Key authentication
        A given value shall not be used more than once."
    ::= { dot11AuthenticationAlgorithmsEntry 2 }

dot11AuthenticationAlgorithmActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute, when true, enables the acceptance of the authentication
        algorithm described in the corresponding table entry in authentication
        frames received that have odd authentication transactions sequence
        numbers(#3381)."
    ::= { dot11AuthenticationAlgorithmsEntry 3 }

-- ************************************************************************
-- *    End of dot11AuthenticationAlgorithms  TABLE
```


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```
-- ************************************************************************

-- ************************************************************************
-- *    dot11WEPDefaultKeys  TABLE
-- ************************************************************************

dot11WEPDefaultKeysTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11WEPDefaultKeysEntry
    MAX-ACCESS not-accessible
    STATUS (#3056)deprecated
    DESCRIPTION
        "(#3056)Deprecated because WEP has been removed from (#6318)IEEE Std
        802.11.
        Conceptual table for WEP default keys. This table contains the four WEP
        default secret key values corresponding to the four possible Key ID
        values. The WEP default secret keys are logically WRITE-ONLY. Attempts to
        read the entries in this table return unsuccessful status and values of
        null or 0. The default value of each WEP default key is null."
    ::= { dot11smt 3 }

dot11WEPDefaultKeysEntry OBJECT-TYPE
    SYNTAX Dot11WEPDefaultKeysEntry
    MAX-ACCESS not-accessible
    STATUS (#3056)deprecated
    DESCRIPTION
        "(#3056)Deprecated because WEP has been removed from (#6318)IEEE Std
        802.11.
        An Entry (conceptual row) in the WEP Default Keys Table.

        ifIndex - Each IEEE 802.11 interface is represented by an ifEntry.
        Interface tables in this MIB module are indexed by ifIndex."
    INDEX { ifIndex, dot11WEPDefaultKeyIndex }
    ::= { dot11WEPDefaultKeysTable  1 }

Dot11WEPDefaultKeysEntry ::=
    SEQUENCE {
        dot11WEPDefaultKeyIndex                                 Unsigned32,
        dot11WEPDefaultKeyValue                                 WEPKeytype }

dot11WEPDefaultKeyIndex OBJECT-TYPE
    SYNTAX Unsigned32 (1..4)
    MAX-ACCESS not-accessible
    STATUS (#3056)deprecated
    DESCRIPTION
        "(#3056)Deprecated because WEP has been removed from (#6318)IEEE Std
        802.11.
        The auxiliary variable used to identify instances of the columnar objects
        in the WEP Default Keys Table. The value of this variable is equal to the
        WEPDefaultKeyID + 1"
    ::= { dot11WEPDefaultKeysEntry 1 }

dot11WEPDefaultKeyValue OBJECT-TYPE
    SYNTAX WEPKeytype
    MAX-ACCESS read-write
    STATUS (#3056)deprecated
    DESCRIPTION
        "(#3056)Deprecated because WEP has been removed from (#6318)IEEE Std
        802.11.
This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        A WEP default secret key value."
    ::= { dot11WEPDefaultKeysEntry 2 }

```

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```
-- ************************************************************************
-- *    End of dot11WEPDefaultKeys  TABLE
-- ************************************************************************

-- ************************************************************************
-- *    dot11WEPKeyMappings  TABLE
-- ************************************************************************

dot11WEPKeyMappingsTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11WEPKeyMappingsEntry
    MAX-ACCESS not-accessible
    STATUS (#3056)deprecated
    DESCRIPTION
        "(#3056)Deprecated because WEP has been removed from (#6318)IEEE Std
        802.11.
        Conceptual table for WEP Key Mappings. The MIB supports the ability to
        share a separate WEP key for each RA/TA pair. The Key Mappings Table
        contains zero or one entries for each MAC address and contains two fields
        for each entry: WEPOn and the corresponding WEP key. The WEP key mappings
        are logically WRITE-ONLY. Attempts to read the entries in this table
        return unsuccessful status and values of null or 0. The default value for
        all WEPOn fields is false."
    ::= { dot11smt 4 }

dot11WEPKeyMappingsEntry OBJECT-TYPE
    SYNTAX Dot11WEPKeyMappingsEntry
    MAX-ACCESS not-accessible
    STATUS (#3056)deprecated
    DESCRIPTION
        "(#3056)Deprecated because WEP has been removed from (#6318)IEEE Std
        802.11.
        An Entry (conceptual row) in the WEP Key Mappings Table.

        ifIndex - Each IEEE 802.11 interface is represented by an ifEntry.
        Interface tables in this MIB module are indexed by ifIndex."
    INDEX { ifIndex, dot11WEPKeyMappingIndex }
    ::= { dot11WEPKeyMappingsTable  1 }

Dot11WEPKeyMappingsEntry ::=
    SEQUENCE {
        dot11WEPKeyMappingIndex                         Unsigned32,
        dot11WEPKeyMappingAddress                       MacAddress,
        dot11WEPKeyMappingWEPOn                         TruthValue,
        dot11WEPKeyMappingValue                         WEPKeytype,
        dot11WEPKeyMappingStatus                        RowStatus }

dot11WEPKeyMappingIndex OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS not-accessible
    STATUS (#3056)deprecated
    DESCRIPTION
        "(#3056)Deprecated because WEP has been removed from (#6318)IEEE Std
        802.11.
        The auxiliary variable used to identify instances of the columnar objects
        in the WEP Key Mappings Table."
    ::= { dot11WEPKeyMappingsEntry 1 }

dot11WEPKeyMappingAddress OBJECT-TYPE
    SYNTAX MacAddress
    MAX-ACCESS read-create
    STATUS (#3056)deprecated
    DESCRIPTION
        "(#3056)Deprecated because WEP has been removed from (#6318)IEEE Std
```


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```
        802.11.
        The MAC address of the STA for which the values from this key mapping
        entry are to be used."
    ::= { dot11WEPKeyMappingsEntry 2 }

dot11WEPKeyMappingWEPOn OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-create
    STATUS (#3056)deprecated
    DESCRIPTION
        "(#3056)Deprecated because WEP has been removed from (#6318)IEEE Std
        802.11.
        Boolean as to whether WEP is to be used when communicating with the
        dot11WEPKeyMappingAddress STA."
    ::= { dot11WEPKeyMappingsEntry 3 }

dot11WEPKeyMappingValue OBJECT-TYPE
    SYNTAX WEPKeytype
    MAX-ACCESS read-create
    STATUS (#3056)deprecated
    DESCRIPTION
        "(#3056)Deprecated because WEP has been removed from (#6318)IEEE Std
        802.11.
        A WEP secret key value."
    ::= { dot11WEPKeyMappingsEntry 4 }

dot11WEPKeyMappingStatus OBJECT-TYPE
    SYNTAX RowStatus
    MAX-ACCESS read-create
    STATUS (#3056)deprecated
    DESCRIPTION
        "(#3056)Deprecated because WEP has been removed from (#6318)IEEE Std
        802.11.
        The status column used for creating, modifying, and deleting instances of
        the columnar objects in the WEP key mapping Table."
    DEFVAL { active }
    ::= { dot11WEPKeyMappingsEntry 5 }

-- ************************************************************************
-- *    End of dot11WEPKeyMappings  TABLE
-- ************************************************************************

-- ************************************************************************
-- *    dot11Privacy TABLE
-- ************************************************************************

dot11PrivacyTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11PrivacyEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "Group containing attributes concerned with IEEE 802.11 Privacy. Created
        as a table to allow multiple instances(#467) on an agent."
    ::= { dot11smt 5 }

dot11PrivacyEntry OBJECT-TYPE
    SYNTAX Dot11PrivacyEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "An entry in the dot11PrivacyTable Table.

        ifIndex - Each IEEE 802.11 interface is represented by an ifEntry.
        Interface tables in this MIB module are indexed by ifIndex."

```

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```
    INDEX { ifIndex }
    ::= { dot11PrivacyTable 1 }

Dot11PrivacyEntry ::=
    SEQUENCE {
        dot11PrivacyInvoked                                 TruthValue,
        dot11WEPDefaultKeyID                                Unsigned32,
        dot11WEPKeyMappingLengthImplemented                 Unsigned32,
        dot11ExcludeUnencrypted                             TruthValue,
        dot11WEPICVErrorCount                               Counter32,
        dot11WEPExcludedCount                               Counter32,
        dot11RSNAActivated                                  TruthValue,
        dot11RSNAPreauthenticationActivated                 TruthValue }

dot11PrivacyInvoked OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS (#3056)deprecated
    DESCRIPTION
        "(#3056)Deprecated because WEP has been removed from (#6318)IEEE Std
        802.11.
        This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        When this attribute is true, it indicates that some level of security is
        invoked for transmitting Data frames. For WEP-only clients, the security
        mechanism used is WEP.

        For RSNA non-AP STAs, an additional variable dot11RSNAActivated indicates
        whether RSNA is enabled. If dot11RSNAActivated is false or the MIB
        attribute does not exist, the security mechanism invoked is WEP; if
        dot11RSNAActivated is true, RSNA security mechanisms invoked are
        configured in the dot11RSNAConfigTable."
    DEFVAL { false }
    ::= { dot11PrivacyEntry 1 }

dot11WEPDefaultKeyID  OBJECT-TYPE
    SYNTAX Unsigned32 (0..3)
    MAX-ACCESS read-write
    STATUS (#3056)deprecated
    DESCRIPTION
        "(#3056)Deprecated because WEP has been removed from (#6318)IEEE Std
        802.11.
        This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute indicates the use of the first, second, third, or fourth
        element of the WEPDefaultKeys array when equal to values of zero, one,
        two, or three."
    DEFVAL { 0 }
    ::= { dot11PrivacyEntry 2 }

dot11WEPKeyMappingLengthImplemented  OBJECT-TYPE
    SYNTAX Unsigned32 (10..4294967295)
    MAX-ACCESS read-only
    STATUS (#3056)deprecated
    DESCRIPTION
        "(#3056)Deprecated because WEP has been removed from (#6318)IEEE Std
        802.11.
        This is a capability variable.
        Its value is determined by (#3375)STA capabilities.
```


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```
        The maximum number of tuples that dot11WEPKeyMappings can hold."
    ::= { dot11PrivacyEntry 3 }

dot11ExcludeUnencrypted  OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS (#3056)deprecated
    DESCRIPTION
        "(#3056)Deprecated because WEP has been removed from (#6318)IEEE Std
        802.11.
        This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        When this attribute is true, the STA does not indicate at the MAC service
        interface received MSDUs that have the Protected Frame subfield of the
        Frame Control field equal to 0. When this attribute is false, the STA may
        accept MSDUs that have the Protected Frame subfield of the Frame Control
        field equal to 0."
    DEFVAL { false }
    ::= { dot11PrivacyEntry 4 }

dot11WEPICVErrorCount  OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS (#3056)deprecated
    DESCRIPTION
        "(#3056)Deprecated because WEP has been removed from (#6318)IEEE Std
        802.11.
        This is a status variable.
        It is written by the MAC when an ICV error is detected.

        This counter increments when a frame is received with the Protected Frame
        subfield of the Frame Control field equal to 1 and the value of the ICV as
        received in the frame does not match the ICV value that is calculated for
        the contents of the received frame. ICV errors for TKIP are not counted in
        this variable but in dot11RSNAStatsTKIPICVErrors."
    ::= { dot11PrivacyEntry 5 }

dot11WEPExcludedCount  OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS (#3056)deprecated
    DESCRIPTION
        "(#3056)Deprecated because WEP has been removed from (#6318)IEEE Std
        802.11.
        This is a status variable.
        It is written by the MAC when a bad frame is received.

        This counter increments when a frame is received with the Protected Frame
        subfield of the Frame Control field equal to 0 and the value of
        dot11ExcludeUnencrypted causes that frame to be discarded."
    ::= { dot11PrivacyEntry 6 }

dot11RSNAActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect for the next MLME-START.request primitive or MLME-
        JOIN.request primitive.
```

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```
        When this object is true, this indicates that RSNA is enabled on this
        entity. Configuration variables for RSNA operation are found in the
        dot11RSNAConfigTable.(#3056)"
    ::= { dot11PrivacyEntry 7 }

dot11RSNAPreauthenticationActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        When this object is true, this indicates that RSNA preauthentication is
        enabled on this entity.

        This object requires that dot11RSNAActivated also be equal to true."
    ::= { dot11PrivacyEntry 8 }

-- ****************************************************************
-- *    End of dot11Privacy  TABLE
-- ****************************************************************

-- ****************************************************************
-- *    dot11SMTnotification Objects
-- ****************************************************************

dot11SMTnotification OBJECT IDENTIFIER ::= { dot11smt 6 }

dot11Disassociate NOTIFICATION-TYPE
    OBJECTS { ifIndex, dot11DisassociateReason, dot11DisassociateStation }
    STATUS current
    DESCRIPTION
        "The disassociate notification is sent when the STA sends a Disassociation
        frame. The value of the notification includes the MAC address of the MAC
        to which the Disassociation frame was sent and the reason for the
        disassociation.

        ifIndex - Each IEEE 802.11 interface is represented by an ifEntry.
        Interface tables in this MIB module are indexed by ifIndex."
    ::= { dot11SMTnotification 0 1 }

dot11Deauthenticate NOTIFICATION-TYPE
    OBJECTS { ifIndex, dot11DeauthenticateReason, dot11DeauthenticateStation }
    STATUS current
    DESCRIPTION
        "The deauthenticate notification is sent when the STA sends a
        Deauthentication frame. The value of the notification includes the MAC
        address of the MAC to which the Deauthentication frame was sent and the
        reason for the deauthentication.

        ifIndex - Each IEEE 802.11 interface is represented by an ifEntry.
        Interface tables in this MIB module are indexed by ifIndex."
    ::= { dot11SMTnotification 0 2 }

dot11AuthenticateFail NOTIFICATION-TYPE
    OBJECTS {
        ifIndex, dot11AuthenticateFailStatus, dot11AuthenticateFailStation }
    STATUS current
    DESCRIPTION
        "The authenticate failure notification is sent when the STA sends an
        Authentication frame with a status code other than SUCCESS. The value of
        the notification includes the MAC address of the MAC to which the
```


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```
        Authentication frame was sent and the reason for the authentication
        failure.

        ifIndex - Each IEEE 802.11 interface is represented by an ifEntry.
        Interface tables in this MIB module are indexed by ifIndex."
    ::= { dot11SMTnotification 0 3 }

dot11Associate NOTIFICATION-TYPE
    OBJECTS { ifIndex, dot11AssociateStation, dot11AssociateID}
    STATUS current
    DESCRIPTION
        "The associate notification is sent when the STA sends an Association
        Response frame with a status code equal to SUCCESS. The value of the
        notification includes the MAC address of the MAC to which the Association
        Response frame was sent and the Association ID. ifIndex - Each IEEE 802.11
        interface is represented by an ifEntry. Interface tables in this MIB
        module are indexed by ifIndex."
    ::= { dot11SMTnotification 0 4 }

dot11AssociateFailed NOTIFICATION-TYPE
    OBJECTS { ifIndex, dot11AssociateFailStatus, dot11AssociateFailStation }
    STATUS current
    DESCRIPTION
        "The associate failed notification is sent when the STA sends an
        Association Response frame with a status code other than SUCCESS. The
        value of the notification includes the MAC address of the MAC to which the
        Association Response frame was sent and the reason for the association
        failure. ifIndex - Each IEEE 802.11 interface is represented by an
        ifEntry. Interface tables in this MIB module are indexed by ifIndex."
    ::= { dot11SMTnotification 0 5 }

dot11Reassociate NOTIFICATION-TYPE
    OBJECTS { ifIndex, dot11ReassociateStation, dot11ReassociateID}
    STATUS current
    DESCRIPTION
        "The reassociate notification is sent when the STA sends a Reassociation
        Response frame with a status code equal to SUCCESS. The value of the
        notification includes the MAC address of the MAC to which the
        Reassociation Response frame was sent and the Reassociation ID. ifIndex -
        Each IEEE 802.11 interface is represented by an ifEntry. Interface tables
        in this MIB module are indexed by ifIndex."
    ::= { dot11SMTnotification 0 6 }

dot11ReassociateFailed NOTIFICATION-TYPE
    OBJECTS { ifIndex, dot11ReassociateFailStatus, dot11ReassociateStation }
    STATUS current
    DESCRIPTION
        "The reassociate failed notification is sent when the STA sends a
        Reassociation Response frame with a status code other than SUCCESS. The
        value of the notification includes the MAC address of the MAC to which the
        Reassociation Response frame was sent and the reason for the reassociation
        failure. ifIndex - Each IEEE 802.11 interface is represented by an
        ifEntry. Interface tables in this MIB module are indexed by ifIndex."
    ::= { dot11SMTnotification 0 7 }
-- ************************************************************************
-- *    End of dot11SMTnotification Objects
-- ************************************************************************

-- ************************************************************************
-- * dot11MultiDomainCapability TABLE
-- ************************************************************************

dot11MultiDomainCapabilityTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11MultiDomainCapabilityEntry
```

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```
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "This (conceptual) table of attributes for cross-domain mobility."
    ::= { dot11smt 7 }

dot11MultiDomainCapabilityEntry OBJECT-TYPE
    SYNTAX Dot11MultiDomainCapabilityEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "An entry (conceptual row) in the Multiple Domain Capability Table.

        IfIndex - Each IEEE 802.11 interface is represented by an ifEntry.
        Interface tables in this MIB are indexed by ifIndex."
    INDEX { ifIndex, dot11MultiDomainCapabilityIndex }
    ::= { dot11MultiDomainCapabilityTable 1 }

Dot11MultiDomainCapabilityEntry ::=
    SEQUENCE {
        dot11MultiDomainCapabilityIndex                      Unsigned32,
        dot11FirstChannelNumber                              Unsigned32,
        dot11NumberofChannels                                Unsigned32,
        dot11MaximumTransmitPowerLevel                       Integer32 }

dot11MultiDomainCapabilityIndex OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "The auxiliary variable used to identify instances of the columnar objects
        in the multidomain Capability Table."
    ::= { dot11MultiDomainCapabilityEntry 1 }

dot11FirstChannelNumber OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute indicates the value of the lowest channel number in the
        subband for the associated domain country string."
    DEFVAL { 0 }
    ::= { dot11MultiDomainCapabilityEntry 2 }

dot11NumberofChannels OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute indicates the value of the total number of channels allowed
        in the subband for the associated domain country string."
    DEFVAL { 0 }
    ::= { dot11MultiDomainCapabilityEntry 3 }

dot11MaximumTransmitPowerLevel OBJECT-TYPE
    SYNTAX Integer32
```


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```
    UNITS "dBm"
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute indicates the maximum transmit power allowed in the subband
        for the associated domain country string."
    DEFVAL { 0 }
    ::= { dot11MultiDomainCapabilityEntry 4 }

-- ************************************************************
-- * End of dot11MultiDomainCapability TABLE
-- ************************************************************
-- ************************************************************
-- * dot11SpectrumManagement TABLE
-- ************************************************************
dot11SpectrumManagementTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11SpectrumManagementEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "(Conceptual) table of attributes for spectrum management"
    ::= {dot11smt 8}

dot11SpectrumManagementEntry OBJECT-TYPE
    SYNTAX Dot11SpectrumManagementEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "An entry (conceptual row) in the Spectrum Management Table.

        IfIndex - Each IEEE 802.11 interface is represented by an ifEntry.
        Interface tables in this MIB are indexed by ifIndex."
    INDEX {ifIndex, dot11SpectrumManagementIndex}
    ::= { dot11SpectrumManagementTable 1 }

Dot11SpectrumManagementEntry ::=
    SEQUENCE {
        dot11SpectrumManagementIndex                    Unsigned32,
        dot11ChannelSwitchTime                          Unsigned32,
        dot11PowerCapabilityMaxImplemented              Integer32,
        dot11PowerCapabilityMinImplemented              Integer32 }

dot11SpectrumManagementIndex OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "The auxiliary variable used to identify instances of the columnar objects
        in the Spectrum Management Table."
    ::= { dot11SpectrumManagementEntry 1 }

-- value 2 is reserved

dot11ChannelSwitchTime OBJECT-TYPE
    SYNTAX Unsigned32
    UNITS "TUs"
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
```

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```
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute indicates assumed channel switch time. The minimum value of
        this attribute is 1 TU."
    DEFVAL { 2 }
    ::= { dot11SpectrumManagementEntry 3 }

dot11PowerCapabilityMaxImplemented OBJECT-TYPE
    SYNTAX Integer32
    UNITS "dBm"
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute indicates the maximum transmit Power Capability of this
        station."
    ::= { dot11SpectrumManagementEntry 4 }

dot11PowerCapabilityMinImplemented OBJECT-TYPE
    SYNTAX Integer32
    UNITS "dBm"
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute indicates the minimum transmit Power Capability of this
        station."
    ::= { dot11SpectrumManagementEntry 5 }
-- ************************************************************
-- * End of dot11SpectrumManagement TABLE
-- ************************************************************


-- ************************************************************************
-- * dot11RSNAConfig TABLE (RSNA(#3056))
-- ************************************************************************

dot11RSNAConfigTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11RSNAConfigEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "The table containing RSNA configuration objects."
    ::= { dot11smt 9 }

dot11RSNAConfigEntry OBJECT-TYPE
    SYNTAX Dot11RSNAConfigEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "An entry in the dot11RSNAConfigTable."
    INDEX { ifIndex }
    ::= { dot11RSNAConfigTable 1 }

Dot11RSNAConfigEntry ::=
    SEQUENCE {
        dot11RSNAConfigVersion                              Unsigned32,
        dot11RSNAConfigPairwiseKeysImplemented              Unsigned32,
        dot11RSNAConfigGroupCipher                          OCTET STRING,
```


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```
        dot11RSNAConfigGroupRekeyMethod                         INTEGER,
        dot11RSNAConfigGroupRekeyTime                           Unsigned32,
        dot11RSNAConfigGroupRekeyPackets                        Unsigned32,
        dot11RSNAConfigGroupRekeyStrict                         TruthValue,
        dot11RSNAConfigPSKValue                                 OCTET STRING,
        dot11RSNAConfigPSKPassPhrase                            DisplayString,
        dot11RSNAConfigGroupUpdateCount                         Unsigned32,
        dot11RSNAConfigPairwiseUpdateCount                      Unsigned32,
        dot11RSNAConfigGroupCipherSize                          Unsigned32,
        dot11RSNAConfigPMKLifetime                              Unsigned32,
        dot11RSNAConfigPMKReauthThreshold                       Unsigned32,
        dot11RSNAConfigNumberOfPTKSAReplayCounters              Unsigned32,
        dot11RSNAConfigSATimeout                                Unsigned32,
        dot11RSNAAuthenticationSuiteSelected                    OCTET STRING,
        dot11RSNAPairwiseCipherSelected                         OCTET STRING,
        dot11RSNAGroupCipherSelected                            OCTET STRING,
        dot11RSNAPMKIDUsed                                      OCTET STRING,
        dot11RSNAAuthenticationSuiteRequested                   OCTET STRING,
        dot11RSNAPairwiseCipherRequested                        OCTET STRING,
        dot11RSNAGroupCipherRequested                           OCTET STRING,
        dot11RSNATKIPCounterMeasuresInvoked                     Unsigned32,
        dot11RSNA4WayHandshakeFailures                          Unsigned32,
        dot11RSNAConfigNumberOfGTKSAReplayCounters              Unsigned32,
        dot11RSNAConfigSTKKeysImplemented                       Unsigned32,
        dot11RSNAConfigSTKCipher                                OCTET STRING,
        dot11RSNAConfigSTKRekeyTime                             Unsigned32,
        dot11RSNAConfigSMKUpdateCount                           Unsigned32,
        dot11RSNAConfigSTKCipherSize                            Unsigned32,
        dot11RSNAConfigSMKLifetime                              Unsigned32,
        dot11RSNAConfigSMKReauthThreshold                       Unsigned32,
        dot11RSNAConfigNumberOfSTKSAReplayCounters              Unsigned32,
        dot11RSNAPairwiseSTKSelected                            OCTET STRING,
        dot11RSNASMKHandshakeFailures                           Unsigned32,
        dot11RSNASAERetransPeriod                               Unsigned32,
        dot11RSNASAEAntiCloggingThreshold                       Unsigned32,
        dot11RSNASAESync                                        Unsigned32,
        dot11RSNAStatsGCMPReplays                               Unsigned32,
        dot11RSNAStatsRobustMgmtGCMPReplays                     Unsigned32,
        (11az)dot11RSNAConfigPASNPTKSATimeout                   Unsigned32,
        (#6020)dot11RSNAConfigGroupManagementCipher             OCTET STRING,
        (#6020)dot11RSNAConfigGroupManagementCipherSize         Unsigned32,
        (#6020)dot11RSNAGroupManagementCipherSelected           OCTET STRING,
        (#6020)dot11RSNAGroupManagementCipherRequested          OCTET STRING}

}

-- dot11RSNAConfigEntry 1 has been deprecated.

dot11RSNAConfigVersion OBJECT-TYPE
   SYNTAX Unsigned32
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a capability variable.
      Its value is determined by (#3375)STA capabilities.

      The highest RSNA version this entity supports. See 9.4.2.7 (Country ele-
      ment)."
   ::= { dot11RSNAConfigEntry 2 }

dot11RSNAConfigPairwiseKeysImplemented OBJECT-TYPE
   SYNTAX Unsigned32
   MAX-ACCESS read-only
   STATUS current
```

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```
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This object indicates how many pairwise keys the entity supports for
        RSNA."
    ::= { dot11RSNAConfigEntry 3 }

dot11RSNAConfigGroupCipher OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(4))
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This object indicates the group data cipher(#6020) suite selector the
        entity uses. The (#6020)group data cipher suite in the RSNE takes its
        value from this variable. It consists of an OUI or CID (the first 3
        octets) and a cipher suite identifier (the last octet)."
    ::= { dot11RSNAConfigEntry 4 }

dot11RSNAConfigGroupRekeyMethod OBJECT-TYPE
SYNTAX INTEGER { disabled(1), timeBased(2), packetBased(3),
    timepacketBased(4) }
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This object selects a mechanism for rekeying the (#1980)(#1509)GTK(#3511).
        Rekeying the GTK is applicable only to an entity acting in the Authentica-
        tor role. (#1588)When equal to disabled, GTK rekeying is not performed,
        except when requested by a Supplicant. When equal to timeBased, GTK rekey-
        ing is performed at regular time intervals (see dot11RSNAConfigGroupRekey-
        Time). When equal to packetBased, GTK rekeying is performed after a
        certain number of packet transmissions (see dot11RSNAConfigGroupRekeyPack-
        ets). When equal to timepacketBased, GTK rekeying is performed at regular
        time intervals (see dot11RSNAConfigGroupRekeyTime) and also after a cer-
        tain number of packet transmissions (see dot11RSNAConfigGroupRekeyPack-
        ets)."
    DEFVAL { timeBased }
    ::= { dot11RSNAConfigEntry 5 }

dot11RSNAConfigGroupRekeyTime OBJECT-TYPE
    SYNTAX Unsigned32 (1..4294967295)
    UNITS "seconds"
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        The time after which the (#1980)(#1509)GTK is (#1382)refreshed (by rekey-
        ing)(#3719), if dot11RSNAConfigGroupRekeyMethod is timeBased(2) or time-
        packetBased(4). The timer starts at the moment the GTK was set using the
        MLME-SETKEYS.request primitive."
    DEFVAL { 86400 } -- once per day
    ::= { dot11RSNAConfigEntry 6 }
```


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```
dot11RSNAConfigGroupRekeyPackets OBJECT-TYPE
   SYNTAX Unsigned32 (1..4294967295)
   UNITS "1000 packets"
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by an external management entity.
      Changes take effect as soon as practical in the implementation.

      (#3719)The packet count after which the (#1980)(#1509)GTK is
      (#1382)refreshed (by rekeying), if dot11RSNAConfigGroupRekeyMethod is
      packetBased(3) or timepacketBased(4). The packet counter starts at the
      moment the GTK was set using the MLME-SETKEYS.request primitive and it
      counts all packets encrypted using  that GTK."
   ::= { dot11RSNAConfigEntry 7 }

dot11RSNAConfigGroupRekeyStrict OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by an external management entity.
      Changes take effect as soon as practical in the implementation.

      This object signals that the GTK be (#1382)refreshed (by rekeying) when-
      ever a STA leaves the BSS that possesses the GTK."
   ::= { dot11RSNAConfigEntry 8 }

dot11RSNAConfigPSKValue OBJECT-TYPE
   SYNTAX OCTET STRING (SIZE(32))
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by an external management entity.
      Changes take effect as soon as practical in the implementation.

      The PSK for when RSNA in PSK mode is the selected (#3266)AKMP. In that
      case, the PMK obtains its value from this object.

      This object is logically write-only. Reading this variable returns
      unsuccessful status or null or 0."
   ::= { dot11RSNAConfigEntry 9 }

dot11RSNAConfigPSKPassPhrase OBJECT-TYPE
   SYNTAX DisplayString
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by an external management entity.
      Changes take effect as soon as practical in the implementation.

      The PSK, for when RSNA in PSK mode is the selected (#3266)AKMP, is
      configured by dot11RSNAConfigPSKValue.

      An alternative manner of setting the PSK uses the password-to-key
      algorithm defined in J.4 (Suggested pass-phrase-to-PSK mapping). This
      variable provides a means to enter a pass-phrase. When this object is
      written, the RSNA entity uses the password-to-key algorithm specified in
      J.4 (Suggested pass-phrase-to-PSK mapping) to derive a preshared and
      populate dot11RSNAConfigPSKValue with this key.
```

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```
        This object is logically write-only. Reading this variable returns
        unsuccessful status or null or 0."
    ::= { dot11RSNAConfigEntry 10 }

-- dot11RSNAConfigEntry 11 and dot11RSNAConfigEntry 12 have been
-- deprecated.

dot11RSNAConfigGroupUpdateCount OBJECT-TYPE
    SYNTAX Unsigned32 (1..4294967295)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        The number of times message 1 in the RSNA group key handshake is retried
        per GTK handshake attempt."
    DEFVAL { 3 }
    ::= { dot11RSNAConfigEntry 13 }

dot11RSNAConfigPairwiseUpdateCount OBJECT-TYPE
    SYNTAX Unsigned32 (1..4294967295)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        The number of times message 1 and message 3 in the RSNA 4-way handshake
        are retried per 4-way handshake attempt."
    DEFVAL { 3 }
    ::= { dot11RSNAConfigEntry 14 }

dot11RSNAConfigGroupCipherSize OBJECT-TYPE
    SYNTAX Unsigned32 (0..4294967295)
    UNITS "bits"
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This object indicates the length of the (#6020)group data cipher key."
    ::= { dot11RSNAConfigEntry 15 }

dot11RSNAConfigPMKLifetime OBJECT-TYPE
    SYNTAX Unsigned32 (1..4294967295)
    UNITS "seconds"
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        The maximum lifetime of a PMK in the PMKSA cache."
    DEFVAL { 43200 }
    ::= { dot11RSNAConfigEntry 16 }

dot11RSNAConfigPMKReauthThreshold OBJECT-TYPE
    SYNTAX Unsigned32 (1..100)
```


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```
    UNITS "percentage"
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        The percentage of the PMK lifetime that should expire before an IEEE
        802.1X reauthentication occurs."
    DEFVAL { 70 }
    ::= { dot11RSNAConfigEntry 17 }

dot11RSNAConfigNumberOfPTKSAReplayCounters OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        Specifies the number of PTKSA replay counters per association and the num-
        ber of TPKSA replay counters per (#2152)TDLS direct link:(#167)
        0 -> 1 replay counter,
        1 -> 2 replay counters,
        2 -> 4 replay counters,
        3 -> 16 replay counters"
    ::= { dot11RSNAConfigEntry 18 }

dot11RSNAConfigSATimeout OBJECT-TYPE
    SYNTAX Unsigned32 (1..4294967295)
    UNITS "seconds"
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        The maximum time a security association takes to set up."
    DEFVAL { 60 }
    ::= { dot11RSNAConfigEntry 19 }

dot11RSNAAuthenticationSuiteSelected OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(4))
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the RSNA Key Management entity in the SME when a security
        association is established.

        The selector of the last (#3266)AKMP negotiated."
    ::= { dot11RSNAConfigEntry 20 }

dot11RSNAPairwiseCipherSelected OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(4))
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the RSNA Key Management entity in the SME when a security
        association is established.
```

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```
        The selector of the last pairwise cipher negotiated."
    ::= { dot11RSNAConfigEntry 21 }

dot11RSNAGroupCipherSelected OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(4))
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the RSNA Key Management entity in the SME when a security
        association is established.

        The selector of the last group data cipher(#6020) negotiated."
    ::= { dot11RSNAConfigEntry 22 }

dot11RSNAPMKIDUsed OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(16))
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the RSNA Key Management entity in the SME when a security
        association is established.

        The selector of the last PMKID used in the last 4-way handshake."
    ::= { dot11RSNAConfigEntry 23 }

dot11RSNAAuthenticationSuiteRequested OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(4))
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the RSNA Key Management entity in the SME when a security
        association is established.

        The selector of the last (#3266)AKMP requested."
    ::= { dot11RSNAConfigEntry 24 }

dot11RSNAPairwiseCipherRequested OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(4))
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the RSNA Key Management entity in the SME when a security
        association is established.

        The selector of the last pairwise cipher requested."
    ::= { dot11RSNAConfigEntry 25 }

dot11RSNAGroupCipherRequested OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(4))
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the RSNA Key Management entity in the SME when a security
        association is established.

        The selector of the last group data cipher(#6020) requested."
    ::= { dot11RSNAConfigEntry 26 }

dot11RSNATKIPCounterMeasuresInvoked OBJECT-TYPE
```



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```
    SYNTAX Unsigned32 (0..4294967295)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the MAC when the condition described below occurs.

        Counts the number of times that a TKIP MIC failure occurred two times
        within 60 s and TKIP countermeasures were invoked. This attribute counts
        both local and remote MIC failure events reported to this STA. It
        increments every time TKIP countermeasures are invoked"
    ::= { dot11RSNAConfigEntry 27 }

dot11RSNA4WayHandshakeFailures OBJECT-TYPE
    SYNTAX Unsigned32 (0..4294967295)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the RSNA Key Management entity in the SME when the condi-
        tion described below occurs.

        Counts the number of 4-way handshake failures."
    ::= { dot11RSNAConfigEntry 28 }

dot11RSNAConfigNumberOfGTKSAReplayCounters OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        Specifies the number of GTKSA replay counters per association:
        0 -> 1 replay counter,
        1 -> 2 replay counters,
        2 -> 4 replay counters,
        3 -> 16 replay counters"
    ::= { dot11RSNAConfigEntry 29 }

dot11RSNAConfigSTKKeysImplemented OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-only
    STATUS deprecated
    DESCRIPTION
        "Deprecated as the related feature has been removed from IEEE Std 802.11.
        This is a capability variable.
        Its value is determined by (#3375)STA capabilities.
        This object indicates how many STKs the entity supports for RSNA."
    ::= { dot11RSNAConfigEntry 30 }

dot11RSNAConfigSTKCipher OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(4))
    MAX-ACCESS read-write
    STATUS deprecated
    DESCRIPTION
        "Deprecated as the related feature has been removed from IEEE Std 802.11.
        This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.
        This object specifies the (#3270)cipher suite used by the STK for a DLS
        link."
    ::= { dot11RSNAConfigEntry 31}
```

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```
dot11RSNAConfigSTKRekeyTime OBJECT-TYPE
   SYNTAX Unsigned32 (1..4294967295)
   UNITS "seconds"
   MAX-ACCESS read-write
   STATUS deprecated
   DESCRIPTION
      "Deprecated as the related feature has been removed from IEEE Std 802.11.
      This is a control variable.
      It is written by an external management entity.
      Changes take effect as soon as practical in the implementation.
      The time after which an RSNA STK is (#1382)refreshed (by rekeying). The
      timer starts at the moment the STK was set using the MLME-SETKEYS.request
      primitive."
   DEFVAL { 86400 } -- once per day
   ::= { dot11RSNAConfigEntry 32 }

dot11RSNAConfigSMKUpdateCount OBJECT-TYPE
   SYNTAX Unsigned32 (1..4294967295)
   MAX-ACCESS read-write
   STATUS deprecated
   DESCRIPTION
      "Deprecated as the related feature has been removed from IEEE Std 802.11.
      This is a control variable.
      It is written by an external management entity.
      Changes take effect as soon as practical in the implementation.
      The number of times message 1 in the RSNA SMK handshake is retried per SMK
      handshake attempt."
   DEFVAL { 3 }
   ::= { dot11RSNAConfigEntry 33 }

dot11RSNAConfigSTKCipherSize OBJECT-TYPE
   SYNTAX Unsigned32 (0..4294967295)
   UNITS "bits"
   MAX-ACCESS read-write
   STATUS deprecated
   DESCRIPTION
      "Deprecated as the related feature has been removed from IEEE Std 802.11.
      This is a control variable.
      It is written by an external management entity.
      Changes take effect as soon as practical in the implementation.
      This object indicates the length of the STK cipher key."
   ::= { dot11RSNAConfigEntry 34 }

dot11RSNAConfigSMKLifetime OBJECT-TYPE
   SYNTAX Unsigned32 (1..4294967295)
   UNITS "seconds"
   MAX-ACCESS read-write
   STATUS deprecated
   DESCRIPTION
      "Deprecated because mechanisms for use of cached SMKSAs are not defined.
      This is a control variable.
      It is written by an external management entity.
      Changes take effect as soon as practical in the implementation.

      The maximum lifetime of an SMK in the SMKSA cache."
   DEFVAL { 43200 }
   ::= { dot11RSNAConfigEntry 35 }

dot11RSNAConfigSMKReauthThreshold OBJECT-TYPE
   SYNTAX Unsigned32 (0..4294967295)
   MAX-ACCESS read-write
   STATUS deprecated
   DESCRIPTION
      "Deprecated because mechanisms for use of cached SMKSAs are not defined.
```


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```
        This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute indicates the number of seconds for which an SMK
        authentication is valid. If a new SMK authentication is not completed
        successfully before the number of seconds indicated by this attribute
        elapse, from the prior authentication, the STA deletes the SMKSA."
    ::= { dot11RSNAConfigEntry 36 }

dot11RSNAConfigNumberOfSTKSAReplayCounters OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-only
    STATUS deprecated
    DESCRIPTION
        "Deprecated as the related feature has been removed from IEEE Std 802.11.
        This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        Specifies the number of STKSA replay counters per association:
        0 -> 1 replay counter,
        1 -> 2 replay counters,
        2 -> 4 replay counters,
        3 -> 16 replay counters"
    ::= { dot11RSNAConfigEntry 37 }

dot11RSNAPairwiseSTKSelected OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(4))
    MAX-ACCESS read-only
    STATUS deprecated
    DESCRIPTION
        "Deprecated as the related feature has been removed from IEEE Std 802.11.
        This is a status variable.
        It is written by the RSNA Key Management entity in the SME when a security
        association is established.

        The selector of the last STK cipher negotiated."
    ::= { dot11RSNAConfigEntry 38 }

dot11RSNASMKHandshakeFailures OBJECT-TYPE
    SYNTAX Unsigned32 (0..4294967295)
    MAX-ACCESS read-only
    STATUS deprecated
    DESCRIPTION
        "Deprecated as the related feature has been removed from IEEE Std 802.11.
        This is a status variable.
        It is written by the RSNA Key Management entity in the SME when the condi-
        tion described below occurs.

        Counts the number of SMK handshake failures."
    ::= { dot11RSNAConfigEntry 39 }

dot11RSNASAERetransPeriod OBJECT-TYPE
    SYNTAX Unsigned32
    UNITS "milliseconds"
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by the SME when establishing or becoming a member of a BSS.
        Changes take effect for the next MLME-START.request or MLME-JOIN.request
        primitive.

        This object specifies the initial retry timeout used by the SAE authenti-
```

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```
        cation and key establishment protocol."
    DEFVAL { 2000 }
    ::= { dot11RSNAConfigEntry 40 }


dot11RSNASAEAntiCloggingThreshold OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This object specifies the maximum number of SAE protocol instances allowed
        to simultaneously be in either Committed or Confirmed state."
    ::= { dot11RSNAConfigEntry 41 }

dot11RSNASAESync OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This object specifies the maximum number of synchronization errors that
        are allowed to happen prior to disassociation of the offending SAE peer."
    ::= { dot11RSNAConfigEntry 42 }

(11az)dot11RSNAConfigPASNPTKSATimeout OBJECT-TYPE
    SYNTAX Unsigned32 (1..4294967295)
    UNITS "seconds"
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable. It is written by an external management
        entity. Changes take effect as soon as practical in the implementation.
        The time for which the derived PTKSA derived from PASN authentication is
        valid."
    DEFVAL { 3600 }
    ::= { dot11RSNAConfigEntry 43 }

(#6020)dot11RSNAConfigGroupManagementCipher OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(4))
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This object indicates the group management cipher suite selector the
        entity uses. The group management cipher suite in the RSNE takes its value
        from this variable. It consists of an OUI or CID (the first 3 octets) and
        a cipher suite identifier (the last octet)."
    ::= { dot11RSNAConfigEntry 44 }

(#6020)dot11RSNAConfigGroupManagementCipherSize OBJECT-TYPE
    SYNTAX Unsigned32 (0..4294967295)
    UNITS "bits"
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
```


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```
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This object indicates the length of the group management cipher key."
    ::= { dot11RSNAConfigEntry 45 }

(#6020)dot11RSNAGroupManagementCipherSelected OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(4))
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the RSNA Key Management entity in the SME when a security
        association is established.

        The selector of the last group management cipher negotiated."
    ::= { dot11RSNAConfigEntry 46 }

(#6020)dot11RSNAGroupManagementCipherRequested OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(4))
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the RSNA Key Management entity in the SME when a security
        association is established.

        The selector of the last group management cipher requested."
    ::= { dot11RSNAConfigEntry 47 }


-- ************************************************************************
-- * End of dot11RSNAConfig TABLE
-- ************************************************************************

-- ************************************************************************
-- * dot11RSNAConfigPairwiseCiphers TABLE
-- ************************************************************************

dot11RSNAConfigPairwiseCiphersTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11RSNAConfigPairwiseCiphersEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "This table lists the (#7189)pairwise cipher suites supported by this
        entity. It allows enabling and disabling of each pairwise cipher by net-
        work management. The pairwise cipher suite list in the RSNE is formed
        using the information in this table."
    ::= { dot11smt 10 }

dot11RSNAConfigPairwiseCiphersEntry OBJECT-TYPE
    SYNTAX Dot11RSNAConfigPairwiseCiphersEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "The table entry, indexed by the interface index (or all interfaces) and
        the pairwise cipher."
    INDEX { ifIndex, dot11RSNAConfigPairwiseCipherIndex }
    ::= { dot11RSNAConfigPairwiseCiphersTable 1 }

Dot11RSNAConfigPairwiseCiphersEntry ::=
    SEQUENCE {
        dot11RSNAConfigPairwiseCipherIndex                    Unsigned32,
        dot11RSNAConfigPairwiseCipherImplemented              OCTET STRING,
```

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```
        dot11RSNAConfigPairwiseCipherActivated                TruthValue,
        dot11RSNAConfigPairwiseCipherSizeImplemented          Unsigned32  }

dot11RSNAConfigPairwiseCipherIndex OBJECT-TYPE
    SYNTAX Unsigned32 (1..4294967295)
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "The auxiliary index into the dot11RSNAConfigPairwiseCiphersTable."
    ::= { dot11RSNAConfigPairwiseCiphersEntry 1 }

dot11RSNAConfigPairwiseCipherImplemented OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(4))
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        The selector of a supported pairwise cipher. It consists of an OUI or CID
        (the first 3 octets) and a cipher suite identifier (the last octet)."
    ::= { dot11RSNAConfigPairwiseCiphersEntry 2 }

dot11RSNAConfigPairwiseCipherActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This object enables or disables the pairwise cipher."
    ::= { dot11RSNAConfigPairwiseCiphersEntry 3 }

dot11RSNAConfigPairwiseCipherSizeImplemented OBJECT-TYPE
    SYNTAX Unsigned32 (0..4294967295)
    UNITS "bits"
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This object indicates the length of the pairwise cipher key. This should
        be 256 for TKIP and 128 or 256 for CCMP and 128 or 256 for GCMP."
    ::= { dot11RSNAConfigPairwiseCiphersEntry 4 }

-- ********************************************************************
-- * End of dot11RSNAConfigPairwiseCiphers TABLE
-- ********************************************************************

-- ********************************************************************
-- * dot11RSNAConfigAuthenticationSuites TABLE
-- ********************************************************************

dot11RSNAConfigAuthenticationSuitesTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11RSNAConfigAuthenticationSuitesEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "This table lists the (#3266)AKMPs supported by this entity. Each
        (#3266)AKMP can be individually enabled and disabled. The AKM suite list
        in the RSNE is formed using the information in this table."
```


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```
    ::= { dot11smt 11 }

dot11RSNAConfigAuthenticationSuitesEntry OBJECT-TYPE
    SYNTAX Dot11RSNAConfigAuthenticationSuitesEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "An entry (row) in the dot11RSNAConfigAuthenticationSuitesTable."
    INDEX { dot11RSNAConfigAuthenticationSuiteIndex }
    ::= { dot11RSNAConfigAuthenticationSuitesTable 1 }

Dot11RSNAConfigAuthenticationSuitesEntry ::=
    SEQUENCE {
        dot11RSNAConfigAuthenticationSuiteIndex               Unsigned32,
        dot11RSNAConfigAuthenticationSuiteImplemented         OCTET STRING,
        dot11RSNAConfigAuthenticationSuiteActivated           TruthValue }

dot11RSNAConfigAuthenticationSuiteIndex OBJECT-TYPE
    SYNTAX Unsigned32 (1..4294967295)
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "The auxiliary variable used as an index into the dot11RSNAConfigAuthenti-
        cationSuitesTable."
    ::= { dot11RSNAConfigAuthenticationSuitesEntry 1 }

dot11RSNAConfigAuthenticationSuiteImplemented OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(4))
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        The selector of an (#3266)AKMP. It consists of an OUI or CID (the first 3
        octets) and a cipher suite identifier (the last octet)."
    ::= { dot11RSNAConfigAuthenticationSuitesEntry 2 }

dot11RSNAConfigAuthenticationSuiteActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This variable indicates whether the corresponding (#3266)AKMP is enabled/
        disabled."
    ::= { dot11RSNAConfigAuthenticationSuitesEntry 3 }

-- ********************************************************************
-- * End of dot11RSNAConfigAuthenticationSuites TABLE
-- ********************************************************************

-- ********************************************************************
-- * dot11RSNAStats TABLE
-- ********************************************************************

dot11RSNAStatsTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11RSNAStatsEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "This table maintains per-STA statistics in an RSN. The entry with
```

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```
        dot11RSNAStatsSTAAddress equal to FF-FF-FF-FF-FF-FF contains statistics
        for group addressed traffic."
    ::= { dot11smt 12 }

dot11RSNAStatsEntry OBJECT-TYPE
    SYNTAX Dot11RSNAStatsEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "An entry in the dot11RSNAStatsTable."
    INDEX { ifIndex, dot11RSNAStatsIndex }
    ::= { dot11RSNAStatsTable 1 }

Dot11RSNAStatsEntry ::=
    SEQUENCE {
        dot11RSNAStatsIndex                                 Unsigned32,
        dot11RSNAStatsSTAAddress                            MacAddress,
        dot11RSNAStatsVersion                               Unsigned32,
        dot11RSNAStatsSelectedPairwiseCipher                OCTET STRING,
        dot11RSNAStatsTKIPICVErrors                         Counter32,
        dot11RSNAStatsTKIPLocalMICFailures                  Counter32,
        dot11RSNAStatsTKIPRemoteMICFailures                 Counter32,
        dot11RSNAStatsCCMPReplays                           Counter32,
        dot11RSNAStatsCCMPDecryptErrors                     Counter32,
        dot11RSNAStatsTKIPReplays                           Counter32,
        dot11RSNAStatsCMACReplays                           Counter32,
        dot11RSNAStatsRobustMgmtCCMPReplays                 Counter32,
        dot11RSNAStatsBIPMICErrors                          Counter32,
        (11ba)dot11RSNAStatsCMACWURReplays                  Counter32
    }

dot11RSNAStatsIndex OBJECT-TYPE
    SYNTAX Unsigned32 (1..4294967295)
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "An auxiliary index into the dot11RSNAStatsTable."
    ::= { dot11RSNAStatsEntry 1 }

dot11RSNAStatsSTAAddress OBJECT-TYPE
    SYNTAX MacAddress
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the RSNA Key Management entity in the SME.

        The MAC address of the STA to which the statistics in this conceptual row
        belong."
    ::= { dot11RSNAStatsEntry 2 }

dot11RSNAStatsVersion OBJECT-TYPE
    SYNTAX Unsigned32 (1..4294967295)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the RSNA Key Management entity in the SME.

        The RSNA version with which the STA associated."
    ::= { dot11RSNAStatsEntry 3 }

dot11RSNAStatsSelectedPairwiseCipher OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(4))
```


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```
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the RSNA Key Management entity in the SME.

        The pairwise cipher suite Selector (as defined in 9.4.2.23.2 (Cipher
        suites)) used during association, in transmission order."
    ::= { dot11RSNAStatsEntry 4 }

dot11RSNAStatsTKIPICVErrors OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the MAC when the condition described below occurs.

        Counts the number of TKIP ICV errors encountered when decrypting packets
        for the STA."
    ::= { dot11RSNAStatsEntry 5 }

dot11RSNAStatsTKIPLocalMICFailures OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the MAC when the condition described below occurs.

        Counts the number of MIC failures encountered when checking the integrity
        of MSDUs(#3243) received from the STA at this entity."
    ::= { dot11RSNAStatsEntry 6 }

dot11RSNAStatsTKIPRemoteMICFailures OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the MAC when the condition described below occurs.

        Counts the number of MIC failures encountered by the STA identified by
        dot11StatsSTAAddress and reported back to this entity."
    ::= { dot11RSNAStatsEntry 7 }

dot11RSNAStatsCCMPReplays OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the MAC when the condition described below occurs.

        (#3538)The number of received Data frames discarded due to CCMP replay
        errors."
    ::= { dot11RSNAStatsEntry 8 }

dot11RSNAStatsCCMPDecryptErrors OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
```

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```
        It is written by the MAC when the condition described below occurs.

        The number of received MPDUs discarded by the CCMP decryption algorithm."
    ::= { dot11RSNAStatsEntry 9 }

dot11RSNAStatsTKIPReplays OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the MAC when the condition described below occurs.

        Counts the number of TKIP replay errors detected."
    ::= { dot11RSNAStatsEntry 10 }

dot11RSNAStatsCMACReplays OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the MAC when the condition described below occurs.

        (#3538)The number of received group addressed robust Management and pro-
        tected Beacon frames discarded (#1401)due to BIP replay errors."
    ::= { dot11RSNAStatsEntry 12 }

dot11RSNAStatsRobustMgmtCCMPReplays OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the MAC when the condition described below occurs.

        (#3538)The number of received individually addressed robust Management
        frames discarded due to CCMP replay errors."
    ::= {dot11RSNAStatsEntry 13}

dot11RSNAStatsBIPMICErrors OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the MAC when the condition described below occurs.

        The number of received MMPDUs discarded due to BIP MIC errors"
    ::= {dot11RSNAStatsEntry 14}

(11ba)dot11RSNAStatsCMACWURReplays OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the MAC when the condition described below occurs

        The number of received WUR frame discarded due to replay errors."

        ::= { dot11RSNAStatsEntry 15 }
```



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```
--
-- ************************************************************************
-- * End of dot11RSNAStats TABLE
-- ************************************************************************

-- ************************************************************************
-- * dot11OperatingClasses TABLE
-- ************************************************************************

dot11OperatingClassesTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11OperatingClassesEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "(Conceptual) table of attributes for operating classes"
    ::= {dot11smt 13}

dot11OperatingClassesEntry OBJECT-TYPE
    SYNTAX Dot11OperatingClassesEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "An entry (conceptual row) in the Operating Classes Table.

        IfIndex - Each IEEE 802.11 interface is represented by an ifEntry.
        Interface tables in this MIB are indexed by ifIndex."
    INDEX {ifIndex, dot11OperatingClassesIndex}
    ::= { dot11OperatingClassesTable 1 }

Dot11OperatingClassesEntry ::=
    SEQUENCE {
        dot11OperatingClassesIndex                          Unsigned32,
        dot11OperatingClass                                 Unsigned32,
        dot11CoverageClass                                  Unsigned32 }

dot11OperatingClassesIndex OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "The auxiliary variable used to identify instances of the columnar objects
        in the Operating Classes Table."
    ::= { dot11OperatingClassesEntry 1 }

dot11OperatingClass OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by the SME or external management entity when the (#4213)STA
        is initialized.

        This attribute indicates the operating class to be used."
    DEFVAL { 0 }
    ::= { dot11OperatingClassesEntry 2 }

dot11CoverageClass OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by the SME or external management entity when the (#4213)STA
        is initialized.
```

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```
        This attribute indicates the coverage class to be used."
    DEFVAL { 0 }
    ::= { dot11OperatingClassesEntry 3 }

-- ************************************************************************
-- * End of dot11OperatingClasses TABLE
-- ************************************************************************
-- ************************************************************************
-- * dot11BeaconRssi TABLE
-- ************************************************************************
dot11BeaconRssiTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11BeaconRssiEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "(Conceptual) table of attributes for received Beacon RSSI."
    ::= {dot11smt 38}

dot11BeaconRssiEntry OBJECT-TYPE
    SYNTAX Dot11BeaconRssiEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "An entry (conceptual row) in the received Beacon RSSI table."
    INDEX { dot11BeaconRssiIndex }
    ::= { dot11BeaconRssiTable 1 }

Dot11BeaconRssiEntry ::=
    SEQUENCE {
        dot11BeaconRssiIndex                                Unsigned32,
        dot11BeaconMACAddress                               MacAddress,
        dot11BeaconRssi                                     Integer32}

dot11BeaconRssiIndex OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "The auxiliary variable used to identify instances of the columnar objects
        in the received Beacon Rssi table."
    ::= { dot11BeaconRssiEntry 1 }

dot11BeaconMACAddress OBJECT-TYPE
    SYNTAX MacAddress
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by the MAC upon receiving a Beacon frame.

        This attribute indicates the MAC address of the AP from which the beacon
        used for Beacon RSSI measurement was transmitted."
    ::= { dot11BeaconRssiEntry 2 }

dot11BeaconRssi OBJECT-TYPE
    SYNTAX Integer32
    UNITS "dBm"
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by the MAC upon receiving a Beacon frame.
```


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```
        This attribute indicates the received signal strength of Beacon frames
        received on the channel, averaged (in linear domain) over all active
        receive chains.  This may be time-averaged over recent history by a
        vendor-specific smoothing function."
    ::= { dot11BeaconRssiEntry 3 }

-- ************************************************************
-- * End of dot11BeaconRssi TABLE
-- ************************************************************
```

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```
$-- ****************************************************************
-- * dot11FastBSSTransitionConfig TABLE
-- ****************************************************************
dot11FastBSSTransitionConfigTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11FastBSSTransitionConfigEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "The table containing fast BSS transition configuration objects."
    ::= { dot11smt 15 }

dot11FastBSSTransitionConfigEntry OBJECT-TYPE
    SYNTAX Dot11FastBSSTransitionConfigEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "An entry in the dot11FastBSSTransitionConfigTable."
    INDEX { ifIndex }
    ::= { dot11FastBSSTransitionConfigTable 1 }

Dot11FastBSSTransitionConfigEntry ::=
    SEQUENCE {
        dot11FastBSSTransitionActivated                    TruthValue,
        dot11FTMobilityDomainID                            OCTET STRING,
        dot11FTOverDSActivated                             TruthValue,
        dot11FTResourceRequestSupported                    TruthValue,
        dot11FTR0KeyHolderID                               OCTET STRING,
        dot11FTR0KeyLifetime                               Unsigned32,
        dot11FTR1KeyHolderID                               OCTET STRING,
        dot11FTReassociationDeadline                       Unsigned32 }

dot11FastBSSTransitionActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        When this object is true, this indicates that fast BSS transition (FT) is
        enabled on this entity. The entity  advertises the FT-related elements in
        its Beacon and Probe Response frames. This object requires that dot11-
        FastBSSTransitionImplemented also be equal to true."
    ::= { dot11FastBSSTransitionConfigEntry 1 }

dot11FTMobilityDomainID OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(2))
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute specifies the (#1776)mobility domain identifier (MDID) of
        this entity.

        The MDID is used to indicate a group of APs, within an ESS, between which
        a STA can use fast BSS transition services. Fast BSS transitions are
        allowed only between APs that have the same MDID and are within the same
        ESS. They are not allowed between APs with different MDIDs or in different
        ESSs.
```


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```
        Since fast BSS transition services are defined only within the scope of an
        ESS, there is no requirement that MDIDs be unique across ESSs."
    ::= { dot11FastBSSTransitionConfigEntry 2 }

dot11FTOverDSActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        When this object is true, this indicates that fast BSS transition via the
        over-the-DS protocol as described in Clause 13 (Fast BSS transition) is
        enabled on this AP entity."
    ::= { dot11FastBSSTransitionConfigEntry 3 }

dot11FTResourceRequestSupported OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        When this object is true, this indicates that the fast BSS transition (FT)
        resource request procedures of 13.10 (Remote request broker (RRB) communi-
        cation) are supported on this AP entity."
    ::= { dot11FastBSSTransitionConfigEntry 4 }

dot11FTR0KeyHolderID OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(1..48))
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute specifies the PMK-R0 key holder identifier (R0KH-ID) of the
        Authenticator of this AP.

        NOTE: Backend protocol might allow longer NAS Client identifiers (e.g.,
        RADIUS allows up to 253-octet NAS-Identifier), but if used with fast BSS
        transition, the maximum length is limited to 48 octets. Subclause 13.2.2
        (Authenticator key holders) requires that the same value is used for the
        NAS Client identifier and dot11FTR0KeyHolderID."
    ::= { dot11FastBSSTransitionConfigEntry 5 }

dot11FTR0KeyLifetime OBJECT-TYPE
    SYNTAX Unsigned32 (60..4294967295)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute specifies the default lifetime of the PMK-R0, in seconds,
        when a Session-Timeout attribute is not provided during the EAP authenti-
        cation. This attribute also applies when the PMK-R0 is derived from a
        PSK."
```

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```
    DEFVAL { 1209600 }
    ::= { dot11FastBSSTransitionConfigEntry 6 }

dot11FTR1KeyHolderID OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(6))
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute specifies the PMK-R1 key holder identifier (R1KH-ID) of the
        Authenticator of this AP. It is equal to a MAC address of the entity hold-
        ing the PMK-R1 in the Authenticator."
    ::= { dot11FastBSSTransitionConfigEntry 7 }

dot11FTReassociationDeadline OBJECT-TYPE
    SYNTAX Unsigned32 (1000..4294967295)
    UNITS "TUs"(#1724)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute specifies the time period(#1724) that this target AP entity
        caches a PTKSA and reserves any specified resources for a STA while wait-
        ing for a reassociation from that STA. It is assumed that this value is
        administered consistently across the mobility domain."
    DEFVAL { 1000 }
    ::= { dot11FastBSSTransitionConfigEntry 8 }

-- ********************************************************************
-- * End of dot11FastBSSTransitionConfig TABLE
-- ********************************************************************

-- ********************************************************************
-- * dot11LCIDSE TABLE
-- ********************************************************************

dot11LCIDSETable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11LCIDSEEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "Group contains conceptual table of attributes for Dependent Station
        Enablement."
    ::= { dot11smt 16 }

dot11LCIDSEEntry OBJECT-TYPE
    SYNTAX Dot11LCIDSEEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "An entry in the dot11LCIDSETable Indexed by dot11LCIDSEIndex."
    INDEX { dot11LCIDSEIndex }
    ::= { dot11LCIDSETable 1 }

Dot11LCIDSEEntry ::=
    SEQUENCE {
        dot11LCIDSEIndex                                Unsigned32,
        dot11LCIDSEIfIndex                              InterfaceIndex,
```


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```
        dot11LCIDSECurrentOperatingClass                Unsigned32,
        dot11LCIDSELatitudeUncertainty                  Unsigned32,
        dot11LCIDSELatitudeInteger                      Integer32,
        dot11LCIDSELatitudeFraction                     Integer32,
        dot11LCIDSELongitudeUncertainty                 Unsigned32,
        dot11LCIDSELongitudeInteger                     Integer32,
        dot11LCIDSELongitudeFraction                    Integer32,
        dot11LCIDSEAltitudeType                         INTEGER,
        dot11LCIDSEAltitudeUncertainty                  Unsigned32,
        dot11LCIDSEAltitude                             Integer32,
        dot11LCIDSEDatum                                Unsigned32,
        dot11RegLocAgreement                            TruthValue,
        dot11RegLocDSE                                  TruthValue,
        dot11DependentSTA                               TruthValue,
        dot11DependentEnablementIdentifier              Unsigned32,
        dot11DSEEnablementTimeLimit                     Unsigned32,
        dot11DSEEnablementFailHoldTime                  Unsigned32,
        dot11DSERenewalTime                             Unsigned32,
        dot11DSETransmitDivisor                         Unsigned32 }

dot11LCIDSEIndex OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "Index for LCI DSE elements in dot11LCIDSETable, greater than 0."
    ::= { dot11LCIDSEEntry 1 }

dot11LCIDSEIfIndex OBJECT-TYPE
    SYNTAX InterfaceIndex
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "Each IEEE 802.11 interface is represented by an ifEntry. Interface Tables
        in this MIB are indexed by ifIndex."
    ::= { dot11LCIDSEEntry 2 }

dot11LCIDSECurrentOperatingClass OBJECT-TYPE
    SYNTAX Unsigned32 (0..255)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by the SME when the (#4213)STA is initialized.

        Current Operating Class is 8 bits indicating the particular Operating
        Class in use by the radio."
    ::= { dot11LCIDSEEntry 3 }

dot11LCIDSELatitudeUncertainty OBJECT-TYPE
    SYNTAX Unsigned32 (0..63)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by the SME when the (#4213)STA is initialized.

        Latitude uncertainty is defined in IETF RFC 6225."
    ::= { dot11LCIDSEEntry 4 }

dot11LCIDSELatitudeInteger OBJECT-TYPE
    SYNTAX Integer32 (-359..359)
    MAX-ACCESS read-only
    STATUS current
```

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```
    DESCRIPTION
        "This is a control variable.
        It is written by the SME when the (#4213)STA is initialized.
        Latitude is represented as a 2s complement 34-bit fixed point value
        consisting of 9 bits of integer and 25 bits of fraction. This field
        contains the 9 bits of integer portion of the latitude."
    ::= { dot11LCIDSEEntry 5 }

dot11LCIDSELatitudeFraction OBJECT-TYPE
    SYNTAX Integer32 (-16777215..16777215)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by the SME when the (#4213)STA is initialized.
        Latitude is represented a 2s complement 34-bit fixed point value
        consisting of 9 bits of integer and 25 bits of fraction. This field
        contains the 25 bits of fraction portion of the latitude."
    ::= { dot11LCIDSEEntry 6 }

dot11LCIDSELongitudeUncertainty OBJECT-TYPE
    SYNTAX Unsigned32 (0..63)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by the SME when the (#4213)STA is initialized.

        Longitude uncertainty is defined in IETF RFC 6225."
    ::= { dot11LCIDSEEntry 7 }

dot11LCIDSELongitudeInteger OBJECT-TYPE
    SYNTAX Integer32 (-359..359)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by the SME when the (#4213)STA is initialized.
        Longitude is represented a 2s complement 34-bit fixed point value
        consisting of 9 bits of integer and 25 bits of fraction. This field
        contains the 9 bits of integer portion of the longitude."
    ::= { dot11LCIDSEEntry 8 }

dot11LCIDSELongitudeFraction OBJECT-TYPE
    SYNTAX Integer32 (-16777215..16777215)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by the SME when the (#4213)STA is initialized.
        Longitude is represented a 2s complement 34-bit fixed point value
        consisting of 9 bits of integer and 25 bits of fraction. This field
        contains the 25 bits of fraction portion of the longitude."
    ::= { dot11LCIDSEEntry 9 }

dot11LCIDSEAltitudeType OBJECT-TYPE
    SYNTAX INTEGER { meters(1), floors(2), hagm(3) }
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by the SME when the (#4213)STA is initialized.

        Altitude Type is 4 bits encoding the type of altitude.
```


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```
        Codes defined are:
        meters : in 2s complement fixed-point 22-bit integer part with 8-bit
        fraction
        floors : in 2s complement fixed-point 22-bit integer part with 8-bit
        fraction
        hagm : Height Above Ground in meters, in 2s complement fixed-point 22-bit
        integer part with 8-bit fraction. "
    DEFVAL { 3 }
    ::= { dot11LCIDSEEntry 10 }

dot11LCIDSEAltitudeUncertainty OBJECT-TYPE
    SYNTAX Unsigned32 (0..63)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by the SME when the (#4213)STA is initialized.

        Altitude resolution is 6 bits indicating the number of valid bits in the
        altitude."
    ::= { dot11LCIDSEEntry 11 }

dot11LCIDSEAltitude OBJECT-TYPE
    SYNTAX Integer32 (-536870912..536870911)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by the SME when the (#4213)STA is initialized.

        Altitude is a 30-bit value defined by the Altitude type field. The field
        is encoded as a 2s complement fixed-point 22-bit integer part with 8-bit
        fraction."
    ::= { dot11LCIDSEEntry 12 }

-- reserved: 13. was dot11LCIDSEAltitudeFraction

dot11LCIDSEDatum OBJECT-TYPE
    SYNTAX Unsigned32 (1..3)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by the SME when the (#4213)STA is initialized.

        Datum is a 3-bit value encoding the horizontal and vertical references
        used for the coordinates given in this LCI. IETF RFC 6225 defines the
        values of Datum. Type 1 is WGS-84, the coordinate system used by GPS. Type
        2 is NAD83 with NAVD88 vertical reference. Type 3 is NAD83 with Mean Lower
        Low Water vertical datum. All other types are reserved."
    DEFVAL { 1 }
    ::= { dot11LCIDSEEntry 14 }

dot11RegLocAgreement OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the MAC when a DSE Enablement frame is received.

        RegLocAgreement reports the Enabling STA's Agreement status. false
        indicates it is operating away from national borders and outside national
        policy zones. true indicates it is operating by agreement near national
```

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```
        borders or inside national policy zones."
    DEFVAL { false }
    ::= { dot11LCIDSEEntry 15 }

dot11RegLocDSE OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the MAC when a DSE Enablement frame is received.

        RegLocDSE reports the Enabling STA's DSE status. false indicates Dependent
        STAs are not enabled. true indicates Dependent STA operation is enabled."
    DEFVAL { false }
    ::= { dot11LCIDSEEntry 16 }

dot11DependentSTA OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the MAC when a DSE Enablement frame is received.

        This attribute reports the Dependent STA status of the STA that sent the
        Beacon or Probe Response frame(s) with this information. false indicates
        that STA is not operating as a Dependent STA. true indicates that STA is
        operating as a Dependent STA."
    DEFVAL { true }
    ::= { dot11LCIDSEEntry 17 }

dot11DependentEnablementIdentifier OBJECT-TYPE
    SYNTAX Unsigned32 (0..65535)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the MAC when a DSE Enablement frame is received.

        This attribute reports the Dependent STA identifier assigned by the
        enabling STA to the dependent station."
    DEFVAL { 0 }
    ::= { dot11LCIDSEEntry 18 }

dot11DSEEnablementTimeLimit OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by the SME when the (#4213)STA is initialized.

        dot11DSEEnablementTimeLimit indicates the maximum number of seconds that a
        dependent STA may transmit in a DSE frequency band while attaining
        enablement with an enabling STA. Unless another value is mandated by
        regulatory authorities, the value is 32 s(#7198)."
    DEFVAL { 32 }
    ::= { dot11LCIDSEEntry 19 }

dot11DSEEnablementFailHoldTime OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-only
    STATUS current
```


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```
    DESCRIPTION
        "This is a control variable.
        It is written by the SME when the (#4213)STA is initialized.

        dot11DSEEnablementFailHoldTime indicates the number of seconds that a
        dependent STA (#6025)shall not transmit in a DSE frequency band when it
        fails to attain enablement with an enabling STA within dot11DSEEnablement-
        TimeLimit seconds. Unless another value is mandated by regulatory author-
        ities, the value is 512 s(#7198)."
    DEFVAL { 512 }
    ::= { dot11LCIDSEEntry 20}

dot11DSERenewalTime OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by the SME when the (#4213)STA is initialized.

        dot11DSERenewalTime indicates the maximum number of seconds that a
        dependent STA may operate in a DSE frequency band without receiving and
        decoding an enabling signal from its enabling STA. Unless another value is
        mandated by regulatory authorities, the value is 60 s(#7198)."
    DEFVAL { 60 }
    ::= { dot11LCIDSEEntry 21}

dot11DSETransmitDivisor OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by the SME when the (#4213)STA is initialized.

        dot11DSETransmitDivisor indicates the value used by a dependent STA when
        operating in a DSE frequency band and transmitting. The dependent STA
        sends an Action frame when the sum of dot11TransmittedFragmentCount,
        dot11GroupTransmittedFrameCount and dot11ReceivedFragmentCount modulo
        dot11DSETransmitDivisor equals 0."
    DEFVAL { 256 }
    ::= { dot11LCIDSEEntry 22}

-- ************************************************************
-- * End of dot11LCIDSE TABLE
-- ************************************************************

-- ************************************************************************
-- * dot11HTStationConfig TABLE
-- ************************************************************************
dot11HTStationConfigTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11HTStationConfigEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "Station Configuration attributes. In tabular form to allow for multiple
        instances on an agent."
    ::= { dot11smt 17 }

dot11HTStationConfigEntry OBJECT-TYPE
    SYNTAX Dot11HTStationConfigEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
```

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```
        "An entry (conceptual row) in the dot11HTStationConfig Table.

        ifIndex - Each IEEE 802.11 interface is represented by an ifEntry.
        Interface tables in this MIB module are indexed by ifIndex."
    INDEX { ifIndex }
    ::= { dot11HTStationConfigTable 1 }

Dot11HTStationConfigEntry ::=
    SEQUENCE {
        dot11HTOperationalMCSSet                              OCTET STRING,
        dot11MIMOPowerSave                                    INTEGER,
        dot11NDelayedBlockAckOptionImplemented                TruthValue,
        dot11MaxAMSDULength                                   INTEGER,
        dot11STBCControlFrameOptionImplemented                TruthValue,
        dot11LsigTxopProtectionOptionImplemented              TruthValue,
        dot11MaxRxAMPDUFactor                                 Unsigned32,
        dot11MinimumMPDUStartSpacing                          Unsigned32,
        dot11PCOOptionImplemented                             TruthValue,
        dot11TransitionTime                                   Unsigned32,
        dot11MCSFeedbackOptionImplemented                     INTEGER,
        dot11HTControlFieldSupported                          TruthValue,
        dot11RDResponderOptionImplemented                     TruthValue,
        dot11SPPAMSDUCapable                                  TruthValue,
        dot11SPPAMSDURequired                                 TruthValue,
        dot11FortyMHzOptionImplemented                        TruthValue }

dot11HTOperationalMCSSet OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(1..127))
    MAX-ACCESS read-write
    STATUS deprecated
    DESCRIPTION
        "Deprecated as the related feature has been removed from IEEE Std 802.11.
        This is a control variable.
        It is written by an external management entity.
        Changes take effect for the next MLME-START.request primitive or MLME-
        JOIN.request primitive.

        This attribute shall specify the set of MCS at which the station may
        transmit data. Each octet contains a value representing a rate. Each MCS
        shall be within the range 1 to 127, and shall be supported for receiving
        data. This value is reported in transmitted Beacon, Probe Request, Probe
        Response, Association Request, Association Response, Reassociation
        Request, and Reassociation Response frames, and is used to determine
        whether a BSS with which the station might synchronize is suitable. It is
        also used when starting a BSS, as specified in 11.3 (STA authentication
        and association)."
    ::= { dot11HTStationConfigEntry 1 }

dot11MIMOPowerSave OBJECT-TYPE
    SYNTAX INTEGER { static(1), dynamic(2), mimo(3) }
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the PHY when the power save condition changes.

        This is an 8-bit integer value that identifies the configured power save
        state of MIMO."
    ::= { dot11HTStationConfigEntry 2 }

dot11NDelayedBlockAckOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS (#3441)deprecated
```


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```
    DESCRIPTION
        "Deprecated as the related feature has been removed from IEEE Std 802.11.
        This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the station implementation is
        capable of supporting the No Acknowledgment option of the delayed block
        ack."
    ::= { dot11HTStationConfigEntry 3 }

dot11MaxAMSDULength OBJECT-TYPE
    SYNTAX INTEGER { short(3839), long(7935) }
    UNITS "octets"
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute indicates the maximum supported size of an A-MSDU."
    ::= { dot11HTStationConfigEntry 4 }

dot11STBCControlFrameOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the station implementation is
        capable of processing the received Control frames that are STBC frames."
    ::= { dot11HTStationConfigEntry 5 }

dot11LsigTxopProtectionOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS deprecated
    DESCRIPTION
        "Deprecated as the related feature has been removed from IEEE Std 802.11.
        This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the station implementation is
        capable of supporting L-SIG TXOP protection option."
    ::= { dot11HTStationConfigEntry 6 }

dot11MaxRxAMPDUFactor OBJECT-TYPE
    SYNTAX Unsigned32 (0..3)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute indicates the maximum length of A-MPDU that the STA can
        receive. The Maximum Rx A-MPDU defined by this field is equal to 2 ^
        (13+dot11MaxRxAMPDUFactor) -1 octets."
    ::= { dot11HTStationConfigEntry 7 }

dot11MinimumMPDUStartSpacing OBJECT-TYPE
    SYNTAX Unsigned32 (0..7)
    MAX-ACCESS read-only
    STATUS current
```

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```
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute indicates the minimum time between the start of adjacent
        MPDUs within an A-MPDU. This time is measured at the PHY SAP; the number
        of octets between the start of two consecutive MPDUs in A-MPDU shall be
        equal or greater than (dot11MinimumMPDUStartSpacing*PHY-bit-rate)/8. The
        encoding of the minimum time to this attribute is:
        0 - no restriction
        1 - 1/4 microsecond
        2 - 1/2 microsecond
        3 - 1 microsecond
        4 - 2 microseconds
        5 - 4 microseconds
        6 - 8 microseconds
        7 - 16 microseconds"
    ::= { dot11HTStationConfigEntry 8 }

dot11PCOOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS deprecated
    DESCRIPTION
        "Deprecated as the related feature has been removed from IEEE Std 802.11.
        This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the station implementation is
        capable of supporting PCO."
    ::= { dot11HTStationConfigEntry 9 }

dot11TransitionTime OBJECT-TYPE
    SYNTAX Unsigned32 (0..3)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute indicates that the maximum transition time within which the
        STA can switch between 20 MHz channel width and 40 MHz channel width with
        a high probability. The encoding of the transition time to this attribute
        is:
        0 - no transition
        1 - 400 microseconds
        2 - 1500 microseconds
        3 - 5000 microseconds"
    ::= { dot11HTStationConfigEntry 10 }

dot11MCSFeedbackOptionImplemented OBJECT-TYPE
    SYNTAX INTEGER { none(0), unsolicited (2), both (3) }
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute indicates the MCS feed back capability supported by the
        station implementation."
    ::= { dot11HTStationConfigEntry 11 }

dot11HTControlFieldSupported OBJECT-TYPE
    SYNTAX TruthValue
```


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```
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the station implementation is
        capable of receiving HT Control field."
    ::= { dot11HTStationConfigEntry 12 }

dot11RDResponderOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the station implementation is
        capable operating as an RD responder."
    ::= { dot11HTStationConfigEntry 13 }

dot11SPPAMSDUCapable OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the STA implementation is
        capable of protecting the A-MSDU bit (Bit 7) in the QoS Control field when
        dot11RSNAActivated is true."
    ::= { dot11HTStationConfigEntry 14 }

dot11SPPAMSDURequired OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS (#3441)deprecated(M57)
    DESCRIPTION
        "Deprecated as the related feature has been removed from the stan-
        dard.(M57)

        This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute, when true, indicates that the STA is configured to
        disallow (i.e., not to send or receive) PP A-MSDUs when dot11RSNAActivated
        is true."
    DEFVAL { false }
    ::= { dot11HTStationConfigEntry 15 }

dot11FortyMHzOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the STA is capable of
        transmitting and receiving on a 40 MHz channel using a 40 MHz mask."
    ::= { dot11HTStationConfigEntry 16 }
```

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```
--
-- ************************************************************************
-- * End of dot11HTStationConfig TABLE
-- ************************************************************************

-- ************************************************************************
-- * dot11WirelessMgmtOptions TABLE
-- ************************************************************************
dot11WirelessMgmtOptionsTable OBJECT-TYPE
   SYNTAX SEQUENCE OF Dot11WirelessMgmtOptionsEntry
   MAX-ACCESS not-accessible
   STATUS current
   DESCRIPTION
      "Wireless Management attributes. In tabular form to allow for multiple
      instances on an agent. This table only applies to the interface if
      dot11WirelessManagementImplemented is equal to true in the
      dot11StationConfigTable."
   ::= { dot11smt 18 }

dot11WirelessMgmtOptionsEntry OBJECT-TYPE
   SYNTAX Dot11WirelessMgmtOptionsEntry
   MAX-ACCESS not-accessible
   STATUS current
   DESCRIPTION
      "An entry in the dot11WirelessMgmtOptionsTable. For all Wireless
      Management features, an Activated MIB attribute is used to activate/enable
      or deactivate/disable the corresponding feature. An Implemented MIB
      attribute is used for an optional feature to indicate whether the feature
      is implemented. A mandatory feature does not have a corresponding
      Implemented MIB attribute. It is possible for there to be multiple IEEE
      802.11 interfaces on one agent, each with its unique MAC address. The
      relationship between an IEEE 802.11 interface and an interface in the
      context of the Internet-standard MIB is one-to-one. As such, the value of
      an ifIndex object instance can be directly used to identify corresponding
      instances of the objects defined herein. ifIndex - Each IEEE 802.11
      interface is represented by an ifEntry. Interface tables in this MIB
      module are indexed by ifIndex."
   INDEX { ifIndex }
   ::= { dot11WirelessMgmtOptionsTable 1 }

Dot11WirelessMgmtOptionsEntry ::=
   SEQUENCE {
      dot11LocationActivated                          TruthValue,
      dot11FMSImplemented                             TruthValue,
      dot11FMSActivated                               TruthValue,
      dot11EventsActivated                            TruthValue,
      dot11DiagnosticsActivated                       TruthValue,
      dot11MultiBSSIDImplemented                      TruthValue,
      dot11MultiBSSIDActivated                        TruthValue,
      dot11TFSImplemented                             TruthValue,
      dot11TFSActivated                               TruthValue,
      dot11WNMSleepModeImplemented                    TruthValue,
      dot11WNMSleepModeActivated                      TruthValue,
      dot11TIMBroadcastImplemented                    TruthValue,
      dot11TIMBroadcastActivated                      TruthValue,
      dot11ProxyARPImplemented                        TruthValue,
      dot11ProxyARPActivated                          TruthValue,
      dot11BSSTransitionActivated                     TruthValue,
      dot11QoSTrafficCapabilityImplemented            TruthValue,
      dot11QoSTrafficCapabilityActivated              TruthValue,
      dot11ACStationCountImplemented                  TruthValue,
      dot11ACStationCountActivated                    TruthValue,
      dot11CoLocIntfReportingImplemented              TruthValue,
      dot11CoLocIntfReportingActivated                TruthValue,
```


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```
        dot11MotionDetectionImplemented                          TruthValue,
        dot11MotionDetectionActivated                            TruthValue,
        dot11TODImplemented                                      TruthValue,
        dot11TODActivated                                        TruthValue,
        dot11TimingMsmtImplemented                               TruthValue,
        dot11TimingMsmtActivated                                 TruthValue,
        dot11ChannelUsageImplemented                             TruthValue,
        dot11ChannelUsageActivated                               TruthValue,
        dot11TriggerSTAStatisticsActivated                       TruthValue,
        dot11SSIDListImplemented                                 TruthValue,
        dot11SSIDListActivated                                   TruthValue,
        dot11MulticastDiagnosticsActivated                       TruthValue,
        dot11LocationTrackingImplemented                         TruthValue,
        dot11LocationTrackingActivated                           TruthValue,
        dot11DMSImplemented                                      TruthValue,
        dot11DMSActivated                                        TruthValue,
        dot11UAPSDCoexistenceImplemented                         TruthValue,
        dot11UAPSDCoexistenceActivated                           TruthValue,
        dot11WNMNotificationImplemented                          TruthValue,
        dot11WNMNotificationActivated                            TruthValue,
        dot11UTCTSFOffsetImplemented                             TruthValue,
        dot11UTCTSFOffsetActivated                               TruthValue,
        dot11FineTimingMsmtRespActivated                         TruthValue,
        dot11FineTimingMsmtInitActivated                         TruthValue,
        dot11LciCivicInNeighborReport                            TruthValue,
        dot11RMFineTimingMsmtRangeRepImplemented                 TruthValue,
        dot11RMFineTimingMsmtRangeRepActivated                   TruthValue,
        dot11RMLCIConfigured                                     TruthValue,
        dot11RMCivicConfigured                                   TruthValue,
        (11az)dot11SecureLTFImplemented                          TruthValue,
        (11az)dot11TriggerBasedRangingRespImplemented            TruthValue,
        (11az)dot11NonTriggerBasedRangingRespImplemented         TruthValue,
        (11az)dot11RSTARequiresPMFActivated                      INTEGER,
        (11az)dot11PassiveTBRangingResponderImplemented          TruthValue,
        (11az)dot11PassiveTBRangingInitiatorImplemented          TruthValue,
        (11az)dot11AOAMeasurementImplemented                     TruthValue,
        (11az)dot11I2RLMRFeedbackPolicy                          TruthValue,
        (11az)dot11LOSAssessmentTXImplemented                    TruthValue,
        (11az)dot11LOSAssessmentRXImplemented                    TruthValue,
        (11az)dot11PassiveTBRangingAODImplemented                TruthValue,
        (11az)dot11PhaseShiftFeedbackImplemented                 TruthValue,
        (#6016)dot11ChannelUsageCapabilityNotificationImplemented         Truth-
        Value
        }


dot11LocationActivated OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by an external management entity or the SME.
      Changes take effect as soon as practical in the implementation.

      This attribute, when true, indicates that the capability of the station to
      provide location is enabled. The capability is disabled, otherwise."
   DEFVAL { false }(#7210)
   ::= { dot11WirelessMgmtOptionsEntry 1 }

dot11FMSImplemented OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-only
   STATUS current
```

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```
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the station implementation is
        capable of supporting FMS when dot11WirelessManagementImplemented is equal
        to true."
    ::= { dot11WirelessMgmtOptionsEntry 2 }

dot11FMSActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        This attribute, when true, indicates that the capability of the station to
        provide FMS is enabled. The capability is disabled, otherwise"
    DEFVAL { false }(#7210)
    ::= { dot11WirelessMgmtOptionsEntry 3 }

dot11EventsActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        This attribute, when true, indicates that the capability of the station to
        provide Event Reporting is enabled. The capability is disabled, otherwise"
    DEFVAL { false }(#7210)
    ::= { dot11WirelessMgmtOptionsEntry 4 }

dot11DiagnosticsActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        This attribute, when true, indicates that the capability of the station to
        provide Diagnostic Reporting is enabled. The capability is disabled,
        otherwise."
    DEFVAL { false }(#7210)
    ::= { dot11WirelessMgmtOptionsEntry 5 }

dot11MultiBSSIDImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the station implementation is
        capable of supporting Multiple BSSID when
        dot11WirelessManagementImplemented is equal to true."
    ::= { dot11WirelessMgmtOptionsEntry 6 }
```


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```
dot11MultiBSSIDActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS deprecated
    DESCRIPTION
        "Deprecated as dot11MultiBSSIDActivated has been removed from IEEE Std
        802.11.
        This is a control variable.
        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        This attribute, when true, indicates that the capability of the station to
        provide Multi BSSID is enabled. The capability is disabled, otherwise."
    DEFVAL { false }(#7210)
    ::= { dot11WirelessMgmtOptionsEntry 7 }

dot11TFSImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the station implementation is
        capable of supporting TFS when dot11WirelessManagementImplemented is equal
        to true."
    ::= { dot11WirelessMgmtOptionsEntry 8 }

dot11TFSActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        This attribute, when true, indicates that TFS is enabled. TFS is disabled
        otherwise."
    DEFVAL { false }(#7210)
    ::= { dot11WirelessMgmtOptionsEntry 9 }

dot11WNMSleepModeImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the station implementation is
        capable of supporting WNM sleep mode when
        dot11WirelessManagementImplemented is equal to true."
    ::= { dot11WirelessMgmtOptionsEntry 10 }

dot11WNMSleepModeActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity or the SME.
```

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```
        Changes take effect as soon as practical in the implementation.

        This attribute, when true, indicates that WNM sleep mode is enabled. WNM
        sleep mode is disabled otherwise."
    DEFVAL { false }(#7210)
    ::= { dot11WirelessMgmtOptionsEntry 11 }

dot11TIMBroadcastImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the station implementation is
        capable of supporting TIM Broadcast when
        dot11WirelessManagementImplemented is equal to true."
    ::= { dot11WirelessMgmtOptionsEntry 12}

dot11TIMBroadcastActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        This attribute, when true, indicates that TIM broadcast is enabled. TIM
        broadcast is disabled otherwise."
    DEFVAL { false }(#7210)
    ::= { dot11WirelessMgmtOptionsEntry 13}

dot11ProxyARPImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the station implementation is
        capable of supporting the proxy ARP service, when
        dot11WirelessManagementImplemented is equal to true."
    ::= { dot11WirelessMgmtOptionsEntry 14 }

dot11ProxyARPActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        This attribute, when true, indicates that the capability of the AP to
        provide the proxy ARP service is enabled. The capability is disabled,
        otherwise."
    DEFVAL { false }(#7210)
    ::= { dot11WirelessMgmtOptionsEntry 15 }

dot11BSSTransitionImplemented OBJECT-TYPE
    SYNTAX TruthValue
```


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```
    MAX-ACCESS read-only
    STATUS (#3441)deprecated
    DESCRIPTION
        "Decrepated as unnecessary; dot11BSSTransitionActivated is used instead.

        This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        (#4123)This attribute, when true, indicates that the station
        implementation is capable of supporting BSS transition management, when
        dot11WirelessManagementImplemented is equal to true."
    ::= { dot11WirelessMgmtOptionsEntry 16 }

dot11BSSTransitionActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        This attribute, when true, indicates that the capability of the station to
        provide BSS transition is enabled. The capability is disabled, otherwise.
        "
    DEFVAL { false }(#7210)
    ::= { dot11WirelessMgmtOptionsEntry 17 }

dot11QoSTrafficCapabilityImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the station implementation is
        capable of supporting QoS traffic capability when
        dot11WirelessManagementImplemented is equal to true."
    ::= { dot11WirelessMgmtOptionsEntry 18 }

dot11QoSTrafficCapabilityActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        This attribute, when true, indicates that the capability of the station to
        provide QoS traffic capability is enabled. QoS traffic capability is
        disabled otherwise."
    DEFVAL { false }(#7210)
    ::= { dot11WirelessMgmtOptionsEntry 19 }

dot11ACStationCountImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.
```

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```
        This attribute, when true, indicates that the station implementation is
        capable of supporting AC Station Count when
        dot11WirelessManagementImplemented is equal to true."
    ::= { dot11WirelessMgmtOptionsEntry 20 }

dot11ACStationCountActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        This attribute, when true, indicates that the capability of the station to
        provide AC Station Count is enabled. AC Station Count is disabled
        otherwise."
    DEFVAL { false }(#7210)
    ::= { dot11WirelessMgmtOptionsEntry 21 }

dot11CoLocIntfReportingImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the station implementation is
        capable of supporting Colocated Interference Reporting. The capability is
        disabled, otherwise."
    ::= { dot11WirelessMgmtOptionsEntry 22 }

dot11CoLocIntfReportingActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        This attribute, when true, indicates that the capability of the station to
        support Colocated Interference Reporting is enabled. The capability is
        disabled, otherwise."
    DEFVAL { false }(#7210)
    ::= { dot11WirelessMgmtOptionsEntry 23 }

dot11MotionDetectionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the station implementation is
        capable of supporting motion detection when
        dot11WirelessManagementImplemented is equal to true. "
    ::= { dot11WirelessMgmtOptionsEntry 24 }

dot11MotionDetectionActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
```


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```
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        This attribute, when true, indicates that the capability to support motion
        detection is enabled."
    DEFVAL { false }(#7210)
    ::= { dot11WirelessMgmtOptionsEntry 25 }

dot11TODImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the station implementation is
        capable of supporting Time Of Departure for Clause 15 (DSSS PHY
        specification for the 2.4 GHz band designated for ISM applications)
        transmitted frames, Clause 17 (Orthogonal frequency division multiplexing
        (OFDM) PHY specification) transmitted frames, Clause 16 (High rate direct
        sequence spread spectrum (HR/DSSS) PHY specification) transmitted frames,
        Clause 18 (Extended Rate PHY (ERP) specification) transmitted frames and
        Clause 19 (High Throughput (HT) PHY specification(#2297)) transmitted
        frames when dot11WirelessManagementImplemented is equal to true."
    ::= { dot11WirelessMgmtOptionsEntry 26 }

dot11TODActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        This attribute, when true, indicates that the capability to support Time
        Of Departure frames for transmitted Clause 15 (DSSS PHY specification for
        the 2.4 GHz band designated for ISM applications), Clause 17 (Orthogonal
        frequency division multiplexing (OFDM) PHY specification), Clause 16 (High
        rate direct sequence spread spectrum (HR/DSSS) PHY specification),
        Clause 18 (Extended Rate PHY (ERP) specification) and Clause 19 (High
        Throughput (HT) PHY specification(#2297)) frames is enabled."
    DEFVAL { false }(#7210)
    ::= { dot11WirelessMgmtOptionsEntry 27 }

dot11TimingMsmtImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the station implementation is
        capable of supporting Timing Measurement capability when
        dot11WirelessManagementImplemented is equal to true."
    ::= { dot11WirelessMgmtOptionsEntry 28 }

dot11TimingMsmtActivated OBJECT-TYPE
    SYNTAX TruthValue
```

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```
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity or the SME.
        Changes take effect at the next occurrence of an MLME-START.request or
        MLME-JOIN.request primitive.

        This attribute, when true, indicates that the station capability for
        Timing Measurement is enabled. false indicates the station has no Timing
        Measurement capability or that the capability is present but is disabled."
    DEFVAL { false }(#7210)
    ::= { dot11WirelessMgmtOptionsEntry 29 }

dot11ChannelUsageImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the station implementation is
        capable of supporting (#3311)channel usage when
        dot11WirelessManagementImplemented is equal to true."
    ::= { dot11WirelessMgmtOptionsEntry 30 }

dot11ChannelUsageActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        This attribute, when true, indicates that (#3311)channel usage is enabled.
        (#3311)channel usage is disabled otherwise."
    DEFVAL { false }(#7210)
    ::= { dot11WirelessMgmtOptionsEntry 31 }

dot11TriggerSTAStatisticsActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        This attribute, when true, indicates that the capability of the station to
        provide triggered STA statistics is enabled. The capability is disabled
        otherwise"
    DEFVAL { false }(#7210)
    ::= { dot11WirelessMgmtOptionsEntry 32 }

dot11SSIDListImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.
```



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```
        This attribute, when true, indicates that the station implementation is
        capable of supporting the SSID List capability when
        dot11WirelessManagementImplemented is true."
    ::= { dot11WirelessMgmtOptionsEntry 33 }

dot11SSIDListActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        This attribute, when true, indicates that the capability of the station to
        support the SSID List capability is enabled. The capability is disabled,
        otherwise"
    DEFVAL { false }(#7210)
    ::= { dot11WirelessMgmtOptionsEntry 34 }

dot11MulticastDiagnosticsActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        This attribute, when true, indicates that the capability of the station to
        provide multicast diagnostic reporting is enabled. The capability is
        disabled, otherwise."
    DEFVAL { false }(#7210)
    ::= { dot11WirelessMgmtOptionsEntry 35 }

dot11LocationTrackingImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the station implementation is
        capable of supporting Location Track when
        dot11WirelessManagementImplemented is true."
    ::= { dot11WirelessMgmtOptionsEntry 36 }

dot11LocationTrackingActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        This attribute, when true, indicates that the capability of the station to
        provide Location Track is enabled. The capability is disabled otherwise."
    DEFVAL { false }(#7210)
    ::= { dot11WirelessMgmtOptionsEntry 37 }

dot11DMSImplemented OBJECT-TYPE
    SYNTAX TruthValue
```

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```
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the station implementation is
        capable of supporting DMS when dot11WirelessManagementImplemented is
        true."
    ::= { dot11WirelessMgmtOptionsEntry 38 }

dot11DMSActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        This attribute, when true, indicates that DMS is enabled. DMS is disabled
        otherwise."
    DEFVAL { false }(#7210)
    ::= { dot11WirelessMgmtOptionsEntry 39 }

dot11UAPSDCoexistenceImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the Station implementation is
        capable of supporting U-APSD coexistence when
        dot11WirelessManagementImplemented is equal to true."
    ::= { dot11WirelessMgmtOptionsEntry 40}

dot11UAPSDCoexistenceActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        This attribute, when true, indicates that U-APSD coexistence is enabled.
        U-APSD coexistence is disabled, otherwise."
    DEFVAL { false }(#7210)
    ::= { dot11WirelessMgmtOptionsEntry 41}

dot11WNMNotificationImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the station implementation is
        capable of supporting WNM notification when
        dot11WirelessManagementImplemented is equal to true."
    ::= { dot11WirelessMgmtOptionsEntry 42}
```


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```
dot11WNMNotificationActivated OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by an external management entity or the SME.
      Changes take effect as soon as practical in the implementation.

      This attribute, when true, indicates that the capability of the station to
      provide WNM notification is enabled. The capability is disabled,
      otherwise."
   DEFVAL { false }(#7210)
   ::= { dot11WirelessMgmtOptionsEntry 43}

dot11UTCTSFOffsetImplemented OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a capability variable.
      Its value is determined by (#3375)STA capabilities.

      This attribute, when true, indicates that the Station implementation is
      capable of supporting UTC TSF Offset advertisement when
      dot11WirelessManagementImplemented is equal to true."
   ::= { dot11WirelessMgmtOptionsEntry 44}

dot11UTCTSFOffsetActivated OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by an external management entity or the SME.
      Changes take effect as soon as practical in the implementation.

      This attribute, when true, indicates that UTC TSF Offset advertisement is
      enabled at the station. The capability is disabled, otherwise."
   DEFVAL { false }(#7210)
   ::= { dot11WirelessMgmtOptionsEntry 45}


dot11FineTimingMsmtRespActivated OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by an external management entity or the SME.
      Changes take effect at the next occurrence of an MLME-START.request or
      MLME-JOIN.request primitive.

      This attribute, when true, indicates that the station capability for
      (#7065)FTM as a responder is enabled. false indicates the station has no
      (#7065)FTM capability as a responder or that the capability is present but
      is disabled."
   DEFVAL { false }(#7210)
   ::= { dot11WirelessMgmtOptionsEntry 47 }

dot11LciCivicInNeighborReport OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-write
```

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```
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        This attribute, when true, indicates that the station includes LCI and
        civic location subelements in the neighbor report without regard to either
        dot11FineTimingMsmtRespActivated or dot11FineTimingMsmtInitActivated."
    DEFVAL { false }(#7210)
    ::= { dot11WirelessMgmtOptionsEntry 48 }

dot11RMFineTimingMsmtRangeRepImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.
        This attribute, when true, indicates that the station implementation is
        capable of supporting (#7065)FTM range reporting."
    ::= { dot11WirelessMgmtOptionsEntry 49}

dot11RMFineTimingMsmtRangeRepActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.
        This attribute, when true, indicates that (#7065)FTM range reporting is
        enabled at the station. The capability is disabled, otherwise."
    DEFVAL { false }(#7210)
    ::= { dot11WirelessMgmtOptionsEntry 50}

dot11FineTimingMsmtInitActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity or the SME.
        Changes take effect at the next occurrence of an MLME-START.request or
        MLME-JOIN.request primitive.

        This attribute, when true, indicates that the station capability for
        (#7065)FTM as an initiator is enabled. false indicates the station has no
        (#7065)FTM capability as an initiator or that the capability is present
        but is disabled."
    DEFVAL { false }(#7210)
    ::= { dot11WirelessMgmtOptionsEntry 51 }

dot11RMLCIConfigured OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity, which sets it to true when
        the external management entity configures a dot11STALCITable entry.

        It is written by the SME, which sets it to false when an external manage-
        ment entity configures dot11STACivicLocation and dot11STACivicLocation-
```


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```
        Type.

        Changes take effect as soon as practical in the implementation. This
        attribute, when true, indicates that that the station is configured with
        an LCI location (LCI is not Unknown). false indicates the station is not
        configured with an LCI location or the configured LCI Location is set to
        Unknown (as defined in 9.4.2.20.10 (LCI report (Location configuration
        information report)))."
    DEFVAL { false }
    ::= { dot11WirelessMgmtOptionsEntry 52 }

dot11RMCivicConfigured OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity, which sets it to true when
        the external management entity configures dot11STACivicLocation and
        dot11STACivicLocationType.

        It is written by the SME, which sets it to false when an external manage-
        ment entity configures a dot11STALCITable entry.

        Changes take effect as soon as practical in the implementation.
        This attribute, when true, indicates that the station is configured with a
        civic location (civic location is not Unknown). false indicates the sta-
        tion is not configured with an civic location or the configured civic
        Location is set to Unknown (as defined in 9.4.2.20.13 (Location Civic
        report))."
    DEFVAL { false }
    ::= { dot11WirelessMgmtOptionsEntry 53 }

(11az)dot11SecureLTFImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by device capabilities.
        This attribute, when true, indicates that a secure HE-LTF measurement
        exchange protocol is implemented (see 11.21.6.4.5 (Secure HE-LTF in the TB
        and non-TB ranging measurement exchange protocol(11az))). The capability
        is disabled otherwise."
    ::= { dot11WirelessMgmtOptionsEntry 54 }

(11az)dot11TriggerBasedRangingRespImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable. Its value is determined by device
        capabilities. This attribute, when true, indicates that support for
        negotiating and executing TB ranging measurement exchange as an RSTA is
        implemented (see 11.21.6 (FTM procedure(#7065))). The capability is
        disabled otherwise."
    ::= { dot11WirelessMgmtOptionsEntry 55 }

(11az)dot11NonTriggerBasedRangingRespImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
```

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```
        Its value is determined by device capabilities.

        This attribute, when true, indicates that support for negotiating and
        executing non-TB ranging measurement exchange as an RSTA is implemented
        (see 11.21.6 (FTM procedure(#7065))). The capability is disabled
        otherwise."
    ::= { dot11WirelessMgmtOptionsEntry 56 }

(11az)dot11RSTARequiresPMFActivated OBJECT-TYPE
    SYNTAX INTEGER {Inactive (0), Required-X20M (1), Required (2)}
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity or the SME.

        Changes take effect at the next occurrence of an MLME-START.request or
        MLME-JOIN.request primitive.

        The attribute applies only to preassociation ranging behavior.

        When set to Required (2), indicates that the station requires Management
        Frame Protection for all management frames exchanged during the
        negotiation and measurement reporting.

        When set to Required-X20M (1), indicates that the station Management Frame
        Protection for all management frames exchanged during the negotiation and
        measurement reporting except those using a 20 MHz bandwidth for
        measurements.

        Otherwise, when set to Inactive (0), indicates that Management Frame
        Protection is not required for ranging.

        See 11.21.6.3.1 (General) and range measurement procedure, 11.21.6.4.3 (TB
        ranging measurement exchange(11az)), 11.21.6.4.4 (Non-TB ranging
        measurement exchange(11az)), and 11.21.6.4.5 (Secure HE-LTF in the TB and
        non-TB ranging measurement exchange protocol(11az)) to successfully
        negotiate a range measurement session."
    DEFVAL { Inactive }
    ::= { dot11WirelessMgmtOptionsEntry 57 }

(11az)dot11PassiveTBRangingResponderImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by device capabilities.

        This attribute, when true, indicates that support for passive TB ranging
        acting as a responder is implemented (see 11.21.6.4.8 (Measurement
        exchange in passive TB ranging mode(11az))). The capability is disabled
        otherwise."
    ::= { dot11WirelessMgmtOptionsEntry 58 }

(11az)dot11PassiveTBRangingInitiatorImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by device capabilities.

        This attribute, when true, indicates that support for passive TB ranging
```



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```
        acting as an initiator is implemented (see 11.21.6.4.8 (Measurement
        exchange in passive TB ranging mode(11az))). The capability is disabled
        otherwise."
    ::= { dot11WirelessMgmtOptionsEntry 59 }

(11az)dot11AOAMeasurementImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by device capabilities.

        This attribute, when true, indicates that the STA supports Angle-of-
        Arrival (AOA) measurements and feedback of these measurements is available
        via the LMR frame. When false, there is no such feedback available in the
        LMR frame."
    ::= { dot11WirelessMgmtOptionsEntry 60 }

(11az)dot11I2RLMRFeedbackPolicy OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity or the SME.

        Changes take effect at the next occurrence of an MLME-START.request or
        MLME-JOIN.request primitive.
        This attribute, when true, indicates that the station (RSTA) does not
        require any initiating stations to support the capability to generate and
        transmit I2R LMRs (see 11.21.6.3.3 (Negotiation for TB and non-TB ranging
        measurement exchange)).
        False indicates that the stations shall negotiate the transmission of I2R
        LMR."
    DEFVAL { true }
    ::= { dot11WirelessMgmtOptionsEntry 61 }

(11az)dot11LOSAssessmentTXImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by device capabilities.
        This attribute, when true, indicates that the station capability for
        participation in LOS assessment FTM exchange by transmitting a Loss
        Assessment PPDU. It is set to false otherwise."
    ::= { dot11WirelessMgmtOptionsEntry 62 }

(11az)dot11LOSAssessmentRXImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by device capabilities.
        This attribute, when true, indicates that the station has capability for
        participation in LOS assessment FTM exchange by switching polarization on
        the TRN field when a Loss Assessment PPDU is received. It is set to false
        otherwise."
    ::= { dot11WirelessMgmtOptionsEntry 63 }

(11az)dot11PassiveTBRangingAODEnablementImplemented OBJECT-TYPE
```

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```
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by device capabilities.

        This attribute, when true, indicates that the station, when performing
        passive TB ranging, is capable of estimating the AOD measurement by the
        client STA that locates itself through passive TB ranging (see 11.21.6.4.8
        (Measurement exchange in passive TB ranging mode(11az))).
        False indicates that the station, when performing passive TB ranging, is
        not capable of estimating the AOD measurement by the client STA that
        locates itself through passive TB ranging. (See 11.21.6.4.8 (Measurement
        exchange in passive TB ranging mode(11az)))."
    ::= { dot11WirelessMgmtOptionsEntry 64 }

(11az)dot11PhaseShiftFeedbackImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by device capabilities. This attribute, when true,
        indicates that the STA supports reporting of time of arrival estimated
        using the Phase Shift feedback method and including these measurements in
        the corresponding LMR frame. When false, the time of arrival estimates
        Reported in the LMR frame are not based on the Phase Shift feedback
        method."
    ::= { dot11WirelessMgmtOptionsEntry 65 }

(6016)dot11ChannelUsageCapabilityNotificationImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by STA capabilities.
        This attribute in an AP, when true, indicates that the AP supports
        reception of a Channel Usage Request frame that includes capabilities
        elements. This attribute in a non-AP STA, when true, indicates that the
        STA supports transmission of a Channel Usage Request frame that includes
        capabilities elements."
    ::= { dot11WirelessMgmtOptionsEntry 66 }


-- ********************************************************************
 -- * dot11LocationServices TABLE
 -- ********************************************************************

dot11LocationServicesNextIndex OBJECT-TYPE
    SYNTAX Unsigned32 (0..4294967295)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "Identifies a hint for the next value of dot11LocationServicesIndex to be
        used in a row creation attempt for dot11LocationServicesTable. If no new
        rows can be created for some reason, such as memory, processing
        requirements, etc, the SME shall set this attribute to 0. It shall update
        this attribute to a proper value other than 0 as soon as it is capable of
        receiving new measurement requests. The nextIndex is not necessarily
        sequential nor monotonically increasing."
    ::= { dot11smt 19 }
```


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```
dot11LocationServicesTable OBJECT-TYPE
   SYNTAX SEQUENCE OF Dot11LocationServicesEntry
   MAX-ACCESS not-accessible
   STATUS current
   DESCRIPTION
      "Group contains conceptual table of attributes for
      WNM LocationServices."
   ::= { dot11smt 20 }

dot11LocationServicesEntry OBJECT-TYPE
   SYNTAX Dot11LocationServicesEntry
   MAX-ACCESS not-accessible
   STATUS current
   DESCRIPTION
      "An entry in the dot11LocationServicesTable
      Indexed by dot11LocationServicesIndex."
   INDEX { dot11LocationServicesIndex }
   ::= { dot11LocationServicesTable 1 }

Dot11LocationServicesEntry ::=
   SEQUENCE {
      dot11LocationServicesIndex                          Unsigned32,
      dot11LocationServicesMACAddress                     MacAddress,
      dot11LocationServicesLIPIndicationMulticastAddress  MacAddress,
      dot11LocationServicesLIPReportIntervalUnits         INTEGER,
      dot11LocationServicesLIPNormalReportInterval        Unsigned32,
      dot11LocationServicesLIPNormalFramesperChannel      Unsigned32,
      dot11LocationServicesLIPInMotionReportInterval      Unsigned32,
      dot11LocationServicesLIPInMotionFramesperChannel    Unsigned32,
      dot11LocationServicesLIPBurstInterframeInterval     Unsigned32,
      dot11LocationServicesLIPTrackingDuration            Unsigned32,
      dot11LocationServicesLIPEssDetectionInterval        Unsigned32,
      dot11LocationServicesLocationIndicationChannelList  OCTET STRING,
      dot11LocationServicesLocationIndicationBroadcastDataRate
                                                          Unsigned32,
      dot11LocationServicesLocationIndicationOptionsUsed  OCTET STRING,
      dot11LocationServicesLocationIndicationIndicationParameters
                                                          OCTET STRING,
      dot11LocationServicesLocationStatus                 Unsigned32
   }

dot11LocationServicesIndex OBJECT-TYPE
   SYNTAX Unsigned32 (1..4294967295)
   MAX-ACCESS not-accessible
   STATUS current
   DESCRIPTION
      "This attribute contains an auxiliary index into the
      dot11LocationServicesTable."
   ::= { dot11LocationServicesEntry 1 }

dot11LocationServicesMACAddress OBJECT-TYPE
   SYNTAX MacAddress
   MAX-ACCESS read-create
   STATUS current
   DESCRIPTION
      "This attribute is the MAC address of the STA reporting location
      information."
   ::= { dot11LocationServicesEntry 2 }

dot11LocationServicesLIPIndicationMulticastAddress OBJECT-TYPE
   SYNTAX MacAddress
   MAX-ACCESS read-create
   STATUS current
   DESCRIPTION
```

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```
        "This attribute is the destination address to which the Location Track
        Notification frames are sent in a BSS that is not an IBSS; see 9.4.2.69.2
        (Location Indication Parameters subelement) and 11.21.4.1 (Location track
        configuration procedures)."
    ::= { dot11LocationServicesEntry 3 }

dot11LocationServicesLIPReportIntervalUnits OBJECT-TYPE
    SYNTAX INTEGER {
        hours(0),
        minutes(1),
        seconds(2),
        milliseconds(3)
        }
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This attribute contains the Location Indication Parameters Report
        Interval Units value."
    ::= { dot11LocationServicesEntry 4 }

dot11LocationServicesLIPNormalReportInterval OBJECT-TYPE
    SYNTAX Unsigned32 (0..65535)
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This attribute contains the time interval, expressed in the units
        indicated in the Report Interval Units field, at which the reporting STA
        is expected to transmit one or more Location Track Notification frames if
        either dot11MotionDetectionActivated is false or the STA is stationary.
        The STA does not transmit Location Track Notification frames when the
        Normal Report Interval is 0."
    ::= { dot11LocationServicesEntry 5 }

dot11LocationServicesLIPNormalFramesperChannel OBJECT-TYPE
    SYNTAX Unsigned32 (0..255)
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This attribute contains the number of Location Track Notification frames
        per channel sent or expected to be sent by the STA at each Normal Report
        Interval."
    ::= { dot11LocationServicesEntry 6 }

dot11LocationServicesLIPInMotionReportInterval OBJECT-TYPE
    SYNTAX Unsigned32 (0..65535)
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This attribute contains the time interval, expressed in the units
        indicated in the Report Interval Units field, at which the STA reports its
        location by sending a Location Track Notification frame when the reporting
        STA is in motion. If dot11MotionDetectionActivated is false, this field is
        set to 0."
    ::= { dot11LocationServicesEntry 7}

dot11LocationServicesLIPInMotionFramesperChannel OBJECT-TYPE
    SYNTAX Unsigned32 (0..255)
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This attribute contains the number of Location Track Notification frames
        per channel sent or expected to be sent by the STA at each In-Motion
        Report Interval. If dot11MotionDetectionActivated is false, this field is
        set to 0."
```


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```
    ::= { dot11LocationServicesEntry 8 }

dot11LocationServicesLIPBurstInterframeInterval OBJECT-TYPE
    SYNTAX Unsigned32 (0..255)
    UNITS "milliseconds"
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This attribute contains the target time interval between the
        transmissions of each of the Normal or In-Motion frames on the same
        channel. The Burst Interframe(#1460) interval value is set to 0 to
        indicate that frames are(M118) transmitted with no target
        interframe(#1460) delay."
    ::= { dot11LocationServicesEntry 9 }

dot11LocationServicesLIPTrackingDuration OBJECT-TYPE
    SYNTAX Unsigned32 (0..255)
    UNITS "minutes"
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This attribute contains the amount of time that a STA sends the Location
        Track Notification frames. The duration starts as soon as the STA sends a
        Location Configuration Response frame with a Location Status value of
        Success. If the Tracking Duration value is a nonzero value the STA
        sends(M118) Location Track Notification frames, based on the Normal and
        In-Motion Report Interval field values, until the duration ends. If the
        Tracking Duration is 0 the STA (M118)continuously sends Location Track
        Notification frames as defined by Normal and In-Motion Report Interval
        field values until transmission is terminated based on 11.21.4.2 (Location
        track notification procedures) procedures."
    ::= { dot11LocationServicesEntry 10}

dot11LocationServicesLIPEssDetectionInterval OBJECT-TYPE
    SYNTAX Unsigned32 (0..255)
    UNITS "minutes"
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This attribute contains the interval that a STA checks for beacons
        transmitted by one or more APs belonging to the same ESS that configured
        the STA. If no beacons from the ESS are received for this period, the STA
        terminates transmission of Location Track Notification frames as described
        in 11.21.4.2 (Location track notification procedures) procedures. The ESS
        Detection Interval field is not used when the ESS Detection Interval field
        value is set to 0."
    ::= { dot11LocationServicesEntry 11}

dot11LocationServicesLocationIndicationChannelList OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE (2..254))
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This attribute contains one or more Operating Class and Channel octet
        pairs."
    ::= { dot11LocationServicesEntry 12}

dot11LocationServicesLocationIndicationBroadcastDataRate OBJECT-TYPE
    SYNTAX Unsigned32 (0..4294967295)
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This attribute specifies the target data rate at which the STA transmits
        Location Track Notification frames. The Broadcast Target Data Rate field
```

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```
        format is specified by the Rate Identification field defined in 9.4.1.30
        (Rate Identification field). A value of 0 indicates the STA transmits
        Location Track Notification frames at a rate chosen by the STA
        transmitting the Location Track Notification frames."
    DEFVAL { 0 }
    ::= { dot11LocationServicesEntry 13}

dot11LocationServicesLocationIndicationOptionsUsed OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(1))
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This attribute indicates the location configuration options used for
        transmitting Location Track Notification frames."
    ::= { dot11LocationServicesEntry 14}

dot11LocationServicesLocationIndicationIndicationParameters OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE (1..255))
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This attribute indicates the location Indication Parameters used for
        transmitting Location Track Notification frames."
    ::= { dot11LocationServicesEntry 15}

dot11LocationServicesLocationStatus OBJECT-TYPE
    SYNTAX Unsigned32 (0..255)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This attribute contains the Location Status value as indicated in
        Table 9-237 (Event Report Status), Event Report Status."
    ::= { dot11LocationServicesEntry 16 }

-- ********************************************************************
 -- * End of dot11LocationServices TABLE
 -- ********************************************************************

 -- ********************************************************************
 -- * dot11WirelessMGTEvent TABLE
 -- ********************************************************************
dot11WirelessMGTEventTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11WirelessMGTEventEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "Group contains the current list of WIRELESS Management reports that have
        been received by the MLME. The report tables shall be maintained as FIFO
        to preserve freshness, thus the rows in this table can be deleted for
        memory constraints or other implementation constraints determined by the
        vendor.
        New rows shall have different RprtIndex values than those deleted within
        the range limitation of the index. One easy way is to increment the
        EventIndex for new reports being written in the table."
    ::= { dot11smt 21 }

dot11WirelessMGTEventEntry OBJECT-TYPE
    SYNTAX Dot11WirelessMGTEventEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "An entry in the dot11WirelessMGTEventTable
        Indexed by dot11WirelessMGTEventIndex."
    INDEX { dot11WirelessMGTEventIndex }
```


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```
    ::= { dot11WirelessMGTEventTable 1 }

Dot11WirelessMGTEventEntry ::=
    SEQUENCE {
        dot11WirelessMGTEventIndex                          Unsigned32,
        dot11WirelessMGTEventMACAddress                     MacAddress,
        dot11WirelessMGTEventType                           INTEGER,
        dot11WirelessMGTEventStatus                         INTEGER,
        dot11WirelessMGTEventTSF                            TSFType,
        dot11WirelessMGTEventUTCOffset                      OCTET STRING,
        dot11WirelessMGTEventTimeError                      OCTET STRING,
        dot11WirelessMGTEventTransitionSourceBSSID          MacAddress,
        dot11WirelessMGTEventTransitionTargetBSSID          MacAddress,
        dot11WirelessMGTEventTransitionTime                 Unsigned32,
        dot11WirelessMGTEventTransitionReason               INTEGER,
        dot11WirelessMGTEventTransitionResult               Unsigned32,
        dot11WirelessMGTEventTransitionSourceRCPI           Unsigned32,
        dot11WirelessMGTEventTransitionSourceRSNI           Unsigned32,
        dot11WirelessMGTEventTransitionTargetRCPI           Unsigned32,
        dot11WirelessMGTEventTransitionTargetRSNI           Unsigned32,
        dot11WirelessMGTEventRSNATargetBSSID                MacAddress,
        dot11WirelessMGTEventRSNAAuthenticationType         OCTET STRING,
        dot11WirelessMGTEventRSNAEAPMethod                  OCTET STRING,
        dot11WirelessMGTEventRSNAResult                     Unsigned32,
        dot11WirelessMGTEventRSNARSNElement                 OCTET STRING,
        dot11WirelessMGTEventPeerSTAAddress                 MacAddress,
        dot11WirelessMGTEventPeerOperatingClass             Unsigned32,
        dot11WirelessMGTEventPeerChannelNumber              Unsigned32,
        dot11WirelessMGTEventPeerSTATxPower                 Integer32,
        dot11WirelessMGTEventPeerConnectionTime             Unsigned32,
        dot11WirelessMGTEventPeerPeerStatus                 Unsigned32,
        dot11WirelessMGTEventWNMLog                         OCTET STRING
    }

dot11WirelessMGTEventIndex OBJECT-TYPE
    SYNTAX Unsigned32 (1..4294967295)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This attribute contains an auxiliary index into the
        dot11WirelessMGTEventTable."
    ::= { dot11WirelessMGTEventEntry 1 }

dot11WirelessMGTEventMACAddress OBJECT-TYPE
    SYNTAX MacAddress
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This attribute is the MAC address of the STA providing the Event report."
    ::= { dot11WirelessMGTEventEntry 2 }

dot11WirelessMGTEventType OBJECT-TYPE
    SYNTAX INTEGER {
        transition(0),
        rsna(1),
        peerToPeer(2),
        wnmLog(3),
        vendorSpecific(221)
        }
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This attribute indicates the request type of this WNM Event request."
    ::= { dot11WirelessMGTEventEntry 3 }
```

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```
dot11WirelessMGTEventStatus OBJECT-TYPE
   SYNTAX INTEGER {
      successful(0),
      requestFailed(1),
      requestRefused(2),
      requestIncapable(3),
      detectedFrequentTransition(4)
      }
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This attribute contains the status value included in the Event report."
   ::= { dot11WirelessMGTEventEntry 4 }

dot11WirelessMGTEventTSF OBJECT-TYPE
   SYNTAX TSFType
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This attribute contains the value of the Event TSF field."
   ::= { dot11WirelessMGTEventEntry 5 }

dot11WirelessMGTEventUTCOffset OBJECT-TYPE
   SYNTAX OCTET STRING (SIZE(10))
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This attribute indicates the UTC Offset Time Value optionally included in
      the Event report."
   ::= { dot11WirelessMGTEventEntry 6}

dot11WirelessMGTEventTimeError OBJECT-TYPE
   SYNTAX OCTET STRING (SIZE(5))
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This attribute contains the value of the Event Time Error field
      optionally included in the Event report."
   ::= { dot11WirelessMGTEventEntry 7}

dot11WirelessMGTEventTransitionSourceBSSID OBJECT-TYPE
   SYNTAX MacAddress
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This attribute contains the value of the Source BSSID field in a
      Transition event report."
   ::= { dot11WirelessMGTEventEntry 8}

dot11WirelessMGTEventTransitionTargetBSSID OBJECT-TYPE
   SYNTAX MacAddress
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This attribute contains the value of the Target BSSID field in a
      Transition event report."
   ::= { dot11WirelessMGTEventEntry 9}

dot11WirelessMGTEventTransitionTime OBJECT-TYPE
   SYNTAX Unsigned32 (0..65535)
   UNITS "TUs"
   MAX-ACCESS read-only
   STATUS current
```


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```
    DESCRIPTION
        "This attribute indicates the transition time for the reported transition
        event in TUs. The Transition time is defined as the time difference
        between the starting time and the ending time of a transition between APs,
        even if the transition results in remaining on the same AP. Start and end
        times for a transition event are defined in 11.21.2.2 (Transition event
        request and report)"
    ::= { dot11WirelessMGTEventEntry 10}

dot11WirelessMGTEventTransitionReason OBJECT-TYPE
    SYNTAX INTEGER {
        unspecified(0),
        excessiveFrameLossRatesPoorConditions(1),
        excessiveDelayForCurrentTrafficStreams(2),
        insufficientQosCapacityForCurrentTrafficStreams(3),
        firstAssociationToEss(4),
        loadBalancing(5),
        betterApFound(6),
        deauthenticatedDisassociatedFromPreviousAp(7),
        certificateToken(8),
        apFailedIeee8021XEapAuthentication(9),
        apFailed4wayHandshake(10),
        excessiveDataMICFailures(11),
        exceededFrameTransmissionRetryLimit(12),
        ecessiveBroadcastDisassociations(13),
        excessiveBroadcastDeauthentications(14),
        previousTransitionFailed(15)
        }
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This attribute indicates the reason for the reported BSS transition
        event. The format for this list of reasons is further detailed in
        9.4.2.66.2 (Transition event report)."
    ::= { dot11WirelessMGTEventEntry 11}

dot11WirelessMGTEventTransitionResult OBJECT-TYPE
    SYNTAX Unsigned32 (0..65535)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This attribute indicates the result of the attempted transition and is
        set to one of the status codes specified in Table 9-80 (Status codes)."
    ::= { dot11WirelessMGTEventEntry 12 }

dot11WirelessMGTEventTransitionSourceRCPI OBJECT-TYPE
    SYNTAX Unsigned32 (0..255)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This attribute indicates the received channel power of the most recently
        measured PPDU containing a frame from the Source BSSID before the STA
        reassociates with(#1427) the Target BSSID. The Source RCPI is a logarithmic
        function of the received signal power, as defined in 9.4.2.36 (RCPI ele-
        ment)."
    ::= { dot11WirelessMGTEventEntry 13 }

dot11WirelessMGTEventTransitionSourceRSNI OBJECT-TYPE
    SYNTAX Unsigned32 (0..255)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This attribute indicates the received signal-to-noise indication of the
        most recently measured frame from the Source BSSID before the STA
```

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```
        reassociates with(#1427) the Target BSSID. The Source RSNI is a
        logarithmic function of the signal-to-noise ratio, as defined in 9.4.2.39
        (RSNI element)."
    ::= { dot11WirelessMGTEventEntry 14 }

dot11WirelessMGTEventTransitionTargetRCPI OBJECT-TYPE
    SYNTAX Unsigned32 (0..255)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This attribute indicates the received channel power of the first measured
        PPDU containing a frame from the Target BSSID just after STA reassociates
        with(#1427) the Target BSSID. If association with target BSSID failed, the
        Target RCPI field indicates the received channel power of the most
        recently measured PPDU containing a frame from the Target BSSID. The
        Target RCPI is a logarithmic function of the received signal power, as
        defined 9.4.2.36 (RCPI element)."
    ::= { dot11WirelessMGTEventEntry 15 }

dot11WirelessMGTEventTransitionTargetRSNI OBJECT-TYPE
    SYNTAX Unsigned32 (0..255)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This attribute indicates the received signal-to-noise indication of the
        first measured frame just after STA reassociates with(#1427) the Target
        BSSID. If association with target BSSID failed, the Target RSNI field
        indicates the received signal-to-noise indication of the most recently
        measured frame from the Target BSSID. The Target RSNI is a logarithmic
        function of the signal-to-noise ratio, as defined in 9.4.2.39 (RSNI ele-
        ment)."
    ::= { dot11WirelessMGTEventEntry 16 }

dot11WirelessMGTEventRSNATargetBSSID OBJECT-TYPE
    SYNTAX MacAddress
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This attribute contains the value of the Target BSSID field in an RSNA
        event report."
    ::= { dot11WirelessMGTEventEntry 17 }

dot11WirelessMGTEventRSNAAuthenticationType OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE (4))
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This attribute indicates the (#3266)AKMP, as defined in Table 9-190 (AKM
        suite selectors). The first three octets indicate the OUI or CID. The last
        octet indicates the suite type."
    ::= { dot11WirelessMGTEventEntry 18 }

dot11WirelessMGTEventRSNAEAPMethod OBJECT-TYPE
    SYNTAX OCTET STRING(SIZE (1..8))
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This attribute indicates a value that identifies the EAP Method. When the
        Authentication Type field is set to the value of either 00-0F-AC:1
        (Authentication negotiated over IEEE Std 802.1X or using PMKSA caching as
        defined in 12.6.8.3 (Cached PMKSAs and RSNA key management)) or 00-0F-AC:3
        (AKM suite selector for fast BSS transition as defined in 12.7.1.6 (FT key
        hierarchy)), the EAP Method field contains the IANA assigned EAP type
        defined at http://www.iana.org/assignments/eap-numbers. The EAP type
```


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```
        contains either the legacy type (1 octet) or the expanded type (1-octet
        type = 254, 3-octet Vendor ID, 4-octet Vendor-Type). The EAP Method field
        is set to 0 otherwise."
    ::= { dot11WirelessMGTEventEntry 19 }

dot11WirelessMGTEventRSNAResult OBJECT-TYPE
    SYNTAX Unsigned32 (0..65535)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This attribute indicates the result of the RSNA event and is set to one
        of the status codes specified in Table 9-80 (Status codes)."
    ::= { dot11WirelessMGTEventEntry 20}

dot11WirelessMGTEventRSNARSNElement OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(0..257))
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This attribute contains (#4263)(#3488)the RSNE in the (Re)Association
        Request frame that resulted in the current RSNA."
    ::= { dot11WirelessMGTEventEntry 21}

dot11WirelessMGTEventPeerSTAAddress OBJECT-TYPE
    SYNTAX MacAddress
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This attribute indicates the MAC address of the peer STA or IBSS BSSID is
        equal to the indicated MAC address. If this event is for a peer-to-peer
        link in an infrastructure BSS, this field contains the MAC address of the
        peer STA. If this event is for a peer-to-peer link in an IBSS, this field
        contains the BSSID."
    ::= { dot11WirelessMGTEventEntry 22 }

dot11WirelessMGTEventPeerOperatingClass OBJECT-TYPE
    SYNTAX Unsigned32 (1..255)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This attribute indicates the channel set for this peer-to-peer link event
        report. Country, Operating Class, and Channel Number together specify the
        channel frequency and spacing for this measurement request. Valid values
        of Operating Class are shown in Annex E."
    ::= { dot11WirelessMGTEventEntry 23 }

dot11WirelessMGTEventPeerChannelNumber OBJECT-TYPE
    SYNTAX Unsigned32 (1..255)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This attribute indicates the current operating channel for this peer-to-
        peer event report. The Channel Number is defined only within the indicated
        Operating Class as shown in Annex E."
    ::= { dot11WirelessMGTEventEntry 24 }

dot11WirelessMGTEventPeerSTATxPower OBJECT-TYPE
    SYNTAX Integer32 (-128..127)
    UNITS "dBm"
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This attribute indicates the STA transmit power used for the peer-to-peer
        link. The STA Tx Power field indicates the target transmit power at the
```

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```
        antenna connector with a tolerance of +/-5 dB for the lowest basic rate of
        the reporting STA. A value of -128 indicates that the value is unknown."
    ::= { dot11WirelessMGTEventEntry 25 }

dot11WirelessMGTEventPeerConnectionTime OBJECT-TYPE
    SYNTAX Unsigned32 (0..16777215)
    UNITS "seconds"
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This attribute indicates a value representing the connection time for the
        reported peer-to-peer link event. If the Peer Status is 0, this field
        indicates the duration of the peer-to-peer link(#1354). If the Peer Status
        is 1, this field indicates the time difference from the time the peer-to-
        peer link(#1354) was established to the time at which the reporting STA
        generated the event report. If the Peer Status is 2, this field indicates
        the duration of the IBSS membership. If the Peer Status is 3, this field
        indicates the time difference from the time the STA joined the IBSS to the
        time at which the reporting STA generated the event report. See 11.21.2.4
        (Peer-to-peer link event request and report)."
    ::= { dot11WirelessMGTEventEntry 26 }

dot11WirelessMGTEventPeerPeerStatus OBJECT-TYPE
    SYNTAX Unsigned32 (0..255)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This attribute indicates the Peer link connection status as indicated in
        Table 9-239 (Peer Status definitions). See 9.4.2.66.4 (Peer-to-peer link
        event report)."
    ::= { dot11WirelessMGTEventEntry 27 }

dot11WirelessMGTEventWNMLog OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(0..2284))
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This attribute contains the entire syslog message, consisting of the PRI,
        HEADER, and MSG portion of a WNM log message as described in IETF RFC
        5424. The TAG field of the MSG portion of the message is a 17-octet string
        containing the ASCII representation of the STA MAC address using
        hexadecimal notation with colons between octets. The octet containing the
        Individual/Group bit occurs last, and that bit is in the least significant
        position within that octet. See 11.21.2.5 (WNM log event request and
        report)."
    ::= { dot11WirelessMGTEventEntry 28 }

 -- ************************************************************
 -- * End of dot11WirelessMGTEvent TABLE
 -- ************************************************************
```


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```
-- ************************************************************************
-- * IEEE 802.11 RM and WNM Interface MIB
-- ************************************************************************

-- * The primary interface to the radio measurements and Wireless
-- * Network Management functions is meant to be real-time information
-- * obtained through the request/response mechanisms of RM and WNM.
-- * A secondary interface to the measurements and management functions
-- * is through retention of information in this MIB. Non-SNMP requests
-- * for information are obtained via object IDs (OIDs) through the NDIS
-- * or wireless interfaces in the operating systems. SNMP requests for
-- * information are obtained via SNMP SETs and GETs (see IETF RFC 1157 [B22]).

-- *  dot11RMRequest and dot11RMReport Usage
-- *
-- * The dot11RMRequest and dot11RMReport portions of the RM MIB
-- * provide access to the Radio Measurement service. By performing
-- * SET operations on the various dot11RMRequest MIB objects,
-- * radio measurements may be initiated directly on the local STA or
-- * on any peer station within the same BSS. Subsequently, by
-- * performing GET operations on the various dot11RMReport MIB
-- * objects the results of the requested measurements may be
-- * retrieved.
-- *
-- * In the diagram below, a radio measurement could be initiated
-- * for STA x by performing a MIB.set operation on the RM MIB of
-- * STA x and specifying the MAC address of STA x in
-- * dot11RMRqstTargetAdd. Additionally, it is possible to have STA x
-- * request a measurement from STA y by performing a MIB.set operation
-- * on the SME MIB of STA x and specifying the MAC address of STA y in
-- * dot11RMRqstTargetAdd. In both cases the result of the measurements
-- * can be retrieved by performing a MIB.get operation on the RM MIB
-- * of STA x upon completion of the measurement.
-- *
-- *
-- *          MIB.Set                                          MIB.Set
-- *             or                                               or
-- *          MIB.Get                                          MIB.Get
-- *     +========|=========+                            +========|=========+
-- *     | SME    |         |                            | SME    |         |
-- *     |       \ /        |                            |       \ /        |
-- *     |   +==========+   |                            |   +==========+   |
-- *     |   | RM and   |   |                            |   | RM and   |   |
-- *     |   | WNM MIB  |   |                            |   | WNM MIB  |   |
-- *     |   |          |   |                            |   |          |   |
-- *     |   |          |   |                            |   |          |   |
-- *     |   +==========+   |                            |   +==========+   |
-- *     |                  |                            |                  |
-- *     |   / \            |                            |   / \            |
-- *     |    |   MREQUEST  |                            |    |   MREQUEST  |
-- *     +====+==============+                           +====+==============+
-- *     |    |   MREPORT    |                            |    |   MREPORT    |
-- *     |   \ /  MEASURE    |     Action frames          |   \ /  MEASURE    |
-- *     |                   | <==Measurement Request==>  |                   |
-- *     |                   | <==Measurement Report===>  |                   |
-- *     | MLME              |                            | MLME              |
-- *     +===================+                            +===================+
-- *           STA x                                            STA y
-- *
-- * Each STA maintains a single dot11RMRequestTable in the SME MIB
-- * used to initiate RM Measurement Requests. Each dot11RMRequestEntry
-- * in the table represents an individual Measurement Request that
-- * makes up a complete Measurement Request frame.
-- * Multiple Measurement Requests may be concatenated into a single

```

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```
-- * Measurement Request frame by setting the same
-- * dot11RMRqstToken value into multiple dot11RMRequestEntrys.
-- *
-- * Each row, dot11RMRequestEntry, of the dot11RMRequestTable
-- * provides read-create access for the initiation of a measurement
-- * request. The dot11RMRequestNextIndex object can be used to
-- * determine which is the next available row. Each row corresponding to
-- * one measurement in the sequence is created with a dot11RMRqstRowStatus
-- * equal to notInService. Once the dot11RMRequestEntry(s) have been
-- * created for a desired measurement sequence the corresponding
-- * dot11RMRqstRowStatus(s) objects are set to active to indicate that
-- * the SME can trigger the appropriate MLME primitives. Upon processing
-- * the request, the SME returns the corresponding dot11RMRqstRowStatus(s)
-- * object to notInService and are now available for additional
-- * measurement requests.
-- *
-- * After a radio measurement is complete the RM populates the RMReport
-- * objects with the results of the measurement. Each STA maintains a set
-- * of RMReport tables, one corresponding to each measurement type. The
-- * results of the entire measurement sequence are spread across the tables
-- * based on the type of measurements requested. Each xxxReportEntry
-- * within a xxxReportTable contains a xxxRprtRqstToken that corresponds
-- * to the original dot11RMRqstToken in the measurement request. So the
-- * results of the measurement can be collected by searching the appropriate
-- * xxxReportTables and retrieve any reports with the matching request
-- * token.
-- *
-- * Similar structures and mechanisms are used for WNM
-- * Request and Reports. The WNM MIB definitions follow the RM MIB definitions
-- * in this Annex.

-- ************************************************************************

-- ************************************************************************
-- * Radio Measurement Interface MIB
-- ************************************************************************

   dot11RadioMeasurement OBJECT IDENTIFIER ::= { dot11smt 14 }
-- ************************************************************************
-- * Radio Measurement Requests
-- ************************************************************************
dot11RMRequest OBJECT IDENTIFIER ::= { dot11RadioMeasurement 1 }

-- ************************************************************************
-- * dot11RMRequest TABLE
-- ************************************************************************
dot11RMRequestNextIndex OBJECT-TYPE
   SYNTAX Unsigned32 (0..65535)
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a status variable.
      It is written by the SME when able to accept a new request.

      Identifies a hint for the next value of dot11RMRqstIndex to be used in a
      row creation attempt for dot11RMRequestTable. If no new rows can be
      created for some reason, such as memory, processing requirements, etc.,
      the SME sets this attribute to 0. It updates this attribute to a proper
      value other than 0 as soon as it is capable of receiving new measurement
      requests. The nextIndex is not necessarily sequential nor monotonically
      increasing."
   ::= { dot11RMRequest 1 }

dot11RMRequestTable OBJECT-TYPE
```


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```
    SYNTAX SEQUENCE OF Dot11RMRequestEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "This group contains the current list of requests for RM reports to be
        issued and have been issued until removed. A network manager adds an RM
        request by creating a row with createAndWait row status and then filling
        in the request parameters/attributes. The request becomes active to be
        issued when the row status is set to Active. The columnar objects or
        attributes other than the rowStatus are not written if the rowStatus is
        Active. The request rows can be deleted, if commanded by a network manager
        via changing the value of dot11RMRqstRowStatus to Destroy. This may leave
        orphaned rows if a manager crashes and forgets which rows are being used
        by it. One recommended way to manage orphaned or finished rows is to
        delete rows if their dot11RMRqstRowStatus remains other than Active for
        longer than a period (recommend at least 5 minutes, IETF RFC 2579). Or
        another recommended way is to delete older rows as needed based on their
        dot11RMRqstTimeStamp values. This can be done by the agent as well as the
        manager. "
    ::= { dot11RMRequest 2 }

dot11RMRequestEntry OBJECT-TYPE
    SYNTAX Dot11RMRequestEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "An entry in the dot11RMRequestTable Indexed by dot11RMRqstIndex."
    INDEX { dot11RMRqstIndex }
    ::= { dot11RMRequestTable 1 }

Dot11RMRequestEntry ::=
    SEQUENCE {
        dot11RMRqstIndex                                Unsigned32,
        dot11RMRqstRowStatus                            RowStatus,
        dot11RMRqstToken                                OCTET STRING,
        dot11RMRqstRepetitions                          Unsigned32,
        dot11RMRqstIfIndex                              InterfaceIndex,
        dot11RMRqstType                                 INTEGER,
        dot11RMRqstTargetAdd                            MacAddress,
        dot11RMRqstTimeStamp                            TimeTicks,
        dot11RMRqstChanNumber                           Unsigned32,
        dot11RMRqstOperatingClass                       Unsigned32,
        dot11RMRqstRndInterval                          Unsigned32,
        dot11RMRqstDuration                             Unsigned32,
        dot11RMRqstParallel                             TruthValue,
        dot11RMRqstEnable                               TruthValue,
        dot11RMRqstRequest                              TruthValue,
        dot11RMRqstReport                               TruthValue,
        dot11RMRqstDurationMandatory                    TruthValue,
        dot11RMRqstBeaconRqstMode                       INTEGER,
        dot11RMRqstBeaconRqstDetail                     INTEGER,
        dot11RMRqstFrameRqstType                        INTEGER,
        dot11RMRqstBssid                                MacAddress,
        dot11RMRqstSSID                                 OCTET STRING,
        dot11RMRqstBeaconReportingCondition             INTEGER,
        dot11RMRqstBeaconThresholdOffset                Integer32,
        dot11RMRqstSTAStatRqstGroupID                   INTEGER,
        dot11RMRqstLCIRqstSubject                       INTEGER,
        dot11RMRqstLCIAzimuthType                       INTEGER,
        dot11RMRqstLCIAzimuthResolution                 Unsigned32,
        dot11RMRqstPauseTime                            Unsigned32,
        dot11RMRqstTransmitStreamPeerQSTAAddress        MacAddress,
        dot11RMRqstTransmitStreamTrafficIdentifier      Unsigned32,
        dot11RMRqstTransmitStreamBin0Range              Unsigned32,
```

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```
        dot11RMRqstTrigdQoSAverageCondition              TruthValue,
        dot11RMRqstTrigdQoSConsecutiveCondition          TruthValue,
        dot11RMRqstTrigdQoSDelayCondition                TruthValue,
        dot11RMRqstTrigdQoSAverageThreshold              Unsigned32,
        dot11RMRqstTrigdQoSConsecutiveThreshold          Unsigned32,
        dot11RMRqstTrigdQoSDelayThresholdRange           Unsigned32,
        dot11RMRqstTrigdQoSDelayThreshold                Unsigned32,
        dot11RMRqstTrigdQoSMeasurementCount              Unsigned32,
        dot11RMRqstTrigdQoSTimeout                       Unsigned32,
        dot11RMRqstChannelLoadReportingCondition         INTEGER,
        dot11RMRqstChannelLoadReference                  Unsigned32,
        dot11RMRqstNoiseHistogramReportingCondition      INTEGER,
        dot11RMRqstAnpiReference                         Unsigned32,
        dot11RMRqstAPChannelReport                       OCTET STRING,
        dot11RMRqstSTAStatPeerSTAAddress                 MacAddress,
        dot11RMRqstFrameTransmitterAddress               MacAddress,
        dot11RMRqstVendorSpecific                        OCTET STRING,
        dot11RMRqstSTAStatTrigMeasCount                  Unsigned32,
        dot11RMRqstSTAStatTrigTimeout                    Unsigned32,
        dot11RMRqstSTAStatTrigCondition                  OCTET STRING,
        dot11RMRqstSTAStatTrigSTAFailedCntThresh         Unsigned32,
        dot11RMRqstSTAStatTrigSTAFCSErrCntThresh         Unsigned32,
        dot11RMRqstSTAStatTrigSTAMultRetryCntThresh      Unsigned32,
        dot11RMRqstSTAStatTrigSTAFrameDupeCntThresh      Unsigned32,
        dot11RMRqstSTAStatTrigSTARTSFailCntThresh        Unsigned32,
        dot11RMRqstSTAStatTrigSTAAckFailCntThresh        Unsigned32,
        dot11RMRqstSTAStatTrigSTARetryCntThresh          Unsigned32,
        dot11RMRqstSTAStatTrigQoSTrigCondition           OCTET STRING,
        dot11RMRqstSTAStatTrigQoSFailedCntThresh         Unsigned32,
        dot11RMRqstSTAStatTrigQoSRetryCntThresh          Unsigned32,
        dot11RMRqstSTAStatTrigQoSMultRetryCntThresh      Unsigned32,
        dot11RMRqstSTAStatTrigQoSFrameDupeCntThresh      Unsigned32,
        dot11RMRqstSTAStatTrigQoSRTSFailCntThresh        Unsigned32,
        dot11RMRqstSTAStatTrigQoSAckFailCntThresh        Unsigned32,
        dot11RMRqstSTAStatTrigQoSDiscardCntThresh        Unsigned32,
        dot11RMRqstSTAStatTrigRsnaTrigCondition          OCTET STRING,
        dot11RMRqstSTAStatTrigRsnaCMACICVErrCntThresh    Unsigned32,
        dot11RMRqstSTAStatTrigRsnaCMACReplayCntThresh    Unsigned32,
        dot11RMRqstSTAStatTrigRsnaRobustCCMPReplayCntThresh
                                                         Unsigned32,
        dot11RMRqstSTAStatTrigRsnaTKIPICVErrCntThresh    Unsigned32,
        dot11RMRqstSTAStatTrigRsnaTKIPReplayCntThresh    Unsigned32,
        dot11RMRqstSTAStatTrigRsnaCCMPDecryptErrCntThreshUnsigned32,
        dot11RMRqstSTAStatTrigRsnaCCMPReplayCntThresh    Unsigned32
    }

dot11RMRqstIndex OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "Index for RM Request elements in dot11RMRequestTable, greater than 0."
    ::= { dot11RMRequestEntry 1 }

dot11RMRqstRowStatus OBJECT-TYPE
    SYNTAX RowStatus
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity when requesting a
        measurement, and by the SME when accepting a measurement request.

        The Row Status column of the current row, used for tracking status of an
```


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```
        individual request. When this attribute is set to Active, AND a
        measurement request can be unambiguously created based on the parameters
        in the row, then the MLME may proceed to issue the request to its intended
        targets when appropriate. If not, this attribute may be set to Not-ready
        immediately to indicate parametric errors. However, it is the network
        managers
        responsibility to correct the error. If the request is successfully issued
        to the target STA, then the rowStatus is set to notInService."
    ::= { dot11RMRequestEntry 2 }

dot11RMRqstToken OBJECT-TYPE
    SYNTAX OCTET STRING
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity when the table entry is
        created, i.e., when requesting a measurement..
        Changes take effect when dot11RMRqstRowStatus is set to Active.

        This attribute indicates a unique string to identify a group of rows to be
        issued as parallel or sequential measurements. To guarantee the uniqueness
        of this token across multiple network managers, it is recommended that
        this token be prefixed with the IP address of the network manager creating
        this row. This token is not necessarily equivalent to the measurement
        tokens in RM request frames. If this attribute is an empty string, then
        this row of request is independent from other requests."
    DEFVAL { ''H }(#1344)
    ::= { dot11RMRequestEntry 3 }

dot11RMRqstRepetitions OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity when requesting a
        measurement.
        Changes take effect when dot11RMRqstRowStatus is set to Active.

        This attribute indicates the requested number of repetitions for all of
        the Measurement Request elements in this frame. A value of 0 in the Number
        of Repetitions field indicates Measurement Request  elements are executed
        once without repetition."
    ::= { dot11RMRequestEntry 4 }

dot11RMRqstIfIndex OBJECT-TYPE
    SYNTAX InterfaceIndex
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity when requesting a
        measurement.
        Changes take effect when dot11RMRqstRowStatus is set to Active.

        The ifIndex on which this row of the RM Request is to be issued."
    ::= { dot11RMRequestEntry 5 }

dot11RMRqstType OBJECT-TYPE
    SYNTAX INTEGER {
        channelLoad(3),
        noiseHistogram(4),
        beacon(5),
```

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```
        frame(6),
        staStatistics(7),
        lci(8),
        transmitStream(9),
        pause(255) }
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity when requesting a
        measurement.
        Changes take effect when dot11RMRqstRowStatus is set to Active.

        This attribute indicates the measurement type of this RM request row."
    ::= { dot11RMRequestEntry 6 }

dot11RMRqstTargetAdd OBJECT-TYPE
    SYNTAX MacAddress
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity when requesting a
        measurement.
        Changes take effect when dot11RMRqstRowStatus is set to Active.

        The MAC address of STA for this row of RM Request is to be issued to. If
        this attribute matches the MAC address of the dot11RMRqstIfIndex, then
        measurement request is for this STA itself to carry out."
    ::= { dot11RMRequestEntry 7 }

dot11RMRqstTimeStamp OBJECT-TYPE
    SYNTAX TimeTicks
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by the SME when dot11RMRqstRowStatus is set to Active.

        This attribute indicates the sysUpTime Value the last time when
        dot11RMRqstRowStatus is set to active or when this row is created the
        first time."
    ::= { dot11RMRequestEntry 8 }

dot11RMRqstChanNumber OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity when requesting a
        measurement.
        Changes take effect when dot11RMRqstRowStatus is set to Active.

        The target STA channel number on which to perform the measurements
        indicated in this request. The Channel Number is defined only within the
        indicated Operating Class for this measurement request. This attribute is
        ignored if dot11RMRqstType = STA Statistics, LCI, Transmit Stream/Category
        Measurement, or Measurement Pause. However, even in that case, the manager
        should set this attribute to the current channel for this interface, so
        that the row can be set to active when ready with all attributes
        indicated."
    ::= { dot11RMRequestEntry 9 }
```


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```
dot11RMRqstOperatingClass OBJECT-TYPE
   SYNTAX Unsigned32 (1..255)
   MAX-ACCESS read-create
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by an external management entity when requesting a
      measurement.
      Changes take effect when dot11RMRqstRowStatus is set to Active.

      This attribute indicates the channel set for this measurement request.
      Country, Operating Class and Channel Number together specify the channel
      frequency and spacing for this measurement request. Valid values of
      Operating Class are shown in Annex E."
   ::= { dot11RMRequestEntry 10 }

dot11RMRqstRndInterval OBJECT-TYPE
   SYNTAX Unsigned32
   UNITS "TUs"
   MAX-ACCESS read-create
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by an external management entity when requesting a
      measurement.
      Changes take effect when dot11RMRqstRowStatus is set to Active.

      This attribute indicates the upper bound of the random delay to be used
      prior to making the measurement. See 11.10.3 (Measurement start time).
      This attribute is ignored if dot11RMRqstType = STA Statistics, LCI,
      Transmit Stream/Category Measurement or Measurement Pause."
   DEFVAL { 0 }
   ::= { dot11RMRequestEntry 11 }

dot11RMRqstDuration OBJECT-TYPE
   SYNTAX Unsigned32
   UNITS "TUs"
   MAX-ACCESS read-create
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by an external management entity when requesting a
      measurement.
      Changes take effect when dot11RMRqstRowStatus is set to Active.

      This attribute indicates the preferred or mandatory measurement duration
      for this Measurement Request. This attribute is ignored if dot11RMRqstType
      = LCI or Measurement Pause."
   DEFVAL { 0 }
   ::= { dot11RMRequestEntry 12 }

dot11RMRqstParallel OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-create
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by an external management entity when requesting a
      measurement.
      Changes take effect when dot11RMRqstRowStatus is set to Active.

      This attribute indicates the Parallel subfield(#291) for this Measurement
      Request element. This attribute, when false, indicates that the
      measurement is performed in sequence. This attribute, when true, indicates
```

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```
        that this measurement should start at the same time as the measurement
        described by the next Measurement Request element in the next row if the
        next row indicates the same value for dot11RMRqstToken."
    DEFVAL { false }
    ::= { dot11RMRequestEntry 13 }

dot11RMRqstEnable OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity when requesting a
        measurement.
        Changes take effect when dot11RMRqstRowStatus is set to Active.

        This attribute indicates the Enable subfield(#291) for this Measurement
        Request element."
    DEFVAL { false }
    ::= { dot11RMRequestEntry 14 }

dot11RMRqstRequest OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity when requesting a
        measurement.
        Changes take effect when dot11RMRqstRowStatus is set to Active.

        This attribute indicates the Request subfield(#291) for this Measurement
        Request element. This attribute, when true, indicates that this STA
        accepts measurement requests from the target STA."
    DEFVAL { false }
    ::= { dot11RMRequestEntry 15 }

dot11RMRqstReport OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity when requesting a
        measurement.
        Changes take effect when dot11RMRqstRowStatus is set to Active.

        This attribute indicates the Report subfield(#291) for this Measurement
        Request element. This attribute, when true, indicates that the target STA
        may enable autonomous measurement reports to the requesting STA."
    DEFVAL { false }
    ::= { dot11RMRequestEntry 16 }

dot11RMRqstDurationMandatory OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity when requesting a
        measurement.
        Changes take effect when dot11RMRqstRowStatus is set to Active.

        This attribute indicates the Duration Mandatory subfield(#291) for this
```


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```
        Measurement Request element. This attribute, when true, indicates that the
        indicated Measurement Duration is a mandatory duration for this
        measurement. This attribute, when false, indicates that the indicated
        Measurement Duration is a maximum duration for this measurement."
    DEFVAL { false }
    ::= { dot11RMRequestEntry 17 }

dot11RMRqstBeaconRqstMode OBJECT-TYPE
    SYNTAX INTEGER {
        passive(0),
        active(1),
        beaconTable(2) }
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity when requesting a
        measurement.
        Changes take effect when dot11RMRqstRowStatus is set to Active.

        This attribute indicates the Measurement Mode for this Beacon request.
        This attribute is valid only if the dot11RMRqstType is 5, indicating a
        Beacon request, and is ignored otherwise."
    DEFVAL { 0 }
    ::= { dot11RMRequestEntry 18 }

dot11RMRqstBeaconRqstDetail OBJECT-TYPE
    SYNTAX INTEGER {
        noBody(0),
        fieldsAndRequestedElements(1),
        allBody(2) }
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity when requesting a
        measurement.
        Changes take effect when dot11RMRqstRowStatus is set to Active.

        dot11RMRqstBeaconRqstDetail indicates the reporting detail(#1502) for
        Beacon request. This attribute is valid only if the dot11RMRqstType is 5,
        indicating a Beacon request, and is ignored otherwise."
    DEFVAL { 2 }
    ::= { dot11RMRequestEntry 19 }

dot11RMRqstFrameRqstType OBJECT-TYPE
    SYNTAX INTEGER { frameCountRep(1) }
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity when requesting a
        measurement.
        Changes take effect when dot11RMRqstRowStatus is set to Active.

        dot11RMRqstFrameRqstType indicates the Frame Request Type for the Frame
        request. This attribute is valid only if the dot11RMRqstType is 6,
        indicating a Frame request, and is ignored otherwise."
    DEFVAL { 1 }
    ::= { dot11RMRequestEntry 20 }

dot11RMRqstBssid OBJECT-TYPE
    SYNTAX MacAddress
    MAX-ACCESS read-create
```

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```
    STATUS current
    DESCRIPTION
       "This is a control variable.
       It is written by an external management entity when requesting a
       measurement.
       Changes take effect when dot11RMRqstRowStatus is set to Active.

       BSSID indicates the BSSID of the BSS of the particular AP for which this
       measurement is requested. The BSSID is set to the wildcard BSSID when the
       measurement is to be performed on the BSS(s) of any AP(s) on the indicated
       channel. This attribute is valid only if the dot11RMRqstType is 5,
       indicating a Beacon request, and is ignored otherwise."
    DEFVAL { 'FFFFFFFFFFFF'H }
    ::= { dot11RMRequestEntry 21 }

dot11RMRqstSSID OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(0..32))
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
       "This is a control variable.
       It is written by an external management entity when requesting a
       measurement.
       Changes take effect when dot11RMRqstRowStatus is set to Active.

       This attribute indicates the SSID for the measurement. Zero-length MIB
       element for SSID indicates the wildcard SSID. The SSID is set to the
       wildcard SSID when the measurement is to be performed on all ESSs/IBSSs on
       the indicated channel. This attribute is valid only if the dot11RMRqstType
       is 5, indicating a Beacon request, and is ignored otherwise."
    DEFVAL { ''H }
    ::= { dot11RMRequestEntry 22 }

dot11RMRqstBeaconReportingCondition OBJECT-TYPE
    SYNTAX INTEGER {
       afterEveryMeasurement(0),
       rcpiAboveAbsoluteThreshold(1),
       rcpiBelowAbsoluteThreshold(2),
       rsniAboveAbsoluteThreshold(3),
       rsniBelowAbsoluteThreshold(4),
       rcpiAboveOffsetThreshold(5),
       rcpiBelowOffsetThreshold(6),
       rsniAboveOffsetThreshold(7),
       rsniBelowOffsetThreshold(8),
       rcpiInBound(9),
       rsniInBound(10) }
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
       "This is a control variable.
       It is written by an external management entity when requesting a
       measurement.
       Changes take effect when dot11RMRqstRowStatus is set to Active.

       This attribute indicates when the Beacon Measurement results are to be
       reported to the requesting STA. This attribute is valid only if the
       dot11RMRqstType is 5, indicating a Beacon request, and is ignored
       otherwise."
    REFERENCE
    "IEEE Std 802.11-2020, Table 9-143 (Reporting Condition subfield for Beacon
       report), Reporting Condition values for Beacon request"
    DEFVAL {0}
    ::= { dot11RMRequestEntry 23 }
```


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```
dot11RMRqstBeaconThresholdOffset OBJECT-TYPE
   SYNTAX Integer32
   MAX-ACCESS read-create
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by an external management entity when requesting a
      measurement.
      Changes take effect when dot11RMRqstRowStatus is set to Active.

      Threshold/Offset provides either the threshold value or the offset value
      to be used for conditional reporting. For indicated reporting conditions
      1-4, the integer range is (0..255). For indicated reporting conditions 5-
      10, the integer range is  (-127..+127). This attribute is valid only if
      the dot11RMRqstType is 5, indicating a Beacon request, and is ignored
      otherwise."
   DEFVAL { 0 }
   ::= { dot11RMRequestEntry 24 }

dot11RMRqstSTAStatRqstGroupID OBJECT-TYPE
   SYNTAX INTEGER {
      dot11CountersTable(0),
      dot11MacStatistics(1),
      dot11QosCountersTableforUP0(2),
      dot11QosCountersTableforUP1(3),
      dot11QosCountersTableforUP2(4),
      dot11QosCountersTableforUP3(5),
      dot11QosCountersTableforUP4(6),
      dot11QosCountersTableforUP5(7),
      dot11QosCountersTableforUP6(8),
      dot11QosCountersTableforUP7(9),
      dot11BSSAverageAccessDelays(10)(#4246),
      dot11CountersGroup6Subset1(11),(#3263)
      dot11CountersGroup6Subset2(12),(#3263)(M118)
      dot11CountersGroup6Subset3(13),(#3263)(M118)
      dot11CountersGroup6Subset4(14),(#3263)(M118)
      dot11CountersGroup6Subset5(15),(#3263)(M118)
      dot11RSNAStatsTable(16)}
   MAX-ACCESS read-create
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by an external management entity when requesting a
      measurement.
      Changes take effect when dot11RMRqstRowStatus is set to Active.

      The attribute indicates the group identity for this Measurement Request
      element. This attribute is valid only if the dot11RMRqstType is 7,
      indicating a STA statistics request, and is ignored otherwise."
   DEFVAL { 0 }
   ::= { dot11RMRequestEntry 25 }

dot11RMRqstLCIRqstSubject OBJECT-TYPE
   SYNTAX INTEGER { local(0), remote(1) }
   MAX-ACCESS read-create
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by an external management entity when requesting a
      measurement.
      Changes take effect when dot11RMRqstRowStatus is set to Active.

      The attribute indicates the subject of the LCI request. This attribute is
      valid only if the dot11RMRqstType is 8, indicating an LCI request, and is
```

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```
        ignored otherwise."
    DEFVAL { 0 }
    ::= { dot11RMRequestEntry 26 }

-- 27 to 29 are reserved

dot11RMRqstLCIAzimuthType OBJECT-TYPE
    SYNTAX INTEGER { frontSurfaceofSta(0), radioBeam(1) }
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity when requesting a
        measurement.
        Changes take effect when dot11RMRqstRowStatus is set to Active.

        This attribute indicates the azimuth reference for the LCI Azimuth
        measurement request. This attribute is valid only if the dot11RMRqstType
        is 8, indicating an LCI request, and is ignored otherwise."
    DEFVAL{ 0 }
    ::= { dot11RMRequestEntry 30 }

dot11RMRqstLCIAzimuthResolution OBJECT-TYPE
    SYNTAX Unsigned32 (0..15)
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity when requesting a
        measurement.
        Changes take effect when dot11RMRqstRowStatus is set to Active.

        This attribute is 4 bits indicating the number of valid
        bits in the fixed-point value of Azimuth of the LCI Azimuth
        measurement request. This attribute is valid only if the dot11RMRqstType
        is 8, indicating an LCI request, and is ignored otherwise."
    ::= { dot11RMRequestEntry 31 }

dot11RMRqstPauseTime OBJECT-TYPE
    SYNTAX Unsigned32 (0..65535)
    UNITS "10 TUs"
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity when requesting a
        measurement.
        Changes take effect when dot11RMRqstRowStatus is set to Active.

        This attribute indicates the time period for which measurements are
        suspended or paused. Measurement Pause requests are used to
        provide time delays between the execution times of measurement
        request elements in a Measurement Request frame. This attribute is valid
        only if the dot11RMRqstType is 255, indicating an pause request, and is
        ignored otherwise."
    DEFVAL { 0 }
    ::= { dot11RMRequestEntry 32 }

dot11RMRqstTransmitStreamPeerQSTAAddress OBJECT-TYPE
    SYNTAX MacAddress
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a control variable.
```


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```
        It is written by an external management entity when requesting a
        measurement.
        Changes take effect when dot11RMRqstRowStatus is set to Active.

        This attribute indicates the peer STA address to be measured for a
        Transmit Stream/Category Measurement measurement. This attribute is valid
        only if the dot11RMRqstType is 9, indicating a transmit stream/category
        request, and is ignored otherwise."
    ::= { dot11RMRequestEntry 33 }

dot11RMRqstTransmitStreamTrafficIdentifier OBJECT-TYPE
    SYNTAX Unsigned32 (0..16)
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity when requesting a
        measurement.
        Changes take effect when dot11RMRqstRowStatus is set to Active.

        This attribute indicates the TC, or TS to be measured for a Transmit
        Stream/Category Measurement measurement. This attribute is valid only if
        the dot11RMRqstType is 9, indicating a transmit stream/category request,
        and is ignored otherwise."
    ::= { dot11RMRequestEntry 34 }

dot11RMRqstTransmitStreamBin0Range OBJECT-TYPE
    SYNTAX Unsigned32 (1..255)
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity when requesting a
        measurement.
        Changes take effect when dot11RMRqstRowStatus is set to Active.

        This attribute indicates the delay range for bin 0 of the transmit delay
        histogram. This attribute is valid only if the dot11RMRqstType is 9,
        indicating a transmit stream/category request, and is ignored otherwise."
    ::= { dot11RMRequestEntry 35 }

dot11RMRqstTrigdQoSAverageCondition OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity when requesting a
        measurement.
        Changes take effect when dot11RMRqstRowStatus is set to Active.

        This attribute, when true, indicates a request for triggered reporting
        with trigger based on the number of discarded MSDUs reaching the
        dot11RMRqstTrigdQoSAverageThreshold when averaged over
        dot11RMRqstTrigdQoSMeasurementCount consecutive MSDUs. This attribute is
        valid only if the dot11RMRqstType is 9, indicating a transmit stream/
        category request, and is ignored otherwise."
    DEFVAL { false }
    ::= { dot11RMRequestEntry 36 }

dot11RMRqstTrigdQoSConsecutiveCondition OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-create
    STATUS current
```

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```
    DESCRIPTION
       "This is a control variable.
       It is written by an external management entity when requesting a
       measurement.
       Changes take effect when dot11RMRqstRowStatus is set to Active.

       This attribute, when true, indicates a request for triggered reporting
       with trigger based on the consecutive number of MSDUs discarded reaching
       dot11RMRqstTrigdQoSConsecutiveThreshold. This attribute is valid only if
       the dot11RMRqstType is 9, indicating a transmit stream/category request,
       and is ignored otherwise."
    DEFVAL { false }
    ::= { dot11RMRequestEntry 37 }

dot11RMRqstTrigdQoSDelayCondition OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
       "This is a control variable.
       It is written by an external management entity when requesting a
       measurement.
       Changes take effect when dot11RMRqstRowStatus is set to Active.

       This attribute, when true, indicates a request for triggered reporting
       with trigger based on the consecutive number of MSDUs that experience a
       transmit delay greater than dot11RMRqstTrigdQoSDelayThresholdRange
       reaching dot11RMRqstTrigdQoSDelayThreshold. This attribute is valid only
       if the dot11RMRqstType is 9, indicating a transmit stream/category
       request, and is ignored otherwise."
    DEFVAL { false }
    ::= { dot11RMRequestEntry 38 }

dot11RMRqstTrigdQoSAverageThreshold OBJECT-TYPE
    SYNTAX Unsigned32 (1..255)
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
       "This is a control variable.
       It is written by an external management entity when requesting a
       measurement.
       Changes take effect when dot11RMRqstRowStatus is set to Active.

       This attribute indicates the trigger threshold for triggered Transmit
       Stream/Category Measurement based on average MSDUs discarded. Trigger
       occurs if the number of MSDUs discarded over the moving average number of
       transmitted MSDUs in dot11RMRqstTrigdQoSMeasurementCount reaches this
       threshold. This attribute is valid only if the dot11RMRqstType is 9,
       indicating a transmit stream/category request, and is ignored otherwise."
    DEFVAL { 10 }
    ::= { dot11RMRequestEntry 39 }

dot11RMRqstTrigdQoSConsecutiveThreshold OBJECT-TYPE
    SYNTAX Unsigned32 (1..255)
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
       "This is a control variable.
       It is written by an external management entity when requesting a
       measurement.
       Changes take effect when dot11RMRqstRowStatus is set to Active.

       This attribute indicates the trigger threshold for triggered Transmit
       Stream/Category Measurement based on consecutive MSDUs discarded. Trigger
```


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```
        occurs if the consecutive number of MSDUs discarded reaches this
        threshold. This attribute is valid only if the dot11RMRqstType is 9,
        indicating a transmit stream/category request, and is ignored otherwise."
    DEFVAL { 5 }
    ::= { dot11RMRequestEntry 40 }

dot11RMRqstTrigdQoSDelayThresholdRange OBJECT-TYPE
    SYNTAX Unsigned32 (0..3)
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity when requesting a
        measurement.
        Changes take effect when dot11RMRqstRowStatus is set to Active.

        This attribute indicates the minimum transmit delay for delayed MSDU
        counts. Trigger occurs if the a consecutive number of MSDUs experience a
        transmit delay greater than or equal to the lower bound of the bin of the
        Transmit Delay Histogram given by the value of this attribute + 2, e.g., if
        this attribute is 1 the lower bound of bin 3. This attribute is valid only
        if the dot11RMRqstType is 9, indicating a transmit stream/category
        request, and is ignored otherwise."
    DEFVAL { 1 }
    ::= { dot11RMRequestEntry 41 }

dot11RMRqstTrigdQoSDelayThreshold OBJECT-TYPE
    SYNTAX Unsigned32 (1..255)
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity when requesting a
        measurement.
        Changes take effect when dot11RMRqstRowStatus is set to Active.

        This attribute indicates the number of consecutive delayed MSDUs needed
        for trigger. Trigger occurs if the consecutive number of MSDUs that
        experience a transmit delay greater than
        dot11RMRqstTrigdQoSDelayThresholdRange reaches this value. This attribute
        is valid only if the dot11RMRqstType is 9, indicating a transmit stream/
        category request, and is ignored otherwise."
    DEFVAL { 20 }
    ::= { dot11RMRequestEntry 42 }

dot11RMRqstTrigdQoSMeasurementCount OBJECT-TYPE
    SYNTAX Unsigned32 (1..255)
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity when requesting a
        measurement.
        Changes take effect when dot11RMRqstRowStatus is set to Active.

        This attribute indicates the number of MSDUs to be used as a moving
        average count in the average error threshold and in determining the scope
        of the reported Transmit Stream/Category measurement in a triggered
        measurement report. This attribute is valid only if the dot11RMRqstType is
        9, indicating a transmit stream/category request, and is ignored
        otherwise."
    DEFVAL { 100 }
    ::= { dot11RMRequestEntry 43 }
```

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```
dot11RMRqstTrigdQoSTimeout OBJECT-TYPE
   SYNTAX Unsigned32 (1..255)
   UNITS "100 TUs"
   MAX-ACCESS read-create
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by an external management entity when requesting a
      measurement.
      Changes take effect when dot11RMRqstRowStatus is set to Active.

      This attribute indicates the timeout interval during which a measuring STA
      does not generate further triggered Transmit Stream/Category measurement
      reports after a trigger condition has been met and a report generated.
      This attribute is valid only if the dot11RMRqstType is 9, indicating a
      transmit stream/category request, and is ignored otherwise."
   DEFVAL { 20 }
   ::= { dot11RMRequestEntry 44 }

dot11RMRqstChannelLoadReportingCondition OBJECT-TYPE
   SYNTAX INTEGER {
      afterEveryMeasurement(0),
      chanLoadAboveReference(1),
      chanLoadBelowReference(2) }
   MAX-ACCESS read-create
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by an external management entity when requesting a
      measurement.
      Changes take effect when dot11RMRqstRowStatus is set to Active.

      This attribute indicates when the Channel Load Measurement results are to
      be reported to the requesting STA. This attribute is valid only if the
      dot11RMRqstType is 3, indicating a Channel Load request, and is ignored
      otherwise."
   DEFVAL {0}
   ::= { dot11RMRequestEntry 45 }

dot11RMRqstChannelLoadReference OBJECT-TYPE
   SYNTAX Unsigned32 (0..255)
   UNITS "1/255"
   MAX-ACCESS read-create
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by an external management entity when requesting a
      measurement.
      Changes take effect when dot11RMRqstRowStatus is set to Active.

      This attribute indicates the channel load reporting condition reference
      value. The measured Channel Load is compared to this reference value and a
      report is issued if the reporting condition is satisfied. The reference
      value is in the same units as Channel Load and represents the fractional
      time of the measurement duration during which the STA determined the
      channel to be busy. This attribute is valid only if the dot11RMRqstType is
      3, indicating a Channel Load request, and is ignored otherwise."
   DEFVAL { 5 }
   ::= { dot11RMRequestEntry 46 }

dot11RMRqstNoiseHistogramReportingCondition OBJECT-TYPE
   SYNTAX INTEGER {
      afterEveryMeasurement(0),
      aNPIAboveReference(1),
```


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```
        aNPIBelowReference(2) }
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity when requesting a
        measurement.
        Changes take effect when dot11RMRqstRowStatus is set to Active.

        This attribute indicates when the Noise Histogram Measurement results are
        to be reported to the requesting STA. This attribute is valid only if the
        dot11RMRqstType is 4, indicating a Noise Histogram request, and is ignored
        otherwise."
    DEFVAL {0}
    ::= { dot11RMRequestEntry 47 }

dot11RMRqstAnpiReference OBJECT-TYPE
    SYNTAX Unsigned32 (0..255)
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity when requesting a
        measurement.
        Changes take effect when dot11RMRqstRowStatus is set to Active.

        This attribute indicates the noise histogram reporting condition ANPI
        reference value. The measured ANPI is compared to this reference value and
        a report is issued if the indicated reporting condition is satisfied.
        ANPIval = Floor((ANPIpower in dBm + 110)*2), for ANPI in the range -110
        dBm to 0 dBm. ANPIval = 220 for ANPI > 0 dBm. ANPIval = 255 when ANPI is
        not available. This attribute is valid only if the dot11RMRqstType is 4,
        indicating a Noise Histogram request, and is ignored otherwise."
    DEFVAL { 5 }
    ::= { dot11RMRequestEntry 48 }

dot11RMRqstAPChannelReport OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(0..255))
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity when requesting a
        measurement.
        Changes take effect when dot11RMRqstRowStatus is set to Active.

        This attribute indicates the specific channels to be used for the
        requested beacon measurements. Each octet indicates a different channel
        within the indicated Operating Class. This list of channels is the Channel
        List field in the AP Channel Report element described in 9.4.2.34 (AP
        Channel Report element). This attribute is valid only if the
        dot11RMRqstType is 5, indicating a Beacon request, and is ignored
        otherwise."
    DEFVAL { ''H }
    ::= { dot11RMRequestEntry 49 }

dot11RMRqstSTAStatPeerSTAAddress OBJECT-TYPE
    SYNTAX MacAddress
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity when requesting a
        measurement.
```

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```
        Changes take effect when dot11RMRqstRowStatus is set to Active.

        This attribute indicates the peer STA address to be measured for a STA
        statistics request. This attribute is valid only if the dot11RMRqstType is
        7, indicating a statistics request, and is ignored otherwise."
    ::= { dot11RMRequestEntry 50 }

dot11RMRqstFrameTransmitterAddress OBJECT-TYPE
    SYNTAX MacAddress
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity when requesting a
        measurement.
        Changes take effect when dot11RMRqstRowStatus is set to Active.

        This attribute indicates the (#300)transmitter address (TA) of the frames
        to be counted in this Frame request. This attribute is valid only if the
        dot11RMRqstType is 6, indicating a Frame request, and is ignored
        otherwise."
    ::= { dot11RMRequestEntry 51 }

dot11RMRqstVendorSpecific OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(0..255))
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity when requesting a
        measurement.
        Changes take effect when dot11RMRqstRowStatus is set to Active.

        This attribute provides an envelope for any optional vendor specific
        subelements which may be included in a Measurement Request element. This
        attribute is valid for all requests."
    DEFVAL { ''H }
    ::= { dot11RMRequestEntry 52 }

dot11RMRqstSTAStatTrigMeasCount OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This attribute indicates the number of MSDUs or MPDUs over which the
        trigger criterion is applied. This attribute is valid only if
        dot11RMRqstType is 7 (STA Statistics) and if the value of the attribute is
        not equal to 0."
    DEFVAL { 0 }
    ::= { dot11RMRequestEntry 53 }

dot11RMRqstSTAStatTrigTimeout OBJECT-TYPE
    SYNTAX Unsigned32 (0..65535)
    UNITS "100 TUs"
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This attribute indicates the interval during which a measuring STA does
        not generate further triggered STA Statistics reports after a trigger
        condition has been met. This attribute is valid only if dot11RMRqstType is
        7 (STA Statistics)."
    DEFVAL { 0 }
    ::= { dot11RMRequestEntry 54 }
```


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```
dot11RMRqstSTAStatTrigCondition OBJECT-TYPE
   SYNTAX OCTET STRING (SIZE(2))
   MAX-ACCESS read-create
   STATUS current
   DESCRIPTION
      "This attribute indicates the trigger values used when requesting
      triggered STA Statistics
      reporting. The format of the STA Counter Trigger Condition field is shown
      in Figure 9-255 (STA Counter Trigger Condition field format)."
   ::= { dot11RMRequestEntry 55 }

dot11RMRqstSTAStatTrigSTAFailedCntThresh OBJECT-TYPE
   SYNTAX Unsigned32
   MAX-ACCESS read-create
   STATUS current
   DESCRIPTION
      "This attribute indicates that a STA Statistics report should be generated
      (triggered) when the dot11FailedCount value has increased more than the
      threshold value indicated here. The counter increase is measured over the
      last n MSDUs or MPDUs, where n is the value of
      dot11RMRqstSTAStatTrigMeasCount. This attribute is valid only if
      dot11RMRqstType is 7 (STA Statistics), and if
      dot11RMRqstSTAStatRqstGroupID is 0 (dot11CountersTable) and if the value
      of the attribute is not equal to 0."
   DEFVAL { 0 }
   ::= { dot11RMRequestEntry 56 }

dot11RMRqstSTAStatTrigSTAFCSErrCntThresh OBJECT-TYPE
   SYNTAX Unsigned32
   MAX-ACCESS read-create
   STATUS current
   DESCRIPTION
      "This attribute indicates that a STA Statistics report should be generated
      (triggered) when the dot11FCSErrorCount value has increased more than the
      threshold value indicated here. The counter increase is measured over the
      last n MSDUs or MPDUs, where n is the value of
      dot11RMRqstSTAStatTrigMeasCount. This attribute is valid only if
      dot11RMRqstType is 7 (STA Statistics), and if
      dot11RMRqstSTAStatRqstGroupID is 0 (dot11CountersTable) and if the value
      of the attribute is not equal to 0."
   DEFVAL { 0 }
   ::= { dot11RMRequestEntry 57 }

dot11RMRqstSTAStatTrigSTAMultRetryCntThresh OBJECT-TYPE
   SYNTAX Unsigned32
   MAX-ACCESS read-create
   STATUS current
   DESCRIPTION
      "This attribute indicates that a STA Statistics report should be generated
      (triggered) when the dot11MultipleRetryCount value has increased more than
      the threshold value indicated here. The counter increase is measured over
      the last n MSDUs or MPDUs, where n is the value of
      dot11RMRqstSTAStatTrigMeasCount. This attribute is valid only if
      dot11RMRqstType is 7 (STA Statistics), and if
      dot11RMRqstSTAStatRqstGroupID is 0 (dot11CountersTable) and if the value
      of the attribute is not equal to 0."
   DEFVAL { 0 }
   ::= { dot11RMRequestEntry 58 }

dot11RMRqstSTAStatTrigSTAFrameDupeCntThresh OBJECT-TYPE
   SYNTAX Unsigned32
   MAX-ACCESS read-create
   STATUS current
   DESCRIPTION
```

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```
        "This attribute indicates that a STA Statistics report should be generated
        (triggered) when the dot11FrameDuplicateCount value has increased more
        than the threshold value indicated here. The counter increase is measured
        over the last n MSDUs or MPDUs, where n is the value of
        dot11RMRqstSTAStatTrigMeasCount. This attribute is valid only if
        dot11RMRqstType is 7 (STA Statistics), and if
        dot11RMRqstSTAStatRqstGroupID is 0 (dot11CountersTable) and if the value
        of the attribute is not equal to 0."
    DEFVAL { 0 }
    ::= { dot11RMRequestEntry 59 }

dot11RMRqstSTAStatTrigSTARTSFailCntThresh OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This attribute indicates that a STA Statistics report should be generated
        (triggered) when the dot11RTSFailureCount value has increased more than
        the threshold value indicated here. The counter increase is measured over
        the last n MSDUs or MPDUs, where n is the value of
        dot11RMRqstSTAStatTrigMeasCount. This attribute is valid only if
        dot11RMRqstType is 7 (STA Statistics), and if
        dot11RMRqstSTAStatRqstGroupID is 0 (dot11CountersTable) and if the value
        of the attribute is not equal to 0."
    DEFVAL { 0 }
    ::= { dot11RMRequestEntry 60 }

dot11RMRqstSTAStatTrigSTAAckFailCntThresh OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This attribute indicates that a STA Statistics report should be generated
        (triggered) when the dot11AckFailureCount value has increased more than
        the threshold value indicated here. The counter increase is measured over
        the last n MSDUs or MPDUs, where n is the value of
        dot11RMRqstSTAStatTrigMeasCount. This attribute is valid only if
        dot11RMRqstType is 7 (STA Statistics), and if
        dot11RMRqstSTAStatRqstGroupID is 0 (dot11CountersTable) and if the value
        of the attribute is not equal to 0."
    DEFVAL { 0 }
    ::= { dot11RMRequestEntry 61 }

dot11RMRqstSTAStatTrigSTARetryCntThresh OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This attribute indicates that a STA Statistics report should be generated
        (triggered) when the dot11RetryCount value has increased more than the
        threshold value indicated here. The counter increase is measured over the
        last n MSDUs or MPDUs, where n is the value of
        dot11RMRqstSTAStatTrigMeasCount. This attribute is valid only if
        dot11RMRqstType is 7 (STA Statistics), and if
        dot11RMRqstSTAStatRqstGroupID is 0 (dot11CountersTable) and if the value
        of the attribute is not equal to 0."
    DEFVAL { 0 }
    ::= { dot11RMRequestEntry 62 }

dot11RMRqstSTAStatTrigQoSTrigCondition OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(2))
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
```


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```
        "This attribute indicates the trigger values used when requesting
        triggered QoS STA Statistics
        reporting. The format of the STA Counter Trigger Condition field is shown
        in Figure 9-257 (QoS STA Counter Trigger Condition field format)."
    ::= { dot11RMRequestEntry 63 }

dot11RMRqstSTAStatTrigQoSFailedCntThresh OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This attribute indicates that a STA Statistics report should be generated
        (triggered) when the dot11QosFailedCount value has increased more than the
        threshold value indicated here. The counter increase is measured over the
        last n MSDUs or MPDUs, where n is the value of
        dot11RMRqstSTAStatTrigMeasCount. This attribute is valid only if
        dot11RMRqstType is 7 (STA Statistics), and if
        dot11RMRqstSTAStatRqstGroupID is 2 to 9 (dot11QosCountersTable) and if the
        value of the attribute is not equal to 0."
    DEFVAL { 0 }
    ::= { dot11RMRequestEntry 64 }

dot11RMRqstSTAStatTrigQoSRetryCntThresh OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This attribute indicates that a STA Statistics report should be generated
        (triggered) when the dot11QosRetryCount value has increased more than the
        threshold value indicated here. The counter increase is measured over the
        last n MSDUs or MPDUs, where n is the value of
        dot11RMRqstSTAStatTrigMeasCount. This attribute is valid only if
        dot11RMRqstType is 7 (STA Statistics), and if
        dot11RMRqstSTAStatRqstGroupID is 2 to 9 (dot11QosCountersTable) and if the
        value of the attribute is not equal to 0."
    DEFVAL { 0 }
    ::= { dot11RMRequestEntry 65 }

dot11RMRqstSTAStatTrigQoSMultRetryCntThresh OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This attribute indicates that a STA Statistics report should be generated
        (triggered) when the dot11QosMultipleRetryCount value has increased more
        than the threshold value indicated here. The counter increase is measured
        over the last n MSDUs or MPDUs, where n is the value of
        dot11RMRqstSTAStatTrigMeasCount. This attribute is valid only if
        dot11RMRqstType is 7 (STA Statistics), and if
        dot11RMRqstSTAStatRqstGroupID is 2 to 9 (dot11QosCountersTable) and if the
        value of the attribute is not equal to 0."
    DEFVAL { 0 }
    ::= { dot11RMRequestEntry 66 }

dot11RMRqstSTAStatTrigQoSFrameDupeCntThresh OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This attribute indicates that a STA Statistics report should be generated
        (triggered) when the dot11QosFrameDuplicateCount value has increased more
        than the threshold value indicated here. The counter increase is measured
        over the last n MSDUs or MPDUs, where n is the value of
        dot11RMRqstSTAStatTrigMeasCount. This attribute is valid only if
```

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```
        dot11RMRqstType is 7 (STA Statistics), and if
        dot11RMRqstSTAStatRqstGroupID is 2 to 9 (dot11QosCountersTable) and if the
        value of the attribute is not equal to 0."
    DEFVAL { 0 }
    ::= { dot11RMRequestEntry 67 }

dot11RMRqstSTAStatTrigQoSRTSFailCntThresh OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This attribute indicates that a STA Statistics report should be generated
        (triggered) when the dot11QosRTSFailureCount value has increased more than
        the threshold value indicated here. The counter increase is measured over
        the last n MSDUs or MPDUs, where n is the value of
        dot11RMRqstSTAStatTrigMeasCount. This attribute is valid only if
        dot11RMRqstType is 7 (STA Statistics), and if
        dot11RMRqstSTAStatRqstGroupID is 2 to 9 (dot11QosCountersTable) and if the
        value of the attribute is not equal to 0."
    DEFVAL { 0 }
    ::= { dot11RMRequestEntry 68 }

dot11RMRqstSTAStatTrigQoSAckFailCntThresh OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This attribute indicates that a STA Statistics report should be generated
        (triggered) when the dot11QosAckFailureCount value has increased more than
        the threshold value indicated here. The counter increase is measured over
        the last n MSDUs or MPDUs, where n is the value of
        dot11RMRqstSTAStatTrigMeasCount. This attribute is valid only if
        dot11RMRqstType is 7 (STA Statistics), and if
        dot11RMRqstSTAStatRqstGroupID is 2 to 9 (dot11QosCountersTable) and if the
        value of the attribute is not equal to 0."
    DEFVAL { 0 }
    ::= { dot11RMRequestEntry 69 }

dot11RMRqstSTAStatTrigQoSDiscardCntThresh OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This attribute indicates that a STA Statistics report should be generated
        (triggered) when the dot11QosDiscardedFrameCount value has increased more
        than the threshold value indicated here. The counter increase is measured
        over the last n MSDUs or MPDUs, where n is the value of
        dot11RMRqstSTAStatTrigMeasCount. This attribute is valid only if
        dot11RMRqstType is 7 (STA Statistics), and if
        dot11RMRqstSTAStatRqstGroupID is 2 to 9 (dot11QosCountersTable) and if the
        value of the attribute is not equal to 0."
    DEFVAL { 0 }
    ::= { dot11RMRequestEntry 70 }

dot11RMRqstSTAStatTrigRsnaTrigCondition OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(2))
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This attribute indicates the trigger values used when requesting
        triggered RSNA STA Statistics
        reporting. The format of the STA Counter Trigger Condition field is shown
        in Figure 9-259 (RSNA Trigger Condition field format)."
    ::= { dot11RMRequestEntry 71 }
```


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```
dot11RMRqstSTAStatTrigRsnaCMACICVErrCntThresh OBJECT-TYPE
   SYNTAX Unsigned32
   MAX-ACCESS read-create
   STATUS current
   DESCRIPTION
      "This attribute indicates that a STA Statistics report should be generated
      (triggered) when the dot11RSNAStatsBIPMICErrors value has increased more
      than the threshold value indicated here. The counter increase is measured
      over the last n MSDUs or MPDUs, where n is the value of
      dot11RMRqstSTAStatTrigMeasCount. This attribute is valid only if
      dot11RMRqstType is 7 (STA Statistics), and if
      dot11RMRqstSTAStatRqstGroupID is 16 (dot11RSNAStatsTable) and if the value
      of the attribute is not equal to 0."
   DEFVAL { 0 }
   ::= { dot11RMRequestEntry 72 }

dot11RMRqstSTAStatTrigRsnaCMACReplayCntThresh OBJECT-TYPE
   SYNTAX Unsigned32
   MAX-ACCESS read-create
   STATUS current
   DESCRIPTION
      "This attribute indicates that a STA Statistics report should be generated
      (triggered) when the dot11RSNAStatsCMACReplays value has increased more
      than the threshold value indicated here. The counter increase is measured
      over the last n MSDUs or MPDUs, where n is the value of
      dot11RMRqstSTAStatTrigMeasCount. This attribute is valid only if
      dot11RMRqstType is 7 (STA Statistics), and if
      dot11RMRqstSTAStatRqstGroupID is 16 (dot11RSNAStatsTable) and if the value
      of the attribute is not equal to 0."
   DEFVAL { 0 }
   ::= { dot11RMRequestEntry 73 }

dot11RMRqstSTAStatTrigRsnaRobustCCMPReplayCntThresh OBJECT-TYPE
   SYNTAX Unsigned32
   MAX-ACCESS read-create
   STATUS current
   DESCRIPTION
      "This attribute indicates that a STA Statistics report should be generated
      (triggered) when the dot11RSNAStatsRobustMgmtCCMPReplays value has
      increased more than the threshold value indicated here. The counter
      increase is measured over the last n MSDUs or MPDUs, where n is the value
      of dot11RMRqstSTAStatTrigMeasCount. This attribute is valid only if
      dot11RMRqstType is 7 (STA Statistics), and if
      dot11RMRqstSTAStatRqstGroupID is 16 (dot11RSNAStatsTable) and if the value
      of the attribute is not equal to 0."
   DEFVAL { 0 }
   ::= { dot11RMRequestEntry 74 }

dot11RMRqstSTAStatTrigRsnaTKIPICVErrCntThresh OBJECT-TYPE
   SYNTAX Unsigned32
   MAX-ACCESS read-create
   STATUS current
   DESCRIPTION
      "This attribute indicates that a STA Statistics report should be generated
      (triggered) when the dot11RSNAStatsTKIPICVErrors value has increased more
      than the threshold value indicated here. The counter increase is measured
      over the last n MSDUs or MPDUs, where n is the value of
      dot11RMRqstSTAStatTrigMeasCount. This attribute is valid only if
      dot11RMRqstType is 7 (STA Statistics), and if
      dot11RMRqstSTAStatRqstGroupID is 16 (dot11RSNAStatsTable) and if the value
      of the attribute is not equal to 0."
   DEFVAL { 0 }
   ::= { dot11RMRequestEntry 75 }
```

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```
dot11RMRqstSTAStatTrigRsnaTKIPReplayCntThresh OBJECT-TYPE
   SYNTAX Unsigned32
   MAX-ACCESS read-create
   STATUS current
   DESCRIPTION
      "This attribute indicates that a STA Statistics report should be generated
      (triggered) when the dot11RSNAStatsTKIPReplays value has increased more
      than the threshold value indicated here. The counter increase is measured
      over the last n MSDUs or MPDUs, where n is the value of
      dot11RMRqstSTAStatTrigMeasCount. This attribute is valid only if
      dot11RMRqstType is 7 (STA Statistics), and if
      dot11RMRqstSTAStatRqstGroupID is 16 (dot11RSNAStatsTable) and if the value
      of the attribute is not equal to 0."
   DEFVAL { 0 }
   ::= { dot11RMRequestEntry 76 }

dot11RMRqstSTAStatTrigRsnaCCMPDecryptErrCntThresh OBJECT-TYPE
   SYNTAX Unsigned32
   MAX-ACCESS read-create
   STATUS current
   DESCRIPTION
      "This attribute indicates that a STA Statistics report should be generated
      (triggered) when the dot11RSNAStatsCCMPDecryptErrors value has increased
      more than the threshold value indicated here. The counter increase is
      measured over the last n MSDUs or MPDUs, where n is the value of
      dot11RMRqstSTAStatTrigMeasCount. This attribute is valid only if
      dot11RMRqstType is 7 (STA Statistics), and if
      dot11RMRqstSTAStatRqstGroupID is 16 (dot11RSNAStatsTable) and if the value
      of the attribute is not equal to 0."
   DEFVAL { 0 }
   ::= { dot11RMRequestEntry 77 }

dot11RMRqstSTAStatTrigRsnaCCMPReplayCntThresh OBJECT-TYPE
   SYNTAX Unsigned32
   MAX-ACCESS read-create
   STATUS current
   DESCRIPTION
      "This attribute indicates that a STA Statistics report should be generated
      (triggered) when the dot11RSNAStatsCCMPReplays value has increased more
      than the threshold value indicated here. The counter increase is measured
      over the last n MSDUs or MPDUs, where n is the value of
      dot11RMRqstSTAStatTrigMeasCount. This attribute is valid only if
      dot11RMRqstType is 7 (STA Statistics), and if
      dot11RMRqstSTAStatRqstGroupID is 16 (dot11RSNAStatsTable) and if the value
      of the attribute is not equal to 0."
   DEFVAL { 0 }
   ::= { dot11RMRequestEntry 78 }

-- ************************************************************************
-- * End of dot11RMRequest TABLE
-- ************************************************************************

-- ************************************************************************
-- * Radio Measurement Reports
-- * Report tables contain measurement reports received by this STA or
-- * results of measurements performed by this STA.
-- ************************************************************************
   dot11RMReport OBJECT IDENTIFIER ::= { dot11RadioMeasurement 2 }

-- ************************************************************************
-- * dot11ChannelLoadReport TABLE
-- ************************************************************************
dot11ChannelLoadReportTable OBJECT-TYPE
```


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```
    SYNTAX SEQUENCE OF Dot11ChannelLoadReportEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
    "This table contains the current list of Channel Load reports that have been
       received by the MLME. The report tables are maintained as a FIFO to
       preserve freshness, thus the rows in this table can be deleted for memory
       constraints or other implementation constraints determined by the vendor.
       New rows have different RprtIndex values than those deleted within the
       range limitation of the index. One easy way is to increment RprtIndex for
       new reports being written in the table."
    ::= { dot11RMReport 1 }

dot11ChannelLoadReportEntry OBJECT-TYPE
    SYNTAX Dot11ChannelLoadReportEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
       "An entry in the dot11ChannelLoadReportTable Indexed by
       dot11ChannelLoadRprtIndex."
    INDEX { dot11ChannelLoadRprtIndex }
    ::= { dot11ChannelLoadReportTable 1 }

Dot11ChannelLoadReportEntry ::=
    SEQUENCE {
       dot11ChannelLoadRprtIndex                        Unsigned32,
       dot11ChannelLoadRprtRqstToken                    OCTET STRING,
       dot11ChannelLoadRprtIfIndex                      InterfaceIndex,
       dot11ChannelLoadMeasuringSTAAddr                 MacAddress,
       dot11ChannelLoadRprtChanNumber                   Unsigned32,
       dot11ChannelLoadRprtOperatingClass               Unsigned32,
       dot11ChannelLoadRprtActualStartTime              TSFType,
       dot11ChannelLoadRprtMeasurementDuration          Unsigned32,
       dot11ChannelLoadRprtChannelLoad                  Unsigned32,
       dot11ChannelLoadRprtVendorSpecific               OCTET STRING,
       dot11ChannelLoadRprtMeasurementMode              INTEGER }

dot11ChannelLoadRprtIndex OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
       "Index for Channel Load report elements in dot11ChannelLoadReportTable,
       greater than 0."
    ::= { dot11ChannelLoadReportEntry 1 }

dot11ChannelLoadRprtRqstToken OBJECT-TYPE
    SYNTAX OCTET STRING
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
       "This is a status variable.
       It is written by the SME when a measurement report is completed.

       This attribute indicates the request token that was indicated in the
       Measurement request that generated this measurement report. This should be
       an exact match to the original dot11RMRqstToken attribute. Note that there
       may be  multiple entries in the table that match this value since a single
       request may generate multiple measurement reports."
    ::= { dot11ChannelLoadReportEntry 2 }

dot11ChannelLoadRprtIfIndex OBJECT-TYPE
    SYNTAX InterfaceIndex
    MAX-ACCESS read-only
```

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```
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        The ifIndex of the interface over which this ChannelLoad Report was
        received."
    ::= { dot11ChannelLoadReportEntry 3 }

dot11ChannelLoadMeasuringSTAAddr OBJECT-TYPE
    SYNTAX MacAddress
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        The MAC address of the measuring STA for this row of the Channel Load
        report."
    ::= { dot11ChannelLoadReportEntry 4 }

dot11ChannelLoadRprtChanNumber OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute indicates the channel number used for this Channel Load
        report. The Channel Number is defined only within the indicated Operating
        Class for this measurement report."
    ::= { dot11ChannelLoadReportEntry 5 }

dot11ChannelLoadRprtOperatingClass OBJECT-TYPE
    SYNTAX Unsigned32 (1..255)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute indicates the channel set for this measurement report.
        Country, Operating Class and Channel Number together specify the channel
        frequency and spacing for this measurement report. Valid values of
        Operating Class are shown in Annex E."
    ::= { dot11ChannelLoadReportEntry 6 }

dot11ChannelLoadRprtActualStartTime OBJECT-TYPE
    SYNTAX TSFType
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute indicates the TSF value at the time when the
        measurement started."
    ::= { dot11ChannelLoadReportEntry 7 }

dot11ChannelLoadRprtMeasurementDuration OBJECT-TYPE
    SYNTAX Unsigned32
    UNITS "TUs"
    MAX-ACCESS read-only
```


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```
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute indicates the duration over which the ChannelLoad Report
        was measured."
    ::= { dot11ChannelLoadReportEntry 8 }

dot11ChannelLoadRprtChannelLoad OBJECT-TYPE
    SYNTAX Unsigned32 (0..255)
    UNITS "1/255"
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        Channel Load contains the fractional duration over which the measuring STA
        determined the channel to be busy during the measurement duration."
    ::= { dot11ChannelLoadReportEntry 9 }

dot11ChannelLoadRprtVendorSpecific OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(0..255))
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute provides an envelope for any optional vendor specific
        subelements which may be included in a measurement report element."
    DEFVAL { ''H }
    ::= { dot11ChannelLoadReportEntry 10 }

dot11ChannelLoadRprtMeasurementMode OBJECT-TYPE
SYNTAX INTEGER {
    success(0),
    incapableBit(1),
    refusedBit(2)
    }
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute indicates the outcome status for the measurement request
        which generated this measurement report; status is indicated using the
        following reason codes: 1 indicates this STA is incapable of generating
        the report, 2 indicates this STA is refusing to generate the report, 0
        indicates the STA successfully carried out the measurement request."
    DEFVAL { 0 }
    ::= { dot11ChannelLoadReportEntry 11 }

-- ************************************************************
-- * End of dot11ChannelLoadReport TABLE
-- ************************************************************

-- ************************************************************
-- * dot11NoiseHistogramReport TABLE
-- ************************************************************
dot11NoiseHistogramReportTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11NoiseHistogramReportEntry
```

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```
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
    "This table contains the current list of Noise Histogram reports that have
       been received by the MLME. The report tables are maintained as a FIFO to
       preserve freshness, thus the rows in this table can be deleted for memory
       constraints or other implementation constraints determined by the vendor.
       New rows have different RprtIndex values than those deleted within the
       range limitation of the index. One easy way is to increment RprtIndex for
       new reports being written in the table."
    ::= { dot11RMReport 2 }

dot11NoiseHistogramReportEntry OBJECT-TYPE
    SYNTAX Dot11NoiseHistogramReportEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
       "An entry in the dot11NoiseHistogramReportTable Indexed by
       dot11NoiseHistogramRprtIndex."
    INDEX { dot11NoiseHistogramRprtIndex }
    ::= { dot11NoiseHistogramReportTable 1 }

Dot11NoiseHistogramReportEntry ::=
    SEQUENCE {
       dot11NoiseHistogramRprtIndex                    Unsigned32,
       dot11NoiseHistogramRprtRqstToken                OCTET STRING,
       dot11NoiseHistogramRprtIfIndex                  InterfaceIndex,
       dot11NoiseHistogramMeasuringSTAAddr             MacAddress,
       dot11NoiseHistogramRprtChanNumber               Unsigned32,
       dot11NoiseHistogramRprtOperatingClass           Unsigned32,
       dot11NoiseHistogramRprtActualStartTime          TSFType,
       dot11NoiseHistogramRprtMeasurementDuration      Unsigned32,
       dot11NoiseHistogramRprtAntennaID                Unsigned32,
       dot11NoiseHistogramRprtANPI                     Unsigned32,
       dot11NoiseHistogramRprtIPIDensity0              Unsigned32,
       dot11NoiseHistogramRprtIPIDensity1              Unsigned32,
       dot11NoiseHistogramRprtIPIDensity2              Unsigned32,
       dot11NoiseHistogramRprtIPIDensity3              Unsigned32,
       dot11NoiseHistogramRprtIPIDensity4              Unsigned32,
       dot11NoiseHistogramRprtIPIDensity5              Unsigned32,
       dot11NoiseHistogramRprtIPIDensity6              Unsigned32,
       dot11NoiseHistogramRprtIPIDensity7              Unsigned32,
       dot11NoiseHistogramRprtIPIDensity8              Unsigned32,
       dot11NoiseHistogramRprtIPIDensity9              Unsigned32,
       dot11NoiseHistogramRprtIPIDensity10             Unsigned32,
       dot11NoiseHistogramRprtVendorSpecific           OCTET STRING,
       dot11NoiseHistogramRprtMeasurementMode          INTEGER}

dot11NoiseHistogramRprtIndex OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
       "Index for Noise Histogram elements in dot11NoiseHistogramReportTable,
       greater than 0."
    ::= { dot11NoiseHistogramReportEntry 1 }

dot11NoiseHistogramRprtRqstToken OBJECT-TYPE
    SYNTAX OCTET STRING
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
       "This is a status variable.
       It is written by the SME when a measurement report is completed.
```


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```
        This attribute indicates the request token that was indicated in the
        measurement request that generated this measurement report. This should be
        an exact match to the original dot11RMRqstToken attribute. Note that there
        may be multiple entries in the table that match this value since a single
        request may generate multiple measurement reports."
    ::= { dot11NoiseHistogramReportEntry 2 }

dot11NoiseHistogramRprtIfIndex OBJECT-TYPE
    SYNTAX InterfaceIndex
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        The ifIndex of the interface over which this Noise Histogram report was
        received. "
    ::= { dot11NoiseHistogramReportEntry 3 }

dot11NoiseHistogramMeasuringSTAAddr OBJECT-TYPE
    SYNTAX MacAddress
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        The MAC address of the measuring STA for this row of Noise Histogram
        report."
    ::= { dot11NoiseHistogramReportEntry 4 }

dot11NoiseHistogramRprtChanNumber OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute indicates the channel number used for this Noise Histogram
        report. The Channel Number is defined only within the indicated Operating
        Class for this measurement report."
    ::= { dot11NoiseHistogramReportEntry 5 }

dot11NoiseHistogramRprtOperatingClass OBJECT-TYPE
    SYNTAX Unsigned32 (1..255)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute indicates the channel set for this measurement report.
        Country, Operating Class and Channel Number together specify the channel
        frequency and spacing for this measurement report. Valid values of
        Operating Class are shown in Annex E."
    ::= { dot11NoiseHistogramReportEntry 6 }

dot11NoiseHistogramRprtActualStartTime OBJECT-TYPE
    SYNTAX TSFType
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
```

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```
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute indicates the TSF value at the time when the
        measurement started."
    ::= { dot11NoiseHistogramReportEntry 7 }

dot11NoiseHistogramRprtMeasurementDuration OBJECT-TYPE
    SYNTAX Unsigned32
    UNITS "TUs"
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute indicates the duration over which the Noise Histogram
        report was measured."
    ::= { dot11NoiseHistogramReportEntry 8 }

dot11NoiseHistogramRprtAntennaID OBJECT-TYPE
    SYNTAX Unsigned32 (0..255)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute indicates the identifying number for the antenna(s) or DMG
        antenna(s) used for this measurement."
    ::= { dot11NoiseHistogramReportEntry 9 }

dot11NoiseHistogramRprtANPI OBJECT-TYPE
    SYNTAX Unsigned32 (0..255)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute indicates the Average Noise Power Indicator (ANPI) for this
        Noise Histogram measurement. The ANPI value represents the average noise
        plus interference power on the measured channel at the antenna connector
        during the measurement duration. To calculate ANPI, the STA measures and
        uses IPI in the indicated channel when NAV is equal to 0 (when virtual CS
        mechanism indicates idle channel) except during frame transmission or
        reception."
    ::= { dot11NoiseHistogramReportEntry 10 }

dot11NoiseHistogramRprtIPIDensity0 OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute indicates the measured IPI density for non-IEEE-802.11
        signals with measured power satisfying the condition: Power <= -92 dBm."
    ::= { dot11NoiseHistogramReportEntry 11 }

dot11NoiseHistogramRprtIPIDensity1 OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-only
```


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```
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute indicates the measured IPI density for non-IEEE-802.11
        signals with measured power satisfying the condition: -92 dBm < Power <= -
        9 dBm."
    ::= { dot11NoiseHistogramReportEntry 12 }

dot11NoiseHistogramRprtIPIDensity2 OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute indicates the measured IPI density for non-IEEE-802.11
        signals with measured power satisfying the condition: -89 dBm < Power <= -
        86 dBm."
    ::= { dot11NoiseHistogramReportEntry 13 }

dot11NoiseHistogramRprtIPIDensity3 OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute indicates the measured IPI density for non-IEEE-802.11
        signals with measured power satisfying the condition: -86 dBm < Power <= -
        83 dBm."
    ::= { dot11NoiseHistogramReportEntry 14 }

dot11NoiseHistogramRprtIPIDensity4 OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute indicates the measured IPI density for non-IEEE-802.11
        signals with measured power satisfying the condition: -83 dBm < Power <= -
        80 dBm."
    ::= { dot11NoiseHistogramReportEntry 15 }

dot11NoiseHistogramRprtIPIDensity5 OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute indicates the measured IPI density for non-IEEE-802.11
        signals with measured power satisfying the condition: -80 dBm < Power <= -
        75 dBm."
    ::= { dot11NoiseHistogramReportEntry 16 }

dot11NoiseHistogramRprtIPIDensity6 OBJECT-TYPE
    SYNTAX Unsigned32
```

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```
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute indicates the measured IPI density for non-IEEE-802.11
        signals with measured power satisfying the condition:
        -75 dBm < Power <= -70 dBm."
    ::= { dot11NoiseHistogramReportEntry 17 }

dot11NoiseHistogramRprtIPIDensity7 OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute indicates the measured IPI density for non-IEEE-802.11
        signals with measured power satisfying the condition:
        -70 dBm < Power <= -65 dBm."
    ::= { dot11NoiseHistogramReportEntry 18 }

dot11NoiseHistogramRprtIPIDensity8 OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute indicates the measured IPI density for non-IEEE-802.11
        signals with measured power satisfying the condition:
        -65 dBm < Power <= -60 dBm."
    ::= { dot11NoiseHistogramReportEntry 19 }

dot11NoiseHistogramRprtIPIDensity9 OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute indicates the measured IPI density for non-IEEE-802.11
        signals with measured power satisfying the condition:
        -60 dBm < Power <= -55 dBm."
    ::= { dot11NoiseHistogramReportEntry 20 }

dot11NoiseHistogramRprtIPIDensity10 OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute indicates the measured IPI density for non-IEEE-802.11
        signals with measured power satisfying the condition:
        -55 dBm < Power."
    ::= { dot11NoiseHistogramReportEntry 21 }

dot11NoiseHistogramRprtVendorSpecific OBJECT-TYPE
```


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```
    SYNTAX OCTET STRING (SIZE(0..255))
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
       "This is a status variable.
       It is written by the SME when a measurement report is completed.

       This attribute provides an envelope for any optional vendor specific
       subelements which may be included in a measurement report element."
    DEFVAL { ''H }
    ::= { dot11NoiseHistogramReportEntry 22 }

dot11NoiseHistogramRprtMeasurementMode OBJECT-TYPE
    SYNTAX INTEGER {
       success(0),
       incapableBit(1),
       refusedBit(2) }
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
       "This is a status variable.
       It is written by the SME when a measurement report is completed.

       This attribute indicates the outcome status for the measurement request
       which generated this measurement report; status is indicated using the
       following reason codes: 1 indicates this STA is incapable of generating
       the report, 2 indicates this STA is refusing to generate the report, 0
       indicates the STA successfully carried out the measurement request."
    DEFVAL { 0 }
    ::= { dot11NoiseHistogramReportEntry 23 }

-- ****************************************************************
-- * End of dot11NoiseHistogramReport TABLE
-- ****************************************************************

-- ****************************************************************
-- * dot11BeaconReport TABLE
-- ****************************************************************
dot11BeaconReportTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11BeaconReportEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
    "This table contains the current list of Beacon reports that have been
       received by the MLME. The report tables are maintained as FIFO to preserve
       freshness, thus the rows in this table can be deleted for memory
       constraints or other implementation constraints determined by the vendor.
       New rows have different RprtIndex values than those deleted within the
       range limitation of the index. One easy way is to increment RprtIndex for
       new reports being written in the table."
    ::= { dot11RMReport 3 }

dot11BeaconReportEntry OBJECT-TYPE
    SYNTAX Dot11BeaconReportEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
       "An entry in the dot11BeaconReportTable Indexed by dot11BeaconRprtIndex."
    INDEX { dot11BeaconRprtIndex }
    ::= { dot11BeaconReportTable 1 }

Dot11BeaconReportEntry ::=
    SEQUENCE {
       dot11BeaconRprtIndex                              Unsigned32,
```

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```
        dot11BeaconRprtRqstToken                        OCTET STRING,
        dot11BeaconRprtIfIndex                          InterfaceIndex,
        dot11BeaconMeasuringSTAAddr                     MacAddress,
        dot11BeaconRprtChanNumber                       Unsigned32,
        dot11BeaconRprtOperatingClass                   Unsigned32,
        dot11BeaconRprtActualStartTime                  TSFType,
        dot11BeaconRprtMeasurementDuration              Unsigned32,
        dot11BeaconRprtPhyType                          INTEGER,
        dot11BeaconRprtReportedFrameType                INTEGER,
        dot11BeaconRprtRCPI                             Unsigned32,
        dot11BeaconRprtRSNI                             Unsigned32,
        dot11BeaconRprtBSSID                            MacAddress,
        dot11BeaconRprtAntennaID                        Unsigned32,
        dot11BeaconRprtParentTSF                        TSFType,
        dot11BeaconRprtReportedFrameBody                OCTET STRING,
        dot11BeaconRprtVendorSpecific                   OCTET STRING,
        dot11BeaconRprtMeasurementMode                  INTEGER}

dot11BeaconRprtIndex OBJECT-TYPE
   SYNTAX Unsigned32
   MAX-ACCESS not-accessible
   STATUS current
   DESCRIPTION
      "Index for Beacon reports in dot11BeaconReportTable, greater than 0."
   ::= { dot11BeaconReportEntry 1 }

dot11BeaconRprtRqstToken OBJECT-TYPE
   SYNTAX OCTET STRING
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a status variable.
      It is written by the SME when a measurement report is completed.

      This attribute indicates the request token that was indicated in the
      measurement request that generated this measurement report. This should be
      an exact match to the original dot11RMRqstToken attribute. Note that there
      may be multiple entries in the table that match this value since a single
      request may generate multiple measurement reports."
   ::= { dot11BeaconReportEntry 2 }

dot11BeaconRprtIfIndex OBJECT-TYPE
   SYNTAX InterfaceIndex
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a status variable.
      It is written by the SME when a measurement report is completed.

      The ifIndex of the interface over which this Beacon report was received."
   ::= { dot11BeaconReportEntry 3 }

dot11BeaconMeasuringSTAAddr OBJECT-TYPE
   SYNTAX MacAddress
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a status variable.
      It is written by the SME when a measurement report is completed.

      The MAC address of the measuring STA for this row of Beacon report."
   ::= { dot11BeaconReportEntry 4 }

dot11BeaconRprtChanNumber OBJECT-TYPE
```


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```
    SYNTAX Unsigned32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute indicates the channel number used for this Beacon report.
        The Channel Number is defined only within the indicated Operating Class
        for this measurement report."
    ::= { dot11BeaconReportEntry 5 }

dot11BeaconRprtOperatingClass OBJECT-TYPE
    SYNTAX Unsigned32 (1..255)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute indicates the channel set for this measurement report.
        Country, Operating Class and Channel Number together specify the channel
        frequency and spacing for this measurement report. Valid values of
        Operating Class are shown in Annex E."
    ::= { dot11BeaconReportEntry 6 }

dot11BeaconRprtActualStartTime OBJECT-TYPE
    SYNTAX TSFType
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute indicates the TSF value at the time when the measurement
        started."
    ::= { dot11BeaconReportEntry 7 }

dot11BeaconRprtMeasurementDuration OBJECT-TYPE
    SYNTAX Unsigned32
    UNITS "TUs"
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute indicates the duration over which the Beacon report was
        measured."
    ::= { dot11BeaconReportEntry 8 }

dot11BeaconRprtPhyType OBJECT-TYPE
    SYNTAX INTEGER {
        dsss(2),
        ofdm(4),
        hrdsss(5),
        erp(6),
        ht(7),
        dmg(8),
        vht(9),
        tvht(10),
        s1g(11),
        cdmg(12),
        cmmg(13),
```

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```
        (11ay)edmg (14)}}
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute indicates the PHY Type for this row of Beacon report."
    ::= { dot11BeaconReportEntry 9 }

dot11BeaconRprtReportedFrameType OBJECT-TYPE
    SYNTAX INTEGER { beaconOrProbeResponse(0), measurementPilot(1) }
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute indicates the frame type reported in
        dot11BeaconRprtReportedFrameBody"
    ::= { dot11BeaconReportEntry 10 }

dot11BeaconRprtRCPI OBJECT-TYPE
    SYNTAX Unsigned32 (0..255)
    UNITS "dBm"
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute indicates the received channel power of the PPDU containing
        a Beacon or Probe Response frame as defined 9.4.2.36 (RCPI element).
        RCPIval = Floor((RCPIpower in dBm + 110)*2), for RCPI in the range -110
        dBm to 0 dBm. RCPIval = 220 for RCPI > 0 dBm. RCPIval = 255 when RCPI is
        not available."
    ::= { dot11BeaconReportEntry 11 }

dot11BeaconRprtRSNI OBJECT-TYPE
    SYNTAX Unsigned32 (0..255)
    UNITS "dB"
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute indicates the received signal-to-noise ratio of the beacon
        or Probe Response frame. RSNI is the received signal-to-noise plus
        interference ratio derived from the measured RCPI for the received frame
        and from the measured ANPI for the channel used to receive the frame. RSNI
        is calculated by the ratio of the received signal power (RCPI - ANPI) over
        the noise plus interference power (ANPI) where
        RSNI = [(ratio(dB) + 10) * 2], for ratios in the range -10 dB to +118 dB."
    ::= { dot11BeaconReportEntry 12 }

dot11BeaconRprtBSSID OBJECT-TYPE
    SYNTAX MacAddress
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.
```


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```
        This attribute indicates the BSSID field of the beacon for this row of
        Beacon report."
    ::= { dot11BeaconReportEntry 13 }

dot11BeaconRprtAntennaID OBJECT-TYPE
    SYNTAX Unsigned32 (0..255)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute indicates the identifying number for the antenna(s) or DMG
        antenna used for this measurement."
    ::= { dot11BeaconReportEntry 14 }

dot11BeaconRprtParentTSF OBJECT-TYPE
    SYNTAX TSFType
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute indicates the TSF value of the serving measuring STA's TSF
        value at the time the measuring STA received the Beacon or Probe Response
        frame."
    ::= { dot11BeaconReportEntry 15 }

dot11BeaconRprtReportedFrameBody OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(0..100))
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute indicates the fields and elements from the frame body of
        the Beacon, Measurement Pilot or Probe Response frame being received. All
        reported TIM elements are truncated to 4 octets."
    ::= { dot11BeaconReportEntry 16 }

dot11BeaconRprtVendorSpecific OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(0..255))
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute provides an envelope for any optional vendor specific
        subelements which may be included in a measurement report element."
    DEFVAL { ''H }
    ::= { dot11BeaconReportEntry 17 }

dot11BeaconRprtMeasurementMode OBJECT-TYPE
    SYNTAX INTEGER {
        success(0),
        incapableBit(1),
        refusedBit(2) }
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
```

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```
        It is written by the SME when a measurement report is completed.

        This attribute indicates the outcome status for the measurement request
        which generated this measurement report; status is indicated using the
        following reason codes: 1 indicates this STA is incapable of generating
        the report, 2 indicates this STA is refusing to generate the report, 0
        indicates the STA successfully carried out the measurement request."
    DEFVAL { 0 }
    ::= { dot11BeaconReportEntry 18 }

-- ************************************************************
-- * End of dot11BeaconReport TABLE
-- ************************************************************

-- ************************************************************
-- * dot11FrameReport TABLE
-- ************************************************************
dot11FrameReportTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11FrameReportEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
    "This table contains the current list of Frame reports that have been
        received by the MLME. The report tables are maintained as a FIFO to
        preserve freshness, thus the rows in this table can be deleted for memory
        constraints or other implementation constraints determined by the vendor.
        New rows have different RprtIndex values than those deleted within the
        range limitation of the index. One easy way is to increment RprtIndex for
        new reports being written in the table."
    ::= { dot11RMReport 4 }

dot11FrameReportEntry OBJECT-TYPE
    SYNTAX Dot11FrameReportEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "An entry in the dot11FrameReportTable Indexed by dot11FrameRprtIndex."
    INDEX { dot11FrameRprtIndex }
    ::= { dot11FrameReportTable 1 }

Dot11FrameReportEntry ::=
    SEQUENCE {
        dot11FrameRprtIndex                     Unsigned32,
        dot11FrameRprtIfIndex                   InterfaceIndex,
        dot11FrameRprtRqstToken                 Unsigned32,
        dot11FrameRprtChanNumber                Unsigned32,
        dot11FrameRprtOperatingClass            Unsigned32,
        dot11FrameRprtActualStartTime           TSFType,
        dot11FrameRprtMeasurementDuration       Unsigned32,
        dot11FrameRprtTransmitSTAAddress        MacAddress,
        dot11FrameRprtBSSID                     MacAddress,
        dot11FrameRprtPhyType                   INTEGER,
        dot11FrameRprtAvgRCPI                   Unsigned32,
        dot11FrameRprtLastRSNI                  Unsigned32,
        dot11FrameRprtLastRCPI                  Unsigned32,
        dot11FrameRprtAntennaID                 Unsigned32,
        dot11FrameRprtNumberFrames              Unsigned32,
        dot11FrameRprtVendorSpecific            OCTET STRING,
        dot11FrameRptMeasurementMode            INTEGER}

dot11FrameRprtIndex OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS not-accessible
    STATUS current
```


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```
    DESCRIPTION
        "Index for Frame reports in dot11FrameReportTable, greater than 0."
    ::= { dot11FrameReportEntry 1 }

dot11FrameRprtIfIndex OBJECT-TYPE
    SYNTAX InterfaceIndex
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        The ifIndex of the interface over which this Frame report was received."
    ::= { dot11FrameReportEntry 2 }

dot11FrameRprtRqstToken OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        INDEX for Frame requests in dot11FrameRequestTable that corresponds to
        this row of frame report. Since a single Frame request can generate
        multiple rows in the frame report table, one per BSSID, this
        dot11FrameRprtRqstToken indicates which request this particular row
        indicates. If this row of report is received without a particular request,
        this attribute should be 0"
    ::= { dot11FrameReportEntry 3 }

dot11FrameRprtChanNumber OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute indicates the channel number used for this Frame report.
        The Channel Number is defined only within the indicated Operating Class
        for this measurement report."
    ::= { dot11FrameReportEntry 4 }

dot11FrameRprtOperatingClass OBJECT-TYPE
    SYNTAX Unsigned32 (1..255)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute indicates the channel set for this measurement report.
        Country, Operating Class and Channel Number together specify the channel
        frequency and spacing for this measurement report. Valid values of
        Operating Class are shown in Annex E."
    ::= { dot11FrameReportEntry 5 }

dot11FrameRprtActualStartTime OBJECT-TYPE
    SYNTAX TSFType
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
```

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```
        It is written by the SME when a measurement report is completed.

        This attribute indicates the TSF value at the time when measurement
        started."
    ::= { dot11FrameReportEntry 6 }

dot11FrameRprtMeasurementDuration OBJECT-TYPE
    SYNTAX Unsigned32
    UNITS "TUs"
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute indicates the duration over which the Frame report was
        measured"
    ::= { dot11FrameReportEntry 7 }

dot11FrameRprtTransmitSTAAddress OBJECT-TYPE
    SYNTAX MacAddress
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        The MAC address of STA for this row of Frame report that it has been
        received from."
    ::= { dot11FrameReportEntry 8 }

dot11FrameRprtBSSID OBJECT-TYPE
    SYNTAX MacAddress
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute indicates the BSSID of the BSS of the STA that transmitted
        this frame."
    ::= { dot11FrameReportEntry 9 }

dot11FrameRprtPhyType OBJECT-TYPE
    SYNTAX INTEGER {
        dsss(2),
        ofdm(4),
        hrdsss(5),
        erp(6),
        ht(7),
        dmg(8),
        vht(9),
        tvht(10),
        s1g(11),
        cdmg(12),
        cmmg(13),
        (11ay)edmg(14)}
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute indicates the PHY used for frame reception in this row of
```


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```
        the frame report."
    ::= { dot11FrameReportEntry 10 }

dot11FrameRprtAvgRCPI OBJECT-TYPE
    SYNTAX Unsigned32 (0..255)
    UNITS "dBm"
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute indicates the average value for the received channel power
        of all of the PPDUs containing the frames received and counted in this
        frame report entry as defined 9.4.2.36 (RCPI element).
        RCPIval = Floor((RCPIpower in dBm + 110)*2), for RCPI in the range -110
        dBm to 0 dBm. RCPIval = 220 for RCPI > 0 dBm. RCPIval = 255 when RCPI is
        not available."
    ::= { dot11FrameReportEntry 11 }

dot11FrameRprtLastRSNI OBJECT-TYPE
    SYNTAX Unsigned32 (0..255)
    UNITS "dBm"
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute indicates the received signal-to-noise ratio of the
        received frame. RSNI is the received signal-to-noise plus interference
        ratio derived from the RCPI for the received frame and from the most
        recent ANPI value measured on the channel used to receive the frame. RSNI
        may be calculated by the ratio of the received signal power (RCPI - ANPI)
        over the noise plus interference power (ANPI) where RSNI = [(ratio(dB) +
        10) * 2], for  ratios in the range -10 dB to +118 dB. Other measurement
        techniques are allowed."
    ::= { dot11FrameReportEntry 12 }

dot11FrameRprtLastRCPI OBJECT-TYPE
    SYNTAX Unsigned32 (0..255)
    UNITS "dBm"
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute indicates the received channel power of the most recently
        measured PPDU containing the frame in this frame report entry as defined
        9.4.2.36 (RCPI element).
        RCPIval = Floor((RCPIpower in dBm + 110)*2), for RCPI in the range -110
        dBm to 0 dBm. RCPIval = 220 for RCPI > 0 dBm. RCPIval = 255 when RCPI is
        not available."
    ::= { dot11FrameReportEntry 13 }

dot11FrameRprtAntennaID OBJECT-TYPE
    SYNTAX Unsigned32 (0..255)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.
```

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```
        This attribute indicates the identifying number for the antenna(s) or DMG
        antenna used for this measurement."
    ::= { dot11FrameReportEntry 14 }

dot11FrameRprtNumberFrames  OBJECT-TYPE
    SYNTAX Unsigned32 (0..65535)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute indicates the number of received frames in the Measurement
        Report frame for this row of the Frame report."
    ::= { dot11FrameReportEntry 15 }

dot11FrameRprtVendorSpecific OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(0..255))
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute provides an envelope for any optional vendor specific
        subelements which may be included in a measurement report element."
    DEFVAL { ''H }
    ::= { dot11FrameReportEntry 16 }

dot11FrameRptMeasurementMode OBJECT-TYPE
    SYNTAX INTEGER {
        success(0),
        incapableBit(1),
        refusedBit(2) }
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute indicates the outcome status for the measurement request
        which generated this measurement report; status is indicated using the
        following reason codes: 1 indicates this STA is incapable of generating
        the report, 2 indicates this STA is refusing to generate the report, 0
        indicates the STA successfully carried out the measurement request."
    DEFVAL { 0 }
    ::= { dot11FrameReportEntry 17 }

-- ************************************************************
-- * End of dot11FrameReport TABLE
-- ************************************************************

-- ************************************************************
-- * dot11STAStatisticsReport TABLE
-- ************************************************************
dot11STAStatisticsReportTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11STAStatisticsReportEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
    "This table contains the current list of STA Statistics reports that have
        been received by the MLME. The report tables are maintained as a FIFO to
        preserve freshness, thus the rows in this table can be deleted for memory
        constraints or other implementation constraints determined by the vendor.

```


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```
        New rows have different RprtIndex values than those deleted within the
        range limitation of the index. One easy way is to increment RprtIndex for
        new reports being written in the table."
    ::= { dot11RMReport 5 }

dot11STAStatisticsReportEntry OBJECT-TYPE
    SYNTAX Dot11STAStatisticsReportEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "An entry in the dot11STAStatisticsReportTable Indexed by
        dot11STAStatisticsReportIndex."
    INDEX { dot11STAStatisticsReportIndex }
    ::= { dot11STAStatisticsReportTable 1 }

Dot11STAStatisticsReportEntry ::=
    SEQUENCE {
        dot11STAStatisticsReportIndex                       Unsigned32,
        dot11STAStatisticsReportToken                       OCTET STRING,
        dot11STAStatisticsIfIndex                           InterfaceIndex,
        dot11STAStatisticsSTAAddress                        MacAddress,
        dot11STAStatisticsMeasurementDuration               Unsigned32,
        dot11STAStatisticsGroupID                           INTEGER,
        dot11STAStatisticsTransmittedFragmentCount          Counter32,
        dot11STAStatisticsGroupTransmittedFrameCount        Counter32,
        dot11STAStatisticsFailedCount                       Counter32,
        dot11STAStatisticsRetryCount                        Counter32,
        dot11STAStatisticsMultipleRetryCount                Counter32,
        dot11STAStatisticsFrameDuplicateCount               Counter32,
        dot11STAStatisticsRTSSuccessCount                   Counter32,
        dot11STAStatisticsRTSFailureCount                   Counter32,
        dot11STAStatisticsAckFailureCount                   Counter32,
        dot11STAStatisticsQosTransmittedFragmentCount       Counter32,
        dot11STAStatisticsQosFailedCount                    Counter32,
        dot11STAStatisticsQosRetryCount                     Counter32,
        dot11STAStatisticsQosMultipleRetryCount             Counter32,
        dot11STAStatisticsQosFrameDuplicateCount            Counter32,
        dot11STAStatisticsQosRTSSuccessCount                Counter32,
        dot11STAStatisticsQosRTSFailureCount                Counter32,
        dot11STAStatisticsQosAckFailureCount                Counter32,
        dot11STAStatisticsQosReceivedFragmentCount          Counter32,
        dot11STAStatisticsQosTransmittedFrameCount          Counter32,
        dot11STAStatisticsQosDiscardedFrameCount            Counter32,
        dot11STAStatisticsQosMPDUsReceivedCount             Counter32,
        dot11STAStatisticsQosRetriesReceivedCount           Counter32,
        dot11STAStatisticsReceivedFragmentCount             Counter32,
        dot11STAStatisticsGroupReceivedFrameCount           Counter32,
        dot11STAStatisticsFCSErrorCount                     Counter32,
        dot11STAStatisticsTransmittedFrameCount             Counter32,
        dot11STAStatisticsAPAverageAccessDelay              Unsigned32,
        dot11STAStatisticsAverageAccessDelayBestEffort      Unsigned32,
        dot11STAStatisticsAverageAccessDelayBackground      Unsigned32,
        dot11STAStatisticsAverageAccessDelayVideo           Unsigned32,
        dot11STAStatisticsAverageAccessDelayVoice           Unsigned32,
        dot11STAStatisticsStationCount                      Integer32,
        dot11STAStatisticsChannelUtilization                Unsigned32,
        dot11STAStatisticsVendorSpecific                    OCTET STRING,
        dot11STAStatisticsRprtMeasurementMode               INTEGER,
        dot11STAStatisticsRSNAStatsBIPMICErrors             Counter32,
        dot11STAStatisticsRSNAStatsCMACReplays              Counter32,
        dot11STAStatisticsRSNAStatsRobustMgmtCCMPReplays    Counter32,
        dot11STAStatisticsRSNAStatsTKIPICVErrors            Counter32,
        dot11STAStatisticsRSNAStatsTKIPReplays              Counter32,
        dot11STAStatisticsRSNAStatsCCMPDecryptErrors        Counter32,
```

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```
        dot11STAStatisticsRSNAStatsCCMPReplays              Counter32,
        dot11STAStatisticsReportingReasonSTACounters        OCTET STRING,
        dot11STAStatisticsReportingReasonQosCounters        OCTET STRING,
        dot11STAStatisticsReportingReasonRsnaCounters       OCTET STRING,
        dot11STAStatisticsTransmittedAMSDUCount             Counter32,
        dot11STAStatisticsFailedAMSDUCount                  Counter32,
        dot11STAStatisticsRetryAMSDUCount                   Counter32,
        dot11STAStatisticsMultipleRetryAMSDUCount           Counter32,
        dot11STAStatisticsTransmittedOctetsInAMSDUCount      Counter64,
        dot11STAStatisticsAMSDUAckFailureCount              Counter32,
        dot11STAStatisticsReceivedAMSDUCount                Counter32,
        dot11STAStatisticsReceivedOctetsInAMSDUCount        Counter64,
        dot11STAStatisticsTransmittedAMPDUCount             Counter32,
        dot11STAStatisticsTransmittedMPDUsInAMPDUCount      Counter32,
        dot11STAStatisticsTransmittedOctetsInAMPDUCount     Counter64,
        dot11STAStatisticsAMPDUReceivedCount                Counter32,
        dot11STAStatisticsMPDUInReceivedAMPDUCount          Counter32,
        dot11STAStatisticsReceivedOctetsInAMPDUCount        Counter64,
        dot11STAStatisticsAMPDUDelimiterCRCErrorCount       Counter32,
        dot11STAStatisticsImplicitBARFailureCount           Counter32,
        dot11STAStatisticsExplicitBARFailureCount           Counter32,
        dot11STAStatisticsChannelWidthSwitchCount           Counter32,
        dot11STAStatisticsTwentyMHzFrameTransmittedCount    Counter32,
        dot11STAStatisticsFortyMHzFrameTransmittedCount     Counter32,
        dot11STAStatisticsTwentyMHzFrameReceivedCount       Counter32,
        dot11STAStatisticsFortyMHzFrameReceivedCount        Counter32,
        dot11STAStatisticsPSMPUTTGrantDuration              Counter32,
        dot11STAStatisticsPSMPUTTUsedDuration               Counter32,
        dot11STAStatisticsGrantedRDGUsedCount               Counter32,
        dot11STAStatisticsGrantedRDGUnusedCount             Counter32,
        dot11STAStatisticsTransmittedFramesInGrantedRDGCount Counter32,
        dot11STAStatisticsTransmittedOctetsInGrantedRDGCount Counter64,
        dot11STAStatisticsDualCTSSuccessCount               Counter32,
        dot11STAStatisticsDualCTSFailureCount               Counter32,
        dot11STAStatisticsBeamformingFrameCount             Counter32,
        dot11STAStatisticsSTBCCTSSuccessCount               Counter32,
        dot11STAStatisticsSTBCCTSFailureCount               Counter32,
        dot11STAStatisticsnonSTBCCTSSuccessCount            Counter32,
        dot11STAStatisticsnonSTBCCTSFailureCount            Counter32,
        dot11STAStatisticsAverageMSDUSizeVideo              Unsigned32,
        dot11STAStatisticsAverageMSDUSizeVoice              Unsigned32,
        dot11STAStatisticsAverageBitrateVideo               Unsigned32,
        dot11STAStatisticsAverageBitrateVoice               Unsigned32
    }

dot11STAStatisticsReportIndex OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "Index for STA Statistics reports in dot11STAStatisticsReportTable,
        greater than 0."
    ::= { dot11STAStatisticsReportEntry 1 }

dot11STAStatisticsReportToken OBJECT-TYPE
    SYNTAX OCTET STRING
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute indicates the token that was indicated in the measurement
        request that generated this measurement report. This should be an exact
```


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```
        match to the original dot11RMRqstToken attribute. Note that there may be
        multiple entries in the table that match this value since a single request
        may generate multiple measurement reports."
    ::= { dot11STAStatisticsReportEntry 2 }

dot11STAStatisticsIfIndex OBJECT-TYPE
    SYNTAX InterfaceIndex
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        Identifies the Interface that this row of STA Statistics report has been
        received on"
    ::= { dot11STAStatisticsReportEntry 3 }

dot11STAStatisticsSTAAddress OBJECT-TYPE
    SYNTAX MacAddress
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        The MAC address of the STA that returned this STA Statistics report."
    ::= { dot11STAStatisticsReportEntry 4 }

dot11STAStatisticsMeasurementDuration OBJECT-TYPE
    SYNTAX Unsigned32
    UNITS "TUs"
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute indicates the duration over which the STA Statistics was
        measured. The value 0 for this attribute indicates that the reported
        statistics are a current snapshot of the statistics variables. A nonzero
        value for this attribute indicates that the reported statistics contain
        the difference in the corresponding statistics variables over the
        indicated duration."
    ::= { dot11STAStatisticsReportEntry 5 }

dot11STAStatisticsGroupID OBJECT-TYPE
    SYNTAX INTEGER {
        dot11CountersTable(0),
        dot11MacStatistics(1),
        dot11QosCountersTableforUP0(2),
        dot11QosCountersTableforUP1(3),
        dot11QosCountersTableforUP2(4),
        dot11QosCountersTableforUP3(5),
        dot11QosCountersTableforUP4(6),
        dot11QosCountersTableforUP5(7),
        dot11QosCountersTableforUP6(8),
        dot11QosCountersTableforUP7(9),
        dot11BSSAverageAccessDelays(10)(#4246),
        dot11CountersGroup6Subset1(11), (#3263)
        dot11CountersGroup6Subset2(12),(#3263)(M118)
        dot11CountersGroup6Subset3(13),(#3263)(M118)
        dot11CountersGroup6Subset4(14),(#3263)(M118)
        dot11CountersGroup6Subset5(15),(#3263)(M118)
        dot11RSNAStatsTable(16) }
```

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```
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute indicates the value of dot11RMRqstSTAStatRqstGroupID
        returned from the STA in this STA Statistics report."
    DEFVAL { 0 }
    ::= { dot11STAStatisticsReportEntry 6 }

dot11STAStatisticsTransmittedFragmentCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        If dot11STAStatisticsMeasurementDuration is 0, this attribute indicates
        the value of dot11TransmittedFragmentCount returned from the STA in this
        STA Statistics report. If dot11STAStatisticsMeasurementDuration indicates
        a nonzero value, this attribute indicates the difference in the referenced
        dot11 variable over the indicated duration. This attribute is valid only
        if the dot11STAStatisticsGroupID is 0 and is ignored otherwise."
    ::= { dot11STAStatisticsReportEntry 7 }

dot11STAStatisticsGroupTransmittedFrameCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        If dot11STAStatisticsMeasurementDuration is 0, this attribute indicates
        the value of dot11GroupTransmittedFrameCount returned from the STA in this
        STA Statistics report. If dot11STAStatisticsMeasurementDuration indicates
        a nonzero value, this attribute indicates the difference in the referenced
        dot11 variable over the indicated duration. This attribute is valid only
        if the dot11STAStatisticsGroupID is 0 and is ignored otherwise."
    ::= { dot11STAStatisticsReportEntry 8 }

dot11STAStatisticsFailedCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        If dot11STAStatisticsMeasurementDuration is 0, this attribute indicates
        the value of dot11FailedCount returned from the STA in this STA Statistics
        report. If dot11STAStatisticsMeasurementDuration indicates a nonzero
        value, this attribute indicates the difference in the referenced dot11
        variable over the indicated duration. This attribute is valid only if the
        dot11STAStatisticsGroupID is 0 and is ignored otherwise."
    ::= { dot11STAStatisticsReportEntry 9 }

dot11STAStatisticsRetryCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
```


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```
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        If dot11STAStatisticsMeasurementDuration is 0, this attribute indicates
        the value of dot11RetryCount returned from the STA in this STA Statistics
        report. If dot11STAStatisticsMeasurementDuration indicates a nonzero
        value, this attribute indicates the difference in the referenced dot11
        variable over the indicated duration. This attribute is valid only if the
        dot11STAStatisticsGroupID is 1 and is ignored otherwise."
    ::= { dot11STAStatisticsReportEntry 10 }

dot11STAStatisticsMultipleRetryCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        If dot11STAStatisticsMeasurementDuration is 0, this attribute indicates
        the value of dot11MultipleRetryCount returned from the STA in this STA
        Statistics report. If dot11STAStatisticsMeasurementDuration indicates a
        nonzero value, this attribute indicates the difference in the referenced
        dot11 variable over the indicated duration. This attribute is valid only
        if the dot11STAStatisticsGroupID is 1 and is ignored otherwise."
    ::= { dot11STAStatisticsReportEntry 11 }

dot11STAStatisticsFrameDuplicateCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        If dot11STAStatisticsMeasurementDuration is 0, this attribute indicates
        the value of dot11FrameDuplicateCount returned from the STA in this STA
        Statistics report. If dot11STAStatisticsMeasurementDuration indicates a
        nonzero value, this attribute indicates the difference in the referenced
        dot11 variable over the indicated duration. This attribute is valid only
        if the dot11STAStatisticsGroupID is 1 and is ignored otherwise."
    ::= { dot11STAStatisticsReportEntry 12 }

dot11STAStatisticsRTSSuccessCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        If dot11STAStatisticsMeasurementDuration is 0, this attribute indicates
        the value of dot11RTSSuccessCount returned from the STA in this STA
        Statistics report. If dot11STAStatisticsMeasurementDuration indicates a
        nonzero value, this attribute indicates the difference in the referenced
        dot11 variable over the indicated duration. This attribute is valid only
        if the dot11STAStatisticsGroupID is 1 and is ignored otherwise."
    ::= { dot11STAStatisticsReportEntry 13 }

dot11STAStatisticsRTSFailureCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
```

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```
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        If dot11STAStatisticsMeasurementDuration is 0, this attribute indicates
        the value of dot11RTSFailureCount returned from the STA in this STA
        Statistics report. If dot11STAStatisticsMeasurementDuration indicates a
        nonzero value, this attribute indicates the difference in the referenced
        dot11 variable over the indicated duration. This attribute is valid only
        if the dot11STAStatisticsGroupID is 1 and is ignored otherwise."
    ::= { dot11STAStatisticsReportEntry 14 }

dot11STAStatisticsAckFailureCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        If dot11STAStatisticsMeasurementDuration is 0, this attribute indicates
        the value of dot11AckFailureCount returned from the STA in this STA
        Statistics report. If dot11STAStatisticsMeasurementDuration indicates a
        nonzero value, this attribute indicates the difference in the referenced
        dot11 variable over the indicated duration. This attribute is valid only
        if the dot11STAStatisticsGroupID is 1 and is ignored otherwise."
    ::= { dot11STAStatisticsReportEntry 15 }

dot11STAStatisticsQosTransmittedFragmentCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        If dot11STAStatisticsMeasurementDuration is 0, this attribute indicates
        the value of dot11QosTransmittedFragmentCount returned from the STA in
        this STA Statistics report. If dot11STAStatisticsMeasurementDuration
        indicates a nonzero value, this attribute indicates the difference in the
        referenced dot11 variable over the indicated duration. This attribute is
        valid only if the dot11STAStatisticsGroupID is 2-9 and is ignored
        otherwise."
    ::= { dot11STAStatisticsReportEntry 16 }

dot11STAStatisticsQosFailedCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        If dot11STAStatisticsMeasurementDuration is 0, this attribute indicates
        the value of dot11QosFailedCount returned from the STA in this STA
        Statistics report. If dot11STAStatisticsMeasurementDuration indicates a
        nonzero value, this attribute indicates the difference in the referenced
        dot11 variable over the indicated duration. This attribute is valid only
        if the dot11STAStatisticsGroupID is 2-9 and is ignored otherwise."
    ::= { dot11STAStatisticsReportEntry 17 }

dot11STAStatisticsQosRetryCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
```


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```
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        If dot11STAStatisticsMeasurementDuration is 0, this attribute indicates
        the value of dot11QosRetryCount returned from the STA in this STA
        Statistics report. If dot11STAStatisticsMeasurementDuration indicates a
        nonzero value, this attribute indicates the difference in the referenced
        dot11 variable over the indicated duration. This attribute is valid only
        if the dot11STAStatisticsGroupID is 2-9 and is ignored otherwise."
    ::= { dot11STAStatisticsReportEntry 18 }

dot11STAStatisticsQosMultipleRetryCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        If dot11STAStatisticsMeasurementDuration is 0, this attribute indicates
        the value of dot11QosMultipleRetryCount returned from the STA in this STA
        Statistics report. If dot11STAStatisticsMeasurementDuration indicates a
        nonzero value, this attribute indicates the difference in the referenced
        dot11 variable over the indicated duration. This attribute is valid only
        if the dot11STAStatisticsGroupID is 2-9 and is ignored otherwise."
    ::= { dot11STAStatisticsReportEntry 19 }

dot11STAStatisticsQosFrameDuplicateCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        If dot11STAStatisticsMeasurementDuration is 0, this attribute indicates
        the value of dot11QosFrameDuplicateCount returned from the STA in this STA
        Statistics report. If dot11STAStatisticsMeasurementDuration indicates a
        nonzero value, this attribute indicates the difference in the referenced
        dot11 variable over the indicated duration. This attribute is valid only
        if the dot11STAStatisticsGroupID is 2-9 and is ignored otherwise."
    ::= { dot11STAStatisticsReportEntry 20 }

dot11STAStatisticsQosRTSSuccessCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        If dot11STAStatisticsMeasurementDuration is 0, this attribute indicates
        the value of dot11QosRTSSuccessCount returned from the STA in this STA
        Statistics report. If dot11STAStatisticsMeasurementDuration indicates a
        nonzero value, this attribute indicates the difference in the referenced
        dot11 variable over the indicated duration. This attribute is valid only
        if the dot11STAStatisticsGroupID is 2-9 and is ignored otherwise."
    ::= { dot11STAStatisticsReportEntry 21 }

dot11STAStatisticsQosRTSFailureCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
```

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```
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        If dot11STAStatisticsMeasurementDuration is 0, this attribute indicates
        the value of dot11QosRTSFailureCount returned from the STA in this STA
        Statistics report. If dot11STAStatisticsMeasurementDuration indicates a
        nonzero value, this attribute indicates the difference in the referenced
        dot11 variable over the indicated duration. This attribute is valid only
        if the dot11STAStatisticsGroupID is 2-9 and is ignored otherwise."
    ::= { dot11STAStatisticsReportEntry 22 }

dot11STAStatisticsQosAckFailureCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        If dot11STAStatisticsMeasurementDuration is 0, this attribute indicates
        the value of dot11QosAckFailureCount returned from the STA in this STA
        Statistics report. If dot11STAStatisticsMeasurementDuration indicates a
        nonzero value, this attribute indicates the difference in the referenced
        dot11 variable over the indicated duration. This attribute is valid only
        if the dot11STAStatisticsGroupID is 2-9 and is ignored otherwise."
    ::= { dot11STAStatisticsReportEntry 23 }

dot11STAStatisticsQosReceivedFragmentCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        If dot11STAStatisticsMeasurementDuration is 0, this attribute indicates
        the value of dot11QosReceivedFragmentCount returned from the STA in this
        STA Statistics report. If dot11STAStatisticsMeasurementDuration indicates
        a nonzero value, this attribute indicates the difference in the referenced
        dot11 variable over the indicated duration. This attribute is valid only
        if the dot11STAStatisticsGroupID is 2-9 and is ignored otherwise."
    ::= { dot11STAStatisticsReportEntry 24 }

dot11STAStatisticsQosTransmittedFrameCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        If dot11STAStatisticsMeasurementDuration is 0, this attribute indicates
        the value of dot11QosTransmittedFrameCount returned from the STA in this
        STA Statistics report. If dot11STAStatisticsMeasurementDuration indicates
        a nonzero value, this attribute indicates the difference in the referenced
        dot11 variable over the indicated duration. This attribute is valid only
        if the dot11STAStatisticsGroupID is 2-9 and is ignored otherwise."
    ::= { dot11STAStatisticsReportEntry 25 }

dot11STAStatisticsQosDiscardedFrameCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
```


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```
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        If dot11STAStatisticsMeasurementDuration is 0, this attribute indicates
        the value of dot11QosDiscardedFrameCount returned from the STA in this STA
        Statistics report. If dot11STAStatisticsMeasurementDuration indicates a
        nonzero value, this attribute indicates the difference in the referenced
        dot11 variable over the indicated duration. This attribute is valid only
        if the dot11STAStatisticsGroupID is 2-9 and is ignored otherwise."
    ::= { dot11STAStatisticsReportEntry 26 }

dot11STAStatisticsQosMPDUsReceivedCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        If dot11STAStatisticsMeasurementDuration is 0, this attribute indicates
        the value of dot11QosMPDUsReceivedCount returned from the STA in this STA
        Statistics report. If dot11STAStatisticsMeasurementDuration indicates a
        nonzero value, this attribute indicates the difference in the referenced
        dot11 variable over the indicated duration. This attribute is valid only
        if the dot11STAStatisticsGroupID is 2-9 and is ignored otherwise."
    ::= { dot11STAStatisticsReportEntry 27 }

dot11STAStatisticsQosRetriesReceivedCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        If dot11STAStatisticsMeasurementDuration is 0, this attribute indicates
        the value of dot11QosRetriesReceivedCount returned from the STA in this
        STA Statistics report. If dot11STAStatisticsMeasurementDuration indicates
        a nonzero value, this attribute indicates the difference in the referenced
        dot11 variable over the indicated duration. This attribute is valid only
        if the dot11STAStatisticsGroupID is 2-9 and is ignored otherwise."
    ::= { dot11STAStatisticsReportEntry 28 }

dot11STAStatisticsReceivedFragmentCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        If dot11STAStatisticsMeasurementDuration is 0, this attribute indicates
        the value of dot11ReceivedFragmentCount returned from the STA in this STA
        Statistics report. If dot11STAStatisticsMeasurementDuration indicates a
        nonzero value, this attribute indicates the difference in the referenced
        dot11 variable over the indicated duration. This attribute is valid only
        if the dot11STAStatisticsGroupID is 0 and is ignored otherwise."
    ::= { dot11STAStatisticsReportEntry 29 }

dot11STAStatisticsGroupReceivedFrameCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
```

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```
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        If dot11STAStatisticsMeasurementDuration is 0, this attribute indicates
        the value of dot11GroupReceivedFrameCount returned from the STA in this
        STA Statistics report. If dot11STAStatisticsMeasurementDuration indicates
        a nonzero value, this attribute indicates the difference in the referenced
        dot11 variable over the indicated duration. This attribute is valid only
        if the dot11STAStatisticsGroupID is 0 and is ignored otherwise."
    ::= { dot11STAStatisticsReportEntry 30 }

dot11STAStatisticsFCSErrorCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        If dot11STAStatisticsMeasurementDuration is 0, this attribute indicates
        the value of dot11FCSErrorCount returned from the STA in this STA
        Statistics report. If dot11STAStatisticsMeasurementDuration indicates a
        nonzero value, this attribute indicates the difference in the referenced
        dot11 variable over the indicated duration. This attribute is valid only
        if the dot11STAStatisticsGroupID is 0 and is ignored otherwise."
    ::= { dot11STAStatisticsReportEntry 31 }

dot11STAStatisticsTransmittedFrameCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        If dot11STAStatisticsMeasurementDuration is 0, this attribute indicates
        the value of dot11TransmittedFrameCount returned from the STA in this STA
        Statistics report. If dot11STAStatisticsMeasurementDuration indicates a
        nonzero value, this attribute indicates the difference in the referenced
        dot11 variable over the indicated duration. This attribute is valid only
        if the dot11STAStatisticsGroupID is 0 and is ignored otherwise."
    ::= { dot11STAStatisticsReportEntry 32 }

dot11STAStatisticsAPAverageAccessDelay OBJECT-TYPE
    SYNTAX Unsigned32 (0..255)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        If dot11STAStatisticsMeasurementDuration is 0, this attribute indicates
        the value of the AP Average Access Delay (AAD)  returned from the STA in
        this STA Statistics report. If dot11STAStatisticsMeasurementDuration
        indicates a nonzero value, this attribute indicates the difference in the
        referenced access delay value over the indicated duration. This attribute
        is valid only if the dot11STAStatisticsGroupID is 10 and is ignored
        otherwise."
    ::= { dot11STAStatisticsReportEntry 33 }

dot11STAStatisticsAverageAccessDelayBestEffort OBJECT-TYPE
    SYNTAX Unsigned32 (0..255)
    MAX-ACCESS read-only
```


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```
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        If dot11STAStatisticsMeasurementDuration is 0, this attribute indicates
        the value of the Average Access Delay (AAD) for the Best Effort Access
        Category returned from the STA in this STA Statistics report. If
        dot11STAStatisticsMeasurementDuration indicates a nonzero value, this
        attribute indicates the difference in the referenced access delay value
        over the indicated duration. This attribute is valid only if the
        dot11STAStatisticsGroupID is 10 and is ignored otherwise."
    ::= { dot11STAStatisticsReportEntry 34 }

dot11STAStatisticsAverageAccessDelayBackground OBJECT-TYPE
    SYNTAX Unsigned32 (0..255)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        If dot11STAStatisticsMeasurementDuration is 0, this attribute indicates
        the value of the Average Access Delay (AAD) for the Background Access
        Category returned from the STA in this STA Statistics report. If
        dot11STAStatisticsMeasurementDuration indicates a nonzero value, this
        attribute indicates the difference in the referenced access delay value
        over the indicated duration. This attribute is valid only if the
        dot11STAStatisticsGroupID is 10 and is ignored otherwise."
    ::= { dot11STAStatisticsReportEntry 35 }

dot11STAStatisticsAverageAccessDelayVideo OBJECT-TYPE
    SYNTAX Unsigned32 (0..255)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        If dot11STAStatisticsMeasurementDuration is 0, this attribute indicates
        the value of the Average Access Delay (AAD) for the Video Access Category
        returned from the STA in this STA Statistics report. If
        dot11STAStatisticsMeasurementDuration indicates a nonzero value, this
        attribute indicates the difference in the referenced access delay value
        over the indicated duration. This attribute is valid only if the
        dot11STAStatisticsGroupID is 10 and is ignored otherwise."
    ::= { dot11STAStatisticsReportEntry 36 }

dot11STAStatisticsAverageAccessDelayVoice OBJECT-TYPE
    SYNTAX Unsigned32 (0..255)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        If dot11STAStatisticsMeasurementDuration is 0, this attribute indicates
        the value of the Average Access Delay (AAD) for the Voice Access Category
        returned from the STA in this STA Statistics report. If
        dot11STAStatisticsMeasurementDuration indicates a nonzero value, this
        attribute indicates the difference in the referenced access delay value
        over the indicated duration. This attribute is valid only if the
        dot11STAStatisticsGroupID is 10 and is ignored otherwise."
    ::= { dot11STAStatisticsReportEntry 37 }
```

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```
dot11STAStatisticsStationCount OBJECT-TYPE
   SYNTAX Integer32 (-255..255)
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a status variable.
      It is written by the SME when a measurement report is completed.

      If dot11STAStatisticsMeasurementDuration is 0, this attribute indicates
      the value of dot11AssociatedStationCount returned from the STA in this STA
      Statistics report. If dot11STAStatisticsMeasurementDuration indicates a
      nonzero value, this attribute indicates the difference in the referenced
      dot11 variable over the indicated duration. This attribute is valid only
      if the dot11STAStatisticsGroupID is 10 and is ignored otherwise."
   ::= { dot11STAStatisticsReportEntry 38 }

dot11STAStatisticsChannelUtilization OBJECT-TYPE
   SYNTAX Unsigned32 (0..255)
   UNITS "1/255"
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a status variable.
      It is written by the SME when a measurement report is completed.

      If dot11STAStatisticsMeasurementDuration is 0, this attribute indicates
      the value of the Channel Utilization returned from the STA in this STA
      Statistics report. If dot11STAStatisticsMeasurementDuration indicates a
      nonzero value, this attribute indicates the difference in the Channel
      Utilization value over the indicated duration. The Channel Utilization is
      the time fraction during which the AP sensed the channel busy. This
      attribute is valid only if the dot11STAStatisticsGroupID is 10 and is
      ignored otherwise."
   ::= { dot11STAStatisticsReportEntry 39 }

dot11STAStatisticsVendorSpecific OBJECT-TYPE
   SYNTAX OCTET STRING (SIZE(0..255))
   MAX-ACCESS read-create
   STATUS current
   DESCRIPTION
      "This is a status variable.
      It is written by the SME when a measurement report is completed.

      This attribute provides an envelope for any optional vendor specific
      subelements which may be included in a measurement report element."
   DEFVAL { ''H }
   ::= { dot11STAStatisticsReportEntry 40 }

dot11STAStatisticsRprtMeasurementMode OBJECT-TYPE
SYNTAX INTEGER {
   success(0),
   incapableBit(1),
   refusedBit(2)
   }
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a status variable.
      It is written by the SME when a measurement report is completed.

      This attribute indicates the outcome status for the measurement request
      which generated this measurement report; status is indicated using the
      following reason codes: 1 indicates this STA is incapable of generating
```


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```
        the report, 2 indicates this STA is refusing to generate the report, 0
        indicates the STA successfully carried out the measurement request."
    DEFVAL { 0 }
    ::= { dot11STAStatisticsReportEntry 41 }

dot11STAStatisticsRSNAStatsBIPMICErrors OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        If dot11STAStatisticsMeasurementDuration is 0, this attribute indicates
        the value of dot11RSNAStatsBIPMICErrors returned from the STA in this STA
        Statistics report. If dot11STAStatisticsMeasurementDuration indicates a
        nonzero value, this attribute indicates the difference in the referenced
        dot11 variable over the indicated duration. This attribute is valid only
        if the dot11STAStatisticsGroupID is 16 and is ignored otherwise."
    ::= { dot11STAStatisticsReportEntry 42 }

dot11STAStatisticsRSNAStatsCMACReplays OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        If dot11STAStatisticsMeasurementDuration is 0, this attribute indicates
        the value of dot11RSNAStatsCMACReplays returned from the STA in this STA
        Statistics report. If dot11STAStatisticsMeasurementDuration indicates a
        nonzero value, this attribute indicates the difference in the referenced
        dot11 variable over the indicated duration. This attribute is valid only
        if the dot11STAStatisticsGroupID is 16 and is ignored otherwise."
    ::= { dot11STAStatisticsReportEntry 43 }

dot11STAStatisticsRSNAStatsRobustMgmtCCMPReplays OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        If dot11STAStatisticsMeasurementDuration is 0, this attribute indicates
        the value of dot11RSNAStatsRobustMgmtCCMPReplays returned from the STA in
        this STA Statistics report. If dot11STAStatisticsMeasurementDuration
        indicates a nonzero value, this attribute indicates the difference in the
        referenced dot11 variable over the indicated duration. This attribute is
        valid only if the dot11STAStatisticsGroupID is 16 and is ignored
        otherwise."
    ::= { dot11STAStatisticsReportEntry 44 }

dot11STAStatisticsRSNAStatsTKIPICVErrors OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        If dot11STAStatisticsMeasurementDuration is 0, this attribute indicates
        the value of dot11RSNAStatsTKIPICVErrors returned from the STA in this STA
```

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```
        Statistics report. If dot11STAStatisticsMeasurementDuration indicates a
        nonzero value, this attribute indicates the difference in the referenced
        dot11 variable over the indicated duration. This attribute is valid only
        if the dot11STAStatisticsGroupID is 16 and is ignored otherwise."
    ::= { dot11STAStatisticsReportEntry 45 }

dot11STAStatisticsRSNAStatsTKIPReplays OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        If dot11STAStatisticsMeasurementDuration is 0, this attribute indicates
        the value of dot11RSNAStatsTKIPReplays returned from the STA in this STA
        Statistics report. If dot11STAStatisticsMeasurementDuration indicates a
        nonzero value, this attribute indicates the difference in the referenced
        dot11 variable over the indicated duration. This attribute is valid only
        if the dot11STAStatisticsGroupID is 16 and is ignored otherwise."
    ::= { dot11STAStatisticsReportEntry 46 }

dot11STAStatisticsRSNAStatsCCMPDecryptErrors OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        If dot11STAStatisticsMeasurementDuration is 0, this attribute indicates
        the value of dot11RSNAStatsCCMPDecryptErrors returned from the STA in this
        STA Statistics report. If dot11STAStatisticsMeasurementDuration indicates
        a nonzero value, this attribute indicates the difference in the referenced
        dot11 variable over the indicated duration. This attribute is valid only
        if the dot11STAStatisticsGroupID is 16 and is ignored otherwise."
    ::= { dot11STAStatisticsReportEntry 47 }

dot11STAStatisticsRSNAStatsCCMPReplays OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        If dot11STAStatisticsMeasurementDuration is 0, this attribute indicates
        the value of dot11RSNAStatsCCMPReplays returned from the STA in this STA
        Statistics report. If dot11STAStatisticsMeasurementDuration indicates a
        nonzero value, this attribute indicates the difference in the referenced
        dot11 variable over the indicated duration. This attribute is valid only
        if the dot11STAStatisticsGroupID is 16 and is ignored otherwise."
    ::= { dot11STAStatisticsReportEntry 48 }

dot11STAStatisticsReportingReasonSTACounters OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(0..1))
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute indicates the trigger reason(s) for this Statistics report.
        Each bit indicates a different trigger condition. When the bit is set to
```


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```
        1, it indicates that the listed trigger threshold has been exceeded:
        B0 (least significant bit): dot11Failed,
        B1: dot11FCSError,
        B2: dot11MultipleRetry,
        B3: dot11FrameDuplicate,
        B4: dot11RTSFailure,
        B5: dot11AckFailureCount,
        B6: dot11Retry,
        B7: Reserved.
        This attribute is valid only if the dot11STAStatisticsGroupID is 0 and is
        ignored otherwise."
    ::= { dot11STAStatisticsReportEntry 49 }

dot11STAStatisticsReportingReasonQosCounters OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(0..1))
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute indicates the trigger reason(s) for this Statistics report.
        Each bit indicates a different trigger condition. When the bit is set to
        1, it indicates that the listed trigger threshold has been exceeded:
        B0 (least significant bit): dot11QoSFailed,
        B1: dot11QoSRetry,
        B2: dot11QoSMultipleRetry,
        B3: dot11QoSFrameDuplicate,
        B4: dot11QoSRTSFailure,
        B5: dot11QoSAckFailure,
        B6: dot11QoSDiscarded,
        B7: Reserved.
        This attribute is valid only if the dot11STAStatisticsGroupID is 2-9 and
        is ignored otherwise."
    ::= { dot11STAStatisticsReportEntry 50 }

dot11STAStatisticsReportingReasonRsnaCounters OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(0..1))
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute indicates the trigger reason(s) for this Statistics report.
        Each bit indicates a different trigger condition. When the bit is set to
        1, it indicates that the listed trigger threshold has been exceeded:
        B0 (least significant bit): dot11RSNAStatsBIPMICErrors,
        B1: dot11RSNAStatsCMACReplays,
        B2: dot11RSNAStatsRobustMgmtCCMPReplays,
        B3: dot11RSNAStatsTKIPICVErrors,
        B4: dot11RSNAStatsCCMPReplays,
        B5: dot11RSNAStatsCCMPDecryptErrors,
        B6: dot11RSNAStatsCCMPReplays,
        B7: Reserved.
        This attribute is valid only if the dot11STAStatisticsGroupID is 16 and is
        ignored otherwise."
    ::= { dot11STAStatisticsReportEntry 51 }

dot11STAStatisticsTransmittedAMSDUCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
```

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```
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        If dot11STAStatisticsMeasurementDuration is zero, this attribute indicates
        the value of dot11TransmittedAMSDUCount returned from the STA in this STA
        Statistics report. If dot11STAStatisticsMeasurementDuration indicates a
        nonzero value, this attribute indicates the difference in the referenced
        dot11 variable over the indicated duration. This attribute is valid only
        if the dot11STAStatisticsGroupID is 11 and is ignored otherwise."
    ::= { dot11STAStatisticsReportEntry 52 }

dot11STAStatisticsFailedAMSDUCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        If dot11STAStatisticsMeasurementDuration is zero, this attribute indicates
        the value of dot11FailedAMSDUCount returned from the STA in this STA
        Statistics report. If dot11STAStatisticsMeasurementDuration indicates a
        nonzero value, this attribute indicates the difference in the referenced
        dot11 variable over the indicated duration. This attribute is valid only
        if the dot11STAStatisticsGroupID is 11 and is ignored otherwise."
    ::= { dot11STAStatisticsReportEntry 53 }

dot11STAStatisticsRetryAMSDUCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        If dot11STAStatisticsMeasurementDuration is zero, this attribute indicates
        the value of dot11RetryAMSDUCount returned from the STA in this STA
        Statistics report. If dot11STAStatisticsMeasurementDuration indicates a
        nonzero value, this attribute indicates the difference in the referenced
        dot11 variable over the indicated duration. This attribute is valid only
        if the dot11STAStatisticsGroupID is 11 and is ignored otherwise."
    ::= { dot11STAStatisticsReportEntry 54 }

dot11STAStatisticsMultipleRetryAMSDUCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        If dot11STAStatisticsMeasurementDuration is zero, this attribute indicates
        the value of dot11MultipleRetryAMSDUCount returned from the STA in this
        STA Statistics report. If dot11STAStatisticsMeasurementDuration indicates
        a nonzero value, this attribute indicates the difference in the referenced
        dot11 variable over the indicated duration. This attribute is valid only
        if the dot11STAStatisticsGroupID is 11 and is ignored otherwise."
    ::= { dot11STAStatisticsReportEntry 55 }

dot11STAStatisticsTransmittedOctetsInAMSDUCount OBJECT-TYPE
    SYNTAX Counter64
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
```


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```
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        If dot11STAStatisticsMeasurementDuration is zero, this attribute indicates
        the value of dot11TransmittedOctetsInAMSDUCount returned from the STA in
        this STA Statistics report. If dot11STAStatisticsMeasurementDuration
        indicates a nonzero value, this attribute indicates the difference in the
        referenced dot11 variable over the indicated duration. This attribute is
        valid only if the dot11STAStatisticsGroupID is 11 and is ignored
        otherwise."
    ::= { dot11STAStatisticsReportEntry 56 }

dot11STAStatisticsAMSDUAckFailureCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        If dot11STAStatisticsMeasurementDuration is zero, this attribute indicates
        the value of dot11AMSDUAckFailureCount returned from the STA in this STA
        Statistics report. If dot11STAStatisticsMeasurementDuration indicates a
        nonzero value, this attribute indicates the difference in the referenced
        dot11 variable over the indicated duration. This attribute is valid only
        if the dot11STAStatisticsGroupID is 11 and is ignored otherwise."
    ::= { dot11STAStatisticsReportEntry 57 }

dot11STAStatisticsReceivedAMSDUCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        If dot11STAStatisticsMeasurementDuration is zero, this attribute indicates
        the value of dot11ReceivedAMSDUCount returned from the STA in this STA
        Statistics report. If dot11STAStatisticsMeasurementDuration indicates a
        nonzero value, this attribute indicates the difference in the referenced
        dot11 variable over the indicated duration. This attribute is valid only
        if the dot11STAStatisticsGroupID is 11 and is ignored otherwise."
    ::= { dot11STAStatisticsReportEntry 58 }

dot11STAStatisticsReceivedOctetsInAMSDUCount OBJECT-TYPE
    SYNTAX Counter64
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        If dot11STAStatisticsMeasurementDuration is zero, this attribute indicates
        the value of dot11ReceivedOctetsInAMSDUCount returned from the STA in this
        STA Statistics report. If dot11STAStatisticsMeasurementDuration indicates
        a nonzero value, this attribute indicates the difference in the referenced
        dot11 variable over the indicated duration. This attribute is valid only
        if the dot11STAStatisticsGroupID is 11 and is ignored otherwise."
    ::= { dot11STAStatisticsReportEntry 59 }

dot11STAStatisticsTransmittedAMPDUCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
```

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```
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        If dot11STAStatisticsMeasurementDuration is zero, this attribute indicates
        the value of dot11TransmittedAMPDUCount returned from the STA in this STA
        Statistics report. If dot11STAStatisticsMeasurementDuration indicates a
        nonzero value, this attribute indicates the difference in the referenced
        dot11 variable over the indicated duration. This attribute is valid only
        if the dot11STAStatisticsGroupID is 12 and is ignored otherwise."
    ::= { dot11STAStatisticsReportEntry 60 }

dot11STAStatisticsTransmittedMPDUsInAMPDUCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        If dot11STAStatisticsMeasurementDuration is zero, this attribute indicates
        the value of dot11TransmittedMPDUsInAMPDUCount returned from the STA in
        this STA Statistics report. If dot11STAStatisticsMeasurementDuration
        indicates a nonzero value, this attribute indicates the difference in the
        referenced dot11 variable over the indicated duration. This attribute is
        valid only if the dot11STAStatisticsGroupID is 12 and is ignored
        otherwise."
    ::= { dot11STAStatisticsReportEntry 61 }

dot11STAStatisticsTransmittedOctetsInAMPDUCount OBJECT-TYPE
    SYNTAX Counter64
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        If dot11STAStatisticsMeasurementDuration is zero, this attribute indicates
        the value of dot11TransmittedOctetsInAMPDUCount returned from the STA in
        this STA Statistics report. If dot11STAStatisticsMeasurementDuration
        indicates a nonzero value, this attribute indicates the difference in the
        referenced dot11 variable over the indicated duration. This attribute is
        valid only if the dot11STAStatisticsGroupID is 12 and is ignored
        otherwise."
    ::= { dot11STAStatisticsReportEntry 62 }

dot11STAStatisticsAMPDUReceivedCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        If dot11STAStatisticsMeasurementDuration is zero, this attribute indicates
        the value of dot11AMPDUReceivedCount returned from the STA in this STA
        Statistics report. If dot11STAStatisticsMeasurementDuration indicates a
        nonzero value, this attribute indicates the difference in the referenced
        dot11 variable over the indicated duration. This attribute is valid only
        if the dot11STAStatisticsGroupID is 12 and is ignored otherwise."
    ::= { dot11STAStatisticsReportEntry 63 }


dot11STAStatisticsMPDUInReceivedAMPDUCount OBJECT-TYPE
```


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```
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
       "This is a status variable.
       It is written by the SME when a measurement report is completed.

       If dot11STAStatisticsMeasurementDuration is zero, this attribute indicates
       the value of dot11MPDUInReceivedAMPDUCount returned from the STA in this
       STA Statistics report. If dot11STAStatisticsMeasurementDuration indicates
       a nonzero value, this attribute indicates the difference in the referenced
       dot11 variable over the indicated duration. This attribute is valid only
       if the dot11STAStatisticsGroupID is 12 and is ignored otherwise."
    ::= { dot11STAStatisticsReportEntry 64 }


dot11STAStatisticsReceivedOctetsInAMPDUCount OBJECT-TYPE
    SYNTAX Counter64
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
       "This is a status variable.
       It is written by the SME when a measurement report is completed.

       If dot11STAStatisticsMeasurementDuration is zero, this attribute indicates
       the value of dot11ReceivedOctetsInAMPDUCount returned from the STA in this
       STA Statistics report. If dot11STAStatisticsMeasurementDuration indicates
       a nonzero value, this attribute indicates the difference in the referenced
       dot11 variable over the indicated duration. This attribute is valid only
       if the dot11STAStatisticsGroupID is 12 and is ignored otherwise."
    ::= { dot11STAStatisticsReportEntry 65 }


dot11STAStatisticsAMPDUDelimiterCRCErrorCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
       "This is a status variable.
       It is written by the SME when a measurement report is completed.

       If dot11STAStatisticsMeasurementDuration is zero, this attribute indicates
       the value of dot11AMPDUDelimiterCRCErrorCount returned from the STA in
       this STA Statistics report. If dot11STAStatisticsMeasurementDuration
       indicates a nonzero value, this attribute indicates the difference in the
       referenced dot11 variable over the indicated duration. This attribute is
       valid only if the dot11STAStatisticsGroupID is 12 and is ignored
       otherwise."
    ::= { dot11STAStatisticsReportEntry 66 }

dot11STAStatisticsImplicitBARFailureCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
       "This is a status variable.
       It is written by the SME when a measurement report is completed.

       If dot11STAStatisticsMeasurementDuration is zero, this attribute indicates
       the value of dot11ImplicitBARFailureCount returned from the STA in this
       STA Statistics report. If dot11STAStatisticsMeasurementDuration indicates
       a nonzero value, this attribute indicates the difference in the referenced
       dot11 variable over the indicated duration. This attribute is valid only
       if the dot11STAStatisticsGroupID is 13 and is ignored otherwise."
```

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```
    ::= { dot11STAStatisticsReportEntry 67 }

dot11STAStatisticsExplicitBARFailureCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        If dot11STAStatisticsMeasurementDuration is zero, this attribute indicates
        the value of dot11ExplicitBARFailureCount returned from the STA in this
        STA Statistics report. If dot11STAStatisticsMeasurementDuration indicates
        a nonzero value, this attribute indicates the difference in the referenced
        dot11 variable over the indicated duration. This attribute is valid only
        if the dot11STAStatisticsGroupID is 13 and is ignored otherwise."
    ::= { dot11STAStatisticsReportEntry 68 }

dot11STAStatisticsChannelWidthSwitchCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        If dot11STAStatisticsMeasurementDuration is zero, this attribute indicates
        the value of dot11ChannelWidthSwitchCount returned from the STA in this
        STA Statistics report. If dot11STAStatisticsMeasurementDuration indicates
        a nonzero value, this attribute indicates the difference in the referenced
        dot11 variable over the indicated duration. This attribute is valid only
        if the dot11STAStatisticsGroupID is 13 and is ignored otherwise."
    ::= { dot11STAStatisticsReportEntry 69 }

dot11STAStatisticsTwentyMHzFrameTransmittedCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        If dot11STAStatisticsMeasurementDuration is zero, this attribute indicates
        the value of dot11TwentyMHzFrameTransmittedCount returned from the STA in
        this STA Statistics report. If dot11STAStatisticsMeasurementDuration
        indicates a nonzero value, this attribute indicates the difference in the
        referenced dot11 variable over the indicated duration. This attribute is
        valid only if the dot11STAStatisticsGroupID is 13 and is ignored
        otherwise."
    ::= { dot11STAStatisticsReportEntry 70 }

dot11STAStatisticsFortyMHzFrameTransmittedCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        If dot11STAStatisticsMeasurementDuration is zero, this attribute indicates
        the value of dot11FortyMHzFrameTransmittedCount returned from the STA in
        this STA Statistics report. If dot11STAStatisticsMeasurementDuration
        indicates a nonzero value, this attribute indicates the difference in the
        referenced dot11 variable over the indicated duration. This attribute is
```


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```
        valid only if the dot11STAStatisticsGroupID is 13 and is ignored
        otherwise."
    ::= { dot11STAStatisticsReportEntry 71 }

dot11STAStatisticsTwentyMHzFrameReceivedCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        If dot11STAStatisticsMeasurementDuration is zero, this attribute indicates
        the value of dot11TwentyMHzFrameReceivedCount returned from the STA in
        this STA Statistics report. If dot11STAStatisticsMeasurementDuration
        indicates a nonzero value, this attribute indicates the difference in the
        referenced dot11 variable over the indicated duration. This attribute is
        valid only if the dot11STAStatisticsGroupID is 13 and is ignored
        otherwise."
    ::= { dot11STAStatisticsReportEntry 72 }

dot11STAStatisticsFortyMHzFrameReceivedCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        If dot11STAStatisticsMeasurementDuration is zero, this attribute indicates
        the value of dot11FortyMHzFrameReceivedCount returned from the STA in this
        STA Statistics report. If dot11STAStatisticsMeasurementDuration indicates
        a nonzero value, this attribute indicates the difference in the referenced
        dot11 variable over the indicated duration. This attribute is valid only
        if the dot11STAStatisticsGroupID is 13 and is ignored otherwise."
    ::= { dot11STAStatisticsReportEntry 73 }

dot11STAStatisticsPSMPUTTGrantDuration OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS deprecated(#3263)
    DESCRIPTION
        "Deprecated as the related feature has been removed from the
        standard.(#3263)
        This is a status variable.
        It is written by the SME when a measurement report is completed.

        If dot11STAStatisticsMeasurementDuration is zero, this attribute indicates
        the value of dot11PSMPUTTGrantDuration returned from the STA in this STA
        Statistics report. If dot11STAStatisticsMeasurementDuration indicates a
        nonzero value, this attribute indicates the difference in the referenced
        dot11 variable over the indicated duration. This attribute is valid only
        if the dot11STAStatisticsGroupID is 13 and is ignored otherwise."
    ::= { dot11STAStatisticsReportEntry 74 }

dot11STAStatisticsPSMPUTTUsedDuration OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS deprecated(#3263)
    DESCRIPTION
        "Deprecated as the related feature has been removed from the
        standard.(#3263)
        This is a status variable.
        It is written by the SME when a measurement report is completed.
```

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```
        If dot11STAStatisticsMeasurementDuration is zero, this attribute indicates
        the value of dot11PSMPUTTUsedDuration returned from the STA in this STA
        Statistics report. If dot11STAStatisticsMeasurementDuration indicates a
        nonzero value, this attribute indicates the difference in the referenced
        dot11 variable over the indicated duration. This attribute is valid only
        if the dot11STAStatisticsGroupID is 13 and is ignored otherwise."
    ::= { dot11STAStatisticsReportEntry 75 }

dot11STAStatisticsGrantedRDGUsedCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        If dot11STAStatisticsMeasurementDuration is zero, this attribute indicates
        the value of dot11GrantedRDGUsedCount returned from the STA in this STA
        Statistics report. If dot11STAStatisticsMeasurementDuration indicates a
        nonzero value, this attribute indicates the difference in the referenced
        dot11 variable over the indicated duration. This attribute is valid only
        if the dot11STAStatisticsGroupID is 14 and is ignored otherwise."
    ::= { dot11STAStatisticsReportEntry 76 }

dot11STAStatisticsGrantedRDGUnusedCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        If dot11STAStatisticsMeasurementDuration is zero, this attribute indicates
        the value of dot11GrantedRDGUnusedCount returned from the STA in this STA
        Statistics report. If dot11STAStatisticsMeasurementDuration indicates a
        nonzero value, this attribute indicates the difference in the referenced
        dot11 variable over the indicated duration. This attribute is valid only
        if the dot11STAStatisticsGroupID is 14 and is ignored otherwise."
    ::= { dot11STAStatisticsReportEntry 77 }

dot11STAStatisticsTransmittedFramesInGrantedRDGCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        If dot11STAStatisticsMeasurementDuration is zero, this attribute indicates
        the value of dot11TransmittedFramesInGrantedRDGCount returned from the STA
        in this STA Statistics report. If dot11STAStatisticsMeasurementDuration
        indicates a nonzero value, this attribute indicates the difference in the
        referenced dot11 variable over the indicated duration. This attribute is
        valid only if the dot11STAStatisticsGroupID is 14 and is ignored
        otherwise."
    ::= { dot11STAStatisticsReportEntry 78 }

dot11STAStatisticsTransmittedOctetsInGrantedRDGCount OBJECT-TYPE
    SYNTAX Counter64
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
```


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```
        It is written by the SME when a measurement report is completed.

        If dot11STAStatisticsMeasurementDuration is zero, this attribute indicates
        the value of dot11TransmittedOctetsInGrantedRDGCount returned from the STA
        in this STA Statistics report. If dot11STAStatisticsMeasurementDuration
        indicates a nonzero value, this attribute indicates the difference in the
        referenced dot11 variable over the indicated duration. This attribute is
        valid only if the dot11STAStatisticsGroupID is 14 and is ignored
        otherwise."
    ::= { dot11STAStatisticsReportEntry 79 }

dot11STAStatisticsDualCTSSuccessCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        If dot11STAStatisticsMeasurementDuration is zero, this attribute indicates
        the value of dot11DualCTSSuccessCount returned from the STA in this STA
        Statistics report. If dot11STAStatisticsMeasurementDuration indicates a
        nonzero value, this attribute indicates the difference in the referenced
        dot11 variable over the indicated duration. This attribute is valid only
        if the dot11STAStatisticsGroupID is 14 and is ignored otherwise."
    ::= { dot11STAStatisticsReportEntry 80 }

dot11STAStatisticsDualCTSFailureCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        If dot11STAStatisticsMeasurementDuration is zero, this attribute indicates
        the value of dot11DualCTSFailureCount returned from the STA in this STA
        Statistics report. If dot11STAStatisticsMeasurementDuration indicates a
        nonzero value, this attribute indicates the difference in the referenced
        dot11 variable over the indicated duration. This attribute is valid only
        if the dot11STAStatisticsGroupID is 14 and is ignored otherwise."
    ::= { dot11STAStatisticsReportEntry 81 }

dot11STAStatisticsBeamformingFrameCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        If dot11STAStatisticsMeasurementDuration is zero, this attribute indicates
        the value of dot11BeamformingFrameCount returned from the STA in this STA
        Statistics report. If dot11STAStatisticsMeasurementDuration indicates a
        nonzero value, this attribute indicates the difference in the referenced
        dot11 variable over the indicated duration. This attribute is valid only
        if the dot11STAStatisticsGroupID is 15 and is ignored otherwise."
    ::= { dot11STAStatisticsReportEntry 84 }

dot11STAStatisticsSTBCCTSSuccessCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
```

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```
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        If dot11STAStatisticsMeasurementDuration is zero, this attribute indicates
        the value of dot11STBCCTSSuccessCount returned from the STA in this STA
        Statistics report. If dot11STAStatisticsMeasurementDuration indicates a
        nonzero value, this attribute indicates the difference in the referenced
        dot11 variable over the indicated duration. This attribute is valid only
        if the dot11STAStatisticsGroupID is 15 and is ignored otherwise."
    ::= { dot11STAStatisticsReportEntry 85 }

dot11STAStatisticsSTBCCTSFailureCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        If dot11STAStatisticsMeasurementDuration is zero, this attribute indicates
        the value of dot11STBCCTSFailureCount returned from the STA in this STA
        Statistics report. If dot11STAStatisticsMeasurementDuration indicates a
        nonzero value, this attribute indicates the difference in the referenced
        dot11 variable over the indicated duration. This attribute is valid only
        if the dot11STAStatisticsGroupID is 15 and is ignored otherwise."
    ::= { dot11STAStatisticsReportEntry 86 }

dot11STAStatisticsnonSTBCCTSSuccessCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        If dot11STAStatisticsMeasurementDuration is zero, this attribute indicates
        the value of dot11nonSTBCCTSSuccessCount returned from the STA in this STA
        Statistics report. If dot11STAStatisticsMeasurementDuration indicates a
        nonzero value, this attribute indicates the difference in the referenced
        dot11 variable over the indicated duration. This attribute is valid only
        if the dot11STAStatisticsGroupID is 15 and is ignored otherwise."
    ::= { dot11STAStatisticsReportEntry 87 }

dot11STAStatisticsnonSTBCCTSFailureCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        If dot11STAStatisticsMeasurementDuration is zero, this attribute indicates
        the value of dot11nonSTBCCTSFailureCount returned from the STA in this STA
        Statistics report. If dot11STAStatisticsMeasurementDuration indicates a
        nonzero value, this attribute indicates the difference in the referenced
        dot11 variable over the indicated duration. This attribute is valid only
        if the dot11STAStatisticsGroupID is 15 and is ignored otherwise."
    ::= { dot11STAStatisticsReportEntry 88 }

dot11STAStatisticsAverageMSDUSizeVideo OBJECT-TYPE
    SYNTAX Unsigned32 (0..7935)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
```


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```
        "This is a status variable.
        It is written by the SME when a measurement report is completed or
        by an external management entity.
        Changes from an external management entity take effect as soon as
        practical in the implementation.

        If dot11STAStatisticsMeasurementDuration is zero, this attribute indicates
        the value of the Average MSDU size for the Video Access Category returned
        from the STA in this STA Statistics report. If
        dot11STAStatisticsMeasurementDuration indicates a nonzero value, this
        attribute indicates the difference in the referenced size over the
        indicated duration. Changes by an external management entity are ignored
        when dot11STAStatisticsMeasurementDuration is nonzero."
    DEFVAL { 1401 }
    ::= { dot11STAStatisticsReportEntry 89 }

dot11STAStatisticsAverageMSDUSizeVoice OBJECT-TYPE
    SYNTAX Unsigned32 (0..7935)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed or by an
        external management entity. Changes from an external management entity
        take effect as soon as practical in the implementation.

        If dot11STAStatisticsMeasurementDuration is zero, this attribute indicates
        the value of the Average MSDU size for the Voice Access Category returned
        from the STA in this STA Statistics report. If
        dot11STAStatisticsMeasurementDuration indicates a nonzero value, this
        attribute indicates the difference in the referenced size over the
        indicated duration. Changes by an external management entity are ignored
        when dot11STAStatisticsMeasurementDuration is nonzero."
    DEFVAL { 365 }
    ::= { dot11STAStatisticsReportEntry 90 }

dot11STAStatisticsAverageBitrateVideo OBJECT-TYPE
    SYNTAX Unsigned32 (0..4294967295)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed or by an
        external management entity.
        Changes from an external management entity take effect as soon as
        practical in the implementation.

        If dot11STAStatisticsMeasurementDuration is zero, this attribute indicates
        the value of the Average PHY bit rate of MPDUs transmitted and received
        using the Video Access Category returned from the STA in this STA
        Statistics report. If dot11STAStatisticsMeasurementDuration indicates a
        nonzero value, this attribute indicates the difference in the referenced
        size over the indicated duration. Changes by an external management entity
        are ignored when dot11STAStatisticsMeasurementDuration is nonzero."
    ::= { dot11STAStatisticsReportEntry 91 }

dot11STAStatisticsAverageBitrateVoice OBJECT-TYPE
    SYNTAX Unsigned32 (0..4294967295)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed or by an
        external management entity.
```

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```
        Changes from an external management entity take effect as soon as
        practical in the implementation.

        If dot11STAStatisticsMeasurementDuration is zero, this attribute indicates
        the value of the Average PHY bit rate of MPDUs transmitted and received
        using the Voice Access Category returned from the STA in this STA
        Statistics report. If dot11STAStatisticsMeasurementDuration indicates a
        nonzero value, this attribute indicates the difference in the referenced
        size over the indicated duration. Changes by an external management entity
        are ignored when dot11STAStatisticsMeasurementDuration is nonzero."
::= { dot11STAStatisticsReportEntry 92 }

-- ****************************************************************
-- * End of dot11STAStatisticsReport TABLE
-- ****************************************************************

-- ****************************************************************
-- * dot11LCIReport TABLE
-- ****************************************************************
dot11LCIReportTable OBJECT-TYPE
   SYNTAX SEQUENCE OF Dot11LCIReportEntry
   MAX-ACCESS not-accessible
   STATUS current
   DESCRIPTION
   "This table contains the current list of LCI reports that have been received
      by the MLME. The report tables are maintained as a FIFO to preserve
      freshness, thus the rows in this table can be deleted for memory
      constraints or other implementation constraints determined by the vendor.
      New rows have different RprtIndex values than those deleted within the
      range limitation of the index. One easy way is to increment RprtIndex for
      new reports being written in the table."
   ::= { dot11RMReport 6 }

dot11LCIReportEntry OBJECT-TYPE
   SYNTAX Dot11LCIReportEntry
   MAX-ACCESS not-accessible
   STATUS current
   DESCRIPTION
      "An entry in the dot11LCIReportTable Indexed by dot11LCIReportIndex."
   INDEX { dot11LCIReportIndex }
   ::= { dot11LCIReportTable 1 }

Dot11LCIReportEntry ::=
   SEQUENCE {
      dot11LCIReportIndex                          Unsigned32,
      dot11LCIReportToken                          OCTET STRING,
      dot11LCIIfIndex                              InterfaceIndex,
      dot11LCISTAAddress                           MacAddress,
      dot11LCILatitudeUncertainty                  Unsigned32,
      dot11LCILatitudeInteger                      Integer32,
      dot11LCILatitudeFraction                     Integer32,
      dot11LCILongitudeUncertainty                 Unsigned32,
      dot11LCILongitudeInteger                     Integer32,
      dot11LCILongitudeFraction                    Integer32,
      dot11LCIAltitudeType                         INTEGER,
      dot11LCIAltitudeUncertainty                  Unsigned32,
      dot11LCIAltitude                             Integer32,
      dot11LCIDatum                                Unsigned32,
      dot11LCIAzimuthType                          INTEGER,
      dot11LCIAzimuthResolution                    Unsigned32,
      dot11LCIAzimuth                              Integer32,
      dot11LCIVendorSpecific                       OCTET STRING,
      dot11LCIRprtMeasurementMode                  INTEGER}
```


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```
dot11LCIReportIndex OBJECT-TYPE
   SYNTAX Unsigned32
   MAX-ACCESS not-accessible
   STATUS current
   DESCRIPTION
      "Index for LCI reports in dot11LCIReportTable, greater than 0."
   ::= { dot11LCIReportEntry 1 }

dot11LCIReportToken OBJECT-TYPE
   SYNTAX OCTET STRING
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a status variable.
      It is written by the SME when a measurement report is completed.

      This attribute indicates the token that was indicated in the measurement
      request that generated this measurement report. This should be an exact
      match to the original dot11RMRqstToken attribute. Note that there may be
      multiple entries in the table that match this value since a single request
      may generate multiple measurement reports."
   ::= { dot11LCIReportEntry 2 }

dot11LCIIfIndex OBJECT-TYPE
   SYNTAX InterfaceIndex
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a status variable.
      It is written by the SME when a measurement report is completed.

      Identifies the Interface that this row of LCI report has been received on"
   ::= { dot11LCIReportEntry 3 }

dot11LCISTAAddress OBJECT-TYPE
   SYNTAX MacAddress
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a status variable.
      It is written by the SME when a measurement report is completed.

      The MAC address of the STA that returned this LCI report."
   ::= { dot11LCIReportEntry 4 }

dot11LCILatitudeUncertainty OBJECT-TYPE
   SYNTAX Unsigned32 (0..63)
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a status variable.
      It is written by the SME when a measurement report is completed.

      This attribute indicates the latitude uncertainty as 6 bits."
   ::= { dot11LCIReportEntry 5 }

dot11LCILatitudeInteger OBJECT-TYPE
   SYNTAX Integer32 (-359..359)
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a status variable.
      It is written by the SME when a measurement report is completed.
```

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```
        This attribute indicates the latitude as a 34-bit fixed point value
        consisting of 9 bits of integer and 25 bits of fraction. This field
        contains the 9 bits of integer portion of Latitude."
    ::= { dot11LCIReportEntry 6 }

dot11LCILatitudeFraction OBJECT-TYPE
    SYNTAX Integer32 (-16777215..16777215)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute indicates the latitude as a 34-bit fixed point value
        consisting of 9 bits of integer and 25 bits of fraction. This field
        contains the 25 bits of fraction portion of Latitude."
    ::= { dot11LCIReportEntry 7 }

dot11LCILongitudeUncertainty OBJECT-TYPE
    SYNTAX Unsigned32 (0..63)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute indicates the longitude uncertainty as 6 bits."
    ::= { dot11LCIReportEntry 8 }

dot11LCILongitudeInteger OBJECT-TYPE
    SYNTAX Integer32 (-359..359)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute indicates the longitude as a 34-bit fixed point value
        consisting of 9 bits of integer and 25 bits of fraction. This field
        contains the 9 bits of integer portion of Longitude."
    ::= { dot11LCIReportEntry 9 }

dot11LCILongitudeFraction OBJECT-TYPE
    SYNTAX Integer32 (-16777215..16777215)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute indicates the longitude as a 34-bit fixed point value
        consisting of 9 bits of integer and 25 bits of fraction. This field
        contains the 25 bits of fraction portion of Longitude."
    ::= { dot11LCIReportEntry 10 }

dot11LCIAltitudeType OBJECT-TYPE
    SYNTAX INTEGER { meters(1), floors(2) }
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute indicates the altitude Type. Codes defined are:
```


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```
        meters : in 2s complement fixed-point 22-bit integer part with 8-bit
        fraction
        floors : in 2s complement fixed-point 22-bit integer part with 8-bit
        fraction. "
    ::= { dot11LCIReportEntry 11 }

dot11LCIAltitudeUncertainty OBJECT-TYPE
    SYNTAX Unsigned32 (0..63)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute indicates the altitude resolution as 6 bits indicating the
        number of valid bits in the altitude."
    ::= { dot11LCIReportEntry 12 }

dot11LCIAltitude OBJECT-TYPE
    SYNTAX Integer32 (-536870912..536870911)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute indicates the altitude as a 30-bit value defined by the
        Altitude type field. The field is encoded as a 2s complement fixed-point
        22-bit integer part with 8-bit fraction."
    ::= { dot11LCIReportEntry 13 }

-- reserved: 14. Was dot11LCIAltitudeFraction.

dot11LCIDatum OBJECT-TYPE
    SYNTAX Unsigned32 (0..255)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute indicates the datum as an 8-bit value encoding the
        horizontal and vertical references used for the coordinates given in this
        LCI."
    ::= { dot11LCIReportEntry 15 }

dot11LCIAzimuthType OBJECT-TYPE
    SYNTAX INTEGER { frontSurfaceOfSTA(0), radioBeam(1) }
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute indicates the azimuth Type as a one bit attribute encoding
        the type of Azimuth. Codes defined are: front surface of STA : in 2s
        complement fixed-point 9-bit integer; and radio beam : in 2s complement
        fixed-point 9-bit integer"
    ::= { dot11LCIReportEntry 16 }

dot11LCIAzimuthResolution OBJECT-TYPE
    SYNTAX Unsigned32 (0..15)
    MAX-ACCESS read-only
    STATUS current
```

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```
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute indicates the azimuth Resolution as 4 bits indicating the
        number of valid bits in the azimuth."
    ::= { dot11LCIReportEntry 17 }

dot11LCIAzimuth OBJECT-TYPE
    SYNTAX Integer32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute indicates the azimuth as a 9-bit value defined by the
        Azimuth Type field.The field is encoded as a 2s complement fixed-point 9-
        bit integer horizontal angle in degrees from true north."
    ::= { dot11LCIReportEntry 18 }

dot11LCIVendorSpecific OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(0..255))
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute provides an envelope for any optional vendor specific
        subelements which may be included in a measurement report element."
    DEFVAL { ''H }
    ::= { dot11LCIReportEntry 19 }

dot11LCIRprtMeasurementMode OBJECT-TYPE
    SYNTAX INTEGER {
        success(0),
        incapableBit(1),
        refusedBit(2) }
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute indicates the outcome status for the measurement request
        which generated this measurement report; status is indicated using the
        following reason codes: 1 indicates this STA is incapable of generating
        the report, 2 indicates this STA is refusing to generate the report, 0
        indicates the STA successfully carried out the measurement request."
    DEFVAL { 0 }
    ::= { dot11LCIReportEntry 20 }

-- ********************************************************************
-- * End of dot11LCIReport TABLE
-- ********************************************************************

-- ********************************************************************
-- * dot11TransmitStreamReport TABLE
-- ********************************************************************

dot11TransmitStreamReportTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11TransmitStreamReportEntry
    MAX-ACCESS not-accessible
```


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```
    STATUS current
    DESCRIPTION
        "This table contains the current list of Transmit Delay Metrics reports
        that have been received by the MLME. The report tables are maintained as a
        FIFO to preserve freshness, thus the rows in this table can be deleted for
        memory constraints or other implementation constraints determined by the
        vendor. New rows have different RprtIndex values than those deleted within
        the range limitation of the index. One easy way is to increment RprtIndex
        for new reports being written in the table."
    ::= { dot11RMReport 7 }

dot11TransmitStreamReportEntry OBJECT-TYPE
    SYNTAX Dot11TransmitStreamReportEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "An entry in the dot11TransmitStreamReportTable Indexed by
        dot11TransmitStreamRprtIndex."
    INDEX { dot11TransmitStreamRprtIndex }
    ::= { dot11TransmitStreamReportTable 1 }

Dot11TransmitStreamReportEntry ::=
    SEQUENCE {
        dot11TransmitStreamRprtIndex                    Unsigned32,
        dot11TransmitStreamRprtRqstToken                OCTET STRING,
        dot11TransmitStreamRprtIfIndex                  InterfaceIndex,
        dot11TransmitStreamMeasuringSTAAddr             MacAddress,
        dot11TransmitStreamRprtActualStartTime          TSFType,
        dot11TransmitStreamRprtMeasurementDuration      Unsigned32,
        dot11TransmitStreamRprtPeerSTAAddress           MacAddress,
        dot11TransmitStreamRprtTID                      Unsigned32,
        dot11TransmitStreamRprtAverageQueueDelay        Unsigned32,
        dot11TransmitStreamRprtAverageTransmitDelay     Unsigned32,
        dot11TransmitStreamRprtTransmittedMSDUCount     Unsigned32,
        dot11TransmitStreamRprtMSDUDiscardedCount       Unsigned32,
        dot11TransmitStreamRprtMSDUFailedCount          Unsigned32,
        dot11TransmitStreamRprtMultipleRetryCount       Unsigned32,
        dot11TransmitStreamRprtCFPollsLostCount         Unsigned32,
        dot11TransmitStreamRprtBin0Range                Unsigned32,
        dot11TransmitStreamRprtDelayHistogram           OCTET STRING,
        dot11TransmitStreamRprtReason                   INTEGER,
        dot11TransmitStreamRprtVendorSpecific           OCTET STRING,
        dot11TransmitStreamRprtMeasurementMode          INTEGER}

dot11TransmitStreamRprtIndex OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "Index for Transmit Delay Metrics Report elements in
        dot11TransmitStreamReportTable, greater than 0."
    ::= { dot11TransmitStreamReportEntry 1 }

dot11TransmitStreamRprtRqstToken OBJECT-TYPE
    SYNTAX OCTET STRING
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute indicates the request token that was indicated in the
        measurement request that generated this measurement report. This should be
        an exact match to the original dot11RMRqstToken attribute. Note that there
```

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```
        may be multiple entries in the table that match this value since a single
        request may generate multiple measurement reports."
    ::= { dot11TransmitStreamReportEntry 2 }

dot11TransmitStreamRprtIfIndex OBJECT-TYPE
    SYNTAX InterfaceIndex
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        The ifIndex of the interface on which this TransmitStream Report was
        received."
    ::= { dot11TransmitStreamReportEntry 3 }

dot11TransmitStreamMeasuringSTAAddr OBJECT-TYPE
    SYNTAX MacAddress
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        The MAC address of the measuring STA for this row of Transmit Delay
        Metrics report."
    ::= { dot11TransmitStreamReportEntry 4 }

dot11TransmitStreamRprtActualStartTime OBJECT-TYPE
    SYNTAX TSFType
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute indicates the TSF value at the time when the measurement
        started or for a triggered Transmit Stream/Category Measurement report the
        TSF value at the reporting QoS STA when the trigger condition was met."
    ::= { dot11TransmitStreamReportEntry 5 }

dot11TransmitStreamRprtMeasurementDuration OBJECT-TYPE
    SYNTAX Unsigned32
    UNITS "TUs"
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute indicates the duration over which the Transmit Delay
        Metrics Report was measured. In a triggered Transmit Stream/Category
        Measurement report, metrics are reported over a number of transmitted
        MSDUs rather than a duration, hence Measurement Duration is equal to 0."
    ::= { dot11TransmitStreamReportEntry 6 }

dot11TransmitStreamRprtPeerSTAAddress OBJECT-TYPE
    SYNTAX MacAddress
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.
```


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```
        The MAC address present in the Address 1 field of the measured  Data
        frames for this row of Transmit Stream/Category Measurement report."
    ::= { dot11TransmitStreamReportEntry 7 }

dot11TransmitStreamRprtTID OBJECT-TYPE
    SYNTAX Unsigned32 (0..16)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute indicates the TC or TS for which traffic is to be measured.
        Values 0 to 15 are defined. Values 16-255 are reserved."
    ::= { dot11TransmitStreamReportEntry 8 }

dot11TransmitStreamRprtAverageQueueDelay OBJECT-TYPE
    SYNTAX Unsigned32
    UNITS "TUs"
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute indicates the average delay of the frames (MSDUs) that are
        passed to the MAC during the measurement duration for the indicated
        destination and the indicated Traffic Identifier. Queue Delay is measured
        from the time the MSDU is passed to the MAC until the transmission
        starts."
    ::= { dot11TransmitStreamReportEntry 9 }

dot11TransmitStreamRprtAverageTransmitDelay OBJECT-TYPE
    SYNTAX Unsigned32
    UNITS "TUs"
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute indicates the average delay of the frames (MSDUs) that are
        successfully transmitted during the measurement duration for the indicated
        destination and the indicated Traffic Identifier. Delay is measured from
        the time the MSDU is passed to the MAC until the Ack frame is received
        from the intermediate destination."
    ::= { dot11TransmitStreamReportEntry 10}

dot11TransmitStreamRprtTransmittedMSDUCount OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute indicates the number of MSDUs to the peer STA for the TC,
        or TS given by the Traffic Identifier successfully transmitted in the
        measurement duration."
    ::= {dot11TransmitStreamReportEntry 11}

dot11TransmitStreamRprtMSDUDiscardedCount OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-only
```

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```
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute indicates the number of MSDUs to the peer STA for the TC,
        or TS given by the Traffic Identifier discarded due either to the number
        of transmit attempts exceeding dot11ShortRetryLimit as appropriate, or due
        to the MSDU lifetime having been reached."
    ::= {dot11TransmitStreamReportEntry 12}

dot11TransmitStreamRprtMSDUFailedCount OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute indicates the number of MSDUs to the peer STA for the TC,
        or TS given by the Traffic Identifier discarded during the measurement
        duration due to the number of transmit attempts exceeding
        dot11ShortRetryLimit as appropriate."
    ::= {dot11TransmitStreamReportEntry 13}

dot11TransmitStreamRprtMultipleRetryCount OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute indicates the number of MSDUs for the TC, or TS given by
        the Traffic Identifier that are successfully transmitted after more than
        one retransmission attempt."
    ::= {dot11TransmitStreamReportEntry 14}

dot11TransmitStreamRprtCFPollsLostCount OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-only
    STATUS deprecated
    DESCRIPTION
        "Deprecated as the related feature has been removed from IEEE Std 802.11.
        This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute indicates the number of QoS (+)CF-Poll frames transmitted
        to the peer STA where there was no response from the QoS STA."
    ::= {dot11TransmitStreamReportEntry 15}

dot11TransmitStreamRprtBin0Range OBJECT-TYPE
    SYNTAX Unsigned32
    UNITS "TUs"
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute indicates the delay range for Bin 0 of the delay
        histogram."
    ::= { dot11TransmitStreamReportEntry 16 }
```


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```
dot11TransmitStreamRprtDelayHistogram OBJECT-TYPE
   SYNTAX OCTET STRING (SIZE (6))
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a status variable.
      It is written by the SME when a measurement report is completed.

      This attribute indicates the histogram of delay of the frames (MSDUs) that
      are successfully transmitted during the measurement duration for the
      indicated Traffic Identifier and the indicated destination. Delay is
      measured from the time the MSDU is passed to the MAC until the Ack frame
      is received from the intermediate destination, in units of TUs."
   ::= { dot11TransmitStreamReportEntry 17 }

dot11TransmitStreamRprtReason OBJECT-TYPE
   SYNTAX INTEGER {
      averageTrigger(0),
      consecutiveTrigger(1),
      delayTrigger(2) }
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a status variable.
      It is written by the SME when a measurement report is completed.

      This attribute indicates the Reason field indicating the reason that the
      measuring QoS STA sent the Transmit Stream/Category measurement report."
   DEFVAL { 0 }
   ::= { dot11TransmitStreamReportEntry 18 }

dot11TransmitStreamRprtVendorSpecific OBJECT-TYPE
   SYNTAX OCTET STRING (SIZE(0..255))
   MAX-ACCESS read-create
   STATUS current
   DESCRIPTION
      "This is a status variable.
      It is written by the SME when a measurement report is completed.

      This attribute provides an envelope for any optional vendor specific
      subelements which may be included in a measurement report element."
   DEFVAL { ''H }
   ::= { dot11TransmitStreamReportEntry 19 }

dot11TransmitStreamRprtMeasurementMode OBJECT-TYPE
   SYNTAX INTEGER {
      success(0),
      incapableBit(1),
      refusedBit(2) }
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a status variable.
      It is written by the SME when a measurement report is completed.

      This attribute indicates the outcome status for the measurement request
      which generated this measurement report; status is indicated using the
      following reason codes: 1 indicates this STA is incapable of generating
      the report, 2 indicates this STA is refusing to generate the report, 0
      indicates the STA successfully carried out the measurement request."
   DEFVAL { 0 }
   ::= { dot11TransmitStreamReportEntry 20 }

-- ************************************************************
```

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```
-- * End of dot11TransmitStreamReport TABLE
-- ************************************************************************

-- ************************************************************************
-- * Radio Measurement Configuration Information
-- ************************************************************************
   dot11RMConfig OBJECT IDENTIFIER ::= { dot11RadioMeasurement 3 }

-- ************************************************************************
-- * dot11APChannelReport TABLE
-- ************************************************************************
dot11APChannelReportTable OBJECT-TYPE
   SYNTAX SEQUENCE OF Dot11APChannelReportEntry
   MAX-ACCESS not-accessible
   STATUS current
   DESCRIPTION
      "AP Channel Report information, in tabular form."
   ::= { dot11RMConfig 1 }

dot11APChannelReportEntry OBJECT-TYPE
   SYNTAX Dot11APChannelReportEntry
   MAX-ACCESS not-accessible
   STATUS current
   DESCRIPTION
      "An entry in the dot11APChannelReportTable. Each entry in the table is
      indexed by dot11APChannelReportIndex."
   INDEX { dot11APChannelReportIndex }
   ::= { dot11APChannelReportTable 1 }

Dot11APChannelReportEntry ::=
   SEQUENCE {
      dot11APChannelReportIndex                    Unsigned32,
      dot11APChannelReportIfIndex                  InterfaceIndex,
      dot11APChannelReportOperatingClass           Unsigned32,
      dot11APChannelReportChannelList              OCTET STRING}

dot11APChannelReportIndex OBJECT-TYPE
   SYNTAX Unsigned32
   MAX-ACCESS not-accessible
   STATUS current
   DESCRIPTION
      "Index for AP channel report entry in dot11APChannelReportTable, greater
      than 0."
   ::= { dot11APChannelReportEntry 1 }

dot11APChannelReportIfIndex OBJECT-TYPE
   SYNTAX InterfaceIndex
   MAX-ACCESS read-create
   STATUS current
   DESCRIPTION
      "This is a status variable.
      It is written by the SME when a measurement report is completed.

      The ifIndex for this row of the AP channel report."
   ::= { dot11APChannelReportEntry 2 }

dot11APChannelReportOperatingClass OBJECT-TYPE
   SYNTAX Unsigned32 (1..255)
   MAX-ACCESS read-create
   STATUS current
   DESCRIPTION
      "This is a status variable.
      It is written by the SME when a measurement report is completed.
```


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```
        This attribute indicates the channel set for this AP Channel report.
        Country, Operating Class and Channel Number together specify the channel
        frequency and spacing for this measurement report. Valid values of
        Operating Class are shown in Annex E."
    ::= { dot11APChannelReportEntry 3 }

dot11APChannelReportChannelList OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(0..255))
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute lists the specific channels in this AP Channel report. Each
        octet indicates a different channel within the indicated Operating Class.
        This list of channels is the Channel List field in the AP Channel Report
        element described in 9.4.2.34 (AP Channel Report element). "
    DEFVAL { ''H }
    ::= { dot11APChannelReportEntry 4 }

-- ****************************************************************
-- * End of dot11APChannelReportTable TABLE
-- ****************************************************************

-- ****************************************************************
-- * dot11RMNeighborReport TABLE
-- ****************************************************************
dot11RMNeighborReportNextIndex OBJECT-TYPE
    SYNTAX Unsigned32 (0..255)
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "Identifies the next available index for managing the neighbor report
        table. If this attribute is 0, it indicates that the neighbor report
        feature is not configurable via SNMP, or the table is full and new rows
        cannot be accepted."
    ::= { dot11RMConfig 2 }

dot11RMNeighborReportTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11RMNeighborReportEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
    "This table contains pertinent information on a collection of BSSIDs that are
        candidates to which STAs can roam. The rows are created using
        createAndWait method and fill in the attributes. When the rowStatus is set
        to active, the row can be included in Neighbor Report elements. If there
        is an error, the rowStatus is set to notReady by SME. Since this table
        contains all Neighbor Report element entries for all interfaces enabled
        with the neighbor report feature, it is possible to have too many entries
        for one interface, while still remaining under the MaxTableSize. In that
        situation, SME includes neighbor report entries only with lower
        dot11RMNeighborReportIFIndex up to the maximum possible number of entries
        for a particular interface identified by ifIndex. SME sets the rowStatus
        to notInService for those rows that cannot be included in the Neighbor
        Report element for that interface."
    ::= { dot11RMConfig 3 }

dot11RMNeighborReportEntry OBJECT-TYPE
    SYNTAX Dot11RMNeighborReportEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
```

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```
        "An entry in the dot11RMNeighborReportTable"
    INDEX { dot11RMNeighborReportIndex }
    ::= { dot11RMNeighborReportTable 1 }

Dot11RMNeighborReportEntry ::=
    SEQUENCE {
        dot11RMNeighborReportIndex                          Unsigned32,
        dot11RMNeighborReportIfIndex                        InterfaceIndex,
        dot11RMNeighborReportBSSID                          MacAddress,
        dot11RMNeighborReportAPReachability                 INTEGER,
        dot11RMNeighborReportSecurity                       TruthValue,
        dot11RMNeighborReportCapSpectrumMgmt                TruthValue,
        dot11RMNeighborReportCapQoS                         TruthValue,
        dot11RMNeighborReportCapAPSD                        TruthValue,
        dot11RMNeighborReportCapRM                          TruthValue,
        dot11RMNeighborReportCapDelayBlockAck               TruthValue,
        dot11RMNeighborReportCapImmediateBlockAck           TruthValue,
        dot11RMNeighborReportKeyScope                       TruthValue,
        dot11RMNeighborReportOperatingClass                 Unsigned32,
        dot11RMNeighborReportChannelNumber                  Unsigned32,
        dot11RMNeighborReportPhyType                        INTEGER,
        dot11RMNeighborReportNeighborTSFInfo                OCTET STRING,
        dot11RMNeighborReportPilotInterval                  Unsigned32,
        dot11RMNeighborReportPilotMultipleBSSID             OCTET STRING,
        dot11RMNeighborReportRMEnabledCapabilities          OCTET STRING,
        dot11RMNeighborReportVendorSpecific                 OCTET STRING,
        dot11RMNeighborReportRowStatus                      RowStatus,
        dot11RMNeighborReportMobilityDomain                 TruthValue,
        dot11RMNeighborReportCapHT                          TruthValue,
        dot11RMNeighborReportHTLDPCCodingCap                TruthValue,
        dot11RMNeighborReportHTSupportedChannelWidthSet
                                                            TruthValue,
        dot11RMNeighborReportHTSMPowerSave                  Unsigned32,
        dot11RMNeighborReportHTGreenfield                   TruthValue,
        dot11RMNeighborReportHTShortGIfor20MHz              TruthValue,
        dot11RMNeighborReportHTShortGIfor40MHz              TruthValue,
        dot11RMNeighborReportHTTxSTBC                       TruthValue,
        dot11RMNeighborReportHTRxSTBC                       Unsigned32,
        dot11RMNeighborReportHTDelayedBlockAck              TruthValue,
        dot11RMNeighborReportHTMaxAMSDULength               TruthValue,
        dot11RMNeighborReportHTDSSCCKModein40MHz            TruthValue,
        dot11RMNeighborReportHTFortyMHzIntolerant           TruthValue,
        dot11RMNeighborReportHTLSIGTXOPProtectionSupport    TruthValue,
        dot11RMNeighborReportHTMaxAMPDULengthExponent       Unsigned32,
        dot11RMNeighborReportHTMinMPDUStartSpacing          Unsigned32,
        dot11RMNeighborReportHTRxMCSBitMask                 OCTET STRING,
        dot11RMNeighborReportHTRxHighestSupportedDataRate   Unsigned32,
        dot11RMNeighborReportHTTxMCSSetDefined              TruthValue,
        dot11RMNeighborReportHTTxRxMCSSetNotEqual           TruthValue,
        dot11RMNeighborReportHTTxMaxNumberSpatialStreamsSupported
                                                            Unsigned32,
        dot11RMNeighborReportHTTxUnequalModulationSupported
                                                            TruthValue,
        dot11RMNeighborReportHTPCO                          TruthValue,
        dot11RMNeighborReportHTPCOTransitionTime            Unsigned32,
        dot11RMNeighborReportHTMCSFeedback                  Unsigned32,
        dot11RMNeighborReportHTCSupport                     TruthValue,
        dot11RMNeighborReportHTRDResponder                  TruthValue,
        dot11RMNeighborReportHTImplictTransmitBeamformingReceivingCap
                                                            TruthValue,
        dot11RMNeighborReportHTReceiveStaggeredSoundingCap
                                                            TruthValue,
        dot11RMNeighborReportHTTransmitStaggeredSoundingCap
                                                            TruthValue,
```


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```
        dot11RMNeighborReportHTReceiveNDPCap              TruthValue,
        dot11RMNeighborReportHTTransmitNDPCap             TruthValue,
        dot11RMNeighborReportHTImplicitTransmitBeamformingCap
                                                          TruthValue,
        dot11RMNeighborReportHTTransmitBeamformingCalibration
                                                          Unsigned32,
        dot11RMNeighborReportHTExplicitCSITransmitBeamformingCap
                                                          TruthValue,
        dot11RMNeighborReportHTExplicitNonCompressedSteeringCap
                                                          TruthValue,
        dot11RMNeighborReportHTExplicitCompressedSteeringCap
                                                          TruthValue,
        dot11RMNeighborReportHTExplicitTransmitBeamformingFeedback
                                                          Unsigned32,
        dot11RMNbRprtHTExplicitNonCompressedBeamformingFeedbackCap
                                                          Unsigned32,
        dot11RMNeighborReportHTExplicitCompressedBeamformingFeedbackCap
                                                          Unsigned32,
        dot11RMNeighborReportHTTransmitBeamformingMinimalGrouping
                                                          Unsigned32,
        dot11RMNbRprtHTCSINumberofTxBeamformingAntennasSuppt
                                                          Unsigned32,
        dot11RMNbRprtHTNonCompressedSteeringNumofTxBmfmingAntennasSuppt
                                                          Unsigned32,
        dot11RMNbRprtHTCompressedSteeringNumberofTxBmfmingAntennasSuppt
                                                          Unsigned32,
        dot11RMNbRprtHTCSIMaxNumberofRowsTxBeamformingSuppt
                                                          Unsigned32,
        dot11RMNeighborReportHTTransmitBeamformingChannelEstimationCap
                                                          Unsigned32,
        dot11RMNeighborReportHTAntSelectionCap            TruthValue,
        dot11RMNeighborReportHTExplicitCSIFeedbackBasedTxASELCap
                                                          TruthValue,
        dot11RMNeighborReportHTAntIndicesFeedbackBasedTxASELCap
                                                          TruthValue,
        dot11RMNeighborReportHTExplicitCSIFeedbackBasedCap
                                                          TruthValue,
        dot11RMNeighborReportHTAntIndicesFeedbackCap      TruthValue,
        dot11RMNeighborReportHTRxASELCap                  TruthValue,
        dot11RMNeighborReportHTTxSoundingPPDUsCap         TruthValue,
        dot11RMNeighborReportHTInfoPrimaryChannel         Unsigned32,
        dot11RMNeighborReportHTInfoSecChannelOffset       Unsigned32,
        dot11RMNeighborReportHTInfoSTAChannelWidth        TruthValue,
        dot11RMNeighborReportHTInfoRIFSMode               TruthValue,
        dot11RMNeighborReportHTInfoProtection             Unsigned32,
        dot11RMNeighborReportHTInfoNonGreenfieldHTSTAsPresent
                                                          TruthValue,
        dot11RMNeighborReportHTInfoOBSSNonHTSTAsPresent
                                                          TruthValue,
        dot11RMNeighborReportHTInfoDualBeacon             TruthValue,
        dot11RMNeighborReportHTInfoDualCTSProtection      TruthValue,
        dot11RMNeighborReportHTInfoSTBCBeacon             TruthValue,
        dot11RMNeighborReportHTInfoLSIGTXOPProtectionSup  TruthValue,
        dot11RMNeighborReportHTInfoPCOActive              TruthValue,
        dot11RMNeighborReportHTInfoPCOPhase               TruthValue,
        dot11RMNeighborReportHTInfoBasicMCSSet            OCTET STRING,
        dot11RMNeighborReportHTSecChannelOffset           Unsigned32,
        dot11RMNeighborReportExtCapPSMPSupport            TruthValue,
        dot11RMNeighborReportExtCapSPSMPSup               TruthValue,
        dot11RMNeighborReportExtCapServiceIntervalGranularity
                                                          Unsigned32,
        dot11RMNeighborReportBSSTransitCandPreference     Unsigned32,
        dot11RMNeighborReportBSSTerminationTSF            TSFType,
        dot11RMNeighborReportBSSTerminationDuration       Unsigned32
```

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```
    }

dot11RMNeighborReportIndex OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "Index for neighbor report configuration table in
        dot11RMNeighborReportTable, greater than 0."
    ::= { dot11RMNeighborReportEntry 1 }

dot11RMNeighborReportIfIndex OBJECT-TYPE
    SYNTAX InterfaceIndex
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        The ifIndex for this row of the neighbor report."
    ::= { dot11RMNeighborReportEntry 2 }

dot11RMNeighborReportBSSID OBJECT-TYPE
    SYNTAX MacAddress
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute indicates the BSSID of the BSS of the AP described by this
        row of neighbor report."
    ::= { dot11RMNeighborReportEntry 3 }

dot11RMNeighborReportAPReachability OBJECT-TYPE
    SYNTAX INTEGER { notReachable(1), unknown(2), reachable(3) }
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute indicates the reachability of the AP represented by the
        dot11RMNeighborReportBSSID."
    ::= { dot11RMNeighborReportEntry 4 }

dot11RMNeighborReportSecurity OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute, when true, indicates that the neighbor AP identified by
        this BSSID supports the same security provisioning as used by the AP which
        provided this neighbor report. This attribute, when false, indicates
        either that the neighbor AP identified by this BSSID does not support the
        same security provisioning or that the security information for this
        neighbor AP is not available at this time."
    ::= { dot11RMNeighborReportEntry 5 }

dot11RMNeighborReportCapSpectrumMgmt OBJECT-TYPE
    SYNTAX TruthValue
```


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```
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute indicates the spectrum management capability of the AP
        represented by dot11RMNeighborReportBSSID."
    ::= { dot11RMNeighborReportEntry 6 }

dot11RMNeighborReportCapQoS OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute indicates the QoS capability of the AP represented by
        dot11RMNeighborReportBSSID."
    ::= { dot11RMNeighborReportEntry 7 }

dot11RMNeighborReportCapAPSD OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute indicates the APSD capability of the AP represented by
        dot11RMNeighborReportBSSID."
    ::= { dot11RMNeighborReportEntry 8 }

dot11RMNeighborReportCapRM OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute is equal to true when the AP, represented by
        dot11RMNeighborReportBSSID, transmits a RM Enabled Capabilities element;
        and is false otherwise."
    ::= { dot11RMNeighborReportEntry 9 }

dot11RMNeighborReportCapDelayBlockAck OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-create
    STATUS (#3441)deprecated
    DESCRIPTION
        "Deprecated as the related feature has been removed from IEEE Std 802.11.
        This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute indicates the delayed block ack capability of the AP
        represented by dot11RMNeighborReportBSSID."
    ::= { dot11RMNeighborReportEntry 10 }

dot11RMNeighborReportCapImmediateBlockAck OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-create
    STATUS current
```

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```
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute indicates the immediate block ack capability of the AP
        represented by dot11RMNeighborReportBSSID."
    ::= { dot11RMNeighborReportEntry 11 }

dot11RMNeighborReportKeyScope OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute, when true, indicates the neighbor AP identified by this
        BSSID has the same Authenticator(#1441)(#1380) as the AP which provided
        this neighbor report. This attribute, when false, indicates that the
        neighbor AP identified by this BSSID has a different
        Authenticator(#1441)(#1380) or that Authenticator(#1441)(#1380)
        information is not available."
    ::= { dot11RMNeighborReportEntry 12 }

dot11RMNeighborReportOperatingClass OBJECT-TYPE
    SYNTAX Unsigned32 (1..255)
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute indicates the channel set for this neighbor report entry.
        Country, Operating Class and Channel Number together specify the channel
        frequency and spacing for this measurement report. Valid values of
        Operating Class are shown in Annex E."
    ::= { dot11RMNeighborReportEntry 13 }

dot11RMNeighborReportChannelNumber OBJECT-TYPE
    SYNTAX Unsigned32 (1..255)
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute indicates the current operating channel of the AP
        represented by the dot11RMNeighborReportBSSID. The Channel Number is
        defined only within the indicated Operating Class for this neighbor report
        entry."
    ::= { dot11RMNeighborReportEntry 14 }

dot11RMNeighborReportPhyType OBJECT-TYPE
    SYNTAX INTEGER {
        dsss(2),
        ofdm(4),
        hrdsss(5),
        erp(6),
        ht(7),
        dmg(8),
        vht(9),
        tvht(10),
        s1g(11),
        cdmg(12),
```


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```
        cmmg(13),
        (11ay)edmg(14)}
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute indicates the PHY Type of the neighbor AP identified by
        this BSSID."
    ::= { dot11RMNeighborReportEntry 15 }

dot11RMNeighborReportNeighborTSFInfo OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE (6))
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute indicates TSF timing information for the neighbor AP
        identified by this BSSID. The TSF timing information includes the TSF
        Offset and the Beacon Interval, as defined in 9.4.2.35 (Neighbor Report
        element)."
    ::= { dot11RMNeighborReportEntry 16 }

dot11RMNeighborReportPilotInterval OBJECT-TYPE
    SYNTAX Unsigned32
    UNITS "TUs"
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute indicates the measurement pilot interval for the neighbor
        AP identified by this BSSID, as defined in 9.4.1.18 (Measurement Pilot
        Interval field)."
    ::= { dot11RMNeighborReportEntry 17 }

dot11RMNeighborReportPilotMultipleBSSID OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(1))
    UNITS "BSSID LSBs"
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute indicates n, where 2^n is the maximum number of BSSIDs in
        the multiple BSSID set, as described in 11.10.14 (Multiple BSSID set)."
    ::= { dot11RMNeighborReportEntry 18 }

dot11RMNeighborReportRMEnabledCapabilities OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(7))
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute indicates the detailed enabled capabilities of the AP
        represented by the dot11RMNeighborReportBSSID, as defined in 9.4.2.43 (RM
        Enabled Capabilities element)."
```

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```
    ::= { dot11RMNeighborReportEntry 19 }

dot11RMNeighborReportVendorSpecific OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(0..255))
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This attribute provides an envelope for any optional vendor specific
        subelements which may be included in a measurement report element."
    DEFVAL { ''H }
    ::= { dot11RMNeighborReportEntry 20 }

dot11RMNeighborReportRowStatus OBJECT-TYPE
    SYNTAX RowStatus
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        Contains the row status of the neighbor report, essentially used for
        indicating whether the row has all valid attributes filled in. Then set to
        active to be used in Neighbor Report elements. If any parameter is
        invalid, the SME sets this attribute back to notReady. It is the
        responsibility of the manager to correct the parameters."
    ::= { dot11RMNeighborReportEntry 21 }

dot11RMNeighborReportMobilityDomain OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        Indicates a common mobility domain identifier (MDID) and an identical
        value of the FT Capability and Policy value."
    ::= { dot11RMNeighborReportEntry 22 }

dot11RMNeighborReportCapHT OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        The High Throughput subfield(#291) when equal to 1 indicates that the AP
        represented by this BSSID is an HT AP including the HT Capabilities
        element in its Beacons and that the contents of that HT Capabilities
        element are identical to the HT Capabilities element advertised by the AP
        sending the report. See 9.4.2.35 (Neighbor Report element)"
    ::= { dot11RMNeighborReportEntry 23 }

dot11RMNeighborReportHTLDPCCodingCap OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.
```


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```
        This variable indicates support for receiving LDPC coded packets, equal to
        false if not supported, equal to true if supported. See 9.4.2.54.2 (HT
        Capability Information field)"
    ::= { dot11RMNeighborReportEntry 24 }

dot11RMNeighborReportHTSupportedChannelWidthSet OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This variable indicates which channel widths the STA supports, equal to
        false if only 20 MHz operation is supported, equal to true if both 20 MHz
        and 40 MHz operation is supported. See 9.4.2.54.2 (HT Capability
        Information field)"
    ::= { dot11RMNeighborReportEntry 25 }

dot11RMNeighborReportHTSMPowerSave OBJECT-TYPE
    SYNTAX Unsigned32 (0..3)
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This variable indicates the SM power save mode, equal to 0 for static SM
        power save mode, equal to 1 for dynamic SM power save mode, equal to 3 for
        SM power save disabled or not supported, the value 2 is reserved; see
        9.4.2.54.2 (HT Capability Information field)"
    ::= { dot11RMNeighborReportEntry 26 }

dot11RMNeighborReportHTGreenfield OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This variable indicates support for the reception of PPDUs with HT-
        greenfield format, equal to false if not supported, equal to true if
        supported. See 9.4.2.54.2 (HT Capability Information field)"
    ::= { dot11RMNeighborReportEntry 27 }

dot11RMNeighborReportHTShortGIfor20MHz OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This variable indicates short GI support for the reception of 20 MHz
        packets, equal to false if not supported, equal to true if supported See
        9.4.2.54.2 (HT Capability Information field)"
    ::= { dot11RMNeighborReportEntry 28 }

dot11RMNeighborReportHTShortGIfor40MHz OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-create
    STATUS current
```

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```
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This variable indicates short GI support for the reception of 40 MHz
        packets, equal to false if not supported, equal to true if supported. See
        9.4.2.54.2 (HT Capability Information field)"
    ::= { dot11RMNeighborReportEntry 29}

dot11RMNeighborReportHTTxSTBC OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This variable indicates support for the transmission of PPDUs using STBC,
        equal to false if not supported, equal to true if supported. See
        9.4.2.54.2 (HT Capability Information field)"
    ::= { dot11RMNeighborReportEntry 30}

dot11RMNeighborReportHTRxSTBC OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This variable indicates support for the reception of PPDUs using STBC,
        equal to 0 for no support, equal to 1 for support of one spatial stream,
        equal to 2 for support of one and two spatial streams, equal to 3 for
        support of one, two, and three spatial streams. See 9.4.2.54.2 (HT
        Capability Information field)"
    ::= { dot11RMNeighborReportEntry 31}

dot11RMNeighborReportHTDelayedBlockAck OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-create
    STATUS (#3441)deprecated
    DESCRIPTION
        "Deprecated as the related feature has been removed from the standard.
        This is a status variable.
        It is written by the SME when a measurement report is completed.

        This variable indicates support for HT-delayed block ack operation, equal
        to false if not supported, equal to true if supported. Support indicates
        that the STA is able to accept an ADDBA request for HT-delayed block ack.
        See 9.4.2.54.2 (HT Capability Information field)"
    ::= { dot11RMNeighborReportEntry 32 }

dot11RMNeighborReportHTMaxAMSDULength OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This variable indicates maximum A-MSDU length, equal to false for 3839
        octets, equal to true for 7935 octets. See 9.4.2.54.2 (HT Capability
        Information field)"
    ::= { dot11RMNeighborReportEntry 33 }
```


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```
dot11RMNeighborReportHTDSSCCKModein40MHz OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-create
   STATUS current
   DESCRIPTION
      "This is a status variable.
      It is written by the SME when a measurement report is completed.

      This variable indicates use of DSSS/CCK mode in a 40MC BSS operating in
      20/40 MHz mode, equal to false if DSSS/CCK in 40 MHz is not allowed, equal
      to true if the DSSS/CCK in 40 MHz is allowed. See 9.4.2.54.2 (HT
      Capability Information field)"
   ::= { dot11RMNeighborReportEntry 34 }

dot11RMNeighborReportHTFortyMHzIntolerant OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-create
   STATUS current
   DESCRIPTION
      "This is a status variable.
      It is written by the SME when a measurement report is completed.

      This variable indicates whether other BSSs receiving this information are
      required to prohibit 40 MHz transmissions, equal to true to prohibit 20/40
      MHz BSS operation, otherwise equal to false. See 9.4.2.54.2 (HT Capability
      Information field)"
   ::= { dot11RMNeighborReportEntry 35 }

dot11RMNeighborReportHTLSIGTXOPProtectionSupport OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-create
   STATUS deprecated
   DESCRIPTION
      "Deprecated as the related feature has been removed from IEEE Std 802.11.
      This is a status variable.
      It is written by the SME when a measurement report is completed.

      This variable indicates support for the L-SIG TXOP protection mechanism,
      equal to false if not supported, equal to true if supported. See
      9.4.2.54.2 (HT Capability Information field)"
   ::= { dot11RMNeighborReportEntry 36 }

dot11RMNeighborReportHTMaxAMPDULengthExponent OBJECT-TYPE
   SYNTAX Unsigned32 (0..3)
   MAX-ACCESS read-create
   STATUS current
   DESCRIPTION
      "This is a status variable.
      It is written by the SME when a measurement report is completed.

      This variable indicates the maximum length of A-MPDU that the STA can
      receive. This field is an integer in the range 0 to 3. The length defined
      by this field is equal to 2 ^ (13 + Maximum A-MPDU Length) - 1 octets. See
      9.4.2.54.3 (A-MPDU Parameters field)"
   ::= { dot11RMNeighborReportEntry 37 }

dot11RMNeighborReportHTMinMPDUStartSpacing OBJECT-TYPE
   SYNTAX Unsigned32 (0..7)
   MAX-ACCESS read-create
   STATUS current
   DESCRIPTION
      "This is a status variable.
      It is written by the SME when a measurement report is completed.
```

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```
        This variable determines the minimum time between the start of adjacent
        MPDUs within an A-MPDU(#4364), measured at the PHY SAP, equal to 0 for no
        restriction, equal to 1 for 1/4 microsecond, equal to 2 for 1/2
        microsecond, equal to 3 for 1 microsecond, equal to 4 for 2 microseconds,
        equal to 5 for 4 microseconds, equal to 6 for 8 microseconds, equal to 7
        for 16 microseconds. See 9.4.2.54.3 (A-MPDU Parameters field)"
    ::= { dot11RMNeighborReportEntry 38 }

dot11RMNeighborReportHTRxMCSBitMask OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(10))
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This variable is a 77-bit bitmap that defines a set of MCS values, where
        (#465)B0 (i.e., the lsb of the first octet) corresponds to MCS 0 and
        (#465)B76 corresponds to MCS 76, equal to 0 when the MCS is not supported,
        equal to 1 when the MCS is supported. See 9.4.2.54.4 (Supported MCS Set
        field)"
    ::= { dot11RMNeighborReportEntry 39}

dot11RMNeighborReportHTRxHighestSupportedDataRate OBJECT-TYPE
    SYNTAX Unsigned32 (1..1023)
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This variable defines the highest HT PPDU data rate that the STA is able
        to receive, in units of 1 Mb/s. See 9.4.2.54.4 (Supported MCS Set field)"
    ::= { dot11RMNeighborReportEntry 40 }

dot11RMNeighborReportHTTxMCSSetDefined OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This variable indicates if the Tx MCS set is defined, equal to false if no
        Tx MCS set is defined, equal to true if Tx MCS set is defined. See
        9.4.2.54.4 (Supported MCS Set field)"
    ::= { dot11RMNeighborReportEntry 41 }

dot11RMNeighborReportHTTxRxMCSSetNotEqual OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This variable indicates if the Tx MCS set is defined to be equal to the Rx
        MCS set, equal to false where no Tx MCS set is defined or where the Tx MCS
        Set is defined to be equal to the RX MCS Set, equal to true where the TX
        MCS set may differ from the Rx MCS set. See 9.4.2.54.4 (Supported MCS Set
        field)"
    ::= { dot11RMNeighborReportEntry 42 }
```


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```
dot11RMNeighborReportHTTxMaxNumberSpatialStreamsSupported OBJECT-TYPE
   SYNTAX Unsigned32 (0..3)
   MAX-ACCESS read-create
   STATUS current
   DESCRIPTION
      "This is a status variable.
      It is written by the SME when a measurement report is completed.

      This variable indicates maximum number of spatial streams supported when
      the Tx MCS Set may differ from the Rx MCS set, equal to 0 where no TX MCS
      set is defined or where the Tx MCS set is defined to be equal to the RX MCS
      set or where the maximum number of spatial streams supported when
      transmitting is 1 spatial stream and the Tx MCS set may differ from the Rx
      MCS set, equal to 1 where the maximum number of spatial streams supported
      when transmitting is 2 spatial streams and the Tx MCS set may differ from
      the Rx MCS set, equal to 2 where the maximum number of spatial streams
      supported when transmitting is 3 spatial streams and the Tx MCS set may
      differ from the Rx MCS set, equal to 3 where the maximum number of spatial
      streams supported when transmitting is 4 spatial streams and the Tx MCS
      set may differ from the Rx MCS set. See 9.4.2.54.4 (Supported MCS Set
      field)"
   ::= { dot11RMNeighborReportEntry 43 }

dot11RMNeighborReportHTTxUnequalModulationSupported OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-create
   STATUS current
   DESCRIPTION
      "This is a status variable.
      It is written by the SME when a measurement report is completed.

      This variable indicates whether transmit UEQM is supported when the Tx MCS
      set may differ from the Rx MCS set, equal to false where no TX MCS set is
      defined or where the Tx MCS set is defined to be equal to the RX MCS set
      or when UEQM is not supported and the Tx MCS set may differ from the Rx MCS
      set, equal to true when UEQM is supported and the Tx MCS set may differ
      from the Rx MCS set. See 9.4.2.54.4 (Supported MCS Set field)"
   ::= { dot11RMNeighborReportEntry 44 }

dot11RMNeighborReportHTPCO OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-create
   STATUS deprecated
   DESCRIPTION
      "Deprecated as the related feature has been removed from IEEE Std 802.11.
      This is a status variable.
      It is written by the SME when a measurement report is completed.

      This variable indicates support for PCO, equal to false if not supported,
      equal to true if supported. See 9.4.2.54.5 (HT Extended Capabilities
      field)"
   ::= { dot11RMNeighborReportEntry 45 }

dot11RMNeighborReportHTPCOTransitionTime OBJECT-TYPE
   SYNTAX Unsigned32 (0..3)
   MAX-ACCESS read-create
   STATUS deprecated
   DESCRIPTION
      "Deprecated as the related feature has been removed from IEEE Std 802.11.
      This is a status variable.
      It is written by the SME when a measurement report is completed.

      This variable indicates that the STA can switch between 20 MHz channel
      width and 40 MHz channel width within the indicated time, equal to 0 for
```

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```
        no transition, equal to 1 for 400 microseconds, equal to 2 for 1.5 ms,
        equal to 3 for 5 ms. For the no transition case (equal to 0) the PCO active
        STA does not change its operation channel width and is able to receive 40
        MHz PPDUs during the 20 MHz phase. See 9.4.2.54.5 (HT Extended
        Capabilities field)"
    ::= { dot11RMNeighborReportEntry 46 }

dot11RMNeighborReportHTMCSFeedback OBJECT-TYPE
    SYNTAX Unsigned32 (0..3)
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This variable indicates the capability of the STA to provide MFB, equal to
        0 if the STA does not provide MFB, equal to 2 if the STA provide only
        unsolicited MFB, equal to 3 if the STA can provide MFB in response to MRQ
        as well as unsolicited MFB. Note the value 1 is reserved. See 9.4.2.54.5
        (HT Extended Capabilities field)"
    ::= { dot11RMNeighborReportEntry 47 }

dot11RMNeighborReportHTCSupport OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This variable indicates support of the HT Control field, equal to false if
        not supported, equal to true if supported. See 9.4.2.54.5 (HT Extended
        Capabilities field)"
    ::= { dot11RMNeighborReportEntry 48 }

dot11RMNeighborReportHTRDResponder OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This variable indicates support for acting as a revere direction
        responder, equal to false if not supported, equal to true if supported.
        See 9.4.2.54.5 (HT Extended Capabilities field)"
    ::= { dot11RMNeighborReportEntry 49}

dot11RMNeighborReportHTImplictTransmitBeamformingReceivingCap OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This variable indicates whether this STA can receive Transmit Beamforming
        steered frames using implicit feedback, equal to false if not supported,
        equal to true if supported. See 9.4.2.54.6 (Transmit Beamforming
        Capabilities)"
    ::= { dot11RMNeighborReportEntry 50 }

dot11RMNeighborReportHTReceiveStaggeredSoundingCap OBJECT-TYPE
    SYNTAX TruthValue
```


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```
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This variable indicates whether this STA can receive staggered sounding
        frames, equal to false if not supported, equal to true if supported. See
        9.4.2.54.6 (Transmit Beamforming Capabilities)"
    ::= { dot11RMNeighborReportEntry 51 }

dot11RMNeighborReportHTTransmitStaggeredSoundingCap OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This variable indicates whether this STA can transmit staggered sounding
        frames, equal to false if not supported, equal to true if supported. See
        9.4.2.54.6 (Transmit Beamforming Capabilities)"
    ::= { dot11RMNeighborReportEntry 52 }

dot11RMNeighborReportHTReceiveNDPCap OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This variable indicates whether this receiver can interpret NDPs as
        sounding frames, equal to false if not supported, equal to true if
        supported. See 9.4.2.54.6 (Transmit Beamforming Capabilities)"
    ::= { dot11RMNeighborReportEntry 53 }

dot11RMNeighborReportHTTransmitNDPCap OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This variable indicates whether this STA can transmit NDPs as sounding
        frames, equal to false if not supported, equal to true if supported. See
        9.4.2.54.6 (Transmit Beamforming Capabilities)"
    ::= { dot11RMNeighborReportEntry 54 }

dot11RMNeighborReportHTImplicitTransmitBeamformingCap OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This variable indicates whether this STA can apply implicit transmit
        beamforming, equal to false if not supported, equal to true if supported.
        See 9.4.2.54.6 (Transmit Beamforming Capabilities)"
    ::= { dot11RMNeighborReportEntry 55 }

dot11RMNeighborReportHTTransmitBeamformingCalibration OBJECT-TYPE
```

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```
    SYNTAX Unsigned32 (0..3)
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This variable indicates that the STA can participate in a calibration
        procedure initiated by another STA that is capable of generating an
        immediate response Sounding PPDU and can provide a CSI report in response
        to a Sounding PPDU, equal to 0 if not supported, equal to 1 is the STA can
        respond to a calibration request using the CSI report but cannot initiate
        calibration, equal to 3 if the STA can both initiate and respond to a
        calibration request. See 9.4.2.54.6 (Transmit Beamforming Capabilities)"
    ::= { dot11RMNeighborReportEntry 56 }

dot11RMNeighborReportHTExplicitCSITransmitBeamformingCap OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This variable indicates whether this STA can apply transmit beamforming
        using SCI explicit feedback in its transmission, equal to false if not
        supported, equal to true if supported. See 9.4.2.54.6 (Transmit
        Beamforming Capabilities)"
    ::= { dot11RMNeighborReportEntry 57 }

dot11RMNeighborReportHTExplicitNonCompressedSteeringCap OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        The variable indicates whether this STA can apply transmit beamforming
        using noncompressed beamforming feedback matrix explicit feedback in its
        transmission, equal to false if not supported, equal to true if supported.
        See 9.4.2.54.6 (Transmit Beamforming Capabilities)"
    ::= { dot11RMNeighborReportEntry 58 }

dot11RMNeighborReportHTExplicitCompressedSteeringCap OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This variable indicates whether this STA can apply transmit beamforming
        using compressed beamforming feedback matrix explicit feedback in its
        transmission, equal to false if not supported, equal to true if supported.
        See 9.4.2.54.6 (Transmit Beamforming Capabilities)"
    ::= { dot11RMNeighborReportEntry 59}

dot11RMNeighborReportHTExplicitTransmitBeamformingFeedback OBJECT-TYPE
    SYNTAX Unsigned32 (0..3)
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a status variable.
```


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```
        It is written by the SME when a measurement report is completed.

        This variable indicates whether this receiver can return CSI explicit
        feedback, equal to 0 if not supported, equal to 1 for delayed feedback,
        equal to 2 for immediate feedback, equal to 3 for delayed and immediate
        feedback. See 9.4.2.54.6 (Transmit Beamforming Capabilities)"
    ::= { dot11RMNeighborReportEntry 60 }

dot11RMNbRprtHTExplicitNonCompressedBeamformingFeedbackCap OBJECT-TYPE
    SYNTAX Unsigned32 (0..3)
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This variable indicates whether this receiver can return noncompressed
        beamforming feedback matrix explicit feedback, equal to 0 if not
        supported, equal to 1 for delayed feedback, equal to 2 for immediate
        feedback, equal to 3 for delayed and immediate feedback. See 9.4.2.54.6
        (Transmit Beamforming Capabilities)"
    ::= { dot11RMNeighborReportEntry 61 }

dot11RMNeighborReportHTExplicitCompressedBeamformingFeedbackCap OBJECT-TYPE
    SYNTAX Unsigned32 (0..3)
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This variable indicates whether this receiver can return compressed
        beamforming feedback matrix explicit feedback, equal to 0 if not
        supported, equal to 1 for delayed feedback, equal to 2 for immediate
        feedback, equal to 3 for delayed and immediate feedback. See 9.4.2.54.6
        (Transmit Beamforming Capabilities)"
    ::= { dot11RMNeighborReportEntry 62 }

dot11RMNeighborReportHTTransmitBeamformingMinimalGrouping OBJECT-TYPE
    SYNTAX Unsigned32 (0..3)
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This variable indicates the minimal grouping used for explicit feedback
        reports, equal to 0 if the STA supports groups of 1 (no grouping), equal
        to 1 to indicate groups of 1, 2, equal to 2 to indicate groups of 1, 4,
        equal to 3 to indicate groups of 1, 2, 4. See 9.4.2.54.6 (Transmit
        Beamforming Capabilities)"
    ::= { dot11RMNeighborReportEntry 63 }

dot11RMNbRprtHTCSINumberofTxBeamformingAntennasSuppt OBJECT-TYPE
    SYNTAX Unsigned32 (0..3)
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This variable indicates the maximum number of beamformer antennas the
        beamformee can support when CSI feedback is required, equal to 0 for
        single Tx antenna sounding, equal to 1 for 2 Tx antenna sounding, equal to
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        2 for 3 Tx antenna sounding, equal to 3 for 4 Tx antenna sounding. See
        9.4.2.54.6 (Transmit Beamforming Capabilities)"
    ::= { dot11RMNeighborReportEntry 64 }

dot11RMNbRprtHTNonCompressedSteeringNumofTxBmfmingAntennasSuppt OBJECT-TYPE
    SYNTAX Unsigned32 (0..3)
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This variable indicates the maximum number of beamformer antennas the
        beamformee can support when noncompressed beamforming feedback matrix is
        required, equal to 0 for single Tx antenna sounding, equal to 1 for 2 Tx
        antenna sounding, equal to 2 for 3 Tx antenna sounding, equal to 3 for 4
        Tx antenna sounding. See 9.4.2.54.6 (Transmit Beamforming Capabilities)"
    ::= { dot11RMNeighborReportEntry 65 }

dot11RMNbRprtHTCompressedSteeringNumberofTxBmfmingAntennasSuppt OBJECT-TYPE
    SYNTAX Unsigned32 (0..3)
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This variable indicates the maximum number of beamformer antennas the
        beamformee can support when compressed beamforming feedback matrix is
        required, equal to 0 for single Tx antenna sounding, equal to 1 for 2 Tx
        antenna sounding, equal to 2 for 3 Tx antenna sounding, equal to 3 for 4
        Tx antenna sounding. See 9.4.2.54.6 (Transmit Beamforming Capabilities)"
    ::= { dot11RMNeighborReportEntry 66 }

dot11RMNbRprtHTCSIMaxNumberofRowsTxBeamformingSuppt OBJECT-TYPE
    SYNTAX Unsigned32 (0..3)
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This variable indicates the maximum number of rows of CSI explicit
        feedback from the beamformee or calibration responder or transmit ASEL
        responder that a beamformer or calibration initiator or transmit ASEL
        initiator can support when SCI feedback is required, equal to 0 for a
        single row of CSI, equal to 1 for 2 rows of CSI, equal to 2 for 3 rows of
        CSI, equal to 3 for 4 rows of CSI. See 9.4.2.54.6 (Transmit Beamforming
        Capabilities)"
    ::= { dot11RMNeighborReportEntry 67 }

dot11RMNeighborReportHTTransmitBeamformingChannelEstimationCap OBJECT-TYPE
    SYNTAX Unsigned32 (0..3)
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This variable indicates the maximum number of space-time streams for which
        channel dimensions can be simultaneously estimated when receiving an NDP
        sounding PPDU or the extension portion of the HT-LTFs in a staggered
        sounding PPDU. Equal to 0 for 1 space-time stream, equal to 1 for 2 space-
        time streams, equal to 2 for 3 space-time streams, equal to 3 for 4 space-
```


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        time streams. See 9.4.2.54.6 (Transmit Beamforming Capabilities)"
    ::= { dot11RMNeighborReportEntry 68 }

dot11RMNeighborReportHTAntSelectionCap OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This variable indicates whether this STA supports ASEL, equal to false if
        not supported, equal to true if supported. See 9.4.2.54.7 (ASEL Capability
        field)"
    ::= { dot11RMNeighborReportEntry 69}

dot11RMNeighborReportHTExplicitCSIFeedbackBasedTxASELCap OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This variable indicates whether this STA has transmit ASEL capability
        based on explicit CSI feedback, equal to false if not supported, equal to
        true if supported. See 9.4.2.54.7 (ASEL Capability field)"
    ::= { dot11RMNeighborReportEntry 70 }

dot11RMNeighborReportHTAntIndicesFeedbackBasedTxASELCap OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This variable indicates whether this STA has transmit ASEL capability
        based on antenna indices feedback, equal to false if not supported, equal
        to true if supported. See 9.4.2.54.7 (ASEL Capability field)"
    ::= { dot11RMNeighborReportEntry 71 }

dot11RMNeighborReportHTExplicitCSIFeedbackBasedCap OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This variable indicates whether this STA can compute CSI and feedback in
        support of ASEL, equal to false if not supported, equal to true is
        supported. See 9.4.2.54.7 (ASEL Capability field)"
    ::= { dot11RMNeighborReportEntry 72 }

dot11RMNeighborReportHTAntIndicesFeedbackCap OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This variable indicates whether this STA has Rx ASEL capability, equal to
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        false if not supported, equal to true if supported. See 9.4.2.54.7 (ASEL
        Capability field)"
    ::= { dot11RMNeighborReportEntry 73 }

dot11RMNeighborReportHTRxASELCap OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This variable indicates whether this STA has Rx ASEL capability, equal to
        false if not supported, equal to true if supported. See 9.4.2.54.7 (ASEL
        Capability field)"
    ::= { dot11RMNeighborReportEntry 74 }

dot11RMNeighborReportHTTxSoundingPPDUsCap OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This variable indicates whether this STA can transmit sounding PPDUs for
        ASEL training per request, equal to false if not supported, equal to true
        if supported. See 9.4.2.54.7 (ASEL Capability field)"
    ::= { dot11RMNeighborReportEntry 75 }

dot11RMNeighborReportHTInfoPrimaryChannel OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This variable indicates the channel number of the primary channel,
        encoding: channel number of the primary channel. See 9.4.2.55 (HT
        Operation element)"
    ::= { dot11RMNeighborReportEntry 76 }

dot11RMNeighborReportHTInfoSecChannelOffset OBJECT-TYPE
    SYNTAX Unsigned32 (0..3)
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This variable indicates the offset of the secondary channel relative to
        the primary channel, equal to 1 if the secondary channel is above the
        primary channel, equal to 3 if the secondary channel is below the primary
        channel, equal to 0 if no secondary channel is present. The value 2 is
        reserved. See 9.4.2.55 (HT Operation element)"
    ::= { dot11RMNeighborReportEntry 77 }

dot11RMNeighborReportHTInfoSTAChannelWidth OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a status variable.
```


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```
        It is written by the SME when a measurement report is completed.

        This variable defines the channel widths that may be used to transmit to
        the STA, equal to false for a 20 MHz channel width, equal to true allows
        use of any channel width in the supported channel width set. See 9.4.2.55
        (HT Operation element)"
    ::= { dot11RMNeighborReportEntry 78 }

dot11RMNeighborReportHTInfoRIFSMode OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This variable indicates whether use of RIFS is permitted within the BSS,
        equal to false if use of RIFS is prohibited, equal to true if use of RIFS
        is permitted. See 9.4.2.55 (HT Operation element)"
    ::= { dot11RMNeighborReportEntry 79}

dot11RMNeighborReportHTInfoProtection OBJECT-TYPE
    SYNTAX Unsigned32 (0..3)
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This variable indicates protection requirements of HT transmissions. Equal
        to 0 if all STAs detected in the primary or the secondary channel or that
        are a member of this BSS are HT STAs and either all STAs that are known by
        the transmitting STA to be a member of this BSS are 20/40 MHz HT in a 20/
        40 MHz BSS or this BSS is a 20 MHz BSS. Equal to 1 (nonmember protection
        mode) if there is at least one non-HT STA detected in either the primary
        or the secondary channel or in both the primary and secondary channels and
        that is not known by the transmitting STA to be a member of this BSS and
        all STAs that are known by the transmitting STA to be a member of this BSS
        are HT STAs. Equal to 2 if all STAs detected in the primary or the
        secondary channel or that are known by the transmitting STA to be a member
        of this BSS are HT STAs and this BSS is a 20/40 MHz BSS and there is at
        least one 20 MHz HT STA associated with this BSS. Equal to 3 (non-HT mixed
        mode) otherwise. See 9.4.2.54.2 (HT Capability Information field)"
    ::= { dot11RMNeighborReportEntry 80 }

dot11RMNeighborReportHTInfoNonGreenfieldHTSTAsPresent OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This variable indicates if any HT STAs that are not HT-greenfield capable
        have associated. Determines when a non-AP STA should use HT-greenfield
        protection. Present in Beacon and Probe Response frames transmitted by an
        AP. Equal to false if all HT STAs that are associated are HT-greenfield
        capable, equal to true if one or more HT STAs that are not HT-greenfield
        capable are associated. See 9.4.2.55 (HT Operation element)"
    ::= { dot11RMNeighborReportEntry 81 }

dot11RMNeighborReportHTInfoOBSSNonHTSTAsPresent OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-create
```

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```
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This variable indicates if the use of protection for non-HT STAs by OBSSs
        is determined to be desirable. Present in Beacon and Probe Response frames
        transmitted by an AP, equal to true if the use of protection for non-HT
        STAs by OBSSs is determined to be desirable, equal to false otherwise. See
        9.4.2.55 (HT Operation element)"
    ::= { dot11RMNeighborReportEntry 82 }

dot11RMNeighborReportHTInfoDualBeacon OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This variable indicates whether the AP transmits an STBC beacon, equal to
        false if no STBC beacon is transmitted, equal to true if an STBC beacon is
        transmitted. See 9.4.2.55 (HT Operation element)"
    ::= { dot11RMNeighborReportEntry 83 }

dot11RMNeighborReportHTInfoDualCTSProtection OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This variable is used by the AP to set a NAV at STAs that do not support
        STBC and at STAs that can associate solely through the secondary beacon,
        equal to false if dual CTS protection is not required, equal to true if
        dual CTS protection is required. See 9.4.2.55 (HT Operation element)"
    ::= { dot11RMNeighborReportEntry 84 }

dot11RMNeighborReportHTInfoSTBCBeacon OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This variable indicates whether the beacon containing this element is a
        primary or a STBC beacon, equal to false in a primary beacon, equal to
        true in a STBC beacon. See 9.4.2.55 (HT Operation element)"
    ::= { dot11RMNeighborReportEntry 85 }

dot11RMNeighborReportHTInfoLSIGTXOPProtectionSup OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-create
    STATUS deprecated
    DESCRIPTION
        "Deprecated as the related feature has been removed from IEEE Std 802.11.
        This is a status variable.
        It is written by the SME when a measurement report is completed.

        This variable indicates whether all HT STA in the BSS support L-SIG TXOP
        protection, equal to false if one or more HT STA in the BSS do not support
        L-SIG TXOP protection, equal to true if all HT STA in the BSS support L-
```


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```
        SIG TXOP protection. See 9.4.2.55 (HT Operation element)"
    ::= { dot11RMNeighborReportEntry 86 }

dot11RMNeighborReportHTInfoPCOActive OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-create
    STATUS deprecated
    DESCRIPTION
        "Deprecated as the related feature has been removed from IEEE Std 802.11.
        This is a status variable.
        It is written by the SME when a measurement report is completed.

        This variable indicates whether PCO is active in the BSS, equal to false
        if PCO is not active in the BSS, equal to true if PCO is active in the BSS.
        See 9.4.2.55 (HT Operation element)"
    ::= { dot11RMNeighborReportEntry 87}

dot11RMNeighborReportHTInfoPCOPhase OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-create
    STATUS deprecated
    DESCRIPTION
        "Deprecated as the related feature has been removed from IEEE Std 802.11.
        This is a status variable.
        It is written by the SME when a measurement report is completed.

        This variable indicates the PCO phase of operation, equal to false
        indicates a switch to or continued 20 MHz phase, equal to true indicates a
        switch to or continuation of 40 MHz phase. See 9.4.2.55 (HT Operation
        element)"
    ::= { dot11RMNeighborReportEntry 88 }

dot11RMNeighborReportHTInfoBasicMCSSet OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(16))
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This variable indicates values that are supported by all HT STAs in the
        BSS. The Basic HT-MCS Set is a bitmap of size 128 bits. Bit 0 corresponds
        to MCS 0. A bit is equal to 1 to indicate support for that MCS, equal to 0
        otherwise. See 9.4.2.55 (HT Operation element)"
    ::= { dot11RMNeighborReportEntry 89 }

dot11RMNeighborReportHTSecChannelOffset OBJECT-TYPE
    SYNTAX Unsigned32 (0..3)
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a measurement report is completed.

        This variable indicates the position of the secondary channel relative to
        the primary channel, equal to 1 to indicate that the secondary channel is
        above the primary channel, equal to 3 to indicate the secondary channel is
        below the primary channel, equal to 0 to indicate that no secondary
        channel is present. The value 2 is reserved. See 9.4.2.18 (Secondary
        Channel Offset element)"
    ::= { dot11RMNeighborReportEntry 90 }

dot11RMNeighborReportExtCapPSMPSupport OBJECT-TYPE
    SYNTAX TruthValue
```

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```
    MAX-ACCESS read-create
    STATUS deprecated(#3263)
    DESCRIPTION
        "Deprecated as the related feature has been removed from the
        standard.(#3263)
        This is a status variable.
        It is written by the SME when a measurement report is completed.

        This variable indicates support for PSMP operation, equal to false if PSMP
        is not supported, equal to true if PSMP operation is supported. See
        9.4.2.25 (Extended Capabilities element)"
    ::= { dot11RMNeighborReportEntry 91 }

dot11RMNeighborReportExtCapSPSMPSup OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-create
    STATUS deprecated(#3263)
    DESCRIPTION
        "(#3263)Deprecated as the related feature has been removed from the
        standard.
        This is a status variable.
        It is written by the SME when a measurement report is completed.

        This variable indicates support for scheduled PSMP, equal to false when
        PSMP is supported is equal to false and when the PSMP Capability field is
        equal to 1 if the STA does not support S-PSMP, equal to true when the PSMP
        Capability field is equal to 1 if the STA supports S-PSMP. See 9.4.2.25
        (Extended Capabilities element)."
    ::= { dot11RMNeighborReportEntry 92 }

dot11RMNeighborReportExtCapServiceIntervalGranularity OBJECT-TYPE
    SYNTAX Unsigned32 (0..7)
    MAX-ACCESS read-create
    STATUS deprecated(#3263)
    DESCRIPTION
        "(#3263)Deprecated as the related feature has been removed from the
        standard.
        This is a status variable.
        It is written by the SME when a measurement report is completed.

        This variable indicates the duration of the shortest SI, equal to 0 for 5
        ms, equal to 1 for 10 ms, equal to 2 for 15 ms, equal to 3 for 20 ms, equal
        to 4 for 25 ms, equal to 5 for 30 ms, equal to 6 for 35 ms, equal to 7 for
        40 ms. See 9.4.2.25 (Extended Capabilities element)."
    ::= { dot11RMNeighborReportEntry 93 }

dot11RMNeighborReportBSSTransitCandPreference OBJECT-TYPE
    SYNTAX Unsigned32 (0..255)
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This attribute indicates the network preference for BSS transition to the
        BSS listed in this BSS Transition Candidate List Entries field in the BSS
        Transition Management Request frame, BSS Transition Management Query frame
        and BSS Transition Management Response frame. The Preference field value
        is a number ranging from 0 to 255 indicating an ordering of preferences
        for the BSS transition candidates for this STA. The value 0 indicates an
        excluded BSS. The values 1-255 the preferred relative ordering of BSSs,
        with 255 indicating the most preferred candidate and 1 indicating the
        least preferred candidate. Additional details describing use of the
        Preference field are provided in 11.21.7.3 (BSS transition management
        request)."
    ::= { dot11RMNeighborReportEntry 94 }
```


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```
dot11RMNeighborReportBSSTerminationTSF OBJECT-TYPE
   SYNTAX TSFType
   MAX-ACCESS read-create
   STATUS current
   DESCRIPTION
      "This attribute indicates the value of the TSF timer when the BSS
      termination will occur in the future. A BSS Termination TSF field value of
      0 indicates that termination of the BSS will occur imminently. Prior to
      termination of the BSS, all associated STAs are disassociated by the AP."
   ::= { dot11RMNeighborReportEntry 95 }

dot11RMNeighborReportBSSTerminationDuration OBJECT-TYPE
   SYNTAX Unsigned32 (1..65535)
   UNITS "minutes"
   MAX-ACCESS read-create
   STATUS current
   DESCRIPTION
      "This attribute indicates the number of minutes for which the BSS is not
      present. The Duration field value of 0 is reserved. The Duration field
      value is set to 65 535 when the BSS is terminated for a period longer than
      or equal to 65 535 minutes."
   ::= { dot11RMNeighborReportEntry 96 }

-- ****************************************************************
-- * End of dot11RMNeighborReport TABLE
-- ****************************************************************

-- ****************************************************************
-- * END of Radio Measurement Interface MIB
-- ****************************************************************

-- ****************************************************************
-- * Wireless Network Management Interface MIB
-- ****************************************************************

dot11WirelessNetworkManagement OBJECT IDENTIFIER ::= { dot11smt 22 }

-- ****************************************************************
-- * Wireless network management requests
-- ****************************************************************

dot11WNMRequest OBJECT IDENTIFIER ::= { dot11WirelessNetworkManagement 1 }

-- ****************************************************************
-- * dot11WNMRequest TABLE
-- ****************************************************************
dot11WNMRequestNextIndex OBJECT-TYPE
   SYNTAX Unsigned32 (0..4294967295)
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a status variable.
      It is written by the SME when able to accept a new request.

      Identifies a hint for the next value of dot11WNMRqstIndex to be used in a
      row creation attempt for dot11WNMRequestTable. If no new rows can be
      created for some reason, such as memory, processing requirements, etc, the
      SME shall set this attribute to 0. It shall update this attribute to a
      proper value other than 0 as soon as it is capable of receiving new
      measurement requests. The nextIndex is not necessarily sequential nor
      monotonically increasing."
   ::= { dot11WNMRequest 1 }

dot11WNMRequestTable OBJECT-TYPE
```

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```
    SYNTAX SEQUENCE OF Dot11WNMRequestEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "This group contains the current list of requests for WNM reports to be
        issued and have been issued until removed. A network manager adds a WNM
        request by creating a row with createAndWait row status and then filling
        in the request parameters/attributes. The request becomes active to be
        issued when the row status is set to Active. The columnar objects or
        attributes other than the rowStatus shall not be written if the rowStatus
        is Active. The request rows can be deleted, if commanded by a network
        manager via changing the value of dot11WNMRqstRowStatus to Destroy. This
        may leave orphaned rows if a manager crashes and forgets which rows are
        being used by it. One recommended way to manage orphaned or finished rows
        is to delete rows if their dot11WNMRqstRowStatus remains other than Active
        for longer than a period (recommend at least 5 minutes, IETF RFC 2579). Or
        another recommended way is to delete older rows as needed based on their
        dot11WNMRqstTimeStamp values. This can be done by the agent as well as the
        manager."
    ::= { dot11WNMRequest 2 }

dot11WNMRequestEntry OBJECT-TYPE
    SYNTAX Dot11WNMRequestEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "An entry in the dot11WNMRequestTable Indexed by dot11WNMRqstIndex."
    INDEX { dot11WNMRqstIndex }
    ::= { dot11WNMRequestTable 1 }

Dot11WNMRequestEntry ::=
    SEQUENCE {
        dot11WNMRqstIndex                                   Unsigned32,
        dot11WNMRqstRowStatus                               RowStatus,
        dot11WNMRqstToken                                   OCTET STRING,
        dot11WNMRqstIfIndex                                 InterfaceIndex,
        dot11WNMRqstType                                    INTEGER,
        dot11WNMRqstTargetAdd                               MacAddress,
        dot11WNMRqstTimeStamp                               TimeTicks,
        dot11WNMRqstRndInterval                             Unsigned32,
        dot11WNMRqstDuration                                Unsigned32,
        dot11WNMRqstMcstGroup                               MacAddress,
        dot11WNMRqstMcstTrigCon                             OCTET STRING,
        dot11WNMRqstMcstTrigInactivityTimeout               Unsigned32,
        dot11WNMRqstMcstTrigReactDelay                      Unsigned32,
        dot11WNMRqstLCRRqstSubject                          INTEGER,
        dot11WNMRqstLCRIntervalUnits                        INTEGER,
        dot11WNMRqstLCRServiceInterval                      Unsigned32,
        dot11WNMRqstLIRRqstSubject                          INTEGER,
        dot11WNMRqstLIRIntervalUnits                        INTEGER,
        dot11WNMRqstLIRServiceInterval                      Unsigned32,
        dot11WNMRqstEventToken                              Unsigned32,
        dot11WNMRqstEventType                               INTEGER,
        dot11WNMRqstEventResponseLimit                      Unsigned32,
        dot11WNMRqstEventTargetBssid                        MacAddress,
        dot11WNMRqstEventSourceBssid                        MacAddress,
        dot11WNMRqstEventTransitTimeThresh                  Unsigned32,
        dot11WNMRqstEventTransitMatchValue                  OCTET STRING,
        dot11WNMRqstEventFreqTransitCountThresh             Unsigned32,
        dot11WNMRqstEventFreqTransitInterval                Unsigned32,
        dot11WNMRqstEventRsnaAuthType                       OCTET STRING,
        dot11WNMRqstEapType                                 Unsigned32,
        dot11WNMRqstEapVendorId                             OCTET STRING,
        dot11WNMRqstEapVendorType                           OCTET STRING,
```


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```
        dot11WNMRqstEventRsnaMatchValue                    OCTET STRING,
        dot11WNMRqstEventPeerMacAddress                    MacAddress,
        dot11WNMRqstOperatingClass                         Unsigned32,
        dot11WNMRqstChanNumber                             Unsigned32,
        dot11WNMRqstDiagToken                              Unsigned32,
        dot11WNMRqstDiagType                               INTEGER,
        dot11WNMRqstDiagTimeout                            Unsigned32,
        dot11WNMRqstDiagBssid                              MacAddress,
        dot11WNMRqstDiagProfileId                          Unsigned32,
        dot11WNMRqstDiagCredentials                        INTEGER,
        dot11WNMRqstLocConfigLocIndParams                  OCTET STRING,
        dot11WNMRqstLocConfigChanList                      OCTET STRING,
        dot11WNMRqstLocConfigBcastRate                     Unsigned32,
        dot11WNMRqstLocConfigOptions                       OCTET STRING,
        dot11WNMRqstBssTransitQueryReason                  INTEGER,
        dot11WNMRqstBssTransitReqMode                      OCTET STRING,
        dot11WNMRqstBssTransitDisocTimer                   Unsigned32,
        dot11WNMRqstBssTransitSessInfoURL                  OCTET STRING,
        dot11WNMRqstBssTransitCandidateList                OCTET STRING,
        dot11WNMRqstColocInterfAutoEnable                  TruthValue,
        dot11WNMRqstColocInterfRptTimeout                  Unsigned32,
        dot11WNMRqstVendorSpecific                         OCTET STRING,
        dot11WNMRqstDestinationURI                         OCTET STRING
    }

dot11WNMRqstIndex OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "Index for WNM Request elements in dot11WNMRequestTable, greater than 0."
    ::= { dot11WNMRequestEntry 1 }

dot11WNMRqstRowStatus OBJECT-TYPE
    SYNTAX RowStatus
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity when requesting a
        measurement, and by the SME when accepting a management request.

        The Row Status column of the current row, used for tracking status of an
        individual request. When this attribute is set to Active, AND a
        measurement request can be unambiguously created based on the parameters
        in the row, then the MLME may proceed to issue the request to its intended
        targets when appropriate. If not, this attribute may be set to Not-ready
        immediately to indicate parametric errors. However, it is the network
        managers
        responsibility to correct the error. If the request is successfully issued
        to the target STA, then the rowStatus is set to notInService."
    ::= { dot11WNMRequestEntry 2 }

dot11WNMRqstToken OBJECT-TYPE
    SYNTAX OCTET STRING
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity when the table entry is
        created, i.e., when requesting a measurement. Changes take effect when
        dot11RMRqstRowStatus is set to Active.

        This attribute indicates a unique string to identify this request. To
```

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```
        guarantee the uniqueness of this token across multiple network managers,
        it is recommended that this token be prefixed with the IP address of the
        network manager creating this row. This token is not necessarily
        equivalent to the measurement tokens in WNM request frames."
    ::= { dot11WNMRequestEntry 3 }

dot11WNMRqstIfIndex OBJECT-TYPE
    SYNTAX InterfaceIndex
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "The ifIndex for this row of WNM Request to be issued on."
    ::= { dot11WNMRequestEntry 4 }

dot11WNMRqstType OBJECT-TYPE
    SYNTAX INTEGER {
        mcastDiagnostics(0),
        locationCivic(1),
        locationIdentifier(2),
        event(3),
        dignostic(4),
        locationConfiguration(5),
        bssTransitionQuery(6),
        bssTransitionRqst(7),
        fms(8),
        colocInterference(9)
        }
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity when making a management
        request. Changes take effect when dot11WNMRqstRowStatus is set to Active.

        This attribute indicates the request type of this WNM request row."
    ::= { dot11WNMRequestEntry 5 }

dot11WNMRqstTargetAdd OBJECT-TYPE
    SYNTAX MacAddress
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity when making a management
        request. Changes take effect when dot11WNMRqstRowStatus is set to Active.

        The MAC address of STA for this row of WNM Request is to be issued to. If
        this attribute matches the MAC address of the dot11WNMRqstIfIndex, then
        measurement request is for this STA itself to carry out."
    ::= { dot11WNMRequestEntry 6 }

dot11WNMRqstTimeStamp OBJECT-TYPE
    SYNTAX TimeTicks
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity when making a management
        request. Changes take effect when dot11WNMRqstRowStatus is set to Active.

        This attribute indicates the SysUpTime Value the last time when
        dot11WNMRqstRowStatus is set to active or when this row is created the
        first time. This attribute shall be set by this STA or AP automatically,
        not by an SNMP manager."
```


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```
    ::= { dot11WNMRequestEntry 7 }

dot11WNMRqstRndInterval OBJECT-TYPE
    SYNTAX Unsigned32
    UNITS "TUs"
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity when making a management
        request. Changes take effect when dot11WNMRqstRowStatus is set to Active.

        This attribute indicates the upper bound of the random delay to be used
        prior to making the measurement. See 11.10.3 (Measurement start time)."
    DEFVAL { 0 }
    ::= { dot11WNMRequestEntry 8 }

dot11WNMRqstDuration OBJECT-TYPE
    SYNTAX Unsigned32
    UNITS "TUs"
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity when making a management
        request. Changes take effect when dot11WNMRqstRowStatus is set to Active.

        This attribute indicates the preferred or mandatory measurement duration
        for this Measurement Request."
    DEFVAL { 0 }
    ::= { dot11WNMRequestEntry 9 }

dot11WNMRqstMcstGroup OBJECT-TYPE
    SYNTAX MacAddress
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity when making a management
        request. Changes take effect when dot11WNMRqstRowStatus is set to Active.

        (#434)Indicates the multicast-group address of the multicast group for
        which diagnostics are requested. The BSSID shall be set to the wildcard
        BSSID when the measurement is to be performed on any multicast group on
        the operating channel. This attribute is valid only if the
        dot11WNMRqstType is 10, indicating a multicast diagnostic request, and is
        ignored otherwise."
    DEFVAL { 'FFFFFFFFFFFF'H }
    ::= { dot11WNMRequestEntry 10 }

dot11WNMRqstMcstTrigCon OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(1))
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity when making a management
        request. Changes take effect when dot11WNMRqstRowStatus is set to Active.

        This attribute indicates the trigger condition for the Multicast
        Diagnostic request."
    ::= { dot11WNMRequestEntry 11 }

dot11WNMRqstMcstTrigInactivityTimeout OBJECT-TYPE
```

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```
    SYNTAX Unsigned32 (1..255)
    UNITS "100 TUs"
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
       "This is a control variable.
       It is written by an external management entity when making a management
       request. Changes take effect when dot11WNMRqstRowStatus is set to Active.

       This attribute indicates the time interval value to be use as the
       threshold value for Trigger Inactivity Timeout trigger condition."
    ::= { dot11WNMRequestEntry 12 }

dot11WNMRqstMcstTrigReactDelay OBJECT-TYPE
    SYNTAX Unsigned32 (1..255)
    UNITS "100 TUs"
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
       "This is a control variable.
       It is written by an external management entity when making a management
       request. Changes take effect when dot11WNMRqstRowStatus is set to Active.

       This attribute indicates the time interval value during which a measuring
       STA does not generate further multicast triggered reports after a trigger
       condition has been met."
    ::= { dot11WNMRequestEntry 13 }

dot11WNMRqstLCRRqstSubject OBJECT-TYPE
    SYNTAX INTEGER {
       local(0),
       remote(1)
       }
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
       "This is a control variable.
       It is written by an external management entity when making a management
       request. Changes take effect when dot11WNMRqstRowStatus is set to Active.

       The attribute indicates the subject of the Location Civic request."
    DEFVAL { 0 }
    ::= { dot11WNMRequestEntry 14 }

dot11WNMRqstLCRIntervalUnits OBJECT-TYPE
    SYNTAX INTEGER {
       seconds(0),
       minutes(1),
       hours(2)
       }
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
       "This is a control variable.
       It is written by an external management entity when making a management
       request. Changes take effect when dot11WNMRqstRowStatus is set to Active.

       This attribute indicates the units used in the Location Civic Request
       Service Interval."
    ::= { dot11WNMRequestEntry 15 }

dot11WNMRqstLCRServiceInterval OBJECT-TYPE
    SYNTAX Unsigned32 (0..65535)
    MAX-ACCESS read-create
```


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```
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity when making a management
        request. Changes take effect when dot11WNMRqstRowStatus is set to Active.

        This attribute indicates the time interval, expressed in the units
        indicated in the Location Civic Request Service Interval Units field, at
        which the STA requests to receive Location Civic reports.  A Location
        Civic Request Service Interval of 0 indicates that only a single Location
        Civic report is requested."
    ::= { dot11WNMRequestEntry 16 }

dot11WNMRqstLIRRqstSubject OBJECT-TYPE
    SYNTAX INTEGER {
        local(0),
        remote(1)
        }
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity when making a management
        request. Changes take effect when dot11WNMRqstRowStatus is set to Active.

        The attribute indicates the subject of the Location Identifier request."
    DEFVAL { 0 }
    ::= { dot11WNMRequestEntry 17 }

dot11WNMRqstLIRIntervalUnits OBJECT-TYPE
    SYNTAX INTEGER {
        seconds(0),
        minutes(1),
        hours(2)
        }
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity when making a management
        request. Changes take effect when dot11WNMRqstRowStatus is set to Active.

        This attribute indicates the units used in the Location Identifier request
        Service Interval."
    ::= { dot11WNMRequestEntry 18 }

dot11WNMRqstLIRServiceInterval OBJECT-TYPE
    SYNTAX Unsigned32 (0..65535)
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity when making a management
        request. Changes take effect when dot11WNMRqstRowStatus is set to Active.

        This attribute indicates the time interval, expressed in the units
        indicated in the Location Identifier Request Interval Units field, at
        which the STA requests to receive Location Identifier reports. A Location
        Identifier Request Service Interval of 0 indicates that only a single
        Location Identifier report is requested."
    ::= { dot11WNMRequestEntry 19 }

dot11WNMRqstEventToken OBJECT-TYPE
    SYNTAX Unsigned32 (1..255)
```

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```
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
       "This is a control variable.
       It is written by an external management entity when making a management
       request. Changes take effect when dot11WNMRqstRowStatus is set to Active.

       This attribute indicates a unique string to identify this request."
    ::= { dot11WNMRequestEntry 20 }

dot11WNMRqstEventType OBJECT-TYPE
    SYNTAX INTEGER {
       transition(0),
       rsna(1),
       peerToPeer(2),
       wnmLog(3),
       vendorSpecific(221)
       }
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
       "This is a control variable.
       It is written by an external management entity when making a management
       request. Changes take effect when dot11WNMRqstRowStatus is set to Active.

       This attribute indicates the request type of this WNM Event request."
    ::= { dot11WNMRequestEntry 21 }

dot11WNMRqstEventResponseLimit OBJECT-TYPE
    SYNTAX Unsigned32 (0..255)
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
       "This is a control variable.
       It is written by an external management entity when making a management
       request. Changes take effect when dot11WNMRqstRowStatus is set to Active.

       This attribute indicates the maximum number of requested Event Reports to
       be included in the Event Report element. A value of 0 indicates that no
       limit is set on the number of Event Reports to be included in the Event
       Report element."
    ::= { dot11WNMRequestEntry 22 }

dot11WNMRqstEventTargetBssid OBJECT-TYPE
    SYNTAX MacAddress
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
       "This is a control variable.
       It is written by an external management entity when making a management
       request. Changes take effect when dot11WNMRqstRowStatus is set to Active.

       This attribute is used to request that a Transition or RSNA Event Report
       includes the event entry when the target BSSID is equal to the indicated
       BSSID. A transition event is a STA movement or attempted movement from one
       BSS (the source BSS) in one ESS to another BSS (the target BSS) within the
       same ESS. The BSSID shall be set to the wildcard BSSID when the
       transitions to any BSSID is requested."
    DEFVAL { 'FFFFFFFFFFFF'H }
    ::= { dot11WNMRequestEntry 23 }

dot11WNMRqstEventSourceBssid OBJECT-TYPE
    SYNTAX MacAddress
    MAX-ACCESS read-create
```


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```
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity when making a management
        request. Changes take effect when dot11WNMRqstRowStatus is set to Active.

        This attribute is used to request that a Transition Event Report includes
        the transition event entry when the source BSSID is equal to the indicated
        BSSID. A transition event is a STA movement or attempted movement from one
        BSS (the source BSS) in one ESS to another BSS (the target BSS) within the
        same ESS. The BSSID shall be set to the wildcard BSSID when the
        transitions from any BSSID is requested."
    DEFVAL { 'FFFFFFFFFFFF'H }
    ::= { dot11WNMRequestEntry 24 }

dot11WNMRqstEventTransitTimeThresh OBJECT-TYPE
    SYNTAX Unsigned32 (0..65535)
    UNITS "TUs"
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity when making a management
        request. Changes take effect when dot11WNMRqstRowStatus is set to Active.

        This attribute indicates a value representing the transition time to be
        used as the threshold value for the Transition Time condition in TUs. The
        Transition Time is defined in 11.21.2.2 (Transition event request and
        report)"
    ::= { dot11WNMRequestEntry 25 }

dot11WNMRqstEventTransitMatchValue OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(1))
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity when making a management
        request. Changes take effect when dot11WNMRqstRowStatus is set to Active.

        This attribute indicates a request for the specified transition results
        that match the bit descriptions of this field. B0 indicates match when
        transition is successful. B1 indicates match when transition fails."
    ::= { dot11WNMRequestEntry 26 }

dot11WNMRqstEventFreqTransitCountThresh OBJECT-TYPE
    SYNTAX Unsigned32 (0..255)
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity when making a management
        request. Changes take effect when dot11WNMRqstRowStatus is set to Active.

        This attribute indicates the minimum number of matching transitions
        detected in the measurement duration to generate a Transition Event
        report."
    ::= { dot11WNMRequestEntry 27 }

dot11WNMRqstEventFreqTransitInterval OBJECT-TYPE
    SYNTAX Unsigned32 (0..65535)
    UNITS "TUs"
    MAX-ACCESS read-create
    STATUS current
```

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```
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity when making a management
        request. Changes take effect when dot11WNMRqstRowStatus is set to Active.

        This attribute indicates the sliding window time interval during which the
        STA detects matching transitions to determine if the Frequent Transition
        Count Threshold is exceeded in order to generate a Transition Event
        report."
    ::= { dot11WNMRequestEntry 28 }

dot11WNMRqstEventRsnaAuthType OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(4))
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity when making a management
        request. Changes take effect when dot11WNMRqstRowStatus is set to Active.

        This attribute is used to request that an RSNA Event Report include the
        event entry when its RSNA Authentication Type matches the indicated RSNA
        authentication type value."
    ::= { dot11WNMRequestEntry 29 }

dot11WNMRqstEapType OBJECT-TYPE
    SYNTAX Unsigned32 (0..255)
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity when making a management
        request. Changes take effect when dot11WNMRqstRowStatus is set to Active.

        This attribute is used to request that an RSNA Event Report include the
        event entry when its EAP Type matches the indicated EAP type value. Valid
        EAP Type numbers are assigned by IANA and are defined at http://
        www.iana.org/assignments/eap-numbers."
    ::= { dot11WNMRequestEntry 30 }

dot11WNMRqstEapVendorId OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(0..3))
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity when making a management
        request. Changes take effect when dot11WNMRqstRowStatus is set to Active.

        This attribute is used to request that an RSNA Event Report include the
        event entry when its EAP Vendor ID matches the indicated vendor ID value.
        The EAP Vendor ID field is included when the EAP Type field is set to 254
        and is excluded otherwise."
    ::= { dot11WNMRequestEntry 31 }

dot11WNMRqstEapVendorType OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(0..4))
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity when making a management
        request. Changes take effect when dot11WNMRqstRowStatus is set to Active.
```


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```
        This attribute is used to request that an RSNA Event Report include the
        event entry when its EAP Vendor Type matches the indicated EAP vendor type
        value. The EAP Vendor ID field is included when the EAP Type field is set
        to 254 and is excluded otherwise."
    ::= { dot11WNMRequestEntry 32 }

dot11WNMRqstEventRsnaMatchValue OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(1))
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity when making a management
        request. Changes take effect when dot11WNMRqstRowStatus is set to Active.

        This attribute indicates a request for the specified transition results
        that match the bit descriptions of this field. B0 (least significant bit)
        indicates match when RSNA is successful. B1 indicates match when RSNA
        fails."
    ::= { dot11WNMRequestEntry 33 }

dot11WNMRqstEventPeerMacAddress OBJECT-TYPE
    SYNTAX MacAddress
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity when making a management
        request. Changes take effect when dot11WNMRqstRowStatus is set to Active.

        This attribute is used to request that a peer-to-peer link event report
        includes the transition event entry when the MAC address of the peer STA
        or IBSS BSSID is equal to the indicated MAC address. The MAC address shall
        be set to the wildcard BSSID when the transitions from any peer STA or
        IBSS BSSID is requested."
    DEFVAL { 'FFFFFFFFFFFF'H }
    ::= { dot11WNMRequestEntry 34 }

dot11WNMRqstOperatingClass OBJECT-TYPE
    SYNTAX Unsigned32 (1..255)
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity when making a management
        request. Changes take effect when dot11WNMRqstRowStatus is set to Active.

        This attribute indicates the channel set for this WNM request. Country,
        Operating Class and Channel Number together specify the channel frequency
        and spacing for this measurement request. Valid values of Operating Class
        are shown in Annex E."
    ::= { dot11WNMRequestEntry 35 }

dot11WNMRqstChanNumber OBJECT-TYPE
    SYNTAX Unsigned32 (1..255)
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity when making a management
        request. Changes take effect when dot11WNMRqstRowStatus is set to Active.

        This attribute indicates the current operating channel for this WNM
        request. The Channel Number is defined only within the indicated Operating
```

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```
        Class as shown in Annex E."
    ::= { dot11WNMRequestEntry 36 }

dot11WNMRqstDiagToken OBJECT-TYPE
    SYNTAX Unsigned32 (1..255)
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity when making a management
        request. Changes take effect when dot11WNMRqstRowStatus is set to Active.

        This attribute indicates a unique string to identify this request."
    ::= { dot11WNMRequestEntry 37 }

dot11WNMRqstDiagType OBJECT-TYPE
    SYNTAX INTEGER {
        cancelRequest(0),
        manufacturerInfoStaRep(1),
        configurationProfile(2),
        associationDiag(3),
        ieee8021xAuthDiag(4),
        vendorSpecific(221)
        }
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity when making a management
        request. Changes take effect when dot11WNMRqstRowStatus is set to Active.

        This attribute indicates the request type of this WNM Diagnostic request."
    ::= { dot11WNMRequestEntry 38 }

dot11WNMRqstDiagTimeout OBJECT-TYPE
    SYNTAX Unsigned32 (0..65535)
    UNITS "seconds"
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity when making a management
        request. Changes take effect when dot11WNMRqstRowStatus is set to Active.

        This attribute indicates a value representing the time interval after a
        Diagnostic Report is generated during which no additional Diagnostic
        Reports shall be sent."
    ::= { dot11WNMRequestEntry 39 }

dot11WNMRqstDiagBssid OBJECT-TYPE
    SYNTAX MacAddress
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity when making a management
        request. Changes take effect when dot11WNMRqstRowStatus is set to Active.

        This attribute indicates a request for a Diagnostic Report from the
        indicated BSSID. The BSSID shall be set to the wildcard BSSID when
        diagnostics from any BSSID is requested."
    DEFVAL { 'FFFFFFFFFFFF'H }
    ::= { dot11WNMRequestEntry 40 }
```


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```
dot11WNMRqstDiagProfileId OBJECT-TYPE
   SYNTAX Unsigned32 (1..255)
   MAX-ACCESS read-create
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by an external management entity when making a management
      request. Changes take effect when dot11WNMRqstRowStatus is set to Active.

      This attribute indicates a unique identifier for referencing a
      configuration profile available on a (#4213)STA. The value of the
      identifier can be any arbitrary value, as long as it is uniquely
      associated to a single configuration profile on the (#4213)STA sending the
      identifier."
   ::= { dot11WNMRequestEntry 41 }

dot11WNMRqstDiagCredentials OBJECT-TYPE
   SYNTAX INTEGER {
      none(0),
      preSharedKey(1),
      usernamePassword(2),
      x509Certificate(3),
      otherCertificate(4),
      oneTimePassword(5),
      token(6)
      }
   MAX-ACCESS read-create
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by an external management entity when making a management
      request. Changes take effect when dot11WNMRqstRowStatus is set to Active.

      This attribute indicates the type of credential used for the IEEE 802.1X
      authentication."
   ::= { dot11WNMRequestEntry 42 }

dot11WNMRqstLocConfigLocIndParams OBJECT-TYPE
   SYNTAX OCTET STRING (SIZE(16))
   MAX-ACCESS read-create
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by an external management entity when making a management
      request. Changes take effect when dot11WNMRqstRowStatus is set to Active.

      This attribute indicates STA Location reporting characteristics. The
      format of these Location Indication Parameters are detailed in 9.4.2.69.2
      (Location Indication Parameters subelement)."
   ::= { dot11WNMRequestEntry 43 }

dot11WNMRqstLocConfigChanList OBJECT-TYPE
   SYNTAX OCTET STRING (SIZE(0..252))
   MAX-ACCESS read-create
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by an external management entity when making a management
      request. Changes take effect when dot11WNMRqstRowStatus is set to Active.

      This attribute lists location reporting channel information for this
      location configuration request. Each pair of octets indicates a different
      operating class and channel number for this request. The detailed format
      for this list of channels is described in 9.4.2.69.3 (Location Indication
```

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```
        Channels subelement)."
    DEFVAL { ''H }
    ::= { dot11WNMRequestEntry 44 }

dot11WNMRqstLocConfigBcastRate OBJECT-TYPE
    SYNTAX Unsigned32 (0..65535)
    UNITS "0.5 Mb/s"
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity when making a management
        request. Changes take effect when dot11WNMRqstRowStatus is set to Active.

        This attribute indicates the target data rate at which the STA transmits
        Location Track Notification frames. A value of 0 indicates the STA
        transmits Location Track Notification frames at a rate chosen by the STA
        transmitting the Location Track Notification frames."
    ::= { dot11WNMRequestEntry 45 }

dot11WNMRqstLocConfigOptions OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(0..255))
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity when making a management
        request. Changes take effect when dot11WNMRqstRowStatus is set to Active.

        This attribute indicates the location track indication options used; see
        9.4.2.69.9 (Location Indication Options subelement)."
    DEFVAL { ''H }
    ::= { dot11WNMRequestEntry 46 }

dot11WNMRqstBssTransitQueryReason OBJECT-TYPE
    SYNTAX INTEGER {
        unspecified(0),
        excessiveFrameLossRatesPoorConditions(1),
        excessiveDelayForCurrentTrafficStreams(2),
        insufficientQosCapacityForCurrentTrafficStreams(3),
        firstAssociationToEss(4),
        loadBalancing(5),
        betterApFound(6),
        deauthenticatedDisassociatedFromPreviousAp(7),
        apFailedIeee8021XEapAuthentication(8),
        apFailed4wayHandshake(9),
        receivedTooManyReplayCounterFailures(10),
        receivedTooManyDataMICFailures(11),
        exceededMaxNumberOfRetransmissions(12),
        receivedTooManyBroadcastDisassociations(13),
        receivedTooManyBroadcastDeauthentications(14),
        previousTransitionFailed(15),
        lowRSSI(16)
        }
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity when making a management
        request. Changes take effect when dot11WNMRqstRowStatus is set to Active.

        This attribute indicates the reason for the BSS Transition Query. The
        format for this list of reasons is further detailed in 9.4.2.66.2
        (Transition event report)."
```


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```
    ::= { dot11WNMRequestEntry 47 }

dot11WNMRqstBssTransitReqMode OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(1))
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity when making a management
        request. Changes take effect when dot11WNMRqstRowStatus is set to Active.

        This attribute indicates the type of BSS request transition. B0 (least
        significant bit) indicates the Preferred Candidate list is included in
        this frame. B1 indicates an abridged format for all BSSIDs not listed in
        this frame. B2 indicates that the STA will be disassociated for the
        current AP. B3 indicates the BSS is shutting down and that the STA will be
        disassociated. B4 indicates that the (M118)STA will be disassociated from
        the ESS. The format for this field is detailed in 9.6.13.9 (BSS Transition
        Management Request frame format)."
    ::= { dot11WNMRequestEntry 48 }

dot11WNMRqstBssTransitDisocTimer OBJECT-TYPE
    SYNTAX Unsigned32 (0..65535)
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity when making a management
        request. Changes take effect when dot11WNMRqstRowStatus is set to Active.

        This attribute indicates the number of TBTTs until the serving AP sends a
        Disassociation frame to this STA. The value 0 indicates unknown. If the
        Disassociation Imminent bit of the Request Mode field is set to 0, this
        field is ignored."
    ::= { dot11WNMRequestEntry 49 }

dot11WNMRqstBssTransitSessInfoURL OBJECT-TYPE
    SYNTAX OCTET STRING
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity when making a management
        request. Changes take effect when dot11WNMRqstRowStatus is set to Active.

        This attribute contains a variable length field formatted in accordance
        with IETF RFC 3986-2005."
    ::= { dot11WNMRequestEntry 50 }

dot11WNMRqstBssTransitCandidateList OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(0..11426))
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity when making a management
        request. Changes take effect when dot11WNMRqstRowStatus is set to Active.

        This attribute lists one or more Neighbor Report elements described in
        9.4.2.35 (Neighbor Report element). If the STA has no Transition Candidate
        information in response to the BSS Transition Management Query frame, the
        candidate list is null. "
    ::= { dot11WNMRequestEntry 51 }
```

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```
dot11WNMRqstColocInterfAutoEnable OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-create
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by an external management entity when making a management
      request. Changes take effect when dot11WNMRqstRowStatus is set to Active.

      This attribute, when true, indicates that the requesting STA requests the
      receiving STA to send the (#2210)Colocated Interference Response frames
      periodically with the Report Period interval, as defined in 9.6.13.13
      ((#2210)Colocated Interference Request frame format), or when the STA
      detects a change in the (#2210)colocated interference."
   ::= { dot11WNMRequestEntry 52 }

dot11WNMRqstColocInterfRptTimeout OBJECT-TYPE
   SYNTAX Unsigned32 (0..127)
   UNITS "100 TUs"
   MAX-ACCESS read-create
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by an external management entity when making a management
      request. Changes take effect when dot11WNMRqstRowStatus is set to Active.

      This attribute indicates the minimum duration between two consecutive
      (#2210)Colocated Interference Response frames from the reporting STA."
   ::= { dot11WNMRequestEntry 53 }

dot11WNMRqstVendorSpecific OBJECT-TYPE
   SYNTAX OCTET STRING (SIZE(0..255))
   MAX-ACCESS read-create
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by an external management entity when making a management
      request. Changes take effect when dot11WNMRqstRowStatus is set to Active.

      This attribute provides an envelope for any optional vendor specific
      subelements that may be included in a WNM request element."
   DEFVAL { ''H }
   ::= { dot11WNMRequestEntry 54}

dot11WNMRqstDestinationURI OBJECT-TYPE
   SYNTAX OCTET STRING (SIZE(0..253))
   MAX-ACCESS read-create
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by an external management entity when making a management
      request. Changes take effect when dot11WNMRqstRowStatus is set to Active.

      This attribute provides the Destination URI which defines an alternate
      destination for the WNM request. The alternate destination may be an
      internet address on an Ethernet adapter, for example, to be used when the
      wireless link to the requesting entity is unavailable or unreliable."
   DEFVAL { ''H }
   ::= { dot11WNMRequestEntry 55}

-- ************************************************************************
-- * End of dot11WNMRequest TABLE
-- ************************************************************************
```



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```
-- ********************************************************************
-- * Wireless network management reports:
-- * Report tables contain WNM reports received by this STA or
-- * results of WNM requests performed by this STA.
-- ********************************************************************

dot11WNMReport OBJECT IDENTIFIER ::= { dot11WirelessNetworkManagement 2 }

-- ********************************************************************
-- * dot11WNMVendorSpecificReport TABLE
-- ********************************************************************
dot11WNMVendorSpecificReportTable OBJECT-TYPE
   SYNTAX SEQUENCE OF Dot11WNMVendorSpecificReportEntry
   MAX-ACCESS not-accessible
   STATUS current
   DESCRIPTION
      "Group contains the current list of Vendor Specific reports that have been
      received by the MLME. The report tables shall be maintained as FIFO to
      preserve freshness, thus the rows in this table can be deleted for memory
      constraints or other implementation constraints determined by the vendor.
      New rows shall have different RprtIndex values than those deleted within
      the range limitation of the index. One easy way is to increment RprtIndex
      for new reports being written in the table."
   ::= { dot11WNMReport 1 }

dot11WNMVendorSpecificReportEntry OBJECT-TYPE
   SYNTAX Dot11WNMVendorSpecificReportEntry
   MAX-ACCESS not-accessible
   STATUS current
   DESCRIPTION
      "An entry in the dot11WNMVendorSpecificReportTable Indexed by
      dot11WNMVendorSpecificRprtIndex."
   INDEX { dot11WNMVendorSpecificRprtIndex }
   ::= { dot11WNMVendorSpecificReportTable 1 }

Dot11WNMVendorSpecificReportEntry ::=
   SEQUENCE {
      dot11WNMVendorSpecificRprtIndex                    Unsigned32,
      dot11WNMVendorSpecificRprtRqstToken                OCTET STRING,
      dot11WNMVendorSpecificRprtIfIndex                  InterfaceIndex,
      dot11WNMVendorSpecificRprtContent                  OCTET STRING }

dot11WNMVendorSpecificRprtIndex OBJECT-TYPE
   SYNTAX Unsigned32
   MAX-ACCESS not-accessible
   STATUS current
   DESCRIPTION
      "Index for Vendor Specific Report elements in
      dot11WNMVendorSpecificReportTable, greater than 0."
   ::= { dot11WNMVendorSpecificReportEntry 1 }

dot11WNMVendorSpecificRprtRqstToken OBJECT-TYPE
   SYNTAX OCTET STRING
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a status variable.
      It is written by the SME when a management report is completed.

      This attribute indicates the request token that was indicated in the WNM
      request that generated this measurement report. This should be an exact
      match to the original dot11WNMRqstToken attribute. Note that there may be
      multiple entries in the table that match this value since a single request
      may generate multiple WNM reports."
```

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```
    ::= { dot11WNMVendorSpecificReportEntry 2 }

dot11WNMVendorSpecificRprtIfIndex OBJECT-TYPE
    SYNTAX InterfaceIndex
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "The ifIndex for this row of WNMVendorSpecific report has been received
        on."
    ::= { dot11WNMVendorSpecificReportEntry 3 }

dot11WNMVendorSpecificRprtContent OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(0..255))
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute provides an envelope for all of the vendor specific
        subelements that may be included in a WNM Vendor Specific request
        element."
    DEFVAL { ''H }
    ::= { dot11WNMVendorSpecificReportEntry 4 }

-- ********************************************************************
-- * End of dot11WNMVendorSpecificReport TABLE
-- ********************************************************************

-- ********************************************************************
-- * dot11WNMMulticastDiagnosticReport TABLE
-- ********************************************************************
dot11WNMMulticastDiagnosticReportTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11WNMMulticastDiagnosticReportEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "Group contains the current list of Multicast Diagnostic reports that have
        been received by the MLME. The report tables shall be maintained as FIFO
        to preserve freshness, thus the rows in this table can be deleted for
        memory constraints or other implementation constraints determined by the
        vendor. New rows shall have different RprtIndex values than those deleted
        within the range limitation of the index. One easy way is to increment
        RprtIndex for new reports being written in the table."
    ::= { dot11WNMReport 2 }

dot11WNMMulticastDiagnosticReportEntry OBJECT-TYPE
    SYNTAX Dot11WNMMulticastDiagnosticReportEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "An entry in the dot11WNMMulticastDiagnosticReportTable Indexed by
        dot11WNMMulticastDiagnosticRprtIndex."
    INDEX { dot11WNMMulticastDiagnosticRprtIndex }
    ::= { dot11WNMMulticastDiagnosticReportTable 1 }

Dot11WNMMulticastDiagnosticReportEntry ::=
    SEQUENCE {
        dot11WNMMulticastDiagnosticRprtIndex                Unsigned32,
        dot11WNMMulticastDiagnosticRprtRqstToken            OCTET STRING,
        dot11WNMMulticastDiagnosticRprtIfIndex              InterfaceIndex,
        dot11WNMMulticastDiagnosticRprtMeasurementTime      TSFType,
        dot11WNMMulticastDiagnosticRprtDuration             Unsigned32,
        dot11WNMMulticastDiagnosticRprtMcstGroup            MacAddress,
```


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```
        dot11WNMMulticastDiagnosticRprtReason                  OCTET STRING,
        dot11WNMMulticastDiagnosticRprtRcvdMsduCount           Unsigned32,
        dot11WNMMulticastDiagnosticRprtFirstSeqNumber          Unsigned32,
        dot11WNMMulticastDiagnosticRprtLastSeqNumber           Unsigned32,
        dot11WNMMulticastDiagnosticRprtMcstRate                Unsigned32  }

dot11WNMMulticastDiagnosticRprtIndex OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "Index for Multicast Diagnostics reports in
        dot11WNMMulticastDiagnosticReportTable, greater than 0."
    ::= { dot11WNMMulticastDiagnosticReportEntry 1 }

dot11WNMMulticastDiagnosticRprtRqstToken OBJECT-TYPE
    SYNTAX OCTET STRING
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute indicates the request token that was indicated in the WNM
        request that generated this measurement report. This should be an exact
        match to the original dot11WNMRqstToken attribute. Note that there may be
        multiple entries in the table that match this value since a single request
        may generate multiple WNM reports."
    ::= { dot11WNMMulticastDiagnosticReportEntry 2 }

dot11WNMMulticastDiagnosticRprtIfIndex OBJECT-TYPE
    SYNTAX InterfaceIndex
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "The ifIndex for this row of WNMMulticastDiagnostic report been received
        on."
    ::= { dot11WNMMulticastDiagnosticReportEntry 3 }

dot11WNMMulticastDiagnosticRprtMeasurementTime OBJECT-TYPE
    SYNTAX TSFType
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute indicates the value of the STA TSF timer at the time the
        measurement started. In a triggered Multicast Diagnostics report, this is
        the TSF value at the reporting STA when the trigger condition was met.
        When the reason for sending the report is Performance Measurement and the
        Multicast Received MSDU Count is nonzero, the Measurement Time field is
        set to the value of the STA TSF timer at the time of the first group
        addressed MSDU received during the measurement interval."
    ::= { dot11WNMMulticastDiagnosticReportEntry 4 }

dot11WNMMulticastDiagnosticRprtDuration OBJECT-TYPE
    SYNTAX Unsigned32
    UNITS "TUs"
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.
```

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```
        This attribute indicates the period over which the Multicast Diagnostics
        report was generated."
    ::= { dot11WNMMulticastDiagnosticReportEntry 5 }

dot11WNMMulticastDiagnosticRprtMcstGroup OBJECT-TYPE
    SYNTAX MacAddress
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        (#434)Indicates the multicast-group address of the multicast group for
        this report element."
    ::= { dot11WNMMulticastDiagnosticReportEntry 6 }

dot11WNMMulticastDiagnosticRprtReason OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(1))
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute indicates the reason why the measuring STA sent the
        Multicast Diagnostics report. B0 (least significant bit) indicates
        Inactivity Timeout Trigger. B1 indicates the measurement result from the
        completed measurement. These are defined further in 9.4.2.20.12 (Multicast
        Diagnostics report)."
    ::= { dot11WNMMulticastDiagnosticReportEntry 7 }

dot11WNMMulticastDiagnosticRprtRcvdMsduCount OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute indicates the total number of group addressed MSDUs with
        the indicated Multicast MAC Address that were received during the
        Measurement Duration. In a triggered multicast diagnostics measurement
        this is the total number of MSDUs received between the acceptance of the
        multicast diagnostics measurement request and the occurrence of the
        trigger condition for MSDUs with the indicated Multicast MAC Address."
    ::= { dot11WNMMulticastDiagnosticReportEntry 8 }

dot11WNMMulticastDiagnosticRprtFirstSeqNumber OBJECT-TYPE
    SYNTAX Unsigned32 (0..65535)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute indicates the twelve least significant bits of the First
        Sequence Number field. When the LSB of the first octet of the Multicast
        MAC address field in the multicast diagnostic request is set to 1, the
        twelve LSBs of the First Sequence Number field contain the sequence number
        of the first frame received with destination address equal to the value in
        the Multicast MAC address field during the measurement period. When the
        LSB of the first octet of the Multicast MAC address field in the multicast
        diagnostic request is set to 0, the twelve LSBs of the First Sequence
```


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```
        Number field contain the sequence number of the first group addressed
        frame, that does not have the broadcast address as its destination,
        received during the measurement period. The four most significant bits of
        the First Sequence Number field are set to 0. This field is set to 0 if the
        Multicast Received MSDU Count is 0."
    ::= { dot11WNMMulticastDiagnosticReportEntry 9 }

dot11WNMMulticastDiagnosticRprtLastSeqNumber OBJECT-TYPE
    SYNTAX Unsigned32 (0..65535)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute indicates the twelve least significant bits of the Last
        Sequence Number field. When the LSB of the first octet of the Multicast
        MAC address field in the multicast diagnostic request is set to 1, the
        twelve LSBs of the Last Sequence Number field contain the sequence number
        of the last frame received with destination address equal to the value in
        the Multicast MAC address field during the measurement period. When the
        LSB of the first octet of the Multicast MAC address field in the multicast
        diagnostic request is 0, the twelve LSBs of the Last Sequence Number field
        contain the sequence number of the last group addressed frame, that does
        not have the broadcast address as its destination, received during the
        measurement period. The four most significant bits of the Last Sequence
        Number field are set to 0. This field is set to 0 if the Multicast
        Received MSDU Count is 0."
    ::= { dot11WNMMulticastDiagnosticReportEntry 10 }

dot11WNMMulticastDiagnosticRprtMcstRate OBJECT-TYPE
    SYNTAX Unsigned32 (0..65535)
    UNITS "0.5 Mb/s"
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute indicates the highest data rate at which the STA has
        received a group addressed frame during the measurement period. The
        Multicast Rate field is encoded with the MSB set to 1 to indicate that the
        data rate is in the basic rate set, and set to 0 to indicate that the data
        rate is not in the basic rate set. The remaining 15-bit value is
        multiplied by 0.5 Mb/s to indicate the data rate. The Multicast Rate field
        is set to 0 by the STA to indicate that it has not received a group
        addressed frame during the measurement period."
    ::= { dot11WNMMulticastDiagnosticReportEntry 11 }

-- ********************************************************************
-- * End of dot11WNMMulticastDiagnosticReport TABLE
-- ********************************************************************

-- ********************************************************************
-- * dot11WNMLocationCivicReport TABLE
-- ********************************************************************
dot11WNMLocationCivicReportTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11WNMLocationCivicReportEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "Group contains the current list of Location Civic reports that have been
        received by the MLME. The report tables shall be maintained as FIFO to
        preserve freshness, thus the rows in this table can be deleted for memory
```

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```
        constraints or other implementation constraints determined by the vendor.
        New rows shall have different RprtIndex values than those deleted within
        the range limitation of the index. One easy way is to increment RprtIndex
        for new reports being written in the table."
    ::= { dot11WNMReport 3 }

dot11WNMLocationCivicReportEntry OBJECT-TYPE
    SYNTAX Dot11WNMLocationCivicReportEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "An entry in the dot11WNMLocationCivicReportTable Indexed by
        dot11WNMLocationCivicRprtIndex."
    INDEX { dot11WNMLocationCivicRprtIndex }
    ::= { dot11WNMLocationCivicReportTable 1 }

Dot11WNMLocationCivicReportEntry ::=
    SEQUENCE {
        dot11WNMLocationCivicRprtIndex                      Unsigned32,
        dot11WNMLocationCivicRprtRqstToken                  OCTET STRING,
        dot11WNMLocationCivicRprtIfIndex                    InterfaceIndex,
        dot11WNMLocationCivicRprtCivicLocation              OCTET STRING }

dot11WNMLocationCivicRprtIndex OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "Index for Location Civic reports in dot11WNMLocationCivicReportTable,
        greater than 0."
    ::= { dot11WNMLocationCivicReportEntry 1 }

dot11WNMLocationCivicRprtRqstToken OBJECT-TYPE
    SYNTAX OCTET STRING
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute indicates the request token that was indicated in the WNM
        request that generated this measurement report. This should be an exact
        match to the original dot11WNMRqstToken attribute. Note that there may be
        multiple entries in the table that match this value since a single request
        may generate multiple WNM reports."
    ::= { dot11WNMLocationCivicReportEntry 2 }

dot11WNMLocationCivicRprtIfIndex OBJECT-TYPE
    SYNTAX InterfaceIndex
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "The ifIndex for this row of WNMLocationCivic report been received on."
    ::= { dot11WNMLocationCivicReportEntry 3 }

dot11WNMLocationCivicRprtCivicLocation OBJECT-TYPE
    SYNTAX OCTET STRING
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute indicates a variable octet field and contains a list of
```


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```
        civic address elements in TLV format as defined in IETF RFC 4776."
    ::= { dot11WNMLocationCivicReportEntry 4}

-- ********************************************************************
-- * End of dot11WNMLocationCivicReport TABLE
-- ********************************************************************

-- ********************************************************************
-- * dot11WNMLocationIdentifierReport TABLE
-- ********************************************************************
dot11WNMLocationIdentifierReportTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11WNMLocationIdentifierReportEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "Group contains the current list of Location Identifier reports that have
        been received by the MLME. The report tables shall be maintained as FIFO
        to preserve freshness, thus the rows in this table can be deleted for
        memory constraints or other implementation constraints determined by the
        vendor. New rows shall have different RprtIndex values than those deleted
        within the range limitation of the index. One easy way is to increment
        RprtIndex for new reports being written in the table."
    ::= { dot11WNMReport 4 }

dot11WNMLocationIdentifierReportEntry OBJECT-TYPE
    SYNTAX Dot11WNMLocationIdentifierReportEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "An entry in the dot11WNMLocationIdentifierReportTable Indexed by
        dot11WNMLocationIdentifierRprtIndex."
    INDEX { dot11WNMLocationIdentifierRprtIndex }
    ::= { dot11WNMLocationIdentifierReportTable 1 }

Dot11WNMLocationIdentifierReportEntry ::=
    SEQUENCE {
        dot11WNMLocationIdentifierRprtIndex                  Unsigned32,
        dot11WNMLocationIdentifierRprtRqstToken              OCTET STRING,
        dot11WNMLocationIdentifierRprtIfIndex                InterfaceIndex,
        dot11WNMLocationIdentifierRprtExpirationTSF          TSFType,
        dot11WNMLocationIdentifierRprtPublicIdUri            OCTET STRING }

dot11WNMLocationIdentifierRprtIndex OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "Index for Location Identifier reports in
        dot11WNMLocationIdentifierReportTable, greater than 0."
    ::= { dot11WNMLocationIdentifierReportEntry 1 }

dot11WNMLocationIdentifierRprtRqstToken OBJECT-TYPE
    SYNTAX OCTET STRING
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute indicates the request token that was indicated in the WNM
        request that generated this measurement report. This should be an exact
        match to the original dot11WNMRqstToken attribute. Note that there may be
        multiple entries in the table that match this value since a single request
        may generate multiple WNM reports."
```

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```
    ::= { dot11WNMLocationIdentifierReportEntry 2 }

dot11WNMLocationIdentifierRprtIfIndex OBJECT-TYPE
    SYNTAX InterfaceIndex
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "The ifIndex for this row of WNMLocationIdentifier report been received
        on."
    ::= { dot11WNMLocationIdentifierReportEntry 3 }

dot11WNMLocationIdentifierRprtExpirationTSF OBJECT-TYPE
    SYNTAX TSFType
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute indicates the value of the STA TSF timer when the Public
        Identifier URI/FQDN field value is no longer valid. The Expiration TSF
        field set to 0 indicates the Public Identifier URI/FQDN does not expire."
    ::= { dot11WNMLocationIdentifierReportEntry 4 }

dot11WNMLocationIdentifierRprtPublicIdUri OBJECT-TYPE
    SYNTAX OCTET STRING
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute contains concatenated Public Identifier URI/FQDN
        subelements, one per Public Identifier URI or FQDN. The format for a
        Public Identifier URI/FQDN subelement is further detailed in 9.4.2.20.14
        (Location Identifier report)."
    ::= { dot11WNMLocationIdentifierReportEntry 5}

-- ********************************************************************
-- * End of dot11WNMLocationIdentifierReport TABLE
-- ********************************************************************

-- ********************************************************************
-- * dot11WNMEventTransitReport TABLE
-- ********************************************************************
dot11WNMEventTransitReportTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11WNMEventTransitReportEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "Group contains the current list of Transition Event reports that have
        been received by the MLME. The report tables shall be maintained as FIFO
        to preserve freshness, thus the rows in this table can be deleted for
        memory constraints or other implementation constraints determined by the
        vendor. New rows shall have different RprtIndex values than those deleted
        within the range limitation of the index. One easy way is to increment
        RprtIndex for new reports being written in the table."
    ::= { dot11WNMReport 5 }

dot11WNMEventTransitReportEntry OBJECT-TYPE
    SYNTAX Dot11WNMEventTransitReportEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
```


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```
        "An entry in the dot11WNMEventTransitReportTable Indexed by
        dot11WNMEventTransitRprtIndex."
    INDEX { dot11WNMEventTransitRprtIndex }
    ::= { dot11WNMEventTransitReportTable 1 }

Dot11WNMEventTransitReportEntry ::=
    SEQUENCE {
        dot11WNMEventTransitRprtIndex                    Unsigned32,
        dot11WNMEventTransitRprtRqstToken                OCTET STRING,
        dot11WNMEventTransitRprtIfIndex                  InterfaceIndex,
        dot11WNMEventTransitRprtEventStatus              INTEGER,
        dot11WNMEventTransitRprtEventTSF                 TSFType,
        dot11WNMEventTransitRprtUTCOffset                OCTET STRING,
        dot11WNMEventTransitRprtTimeError                OCTET STRING,
        dot11WNMEventTransitRprtSourceBssid              MacAddress,
        dot11WNMEventTransitRprtTargetBssid              MacAddress,
        dot11WNMEventTransitRprtTransitTime              Unsigned32,
        dot11WNMEventTransitRprtTransitReason            INTEGER,
        dot11WNMEventTransitRprtTransitResult            Unsigned32,
        dot11WNMEventTransitRprtSourceRCPI               Unsigned32,
        dot11WNMEventTransitRprtSourceRSNI               Unsigned32,
        dot11WNMEventTransitRprtTargetRCPI               Unsigned32,
        dot11WNMEventTransitRprtTargetRSNI               Unsigned32 }

dot11WNMEventTransitRprtIndex OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "Index for Transition Event Report elements in
        dot11WNMEventTransitReportTable, greater than 0."
    ::= { dot11WNMEventTransitReportEntry 1 }

dot11WNMEventTransitRprtRqstToken OBJECT-TYPE
    SYNTAX OCTET STRING
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute indicates the request token that was indicated in the WNM
        request that generated this measurement report. This should be an exact
        match to the original dot11WNMRqstToken attribute. Note that there may be
        multiple entries in the table that match this value since a single request
        may generate multiple WNM reports."
    ::= { dot11WNMEventTransitReportEntry 2 }

dot11WNMEventTransitRprtIfIndex OBJECT-TYPE
    SYNTAX InterfaceIndex
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "The ifIndex for this row of WNMEventTransit report been received on."
    ::= { dot11WNMEventTransitReportEntry 3 }

dot11WNMEventTransitRprtEventStatus OBJECT-TYPE
    SYNTAX INTEGER {
        successful(0),
        requestFailed(1),
        requestRefused(2),
        requestIncapable(3),
        detectedFrequentTransition(4)
        }
```

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```
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute contains the status value included in the Event report."
    ::= { dot11WNMEventTransitReportEntry 4 }

dot11WNMEventTransitRprtEventTSF OBJECT-TYPE
    SYNTAX TSFType
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute contains the value of the Event TSF field."
    ::= { dot11WNMEventTransitReportEntry 5 }

dot11WNMEventTransitRprtUTCOffset OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(10))
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute indicates the UTC Offset Time Value optionally included in
        the Event report."
    ::= { dot11WNMEventTransitReportEntry 6 }

dot11WNMEventTransitRprtTimeError OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(5))
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute contains the value of the Event Time Error field optionally
        included in the Event report."
    ::= { dot11WNMEventTransitReportEntry 7 }

dot11WNMEventTransitRprtSourceBssid OBJECT-TYPE
    SYNTAX MacAddress
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute indicates the source BSSID for the reported transition
        event."
    ::= { dot11WNMEventTransitReportEntry 8 }

dot11WNMEventTransitRprtTargetBssid OBJECT-TYPE
    SYNTAX MacAddress
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.
```


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```
        This attribute indicates the target BSSID for the reported transition
        event."
    ::= { dot11WNMEventTransitReportEntry 9 }

dot11WNMEventTransitRprtTransitTime OBJECT-TYPE
    SYNTAX Unsigned32 (0..65535)
    UNITS "TUs"
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute indicates the transition time for the reported transition
        event in TUs. The Transition time is defined as the time difference
        between the starting time and the ending time of a transition between APs,
        even if the transition results in remaining on the same AP. Start and end
        times for a transition event are defined in 11.21.2.2 (Transition event
        request and report)"
    ::= { dot11WNMEventTransitReportEntry 10 }

dot11WNMEventTransitRprtTransitReason OBJECT-TYPE
    SYNTAX INTEGER {
        unspecified(0),
        excessiveFrameLossRatesPoorConditions(1),
        excessiveDelayForCurrentTrafficStreams(2),
        insufficientQosCapacityForCurrentTrafficStreams(3),
        firstAssociationToEss(4),
        loadBalancing(5),
        betterApFound(6),
        deauthenticatedDisassociatedFromPreviousAp(7),
        apFailedIeee8021XEapAuthentication(8),
        apFailed4wayHandshake(9),
        receivedTooManyReplayCounterFailures(10),
        receivedTooManyDataMICFailures(11),
        exceededMaxNumberOfRetransmissions(12),
        receivedTooManyBroadcastDisassociations(13),
        receivedTooManyBroadcastDeauthentications(14),
        previousTransitionFailed(15),
        lowRSSI(16)
        }
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute indicates the reason for the reported BSS Transition event.
        The format for this list of reasons is further detailed in 9.4.2.66.2
        (Transition event report)."
    ::= { dot11WNMEventTransitReportEntry 11 }

dot11WNMEventTransitRprtTransitResult OBJECT-TYPE
    SYNTAX Unsigned32 (0..65535)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute indicates the result of the attempted transition and is set
        to one of the status codes specified in Table 9-80 (Status codes) in
        9.4.1.9 (Status Code field)."
    ::= { dot11WNMEventTransitReportEntry 12 }
```

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```
dot11WNMEventTransitRprtSourceRCPI OBJECT-TYPE
   SYNTAX Unsigned32 (0..255)
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a status variable.
      It is written by the SME when a management report is completed.

      This attribute indicates the received channel power of the most recently
      measured PPDU containing a frame from the Source BSSID before the STA
      reassociates with(#1427) the Target BSSID. The Source RCPI is a
      logarithmic function of the received signal power, as defined 9.4.2.36
      (RCPI element)."
   ::= { dot11WNMEventTransitReportEntry 13 }

dot11WNMEventTransitRprtSourceRSNI OBJECT-TYPE
   SYNTAX Unsigned32 (0..255)
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a status variable.
      It is written by the SME when a management report is completed.

      This attribute indicates the received signal-to-noise indication of the
      most recently measured frame from the Source BSSID before the STA
      reassociates with(#1427) the Target BSSID. The Source RSNI is a
      logarithmic function of the signal-to-noise ratio, as defined in 9.4.2.39
      (RSNI element)."
   ::= { dot11WNMEventTransitReportEntry 14 }

dot11WNMEventTransitRprtTargetRCPI OBJECT-TYPE
   SYNTAX Unsigned32 (0..255)
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a status variable.
      It is written by the SME when a management report is completed.

      This attribute indicates the received channel power of the first measured
      PPDU containing a frame from the Target BSSID just after STA reassociates
      with(#1427) the Target BSSID. If association with target BSSID failed, the
      Target RCPI field indicates the received channel power of the most
      recently measured PPDU containing a frame from the Target BSSID. The
      Target RCPI is a logarithmic function of the received signal power, as
      defined 9.4.2.36 (RCPI element)."
   ::= { dot11WNMEventTransitReportEntry 15 }

dot11WNMEventTransitRprtTargetRSNI OBJECT-TYPE
   SYNTAX Unsigned32 (0..255)
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a status variable.
      It is written by the SME when a management report is completed.

      This attribute indicates the received signal-to-noise indication of the
      first measured frame just after STA reassociates with(#1427) the Target
      BSSID. If association with target BSSID failed, the Target RSNI field
      indicates the received signal-to-noise indication of the most recently
      measured frame from the Target BSSID. The Target RSNI is a logarithmic
      function of the signal-to-noise ratio, as defined in 9.4.2.39 (RSNI
      element)."
   ::= { dot11WNMEventTransitReportEntry 16 }
```


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```
--
-- ****************************************************************
-- * End of dot11WNMEventTransitReport TABLE
-- ****************************************************************

-- ****************************************************************
-- * dot11WNMEventRsnaReport TABLE
-- ****************************************************************
dot11WNMEventRsnaReportTable OBJECT-TYPE
   SYNTAX SEQUENCE OF Dot11WNMEventRsnaReportEntry
   MAX-ACCESS not-accessible
   STATUS current
   DESCRIPTION
      "Group contains the current list of RSNA Event reports that have been
      received by the MLME. The report tables shall be maintained as FIFO to
      preserve freshness, thus the rows in this table can be deleted for memory
      constraints or other implementation constraints determined by the vendor.
      New rows shall have different RprtIndex values than those deleted within
      the range limitation of the index. One easy way is to increment RprtIndex
      for new reports being written in the table."
   ::= { dot11WNMReport 6 }

dot11WNMEventRsnaReportEntry OBJECT-TYPE
   SYNTAX Dot11WNMEventRsnaReportEntry
   MAX-ACCESS not-accessible
   STATUS current
   DESCRIPTION
      "An entry in the dot11WNMEventRsnaReportTable Indexed by
      dot11WNMEventRsnaRprtIndex."
   INDEX { dot11WNMEventRsnaRprtIndex }
   ::= { dot11WNMEventRsnaReportTable 1 }

Dot11WNMEventRsnaReportEntry ::=
   SEQUENCE {
      dot11WNMEventRsnaRprtIndex                    Unsigned32,
      dot11WNMEventRsnaRprtRqstToken                OCTET STRING,
      dot11WNMEventRsnaRprtIfIndex                  InterfaceIndex,
      dot11WNMEventRsnaRprtEventStatus              INTEGER,
      dot11WNMEventRsnaRprtEventTSF                 TSFType,
      dot11WNMEventRsnaRprtUTCOffset                OCTET STRING,
      dot11WNMEventRsnaRprtTimeError                OCTET STRING,
      dot11WNMEventRsnaRprtTargetBssid              MacAddress,
      dot11WNMEventRsnaRprtAuthType                 OCTET STRING,
      dot11WNMEventRsnaRprtEapMethod                OCTET STRING,
      dot11WNMEventRsnaRprtResult                   Unsigned32,
      dot11WNMEventRsnaRprtRsnElement               OCTET STRING }

dot11WNMEventRsnaRprtIndex OBJECT-TYPE
   SYNTAX Unsigned32
   MAX-ACCESS not-accessible
   STATUS current
   DESCRIPTION
      "Index for RSNA Event Report elements in dot11WNMEventRsnaReportTable,
      greater than 0."
   ::= { dot11WNMEventRsnaReportEntry 1 }

dot11WNMEventRsnaRprtRqstToken OBJECT-TYPE
   SYNTAX OCTET STRING
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a status variable.
      It is written by the SME when a management report is completed.
```

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```
        This attribute indicates the request token that was indicated in the WNM
        request that generated this measurement report. This should be an exact
        match to the original dot11WNMRqstToken attribute. Note that there may be
        multiple entries in the table that match this value since a single request
        may generate multiple WNM reports."
    ::= { dot11WNMEventRsnaReportEntry 2 }

dot11WNMEventRsnaRprtIfIndex OBJECT-TYPE
    SYNTAX InterfaceIndex
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "The ifIndex for this row of WNMEventRsna report been received on."
    ::= { dot11WNMEventRsnaReportEntry 3 }

dot11WNMEventRsnaRprtEventStatus OBJECT-TYPE
    SYNTAX INTEGER {
        successful(0),
        requestFailed(1),
        requestRefused(2),
        requestIncapable(3),
        detectedFrequentTransition(4)
        }
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute contains the status value included in the Event report."
    ::= { dot11WNMEventRsnaReportEntry 4 }

dot11WNMEventRsnaRprtEventTSF OBJECT-TYPE
    SYNTAX TSFType
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute contains the value of the Event TSF field."
    ::= { dot11WNMEventRsnaReportEntry 5 }

dot11WNMEventRsnaRprtUTCOffset OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(10))
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute indicates the UTC Offset Time Value optionally included in
        the Event report."
    ::= { dot11WNMEventRsnaReportEntry 6 }

dot11WNMEventRsnaRprtTimeError OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(5))
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute contains the value of the Event Time Error field optionally
```


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```
        included in the Event report."
    ::= { dot11WNMEventRsnaReportEntry 7 }

dot11WNMEventRsnaRprtTargetBssid OBJECT-TYPE
    SYNTAX MacAddress
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute indicates the BSSID of the BSS of the AP accepting the
        authorization attempt."
    ::= { dot11WNMEventRsnaReportEntry 8 }

dot11WNMEventRsnaRprtAuthType OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(4))
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute indicates the (#3266)AKMP, as defined in Table 9-190 (AKM
        suite selectors) in 9.4.2.23.3 (AKM suites). The first three octets
        indicate the OUI or CID. The last octet indicates the suite type."
    ::= { dot11WNMEventRsnaReportEntry 9 }

dot11WNMEventRsnaRprtEapMethod OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(1..8))
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute indicates a value that identifies the EAP Method. When the
        Authentication Type field is set to (#3266)either 00-0F-AC:1
        (Authentication negotiated over IEEE Std 802.1X or using PMKSA caching as
        defined in 12.6.8.3 (Cached PMKSAs and RSNA key management)) or 00-0F-AC:3
        (AKM suite selector for fast BSS transition as defined in 12.7.1.6 (FT key
        hierarchy)), the EAP Method field contains the IANA assigned EAP type
        defined at http://www.iana.org/assignments/eap-numbers. The EAP type
        contains either the legacy type (1 octet) or the expanded type (1-octet
        type = 254, 3-octet Vendor ID, 4-octet Vendor-Type). The EAP Method field
        is set to 0 otherwise."
    ::= { dot11WNMEventRsnaReportEntry 10 }

dot11WNMEventRsnaRprtResult OBJECT-TYPE
    SYNTAX Unsigned32 (0..65535)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute indicates the result of the RSNA event and is set to one of
        the status codes specified in Table 9-80 (Status codes) in 9.4.1.9 (Status
        Code field)."
    ::= { dot11WNMEventRsnaReportEntry 11 }

dot11WNMEventRsnaRprtRsnElement OBJECT-TYPE
    SYNTAX OCTET STRING
    MAX-ACCESS read-only
```

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```
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute contains the (#3488)Information field of (#4263)the RSNE in
        the (Re)Association Request frame that resulted in the current RSNA,
        truncated to the maximum length allowed for the RSNE field in the RSNA
        event report, if necessary."
    ::= { dot11WNMEventRsnaReportEntry 12 }

-- ********************************************************************
-- * End of dot11WNMEventRsnaReport TABLE
-- ********************************************************************

-- ********************************************************************
-- * dot11WNMEventPeerReport TABLE
-- ********************************************************************
dot11WNMEventPeerReportTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11WNMEventPeerReportEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "Group contains the current list of peer-to-peer link event reports that
        have been received by the MLME. The report tables shall be maintained as
        FIFO to preserve freshness, thus the rows in this table can be deleted for
        memory constraints or other implementation constraints determined by the
        vendor. New rows shall have different RprtIndex values than those deleted
        within the range limitation of the index. One easy way is to increment
        RprtIndex for new reports being written in the table."
    ::= { dot11WNMReport 7 }

dot11WNMEventPeerReportEntry OBJECT-TYPE
    SYNTAX Dot11WNMEventPeerReportEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "An entry in the dot11WNMEventPeerReportTable Indexed by
        dot11WNMEventPeerRprtIndex."
    INDEX { dot11WNMEventPeerRprtIndex }
    ::= { dot11WNMEventPeerReportTable 1 }

Dot11WNMEventPeerReportEntry ::=
    SEQUENCE {
        dot11WNMEventPeerRprtIndex                      Unsigned32,
        dot11WNMEventPeerRprtRqstToken                  OCTET STRING,
        dot11WNMEventPeerRprtIfIndex                    InterfaceIndex,
        dot11WNMEventPeerRprtEventStatus                INTEGER,
        dot11WNMEventPeerRprtEventTSF                   TSFType,
        dot11WNMEventPeerRprtUTCOffset                  OCTET STRING,
        dot11WNMEventPeerRprtTimeError                  OCTET STRING,
        dot11WNMEventPeerRprtPeerMacAddress             MacAddress,
        dot11WNMEventPeerRprtOperatingClass             Unsigned32,
        dot11WNMEventPeerRprtChanNumber                 Unsigned32,
        dot11WNMEventPeerRprtStaTxPower                 Integer32,
        dot11WNMEventPeerRprtConnTime                   Unsigned32,
        dot11WNMEventPeerRprtPeerStatus                 INTEGER }

dot11WNMEventPeerRprtIndex OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "Index for Peer-to-Peer Link Event Report elements in
```


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```
        dot11WNMEventPeerReportTable, greater than 0."
    ::= { dot11WNMEventPeerReportEntry 1 }

dot11WNMEventPeerRprtRqstToken OBJECT-TYPE
    SYNTAX OCTET STRING
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute indicates the request token that was indicated in the WNM
        request that generated this measurement report. This should be an exact
        match to the original dot11WNMRqstToken attribute. Note that there may be
        multiple entries in the table that match this value since a single request
        may generate multiple WNM reports."
    ::= { dot11WNMEventPeerReportEntry 2 }

dot11WNMEventPeerRprtIfIndex OBJECT-TYPE
    SYNTAX InterfaceIndex
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "The ifIndex for this row of WNMEventPeer report been received on."
    ::= { dot11WNMEventPeerReportEntry 3 }

dot11WNMEventPeerRprtEventStatus OBJECT-TYPE
    SYNTAX INTEGER {
        successful(0),
        requestFailed(1),
        requestRefused(2),
        requestIncapable(3),
        detectedFrequentTransition(4)
        }
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute contains the status value included in the Event report."
    ::= { dot11WNMEventPeerReportEntry 4 }

dot11WNMEventPeerRprtEventTSF OBJECT-TYPE
    SYNTAX TSFType
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute contains the value of the Event TSF field."
    ::= { dot11WNMEventPeerReportEntry 5 }

dot11WNMEventPeerRprtUTCOffset OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(10))
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute indicates the UTC Offset Time Value optionally included in
        the Event report."
```

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```
    ::= { dot11WNMEventPeerReportEntry 6 }

dot11WNMEventPeerRprtTimeError OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(5))
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute contains the value of the Event Time Error field optionally
        included in the Event report."
    ::= { dot11WNMEventPeerReportEntry 7 }

dot11WNMEventPeerRprtPeerMacAddress OBJECT-TYPE
    SYNTAX MacAddress
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute indicates the MAC address of the peer STA or IBSS BSSID. If
        this event is for a peer-to-peer link in an infrastructure BSS, this field
        contains the MAC address of the peer STA. If this event is for a peer-to-
        peer link in an IBSS, this field contains the BSSID."
    ::= { dot11WNMEventPeerReportEntry 8 }

dot11WNMEventPeerRprtOperatingClass OBJECT-TYPE
    SYNTAX Unsigned32 (1..255)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute indicates the channel set for this peer-to-peer link event
        report. Country, Operating Class and Channel Number together specify the
        channel frequency and spacing for this measurement request. Valid values
        of Operating Class as shown in Annex E."
    ::= { dot11WNMEventPeerReportEntry 9 }

dot11WNMEventPeerRprtChanNumber OBJECT-TYPE
    SYNTAX Unsigned32 (1..255)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute indicates the current operating channel for this peer-to-
        peer link event report. The Channel Number is defined only within the
        indicated Operating Class as shown in Annex E."
    ::= { dot11WNMEventPeerReportEntry 10 }

dot11WNMEventPeerRprtStaTxPower OBJECT-TYPE
    SYNTAX Integer32 (-128..127)
    UNITS "dBm"
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.
```


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```
        This attribute indicates the STA transmit power used for the peer-to-peer
        link. The STA Tx Power field indicates the target transmit power at the
        antenna connector with a tolerance of +/-5 dB for the lowest basic rate of
        the reporting STA."
    ::= { dot11WNMEventPeerReportEntry 11 }

dot11WNMEventPeerRprtConnTime OBJECT-TYPE
    SYNTAX Unsigned32 (0..16777215)
    UNITS "seconds"
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute indicates a value representing the connection time for the
        reported peer-to-peer link event. If the Peer Status is 0, this field
        indicates the duration of the peer-to-peer link(#1354). If the Peer Status
        is 1, this field indicates the time difference from the time the peer-to-
        peer link(#1354) was established to the time at which the reporting STA
        generated the event report. If the Peer Status is 2, this field indicates
        the duration of the IBSS membership. If the Peer Status is 3, this field
        indicates the time difference from the time the STA joined the IBSS to the
        time at which the reporting STA generated the event report. See 11.21.2.4
        (Peer-to-peer link event request and report)."
    ::= { dot11WNMEventPeerReportEntry 12 }

dot11WNMEventPeerRprtPeerStatus OBJECT-TYPE
    SYNTAX INTEGER {
        directLinkTerminated(0),
        directLinkActive(1),
        ibssMembershipTerminated(2),
        ibssMembershipActive(3)
        }
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute indicates the peer link connection status."
    ::= { dot11WNMEventPeerReportEntry 13 }

-- ********************************************************************
-- * End of dot11WNMEventPeerReport TABLE
-- ********************************************************************

-- ********************************************************************
-- * dot11WNMEventWNMLogReport TABLE
-- ********************************************************************
dot11WNMEventWNMLogReportTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11WNMEventWNMLogReportEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "Group contains the current list of WNMLog Event reports that have been
        received by the MLME. The report tables shall be maintained as FIFO to
        preserve freshness, thus the rows in this table can be deleted for memory
        constraints or other implementation constraints determined by the vendor.
        New rows shall have different RprtIndex values than those deleted within
        the range limitation of the index. One easy way is to increment RprtIndex
        for new reports being written in the table."
    ::= { dot11WNMReport 8 }
```

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```
dot11WNMEventWNMLogReportEntry OBJECT-TYPE
   SYNTAX Dot11WNMEventWNMLogReportEntry
   MAX-ACCESS not-accessible
   STATUS current
   DESCRIPTION
      "An entry in the dot11WNMEventWNMLogReportTable Indexed by
      dot11WNMEventWNMLogRprtIndex."
   INDEX { dot11WNMEventWNMLogRprtIndex }
   ::= { dot11WNMEventWNMLogReportTable 1 }

Dot11WNMEventWNMLogReportEntry ::=
   SEQUENCE {
      dot11WNMEventWNMLogRprtIndex                          Unsigned32,
      dot11WNMEventWNMLogRprtRqstToken                      OCTET STRING,
      dot11WNMEventWNMLogRprtIfIndex                        InterfaceIndex,
      dot11WNMEventWNMLogRprtEventStatus                    INTEGER,
      dot11WNMEventWNMLogRprtEventTSF                       TSFType,
      dot11WNMEventWNMLogRprtUTCOffset                      OCTET STRING,
      dot11WNMEventWNMLogRprtTimeError                      OCTET STRING,
      dot11WNMEventWNMLogRprtContent                        OCTET STRING }

dot11WNMEventWNMLogRprtIndex OBJECT-TYPE
   SYNTAX Unsigned32
   MAX-ACCESS not-accessible
   STATUS current
   DESCRIPTION
      "Index for WNMLog Event Report elements in dot11WNMEventWNMLogReportTable,
      greater than 0."
   ::= { dot11WNMEventWNMLogReportEntry 1 }

dot11WNMEventWNMLogRprtRqstToken OBJECT-TYPE
   SYNTAX OCTET STRING
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a status variable.
      It is written by the SME when a management report is completed.

      This attribute indicates the request token that was indicated in the WNM
      request that generated this measurement report. This should be an exact
      match to the original dot11WNMRqstToken attribute. Note that there may be
      multiple entries in the table that match this value since a single request
      may generate multiple WNM reports."
   ::= { dot11WNMEventWNMLogReportEntry 2 }

dot11WNMEventWNMLogRprtIfIndex OBJECT-TYPE
   SYNTAX InterfaceIndex
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "The ifIndex for this row of WNMEventWNMLog report been received on."
   ::= { dot11WNMEventWNMLogReportEntry 3 }

dot11WNMEventWNMLogRprtEventStatus OBJECT-TYPE
   SYNTAX INTEGER {
      successful(0),
      requestFailed(1),
      requestRefused(2),
      requestIncapable(3),
      detectedFrequentTransition(4)
      }
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
```


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```
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute contains the status value included in the Event report."
    ::= { dot11WNMEventWNMLogReportEntry 4 }

dot11WNMEventWNMLogRprtEventTSF OBJECT-TYPE
    SYNTAX TSFType
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute contains the value of the Event TSF field."
    ::= { dot11WNMEventWNMLogReportEntry 5 }

dot11WNMEventWNMLogRprtUTCOffset OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(10))
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute indicates the UTC Offset Time Value optionally included in
        the Event report."
    ::= { dot11WNMEventWNMLogReportEntry 6 }

dot11WNMEventWNMLogRprtTimeError OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(5))
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute contains the value of the Event Time Error field optionally
        included in the Event report."
    ::= { dot11WNMEventWNMLogReportEntry 7 }

dot11WNMEventWNMLogRprtContent OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(0..2284))
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute contains the entire syslog message, consisting of the PRI,
        HEADER, and MSG portion of a WNM log message as described in IETF RFC
        5424. The TAG field of the MSG portion of the message is a 17-octet string
        containing the ASCII representation of the STA MAC address using
        hexadecimal notation with colons between octets. The octet containing the
        Individual/Group bit occurs last, and that bit is in the least significant
        position within that octet. See 11.21.2.5 (WNM log event request and
        report)."
    ::= { dot11WNMEventWNMLogReportEntry 8 }

-- ************************************************************
-- * End of dot11WNMEventWNMLogReport TABLE
-- ************************************************************

-- ************************************************************
```

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```
-- * dot11WNMDiagMfrInfoReport TABLE
-- ************************************************************
dot11WNMDiagMfrInfoReportTable OBJECT-TYPE
   SYNTAX SEQUENCE OF Dot11WNMDiagMfrInfoReportEntry
   MAX-ACCESS not-accessible
   STATUS current
   DESCRIPTION
      "Group contains the current list of Manufacturer Information STA reports
      that have been received by the MLME. The report tables shall be maintained
      as FIFO to preserve freshness, thus the rows in this table can be deleted
      for memory constraints or other implementation constraints determined by
      the vendor. New rows shall have different RprtIndex values than those
      deleted within the range limitation of the index. One easy way is to
      increment RprtIndex for new reports being written in the table."
   ::= { dot11WNMReport 9 }

dot11WNMDiagMfrInfoReportEntry OBJECT-TYPE
   SYNTAX Dot11WNMDiagMfrInfoReportEntry
   MAX-ACCESS not-accessible
   STATUS current
   DESCRIPTION
      "An entry in the dot11WNMDiagMfrInfoReportTable Indexed by
      dot11WNMDiagMfrInfoRprtIndex."
   INDEX { dot11WNMDiagMfrInfoRprtIndex }
   ::= { dot11WNMDiagMfrInfoReportTable 1 }

Dot11WNMDiagMfrInfoReportEntry ::=
   SEQUENCE {
      dot11WNMDiagMfrInfoRprtIndex                          Unsigned32,
      dot11WNMDiagMfrInfoRprtRqstToken                      OCTET STRING,
      dot11WNMDiagMfrInfoRprtIfIndex                        InterfaceIndex,
      dot11WNMDiagMfrInfoRprtEventStatus                    INTEGER,
      dot11WNMDiagMfrInfoRprtMfrOi                          OCTET STRING,
      dot11WNMDiagMfrInfoRprtMfrIdString                    OCTET STRING,
      dot11WNMDiagMfrInfoRprtMfrModelString                 OCTET STRING,
      dot11WNMDiagMfrInfoRprtMfrSerialNumberString          OCTET STRING,
      dot11WNMDiagMfrInfoRprtMfrFirmwareVersion             OCTET STRING,
      dot11WNMDiagMfrInfoRprtMfrAntennaType                 OCTET STRING,
      dot11WNMDiagMfrInfoRprtCollocRadioType                INTEGER,
      dot11WNMDiagMfrInfoRprtDeviceType                     INTEGER,
      dot11WNMDiagMfrInfoRprtCertificateID                  OCTET STRING}

dot11WNMDiagMfrInfoRprtIndex OBJECT-TYPE
   SYNTAX Unsigned32
   MAX-ACCESS not-accessible
   STATUS current
   DESCRIPTION
      "Index for Manufacturer Information STA Report elements in
      dot11WNMDiagMfrInfoReportTable, greater than 0."
   ::= { dot11WNMDiagMfrInfoReportEntry 1 }

dot11WNMDiagMfrInfoRprtRqstToken OBJECT-TYPE
   SYNTAX OCTET STRING
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a status variable.
      It is written by the SME when a management report is completed.

      This attribute indicates the request token that was indicated in the WNM
      request that generated this measurement report. This should be an exact
      match to the original dot11WNMRqstToken attribute. Note that there may be
      multiple entries in the table that match this value since a single request
      may generate multiple WNM reports."
```


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```
    ::= { dot11WNMDiagMfrInfoReportEntry 2 }

dot11WNMDiagMfrInfoRprtIfIndex OBJECT-TYPE
    SYNTAX InterfaceIndex
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "The ifIndex for this row of WNMDiagMfrInfo report been received on."
    ::= { dot11WNMDiagMfrInfoReportEntry 3 }

dot11WNMDiagMfrInfoRprtEventStatus OBJECT-TYPE
    SYNTAX INTEGER {
        successful(0),
        requestFailed(1),
        requestRefused(2),
        requestIncapable(3),
        detectedFrequentTransition(4)
        }
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute contains the status value included in the Event report."
    ::= { dot11WNMDiagMfrInfoReportEntry 4}

dot11WNMDiagMfrInfoRprtMfrOi OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(0..5))
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute indicates the Manufacturer OI for the reported Manufacturer
        Information STA Diagnostic."
    ::= { dot11WNMDiagMfrInfoReportEntry 5 }

dot11WNMDiagMfrInfoRprtMfrIdString OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(0..255))
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute indicates the Manufacturer ID string for the reported
        Manufacturer Information STA Diagnostic. The ID attribute contains an
        ASCII string indicating the manufacturer identifier of the wireless
        network adaptor. This string is not null terminated."
    ::= { dot11WNMDiagMfrInfoReportEntry 6 }

dot11WNMDiagMfrInfoRprtMfrModelString OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(0..255))
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute indicates the Manufacturer model string for the reported
        Manufacturer Information STA Diagnostic. The model attribute contains an
        ASCII string indicating the model of the wireless network adaptor. This
```

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```
        string is not null terminated."
    ::= { dot11WNMDiagMfrInfoReportEntry 7 }

dot11WNMDiagMfrInfoRprtMfrSerialNumberString OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(0..255))
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute indicates the Manufacturer serial number string for the
        reported Manufacturer Information STA Diagnostic. The serial number
        attribute contains an ASCII string indicating the serial number of the
        wireless network adaptor. This string is not null terminated."
    ::= { dot11WNMDiagMfrInfoReportEntry 8 }

dot11WNMDiagMfrInfoRprtMfrFirmwareVersion OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(0..255))
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute indicates the Manufacturer firmware version string for the
        reported Manufacturer Information STA Diagnostic. The firmware version
        attribute contains an ASCII string identifying the version of firmware
        currently installed on the wireless network adaptor. This string is not
        null terminated."
    ::= { dot11WNMDiagMfrInfoReportEntry 9 }

dot11WNMDiagMfrInfoRprtMfrAntennaType OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(0..255))
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute indicates the Manufacturer antenna type string for the
        reported Manufacturer Information STA Diagnostic. The first octet of this
        string indicates the antenna count, and the second octet indicates the
        antenna gain. The antenna gain indicates the peak gain in dBi of the
        antenna connected to the wireless network adaptor. The remaining octets
        contain an ASCII string indicating the type of antenna connected to the
        wireless network adaptor."
    ::= { dot11WNMDiagMfrInfoReportEntry 10 }

dot11WNMDiagMfrInfoRprtCollocRadioType OBJECT-TYPE
    SYNTAX INTEGER {
        reserved(0),
        cellular(1),
        cordless(2),
        gps(3),
        ieee80211(4),
        ieee80215(5),
        ieee80216(6),
        ieee80220(7),
        ieee80222(8),
        digitalAudioBroadcasting(9),
        digitalVideoBroadcasting(10)
        }
    MAX-ACCESS read-only
```


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```
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute contains the type of the (#2210)colocated radio."
    ::= { dot11WNMDiagMfrInfoReportEntry 11 }

dot11WNMDiagMfrInfoRprtDeviceType OBJECT-TYPE
    SYNTAX INTEGER {
        reserved(0),
        referenceDesign(1),
        accessPointWirelessRouterSoho(2),
        enterpriseAccessPoint(3),
        broadbandGateway(4),
        digitalStillCamera(5),
        portableVideoCamera(6),
        networkedWebCamera(7),
        digitalAudioStationary(8),
        digitalAudioPortable(9),
        setTopBoxMediaServer(10),
        tvMonitorDigitalPictureFrame(11),
        gameConsoleGameAdaptor(12),
        gamingDevice(13),
        mediaServerMediaAdaptor(14),
        networkStorageDevice(15),
        externalCard(16),
        internalCard(17),
        ultraMobilPc(18),
        notebookComputer(19),
        personalDigitalAssistant(20),
        printerPrintServer(21),
        phoneDualMode(22),
        phoneSingleMode(23),
        smartphoneDualMode(24),
        smartphoneSingleMode(25),
        otherDevices(221)
        }
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute indicates the type of device in which the IEEE 802.11 STA
        resides."
    ::= { dot11WNMDiagMfrInfoReportEntry 12 }

dot11WNMDiagMfrInfoRprtCertificateID OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(0..251))
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute indicates the Certificate ID for the
        reported Manufacturer Information STA Diagnostic."
    ::= { dot11WNMDiagMfrInfoReportEntry 13 }

-- ************************************************************
-- * End of dot11WNMDiagMfrInfoReport TABLE
-- ************************************************************
```

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```
-- ************************************************************
-- * dot11WNMDiagConfigProfReport TABLE
-- ************************************************************
dot11WNMDiagConfigProfReportTable OBJECT-TYPE
   SYNTAX SEQUENCE OF Dot11WNMDiagConfigProfReportEntry
   MAX-ACCESS not-accessible
   STATUS current
   DESCRIPTION
      "Group contains the current list of Configuration Profile reports that
      have been received by the MLME. The report tables shall be maintained as
      FIFO to preserve freshness, thus the rows in this table can be deleted for
      memory constraints or other implementation constraints determined by the
      vendor. New rows shall have different RprtIndex values than those deleted
      within the range limitation of the index. One easy way is to increment
      RprtIndex for new reports being written in the table."
   ::= { dot11WNMReport 10 }

dot11WNMDiagConfigProfReportEntry OBJECT-TYPE
   SYNTAX Dot11WNMDiagConfigProfReportEntry
   MAX-ACCESS not-accessible
   STATUS current
   DESCRIPTION
      "An entry in the dot11WNMDiagConfigProfReportTable Indexed by
      dot11WNMDiagConfigProfRprtIndex."
   INDEX { dot11WNMDiagConfigProfRprtIndex }
   ::= { dot11WNMDiagConfigProfReportTable 1 }

Dot11WNMDiagConfigProfReportEntry ::=
   SEQUENCE {
      dot11WNMDiagConfigProfRprtIndex                        Unsigned32,
      dot11WNMDiagConfigProfRprtRqstToken                    OCTET STRING,
      dot11WNMDiagConfigProfRprtIfIndex                      InterfaceIndex,
      dot11WNMDiagConfigProfRprtEventStatus                  INTEGER,
      dot11WNMDiagConfigProfRprtProfileId                    Unsigned32,
      dot11WNMDiagConfigProfRprtSupportedOperatingClasses    OCTET STRING,
      dot11WNMDiagConfigProfRprtTxPowerMode                  INTEGER,
      dot11WNMDiagConfigProfRprtTxPowerLevels                OCTET STRING,
      dot11WNMDiagConfigProfRprtCipherSuite                  OCTET STRING,
      dot11WNMDiagConfigProfRprtAkmSuite                     OCTET STRING,
      dot11WNMDiagConfigProfRprtEapType                      Unsigned32,
      dot11WNMDiagConfigProfRprtEapVendorID                  OCTET STRING,
      dot11WNMDiagConfigProfRprtEapVendorType                OCTET STRING,
      dot11WNMDiagConfigProfRprtCredentialType               INTEGER,
      dot11WNMDiagConfigProfRprtSSID                         OCTET STRING,
      dot11WNMDiagConfigProfRprtPowerSaveMode                INTEGER }

dot11WNMDiagConfigProfRprtIndex OBJECT-TYPE
   SYNTAX Unsigned32
   MAX-ACCESS not-accessible
   STATUS current
   DESCRIPTION
      "Index for Configuration Profile Report elements in
      dot11WNMDiagConfigProfReportTable, greater than 0."
   ::= { dot11WNMDiagConfigProfReportEntry 1 }

dot11WNMDiagConfigProfRprtRqstToken OBJECT-TYPE
   SYNTAX OCTET STRING
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a status variable.
      It is written by the SME when a management report is completed.

      This attribute indicates the request token that was indicated in the WNM
```


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```
        request that generated this measurement report. This should be an exact
        match to the original dot11WNMRqstToken attribute. Note that there may be
        multiple entries in the table that match this value since a single request
        may generate multiple WNM reports."
    ::= { dot11WNMDiagConfigProfReportEntry 2 }

dot11WNMDiagConfigProfRprtIfIndex OBJECT-TYPE
    SYNTAX InterfaceIndex
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "The ifIndex for this row of WNMDiagConfigProf report been received on."
    ::= { dot11WNMDiagConfigProfReportEntry 3 }

dot11WNMDiagConfigProfRprtEventStatus OBJECT-TYPE
    SYNTAX INTEGER {
        successful(0),
        requestFailed(1),
        requestRefused(2),
        requestIncapable(3),
        detectedFrequentTransition(4)
        }
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute contains the status value included in the Event report."
    ::= { dot11WNMDiagConfigProfReportEntry 4}

dot11WNMDiagConfigProfRprtProfileId OBJECT-TYPE
    SYNTAX Unsigned32 (0..255)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute indicates a unique identifier for referencing a
        configuration profile available on a (#4213)STA. The value of the
        identifier can be any arbitrary value, as long as it is uniquely
        associated to a single configuration profile on the (#4213)STA sending the
        identifier."
    ::= { dot11WNMDiagConfigProfReportEntry 5 }

dot11WNMDiagConfigProfRprtSupportedOperatingClasses OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(0..255))
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute indicates the current Operating Class followed by a list of
        each Supported Operating Class, as defined in 9.4.2.52 (Supported
        Operating Classes element). Each octet contains an integer representing an
        operating class. Operating Classes are defined in Annex E."
    DEFVAL { ''H }
    ::= { dot11WNMDiagConfigProfReportEntry 6 }

dot11WNMDiagConfigProfRprtTxPowerMode OBJECT-TYPE
    SYNTAX INTEGER {
        fixedPowerMode(0),
```

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```
        automaticPowerMode(1)
        }
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute indicates the power mode of the STA."
    ::= { dot11WNMDiagConfigProfReportEntry 7 }

dot11WNMDiagConfigProfRprtTxPowerLevels OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(1..255))
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute lists the power levels for the STA. Each octet contains an
        integer representing a power level encoded as a 2s complement value in
        dBm, rounded to the nearest integer. If the Power Mode is automatic, the
        list contains only the minimum and the maximum power levels for the STA.
        If the Power Mode is fixed, the list contains one or more fixed power
        level settings available at this STA, arranged in increasing
        (#4317)numeric order."
    ::= { dot11WNMDiagConfigProfReportEntry 8 }

dot11WNMDiagConfigProfRprtCipherSuite OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(4))
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute indicates the cipher suite, as defined in Table 9-188
        (Cipher suite selectors). The first three octets indicate the OUI or CID.
        The last octet indicates the suite type."
    ::= { dot11WNMDiagConfigProfReportEntry 9 }

dot11WNMDiagConfigProfRprtAkmSuite OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(4))
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute indicates the (#3266)AKMP, as defined in Table 9-190 (AKM
        suite selectors) in 9.4.2.23.3 (AKM suites). The first three octets
        indicate the OUI or CID. The last octet indicates the suite type."
    ::= { dot11WNMDiagConfigProfReportEntry 10 }

dot11WNMDiagConfigProfRprtEapType OBJECT-TYPE
    SYNTAX Unsigned32 (0..255)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute indicates the single EAP method used by the STA. Valid EAP
        Type numbers are assigned by IANA and are defined at http://www.iana.org/
```


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```
        assignments/eap-numbers."
    ::= { dot11WNMDiagConfigProfReportEntry 11 }

dot11WNMDiagConfigProfRprtEapVendorID OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(0..3))
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute indicates the EAP Vendor ID number for the EAP method used
        by the STA. The EAP Vendor ID field is included when the EAP Type field is
        set to 254 and is excluded otherwise."
    ::= { dot11WNMDiagConfigProfReportEntry 12 }

dot11WNMDiagConfigProfRprtEapVendorType OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(0..4))
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute indicates the EAP Vendor Type number for the EAP method
        used by the STA. The EAP Vendor Type field is included when the EAP Type
        field is set to 254 and is excluded otherwise."
    ::= { dot11WNMDiagConfigProfReportEntry 13 }

dot11WNMDiagConfigProfRprtCredentialType OBJECT-TYPE
    SYNTAX INTEGER {
        none(0),
        preSharedKey(1),
        userNamePassword(2),
        x509Certificate(3),
        otherCertificate(4),
        oneTimePassword(5),
        token(6)
        }
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute indicates the type of IEEE 802.1X credentials used by the
        STA for this authentication diagnostic."
    ::= { dot11WNMDiagConfigProfReportEntry 14 }

dot11WNMDiagConfigProfRprtSSID OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(1..32))
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute indicates the SSID for the diagnostic report, as defined in
        9.4.2.2 (SSID element)."
    ::= { dot11WNMDiagConfigProfReportEntry 15 }

dot11WNMDiagConfigProfRprtPowerSaveMode OBJECT-TYPE
    SYNTAX INTEGER {
        unknownMode(0),
```

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```
        none(1),
        psDtims1Mode(2),
        psDtims0Mode(3),
        uapsdMode(4),
        sapsdMode(5),(#3263)
        smpsMode(8),
        wnmSleepMode(9),
        fmsMode(10),
        timBroadcastMode(11),
        tfsMode(12),
        tdlsPeerUapsdMode(13),
        tdlsPeerPsmMode(14)
        }
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute indicates the power save mode in use by the STA, as defined
        in Table 9-247 (Power Save Mode definition)."
    ::= { dot11WNMDiagConfigProfReportEntry 16 }

-- ********************************************************************
-- * End of dot11WNMDiagConfigProfReport TABLE
-- ********************************************************************

-- ********************************************************************
-- * dot11WNMDiagAssocReport TABLE
-- ********************************************************************
dot11WNMDiagAssocReportTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11WNMDiagAssocReportEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "Group contains the current list of Association Diagnostic reports that
        have been received by the MLME. The report tables shall be maintained as
        FIFO to preserve freshness, thus the rows in this table can be deleted for
        memory constraints or other implementation constraints determined by the
        vendor. New rows shall have different RprtIndex values than those deleted
        within the range limitation of the index. One easy way is to increment
        RprtIndex for new reports being written in the table."
    ::= { dot11WNMReport 11 }

dot11WNMDiagAssocReportEntry OBJECT-TYPE
    SYNTAX Dot11WNMDiagAssocReportEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "An entry in the dot11WNMDiagAssocReportTable Indexed by
        dot11WNMDiagAssocRprtIndex."
    INDEX { dot11WNMDiagAssocRprtIndex }
    ::= { dot11WNMDiagAssocReportTable 1 }

Dot11WNMDiagAssocReportEntry ::=
    SEQUENCE {
        dot11WNMDiagAssocRprtIndex                  Unsigned32,
        dot11WNMDiagAssocRprtRqstToken              OCTET STRING,
        dot11WNMDiagAssocRprtIfIndex                InterfaceIndex,
        dot11WNMDiagAssocRprtEventStatus            INTEGER,
        dot11WNMDiagAssocRprtBssid                  MacAddress,
        dot11WNMDiagAssocRprtOperatingClass         Unsigned32,
        dot11WNMDiagAssocRprtChannelNumber          Unsigned32,
        dot11WNMDiagAssocRprtStatusCode             Unsigned32 }
```


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```
dot11WNMDiagAssocRprtIndex OBJECT-TYPE
   SYNTAX Unsigned32
   MAX-ACCESS not-accessible
   STATUS current
   DESCRIPTION
      "Index for Association Diagnostic Report elements in
      dot11WNMDiagAssocReportTable, greater than 0."
   ::= { dot11WNMDiagAssocReportEntry 1 }

dot11WNMDiagAssocRprtRqstToken OBJECT-TYPE
   SYNTAX OCTET STRING
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a status variable.
      It is written by the SME when a management report is completed.

      This attribute indicates the request token that was indicated in the WNM
      request that generated this measurement report. This should be an exact
      match to the original dot11WNMRqstToken attribute. Note that there may be
      multiple entries in the table that match this value since a single request
      may generate multiple WNM reports."
   ::= { dot11WNMDiagAssocReportEntry 2 }

dot11WNMDiagAssocRprtIfIndex OBJECT-TYPE
   SYNTAX InterfaceIndex
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "The ifIndex for this row of WNMDiagAssoc report been received on."
   ::= { dot11WNMDiagAssocReportEntry 3 }

dot11WNMDiagAssocRprtEventStatus OBJECT-TYPE
   SYNTAX INTEGER {
      successful(0),
      requestFailed(1),
      requestRefused(2),
      requestIncapable(3),
      detectedFrequentTransition(4)
      }
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a status variable.
      It is written by the SME when a management report is completed.

      This attribute contains the status value included in the Event report."
   ::= { dot11WNMDiagAssocReportEntry 4 }

dot11WNMDiagAssocRprtBssid OBJECT-TYPE
   SYNTAX MacAddress
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a status variable.
      It is written by the SME when a management report is completed.

      This attribute indicates the BSSID for the target AP for this Association
      Diagnostic report."
   ::= { dot11WNMDiagAssocReportEntry 5 }

dot11WNMDiagAssocRprtOperatingClass OBJECT-TYPE
   SYNTAX Unsigned32 (1..255)
```

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```
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute indicates the channel set for the target AP for this
        Association Diagnostic report. Country, Operating Class and Channel Number
        together specify the channel frequency and spacing for this measurement
        request. Valid values of Operating Class as shown in Annex E."
    ::= { dot11WNMDiagAssocReportEntry 6 }

dot11WNMDiagAssocRprtChannelNumber OBJECT-TYPE
    SYNTAX Unsigned32 (1..255)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute indicates the operating channel of the target AP for this
        Association Diagnostic report. The Channel Number is defined only within
        the indicated Operating Class as sown in Annex E."
    ::= { dot11WNMDiagAssocReportEntry 7 }

dot11WNMDiagAssocRprtStatusCode OBJECT-TYPE
    SYNTAX Unsigned32 (0..65535)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute indicates the result of the association diagnostic and is
        set to one of the status codes specified in Table 9-80 (Status codes) in
        9.4.1.9 (Status Code field)."
    ::= { dot11WNMDiagAssocReportEntry 8 }

-- ********************************************************************
-- * End of dot11WNMDiagAssocReport TABLE
-- ********************************************************************

-- ********************************************************************
-- * dot11WNMDiag8021xAuthReport TABLE
-- ********************************************************************
dot11WNMDiag8021xAuthReportTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11WNMDiag8021xAuthReportEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "Group contains the current list of IEEE 802.1X Authentication Diagnostic
        reports that have been received by the MLME. The report tables shall be
        maintained as FIFO to preserve freshness, thus the rows in this table can
        be deleted for memory constraints or other implementation constraints
        determined by the vendor. New rows shall have different RprtIndex values
        than those deleted within the range limitation of the index. One easy way
        is to increment RprtIndex for new reports being written in the table."
    ::= { dot11WNMReport 12 }

dot11WNMDiag8021xAuthReportEntry OBJECT-TYPE
    SYNTAX Dot11WNMDiag8021xAuthReportEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
```


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```
        "An entry in the dot11WNMDiag8021xAuthReportTable Indexed by
        dot11WNMDiag8021xAuthRprtIndex."
    INDEX { dot11WNMDiag8021xAuthRprtIndex }
    ::= { dot11WNMDiag8021xAuthReportTable 1 }

Dot11WNMDiag8021xAuthReportEntry ::=
    SEQUENCE {
        dot11WNMDiag8021xAuthRprtIndex                      Unsigned32,
        dot11WNMDiag8021xAuthRprtRqstToken                  OCTET STRING,
        dot11WNMDiag8021xAuthRprtIfIndex                    InterfaceIndex,
        dot11WNMDiag8021xAuthRprtEventStatus                INTEGER,
        dot11WNMDiag8021xAuthRprtBssid                      MacAddress,
        dot11WNMDiag8021xAuthRprtOperatingClass             Unsigned32,
        dot11WNMDiag8021xAuthRprtChannelNumber              Unsigned32,
        dot11WNMDiag8021xAuthRprtEapType                    Unsigned32,
        dot11WNMDiag8021xAuthRprtEapVendorID                OCTET STRING,
        dot11WNMDiag8021xAuthRprtEapVendorType              OCTET STRING,
        dot11WNMDiag8021xAuthRprtCredentialType             INTEGER,
        dot11WNMDiag8021xAuthRprtStatusCode                 Unsigned32 }

dot11WNMDiag8021xAuthRprtIndex OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "Index for IEEE 802.1X Authentication Diagnostic Report elements in
        dot11WNMDiag8021xAuthReportTable, greater than 0."
    ::= { dot11WNMDiag8021xAuthReportEntry 1 }

dot11WNMDiag8021xAuthRprtRqstToken OBJECT-TYPE
    SYNTAX OCTET STRING
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute indicates the request token that was indicated in the WNM
        request that generated this measurement report. This should be an exact
        match to the original dot11WNMRqstToken attribute. Note that there may be
        multiple entries in the table that match this value since a single request
        may generate multiple WNM reports."
    ::= { dot11WNMDiag8021xAuthReportEntry 2 }

dot11WNMDiag8021xAuthRprtIfIndex OBJECT-TYPE
    SYNTAX InterfaceIndex
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "The ifIndex for this row of WNMDiag8021xAuth report been received on."
    ::= { dot11WNMDiag8021xAuthReportEntry 3 }

dot11WNMDiag8021xAuthRprtEventStatus OBJECT-TYPE
    SYNTAX INTEGER {
        successful(0),
        requestFailed(1),
        requestRefused(2),
        requestIncapable(3),
        detectedFrequentTransition(4)
        }
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
```

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```
        It is written by the SME when a management report is completed.

        This attribute contains the status value included in the Event report."
    ::= { dot11WNMDiag8021xAuthReportEntry 4 }

dot11WNMDiag8021xAuthRprtBssid OBJECT-TYPE
    SYNTAX MacAddress
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute indicates the BSSID for the target AP for this
        Authentication Diagnostic report."
    ::= { dot11WNMDiag8021xAuthReportEntry 5 }

dot11WNMDiag8021xAuthRprtOperatingClass OBJECT-TYPE
    SYNTAX Unsigned32 (1..255)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute indicates the channel set for the target AP for this
        Authentication Diagnostic report. Country, Operating Class and Channel
        Number together specify the channel frequency and spacing for this
        measurement request. Valid values of Operating Class as shown in Annex E."
    ::= { dot11WNMDiag8021xAuthReportEntry 6 }

dot11WNMDiag8021xAuthRprtChannelNumber OBJECT-TYPE
    SYNTAX Unsigned32 (1..255)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute indicates the operating channel of the target AP for this
        Authentication Diagnostic report. The Channel Number is defined only
        within the indicated Operating Class as shown in Annex E."
    ::= { dot11WNMDiag8021xAuthReportEntry 7 }

dot11WNMDiag8021xAuthRprtEapType OBJECT-TYPE
    SYNTAX Unsigned32 (0..255)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute indicates the single EAP method used by the STA. Valid EAP
        Type numbers are assigned by IANA and are defined at http://www.iana.org/
        assignments/eap-numbers."
    ::= { dot11WNMDiag8021xAuthReportEntry 8 }

dot11WNMDiag8021xAuthRprtEapVendorID OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(0..3))
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.
```


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```
        This attribute indicates the EAP Vendor ID number for the EAP method used
        by the STA. The EAP Vendor ID field is included when the EAP Type field is
        set to 254 and is excluded otherwise."
    ::= { dot11WNMDiag8021xAuthReportEntry 9 }

dot11WNMDiag8021xAuthRprtEapVendorType OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(0..4))
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute indicates the EAP Vendor Type number for the EAP method
        used by the STA. The EAP Vendor Type field is included when the EAP Type
        field is set to 254 and is excluded otherwise."
    ::= { dot11WNMDiag8021xAuthReportEntry 10 }

dot11WNMDiag8021xAuthRprtCredentialType OBJECT-TYPE
    SYNTAX INTEGER {
        none(0),
        preSharedKey(1),
        userNamePassword(2),
        x509Certificate(3),
        otherCertificate(4),
        oneTimePassword(5),
        token(6)
        }
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute indicates the type of IEEE 802.1X credentials used by the
        STA for this authentication diagnostic."
    ::= { dot11WNMDiag8021xAuthReportEntry 11 }

dot11WNMDiag8021xAuthRprtStatusCode OBJECT-TYPE
    SYNTAX Unsigned32 (0..65535)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute indicates the result of the authentication diagnostic and
        is set to one of the status codes specified in Table 9-80 (Status codes)."
    ::= { dot11WNMDiag8021xAuthReportEntry 12 }

-- ********************************************************************
-- * End of dot11WNMDiag8021xAuthReport TABLE
-- ********************************************************************

-- ********************************************************************
-- * dot11WNMLocConfigReport TABLE
-- ********************************************************************
dot11WNMLocConfigReportTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11WNMLocConfigReportEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "Group contains the current list of location configuration reports that
```

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```
        have been received by the MLME. The report tables shall be maintained as
        FIFO to preserve freshness, thus the rows in this table can be deleted for
        memory constraints or other implementation constraints determined by the
        vendor. New rows shall have different RprtIndex values than those deleted
        within the range limitation of the index. One easy way is to increment
        RprtIndex for new reports being written in the table."
    ::= { dot11WNMReport 13 }

dot11WNMLocConfigReportEntry OBJECT-TYPE
    SYNTAX Dot11WNMLocConfigReportEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "An entry in the dot11WNMLocConfigReportTable Indexed by
        dot11WNMLocConfigRprtIndex."
    INDEX { dot11WNMLocConfigRprtIndex }
    ::= { dot11WNMLocConfigReportTable 1 }

Dot11WNMLocConfigReportEntry ::=
    SEQUENCE {
        dot11WNMLocConfigRprtIndex                              Unsigned32,
        dot11WNMLocConfigRprtRqstToken                          OCTET STRING,
        dot11WNMLocConfigRprtIfIndex                            InterfaceIndex,
        dot11WNMLocConfigRprtLocIndParams                       OCTET STRING,
        dot11WNMLocConfigRprtLocIndChanList                     OCTET STRING,
        dot11WNMLocConfigRprtLocIndBcastRate                    Unsigned32,
        dot11WNMLocConfigRprtLocIndOptions                      OCTET STRING,
        dot11WNMLocConfigRprtStatusConfigSubelemId              INTEGER,
        dot11WNMLocConfigRprtStatusResult                       INTEGER,
        dot11WNMLocConfigRprtVendorSpecificRprtContent          OCTET STRING }

dot11WNMLocConfigRprtIndex OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "Index for Location Configuration Report elements in
        dot11WNMLocConfigReportTable, greater than 0."
    ::= { dot11WNMLocConfigReportEntry 1 }

dot11WNMLocConfigRprtRqstToken OBJECT-TYPE
    SYNTAX OCTET STRING
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute indicates the request token that was indicated in the WNM
        request that generated this measurement report. This should be an exact
        match to the original dot11WNMRqstToken attribute. Note that there may be
        multiple entries in the table that match this value since a single request
        may generate multiple WNM reports."
    ::= { dot11WNMLocConfigReportEntry 2 }

dot11WNMLocConfigRprtIfIndex OBJECT-TYPE
    SYNTAX InterfaceIndex
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "The ifIndex for this row of WNMLocConfig report been received on."
    ::= { dot11WNMLocConfigReportEntry 3 }

dot11WNMLocConfigRprtLocIndParams OBJECT-TYPE
```


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```
    SYNTAX OCTET STRING (SIZE(16))
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
       "This is a status variable.
       It is written by the SME when a management report is completed.

       This attribute indicates STA Location reporting characteristics. The
       format of these Location Indication Parameters are detailed in 9.4.2.69.2
       (Location Indication Parameters subelement)."
    ::= { dot11WNMLocConfigReportEntry 4 }

dot11WNMLocConfigRprtLocIndChanList OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(0..254))
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
       "This is a status variable.
       It is written by the SME when a management report is completed.

       This attribute lists location indication reporting channel information for
       this location configuration report. Each pair of octets indicates a
       different Operating Class and channel number for this request. The
       detailed format for this list of channels as described in 9.4.2.69.3
       (Location Indication Channels subelement)."
    DEFVAL { ''H }
    ::= { dot11WNMLocConfigReportEntry 5 }

dot11WNMLocConfigRprtLocIndBcastRate OBJECT-TYPE
    SYNTAX Unsigned32 (0..65535)
    UNITS "0.5 Mb/s"
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
       "This is a status variable.
       It is written by the SME when a management report is completed.

       This attribute indicates the data rate at which the STA broadcasts its
       Location Track Notification frames."
    ::= { dot11WNMLocConfigReportEntry 6 }

dot11WNMLocConfigRprtLocIndOptions OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(0..255))
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
       "This is a status variable.
       It is written by the SME when a management report is completed.

       This attribute indicates the location track indication options used; see
       9.4.2.69.9 (Location Indication Options subelement)."
    ::= { dot11WNMLocConfigReportEntry 7}

dot11WNMLocConfigRprtStatusConfigSubelemId OBJECT-TYPE
    SYNTAX INTEGER {
       multipleSubelemIds(0),
       locationIndicationParams(1),
       locationIndicationChannels(2),
       locationStatus(3),
       radioInformation(4),
       motion(5),
       locationIndicationBcastDataRate(6),
       timeOfDeparture(7),
       vendorSpecific(8)
```

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```
        }
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute is set to a specific Location Parameters subelement ID
        transmitted in a Location Configuration Request frame. If the following
        StatusResult attribute field value applies to more than one subelement
        then the Config subelement ID is set to 0. If the Status field value
        applies to one subelement, then a Location Status subelement may be
        included in the Location Configuration Response for each configuration
        subelement that has a non-Success Status value."
    ::= { dot11WNMLocConfigReportEntry 8 }

dot11WNMLocConfigRprtStatusResult OBJECT-TYPE
    SYNTAX INTEGER {
        successful(0),
        requestFailed(1),
        requestRefused(2),
        requestIncapable(3),
        detectedFrequentTransition(4)
        }

    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute contains the resulting status of the Location Configuration
        Request frame for the indicated Location Parameter subelement ID, as
        listed in Table 9-237 (Event Report Status), Event Report Status."
    ::= { dot11WNMLocConfigReportEntry 9 }

dot11WNMLocConfigRprtVendorSpecificRprtContent OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(0..255))
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute provides an envelope for all of the vendor specific
        subelements that may be included in Location Configuration Report
        element."
    DEFVAL { ''H }
    ::= { dot11WNMLocConfigReportEntry 10 }

-- ************************************************************
-- * End of dot11WNMLocConfigReport TABLE
-- ************************************************************

-- ************************************************************
-- * dot11WNMBssTransitReport TABLE
-- ************************************************************
dot11WNMBssTransitReportTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11WNMBssTransitReportEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "Group contains the current list of BSS Transition Management reports that
        have been received by the MLME. The report tables shall be maintained as
```


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```
        FIFO to preserve freshness, thus the rows in this table can be deleted for
        memory constraints or other implementation constraints determined by the
        vendor. New rows shall have different RprtIndex values than those deleted
        within the range limitation of the index. One easy way is to increment
        RprtIndex for new reports being written in the table."
    ::= { dot11WNMReport 14 }

dot11WNMBssTransitReportEntry OBJECT-TYPE
    SYNTAX Dot11WNMBssTransitReportEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "An entry in the dot11WNMBssTransitReportTable Indexed by
        dot11WNMBssTransitRprtIndex."
    INDEX { dot11WNMBssTransitRprtIndex }
    ::= { dot11WNMBssTransitReportTable 1 }

Dot11WNMBssTransitReportEntry ::=
    SEQUENCE {
        dot11WNMBssTransitRprtIndex                         Unsigned32,
        dot11WNMBssTransitRprtRqstToken                     OCTET STRING,
        dot11WNMBssTransitRprtIfIndex                       InterfaceIndex,
        dot11WNMBssTransitRprtStatusCode                    INTEGER,
        dot11WNMBssTransitRprtBSSTerminationDelay           Unsigned32,
        dot11WNMBssTransitRprtTargetBssid                   MacAddress,
        dot11WNMBssTransitRprtCandidateList                 OCTET STRING }

dot11WNMBssTransitRprtIndex OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "Index for BSS Transition Management Report elements in
        dot11WNMBssTransitReportTable, greater than 0."
    ::= { dot11WNMBssTransitReportEntry 1 }

dot11WNMBssTransitRprtRqstToken OBJECT-TYPE
    SYNTAX OCTET STRING
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute indicates the request token that was indicated in the WNM
        request that generated this measurement report. This should be an exact
        match to the original dot11WNMRqstToken attribute. Note that there may be
        multiple entries in the table that match this value since a single request
        may generate multiple WNM reports."
    ::= { dot11WNMBssTransitReportEntry 2 }

dot11WNMBssTransitRprtIfIndex OBJECT-TYPE
    SYNTAX InterfaceIndex
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "The ifIndex for this row of WNMBssTransit report been received on."
    ::= { dot11WNMBssTransitReportEntry 3 }

dot11WNMBssTransitRprtStatusCode OBJECT-TYPE
    SYNTAX INTEGER {
        accept(0),
        rejectUnspecified(1),
        rejectInsufficientBeacons(2),
```

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```
        rejectInsufficientCapacity(3),
        rejectBssTerminationUndesired(4),
        rejectBssTerminationDelayRequest(5),
        rejectBssTransitionCandidateListprovided(6),
        rejectNoSuitableBssTransitionCandidates(7),
        rejectLeavingEss(8)
        }
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute indicates the status of this BSS Transition report."
    ::= { dot11WNMBssTransitReportEntry 4 }

dot11WNMBssTransitRprtBSSTerminationDelay OBJECT-TYPE
    SYNTAX Unsigned32 (1..255)
    UNITS "minutes"
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute indicates the time that the responding STA requests the BSS
        to delay termination. This attribute is included only if the Status Code
        field value is set to 5."
    ::= { dot11WNMBssTransitReportEntry 5 }

dot11WNMBssTransitRprtTargetBssid OBJECT-TYPE
    SYNTAX MacAddress
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute indicates the target BSSID for this BSS Transition report."
    ::= { dot11WNMBssTransitReportEntry 6 }

dot11WNMBssTransitRprtCandidateList OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(0..11426))
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute lists one or more Neighbor Report elements which are BSS
        transition candidates for this request.  The Neighbor Report elements are
        described in 9.4.2.35 (Neighbor Report element)."
::= { dot11WNMBssTransitReportEntry 7 }


-- ********************************************************************
-- * End of dot11WNMBssTransitReport TABLE
-- ********************************************************************

-- ********************************************************************
-- * dot11WNMColocInterfReport TABLE
-- ********************************************************************
dot11WNMColocInterfReportTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11WNMColocInterfReportEntry

```


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```
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "Group contains the current list of (#2210)Colocated Interference reports
        that have been received by the MLME. The report tables shall be maintained
        as FIFO to preserve freshness, thus the rows in this table can be deleted
        for memory constraints or other implementation constraints determined by
        the vendor. New rows shall have different RprtIndex values than those
        deleted within the range limitation of the index. One easy way is to
        increment RprtIndex for new reports being written in the table."
    ::= { dot11WNMReport 16 }

dot11WNMColocInterfReportEntry OBJECT-TYPE
    SYNTAX Dot11WNMColocInterfReportEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "An entry in the dot11WNMColocInterfReportTable Indexed by
        dot11WNMColocInterfRprtIndex."
    INDEX { dot11WNMColocInterfRprtIndex }
    ::= { dot11WNMColocInterfReportTable 1 }

Dot11WNMColocInterfReportEntry ::=
    SEQUENCE {
        dot11WNMColocInterfRprtIndex                    Unsigned32,
        dot11WNMColocInterfRprtRqstToken                OCTET STRING,
        dot11WNMColocInterfRprtIfIndex                  InterfaceIndex,
        dot11WNMColocInterfRprtPeriod                   Unsigned32,
        dot11WNMColocInterfRprtInterfLevel              Integer32,
        dot11WNMColocInterfRprtInterfAccuracy           Unsigned32,
        dot11WNMColocInterfRprtInterfIndex              Unsigned32,
        dot11WNMColocInterfRprtInterfInterval           Integer32,
        dot11WNMColocInterfRprtInterfBurstLength        Integer32,
        dot11WNMColocInterfRprtInterfStartTime          Integer32,
        dot11WNMColocInterfRprtInterfCenterFreq         Integer32,
        dot11WNMColocInterfRprtInterfBandwidth          Unsigned32 }

dot11WNMColocInterfRprtIndex OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "Index for (#2210)Colocated Interference Report elements in
        dot11WNMColocInterfReportTable, greater than 0."
    ::= { dot11WNMColocInterfReportEntry 1 }

dot11WNMColocInterfRprtRqstToken OBJECT-TYPE
    SYNTAX OCTET STRING
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute indicates the request token that was indicated in the WNM
        request that generated this measurement report. This should be an exact
        match to the original dot11WNMRqstToken attribute. Note that there may be
        multiple entries in the table that match this value since a single request
        may generate multiple WNM reports."
    ::= { dot11WNMColocInterfReportEntry 2 }

dot11WNMColocInterfRprtIfIndex OBJECT-TYPE
    SYNTAX InterfaceIndex
    MAX-ACCESS read-only
```

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```
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        The ifIndex for this row of WNMColocInterf report been received on."
    ::= { dot11WNMColocInterfReportEntry 3 }

dot11WNMColocInterfRprtPeriod OBJECT-TYPE
    SYNTAX Unsigned32 (0..255)
    UNITS "100 TU"
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute indicates how often the STA periodically reports the
        (#2210)colocated interference. If the Report Period field is set to 0,
        then the reporting is not periodic, and a report is generated when the STA
        detects a change in the (#2210)colocated interference. See 11.21.9
        ((#2210)Colocated interference reporting) for further details."
    ::= { dot11WNMColocInterfReportEntry 4 }

dot11WNMColocInterfRprtInterfLevel OBJECT-TYPE
    SYNTAX Integer32 (-128..127)
    UNITS "dBm"
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute indicates the maximum level of the (#2210)colocated
        interference power in units of dBm over all receive chains averaged over a
        4 s period during an interference period and across interference
        bandwidth. When the interference level is unknown, the field is set to
        +127 dBm. When the interference level is equal or greater than 126 dBm,
        the field is set to +126 dBm. If no (#2210)colocated interference is
        present the field is set to -128 dBm. When the interference level is equal
        or lower than -127 dBm, the field is set to -127 dBm. The interference
        level is referenced to the antenna connector (see definition in Clause 3
        (Definitions, acronyms, and abbreviations)) used for reception, like
        RCPI."
    ::= { dot11WNMColocInterfReportEntry 5 }

dot11WNMColocInterfRprtInterfAccuracy OBJECT-TYPE
    SYNTAX Unsigned32 (0..15)
    UNITS "dB"
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when a management report is completed.

        This attribute indicates the expected accuracy of the estimate of
        interference in dB with 95% confidence interval. If the Interference Level
        field is X (dBm) and the expected accuracy field is Y (dB), the actual
        interference level is in the range X - Y to X +Y with the probability of
        95%. If the accuracy is unknown then the Expected Accuracy field is set to
        15."
    ::= { dot11WNMColocInterfReportEntry 6 }

dot11WNMColocInterfRprtInterfIndex OBJECT-TYPE
```


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```
    SYNTAX Unsigned32 (0..15)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
       "This is a status variable.
       It is written by the SME when a management report is completed.

       This attribute indicates the interference index that is unique for each
       type of interference source. The field set to 0 indicates that no
       (#2210)colocated interference is present. See 11.21.9 ((#2210)Colocated
       interference reporting) for further details."
    ::= { dot11WNMColocInterfReportEntry 7 }

dot11WNMColocInterfRprtInterfInterval OBJECT-TYPE
    SYNTAX Integer32
    UNITS "microseconds"
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
       "This is a status variable.
       It is written by the SME when a management report is completed.

       This attribute indicates the interval between two successive periods of
       interference. When the interval between two successive periods of
       interference is variable the field is set to 2^32-1. When the interval
       between two successive periods of interference is equal or greater than
       2**32-2 the field is set to 2^32-2. If no (#2210)colocated interference is
       present the field is set to 0."
    ::= { dot11WNMColocInterfReportEntry 8 }

dot11WNMColocInterfRprtInterfBurstLength OBJECT-TYPE
    SYNTAX Integer32
    UNITS "microseconds"
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
       "This is a status variable.
       It is written by the SME when a management report is completed.

       This attribute indicates the duration of each period of interference. When
       the duration of each period of interference is variable the field is set
       to 2^32-1). When the duration of each period of interference is equal or
       greater than 2^32-2, the field is set to 2^32-2. If no (#2210)colocated
       interference is present the field is set to 0."
    ::= { dot11WNMColocInterfReportEntry 9 }

dot11WNMColocInterfRprtInterfStartTime OBJECT-TYPE
    SYNTAX Integer32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
       "This is a status variable.
       It is written by the SME when a management report is completed.

       This attribute contains the least significant 4 octets (i.e., B0-B31) of
       the TSF timer at the start of the interference burst. When either the
       Interference Interval or the Interference Burst Length fields are set to
       2^32-1, this field indicates the average duty cycle. The average duty
       cycle value is defined as Floor((2^32-2) * [average interference burst
       length (microsecond)]/[average interference interval (microsecond)] +
       0.5). When the interference is nonperiodic the Interference Start Time
       field is set to 0. If no (#2210)colocated interference is present the
       field is set to 0."
    ::= { dot11WNMColocInterfReportEntry 10 }
```

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```
dot11WNMColocInterfRprtInterfCenterFreq OBJECT-TYPE
   SYNTAX Integer32
   UNITS "5 kHz"
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a status variable.
      It is written by the SME when a management report is completed.

      This attribute indicates center frequency of interference. When center
      frequency is unknown, the center frequency of the STA's operating channel
      is reported. If no (#2210)colocated interference is present the field is
      set to 0."
   ::= { dot11WNMColocInterfReportEntry 11 }

dot11WNMColocInterfRprtInterfBandwidth OBJECT-TYPE
   SYNTAX Unsigned32 (0..65535)
   UNITS "5 kHz"
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a status variable.
      It is written by the SME when a management report is completed.

      This attribute indicates the bandwidth at the -3 dB roll-off point of the
      interference signal. When bandwidth of the interference signal is unknown,
      the field is set to 65 535. When bandwidth of the interference signal is
      equal or greater than 65 534 the field is set to 65 534. If no
      (#2210)colocated interference is present the field is set to 0."
   ::= { dot11WNMColocInterfReportEntry 12 }

-- ************************************************************
-- * End of dot11WNMColocInterfReport TABLE
-- ************************************************************

-- ************************************************************
-- * END of Wireless Network Management Interface MIB
-- ************************************************************

-- ************************************************************************
-- * END of IEEE 802.11 RM and WNM Interface MIB
-- ************************************************************************
```



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```
(-- ********************************************************************
-- * dot11MeshSTAConfig TABLE
-- ********************************************************************

dot11MeshSTAConfigTable OBJECT-TYPE
   SYNTAX SEQUENCE OF Dot11MeshSTAConfigEntry
   MAX-ACCESS not-accessible
   STATUS current
   DESCRIPTION
      "Mesh Station Configuration attributes. In tabular form to allow for
      multiple instances on an agent."
   ::= { dot11smt 23 }

dot11MeshSTAConfigEntry  OBJECT-TYPE
   SYNTAX Dot11MeshSTAConfigEntry
   MAX-ACCESS not-accessible
   STATUS current
   DESCRIPTION
      "An entry in the dot11MeshStationConfigTable. It is possible for there to
      be multiple IEEE 802.11 interfaces on one agent, each with its unique MAC
      address. The relationship between an IEEE 802.11 interface and an
      interface in the context of the Internet-standard MIB is one-to-one. As
      such, the value of an ifIndex object instance can be directly used to
      identify corresponding instances of the objects defined herein.
      ifIndex - Each IEEE 802.11 interface is represented by an ifEntry. Inter-
      face tables in this MIB module are indexed by ifIndex."
   INDEX { ifIndex }
   ::= { dot11MeshSTAConfigTable 1 }

Dot11MeshSTAConfigEntry ::=
   SEQUENCE {
      dot11MeshID                                    OCTET STRING,
      dot11MeshNumberOfPeerings                      Unsigned32,
      dot11MeshAcceptingAdditionalPeerings           TruthValue,
      dot11MeshConnectedToMeshGate                   TruthValue,
      dot11MeshSecurityActivated                     TruthValue,
      dot11MeshActiveAuthenticationProtocol          INTEGER,
      dot11MeshMaxRetries                            Unsigned32,
      dot11MeshRetryTimeout                          Unsigned32,
      dot11MeshConfirmTimeout                        Unsigned32,
      dot11MeshHoldingTimeout                        Unsigned32,
      dot11MeshConfigGroupUpdateCount                Unsigned32,
      dot11MeshActivePathSelectionProtocol           INTEGER,
      dot11MeshActivePathSelectionMetric             INTEGER,
      dot11MeshForwarding                            TruthValue,
      dot11MeshTTL                                   Unsigned32,
      dot11MeshGateAnnouncements                     TruthValue,
      dot11MeshGateAnnouncementInterval              Unsigned32,
      dot11MeshActiveCongestionControlMode           INTEGER,
      dot11MeshActiveSynchronizationMethod           INTEGER,
      dot11MeshNbrOffsetMaxNeighbor                  Unsigned32,
      dot11MBCAActivated                             TruthValue,
      dot11MeshBeaconTimingReportInterval            Unsigned32,
      dot11MeshBeaconTimingReportMaxNum              Unsigned32,
      dot11MeshDelayedBeaconTxInterval               Unsigned32,
      dot11MeshDelayedBeaconTxMaxDelay               Unsigned32,
      dot11MeshDelayedBeaconTxMinDelay               Unsigned32,
      dot11MeshAverageBeaconFrameDuration            Unsigned32,
      dot11MeshSTAMissingAckRetryLimit               Unsigned32,
      dot11MeshAwakeWindowDuration                   Unsigned32,
      dot11MCCAImplemented                           TruthValue,
      dot11MCCAActivated                             TruthValue,
      dot11MAFlimit                                  Unsigned32,
      dot11MCCAScanDuration                          Unsigned32,
```

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```
        dot11MCCAAdvertPeriodMax                                    Unsigned32,
        dot11MCCATrackStatesCapable                                 Unsigned32,
        dot11MCCATrackStatesActive                                  Unsigned32,
        dot11MCCAOPtimeout                                          Unsigned32,
        dot11MCCACWmin                                              Unsigned32,
        dot11MCCACWmax                                              Unsigned32,
        dot11MCCAAIFSN                                              Unsigned32
        }


dot11MeshID OBJECT-TYPE
   SYNTAX OCTET STRING (SIZE(0..32))
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by an external management entity.
      Changes take effect for the next MLME-START.request primitive.

      This attribute reflects the mesh ID(#1755) configured in this entity."
   ::= { dot11MeshSTAConfigEntry 1 }

dot11MeshNumberOfPeerings OBJECT-TYPE
   SYNTAX Unsigned32 (0..255)
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by an external management entity.
      Changes take effect as soon as practical in the implementation.

      This attribute indicates the number of mesh peering currently maintained
      by the STA. This value is reflected in the Number of Peerings subfield in
      the Mesh Formation Info field in the Mesh Configuration element."
   ::= { dot11MeshSTAConfigEntry 2 }

dot11MeshAcceptingAdditionalPeerings OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by an external management entity.
      Changes take effect as soon as practical in the implementation.

      This attribute indicates whether the station is willing to accept
      additional peerings. This value is reflected in the Accepting Additional
      Mesh Peerings subfield in the Mesh Capability field in the Mesh
      Configuration element."
   ::= { dot11MeshSTAConfigEntry 3 }

dot11MeshConnectedToMeshGate OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by an external management entity.
      Changes take effect as soon as practical in the implementation.

      This attribute indicates whether the station has a mesh path to a mesh
      gate. This value is reflected in the Connected to Mesh Gate subfield in
      the Mesh Formation Info field in the Mesh Configuration element."
   ::= { dot11MeshSTAConfigEntry 4 }
```


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```
dot11MeshSecurityActivated OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by an external management entity.
      Changes take effect for the next MLME-START.request primitive.

      This attribute specifies whether the station is security enabled."
   ::= { dot11MeshSTAConfigEntry 5 }

dot11MeshActiveAuthenticationProtocol OBJECT-TYPE
   SYNTAX INTEGER {
      null (0),
      sae (1),
      ieee8021x (2),
      vendorSpecific (255) }
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by an external management entity.
      Changes take effect for the next MLME-START.request primitive.

      This attribute specifies the active authentication protocol."
   DEFVAL { null }
   ::= { dot11MeshSTAConfigEntry 6 }

dot11MeshMaxRetries OBJECT-TYPE
   SYNTAX Unsigned32 (0..16)
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by an external management entity.
      Changes take effect as soon as practical in the implementation.

      This attribute specifies the maximum number of Mesh Peering Open retries
      that can be sent to establish a new mesh peering instance in a mesh BSS."
   DEFVAL { 2 }
   ::= { dot11MeshSTAConfigEntry 7 }

dot11MeshRetryTimeout OBJECT-TYPE
   SYNTAX Unsigned32 (1..255)
   UNITS "milliseconds"
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by an external management entity.
      Changes take effect as soon as practical in the implementation.

      This attribute specifies the initial retry timeout used by the Mesh
      Peering Open message."
   DEFVAL { 40 }
   ::= { dot11MeshSTAConfigEntry 8 }

dot11MeshConfirmTimeout OBJECT-TYPE
   SYNTAX Unsigned32 (1..255)
   UNITS "milliseconds"
   MAX-ACCESS read-write
   STATUS current
```

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```
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute specifies the initial retry timeout used by the Mesh
        Peering Open message."
    DEFVAL { 40 }
    ::= { dot11MeshSTAConfigEntry 9 }

dot11MeshHoldingTimeout OBJECT-TYPE
    SYNTAX Unsigned32 (1..255)
    UNITS "milliseconds"
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute specifies the confirm timeout used by the mesh peering
        management to close a mesh peering."
    DEFVAL { 40 }
    ::= { dot11MeshSTAConfigEntry 10 }

dot11MeshConfigGroupUpdateCount OBJECT-TYPE
    SYNTAX Unsigned32 (1..4294967295)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute specifies how many times the Mesh Group Key Inform frame
        will be retried per mesh group key handshake attempt."
    DEFVAL { 3 }
    ::= { dot11MeshSTAConfigEntry 11 }

dot11MeshActivePathSelectionProtocol OBJECT-TYPE
    SYNTAX INTEGER { hwmp (1), vendorSpecific (255) }
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect for the next MLME-START.request primitive.

        This attribute specifies the active path selection protocol."
    DEFVAL { hwmp }
    ::= { dot11MeshSTAConfigEntry 12 }

dot11MeshActivePathSelectionMetric OBJECT-TYPE
    SYNTAX INTEGER { airtimeLinkMetric (1), highPHYRateAirtimeLinkMetric (2),
        vendorSpecific (255) }
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect for the next MLME-START.request primitive.

        This attribute specifies the active path selection metric."
    DEFVAL { airtimeLinkMetric }
```


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```
    ::= { dot11MeshSTAConfigEntry 13 }

dot11MeshForwarding OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute specifies the ability of a mesh STA to forward MSDUs."
    DEFVAL { true }
    ::= { dot11MeshSTAConfigEntry 14 }

dot11MeshTTL OBJECT-TYPE
    SYNTAX Unsigned32 (1..255)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute specifies the value of Mesh TTL subfield set at a source
        mesh STA."
    DEFVAL { 31 }
    ::= { dot11MeshSTAConfigEntry 15 }

dot11MeshGateAnnouncements OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute specifies whether the mesh STA activates mesh gate
        announcements."
    DEFVAL { false }
    ::= { dot11MeshSTAConfigEntry 16 }

dot11MeshGateAnnouncementInterval OBJECT-TYPE
    SYNTAX Unsigned32 (1..65535)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute specifies the gate announcement interval. The gate
        announcement interval is the number of seconds between the transmission of
        two gate announcements."
    DEFVAL { 10 }
    ::= { dot11MeshSTAConfigEntry 17 }

dot11MeshActiveCongestionControlMode OBJECT-TYPE
    SYNTAX INTEGER {
        null (0),
        congestionControlSignaling (1),
        vendorSpecific (255) }
    MAX-ACCESS read-write
```

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```
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect for the next MLME-START.request primitive.

        This attribute specifies the active congestion control protocol."
    DEFVAL { null }
    ::= { dot11MeshSTAConfigEntry 18 }

dot11MeshActiveSynchronizationMethod OBJECT-TYPE
    SYNTAX INTEGER {
        neighborOffsetSynchronization (1),
        vendorSpecific (255) }
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect for the next MLME-START.request primitive.

        This attribute specifies the MBSS's active synchronization method."
    DEFVAL { neighborOffsetSynchronization }
    ::= { dot11MeshSTAConfigEntry 19 }

dot11MeshNbrOffsetMaxNeighbor OBJECT-TYPE
    SYNTAX Unsigned32 (1..255)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute specifies the maximum number of neighbor STAs with which
        the mesh STA maintains synchronization using the neighbor offset
        synchronization method."
    ::= { dot11MeshSTAConfigEntry 20 }

dot11MBCAActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute specifies whether the station activates mesh beacon
        collision avoidance mechanisms."
    DEFVAL { false }
    ::= { dot11MeshSTAConfigEntry 21 }

dot11MeshBeaconTimingReportInterval OBJECT-TYPE
    SYNTAX Unsigned32 (1..255)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.

        This attribute specifies when the Beacon Timing element is present in
        Beacon frames. The Beacon Timing element is present when the DTIM Count
        value in the Beacon frame is zero or equal to an integer multiple of the
        set value."
```


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```
    DEFVAL { 4 }
    ::= { dot11MeshSTAConfigEntry 22 }

dot11MeshBeaconTimingReportMaxNum OBJECT-TYPE
    SYNTAX Unsigned32 (0..50)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute specifies the maximum number of the Beacon Timing
        Information field contained in a Beacon Timing element in the transmitting
        Beacon frames."
    DEFVAL { 16 }
    ::= { dot11MeshSTAConfigEntry 23 }

dot11MeshDelayedBeaconTxInterval OBJECT-TYPE
    SYNTAX Unsigned32 (0..255)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute specifies the interval of the delayed beacon transmission
        for the purpose of MBCA. The value is expressed in units of Beacon
        Interval. The value 0 indicates that the delayed beacon transmission is
        disabled."
    DEFVAL { 0 }
    ::= { dot11MeshSTAConfigEntry 24 }

dot11MeshDelayedBeaconTxMaxDelay OBJECT-TYPE
    SYNTAX Unsigned32 (0..65535)
    UNITS "microseconds"
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute specifies the maximum delay time from a TBTT of delayed
        beacon transmissions for the purpose of MBCA."
    DEFVAL { 2048 }
    ::= { dot11MeshSTAConfigEntry 25 }

dot11MeshDelayedBeaconTxMinDelay OBJECT-TYPE
    SYNTAX Unsigned32 (0..4023)
    UNITS "microseconds"
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute specifies the minimum delay time from a TBTT of delayed
        beacon transmissions for the purpose of MBCA."
    DEFVAL { 0 }
    ::= { dot11MeshSTAConfigEntry 26 }
```

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```
dot11MeshAverageBeaconFrameDuration OBJECT-TYPE
   SYNTAX Unsigned32 (0..16383)
   UNITS "microseconds"
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by an external management entity.
      Changes take effect as soon as practical in the implementation.

      This attribute specifies the average duration of the last 16 Beacon frames
      of other mesh STAs received by this mesh STA."
   ::= { dot11MeshSTAConfigEntry 27 }

dot11MeshSTAMissingAckRetryLimit OBJECT-TYPE
   SYNTAX Unsigned32 (0..100)
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by an external management entity.
      Changes take effect as soon as practical in the implementation.

      This attribute specifies the number of times the mesh STA may retry a
      frame for which it does not receive an Ack frame for a STA in power save
      mode after the mesh STA does not receive an Ack frame to an individually
      addressed MPDU sent with the EOSP subfield set to 1."
   ::= { dot11MeshSTAConfigEntry 28 }

dot11MeshAwakeWindowDuration OBJECT-TYPE
   SYNTAX Unsigned32 (0..65535)
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by an external management entity.
      Changes take effect as soon as practical in the implementation.

      This attribute specifies the duration of the mesh awake window(#3110) in
      TUs. This value is reflected in the value of the Mesh Awake Window ele-
      ment."
   ::= { dot11MeshSTAConfigEntry 29 }

dot11MCCAImplemented OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a capability variable.
      Its value is determined by (#3375)STA capabilities.

      This attribute specifies whether the MCCA is implemented in this station."
   ::= { dot11MeshSTAConfigEntry 30 }

dot11MCCAActivated OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by an external management entity.
      Changes take effect as soon as practical in the implementation.

      This attribute specifies whether the station is MCCA enabled."
```


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```
    DEFVAL { false }
    ::= { dot11MeshSTAConfigEntry 31 }

dot11MAFlimit OBJECT-TYPE
    SYNTAX Unsigned32 (0..255)
    UNITS "1/255"
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute specifies the maximum MCCA access fraction allowed at the
        mesh STA."
    DEFVAL { 128 }
    ::= { dot11MeshSTAConfigEntry 32 }

dot11MCCAScanDuration OBJECT-TYPE
    SYNTAX Unsigned32 (1..65535)
    UNITS "TUs"
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute specifies the duration after the activation of MCCA that
        the mesh STA shall not initiate or accept MCCAOP Setup Requests."
    DEFVAL { 3200 } -- (2 ^ 5) * 100
    ::= { dot11MeshSTAConfigEntry 33 }

dot11MCCAAdvertPeriodMax OBJECT-TYPE
    SYNTAX Unsigned32 (0..255)
    UNITS "DTIM intervals"
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute specifies the maximum interval that a mesh STA with
        dot11MCCAActivated equal to true waits for an MCCAOP advertisement."
    DEFVAL { 1 }
    ::= { dot11MeshSTAConfigEntry 34 }


dot11MCCATrackStatesCapable OBJECT-TYPE
    SYNTAX Unsigned32 (83..65535)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute specifies the number of MCCAOP reservations that the MAC
        entity is able to track."
::= { dot11MeshSTAConfigEntry 35 }


dot11MCCATrackStatesActive OBJECT-TYPE
    SYNTAX Unsigned32 (0..65535)(#1466)
```

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```
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
       "This is a status variable.
       It is written by the MAC when the STA begins or stops tracking an MCCAOP
       reservation.

       This counter shall be incremented each time the STA begins tracking an
       MCCAOP reservation. This counter shall be decremented each time the STA
       stops tracking an MCCAOP reservation."(#1466)
    ::= { dot11MeshSTAConfigEntry 36 }

dot11MCCAOPtimeout OBJECT-TYPE
    SYNTAX Unsigned32
    UNITS "TUs"
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
       "This is a control variable.
       It is written by an external management entity.
       Changes take effect as soon as practical in the implementation.

       This attribute specifies the timeout value for an MCCAOP teardown."
    DEFVAL { 10000 }
    ::= { dot11MeshSTAConfigEntry 37 }

dot11MCCACWmin OBJECT-TYPE
    SYNTAX Unsigned32 (0..65535)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
       "This is a control variable.
       It is written by an external management entity.
       Changes take effect as soon as practical in the implementation.

       This attribute specifies the value of the minimum size of the window that
       shall be used by the mesh STA during the MCCAOP for which it is the MCCAOP
       owner for generating a random number for the backoff."
    DEFVAL { 0 }
    ::= { dot11MeshSTAConfigEntry 38 }

dot11MCCACWmax OBJECT-TYPE
    SYNTAX Unsigned32 (0..65535)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
       "This is a control variable.
       It is written by an external management entity.
       Changes take effect as soon as practical in the implementation.

       This attribute specifies the value of the maximum size of the window that
       shall be used by the mesh STA during the MCCAOP for which it is the MCCAOP
       owner for generating a random number for the backoff. The value of this
       attribute shall be such that it could always be expressed in the form of
       2^X - 1, where X is an integer."
    DEFVAL { 31 }
    ::= { dot11MeshSTAConfigEntry 39 }

dot11MCCAAIFSN OBJECT-TYPE
    SYNTAX Unsigned32 (0..15)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
       "This is a control variable.
```


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```
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute specifies the number of slots, after a SIFS, that the mesh
        STA shall sense the medium idle either before transmitting or executing a
        backoff during an MCCAOP for which it is the MCCAOP owner."
    DEFVAL { 1 }
    ::= { dot11MeshSTAConfigEntry 40 }

-- ********************************************************************
-- * End of dot11MeshSTAConfig TABLE
-- ********************************************************************

-- ********************************************************************
-- * dot11MeshHWMPConfig TABLE
-- ********************************************************************

dot11MeshHWMPConfigTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11MeshHWMPConfigEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "Mesh Station HWMP Configuration attributes. In tabular form to allow for
        multiple instances on an agent."
    ::= { dot11smt 24 }

dot11MeshHWMPConfigEntry  OBJECT-TYPE
    SYNTAX Dot11MeshHWMPConfigEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "An entry in the dot11MeshHWMPConfigTable. It is possible for there to be
        multiple IEEE 802.11 interfaces on one agent, each with its unique MAC
        address. The relationship between an IEEE 802.11 interface and an
        interface in the context of the Internet-standard MIB is one-to-one. As
        such, the value of an ifIndex object instance can be directly used to
        identify corresponding instances of the objects defined herein.
        ifIndex - Each IEEE 802.11 interface is represented by an ifEntry.
        Interface tables in this MIB module are indexed by ifIndex."
    INDEX { ifIndex }
    ::= { dot11MeshHWMPConfigTable 1 }

Dot11MeshHWMPConfigEntry ::=
    SEQUENCE {
        dot11MeshHWMPmaxPREQretries                     Unsigned32,
        dot11MeshHWMPnetDiameter                        Unsigned32,
        dot11MeshHWMPnetDiameterTraversalTime           Unsigned32,
        dot11MeshHWMPpreqMinInterval                    Unsigned32,
        dot11MeshHWMPperrMinInterval                    Unsigned32,
        dot11MeshHWMPactivePathToRootTimeout            Unsigned32,
        dot11MeshHWMPactivePathTimeout                  Unsigned32,
        dot11MeshHWMProotMode                           INTEGER,
        dot11MeshHWMProotInterval                       Unsigned32,
        dot11MeshHWMPrannInterval                       Unsigned32,
        dot11MeshHWMPtargetOnly                         INTEGER,
        dot11MeshHWMPmaintenanceInterval                Unsigned32,
        dot11MeshHWMPconfirmationInterval               Unsigned32
        }

dot11MeshHWMPmaxPREQretries OBJECT-TYPE
    SYNTAX Unsigned32 (0..255)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
```

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```
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute specifies the number of Action frames containing a PREQ
        element that an originator mesh STA can send to a particular path target
        for a specific path discovery."
    DEFVAL { 3 }
    ::= { dot11MeshHWMPConfigEntry 1}

dot11MeshHWMPnetDiameter OBJECT-TYPE
    SYNTAX Unsigned32 (1..255)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute specifies the estimate of the maximum number of hops that
        it takes for an HWMP element to propagate across the mesh BSS."
    DEFVAL { 31 }
    ::= { dot11MeshHWMPConfigEntry 2}

dot11MeshHWMPnetDiameterTraversalTime OBJECT-TYPE
    SYNTAX Unsigned32 (1..65535)
    UNITS "TUs"
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute specifies the estimate of the interval of time that it
        takes for an HWMP element to propagate across the mesh BSS."
    DEFVAL { 500 }
    ::= { dot11MeshHWMPConfigEntry 3}

dot11MeshHWMPpreqMinInterval OBJECT-TYPE
    SYNTAX Unsigned32 (1..65535)
    UNITS "TUs"
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute specifies the minimum interval of time during which a mesh
        STA can send only one Action frame containing a PREQ element."
    DEFVAL { 100 }
    ::= { dot11MeshHWMPConfigEntry 4}

dot11MeshHWMPperrMinInterval OBJECT-TYPE
    SYNTAX Unsigned32 (1..65535)
    UNITS "TUs"
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.
```


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```
        This attribute specifies the minimum interval of time during which a mesh
        STA can send only one Action frame containing a PERR element."
    DEFVAL { 100 }
    ::= { dot11MeshHWMPConfigEntry 5}

dot11MeshHWMPactivePathToRootTimeout OBJECT-TYPE
    SYNTAX Unsigned32 (1..65535)
    UNITS "TUs"
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This object shall specify the time for which mesh STAs receiving a
        proactive PREQ element shall consider the forwarding information to the
        root mesh STA to be valid; it needs to be greater than
        dot11MeshHWMProotInterval."
    DEFVAL { 5000 }
    ::= { dot11MeshHWMPConfigEntry 6}

dot11MeshHWMPactivePathTimeout OBJECT-TYPE
    SYNTAX Unsigned32 (1..65535)
    UNITS "TUs"
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute specifies the time for which mesh STAs receiving a PREQ
        element to individual target(s) shall consider the forwarding information
        to be valid."
    DEFVAL { 5000 }
    ::= { dot11MeshHWMPConfigEntry 7}

dot11MeshHWMProotMode OBJECT-TYPE
    SYNTAX INTEGER {
        noRoot(0),
        proactivePREQnoPREP(2),
        proactivePREQwithPREP(3),
        rann(4) }
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute controls the configuration of a mesh STA as root mesh STA.
        A mesh STA is configured as a root mesh STA if dot11MeshHWMProotMode is
        set to 2, 3 or 4. Different values correspond to different modes of the
        root mesh STA. The mesh STA is not a root mesh STA when the attribute is
        set to 0."
    DEFVAL { noRoot }
    ::= { dot11MeshHWMPConfigEntry 8}

dot11MeshHWMProotInterval OBJECT-TYPE
    SYNTAX Unsigned32 (1..65535)
    UNITS "TUs"
    MAX-ACCESS read-write
    STATUS current
```

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```
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute specifies the minimum interval of time during which a root
        mesh STA can send only one Action frame containing a proactive PREQ
        element."
    DEFVAL { 2000 }
    ::= { dot11MeshHWMPConfigEntry 9}

dot11MeshHWMPprannInterval OBJECT-TYPE
    SYNTAX Unsigned32 (1..65535)
    UNITS "TUs"
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute specifies the minimum interval of time during which a mesh
        STA can send only one Action frame containing a RANN element."
    DEFVAL { 2000 }
    ::= { dot11MeshHWMPConfigEntry 10}

dot11MeshHWMPtargetOnly OBJECT-TYPE
    SYNTAX INTEGER { intermediateMSTA(0), targetOnly(1) }
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute, when set to intermediateMSTA (0), allows intermediate mesh
        STAs to respond with a PREP element to a PREQ element if they have valid
        forwarding information to the requested target. When set to targetOnly
        (1), only the target mesh STA is allowed to respond with a PREP element to
        a PREQ element."
    DEFVAL { targetOnly }
    ::= { dot11MeshHWMPConfigEntry 11}

dot11MeshHWMPmaintenanceInterval OBJECT-TYPE
    SYNTAX Unsigned32 (1..65535)
    UNITS "TUs"
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute specifies the minimum interval of time during which a mesh
        STA can send only one Action frame containing a PREQ element for path
        maintenance."
    DEFVAL { 2000 }
    ::= { dot11MeshHWMPConfigEntry 12}

dot11MeshHWMPconfirmationInterval OBJECT-TYPE
    SYNTAX Unsigned32 (1..65535)
    UNITS "TUs"
    MAX-ACCESS read-write
    STATUS current
```


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```
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute specifies the minimum interval of time during which a mesh
        STA can send only one Action frame containing a PREQ element for root path
        confirmation."
    DEFVAL { 2000 }
    ::= { dot11MeshHWMPConfigEntry 13}

-- ********************************************************************
-- * End of dot11MeshHWMPConfig TABLE
-- ********************************************************************

-- ********************************************************************
-- * dot11RSNAConfigPasswordValue TABLE
-- ********************************************************************

dot11RSNAConfigPasswordValueTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11RSNAConfigPasswordValueEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "When SAE authentication is the selected AKM suite,
        this table is used to locate the binary representation
        of a shared, secret, and potentially low-entropy word,
        phrase, code, or key to(M118) be used as the
        authentication credential between a TA/RA pair.

        This table is logically write-only. Reading this table
        returns unsuccessful status or null or zero."
    ::= { dot11smt 25 }

dot11RSNAConfigPasswordValueEntry OBJECT-TYPE
    SYNTAX Dot11RSNAConfigPasswordValueEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "An entry (conceptual row) in the Password Value Table"
    INDEX { dot11RSNAConfigPasswordValueIndex }
    ::= { dot11RSNAConfigPasswordValueTable 1 }

Dot11RSNAConfigPasswordValueEntry ::=
    SEQUENCE {
        dot11RSNAConfigPasswordValueIndex                    Unsigned32,
        dot11RSNAConfigPasswordCredential                    OCTET STRING,
        dot11RSNAConfigPasswordIdentifier                    OCTET STRING,
        dot11RSNAConfigPasswordPeerMac                       MacAddress}

dot11RSNAConfigPasswordValueIndex OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "The auxiliary variable used to identify instances of the columnar
        objects in the Password Value table."
    ::= { dot11RSNAConfigPasswordValueEntry 1 }

dot11RSNAConfigPasswordCredential OBJECT-TYPE
    SYNTAX OCTET STRING
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
```

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```
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This variable is an octet string representation of a shared,
        secret, and potentially low-entropy word, phrase, code
        or key used as an authentication credential.

        Any character-based word or phrase shall be converted
        into a canonical representation according to
        12.4.3 (Representation of a password) before populating the Password Cre-
        dential."
    ::= { dot11RSNAConfigPasswordValueEntry 2 }

dot11RSNAConfigPasswordIdentifier OBJECT-TYPE
    SYNTAX OCTET STRING
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.
        This variable is an octet string that an implementation uses to uniquely
        identify a password to support provisioning multiple passwords for
        a single peer MAC entity. It shall be converted into a canonical represen-
        tation according to 12.4.3 (Representation of a password) before populat-
        ing the Password Identifier."
    DEFVAL { ''H }(#175)
    ::= { dot11RSNAConfigPasswordValueEntry  3 }

dot11RSNAConfigPasswordPeerMac OBJECT-TYPE
    SYNTAX MacAddress
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This variable represents the MAC address of the peer
        that is to be authenticated. A wildcard BSSID is
        permitted when passwords are shared among peers."
    ::= { dot11RSNAConfigPasswordValueEntry 4}

-- ********************************************************************
-- * End of dot11RSNAConfigPasswordValue TABLE
-- ********************************************************************

-- ********************************************************************
-- * dot11RSNAConfigDLCGroup TABLE
-- ********************************************************************

dot11RSNAConfigDLCGroupTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11RSNAConfigDLCGroupEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "This table gives a prioritized list of domain parameter set
        Identifiers for discrete logarithm cryptography (DLC) groups."
    ::= { dot11smt 26 }

dot11RSNAConfigDLCGroupEntry OBJECT-TYPE
    SYNTAX Dot11RSNAConfigDLCGroupEntry
    MAX-ACCESS not-accessible
```


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```
    STATUS current
    DESCRIPTION
        "An entry (conceptual row) in the DLC Group Table."
    INDEX { dot11RSNAConfigDLCGroupIndex }
    ::= { dot11RSNAConfigDLCGroupTable 1 }

Dot11RSNAConfigDLCGroupEntry ::=
    SEQUENCE {
        dot11RSNAConfigDLCGroupIndex                          Unsigned32,
        dot11RSNAConfigDLCGroupIdentifier                     Unsigned32 }

dot11RSNAConfigDLCGroupIndex OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "The variable used to identify instances of the columnar
        objects in the DLC Group Table. Entries are sorted
        based on the Group Index according to the priority
        of the Group Identifier relative to other objects.

        More preferred Group Identifiers (M118)have a lower
        index in the Group Entry."
    ::= { dot11RSNAConfigDLCGroupEntry 1 }

dot11RSNAConfigDLCGroupIdentifier OBJECT-TYPE
    SYNTAX Unsigned32 (0..65535)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This variable uniquely identifies a domain parameter
        set for a group in the repository maintained by IANA as `Group Descrip-
        tion'
        attributes for IETF RFC 2409 (IKE)[B14][B29]."
    ::= { dot11RSNAConfigDLCGroupEntry 2 }

-- ********************************************************************
-- *    End of dot11RSNAConfigDLCGroup TABLE
-- ********************************************************************

-- ********************************************************************
-- * dot11DMGSTAConfigTable TABLE
-- ********************************************************************

dot11DMGSTAConfigTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11DMGSTAConfigEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "This is a table management object.
        The dot11DMGSTAConfig Table"
    ::= { dot11smt 27 }

dot11DMGSTAConfigEntry OBJECT-TYPE
    SYNTAX Dot11DMGSTAConfigEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "This is an entry in the dot11DMGSTAConfig Table.
        ifIndex - Each IEEE 802.11 interface is represented by an ifEntry.
```

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```
        Interface tables in this MIB module are indexed by ifIndex."
    INDEX { ifIndex }
    ::= { dot11DMGSTAConfigTable 1 }

Dot11DMGSTAConfigEntry ::=
    SEQUENCE {
        dot11DMGOptionImplemented                       TruthValue,
        dot11RelayActivated                             TruthValue,
        dot11REDSActivated                              TruthValue,
        dot11RDSActivated                               TruthValue,
        dot11MultipleMACActivated                       TruthValue,
        dot11ClusteringActivated                        TruthValue,(#1285)
        (11ay)dot11DiscoveryAssistanceActivated         TruthValue,(#1286)
        (11ay)dot11DMGTDDLocalClockModeActivated        TruthValue,
        (11ay)dot11DMGTimeAdvertisementBeaconInterval   Unsigned32,
        (11ay)dot11ExtendedTPCActivated                 INTEGER,
        (11ay)dot11TDDOptionImplemented                 TruthValue,
        (11ay)dot11SAROptionImplemented                 TruthValue,
        (11ay)dot11ProtectedAnnounceImplemented         TruthValue,
        (11ay)dot11DMGExtendedMPDULimitValid            TruthValue,
        (11ay)dot11DMGSTATxActivityReportImplemented    TruthValue,
        (11ay)dot11DMGSTATxActivityReportActivated      TruthValue,
        (11bd)dot11DMGOCBActivated                      TruthValue
        }

dot11DMGOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        DMG Capable Object
        This attribute, when true, indicates the STA is DMG
        capable. This attribute, when false, indicates the STA is not DMG capa-
        ble."
    ::= { dot11DMGSTAConfigEntry 1 }

dot11RelayActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates the DMG STA is Relay
        capable.  This attribute, when false, indicates the STA is not Relay capa-
        ble."
    ::= { dot11DMGSTAConfigEntry 2 }

dot11REDSActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates the DMG STA is capable of operating
        as a REDS. This attribute, when false, indicates the STA is not capable of
        operating as a REDS."
    ::= { dot11DMGSTAConfigEntry 3 }
```


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```
dot11RDSActivated OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a capability variable.
      Its value is determined by (#3375)STA capabilities.

      This attribute, when true, indicates the DMG STA is capable of operating
      as a RDS. This attribute, when false, indicates the STA is not capable of
      operating as a RDS."
   ::= { dot11DMGSTAConfigEntry 4 }

dot11MultipleMACActivated OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a capability variable.
      Its value is determined by (#3375)STA capabilities.

      If dot11MultipleMACActivated is true, the STA is capable of managing more
      than one MAC address."
   ::= { dot11DMGSTAConfigEntry 5 }

dot11ClusteringActivated OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a capability variable.
      Its value is determined by (#3375)STA capabilities.

      If dot11ClusteringActivated is true, the STA is capable of supporting AP
      or PCP Clustering."
   ::= { dot11DMGSTAConfigEntry 6 }


(11ay)dot11DiscoveryAssistanceActivated OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by the SME or external management entity.
      Changes take effect as soon as practical in the implementation.

      This attribute, when true, indicates that the discovery assistance feature
      is currently operational. This attribute, when false or not present,
      indicates that the discovery assistance feature is currently not
      operational."
   ::= { dot11DMGSTAConfigEntry 7 }

(11ay)dot11DMGTDDLocalClockModeActivated OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by the SME or an external management entity.
      Changes take effect as soon as practical in the implementation.

      This attribute, when true, indicates that the STA uses a TSF timer that is
```

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```
        synchronized to a local source of timing."
    DEFVAL { false }
    ::= { dot11DMGSTAConfigEntry 8 }

(11ay)dot11DMGTimeAdvertisementBeaconInterval OBJECT-TYPE
    SYNTAX Unsigned32 (0..65535)
    UNITS "beacon interval"
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by the SME or external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute indicates the number of beacon intervals between successive
        DMG Beacon frame transmissions that includes the Time Advertisement
        element."
    DEFVAL { 4 }
    ::= { dot11DMGSTAConfigEntry 9 }

(11ay)dot11ExtendedTPCActivated OBJECT-TYPE
    SYNTAX INTEGER { none(0), tx(1), rx(2) }
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by the SME or external management entity.
        Changes take effect for the next MLME-LINKMEASURE.request primitive.

        A STA uses the defined TPC procedure according to this attribute if
        attribute is > 0; otherwise, it does not use any defined TPC procedure."
    DEFVAL { 0 }
    ::= { dot11DMGSTAConfigEntry 10 }

(11ay)dot11TDDOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        " This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the station supports TDD
        procedures."
    ::= { dot11DMGSTAConfigEntry 11 }

(11ay)dot11SAROptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by the SME or external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute, when true, indicates that the station supports SAR
        procedures."
    DEFVAL { false }
    ::= { dot11DMGSTAConfigEntry 12 }

(11ay)dot11ProtectedAnnounceImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
```


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```
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute, when true indicates the station supports the use of
        Protected Announce Action frame. The attribute is set to true only if the
        dot11RSNAProtectedManagementFramesActivated is true."
    DEFVAL { false }
    ::= { dot11DMGSTAConfigEntry 13 }

(11ay)dot11DMGExtendedMPDULimitValid OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by the SME or external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute, when true, indicates that the station can receive MPDUs
        larger than 7989 octets.”
    DEFVAL { false }
    ::= { dot11DMGSTAConfigEntry 14 }

(11ay)dot11DMGSTATxActivityReportImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by the SME or an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute, when true, indicates that the STA supports transmitting
        DMG STA Directional Transmit Activity Report frames."
    DEFVAL { false }
    ::= { dot11DMGSTAConfigEntry 15 }

(11ay)dot11DMGSTATxActivityReportActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by the SME or an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute, when true, indicates that the STA transmits DMG STA
        Directional Transmit Activity Report frames using each antenna pattern and
        2.16 GHz channel that is actively being used for data communication, as
        long as the STA supports this feature."
    DEFVAL { false }
    ::= { dot11DMGSTAConfigEntry 16 }

(11bd)dot11DMGOCBActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by the SME or an external management entity.
        Changes take effect at the next occurrence of an MLME-START.request or
        MLME-DMG-OCB-START.request primitive.
```

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```
        This attribute, when true, indicates that the STA supports communication
        outside the context of a BSS. This STA also has dot11OCBActivated equal to
        true."
    DEFVAL { false }
    ::= { dot11DMGSTAConfigEntry 17 }
-- ************************************************************
-- * End of dot11DMGSTAConfigTable TABLE
-- ************************************************************


-- ************************************************************
-- * dot11AVOptions TABLE
-- ************************************************************

dot11AVOptionsTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11AVOptionsEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "AV streaming attributes. In tabular form to allow for multiple instances
        on an agent. This table applies to the interface only if
        dot11RobustAVStreamingImplemented is true in the dot11StationConfigTable.
        Otherwise this table should be ignored."
    ::= { dot11smt 28 }

dot11AVOptionsEntry OBJECT-TYPE
    SYNTAX Dot11AVOptionsEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "An entry in the dot11AVOptionsTable. For all AV Streaming features, an
        Activated MIB attribute is used to activate/enable or deactivate/disable
        the corresponding feature. An Implemented MIB attribute is used for an
        optional feature to indicate whether the feature is implemented. A
        mandatory feature does not have a corresponding Implemented MIB attribute.
        It is possible for there to be multiple IEEE 802.11 interfaces on one
        agent, each with its unique MAC address. The relationship between an IEEE
        802.11 interface and an interface in the context of the Internet-standard
        MIB is one-to-one. As such, the value of an ifIndex object instance can be
        directly used to identify corresponding instances of the objects defined
        herein.

        ifIndex - Each IEEE 802.11 interface is represented by an ifEntry.
        Interface tables in this MIB module are indexed by ifIndex."
    INDEX { ifIndex }
    ::= { dot11AVOptionsTable 1 }

Dot11AVOptionsEntry ::=
    SEQUENCE {
        dot11GCRActivated                                   TruthValue,
        dot11AdvancedGCRImplemented                         TruthValue,
        dot11AdvancedGCRActivated                           TruthValue,
        dot11SCSImplemented                                 TruthValue,
        dot11SCSActivated                                   TruthValue,
        dot11QLoadReportActivated                           TruthValue,
        dot11AlternateEDCAActivated                         TruthValue,
        dot11GCRGroupMembershipAnnouncementActivated        TruthValue,
        dot11PublicHCCATXOPNegotiationImplemented           TruthValue,
        dot11PublicHCCATXOPNegotiationActivated             TruthValue,
        dot11ProtectedHCCATXOPNegotiationImplemented        TruthValue,
        dot11ProtectedHCCATXOPNegotiationActivated          TruthValue,
        dot11ProtectedQLoadReportImplemented                TruthValue,
        dot11ProtectedQLoadReportActivated                  TruthValue,
```


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```
        dot11MeshGCRImplemented                                 TruthValue,
        dot11MeshGCRActivated                                   TruthValue }

dot11GCRActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by the SME or external management entity.
        Changes take effect for the next MLME-START.request primitive
        or MLME-JOIN.request primitive.

        This attribute, when true, indicates that the station
        implementation supports the GCR procedures as defined in 11.21.16.3 (GCR
        procedures) and that this has been activated."
    DEFVAL { false }
    ::= { dot11AVOptionsEntry 1 }

dot11AdvancedGCRImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the station implementation
        supports the Advanced GCR features."
    ::= { dot11AVOptionsEntry 2 }

dot11AdvancedGCRActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by the SME or external management entity.
        Changes take effect for the next MLME-START.request primitive
        or MLME-JOIN.request primitive.

        This attribute, when true, indicates that the station implementation
        supports the GCR procedures as defined in 11.21.16.3 (GCR procedures) and
        that this has been activated."
    DEFVAL { false }
    ::= { dot11AVOptionsEntry 3 }

dot11SCSImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the station implementation
        supports the stream classification service."
    ::= { dot11AVOptionsEntry 4 }

dot11SCSActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
```

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```
        "This is a control variable.
        It is written by the SME or external management entity.
        Changes take effect for the next MLME-START.request primitive
        or MLME-JOIN.request primitive.

        This attribute, when true, indicates that the station implementation
        supports the stream classification service and that this has been
        activated."
    DEFVAL { false }
    ::= { dot11AVOptionsEntry 5 }

dot11QLoadReportActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by the SME or external management entity.
        Changes take effect for the next MLME-START.request primitive.

        This attribute, when true, indicates that the AP performs the QLoad report
        procedures described in 11.26.2 (QLoad Report element)."
    DEFVAL { false }
    ::= { dot11AVOptionsEntry 6 }

dot11AlternateEDCAActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by the SME or external management entity.
        Changes take effect for the next MLME-START.request primitive.

        This attribute, when true, indicates that the station can additionally use
        the (#476)alternate EDCA transmit queues."
    DEFVAL { false }
    ::= { dot11AVOptionsEntry 7 }

dot11GCRGroupMembershipAnnouncementActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by the SME or external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute, when true, indicates that the STA sends unsolicited Group
        Membership Response frames when its dot11GroupAddressesTable changes."
    DEFVAL { false }
    ::= { dot11AVOptionsEntry 8 }

dot11PublicHCCATXOPNegotiationImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the station implementation
        supports the negotiation of HCCA TXOPs using Public Action frames."
    ::= { dot11AVOptionsEntry 9 }
```


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```
dot11PublicHCCATXOPNegotiationActivated OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by the SME or external management entity.
      Changes take effect for the next MLME-START.request primitive.

      This attribute, when true, indicates that the AP can negotiate HCCA TXOPs
      using Public Action frames."
   DEFVAL { true }
   ::= { dot11AVOptionsEntry 10 }

dot11ProtectedHCCATXOPNegotiationImplemented OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a capability variable.
      Its value is determined by (#3375)STA capabilities.

      This attribute, when true, indicates that the station implementation
      supports the negotiation of HCCA TXOPs using Protected Dual of Public
      Action frames."
   ::= { dot11AVOptionsEntry 11 }

dot11ProtectedHCCATXOPNegotiationActivated OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by the SME or external management entity.
      Changes take effect for the next MLME-START.request primitive.

      This attribute, when true, indicates that the AP can negotiate HCCA TXOPs
      using Protected Dual of Public Action frames."
   DEFVAL { true }
   ::= { dot11AVOptionsEntry 12 }

dot11ProtectedQLoadReportImplemented OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a capability variable.
      Its value is determined by (#3375)STA capabilities.

      This attribute, when true, indicates that the station implementation
      supports the reporting of QLoad using Protected Dual of Public Action
      frames."
   ::= { dot11AVOptionsEntry 13 }

dot11ProtectedQLoadReportActivated OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by the SME or external management entity.
      Changes take effect for the next MLME-START.request primitive.
```

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```
        This attribute, when true, indicates that the AP can report QLoad using
        Protected Dual of Public Action frames."
    DEFVAL { true }
    ::= { dot11AVOptionsEntry 14 }

dot11MeshGCRImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the mesh station implementation
        supports the Advanced GCR features."
    ::= { dot11AVOptionsEntry 15 }

dot11MeshGCRActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by the SME or external management entity.
        Changes take effect for the next MLME-START.request primitive or MLME-
        JOIN.request primitive.

        This attribute, when true, indicates that the mesh station implementation
        supports the GCR procedures as defined in 11.21.16.3 (GCR procedures) and
        that this has been activated."
    DEFVAL { false }
    ::= { dot11AVOptionsEntry 16 }

-- ************************************************************************
-- * End of dot11AVOptions TABLE
-- ************************************************************************

-- ************************************************************************
-- * dot11AVConfig TABLE
-- ************************************************************************

dot11AVConfigTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11AVConfigEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "AV streaming attributes. In tabular form to allow for multiple instances
        on an agent. This table only applies to the interface if
        dot11RobustAVStreamingImplemented is true in the dot11StationConfigTable.
        Otherwise this table should be ignored."
    ::= { dot11smt 29 }

dot11AVConfigEntry OBJECT-TYPE
    SYNTAX Dot11AVConfigEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "An entry in the dot11AVConfigTable. It is possible for there to be
        multiple IEEE 802.11 interfaces on one agent, each with its unique MAC
        address. The relationship between an IEEE 802.11 interface and an
        interface in the context of the Internet-standard MIB is one-to-one. As
        such, the value of an ifIndex object instance can be directly used to
        identify corresponding instances of the objects defined herein.
```


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```
        ifIndex - Each IEEE 802.11 interface is represented by an ifEntry.
        Interface tables in this MIB module are indexed by ifIndex."
    INDEX { ifIndex }
    ::= { dot11AVConfigTable 1 }

Dot11AVConfigEntry ::=
    SEQUENCE {
        dot11GCRPolicyChangeTimeout                    Unsigned32,
        dot11QLoadReportIntervalDTIM                   Unsigned32,
        dot11HCCATXOPBeaconTimeout                     Unsigned32,
        dot11GCRConcealmentAddress                     MacAddress,
        dot11QLoadReportDelay                          Unsigned32,
        dot11ShortDEIRetryLimit                        Unsigned32,
        dot11LongDEIRetryLimit                         Unsigned32,
        dot11UnsolicitedRetryLimit                     Unsigned32,
        dot11DefaultSurplusBandwidthAllowance          Unsigned32 }

dot11GCRPolicyChangeTimeout OBJECT-TYPE
    SYNTAX Unsigned32 (5..18000)
    UNITS "100 TUs"
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by the SME or external management entity.
        Changes take effect for the next MLME-START.request primitive or
        MLME-JOIN.request primitive.

        This attribute indicates the interval after which a STA updates its
        GCR delivery mode or retransmission policy state using the procedures
        defined in 11.21.16.3.4 (GCR operation)."
    DEFVAL { 100 }
    ::= { dot11AVConfigEntry 1 }

dot11QLoadReportIntervalDTIM OBJECT-TYPE
    SYNTAX Unsigned32 (1..255)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect at the next MLME-START.request primitive.

        This attribute describes the number of DTIM intervals between
        transmissions of Beacon frames containing a Qload Report element."
    ::= { dot11AVConfigEntry 2 }

dot11HCCATXOPBeaconTimeout OBJECT-TYPE
    SYNTAX Unsigned32 (1..100)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by the MAC or external management entity.
        Changes take effect for the next MLME-START.request primitive.

        This attribute specifies the number of beacon periods an AP defers
        scheduling new potentially conflicting HCCA TXOPs while performing the
        HCCA TXOP procedures defined in 11.26.3 (HCCA TXOP negotiation)."
    DEFVAL { 3 }
    ::= { dot11AVConfigEntry 3 }

dot11GCRConcealmentAddress OBJECT-TYPE
    SYNTAX MacAddress
```

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```
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
       "This is a control variable.
       It is written by the SME or external management entity.
       In a non-AP STA or mesh STA receiving GCR service, it is written by the
       MAC when it receives a DMS Response frame that contains a DMS Status field
       with a GCR Response subelement and a Response Type subfield set to Accept.
       In an AP or mesh STA providing GCR service, changes take effect for the
       next MLME-START.request primitive.
       In a non-AP STA or mesh STA receiving GCR service, changes take effect as
       soon as practical in the implementation.

       The purpose of dot11GCRConcealmentAddress is to define the group address
       that is used by the GCR procedures (as defined in 11.21.16.3.5 (Conceal-
       ment of GCR transmissions)) to conceal group addressed frames from STAs
       that do not support GCR."
    DEFVAL {'010FAC474352'H}
    ::= { dot11AVConfigEntry 4 }

dot11QLoadReportDelay OBJECT-TYPE
    SYNTAX Unsigned32 (1..60)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
       "This is a control variable.
       It is written by an external management entity.
       Changes take effect at the next MLME-START.request primitive.

       This attribute describes the maximum number of seconds an AP delays
       sending an unsolicited QLoad Report action frame."
    DEFVAL { 10 }
    ::= { dot11AVConfigEntry 5 }

dot11ShortDEIRetryLimit OBJECT-TYPE
    SYNTAX Unsigned32 (1..65535)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
       "This is a control variable.
       It is written by an external management entity.
       Changes take effect as soon as practical in the implementation.

       This attribute indicates the maximum number of transmission attempts that
       are made before a failure condition is indicated."
    DEFVAL { 5 }
    ::= { dot11AVConfigEntry 6 }

dot11LongDEIRetryLimit OBJECT-TYPE
    SYNTAX Unsigned32 (1..255)
    MAX-ACCESS read-write
    STATUS (#3441)deprecated
    DESCRIPTION
       "Deprecated as the long retry counter (QLDRC) associated with this MIB
       variable has been deleted.

       This is a control variable.
       It is written by an external management entity.
       Changes take effect as soon as practical in the implementation.

       For frames where the DEI subfield has the value of one and length greater
       than dot11RTSThreshold, this attribute indicates the maximum number of
       transmission attempts that are made before a failure condition is
       indicated."
```


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```
    DEFVAL { 3 }
    ::= { dot11AVConfigEntry 7 }

dot11UnsolicitedRetryLimit OBJECT-TYPE
    SYNTAX Unsigned32 (1..65535)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute indicates the maximum number of transmission attempts of a
        frame delivered using the GCR unsolicited retry retransmission policy."
    DEFVAL { 7 }
    ::= { dot11AVConfigEntry 8 }

dot11DefaultSurplusBandwidthAllowance OBJECT-TYPE
    SYNTAX Unsigned32 (100..255)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        " This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This object specifies the default percentage surplus bandwidth allowance
        when calculating medium time.
        "
    DEFVAL { 110 }
    ::= { dot11AVConfigEntry 9 }

-- ************************************************************************
-- * End of dot11AVConfig TABLE
-- ************************************************************************

-- ************************************************************************
-- * dot11APC TABLE
-- ************************************************************************

dot11APCTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11APCEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "Group contains conceptual table of attributes for MIB-based HCCA TXOP
        negotiation."
    ::= { dot11smt 30 }

dot11APCTableEntry OBJECT-TYPE
    SYNTAX Dot11APCEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "An entry in the dot11APCTable, Indexed by dot11APCIndex."
    INDEX { dot11APCIndex }
    ::= { dot11APCTable 1 }

Dot11APCEntry ::=
    SEQUENCE {
        dot11APCIndex                                   Unsigned32,
        dot11APCEntryAvoidanceDuration                  Unsigned32,
        dot11APCEntryAvoidanceServiceInterval           Unsigned32,
        dot11APCEntryAvoidanceOffset                    Unsigned32,
```

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```
        dot11APCEntryMACAddress                                    MacAddress }

dot11APCIndex OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "The auxiliary variable used to identify instances of the columnar objects
        in the HCCA TXOP Table."
    ::= { dot11APCTableEntry 1 }

dot11APCEntryAvoidanceDuration OBJECT-TYPE
    SYNTAX Unsigned32 (0..131071)
    UNITS "32 microseconds"
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        This attribute contains the duration of a TXOP reservation that the AP
        attempts to avoid when scheduling new HCCA TXOPs."
    ::= { dot11APCTableEntry 2 }

dot11APCEntryAvoidanceServiceInterval OBJECT-TYPE
    SYNTAX Unsigned32 (0..255)
    UNITS "milliseconds"
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        This attribute contains the duration of the period between successive HCCA
        TXOPs. When zero, no period has been reserved."
    ::= { dot11APCTableEntry 3 }

dot11APCEntryAvoidanceOffset OBJECT-TYPE
    SYNTAX Unsigned32 (0..131071)
    UNITS "TUs"
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        This attribute contains the offset from the scheduled start of the Beacon
        transmission until the start of the time period for a TXOP reservation
        that the AP attempts to avoid when scheduling new HCCA TXOPs."
    ::= { dot11APCTableEntry 4 }

dot11APCEntryMACAddress OBJECT-TYPE
    SYNTAX MacAddress
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        This attribute contains the MAC address of the peer AP that has scheduled
```


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```
        an HCCA TXOP in the time period defined by dot11APCEntryAvoidanceDuration,
        dot11APCEntryAvoidanceServiceInterval, and dot11APCEntryAvoidanceOffset."
    ::= { dot11APCTableEntry 5 }

-- ************************************************************************
-- * End of dot11APC TABLE
-- ************************************************************************

-- ************************************************************************
-- * dot11VHTStationConfig TABLE
-- ************************************************************************
dot11VHTStationConfigTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11VHTStationConfigEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "Station Configuration attributes. In tabular form to allow for multiple
        instances on an agent."
    ::= { dot11smt 31 }

dot11VHTStationConfigEntry OBJECT-TYPE
    SYNTAX Dot11VHTStationConfigEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "An entry (conceptual row) in the dot11VHTStationConfig Table.

        ifIndex - Each IEEE 802.11 interface is represented by an ifEntry.
        Interface tables in this MIB module are indexed by ifIndex."
    INDEX { ifIndex }
    ::= { dot11VHTStationConfigTable 1 }

Dot11VHTStationConfigEntry ::=
    SEQUENCE {
        dot11MaxMPDULength                                  INTEGER,
        dot11VHTMaxRxAMPDUFactor                            Unsigned32,
        dot11VHTControlFieldOptionImplemented               TruthValue,
        dot11VHTTXOPPowerSaveOptionImplemented              TruthValue,
        dot11VHTRxVHTMCSMap                                 OCTET STRING,
        dot11VHTRxHighestDataRateSupported                  Unsigned32,
        dot11VHTTxVHTMCSMap                                 OCTET STRING,
        dot11VHTTxHighestDataRateSupported                  Unsigned32,
        dot11VHTOBSSScanCount                               Unsigned32
        }

dot11MaxMPDULength OBJECT-TYPE
    SYNTAX INTEGER { short(3895), medium(7991), long(11454) }
    UNITS "octets"
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute indicates the maximum supported size of an MPDU received in
        a VHT PPDU."
    ::= { dot11VHTStationConfigEntry 1 }

dot11VHTMaxRxAMPDUFactor OBJECT-TYPE
    SYNTAX Unsigned32 (0..7)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
```

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```
        Its value is determined by (#3375)STA capabilities.

        This attribute indicates the maximum length of A-MPDU that the STA can
        receive. The Maximum Rx A-MPDU defined by this field is equal to
        2^(13+dot11VHTMaxRxAMPDUFactor) -1 octets."
    ::= { dot11VHTStationConfigEntry 2 }

dot11VHTControlFieldOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the station implementation is
        capable of receiving the VHT variant HT Control field."
    ::= { dot11VHTStationConfigEntry 3 }

dot11VHTTXOPPowerSaveOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the station implementation is
        capable of VHT TXOP power save operation."
    ::= { dot11VHTStationConfigEntry 4 }

dot11VHTRxVHTMCSMap OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(8))
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        Each octet represents the highest VHT-MCS supported (for Rx) on the number
        of streams represented by the octet position (first octet represents 1
        stream, second octet represents 2 streams, etc.) A value 0 indicates that
        VHT-MCSs 0-7 are supported. A value 1 indicates that VHT-MCSs 0-8 are
        supported. A value 2 indicates that VHT-MCSs 0-9 are supported. A value 3
        indicates no support for that number of spatial streams."
    ::= { dot11VHTStationConfigEntry 5 }

dot11VHTRxHighestDataRateSupported OBJECT-TYPE
    SYNTAX Unsigned32
    UNITS "Mb/s"
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        Represents the highest data rate that the STA is capable of receiving."
    ::= { dot11VHTStationConfigEntry 6 }

dot11VHTTxVHTMCSMap OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(8))
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
```


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```
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        Each octet represents the highest VHT-MCS supported (for Tx) on the number
        of streams represented by the octet position (first octet represents 1
        stream, second octet represents 2 streams, etc.). A value 0 indicates that
        VHT-MCSs 0-7 are supported. A value 1 indicates that VHT-MCSs 0-8 are
        supported. A value 2 indicates that VHT-MCSs 0-9 are supported. A value 3
        indicates no support for that number of spatial streams."
    ::= { dot11VHTStationConfigEntry 7 }

dot11VHTTxHighestDataRateSupported OBJECT-TYPE
    SYNTAX Unsigned32
    UNITS "Mb/s"
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        Represents the highest data rate that the STA is capable of transmitting."
    ::= { dot11VHTStationConfigEntry 8 }

dot11VHTOBSSScanCount OBJECT-TYPE
    SYNTAX Unsigned32 (3..100)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        This attribute indicates the minimum number of scan operations performed
        on a channel to detect another OBSS."
    DEFVAL { 3 }
    ::= { dot11VHTStationConfigEntry 9 }

-- ********************************************************************
-- * End of dot11VHTStationConfigTable TABLE
-- ********************************************************************

-- ********************************************************************
-- * dot11TVHTStationConfig TABLE
-- ********************************************************************
dot11TVHTStationConfigTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11TVHTStationConfigEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "Station Configuration attributes. In tabular form to allow for multiple
        instances on an agent."
    ::= { dot11smt 32 }

dot11TVHTStationConfigEntry OBJECT-TYPE
    SYNTAX Dot11TVHTStationConfigEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "An entry (conceptual row) in the dot11HTStationConfig Table. ifIndex -
        Each IEEE 802.11 interface is represented by an ifEntry. Interface tables
        in this MIB module are indexed by ifIndex."
    INDEX { ifIndex }
    ::= { dot11TVHTStationConfigTable 1 }
```

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```
Dot11TVHTStationConfigEntry ::=
   SEQUENCE {
      dot11TVHTMaxMPDULength                                INTEGER,
      dot11TVHTMaxRxAMPDUFactor                             Unsigned32,
      dot11TVHTControlFieldOptionImplemented                TruthValue,
      dot11TVHTTXOPPowerSaveOptionImplemented               TruthValue,
      dot11TVHTRxVHTMCSMap                                  OCTET STRING,
      dot11TVHTRxHighestDataRateSupported                   Unsigned32,
      dot11TVHTTxVHTMCSMap                                  OCTET STRING,
      dot11TVHTTxHighestDataRateSupported                   Unsigned32,
      dot11TVHTOBSSScanCount                                Unsigned32
   }

dot11TVHTMaxMPDULength OBJECT-TYPE
   SYNTAX INTEGER { short(3895), medium(7991), long(11454) }
   UNITS "octets"
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a capability variable.
      Its value is determined by (#3375)STA capabilities.
      This attribute indicates the maximum supported size of an MPDU received in
      a TVHT PPDU."
   ::= { dot11TVHTStationConfigEntry 1 }

dot11TVHTMaxRxAMPDUFactor OBJECT-TYPE
   SYNTAX Unsigned32 (0..7)
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a capability variable.
      Its value is determined by (#3375)STA capabilities.
      This attribute indicates the maximum length of A-MPDU that the STA can
      receive. The Maximum Rx A-MPDU defined by this field is equal to
      2^(13+dot11TVHTMaxRxAMPDUFactor)-1 octets."
   ::= { dot11TVHTStationConfigEntry 2 }

dot11TVHTControlFieldOptionImplemented OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a capability variable.
      Its value is determined by (#3375)STA capabilities.
      This attribute, when true, indicates that the STA implementation is
      capable of receiving the VHT variant HT Control field."
   ::= { dot11TVHTStationConfigEntry 3 }

dot11TVHTTXOPPowerSaveOptionImplemented OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a capability variable.
      Its value is determined by (#3375)STA capabilities.
      This attribute, when true, indicates that the STA
      implementation is capable of VHT TXOP power save operation."
   ::= { dot11TVHTStationConfigEntry 4 }

dot11TVHTRxVHTMCSMap OBJECT-TYPE
   SYNTAX OCTET STRING (SIZE(8))
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
```


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```
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.
        Each octet represents the highest VHT-MCS supported (for Rx) on the number
        of streams represented by the octet position (first octet represents 1
        stream(#7198), second octet represents 2 streams, etc.). A value 0 indi-
        cates that VHT-MCSs 0-7 are supported. A value 1 indicates that VHT-MCSs
        0-8 are
        supported. A value 2 indicates that VHT-MCSs 0-9 are supported. A value
        3 indicates no support for that number of spatial streams."
    ::= { dot11TVHTStationConfigEntry 5 }

dot11TVHTRxHighestDataRateSupported OBJECT-TYPE
    SYNTAX Unsigned32
    UNITS "Mb/s"
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.
        Represents the highest data rate that the STA is capable of receiving."
    ::= { dot11TVHTStationConfigEntry 6 }

dot11TVHTTxVHTMCSMap OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(8))
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.
        Each octet represents the highest VHT-MCS supported (for Tx) on the number
        of streams represented by the octet position (first octet represents 1
        stream, second octet represents 2 streams, etc.).
        A value 0 indicates that VHT-MCSs 0-7 are supported. A value 1 indicates
        that VHT-MCSs 0-8 are supported. A value 2 indicates that VHT-MCSs 0-9 are
        supported. A value 3 indicates no support for that number of spatial
        streams."
    ::= { dot11TVHTStationConfigEntry 7 }

dot11TVHTTxHighestDataRateSupported OBJECT-TYPE
    SYNTAX Unsigned32
    UNITS "Mb/s"
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.
        Represents the highest data rate that the STA is capable of transmitting."
    ::= { dot11TVHTStationConfigEntry 8 }

dot11TVHTOBSSScanCount OBJECT-TYPE
    SYNTAX Unsigned32 (3..100)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.
        This attribute indicates the minimum number of scan operations performed
        on a channel to detect another OBSS."
    DEFVAL { 3 }
    ::= { dot11TVHTStationConfigEntry 9 }

-- ************************************************************
-- * End of dot11TVHTStationConfigTable TABLE
```

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```
-- ********************************************************************

-- ********************************************************************
-- * dot11FILSConfigTable TABLE
-- ********************************************************************
dot11FILSConfigTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11FILSConfigEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "The table containing fast initial link setup configuration objects."
    ::= { dot11smt 35 }

dot11FILSConfigEntry OBJECT-TYPE
    SYNTAX Dot11FILSConfigEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "An entry in the dot11FILSConfigTable."
    INDEX { ifIndex }
    ::= { dot11FILSConfigTable 1 }

Dot11FILSConfigEntry ::=
    SEQUENCE {
        dot11FILSFDFrameBeaconMinimumInterval                    Unsigned32,
        dot11FILSBeaconResponseWindow                            Unsigned32,
        dot11FILSFDFrameBeaconMaximumInterval                    Unsigned32,
        dot11FILSOmitReplicateProbeResponses                     TruthValue,
        dot11DILSImplemented                                     TruthValue,
        dot11FILSProbeDelay                                      Unsigned32,
        dot11HLPWaitTime                                         Unsigned32,
        dot11CacheIdentifier                                     OCTET STRING
    }

dot11FILSFDFrameBeaconMinimumInterval OBJECT-TYPE
    SYNTAX Unsigned32 (0..10000)
    UNITS "TUs"
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        The STA is allowed to transmit a FILS Discovery frame if a duration
        defined by this value has elapsed since the previous Beacon or FILS Dis-
        covery frame transmission and the next TBTT is later than a duration
        defined by this value."
    DEFVAL { 20 }
    ::= { dot11FILSConfigEntry 1 }

dot11FILSFDFrameBeaconMaximumInterval OBJECT-TYPE
    SYNTAX Unsigned32 (0..10000)
    UNITS "TUs"
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable. It is written by an external management
        entity. Changes take effect as soon as practical in the implementation. If
        this value is not equal to 0, the STA queues for transmission a FILS Dis-
        covery frame or a Beacon frame if a duration defined by this value has
        elapsed since the previous Beacon or FILS Discovery frame transmission
        unless the next TBTT is within a duration defined by the value of dot11-
        FILSFDFrameBeaconMinimumInterval."
    DEFVAL { 0 }
    ::= { dot11FILSConfigEntry 2 }

```


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```
dot11FILSBeaconResponseWindow OBJECT-TYPE
   SYNTAX Unsigned32 (0..1000000)
   UNITS "0.1 milliseconds"
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by an external management entity.
      Changes take effect as soon as practical in the implementation.
      If the duration from the reception of the Probe Request frame to the TBTT
      is less than the value, the STA does not transmit a Probe Response frame
      as response to the Probe Request frame."
   DEFVAL { 50 }
   ::= { dot11FILSConfigEntry 3 }

dot11FILSOmitReplicateProbeResponses OBJECT-TYPE
   SYNTAX  TruthValue
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a policy  variable.
      It is written by an external management entity. Changes take effect for
      the next Probe Response frame.
      This attribute, when true, indicates that the station may respond to one
      or more received Probe Request frames with a single Probe Response frame
      addressed to the broadcast address or alternatively, by not transmitting a
      Probe Response frame and instead letting the next Beacon frame be the
      response to the Probe Request frame(s)."
   DEFVAL { false }
   ::= { dot11FILSConfigEntry 4 }

dot11DILSImplemented OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a capability variable.
      Its value is determined by (#3375)STA capabilities.
      This attribute, when true, indicates that the station implementation is
      capable of supporting DILS category.
      The capability is disabled, otherwise."
   ::= { dot11FILSConfigEntry 5 }

dot11FILSProbeDelay OBJECT-TYPE
   SYNTAX Unsigned32 (0..100000)
   UNITS "microseconds"
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by an external management entity.
      Changes take effect as soon as practical in the implementation.
      If a FILS STA receives a suitable Probe Request, Probe Response, Beacon,
      FILS Discovery or Measurement Pilot frame within this duration of the
      start of active scanning on a given channel, it does not transmit a Probe
      Request frame."
   DEFVAL { 5000 }
   ::= { dot11FILSConfigEntry 6 }

dot11HLPWaitTime OBJECT-TYPE
   SYNTAX Unsigned32
   UNITS "TUs"
   MAX-ACCESS read-write
```

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```
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.
        This value specifies a time that the FILS AP waits for incoming HLP pack-
        ets after receiving a (Re)Association Request frame."
    DEFVAL { 30 }
    ::= { dot11FILSConfigEntry 7 }

dot11CacheIdentifier OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(2))
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.
        This value specifies the Cache Identifier that the FILS AP advertises in
        FILS Indication elements."
    ::= { dot11FILSConfigEntry 8 }

-- ****************************************************************
-- * End of dot11FILSConfigTable TABLE
-- ****************************************************************

-- ****************************************************************
-- * dot11STALCI TABLE
-- ****************************************************************

dot11STALCITable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11STALCIEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "This table represents the geolocation of the STA as specified in 11.42.1
        (General)."
    ::= { dot11smt 33 }

dot11STALCIEntry OBJECT-TYPE
    SYNTAX Dot11STALCIEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
         "STA's location information in geospatial coordinates"
    INDEX {dot11STALCIIndex }
    ::= { dot11STALCITable 1 }

Dot11STALCIEntry ::=
    SEQUENCE {
        dot11STALCIIndex                                Unsigned32,
        dot11STALCILatitudeUncertainty                  Unsigned32,
        dot11STALCILatitudeInteger                      Integer32,
        dot11STALCILatitudeFraction                     Integer32,
        dot11STALCILongitudeUncertainty                 Unsigned32,
        dot11STALCILongitudeInteger                     Integer32,
        dot11STALCILongitudeFraction                    Integer32,
        dot11STALCIAltitudeType                         INTEGER,
        dot11STALCIAltitudeUncertainty                  Unsigned32,
        dot11STALCIAltitude                             Integer32,
        dot11STALCIDatum                                INTEGER }

dot11STALCIIndex OBJECT-TYPE
    SYNTAX Unsigned32
```


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```
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "Index for STA LCI elements in dot11STALCITable, greater than 0."
    ::= { dot11STALCIEntry 1 }

dot11STALCILatitudeUncertainty OBJECT-TYPE
    SYNTAX Unsigned32 (0..63)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the
        implementation.

        Latitude uncertainty is 6 bits indicating the amount of uncertainty in
        latitude value. A value of 0 is reserved to indicate that the uncertainty
        is unknown; values greater than 34 are reserved. This field is derived
        from IETF RFC 6225."
    ::= { dot11STALCIEntry 2 }

dot11STALCILatitudeInteger OBJECT-TYPE
    SYNTAX Integer32 (-359..359)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        Latitude is a 2s complement 34-bit fixed point value consisting of 9 bits
        of integer and 25 bits of fraction. This field contains the 9 bits of
        integer portion of Latitude. This field is derived from IETF RFC 6225."
    ::= { dot11STALCIEntry 3 }

dot11STALCILatitudeFraction OBJECT-TYPE
    SYNTAX Integer32 (-16777215..16777215)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        Latitude is a 2s complement 34-bit fixed point value consisting of 9 bits
        of integer and 25 bits of fraction. This field contains the 25 bits of
        fraction portion of Latitude. This field is derived from IETF RFC 6225."
    ::= { dot11STALCIEntry 4 }

dot11STALCILongitudeUncertainty OBJECT-TYPE
    SYNTAX Unsigned32 (0..63)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        Longitude uncertainty is 6 bits indicating the amount of uncertainty in
        longitude value. A value of 0 is reserved to indicate that the uncertainty
        is unknown; values greater than 34 are reserved. This field is derived
        from IETF RFC 6225."
    ::= { dot11STALCIEntry 5 }
```

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```
dot11STALCILongitudeInteger OBJECT-TYPE
   SYNTAX Integer32 (-359..359)
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by an external management entity or the SME.
      Changes take effect as soon as practical in the implementation.

      Longitude is a 2s complement 34-bit fixed point value consisting of 9 bits
      of integer and 25 bits of fraction. This field contains the 9 bits of
      integer portion of Longitude. This field is derived from IETF RFC 6225."
   ::= { dot11STALCIEntry 6 }

dot11STALCILongitudeFraction OBJECT-TYPE
   SYNTAX Integer32 (-16777215..16777215)
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by an external management entity or the SME.
      Changes take effect as soon as practical in the implementation.

      Longitude is a 2s complement 34-bit fixed point value consisting of 9 bits
      of integer and 25 bits of fraction. This field contains the 25 bits of
      fraction portion of Longitude. This field is derived from IETF RFC 6225."
   ::= { dot11STALCIEntry 7 }

dot11STALCIAltitudeType OBJECT-TYPE
   SYNTAX INTEGER {
      meters(1),
      floors(2),
      hagm (3) }
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by an external management entity or the SME.
      Changes take effect as soon as practical in the implementation.

      Altitude Type is four bits encoding the type of altitude.
      Codes defined are:
      meters in 2s complement fixed-point 22-bit integer part with 8-bit
      fraction
      floors: in 2s complement fixed-point 22-bit integer part with 8-bit
      fraction
      hagm: Height Above Ground in meters, in 2s complement fixed-point 22-bit
      integer part with 8-bit fraction
      This field is derived from IETF RFC 6225."
   ::= { dot11STALCIEntry 8 }

dot11STALCIAltitudeUncertainty OBJECT-TYPE
   SYNTAX Unsigned32 (0..63)
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by an external management entity or the SME.
      Changes take effect as soon as practical in the
      implementation.

      Altitude uncertainty is 6 bits indicating the amount of uncertainty in the
      altitude value. A value of 0 is reserved to indicate that altitude
```


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```
        uncertainty is not known; values above 30 are also reserved. Altitude
        uncertainty applies only to Altitude Type 1. This field is derived from
        IETF RFC 6225."
    ::= { dot11STALCIEntry 9 }

dot11STALCIAltitude OBJECT-TYPE
    SYNTAX Integer32 (-536870912..536870911)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        Altitude is a 30-bit value defined by the Altitude type field. The field
        is encoded as a 2s complement fixed-point 22-bit integer part with 8-bit
        fraction. This field is derived from IETF RFC 6225."
    ::= { dot11STALCIEntry 10 }

-- Reserved: 11. Was dot11STALCIAltitudeFraction.

dot11STALCIDatum OBJECT-TYPE
    SYNTAX INTEGER { wgs84 (1), nad83navd88 (2), nad93mllwvd (3) }
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        Datum is an 8-bit value encoding the horizontal and vertical references
        used for the coordinates given in this LCI. IETF RFC 6225 defines the
        values of Datum. Type 1 is WGS-84, the coordinate system used by GPS. Type
        2 is NAD83 with NAVD88 vertical reference. Type 3 is NAD83 with Mean Lower
        Low Water vertical datum. All other types are reserved. This field is
        derived from IETF RFC 6225."
    ::= { dot11STALCIEntry 12 }

-- ************************************************************************
-- * End of dot11STALCI TABLE
-- ************************************************************************

-- ************************************************************************
-- * dot11S1GStationConfig TABLE
-- ************************************************************************
dot11S1GStationConfigTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11S1GStationConfigEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "Station Configuration attributes. In tabular form to allow for multiple
        instances on an agent."
    ::= { dot11smt 34 }

dot11S1GStationConfigEntry OBJECT-TYPE
    SYNTAX Dot11S1GStationConfigEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "An entry (conceptual row) in the dot11HTStationConfig Table.

        ifIndex - Each IEEE 802.11 interface is represented by an ifEntry. Inter-
        face tables in this MIB module are indexed by ifIndex."
    INDEX { ifIndex }
```

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```
    ::= { dot11S1GStationConfigTable 1 }

Dot11S1GStationConfigEntry ::=
    SEQUENCE {
        dot11S1GMaxMPDULength                                   INTEGER,
        dot11S1GMaxRxAMPDUFactor                                Unsigned32,
        dot11S1GControlFieldOptionImplemented                   TruthValue,
        dot11S1GRxS1GMCSMap                                     OCTET STRING,
        dot11S1GTxS1GMCSMap                                     OCTET STRING,
        dot11S1GOBSSScanCount                                   Unsigned32,
        dot11ShortBeaconInterval                                TruthValue,
        dot11ShortBeaconPeriod                                  Unsigned32,
        dot11ShortBeaconDTIMPeriod                              Unsigned32,
        dot11PV1MACHeaderOptionImplemented                      TruthValue,
        dot11PV1ProbeResponseOptionImplemented                  TruthValue,
        dot11HeaderCompressionResponseTimeout                   Unsigned32,
        dot11TSFTimerAccuracyImplemented                        TruthValue,
        dot11NonTIMModeActivated                                TruthValue,
        dot11PageSlicingImplemented                             TruthValue,
        dot11PageSlicingActivated                               TruthValue,
        dot11DynamicAIDActivated                                TruthValue,
        dot11GroupAIDActivated                                  TruthValue,
        dot11AMSDUImplemented                                   TruthValue,
        dot11AMPDUImplemented                                   TruthValue,
        dot11MCSNegotiation                                     TruthValue,
        dot11AsymmetricBlockAckActivated                        TruthValue,
        dot11FragmentBAOptionImplemented                        TruthValue,
        dot11RAWOperationImplemented                            TruthValue,
        dot11RAWOperationActivated                              TruthValue,
        dot11S1GUplinkSyncOptionImplemented                     TruthValue,
        dot11TWTOptionActivated                                 TruthValue,
        dot11BATImplemented                                     TruthValue,
        dot11PollTACKResponseImplemented                        TruthValue,
        dot11NDPProbingActivated                                TruthValue,
        dot11NDPPSPollSupport                                   TruthValue,
        dot11RelayAPImplemented                                 TruthValue,
        dot11RelayAPOperationActivated                          TruthValue,
        dot11RelaySTAImplemented                                TruthValue,
        dot11RelaySTAOperationActivated                         TruthValue,
        dot11RelayDiscoveryOptionImplemented                    TruthValue,
        dot11TXOPSharingImplicitACKImplemented                  TruthValue,
        dot11S1GELOperationActivated                            TruthValue,
        dot11S1GCentralizedAuthenticationControlActivated       TruthValue,
        dot11S1GDistributedAuthenticationControlActivated       TruthValue,
        dot11SubchannelSelectiveTransmissionActivated           TruthValue,
        dot11S1GSectorImplemented                               TruthValue,
        dot11S1GSectorizationActivated                          TruthValue,
        dot11S1GSectorTrainingOperationImplemented              TruthValue,
        dot11NDPBeamformingReportPollImplemented                TruthValue,
        dot11UnsolicitedDynamicAIDActivated                     TruthValue,
        dot11TIMADEImplemented                                  TruthValue,
        dot11SelectiveSubchannelTransmissionPermitted           TruthValue,
        dot11MaxAwayDuration                                    Unsigned32,
        dot11APPMActivated                                      TruthValue,
        dot11BDTImplemented                                     TruthValue,
        dot11S1GCACDeferral                                     TruthValue,
        dot11S1GCACThreshold                                    Unsigned32,
        dot11S1GDACTac                                          Unsigned32,
        dot11S1GDACTImin                                        Unsigned32,
        dot11S1GDACTImax                                        Unsigned32,
        dot11ProtectedTWTOperationsImplemented                  TruthValue,
        dot11ExtendedS1GActionProtectionOperationsImplemented   TruthValue,(#1276)
        dot11BIPCompactEncapsulation                            TruthValue(#6054)
        }
```



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```
dot11S1GMaxMPDULength OBJECT-TYPE
   SYNTAX INTEGER { short(3895), long (7991) }
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a capability variable.
      Its value is determined by (#3375)STA capabilities.

      This attribute indicates the supported maximum MPDU size."
   ::= { dot11S1GStationConfigEntry 1 }

dot11S1GMaxRxAMPDUFactor OBJECT-TYPE
   SYNTAX Unsigned32 (0..7)
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a capability variable.
      Its value is determined by (#3375)STA capabilities.

      This attribute indicates the maximum length of A-MPDU that the STA can
      receive. The maximum receive A-MPDU defined by this field is equal to
      2^(13+dot11S1GMaxRxAMPDUFactor) -1 octets."
   ::= { dot11S1GStationConfigEntry 2 }

dot11S1GControlFieldOptionImplemented OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a capability variable.
      Its value is determined by (#3375)STA capabilities.

      This attribute, when true, indicates that the STA implementation is
      capable of receiving the VHT variant HT Control field. See 10.8 (HT
      Control field operation)."
   ::= { dot11S1GStationConfigEntry 3 }

dot11S1GRxS1GMCSMap OBJECT-TYPE
   SYNTAX OCTET STRING (SIZE(4))
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a capability variable.
      Its value is determined by (#3375)STA capabilities.

      Each octet represents the highest S1G-MCS supported (for Rx) on the number
      of streams represented by the octet position (e.g., first octet represents
      1 stream, second octet represents 2 streams). A value 0 indicates that
      S1G-MCSs 0-2 are supported. A value 1 indicates that S1G-MCSs 0-7 are
      supported. A value 2 indicates that S1G-MCSs 0-9 are supported. A value 3
      indicates no support for that number of spatial streams. A value of 4
      indicates that S1G-MCSs 0-9, 11 and 12 are supported for 2 MHz wide and
      greater.(M102)
      For 1 MHz, MCS 10 is always supported."
   ::= { dot11S1GStationConfigEntry 4 }

dot11S1GTxS1GMCSMap OBJECT-TYPE
   SYNTAX OCTET STRING (SIZE(4))
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a capability variable.
      Its value is determined by (#3375)STA capabilities.
```

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```
        Each octet represents the highest S1G-MCS supported (for Tx) on the number
        of streams represented by the octet position (e.g., first octet represents
        1 stream, second octet represents 2 streams). A value 0 indicates that
        S1G-MCSs 0-2 are supported. A value 1 indicates that S1G-MCSs 0-7 are
        supported. A value 2 indicates that S1G-MCSs 0-9 are supported. A value 3
        indicates no support for that number of spatial streams. A value of 4
        indicates that S1G-MCSs 0-9, 11 and 12 are supported for 2 MHz wide and
        greater.(M102)
        For 1 MHz, MCS 10 is always supported."
    ::= { dot11S1GStationConfigEntry 5 }

dot11S1GOBSSScanCount OBJECT-TYPE
    SYNTAX Unsigned32 (3..100)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        This attribute indicates the minimum number of scan operations performed
        on a channel to detect another OBSS."
    DEFVAL { 3 }
    ::= { dot11S1GStationConfigEntry 6 }

dot11ShortBeaconInterval OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        This is a primary/secondary variable.  Its value on an AP or IBSS initia-
        tor is written by external management entity and changes take effect for
        the next MLME-START.request primitive.  Its value on non-AP STA is written
        by the MLME, adopted from the information received in a Beacon, Probe
        Response or PV1 Probe Response, when joining an S1G BSS or S1G IBSS.
        This attribute, when true, indicates that that the AP schedules for trans-
        mission a Beacon frame in a TSBTT that is not a TBTT."
    ::= { dot11S1GStationConfigEntry 7 }

dot11ShortBeaconPeriod OBJECT-TYPE
    SYNTAX Unsigned32 (1..65535)
    UNITS "TUs"(#1724)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect for the next MLME-START.request primitive.

        This attribute specifies the time period(#1724) that a STA uses for sched-
        uling S1G Beacon transmissions in a TSBTT that is not a TBTT. This value
        is transmitted in the S1G Beacon, Probe Response, and PV1 Probe Response
        frames."
    ::= { dot11S1GStationConfigEntry 8 }

dot11ShortBeaconDTIMPeriod OBJECT-TYPE
    SYNTAX Unsigned32 (1..255)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
```


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```
        Changes take effect for the next MLME-START.request primitive.

        This attribute specifies the number of short beacon intervals that elapse
        between transmission of S1G Beacon frames containing a TIM element whose
        DTIM Count field is 0. This value is transmitted in S1G Beacon frames."
    ::= { dot11S1GStationConfigEntry 9 }

dot11PV1MACHeaderOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the STA implementation is capa-
        ble of generating frames with PV1 MAC Header. The capability is disabled,
        otherwise."
    ::= { dot11S1GStationConfigEntry 10 }

dot11PV1ProbeResponseOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the STA implementation is capa-
        ble of supporting PV1 Probe Response frames. The capability is disabled,
        otherwise."
    ::= { dot11S1GStationConfigEntry 11 }

dot11HeaderCompressionResponseTimeout OBJECT-TYPE
    SYNTAX Unsigned32 (1..4294967295)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.

        This attribute indicates the amount of time, in units of milliseconds, the
        STA waits before timing out a Header Compression frame request."
    DEFVAL { 5 }
    ::= { dot11S1GStationConfigEntry 12 }

dot11TSFTimerAccuracyImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the STA implementation is capa-
        ble of supporting the TSF Timer Accuracy option. The capability is dis-
        abled, otherwise."
    ::= { dot11S1GStationConfigEntry 13 }

dot11NonTIMModeActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
```

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```
        "This is a control variable.
        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        This attribute, when true, indicates that the non-TIM mode is enabled. The
        non-TIM mode is disabled otherwise."
    DEFVAL { false }
    ::= { dot11S1GStationConfigEntry 14 }

dot11PageSlicingImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the STA implementation is capa-
        ble of supporting the page slicing option. The capability is disabled,
        otherwise."
    ::= { dot11S1GStationConfigEntry 15 }

dot11PageSlicingActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        This attribute, when true, indicates that the page slicing option is
        enabled. The page slicing option is disabled otherwise."
    DEFVAL { false }
    ::= { dot11S1GStationConfigEntry 16 }

dot11DynamicAIDActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        This attribute, when true, indicates that the dynamic AID is enabled. The
        dynamic AID is disabled otherwise."
    DEFVAL { false }
    ::= { dot11S1GStationConfigEntry 17 }

dot11GroupAIDActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        This attribute, when true, indicates that the group AID is enabled. The
        group AID is disabled otherwise."
    DEFVAL { false }
    ::= { dot11S1GStationConfigEntry 18 }
```


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```
dot11AMSDUImplemented OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a capability variable.
      Its value is determined by (#3375)STA capabilities.

      This attribute, when true, indicates that the (#4213)STA is capable of
      receiving A-MSDU carried in S1G PPDUs."
   ::= { dot11S1GStationConfigEntry 19 }

dot11AMPDUImplemented OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a capability variable.
      Its value is determined by (#3375)STA capabilities.

      This attribute, when true, indicates that the (#4213)STA is capable of
      receiving an A-MPDU frame that is not a S-MPDU carried in S1G PPDUs."
   ::= { dot11S1GStationConfigEntry 20 }

dot11MCSNegotiation OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by an external management entity or the SME.
      Changes take effect as soon as practical in the implementation.

      This attribute, when true, indicates that the MCS negotiation is enabled.
      The MCS negotiation is disabled otherwise."
   DEFVAL { false }
   ::= { dot11S1GStationConfigEntry 21 }

dot11AsymmetricBlockAckActivated OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by an external management entity or the SME.
      Changes take effect as soon as practical in the implementation.

      This attribute, when true, indicates that asymmetric BA is enabled. Asym-
      metric BA is disabled otherwise."
   DEFVAL { false }
   ::= { dot11S1GStationConfigEntry 22 }

dot11FragmentBAOptionImplemented OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a capability variable.
      Its value is determined by (#3375)STA capabilities.

      This attribute, when true, indicates that the STA implementation is capa-
      ble of supporting fragment BA. The capability is disabled, otherwise."
   ::= { dot11S1GStationConfigEntry 23 }
```

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```
dot11RAWOperationImplemented OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a capability variable.
      Its value is determined by (#3375)STA capabilities.

      This attribute, when true, indicates that the STA implementation is capa-
      ble of supporting the RAW operation. The capability is disabled, other-
      wise."
   ::= { dot11S1GStationConfigEntry 24 }

dot11RAWOperationActivated OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by an external management entity or the SME.
      Changes take effect as soon as practical in the implementation.

      This attribute, when true, indicates that the RAW operation is enabled.
      The RAW operation is disabled otherwise."
   DEFVAL { false }
   ::= { dot11S1GStationConfigEntry 25 }

dot11S1GUplinkSyncOptionImplemented OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a capability variable.
      Its value is determined by (#3375)STA capabilities.

      This attribute, when true, indicates that the STA implementation is capa-
      ble of supporting the uplink synch option. The capability is disabled,
      otherwise."
   ::= { dot11S1GStationConfigEntry 26 }

dot11TWTOptionActivated OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by an external management entity.
      Changes take effect as soon as practical in the implementation.

      This attribute, when true, indicates that the STA capability for the tar-
      get wake time function is enabled. A value of false indicates that the STA
      has no capability for the target wake time function, or that the capabil-
      ity is present, but disabled."
   DEFVAL { false }
   ::= { dot11S1GStationConfigEntry 27}

dot11BATImplemented OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a capability variable.
      Its value is determined by (#3375)STA capabilities.
```


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```
        This attribute, when true, indicates that the STA implementation is capa-
        ble of supporting BAT operation. The capability is disabled, otherwise."
    ::= { dot11S1GStationConfigEntry 28 }

dot11PollTACKResponseImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the STA implementation is capa-
        ble of generating a TACK frame as a response to a PS-Poll with the Poll
        Type subfield equal to 1. The capability is disabled, otherwise."
    ::= { dot11S1GStationConfigEntry 29 }

dot11NDPProbingActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        This attribute, when true, indicates that the NDP Probing is enabled. The
        NDP Probing is disabled otherwise."
    DEFVAL { false }
    ::= { dot11S1GStationConfigEntry 30 }

dot11NDPPSPollSupport OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        This attribute, when true, indicates that the NDP PS-Poll operation is
        enabled. The NDP PS-Poll operation is disabled otherwise."
    DEFVAL { false }
    ::= { dot11S1GStationConfigEntry 31 }

dot11RelayAPImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the STA permits association by a
        relay STA. The capability is disabled, otherwise."
    ::= { dot11S1GStationConfigEntry 32 }

dot11RelayAPOperationActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity or the SME.
```

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```
        Changes take effect as soon as practical in the implementation.

        This attribute, when true, indicates that the relay AP operation is
        enabled. The relay AP operation is disabled otherwise."
    DEFVAL { false }
    ::= { dot11S1GStationConfigEntry 33 }

dot11RelaySTAImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the STA implementation is a
        relay STA inside a relay. This should not be modified during the life of
        the STA."
    ::= { dot11S1GStationConfigEntry 34 }

dot11RelaySTAOperationActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        This attribute, when true, indicates that the relay STA operation is
        enabled. This attribute can be modified during the life of the STA in the
        BSS by sending Relay Activation element. The relay STA operation is dis-
        abled otherwise."
    DEFVAL { false }
    ::= { dot11S1GStationConfigEntry 35 }

dot11RelayDiscoveryOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the STA implementation is capa-
        ble of supporting Relay Discovery option. The capability is disabled, oth-
        erwise."
    ::= { dot11S1GStationConfigEntry 36 }

dot11TXOPSharingImplicitACKImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities
        This attribute, when true, indicates that the TXOP sharing implicit Ack
        operation is enabled. The TXOP sharing implicit Ack operation is disabled
        otherwise."
    ::= { dot11S1GStationConfigEntry 37 }

dot11S1GELOperationActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
```


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```
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        This attribute, when true, indicates that the EL operation is enabled. The
        EL operation is disabled otherwise."
    DEFVAL { false }
    ::= { dot11S1GStationConfigEntry 38 }

dot11S1GCentralizedAuthenticationControlActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        This attribute, when true, indicates that the Centralized Authentication
        Control operation is enabled. The Centralized Authentication Control oper-
        ation is disabled otherwise."
    DEFVAL { false }
    ::= { dot11S1GStationConfigEntry 39 }

dot11S1GDistributedAuthenticationControlActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        This attribute, when true, indicates that the Distributed Authentication
        Control operation is enabled. The Distributed Authentication Control oper-
        ation is disabled otherwise."
    DEFVAL { false }
    ::= { dot11S1GStationConfigEntry 40 }

dot11SubchannelSelectiveTransmissionActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        This attribute, when true, indicates that the Subchannel Selective Trans-
        mission is enabled. The Subchannel Selective Transmission is disabled oth-
        erwise."
    DEFVAL { false }
    ::= { dot11S1GStationConfigEntry 41 }

dot11S1GSectorImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.
```

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```
        This attribute, when true, indicates that the STA implementation is capa-
        ble of supporting S1G Sector option. The capability is disabled, other-
        wise."
    ::= { dot11S1GStationConfigEntry 42 }

dot11S1GSectorizationActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        This attribute, when true, indicates that the S1G Sector operation is
        enabled. The S1G Sector operation is disabled otherwise."
    DEFVAL { false }
    ::= { dot11S1GStationConfigEntry 43 }

dot11S1GSectorTrainingOperationImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the STA implementation is capa-
        ble of supporting the S1G Sector Training option. The capability is dis-
        abled, otherwise."
    ::= { dot11S1GStationConfigEntry 44 }

dot11NDPBeamformingReportPollImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the NDP Beamforming Report Poll
        operation is enabled. The NDP Beamforming Report Poll operation is dis-
        abled otherwise."
    ::= { dot11S1GStationConfigEntry 45 }

dot11UnsolicitedDynamicAIDActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        This attribute, when true, indicates that the unsolicited dynamic AID is
        enabled. The unsolicited dynamic AID is disabled otherwise."
    DEFVAL { false }
    ::= { dot11S1GStationConfigEntry 46 }

dot11TIMADEImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
```


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```
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the STA implementation is capa-
        ble of supporting the ADE mode of TIM bitmap encoding. The capability is
        disabled, otherwise."
    ::= { dot11S1GStationConfigEntry 47 }

dot11SelectiveSubchannelTransmissionPermitted OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        When this object is true, this indicates that Selective Subchannel Trans-
        mission is permitted by this entity."
    DEFVAL { false }
::= { dot11S1GStationConfigEntry 48}

dot11MaxAwayDuration OBJECT-TYPE
    SYNTAX Unsigned32 (0..65535)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        " This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute indicates from the STA, the maximum allowed duration for
        the AP to be not reachable, from the AP, the maximum duration that AP
        guarantees to be reachable by the STA."
    DEFVAL { 65535 }
    ::= { dot11S1GStationConfigEntry 49}

dot11APPMActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute indicates if the AP may go to doze state."
    DEFVAL { false }
    ::= { dot11S1GStationConfigEntry 50}

dot11BDTImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute, when true, indicates that the station implementation is
        capable of supporting the bidirectional TXOP Operation. The capability is
        disabled, otherwise."
    DEFVAL { false }
    ::= { dot11S1GStationConfigEntry 51}
```

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```
dot11S1GCACDeferral OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by the MAC upon receiving an Authentication Control element
      with Control subfield equal to 0.
      Changes take effect as soon as practical in the implementation.

      This attribute specifies whether the deferred channel access is used by
      the Centralized Authentication Control operation."
   DEFVAL { false }
   ::= { dot11S1GStationConfigEntry 52 }

dot11S1GCACThreshold OBJECT-TYPE
   SYNTAX Unsigned32
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by the MAC upon receiving an Authentication Control element
      with Control subfield equal to 0.
      Changes take effect as soon as practical in the implementation.

      This attribute specifies the threshold value that is used by the Central-
      ized Authentication Control operation."
   DEFVAL { 1024 }
   ::= { dot11S1GStationConfigEntry 53 }

dot11S1GDACTac OBJECT-TYPE
   SYNTAX Unsigned32
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by the MAC upon receiving an Authentication Control element
      with Control subfield equal to 1.
      Changes take effect as soon as practical in the implementation.

      This attribute specifies the Authentication Slot Duration that is used by
      the Distributed Authentication Control operation."
   DEFVAL { 10 }
   ::= { dot11S1GStationConfigEntry 54 }

dot11S1GDACTImin OBJECT-TYPE
   SYNTAX Unsigned32
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by the MAC upon receiving an Authentication Control element
      with Control subfield equal to 1.
      Changes take effect as soon as practical in the implementation.

      This attribute specifies the minimum transmission interval that is used by
      the Distributed Authentication Control operation."
   DEFVAL { 8 }
   ::= { dot11S1GStationConfigEntry 55 }

dot11S1GDACTImax OBJECT-TYPE
   SYNTAX Unsigned32
   MAX-ACCESS read-write
   STATUS current
```


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```
    DESCRIPTION
        "This is a control variable.
        It is written by the MAC upon receiving an Authentication Control element
        with Control subfield equal to 1.
        Changes take effect as soon as practical in the implementation.

        This attribute specifies the maximum transmission interval that is used by
        the Distributed Authentication Control operation."
    DEFVAL { 256 }
    ::= { dot11S1GStationConfigEntry 56 }

dot11ProtectedTWTOperationsImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute indicates whether the entity is capable of protected TWT
        operations."
    ::= { dot11S1GStationConfigEntry 57 }
(#1276)dot11ExtendedS1GActionProtectionOperationsImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute indicates whether the entity is capable of extended S1G
        action protection."
    ::= { dot11S1GStationConfigEntry 58}

(#6054)dot11BIPCompactEncapsulation OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute, when true indicates the station supports the use of BIP
        compact encapsulation of protected S1G Beacon frames. The attribute is set
        to true only if dot11BeaconProtectionEnabled is true."
    DEFVAL { false }
    ::= { dot11S1GStationConfigEntry 59 }


-- ************************************************************
-- * End of dot11S1GStationConfigTable TABLE
-- ************************************************************

--************************************************************
-- * dot11CDMGSTAConfigTable TABLE
--************************************************************

dot11CDMGSTAConfigTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11CDMGSTAConfigEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "This is a table management object.

```

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```
        The dot11CDMGSTAConfig Table"
    ::= { dot11smt 39 }

dot11CDMGSTAConfigEntry OBJECT-TYPE
    SYNTAX Dot11CDMGSTAConfigEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "This is an entry in the dot11CDMGSTAConfig Table.
        ifIndex - Each IEEE Std 802.11 interface is represented by an ifEntry.
        Interface tables in this MIB module are indexed by ifIndex."
    INDEX { ifIndex }
    ::= { dot11CDMGSTAConfigTable 1 }

Dot11CDMGSTAConfigEntry ::=
    SEQUENCE {
        dot11CDMGOptionImplemented                          TruthValue,
        dot11DynamicChannelTransferActivated                TruthValue,
        dot11OpportunisticTransmissionsImplemented          TruthValue
        }

dot11CDMGOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        CDMG Capable Object
        This attribute, when true, indicates the STA is CDMG
        capable. This attribute, when false, indicates the STA is not CDMG
        capable."
    ::= { dot11CDMGSTAConfigEntry 1 }

dot11DynamicChannelTransferImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS (#3441)deprecated
    DESCRIPTION
        "Deprecated as the related feature has been removed from the standard.
        This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates the CDMG STA is dynamic channel
        selection capable. This attribute, when false, indicates the STA is not
        dynamic channel selection capable."
    ::= { dot11CDMGSTAConfigEntry 2 }

dot11DynamicChannelTransferActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute, when true, indicates that the dynamic channel selection is
        activated."
    DEFVAL { false }
    ::= { dot11CDMGSTAConfigEntry 3 }

dot11OpportunisticTransmissionsActivated OBJECT-TYPE
```



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```
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS (#3441)deprecated
    DESCRIPTION
        "Deprecated as the related feature has been removed from the standard.
        This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        If dot11OpportunisticTransmissionsActivated is true, the STA is capable of
        supporting opportunistic transmissions."
    ::= { dot11CDMGSTAConfigEntry 4 }

dot11CDMGSpatialsharingActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS (#3441)deprecated
    DESCRIPTION
        "Deprecated as the related feature has been removed from the standard.
        This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        If dot11CDMGSpatialsharingActivated is true, the STA is capable of
        supporting CDMG spatial sharing."
    ::= { dot11CDMGSTAConfigEntry 5 }

dot11CDMGClusteringActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS (#3441)deprecated
    DESCRIPTION
        "Deprecated as the related feature has been removed from the standard.
        This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        If dot11CDMGClusteringActivated is true, the STA is capable of supporting
        CDMG AP or PCP clustering."
    ::= { dot11CDMGSTAConfigEntry 6 }

dot11OpportunisticTransmissionsImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        If dot11OpportunisticTransmissionsImplemented is true, the STA is capable
        of supporting opportunistic transmissions."
    DEFVAL { false }
    ::= { dot11CDMGSTAConfigEntry 7 }

--*****************************************************************
-- * End of dot11CDMGSTAConfigTable TABLE
--*****************************************************************

--*****************************************************************
-- * dot11CMMGSTAConfigTable TABLE
--*****************************************************************

dot11CMMGSTAConfigTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11CMMGSTAConfigEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
```

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```
        "This is a table management object.
        The dot11CMMGSTAConfig Table"
    ::= { dot11smt 40 }

dot11CMMGSTAConfigEntry OBJECT-TYPE
    SYNTAX Dot11CMMGSTAConfigEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "This is an entry in the dot11CMMGSTAConfig Table.
        ifIndex - Each IEEE Std 802.11 interface is represented by an ifEntry.
        Interface tables in this MIB module are indexed by ifIndex."
    INDEX { ifIndex }
    ::= { dot11CMMGSTAConfigTable 1 }

Dot11CMMGSTAConfigEntry ::=
    SEQUENCE {
        dot11CMMGMaxMPDULength                              INTEGER,
        dot11CMMGMaxRxAMPDUFactor                           Unsigned32,
        dot11CMMGControlFieldOptionImplemented              TruthValue,
        dot11CMMGTXOPPowerSaveOptionImplemented             TruthValue,
        dot11CMMGRxCMMGMCSMap                               OCTET STRING,
        dot11CMMGRxHighestDataRateSupported                 Unsigned32,
        dot11CMMGTxCMMGMCSMap                               OCTET STRING,
        dot11CMMGTxHighestDataRateSupported                 Unsigned32,
        dot11CMMGOptionImplemented                          TruthValue,
        dot11CMMGClusteringActivated                        TruthValue,
        dot11CMMGOBSSScanCount                              Unsigned32
        }

dot11CMMGMaxMPDULength OBJECT-TYPE
    SYNTAX INTEGER { short(3895), medium(7991), long(11454) }
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute indicates the supported maximum MPDU size."
    ::= { dot11CMMGSTAConfigEntry  1 }

dot11CMMGMaxRxAMPDUFactor OBJECT-TYPE
    SYNTAX Unsigned32 (0..7)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute indicates the maximum length of A-MPDU that the STA can
        receive. The Maximum Rx A-MPDU defined by this field is equal to
        2^(13+dot11CMMGMaxRxAMPDUFactor)-1 octets."
    ::= { dot11CMMGSTAConfigEntry 2 }

dot11CMMGControlFieldOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the station implementation is
        capable of receiving the CMMG variant HT Control field."
```


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```
    ::= { dot11CMMGSTAConfigEntry 3 }

dot11CMMGTXOPPowerSaveOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the station implementation is
        capable of TXOP Power Save operation."
    ::= { dot11CMMGSTAConfigEntry 4 }

dot11CMMGRxCMMGMCSMap OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(8))
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        Each octet represents the highest CMMG-MCS supported (for Rx) on the
        number of streams represented by the octet position (first octet
        represents 1 stream, second octet represents 2 streams, etc.) A value 0
        indicates that CMMG-MCSs SC 1-5 (OFDM 9-13) are supported. A value 1
        indicates that CMMG-MCSs SC 1-6 (OFDM 9-14) are supported. A value 2
        indicates that CMMG-MCSs SC 1-7 (OFDM 9-15) are supported. A value 2
        indicates that CMMG-MCSs SC 1-8 (OFDM 9-16) are supported. A value 4-7
        indicates no support for that number of spatial streams."
    ::= { dot11CMMGSTAConfigEntry 5 }

dot11CMMGRxHighestDataRateSupported OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        Represents the highest data rate in Mb/s that the STA is capable of
        receiving."
    ::= { dot11CMMGSTAConfigEntry 6 }

dot11CMMGTxCMMGMCSMap OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(8))
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        Each octet represents the highest CMMG-MCS supported (for Rx) on the num-
        ber of streams represented by the octet position (first octet represents 1
        stream, second octet represents 2 streams, etc.) A value 0 indicates that
        CMMG-MCSs SC 1-5 (OFDM 9-13) are supported. A value 1 indicates that CMMG-
        MCSs SC 1-6 (OFDM 9-14) are supported. A value 2 indicates that CMMG-MCSs
        SC 1-7 (OFDM 9-15) are supported. A value 2 indicates that CMMG-MCSs SC 1-
        8 (OFDM 9-16) are supported. A value 4-7 indicates no support for that
        number of spatial streams."
    ::= { dot11CMMGSTAConfigEntry 7 }

dot11CMMGTxHighestDataRateSupported OBJECT-TYPE
    SYNTAX Unsigned32
```

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```
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        Represents the highest data rate in Mb/s that the STA is capable of
        receiving."
    ::= { dot11CMMGSTAConfigEntry 8 }

dot11CMMGOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        CMMG Capable Object
        This attribute, when true, indicates the STA is CMMG
        capable. This attribute, when false, indicates the STA is not CMMG capa-
        ble.."
    ::= { dot11CMMGSTAConfigEntry 9 }

dot11CMMGClusteringActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        If dot11CMMGClusteringActivated is true, the STA is capable of supporting
        CMMG AP or PCP clustering."
    ::= { dot11CMMGSTAConfigEntry 10 }

dot11CMMGOBSSScanCount OBJECT-TYPE
    SYNTAX Unsigned32 (3..100)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.
        This attribute indicates the minimum number of scan operations performed
        on a channel to detect another OBSS."
    DEFVAL { 3 }
    ::= { dot11CMMGSTAConfigEntry 11 }

--*****************************************************************
-- * End of dot11CMMGSTAConfigTable TABLE
--*****************************************************************


-- ***************************************************************
-- * dot11GLKLinkMetrics TABLE
-- ***************************************************************

dot11GLKLinkMetricsTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11GLKLinkMetricsEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "Table of GLK Link metrics information. One entry per association or peer-
```



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```
        ing."
    ::= { dot11smt 41 }

dot11GLKLinkMetricsEntry OBJECT-TYPE
    SYNTAX Dot11GLKLinkMetricsEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "An entry in the dot11GLKLinkMetricsTable"
    INDEX { ifIndex }
    ::= { dot11GLKLinkMetricsTable 1 }

Dot11GLKLinkMetricsEntry ::=
    SEQUENCE {
        dot11GLKLinkRawRate                              Unsigned32,
        dot11GLKLinkMinRate                              Unsigned32,
        dot11GLKLinkAvgRate                              Unsigned32,
        dot11GLKLinkGeoRate                              Unsigned32,
        dot11GLKLinkSTDRate                              Unsigned32,
        dot11GLKLinkRateReported                         Unsigned32
    }

dot11GLKLinkRawRate OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "The maximum achievable data rate given the enabled STA features in units
        of 100 kb/s.
        This is a status variable."
    ::= { dot11GLKLinkMetricsEntry 1 }

dot11GLKLinkMinRate OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "The minimum data rate seen in the window of samples in units of 100 kb/s.
         This is a status variable."
    ::= { dot11GLKLinkMetricsEntry 2 }

dot11GLKLinkAvgRate OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "The arithmetic mean data rate seen across the window of samples in units
        of 100 kb/s.
        This is a status variable."
    ::= { dot11GLKLinkMetricsEntry 3 }

dot11GLKLinkGeoRate OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "The geometric mean of the data rates seen across the window of samples in
        units of 100 kb/s.
        This is a status variable."
    ::= { dot11GLKLinkMetricsEntry 4 }

dot11GLKLinkSTDRate OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-only
```

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```
    STATUS current
    DESCRIPTION
        "The standard deviation of the data rates seen across the window of sam-
        ples in units of 100 kb/s.
        This is a status variable."
    ::= { dot11GLKLinkMetricsEntry 5 }

dot11GLKLinkRateReported OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "The reported link data rate in units of 100 kb/s.
        This is a status variable."
    ::= { dot11GLKLinkMetricsEntry 6 }

-- ************************************************************
-- * End of dot11GLKLinkMetrics TABLE
-- ************************************************************

-- ************************************************************************
-- * (11ax)dot11HEStationConfig TABLE
-- ************************************************************************

(11ax)dot11HEStationConfigTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11HEStationConfigEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "Station Configuration attributes. In tabular form to allow for multiple
        instances on an agent."
    ::= { dot11smt 42 }

(11ax)dot11HEStationConfigEntry OBJECT-TYPE
    SYNTAX Dot11HEStationConfigEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "An entry (conceptual row) in the dot11HEStationConfig Table.

        ifIndex - Each IEEE 802.11 interface is represented by an ifEntry.
        Interface tables in this MIB module are indexed by ifIndex."
    INDEX { ifIndex }
    ::= { dot11HEStationConfigTable 1 }

(11ax)Dot11HEStationConfigEntry ::=
    SEQUENCE {
        dot11TRSOptionImplemented                               TruthValue,
        dot11OFDMARandomAccessOptionImplemented                 TruthValue,
        dot11HEControlFieldOptionImplemented                    TruthValue,
        dot11OMIOptionImplemented                               TruthValue,
        dot11HEMCSFeedbackOptionImplemented                     INTEGER,
        dot11HEDynamicFragmentationLevel                        INTEGER,
        dot11AMPDUwithMultipleTIDOptionImplemented              TruthValue,
        dot11MPDUAskedforAckInMultiTIDAMPDU                     TruthValue,
        dot11TXOPDurationRTSThreshold                           Unsigned32,
        dot11PPEThresholdsRequired                              TruthValue,
        dot11IntraPPDUPowerSaveOptionActivated                  TruthValue,
        dot11AMSDUFragmentationOptionImplemented                TruthValue,
        dot11BSSColorCollisionAPPeriod                          INTEGER,
        dot11BSSColorCollisionSTAPeriod                         Unsigned32,
        dot11AutonomousBSSColorCollisionReportingImplemented    TruthValue,
        dot11HEPSROptionImplemented                             TruthValue,
        dot11HEBSRControlImplemented                            TruthValue,
```


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```
        dot11HEBQRControlImplemented                          TruthValue,
        dot11HECASControlImplemented                          TruthValue,
        dot11PartialBSSColorImplemented                       TruthValue,
        dot11ObssNbRuToleranceTime                            Unsigned32,
        dot11HESubchannelSelectiveTransmissionImplemented     TruthValue,
        dot11SRResponderOptionImplemented                     TruthValue,
        dot11AutonomousBSSColorInUseReportingImplemented      TruthValue,
        dot11ShortSSIDListImplemented                         TruthValue,
        dot11SRGAPOBSSPDMinOffset                             Integer32,
        dot11SRGAPOBSSPDMaxOffset                             Integer32,
        dot11SRGAPBSSColorBitmap                              OCTET STRING,
        dot11SRGAPBSSIDBitmap                                 OCTET STRING,
        dot11NonSRGAPOBSSPDMaxOffset                          Integer32,
        dot11HTVHTTriggerOptionImplemented                    TruthValue,
        dot11HEDynamicSMPowerSaveOptionImplemented            TruthValue,
        dot11MUEDCAParametersActivated                        TruthValue,
        dot11CoHostedBSSIDImplemented                         TruthValue,
        dot11UnsolicitedProbeResponseOptionActivated          TruthValue,
        dot11MemberOfColocated6GHzESSOptionActivated          TruthValue,
        dot11AckEnabledAMPDUOptionImplemented                 TruthValue,
        dot11MinPSCProbeDelay                                 Unsigned32,
        dot11OCWmin                                           Unsigned32,
        dot11OCWmax                                           Unsigned32 }

(11ax)dot11TRSOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the station implementation is
        capable of receiving frames with a TRS Control subfield. The capability is
        disabled otherwise."
    DEFVAL { false }
    ::= { dot11HEStationConfigEntry 1 }

(11ax)dot11OFDMARandomAccessOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the station implementation is
        capable of an OFDMA random access operation. The capability is disabled
        otherwise."
    DEFVAL { false }
    ::= { dot11HEStationConfigEntry 2}

(11ax)dot11HEControlFieldOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the station implementation is
        capable of receiving the HE variant HT Control field. The capability is
        disabled otherwise."
    DEFVAL { false }
```

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```
    ::= { dot11HEStationConfigEntry 3}

(11ax)dot11OMIOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the station implementation is
        capable of receiving frames with an OM Control subfield. The capability is
        disabled otherwise."
    DEFVAL { false }
    ::= { dot11HEStationConfigEntry 4}

(11ax)dot11HEMCSFeedbackOptionImplemented OBJECT-TYPE
    SYNTAX INTEGER {none(0), unsolicited(2), solicitedandunsolicited(3)}
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute indicates the HE-MCS feedback capability supported by the
        station implementation."
    DEFVAL { 0 }
    ::= { dot11HEStationConfigEntry 5}

(11ax)dot11HEDynamicFragmentationLevel OBJECT-TYPE
    SYNTAX INTEGER{hedynamicfragmentationlevel1(1),
        hedynamicfragmentationlevel2(2), hedynamicfragmentationlevel3(3)}
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        hedynamicfragmentationlevel1 indicates support for up to one dynamic
        fragment that is a non-A-MPDU frame, no support for dynamic fragments
        within an A-MPDU that does not contain an S-MPDU.

        hedynamicfragmentationlevel2 indicates support for up to one dynamic
        fragment that is a non-A-MPDU frame and support for up to one dynamic
        fragment for each MSDU, each A-MSDU (if supported by the recipient) and
        one MMPDU (if present) within an A-MPDU that does not contain an S-MPDU.

        hedynamicfragmentationlevel3 indicates support for up to one dynamic
        fragment that is a non-A-MPDU frame and support for up to 4 dynamic
        fragments for each MSDU and for each A-MSDU (if supported by the
        recipient) within an A-MPDU and up to one dynamic fragment for one MMPDU
        (if present) in an A-MPDU that does not contain an S-MPDU"
    ::= { dot11HEStationConfigEntry 6}

(11ax)dot11HEAMPDUwithMultipleTIDOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the station implementation is
        capable of receiving an A-MPDU that contains QoS Data frames with two or
```


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```
        more different TID values. The capability is disabled otherwise."
    DEFVAL { false }
    ::= { dot11HEStationConfigEntry 7}

(11ax)dot11MPDUAskedforAckInMultiTIDAMPDU OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the station implementation is
        capable of receiving a multi-TID A-MPDU that can solicit either Ack or
        BlockAck, or both. The capability is disabled otherwise."
    DEFVAL { false }
    ::= { dot11HEStationConfigEntry 8}

(11ax)dot11TXOPDurationRTSThreshold OBJECT-TYPE
    SYNTAX Unsigned32 (1..1023)
    UNITS "32 microseconds"
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity or by the MAC of a non-AP
        HE STA upon receiving an HE Operation element from the HE AP with which it
        is associated.
        Changes take effect as soon as practical in the implementation.

        This attribute indicates the duration of the transmission or TXOP above
        which an RTS/CTS handshake is performed. The value 1023 means this feature
        is disabled."
    DEFVAL { 1023 }
    ::= { dot11HEStationConfigEntry 9 }

(11ax)dot11PPEThresholdsRequired OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.
        This attribute, when true, indicates that PPE thresholds exist and are
        provided in dot11PPEThresholdsTable."
    DEFVAL { false }
    ::= { dot11HEStationConfigEntry 10 }

(11ax)dot11IntraPPDUPowerSaveOptionActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the station implementation is
        capable of Intra PPDU Power Save operation. The capability is disabled
        otherwise."
    DEFVAL { false }
    ::= { dot11HEStationConfigEntry 11 }

(11ax)dot11AMSDUFragmentationOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
```

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```
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

         This attribute, when true, indicates that the STA implementation is
         capable of receiving dynamic fragments of A-MSDUs. The capability is
         disabled otherwise."
    DEFVAL { false }
::= { dot11HEStationConfigEntry 12 }

(11ax)dot11BSSColorCollisionAPPeriod OBJECT-TYPE
    SYNTAX INTEGER (-1..120)
    UNITS "seconds"
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute indicates the duration for which an HE AP waits before
        disabling BSS color when a color collision is detected. The value -1 means
        that this feature is disabled."
    DEFVAL { 50 }
    ::= { dot11HEStationConfigEntry 13 }

(11ax)dot11BSSColorCollisionSTAPeriod OBJECT-TYPE
    SYNTAX Unsigned32 (30..120)
    UNITS "seconds"
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute indicates the interval between successive BSS color
        event collision reports sent by a(#1426) non-AP HE STA."
    DEFVAL { 30}
    ::= { dot11HEStationConfigEntry 14 }

(11ax)dot11AutonomousBSSColorCollisionReportingImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.
        This attribute, when true, indicates that autonomously detecting and
        reporting of BSS color collision is implemented."
    ::= { dot11HEStationConfigEntry 15 }

(11ax)dot11HEPSROptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable. Its value is determined by (#3375)STA
        capabilities.

        This attribute, when true, indicates that the STA implementation is
        capable of transmitting Spatial Reuse Parameters in HE PPDUs. The
```



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```
        capability is disabled otherwise."
    DEFVAL { false }
    ::= { dot11HEStationConfigEntry 16 }

(11ax)dot11HEBSRControlImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the station implementation is
        capable of receiving frames with a BSR Control subfield. The capability is
        disabled otherwise."
    DEFVAL { false }
    ::= { dot11HEStationConfigEntry 17 }

(11ax)dot11HEBQRControlImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the station implementation is
        capable of receiving frames with a BQR Control subfield. The capability is
        disabled otherwise."
    DEFVAL { false }
    ::= { dot11HEStationConfigEntry 18 }

(11ax)dot11HECASControlImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the station implementation is
        capable of receiving frames with a CAS Control subfield. The capability is
        disabled otherwise."
    DEFVAL { false }
    ::= { dot11HEStationConfigEntry 19 }

(11ax)dot11PartialBSSColorImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.
        This attribute, when true, indicates that the partial BSS color (see
        26.17.4 (AID assignment)) is implemented. The capability is disabled
        otherwise."
    DEFVAL { false }
    ::= { dot11HEStationConfigEntry 20 }

(11ax)dot11ObssNbRuToleranceTime OBJECT-TYPE
    SYNTAX Unsigned32 (0..3600)
    UNITS "seconds"
    MAX-ACCESS read-write
    STATUS current
```

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```
    DESCRIPTION
        "It is a status variable.
        It is written by an external management entity. Changes take effect as
        soon as practical in the implementation.
        This attribute indicates the minimum time that needs to pass since the
        reception of the last Beacon frame from an OBSS AP that did not indicate
        tolerance to narrow bandwidth RU in OFDMA before the STA can transmit a
        triggering frame that allocates a 26-tone RU, or transmit an HE TB PPDU in
        a 26-tone RU."
    DEFVAL { 1800 }
    ::= { dot11HEStationConfigEntry 21 }

(11ax)dot11HESubchannelSelectiveTransmissionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.
        This attribute, when true, indicates that an HE subchannel selective
        transmission operation is implemented. The capability is disabled
        otherwise."
    DEFVAL { false }
::= { dot11HEStationConfigEntry 22 }

(11ax)dot11SRResponderOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the PSR-based PSRT PPDU
        reception (see 26.10.3 (PSR-based spatial reuse operation)) is
        implemented. The capability is disabled otherwise."
    DEFVAL { false }
    ::= { dot11HEStationConfigEntry 23 }

(11ax)dot11AutonomousBSSColorInUseReportingImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that autonomously
        reporting of BSS color in use is implemented."
    DEFVAL { false }
    ::= { dot11HEStationConfigEntry 24 }

(11ax)dot11ShortSSIDListImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable. Its value is determined by (#3375)STA
        capabilities.

        This attribute, when true, indicates that the STA implementation is
        capable of transmitting and receiving Short SSID List element in Probe
        Request frames. The capability is disabled otherwise."
    DEFVAL { false }
```


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```
    ::= { dot11HEStationConfigEntry 25 }

(11ax)dot11SRGAPOBSSPDMinOffset OBJECT-TYPE
    SYNTAX Integer32
    UNITS "dBm"
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute indicates the SRG OBSS PD Min Offset for an AP."
    DEFVAL { 0 }
    ::= { dot11HEStationConfigEntry 26 }

(11ax)dot11SRGAPOBSSPDMaxOffset OBJECT-TYPE
    SYNTAX Integer32
    UNITS "dBm"
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute indicates the SRG OBSS PD Max Offset for an AP."
    DEFVAL { 0 }
    ::= { dot11HEStationConfigEntry 27 }

(11ax)dot11SRGAPBSSColorBitmap OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(8))
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        This variable is a 64 bit bitmap that indicates which BSS color values are
        used by members of the SRG of which the AP is a member.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute indicates the SRG BSS Color Bitmap for an AP."
    ::= { dot11HEStationConfigEntry 28 }

(11ax)dot11SRGAPBSSIDBitmap OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(8))
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        This variable is a 64 bit bitmap that indicates which Partial BSSID values
        are used by members of the SRG of which the AP is a member.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute indicates the SRG BSSID Bitmap for an AP."
    ::= { dot11HEStationConfigEntry 29}

(11ax)dot11NonSRGAPOBSSPDMaxOffset OBJECT-TYPE
    SYNTAX Integer32
    UNITS "dBm"
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
```

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```
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute indicates the Non SRG OBSS PD Max Offset for an AP."
    DEFVAL { 0 }
    ::= { dot11HEStationConfigEntry 30 }

(11ax)dot11HTVHTTriggerOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the STA implementation is
        capable of receiving Trigger frames in HT PPDUs and VHT PPDUs. The
        capability is disabled, otherwise."
    DEFVAL { false }
    ::= { dot11HEStationConfigEntry 31 }

(11ax)dot11HEDynamicSMPowerSaveOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable. Its value is determined by (#3375)STA
        capabilities.

        This attribute, when true, indicates that the STA implementation is
        capable of enabling its multiple receive chains when it receives a
        Trigger frame. The capability is disabled otherwise."
    DEFVAL { false }
    ::= { dot11HEStationConfigEntry 32 }

(11ax)dot11MUEDCAParametersActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable used only if the STA is an AP. It is set to
        true by an AP that advertises MU EDCA parameters so that its associated
        STAs use MU EDCA parameters."
    DEFVAL { true }
    ::= { dot11HEStationConfigEntry 33 }

(11ax)dot11CoHostedBSSIDImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.
        This attribute, when true, indicates that the station implementation is
        capable of supporting Co-Hosted BSSID."
    DEFVAL { false }
    ::= { dot11HEStationConfigEntry 34 }

(11ax)dot11UnsolicitedProbeResponseOptionActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
```


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```
        "This is a control variable.
        It is written by an external management entity. Changes take effect as
        soon as practical in the implementation.
        This attribute, when true, indicates that the station implementation is an
        AP and is part of an ESS where all the APs operating in the 6 GHz band that
        operate in the same channel as the AP and whose transmitted frames might
        be detected by a STA receiving this frame schedules for transmission
        unsolicited Probe Response frames every 20 TUs or less (see 26.17.2.3.2
        (AP behavior for fast passive scanning)). The capability is disabled
        otherwise."
    ::= { dot11HEStationConfigEntry 35 }

(11ax)dot11MemberOfColocated6GHzESSOptionActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.

        This attribute, when true, indicates that the station implementation is an
        AP that operates in the 6 GHz band and is part of an ESS where each AP has
        a corresponding AP operating in the 2.4 GHz or 5 GHz band that is in the
        same (#2210)colocated AP set as that AP (see 11.53 (Out-of-band discovery
        of a 6 GHz BSS(11ax))). The capability is disabled otherwise."
    ::= { dot11HEStationConfigEntry 36 }

(11ax)dot11AckEnabledAMPDUOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the station implementation is
        capable of receiving ack-enabled single-TID A-MPDU. The capability is
        disabled otherwise."
    ::= { dot11HEStationConfigEntry 37 }

(11ax)dot11MinPSCProbeDelay OBJECT-TYPE
    SYNTAX Unsigned32 (5484..100000)
    UNITS "microseconds"
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        A STA does not send a Probe Request frame if it is scanning a preferred
        scanning channel in the 6 GHz band, unless the channel has been
        continuously idle for this duration since the start of the scan on that
        channel."
    DEFVAL { 7000 }
    ::= { dot11HEStationConfigEntry 38 }

(11ax)dot11OCWmin OBJECT-TYPE
    SYNTAX Unsigned32 (0..127)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by the MAC upon receiving an UORA Parameter Set.
```

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```
        Changes take effect as soon as practical in the implementation.

        This attribute specifies the value of the minimum size of the OFDMA
        contention window (OCW) that is used by the non-AP STA for UL OFDMA-based
        random access. The value of this attribute is such that it could always be
        expressed in the form of 2^X - 1, where X is an integer."
    DEFVAL { 7 }
    ::= { dot11HEStationConfigEntry 39}

(11ax)dot11OCWmax OBJECT-TYPE
    SYNTAX Unsigned32 (0..127)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by the MAC upon receiving an UORA Parameter Set.
        Changes take effect as soon as practical in the implementation.

        This attribute specifies the value of the maximum size of the OFDMA
        contention window (OCW) that is used by the non-AP STA for UL OFDMA-based
        random access. The value of this attribute is such that it could always be
        expressed in the form of 2^X - 1, where X is an integer."
    DEFVAL { 31 }
    ::= { dot11HEStationConfigEntry 40 }

-- ********************************************************************
-- * (11ax)End of dot11HEStationConfig TABLE
-- ********************************************************************

-- ********************************************************************
-- * (11ax)dot11PPEThresholdsMappings TABLE
-- ********************************************************************
(11ax)dot11PPEThresholdsMappingsTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11PPEThresholdsMappingsEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "A conceptual table for PPE thresholds mappings, which determines the
        nominal packet padding value as a function of the two PPE thresholds,
        PPET8 and PPET16, for an HE PPDU of a particular RU allocation size and
        NSTS value. The MIB supports the ability to share separate PPE thresholds
        for each NSTS/RU pair. The thresholds mappings table contains one entry
        for each NSTS/RU pair and contains two fields for each entry: PPET8 and
        PPET16."
    REFERENCE "IEEE Std 802.11-2020, 26.12 (HE PPDU post-FEC padding and packet
        extension)"
    ::= { dot11smt 43}

(11ax)dot11PPEThresholdsMappingsEntry OBJECT-TYPE
    SYNTAX Dot11PPEThresholdsMappingsEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "An Entry (conceptual row) in the PPE Thresholds Mappings Table.
         ifIndex - Each IEEE Std 802.11 interface is represented by an ifEntry.
         Interface tables in this MIB module are indexed by ifIndex."
    INDEX { ifIndex, dot11PPEThresholdsMappingIndex }
    ::= { dot11PPEThresholdsMappingsTable 1 }

(11ax)Dot11PPEThresholdsMappingsEntry ::= SEQUENCE {
    dot11PPEThresholdsMappingIndex                  Unsigned32,
    dot11PPEThresholdsMappingNSS                    Unsigned32,
    dot11PPEThresholdsMappingRUIndex                Unsigned32,
    dot11PPEThresholdsMappingPPET8                  INTEGER,
```


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```
    dot11PPEThresholdsMappingPPET16                          INTEGER,
    dot11PPEThresholdsMappingStatus                          RowStatus}

(11ax)dot11PPEThresholdsMappingIndex OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "The auxiliary variable used to identify instances of the columnar objects
        in the PPE Thresholds Mappings Table."
    ::= { dot11PPEThresholdsMappingsEntry 1 }

(11ax)dot11PPEThresholdsMappingNSS OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "The NSS value portion of the NSS/RU pair for which the values from this
        Thresholds mapping entry are to be used."
    ::= { dot11PPEThresholdsMappingsEntry 2 }

(11ax)dot11PPEThresholdsMappingRUIndex OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "The index of the RU value portion of the NSS/RU pair for which the values
        from this thresholds mapping entry are to be used. The index values map to
        an RU as follows: RU Index of 0 is 242 tones, 1 is 448 tones, 2 is 996
        tones, 3 is 2x996 tones."
    ::= { dot11PPEThresholdsMappingsEntry 3 }

(11ax)dot11PPEThresholdsMappingPPET8 OBJECT-TYPE
    SYNTAX INTEGER{BPSK(0), QPSK(1), 16-QAM(2), 64-QAM(3), 256-QAM(4), 1024-
        QAM(5), NONE(7)}
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "An index that determines a constellation value at or above which a
        nominal packet padding value of at least 8 microseconds is required for
        the given NSS/RU pair corresponding to the row of the entry."
    ::= { dot11PPEThresholdsMappingsEntry 4 }

(11ax)dot11PPEThresholdsMappingPPET16 OBJECT-TYPE
    SYNTAX INTEGER{BPSK(0), QPSK(1), 16-QAM(2), 64-QAM(3), 256-QAM(4), 1024-
        QAM(5), NONE(7)}
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "An index that determines a constellation value at or above which a
        nominal packet padding value of 16 microseconds is required for the given
        NSS/RU pair corresponding to the row of the entry."
    ::= { dot11PPEThresholdsMappingsEntry 5 }

(11ax)dot11PPEThresholdsMappingStatus OBJECT-TYPE
    SYNTAX RowStatus
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "The status column used for creating, modifying, and deleting instances of
        the columnar objects in the PPE thresholds mapping table."
    DEFVAL { active }
    ::= { dot11PPEThresholdsMappingsEntry 6 }
```

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```
-- ************************************************************************
-- * (11ax)End of dot11PPEThresholdsMappings TABLE
-- ************************************************************************

-- ************************************************************************
-- * (11ay)dot11EDMGSTAConfig TABLE
-- ************************************************************************

dot11EDMGSTAConfigTable OBJECT-TYPE
   SYNTAX SEQUENCE OF Dot11EDMGSTAConfigEntry
   MAX-ACCESS not-accessible
   STATUS current
   DESCRIPTION
      "This is a table management object.
   ::= { dot11smt 44 }

dot11EDMGSTAConfigEntry OBJECT-TYPE
   SYNTAX Dot11EDMGSTAConfigEntry
   MAX-ACCESS not-accessible
   STATUS current
   DESCRIPTION
      "This is an entry in the dot11EDMGSTAConfig Table.

      ifIndex - Each IEEE 802.11 interface is represented by an ifEntry.
      Interface tables in this MIB module are indexed by ifIndex."
   INDEX { ifIndex }
   ::= { dot11EDMGSTAConfigTable 1 }

Dot11EDMGSTAConfigEntry ::=
      SEQUENCE {
            dot11EDMGOptionImplemented                    TruthValue,
            dot11EDMGAMPDUwithMultipleTIDOptionImplemented TruthValue,
            dot11EDMGScheduledRDImplemented               TruthValue
      }

dot11EDMGOptionImplemented OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a capability variable. Its value is determined by (#3375)STA
      capabilities.

      This attribute, when true, indicates the STA is EDMG capable. This
      attribute, when false, indicates the STA is not EDMG capable. The default
      value of this attribute is false."
   DEFVAL { false }
   ::= { dot11EDMGSTAConfigEntry 1 }

dot11EDMGAMPDUwithMultipleTIDOptionImplemented OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a capability variable. Its value is determined by (#3375)STA
      capabilities.

      This attribute, when true, indicates that the station implementation is
      capable of generating an A-MPDU that contains QoS Data frames with two or
      more different TID values. The capability is disabled, otherwise."
   DEFVAL { false }
   ::= { dot11EDMGSTAConfigEntry 2 }

dot11EDMGScheduledRDImplemented OBJECT-TYPE
```



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```
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
       "This is a capability variable. Its value is determined by (#3375)STA
       capabilities.

       This attribute, when true, indicates the STA supports Scheduled Reverse
       Direction. This attribute, when false, indicates the STA does not support
       Scheduled Reverse Direction. "
    DEFVAL { false }
    ::= { dot11EDMGSTAConfigEntry 3 }

-- ************************************************************************
-- * (11ay)End of dot11EDMGSTAConfig TABLE
-- ************************************************************************

-- ************************************************************************
-- * (11ba)dot11WURStationConfig TABLE
-- ************************************************************************

dot11WURStationConfigTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11WURStationConfigEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
       "Station Configuration attributes. In tabular form to allow for multiple
       instances on an agent."
    ::= { dot11smt 45}

dot11WURStationConfigEntry OBJECT-TYPE
    SYNTAX Dot11WURStationConfigEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
       "An entry (conceptual row) in the dot11WURStationConfig Table.

       ifIndex - Each IEEE 802.11 interface is represented by an ifEntry.
       Interface tables in this MIB module are indexed by ifIndex."
    INDEX { ifIndex }
    ::= { dot11WURStationConfigTable 1 }

Dot11WURStationConfigEntry ::=
    SEQUENCE {
       dot11WURBeaconPeriod                                Unsigned32,
       dot11WURFDMAChannelSwitchImplemented                TruthValue,
       dot11WURDiscoveryImplemented                        TruthValue,
       dot11WURNeighborDiscoveryImplemented                TruthValue,
       dot11WURDiscoveryPeriod                             Unsigned32,
       dot11RSNAWURFrameProtectionActivated                TruthValue
    }

dot11WURBeaconPeriod OBJECT-TYPE
    SYNTAX Unsigned32(1..65535)
    UNITS "TUs"
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
       "This is a control variable.
```

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```
        It is written by an external management entity. Changes take effect for
        the next MLME-START.request primitive.
        For WUR APs, this attribute specifies the time period(#1724) that a
        station uses for scheduling WUR Beacon transmissions. This value is
        transmitted in Beacon, Probe Response frames, Association Response frames,
        or Reassociation Response frames."
    ::= { dot11WURStationConfigEntry 1}

dot11WURFDMAChannelSwitchImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capability.
        This attribute when true, indicates that the STA is capable of switching
        the WUR channel for receiving WUR Beacon and WUR Short Wake-up frames or
        WUR Wake-up frames or WUR Vendor Specific frames that are transmitted in
        different channels (see 29.11 (WUR FDMA operation)). The capability is
        disabled otherwise."
    DEFVAL { false }
    ::= { dot11WURStationConfigEntry 2}

dot11WURDiscoveryImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        This attribute when true, indicates that for an AP, the AP is capable of
        transmitting WUR Discovery frames, and for a non-AP STA, the non-AP STA is
        capable of WUR discovery procedure (i.e., receiving WUR Discovery
        frames)(see 29.12 (WUR discovery)). The capability is disabled otherwise."
    DEFVAL { false }
    ::= { dot11WURStationConfigEntry 3 }

dot11WURNeighborDiscoveryImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        This attribute when true, indicates that the STA is capable of transmit-
        ting WUR Discovery element to advertise the WUR discovery channels used by
        neighboring WUR APs (see 29.12 (WUR discovery)). The capability is dis-
        abled otherwise."
    DEFVAL { false }
    ::= { dot11WURStationConfigEntry 4 }

dot11WURDiscoveryPeriod OBJECT-TYPE
    SYNTAX Unsigned32(1..65535)
    UNITS "TUs"(#1724)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity. Changes take effect for
        the next MLME-START.request primitive.
        For WUR STAs, this attribute specifies the time period(#1724) that a
        station uses for scheduling WUR Discovery frame transmissions. This value
```


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```
        is transmitted in Beacon or Probe Response frames."
    ::= { dot11WURStationConfigEntry 5 }

dot11RSNAWURFrameProtectionActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity. Changes take effect for
        the next MLME-START.request primitive or MLME-JOIN.request primitive.
        This attribute, when true, indicates that the station, if a WUR AP, is
        capable of transmitting protected WUR frames, or if a WUR non-AP STA, is
        capable of receiving protected WUR frames. Otherwise, the capability is
        disabled."
    DEFVAL { false }
    ::= { dot11WURStationConfigEntry 6 }

-- ****************************************************************
-- * End of dot11WURStationConfig TABLE
-- ****************************************************************


-- ****************************************************************
-- * (11bc)dot11EBCSTrafficStreamTable TABLE
-- ****************************************************************

(11bc)dot11EBCSTrafficStreamTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11EBCSTrafficStreamEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "This table of attributes is a set of all of the EBCS traffic stream
        information."
    ::= { dot11smt 48 }

(11bc)dot11EBCSTrafficStreamEntry OBJECT-TYPE
    SYNTAX Dot11EBCSTrafficStreamEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "An entry in the dot11EBCSTrafficStreamTable."
    INDEX { ifIndex }
    ::= {dot11EBCSTrafficStreamTable 1 }

(11bc)Dot11EBCSTrafficStreamEntry ::=
    SEQUENCE {
        dot11EBCSTrafficStreamTXMACAddress                    MacAddress,
        dot11EBCSTrafficStreamAPGroupID                       Unsigned32,
        dot11EBCSTrafficStreamContentID                       Unsigned32,
        dot11EBCSTrafficStreamAuthenticationAlgorithm         INTEGER,
        dot11EBCSTrafficStreamAddressType                     INTEGER,
        dot11EBCSTrafficStreamAddress                         OCTET STRING,
        dot11EBCSTrafficStreamTitle                           OCTET STRING,
        dot11EBCSTrafficStreamPHYType                         Unsigned32,
        dot11EBCSTrafficStreamTXRate                          OCTET STRING,
        dot11EBCSTrafficStreamNegotiationMethod               INTEGER,
        dot11EBCSTrafficStreamNextTXSchedule                  Unsigned32,
        dot11EBCSTrafficStreamTimeToTermination               Unsigned32,
        dot11EBCSTrafficStreamBufferableActivated             TruthValue,
        dot11EBCSTrafficStreamActivated                       TruthValue
    }

(11bc)dot11EBCSTrafficStreamTXMACAddress OBJECT-TYPE
```

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```
    SYNTAX MacAddress
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external entity or the SME. Changes take effect as
        soon as practical in the implementation.
        This variable is used to identify EBCS traffic by an EBCS receiver."
    ::= { dot11EBCSTrafficStreamEntry 1 }

(11bc)dot11EBCSTrafficStreamAPGroupID OBJECT-TYPE
    SYNTAX Unsigned32 (0..65535)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external entity or the SME. Changes take effect as
        soon as practical in the implementation.
        This variable is used to identify EBCS traffic by an EBCS receiver."
    ::= { dot11EBCSTrafficStreamEntry 2 }

(11bc)dot11EBCSTrafficStreamContentID OBJECT-TYPE
    SYNTAX Unsigned32 (0..255)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external entity or the SME. Changes take effect as
        soon as practical in the implementation.
        This variable is used to identify an EBCS traffic stream."
    ::= { dot11EBCSTrafficStreamEntry 3 }

(11bc)dot11EBCSTrafficStreamAuthenticationAlgorithm OBJECT-TYPE
    SYNTAX INTEGER {
        hlsa(0),
        pkfa(1),
        hcfawithoutinstantauthentication(2),
        hcfawithinstantauthentication(3)
    }
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external entity or the SME. Changes take effect as
        soon as practical in the implementation.
        This variable specifies the authentication algorithm of the EBCS traffic
        stream. The following values can be used here.
        Value = 0: HLSA
        Value = 1: PKFA
        Value = 2: HCFA without instant authentication
        Value = 3: HCFA with instant authentication"
    ::= { dot11EBCSTrafficStreamEntry 4 }

(11bc)dot11EBCSTrafficStreamAddressType OBJECT-TYPE
    SYNTAX INTEGER {
        udpipv4(0),
        udpipv6(1),
        macaddress(2)
    }
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external entity or the SME. Changes take effect as
```



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```
        soon as practical in the implementation.
        This variable specifies the address type of the dot11EBCSTrafficStreamAd-
        dress. The following values can be used here.
        Value = 0: UDP/IPv4
        Value = 1: UDP/IPv6
        Value = 2: MAC address"
    ::= { dot11EBCSTrafficStreamEntry 5 }

(11bc)dot11EBCSTrafficStreamAddress OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(10..34))
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external entity or the SME. Changes take effect as
        soon as practical in the implementation.
        This variable specifies the source and destination address of the EBCS
        traffic stream encoded in the Content Address subfield format in 9.4.5.30
        (EBCS ANQP-element(11bc))."
    ::= { dot11EBCSTrafficStreamEntry 6 }

(11bc)dot11EBCSTrafficStreamTitle OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(0..255))
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external entity or the SME. Changes take effect as
        soon as practical in the implementation.
        This variable specifies the human readable title of the EBCS traffic
        stream encoded in UTF-8."
    ::= { dot11EBCSTrafficStreamEntry 7 }

(11bc)dot11EBCSTrafficStreamPHYType OBJECT-TYPE
    SYNTAX Unsigned32 (0..255)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external entity or the SME. Changes take effect as
        soon as practical in the implementation.
        This variable specifies the transmission PHY type of the EBCS Data frames
        of the EBCS traffic stream encoded in the PHY Type subfield value in
        Table 9-438 (PHY Type subfield(11bc)). A value of 255 indicates the PHY
        type is not specified."
    ::= { dot11EBCSTrafficStreamEntry 8 }

(11bc)dot11EBCSTrafficStreamTXRate OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(1..3))
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external entity or the SME. Changes take effect as
        soon as practical in the implementation.
        This variable specifies the transmission rate of the EBCS Data frames of
        the EBCS traffic stream encoded as in the TX Rate subfield format in
        9.4.5.30 (EBCS ANQP-element(11bc))."
    ::= { dot11EBCSTrafficStreamEntry 9 }

(11bc)dot11EBCSTrafficStreamNegotiationMethod OBJECT-TYPE
    SYNTAX INTEGER { hlsa (0), pkfa (1), hcfawithoutauthentication (2), hcfawith-
        instantauthentication (3) } OCTET STRING (SIZE(1))
    MAX-ACCESS read-write
```

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```
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external entity or the SME. Changes take effect as
        soon as practical in the implementation.
        This variable specifies the negotiation method of the EBCS traffic stream
        encoded as in Table 9-436 (Content Authentication Algorithms(11bc))."
    ::= { dot11EBCSTrafficStreamEntry 10 }

(11bc)dot11EBCSTrafficStreamNextTXSchedule OBJECT-TYPE
    SYNTAX Unsigned32 (0..65535)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external entity or the SME. Changes take effect as
        soon as practical in the implementation.
        This variable specifies the next transmission timing of the EBCS traffic
        stream in unit of TBTT. A value of 0 indicates that this transmission
        occurs in the beacon interval that starts at the next TBTT. A value of 1
        indicates that it occurs in the beacon interval that follows that beacon
        interval. A value of 65535 indicates that there is no specific transmis-
        sion starting time."
    ::= { dot11EBCSTrafficStreamEntry 11 }

(11bc)dot11EBCSTrafficStreamTimeToTermination OBJECT-TYPE
    SYNTAX Unsigned32 (0..65535)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external entity or the SME. Changes take effect as
        soon as practical in the implementation.
        This variable specifies the transmission termination timing of the EBCS
        traffic stream in unit of TBTT. A value of 0 indicates that this transmis-
        sion occurs in the beacon interval that starts at the next TBTT. A value
        of 1 indicates that it occurs in the beacon interval that follows that
        beacon interval. A value of 65535 indicates that there is no specific
        transmission termination time."
    ::= { dot11EBCSTrafficStreamEntry 12 }

(11bc)dot11EBCSTrafficStreamBufferableActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external entity or the SME. Changes take effect as
        soon as practical in the implementation.
        This variable, when true, indicates that the EBCS traffic stream is buff-
        ered and transmitted after an indication in an EBCS TIM field or an EBCS
        TIM element."
    ::= { dot11EBCSTrafficStreamEntry 13 }

(11bc)dot11EBCSTrafficStreamActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external entity or the SME. Changes take effect as
        soon as practical in the implementation.
        This variable is used by the EBCS receiver.
        This variable, when false, indicates that the EBCS receiver filters the
```


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```
        EBCS traffic stream."
    ::= { dot11EBCSTrafficStreamEntry 14 }

--********************************************************************
-- * End of dot11EBCSTrafficStreamTable TABLE
--********************************************************************


-- ************************************************************
-- * dot11STALCIConfig Table
-- ************************************************************
dot11STALCIConfigTable  OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11STALCIConfiguration
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "This object represents the sequence of STA's geospatial coordinates."

    ::= { dot11smt 36 }

dot11STALCIConfiguration OBJECT-TYPE
    SYNTAX Dot11STALCIConfiguration
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "This object represents the geospatial coordinates
        of the STA."
    INDEX { ifIndex }
    ::= { dot11STALCIConfigTable 1 }


Dot11STALCIConfiguration ::=
    SEQUENCE {
        dot11STALCIConfigLatitudeUncertainty                Unsigned32,
        dot11STALCIConfigLatitudeInteger                    Integer32,
        dot11STALCIConfigLatitudeFraction                   Integer32,
        dot11STALCIConfigLongitudeUncertainty               Unsigned32,
        dot11STALCIConfigLongitudeInteger                   Integer32,
        dot11STALCIConfigLongitudeFraction                  Integer32,
        dot11STALCIConfigAltitudeType                       INTEGER,
        dot11STALCIConfigAltitudeUncertainty                Unsigned32,
        dot11STALCIConfigAltitude                           Integer32,
        dot11STALCIConfigDatum                              INTEGER }

dot11STALCIConfigLatitudeUncertainty OBJECT-TYPE
    SYNTAX Unsigned32 (0..63)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.
        Latitude uncertainty is 6 bits indicating the amount of
        uncertainty in latitude value. A value of 0 is reserved to
        indicate that the uncertainty is unknown; values greater than
        34 are reserved. This field is derived from IETF RFC 6225."
    ::= { dot11STALCIConfiguration 1 }

dot11STALCIConfigLatitudeInteger OBJECT-TYPE
    SYNTAX Integer32 (-359..359)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
```

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```
        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.
        Latitude is a 2s complement 34-bit fixed point value consisting
        of 9 bits of integer and 25 bits of fraction. This field contains
        the 9 bits of integer portion of Latitude. This field is derived
        from IETF RFC 6225."
    ::= { dot11STALCIConfiguration 2 }

dot11STALCIConfigLatitudeFraction OBJECT-TYPE
    SYNTAX Integer32 (-16777215..16777215)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.
        Latitude is a 2s complement 34-bit fixed point value consisting
        of 9 bits of integer and 25 bits of fraction. This field contains
        the 25 bits of fraction portion of Latitude. This field is
        derived from IETF RFC 6225."
    ::= { dot11STALCIConfiguration 3 }

dot11STALCIConfigLongitudeUncertainty OBJECT-TYPE
    SYNTAX Unsigned32 (0..63)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.
        Longitude uncertainty is 6 bits indicating the amount of
        uncertainty in longitude value. A value of 0 is reserved to
        indicate that the uncertainty is unknown; values greater than 34
        are reserved. This field is derived from IETF RFC 6225."
    ::= { dot11STALCIConfiguration 4 }

dot11STALCIConfigLongitudeInteger OBJECT-TYPE
    SYNTAX Integer32 (-359..359)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.
        Longitude is a 2s complement 34-bit fixed point value consisting
        of 9 bits of integer and 25 bits of fraction. This field contains
        the 9 bits of integer portion of Longitude. This field is derived
        from IETF RFC 6225."
    ::= { dot11STALCIConfiguration 5 }

dot11STALCIConfigLongitudeFraction OBJECT-TYPE
    SYNTAX Integer32 (-16777215..16777215)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.
        Longitude is a 2s complement 34-bit fixed point value consisting
        of 9 bits of integer and 25 bits of fraction. This field contains
        the 25 bits of fraction portion of Longitude. This field is
        derived from IETF RFC 6225."
    ::= { dot11STALCIConfiguration 6 }
```


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```
dot11STALCIConfigAltitudeType OBJECT-TYPE
   SYNTAX INTEGER {
      meters(1),
      floors(2),
      hagm (3) }
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by an external management entity or the SME.
      Changes take effect as soon as practical in the implementation.
      Altitude Type is four bits encoding the type of altitude.
      Codes defined are:
      meters in 2s complement fixed-point 22-bit integer part with
      8-bit fraction
      floors: in 2s complement fixed-point 22-bit integer part with
      8-bit fraction
      hagm: Height Above Ground in meters, in 2s complement
      fixed-point 22-bit integer part with 8-bit fraction
      This field is derived from IETF RFC 6225."
   ::= { dot11STALCIConfiguration 7 }

dot11STALCIConfigAltitudeUncertainty OBJECT-TYPE
   SYNTAX Unsigned32 (0..63)
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by an external management entity or the SME.
      Changes take effect as soon as practical in the implementation.
      Altitude uncertainty is 6 bits indicating the amount of
      uncertainty in the altitude value. A value of 0 is reserved to
      indicate that altitude uncertainty is not known; values above 30
      are also reserved. Altitude uncertainty applies only to Altitude
      Type 1. This field is derived from IETF RFC 6225."
   ::= { dot11STALCIConfiguration 8 }

dot11STALCIConfigAltitude OBJECT-TYPE
   SYNTAX Integer32 (-536870912..536870911)
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by an external management entity or the SME.
      Changes take effect as soon as practical in the implementation.
      Altitude is a 30-bit value defined by the Altitude type field.
      The field is encoded as a 2s complement fixed-point 22-bit
      integer part with 8-bit fraction. This field is derived from IETF
      RFC 6225."
   ::= { dot11STALCIConfiguration 9 }

dot11STALCIConfigDatum OBJECT-TYPE
   SYNTAX INTEGER { wgs84 (1), nad83navd88 (2), nad93mllwvd (3) }
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by an external management entity or the SME.
      Changes take effect as soon as practical in the implementation.
      Datum is an 8-bit value encoding the horizontal and vertical
      References used for the coordinates given in this LCI.
      IETF RFC 6225 defines the values of Datum.
      Type 1 is WGS-84, the coordinate system used by GPS.
      Type 2 is NAD83 with NAVD88 vertical reference.
```

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```
        Type 3 is NAD83 with Mean Lower Low Water vertical datum.
        All other types are reserved.
        This field is derived from IETF RFC 6225."
    ::= { dot11STALCIConfiguration 10 }

-- ************************************************************
-- * End of dot11STALCIConfig
-- ************************************************************

-- ************************************************************
-- * dot11STACivicLocationConfig Table
-- ************************************************************
dot11STACivicLocationConfigTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11STACivicLocationConfiguration
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "This object represents the sequence of STA's civic location."
    ::= { dot11smt 37 }

dot11STACivicLocationConfiguration OBJECT-TYPE
    SYNTAX Dot11STACivicLocationConfiguration
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "This object represents the civic location of the STA."
    INDEX { ifIndex }
    ::= { dot11STACivicLocationConfigTable 1 }

Dot11STACivicLocationConfiguration ::=
    SEQUENCE {
        dot11STACivicLocationType                    INTEGER,
        dot11STACivicLocation                        OCTET STRING
        }

dot11STACivicLocationType OBJECT-TYPE
    SYNTAX INTEGER (0..255)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.
        Civic Location type is defined in 9.4.2.19.14 (Location Civic request)."
    ::= { dot11STACivicLocationConfiguration 1 }

dot11STACivicLocation OBJECT-TYPE
    SYNTAX OCTET STRING
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.
        Civic Location is defined in 9.4.2.20.13 (Location Civic report)."
    ::= { dot11STACivicLocationConfiguration 2 }

-- ************************************************************
-- * End of dot11STACivicLocationConfig
-- ************************************************************

-- ************************************************************
-- * MAC Attribute Templates
-- ************************************************************
```


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```
--
-- ****************************************************************
-- * dot11Operation TABLE
-- ****************************************************************

dot11OperationTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11OperationEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "Group contains MAC attributes pertaining to the operation of the MAC.
        This has been implemented as a table in order to allow for multiple
        instances(#467) on an agent."
    ::= { dot11mac 1 }

dot11OperationEntry OBJECT-TYPE
    SYNTAX Dot11OperationEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "An entry in the dot11OperationEntry Table.

        ifIndex - Each IEEE 802.11 interface is represented by an ifEntry.
        Interface tables in this MIB module are indexed by ifIndex."
    INDEX { ifIndex }
    ::= { dot11OperationTable 1 }

Dot11OperationEntry ::=
    SEQUENCE {
        dot11MACAddress                                 MacAddress,
        dot11RTSThreshold                               Unsigned32,
        dot11ShortRetryLimit                            Unsigned32,
        dot11LongRetryLimit                             Unsigned32,
        dot11FragmentationThreshold                     Unsigned32,
        dot11MaxTransmitMSDULifetime                    Unsigned32,
        dot11MaxReceiveLifetime                         Unsigned32,
        dot11ManufacturerID                             DisplayString,
        dot11ProductID                                  DisplayString,
        dot11CAPLimit                                   Unsigned32,
        dot11HCCWmin                                    Unsigned32,
        dot11HCCWmax                                    Unsigned32,
        dot11HCCAIFSN                                   Unsigned32,
        dot11ADDBAResponseTimeout                       Unsigned32,
        dot11ADDTSResponseTimeout                       Unsigned32,
        dot11ChannelUtilizationBeaconIntervals          Unsigned32,
        dot11ScheduleTimeout                            Unsigned32,
        dot11DLSResponseTimeout                         Unsigned32,
        dot11QAPMissingAckRetryLimit                    Unsigned32,
        dot11EDCAAveragingPeriod                        Unsigned32,
        dot11HTProtection                               INTEGER,
        dot11RIFSMode                                   TruthValue,
        dot11PSMPControlledAccess                       TruthValue,
        dot11ServiceIntervalGranularity                 Unsigned32,
        dot11DualCTSProtection                          TruthValue,
        dot11LSIGTXOPFullProtectionActivated            TruthValue,
        dot11NonGFEntitiesPresent                       TruthValue,
        dot11PCOActivated                               TruthValue,
        dot11PCOFortyMaxDuration                        Unsigned32,
        dot11PCOTwentyMaxDuration                       Unsigned32,
        dot11PCOFortyMinDuration                        Unsigned32,
        dot11PCOTwentyMinDuration                       Unsigned32,
        dot11FortyMHzIntolerant                         TruthValue,
        dot11BSSWidthTriggerScanInterval                Unsigned32,
        dot11BSSWidthChannelTransitionDelayFactor       Unsigned32,
```

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```
        dot11OBSSScanPassiveDwell                                Unsigned32,
        dot11OBSSScanActiveDwell                                 Unsigned32,
        dot11OBSSScanPassiveTotalPerChannel                      Unsigned32,
        dot11OBSSScanActiveTotalPerChannel                       Unsigned32,
        dot112040BSSCoexistenceManagementSupport                 TruthValue,
        dot11OBSSScanActivityThreshold                           Unsigned32 }

dot11MACAddress OBJECT-TYPE
    SYNTAX MacAddress
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        Unique MAC Address assigned to the STA."
    ::= { dot11OperationEntry 1 }

dot11RTSThreshold OBJECT-TYPE
    SYNTAX Unsigned32 (0..6500631)(11ax)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute indicates the number of octets in a PSDU, below which an
        RTS/CTS handshake is not performed if dot11TXOPDurationRTSThreshold is
        1023 or it is not present,(11ax) except as RTS/CTS is used as a cross mod-
        ulation protection mechanism as defined in 10.27 (Protection mechanisms).
        An RTS/CTS handshake is performed at the beginning of any frame exchange
        sequence where the PSDU contains an MPDU with the Type subfield equal to
        Data or Management and an individual address in the Address 1 field, and
        the length of the PSDU is greater than this threshold. Setting this attri-
        bute to be larger than the maximum PSDU size has the effect of turning off
        the RTS/CTS handshake for frames of Data or Management type transmitted by
        this STA. Setting this attribute to 0 has the effect of turning on the
        RTS/CTS handshake for all frames of Data or Management type transmitted by
        this STA."
    DEFVAL { 6500631 }(11ax)
    ::= { dot11OperationEntry 2 }

dot11ShortRetryLimit OBJECT-TYPE
    SYNTAX Unsigned32 (1..65535)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute indicates the maximum number of transmission attempts of a
        frame that are made before a failure condition is indicated."
    DEFVAL { 7 }
    ::= { dot11OperationEntry 3 }

dot11LongRetryLimit OBJECT-TYPE
    SYNTAX Unsigned32 (1..255)
    MAX-ACCESS read-write
    STATUS deprecated
    DESCRIPTION
        "Deprecated as the related feature has been removed from IEEE Std 802.11.
        This is a control variable.
```


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```
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute indicates the maximum number of transmission attempts of a
        frame, in a PSDU of length that is greater than dot11RTSThreshold, that is
        made before a failure condition is indicated."
    DEFVAL { 4 }
    ::= { dot11OperationEntry 4 }

dot11FragmentationThreshold OBJECT-TYPE
    SYNTAX Unsigned32 (256..65535)
    UNITS "octets"
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute specifies the maximum size of an individually addressed
        MPDU beyond which the corresponding MSDU or MMPDU is fragmented, except
        when an MSDU is transmitted under an HT-immediate block ack agreement, or
        when an MSDU is carried in an A-MSDU, or when an MSDU or MMPDU is carried
        in an A-MPDU that does not contain a S-MPDU. Fields added to the MPDU by
        security encapsulation are not counted against the limit specified by this
        attribute. An MSDU or MMPDU might be fragmented even if it is smaller."
    DEFVAL { 65535 }
    ::= { dot11OperationEntry 5 }

dot11MaxTransmitMSDULifetime OBJECT-TYPE
    SYNTAX Unsigned32 (1..4294967295)
    UNITS "TUs"
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute specifies the elapsed time, after the initial transmission
        of an MSDU/MMPDU (or the first fragment thereof), after which further
        attempts to transmit the MSDU/MMPDU are terminated."
    DEFVAL { 512 }
    ::= { dot11OperationEntry 6 }

dot11MaxReceiveLifetime OBJECT-TYPE
    SYNTAX Unsigned32 (1..4294967295)
    UNITS "TUs"
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        The MaxReceiveLifetime is the elapsed time, after the initial reception of
        a fragmented MMPDU or MSDU, after which further attempts to reassemble the
        MMPDU or MSDU are terminated."
    DEFVAL { 512 }
    ::= { dot11OperationEntry 7 }

dot11ManufacturerID OBJECT-TYPE
    SYNTAX DisplayString (SIZE(0..128))
    MAX-ACCESS read-only
```

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```
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        The ManufacturerID includes, at a minimum, the name of the manufacturer.
        It may include additional information at the manufacturer's discretion."
    ::= { dot11OperationEntry 8 }

dot11ProductID OBJECT-TYPE
    SYNTAX DisplayString (SIZE(0..128))
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        The ProductID includes, at a minimum, an identifier that is unique to the
        manufacturer. It may include additional information at the manufacturer's
        discretion."
    ::= { dot11OperationEntry 9 }

dot11CAPLimit OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute specifies the maximum number of TUs a Controlled access
        phase(CAP) can last."
    ::= { dot11OperationEntry 10 }

dot11HCCWmin OBJECT-TYPE
    SYNTAX Unsigned32 -- (0..aCWmin)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute specifies the value of the minimum size of the window that
        is used by the HC for generating a random number for the backoff. The
        value of this attribute is such that it could always be expressed in the
        form of 2^X - 1, where X is an integer."
    DEFVAL { 0 }
    ::= { dot11OperationEntry 11 }

dot11HCCWmax OBJECT-TYPE
    SYNTAX Unsigned32 -- (0..aCWmax)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute specifies the value of the maximum size of the window that
        is used by the HC for generating a random number for the backoff. The
        value of this attribute is such that it could always be expressed in the
        form of 2^X - 1, where X is an integer."
```


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```
    DEFVAL { 0 }
    ::= { dot11OperationEntry 12 }

dot11HCCAIFSN OBJECT-TYPE
    SYNTAX Unsigned32 (1..15)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute specifies the number of slots, after a SIFS, that the HC
        senses the medium idle either before transmitting or executing a backoff."
    DEFVAL { 1 }
    ::= { dot11OperationEntry 13 }

dot11ADDBAResponseTimeout OBJECT-TYPE
    SYNTAX Unsigned32 (1..65535)
    UNITS "seconds"
    MAX-ACCESS read-write
    STATUS deprecated
    DESCRIPTION
        "Deprecated as the related feature has been removed from IEEE Std 802.11.
        This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute specifies the timeout for an ADDBA Response frame that is a
        response to an ADDBA Request frame."
    DEFVAL { 1 }
    ::= { dot11OperationEntry 14 }

dot11ADDTSResponseTimeout OBJECT-TYPE
    SYNTAX Unsigned32 (1..65535)
    MAX-ACCESS read-write
    STATUS deprecated
    DESCRIPTION
        "Deprecated as the related feature has been removed from IEEE Std 802.11.
        This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute specifies the maximum number of seconds an ADDTS request is
        to be responded."
    DEFVAL { 1 }
    ::= { dot11OperationEntry 15 }

dot11ChannelUtilizationBeaconIntervals OBJECT-TYPE
    SYNTAX Unsigned32 (1..100)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute indicates the number of beacon intervals over which the
        channel busy time should be averaged."
    DEFVAL { 50 }
    ::= { dot11OperationEntry 16 }

dot11ScheduleTimeout OBJECT-TYPE
    SYNTAX Unsigned32 (1..100)
```

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```
    UNITS "TUs"
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
       "This is a control variable.
       It is written by an external management entity.
       Changes take effect as soon as practical in the implementation.

       This attribute indicates the duration after which a STA could go into
       power save mode."
    DEFVAL { 10 }
    ::= { dot11OperationEntry 17 }

dot11DLSResponseTimeout OBJECT-TYPE
    SYNTAX Unsigned32 (1..65535)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
       "This is a control variable.
       It is written by an external management entity.
       Changes take effect as soon as practical in the implementation.

       This attribute specifies the maximum number of seconds a direct link
       request is to be responded."
    DEFVAL { 10 }
    ::= { dot11OperationEntry 18 }

dot11QAPMissingAckRetryLimit OBJECT-TYPE
    SYNTAX Unsigned32 (1..100)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
       "This is a control variable.
       It is written by an external management entity.
       Changes take effect as soon as practical in the implementation.

       This attribute indicates the number of times the AP may retry a frame for
       which it does not receive an acknowledgment for a STA in power save mode
       after receiving a PS-Poll frame and sending an individually addressed
       response or after receiving a U-APSD trigger frame and sending an individ-
       ually addressed response with the EOSP subfield equal to 1."
    ::= { dot11OperationEntry 19 }

dot11EDCAAveragingPeriod OBJECT-TYPE
    SYNTAX Unsigned32 (1..100)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
       "This is a control variable.
       It is written by an external management entity.
       Changes take effect as soon as practical in the implementation.

       This attribute indicates the number of seconds over which the admitted_-
       time and used_time are computed."
    DEFVAL { 5 }
    ::= { dot11OperationEntry 20 }

dot11HTProtection OBJECT-TYPE
    SYNTAX INTEGER {
       htNoProtection (0),
       htNonmemberProtection(1),
       ht20MHzProtection(2),
       htNonHTmixed(3) }
    MAX-ACCESS read-write
```


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```
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute indicates the level of protection that needs to be provided
        to the transmissions in an IEEE 802.11 network with HT STAs."
    DEFVAL { htNoProtection }
    ::= { dot11OperationEntry 21 }

dot11RIFSMode OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute, when true, indicates that use of RIFS is allowed in the
        BSS."
    DEFVAL { false }
    ::= { dot11OperationEntry 22 }

dot11PSMPControlledAccess OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS deprecated(#3263)
    DESCRIPTION
        "(#3263)Deprecated as the related feature has been removed from the stan-
        dard.
        This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute, when true indicates that the AP accepts associations only
        from STAs for which dot11PSMPOptionImplemented is true."
    DEFVAL { false }
    ::= { dot11OperationEntry 23 }

dot11ServiceIntervalGranularity OBJECT-TYPE
    SYNTAX Unsigned32 (0..7)
    MAX-ACCESS read-write
    STATUS deprecated(#3263)
    DESCRIPTION
        "(#3263)Deprecated as the related feature has been removed from the stan-
        dard.
        This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute indicates the SI granularity to be used for scheduled PSMP.
        The value of the granularity is given by
        (dot11ServiceIntervalGranularity+1)*5 ms."
    DEFVAL { 0 }
    ::= { dot11OperationEntry 24 }

dot11DualCTSProtection OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
```

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```
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute, when true indicates that the AP uses dual CTS protection
        to protect the non-STBC frame and STBC frame transmissions."
    DEFVAL { false }
    ::= { dot11OperationEntry 25 }

dot11LSIGTXOPFullProtectionActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS deprecated
    DESCRIPTION
        "Deprecated as the related feature has been removed from IEEE Std 802.11.
        This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute, when true, indicates that the L-SIG TXOP protection may be
        used by STAs that have the attribute
        dot11LsigTxopProtectionOptionImplemented equal to true."
    DEFVAL { false }
    ::= { dot11OperationEntry 26 }

dot11NonGFEntitiesPresent OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when it determines that the presence of
        greenfield stations in the BSS has changed.

        This attribute, when true, indicates that STA that are not HT-greenfield
        Capable are present in the BSS."
    DEFVAL { false }
    ::= { dot11OperationEntry 27 }

dot11PCOActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS deprecated
    DESCRIPTION
        "Deprecated as the related feature has been removed from IEEE Std 802.11.
        This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute, when true, indicates that the PCO is activated."
    DEFVAL { false }
    ::= { dot11OperationEntry 28 }

dot11PCOFortyMaxDuration OBJECT-TYPE
    SYNTAX Unsigned32 (1..200)
    MAX-ACCESS read-write
    STATUS deprecated
    DESCRIPTION
        "Deprecated as the related feature has been removed from IEEE Std 802.11.
        This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        The attribute indicates the maximum duration of 40 MHz phase in TU under
        PCO operation. The value of this attribute shall be equal to or larger
```


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```
        than dot11PCOFortyMinDuration."
    DEFVAL { 30 }
    ::= { dot11OperationEntry 29 }

dot11PCOTwentyMaxDuration OBJECT-TYPE
    SYNTAX Unsigned32 (1..200)
    MAX-ACCESS read-write
    STATUS deprecated
    DESCRIPTION
        "Deprecated as the related feature has been removed from IEEE Std 802.11.
        This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        The attribute indicates the maximum duration of 20 MHz phase in TU under
        PCO operation. The value of this attribute shall be equal to or larger
        than dot11PCOTwentyMinDuration."
    DEFVAL { 30 }
    ::= { dot11OperationEntry 30 }

dot11PCOFortyMinDuration OBJECT-TYPE
    SYNTAX Unsigned32 (1..200)
    MAX-ACCESS read-write
    STATUS deprecated
    DESCRIPTION
        "Deprecated as the related feature has been removed from IEEE Std 802.11.
        This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        The attribute indicates the minimum duration of 40 MHz phase in TU under
        PCO operation."
    DEFVAL { 20 }
    ::= { dot11OperationEntry 31 }

dot11PCOTwentyMinDuration OBJECT-TYPE
    SYNTAX Unsigned32 (1..200)
    MAX-ACCESS read-write
    STATUS deprecated
    DESCRIPTION
        "Deprecated as the related feature has been removed from IEEE Std 802.11.
        This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        The attribute indicates the minimum duration of 20 MHz phase in TU under
        PCO operation."
    DEFVAL { 20 }
    ::= { dot11OperationEntry 32 }

dot11FortyMHzIntolerant OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute, when true, indicates that the STA requests that 40 MHz
        mask PPDUs are not transmitted within range of the STA."
    DEFVAL { false }
    ::= { dot11OperationEntry 33 }
```

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```
dot11BSSWidthTriggerScanInterval OBJECT-TYPE
   SYNTAX Unsigned32 (10..900)
   UNITS "seconds"
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by an external management entity.
      Changes take effect as soon as practical in the implementation.

      This attribute indicates the maximum interval between scan operations to
      be performed to detect BSS channel width trigger events."
   DEFVAL { 300 }
   ::= { dot11OperationEntry 34 }

dot11BSSWidthChannelTransitionDelayFactor OBJECT-TYPE
   SYNTAX Unsigned32 (5..100)
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by an external management entity.
      Changes take effect as soon as practical in the implementation.

      This attribute indicates the minimum ratio between the delay time in
      performing a switch from 20 MHz BSS operation to 20/40 MHz BSS operation
      and the maximum interval between OBSS scan operations."
   DEFVAL { 5 }
   ::= { dot11OperationEntry 35 }

dot11OBSSScanPassiveDwell OBJECT-TYPE
   SYNTAX Unsigned32 (5..1000)
   UNITS "TUs"
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by an external management entity.
      Changes take effect as soon as practical in the implementation.

      This attribute indicates the minimum amount of time that the STA
      continuously scans each channel when performing a passive OBSS scan
      operation."
   DEFVAL { 20 }
   ::= { dot11OperationEntry 36 }

dot11OBSSScanActiveDwell OBJECT-TYPE
   SYNTAX Unsigned32 (10..1000)
   UNITS "TUs"
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by an external management entity.
      Changes take effect as soon as practical in the implementation.

      This attribute indicates the minimum amount of time that the STA
      continuously scans each channel when performing an active OBSS scan
      operation."
   DEFVAL { 10 }
   ::= { dot11OperationEntry 37 }

dot11OBSSScanPassiveTotalPerChannel OBJECT-TYPE
   SYNTAX Unsigned32 (200..10000)
```


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```
    UNITS "TUs"
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
       "This is a control variable.
       It is written by an external management entity.
       Changes take effect as soon as practical in the implementation.

       This attribute indicates the minimum total amount of time that the STA
       scans each channel when performing a passive OBSS scan operation."
    DEFVAL { 200 }
    ::= { dot11OperationEntry 38 }

dot11OBSSScanActiveTotalPerChannel OBJECT-TYPE
    SYNTAX Unsigned32 (20..10000)
    UNITS "TUs"
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
       "This is a control variable.
       It is written by an external management entity.
       Changes take effect as soon as practical in the implementation.

       This attribute indicates the minimum total amount of time that the STA
       scans each channel when performing an active OBSS scan operation."
    DEFVAL { 20 }
    ::= { dot11OperationEntry 39 }

dot112040BSSCoexistenceManagementSupport OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
       "This is a capability variable.
       Its value is determined by (#3375)STA capabilities.

       This attribute, when true, indicates that the STA supports the
       transmission and reception of the 20/40 BSS Coexistence Management frame."
    ::= { dot11OperationEntry 40 }

dot11OBSSScanActivityThreshold OBJECT-TYPE
    SYNTAX Unsigned32 (0..100)
    UNITS "0.01%"
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
       "This is a control variable.
       It is written by an external management entity.
       Changes take effect as soon as practical in the implementation.

       This attribute indicates the maximum total time that a STA may be active
       on the medium during a period of dot11BSSWidthChannelTransitionDelayFactor
       * dot11BSSWidthTriggerScanInterval seconds without being obligated to
       perform OBSS Scan operations."
    DEFVAL { 25 }
    ::= { dot11OperationEntry 41}

-- ****************************************************************
-- *    End of dot11Operation TABLE
-- ****************************************************************

-- ****************************************************************
-- *    dot11Counters TABLE
-- ****************************************************************

```

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```
dot11CountersTable OBJECT-TYPE
   SYNTAX SEQUENCE OF Dot11CountersEntry
   MAX-ACCESS not-accessible
   STATUS current
   DESCRIPTION
      "Group containing attributes that are MAC counters. Implemented as a table
      to allow for multiple instances(#467) on an agent."
   ::= { dot11mac 2 }

dot11CountersEntry OBJECT-TYPE
   SYNTAX Dot11CountersEntry
   MAX-ACCESS not-accessible
   STATUS current
   DESCRIPTION
      "An entry in the dot11CountersEntry Table.

      ifIndex - Each IEEE 802.11 interface is represented by an ifEntry.
      Interface tables in this MIB module are indexed by ifIndex."
   INDEX { ifIndex }
   ::= { dot11CountersTable 1 }

Dot11CountersEntry ::=
   SEQUENCE {
      dot11TransmittedFragmentCount                  Counter32,
      dot11GroupTransmittedFrameCount                Counter32,
      dot11FailedCount                               Counter32,
      dot11RetryCount                                Counter32,
      dot11MultipleRetryCount                        Counter32,
      dot11FrameDuplicateCount                       Counter32,
      dot11RTSSuccessCount                           Counter32,
      dot11RTSFailureCount                           Counter32,
      dot11AckFailureCount                           Counter32,
      dot11ReceivedFragmentCount                     Counter32,
      dot11GroupReceivedFrameCount                   Counter32,
      dot11FCSErrorCount                             Counter32,
      dot11TransmittedFrameCount                     Counter32,
      dot11WEPUndecryptableCount                     Counter32,
      dot11QosDiscardedFragmentCount                 Counter32,
      dot11AssociatedStationCount                    Counter32,
      dot11QosCFPollsReceivedCount                   Counter32,
      dot11QosCFPollsUnusedCount                     Counter32,
      dot11QosCFPollsUnusableCount                   Counter32,
      dot11QosCFPollsLostCount                       Counter32,
      dot11TransmittedAMSDUCount                     Counter32,
      dot11FailedAMSDUCount                          Counter32,
      dot11RetryAMSDUCount                           Counter32,
      dot11MultipleRetryAMSDUCount                   Counter32,
      dot11TransmittedOctetsInAMSDUCount             Counter64,
      dot11AMSDUAckFailureCount                      Counter32,
      dot11ReceivedAMSDUCount                        Counter32,
      dot11ReceivedOctetsInAMSDUCount                Counter64,
      dot11TransmittedAMPDUCount                     Counter32,
      dot11TransmittedMPDUsInAMPDUCount              Counter32,
      dot11TransmittedOctetsInAMPDUCount             Counter64,
      dot11AMPDUReceivedCount                        Counter32,
      dot11MPDUInReceivedAMPDUCount                  Counter32,
      dot11ReceivedOctetsInAMPDUCount                Counter64,
      dot11AMPDUDelimiterCRCErrorCount               Counter32,
      dot11ImplicitBARFailureCount                   Counter32,
      dot11ExplicitBARFailureCount                   Counter32,
      dot11ChannelWidthSwitchCount                   Counter32,
      dot11TwentyMHzFrameTransmittedCount            Counter32,
      dot11FortyMHzFrameTransmittedCount             Counter32,
```


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```
        dot11TwentyMHzFrameReceivedCount                Counter32,
        dot11FortyMHzFrameReceivedCount                 Counter32,
        dot11PSMPUTTGrantDuration                       Counter32,
        dot11PSMPUTTUsedDuration                        Counter32,
        dot11GrantedRDGUsedCount                        Counter32,
        dot11GrantedRDGUnusedCount                      Counter32,
        dot11TransmittedFramesInGrantedRDGCount         Counter32,
        dot11TransmittedOctetsInGrantedRDGCount         Counter64,
        dot11BeamformingFrameCount                      Counter32,
        dot11DualCTSSuccessCount                        Counter32,
        dot11DualCTSFailureCount                        Counter32,
        dot11STBCCTSSuccessCount                        Counter32,
        dot11STBCCTSFailureCount                        Counter32,
        dot11nonSTBCCTSSuccessCount                     Counter32,
        dot11nonSTBCCTSFailureCount                     Counter32,
        dot11RTSLSIGSuccessCount                        Counter32,
        dot11RTSLSIGFailureCount                        Counter32,
        dot11PBACErrors                                 Counter32,
        dot11DeniedAssociationCounterDueToBSSLoad       Counter32,
        dot11TransmittedMSDUOctetsCount                 Counter64,
        dot11ReceivedMSDUOctetsCount                    Counter64
    }

dot11TransmittedFragmentCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "(#6157)This is a status variable.

        (#7208)This counter is incremented when a Data (including QoS Data and
        (QoS) Null) or Management frame is successfully transmitted."
    ::= { dot11CountersEntry 1 }

dot11GroupTransmittedFrameCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "(#6158)This is a status variable.

        This counter is incremented when an MSDU with a destination address that
        is a group address is successfully transmitted (not necessarily in a sin-
        gle frame)."
    ::= { dot11CountersEntry 2 }

dot11FailedCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the MAC when the condition described below occurs.

        This counter increments when an MSDU is not transmitted successfully due
        to the number of transmit attempts exceeding the dot11ShortRetryLimit."
    ::= { dot11CountersEntry 3 }

dot11RetryCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
```

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```
        It is written by the MAC when the condition described below occurs.

        This counter increments when an MSDU is successfully transmitted after one
        or more retransmissions."
    ::= { dot11CountersEntry 4 }

dot11MultipleRetryCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the MAC when the condition described below occurs.

        This counter increments when an MSDU is successfully transmitted after
        more than one retransmission."
    ::= { dot11CountersEntry 5 }

dot11FrameDuplicateCount  OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the MAC when the condition described below occurs.

        This counter increments when a frame is received that the Sequence Control
        field indicates is a duplicate."
    ::= { dot11CountersEntry 6 }

dot11RTSSuccessCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the MAC when a CTS frame is received in response to an
        RTS.

        This counter increments when a CTS frame is received in response to an
        RTS."
    ::= {  dot11CountersEntry 7 }

dot11RTSFailureCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the MAC when the condition described below occurs.

        This counter increments when a CTS frame is not received in response to an
        RTS."
    ::= { dot11CountersEntry 8 }

dot11AckFailureCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the MAC when the condition described below occurs.

        This counter increments when an Ack frame is not received when expected."
```


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```
    ::= {  dot11CountersEntry 9 }

dot11ReceivedFragmentCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the MAC when a fragment is received.

        This counter is incremented for each received MPDU with the Type subfield
        equal to Data or Management."
    ::= { dot11CountersEntry 10 }

dot11GroupReceivedFrameCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the MAC when a group addressed frame is received.

        This counter increments when an MSDU is received with the group bit set in
        the destination MAC address."
    ::= { dot11CountersEntry 11 }

dot11FCSErrorCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the MAC when the condition described below occurs.

        This counter increments when an FCS error is detected in a received MPDU."
    ::= { dot11CountersEntry 12 }

dot11TransmittedFrameCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "(#6158)This is a status variable.

        This counter is incremented when an MSDU is successfully transmitted (not
        necessarily in a single frame)."
    ::= { dot11CountersEntry 13 }

dot11WEPUndecryptableCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS deprecated(#4073)
    DESCRIPTION
        "(#4073)Deprecated because WEP has been removed from (#6318)IEEE Std
        802.11.
        This is a status variable.
        It is written by the MAC when the condition described below occurs.

        This counter increments when a frame is received with the Protected Frame
        subfield of the Frame Control field equal to 1 and the WEPOn value for the
        key mapped to the transmitter's MAC address indicates that the frame
        should not have been encrypted or that frame is discarded due to the
        receiving STA not implementing the privacy option."
    ::= { dot11CountersEntry 14 }
```

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```
dot11QosDiscardedFragmentCount OBJECT-TYPE
   SYNTAX Counter32
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a status variable.
      It is written by the MAC when the condition described below occurs.

      This counter increments for each QoS Data frame that has been discarded."
   ::= { dot11CountersEntry 15 }

dot11AssociatedStationCount OBJECT-TYPE
   SYNTAX Counter32
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a status variable.
      It is written by the MAC when a STA associates or disassociates.

      This counter, only available at AP, increments when a station associates
      or reassociates. This counter decrements when a station disassociates."
   ::= { dot11CountersEntry 16 }

dot11QosCFPollsReceivedCount OBJECT-TYPE
   SYNTAX Counter32
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a status variable.
      It is written by the MAC when a CF-Poll is received.

      This counter increments for each QoS (+)CF-Poll that has been received."
   ::= { dot11CountersEntry 17 }

dot11QosCFPollsUnusedCount OBJECT-TYPE
   SYNTAX Counter32
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a status variable.
      It is written by the MAC when a CF-Poll is unused.

      This counter increments for each QoS (+)CF-Poll that has been received but
      not used."
   ::= { dot11CountersEntry 18 }

dot11QosCFPollsUnusableCount OBJECT-TYPE
   SYNTAX Counter32
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a status variable.
      It is written by the MAC when the condition described below occurs.

      This counter increments for each QoS (+)CF-Poll that has been received but
      could not be used due to the TXOP size being smaller than the time that is
      required for one frame exchange sequence."
   ::= { dot11CountersEntry 19 }

dot11QosCFPollsLostCount OBJECT-TYPE
   SYNTAX Counter32
   MAX-ACCESS read-only
   STATUS current
```


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```
    DESCRIPTION
        "This is a status variable.
        It is written by the MAC when the condition described below occurs.

        This counter increments for each QoS (+)CF-Poll that has been issued where
        there was no response from the QoS STA."
    ::= { dot11CountersEntry 20 }

dot11TransmittedAMSDUCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the MAC when a transmitted A-MSDU is acknowledged.

        This counter shall be incremented for an acknowledged frame that contains
        an A-MSDU(#1996) with an individual address in the Address 1 field or a
        frame that contains an A-MSDU(#1996) with a group address in the Address 1
        field."
    ::= { dot11CountersEntry 21 }

dot11FailedAMSDUCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the MAC when the condition described below occurs.

        This counter shall be incremented when an A-MSDU is not transmitted
        successfully due to the number of transmit attempts exceeding the
        dot11ShortRetryLimit."
    ::= { dot11CountersEntry 22 }

dot11RetryAMSDUCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the MAC when a transmitted A-MSDU is acknowledged only
        after one or more retransmissions.

        This counter shall be incremented when an A-MSDU is successfully
        transmitted after one or more retransmissions."
    ::= { dot11CountersEntry 23 }

dot11MultipleRetryAMSDUCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the MAC when a transmitted A-MSDU is acknowledged only
        after more than one retransmission.

        This counter shall be incremented when an A-MSDU is successfully
        transmitted after more than one retransmission."
    ::= { dot11CountersEntry 24 }

dot11TransmittedOctetsInAMSDUCount OBJECT-TYPE
    SYNTAX Counter64
    MAX-ACCESS read-only
```

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```
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the MAC when an A-MSDU is transmitted.

        This counter shall be incremented by the number of octets in the frame
        body of a frame that contains an A-MSDU when it is(#1996) successfully
        transmitted."
    ::= { dot11CountersEntry 25 }

dot11AMSDUAckFailureCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the MAC when the condition described below occurs.

        This counter shall be incremented when an acknowledgment to an A-MSDU is
        not received when expected. This acknowledgment can be in an Ack or Block-
        Ack frame."
    ::= { dot11CountersEntry 26 }

dot11ReceivedAMSDUCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the MAC when an A-MSDU is received.

        This counter shall be incremented for a received frame that contains an A-
        MSDU(#1996) with the STA's MAC address in the Address 1 field or a frame
        that contains an A-MSDU(#1996) with a group address in the Address 1
        field."
    ::= { dot11CountersEntry 27 }

dot11ReceivedOctetsInAMSDUCount OBJECT-TYPE
    SYNTAX Counter64
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the MAC when an A-MSDU is received.

        This counter shall be incremented by the number of octets in the frame
        body of an A-MSDU frame when an A-MSDU frame is received."
    ::= { dot11CountersEntry 28 }

dot11TransmittedAMPDUCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the MAC when an A-MPDU is transmitted.

        This counter shall be incremented when an A-MPDU is transmitted."
    ::= { dot11CountersEntry 29 }

dot11TransmittedMPDUsInAMPDUCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
```


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```
    DESCRIPTION
        "This is a status variable.
        It is written by the MAC when an A-MPDU is transmitted.

        This counter shall increment by the number of MPDUs in the A-MPDU when an
        A-MPDU is transmitted."
    ::= { dot11CountersEntry 30 }

dot11TransmittedOctetsInAMPDUCount OBJECT-TYPE
    SYNTAX Counter64
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the MAC when an A-MPDU is transmitted.

        This counter shall be incremented by the number of octets in the A-MPDU
        frame when an A-MPDU frame is transmitted."
    ::= { dot11CountersEntry 31 }

dot11AMPDUReceivedCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the MAC when an A-MPDU is received.

        This counter shall be incremented when the MAC receives an A-MPDU from the
        PHY."
    ::= { dot11CountersEntry 32 }

dot11MPDUInReceivedAMPDUCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the MAC when an A-MPDU is received.

        This counter shall be incremented by the number of MPDUs received in the
        A-MPDU when an A-MPDU is received."
    ::= { dot11CountersEntry 33 }

dot11ReceivedOctetsInAMPDUCount OBJECT-TYPE
    SYNTAX Counter64
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the MAC when an A-MPDU is received.

        This counter shall be incremented by the number of octets in the A-MPDU
        frame when an A-MPDU frame is received."
    ::= { dot11CountersEntry 34 }

dot11AMPDUDelimiterCRCErrorCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the MAC when the condition described below occurs.
```

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```
        This counter shall be incremented when an MPDU delimiter has a CRC error
        when this is the first CRC error in the received A-MPDU or when the
        previous delimiter has been decoded correctly."
    ::= { dot11CountersEntry 35 }

dot11ImplicitBARFailureCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the MAC when the condition described below occurs.

        This counter shall be incremented when the expected BlockAck frame is not
        received in response to an implicit block ack request."
    ::= { dot11CountersEntry 36 }

dot11ExplicitBARFailureCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the MAC when the condition described below occurs.

        This counter shall be incremented when the expected BlockAck frame is not
        received in response to a BlockAckReq frame."
    ::= { dot11CountersEntry 37 }

dot11ChannelWidthSwitchCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the MAC when the bandwidth is switched.

        This counter shall be increment when the bandwidth used is switched from
        20 to 40 or vice versa."
    ::= { dot11CountersEntry 38 }

dot11TwentyMHzFrameTransmittedCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the MAC when a frame is transmitted only on the primary
        channel.

        This counter shall be incremented when a frame is transmitted only on the
        primary channel."
    ::= { dot11CountersEntry 39 }

dot11FortyMHzFrameTransmittedCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the MAC when a frame is transmitted on both control and
        secondary channels.

        This counter shall be incremented when a frame is transmitted on both
```


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```
        control and secondary channels."
    ::= { dot11CountersEntry 40 }

dot11TwentyMHzFrameReceivedCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the MAC when a frame is received only on the primary
        channel.

        This counter shall be incremented when a frame is received only on the
        primary channel."
    ::= { dot11CountersEntry 41 }

dot11FortyMHzFrameReceivedCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the MAC when a frame is received on both the control and
        secondary channels.

        This counter shall be incremented when a frame is received on both the
        control and secondary channels."
    ::= { dot11CountersEntry 42 }

dot11PSMPUTTGrantDuration OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS deprecated(#3263)
    DESCRIPTION
        "(#3263)Deprecated as the related feature has been removed from the stan-
        dard.
        This is a status variable.
        It is written by the MAC when a PSMP-UTT is granted.

        This counter contains the cumulative duration of PSMP-UTT granted to the
        STA, in units of 4 microseconds."
    ::= { dot11CountersEntry 43 }

dot11PSMPUTTUsedDuration OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS deprecated(#3263)
    DESCRIPTION
        "(#3263)Deprecated as the related feature has been removed from the stan-
        dard.
        This is a status variable.
        It is written by the MAC when a PSMP-UTT is used.

        This counter contains the cumulative duration of transmission by the STA
        during its allocated PSMP-UTT, in units of 4 microseconds"
    ::= { dot11CountersEntry 44 }

dot11GrantedRDGUsedCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the MAC when an RDG is used.
```

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```
        This counter at the RD initiator shall be incremented when an allocated
        RDG is used by the station, apart from transmitting a response frame such
        as Ack or BlockAck frames."
    ::= { dot11CountersEntry 45 }

dot11GrantedRDGUnusedCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the MAC when an RDG is not used.

        This counter at the initiator shall be incremented when an allocated RDG
        is not used by the station, apart from transmitting a response frame such
        as Ack or BlockAck frames."
    ::= { dot11CountersEntry 46 }

dot11TransmittedFramesInGrantedRDGCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the MAC when an RDG is used.

        This counter at the initiator shall be incremented for every frame, other
        than response frames such as Ack or BlockAck frames, transmitted by the
        station during a granted RDG."
    ::= { dot11CountersEntry 47 }

dot11TransmittedOctetsInGrantedRDGCount OBJECT-TYPE
    SYNTAX Counter64
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the MAC when an RDG is used.

        This counter at the initiator shall be incremented by the number of octets
        in the frame body of a frame, other than response frames such as Ack or
        BlockAck frames, transmitted by the station during a granted RDG."
    ::= { dot11CountersEntry 48 }

dot11BeamformingFrameCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the MAC when a frame with beamforming parameters is sent.

        This counter shall be incremented when the transmitter sends a frame with
        new/updated beamforming parameters."
    ::= { dot11CountersEntry 49 }

dot11DualCTSSuccessCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the MAC when a dual CTS is sent.
```


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```
        This counter shall be incremented when AP sends a dual CTS in response to
        a STA initiating TXOP in extended range."
    ::= { dot11CountersEntry 50 }

dot11DualCTSFailureCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the MAC when a dual CTS is not sent.

        This counter shall be incremented when AP fails to send a dual CTS in
        response to a STA initiating TXOP in extended range."
    ::= { dot11CountersEntry 51 }

dot11STBCCTSSuccessCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the MAC when no collision is detected.

        This counter shall be incremented when AP does not detect a collision PIFS
        after sending a CTS to self STBC frame in extended range."
    ::= { dot11CountersEntry 52 }

dot11STBCCTSFailureCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the MAC when a collision is detected.

        This counter shall be incremented when AP detects a collision PIFS after
        sending a CTS to self STBC frame in extended range."
    ::= { dot11CountersEntry 53 }

dot11nonSTBCCTSSuccessCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the MAC when no collision is detected.

        This counter shall be incremented when AP does not detect a collision PIFS
        after sending a CTS to self that is a(#1426) non-STBC frame in extended
        range."
    ::= { dot11CountersEntry 54 }

dot11nonSTBCCTSFailureCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the MAC when a collision is detected.

        This counter shall be incremented when AP detects a collision PIFS after
        sending a CTS to self that is a(#1426) non-STBC frame in extended range."
```

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```
    ::= { dot11CountersEntry 55 }

dot11RTSLSIGSuccessCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS deprecated
    DESCRIPTION
        "Deprecated as the related feature has been removed from IEEE Std 802.11.
        This is a status variable.
        It is written by the MAC when the condition described below occurs.

        This counter shall be incremented when the duration/ID field is set
        according to the rules of L-SIG TXOP protection in the received CTS
        following a transmission of RTS in L-SIG TXOP protection mode."
    ::= { dot11CountersEntry 56 }

dot11RTSLSIGFailureCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS deprecated
    DESCRIPTION
        "Deprecated as the related feature has been removed from IEEE Std 802.11.
        This is a status variable.
        It is written by the MAC when the condition described below occurs.

        This counter shall be incremented when the duration/ID field is not set
        according to the rules of L-SIG TXOP protection in the received CTS
        following a transmission of RTS in L-SIG TXOP protection mode."
    ::= { dot11CountersEntry 57 }


dot11PBACErrors OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the MAC when the condition described below occurs.

        This variable indicates the number of errors encountered in the PBAC
        procedures."
    ::= { dot11CountersEntry 58}

dot11DeniedAssociationCounterDueToBSSLoad OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the SME when the condition described below occurs.

        This counter, available at a WNM AP, shall increment when an
        (re)association request is denied because the AP has insufficient
        bandwidth to handle the additional STA."
    ::= { dot11CountersEntry 59}



dot11TransmittedMSDUOctetsCount OBJECT-TYPE
    SYNTAX Counter64
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
```


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```
        It is written by the MAC when an MSDU is successfully transmitted.
        This counter is incremented by the number of octets in the MSDU when an
        MSDU is successfully transmitted."
    ::= { dot11CountersEntry 60 }

dot11ReceivedMSDUOctetsCount OBJECT-TYPE
    SYNTAX Counter64
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the MAC when an MSDU is received that is addressed to the
        STA (either individually or globally).
        This counter is incremented by the number of octets in the MSDU."
    ::= { dot11CountersEntry 61 }


-- ****************************************************************
-- * End of dot11Counters TABLE
-- ****************************************************************

-- ****************************************************************
-- * dot11GroupAddresses  TABLE
-- ****************************************************************

dot11GroupAddressesTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11GroupAddressesEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "A conceptual table containing a set of MAC addresses identifying the
        multicast-group addresses for which this STA receives frames."
    ::= { dot11mac 3 }

dot11GroupAddressesEntry OBJECT-TYPE
    SYNTAX Dot11GroupAddressesEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "An Entry (conceptual row) in the Group Addresses Table.

        ifIndex - Each IEEE 802.11 interface is represented by an ifEntry.
        Interface tables in this MIB module are indexed by ifIndex."
    INDEX { ifIndex, dot11GroupAddressesIndex }
    ::= { dot11GroupAddressesTable  1 }

Dot11GroupAddressesEntry ::=
    SEQUENCE {
        dot11GroupAddressesIndex                    InterfaceIndex,
        dot11GroupAddress                           MacAddress,
        dot11GroupAddressesStatus                   RowStatus }

dot11GroupAddressesIndex OBJECT-TYPE
    SYNTAX InterfaceIndex
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "The auxiliary variable used to identify instances of the columnar objects
        in the Group Addresses Table."
    ::= { dot11GroupAddressesEntry 1 }

dot11GroupAddress OBJECT-TYPE
    SYNTAX MacAddress
    MAX-ACCESS read-create
```

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```
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        MAC address identifying multicast-group addresses from which this STA
        receives frames."
    ::= { dot11GroupAddressesEntry 2 }

dot11GroupAddressesStatus OBJECT-TYPE
    SYNTAX RowStatus
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "The status column used for creating, modifying, and deleting instances of
        the columnar objects in the Group Addresses Table."
    DEFVAL { active }
    ::= { dot11GroupAddressesEntry 3 }

-- ****************************************************************
-- *    End of dot11GroupAddresses TABLE
-- ****************************************************************

-- ****************************************************************
-- *    SMT EDCA Config TABLE
-- ****************************************************************

dot11EDCATable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11EDCAEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "Conceptual table for EDCA parameters(#1660) at a non-AP STA. This table
        contains the four entries of the EDCA parameters corresponding to four
        possible ACs. Index 1 corresponds to AC_BK, index 2 to AC_BE, index 3 to
        AC_VI, and index 4 to AC_VO.
        An AP uses this table to select the values to advertise in the EDCA Param-
        eter Set element."
    ::= { dot11mac 4 }

dot11EDCAEntry OBJECT-TYPE
    SYNTAX Dot11EDCAEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "An Entry (conceptual row) in the EDCA Table.

        ifIndex - Each IEEE 802.11 interface is represented by an ifEntry.
        Interface tables in this MIB module are indexed by ifIndex."
    INDEX { ifIndex, dot11EDCATableIndex }
    ::= { dot11EDCATable  1 }

Dot11EDCAEntry ::=
    SEQUENCE {
        dot11EDCATableIndex                                 Unsigned32,
        dot11EDCATableCWmin                                 Unsigned32,
        dot11EDCATableCWmax                                 Unsigned32,
        dot11EDCATableAIFSN                                 Unsigned32,
        dot11EDCATableTXOPLimit                             Unsigned32,
        dot11EDCATableMSDULifetime                          Unsigned32,
        dot11EDCATableMandatory                             TruthValue }

dot11EDCATableIndex OBJECT-TYPE
```


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```
    SYNTAX Unsigned32 (1..4)
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "The auxiliary variable used to identify instances of the columnar objects
        in the EDCA Table. The value of this variable is
        1, if the value of the AC is AC_BK.
        2, if the value of the AC is AC_BE.
        3, if the value of the AC is AC_VI.
        4, if the value of the AC is AC_VO."
    ::= { dot11EDCAEntry 1 }

dot11EDCATableCWmin OBJECT-TYPE
    SYNTAX Unsigned32 (0..32767)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a status variable at a non-AP QoS STA and a control variable at a
        QoS AP.
        At a QoS AP, it is written by an external management entity and used to
        select the value to advertise in the EDCA Parameter Set element.
        At a non-AP QoS STA, it is written by the MAC upon receiving an EDCA
        Parameter Set element.
        Changes take effect as soon as practical in the implementation.

        This attribute specifies the value of the minimum size of the window that
        is used by a STA for a particular AC for generating a random number for
        the backoff. The value of this attribute is such that it could always be
        expressed in the form of 2^X - 1, where X is an integer. See Table 9-194
        (Default EDCA Parameter Set element (#1660)parameters
        if dot11OCBActivated is false and the STA is a non-sensor STA(#251)) and
        Table 9-195 (Default EDCA parameter set for STA operation if dot11OCBActi-
        vated is true)."
    ::= { dot11EDCAEntry 2 }

dot11EDCATableCWmax OBJECT-TYPE
    SYNTAX Unsigned32 (0..32767)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a status variable at a non-AP QoS STA and a control variable at a
        QoS AP.
        At a QoS AP, it is written by an external management entity and used to
        select the value to advertise in the EDCA Parameter Set element.
        At a non-AP QoS STA, it is written by the MAC upon receiving an EDCA
        Parameter Set element.
        Changes take effect as soon as practical in the implementation.

        This attribute specifies the value of the maximum size of the window that
        is used by a STA for a particular AC for generating a random number for
        the backoff. The value of this attribute is such that it could always be
        expressed in the form of 2^X - 1, where X is an integer. See Table 9-194
        (Default EDCA Parameter Set element (#1660)parameters
        if dot11OCBActivated is false and the STA is a non-sensor STA(#251)) and
        Table 9-195 (Default EDCA parameter set for STA operation if dot11OCBActi-
        vated is true)."
    ::= { dot11EDCAEntry 3 }

dot11EDCATableAIFSN OBJECT-TYPE
    SYNTAX Unsigned32 (2..15)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a status variable at a non-AP QoS STA and a control variable at a
```

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```
        QoS AP.
        At a QoS AP, it is written by an external management entity and used to
        select the value to advertise in the EDCA Parameter Set element.
        At a non-AP QoS STA, it is written by the MAC upon receiving an EDCA
        Parameter Set element.
        Changes take effect as soon as practical in the implementation.

        This attribute specifies the number of slots, after a SIFS, that the STA,
        for a particular AC, senses the medium idle either before transmitting or
        executing a backoff. See Table 9-194 (Default EDCA Parameter Set element
        (#1660)parameters if dot11OCBActivated is false and the STA is a non-sen-
        sor STA(#251)) and Table 9-195 (Default EDCA parameter set for STA opera-
        tion if dot11OCBActivated is true)."
    ::= { dot11EDCAEntry 4 }

dot11EDCATableTXOPLimit OBJECT-TYPE
    SYNTAX Unsigned32 (0..65535)
    UNITS "32 microseconds"
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a status variable at a non-AP QoS STA and a control variable at a
        QoS AP.
        At a QoS AP, it is written by an external management entity and used to
        select the value to advertise in the EDCA Parameter Set element.
        At a non-AP QoS STA, it is written by the MAC upon receiving an EDCA
        Parameter Set element.
        Changes take effect as soon as practical in the implementation.

        This attribute specifies the maximum duration of an EDCA TXOP for a given
        AC, for a non-AP non-OCB STA. The default value for this attribute is
        given (in different units) in Table 9-194 (Default EDCA Parameter Set ele-
        ment (#1660)parameters if dot11OCBActivated is false and the STA is a non-
        sensor STA(#251)).
    ::= { dot11EDCAEntry 5 }

dot11EDCATableMSDULifetime OBJECT-TYPE
    SYNTAX Unsigned32 (1..4294967295)
    UNITS "TUs"
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable at a non-AP STA.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute specifies the maximum duration an MSDU/MMPDU, for a given
        AC, would be retained by the MAC at the non-AP STA before it is dis-
        carded."
    DEFVAL { 500 }
    ::= { dot11EDCAEntry 6 }

dot11EDCATableMandatory OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a status variable at a non-AP QoS STA and a control variable at a
        QoS AP.
        At a QoS AP, it is written by an external management entity and used to
        select the value to advertise in the EDCA Parameter Set element.
        At a non-AP QoS STA, it is written by the MAC upon receiving an EDCA
        Parameter Set element.
        Changes take effect as soon as practical in the implementation.
```


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```
        This attribute, when true, indicates that admission control is mandatory
        for the given AC. When false, this attribute indicates that admission
        control is not mandatory for the given AC."
    DEFVAL { false }
    ::= { dot11EDCAEntry 7 }

-- ************************************************************************
-- *    End of SMT EDCA Config TABLE
-- ************************************************************************

-- ************************************************************************
-- *    SMT AP EDCA Config TABLE
-- ************************************************************************

dot11QAPEDCATable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11QAPEDCAEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "Conceptual table for EDCA default parameter values at the AP. This table
        contains the four entries of the EDCA parameters corresponding to four
        possible ACs. Index 1 corresponds to AC_BK, index 2 to AC_BE, index 3 to
        AC_VI, and index 4 to AC_VO."
    ::= { dot11mac 5 }

dot11QAPEDCAEntry OBJECT-TYPE
    SYNTAX Dot11QAPEDCAEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "An Entry (conceptual row) in the EDCA Table.

        ifIndex - Each IEEE 802.11 interface is represented by an ifEntry. Inter-
        face tables in this MIB module are indexed by ifIndex."
    INDEX { ifIndex, dot11QAPEDCATableIndex }
    ::= { dot11QAPEDCATable  1 }

Dot11QAPEDCAEntry ::=
    SEQUENCE {
        dot11QAPEDCATableIndex                          Unsigned32,
        dot11QAPEDCATableCWmin                          Unsigned32,
        dot11QAPEDCATableCWmax                          Unsigned32,
        dot11QAPEDCATableAIFSN                          Unsigned32,
        dot11QAPEDCATableTXOPLimit                      Unsigned32,
        dot11QAPEDCATableMSDULifetime                   Unsigned32,
        dot11QAPEDCATableMandatory                      TruthValue }

dot11QAPEDCATableIndex OBJECT-TYPE
    SYNTAX Unsigned32 (1..4)
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "The auxiliary variable used to identify instances of the columnar objects
        in the EDCA Table. The value of this variable is
        1, if the value of the AC is AC_BK.
        2, if the value of the AC is AC_BE.
        3, if the value of the AC is AC_VI.
        4, if the value of the AC is AC_VO."
    ::= { dot11QAPEDCAEntry 1 }

dot11QAPEDCATableCWmin OBJECT-TYPE
    SYNTAX Unsigned32 (0..255)
    MAX-ACCESS read-write
```

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```
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute specifies the value of the minimum size of the window that
        is used by an AP for a particular AC for generating a random number for
        the backoff. The value of this attribute is such that it could always be
        expressed in the form of 2^X - 1, where X is an integer. The default value
        for this attribute is
        aCWmin, if dot11QAPEDCATableIndex is 1 or 2.
        (aCWmin+1)/2 - 1, if dot11QAPEDCATableIndex is 3.
        (aCWmin+1)/4 - 1, if dot11QAPEDCATableIndex is 4."
    ::= { dot11QAPEDCAEntry 2 }

dot11QAPEDCATableCWmax OBJECT-TYPE
    SYNTAX Unsigned32 (0..65535)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute specifies the value of the maximum size of the window that
        is used by an AP for a particular AC for generating a random number for
        the backoff. The value of this attribute is such that it could always be
        expressed in the form of 2^X - 1, where X is an integer. The default value
        for this attribute is
        aCWmax, if dot11QAPEDCATableIndex is 1.
        4*(aCWmin+1) - 1, if dot11QAPEDCATableIndex is 2.
        aCWmin, if dot11QAPEDCATableIndex is 3.
        (aCWmin+1)/2 - 1, if dot11QAPEDCATableIndex is 4."
    ::= { dot11QAPEDCAEntry 3 }

dot11QAPEDCATableAIFSN OBJECT-TYPE
    SYNTAX Unsigned32 (1..15)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute specifies the number of slots, after a SIFS, that the AP,
        for a particular AC, senses the medium idle either before transmitting or
        executing a backoff. The default value for this attribute is
        7, if dot11QAPEDCATableIndex is 1,
        3, if dot11QAPEDCATableIndex is 2
        1, otherwise."
    ::= { dot11QAPEDCAEntry 4 }

dot11QAPEDCATableTXOPLimit OBJECT-TYPE
    SYNTAX Unsigned32 (0..65535)
    UNITS "32 microseconds"
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute specifies the maximum duration of an EDCA TXOP for a given
```


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```
        AC, for an AP. The default value for this attribute is given (in different
        units) in Table 9-194 (Default EDCA Parameter Set element (#1660)parame-
        ters if dot11OCBActivated is false and the STA is a non-sensor STA(#251)).
    ::= { dot11QAPEDCAEntry 5 }

dot11QAPEDCATableMSDULifetime OBJECT-TYPE
    SYNTAX Unsigned32 (1..4294967295)
    UNITS "TUs"
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute specifies the maximum duration an MSDU/MMPDU, for a given
        AC, would be retained by the MAC at the AP before it is discarded."
    DEFVAL { 500 }
    ::= { dot11QAPEDCAEntry 6 }

dot11QAPEDCATableMandatory OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute, when true, indicates that admission control is mandatory
        for the given AC. When false, this attribute indicates that admission
        control is not mandatory for the given AC. The default value for this
        parameter is false."
    ::= { dot11QAPEDCAEntry 7 }

-- ************************************************************************
-- *    End of SMT AP EDCA Config TABLE
-- ************************************************************************

-- ************************************************************************
-- *    dot11QosCounters TABLE
-- ************************************************************************

dot11QosCountersTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11QosCountersEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "Group containing attributes that are MAC counters implemented as a table
        to allow for multiple instances(#467) on an agent."
    ::= { dot11mac 6 }

dot11QosCountersEntry OBJECT-TYPE
    SYNTAX Dot11QosCountersEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "An Entry (conceptual row) in the QoSCounters Table.

        ifIndex - Each IEEE 802.11 interface is represented by an ifEntry.
        Interface tables in this MIB module are indexed by ifIndex."
    INDEX { ifIndex, dot11QosCountersIndex }
    ::= { dot11QosCountersTable 1 }
```

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```
Dot11QosCountersEntry ::=
   SEQUENCE {
      dot11QosCountersIndex                                Unsigned32,
      dot11QosTransmittedFragmentCount                     Counter32,
      dot11QosFailedCount                                  Counter32,
      dot11QosRetryCount                                   Counter32,
      dot11QosMultipleRetryCount                           Counter32,
      dot11QosFrameDuplicateCount                          Counter32,
      dot11QosRTSSuccessCount                              Counter32,
      dot11QosRTSFailureCount                              Counter32,
      dot11QosAckFailureCount                              Counter32,
      dot11QosReceivedFragmentCount                        Counter32,
      dot11QosTransmittedFrameCount                        Counter32,
      dot11QosDiscardedFrameCount                          Counter32,
      dot11QosMPDUsReceivedCount                           Counter32,
      dot11QosRetriesReceivedCount                         Counter32 }

dot11QosCountersIndex OBJECT-TYPE
   SYNTAX Unsigned32 (1..16)
   MAX-ACCESS not-accessible
   STATUS current
   DESCRIPTION
      "The auxiliary variable used to identify instances of the columnar objects
      in the QoSCounters Table. The value of this variable is equal to TID + 1."
   ::= { dot11QosCountersEntry 1 }

dot11QosTransmittedFragmentCount OBJECT-TYPE
   SYNTAX Counter32
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "(#6157)This is a status variable.

      (#7208)This counter is incremented when a QoS Data frame (which may or may
      not be a fragment) or QoS Null frame for a particular UP is successfully
      transmitted. This counter has relevance only for TIDs between 0 and 7."
   ::= { dot11QosCountersEntry 2 }

dot11QosFailedCount OBJECT-TYPE
   SYNTAX Counter32
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a status variable.
      It is written by the MAC when the condition described below occurs.

      This counter increments when an MSDU, for a particular UP, is not
      transmitted successfully due to the number of transmit attempts exceeding
      the dot11ShortRetryLimit. This counter has relevance only for TIDs between
      0 and 7."
   ::= { dot11QosCountersEntry 3 }

dot11QosRetryCount OBJECT-TYPE
   SYNTAX Counter32
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a status variable.
      It is written by the MAC when the condition described below occurs.

      This counter increments when an MSDU, of a particular UP, is successfully
      transmitted after one or more retransmissions. This counter has relevance
      only for TIDs between 0 and 7."
   ::= { dot11QosCountersEntry 4 }
```


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```
dot11QosMultipleRetryCount OBJECT-TYPE
   SYNTAX Counter32
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a status variable.
      It is written by the MAC when the condition described below occurs.

      This counter increments when an MSDU, of a particular UP, is successfully
      transmitted after more than one retransmissions. This counter has
      relevance only for TIDs between 0 and 7."
   ::= { dot11QosCountersEntry 5 }

dot11QosFrameDuplicateCount OBJECT-TYPE
   SYNTAX Counter32
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a status variable.
      It is written by the MAC when the condition described below occurs.

      This counter increments when a frame, of a particular UP, is received that
      the Sequence Control field indicates is a duplicate. This counter has
      relevance only for TIDs between 0 and 7."
   ::= { dot11QosCountersEntry 6 }

dot11QosRTSSuccessCount OBJECT-TYPE
   SYNTAX Counter32
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a status variable.
      It is written by the MAC when a CTS frame is received in response to an
      RTS.

      This counter increments when a CTS frame is received in response to an RTS
      that has been sent for the transmission of an MPDU of a particular UP.
      This counter has relevance only for TIDs between 0 and 7."
   ::= { dot11QosCountersEntry 7 }

dot11QosRTSFailureCount OBJECT-TYPE
   SYNTAX Counter32
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a status variable.
      It is written by the MAC when the condition described below occurs.

      This counter increments when a CTS frame is not received in response to an
      RTS that has been sent for the transmission of an MPDU of a particular UP.
      This counter has relevance only for TIDs between 0 and 7."
   ::= { dot11QosCountersEntry 8 }

dot11QosAckFailureCount OBJECT-TYPE
   SYNTAX Counter32
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a status variable.
      It is written by the MAC when the condition described below occurs.

      This counter increments when an Ack frame is not received in response to
      an MPDU of a particular UP. This counter has relevance only for TIDs
```

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```
        between 0 and 7."
    ::= { dot11QosCountersEntry 9 }

dot11QosReceivedFragmentCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the MAC when a QoS fragment is received.

        This counter is incremented for each received MPDU with the Type subfield
        equal to Data of a particular UP. This counter has relevance only for TIDs
        between 0 and 7."
    ::= { dot11QosCountersEntry 10 }

dot11QosTransmittedFrameCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "(#6158)This is a status variable.

        This counter is incremented when an MSDU with a particular integer
        priority is successfully transmitted (not necessarily in a single frame).
        This counter has relevance only for priorities between 0 and 7."
    ::= { dot11QosCountersEntry 11 }

dot11QosDiscardedFrameCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the MAC when the condition described below occurs.

        This counter increments for each Discarded MSDU of a particular UP. This
        counter has relevance only for TIDs between 0 and 7."
    ::= { dot11QosCountersEntry 12 }

dot11QosMPDUsReceivedCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the MAC when a QoS MPDU is received.

        This counter increments for each received MPDU of a particular TID."
    ::= { dot11QosCountersEntry 13 }

dot11QosRetriesReceivedCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the MAC when the condition described below occurs.

        This counter increments for each received MPDU of a particular TID with
        the Retry subfield equal to 1."
    ::= { dot11QosCountersEntry 14 }

-- ************************************************************************
```


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```
-- *    End of dot11QosCounters TABLE
-- ************************************************************************

-- ************************************************************************
-- *    Resource Type Attribute Templates
-- ************************************************************************

dot11ResourceTypeIDName OBJECT-TYPE
   SYNTAX DisplayString (SIZE(4))
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "Contains the name of the Resource Type ID managed object. The attribute
      is read-only and always contains the value RTID. This attribute value is
      not used as a naming attribute for any other managed object class."
   REFERENCE "IEEE Std 802.1F-1993, A.7"
   DEFVAL { "RTID" }
   ::= { dot11resAttribute 1 }

-- ************************************************************************
-- *    dot11ResourceInfo  TABLE
-- ************************************************************************

dot11ResourceInfoTable OBJECT-TYPE
   SYNTAX SEQUENCE OF Dot11ResourceInfoEntry
   MAX-ACCESS not-accessible
   STATUS current
   DESCRIPTION
      "provides a means of indicating, in data readable from a managed object,
      information that identifies the source of the implementation."
   REFERENCE "IEEE Std 802.1F-1993, A.7. Note that this standard has been
      withdrawn."
   ::= { dot11resAttribute 2 }

dot11ResourceInfoEntry OBJECT-TYPE
   SYNTAX Dot11ResourceInfoEntry
   MAX-ACCESS not-accessible
   STATUS current
   DESCRIPTION
      "An entry in the dot11ResourceInfo Table.

      ifIndex - Each IEEE 802.11 interface is represented by an ifEntry.
      Interface tables in this MIB module are indexed by ifIndex."
   INDEX { ifIndex }
   ::= { dot11ResourceInfoTable 1 }

Dot11ResourceInfoEntry ::=
   SEQUENCE {
      dot11manufacturerOUI                                OCTET STRING,
      dot11manufacturerName                               DisplayString,
      dot11manufacturerProductName                        DisplayString,
      dot11manufacturerProductVersion                     DisplayString }

dot11manufacturerOUI OBJECT-TYPE
   SYNTAX OCTET STRING (SIZE(3))
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a capability variable.
      Its value is determined by (#3375)STA capabilities.

      Takes the value of an IEEE assigned unique identifier (OUI or CID)."
   ::= { dot11ResourceInfoEntry 1 }
```

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```
dot11manufacturerName OBJECT-TYPE
   SYNTAX DisplayString (SIZE(0..128))
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a capability variable.
      Its value is determined by (#3375)STA capabilities.

      A printable string used to identify the manufacturer of the
      resource.(#261)"
   ::= { dot11ResourceInfoEntry 2 }

dot11manufacturerProductName OBJECT-TYPE
   SYNTAX DisplayString (SIZE(0..128))
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a capability variable.
      Its value is determined by (#3375)STA capabilities.

      A printable string used to identify the manufacturer's product name of the
      resource.(#261)"
   ::= { dot11ResourceInfoEntry 3 }

dot11manufacturerProductVersion OBJECT-TYPE
   SYNTAX DisplayString (SIZE(0..128))
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a capability variable.
      Its value is determined by (#3375)STA capabilities.

      Printable string used to identify the manufacturer's product version of
      the resource.(#261)"
   ::= { dot11ResourceInfoEntry 4 }

-- ****************************************************************
-- * End of dot11ResourceInfo  TABLE
-- ****************************************************************

-- ****************************************************************
-- * dot11DMGOperation TABLE
-- ****************************************************************

dot11DMGOperationTable OBJECT-TYPE
   SYNTAX SEQUENCE OF Dot11DMGOperationEntry
   MAX-ACCESS not-accessible
   STATUS current
   DESCRIPTION
      "This is a Table management object.
      The dot11DMGOperation Table"
   ::= { dot11mac 8 }

dot11DMGOperationEntry OBJECT-TYPE
   SYNTAX Dot11DMGOperationEntry
   MAX-ACCESS not-accessible
   STATUS current
   DESCRIPTION
      "This is an entry in the dot11DMGOperation Table.
      ifIndex - Each IEEE 802.11 interface is represented by an
      ifEntry.  Interface tables in this MIB module are indexed
      by ifIndex."
   INDEX { ifIndex }
   ::= { dot11DMGOperationTable 1 }
```



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```
Dot11DMGOperationEntry ::=
   SEQUENCE {
      dot11MaxLostBeacons                                    Unsigned32,
      dot11MinBHIDuration                                    Unsigned32,
      dot11PSRequestSuspensionInterval                       Unsigned32,
      dot11BroadcastSTAInfoDuration                          Unsigned32,
      dot11NbrOfChangeBeacons                                Unsigned32,
      dot11ImplicitHandoverLostBeacons                       Unsigned32,
      dot11MinPPDuration                                     Unsigned32,
      dot11SPIdleTimeout                                     Unsigned32,
      dot11QABTimeout                                        Unsigned32,
      dot11ClusterEnableTime                                 Unsigned32,
      dot11PNWarningThresholdLow                             Unsigned32,
      dot11PNWarningThresholdHigh                            INTEGER,(#1287)
      dot11BeaconSPDuration                                  Unsigned32,
      dot11PNExhaustionThresholdLow                          Unsigned32,
      dot11PNExhaustionThresholdHigh                         INTEGER,(#1287)
      dot11MaxNumberOfClusteringMonitoringPeriods            Unsigned32,
      dot11DMGEcssPolicyDetailUpdateDurationMax              Unsigned32,
      dot11DMGEcssClusterReportDurationMin                   Unsigned32,
      dot11DMGNavSync                                        Unsigned32
      (11ay)dot11DMGChannelAccessScheme                      INTEGER,
      (11ay)dot11DMGSTATxActivityReportTimeUnit              Unsigned32,
      (11ay)dot11DMGSTATxActivityReportMinActiveTimeUnits    Unsigned32,
      (11ay)dot11DMGSTATxActivityReportActiveMonitoringTime  Unsigned32,
      (11ay)dot11DMGSTATxActivityReportInterval              Unsigned32
      }

dot11MaxLostBeacons OBJECT-TYPE
   SYNTAX Unsigned32 (1..32)
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by the SME or an external management entity.
      Changes take effect as soon as practical in the implementation.

      Maximum Number of Lost Beacons"
   DEFVAL { 4 }
   ::= { dot11DMGOperationEntry 1 }

dot11MinBHIDuration OBJECT-TYPE
   SYNTAX Unsigned32 (1..100000)
   UNITS "microseconds"
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by the SME or an external management entity.
      Changes take effect as soon as practical in the implementation.

      Minimum Beacon Header Interval duration."
   DEFVAL { 5000 }
   ::= { dot11DMGOperationEntry 2 }

dot11PSRequestSuspensionInterval OBJECT-TYPE
   SYNTAX Unsigned32 (1..64)
   UNITS "beacon intervals"
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by the SME or an external management entity.
```

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```
        Changes take effect as soon as practical in the implementation.

        PS Request Suspension Interval"
    DEFVAL { 8 }
    ::= { dot11DMGOperationEntry 3 }


dot11BroadcastSTAInfoDuration OBJECT-TYPE
    SYNTAX Unsigned32 (1..512)
    UNITS "beacon intervals"
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by the SME or an external management entity.
        Changes take effect as soon as practical in the implementation.

        Broadcast STA Information Duration."
    DEFVAL { 32 }
    ::= { dot11DMGOperationEntry 5 }

dot11NbrOfChangeBeacons OBJECT-TYPE
    SYNTAX Unsigned32 (1..32)
    UNITS "beacon intervals"
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by the SME or an external management entity.
        Changes take effect as soon as practical in the implementation.

        Number of Change Beacons."
    DEFVAL { 4 }
    ::= { dot11DMGOperationEntry 6 }

dot11ImplicitHandoverLostBeacons OBJECT-TYPE
    SYNTAX Unsigned32 (1..32)
    UNITS "beacon intervals"
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by the SME or an external management entity.
        Changes take effect as soon as practical in the implementation.

        Implicit handover lost beacons."
    DEFVAL { 8 }
    ::= { dot11DMGOperationEntry 7 }

dot11MinPPDuration OBJECT-TYPE
    SYNTAX Unsigned32 (1..100000)
    UNITS "microseconds"
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by the SME or an external management entity.
        Changes take effect as soon as practical in the implementation.

        (#3321)This attribute indicates the minimum duration of the
        PP and GP as part of the dynamic allocation of service period
        mechanism."
    DEFVAL { 200 }
    ::= { dot11DMGOperationEntry 8 }
```


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```
dot11SPIdleTimeout OBJECT-TYPE
   SYNTAX Unsigned32 (1..100000)
   UNITS "microseconds"
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by the SME or an external management entity.
      Changes take effect as soon as practical in the implementation.

      (#3321)This attribute indicates the time during which a DMG STA
      expects to receive a frame from its partner STA."
   DEFVAL { 200 }
   ::= { dot11DMGOperationEntry 9 }

dot11QABTimeout OBJECT-TYPE
   SYNTAX Unsigned32 (1..64000)
   UNITS "milliseconds"
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by the SME or an external management entity.
      Changes take effect as soon as practical in the implementation.

      Quiet Adjacent BSS Operation Timeout."
   DEFVAL { 1000 }
   ::= { dot11DMGOperationEntry 10 }

dot11ClusterEnableTime OBJECT-TYPE
   SYNTAX Unsigned32 (1..32)
   UNITS "beacon intervals"
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by the SME or an external management entity.
      Changes take effect as soon as practical in the implementation.

      Frequency with which a non-AP and non-PCP is allowed to retransmit a
      cluster request element to its AP or PCP."
   DEFVAL { 8 }
   ::= { dot11DMGOperationEntry 11 }

dot11PNWarningThresholdLow OBJECT-TYPE
   SYNTAX Unsigned32 (0..4294967295)
   UNITS "packet number"
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by the SME or an external management entity.
      Changes take effect as soon as practical in the implementation.

      Threshold used for generating a warning to the MLME about a potential PN
      exhaustion.
      Threshold is a 48-bit integer. This field contains the least significant
      32 bits of the threshold."
   DEFVAL { 4294967295 }
   ::= { dot11DMGOperationEntry 12 }

dot11PNWarningThresholdHigh OBJECT-TYPE
   SYNTAX INTEGER (0..65535)
```

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```
    UNITS "packet number"
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
       "This is a control variable.
       It is written by the SME or an external management entity.
       Changes take effect as soon as practical in the implementation.

       Threshold used for generating a warning to the MLME about a potential PN
       exhaustion.
       Threshold is a 48-bit integer. This field contains the most significant 16
       bits of the threshold."
    DEFVAL { 65535  }
    ::= { dot11DMGOperationEntry 13 }

dot11BeaconSPDuration OBJECT-TYPE
    SYNTAX Unsigned32 (1..100000)
    UNITS "microseconds"
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
       "This is a control variable.
       It is written by the SME or an external management entity.
       Changes take effect as soon as practical in the implementation.

       The size of a Beacon SP used for AP or PCP clustering."
    DEFVAL { 600 }
    ::= { dot11DMGOperationEntry 14 }


dot11PNExhaustionThresholdLow OBJECT-TYPE
    SYNTAX Unsigned32 (0..4294967295)
    UNITS "packet number"
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
       "This is a control variable.
       It is written by the SME or an external management entity.
       Changes take effect as soon as practical in the implementation.

       Threshold used for indicating an imminent PN exhaustion.
       Threshold is a 48-bit integer. This field contains the least significant
       32 bits of the threshold."
    DEFVAL { 4294967295 }
    ::= { dot11DMGOperationEntry 15 }


dot11PNExhaustionThresholdHigh OBJECT-TYPE
    SYNTAX INTEGER (0..65535)
    UNITS "packet number"
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
       "This is a control variable.
       It is written by the SME or an external management entity.
       Changes take effect as soon as practical in the implementation.

       Threshold used for indicating an imminent PN exhaustion.
       Threshold is a 48-bit integer. This field contains the most significant 16
       bits of the threshold."
    DEFVAL { 65535 }
    ::= { dot11DMGOperationEntry 16 }
```


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```
dot11MaxNumberOfClusteringMonitoringPeriods OBJECT-TYPE
   SYNTAX Unsigned32 (1..16)
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by the SME or an external management entity.
      Changes take effect as soon as practical in the implementation.

      Number of clustering monitoring periods until determination of the loss of
      an S-AP or S-PCP."
   DEFVAL { 3 }
   ::= { dot11DMGOperationEntry 17 }

dot11DMGEcssPolicyDetailUpdateDurationMax OBJECT-TYPE
   SYNTAX Unsigned32 (10..30000)
   UNITS "TUs"
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by the SME or an external management entity.
      Changes take effect as soon as practical in the implementation.

      Maximum duration between attempts by a member AP or member PCP in a
      centralized AP or PCP cluster to receive a DMG Beacon frame from the S-AP
      of the centralized AP or PCP cluster"
   DEFVAL { 1000 }
   ::= { dot11DMGOperationEntry 18 }

dot11DMGEcssClusterReportDurationMin OBJECT-TYPE
   SYNTAX Unsigned32 (100..36000000)
   UNITS "TUs"
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by the SME or an external management entity.
      Changes take effect as soon as practical in the implementation.

      Minimum duration between the transmission of interference reports by a
      member AP or member PCP in a centralized AP or PCP cluster to the S-AP of
      the centralized AP or PCP cluster"
   DEFVAL { 1000 }
   ::= { dot11DMGOperationEntry 19 }

dot11DMGNavSync OBJECT-TYPE
   SYNTAX Unsigned32 (0..10000)
   UNITS "microseconds"
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by the SME or an external management entity.
      Changes take effect as soon as practical in the implementation.

      Delay to be used by a DMG STA prior to transmitting a Probe Request
      frame."
   DEFVAL { 0 }
   ::= { dot11DMGOperationEntry 20 }


(11ay)dot11DMGChannelAccessScheme OBJECT-TYPE
   SYNTAX INTEGER ( dmgChannelAccessOnly (0), tddChannelAccessOnly (1),
```

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```
        dmgAndTddMixedChannelAccess (2) }
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by the SME or an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute indicates which channel access scheme the STA activates. "
    DEFVAL { 0 }
    ::= { dot11DMGOperationEntry 21 }

(11ay)dot11DMGSTATxActivityReportTimeUnit OBJECT-TYPE
    SYNTAX Unsigned32 (1..60000000)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by the SME or an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute specifies the duration of the time unit, in microseconds,
        which is used to monitor the transmit activity of the STA for different
        antenna patterns and 2.16 GHz channels."
    DEFVAL { 1000000 }
    ::= { dot11DMGOperationEntry 22 }

(11ay)dot11DMGSTATxActivityReportMinActiveTimeUnits OBJECT-TYPE
    SYNTAX Unsigned32 (0..60000)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by the SME or an external management entity.
        Changes take effect as soon as practical in the implementation.

        For a given receiver (or group of receivers always reached through a
        common transmit antenna pattern and transmit power) and a given 2.16 GHz
        channel, this attribute specifies the minimum number of active contiguous
        or (#3387)noncontiguous time units (specified by another MIB variable)
        inside a sliding window of a given duration (specified by another MIB
        variable) that would require the STA to transmit DMG STA Directional
        Transmit Activity Report frames using that antenna pattern and 2.16 GHz
        channel."
    DEFVAL { 10 }
    ::= { dot11DMGOperationEntry 23 }

(11ay)dot11DMGSTATxActivityReportActiveMonitoringTime OBJECT-TYPE
    SYNTAX Unsigned32 (1..60000)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by the SME or an external management entity.
        Changes take effect as soon as practical in the implementation.

        For a given receiver (or group of receivers always reached through a
        common transmit antenna pattern and transmit power) and a given 2.16 GHz
        channel, this attribute specifies the duration of a sliding time window,
        as a multiple of a given time unit (specified by another MIB variable),
        during which the transmit activity of the STA is monitored to determine a
        minimum level of transmit activity (specified by another MIB variable)
        that would require the STA to transmit DMG STA Directional Transmit
        Activity Report frames using that antenna pattern and 2.16 GHz channel."
```


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```
    DEFVAL { 60 }
    ::= { dot11DMGOperationEntry 24 }

(11ay)dot11DMGSTATxActivityReportInterval OBJECT-TYPE
    SYNTAX Unsigned32 (1.. 2000000)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by the SME or an external management entity.
        Changes take effect as soon as practical in the implementation.

        For a given receiver (or group of receivers always reached through a
        common transmit antenna pattern and transmit power) and a given 2.16 GHz
        channel, this attribute specifies the duration of a time interval, in
        microseconds, during which the STA (#6025)shall transmit at least one DMG
        STA Directional Transmit Activity Report frame using that antenna pattern
        and 2.16 GHz channel, provided that the STA has been (#1662)transmitting
        data using that antenna pattern and 2.16 GHz channel, where the threshold
        for active transmission is specified by other MIB variables."
    DEFVAL { 1000000 }
    ::= { dot11DMGOperationEntry 25 }

-- ****************************************************************
-- * End of dot11DMGOperation TABLE
-- ****************************************************************

-- ****************************************************************
-- * dot11DMGCounters TABLE
-- ****************************************************************

dot11DMGCountersTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11DMGCountersEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "This is a Table management object.
        The dot11DMGCountersTable Table"
    ::= { dot11mac 9 }

dot11DMGCountersEntry OBJECT-TYPE
    SYNTAX Dot11DMGCountersEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "This is an entry in the dot11DMGCountersTable Table.
        ifIndex - Each IEEE 802.11 interface is represented by an
        ifEntry.  Interface tables in this MIB module are indexed
        by ifIndex."
    INDEX { ifIndex }
    ::= { dot11DMGCountersTable 1 }

Dot11DMGCountersEntry ::=
    SEQUENCE {
        dot11RSNAStatsGCMPReplays                    Unsigned32,
        dot11RSNAStatsRobustMgmtGCMPReplays          Unsigned32
        }

dot11RSNAStatsGCMPReplays OBJECT-TYPE
    SYNTAX Unsigned32 (0..4294967295)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the (#3538)MAC when the condition described below occurs.
```

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```
        (#3538)The number of received Data frames discarded due to GCMP replay
        errors."
    DEFVAL { 0 }
    ::= { dot11DMGCountersEntry 1 }

dot11RSNAStatsRobustMgmtGCMPReplays OBJECT-TYPE
    SYNTAX Unsigned32 (0..4294967295)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the (#3538)MAC when the condition described below occurs.

        (#3538)The number of received individually addressed robust Management
        frames discarded due to GCMP replay errors."
    DEFVAL { 0 }
    ::= { dot11DMGCountersEntry 2 }

-- ********************************************************************
-- * End of dot11DMGCounters TABLE
-- ********************************************************************

-- ********************************************************************
-- * dot11BSSStatisticsTable TABLE
-- ********************************************************************
dot11BSSStatisticsTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11BSSStatisticsEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "This is a Table management object.
        The dot11BSSStatisticsTable Table contains objects related to BSS
        Statistics. It is present only in an AP."
    ::= { dot11mac 10 }

dot11BSSStatisticsEntry OBJECT-TYPE
    SYNTAX Dot11BSSStatisticsEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "This is an entry in the dot11BSSStatisticsTable Table.
        ifIndex - Each IEEE 802.11 interface is represented by an
        ifEntry. Interface tables in this MIB module are indexed by ifIndex."
    INDEX { ifIndex }
    ::= { dot11BSSStatisticsTable 1 }

Dot11BSSStatisticsEntry ::=
    SEQUENCE {
        dot11BSSLoadChannelUtilization                      Unsigned32,
        dot11BSSLoadAvailableAdmissionCapacity              Unsigned32,
        dot11BSSLoadAssocAttemptCount                       Unsigned32,
        dot11BSSLoadAssocFailCount                          Unsigned32,
        dot11BSSLoadReassocAttemptCount                     Unsigned32,
        dot11BSSLoadReassocFailCount                        Unsigned32
        }

dot11BSSLoadChannelUtilization OBJECT-TYPE
    SYNTAX Unsigned32 (0..255)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the MLME.
```


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```
        This object indicates the percentage of time, linearly scaled with 255
        representing 100%, that the AP sensed the medium was busy, as indicated by
        either the physical or virtual carrier sense (CS) mechanism."
    DEFVAL { 0 }
    ::= { dot11BSSStatisticsEntry 1 }

dot11BSSLoadAvailableAdmissionCapacity OBJECT-TYPE
    SYNTAX Unsigned32 (0..65535)
    UNITS "32 microseconds/second"
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the MLME.
        This object indicates the remaining amount of medium time available via
        explicit admission control."
    DEFVAL { 0 }
    ::= { dot11BSSStatisticsEntry 2 }

dot11BSSLoadAssocAttemptCount OBJECT-TYPE
    SYNTAX Unsigned32 (0..4294967295)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the MLME.
        This object contains the count of the number of association procedures
        started at the AP. It reports the count of such events since the AP
        started the operation of its BSS (i.e., since the last MLME-START.request
        primitive)."
    DEFVAL { 0 }
    ::= { dot11BSSStatisticsEntry 3 }

dot11BSSLoadAssocFailCount OBJECT-TYPE
    SYNTAX Unsigned32 (0..4294967295)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the MLME.
        This object contains the count of the number of unsuccessful association
        procedures at the AP (i.e., it is the number of association procedures
        started less those that completed successfully). It reports the count of
        such events since the AP started the operation of its BSS (i.e., since the
        last MLME-START.request primitive)."
    DEFVAL { 0 }
    ::= { dot11BSSStatisticsEntry 4 }

dot11BSSLoadReassocAttemptCount OBJECT-TYPE
    SYNTAX Unsigned32 (0..4294967295)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the MLME.
        This object contains the count of the number of reassociation procedures
        started at the AP. It reports the count of such events since the AP
        started the operation of its BSS (i.e., since the last MLME-START.request
        primitive)."
    DEFVAL { 0 }
    ::= { dot11BSSStatisticsEntry 5 }

dot11BSSLoadReassocFailCount OBJECT-TYPE
    SYNTAX Unsigned32 (0..4294967295)
```

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```
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the MLME.
        This object contains the count of the number of unsuccessful reassociation
        procedures at the AP (i.e., it is the number of reassociation procedures
        started less those that completed successfully). It reports the count of
        such events since the AP started the operation of its BSS (i.e., since the
        last MLME-START.request primitive)."
    DEFVAL { 0 }
    ::= { dot11BSSStatisticsEntry 6 }

-- ************************************************************************
-- * End of dot11BSSStatisticsTable TABLE
-- ************************************************************************

-- ************************************************************************
-- * dot11CDMGOperation TABLE
-- ************************************************************************

dot11CDMGOperationTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11CDMGOperationEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "This is a Table management object.
         The dot11CDMGOperation Table"
    ::= { dot11mac 11 }

dot11CDMGOperationEntry OBJECT-TYPE
    SYNTAX Dot11CDMGOperationEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "This is an entry in the dot11CDMGOperation Table.
        ifIndex - Each IEEE Std 802.11 interface is represented by an
        ifEntry.  Interface tables in this MIB module are indexed
        by ifIndex."
    INDEX { ifIndex }
    ::= { dot11CDMGOperationTable 1 }

Dot11CDMGOperationEntry ::=
    SEQUENCE {
        dot11DCSTimeout                                    Unsigned32
        }

dot11DCSTimeout OBJECT-TYPE
    SYNTAX Unsigned32 (1..64000)
    UNITS "milliseconds"
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by the SME or an external management entity.
        Changes take effect as soon as practical in the implementation.

        Dynamic channel selection timeout (in milliseconds)"
    DEFVAL { 1000 }
    ::= { dot11CDMGOperationEntry 1 }

-- ************************************************************************
-- * End of dot11CDMGOperation TABLE
-- ************************************************************************
```


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```
-- ************************************************************************
-- * (11ay)dot11EDMGOperation TABLE
-- ************************************************************************

dot11EDMGOperationTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11EDMGOperationEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "This is a table management object."
    ::= { dot11mac 14 }

dot11EDMGOperationEntry OBJECT-TYPE
    SYNTAX Dot11EDMGOperationEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "This is an entry in the dot11EDMGOperatingTable Table.

        ifIndex - Each IEEE 802.11 interface is represented by an ifEntry.
        Interface tables in this MIB module are indexed by ifIndex."
    INDEX { ifIndex }
    ::= { dot11EDMGOperationTable 1 }

Dot11EDMGOperationEntry ::=
        SEQUENCE {
               dot11EDMGDistributedSchedulingProtocolActivated TruthValue
        }

dot11EDMGDistributedSchedulingProtocolActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
    "This is a control variable.

        It is written by the SME or an external management entity. Changes take
        effect as soon as practical in the implementation. If true, distributed
        scheduling is activated. Otherwise, distributed scheduling is not
        activated."
    DEFVAL { false }
    ::= { dot11EDMGOperationEntry 1 }

-- ************************************************************************
-- * (11ay)End of dot11EDMGOperation TABLE
-- ************************************************************************


-- ************************************************************************
-- * (11ax)SMT MU EDCA Config TABLE
-- ************************************************************************

(11ax)dot11MUEDCATable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11MUEDCAEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "Conceptual table for MU EDCA parameters(#1660) at a non-AP STA. This
        table contains the four entries of the MU EDCA parameters corresponding to
        four possible ACs. Index 1 corresponds to AC_BK, index 2 to AC_BE, index 3
        to AC_VI, and index 4 to AC_VO."
```

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```
    ::= { dot11mac 15 }

(11ax)dot11MUEDCAEntry OBJECT-TYPE
    SYNTAX Dot11MUEDCAEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "An Entry (conceptual row) in the MU EDCA Table.

        ifIndex - Each IEEE 802.11 interface is represented by an ifEntry.
        Interface tables in this MIB module are indexed by ifIndex."
    INDEX { ifIndex, dot11MUEDCATableIndex }
    ::= { dot11MUEDCATable  1 }

(11ax)Dot11MUEDCAEntry ::=
    SEQUENCE {
        dot11MUEDCATableIndex                                   Unsigned32,
        dot11MUEDCATableCWmin                                   Unsigned32,
        dot11MUEDCATableCWmax                                   Unsigned32,
        dot11MUEDCATableAIFSN                                   Unsigned32,
        dot11MUEDCATableTimer                                   Unsigned32
}

(11ax)dot11MUEDCATableIndex OBJECT-TYPE
    SYNTAX Unsigned32 (1..4)
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "The auxiliary variable used to identify instances of the columnar objects
        in the MU EDCA Table. The value of this variable is
        1, if the value of the AC is AC_BK.
        2, if the value of the AC is AC_BE.
        3, if the value of the AC is AC_VI.
        4, if the value of the AC is AC_VO."
    ::= { dot11MUEDCAEntry 1 }

(11ax)dot11MUEDCATableCWmin OBJECT-TYPE
    SYNTAX Unsigned32 (0..255)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by the MAC upon receiving an MU EDCA Parameter Set.
        Changes take effect as soon as practical in the implementation.

        This attribute specifies the value of the minimum size of the window that
        is used by a STA for a particular AC for generating a random number for
        the backoff. The value of this attribute is such that it could always be
        expressed in the form of 2**X - 1, where X is an integer. "
    ::= { dot11MUEDCAEntry 2 }

(11ax)dot11MUEDCATableCWmax OBJECT-TYPE
    SYNTAX Unsigned32 (0..65535)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by the MAC upon receiving an MU EDCA Parameter Set.
        Changes take effect as soon as practical in the implementation.

        This attribute specifies the value of the maximum size of the window that
        is used by a STA for a particular AC for generating a random number for
        the backoff. The value of this attribute is such that it could always be
        expressed in the form of 2**X - 1, where X is an integer."
```


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```
    ::= { dot11MUEDCAEntry 3 }

(11ax)dot11MUEDCATableAIFSN OBJECT-TYPE
    SYNTAX Unsigned32 (0..15)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by the MAC upon receiving an MU EDCA Parameter Set element.
        Changes take effect as soon as practical in the implementation.

        This attribute specifies the number of slots, after a SIFS, that the STA,
        for a particular AC, senses the medium idle either before transmitting or
        executing a backoff, except that the value 0 indicates that EDCA is
        disabled for that AC."
    ::= { dot11MUEDCAEntry 4 }

(11ax)dot11MUEDCATableTimer OBJECT-TYPE
    SYNTAX Unsigned32 (1..255)
    UNITS "8 TUs"
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as the STA sends a frame in response to a
        Basic Trigger frame.

        This attribute specifies the duration of time during which the HE STA uses
        the MU EDCA parameters for the corresponding AC."
        REFERENCE
        "26.2.7 (EDCA operation using MU EDCA parameters)"
    ::= { dot11MUEDCAEntry 5 }

-- ****************************************************************
-- * (11ax)End of SMT MU EDCA Config TABLE
-- ****************************************************************

-- ****************************************************************
-- * PHY Attribute Templates
-- ****************************************************************

-- ****************************************************************
-- * dot11PhyOperation TABLE
-- ****************************************************************

dot11PhyOperationTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11PhyOperationEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "PHY level attributes concerned with operation. Implemented as a table
        indexed on ifIndex to allow for multiple instances(#467) on an Agent."
    ::= { dot11phy 1 }

dot11PhyOperationEntry OBJECT-TYPE
    SYNTAX Dot11PhyOperationEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "An entry in the dot11PhyOperation Table.

        ifIndex - Each IEEE 802.11 interface is represented by an ifEntry.
        Interface tables in this MIB module are indexed by ifIndex."
```

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```
    INDEX { ifIndex }
    ::= { dot11PhyOperationTable 1 }

Dot11PhyOperationEntry ::=
    SEQUENCE {
        dot11PHYType                                        INTEGER,
        dot11CurrentRegDomain                               Unsigned32,
        dot11TempType                                       INTEGER }

dot11PHYType OBJECT-TYPE
    SYNTAX INTEGER {
        dsss(2),
        ofdm(4),
        hrdsss(5),
        erp(6),
        ht(7),
        dmg(8),
        vht(9),
        tvht(10),
        s1g(11),
        cdmg(12),
        cmmg(13),
        he(14),(11ax)
        edmg(15),(11ay)
        ngv(17)(11bd)}
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the PHY.

        This is an 8-bit integer value that identifies the supported PHY type.
        Currently defined values and their corresponding PHY types are:

        DSSS 2.4 GHz = 2, OFDM = 4, HRDSSS = 5, ERP = 6, HT = 7, DMG = 8, VHT = 9,
        TVHT = 10, S1G = 11, CDMG = 12, CMMG = 13, HE = 14(11ax), EDMG = 15(11ay),
        NGV = 17(11bd)"
    ::= { dot11PhyOperationEntry 1 }

dot11CurrentRegDomain OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by the SME when the (#4213)STA is initialized.

        The current regulatory domain this instance of the PHY is supporting. This
        object corresponds to one of the RegDomains listed in
        dot11RegDomainsSupported."
    ::= { dot11PhyOperationEntry 2 }

dot11TempType OBJECT-TYPE
    SYNTAX INTEGER { tempType1(1), tempType2(2) }
    MAX-ACCESS read-only
    STATUS deprecated
    DESCRIPTION
        "The use of dot11TempType is deprecated because the associated behavior
        has been removed from IEEE Std 802.11-2016, and this entity may be removed
        in a later revision of the standard.
        This is a status variable.
        It is written by the PHY.

        There are different operating temperature requirements dependent on the
```



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```
        anticipated environmental conditions. This attribute describes the current
        PHY's operating temperature range capability. Currently defined values and
        their corresponding temperature ranges are:

        Type 1 = X'01'-Commercial range of 0 to 40 degrees C,

        Type 2 = X'02'-Industrial range of -30 to 70 degrees C."
    ::= { dot11PhyOperationEntry 3 }

-- ****************************************************************
-- * End of dot11PhyOperation  TABLE
-- ****************************************************************

-- ****************************************************************
-- * dot11PhyAntenna  TABLE
-- ****************************************************************

dot11PhyAntennaTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11PhyAntennaEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "Group of attributes for PhyAntenna. Implemented as a table indexed on
        ifIndex to allow for multiple instances on an agent."
    ::= { dot11phy 2}

dot11PhyAntennaEntry OBJECT-TYPE
    SYNTAX Dot11PhyAntennaEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "An entry in the dot11PhyAntenna Table.

        ifIndex - Each IEEE 802.11 interface is represented by an ifEntry.
        Interface tables in this MIB module are indexed by ifIndex."
    INDEX { ifIndex }
    ::= { dot11PhyAntennaTable 1 }

Dot11PhyAntennaEntry ::=
    SEQUENCE {
        dot11CurrentTxAntenna                                   Unsigned32,
        dot11DiversitySupportImplemented                        INTEGER,
        dot11CurrentRxAntenna                                   Unsigned32,
        dot11AntennaSelectionOptionImplemented                  TruthValue,
        dot11TransmitExplicitCSIFeedbackASOptionImplemented     TruthValue,
        dot11TransmitIndicesFeedbackASOptionImplemented         TruthValue,
        dot11ExplicitCSIFeedbackASOptionImplemented             TruthValue,
        dot11TransmitIndicesComputationASOptionImplemented      TruthValue,
        dot11ReceiveAntennaSelectionOptionImplemented           TruthValue,
        dot11TransmitSoundingPPDUOptionImplemented              TruthValue,
        dot11NumberOfActiveRxAntennas                           Unsigned32 }

dot11CurrentTxAntenna OBJECT-TYPE
    SYNTAX Unsigned32 (1..255)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        The current antenna being used to transmit. This value is one of the
        values appearing in dot11TxAntennaImplemented. This may be used by a
        management agent to control which antenna is used for transmission."
```

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```
    ::= { dot11PhyAntennaEntry 1 }

dot11DiversitySupportImplemented OBJECT-TYPE
    SYNTAX INTEGER { fixedlist(1), notsupported(2), dynamic(3) }
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This implementation's support for diversity, encoded as:

        X'01'-diversity is available and is performed over the fixed list of
        antennas defined in dot11DiversitySelectionRxImplemented.

        X'02'-diversity is not supported.

        X'03'-diversity is supported and control of diversity is also available,
        in which case the attribute dot11DiversitySelectionRxImplemented can be
        dynamically modified by the LME."
    ::= { dot11PhyAntennaEntry 2 }

dot11CurrentRxAntenna OBJECT-TYPE
    SYNTAX Unsigned32 (0..255)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the PHY.

        The current antenna being used to receive, if dot11DiversitySupportImple-
        mented indicates that diversity is not supported. The selected antenna is
        one of the antennae marked for receive in the dot11AntennasListTable."
    ::= { dot11PhyAntennaEntry 3 }

dot11AntennaSelectionOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that ASEL is supported by the station
        implementation."
    ::= { dot11PhyAntennaEntry 4 }

dot11TransmitExplicitCSIFeedbackASOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the transmit ASEL based on
        explicit CSI feedback is supported by the station implementation."
    ::= { dot11PhyAntennaEntry 5 }

dot11TransmitIndicesFeedbackASOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
```


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```
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the transmit ASEL based on
        antenna indices feedback is supported by the station implementation."
    ::= { dot11PhyAntennaEntry 6 }

dot11ExplicitCSIFeedbackASOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the computation of CSI and
        feedback the results to support the peer to do ASEL is supported by the
        station implementation."
    ::= { dot11PhyAntennaEntry 7 }

dot11TransmitIndicesComputationASOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the transmit ASEL based on
        antenna indices selection computation and feedback the results to support
        the peer to do ASEL is supported by the station implementation."
    ::= { dot11PhyAntennaEntry 8 }

dot11ReceiveAntennaSelectionOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the receive ASEL is supported by
        the station implementation."
    ::= { dot11PhyAntennaEntry 9 }

dot11TransmitSoundingPPDUOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the transmission of sounding
        PPDUs is supported by the station implementation."
    ::= { dot11PhyAntennaEntry 10 }

dot11NumberOfActiveRxAntennas OBJECT-TYPE
    SYNTAX Unsigned32 (1..4)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the PHY.
```

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```
        This attribute indicates the number of current active antennas being used
        to receive."
    ::= { dot11PhyAntennaEntry 11 }

-- ************************************************************************
-- * End of dot11PhyAntenna  TABLE
-- ************************************************************************

-- ************************************************************************
-- * dot11PhyTxPower  TABLE
-- ************************************************************************

dot11PhyTxPowerTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11PhyTxPowerEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "Group of attributes for dot11PhyTxPowerTable. Implemented as a table
        indexed on STA ID to allow for multiple instances on an Agent."
    ::= { dot11phy 3}

dot11PhyTxPowerEntry OBJECT-TYPE
    SYNTAX Dot11PhyTxPowerEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "An entry in the dot11PhyTxPower Table.

        ifIndex - Each IEEE 802.11 interface is represented by an ifEntry.
        Interface tables in this MIB module are indexed by ifIndex."
    INDEX { ifIndex }
    ::= { dot11PhyTxPowerTable 1 }

Dot11PhyTxPowerEntry ::=
    SEQUENCE {
        dot11NumberSupportedPowerLevelsImplemented          Unsigned32,
        dot11TxPowerLevel1                                  Unsigned32,
        dot11TxPowerLevel2                                  Unsigned32,
        dot11TxPowerLevel3                                  Unsigned32,
        dot11TxPowerLevel4                                  Unsigned32,
        dot11TxPowerLevel5                                  Unsigned32,
        dot11TxPowerLevel6                                  Unsigned32,
        dot11TxPowerLevel7                                  Unsigned32,
        dot11TxPowerLevel8                                  Unsigned32,
        dot11CurrentTxPowerLevel                            Unsigned32,
        dot11TxPowerLevelExtended                           OCTET STRING,
        dot11CurrentTxPowerLevelExtended                    Unsigned32 }

dot11NumberSupportedPowerLevelsImplemented OBJECT-TYPE
    SYNTAX Unsigned32 (1..8)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        The number of power levels supported by the PHY. This attribute can have a
        value of 1 to 8."
    ::= { dot11PhyTxPowerEntry 1 }

dot11TxPowerLevel1 OBJECT-TYPE
    SYNTAX Unsigned32 (0..10000)
    UNITS "mW"
```


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```
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        The transmit output power for LEVEL1. This is also the default power
        level."
    ::= { dot11PhyTxPowerEntry 2 }

dot11TxPowerLevel2 OBJECT-TYPE
    SYNTAX Unsigned32 (0..10000)
    UNITS "mW"
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        The transmit output power for LEVEL2."
    ::= { dot11PhyTxPowerEntry 3 }

dot11TxPowerLevel3 OBJECT-TYPE
    SYNTAX Unsigned32 (0..10000)
    UNITS "mW"
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        The transmit output power for LEVEL3."
    ::= { dot11PhyTxPowerEntry 4 }

dot11TxPowerLevel4 OBJECT-TYPE
    SYNTAX Unsigned32 (0..10000)
    UNITS "mW"
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        The transmit output power for LEVEL4."
    ::= { dot11PhyTxPowerEntry 5 }

dot11TxPowerLevel5 OBJECT-TYPE
    SYNTAX Unsigned32 (0..10000)
    UNITS "mW"
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        The transmit output power for LEVEL5."
    ::= { dot11PhyTxPowerEntry 6 }

dot11TxPowerLevel6 OBJECT-TYPE
    SYNTAX Unsigned32 (0..10000)
    UNITS "mW"
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
```

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```
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        The transmit output power for LEVEL6."
    ::= { dot11PhyTxPowerEntry 7 }

dot11TxPowerLevel7 OBJECT-TYPE
    SYNTAX Unsigned32 (0..10000)
    UNITS "mW"
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        The transmit output power for LEVEL7."
    ::= { dot11PhyTxPowerEntry 8 }

dot11TxPowerLevel8 OBJECT-TYPE
    SYNTAX Unsigned32 (0..10000)
    UNITS "mW"
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        The transmit output power for LEVEL8."
    ::= { dot11PhyTxPowerEntry 9 }

dot11CurrentTxPowerLevel OBJECT-TYPE
    SYNTAX Unsigned32 (1..8)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the PHY.

        Set to min(N,8) where N is an index into dot11TxPowerLevel<N> or
        dot11TxPowerLevelExtended and identifies the transmit power level
        currently being used to transmit data. Some PHYs also use this value to
        determine the receiver sensitivity requirements for CCA."
    ::= { dot11PhyTxPowerEntry 10 }

dot11TxPowerLevelExtended OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(2..256))
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        It has an even number of octets. It is organized as a variable length list
        of octet pairs, where each octet pair defines a big-endian 16-bit integer.
        The N-th integer represents the N-th EIRP, in units of 250 microWatts. The
        values dot11TxPowerLevel1 to dot11TxPowerLevel<min(8,
        dot11NumberSupportedPowerLevelsImplemented)> inclusive, in order,
        correspond to the first to min(8,
        dot11NumberSupportedPowerLevelsImplemented)-th integers in this variable.
        Where dot11TxPowerLevel1 to dot11TxPowerLevel<min(8,
        dot11NumberSupportedPowerLevelsImplemented)> inclusive contain EIRP
        values then, when converted from units of milliWatts to 250 microWatts,
        they shall appear in order in positions 1 to min(8,
        dot11NumberSupportedPowerLevelsImplemented) in this variable."
```


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```
    ::= { dot11PhyTxPowerEntry 11 }

dot11CurrentTxPowerLevelExtended OBJECT-TYPE
    SYNTAX Unsigned32 (1..128)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the PHY.

        Contains an index into the integer array in dot11TxPowerLevelExtended
        (where the value 1 indicates the first value in dot11TxPowerLevelExtended,
        and so on) that identifies the transmit output power currently being used
        to transmit data."
    ::= { dot11PhyTxPowerEntry 12 }

-- ****************************************************************
-- * End of dot11PhyTxPower  TABLE
-- ****************************************************************

-- ****************************************************************
-- * dot11PhyDSSSEntry  TABLE
-- ****************************************************************

dot11PhyDSSSTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11PhyDSSSEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "Entry of attributes for dot11PhyDSSSEntry. Implemented as a table indexed
        on ifIndex to allow for multiple instances on an Agent."
    ::= { dot11phy 5 }

dot11PhyDSSSEntry OBJECT-TYPE
    SYNTAX Dot11PhyDSSSEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "An entry in the dot11PhyDSSSEntry Table.

        ifIndex - Each IEEE 802.11 interface is represented by an ifEntry.
        Interface tables in this MIB module are indexed by ifIndex."
    INDEX { ifIndex }
    ::= { dot11PhyDSSSTable 1 }

Dot11PhyDSSSEntry ::=
    SEQUENCE {
        dot11CurrentChannel                                 Unsigned32,
        dot11CCAModeSupported                               Unsigned32,
        dot11CurrentCCAMode                                 INTEGER,
        dot11EDThreshold                                    Integer32 }

dot11CurrentChannel OBJECT-TYPE
    SYNTAX Unsigned32 (1..14)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the PHY.

        The current operating frequency channel of the DSSS PHY. Valid channel
        numbers are as defined in 15.4.4.3 (Channel Numbering of operating chan-
        nels)"
    ::= { dot11PhyDSSSEntry 1 }
```

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```
dot11CCAModeSupported OBJECT-TYPE
   SYNTAX Unsigned32 (1..7)
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a capability variable.
      Its value is determined by (#3375)STA capabilities.

      dot11CCAModeSupported is a bit-significant value, representing all of the
      CCA modes supported by the DSSS PHY in addition to detection of energy
      above -62 dBm (which is always supported). Valid values are:

      energy detect only (edonly) = 01,
      carrier sense only (csonly) = 02,
      carrier sense and energy detect (csanded)= 04
      or the logical sum of any of these values."
   ::= { dot11PhyDSSSEntry 2 }

dot11CurrentCCAMode OBJECT-TYPE
   SYNTAX INTEGER {
      edonly(1),
      csonly(2),
      csanded(4), cswithtimer(8),
      hrcsanded(16) }
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by an external management entity.
      Changes take effect as soon as practical in the implementation.

      The current CCA method in operation for a DSSS or HR/DSSS PHY, in addition
      to detection of energy above -62 dBm (which is always supported). Valid
      values are:
      energy detect only (edonly) = 01,
      carrier sense only (csonly) = 02,
      carrier sense and energy detect (csanded)= 04
      carrier sense with timer (cswithtimer)= 08
      high rate carrier sense and energy detect (hrcsanded)=16,
      subject to the support indicated in dot11CCAModeSupported (for the DSSS
      PHY) or dot11HRCCAModeImplemented (for the HR/DSSS PHY)."
   ::= { dot11PhyDSSSEntry 3 }

dot11EDThreshold OBJECT-TYPE
   SYNTAX Integer32 (-100..-70)
   UNITS "dBm"
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by an external management entity.
      Changes take effect as soon as practical in the implementation.
      The current energy detect threshold being used by the DSSS PHY or HR/DSSS
      PHY."
   ::= { dot11PhyDSSSEntry 4 }

-- ************************************************************************
-- * End of dot11PhyDSSSEntry  TABLE
-- ************************************************************************

-- ************************************************************************
-- * dot11RegDomainsSupported  TABLE
-- ************************************************************************
```


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```
dot11RegDomainsSupportedTable OBJECT-TYPE
   SYNTAX SEQUENCE OF Dot11RegDomainsSupportedEntry
   MAX-ACCESS not-accessible
   STATUS deprecated
           DESCRIPTION
      "Superseded by dot11OperatingClassesTable.

      There are different operational requirements dependent on the regulatory
      domain. This attribute list describes the regulatory domains the PHY
      supports in this implementation. Currently defined values and their
      corresponding Regulatory Domains are:

      FCC (USA and its territories(#296)) = X'10', DOC (Canada) = X'20', ETSI
      (most of Europe) = X'30', Spain = X'31', France = X'32', Japan = X'40',
      China = X'50', Other = X'00' "
   ::= { dot11phy 7}

dot11RegDomainsSupportedEntry OBJECT-TYPE
   SYNTAX Dot11RegDomainsSupportedEntry
   MAX-ACCESS not-accessible
   STATUS deprecated
   DESCRIPTION
      "Superseded by dot11OperatingClassesTable.
      An entry in the dot11RegDomainsSupportedTable.

      ifIndex - Each IEEE 802.11 interface is represented by an ifEntry.
      Interface tables in this MIB module are indexed by ifIndex."
   INDEX { ifIndex, dot11RegDomainsSupportedIndex }
   ::= { dot11RegDomainsSupportedTable 1 }

Dot11RegDomainsSupportedEntry ::=
   SEQUENCE {
      dot11RegDomainsSupportedIndex                    Unsigned32,
      dot11RegDomainsImplementedValue                  INTEGER }

dot11RegDomainsSupportedIndex OBJECT-TYPE
   SYNTAX Unsigned32
   MAX-ACCESS not-accessible
   STATUS deprecated
   DESCRIPTION
      "The auxiliary variable used to identify instances of the columnar objects
      in the RegDomainsSupport Table."
   ::= { dot11RegDomainsSupportedEntry 1 }

dot11RegDomainsImplementedValue OBJECT-TYPE
   SYNTAX INTEGER {
      other (0),
      fcc(16),
      doc(32),
      etsi(48),
      spain (49),
      france(50),
      japan (64)}
   MAX-ACCESS read-only
   STATUS deprecated
   DESCRIPTION
      "This is a capability variable.
      Its value is determined by (#3375)STA capabilities.

      There are different operational requirements dependent on the regulatory
      domain. This attribute list describes the regulatory domains the PHY
      supports in this implementation. Currently defined values and their
      corresponding Regulatory Domains are:
```

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```
        FCC (USA and its territories(#296)) = X'10', DOC (Canada) = X'20', ETSI
        (most of Europe) = X'30', Spain = X'31', France = X'32', Japan = X'40',
        China = X'50' "
    ::= { dot11RegDomainsSupportedEntry 2 }

-- ****************************************************************
-- * End of dot11RegDomainsSupported  TABLE
-- ****************************************************************

-- ****************************************************************
-- * dot11AntennasList  TABLE
-- ****************************************************************

dot11AntennasListTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11AntennasListEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "This table represents the list of antennae. An antenna can be marked to
        be capable of transmitting, receiving, and/or for participation in receive
        diversity. Each entry in this table represents a single antenna with its
        properties. The maximum number of antennae that can be contained in this
        table is 255."
    ::= { dot11phy 8 }

dot11AntennasListEntry OBJECT-TYPE
    SYNTAX Dot11AntennasListEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "An entry in the dot11AntennasListTable, representing the properties of a
        single antenna.

        ifIndex - Each IEEE 802.11 interface is represented by an ifEntry.
        Interface tables in this MIB module are indexed by ifIndex."
    INDEX { ifIndex, dot11AntennaListIndex }
    ::= { dot11AntennasListTable 1 }

Dot11AntennasListEntry ::=
    SEQUENCE {
        dot11AntennaListIndex                                Unsigned32,
        dot11TxAntennaImplemented                            TruthValue,
        dot11RxAntennaImplemented                            TruthValue,
        dot11DiversitySelectionRxImplemented                 TruthValue }

dot11AntennaListIndex OBJECT-TYPE
    SYNTAX Unsigned32 (1..254)
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "The unique index of an antenna which is used to identify the columnar
        objects in the dot11AntennasList Table."
    ::= { dot11AntennasListEntry 1 }

dot11TxAntennaImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        When true, this object indicates that the antenna represented by
```


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```
        dot11AntennaListIndex can be used as a transmit antenna."
    ::= { dot11AntennasListEntry 2 }

dot11RxAntennaImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        When true, this object indicates that the antenna represented by the
        dot11AntennaListIndex can be used as a receive antenna."
    ::= { dot11AntennasListEntry 3 }

dot11DiversitySelectionRxImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        When true, this object indicates that the antenna represented by
        dot11AntennaListIndex can be used for receive diversity. This object is
        true only if the antenna can be used as a receive antenna, as indicated by
        dot11RxAntennaImplemented."
    ::= { dot11AntennasListEntry 4 }

-- ****************************************************************
-- * End of dot11AntennasList  TABLE
-- ****************************************************************

-- ****************************************************************
-- * dot11SupportedDataRatesTx  TABLE
-- ****************************************************************

dot11SupportedDataRatesTxTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11SupportedDataRatesTxEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "The Transmit bit rates supported by the PHY, represented by a count from
        X'02-X'7f, corresponding to data rates in increments of 500 kb/s from 1
        Mb/s to 63.5 Mb/s subject to limitations of each individual PHY."
    ::= { dot11phy 9 }

dot11SupportedDataRatesTxEntry OBJECT-TYPE
    SYNTAX Dot11SupportedDataRatesTxEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "An Entry (conceptual row) in the dot11SupportedDataRatesTx Table.

        ifIndex - Each IEEE 802.11 interface is represented by an ifEntry.
        Interface tables in this MIB module are indexed by ifIndex."
    INDEX { ifIndex, dot11SupportedDataRatesTxIndex }
    ::= { dot11SupportedDataRatesTxTable  1 }

Dot11SupportedDataRatesTxEntry ::=
    SEQUENCE {
        dot11SupportedDataRatesTxIndex                      Unsigned32,
        dot11ImplementedDataRatesTxValue                    Unsigned32 }
```

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```
dot11SupportedDataRatesTxIndex OBJECT-TYPE
   SYNTAX Unsigned32 (1..255)
   MAX-ACCESS not-accessible
   STATUS current
   DESCRIPTION
      "Index object that identifies which data rate to access. Range is 1..255."
   ::= { dot11SupportedDataRatesTxEntry 1 }

dot11ImplementedDataRatesTxValue OBJECT-TYPE
   SYNTAX Unsigned32 (2..127)
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a capability variable.
      Its value is determined by (#3375)STA capabilities.

      The Transmit bit rates supported by the PHY, represented by a count from
      X'02-X'7f, corresponding to data rates in increments of 500 kb/s from 1
      Mb/s to 63.5 Mb/s subject to limitations of each individual PHY."
   ::= { dot11SupportedDataRatesTxEntry 2 }

-- ****************************************************************
-- * End of dot11SupportedDataRatesTx  TABLE
-- ****************************************************************

-- ****************************************************************
-- * dot11SupportedDataRatesRx  TABLE
-- ****************************************************************

dot11SupportedDataRatesRxTable OBJECT-TYPE
   SYNTAX SEQUENCE OF Dot11SupportedDataRatesRxEntry
   MAX-ACCESS not-accessible
   STATUS current
   DESCRIPTION
      "The receive bit rates supported by the PHY, represented by a count from
      X'002-X'7f, corresponding to data rates in increments of 500 kb/s from 1
      Mb/s to 63.5 Mb/s."
   ::= { dot11phy 10 }

dot11SupportedDataRatesRxEntry OBJECT-TYPE
   SYNTAX Dot11SupportedDataRatesRxEntry
   MAX-ACCESS not-accessible
   STATUS current
   DESCRIPTION
      "An Entry (conceptual row) in the dot11SupportedDataRatesRx Table.

      ifIndex - Each IEEE 802.11 interface is represented by an ifEntry.
      Interface tables in this MIB module are indexed by ifIndex."
   INDEX { ifIndex, dot11SupportedDataRatesRxIndex }
   ::= { dot11SupportedDataRatesRxTable  1 }

Dot11SupportedDataRatesRxEntry ::=
   SEQUENCE {
      dot11SupportedDataRatesRxIndex                    Unsigned32,
      dot11ImplementedDataRatesRxValue                  Unsigned32 }

dot11SupportedDataRatesRxIndex OBJECT-TYPE
   SYNTAX Unsigned32 (1..255)
   MAX-ACCESS not-accessible
   STATUS current
   DESCRIPTION
      "Index object that identifies which data rate to access. Range is 1..255."
   ::= { dot11SupportedDataRatesRxEntry 1 }
```


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```
dot11ImplementedDataRatesRxValue OBJECT-TYPE
   SYNTAX Unsigned32 (2..127)
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a capability variable.
      Its value is determined by (#3375)STA capabilities.

      The receive bit rates supported by the PHY, represented by a count from
      X'02-X'7f, corresponding to data rates in increments of 500 kb/s from 1
      Mb/s to 63.5 Mb/s."
   ::= { dot11SupportedDataRatesRxEntry 2 }

-- ************************************************************************
-- * End of dot11SupportedDataRatesRx  TABLE
-- ************************************************************************

-- ************************************************************************
-- * dot11PhyOFDM TABLE
-- ************************************************************************

dot11PhyOFDMTable OBJECT-TYPE
   SYNTAX SEQUENCE OF Dot11PhyOFDMEntry
   MAX-ACCESS not-accessible
   STATUS current
   DESCRIPTION
      "Group of attributes for dot11PhyOFDMTable. Implemented as a table indexed
      on ifindex to allow for multiple instances on an Agent."
   ::= { dot11phy 11 }

dot11PhyOFDMEntry OBJECT-TYPE
   SYNTAX Dot11PhyOFDMEntry
   MAX-ACCESS not-accessible
   STATUS current
   DESCRIPTION
      "An entry in the dot11PhyOFDM Table.

      ifIndex - Each IEEE 802.11 interface is represented by an ifEntry.
      Interface tables in this MIB module are indexed by ifIndex."
   INDEX { ifIndex }
   ::= { dot11PhyOFDMTable 1 }

Dot11PhyOFDMEntry ::=
   SEQUENCE {
      dot11CurrentFrequency                              Unsigned32,
      dot11TIThreshold                                   Integer32,
      dot11FrequencyBandsImplemented                     Unsigned32,
      dot11ChannelStartingFactor                         Unsigned32,
      dot11FiveMHzOperationImplemented                   TruthValue,
      dot11TenMHzOperationImplemented                    TruthValue,
      dot11TwentyMHzOperationImplemented                 TruthValue,
      dot11PhyOFDMChannelWidth                           INTEGER,
      dot11OFDMCCAEDImplemented                          TruthValue,
      dot11OFDMCCAEDRequired                             TruthValue,
      dot11OFDMEDThreshold                               Unsigned32,
      dot11STATransmitPowerClass                         INTEGER,
      dot11ACRType                                       INTEGER }

dot11CurrentFrequency OBJECT-TYPE
   SYNTAX Unsigned32 (0..200)
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a status variable.
```

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```
        It is written by the PHY.

        The number of the current operating frequency channel of the OFDM PHY."
    ::= { dot11PhyOFDMEntry 1 }

dot11TIThreshold OBJECT-TYPE
    SYNTAX Integer32
    MAX-ACCESS read-write
    STATUS deprecated
    DESCRIPTION
        "Superseded by PHY-specific or regulatory CCA energy detect limits.

        The Threshold being used to detect a busy medium (frequency). CCA reports
        a busy medium upon detecting the RSSI above this threshold."
    ::= { dot11PhyOFDMEntry 2 }

dot11FrequencyBandsImplemented OBJECT-TYPE
    SYNTAX Unsigned32 (1..127)
    MAX-ACCESS read-only
    STATUS deprecated
            DESCRIPTION
        "Superseded by subband-specific supported operating classes.
        This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        The capability of the OFDM PHY implementation to operate in the 4.9 GHz
        and 5 GHz bands. Coded as an integer value with bit 0 LSB as follows:
        bit 0 .. capable of operating in the 5.15-5.25 GHz band
        bit 1 .. capable of operating in the 5.25-5.35 GHz band
        bit 2 .. capable of operating in the 5.725-5.825 GHz band
        bit 3 .. capable of operating in the 5.47-5.725 GHz band
        bit 4 .. capable of operating in the lower Japanese (5.15-5.25 GHz) band
        bit 5 .. capable of operating in the 5.03-5.091 GHz band
        bit 6 .. capable of operating in the 4.94-4.99 GHz band
        For example, for an implementation capable of operating in the 5.15-5.35
        GHz bands this attribute would take the value 3."
    ::= { dot11PhyOFDMEntry 3 }

dot11ChannelStartingFactor OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        The base factor from which channel center frequencies are calculated. This
        number is multiplied by 500 kHz to form the base frequency to be added to
        the channel number x 5 MHz."
    DEFVAL { 10000 }
    ::= { dot11PhyOFDMEntry 4 }

dot11FiveMHzOperationImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the 5 MHz Operation is
        implemented."
    ::= { dot11PhyOFDMEntry 5 }
```


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```
dot11TenMHzOperationImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the 10 MHz Operation is
        implemented."
    ::= { dot11PhyOFDMEntry 6 }

dot11TwentyMHzOperationImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the 20 MHz Operation is
        implemented."
    ::= { dot11PhyOFDMEntry 7 }

dot11PhyOFDMChannelWidth OBJECT-TYPE
    SYNTAX INTEGER { width5MHz(1), width10MHz(2), width20MHz(3)}
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by the SME.
        Changes take effect as soon as practical in the implementation.

        This is an 8-bit integer value that identifies the OFDM PHY channel width.
        Currently defined values and their corresponding Channel widths are:
        5 MHz = 01, 10 MHz = 02, 20 MHz = 03"
    ::= { dot11PhyOFDMEntry 8 }

dot11OFDMCCAEDImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute indicates that the OFDM PHY is capable of (#2365)CCA-Oper-
        ating Class Specific Energy Detect."
    ::= { dot11PhyOFDMEntry 9 }

dot11OFDMCCAEDRequired OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by the SME when the (#4213)STA is initialized for operation
        in a band defined by an Operating Class.

        This attribute indicates that the PHY (#2365)CCA-Operating Class Specific
        Energy Detect functionality is enabled."
    ::= { dot11PhyOFDMEntry 10 }
```

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```
dot11OFDMEDThreshold OBJECT-TYPE
   SYNTAX Unsigned32 (0..255)
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written the SME when the (#4213)STA is initialized for operation in
      a band defined by an Operating Class, or written by an external management
      entity.
      Changes take effect as soon as practical in the implementation.

      The current (#2365)CCA-Operating Class Specific Energy Detect Threshold
      being used by the OFDM PHY."
   ::= { dot11PhyOFDMEntry 11 }

dot11STATransmitPowerClass OBJECT-TYPE
   SYNTAX INTEGER { classA(1), classB(2), classC(3), classD(4) }
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a capability variable. Its value is determined by (#3375)STA
      capabilities.
      The station transmit power class: Class A=1, Class B=2, Class C=3, Class
      D=4 (as defined in D.2.2 (Transmit power levels))."
   ::=  { dot11PhyOFDMEntry 12 }

dot11ACRType OBJECT-TYPE
   SYNTAX INTEGER { standard(1), enhanced(2) }
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a status variable.
      It is written by the SME.

      The Adjacent and Nonadjacent Channel Rejection performance:
      when this attribute = 1 the levels in Table 17-21 (Receiver performance
      requirements) apply; when this attribute = 2 the levels in Table 17-22
      (Optional enhanced receiver performance requirements) apply."
   DEFVAL { 1 }
   ::=  { dot11PhyOFDMEntry 13 }

-- ****************************************************************
-- * End of dot11PhyOFDM TABLE
-- ****************************************************************

-- ****************************************************************
-- * dot11PhyHRDSSSEntry TABLE
-- ****************************************************************

dot11PhyHRDSSSTable OBJECT-TYPE
   SYNTAX SEQUENCE OF Dot11PhyHRDSSSEntry
   MAX-ACCESS not-accessible
   STATUS current
   DESCRIPTION
      "Entry of attributes for dot11PhyHRDSSSEntry. Implemented as a table
      indexed on ifIndex to allow for multiple instances on an Agent."
   ::= { dot11phy 12 }

dot11PhyHRDSSSEntry OBJECT-TYPE
   SYNTAX Dot11PhyHRDSSSEntry
   MAX-ACCESS not-accessible
   STATUS current
   DESCRIPTION
      "An entry in the dot11PhyHRDSSSEntry Table.
```


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```
        ifIndex - Each IEEE 802.11 interface is represented by an ifEntry.
        Interface tables in this MIB module are indexed by ifIndex."
    INDEX { ifIndex }
    ::= { dot11PhyHRDSSSTable 1 }

Dot11PhyHRDSSSEntry ::=
    SEQUENCE {
        dot11ShortPreambleOptionImplemented                    TruthValue,
        dot11HRCCAModeImplemented                              Unsigned32 }

dot11ShortPreambleOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the short preamble option as
        defined in 16.2.2.3 (Short PPDU format) is implemented."
    ::= { dot11PhyHRDSSSEntry 1 }


dot11HRCCAModeImplemented OBJECT-TYPE
    SYNTAX Unsigned32 (1..31)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        dot11HRCCAModeImplemented is a bit-significant value, representing all of
        the CCA modes supported by the HR/DSSS PHY, in addition to detection of
        energy above -62 dBm (which is always supported). Valid values are:
        energy detect only (edonly) = 01,
        carrier sense with timer (cswithtimer)= 08,
        high rate carrier sense and energy detect (hrcsanded)= 16
        or the logical sum of any of these values."
    ::= { dot11PhyHRDSSSEntry 5 }

-- ****************************************************************
-- * End of dot11PhyHRDSSSEntry TABLE
-- ****************************************************************

-- ****************************************************************
-- * dot11HoppingPattern TABLE
-- ****************************************************************

dot11HoppingPatternTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11HoppingPatternEntry
    MAX-ACCESS not-accessible
    STATUS deprecated
    DESCRIPTION
        "This attribute is deprecated because the frequency hopping PHY is no
        longer present in IEEE Std 802.11.

        The (conceptual) table of attributes necessary for a frequency hopping
        implementation to be able to create the hopping sequences necessary to
        operate in the subband for the associated domain country string."
    ::= { dot11phy 13 }

dot11HoppingPatternEntry OBJECT-TYPE
    SYNTAX Dot11HoppingPatternEntry
```

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```
    MAX-ACCESS not-accessible
    STATUS deprecated
    DESCRIPTION
        "This attribute is deprecated because the frequency hopping PHY is no
        longer present in IEEE Std 802.11.

        An entry (conceptual row) in the Hopping Pattern Table that indicates the
        random hopping sequence to be followed.

        IfIndex - Each IEEE 802.11 interface is represented by an ifEntry.
        Interface tables in this MIB are indexed by ifIndex."
    INDEX { ifIndex, dot11HoppingPatternIndex }
    ::= { dot11HoppingPatternTable 1 }

Dot11HoppingPatternEntry ::=
    SEQUENCE {
        dot11HoppingPatternIndex                        Unsigned32,
        dot11RandomTableFieldNumber                     Unsigned32 }

dot11HoppingPatternIndex OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS not-accessible
    STATUS deprecated
    DESCRIPTION
        "This attribute is deprecated because the frequency hopping PHY is no
        longer present in IEEE Std 802.11.

        The auxiliary variable used to identify instances of the columnar objects
        in the Hopping Pattern Table."
    ::= { dot11HoppingPatternEntry 1 }

dot11RandomTableFieldNumber OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-only
    STATUS deprecated
    DESCRIPTION
        "This attribute is deprecated because the frequency hopping PHY is no
        longer present in IEEE Std 802.11.

        This is a control variable.
        It is written by the SME when the (#4213)STA is initialized.

        This attribute indicates the value of the starting channel number in the
        hopping sequence of the subband for the associated domain country string."
    DEFVAL { 0 }
    ::= { dot11HoppingPatternEntry 2 }

-- ****************************************************************
-- * End of dot11HoppingPattern TABLE
-- ****************************************************************

-- ****************************************************************
-- * dot11PhyERP TABLE
-- ****************************************************************

dot11PhyERPTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11PhyERPEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "Entry of attributes for dot11PhyERPEntry. Implemented as a table indexed
        on ifIndex to allow for multiple instances on an Agent."
    ::= { dot11phy 14 }
```


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```
dot11PhyERPEntry OBJECT-TYPE
   SYNTAX Dot11PhyERPEntry
   MAX-ACCESS not-accessible
   STATUS current
   DESCRIPTION
      "An entry in the dot11PhyERPEntry Table.
      ifIndex - Each IEEE 802.11 interface is represented by an ifEntry.
      Interface tables in this MIB module are indexed by ifIndex."
   INDEX {ifIndex}
   ::= { dot11PhyERPTable 1 }

Dot11PhyERPEntry ::=
   SEQUENCE {
      dot11ShortSlotTimeOptionImplemented                    TruthValue,
      dot11ShortSlotTimeOptionActivated                      TruthValue,
      dot11Class2CapabilitiesOptionImplemented               TruthValue}

dot11ShortSlotTimeOptionImplemented OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a capability variable.
      Its value is determined by (#3375)STA capabilities.

      This attribute, when true, indicates that short slot time as defined in
      9.4.1.4 (Capability Information field) is implemented."
   ::= { dot11PhyERPEntry 5}

dot11ShortSlotTimeOptionActivated OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by an external management entity.
      Changes take effect as soon as practical in the implementation.

      This attribute, when true, indicates that short slot time as defined in
      9.4.1.4 (Capability Information field) is enabled."
   DEFVAL { false }
   ::= { dot11PhyERPEntry 6 }

dot11Class2CapabilitiesOptionImplemented OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a capability variable.
      Its value is determined by (#3375)STA capabilities.

      This attribute, when true, indicates that the station is a Class 2 ERP or
      Class 2 HT STA. This attribute is false if the STA is not operating in the
      2.4 GHz band."
   ::= { dot11PhyERPEntry 7 }

-- ************************************************************************
-- * End of dot11PhyERP TABLE
-- ************************************************************************

-- ************************************************************************
-- * dot11 Phy HT TABLE
-- ************************************************************************
```

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```
dot11PhyHTTable OBJECT-TYPE
   SYNTAX SEQUENCE OF Dot11PhyHTEntry
   MAX-ACCESS not-accessible
   STATUS current
   DESCRIPTION
      "Entry of attributes for dot11PhyHTTable. Implemented as a table indexed
      on ifIndex to allow for multiple instances on an Agent."
   ::= { dot11phy 15 }

dot11PhyHTEntry OBJECT-TYPE
   SYNTAX Dot11PhyHTEntry
   MAX-ACCESS not-accessible
   STATUS current
   DESCRIPTION
      "An entry in the dot11PhyHTEntry Table. ifIndex - Each IEEE 802.11
      interface is represented by an ifEntry. Interface tables in this MIB
      module are indexed by ifIndex."
   INDEX {ifIndex}
   ::= { dot11PhyHTTable 1 }

Dot11PhyHTEntry ::=
   SEQUENCE {
      dot11FortyMHzOperationImplemented                    TruthValue,
      dot11FortyMHzOperationActivated                      TruthValue,
      dot11CurrentPrimaryChannel                           Unsigned32,
      dot11CurrentSecondaryChannel                         Unsigned32,
      dot11NumberOfSpatialStreamsImplemented               Unsigned32,
      dot11NumberOfSpatialStreamsActivated                 Unsigned32,
      dot11HTGreenfieldOptionImplemented                   TruthValue,
      dot11HTGreenfieldOptionActivated                     TruthValue,
      dot11ShortGIOptionInTwentyImplemented                TruthValue,
      dot11ShortGIOptionInTwentyActivated                  TruthValue,
      dot11ShortGIOptionInFortyImplemented                 TruthValue,
      dot11ShortGIOptionInFortyActivated                   TruthValue,
      dot11LDPCCodingOptionImplemented                     TruthValue,
      dot11LDPCCodingOptionActivated                       TruthValue,
      dot11TxSTBCOptionImplemented                         TruthValue,
      dot11TxSTBCOptionActivated                           TruthValue,
      dot11RxSTBCOptionImplemented                         TruthValue,
      dot11RxSTBCOptionActivated                           TruthValue,
      dot11BeamFormingOptionImplemented                    TruthValue,
      dot11BeamFormingOptionActivated                      TruthValue,
      dot11HighestSupportedDataRate                        Unsigned32,
      dot11TxMCSSetDefined                                 TruthValue,
      dot11TxRxMCSSetNotEqual                              TruthValue,
      dot11TxMaximumNumberSpatialStreamsSupported          Unsigned32,
      dot11TxUnequalModulationSupported                    TruthValue }

dot11FortyMHzOperationImplemented OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a capability variable.
      Its value is determined by (#3375)STA capabilities.

      This attribute, when true, indicates that the 40 MHz (#3485)operation is
      implemented.
      (#3485)false or not present in a 20 MHz-only non-AP HE STA that is an HT
      STA.
      (#3485)true in a VHT STA that is not a 20 MHz-only non-AP HE STA."
   ::= { dot11PhyHTEntry 1 }

dot11FortyMHzOperationActivated OBJECT-TYPE
```


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```
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute, when true, indicates that the 40 MHz (#3485)operation is
        enabled.
        (#3485)false or not present in a 20 MHz-only non-AP HE STA that is an HT
        STA.
        (#3485)true in a VHT STA that is not a 20 MHz-only non-AP HE STA."
    DEFVAL { false }
    ::= { dot11PhyHTEntry 2 }

dot11CurrentPrimaryChannel OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the PHY.

        This attribute indicates the operating channel. If 20/40 MHz BSS is
        currently in use then this attribute indicates the primary channel."
    ::= { dot11PhyHTEntry 3 }

dot11CurrentSecondaryChannel OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the PHY.

        This attribute indicates the channel number of the secondary channel. If
        20/40 MHz BSS is not currently in use, this attribute value shall be 0."
    ::= { dot11PhyHTEntry 4 }

dot11NumberOfSpatialStreamsImplemented OBJECT-TYPE
    SYNTAX Unsigned32 (1..8)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute indicates the maximum number of spatial streams imple-
        mented."
    ::= { dot11PhyHTEntry 5 }

dot11NumberOfSpatialStreamsActivated OBJECT-TYPE
    SYNTAX Unsigned32 (1..8)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute indicates the maximum number of spatial streams enabled."
    DEFVAL { 2 }
    ::= { dot11PhyHTEntry 6 }
```

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```
dot11HTGreenfieldOptionImplemented OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a capability variable.
      Its value is determined by (#3375)STA capabilities.

      This attribute, when true, indicates that the HT-greenfield option is
      implemented."
   ::= { dot11PhyHTEntry 7 }

dot11HTGreenfieldOptionActivated OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by an external management entity.
      Changes take effect as soon as practical in the implementation.

      This attribute, when true, indicates that the HT-greenfield option is
      enabled."
   DEFVAL { false }
   ::= { dot11PhyHTEntry 8 }

dot11ShortGIOptionInTwentyImplemented OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a capability variable.
      Its value is determined by (#3375)STA capabilities.

      This attribute, when true, indicates that the Short Guard option is
      implemented for 20 MHz operation."
   ::= { dot11PhyHTEntry 9 }

dot11ShortGIOptionInTwentyActivated OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by an external management entity.
      Changes take effect as soon as practical in the implementation.

      This attribute, when true, indicates that the Short Guard option is
      enabled for 20 MHz operation."
   DEFVAL { false }
   ::= { dot11PhyHTEntry 10 }

dot11ShortGIOptionInFortyImplemented OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a capability variable.
      Its value is determined by (#3375)STA capabilities.

      This attribute, when true, indicates that the Short Guard option is
      implemented for 40 MHz operation."
   ::= { dot11PhyHTEntry 11 }
```


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```
dot11ShortGIOptionInFortyActivated OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by an external management entity.
      Changes take effect as soon as practical in the implementation.

      This attribute, when true, indicates that the Short Guard option is
      enabled for 40 MHz operation."
   DEFVAL { false }
   ::= { dot11PhyHTEntry 12 }

dot11LDPCCodingOptionImplemented OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a capability variable.
      Its value is determined by (#3375)STA capabilities.

      This attribute, when true, indicates that the LDPC coding option is
      implemented."
   ::= { dot11PhyHTEntry 13 }

dot11LDPCCodingOptionActivated OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by an external management entity.
      Changes take effect as soon as practical in the implementation.

      This attribute, when true, indicates that the LDPC coding option is
      enabled."
   DEFVAL { false }
   ::= { dot11PhyHTEntry 14 }

dot11TxSTBCOptionImplemented OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a capability variable.
      Its value is determined by (#3375)STA capabilities.

      This attribute, when true, indicates that the entity is capable of
      transmitting frames using STBC option."
   ::= { dot11PhyHTEntry 15 }

dot11TxSTBCOptionActivated OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by an external management entity.
      Changes take effect as soon as practical in the implementation.

      This attribute, when true, indicates that the entity's capability of
      transmitting frames using STBC option is enabled."
```

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```
    DEFVAL { false }
    ::= { dot11PhyHTEntry 16 }

dot11RxSTBCOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the entity is capable of
        receiving frames that are sent using the STBC."
    ::= { dot11PhyHTEntry 17 }

dot11RxSTBCOptionActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute, when true, indicates that the entity's capability of
        receiving frames that are sent using the STBC is enabled."
    DEFVAL { false }
    ::= { dot11PhyHTEntry 18 }

dot11BeamFormingOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the beamforming option is
        implemented."
    ::= { dot11PhyHTEntry 19 }

dot11BeamFormingOptionActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute, when true, indicates that the beamforming option is
        enabled."
    DEFVAL { false }
    ::= { dot11PhyHTEntry 20 }

dot11HighestSupportedDataRate OBJECT-TYPE
    SYNTAX Unsigned32 (0..600)
    UNITS "Mb/s"
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.
```


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```
        This attribute shall specify the Highest Data Rate at which the station
        may receive data."
    ::= { dot11PhyHTEntry 21 }

dot11TxMCSSetDefined OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute, when true, indicates that the Tx MCS set is defined."
    DEFVAL { false }
    ::= { dot11PhyHTEntry 22 }

dot11TxRxMCSSetNotEqual OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the PHY.

        This attribute, when true, indicates that the supported Tx and Rx MCS sets
        are not equal."
    DEFVAL { false }
    ::= { dot11PhyHTEntry 23 }

dot11TxMaximumNumberSpatialStreamsSupported OBJECT-TYPE
    SYNTAX Unsigned32 (0..3)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute indicates the Tx maximum number of spatial streams sup-
        ported."
    ::= { dot11PhyHTEntry 24 }

dot11TxUnequalModulationSupported OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that Tx UEQM is supported."
    ::= { dot11PhyHTEntry 25 }

-- ************************************************************************
-- * End of dot11 PHY HT TABLE
-- ************************************************************************

-- ************************************************************************
-- * dot11 Supported MCS Tx TABLE
-- ************************************************************************
dot11SupportedHTMCSTxTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11SupportedHTMCSTxEntry
    MAX-ACCESS not-accessible
    STATUS current
```

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```
    DESCRIPTION
        "(#3245)The Transmit MCS supported by the PHY, represented by a count from
        1 to 127, subject to limitations of each individual PHY."
    ::= { dot11phy 16 }

dot11SupportedHTMCSTxEntry OBJECT-TYPE
    SYNTAX Dot11SupportedHTMCSTxEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "An Entry (conceptual row) in the dot11SupportedHTMCSTx Table.
        ifIndex - Each IEEE 802.11 interface is represented by an
        ifEntry. Interface tables in this MIB module are indexed by ifIndex."
    INDEX { ifIndex, dot11SupportedHTMCSTxIndex }
    ::= { dot11SupportedHTMCSTxTable 1 }

Dot11SupportedHTMCSTxEntry ::=
    SEQUENCE {
        dot11SupportedHTMCSTxIndex                              Unsigned32,
        dot11SupportedHTMCSTxValue                              Unsigned32 }

dot11SupportedHTMCSTxIndex OBJECT-TYPE
    SYNTAX Unsigned32 (1..255)
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "Index object that identifies which MCS to access. Range is 1..255."
    ::= { dot11SupportedHTMCSTxEntry 1 }

dot11SupportedHTMCSTxValue OBJECT-TYPE
    SYNTAX Unsigned32 (1..127)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        The Transmit MCS supported by the PHY, represented by a count from 1 to
        127, subject to limitations of each individual PHY."
    ::= { dot11SupportedHTMCSTxEntry 2 }

-- ************************************************************************
-- * End of dot11 Supported MCS Tx TABLE
-- ************************************************************************

-- ************************************************************************
-- * dot11 Supported MCS Rx TABLE
-- ************************************************************************

dot11SupportedHTMCSRxTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11SupportedHTMCSRxEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "The receive MCS supported by the PHY, represented by a count from 1 to
        127, subject to limitations of each individual PHY."
    ::= { dot11phy 17 }

dot11SupportedHTMCSRxEntry OBJECT-TYPE
    SYNTAX Dot11SupportedHTMCSRxEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "An Entry (conceptual row) in the dot11SupportedHTMCSRx Table. ifIndex -
```



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```
        Each IEEE 802.11 interface is represented by an ifEntry. Interface tables
        in this MIB module are indexed by ifIndex."
    INDEX { ifIndex, dot11SupportedHTMCSRxIndex }
    ::= { dot11SupportedHTMCSRxTable 1 }

Dot11SupportedHTMCSRxEntry ::=
    SEQUENCE {
        dot11SupportedHTMCSRxIndex                          Unsigned32,
        dot11SupportedHTMCSRxValue                          Unsigned32 }

dot11SupportedHTMCSRxIndex OBJECT-TYPE
    SYNTAX Unsigned32 (1..255)
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "Index object that identifies which MCS to access. Range is 1..255."
    ::= { dot11SupportedHTMCSRxEntry 1 }

dot11SupportedHTMCSRxValue OBJECT-TYPE
    SYNTAX Unsigned32 (1..127)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        The receive MCS supported by the PHY, represented by a count from 1 to
        127, subject to limitations of each individual PHY."
    ::= { dot11SupportedHTMCSRxEntry 2 }

-- ****************************************************************
-- * End of dot11 Supported MCS Rx TABLE
-- ****************************************************************

-- ****************************************************************
-- * dot11 Transmit Beamforming Config TABLE
-- ****************************************************************

dot11TransmitBeamformingConfigTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11TransmitBeamformingConfigEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "Entry of attributes for dot11TransmitBeamformingConfigTable. Implemented
        as a table indexed on ifIndex to allow for multiple instances on an
        Agent."
    ::= { dot11phy 18 }

dot11TransmitBeamformingConfigEntry OBJECT-TYPE
    SYNTAX Dot11TransmitBeamformingConfigEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "An entry in the dot11TransmitBeamformingConfig Table.
        ifIndex - Each IEEE 802.11 interface is represented by an ifEntry.
        Interface tables in this MIB module are indexed by ifIndex."
    INDEX {ifIndex}
    ::= { dot11TransmitBeamformingConfigTable 1 }

Dot11TransmitBeamformingConfigEntry ::=
    SEQUENCE {
        dot11ReceiveStaggerSoundingOptionImplemented        TruthValue,
        dot11TransmitStaggerSoundingOptionImplemented       TruthValue,
        dot11ReceiveNDPOptionImplemented                    TruthValue,
```

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```
        dot11TransmitNDPOptionImplemented                       TruthValue,
        dot11ImplicitTransmitBeamformingOptionImplemented       TruthValue,
        dot11CalibrationOptionImplemented                       INTEGER,
        dot11ExplicitCSITransmitBeamformingOptionImplemented    TruthValue,
        dot11ExplicitNonCompressedBeamformingMatrixOptionImplemented
                                                                TruthValue,
        dot11ExplicitTransmitBeamformingCSIFeedbackOptionImplemented
                                                                INTEGER,
        dot11ExplicitNonCompressedBeamformingFeedbackOptionImplemented
                                                                INTEGER,
        dot11ExplicitCompressedBeamformingFeedbackOptionImplemented
                                                                INTEGER,
        dot11NumberBeamFormingCSISupportAntenna                 Unsigned32,
        dot11NumberNonCompressedBeamformingMatrixSupportAntenna
                                                                Unsigned32,
        dot11NumberCompressedBeamformingMatrixSupportAntenna    Unsigned32 }

dot11ReceiveStaggerSoundingOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the STA implementation supports
        the receiving of staggered sounding frames."
    ::= { dot11TransmitBeamformingConfigEntry 1 }

dot11TransmitStaggerSoundingOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the STA implementation supports
        the transmission of staggered sounding frames."
    ::= { dot11TransmitBeamformingConfigEntry 2 }

dot11ReceiveNDPOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the STA implementation is
        capable of receiving NDP as sounding frames."
    ::= { dot11TransmitBeamformingConfigEntry 3 }

dot11TransmitNDPOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the STA implementation is
        capable of transmitting NDP as sounding frames."
    ::= { dot11TransmitBeamformingConfigEntry 4 }
```


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```
dot11ImplicitTransmitBeamformingOptionImplemented OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a capability variable.
      Its value is determined by (#3375)STA capabilities.

      This attribute, when true, indicates that STA implementation is capable of
      applying implicit transmit beamforming."
   ::= { dot11TransmitBeamformingConfigEntry 5 }

dot11CalibrationOptionImplemented OBJECT-TYPE
   SYNTAX INTEGER {
      inCapable (0),
      unableToInitiate (1),
      ableToInitiate (2),
      fullyCapable (3) }
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a capability variable.
      Its value is determined by (#3375)STA capabilities.

      This attribute indicates the level of calibration supported by the STA
      implementation."
   ::= { dot11TransmitBeamformingConfigEntry 6 }

dot11ExplicitCSITransmitBeamformingOptionImplemented OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a capability variable.
      Its value is determined by (#3375)STA capabilities.

      This attribute, when true, indicates that STA implementation is capable of
      applying transmit beamforming using CSI explicit feedback in its
      transmission."
   ::= { dot11TransmitBeamformingConfigEntry 7 }

dot11ExplicitNonCompressedBeamformingMatrixOptionImplemented OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a capability variable.
      Its value is determined by (#3375)STA capabilities.

      This attribute, when true, indicates that STA implementation is capable of
      applying transmit beamforming using noncompressed beamforming feedback
      matrix explicit feedback in its transmission."
   ::= { dot11TransmitBeamformingConfigEntry 8 }

dot11ExplicitTransmitBeamformingCSIFeedbackOptionImplemented OBJECT-TYPE
   SYNTAX INTEGER {
      inCapable (0),
      delayed (1),
      immediate (2),
      unsolicitedImmediate (3),
      aggregated (4),
      delayedAggregated (5),
      immediateAggregated(6),
```

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```
        unsolicitedImmediateAggregated (7) }
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute indicates the level of CSI explicit feedback returned by
        the STA implementation."
    ::= { dot11TransmitBeamformingConfigEntry 9 }

dot11ExplicitNonCompressedBeamformingFeedbackOptionImplemented OBJECT-TYPE
    SYNTAX INTEGER {
        inCapable (0),
        delayed (1),
        immediate (2),
        unsolicitedImmediate (3),
        aggregated (4),
        delayedAggregated (5),
        immediateAggregated(6),
        unsolicitedImmediateAggregated (7) }
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute indicates the level of noncompressed beamforming feedback
        matrix explicit feedback returned by the STA implementation."
    ::= { dot11TransmitBeamformingConfigEntry 10 }

dot11ExplicitCompressedBeamformingFeedbackOptionImplemented OBJECT-TYPE
    SYNTAX INTEGER {
        inCapable (0),
        delayed (1),
        immediate (2),
        unsolicitedImmediate (3),
        aggregated (4),
        delayedAggregated (5),
        immediateAggregated(6),
        unsolicitedImmediateAggregated (7) }
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute indicates the level of noncompressed beamforming feedback
        matrix explicit feedback returned by the STA implementation."
    ::= { dot11TransmitBeamformingConfigEntry 11 }

dot11NumberBeamFormingCSISupportAntenna OBJECT-TYPE
    SYNTAX Unsigned32 (1..4)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute indicates the maximum number of beamforming antennas the
        beamformee can support when CSI feedback is required."
    ::= { dot11TransmitBeamformingConfigEntry 12 }

dot11NumberNonCompressedBeamformingMatrixSupportAntenna OBJECT-TYPE
```


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```
    SYNTAX Unsigned32 (1..4)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute indicates the maximum number of beamforming antennas the
        beamformee can support when noncompressed beamforming feedback matrix
        feedback is required."
    ::= { dot11TransmitBeamformingConfigEntry 13 }

dot11NumberCompressedBeamformingMatrixSupportAntenna OBJECT-TYPE
    SYNTAX Unsigned32 (1..8)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute indicates the maximum number of beamforming antennas the
        beamformee can support when compressed beamforming feedback matrix
        feedback is required."
    ::= { dot11TransmitBeamformingConfigEntry 14 }

-- ************************************************************************
-- * End of dot11 Transmit Beamforming Config TABLE
-- ************************************************************************

-- ************************************************************
-- * dot11 Phy DMG TABLE
-- ************************************************************

dot11PHYDMGTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11PHYDMGEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "Entry of attributes for dot11PhyDMGTable. Implemented as a table indexed
        on ifIndex to allow for multiple instances on an Agent."
    ::= { dot11phy 19 }

dot11PHYDMGEntry OBJECT-TYPE
    SYNTAX Dot11PHYDMGEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "An entry in dot11PHYDMGTable. ifIndex - Each IEEE 802.11 interface is
        represented by an ifEntry. Interface tables in this MIB module are indexed
        by ifIndex."
    INDEX {ifIndex}
    ::= { dot11PHYDMGTable 1 }

Dot11PHYDMGEntry ::=
    SEQUENCE {
        dot11LowPowerSCPHYImplemented                    TruthValue,
        dot11LowPowerSCPHYActivated                      TruthValue }

dot11LowPowerSCPHYImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
```

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```
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the low power SC mode is imple-
        mented."
    ::= { dot11PHYDMGEntry 1 }

dot11LowPowerSCPHYActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute, when true, indicates that the low power SC mode is
        activated."
    DEFVAL { false }
    ::= { dot11PHYDMGEntry 2 }

-- ****************************************************************
-- * End of dot11 PHY DMG TABLE
-- ****************************************************************

-- ****************************************************************
-- * dot11DMGBeamformingConfig TABLE
-- ****************************************************************

dot11DMGBeamformingConfigTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11DMGBeamformingConfigEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "This is a Table management object.
        The dot11DMGBeamformingConfig Table"
    ::= { dot11phy 22 }

dot11DMGBeamformingConfigEntry OBJECT-TYPE
    SYNTAX Dot11DMGBeamformingConfigEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "This is an entry in the dot11DMGBeamformingConfigTable Table.
        ifIndex - Each IEEE 802.11 interface is represented by an ifEntry.
        Interface tables in this MIB module are indexed by ifIndex."
    INDEX { ifIndex }
    ::= { dot11DMGBeamformingConfigTable 1 }

Dot11DMGBeamformingConfigEntry ::=
    SEQUENCE {
        dot11MaxBFTime                                  Unsigned32,
        dot11BFTXSSTime                                 Unsigned32,
        dot11MaximalSectorScan                          Unsigned32,
        dot11ABFTRTXSSSwitch                            Unsigned32,
        dot11RSSRetryLimit                              Unsigned32,
        dot11RSSBackoff                                 Unsigned32,
        dot11BFRetryLimit                               Unsigned32,
        dot11BeamLinkMaintenanceTime                    Unsigned32,
        dot11AntennaSwitchingTime                       Unsigned32,
        dot11ChanMeasFBCKNtaps                          Unsigned32,
        dot11BeamTrackingTimeLimit                      Unsigned32
        }

dot11MaxBFTime OBJECT-TYPE
```


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```
    SYNTAX Unsigned32 (1..16)
    UNITS "beacon intervals"
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
       "This is a control variable.
       It is written by the SME or an external management entity.
       Changes take effect as soon as practical in the implementation.

       (#7228)This attribute indicates the maximum duration supported by the STA
       for beamforming training (SLS and BRP)."
    DEFVAL { 4 }
    ::= { dot11DMGBeamformingConfigEntry 1 }

dot11BFTXSSTime OBJECT-TYPE
    SYNTAX Unsigned32 (1..256)
    UNITS "milliseconds"
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
       "This is a control variable.
       It is written by the SME or an external management entity.
       Changes take effect as soon as practical in the implementation.

       (#7228)This attribute indicates the (#8221)maximum duration supported by
       the non-AP STA for a transmit sector sweep."
    DEFVAL { 100 }
    ::= { dot11DMGBeamformingConfigEntry 2 }

dot11MaximalSectorScan OBJECT-TYPE
    SYNTAX Unsigned32 (1..32)
    UNITS "beacon intervals"
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
       "This is a control variable.
       It is written by the SME or an external management entity.
       Changes take effect as soon as practical in the implementation.

       (#7228)This attribute indicates the maximum TXSS duration supported by the
       AP or PCP."
    DEFVAL { 8 }
    ::= { dot11DMGBeamformingConfigEntry 3 }

dot11ABFTRTXSSSwitch OBJECT-TYPE
    SYNTAX Unsigned32 (1..32)
    UNITS "beacon intervals"
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
       "This is a control variable.
       It is written by the SME or an external management entity.
       Changes take effect as soon as practical in the implementation.

       (#7228)This attribute indicates the maximum duration in which an A-BFT is
       present, in which the AP or PCP allocates an A-BFT as a responder TXSS."
    DEFVAL { 4 }
    ::= { dot11DMGBeamformingConfigEntry 4 }

dot11RSSRetryLimit OBJECT-TYPE
    SYNTAX Unsigned32 (0..3)(#7228)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
```

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```
        "This is a control variable.
        It is written by the SME or an external management entity.
        Changes take effect as soon as practical in the implementation.

        (#7228)This attribute indicates the retry limit that a STA attempting to
        access the A-BFT of a BSS uses:
        0, for 2 retries;
        1, for 4 retries;
        2, for 6 retries; and
        3, for 8 retries."
    DEFVAL { 3 }(#7228)
    ::= { dot11DMGBeamformingConfigEntry 5 }

dot11RSSBackoff OBJECT-TYPE
    SYNTAX Unsigned32 (1..32)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by the SME or an external management entity.
        Changes take effect as soon as practical in the implementation.

        (#7228)This attribute indicates the maximum number of A-BFT periods that
        the STA waits after a consecutive number of times (FailedRSSAttempts) that
        the STA initiates RSS during A-BFTs but does not receive an SSW-Feedback
        frame as a response."
    DEFVAL { 8 }
    ::= { dot11DMGBeamformingConfigEntry 6 }

dot11BFRetryLimit OBJECT-TYPE
    SYNTAX Unsigned32 (1..32)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by the SME or an external management entity.
        Changes take effect as soon as practical in the implementation.

        (#7228)This attribute indicates the number of times an initiator may start
        an SSW feedback procedure if it does not receive an SSW-Ack frame from the
        responder following the completion of the SSW feedback procedure."
    DEFVAL { 8 }
    ::= { dot11DMGBeamformingConfigEntry 7 }

dot11BeamLinkMaintenanceTime OBJECT-TYPE
    SYNTAX Unsigned32 (0..64000000)
    UNITS "microseconds"
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by the MAC or SME.
        Changes take effect as soon as practical in the implementation.

        (#7228)This attribute indicates the beam link maintenance time. The value
        0 indicates that the STA does not participate in beamformed link mainte-
        nance."
    DEFVAL { 0 }
    ::= { dot11DMGBeamformingConfigEntry 8 }

dot11AntennaSwitchingTime OBJECT-TYPE
    SYNTAX Unsigned32 (0..64000000)
    UNITS "microseconds"
    MAX-ACCESS read-write
```


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```
    STATUS current
    DESCRIPTION
        "This is a control variable. It is written by the MAC or SME.
        Changes take effect as soon as practical in the implementation."

        (#7228)This attribute indicates the time it takes the STA to switch DMG
        antennas.
    DEFVAL { 0 }
    ::= { dot11DMGBeamformingConfigEntry 9 }

dot11ChanMeasFBCKNtaps OBJECT-TYPE
    SYNTAX Unsigned32 (1..255)(#8224)(#8223)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable. It is written by the MAC or SME.
        Changes take effect as soon as practical in the implementation.

        (#7228)This attribute indicates the number of channel impulse response
        taps measured by the STA."
    DEFVAL { 1 }
    ::= { dot11DMGBeamformingConfigEntry 10 }

dot11BeamTrackingTimeLimit OBJECT-TYPE
    SYNTAX Unsigned32 (0..65535)
    UNITS "microseconds"
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by the MAC or SME.
        Changes take effect as soon as practical in the implementation.

        (#7228)This attribute indicates the maximum time in which a feedback
        response is sent after a request for beam tracking feedback is received."
    DEFVAL { 10000 }
    ::= { dot11DMGBeamformingConfigEntry  11 }

-- ********************************************************************
-- * End of dot11DMGBeamformingConfig TABLE
-- ********************************************************************

-- ********************************************************************
-- * dot11 Phy VHT TABLE
-- ********************************************************************

dot11PhyVHTTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11PhyVHTEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "Entry of attributes for dot11PhyVHTTable. Implemented as a table indexed
        on ifIndex to allow for multiple instances on an Agent."
    ::= { dot11phy 23 }

dot11PhyVHTEntry OBJECT-TYPE
    SYNTAX Dot11PhyVHTEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "An entry in the dot11PhyHTEntry Table. ifIndex - Each IEEE 802.11
        interface is represented by an ifEntry. Interface tables in this MIB
        module are indexed by ifIndex."
    INDEX {ifIndex}
```

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```
    ::= { dot11PhyVHTTable 1 }

Dot11PhyVHTEntry ::=
    SEQUENCE {
        dot11VHTChannelWidthOptionImplemented                 INTEGER,
        dot11CurrentChannelWidth                              INTEGER,
        dot11CurrentChannelCenterFrequencyIndex0              Unsigned32,
        dot11CurrentChannelCenterFrequencyIndex1              Unsigned32,
        dot11VHTShortGIOptionIn80Implemented                  TruthValue,
        dot11VHTShortGIOptionIn80Activated                    TruthValue,
        dot11VHTShortGIOptionIn160and80p80Implemented         TruthValue,
        dot11VHTShortGIOptionIn160and80p80Activated           TruthValue,
        dot11VHTLDPCCodingOptionImplemented                   TruthValue,
        dot11VHTLDPCCodingOptionActivated                     TruthValue,
        dot11VHTTxSTBCOptionImplemented                       TruthValue,
        dot11VHTTxSTBCOptionActivated                         TruthValue,
        dot11VHTRxSTBCOptionImplemented                       TruthValue,
        dot11VHTRxSTBCOptionActivated                         TruthValue,
        dot11VHTMUMaxUsersImplemented                         Unsigned32,
        dot11VHTMUMaxNSTSPerUserImplemented                   Unsigned32,
        dot11VHTMUMaxNSTSTotalImplemented                     Unsigned32,
        dot11VHTMaxNTxChainsImplemented                       Unsigned32,
        dot11VHTMaxNTxChainsActivated                         Unsigned32,
        (11ax)dot11EightyMHzOperationImplemented              TruthValue
    }

dot11VHTChannelWidthOptionImplemented OBJECT-TYPE
    SYNTAX INTEGER { contiguous80(0), contiguous160(1), noncontiguous80plus80(2)
        }
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute indicates the channel widths supported: 20/40/80 MHz, 20/
        40/80/160 MHz or 20/40/80/160/80+80 MHz.
        (#3485)Reserved in a 20 MHz-only non-AP HE STA that is a VHT STA."
    ::= { dot11PhyVHTEntry 1 }

dot11CurrentChannelWidth OBJECT-TYPE
    SYNTAX INTEGER { cbw20(0), cbw40(1), cbw80(2), cbw160(3), cbw80p80(4) }
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        Written by the PHY.
        This attribute indicates the operating channel width."
    DEFVAL { cbw20 }
    ::= { dot11PhyVHTEntry 2 }

dot11CurrentChannelCenterFrequencyIndex0 OBJECT-TYPE
    SYNTAX Unsigned32 (0..200)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        Written by the PHY.
        For a 20 MHz, 40 MHz, 80 MHz, or 160 MHz channel, denotes the channel
        center frequency.
        For an 80+80 MHz channel, denotes the center frequency of frequency
        segment 0. See 21.3.14 (Channelization)."
    DEFVAL { 0 }
    ::= { dot11PhyVHTEntry 3 }
```


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```
dot11CurrentChannelCenterFrequencyIndex1 OBJECT-TYPE
   SYNTAX Unsigned32 (0..200)
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a status variable.
      Written by the PHY.
      For an 80+80 MHz channel, denotes the center frequency of frequency
      segment 1.
      Set to 0 for a 20 MHz, 40 MHz, 80 MHz, or 160 MHz channel. See 21.3.14
      (Channelization)."
   DEFVAL { 0 }
   ::= { dot11PhyVHTEntry 4 }

dot11VHTShortGIOptionIn80Implemented OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a capability variable.
      Its value is determined by (#3375)STA capabilities.

      This attribute, when true, indicates that the (#4213)STA is capable of
      receiving 80 MHz short guard interval packets."
   ::= { dot11PhyVHTEntry 5 }

dot11VHTShortGIOptionIn80Activated OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by an external management entity.
      Changes take effect as soon as practical in the implementation. Changes
      made while associated with an AP or while operating a BSS should take
      effect only after disassociation or the deactivation of the BSS,
      respectively.

      This attribute, when true, indicates that the reception of 80 MHz short
      guard interval packets is enabled."
   DEFVAL { false }
   ::= { dot11PhyVHTEntry 6 }

dot11VHTShortGIOptionIn160and80p80Implemented OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a capability variable.
      Its value is determined by (#3375)STA capabilities.

      This attribute, when true, indicates that the (#4213)STA is capable of
      receiving 160 MHz and 80+80 MHz short guard interval packets."
   ::= { dot11PhyVHTEntry 7 }

dot11VHTShortGIOptionIn160and80p80Activated OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.
      It is written by an external management entity.
      Changes take effect as soon as practical in the implementation. Changes
```

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```
        made while associated with an AP or while operating a BSS should take
        effect only after disassociation or the deactivation of the BSS,
        respectively.

        This attribute, when true, indicates that the reception of 160 MHz and
        80+80 MHz short guard interval packets is enabled."
    DEFVAL { false }
    ::= { dot11PhyVHTEntry 8 }

dot11VHTLDPCCodingOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the LDPC coding option for VHT
        packets is implemented."
    ::= { dot11PhyVHTEntry 9 }

dot11VHTLDPCCodingOptionActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation. Changes
        made while associated with an AP or while operating a BSS should take
        effect only after disassociation or the deactivation of the BSS,
        respectively.

        This attribute, when true, indicates that the LDPC coding option for VHT
        packets is enabled."
    DEFVAL { false }
    ::= { dot11PhyVHTEntry 10 }

dot11VHTTxSTBCOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the (#4213)STA is capable of
        transmitting VHT PPDUs using STBC."
    ::= { dot11PhyVHTEntry 11 }

dot11VHTTxSTBCOptionActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation. Changes
        made while associated with an AP or while operating a BSS should take
        effect only after disassociation or the deactivation of the BSS,
        respectively.

        This attribute, when true, indicates that the entity's capability for
        transmitting VHT PPDUs using STBC is enabled."
```


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```
    DEFVAL { false }
    ::= { dot11PhyVHTEntry 12 }

dot11VHTRxSTBCOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the (#4213)STA is capable of
        receiving VHT PPDUs using STBC."
    ::= { dot11PhyVHTEntry 13 }

dot11VHTRxSTBCOptionActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation. Changes
        made while associated with an AP or while operating a BSS should take
        effect only after disassociation or the deactivation of the BSS,
        respectively.

        This attribute, when true, indicates that the entity's capability for
        receiving VHT PPDUs using STBC is enabled."
    DEFVAL { false }
    ::= { dot11PhyVHTEntry 14 }

dot11VHTMUMaxUsersImplemented OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute indicates the maximum number of users to which this
        (#4213)STA is capable of transmitting within a VHT MU PPDU."
    ::= { dot11PhyVHTEntry 15 }

dot11VHTMUMaxNSTSPerUserImplemented OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute indicates the maximum number of space-time streams per user
        that this (#4213)STA is capable of transmitting within a VHT MU PPDU."
    ::= { dot11PhyVHTEntry 16 }

dot11VHTMUMaxNSTSTotalImplemented OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.
```

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```
        This attribute indicates the maximum number of space-time streams for all
        users that this (#4213)STA is capable of transmitting within a VHT MU
        PPDU."
    ::= { dot11PhyVHTEntry 17 }

dot11VHTMaxNTxChainsImplemented OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute indicates the maximum number of transmit chains within this
        (#4213)STA."
    ::= { dot11PhyVHTEntry 18 }

dot11VHTMaxNTxChainsActivated OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute indicates the maximum number of transmit chains that are
        activated within this (#4213)STA, unless this attribute exceeds
        dot11VHTMaxNTxChainsImplemented, in which case the maximum number of
        transmit chains that are activated within this (#4213)STA is equal to
        dot11VHTMaxNTxChainsImplemented."
    DEFVAL { 2147483647}
    ::= { dot11PhyVHTEntry 19 }

(11ax)dot11EightyMHzOperationImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the 80 MHz operation is
        implemented"
    DEFVAL { false }
    ::= { dot11PhyVHTEntry 20 }

-- ****************************************************************
-- * End of dot11PhyVHT TABLE
-- ****************************************************************

-- ****************************************************************
-- * dot11 VHT Transmit Beamforming Config TABLE
-- ****************************************************************

dot11VHTTransmitBeamformingConfigTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11VHTTransmitBeamformingConfigEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "Entry of attributes for dot11VHTTransmitBeamformingConfigTable.
        Implemented as a table indexed on ifIndex to allow for multiple instances
        on an Agent."
    ::= { dot11phy 24 }
```



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```
dot11VHTTransmitBeamformingConfigEntry OBJECT-TYPE
   SYNTAX Dot11VHTTransmitBeamformingConfigEntry
   MAX-ACCESS not-accessible
   STATUS current
   DESCRIPTION
      "An entry in the dot11VHTTransmitBeamformingConfig Table.
      ifIndex - Each IEEE 802.11 interface is represented by an ifEntry.
      Interface tables in this MIB module are indexed by ifIndex."
   INDEX {ifIndex}
   ::= { dot11VHTTransmitBeamformingConfigTable 1 }

Dot11VHTTransmitBeamformingConfigEntry ::=
   SEQUENCE {
      dot11VHTSUBeamformeeOptionImplemented                TruthValue,
      dot11VHTSUBeamformerOptionImplemented                TruthValue,
      dot11VHTMUBeamformeeOptionImplemented                TruthValue,
      dot11VHTMUBeamformerOptionImplemented                TruthValue,
      dot11VHTNumberSoundingDimensions                     Unsigned32,
      dot11VHTBeamformeeNTxSupport                         Unsigned32,
      (#4284)dot11VHTMaxNstsTotal                          Unsigned32
   }

dot11VHTSUBeamformeeOptionImplemented OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a capability variable.
      Its value is determined by (#3375)STA capabilities.

      This attribute, when true, indicates that the STA supports the SU
      Beamformee role."
   ::= { dot11VHTTransmitBeamformingConfigEntry 1 }

dot11VHTSUBeamformerOptionImplemented OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a capability variable.
      Its value is determined by (#3375)STA capabilities.

      This attribute, when true, indicates that the STA supports the SU
      Beamformer role."
   ::= { dot11VHTTransmitBeamformingConfigEntry 2 }

dot11VHTMUBeamformeeOptionImplemented OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a capability variable.
      Its value is determined by (#3375)STA capabilities.

      This attribute, when true, indicates that the STA supports the MU
      Beamformee role."
   ::= { dot11VHTTransmitBeamformingConfigEntry 3 }

dot11VHTMUBeamformerOptionImplemented OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
```

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```
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the STA supports the MU
        Beamformer role."
    ::= { dot11VHTTransmitBeamformingConfigEntry 4 }

dot11VHTNumberSoundingDimensions OBJECT-TYPE
    SYNTAX Unsigned32 (2..8)(#2044)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        (#3694)This attribute indicates the maximum number of antennas used by the
        beamformer when sending beamformed transmissions."
    ::= { dot11VHTTransmitBeamformingConfigEntry 5 }

dot11VHTBeamformeeNTxSupport OBJECT-TYPE
    SYNTAX Unsigned32 (2..8)(#2044)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute indicates the maximum number of space-time streams that the
        STA can receive in a VHT NDP (#4284)and the maximum value of Nr that the
        STA transmits in a VHT Compressed Beamforming frame."
    ::= { dot11VHTTransmitBeamformingConfigEntry 6 }

(#4284)dot11VHTMaxNstsTotal OBJECT-TYPE
    SYNTAX Unsigned32 (2..8)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by STA capabilities.

        This attribute indicates the maximum value for NSTS,total that can be sent
        to the STA in a VHT MU PPDU if the STA is MU beamformee capable.
        The value of this attribute is greater than or equal to
        dot11VHTBeamformeeNTxSupport if the STA is MU beamformee capable"
    ::= { dot11VHTTransmitBeamformingConfigEntry 7 }

-- ****************************************************************
-- * End of dot11 VHT Transmit Beamforming Config TABLE
-- ****************************************************************

-- ****************************************************************
-- * dot11 Phy TVHT TABLE
-- ****************************************************************

dot11PhyTVHTTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11PhyTVHTEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "Entry of attributes for dot11PhyTVHTTable. Implemented as a table indexed
        on ifIndex to allow for multiple instances on an Agent."
    ::= { dot11phy 25 }

dot11PhyTVHTEntry OBJECT-TYPE
```


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```
    SYNTAX Dot11PhyTVHTEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "An entry in the dot11PhyTVHTEntry Table. ifIndex - Each IEEE 802.11
        interface is represented by an ifEntry. Interface tables in this MIB
        module are indexed by ifIndex."
    INDEX {ifIndex}
    ::= { dot11PhyTVHTTable 1 }

Dot11PhyTVHTEntry ::=
    SEQUENCE {
        dot11TVHTChannelWidthOptionImplemented                INTEGER,
        dot11TVHTCurrentChannelWidth                          INTEGER,
        dot11TVHTCurrentChannelCenterFrequencyIndex0          Unsigned32,
        dot11TVHTCurrentChannelCenterFrequencyIndex1          Unsigned32,
        dot11TVHTShortGIOptionIn4WImplemented                 TruthValue,
        dot11TVHTShortGIOptionIn4WActivated                   TruthValue,
        dot11TVHTLDPCCodingOptionImplemented                  TruthValue,
        dot11TVHTLDPCCodingOptionActivated                    TruthValue,
        dot11TVHTTxSTBCOptionImplemented                      TruthValue,
        dot11TVHTTxSTBCOptionActivated                        TruthValue,
        dot11TVHTRxSTBCOptionImplemented                      TruthValue,
        dot11TVHTRxSTBCOptionActivated                        TruthValue,
        dot11TVHTMUMaxUsersImplemented                        Unsigned32,
        dot11TVHTMUMaxNSTSPerUserImplemented                  Unsigned32,
        dot11TVHTMUMaxNSTSTotalImplemented                    Unsigned32,
        dot11TVHTMaxNTxChainsImplemented                      Unsigned32,
        dot11TVHTMaxNTxChainsActivated                        Unsigned32
    }

dot11TVHTChannelWidthOptionImplemented OBJECT-TYPE
    SYNTAX INTEGER { tvhtmode1(0), tvhtmode2c(1), tvhtmode2n(2),
        tvhtmode4c(3), tvhtmode4n(4) }
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute indicates the channel widths supported: W MHz, 2W MHz, W+W
        MHz, 4W MHz or 2W+2W MHz."
    ::= { dot11PhyTVHTEntry 1 }

dot11TVHTCurrentChannelWidth OBJECT-TYPE
    SYNTAX INTEGER { tvhtw(0), tvht2w(1), tvhtwpw(2), tvht4w(3), tvht2wp2w(4) }
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        Written by the PHY.
        This attribute indicates the operating channel width."
    DEFVAL { tvhtw }
    ::= { dot11PhyTVHTEntry 2 }

dot11TVHTCurrentChannelCenterFrequencyIndex0 OBJECT-TYPE
    SYNTAX Unsigned32 (0..200)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        Written by the PHY.
        For a W MHz, 2W MHz or 4W MHz channel, denotes the channel center
        frequency.
```

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```
        For an W+W or 2W+2W MHz channel, denotes the center frequency of frequency
        segment 0. See 22.3.14 (Channelization)."
    DEFVAL { 0 }
    ::= { dot11PhyTVHTEntry 3 }

dot11TVHTCurrentChannelCenterFrequencyIndex1 OBJECT-TYPE
    SYNTAX Unsigned32 (0..200)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        Written by the PHY.
        For an W+W or 2W+2W MHz channel, denotes the center frequency of frequency
        segment 1.
        Set to 0 for a W MHz, 2W MHz or 4W MHz channel. See 22.3.14 (Channeliza-
        tion)."
    DEFVAL { 0 }
    ::= { dot11PhyTVHTEntry 4 }

dot11TVHTShortGIOptionIn4WImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the (#4213)STA is capable of
        receiving 4W MHz short guard interval packets."
    ::= { dot11PhyTVHTEntry 5 }

dot11TVHTShortGIOptionIn4WActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation. Changes
        made while associated with an AP or while operating a BSS should take
        effect only after disassociation or the deactivation of the BSS,
        respectively.

        This attribute, when true, indicates that the reception of 4W MHz short
        guard interval packets is enabled."
    DEFVAL { false }
    ::= { dot11PhyTVHTEntry 6 }

dot11TVHTLDPCCodingOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the LDPC coding option for TVHT
        packets is implemented."
    ::= { dot11PhyTVHTEntry 7 }

dot11TVHTLDPCCodingOptionActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
```


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```
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation. Changes
        made while associated with an AP or while operating a BSS should take
        effect only after disassociation or the deactivation of the BSS,
        respectively.

        This attribute, when true, indicates that the LDPC coding option for TVHT
        packets is enabled."
    DEFVAL { false }
    ::= { dot11PhyTVHTEntry 8 }

dot11TVHTTxSTBCOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the (#4213)STA is capable of
        transmitting TVHT PPDUs using STBC."
    ::= { dot11PhyTVHTEntry 9 }

dot11TVHTTxSTBCOptionActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation. Changes
        made while associated with an AP or while operating a BSS should take
        effect only after disassociation or the deactivation of the BSS,
        respectively.

        This attribute, when true, indicates that the entity's capability for
        transmitting TVHT PPDUs using STBC is enabled."
    DEFVAL { false }
    ::= { dot11PhyTVHTEntry 10 }

dot11TVHTRxSTBCOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the (#4213)STA is capable of
        receiving TVHT PPDUs using STBC."
    ::= { dot11PhyTVHTEntry 11 }

dot11TVHTRxSTBCOptionActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation. Changes
        made while associated with an AP or while operating a BSS should take
        effect only after disassociation or the deactivation of the BSS,
```

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```
        respectively.

        This attribute, when true, indicates that the entity's capability for
        receiving TVHT PPDUs using STBC is enabled."
    DEFVAL { false }
    ::= { dot11PhyTVHTEntry 12 }

dot11TVHTMUMaxUsersImplemented OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute indicates the maximum number of users to which this
        (#4213)STA is capable of transmitting within a TVHT MU PPDU."
    ::= { dot11PhyTVHTEntry 13 }

dot11TVHTMUMaxNSTSPerUserImplemented OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute indicates the maximum number of space-time streams per user
        that this (#4213)STA is capable of transmitting within a TVHT MU PPDU."
    ::= { dot11PhyTVHTEntry 14 }

dot11TVHTMUMaxNSTSTotalImplemented OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute indicates the maximum number of space-time streams for all
        users that this (#4213)STA is capable of transmitting within a TVHT MU
        PPDU."
    ::= { dot11PhyTVHTEntry 15 }

dot11TVHTMaxNTxChainsImplemented OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute indicates the maximum number of transmit chains within this
        (#4213)STA."
    ::= { dot11PhyTVHTEntry 16 }

dot11TVHTMaxNTxChainsActivated OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.
```



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```
        This attribute indicates the maximum number of transmit chains that are
        activated within this (#4213)STA, unless this attribute exceeds
        dot11TVHTMaxNTxChainsImplemented, in which case the maximum number of
        transmit chains that are activated within this (#4213)STA is equal to
        dot11TVHTMaxNTxChainsImplemented."
    DEFVAL { 2147483647 }
::= { dot11PhyTVHTEntry 17 }

-- ****************************************************************
-- * End of dot11PhyTVHT TABLE
-- ****************************************************************

-- ****************************************************************
-- * dot11 TVHT Transmit Beamforming Config TABLE
-- ****************************************************************

dot11TVHTTransmitBeamformingConfigTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11TVHTTransmitBeamformingConfigEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "Entry of attributes for dot11TVHTTransmitBeamformingConfigTable.
        Implemented as a table indexed on ifIndex to allow for multiple instances
        on an Agent."
    ::= { dot11phy 26 }

dot11TVHTTransmitBeamformingConfigEntry OBJECT-TYPE
    SYNTAX Dot11TVHTTransmitBeamformingConfigEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "An entry in the dot11TVHTTransmitBeamformingConfig Table.
        ifIndex - Each IEEE 802.11 interface is represented by an ifEntry.
        Interface tables in this MIB module are indexed by ifIndex."
    INDEX {ifIndex}
    ::= { dot11TVHTTransmitBeamformingConfigTable 1 }

Dot11TVHTTransmitBeamformingConfigEntry ::=
    SEQUENCE {
        dot11TVHTSUBeamformeeOptionImplemented                TruthValue,
        dot11TVHTSUBeamformerOptionImplemented                TruthValue,
        dot11TVHTMUBeamformeeOptionImplemented                TruthValue,
        dot11TVHTMUBeamformerOptionImplemented                TruthValue,
        dot11TVHTNumberSoundingDimensions                     Unsigned32,
        dot11TVHTBeamformeeNTxSupport                         Unsigned32
    }

dot11TVHTSUBeamformeeOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the STA supports the SU
        Beamformee role."
    ::= { dot11TVHTTransmitBeamformingConfigEntry 1 }

dot11TVHTSUBeamformerOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
```

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```
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the STA supports the SU
        Beamformer role."
    ::= { dot11TVHTTransmitBeamformingConfigEntry 2 }

dot11TVHTMUBeamformeeOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the STA supports the MU
        Beamformee role."
    ::= { dot11TVHTTransmitBeamformingConfigEntry 3 }

dot11TVHTMUBeamformerOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the STA supports the MU
        Beamformer role."
    ::= { dot11TVHTTransmitBeamformingConfigEntry 4 }

dot11TVHTNumberSoundingDimensions OBJECT-TYPE
    SYNTAX Unsigned32 (2..8)(#2044)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute indicates the number of antennas used by the beamformer
        when sending beamformed transmissions."
    ::= { dot11TVHTTransmitBeamformingConfigEntry 5 }

dot11TVHTBeamformeeNTxSupport OBJECT-TYPE
    SYNTAX Unsigned32 (1..8)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute indicates the maximum number of space-time streams that the
        STA can receive in a TVHT NDP, the maximum value for NSTS, total that can
        be sent to the STA in a TVHT MU PPDU if the STA is MU beamformee capable
        and the maximum value of Nr that the STA transmits in a TVHT Compressed
        Beamforming frame."
    ::= { dot11TVHTTransmitBeamformingConfigEntry 6 }

-- ************************************************************************
-- * End of dot11 TVHT Transmit Beamforming Config TABLE
-- ************************************************************************
```



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```
-- ************************************************************************
-- * (11bd)dot11 Phy NGV TABLE
-- ************************************************************************

(11bd)dot11PhyNGVTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11PhyNGVEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "Entry of attributes for dot11PhyNGVTable. Implemented as a table indexed
        on ifIndex to allow for multiple instances on an Agent."
    ::= { dot11phy 37 }

(11bd)dot11PhyNGVEntry OBJECT-TYPE
    SYNTAX Dot11PhyNGVEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "An entry in dot11PhyNGVEntryTable. ifIndex - Each IEEE Std 802.11
        interface is represented by an ifEntry. Interface tables in this MIB
        module are indexed by ifIndex."
    INDEX {ifIndex}
    ::= { dot11PhyNGVTable 1 }

(11bd)Dot11PhyNGVEntry ::= SEQUENCE
{
    dot11NGVCurrentChannelWidth                         INTEGER,
    dot11NGVCurrentPrimaryChannel                       Unsigned32,
    dot11NGVCurrentSecondaryChannel                     Unsigned32,
    dot11NGVDYN20MAllowed                               TruthValue
}

(11bd)dot11NGVCurrentChannelWidth OBJECT-TYPE
    SYNTAX INTEGER { cbw10(0), cbw20(1) }
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        Written by the PHY.

        This attribute indicates the operating channel width."
    DEFVAL { cbw10 }
    ::= { dot11PhyNGVEntry 1 }

(11bd)dot11NGVCurrentPrimaryChannel OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the PHY.

        This attribute indicates the operating channel. If 10/20 MHz OCB is
        currently in use then this attribute indicates the primary channel."
    ::= { dot11PhyNGVEntry 2 }

(11bd)dot11NGVCurrentSecondaryChannel OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the PHY.
```

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```
        This attribute indicates the channel number of the secondary channel. If
        10/20 MHz OCB is not currently in use, this attribute value shall be 0."
    ::= { dot11PhyNGVEntry 3 }

(11bd)dot11NGVDYN20MAllowed OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by device capabilities.

        This attribute, when true, indicates that the NGV STA implementation
        supports dynamic 20 MHz operation. This capability is disabled otherwise."
    ::= { dot11PhyNGVEntry 6}


-- ********************************************************************
-- * (11ax)dot11PhyHETABLE
-- ********************************************************************
(11ax)dot11PhyHETable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11PhyHEEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "Entry of attributes for dot11PhyHETable. Implemented as a table indexed
         on ifIndex to allow for multiple instances on an Agent."
    ::= { dot11phy 31 }

(11ax)dot11PhyHEEntry OBJECT-TYPE
    SYNTAX Dot11PhyHEEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "An entry in dot11PhyHEEntryTable. ifIndex - Each IEEE Std 802.11
         interface is represented by an ifEntry. Interface tables in this MIB
         module are indexed by ifIndex."
    INDEX {ifIndex}
    ::= { dot11PhyHETable 1 }

(11ax)Dot11PhyHEEntry ::=
    SEQUENCE {
        dot11HECurrentChannelWidthSet                          Unsigned32,
        dot11HEPuncturedPreambleRxImplemented                  OCTET STRING,
        dot11HEDeviceClass                                     TruthValue,
        dot11HELDPCCodingInPayloadImplemented                  TruthValue,
        dot11HESUPPDUwith1xHELTFand0point8GIlmplemented        TruthValue,
        dot11HESUPPDUandHEMUPPDUwith4xHELTFand0point8GIlmplemented
                                                               TruthValue,
        dot11HEERSUPPDUwith4xHELTFand0point8GIImplemented      TruthValue,
        dot11HEERSUPPDUwith1xHELTFand0point8GIImplemented      TruthValue,
        dot11HEMidambleRxMaxNSTS                               Unsigned32,
        dot11HENDPwith4xHELTFand3point2GIImplemented           TruthValue,
        dot11HESTBCTxLessThanOrEqualTo80Implemented            TruthValue,
        dot11HESTBCRxLessThanOrEqualTo80Implemented            TruthValue,
        dot11HESTBCTxGreaterThan80Implemented                  TruthValue,
        dot11HESTBCRxGreaterThan80Implemented                  TruthValue,
        dot11HEDopplerTxImplemented                            TruthValue,
        dot11HEDopplerRxImplemented                            TruthValue,
        dot11HEDCMImplemented                                  TruthValue,
        dot11HEFullBWULMUMIMOImplemented                       TruthValue,
        dot11HEPartialBWULMUMIMOImplemented                    TruthValue,
        dot11HEPartialBWDLMUMIMOImplemented                    TruthValue,
        dot11HEULMUPayloadImplemented                          TruthValue,
```


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```
        dot11HEPSRbasedSRSupportImplemented                    TruthValue,
        dot11HEPowerBoostFactorImplemented                     TruthValue,
        dot11HEPartialBWERSUPayloadImplemented                 TruthValue,
        dot11HEPuncturedSoundingOptionImplemented              TruthValue,
        (#1072)dot11HEChannelWidthOptionImplemented            INTEGER
    }

(11ax)dot11HECurrentChannelWidthSet OBJECT-TYPE
    SYNTAX Unsigned32 (0..127)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.

        This attribute specifies the STA's channel width set."
    REFERENCE
        "IEEE Std 802.11ax-2021, Table 9-376 (Subfields of the HE PHY Capabilities
        Information field(11ax)), Support Channel Width Set subfield"
::= { dot11PhyHEEntry 1 }

(11ax)dot11HEPuncturedPreambleRxImplemented OBJECT-TYPE
    SYNTAX OCTET STRING(SIZE(1))
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute is a bitmap that indicates the preamble puncturing
        support, where bit 0 is set to 1 to indicate support for the reception of
        an 80 MHz preamble where the only punctured subchannel is the secondary 20
        MHz subchannel, bit 1 is set to 1 to indicate support for the reception of
        an 80 MHz preamble where the only punctured subchannel is one of the two
        20 MHz subchannels in the secondary 40 MHz channel, bit 2 is set to 1 to
        indicate support for the reception of a 160 MHz or 80+80 MHz preamble
        where the only punctured subchannels are the secondary 20 MHz channel and
        zero to two of the 20 MHz subchannels in the secondary 80 MHz channel, and
        bit 3 is set to 1 to indicate support for the reception of a 160 MHz or
        80+80 MHz preamble where the only punctured subchannels are zero, one or
        both of the 20 MHz subchannels in the secondary 40 MHz channel and zero to
        two of the 20 MHz subchannels in the secondary 80 MHz channel with at
        least one 20 MHz subchannel punctured. For bits 2 and 3, if two of the 20
        MHz subchannels in the secondary 80 MHz channel are punctured, these are
        either the lower two or the higher two. No more than two adjacent 20 MHz
        subchannels are punctured across a 160 MHz preamble."
    ::= { dot11PhyHEEntry 2 }

(11ax)dot11HEDeviceClass OBJECT-TYPE
    SYNTAX INTEGER{ClassB(0), ClassA(1)}
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.
        This attribute specifies the device class of a non-AP STA."
    ::= { dot11PhyHEEntry 3 }

(11ax)dot11HELDPCCodingInPayloadImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.
```

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```
        This attribute, when true, indicates that the STA is capable of
        transmitting and receiving LDPC encoded packets. This capability is
        disabled otherwise."
    DEFVAL { false }
    ::= { dot11PhyHEEntry 4 }

(11ax)dot11HESUPPDUwith1xHELTFand0point8GIlmplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the non-AP STA is capable of
        receiving an HE SU PPDU with 1x HE-LTF and 0.8 microsecond guard interval
        duration. This capability is disabled otherwise."
    DEFVAL { false }
    ::= { dot11PhyHEEntry 5}

(11ax)dot11HESUPPDUandHEMUPPDUwith4xHELTFand0point8GIlmplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the non-AP STA is capable of
        receiving an HE SU PPDU and HE MU PPDU with 4x HE-LTF and 0.8 microsecond
        guard interval duration. This capability is disabled otherwise."
    DEFVAL { false }
    ::= { dot11PhyHEEntry 6}

(11ax)dot11HEERSUPPDUwith4xHELTFand0point8GIImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the non-AP STA is capable of
        receiving an HE ER SU PPDU with 4x HE-LTF and 0.8 microsecond guard
        interval duration. This capability is disabled otherwise."
    DEFVAL { false }
    ::= { dot11PhyHEEntry 7}

(11ax)dot11HEERSUPPDUwith1xHELTFand0point8GIImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the non-AP STA is capable of
        receiving an HE ER SU PPDU with 1x HE-LTF and 0.8 microsecond guard
        interval duration. This capability is disabled otherwise."
    DEFVAL { false }
    ::= { dot11PhyHEEntry 8}

(11ax)dot11HEMidambleRxMaxNSTS OBJECT-TYPE
```



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```
    SYNTAX Unsigned32 (0..3)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute specifies the maximum number of space-time streams
        supported for reception when a midamble is present in the Data field,
        equal to 0 for 1 space-time stream, equal to 1 for 2 space-time streams,
        equal to 2 for 3 space-time streams, and equal to 3 for 4 space-time
        streams."
    DEFVAL { 0 }
    ::= { dot11PhyHEEntry 9 }

(11ax)dot11HENDPwith4xHELTFand3point2GIImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the non-AP STA is capable of
        receiving an NDP with 4x HE-LTF and 3.2 microsecond guard interval
        duration. This capability is disabled otherwise."
    DEFVAL { false }
    ::= { dot11PhyHEEntry 10 }

(11ax)dot11HESTBCTxLessThanOrEqualTo80Implemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the non-AP STA is capable of
        transmitting an HE PPDU that has a bandwidth less than or equal to 80 MHz
        and is using STBC with one spatial stream. This capability is disabled
        otherwise."
    DEFVAL { false }
    ::= { dot11PhyHEEntry 11 }

(11ax)dot11HESTBCRxLessThanOrEqualTo80Implemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the non-AP STA is capable of
        receiving an HE PPDU that has a bandwidth less than or equal to 80 MHz and
        is using STBC with one spatial stream. This capability is disabled
        otherwise."
    DEFVAL { false }
    ::= { dot11PhyHEEntry 12 }

(11ax)dot11HESTBCTxGreaterThan80Implemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
```

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```
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the non-AP STA is capable of
        transmitting an HE PPDU that has a bandwidth greater than 80 MHz and is
        using STBC with one spatial stream. This capability is disabled
        otherwise."
    DEFVAL { false }
    ::= { dot11PhyHEEntry 13 }

(11ax)dot11HESTBCRxGreaterThan80Implemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the non-AP STA is capable of
        receiving an HE PPDU that has a bandwidth greater than 80 MHz and is using
        STBC with one spatial stream. This capability is disabled otherwise."
    DEFVAL { false }
    ::= { dot11PhyHEEntry 14 }

(11ax)dot11HEDopplerTxImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the non-AP STA is capable of
        transmitting HE PPDUs with midamble. This capability is disabled
        otherwise."
    DEFVAL { false }
    ::= { dot11PhyHEEntry 15 }

(11ax)dot11HEDopplerRxImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the non-AP STA is capable of
        receiving HE PPDUs with midamble. This capability is disabled otherwise."
    DEFVAL { false }
    ::= { dot11PhyHEEntry 16 }

(11ax)dot11HEDCMImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the non-AP STA implementation
        supports DCM. This capability is disabled otherwise."
    ::= { dot11PhyHEEntry 17 }

(11ax)dot11HEFullBWULMUMIMOImplemented OBJECT-TYPE
```


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```
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that for an AP implementation, the
        MU-MIMO reception of an HE TB PPDU on an RU that spans the entire PPD
        bandwidth is supported; and for a non-AP STA implementation, the
        transmission of an HE TB PPDU on an RU that spans the entire PPDU
        bandwidth is supported. This capability is disabled otherwise."
    DEFVAL { false }
    ::= { dot11PhyHEEntry 18 }

(11ax)dot11HEPartialBWULMUMIMOImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that an AP is capable of receiving an
        RU in an HE TB PPDU where MU-MIMO is employed in the RU, the RU size is
        greater than or equal to 106 tones, and the RU does not span the entire
        PPDU bandwidth; and a non-AP STA is capable of transmitting an RU in an HE
        TB PPDU where MU-MIMO is employed in the RU, the RU size is greater than
        or equal to 106 tones, and the RU does not span the entire PPDU bandwidth.
        This capability is disabled otherwise."
    DEFVAL { false }
    ::= { dot11PhyHEEntry 19 }

(11ax)dot11HEPartialBWDLMUMIMOImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the non-AP STA is capable of
        receiving a DL MU-MIMO transmission on an RU in an HE MU PPDU where the RU
        does not span the entire PPDU bandwidth. This capability is disabled
        otherwise."
    DEFVAL { false }
    ::= { dot11PhyHEEntry 20 }

(11ax)dot11HEULMUPayloadImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the AP is capable of receiving
        the payload on an RU in an HE MU PPDU where RU spans the entire PPDU
        bandwidth or a 106-tone RU within 20 MHz PPDU bandwidth.  This capability
        is disabled otherwise."
    DEFVAL { false }
    ::= { dot11PhyHEEntry 21 }

(11ax)dot11HEPSRbasedSRSupportImplemented OBJECT-TYPE
```

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```
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the non-AP STA is capable of
        supporting the PSR-based SR operation. This capability is disabled
        otherwise."
    DEFVAL { false }
    ::= { dot11PhyHEEntry 22 }

(11ax)dot11HEPowerBoostFactorImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the non-AP STA implementation
        supports a power boost factor for the r-th RU in the range [0.5, 2]. This
        capability is disabled otherwise."
    DEFVAL { false }
    ::= { dot11PhyHEEntry 23 }

(11ax)dot11HEPartialBWERSUPayloadImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the non-AP STA is capable of
        transmitting and receiving an HE ER SU PPDU in which the HE modulated
        fields are transmitted over the higher frequency 106-tone RU within
        primary 20 MHz channel. This capability is disabled otherwise."
    DEFVAL { false }
    ::= { dot11PhyHEEntry 24 }

(11ax)dot11HEPuncturedSoundingOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the STA implementation is
        capable of operating in a mode where some 242-tone RUs are not allowed to
        be used within a channel of width 80 MHz or 160 MHz. The capability is
        disabled, otherwise"
    DEFVAL { false }
    ::= { dot11PhyHEEntry 25 }

(#1072)dot11HEChannelWidthOptionImplemented OBJECT-TYPE
    SYNTAX INTEGER { contiguous80(0), contiguous160(1), noncontiguous80plus80(2)
        }
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
```



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```
        Its value is determined by (#3375)STA capabilities.

        This attribute indicates the channel widths supported: 20/40/80 MHz, 20/
        40/80/160 MHz or 20/40/80/160/80+80 MHz. For the 5 GHz band, the value of
        dot11HEChannelWidthOptionImplemented equals
        dot11VHTChannelWidthOptionImplemented. Reserved in the 2.4 GHz band
        (#3485)(see dot11FortyMHzOperationImplemented and
        dot11FortyMHzOperationActivated). Reserved in a 20 MHz-only non-AP HE
        STA."
    ::= { dot11PhyHEEntry 26 }
-- ****************************************************************
-- * (11ax)End of dot11PhyHETABLE
-- ****************************************************************

-- ****************************************************************
-- * (11ax)dot11HETransmitBeamformingConfig TABLE
-- ****************************************************************

(11ax)dot11HETransmitBeamformingConfigTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11HETransmitBeamformingConfigEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "Entry of attributes for dot11HETransmitBeamformingConfigTable.
        Implemented as a table indexed on ifIndex to allow for multiple instances
        on an Agent."
    ::= { dot11phy 32 }

(11ax)dot11HETransmitBeamformingConfigEntry OBJECT-TYPE
    SYNTAX Dot11HETransmitBeamformingConfigEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "An entry in dot11HETransmitBeamformingConfigTable.
        ifIndex - Each IEEE 802.11 interface is represented by an ifEntry.
        Interface tables in this MIB module are indexed by ifIndex."
    INDEX {ifIndex}
    ::= { dot11HETransmitBeamformingConfigTable 1 }

(11ax)Dot11HETransmitBeamformingConfigEntry ::=
    SEQUENCE {
        dot11HESUBeamformerOptionImplemented                TruthValue,
        dot11HESUBeamformeeOptionImplemented                TruthValue,
        dot11HEMUBeamformerOptionImplemented                TruthValue,
        dot11HEBeamformeeSTSSupportLessThanOrEqualTo80      Unsigned32,
        dot11HEBeamformeeSTSSupportGreaterThan80            Unsigned32,
        dot11HENumberSoundingDimensionsLessThanOrEqualTo80  Unsigned32,
        dot11HENumberSoundingDimensionsGreaterThan80        Unsigned32,
        dot11HENG16SUFeedbackSupport                        TruthValue,
        dot11HENG16MUFeedbackSupport                        TruthValue,
        dot11HECodebookSizePhi4Psi2SUFeedbackSupport        TruthValue,
        dot11HECodebookSizePhi7Psi5MUFeedbackSupport        TruthValue,
        dot11HETriggeredSUBeamformingFeedbackImplemented    TruthValue,
        dot11HETriggeredMUBeamformingFeedbackImplemented    TruthValue,
        dot11HETriggeredCQIFeedbackSupportImplemented       TruthValue
    }

(11ax)dot11HESUBeamformerOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.
```

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```
        This attribute, when true, indicates that operation as an SU beamformer is
        supported. This attribute, when false, indicates that operation as an SU
        beamformer is not supported."
    DEFVAL { false }
::= { dot11HETransmitBeamformingConfigEntry 1 }

(11ax)dot11HESUBeamformeeOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that for an AP implementation
        operation as an SU beamformee is supported; for a non-AP STA
        implementation operation as an SU beamformee is supported; for an AP
        implementation operation as an SU beamformer is mandatory if the AP
        supports 4 or more spatial streams. This attribute, when false, indicates
        that for an AP implementation operation as an SU beamformee is not
        supported."
    DEFVAL { false }
    ::= { dot11HETransmitBeamformingConfigEntry 2 }

(11ax)dot11HEMUBeamformerOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that for an AP implementation
        operation as an MU beamformer is supported when the SU Beamformer field is
        1. This attribute, when false, indicates that for an AP implementation
        operation as an MU beamformer is not supported; for a non-AP STA
        implementation operation as an MU beamformer is not supported."
    DEFVAL { false }
    ::= { dot11HETransmitBeamformingConfigEntry 3 }

(11ax)dot11HEBeamformeeSTSSupportLessThanOrEqualTo80 OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute indicates the maximum number of space-time streams that the
        non-AP STA can receive in an HE sounding NDP, the maximum value for the
        total number of space-time streams over all the users in RU r,
        NSTS,r,total that can be sent in a DL MU-MIMO transmission on an RU where
        the RU might or might not span the entire PPDU bandwidth, which includes
        that non-AP STA."
    ::= { dot11HETransmitBeamformingConfigEntry 4 }

(11ax)dot11HEBeamformeeSTSSupportGreaterThan80 OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.
```


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```
        This attribute indicates the maximum number of space-time streams that the
        non-AP STA can receive in an HE sounding NDP, the maximum value for the
        total number of space-time streams over all the users in RU r,
        NSTS,r,total that can be sent in a DL MU-MIMO transmission on an RU where
        the RU might or might not span the entire PPDU bandwidth, which includes
        that STA."
    ::= { dot11HETransmitBeamformingConfigEntry 5 }

(11ax)dot11HENumberSoundingDimensionsLessThanOrEqualTo80 OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute specifies, for bandwidth less than or equal to 80 MHz, the
        beamformer's capability to indicate the maximum value of the TXVECTOR
        parameter NUM_STS for an HE sounding NDP."
    ::= { dot11HETransmitBeamformingConfigEntry 6 }

(11ax)dot11HENumberSoundingDimensionsGreaterThan80 OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute specifies, for bandwidth greater than 80 MHz, the
        beamformer's capability to indicate the maximum value of the TXVECTOR
        parameter NUM_STS for an HE sounding NDP."
    ::= { dot11HETransmitBeamformingConfigEntry 7 }

(11ax)dot11HENG16SUFeedbackSupport OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates the HE beamformee support for a tone
        grouping of 16 in the HE Compressed Beamforming Report field for SU
        feedback. This capability is disabled otherwise."
    DEFVAL { false }
    ::= { dot11HETransmitBeamformingConfigEntry 8 }

(11ax)dot11HENG16MUFeedbackSupport OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates the HE beamformee support for a tone
        grouping of 16 in the HE Compressed Beamforming Report field for MU
        feedback. This capability is disabled otherwise."
    DEFVAL { false }
    ::= { dot11HETransmitBeamformingConfigEntry 9 }

(11ax)dot11HECodebookSizePhi4Psi2SUFeedbackSupport OBJECT-TYPE
```

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```
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates the HE beamformee support for a
        codebook size (psi, phi(#2370)) = {4, 2} in the HE Compressed Beamforming
        Report field for SU feedback. This capability is disabled otherwise."
    DEFVAL { false }
    ::= { dot11HETransmitBeamformingConfigEntry 10 }

(11ax)dot11HECodebookSizePhi7Psi5MUFeedbackSupport OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates the HE beamformee support for a
        codebook size (psi, phi(#2370)) = {7, 5} in the HE Compressed Beamforming
        Report field for MU feedback. This capability is disabled otherwise."
    DEFVAL { false }
    ::= { dot11HETransmitBeamformingConfigEntry 11 }

(11ax)dot11HETriggeredSUBeamformingFeedbackImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that for an AP implementation, the
        reception of partial- and full-bandwidth SU feedback in an HE TB sounding
        sequence is supported; for a non-AP STA implementation, the transmission
        of partial- and full-bandwidth SU feedback in an HE TB sounding sequence
        is supported. This capability is disabled otherwise."
    DEFVAL { false }
    ::= { dot11HETransmitBeamformingConfigEntry 12 }

(11ax)dot11HETriggeredMUBeamformingFeedbackImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that for an AP implementation, the
        reception of partial-bandwidth MU feedback in an HE TB sounding sequence
        is supported; for a non-AP STA implementation, the transmission of
        partial-bandwidth MU feedback in an HE TB sounding sequence is supported.
        This capability is disabled otherwise."
    DEFVAL { false }
    ::= { dot11HETransmitBeamformingConfigEntry 13 }

(11ax)dot11HETriggeredCQIFeedbackSupportImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
```


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```
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that for an AP implementation, the
        reception of partial- and full-bandwidth CQI feedback in an HE TB sounding
        sequence is supported; for a non-AP STA implementation, the transmission
        of partial- and full-bandwidth CQI feedback in an HE TB sounding sequence
        is supported. This capability is disabled otherwise."
    DEFVAL { false }
    ::= { dot11HETransmitBeamformingConfigEntry 14 }

-- ************************************************************************
-- * (11ax)End of dot11HETransmitBeamformingConfig TABLE
-- ************************************************************************


-- ************************************************************************
-- * (11ay)dot11 PHY EDMG TABLE
-- ************************************************************************

dot11PHYEDMGTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11PHYEDMGEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "Entry of attributes for dot11PhyEDMGTable. Implemented as a table indexed
        on ifIndex to allow for multiple instances on an Agent."
    ::= { dot11phy 33 }

dot11PHYEDMGEntry OBJECT-TYPE
    SYNTAX Dot11PHYEDMGEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "An entry in the dot11PHYEDMGEntry Table.

        ifIndex - Each IEEE 802.11 interface is represented by an ifEntry.
        Interface tables in this MIB module are indexed by ifIndex."
    INDEX {ifIndex}
    ::= { dot11PHYEDMGTable 1 }

Dot11PHYEDMGEntry ::=
        SEQUENCE {
              dot11EDMGCurrentChannelWidth                    INTEGER,
              dot11EDMGCurrentChannelCenterFrequencyIndex0    Unsigned32,
              dot11EDMGCurrentChannelCenterFrequencyIndex1    Unsigned32,
              dot11EDMGCurrentPrimaryChannel                  Unsigned32,
              dot11EDMGPolarizationCapability                 OCTET STRING(#1288),
              dot11EDMGSCMaxSUSpatialStreams                  Unsigned32,
              dot11EDMGOFDMMaxSUSpatialStreams                Unsigned32,
              dot11EDMGNumConcurrentRFChains                  Unsigned32,
              dot11EDMGPhaseHoppingImplemented                TruthValue,
              dot11EDMGOpenLoopPrecodingImplemented           TruthValue,
              dot11EDMGDCMBPSKImplemented                     TruthValue,
              dot11EDMGShortCWPuncturedImplemented            TruthValue,
              dot11EDMGShortCWSuperimposedImplemented         TruthValue,
              dot11EDMGLongCWPuncturedImplemented             TruthValue,
              dot11EDMGLongCWSuperimposedImplemented          TruthValue,
              dot11EDMGNUCTXImplemented                       TruthValue,
              dot11EDMGNUCRXImplemented                       TruthValue,
              dot11EDMG8PSKImplemented                        TruthValue,
              dot11EDMGSTBCType                               INTEGER,
```

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```
                dot11EDMGAPPDUImplemented                       TruthValue,
                dot11EDMGLongCWImplemented                      TruthValue
        }

dot11EDMGCurrentChannelWidth OBJECT-TYPE
    SYNTAX INTEGER { cbw216(0), cbw432(1), cbw648(2), cbw864(3), cbw216p216(4),
        cbw432p432(5) }
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.

        Indicates the operating channel width.
                0 = 2.16 GHz
                1 = 4.32 GHz
                2 = 6.48 GHz
                3 = 8.64 GHz
                4 = 2.16+2.16 GHz
                5 = 4.32+4.32 GHz"
    DEFVAL { cbw216 }
    ::= { dot11PHYEDMGEntry 3 }

dot11EDMGCurrentChannelCenterFrequencyIndex0 OBJECT-TYPE
    SYNTAX Unsigned32 (0..3000)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.

        For a 2.16 GHz, 4.32 GHz, 6.48 GHz, or 8.64 GHz channel, denotes the
        channel center frequency.
        For a 2.16+2.16 GHz or 4.32+4.32 GHz channel, denotes the channel center
        frequency of frequency segment 0."
    DEFVAL { 0 }
    ::= { dot11PHYEDMGEntry 4 }

dot11EDMGCurrentChannelCenterFrequencyIndex1 OBJECT-TYPE
    SYNTAX Unsigned32 (0..3000)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.

        Set to 0 for a 2.16 GHz, 4.32 GHz, 6.48 GHz, or 8.64 GHz channel.
        For a 2.16+2.16 GHz or 4.32+4.32 GHz channel, denotes the channel center
        frequency of frequency segment 1."
    DEFVAL { 0 }
    ::= { dot11PHYEDMGEntry 5 }

dot11EDMGCurrentPrimaryChannel OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable. It is written by the PHY.

        This attribute indicates the primary channel number."
    ::= { dot11PHYEDMGEntry 6 }

dot11EDMGPolarizationCapability OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(0..9))
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
```


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```
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute indicates EDMG antenna polarization capabilities defined in
        the Antenna Polarization Capability field in the EDMG Capabilities
        element."
    ::= { dot11PHYEDMGEntry 7 }

dot11EDMGSCMaxSUSpatialStreams OBJECT-TYPE
    SYNTAX Unsigned32 (1..8)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute indicates number of supported spatial streams for EDMG SC
        PHY."
    DEFVAL { 1 }
    ::= { dot11PHYEDMGEntry 8 }

dot11EDMGOFDMMaxSUSpatialStreams OBJECT-TYPE
    SYNTAX Unsigned32 (1..8)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute indicates number of supported spatial streams for EDMG OFDM
        PHY."
    DEFVAL { 1 }
    ::= { dot11PHYEDMGEntry 9 }

dot11EDMGNumConcurrentRFChains OBJECT-TYPE
    SYNTAX Unsigned32 (1..8)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute indicates number of concurrent RF chains the EDMG PHY
        supports."
    DEFVAL { 1 }
    ::= { dot11PHYEDMGEntry 10 }

dot11EDMGPhaseHoppingImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute indicates support for phase hopping."
    DEFVAL { false }
    ::= { dot11PHYEDMGEntry 11 }

dot11EDMGOpenLoopPrecodingImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
```

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```
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute indicates support for open loop precoding."
    DEFVAL { false }
    ::= { dot11PHYEDMGEntry 12 }

dot11EDMGDCMBPSKImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute indicates support for DCM Pi/2 BPSK."
    DEFVAL { false }
    ::= { dot11PHYEDMGEntry 13 }

dot11EDMGShortCWPuncturedImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute indicates support for punctured short CW."
    DEFVAL { false }
    ::= { dot11PHYEDMGEntry 14 }

dot11EDMGShortCWSuperimposedImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute indicates support for superimposed short CW."
    DEFVAL { false }
    ::= { dot11PHYEDMGEntry 15 }

dot11EDMGLongCWPuncturedImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute indicates support for punctured Long CW."
    DEFVAL { false }
    ::= { dot11PHYEDMGEntry 16 }

dot11EDMGLongCWSuperimposedImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute indicates support for superimposed Long CW."
```


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```
    DEFVAL { false }
    ::= { dot11PHYEDMGEntry 17 }

dot11EDMGNUCTXImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute indicates support for NUC TX."
    DEFVAL { false }
    ::= { dot11PHYEDMGEntry 18 }

dot11EDMGNUCRXImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute indicates support for NUC RX."
    DEFVAL { false }
    ::= { dot11PHYEDMGEntry 19 }

dot11EDMG8PSKImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute indicates support for Pi/2 8PSK."
    DEFVAL { false }
    ::= { dot11PHYEDMGEntry 20 }

dot11EDMGSTBCType OBJECT-TYPE
    SYNTAX INTEGER {notSupported (0), singleStreamRx (1), oneOrMoreStreamRx (2)}
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute indicates support for STBC."
    DEFVAL { 0 }
    ::= { dot11PHYEDMGEntry 21 }

dot11EDMGAPPDUImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute indicates support for A-PPDU."
    DEFVAL { false }
    ::= { dot11PHYEDMGEntry 22 }

dot11EDMGLongCWImplemented OBJECT-TYPE
```

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```
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute indicates support for the long (1344) LDPC codeword
        length."
    DEFVAL { false }
    ::= { dot11PHYEDMGEntry 23 }

-- ****************************************************************
-- * (11ay)End of dot11 Phy EDMG TABLE
-- ****************************************************************


-- ****************************************************************
-- * (11ay)dot11EDMGBeamformingConfig TABLE
-- ****************************************************************

dot11EDMGBeamformingConfigTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11EDMGBeamformingConfigEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "This is a table management object."
    ::= { dot11phy 34 }

dot11EDMGBeamformingConfigEntry OBJECT-TYPE
    SYNTAX Dot11EDMGBeamformingConfigEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "This is an entry in the dot11EDMGBeamformingConfigTable Table.
        ifIndex - Each IEEE 802.11 interface is represented by an ifEntry.
        Interface tables in this MIB module are indexed by ifIndex."
    INDEX { ifIndex }
    ::= { dot11EDMGBeamformingConfigTable 1 }

Dot11EDMGBeamformingConfigEntry ::=
        SEQUENCE {
                dot11RequestedBRPMinDataLength                Unsigned32,
                dot11EDMGMIMOSupport                          INTEGER,
                dot11EDMGBFGrantRequired                      TruthValue,
                dot11EDMGBFDMGTRNRXOnlyImplemented            TruthValue,
                dot11FirstPathTrainingImplemented             TruthValue,
                dot11EDMGHybridMUMIMOImplemented              TruthValue,
                dot11EDMGHybridSUMIMOImplemented              TruthValue,
                dot11EDMGBFGrantLargestNgSupported            Integer32,
                dot11EDMGBFDynamicGroupingImplemented         TruthValue
        }

dot11RequestedBRPMinDataLength OBJECT-TYPE
    SYNTAX Unsigned32 (0..65535)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute indicates the minimum number of data SC blocks or OFDM
        symbols that the STA requests be included in a PPDU carrying a TRN field
        and transmitted to the STA."
```


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```
    DEFVAL { 1 }
    ::= { dot11EDMGBeamformingConfigEntry 1 }

dot11EDMGMIMOSupport OBJECT-TYPE
    SYNTAX INTEGER {notSupported (0), suMimoOnly (1), muAndSuMimo (2),
       reciprocalMuMimoAndSuMimo (3)}
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
       "This is a capability variable.
       Its value is determined by (#3375)STA capabilities.

       This attribute indicates EDMG MIMO Capabilities."
    DEFVAL { 0 }
    ::= { dot11EDMGBeamformingConfigEntry 2 }

dot11EDMGBFGrantRequired OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
       "This a primary/secondary variable. Its value is determined by (#3375)STA
       capabilities of the STA when responding to a MIMO setup, to indicate that
       the MIMO initiator has to transmit a Grant frame before initiating MIMO
       channel access."
    DEFVAL { false }
    ::= { dot11EDMGBeamformingConfigEntry 3 }

dot11EDMGBFDMGTRNRXOnlyImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
       "This is a capability variable.
       Its value is determined by (#3375)STA capabilities.

       This attribute indicates EDMG Beamforming TRN RX Only Capabilities."
    DEFVAL { false }
    ::= { dot11EDMGBeamformingConfigEntry 4 }

dot11FirstPathTrainingImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
       "This is a capability variable.
       Its value is determined by (#3375)STA capabilities.

       This attribute indicates EDMG Beamforming First Path Training Supported."
    DEFVAL { false }
    ::= { dot11EDMGBeamformingConfigEntry 5 }

dot11EDMGHybridMUMIMOImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
       "This is a capability variable.
       Its value is determined by (#3375)STA capabilities.

       This attribute indicates EDMG Hybrid BF MU-MIMO Capability."
    DEFVAL { false }
    ::= { dot11EDMGBeamformingConfigEntry 6 }
```

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```
dot11EDMGHybridSUMIMOImplemented OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a capability variable.
      Its value is determined by (#3375)STA capabilities.

      This attribute indicates EDMG Hybrid BF SU-MIMO Capability."
   DEFVAL { false }
   ::= { dot11EDMGBeamformingConfigEntry 7 }

dot11EDMGBFGrantLargestNgSupported OBJECT-TYPE
   SYNTAX Integer32 (0..2)
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a capability variable.
      Its value is determined by (#3375)STA capabilities.

      This attribute indicates largest value of Ng that the EDMG STA supports
      for the beamforming feedback matrix."
   DEFVAL { 1 }
   ::= { dot11EDMGBeamformingConfigEntry 8 }

dot11EDMGBFDynamicGroupingImplemented OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a capability variable.
      Its value is determined by (#3375)STA capabilities.

      This attribute indicates support for dynamic grouping."
   DEFVAL { false }
   ::= { dot11EDMGBeamformingConfigEntry 9 }

-- ************************************************************************
-- * (11ay)End of dot11EDMGBeamformingConfig TABLE
-- ************************************************************************


-- ************************************************************************
-- * dot11 Phy S1G TABLE
-- ************************************************************************

dot11PhyS1GTable OBJECT-TYPE
   SYNTAX SEQUENCE OF Dot11PhyS1GEntry
   MAX-ACCESS not-accessible
   STATUS current
   DESCRIPTION
      "Entry of attributes for dot11PhyS1GTable. Implemented as a table indexed
      on ifIndex to allow for multiple instances on an Agent."
   ::= { dot11phy 27 }

dot11PhyS1GEntry OBJECT-TYPE
   SYNTAX Dot11PhyS1GEntry
   MAX-ACCESS not-accessible
   STATUS current
   DESCRIPTION
      "An entry in the dot11PhyHTEntry Table. ifIndex - Each IEEE 802.11 inter-
      face is represented by an ifEntry. Interface tables in this MIB module are
      indexed by ifIndex."
   INDEX {ifIndex}

```


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```
    ::= { dot11PhyS1GTable 1 }

Dot11PhyS1GEntry ::=
    SEQUENCE {
        dot11S1GChannelWidthOptionImplemented                 INTEGER,
        dot11S1GCurrentPrimaryChannel                         Unsigned32,
        dot11S1GCurrentChannelWidth                           INTEGER,
        dot11S1GCurrentChannelCenterFrequencyIndex            Unsigned32,
        dot11ShortGIOptionIn1MImplemented                     TruthValue,
        dot11ShortGIOptionIn1MActivated                       TruthValue,
        dot11ShortGIOptionIn2MImplemented                     TruthValue,
        dot11ShortGIOptionIn2MActivated                       TruthValue,
        dot11ShortGIOptionIn4MImplemented                     TruthValue,
        dot11ShortGIOptionIn4MActivated                       TruthValue,
        dot11ShortGIOptionIn8MImplemented                     TruthValue,
        dot11ShortGIOptionIn8MActivated                       TruthValue,
        dot11ShortGIOptionIn16MImplemented                    TruthValue,
        dot11ShortGIOptionIn16MActivated                      TruthValue,
        dot11S1GLDPCCodingOptionImplemented                   TruthValue,
        dot11S1GLDPCCodingOptionActivated                     TruthValue,
        dot11S1GTxSTBCOptionImplemented                       TruthValue,
        dot11S1GTxSTBCOptionActivated                         TruthValue,
        dot11S1GRxSTBCOptionImplemented                       TruthValue,
        dot11S1GRxSTBCOptionActivated                         TruthValue,
        dot11S1GMUMaxUsersImplemented                         Unsigned32,
        dot11S1GMUMaxNSTSPerUserImplemented                   Unsigned32,
        dot11S1GMUMaxNSTSTotalImplemented                     Unsigned32,
        dot11S1GMaxNTxChainsImplemented                       Unsigned32,
        dot11S1GMaxNTxChainsActivated                         Unsigned32,
        dot11S1GTravelingPilotOptionImplemented               TruthValue,
        dot11S1GTravelingPilotOptionActivated                 TruthValue,
        dot11S1GLONGOptionImplemented                         TruthValue,
        dot11S1GLONGOptionActivated                           TruthValue
    }

dot11S1GChannelWidthOptionImplemented OBJECT-TYPE
    SYNTAX INTEGER { contiguous2(0), contiguous4(1), contiguous8(2), contigu-
        ous16(3) }
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute indicates the channel widths supported: 1/2 MHz, 1/2/4 MHz,
        1/2/4/8 MHz or 1/2/4/8/16 MHz."
    ::= { dot11PhyS1GEntry 1 }

dot11S1GCurrentPrimaryChannel OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the PHY.

        This attribute indicates the channel number of the 2 MHz primary channel
        or of the 1 MHz primary channel."
    ::= { dot11PhyS1GEntry 2 }

dot11S1GCurrentChannelWidth OBJECT-TYPE
    SYNTAX INTEGER { cbw1(0), cbw2(1), cbw4(2), cbw8(3), cbw16(4) }
    MAX-ACCESS read-only
    STATUS current
```

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```
    DESCRIPTION
        "This is a status variable.
        It is written by the PHY.

        This attribute indicates the operating channel width."
    DEFVAL { cbw1 }
    ::= { dot11PhyS1GEntry 3 }

dot11S1GCurrentChannelCenterFrequencyIndex OBJECT-TYPE
    SYNTAX Unsigned32 (0..200)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the PHY.

        For a 1 MHz, 2 MHz, 4 MHz, 8 MHz, or 16 MHz channel, denotes the channel
        center frequency."
    DEFVAL { 0 }
    ::= { dot11PhyS1GEntry 4 }

dot11ShortGIOptionIn1MImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the (#4213)STA is capable of
        receiving 1 MHz short guard interval packets."
    ::= { dot11PhyS1GEntry 5 }

dot11ShortGIOptionIn1MActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation. Changes
        made while associated with an AP or while operating a BSS should take
        effect only after disassociation or the deactivation of the BSS, respec-
        tively.

        This attribute, when true, indicates that the reception of 1 MHz short
        guard interval packets is enabled."
    DEFVAL { false }
    ::= { dot11PhyS1GEntry 6 }

dot11ShortGIOptionIn2MImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the (#4213)STA is capable of
        receiving 2 MHz short guard interval packets."
    ::= { dot11PhyS1GEntry 7 }

dot11ShortGIOptionIn2MActivated OBJECT-TYPE
    SYNTAX TruthValue
```


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```
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
       "This is a control variable.
       It is written by an external management entity.
       Changes take effect as soon as practical in the implementation. Changes
       made while associated with an AP or while operating a BSS should take
       effect only after disassociation or the deactivation of the BSS, respec-
       tively.

       This attribute, when true, indicates that the reception of 2 MHz short
       guard interval packets is enabled."
    DEFVAL { false }
    ::= { dot11PhyS1GEntry 8 }

dot11ShortGIOptionIn4MImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
       "This is a capability variable.
       Its value is determined by (#3375)STA capabilities.

       This attribute, when true, indicates that the (#4213)STA is capable of
       receiving 4 MHz short guard interval packets."
    ::= { dot11PhyS1GEntry 9 }

dot11ShortGIOptionIn4MActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
       "This is a control variable.
       It is written by an external management entity.
       Changes take effect as soon as practical in the implementation. Changes
       made while associated with an AP or while operating a BSS should take
       effect only after disassociation or the deactivation of the BSS, respec-
       tively.

       This attribute, when true, indicates that the reception of 4 MHz short
       guard interval packets is enabled."
    DEFVAL { false }
    ::= { dot11PhyS1GEntry 10 }

dot11ShortGIOptionIn8MImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
       "This is a capability variable.
       Its value is determined by (#3375)STA capabilities.

       This attribute, when true, indicates that the (#4213)STA is capable of
       receiving 8 MHz short guard interval packets."
    ::= { dot11PhyS1GEntry 11 }

dot11ShortGIOptionIn8MActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
       "This is a control variable.
       It is written by an external management entity.
       Changes take effect as soon as practical in the implementation. Changes
```

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```
        made while associated with an AP or while operating a BSS should take
        effect only after disassociation or the deactivation of the BSS, respec-
        tively.

        This attribute, when true, indicates that the reception of 8 MHz short
        guard interval packets is enabled."
    DEFVAL { false }
    ::= { dot11PhyS1GEntry 12 }

dot11ShortGIOptionIn16MImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the (#4213)STA is capable of
        receiving 16 MHz short guard interval packets."
    ::= { dot11PhyS1GEntry 13 }

dot11ShortGIOptionIn16MActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation. Changes
        made while associated with an AP or while operating a BSS should take
        effect only after disassociation or the deactivation of the BSS, respec-
        tively.

        This attribute, when true, indicates that the reception of 16 MHz short
        guard interval packets is enabled."
    DEFVAL { false }
    ::= { dot11PhyS1GEntry 14 }

dot11S1GLDPCCodingOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the LDPC coding option for S1G
        packets is implemented."
    ::= { dot11PhyS1GEntry 15 }

dot11S1GLDPCCodingOptionActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation. Changes
        made while associated with an AP or while operating a BSS should take
        effect only after disassociation or the deactivation of the BSS, respec-
        tively.

        This attribute, when true, indicates that the LDPC coding option for S1G
        packets is enabled."
```


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```
    DEFVAL { false }
    ::= { dot11PhyS1GEntry 16 }

dot11S1GTxSTBCOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the (#4213)STA is capable of
        transmitting S1G PPDUs using STBC."
    ::= { dot11PhyS1GEntry 17 }

dot11S1GTxSTBCOptionActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation. Changes
        made while associated with an AP or while operating a BSS should take
        effect only after disassociation or the deactivation of the BSS, respec-
        tively.

        This attribute, when true, indicates that the entity's capability for
        transmitting S1G PPDUs using STBC is enabled."
    DEFVAL { false }
    ::= { dot11PhyS1GEntry 18 }

dot11S1GRxSTBCOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the (#4213)STA is capable of
        receiving S1G PPDUs using STBC."
    ::= { dot11PhyS1GEntry 19 }

dot11S1GRxSTBCOptionActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation. Changes
        made while associated with an AP or while operating a BSS should take
        effect only after disassociation or the deactivation of the BSS, respec-
        tively.

        This attribute, when true, indicates that the entity's capability for
        receiving S1G PPDUs using STBC is enabled."
    DEFVAL { false }
    ::= { dot11PhyS1GEntry 20 }

dot11S1GMUMaxUsersImplemented OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-only
```

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```
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute indicates the maximum number of users to which this
        (#4213)STA is capable of transmitting within an S1G MU PPDU."
    ::= { dot11PhyS1GEntry 21 }

dot11S1GMUMaxNSTSPerUserImplemented OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute indicates the maximum number of space-time streams per user
        that this (#4213)STA is capable of transmitting within an S1G MU PPDU."
    ::= { dot11PhyS1GEntry 22 }

dot11S1GMUMaxNSTSTotalImplemented OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute indicates the maximum number of space-time streams for all
        users that this (#4213)STA is capable of transmitting within an S1G MU
        PPDU."
    ::= { dot11PhyS1GEntry 23 }

dot11S1GMaxNTxChainsImplemented OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute indicates the maximum number of transmit chains within this
        (#4213)STA."
    ::= { dot11PhyS1GEntry 24 }

dot11S1GMaxNTxChainsActivated OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute indicates the maximum number of transmit chains that are
        activated within this (#4213)STA, unless this attribute exceeds
        dot11S1GMaxNTxChainsImplemented, in which case the maximum number of
        transmit chains that are activated within this (#4213)STA is equal to
        dot11S1GMaxNTxChainsImplemented."
    DEFVAL { 1 }
::= { dot11PhyS1GEntry 25 }

dot11S1GTravelingPilotOptionImplemented OBJECT-TYPE
```


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```
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the traveling pilot option is
        implemented."
    ::= { dot11PhyS1GEntry 26 }

dot11S1GTravelingPilotOptionActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute, when true, indicates that the traveling pilot option is
        enabled."
    DEFVAL { false }
    ::= { dot11PhyS1GEntry 27 }

dot11S1GLONGOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the S1G_Long operation is imple-
        mented."
    ::= { dot11PhyS1GEntry 28 }

dot11S1GLONGOptionActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute, when true, indicates that the S1G_Long operation is
        enabled."
    DEFVAL { false }
    ::= { dot11PhyS1GEntry 29 }

-- ************************************************************************
-- * End of dot11PhyS1G TABLE
-- ************************************************************************

-- ************************************************************************
-- * dot11 S1G Transmit Beamforming Config TABLE
-- ************************************************************************

dot11S1GTransmitBeamformingConfigTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11S1GTransmitBeamformingConfigEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
```

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```
        "Entry of attributes for dot11S1GTransmitBeamformingConfigTable. Imple-
        mented as a table indexed on ifIndex to allow for multiple instances on an
        Agent."
    ::= { dot11phy 28 }

dot11S1GTransmitBeamformingConfigEntry OBJECT-TYPE
    SYNTAX Dot11S1GTransmitBeamformingConfigEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "An entry in the dot11S1GTransmitBeamformingConfig Table.
        ifIndex - Each IEEE 802.11 interface is represented by an ifEntry. Inter-
        face tables in this MIB module are indexed by ifIndex."
    INDEX {ifIndex}
    ::= { dot11S1GTransmitBeamformingConfigTable 1 }

Dot11S1GTransmitBeamformingConfigEntry ::=
    SEQUENCE {
        dot11S1GSUBeamformerOptionImplemented                TruthValue,
        dot11S1GSUBeamformeeOptionImplemented                TruthValue,
        dot11S1GMUBeamformerOptionImplemented                TruthValue,
        dot11S1GMUBeamformeeOptionImplemented                TruthValue,
        dot11S1GNumberSoundingDimensions                     Unsigned32,
        dot11S1GBeamformeeNTxSupport                         Unsigned32
    }

dot11S1GSUBeamformeeOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the STA supports the SU Beamfor-
        mee role."
    ::= { dot11S1GTransmitBeamformingConfigEntry 1 }

dot11S1GSUBeamformerOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the STA supports the SU Beam-
        former role."
    ::= { dot11S1GTransmitBeamformingConfigEntry 2 }

dot11S1GMUBeamformeeOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the STA supports the MU Beamfor-
        mee role."
    ::= { dot11S1GTransmitBeamformingConfigEntry 3 }

dot11S1GMUBeamformerOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
```


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```
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the STA supports the MU Beam-
        former role."
    ::= { dot11S1GTransmitBeamformingConfigEntry 4 }

dot11S1GNumberSoundingDimensions OBJECT-TYPE
    SYNTAX Unsigned32 (2..8)(#2044)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute indicates the number of antennas used by the beamformer
        when sending beamformed tansmissions."
    ::= { dot11S1GTransmitBeamformingConfigEntry 5 }

dot11S1GBeamformeeNTxSupport OBJECT-TYPE
    SYNTAX Unsigned32 (2..8)(#2044)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute indicates the maximum number of space-time streams that the
        STA can receive in an S1G NDP, the maximum value for NSTS,total that can
        be sent to the STA in an S1G MU PPDU if the STA is MU beamformee capable
        and the maximum value of Nr that the STA transmits in an S1G Compressed
        Beamforming frame."
    ::= { dot11S1GTransmitBeamformingConfigEntry 6 }

-- ************************************************************************
-- * End of dot11 S1G Transmit Beamforming Config TABLE
-- ************************************************************************


--************************************************************************
-- * dot11 Phy CDMG TABLE
--************************************************************************

dot11PHYCDMGTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11PHYCDMGEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "Entry of attributes for dot11PhyCDMGTable. Implemented as a table indexed
        on ifIndex to allow for multiple instances on an agent."
    ::= { dot11phy 29 }

dot11PHYCDMGEntry OBJECT-TYPE
    SYNTAX Dot11PHYCDMGEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "An entry in the dot11PHYCDMGEntry Table. ifIndex - Each IEEE
        802.11 interface is represented by an ifEntry. Interface tables in this
        MIB module are indexed by ifIndex."
    INDEX {ifIndex}
```

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```
    ::= { dot11PHYCDMGTable 1 }

Dot11PHYCDMGEntry ::=
    SEQUENCE {
        dot11CDMGLowPowerSCPHYImplemented                    TruthValue,
        dot11CDMGLowPowerSCPHYActivated                      TruthValue
        }

dot11CDMGLowPowerSCPHYImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the CDMG low power SC PHY is
        implemented."
    ::= { dot11PHYCDMGEntry 1 }

dot11CDMGLowPowerSCPHYActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.
        Changes take effect as soon as practical in the implementation.

        This attribute, when true, indicates that the CDMG low power SC PHY is
        activated."
    DEFVAL { false }
    ::= { dot11PHYCDMGEntry 2 }

-- ************************************************************************
-- * End of dot11 PHY CDMG TABLE
-- ************************************************************************

--************************************************************************
-- * dot11 Phy CMMG TABLE
--************************************************************************

dot11PHYCMMGTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11PHYCMMGEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "Entry of attributes for dot11PhyCMMGTable. Implemented as a table indexed
        on ifIndex to allow for multiple instances on an agent."
    ::= { dot11phy 30 }

dot11PHYCMMGEntry OBJECT-TYPE
    SYNTAX Dot11PHYCMMGEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "An entry in the dot11PHYCMMGEntry Table. ifIndex - Each IEEE
        802.11 interface is represented by an ifEntry. Interface tables in this
        MIB module are indexed by ifIndex."
    INDEX {ifIndex}
    ::= { dot11PHYCMMGTable 1 }

Dot11PHYCMMGEntry ::=
    SEQUENCE {
```


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```
        dot11CMMGCurrentChannelWidth                              INTEGER,
        dot11CMMGCurrentChannelCenterFrequencyIndex               Unsigned32,
        dot11CMMGShortGIOptionImplemented                         TruthValue,
        dot11CMMGShortGIOptionActivated                           TruthValue,
        dot11CMMGTxSTBCOptionImplemented                          TruthValue,
        dot11CMMGTxSTBCOptionActivated                            TruthValue,
        dot11CMMGRxSTBCOptionImplemented                          TruthValue,
        dot11CMMGRxSTBCOptionActivated                            TruthValue,
        dot11CMMGBeamFormingOptionImplemented                     TruthValue,
        dot11CMMGBeamFormingOptionActivated                       TruthValue,
        dot11CMMGMaxNTxChainsImplemented                          Unsigned32,
        dot11CMMGMaxNTxChainsActivated                            Unsigned32
        }

dot11CMMGCurrentChannelWidth OBJECT-TYPE
    SYNTAX INTEGER { cbw540(0), cbw1080(1)}
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        Written by the PHY.
        This attribute indicates the operating channel width."
    DEFVAL { cbw540 }
    ::= { dot11PHYCMMGEntry 1 }

dot11CMMGCurrentChannelCenterFrequencyIndex OBJECT-TYPE
    SYNTAX Unsigned32 (1..10)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        Written by the PHY.
        Denotes the channel center frequency.
        If dot11CMMGCurrentChannelWidth is cbw1080(1) then it does not exceed 5.
        See 25.10 (Channelization)."
    ::= { dot11PHYCMMGEntry 2 }

dot11CMMGShortGIOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the (#4213)STA is capable of
        receiving short guard interval packets."
    ::= { dot11PHYCMMGEntry 3 }

dot11CMMGShortGIOptionActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.

        Changes take effect as soon as practical in the implementation. Changes
        made while associated with an AP or while operating a BSS should take
        effect only after disassociation or the deactivation of the BSS,
        respectively.
        This attribute, when true, indicates that the reception of short guard
        interval packets is enabled."
    DEFVAL { false }
```

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```
    ::= { dot11PHYCMMGEntry 4 }

dot11CMMGTxSTBCOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the (#4213)STA is capable of
        transmitting CMMG PPDUs using STBC."
::= { dot11PHYCMMGEntry 5 }

dot11CMMGTxSTBCOptionActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.

        Changes take effect as soon as practical in the implementation.
        This attribute, when true, indicates that the entity's capability of
        transmitting frames using STBC option is enabled."
    DEFVAL { false }
    ::= { dot11PHYCMMGEntry 6 }

dot11CMMGRxSTBCOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute, when true, indicates that the (#4213)STA is capable of
        receiving CMMG PPDUs using STBC."
    ::= { dot11PHYCMMGEntry 7 }

dot11CMMGRxSTBCOptionActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.

        Changes take effect as soon as practical in the implementation. Changes
        made while associated with an AP or while operating a BSS should take
        effect only after disassociation or the deactivation of the BSS,
        respectively.
        This attribute, when true, indicates that the entity's capability for
        receiving CMMG PPDUs using STBC is enabled."
    DEFVAL { false }
    ::= { dot11PHYCMMGEntry 8 }

dot11CMMGBeamFormingOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.
```


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```
        This attribute, when true, indicates that the beamforming option is
        implemented."
    ::= { dot11PHYCMMGEntry 9 }

dot11CMMGBeamFormingOptionActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.

        Changes take effect as soon as practical in the implementation.
        This attribute, when true, indicates that the beamforming option is
        enabled."
    DEFVAL { false }
    ::= { dot11PHYCMMGEntry 10 }

dot11CMMGMaxNTxChainsImplemented OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by (#3375)STA capabilities.

        This attribute indicates the maximum number of transmit chains within
        this (#4213)STA."
    ::= { dot11PHYCMMGEntry 11 }

dot11CMMGMaxNTxChainsActivated OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity.

        Changes take effect as soon as practical in the implementation.
        This attribute indicates the maximum number of transmit chains that are
        activated within this (#4213)STA, unless this attribute exceeds
        dot11CMMGMax-
        NTxChainsImplemented, in which case the maximum number of transmit chains
        that are activated within this (#4213)STA is equal to
        dot11CMMGMaxNTxChainsImplemented."
    DEFVAL { 2147483647 }
    ::= { dot11PHYCMMGEntry 12 }

-- ************************************************************
-- * End of dot11 PHY CMMG TABLE
-- ************************************************************


-- Interworking Management (IMT) Attributes
-- DEFINED AS "The Interworking management object class provides
-- the necessary support for an SSPN Interface function to manage
-- interworking with external systems. IMT objects are conceptual
-- objects for Interworking Service and are defined only for the
-- AP."

dot11imt OBJECT IDENTIFIER ::= {ieee802dot11 6}

-- IMT GROUPS
```

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```
-- dot11BSSIdTable                  ::= { dot11imt 1 }
-- dot11InterworkingTable           ::= { dot11imt 2 }
-- dot11APLCITable                  ::= { dot11imt 3 }
-- dot11APCivicLocationTable        ::= { dot11imt 4 }
-- dot11RoamingConsortiumTable      ::= { dot11imt 5 }
-- dot11DomainNameTable             ::= { dot11imt 6 }

-- Generic Advertisement Service (GAS) Attributes
-- DEFINED AS "The Generic Advertisement Service management
-- object class provides the necessary support for an Advertisement
-- service to interwork with external systems."

-- GAS GROUPS
-- dot11GASAdvertisementTable       ::= { dot11imt 7 }

--*****************************************************************
-- * dot11BSSId TABLE
--*****************************************************************

dot11BSSIdTable OBJECT-TYPE
   SYNTAX         SEQUENCE OF Dot11BSSIdEntry
   MAX-ACCESS     not-accessible
   STATUS         current
   DESCRIPTION
      "This object is a table of BSSIDs contained within an Access Point (AP)."
   ::= { dot11imt 1 }

dot11BSSIdEntry OBJECT-TYPE
   SYNTAX     Dot11BSSIdEntry
   MAX-ACCESS not-accessible
   STATUS     current
   DESCRIPTION
      "This object provides the attributes identifying a particular BSSID within
      an AP."
   INDEX { dot11APMacAddress }
   ::= { dot11BSSIdTable 1 }

Dot11BSSIdEntry ::=
   SEQUENCE{
      dot11APMacAddress                                    MacAddress
      }
dot11APMacAddress OBJECT-TYPE
   SYNTAX     MacAddress
   MAX-ACCESS read-only
   STATUS     current
   DESCRIPTION
      "This is a status variable.

      Changes take effect for the next MLME-START.request primitive.

      This object specifies the MAC address of the BSSID represented on a
      particular BSSID interface and uniquely identifies this entry."
   ::= { dot11BSSIdEntry 1 }

--*****************************************************************
-- * End of dot11BSSId TABLE
--*****************************************************************

--*****************************************************************
-- * dot11Interworking TABLE
--*****************************************************************
dot11InterworkingTable OBJECT-TYPE
   SYNTAX SEQUENCE OF Dot11InterworkingEntry
   MAX-ACCESS not-accessible
```


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```
    STATUS current
    DESCRIPTION
        "This table represents the non-AP STAs associated to the AP. An entry is
        created automatically by the AP when the STA becomes associated to the AP.
        The corresponding entry is deleted when the STA disassociates. Each STA
        added to this table is uniquely identified by its MAC address. This table
        is moved to a new AP following a successful STA BSS transition event."
    ::= { dot11imt 2 }

dot11InterworkingEntry OBJECT-TYPE
    SYNTAX Dot11InterworkingEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "Each entry represents a conceptual row in the dot11InterworkingTable and
        provides information about permissions received from an SSPN Interface. If
        a non-AP STA does not receive permissions for one or more of these
        objects, then the object's default values or AP's locally defined
        configuration may be used instead. If the AP's local policy(s) is more
        restrictive than an object's value received from the SSPN Interface, then
        the AP's local policy shall be enforced. An entry is identified by the
        AP's MAC address to which the STA is associated and the STA's MAC
        address."
    INDEX { dot11APMacAddress, dot11NonAPStationMacAddress }
    ::= { dot11InterworkingTable 1 }

Dot11InterworkingEntry ::=
    SEQUENCE {
        dot11NonAPStationMacAddress                         MacAddress,
        dot11NonAPStationUserIdentity                       DisplayString,
        dot11NonAPStationInterworkingCapability             BITS,
        dot11NonAPStationAssociatedSSID                     OCTET STRING,
        dot11NonAPStationUnicastCipherSuite                 OCTET STRING,
        dot11NonAPStationBroadcastCipherSuite(#6020)        OCTET STRING,
        dot11NonAPStationAuthAccessCategories               BITS,
        dot11NonAPStationAuthMaxVoiceRate                   Unsigned32,
        dot11NonAPStationAuthMaxVideoRate                   Unsigned32,
        dot11NonAPStationAuthMaxBestEffortRate              Unsigned32,
        dot11NonAPStationAuthMaxBackgroundRate              Unsigned32,
        dot11NonAPStationAuthMaxVoiceOctets                 Unsigned32,
        dot11NonAPStationAuthMaxVideoOctets                 Unsigned32,
        dot11NonAPStationAuthMaxBestEffortOctets            Unsigned32,
        dot11NonAPStationAuthMaxBackgroundOctets            Unsigned32,
        dot11NonAPStationAuthMaxHCCAHEMMOctets              Unsigned32,
        dot11NonAPStationAuthMaxTotalOctets                 Unsigned32,
        dot11NonAPStationAuthHCCAHEMM                       TruthValue,
        dot11NonAPStationAuthMaxHCCAHEMMRate                Unsigned32,
        dot11NonAPStationAuthHCCAHEMMDelay                  Unsigned32,
        dot11NonAPStationAuthSourceMulticast                TruthValue,
        dot11NonAPStationAuthMaxSourceMulticastRate         Unsigned32,
        dot11NonAPStationVoiceMSDUCount                     Counter32,
        dot11NonAPStationDroppedVoiceMSDUCount              Counter32,
        dot11NonAPStationVoiceOctetCount                    Counter32,
        dot11NonAPStationDroppedVoiceOctetCount             Counter32,
        dot11NonAPStationVideoMSDUCount                     Counter32,
        dot11NonAPStationDroppedVideoMSDUCount              Counter32,
        dot11NonAPStationVideoOctetCount                    Counter32,
        dot11NonAPStationDroppedVideoOctetCount             Counter32,
        dot11NonAPStationBestEffortMSDUCount                Counter32,
        dot11NonAPStationDroppedBestEffortMSDUCount         Counter32,
        dot11NonAPStationBestEffortOctetCount               Counter32,
        dot11NonAPStationDroppedBestEffortOctetCount        Counter32,
        dot11NonAPStationBackgroundMSDUCount                Counter32,
        dot11NonAPStationDroppedBackgroundMSDUCount         Counter32,
```

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```
        dot11NonAPStationBackgroundOctetCount                 Counter32,
        dot11NonAPStationDroppedBackgroundOctetCount          Counter32,
        dot11NonAPStationHCCAHEMMMSDUCount                    Counter32,
        dot11NonAPStationDroppedHCCAHEMMMSDUCount             Counter32,
        dot11NonAPStationHCCAHEMMOctetCount                   Counter32,
        dot11NonAPStationDroppedHCCAHEMMOctetCount            Counter32,
        dot11NonAPStationMulticastMSDUCount                   Counter32,
        dot11NonAPStationDroppedMulticastMSDUCount            Counter32,
        dot11NonAPStationMulticastOctetCount                  Counter32,
        dot11NonAPStationDroppedMulticastOctetCount           Counter32,
        dot11NonAPStationPowerManagementMode                  INTEGER,
        dot11NonAPStationAuthDls                              TruthValue,
        dot11NonAPStationVLANId                               Unsigned32,
        dot11NonAPStationVLANName                             DisplayString,
        dot11NonAPStationAddtsResultCode                      INTEGER}

dot11NonAPStationMacAddress OBJECT-TYPE
    SYNTAX     MacAddress
    MAX-ACCESS read-only
    STATUS     current
    DESCRIPTION
        "This is a status variable.

        It is written by the SME after a non-AP STA associates with(#1427) the
        BSS.

        This object specifies the MAC address of the non-AP STA for this entry and
        uniquely identifies this entry."
    ::= { dot11InterworkingEntry 1 }

dot11NonAPStationUserIdentity OBJECT-TYPE
    SYNTAX DisplayString (SIZE(0..255))
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.

        It is written by the SME after a non-AP STA associates with(#1427) the
        BSS.

        This attribute reflects the user identity for the subscriber operating
        this non-AP STA"
    ::= { dot11InterworkingEntry 2 }

dot11NonAPStationInterworkingCapability OBJECT-TYPE
    SYNTAX BITS {
        interworkingCapability(0),
        qosMapCapability(1),
        expeditedBwReqCapability(2),
        msgcfCapability(3)
    }
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.

        It is written by the SME after a non-AP STA associates with(#1427) the
        BSS.

        This attribute defines the (#2164)interworking capabilities possessed by a
        non-AP STA. (#2164)Interworking capability is set to 1 when the STA
        includes the Interworking element in its (re)association request. The
        QosMapCapability, ExpeditedBwReqCapability and MSGCFCapability bits
        reflect the same values and meanings as those defined in 9.4.2.25
```


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```
        (Extended Capabilities element)"
    ::= { dot11InterworkingEntry 3 }

dot11NonAPStationAssociatedSSID OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(0..32))
    MAX-ACCESS read-only
    STATUS deprecated(#3271)
    DESCRIPTION
        "(#3271)Deprecated as this is not required for interworking.
        This is a status variable.

        It is written by the SME after a non-AP STA associates with(#1427) the
        BSS.

        This attribute reflects the SSID to which the non-AP STA is associated"
    ::= { dot11InterworkingEntry 4 }

dot11NonAPStationUnicastCipherSuite OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(4))
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.

        It is written by the SME after a non-AP STA authenticates with the BSS.

        The selector of the (#1649)pairwise cipher suite that is currently in use
        by the non-AP STA. It consists of an OUI or CID (the first 3 octets) and a
        cipher suite identifier (the last octet)."
    ::= { dot11InterworkingEntry 5 }

dot11NonAPStationBroadcastCipherSuite OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(4))
    MAX-ACCESS read-only
    STATUS deprecated(#3271)
    DESCRIPTION
        "(#3271)Deprecated as this is not required for interworking.
        This is a status variable.

        It is written by the SME after a non-AP STA authenticates with the BSS.

        (#3256)The selector of the group cipher suite that is currently in use by
        the non-AP STA for Data frames.(#1649) It consists of an OUI or CID (the
        first 3 octets) and a cipher suite identifier the last octet)."
    ::= { dot11InterworkingEntry 6 }

dot11NonAPStationAuthAccessCategories OBJECT-TYPE
    SYNTAX BITS {
        bestEffort(0),
        background(1),
        video(2),
        voice(3)
    }
    MAX-ACCESS read-write
    STATUS     current
    DESCRIPTION
        "This is a control variable.

        It is written by the SME after the AP receives the permissions for the
        non-AP STA from the SSPN Interface.

        The object that represents the access categories which the non-AP STA is
        permitted to use when admission control is configured on that AC. An AC is
        permitted to be used if its corresponding bit is set to 1; otherwise it is
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```
        not permitted to be used."
    DEFVAL { { bestEffort, background, video, voice } }
    ::= { dot11InterworkingEntry 7 }

dot11NonAPStationAuthMaxVoiceRate OBJECT-TYPE
    SYNTAX Unsigned32 (1..4294967295)
    UNITS  "kb/s"
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.

        It is written by the SME after the AP receives the permissions for the
        non-AP STA from the SSPN Interface.

        This attribute indicates the maximum authorized data rate the non-AP STA
        may use, either transmitting to an AP or receiving from an AP on the voice
        access category. If this rate is exceeded, the AP should police the flows
        traversing this AC. The value (#1587)4294967295, which is the default
        value, means that the SSP is not requesting the AP to limit the data rate
        used by the non-AP STA. Local configuration of the AP, however, might
        cause the rate to be limited, especially when the AC is configured for
        mandatory admission control."
    DEFVAL {4294967295}
    ::= { dot11InterworkingEntry 8 }

dot11NonAPStationAuthMaxVideoRate OBJECT-TYPE
    SYNTAX Unsigned32 (1..4294967295)
    UNITS "kb/s"
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.

        It is written by the SME after the AP receives the permissions for the
        non-AP STA from the SSPN Interface.

        This attribute indicates the maximum authorized data rate the non-AP STA
        may use, either transmitting to an AP or receiving from an AP on the video
        access category. If this rate is exceeded, the AP should police the flows
        traversing this AC. The value (#1587)4294967295, which is the default
        value, means that the SSP is not requesting the AP to limit the data rate
        used by the non-AP STA. Local configuration of the AP, however, might
        cause the rate to be limited, especially when the AC is configured for
        mandatory admission control."
    DEFVAL {4294967295}
    ::= { dot11InterworkingEntry 9 }

dot11NonAPStationAuthMaxBestEffortRate OBJECT-TYPE
    SYNTAX Unsigned32 (1..4294967295)
    UNITS "kb/s"
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.

        It is written by the SME after the AP receives the permissions for the
        non-AP STA from the SSPN Interface.

        This attribute indicates the maximum authorized data rate the non-AP STA
        may use, either transmitting to an AP or receiving from an AP on the best
        effort access category. If this rate is exceeded, the AP should police the
        flows traversing this AC. The value (#1587)4294967295, which is the
        default value, means that the SSP is not requesting the AP to limit the
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        data rate used by the non-AP STA. Local configuration of the AP, however,
        might cause the rate to be limited, especially when the AC is configured
        for mandatory admission control."
    DEFVAL {4294967295}
    ::= { dot11InterworkingEntry 10 }

dot11NonAPStationAuthMaxBackgroundRate OBJECT-TYPE
    SYNTAX Unsigned32 (1..4294967295)
    UNITS "kb/s"
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.

        It is written by the SME after the AP receives the permissions for the
        non-AP STA from the SSPN Interface.

        This attribute indicates the maximum authorized data rate the non-AP STA
        may use, either transmitting to an AP or receiving from an AP on the
        background access category. If this rate is exceeded, the AP should police
        the flows traversing this AC. The value (#1587)4294967295, which is the
        default value, means that the SSP is not requesting the AP to limit the
        data rate used by the non-AP STA. Local configuration of the AP, however,
        might cause the rate to be limited, especially when the AC is configured
        for mandatory admission control."
    DEFVAL {4294967295}
    ::= { dot11InterworkingEntry 11 }

dot11NonAPStationAuthMaxVoiceOctets OBJECT-TYPE
    SYNTAX Unsigned32 (0..4294967295)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.

        It is written by the SME after the AP receives the permissions for the
        non-AP STA from the SSPN Interface.

        This attribute indicates the maximum authorized total octet count that a
        STA may use on the voice access category. If this octet count is exceeded,
        the AP should disassociate the non-AP STA. A value of 0 indicates that
        there is no octet limit."
    DEFVAL {0}
    ::= { dot11InterworkingEntry 12 }

dot11NonAPStationAuthMaxVideoOctets OBJECT-TYPE
    SYNTAX Unsigned32 (0..4294967295)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.

        It is written by the SME after the AP receives the permissions for the
        non-AP STA from the SSPN Interface.

        This attribute indicates the maximum authorized total octet count that a
        STA may use on the video access category. If this octet count is exceeded,
        the AP should disassociate the non-AP STA. A value of 0 indicates that
        there is no octet limit."
    DEFVAL {0}
    ::= { dot11InterworkingEntry 13 }

dot11NonAPStationAuthMaxBestEffortOctets OBJECT-TYPE
    SYNTAX Unsigned32 (0..4294967295)
```

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```
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
       "This is a control variable.

       It is written by the SME after the AP receives the permissions for the
       non-AP STA from the SSPN Interface.

       This attribute indicates the maximum authorized total octet count that a
       STA may use on the best effort access category. If this octet count is
       exceeded, the AP should disassociate the non-AP STA. A value of 0
       indicates that there is no octet limit."
    DEFVAL {0}
    ::= { dot11InterworkingEntry 14 }

dot11NonAPStationAuthMaxBackgroundOctets OBJECT-TYPE
    SYNTAX Unsigned32 (0..4294967295)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
       "This is a control variable.

       It is written by the SME after the AP receives the permissions for the
       non-AP STA from the SSPN Interface.

       This attribute indicates the maximum authorized total octet count that a
       STA may use on the background access category. If this octet count is
       exceeded, the AP should disassociate the non-AP STA. A value of 0
       indicates that there is no octet limit."
    DEFVAL {0}
    ::= { dot11InterworkingEntry 15 }

dot11NonAPStationAuthMaxHCCAHEMMOctets OBJECT-TYPE
    SYNTAX Unsigned32 (0..4294967295)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
       "This is a control variable.

       It is written by the SME after the AP receives the permissions for the
       non-AP STA from the SSPN Interface.

       This attribute indicates the maximum authorized total octet count that a
       STA may use with HCCA or HEMM access. If this octet count is exceeded, the
       AP should disassociate the non-AP STA. A value of 0 indicates that there
       is no octet limit."
    DEFVAL {0}
    ::= { dot11InterworkingEntry 16 }

dot11NonAPStationAuthMaxTotalOctets OBJECT-TYPE
    SYNTAX Unsigned32 (0..4294967295)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
       "This is a control variable.

       It is written by the SME after the AP receives the permissions for the
       non-AP STA from the SSPN Interface.

       This attribute indicates the maximum authorized total octet count that a
       STA may use on all access categories combined. If this octet count is
       exceeded, the AP should disassociate the non-AP STA. A value of 0
       indicates that there is no octet limit."
    DEFVAL {0}
```


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```
    ::= { dot11InterworkingEntry 17 }

dot11NonAPStationAuthHCCAHEMM OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.

        It is written by the SME after the AP receives the permissions for the
        non-AP STA from the SSPN Interface.

        This attribute, when true, indicates that the non-AP STA is permitted by
        the SSP to request HCCA or HEMM service via ADDTS frames. If this
        attribute is false, then HCCA or HEMM service is not permitted by the
        SSP."
    DEFVAL {true}
    ::= { dot11InterworkingEntry 18 }

dot11NonAPStationAuthMaxHCCAHEMMRate OBJECT-TYPE
    SYNTAX Unsigned32 (1..4294967295)
    UNITS "kb/s"
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.

        It is written by the SME after the AP receives the permissions for the
        non-AP STA from the SSPN Interface.

        This attribute indicates the maximum authorized data rate the non-AP STA
        may use, either transmitting to an AP or receiving from an AP via HCCA or
        HEMM. The value (#1587)4294967295, which is the default value, means that
        the SSP is not requesting the AP to limit the data rate used by the non-AP
        STA. Local configuration of the AP, however, might cause the rate to be
        otherwise limited."
    DEFVAL {4294967295}
    ::= { dot11InterworkingEntry 19 }

dot11NonAPStationAuthHCCAHEMMDelay OBJECT-TYPE
    SYNTAX Unsigned32 (1..4294967295)
    UNITS "microseconds"
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.

        It is written by the SME after the AP receives the permissions for the
        non-AP STA from the SSPN Interface.

        This attribute indicates the delay bound for frames queued at an AP to a
        non-AP STA in the HCCA or HEMM queue. An AP should deliver frames to the
        non-AP STA within the time period specified in this attribute. When a non-
        AP STA requests admission control to the HCCA or HEMM queue, the requested
        delay will be equal to or higher than this value. The value
        (#1587)4294967295, which is the default value, means that the SSP is not
        requesting the AP limit the delay bound in this queue for transmissions to
        the non-AP STA."
    DEFVAL {4294967295}
    ::= { dot11InterworkingEntry 20 }

dot11NonAPStationAuthSourceMulticast OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
```

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```
    STATUS current
    DESCRIPTION
        "This is a control variable.

        It is written by the SME after the AP receives the permissions for the
        non-AP STA from the SSPN Interface.

        This attribute, when true, indicates that the AP's MAC sublayer shall
        perform rate limiting to enforce the resource utilization limit in
        dot11NonAPStationAuthMaxSourceMulticastRate in the dot11InterworkingEntry
        identified by the source MAC address of the received frame. If this
        attribute is false, at an AP for which dot11SSPNInterfaceActivated is
        true, upon receipt of a frame with the Type subfield equal to Data with
        group DA, then the AP's MAC sublayer shall discard the frame."
    DEFVAL {true}
    ::= { dot11InterworkingEntry 21 }

dot11NonAPStationAuthMaxSourceMulticastRate OBJECT-TYPE
    SYNTAX Unsigned32 (1..4294967295)
    UNITS "kb/s"
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.

        It is written by the SME after the AP receives the permissions for the
        non-AP STA from the SSPN Interface.

        This attribute indicates the maximum authorized data rate which the non-AP
        STA may transmit group addressed frames to an AP. If this rate is
        exceeded, the AP should police the flows. The value (#1587)4294967295,
        which is the default value, means that the SSP is not requesting the AP to
        limit the multicast data rate used by the non-AP STA."
    DEFVAL {4294967295}
    ::= { dot11InterworkingEntry 22 }

dot11NonAPStationVoiceMSDUCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.

        It is written by the AP's MAC after the completion of an MA-
        UNITDATA.confirm or MA-UNITDATA.indication primitive.

        For EDCA operation, this counter shall be incremented for each MSDU
        successfully transmitted by the AP on the voice access category and for
        each MSDU received on either user priority 6 or 7."
    ::= { dot11InterworkingEntry 23 }

dot11NonAPStationDroppedVoiceMSDUCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.

        It is written by the AP's MAC after the completion of an MA-
        UNITDATA.confirm or MA-UNITDATA.indication primitive.

        For EDCA operation, this counter shall be incremented for each MSDU
        (#3683)discarded by the AP on the voice access category."
    ::= { dot11InterworkingEntry 24 }
```


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```
dot11NonAPStationVoiceOctetCount OBJECT-TYPE
   SYNTAX Counter32
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a status variable.

      It is written by the AP's MAC after the completion of an MA-
      UNITDATA.confirm or MA-UNITDATA.indication primitive.

      For EDCA operation, this counter shall be incremented by the octet length
      of each MSDU successfully transmitted by the AP on the voice access
      category and by the octet length of each MSDU received on either user
      priority 6 or 7."
   ::= { dot11InterworkingEntry 25 }

dot11NonAPStationDroppedVoiceOctetCount OBJECT-TYPE
   SYNTAX Counter32
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a status variable.

      It is written by the AP's MAC after the completion of an MA-
      UNITDATA.confirm or MA-UNITDATA.indication primitive.

      For EDCA operation, this counter shall be incremented for each octet
      (#3683)discarded by the AP on the voice access category."
   ::= { dot11InterworkingEntry 26 }

dot11NonAPStationVideoMSDUCount OBJECT-TYPE
   SYNTAX Counter32
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a status variable.

      It is written by the AP's MAC after the completion of an MA-
      UNITDATA.confirm or MA-UNITDATA.indication primitive.

      For EDCA operation, this counter shall be incremented for each MSDU
      successfully transmitted by the AP on the video access category and for
      each MSDU received on either user priority 4 or 5."
   ::= { dot11InterworkingEntry 27 }

dot11NonAPStationDroppedVideoMSDUCount OBJECT-TYPE
   SYNTAX Counter32
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a status variable.

      It is written by the AP's MAC after the completion of an MA-
      UNITDATA.confirm or MA-UNITDATA.indication primitive.

      For EDCA operation, this counter shall be incremented for each MSDU
      (#3683)discarded by the AP on the video access category."
   ::= { dot11InterworkingEntry 28 }
dot11NonAPStationVideoOctetCount OBJECT-TYPE
   SYNTAX Counter32
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
```

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```
        "This is a status variable.

        It is written by the AP's MAC after the completion of an MA-
        UNITDATA.confirm or MA-UNITDATA.indication primitive.

        For EDCA operation, this counter shall be incremented by the octet length
        of each MSDU successfully transmitted by the AP on the voice access
        category and by the octet length of each MSDU received on either user
        priority 4 or 5."
    ::= { dot11InterworkingEntry 29 }

dot11NonAPStationDroppedVideoOctetCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.

        It is written by the AP's MAC after the completion of an MA-
        UNITDATA.confirm or MA-UNITDATA.indication primitive.

        For EDCA operation, this counter shall be incremented for each octet
        (#3683)discarded by the AP on the video access category."
    ::= { dot11InterworkingEntry 30 }

dot11NonAPStationBestEffortMSDUCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.

        It is written by the AP's MAC after the completion of an MA-
        UNITDATA.confirm or MA-UNITDATA.indication primitive.

        For EDCA operation, this counter shall be incremented for each MSDU
        successfully transmitted by the AP on the best effort access category and
        for each MSDU received on either user priority 0 or 3. For DCF operation,
        this counter shall be incremented for each MSDU successfully transmitted
        or received by the AP."
    ::= { dot11InterworkingEntry 31 }

dot11NonAPStationDroppedBestEffortMSDUCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.

        It is written by the AP's MAC after the completion of an MA-
        UNITDATA.confirm or MA-UNITDATA.indication primitive.

        For EDCA operation, this counter shall be incremented for each MSDU
        (#3683)discarded by the AP on the best effort access category and for each
        MSDU (#3683)discarded by the AP on either user priority 0 or 3. For DCF
        operation, this counter shall be incremented for each MSDU
        (#3683)discarded by the AP."
    ::= { dot11InterworkingEntry 32 }

dot11NonAPStationBestEffortOctetCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
```


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```
        "This is a status variable.

        It is written by the AP's MAC after the completion of an MA-
        UNITDATA.confirm or MA-UNITDATA.indication primitive.

        For EDCA operation, this counter shall be incremented by the octet length
        of each MSDU successfully transmitted by the AP on the best effort access
        category and by the octet length of each MSDU received on either user pri-
        ority 0 or 3. For DCF operation, this counter shall be incremented the
        octet length of each MSDU successfully transmitted or received by the AP."
    ::= { dot11InterworkingEntry 33 }

dot11NonAPStationDroppedBestEffortOctetCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.

        It is written by the AP's MAC after the completion of an MA-
        UNITDATA.confirm or MA-UNITDATA.indication primitive.

        For EDCA operation, this counter shall be incremented for the octet length
        of each MSDU (#3683)discarded by the AP on the best effort access category
        and by the octet length of each MSDU (#3683)discarded by the AP for either
        user priority 0 or 3. For DCF operation, this counter shall be incremented
        for the octet length of each MSDU (#3683)discarded by the AP."
    ::= { dot11InterworkingEntry 34 }

dot11NonAPStationBackgroundMSDUCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.

        It is written by the AP's MAC after the completion of an MA-
        UNITDATA.confirm or MA-UNITDATA.indication primitive.

        For EDCA operation, this counter shall be incremented for each MSDU
        successfully transmitted by the AP on the background access category and
        for each MSDU received on either user priority 1 or 2."
    ::= { dot11InterworkingEntry 35 }

dot11NonAPStationDroppedBackgroundMSDUCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.

        It is written by the AP's MAC after the completion of an MA-
        UNITDATA.confirm or MA-UNITDATA.indication primitive.

        For EDCA operation, this counter shall be incremented for each MSDU
        (#3683)discarded by the AP on the background access category"
    ::= { dot11InterworkingEntry 36 }

dot11NonAPStationBackgroundOctetCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
```

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        It is written by the AP's MAC after the completion of an MA-
        UNITDATA.confirm or MA-UNITDATA.indication primitive.

        For EDCA operation, this counter shall be incremented by the octet length
        of each MSDU successfully transmitted by the AP on the background access
        category and by the octet length of each MSDU received on either user pri-
        ority 1 or 2."
    ::= { dot11InterworkingEntry 37 }

dot11NonAPStationDroppedBackgroundOctetCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.

        It is written by the AP's MAC after the completion of an MA-
        UNITDATA.confirm or MA-UNITDATA.indication primitive.

        For EDCA operation, this counter shall be incremented by the octet length
        of each MSDU (#3683)discarded by the AP on the background access category"
    ::= { dot11InterworkingEntry 38 }

dot11NonAPStationHCCAHEMMMSDUCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.

        It is written by the AP's MAC after the completion of an MA-
        UNITDATA.confirm or MA-UNITDATA.indication primitive.

        For HCCA or HEMM operation, this counter shall be incremented for each
        MSDU successfully transmitted by the AP and for each MSDU received."
    ::= { dot11InterworkingEntry 39 }

dot11NonAPStationDroppedHCCAHEMMMSDUCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.

        It is written by the AP's MAC after the completion of an MA-
        UNITDATA.confirm or MA-UNITDATA.indication primitive.

        For HCCA or HEMM operation, this counter shall be incremented for each
        MSDU (#3683)discarded by the AP."
    ::= { dot11InterworkingEntry 40 }

dot11NonAPStationHCCAHEMMOctetCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.

        It is written by the AP's MAC after the completion of an MA-
        UNITDATA.confirm or MA-UNITDATA.indication primitive.

        For HCCA or HEMM operation, this counter shall be incremented by the octet
        length of each MSDU successfully transmitted by the AP and by the octet
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        length of each MSDU received."
    ::= { dot11InterworkingEntry 41 }

dot11NonAPStationDroppedHCCAHEMMOctetCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.

        It is written by the AP's MAC after the completion of an MA-
        UNITDATA.confirm or MA-UNITDATA.indication primitive.

        For HCCA or HEMM operation, this counter shall be incremented by the octet
        length of each MSDU (#3683)discarded by the AP."
    ::= { dot11InterworkingEntry 42 }

dot11NonAPStationMulticastMSDUCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.

        It is written by the AP's MAC after the completion of an MA-
        UNITDATA.confirm or MA-UNITDATA.indication primitive.

        For Multicast operation, this counter shall be incremented for each group
        addressed MSDU successfully transmitted by the AP and for each group
        addressed MSDU received at the AP."
    ::= { dot11InterworkingEntry 43 }

dot11NonAPStationDroppedMulticastMSDUCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.

        It is written by the AP's MAC after the completion of an MA-
        UNITDATA.confirm or MA-UNITDATA.indication primitive.

        For Multicast operation, this counter shall be incremented for each group
        addressed MSDU (#3683)discarded by the AP."
    ::= { dot11InterworkingEntry 44 }

dot11NonAPStationMulticastOctetCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.

        It is written by the AP's MAC after the completion of an MA-
        UNITDATA.confirm or MA-UNITDATA.indication primitive.

        For Multicast operation, this counter shall be incremented by the octet
        length of each MSDU successfully transmitted by the AP and by the octet
        length of each group addressed MSDU received."
    ::= { dot11InterworkingEntry 45 }

dot11NonAPStationDroppedMulticastOctetCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
```

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```
    STATUS current
    DESCRIPTION
        "This is a status variable.

        It is written by the AP's MAC after the completion of an MA-
        UNITDATA.confirm or MA-UNITDATA.indication primitive.

        For Multicast operation, this counter shall be incremented by the octet
        length of each group addressed MSDU (#3683)discarded by the AP."
    ::= { dot11InterworkingEntry 46 }

dot11NonAPStationPowerManagementMode OBJECT-TYPE
    SYNTAX INTEGER { active(1), powersave(2) }
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.

        It is written by the AP's MAC after the non-AP STA changes its power
        management mode.

        This attribute indicates the power management mode of the non-AP STA."
    ::= { dot11InterworkingEntry 47 }

dot11NonAPStationAuthDls OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS deprecated
    DESCRIPTION
        "Deprecated as the related feature has been removed from IEEE Std 802.11.
        This is a control variable.

        It is written by the SME after the AP receives the permissions for the
        non-AP STA from the SSPN Interface.

        This attribute, when true, indicates that the non-AP STA is permitted by
        the SSPN Interface to use direct link service (DLS). Note this attribute
        is an SSP permission and is independent of whether DLS is allowed in the
        BSS as governed by dot11DLSAllowedInQBSS. This service is disabled
        otherwise."
    DEFVAL {true}
    ::= { dot11InterworkingEntry 48 }

dot11NonAPStationVLANId OBJECT-TYPE
    SYNTAX Unsigned32 (0..4095)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.

        It is written by the SME after a non-AP STA associates with(#1427) the
        BSS.

        This attribute indicates the VLAN ID on the an external network to which
        frames from the non-AP STA are bridged."
    ::= { dot11InterworkingEntry 49 }

dot11NonAPStationVLANName OBJECT-TYPE
    SYNTAX DisplayString (SIZE(0..64))
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
```


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```
        It is written by the SME after a non-AP STA associates with(#1427) the
        BSS.

        This attribute indicates the VLAN name corresponding to the VLAN ID on the
        external network to which frames from the non-AP STA are bridged."
    ::= { dot11InterworkingEntry 50 }

dot11NonAPStationAddtsResultCode OBJECT-TYPE
    SYNTAX INTEGER {
        success(1),
        invalidParameters(2),
        rejectedWithSuggestedChanges(3),
        rejectedForDelayPeriod(4),
        rejectedForSspPermissions(5),
        rejectedWithSuggestedBssTransition (6),
        requestedTclasNotSupported (7),
        tclasResourcesExhausted (8),
        rejectedHomeWithSuggestedChanges (9)
    }
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.

        It is written by the MAC after the AP transmits an ADDTS Response frame to
        the non-AP STA or after the AP includes a RIC element in a Reassociation
        Response frame.

        This attribute indicates the most recent status code(#1780) returned by
        the AP in an ADDTS Response."
    ::= { dot11InterworkingEntry 51 }

-- ************************************************************************
-- * End of dot11Interworking TABLE
-- ************************************************************************


-- ************************************************************************
-- * dot11APLCI TABLE
-- ************************************************************************

dot11APLCITable OBJECT-TYPE
    SYNTAX          SEQUENCE OF Dot11APLCIEntry
    MAX-ACCESS      not-accessible
    STATUS          current
    DESCRIPTION
        "This table represents the (#6578)(#7178)geospatial location of the AP in
        civic format using the Civic Address Type elements defined in IETF RFC
        5139 [B47]. When this table is used for the AP Civic Location ANQP-ele-
        ment, only one of the entries is used."
    ::= { dot11imt 3 }

dot11APLCIEntry OBJECT-TYPE
    SYNTAX Dot11APLCIEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "AP location in geospatial coordinates"
    INDEX { dot11APLCIIndex }
    ::= { dot11APLCITable 1 }

Dot11APLCIEntry ::=
    SEQUENCE {
        dot11APLCIIndex                                    Unsigned32,
```

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```
        dot11APLCILatitudeUncertainty                          Unsigned32,
        dot11APLCILatitudeInteger                              Integer32,
        dot11APLCILatitudeFraction                             Integer32,
        dot11APLCILongitudeUncertainty                         Unsigned32,
        dot11APLCILongitudeInteger                             Integer32,
        dot11APLCILongitudeFraction                            Integer32,
        dot11APLCIAltitudeType                                 INTEGER,
        dot11APLCIAltitudeUncertainty                          Unsigned32,
        dot11APLCIAltitude                                     Integer32,
        dot11APLCIDatum                                        INTEGER,
        dot11APLCIAzimuthType                                  INTEGER,
        dot11APLCIAzimuthResolution                            Unsigned32,
        dot11APLCIAzimuth                                      Integer32
        }
dot11APLCIIndex OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "Index for AP LCI elements in dot11APLCITable, greater than 0."
    ::= { dot11APLCIEntry 1 }

dot11APLCILatitudeUncertainty OBJECT-TYPE
    SYNTAX Unsigned32 (0..63)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.

        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        Latitude uncertainty is defined in IETF RFC 6225."
    ::= { dot11APLCIEntry 2 }

dot11APLCILatitudeInteger OBJECT-TYPE
    SYNTAX Integer32 (-90..90)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.

        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        Latitude is a 34-bit fixed point value consisting of 9 bits of integer and
        25 bits of fraction. This field contains the 9 bits of integer portion of
        Latitude."
    ::= { dot11APLCIEntry 3 }

dot11APLCILatitudeFraction OBJECT-TYPE
    SYNTAX Integer32 (-16777215..16777215)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.

        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        Latitude is a 34-bit fixed point value consisting of 9 bits of integer and
        25 bits of fraction. This field contains the 25 bits of fraction portion
        of Latitude."
    ::= { dot11APLCIEntry 4 }
```


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```
dot11APLCILongitudeUncertainty OBJECT-TYPE
   SYNTAX Unsigned32 (0..63)
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.

      It is written by an external management entity or the SME.
      Changes take effect as soon as practical in the implementation.

      Longitude uncertainty is defined in IETF RFC 6225."
   ::= { dot11APLCIEntry 5 }

dot11APLCILongitudeInteger OBJECT-TYPE
   SYNTAX Integer32 (-180..180)
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.

      It is written by an external management entity or the SME.
      Changes take effect as soon as practical in the implementation.

      Longitude is a 34-bit fixed point value consisting of 9 bits of integer
      and 25 bits of fraction. This field contains the 9 bits of integer portion
      of Longitude."
   ::= { dot11APLCIEntry 6 }

dot11APLCILongitudeFraction OBJECT-TYPE
   SYNTAX Integer32 (-16777215..16777215)
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.

      It is written by an external management entity or the SME.
      Changes take effect as soon as practical in the implementation.

      Longitude is a 2s complement 34-bit fixed point value consisting of 9 bits
      of integer and 25 bits of fraction. This field contains the 25 bits of
      fraction portion of Longitude."
   ::= { dot11APLCIEntry 7 }

dot11APLCIAltitudeType OBJECT-TYPE
   SYNTAX INTEGER { meters(1), floors(2), hagm (3) }
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.

      It is written by an external management entity or the SME.
      Changes take effect as soon as practical in the implementation.

      Altitude Type is four bits encoding the type of altitude. Codes defined
      are: meters in 2s complement fixed-point 22-bit integer part with 8-bit
      fraction floors in 2s complement fixed-point 22-bit integer part with 8-
      bit fraction hagm: Height Above Ground in meters, in 2s complement fixed-
      point 22-bit integer part with 8-bit fraction."
   ::= { dot11APLCIEntry 8 }

dot11APLCIAltitudeUncertainty OBJECT-TYPE
   SYNTAX Unsigned32 (0..63)
   MAX-ACCESS read-write
```

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```
    STATUS current
    DESCRIPTION
        "This is a control variable.

        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        Altitude resolution is 6 bits indicating the number of valid bits in the
        altitude."
    ::= { dot11APLCIEntry 9 }

dot11APLCIAltitude OBJECT-TYPE
    SYNTAX Integer32 (-536870912..536870911)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.

        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        Altitude is a 30-bit value defined by the Altitude type field. The field
        is encoded as a 2s complement fixed-point 22-bit integer part with 8-bit
        fraction."
    ::= { dot11APLCIEntry 10 }

-- Reserved: 11. Was dot11APLCIAltitudeFraction.

dot11APLCIDatum OBJECT-TYPE
    SYNTAX INTEGER {
        wgs84 (1),
        nad83navd88 (2),
        nad93mllwvd (3)
    }
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.

        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        Datum is a 3-bit value encoding the horizontal and vertical references
        used for the coordinates given in this LCI. IETF RFC 6225 defines the
        values of Datum. Type 1 is WGS-84, the coordinate system used by GPS. Type
        2 is NAD83 with NAVD88 vertical reference. Type 3 is NAD83 with Mean Lower
        Low Water vertical datum. All other types are reserved."
    ::= { dot11APLCIEntry 12 }

dot11APLCIAzimuthType OBJECT-TYPE
    SYNTAX INTEGER { frontSurfaceOfSTA(0), radioBeam(1) }
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.

        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        Azimuth Type is a one bit attribute encoding the type of Azimuth. Codes
        defined are: front surface of STA: in 2s complement fixed-point 9-bit
        integer radio beam: in 2s complement fixed-point 9-bit integer."
    ::= { dot11APLCIEntry 13 }
```


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```
dot11APLCIAzimuthResolution OBJECT-TYPE
   SYNTAX Unsigned32 (0..15)
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.

      It is written by an external management entity or the SME.
      Changes take effect as soon as practical in the implementation.

      Azimuth Resolution is 4 bits indicating the number of valid bits in the
      azimuth."
   ::= { dot11APLCIEntry 14 }

dot11APLCIAzimuth OBJECT-TYPE
   SYNTAX Integer32 (-511..511)
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.

      It is written by an external management entity or the SME.
      Changes take effect as soon as practical in the implementation.

      Azimuth is a 9-bit value defined by the Azimuth Type field.The field is
      encoded as a 2s complement fixed-point 9-bit integer horizontal angle in
      degrees from true north."
   ::= { dot11APLCIEntry 15 }

-- ************************************************************************
-- * End of dot11APLCI TABLE
-- ************************************************************************

-- ************************************************************************
-- * dot11APCivicLocation TABLE
-- ************************************************************************
dot11APCivicLocationTable OBJECT-TYPE
   SYNTAX SEQUENCE OF Dot11ApCivicLocationEntry
   MAX-ACCESS not-accessible
   STATUS current
   DESCRIPTION
      "This table represents the (#6578)Geospatial location of the AP as speci-
      fied in 9.4.2.20.10 (LCI report (Location configuration information
      report)). When this table is used for the AP Geospatial Location ANQP-ele-
      ment, only one of the entries is used."
   ::= { dot11imt 4 }

dot11APCivicLocationEntry OBJECT-TYPE
   SYNTAX Dot11ApCivicLocationEntry
   MAX-ACCESS not-accessible
   STATUS current
   DESCRIPTION
      "Civic Address location of the AP described with Civic Address Type
      elements defined in IETF RFC 5139 [B47]."
   INDEX {dot11APCivicLocationIndex} ::= {dot11APCivicLocationTable 1}

Dot11ApCivicLocationEntry ::=
   SEQUENCE {
      dot11APCivicLocationIndex                    Unsigned32,
      dot11APCivicLocationCountry                  OCTET STRING,
      dot11APCivicLocationA1                       OCTET STRING,
      dot11APCivicLocationA2                       OCTET STRING,
      dot11APCivicLocationA3                       OCTET STRING,
      dot11APCivicLocationA4                       OCTET STRING,
```

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```
        dot11APCivicLocationA5                                  OCTET STRING,
        dot11APCivicLocationA6                                  OCTET STRING,
        dot11APCivicLocationPrd                                 OCTET STRING,
        dot11APCivicLocationPod                                 OCTET STRING,
        dot11APCivicLocationSts                                 OCTET STRING,
        dot11APCivicLocationHno                                 OCTET STRING,
        dot11APCivicLocationHns                                 OCTET STRING,
        dot11APCivicLocationLmk                                 OCTET STRING,
        dot11APCivicLocationLoc                                 OCTET STRING,
        dot11APCivicLocationNam                                 OCTET STRING,
        dot11APCivicLocationPc                                  OCTET STRING,
        dot11APCivicLocationBld                                 OCTET STRING,
        dot11APCivicLocationUnit                                OCTET STRING,
        dot11APCivicLocationFlr                                 OCTET STRING,
        dot11APCivicLocationRoom                                OCTET STRING,
        dot11APCivicLocationPlc                                 OCTET STRING,
        dot11APCivicLocationPcn                                 OCTET STRING,
        dot11APCivicLocationPobox                               OCTET STRING,
        dot11APCivicLocationAddcode                             OCTET STRING,
        dot11APCivicLocationSeat                                OCTET STRING,
        dot11APCivicLocationRd                                  OCTET STRING,
        dot11APCivicLocationRdsec                               OCTET STRING,
        dot11APCivicLocationRdbr                                OCTET STRING,
        dot11APCivicLocationRdsubbr                             OCTET STRING,
        dot11APCivicLocationPrm                                 OCTET STRING,
        dot11APCivicLocationPom                                 OCTET STRING
        }
dot11APCivicLocationIndex OBJECT-TYPE
   SYNTAX Unsigned32
   MAX-ACCESS not-accessible
   STATUS current
   DESCRIPTION
      "This is a control variable.

      It is written by an external management entity or the SME.
      Changes take effect as soon as practical in the implementation.

      Index for APCivicLocation elements in dot11APCivicLocationTable, greater
      than 0."
   ::= { dot11APCivicLocationEntry 1 }

dot11APCivicLocationCountry OBJECT-TYPE
   SYNTAX OCTET STRING (SIZE(0..255))
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.

      It is written by an external management entity or the SME.
      Changes take effect as soon as practical in the implementation.

      This attribute contains the two uppercase characters which correspond to
      the alpha-2 codes in ISO 3166-1. Example: US."
   ::= { dot11APCivicLocationEntry 2 }

dot11APCivicLocationA1 OBJECT-TYPE
   SYNTAX OCTET STRING (SIZE(0..255))
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.

      It is written by an external management entity or the SME.
      Changes take effect as soon as practical in the implementation.
```


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```
        This attribute contains the national subdivisions (state, Region,
        province, prefecture). Example: California. The A1 element is used for the
        top level subdivision within a country. In the absence of a country-
        specific guide on how to use the A-series of elements, the second part of
        the ISO 3166-2 code for a country subdivision SHOULD be used. The ISO
        3166-2 code is a formed of a country code and hyphen plus a code of one,
        two or three characters or numerals. For the A1 element, the leading
        country code and hyphen are omitted and only the subdivision code is
        included.

        For example, the codes for Canada include CA-BC, CA-ON, CA-QC; Luxembourg
        has just three single character codes: LU-D, LU-G And LU-L; Australia uses
        both two and three character codes: AU-ACT, AU-NSW, AU-NT; France uses
        (#4317)numeric codes for mainland France and letters for territories: FR-
        75, FR-NC."
    ::= { dot11APCivicLocationEntry 3 }

dot11APCivicLocationA2 OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(0..255))
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.

        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        This attribute contains the county, parish, gun (JP), district (IN).
        Example: King's County."
    ::= { dot11APCivicLocationEntry 4 }

dot11APCivicLocationA3 OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(0..255))
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.

        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        This attribute contains the city, township, shi (JP). Example: San
        Francisco."
    ::= { dot11APCivicLocationEntry 5 }

dot11APCivicLocationA4 OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(0..255))
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.

        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        This attribute contains the city division, borough, city district, ward,
        chou (JP). Example: Manhattan."
    ::= { dot11APCivicLocationEntry 6 }

dot11APCivicLocationA5 OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(0..255))
    MAX-ACCESS read-write
    STATUS current
```

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```
    DESCRIPTION
        "This is a control variable.

        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        This attribute contains the neighborhood, block. Example: Morningside
        Heights."
    ::= { dot11APCivicLocationEntry 7 }

dot11APCivicLocationA6 OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(0..255))
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.

        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        This attribute contains the street. Example: Broadway. The A6 element is
        retained for use in those countries that require this level of detail.
        Where A6 was previously used for street names in IETF RFC 5139 [B47], it
        is no longer(M118) used, the RD element is(M118) used for thoroughfare
        data. However, without additional information these fields (M118)are not
        interchanged when converting between different civic formats. Where Civic
        address information is obtained from another format, such as the DHCP form
        IETF RFC 4776 [B45], the A6 element is(M118) copied directly from the
        source format."
    ::= { dot11APCivicLocationEntry 8 }

dot11APCivicLocationPrd OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(0..255))
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.

        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        This attribute contains the leading street direction. Example: NW."
    ::= { dot11APCivicLocationEntry 9 }

dot11APCivicLocationPod OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(0..255))
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.

        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        This attribute contains the trailing street suffix. Example: SW."
    ::= { dot11APCivicLocationEntry 10 }

dot11APCivicLocationSts OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(0..255))
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
```


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```
        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        This attribute contains the street suffix. Example: Avenue, 'Platz,
        Street'."
    ::= { dot11APCivicLocationEntry 11 }

dot11APCivicLocationHno OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(0..255))
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.

        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        This attribute contains the numeric part only of the
        House number. Example: 123."
    ::= { dot11APCivicLocationEntry 12 }

dot11APCivicLocationHns OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(0..255))
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.

        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        This attribute contains the house number suffix. Example: A, 1/2"
    ::= { dot11APCivicLocationEntry 13 }

dot11APCivicLocationLmk OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(0..255))
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.

        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        This attribute contains the landmark or vanity address. Example: Low
        Library."
    ::= { dot11APCivicLocationEntry 14 }

dot11APCivicLocationLoc OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(0..255))
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.

        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        This attribute contains additional location information. Example: Room
        543."
    ::= { dot11APCivicLocationEntry 15 }

dot11APCivicLocationNam OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(0..255))
```

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```
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.

        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        This attribute contains the name (residence, business, or office occupant.
        Example: Joe's Barbershop."
    ::= { dot11APCivicLocationEntry 16 }

dot11APCivicLocationPc OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(0..255))
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.

        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        This attribute contains the postal code. Example: 10027-0401."
    ::= { dot11APCivicLocationEntry 17 }

dot11APCivicLocationBld OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(0..255))
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.

        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        This attribute contains the building (structure). Example: Hope Theater."
    ::= { dot11APCivicLocationEntry 18 }

dot11APCivicLocationUnit OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(0..255))
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.

        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        This attribute contains the unit (apartment, suite). Example: 12a."
    ::= { dot11APCivicLocationEntry 19 }

dot11APCivicLocationFlr OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(0..255))
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.

        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        This attribute contains the floor number. Example: 5."
    ::= { dot11APCivicLocationEntry 20 }
```


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```
dot11APCivicLocationRoom OBJECT-TYPE
   SYNTAX OCTET STRING (SIZE(0..255))
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.

      It is written by an external management entity or the SME.
      Changes take effect as soon as practical in the implementation.

      This attribute contains the room. Example: 450F."
   ::= { dot11APCivicLocationEntry 21 }

dot11APCivicLocationPlc OBJECT-TYPE
   SYNTAX OCTET STRING (SIZE(0..255))
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.

      It is written by an external management entity or the SME.
      Changes take effect as soon as practical in the implementation.

      This attribute contains the place type. Example: office."
   ::= { dot11APCivicLocationEntry 22 }

dot11APCivicLocationPcn OBJECT-TYPE
   SYNTAX OCTET STRING (SIZE(0..255))
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.

      It is written by an external management entity or the SME.
      Changes take effect as soon as practical in the implementation.

      This attribute contains the postal community name. Example: Leonia."
   ::= { dot11APCivicLocationEntry 23 }

dot11APCivicLocationPobox OBJECT-TYPE
   SYNTAX OCTET STRING (SIZE(0..255))
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.

      It is written by an external management entity or the SME.
      Changes take effect as soon as practical in the implementation.

      This attribute contains the post office box (P.O. Box). Example: U40."
   ::= { dot11APCivicLocationEntry 24 }

dot11APCivicLocationAddcode OBJECT-TYPE
   SYNTAX OCTET STRING (SIZE(0..255))
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.

      It is written by an external management entity or the SME.
      Changes take effect as soon as practical in the implementation.

      This attribute contains the additional code. Example: 13203000003."
   ::= { dot11APCivicLocationEntry 25 }
```

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```
dot11APCivicLocationSeat OBJECT-TYPE
   SYNTAX OCTET STRING (SIZE(0..255))
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.

      It is written by an external management entity or the SME.
      Changes take effect as soon as practical in the implementation.

      This attribute contains the seat (desk, cubicle, workstation). Example: WS
      181."
   ::= { dot11APCivicLocationEntry 26 }

dot11APCivicLocationRd OBJECT-TYPE
   SYNTAX OCTET STRING (SIZE(0..255))
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.

      It is written by an external management entity or the SME.
      Changes take effect as soon as practical in the implementation.

      This attribute contains the primary road or street. Example: Broadway."
   ::= { dot11APCivicLocationEntry 27 }

dot11APCivicLocationRdsec OBJECT-TYPE
   SYNTAX OCTET STRING (SIZE(0..255))
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.

      It is written by an external management entity or the SME.
      Changes take effect as soon as practical in the implementation.

      This attribute contains the road section. Example: 14.In some countries a
      thoroughfare can be broken up into sections, and it is not uncommon for
      street numbers to be repeated between sections. A road section identifier
      might be needed to make that an address unique. For example, West Alice
      Parade has 5 sections, each numbered from 1; unless the section is
      specified 7 West Alice Parade could exist in 5 different places."
   ::= { dot11APCivicLocationEntry 28 }

dot11APCivicLocationRdbr OBJECT-TYPE
   SYNTAX OCTET STRING (SIZE(0..255))
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.

      It is written by an external management entity or the SME.
      Changes take effect as soon as practical in the implementation.

      This attribute contains the road branch. Example: 'Lane 7'. Minor streets
      can share the same name, so that they can only Be distinguished by the
      major thoroughfare with which they intersect. For example, both West Alice
      Parade, Section 3 and Bob Street could both be interested by a Carol Lane.
      This element is used to specify a road branch where the name of the branch
      does not uniquely identify the road. Road branches MAY also be used where
      a major thoroughfare is split into sections."
   ::= { dot11APCivicLocationEntry 29 }
```


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```
dot11APCivicLocationRdsubbr OBJECT-TYPE
   SYNTAX OCTET STRING (SIZE(0..255))
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.

      It is written by an external management entity or the SME.
      Changes take effect as soon as practical in the implementation.

      This attribute contains the road sub-branch. Example: Alley 8."
   ::= { dot11APCivicLocationEntry 30 }

dot11APCivicLocationPrm OBJECT-TYPE
   SYNTAX OCTET STRING (SIZE(0..255))
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.

      It is written by an external management entity or the SME.
      Changes take effect as soon as practical in the implementation.

      This attribute contains the road premodifier. Example: Old."
   ::= { dot11APCivicLocationEntry 31 }

dot11APCivicLocationPom OBJECT-TYPE
   SYNTAX OCTET STRING (SIZE(0..255))
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.

      It is written by an external management entity or the SME.
      Changes take effect as soon as practical in the implementation.

      This attribute contains the road post-modifier. Example: Extended."
   ::= { dot11APCivicLocationEntry 32 }

-- ************************************************************************
-- * End of dot11APCivicLocation TABLE
-- ************************************************************************

-- ************************************************************************
-- * dot11RoamingConsortium TABLE
-- ************************************************************************
dot11RoamingConsortiumTable OBJECT-TYPE
   SYNTAX SEQUENCE OF Dot11RoamingConsortiumEntry
   MAX-ACCESS not-accessible
   STATUS current
   DESCRIPTION
      "This is a Table of OIs which are to be transmitted in an ANQP Roaming
      Consortium ANQP-element. Each table entry corresponds to a roaming
      consortium or single SSP. The first 3 entries in this table are
      transmitted in Beacon and Probe Response frames."
   ::= { dot11imt 5 }

dot11RoamingConsortiumEntry OBJECT-TYPE
   SYNTAX Dot11RoamingConsortiumEntry
   MAX-ACCESS not-accessible
   STATUS current
   DESCRIPTION
      "Each OI identifies a roaming consortium (group of SSPs with inter-SSP
```

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```
        roaming agreement) or a single SSP. A non-AP STA in possession of security
        credentials for the SSPN(s) identified by the OI should be able to
        successfully authenticate to this AP."
    INDEX { dot11RoamingConsortiumOI }
    ::= { dot11RoamingConsortiumTable 1 }

Dot11RoamingConsortiumEntry ::=
    SEQUENCE {
        dot11RoamingConsortiumOI OCTET STRING,
        dot11RoamingConsortiumRowStatus RowStatus
        }

dot11RoamingConsortiumOI OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(16))
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.

        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        This attribute contains the IEEE defined OI as defined in 9.4.1.29 (Orga-
        nization Identifier field)."
    ::= { dot11RoamingConsortiumEntry 1 }

dot11RoamingConsortiumRowStatus OBJECT-TYPE
    SYNTAX RowStatus
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This object represents the status column for a conceptual row in this
        table."
    ::= { dot11RoamingConsortiumEntry 2 }

-- ************************************************************************
-- * End of dot11RoamingConsortium TABLE
-- ************************************************************************

-- ************************************************************************
-- * dot11DomainName TABLE
-- ************************************************************************
dot11DomainNameTable   OBJECT-TYPE
    SYNTAX                SEQUENCE OF Dot11DomainNameEntry
    MAX-ACCESS            not-accessible
    STATUS                current
    DESCRIPTION
        "This is a table of Domain Names which form the Domain Name list in access
        network query protocol. The Domain Name list may be transmitted to a non-
        AP STA in a GAS Response. Each table entry corresponds to a single Domain
        Name."
    ::= { dot11imt 6 }

dot11DomainNameEntry OBJECT-TYPE
    SYNTAX     Dot11DomainNameEntry
    MAX-ACCESS not-accessible
    STATUS     current
    DESCRIPTION
        "This is a control variable.

        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        Each Domain Name identifies a domain names of the entity operating the
```


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```
        IEEE 802.11 access network."
    INDEX { dot11DomainNameOui }
    ::= { dot11DomainNameTable 1 }

Dot11DomainNameEntry ::=
    SEQUENCE {
        dot11DomainName                                    OCTET STRING,
        dot11DomainNameRowStatus                           RowStatus,
        dot11DomainNameOui                                 OCTET STRING
        }

dot11DomainName OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(255))
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.

        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        This attribute contains a Domain Name of up to 255 octets formatted in
        accordance with the 'Preferred Name Syntax' as defined in IETF RFC 1035."
    ::= { dot11DomainNameEntry 1 }

dot11DomainNameRowStatus OBJECT-TYPE
    SYNTAX RowStatus
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "This object represents the status column for a conceptual row in this
        table."
    ::= { dot11DomainNameEntry 2 }
dot11DomainNameOui OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(3..5))
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This object represents an IEEE assigned unique identifier (OUI, OUI-36 or
        CID), used as an index into the Domain Name table."
    ::= { dot11DomainNameEntry 3 }



-- ************************************************************************
-- * End of dot11DomainName TABLE
-- ************************************************************************

-- ************************************************************************
-- * dot11GASAdvertisement TABLE
-- ************************************************************************
dot11GASAdvertisementTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11GASAdvertisementEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "This object is a table of GAS counters that allows for multiple
        instances(#467) of those counters on a STA."
    ::= { dot11imt 7 }

dot11GASAdvertisementEntry OBJECT-TYPE
    SYNTAX Dot11GASAdvertisementEntry
    MAX-ACCESS not-accessible
    STATUS current

```

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```
    DESCRIPTION
        "This object provides the attributes identifying a GAS counter within a
        STA."
    INDEX { dot11GASAdvertisementId }
    ::= { dot11GASAdvertisementTable 1 }

Dot11GASAdvertisementEntry ::=
    SEQUENCE{
        dot11GASAdvertisementId                              Unsigned32,
        dot11GASPauseForServerResponse                       TruthValue,
        dot11GASResponseTimeout                              Unsigned32,
        dot11GASComebackDelay                                Unsigned32,
        dot11GASResponseBufferingTime                        Unsigned32,
        dot11GASQueryResponseLengthLimit                     Unsigned32,
        dot11GASQueries                                      Counter32,
        dot11GASQueryRate                                    Gauge32,
        dot11GASResponses                                    Counter32,
        dot11GASResponseRate                                 Gauge32,
        dot11GASNoRequestOutstanding                         Counter32,
        dot11GASResponsesDiscarded                           Counter32,
        dot11GASFailedResponses                              Counter32,
        (#6058)dot11GASRequestBufferingTime                  Unsigned32,
        (#6058)dot11GASQueryRequestLengthLimit               Unsigned32

        }

dot11GASAdvertisementId OBJECT-TYPE
    SYNTAX Unsigned32 (0..255)
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "This is a control variable.

        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        The 1-octet identification number for the GAS advertisement protocol, as
        defined in Table 9-277 (Advertisement protocol ID definitions), for which
        statistics are stored the logical row of the GASAdvertisement table."
    ::= { dot11GASAdvertisementEntry 1 }

dot11GASPauseForServerResponse OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.

        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        This attribute is used only by the responding STA in a GAS exchange. When
        true, it indicates that the responding STA does not transmit a GAS Initial
        Response frame until it receives the query response from the advertisement
        server(#571) or a timeout occurs. When false, the STA does not wait for a
        response from the advertisement server(#571) before transmitting the GAS
        Initial Response frame. The setting of this MIB object is outside the
        scope of this standard."
    ::= { dot11GASAdvertisementEntry 2 }

dot11GASResponseTimeout OBJECT-TYPE
    SYNTAX Unsigned32 (10..65535)
    UNITS "TUs"
    MAX-ACCESS read-write
```


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```
    STATUS current
    DESCRIPTION
        "This is a control variable.

        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        This parameter shall indicate the GAS response timeout value."
    DEFVAL {50}
    ::= { dot11GASAdvertisementEntry 3 }

dot11GASComebackDelay OBJECT-TYPE
    SYNTAX Unsigned32 (0..65535)
    UNITS "TUs"
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.

        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        This object identifies the GAS comeback delay(#4356) to be used for this
        advertisement protocol"
    DEFVAL {1000}
    ::= { dot11GASAdvertisementEntry 4 }

dot11GASResponseBufferingTime OBJECT-TYPE
    SYNTAX Unsigned32 (0..65535)
    UNITS "TUs"
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.

        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        This object defines the time after the expiration of the GAS comeback
        delay timer(#4356) that a STA will buffer a Query Response. Upon expira-
        tion of this time, the STA may discard the Query Response."
    DEFVAL {1000}

    ::= { dot11GASAdvertisementEntry 5 }

dot11GASQueryResponseLengthLimit OBJECT-TYPE
    SYNTAX Unsigned32 (1..127)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.

        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        This object indicates the maximum number of octets an AP will transmit in
        one or more Query Response fields contained within GAS Comeback Response
        frame(s). A value of 127 means the maximum limit enforced is contained by
        the maximum allowable number of fragments in the GAS Query Fragment
        Response ID"
    ::= { dot11GASAdvertisementEntry 6 }

dot11GASQueries OBJECT-TYPE
    SYNTAX Counter32
```

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```
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.

        It is written by the SME after transmission of an MLME-GAS.request or
        receipt of an MLME-GAS.indication primitive.

        The number of GAS queries sent or received for the protocol identified by
        dot11GASAdvertisementId."
    ::= { dot11GASAdvertisementEntry 7 }

dot11GASQueryRate OBJECT-TYPE
    SYNTAX Gauge32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.

        It is written by the SME after receipt of an MLME-GAS.indication
        primitive.

        The number of GAS queries per minute received for the protocol identified
        by dot11GASAdvertisementId, averaged over the previous ten minutes."
    ::= { dot11GASAdvertisementEntry 8 }

dot11GASResponses OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.

        It is written by the SME after transmission of an MLME-GAS.response
        primitive or receipt of an MLME-GAS.confirm primitive.

        The number of GAS responses sent or received for the protocol identified
        by dot11GASAdvertisementId."
    ::= { dot11GASAdvertisementEntry 9 }

dot11GASResponseRate OBJECT-TYPE
    SYNTAX Gauge32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.

        It is written by the SME after transmission of an MLME-GAS.response
        primitive.

        The number of responses to GAS queries per minute transmitted by an AP for
        the protocol identified by dot11GASAdvertisementId, averaged over the
        previous ten minutes. This MIB attribute is not used in non-AP STAs."
    ::= { dot11GASAdvertisementEntry 10 }

dot11GASNoRequestOutstanding OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.

        It is written by the SME after transmission of an MLME-GAS.response
        primitive.
```


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```
        This counter shall be incremented each time a STA returns a status code of
        NO_OUTSTANDING_GAS_REQUEST in a GAS Initial Response or GAS Comeback
        Response frame for the protocol identified by dot11GASAdvertisementId."
    ::= { dot11GASAdvertisementEntry 13 }

dot11GASResponsesDiscarded OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.

        It is written by the SME after transmission of an MLME-GAS.response
        primitive.

        This counter shall be incremented each a STA discards a GAS response due
        to the expiration of the dot11GASResponseBufferingTime timer for the
        protocol identified by dot11GASAdvertisementId."
    ::= { dot11GASAdvertisementEntry 14 }

dot11GASFailedResponses OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.

        It is written by the SME after transmission of an MLME-GAS.response
        primitive.

        This counter shall be incremented each time a STA commences transmitting a
        GAS response but fails to successfully complete the transmission of all
        GAS fragments in that response due to the (#6063)expiration of the
        dot11GASResponseTimeout timer for the protocol identified by
        dot11GASAdvertisementId."
    ::= { dot11GASAdvertisementEntry 15 }


(#6058)dot11GASRequestBufferingTime OBJECT-TYPE
    SYNTAX Unsigned32 (0..65535)
    UNITS "TUs"
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.

        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation. This
        object defines the time that a STA will buffer a query request. Upon expi-
        ration of this time, the STA may discard the query request."
    DEFVAL {1000}
    ::= { dot11GASAdvertisementEntry 16 }


(#6058)dot11GASQueryRequestLengthLimit OBJECT-TYPE
    SYNTAX Unsigned32 (1..127)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.
```

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```
        This object indicates the maximum number of octets a STA will transmit in
        one or more Query Request fields contained within GAS Comeback Request
        Fragment frame(s). A value of 127 means the maximum limit enforced is con-
        strained by the maximum allowable number of fragments in the GAS Query
        Fragment ID."
    DEFVAL { 127 }
    ::= { dot11GASAdvertisementEntry 17 }

-- ****************************************************************
-- * End of dot11GASAdvertisement TABLE
-- ****************************************************************


-- ****************************************************************
-- * MAC state generic convergence function
-- ****************************************************************

-- MAC state generic convergence function attributes
   -- DEFINED AS "The MAC state generic convergence function object
   -- class provides the necessary support for support of event-driven
   -- triggers to higher layer protocols and the capabilities to
   -- support those triggers."

dot11MSGCF OBJECT IDENTIFIER ::= { ieee802dot11 7}

      -- MAC state generic convergence function GROUPS
      -- dot11MACStateConfigTable ::= { dot11MSGCF 1 }
      -- dot11MACStateParameterTable ::= { dot11MSGCF 2 }
      -- dot11MACStateESSLinkTable ::= { dot11MSGCF 3 }

-- ****************************************************************
-- * dot11ESSLinkIdentifier type definition
-- ****************************************************************
Dot11ESSLinkIdentifier ::= OCTET STRING (SIZE(0..38))
   -- This object type holds the identifier for an IEEE 802.11
   -- network. It is composed of the SSID string concatenated
   -- with the HESSID, if present.

-- ****************************************************************
-- * dot11MACStateConfig TABLE
-- ****************************************************************
dot11MACStateConfigTable OBJECT-TYPE
   SYNTAX SEQUENCE OF Dot11MACStateConfigEntry
   MAX-ACCESS not-accessible
   STATUS current
   DESCRIPTION
      "This table holds configuration parameters for the IEEE 802.11 MAC
      state generic convergence function."
   ::= { dot11MSGCF 1 }

dot11MACStateConfigEntry OBJECT-TYPE
   SYNTAX Dot11MACStateConfigEntry
   MAX-ACCESS not-accessible
   STATUS current
   DESCRIPTION
      "Each entry represents a conceptual row in the dot11MACStateConfigTable
      and provides information about network configuration parameters used in
      the MAC state generic convergence function."
   INDEX { dot11MSCEESSLinkIdentifier, dot11MSCENonAPStationMacAddress }
   ::= { dot11MACStateConfigTable 1 }

Dot11MACStateConfigEntry ::=
   SEQUENCE {
      dot11ESSDisconnectFilterInterval Unsigned32,
```


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```
        dot11ESSLinkDetectionHoldInterval Unsigned32,
        dot11MSCEESSLinkIdentifier Dot11ESSLinkIdentifier,
        dot11MSCENonAPStationMacAddress MacAddress
        }

dot11ESSDisconnectFilterInterval OBJECT-TYPE
    SYNTAX Unsigned32
    UNITS "TUs"
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.

        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        This attribute is set to the time that will elapse after an MLME-
        DISASSOCIATE.confirm or MLME-DEAUTHENTICATE.confirm primitive without a
        subsequent association before the link is declared down. This interval is
        intended to allow a non-AP STA time to transition to another AP within the
        same ESS before declaring that the link to the ESS is lost."
    ::= { dot11MACStateConfigEntry 1 }

dot11ESSLinkDetectionHoldInterval OBJECT-TYPE
    SYNTAX Unsigned32
    UNITS "TUs"
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.

        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        This attribute is set to the time that an ESS is held in the
        dot11MACStateESSLink table after its last observation before purging the
        entry from the table."
    ::= { dot11MACStateConfigEntry 2 }

dot11MSCEESSLinkIdentifier OBJECT-TYPE
    SYNTAX Dot11ESSLinkIdentifier
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "This is an auxiliary variable used to identify instances of the columnar
        objects in the dot11MACStateConfigTable table."

    ::= { dot11MACStateConfigEntry 3 }

dot11MSCENonAPStationMacAddress OBJECT-TYPE
    SYNTAX MacAddress
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "This is an auxiliary variable used to identify instances of the columnar
        objects in the dot11MACStateConfigTable table."

    ::= { dot11MACStateConfigEntry 4 }

-- ************************************************************************
-- * End of dot11MACStateConfig TABLE
-- ************************************************************************

-- ************************************************************************
```

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```
-- * dot11MACStateParameter TABLE
-- ************************************************************************

dot11MACStateParameterTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11MACStateParameterEntry
    MAX-ACCESS not-accessible
    STATUS     current
    DESCRIPTION
        "This table holds the current parameters used for each IEEE 802.11 network
        for IEEE 802.11 MAC convergence functions."
    ::= { dot11MSGCF 2 }

dot11MACStateParameterEntry OBJECT-TYPE
    SYNTAX         Dot11MACStateParameterEntry
    MAX-ACCESS     not-accessible
    STATUS         current
    DESCRIPTION
        "Each entry represents a conceptual row in the dot11MACStateParameterTable
        and provides information about link configuration parameters used in the
        MAC state generic convergence function."
    INDEX { dot11MSPEESSLinkIdentifier, dot11MSPENonAPStationMacAddress }
    ::= { dot11MACStateParameterTable 1 }

Dot11MACStateParameterEntry ::=
    SEQUENCE {
        dot11ESSLinkDownTimeInterval                          Unsigned32,
        dot11ESSLinkRssiDataThreshold                         Unsigned32,
        dot11ESSLinkRssiBeaconThreshold                       Unsigned32,
        dot11ESSLinkDataSnrThreshold                          Unsigned32,
        dot11ESSLinkBeaconSnrThreshold                        Unsigned32,
        dot11ESSLinkBeaconFrameErrorRateThresholdInteger      Unsigned32,
        dot11ESSLinkBeaconFrameErrorRateThresholdFraction     Unsigned32,
        dot11ESSLinkBeaconFrameErrorRateThresholdExponent     Unsigned32,
        dot11ESSLinkFrameErrorRateThresholdInteger            Unsigned32,
        dot11ESSLinkFrameErrorRateThresholdFraction           Unsigned32,
        dot11ESSLinkFrameErrorRateThresholdExponent           Unsigned32,
        dot11PeakOperationalRate                              Unsigned32,
        dot11MinimumOperationalRate                           Unsigned32,
        dot11ESSLinkDataThroughputInteger                     Unsigned32,
        dot11ESSLinkDataThroughputFraction                    Unsigned32,
        dot11ESSLinkDataThroughputExponent                    Unsigned32,
        dot11MSPEESSLinkIdentifier                Dot11ESSLinkIdentifier,
        dot11MSPENonAPStationMacAddress                       MacAddress
        }


dot11ESSLinkDownTimeInterval OBJECT-TYPE
    SYNTAX Unsigned32
    UNITS "TUs"
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.

        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        This attribute defines the time interval over which the MAC state generic
        convergence function will attempt to predict the failure of an IEEE 802.11
        network. The convergence function should issue predicted network failure
        events at least this time interval before the network failure is
        detected."
    ::= { dot11MACStateParameterEntry 2 }
```


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```
dot11ESSLinkRssiDataThreshold OBJECT-TYPE
   SYNTAX Unsigned32
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.

      It is written by an external management entity or the SME.
      Changes take effect as soon as practical in the implementation.

      This attribute defines the threshold value for RSSI on Data frames. When
      the RSSI drops below this threshold, a report is issued."
   ::= { dot11MACStateParameterEntry 3 }

dot11ESSLinkRssiBeaconThreshold OBJECT-TYPE
   SYNTAX Unsigned32
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.

      It is written by an external management entity or the SME.
      Changes take effect as soon as practical in the implementation.

      This attribute defines the threshold value for RSSI on Beacon frames. When
      the RSSI drops below this threshold, a report is issued."
   ::= { dot11MACStateParameterEntry 4 }

dot11ESSLinkBeaconSnrThreshold OBJECT-TYPE
   SYNTAX Unsigned32
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.

      It is written by an external management entity or the SME.
      Changes take effect as soon as practical in the implementation.

      This attribute defines the threshold value for SNR on received Beacon
      frames. When the SNR drops below this threshold, a report is issued"
   ::= { dot11MACStateParameterEntry 5 }

dot11ESSLinkDataSnrThreshold OBJECT-TYPE
   SYNTAX Unsigned32
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.

      It is written by an external management entity or the SME.
      Changes take effect as soon as practical in the implementation.

      This attribute defines the threshold value for SNR on received Data
      frames. When the SNR drops below this threshold, a report is issued."
   ::= { dot11MACStateParameterEntry 6 }

dot11ESSLinkBeaconFrameErrorRateThresholdInteger OBJECT-TYPE
   SYNTAX Unsigned32
   MAX-ACCESS read-write
   STATUS current
   DESCRIPTION
      "This is a control variable.

      It is written by an external management entity or the SME.
```

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```
        Changes take effect as soon as practical in the implementation.

        The Beacon frame error rate is stored in scientific notation as a
        significant and exponent. This attribute contains the integer value of the
        significand."
    ::= { dot11MACStateParameterEntry 7 }

dot11ESSLinkBeaconFrameErrorRateThresholdFraction OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.

        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        The Beacon frame error rate is stored in scientific notation as a
        significant and exponent. This attribute contains the fractional value of
        the significand."
    ::= { dot11MACStateParameterEntry 8 }

dot11ESSLinkBeaconFrameErrorRateThresholdExponent OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.

        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        The Beacon frame error rate is stored in scientific notation as a
        significant and exponent. This attribute contains the integer value of the
        exponent."
    ::= { dot11MACStateParameterEntry 9 }

dot11ESSLinkFrameErrorRateThresholdInteger OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.

        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        The frame error rate of the network is stored in scientific notation as a
        significant and exponent. This attribute contains the integer value of the
        significand."
    ::= { dot11MACStateParameterEntry 10 }

dot11ESSLinkFrameErrorRateThresholdFraction OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.

        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        The frame error rate of the network is stored in scientific notation as a
        significant and exponent. This attribute contains the fractional value of
```


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```
        the significand."
    ::= { dot11MACStateParameterEntry 11 }

dot11ESSLinkFrameErrorRateThresholdExponent OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.

        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        The frame error rate of the network is stored in scientific notation as a
        significant and exponent. This attribute contains the integer value of the
        exponent."
    ::= { dot11MACStateParameterEntry 12 }

dot11PeakOperationalRate OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.

        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        The highest operational rate used for transmission of Data frames, encoded
        as defined in 9.4.2.3 (Supported Rates and BSS Membership Selectors ele-
        ment)."
    ::= { dot11MACStateParameterEntry 13 }

dot11MinimumOperationalRate OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.

        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        The lowest operational rate used for transmission of Data frames, encoded
        as defined in 9.4.2.3 (Supported Rates and BSS Membership Selectors ele-
        ment)."
    ::= { dot11MACStateParameterEntry 14 }

dot11ESSLinkDataThroughputInteger OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.

        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        The data throughput rate is of the network is stored in scientific
        notation as a significant and exponent. This attribute contains the
        integer value of the significand."
    ::= { dot11MACStateParameterEntry 15 }

dot11ESSLinkDataThroughputFraction OBJECT-TYPE
```

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```
    SYNTAX Unsigned32
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.

        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        The data throughput rate is of the network is stored in scientific
        notation as a significant and exponent. This attribute contains the
        fractional value of the significand."
    ::= { dot11MACStateParameterEntry 16 }

dot11ESSLinkDataThroughputExponent OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.

        It is written by an external management entity or the SME.
        Changes take effect as soon as practical in the implementation.

        The data throughput rate is of the network is stored in scientific
        notation as a significant and exponent. This attribute contains the
        integer value of the exponent."
    ::= { dot11MACStateParameterEntry 17 }

dot11MSPEESSLinkIdentifier OBJECT-TYPE
    SYNTAX Dot11ESSLinkIdentifier
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "This is an auxiliary variable used to identify instances of the columnar
        objects in the dot11MACStateParameterTable table."

    ::= { dot11MACStateParameterEntry 18 }

dot11MSPENonAPStationMacAddress OBJECT-TYPE
    SYNTAX MacAddress
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "This is an auxiliary variable used to identify instances of the columnar
        objects in the dot11MACStateParameterTable table."

    ::= { dot11MACStateParameterEntry 19 }


-- ********************************************************************
-- * End of dot11MACStateParameter TABLE
-- ********************************************************************

-- ********************************************************************
-- * dot11MACStateESSLink TABLE
-- ********************************************************************
dot11MACStateESSLinkDetectedTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11MACStateESSLinkDetectedEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "This table holds the detected IEEE 802.11 network list used for MAC
        convergence functions."
```


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```
    ::= { dot11MSGCF 3 }

dot11MACStateESSLinkDetectedEntry OBJECT-TYPE
    SYNTAX Dot11MACStateESSLinkDetectedEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "Each entry represents a conceptual row in the dot11MACStateESSLinkTable
        and provides information about available networks for use in the MAC state
        generic convergence function."
    INDEX { dot11MSELDEESSLinkIdentifier, dot11MSELDENonAPStationMacAddress }
    ::= { dot11MACStateESSLinkDetectedTable 1 }

Dot11MACStateESSLinkDetectedEntry ::=
    SEQUENCE {
        dot11ESSLinkDetectedIndex                    Unsigned32,
        dot11ESSLinkDetectedNetworkId                OCTET STRING,
        dot11ESSLinkDetectedNetworkDetectTime        Unsigned32,
        dot11ESSLinkDetectedNetworkModifiedTime      Unsigned32,
        dot11ESSLinkDetectedNetworkMISCapabilities   BITS,
        dot11MSELDEESSLinkIdentifier                 Dot11ESSLinkIdentifier,
        dot11MSELDENonAPStationMacAddress            MacAddress
        }

dot11ESSLinkDetectedIndex OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "Index for ESSLinkDetected elements in dot11ESSLinkDetectedTable, greater
        than 0."
    ::= { dot11MACStateESSLinkDetectedEntry 1 }

dot11ESSLinkDetectedNetworkId OBJECT-TYPE
    SYNTAX OCTET STRING
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.

        It is written by the MSGCF after reception of an MSGCF-ESS-LINK-
        DETECTED.indication primitive.

        The string used to identify the network represented by this row in the
        table. It is composed of the SSID of the network concatenated with the
        HESSID, if present."
    ::= { dot11MACStateESSLinkDetectedEntry 2 }


dot11ESSLinkDetectedNetworkDetectTime OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a status variable.
        It is written by the MSGCF after reception of an MSGCF-ESS-LINK-
        DETECTED.indication primitive.

        The STA's TSF timer when any BSSID supporting the network was first
        detected."
    ::= { dot11MACStateESSLinkDetectedEntry 4 }

dot11ESSLinkDetectedNetworkModifiedTime OBJECT-TYPE
    SYNTAX Unsigned32
```

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```
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
       "This is a status variable.

       It is written by the MSGCF after reception of an MSGCF-ESS-LINK-
       DETECTED.indication primitive.

       The STA's TSF timer value when changes were made to any part of this row
       in the table, such as by addition of a BSSID to the BSSID list."
    ::= { dot11MACStateESSLinkDetectedEntry 5 }

dot11ESSLinkDetectedNetworkMISCapabilities OBJECT-TYPE
    SYNTAX BITS {
       misIsSupport(0),
       misCsEsSupport(1)
    }
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
       "This is a status variable.

       It is written by the MSGCF after reception of an MSGCF-ESS-LINK-
       DETECTED.indication primitive.

       The object reports whether the network supports IEEE 802.21 MIS
       information services and/or IEEE 802.21 MIS command/event services. These
       values are determined by examining the Interworking information in frames
       that caused the network to be detected."
    ::= { dot11MACStateESSLinkDetectedEntry 6 }

dot11MSELDEESSLinkIdentifier OBJECT-TYPE
    SYNTAX Dot11ESSLinkIdentifier
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
       "This is an auxiliary variable used to identify instances of the columnar
       objects in the dot11MACStateESSLinkDetectedTable table."

    ::= { dot11MACStateESSLinkDetectedEntry 7 }

dot11MSELDENonAPStationMacAddress OBJECT-TYPE
    SYNTAX MacAddress
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
       "This is an auxiliary variable used to identify instances of the columnar
       objects in the dot11MACStateESSLinkDetectedTable table."

    ::= { dot11MACStateESSLinkDetectedEntry 8 }


-- ************************************************************************
-- * End of dot11MACStateESSLink TABLE
-- ************************************************************************

-- ************************************************************************
-- * Compliance Information
-- ************************************************************************

dot11Conformance OBJECT IDENTIFIER ::= { ieee802dot11 5 }
dot11Groups      OBJECT IDENTIFIER ::= { dot11Conformance 1 }
dot11Compliances OBJECT IDENTIFIER ::= { dot11Conformance 2 }
```


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```
-- ************************************************************************
-- *   Groups - units of compliance
-- ************************************************************************

dot11SMTbase OBJECT-GROUP
   OBJECTS {
      dot11StationID,
      dot11MediumOccupancyLimit,
      dot11CFPollable,
      dot11CFPPeriod,
      dot11CFPMaxDuration,
      dot11AuthenticationResponseTimeout,
      dot11PrivacyOptionImplemented,
      dot11PowerManagementMode,
      dot11DesiredSSID, dot11DesiredBSSType,
      dot11OperationalRateSet,
      dot11BeaconPeriod, dot11DTIMPeriod,
      dot11AssociationResponseTimeout }
   STATUS deprecated
   DESCRIPTION
      "Superseded by dot11SMTbase2.
      The SMT object class provides the necessary support at the STA to manage
      the processes in the STA such that the STA may work cooperatively as a
      part of an IEEE 802.11 network."
   ::= { dot11Groups 1 }

dot11SMTprivacy OBJECT-GROUP
   OBJECTS {
      dot11PrivacyInvoked,
      dot11WEPKeyMappingLengthImplemented,
      dot11ExcludeUnencrypted,
      dot11WEPICVErrorCount,
      dot11WEPExcludedCount,
      dot11WEPDefaultKeyID,
      dot11WEPDefaultKeyValue,
      dot11WEPKeyMappingWEPOn,
      dot11WEPKeyMappingValue,
      dot11WEPKeyMappingAddress,
      dot11WEPKeyMappingStatus }
   STATUS deprecated(#4074)
   DESCRIPTION
      "(#4074)The SMTPrivacy package is a deprecated set of attributes."
   ::= { dot11Groups 2 }

dot11MACbase OBJECT-GROUP
   OBJECTS {
      dot11MACAddress,
      dot11GroupAddress,
      dot11GroupAddressesStatus,
      dot11RTSThreshold,
      dot11ShortRetryLimit,
      dot11LongRetryLimit,
      dot11FragmentationThreshold,
      dot11MaxTransmitMSDULifetime,
      dot11MaxReceiveLifetime,
      dot11ManufacturerID,
      dot11ProductID }
   STATUS deprecated
   DESCRIPTION
      "Superseded by dot11MACbase2.
      The MAC object class provides the necessary support for the access
      control, generation, and verification of frame check sequences (FCSs), and
      proper delivery of valid data to upper layers."
   ::= { dot11Groups 3 }
```

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```
dot11MACStatistics OBJECT-GROUP
   OBJECTS {
      dot11RetryCount,
      dot11MultipleRetryCount,
      dot11RTSSuccessCount,
      dot11RTSFailureCount,
      dot11AckFailureCount,
      dot11FrameDuplicateCount }
   STATUS current
   DESCRIPTION
      "The MACStatistics package provides extended statistical information on
      the operation of the MAC. This package is completely optional."
   ::= { dot11Groups 4 }

dot11ResourceTypeID OBJECT-GROUP
   OBJECTS {
      dot11ResourceTypeIDName,
      dot11manufacturerOUI,
      dot11manufacturerName,
      dot11manufacturerProductName,
      dot11manufacturerProductVersion }
   STATUS current
   DESCRIPTION
      "Attributes used to identify a STA, its manufacturer, and various product
      names and versions."
   ::= { dot11Groups 5 }

dot11SmtAuthenticationAlgorithms OBJECT-GROUP
   OBJECTS {
      dot11AuthenticationAlgorithm,
      dot11AuthenticationAlgorithmActivated }
   STATUS current
   DESCRIPTION
      "Authentication Algorithm Table."
   ::= { dot11Groups 6 }

dot11PhyOperationComplianceGroup OBJECT-GROUP
   OBJECTS { dot11PHYType, dot11CurrentRegDomain, dot11TempType }
   STATUS deprecated
            DESCRIPTION
      "Superseded by dot11PhyOperationComplianceGroup2.
      PHY operations attributes."
   ::= { dot11Groups 7 }

dot11PhyAntennaComplianceGroup OBJECT-GROUP
   OBJECTS {
      dot11CurrentTxAntenna,
      dot11DiversitySupportImplemented,
      dot11CurrentRxAntenna }
   STATUS deprecated
   DESCRIPTION
      "Attributes for Data Rates for IEEE Std 802.11."
   ::= { dot11Groups 8 }

dot11PhyTxPowerComplianceGroup OBJECT-GROUP
   OBJECTS {
      dot11NumberSupportedPowerLevelsImplemented,
      dot11TxPowerLevel1,
      dot11TxPowerLevel2,
      dot11TxPowerLevel3,
      dot11TxPowerLevel4,
      dot11TxPowerLevel5,
      dot11TxPowerLevel6,
```


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```
        dot11TxPowerLevel7,
        dot11TxPowerLevel8,
        dot11CurrentTxPowerLevel }
    STATUS current
    DESCRIPTION
        "Attributes for Control and Management of transmit power."
    ::= { dot11Groups 9 }


dot11PhyDSSSComplianceGroup OBJECT-GROUP
    OBJECTS {
        dot11CurrentChannel,
        dot11CCAModeSupported,
        dot11CurrentCCAMode,
        dot11EDThreshold }
    STATUS current
    DESCRIPTION
        "Attributes that configure the DSSS PHY for IEEE Std 802.11."
    ::= { dot11Groups 11 }


dot11PhyRegDomainsSupportGroup OBJECT-GROUP
    OBJECTS { dot11RegDomainsImplementedValue  }
    STATUS deprecated
    DESCRIPTION
        "Attributes that specify the supported Regulation Domains."
    ::= { dot11Groups 13 }

dot11PhyAntennasListGroup OBJECT-GROUP
    OBJECTS {
        dot11TxAntennaImplemented,
        dot11RxAntennaImplemented,
        dot11DiversitySelectionRxImplemented }
    STATUS current
    DESCRIPTION
        "Attributes that specify the supported Regulation Domains."
    ::= { dot11Groups 14 }

dot11PhyRateGroup OBJECT-GROUP
    OBJECTS {
        dot11ImplementedDataRatesTxValue,
        dot11ImplementedDataRatesRxValue }
    STATUS current
    DESCRIPTION
        "Attributes for Data Rates for IEEE Std 802.11."
    ::= { dot11Groups 15 }

dot11CountersGroup OBJECT-GROUP
    OBJECTS {
        dot11TransmittedFragmentCount,
        dot11GroupTransmittedFrameCount,
        dot11FailedCount,
        dot11ReceivedFragmentCount,
        dot11GroupReceivedFrameCount,
        dot11FCSErrorCount,
        dot11WEPUndecryptableCount,
        dot11TransmittedFrameCount }
    STATUS deprecated
    DESCRIPTION
        "Superseded by dot11CountersGroup2.
        Attributes from the dot11CountersGroup that are not described in the
        dot11MACStatistics group. These objects are mandatory."
    ::= { dot11Groups 16 }
```

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```
dot11NotificationGroup NOTIFICATION-GROUP
   NOTIFICATIONS {
      dot11Disassociate,
      dot11Deauthenticate,
      dot11AuthenticateFail,
      dot11Associate,
      dot11AssociateFailed,
      dot11Reassociate,
      dot11ReassociateFailed   }
   STATUS current
   DESCRIPTION
      "IEEE 802.11 notifications"
   ::= { dot11Groups 17 }

dot11SMTbase2 OBJECT-GROUP
   OBJECTS {
      dot11MediumOccupancyLimit,
      dot11CFPollable,
      dot11CFPPeriod,
      dot11CFPMaxDuration,
      dot11AuthenticationResponseTimeout,
      dot11PrivacyOptionImplemented,
      dot11PowerManagementMode,
      dot11DesiredSSID,
      dot11DesiredBSSType,
      dot11OperationalRateSet,
      dot11BeaconPeriod,
      dot11DTIMPeriod,
      dot11AssociationResponseTimeout,
      dot11DisassociateReason,
      dot11DisassociateStation,
      dot11DeauthenticateReason,
      dot11DeauthenticateStation,
      dot11AuthenticateFailStatus,
      dot11AuthenticateFailStation }
   STATUS deprecated
   DESCRIPTION
      "Superseded by dot11SMTbase3.
      The SMTbase2 object class provides the necessary support at the STA to
      manage the processes in the STA such that the STA may work cooperatively
      as a part of an IEEE 802.11 network."
   ::= { dot11Groups 18 }

dot11PhyOFDMComplianceGroup OBJECT-GROUP
   OBJECTS {
      dot11CurrentFrequency,
      dot11TIThreshold,
      dot11FrequencyBandsImplemented,
      dot11ChannelStartingFactor }
   STATUS deprecated
   DESCRIPTION
      "Superseded by dot11PhyOFDMComplianceGroup2.
      Attributes that configure the OFDM PHY for IEEE Std 802.11."
   ::= { dot11Groups 19 }

dot11SMTbase3 OBJECT-GROUP
   OBJECTS {
      dot11MediumOccupancyLimit,
      dot11CFPollable,
      dot11CFPPeriod,
      dot11CFPMaxDuration,
      dot11AuthenticationResponseTimeout,
      dot11PrivacyOptionImplemented,
      dot11PowerManagementMode,
```


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```
        dot11DesiredSSID,
        dot11DesiredBSSType,
        dot11OperationalRateSet,
        dot11BeaconPeriod,
        dot11DTIMPeriod,
        dot11AssociationResponseTimeout,
        dot11DisassociateReason,
        dot11DisassociateStation,
        dot11DeauthenticateReason,
        dot11DeauthenticateStation,
        dot11AuthenticateFailStatus,
        dot11AuthenticateFailStation,
        dot11MultiDomainCapabilityImplemented,
        dot11MultiDomainCapabilityActivated,
        dot11CountryString }
    STATUS deprecated
    DESCRIPTION
        "Superseded by dot11SMTbase4.
        The SMTbase3 object class provides the necessary support at the STA to
        manage the processes in the STA such that the STA may work cooperatively
        as a part of an IEEE 802.11 network, when the STA is capable of
        multidomain operation. This object group should be implemented when the
        multidomain capability option is implemented."
    ::= { dot11Groups 20 }

dot11MultiDomainCapabilityGroup OBJECT-GROUP
    OBJECTS {
        dot11FirstChannelNumber,
        dot11NumberofChannels,
        dot11MaximumTransmitPowerLevel }
    STATUS current
    DESCRIPTION
        "The dot11MultiDomainCapabilityGroup object class provides the objects
        necessary to manage the channels usable by a STA, when the multidomain
        capability option is implemented."
    ::= { dot11Groups 21 }


dot11PhyHRDSSSComplianceGroup OBJECT-GROUP
    OBJECTS {
        dot11CurrentChannel,
        dot11CCAModeSupported,
        dot11CurrentCCAMode,
        dot11EDThreshold,
        dot11ShortPreambleOptionImplemented,
        dot11HRCCAModeImplemented }
    STATUS current
    DESCRIPTION
        "Attributes that configure the HRDSSS PHY for IEEE Std 802.11."
    ::= { dot11Groups 23 }

dot11PhyERPComplianceGroup OBJECT-GROUP
    OBJECTS { dot11CurrentChannel,
        dot11ShortPreambleOptionImplemented,
        dot11ShortSlotTimeOptionImplemented,
        dot11ShortSlotTimeOptionActivated }
    STATUS current
    DESCRIPTION
        "Attributes that configure the ERP."
    ::= { dot11Groups 24 }

dot11RSNAadditions OBJECT-GROUP
    OBJECTS {
        dot11RSNAActivated,
```

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```
        dot11RSNAPreauthenticationActivated }
    STATUS current
    DESCRIPTION
        "This object class provides the objects from the IEEE 802.11 MIB required
        to manage RSNA functionality. Note that additional objects for managing
        this functionality are located in the IEEE 802.11 RSN MIB."
    ::= { dot11Groups 25 }

dot11SMTbase4 OBJECT-GROUP
    OBJECTS {
        dot11MediumOccupancyLimit,
        dot11CFPollable,
        dot11CFPPeriod,
        dot11CFPMaxDuration,
        dot11AuthenticationResponseTimeout,
        dot11PrivacyOptionImplemented,
        dot11PowerManagementMode,
        dot11DesiredSSID, dot11DesiredBSSType,
        dot11OperationalRateSet,
        dot11BeaconPeriod, dot11DTIMPeriod,
        dot11AssociationResponseTimeout,
        dot11DisassociateReason,
        dot11DisassociateStation,
        dot11DeauthenticateReason,
        dot11DeauthenticateStation,
        dot11AuthenticateFailStatus,
        dot11AuthenticateFailStation,
        dot11MultiDomainCapabilityImplemented,
        dot11MultiDomainCapabilityActivated,
        dot11CountryString,
        dot11RSNAOptionImplemented }
    STATUS deprecated
    DESCRIPTION
        "Superseded by dot11SMTbase5.
        The SMTbase4 object class provides the necessary support at the IEEE STA
        to manage the processes in the STA so that the STA may work cooperatively
        as a part of an IEEE 802.11 network."
    ::= { dot11Groups 26 }

-- ********************************************************************
-- * Groups - units of compliance - RSN
-- ********************************************************************

dot11RSNBase OBJECT-GROUP
    OBJECTS {
        dot11RSNAConfigVersion,
        dot11RSNAConfigPairwiseKeysImplemented,
        dot11RSNAConfigGroupCipher,
        dot11RSNAConfigGroupRekeyMethod,
        dot11RSNAConfigGroupRekeyTime,
        dot11RSNAConfigGroupRekeyPackets,
        dot11RSNAConfigGroupRekeyStrict,
        dot11RSNAConfigPSKValue,
        dot11RSNAConfigPSKPassPhrase,
        dot11RSNAConfigGroupUpdateCount,
        dot11RSNAConfigPairwiseUpdateCount,
        dot11RSNAConfigGroupCipherSize,
        dot11RSNAConfigPairwiseCipherImplemented,
        dot11RSNAConfigPairwiseCipherActivated,
        dot11RSNAConfigPairwiseCipherSizeImplemented,
        dot11RSNAConfigAuthenticationSuiteImplemented,
        dot11RSNAConfigAuthenticationSuiteActivated,
        dot11RSNAConfigNumberOfPTKSAReplayCounters,
        dot11RSNAConfigSATimeout,
```


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```
        dot11RSNAConfigNumberOfGTKSAReplayCounters,
        dot11RSNAAuthenticationSuiteSelected,
        dot11RSNAPairwiseCipherSelected,
        dot11RSNAGroupCipherSelected,
        dot11RSNAPMKIDUsed,
        dot11RSNAAuthenticationSuiteRequested,
        dot11RSNAPairwiseCipherRequested,
        dot11RSNAGroupCipherRequested,
        dot11RSNATKIPCounterMeasuresInvoked,
        dot11RSNA4WayHandshakeFailures,
        dot11RSNAStatsSTAAddress,
        dot11RSNAStatsVersion,
        dot11RSNAStatsSelectedPairwiseCipher,
        dot11RSNAStatsTKIPICVErrors,
        dot11RSNAStatsTKIPLocalMICFailures,
        dot11RSNAStatsTKIPRemoteMICFailures,
        dot11RSNAStatsCCMPReplays,
        dot11RSNAStatsCCMPDecryptErrors,
        dot11RSNAStatsTKIPReplays,
        dot11RSNAConfigSTKKeysImplemented,
        dot11RSNAConfigSTKCipher,
        dot11RSNAConfigSTKRekeyTime,
        dot11RSNAConfigSMKUpdateCount,
        dot11RSNAConfigSTKCipherSize,
        dot11RSNAConfigNumberOfSTKSAReplayCounters,
        dot11RSNAPairwiseSTKSelected,
        dot11RSNAPreauthenticationImplemented,
        dot11RSNASMKHandshakeFailures }
    STATUS deprecated
    DESCRIPTION
        "Superseded by dot11RSNBase2.The dot11RSNBase object class provides the
        necessary support for managing RSNA functionality in the STA."
    ::= { dot11Groups 27 }

dot11RSNPMKcachingGroup OBJECT-GROUP
    OBJECTS {
        dot11RSNAConfigPMKLifetime,
        dot11RSNAConfigPMKReauthThreshold }
    STATUS current
    DESCRIPTION
        "The dot11RSNPMKcachingGroup object class provides the necessary support
        for managing PMKSA caching functionality in the STA."
    ::= { dot11Groups 28 }

dot11RSNSMKcachingGroup OBJECT-GROUP
    OBJECTS {
        dot11RSNAConfigSMKLifetime,
        dot11RSNAConfigSMKReauthThreshold }
    STATUS deprecated
    DESCRIPTION
        "Deprecated because mechanisms for use of cached SMKSAs are not defined.
        The dot11RSNSMKcachingGroup object class provides the necessary support
        for managing SMKSA caching functionality in the STA."
    ::= { dot11Groups 29 }

dot11SMTbase5 OBJECT-GROUP
    OBJECTS {
        dot11MediumOccupancyLimit,
        dot11CFPollable,
        dot11CFPPeriod,
        dot11CFPMaxDuration,
        dot11AuthenticationResponseTimeout,
        dot11PrivacyOptionImplemented,
        dot11PowerManagementMode,
```

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```
        dot11DesiredSSID, dot11DesiredBSSType,
        dot11OperationalRateSet,
        dot11BeaconPeriod, dot11DTIMPeriod,
        dot11AssociationResponseTimeout,
        dot11DisassociateReason,
        dot11DisassociateStation,
        dot11DeauthenticateReason,
        dot11DeauthenticateStation,
        dot11AuthenticateFailStatus,
        dot11AuthenticateFailStation,
        dot11MultiDomainCapabilityImplemented,
        dot11MultiDomainCapabilityActivated,
        dot11CountryString,
        dot11SpectrumManagementImplemented,
        dot11SpectrumManagementRequired,
        dot11RSNAOptionImplemented,
        dot11OperatingClassesImplemented,
        dot11OperatingClassesRequired }
    STATUS deprecated
    DESCRIPTION
        "Superseded by dot11SMTbase6.
        The SMTbase5 object class provides the necessary support at the STA to
        manage the processes in the STA so that the STA may work cooperatively as
        a part of an IEEE 802.11 network, when the STA is capable of multidomain
        operation. This object group should be implemented when the multidomain
        capability option is implemented."
    ::= { dot11Groups 30 }

dot11MACbase2 OBJECT-GROUP
    OBJECTS {
        dot11MACAddress,
        dot11GroupAddress,
        dot11GroupAddressesStatus,
        dot11RTSThreshold,
        dot11ShortRetryLimit,
        dot11LongRetryLimit,
        dot11FragmentationThreshold,
        dot11MaxTransmitMSDULifetime,
        dot11MaxReceiveLifetime,
        dot11ManufacturerID,
        dot11ProductID,
        dot11CAPLimit,
        dot11HCCWmin,
        dot11HCCWmax,
        dot11HCCAIFSN,
        dot11ADDBAResponseTimeout,
        dot11ADDTSResponseTimeout,
        dot11ChannelUtilizationBeaconIntervals,
        dot11ScheduleTimeout,
        dot11DLSResponseTimeout,
        dot11QAPMissingAckRetryLimit,
        dot11EDCAAveragingPeriod }
    STATUS deprecated
        DESCRIPTION
        "Superseded by dot11MACbase3.
        The MAC object class provides the necessary support for the access
        control, generation, and verification of frame check sequences (FCSs), and
        proper delivery of valid data to upper layers."
    ::= { dot11Groups 31 }

dot11CountersGroup2 OBJECT-GROUP
    OBJECTS {
        dot11TransmittedFragmentCount,
        dot11GroupTransmittedFrameCount,
```


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```
        dot11FailedCount,
        dot11ReceivedFragmentCount,
        dot11GroupReceivedFrameCount,
        dot11FCSErrorCount,
        dot11WEPUndecryptableCount,
        dot11TransmittedFrameCount,
        dot11QosDiscardedFragmentCount,
        dot11AssociatedStationCount,
        dot11QosCFPollsReceivedCount,
        dot11QosCFPollsUnusedCount,
        dot11QosCFPollsUnusableCount }
    STATUS deprecated
        DESCRIPTION
        "Superseded by dot11CountersGroup3.
        Attributes from the dot11CountersGroup that are not described in the
        dot11MACStatistics group. These objects are mandatory."
    ::= { dot11Groups 32 }

dot11Qosadditions OBJECT-GROUP
    OBJECTS {
--      dot11EDCATable,
        dot11EDCATableCWmin,
        dot11EDCATableCWmax,
        dot11EDCATableAIFSN,
        dot11EDCATableTXOPLimit,
        dot11EDCATableMSDULifetime,
        dot11EDCATableMandatory,

--      dot11QAPEDCATable,
        dot11QAPEDCATableCWmin,
        dot11QAPEDCATableCWmax,
        dot11QAPEDCATableAIFSN,
        dot11QAPEDCATableTXOPLimit,
        dot11QAPEDCATableMSDULifetime,
        dot11QAPEDCATableMandatory,

--      dot11QosCountersTable
        dot11QosTransmittedFragmentCount,
        dot11QosFailedCount,
        dot11QosRetryCount,
        dot11QosMultipleRetryCount,
        dot11QosFrameDuplicateCount,
        dot11QosRTSSuccessCount,
        dot11QosRTSFailureCount,
        dot11QosAckFailureCount,
        dot11QosReceivedFragmentCount,
        dot11QosTransmittedFrameCount,
        dot11QosDiscardedFrameCount,
        dot11QosMPDUsReceivedCount,
        dot11QosRetriesReceivedCount }
    STATUS current
    DESCRIPTION
        "This object class provides the objects from the IEEE 802.11 MIB required
        to manage QoS functionality."
    ::= { dot11Groups 33 }

dot11SMTbase6 OBJECT-GROUP
    OBJECTS {
        dot11MediumOccupancyLimit,
        dot11CFPollable,
        dot11CFPPeriod,
        dot11CFPMaxDuration,
        dot11AuthenticationResponseTimeout,
        dot11PrivacyOptionImplemented,
```

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```
        dot11PowerManagementMode,
        dot11DesiredSSID,
        dot11DesiredBSSType,
        dot11OperationalRateSet,
        dot11BeaconPeriod,
        dot11DTIMPeriod,
        dot11AssociationResponseTimeout,
        dot11DisassociateReason,
        dot11DisassociateStation,
        dot11DeauthenticateReason,
        dot11DeauthenticateStation,
        dot11AuthenticateFailStatus,
        dot11AuthenticateFailStation,
        dot11MultiDomainCapabilityImplemented,
        dot11MultiDomainCapabilityActivated,
        dot11CountryString,
        dot11RSNAOptionImplemented,
        dot11OperatingClassesImplemented,
        dot11OperatingClassesRequired,
        dot11QosOptionImplemented,
        dot11ImmediateBlockAckOptionImplemented,
        dot11DelayedBlockAckOptionImplemented,
        dot11DirectOptionImplemented,
        dot11APSDOptionImplemented,
        dot11QAckOptionImplemented,
        dot11QBSSLoadImplemented,
        dot11QueueRequestOptionImplemented,
        dot11TXOPRequestOptionImplemented,
        dot11MoreDataAckOptionImplemented,
        dot11AssociateInNQBSS,
        dot11DLSAllowedInQBSS,
        dot11DLSAllowed }
    STATUS deprecated
    DESCRIPTION
        "Superseded by dot11SMTbase7.
        The SMTbase6 object class provides the necessary support at the STA to
        manage the processes in the STA such that the STA may work cooperatively
        as a part of an IEEE 802.11 network."
    ::= { dot11Groups 34 }

dot11PhyOFDMComplianceGroup2 OBJECT-GROUP
    OBJECTS {
        dot11CurrentFrequency,
        dot11TIThreshold,
        dot11FrequencyBandsImplemented,
        dot11ChannelStartingFactor,
        dot11FiveMHzOperationImplemented,
        dot11TenMHzOperationImplemented,
        dot11TwentyMHzOperationImplemented,
        dot11PhyOFDMChannelWidth }
    STATUS deprecated
    DESCRIPTION
        "Superseded by dot11PhyOFDMComplianceGroup3.
        Attributes that configure the OFDM PHY for IEEE Std 802.11."
    ::= { dot11Groups 35}

dot11SMTbase7 OBJECT-GROUP
    OBJECTS{
        dot11MediumOccupancyLimit,
        dot11CFPollable,
        dot11CFPPeriod,
        dot11CFPMaxDuration,
        dot11AuthenticationResponseTimeout,
        dot11PrivacyOptionImplemented,
```


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```
        dot11PowerManagementMode,
        dot11DesiredSSID,
        dot11DesiredBSSType,
        dot11OperationalRateSet,
        dot11BeaconPeriod,
        dot11DTIMPeriod,
        dot11AssociationResponseTimeout,
        dot11DisassociateReason,
        dot11DisassociateStation,
        dot11DeauthenticateReason,
        dot11DeauthenticateStation,
        dot11AuthenticateFailStatus,
        dot11AuthenticateFailStation,
        dot11MultiDomainCapabilityImplemented,
        dot11MultiDomainCapabilityActivated,
        dot11CountryString,
        dot11SpectrumManagementImplemented,
        dot11SpectrumManagementRequired,
        dot11RSNAOptionImplemented,
        dot11OperatingClassesImplemented,
        dot11OperatingClassesRequired,
        dot11QosOptionImplemented,
        dot11ImmediateBlockAckOptionImplemented,
        dot11DelayedBlockAckOptionImplemented,
        dot11DirectOptionImplemented,
        dot11APSDOptionImplemented,
        dot11QAckOptionImplemented,
        dot11QBSSLoadImplemented,
        dot11QueueRequestOptionImplemented,
        dot11TXOPRequestOptionImplemented,
        dot11MoreDataAckOptionImplemented,
        dot11AssociateInNQBSS,
        dot11DLSAllowedInQBSS,
        dot11DLSAllowed,
        dot11AssociateStation,
        dot11AssociateID,
        dot11AssociateFailStation,
        dot11AssociateFailStatus,
        dot11ReassociateStation,
        dot11ReassociateID,
        dot11ReassociateFailStation,
        dot11ReassociateFailStatus,
        dot11RadioMeasurementImplemented,
        dot11RadioMeasurementActivated,
        dot11RMMeasurementNavSync,
        dot11RMMeasurementPilotPeriod,
        dot11RMLinkMeasurementActivated,
        dot11RMNeighborReportActivated,
        dot11RMParallelMeasurementsActivated,
        dot11RMRepeatedMeasurementsActivated,
        dot11RMBeaconPassiveMeasurementActivated,
        dot11RMBeaconActiveMeasurementActivated,
        dot11RMBeaconTableMeasurementActivated,
        dot11RMBeaconMeasurementReportingConditionsActivated,
        dot11RMFrameMeasurementActivated,
        dot11RMChannelLoadMeasurementActivated,
        dot11RMNoiseHistogramMeasurementActivated,
        dot11RMStatisticsMeasurementActivated,
        dot11RMLCIMeasurementActivated,
        dot11RMLCIAzimuthActivated,
        dot11RMTransmitStreamCategoryMeasurementActivated,
        dot11RMTriggeredTransmitStreamCategoryMeasurementActivated,
        dot11RMAPChannelReportActivated,
        dot11RMMIBActivated,
```

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```
        dot11RMMaxMeasurementDuration,
        dot11RMNonOperatingChannelMaxMeasurementDuration,
        dot11RMMeasurementPilotTransmissionInformationActivated,
        dot11RMMeasurementPilotActivated,
        dot11RMNeighborReportTSFOffsetActivated,
        dot11RMRCPIMeasurementActivated,
        dot11RMRSNIMeasurementActivated,
        dot11RMBSSAverageAccessDelayActivated,
        dot11RMBSSAvailableAdmissionCapacityActivated,
        dot11RMAntennaInformationActivated}
    STATUS deprecated
    DESCRIPTION
        "Superseded by dot11SMTbase8.
        The SMTbase7 object class provides the necessary support at the STA to
        manage the processes in the STA such that the STA may work cooperatively
        as a part of an IEEE 802.11 network, when the STA is capable of
        multidomain operation. This object group should be implemented when the
        multidomain capability option is implemented."
    ::= { dot11Groups 36 }

dot11SMTRMRequest OBJECT-GROUP
    OBJECTS {
        dot11RMRqstRowStatus,
        dot11RMRqstToken,
        dot11RMRqstRepetitions,
        dot11RMRqstIfIndex,
        dot11RMRqstType,
        dot11RMRqstTargetAdd,
        dot11RMRqstTimeStamp,
        dot11RMRqstChanNumber,
        dot11RMRqstOperatingClass,
        dot11RMRqstRndInterval,
        dot11RMRqstDuration,
        dot11RMRqstParallel,
        dot11RMRqstEnable,
        dot11RMRqstRequest,
        dot11RMRqstReport,
        dot11RMRqstDurationMandatory,
        dot11RMRqstBeaconRqstMode,
        dot11RMRqstBeaconRqstDetail,
        dot11RMRqstFrameRqstType,
        dot11RMRqstBssid,
        dot11RMRqstSSID,
        dot11RMRqstBeaconReportingCondition,
        dot11RMRqstBeaconThresholdOffset,
        dot11RMRqstSTAStatRqstGroupID,
        dot11RMRqstLCIRqstSubject,
        dot11RMRqstLCIAzimuthType,
        dot11RMRqstLCIAzimuthResolution,
        dot11RMRqstPauseTime,
        dot11RMRqstTransmitStreamPeerQSTAAddress,
        dot11RMRqstTransmitStreamTrafficIdentifier,
        dot11RMRqstTransmitStreamBin0Range,
        dot11RMRqstTrigdQoSAverageCondition,
        dot11RMRqstTrigdQoSConsecutiveCondition,
        dot11RMRqstTrigdQoSDelayCondition,
        dot11RMRqstTrigdQoSAverageThreshold,
        dot11RMRqstTrigdQoSConsecutiveThreshold,
        dot11RMRqstTrigdQoSDelayThresholdRange,
        dot11RMRqstTrigdQoSDelayThreshold,
        dot11RMRqstTrigdQoSMeasurementCount,
        dot11RMRqstTrigdQoSTimeout,
        dot11RMRqstChannelLoadReportingCondition,
        dot11RMRqstChannelLoadReference,
```


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```
        dot11RMRqstNoiseHistogramReportingCondition,
        dot11RMRqstAnpiReference,
        dot11RMRqstAPChannelReport,
        dot11RMRqstSTAStatPeerSTAAddress,
        dot11RMRqstFrameTransmitterAddress,
        dot11RMRqstVendorSpecific }
    STATUS current
    DESCRIPTION
        "The SMTRMRequest package is a set of attributes that are present if the
        STA supports the Radio Measurement service."
    ::= { dot11Groups 37 }

dot11SMTRMReport OBJECT-GROUP
    OBJECTS {
        dot11ChannelLoadRprtRqstToken,
        dot11ChannelLoadRprtIfIndex,
        dot11ChannelLoadMeasuringSTAAddr,
        dot11ChannelLoadRprtChanNumber,
        dot11ChannelLoadRprtOperatingClass,
        dot11ChannelLoadRprtActualStartTime,
        dot11ChannelLoadRprtMeasurementDuration,
        dot11ChannelLoadRprtChannelLoad,
        dot11ChannelLoadRprtVendorSpecific,
        dot11ChannelLoadRprtMeasurementMode,
        dot11NoiseHistogramRprtRqstToken,
        dot11NoiseHistogramRprtIfIndex,
        dot11NoiseHistogramMeasuringSTAAddr,
        dot11NoiseHistogramRprtChanNumber,
        dot11NoiseHistogramRprtOperatingClass,
        dot11NoiseHistogramRprtActualStartTime,
        dot11NoiseHistogramRprtMeasurementDuration,
        dot11NoiseHistogramRprtAntennaID,
        dot11NoiseHistogramRprtANPI,
        dot11NoiseHistogramRprtIPIDensity0,
        dot11NoiseHistogramRprtIPIDensity1,
        dot11NoiseHistogramRprtIPIDensity2,
        dot11NoiseHistogramRprtIPIDensity3,
        dot11NoiseHistogramRprtIPIDensity4,
        dot11NoiseHistogramRprtIPIDensity5,
        dot11NoiseHistogramRprtIPIDensity6,
        dot11NoiseHistogramRprtIPIDensity7,
        dot11NoiseHistogramRprtIPIDensity8,
        dot11NoiseHistogramRprtIPIDensity9,
        dot11NoiseHistogramRprtIPIDensity10,
        dot11NoiseHistogramRprtVendorSpecific,
        dot11NoiseHistogramRprtMeasurementMode,
        dot11BeaconRprtRqstToken,
        dot11BeaconRprtIfIndex,
        dot11BeaconMeasuringSTAAddr,
        dot11BeaconRprtChanNumber,
        dot11BeaconRprtOperatingClass,
        dot11BeaconRprtActualStartTime,
        dot11BeaconRprtMeasurementDuration,
        dot11BeaconRprtPhyType,
        dot11BeaconRprtReportedFrameType,
        dot11BeaconRprtRCPI,
        dot11BeaconRprtRSNI,
        dot11BeaconRprtBSSID,
        dot11BeaconRprtAntennaID,
        dot11BeaconRprtParentTSF,
        dot11BeaconRprtReportedFrameBody,
        dot11BeaconRprtVendorSpecific,
        dot11BeaconRprtMeasurementMode,
        dot11FrameRprtIfIndex,
```

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```
        dot11FrameRprtRqstToken,
        dot11FrameRprtChanNumber,
        dot11FrameRprtOperatingClass,
        dot11FrameRprtActualStartTime,
        dot11FrameRprtMeasurementDuration,
        dot11FrameRprtTransmitSTAAddress,
        dot11FrameRprtBSSID,
        dot11FrameRprtPhyType,
        dot11FrameRprtAvgRCPI,
        dot11FrameRprtLastRSNI,
        dot11FrameRprtLastRCPI,
        dot11FrameRprtAntennaID,
        dot11FrameRprtNumberFrames,
        dot11FrameRprtVendorSpecific,
        dot11FrameRptMeasurementMode,
        dot11STAStatisticsReportToken,
        dot11STAStatisticsIfIndex,
        dot11STAStatisticsSTAAddress,
        dot11STAStatisticsMeasurementDuration,
        dot11STAStatisticsGroupID,
        dot11STAStatisticsTransmittedFragmentCount,
        dot11STAStatisticsGroupTransmittedFrameCount,
        dot11STAStatisticsFailedCount,
        dot11STAStatisticsRetryCount,
        dot11STAStatisticsMultipleRetryCount,
        dot11STAStatisticsFrameDuplicateCount,
        dot11STAStatisticsRTSSuccessCount,
        dot11STAStatisticsRTSFailureCount,
        dot11STAStatisticsAckFailureCount,
        dot11STAStatisticsQosTransmittedFragmentCount,
        dot11STAStatisticsQosFailedCount,
        dot11STAStatisticsQosRetryCount,
        dot11STAStatisticsQosMultipleRetryCount,
        dot11STAStatisticsQosFrameDuplicateCount,
        dot11STAStatisticsQosRTSSuccessCount,
        dot11STAStatisticsQosRTSFailureCount,
        dot11STAStatisticsQosAckFailureCount,
        dot11STAStatisticsQosReceivedFragmentCount,
        dot11STAStatisticsQosTransmittedFrameCount,
        dot11STAStatisticsQosDiscardedFrameCount,
        dot11STAStatisticsQosMPDUsReceivedCount,
        dot11STAStatisticsQosRetriesReceivedCount,
        dot11STAStatisticsReceivedFragmentCount,
        dot11STAStatisticsGroupReceivedFrameCount,
        dot11STAStatisticsFCSErrorCount,
        dot11STAStatisticsTransmittedFrameCount,
        dot11STAStatisticsAPAverageAccessDelay,
        dot11STAStatisticsAverageAccessDelayBestEffort,
        dot11STAStatisticsAverageAccessDelayBackground,
        dot11STAStatisticsAverageAccessDelayVideo,
        dot11STAStatisticsAverageAccessDelayVoice,
        dot11STAStatisticsStationCount,
        dot11STAStatisticsChannelUtilization,
        dot11STAStatisticsVendorSpecific,
        dot11STAStatisticsRprtMeasurementMode,
        dot11LCIReportToken,
        dot11LCIIfIndex,
        dot11LCISTAAddress,
        dot11LCILatitudeUncertainty,
        dot11LCILatitudeInteger,
        dot11LCILatitudeFraction,
        dot11LCILongitudeUncertainty,
        dot11LCILongitudeInteger,
        dot11LCILongitudeFraction,
```


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```
        dot11LCIAltitudeType,
        dot11LCIAltitudeUncertainty,
        dot11LCIAltitude,
        dot11LCIDatum,
        dot11LCIAzimuthType,
        dot11LCIAzimuthResolution,
        dot11LCIAzimuth,
        dot11LCIVendorSpecific,
        dot11LCIRprtMeasurementMode,
        dot11TransmitStreamRprtRqstToken,
        dot11TransmitStreamRprtIfIndex,
        dot11TransmitStreamMeasuringSTAAddr,
        dot11TransmitStreamRprtActualStartTime,
        dot11TransmitStreamRprtMeasurementDuration,
        dot11TransmitStreamRprtPeerSTAAddress,
        dot11TransmitStreamRprtTID,
        dot11TransmitStreamRprtAverageQueueDelay,
        dot11TransmitStreamRprtAverageTransmitDelay,
        dot11TransmitStreamRprtTransmittedMSDUCount,
        dot11TransmitStreamRprtMSDUDiscardedCount,
        dot11TransmitStreamRprtMSDUFailedCount,
        dot11TransmitStreamRprtMultipleRetryCount,
        dot11TransmitStreamRprtCFPollsLostCount,
        dot11TransmitStreamRprtBin0Range,
        dot11TransmitStreamRprtDelayHistogram,
        dot11TransmitStreamRprtReason,
        dot11TransmitStreamRprtVendorSpecific,
        dot11TransmitStreamRprtMeasurementMode }
    STATUS deprecated
    DESCRIPTION
        "Superseded by dot11SMTRMReport2.The SMTRMReport package is a set of
        attributes that are present if the STA supports the Radio Measurement ser-
        vice."
    ::= { dot11Groups 38 }

dot11SMTRMConfig OBJECT-GROUP
    OBJECTS {
        dot11APChannelReportIfIndex,
        dot11APChannelReportOperatingClass,
        dot11APChannelReportChannelList,
        dot11RMNeighborReportIfIndex,
        dot11RMNeighborReportBSSID,
        dot11RMNeighborReportAPReachability,
        dot11RMNeighborReportSecurity,
        dot11RMNeighborReportCapSpectrumMgmt,
        dot11RMNeighborReportCapQoS,
        dot11RMNeighborReportCapAPSD,
        dot11RMNeighborReportCapRM,
        dot11RMNeighborReportCapDelayBlockAck,
        dot11RMNeighborReportCapImmediateBlockAck,
        dot11RMNeighborReportKeyScope,
        dot11RMNeighborReportChannelNumber,
        dot11RMNeighborReportOperatingClass,
        dot11RMNeighborReportPhyType,
        dot11RMNeighborReportNeighborTSFInfo,
        dot11RMNeighborReportPilotInterval,
        dot11RMNeighborReportPilotMultipleBSSID,
        dot11RMNeighborReportRMEnabledCapabilities,
        dot11RMNeighborReportVendorSpecific,
        dot11RMNeighborReportRowStatus,
        dot11RMNeighborReportCapHT,
        dot11RMNeighborReportHTLDPCCodingCap,
        dot11RMNeighborReportHTSupportedChannelWidthSet,
        dot11RMNeighborReportHTSMPowerSave,
```

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```
        dot11RMNeighborReportHTGreenfield,
        dot11RMNeighborReportHTShortGIfor20MHz,
        dot11RMNeighborReportHTShortGIfor40MHz,
        dot11RMNeighborReportHTTxSTBC,
        dot11RMNeighborReportHTRxSTBC,
        dot11RMNeighborReportHTDelayedBlockAck,
        dot11RMNeighborReportHTMaxAMSDULength,
        dot11RMNeighborReportHTDSSCCKModein40MHz,
        dot11RMNeighborReportHTFortyMHzIntolerant,
        dot11RMNeighborReportHTLSIGTXOPProtectionSupport,
        dot11RMNeighborReportHTMaxAMPDULengthExponent,
        dot11RMNeighborReportHTMinMPDUStartSpacing,
        dot11RMNeighborReportHTRxMCSBitMask,
        dot11RMNeighborReportHTRxHighestSupportedDataRate,
        dot11RMNeighborReportHTTxMCSSetDefined,
        dot11RMNeighborReportHTTxRxMCSSetNotEqual,
        dot11RMNeighborReportHTTxMaxNumberSpatialStreamsSupported,
        dot11RMNeighborReportHTTxUnequalModulationSupported,
        dot11RMNeighborReportHTPCO,
        dot11RMNeighborReportHTPCOTransitionTime,
        dot11RMNeighborReportHTMCSFeedback,
        dot11RMNeighborReportHTCSupport,
        dot11RMNeighborReportHTRDResponder,
        dot11RMNeighborReportHTImplictTransmitBeamformingReceivingCap,
        dot11RMNeighborReportHTReceiveStaggeredSoundingCap,
        dot11RMNeighborReportHTTransmitStaggeredSoundingCap,
        dot11RMNeighborReportHTReceiveNDPCap,
        dot11RMNeighborReportHTTransmitNDPCap,
        dot11RMNeighborReportHTImplicitTransmitBeamformingCap,
        dot11RMNeighborReportHTTransmitBeamformingCalibration,
        dot11RMNeighborReportHTExplicitCSITransmitBeamformingCap,
        dot11RMNeighborReportHTExplicitNonCompressedSteeringCap,
        dot11RMNeighborReportHTExplicitCompressedSteeringCap,
        dot11RMNeighborReportHTExplicitTransmitBeamformingFeedback,
        dot11RMNbRprtHTExplicitNonCompressedBeamformingFeedbackCap,
        dot11RMNeighborReportHTExplicitCompressedBeamformingFeedbackCap,
        dot11RMNeighborReportHTTransmitBeamformingMinimalGrouping,
        dot11RMNbRprtHTCSINumberofTxBeamformingAntennasSuppt,
        dot11RMNbRprtHTNonCompressedSteeringNumofTxBmfmingAntennasSuppt,
        dot11RMNbRprtHTCompressedSteeringNumberofTxBmfmingAntennasSuppt,
        dot11RMNbRprtHTCSIMaxNumberofRowsTxBeamformingSuppt,
        dot11RMNeighborReportHTTransmitBeamformingChannelEstimationCap,
        dot11RMNeighborReportHTAntSelectionCap,
        dot11RMNeighborReportHTExplicitCSIFeedbackBasedTxASELCap,
        dot11RMNeighborReportHTAntIndicesFeedbackBasedTxASELCap,
        dot11RMNeighborReportHTExplicitCSIFeedbackBasedCap,
        dot11RMNeighborReportHTAntIndicesFeedbackCap,
        dot11RMNeighborReportHTRxASELCap,
        dot11RMNeighborReportHTTxSoundingPPDUsCap,
        dot11RMNeighborReportHTInfoPrimaryChannel,
        dot11RMNeighborReportHTInfoSecChannelOffset,
        dot11RMNeighborReportHTInfoSTAChannelWidth,
        dot11RMNeighborReportHTInfoRIFSMode,
        dot11RMNeighborReportHTInfoProtection,
        dot11RMNeighborReportHTInfoNonGreenfieldHTSTAsPresent,
        dot11RMNeighborReportHTInfoOBSSNonHTSTAsPresent,
        dot11RMNeighborReportHTInfoDualBeacon,
        dot11RMNeighborReportHTInfoDualCTSProtection,
        dot11RMNeighborReportHTInfoSTBCBeacon,
        dot11RMNeighborReportHTInfoLSIGTXOPProtectionSup,
        dot11RMNeighborReportHTInfoPCOActive,
        dot11RMNeighborReportHTInfoPCOPhase,
        dot11RMNeighborReportHTInfoBasicMCSSet,
        dot11RMNeighborReportHTSecChannelOffset,
```


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```
        dot11RMNeighborReportExtCapPSMPSupport,
        dot11RMNeighborReportExtCapSPSMPSup,
        dot11RMNeighborReportExtCapServiceIntervalGranularity }
    STATUS deprecated
    DESCRIPTION
        "Superseded by dot11SMTRMConfig2. The SMTRMConfig package is a set of
        attributes that are present if the STA supports the Radio Measurement ser-
        vice."
    ::= { dot11Groups 39 }

dot11FTComplianceGroup OBJECT-GROUP
    OBJECTS {
        -- Dot11FastBSSTransitionConfigEntry
        dot11FastBSSTransitionActivated,
        dot11FTMobilityDomainID,
        dot11FTOverDSActivated,
        dot11FTResourceRequestSupported,
        dot11FTR0KeyHolderID,
        dot11FTR0KeyLifetime,
        dot11FTR1KeyHolderID,
        dot11FTReassociationDeadline,
        -- Dot11RMNeighborReportEntry
        dot11RMNeighborReportMobilityDomain }
    STATUS current
    DESCRIPTION
        "This object class provides the objects from the IEEE 802.11 MIB required
        to manage fast BSS transition functionality. Note that additional objects
        for managing this functionality are located in the dot11FastBSS
        TransitionConfigTable."
    ::= { dot11Groups 40}

dot11SMTbase8 OBJECT-GROUP
    OBJECTS {
        dot11MediumOccupancyLimit,
        dot11CFPollable,
        dot11CFPPeriod,
        dot11CFPMaxDuration,
        dot11AuthenticationResponseTimeout,
        dot11PrivacyOptionImplemented,
        dot11PowerManagementMode,
        dot11DesiredSSID, dot11DesiredBSSType,
        dot11OperationalRateSet,
        dot11BeaconPeriod, dot11DTIMPeriod,
        dot11AssociationResponseTimeout,
        dot11DisassociateReason,
        dot11DisassociateStation,
        dot11DeauthenticateReason,
        dot11DeauthenticateStation,
        dot11AuthenticateFailStatus,
        dot11AuthenticateFailStation,
        dot11MultiDomainCapabilityImplemented,
        dot11MultiDomainCapabilityActivated,
        dot11CountryString,
        dot11SpectrumManagementImplemented,
        dot11SpectrumManagementRequired,
        dot11RSNAOptionImplemented,
        dot11OperatingClassesImplemented,
        dot11OperatingClassesRequired,
        dot11QosOptionImplemented,
        dot11ImmediateBlockAckOptionImplemented,
        dot11DelayedBlockAckOptionImplemented,
        dot11DirectOptionImplemented,
        dot11APSDOptionImplemented,
        dot11QAckOptionImplemented,
```

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```
        dot11QBSSLoadImplemented,
        dot11QueueRequestOptionImplemented,
        dot11TXOPRequestOptionImplemented,
        dot11MoreDataAckOptionImplemented,
        dot11AssociateInNQBSS,
        dot11DLSAllowedInQBSS,
        dot11DLSAllowed,
        dot11AssociateStation,
        dot11AssociateID,
        dot11AssociateFailStation,
        dot11AssociateFailStatus,
        dot11ReassociateStation,
        dot11ReassociateID,
        dot11ReassociateFailStation,
        dot11ReassociateFailStatus,
        dot11RadioMeasurementImplemented,
        dot11RadioMeasurementActivated,
        dot11RMMeasurementNavSync,
        dot11RMMeasurementPilotPeriod,
        dot11RMLinkMeasurementActivated,
        dot11RMNeighborReportActivated,
        dot11RMParallelMeasurementsActivated,
        dot11RMRepeatedMeasurementsActivated,
        dot11RMBeaconPassiveMeasurementActivated,
        dot11RMBeaconActiveMeasurementActivated,
        dot11RMBeaconTableMeasurementActivated,
        dot11RMBeaconMeasurementReportingConditionsActivated,
        dot11RMFrameMeasurementActivated,
        dot11RMChannelLoadMeasurementActivated,
        dot11RMNoiseHistogramMeasurementActivated,
        dot11RMStatisticsMeasurementActivated,
        dot11RMLCIMeasurementActivated,
        dot11RMLCIAzimuthActivated,
        dot11RMTransmitStreamCategoryMeasurementActivated,
        dot11RMTriggeredTransmitStreamCategoryMeasurementActivated,
        dot11RMAPChannelReportActivated,
        dot11RMMIBActivated,
        dot11RMMaxMeasurementDuration,
        dot11RMNonOperatingChannelMaxMeasurementDuration,
        dot11RMMeasurementPilotTransmissionInformationActivated,
        dot11RMMeasurementPilotActivated,
        dot11RMNeighborReportTSFOffsetActivated,
        dot11RMRCPIMeasurementActivated,
        dot11RMRSNIMeasurementActivated,
        dot11RMBSSAverageAccessDelayActivated,
        dot11RMBSSAvailableAdmissionCapacityActivated,
        dot11RMAntennaInformationActivated,
        dot11FastBSSTransitionImplemented }
    STATUS deprecated
    DESCRIPTION
        "Superseded by dot11SMTbase9.
        The SMTbase8 object class provides the necessary support at the STA to
        manage the processes in the STA so that the STA may work cooperatively as
        a part of an IEEE 802.11 network, when the STA is capable of multidomain
        operation. This object group should be implemented when the multidomain
        capability option is implemented."
    ::= { dot11Groups 41 }

dot11PhyOFDMComplianceGroup3 OBJECT-GROUP
    OBJECTS {
        dot11CurrentFrequency,
        dot11FrequencyBandsImplemented,
        dot11ChannelStartingFactor,
        dot11FiveMHzOperationImplemented,
```


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```
        dot11TenMHzOperationImplemented,
        dot11TwentyMHzOperationImplemented,
        dot11PhyOFDMChannelWidth,
        dot11OFDMCCAEDImplemented,
        dot11OFDMCCAEDRequired,
        dot11OFDMEDThreshold,
        dot11STATransmitPowerClass,
        dot11ACRType }
    STATUS current
    DESCRIPTION
        "Attributes that configure the OFDM PHY for IEEE Std 802.11."
    ::= { dot11Groups 42}

dot11SMTbase9 OBJECT-GROUP
    OBJECTS {
        dot11MediumOccupancyLimit,
        dot11CFPollable,
        dot11CFPPeriod,
        dot11CFPMaxDuration,
        dot11AuthenticationResponseTimeout,
        dot11PrivacyOptionImplemented,
        dot11PowerManagementMode,
        dot11DesiredSSID, dot11DesiredBSSType,
        dot11OperationalRateSet,
        dot11BeaconPeriod, dot11DTIMPeriod,
        dot11AssociationResponseTimeout,
        dot11DisassociateReason,
        dot11DisassociateStation,
        dot11DeauthenticateReason,
        dot11DeauthenticateStation,
        dot11AuthenticateFailStatus,
        dot11AuthenticateFailStation,
        dot11MultiDomainCapabilityImplemented,
        dot11MultiDomainCapabilityActivated,
        dot11CountryString,
        dot11RSNAOptionImplemented,
        dot11OperatingClassesImplemented,
        dot11OperatingClassesRequired,
        dot11QosOptionImplemented,
        dot11ImmediateBlockAckOptionImplemented,
        dot11DelayedBlockAckOptionImplemented,
        dot11DirectOptionImplemented,
        dot11APSDOptionImplemented,
        dot11QAckOptionImplemented,
        dot11QBSSLoadImplemented,
        dot11QueueRequestOptionImplemented,
        dot11TXOPRequestOptionImplemented,
        dot11MoreDataAckOptionImplemented,
        dot11AssociateInNQBSS,
        dot11DLSAllowedInQBSS,
        dot11DLSAllowed,
        dot11RadioMeasurementImplemented,
        dot11RadioMeasurementActivated,
        dot11FastBSSTransitionImplemented,
        dot11LCIDSEImplemented,
        dot11LCIDSERequired,
        dot11DSERequired,
        dot11ExtendedChannelSwitchActivated }
    STATUS deprecated
    DESCRIPTION
        "Superseded by dot11SMTbase10.
        The SMTbase9 object class provides the necessary support at the STA to
        manage the processes in the STA such that the STA may work cooperatively
        as a part of an IEEE 802.11 network, when the STA is capable of
```

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```
        multidomain operation. This object group should be implemented when the
        multidomain capability option is implemented."
    ::= { dot11Groups 43 }

dot11PhyAntennaComplianceGroup2 OBJECT-GROUP
    OBJECTS {
        dot11CurrentTxAntenna,
        dot11DiversitySupportImplemented,
        dot11CurrentRxAntenna,
        dot11AntennaSelectionOptionImplemented,
        dot11TransmitExplicitCSIFeedbackASOptionImplemented,
        dot11TransmitIndicesFeedbackASOptionImplemented,
        dot11ExplicitCSIFeedbackASOptionImplemented,
        dot11TransmitIndicesComputationASOptionImplemented,
        dot11ReceiveAntennaSelectionOptionImplemented }
    STATUS current
    DESCRIPTION
        "Attributes for Data Rates for IEEE Std 802.11."
    ::= { dot11Groups 44 }

dot11MACbase3 OBJECT-GROUP
    OBJECTS {
        dot11MACAddress,
        dot11GroupAddress,
        dot11GroupAddressesStatus,
        dot11RTSThreshold,
        dot11ShortRetryLimit,
        dot11LongRetryLimit,
        dot11FragmentationThreshold,
        dot11MaxTransmitMSDULifetime,
        dot11MaxReceiveLifetime,
        dot11ManufacturerID,
        dot11ProductID,
        dot11CAPLimit,
        dot11HCCWmin,
        dot11HCCWmax,
        dot11HCCAIFSN,
        dot11ADDBAResponseTimeout,
        dot11ADDTSResponseTimeout,
        dot11ChannelUtilizationBeaconIntervals,
        dot11ScheduleTimeout,
        dot11DLSResponseTimeout,
        dot11QAPMissingAckRetryLimit,
        dot11EDCAAveragingPeriod,
        dot11HTProtection,
        dot11RIFSMode,
        dot11PSMPControlledAccess,
        dot11ServiceIntervalGranularity,
        dot11DualCTSProtection,
        dot11LSIGTXOPFullProtectionActivated,
        dot11NonGFEntitiesPresent, dot11PCOActivated,
        dot11PCOFortyMaxDuration,
        dot11PCOTwentyMaxDuration,
        dot11PCOFortyMinDuration,
        dot11PCOTwentyMinDuration }
    STATUS deprecated
    DESCRIPTION
        "Superseded by dot11MACbase4.
        The MAC object class provides the necessary support for the access
        control, generation, and verification of frame check sequences (FCSs), and
        proper delivery of valid data to upper layers."
    ::= { dot11Groups 45 }

dot11CountersGroup3 OBJECT-GROUP
```


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```
    OBJECTS {
        dot11TransmittedFragmentCount,
        dot11TransmittedFrameCount,
        dot11FailedCount,
        dot11ReceivedFragmentCount,
        dot11GroupReceivedFrameCount,
        dot11FCSErrorCount,
        dot11WEPUndecryptableCount,
        dot11TransmittedFrameCount,
        dot11QosDiscardedFragmentCount,
        dot11AssociatedStationCount,
        dot11QosCFPollsReceivedCount,
        dot11QosCFPollsUnusedCount,
        dot11QosCFPollsUnusableCount,
        dot11QosCFPollsLostCount,
        dot11TransmittedAMSDUCount,
        dot11FailedAMSDUCount,
        dot11RetryAMSDUCount,
        dot11MultipleRetryAMSDUCount,
        dot11TransmittedOctetsInAMSDUCount,
        dot11AMSDUAckFailureCount,
        dot11ReceivedAMSDUCount,
        dot11ReceivedOctetsInAMSDUCount,
        dot11TransmittedAMPDUCount,
        dot11TransmittedMPDUsInAMPDUCount,
        dot11TransmittedOctetsInAMPDUCount,
        dot11AMPDUReceivedCount,
        dot11MPDUInReceivedAMPDUCount,
        dot11ReceivedOctetsInAMPDUCount,
        dot11AMPDUDelimiterCRCErrorCount,
        dot11ImplicitBARFailureCount,
        dot11ExplicitBARFailureCount,
        dot11ChannelWidthSwitchCount,
        dot11TwentyMHzFrameTransmittedCount,
        dot11FortyMHzFrameTransmittedCount,
        dot11TwentyMHzFrameReceivedCount,
        dot11FortyMHzFrameReceivedCount,
        dot11PSMPUTTGrantDuration,
        dot11PSMPUTTUsedDuration,
        dot11GrantedRDGUsedCount,
        dot11GrantedRDGUnusedCount,
        dot11TransmittedFramesInGrantedRDGCount,
        dot11TransmittedOctetsInGrantedRDGCount,
        dot11BeamformingFrameCount,
        dot11DualCTSSuccessCount,
        dot11DualCTSFailureCount,
        dot11STBCCTSSuccessCount,
        dot11STBCCTSFailureCount,
        dot11nonSTBCCTSSuccessCount,
        dot11nonSTBCCTSFailureCount,
        dot11RTSLSIGSuccessCount,
        dot11RTSLSIGFailureCount}
    STATUS deprecated
    DESCRIPTION
        "Superseded by dot11CountersGroup4.
        Attributes from the dot11CountersGroup that are not described in the
        dot11MACStatistics group. These objects are mandatory."
    ::= { dot11Groups 46 }

dot11SMTbase10 OBJECT-GROUP
    OBJECTS {
        dot11MediumOccupancyLimit,
        dot11CFPollable,
        dot11CFPPeriod,
```

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```
        dot11CFPMaxDuration,
        dot11AuthenticationResponseTimeout,
        dot11PrivacyOptionImplemented,
        dot11PowerManagementMode,
        dot11DesiredSSID,
        dot11DesiredBSSType,
        dot11OperationalRateSet,
        dot11BeaconPeriod,
        dot11DTIMPeriod,
        dot11AssociationResponseTimeout,
        dot11DisassociateReason,
        dot11DisassociateStation,
        dot11DeauthenticateReason,
        dot11DeauthenticateStation,
        dot11AuthenticateFailStatus,
        dot11AuthenticateFailStation,
        dot11MultiDomainCapabilityImplemented,
        dot11MultiDomainCapabilityActivated,
        dot11CountryString,
        dot11RSNAOptionImplemented,
        dot11OperatingClassesImplemented,
        dot11OperatingClassesRequired,
        dot11QosOptionImplemented,
        dot11ImmediateBlockAckOptionImplemented,
        dot11DelayedBlockAckOptionImplemented,
        dot11DirectOptionImplemented,
        dot11APSDOptionImplemented,
        dot11QAckOptionImplemented,
        dot11QBSSLoadImplemented,
        dot11QueueRequestOptionImplemented,
        dot11TXOPRequestOptionImplemented,
        dot11MoreDataAckOptionImplemented,
        dot11AssociateInNQBSS,
        dot11DLSAllowedInQBSS,
        dot11DLSAllowed,
        dot11AssociateStation,
        dot11AssociateID,
        dot11AssociateFailStation,
        dot11AssociateFailStatus,
        dot11ReassociateStation,
        dot11ReassociateID,
        dot11ReassociateFailStation,
        dot11ReassociateFailStatus,
        dot11RadioMeasurementImplemented,
        dot11RadioMeasurementActivated,
        dot11FastBSSTransitionImplemented,
        dot11LCIDSEImplemented,
        dot11LCIDSERequired,
        dot11DSERequired,
        dot11ExtendedChannelSwitchActivated,
        dot11HighThroughputOptionImplemented,
        dot11RSNAPBACRequired,
        dot11PSMPOptionImplemented }
    STATUS deprecated
    DESCRIPTION
        "Superseded by dot11SMTbase 11.
        The SMTbase10 object class provides the necessary support at the STA to
        manage the processes in the STA such that the STA may work cooperatively
        as a part of an IEEE 802.11 network."
    ::= { dot11Groups 47 }

dot11PhyMCSGroup OBJECT-GROUP
    OBJECTS {
        dot11SupportedHTMCSTxValue,
```



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```
        dot11SupportedHTMCSRxValue }
    STATUS current
    DESCRIPTION
        "Attributes for MCS for IEEE 802.11 HT."
    ::= { dot11Groups 48 }

dot11PhyHTComplianceGroup OBJECT-GROUP
    OBJECTS {
        dot11HighThroughputOptionImplemented,
        dot11FortyMHzOperationImplemented,
        dot11FortyMHzOperationActivated,
        dot11FortyMHzIntolerant,
        dot11FortyMHzOptionImplemented,
        dot11CurrentPrimaryChannel,
        dot11CurrentSecondaryChannel,
        dot11HTGreenfieldOptionImplemented,
        dot11HTGreenfieldOptionActivated,
        dot11ShortGIOptionInTwentyImplemented,
        dot11ShortGIOptionInTwentyActivated,
        dot11ShortGIOptionInFortyImplemented,
        dot11ShortGIOptionInFortyActivated,
        dot11LDPCCodingOptionImplemented,
        dot11LDPCCodingOptionActivated,
        dot11TxSTBCOptionImplemented,
        dot11TxSTBCOptionActivated,
        dot11RxSTBCOptionImplemented,
        dot11RxSTBCOptionActivated,
        dot11BeamFormingOptionImplemented,
        dot11BeamFormingOptionActivated,
        dot11NumberOfSpatialStreamsImplemented,
        dot11NumberOfSpatialStreamsActivated,
        dot11HighestSupportedDataRate,
        dot11TxMCSSetDefined,
        dot11TxRxMCSSetNotEqual,
        dot11TxMaximumNumberSpatialStreamsSupported,
        dot11TxUnequalModulationSupported,
        dot11TransmitSoundingPPDUOptionImplemented,
        dot11NumberOfActiveRxAntennas  }
    STATUS current
    DESCRIPTION
        "Attributes that configure the HT PHY for IEEE Std 802.11."
    ::= { dot11Groups 49 }

dot11HTMACAdditions OBJECT-GROUP
    OBJECTS {
        dot11HTOperationalMCSSet,
        dot11MIMOPowerSave,
        dot11NDelayedBlockAckOptionImplemented,
        dot11MaxAMSDULength,
        dot11STBCControlFrameOptionImplemented,
        dot11LsigTxopProtectionOptionImplemented,
        dot11MaxRxAMPDUFactor,
        dot11MinimumMPDUStartSpacing,
        dot11PCOOptionImplemented,
        dot11TransitionTime,
        dot11MCSFeedbackOptionImplemented,
        dot11HTControlFieldSupported,
        dot11RDResponderOptionImplemented,
        dot11BSSWidthTriggerScanInterval,
        dot11BSSWidthChannelTransitionDelayFactor,
        dot11OBSSScanPassiveDwell,
        dot11OBSSScanActiveDwell,
        dot11OBSSScanPassiveTotalPerChannel,
        dot11OBSSScanActiveTotalPerChannel,
```

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```
        dot112040BSSCoexistenceManagementSupport,
        dot11OBSSScanActivityThreshold,
        dot11SPPAMSDUCapable,
        dot11SPPAMSDURequired }
    STATUS deprecated
    DESCRIPTION
        "Superseded by dot11HTMACAdditions2 as dot11HTMACAdditions contains an
        object no longer used by IEEE Std 802.11
        Attributes that configure the HT PHY for IEEE Std 802.11."
    ::= { dot11Groups 50 }

dot11TransmitBeamformingGroup OBJECT-GROUP
    OBJECTS {
        dot11ReceiveStaggerSoundingOptionImplemented,
        dot11TransmitStaggerSoundingOptionImplemented,
        dot11ReceiveNDPOptionImplemented,
        dot11TransmitNDPOptionImplemented,
        dot11ImplicitTransmitBeamformingOptionImplemented,
        dot11CalibrationOptionImplemented,
        dot11ExplicitCSITransmitBeamformingOptionImplemented,
        dot11ExplicitNonCompressedBeamformingMatrixOptionImplemented,
        dot11ExplicitTransmitBeamformingCSIFeedbackOptionImplemented,
        dot11ExplicitNonCompressedBeamformingFeedbackOptionImplemented,
        dot11ExplicitCompressedBeamformingFeedbackOptionImplemented,
        dot11NumberBeamFormingCSISupportAntenna,
        dot11NumberNonCompressedBeamformingMatrixSupportAntenna,
        dot11NumberCompressedBeamformingMatrixSupportAntenna }
    STATUS current
    DESCRIPTION
        "Attributes that configure the Beamforming for IEEE 802.11 HT."
    ::= { dot11Groups 51 }


dot11SMTbase11 OBJECT-GROUP
    OBJECTS {
        dot11MediumOccupancyLimit,
        dot11CFPollable,
        dot11CFPPeriod,
        dot11CFPMaxDuration,
        dot11AuthenticationResponseTimeout,
        dot11PrivacyOptionImplemented,
        dot11PowerManagementMode,
        dot11DesiredSSID,
        dot11DesiredBSSType,
        dot11OperationalRateSet,
        dot11BeaconPeriod,
        dot11DTIMPeriod,
        dot11AssociationResponseTimeout,
        dot11DisassociateReason,
        dot11DisassociateStation,
        dot11DeauthenticateReason,
        dot11DeauthenticateStation,
        dot11AuthenticateFailStatus,
        dot11AuthenticateFailStation,
        dot11MultiDomainCapabilityImplemented,
        dot11MultiDomainCapabilityActivated,
        dot11CountryString,
        dot11SpectrumManagementImplemented,
        dot11SpectrumManagementRequired,
        dot11RSNAOptionImplemented,
        dot11OperatingClassesImplemented,
        dot11OperatingClassesRequired,
        dot11QosOptionImplemented,
        dot11ImmediateBlockAckOptionImplemented,
```


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```
        dot11DelayedBlockAckOptionImplemented,
        dot11DirectOptionImplemented,
        dot11APSDOptionImplemented,
        dot11QAckOptionImplemented,
        dot11QBSSLoadImplemented,
        dot11QueueRequestOptionImplemented,
        dot11TXOPRequestOptionImplemented,
        dot11MoreDataAckOptionImplemented,
        dot11AssociateInNQBSS,
        dot11DLSAllowedInQBSS,
        dot11DLSAllowed,
        dot11AssociateStation,
        dot11AssociateID,
        dot11AssociateFailStation,
        dot11AssociateFailStatus,
        dot11ReassociateStation,
        dot11ReassociateID,
        dot11ReassociateFailStation,
        dot11ReassociateFailStatus,
        dot11RadioMeasurementImplemented,
        dot11RadioMeasurementActivated,
        dot11RMMeasurementNavSync,
        dot11RMMeasurementPilotPeriod,
        dot11RMLinkMeasurementActivated,
        dot11RMNeighborReportActivated,
        dot11RMParallelMeasurementsActivated,
        dot11RMRepeatedMeasurementsActivated,
        dot11RMBeaconPassiveMeasurementActivated,
        dot11RMBeaconActiveMeasurementActivated,
        dot11RMBeaconTableMeasurementActivated,
        dot11RMBeaconMeasurementReportingConditionsActivated,
        dot11RMFrameMeasurementActivated,
        dot11RMChannelLoadMeasurementActivated,
        dot11RMNoiseHistogramMeasurementActivated,
        dot11RMStatisticsMeasurementActivated,
        dot11RMLCIMeasurementActivated,
        dot11RMLCIAzimuthActivated,
        dot11RMTransmitStreamCategoryMeasurementActivated,
        dot11RMTriggeredTransmitStreamCategoryMeasurementActivated,
        dot11RMAPChannelReportActivated,
        dot11RMMIBActivated,
        dot11RMMaxMeasurementDuration,
        dot11RMNonOperatingChannelMaxMeasurementDuration,
        dot11RMMeasurementPilotTransmissionInformationActivated,
        dot11RMMeasurementPilotActivated,
        dot11RMNeighborReportTSFOffsetActivated,
        dot11RMRCPIMeasurementActivated,
        dot11RMRSNIMeasurementActivated,
        dot11RMBSSAverageAccessDelayActivated,
        dot11RMBSSAvailableAdmissionCapacityActivated,
        dot11FastBSSTransitionImplemented,
        dot11LCIDSEImplemented,
        dot11LCIDSERequired,
        dot11DSERequired,
        dot11ExtendedChannelSwitchActivated,
        dot11HighThroughputOptionImplemented,
        dot11WirelessManagementImplemented,
        dot11RSNAPBACRequired,
        dot11PSMPOptionImplemented }
    STATUS deprecated
    DESCRIPTION
        "Superseded by dot11SMTbase12.
        The SMTbase11 object class provides the necessary support at the STA to
        manage the processes in the STA so that the STA may work cooperatively as
```

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```
        a part of an IEEE 802.11 network, when the STA is capable of multidomain
        operation. This object group should be implemented when the multidomain
        capability option is implemented."
    ::= { dot11Groups 53 }

dot11SMTWNMRequest OBJECT-GROUP
    OBJECTS {                                                   dot11WNMRqstRowSta-
        tus,
        dot11WNMRqstToken,
        dot11WNMRqstIfIndex,
        dot11WNMRqstType,
        dot11WNMRqstTargetAdd,
        dot11WNMRqstTimeStamp,
        dot11WNMRqstRndInterval,
        dot11WNMRqstDuration,
        dot11WNMRqstMcstGroup,
        dot11WNMRqstMcstTrigCon,
        dot11WNMRqstMcstTrigInactivityTimeout,
        dot11WNMRqstMcstTrigReactDelay,
        dot11WNMRqstLCRRqstSubject,
        dot11WNMRqstLCRIntervalUnits,
        dot11WNMRqstLCRServiceInterval,
        dot11WNMRqstLIRRqstSubject,
        dot11WNMRqstLIRIntervalUnits,
        dot11WNMRqstLIRServiceInterval,
        dot11WNMRqstEventToken,
        dot11WNMRqstEventType,
        dot11WNMRqstEventResponseLimit,
        dot11WNMRqstEventTargetBssid,
        dot11WNMRqstEventSourceBssid,
        dot11WNMRqstEventTransitTimeThresh,
        dot11WNMRqstEventTransitMatchValue,
        dot11WNMRqstEventFreqTransitCountThresh,
        dot11WNMRqstEventFreqTransitInterval,
        dot11WNMRqstEventRsnaAuthType,
        dot11WNMRqstEapType,
        dot11WNMRqstEapVendorId,
        dot11WNMRqstEapVendorType,
        dot11WNMRqstEventRsnaMatchValue,
        dot11WNMRqstEventPeerMacAddress,
        dot11WNMRqstOperatingClass,
        dot11WNMRqstChanNumber,
        dot11WNMRqstDiagToken,
        dot11WNMRqstDiagType,
        dot11WNMRqstDiagTimeout,
        dot11WNMRqstDiagBssid,
        dot11WNMRqstDiagProfileId,
        dot11WNMRqstDiagCredentials,
        dot11WNMRqstLocConfigLocIndParams,
        dot11WNMRqstLocConfigChanList,
        dot11WNMRqstLocConfigBcastRate,
        dot11WNMRqstLocConfigOptions,
        dot11WNMRqstBssTransitQueryReason,
        dot11WNMRqstBssTransitReqMode,
        dot11WNMRqstBssTransitDisocTimer,
        dot11WNMRqstBssTransitSessInfoURL,
        dot11WNMRqstBssTransitCandidateList,
        dot11WNMRqstColocInterfAutoEnable,
        dot11WNMRqstColocInterfRptTimeout,
        dot11WNMRqstVendorSpecific }
    STATUS current
    DESCRIPTION
        "The SMTWNMRequest package is a set of attributes that shall be present if
        the STA supports the WNM service."
```


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```
    ::= { dot11Groups 54 }

dot11SMTWNMReport OBJECT-GROUP
    OBJECTS {
        dot11WNMVendorSpecificRprtRqstToken,
        dot11WNMVendorSpecificRprtIfIndex,
        dot11WNMVendorSpecificRprtContent,
        dot11WNMMulticastDiagnosticRprtRqstToken,
        dot11WNMMulticastDiagnosticRprtIfIndex,
        dot11WNMMulticastDiagnosticRprtMeasurementTime,
        dot11WNMMulticastDiagnosticRprtDuration,
        dot11WNMMulticastDiagnosticRprtMcstGroup,
        dot11WNMMulticastDiagnosticRprtReason,
        dot11WNMMulticastDiagnosticRprtRcvdMsduCount,
        dot11WNMMulticastDiagnosticRprtFirstSeqNumber,
        dot11WNMMulticastDiagnosticRprtLastSeqNumber,
        dot11WNMMulticastDiagnosticRprtMcstRate,
        dot11WNMLocationCivicRprtRqstToken,
        dot11WNMLocationCivicRprtIfIndex,
        dot11WNMLocationCivicRprtCivicLocation,
        dot11WNMLocationIdentifierRprtRqstToken,
        dot11WNMLocationIdentifierRprtIfIndex,
        dot11WNMLocationIdentifierRprtExpirationTSF,
        dot11WNMLocationIdentifierRprtPublicIdUri,
        dot11WNMEventTransitRprtRqstToken,
        dot11WNMEventTransitRprtIfIndex,
        dot11WNMEventTransitRprtEventStatus,
        dot11WNMEventTransitRprtEventTSF,
        dot11WNMEventTransitRprtUTCOffset,
        dot11WNMEventTransitRprtTimeError,
        dot11WNMEventTransitRprtSourceBssid,
        dot11WNMEventTransitRprtTargetBssid,
        dot11WNMEventTransitRprtTransitTime,
        dot11WNMEventTransitRprtTransitReason,
        dot11WNMEventTransitRprtTransitResult,
        dot11WNMEventTransitRprtSourceRCPI,
        dot11WNMEventTransitRprtSourceRSNI,
        dot11WNMEventTransitRprtTargetRCPI,
        dot11WNMEventTransitRprtTargetRSNI,
        dot11WNMEventRsnaRprtRqstToken,
        dot11WNMEventRsnaRprtIfIndex,
        dot11WNMEventRsnaRprtEventStatus,
        dot11WNMEventRsnaRprtEventTSF,
        dot11WNMEventRsnaRprtUTCOffset,
        dot11WNMEventRsnaRprtTimeError,
        dot11WNMEventRsnaRprtTargetBssid,
        dot11WNMEventRsnaRprtAuthType,
        dot11WNMEventRsnaRprtEapMethod,
        dot11WNMEventRsnaRprtResult,
        dot11WNMEventRsnaRprtRsnElement,
        dot11WNMEventPeerRprtRqstToken,
        dot11WNMEventPeerRprtIfIndex,
        dot11WNMEventPeerRprtEventStatus,
        dot11WNMEventPeerRprtEventTSF,
        dot11WNMEventPeerRprtUTCOffset,
        dot11WNMEventPeerRprtTimeError,
        dot11WNMEventPeerRprtPeerMacAddress,
        dot11WNMEventPeerRprtOperatingClass,
        dot11WNMEventPeerRprtChanNumber,
        dot11WNMEventPeerRprtStaTxPower,
        dot11WNMEventPeerRprtConnTime,
        dot11WNMEventPeerRprtPeerStatus,
        dot11WNMEventWNMLogRprtRqstToken,
        dot11WNMEventWNMLogRprtIfIndex,
```

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```
        dot11WNMEventWNMLogRprtEventStatus,
        dot11WNMEventWNMLogRprtEventTSF,
        dot11WNMEventWNMLogRprtUTCOffset,
        dot11WNMEventWNMLogRprtTimeError,
        dot11WNMEventWNMLogRprtContent,
        dot11WNMDiagMfrInfoRprtRqstToken,
        dot11WNMDiagMfrInfoRprtIfIndex,
        dot11WNMDiagMfrInfoRprtEventStatus,
        dot11WNMDiagMfrInfoRprtMfrOi,
        dot11WNMDiagMfrInfoRprtMfrIdString,
        dot11WNMDiagMfrInfoRprtMfrModelString,
        dot11WNMDiagMfrInfoRprtMfrSerialNumberString,
        dot11WNMDiagMfrInfoRprtMfrFirmwareVersion,
        dot11WNMDiagMfrInfoRprtMfrAntennaType,
        dot11WNMDiagMfrInfoRprtCollocRadioType,
        dot11WNMDiagMfrInfoRprtDeviceType,
        dot11WNMDiagMfrInfoRprtCertificateID,
        dot11WNMDiagConfigProfRprtRqstToken,
        dot11WNMDiagConfigProfRprtIfIndex,
        dot11WNMDiagConfigProfRprtEventStatus,
        dot11WNMDiagConfigProfRprtProfileId,
        dot11WNMDiagConfigProfRprtSupportedOperatingClasses,
        dot11WNMDiagConfigProfRprtTxPowerMode,
        dot11WNMDiagConfigProfRprtTxPowerLevels,
        dot11WNMDiagConfigProfRprtCipherSuite,
        dot11WNMDiagConfigProfRprtAkmSuite,
        dot11WNMDiagConfigProfRprtEapType,
        dot11WNMDiagConfigProfRprtEapVendorID,
        dot11WNMDiagConfigProfRprtEapVendorType,
        dot11WNMDiagConfigProfRprtCredentialType,
        dot11WNMDiagConfigProfRprtSSID,
        dot11WNMDiagConfigProfRprtPowerSaveMode,
        dot11WNMDiagAssocRprtRqstToken,
        dot11WNMDiagAssocRprtIfIndex,
        dot11WNMDiagAssocRprtEventStatus,
        dot11WNMDiagAssocRprtBssid,
        dot11WNMDiagAssocRprtOperatingClass,
        dot11WNMDiagAssocRprtChannelNumber,
        dot11WNMDiagAssocRprtStatusCode,
        dot11WNMDiag8021xAuthRprtRqstToken,
        dot11WNMDiag8021xAuthRprtIfIndex,
        dot11WNMDiag8021xAuthRprtEventStatus,
        dot11WNMDiag8021xAuthRprtBssid,
        dot11WNMDiag8021xAuthRprtOperatingClass,
        dot11WNMDiag8021xAuthRprtChannelNumber,
        dot11WNMDiag8021xAuthRprtEapType,
        dot11WNMDiag8021xAuthRprtEapVendorID,
        dot11WNMDiag8021xAuthRprtEapVendorType,
        dot11WNMDiag8021xAuthRprtCredentialType,
        dot11WNMDiag8021xAuthRprtStatusCode,
        dot11WNMLocConfigRprtRqstToken,
        dot11WNMLocConfigRprtIfIndex,
        dot11WNMLocConfigRprtLocIndParams,
        dot11WNMLocConfigRprtLocIndChanList,
        dot11WNMLocConfigRprtLocIndBcastRate,
        dot11WNMLocConfigRprtLocIndOptions,
        dot11WNMLocConfigRprtStatusConfigSubelemId,
        dot11WNMLocConfigRprtStatusResult,
        dot11WNMLocConfigRprtVendorSpecificRprtContent,
        dot11WNMBssTransitRprtRqstToken,
        dot11WNMBssTransitRprtIfIndex,
        dot11WNMBssTransitRprtStatusCode,
        dot11WNMBssTransitRprtBSSTerminationDelay,
        dot11WNMBssTransitRprtTargetBssid,
```


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```
        dot11WNMBssTransitRprtCandidateList,
        dot11WNMColocInterfRprtRqstToken,
        dot11WNMColocInterfRprtIfIndex,
        dot11WNMColocInterfRprtPeriod,
        dot11WNMColocInterfRprtInterfLevel,
        dot11WNMColocInterfRprtInterfAccuracy,
        dot11WNMColocInterfRprtInterfIndex,
        dot11WNMColocInterfRprtInterfInterval,
        dot11WNMColocInterfRprtInterfBurstLength,
        dot11WNMColocInterfRprtInterfStartTime,
        dot11WNMColocInterfRprtInterfCenterFreq,
        dot11WNMColocInterfRprtInterfBandwidth }
    STATUS current
    DESCRIPTION
        "The SMTWNMReport package is a set of attributes that shall be present if
        the STA supports the WNM service."
    ::= { dot11Groups 55 }

dot11SMTbase12 OBJECT-GROUP
    OBJECTS {
        dot11MediumOccupancyLimit,
        dot11CFPollable,
        dot11CFPPeriod,
        dot11CFPMaxDuration,
        dot11AuthenticationResponseTimeout,
        dot11PrivacyOptionImplemented,
        dot11PowerManagementMode,
        dot11DesiredSSID,
        dot11DesiredBSSType,
        dot11OperationalRateSet,
        dot11BeaconPeriod,
        dot11DTIMPeriod,
        dot11AssociationResponseTimeout,
        dot11DisassociateReason,
        dot11DisassociateStation,
        dot11DeauthenticateReason,
        dot11DeauthenticateStation,
        dot11AuthenticateFailStatus,
        dot11AuthenticateFailStation,
        dot11MultiDomainCapabilityImplemented,
        dot11MultiDomainCapabilityActivated,
        dot11CountryString,
        dot11SpectrumManagementImplemented,
        dot11SpectrumManagementRequired,
        dot11RSNAOptionImplemented,
        dot11OperatingClassesImplemented,
        dot11OperatingClassesRequired,
        dot11QosOptionImplemented,
        dot11ImmediateBlockAckOptionImplemented,
        dot11DelayedBlockAckOptionImplemented,
        dot11DirectOptionImplemented,
        dot11APSDOptionImplemented,
        dot11QAckOptionImplemented,
        dot11QBSSLoadImplemented,
        dot11QueueRequestOptionImplemented,
        dot11TXOPRequestOptionImplemented,
        dot11MoreDataAckOptionImplemented,
        dot11AssociateInNQBSS,
        dot11DLSAllowedInQBSS,
        dot11DLSAllowed,
        dot11AssociateStation,
        dot11AssociateID,
        dot11AssociateFailStation,
        dot11AssociateFailStatus,
```

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```
        dot11ReassociateStation,
        dot11ReassociateID,
        dot11ReassociateFailStation,
        dot11ReassociateFailStatus,
        dot11RadioMeasurementImplemented,
        dot11RadioMeasurementActivated,
        dot11RMMeasurementNavSync,
        dot11RMMeasurementPilotPeriod,
        dot11RMLinkMeasurementActivated,
        dot11RMNeighborReportActivated,
        dot11RMParallelMeasurementsActivated,
        dot11RMRepeatedMeasurementsActivated,
        dot11RMBeaconPassiveMeasurementActivated,
        dot11RMBeaconActiveMeasurementActivated,
        dot11RMBeaconTableMeasurementActivated,
        dot11RMBeaconMeasurementReportingConditionsActivated,
        dot11RMFrameMeasurementActivated,
        dot11RMChannelLoadMeasurementActivated,
        dot11RMNoiseHistogramMeasurementActivated,
        dot11RMStatisticsMeasurementActivated,
        dot11RMLCIMeasurementActivated,
        dot11RMLCIAzimuthActivated,
        dot11RMTransmitStreamCategoryMeasurementActivated,
        dot11RMTriggeredTransmitStreamCategoryMeasurementActivated,
        dot11RMAPChannelReportActivated,
        dot11RMMIBActivated,
        dot11RMMaxMeasurementDuration,
        dot11RMNonOperatingChannelMaxMeasurementDuration,
        dot11RMMeasurementPilotTransmissionInformationActivated,
        dot11RMMeasurementPilotActivated,
        dot11RMNeighborReportTSFOffsetActivated,
        dot11RMRCPIMeasurementActivated,
        dot11RMRSNIMeasurementActivated,
        dot11RMBSSAverageAccessDelayActivated,
        dot11RMBSSAvailableAdmissionCapacityActivated,
        dot11FastBSSTransitionImplemented,
        dot11LCIDSEImplemented,
        dot11LCIDSERequired,
        dot11DSERequired,
        dot11ExtendedChannelSwitchActivated,
        dot11HighThroughputOptionImplemented,
        dot11WirelessManagementImplemented,
        dot11MeshActivated,
        dot11RSNAPBACRequired,
        dot11PSMPOptionImplemented}
    STATUS deprecated
    DESCRIPTION
        "Superseded by dot11SMTbase13.
        The SMTbase12 object class provides the necessary support at the STA to
        manage the processes in the STA such that the STA may work cooperatively
        as a part of an IEEE 802.11 network."
    ::= { dot11Groups 57 }


dot11OperatingClassesGroup OBJECT-GROUP
    OBJECTS {
        dot11OperatingClass,
        dot11CoverageClass }
    STATUS current
    DESCRIPTION
        "Attributes that configure the OFDM PHY for IEEE Std 802.11 in many
        regulatory domains."
    ::= { dot11Groups 58 }
```


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```
dot11PhyOperationComplianceGroup2 OBJECT-GROUP
   OBJECTS { dot11PHYType, dot11CurrentRegDomain }
   STATUS current
   DESCRIPTION
      "PHY operations attributes."
   ::= { dot11Groups 59 }

dot11MeshComplianceGroup OBJECT-GROUP
   OBJECTS {
      -- dot11MeshSTAConfigTable
      dot11MeshID,
      dot11MeshNumberOfPeerings,
      dot11MeshAcceptingAdditionalPeerings,
      dot11MeshConnectedToMeshGate,
      dot11MeshSecurityActivated,
      dot11MeshActiveAuthenticationProtocol,
      dot11MeshMaxRetries,
      dot11MeshRetryTimeout,
      dot11MeshConfirmTimeout,
      dot11MeshHoldingTimeout,
      dot11MeshActivePathSelectionProtocol,
      dot11MeshActivePathSelectionMetric,
      dot11MeshForwarding,
      dot11MeshTTL,
      dot11MeshGateAnnouncements,
      dot11MeshActiveCongestionControlMode,
      dot11MeshActiveSynchronizationMethod,
      dot11MeshNbrOffsetMaxNeighbor,
      dot11MBCAActivated,
      dot11MCCAImplemented,
      dot11MCCAActivated }
   STATUS current
   DESCRIPTION
      "This object class provides the objects from the IEEE 802.11 MIB required
      to manage mandatory mesh functionality. Note that additional objects for
      managing mesh functionality are located in the dot11MeshOptionGroup,
      dot11MeshHWMPComplianceGroup, and dot11PasswordAuthComplianceGroup."
   ::= { dot11Groups 56}


dot11MeshOptionGroup OBJECT-GROUP
   OBJECTS {
      -- dot11MeshSTAConfigTable
      dot11MeshConfigGroupUpdateCount,
      dot11MeshGateAnnouncementInterval,
      dot11MeshBeaconTimingReportInterval,
      dot11MeshBeaconTimingReportMaxNum,
      dot11MeshDelayedBeaconTxInterval,
      dot11MeshDelayedBeaconTxMaxDelay,
      dot11MeshDelayedBeaconTxMinDelay,
      dot11MeshAverageBeaconFrameDuration,
      dot11MeshSTAMissingAckRetryLimit,
      dot11MeshAwakeWindowDuration,
      dot11MAFlimit,
      dot11MCCAScanDuration,
      dot11MCCAAdvertPeriodMax,
      dot11MCCATrackStatesCapable,
      dot11MCCATrackStatesActive,
      dot11MCCAOPtimeout,
      dot11MCCACWmin,
      dot11MCCACWmax,
      dot11MCCAAIFSN
      }
   STATUS current
```

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```
    DESCRIPTION
        "This object class provides the objects from the IEEE 802.11 MIB required
        to manage optional mesh functionality. Note that other objects for
        managing mesh functionality are located in the dot11MeshComplianceGroup,
        dot11MeshHWMPComplianceGroup, and dot11PasswordAuthComplianceGroup."
    ::= { dot11Groups 60 }


dot11MeshHWMPComplianceGroup OBJECT-GROUP
    OBJECTS {
        -- dot11MeshHWMPConfigTable
        dot11MeshHWMPmaxPREQretries,
        dot11MeshHWMPnetDiameter,
        dot11MeshHWMPnetDiameterTraversalTime,
        dot11MeshHWMPpreqMinInterval,
        dot11MeshHWMPperrMinInterval,
        dot11MeshHWMPactivePathToRootTimeout,
        dot11MeshHWMPactivePathTimeout,
        dot11MeshHWMProotMode,
        dot11MeshHWMProotInterval,
        dot11MeshHWMPrannInterval,
        dot11MeshHWMPtargetOnly,
        dot11MeshHWMPmaintenanceInterval,
        dot11MeshHWMPconfirmationInterval }
    STATUS current
    DESCRIPTION
        "This object class provides the objects from the IEEE 802.11 MIB required
        to manage HWMP path selection functionality. Note that other objects for
        managing mesh functionality are located in the dot11MeshComplianceGroup,
        dot11MeshOptionGroup, and dot11PasswordAuthComplianceGroup."
    ::= { dot11Groups 61 }


dot11PasswordAuthComplianceGroup OBJECT-GROUP
    OBJECTS {
        -- dot11RSNAConfigTable
        dot11RSNASAERetransPeriod,
        dot11RSNASAEAntiCloggingThreshold,
        dot11RSNASAESync,
        -- dot11RSNAConfigPasswordValueTable
--      dot11RSNAConfigPasswordValueIndex,
        dot11RSNAConfigPasswordCredential,
        dot11RSNAConfigPasswordPeerMac,
        -- dot11RSNAConfigDLCGroupTable
--      dot11RSNAConfigDLCGroupIndex,
        dot11RSNAConfigDLCGroupIdentifier }
    STATUS current
    DESCRIPTION
        "This object class provides the objects from the IEEE 802.11 MIB required
        to manage password authentication. Note that other objects for managing
        mesh functionality are located in the dot11MeshComplianceGroup,
        dot11MeshOptionGroup, and dot11MeshHWMPComplianceGroup."
    ::= { dot11Groups 62 }

dot11QMFComplianceGroup OBJECT-GROUP
    OBJECTS {
        dot11QMFActivated,
        dot11QMFReconfigurationActivated,
        dot11QMFPolicyChangeTimeout }
    STATUS current
    DESCRIPTION
        "This object group provides the objects from the IEEE 802.11 MIB required
        to manage (M118)QoS management Frame functionality."
    ::= { dot11Groups 63 }
```



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```
dot11DMGComplianceGroup OBJECT-GROUP
   OBJECTS {dot11MultibandImplemented, dot11DMGOptionImplemented,
      dot11RelayActivated, dot11REDSActivated, dot11RDSActivated,
      dot11RSNAProtectedManagementFramesActivated,
      dot11MultipleMACActivated,
      dot11ClusteringActivated,
      dot11LowPowerSCPHYImplemented,
      dot11LowPowerSCPHYActivated,
      (11ay)dot11RSNAOperatingChannelValidationActivated,
      dot11DiscoveryAssistanceActivated,
      dot11DMGTDDLocalClockModeActivated,
      dot11DMGTimeAdvertisementBeaconInterval,
      dot11ExtendedTPCActivated,
      dot11TDDOptionImplemented,
      dot11SAROptionImplemented,
      dot11UnsolicitedBAActivated,
      dot11DMGExtendedMPDULimitValid,
      dot11DMGSTATxActivityReportImplemented,
      dot11DMGSTATxActivityReportActivated,
      (11bd)dot11DMGOCBActivated
      }
   STATUS current
   DESCRIPTION
      "Attributes that configure the DMG Group for IEEE Std 802.11."
   ::= { dot11Groups 64 }

dot11DMGOperationsComplianceGroup OBJECT-GROUP
   OBJECTS {dot11MaxLostBeacons, dot11MinBHIDuration,
      dot11PSRequestSuspensionInterval,
      dot11BroadcastSTAInfoDuration, dot11NbrOfChangeBeacons,
      dot11ImplicitHandoverLostBeacons, dot11MinPPDuration,
      dot11SPIdleTimeout, dot11QABTimeout, dot11ClusterEnableTime,
      dot11PNWarningThresholdLow,dot11PNWarningThresholdHigh,
      dot11BeaconSPDuration,
      dot11PNExhaustionThresholdLow,dot11PNExhaustionThresholdHigh,
      dot11MaxNumberOfClusteringMonitoringPeriods,
      dot11DMGEcssPolicyDetailUpdateDurationMax,
      dot11DMGEcssClusterReportDurationMin,
      dot11DMGNavSync(11ay),
      dot11DMGChannelAccessScheme,
      dot11DMGSTATxActivityReportTimeUnit,
      dot11DMGSTATxActivityReportMinActiveTimeUnits,
      dot11DMGSTATxActivityReportActiveMonitoringTime,
      dot11DMGSTATxActivityReportInterval
      }
   STATUS current
   DESCRIPTION
      "Attributes that configure the DMG Operation for IEEE Std 802.11."
   ::= { dot11Groups 65 }

dot11DMGBeamformingComplianceGroup OBJECT-GROUP
   OBJECTS {dot11MaxBFTime, dot11BFTXSSTime, dot11MaximalSectorScan,
      dot11ABFTRTXSSSwitch, dot11RSSRetryLimit, dot11RSSBackoff,
      dot11BFRetryLimit, dot11BFTXSSTime,
      dot11BeamLinkMaintenanceTime,dot11BeamTrackingTimeLimit
      }
   STATUS current
   DESCRIPTION
      "Attributes that configure the DMG Beamforming functionality
      for IEEE Std 802.11."
   ::= { dot11Groups 66 }

dot11DMGCountersComplianceGroup OBJECT-GROUP
```

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```
    OBJECTS {dot11RSNAStatsGCMPReplays,
        dot11RSNAStatsRobustMgmtGCMPReplays
        }
    STATUS current
    DESCRIPTION
        "Attributes that are used as counters for a DMG STA
        for IEEE Std 802.11."
    ::= { dot11Groups 67 }


dot11AVSBase OBJECT-GROUP
    OBJECTS {
        dot11RobustAVStreamingImplemented,
        dot11GCRActivated,
        dot11AdvancedGCRImplemented,
        dot11AdvancedGCRActivated,
        dot11SCSImplemented,
        dot11SCSActivated,
        dot11QLoadReportActivated,
        dot11AlternateEDCAActivated,
        dot11PublicHCCATXOPNegotiationActivated,
        dot11GCRGroupMembershipAnnouncementActivated,
        dot11MeshGCRImplemented,
        dot11MeshGCRActivated,
        dot11PublicHCCATXOPNegotiationImplemented,
        dot11PublicHCCATXOPNegotiationActivated,
        dot11ProtectedHCCATXOPNegotiationImplemented,
        dot11ProtectedHCCATXOPNegotiationActivated,
        dot11ProtectedQLoadReportImplemented,
        dot11ProtectedQLoadReportActivated,
        dot11QLoadReportIntervalDTIM,
        dot11HCCATXOPBeaconTimeout,
        dot11GCRConcealmentAddress,
        dot11GCRPolicyChangeTimeout,
        dot11QLoadReportDelay,
        dot11DefaultSurplusBandwidthAllowance,
        dot11ShortDEIRetryLimit,
        dot11LongDEIRetryLimit,
        dot11UnsolicitedRetryLimit,
        dot11STAStatisticsAverageMSDUSizeVideo,
        dot11STAStatisticsAverageMSDUSizeVoice,
        dot11STAStatisticsAverageBitrateVideo,
        dot11STAStatisticsAverageBitrateVoice
        }
    STATUS (#3441)deprecated
    DESCRIPTION
        "Superseded by dot11AVSBase2.
        The AVSBase package is a set of attributes that are present if the STA
        supports the robust audio video streaming features."
    ::= { dot11Groups 68 }

dot11AVSAPCGroup OBJECT-GROUP
    OBJECTS {
        dot11APCEntryAvoidanceDuration,
        dot11APCEntryAvoidanceServiceInterval,
        dot11APCEntryAvoidanceOffset,
        dot11APCEntryMACAddress
        }
    STATUS current
    DESCRIPTION
        "The AVSAPCGroup package is a set of attributes that are present if the
        STA supports HCCA TXOP negotiation."
    ::= { dot11Groups 69 }
```


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```
dot11TVWSComplianceGroup OBJECT-GROUP
   OBJECTS {
      dot11ChannelScheduleManagementActivated,
      dot11ContactVerificationSignalActivated,
      dot11NetworkChannelControlActivated,
      dot11WhiteSpaceMapActivated,
      dot11GDDActivated,
      dot11TVHTOptionImplemented
      }
   STATUS current
   DESCRIPTION
      "Attributes that configure the TVWS Group for IEEE Std 802.11."
   ::= { dot11Groups 70 }

dot11SpectrumManagementGroup OBJECT-GROUP
   OBJECTS {
      -- Dot11SpectrumManagementEntry
      -- dot11SpectrumManagementIndex,
      dot11ChannelSwitchTime,
      dot11PowerCapabilityMaxImplemented,
      dot11PowerCapabilityMinImplemented  }
   STATUS current
   DESCRIPTION
      "This object class provides the objects from the IEEE 802.11 MIB for
      spectrum management."
   ::= { dot11Groups 72 }

dot11ProtectedManagementFrameGroup OBJECT-GROUP
   OBJECTS {
      -- Dot11StationConfigEntry
      dot11RSNAProtectedManagementFramesActivated,
      dot11RSNAUnprotectedManagementFramesAllowed,
      dot11AssociationSAQueryMaximumTimeout,
      dot11AssociationSAQueryRetryTimeout,
      -- dot11RSNAStatsEntry
      dot11RSNAStatsCMACReplays,
      dot11RSNAStatsRobustMgmtCCMPReplays,
      dot11RSNAStatsBIPMICErrors,
      dot11RSNAOperatingChannelValidationActivated}
   STATUS current
   DESCRIPTION
      "This object class provides the objects from the IEEE 802.11 MIB required
      to operate management frame protection."
   ::= { dot11Groups 73 }

dot11LCIDSEGroup OBJECT-GROUP
   OBJECTS {
      -- Dot11LCIDSEEntry
      -- dot11LCIDSEIndex,
      dot11LCIDSEIfIndex,
      dot11LCIDSECurrentOperatingClass,
      dot11LCIDSELatitudeUncertainty,
      dot11LCIDSELatitudeInteger,
      dot11LCIDSELatitudeFraction,
      dot11LCIDSELongitudeUncertainty,
      dot11LCIDSELongitudeInteger,
      dot11LCIDSELongitudeFraction,
      dot11LCIDSEAltitudeType,
      dot11LCIDSEAltitudeUncertainty,
      dot11LCIDSEAltitude,
      dot11LCIDSEDatum,
      dot11RegLocAgreement,
      dot11RegLocDSE,
```

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```
        dot11DependentSTA,
        dot11DependentEnablementIdentifier,
        dot11DSEEnablementTimeLimit,
        dot11DSEEnablementFailHoldTime,
        dot11DSERenewalTime,
        dot11DSETransmitDivisor }
    STATUS current
    DESCRIPTION
        "This object class provides the objects from the IEEE 802.11 MIB required
        to enable 3650-3700 MHz Operation in the USA and its territories(#296)."
    ::= { dot11Groups 74 }

dot11TDLSComplianceGroup OBJECT-GROUP
    OBJECTS {
        -- Dot11StationConfigEntry
        dot11TunneledDirectLinkSetupImplemented,
        dot11TDLSPeerUAPSDBufferSTAActivated,
        dot11TDLSPeerPSMActivated,
        dot11TDLSPeerUAPSDIndicationWindow,
        dot11TDLSChannelSwitchingActivated,
        dot11TDLSPeerSTAMissingAckRetryLimit,
        dot11TDLSResponseTimeout,
        dot11OCBActivated,
        dot11TDLSNavSync,
        dot11TDLSDiscoveryRequestWindow,
        dot11TDLSACDeterminationInterval }
    STATUS (#3441)deprecated(#1712)
    DESCRIPTION
        "Superseded by dot11TDLSComplianceGroup1. (#1712)
        This object class provides the objects from the IEEE 802.11 MIB required
        to operate tunneled direct link setup."
    ::= { dot11Groups 75 }

dot11VHTTransmitBeamformingGroup OBJECT-GROUP
    OBJECTS {
        dot11VHTSUBeamformeeOptionImplemented,
        dot11VHTSUBeamformerOptionImplemented,
        dot11VHTMUBeamformeeOptionImplemented,
        dot11VHTMUBeamformerOptionImplemented,
        dot11VHTNumberSoundingDimensions,
        dot11VHTBeamformeeNTxSupport,
        (#4284)dot11VHTMaxNstsTotal }
    STATUS current
    DESCRIPTION
        "Attributes that configure VHT transmit beamforming for IEEE Std 802.11."
    ::= { dot11Groups 76 }

dot11PhyVHTComplianceGroup OBJECT-GROUP
    OBJECTS {
        dot11VHTChannelWidthOptionImplemented,
        dot11CurrentChannelWidth,
        dot11CurrentChannelCenterFrequencyIndex0,
        dot11CurrentChannelCenterFrequencyIndex1,
        dot11VHTShortGIOptionIn80Implemented,
        dot11VHTShortGIOptionIn80Activated,
        dot11VHTShortGIOptionIn160and80p80Implemented,
        dot11VHTShortGIOptionIn160and80p80Activated,
        dot11VHTLDPCCodingOptionImplemented,
        dot11VHTLDPCCodingOptionActivated,
        dot11VHTTxSTBCOptionImplemented,
        dot11VHTTxSTBCOptionActivated,
        dot11VHTRxSTBCOptionImplemented,
        dot11VHTRxSTBCOptionActivated,
        dot11VHTMUMaxUsersImplemented,
```


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```
        dot11VHTMUMaxNSTSPerUserImplemented,
        dot11VHTMUMaxNSTSTotalImplemented,
        dot11VHTMaxNTxChainsImplemented,
        dot11VHTMaxNTxChainsActivated}
    STATUS current
    DESCRIPTION
        "Attributes that configure the VHT PHY."
    ::= { dot11Groups 77 }

dot11VHTMACAdditions OBJECT-GROUP
    OBJECTS {
        dot11VHTOptionImplemented,
        dot11OperatingModeNotificationImplemented,
        dot11MaxMPDULength,
        dot11VHTMaxRxAMPDUFactor,
        dot11VHTControlFieldOptionImplemented,
        dot11VHTTXOPPowerSaveOptionImplemented,
        dot11VHTRxVHTMCSMap,
        dot11VHTRxHighestDataRateSupported,
        dot11VHTTxVHTMCSMap,
        dot11VHTTxHighestDataRateSupported,
        dot11VHTOBSSScanCount,
        dot11VHTExtendedNSSBWCapable
}
    STATUS current
    DESCRIPTION
        "Attributes that configure the VHT MAC."
    ::= { dot11Groups 78 }

dot11PhyTxPowerComplianceGroup2 OBJECT-GROUP
    OBJECTS {
        dot11TxPowerLevelExtended,
        dot11CurrentTxPowerLevelExtended }
    STATUS current
    DESCRIPTION
        "Additional attributes for Control and Management of transmit power."
    ::= { dot11Groups 79 }

dot11TVHTTransmitBeamformingGroup OBJECT-GROUP
    OBJECTS {
        dot11TVHTSUBeamformeeOptionImplemented,
        dot11TVHTSUBeamformerOptionImplemented,
        dot11TVHTMUBeamformeeOptionImplemented,
        dot11TVHTMUBeamformerOptionImplemented,
        dot11TVHTNumberSoundingDimensions,
        dot11TVHTBeamformeeNTxSupport
        }
    STATUS current
    DESCRIPTION
        "Attributes that configure TVHT transmit beamforming for IEEE Std 802.11."
    ::= { dot11Groups 80 }

dot11PhyTVHTComplianceGroup OBJECT-GROUP
    OBJECTS {
        dot11TVHTChannelWidthOptionImplemented,
        dot11TVHTCurrentChannelWidth,
        dot11TVHTCurrentChannelCenterFrequencyIndex0,
        dot11TVHTCurrentChannelCenterFrequencyIndex1,
        dot11TVHTShortGIOptionIn4WImplemented,
        dot11TVHTShortGIOptionIn4WActivated,
        dot11TVHTLDPCCodingOptionImplemented,
        dot11TVHTLDPCCodingOptionActivated,
        dot11TVHTTxSTBCOptionImplemented,
        dot11TVHTTxSTBCOptionActivated,
```

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```
        dot11TVHTRxSTBCOptionImplemented,
        dot11TVHTRxSTBCOptionActivated,
        dot11TVHTMUMaxUsersImplemented,
        dot11TVHTMUMaxNSTSPerUserImplemented,
        dot11TVHTMUMaxNSTSTotalImplemented,
        dot11TVHTMaxNTxChainsImplemented,
        dot11TVHTMaxNTxChainsActivated
        }
    STATUS current
    DESCRIPTION
        "Attributes that configure the TVHT PHY."
    ::= { dot11Groups 81 }

dot11MACbase4 OBJECT-GROUP
    OBJECTS {
        dot11MACAddress,
        dot11GroupAddress,
        dot11GroupAddressesStatus,
        dot11RTSThreshold,
        dot11ShortRetryLimit,
        dot11LongRetryLimit,
        dot11FragmentationThreshold,
        dot11MaxTransmitMSDULifetime,
        dot11MaxReceiveLifetime,
        dot11ManufacturerID,
        dot11ProductID,
        dot11CAPLimit,
        dot11HCCWmin,
        dot11HCCWmax,
        dot11HCCAIFSN,
        dot11ChannelUtilizationBeaconIntervals,
        dot11ScheduleTimeout,
        dot11DLSResponseTimeout,
        dot11QAPMissingAckRetryLimit,
        dot11EDCAAveragingPeriod,
        dot11HTProtection,
        dot11RIFSMode,
        dot11PSMPControlledAccess,
        dot11ServiceIntervalGranularity,
        dot11DualCTSProtection,
        dot11LSIGTXOPFullProtectionActivated,
        dot11NonGFEntitiesPresent, dot11PCOActivated,
        dot11PCOFortyMaxDuration,
        dot11PCOTwentyMaxDuration,
        dot11PCOFortyMinDuration,
        dot11PCOTwentyMinDuration }
    STATUS deprecated
    DESCRIPTION
        " Superseded by dot11MACbase5. The MAC object class provides the necessary
        support for the access control, generation, and verification of frame
        check sequences (FCSs), and proper delivery of valid data to upper
        layers."
    ::= { dot11Groups 84 }

dot11CountersGroup4 OBJECT-GROUP
    OBJECTS {
        dot11TransmittedFragmentCount,
        dot11TransmittedFrameCount,
        dot11FailedCount,
        dot11ReceivedFragmentCount,
        dot11GroupReceivedFrameCount,
        dot11FCSErrorCount,
        dot11WEPUndecryptableCount,
        dot11TransmittedFrameCount,
```


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```
        dot11QosDiscardedFragmentCount,
        dot11AssociatedStationCount,
        dot11QosCFPollsReceivedCount,
        dot11QosCFPollsUnusedCount,
        dot11QosCFPollsUnusableCount,
        dot11QosCFPollsLostCount,
        dot11TransmittedAMSDUCount,
        dot11FailedAMSDUCount,
        dot11RetryAMSDUCount,
        dot11MultipleRetryAMSDUCount,
        dot11TransmittedOctetsInAMSDUCount,
        dot11AMSDUAckFailureCount,
        dot11ReceivedAMSDUCount,
        dot11ReceivedOctetsInAMSDUCount,
        dot11TransmittedAMPDUCount,
        dot11TransmittedMPDUsInAMPDUCount,
        dot11TransmittedOctetsInAMPDUCount,
        dot11AMPDUReceivedCount,
        dot11MPDUInReceivedAMPDUCount,
        dot11ReceivedOctetsInAMPDUCount,
        dot11AMPDUDelimiterCRCErrorCount,
        dot11ImplicitBARFailureCount,
        dot11ExplicitBARFailureCount,
        dot11ChannelWidthSwitchCount,
        dot11TwentyMHzFrameTransmittedCount,
        dot11FortyMHzFrameTransmittedCount,
        dot11TwentyMHzFrameReceivedCount,
        dot11FortyMHzFrameReceivedCount,
        dot11PSMPUTTGrantDuration,
        dot11PSMPUTTUsedDuration,
        dot11GrantedRDGUsedCount,
        dot11GrantedRDGUnusedCount,
        dot11TransmittedFramesInGrantedRDGCount,
        dot11TransmittedOctetsInGrantedRDGCount,
        dot11BeamformingFrameCount,
        dot11DualCTSSuccessCount,
        dot11DualCTSFailureCount,
        dot11STBCCTSSuccessCount,
        dot11STBCCTSFailureCount,
        dot11nonSTBCCTSSuccessCount,
        dot11nonSTBCCTSFailureCount,
        dot11RTSLSIGSuccessCount,
        dot11RTSLSIGFailureCount,
        dot11TransmittedMSDUOctetsCount,
        dot11ReceivedMSDUOctetsCount
        }
    STATUS deprecated
    DESCRIPTION
        "Superseded by dot11CountersGroup5. Attributes from the dot11CountersGroup
        that are not described in the dot11MACStatistics group. These objects are
        mandatory."
    ::= { dot11Groups 85 }

dot11BSSStatisticsGroup OBJECT-GROUP
    OBJECTS {
        dot11AssociatedStationCount,
        dot11BSSLoadChannelUtilization,
        dot11BSSLoadAvailableAdmissionCapacity,
        dot11BSSLoadAssocAttemptCount,
        dot11BSSLoadAssocFailCount,
        dot11BSSLoadReassocAttemptCount,
        dot11BSSLoadReassocFailCount
        }
    STATUS current
```

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```
    DESCRIPTION
        "The BSS Statistics group defines those objects that provide access to
        local measurements by an AP of its BSS."
    ::= { dot11Groups 86 }

dot11HTMACAdditions2 OBJECT-GROUP
    OBJECTS {
        dot11MIMOPowerSave,
        dot11NDelayedBlockAckOptionImplemented,
        dot11MaxAMSDULength,
        dot11STBCControlFrameOptionImplemented,
        dot11LsigTxopProtectionOptionImplemented,
        dot11MaxRxAMPDUFactor,
        dot11MinimumMPDUStartSpacing,
        dot11PCOOptionImplemented,
        dot11TransitionTime,
        dot11MCSFeedbackOptionImplemented,
        dot11HTControlFieldSupported,
        dot11RDResponderOptionImplemented,
        dot11BSSWidthTriggerScanInterval,
        dot11BSSWidthChannelTransitionDelayFactor,
        dot11OBSSScanPassiveDwell,
        dot11OBSSScanActiveDwell,
        dot11OBSSScanPassiveTotalPerChannel,
        dot11OBSSScanActiveTotalPerChannel,
        dot112040BSSCoexistenceManagementSupport,
        dot11OBSSScanActivityThreshold,
        dot11SPPAMSDUCapable,
        dot11SPPAMSDURequired }
    STATUS deprecated
    DESCRIPTION
        "Superseded by dot11HTMACAdditions3. Attributes that configure the HT PHY
        for IEEE Std 802.11."
    ::= { dot11Groups 87 }

dot11S1GTransmitBeamformingGroup OBJECT-GROUP
    OBJECTS {
        dot11S1GSUBeamformerOptionImplemented,
        dot11S1GSUBeamformeeOptionImplemented,
        dot11S1GMUBeamformerOptionImplemented,
        dot11S1GMUBeamformeeOptionImplemented,
        dot11S1GNumberSoundingDimensions,
        dot11S1GBeamformeeNTxSupport }
    STATUS current
    DESCRIPTION
        "Attributes that configure S1G transmit beamforming for IEEE 802.11."
    ::= { dot11Groups 88 }

dot11PhyS1GComplianceGroup OBJECT-GROUP
    OBJECTS {
        dot11S1GChannelWidthOptionImplemented,
        dot11S1GCurrentPrimaryChannel,
        dot11S1GCurrentChannelWidth,
        dot11S1GCurrentChannelCenterFrequencyIndex,
        dot11ShortGIOptionIn1MImplemented,
        dot11ShortGIOptionIn1MActivated,
        dot11ShortGIOptionIn2MImplemented,
        dot11ShortGIOptionIn2MActivated,
        dot11ShortGIOptionIn4MImplemented,
        dot11ShortGIOptionIn4MActivated,
        dot11ShortGIOptionIn8MImplemented,
        dot11ShortGIOptionIn8MActivated,
        dot11ShortGIOptionIn16MImplemented,
        dot11ShortGIOptionIn16MActivated,
```


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```
        dot11S1GLDPCCodingOptionImplemented,
        dot11S1GLDPCCodingOptionActivated,
        dot11S1GTxSTBCOptionImplemented,
        dot11S1GTxSTBCOptionActivated,
        dot11S1GRxSTBCOptionImplemented,
        dot11S1GRxSTBCOptionActivated,
        dot11S1GMUMaxUsersImplemented,
        dot11S1GMUMaxNSTSPerUserImplemented,
        dot11S1GMUMaxNSTSTotalImplemented,
        dot11S1GMaxNTxChainsImplemented,
        dot11S1GMaxNTxChainsActivated,
        dot11S1GTravelingPilotOptionImplemented,
        dot11S1GTravelingPilotOptionActivated,
        dot11S1GLONGOptionImplemented,
        dot11S1GLONGOptionActivated }
    STATUS current
    DESCRIPTION
        "Attributes that configure the S1G PHY."
    ::= { dot11Groups 89 }

dot11S1GComplianceGroup OBJECT-GROUP
    OBJECTS {
        dot11S1GOptionImplemented,
        dot11S1GMaxMPDULength,
        dot11S1GMaxRxAMPDUFactor,
        dot11S1GControlFieldOptionImplemented,
        dot11S1GRxS1GMCSMap,
        dot11S1GTxS1GMCSMap,
        dot11S1GOBSSScanCount,
        dot11ShortBeaconInterval,
        dot11ShortBeaconPeriod,
        dot11ShortBeaconDTIMPeriod,
        dot11PV1MACHeaderOptionImplemented,
        dot11PV1ProbeResponseOptionImplemented,
        dot11HeaderCompressionResponseTimeout,
        dot11TSFTimerAccuracyImplemented,
        dot11NonTIMModeActivated,
        dot11PageSlicingImplemented,
        dot11PageSlicingActivated,
        dot11DynamicAIDActivated,
        dot11GroupAIDActivated,
        dot11AMSDUImplemented,
        dot11AMPDUImplemented,
        dot11MCSNegotiation,
        dot11AsymmetricBlockAckActivated,
        dot11FragmentBAOptionImplemented,
        dot11RAWOperationImplemented,
        dot11RAWOperationActivated,
        dot11S1GUplinkSyncOptionImplemented,
        dot11TWTOptionActivated,
        dot11BATImplemented,
        dot11PollTACKResponseImplemented,
        dot11NDPProbingActivated,
        dot11NDPPSPollSupport,
        dot11RelayAPImplemented,
        dot11RelayAPOperationActivated,
        dot11RelaySTAImplemented,
        dot11RelaySTAOperationActivated,
        dot11RelayDiscoveryOptionImplemented,
        dot11TXOPSharingImplicitACKImplemented,
        dot11S1GELOperationActivated,
        dot11S1GCentralizedAuthenticationControlActivated,
        dot11S1GDistributedAuthenticationControlActivated,
        dot11SubchannelSelectiveTransmissionActivated,
```

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```
        dot11S1GSectorImplemented,
        dot11S1GSectorizationActivated,
        dot11S1GSectorTrainingOperationImplemented,
        dot11NDPBeamformingReportPollImplemented,
        dot11UnsolicitedDynamicAIDActivated,
        dot11TIMADEImplemented,
        dot11SelectiveSubchannelTransmissionPermitted,
        dot11MaxAwayDuration,
        dot11APPMActivated,
        dot11BDTImplemented,
        dot11S1GCACDeferral,
        dot11S1GCACThreshold,
        dot11S1GDACTac,
        dot11S1GDACTImin,
        dot11S1GDACTImax,
        dot11ProtectedTWTOperationsImplemented,(#1276)
        dot11ExtendedS1GActionProtectionOperationsImplemented(#1276)}
    STATUS current
    DESCRIPTION
        "Attributes that configure the S1G Group for IEEE 802.11."
    ::= { dot11Groups 90 }

dot11FILSComplianceGroup OBJECT-GROUP
    OBJECTS {
        dot11FILSActivated,
        dot11FILSFDFrameBeaconMinimumInterval,
        dot11FILSFDFrameBeaconMaximumInterval,
        dot11FILSBeaconResponseWindow,
        dot11FILSOmitReplicateProbeResponses,
        dot11DILSImplemented,
        dot11FILSProbeDelay,
        dot11HLPWaitTime,
        dot11CacheIdentifier
        }
    STATUS current
    DESCRIPTION
        "The FILS Compliance group defines those objects that provide fast initial
        link setup for IEEE Std 802.11."
    ::= { dot11Groups 91 }(#2334)


dot11SMTbase13 OBJECT-GROUP
    OBJECTS {
        dot11MediumOccupancyLimit,
        dot11CFPollable,
        dot11CFPPeriod,
        dot11CFPMaxDuration,
        dot11PrivacyOptionImplemented,
        dot11PowerManagementMode,
        dot11DesiredSSID,
        dot11DesiredBSSType,
        dot11OperationalRateSet,
        dot11BeaconPeriod,
        dot11DTIMPeriod,
        dot11AssociationResponseTimeout,
        dot11DisassociateReason,
        dot11DisassociateStation,
        dot11DeauthenticateReason,
        dot11DeauthenticateStation,
        dot11AuthenticateFailStatus,
        dot11AuthenticateFailStation,
        dot11MultiDomainCapabilityImplemented,
        dot11MultiDomainCapabilityActivated,
        dot11CountryString,
```


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```
        dot11SpectrumManagementImplemented,
        dot11SpectrumManagementRequired,
        dot11RSNAOptionImplemented,
        dot11OperatingClassesImplemented,
        dot11OperatingClassesRequired,
        dot11QosOptionImplemented,
        dot11ImmediateBlockAckOptionImplemented,
        dot11DelayedBlockAckOptionImplemented,
        dot11DirectOptionImplemented,
        dot11APSDOptionImplemented,
        dot11QAckOptionImplemented,
        dot11QBSSLoadImplemented,
        dot11QueueRequestOptionImplemented,
        dot11TXOPRequestOptionImplemented,
        dot11MoreDataAckOptionImplemented,
        dot11AssociateInNQBSS,
        dot11DLSAllowedInQBSS,
        dot11DLSAllowed,
        dot11AssociateStation,
        dot11AssociateID,
        dot11AssociateFailStation,
        dot11AssociateFailStatus,
        dot11ReassociateStation,
        dot11ReassociateID,
        dot11ReassociateFailStation,
        dot11ReassociateFailStatus,
        dot11RadioMeasurementImplemented,
        dot11RadioMeasurementActivated,
        dot11RMMeasurementNavSync,
        dot11RMMeasurementPilotPeriod,
        dot11RMLinkMeasurementActivated,
        dot11RMNeighborReportActivated,
        dot11RMParallelMeasurementsActivated,
        dot11RMRepeatedMeasurementsActivated,
        dot11RMBeaconPassiveMeasurementActivated,
        dot11RMBeaconActiveMeasurementActivated,
        dot11RMBeaconTableMeasurementActivated,
        dot11RMBeaconMeasurementReportingConditionsActivated,
        dot11RMFrameMeasurementActivated,
        dot11RMChannelLoadMeasurementActivated,
        dot11RMNoiseHistogramMeasurementActivated,
        dot11RMStatisticsMeasurementActivated,
        dot11RMLCIMeasurementActivated,
        dot11RMLCIAzimuthActivated,
        dot11RMTransmitStreamCategoryMeasurementActivated,
        dot11RMTriggeredTransmitStreamCategoryMeasurementActivated,
        dot11RMAPChannelReportActivated,
        dot11RMMIBActivated,
        dot11RMMaxMeasurementDuration,
        dot11RMNonOperatingChannelMaxMeasurementDuration,
        dot11RMMeasurementPilotTransmissionInformationActivated,
        dot11RMMeasurementPilotActivated,
        dot11RMNeighborReportTSFOffsetActivated,
        dot11RMRCPIMeasurementActivated,
        dot11RMRSNIMeasurementActivated,
        dot11RMBSSAverageAccessDelayActivated,
        dot11RMBSSAvailableAdmissionCapacityActivated,
        dot11FastBSSTransitionImplemented,
        dot11LCIDSEImplemented,
        dot11LCIDSERequired,
        dot11DSERequired,
        dot11ExtendedChannelSwitchActivated,
        dot11HighThroughputOptionImplemented,
        dot11WirelessManagementImplemented,
```

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```
        dot11MeshActivated,
        dot11RSNAPBACRequired,
        dot11PSMPOptionImplemented,
        dot11MaxMSDULength,
        dot11ExtendedSpectrumManagementImplemented,
        dot11EstimatedServiceParametersInboundOptionImplemented,
        dot11FutureChannelGuidanceActivated
}
    STATUS deprecated
    DESCRIPTION
        "Superseded by dot11SMTbase15.(#2334)
        The SMTbase13 object class provides the necessary support at the STA to
        manage the processes in the STA such that the STA may work cooperatively
        as a part of an IEEE 802.11 network."
    ::= { dot11Groups 92 }

dot11FineTimingMeasurement OBJECT-GROUP
    OBJECTS {
        dot11WirelessManagementImplemented,
        dot11FineTimingMsmtRespActivated,
        dot11FineTimingMsmtInitActivated,
        dot11LciCivicInNeighborReport,
        dot11RMFineTimingMsmtRangeRepImplemented,
        dot11RMFineTimingMsmtRangeRepActivated,
        dot11RMLCIMeasurementActivated,
        dot11RMLCIConfigured,
        dot11RMCivicMeasurementActivated,
        dot11RMCivicConfigured,
        (11az)dot11PASNActivated,
        (11az)dot11NoAuthPASNActivated,
        (11az)dot11SecureLTFImplemented,
        (11az)dot11TriggerBasedRangingRespImplemented,
        (11az)dot11NonTriggerBasedRangingRespImplemented,
        (11az)dot11RSTARequiresPMFActivated,
        (11az)dot11PassiveTBRangingResponderImplemented,
        (11az)dot11PassiveTBRangingInitiatorImplemented,
        (11az)dot11AOAMeasurementImplemented,
        (11az)dot11I2RLMRFeedbackPolicy,
        (11az)dot11RSNAConfigPASNPTKSATimeout,
        (11az)dot11LOSAssessmentRXImplemented,
        (11az)dot11LOSAssessmentTXImplemented,
        (11az)dot11PhaseShiftFeedbackImplemented,
        (11az)dot11PassiveTBRangingAODImplemented
    }
    STATUS current
    DESCRIPTION
        "Attributes that configure the (#7065)FTM feature for IEEE Std 802.11."
    ::= { dot11Groups 93 }

dot11PADComplianceGroup OBJECT-GROUP
    OBJECTS {
        dot11SolicitedPADActivated,
        dot11UnsolicitedPADActivated
    }
    STATUS current
    DESCRIPTION
        "This object group provides the objects from the IEEE 802.11 MIB required
        to manage preassociation discovery functionality."
    ::= { dot11Groups 94 }

dot11CDMGComplianceGroup OBJECT-GROUP
    OBJECTS {
        dot11CDMGOptionImplemented,
        dot11DynamicChannelTransferImplemented,
```


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```
        dot11DynamicChannelTransferActivated,
        dot11CDMGSpatialsharingActivated,
        dot11CDMGClusteringActivated
        }
    STATUS (#3441)deprecated
    DESCRIPTION
        "Superseded by dot11CDMGComplianceGroup1. Attributes that configure the
        CDMG Group for IEEE Std 802.11."
    ::= { dot11Groups 95 }

dot11CDMGOperationsComplianceGroup OBJECT-GROUP
    OBJECTS {dot11DCSTimeout}
    STATUS current
    DESCRIPTION
        "Attributes that configure the CDMG Operation for IEEE Std 802.11."
    ::= { dot11Groups 96 }

dot11CMMGComplianceGroup OBJECT-GROUP
    OBJECTS {
        dot11CMMGOptionImplemented,
        dot11CMMGClusteringActivated
        }
    STATUS current
    DESCRIPTION
        "Attributes that configure the CMMG Group for IEEE Std 802.11."
    ::= { dot11Groups 97 }

(11ax)dot11HEComplianceGroup OBJECT-GROUP
    OBJECTS {
        dot11HEOptionImplemented,
        dot11OBSSNarrowBWRUinOFDMATolerated,
        dot11HE6GOptionImplemented,
        dot11OCTOptionImplemented,
        dot11QTPOptionImplemented,
        dot11TRSOptionImplemented,
        dot11OFDMARandomAccessOptionImplemented,
        dot11HEControlFieldOptionImplemented,
        dot11OMIOptionImplemented,
        dot11HEMCSFeedbackOptionImplemented,
        dot11HEDynamicFragmentationLevel,
        dot11AMPDUwithMultipleTIDOptionImplemented,
        dot11MPDUAskedforAckInMultiTIDAMPDU,
        dot11TXOPDurationRTSThreshold,
        dot11PPEThresholdsRequired,
        dot11IntraPPDUPowerSaveOptionActivated,
        dot11AMSDUFragmentationOptionImplemented,
        dot11BSSColorCollisionAPPeriod,
        dot11BSSColorCollisionSTAPeriod,
        dot11AutonomousBSSColorCollisionReportingImplemented,
        dot11HEPSROptionImplemented,
        dot11HEBSRControlImplemented,
        dot11HEBQRControlImplemented,
        dot11HECASControlImplemented,
        dot11PartialBSSColorImplemented,
        dot11ObssNbRuToleranceTime,
        dot11HESubchannelSelectiveTransmissionImplemented,
        dot11SRResponderOptionImplemented,
        dot11AutonomousBSSColorInUseReportingImplemented,
        dot11ShortSSIDListImplemented,
        dot11ColocatedRNRImplemented,
        dot11SRGAPOBSSPDMinOffset,
        dot11SRGAPOBSSPDMaxOffset,
        dot11SRGAPBSSColorBitmap,
        dot11SRGAPBSSIDBitmap,
```

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```
        dot11NonSRGAPOBSSPDMaxOffset,
        dot11HTVHTTriggerOptionImplemented,
        dot11HEDynamicSMPowerSaveOptionImplemented,
        dot11MUEDCAParametersActivated,
        dot11CoHostedBSSIDImplemented,
        dot11UnsolicitedProbeResponseOptionActivated,
        dot11MemberOfColocated6GHzESSOptionActivated,
        dot11AckEnabledAMPDUOptionImplemented,
        dot11MinPSCProbeDelay,
        dot11OCWmin,
        dot11OCWmax}
    STATUS current
    DESCRIPTION
        "Attributes that configure the HE Group for IEEE 802.11."
    ::= { dot11Groups 100 }

-- Amendments to Std 802.11-2024 should not make any modifications to
        dot11SMTbase16. The first amendment needing to modify the dot11SMTbase
        object should deprecate dot11SMTbase16 and define a replacement to hold
        changes.(#2334)(#8230)

(11ax)dot11SMTbase16 OBJECT-GROUP
    OBJECTS {
        dot11PrivacyOptionImplemented,
        dot11PowerManagementMode,
        dot11DesiredSSID,
        dot11DesiredBSSType,
        dot11OperationalRateSet,
        dot11BeaconPeriod,
        dot11DTIMPeriod,
        dot11AssociationResponseTimeout,
        dot11DisassociateReason,
        dot11DisassociateStation,
        dot11DeauthenticateReason,
        dot11DeauthenticateStation,
        dot11AuthenticateFailStatus,
        dot11AuthenticateFailStation,
        dot11MultiDomainCapabilityImplemented,
        dot11MultiDomainCapabilityActivated,
        dot11CountryString,
        dot11SpectrumManagementImplemented,
        dot11SpectrumManagementRequired,
        dot11RSNAOptionImplemented,
        dot11OperatingClassesImplemented,
        dot11OperatingClassesRequired,
        dot11QosOptionImplemented,
        dot11ImmediateBlockAckOptionImplemented,
        dot11DirectOptionImplemented,
        dot11APSDOptionImplemented,
        dot11QAckOptionImplemented,
        dot11QBSSLoadImplemented,
        dot11QueueRequestOptionImplemented,
        dot11TXOPRequestOptionImplemented,
        dot11MoreDataAckOptionImplemented,
        dot11AssociateInNQBSS,
        dot11AssociateStation,
        dot11AssociateID,
        dot11AssociateFailStation,
        dot11AssociateFailStatus,
        dot11ReassociateStation,
        dot11ReassociateID,
        dot11ReassociateFailStation,
        dot11ReassociateFailStatus,
        dot11RadioMeasurementImplemented,
```


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```
        dot11RadioMeasurementActivated,
        dot11RMMeasurementNavSync,
        dot11RMMeasurementPilotPeriod,
        dot11RMLinkMeasurementActivated,
        dot11RMNeighborReportActivated,
        dot11RMParallelMeasurementsActivated,
        dot11RMRepeatedMeasurementsActivated,
        dot11RMBeaconPassiveMeasurementActivated,
        dot11RMBeaconActiveMeasurementActivated,
        dot11RMBeaconTableMeasurementActivated,
        dot11RMBeaconMeasurementReportingConditionsActivated,
        dot11RMFrameMeasurementActivated,
        dot11RMChannelLoadMeasurementActivated,
        dot11RMNoiseHistogramMeasurementActivated,
        dot11RMStatisticsMeasurementActivated,
        dot11RMLCIMeasurementActivated,
        dot11RMLCIAzimuthActivated,
        dot11RMTransmitStreamCategoryMeasurementActivated,
        dot11RMTriggeredTransmitStreamCategoryMeasurementActivated,
        dot11RMAPChannelReportActivated,
        dot11RMMIBActivated,
        dot11RMMaxMeasurementDuration,
        dot11RMNonOperatingChannelMaxMeasurementDuration,
        dot11RMMeasurementPilotTransmissionInformationActivated,
        dot11RMMeasurementPilotActivated,
        dot11RMNeighborReportTSFOffsetActivated,
        dot11RMRCPIMeasurementActivated,
        dot11RMRSNIMeasurementActivated,
        dot11RMBSSAverageAccessDelayActivated,
        dot11RMBSSAvailableAdmissionCapacityActivated,
        dot11FastBSSTransitionImplemented,
        dot11LCIDSEImplemented,
        dot11LCIDSERequired,
        dot11DSERequired,
        dot11ExtendedChannelSwitchActivated,
        dot11HighThroughputOptionImplemented,
        dot11WirelessManagementImplemented,
        dot11MeshActivated,
        dot11RSNAPBACRequired,(#3263)
        dot11MaxMSDULength,
        dot11ExtendedSpectrumManagementImplemented,
        dot11EstimatedServiceParametersInboundOptionImplemented,
        dot11EstimatedServiceParametersOutboundOptionImplemented,
        dot11FutureChannelGuidanceActivated,(#2334)
        dot11HEOptionImplemented
    }
    STATUS current
    DESCRIPTION
        "The SMTbase16 object class provides the necessary support at the STA to
        manage the processes in the STA such that the STA may work cooperatively
        as a part of an IEEE 802.11 network."
    ::= { dot11Groups 101 }

(11ax)dot11HETransmitBeamformingGroup OBJECT-GROUP
    OBJECTS {
        dot11HESUBeamformerOptionImplemented,
        dot11HESUBeamformeeOptionImplemented,
        dot11HEMUBeamformerOptionImplemented,
        dot11HEBeamformeeSTSSupportLessThanOrEqualTo80,
        dot11HEBeamformeeSTSSupportGreaterThan80,
        dot11HENumberSoundingDimensionsLessThanOrEqualTo80,
        dot11HENumberSoundingDimensionsGreaterThan80,
        dot11HENG16SUFeedbackSupport,
        dot11HENG16MUFeedbackSupport,
```

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```
        dot11HECodebookSizePhi4Psi2SUFeedbackSupport,
        dot11HECodebookSizePhi7Psi5MUFeedbackSupport,
        dot11HETriggeredSUBeamformingFeedbackImplemented,
        dot11HETriggeredMUBeamformingFeedbackImplemented,
        dot11HETriggeredCQIFeedbackSupportImplemented }
    STATUS current
    DESCRIPTION
        "Attributes that configure HE transmit beamforming for IEEE 802.11."
    ::= { dot11Groups 102 }

(11ax)dot11PhyHEComplianceGroup OBJECT-GROUP
    OBJECTS {
        dot11HECurrentChannelWidthSet,
        dot11HEPuncturedPreambleRxImplemented,
        dot11HEPuncturedPreambleRxActivated,
        dot11HEDeviceClass,
        dot11HELDPCCodingInPayloadImplemented,
        dot11HESUPPDUwith1xHELTFand0point8GIlmplemented,
        dot11HESUPPDUandHEMUPPDUwith4xHELTFand0point8GIlmplemented,
        dot11HEERSUPPDUwith4xHELTFand0point8GIImplemented,
        dot11HEERSUPPDUwith1xHELTFand0point8GIImplemented,
        dot11HEMidambleRxMaxNSTS,
        dot11HENDPwith4xHELTFand3point2GIImplemented,
        dot11HESTBCTxLessThanOrEqualTo80Implemented,
        dot11HESTBCRxLessThanOrEqualTo80Implemented,
        dot11HESTBCTxGreaterThan80Implemented,
        dot11HESTBCRxGreaterThan80Implemented,
        dot11HEDopplerTxImplemented,
        dot11HEDopplerRxImplemented,
        dot11HEDCMImplemented,
        dot11HEFullBWULMUMIMOImplemented,
        dot11HEPartialBWULMUMIMOImplemented,
        dot11HEPartialBWDLMUMIMOImplemented,
        dot11HEULMUPayloadImplemented,
        dot11HEPSRbasedSRSupportImplemented,
        dot11HEPowerBoostFactorImplemented,
        dot11HEPartialBWERSUPayloadImplemented,
        dot11HEPuncturedSoundingOptionImplemented(#3484),
        dot11HEChannelWidthOptionImplemented(#3484)}
    STATUS current
    DESCRIPTION
        "Attributes that configure the HE PHY."
    ::= { dot11Groups 103 }

(11ba)dot11WURComplianceGroup OBJECT-GROUP
    OBJECTS {
        dot11WUROptionImplemented,
        dot11WURBeaconPeriod,
        dot11WURFDMAChannelSwitchImplemented,
        dot11WURDiscoveryImplemented,
        dot11WURNeighborDiscoveryImplemented,
        dot11WURDiscoveryPeriod,
        dot11RSNAWURFrameProtectionActivated,
        dot11RSNAStatsCMACWURReplays}
    STATUS current
    DESCRIPTION
        "The WUR Compliance group defines those objects that provide wake-up radio
        operation for IEEE Std 802.11."
    ::= { dot11Groups 119 }

(11bc)dot11EBCSComplianceGroup OBJECT-GROUP
```


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```
    OBJECTS {
        dot11EBCSSupportActivated,
        dot11EBCSInfoInterval,
        dot11EBCSHCFAKeyChangeInterval,
        dot11EBCSHCFAHashDistance,
        dot11EBCSInfoPHYType,
        dot11EBCSInfoTxRate,
        dot11EBCSDTIMPeriod,
        dot11EBCSTerminationNoticeTime,
        dot11EBCSTerminationNoticeMinimumInterval,
        dot11EBCSTerminationNoticeMaximumInterval,
        dot11EBCSRelayingServiceSupported,
        dot11EBCSTIMInBeacon,
        dot11EBCSAPGroupID
    }
    STATUS current
    DESCRIPTION
        "The EBCS Compliance group defines those objects that provide enhanced
        broadcast services for IEEE Std 802.11."
    ::= { dot11Groups 124 }

dot11RSNBase2 OBJECT-GROUP
    OBJECTS {
        dot11RSNAConfigVersion,
        dot11RSNAConfigPairwiseKeysImplemented,
        dot11RSNAConfigGroupCipher,
        dot11RSNAConfigGroupRekeyMethod,
        dot11RSNAConfigGroupRekeyTime,
        dot11RSNAConfigGroupRekeyPackets,
        dot11RSNAConfigGroupRekeyStrict,
        dot11RSNAConfigPSKValue,
        dot11RSNAConfigPSKPassPhrase,
        dot11RSNAConfigGroupUpdateCount,
        dot11RSNAConfigPairwiseUpdateCount,
        dot11RSNAConfigGroupCipherSize,
        dot11RSNAConfigPairwiseCipherImplemented,
        dot11RSNAConfigPairwiseCipherActivated,
        dot11RSNAConfigPairwiseCipherSizeImplemented,
        dot11RSNAConfigAuthenticationSuiteImplemented,
        dot11RSNAConfigAuthenticationSuiteActivated,
        dot11RSNAConfigNumberOfPTKSAReplayCounters,
        dot11RSNAConfigSATimeout,
        dot11RSNAConfigNumberOfGTKSAReplayCounters,
        dot11RSNAAuthenticationSuiteSelected,
        dot11RSNAPairwiseCipherSelected,
        dot11RSNAGroupCipherSelected,
        dot11RSNAPMKIDUsed,
        dot11RSNAAuthenticationSuiteRequested,
        dot11RSNAPairwiseCipherRequested,
        dot11RSNAGroupCipherRequested,
        dot11RSNATKIPCounterMeasuresInvoked,
        dot11RSNA4WayHandshakeFailures,
        dot11RSNAStatsSTAAddress,
        dot11RSNAStatsVersion,
        dot11RSNAStatsSelectedPairwiseCipher,
        dot11RSNAStatsTKIPICVErrors,
        dot11RSNAStatsTKIPLocalMICFailures,
        dot11RSNAStatsTKIPRemoteMICFailures,
        dot11RSNAStatsCCMPReplays,
        dot11RSNAStatsCCMPDecryptErrors,
        dot11RSNAStatsTKIPReplays,
        dot11RSNAPreauthenticationImplemented,
        dot11RSNAStatsGCMPReplays,
        dot11RSNAStatsRobustMgmtGCMPReplays}
```

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```
    STATUS current
    DESCRIPTION
        "The dot11RSNBase2 object class provides the necessary support for manag-
        ing RSNA functionality in the STA."
    ::= { dot11Groups 104 }

dot11HTMACAdditions3 OBJECT-GROUP
    OBJECTS {
        dot11MIMOPowerSave,
        dot11MaxAMSDULength,
        dot11STBCControlFrameOptionImplemented,
        dot11MaxRxAMPDUFactor,
        dot11MinimumMPDUStartSpacing,
        dot11TransitionTime,
        dot11MCSFeedbackOptionImplemented,
        dot11HTControlFieldSupported,
        dot11RDResponderOptionImplemented,
        dot11BSSWidthTriggerScanInterval,
        dot11BSSWidthChannelTransitionDelayFactor,
        dot11OBSSScanPassiveDwell,
        dot11OBSSScanActiveDwell,
        dot11OBSSScanPassiveTotalPerChannel,
        dot11OBSSScanActiveTotalPerChannel,
        dot112040BSSCoexistenceManagementSupport,
        dot11OBSSScanActivityThreshold,
        dot11SPPAMSDUCapable,
        dot11SPPAMSDURequired }
    STATUS deprecated(M57)
    DESCRIPTION
        "(M57)Superseded by dot11HTMACAdditions4. Attributes that configure the HT
        PHY for IEEE Std 802.11."
    ::= { dot11Groups 105 }


dot11SMTRMConfig2 OBJECT-GROUP
    OBJECTS {
        dot11APChannelReportIfIndex,
        dot11APChannelReportOperatingClass,
        dot11APChannelReportChannelList,
        dot11RMNeighborReportIfIndex,
        dot11RMNeighborReportBSSID,
        dot11RMNeighborReportAPReachability,
        dot11RMNeighborReportSecurity,
        dot11RMNeighborReportCapSpectrumMgmt,
        dot11RMNeighborReportCapQoS,
        dot11RMNeighborReportCapAPSD,
        dot11RMNeighborReportCapRM,
        dot11RMNeighborReportCapImmediateBlockAck,
        dot11RMNeighborReportKeyScope,
        dot11RMNeighborReportChannelNumber,
        dot11RMNeighborReportOperatingClass,
        dot11RMNeighborReportPhyType,
        dot11RMNeighborReportNeighborTSFInfo,
        dot11RMNeighborReportPilotInterval,
        dot11RMNeighborReportPilotMultipleBSSID,
        dot11RMNeighborReportRMEnabledCapabilities,
        dot11RMNeighborReportVendorSpecific,
        dot11RMNeighborReportRowStatus,
        dot11RMNeighborReportCapHT,
        dot11RMNeighborReportHTLDPCCodingCap,
        dot11RMNeighborReportHTSupportedChannelWidthSet,
        dot11RMNeighborReportHTSMPowerSave,
        dot11RMNeighborReportHTGreenfield,
        dot11RMNeighborReportHTShortGIfor20MHz,
```


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```
        dot11RMNeighborReportHTShortGIfor40MHz,
        dot11RMNeighborReportHTTxSTBC,
        dot11RMNeighborReportHTRxSTBC,
        dot11RMNeighborReportHTDelayedBlockAck,
        dot11RMNeighborReportHTMaxAMSDULength,
        dot11RMNeighborReportHTDSSCCKModein40MHz,
        dot11RMNeighborReportHTFortyMHzIntolerant,
        dot11RMNeighborReportHTMaxAMPDULengthExponent,
        dot11RMNeighborReportHTMinMPDUStartSpacing,
        dot11RMNeighborReportHTRxMCSBitMask,
        dot11RMNeighborReportHTRxHighestSupportedDataRate,
        dot11RMNeighborReportHTTxMCSSetDefined,
        dot11RMNeighborReportHTTxRxMCSSetNotEqual,
        dot11RMNeighborReportHTTxMaxNumberSpatialStreamsSupported,
        dot11RMNeighborReportHTTxUnequalModulationSupported,
        dot11RMNeighborReportHTMCSFeedback,
        dot11RMNeighborReportHTCSupport,
        dot11RMNeighborReportHTRDResponder,
        dot11RMNeighborReportHTImplictTransmitBeamformingReceivingCap,
        dot11RMNeighborReportHTReceiveStaggeredSoundingCap,
        dot11RMNeighborReportHTTransmitStaggeredSoundingCap,
        dot11RMNeighborReportHTReceiveNDPCap,
        dot11RMNeighborReportHTTransmitNDPCap,
        dot11RMNeighborReportHTImplicitTransmitBeamformingCap,
        dot11RMNeighborReportHTTransmitBeamformingCalibration,
        dot11RMNeighborReportHTExplicitCSITransmitBeamformingCap,
        dot11RMNeighborReportHTExplicitNonCompressedSteeringCap,
        dot11RMNeighborReportHTExplicitCompressedSteeringCap,
        dot11RMNeighborReportHTExplicitTransmitBeamformingFeedback,
        dot11RMNbRprtHTExplicitNonCompressedBeamformingFeedbackCap,
        dot11RMNeighborReportHTExplicitCompressedBeamformingFeedbackCap,
        dot11RMNeighborReportHTTransmitBeamformingMinimalGrouping,
        dot11RMNbRprtHTCSINumberofTxBeamformingAntennasSuppt,
        dot11RMNbRprtHTNonCompressedSteeringNumofTxBmfmingAntennasSuppt,
        dot11RMNbRprtHTCompressedSteeringNumberofTxBmfmingAntennasSuppt,
        dot11RMNbRprtHTCSIMaxNumberofRowsTxBeamformingSuppt,
        dot11RMNeighborReportHTTransmitBeamformingChannelEstimationCap,
        dot11RMNeighborReportHTAntSelectionCap,
        dot11RMNeighborReportHTExplicitCSIFeedbackBasedTxASELCap,
        dot11RMNeighborReportHTAntIndicesFeedbackBasedTxASELCap,
        dot11RMNeighborReportHTExplicitCSIFeedbackBasedCap,
        dot11RMNeighborReportHTAntIndicesFeedbackCap,
        dot11RMNeighborReportHTRxASELCap,
        dot11RMNeighborReportHTTxSoundingPPDUsCap,
        dot11RMNeighborReportHTInfoPrimaryChannel,
        dot11RMNeighborReportHTInfoSecChannelOffset,
        dot11RMNeighborReportHTInfoSTAChannelWidth,
        dot11RMNeighborReportHTInfoRIFSMode,
        dot11RMNeighborReportHTInfoProtection,
        dot11RMNeighborReportHTInfoNonGreenfieldHTSTAsPresent,
        dot11RMNeighborReportHTInfoOBSSNonHTSTAsPresent,
        dot11RMNeighborReportHTInfoDualBeacon,
        dot11RMNeighborReportHTInfoDualCTSProtection,
        dot11RMNeighborReportHTInfoSTBCBeacon,
        dot11RMNeighborReportHTInfoBasicMCSSet,
        dot11RMNeighborReportHTSecChannelOffset,
        dot11RMNeighborReportExtCapPSMPSupport,
        dot11RMNeighborReportExtCapSPSMPSup,
        dot11RMNeighborReportExtCapServiceIntervalGranularity }
    STATUS deprecated(Ed1)
    DESCRIPTION
        "Superseded by dot11SMTRMConfig3. The SMTRMConfig package is a set of
        attributes that are present if the STA supports the Radio Measurement ser-
        vice."
```

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```
    ::= { dot11Groups 106 }

dot11CountersGroup5 OBJECT-GROUP
    OBJECTS {
        dot11TransmittedFragmentCount,
        dot11TransmittedFrameCount,
        dot11FailedCount,
        dot11ReceivedFragmentCount,
        dot11GroupReceivedFrameCount,
        dot11FCSErrorCount,
        dot11WEPUndecryptableCount,
        dot11TransmittedFrameCount,
        dot11QosDiscardedFragmentCount,
        dot11AssociatedStationCount,
        dot11QosCFPollsReceivedCount,
        dot11QosCFPollsUnusedCount,
        dot11QosCFPollsUnusableCount,
        dot11QosCFPollsLostCount,
        dot11TransmittedAMSDUCount,
        dot11FailedAMSDUCount,
        dot11RetryAMSDUCount,
        dot11MultipleRetryAMSDUCount,
        dot11TransmittedOctetsInAMSDUCount,
        dot11AMSDUAckFailureCount,
        dot11ReceivedAMSDUCount,
        dot11ReceivedOctetsInAMSDUCount,
        dot11TransmittedAMPDUCount,
        dot11TransmittedMPDUsInAMPDUCount,
        dot11TransmittedOctetsInAMPDUCount,
        dot11AMPDUReceivedCount,
        dot11MPDUInReceivedAMPDUCount,
        dot11ReceivedOctetsInAMPDUCount,
        dot11AMPDUDelimiterCRCErrorCount,
        dot11ImplicitBARFailureCount,
        dot11ExplicitBARFailureCount,
        dot11ChannelWidthSwitchCount,
        dot11TwentyMHzFrameTransmittedCount,
        dot11FortyMHzFrameTransmittedCount,
        dot11TwentyMHzFrameReceivedCount,
        dot11FortyMHzFrameReceivedCount,
        dot11PSMPUTTGrantDuration,
        dot11PSMPUTTUsedDuration,
        dot11GrantedRDGUsedCount,
        dot11GrantedRDGUnusedCount,
        dot11TransmittedFramesInGrantedRDGCount,
        dot11TransmittedOctetsInGrantedRDGCount,
        dot11BeamformingFrameCount,
        dot11DualCTSSuccessCount,
        dot11DualCTSFailureCount,
        dot11STBCCTSSuccessCount,
        dot11STBCCTSFailureCount,
        dot11nonSTBCCTSSuccessCount,
        dot11nonSTBCCTSFailureCount,
        dot11TransmittedMSDUOctetsCount,
        dot11ReceivedMSDUOctetsCount
        }
    STATUS deprecated(#3263)
    DESCRIPTION
        "(#3263)Superseded by dot11CountersGroup6. Attributes from the
        dot11CountersGroup that are not described in the dot11MACStatistics group.
        These objects are mandatory."
    ::= { dot11Groups 107 }

dot11MACbase5 OBJECT-GROUP
```



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```
    OBJECTS {
        dot11MACAddress,
        dot11GroupAddress,
        dot11GroupAddressesStatus,
        dot11RTSThreshold,
        dot11ShortRetryLimit,
        dot11FragmentationThreshold,
        dot11MaxTransmitMSDULifetime,
        dot11MaxReceiveLifetime,
        dot11ManufacturerID,
        dot11ProductID,
        dot11CAPLimit,
        dot11HCCWmin,
        dot11HCCWmax,
        dot11HCCAIFSN,
        dot11ChannelUtilizationBeaconIntervals,
        dot11ScheduleTimeout,
        dot11DLSResponseTimeout,
        dot11QAPMissingAckRetryLimit,
        dot11EDCAAveragingPeriod,
        dot11HTProtection,
        dot11RIFSMode,
        dot11PSMPControlledAccess,
        dot11ServiceIntervalGranularity,
        dot11DualCTSProtection,
        dot11NonGFEntitiesPresent}
    STATUS deprecated(#3263)
    DESCRIPTION
        "(#3263)Superseded by dot11MACbase6. The MAC object class provides the
        necessary support for the access control, generation, and verification of
        frame check sequences (FCSs), and proper delivery of valid data to upper
        layers."
    ::= { dot11Groups 108 }


dot11SMTbase15 OBJECT-GROUP
    OBJECTS {
        dot11PrivacyOptionImplemented,
        dot11PowerManagementMode,
        dot11DesiredSSID,
        dot11DesiredBSSType,
        dot11OperationalRateSet,
        dot11BeaconPeriod,
        dot11DTIMPeriod,
        dot11AssociationResponseTimeout,
        dot11DisassociateReason,
        dot11DisassociateStation,
        dot11DeauthenticateReason,
        dot11DeauthenticateStation,
        dot11AuthenticateFailStatus,
        dot11AuthenticateFailStation,
        dot11MultiDomainCapabilityImplemented,
        dot11MultiDomainCapabilityActivated,
        dot11CountryString,
        dot11SpectrumManagementImplemented,
        dot11SpectrumManagementRequired,
        dot11RSNAOptionImplemented,
        dot11OperatingClassesImplemented,
        dot11OperatingClassesRequired,
        dot11QosOptionImplemented,
        dot11ImmediateBlockAckOptionImplemented,
        dot11DirectOptionImplemented,
        dot11APSDOptionImplemented,
        dot11QAckOptionImplemented,
```

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```
        dot11QBSSLoadImplemented,
        dot11QueueRequestOptionImplemented,
        dot11TXOPRequestOptionImplemented,
        dot11MoreDataAckOptionImplemented,
        dot11AssociateInNQBSS,
        dot11AssociateStation,
        dot11AssociateID,
        dot11AssociateFailStation,
        dot11AssociateFailStatus,
        dot11ReassociateStation,
        dot11ReassociateID,
        dot11ReassociateFailStation,
        dot11ReassociateFailStatus,
        dot11RadioMeasurementImplemented,
        dot11RadioMeasurementActivated,
        dot11RMMeasurementNavSync,
        dot11RMMeasurementPilotPeriod,
        dot11RMLinkMeasurementActivated,
        dot11RMNeighborReportActivated,
        dot11RMParallelMeasurementsActivated,
        dot11RMRepeatedMeasurementsActivated,
        dot11RMBeaconPassiveMeasurementActivated,
        dot11RMBeaconActiveMeasurementActivated,
        dot11RMBeaconTableMeasurementActivated,
        dot11RMBeaconMeasurementReportingConditionsActivated,
        dot11RMFrameMeasurementActivated,
        dot11RMChannelLoadMeasurementActivated,
        dot11RMNoiseHistogramMeasurementActivated,
        dot11RMStatisticsMeasurementActivated,
        dot11RMLCIMeasurementActivated,
        dot11RMLCIAzimuthActivated,
        dot11RMTransmitStreamCategoryMeasurementActivated,
        dot11RMTriggeredTransmitStreamCategoryMeasurementActivated,
        dot11RMAPChannelReportActivated,
        dot11RMMIBActivated,
        dot11RMMaxMeasurementDuration,
        dot11RMNonOperatingChannelMaxMeasurementDuration,
        dot11RMMeasurementPilotTransmissionInformationActivated,
        dot11RMMeasurementPilotActivated,
        dot11RMNeighborReportTSFOffsetActivated,
        dot11RMRCPIMeasurementActivated,
        dot11RMRSNIMeasurementActivated,
        dot11RMBSSAverageAccessDelayActivated,
        dot11RMBSSAvailableAdmissionCapacityActivated,
        dot11FastBSSTransitionImplemented,
        dot11LCIDSEImplemented,
        dot11LCIDSERequired,
        dot11DSERequired,
        dot11ExtendedChannelSwitchActivated,
        dot11HighThroughputOptionImplemented,
        dot11WirelessManagementImplemented,
        dot11MeshActivated,
        dot11RSNAPBACRequired,
        dot11PSMPOptionImplemented,
        dot11MaxMSDULength,
        dot11ExtendedSpectrumManagementImplemented,
        dot11EstimatedServiceParametersInboundOptionImplemented,
        dot11EstimatedServiceParametersOutboundOptionImplemented,
        dot11FutureChannelGuidanceActivated
}
    STATUS deprecated(#2334)
    DESCRIPTION
        "(11ax)Superseded by dot11SMTbase16.
        The SMTbase15 object class provides the necessary support at the STA to
```


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```
        manage the processes in the STA such that the STA may work cooperatively
        as a part of an IEEE 802.11 network."
    ::= { dot11Groups 109 }


dot11SMTRMReport2 OBJECT-GROUP
    OBJECTS {
        dot11ChannelLoadRprtRqstToken,
        dot11ChannelLoadRprtIfIndex,
        dot11ChannelLoadMeasuringSTAAddr,
        dot11ChannelLoadRprtChanNumber,
        dot11ChannelLoadRprtOperatingClass,
        dot11ChannelLoadRprtActualStartTime,
        dot11ChannelLoadRprtMeasurementDuration,
        dot11ChannelLoadRprtChannelLoad,
        dot11ChannelLoadRprtVendorSpecific,
        dot11ChannelLoadRprtMeasurementMode,
        dot11NoiseHistogramRprtRqstToken,
        dot11NoiseHistogramRprtIfIndex,
        dot11NoiseHistogramMeasuringSTAAddr,
        dot11NoiseHistogramRprtChanNumber,
        dot11NoiseHistogramRprtOperatingClass,
        dot11NoiseHistogramRprtActualStartTime,
        dot11NoiseHistogramRprtMeasurementDuration,
        dot11NoiseHistogramRprtAntennaID,
        dot11NoiseHistogramRprtANPI,
        dot11NoiseHistogramRprtIPIDensity0,
        dot11NoiseHistogramRprtIPIDensity1,
        dot11NoiseHistogramRprtIPIDensity2,
        dot11NoiseHistogramRprtIPIDensity3,
        dot11NoiseHistogramRprtIPIDensity4,
        dot11NoiseHistogramRprtIPIDensity5,
        dot11NoiseHistogramRprtIPIDensity6,
        dot11NoiseHistogramRprtIPIDensity7,
        dot11NoiseHistogramRprtIPIDensity8,
        dot11NoiseHistogramRprtIPIDensity9,
        dot11NoiseHistogramRprtIPIDensity10,
        dot11NoiseHistogramRprtVendorSpecific,
        dot11NoiseHistogramRprtMeasurementMode,
        dot11BeaconRprtRqstToken,
        dot11BeaconRprtIfIndex,
        dot11BeaconMeasuringSTAAddr,
        dot11BeaconRprtChanNumber,
        dot11BeaconRprtOperatingClass,
        dot11BeaconRprtActualStartTime,
        dot11BeaconRprtMeasurementDuration,
        dot11BeaconRprtPhyType,
        dot11BeaconRprtReportedFrameType,
        dot11BeaconRprtRCPI,
        dot11BeaconRprtRSNI,
        dot11BeaconRprtBSSID,
        dot11BeaconRprtAntennaID,
        dot11BeaconRprtParentTSF,
        dot11BeaconRprtReportedFrameBody,
        dot11BeaconRprtVendorSpecific,
        dot11BeaconRprtMeasurementMode,
        dot11FrameRprtIfIndex,
        dot11FrameRprtRqstToken,
        dot11FrameRprtChanNumber,
        dot11FrameRprtOperatingClass,
        dot11FrameRprtActualStartTime,
        dot11FrameRprtMeasurementDuration,
        dot11FrameRprtTransmitSTAAddress,
        dot11FrameRprtBSSID,
```

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```
        dot11FrameRprtPhyType,
        dot11FrameRprtAvgRCPI,
        dot11FrameRprtLastRSNI,
        dot11FrameRprtLastRCPI,
        dot11FrameRprtAntennaID,
        dot11FrameRprtNumberFrames,
        dot11FrameRprtVendorSpecific,
        dot11FrameRptMeasurementMode,
        dot11STAStatisticsReportToken,
        dot11STAStatisticsIfIndex,
        dot11STAStatisticsSTAAddress,
        dot11STAStatisticsMeasurementDuration,
        dot11STAStatisticsGroupID,
        dot11STAStatisticsTransmittedFragmentCount,
        dot11STAStatisticsGroupTransmittedFrameCount,
        dot11STAStatisticsFailedCount,
        dot11STAStatisticsRetryCount,
        dot11STAStatisticsMultipleRetryCount,
        dot11STAStatisticsFrameDuplicateCount,
        dot11STAStatisticsRTSSuccessCount,
        dot11STAStatisticsRTSFailureCount,
        dot11STAStatisticsAckFailureCount,
        dot11STAStatisticsQosTransmittedFragmentCount,
        dot11STAStatisticsQosFailedCount,
        dot11STAStatisticsQosRetryCount,
        dot11STAStatisticsQosMultipleRetryCount,
        dot11STAStatisticsQosFrameDuplicateCount,
        dot11STAStatisticsQosRTSSuccessCount,
        dot11STAStatisticsQosRTSFailureCount,
        dot11STAStatisticsQosAckFailureCount,
        dot11STAStatisticsQosReceivedFragmentCount,
        dot11STAStatisticsQosTransmittedFrameCount,
        dot11STAStatisticsQosDiscardedFrameCount,
        dot11STAStatisticsQosMPDUsReceivedCount,
        dot11STAStatisticsQosRetriesReceivedCount,
        dot11STAStatisticsReceivedFragmentCount,
        dot11STAStatisticsGroupReceivedFrameCount,
        dot11STAStatisticsFCSErrorCount,
        dot11STAStatisticsTransmittedFrameCount,
        dot11STAStatisticsAPAverageAccessDelay,
        dot11STAStatisticsAverageAccessDelayBestEffort,
        dot11STAStatisticsAverageAccessDelayBackground,
        dot11STAStatisticsAverageAccessDelayVideo,
        dot11STAStatisticsAverageAccessDelayVoice,
        dot11STAStatisticsStationCount,
        dot11STAStatisticsChannelUtilization,
        dot11STAStatisticsVendorSpecific,
        dot11STAStatisticsRprtMeasurementMode,
        dot11LCIReportToken,
        dot11LCIIfIndex,
        dot11LCISTAAddress,
        dot11LCILatitudeUncertainty,
        dot11LCILatitudeInteger,
        dot11LCILatitudeFraction,
        dot11LCILongitudeUncertainty,
        dot11LCILongitudeInteger,
        dot11LCILongitudeFraction,
        dot11LCIAltitudeType,
        dot11LCIAltitudeUncertainty,
        dot11LCIAltitude,
        dot11LCIDatum,
        dot11LCIAzimuthType,
        dot11LCIAzimuthResolution,
        dot11LCIAzimuth,
```


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```
        dot11LCIVendorSpecific,
        dot11LCIRprtMeasurementMode,
        dot11TransmitStreamRprtRqstToken,
        dot11TransmitStreamRprtIfIndex,
        dot11TransmitStreamMeasuringSTAAddr,
        dot11TransmitStreamRprtActualStartTime,
        dot11TransmitStreamRprtMeasurementDuration,
        dot11TransmitStreamRprtPeerSTAAddress,
        dot11TransmitStreamRprtTID,
        dot11TransmitStreamRprtAverageQueueDelay,
        dot11TransmitStreamRprtAverageTransmitDelay,
        dot11TransmitStreamRprtTransmittedMSDUCount,
        dot11TransmitStreamRprtMSDUDiscardedCount,
        dot11TransmitStreamRprtMSDUFailedCount,
        dot11TransmitStreamRprtMultipleRetryCount,
        dot11TransmitStreamRprtBin0Range,
        dot11TransmitStreamRprtDelayHistogram,
        dot11TransmitStreamRprtReason,
        dot11TransmitStreamRprtVendorSpecific,
        dot11TransmitStreamRprtMeasurementMode }
    STATUS current
    DESCRIPTION
        "The SMTRMReport package is a set of attributes that are present if the
        STA supports the Radio Measurement service."
    ::= { dot11Groups 110 }

(11ay)dot11EDMGComplianceGroup OBJECT-GROUP
    OBJECTS {
        dot11EDMGOptionImplemented,
        dot11EDMGAMPDUwithMultipleTIDOptionImplemented,
        dot11EDMGScheduledRDImplemented
        }
    STATUS current
    DESCRIPTION
        "Attributes that configure the EDMG Group for IEEE 802.11."
    ::= { dot11Groups 111 }

(11ay)dot11EDMGOperationsComplianceGroup OBJECT-GROUP
    OBJECTS {
        dot11EDMGCurrentChannelWidth,
        dot11EDMGCurrentChannelCenterFrequencyIndex0,
        dot11EDMGCurrentChannelCenterFrequencyIndex1,
        dot11EDMGCurrentPrimaryChannel
        }
    STATUS current
    DESCRIPTION
        "Attributes that configure the EDMG Operation for IEEE 802.11."
    ::= { dot11Groups 112 }

(11ay)dot11EDMGPHYComplianceGroup OBJECT-GROUP
    OBJECTS {
        dot11EDMGPolarizationCapability,
        dot11EDMGSCMaxSUSpatialStreams,
        dot11EDMGOFDMMaxSUSpatialStreams,
        dot11EDMGNumConcurrentRFChains,
        dot11EDMGPhaseHoppingImplemented,
        dot11EDMGOpenLoopPrecodingImplemented,
        dot11EDMGDCMBPSKImplemented,
        dot11EDMGShortCWPuncturedImplemented,
        dot11EDMGShortCWSuperimposedImplemented,
        dot11EDMGLongCWPuncturedImplemented,
        dot11EDMGLongCWSuperimposedImplemented,
        dot11EDMGNUCTXImplemented,
        dot11EDMGNUCRXImplemented,
```

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```
        dot11EDMG8PSKImplemented,
        dot11EDMGSTBCType,
        dot11EDMGAPPDUImplemented
        }
    STATUS current
    DESCRIPTION
        "Attributes that configure the EDMG PHY for IEEE 802.11."
    ::= { dot11Groups 113 }

(11ay)dot11EDMGBeamformingComplianceGroup OBJECT-GROUP
    OBJECTS {
        dot11RequestedBRPMinDataLength,
        dot11EDMGMIMOSupport,
        dot11EDMGBFGrantRequired,
        dot11EDMGBFDMGTRNRXOnlyImplemented,
        dot11FirstPathTrainingImplemented,
        dot11EDMGHybridMUMIMOImplemented,
        dot11EDMGHybridSUMIMOImplemented,
        dot11EDMGBFGrantLargestNgSupported,
        dot11EDMGBFDynamicGroupingImplemented
        }
    STATUS current
    DESCRIPTION
        "Attributes that configure the EDMG beamforming for IEEE 802.11."
    ::= { dot11Groups 114 }

dot11AVSBase2 OBJECT-GROUP
    OBJECTS {
        dot11RobustAVStreamingImplemented,
        dot11GCRActivated,
        dot11AdvancedGCRImplemented,
        dot11AdvancedGCRActivated,
        dot11SCSImplemented,
        dot11SCSActivated,
        dot11QLoadReportActivated,
        dot11AlternateEDCAActivated,
        dot11PublicHCCATXOPNegotiationActivated,
        dot11GCRGroupMembershipAnnouncementActivated,
        dot11MeshGCRImplemented,
        dot11MeshGCRActivated,
        dot11PublicHCCATXOPNegotiationImplemented,
        dot11PublicHCCATXOPNegotiationActivated,
        dot11ProtectedHCCATXOPNegotiationImplemented,
        dot11ProtectedHCCATXOPNegotiationActivated,
        dot11ProtectedQLoadReportImplemented,
        dot11ProtectedQLoadReportActivated,
        dot11QLoadReportIntervalDTIM,
        dot11HCCATXOPBeaconTimeout,
        dot11GCRConcealmentAddress,
        dot11GCRPolicyChangeTimeout,
        dot11QLoadReportDelay,
        dot11DefaultSurplusBandwidthAllowance,
        dot11ShortDEIRetryLimit,
        dot11UnsolicitedRetryLimit,
        dot11STAStatisticsAverageMSDUSizeVideo,
        dot11STAStatisticsAverageMSDUSizeVoice,
        dot11STAStatisticsAverageBitrateVideo,
        dot11STAStatisticsAverageBitrateVoice
        }
    STATUS current
    DESCRIPTION
        "The AVSBase package is a set of attributes that are present if the STA
        supports the robust audio video streaming features."
    ::= { dot11Groups 118 }
```


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```
dot11SMTRMConfig3 OBJECT-GROUP
   OBJECTS {
      dot11APChannelReportIfIndex,
      dot11APChannelReportOperatingClass,
      dot11APChannelReportChannelList,
      dot11RMNeighborReportIfIndex,
      dot11RMNeighborReportBSSID,
      dot11RMNeighborReportAPReachability,
      dot11RMNeighborReportSecurity,
      dot11RMNeighborReportCapSpectrumMgmt,
      dot11RMNeighborReportCapQoS,
      dot11RMNeighborReportCapAPSD,
      dot11RMNeighborReportCapRM,
      dot11RMNeighborReportCapImmediateBlockAck,
      dot11RMNeighborReportKeyScope,
      dot11RMNeighborReportChannelNumber,
      dot11RMNeighborReportOperatingClass,
      dot11RMNeighborReportPhyType,
      dot11RMNeighborReportNeighborTSFInfo,
      dot11RMNeighborReportPilotInterval,
      dot11RMNeighborReportPilotMultipleBSSID,
      dot11RMNeighborReportRMEnabledCapabilities,
      dot11RMNeighborReportVendorSpecific,
      dot11RMNeighborReportRowStatus,
      dot11RMNeighborReportCapHT,
      dot11RMNeighborReportHTLDPCCodingCap,
      dot11RMNeighborReportHTSupportedChannelWidthSet,
      dot11RMNeighborReportHTSMPowerSave,
      dot11RMNeighborReportHTGreenfield,
      dot11RMNeighborReportHTShortGIfor20MHz,
      dot11RMNeighborReportHTShortGIfor40MHz,
      dot11RMNeighborReportHTTxSTBC,
      dot11RMNeighborReportHTRxSTBC,
      dot11RMNeighborReportHTMaxAMSDULength,
      dot11RMNeighborReportHTDSSCCKModein40MHz,
      dot11RMNeighborReportHTFortyMHzIntolerant,
      dot11RMNeighborReportHTMaxAMPDULengthExponent,
      dot11RMNeighborReportHTMinMPDUStartSpacing,
      dot11RMNeighborReportHTRxMCSBitMask,
      dot11RMNeighborReportHTRxHighestSupportedDataRate,
      dot11RMNeighborReportHTTxMCSSetDefined,
      dot11RMNeighborReportHTTxRxMCSSetNotEqual,
      dot11RMNeighborReportHTTxMaxNumberSpatialStreamsSupported,
      dot11RMNeighborReportHTTxUnequalModulationSupported,
      dot11RMNeighborReportHTMCSFeedback,
      dot11RMNeighborReportHTCSupport,
      dot11RMNeighborReportHTRDResponder,
      dot11RMNeighborReportHTImplictTransmitBeamformingReceivingCap,
      dot11RMNeighborReportHTReceiveStaggeredSoundingCap,
      dot11RMNeighborReportHTTransmitStaggeredSoundingCap,
      dot11RMNeighborReportHTReceiveNDPCap,
      dot11RMNeighborReportHTTransmitNDPCap,
      dot11RMNeighborReportHTImplicitTransmitBeamformingCap,
      dot11RMNeighborReportHTTransmitBeamformingCalibration,
      dot11RMNeighborReportHTExplicitCSITransmitBeamformingCap,
      dot11RMNeighborReportHTExplicitNonCompressedSteeringCap,
      dot11RMNeighborReportHTExplicitCompressedSteeringCap,
      dot11RMNeighborReportHTExplicitTransmitBeamformingFeedback,
      dot11RMNbRprtHTExplicitNonCompressedBeamformingFeedbackCap,
      dot11RMNeighborReportHTExplicitCompressedBeamformingFeedbackCap,
      dot11RMNeighborReportHTTransmitBeamformingMinimalGrouping,
      dot11RMNbRprtHTCSINumberofTxBeamformingAntennasSuppt,
      dot11RMNbRprtHTNonCompressedSteeringNumofTxBmfmingAntennasSuppt,
```

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```
        dot11RMNbRprtHTCompressedSteeringNumberofTxBmfmingAntennasSuppt,
        dot11RMNbRprtHTCSIMaxNumberofRowsTxBeamformingSuppt,
        dot11RMNeighborReportHTTransmitBeamformingChannelEstimationCap,
        dot11RMNeighborReportHTAntSelectionCap,
        dot11RMNeighborReportHTExplicitCSIFeedbackBasedTxASELCap,
        dot11RMNeighborReportHTAntIndicesFeedbackBasedTxASELCap,
        dot11RMNeighborReportHTExplicitCSIFeedbackBasedCap,
        dot11RMNeighborReportHTAntIndicesFeedbackCap,
        dot11RMNeighborReportHTRxASELCap,
        dot11RMNeighborReportHTTxSoundingPPDUsCap,
        dot11RMNeighborReportHTInfoPrimaryChannel,
        dot11RMNeighborReportHTInfoSecChannelOffset,
        dot11RMNeighborReportHTInfoSTAChannelWidth,
        dot11RMNeighborReportHTInfoRIFSMode,
        dot11RMNeighborReportHTInfoProtection,
        dot11RMNeighborReportHTInfoNonGreenfieldHTSTAsPresent,
        dot11RMNeighborReportHTInfoOBSSNonHTSTAsPresent,
        dot11RMNeighborReportHTInfoDualBeacon,
        dot11RMNeighborReportHTInfoDualCTSProtection,
        dot11RMNeighborReportHTInfoSTBCBeacon,
        dot11RMNeighborReportHTInfoBasicMCSSet,
        dot11RMNeighborReportHTSecChannelOffset,
        dot11RMNeighborReportExtCapPSMPSupport,
        dot11RMNeighborReportExtCapSPSMPSup,
        dot11RMNeighborReportExtCapServiceIntervalGranularity }
    STATUS deprecated(#3263)
    DESCRIPTION
        "Superseded by dot11SMTRMConfig4.(#3263) The SMTRMConfig3 package is a set
        of attributes that are present if the STA supports the Radio Measurement
        service."
    ::= { dot11Groups 119 }

(11bd)dot11NGVComplianceGroup OBJECT-GROUP
    OBJECTS {
        dot11NGVOptionImplemented,
        dot11RadioEnvironmentMeasurementPeriod,
        dot11VirtualCSonOCBSecondaryImplemented,
        dot11NONNGVRadioEnvironmentImplemented,
        dot11StationMeasurementPeriod }
    STATUS current
    DESCRIPTION
        "Attributes that configure the NGV Group for IEEE Std 802.11."
    ::= { dot11Groups 125 }

(11bd)dot11PhyNGVComplianceGroup OBJECT-GROUP
    OBJECTS {
        dot11NGVCurrentChannelWidth,
        dot11NGVCurrentPrimaryChannel,
        dot11NGVCurrentSecondaryChannel,
        dot11NGVDYN20MAllowed }
    STATUS current
    DESCRIPTION
        "Attributes that configure the NGV PHY."
    ::= { dot11Groups 126 }

dot11CDMGComplianceGroup1 OBJECT-GROUP
    OBJECTS {
        dot11CDMGOptionImplemented,
        dot11DynamicChannelTransferActivated,
        dot11OpportunisticTransmissionsImplemented
        }
    STATUS (#3441)deprecated
    DESCRIPTION
        "Attributes that configure the CDMG Group for IEEE Std 802.11."
```


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```
    ::= { dot11Groups 127(Ed1)(#1191) }

(M57)dot11HTMACAdditions4 OBJECT-GROUP
    OBJECTS {
        dot11MIMOPowerSave,
        dot11MaxAMSDULength,
        dot11STBCControlFrameOptionImplemented,
        dot11MaxRxAMPDUFactor,
        dot11MinimumMPDUStartSpacing,
        dot11TransitionTime,
        dot11MCSFeedbackOptionImplemented,
        dot11HTControlFieldSupported,
        dot11RDResponderOptionImplemented,
        dot11BSSWidthTriggerScanInterval,
        dot11BSSWidthChannelTransitionDelayFactor,
        dot11OBSSScanPassiveDwell,
        dot11OBSSScanActiveDwell,
        dot11OBSSScanPassiveTotalPerChannel,
        dot11OBSSScanActiveTotalPerChannel,
        dot112040BSSCoexistenceManagementSupport,
        dot11OBSSScanActivityThreshold,
        dot11SPPAMSDUCapable}
    STATUS current
    DESCRIPTION
        "Attributes that configure the HT PHY for IEEE Std 802.11."
    ::= { dot11Groups 128 }


(#1712)dot11TDLSComplianceGroup1 OBJECT-GROUP
    OBJECTS {
        -- Dot11StationConfigEntry
        dot11TunneledDirectLinkSetupImplemented,
        dot11TDLSPeerUAPSDBufferSTAActivated,
        dot11TDLSPeerPSMActivated,
        dot11TDLSPeerUAPSDIndicationWindow,
        dot11TDLSChannelSwitchingActivated,
        dot11TDLSPeerSTAMissingAckRetryLimit,
        dot11TDLSResponseTimeout,
        dot11OCBActivated,
        dot11TDLSNavSync,
        dot11TDLSACDeterminationInterval }
    STATUS current
    DESCRIPTION
        "This object class provides the objects from the IEEE 802.11 MIB required
        to operate tunneled direct link setup."
    ::= { dot11Groups 129 }

(#3263)dot11CountersGroup6 OBJECT-GROUP
    OBJECTS {
        dot11TransmittedFragmentCount,
        dot11TransmittedFrameCount,
        dot11FailedCount,
        dot11ReceivedFragmentCount,
        dot11GroupReceivedFrameCount,
        dot11FCSErrorCount,(#4073)(#8230)
        dot11QosDiscardedFragmentCount,
        dot11AssociatedStationCount,
        dot11QosCFPollsReceivedCount,
        dot11QosCFPollsUnusedCount,
        dot11QosCFPollsUnusableCount,
        dot11QosCFPollsLostCount,
        dot11TransmittedAMSDUCount,
        dot11FailedAMSDUCount,
        dot11RetryAMSDUCount,
```

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```
        dot11MultipleRetryAMSDUCount,
        dot11TransmittedOctetsInAMSDUCount,
        dot11AMSDUAckFailureCount,
        dot11ReceivedAMSDUCount,
        dot11ReceivedOctetsInAMSDUCount,
        dot11TransmittedAMPDUCount,
        dot11TransmittedMPDUsInAMPDUCount,
        dot11TransmittedOctetsInAMPDUCount,
        dot11AMPDUReceivedCount,
        dot11MPDUInReceivedAMPDUCount,
        dot11ReceivedOctetsInAMPDUCount,
        dot11AMPDUDelimiterCRCErrorCount,
        dot11ImplicitBARFailureCount,
        dot11ExplicitBARFailureCount,
        dot11ChannelWidthSwitchCount,
        dot11TwentyMHzFrameTransmittedCount,
        dot11FortyMHzFrameTransmittedCount,
        dot11TwentyMHzFrameReceivedCount,
        dot11FortyMHzFrameReceivedCount,
        dot11GrantedRDGUsedCount,
        dot11GrantedRDGUnusedCount,
        dot11TransmittedFramesInGrantedRDGCount,
        dot11TransmittedOctetsInGrantedRDGCount,
        dot11BeamformingFrameCount,
        dot11DualCTSSuccessCount,
        dot11DualCTSFailureCount,
        dot11STBCCTSSuccessCount,
        dot11STBCCTSFailureCount,
        dot11nonSTBCCTSSuccessCount,
        dot11nonSTBCCTSFailureCount,
        dot11TransmittedMSDUOctetsCount,
        dot11ReceivedMSDUOctetsCount
        }
    STATUS current(#8230)
    DESCRIPTION
        "Attributes from the dot11CountersGroup that are not described in the
        dot11MACStatistics group. These objects are mandatory."(#8230)
    ::= { dot11Groups 130 }


(#3263)dot11MACbase6 OBJECT-GROUP
    OBJECTS {
        dot11MACAddress,
        dot11GroupAddress,
        dot11GroupAddressesStatus,
        dot11RTSThreshold,
        dot11ShortRetryLimit,
        dot11FragmentationThreshold,
        dot11MaxTransmitMSDULifetime,
        dot11MaxReceiveLifetime,
        dot11ManufacturerID,
        dot11ProductID,
        dot11CAPLimit,
        dot11HCCWmin,
        dot11HCCWmax,
        dot11HCCAIFSN,
        dot11ChannelUtilizationBeaconIntervals,
        dot11ScheduleTimeout,
        dot11DLSResponseTimeout,
        dot11QAPMissingAckRetryLimit,
        dot11EDCAAveragingPeriod,
        dot11HTProtection,
        dot11RIFSMode,
        dot11DualCTSProtection,
```


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```
        dot11NonGFEntitiesPresent}
    STATUS current
    DESCRIPTION
        "The MAC object class provides the necessary support for the access
        control, generation, and verification of frame check sequences (FCSs), and
        proper delivery of valid data to upper layers."
    ::= { dot11Groups 131 }


(#3263)dot11SMTRMConfig4 OBJECT-GROUP
    OBJECTS {
        dot11APChannelReportIfIndex,
        dot11APChannelReportOperatingClass,
        dot11APChannelReportChannelList,
        dot11RMNeighborReportIfIndex,
        dot11RMNeighborReportBSSID,
        dot11RMNeighborReportAPReachability,
        dot11RMNeighborReportSecurity,
        dot11RMNeighborReportCapSpectrumMgmt,
        dot11RMNeighborReportCapQoS,
        dot11RMNeighborReportCapAPSD,
        dot11RMNeighborReportCapRM,
        dot11RMNeighborReportCapImmediateBlockAck,
        dot11RMNeighborReportKeyScope,
        dot11RMNeighborReportChannelNumber,
        dot11RMNeighborReportOperatingClass,
        dot11RMNeighborReportPhyType,
        dot11RMNeighborReportNeighborTSFInfo,
        dot11RMNeighborReportPilotInterval,
        dot11RMNeighborReportPilotMultipleBSSID,
        dot11RMNeighborReportRMEnabledCapabilities,
        dot11RMNeighborReportVendorSpecific,
        dot11RMNeighborReportRowStatus,
        dot11RMNeighborReportCapHT,
        dot11RMNeighborReportHTLDPCCodingCap,
        dot11RMNeighborReportHTSupportedChannelWidthSet,
        dot11RMNeighborReportHTSMPowerSave,
        dot11RMNeighborReportHTGreenfield,
        dot11RMNeighborReportHTShortGIfor20MHz,
        dot11RMNeighborReportHTShortGIfor40MHz,
        dot11RMNeighborReportHTTxSTBC,
        dot11RMNeighborReportHTRxSTBC,
        dot11RMNeighborReportHTMaxAMSDULength,
        dot11RMNeighborReportHTDSSCCKModein40MHz,
        dot11RMNeighborReportHTFortyMHzIntolerant,
        dot11RMNeighborReportHTMaxAMPDULengthExponent,
        dot11RMNeighborReportHTMinMPDUStartSpacing,
        dot11RMNeighborReportHTRxMCSBitMask,
        dot11RMNeighborReportHTRxHighestSupportedDataRate,
        dot11RMNeighborReportHTTxMCSSetDefined,
        dot11RMNeighborReportHTTxRxMCSSetNotEqual,
        dot11RMNeighborReportHTTxMaxNumberSpatialStreamsSupported,
        dot11RMNeighborReportHTTxUnequalModulationSupported,
        dot11RMNeighborReportHTMCSFeedback,
        dot11RMNeighborReportHTCSupport,
        dot11RMNeighborReportHTRDResponder,
        dot11RMNeighborReportHTImplictTransmitBeamformingReceivingCap,
        dot11RMNeighborReportHTReceiveStaggeredSoundingCap,
        dot11RMNeighborReportHTTransmitStaggeredSoundingCap,
        dot11RMNeighborReportHTReceiveNDPCap,
        dot11RMNeighborReportHTTransmitNDPCap,
        dot11RMNeighborReportHTImplicitTransmitBeamformingCap,
        dot11RMNeighborReportHTTransmitBeamformingCalibration,
        dot11RMNeighborReportHTExplicitCSITransmitBeamformingCap,
```

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```
        dot11RMNeighborReportHTExplicitNonCompressedSteeringCap,
        dot11RMNeighborReportHTExplicitCompressedSteeringCap,
        dot11RMNeighborReportHTExplicitTransmitBeamformingFeedback,
        dot11RMNbRprtHTExplicitNonCompressedBeamformingFeedbackCap,
        dot11RMNeighborReportHTExplicitCompressedBeamformingFeedbackCap,
        dot11RMNeighborReportHTTransmitBeamformingMinimalGrouping,
        dot11RMNbRprtHTCSINumberofTxBeamformingAntennasSuppt,
        dot11RMNbRprtHTNonCompressedSteeringNumofTxBmfmingAntennasSuppt,
        dot11RMNbRprtHTCompressedSteeringNumberofTxBmfmingAntennasSuppt,
        dot11RMNbRprtHTCSIMaxNumberofRowsTxBeamformingSuppt,
        dot11RMNeighborReportHTTransmitBeamformingChannelEstimationCap,
        dot11RMNeighborReportHTAntSelectionCap,
        dot11RMNeighborReportHTExplicitCSIFeedbackBasedTxASELCap,
        dot11RMNeighborReportHTAntIndicesFeedbackBasedTxASELCap,
        dot11RMNeighborReportHTExplicitCSIFeedbackBasedCap,
        dot11RMNeighborReportHTAntIndicesFeedbackCap,
        dot11RMNeighborReportHTRxASELCap,
        dot11RMNeighborReportHTTxSoundingPPDUsCap,
        dot11RMNeighborReportHTInfoPrimaryChannel,
        dot11RMNeighborReportHTInfoSecChannelOffset,
        dot11RMNeighborReportHTInfoSTAChannelWidth,
        dot11RMNeighborReportHTInfoRIFSMode,
        dot11RMNeighborReportHTInfoProtection,
        dot11RMNeighborReportHTInfoNonGreenfieldHTSTAsPresent,
        dot11RMNeighborReportHTInfoOBSSNonHTSTAsPresent,
        dot11RMNeighborReportHTInfoDualBeacon,
        dot11RMNeighborReportHTInfoDualCTSProtection,
        dot11RMNeighborReportHTInfoSTBCBeacon,
        dot11RMNeighborReportHTInfoBasicMCSSet,
        dot11RMNeighborReportHTSecChannelOffset}
    STATUS current
    DESCRIPTION
        "The SMTRMConfig4 package is a set of attributes that are present if the
        STA supports the Radio Measurement service."
    ::= { dot11Groups 132 }

-- ****************************************************************
-- * Compliance Statements
-- ****************************************************************

dot11Compliance MODULE-COMPLIANCE
    STATUS current
    DESCRIPTION
        "The compliance statement for SNMPv2 entities that implement the IEEE
        802.11 MIB."
    MODULE  -- this module
    MANDATORY-GROUPS {
        dot11SMTbase16(11ax),
        dot11MACbase6(#3263),
        dot11CountersGroup6(#8230)(#6160)(#3263),
        dot11SmtAuthenticationAlgorithms,
        dot11ResourceTypeID,
        dot11PhyOperationComplianceGroup2,
        (11ay)dot11EDMGComplianceGroup}

    GROUP dot11PhyDSSSComplianceGroup
    DESCRIPTION
        "Implementation of this group is required when object dot11PHYType is
        dsss.
        This group is mutually exclusive to the following groups:
        dot11PhyOFDMComplianceGroup3
        dot11PhyHRDSSSComplianceGroup
        dot11PhyERPComplianceGroup
        dot11PhyHTComplianceGroup
```


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```
        dot11DMGComplianceGroup
        dot11PhyVHTComplianceGroup
        dot11PhyTVHTComplianceGroup
        dot11PhyS1GComplianceGroup
        dot11CDMGComplianceGroup1
        dot11CMMGComplianceGroup,
        dot11PhyHEComplianceGroup(11ax)
        (11ay)dot11EDMGComplianceGroup
        (11bd)dot11PhyNGVComplianceGroup"

    GROUP dot11PhyOFDMComplianceGroup3
    DESCRIPTION
        "Implementation of this group is required when object dot11PHYType is
        ofdm.
        This group is mutually exclusive to the following groups:
        dot11PhyDSSSComplianceGroup
        dot11PhyHRDSSSComplianceGroup
        dot11PhyERPComplianceGroup
        dot11PhyHTComplianceGroup
        dot11DMGComplianceGroup
        dot11PhyVHTComplianceGroup
        dot11PhyTVHTComplianceGroup
        dot11PhyS1GComplianceGroup
        dot11CDMGComplianceGroup1
        dot11CMMGComplianceGroup
        dot11PhyHEComplianceGroup(11ax)
        (11ay)dot11EDMGComplianceGroup
        (11bd)dot11PhyNGVComplianceGroup"

    GROUP dot11PhyHRDSSSComplianceGroup
    DESCRIPTION
        "Implementation of this group is required when object dot11PHYType is
        hrdsss.
        This group is mutually exclusive to the following groups:
        dot11PhyDSSSComplianceGroup
        dot11PhyOFDMComplianceGroup3
        dot11PhyERPComplianceGroup
        dot11PhyHTComplianceGroup
        dot11DMGComplianceGroup
        dot11PhyVHTComplianceGroup
        dot11PhyTVHTComplianceGroup
        dot11PhyS1GComplianceGroup
        dot11CDMGComplianceGroup1
        dot11CMMGComplianceGroup
        dot11PhyHEComplianceGroup(11ax)
        (11ay)dot11EDMGComplianceGroup
        (11bd)dot11PhyNGVComplianceGroup"

    GROUP dot11PhyERPComplianceGroup
    DESCRIPTION
        "Implementation of this group is required when object dot11PHYType is erp.
        This group is mutually exclusive to the following groups:
        dot11PhyDSSSComplianceGroup
        dot11PhyOFDMComplianceGroup3
        dot11PhyHRDSSSComplianceGroup
        dot11PhyHTComplianceGroup
        dot11DMGComplianceGroup
        dot11PhyVHTComplianceGroup
        dot11PhyTVHTComplianceGroup
        dot11PhyS1GComplianceGroup
        dot11CDMGComplianceGroup1
        dot11CMMGComplianceGroup
        dot11PhyHEComplianceGroup(11ax)
        (11ay)dot11EDMGComplianceGroup
```

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```
        (11bd)dot11PhyNGVComplianceGroup"

    GROUP dot11PhyHTComplianceGroup
    DESCRIPTION
        "Implementation of this group is required when object dot11PHYType is ht.
        This group is mutually exclusive to the following groups:
        dot11PhyDSSSComplianceGroup
        dot11PhyOFDMComplianceGroup3
        dot11PhyHRDSSSComplianceGroup
        dot11PhyERPComplianceGroup
        dot11DMGComplianceGroup
        dot11PhyVHTComplianceGroup
        dot11PhyTVHTComplianceGroup
        dot11PhyS1GComplianceGroup
        dot11CDMGComplianceGroup1
        dot11CMMGComplianceGroup
        dot11PhyHEComplianceGroup(11ax)
        (11ay)dot11EDMGComplianceGroup
        (11bd)dot11PhyNGVComplianceGroup"

    GROUP dot11PhyVHTComplianceGroup
    DESCRIPTION
        "Implementation of this group is required when object dot11PHYType is vht.
        This group is mutually exclusive to the following groups:
        dot11PhyDSSSComplianceGroup
        dot11PhyOFDMComplianceGroup3
        dot11PhyHRDSSSComplianceGroup
        dot11PhyERPComplianceGroup
        dot11DMGComplianceGroup
        dot11PhyHTComplianceGroup
        dot11PhyTVHTComplianceGroup
        dot11PhyS1GComplianceGroup
        dot11CDMGComplianceGroup1
        dot11CMMGComplianceGroup
        dot11PhyHEComplianceGroup(11ax)
        (11ay)dot11EDMGComplianceGroup
        (11bd)dot11PhyNGVComplianceGroup"

    GROUP dot11PhyTVHTComplianceGroup
    DESCRIPTION
        "Implementation of this group is required when object dot11PHYType is
        tvht.
        This group is mutually exclusive to the following groups:
        dot11PhyDSSSComplianceGroup
        dot11PhyOFDMComplianceGroup3
        dot11PhyHRDSSSComplianceGroup
        dot11PhyERPComplianceGroup
        dot11PhyHTComplianceGroup
        dot11DMGComplianceGroup
        dot11PhyVHTComplianceGroup
        dot11PhyS1GComplianceGroup
        dot11CDMGComplianceGroup1
        dot11CMMGComplianceGroup
        dot11PhyHEComplianceGroup(11ax)
        (11ay)dot11EDMGComplianceGroup
        (11bd)dot11PhyNGVComplianceGroup"

    GROUP dot11PhyS1GComplianceGroup
    DESCRIPTION
        "Implementation of this group is required when object dot11PHYType is s1g.
        This group is mutually exclusive to the following groups:
        dot11PhyDSSSComplianceGroup
        dot11PhyOFDMComplianceGroup3
        dot11PhyHRDSSSComplianceGroup
```


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```
        dot11PhyERPComplianceGroup
        dot11PhyHTComplianceGroup
        dot11DMGComplianceGroup
        dot11PhyVHTComplianceGroup
        dot11PhyTVHTComplianceGroup
        dot11CDMGComplianceGroup1
        dot11CMMGComplianceGroup
        dot11PhyHEComplianceGroup(11ax)
        (11bd)dot11PhyNGVComplianceGroup"

    (11ax)GROUP dot11PhyHEComplianceGroup
    DESCRIPTION
        "Implementation of this group is required when object dot11PHYType has the
        value of HE.
        This group is mutually exclusive to the following groups:
        dot11PhyDSSSComplianceGroup
        dot11PhyOFDMComplianceGroup3
        dot11PhyHRDSSSComplianceGroup
        dot11PhyERPComplianceGroup
        dot11PhyHTComplianceGroup
        dot11DMGComplianceGroup
        dot11PhyVHTComplianceGroup
        dot11PhyTVHTComplianceGroup
        dot11PhyS1GComplianceGroup
        dot11CDMGComplianceGroup1
        dot11CMMGComplianceGroup
        (11bd)dot11PhyNGVComplianceGroup"

(11bd)GROUP dot11PhyNGVComplianceGroup
    DESCRIPTION
        "Implementation of this group is required when the object dot11PHYType has
        the value of ngv.
        This group is mutually exclusive to the following groups:
        dot11PhyDSSSComplianceGroup
        dot11PhyOFDMComplianceGroup3
        dot11PhyHRDSSSComplianceGroup
        dot11PhyERPComplianceGroup
        dot11HTComplianceGroup
        dot11DMGComplianceGroup
        dot11PhyVHTComplianceGroup
        dot11PhyTVHTComplianceGroup
        dot11PhyS1GComplianceGroup
        dot11CDMGComplianceGroup1
        dot11CMMGComplianceGroup
        dot11PhyHEComplianceGroup
        dot11EDMGComplianceGroup"

    GROUP dot11HTMACAdditions4(M57)
    DESCRIPTION
        "The dot11HTMACAdditions4(M57) group is optional."

    GROUP dot11SMTprivacy
    DESCRIPTION
        "(#4074)The dot11SMTprivacy group is deprecated."

    GROUP dot11MACStatistics
    DESCRIPTION
        "The dot11MACStatistics group is optional."

    GROUP dot11PhyTxPowerComplianceGroup
    DESCRIPTION
        "The dot11PhyTxPowerComplianceGroup group is optional."

    GROUP dot11PhyTxPowerComplianceGroup2
```

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```
    DESCRIPTION
        "The dot11PhyTxPowerComplianceGroup2 group is optional, but dependent on
        dot11PhyTxPowerComplianceGroup."

    GROUP dot11PhyRegDomainsSupportGroup
    DESCRIPTION
        "The dot11PhyRegDomainsSupportGroup group is optional."

    GROUP dot11PhyAntennasListGroup
    DESCRIPTION
        "The dot11PhyAntennasListGroup group is optional."

    GROUP dot11PhyRateGroup
    DESCRIPTION
        "The dot11PhyRateGroup group is optional."

    GROUP dot11MultiDomainCapabilityGroup
    DESCRIPTION
        "The dot11MultiDomainCapabilityGroup group is optional."

    GROUP dot11RSNAadditions
    DESCRIPTION
        "The dot11RSNAadditions group is optional."

    GROUP dot11OperatingClassesGroup
    DESCRIPTION
        "The dot11OperatingClassesGroup group is optional."

    GROUP dot11Qosadditions
    DESCRIPTION
        "The dot11Qosadditions group is optional."

    GROUP dot11FTComplianceGroup
    DESCRIPTION
        "The dot11FTComplianceGroup group is optional."

    GROUP dot11PhyAntennaComplianceGroup2
    DESCRIPTION
        "The dot11PhyAntennaComplianceGroup2 group is optional."

    GROUP dot11PhyMCSGroup
    DESCRIPTION
        "The dot11PhyMCSGroup group is optional."

    GROUP dot11TransmitBeamformingGroup
    DESCRIPTION
        "The dot11TransmitBeamformingGroup group is optional."

(11ay)GROUP dot11EDMGComplianceGroup
    DESCRIPTION
        "Implementation of this group is required when the object dot11PHYType has
        the value of EDMG.
        This group is mutually exclusive to the following groups:
              dot11PhyDSSSComplianceGroup
              dot11PhyOFDMComplianceGroup3
              dot11PhyHRDSSSComplianceGroup
              dot11PhyERPComplianceGroup
              dot11PhyHTComplianceGroup
              dot11PhyVHTComplianceGroup
              dot11PhyTVHTComplianceGroup
              (11bd)dot11PhyNGVComplianceGroup"

(11ay)GROUP dot11EDMGOperationsComplianceGroup
    DESCRIPTION
```


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```
        "EDMG operations compliance group"

(11ay)GROUP dot11EDMGPHYComplianceGroup
    DESCRIPTION
        "EDMG PHY compliance group."

(11ay)GROUP dot11EDMGBeamformingComplianceGroup
    DESCRIPTION
        "EDMG beamforming compliance group"

    GROUP dot11VHTTransmitBeamformingGroup
    DESCRIPTION
        "The dot11VHTTransmitBeamformingGroup group is optional."

    GROUP dot11VHTMACAdditions
    DESCRIPTION
        "The dot11VHTMACAdditions group is optional."

    (11ax)GROUP dot11HETransmitBeamformingGroup
    DESCRIPTION
        "The dot11HETransmitBeamformingGroup group is optional."

    (11ax)GROUP dot11HEComplianceGroup
    DESCRIPTION
        "The dot11HEComplianceGroup group is optional."

    (11ba)GROUP dot11WURComplianceGroup
    DESCRIPTION
        "WUR Compliance Group."

    GROUP dot11S1GTransmitBeamformingGroup
    DESCRIPTION
        "The dot11S1GTransmitBeamformingGroup group is optional."

    GROUP dot11S1GComplianceGroup
    DESCRIPTION
        "The dot11S1GComplianceGroup group is optional."

    GROUP dot11DMGComplianceGroup
    DESCRIPTION
        "Implementation of this group is required when the object
        dot11PHYType is dmg.
        This group is mutually exclusive to the following groups:
        dot11PhyDSSSComplianceGroup
        dot11PhyOFDMComplianceGroup3
        dot11PhyHRDSSSComplianceGroup
        dot11PhyERPComplianceGroup
        dot11PhyHTComplianceGroup
        dot11PhyVHTComplianceGroup
        dot11PhyTVHTComplianceGroup
        dot11PhyS1GComplianceGroup
        dot11CDMGComplianceGroup1
        dot11CMMGComplianceGroup
        (11ax)dot11PhyHEComplianceGroup
        (11bd)dot11PhyNGVComplianceGroup"

    GROUP dot11DMGOperationsComplianceGroup
    DESCRIPTION
        "DMG Operations Compliance Group"

    GROUP dot11DMGBeamformingComplianceGroup
    DESCRIPTION
        "DMG Beamforming Compliance Group"
```

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```
    GROUP dot11DMGCountersComplianceGroup
    DESCRIPTION
       "DMG Counters Compliance Group."

    GROUP dot11TVWSComplianceGroup
    DESCRIPTION
       "The dot11TVWSComplianceGroup is optional."

    GROUP dot11BSSStatisticsGroup
    DESCRIPTION
       "Implementation of this group is optional by an AP."

    GROUP dot11FILSComplianceGroup
    DESCRIPTION
       "FILS Compliance Group."

    GROUP dot11CDMGComplianceGroup1
    DESCRIPTION
       "Implementation of this group is required when the object
       dot11PHYType has the value of CDMG.
       This group is mutually exclusive to the following groups:
       dot11PhyDSSSComplianceGroup
       dot11PhyOFDMComplianceGroup3
       dot11PhyHRDSSSComplianceGroup
       dot11PhyERPComplianceGroup
       dot11PhyHTComplianceGroup
       dot11PhyVHTComplianceGroup
       dot11PhyTVHTComplianceGroup
       dot11PhyDMGComplianceGroup
       dot11PhyCMMGComplianceGroup
       (11bd)dot11PhyNGVComplianceGroup"

    GROUP dot11CDMGOperationsComplianceGroup
    DESCRIPTION
       "CDMG Operations Compliance Group"

    GROUP dot11CMMGComplianceGroup
    DESCRIPTION
       "Implementation of this group is required when the object
       dot11PHYType has the value of CMMG.
       This group is mutually exclusive to the following groups:
       dot11PhyDSSSComplianceGroup
       dot11PhyOFDMComplianceGroup3
       dot11PhyHRDSSSComplianceGroup
       dot11PhyERPComplianceGroup
       dot11PhyHTComplianceGroup
       dot11PhyVHTComplianceGroup
       dot11PhyTVHTComplianceGroup
       dot11PhyDMGComplianceGroup
       dot11PhyCDMGComplianceGroup
       (11bd)dot11PhyNGVComplianceGroup"

    GROUP dot11CMMGOperationsComplianceGroup
    DESCRIPTION
       "CMMG Operations Compliance Group"

    (11bd)GROUP dot11NGVComplianceGroup
    DESCRIPTION
       "NGV Compliance Group"

    (11bc)GROUP dot11EBCSComplianceGroup
    DESCRIPTION
       "EBCS Compliance Group"
```


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```
-- OPTIONAL-GROUPS {
    -- dot11MACStatistics,(#4074)
    -- dot11PhyTxPowerComplianceGroup,
    -- dot11PhyRegDomainsSupportGroup,
    -- dot11PhyAntennasListGroup,
    -- dot11PhyRateGroup,
    -- dot11MultiDomainCapabilityGroup,
    -- dot11RSNAadditions,
    -- dot11OperatingClassesGroup,
    -- dot11Qosadditions,
    -- dot11RMCompliance,
    -- dot11FTComplianceGroup,
    -- dot11PhyAntennaComplianceGroup2,
    -- dot11HTMACadditions4(M57),
    -- dot11PhyMCSGroup,
    -- dot11TransmitBeamformingGroup,
    -- dot11TVHTTransmitBeamformingGroup,
    -- dot11PhyTVHTComplianceGroup,
    -- dot11S1GTransmitBeamformingGroup,
    -- dot11PhyS1GComplianceGroup,
    -- dot11S1GComplianceGroup,
    -- dot11WNMCompliance,
    -- dot11BSSStatisticsGroup,
    -- dot11VHTTransmitBeamformingGroup,
    -- dot11PhyVHTComplianceGroup,
    -- dot11VHTMACAdditions,
    -- dot11TVWSComplianceGroup,
    -- dot11FILSComplianceGroup,
    -- dot11PADComplianceGroup,
    -- dot11HETransmitBeamformingGroup(11ax),
    -- dot11PhyHEComplianceGroup(11ax),
    -- dot11HEComplianceGroup(11ax),
    -- dot11WURComplianceGroup(11ba),
    -- dot11EBCSComplianceGroup(11bc)}
    ::= { dot11Compliances 1 }

-- ****************************************************************
-- * Compliance Statements - RSN
-- ****************************************************************
dot11RSNCompliance MODULE-COMPLIANCE
    STATUS current
    DESCRIPTION
        "The compliance statement for SNMPv2 entities that implement the IEEE
        802.11 RSN MIB."
    MODULE -- this module
    MANDATORY-GROUPS { dot11RSNBase2 }
-- OPTIONAL-GROUPS { dot11RSNPMKcachingGroup }
    ::= { dot11Compliances 2 }

-- ****************************************************************
-- * Compliance Statements - RM
-- ****************************************************************
dot11RMCompliance MODULE-COMPLIANCE
    STATUS current
    DESCRIPTION
        "The compliance statement for SNMPv2 entities that implement the IEEE
        802.11 MIB for Measurement Services."
    MODULE -- this module
    MANDATORY-GROUPS {
        dot11SMTRMRequest,
        dot11SMTRMReport,
        dot11SMTRMConfig4(#3263) }
-- OPTIONAL-GROUPS { }
    ::= { dot11Compliances 3 }
```

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```
1
2   -- ************************************************************************
3   -- * Compliance Statements - Mesh
4   -- ************************************************************************
5
6   dot11MeshCompliance MODULE-COMPLIANCE
7      STATUS current
8      DESCRIPTION
9         "The compliance statement for SNMPv2 entities that implement the IEEE
10        802.11 MIB for Mesh."
11     MODULE -- this module
12     MANDATORY-GROUPS {
13        dot11MeshComplianceGroup,
14        dot11MeshHWMPComplianceGroup,
15        dot11PasswordAuthComplianceGroup }
16  -- OPTIONAL-GROUPS { dot11MeshOptionGroup }
17     ::= { dot11Compliances 4 }
18
19  -- ************************************************************************
20  -- * Compliance Statements - WNM
21  -- ************************************************************************
22  dot11WNMCompliance MODULE-COMPLIANCE
23     STATUS current
24     DESCRIPTION
25        " This object class provides the objects from the IEEE 802.11
26        MIB required to manage wireless network management
27        functionality. Note that additional objects for managing this
28        functionality are located in the IEEE 802.11 WNM MIB."
29
30     MODULE -- this module
31     MANDATORY-GROUPS { dot11SMTRMRequest, dot11SMTRMReport, dot11SMTRMCon-
32        fig4(#3263)}
33
34     GROUP dot11SMTbase12
35     DESCRIPTION "At least the dot11WirelessManagementImplemented object is
36        required from dot11SMTbase12"
37
38     GROUP dot11FineTimingMeasurement
39     DESCRIPTION
40        "The dot11FineTimingMeasurement group is optional"
41
42     OBJECT dot11WirelessManagementImplemented
43     DESCRIPTION "Required object"
44     ::= { dot11Compliances 5 }
45
46  -- ************************************************************************
47  -- * Compliance Statements - QMF
48  -- ************************************************************************
49  dot11QMFCompliance MODULE-COMPLIANCE
50     STATUS current
51     DESCRIPTION
52        "This object class provides the objects from the IEEE 802.11 MIB required
53        to manage QoS Management Frame functionality."
54     MODULE -- this module
55     MANDATORY-GROUPS {
56        dot11QMFComplianceGroup }
57     ::= { dot11Compliances 6 }
58
59  -- ************************************************************************
60  -- * Compliance Statements - AVS
61  -- ************************************************************************
62
63  dot11AVSCompliance MODULE-COMPLIANCE
64     STATUS current
65
```


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```
    DESCRIPTION
        "The compliance statement for SNMPv2 entities that implement the IEEE
        Std 802.11 Robust Audio/Video Streaming feature.
        Note that additional objects for managing this functionality are located
        in the IEEE 802.11 AVS MIB."
    MODULE -- this module
    GROUP dot11AVSBase2
        DESCRIPTION "At least the dot11RobustAVStreamingImplemented object is
        required from dot11StationConfigEntry."
    OBJECT dot11RobustAVStreamingImplemented
    DESCRIPTION "Required object"
    ::= { dot11Compliances 7 }

dot11AVSAPCCompliance MODULE-COMPLIANCE
    STATUS current
    DESCRIPTION
        "The compliance statement for SNMPv2 entities that implement the IEEE
        Std 802.11 HCCA TXOP Negotiation feature.
        Note that additional objects for managing this
        functionality are located in the IEEE 802.11 AVS MIB."
    MODULE -- this module
    MANDATORY-GROUPS { dot11AVSBase2 }
    GROUP dot11AVSAPCGroup
        DESCRIPTION "At least the dot11RobustAVStreamingImplemented object is
        required from dot11StationConfigEntry."
    OBJECT dot11RobustAVStreamingImplemented
    DESCRIPTION "Required object"
    ::= { dot11Compliances 8 }


-- ****************************************************************
-- * Compliance Statements - DMG
-- ****************************************************************
dot11DMGCompliance MODULE-COMPLIANCE
    STATUS current
    DESCRIPTION
        "The compliance statement for SNMPv2 entities that implement the IEEE
        802.11 MIB for DMG operation."
    MODULE -- this module
    MANDATORY-GROUPS {
        dot11DMGComplianceGroup,
        dot11DMGOperationsComplianceGroup,
        dot11DMGBeamformingComplianceGroup,
        dot11DMGCountersComplianceGroup }
    ::= { dot11Compliances 9 }

-- ****************************************************************
-- * Compliance Statements - Spectrum Management
-- ****************************************************************
dot11SpectrumManagementCompliance MODULE-COMPLIANCE
    STATUS current
    DESCRIPTION
        "This object class provides the objects from the IEEE 802.11
        MIB used to operate higher throughput."
    MODULE -- this module
    MANDATORY-GROUPS { dot11SpectrumManagementGroup }
--  OPTIONAL-GROUPS { }
    ::= { dot11Compliances 10 }

-- ****************************************************************
-- * Compliance Statements - Management frame protection
-- ****************************************************************
dot11ProtectedManagementFrameCompliance MODULE-COMPLIANCE
    STATUS current

```

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```
    DESCRIPTION
        "This object class provides the objects from the IEEE 802.11
        MIB required to operate management frame protection."
    MODULE -- this module
    MANDATORY-GROUPS { dot11ProtectedManagementFrameGroup }
--  OPTIONAL-GROUPS { }
    ::= { dot11Compliances 11 }

-- ****************************************************************
-- * Compliance Statements - LCIDSE
-- ****************************************************************
dot11LCIDSECompliance MODULE-COMPLIANCE
    STATUS current
    DESCRIPTION
        "This object class provides the objects from the IEEE 802.11
        MIB required to enable 3650-3700 MHz Operation in the USA and its territo-
        ries(#296)."
    MODULE -- this module
    MANDATORY-GROUPS { dot11LCIDSEGroup }
--  OPTIONAL-GROUPS { }
    ::= { dot11Compliances 12 }

-- ****************************************************************
-- * Compliance Statements - TDLS
-- ****************************************************************
dot11TDLSCompliance MODULE-COMPLIANCE
    STATUS current
    DESCRIPTION
        "This object class provides the objects from the IEEE 802.11
        MIB required to manage tunneled direct link setup."
    MODULE -- this module
    MANDATORY-GROUPS { dot11TDLSComplianceGroup1(#1712)}
--  OPTIONAL-GROUPS {  }
    ::= { dot11Compliances 13 }


-- ****************************************************************
-- * Compliance Statements - VHT
-- ****************************************************************
dot11VHTCompliance MODULE-COMPLIANCE
    STATUS current
    DESCRIPTION
        "This object class provides the objects from the IEEE 802.11
        MIB used to operate at very high throughput."
    MODULE -- this module
    MANDATORY-GROUPS { dot11PhyVHTComplianceGroup, dot11PhyTxPowerCompliance-
        Group2, dot11VHTTransmitBeamformingGroup, dot11VHTMACAdditions }
--  OPTIONAL-GROUPS { }
    ::= { dot11Compliances 14 }

-- ****************************************************************
-- * Compliance Statements - TVWS
-- ****************************************************************
dot11TVHTCompliance MODULE-COMPLIANCE
    STATUS current
    DESCRIPTION
        "The compliance statement for SNMPv2 entities that implement the IEEE
        802.11 MIB for TVWS operation."
    MODULE -- this module
    MANDATORY-GROUPS {
        dot11PhyTVHTComplianceGroup,
        dot11PhyTxPowerComplianceGroup2,
        dot11TVHTTransmitBeamformingGroup,
        dot11VHTMACAdditions, dot11TVWSComplianceGroup }

```


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```
    ::= { dot11Compliances 15 }

-- ****************************************************************
-- * Compliance Statements - S1G
-- ****************************************************************
dot11S1GCompliance MODULE-COMPLIANCE
    STATUS current
    DESCRIPTION
        "This object class provides the objects from the IEEE 802.11
        MIB used to operate at sub 1 GHz."
    MODULE -- this module
    MANDATORY-GROUPS { dot11PhyS1GComplianceGroup, dot11PhyTxPowerCompliance-
        Group2, dot11S1GTransmitBeamformingGroup, dot11S1GComplianceGroup }
--  OPTIONAL-GROUPS { }
    ::= { dot11Compliances 16 }

-- ****************************************************************
-- * Compliance Statements - FILS
-- ****************************************************************
dot11FILSCompliance MODULE-COMPLIANCE
    STATUS current
    DESCRIPTION
        "The compliance statement for SNMPv2 entities that implement the IEEE
        802.11 MIB for FILS operation."
    MODULE -- this module
    MANDATORY-GROUPS { dot11FILSComplianceGroup }
--  OPTIONAL-GROUPS { }
    ::= { dot11Compliances 17 }

-- ****************************************************************
-- * Compliance Statements - CDMG
-- ****************************************************************

dot11CDMGCompliance MODULE-COMPLIANCE
    STATUS current
    DESCRIPTION
        "The compliance statement for SNMPv2 entities that implement the IEEE Std
        802.11 MIB for CDMG operation."
        MODULE -- this module
    MANDATORY-GROUPS {
        dot11CDMGComplianceGroup1,
        dot11CDMGOperationsComplianceGroup}
    ::= { dot11Compliances 18 }

-- ****************************************************************
-- * Compliance Statements - CMMG
-- ****************************************************************

dot11CMMGCompliance MODULE-COMPLIANCE
    STATUS current
    DESCRIPTION
        "The compliance statement for SNMPv2 entities that implement the IEEE Std
        802.11 MIB for CMMG operation."
        MODULE -- this module
    MANDATORY-GROUPS {
        dot11CMMGComplianceGroup,
        dot11CMMGOperationsComplianceGroup}
    ::= { dot11Compliances 19 }

-- ****************************************************************
-- * Compliance Statements- PAD
-- ****************************************************************

dot11PADCompliance MODULE-COMPLIANCE

```

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```
    STATUS current
    DESCRIPTION
        "This object class provides the objects from the IEEE 802.11 MIB required
        to manage preassociation discovery functionality."
        MODULE -- this module
    MANDATORY-GROUPS { dot11PADComplianceGroup }
::= { dot11Compliances 20 }

-- ************************************************************
-- * Compliance Statements - GLK
-- ************************************************************

dot11GLKComplianceGroup OBJECT-GROUP
    OBJECTS {
    dot11GLKImplemented,
    dot11GLKRequired,
    dot11EPDImplemented,
    dot11EPDRequired,
    dot11GLKLinkRateSamples,
    dot11GLKLinkRateWindowSize,
    dot11GLKLinkRateWmin,
    dot11GLKLinkRateWavg,
    dot11GLKLinkRateWgeo,
    dot11GLKLinkRateScaling,
    dot11GLKLinkRateHysteresis,
    dot11GLKGCRImplemented }
    STATUS current
    DESCRIPTION
        "This object group provides the objects from the IEEE 802.11
        MIB required to manage General Link functionality."
    ::= { dot11Groups 99 }

dot11GLKCompliance MODULE-COMPLIANCE
    STATUS current
    DESCRIPTION
        "This object class provides the objects from the IEEE 802.11
        MIB required to manage General Link functionality."
    MODULE -- this module
    MANDATORY-GROUPS {
    dot11GLKComplianceGroup }
    ::= { dot11Compliances 21 }

-- ************************************************************************
-- * (11ax)Compliance Statements - HE
-- ************************************************************************

(11ax)dot11HECompliance MODULE-COMPLIANCE
    STATUS current
    DESCRIPTION
        "This object class provides the objects from the IEEE 802.11
        MIB used to operate at high efficiency."
    MODULE -- this module
    MANDATORY-GROUPS { dot11PhyHEComplianceGroup,
        dot11PhyTxPowerComplianceGroup2, dot11HETransmitBeamformingGroup,
        dot11HEComplianceGroup }
--  OPTIONAL-GROUPS { }
    ::= { dot11Compliances 22 }

-- ************************************************************************
-- * (11ay)Compliance Statements - EDMG
-- ************************************************************************

dot11EDMGCompliance MODULE-COMPLIANCE
    STATUS current
```


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```
    DESCRIPTION
        "The compliance statement for SNMPv2 entities that implement the IEEE
        802.11 MIB for EDMG operation."
    MODULE -- this module
    MANDATORY-GROUPS {
        dot11EDMGComplianceGroup,
        dot11EDMGOperationsComplianceGroup,
        dot11EDMGPHYComplianceGroup,
        dot11EDMGBeamformingComplianceGroup
        }

    -- OPTIONAL-GROUPS { }
    ::= { dot11Compliances 23 }

-- ****************************************************************
-- * (11ba)Compliance Statements - WUR
-- ****************************************************************
dot11WURCompliance MODULE-COMPLIANCE
    STATUS current
    DESCRIPTION
        "The compliance statement for SNMPv2 entities that implement the IEEE
802.11 MIB for WUR operation."
    MODULE -- this module
    MANDATORY-GROUPS {
        dot11WURComplianceGroup
        }
    -- OPTIONAL-GROUPS { }
        ::= { dot11Compliances 24}

-- ****************************************************************
-- * (11bc)Compliance Statements - EBCS
-- ****************************************************************

(11bc)dot11EBCSCompliance MODULE-COMPLIANCE
    STATUS current
    DESCRIPTION
        "This object class provides the objects from the IEEE 802.11
        MIB required to manage Enhanced Broadcast Services functionality."
    MODULE -- this module
    MANDATORY-GROUPS
         {
          dot11EBCSComplianceGroup
         }
    ::= { dot11Compliances 26 }


-- ****************************************************************
-- * (11bd)Compliance Statements - NGV
-- ****************************************************************

(11bd)dot11NGVCompliance MODULE-COMPLIANCE
    STATUS current
    DESCRIPTION
        "This object class provides the objects from IEEE 802.11
        MIB required to manage Next Generation V2X functionality."
    MODULE - this module
    MANDATORY-GROUPS {
        dot11NGVComplianceGroup,
        dot11PhyNGVComplianceGroup }
-- OPTIONAL-GROUPS {  }
    ::= { dot11Compliances 27 }

-- ****************************************************************
```

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```
-- *   End of IEEE 802.11 MIB
-- ************************************************************************

    END
```


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# Annex D

(normative)

# Regulatory references

## D.1 External regulatory references

This annex and Annex E provide information and specifications for operation in many regulatory domains.

WLANs implemented in accordance with this standard and the specifications and definitions referenced in it are subject to equipment certification and operating requirements established by regional and national regulatory administrations. The specification establishes minimum technical requirements for interoperability, based upon established regulations at the time this standard was issued. These regional and national regulations are subject to revision or may be superseded. Regulatory requirements that do not affect interoperability are not addressed in this standard. Implementers are referred to the regulatory sources in Table D-1 (Regulatory requirement list) for further information. Operation in countries within defined regulatory domains may be subject to additional or alternative national regulations.

The documents listed in Table D-1 (Regulatory requirement list) specify current regulatory requirements for various frequency bands and geographic areas at the time this standard was developed. They are provided for information only and are subject to change or revision at any time.

**Table D-1—Regulatory requirement list**

| Geographic area | Approval standards | Documents | Approval authority |
|---|---|---|---|
| Australia | Federal Register of Legislative Instruments | Radiocommunications (Low Interference Potential Devices) Class Licence 2000, Sections 132 and 135 | FRLI |
| Canada | Minister of Industry | RSS-210 — License-exempt Radio Apparatus (All Frequency Bands): Category I Equipment | Industry Canada |
| China | Ministry of Industry and Information Technology (MIIT) | Xin Bu Wu [2002] #353,<br>Xin Bu Wu [2002] #277,<br>Gong Xin Bu Wu Han [2012] #620,<br>MIIT Wireless [2005] 423 | MIIT |
| Europe | European Conference of Postal and Telecommunications (CEPT) Administrations and its Electronic Communications Committee (ECC). Also, European Radiocommunications Office, European Telecommunications Standards Institute (ETSI) | ECC DEC (04) 08,<br>ETSI EN 300 328 [B10],<br>ETSI EN 301 893,<br>ETSI ES 202 663 [B12],<br>ETSI EN 302 571 [B11], Clause 5 (MAC service definition),<br>ERC Recommendation 70-03 [B8] | CEPT |
| Japan | Ministry of Internal Affairs and Communications (MIC) | MIC Equipment Ordinance (EO) for Regulating Radio Equipment Articles 7, 49.20, 49.21[a], 49.14, 54.5 | MIC |

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**Table D-1—Regulatory requirement list *(continued)***

| Geographic area | Approval standards | Documents | Approval authority |
|---|---|---|---|
| New Zealand | Radio Spectrum Management | Section 111 of Radiocommunications Act 1989, Regulation 9 of Radiocommunications Regulations 2001 | Ministry of Economic Develop-ment |
| United States and its territories(#296) | Federal Communications Commission (FCC) | 47 CFR [B6], Part 15, Sections 15.205, 15.209, 15.247 and 15.255; and Subpart E, Sections 15.401–15.407, and Subpart H, Sections 15.701–15.716, Section 90.210, Sections 90.371–383, Sections 90.1201–90.1217, Sections 90.1301–90.1337, Section 95.639, Sections 95.1501–1511 (#2235)First Report and Order, 35 FCC Rcd. 13440 (15)[b] | FCC |
| Singapore | Infocomm Development Authority of Singapore | IDA TS SRD 2011 Technical Specification for Short Range Devices | IDA |
| South Korea | Ministry of Science, ICT and Future Planning / Radio Research Agency (MSIP RRA) Public Regulations Announcement | Doc. No. 2012-101 “Wireless Facilities” | MSIP RRA |

[a] Frequency planning for licensed STAs in Japan is performed by the regulatory authority and the licensees, addressing the coexistence among STAs operating with a variety of air propagation times and the coexistence between STAs using 20 MHz channel spacing, STAs operating with 10 MHz channel spacing, and STAs operating with 5 MHz channel spacing. Note also the CCA mechanism is preserved in licensed operation.

[b] The FCC adopted on (#2236)18 November 2020 a First Report and Order to make the 5.9 GHz band’s lower 45 MHz available for unlicensed operations.

Behavior limits are listed in Table D-2 (Behavior limits).

**Table D-2—Behavior limits**

| Behavior limit | Description |
|---|---|
| NomadicBehavior | The location of the station may change but is stationary while in use. The nomadic use EIRP power limits apply if the country allows more than one transmit power limit in the band. This behavior is specified only in bands where behavior 10 License Exempt bands is also allowed. |
| LicenseExemptBehavior | Frequency bands where some fixed stations can be operated without a license at a higher radiated transmit power than permitted for nomadic use. This behavior is specified only in bands where behavior 1 nomadic use is also allowed. |


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**Table D-2—Behavior limits *(continued)***

| Behavior limit | Description |
|---|---|
| PrimaryChannelLowerBehavior[a] | 20/40 MHz BSS primary channel with secondary channel above the primary channel or 20 MHz BSS primary channel operated by a 40MC HT AP and also 20 MHz operational channel for a non-AP STA when the non-AP STA is associated with a 40MC HT AP.<br><br>See NOTE 1. |
| PrimaryChannelUpperBehavior[a] | 14 20/40 MHz BSS primary channel with secondary channel below the primary channel or 20 MHz BSS primary channel operated by a 40MC HT AP and also 20 MHz operational channel for a non-AP STA when the non-AP STA is associated with a 40MC HT AP.<br>See NOTE 1. |
| (#2365)CCA-OCSEDBehavior[b] | The PHY shall also indicate a medium busy condition when CCA-Operating Class Specific Energy Detect detects a channel busy condition. |
| DFS_50_100_Behavior | A station operating in a band where radiolocation radar is primary, and station operation has in-service monitoring requirements for 50-100 μs radar pulses. |
| ITS_nonmobile_operations | Operations related to an ITS station operating at a fixed location registered with regulatory authorities, e.g., a Dedicated Short Range Communication Services (DSRCS) Roadside Unit (RSU). |
| ITS_mobile_operations | Operations related to an ITS mobile station, e.g., a vehicle's DSRCS On-board Unit (OBU). |
| 80+ | In a channel width that contains two or more frequency segments, the frequency segment that does not contain the primary 80 MHz channel (see NOTE 2) |
| UseEirpForVHTTxPowEnv | A STA that sends one or more Transmit Power Envelope elements shall indicate EIRP in the Local Maximum Transmit Power Unit Interpretation subfield in one of the Transmit Power Envelope elements |
| GeoDB | A STA operating in a TVWS band where broadcast TV operation is primary and STA operation has GDB requirements. When operating in TVWS, channel numbers are as assigned in regulation. |
| DSSSonly | A STA operating in a band where modulation is restricted to the DSSS PHY or HR/DSSS PHY as described in Clause 15 (DSSS PHY specification for the 2.4 GHz band designated for ISM applications) and Clause 16 (High rate direct sequence spread spectrum (HR/DSSS) PHY specification), respectively. |
| NOTE 1—The fields that specify the 40 MHz channels are described in 19.3.15.4 (40 MHz channelization).<br>NOTE 2—(#4369)The maximum number of frequency segments is PHY dependent. | |

[a] For 20 MHz operation where the operating class signifies 40 MHz channel spacing, the 20 MHz channel corresponds to the channel number indicated.

[b] Procedures that may be used to improve sharing spectrum in addition to explicit regulatory requirements.

## D.2 Radio performance specifications

### D.2.1 Transmit and receive in-band and out-of-band spurious emissions

Spurious transmissions shall comply with national regulations.

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### D.2.2 Transmit power levels

The maximum allowable output power is measured in accordance with practices specified by the appropriate regulatory bodies.

The maximum allowable STA transmit power classifications for ITS nonmobile operations in the United States and its territories(#296) 5.85–5.925 GHz band are shown in Table D-3 (Maximum STA transmit power classification for the 5.85–5.925 GHz band in the United States and its territories(#296)).

**Table D-3—Maximum STA transmit power classification for the 5.85–5.925 GHz band in the United States and its territories(#296)**

| STA transmit power classification | Maximum STA transmit power (mW) | Maximum permitted EIRP (dBm) |
|---|---|---|
| A | 1 | 23 |
| B | 10 | 23 |
| C | 100 | 33 |
| D | 760<br>Note that for this class higher power is permitted as long as the power level is reduced to this level at the antenna connector and the emission mask specifications are met. | 33 for nongovernment<br><br>44.8 for government |

The maximum allowed transmit power and maximum bandwidth (BW) limits for an S1G STA are shown by country in Table D-4 (Maximum STA transmit power and maximum BW allowed for the S1G band).

**Table D-4—Maximum STA transmit power and maximum BW allowed for the S1G band**

| Geographic area | Frequency (MHz) | Maximum BW allowed (MHz) | Maximum STA transmit power (Max EIRP (mW) except where noted) |
|---|---|---|---|
| Australia | 915–928 | 8 | See NOTE 1 |
| Europe | 863–868 | 1 | See NOTE 5 |
| | 917.4–919.4 | | |
| Japan | (#2386)915.9–916.9 | 1 | (#2386)See NOTE 6 |
| | (#2386)920.5–929.7 | (#2386)4 | (#2386)See NOTE 2 |
| | 920.5–923.5 | (#2386)1 | See NOTE 3 |
| New Zealand | 915–928 | 8 | See NOTE 4 |
| United States and its territo-ries(#296) | 902–928 | Not defined | 1000 |
| Singapore | 866–869, 920–925 | (#38)4 | 500 |



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**Table D-4—Maximum STA transmit power and maximum BW allowed for the S1G band**

| Geographic area | Frequency (MHz) | Maximum BW allowed (MHz) | Maximum STA transmit power (Max EIRP (mW) except where noted) |
|---|---|---|---|
| South Korea | 917–923.5 | Not defined | 3, 10 |

NOTE 1—Max EIRP ≤ 30 dBm and PSD ≤ 25 mW/3 kHz

NOTE 2—1 or 20 mW transmitter output power plus up to 3 dBi antenna gain (maximum (#2386)EIRP is 1 or 20 mW + 3 dBi)

NOTE 3—250 mW transmitter output power plus up to 3 dBi antenna gain (maximum (#2386)EIRP is 250 mW + 3 dBi)

NOTE 4—Max EIRP ≤ 5 dBm (915 MHz to 928 MHz) for general sensor-type devices and Max EIRP ≤ 36 dBm (921.5 MHz to 928 MHz) for digital modulation transmitters

NOTE 5—Maximum effective radiated power ≤ 25 mW

(#2386)NOTE 6—1 mW transmitter output power plus up to 3 dBi antenna gain (maximum EIRP is 1 mW + 3 dBi)

## D.2.3 Transmit spectrum mask

Transmit spectrum masks defined in regulation are subject to change or revision at any time.

For operation in the 5.85–5.925 GHz band the transmitted spectrum shall be as follows:

a) For any STA using 5 MHz channel spacing, the transmitted spectral density shall have a 0 dBr bandwidth not exceeding 4.5 MHz and shall not exceed the spectrum mask created using the permitted power spectral density levels listed in Table D-5 (Spectrum mask data for 5 MHz channel spacing) for the transmit power class of the STA.

b) For any STA using 10 MHz channel spacing, the transmitted spectral density shall have a 0 dBr bandwidth not exceeding 9 MHz and shall not exceed the spectrum mask created using the permitted power spectral density levels listed in Table D-6 (Spectrum mask data for 10 MHz channel spacing) for the transmit power class of the STA.

c) For any STA using 20 MHz channel spacing (11bd)and transmitting a PPDU that is not a 20 MHz NGV PPDU or 20 MHz non-NGV duplicate PPDU, the transmitted spectral density shall have a 0 dBr bandwidth not exceeding 18 MHz and shall not exceed the spectrum mask created using the permitted power spectral density levels listed in Table D-7 (Spectrum mask data for 20 MHz channel spacing) for the transmit power class of the STA.

(11bd)NOTE—The conditions under which conformance to transmit spectral mask C2 is required are specified in 32.3.11.1 (Transmit spectrum mask).

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**Table D-5—Spectrum mask data for 5 MHz channel spacing**

| STA transmit power class | Permitted power spectral density, dBr | | | | |
|---|---|---|---|---|---|
| | ± 2.25 MHz offset (±f1) | ± 2.5 MHz offset (±f2) | ± 2.75 MHz offset (±f3) | ±5 MHz offset (±f4) | ± 7.5 MHz offset (±f5) |
| Class A | 0 | –10 | –20 | –28 | –40 |
| Class B | 0 | –16 | –20 | –28 | –40 |
| Class C | 0 | –26 | –32 | –40 | –50 |
| Class D | 0 | –35 | –45 | –55 | –65 |

**Table D-6—Spectrum mask data for 10 MHz channel spacing**

| STA transmit power class | Permitted power spectral density, dBr | | | | |
|---|---|---|---|---|---|
| | ± 4.5 MHz offset (±f1) | ± 5.0 MHz offset (±f2) | ± 5.5 MHz offset (±f3) | ± 10 MHz offset (±f4) | ± 15 MHz offset (±f5) |
| Class A | 0 | –10 | –20 | –28 | –40 |
| Class B | 0 | –16 | –20 | –28 | –40 |
| Class C | 0 | –26 | –32 | –40 | –50 |
| Class D | 0 | –35 | –45 | –55 | –65 |

**Table D-7—Spectrum mask data for 20 MHz channel spacing**

| STA transmit power class | Permitted power spectral density, dBr | | | | |
|---|---|---|---|---|---|
| | ± 9 MHz offset (±f1) | ± 10.0 MHz offset (±f2) | ± 11 MHz offset (±f3) | ± 20 MHz offset (±f4) | ± 30 MHz offset (±f5) |
| Class A | 0 | –10 | –20 | –28 | –40 |
| Class B | 0 | –16 | –20 | –28 | –40 |
| Class C | 0 | –26 | –32 | –40 | –50 |
| Class D | 0 | –35 | –45 | –55 | –65 |


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The transmit spectral mask is created and applied as shown in Figure D-1 (Transmit spectrum mask and application) about the channel center frequency (Fc) defined by the channel starting frequency and channel number from the operating class. The 0 dBr level is the maximum power spectral density measured in the channel. The measurements of transmit spectral density are made using a 100 kHz resolution bandwidth and a 30 kHz video bandwidth.

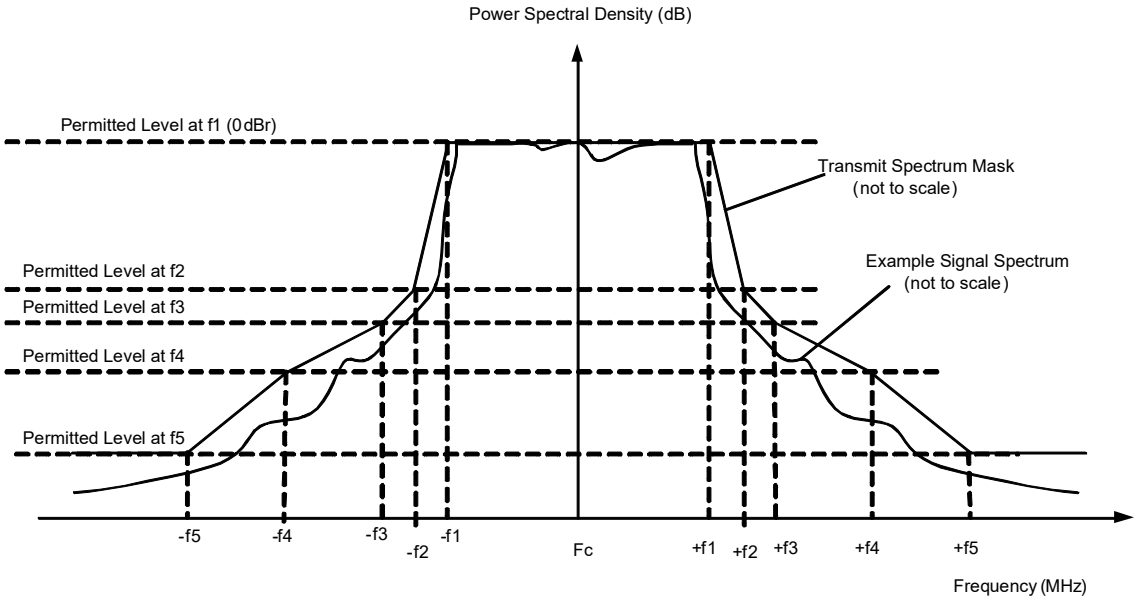


**Figure D-1—Transmit spectrum mask and application**

## D.2.4 Transmit Mask M

This subclause defines the characteristics of transmit mask M.

The power spectral density of the emissions shall be attenuated below the output power of the transmitter as follows:

a) On any frequency removed from the center frequency between 0% and 45% of the channel bandwidth (BW): 0 dB.

b) On any frequency removed from the center frequency between 45% and 50% of the channel bandwidth: 568 log10 (% of (BW)/45) dB.(#315)

c) On any frequency removed from the center frequency between 50% and 55% of the channel bandwidth: 26 + 145 log10 (% of BW/50) dB.(#315)

d) On any frequency removed from the center frequency between 55% and 100% of the channel bandwidth: 32 + 31 log10 (% of (BW)/55) dB.(#315)

e) On any frequency removed from the center frequency between 100% and 150% of the channel bandwidth: 40 + 57 log10 (% of (BW)/100) dB.(#315)

f) On any frequency removed from the center frequency between above 150% of the channel bandwidth: 50 dB or 55 + 10 log10 (P) dB,(#315) whichever is the lesser attenuation.

g) The 0 dB reference is measured relative to the highest average power of the fundamental emission measured across the designated channel bandwidth using a resolution bandwidth of 100 kHz and a video bandwidth of 30 kHz. The power spectral density is the power measured within the resolution bandwidth of the measurement device divided by the resolution bandwidth of the measurement

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device. Emission levels are also based on the use of measurement instrumentation employing a resolution bandwidth of at least one percent of the occupied bandwidth.

### D.2.5 CCA-OCSED threshold(#2365)

CCA-OCSED thresholds for operation in specific bands are given in E.2 (Band-specific operating requirements).


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# Annex E

(normative)

# Country elements and operating classes

## E.1 Country information and operating classes

WLANs implemented in accordance with this standard and the specifications and definitions referenced in it may be subject to equipment certification and operating requirements established by regional and national regulatory administrations. The specification establishes minimum technical requirements for interoperability, taking into consideration established regulations at the time this standard was issued. These regional and national regulations may be revised or may be superseded. Regulatory requirements that do not affect interoperability are not addressed in this standard. Implementers are referred to the regulatory sources in Table D-1 (Regulatory requirement list) and their successors for further information. Operation in countries within defined regulatory domains may be subject to additional or alternative national regulations.

The Country element (see 9.4.2.7 (Country element)) allows a STA to configure its PHY and MAC for operation when the Operating Triplet field is present. The Operating Triplet field indicates both PHY and MAC configuration characteristics and operational characteristics. The First Channel Number field of subsequent Subband Triplet fields is based on the dot11ChannelStartingFactor that is indicated by the Operating Class field.

The operating class value is an index into sets of values for radio operation in a regulatory domain. An operating class value indicates:

- The frequencies corresponding to channel numbers (they are defined in PHY clauses)
- The channel center frequencies that may be used (they are defined in PHY clauses)
- The maximum channel width that may be used
- Behavioral constraints listed in Table D-2 (Behavior limits)

The channel starting frequency variable is a frequency, used together with an operating class number and a channel number, to calculate a channel center frequency. A "—" in the Channel starting frequency column of the operating classes tables (Table E-1 (Operating classes in the United States and its territories(#296)) to Table E-6 (Operating classes in China)) indicates the channel starting frequency is not defined by the operating class and is derived from regulation.

Channel spacing is the frequency difference between nonoverlapping adjacent channel center frequencies when using the maximum bandwidth of one frequency segment allowed for this operating class.

The channel set is the list of integer channel numbers that are legal for a regulatory domain and class. A "—" in the Channel set column of the operating classes tables (Table E-1 (Operating classes in the United States and its territories(#296)) to Table E-6 (Operating classes in China)) indicates either that the values in the channel number of the center frequency(#6420) field apply for calculating channel center frequencies of this operating class, or where both the channel set field and the channel number of the center frequency(#6420) field are "—" indicates that the channel set is not defined by the operating class and is derived from regulation. It is not required that a station supports operation on any of the channels in the channel set.

The channel number of the center frequency(#6420) is the set of integer channel numbers that correspond to frequency segments and that are allowed for the operating class. A"—" in the channel number of the center

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frequency(#6420) column of the operating classes tables (Table E-1 (Operating classes in the United States and its territories(#296)) to Table E-6 (Operating classes in China)) indicates either that the values in the channel set field apply for calculating channel center frequencies of this operating class or, when both the Channel set and the channel number of the center frequency(#6420) column of the operating classes tables (Table E-1 (Operating classes in the United States and its territories(#296)) to Table E-6 (Operating classes in China)) are "—", indicates that the channel number of the center frequency(#6420) is not defined by the operating class and is derived from regulation.

A behavior limits set is an enumerated list, each element of which points to a row in Table D-2 (Behavior limits) containing behavior limits in various regulatory domains.

Operating classes for operation in the United States and its territories(#296) are enumerated in Table E-1 (Operating classes in the United States and its territories(#296)).

**Table E-1—Operating classes in the United States and its territories(#296)**

| Operating class | Global operating class (see Table E-4 (Global operating classes)) | Channel starting frequency (GHz) | Channel spacing (MHz) | LC IF Channel starting frequency (MHz)(11bb) | Channel set | Channel number of the center frequency (#6420) | Behavior limits set |
|---|---|---|---|---|---|---|---|
| 1 | 115 | 5 | 20 | –154 | 36, 40, 44, 48 | — | Applicable to LC(11bb) |
| 2 | 118 | 5 | 20 | –154 | 52, 56, 60, 64 | — | DFS_50_100_Behavior, Applicable to LC(11bb) |
| 3 | 124 | 5 | 20 | | 149, 153, 157, 161 | — | NomadicBehavior |
| 4 | 121 | 5 | 20 | | 100, 104, 108, 112, 116, 120, 124, 128, 132, 136, 140, 144 | — | DFS_50_100_Behavior, UseEirpForVHTTxPowEnv |
| 5 | 125 | 5 | 20 | | 149, 153, 157, 161, 165 | — | LicenseExemptBehavior |
| 6 | 103 | 4.9375 | 5 | | 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 | — | |
| 7 | 103 | 4.9375 | 5 | | 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 | — | |
| 8 | 102 | 4.89 | 10 | | 11, 13, 15, 17, 19 | — | |
| 9 | 102 | 4.89 | 10 | | 11, 13, 15, 17, 19 | — | |
| 10 | 101 | 4.85 | 20 | | 21, 25 | — | |
| 11 | 101 | 4.85 | 20 | | 21, 25 | — | |
| 12 | 81 | 2.407 | 25 | | 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11 | — | LicenseExemptBehavior |
| 13 | 94 | 3.000 | 20 | | 133, 137 | — | (#2365)CCA-OCSEDBehavior |
| 14 | 95 | 3.000 | 10 | | 132, 134, 136, 138 | — | (#2365)CCA-OCSEDBehavior |
| 15 | 96 | 3.0025 | 5 | | 131, 132, 133, 134, 135, 136, 137, 138 | — | (#2365)CCA-OCSEDBehavior |


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**Table E-1—Operating classes in the United States and its territories(#296) *(continued)***

| Operating class | Global operating class (see Table E-4 (Global operating classes)) | Channel starting frequency (GHz) | Channel spacing (MHz) | LC IF Channel starting frequency (MHz)(11bb) | Channel set | Channel number of the center frequency (#6420) | Behavior limits set |
|---|---|---|---|---|---|---|---|
| 16[a] | — | 5.0025 | 5 | | 170–184 | — | ITS_nonmobile_operations, ITS_mobile_operations |
| 17[a, b] | — | 5 | 10 | | 171–184 | — | ITS_nonmobile_operations, ITS_mobile_operations |
| 18[a, b] | — | 5 | 20 | | 172–183 | — | ITS_nonmobile_operations, ITS_mobile_operations |
| 19–21 | Reserved | Reserved | Reserved | | Reserved | Reserved | Reserved |
| 22 | 116 | 5 | 40 | –154 | 36, 44 | — | PrimaryChannelLowerBehavior, Applicable to LC(11bb) |
| 23 | 119 | 5 | 40 | –154 | 52, 60 | — | PrimaryChannelLowerBehavior, Applicable to LC(11bb) |
| 24 | 122 | 5 | 40 | | 100, 108, 116, 124, 132, 140 | — | PrimaryChannelLowerBehavior, DFS_50_100_Behavior, UseEirpForVHTTxPowEnv |
| 25 | 126 | 5 | 40 | | 149, 157 | — | PrimaryChannelLowerBehavior |
| 26 | 126 | 5 | 40 | | 149, 157 | — | LicenseExemptBehavior, PrimaryChannelLowerBehavior |
| 27 | 117 | 5 | 40 | –154 | 40, 48 | — | PrimaryChannelUpperBehavior, Applicable to LC(11bb) |
| 28 | 120 | 5 | 40 | –154 | 56, 64 | — | PrimaryChannelUpperBehavior, Applicable to LC(11bb) |
| 29 | 123 | 5 | 40 | | 104, 112, 120, 128, 136, 144 | — | NomadicBehavior, PrimaryChannelUpperBehavior, DFS_50_100_Behavior, UseEirpForVHTTxPowEnv |
| 30 | 127 | 5 | 40 | | 153, 161 | — | NomadicBehavior, PrimaryChannelUpperBehavior |
| 31 | 127 | 5 | 40 | | 153, 161 | — | LicenseExemptBehavior, PrimaryChannelUpperBehavior |

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**Table E-1—Operating classes in the United States and its territories(#296) *(continued)***

| Operating class | Global operating class (see Table E-4 (Global operating classes)) | Channel starting frequency (GHz) | Channel spacing (MHz) | LC IF Channel starting frequency (MHz)(11bb) | Channel set | Channel number of the center frequency (#6420) | Behavior limits set |
|---|---|---|---|---|---|---|---|
| 32 | 83 | 2.407 | 40 | | 1–7 | — | LicenseExemptBehavior, PrimaryChannelLowerBehavior |
| 33 | 84 | 2.407 | 40 | | 5–11 | — | LicenseExemptBehavior, PrimaryChannelUpperBehavior |
| 34 | 180 | 56.16 | 2160 | | (11ay)1, 2, 3, 4, 5, 6, 7, 8 | — | — |
| (11ay)35 | 181 | 56.16 | 4320 | | 9, 10, 11, 12, 13, 14, 15 | — | — |
| (11ay)36 | 182 | 56.16 | 6480 | | 17, 18, 19, 20, 21, 22 | — | — |
| (11ay)37 | 183 | 56.16 | 8640 | | 25, 26, 27, 28, 29 | — | — |
| (11ay)38–127 | Reserved | Reserved | Reserved | | Reserved | Reserved | Reserved |
| 128 | 128 | 5 | 80 | –154 | — | 42, 58, 106, 122, 138, 155 | UseEirpForVHTTxPowEnv, Applicable to LC(11bb) |
| 129 | 129 | 5 | 160 | –154 | — | 50, 114 | UseEirpForVHTTxPowEnv, Applicable to LC(11bb) |
| 130 | 130 | 5 | 80 | | — | 42, 58, 106, 122, 138, 155 | 80+, UseEirpForVHTTxPowEnv |
| 131–255 | Reserved | Reserved | Reserved | | Reserved | Reserved | Reserved |

NOTE 1—The channel spacing for operating classes 22 to 33 specifies the maximum radio bandwidth of one frequency segment. In these operating classes, the AP operating in a 20/40 MHz BSS, and the operating channel width for a non-AP STA is either 20 MHz or 40 MHz.

NOTE 2—The channel spacing for operating classes 128, 129, and 130 specifies the maximum radio bandwidth of one frequency segment.

[a] This operating class specifies a list of channels in the 5.9 GHz band. Current regulations might permit only a subset of these channels.

[b] It is the responsibility of management layers outside the scope of this standard to ensure that channels in use at any location are nonoverlapping.



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Operating classes for operation in Europe are enumerated in Table E-2 (Operating classes in Europe).

**Table E-2—Operating classes in Europe**

| Operating class | Global operating class (see Table E-4 (Global operating classes)) | Channel starting frequency (GHz) | Channel spacing (MHz) | LC IF Channel starting frequency (MHz)(11bb) | Channel set | Channel number of the center frequency (#6420) | Behavior limits set |
|---|---|---|---|---|---|---|---|
| 1 | 115 | 5 | 20 | –154 | 36, 40, 44, 48 | — | Applicable to LC(11bb) |
| 2 | 118 | 5 | 20 | –154 | 52, 56, 60, 64 | — | NomadicBehavior, Applicable to LC(11bb) |
| 3 | 121 | 5 | 20 | | 100, 104, 108, 112, 116, 120, 124, 128, 132, 136, 140 | — | |
| 4 | 81 | 2.407 | 25 | | 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13 | — | LicenseExemptBehavior |
| 5 | 116 | 5 | 40 | –154 | 36, 44 | — | PrimaryChannelLowerBehavior, Applicable to LC(11bb) |
| 6 | 119 | 5 | 40 | –154 | 52, 60 | — | PrimaryChannelLowerBehavior, Applicable to LC(11bb) |
| 7 | 122 | 5 | 40 | | 100, 108, 116, 124, 132 | — | PrimaryChannelLowerBehavior |
| 8 | 117 | 5 | 40 | –154 | 40, 48 | — | PrimaryChannelUpperBehavior, Applicable to LC(11bb) |
| 9 | 120 | 5 | 40 | –154 | 56, 64 | — | PrimaryChannelUpperBehavior, Applicable to LC(11bb) |
| 10 | 123 | 5 | 40 | | 104, 112, 120, 128, 136 | — | PrimaryChannelUpperBehavior |
| 11 | 83 | 2.407 | 40 | | 1–9 | — | LicenseExemptBehavior, PrimaryChannelLowerBehavior |
| 12 | 84 | 2.407 | 40 | | 5–13 | — | LicenseExemptBehavior, PrimaryChannelUpperBehavior |
| 13[a] | — | 5.0025 | 5 | | 171–184 | — | ITS_nonmobile_operations, ITS_mobile_operations |

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**Table E-2—Operating classes in Europe *(continued)***

| Operating class | Global operating class (see Table E-4 (Global operating classes)) | Channel starting frequency (GHz) | Channel spacing (MHz) | LC IF Channel starting frequency (MHz)(11bb) | Channel set | Channel number of the center frequency (#6420) | Behavior limits set |
|---|---|---|---|---|---|---|---|
| 14[a, b] | — | 5 | 10 | | 171–184 | — | ITS_nonmobile_operations, ITS_mobile_operations |
| 15[a, b] | — | 5 | 20 | | 172–183 | — | ITS_nonmobile_operations, ITS_mobile_operations |
| 16 | — | 5 | 20 | | 100, 104, 108, 112, 116, 120, 124, 128, 132, 136, 140 | — | ITS_nonmobile_operations, ITS_mobile_operations |
| 17 | 125 | 5 | 20 | | 149, 153, 157, 161, 165, 169 | — | |
| 18 | 180 | 56.16 | 2160 | | 1, 2, 3, 4 | — | — |
| (11ay)19 | 181 | 56.16 | 4320 | | 9, 10, 11 | — | — |
| (11ay)20 | 182 | 56.16 | 6480 | | 17, 18 | — | — |
| (11ay)21 | 183 | 56.16 | 8640 | | 25 | — | — |
| (11ay)22–127 | Reserved | Reserved | Reserved | | Reserved | Reserved | Reserved |
| 128 | 128 | 5 | 80 | –154 | — | 42, 58, 106, 122 | UseEirpForVHTTxPowEnv, Applicable to LC(11bb) |
| 129 | 129 | 5 | 160 | –154 | — | 50, 114 | UseEirpForVHTTxPowEnv, Applicable to LC(11bb) |
| 130 | 130 | 5 | 80 | –154 | — | 42, 58, 106, 122 | 80+, UseEirpForVHTTxPowEnv, Applicable to LC(11bb) |
| 131–255 | Reserved | Reserved | Reserved | | Reserved | Reserved | Reserved |

NOTE 1—The channel spacing for operating classes 5 to 12 specifies the maximum radio bandwidth of one frequency segment In these operating classes, the AP operates in a 20/40 MHz BSS, and the operating channel width for a non-AP STA is either 20 MHz or 40 MHz.

NOTE 2—The channel spacing for operating classes 128, 129, and 130 specifies the maximum radio bandwidth of one frequency segment.

[a] This operating class specifies a list of channels in the 5.9 GHz band. Current regulations might permit only a subset of these channels.

[b] It is the responsibility of management layers outside the scope of this standard to ensure that channels in use at any location are nonoverlapping.



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Operating classes for operation in Japan are enumerated in Table E-3 (Operating classes in Japan).

**Table E-3—Operating classes in Japan**

| Operating class | Global operating class (see Table E-4 (Global operating classes)) | Channel starting frequency (GHz) | Channel spacing (MHz) | LC IF Channel starting frequency (MHz)(11bb) | Channel set | Channel number of the center frequency(#6420) | Behavior limits set |
|---|---|---|---|---|---|---|---|
| 1 | 115 | 5 | 20 | –154 | 34, 38, 42, 46[a]<br>36, 40, 44, 48 | — | Applicable to LC(11bb) |
| 2 | Reserved | Reserved | Reserved | | Reserved | Reserved | Reserved |
| 3 | Reserved | Reserved | Reserved | | Reserved | Reserved | Reserved |
| 4–5 | Reserved | Reserved | Reserved | | Reserved | Reserved | Reserved |
| 6 | Reserved | Reserved | Reserved | | Reserved | Reserved | Reserved |
| 7 | Reserved | Reserved | Reserved | | Reserved | Reserved | Reserved |
| 8 | 109 | 4 | 20 | | 184, 188, 192, 196 | — | LicenseExemptBehavior |
| 9–10 | Reserved | Reserved | Reserved | | Reserved | Reserved | Reserved |
| 11 | 109 | 4 | 20 | | 184, 188, 192, 196 | — | LicenseExemptBehavior |
| 12 | Reserved | Reserved | Reserved | | Reserved | Reserved | Reserved |
| 13 | Reserved | Reserved | Reserved | | Reserved | Reserved | Reserved |
| 14–16 | Reserved | Reserved | Reserved | | Reserved | Reserved | Reserved |
| 17 | 110 | 4 | 10 | | 183, 184, 185, 187, 188, 189 | — | LicenseExemptBehavior |
| 18–19 | Reserved | Reserved | Reserved | | Reserved | Reserved | Reserved |
| 20 | 110 | 4 | 10 | | 183, 184, 185, 187, 188, 189 | — | LicenseExemptBehavior |
| 21 | Reserved | Reserved | Reserved | | Reserved | Reserved | Reserved |
| 22 | Reserved | Reserved | Reserved | | Reserved | Reserved | Reserved |
| 23–24 | Reserved | Reserved | Reserved | | Reserved | Reserved | Reserved |
| 25 | 111 | 4.0025 | 5 | | 182, 183, 184, 185, 186, 187, 188, 189 | — | LicenseExemptBehavior |
| 26 | 111 | 4.0025 | 5 | | 182, 183, 184, 185, 186, 187, 188, 189 | — | LicenseExemptBehavior |
| 27–28 | Reserved | Reserved | Reserved | | Reserved | Reserved | Reserved |

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**Table E-3—Operating classes in Japan *(continued)***

| Operating class | Global operating class (see Table E-4 (Global operating classes)) | Channel starting frequency (GHz) | Channel spacing (MHz) | LC IF Channel starting frequency (MHz)(11bb) | Channel set | Channel number of the center frequency(#6420) | Behavior limits set |
|---|---|---|---|---|---|---|---|
| 29 | 111 | 4.0025 | 5 | | 182, 183, 184, 185, 186, 187, 188, 189 | — | LicenseExemptBehavior |
| 30 | 81 | 2.407 | 25 | | 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13 | — | LicenseExemptBehavior |
| 31 | 82 | 2.414 | 25 | | 14 | — | LicenseExemptBehavior, DSSSonly |
| 32 | 118 | 5 | 20 | –154 | 52, 56, 60, 64 | — | Applicable to LC(11bb) |
| 33 | 118 | 5 | 20 | –154 | 52, 56, 60, 64 | — | Applicable to LC(11bb) |
| 34 | 121 | 5 | 20 | | 100, 104, 108, 112, 116, 120, 124, 128, 132, 136, 140, 144 | — | DFS_50_100_Behavior |
| 35 | Reserved | Reserved | Reserved | | Reserved | Reserved | Reserved |
| 36 | 116 | 5 | 40 | –154 | 36, 44 | — | PrimaryChannelLowerBehavior, Applicable to LC(11bb) |
| 37 | 119 | 5 | 40 | –154 | 52, 60 | — | PrimaryChannelLowerBehavior, Applicable to LC(11bb) |
| 38 | Reserved | Reserved | Reserved | | Reserved | Reserved | Reserved |
| 39 | 122 | 5 | 40 | | 100, 108, 116, 124, 132, 140 | — | PrimaryChannelLowerBehavior, DFS_50_100_Behavior |
| 40 | Reserved | Reserved | Reserved | | Reserved | Reserved | Reserved |
| 41 | 117 | 5 | 40 | –154 | 40, 48 | — | PrimaryChannelUpperBehavior, Applicable to LC(11bb) |
| 42 | 120 | 5 | 40 | –154 | 56, 64 | — | PrimaryChannelUpperBehavior, Applicable to LC(11bb) |
| 43 | Reserved | Reserved | Reserved | | Reserved | Reserved | Reserved |
| 44 | 123 | 5 | 40 | | 104, 112, 120, 128, 136, 144 | — | PrimaryChannelUpperBehavior, DFS_50_100_Behavior |
| 45 | Reserved | Reserved | Reserved | | Reserved | Reserved | Reserved |



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**Table E-3—Operating classes in Japan *(continued)***

| Operating class | Global operating class (see Table E-4 (Global operating classes)) | Channel starting frequency (GHz) | Channel spacing (MHz) | LC IF Channel starting frequency (MHz)(11bb) | Channel set | Channel number of the center frequency(#6420) | Behavior limits set |
|---|---|---|---|---|---|---|---|
| 46 | 104 | 4 | 40 | | 184, 192 | — | PrimaryChannelLowerBehavior |
| 47–50 | Reserved | Reserved | Reserved | | Reserved | Reserved | Reserved |
| 51 | 105 | 4 | 40 | | 188, 196 | — | PrimaryChannelUpperBehavior |
| 52–55 | Reserved | Reserved | Reserved | | Reserved | Reserved | Reserved |
| 56 | 83 | 2.407 | 40 | | 1–9 | — | LicenseExemptBehavior, PrimaryChannelLowerBehavior |
| 57 | 84 | 2.407 | 40 | | 5–13 | — | LicenseExemptBehavior, PrimaryChannelUpperBehavior |
| 58 | 121 | 5 | 20 | | 100, 104, 108, 112, 116, 120, 124, 128, 132, 136, 140, 144 | — | NomadicBehavior, LicenseExemptBehavior |
| 59 | 180 | 56.16 | 2160 | | 1, 2, 3, 4 | — | — |
| (11ay)60 | 181 | 56.16 | 4320 | | 9, 10, 11 | — | — |
| (11ay)61 | 182 | 56.16 | 6480 | | 17, 18 | — | — |
| (11ay)62 | 183 | 56.16 | 8640 | | 25 | — | — |
| (11ay)63–127 | Reserved | Reserved | Reserved | | Reserved | Reserved | Reserved |
| 128 | 128 | 5 | 80 | –154 | — | 42, 58, 106, 122, 138 | UseEirpForVHTTxPowEnv, Applicable to LC(11bb) |
| 129 | 129 | 5 | 160 | –154 | — | 50, 114 | UseEirpForVHTTxPowEnv, Applicable to LC(11bb) |
| 130 | 130 | 5 | 80 | –154 | — | 42, 58, 106, 122, 138 | 80+, UseEirpForVHTTxPowEnv, Applicable to LC(11bb) |
| 131–255 | Reserved | Reserved | Reserved | | Reserved | Reserved | Reserved |

NOTE 1—The channel spacing for operating classes 34–55 specifies the maximum radio bandwidth of one frequency segment In these regulatory domains, the AP operates in a 20/40 MHz BSS, and the operating channel width of a non-AP STA is either

NOTE 2—The channel spacing for operating classes 128, 129, and 130 specifies the maximum radio bandwidth of one frequency segment.

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[a] The use of channels 34, 38, 42, and 46 was included in the initial 5 GHz rules in May, 2005 and cannot be used after May 2012.

Operating classes for operation anywhere in the world are enumerated in Table E-4 (Global operating classes), and are used in addition to the operating classes enumerated in Table E-1 (Operating classes in the United States and its territories(#296)), Table E-2 (Operating classes in Europe), Table E-3 (Operating classes in Japan), Table E-5 (S1G operating classes), and Table E-6 (Operating classes in China) (see 9.4.2.52 (Supported Operating Classes element)). Where a BSS includes STAs that do not support global operating classes, then all requests and Action frames to those STAs that convey elements containing operating classes shall use nonglobal operating class values.

**Table E-4—Global operating classes**

| Operating class | Nonglobal operating class(es) (see NOTE 3) | Channel starting frequency (GHz) | Channel spacing (MHz) | LC IF Channel starting frequency (MHz)(11bb) | Channel set | Channel number of the center frequency(#6420) | Behavior limits set |
|---|---|---|---|---|---|---|---|
| 1–49 (#2387) (#7009) (#7014) | — | Reserved | Reserved | | Reserved | — | Reserved |
| 50 (#7014) | E-5-22, E-5-26 | 0.902 | 1 | | — | Reserved | — |
| 51 (#7014) | E-5-23, E-5-27 | 0.902 | 2 | | — | Reserved | — |
| 52 (#7014) | E-5-24, E-5-28 | 0.902 | 4 | | — | Reserved | — |
| 53 (#7014) | E-5-25, E-5-29 | 0.902 | 8 | | — | Reserved | — |
| 54 (#7014) | E-5-32 | 0.902 | 1 | | — | Reserved | — |
| 55 (#7014) | E-5-33 | 0.902 | 2 | | — | Reserved | — |
| 56 (#7014) | E-5-34 | 0.902 | 4 | | — | Reserved | — |
| 57 (#7014) | E-5-35 | 0.840 | 2 | | — | Reserved | — |
| 58 (#7014) | E-5-36 | 0.840 | 4 | | — | Reserved | — |
| 59 (#7014) | E-5-37 | 0.840 | 8 | | — | Reserved | — |
| 60 (#7014) | E-5-38 | 0.840 | 16 | | — | Reserved | — |
| 61 (#7009) | E-5-20 | 0.902 | 2 | | — | Reserved | — |


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**Table E-4—Global operating classes *(continued)***

| Operating class | Nonglobal operating class(es) (see NOTE 3) | Channel starting frequency (GHz) | Channel spacing (MHz) | LC IF Channel starting frequency (MHz)(11bb) | Channel set | Channel number of the center frequency(#6420) | Behavior limits set |
|---|---|---|---|---|---|---|---|
| 62 (#7009) | E-5-21 | 0.902 | 4 | | — | Reserved | — |
| 63 (#7009) | E-5-31 | 0.902 | 8 | | — | Reserved | — |
| 64 (#2387) | E-5-9, E-5-10 | 0.9225 | 2 | | — | Reserved | — |
| 65 (#2387) | E-5-11, E-5-12 | 0.9065 | 4 | | — | Reserved | — |
| 66 | E-5-6, E-5-17 | 0.863 | 1 | | — | Reserved | — |
| 67 | E-5-7, E-5-19 (#7009) | 0.863 | 2 | | — | Reserved | — |
| 68 | E-5-1, E-5-18(#7014) | 0.902 | 1 | | — | Reserved | — |
| 69 | E-5-2, E-5-20 (#7009) (#7014) | 0.902 | 2 | | — | Reserved | — |
| 70 | E-5-3, E-5-21 (#7009) (#7014) | 0.902 | 4 | | — | Reserved | — |
| 71 | E-5-4(#7014) | 0.902 | 8 | | — | Reserved | — |
| 72 | E-5-5 | 0.902 | 16 | | — | Reserved | — |
| 73 | E-5-8 | 0.9165 | 1 | | — | Reserved | — |
| 74 | E-5-14 | 0.9175 | 1 | | — | Reserved | — |
| 75 | E-5-15 | 0.9175 | 2 | | — | Reserved | — |
| 76 | E-5-16 | 0.9175 | 4 | | — | Reserved | — |
| 77 | E-5-30 | 0.9014 | 1 | | — | Reserved | — |
| 78–80 | — | Reserved | Reserved | | Reserved | — | Reserved |
| 81 | E-1-12, E-2-4, E-3-30, E-6-7 | 2.407 | 25 | | 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13 | — | |
| 82 | E-3-31 | 2.414 | 25 | | 14 | — | LicenseExemptBehavior, DSSSonly |
| 83 | E-1-32, E-2-11, E-3-56, E-6-8 | 2.407 | 40 | | 1, 2, 3, 4, 5, 6, 7, 8, 9 | — | PrimaryChannelLowerBehavior |

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**Table E-4—Global operating classes *(continued)***

| Operating class | Nonglobal operating class(es) (see NOTE 3) | Channel starting frequency (GHz) | Channel spacing (MHz) | LC IF Channel starting frequency (MHz)(11bb) | Channel set | Channel number of the center frequency(#6420) | Behavior limits set |
|---|---|---|---|---|---|---|---|
| 84 | E-1-33, E-2-12, E-3-57, E-6-9 | 2.407 | 40 | | 5, 6, 7, 8, 9, 10, 11, 12, 13 | — | PrimaryChannelUpperBehavior |
| 85 | — | — | 6, 7, 8 | | — | — | GeoDB |
| 86 | — | — | 12, 14, 16 | | — | — | GeoDB |
| 87 | — | — | 24, 28, 32 | | — | — | GeoDB |
| 88-93 | — | Reserved | Reserved | | Reserved | Reserved | Reserved |
| 94 | E-1-13 | 3 | 20 | | 133, 137 | — | (#2365)CCA-OCSEDBehavior |
| 95 | E-1-14 | 3 | 10 | | 132, 134, 136, 138 | — | (#2365)CCA-OCSEDBehavior |
| 96 | E-1-15 | 3.0025 | 5 | | 131, 132, 133, 134, 135, 136, 137, 138 | — | (#2365)CCA-OCSEDBehavior |
| 97–100 | — | Reserved | Reserved | | Reserved | Reserved | Reserved |
| 101 | E-1-10,11 | 4.85 | 20 | | 21, 25 | — | |
| 102 | E-1-8,9 | 4.89 | 10 | | 11, 13, 15, 17, 19 | — | |
| 103 | E-1-6,7 | 4.9375 | 5 | | 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 | — | |
| 104 | E-3-46,47,48, 49,50 | 4 | 40 | | 184, 192 | — | PrimaryChannelLowerBehavior |
| 105 | E-3-51,52,53, 54,55 | 4 | 40 | | 188, 196 | — | PrimaryChannelUpperBehavior |
| 106 | — | 4 | 20 | | 191, 195 | — | |
| 107 | — | 4 | 10 | | 189, 191, 193, 195, 197 | — | |
| 108 | — | 4.0025 | 5 | | 188, 189, 190, 191, 192, 193, 194, 195, 196, 197 | — | |
| 109 | E-3-7,8,9,10,11 | 4 | 20 | | 184, 188, 192, 196 | — | |



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**Table E-4—Global operating classes *(continued)***

| Operating class | Nonglobal operating class(es) (see NOTE 3) | Channel starting frequency (GHz) | Channel spacing (MHz) | LC IF Channel starting frequency (MHz)(11bb) | Channel set | Channel number of the center frequency(#6420) | Behavior limits set |
|---|---|---|---|---|---|---|---|
| 110 | E-3-16,17,18, 19,20 | 4 | 10 | | 183, 184, 185, 186, 187, 188, 189 | — | |
| 111 | E-3-25,26,27, 28,29 | 4.0025 | 5 | | 182, 183, 184, 185, 186, 187, 188, 189 | — | |
| 112 | Reserved | Reserved | Reserved | | Reserved | Reserved | Reserved |
| 113 | Reserved | Reserved | Reserved | | Reserved | Reserved | Reserved |
| 114 | Reserved | Reserved | Reserved | | Reserved | Reserved | Reserved |
| 115 | E-1-1, E-2-1, E-3-1, E-6-1 | 5 | 20 | –154 | 36, 40, 44, 48 | — | UseEirpForVHTTxPowEnv, Applicable to LC(11bb) |
| 116 | E-1-22, E-2-5, E-3-36, E-6-4 | 5 | 40 | –154 | 36, 44 | — | PrimaryChannelLowerBehavior, UseEirpForVHTTxPowEnv, Applicable to LC(11bb) |
| 117 | E-1-27, E-2-8, E-3-41 | 5 | 40 | –154 | 40, 48 | — | PrimaryChannelUpperBehavior, UseEirpForVHTTxPowEnv, Applicable to LC(11bb) |
| 118 | E-1-2, E-2-2, E-3-32,33, E-6-2 | 5 | 20 | –154 | 52, 56, 60, 64 | — | DFS_50_100_Behavior, UseEirpForVHTTxPowEnv, Applicable to LC(11bb) |
| 119 | E-1-23, E-2-6, E-3-37,38, E-6-5 | 5 | 40 | –154 | 52, 60 | — | PrimaryChannelLowerBehavior, DFS_50_100_Behavior, UseEirpForVHTTxPowEnv, Applicable to LC(11bb) |
| 120 | E-1-28, E-2-9, E-3-42,43 | 5 | 40 | –154 | 56, 64 | — | PrimaryChannelUpperBehavior, DFS_50_100_Behavior, UseEirpForVHTTxPowEnv, Applicable to LC(11bb) |

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**Table E-4—Global operating classes *(continued)***

| Operating class | Nonglobal operating class(es) (see NOTE 3) | Channel starting frequency (GHz) | Channel spacing (MHz) | LC IF Channel starting frequency (MHz)(11bb) | Channel set | Channel number of the center frequency(#6420) | Behavior limits set |
|---|---|---|---|---|---|---|---|
| 121 | E-1-4, E-2-3, E-3-34, 35,58 | 5 | 20 | | 100, 104, 108, 112, 116, 120, 124, 128, 132, 136, 140, 144 | — | DFS_50_100_Behavior, UseEirpForVHTTxPowEnv |
| 122 | E-1-24, E-2-7, E-3-39,40 | 5 | 40 | | 100, 108, 116, 124, 132, 140 | — | PrimaryChannelLowerBehavior, DFS_50_100_Behavior, UseEirpForVHTTxPowEnv |
| 123 | E-1-29, E-2-10, E-3-44,45 | 5 | 40 | | 104, 112, 120, 128, 136, 144 | — | PrimaryChannelUpperBehavior, DFS_50_100_Behavior, UseEirpForVHTTxPowEnv |
| 124 | E-1-3 | 5 | 20 | | 149, 153, 157, 161 | — | NomadicBehavior, UseEirpForVHTTxPowEnv |
| 125 | E-1-5, E-2-17, E-6-3 | 5 | 20 | | 149, 153, 157, 161, 165, 169, 173, 177(11ax) | — | LicenseExemptBehavior, UseEirpForVHTTxPowEnv |
| 126 | E-1-25,26, E-6-6 | 5 | 40 | | 149, 157, 165, 173(11ax) | — | PrimaryChannelLowerBehavior, UseEirpForVHTTxPowEnv |
| 127 | E-1-30,31 | 5 | 40 | | 153, 161, 169, 177(11ax) | — | PrimaryChannelUpperBehavior, UseEirpForVHTTxPowEnv |
| 128 | E-1-128, E-2-128, E-3-128, E-6-128 | 5 | 80 | –154 | — | 42, 58, 106, 122, 138, 155, 171(11ax) | UseEirpForVHTTxPowEnv, Applicable to LC(11bb) |
| 129 | E-1-129, E-2-129, E-3-129, E-6-129 | 5 | 160 | –154 | — | 50, 114, 163(11ax) | UseEirpForVHTTxPowEnv, Applicable to LC(11bb) |
| 130 | E-1-130, E-2-130, E-3-130, E-6-130 | 5 | 80 | –154 | — | 42, 58, 106, 122, 138, 155, 171(11ax) | 80+, UseEirpForVHTTxPowEnv, Applicable to LC(11bb) |



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**Table E-4—Global operating classes *(continued)***

| Operating class | Nonglobal operating class(es) (see NOTE 3) | Channel starting frequency (GHz) | Channel spacing (MHz) | LC IF Channel starting frequency (MHz)(11bb) | Channel set | Channel number of the center frequency(#6420) | Behavior limits set |
|---|---|---|---|---|---|---|---|
| (11ax)131 | | 5.950 | 20 | –181 | 1, 5, 9, 13, 17, 21, 25, 29, 33, 37, 41, 45, 49, 53, 57, 61, 65, 69, 73, 77, 81, 85, 89, 93, 97, 101, 105, 109, 113, 117, 121, 125, 129, 133, 137, 141, 145, 149, 153, 157, 161, 165, 169, 173, 177, 181, 185, 189, 193, 197, 201, 205, 209, 213, 217, 221, 225, 229, 233 | — | Applicable to LC(11bb) |
| (11ax)132 | | 5.950 | 40 | –181 | — | 3, 11, 19, 27, 35, 43, 51, 59, 67, 75, 83, 91, 99, 107, 115, 123, 131, 139, 147, 155, 163, 171, 179, 187, 195, 203, 211, 219, 227 | Applicable to LC(11bb) |
| (11ax)133 | | 5.950 | 80 | –181 | — | 7, 23, 39, 55, 71, 87, 103, 119, 135, 151, 167, 183, 199, 215 | Applicable to LC(11bb) |
| (11ax)134 | | 5.950 | 160 | –181 | — | 15, 47, 79, 111, 143, 175, 207 | Applicable to LC(11bb) |

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**Table E-4—Global operating classes *(continued)***

| Operating class | Nonglobal operating class(es) (see NOTE 3) | Channel starting frequency (GHz) | Channel spacing (MHz) | LC IF Channel starting frequency (MHz)(11bb) | Channel set | Channel number of the center frequency(#6420) | Behavior limits set |
|---|---|---|---|---|---|---|---|
| (11ax)135 | | 5.950 | 80 | –181 | — | 7, 23, 39, 55, 71, 87, 103, 119, 135, 151, 167, 183, 199, 215 | 80+, Applicable to LC(11bb) |
| (11ax)136 | | 5.925 | 20 | | — | 2 | |
| (11ax)137–179 | — | Reserved | Reserved | | Reserved | Reserved | Reserved |
| 180 | E-1-34, E-2-18, E-3-59 | 56.16 | 2160 | | 1, 2, 3, 4, 5, 6 | — | — |
| 181 | E-6-10 | 56.16 | 2160 | | 2, 3 | — | — |
| 182 | E-6-11 | 56.70 | 1080 | | 35, 36, 37, 38 | — | — |
| 183 | E-6-12 | 42.66 | 540 | | 1, 2, 3, 4, 5, 6, 7, 8 | — | LicenseExemptBehavior |
| 184 | E-6-13 | 47.52 | 540 | | 9, 10 | — | LicenseExemptBehavior |
| 185 | E-6-14 | 42.93 | 1080 | | 11,12,13,14 | — | LicenseExemptBehavior |
| 186 | E-6-15 | 47.79 | 1080 | | 15 | — | LicenseExemptBehavior |
| (11ay)187 | E-1-37, E-2-21, E-3-62 | 56.16 | 4320 | | 9, 10, 11, 12, 13 | — | — |
| (11ay)188 | E-1-38, E-2-22, E-3-63 | 56.16 | 6480 | | 17, 18, 19, 20 | — | — |
| (11ay)189 | E-1-39, E-2-23, E-3-64 | 56.16 | 8640 | | 25, 26, 27 | — | — |
| (11ay)190–191 | — | Reserved | Reserved | | Reserved | — | Reserved |



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**Table E-4—Global operating classes *(continued)***

| Operating class | Nonglobal operating class(es) (see NOTE 3) | Channel starting frequency (GHz) | Channel spacing (MHz) | LC IF Channel starting frequency (MHz)(11bb) | Channel set | Channel number of the center frequency(#6420) | Behavior limits set |
|---|---|---|---|---|---|---|---|
| 192–254 | — | Vendor specific | Vendor specific | | Vendor specific | — | Vendor specific |
| 255 | — | Reserved | Reserved | | Reserved | — | Reserved |

NOTE 1—The channel spacing for operating classes 116, 117, 119, 120, 122, 123, 126, and 127 specifies the maximum radio bandwidth of one frequency segment In these operating classes, the AP operates in a 20/40 MHz BSS, and the operating channel width for a non-AP STA is either 20 MHz or 40 MHz.

NOTE 2—The channel spacing for operating classes 128, 129, and 130 specifies the maximum radio bandwidth of one frequency segment.

NOTE 3—E-x-y refers to operating class y in Table E-x.

For Behavior limit GeoDB, the channel starting frequency shall be the frequency that results in the regulatory domain's channel number being the RLAN channel number.

S1G operating classes are enumerated in Table E-5 (S1G operating classes). Definition of type 1 and type 2 channels for CCA Level Classification and required behavior is described in #23.3.18.5.3 (CCA sensitivity for signals occupying the primary 2 MHz and/or primary 1 MHz channel) and 23.3.18.5.4 (CCA sensitivity for signals not occupying the primary 2 MHz channel).

**Table E-5—S1G operating classes**

| S1G operating Class | Global operating Class (see Table E-4) | Channel starting frequency (GHz) | Channel spacing (MHz) | Channel number of the center frequency(#6420) | CCA Level Classification | Behavior limits set |
|---|---|---|---|---|---|---|
| 1 (United States and its territories(#296)) | 68 | 0.902 | 1 | 1, 3, 37, 39, 41, 43, 45, 47, 49, 51 | Type 1 (902–904 MHz, 920–928 MHz) | — |
| | | | | 5, 7, 9, 11, 13, 15, 17, 19, 21, 23, 25, 27, 29, 31, 33, 35 | Type 2 (904–920 MHz) | |
| 2 (United States and its territories(#296)) | 69 | 0.902 | 2 | 2, 38, 42, 46, 50 | Type 1 (902–904 MHz, 920–928 MHz) | — |
| | | | | 6, 10, 14, 18, 22, 26, 30, 34 | Type 2 (904–920 MHz) | |
| 3 (United States and its territories(#296)) | 70 | 0.902 | 4 | 40, 48 | Type 1 (920–928 MHz) | — |
| | | | | 8, 16, 24, 32 | Type 2 (904–920 MHz) | |

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**Table E-5—S1G operating classes *(continued)***

| S1G operating Class | Global operating Class (see Table E-4) | Channel starting frequency (GHz) | Channel spacing (MHz) | Channel number of the center frequency(#6420) | CCA Level Classification | Behavior limits set |
|---|---|---|---|---|---|---|
| 4 (United States and its territories(#296)) | 71 | 0.902 | 8 | 44 | Type 1 (920–928 MHz) | — |
| | | | | 12, 28 | Type 2 (904–920 MHz) | |
| 5 (United States and its territories(#296)) | 72 | 0.902 | 16 | 20 | Type 2 (904–920 MHz) | — |
| 6 (Europe) | 66 | 0.863 | 1 | 1, 3, 5, 7, 9 | Type 1 (863–868 MHz) | — |
| 7 (Europe) (#7010) | 67 | 0.863 | 2 | 6 | Type 1 (863–868 MHz) | — |
| 8 (Japan) | 73 | 0.9165 | 1 | (#3821)(#2387)9, 13,15, 17, 19, 21 | (#2387)Type 1 (920.5–927.5 MHz) | — |
| 9(#2387) | 64 | 0.9225 | 2 | 2, 6 | Type 1 (922.5–926.5 MHz) | — |
| 10(#2387) | 64 | 0.9225 | 2 | 4, 8 | Type 1 (923.5–927.5 MHz) | — |
| 11(#2387) | 65 | 0.9065 | 4 | 36 | Type 1 (922.5–926.5 MHz) | — |
| 12(#2387) | 65 | 0.9065 | 4 | 38 | Type 1 (923.5–927.5 MHz) | — |
| 13(#2387) | — | Reserved | Reserved | Reserved | Reserved | Reserved |
| 14 (Korea) (#7014) | 74 | 0.9175 | 1 | 1, 3, 5, 7, 9, 11, 18, 20, 22, 24 | Type 1 (917.5–931 MHz) | — |
| 15 (Korea) | 75 | 0.9175 | 2 | 2, 6, 10, 19, 23 | Type 1 (917.5–931 MHz) | — |
| 16 (Korea) | 76 | 0.9175 | 4 | 8 | Type 1 (917.5–923.5 MHz) | — |
| 17 (Singapore) | 66 | 0.863 | 1 | 7, 9, 11 | Type 1 (866–869 MHz) | — |
| 18 (Singapore) | 68 | 0.902 | 1 | 31, 33, 35, 37, 39, 41, 43, 45 (#7009) | Type 1 (917–925 MHz) (#7009) | — |
| 19 (Singapore) | 67 | 0.863 | 2 | 10 | Type 1 (866–869 MHz) | — |



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**Table E-5—S1G operating classes *(continued)***

| S1G operating Class | Global operating Class (see Table E-4) | Channel starting frequency (GHz) | Channel spacing (MHz) | Channel number of the center frequency(#6420) | CCA Level Classification | Behavior limits set |
|---|---|---|---|---|---|---|
| 20 (Singapore) | 61 (#7009) | 0.902 | 2 | 32, 36, 40, 44 (#7009) | Type 1 (917–925 MHz) (#7009) | — |
| 21 (Singapore) | 62 (#7009) | 0.902 | 4 | 34, 42 (#7009) | Type 1 (917–925 MHz) (#7009) | — |
| 22 (Australia) (#7014) | 50 | 0.902 | 1 | 28, 30, 32, 34, 36, 38, 40, 42, 44, 46, 48, 50 | Type 1 (915–928 MHz) | — |
| 23 (Australia) (#7014) | 51 | 0.902 | 2 | 29, 33, 37, 41, 45, 49 | Type 1 (915–928 MHz) | — |
| 24 (Australia) (#7014) | 52 | 0.902 | 4 | 31, 39, 47 | Type 1 (915–928 MHz) | — |
| 25 (Australia) (#7014) | 53 | 0.902 | 8 | 35, 43 | Type 1 (915–928 MHz) | — |
| 26 (New Zealand) (#7014) | 50 | 0.902 | 1 | 28, 30, 32, 34, 36, 38, 40, 42, 44, 46, 48, 50 | Type 1 (915–928 MHz) | — |
| 27 (New Zealand) (#7014) | 51 | 0.902 | 2 | 29, 33, 37, 41, 45, 49 | Type 1 (915–928 MHz) | — |
| 28 (New Zealand) (#7014) | 52 | 0.902 | 4 | 31, 39, 47 | Type 1 (915–928 MHz) | — |
| 29 (New Zealand) (#7014) | 53 | 0.902 | 8 | 35, 43 | Type 1 (915–928 MHz) | — |
| 30 (Europe) | 77 | 0.9014 | 1 | 31, 33, 35 (#7010) | Type 1 (916.4–919.4 MHz) (#7010) | — |
| 31 (Singapore) (#7009) | 63 | 0.902 | 8 | 38 | Type 1 (917–925 MHz) | — |
| 32 (Taiwan) (#7014) | 54 | 0.902 | 1 | 38, 40, 42, 44 | Type 1 (920–925 MHz) | — |
| 33 (Taiwan) (#7014) | 55 | 0.902 | 2 | 39, 43 | Type 1 (920–925 MHz) | — |

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**Table E-5—S1G operating classes *(continued)***

| S1G operating Class | Global operating Class (see Table E-4) | Channel starting frequency (GHz) | Channel spacing (MHz) | Channel number of the center frequency(#6420) | CCA Level Classification | Behavior limits set |
|---|---|---|---|---|---|---|
| 34 (Taiwan) (#7014) | 56 | 0.902 | 4 | 41 | Type 1 (920–925 MHz) | — |
| 35 (United States and its territories) (#7014) | 57 | 0.840 | 2 | 128, 132, 136, 140, 144, 148, 152, 156, 160, 164, 168, 172 | Type 1 (902–928 MHz) | — |
| 36 (United States and its territories) (#7014) | 58 | 0.840 | 4 | 130, 138, 146, 154, 162, 170 | Type 1 (902–928 MHz) | — |
| 37 (United States and its territories) (#7014) | 59 | 0.840 | 8 | 134, 150, 166 | Type 1 (902–928 MHz) | — |
| 38 (United States and its territories) (#7014) | 60 | 0.840 | 16 | 142 | Type 1 (902–928 MHz) | — |

Operating classes for operation in China are enumerated in Table E-6 (Operating classes in China).

**Table E-6—Operating classes in China**

| Operating class | Global operating class (see Table E-4 (Global operating classes)) | Channel starting frequency (GHz) | Channel spacing (MHz) | Channel set | Channel number of the center frequency(#6420) | Behavior limits set |
|---|---|---|---|---|---|---|
| 1 | 115 | 5 | 20 | 36, 40, 44, 48 | — | UseEirpForVHTTxPowEnv |
| 2 | 118 | 5 | 20 | 52, 56, 60, 64 | — | DFS_50_100_Behavior, UseEirpForVHTTxPowEnv |


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**Table E-6—Operating classes in China *(continued)***

| Operating class | Global operating class (see Table E-4 (Global operating classes)) | Channel starting frequency (GHz) | Channel spacing (MHz) | Channel set | Channel number of the center frequency( #6420) | Behavior limits set |
|---|---|---|---|---|---|---|
| 3 | 125 | 5 | 20 | 149, 153, 157, 161, 165 | — | UseEirpForVHTTxPowEnv |
| 4 | 116 | 5 | 40 | 36, 44 | — | PrimaryChannelLowerBehavior UseEirpForVHTTxPowEnv |
| 5 | 119 | 5 | 40 | 52, 60 | — | PrimaryChannelLowerBehavior DFS_50_100_Behavior UseEirpForVHTTxPowEnv |
| 6 | 126 | 5 | 40 | 149, 157 | — | PrimaryChannelLowerBehavior UseEirpForVHTTxPowEnv |
| 7 | 81 | 2.407 | 25 | 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13 | — | LicenseExemptBehavior |
| 8 | 83 | 2.407 | 40 | 1-9 | — | LicenseExemptBehavior, PrimaryChannelLowerBehavior |
| 9 | 84 | 2.407 | 40 | 5-13 | — | LicenseExemptBehavior, PrimaryChannelUpperBehavior |
| 10 | 181 | 56.16 | 2160 | 2, 3 | — | — |
| 11 | 182 | 56.70 | 1080 | 35, 36, 37, 38 | — | — |
| 12 | 183 | 42.66 | 540 | 1, 2, 3, 4, 5, 6, 7, 8 | — | LicenseExemptBehavior |
| 13 | 184 | 47.52 | 540 | 9, 10 | — | LicenseExemptBehavior |
| 14 | 185 | 42.93 | 1080 | 11, 12, 13, 14 | — | LicenseExemptBehavior |
| 15 | 186 | 47.79 | 1080 | 15 | — | LicenseExemptBehavior |
| 16–127 | Reserved | Reserved | Reserved | Reserved | Reserved | Reserved |
| 128 | 128 | 5 | 80 | — | 42, 58, 155 | UseEirpForVHTTxPowEnv |
| 129 | 129 | 5 | 160 | — | 50 | UseEirpForVHTTxPowEnv |
| 130 | 130 | 5 | 80 | — | 42, 58, 155 | 80+ UseEirpForVHTTxPowEnv |

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**Table E-6—Operating classes in China *(continued)***

| Operating class | Global operating class (see Table E-4 (Global operating classes)) | Channel starting frequency (GHz) | Channel spacing (MHz) | Channel set | Channel number of the center frequency(#6420) | Behavior limits set |
|---|---|---|---|---|---|---|
| 131–255 | Reserved | Reserved | Reserved | Reserved | Reserved | Reserved |

NOTE 1—The channel spacing for operating classes 4 to 6 specifies the maximum radio bandwidth of one frequency segment In these operating classes, the AP operates in a 20/40 MHz BSS, and the operating channel width for a non-AP STA is either 20 MHz or 40 MHz.

NOTE 2—The channel spacing for operating classes 128, 129, and 130 specifies the maximum radio bandwidth of one frequency segment.

Nonglobal operating classes refer to the operating classes enumerated in the leftmost column of Table E-1 (Operating classes in the United States and its territories(#296)), Table E-2 (Operating classes in Europe), Table E-3 (Operating classes in Japan), and Table E-6 (Operating classes in China) (see 9.4.2.52 (Supported Operating Classes element)).

NOTE 1—The following example Country element (see Figure 9-224 (Country element format)) describes U.S. operation (55, 53) using both Table E-1 (Operating classes in the United States and its territories(#296)) class 12 (nonglobal) and Table E-4 (Global operating classes) class 81 (global) for the 2.4 GHz band, 11 channels at 20 dBm limit (in hexadecimal): 07, 0F, 55, 53, 04, C9, 0C, 00, 01, 0B, 14, C9, 51, 0, 01, 0B, 14.

NOTE 2—The following example Country element describes U.S. operation for an 80+80 MHz BSS using Table E-4 (Global operating classes) classes 116, 128 and 130 at a 100 mW limit for 40 MHz. The contents (in decimal) are 7 [Country element ID], 18 [Length], 85, 83, 4 [Country string indicating the United States and Table E-4 (Global operating classes)], 201, 116, 0 [Operating Triplet field for 20/40 MHz with the primary 20 MHz channel on the lower 20 MHz], 36, 1, 20 [Subband triplet field indicating 20 dBm on the 40 MHz channel 36+40], 201, 128, 0 [Operating Triplet field for 80 MHz], 201, 130, 0, 201, 128, 0 [Pair of Operating Triplet field indicating 80+80 MHz]. Although the Operating Triplet fields for 80 MHz and 80+80 MHz only express BSS bandwidths rather than specific regulatory permissions (so are optional), they are included in this example.

Vendor Specific operating classes are used to carry information not defined in this standard within a single defined format, so that reserved operating classes are not usurped for nonstandard purposes and so that interoperability is more easily achieved in the presence of nonstandard information.

## E.2 Band-specific operating requirements

### E.2.1 General

E.2 (Band-specific operating requirements) contains requirements specific to particular bands and regulatory domains.

### E.2.2 3650–3700 MHz band in the United States and its territories(#296)

FCC Part 96 rules for operation in the 3550–3700 MHz frequency band are in force, and operating in the 3650–3700 MHz band under Part 90 Subpart Z rules [B7] ends May 2020. The following text in this subclause contains requirements for operation under Part 90 Subpart Z rules.


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The registration authority is the FCC's Universal Licensing System (ULS).

Regulations specify the following:

- Certified mobile and portable STAs do not need to be registered, but they "must" operate under the control of an enabling STA (using DSE procedures).
- A registered STA "must" be a fixed STA.
- A registered STA "must" not operate as an enabling STA until the licensee has registered it as a "base station" in ULS.

Enabling STAs and fixed STAs are registered STAs. Dependent non-AP STAs and dependent APs are dependent STAs.

A STA shall use the following:

- CCA-OCSED(#2365)
- CS/CCA
- TPC
- DFS

For OFDM PHY operation in this specific band, the CCA-OCSED thresholds shall be less than or equal to –72 dBm for 20 MHz channel widths, –75 dBm for 10 MHz channel widths, and –78 dBm for 5 MHz channel widths (minimum sensitivity for BPSK, R=1/2 + 10 dB in Table 17-21 (Receiver performance requirements)).

No STA shall use channel switch announcement.

No station may transmit for more than 4 ms without carrier sensing, whether transmitting fragments or frames, unless it is controlled by another STA.

A STA shall have the following equal to true:

- dot11LCIDSERequired
- dot11SpectrumManagementRequired
- dot11MultiDomainCapabilityActivated
- dot11ExtendedChannelSwitchActivated

A STA shall support(#546) receiving all channels associated with operating classes 13–15.

A STA shall support(#546) transmitting on all channels associated with operating class 15.

A STA shall set the value of dot11DSETransmitDivisor to 256 and the other dot11DSE timer values as shown in Table E-7 (DSE timer limits).

**Table E-7—DSE timer limits**

| Parameter | Seconds |
|---|---|
| dot11DSEEnablementTimeLimit | 32 |
| dot11DSEEnablementFailHoldTime | 512 |
| dot11DSERenewalTime | 60 |

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### E.2.3 5.9 GHz band in the United States and its territories (5.850–5.925 GHz)(#296)

STAs operating with a behavior limit of ITS_nonmobile_operations in Table D-2 (Behavior limits) are required to be registered with the FCC ULS. The registration includes the following:

— Classification by coverage size, which is defined by EIRP, and
— Identification of channels the STA is permitted to use.

A STA shall be classified for operation in this band by their maximum transmit power capability, as listed in Table D-3 (Maximum STA transmit power classification for the 5.85–5.925 GHz band in the United States and its territories(#296)) in D.2.2 (Transmit power levels). A STA shall be compliant with the spectral emission requirements for their class listed in D.2.3 (Transmit spectrum mask).

A STA shall have dot11OCBActivated equal to true.

EPD as defined in IEEE Std 802 shall be used for transmission of all MSDUs.

### E.2.4 5.9 GHz band in Europe (5.855–5.925 GHz)

A STA shall have dot11OCBActivated equal to true.

EPD as defined in IEEE Std 802 shall be used for transmission of all MSDUs.

### E.2.5 TVWS band in the United States and its territories and Canada (54–698 MHz)(#296)

Each GDD enabling STA and AP in TVWS determines the available TV channels at its location using its own geographic location identification and TV bands database access capabilities. Each GDD dependent STA in TVWS receives an available TV channel list from the STA that enables its operation.

The registration authorities are FCC designated TV bands administrators (FCC 47 CFR [B6], sections 15.713–715).

NOTE 1—IEEE 802.11 terms differ from FCC 47 CFR [B6], section 15.703, in many particulars. However, generally, a GDD enabling STA is Fixed or Mode II TVBD, and each GDD dependent STA has only one GDD enabling STA at any time. Generally, GDD dependent STAs are Mode I TVBDs. Each Fixed or Mode II TVBD is required to contact an authorized TV bands device database and operate based on the information received from that TV bands database. Fixed and Mode II TVBDs are certified to operate with specific TV bands databases using protocols specified by TV bands database administrators. FCC regulations require an encrypted Contact Verification Signal be received by Mode I TVBD to verify the integrity of the list of available channels FCC 47 CFR, section 15.711. Canadian regulation RSS-196 allows Remote Rural Broadband operation at transmit powers to 125 W in 6 MHz. The Canadian Minister of Industry held a consultation documented in SMSE-012-12, wherein a decision to act in concert with FCC license-exempt low power regulations was taken. It is expected that Canadian RSS-210 will be revised to align with FCC 47 CFR, Part 15, Subpart H-Television Band Devices.

STAs operating in TVWS shall use

— CS/CCA
— DFS

No STA operating in TVWS shall use Channel Switch Announcement.

STAs operating in TVWS shall have the following equal to true

— dot11GDDActivated


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— dot11OperatingClassesRequired
— dot11SpectrumManagementRequired
— dot11MultiDomainCapabilityActivated
— dot11ContactVerificationSignalActivated

For GDD dependent STA operation in TVWS, the GDD enabling signal (see 11.42.2 (GDD enabling STA operation)) is received directly from a GDD enabling STA and is a Beacon frame or Probe Response frame containing a Geodatabase Inband Enabling Signal field indicating that enablement in the frequency band is possible.

All GDD dependent STAs shall set dot11GDD timer values as shown in Table E-8 (TVWS GDD timer limits), unless otherwise mandated by regulatory authorities.

**Table E-8—TVWS GDD timer limits**

| Parameter | Seconds |
|---|---|
| dot11GDDEnablementTimeLimit | 32 |
| dot11GDDEnablementFailHoldTime | 512 |
| dot11ContactVerificationSignalInterval | 60 |

NOTE 2—Be aware that most protocols above the MAC operate in the opposite endianness from what is used in Table E-9 (Device Identification Information Value fields) and Table E-10 (WSM Information Value fields).

The Device Identification Information format is shown in Table E-9 (Device Identification Information Value fields). (#296)US is to be understood as also including the United States' territories

**Table E-9—Device Identification Information Value fields**

| Name | Type | Length (octets) | Value | Scope/ Country code |
|---|---|---|---|---|
| FCC ID | 4 | 14 | The device identification contains the 14-octet FCC ID of the device. | US |
| Industry Canada ID | 5 | 11 | The device identification contains the 11-octet Industry Canada ID of the device. (#367)(#296). | CA |
| Device Serial Number | 6 | 4 | The Device Serial Number field contains the manufacturer's serial number. This field is present only if the Device Class field (Table 9-419 (Device Class field definition)) is equal to 2 (GDD AP) or 3 (GDD fixed STA); otherwise, this field is not present. | US |

The WSM Information Value fields format is shown in Table E-10 (WSM Information Value fields). In some regulatory domains, an AP can retrieve the WSM information from the GDB through the upper layer protocol (e.g., IETF RFC 7545 [B53]). When the AP retrieves the WSM information from the upper layer, it may translate it to the WSM Information field format shown in Table E-10 (WSM Information Value fields),

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which is the link-layer-specific information. (#296)US is to be understood as also including the United States' territories

**Table E-10—WSM Information Value fields**

| Name | Length (octets) | Value | Scope/ Country code |
|---|---|---|---|
| Device Class | 1 | Single octet TLV comprising fields in Table 9-419 (Device Class field definition). | WSM |
| Map ID | 1 | Bit 0: The Type bit, which indicates whether the following channel list is a full channel list or a partial channel list. If the Type bit is 1, the following channel list is a full channel list; and if the Type bit is 0, the following channel list is a partial channel list.<br>Bits 1–7: The Map version field, which identifies the version of the WSM. | WSM |
| Channel Number | 1 | The Channel Number field is a positive integer value as defined in E.1 (Country information and operating classes) that indicates the available TV channel for WLAN operation. When the Channel Number field and Maximum Power Level field pairs are repeated, they are listed in ascending TV channel order. | WSM, US |
| Maximum Power Level | 1 | The Maximum Power Level field indicates the maximum power, in units of 0.5 dBm, allowed to be transmitted on the channel indicated in the Channel Number field. | WSM, US |

NOTE 3—(#1605)(#296)In the United States and its territories, an example for a GDD non-AP STA describing two available channels with power limits of 100 mW and 40 mW is shown as 85, 0x06, 0x00, 0x03, 0x15, 0x28, 0x33, 0x20. Type is 85, length is 0x06, device class is 0x00, a full map with version 1 is 0x03, TV channel 21 is 0x15, 20 dBm maximum power level is 0x28, TV channel 51 is 0x33, 16 dBm maximum power level is 0x20.

## E.2.6 TVWS band in Europe

Each GDD enabling STA and AP in TVWS determines the available TV channels at its location using its own geographic location identification and TV bands database access capabilities. Each GDD dependent STA in TVWS receives an available TV channel list from the STA that enables its operation.

The Harmonized Standard for unlicensed device operation in TVWS is EN 301 598.

STAs operating in TVWS shall use:

— CS/CCA
— DFS

No STA operating in TVWS shall use Channel Switch Announcement.

STAs operating in TVWS shall have the following equal to true

— dot11GDDActivated
— dot11OperatingClassesRequired
— dot11SpectrumManagementRequired
— dot11MultiDomainCapabilityActivated


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— dot11ContactVerificationSignalActivated

For GDD dependent STA operation in TVWS, the GDD enabling signal (see 11.42.2 (GDD enabling STA operation)) is received directly from a GDD enabling STA and is a Beacon frame or Probe Response frame containing a Geodatabase Inband Enabling Signal field indicating that enablement in the frequency band is possible.

All GDD dependent STAs shall set dot11GDD timer values as shown in Table E-11 (TVWS GDD timer limits), unless otherwise mandated by regulatory authorities.

**Table E-11—TVWS GDD timer limits**

| Parameter | Seconds |
|---|---|
| dot11GDDEnablementTimeLimit | 32 |
| dot11GDDEnablementFailHoldTime | 512 |
| dot11ContactVerificationSignalInterval | 60 |

### E.2.7 6 GHz band(11ax)(#600)

(#600)When operating in the 6 GHz band, Table E-4 (Global operating classes) is used for the operating classes, so the third octet of the dot11CountryString is 4. For example, when operating in the 6 GHz band in the United States, the Country String field in the Country element is set to (in hexadecimal) 0x55, 0x53, 0x04.

NOTE 1—The first two octets indicate the United States. The third octet indicates that Table E-4 (Global operating classes) is in use (see Annex C).

The Regulatory Info subfield in the Control field of the 6 GHz Operation Information field of the HE Operation element (#4019)expresses the current operational mode of the AP and is interpreted (#6077)by non-AP STAs with dot11ExtendedRegInfoSupport not set to true as shown in Table E-12 (Regulatory Info subfield interpretation by non-AP STAs with dot11ExtendedRegInfoSupport not set to true(#6077)(#600)), and is interpreted by non-AP STAs with dott11ExtendedRegInfoSupport set to true as shown in Table E-13 (Regulatory Info subfield interpretation by non-AP STAs with dot11ExtendedRegInfoSupport set to true(#6077)) when operating in the 6 GHz band.

(#6077)NOTE 2—Non-AP STAs with dott11ExtendedRegInfoSupport not set to true parse B3 to B5 of the Control field as the Regulatory Info subfield, and ignore B6 of the Control field.

Each regulatory domain might have additional regulations for each Regulatory Info subfield value. Operation in such regulatory domains is subject to the additional regulations. (#6077)If a non-AP STA is unable to interpret the value of the Regulatory Info field, it might still, in accordance with local regulations, be able to determine a regulatory maximum transmit power to connect to the AP using received Transmit Power Envelope element(s) and/or local sources (see 11.7.5 (Specification of regulatory and local maximum transmit power levels)).

Some values defined in Table E-12 (Regulatory Info subfield interpretation by non-AP STAs with dot11ExtendedRegInfoSupport not set to true(#6077)(#600)) (#6077)and Table E-13 (Regulatory Info subfield interpretation by non-AP STAs with dot11ExtendedRegInfoSupport set to true(#6077)) might not

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be valid in all regulatory domains. If a certain Regulatory Info subfield encoding value is not valid in a regulatory domain, then the value is not used when operating in that regulatory domain.(#600)

**Table E-12—Regulatory Info subfield interpretation by non-AP STAs with dot11ExtendedRegInfoSupport not set to true(#6077)(#600)**

| Value | Description |
|---|---|
| (#6077)0 or 8 | Indoor AP<br><br>An AP whose operation does not require control from an external system such as an Automated Frequency Coordination (AFC) system but (#6077)operates under regulatory rules requiring indoor operation, and is subject to additional regulatory requirements intended to prohibit outdoor operation. |
| (#6077)1 or 9 | Standard power AP<br><br>An AP whose operation requires control from an external system such as an AFC system. |
| (#6077)2 or 10 | Very low power AP<br><br>An AP whose operation does not require control from an external system such as an AFC system, is not subject to additional regulatory requirements intended to prohibit outdoor operation, and is restricted to very low transmit power.<br><br>(#6077)NOTE—A 6 GHz non-AP STA conformant with an amendment to a previous revision of this standard might not be able to interpret these values. |
| (#6077)3 or 11 | Indoor enabled AP<br><br>An AP whose operation relies on being able to successfully receive an enabling signal (as defined by the regulatory rules) from an indoor AP or an indoor standard power AP.<br><br>(#6077)NOTE—A 6 GHz non-AP STA conformant with an amendment to a previous revision of this standard might not be able to interpret these values. |
| (#6077)4 or 12 | (#6077)Indoor standard power AP (deprecated)<br><br>An AP whose operation requires control from an external system such as an AFC system and that is subject to additional regulatory requirements intended to prohibit outdoor operation.<br><br>(#6077)NOTE—A 6 GHz non-AP STA conformant with an amendment to a previous revision of this standard might not be able to interpret these values. |


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**Table E-12—Regulatory Info subfield interpretation by non-AP STAs with dot11ExtendedRegInfoSupport not set to true(#6077)(#600) *(continued)***

| Value | Description |
|---|---|
| (#6077)(#4020)5 or 13 | Reserved |
| (#6077)6 or 14 | Reserved |
| (#6077)7 or 15 | AP role not relevant.<br><br>An AP whose operation does not affect the regulated behavior of associated or enabled devices.<br><br>NOTE 1—For instance, the transmission of Transmit Power Envelope elements by the AP might suffice.<br><br>(#6077)NOTE 2—A 6 GHz non-AP STA conformant with an amendment to a previous revision of this standard might not be able to interpret these values. |

**Table E-13—Regulatory Info subfield interpretation by non-AP STAs with dot11ExtendedRegInfoSupport set to true(#6077)**

| Value | Description |
|---|---|
| 0 | Indoor AP<br><br>An AP whose operation does not require control from an external system such as an Automated Frequency Coordination (AFC) system but operates under regulatory rules requiring indoor operation, and is subject to additional regulatory requirements intended to prohibit outdoor operation. |
| 1 | Standard power AP<br><br>An AP whose operation requires control from an external system such as an AFC systems. |
| 2 | Very low power AP<br><br>An AP whose operation does not require control from an external system such as an AFC system, is not subject to additional regulatory requirements intended to prohibit outdoor operation, and is restricted to very low transmit power. |
| 3 | Indoor enabled AP<br><br>An AP whose operation relies on being able to successfully receive an enabling signal (as defined by the regulatory rules) from an indoor AP or an indoor standard power AP. |
| 4–6 | Reserved |

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**Table E-13—Regulatory Info subfield interpretation by non-AP STAs with dot11ExtendedRegInfoSupport set to true(#6077) *(continued)***

| Value | Description |
|---|---|
| 7 | AP role not relevant<br><br>An AP whose operation does not affect the regulated behavior of associated or enabled devices.<br><br>NOTE—For instance, the transmission of Transmit Power Envelope elements by the AP might suffice. |
| 8 | Indoor standard power AP<br><br>An AP whose operation requires control from an external system such as an AFC system and also operates under regulatory rules requiring indoor operation, and is subject to additional regulatory requirements intended to prohibit outdoor operation. |
| 9–15 | Reserved |

(#600)(#6077)In Table E-12 (Regulatory Info subfield interpretation by non-AP STAs with dot11ExtendedRegInfoSupport not set to true(#6077)(#600)) and Table E-13 (Regulatory Info subfield interpretation by non-AP STAs with dot11ExtendedRegInfoSupport set to true(#6077)), a WLAN STA is not an external system.

NOTE 3—For example, an indoor enabled AP is not a standard power AP because the indoor AP or the indoor standard power AP (from which the indoor enabled AP receives the enabling signal) are not external systems.(#600)

(#600)(#6077)The values 8 (indoor standard power AP) for the Regulatory Info subfield are used instead of the value 0 (indoor AP) when the transmit power for all or part of the indoor AP's BSS bandwidth is controlled by an external system such as an AFC system.

(#6076)A *fixed client device* is a non-AP STA that operates only on channels provided by an external system for the regulatory domain in which the non-AP STA is operating such as an AFC system with additional requirements specified by the regulatory domain.

(#6076)A non-AP STA that is capable of operating as a STA 6G and has dot11ExtendedRegInfoSupport equal to true may transmit in a Non-AP STA Regulatory Connectivity element (see 9.4.2.311 (Non-AP STA Regulatory Connectivity element(#6076))) in Probe Request frames and in (Re)Association Request frames to (M153)an HE AP that does not transmit a Country element. A non-AP STA that is capable of operating as a STA 6G and has dot11ExtendedRegInfoSupport equal to true shall transmit a Non-AP STA Regulatory Connectivity element (see 9.4.2.311 (Non-AP STA Regulatory Connectivity element(#6076))) in (Re)Association Request frames to an AP (#8123)that transmits a Country element.

The Maximum Transmit Power Category subfield in the Transmit Power Information field of the Transmit Power Envelope element is interpreted as shown in Table E-14 (Maximum Transmit Power Category subfield encoding(#600)) when operating in the 6 GHz band. (#6077)This table describes the non-AP STAs for which a Transmit Power Envelope element with a given Maximum Transmit Power Category field value is applicable. Each regulatory domain might have additional regulations for each Maximum Transmit Power Category subfield value. Operation in such regulatory domains is subject to the additional regulations. Some values defined in Table E-14 (Maximum Transmit Power Category subfield encoding(#600)) might not be


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valid in all regulatory domains. If a certain Maximum Transmit Power Category subfield encoding value is not valid in a regulatory domain, then the value is not used when operating in that regulatory domain.(#600)

**Table E-14—Maximum Transmit Power Category subfield encoding(#600)**

| Value | Description |
|---|---|
| 0 | Default |
| 1 | Subordinate device<br>A device that operates under the control of an indoor AP with additional requirements specified by the regulatory domain in which the AP is operating.(#600) |
| 2–3 | Reserved |

(#600)An AP operating in the 6 GHz band shall send at least one Transmit Power Envelope element in Beacon and Probe Response frames as follows:

— Maximum Transmit Power Category subfield = Default; (#6076)Maximum Transmit Power Interpretation subfield = (#3452)Regulatory client EIRP PSD

(#600)When operating in the 6 GHz band in a regulatory domain in which a subordinate device (see Table E-14 (Maximum Transmit Power Category subfield encoding(#600))) is supported, an AP that is an indoor AP or indoor standard power AP per regulatory rules shall also send the following Transmit Power Envelope element in Beacon and Probe Response frames:

— Maximum Transmit Power Category subfield = Subordinate device; (#6076)Maximum Transmit Power Interpretation subfield = Regulatory client EIRP PSD

(#6076)An AP that transmits a Regulatory Information field indicating indoor standard power AP shall send at least one Transmit Power Envelope element in Beacon and Probe Response frames as follows:

— Maximum Transmit Power Category subfield = Default; Maximum Transmit Power Interpretation subfield = Additional regulatory client EIRP PSD

(#6076)An *SP only client* is a non-AP STA that is capable of operating under the control of a standard power AP and is incapable of operating under the control of an indoor AP per regulatory rules. An *LPI only client* is a non-AP STA that is capable of operating under the control of an indoor AP and is incapable of operating under the control of a standard power AP per regulatory rules.

A regulatory client EIRP PSD value advertised by an AP that is a standard power AP (#6076)shall be set to the highest value that meets the authorized client transmit power limits for the corresponding category obtained from the external system required by the regulatory rules, such as an AFC system, and any other client PSD regulatory rules for the corresponding 20 MHz channel.(#600)

(#6076)A regulatory client EIRP PSD value advertised by an AP that is an indoor standard power AP shall be set o the higher of the following two values:

— The highest value that meets the authorized client transmit power limits for the corresponding category obtained from the external system required by the regulatory rules, such as an AFC system, and any other client PSD regulatory rules for the corresponding 20 MHz channel.

— The highest value that meets the LPI only client transmit power limits authorized by the regulatory rules for the corresponding category for the corresponding 20 MHz channel.

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(#6076)An additional regulatory client EIRP PSD value advertised by an AP that is an indoor standard power AP shall be set to the highest value that meets the authorized client transmit power limits for the corresponding category obtained from the external system required by the regulatory rules, such as an AFC system, and any other client PSD regulatory rules for the corresponding 20 MHz channel.

If the regulatory client EIRP PSD values advertised by an AP that is a (#600)standard power AP or indoor standard power AP are insufficient to ensure that regulatory client limits on total EIRP are always met for all transmission bandwidths within the bandwidth of the AP's BSS, the AP shall also send a Transmit Power Envelope element in Beacon and Probe Response frames as follows:

— Maximum Transmit Power Category subfield = Default; (#6076)Maximum Transmit Power Interpretation subfield = Regulatory client EIRP

NOTE 4—In the case of regulatory rules where the maximum transmit power for client devices is lower than the maximum transmit power for APs(#600), the regulatory client maximum transmit power advertised by the AP for client devices might be lower than the regulatory client maximum transmit power the AP is authorized to use for its own transmissions.

(#6077)If a non-AP STA receives a Transmit Power Envelope element with Maximum Transmit Power Category subfield that is not applicable to that non-AP STA, the non-AP STA may ignore that element.

(#6077)NOTE 5—For example, if the non-AP STA is a (#600)subordinate device per regulatory rules and receives a Transmit Power Envelope element with Maximum Transmit Power Category subfield indicating (#600)a subordinate device, it may ignore any other received Transmit Power Envelope elements that indicate other values in the Maximum Transmit Power Category subfield.(#600)

(#6077)NOTE 6—For example, if the non-AP STA is a device that, per regulatory rules, determines its regulatory client transmit power entirely using sources other than the AP (see 11.7.5 (Specification of regulatory and local maximum transmit power levels)), it can ignore all received Transmit Power Envelope elements with unit interpretation of Regulatory Client EIRP PSD or Regulatory Client EIRP from that AP.

(#6076)An SP only client that is associated to an indoor standard power AP that receives, from the AP, one Transmit Power Envelope element with the Maximum Transmit Power Category subfield indicating Default and with the Maximum Transmit Power Interpretation subfield indicating Regulatory Client EIRP and another Transmit Power Envelope element with the Maximum Transmit Power Category subfield also indicating Default yet with the Maximum Transmit Power Interpretation subfield indicating Additional Regulatory Client EIRP shall comply with both elements.

(#6076)An SP only client that is associated to an indoor standard power AP that receives, from the AP, one Transmit Power Envelope element with the Maximum Transmit Power Category subfield indicating Default and with the Maximum Transmit Power Interpretation subfield indicating Regulatory Client EIRP PSD and another Transmit Power Envelope element with the Maximum Transmit Power Category subfield also indicating Default yet with the Maximum Transmit Power Interpretation subfield indicating Additional Regulatory Client EIRP PSD shall comply with both elements.

(#6076)NOTE 7—The Transmit Power Envelope element sent by an indoor standard power AP are insufficient for a client that is not an SP only client to determine its regulatory maximum power level; rather the client uses the regulatory maximum transmit power for the channel in the current regulatory domain known by the client from other sources following 11.7.5 (Specification of regulatory and local maximum transmit power levels) and 11.7.6 (Transmit power selection).


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# Annex F

(normative)

# HT LDPC matrix definitions

Table F-1 (Matrix prototypes for codeword block length n = 648 bits, subblock size is Z = 27 bits) defines the matrix prototypes of the parity-check matrices for a codeword block length $n$ = 648 bits, with a subblock size $Z$ = 27 bits.

**Table F-1—Matrix prototypes for codeword block length *n* = 648 bits, subblock size is *Z* = 27 bits**

(a) Coding rate R = 1/2.

| | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | – | – | – | 0 | 0 | – | – | 0 | – | – | 0 | 1 | 0 | – | – | – | – | – | – | – | – | – | – |
| 22 | 0 | – | – | 17 | – | 0 | 0 | 12 | – | – | – | – | 0 | 0 | – | – | – | – | – | – | – | – | – |
| 6 | – | 0 | – | 10 | – | – | – | 24 | – | 0 | – | – | – | 0 | 0 | – | – | – | – | – | – | – | – |
| 2 | – | – | 0 | 20 | – | – | – | 25 | 0 | – | – | – | – | – | 0 | 0 | – | – | – | – | – | – | – |
| 23 | – | – | – | 3 | – | – | – | 0 | – | 9 | 11 | – | – | – | – | 0 | 0 | – | – | – | – | – | – |
| 24 | – | 23 | 1 | 17 | – | 3 | – | 10 | – | – | – | – | – | – | – | – | 0 | 0 | – | – | – | – | – |
| 25 | – | – | – | 8 | – | – | – | 7 | 18 | – | – | 0 | – | – | – | – | – | 0 | 0 | – | – | – | – |
| 13 | 24 | – | – | 0 | – | 8 | – | 6 | – | – | – | – | – | – | – | – | – | – | 0 | 0 | – | – | – |
| 7 | 20 | – | 16 | 22 | 10 | – | – | 23 | – | – | – | – | – | – | – | – | – | – | – | 0 | 0 | – | – |
| 11 | – | – | – | 19 | – | – | – | 13 | – | 3 | 17 | – | – | – | – | – | – | – | – | – | 0 | 0 | – |
| 25 | – | 8 | – | 23 | 18 | – | 14 | 9 | – | – | – | – | – | – | – | – | – | – | – | – | – | 0 | 0 |
| 3 | – | – | – | 16 | – | – | 2 | 25 | 5 | – | – | 1 | – | – | – | – | – | – | – | – | – | – | 0 |

(b) Coding rate R = 2/3.

| | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 25 | 26 | 14 | – | 20 | – | 2 | – | 4 | – | – | 8 | – | 16 | – | 18 | 1 | 0 | – | – | – | – | – | – | |
| 10 | 9 | 15 | 11 | – | 0 | – | 1 | – | – | 18 | – | 8 | – | 10 | – | – | 0 | 0 | – | – | – | – | – | |
| 16 | 2 | 20 | 26 | 21 | – | 6 | – | 1 | 26 | – | 7 | – | – | – | – | – | – | 0 | 0 | – | – | – | – | |
| 10 | 13 | 5 | 0 | – | 3 | – | 7 | – | – | 26 | – | – | 13 | – | 16 | – | – | – | 0 | 0 | – | – | – | |
| 23 | 14 | 24 | – | 12 | – | 19 | – | 17 | – | – | – | 20 | – | 21 | – | 0 | – | – | – | 0 | 0 | – | – | |
| 6 | 22 | 9 | 20 | – | 25 | – | 17 | – | 8 | – | 14 | – | 18 | – | – | – | – | – | – | – | 0 | 0 | – | |
| 14 | 23 | 21 | 11 | 20 | – | 24 | – | 18 | – | 19 | – | – | – | – | 22 | – | – | – | – | – | – | 0 | 0 | |
| 17 | 11 | 11 | 20 | – | 21 | – | 26 | – | 3 | – | – | 18 | – | 26 | – | 1 | – | – | – | – | – | – | 0 | |

(c) Coding rate R = 3/4.

| | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 16 | 17 | 22 | 24 | 9 | 3 | 14 | – | 4 | 2 | 7 | – | 26 | – | 2 | – | 21 | – | 1 | 0 | – | – | – | – | |
| 25 | 12 | 12 | 3 | 3 | 26 | 6 | 21 | – | 15 | 22 | – | 15 | – | 4 | – | – | 16 | – | 0 | 0 | – | – | – | |
| 25 | 18 | 26 | 16 | 22 | 23 | 9 | – | 0 | – | 4 | – | 4 | – | 8 | 23 | 11 | – | – | – | 0 | 0 | – | – | |
| 9 | 7 | 0 | 1 | 17 | – | – | 7 | 3 | – | 3 | 23 | – | 16 | – | – | 21 | – | 0 | – | – | 0 | 0 | – | |
| 24 | 5 | 26 | 7 | 1 | – | – | 15 | 24 | 15 | – | 8 | – | 13 | – | 13 | – | 11 | – | – | – | – | 0 | 0 | |
| 2 | 2 | 19 | 14 | 24 | 1 | 15 | 19 | – | 21 | – | 2 | – | 24 | – | 3 | – | 2 | 1 | – | – | – | – | 0 | |

(d) Coding rate R = 5/6.

| | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 17 | 13 | 8 | 21 | 9 | 3 | 18 | 12 | 10 | 0 | 4 | 15 | 19 | 2 | 5 | 10 | 26 | 19 | 13 | 13 | 1 | 0 | – | – | |
| 3 | 12 | 11 | 14 | 11 | 25 | 5 | 18 | 0 | 9 | 2 | 26 | 26 | 10 | 24 | 7 | 14 | 20 | 4 | 2 | – | 0 | 0 | – | |
| 22 | 16 | 4 | 3 | 10 | 21 | 12 | 5 | 21 | 14 | 19 | 5 | – | 8 | 5 | 18 | 11 | 5 | 5 | 15 | 0 | – | 0 | 0 | |
| 7 | 7 | 14 | 14 | 4 | 16 | 16 | 24 | 24 | 10 | 1 | 7 | 15 | 6 | 10 | 26 | 8 | 18 | 21 | 14 | 1 | – | – | 0 | |

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Table F-2 (Matrix prototypes for codeword block length n = 1296 bits, subblock size is Z = 54 bits) defines the matrix prototypes of the parity-check matrices for a codeword block length $n$ = 1296 bits, with a subblock size $Z$ = 54 bits.

**Table F-2—Matrix prototypes for codeword block length *n* = 1296 bits, subblock size is *Z* = 54 bits**

(a) Coding rate R = 1/2.

| | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 40 | - | - | - | 22 | - | 49 | 23 | 43 | - | - | - | 1 | 0 | - | - | - | - | - | - | - | - | - | - |
| 50 | 1 | - | - | 48 | 35 | - | - | 13 | - | 30 | - | - | 0 | 0 | - | - | - | - | - | - | - | - | - |
| 39 | 50 | - | - | 4 | - | 2 | - | - | - | - | 49 | - | - | 0 | 0 | - | - | - | - | - | - | - | - |
| 33 | - | - | 38 | 37 | - | - | 4 | 1 | - | - | - | - | - | - | 0 | 0 | - | - | - | - | - | - | - |
| 45 | - | - | - | 0 | 22 | - | - | 20 | 42 | - | - | - | - | - | - | 0 | 0 | - | - | - | - | - | - |
| 51 | - | - | 48 | 35 | - | - | - | 44 | - | 18 | - | - | - | - | - | - | 0 | 0 | - | - | - | - | - |
| 47 | 11 | - | - | - | 17 | - | - | 51 | - | - | - | 0 | - | - | - | - | - | 0 | 0 | - | - | - | - |
| 5 | - | 25 | - | 6 | - | 45 | - | 13 | 40 | - | - | - | - | - | - | - | - | - | 0 | 0 | - | - | - |
| 33 | - | - | 34 | 24 | - | - | - | 23 | - | - | 46 | - | - | - | - | - | - | - | - | 0 | 0 | - | - |
| 1 | - | 27 | - | 1 | - | - | - | 38 | - | 44 | - | - | - | - | - | - | - | - | - | - | 0 | 0 | - |
| - | 18 | - | - | 23 | - | - | 8 | 0 | 35 | - | - | - | - | - | - | - | - | - | - | - | - | 0 | 0 |
| 49 | - | 17 | - | 30 | - | - | - | 34 | - | - | 19 | 1 | - | - | - | - | - | - | - | - | - | - | 0 |

(b) Coding rate R = 2/3.

| | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 39 | 31 | 22 | 43 | - | 40 | 4 | - | 11 | - | - | 50 | - | - | - | 6 | 1 | 0 | - | - | - | - | - | - |
| 25 | 52 | 41 | 2 | 6 | - | 14 | - | 34 | - | - | - | 24 | - | 37 | - | - | 0 | 0 | - | - | - | - | - |
| 43 | 31 | 29 | 0 | 21 | - | 28 | - | - | 2 | - | - | 7 | - | 17 | - | - | - | 0 | 0 | - | - | - | - |
| 20 | 33 | 48 | - | 4 | 13 | - | 26 | - | - | 22 | - | - | 46 | 42 | - | - | - | - | 0 | 0 | - | - | - |
| 45 | 7 | 18 | 51 | 12 | 25 | - | - | - | 50 | - | - | 5 | - | - | - | 0 | - | - | - | 0 | 0 | - | - |
| 35 | 40 | 32 | 16 | 5 | - | - | 18 | - | - | 43 | 51 | - | 32 | - | - | - | - | - | - | - | - | 0 | 0 | - |
| 9 | 24 | 13 | 22 | 28 | - | - | 37 | - | - | 25 | - | - | 52 | - | 13 | - | - | - | - | - | - | - | 0 | 0 |
| 32 | 22 | 4 | 21 | 16 | - | - | - | 27 | 28 | - | 38 | - | - | - | 8 | 1 | - | - | - | - | - | - | 0 |

(c) Coding rate R = 3/4.

| | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 39 | 40 | 51 | 41 | 3 | 29 | 8 | 36 | - | 14 | - | 6 | - | 33 | - | 11 | - | 4 | 1 | 0 | - | - | - | - |
| 48 | 21 | 47 | 9 | 48 | 35 | 51 | - | 38 | - | 28 | - | 34 | - | 50 | - | 50 | - | - | 0 | 0 | - | - | - |
| 30 | 39 | 28 | 42 | 50 | 39 | 5 | 17 | - | 6 | - | 18 | - | 20 | - | 15 | - | 40 | - | - | 0 | 0 | - | - |
| 29 | 0 | 1 | 43 | 36 | 30 | 47 | - | 49 | - | 47 | - | 3 | - | 35 | - | 34 | - | 0 | - | - | 0 | 0 | - |
| 1 | 32 | 11 | 23 | 10 | 44 | 12 | 7 | - | 48 | - | 4 | - | 9 | - | 17 | - | 16 | - | - | - | - | 0 | 0 |
| 13 | 7 | 15 | 47 | 23 | 16 | 47 | - | 43 | - | 29 | - | 52 | - | 2 | - | 53 | - | 1 | - | - | - | - | 0 |

(d) Coding rate R = 5/6.

| | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 48 | 29 | 37 | 52 | 2 | 16 | 6 | 14 | 53 | 31 | 34 | 5 | 18 | 42 | 53 | 31 | 45 | - | 46 | 52 | 1 | 0 | - | - |
| 17 | 4 | 30 | 7 | 43 | 11 | 24 | 6 | 14 | 21 | 6 | 39 | 17 | 40 | 47 | 7 | 15 | 41 | 19 | - | - | 0 | 0 | - |
| 7 | 2 | 51 | 31 | 46 | 23 | 16 | 11 | 53 | 40 | 10 | 7 | 46 | 53 | 33 | 35 | - | 25 | 35 | 38 | 0 | - | 0 | 0 |
| 19 | 48 | 41 | 1 | 10 | 7 | 36 | 47 | 5 | 29 | 52 | 52 | 31 | 10 | 26 | 6 | 3 | 2 | - | 51 | 1 | - | - | 0 |



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Table F-3 (Matrix prototypes for codeword block length n = 1944 bits, subblock size is Z = 81 bits) defines the matrix prototypes of the parity-check matrices for a codeword block length $n$ = 1944 bits, with a subblock size $Z$ = 81 bits.

**Table F-3—Matrix prototypes for codeword block length *n* = 1944 bits, subblock size is *Z* = 81 bits**

(a) Coding rate R = 1/2.

| | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 57 | - | - | - | 50 | - | 11 | - | 50 | - | 79 | - | 1 | 0 | - | - | - | - | - | - | - | - | - | - |
| 3 | - | 28 | - | 0 | - | - | - | 55 | 7 | - | - | - | 0 | 0 | - | - | - | - | - | - | - | - | - |
| 30 | - | - | - | 24 | 37 | - | - | 56 | 14 | - | - | - | - | 0 | 0 | - | - | - | - | - | - | - | - |
| 62 | 53 | - | - | 53 | - | - | 3 | 35 | - | - | - | - | - | - | 0 | 0 | - | - | - | - | - | - | - |
| 40 | - | - | 20 | 66 | - | - | 22 | 28 | - | - | - | - | - | - | - | 0 | 0 | - | - | - | - | - | - |
| 0 | - | - | - | 8 | - | 42 | - | 50 | - | - | 8 | - | - | - | - | - | 0 | 0 | - | - | - | - | - |
| 69 | 79 | 79 | - | - | - | 56 | - | 52 | - | - | - | 0 | - | - | - | - | - | 0 | 0 | - | - | - | - |
| 65 | - | - | - | 38 | 57 | - | - | 72 | - | 27 | - | - | - | - | - | - | - | - | 0 | 0 | - | - | - |
| 64 | - | - | - | 14 | 52 | - | - | 30 | - | - | 32 | - | - | - | - | - | - | - | - | 0 | 0 | - | - |
| - | 45 | - | 70 | 0 | - | - | - | 77 | 9 | - | - | - | - | - | - | - | - | - | - | - | 0 | 0 | - |
| 2 | 56 | - | 57 | 35 | - | - | - | - | - | 12 | - | - | - | - | - | - | - | - | - | - | - | 0 | 0 |
| 24 | - | 61 | - | 60 | - | - | 27 | 51 | - | - | 16 | 1 | - | - | - | - | - | - | - | - | - | - | 0 |

(b) Coding rate R = 2/3.

| | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 61 | 75 | 4 | 63 | 56 | - | - | - | - | - | - | 8 | - | 2 | 17 | 25 | 1 | 0 | - | - | - | - | - | - |
| 56 | 74 | 77 | 20 | - | - | - | 64 | 24 | 4 | 67 | - | 7 | - | - | - | - | 0 | 0 | - | - | - | - | - |
| 28 | 21 | 68 | 10 | 7 | 14 | 65 | - | - | - | 23 | - | - | - | 75 | - | - | - | 0 | 0 | - | - | - | - |
| 48 | 38 | 43 | 78 | 76 | - | - | - | - | 5 | 36 | - | 15 | 72 | - | - | - | - | - | 0 | 0 | - | - | - |
| 40 | 2 | 53 | 25 | - | 52 | 62 | - | 20 | - | - | 44 | - | - | - | - | 0 | - | - | - | 0 | 0 | - | - |
| 69 | 23 | 64 | 10 | 22 | - | 21 | - | - | - | - | - | 68 | 23 | 29 | - | - | - | - | - | - | 0 | 0 | - |
| 12 | 0 | 68 | 20 | 55 | 61 | - | 40 | - | - | - | 52 | - | - | - | 44 | - | - | - | - | - | - | 0 | 0 |
| 58 | 8 | 34 | 64 | 78 | - | - | 11 | 78 | 24 | - | - | - | - | - | 58 | 1 | - | - | - | - | - | - | 0 |

(c) Coding rate R = 3/4.

| | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 48 | 29 | 28 | 39 | 9 | 61 | - | - | - | 63 | 45 | 80 | - | - | - | 37 | 32 | 22 | 1 | 0 | - | - | - | - |
| 4 | 49 | 42 | 48 | 11 | 30 | - | - | - | 49 | 17 | 41 | 37 | 15 | - | 54 | - | - | - | 0 | 0 | - | - | - |
| 35 | 76 | 78 | 51 | 37 | 35 | 21 | - | 17 | 64 | - | - | - | 59 | 7 | - | - | 32 | - | - | 0 | 0 | - | - |
| 9 | 65 | 44 | 9 | 54 | 56 | 73 | 34 | 42 | - | - | - | 35 | - | - | - | 46 | 39 | 0 | - | - | 0 | 0 | - |
| 3 | 62 | 7 | 80 | 68 | 26 | - | 80 | 55 | - | 36 | - | 26 | - | 9 | - | 72 | - | - | - | - | - | 0 | 0 |
| 26 | 75 | 33 | 21 | 69 | 59 | 3 | 38 | - | - | - | 35 | - | 62 | 36 | 26 | - | - | 1 | - | - | - | - | 0 |

(d) Coding rate R = 5/6.

| | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 13 | 48 | 80 | 66 | 4 | 74 | 7 | 30 | 76 | 52 | 37 | 60 | - | 49 | 73 | 31 | 74 | 73 | 23 | - | 1 | 0 | - | - |
| 69 | 63 | 74 | 56 | 64 | 77 | 57 | 65 | 6 | 16 | 51 | - | 64 | - | 68 | 9 | 48 | 62 | 54 | 27 | - | 0 | 0 | - |
| 51 | 15 | 0 | 80 | 24 | 25 | 42 | 54 | 44 | 71 | 71 | 9 | 67 | 35 | - | 58 | - | 29 | - | 53 | 0 | - | 0 | 0 |
| 16 | 29 | 36 | 41 | 44 | 56 | 59 | 37 | 50 | 24 | - | 65 | 4 | 65 | 52 | - | 4 | - | 73 | 52 | 1 | - | - | 0 |

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# Annex G

(informative)

# Frame exchange sequences(#109)

## G.1 General

The allowable frame exchange sequences are defined using an extension of the EBNF format as defined in ISO/IEC 14977:1996 [B60]. The elements of this syntax that are used here are as follows:

- [a] = a is optional.
- {a} = a is repeated zero or more times.
- n{a} = a is repeated n or more times. For example, 3{a} requires 3 or more "a". This notation is an extension to ISO/IEC 14977 and equivalent to n*a{a} as defined in that standard.
- a|b|c|... = selection between mutually exclusive alternatives, a, b, c ....
- ( ) = grouping, e.g., "a (b|c)" is equivalent to "a b | a c".
- (* a *) = "a" is a comment. Comments are placed before the text they relate to.
- < > = order of frames not relevant. For example, <a b> is either "a b" or "b a".
- A rule is terminated by a semicolon ';'
- The meaning of whitespace is changed from ISO/IEC 14977. The name of terminals do not contain whitespace, and the concatenate-symbol (comma in ISO/IEC 14977) is replaced by white space. Whitespace appearing between the names of terminals indicates concatenation. Otherwise, whitespace is not significant and is used to highlight the nesting of grouped terms.

Two types of terminals are defined:

- **Frames.** The name of a frame is shown in **bold** and identified by its type/subtype (e.g., **Beacon**, **Data**). Frames are shown with an initial capital letter.
- *Attributes.* The name of attributes are shown in *italic*. An attribute is introduced by the '+' character. The attribute specifies a condition that applies to the frame (or alternatively, for the attributes that start +mu, the A-MPDU) that precedes it. Where there are multiple attributes applied, they are generally ordered in the same order of the fields in the frame to which they refer. The syntax a+(b|c) where b and c are attributes is equivalent to (a+b) | (a+c).

In this syntax the names of nonterminals are shown in a normal font, i.e., a sequence of words joined by hyphens (e.g., cf-frame-exchange-sequence).

The attributes are defined in Table G-1 (Attributes applicable to frame exchange sequence definition).

**Table G-1—Attributes applicable to frame exchange sequence definition**

| Attribute | Description |
|---|---|
| *a-mpdu* | Frame is part of an A-MPDU aggregate. See NOTE 2. |
| *a-mpdu-end* | Frame is the last frame in an A-MPDU aggregate. See NOTE 2. |
| *block-ack* | QoS Data frame with Block Ack ack policy. |
| *broadcast* | Frame RA is the broadcast address. |


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**Table G-1—Attributes applicable to frame exchange sequence definition *(continued)***

| Attribute | Description |
|---|---|
| *csi* | An Action frame carrying channel state feedback (i.e., CSI, uncompressed beamforming, or compressed beamforming feedback matrices). |
| *csi-request* | A +HTC frame with the Feedback Request field equal to a value > 0. |
| *delayed* | BlockAck or BlockAckReq frame under a delayed policy.(#3262) |
| *DTIM* | Beacon is a DTIM. |
| *frag* | Frame has its More Fragments subfield equal to 1. |
| *group* | Frame RA has Individual/Group bit equal to 1. |
| *HTC* | +HTC frame, i.e., a frame that contains the HT Control field, including the Control Wrapper frame. See NOTE 1. |
| *I2R(#7075)* | ISTA to RSTA transmission |
| *implicit-bar* | QoS Data frame in an A-MPDU with Implicit BAR ack policy. |
| *individual* | Frame RA has Individual/Group bit equal to 0 or is sent to an AP or PCP. |
| *last* | Frame has its More Fragments subfield equal to 0. |
| *action-no-ack* | Management frame of subtype Action No Ack. |
| *mfb* | A +HTC frame with the MFB field is not equal to all 1s.(#3263) |
| *mrq* | A +HTC frame with the MRQ subfield equal to 1. |
| *mu-ppdu-end* | This attribute delineates the end of a VHT MU PPDU. See NOTE 3 and NOTE 4. |
| *mu-user-respond* | The preceding frame or A-MPDU is part of a VHT MU PPDU and is addressed to a user from which an immediate response is expected. See NOTE 3 and NOTE 4. |
| (11ax)*mu-users-respond* | (11ax)The preceding frame or A-MPDU is part of an HE MU PPDU. |
| *mu-user-not-respond* | The preceding frame or A-MPDU is part of a VHT MU PPDU and is addressed to a user from which no immediate response is expected. See NOTE 3 and NOTE 4. |
| *ndp-announce* | A +HTC frame with the HT NDP Announcement subfield equal to 1. |
| *no-ack* | QoS Data frame with No Ack ack policy.(#3263) |
| *normal-ack* | QoS Data frame with Normal Ack ack policy. |
| *non-QAP* | Frame is transmitted by a non-AP QoS STA. |
| *non-stbc* | PPDU TXVECTOR STBC parameter is equal to 0. |
| *null* | Data type Null Data subtype bit (Frame Control field B6) equal to 1. |
| *pifs* | Frame is transmitted following a PIFS.(#3263) |
| *QAP* | (11ay)Frame is transmitted by a QoS AP or a PCP. |
| *QoS* | Data type QoS subtype bit (Frame Control field B7) equal to 1. |
| *R2I(#7075)* | RSTA to ISTA transmission |
| *ranging-poll(#7075)* | Trigger frame of type Ranging Subtype Poll |
| *ranging-secure-sound(#7075)* | Trigger frame of type Ranging Subtype Secure Sounding |
| *ranging-sound(#7075)* | Trigger frame of type Ranging Subtype Sounding |
| *RD* | (11ay)For a non-DMG STA, frame includes an HT Control field in which the RDG/More PPDU subfield is equal to 1. For a DMG STA, frame has RDG/More PPDU subfield in the QoS Control field equal to 1. |

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**Table G-1—Attributes applicable to frame exchange sequence definition *(continued)***

| Attribute | Description |
|---|---|
| *self* | Frame RA = TA. |
| *sounding* | PPDU TXVECTOR SOUNDING parameter is present and equal to SOUNDING. |
| *stbc* | PPDU TXVECTOR STBC parameter is equal to a value >0. |
| *to-ap* | Frame is addressed to the AP. |
| *trq* | Frame is a +HTC frame with the TRQ field equal to 1. |
| *non-S1GAP* | Frame is transmitted by a non-AP S1G STA. |
| *S1GAP* | Frame is transmitted by an S1G AP. |
| (11ay)*CT* | (11ay)A frame that contains a control trailer. |
| (11ay)*TRN* | (11ay)A DMG PPDU that carries a TRN field. |
| (11ay)*ssw* | (11ay)TDD Beamforming frame with TDD Beamforming Frame Type subfield set to 0. |
| (11ay)*ssw-ack* | (11ay)TDD Beamforming frame with TDD Beamforming Frame Type subfield set to 2. |
| (11ay)*ssw-feedback* | (11ay)TDD Beamforming frame with TDD Beamforming Frame Type subfield set to 1. |

NOTE 1—A Control frame that contains the HT Control field is always transmitted using the Control Wrapper frame.

NOTE 2—In the case of S-MPDU, a single MPDU is carried in an A-MPDU, but the attributes +*a-mpdu* and +*a-mpdu-end* are not used.

NOTE 3—+*mu-ppdu-end*, +*mu-user-respond* and +*mu-user-other* are used in productions that generate VHT MU PPDUs, according to the pattern: ["an A-MPDU (which might contain a S-MPDU) needing a response" +*mu-user-respond* ] {"an A-MPDU (which might contain a S-MPDU) not needing a response" +*mu-user-not-respond*} +*mu-ppdu-end*. There is at least one of +*mu-user-respond* or +*mu-user-not-respond* in a VHT MU PPDU.

NOTE 4—In the sequence **A**+*mu-user-respond* **B**+*mu-user-not-respond* … +*mu-ppdu-end*, although the terms **A**, **B** … (which represent one or more frames) are listed sequentially in these productions, the per-user sequence of frames represented by **A**, **B**, ... are transmitted simultaneously per-user using a VHT MU PPDU.

## G.2 Basic sequences

An allowable frame exchange sequence is defined by the rule frame-exchange-sequence. Except where modified by the *pifs* attribute, frames are separated by a SIFS or RIFS.

(* This rule defines all of the allowable frame exchange sequences *)
frame-exchange-sequence =
( [**CTS**] (**Management** +*broadcast* | **Data** +*group*) ) |
( [**CTS** | **RTS CTS** | **PS-Poll**] {frag-frame **Ack**} last-frame **Ack** ) |
(**PS-Poll Ack**) |
hcf-sequence |
mcf-sequence |
s1g-sequence |
dmg-sequence;(11ay)

(* A frag-frame is a nonfinal part of an individually addressed MSDU or MMPDU *)
frag-frame = (**Data** | **Management**) +*individual* +*frag*;


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(* This is the last (or only) part of a an individually addressed MSDU or MMPDU *)
last-frame = (**Data** | **Management**) +*individual* +*last*;

## G.3 EDCA and HCCA sequences

(* An hcf-sequence represents all of the sequences that may be generated under HCCA or EDCA. The sequence may be initiated by an HC within a CAP, or it may be initiated by a STA using EDCA channel access. *)
hcf-sequence =
( [**CTS**] 1{(**Data** +*group* [+*QoS*] ) | **Management** +*broadcast*) +pifs} |
( [**CTS**] 1{txop-sequence} ) |

(* HC only, polled TXOP delivery *)
( [**RTS CTS**] non-cf-ack-piggybacked-qos-poll-sequence ) |

(* HC only, polled TXOP delivery *)
cf-ack-piggybacked-qos-poll-sequence |

(* HC only, self TXOP delivery or termination *)
**Data** +*self* +*null* +*CF-Poll* +*QoS*;

(* A cf-ack-piggybacked-qos-poll-sequence is the start of a polled TXOP that also delivers a CF-Ack. There are two main variants, polls that deliver data and, therefore, need immediate acknowledgment and polls that do not. *)
cf-ack-piggybacked-qos-poll-sequence=
(qos-poll-requiring-no-ack +*CF-Ack* (
[**CTS** +*self*] polled-txop-content |
polled-txop-termination) ) |
(qos-poll-requiring-ack +*CF-Ack* (
**Ack** (
polled-txop-content |
polled-txop-termination) ) |
cf-ack-piggybacked-qos-data-sequence);

(* A non-cf-ack-piggybacked-qos-poll-sequence is the start of a polled TXOP that does not deliver a CF-Ack. Except for this, it is identical to the CF-Ack version. *)
non-cf-ack-piggybacked-qos-poll-sequence=
(qos-poll-requiring-no-ack (
[**CTS** +*self*] polled-txop-content |
polled-txop-termination) ) |
(qos-poll-requiring-ack (
**Ack** (
polled-txop-content |
polled-txop-termination) ) |
cf-ack-piggybacked-qos-data-sequence);

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(* This sequence is the delivery of a single frame that is the TXOP poll frame that does not require immediate acknowledgment either because the frame carries no data or because the frame carries data that do not require immediate acknowledgment. *)
qos-poll-requiring-no-ack =
    **Data** +*null* +*CF-Poll* +*QoS* |
    **Data** +*individual* +*CF-Poll* +*QoS* +*no-ack*|;

(* A qos-poll-requiring-ack is the delivery of a single frame that is a TXOP poll frame, but also carries data that require immediate acknowledgment. *)
qos-poll-requiring-ack =
    **Data** +*individual* +*CF-Poll* [+*CF-Ack*] +*QoS* +*normal-ack*;

(* Polled-txop-content is what may occur after the delivery of a polled TXOP. A QoS STA transmits the first frame in this sequence *)
polled-txop-content =
    1{txop-sequence} [polled-txop-termination];

(* A polled-txop-termination may be used by a QoS STA to terminate the polled TXOP. The Data frame is addressed to the HC, which regains control of the medium and may reuse any unused polled TXOP duration. *)
polled-txop-termination =
    **Data** +*individual* +*null* +*QoS* +*normal-ack* **Ack**;

(* A TXOP (either polled or EDCA) may be filled with txop-sequences, which are initiated by the TXOP holder. *)
txop-sequence =
    ( ( (**RTS CTS**) | **CTS** +*self*) **Data** +*individual* +*QoS* + | *no-ack* ) |
    [**RTS CTS**] (txop-part-requiring-ack txop-part-providing-ack )|
    [**RTS CTS**] (**Management** | (**Data** +*QAP*)) +*individual* **Ack** |
    [**RTS CTS**] (**BlockAckReq BlockAck**) |
    ht-txop-sequence;

(* These Data frames require immediate acknowledgment *)
(#565)txop-part-requiring-ack =
    **Data** +*individual* [+*null*] |
    **Data** +*individual* [+*null*] +*QoS* +*normal-ack*;

(* These frames provide acknowledgment to the txop-part-requiring-ack *)
txop-part-providing-ack=
    **Ack** | **NDP-Ack** |
    cf-ack-piggybacked-qos-poll-sequence |  (* An HC responds with a new polled TXOP on expiration of current TXOP *)
    cf-ack-piggybacked-qos-data-sequence |  (* An HC responds with CF-Ack and its own data on expiration of TXOP *)
    **Data** +*CF-Ack* +*QoS*;

(* An HC has received a frame requiring immediate acknowledgment with a duration value indicating the end of the TXOP. The HC continues the CAP by transmitting its own data. *)
cf-ack-piggybacked-qos-data-sequence =


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( **Data** +*individual* +*CF-Ack* +*QoS* +(*no-ack*|*block-ack*) polled-txop-content ) |
( **Data** +*individual* +*CF-Ack* +*QoS*+*normal-ack* (
**Ack** polled-txop-content |
**Data** +*CF-Ack* +*QoS*|
cf-ack-piggybacked-qos-poll-sequence ) ) ;

(* An mcf-sequence represents all of the sequences that may be generated under MCF. The sequence may be initiated by a mesh STA using EDCA channel access or MCCA channel access. *)
mcf-sequence =
( [**CTS**] |{(**Data**+*group*+*QoS* ) | **Management**+*broadcast*} ) | ( [**CTS**] 1{txop-sequence} ) |
group-mccaop-abandon;

(* A group-mccaop-abandon is the delivery of a single QoS Null frame by a mesh STA that has dot11MCCAActivated true. *)
group-mccaop-abandon =
**Data**+*broadcast*+*null*+*QoS*

## G.4 HT, VHT, S1G, and DMG sequences(11ay)

(* The ht-txop-sequence describes the additional sequences that may be initiated by an HT STA that is the holder of a TXOP *)
ht-txop-sequence = ht-nav-protected-sequence |
dual-cts-protected-sequence |
1{initiator-sequence};

(* an ht-nav-protected sequence consists of setting the NAV, performing one or more initiator-sequences and then resetting the NAV if time permits *)
ht-nav-protected-sequence = nav-set 1{initiator-sequence} [resync-sequence] ;

(* a dual-cts-protected-sequence is a sequence protected using the dual CTS protection feature *)
dual-cts-protected-sequence = dual-cts-nav-set 1{initiator-sequence} [dual-cts-nav-reset];

(* a dual-cts-nav-set is an initial exchange that establishes NAV protection using dual CTS protection. *)
dual-cts-nav-set = (* A dual CTS initiated by a non-AP HT STA that is not STBC-capable, preceded by an optional CTS frame addressed to the AP. *)
(
[ CTS+*to-ap*+*non-stbc*+*non-QAP* ]
**RTS**+*non-stbc*+*non-QAP*
**CTS**+*non-stbc*+*QAP*
[ **CTS**+*stbc*+*pifs*+*QAP* ]
) |

(* A dual CTS initiated by a non-AP STA that is STBC-capable, preceded by an optional CTS frame addressed to the AP. *)
(
[ CTS+*to-ap*+*stbc*+*non-QAP* ]
**RTS**+*stbc*+*non-QAP*
**CTS**+*stbc*+*QAP*
**CTS**+*non-stbc*+*QAP*
) |

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```
                    (* An STBC initiator-sequence (i.e., containing STBC PPDUs) transmitted by
                    the AP is protected by non-STBC CTS to self *)
                    (CTS+self+non-stbc+QAP) |

                    (* A non-STBC initiator-sequence transmitted by the AP is protected by STBC
                    CTS to self *)
                    (CTS+self+stbc+QAP);

(* a dual-cts-nav-reset resets the NAV in the vicinity of the transmitting non-AP STA, and resets the NAV
of both STBC and non-STBC-capable STA in the vicinity of the AP *)
dual-cts-nav-reset = [CF-End+non-QAP]  CF-End+stbc+QAP CF-End+non-stbc+QAP);

(* an ma-no-ack-htc represents an Action No Ack + HTC frame *)
ma-no-ack-htc =     Management+action-no-ack+HTC;

(* These are the series of frames that establish NAV protection for an HT sequence *)
nav-set =           (RTS[+HTC] CTS[+HTC]) |
                    CTS+self |
                    (Data[+HTC]+individual[+null][+QoS+normal-ack] Ack) |
                    Data[+HTC]+individual[+QoS+(block-ack)] |
                    Data+group[+null][+QoS] |
                    ( 1{ Data[+HTC]+individual+QoS+implicit-bar+a-mpdu}+a-mpdu-end
                                BlockAck[+HTC]
                    ) |
                    (BlockAckReq[+HTC] (BlockAck[+HTC]|Ack[+HTC])) |
                    (BlockAck[+HTC] Ack)
                    1{vht-rts-cts};

(* The vht-rts-cts term applies to RTS transmitted by a VHT STA to another VHT STA. When the RTS is
transmitted using a non-HT or non-HT duplicate PPDU, the transmission of the RTS is delayed so that at
least a PIFS has elapsed since the previous frame exchange sequence (see 10.23.2.8 (Multiple frame
exchange sequences in an EDCA TXOP(#109))) and the RTS is transmitted with a signaling TA (see
10.3.2.7 (VHT and S1G RTS procedure)). *)
vht-rts-cts =       RTS+pifs [+HTC] CTS[+HTC];

resync-sequence =   CF-End | (CF-End+non-QAP CF-End+QAP);

(* This is an initiator sequence. The different forms arise from whether the initiator transmits a frame that
requires a BlockAck frame, and whether it delivers an RDG. When an RDG is delivered, the response is
distinguished according to whether it demands a BlockAck frame response from the initiator. *)
initiator-sequence =    (* No BlockAck frame expected, no RDG *)
                        burst |

                        (* block ack request delivered, BlockAck frame expected. No RD *)
                        (burst-bar (BlockAck[+HTC] |Ack) [+HTC] | NDP-BlockAck | NDP-Ack) |

                        (* No block ack request delivered, RDG *)
                        (burst-rd       (
                                        burst |
                                        burst-bar initiator-sequence-ba
                                        )
                        ) |

                        (burst-rd-bar (BlockAck[+HTC] |Ack) [+HTC] | NDP-BlockAck | NDP-Ack) |
```



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```
                    (burst-rd-bar       (
                                        burst-ba |
                                        burst-ba-bar initiator-sequence-ba
                                        )
                    ) |
                    ht-ack-sequence |(#3263)
                    link-adaptation-exchange ;

(* This is the same as the initiator-sequence, except the initiator is constrained to generate a BlockAck frame
response because a previous RD response contained a block ack request *)
initiator-sequence-ba =  burst-ba |
                    (burst-ba-bar (BlockAck[+HTC] |Ack) [+HTC] | NDP-BlockAck | NDP-Ack) |
                    (burst-ba-rd        (
                                        burst |
                                        burst-bar initiator-sequence-ba
                                        )
                    ) |
                    (burst-ba-rd-bar (BlockAck[+HTC] |Ack) [+HTC] | NDP-BlockAck | NDP-
                    Ack) |
                    (burst-ba-rd-bar (
                                        burst-ba |
                                        burst-ba-bar initiator-sequence-ba
                                        )
                    );

(* These are sequences that occur within an ht-txop-sequence that have an ack response *)
(#565)ht-ack-sequence =  Data[+HTC]+individual[+null][+QoS+normal-ack][+mu-user-respond other-
                    users] Ack[+HTC] | NDP-Ack;

(* The per-user parts of a VHT MU PPDU (11ax)and HE MU PPDU that do not require a response *)
other-users =       {ppdu-not-requiring-response-per-user +mu-user-not-respond} +mu-ppdu-end;

(* A burst is a sequence of one or more packets, none of them requiring a response *)
burst =             1{ppdu-not-requiring-response};

(* A burst containing a block ack request *)
burst-bar =         {ppdu-not-requiring-response} ppdu-bar;

(* A burst containing a BlockAck frame *)
burst-ba =          ppdu-ba {ppdu-not-requiring-response};

(* A burst containing a BlockAck frame and block ack request, either in the same packet, or in separate
packets. *)
burst-ba-bar =      (ppdu-ba {ppdu-not-requiring-response} ppdu-bar) |
                    ppdu-ba-bar;

(* A burst delivering an RDG *)
burst-rd =          {ppdu-not-requiring-response} ppdu-rd;

(* A burst containing a block ack request and delivering an RDG *)
burst-rd-bar = burst ppdu-rd-bar;

(* A burst containing a BlockAck frame and delivering an RDG *)
burst-ba-rd =       (ppdu-ba {ppdu-not-requiring-response} ppdu-rd) |
```

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ppdu-ba-rd;

(* A burst containing a block ack request and BlockAck frame and delivering an RDG *)
burst-ba-rd-bar = (ppdu-ba {ppdu-not-requiring-response} ppdu-rd-bar) |
ppdu-ba-rd-bar;

(* The per-user part of a PPDU not requiring a response is either a single frame not requiring response, or an A-MPDU of such frames.*)
ppdu-not-requiring-response-per-user =
frame-not-requiring-response-non-ampdu | (* Includes S-MPDU *)
1{frame-not-requiring-response-ampdu+*a-mpdu*}+*a-mpdu-end*;

(* A PPDU not requiring a response is either a single frame not requiring response, or an A-MPDU of such frames.*)
ppdu-not-requiring-response =
ppdu-not-requiring-response-per-user [+*mu-user-not-respond* other-users];

(* A frame-not-requiring-response-non-ampdu is a frame that does not require a response and that may be sent outside A-MPDU. It includes frames that do not require a response and that are not allowed within an A-MPDU. *)
frame-not-requiring-response-non-ampdu =
**Data**[+*HTC*]+*QoS*+*no-ack* |
frame-not-requiring-response-ampdu;

(* A frame-not-requiring-response-ampdu is a frame that does not require a response and can be sent within an A-MPDU. (#3262)It is a Data frame that does not require an immediate ack or an Action No Ack frame. A frame-not-requiring-response may be included with any of the following sequences in any position, except the initial position when this contains a BlockAck frame or (#4251)EDMG Multi-TID BlockAck frame: ppdu-bar, ppdu-ba-bar, ppdu-ba, ppdu-rd, ppdu-rd-bar, ppdu-ba-rd-bar(#3263)*)
frame-not-requiring-response-ampdu =
**Data**[+*HTC*]+*QoS*+*block-ack* |
ma-no-ack-htc;

(* A PPDU containing a block ack request is either a non-A-MPDU BlockAckReq frame, or an A-MPDU containing Data carrying implicit block ack request*).
ppdu-bar= ( **(BlockAckReq**[+*HTC*] | **NDP-BlockAck** |
(1{**Data**[+*HTC*]+*QoS*+*implicit-bar*+*a-mpdu*} + *a-mpdu-end*);
) [+*mu-user-respond* other-users];

(* A PPDU containing both BlockAck frame and block ack request is an A-MPDU that contains a BlockAck frame, plus either a BlockAckReq frame, or one or more Data frames carrying implicit block ack request. *)
ppdu-ba-bar= ( **BlockAck**[+*HTC*]+*a-mpdu*
(
**BlockAckReq**[+*HTC*]+*a-mpdu* |
1{**Data**[+*HTC*]+*QoS*+*implicit-bar*+*a-mpdu*}
) + *a-mpdu-end*
) [+*mu-user-respond* other-users];

(*A PPDU containing BlockAck frame is either a non-A-MPDU BlockAck frame, or an A-MPDU containing a BlockAck frame, and also containing data that does not carry implicit block ack request. *)
ppdu-ba= ( **BlockAck**[+*HTC*] |
(
**BlockAck**[+*HTC*]+*a-mpdu*


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1 {**Data**[+*HTC*]+*QoS*+(*no-ack*|*block-ack*)+*a-mpdu*}
) + *a-mpdu-end;*
) [+*mu-user-respond* other-users];

(* A PPDU delivering an RDG, but not delivering a block ack request is either a Data frame, not requiring immediate acknowledgment, or a BlockAck frame or BlockAckReq frame, not requiring immediate acknowledgment *).
ppdu-rd= ( **Data**+*HTC*[+*null*]+*QoS*+(*no-ack*|*block-ack*)+*RD* |
**(BlockAck**|**BlockAckReq)**+*HTC*+*delayed-no-ack*+*RD* |
(
1{**Data**+*HTC*+*QoS*+*RD*+*a-mpdu*}
) + *a-mpdu-end*;
) [+*mu-user-respond* other-users];

(* A PPDU containing a block ack request and delivering an RDG is either a(#1426) non-A-MPDU BlockAckReq frame, or an A-MPDU containing at least one Data frame with RD and implicit-bar. *)
ppdu-rd-bar= ( **BlockAckReq**+*HTC*+*RD* |
(
1{**Data**+*HTC*+*QoS*+*implicit-bar*+*RD*+*a-mpdu*}
) + *a-mpdu-end*;
) [+*mu-user-respond* other-users];

(* A PPDU containing a BlockAck frame and granting RD is either an unaggregated BlockAck frame or an A-MPDU that contains a BlockAck frame and at least one Data frame containing RD, but not implicit block ack request. *)
ppdu-ba-rd= ( **BlockAck**+*HTC*+*RD* |
(
**BlockAck**+*a-mpdu* (
1{**Data**+*HTC*+*QoS*+(*no-ack*|*block-ack*)+*RD*+*a-mpdu*}
)
) + *a-mpdu-end;*
) [+*mu-user-respond* other-users];

(* A PPDU containing a BlockAck frame, block ack request and granting RD is an A-MPDU that contains a BlockAck frame and either an explicit BlockAckReq frame (and no Data frames) or Data frames carrying the implicit block ack request. The RD attribute is present in all frames carrying an HT Control field, and at least one of these frames is present. This constraint is not expressed in the syntax below. *)
ppdu-ba-rd-bar= (
(
**BlockAck**[+*HTC*+*RD*]+*a-mpdu*
**BlockAckReq**[+*HTC*+*RD*]+*a-mpdu*
) + *a-mpdu-end* |
(
**BlockAck**[+*HTC*+*RD*]+*a-mpdu*
1{ **Data**[+*HTC*+*RD*]+*QoS*+*implicit-bar*+*a-mpdu*}
) + *a-mpdu-end*;
) [+*mu-user-respond* other-users];
(#3263)
(* A link adaptation exchange is a frame exchange sequence in which over-the-WM signaling is used to control or return the results of link measurements so that the initiator device can choose effective values for its TXVECTOR parameters. *)
link-adaptation-exchange =
mcs-adaptation |
implict-txbf |

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explicit-txbf |
vht-bf;

(* An mcs-adaptation exchange includes an MCS measurement request and subsequent MFB. The MRQ and MFB may be present in any +HTC frame. The exchange can occur either as a fast exchange, in which the feedback is supplied in a response frame, an exchange in which the response is supplied along with some other Data frame within the same TXOP, or an exchange in which the response is supplied in a subsequent TXOP won by the MCS responder. Only the fast response is shown in the syntax that follows. The sequences shown below are representative examples only and are not exhaustive.*)
mcs-adaptation =
(* RTS/CTS *)
(**RTS**+*HTC*+*mrq* **CTS**+*HTC*+*mfb*) |

(* nonaggregated Data/Ack *)
(**Data**+*HTC*+*QoS*+*mrq*+*normal-ack* **Ack**+*HTC*+*mfb*) |

(* nonaggregated BlockAck *)
(**BlockAckReq**+*HTC*+*mrq* (**BlockAck**+*HTC*+*mfb* | **Ack**+*HTC*+*mfb*)) |

(* aggregated data with implicit block ack request and MRQ *)
(
(
1{**Data**[+*HTC*]+*mrq* [+*rdg*] +*QoS*+*implicit-bar*+*a-mpdu*}
) + *a-mpdu-end*
(
(* Unaggregated BlockAck frame response *)
**BlockAck**+*HTC* +*mfb* |

(* Aggregated BlockAck frame response *)
(
**BlockAck**[+*HTC*+*mfb*] +*a-mpdu*
1{**Data**[+*HTC*+*mfb*]+*QoS*+(*no-ack*|*block-ack*)+*a-mpdu*}
) + *a-mpdu-end*
)
);

(* An implicit-txbf (implicit transmit beamforming) starts with the transmission of a request to sound the channel. The initiator measures the channel based on the sounding PPDU and updates its beamforming feedback matrices based on its observations of the sounding PPDU. No channel measurements are sent over the air.*)
implict-txbf =
(**RTS**+*HTC*+*trq* **CTS**+*sounding*) |
(**Data**+*HTC*+*trq*+*QoS*+*normal-ack*
(**Ack**+*sounding* | **Ack**+*HTC*+*ndp-announce* **NDP**)
) |
(**BlockAckReq**+*HTC*+*trq*
(**BlockAck**+*sounding* |
**BlockAck**+*HTC*+*ndp-announce* **NDP**
)
)(#565)
(* The trq/sounding protocol also operates within aggregates. In this case the TRQ is carried in all +HTC frames (of which there has to be at least one) within the TRQ initiator's transmission. The response PPDU either is a sounding PPDU, or carries at least one +HTC frame with an ndp-announce, in which case the


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following PPDU is an NDP sounding PPDU. The following syntax is an simplified representation of this sequence. *)
(**[BlockAck**+*HTC*+*trq*+*a-mpdu***]** **{Data**+*HTC*+*trq*+*QoS*+*a-mpdu*}+*a-mpdu-end*)
(
(**[BlockAck**+*HTC*+*a-mpdu***]**
**{Data**+*HTC*+*QoS*+*a-mpdu*}+*a-mpdu-end*+*sounding*)
) |
(
(**[BlockAck**+*HTC*+*ndp-announce*+*a-mpdu***]**
**{Data**+*HTC*+*ndp-announce*+*QoS*+*a-mpdu*}+*a-mpdu-end*)
) **NDP** |
(**BlockAck**+*HTC*+*sounding*) |
(**BlockAck**+*HTC*+*ndp-announce NDP*);

(* During operation of explicit transmit beamforming (explicit-txbf), there are three encodings of feedback information. These are not distinguished here and are all identified by the *csi* attribute. The feedback position may be immediate, aggregate, or delayed. Immediate feedback follows a SIFS after the sounding PPDU (identified by the *sounding* attribute) or the NDP. Aggregate feedback occurs during an aggregate within the same TXOP and may accompany Data frames in the same PPDU. Delayed feedback occurs during a subsequent TXOP during which the CSI responder is TXOP initiator. Only immediate feedback is described in the syntax below. The frame indicating any *csi-request* is carried in a sounding PPDU or followed by an NDP. The CSI response is carried in an Action No Ack frame, which may be aggregated with a response that is a BlockAck or Ack frame.
There are also two sets of sequences "staggered" and "NDP" that use either staggered sounding, or NDP sounding respectively.*)
explicit-txbf = explicit-txbf-staggered | explicit-txbf-NDP;

(* Staggered sounding. In this case, the sounding request is present in a frame that also generates an immediate response. The response is aggregated with the feedback in an A-MPDU. *)
explicit-txbf-staggered =
(
**Data**+*HTC*+*csi-request*+*QoS*+*normal-ack*+*sounding*
**(Ack**+*a-mpdu*
**Management**+*action-no-ack* +*csi*+*a-mpdu-end*)
) |
(
**BlockAckReq**+*HTC*+*csi-request*+*sounding*
**(BlockAck**+*a-mpdu*
**Management**+*action-no-ack* +*csi*+*a-mpdu-end*)
);(#565)

(* NDP sounding. In this case, the HT NDP announcement is present in a frame that also generates an immediate response. The beamformer transmits an NDP once the immediate response is received, and the beamformee transmits immediate feedback once it receives the NDP. *)
explicit-txbf-NDP =
(
**RTS**+*HTC*+*csi-request*+*ndp-announce*
**CTS**
**NDP**
**Management**+*action-no-ack* +*csi*
) |
(
**Data**+*HTC*+*csi-request*+*QoS*+*normal-ack*+*ndp-announce*

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**Ack**
**NDP**
**Management**+*action-no-ack* +*csi*
) |
(
**BlockAckReq**+*HTC*+*csi-request*+*ndp-announce*
**BlockAck**
**NDP**
**Management**+*action-no-ack* +*csi*
);(#565)

(* The VHT beamforming sequence starts with a VHT NDP Announcement frame, followed by a VHT NDP. One of the STAs in the sequence responds immediately with explicit feedback. The VHT AP might transmit Beamforming Report Poll to poll the other STAs to obtain their feedback before generating an MU transmission. The S1G AP might transmit Beamforming Report Poll or NDP Beamforming Report Poll to poll the other STAs to obtain their feedback before generating an MU transmission. The names of the frames include spaces, so they are delimited using parentheses. *)
vht-bf =
(**VHT NDP Announcement**) (**VHT NDP**) vht-feedback
{(**Beamforming Report Poll** | **NDP-Beamforming-Report-Poll**) vht-feedback};

(* VHT feedback is provided using VHT Compressed Beamforming frames. Multiple frames may be needed to provide feedback. *)
vht-feedback =
(**VHT Compressed Beamforming frame**) | (* S-MPDU or non-VHT PPDU *)
1{(**VHT Compressed Beamforming frame**) +*a-mpdu*} +*a-mpdu-end*;

(* An s1g-sequence represents additional sequences that may be generated by an S1G STA using EDCA channel access.*)
s1g-sequence =
([**CTS** | **NDP-CTS**] **1**{(**Data** +*group* +*QoS* | **Management** +*broadcast*) +*pifs*} |
([**CTS** | **NDP-CTS** | **RTS** (**CTS** | **NDP-CTS**) | **PS-Poll** | **NDP-PS-Poll**] {frag-frame (**Ack** | **NDP-Ack**)} last-frame (**Ack** | **NDP-Ack**)) |
(**PS-Poll Ack**) | (**NDP-PS-Poll NDP-PS-Poll-Ack**) |
([**CTS** | **NDP-CTS**] **1**{s1g-txop-sequence});

(* A TXOP may be filled with s1g-txop-sequences, which are initiated by the S1G TXOP holder. *)
s1g-txop-sequence =
(((**RTS** (**CTS** | **NDP-CTS**)) | **CTS**+*self* | **NDP-CTS** +*self*) **Data** +*individual* +*QoS* +(*block-ack* | *no-ack*)) |
[**RTS** (**CTS** | **NDP-CTS**)] (txop-part-requiring-ack txop-part-providing-ack )|
[**RTS** (**CTS** | **NDP-CTS**)] (**Management** | (**Data** +*S1GAP*)) +*individual* (**Ack** | **NDP-ACK**) |
[**RTS** (**CTS** | **NDP-CTS**)] (**BlockAckReq** (**BlockAck** | **NDP-BlockAck**)) |
s1g-nav-protected-sequence |
**1**{initiator-sequence};

(* an s1g-nav-protected sequence consists of setting the NAV, performing one or more initiator-sequences and then resetting the NAV if time permits *)
s1g-nav-protected-sequence = s1g-nav-set **1**{initiator-sequence} [s1g-resync-sequence] ;

(* These are the series of frames that establish NAV protection for an S1G sequence *)
s1g-nav-set = (**RTS**[+*HTC*] (**CTS**[+*HTC*]) | **NDP-CTS**) |


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**CTS**+*self* | **NDP-CTS**+*self* |
(**Data**[+*HTC*]+*individual*[+*null*][+*QoS*+*normal-ack*] (**Ack** | **NDP-Ack**)) |
**Data**[+*HTC]*+*individual*+*QoS*[+(*no-ack*|*block-ack*)] |
**Data**+*group*[+*null*]+*QoS* |
(**1**{ **Data**[+*HTC*]+*individual*+*QoS*+*implicit-bar*+*a-mpdu*}+*a-mpdu-end* (**BlockAck**[+*HTC*] | **NDP-BlockAck**)) |
(**BlockAckReq**[+*HTC*] (**BlockAck**[+*HTC*] | **Ack**[+*HTC*]) | **NDP-BlockAck** | **NDP-Ack**)) |
**1**{s1g-rts-cts};

(* The s1g-rts-cts term applies to RTS transmitted by an S1G STA(#371). When the RTS is transmitted using an S1G non-duplicate PPDU or S1G 2 MHz duplicate PPDU, the transmission of the RTS is delayed so that at least a PIFS has elapsed since the previous frame exchange sequence (see 10.23.2.7 (Sharing an EDCA TXOP)) and the RTS is transmitted with a Dynamic Indication field set to 1 (see 10.3.2.6 (RTS/CTS with fragmentation)). *)

s1g-rts-cts = **RTS**+*pifs* [+*HTC*] (**CTS**[+*HTC*] | **NDP-CTS**);

s1g-resync-sequence = **CF-End** | (**CF-End**+*non-S1GAP* **CF-End**+ *S1GAP*) | **NDP-CF-End** |
(**NDP-CF-End**+*non-S1GAP* **NDP-CF-End**+ *S1GAP*) | ;

(11ay)(* A dmg-sequence represents additional sequences that may be generated by a DMG STA during a BTI, A-BFT, ATI, CBAP and SP.*)

dmg-sequence =
bti-sequence |
abft-bf-sequence |
ati-sequence |
(**[DMG CTS+self[+CT]]** 1{(**Data** +group +QoS | **Management** +broadcast)} |
(**[DMG CTS+self[+CT]** | **RTS[+CT] DMG CTS[+CT]** | **Grant** [**Grant Ack**] | **Poll SPR Grant**] {frag-frame **Ack**} last-frame **Ack**) |
dmg-bf-sequence |
(**RTS[+CT] DMG DTS[+CT]**) |
(**[DMG CTS+self[+CT]** | **RTS[+CT] DMG CTS[+CT]** | **Grant** [**Grant Ack**] | **Poll SPR Grant**] 1{dmg-txop-sequence}) |
tdd-sequence;

bti-sequence =
(1{**DMG Beacon**});

ati-sequence =
(**Management** +individual **Management** +individual) |
(**Management** +individual **Ack**);

abft-sequence =
(1{**SSW**} **SSW-Feedback**) |
([1{**Short SSW**} **SSW-Feedback**]);

dmg-bf-sequence =
(1{**SSW**} 1{**SSW**} **SSW-Feedback SSW-Ack**) |
([1{**Short SSW**} 1{**Short SSW**} **SSW-Feedback SSW-Ack**]) |
([**BRP BRP**] 1{**BRP[+TRN] BRP[+TRN]**}) |

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(**[BRP BRP 1{BRP[+TRN]} BRP BRP 1{BRP[+TRN]} BRP 1{BRP[+TRN]} BRP]**);

(* A TXOP may be filled with dmg-txop-sequences, which are initiated by a TXOP holder. *)
dmg-txop-sequence =
dmg-bf-sequence |
(((**RTS[+CT] DMG CTS[+CT]**) | **DMG CTS+self[+CT]**) **Data** +individual +QoS +(block-ack | no-ack)) |
**[RTS[+CT] DMG CTS[+CT]]** (txop-part-requiring-ack txop-part-providing-ack) |
**[RTS[+CT] DMG CTS[+CT]]** (**Management** | (**Data** +QAP)) +individual **Ack** |
**[RTS[+CT] DMG CTS[+CT]]** (**BlockAckReq BlockAck**) |
dmg-nav-protected-sequence |
1{initiator-sequence};

(* a dmg-nav-protected sequence consists of setting the NAV, performing one or more initiator-sequences and then resetting the NAV if time permits *)
dmg-nav-protected-sequence =
dmg-nav-set 1{initiator-sequence} [**CF-End**];

(* These are the series of frames that establish NAV protection for a DMG sequence *)
dmg-nav-set =
(**RTS[+CT] DMG CTS[+CT]**) |
**DMG CTS+self[+CT]** |
(**Grant [Grant Ack]**) |
(**Data** +individual [+null] [+QoS +normal-ack] **Ack**) |
**Data** +individual +QoS [+(no-ack|block-ack)] |
**Data** +group [+null] +QoS |
(1{ **Data** +individual +QoS +implicit-bar +a-mpdu} +a-mpdu-end **BlockAck**) |
(**BlockAckReq BlockAck**) |
1{**RTS[+CT] DMG CTS[+CT]**};

(* These are the frame exchanges that can take place within a TDD slot in a TDD SP. *)
tdd-sequence =
dmg-tdd-beamforming-sequence |
dmg-tdd-basic-slot-sequence |
dmg-tdd-data-slot-sequence

(* Series of frames transmitted during BF TDD slots. *)
dmg-tdd-beamforming-sequence =
({**TDD Beamforming** +*ssw*}{**TDD Beamforming** +*ssw-ack*}) |
{**TDD Beamforming** +*ssw-feedback*};

(* Series of frames transmitted during Basic TDD slots; dmg-tdd-ack and dmg-tdd-block-ack sequences can appear only once during the slot. *)
dmg-tdd-basic-slot-sequence =
{dmg-tdd-ack}{dmg-tdd-block-ack}{dmg-tdd-mgmt}{dmg-tdd-extension}{dmg-tdd-mgmt-data}{dmg-tdd-data}

(* Series of frames transmitted during Data TDD slots; dmg-tdd-ack and dmg-tdd-block-ack sequences represent acknowledgment of Management and Data frames received in a prior TDD slot, and can appear only once during the slot. *)
dmg-tdd-data-slot-sequence =
{dmg-tdd-data}{dmg-tdd-ack}{dmg-tdd-block-ack}{dmg-tdd-extension}{dmg-tdd-mgmt}


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dmg-tdd-data = {[**DMG CTS** +*self*[**+CT**]] 1{**Data**} [**DMG CTS** +*self*[**+CT**]] **[BlockAckReq]**};

dmg-tdd-ack = **Ack** | (1{**Ack** +*a-mpdu*} 1{**Management** +*action-no-ack*+*a-mpdu*}+*a-mpdu-end*);

dmg-tdd-block-ack = [**BlockAck**] | (1{**BlockAck** +*a-mpdu*} 1{**Management** +*action-no-ack*+*a-mpdu*}+*a-mpdu-end*);

dmg-tdd-extension = 1{**Extension**};

dmg-tdd-mgmt = {([**DMG CTS** +*self*[**+CT**]] 1{**Management**} [**DMG CTS** +*self*[**+CT**]])};
dmg-tdd-mgmt-data = {([**DMG CTS** +*self* [**+CT**]] 1{**Management** +*a-mpdu*}1{**Data** +*a-mpdu*} [**DMG CTS** +*self*[**+CT**]])};

## G.5 HE sequences(11ax)

he-txop-sequence = he-nav-protected-sequence |
1{initiator-sequence};

(* an he-nav-protected-sequence consists of setting the NAV, performing one or more initiator-sequences and then resetting the NAV if time permits *)
he-nav-protected-sequence = he-nav-set 1 {initiator-sequence} [resync-sequence];

(* This is the sequence of frames that establish protection use MU-RTS *)
he-nav-set = (**MU-RTS Trigger** 1{**CTS**}) |
(**Data**[+HTC]+*individual*[+*null*][+*QoS*+*normal-ack*] **Ack**) |
**Data**[+HTC]+*individual*[+*QoS*+*block-ack*] |
**Data**+*group*[+*null*][+*QoS*] |
(1 {**Data**[+HTC]+*individual*+*QoS*+*implicit-bar*+*a-mpdu*}+*a-mpdu-end*} **BlockAck**) |
(**BlockAckReq** (**BlockAck**|**Ack**)) |
(**BlockAck**|**Ack**);

he-dl-mu-sequence = (**BlockAck**+*delayed*[+*mu-users-respond*] **Ack** |
(**BlockAckReq**+delayed[+*mu-users-respond*] **Ack**) |
(**Data**[+HTC]+*individual*[+*null*][+*QoS*+*normal-ack*][+*mu-user-respond*] **Ack** |
**Ack**);

(* Trigger frame is sent by the AP to initiate non-AP UL transmission. A PPDU containing a Trigger frame is either a non-A-MPDU Trigger frame or an A-MPDU carrying a Trigger frame *)

he-ul-mu-sequence = (**Basic Trigger**) | (**Basic Trigger**+*a-mpdu*+*mu-user-respond*+*a-mpdu-end*)
1{**Data**[+*HTC*]+*QoS*+(*no-ack* | *block-ack*)+*a-mpdu*}
+ *a-mpdu-end* | **MU-BAR Trigger BlockAck**;

he-cascading-sequence = he-dl-mu-sequence + he-ul-mu-sequence

(* HE beamforming sequence *)

he-non-trigger-based-sounding =
(**HE NDP Announcement**) (**HE sounding NDP**)
**HE Compressed Beamforming/CQI**;

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he-trigger-based-sounding = (**HE NDP Announcement**) (**HE sounding NDP**) he-feedback
{**BFRP Trigger** he-feedback};

he-feedback = (**HE Compressed Beamforming/CQI**) | (* S-MPDU or non-HE PPDU *)
1{(**HE Compressed Beamforming/CQI**)+a-mpdu}+a-mpdu-end;

he-nfrp-report = (**NFRP Trigger**) n (**HE TB feedback NDP**)

(#7075)(* HE Ranging and Sensing Sequences *)
(#7075)(* HE Non-TB Ranging with or without Secure LTF *)
(#7075)he-ntb-ranging-sequence = (**HE Ranging NDP Announcement** +*individual*)
**HE Ranging NDP** (* I2R Ranging NDP *)
**HE Ranging NDP** (* R2I Ranging NDP *)
(**LMR** +*R2I* +*individual* +*action-no-ack*)(* R2I LMR *)
[(**LMR** +*I2R* +*individual* +*action-no-ack*)]; (* optional I2R LMR*)

(#7075)(* HE TB Ranging with or without Secure LTFs *)
(#7075)he-tb-ranging-sequence = (**Ranging Trigger** +*ranging-poll*) (* TF of polling phase *)
(**CTS** +*mu-users-respond*) (* allocation requests from ISTAs *)
1{ (**Ranging Trigger** +*ranging-sound*|*ranging-secure-sound*)
(**HE TB Ranging NDP**)} (* one or more I2R NDP *)
**Ranging NDP Announcement**
**HE Ranging NDP** (* single R2I NDP *)
(**LMR** +*R2I* +*mu-users-respond*) (* R2I LMR *)
[(**Basic Trigger)**
(**LMR** +*I2R* +*individual* +*action-no-ack*)](* optional MU I2R LMR *)

(#7075)(* HE Passive TB Ranging *)
(#7075)he-passive-tb-ranging-sequence = (**Ranging Trigger** +*ranging-poll*) (* TF of polling phase *)
(**CTS** +*mu-users-respond*) (* response from ISTAs *)
1{(**Ranging Trigger** +*ranging-sound*)
(**HE Ranging NDP**)} (* one or more single ISTA SU UL sounding *)
**Ranging NDP Announcement**
**HE Ranging NDP** (* single DL NDP *)
(**LMR** +*R2I* +*mu-users-respond*) (* R2I LMR *)
**Basic Trigger**
(**LMR** +*I2R* +*individual* +*action-no-ack*) (* MU I2R LMR *)
(**Primary RSTA Broadcast Passive TB Ranging Measurement Report** +*broadcast*)
(**Secondary Broadcast Passive TB Ranging Measurement Report** +*broadcast*)

## G.6 NGV sequences(11bd)(#7076)

(* NGV Ranging Sequences *)
Frames are separated by a SIFS.

(* NGV Non-TB Ranging *)
ngv-ntb-ranging-sequence = (**Ranging NDP Announcement** +*individual*)
**NGV Ranging NDP** (* I2R Ranging NDP *)
**NGV Ranging NDP** (* R2I Ranging NDP *)


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(**LMR** +*R2I* +*individual* +*action-no-ack*)(* R2I LMR *)
[(**LMR** +*I2R* +*individual* +*action-no-ack*)]; (* optional I2R LMR*)

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# Annex H

(normative)

# Usage of EtherType 89-0d(#2186)

(#3370)The MSDU with (#2186)EtherType 89-0d is specified in Figure H-1 (MSDU with EtherType 89-0d frame (#2186)(#3370)).

| | LLC | SNAP | Payload Type | Payload |
|---|---|---|---|---|
| Octets: | 3 | 5 | 1 | variable |

**Figure H-1—MSDU with EtherType 89-0d frame (#2186)(#3370)**

LLC is defined in ISO/IEC 8802-2:1998.

SNAP is defined in IEEE Std 802. The formatting of the SNAP header is according to IETF RFC 1042. The EtherType(#3370)(#2186) field is set to 89-0d.

The Payload Type field is set to one of the values in Table H-1 (Payload Type field values).

**Table H-1—Payload Type field values**

| Protocol name | Payload type | Subclause |
|---|---|---|
| Remote Request/Response | 1 | 13.10.3 (Remote Request/Response frame definition) |
| TDLS | 2 | 11.20.2 (TDLS payload) |
| FST | 3 | 11.31.6 (FST payload) |
| RLQP | 4 | 11.22.3.4 (Registered location query protocol (RLQP) procedures) |
| Reserved | 0, 5–255(#4256) | |

The Payload depends on the value inside the Payload Type field and is defined in the subclauses listed in Table H-1 (Payload Type field values).


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# Annex I

(informative)

# Examples of encoding a frame for OFDM PHYs, DMG PHYs, and EDMG PHYs(11ay)

## I.1 Example 1—BCC encoding

### I.1.1 Introduction

The purpose of this annex is to show an example of encoding a frame for the OFDM PHY, as described in Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification). This example covers all of the encoding details defined by this standard.

The encoding illustration goes through the following stages:

a) Generating the short training sequence section of the preamble;
b) Generating the long preamble sequence section of the preamble;
c) Generating the SIGNAL field bits;
d) Coding and interleaving the SIGNAL field bits;
e) Mapping the SIGNAL field into frequency domain;
f) Pilot insertion;
g) Transforming into time domain;
h) Delineating the data octet stream into a bit stream;
i) Prepending the SERVICE field and adding the pad bits, thus forming the DATA;
j) Scrambling and zeroing the tail bits;
k) Encoding the DATA with a convolutional encoder and puncturing;
l) Mapping into complex 16-QAM symbols;
m) Pilot insertion;
n) Transforming from frequency to time and adding a circular prefix;
o) Concatenating the OFDM symbols into a single, time-domain signal.

In the description of time domain waveforms, a complex baseband signal at 20 Msample/s shall be used.

This example uses the 36 Mb/s data rate and a message of 100 octets. These parameters are chosen in order to illustrate as many nontrivial aspects of the processing as possible:

— Use of several bits per symbol (4 in this case);
— Puncturing of the convolutional code;
— Interleaving, which uses the LSB–MSB swapping stage;
— Scrambling of the pilot subcarriers.

In each Annex I table that has (#4177)Binary value columns, the bit positions of the binary values are specified in the header of the table.

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### I.1.2 The message for the BCC example

The message being encoded consists of the first 72 characters (shown in **bold** and including line breaks) of the well-known "Ode to Joy" by F. Schiller:

**Joy, bright spark of divinity,**
**Daughter of Elysium,**
**Fire-insired we trea**d
Thy sanctuary.
Thy magic power (M118)reunites
All that custom has divided,
All men become brothers
Under the sway of thy gentle wings.

NOTE—The typo in "Fire-insired" is deliberate.

The message is converted to ASCII, using LF (0x0A) for line breaks; then it is prepended with an appropriate MAC header and an FCS is added. The resulting 100-octet PSDU is shown in Table I-1 (The message for the BCC example).

**Table I-1—The message for the BCC example**

| Octet ## | Val | Val | Val | Val | Val |
|---|---|---|---|---|---|
| 1...5 | 0x04 | 0x02 | 0x00 | 0x2E | 0x00 |
| 6...10 | 0x60 | 0x08 | 0xCD | 0x37 | 0xA6 |
| 11...15 | 0x00 | 0x20 | 0xD6 | 0x01 | 0x3C |
| 16...20 | 0xF1 | 0x00 | 0x60 | 0x08 | 0xAD |
| 21...25 | 0x3B | 0xAF | 0x00 | 0x00 | 0x4A |
| 26...30 | 0x6F | 0x79 | 0x2C | 0x20 | 0x62 |
| 31...35 | 0x72 | 0x69 | 0x67 | 0x68 | 0x74 |
| 36...40 | 0x20 | 0x73 | 0x70 | 0x61 | 0x72 |
| 41...45 | 0x6B | 0x20 | 0x6F | 0x66 | 0x20 |
| 46...50 | 0x64 | 0x69 | 0x76 | 0x69 | 0x6E |


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**Table I-1—The message for the BCC example *(continued)***

| Octet ## | Val | Val | Val | Val | Val |
|---|---|---|---|---|---|
| 51...55 | 0x69 | 0x74 | 0x79 | 0x2C | 0x0A |
| 56...60 | 0x44 | 0x61 | 0x75 | 0x67 | 0x68 |
| 61...65 | 0x74 | 0x65 | 0x72 | 0x20 | 0x6F |
| 66...70 | 0x66 | 0x20 | 0x45 | 0x6C | 0x79 |
| 71...75 | 0x73 | 0x69 | 0x75 | 0x6D | 0x2C |
| 76...80 | 0x0A | 0x46 | 0x69 | 0x72 | 0x65 |
| 81...85 | 0x2D | 0x69 | 0x6E | 0x73 | 0x69 |
| 86...90 | 0x72 | 0x65 | 0x64 | 0x20 | 0x77 |
| 91...95 | 0x65 | 0x20 | 0x74 | 0x72 | 0x65 |
| 96...100 | 0x61 | 0x67 | 0x33 | 0x21 | 0xB6 |

## I.1.3 Generation of the preamble

### I.1.3.1 Generation of the short sequences

The short sequences section of the preamble is described by its frequency domain representation, given in Table I-2 (Frequency domain representation of the short sequences).

**Table I-2—Frequency domain representation of the short sequences**

| ## | Re | Im | ## | Re | Im | ## | Re | Im | ## | Re | Im |
|---|---|---|---|---|---|---|---|---|---|---|---|
| –32 | 0.0 | 0.0 | –16 | 1.472 | 1.472 | 0 | 0.0 | 0.0 | 16 | 1.472 | 1.472 |
| –31 | 0.0 | 0.0 | –15 | 0.0 | 0.0 | 1 | 0.0 | 0.0 | 17 | 0.0 | 0.0 |
| –30 | 0.0 | 0.0 | –14 | 0.0 | 0.0 | 2 | 0.0 | 0.0 | 18 | 0.0 | 0.0 |
| –29 | 0.0 | 0.0 | –13 | 0.0 | 0.0 | 3 | 0.0 | 0.0 | 19 | 0.0 | 0.0 |
| –28 | 0.0 | 0.0 | –12 | –1.472 | –1.472 | 4 | –1.472 | –1.472 | 20 | 1.472 | 1.472 |
| –27 | 0.0 | 0.0 | –11 | 0.0 | 0.0 | 5 | 0.0 | 0.0 | 21 | 0.0 | 0.0 |
| –26 | 0.0 | 0.0 | –10 | 0.0 | 0.0 | 6 | 0.0 | 0.0 | 22 | 0.0 | 0.0 |
| –25 | 0.0 | 0.0 | –9 | 0.0 | 0.0 | 7 | 0.0 | 0.0 | 23 | 0.0 | 0.0 |
| –24 | 1.472 | 1.472 | –8 | –1.472 | –1.472 | 8 | –1.472 | –1.472 | 24 | 1.472 | 1.472 |
| –23 | 0.0 | 0.0 | –7 | 0.0 | 0.0 | 9 | 0.0 | 0.0 | 25 | 0.0 | 0.0 |
| –22 | 0.0 | 0.0 | –6 | 0.0 | 0.0 | 10 | 0.0 | 0.0 | 26 | 0.0 | 0.0 |
| –21 | 0.0 | 0.0 | –5 | 0.0 | 0.0 | 11 | 0.0 | 0.0 | 27 | 0.0 | 0.0 |
| –20 | –1.472 | –1.472 | –4 | 1.472 | 1.472 | 12 | 1.472 | 1.472 | 28 | 0.0 | 0.0 |
| –19 | 0.0 | 0.0 | –3 | 0.0 | 0.0 | 13 | 0.0 | 0.0 | 29 | 0.0 | 0.0 |

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**Table I-2—Frequency domain representation of the short sequences**

| ## | Re | Im | ## | Re | Im | ## | Re | Im | ## | Re | Im |
|---|---|---|---|---|---|---|---|---|---|---|---|
| –18 | 0.0 | 0.0 | –2 | 0.0 | 0.0 | 14 | 0.0 | 0.0 | 30 | 0.0 | 0.0 |
| –17 | 0.0 | 0.0 | –1 | 0.0 | 0.0 | 15 | 0.0 | 0.0 | 31 | 0.0 | 0.0 |

One period of the IFFT on the contents of Table I-2 (Frequency domain representation of the short sequences) is given in Table I-3 (One period of IFFT of the short sequences).

**Table I-3—One period of IFFT of the short sequences**

| ## | Re | Im | ## | Re | Im | ## | Re | Im | ## | Re | Im |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0.046 | 0.046 | 1 | –0.132 | 0.002 | 2 | –0.013 | –0.079 | 3 | 0.143 | –0.013 |
| 4 | 0.092 | 0.000 | 5 | 0.143 | –0.013 | 6 | –0.013 | –0.079 | 7 | –0.132 | 0.002 |
| 8 | 0.046 | 0.046 | 9 | 0.002 | –0.132 | 10 | –0.079 | –0.013 | 11 | –0.013 | 0.143 |
| 12 | 0.000 | 0.092 | 13 | –0.013 | 0.143 | 14 | –0.079 | –0.013 | 15 | 0.002 | –0.132 |
| 16 | 0.046 | 0.046 | 17 | –0.132 | 0.002 | 18 | –0.013 | –0.079 | 19 | 0.143 | –0.013 |
| 20 | 0.092 | 0.000 | 21 | 0.143 | –0.013 | 22 | –0.013 | –0.079 | 23 | –0.132 | 0.002 |
| 24 | 0.046 | 0.046 | 25 | 0.002 | –0.132 | 26 | –0.079 | –0.013 | 27 | –0.013 | 0.143 |
| 28 | 0.000 | 0.092 | 29 | –0.013 | 0.143 | 30 | –0.079 | –0.013 | 31 | 0.002 | –0.132 |
| 32 | 0.046 | 0.046 | 33 | –0.132 | 0.002 | 34 | –0.013 | –0.079 | 35 | 0.143 | –0.013 |
| 36 | 0.092 | 0.000 | 37 | 0.143 | –0.013 | 38 | –0.013 | –0.079 | 39 | –0.132 | 0.002 |
| 40 | 0.046 | 0.046 | 41 | 0.002 | –0.132 | 42 | –0.079 | –0.013 | 43 | –0.013 | 0.143 |
| 44 | 0.000 | 0.092 | 45 | –0.013 | 0.143 | 46 | –0.079 | –0.013 | 47 | 0.002 | –0.132 |
| 48 | 0.046 | 0.046 | 49 | –0.132 | 0.002 | 50 | –0.013 | –0.079 | 51 | 0.143 | –0.013 |
| 52 | 0.092 | 0.000 | 53 | 0.143 | –0.013 | 54 | –0.013 | –0.079 | 55 | –0.132 | 0.002 |
| 56 | 0.046 | 0.046 | 57 | 0.002 | –0.132 | 58 | –0.079 | –0.013 | 59 | –0.013 | 0.143 |
| 60 | 0.000 | 0.092 | 61 | –0.013 | 0.143 | 62 | –0.079 | –0.013 | 63 | 0.002 | –0.132 |

The single period of the short training sequence is extended periodically for 161 samples (about 8 μs), and then multiplied by the window function:

$$W(k) = \begin{bmatrix} 0.5 & k = 0 \\ 1 & 1 \le k \le 159 \\ 0.5 & k = 160 \end{bmatrix}$$

The last sample serves as an overlap with the following OFDM symbol. The 161 samples vector is shown in Table I-4 (Time domain representation of the short sequence). The time-windowing feature illustrated here is not part of the normative specifications.


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**Table I-4—Time domain representation of the short sequence**

| ## | Re | Im | ## | Re | Im | ## | Re | Im | ## | Re | Im |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0.023 | 0.023 | 1 | –0.132 | 0.002 | 2 | –0.013 | –0.079 | 3 | 0.143 | –0.013 |
| 4 | 0.092 | 0.000 | 5 | 0.143 | –0.013 | 6 | –0.013 | –0.079 | 7 | –0.132 | 0.002 |
| 8 | 0.046 | 0.046 | 9 | 0.002 | –0.132 | 10 | –0.079 | –0.013 | 11 | –0.013 | 0.143 |
| 12 | 0.000 | 0.092 | 13 | –0.013 | 0.143 | 14 | –0.079 | –0.013 | 15 | 0.002 | –0.132 |
| 16 | 0.046 | 0.046 | 17 | –0.132 | 0.002 | 18 | –0.013 | –0.079 | 19 | 0.143 | –0.013 |
| 20 | 0.092 | 0.000 | 21 | 0.143 | –0.013 | 22 | –0.013 | –0.079 | 23 | –0.132 | 0.002 |
| 24 | 0.046 | 0.046 | 25 | 0.002 | –0.132 | 26 | –0.079 | –0.013 | 27 | –0.013 | 0.143 |
| 28 | 0.000 | 0.092 | 29 | –0.013 | 0.143 | 30 | –0.079 | –0.013 | 31 | 0.002 | –0.132 |
| 32 | 0.046 | 0.046 | 33 | –0.132 | 0.002 | 34 | –0.013 | –0.079 | 35 | 0.143 | –0.013 |
| 36 | 0.092 | 0.000 | 37 | 0.143 | –0.013 | 38 | –0.013 | –0.079 | 39 | –0.132 | 0.002 |
| 40 | 0.046 | 0.046 | 41 | 0.002 | –0.132 | 42 | –0.079 | –0.013 | 43 | –0.013 | 0.143 |
| 44 | 0.000 | 0.092 | 45 | –0.013 | 0.143 | 46 | –0.079 | –0.013 | 47 | 0.002 | –0.132 |
| 48 | 0.046 | 0.046 | 49 | –0.132 | 0.002 | 50 | –0.013 | –0.079 | 51 | 0.143 | –0.013 |
| 52 | 0.092 | 0.000 | 53 | 0.143 | –0.013 | 54 | –0.013 | –0.079 | 55 | –0.132 | 0.002 |
| 56 | 0.046 | 0.046 | 57 | 0.002 | –0.132 | 58 | –0.079 | –0.013 | 59 | –0.013 | 0.143 |
| 60 | 0.000 | 0.092 | 61 | –0.013 | 0.143 | 62 | –0.079 | –0.013 | 63 | 0.002 | –0.132 |
| 64 | 0.046 | 0.046 | 65 | –0.132 | 0.002 | 66 | –0.013 | –0.079 | 67 | 0.143 | –0.013 |
| 68 | 0.092 | 0.000 | 69 | 0.143 | –0.013 | 70 | –0.013 | –0.079 | 71 | –0.132 | 0.002 |
| 72 | 0.046 | 0.046 | 73 | 0.002 | –0.132 | 74 | –0.079 | –0.013 | 75 | –0.013 | 0.143 |
| 76 | 0.000 | 0.092 | 77 | –0.013 | 0.143 | 78 | –0.079 | –0.013 | 79 | 0.002 | –0.132 |
| 80 | 0.046 | 0.046 | 81 | –0.132 | 0.002 | 82 | –0.013 | –0.079 | 83 | 0.143 | –0.013 |
| 84 | 0.092 | 0.000 | 85 | 0.143 | –0.013 | 86 | –0.013 | –0.079 | 87 | –0.132 | 0.002 |
| 88 | 0.046 | 0.046 | 89 | 0.002 | –0.132 | 90 | –0.079 | –0.013 | 91 | –0.013 | 0.143 |
| 92 | 0.000 | 0.092 | 93 | –0.013 | 0.143 | 94 | –0.079 | –0.013 | 95 | 0.002 | –0.132 |
| 96 | 0.046 | 0.046 | 97 | –0.132 | 0.002 | 98 | –0.013 | –0.079 | 99 | 0.143 | –0.013 |
| 100 | 0.092 | 0.000 | 101 | 0.143 | –0.013 | 102 | –0.013 | –0.079 | 103 | –0.132 | 0.002 |
| 104 | 0.046 | 0.046 | 105 | 0.002 | –0.132 | 106 | –0.079 | –0.013 | 107 | –0.013 | 0.143 |
| 108 | 0.000 | 0.092 | 109 | –0.013 | 0.143 | 110 | –0.079 | –0.013 | 111 | 0.002 | –0.132 |
| 112 | 0.046 | 0.046 | 113 | –0.132 | 0.002 | 114 | –0.013 | –0.079 | 115 | 0.143 | –0.013 |
| 116 | 0.092 | 0.000 | 117 | 0.143 | –0.013 | 118 | –0.013 | –0.079 | 119 | –0.132 | 0.002 |
| 120 | 0.046 | 0.046 | 121 | 0.002 | –0.132 | 122 | –0.079 | –0.013 | 123 | –0.013 | 0.143 |
| 124 | 0.000 | 0.092 | 125 | –0.013 | 0.143 | 126 | –0.079 | –0.013 | 127 | 0.002 | –0.132 |
| 128 | 0.046 | 0.046 | 129 | –0.132 | 0.002 | 130 | –0.013 | –0.079 | 131 | 0.143 | –0.013 |

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**Table I-4—Time domain representation of the short sequence *(continued)***

| ## | Re | Im | ## | Re | Im | ## | Re | Im | ## | Re | Im |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 132 | 0.092 | 0.000 | 133 | 0.143 | –0.013 | 134 | –0.013 | –0.079 | 135 | –0.132 | 0.002 |
| 136 | 0.046 | 0.046 | 137 | 0.002 | –0.132 | 138 | –0.079 | –0.013 | 139 | –0.013 | 0.143 |
| 140 | 0.000 | 0.092 | 141 | –0.013 | 0.143 | 142 | –0.079 | –0.013 | 143 | 0.002 | –0.132 |
| 144 | 0.046 | 0.046 | 145 | –0.132 | 0.002 | 146 | –0.013 | –0.079 | 147 | 0.143 | –0.013 |
| 148 | 0.092 | 0.000 | 149 | 0.143 | –0.013 | 150 | –0.013 | –0.079 | 151 | –0.132 | 0.002 |
| 152 | 0.046 | 0.046 | 153 | 0.002 | –0.132 | 154 | –0.079 | –0.013 | 155 | –0.013 | 0.143 |
| 156 | 0.000 | 0.092 | 157 | –0.013 | 0.143 | 158 | –0.079 | –0.013 | 159 | 0.002 | –0.132 |
| 160 | 0.023 | 0.023 | | | | | | | | | |

### I.1.3.2 Generation of the long sequences

The frequency domain representation of the long training sequence part of the preamble is given in Table I-5 (Frequency domain representation of the long sequences).

**Table I-5—Frequency domain representation of the long sequences**

| ## | Re | Im | ## | Re | Im | ## | Re | Im | ## | Re | Im |
|---|---|---|---|---|---|---|---|---|---|---|---|
| –32 | 0.000 | 0.000 | –16 | 1.000 | 0.000 | 0 | 0.000 | 0.000 | 16 | 1.000 | 0.000 |
| –31 | 0.000 | 0.000 | –15 | 1.000 | 0.000 | 1 | 1.000 | 0.000 | 17 | –1.000 | 0.000 |
| –30 | 0.000 | 0.000 | –14 | 1.000 | 0.000 | 2 | –1.000 | 0.000 | 18 | –1.000 | 0.000 |
| –29 | 0.000 | 0.000 | –13 | 1.000 | 0.000 | 3 | –1.000 | 0.000 | 19 | 1.000 | 0.000 |
| –28 | 0.000 | 0.000 | –12 | 1.000 | 0.000 | 4 | 1.000 | 0.000 | 20 | –1.000 | 0.000 |
| –27 | 0.000 | 0.000 | –11 | –1.000 | 0.000 | 5 | 1.000 | 0.000 | 21 | 1.000 | 0.000 |
| –26 | 1.000 | 0.000 | –10 | –1.000 | 0.000 | 6 | –1.000 | 0.000 | 22 | –1.000 | 0.000 |
| –25 | 1.000 | 0.000 | –9 | 1.000 | 0.000 | 7 | 1.000 | 0.000 | 23 | 1.000 | 0.000 |
| –24 | –1.000 | 0.000 | –8 | 1.000 | 0.000 | 8 | –1.000 | 0.000 | 24 | 1.000 | 0.000 |
| –23 | –1.000 | 0.000 | –7 | –1.000 | 0.000 | 9 | 1.000 | 0.000 | 25 | 1.000 | 0.000 |
| –22 | 1.000 | 0.000 | –6 | 1.000 | 0.000 | 10 | –1.000 | 0.000 | 26 | 1.000 | 0.000 |
| –21 | 1.000 | 0.000 | –5 | –1.000 | 0.000 | 11 | –1.000 | 0.000 | 27 | 0.000 | 0.000 |
| –20 | –1.000 | 0.000 | –4 | 1.000 | 0.000 | 12 | –1.000 | 0.000 | 28 | 0.000 | 0.000 |
| –19 | 1.000 | 0.000 | –3 | 1.000 | 0.000 | 13 | –1.000 | 0.000 | 29 | 0.000 | 0.000 |
| –18 | –1.000 | 0.000 | –2 | 1.000 | 0.000 | 14 | –1.000 | 0.000 | 30 | 0.000 | 0.000 |
| –17 | 1.000 | 0.000 | –1 | 1.000 | 0.000 | 15 | 1.000 | 0.000 | 31 | 0.000 | 0.000 |


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The time domain representation is derived by performing IFFT on the contents of Table I-5 (Frequency domain representation of the long sequences), cyclically extending the result to get the cyclic prefix, and then multiplying with the window function given in I.1.3.1 (Generation of the short sequences). The resulting 161 points vector is shown in Table I-6 (Time domain representation of the long sequence). The samples are appended to the short sequence section by overlapping and adding element 160 of Table I-4 (Time domain representation of the short sequence) to element 0 of Table I-6 (Time domain representation of the long sequence).

**Table I-6—Time domain representation of the long sequence**

| ## | Re | Im | ## | Re | Im | ## | Re | Im | ## | Re | Im |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | –0.078 | 0.000 | 1 | 0.012 | –0.098 | 2 | 0.092 | –0.106 | 3 | –0.092 | –0.115 |
| 4 | –0.003 | –0.054 | 5 | 0.075 | 0.074 | 6 | –0.127 | 0.021 | 7 | –0.122 | 0.017 |
| 8 | –0.035 | 0.151 | 9 | –0.056 | 0.022 | 10 | –0.060 | –0.081 | 11 | 0.070 | –0.014 |
| 12 | 0.082 | –0.092 | 13 | –0.131 | –0.065 | 14 | –0.057 | –0.039 | 15 | 0.037 | –0.098 |
| 16 | 0.062 | 0.062 | 17 | 0.119 | 0.004 | 18 | –0.022 | –0.161 | 19 | 0.059 | 0.015 |
| 20 | 0.024 | 0.059 | 21 | –0.137 | 0.047 | 22 | 0.001 | 0.115 | 23 | 0.053 | –0.004 |
| 24 | 0.098 | 0.026 | 25 | –0.038 | 0.106 | 26 | –0.115 | 0.055 | 27 | 0.060 | 0.088 |
| 28 | 0.021 | –0.028 | 29 | 0.097 | –0.083 | 30 | 0.040 | 0.111 | 31 | –0.005 | 0.120 |
| 32 | 0.156 | 0.000 | 33 | –0.005 | –0.120 | 34 | 0.040 | –0.111 | 35 | 0.097 | 0.083 |
| 36 | 0.021 | 0.028 | 37 | 0.060 | –0.088 | 38 | –0.115 | –0.055 | 39 | –0.038 | –0.106 |
| 40 | 0.098 | –0.026 | 41 | 0.053 | 0.004 | 42 | 0.001 | –0.115 | 43 | –0.137 | –0.047 |
| 44 | 0.024 | –0.059 | 45 | 0.059 | –0.015 | 46 | –0.022 | 0.161 | 47 | 0.119 | –0.004 |
| 48 | 0.062 | –0.062 | 49 | 0.037 | 0.098 | 50 | –0.057 | 0.039 | 51 | –0.131 | 0.065 |
| 52 | 0.082 | 0.092 | 53 | 0.070 | 0.014 | 54 | –0.060 | 0.081 | 55 | –0.056 | –0.022 |
| 56 | –0.035 | –0.151 | 57 | –0.122 | –0.017 | 58 | –0.127 | –0.021 | 59 | 0.075 | –0.074 |
| 60 | –0.003 | 0.054 | 61 | –0.092 | 0.115 | 62 | 0.092 | 0.106 | 63 | 0.012 | 0.098 |
| 64 | –0.156 | 0.000 | 65 | 0.012 | –0.098 | 66 | 0.092 | –0.106 | 67 | –0.092 | –0.115 |
| 68 | –0.003 | –0.054 | 69 | 0.075 | 0.074 | 70 | –0.127 | 0.021 | 71 | –0.122 | 0.017 |
| 72 | –0.035 | 0.151 | 73 | –0.056 | 0.022 | 74 | –0.060 | –0.081 | 75 | 0.070 | –0.014 |
| 76 | 0.082 | –0.092 | 77 | –0.131 | –0.065 | 78 | –0.057 | –0.039 | 79 | 0.037 | –0.098 |
| 80 | 0.062 | 0.062 | 81 | 0.119 | 0.004 | 82 | –0.022 | –0.161 | 83 | 0.059 | 0.015 |
| 84 | 0.024 | 0.059 | 85 | –0.137 | 0.047 | 86 | 0.001 | 0.115 | 87 | 0.053 | –0.004 |
| 88 | 0.098 | 0.026 | 89 | –0.038 | 0.106 | 90 | –0.115 | 0.055 | 91 | 0.060 | 0.088 |
| 92 | 0.021 | –0.028 | 93 | 0.097 | –0.083 | 94 | 0.040 | 0.111 | 95 | –0.005 | 0.120 |
| 96 | 0.156 | 0.000 | 97 | –0.005 | –0.120 | 98 | 0.040 | –0.111 | 99 | 0.097 | 0.083 |
| 100 | 0.021 | 0.028 | 101 | 0.060 | –0.088 | 102 | –0.115 | –0.055 | 103 | –0.038 | –0.106 |
| 104 | 0.098 | –0.026 | 105 | 0.053 | 0.004 | 106 | 0.001 | –0.115 | 107 | –0.137 | –0.047 |

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**Table I-6—Time domain representation of the long sequence *(continued)***

| ## | Re | Im | ## | Re | Im | ## | Re | Im | ## | Re | Im |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 108 | 0.024 | –0.059 | 109 | 0.059 | –0.015 | 110 | –0.022 | 0.161 | 111 | 0.119 | –0.004 |
| 112 | 0.062 | –0.062 | 113 | 0.037 | 0.098 | 114 | –0.057 | 0.039 | 115 | –0.131 | 0.065 |
| 116 | 0.082 | 0.092 | 117 | 0.070 | 0.014 | 118 | –0.060 | 0.081 | 119 | –0.056 | –0.022 |
| 120 | –0.035 | –0.151 | 121 | –0.122 | –0.017 | 122 | –0.127 | –0.021 | 123 | 0.075 | –0.074 |
| 124 | –0.003 | 0.054 | 125 | –0.092 | 0.115 | 126 | 0.092 | 0.106 | 127 | 0.012 | 0.098 |
| 128 | –0.156 | 0.000 | 129 | 0.012 | –0.098 | 130 | 0.092 | –0.106 | 131 | –0.092 | –0.115 |
| 132 | –0.003 | –0.054 | 133 | 0.075 | 0.074 | 134 | –0.127 | 0.021 | 135 | –0.122 | 0.017 |
| 136 | –0.035 | 0.151 | 137 | –0.056 | 0.022 | 138 | –0.060 | –0.081 | 139 | 0.070 | –0.014 |
| 140 | 0.082 | –0.092 | 141 | –0.131 | –0.065 | 142 | –0.057 | –0.039 | 143 | 0.037 | –0.098 |
| 144 | 0.062 | 0.062 | 145 | 0.119 | 0.004 | 146 | –0.022 | –0.161 | 147 | 0.059 | 0.015 |
| 148 | 0.024 | 0.059 | 149 | –0.137 | 0.047 | 150 | 0.001 | 0.115 | 151 | 0.053 | –0.004 |
| 152 | 0.098 | 0.026 | 153 | –0.038 | 0.106 | 154 | –0.115 | 0.055 | 155 | 0.060 | 0.088 |
| 156 | 0.021 | –0.028 | 157 | 0.097 | –0.083 | 158 | 0.040 | 0.111 | 159 | –0.005 | 0.120 |
| 160 | 0.078 | 0 | | | | | | | | | |

## I.1.4 Generation of the SIGNAL field

### I.1.4.1 SIGNAL field bit assignment

The SIGNAL field bit assignment follows 17.3.4 (SIGNAL field) and Figure 17-5 (SIGNAL field bit assignment). The transmitted bits are shown in Table I-7 (Bit assignment for SIGNAL field), where bit 0 is transmitted first.

**Table I-7—Bit assignment for SIGNAL field**

| ## | Bit | Meaning | | ## | Bit | Meaning |
|---|---|---|---|---|---|---|
| 0 | 1 | RATE: R1 | | 12 | 0 | — |
| 1 | 0 | RATE: R2 | | 13 | 0 | — |
| 2 | 1 | RATE: R3 | | 14 | 0 | — |
| 3 | 1 | RATE: R4 | | 15 | 0 | — |
| 4 | 0 | Reserved | | 16 | 0 | LENGTH (MSB) |
| 5 | 0 | LENGTH (LSB) | | 17 | 0 | Parity |
| 6 | 0 | — | | 18 | 0 | SIGNAL TAIL |
| 7 | 1 | — | | 19 | 0 | SIGNAL TAIL |
| 8 | 0 | — | | 20 | 0 | SIGNAL TAIL |


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**Table I-7—Bit assignment for SIGNAL field**

| | | | | | | |
|---|---|---|---|---|---|---|
| 9 | 0 | — | | 21 | 0 | SIGNAL TAIL |
| 10 | 1 | — | | 22 | 0 | SIGNAL TAIL |
| 11 | 1 | — | | 23 | 0 | SIGNAL TAIL |

### I.1.4.2 Coding the SIGNAL field bits

The bits are encoded by the rate 1/2 convolutional encoder to yield the 48 bits given in Table I-8 (SIGNAL field bits after encoding).

**Table I-8—SIGNAL field bits after encoding**

| ## | Bit | | ## | Bit | | ## | Bit | | ## | Bit | | ## | Bit | | ## | Bit |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 1 | | 8 | 1 | | 16 | 0 | | 24 | 0 | | 32 | 0 | | 40 | 0 |
| 1 | 1 | | 9 | 0 | | 17 | 0 | | 25 | 0 | | 33 | 1 | | 41 | 0 |
| 2 | 0 | | 10 | 1 | | 18 | 0 | | 26 | 1 | | 34 | 1 | | 42 | 0 |
| 3 | 1 | | 11 | 0 | | 19 | 0 | | 27 | 1 | | 35 | 1 | | 43 | 0 |
| 4 | 0 | | 12 | 0 | | 20 | 0 | | 28 | 1 | | 36 | 0 | | 44 | 0 |
| 5 | 0 | | 13 | 0 | | 21 | 0 | | 29 | 1 | | 37 | 0 | | 45 | 0 |
| 6 | 0 | | 14 | 0 | | 22 | 1 | | 30 | 1 | | 38 | 0 | | 46 | 0 |
| 7 | 1 | | 15 | 1 | | 23 | 0 | | 31 | 0 | | 39 | 0 | | 47 | 0 |

### I.1.4.3 Interleaving the SIGNAL field bits

The encoded bits are interleaved according to the interleaver of 17.3.5.7 (Data interleaving). A detailed breakdown of the interleaving operation is described in I.1.6.2 (Interleaving the DATA bits). The interleaved SIGNAL field bits are shown in Table I-9 (SIGNAL field bits after interleaving).

**Table I-9—SIGNAL field bits after interleaving**

| ## | Bit | | ## | Bit | | ## | Bit | | ## | Bit | | ## | Bit | | ## | Bit |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 1 | | 8 | 1 | | 16 | 0 | | 24 | 1 | | 32 | 0 | | 40 | 1 |
| 1 | 0 | | 9 | 1 | | 17 | 0 | | 25 | 0 | | 33 | 0 | | 41 | 0 |
| 2 | 0 | | 10 | 0 | | 18 | 0 | | 26 | 0 | | 34 | 1 | | 42 | 0 |
| 3 | 1 | | 11 | 1 | | 19 | 1 | | 27 | 0 | | 35 | 0 | | 43 | 1 |
| 4 | 0 | | 12 | 0 | | 20 | 0 | | 28 | 0 | | 36 | 0 | | 44 | 0 |
| 5 | 1 | | 13 | 0 | | 21 | 1 | | 29 | 0 | | 37 | 1 | | 45 | 1 |

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**Table I-9—SIGNAL field bits after interleaving**

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6 | 0 | | 14 | 0 | | 22 | 0 | | 30 | 1 | | 38 | 0 | | 46 | 0 |
| 7 | 0 | | 15 | 0 | | 23 | 0 | | 31 | 1 | | 39 | 0 | | 47 | 0 |

### I.1.4.4 SIGNAL field frequency domain

The encoded and interleaved bits are BPSK modulated to yield the frequency domain representation given in Table I-10 (Frequency domain representation of SIGNAL field). Locations –21, –7, 7, and 21 are skipped and are used for pilot insertion.

**Table I-10—Frequency domain representation of SIGNAL field**

| ## | Re | Im | | ## | Re | Im | | ## | Re | Im | | ## | Re | Im |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| –32 | 0.000 | 0.000 | | –16 | 1.000 | 0.000 | | 0 | 0.000 | 0.000 | | 16 | –1.000 | 0.000 |
| –31 | 0.000 | 0.000 | | –15 | –1.000 | 0.000 | | 1 | 1.000 | 0.000 | | 17 | –1.000 | 0.000 |
| –30 | 0.000 | 0.000 | | –14 | 1.000 | 0.000 | | 2 | –1.000 | 0.000 | | 18 | 1.000 | 0.000 |
| –29 | 0.000 | 0.000 | | –13 | –1.000 | 0.000 | | 3 | –1.000 | 0.000 | | 19 | –1.000 | 0.000 |
| –28 | 0.000 | 0.000 | | –12 | –1.000 | 0.000 | | 4 | –1.000 | 0.000 | | 20 | –1.000 | 0.000 |
| –27 | 0.000 | 0.000 | | –11 | –1.000 | 0.000 | | 5 | –1.000 | 0.000 | | 21 | X | X |
| –26 | 1.000 | 0.000 | | –10 | –1.000 | 0.000 | | 6 | –1.000 | 0.000 | | 22 | 1.000 | 0.000 |
| –25 | –1.000 | 0.000 | | –9 | –1.000 | 0.000 | | 7 | X | X | | 23 | –1.000 | 0.000 |
| –24 | –1.000 | 0.000 | | –8 | –1.000 | 0.000 | | 8 | 1.000 | 0.000 | | 24 | 1.000 | 0.000 |
| –23 | 1.000 | 0.000 | | –7 | X | X | | 9 | 1.000 | 0.000 | | 25 | –1.000 | 0.000 |
| –22 | –1.000 | 0.000 | | –6 | –1.000 | 0.000 | | 10 | –1.000 | 0.000 | | 26 | –1.000 | 0.000 |
| –21 | X | X | | –5 | 1.000 | 0.000 | | 11 | –1.000 | 0.000 | | 27 | 0.000 | 0.000 |
| –20 | 1.000 | 0.000 | | –4 | –1.000 | 0.000 | | 12 | 1.000 | 0.000 | | 28 | 0.000 | 0.000 |
| –19 | –1.000 | 0.000 | | –3 | 1.000 | 0.000 | | 13 | –1.000 | 0.000 | | 29 | 0.000 | 0.000 |
| –18 | –1.000 | 0.000 | | –2 | –1.000 | 0.000 | | 14 | –1.000 | 0.000 | | 30 | 0.000 | 0.000 |
| –17 | 1.000 | 0.000 | | –1 | –1.000 | 0.000 | | 15 | 1.000 | 0.000 | | 31 | 0.000 | 0.000 |

Four pilot subcarriers are added by taking the values {1.0,1.0,1.0,–1.0}, multiplying them by the first element of sequence $p_{0...126}$, given in Equation (17-22) (in 17.3.5.10 (OFDM modulation)), and


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inserting them into location {–21,–7,7,21}, respectively. The resulting frequency domain values are given in Table I-11 (Frequency domain representation of SIGNAL field with pilots inserted).

**Table I-11—Frequency domain representation of SIGNAL field with pilots inserted**

| ## | Re | Im | ## | Re | Im | ## | Re | Im | ## | Re | Im |
|---|---|---|---|---|---|---|---|---|---|---|---|
| –32 | 0.000 | 0.000 | –16 | 1.000 | 0.000 | 0 | 0.000 | 0.000 | 16 | –1.000 | 0.000 |
| –31 | 0.000 | 0.000 | –15 | –1.000 | 0.000 | 1 | 1.000 | 0.000 | 17 | –1.000 | 0.000 |
| –30 | 0.000 | 0.000 | –14 | 1.000 | 0.000 | 2 | –1.000 | 0.000 | 18 | 1.000 | 0.000 |
| –29 | 0.000 | 0.000 | –13 | –1.000 | 0.000 | 3 | –1.000 | 0.000 | 19 | –1.000 | 0.000 |
| –28 | 0.000 | 0.000 | –12 | –1.000 | 0.000 | 4 | –1.000 | 0.000 | 20 | –1.000 | 0.000 |
| –27 | 0.000 | 0.000 | –11 | –1.000 | 0.000 | 5 | –1.000 | 0.000 | 21 | –1.000 | 0.000 |
| –26 | 1.000 | 0.000 | –10 | –1.000 | 0.000 | 6 | –1.000 | 0.000 | 22 | 1.000 | 0.000 |
| –25 | –1.000 | 0.000 | –9 | –1.000 | 0.000 | 7 | 1.000 | 0.000 | 23 | –1.000 | 0.000 |
| –24 | –1.000 | 0.000 | –8 | –1.000 | 0.000 | 8 | 1.000 | 0.000 | 24 | 1.000 | 0.000 |
| –23 | 1.000 | 0.000 | –7 | 1.000 | 0.000 | 9 | 1.000 | 0.000 | 25 | –1.000 | 0.000 |
| –22 | –1.000 | 0.000 | –6 | –1.000 | 0.000 | 10 | –1.000 | 0.000 | 26 | –1.000 | 0.000 |
| –21 | 1.000 | 0.000 | –5 | 1.000 | 0.000 | 11 | –1.000 | 0.000 | 27 | 0.000 | 0.000 |
| –20 | 1.000 | 0.000 | –4 | –1.000 | 0.000 | 12 | 1.000 | 0.000 | 28 | 0.000 | 0.000 |
| –19 | –1.000 | 0.000 | –3 | 1.000 | 0.000 | 13 | –1.000 | 0.000 | 29 | 0.000 | 0.000 |
| –18 | –1.000 | 0.000 | –2 | –1.000 | 0.000 | 14 | –1.000 | 0.000 | 30 | 0.000 | 0.000 |
| –17 | 1.000 | 0.000 | –1 | –1.000 | 0.000 | 15 | 1.000 | 0.000 | 31 | 0.000 | 0.000 |

### I.1.4.5 SIGNAL field time domain

The time domain representation is derived by performing IFFT on the contents of Table I-11 (Frequency domain representation of SIGNAL field with pilots inserted), extending cyclically, and multiplying by the window function

$$W(k) = \begin{bmatrix} 0.5 & \mathrm{k} = 0 \\ 1 & 1 \le k \le 79 \\ 0.5 & \mathrm{k} = 80 \end{bmatrix}.$$

The resulting 81 samples vector is shown in Table I-12 (Time domain representation of SIGNAL field). Note that the time-windowing feature illustrated here is not a part of the normative specifications.

The SIGNAL field samples are appended with one sample overlap to the preamble, given in Table I-6 (Time domain representation of the long sequence).

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**Table I-12—Time domain representation of SIGNAL field**

| ## | Re | Im | ## | Re | Im | ## | Re | Im | ## | Re | Im |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0.031 | 0.000 | 1 | 0.033 | –0.044 | 2 | –0.002 | –0.038 | 3 | –0.081 | 0.084 |
| 4 | 0.007 | –0.100 | 5 | –0.001 | –0.113 | 6 | –0.021 | –0.005 | 7 | 0.136 | –0.105 |
| 8 | 0.098 | –0.044 | 9 | 0.011 | –0.002 | 10 | –0.033 | 0.044 | 11 | –0.060 | 0.124 |
| 12 | 0.010 | 0.097 | 13 | 0.000 | –0.008 | 14 | 0.018 | –0.083 | 15 | –0.069 | 0.027 |
| 16 | –0.219 | 0.000 | 17 | –0.069 | –0.027 | 18 | 0.018 | 0.083 | 19 | 0.000 | 0.008 |
| 20 | 0.010 | –0.097 | 21 | –0.060 | –0.124 | 22 | –0.033 | –0.044 | 23 | 0.011 | 0.002 |
| 24 | 0.098 | 0.044 | 25 | 0.136 | 0.105 | 26 | –0.021 | 0.005 | 27 | –0.001 | 0.113 |
| 28 | 0.007 | 0.100 | 29 | –0.081 | –0.084 | 30 | –0.002 | 0.038 | 31 | 0.033 | 0.044 |
| 32 | 0.062 | 0.000 | 33 | 0.057 | 0.052 | 34 | 0.016 | 0.174 | 35 | 0.035 | 0.116 |
| 36 | –0.051 | –0.202 | 37 | 0.011 | 0.036 | 38 | 0.089 | 0.209 | 39 | –0.049 | –0.008 |
| 40 | –0.035 | 0.044 | 41 | 0.017 | –0.059 | 42 | 0.053 | –0.017 | 43 | 0.099 | 0.100 |
| 44 | 0.034 | –0.148 | 45 | –0.003 | –0.094 | 46 | –0.120 | 0.042 | 47 | –0.136 | –0.070 |
| 48 | –0.031 | 0.000 | 49 | –0.136 | 0.070 | 50 | –0.120 | –0.042 | 51 | –0.003 | 0.094 |
| 52 | 0.034 | 0.148 | 53 | 0.099 | –0.100 | 54 | 0.053 | 0.017 | 55 | 0.017 | 0.059 |
| 56 | –0.035 | –0.044 | 57 | –0.049 | 0.008 | 58 | 0.089 | –0.209 | 59 | 0.011 | –0.036 |
| 60 | –0.051 | 0.202 | 61 | 0.035 | –0.116 | 62 | 0.016 | –0.174 | 63 | 0.057 | –0.052 |
| 64 | 0.062 | 0.000 | 65 | 0.033 | –0.044 | 66 | –0.002 | –0.038 | 67 | –0.081 | 0.084 |
| 68 | 0.007 | –0.100 | 69 | –0.001 | –0.113 | 70 | –0.021 | –0.005 | 71 | 0.136 | –0.105 |
| 72 | 0.098 | –0.044 | 73 | 0.011 | –0.002 | 74 | –0.033 | 0.044 | 75 | –0.060 | 0.124 |
| 76 | 0.010 | 0.097 | 77 | 0.000 | –0.008 | 78 | 0.018 | –0.083 | 79 | –0.069 | 0.027 |
| 80 | –0.109 | 0.000 | | | | | | | | | |

## I.1.5 Generating the DATA bits for the BCC example

### I.1.5.1 Delineating, SERVICE field prepending, and zero padding

The transmitted message shown in Table I-1 (The message for the BCC example) contains 100 octets or, equivalently, 800 bits. The bits are prepended by the 16 SERVICE field bits and are appended by 6 tail bits. The resulting 822 bits are appended by some number of bits with value 0 to yield an integer number of OFDM symbols. For the 36 Mb/s mode, there are 144 data bits per OFDM symbol; the overall number of bits is $\lceil 822/144 \rceil \times 144 = 864$. Hence, $864 - 822 = 42$ zero bits are appended.


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The DATA bits are shown in Table I-13 (The DATA bits before scrambling).

**Table I-13—The DATA bits before scrambling**

| Bit ## | Binary value B7 B0 | Binary value B15 B8 | Binary value B23 B16 | Hexadecimal value | Hexadecimal value | Hexadecimal value |
|---|---|---|---|---|---|---|
| 000-023 | 00000000 | 00000000 | 00000100 | 0x00 | 0x00 | 0x04 |
| 024-047 | 00000010 | 00000000 | 00101110 | 0x02 | 0x00 | 0x2E |
| 048-071 | 00000000 | 01100000 | 00001000 | 0x00 | 0x60 | 0x08 |
| 072-095 | 11001101 | 00110111 | 10100110 | 0xCD | 0x37 | 0xA6 |
| 096-119 | 00000000 | 00100000 | 11010110 | 0x00 | 0x20 | 0xD6 |
| 120-143 | 00000001 | 00111100 | 11110001 | 0x01 | 0x3C | 0xF1 |
| 144-167 | 00000000 | 01100000 | 00001000 | 0x00 | 0x60 | 0x08 |
| 168-191 | 10101101 | 00111011 | 10101111 | 0xAD | 0x3B | 0xAF |
| 192-215 | 00000000 | 00000000 | 01001010 | 0x00 | 0x00 | 0x4A |
| 216-239 | 01101111 | 01111001 | 00101100 | 0x6F | 0x79 | 0x2C |
| 240-263 | 00100000 | 01100010 | 01110010 | 0x20 | 0x62 | 0x72 |
| 264-287 | 01101001 | 01100111 | 01101000 | 0x69 | 0x67 | 0x68 |
| 288-311 | 01110100 | 00100000 | 01110011 | 0x74 | 0x20 | 0x73 |
| 312-335 | 01110000 | 01100001 | 01110010 | 0x70 | 0x61 | 0x72 |
| 336-359 | 01101011 | 00100000 | 01101111 | 0x6B | 0x20 | 0x6F |
| 360-383 | 01100110 | 00100000 | 01100100 | 0x66 | 0x20 | 0x64 |
| 384-407 | 01101001 | 01110110 | 01101001 | 0x69 | 0x76 | 0x69 |
| 408-431 | 01101110 | 01101001 | 01110100 | 0x6E | 0x69 | 0x74 |
| 432-455 | 01111001 | 00101100 | 00001010 | 0x79 | 0x2C | 0x0A |
| 456-479 | 01000100 | 01100001 | 01110101 | 0x44 | 0x61 | 0x75 |
| 480-503 | 01100111 | 01101000 | 01110100 | 0x67 | 0x68 | 0x74 |
| 504-527 | 01100101 | 01110010 | 00100000 | 0x65 | 0x72 | 0x20 |
| 528-551 | 01101111 | 01100110 | 00100000 | 0x6F | 0x66 | 0x20 |
| 552-575 | 01000101 | 01101100 | 01111001 | 0x45 | 0x6C | 0x79 |
| 576-599 | 01110011 | 01101001 | 01110101 | 0x73 | 0x69 | 0x75 |
| 600-623 | 01101101 | 00101100 | 00001010 | 0x6D | 0x2C | 0x0A |
| 624-647 | 01000110 | 01101001 | 01110010 | 0x46 | 0x69 | 0x72 |
| 648-671 | 01100101 | 00101101 | 01101001 | 0x65 | 0x2D | 0x69 |
| 672-695 | 01101110 | 01110011 | 01101001 | 0x6E | 0x73 | 0x69 |
| 696-719 | 01110010 | 01100101 | 01100100 | 0x72 | 0x65 | 0x64 |
| 720-743 | 00100000 | 01110111 | 01100101 | 0x20 | 0x77 | 0x65 |

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**Table I-13—The DATA bits before scrambling *(continued)***

| Bit ## | Binary value B7 B0 | Binary value B15 B8 | Binary value B23 B16 | Hexadecimal value | Hexadecimal value | Hexadecimal value |
|---|---|---|---|---|---|---|
| 744-767 | 00100000 | 01110100 | 01110010 | 0x20 | 0x74 | 0x72 |
| 768-791 | 01100101 | 01100001 | 01100111 | 0x65 | 0x61 | 0x67 |
| 792-815 | 00110011 | 00100001 | 10110110 | 0x33 | 0x21 | 0xB6 |
| 816-839 | 00000000 | 00000000 | 00000000 | 0x00 | 0x00 | 0x00 |
| 840-863 | 00000000 | 00000000 | 00000000 | 0x00 | 0x00 | 0x00 |

### I.1.5.2 Scrambling the BCC example

The 864 bits are scrambled by the scrambler defined in 17.3.5.5 (PHY DATA scrambler and descrambler). (#602)The TXVECTOR parameter SCRAMBLER_INITIAL_VALUE is 54. The generated scrambling sequence is given in Table I-14 (Scrambling sequence for TXVECTOR parameter SCRAMBLER_INITIAL_VALUE equal to 54(#602)).

**Table I-14—Scrambling sequence for TXVECTOR parameter SCRAMBLER_INITIAL_VALUE equal to 54(#602)**

| ## | Bit | ## | Bit | ## | Bit | ## | Bit | ## | Bit | ## | Bit | ## | Bit | ## | Bit |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 16 | 1 | 32 | 0 | 48 | 1 | 64 | 0 | 80 | 0 | 96 | 0 | 112 | 1 |
| 1 | 1 | 17 | 0 | 33 | 1 | 49 | 1 | 65 | 1 | 81 | 0 | 97 | 0 | 113 | 0 |
| 2 | 1 | 18 | 1 | 34 | 1 | 50 | 1 | 66 | 1 | 82 | 1 | 98 | 1 | 114 | 0 |
| 3 | 0 | 19 | 0 | 35 | 0 | 51 | 1 | 67 | 1 | 83 | 1 | 99 | 0 | 115 | 1 |
| 4 | 1 | 20 | 1 | 36 | 1 | 52 | 0 | 68 | 0 | 84 | 1 | 100 | 0 | 116 | 1 |
| 5 | 1 | 21 | 0 | 37 | 0 | 53 | 1 | 69 | 0 | 85 | 0 | 101 | 1 | 117 | 0 |
| 6 | 0 | 22 | 0 | 38 | 0 | 54 | 0 | 70 | 0 | 86 | 1 | 102 | 0 | 118 | 0 |
| 7 | 0 | 23 | 1 | 39 | 0 | 55 | 0 | 71 | 1 | 87 | 1 | 103 | 0 | 119 | 0 |
| 8 | 0 | 24 | 1 | 40 | 0 | 56 | 1 | 72 | 1 | 88 | 1 | 104 | 0 | 120 | 1 |
| 9 | 0 | 25 | 1 | 41 | 1 | 57 | 0 | 73 | 1 | 89 | 1 | 105 | 0 | 121 | 0 |
| 10 | 0 | 26 | 0 | 42 | 0 | 58 | 1 | 74 | 1 | 90 | 0 | 106 | 0 | 122 | 1 |
| 11 | 1 | 27 | 0 | 43 | 1 | 59 | 0 | 75 | 1 | 91 | 0 | 107 | 0 | 123 | 1 |
| 12 | 1 | 28 | 1 | 44 | 0 | 60 | 0 | 76 | 1 | 92 | 1 | 108 | 1 | 124 | 1 |
| 13 | 0 | 29 | 1 | 45 | 1 | 61 | 0 | 77 | 1 | 93 | 0 | 109 | 0 | 125 | 0 |
| 14 | 0 | 30 | 1 | 46 | 0 | 62 | 1 | 78 | 0 | 94 | 1 | 110 | 0 | 126 | 1 |
| 15 | 1 | 31 | 1 | 47 | 1 | 63 | 1 | 79 | 0 | 95 | 1 | 111 | 0 | | |


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After scrambling, the 6 bits in location 816 (i.e., bit 817) to 821 (i.e., bit 822) are set to 0. The scrambled DATA bits are shown in Table I-15 (The DATA bits after scrambling).

**Table I-15—The DATA bits after scrambling**

| Bit ## | Binary value B0 B7 | Binary value B8 B15 | Binary value B16 B23 | Hexadecimal value | Hexadecimal value | Hexadecimal value |
|---|---|---|---|---|---|---|
| 000-023 | 01101100 | 00011001 | 10001001 | 0x6C | 0x19 | 0x89 |
| 024-047 | 10001111 | 01101000 | 00100001 | 0x8F | 0x68 | 0x21 |
| 048-071 | 11110100 | 10100101 | 01100001 | 0xF4 | 0xA5 | 0x61 |
| 072-095 | 01001111 | 11010111 | 10101110 | 0x4F | 0xD7 | 0xAE |
| 096-119 | 00100100 | 00001100 | 11110011 | 0x24 | 0x0C | 0xF3 |
| 120-143 | 00111010 | 11100100 | 10111100 | 0x3A | 0xE4 | 0xBC |
| 144-167 | 01010011 | 10011000 | 11000000 | 0x53 | 0x98 | 0xC0 |
| 168-191 | 00011110 | 00110101 | 10110011 | 0x1E | 0x35 | 0xB3 |
| 192-215 | 11100011 | 11111000 | 00100101 | 0xE3 | 0xF8 | 0x25 |
| 216-239 | 01100000 | 11010110 | 00100101 | 0x60 | 0xD6 | 0x25 |
| 240-263 | 00110101 | 00110011 | 11111110 | 0x35 | 0x33 | 0xFE |
| 264-287 | 11110000 | 01000001 | 00101011 | 0xF0 | 0x41 | 0x2B |
| 288-311 | 10001111 | 01010011 | 00011100 | 0x8F | 0x53 | 0x1C |
| 312-335 | 10000011 | 01000001 | 10111110 | 0x83 | 0x41 | 0xBE |
| 336-359 | 00111001 | 00101000 | 01100110 | 0x39 | 0x28 | 0x66 |
| 360-383 | 01000100 | 01100110 | 11001101 | 0x44 | 0x66 | 0xCD |
| 384-407 | 11110110 | 10100011 | 11011000 | 0xF6 | 0xA3 | 0xD8 |
| 408-431 | 00001101 | 11010100 | 10000001 | 0x0D | 0xD4 | 0x81 |
| 432-455 | 00111011 | 00101111 | 11011111 | 0x3B | 0x2F | 0xDF |
| 456-479 | 11000011 | 01011000 | 11110111 | 0xC3 | 0x58 | 0xF7 |
| 480-503 | 11000110 | 01010010 | 11101011 | 0xC6 | 0x52 | 0xEB |
| 504-527 | 01110000 | 10001111 | 10011110 | 0x70 | 0x8F | 0x9E |
| 528-551 | 01101010 | 10010000 | 10000001 | 0x6A | 0x90 | 0x81 |
| 552-575 | 11111101 | 01111100 | 10101001 | 0xFD | 0x7C | 0xA9 |
| 576-599 | 11010001 | 01010101 | 00010010 | 0xD1 | 0x55 | 0x12 |
| 600-623 | 00000100 | 01110100 | 11011001 | 0x04 | 0x74 | 0xD9 |
| 624-647 | 11101001 | 00111011 | 11001101 | 0xE9 | 0x3B | 0xCD |
| 648-671 | 10010011 | 10001101 | 01111011 | 0x93 | 0x8D | 0x7B |
| 672-695 | 01111100 | 01110000 | 00000010 | 0x7C | 0x70 | 0x02 |
| 696-719 | 00100000 | 10011001 | 10100001 | 0x20 | 0x99 | 0xA1 |

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**Table I-15—The DATA bits after scrambling *(continued)***

| Bit ## | Binary value B0 B7 | Binary value B8 B15 | Binary value B16 B23 | Hexadecimal value | Hexadecimal value | Hexadecimal value |
|---|---|---|---|---|---|---|
| 720-743 | 01111101 | 10001010 | 00100111 | 0x7D | 0x8A | 0x27 |
| 744-767 | 00010111 | 00111001 | 00010101 | 0x17 | 0x39 | 0x15 |
| 768-791 | 10100000 | 11101100 | 10010101 | 0xA0 | 0xEC | 0x95 |
| 792-815 | 00010110 | 10010001 | 00010000 | 0x16 | 0x91 | 0x10 |
| 816-839 | 00000000 | 11011100 | 01111111 | 0x00 | 0xDC | 0x7F |
| 840-863 | 00001110 | 11110010 | 11001001 | 0x0E | 0xF2 | 0xC9 |

## I.1.6 Generating the first DATA symbol for the BCC example

### I.1.6.1 Coding the DATA bits

The scrambled bits are coded with a rate 3/4 convolutional code. The DATA encoded bits are shown in Table I-16 (The BCC encoded DATA bits).

**Table I-16—The BCC encoded DATA bits**

| Bit ## | Binary value B0 B7 | Binary value B8 B15 | Binary value B16 B23 | Binary value B24 B31 | Hexa-decimal value | Hexa-decimal value | Hexa-decimal value | Hexa-decimal value |
|---|---|---|---|---|---|---|---|---|
| 0000–0031 | 00101011 | 00001000 | 10100001 | 11110000 | 0x2B | 0x08 | 0xA1 | 0xF0 |
| 0032–0063 | 10011101 | 10110101 | 10011010 | 00011101 | 0x9D | 0xB5 | 0x9A | 0x1D |
| 0064–0095 | 01001010 | 11111011 | 11101000 | 11000010 | 0x4A | 0xFB | 0xE8 | 0xC2 |
| 0096–0127 | 10001111 | 11000000 | 11001000 | 01110011 | 0x8F | 0xC0 | 0xC8 | 0x73 |
| 0128–0159 | 11000000 | 01000011 | 11100000 | 00011001 | 0xC0 | 0x43 | 0xE0 | 0x19 |
| 0160–0191 | 11100000 | 11010011 | 11101011 | 10110010 | 0xE0 | 0xD3 | 0xEB | 0xB2 |
| 0192–0223 | 10101111 | 10011000 | 11111101 | 01011001 | 0xAF | 0x98 | 0xFD | 0x59 |
| 0224–0255 | 00001111 | 10001011 | 01101001 | 01100110 | 0x0F | 0x8B | 0x69 | 0x66 |
| 0256–0287 | 00001100 | 10101010 | 11011001 | 00010000 | 0x0C | 0xAA | 0xD9 | 0x10 |
| 0288–0319 | 01010110 | 10001011 | 10100110 | 01000000 | 0x56 | 0x8B | 0xA6 | 0x40 |


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**Table I-16—The BCC encoded DATA bits *(continued)***

| Bit ## | Binary value B0 B7 | Binary value B8 B15 | Binary value B16 B23 | Binary value B24 B31 | Hexa-decimal value | Hexa-decimal value | Hexa-decimal value | Hexa-decimal value |
|---|---|---|---|---|---|---|---|---|
| 0320–0351 | 01100100 | 10110011 | 00100001 | 10011110 | 0x64 | 0xB3 | 0x21 | 0x9E |
| 0352–0383 | 10001110 | 10010001 | 11000001 | 00000101 | 0x8E | 0x91 | 0xC1 | 0x05 |
| 0384–0415 | 10110111 | 10110111 | 11000101 | 11011000 | 0xB7 | 0xB7 | 0xC5 | 0xD8 |
| 0416–0447 | 10000000 | 00101111 | 10100010 | 11011101 | 0x80 | 0x2F | 0xA2 | 0xDD |
| 0448–0479 | 01101111 | 00101011 | 10010111 | 01100001 | 0x6F | 0x2B | 0x97 | 0x61 |
| 0480–0511 | 11011001 | 11011101 | 00001101 | 00010010 | 0xD9 | 0xDD | 0x0D | 0x12 |
| 0512–0543 | 01110110 | 00100111 | 00000010 | 01001100 | 0x76 | 0x27 | 0x02 | 0x4C |
| 0544–0575 | 10010010 | 10111100 | 00010010 | 01001011 | 0x92 | 0xBC | 0x12 | 0x4B |
| 0576–0607 | 01101010 | 11110111 | 01110000 | 00100011 | 0x6A | 0xF7 | 0x70 | 0x23 |
| 0608–0639 | 00100111 | 10001110 | 00000001 | 10110100 | 0x27 | 0x8E | 0x01 | 0xB4 |
| 0640–0671 | 11010110 | 11000011 | 01101010 | 01100000 | 0xD6 | 0xC3 | 0x6A | 0x60 |
| 0672–0703 | 01001101 | 01001011 | 11001011 | 01010001 | 0x4D | 0x4B | 0xCB | 0x51 |
| 0704–0735 | 10011100 | 10110000 | 10000000 | 11101011 | 0x9C | 0xB0 | 0x80 | 0xEB |
| 0736–0767 | 10001001 | 00110100 | 00010100 | 01000000 | 0x89 | 0x34 | 0x14 | 0x40 |
| 0768–0799 | 01101100 | 10011110 | 00101100 | 01010001 | 0x6C | 0x9E | 0x2C | 0x51 |
| 0800–0831 | 01001011 | 01111100 | 01101001 | 00010001 | 0x4B | 0x7C | 0x69 | 0x11 |

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**Table I-16—The BCC encoded DATA bits *(continued)***

| Bit ## | Binary value B0 B7 | Binary value B8 B15 | Binary value B16 B23 | Binary value B24 B31 | Hexa-decimal value | Hexa-decimal value | Hexa-decimal value | Hexa-decimal value |
|---|---|---|---|---|---|---|---|---|
| 0832–0863 | 00010101 | 10000110 | 11111101 | 10111110 | 0x15 | 0x86 | 0xFD | 0xBE |
| 0864–0895 | 01011110 | 11111001 | 10111110 | 00101000 | 0x5E | 0xF9 | 0xBE | 0x28 |
| 0896–0927 | 11101111 | 11001010 | 01010101 | 00000011 | 0xEF | 0xCA | 0x55 | 0x03 |
| 0928–0959 | 11111101 | 00100110 | 10010001 | 00111011 | 0xFD | 0x26 | 0x91 | 0x3B |
| 0960–0991 | 10010101 | 11101100 | 01011011 | 00100011 | 0x95 | 0xEC | 0x5B | 0x23 |
| 0992–1023 | 10011001 | 01011111 | 00101000 | 00111110 | 0x99 | 0x5F | 0x28 | 0x3E |
| 1024–1055 | 11010100 | 11101001 | 11110111 | 10111000 | 0xD4 | 0xE9 | 0xF7 | 0xB8 |
| 1056–1087 | 00010011 | 01110101 | 10001110 | 11110010 | 0x13 | 0x75 | 0x8E | 0xF2 |
| 1088–1119 | 10100000 | 00011011 | 01101100 | 11101001 | 0xA0 | 0x1B | 0x6C | 0xE9 |
| 1120–1151 | 00000111 | 01011101 | 10110000 | 10111111 | 0x07 | 0x5D | 0xB0 | 0xBF |

### I.1.6.2 Interleaving the DATA bits

The interleaver is defined as a two-permutation process. The index of the coded bit before the first permutation shall be denoted by $k$; $i$ shall be the index after the first and before the second permutation; and $j$ shall be the index after the second permutation, just prior to modulation mapping. The mapping from $k$ to $i$ is shown in Table I-17 (First permutation), and the mapping from $i$ to $j$ is shown in Table I-18 (Second permutation).

As a specific example, consider the case of $k = 17$ (the $18^{th}$ bit after encoding and puncturing). It is mapped by the first permutation to $i = 13$ and by the second permutation to $j = 12$ (the $13^{th}$ bit before mapping).

**Table I-17—First permutation**

| *k* | *i* | *k* | *i* | *k* | *i* | *k* | *i* | *k* | *i* | *k* | *i* | *k* | *i* | *k* | *i* | *k* | *i* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 24 | 97 | 48 | 3 | 72 | 100 | 96 | 6 | 120 | 103 | 144 | 9 | 168 | 106 | | |
| 1 | 12 | 25 | 109 | 49 | 15 | 73 | 112 | 97 | 18 | 121 | 115 | 145 | 21 | 169 | 118 | | |
| 2 | 24 | 26 | 121 | 50 | 27 | 74 | 124 | 98 | 30 | 122 | 127 | 146 | 33 | 170 | 130 | | |
| 3 | 36 | 27 | 133 | 51 | 39 | 75 | 136 | 99 | 42 | 123 | 139 | 147 | 45 | 171 | 142 | | |
| 4 | 48 | 28 | 145 | 52 | 51 | 76 | 148 | 100 | 54 | 124 | 151 | 148 | 57 | 172 | 154 | | |


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**Table I-17—First permutation *(continued)***

| *k* | *i* | *k* | *i* | *k* | *i* | *k* | *i* | *k* | *i* | *k* | *i* | *k* | *i* | *k* | *i* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5 | 60 | 29 | 157 | 53 | 63 | 77 | 160 | 101 | 66 | 125 | 163 | 149 | 69 | 173 | 166 |
| 6 | 72 | 30 | 169 | 54 | 75 | 78 | 172 | 102 | 78 | 126 | 175 | 150 | 81 | 174 | 178 |
| 7 | 84 | 31 | 181 | 55 | 87 | 79 | 184 | 103 | 90 | 127 | 187 | 151 | 93 | 175 | 190 |
| 8 | 96 | 32 | 2 | 56 | 99 | 80 | 5 | 104 | 102 | 128 | 8 | 152 | 105 | 176 | 11 |
| 9 | 108 | 33 | 14 | 57 | 111 | 81 | 17 | 105 | 114 | 129 | 20 | 153 | 117 | 177 | 23 |
| 10 | 120 | 34 | 26 | 58 | 123 | 82 | 29 | 106 | 126 | 130 | 32 | 154 | 129 | 178 | 35 |
| 11 | 132 | 35 | 38 | 59 | 135 | 83 | 41 | 107 | 138 | 131 | 44 | 155 | 141 | 179 | 47 |
| 12 | 144 | 36 | 50 | 60 | 147 | 84 | 53 | 108 | 150 | 132 | 56 | 156 | 153 | 180 | 59 |
| 13 | 156 | 37 | 62 | 61 | 159 | 85 | 65 | 109 | 162 | 133 | 68 | 157 | 165 | 181 | 71 |
| 14 | 168 | 38 | 74 | 62 | 171 | 86 | 77 | 110 | 174 | 134 | 80 | 158 | 177 | 182 | 83 |
| 15 | 180 | 39 | 86 | 63 | 183 | 87 | 89 | 111 | 186 | 135 | 92 | 159 | 189 | 183 | 95 |
| 16 | 1 | 40 | 98 | 64 | 4 | 88 | 101 | 112 | 7 | 136 | 104 | 160 | 10 | 184 | 107 |
| 17 | 13 | 41 | 110 | 65 | 16 | 89 | 113 | 113 | 19 | 137 | 116 | 161 | 22 | 185 | 119 |
| 18 | 25 | 42 | 122 | 66 | 28 | 90 | 125 | 114 | 31 | 138 | 128 | 162 | 34 | 186 | 131 |
| 19 | 37 | 43 | 134 | 67 | 40 | 91 | 137 | 115 | 43 | 139 | 140 | 163 | 46 | 187 | 143 |
| 20 | 49 | 44 | 146 | 68 | 52 | 92 | 149 | 116 | 55 | 140 | 152 | 164 | 58 | 188 | 155 |
| 21 | 61 | 45 | 158 | 69 | 64 | 93 | 161 | 117 | 67 | 141 | 164 | 165 | 70 | 189 | 167 |
| 22 | 73 | 46 | 170 | 70 | 76 | 94 | 173 | 118 | 79 | 142 | 176 | 166 | 82 | 190 | 179 |
| 23 | 85 | 47 | 182 | 71 | 88 | 95 | 185 | 119 | 91 | 143 | 188 | 167 | 94 | 191 | 191 |

**Table I-18—Second permutation**

| *i* | *j* | *i* | *j* | *i* | *j* | *i* | *j* | *i* | *j* | *i* | *j* | *i* | *j* | *i* | *j* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 24 | 24 | 48 | 48 | 72 | 72 | 96 | 96 | 120 | 120 | 144 | 144 | 168 | 168 |
| 1 | 1 | 25 | 25 | 49 | 49 | 73 | 73 | 97 | 97 | 121 | 121 | 145 | 145 | 169 | 169 |
| 2 | 2 | 26 | 26 | 50 | 50 | 74 | 74 | 98 | 98 | 122 | 122 | 146 | 146 | 170 | 170 |
| 3 | 3 | 27 | 27 | 51 | 51 | 75 | 75 | 99 | 99 | 123 | 123 | 147 | 147 | 171 | 171 |
| 4 | 4 | 28 | 28 | 52 | 52 | 76 | 76 | 100 | 100 | 124 | 124 | 148 | 148 | 172 | 172 |
| 5 | 5 | 29 | 29 | 53 | 53 | 77 | 77 | 101 | 101 | 125 | 125 | 149 | 149 | 173 | 173 |
| 6 | 6 | 30 | 30 | 54 | 54 | 78 | 78 | 102 | 102 | 126 | 126 | 150 | 150 | 174 | 174 |
| 7 | 7 | 31 | 31 | 55 | 55 | 79 | 79 | 103 | 103 | 127 | 127 | 151 | 151 | 175 | 175 |
| 8 | 8 | 32 | 32 | 56 | 56 | 80 | 80 | 104 | 104 | 128 | 128 | 152 | 152 | 176 | 176 |
| 9 | 9 | 33 | 33 | 57 | 57 | 81 | 81 | 105 | 105 | 129 | 129 | 153 | 153 | 177 | 177 |

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**Table I-18—Second permutation *(continued)***

| *i* | *j* | *i* | *j* | *i* | *j* | *i* | *j* | *i* | *j* | *i* | *j* | *i* | *j* | *i* | *j* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10 | 10 | 34 | 34 | 58 | 58 | 82 | 82 | 106 | 106 | 130 | 130 | 154 | 154 | 178 | 178 |
| 11 | 11 | 35 | 35 | 59 | 59 | 83 | 83 | 107 | 107 | 131 | 131 | 155 | 155 | 179 | 179 |
| 12 | 13 | 36 | 37 | 60 | 61 | 84 | 85 | 108 | 109 | 132 | 133 | 156 | 157 | 180 | 181 |
| 13 | 12 | 37 | 36 | 61 | 60 | 85 | 84 | 109 | 108 | 133 | 132 | 157 | 156 | 181 | 180 |
| 14 | 15 | 38 | 39 | 62 | 63 | 86 | 87 | 110 | 111 | 134 | 135 | 158 | 159 | 182 | 183 |
| 15 | 14 | 39 | 38 | 63 | 62 | 87 | 86 | 111 | 110 | 135 | 134 | 159 | 158 | 183 | 182 |
| 16 | 17 | 40 | 41 | 64 | 65 | 88 | 89 | 112 | 113 | 136 | 137 | 160 | 161 | 184 | 185 |
| 17 | 16 | 41 | 40 | 65 | 64 | 89 | 88 | 113 | 112 | 137 | 136 | 161 | 160 | 185 | 184 |
| 18 | 19 | 42 | 43 | 66 | 67 | 90 | 91 | 114 | 115 | 138 | 139 | 162 | 163 | 186 | 187 |
| 19 | 18 | 43 | 42 | 67 | 66 | 91 | 90 | 115 | 114 | 139 | 138 | 163 | 162 | 187 | 186 |
| 20 | 21 | 44 | 45 | 68 | 69 | 92 | 93 | 116 | 117 | 140 | 141 | 164 | 165 | 188 | 189 |
| 21 | 20 | 45 | 44 | 69 | 68 | 93 | 92 | 117 | 116 | 141 | 140 | 165 | 164 | 189 | 188 |
| 22 | 23 | 46 | 47 | 70 | 71 | 94 | 95 | 118 | 119 | 142 | 143 | 166 | 167 | 190 | 191 |
| 23 | 22 | 47 | 46 | 71 | 70 | 95 | 94 | 119 | 118 | 143 | 142 | 167 | 166 | 191 | 190 |

The interleaved bits are shown in Table I-19 (Interleaved bits of first DATA symbol).

**Table I-19—Interleaved bits of first DATA symbol**

| ## | Bit | ## | Bit | ## | Bit | ## | Bit | ## | Bit | ## | Bit |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 32 | 0 | 64 | 0 | 96 | 0 | 128 | 0 | 160 | 0 |
| 1 | 1 | 33 | 1 | 65 | 0 | 97 | 1 | 129 | 0 | 161 | 0 |
| 2 | 1 | 34 | 1 | 66 | 0 | 98 | 1 | 130 | 0 | 162 | 0 |
| 3 | 1 | 35 | 1 | 67 | 1 | 99 | 0 | 131 | 1 | 163 | 0 |
| 4 | 0 | 36 | 0 | 68 | 0 | 100 | 1 | 132 | 1 | 164 | 0 |
| 5 | 1 | 37 | 0 | 69 | 0 | 101 | 1 | 133 | 0 | 165 | 0 |
| 6 | 1 | 38 | 1 | 70 | 0 | 102 | 1 | 134 | 1 | 166 | 0 |
| 7 | 1 | 39 | 1 | 71 | 0 | 103 | 0 | 135 | 1 | 167 | 0 |
| 8 | 1 | 40 | 0 | 72 | 1 | 104 | 0 | 136 | 0 | 168 | 0 |
| 9 | 1 | 41 | 0 | 73 | 0 | 105 | 0 | 137 | 1 | 169 | 0 |
| 10 | 1 | 42 | 0 | 74 | 0 | 106 | 1 | 138 | 1 | 170 | 0 |
| 11 | 1 | 43 | 0 | 75 | 1 | 107 | 1 | 139 | 0 | 171 | 0 |
| 12 | 0 | 44 | 0 | 76 | 1 | 108 | 1 | 140 | 1 | 172 | 1 |


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**Table I-19—Interleaved bits of first DATA symbol *(continued)***

| ## | Bit | ## | Bit | ## | Bit | ## | Bit | ## | Bit | ## | Bit |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 13 | 0 | 45 | 0 | 77 | 0 | 109 | 0 | 141 | 0 | 173 | 1 |
| 14 | 0 | 46 | 0 | 78 | 1 | 110 | 0 | 142 | 1 | 174 | 0 |
| 15 | 0 | 47 | 0 | 79 | 0 | 111 | 0 | 143 | 1 | 175 | 1 |
| 16 | 1 | 48 | 1 | 80 | 0 | 112 | 1 | 144 | 1 | 176 | 1 |
| 17 | 1 | 49 | 0 | 81 | 0 | 113 | 1 | 145 | 0 | 177 | 0 |
| 18 | 1 | 50 | 1 | 82 | 0 | 114 | 1 | 146 | 0 | 178 | 1 |
| 19 | 0 | 51 | 1 | 83 | 1 | 115 | 1 | 147 | 1 | 179 | 1 |
| 20 | 1 | 52 | 1 | 84 | 1 | 116 | 0 | 148 | 1 | 180 | 0 |
| 21 | 1 | 53 | 1 | 85 | 1 | 117 | 1 | 149 | 0 | 181 | 0 |
| 22 | 1 | 54 | 1 | 86 | 0 | 118 | 0 | 150 | 0 | 182 | 1 |
| 23 | 1 | 55 | 1 | 87 | 1 | 119 | 1 | 151 | 0 | 183 | 1 |
| 24 | 1 | 56 | 0 | 88 | 0 | 120 | 0 | 152 | 0 | 184 | 0 |
| 25 | 1 | 57 | 0 | 89 | 0 | 121 | 1 | 153 | 1 | 185 | 1 |
| 26 | 0 | 58 | 0 | 90 | 0 | 122 | 1 | 154 | 0 | 186 | 1 |
| 27 | 0 | 59 | 1 | 91 | 1 | 123 | 0 | 155 | 0 | 187 | 0 |
| 28 | 0 | 60 | 0 | 92 | 0 | 124 | 1 | 156 | 0 | 188 | 1 |
| 29 | 1 | 61 | 0 | 93 | 0 | 125 | 0 | 157 | 0 | 189 | 1 |
| 30 | 0 | 62 | 0 | 94 | 1 | 126 | 0 | 158 | 1 | 190 | 0 |
| 31 | 0 | 63 | 1 | 95 | 0 | 127 | 1 | 159 | 1 | 191 | 1 |

### I.1.6.3 Mapping into symbols

The frequency domain symbols are generated by grouping 4 coded bits and mapping into complex 16-QAM symbols according to Table 17-17 (16-QAM encoding table) (in 17.3.5.8 (Subcarrier modulation mapping)). For instance, the first 4 bits (0 1 1 1) are mapped to the complex value, –0.316 + 0.316j, inserted at subcarrier #26.

Four pilot subcarriers are added by taking the values {1.0,1.0,1.0,–1.0}, multiplying them by the second element of sequence p, given in Equation (17-22) (in 17.3.5.10 (OFDM modulation)), and inserting them into location {–21,–7,7,21}, respectively.

The frequency domain is shown in Table I-20 (Frequency domain of first DATA symbol).

The time domain samples are produced by performing IFFT, cyclically extending, and multiplying with the window function in the same manner as described in I.1.4.5 (SIGNAL field time domain). The time domain samples are appended with one sample overlap to the SIGNAL field symbol.

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**Table I-20—Frequency domain of first DATA symbol**

| ## | Re | Im | ## | Re | Im | ## | Re | Im | ## | Re | Im |
|---|---|---|---|---|---|---|---|---|---|---|---|
| –32 | 0.000 | 0.000 | –16 | –0.949 | 0.316 | 0 | 0.000 | 0.000 | 16 | –0.316 | –0.949 |
| –31 | 0.000 | 0.000 | –15 | –0.949 | –0.949 | 1 | –0.316 | 0.949 | 17 | –0.949 | 0.316 |
| –30 | 0.000 | 0.000 | –14 | –0.949 | –0.949 | 2 | 0.316 | 0.949 | 18 | –0.949 | –0.949 |
| –29 | 0.000 | 0.000 | –13 | 0.949 | 0.316 | 3 | –0.949 | 0.316 | 19 | –0.949 | –0.949 |
| –28 | 0.000 | 0.000 | –12 | 0.316 | 0.316 | 4 | 0.949 | –0.949 | 20 | –0.949 | –0.949 |
| –27 | 0.000 | 0.000 | –11 | –0.949 | –0.316 | 5 | 0.316 | 0.316 | 21 | –1.000 | 0.000 |
| –26 | –0.316 | 0.316 | –10 | –0.949 | –0.316 | 6 | –0.316 | –0.316 | 22 | 0.316 | –0.316 |
| –25 | –0.316 | 0.316 | –9 | –0.949 | –0.316 | 7 | 1.000 | 0.000 | 23 | 0.949 | 0.316 |
| –24 | 0.316 | 0.316 | –8 | –0.949 | –0.949 | 8 | –0.316 | 0.949 | 24 | –0.949 | 0.316 |
| –23 | –0.949 | –0.949 | –7 | 1.000 | 0.000 | 9 | 0.949 | –0.316 | 25 | –0.316 | 0.949 |
| –22 | 0.316 | 0.949 | –6 | 0.949 | –0.316 | 10 | –0.949 | –0.316 | 26 | 0.316 | –0.316 |
| –21 | 1.000 | 0.000 | –5 | 0.949 | 0.949 | 11 | 0.949 | 0.316 | 27 | 0.000 | 0.000 |
| –20 | 0.316 | 0.316 | –4 | –0.949 | –0.316 | 12 | –0.316 | 0.949 | 28 | 0.000 | 0.000 |
| –19 | 0.316 | –0.949 | –3 | 0.316 | –0.316 | 13 | 0.949 | 0.316 | 29 | 0.000 | 0.000 |
| –18 | –0.316 | –0.949 | –2 | –0.949 | –0.316 | 14 | 0.949 | –0.316 | 30 | 0.000 | 0.000 |
| –17 | –0.316 | 0.316 | –1 | –0.949 | 0.949 | 15 | 0.949 | –0.949 | 31 | 0.000 | 0.000 |

### I.1.7 Generating the additional DATA symbols

The generation of the additional five data symbols follows the same procedure as described in Clause 4 (General description). Special attention should be paid to the scrambling of the pilot subcarriers. Table I-21 (Polarity of the pilot subcarriers) lists the polarity of the pilot subcarriers and the elements of the sequence $p_{0...126}$ for the DATA symbols. For completeness, the pilots in the SIGNAL are included as well. The symbols are appended one after the other with a one-sample overlap.

**Table I-21—Polarity of the pilot subcarriers**

| i | OFDM symbol | Element of $p_i$ | Pilot at #–21 | Pilot at #–7 | Pilot at #7 | Pilot at #21 |
|---|---|---|---|---|---|---|
| 0 | SIGNAL | 1 | 1.0 +0 j | 1.0 +0 j | 1.0 +0 j | –1.0 +0 j |
| 1 | DATA 1 | 1 | 1.0 +0 j | 1.0 +0 j | 1.0 +0 j | –1.0 +0 j |
| 2 | DATA 2 | 1 | 1.0 +0 j | 1.0 +0 j | 1.0 +0 j | –1.0 +0 j |
| 3 | DATA 3 | 1 | 1.0 +0 j | 1.0 +0 j | 1.0 +0 j | –1.0 +0 j |
| 4 | DATA 4 | –1 | –1.0 +0 j | –1.0 +0 j | –1.0 +0 j | 1.0 +0 j |
| 5 | DATA 5 | –1 | –1.0 +0 j | –1.0 +0 j | –1.0 +0 j | 1.0 +0 j |
| 6 | DATA 6 | –1 | –1.0 +0 j | –1.0 +0 j | –1.0 +0 j | 1.0 +0 j |


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### I.1.8 The entire PPDU for the BCC example(#14)

The (#14)PPDU in its entirety is shown in the tables in this subclause. These tables illustrate the short training sequence section (Table I-22 (Time domain representation of the short training sequence)), the long training sequence section (Table I-23 (Time domain representation of the long training sequence)), the SIGNAL field (Table I-24 (Time domain representation of the SIGNAL field (1 symbol))), and the six DATA symbols (Table I-25 (Time domain representation of the DATA field: symbol 1of 6) to Table I-30 (Time domain representation of the DATA field: symbol 6 of 6)).

**Table I-22—Time domain representation of the short training sequence**

| ## | Re | Im | ## | Re | Im | ## | Re | Im | ## | Re | Im |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0.023 | 0.023 | 1 | –0.132 | 0.002 | 2 | –0.013 | –0.079 | 3 | 0.143 | –0.013 |
| 4 | 0.092 | 0.000 | 5 | 0.143 | –0.013 | 6 | –0.013 | –0.079 | 7 | –0.132 | 0.002 |
| 8 | 0.046 | 0.046 | 9 | 0.002 | –0.132 | 10 | –0.079 | –0.013 | 11 | –0.013 | 0.143 |
| 12 | 0.000 | 0.092 | 13 | –0.013 | 0.143 | 14 | –0.079 | –0.013 | 15 | 0.002 | –0.132 |
| 16 | 0.046 | 0.046 | 17 | –0.132 | 0.002 | 18 | –0.013 | –0.079 | 19 | 0.143 | –0.013 |
| 20 | 0.092 | 0.000 | 21 | 0.143 | –0.013 | 22 | –0.013 | –0.079 | 23 | –0.132 | 0.002 |
| 24 | 0.046 | 0.046 | 25 | 0.002 | –0.132 | 26 | –0.079 | –0.013 | 27 | –0.013 | 0.143 |
| 28 | 0.000 | 0.092 | 29 | –0.013 | 0.143 | 30 | –0.079 | –0.013 | 31 | 0.002 | –0.132 |
| 32 | 0.046 | 0.046 | 33 | –0.132 | 0.002 | 34 | –0.013 | –0.079 | 35 | 0.143 | –0.013 |
| 36 | 0.092 | 0.000 | 37 | 0.143 | –0.013 | 38 | –0.013 | –0.079 | 39 | –0.132 | 0.002 |
| 40 | 0.046 | 0.046 | 41 | 0.002 | –0.132 | 42 | –0.079 | –0.013 | 43 | –0.013 | 0.143 |
| 44 | 0.000 | 0.092 | 45 | –0.013 | 0.143 | 46 | –0.079 | –0.013 | 47 | 0.002 | –0.132 |
| 48 | 0.046 | 0.046 | 49 | –0.132 | 0.002 | 50 | –0.013 | –0.079 | 51 | 0.143 | –0.013 |
| 52 | 0.092 | 0.000 | 53 | 0.143 | –0.013 | 54 | –0.013 | –0.079 | 55 | –0.132 | 0.002 |
| 56 | 0.046 | 0.046 | 57 | 0.002 | –0.132 | 58 | –0.079 | –0.013 | 59 | –0.013 | 0.143 |
| 60 | 0.000 | 0.092 | 61 | –0.013 | 0.143 | 62 | –0.079 | –0.013 | 63 | 0.002 | –0.132 |
| 64 | 0.046 | 0.046 | 65 | –0.132 | 0.002 | 66 | –0.013 | –0.079 | 67 | 0.143 | –0.013 |
| 68 | 0.092 | 0.000 | 69 | 0.143 | –0.013 | 70 | –0.013 | –0.079 | 71 | –0.132 | 0.002 |
| 72 | 0.046 | 0.046 | 73 | 0.002 | –0.132 | 74 | –0.079 | –0.013 | 75 | –0.013 | 0.143 |
| 76 | 0.000 | 0.092 | 77 | –0.013 | 0.143 | 78 | –0.079 | –0.013 | 79 | 0.002 | –0.132 |
| 80 | 0.046 | 0.046 | 81 | –0.132 | 0.002 | 82 | –0.013 | –0.079 | 83 | 0.143 | –0.013 |
| 84 | 0.092 | 0.000 | 85 | 0.143 | –0.013 | 86 | –0.013 | –0.079 | 87 | –0.132 | 0.002 |
| 88 | 0.046 | 0.046 | 89 | 0.002 | –0.132 | 90 | –0.079 | –0.013 | 91 | –0.013 | 0.143 |
| 92 | 0.000 | 0.092 | 93 | –0.013 | 0.143 | 94 | –0.079 | –0.013 | 95 | 0.002 | –0.132 |
| 96 | 0.046 | 0.046 | 97 | –0.132 | 0.002 | 98 | –0.013 | –0.079 | 99 | 0.143 | –0.013 |
| 100 | 0.092 | 0.000 | 101 | 0.143 | –0.013 | 102 | –0.013 | –0.079 | 103 | –0.132 | 0.002 |

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**Table I-22—Time domain representation of the short training sequence *(continued)***

| ## | Re | Im | ## | Re | Im | ## | Re | Im | ## | Re | Im |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 104 | 0.046 | 0.046 | 105 | 0.002 | –0.132 | 106 | –0.079 | –0.013 | 107 | –0.013 | 0.143 |
| 108 | 0.000 | 0.092 | 109 | –0.013 | 0.143 | 110 | –0.079 | –0.013 | 111 | 0.002 | –0.132 |
| 112 | 0.046 | 0.046 | 113 | –0.132 | 0.002 | 114 | –0.013 | –0.079 | 115 | 0.143 | –0.013 |
| 116 | 0.092 | 0.000 | 117 | 0.143 | –0.013 | 118 | –0.013 | –0.079 | 119 | –0.132 | 0.002 |
| 120 | 0.046 | 0.046 | 121 | 0.002 | –0.132 | 122 | –0.079 | –0.013 | 123 | –0.013 | 0.143 |
| 124 | 0.000 | 0.092 | 125 | –0.013 | 0.143 | 126 | –0.079 | –0.013 | 127 | 0.002 | –0.132 |
| 128 | 0.046 | 0.046 | 129 | –0.132 | 0.002 | 130 | –0.013 | –0.079 | 131 | 0.143 | –0.013 |
| 132 | 0.092 | 0.000 | 133 | 0.143 | –0.013 | 134 | –0.013 | –0.079 | 135 | –0.132 | 0.002 |
| 136 | 0.046 | 0.046 | 137 | 0.002 | –0.132 | 138 | –0.079 | –0.013 | 139 | –0.013 | 0.143 |
| 140 | 0.000 | 0.092 | 141 | –0.013 | 0.143 | 142 | –0.079 | –0.013 | 143 | 0.002 | –0.132 |
| 144 | 0.046 | 0.046 | 145 | –0.132 | 0.002 | 146 | –0.013 | –0.079 | 147 | 0.143 | –0.013 |
| 148 | 0.092 | 0.000 | 149 | 0.143 | –0.013 | 150 | –0.013 | –0.079 | 151 | –0.132 | 0.002 |
| 152 | 0.046 | 0.046 | 153 | 0.002 | –0.132 | 154 | –0.079 | –0.013 | 155 | –0.013 | 0.143 |
| 156 | 0.000 | 0.092 | 157 | –0.013 | 0.143 | 158 | –0.079 | –0.013 | 159 | 0.002 | –0.132 |

**Table I-23—Time domain representation of the long training sequence**

| ## | Re | Im | ## | Re | Im | ## | Re | Im | ## | Re | Im |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 160 | –0.055 | 0.023 | 161 | 0.012 | –0.098 | 162 | 0.092 | –0.106 | 163 | –0.092 | –0.115 |
| 164 | –0.003 | –0.054 | 165 | 0.075 | 0.074 | 166 | –0.127 | 0.021 | 167 | –0.122 | 0.017 |
| 168 | –0.035 | 0.151 | 169 | –0.056 | 0.022 | 170 | –0.060 | –0.081 | 171 | 0.070 | –0.014 |
| 172 | 0.082 | –0.092 | 173 | –0.131 | –0.065 | 174 | –0.057 | –0.039 | 175 | 0.037 | –0.098 |
| 176 | 0.062 | 0.062 | 177 | 0.119 | 0.004 | 178 | –0.022 | –0.161 | 179 | 0.059 | 0.015 |
| 180 | 0.024 | 0.059 | 181 | –0.137 | 0.047 | 182 | 0.001 | 0.115 | 183 | 0.053 | –0.004 |
| 184 | 0.098 | 0.026 | 185 | –0.038 | 0.106 | 186 | –0.115 | 0.055 | 187 | 0.060 | 0.088 |
| 188 | 0.021 | –0.028 | 189 | 0.097 | –0.083 | 190 | 0.040 | 0.111 | 191 | –0.005 | 0.120 |
| 192 | 0.156 | 0.000 | 193 | –0.005 | –0.120 | 194 | 0.040 | –0.111 | 195 | 0.097 | 0.083 |
| 196 | 0.021 | 0.028 | 197 | 0.060 | –0.088 | 198 | –0.115 | –0.055 | 199 | –0.038 | –0.106 |
| 200 | 0.098 | –0.026 | 201 | 0.053 | 0.004 | 202 | 0.001 | –0.115 | 203 | –0.137 | –0.047 |
| 204 | 0.024 | –0.059 | 205 | 0.059 | –0.015 | 206 | –0.022 | 0.161 | 207 | 0.119 | –0.004 |
| 208 | 0.062 | –0.062 | 209 | 0.037 | 0.098 | 210 | –0.057 | 0.039 | 211 | –0.131 | 0.065 |
| 212 | 0.082 | 0.092 | 213 | 0.070 | 0.014 | 214 | –0.060 | 0.081 | 215 | –0.056 | –0.022 |
| 216 | –0.035 | –0.151 | 217 | –0.122 | –0.017 | 218 | –0.127 | –0.021 | 219 | 0.075 | –0.074 |


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**Table I-23—Time domain representation of the long training sequence *(continued)***

| ## | Re | Im | ## | Re | Im | ## | Re | Im | ## | Re | Im |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 220 | –0.003 | 0.054 | 221 | –0.092 | 0.115 | 222 | 0.092 | 0.106 | 223 | 0.012 | 0.098 |
| 224 | –0.156 | 0.000 | 225 | 0.012 | –0.098 | 226 | 0.092 | –0.106 | 227 | –0.092 | –0.115 |
| 228 | –0.003 | –0.054 | 229 | 0.075 | 0.074 | 230 | –0.127 | 0.021 | 231 | –0.122 | 0.017 |
| 232 | –0.035 | 0.151 | 233 | –0.056 | 0.022 | 234 | –0.060 | –0.081 | 235 | 0.070 | –0.014 |
| 236 | 0.082 | –0.092 | 237 | –0.131 | –0.065 | 238 | –0.057 | –0.039 | 239 | 0.037 | –0.098 |
| 240 | 0.062 | 0.062 | 241 | 0.119 | 0.004 | 242 | –0.022 | –0.161 | 243 | 0.059 | 0.015 |
| 244 | 0.024 | 0.059 | 245 | –0.137 | 0.047 | 246 | 0.001 | 0.115 | 247 | 0.053 | –0.004 |
| 248 | 0.098 | 0.026 | 249 | –0.038 | 0.106 | 250 | –0.115 | 0.055 | 251 | 0.060 | 0.088 |
| 252 | 0.021 | –0.028 | 253 | 0.097 | –0.083 | 254 | 0.040 | 0.111 | 255 | –0.005 | 0.120 |
| 256 | 0.156 | 0.000 | 257 | –0.005 | –0.120 | 258 | 0.040 | –0.111 | 259 | 0.097 | 0.083 |
| 260 | 0.021 | 0.028 | 261 | 0.060 | –0.088 | 262 | –0.115 | –0.055 | 263 | –0.038 | –0.106 |
| 264 | 0.098 | –0.026 | 265 | 0.053 | 0.004 | 266 | 0.001 | –0.115 | 267 | –0.137 | –0.047 |
| 268 | 0.024 | –0.059 | 269 | 0.059 | –0.015 | 270 | –0.022 | 0.161 | 271 | 0.119 | –0.004 |
| 272 | 0.062 | –0.062 | 273 | 0.037 | 0.098 | 274 | –0.057 | 0.039 | 275 | –0.131 | 0.065 |
| 276 | 0.082 | 0.092 | 277 | 0.070 | 0.014 | 278 | –0.060 | 0.081 | 279 | –0.056 | –0.022 |
| 280 | –0.035 | –0.151 | 281 | –0.122 | –0.017 | 282 | –0.127 | –0.021 | 283 | 0.075 | –0.074 |
| 284 | –0.003 | 0.054 | 285 | –0.092 | 0.115 | 286 | 0.092 | 0.106 | 287 | 0.012 | 0.098 |
| 288 | –0.156 | 0.000 | 289 | 0.012 | –0.098 | 290 | 0.092 | –0.106 | 291 | –0.092 | –0.115 |
| 292 | –0.003 | –0.054 | 293 | 0.075 | 0.074 | 294 | –0.127 | 0.021 | 295 | –0.122 | 0.017 |
| 296 | –0.035 | 0.151 | 297 | –0.056 | 0.022 | 298 | –0.060 | –0.081 | 299 | 0.070 | –0.014 |
| 300 | 0.082 | –0.092 | 301 | –0.131 | –0.065 | 302 | –0.057 | –0.039 | 303 | 0.037 | –0.098 |
| 304 | 0.062 | 0.062 | 305 | 0.119 | 0.004 | 306 | –0.022 | –0.161 | 307 | 0.059 | 0.015 |
| 308 | 0.024 | 0.059 | 309 | –0.137 | 0.047 | 310 | 0.001 | 0.115 | 311 | 0.053 | –0.004 |
| 312 | 0.098 | 0.026 | 313 | –0.038 | 0.106 | 314 | –0.115 | 0.055 | 315 | 0.060 | 0.088 |
| 316 | 0.021 | –0.028 | 317 | 0.097 | –0.083 | 318 | 0.040 | 0.111 | 319 | –0.005 | 0.120 |

**Table I-24—Time domain representation of the SIGNAL field (1 symbol)**

| ## | Re | Im | ## | Re | Im | ## | Re | Im | ## | Re | Im |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 320 | 0.109 | 0.000 | 321 | 0.033 | –0.044 | 322 | –0.002 | –0.038 | 323 | –0.081 | 0.084 |
| 324 | 0.007 | –0.100 | 325 | –0.001 | –0.113 | 326 | –0.021 | –0.005 | 327 | 0.136 | –0.105 |
| 328 | 0.098 | –0.044 | 329 | 0.011 | –0.002 | 330 | –0.033 | 0.044 | 331 | –0.060 | 0.124 |
| 332 | 0.010 | 0.097 | 333 | 0.000 | –0.008 | 334 | 0.018 | –0.083 | 335 | –0.069 | 0.027 |

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**Table I-24—Time domain representation of the SIGNAL field (1 symbol) *(continued)***

| ## | Re | Im | ## | Re | Im | ## | Re | Im | ## | Re | Im |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 336 | –0.219 | 0.000 | 337 | –0.069 | –0.027 | 338 | 0.018 | 0.083 | 339 | 0.000 | 0.008 |
| 340 | 0.010 | –0.097 | 341 | –0.060 | –0.124 | 342 | –0.033 | –0.044 | 343 | 0.011 | 0.002 |
| 344 | 0.098 | 0.044 | 345 | 0.136 | 0.105 | 346 | –0.021 | 0.005 | 347 | –0.001 | 0.113 |
| 348 | 0.007 | 0.100 | 349 | –0.081 | –0.084 | 350 | –0.002 | 0.038 | 351 | 0.033 | 0.044 |
| 352 | 0.062 | 0.000 | 353 | 0.057 | 0.052 | 354 | 0.016 | 0.174 | 355 | 0.035 | 0.116 |
| 356 | –0.051 | –0.202 | 357 | 0.011 | 0.036 | 358 | 0.089 | 0.209 | 359 | –0.049 | –0.008 |
| 360 | –0.035 | 0.044 | 361 | 0.017 | –0.059 | 362 | 0.053 | –0.017 | 363 | 0.099 | 0.100 |
| 364 | 0.034 | –0.148 | 365 | –0.003 | –0.094 | 366 | –0.120 | 0.042 | 367 | –0.136 | –0.070 |
| 368 | –0.031 | 0.000 | 369 | –0.136 | 0.070 | 370 | –0.120 | –0.042 | 371 | –0.003 | 0.094 |
| 372 | 0.034 | 0.148 | 373 | 0.099 | –0.100 | 374 | 0.053 | 0.017 | 375 | 0.017 | 0.059 |
| 376 | –0.035 | –0.044 | 377 | –0.049 | 0.008 | 378 | 0.089 | –0.209 | 379 | 0.011 | –0.036 |
| 380 | –0.051 | 0.202 | 381 | 0.035 | –0.116 | 382 | 0.016 | –0.174 | 383 | 0.057 | –0.052 |
| 384 | 0.062 | 0.000 | 385 | 0.033 | –0.044 | 386 | –0.002 | –0.038 | 387 | –0.081 | 0.084 |
| 388 | 0.007 | –0.100 | 389 | –0.001 | –0.113 | 390 | –0.021 | –0.005 | 391 | 0.136 | –0.105 |
| 392 | 0.098 | –0.044 | 393 | 0.011 | –0.002 | 394 | –0.033 | 0.044 | 395 | –0.060 | 0.124 |
| 396 | 0.010 | 0.097 | 397 | 0.000 | –0.008 | 398 | 0.018 | –0.083 | 399 | –0.069 | 0.027 |

**Table I-25—Time domain representation of the DATA field: symbol 1of 6**

| ## | Re | Im | ## | Re | Im | ## | Re | Im | ## | Re | Im |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 400 | –0.139 | 0.050 | 401 | 0.004 | 0.014 | 402 | 0.011 | –0.100 | 403 | –0.097 | –0.020 |
| 404 | 0.062 | 0.081 | 405 | 0.124 | 0.139 | 406 | 0.104 | –0.015 | 407 | 0.173 | –0.140 |
| 408 | –0.040 | 0.006 | 409 | –0.133 | 0.009 | 410 | –0.002 | –0.043 | 411 | –0.047 | 0.092 |
| 412 | –0.109 | 0.082 | 413 | –0.024 | 0.010 | 414 | 0.096 | 0.019 | 415 | 0.019 | –0.023 |
| 416 | –0.087 | –0.049 | 417 | 0.002 | 0.058 | 418 | –0.021 | 0.228 | 419 | –0.103 | 0.023 |
| 420 | –0.019 | –0.175 | 421 | 0.018 | 0.132 | 422 | –0.071 | 0.160 | 423 | –0.153 | –0.062 |
| 424 | –0.107 | 0.028 | 425 | 0.055 | 0.140 | 426 | 0.070 | 0.103 | 427 | –0.056 | 0.025 |
| 428 | –0.043 | 0.002 | 429 | 0.016 | –0.118 | 430 | 0.026 | –0.071 | 431 | 0.033 | 0.177 |
| 432 | 0.020 | –0.021 | 433 | 0.035 | –0.088 | 434 | –0.008 | 0.101 | 435 | –0.035 | –0.010 |
| 436 | 0.065 | 0.030 | 437 | 0.092 | –0.034 | 438 | 0.032 | –0.123 | 439 | –0.018 | 0.092 |
| 440 | 0.000 | –0.006 | 441 | –0.006 | –0.056 | 442 | –0.019 | 0.040 | 443 | 0.053 | –0.131 |
| 444 | 0.022 | –0.133 | 445 | 0.104 | –0.032 | 446 | 0.163 | –0.045 | 447 | –0.105 | –0.030 |
| 448 | –0.110 | –0.069 | 449 | –0.008 | –0.092 | 450 | –0.049 | –0.043 | 451 | 0.085 | –0.017 |


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**Table I-25—Time domain representation of the DATA field: symbol 1of 6 *(continued)***

| ## | Re | Im | ## | Re | Im | ## | Re | Im | ## | Re | Im |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 452 | 0.090 | 0.063 | 453 | 0.015 | 0.153 | 454 | 0.049 | 0.094 | 455 | 0.011 | 0.034 |
| 456 | –0.012 | 0.012 | 457 | –0.015 | –0.017 | 458 | –0.061 | 0.031 | 459 | –0.070 | –0.040 |
| 460 | 0.011 | –0.109 | 461 | 0.037 | –0.060 | 462 | –0.003 | –0.178 | 463 | –0.007 | –0.128 |
| 464 | –0.059 | 0.100 | 465 | 0.004 | 0.014 | 466 | 0.011 | –0.100 | 467 | –0.097 | –0.020 |
| 468 | 0.062 | 0.081 | 469 | 0.124 | 0.139 | 470 | 0.104 | –0.015 | 471 | 0.173 | –0.140 |
| 472 | –0.040 | 0.006 | 473 | –0.133 | 0.009 | 474 | –0.002 | –0.043 | 475 | –0.047 | 0.092 |
| 476 | –0.109 | 0.082 | 477 | –0.024 | 0.010 | 478 | 0.096 | 0.019 | 479 | 0.019 | –0.023 |

**Table I-26—Time domain representation of the DATA field: symbol 2 of 6**

| ## | Re | Im | ## | Re | Im | ## | Re | Im | ## | Re | Im |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 480 | –0.058 | 0.016 | 481 | –0.096 | –0.045 | 482 | –0.110 | 0.003 | 483 | –0.070 | 0.216 |
| 484 | –0.040 | 0.059 | 485 | 0.010 | –0.056 | 486 | 0.034 | 0.065 | 487 | 0.117 | 0.033 |
| 488 | 0.078 | –0.133 | 489 | –0.043 | –0.146 | 490 | 0.158 | –0.071 | 491 | 0.254 | –0.021 |
| 492 | 0.068 | 0.117 | 493 | –0.044 | 0.114 | 494 | –0.035 | 0.041 | 495 | 0.085 | 0.070 |
| 496 | 0.120 | 0.010 | 497 | 0.057 | 0.055 | 498 | 0.063 | 0.188 | 499 | 0.091 | 0.149 |
| 500 | –0.017 | –0.039 | 501 | –0.078 | –0.075 | 502 | 0.049 | 0.079 | 503 | –0.014 | –0.007 |
| 504 | 0.030 | –0.027 | 505 | 0.080 | 0.054 | 506 | –0.186 | –0.067 | 507 | –0.039 | –0.027 |
| 508 | 0.043 | –0.072 | 509 | –0.092 | –0.089 | 510 | 0.029 | 0.105 | 511 | –0.144 | 0.003 |
| 512 | –0.069 | –0.041 | 513 | 0.132 | 0.057 | 514 | –0.126 | 0.070 | 515 | –0.031 | 0.109 |
| 516 | 0.161 | –0.009 | 517 | 0.056 | –0.046 | 518 | –0.004 | 0.028 | 519 | –0.049 | 0.000 |
| 520 | –0.078 | –0.005 | 521 | 0.015 | –0.087 | 522 | 0.149 | –0.104 | 523 | –0.021 | –0.051 |
| 524 | –0.154 | –0.106 | 525 | 0.024 | 0.030 | 526 | 0.046 | 0.123 | 527 | –0.004 | –0.098 |
| 528 | –0.061 | –0.128 | 529 | –0.024 | –0.038 | 530 | 0.066 | –0.048 | 531 | –0.067 | 0.027 |
| 532 | 0.054 | –0.050 | 533 | 0.171 | –0.049 | 534 | –0.108 | 0.132 | 535 | –0.161 | –0.019 |
| 536 | –0.070 | –0.072 | 537 | –0.177 | 0.049 | 538 | –0.172 | –0.050 | 539 | 0.051 | –0.075 |
| 540 | 0.122 | –0.057 | 541 | 0.009 | –0.044 | 542 | –0.012 | –0.021 | 543 | 0.004 | 0.009 |
| 544 | –0.030 | 0.081 | 545 | –0.096 | –0.045 | 546 | –0.110 | 0.003 | 547 | –0.070 | 0.216 |
| 548 | –0.040 | 0.059 | 549 | 0.010 | –0.056 | 550 | 0.034 | 0.065 | 551 | 0.117 | 0.033 |
| 552 | 0.078 | –0.133 | 553 | –0.043 | –0.146 | 554 | 0.158 | –0.071 | 555 | 0.254 | –0.021 |
| 556 | 0.068 | 0.117 | 557 | –0.044 | 0.114 | 558 | –0.035 | 0.041 | 559 | 0.085 | 0.070 |

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**Table I-27—Time domain representation of the DATA field: symbol 3 of 6**

| ## | Re | Im | ## | Re | Im | ## | Re | Im | ## | Re | Im |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 560 | 0.001 | 0.011 | 561 | –0.099 | –0.048 | 562 | 0.054 | –0.196 | 563 | 0.124 | 0.035 |
| 564 | 0.092 | 0.045 | 565 | –0.037 | –0.066 | 566 | –0.021 | –0.004 | 567 | 0.042 | –0.065 |
| 568 | 0.061 | 0.048 | 569 | 0.046 | 0.004 | 570 | –0.063 | –0.045 | 571 | –0.102 | 0.152 |
| 572 | –0.039 | –0.019 | 573 | –0.005 | –0.106 | 574 | 0.083 | 0.031 | 575 | 0.226 | 0.028 |
| 576 | 0.140 | –0.010 | 577 | –0.132 | –0.033 | 578 | –0.116 | 0.088 | 579 | 0.023 | 0.052 |
| 580 | –0.171 | –0.080 | 581 | –0.246 | –0.025 | 582 | –0.062 | –0.038 | 583 | –0.055 | –0.062 |
| 584 | –0.004 | –0.060 | 585 | 0.034 | 0.000 | 586 | –0.030 | 0.021 | 587 | 0.075 | –0.122 |
| 588 | 0.043 | –0.080 | 589 | –0.022 | 0.041 | 590 | 0.026 | 0.013 | 591 | –0.031 | –0.018 |
| 592 | 0.059 | 0.008 | 593 | 0.109 | 0.078 | 594 | 0.002 | 0.101 | 595 | –0.016 | 0.054 |
| 596 | –0.059 | 0.070 | 597 | 0.017 | 0.114 | 598 | 0.104 | –0.034 | 599 | –0.024 | –0.059 |
| 600 | –0.081 | 0.051 | 601 | –0.040 | –0.069 | 602 | –0.069 | 0.058 | 603 | –0.067 | 0.117 |
| 604 | 0.007 | –0.131 | 605 | 0.009 | 0.028 | 606 | 0.075 | 0.117 | 607 | 0.118 | 0.030 |
| 608 | –0.041 | 0.148 | 609 | 0.005 | 0.098 | 610 | 0.026 | 0.002 | 611 | –0.116 | 0.045 |
| 612 | –0.020 | 0.084 | 613 | 0.101 | 0.006 | 614 | 0.205 | –0.064 | 615 | 0.073 | –0.063 |
| 616 | –0.174 | –0.118 | 617 | –0.024 | 0.026 | 618 | –0.041 | 0.129 | 619 | –0.042 | –0.053 |
| 620 | 0.148 | –0.126 | 621 | –0.030 | –0.049 | 622 | –0.015 | –0.021 | 623 | 0.089 | –0.069 |
| 624 | –0.119 | 0.011 | 625 | –0.099 | –0.048 | 626 | 0.054 | –0.196 | 627 | 0.124 | 0.035 |
| 628 | 0.092 | 0.045 | 629 | –0.037 | –0.066 | 630 | –0.021 | –0.004 | 631 | 0.042 | –0.065 |
| 632 | 0.061 | 0.048 | 633 | 0.046 | 0.004 | 634 | –0.063 | –0.045 | 635 | –0.102 | 0.152 |
| 636 | –0.039 | –0.019 | 637 | –0.005 | –0.106 | 638 | 0.083 | 0.031 | 639 | 0.226 | 0.028 |

**Table I-28—Time domain representation of the DATA field: symbol 4 of 6**

| ## | Re | Im | ## | Re | Im | ## | Re | Im | ## | Re | Im |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 640 | 0.085 | –0.065 | 641 | 0.034 | –0.142 | 642 | 0.004 | –0.012 | 643 | 0.126 | –0.043 |
| 644 | 0.055 | 0.068 | 645 | –0.020 | 0.077 | 646 | 0.008 | –0.056 | 647 | –0.034 | 0.046 |
| 648 | –0.040 | –0.134 | 649 | –0.056 | –0.131 | 650 | 0.014 | 0.097 | 651 | 0.045 | –0.009 |
| 652 | –0.113 | –0.170 | 653 | –0.065 | –0.230 | 654 | 0.065 | –0.011 | 655 | 0.011 | 0.048 |
| 656 | –0.091 | –0.059 | 657 | –0.110 | 0.024 | 658 | 0.074 | –0.034 | 659 | 0.124 | 0.022 |
| 660 | –0.037 | 0.071 | 661 | 0.015 | 0.002 | 662 | 0.028 | 0.099 | 663 | –0.062 | 0.068 |
| 664 | 0.064 | 0.016 | 665 | 0.078 | 0.156 | 666 | 0.009 | 0.219 | 667 | 0.147 | 0.024 |
| 668 | 0.106 | 0.030 | 669 | –0.080 | 0.143 | 670 | –0.049 | –0.100 | 671 | –0.036 | –0.082 |
| 672 | –0.089 | 0.021 | 673 | –0.070 | –0.029 | 674 | –0.086 | 0.048 | 675 | –0.066 | –0.015 |



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**Table I-28—Time domain representation of the DATA field: symbol 4 of 6 *(continued)***

| ## | Re | Im | ## | Re | Im | ## | Re | Im | ## | Re | Im |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 676 | –0.024 | 0.002 | 677 | –0.030 | –0.023 | 678 | –0.032 | 0.020 | 679 | –0.002 | 0.212 |
| 680 | 0.158 | –0.024 | 681 | 0.141 | –0.119 | 682 | –0.146 | 0.058 | 683 | –0.155 | 0.083 |
| 684 | –0.002 | –0.030 | 685 | 0.018 | –0.129 | 686 | 0.012 | –0.018 | 687 | –0.008 | –0.037 |
| 688 | 0.031 | 0.040 | 689 | 0.023 | 0.097 | 690 | 0.014 | –0.039 | 691 | 0.050 | 0.019 |
| 692 | –0.072 | –0.141 | 693 | –0.023 | –0.051 | 694 | 0.024 | 0.099 | 695 | –0.127 | –0.116 |
| 696 | 0.094 | 0.102 | 697 | 0.183 | 0.098 | 698 | –0.040 | –0.020 | 699 | 0.065 | 0.077 |
| 700 | 0.088 | –0.147 | 701 | –0.039 | –0.059 | 702 | –0.057 | 0.124 | 703 | –0.077 | 0.020 |
| 704 | 0.030 | –0.120 | 705 | 0.034 | –0.142 | 706 | 0.004 | –0.012 | 707 | 0.126 | –0.043 |
| 708 | 0.055 | 0.068 | 709 | –0.020 | 0.077 | 710 | 0.008 | –0.056 | 711 | –0.034 | 0.046 |
| 712 | –0.040 | –0.134 | 713 | –0.056 | –0.131 | 714 | 0.014 | 0.097 | 715 | 0.045 | –0.009 |
| 716 | –0.113 | –0.170 | 717 | –0.065 | –0.230 | 718 | 0.065 | –0.011 | 719 | 0.011 | 0.048 |
| 720 | –0.026 | –0.021 | 721 | –0.002 | 0.041 | 722 | 0.001 | 0.071 | 723 | –0.037 | –0.117 |

**Table I-29—Time domain representation of the DATA field: symbol 5 of 6**

| ## | Re | Im | ## | Re | Im | ## | Re | Im | ## | Re | Im |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 724 | –0.106 | –0.062 | 725 | 0.002 | 0.057 | 726 | –0.008 | –0.011 | 727 | 0.019 | 0.072 |
| 728 | 0.016 | 0.059 | 729 | –0.065 | –0.077 | 730 | 0.142 | –0.062 | 731 | 0.087 | 0.025 |
| 732 | –0.003 | –0.103 | 733 | 0.107 | –0.152 | 734 | –0.054 | 0.036 | 735 | –0.030 | –0.003 |
| 736 | 0.058 | –0.020 | 737 | –0.028 | 0.007 | 738 | –0.027 | –0.099 | 739 | 0.049 | –0.075 |
| 740 | 0.174 | 0.031 | 741 | 0.134 | 0.156 | 742 | 0.060 | 0.077 | 743 | –0.010 | –0.022 |
| 744 | –0.084 | 0.040 | 745 | –0.074 | 0.011 | 746 | –0.163 | 0.054 | 747 | –0.052 | –0.008 |
| 748 | 0.076 | –0.042 | 749 | 0.043 | 0.101 | 750 | 0.058 | –0.018 | 751 | 0.003 | –0.090 |
| 752 | 0.059 | –0.018 | 753 | 0.023 | –0.031 | 754 | 0.007 | –0.017 | 755 | 0.066 | –0.017 |
| 756 | –0.135 | –0.098 | 757 | –0.056 | –0.081 | 758 | 0.089 | 0.154 | 759 | 0.120 | 0.122 |
| 760 | 0.102 | 0.001 | 761 | –0.141 | 0.102 | 762 | 0.006 | –0.011 | 763 | 0.057 | –0.039 |
| 764 | –0.059 | 0.066 | 765 | 0.132 | 0.111 | 766 | 0.012 | 0.114 | 767 | 0.047 | –0.106 |
| 768 | 0.160 | –0.099 | 769 | –0.076 | 0.084 | 770 | –0.049 | 0.073 | 771 | 0.005 | –0.086 |
| 772 | –0.052 | –0.108 | 773 | –0.073 | 0.129 | 774 | –0.129 | –0.034 | 775 | –0.153 | –0.111 |
| 776 | –0.193 | 0.098 | 777 | –0.107 | –0.068 | 778 | 0.004 | –0.009 | 779 | –0.039 | 0.024 |
| 780 | –0.054 | –0.079 | 781 | 0.024 | 0.084 | 782 | 0.052 | –0.002 | 783 | 0.028 | –0.044 |

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**Table I-29—Time domain representation of the DATA field: symbol 5 of 6 *(continued)***

| ## | Re | Im | ## | Re | Im | ## | Re | Im | ## | Re | Im |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 784 | 0.040 | 0.018 | 785 | –0.002 | 0.041 | 786 | 0.001 | 0.071 | 787 | –0.037 | –0.117 |
| 788 | –0.106 | –0.062 | 789 | 0.002 | 0.057 | 790 | –0.008 | –0.011 | 791 | 0.019 | 0.072 |
| 792 | 0.016 | 0.059 | 793 | –0.065 | –0.077 | 794 | 0.142 | –0.062 | 795 | 0.087 | 0.025 |
| 796 | –0.003 | –0.103 | 797 | 0.107 | –0.152 | 798 | –0.054 | 0.036 | 799 | –0.030 | –0.003 |

**Table I-30—Time domain representation of the DATA field: symbol 6 of 6**

| ## | Re | Im | ## | Re | Im | ## | Re | Im | ## | Re | Im |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 800 | 0.029 | –0.026 | 801 | –0.047 | 0.077 | 802 | –0.007 | –0.002 | 803 | 0.050 | –0.021 |
| 804 | 0.046 | –0.040 | 805 | –0.061 | –0.099 | 806 | –0.121 | 0.008 | 807 | 0.014 | 0.050 |
| 808 | 0.145 | 0.034 | 809 | 0.001 | –0.046 | 810 | –0.058 | –0.121 | 811 | 0.040 | 0.001 |
| 812 | –0.029 | 0.041 | 813 | 0.002 | –0.066 | 814 | 0.015 | –0.054 | 815 | 0.010 | –0.029 |
| 816 | 0.008 | –0.119 | 817 | –0.134 | 0.002 | 818 | 0.064 | 0.079 | 819 | 0.095 | –0.102 |
| 820 | –0.069 | –0.014 | 821 | 0.156 | 0.037 | 822 | 0.047 | –0.008 | 823 | –0.076 | 0.025 |
| 824 | 0.117 | –0.143 | 825 | 0.056 | –0.042 | 826 | 0.002 | 0.075 | 827 | –0.039 | –0.058 |
| 828 | –0.092 | 0.014 | 829 | –0.041 | 0.047 | 830 | –0.058 | 0.092 | 831 | 0.012 | 0.154 |
| 832 | 0.079 | 0.091 | 833 | –0.067 | 0.017 | 834 | –0.102 | –0.032 | 835 | 0.039 | 0.084 |
| 836 | –0.036 | 0.014 | 837 | –0.001 | –0.046 | 838 | 0.195 | 0.131 | 839 | 0.039 | 0.067 |
| 840 | –0.007 | 0.045 | 841 | 0.051 | 0.008 | 842 | –0.074 | –0.109 | 843 | –0.033 | 0.070 |
| 844 | –0.028 | 0.176 | 845 | –0.041 | 0.045 | 846 | 0.014 | –0.084 | 847 | 0.054 | –0.040 |
| 848 | 0.110 | –0.020 | 849 | 0.014 | –0.021 | 850 | 0.006 | 0.139 | 851 | 0.008 | 0.011 |
| 852 | –0.060 | –0.040 | 853 | 0.008 | 0.179 | 854 | 0.008 | 0.020 | 855 | 0.044 | –0.114 |
| 856 | 0.021 | –0.015 | 857 | –0.008 | –0.052 | 858 | 0.091 | –0.109 | 859 | –0.025 | –0.040 |
| 860 | –0.049 | 0.006 | 861 | –0.043 | –0.041 | 862 | –0.178 | –0.026 | 863 | –0.073 | –0.057 |
| 864 | 0.000 | –0.031 | 865 | –0.047 | 0.077 | 866 | –0.007 | –0.002 | 867 | 0.050 | –0.021 |
| 868 | 0.046 | –0.040 | 869 | –0.061 | –0.099 | 870 | –0.121 | 0.008 | 871 | 0.014 | 0.050 |
| 872 | 0.145 | 0.034 | 873 | 0.001 | –0.046 | 874 | –0.058 | –0.121 | 875 | 0.040 | 0.001 |
| 876 | –0.029 | 0.041 | 877 | 0.002 | –0.066 | 878 | 0.015 | –0.054 | 879 | 0.010 | –0.029 |
| 880 | 0.004 | –0.059 | | | | | | | | | |


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## I.2 Generating encoded DATA bits—LDPC example 1

### I.2.1 General

LDPC example 1 is similar to the BCC example. This example illustrates LDPC shortening, encoding, and puncturing of a single codeword.

Input TXVECTOR parameters for LDPC example 1:

- FEC_CODING = LDPC_CODING = 1 (LDPC encoder; not BCC)
- CH_BANDWIDTH = HT_CBW20 = 0 (CH_BANDWIDTH = 0 => 20 MHz)
- MCS = 4 (MCS = 4; 16-QAM; Coding rate = 3/4)
- Coding rate R = 3/4
- LENGTH = 100 octets (with 16-bit SERVICE field becomes 102 Octets = 816 bits to scramble and encode)
- STBC = 0 (STBC = 0 => OFF; m_STBC=1)

### I.2.2 The message for LDPC example 1

The message being encoded consists of the first 72 characters (shown in **bold** and including line breaks) of the well-known “Ode to Joy” by F. Schiller:

**Joy, bright spark of divinity,**
**Daughter of Elysium,**
**Fire-insired we trea**d
Thy sanctuary.
Thy magic power (M118)reunites
All that custom has divided,
All men become brothers
Under the sway of thy gentle wings.

NOTE 1—The typo in "Fire-insired" is deliberate.

The message is converted to ASCII, using LF (0x0A) for line breaks; then it is prepended with an appropriate MAC header, and an FCS is added. The resulting 100-octet PSDU is shown in Table I-31 (Message for LDPC example 1).

NOTE 2—The message for LDPC example 1 is identical to the message for the BCC example; in other words, the FCS field (octets 97–100) has the same value.

NOTE 3—The DurationID field (i.e., octets 3 and 4) remains 0x02E = 46 μs.

**Table I-31—Message for LDPC example 1**

| Octet ## | Value | Value | Value | Value | Value |
|---|---|---|---|---|---|
| 1...5 | 0x04 | 0x02 | 0x00 | 0x2E | 0x00 |
| 6...10 | 0x60 | 0x08 | 0xCD | 0x37 | 0xA6 |
| 11...15 | 0x00 | 0x20 | 0xD6 | 0x01 | 0x3C |
| 16...20 | 0xF1 | 0x00 | 0x60 | 0x08 | 0xAD |

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**Table I-31—Message for LDPC example 1 *(continued)***

| Octet ## | Value | Value | Value | Value | Value |
|---|---|---|---|---|---|
| 21...25 | 0x3B | 0xAF | 0x00 | 0x00 | 0x4A |
| 26...30 | 0x6F | 0x79 | 0x2C | 0x20 | 0x62 |
| 31...35 | 0x72 | 0x69 | 0x67 | 0x68 | 0x74 |
| 36...40 | 0x20 | 0x73 | 0x70 | 0x61 | 0x72 |
| 41...45 | 0x6B | 0x20 | 0x6F | 0x66 | 0x20 |
| 46...50 | 0x64 | 0x69 | 0x76 | 0x69 | 0x6E |
| 51...55 | 0x69 | 0x74 | 0x79 | 0x2C | 0x0A |
| 56...60 | 0x44 | 0x61 | 0x75 | 0x67 | 0x68 |
| 61...65 | 0x74 | 0x65 | 0x72 | 0x20 | 0x6F |
| 66...70 | 0x66 | 0x20 | 0x45 | 0x6C | 0x79 |
| 71...75 | 0x73 | 0x69 | 0x75 | 0x6D | 0x2C |
| 76...80 | 0x0A | 0x46 | 0x69 | 0x72 | 0x65 |
| 81...85 | 0x2D | 0x69 | 0x6E | 0x73 | 0x69 |
| 86...90 | 0x72 | 0x65 | 0x64 | 0x20 | 0x77 |
| 91...95 | 0x65 | 0x20 | 0x74 | 0x72 | 0x65 |
| 96...100 | 0x61 | 0x67 | 0x33 | 0x21 | 0xB6 |

### I.2.3 Prepending the SERVICE field for LDPC example 1

The transmitted message shown in Table I-31 (Message for LDPC example 1) contains 100 octets, or equivalently, 800 bits. The bits are prepended by the 16 SERVICE field bits (bits 0–15 in Table I-32 (DATA bits for LDPC example 1 before scrambling)), as defined in 19.3.11.2 (SERVICE field), but tail bits and padding bits are not appended as in the BCC example. The resulting 816 bits are shown in Table I-32 (DATA bits for LDPC example 1 before scrambling).

**Table I-32—DATA bits for LDPC example 1 before scrambling**

| Bit ## | Binary value B7 B0 | Binary value B15 B8 | Binary value B23 B16 | Hexadecimal value | Hexadecimal value | Hexadecimal value |
|---|---|---|---|---|---|---|
| 000–023 | 00000000 | 00000000 | 00000100 | 0x00 | 0x00 | 0x04 |
| 024–047 | 00000010 | 00000000 | 00101110 | 0x02 | 0x00 | 0x2E |
| 048–071 | 00000000 | 01100000 | 00001000 | 0x00 | 0x60 | 0x08 |
| 072–095 | 11001101 | 00110111 | 10100110 | 0xCD | 0x37 | 0xA6 |
| 096–119 | 00000000 | 00100000 | 11010110 | 0x00 | 0x20 | 0xD6 |
| 120–143 | 00000001 | 00111100 | 11110001 | 0x01 | 0x3C | 0xF1 |


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**Table I-32—DATA bits for LDPC example 1 before scrambling *(continued)***

| Bit ## | Binary value B7 B0 | Binary value B15 B8 | Binary value B23 B16 | Hexadecimal value | Hexadecimal value | Hexadecimal value |
|---|---|---|---|---|---|---|
| 144–167 | 00000000 | 01100000 | 00001000 | 0x00 | 0x60 | 0x08 |
| 168–191 | 10101101 | 00111011 | 10101111 | 0xAD | 0x3B | 0xAF |
| 192–215 | 00000000 | 00000000 | 01001010 | 0x00 | 0x00 | 0x4A |
| 216–239 | 01101111 | 01111001 | 00101100 | 0x6F | 0x79 | 0x2C |
| 240–263 | 00100000 | 01100010 | 01110010 | 0x20 | 0x62 | 0x72 |
| 264–287 | 01101001 | 01100111 | 01101000 | 0x69 | 0x67 | 0x68 |
| 288–311 | 01110100 | 00100000 | 01110011 | 0x74 | 0x20 | 0x73 |
| 312–335 | 01110000 | 01100001 | 01110010 | 0x70 | 0x61 | 0x72 |
| 336–359 | 01101011 | 00100000 | 01101111 | 0x6B | 0x20 | 0x6F |
| 360–383 | 01100110 | 00100000 | 01100100 | 0x66 | 0x20 | 0x64 |
| 384–407 | 01101001 | 01110110 | 01101001 | 0x69 | 0x76 | 0x69 |
| 408–431 | 01101110 | 01101001 | 01110100 | 0x6E | 0x69 | 0x74 |
| 432–455 | 01111001 | 00101100 | 00001010 | 0x79 | 0x2C | 0x0A |
| 456–479 | 01000100 | 01100001 | 01110101 | 0x44 | 0x61 | 0x75 |
| 480–503 | 01100111 | 01101000 | 01110100 | 0x67 | 0x68 | 0x74 |
| 504–527 | 01100101 | 01110010 | 00100000 | 0x65 | 0x72 | 0x20 |
| 528–551 | 01101111 | 01100110 | 00100000 | 0x6F | 0x66 | 0x20 |
| 552–575 | 01000101 | 01101100 | 01111001 | 0x45 | 0x6C | 0x79 |
| 576–599 | 01110011 | 01101001 | 01110101 | 0x73 | 0x69 | 0x75 |
| 600–623 | 01101101 | 00101100 | 00001010 | 0x6D | 0x2C | 0x0A |
| 624–647 | 01000110 | 01101001 | 01110010 | 0x46 | 0x69 | 0x72 |
| 648–671 | 01100101 | 00101101 | 01101001 | 0x65 | 0x2D | 0x69 |
| 672–695 | 01101110 | 01110011 | 01101001 | 0x6E | 0x73 | 0x69 |
| 696–719 | 01110010 | 01100101 | 01100100 | 0x72 | 0x65 | 0x64 |
| 720–743 | 00100000 | 01110111 | 01100101 | 0x20 | 0x77 | 0x65 |
| 744–767 | 00100000 | 01110100 | 01110010 | 0x20 | 0x74 | 0x72 |
| 768–791 | 01100101 | 01100001 | 01100111 | 0x65 | 0x61 | 0x67 |
| 792–815 | 00110011 | 00100001 | 10110110 | 0x33 | 0x21 | 0xB6 |

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### I.2.4 Scrambling LDPC example 1

The 816 bits are scrambled by the scrambler defined in 17.3.5.5 (PHY DATA scrambler and descrambler). The initial state of the scrambler is the state 1011101 binary (0x5D). The scrambled sequence is given in Table I-33 (DATA bits for LDPC example 1 after scrambling).

NOTE—The scrambled entries for the correct FCS field value are given in bits 784–815.

**Table I-33—DATA bits for LDPC example 1 after scrambling**

| Bit ## | Binary value B0 B7 | Binary value B8 B15 | Binary value B16 B23 | Hexadecimal value | Hexadecimal value | Hexadecimal value |
|---|---|---|---|---|---|---|
| 000–023 | 01101100 | 00011001 | 10001001 | 0x6C | 0x19 | 0x89 |
| 024–047 | 10001111 | 01101000 | 00100001 | 0x8F | 0x68 | 0x21 |
| 048–071 | 11110100 | 10100101 | 01100001 | 0xF4 | 0xA5 | 0x61 |
| 072–095 | 01001111 | 11010111 | 10101110 | 0x4F | 0xD7 | 0xAE |
| 096–119 | 00100100 | 00001100 | 11110011 | 0x24 | 0x0C | 0xF3 |
| 120–143 | 00111010 | 11100100 | 10111100 | 0x3A | 0xE4 | 0xBC |
| 144–167 | 01010011 | 10011000 | 11000000 | 0x53 | 0x98 | 0xC0 |
| 168–191 | 00011110 | 00110101 | 10110011 | 0x1E | 0x35 | 0xB3 |
| 192–215 | 11100011 | 11111000 | 00100101 | 0xE3 | 0xF8 | 0x25 |
| 216–239 | 01100000 | 11010110 | 00100101 | 0x60 | 0xD6 | 0x25 |
| 240–263 | 00110101 | 00110011 | 11111110 | 0x35 | 0x33 | 0xFE |
| 264–287 | 11110000 | 01000001 | 00101011 | 0xF0 | 0x41 | 0x2B |
| 288–311 | 10001111 | 01010011 | 00011100 | 0x8F | 0x53 | 0x1C |
| 312–335 | 10000011 | 01000001 | 10111110 | 0x83 | 0x41 | 0xBE |
| 336–359 | 00111001 | 00101000 | 01100110 | 0x39 | 0x28 | 0x66 |
| 360–383 | 01000100 | 01100110 | 11001101 | 0x44 | 0x66 | 0xCD |
| 384–407 | 11110110 | 10100011 | 11011000 | 0xF6 | 0xA3 | 0xD8 |
| 408–431 | 00001101 | 11010100 | 10000001 | 0x0D | 0xD4 | 0x81 |
| 432–455 | 00111011 | 00101111 | 11011111 | 0x3B | 0x2F | 0xDF |
| 456–479 | 11000011 | 01011000 | 11110111 | 0xC3 | 0x58 | 0xF7 |
| 480–503 | 11000110 | 01010010 | 11101011 | 0xC6 | 0x52 | 0xEB |
| 504–527 | 01110000 | 10001111 | 10011110 | 0x70 | 0x8F | 0x9E |
| 528–551 | 01101010 | 10010000 | 10000001 | 0x6A | 0x90 | 0x81 |
| 552–575 | 11111101 | 01111100 | 10101001 | 0xFD | 0x7C | 0xA9 |
| 576–599 | 11010001 | 01010101 | 00010010 | 0xD1 | 0x55 | 0x12 |
| 600–623 | 00000100 | 01110100 | 11011001 | 0x04 | 0x74 | 0xD9 |
| 624–647 | 11101001 | 00111011 | 11001101 | 0xE9 | 0x3B | 0xCD |


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**Table I-33—DATA bits for LDPC example 1 after scrambling *(continued)***

| Bit ## | Binary value B0 B7 | Binary value B8 B15 | Binary value B16 B23 | Hexadecimal value | Hexadecimal value | Hexadecimal value |
|---|---|---|---|---|---|---|
| 648–671 | 10010011 | 10001101 | 01111011 | 0x93 | 0x8D | 0x7B |
| 672–695 | 01111100 | 01110000 | 00000010 | 0x7C | 0x70 | 0x02 |
| 696–719 | 00100000 | 10011001 | 10100001 | 0x20 | 0x99 | 0xA1 |
| 720–743 | 01111101 | 10001010 | 00100111 | 0x7D | 0x8A | 0x27 |
| 744–767 | 00010111 | 00111001 | 00010101 | 0x17 | 0x39 | 0x15 |
| 768–791 | 10100000 | 11101100 | 10010101 | 0xA0 | 0xEC | 0x95 |
| 792–815 | 00010110 | 10010001 | 00010000 | 0x16 | 0x91 | 0x10 |

## I.2.5 Inserting shortening bits for LDPC example 1

The equations of 19.3.11.7.5 (LDPC PPDU encoding process) are solved to calculate the following derived parameters for LDPC example 1 from the input TXVECTOR parameters:

— $N_{CW} = 1$ (number of codewords)
— $L_{LDPC} = 1944$ (size of codeword)
— $N_{CBPS} = 208$ (number of coded bits per symbol)
— $N_{avbits} = 1248$ (number of available bits)
— $N_{shrt} = 642$ (number of bits to be shortened)
— $N_{punc} = 54$ (number of bits to be punctured)
— $N_{SYM} = 6$ (number of OFDM symbols)
— $N_{rep} = 0$ (number of bits to be repeated)

The results of applying shortening bits, as prescribed in paragraph (c) of 19.3.11.7.5 (LDPC PPDU encoding process), is given in Table I-34 (DATA bits for LDPC example 1 after insertion of shortening bits).

NOTE—$N_{shrt} = 642$ shortening bits have been inserted as 0s in bits 816–1457.

**Table I-34—DATA bits for LDPC example 1 after insertion of shortening bits**

| Bit ## | Binary value B0 B7 | Binary value B8 B15 | Binary value B16 B23 | Hexadecimal value | Hexadecimal value | Hexadecimal value |
|---|---|---|---|---|---|---|
| 0000–0023 | 01101100 | 00011001 | 10001001 | 0x6C | 0x19 | 0x89 |
| 0024–0047 | 10001111 | 01101000 | 00100001 | 0x8F | 0x68 | 0x21 |
| 0048–0071 | 11110100 | 10100101 | 01100001 | 0xF4 | 0xA5 | 0x61 |
| 0072–0095 | 01001111 | 11010111 | 10101110 | 0x4F | 0xD7 | 0xAE |
| 0096–0119 | 00100100 | 00001100 | 11110011 | 0x24 | 0x0C | 0xF3 |
| 0120–0143 | 00111010 | 11100100 | 10111100 | 0x3A | 0xE4 | 0xBC |
| 0144–0167 | 01010011 | 10011000 | 11000000 | 0x53 | 0x98 | 0xC0 |

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**Table I-34—DATA bits for LDPC example 1 after insertion of shortening bits *(continued)***

| Bit ## | Binary value B0 B7 | Binary value B8 B15 | Binary value B16 B23 | Hexadecimal value | Hexadecimal value | Hexadecimal value |
|---|---|---|---|---|---|---|
| 0168–0191 | 00011110 | 00110101 | 10110011 | 0x1E | 0x35 | 0xB3 |
| 0192–0215 | 11100011 | 11111000 | 00100101 | 0xE3 | 0xF8 | 0x25 |
| 0216–0239 | 01100000 | 11010110 | 00100101 | 0x60 | 0xD6 | 0x25 |
| 0240–0263 | 00110101 | 00110011 | 11111110 | 0x35 | 0x33 | 0xFE |
| 0264–0287 | 11110000 | 01000001 | 00101011 | 0xF0 | 0x41 | 0x2B |
| 0288–0311 | 10001111 | 01010011 | 00011100 | 0x8F | 0x53 | 0x1C |
| 0312–0335 | 10000011 | 01000001 | 10111110 | 0x83 | 0x41 | 0xBE |
| 0336–0359 | 00111001 | 00101000 | 01100110 | 0x39 | 0x28 | 0x66 |
| 0360–0383 | 01000100 | 01100110 | 11001101 | 0x44 | 0x66 | 0xCD |
| 0384–0407 | 11110110 | 10100011 | 11011000 | 0xF6 | 0xA3 | 0xD8 |
| 0408–0431 | 00001101 | 11010100 | 10000001 | 0x0D | 0xD4 | 0x81 |
| 0432–0455 | 00111011 | 00101111 | 11011111 | 0x3B | 0x2F | 0xDF |
| 0456–0479 | 11000011 | 01011000 | 11110111 | 0xC3 | 0x58 | 0xF7 |
| 0480–0503 | 11000110 | 01010010 | 11101011 | 0xC6 | 0x52 | 0xEB |
| 0504–0527 | 01110000 | 10001111 | 10011110 | 0x70 | 0x8F | 0x9E |
| 0528–0551 | 01101010 | 10010000 | 10000001 | 0x6A | 0x90 | 0x81 |
| 0552–0575 | 11111101 | 01111100 | 10101001 | 0xFD | 0x7C | 0xA9 |
| 0576–0599 | 11010001 | 01010101 | 00010010 | 0xD1 | 0x55 | 0x12 |
| 0600–0623 | 00000100 | 01110100 | 11011001 | 0x04 | 0x74 | 0xD9 |
| 0624–0647 | 11101001 | 00111011 | 11001101 | 0xE9 | 0x3B | 0xCD |
| 0648–0671 | 10010011 | 10001101 | 01111011 | 0x93 | 0x8D | 0x7B |
| 0672–0695 | 01111100 | 01110000 | 00000010 | 0x7C | 0x70 | 0x02 |
| 0696–0719 | 00100000 | 10011001 | 10100001 | 0x20 | 0x99 | 0xA1 |
| 0720–0743 | 01111101 | 10001010 | 00100111 | 0x7D | 0x8A | 0x27 |
| 0744–0767 | 00010111 | 00111001 | 00010101 | 0x17 | 0x39 | 0x15 |
| 0768–0791 | 10100000 | 11101100 | 10010101 | 0xA0 | 0xEC | 0x95 |
| 0792–0815 | 00010110 | 10010001 | 00010000 | 0x16 | 0x91 | 0x10 |
| 0816–0839 | 00000000 | 00000000 | 00000000 | 0x00 | 0x00 | 0x00 |
| 0840–0863 | 00000000 | 00000000 | 00000000 | 0x00 | 0x00 | 0x00 |
| 0864–0887 | 00000000 | 00000000 | 00000000 | 0x00 | 0x00 | 0x00 |
| 0888–0911 | 00000000 | 00000000 | 00000000 | 0x00 | 0x00 | 0x00 |
| 0912–0935 | 00000000 | 00000000 | 00000000 | 0x00 | 0x00 | 0x00 |


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**Table I-34—DATA bits for LDPC example 1 after insertion of shortening bits *(continued)***

| Bit ## | Binary value B0 B7 | Binary value B8 B15 | Binary value B16 B23 | Hexadecimal value | Hexadecimal value | Hexadecimal value |
|---|---|---|---|---|---|---|
| 0936–0959 | 00000000 | 00000000 | 00000000 | 0x00 | 0x00 | 0x00 |
| 0960–0983 | 00000000 | 00000000 | 00000000 | 0x00 | 0x00 | 0x00 |
| 0984–1007 | 00000000 | 00000000 | 00000000 | 0x00 | 0x00 | 0x00 |
| 1008–1031 | 00000000 | 00000000 | 00000000 | 0x00 | 0x00 | 0x00 |
| 1032–1055 | 00000000 | 00000000 | 00000000 | 0x00 | 0x00 | 0x00 |
| 1056–1079 | 00000000 | 00000000 | 00000000 | 0x00 | 0x00 | 0x00 |
| 1080–1103 | 00000000 | 00000000 | 00000000 | 0x00 | 0x00 | 0x00 |
| 1104–1127 | 00000000 | 00000000 | 00000000 | 0x00 | 0x00 | 0x00 |
| 1128–1151 | 00000000 | 00000000 | 00000000 | 0x00 | 0x00 | 0x00 |
| 1152–1175 | 00000000 | 00000000 | 00000000 | 0x00 | 0x00 | 0x00 |
| 1176–1199 | 00000000 | 00000000 | 00000000 | 0x00 | 0x00 | 0x00 |
| 1200–1223 | 00000000 | 00000000 | 00000000 | 0x00 | 0x00 | 0x00 |
| 1224–1247 | 00000000 | 00000000 | 00000000 | 0x00 | 0x00 | 0x00 |
| 1248–1271 | 00000000 | 00000000 | 00000000 | 0x00 | 0x00 | 0x00 |
| 1272–1295 | 00000000 | 00000000 | 00000000 | 0x00 | 0x00 | 0x00 |
| 1296–1319 | 00000000 | 00000000 | 00000000 | 0x00 | 0x00 | 0x00 |
| 1320–1343 | 00000000 | 00000000 | 00000000 | 0x00 | 0x00 | 0x00 |
| 1344–1367 | 00000000 | 00000000 | 00000000 | 0x00 | 0x00 | 0x00 |
| 1368–1391 | 00000000 | 00000000 | 00000000 | 0x00 | 0x00 | 0x00 |
| 1392–1415 | 00000000 | 00000000 | 00000000 | 0x00 | 0x00 | 0x00 |
| 1416–1439 | 00000000 | 00000000 | 00000000 | 0x00 | 0x00 | 0x00 |
| 1440–1457 | 00000000 | 00000000 | 00 - - - - - - | 0x00 | 0x00 | 0x0- |

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## I.2.6 Encoding data for LDPC example 1

The DATA with shortening bits are LDPC encoded as a single ($N_{CW}$=1) codeword ($L_{LDPC}$=1944; R=3/4) as prescribed by paragraph (c) of 19.3.11.7.5 (LDPC PPDU encoding process). The results are given in Table I-35 (DATA bits for LDPC example 1 after LDPC encoding).

NOTE—The LDPC encoder appends 486 bits (i.e., bits 1458–1943) after the shortening bits.

**Table I-35—DATA bits for LDPC example 1 after LDPC encoding**

| Bit ## | Binary value B0 B7 | Binary value B8 B15 | Binary value B16 B23 | Hexadecimal value | Hexadecimal value | Hexadecimal value |
|---|---|---|---|---|---|---|
| 0000–0023 | 01101100 | 00011001 | 10001001 | 0x6C | 0x19 | 0x89 |
| 0024–0047 | 10001111 | 01101000 | 00100001 | 0x8F | 0x68 | 0x21 |
| 0048–0071 | 11110100 | 10100101 | 01100001 | 0xF4 | 0xA5 | 0x61 |
| 0072–0095 | 01001111 | 11010111 | 10101110 | 0x4F | 0xD7 | 0xAE |
| 0096–0119 | 00100100 | 00001100 | 11110011 | 0x24 | 0x0C | 0xF3 |
| 0120–0143 | 00111010 | 11100100 | 10111100 | 0x3A | 0xE4 | 0xBC |
| 0144–0167 | 01010011 | 10011000 | 11000000 | 0x53 | 0x98 | 0xC0 |
| 0168–0191 | 00011110 | 00110101 | 10110011 | 0x1E | 0x35 | 0xB3 |
| 0192–0215 | 11100011 | 11111000 | 00100101 | 0xE3 | 0xF8 | 0x25 |
| 0216–0239 | 01100000 | 11010110 | 00100101 | 0x60 | 0xD6 | 0x25 |
| 0240–0263 | 00110101 | 00110011 | 11111110 | 0x35 | 0x33 | 0xFE |
| 0264–0287 | 11110000 | 01000001 | 00101011 | 0xF0 | 0x41 | 0x2B |
| 0288–0311 | 10001111 | 01010011 | 00011100 | 0x8F | 0x53 | 0x1C |
| 0312–0335 | 10000011 | 01000001 | 10111110 | 0x83 | 0x41 | 0xBE |
| 0336–0359 | 00111001 | 00101000 | 01100110 | 0x39 | 0x28 | 0x66 |
| 0360–0383 | 01000100 | 01100110 | 11001101 | 0x44 | 0x66 | 0xCD |
| 0384–0407 | 11110110 | 10100011 | 11011000 | 0xF6 | 0xA3 | 0xD8 |
| 0408–0431 | 00001101 | 11010100 | 10000001 | 0x0D | 0xD4 | 0x81 |
| 0432–0455 | 00111011 | 00101111 | 11011111 | 0x3B | 0x2F | 0xDF |
| 0456–0479 | 11000011 | 01011000 | 11110111 | 0xC3 | 0x58 | 0xF7 |
| 0480–0503 | 11000110 | 01010010 | 11101011 | 0xC6 | 0x52 | 0xEB |
| 0504–0527 | 01110000 | 10001111 | 10011110 | 0x70 | 0x8F | 0x9E |
| 0528–0551 | 01101010 | 10010000 | 10000001 | 0x6A | 0x90 | 0x81 |
| 0552–0575 | 11111101 | 01111100 | 10101001 | 0xFD | 0x7C | 0xA9 |
| 0576–0599 | 11010001 | 01010101 | 00010010 | 0xD1 | 0x55 | 0x12 |
| 0600–0623 | 00000100 | 01110100 | 11011001 | 0x04 | 0x74 | 0xD9 |
| 0624–0647 | 11101001 | 00111011 | 11001101 | 0xE9 | 0x3B | 0xCD |


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**Table I-35—DATA bits for LDPC example 1 after LDPC encoding *(continued)***

| Bit ## | Binary value B0 B7 | Binary value B8 B15 | Binary value B16 B23 | Hexadecimal value | Hexadecimal value | Hexadecimal value |
|---|---|---|---|---|---|---|
| 0648–0671 | 10010011 | 10001101 | 01111011 | 0x93 | 0x8D | 0x7B |
| 0672–0695 | 01111100 | 01110000 | 00000010 | 0x7C | 0x70 | 0x02 |
| 0696–0719 | 00100000 | 10011001 | 10100001 | 0x20 | 0x99 | 0xA1 |
| 0720–0743 | 01111101 | 10001010 | 00100111 | 0x7D | 0x8A | 0x27 |
| 0744–0767 | 00010111 | 00111001 | 00010101 | 0x17 | 0x39 | 0x15 |
| 0768–0791 | 10100000 | 11101100 | 10010101 | 0xA0 | 0xEC | 0x95 |
| 0792–0815 | 00010110 | 10010001 | 00010000 | 0x16 | 0x91 | 0x10 |
| 0816–0839 | 00000000 | 00000000 | 00000000 | 0x00 | 0x00 | 0x00 |
| 0840–0863 | 00000000 | 00000000 | 00000000 | 0x00 | 0x00 | 0x00 |
| 0864–0887 | 00000000 | 00000000 | 00000000 | 0x00 | 0x00 | 0x00 |
| 0888–0911 | 00000000 | 00000000 | 00000000 | 0x00 | 0x00 | 0x00 |
| 0912–0935 | 00000000 | 00000000 | 00000000 | 0x00 | 0x00 | 0x00 |
| 0936–0959 | 00000000 | 00000000 | 00000000 | 0x00 | 0x00 | 0x00 |
| 0960–0983 | 00000000 | 00000000 | 00000000 | 0x00 | 0x00 | 0x00 |
| 0984–1007 | 00000000 | 00000000 | 00000000 | 0x00 | 0x00 | 0x00 |
| 1008–1031 | 00000000 | 00000000 | 00000000 | 0x00 | 0x00 | 0x00 |
| 1032–1055 | 00000000 | 00000000 | 00000000 | 0x00 | 0x00 | 0x00 |
| 1056–1079 | 00000000 | 00000000 | 00000000 | 0x00 | 0x00 | 0x00 |
| 1080–1103 | 00000000 | 00000000 | 00000000 | 0x00 | 0x00 | 0x00 |
| 1104–1127 | 00000000 | 00000000 | 00000000 | 0x00 | 0x00 | 0x00 |
| 1128–1151 | 00000000 | 00000000 | 00000000 | 0x00 | 0x00 | 0x00 |
| 1152–1175 | 00000000 | 00000000 | 00000000 | 0x00 | 0x00 | 0x00 |
| 1176–1199 | 00000000 | 00000000 | 00000000 | 0x00 | 0x00 | 0x00 |
| 1200–1223 | 00000000 | 00000000 | 00000000 | 0x00 | 0x00 | 0x00 |
| 1224–1247 | 00000000 | 00000000 | 00000000 | 0x00 | 0x00 | 0x00 |
| 1248–1271 | 00000000 | 00000000 | 00000000 | 0x00 | 0x00 | 0x00 |
| 1272–1295 | 00000000 | 00000000 | 00000000 | 0x00 | 0x00 | 0x00 |
| 1296–1319 | 00000000 | 00000000 | 00000000 | 0x00 | 0x00 | 0x00 |
| 1320–1343 | 00000000 | 00000000 | 00000000 | 0x00 | 0x00 | 0x00 |
| 1344–1367 | 00000000 | 00000000 | 00000000 | 0x00 | 0x00 | 0x00 |
| 1368–1391 | 00000000 | 00000000 | 00000000 | 0x00 | 0x00 | 0x00 |
| 1392–1415 | 00000000 | 00000000 | 00000000 | 0x00 | 0x00 | 0x00 |
| 1416–1439 | 00000000 | 00000000 | 00000000 | 0x00 | 0x00 | 0x00 |

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**Table I-35—DATA bits for LDPC example 1 after LDPC encoding *(continued)***

| Bit ## | Binary value B0 B7 | Binary value B8 B15 | Binary value B16 B23 | Hexadecimal value | Hexadecimal value | Hexadecimal value |
|---|---|---|---|---|---|---|
| 1440–1463 | 00000000 | 00000000 | 00100110 | 0x00 | 0x00 | 0x26 |
| 1464–1487 | 00111101 | 10101001 | 10011100 | 0x3D | 0xA9 | 0x9C |
| 1488–1511 | 01000000 | 11010111 | 10110010 | 0x40 | 0xD7 | 0xB2 |
| 1512–1535 | 10000110 | 11100011 | 10111111 | 0x86 | 0xE3 | 0xBF |
| 1536–1559 | 01000011 | 10100101 | 11011001 | 0x43 | 0xA5 | 0xD9 |
| 1560–1583 | 00001101 | 00000110 | 11010110 | 0x0D | 0x06 | 0xD6 |
| 1584–1607 | 01100000 | 11110100 | 00011111 | 0x60 | 0xF4 | 0x1F |
| 1608–1631 | 00110001 | 00001100 | 00010011 | 0x31 | 0x0C | 0x13 |
| 1632–1655 | 01110110 | 00001111 | 10011111 | 0x76 | 0x0F | 0x9F |
| 1656–1679 | 11011010 | 10011111 | 10101001 | 0xDA | 0x9F | 0xA9 |
| 1680–1703 | 01110100 | 01011001 | 11011100 | 0x74 | 0x59 | 0xDC |
| 1704–1727 | 10001001 | 11110010 | 11100010 | 0x89 | 0xF2 | 0xE2 |
| 1728–1751 | 11011000 | 01101000 | 10100001 | 0xD8 | 0x68 | 0xA1 |
| 1752–1775 | 01100011 | 00011101 | 10100101 | 0x63 | 0x1D | 0xA5 |
| 1776–1799 | 10100110 | 10000000 | 11010001 | 0xA6 | 0x80 | 0xD1 |
| 1800–1823 | 10001001 | 01010111 | 11011100 | 0x89 | 0x57 | 0xDC |
| 1824–1847 | 10110011 | 01011101 | 00110011 | 0xB3 | 0x5D | 0x33 |
| 1848–1871 | 01110000 | 11011100 | 10110010 | 0x70 | 0xDC | 0xB2 |
| 1872–1895 | 11110110 | 00111001 | 00111101 | 0xF6 | 0x39 | 0x3D |
| 1896–1919 | 00100011 | 10011011 | 00110110 | 0x23 | 0x9B | 0x36 |
| 1920–1943 | 00111110 | 00010101 | 00010001 | 0x3E | 0x15 | 0x11 |

## I.2.7 Removing shortening bits and puncturing for LDPC example 1

The shortening bits, applied before LDPC encoding, are now removed as prescribed in paragraph (c) of 19.3.11.7.5 (LDPC PPDU encoding process). Finally, either puncturing is applied as described in paragraph (d) of the same subclause, or the copying of repeated bits is applied as described in paragraph (e) of the same subclause. In LDPC example 1, because $N_{punc}$ = 54 is nonzero and $N_{rep}$ = 0, puncturing is prescribed and completes the LDPC encoding process.

The results are given in Table I-36 (DATA bits after puncturing and removal of shortening bits).

NOTE—The $N_{shrt}$ = 642 shortening bits have been removed, and the $N_{punc}$ = 54 bits have been punctured from Table I-35 (DATA bits for LDPC example 1 after LDPC encoding) to produce bits 816–1247 of Table I-36 (DATA bits after puncturing and removal of shortening bits).


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**Table I-36—DATA bits after puncturing and removal of shortening bits**

| Bit ## | Binary value B0 B7 | Binary value B8 B15 | Binary value B16 B23 | Hexadecimal value | Hexadecimal value | Hexadecimal value |
|---|---|---|---|---|---|---|
| 0000–0023 | 01101100 | 00011001 | 10001001 | 0x6C | 0x19 | 0x89 |
| 0024–0047 | 10001111 | 01101000 | 00100001 | 0x8F | 0x68 | 0x21 |
| 0048–0071 | 11110100 | 10100101 | 01100001 | 0xF4 | 0xA5 | 0x61 |
| 0072–0095 | 01001111 | 11010111 | 10101110 | 0x4F | 0xD7 | 0xAE |
| 0096–0119 | 00100100 | 00001100 | 11110011 | 0x24 | 0x0C | 0xF3 |
| 0120–0143 | 00111010 | 11100100 | 10111100 | 0x3A | 0xE4 | 0xBC |
| 0144–0167 | 01010011 | 10011000 | 11000000 | 0x53 | 0x98 | 0xC0 |
| 0168–0191 | 00011110 | 00110101 | 10110011 | 0x1E | 0x35 | 0xB3 |
| 0192–0215 | 11100011 | 11111000 | 00100101 | 0xE3 | 0xF8 | 0x25 |
| 0216–0239 | 01100000 | 11010110 | 00100101 | 0x60 | 0xD6 | 0x25 |
| 0240–0263 | 00110101 | 00110011 | 11111110 | 0x35 | 0x33 | 0xFE |
| 0264–0287 | 11110000 | 01000001 | 00101011 | 0xF0 | 0x41 | 0x2B |
| 0288–0311 | 10001111 | 01010011 | 00011100 | 0x8F | 0x53 | 0x1C |
| 0312–0335 | 10000011 | 01000001 | 10111110 | 0x83 | 0x41 | 0xBE |
| 0336–0359 | 00111001 | 00101000 | 01100110 | 0x39 | 0x28 | 0x66 |
| 0360–0383 | 01000100 | 01100110 | 11001101 | 0x44 | 0x66 | 0xCD |
| 0384–0407 | 11110110 | 10100011 | 11011000 | 0xF6 | 0xA3 | 0xD8 |
| 0408–0431 | 00001101 | 11010100 | 10000001 | 0x0D | 0xD4 | 0x81 |
| 0432–0455 | 00111011 | 00101111 | 11011111 | 0x3B | 0x2F | 0xDF |
| 0456–0479 | 11000011 | 01011000 | 11110111 | 0xC3 | 0x58 | 0xF7 |
| 0480–0503 | 11000110 | 01010010 | 11101011 | 0xC6 | 0x52 | 0xEB |
| 0504–0527 | 01110000 | 10001111 | 10011110 | 0x70 | 0x8F | 0x9E |
| 0528–0551 | 01101010 | 10010000 | 10000001 | 0x6A | 0x90 | 0x81 |
| 0552–0575 | 11111101 | 01111100 | 10101001 | 0xFD | 0x7C | 0xA9 |
| 0576–0599 | 11010001 | 01010101 | 00010010 | 0xD1 | 0x55 | 0x12 |
| 0600–0623 | 00000100 | 01110100 | 11011001 | 0x04 | 0x74 | 0xD9 |
| 0624–0647 | 11101001 | 00111011 | 11001101 | 0xE9 | 0x3B | 0xCD |
| 0648–0671 | 10010011 | 10001101 | 01111011 | 0x93 | 0x8D | 0x7B |
| 0672–0695 | 01111100 | 01110000 | 00000010 | 0x7C | 0x70 | 0x02 |
| 0696–0719 | 00100000 | 10011001 | 10100001 | 0x20 | 0x99 | 0xA1 |
| 0720–0743 | 01111101 | 10001010 | 00100111 | 0x7D | 0x8A | 0x27 |
| 0744–0767 | 00010111 | 00111001 | 00010101 | 0x17 | 0x39 | 0x15 |
| 0768–0791 | 10100000 | 11101100 | 10010101 | 0xA0 | 0xEC | 0x95 |

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**Table I-36—DATA bits after puncturing and removal of shortening bits *(continued)***

| Bit ## | Binary value B0 B7 | Binary value B8 B15 | Binary value B16 B23 | Hexadecimal value | Hexadecimal value | Hexadecimal value |
|---|---|---|---|---|---|---|
| 0792–0815 | 00010110 | 10010001 | 00010000 | 0x16 | 0x91 | 0x10 |
| 0816–0839 | 10011000 | 11110110 | 10100110 | 0x98 | 0xF6 | 0xA6 |
| 0840–0863 | 01110001 | 00000011 | 01011110 | 0x71 | 0x03 | 0x5E |
| 0864–0887 | 11001010 | 00011011 | 10001110 | 0xCA | 0x1B | 0x8E |
| 0888–0911 | 11111101 | 00001110 | 10010111 | 0xFD | 0x0E | 0x97 |
| 0912–0935 | 01100100 | 00110100 | 00011011 | 0x64 | 0x34 | 0x1B |
| 0936–0959 | 01011001 | 10000011 | 11010000 | 0x59 | 0x83 | 0xD0 |
| 0960–0983 | 01111100 | 11000100 | 00110000 | 0x7C | 0xC4 | 0x30 |
| 0984–1007 | 01001101 | 11011000 | 00111110 | 0x4D | 0xD8 | 0x3E |
| 1008–1031 | 01111111 | 01101010 | 01111110 | 0x7F | 0x6A | 0x7E |
| 1032–1055 | 10100101 | 11010001 | 01100111 | 0xA5 | 0xD1 | 0x67 |
| 1056–1079 | 01110010 | 00100111 | 11001011 | 0x72 | 0x27 | 0xCB |
| 1080–1103 | 10001011 | 01100001 | 10100010 | 0x8B | 0x61 | 0xA2 |
| 1104–1127 | 10000101 | 10001100 | 01110110 | 0x85 | 0x8C | 0x76 |
| 1128–1151 | 10010110 | 10011010 | 00000011 | 0x96 | 0x9A | 0x03 |
| 1152–1175 | 01000110 | 00100101 | 01011111 | 0x46 | 0x25 | 0x5F |
| 1176–1199 | 01110010 | 11001101 | 01110100 | 0x72 | 0xCD | 0x74 |
| 1200–1223 | 11001101 | 11000011 | 01110010 | 0xCD | 0xC3 | 0x72 |
| 1224–1247 | 11001011 | 11011000 | 11100100 | 0xCB | 0xD8 | 0xE4 |

## I.3 Generating encoded DATA bits—LDPC example 2

### I.3.1 General

LDPC example 2 exercises the alternative branches of the LDPC encoding procedure not exercised in LDPC example 1. Example 2 also exhibits LDPC shortening, encoding, and padding by repetition and employs multiple codewords and diversifies the TXVECTOR parameters—all without making the length of this example cumbersome.

The length of the text of the message is increased by 40 octets, from 72 characters to 112 characters, in order to illustrate padding (rather than puncturing) and encoding of multiple codewords.

Input TXVECTOR parameters for LDPC example 2:

- FEC_CODING = LDPC_CODING = 1 (LDPC encoder; not BCC)
- CH_BANDWIDTH = HT_CBW40 = 1 (CH_BANDWIDTH = 1 => 40 MHz)
- MCS = 1 (MCS = 1; QPSK; coding rate = 1/2)
- Coding rate R = 1/2


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— LENGTH = 140 octets (with 16-bit SERVICE field becomes 142 octets = 1136 bits to scramble and encode)

— STBC = 1 (STBC = 1 => ON; m_STBC = 2)

### I.3.2 The message for LDPC example 2

The message being encoded consists of the first 112 characters (shown in **bold** and including line breaks) of the well-known “Ode to Joy” by F. Schiller:

**Joy, bright spark of divinity,**
**Daughter of Elysium,**
**Fire-insired we tread**
**Thy sanctuary.**
**Thy magic power (M118)reunites**
All that custom has divided,
All men become brothers
Under the sway of thy gentle wings.

NOTE—The typo in "Fire-insired" is deliberate.

The message is converted to ASCII, using LF (0x0A) for line breaks; then it is prepended with an appropriate MAC header and an FCS is added. The resulting 140-octet PSDU is shown in Table I-37 (Message for LDPC example 2).

Because of the additional 40 characters, note that the message for LDPC example 2 has a different FCS field (octets 137–140) than the previous examples and that the DurationID field (i.e., octets 3 and 4) changes to 0x036 = 54 μs.

**Table I-37—Message for LDPC example 2**

| Octet ## | Value | Value | Value | Value | Value |
|---|---|---|---|---|---|
| 1...5 | 0x04 | 0x02 | 0x00 | 0x36 | 0x00 |
| 6...10 | 0x60 | 0x08 | 0xCD | 0x37 | 0xA6 |
| 11...15 | 0x00 | 0x20 | 0xD6 | 0x01 | 0x3C |
| 16...20 | 0xF1 | 0x00 | 0x60 | 0x08 | 0xAD |
| 21...25 | 0x3B | 0xAF | 0x00 | 0x00 | 0x4A |
| 26...30 | 0x6F | 0x79 | 0x2C | 0x20 | 0x62 |
| 31...35 | 0x72 | 0x69 | 0x67 | 0x68 | 0x74 |
| 36...40 | 0x20 | 0x73 | 0x70 | 0x61 | 0x72 |
| 41...45 | 0x6B | 0x20 | 0x6F | 0x66 | 0x20 |
| 46...50 | 0x64 | 0x69 | 0x76 | 0x69 | 0x6E |
| 51...55 | 0x69 | 0x74 | 0x79 | 0x2C | 0x0A |
| 56...60 | 0x44 | 0x61 | 0x75 | 0x67 | 0x68 |
| 61...65 | 0x74 | 0x65 | 0x72 | 0x20 | 0x6F |
| 66...70 | 0x66 | 0x20 | 0x45 | 0x6C | 0x79 |

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**Table I-37—Message for LDPC example 2 *(continued)***

| Octet ## | Value | Value | Value | Value | Value |
|---|---|---|---|---|---|
| 71...75 | 0x73 | 0x69 | 0x75 | 0x6D | 0x2C |
| 76...80 | 0x0A | 0x46 | 0x69 | 0x72 | 0x65 |
| 81...85 | 0x2D | 0x69 | 0x6E | 0x73 | 0x69 |
| 86...90 | 0x72 | 0x65 | 0x64 | 0x20 | 0x77 |
| 91...95 | 0x65 | 0x20 | 0x74 | 0x72 | 0x65 |
| 96...100 | 0x61 | 0x64 | 0x0A | 0x54 | 0x68 |
| 101...105 | 0x79 | 0x20 | 0x73 | 0x61 | 0x6E |
| 106...110 | 0x63 | 0x74 | 0x75 | 0x61 | 0x72 |
| 111...115 | 0x79 | 0x2E | 0x0A | 0x54 | 0x68 |
| 116...120 | 0x79 | 0x20 | 0x6D | 0x61 | 0x67 |
| 121...125 | 0x69 | 0x63 | 0x20 | 0x70 | 0x6F |
| 126...130 | 0x77 | 0x65 | 0x72 | 0x20 | 0x72 |
| 131...135 | 0x65 | 0x2D | 0x75 | 0x6E | 0x69 |
| 136...140 | 0x74 | 0x3B | 0xDB | 0xB5 | 0x22 |

### I.3.3 Prepending the SERVICE field for LDPC example 2

The transmitted message shown in Table I-37 (Message for LDPC example 2) contains 140 octets, or equivalently, 1120 bits. The bits are prepended by the 16 SERVICE field bits (bits 0–15 in Table I-38 (DATA bits for LDPC example 2 before scrambling)), as defined by 19.3.11.2 (SERVICE field), but tail bits and padding bits are not appended as in the BCC example. The resulting 1136 bits are shown in Table I-38 (DATA bits for LDPC example 2 before scrambling).

**Table I-38—DATA bits for LDPC example 2 before scrambling**

| Bit ## | Binary value B7 B0 | Binary value B15 B8 | Binary value B23 B16 | Hexadecimal value | Hexadecimal value | Hexadecimal value |
|---|---|---|---|---|---|---|
| 0000–0023 | 00000000 | 00000000 | 00000100 | 0x00 | 0x00 | 0x04 |
| 0024–0047 | 00000010 | 00000000 | 00110110 | 0x02 | 0x00 | 0x36 |
| 0048–0071 | 00000000 | 01100000 | 00001000 | 0x00 | 0x60 | 0x08 |
| 0072–0095 | 11001101 | 00110111 | 10100110 | 0xCD | 0x37 | 0xA6 |
| 0096–0119 | 00000000 | 00100000 | 11010110 | 0x00 | 0x20 | 0xD6 |
| 0120–0143 | 00000001 | 00111100 | 11110001 | 0x01 | 0x3C | 0xF1 |
| 0144–0167 | 00000000 | 01100000 | 00001000 | 0x00 | 0x60 | 0x08 |
| 0168–0191 | 10101101 | 00111011 | 10101111 | 0xAD | 0x3B | 0xAF |
| 0192–0215 | 00000000 | 00000000 | 01001010 | 0x00 | 0x00 | 0x4A |


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**Table I-38—DATA bits for LDPC example 2 before scrambling**

| Bit ## | Binary value B7 B0 | Binary value B15 B8 | Binary value B23 B16 | Hexadecimal value | Hexadecimal value | Hexadecimal value |
|---|---|---|---|---|---|---|
| 0216–0239 | 01101111 | 01111001 | 00101100 | 0x6F | 0x79 | 0x2C |
| 0240–0263 | 00100000 | 01100010 | 01110010 | 0x20 | 0x62 | 0x72 |
| 0264–0287 | 01101001 | 01100111 | 01101000 | 0x69 | 0x67 | 0x68 |
| 0288–0311 | 01110100 | 00100000 | 01110011 | 0x74 | 0x20 | 0x73 |
| 0312–0335 | 01110000 | 01100001 | 01110010 | 0x70 | 0x61 | 0x72 |
| 0336–0359 | 01101011 | 00100000 | 01101111 | 0x6B | 0x20 | 0x6F |
| 0360–0383 | 01100110 | 00100000 | 01100100 | 0x66 | 0x20 | 0x64 |
| 0384–0407 | 01101001 | 01110110 | 01101001 | 0x69 | 0x76 | 0x69 |
| 0408–0431 | 01101110 | 01101001 | 01110100 | 0x6E | 0x69 | 0x74 |
| 0432–0455 | 01111001 | 00101100 | 00001010 | 0x79 | 0x2C | 0x0A |
| 0456–0479 | 01000100 | 01100001 | 01110101 | 0x44 | 0x61 | 0x75 |
| 0480–0503 | 01100111 | 01101000 | 01110100 | 0x67 | 0x68 | 0x74 |
| 0504–0527 | 01100101 | 01110010 | 00100000 | 0x65 | 0x72 | 0x20 |
| 0528–0551 | 01101111 | 01100110 | 00100000 | 0x6F | 0x66 | 0x20 |
| 0552–0575 | 01000101 | 01101100 | 01111001 | 0x45 | 0x6C | 0x79 |
| 0576–0599 | 01110011 | 01101001 | 01110101 | 0x73 | 0x69 | 0x75 |
| 0600–0623 | 01101101 | 00101100 | 00001010 | 0x6D | 0x2C | 0x0A |
| 0624–0647 | 01000110 | 01101001 | 01110010 | 0x46 | 0x69 | 0x72 |
| 0648–0671 | 01100101 | 00101101 | 01101001 | 0x65 | 0x2D | 0x69 |
| 0672–0695 | 01101110 | 01110011 | 01101001 | 0x6E | 0x73 | 0x69 |
| 0696–0719 | 01110010 | 01100101 | 01100100 | 0x72 | 0x65 | 0x64 |
| 0720–0743 | 00100000 | 01110111 | 01100101 | 0x20 | 0x77 | 0x65 |
| 0744–0767 | 00100000 | 01110100 | 01110010 | 0x20 | 0x74 | 0x72 |
| 0768–0791 | 01100101 | 01100001 | 01100100 | 0x65 | 0x61 | 0x64 |
| 0792–0815 | 00001010 | 01010100 | 01101000 | 0x0A | 0x54 | 0x68 |
| 0816–0839 | 01111001 | 00100000 | 01110011 | 0x79 | 0x20 | 0x73 |
| 0840–0863 | 01100001 | 01101110 | 01100011 | 0x61 | 0x6E | 0x63 |
| 0864–0887 | 01110100 | 01110101 | 01100001 | 0x74 | 0x75 | 0x61 |
| 0888–0911 | 01110010 | 01111001 | 00101110 | 0x72 | 0x79 | 0x2E |
| 0912–0935 | 00001010 | 01010100 | 01101000 | 0x0A | 0x54 | 0x68 |
| 0936–0959 | 01111001 | 00100000 | 01101101 | 0x79 | 0x20 | 0x6D |
| 0960–0983 | 01100001 | 01100111 | 01101001 | 0x61 | 0x67 | 0x69 |
| 0984–1007 | 01100011 | 00100000 | 01110000 | 0x63 | 0x20 | 0x70 |

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**Table I-38—DATA bits for LDPC example 2 before scrambling**

| Bit ## | Binary value B7 B0 | Binary value B15 B8 | Binary value B23 B16 | Hexadecimal value | Hexadecimal value | Hexadecimal value |
|---|---|---|---|---|---|---|
| 1008–1031 | 01101111 | 01110111 | 01100101 | 0x6F | 0x77 | 0x65 |
| 1032–1055 | 01110010 | 00100000 | 01110010 | 0x72 | 0x20 | 0x72 |
| 1056–1079 | 01100101 | 00101101 | 01110101 | 0x65 | 0x2D | 0x75 |
| 1080–1103 | 01101110 | 01101001 | 01110100 | 0x6E | 0x69 | 0x74 |
| 1104–1127 | 00111011 | 11011011 | 10110101 | 0x3B | 0xDB | 0xB5 |
| 1128–1135 | 00100010 | -------- | -------- | 0x22 | ---- | ---- |

## I.3.4 Scrambling LDPC example 2

The 1136 bits are scrambled by the scrambler defined in 17.3.5.5 (PHY DATA scrambler and descrambler). The initial state of the scrambler is the state 1011101 binary (0x5D). The scrambled sequence is given in Table I-39 (DATA bits for LDPC example 2 after scrambling).

**Table I-39—DATA bits for LDPC example 2 after scrambling**

| Bit ## | Binary value B0 B7 | Binary value B8 B15 | Binary value B16 B23 | Hexadecimal value | Hexadecimal value | Hexadecimal value |
|---|---|---|---|---|---|---|
| 0000–0023 | 01101100 | 00011001 | 10001001 | 0x6C | 0x19 | 0x89 |
| 0024–0047 | 10001111 | 01101000 | 00111001 | 0x8F | 0x68 | 0x39 |
| 0048–0071 | 11110100 | 10100101 | 01100001 | 0xF4 | 0xA5 | 0x61 |
| 0072–0095 | 01001111 | 11010111 | 10101110 | 0x4F | 0xD7 | 0xAE |
| 0096–0119 | 00100100 | 00001100 | 11110011 | 0x24 | 0x0C | 0xF3 |
| 0120–0143 | 00111010 | 11100100 | 10111100 | 0x3A | 0xE4 | 0xBC |
| 0144–0167 | 01010011 | 10011000 | 11000000 | 0x53 | 0x98 | 0xC0 |
| 0168–0191 | 00011110 | 00110101 | 10110011 | 0x1E | 0x35 | 0xB3 |
| 0192–0215 | 11100011 | 11111000 | 00100101 | 0xE3 | 0xF8 | 0x25 |
| 0216–0239 | 01100000 | 11010110 | 00100101 | 0x60 | 0xD6 | 0x25 |
| 0240–0263 | 00110101 | 00110011 | 11111110 | 0x35 | 0x33 | 0xFE |
| 0264–0287 | 11110000 | 01000001 | 00101011 | 0xF0 | 0x41 | 0x2B |
| 0288–0311 | 10001111 | 01010011 | 00011100 | 0x8F | 0x53 | 0x1C |
| 0312–0335 | 10000011 | 01000001 | 10111110 | 0x83 | 0x41 | 0xBE |
| 0336–0359 | 00111001 | 00101000 | 01100110 | 0x39 | 0x28 | 0x66 |
| 0360–0383 | 01000100 | 01100110 | 11001101 | 0x44 | 0x66 | 0xCD |
| 0384–0407 | 11110110 | 10100011 | 11011000 | 0xF6 | 0xA3 | 0xD8 |
| 0408–0431 | 00001101 | 11010100 | 10000001 | 0x0D | 0xD4 | 0x81 |


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**Table I-39—DATA bits for LDPC example 2 after scrambling**

| Bit ## | Binary value B0 B7 | Binary value B8 B15 | Binary value B16 B23 | Hexadecimal value | Hexadecimal value | Hexadecimal value |
|---|---|---|---|---|---|---|
| 0432–0455 | 00111011 | 00101111 | 11011111 | 0x3B | 0x2F | 0xDF |
| 0456–0479 | 11000011 | 01011000 | 11110111 | 0xC3 | 0x58 | 0xF7 |
| 0480–0503 | 11000110 | 01010010 | 11101011 | 0xC6 | 0x52 | 0xEB |
| 0504–0527 | 01110000 | 10001111 | 10011110 | 0x70 | 0x8F | 0x9E |
| 0528–0551 | 01101010 | 10010000 | 10000001 | 0x6A | 0x90 | 0x81 |
| 0552–0575 | 11111101 | 01111100 | 10101001 | 0xFD | 0x7C | 0xA9 |
| 0576–0599 | 11010001 | 01010101 | 00010010 | 0xD1 | 0x55 | 0x12 |
| 0600–0623 | 00000100 | 01110100 | 11011001 | 0x04 | 0x74 | 0xD9 |
| 0624–0647 | 11101001 | 00111011 | 11001101 | 0xE9 | 0x3B | 0xCD |
| 0648–0671 | 10010011 | 10001101 | 01111011 | 0x93 | 0x8D | 0x7B |
| 0672–0695 | 01111100 | 01110000 | 00000010 | 0x7C | 0x70 | 0x02 |
| 0696–0719 | 00100000 | 10011001 | 10100001 | 0x20 | 0x99 | 0xA1 |
| 0720–0743 | 01111101 | 10001010 | 00100111 | 0x7D | 0x8A | 0x27 |
| 0744–0767 | 00010111 | 00111001 | 00010101 | 0x17 | 0x39 | 0x15 |
| 0768–0791 | 10100000 | 11101100 | 01010101 | 0xA0 | 0xEC | 0x55 |
| 0792–0815 | 10001010 | 00111111 | 01101011 | 0x8A | 0x3F | 0x6B |
| 0816–0839 | 10110110 | 11011000 | 10110001 | 0xB6 | 0xD8 | 0xB1 |
| 0840–0863 | 10001000 | 10000100 | 00001111 | 0x88 | 0x84 | 0x0F |
| 0864–0887 | 00101100 | 10001000 | 10101000 | 0x2C | 0x88 | 0xA8 |
| 0888–0911 | 11111000 | 10010010 | 10100000 | 0xF8 | 0x92 | 0xA0 |
| 0912–0935 | 10110111 | 10011110 | 00111100 | 0xB7 | 0x9E | 0x3C |
| 0936–0959 | 01100100 | 01010101 | 00001110 | 0x64 | 0x55 | 0x0E |
| 0960–0983 | 01111000 | 11111011 | 01110011 | 0x78 | 0xFB | 0x73 |
| 0984–1007 | 01010100 | 00000000 | 01000010 | 0x54 | 0x00 | 0x42 |
| 1008–1031 | 10101011 | 10000010 | 10111111 | 0xAB | 0x82 | 0xBF |
| 1032–1055 | 11100111 | 11001011 | 00100110 | 0xE7 | 0xCB | 0x26 |
| 1056–1079 | 11110011 | 01000000 | 00001101 | 0xF3 | 0x40 | 0x0D |
| 1080–1103 | 00000111 | 01101010 | 00010101 | 0x07 | 0x6A | 0x15 |
| 1104–1127 | 00010111 | 11111111 | 10100101 | 0x17 | 0xFF | 0xA5 |
| 1128–1135 | 11011100 | -------- | -------- | 0xDC | ---- | ---- |

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### I.3.5 Inserting the shortening bits for LDPC example 2

The equations of 19.3.11.7.5 (LDPC PPDU encoding process) are solved to calculate the following derived parameters for LDPC example 2 from the input TXVECTOR parameters:

- $N_{CW} = 2$ (number of codewords)
- $L_{LDPC} = 1296$ (size of codeword)
- $N_{CBPS} = 216$ (number of coded bits per symbol)
- $N_{avbits} = 2592$ (number of available bits)
- $N_{shrt} = 160$ (number of bits to be shortened)
- $N_{punc} = 0$ (number of bits to be punctured)
- $N_{SYM} = 12$ (number of OFDM symbols)
- $N_{rep} = 160$ (number of bits to be repeated)

The results of applying shortening bits, as prescribed in paragraph (c) of 19.3.11.7.5 (LDPC PPDU encoding process), is given in Table I-40 (DATA bits for LDPC example 2 after insertion of shortening bits).

NOTE—$N_{shrt} = 160$ shortening bits have been inserted as 0s: 80 0s at bits 568–647 and 80 0s at bits 1216–1295; this order equally distributes the shortening bits across the $N_{CW} = 2$ codewords.

**Table I-40—DATA bits for LDPC example 2 after insertion of shortening bits**

| Bit ## | Binary value B0 B7 | Binary value B8 B15 | Binary value B16 B23 | Hexadecimal value | Hexadecimal value | Hexadecimal value |
|---|---|---|---|---|---|---|
| 0000–0023 | 01101100 | 00011001 | 10001001 | 0x6C | 0x19 | 0x89 |
| 0024–0047 | 10001111 | 01101000 | 00111001 | 0x8F | 0x68 | 0x39 |
| 0048–0071 | 11110100 | 10100101 | 01100001 | 0xF4 | 0xA5 | 0x61 |
| 0072–0095 | 01001111 | 11010111 | 10101110 | 0x4F | 0xD7 | 0xAE |
| 0096–0119 | 00100100 | 00001100 | 11110011 | 0x24 | 0x0C | 0xF3 |
| 0120–0143 | 00111010 | 11100100 | 10111100 | 0x3A | 0xE4 | 0xBC |
| 0144–0167 | 01010011 | 10011000 | 11000000 | 0x53 | 0x98 | 0xC0 |
| 0168–0191 | 00011110 | 00110101 | 10110011 | 0x1E | 0x35 | 0xB3 |
| 0192–0215 | 11100011 | 11111000 | 00100101 | 0xE3 | 0xF8 | 0x25 |
| 0216–0239 | 01100000 | 11010110 | 00100101 | 0x60 | 0xD6 | 0x25 |
| 0240–0263 | 00110101 | 00110011 | 11111110 | 0x35 | 0x33 | 0xFE |
| 0264–0287 | 11110000 | 01000001 | 00101011 | 0xF0 | 0x41 | 0x2B |
| 0288–0311 | 10001111 | 01010011 | 00011100 | 0x8F | 0x53 | 0x1C |
| 0312–0335 | 10000011 | 01000001 | 10111110 | 0x83 | 0x41 | 0xBE |
| 0336–0359 | 00111001 | 00101000 | 01100110 | 0x39 | 0x28 | 0x66 |
| 0360–0383 | 01000100 | 01100110 | 11001101 | 0x44 | 0x66 | 0xCD |
| 0384–0407 | 11110110 | 10100011 | 11011000 | 0xF6 | 0xA3 | 0xD8 |
| 0408–0431 | 00001101 | 11010100 | 10000001 | 0x0D | 0xD4 | 0x81 |


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**Table I-40—DATA bits for LDPC example 2 after insertion of shortening bits *(continued)***

| Bit ## | Binary value B0 B7 | Binary value B8 B15 | Binary value B16 B23 | Hexadecimal value | Hexadecimal value | Hexadecimal value |
|---|---|---|---|---|---|---|
| 0432–0455 | 00111011 | 00101111 | 11011111 | 0x3B | 0x2F | 0xDF |
| 0456–0479 | 11000011 | 01011000 | 11110111 | 0xC3 | 0x58 | 0xF7 |
| 0480–0503 | 11000110 | 01010010 | 11101011 | 0xC6 | 0x52 | 0xEB |
| 0504–0527 | 01110000 | 10001111 | 10011110 | 0x70 | 0x8F | 0x9E |
| 0528–0551 | 01101010 | 10010000 | 10000001 | 0x6A | 0x90 | 0x81 |
| 0552–0575 | 11111101 | 01111100 | 00000000 | 0xFD | 0x7C | 0x00 |
| 0576–0599 | 00000000 | 00000000 | 00000000 | 0x00 | 0x00 | 0x00 |
| 0600–0623 | 00000000 | 00000000 | 00000000 | 0x00 | 0x00 | 0x00 |
| 0624–0647 | 00000000 | 00000000 | 00000000 | 0x00 | 0x00 | 0x00 |
| 0648–0671 | 10101001 | 11010001 | 01010101 | 0xA9 | 0xD1 | 0x55 |
| 0672–0695 | 00010010 | 00000100 | 01110100 | 0x12 | 0x04 | 0x74 |
| 0696–0719 | 11011001 | 11101001 | 00111011 | 0xD9 | 0xE9 | 0x3B |
| 0720–0743 | 11001101 | 10010011 | 10001101 | 0xCD | 0x93 | 0x8D |
| 0744–0767 | 01111011 | 01111100 | 01110000 | 0x7B | 0x7C | 0x70 |
| 0768–0791 | 00000010 | 00100000 | 10011001 | 0x02 | 0x20 | 0x99 |
| 0792–0815 | 10100001 | 01111101 | 10001010 | 0xA1 | 0x7D | 0x8A |
| 0816–0839 | 00100111 | 00010111 | 00111001 | 0x27 | 0x17 | 0x39 |
| 0840–0863 | 00010101 | 10100000 | 11101100 | 0x15 | 0xA0 | 0xEC |
| 0864–0887 | 01010101 | 10001010 | 00111111 | 0x55 | 0x8A | 0x3F |
| 0888–0911 | 01101011 | 10110110 | 11011000 | 0x6B | 0xB6 | 0xD8 |
| 0912–0935 | 10110001 | 10001000 | 10000100 | 0xB1 | 0x88 | 0x84 |
| 0936–0959 | 00001111 | 00101100 | 10001000 | 0x0F | 0x2C | 0x88 |
| 0960–0983 | 10101000 | 11111000 | 10010010 | 0xA8 | 0xF8 | 0x92 |
| 0984–1007 | 10100000 | 10110111 | 10011110 | 0xA0 | 0xB7 | 0x9E |
| 1008–1031 | 00111100 | 01100100 | 01010101 | 0x3C | 0x64 | 0x55 |
| 1032–1055 | 00001110 | 01111000 | 11111011 | 0x0E | 0x78 | 0xFB |
| 1056–1079 | 01110011 | 01010100 | 00000000 | 0x73 | 0x54 | 0x00 |
| 1080–1103 | 01000010 | 10101011 | 10000010 | 0x42 | 0xAB | 0x82 |
| 1104–1127 | 10111111 | 11100111 | 11001011 | 0xBF | 0xE7 | 0xCB |
| 1128–1151 | 00100110 | 11110011 | 01000000 | 0x26 | 0xF3 | 0x40 |
| 1152–1175 | 00001101 | 00000111 | 01101010 | 0x0D | 0x07 | 0x6A |
| 1176–1199 | 00010101 | 00010111 | 11111111 | 0x15 | 0x17 | 0xFF |

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**Table I-40—DATA bits for LDPC example 2 after insertion of shortening bits *(continued)***

| Bit ## | Binary value B0 B7 | Binary value B8 B15 | Binary value B16 B23 | Hexadecimal value | Hexadecimal value | Hexadecimal value |
|---|---|---|---|---|---|---|
| 1200–1223 | 10100101 | 11011100 | 00000000 | 0xA5 | 0xDC | 0x00 |
| 1224–1247 | 00000000 | 00000000 | 00000000 | 0x00 | 0x00 | 0x00 |
| 1248–1271 | 00000000 | 00000000 | 00000000 | 0x00 | 0x00 | 0x00 |
| 1272–1295 | 00000000 | 00000000 | 00000000 | 0x00 | 0x00 | 0x00 |

## I.3.6 Encoding the data for LDPC example 2

The DATA with shortening bits are LDPC encoded as two ($N_{CW}$ = 2) codewords ($L_{LDPC}$ = 1296; R = 1/2) as prescribed by paragraph (c) of 19.3.11.7.5 (LDPC PPDU encoding process). The results are given in Table I-41 (DATA bits for LDPC example 2 after LDPC encoding).

NOTE—The LDPC encoder appends 648 bits as follows: bits 648–1295 after the first shortened codeword and another 648 bits (bits 1944–2591) after the second shortened codeword.

**Table I-41—DATA bits for LDPC example 2 after LDPC encoding**

| Bit ## | Binary value B0 B7 | Binary value B8 B15 | Binary value B16 B23 | Hexadecimal value | Hexadecimal value | Hexadecimal value |
|---|---|---|---|---|---|---|
| 0000–0023 | 01101100 | 00011001 | 10001001 | 0x6C | 0x19 | 0x89 |
| 0024–0047 | 10001111 | 01101000 | 00111001 | 0x8F | 0x68 | 0x39 |
| 0048–0071 | 11110100 | 10100101 | 01100001 | 0xF4 | 0xA5 | 0x61 |
| 0072–0095 | 01001111 | 11010111 | 10101110 | 0x4F | 0xD7 | 0xAE |
| 0096–0119 | 00100100 | 00001100 | 11110011 | 0x24 | 0x0C | 0xF3 |
| 0120–0143 | 00111010 | 11100100 | 10111100 | 0x3A | 0xE4 | 0xBC |
| 0144–0167 | 01010011 | 10011000 | 11000000 | 0x53 | 0x98 | 0xC0 |
| 0168–0191 | 00011110 | 00110101 | 10110011 | 0x1E | 0x35 | 0xB3 |
| 0192–0215 | 11100011 | 11111000 | 00100101 | 0xE3 | 0xF8 | 0x25 |
| 0216–0239 | 01100000 | 11010110 | 00100101 | 0x60 | 0xD6 | 0x25 |
| 0240–0263 | 00110101 | 00110011 | 11111110 | 0x35 | 0x33 | 0xFE |
| 0264–0287 | 11110000 | 01000001 | 00101011 | 0xF0 | 0x41 | 0x2B |
| 0288–0311 | 10001111 | 01010011 | 00011100 | 0x8F | 0x53 | 0x1C |
| 0312–0335 | 10000011 | 01000001 | 10111110 | 0x83 | 0x41 | 0xBE |
| 0336–0359 | 00111001 | 00101000 | 01100110 | 0x39 | 0x28 | 0x66 |
| 0360–0383 | 01000100 | 01100110 | 11001101 | 0x44 | 0x66 | 0xCD |
| 0384–0407 | 11110110 | 10100011 | 11011000 | 0xF6 | 0xA3 | 0xD8 |


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**Table I-41—DATA bits for LDPC example 2 after LDPC encoding *(continued)***

| Bit ## | Binary value B0 B7 | Binary value B8 B15 | Binary value B16 B23 | Hexadecimal value | Hexadecimal value | Hexadecimal value |
|---|---|---|---|---|---|---|
| 0408–0431 | 00001101 | 11010100 | 10000001 | 0x0D | 0xD4 | 0x81 |
| 0432–0455 | 00111011 | 00101111 | 11011111 | 0x3B | 0x2F | 0xDF |
| 0456–0479 | 11000011 | 01011000 | 11110111 | 0xC3 | 0x58 | 0xF7 |
| 0480–0503 | 11000110 | 01010010 | 11101011 | 0xC6 | 0x52 | 0xEB |
| 0504–0527 | 01110000 | 10001111 | 10011110 | 0x70 | 0x8F | 0x9E |
| 0528–0551 | 01101010 | 10010000 | 10000001 | 0x6A | 0x90 | 0x81 |
| 0552–0575 | 11111101 | 01111100 | 00000000 | 0xFD | 0x7C | 0x00 |
| 0576–0599 | 00000000 | 00000000 | 00000000 | 0x00 | 0x00 | 0x00 |
| 0600–0623 | 00000000 | 00000000 | 00000000 | 0x00 | 0x00 | 0x00 |
| 0624–0647 | 00000000 | 00000000 | 00000000 | 0x00 | 0x00 | 0x00 |
| 0648–0671 | 00001001 | 11000001 | 11111011 | 0x09 | 0xC1 | 0xFB |
| 0672–0695 | 01101000 | 11001101 | 00000101 | 0x68 | 0xCD | 0x05 |
| 0696–0719 | 10110110 | 11000111 | 01100101 | 0xB6 | 0xC7 | 0x65 |
| 0720–0743 | 10100101 | 10011001 | 11100000 | 0xA5 | 0x99 | 0xE0 |
| 0744–0767 | 01110011 | 01110000 | 01101101 | 0x73 | 0x70 | 0x6D |
| 0768–0791 | 01011110 | 01111001 | 11100011 | 0x5E | 0x79 | 0xE3 |
| 0792–0815 | 01100111 | 00100111 | 01011110 | 0x67 | 0x27 | 0x5E |
| 0816–0839 | 10010101 | 10101000 | 11110110 | 0x95 | 0xA8 | 0xF6 |
| 0840–0863 | 00110101 | 01001000 | 10100111 | 0x35 | 0x48 | 0xA7 |
| 0864–0887 | 00100110 | 00101001 | 00110001 | 0x26 | 0x29 | 0x31 |
| 0888–0911 | 00101110 | 00011001 | 11110100 | 0x2E | 0x19 | 0xF4 |
| 0912–0935 | 00110100 | 01101111 | 01010000 | 0x34 | 0x6F | 0x50 |
| 0936–0959 | 01010000 | 11101001 | 11000100 | 0x50 | 0xE9 | 0xC4 |
| 0960–0983 | 00000110 | 11011001 | 11101110 | 0x06 | 0xD9 | 0xEE |
| 0984–1007 | 11111000 | 00011011 | 11011001 | 0xF8 | 0x1B | 0xD9 |
| 1008–1031 | 01101100 | 10000110 | 11010011 | 0x6C | 0x86 | 0xD3 |
| 1032–1055 | 11101001 | 01100100 | 11001000 | 0xE9 | 0x64 | 0xC8 |
| 1056–1079 | 11110001 | 10100001 | 00001011 | 0xF1 | 0xA1 | 0x0B |
| 1080–1103 | 11000010 | 01000100 | 01010100 | 0xC2 | 0x44 | 0x54 |
| 1104–1127 | 10100000 | 10001100 | 10111011 | 0xA0 | 0x8C | 0xBB |
| 1128–1151 | 10100011 | 11100100 | 10101001 | 0xA3 | 0xE4 | 0xA9 |
| 1152–1175 | 10101011 | 01010000 | 11100010 | 0xAB | 0x50 | 0xE2 |
| 1176–1199 | 01110000 | 00101000 | 00110110 | 0x70 | 0x28 | 0x36 |

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**Table I-41—DATA bits for LDPC example 2 after LDPC encoding *(continued)***

| Bit ## | Binary value B0 B7 | Binary value B8 B15 | Binary value B16 B23 | Hexadecimal value | Hexadecimal value | Hexadecimal value |
|---|---|---|---|---|---|---|
| 1200–1223 | 11111100 | 00110000 | 00110100 | 0xFC | 0x30 | 0x34 |
| 1224–1247 | 01101010 | 01001001 | 00100010 | 0x6A | 0x49 | 0x22 |
| 1248–1271 | 11010101 | 00000111 | 11001111 | 0xD5 | 0x07 | 0xCF |
| 1272–1295 | 00110101 | 00111010 | 10001110 | 0x35 | 0x3A | 0x8E |
| 1296–1319 | 10101001 | 11010001 | 01010101 | 0xA9 | 0xD1 | 0x55 |
| 1320–1343 | 00010010 | 00000100 | 01110100 | 0x12 | 0x04 | 0x74 |
| 1344–1367 | 11011001 | 11101001 | 00111011 | 0xD9 | 0xE9 | 0x3B |
| 1368–1391 | 11001101 | 10010011 | 10001101 | 0xCD | 0x93 | 0x8D |
| 1392–1415 | 01111011 | 01111100 | 01110000 | 0x7B | 0x7C | 0x70 |
| 1416–1439 | 00000010 | 00100000 | 10011001 | 0x02 | 0x20 | 0x99 |
| 1440–1463 | 10100001 | 01111101 | 10001010 | 0xA1 | 0x7D | 0x8A |
| 1464–1487 | 00100111 | 00010111 | 00111001 | 0x27 | 0x17 | 0x39 |
| 1488–1511 | 00010101 | 10100000 | 11101100 | 0x15 | 0xA0 | 0xEC |
| 1512–1535 | 01010101 | 10001010 | 00111111 | 0x55 | 0x8A | 0x3F |
| 1536–1559 | 01101011 | 10110110 | 11011000 | 0x6B | 0xB6 | 0xD8 |
| 1560–1583 | 10110001 | 10001000 | 10000100 | 0xB1 | 0x88 | 0x84 |
| 1584–1607 | 00001111 | 00101100 | 10001000 | 0x0F | 0x2C | 0x88 |
| 1608–1631 | 10101000 | 11111000 | 10010010 | 0xA8 | 0xF8 | 0x92 |
| 1632–1655 | 10100000 | 10110111 | 10011110 | 0xA0 | 0xB7 | 0x9E |
| 1656–1679 | 00111100 | 01100100 | 01010101 | 0x3C | 0x64 | 0x55 |
| 1680–1703 | 00001110 | 01111000 | 11111011 | 0x0E | 0x78 | 0xFB |
| 1704–1727 | 01110011 | 01010100 | 00000000 | 0x73 | 0x54 | 0x00 |
| 1728–1751 | 01000010 | 10101011 | 10000010 | 0x42 | 0xAB | 0x82 |
| 1752–1775 | 10111111 | 11100111 | 11001011 | 0xBF | 0xE7 | 0xCB |
| 1776–1799 | 00100110 | 11110011 | 01000000 | 0x26 | 0xF3 | 0x40 |
| 1800–1823 | 00001101 | 00000111 | 01101010 | 0x0D | 0x07 | 0x6A |
| 1824–1847 | 00010101 | 00010111 | 11111111 | 0x15 | 0x17 | 0xFF |
| 1848–1871 | 10100101 | 11011100 | 00000000 | 0xA5 | 0xDC | 0x00 |
| 1872–1895 | 00000000 | 00000000 | 00000000 | 0x00 | 0x00 | 0x00 |
| 1896–1919 | 00000000 | 00000000 | 00000000 | 0x00 | 0x00 | 0x00 |
| 1920–1943 | 00000000 | 00000000 | 00000000 | 0x00 | 0x00 | 0x00 |
| 1944–1967 | 01100100 | 10110110 | 01010100 | 0x64 | 0xB6 | 0x54 |
| 1968–1991 | 00110001 | 00000001 | 01100001 | 0x31 | 0x01 | 0x61 |


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**Table I-41—DATA bits for LDPC example 2 after LDPC encoding *(continued)***

| Bit ## | Binary value B0 B7 | Binary value B8 B15 | Binary value B16 B23 | Hexadecimal value | Hexadecimal value | Hexadecimal value |
|---|---|---|---|---|---|---|
| 1992–2015 | 00101001 | 00010011 | 01110000 | 0x29 | 0x13 | 0x70 |
| 2016–2039 | 01010000 | 10000000 | 11001110 | 0x50 | 0x80 | 0xCE |
| 2040–2063 | 01000101 | 11000000 | 10101000 | 0x45 | 0xC0 | 0xA8 |
| 2064–2087 | 11001101 | 11111000 | 01111100 | 0xCD | 0xF8 | 0x7C |
| 2088–2111 | 01010011 | 01010001 | 01001110 | 0x53 | 0x51 | 0x4E |
| 2112–2135 | 11010011 | 10101110 | 00010011 | 0xD3 | 0xAE | 0x13 |
| 2136–2159 | 11110000 | 11101101 | 10111111 | 0xF0 | 0xED | 0xBF |
| 2160–2183 | 10001110 | 10010100 | 00110100 | 0x8E | 0x94 | 0x34 |
| 2184–2207 | 11111011 | 00010000 | 11011001 | 0xFB | 0x10 | 0xD9 |
| 2208–2231 | 10111110 | 00110001 | 10011111 | 0xBE | 0x31 | 0x9F |
| 2232–2255 | 01100000 | 00011100 | 10100110 | 0x60 | 0x1C | 0xA6 |
| 2256–2279 | 01010101 | 11111001 | 10100110 | 0x55 | 0xF9 | 0xA6 |
| 2280–2303 | 10101010 | 00111000 | 01110001 | 0xAA | 0x38 | 0x71 |
| 2304–2327 | 01111010 | 10101100 | 10110010 | 0x7A | 0xAC | 0xB2 |
| 2328–2351 | 11110101 | 11010001 | 10000001 | 0xF5 | 0xD1 | 0x81 |
| 2352–2375 | 01010000 | 11110001 | 00001011 | 0x50 | 0xF1 | 0x0B |
| 2376–2399 | 10111101 | 10010011 | 10001011 | 0xBD | 0x93 | 0x8B |
| 2400–2423 | 10100010 | 10010110 | 00100101 | 0xA2 | 0x96 | 0x25 |
| 2424–2447 | 11100011 | 01101100 | 11000111 | 0xE3 | 0x6C | 0xC7 |
| 2448–2471 | 00000101 | 00011000 | 00101000 | 0x05 | 0x18 | 0x28 |
| 2472–2495 | 11110011 | 00111001 | 11011000 | 0xF3 | 0x39 | 0xD8 |
| 2496–2519 | 00010001 | 01110101 | 00010111 | 0x11 | 0x75 | 0x17 |
| 2520–2543 | 11011101 | 11111011 | 11010010 | 0xDD | 0xFB | 0xD2 |
| 2544–2567 | 10101010 | 11101011 | 10100110 | 0xAA | 0xEB | 0xA6 |
| 2568–2591 | 10000101 | 10110011 | 01011000 | 0x85 | 0xB3 | 0x58 |

### I.3.7 Removing shortening bits and repetition for LDPC example 2

The shortening bits, applied before LDPC encoding, are now removed as prescribed in paragraph (c) of 19.3.11.7.5 (LDPC PPDU encoding process). Finally, either puncturing is applied as described in paragraph (d) of the same subclause, or the copying of repeated bits is applied as described in paragraph (e) of the same subclause. In LDPC example 2, because $N_{punc} = 0$ and $N_{rep} = 160$ are nonzero, repetition is prescribed and completes the LDPC encoding process.

The results are given in Table I-42 (DATA bits after removal of shortening bits and copying of repetition bits).

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NOTE—The first 80 shortening bits (bits 568–647 from Table I-41 (DATA bits for LDPC example 2 after LDPC encoding)) have been removed from the first codeword between bits 567 and 568 of Table I-42 (DATA bits after removal of shortening bits and copying of repetition bits), and the second 80 shortening bits (bits 1864–1943 of Table I-41 (DATA bits for LDPC example 2 after LDPC encoding)) have been removed between bits 1215 and 1216 of Table I-42 (DATA bits after removal of shortening bits and copying of repetition bits). Also, 80 bits have been repeated from the beginning of the first codeword (bits 0–79) to the end of the first codeword (bits 1216–1295), and 80 bits have been repeated from the beginning of the second codeword (bits 1296–1375) to end of the second codeword (bits 2512–2591) in Table I-42 (DATA bits after removal of shortening bits and copying of repetition bits).

**Table I-42—DATA bits after removal of shortening bits and copying of repetition bits**

| Bit ## | Binary value B0 B7 | Binary value B8 B15 | Binary value B16 B23 | Hexadecimal value | Hexadecimal value | Hexadecimal value |
|---|---|---|---|---|---|---|
| 0000–0023 | 01101100 | 00011001 | 10001001 | 0x6C | 0x19 | 0x89 |
| 0024–0047 | 10001111 | 01101000 | 00111001 | 0x8F | 0x68 | 0x39 |
| 0048–0071 | 11110100 | 10100101 | 01100001 | 0xF4 | 0xA5 | 0x61 |
| 0072–0095 | 01001111 | 11010111 | 10101110 | 0x4F | 0xD7 | 0xAE |
| 0096–0119 | 00100100 | 00001100 | 11110011 | 0x24 | 0x0C | 0xF3 |
| 0120–0143 | 00111010 | 11100100 | 10111100 | 0x3A | 0xE4 | 0xBC |
| 0144–0167 | 01010011 | 10011000 | 11000000 | 0x53 | 0x98 | 0xC0 |
| 0168–0191 | 00011110 | 00110101 | 10110011 | 0x1E | 0x35 | 0xB3 |
| 0192–0215 | 11100011 | 11111000 | 00100101 | 0xE3 | 0xF8 | 0x25 |
| 0216–0239 | 01100000 | 11010110 | 00100101 | 0x60 | 0xD6 | 0x25 |
| 0240–0263 | 00110101 | 00110011 | 11111110 | 0x35 | 0x33 | 0xFE |
| 0264–0287 | 11110000 | 01000001 | 00101011 | 0xF0 | 0x41 | 0x2B |
| 0288–0311 | 10001111 | 01010011 | 00011100 | 0x8F | 0x53 | 0x1C |
| 0312–0335 | 10000011 | 01000001 | 10111110 | 0x83 | 0x41 | 0xBE |
| 0336–0359 | 00111001 | 00101000 | 01100110 | 0x39 | 0x28 | 0x66 |
| 0360–0383 | 01000100 | 01100110 | 11001101 | 0x44 | 0x66 | 0xCD |
| 0384–0407 | 11110110 | 10100011 | 11011000 | 0xF6 | 0xA3 | 0xD8 |
| 0408–0431 | 00001101 | 11010100 | 10000001 | 0x0D | 0xD4 | 0x81 |
| 0432–0455 | 00111011 | 00101111 | 11011111 | 0x3B | 0x2F | 0xDF |
| 0456–0479 | 11000011 | 01011000 | 11110111 | 0xC3 | 0x58 | 0xF7 |
| 0480–0503 | 11000110 | 01010010 | 11101011 | 0xC6 | 0x52 | 0xEB |
| 0504–0527 | 01110000 | 10001111 | 10011110 | 0x70 | 0x8F | 0x9E |
| 0528–0551 | 01101010 | 10010000 | 10000001 | 0x6A | 0x90 | 0x81 |
| 0552–0575 | 11111101 | 01111100 | 00001001 | 0xFD | 0x7C | 0x09 |
| 0576–0599 | 11000001 | 11111011 | 01101000 | 0xC1 | 0xFB | 0x68 |
| 0600–0623 | 11001101 | 00000101 | 10110110 | 0xCD | 0x05 | 0xB6 |


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**Table I-42—DATA bits after removal of shortening bits and copying of repetition bits *(continued)***

| Bit ## | Binary value B0 B7 | Binary value B8 B15 | Binary value B16 B23 | Hexadecimal value | Hexadecimal value | Hexadecimal value |
|---|---|---|---|---|---|---|
| 0624–0647 | 11000111 | 01100101 | 10100101 | 0xC7 | 0x65 | 0xA5 |
| 0648–0671 | 10011001 | 11100000 | 01110011 | 0x99 | 0xE0 | 0x73 |
| 0672–0695 | 01110000 | 01101101 | 01011110 | 0x70 | 0x6D | 0x5E |
| 0696–0719 | 01111001 | 11100011 | 01100111 | 0x79 | 0xE3 | 0x67 |
| 0720–0743 | 00100111 | 01011110 | 10010101 | 0x27 | 0x5E | 0x95 |
| 0744–0767 | 10101000 | 11110110 | 00110101 | 0xA8 | 0xF6 | 0x35 |
| 0768–0791 | 01001000 | 10100111 | 00100110 | 0x48 | 0xA7 | 0x26 |
| 0792–0815 | 00101001 | 00110001 | 00101110 | 0x29 | 0x31 | 0x2E |
| 0816–0839 | 00011001 | 11110100 | 00110100 | 0x19 | 0xF4 | 0x34 |
| 0840–0863 | 01101111 | 01010000 | 01010000 | 0x6F | 0x50 | 0x50 |
| 0864–0887 | 11101001 | 11000100 | 00000110 | 0xE9 | 0xC4 | 0x06 |
| 0888–0911 | 11011001 | 11101110 | 11111000 | 0xD9 | 0xEE | 0xF8 |
| 0912–0935 | 00011011 | 11011001 | 01101100 | 0x1B | 0xD9 | 0x6C |
| 0936–0959 | 10000110 | 11010011 | 11101001 | 0x86 | 0xD3 | 0xE9 |
| 0960–0983 | 01100100 | 11001000 | 11110001 | 0x64 | 0xC8 | 0xF1 |
| 0984–1007 | 10100001 | 00001011 | 11000010 | 0xA1 | 0x0B | 0xC2 |
| 1008–1031 | 01000100 | 01010100 | 10100000 | 0x44 | 0x54 | 0xA0 |
| 1032–1055 | 10001100 | 10111011 | 10100011 | 0x8C | 0xBB | 0xA3 |
| 1056–1079 | 11100100 | 10101001 | 10101011 | 0xE4 | 0xA9 | 0xAB |
| 1080–1103 | 01010000 | 11100010 | 01110000 | 0x50 | 0xE2 | 0x70 |
| 1104–1127 | 00101000 | 00110110 | 11111100 | 0x28 | 0x36 | 0xFC |
| 1128–1151 | 00110000 | 00110100 | 01101010 | 0x30 | 0x34 | 0x6A |
| 1152–1175 | 01001001 | 00100010 | 11010101 | 0x49 | 0x22 | 0xD5 |
| 1176–1199 | 00000111 | 11001111 | 00110101 | 0x07 | 0xCF | 0x35 |
| 1200–1223 | 00111010 | 10001110 | 01101100 | 0x3A | 0x8E | 0x6C |
| 1224–1247 | 00011001 | 10001001 | 10001111 | 0x19 | 0x89 | 0x8F |
| 1248–1271 | 01101000 | 00111001 | 11110100 | 0x68 | 0x39 | 0xF4 |
| 1272–1295 | 10100101 | 01100001 | 01001111 | 0xA5 | 0x61 | 0x4F |
| 1296–1319 | 10101001 | 11010001 | 01010101 | 0xA9 | 0xD1 | 0x55 |
| 1320–1343 | 00010010 | 00000100 | 01110100 | 0x12 | 0x04 | 0x74 |
| 1344–1367 | 11011001 | 11101001 | 00111011 | 0xD9 | 0xE9 | 0x3B |
| 1368–1391 | 11001101 | 10010011 | 10001101 | 0xCD | 0x93 | 0x8D |

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**Table I-42—DATA bits after removal of shortening bits and copying of repetition bits *(continued)***

| Bit ## | Binary value B0 B7 | Binary value B8 B15 | Binary value B16 B23 | Hexadecimal value | Hexadecimal value | Hexadecimal value |
|---|---|---|---|---|---|---|
| 1392–1415 | 01111011 | 01111100 | 01110000 | 0x7B | 0x7C | 0x70 |
| 1416–1439 | 00000010 | 00100000 | 10011001 | 0x02 | 0x20 | 0x99 |
| 1440–1463 | 10100001 | 01111101 | 10001010 | 0xA1 | 0x7D | 0x8A |
| 1464–1487 | 00100111 | 00010111 | 00111001 | 0x27 | 0x17 | 0x39 |
| 1488–1511 | 00010101 | 10100000 | 11101100 | 0x15 | 0xA0 | 0xEC |
| 1512–1535 | 01010101 | 10001010 | 00111111 | 0x55 | 0x8A | 0x3F |
| 1536–1559 | 01101011 | 10110110 | 11011000 | 0x6B | 0xB6 | 0xD8 |
| 1560–1583 | 10110001 | 10001000 | 10000100 | 0xB1 | 0x88 | 0x84 |
| 1584–1607 | 00001111 | 00101100 | 10001000 | 0x0F | 0x2C | 0x88 |
| 1608–1631 | 10101000 | 11111000 | 10010010 | 0xA8 | 0xF8 | 0x92 |
| 1632–1655 | 10100000 | 10110111 | 10011110 | 0xA0 | 0xB7 | 0x9E |
| 1656–1679 | 00111100 | 01100100 | 01010101 | 0x3C | 0x64 | 0x55 |
| 1680–1703 | 00001110 | 01111000 | 11111011 | 0x0E | 0x78 | 0xFB |
| 1704–1727 | 01110011 | 01010100 | 00000000 | 0x73 | 0x54 | 0x00 |
| 1728–1751 | 01000010 | 10101011 | 10000010 | 0x42 | 0xAB | 0x82 |
| 1752–1775 | 10111111 | 11100111 | 11001011 | 0xBF | 0xE7 | 0xCB |
| 1776–1799 | 00100110 | 11110011 | 01000000 | 0x26 | 0xF3 | 0x40 |
| 1800–1823 | 00001101 | 00000111 | 01101010 | 0x0D | 0x07 | 0x6A |
| 1824–1847 | 00010101 | 00010111 | 11111111 | 0x15 | 0x17 | 0xFF |
| 1848–1871 | 10100101 | 11011100 | 01100100 | 0xA5 | 0xDC | 0x64 |
| 1872–1895 | 10110110 | 01010100 | 00110001 | 0xB6 | 0x54 | 0x31 |
| 1896–1919 | 00000001 | 01100001 | 00101001 | 0x01 | 0x61 | 0x29 |
| 1920–1943 | 00010011 | 01110000 | 01010000 | 0x13 | 0x70 | 0x50 |
| 1944–1967 | 10000000 | 11001110 | 01000101 | 0x80 | 0xCE | 0x45 |
| 1968–1991 | 11000000 | 10101000 | 11001101 | 0xC0 | 0xA8 | 0xCD |
| 1992–2015 | 11111000 | 01111100 | 01010011 | 0xF8 | 0x7C | 0x53 |
| 2016–2039 | 01010001 | 01001110 | 11010011 | 0x51 | 0x4E | 0xD3 |
| 2040–2063 | 10101110 | 00010011 | 11110000 | 0xAE | 0x13 | 0xF0 |
| 2064–2087 | 11101101 | 10111111 | 10001110 | 0xED | 0xBF | 0x8E |
| 2088–2111 | 10010100 | 00110100 | 11111011 | 0x94 | 0x34 | 0xFB |
| 2112–2135 | 00010000 | 11011001 | 10111110 | 0x10 | 0xD9 | 0xBE |
| 2136–2159 | 00110001 | 10011111 | 01100000 | 0x31 | 0x9F | 0x60 |



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**Table I-42—DATA bits after removal of shortening bits and copying of repetition bits *(continued)***

| Bit ## | Binary value B0 B7 | Binary value B8 B15 | Binary value B16 B23 | Hexadecimal value | Hexadecimal value | Hexadecimal value |
|---|---|---|---|---|---|---|
| 2160–2183 | 00011100 | 10100110 | 01010101 | 0x1C | 0xA6 | 0x55 |
| 2184–2207 | 11111001 | 10100110 | 10101010 | 0xF9 | 0xA6 | 0xAA |
| 2208–2231 | 00111000 | 01110001 | 01111010 | 0x38 | 0x71 | 0x7A |
| 2232–2255 | 10101100 | 10110010 | 11110101 | 0xAC | 0xB2 | 0xF5 |
| 2256–2279 | 11010001 | 10000001 | 01010000 | 0xD1 | 0x81 | 0x50 |
| 2280–2303 | 11110001 | 00001011 | 10111101 | 0xF1 | 0x0B | 0xBD |
| 2304–2327 | 10010011 | 10001011 | 10100010 | 0x93 | 0x8B | 0xA2 |
| 2328–2351 | 10010110 | 00100101 | 11100011 | 0x96 | 0x25 | 0xE3 |
| 2352–2375 | 01101100 | 11000111 | 00000101 | 0x6C | 0xC7 | 0x05 |
| 2376–2399 | 00011000 | 00101000 | 11110011 | 0x18 | 0x28 | 0xF3 |
| 2400–2423 | 00111001 | 11011000 | 00010001 | 0x39 | 0xD8 | 0x11 |
| 2424–2447 | 01110101 | 00010111 | 11011101 | 0x75 | 0x17 | 0xDD |
| 2448–2471 | 11111011 | 11010010 | 10101010 | 0xFB | 0xD2 | 0xAA |
| 2472–2495 | 11101011 | 10100110 | 10000101 | 0xEB | 0xA6 | 0x85 |
| 2496–2519 | 10110011 | 01011000 | 10101001 | 0xB3 | 0x58 | 0xA9 |
| 2520–2543 | 11010001 | 01010101 | 00010010 | 0xD1 | 0x55 | 0x12 |
| 2544–2567 | 00000100 | 01110100 | 11011001 | 0x04 | 0x74 | 0xD9 |
| 2568–2591 | 11101001 | 00111011 | 11001101 | 0xE9 | 0x3B | 0xCD |

## I.4 DMG example data vectors

I.5 (DMG Example 1—DMG control mode encoding), I.6 (DMG Example 2—DMG SC mode encoding), and I.7 (DMG Example 3—DMG low-power SC mode encoding) contain example data vectors for the DMG PHY (see Clause 20 (Directional multi-gigabit (DMG) PHY specification)).

For each described node, there is a cross-reference in this annex that is of the form

Reference: <**filename.txt**>

where the named file is one of the text files contained in the DMGEncodingExamples.zip file embedded in the IEEE 802.11 Working Group document 11-12/0751r1, located at https://mentor.ieee.org/802.11/dcn/12/11-12-0751-01-00ad-dmg-encoding-examples.docx).

Depending on the node being illustrated, the text file might represent bit data, symbol data, or sample data:

— For bit data, the text file contains a time ordered sequence of 1 and 0 characters, separated by spaces and without any carriage control characters.

— For symbol data, the text file contains a time ordered sequence of signed integers, separated by spaces and without any carriage control characters.

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— For sample data, the text file contains a time ordered sequence of complex values, formatted as ±<re>±<im>j, separated by spaces and without any carriage control characters.

When referencing specific bits, symbols, or samples in the files, they are considered to be numbered starting from 1.

This formatting of the text files has been chosen to facilitate import into other tools. For example, the files can be read using the MATLAB `dlmread('filename')` command.

For DMG control mode, SC mode and low-power (LP) SC mode modulation samples, no spectrum shaping has been applied to the data because the implementation of spectrum shaping is not defined in this standard.

## I.5 DMG Example 1—DMG control mode encoding

### I.5.1 DMG control mode preamble

The DMG control mode preamble Short Training field (STF) and Channel Estimation field (CEF) are each constructed from a concatenation of real valued bipolar Golay sequences that is π/2-BPSK modulated, as shown in Figure I-1 (DMG control mode preamble expressed in Ga128 and Gb128 sequences).

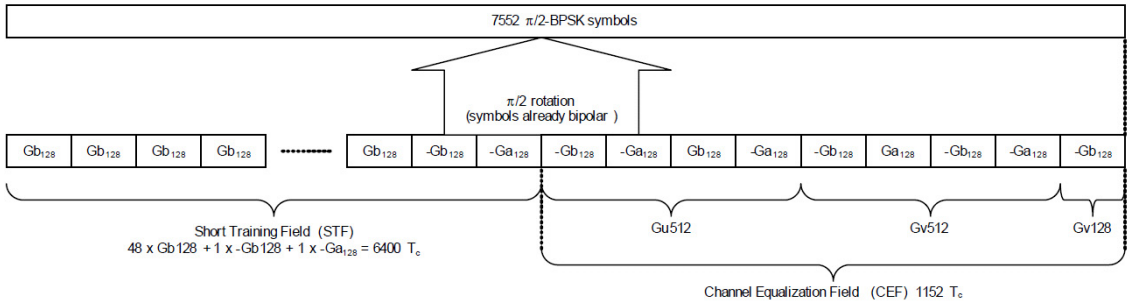


**Figure I-1—DMG control mode preamble expressed in $Ga_{128}$ and $Gb_{128}$ sequences**

The DMG control mode preamble is 7552 samples long.

Reference: **CPHY_Preamble Samples.txt**

### I.5.2 Control mode header

#### I.5.2.1 General

The DMG control mode header coding and modulation are shown in Figure I-2 (DMG control mode header coding and modulation).

#### I.5.2.2 DMG control mode header and payload bits

Figure I-2 (DMG control mode header coding and modulation) node ①. The 5 octets of header data followed by the payload data. The first 6 octets of the data payload are used to complete the construction of the single LDPC codeword of the DMG control mode header. For this example, the DMG control mode header fields(#291) are set as listed in Table I-43 (DMG control mode header settings).


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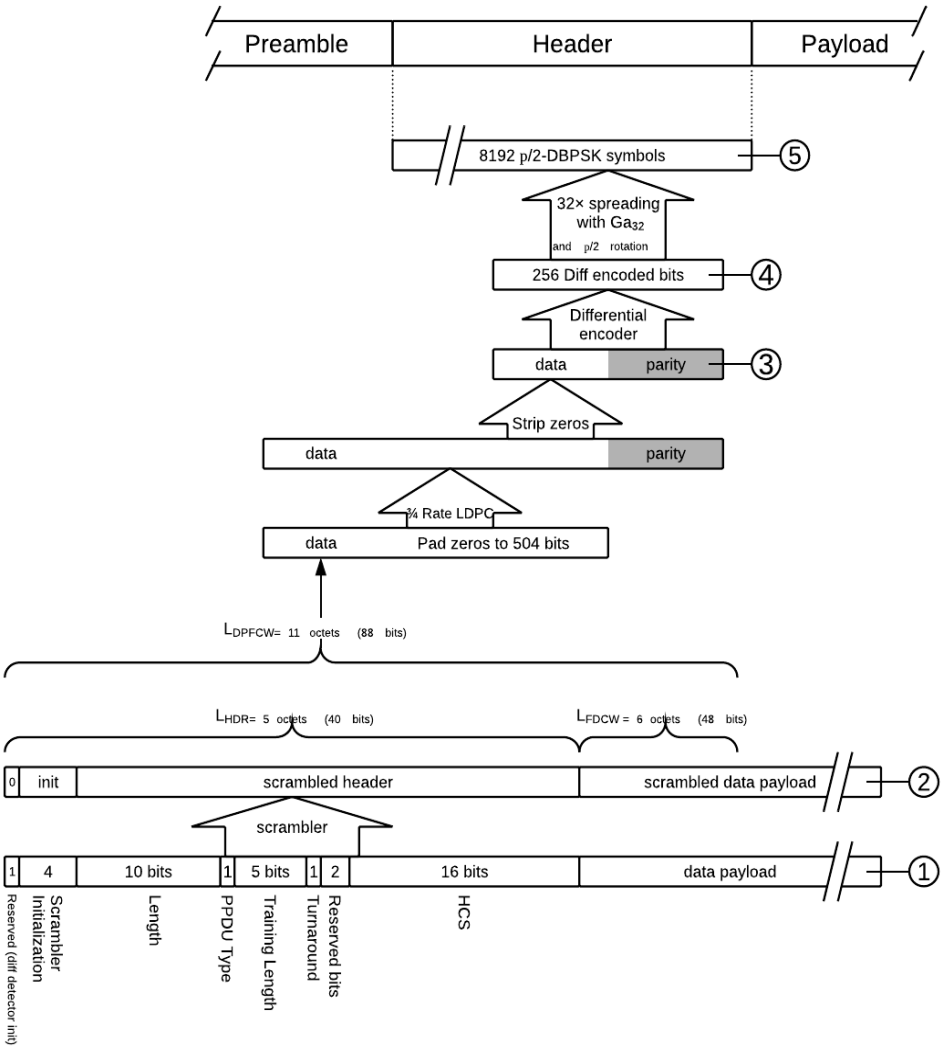


**Figure I-2—DMG control mode header coding and modulation**

The data payload octets are provided by a count, modulo 256, starting at 0. The resulting header and payload sequence is 1000 bits long, of which the first 88 bits are encoded in the header modulation block. For this example, with a payload of 120 octets, $L_{DPFCW} = 88$, $L_{DPCW} = 152$ and $L_{DPLCW} = 152$.

These numbers illustrate that the payload is not simply packed 168 bits at a time into the LDPC encoding, with the last few bits (modulo 168) in the last PPDU(#3243) getting disproportionate coding gain. The specified calculation spreads the excess coding gain evenly across all of the packets, so the number of payload bits in each packet varies between approximately 120 and the maximum 168.

Reference: Bits 1 to 88 of the file **CPHY_Header and Payload bits.txt**

### I.5.2.3 DMG control mode scrambled header and payload bits

Figure I-2 (DMG control mode header coding and modulation) node ②. The 5 header plus 6 data = 11 octets after scrambling.

Reference: Bits 1 to 88 of the file **CPHY_Scrambled Header and Payload bits.txt**

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**Table I-43—DMG control mode header settings**

| Field | Value |
|---|---|
| Scrambler Initialization | 2 |
| Length | 120 |
| PPDU Type | 0 |
| Training Length | 0 |
| Turnaround | 0 |
| Reserved bits | 0 |

### I.5.2.4 DMG control mode LDPC encoded header bits

Figure I-2 (DMG control mode header coding and modulation) node ③. In this example there are 7 LDPC codewords. The number of bits produced by the first codeword after zero stripping is 88 + 168 = 256, and the number of bits produced by each of the remaining 6 codewords is 152 + 168 = 320. The total number of bits after LDPC encoding is 256 + 6 x 320 = 2176, of which the first 256 bits correspond to the LDPC encoded header.

Reference: Bits 1 to 256 of the file **CPHY_LDPC Encoded Header and Payload bits.txt**

### I.5.2.5 DMG control mode differentially encoded header symbols

Figure I-2 (DMG control mode header coding and modulation) node ④. The 256 LDPC encoded header bits are differentially encoded.

Reference: Symbols 1 to 256 of the file **CPHY_Diff Encoded Header and Payload symbols.txt**

### I.5.2.6 DMG control mode header samples

Figure I-2 (DMG control mode header coding and modulation) node ⑤. The 256 differentially encoded bipolar symbol values are spread using the $Ga_{32}$ Golay sequence, then $\pi/2$ rotated to produce 8192 chips at $F_c$ = 1760 MHz.

Reference: Samples 1 to 8192 of the file **CPHY_Header and Payload samples.txt**


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## I.5.3 DMG control mode payload

### I.5.3.1 General

The DMG control mode payload coding and modulation are shown in Figure I-3 (DMG control mode payload coding and modulation).

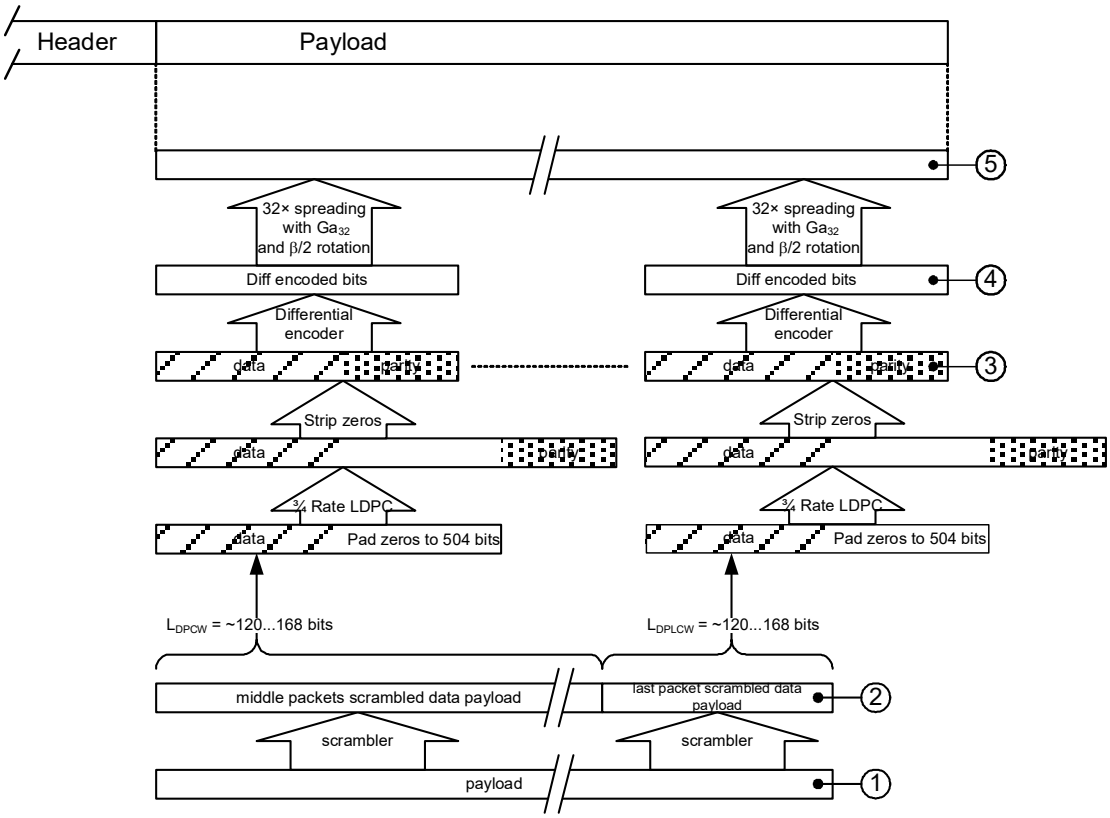


**Figure I-3—DMG control mode payload coding and modulation**

### I.5.3.2 DMG control mode payload bits

Figure I-3 (DMG control mode payload coding and modulation) node ①.

Reference: Bits 89 to 1000 of the file **CPHY_Header and Payload bits.txt**

### I.5.3.3 DMG control mode scrambled payload bits

Figure I-3 (DMG control mode payload coding and modulation) node ②.

Reference: Bits 89 to 1000 of the file **CPHY_Scrambled Header and Payload bits.txt**

### I.5.3.4 DMG control mode LDPC encoded payload bits

Figure I-3 (DMG control mode payload coding and modulation) node ③.

Reference: Bits 257 to 2176 of the file **CPHY_LDPC Encoded Header and Payload bits.txt**

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#### I.5.3.5 DMG control mode differentially encoded payload symbols

Figure I-3 (DMG control mode payload coding and modulation) node ④.

Reference: Symbols 257 to 2176 of the file **CPHY_Diff Encoded Header and Data symbols.txt**

#### I.5.3.6 DMG control mode payload samples

Figure I-3 (DMG control mode payload coding and modulation) node ⑤.

In this example, the 320 differentially encoded bipolar symbol values from each of the 6 payload bearing LDPC codewords, including the last one, gives a total of 6 x 320 = 1920 symbols which are then spread using the $Ga_{32}$ Golay sequence and π/2 rotated to produce 61 440 chips at *Fc* = 1.76 GHz.

Reference: Samples 8193 to 69 632 of the file **CPHY_Header and Payload samples.txt**

## I.6 DMG Example 2—DMG SC mode encoding

### I.6.1 DMG SC mode preamble

The DMG SC mode preamble Short Training field (STF) and Channel Estimation field (CEF) are each constructed from a concatenation of real valued bipolar Golay sequences that is π/2-BPSK modulated, as shown in Figure I-4 (DMG SC mode preamble expressed in Ga128 and Gb128 sequences).

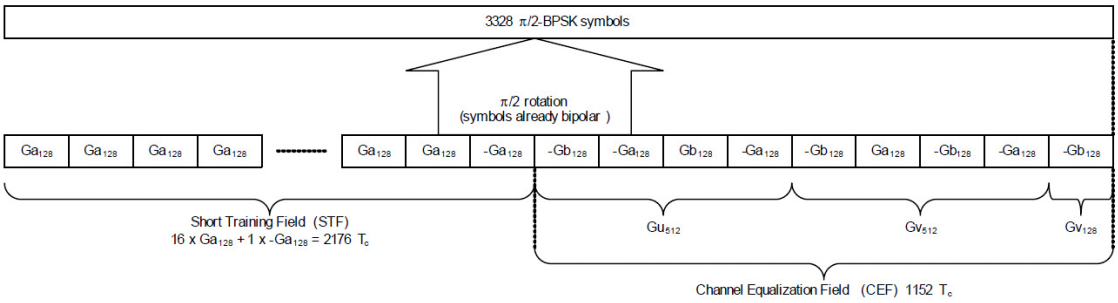


**Figure I-4—DMG SC mode preamble expressed in $Ga_{128}$ and $Gb_{128}$ sequences**

The preamble is 3328 samples long.

Reference: **SCPHY_Preamble Samples.txt**

### I.6.2 DMG SC mode header

#### I.6.2.1 General

The DMG SC mode header coding and modulation are shown in Figure I-5 (DMG SC mode header coding and modulation).


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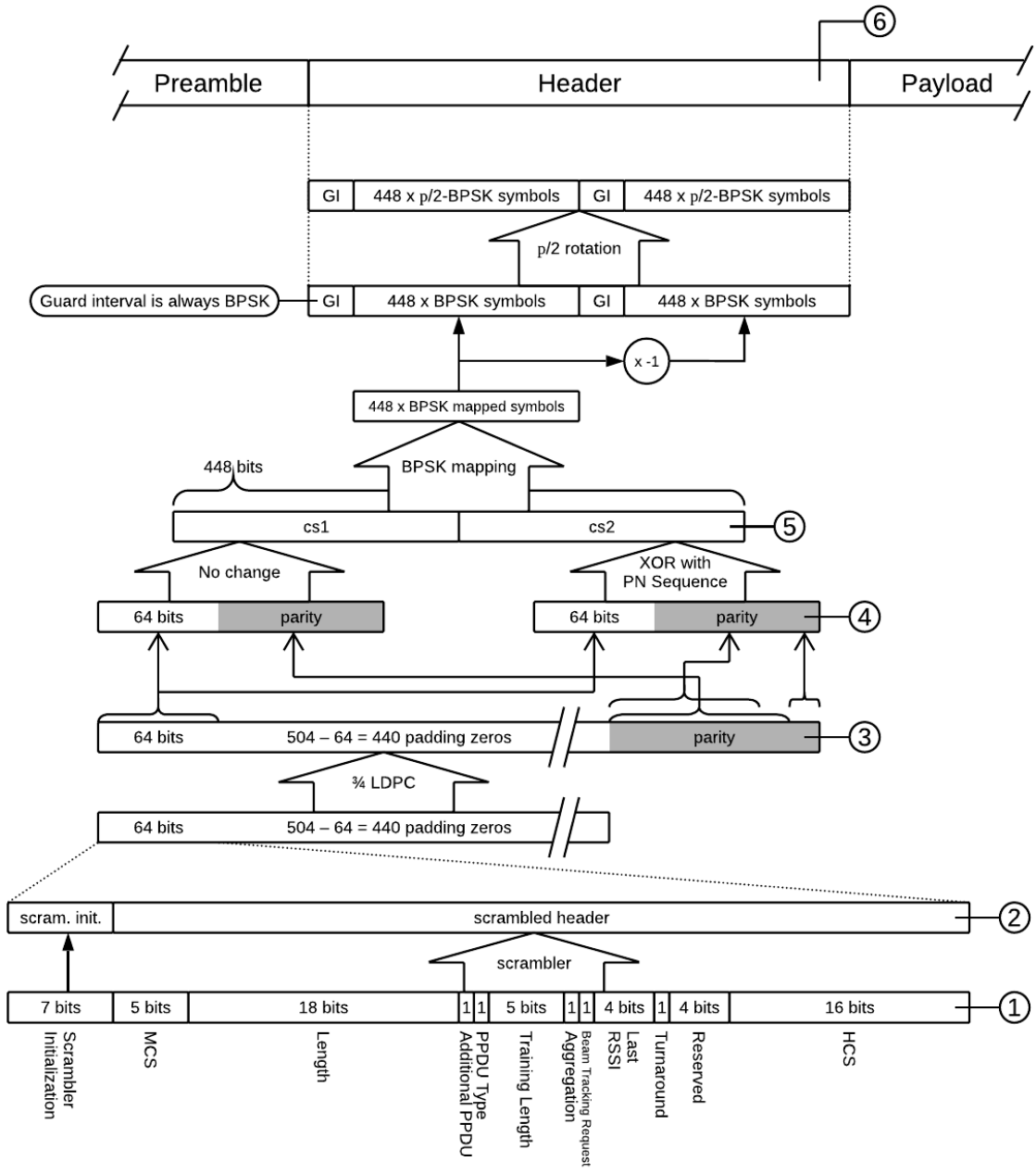


**Figure I-5—DMG SC mode header coding and modulation**

### I.6.2.2 DMG SC control header bits

Figure I-5 (DMG SC mode header coding and modulation) node ①. The 8 octets of header data. For this example, the DMG SC control mode header fields(#291) are set as listed in Table I-44 (DMG SC control header settings).

Reference: **SCPHY_MCS2_Header bits.txt**

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**Table I-44—DMG SC control header settings**

| Field | Value |
|---|---|
| Scrambler Initialization | 66 |
| MCS | 2 |
| Length | 1000 |
| Additional PPDU | 0 |
| PPDU Type | 0 |
| Training Length | 0 |
| Aggregation | 0 |
| Beam Tracking Request | 0 |
| Last RSSI | 0 |
| Turnaround | 0 |
| Reserved bits | 0 |

#### I.6.2.3 DMG SC mode scrambled header bits

Figure I-5 (DMG SC mode header coding and modulation) node ②. The header bits after scrambling bits 8 to 64 of the header using the seed 66 (0x42).

Reference: **SCPHY_MCS2_Scrambled Header bits.txt**

#### I.6.2.4 DMG SC mode LDPC encoded header bits

Figure I-5 (DMG SC mode header coding and modulation) node ③. The scrambled header data after LDPC encoding but prior to zero stripping.

Reference: **SCPHY_MCS2_LDPC Encoded Header bits.txt**

#### I.6.2.5 DMG SC mode LDPC data shortened bits

Figure I-5 (DMG SC mode header coding and modulation) node ④. The dimension of DMG SC mode modulation blocks requires that the CS1 and CS2 sequences are each 224 bits long; this in turn requires that, in addition to the 0s(M118), some of the parity bits are discarded in order to shorten the LDPC codewords to 224 bits.

The data for the second shortened LDPC codeword is given as they are before they are scrambled to provide CS2.

Reference: **SCPHY_MCS2_Shortened LDPC for CS1 bits.txt**

Reference: **SCPHY_MCS2_Shortened LDPC for CS2 bits.txt**

#### I.6.2.6 DMG SC mode CS1/CS2 sequence bits

Figure I-5 (DMG SC mode header coding and modulation) node ⑤. The 448 bit concatenated CS1/CS2 sequence including the PN scrambling of CS2.


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Reference: **SCPHY_MCS2_Final CS1 CS2 Sequence bits.txt**

#### I.6.2.7 DMG SC mode header samples

Figure I-5 (DMG SC mode header coding and modulation) node ⑥. The fully modulated signal after BPSK mapping, duplication (with negation), guard interval addition and π/2 rotation are applied.

The 448 header bits are BPSK mapped to 448 modulation symbols and increased to 512 symbols by the addition of a 64 symbol guard interval. A second, negated, copy of the 448 modulation symbols is also increased to 512 symbols by the addition of a 64 symbol guard interval. The two 512 symbol blocks are concatenated and π/2 rotated to create 1024 samples.

Reference: **SCPHY_MCS2_Header Samples.txt**

### I.6.3 DMG SC mode payload

#### I.6.3.1 General

The DMG SC mode payload coding and modulation are shown in Figure I-6 (DMG SC mode MCS 1 payload coding and modulation) (for MCS1) and Figure I-7 (DMG SC mode MCS 2—MCS 12 payload coding and modulation) (for MCS2–MCS12).

#### I.6.3.2 DMG SC mode MCS 1 payload

##### I.6.3.2.1 Payload bits

Figure I-6 (DMG SC mode MCS 1 payload coding and modulation) node ①. The payload at node ① is a count, modulo 256, starting at 0.

For MCS 1 each rate 1/2 LDPC codeword encodes 168 bits (with $\rho = 2$ repetition) so the payload padding calculation gives $N_{CW} = 48$ and $N_{DATA\_PAD} = 64$.

There are 1000 × 8 = 8000 payload bits plus 64 padding bits giving a total of 8 064 bits.

Reference: **SCPHY_MCS1_Payload bits.txt**

##### I.6.3.2.2 Scrambled payload bits

Figure I-6 (DMG SC mode MCS 1 payload coding and modulation) node ②. All 8 064 bits are scrambled according to a scrambler initialization value of 66.

Reference: **SCPHY_MCS1_Scrambled Payload bits.txt**

##### I.6.3.2.3 Rate 1/2 LDPC encoded bits before scrambled duplication

Figure I-6 (DMG SC mode MCS 1 payload coding and modulation) node ③. The rate 1/2 LDPC encoding of each block of $L_z = 168$ scrambled payload bits plus $L_z = 168$ padding zero bits. In this example, the 8064 actual payload bits are doubled, by repetition, to an effective payload of 16 128 bits, then doubled again to 32 256 bits by LDPC encoding.

This node, unique to MCS 1, is the raw LDPC encoded payload bits before scrambled duplication.

Reference: **SCPHY_MCS1_LDPC Encoder Output bits.txt**

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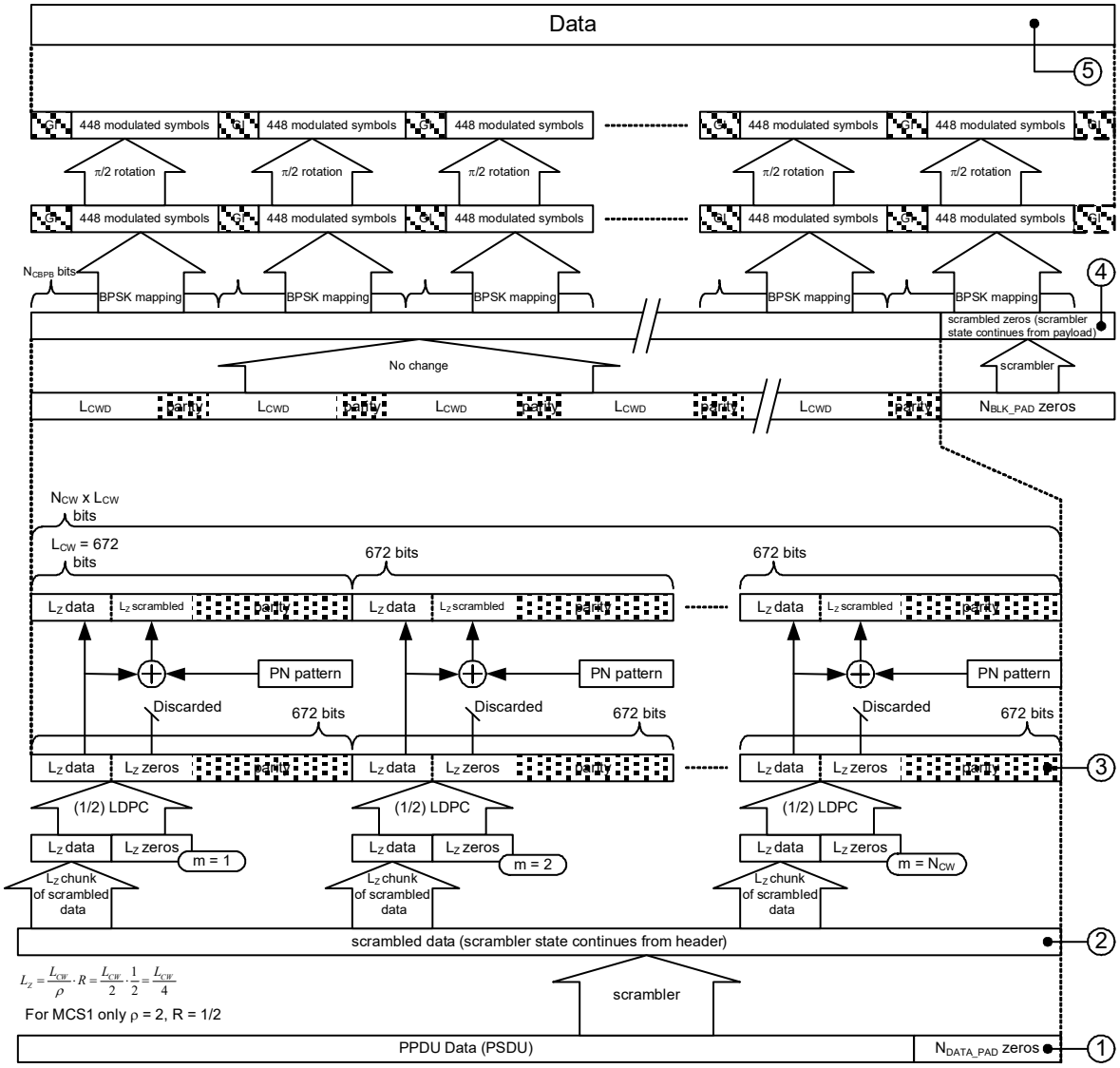


**Figure I-6—DMG SC mode MCS 1 payload coding and modulation**

### I.6.3.2.4 Rate 1/2 LDPC encoded bits after scrambled duplication

Figure I-6 (DMG SC mode MCS 1 payload coding and modulation) node ④. The LDPC codewords after the $L_z = 168$ 0s(M118) have been replaced by the $L_z = 168$ rescrambled data octets. The data at this node also includes the appended $N_{BLK\_PAD}$ scrambled 0s(M118); however, in this example, $N_{BLK\_PAD} = 0$, so there are still 32 256 bits.

Each 448 bits in the reference file is the $N_{CBPB} = 448$ bits required to build a modulation block of the MCS 1 payload.

Reference: **SCPHY_MCS1_LDPC Encoded Payload Bits.txt**


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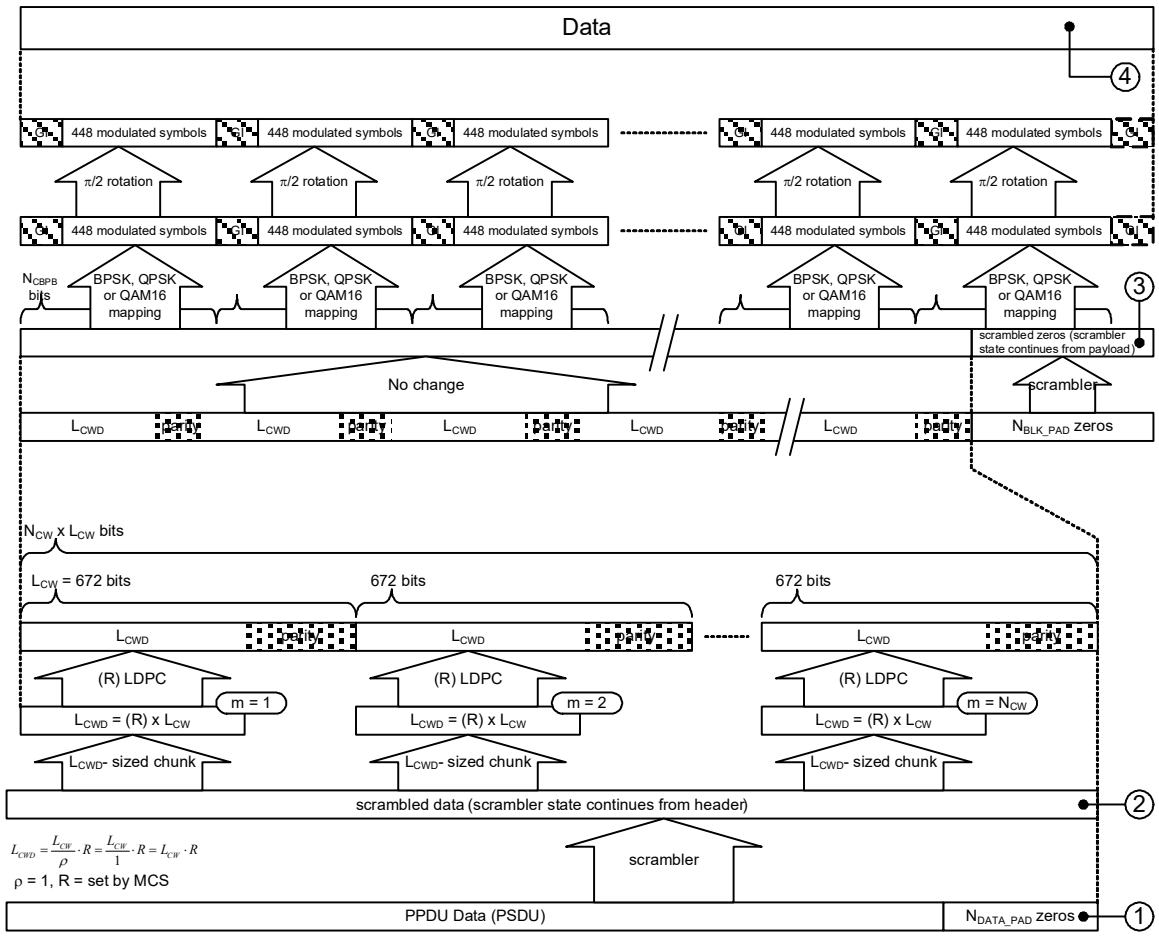


**Figure I-7—DMG SC mode MCS 2—MCS 12 payload coding and modulation**

### I.6.3.2.5 Payload samples

Figure I-6 (DMG SC mode MCS 1 payload coding and modulation) node ⑤. The modulated signal after BPSK mapping, guard interval addition and π/2 rotation has been applied.

In this example, the 32 256 encoded bits are divided into 72 × 448 bit blocks. BPSK mapping converts this to 72 × 448 modulation symbols which the guard interval increases to 72 × 512 modulation symbols. When the closing 64-symbol guard interval is added, it results in a total of 72 × 512 + 64 = 36 928 payload samples.

Reference: **SCPHY_MCS1_Payload Samples.txt**

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#### I.6.3.3 DMG SC mode MCS 5 payload

##### I.6.3.3.1 Payload bits

Figure I-7 (DMG SC mode MCS 2—MCS 12 payload coding and modulation) node ①. The payload at node ① is a count, modulo 256, starting at 0.

For MCS 5 each rate 13/16 LDPC codeword encodes 546 bits so the payload padding calculation gives $N_{CW} = 15$ and $N_{DATA\_PAD} = 190$.

There are $1000 \times 8 = 8000$ payload bits plus 190 padding bits giving a total of 8 190 bits.

Reference: **SCPHY_MCS5_Payload bits.txt**

##### I.6.3.3.2 Scrambled payload bits

Figure I-7 (DMG SC mode MCS 2—MCS 12 payload coding and modulation) node ②. All 8 190 bits are scrambled according to a scrambler initialization value of 66.

Reference: **SCPHY_MCS5_Scrambled Payload bits.txt**

##### I.6.3.3.3 Rate 13/16 LDPC encoded payload bits

Figure I-6 (DMG SC mode MCS 1 payload coding and modulation) node ③. The rate 13/16 LDPC encoding of each block of $L_{CWD} = 546$ scrambled payload bits. In this example, the 8 190 payload bits are increased to 10 080 bits by the LDPC encoding.

The data at this node also includes the appended $N_{BLK\_PAD}$ scrambled 0s(M118). In this example, $N_{BLK\_PAD} = 224$, so the total number of bits is 10 080 + 224 = 10 304.

Reference: **SCPHY_MCS5_LDPC Encoded Payload Bits.txt**

##### I.6.3.3.4 Payload samples

Figure I-7 (DMG SC mode MCS 2—MCS 12 payload coding and modulation) node ④. The modulated signal after BPSK mapping, guard interval addition and π/2 rotation has been applied.

In this example, the 10 304 encoded bits are divided into $23 \times 448$ bit blocks. BPSK mapping converts this to $23 \times 448$ modulation symbols which the guard interval increases to $23 \times 512$ modulation symbols. When the closing 64-symbol guard interval is added, it results in a total of $23 \times 512 + 64 = 11\,840$ payload samples.

Reference: **SCPHY_MCS5_Payload Samples.txt**

#### I.6.3.4 DMG SC mode MCS 7 payload

##### I.6.3.4.1 Payload bits

Figure I-7 (DMG SC mode MCS 2—MCS 12 payload coding and modulation) node ①. The payload at node ① is a count, modulo 256, starting at 0.

For MCS 7 each rate 5/8 LDPC codeword encodes 420 bits so the payload padding calculation gives $N_{CW} = 20$ and $N_{DATA\_PAD} = 400$.


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There are 1000 × 8 = 8000 payload bits plus 400 padding bits giving a total of 8 400 bits.

Reference: **SCPHY_MCS7_Payload bits.txt**

#### I.6.3.4.2 Scrambled payload bits

Figure I-6 (DMG SC mode MCS 1 payload coding and modulation) node ②. All 8 400 bits are scrambled according to a scrambler initialization value of 66.

Reference: **SCPHY_MCS7_Scrambled Payload bits.txt**

#### I.6.3.4.3 Rate 5/8 LDPC encoded payload bits

Figure I-7 (DMG SC mode MCS 2—MCS 12 payload coding and modulation) node ③. The rate 5/8 LDPC encoding of each block of $L_{CWD}$ = 420 scrambled payload bits. In this example, the 8 400 payload bits are increased to 13 440 bits by the LDPC encoding.

The data at this node also includes the appended $N_{BLK\_PAD}$ scrambled 0s(M118). In this example, $N_{BLK\_PAD}$ = 0, so there are still a total of 13 440 bits.

Reference: **SCPHY_MCS7_LDPC Encoded Payload Bits.txt**

#### I.6.3.4.4 Payload samples

Figure I-7 (DMG SC mode MCS 2—MCS 12 payload coding and modulation) node ④. The modulated signal after QPSK mapping, guard interval addition and π/2 rotation has been applied.

In this example, the 13 440 encoded bits are divided into 15 × 896 bit blocks. QPSK mapping converts this to 15 × 448 modulation symbols which the guard interval increases to 15 × 512 modulation symbols. When the closing 64-symbol guard interval is added, it results in a total of 15 × 512 + 64 = 7 744 payload samples.

Reference: **SCPHY_MCS7_Payload Samples.txt**

### I.6.3.5 DMG SC mode MCS 12 payload

#### I.6.3.5.1 Payload bits

Figure I-7 (DMG SC mode MCS 2—MCS 12 payload coding and modulation) node ①. The payload at node ① is a count, modulo 256, starting at 0.

For MCS 12 each rate 3/4 LDPC codeword encodes 504 bits so the payload padding calculation gives $N_{CW}$ = 16 and $N_{DATA\_PAD}$ = 64.

There are 1000 × 8 = 8000 payload bits plus 64 padding bits giving a total of 8 064 bits.

Reference: **SCPHY_MCS12_Payload bits.txt**

#### I.6.3.5.2 Scrambled payload bits

Figure I-7 (DMG SC mode MCS 2—MCS 12 payload coding and modulation) node ②. All 8 064 bits are scrambled according to a scrambler initialization value of 66.

Reference: **SCPHY_MCS12_Scrambled Payload bits.txt**

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#### I.6.3.5.3 Rate 3/4 LDPC encoded payload bits

Figure I-7 (DMG SC mode MCS 2—MCS 12 payload coding and modulation) node ③. The rate 3/4 LDPC encoding of each block of $L_{CWD}$ = 504 scrambled payload bits. In this example, the 8 064 payload bits are increased to 10 752 bits by the LDPC encoding.

The data at this node also includes the appended $N_{BLK\_PAD}$ scrambled 0s(M118). In this example, $N_{BLK\_PAD}$ = 0, so there are still a total of 10 752 bits.

Reference: **SCPHY_MCS12_LDPC Encoded Payload Bits.txt**

#### I.6.3.5.4 Payload samples

Figure I-7 (DMG SC mode MCS 2—MCS 12 payload coding and modulation) node ④. The modulated signal after 16-QAM mapping, guard interval addition and π/2 rotation has been applied.

In this example, the 10 752 encoded bits are divided into 6 × 1 792 bit blocks. 16-QAM mapping converts this to 6 × 448 modulation symbols which the guard interval increases to 6 × 512 modulation symbols. When the closing 64-symbol guard interval is added, it results in a total of 6 × 512 + 64 = 3 136 payload samples.

Reference: **SCPHY_MCS12_Payload Samples.txt**

## I.7 DMG Example 3—DMG low-power SC mode encoding

### I.7.1 Introduction(#3385)

The DMG low-power SC mode is obsolete.

### I.7.2 DMG low-power SC mode preamble

The DMG low-power SC mode preamble is identical to the DMG SC mode preamble.

### I.7.3 DMG low-power SC mode header

The DMG low-power SC mode header fields are the same as the DMG SC mode header fields. The DMG low-power SC mode header is encoded and modulated in the same way as the DMG SC mode header.

### I.7.4 DMG low-power SC mode MCS 26 payload

#### I.7.4.1 General

The DMG low-power SC mode payload coding and modulation are shown in Figure I-8 (DMG low-power SC mode payload coding and modulation).

#### I.7.4.2 Payload bits

Figure I-8 (DMG low-power SC mode payload coding and modulation) node ①. The payload at node is a count, modulo 256, starting at 0.


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For MCS 26, the DMG low-power SC mode payload padding calculation gives $N_{DATA\_PAD} = 368$; however, unlike the other modes, this padding data is not appended before FEC computation.

So there are just 1000 × 8 = 8000 payload bits.

Reference: **LPSCPHY_MCS26_Payload bits.txt**

#### I.7.4.3 Scrambled payload bits

Figure I-8 (DMG low-power SC mode payload coding and modulation) node ②. All 8000 bits are scrambled according to a scrambler initialization value of 66.

Reference: **LPSCPHY_MCS26_Scrambled Payload bits.txt**

#### I.7.4.4 RS(224,208) encoded payload bits

Figure I-8 (DMG low-power SC mode payload coding and modulation) node ③. In this example, there are 4 RS(224,208) codewords and one shortened RS(184,168) codeword, giving a total of (4 × 224 + 1 × 184) × 8 = 8 640 bits at this node.

Reference: **LPSCPHY_MCS26_RS(224,208) Output bits.txt**

#### I.7.4.5 (12,8) block coded payload bits

Figure I-8 (DMG low-power SC mode payload coding and modulation) node ④. The (12,8) block coder increases the effective bits from 8 640 to 12 960.

Reference: **LPSCPHY_MCS26_Block Coded Payload bits.txt**

#### I.7.4.6 Interleaved payload bits

Figure I-8 (DMG low-power SC mode payload coding and modulation) node ⑤. Before interleaving the block coder output is padded with $N_{DATA\_PAD} = 368$ scrambled 0s(M118) to give 13 328 bits (34 x 392). The interleaver then redistributes these bits in time, as specified.

Reference: **LPSCPHY_MCS26_RS Encoded and Interleaved Payload bits.txt**

#### I.7.4.7 Payload samples

Figure I-8 (DMG low-power SC mode payload coding and modulation) node ⑥. Each block of 392 bits from the interleaver output is BPSK mapped to 392 modulation symbols, prepended with a $Ga_{64}$ sequence as a guard interval and punctuated by $G_8$ (last 8 samples of $Ga_{64}$) guard intervals, then π/2 rotated, thus resulting in a 512 symbol π/2-BPSK modulation block.

In this example, there are 34 modulation blocks and, as specified, the last one is followed by a terminating $Ga_{64}$ guard interval sequence, so there are 34 × 512 + 64 = 17 472 samples at this node.

Reference: **LPSCPHY_MCS26_Payload Samples.txt**

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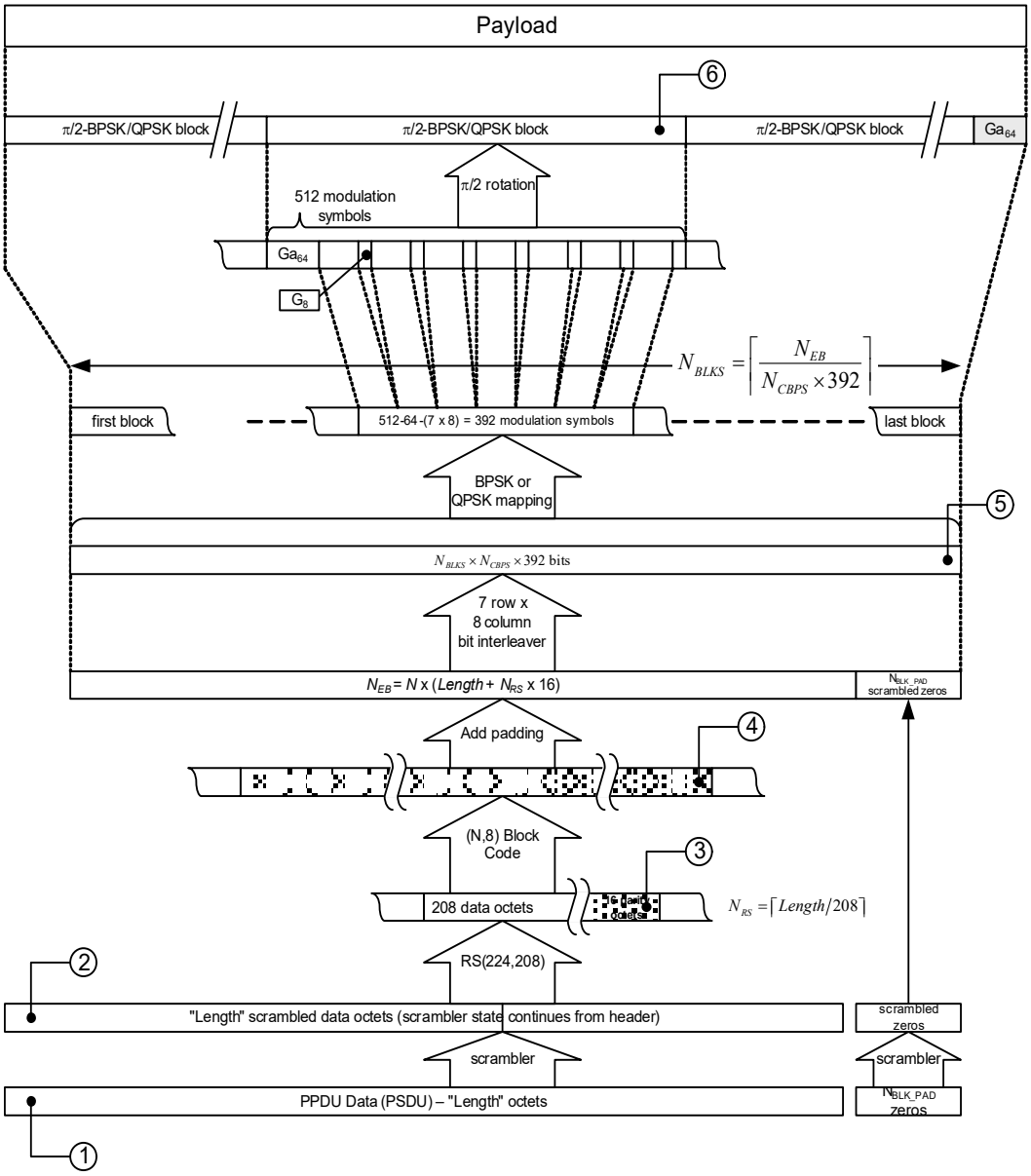


**Figure I-8—DMG low-power SC mode payload coding and modulation**

## I.7.5 DMG low-power SC mode MCS 30 payload

### I.7.5.1 Payload bits

Figure I-8 (DMG low-power SC mode payload coding and modulation) node ①. The payload at node is a count, modulo 256, starting at 0.


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For MCS 30, the DMG low-power SC mode payload padding calculation gives $N_{DATA\_PAD} = 472$; however, unlike the other modes, this padding data is not appended before FEC computation.

So there are just 1000 × 8 = 8000 payload bits.

Reference: **LPSCPHY_MCS30_Payload bits.txt**

#### I.7.5.2 Scrambled payload bits

Figure I-8 (DMG low-power SC mode payload coding and modulation) node ②. All 8000 bits are scrambled according to a scrambler initialization value of 66.

Reference: **LPSCPHY_MCS30_Scrambled Payload bits.txt**

#### I.7.5.3 RS(224,208) encoded payload bits

Figure I-8 (DMG low-power SC mode payload coding and modulation) node ③. In this example, there are 4 RS(224,208) codewords and one shortened RS(184,168) codeword, giving a total of (4 × 224 + 1 × 184) × 8 = 8 640 bits at this node.

Reference: **LPSCPHY_MCS30_RS(224,208) Output bits.txt**

#### I.7.5.4 Spc(9,8) block coded payload bits

Figure I-8 (DMG low-power SC mode payload coding and modulation) node ④. The (9,8) block coder increases the effective bits from 8 640 to 9 720.

Reference: **LPSCPHY_MCS30_Block Coded Payload bits.txt**

#### I.7.5.5 Interleaved payload bits

Figure I-8 (DMG low-power SC mode payload coding and modulation) node ⑤. Before interleaving the block coder output is padded with $N_{DATA\_PAD} = 472$ scrambled zeros to give 10 192 bits (26 × 392). The interleaver then redistributes these bits in time, as specified.

Reference: **LPSCPHY_MCS30_RS Encoded and Interleaved Payload bits.txt**

#### I.7.5.6 Payload samples

Figure I-8 (DMG low-power SC mode payload coding and modulation) node ⑥. Each block of 784 bits from the interleaver output is QPSK mapped to 392 modulation symbols, prepended with a $Ga_{64}$ sequence as a guard interval and punctuated by $G_8$ (last 8 samples of $Ga_{64}$) guard intervals, then π/2 rotated, thus resulting in a 512 symbol π/2-BPSK modulation block.

In this example, there are 13 modulation blocks and, as specified, the last one is followed by a terminating $Ga_{64}$ guard interval sequence, so there are 13 × 512 + 64 = 6 720 samples at this node.

Reference: **LPSCPHY_MCS30_Payload Samples.txt**

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## I.8 EDMG example data vectors(11ay)

Encoding examples are provided for the FORMAT parameter set to EDMG and the EDMG_MODULATION parameter set to EDMG_C_MODE or EDMG_SC_MODE. Encoding examples for the EDMG_OFDM_MODE are not provided.

Encoding examples are contained in the EDMGEncodingExamples.zip file embedded into the IEEE 802.11 Working Group document 11-18/1346r0, located at https://mentor.ieee.org/802.11/documents?is_dcn=1346&is_group=00ay. The specified document provides the detailed description of the input and output interfaces as well as the modes that were tested.

The EDMGEncodingExamples.zip contains three types of files:

— "PSDU.txt" – the TXT-file containing a time ordered sequence of 1 and 0 digits, separated by commas. It contains PSDU payload bit content used in all configuration modes.

— "*.xlsx" – the XLSX-file containing the configuration parameters for given mode of operation. The file represents an XL table with fields used to configure the PPDU transmission. Each field is represented in the decimal notation with bit precision defined in the EDMG PHY. The field names are aligned with the ones used in the TX/RXVECTOR and PHY headers.

— "*.mat" – the MATLAB MAT-file containing the output encoded and modulated PPDU. The file names for the MAT-files are identical to the XLSX-files to which they are coupled. The MAT-file contains a time ordered sequence of complex symbols, formatted as ±<real>±<imag>*j* with double floating point precision.

For EDMG_C_MODE and EDMG_SC_MODE, the spectrum shaping filter is not applied to the output PPDU and it is defined at the original chip rate. The shaping filter is not defined in the EDMG PHY and is implementation dependent.

For EDMG_C_MODE, the Preamble and Data fields are defined at the chip rate $F_c$ = 1.76 GHz and the TRN field (if present) is defined at the chip rate $F_{c\ EDMG}$ = 1.76 × $N_{CB}$ GHz, where $N_{CB}$ defines the number of contiguous 2.16 GHz channels. For EDMG_SC_MODE, the pre-EDMG modulated fields are defined at the chip rate $F_c$ = 1.76 GHz and the EDMG modulated fields are defined at the chip rate $F_{c\ EDMG}$ = 1.76 × $N_{CB}$ GHz.

The TXT, XLSX, and MAT-files can be read using the standard MATLAB dlmread(), xlsread(), and load() functions respectively. To convert the cell array into the ordinary array and to the char array, the standard MATLAB cell2mat() and char() functions can be used.


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# Annex J

(informative)

# RSNA reference implementations and test vectors

## J.1 TKIP temporal key mixing function reference implementation and test vector

### J.1.1 TKIP temporal key mixing function reference implementation

This clause provides a C-language reference implementation of the temporal key mixing function.

```
/************************************************************************

   Contents:    Generate IEEE 802.11 per-frame ARC4 key hash test vectors
   Date:        April 19, 2002
   Notes:
   This code is written for pedagogical purposes, NOT for performance.

************************************************************************/

#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#include <assert.h>
#include <time.h>

typedef unsigned char  byte;   /*  8-bit byte (octet)  */
typedef unsigned short u16b;   /* 16-bit unsigned word */
typedef unsigned long  u32b;   /* 32-bit unsigned word */

/* macros for extraction/creation of byte/u16b values  */
#define RotR1(v16)   ((((v16) >> 1) & 0x7FFF) ^ (((v16) & 1) << 15))
#define   Lo8(v16)   ((byte)( (v16)       & 0x00FF))
#define   Hi8(v16)   ((byte)(((v16) >> 8) & 0x00FF))
#define  Lo16(v32)   ((u16b)( (v32)       & 0xFFFF))
#define  Hi16(v32)   ((u16b)(((v32) >>16) & 0xFFFF))
#define  Mk16(hi,lo) ((lo) ^ (((u16b)(hi)) << 8))

/* select the Nth 16-bit word of the Temporal Key byte array TK[]   */
#define  TK16(N)     Mk16(TK[2*(N)+1],TK[2*(N)])

/* S-box lookup: 16 bits --> 16 bits */
#define _S_(v16)     (Sbox[0][Lo8(v16)] ^ Sbox[1][Hi8(v16)])
```

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```
/* fixed algorithm "parameters" */
#define PHASE1_LOOP_CNT   8    /* this needs to be "big enough"     */
#define TA_SIZE           6    /*  48-bit transmitter address       */
#define TK_SIZE          16    /* 128-bit Temporal Key              */
#define P1K_SIZE         10    /*  80-bit Phase1 key                */
#define ARC4_KEY_SIZE    16    /* 128-bit ARC4KEY (104 bits unknown)*/

/* configuration settings */
#define DO_SANITY_CHECK   1    /* validate properties of S-box?     */

/* 2-byte by 2-byte subset of the full AES S-box table */
const u16b Sbox[2][256]=       /* Sbox for hash (can be in ROM)     */
{ {
   0xC6A5,0xF884,0xEE99,0xF68D,0xFF0D,0xD6BD,0xDEB1,0x9154,
   0x6050,0x0203,0xCEA9,0x567D,0xE719,0xB562,0x4DE6,0xEC9A,
   0x8F45,0x1F9D,0x8940,0xFA87,0xEF15,0xB2EB,0x8EC9,0xFB0B,
   0x41EC,0xB367,0x5FFD,0x45EA,0x23BF,0x53F7,0xE496,0x9B5B,
   0x75C2,0xE11C,0x3DAE,0x4C6A,0x6C5A,0x7E41,0xF502,0x834F,
   0x685C,0x51F4,0xD134,0xF908,0xE293,0xAB73,0x6253,0x2A3F,
   0x080C,0x9552,0x4665,0x9D5E,0x3028,0x37A1,0x0A0F,0x2FB5,
   0x0E09,0x2436,0x1B9B,0xDF3D,0xCD26,0x4E69,0x7FCD,0xEA9F,
   0x121B,0x1D9E,0x5874,0x342E,0x362D,0xDCB2,0xB4EE,0x5BFB,
   0xA4F6,0x764D,0xB761,0x7DCE,0x527B,0xDD3E,0x5E71,0x1397,
   0xA6F5,0xB968,0x0000,0xC12C,0x4060,0xE31F,0x79C8,0xB6ED,
   0xD4BE,0x8D46,0x67D9,0x724B,0x94DE,0x98D4,0xB0E8,0x854A,
   0xBB6B,0xC52A,0x4FE5,0xED16,0x86C5,0x9AD7,0x6655,0x1194,
   0x8ACF,0xE910,0x0406,0xFE81,0xA0F0,0x7844,0x25BA,0x4BE3,
   0xA2F3,0x5DFE,0x80C0,0x058A,0x3FAD,0x21BC,0x7048,0xF104,
   0x63DF,0x77C1,0xAF75,0x4263,0x2030,0xE51A,0xFD0E,0xBF6D,
   0x814C,0x1814,0x2635,0xC32F,0xBEE1,0x35A2,0x88CC,0x2E39,
   0x9357,0x55F2,0xFC82,0x7A47,0xC8AC,0xBAE7,0x322B,0xE695,
   0xC0A0,0x1998,0x9ED1,0xA37F,0x4466,0x547E,0x3BAB,0x0B83,
   0x8CCA,0xC729,0x6BD3,0x283C,0xA779,0xBCE2,0x161D,0xAD76,
   0xDB3B,0x6456,0x744E,0x141E,0x92DB,0x0C0A,0x486C,0xB8E4,
   0x9F5D,0xBD6E,0x43EF,0xC4A6,0x39A8,0x31A4,0xD337,0xF28B,
   0xD532,0x8B43,0x6E59,0xDAB7,0x018C,0xB164,0x9CD2,0x49E0,
   0xD8B4,0xACFA,0xF307,0xCF25,0xCAAF,0xF48E,0x47E9,0x1018,
   0x6FD5,0xF088,0x4A6F,0x5C72,0x3824,0x57F1,0x73C7,0x9751,
   0xCB23,0xA17C,0xE89C,0x3E21,0x96DD,0x61DC,0x0D86,0x0F85,
   0xE090,0x7C42,0x71C4,0xCCAA,0x90D8,0x0605,0xF701,0x1C12,
   0xC2A3,0x6A5F,0xAEF9,0x69D0,0x1791,0x9958,0x3A27,0x27B9,
   0xD938,0xEB13,0x2BB3,0x2233,0xD2BB,0xA970,0x0789,0x33A7,
   0x2DB6,0x3C22,0x1592,0xC920,0x8749,0xAAFF,0x5078,0xA57A,
   0x038F,0x59F8,0x0980,0x1A17,0x65DA,0xD731,0x84C6,0xD0B8,
   0x82C3,0x29B0,0x5A77,0x1E11,0x7BCB,0xA8FC,0x6DD6,0x2C3A,
```



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```
  },

  {  /* second half of table is byte-reversed version of first! */
   0xA5C6,0x84F8,0x99EE,0x8DF6,0x0DFF,0xBDD6,0xB1DE,0x5491,
   0x5060,0x0302,0xA9CE,0x7D56,0x19E7,0x62B5,0xE64D,0x9AEC,
   0x458F,0x9D1F,0x4089,0x87FA,0x15EF,0xEBB2,0xC98E,0x0BFB,
   0xEC41,0x67B3,0xFD5F,0xEA45,0xBF23,0xF753,0x96E4,0x5B9B,
   0xC275,0x1CE1,0xAE3D,0x6A4C,0x5A6C,0x417E,0x02F5,0x4F83,
   0x5C68,0xF451,0x34D1,0x08F9,0x93E2,0x73AB,0x5362,0x3F2A,
   0x0C08,0x5295,0x6546,0x5E9D,0x2830,0xA137,0x0F0A,0xB52F,
   0x090E,0x3624,0x9B1B,0x3DDF,0x26CD,0x694E,0xCD7F,0x9FEA,
   0x1B12,0x9E1D,0x7458,0x2E34,0x2D36,0xB2DC,0xEEB4,0xFB5B,
   0xF6A4,0x4D76,0x61B7,0xCE7D,0x7B52,0x3EDD,0x715E,0x9713,
   0xF5A6,0x68B9,0x0000,0x2CC1,0x6040,0x1FE3,0xC879,0xEDB6,
   0xBED4,0x468D,0xD967,0x4B72,0xDE94,0xD498,0xE8B0,0x4A85,
   0x6BBB,0x2AC5,0xE54F,0x16ED,0xC586,0xD79A,0x5566,0x9411,
   0xCF8A,0x10E9,0x0604,0x81FE,0xF0A0,0x4478,0xBA25,0xE34B,
   0xF3A2,0xFE5D,0xC080,0x8A05,0xAD3F,0xBC21,0x4870,0x04F1,
   0xDF63,0xC177,0x75AF,0x6342,0x3020,0x1AE5,0x0EFD,0x6DBF,
   0x4C81,0x1418,0x3526,0x2FC3,0xE1BE,0xA235,0xCC88,0x392E,
   0x5793,0xF255,0x82FC,0x477A,0xACC8,0xE7BA,0x2B32,0x95E6,
   0xA0C0,0x9819,0xD19E,0x7FA3,0x6644,0x7E54,0xAB3B,0x830B,
   0xCA8C,0x29C7,0xD36B,0x3C28,0x79A7,0xE2BC,0x1D16,0x76AD,
   0x3BDB,0x5664,0x4E74,0x1E14,0xDB92,0x0A0C,0x6C48,0xE4B8,
   0x5D9F,0x6EBD,0xEF43,0xA6C4,0xA839,0xA431,0x37D3,0x8BF2,
   0x32D5,0x438B,0x596E,0xB7DA,0x8C01,0x64B1,0xD29C,0xE049,
   0xB4D8,0xFAAC,0x07F3,0x25CF,0xAFCA,0x8EF4,0xE947,0x1810,
   0xD56F,0x88F0,0x6F4A,0x725C,0x2438,0xF157,0xC773,0x5197,
   0x23CB,0x7CA1,0x9CE8,0x213E,0xDD96,0xDC61,0x860D,0x850F,
   0x90E0,0x427C,0xC471,0xAACC,0xD890,0x0506,0x01F7,0x121C,
   0xA3C2,0x5F6A,0xF9AE,0xD069,0x9117,0x5899,0x273A,0xB927,
   0x38D9,0x13EB,0xB32B,0x3322,0xBBD2,0x70A9,0x8907,0xA733,
   0xB62D,0x223C,0x9215,0x20C9,0x4987,0xFFAA,0x7850,0x7AA5,
   0x8F03,0xF859,0x8009,0x171A,0xDA65,0x31D7,0xC684,0xB8D0,
   0xC382,0xB029,0x775A,0x111E,0xCB7B,0xFCA8,0xD66D,0x3A2C,
  }
};

#if DO_SANITY_CHECK
/*
*********************************************************************
* Routine: SanityCheckTable -- verify Sbox properties
*
* Inputs:  Sbox
* Output:  None, but an assertion fails if the tables are wrong
* Notes:
```

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```
*   The purpose of this routine is solely to illustrate and
*   verify the following properties of the Sbox table:
*      - the Sbox is a "2×2" subset of the AES table:
*            Sbox + affine transform + MDS.
*      - the Sbox table can be easily designed to fit in a
*            512-byte table, using a byte swap
*      - the Sbox table can be easily designed to fit in a
*            256-byte table, using some shifts and a byte swap
**********************************************************************
*/
void SanityCheckTable(void)
    {
    const static int  M_x = 0x11B;   /* AES irreducible polynomial */
    const static byte Sbox8[256] = { /* AES 8-bit Sbox */
        0x63,0x7c,0x77,0x7b,0xf2,0x6b,0x6f,0xc5,
        0x30,0x01,0x67,0x2b,0xfe,0xd7,0xab,0x76,
        0xca,0x82,0xc9,0x7d,0xfa,0x59,0x47,0xf0,
        0xad,0xd4,0xa2,0xaf,0x9c,0xa4,0x72,0xc0,
        0xb7,0xfd,0x93,0x26,0x36,0x3f,0xf7,0xcc,
        0x34,0xa5,0xe5,0xf1,0x71,0xd8,0x31,0x15,
        0x04,0xc7,0x23,0xc3,0x18,0x96,0x05,0x9a,
        0x07,0x12,0x80,0xe2,0xeb,0x27,0xb2,0x75,
        0x09,0x83,0x2c,0x1a,0x1b,0x6e,0x5a,0xa0,
        0x52,0x3b,0xd6,0xb3,0x29,0xe3,0x2f,0x84,
        0x53,0xd1,0x00,0xed,0x20,0xfc,0xb1,0x5b,
        0x6a,0xcb,0xbe,0x39,0x4a,0x4c,0x58,0xcf,
        0xd0,0xef,0xaa,0xfb,0x43,0x4d,0x33,0x85,
        0x45,0xf9,0x02,0x7f,0x50,0x3c,0x9f,0xa8,
        0x51,0xa3,0x40,0x8f,0x92,0x9d,0x38,0xf5,
        0xbc,0xb6,0xda,0x21,0x10,0xff,0xf3,0xd2,
        0xcd,0x0c,0x13,0xec,0x5f,0x97,0x44,0x17,
        0xc4,0xa7,0x7e,0x3d,0x64,0x5d,0x19,0x73,
        0x60,0x81,0x4f,0xdc,0x22,0x2a,0x90,0x88,
        0x46,0xee,0xb8,0x14,0xde,0x5e,0x0b,0xdb,
        0xe0,0x32,0x3a,0x0a,0x49,0x06,0x24,0x5c,
        0xc2,0xd3,0xac,0x62,0x91,0x95,0xe4,0x79,
        0xe7,0xc8,0x37,0x6d,0x8d,0xd5,0x4e,0xa9,
        0x6c,0x56,0xf4,0xea,0x65,0x7a,0xae,0x08,
        0xba,0x78,0x25,0x2e,0x1c,0xa6,0xb4,0xc6,
        0xe8,0xdd,0x74,0x1f,0x4b,0xbd,0x8b,0x8a,
        0x70,0x3e,0xb5,0x66,0x48,0x03,0xf6,0x0e,
        0x61,0x35,0x57,0xb9,0x86,0xc1,0x1d,0x9e,
        0xe1,0xf8,0x98,0x11,0x69,0xd9,0x8e,0x94,
        0x9b,0x1e,0x87,0xe9,0xce,0x55,0x28,0xdf,
        0x8c,0xa1,0x89,0x0d,0xbf,0xe6,0x42,0x68,
        0x41,0x99,0x2d,0x0f,0xb0,0x54,0xbb,0x16 };
```


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```
    int i,k,k2,k3;
    byte bitmap[0x2000];

    /* show that smaller tables can be used */
    for (i=0;i<256;i++)
        {
        k  = Sbox8[i];
        k2 = (k << 1) ^ ((k & 0x80) ? M_x : 0);
        k3 =  k ^ k2;
        assert(Sbox[0][i] == ((k2 << 8) ^ k3));
        assert(Sbox[1][i] == ((k3 << 8) ^ k2));
        }

    /* now make sure that it's a 16-bit permutation */
    memset(bitmap,0,sizeof(bitmap));
    for (i=0;i<0x10000;i++)
        {
        k = _S_(i); /* do an S-box lookup: 16 --> 16 bits */
        assert(k < (1 << 16));
        assert((bitmap[k >> 3] & (1 << (k & 7))) == 0);
        bitmap[k >> 3] |= 1 << (k & 7);
        }
    for (i=0;i<sizeof(bitmap);i++)
        assert(bitmap[i] == 0xFF);

    /* if we reach here, the 16-bit Sbox is ok */
    printf("Table sanity check successful\n");
    }
#endif

/*
**********************************************************************
* Routine: Phase 1 -- generate P1K, given TA, TK, IV32
*
* Inputs:
*     TK[]      = Temporal Key                        [128 bits]
*     TA[]      = transmitter's MAC address           [ 48 bits]
*     IV32      = upper 32 bits of IV                 [ 32 bits]
* Output:
*     P1K[]     = Phase 1 key                         [ 80 bits]
*
* Note:
*     This function only needs to be called every 2**16 frames,
*     although in theory it could be called every frame.
*
```

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```
1       ************************************************************************
2       */
3       void Phase1(u16b *P1K,const byte *TK,const byte *TA,u32b IV32)
4           {
5           int  i;
6
7           /* Initialize the 80 bits of P1K[] from IV32 and TA[0..5]     */
8           P1K[0]      = Lo16(IV32);
9           P1K[1]      = Hi16(IV32);
10          P1K[2]      = Mk16(TA[1],TA[0]); /* use TA[] as little-endian */
11          P1K[3]      = Mk16(TA[3],TA[2]);
12          P1K[4]      = Mk16(TA[5],TA[4]);
13
14          /* Now compute an unbalanced Feistel cipher with 80-bit block */
15          /* size on the 80-bit block P1K[], using the 128-bit key TK[] */
16          for (i=0; i < PHASE1_LOOP_CNT ;i++)
17              {                /* Each add operation here is mod 2**16 */
18              P1K[0] += _S_(P1K[4] ^ TK16((i&1)+0));
19              P1K[1] += _S_(P1K[0] ^ TK16((i&1)+2));
20              P1K[2] += _S_(P1K[1] ^ TK16((i&1)+4));
21              P1K[3] += _S_(P1K[2] ^ TK16((i&1)+6));
22              P1K[4] += _S_(P1K[3] ^ TK16((i&1)+0));
23              P1K[4] +=  i;                    /* avoid "slide attacks" */
24              }
25          }
26
27      /*
28      ************************************************************************
29      * Routine: Phase 2 -- generate ARC4KEY, given TK, P1K, IV16
30      *
31      * Inputs:
32      *     TK[]      = Temporal Key                        [128 bits]
33      *     P1K[]     = Phase 1 output key                  [ 80 bits]
34      *     IV16      = low 16 bits of IV counter           [ 16 bits]
35      * Output:
36      *     ARC4KEY[]  = the key used to encrypt the frame  [128 bits]
37      *
38      * Note:
39      *     The value {TA,IV32,IV16} for Phase1/Phase2 shall be unique
40      *     across all frames using the same key TK value. Then, for a
41      *     given value of TK[], this TKIP48 construction guarantees that
42      *     the final ARC4KEY value is unique across all frames.
43      *
44      * Suggested implementation optimization: if PPK[] is "overlaid"
45      *     appropriately on ARC4KEY[], there is no need for the final
46      *     for loop below that copies the PPK[] result into ARC4KEY[].
47
```



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```
*
**********************************************************************
*/
void Phase2(byte *ARC4KEY,const byte *TK,const u16b *P1K,u16b IV16)
    {
    int  i;
    u16b PPK[6];                        /* temporary key for mixing    */

    /* all adds in the PPK[] equations below are mod 2**16         */
    for (i=0;i<5;i++) PPK[i]=P1K[i];    /* first, copy P1K to PPK      */
    PPK[5]  =  P1K[4] + IV16;           /* next, add in IV16           */

    /* Bijective non-linear mixing of the 96 bits of PPK[0..5]         */
    PPK[0] +=    _S_(PPK[5] ^ TK16(0)); /* Mix key in each "round"     */
    PPK[1] +=    _S_(PPK[0] ^ TK16(1));
    PPK[2] +=    _S_(PPK[1] ^ TK16(2));
    PPK[3] +=    _S_(PPK[2] ^ TK16(3));
    PPK[4] +=    _S_(PPK[3] ^ TK16(4));
    PPK[5] +=    _S_(PPK[4] ^ TK16(5)); /* Total # S-box lookups == 6  */

    /* Final sweep: bijective, linear. Rotates kill LSB correlations   */
    PPK[0] +=  RotR1(PPK[5] ^ TK16(6));
    PPK[1] +=  RotR1(PPK[0] ^ TK16(7)); /* Use all of TK[] in Phase2   */
    PPK[2] +=  RotR1(PPK[1]);
    PPK[3] +=  RotR1(PPK[2]);
    PPK[4] +=  RotR1(PPK[3]);
    PPK[5] +=  RotR1(PPK[4]);
    /* At this point, for a given key TK[0..15], the 96-bit output */
    /*     value PPK[0..5] is guaranteed to be unique, as a function   */
    /*     of the 96-bit "input" value   {TA,IV32,IV16}. That is, P1K  */
    /*     is now a keyed permutation of {TA,IV32,IV16}.               */

    /* Set ARC4KEY[0..3], which includes cleartext portion of ARC4 key  */
    ARC4KEY[0] = Hi8(IV16);             /* ARC4KEY[0..2] is the WEP IV  */
    ARC4KEY[1] =(Hi8(IV16) | 0x20) & 0x7F; /* Help avoid FMS weak keys  */
    ARC4KEY[2] = Lo8(IV16);
    ARC4KEY[3] = Lo8((PPK[5] ^ TK16(0)) >> 1);

    /* Copy 96 bits of PPK[0..5] to ARC4KEY[4..15]  (little-endian)      */
    for (i=0;i<6;i++)
        {
        ARC4KEY[4+2*i] = Lo8(PPK[i]);
        ARC4KEY[5+2*i] = Hi8(PPK[i]);
        }
    }
```

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```
/*
************************************************************************
* Routine: doTestCase -- execute a test case, and print results
************************************************************************
*/
void  DoTestCase(byte  *ARC4KEY,u32b  IV32,u16b  IV16,const  byte  *TA,const
byte *TK)
    {
    int  i;
    u16b P1K[P1K_SIZE/2];  /* "temp" copy of phase1 key */

    printf("\nTK    =");
    for (i=0;i<TK_SIZE;i++) printf(" %02X",TK[i]);
    printf("\nTA    =");
    for (i=0;i<TA_SIZE;i++) printf(" %02X",TA[i]);
    printf("\nIV32  = %08X   [transmitted as",IV32);  /* show byte order */
    for (i=0;i<4;i++) printf(" %02X",(IV32 >> (24-8*i)) & 0xFF);
    printf("]");
    printf("\nIV16  = %04X",IV16);

    Phase1(P1K,TK,TA,IV32);

    printf("\nP1K   =");
    for (i=0;i<P1K_SIZE/2;i++) printf(" %04X ",P1K[i] & 0xFFFF);

    Phase2(ARC4KEY,TK,P1K,IV16);

    printf("\nARC4KEY= ");
    for (i=0;i<ARC4_KEY_SIZE;i++) printf("%02X ",ARC4KEY[i]);
    }

/*
************************************************************************
* Static (Repeatable) Test Cases
************************************************************************
*/
void DoStaticTestCases(int testCnt)
    {
    int  i,j;
    byte TA[TA_SIZE],TK[TK_SIZE],ARC4KEY[ARC4_KEY_SIZE];
    u16b IV16=0;
    u32b IV32=0;

    /* set a fixed starting point */
    for (i=0;i<TK_SIZE;i++) TK[i]=i;
    for (i=0;i<TA_SIZE;i++) TA[i]=(i+1)*17;
```



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```
    TA[0] = TA[0] & 0xFC;             /* set to 0 Individual/Group and U/L
bits in OUI */

    /* now generate tests, feeding results back into new tests */
    for (i=0; i<testCnt/2; i++)
        {
        printf("\n\nTest vector #%d:",2*i+1);
        DoTestCase(ARC4KEY,IV32,IV16,TA,TK);
        IV16++;                      /* emulate per-frame "increment" */
        if (IV16 == 0) IV32++;
        printf("\n\nTest vector #%d:",2*i+2);
        DoTestCase(ARC4KEY,IV32,IV16,TA,TK);
        /* feed results back to seed the next test input values    */
        IV16 = (i) ? Mk16(ARC4KEY[15],ARC4KEY[4]) : 0xFFFF;/* force wrap */
        IV32 =       Mk16(ARC4KEY[14],ARC4KEY[5]);
        IV32 =       Mk16(ARC4KEY[13],ARC4KEY[7]) + (IV32 << 16);
        for (j=0;j<TA_SIZE;j++) TA[j]^=ARC4KEY[12-j];
        for (j=0;j<TK_SIZE;j++) TK[j]^=ARC4KEY[(j+i+1) % ARC4_KEY_SIZE] ^
                                    ARC4KEY[(j+i+7) % ARC4_KEY_SIZE] ;
        TA[0] = TA[0] & 0xFC;         /* set to 0 Individual/Group and U/L
bits in OUI */
        }
    /* comparing the final output is a good check of correctness   */
    printf("\n");
    }

/*
********************************************************************
* Test Cases Generated at Random
********************************************************************
*/
void DoRandomTestCases(int testCnt)
    {
    int  i,j;
    u16b IV16;
    u32b IV32;
    byte TA[TA_SIZE],ARC4KEY[ARC4_KEY_SIZE],TK[TK_SIZE];

    printf("Random tests:\n");
    /* now generate tests "recursively" */
    for (i=0; i<testCnt; i++)
        {
        IV16 = rand() & 0xFFFF;
        IV32 = rand() + (rand() << 16);
        for (j=0;j<TK_SIZE;j++) TK[j]=rand() & 0xFF;
        for (j=0;j<TA_SIZE;j++) TA[j]=rand() & 0xFF;
```

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```
            TA[0] = TA[0] & 0xFC;         /* set to 0 Individual/Group and U/L
        bits in OUI */
            printf("\n\nRandom test vector #%d:",i+1);
            DoTestCase(ARC4KEY,IV32,IV16,TA,TK);
            }
        printf("\n");
        }

    /*
    ************************************************************************
    * Usage text
    ************************************************************************
    */
    #define NUM_TEST_CNT  8
    void Usage(void)
        {
        printf(
            "Usage:   TKIP48 [options]\n"
            "Purpose: Generate test vectors for IEEE 802.11 TKIP48\n"
            "Options  -?   -- output this usage text\n"
            "         -r   -- generate test vectors at random\n"
            "         -sN  -- init random seed to N\n"
            "         -tN  -- generate N tests (default = %d)\n",
            NUM_TEST_CNT
            );
        exit(0);
        }

    /*
    ************************************************************************
    * Main
    ************************************************************************
    */
    int main(int argc, char **argv)
        {
        char *parg;
        int   i,doRand = 0;
        int   testCnt  = NUM_TEST_CNT;
        u32b  seed     = (u32b) time(NULL);

    #if DO_SANITY_CHECK
        SanityCheckTable();
    #endif

        for (i=1; i<argc; i++)
            {
```


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```
            parg = argv[i];
            switch (parg[0])
                {
                case '-':
                    switch (parg[1])
                        {
                        case '?':
                        case 'H':
                        case 'h':
                            Usage();
                            return 0;
                        case 'R':
                        case 'r':  /* generate some random test vectors */
                            doRand  = 1;
                            break;
                        case 'S':
                        case 's':
                            seed    = atoi(parg+2);
                            break;
                        case 'T':
                        case 't':
                            testCnt = atoi(parg+2);
                            break;
                        default:
                            break;
                        }
                    break;
                case '?':
                    Usage();
                    return 0;
                default:
                    printf("Invalid argument: \"%s\"\n", parg);
                    return 1;
                }
            }
        srand(seed);
        if (doRand) printf("Seed = %u\n",seed);

        /* generate some test vectors */
        if (doRand) DoRandomTestCases(testCnt);
        else        DoStaticTestCases(testCnt);

        return 0;
        }
```

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### J.1.2 Test vectors

The following output is provided to test implementations of the temporal key hash algorithm. All input and output values are shown in hexadecimal.

```
Test vector #1:
TK    = 00 01 02 03 04 05 06 07 08 09 0A 0B 0C 0D 0E 0F [LSB on left, MSB on right]
TA    = 10-22-33-44-55-66
PN    = 000000000000
IV32  = 00000000
IV16  = 0000
P1K   = 3DD2  016E  76F4  8697  B2E8
ARC4KEY= 00 20 00 33 EA 8D 2F 60 CA 6D 13 74 23 4A 66 0B

Test vector #2:
TK    = 00 01 02 03 04 05 06 07 08 09 0A 0B 0C 0D 0E 0F [LSB on left, MSB on right]
TA    = 10-22-33-44-55-66
PN    = 000000000001
IV32  = 00000000
IV16  = 0001
P1K   = 3DD2  016E  76F4  8697  B2E8
ARC4KEY= 00 20 01 90 FF DC 31 43 89 A9 D9 D0 74 FD 20 AA

Test vector #3:
TK    = 63 89 3B 25 08 40 B8 AE 0B D0 FA 7E 61 D2 78 3E [LSB on left, MSB on right]
TA    = 64-F2-EA-ED-DC-25
PN    = 20DCFD43FFFF
IV32  = 20DCFD43
IV16  = FFFF
P1K   = 7C67  49D7  9724  B5E9  B4F1
ARC4KEY= FF 7F FF 93 81 0F C6 E5 8F 5D D3 26 25 15 44 CE

Test vector #4:
TK    = 63 89 3B 25 08 40 B8 AE 0B D0 FA 7E 61 D2 78 3E [LSB on left, MSB on right]
TA    = 64-F2-EA-ED-DC-25
PN    = 20DCFD440000
IV32  = 20DCFD44
IV16  = 0000
P1K   = 5A5D  73A8  A859  2EC1  DC8B
ARC4KEY= 00 20 00 49 8C A4 71 FC FB FA A1 6E 36 10 F0 05

Test vector #5:
TK    = 98 3A 16 EF 4F AC B3 51 AA 9E CC 27 1D 73 09 E2 [LSB on left, MSB on right]
TA    = 50-9C-4B-17-27-D9
PN    = F0A410FC058C
IV32  = F0A410FC
IV16  = 058C
P1K   = F2DF  EBB1  88D3  5923  A07C
ARC4KEY= 05 25 8C F4 D8 51 52 F4 D9 AF 1A 64 F1 D0 70 21

Test vector #6:
TK    = 98 3A 16 EF 4F AC B3 51 AA 9E CC 27 1D 73 09 E2 [LSB on left, MSB on right]
TA    = 50-9C-4B-17-27-D9
PN    = F0A410FC058D
IV32  = F0A410FC
IV16  = 058D
P1K   = F2DF  EBB1  88D3  5923  A07C
ARC4KEY= 05 25 8D 09 F8 15 43 B7 6A 59 6F C2 C6 73 8B 30

Test vector #7:
TK    = C8 AD C1 6A 8B 4D DA 3B 4D D5 B6 54 38 35 9B 05 [LSB on left, MSB on right]
TA    = 94-5E-24-4E-4D-6E
PN    = 8B1573B730F8
IV32  = 8B1573B7
```


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```
IV16  = 30F8
P1K   = EFF1  3F38  A364  60A9  76F3
ARC4KEY= 30 30 F8 65 0D A0 73 EA 61 4E A8 F4 74 EE 03 19

Test vector #8:
TK    = C8 AD C1 6A 8B 4D DA 3B 4D D5 B6 54 38 35 9B 05 [LSB on left, MSB on right]
TA    = 94-5E-24-4E-4D-6E
PN    = 8B1573B730F9
IV32  = 8B1573B7
IV16  = 30F9
P1K   = EFF1  3F38  A364  60A9  76F3
ARC4KEY= 30 30 F9 31 55 CE 29 34 37 CC 76 71 27 16 AB 8F
```

## J.2 Michael reference implementation and test vectors

### J.2.1 Michael test vectors

#### J.2.1.1 Introduction

Test vectors are provided below in order to support correct implementation of michael. These test vectors still have to be confirmed by an independent implementation.

#### J.2.1.2 Block function

Table J-1 (Test vectors for block function) gives some test vectors for the block function.

**Table J-1—Test vectors for block function**

| Input | # times | Output |
|---|---|---|
| (00000000, 00000000) | 1 | (00000000, 00000000) |
| (00000000, 00000001) | 1 | (c00015a8, c0000b95) |
| (00000001, 00000000) | 1 | (6b519593, 572b8b8a) |
| (01234567, 83659326) | 1 | (441492c2, 1d8427ed) |
| (00000001, 00000000) | 1000 | (9f04c4ad, 2ec6c2bf) |

The first four rows give test vectors for a single application of the block function *b*. The last row gives a test vector for 1000 repeated applications of the block function. Together these should provide adequate test coverage.

#### J.2.1.3 Michael

Table J-2 (Test vectors for michael) gives some test vectors for michael.

Note that each key is the result of the previous line, which makes it easy to construct a single test out of all of these test cases.

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**Table J-2—Test vectors for michael**

| Key | Message | Output |
|---|---|---|
| 0000000000000000 | "" | 82925c1ca1d130b8 |
| 82925c1ca1d130b8 | "M” | 434721ca40639b3f |
| 434721ca40639b3f | "Mi “ | e8f9becae97e5d29 |
| E8f9becae97e5d29 | "Mic" | 90038fc6cf13c1db |
| 90038fc6cf13c1db | "Mich" | D55e100510128986 |
| D55e100510128986 | "Michael" | 0a942b124ecaa546 |

### J.2.2 Sample code for michael

```
//
// Michael.h    Reference implementation for michael

//
// A michael object implements the computation of the MIC.
//
// Conceptually, the object stores the message to be authenticated.
// At construction the message is empty.
// The append() method appends bytes to the message.
// The getMic() method computes the MIC over the message and returns the
// result.
// As a side-effect it also resets the stored message
// to the empty message so that the object can be reused
// for another MIC computation.

class Michael
{

public:
    // Constructor requires a pointer to 8 bytes of key
    Michael( Byte * key );

    // Destructor
    ~Michael();

    // Clear the internal message,
    // resets the object to the state just after construction.
    void clear();

    // Set the key to a new value
    void setKey( Byte * key );
```



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```
        // Append bytes to the message to be MICed
        void append( Byte * src, int nBytes );

        // Get the MIC result. Destination should accept 8 bytes of result.
        // This also resets the message to empty.
        void getMIC( Byte * dst );

        // Run the test plan to verify proper operations
        static void runTestPlan();

    private:
        // Copy constructor declared but not defined,
        //avoids compiler-generated version.
        Michael( const Michael & );
        // Assignment operator declared but not defined,
        //avoids compiler-generated version.
        void operator=( const Michael & );

        // A bunch of internal functions

        // Get UInt32 from 4 bytes LSByte first
        static UInt32 getUInt32( Byte * p );

        // Put UInt32 into 4 bytes LSByte first
        static void putUInt32( Byte * p, UInt32 val );

        // Add a single byte to the internal message
        void appendByte( Byte b );

        // Conversion of hex string to binary string
        static void hexToBin( char *src, Byte * dst );

        // More conversion of hex string to binary string
        static void hexToBin( char *src, int nChars, Byte * dst );

        // Helper function for hex conversion
        static Byte hexToBinNibble( char c );

        // Run a single test case
        static void runSingleTest( char * cKey, char * cMsg, char * cResult );

        UInt32  K0, K1;         // Key
        UInt32  L, R;           // Current state
        UInt32  M;              // Message accumulator (single word)
        int     nBytesInM;      // # bytes in M
    };
```

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```
//
// Michael.cpp  Reference implementation for Michael
//

// Adapt these typedefs to your local platform
typedef unsigned long UInt32;
typedef unsigned char Byte;

#include <assert.h>
#include <stdio.h>
#include <stdlib.h>
#include <string.h>

#include "Michael.h"

// Rotation functions on 32 bit values
#define ROL32( A, n ) \
 ( ((A) << (n)) | ( ((A) >> (32-(n)))  & ( (1UL << (n)) - 1 ) ) )
#define ROR32( A, n ) ROL32( (A), 32-(n) )

UInt32 Michael::getUInt32( Byte * p )
// Convert from Byte[] to UInt32 in a portable way
{
    UInt32 res = 0;
    for( int i=0; i<4; i++ )
    {
        res |= (*p++) << (8*i);
    }
    return res;
}

void Michael::putUInt32( Byte * p, UInt32 val )
// Convert from UInt32 to Byte[] in a portable way
{
    for( int i=0; i<4; i++ )
    {
        *p++ = (Byte) (val & 0xff);
        val >>= 8;
    }
}

void Michael::clear()
{
    // Reset the state to the empty message.
    L = K0;
```


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```
    R = K1;
    nBytesInM = 0;
    M = 0;
}

void Michael::setKey( Byte * key )
{
    // Set the key
    K0 = getUInt32( key );
    K1 = getUInt32( key + 4 );
    // and reset the message
    clear();
}

Michael::Michael( Byte * key )
{
    setKey( key );
}

Michael::~Michael()
{
    // Wipe the key material
    K0 = 0;
    K1 = 0;

    // And the other fields as well.
    //Note that this sets (L,R) to (K0,K1) which is just fine.
    clear();
}

void Michael::appendByte( Byte b )
{
    // Append the byte to our word-sized buffer
    M |= b << (8*nBytesInM);
    nBytesInM++;
    // Process the word if it is full.
    if( nBytesInM >= 4 )
    {
        L ^= M;
        R ^= ROL32( L, 17 );
        L += R;
        R ^= ((L & 0xff00ff00) >> 8) | ((L & 0x00ff00ff) << 8);
        L += R;
        R ^= ROL32( L, 3 );
        L += R;
        R ^= ROR32( L, 2 );
```

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```
            L += R;
            // Clear the buffer
            M = 0;
            nBytesInM = 0;
        }
    }

    void Michael::append( Byte * src, int nBytes )
    {
        // This is simple
        while( nBytes > 0 )
        {
            appendByte( *src++ );
            nBytes--;
        }
    }

    void Michael::getMIC( Byte * dst )
    {
        // Append the minimum padding
        appendByte( 0x5a );
        appendByte( 0 );
        appendByte( 0 );
        appendByte( 0 );
        appendByte( 0 );
        // and then 0s until the length is a multiple of 4
        while( nBytesInM != 0 )
        {
            appendByte( 0 );
        }
        // The appendByte function has already computed the result.
        putUInt32( dst, L );
        putUInt32( dst+4, R );
        // Reset to the empty message.
        clear();
    }

    void Michael::hexToBin( char *src, Byte * dst )
    {
        // Simple wrapper
        hexToBin( src, strlen( src ), dst );
    }

    void Michael::hexToBin( char *src, int nChars, Byte * dst )
    {
        assert( (nChars & 1) == 0 );
```


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```
    int nBytes = nChars/2;

    // Straightforward conversion
    for( int i=0; i<nBytes; i++ )
    {
        dst[i] = (Byte)((hexToBinNibble( src[0] ) << 4) |
            hexToBinNibble( src[1] ));
        src += 2;
    }
}

Byte Michael::hexToBinNibble( char c )
{
    if( '0' <= c && c <= '9' )
    {
        return (Byte)(c - '0');
    }
    // Make it upper case
    c &= ~('a'-'A');

    assert( 'A' <= c && c <= 'F' );
    return (Byte)(c - 'A' + 10);
}

void Michael::runSingleTest( char * cKey, char * cMsg, char * cResult )
{
    Byte key[ 8 ];
    Byte result[ 8 ];
    Byte res[ 8 ];

    // Convert key and result to binary form
    hexToBin( cKey, key );
    hexToBin( cResult, result );

    // Compute the MIC value
    Michael mic( key );
    mic.append( (Byte *)cMsg, strlen( cMsg) );
    mic.getMIC( res );

    // Check that it matches
    assert( memcmp( res, result, 8 ) == 0 );
}

void Michael::runTestPlan()
{
    Byte key[8] ;
```

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```
        Byte msg[12];
        int i;

        // First we test the test vectors for the block function

        // The case (0,0)
        putUInt32( key, 0 );
        putUInt32( key+4, 0 );
        putUInt32( msg, 0 );

        Michael mic( key );
        mic.append( msg, 4 );

        assert( mic.L == 0 && mic.R == 0 );

        // The case (0,1)
        putUInt32( key, 0 );
        putUInt32( key+4, 1 );
        mic.setKey( key );
        mic.append( msg, 4 );

        assert( mic.L == 0xc00015a8 && mic.R == 0xc0000b95 );

        // The case (1,0)
        putUInt32( key, 1 );
        putUInt32( key+4, 0 );
        mic.setKey( key );
        mic.append( msg, 4 );

        assert( mic.L == 0x6b519593 && mic.R == 0x572b8b8a );

        // The case (01234567, 83659326)
        putUInt32( key, 0x01234567 );
        putUInt32( key+4, 0x83659326 );
        mic.setKey( key );
        mic.append( msg, 4 );

        assert( mic.L == 0x441492c2 && mic.R == 0x1d8427ed );

        // The repeated case
        putUInt32( key, 1 );
        putUInt32( key+4,0 );
        mic.setKey( key );

        for( i=0; i<1000; i++ )
        {
```


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```
            mic.append( msg, 4 );
        }

        assert( mic.L == 0x9f04c4ad && mic.R == 0x2ec6c2bf );

        // And now for the real test cases
        runSingleTest( "0000000000000000", ""         , "82925c1ca1d130b8" );
        runSingleTest( "82925c1ca1d130b8", "M"        , "434721ca40639b3f" );
        runSingleTest( "434721ca40639b3f", "Mi"       , "e8f9becae97e5d29" );
        runSingleTest( "e8f9becae97e5d29", "Mic"      , "90038fc6cf13c1db" );
        runSingleTest( "90038fc6cf13c1db", "Mich"     , "d55e100510128986" );
        runSingleTest( "d55e100510128986", "Michael"  , "0a942b124ecaa546" );
    }
```

## J.3 PRF reference implementation and test vectors

### J.3.1 PRF reference code

```
    /*
     * PRF -- Length of output is in octets rather than bits
     *     since length is always a multiple of 8 output array is
     *     organized so first N octets starting from 0 contains PRF output
     *
     *     supported inputs are 16, 24, 32, 48, 64
     *     output array must be 80 octets to allow for SHA-1 overflow
     */
    void PRF(
        unsigned char *key, int key_len,
        unsigned char *prefix, int prefix_len,
        unsigned char *data, int data_len,
        unsigned char *output, int len)
    {
        int i;
        unsigned char input[1024]; /* concatenated input */
        int currentindex = 0;
        int total_len;

        memcpy(input, prefix, prefix_len);
        input[prefix_len] = 0; /* single octet 0 */
        memcpy(&input[prefix_len+1], data, data_len);
        total_len = prefix_len + 1 + data_len;
        input[total_len] = 0; /* single octet count, starts at 0 */
        total_len++;
        for (i = 0; i < (len+19)/20; i++) {
            hmac_sha_1(input, total_len, key, key_len,
                &output[currentindex]);
```

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```
            currentindex += 20;/* next concatenation location */
            input[total_len-1]++; /* increment octet count */
        }
    }
```

### J.3.2 PRF test vectors

```
Test case 1
Key             0x0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b0b
Key length      20
Prefix          “prefix”
Prefix length   6
Data            "Hi There"
Data length     8
PRF-512         0xbcd4c650b30b9684951829e0d75f9d54
                0xb862175ed9f00606e17d8da35402ffee
                0x75df78c3d31e0f889f012120c0862beb
                0x67753e7439ae242edb8373698356cf5a

Test case 2
Key             "Jefe"
Key length      4
Prefix          “prefix”
Prefix length   6
Data            "what do ya want for nothing?"
Data length     28
PRF-512         0x51f4de5b33f249adf81aeb713a3c20f4
                0xfe631446fabdfa58244759ae58ef9009
                0xa99abf4eac2ca5fa87e692c440eb4002
                0x3e7babb206d61de7b92f41529092b8fc

Test case 3
Key             0xaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaa
Key length      20
Prefix          “prefix”
Prefix length   6
Data            0xdd repeated 50 times
Data length     50
PRF-512         0xe1ac546ec4cb636f9976487be5c86be1
                0x7a0252ca5d8d8df12cfb0473525249ce
                0x9dd8d177ead710bc9b590547239107ae
                0xf7b4abd43d87f0a68f1cbd9e2b6f7607
```

## J.4 Suggested pass-phrase-to-PSK mapping

### J.4.1 Introduction

The RSNA PSK consists of 256 bits, or 64 octets when represented in hexadecimal. It is difficult for a user to correctly enter 64 hexadecimal characters. Most users, however, are familiar with passwords and pass-phrases and feel more comfortable entering them than entering keys. A user is more likely to be able to enter an ASCII password or pass-phrase, even though doing so limits the set of possible keys. This suggests that the best that can be done is to introduce a pass-phrase to PSK mapping.

This subclause defines a pass-phrase–to–PSK mapping that is the recommended practice for use with RSNAs. This pass-phrase mapping was introduced to encourage users unfamiliar with cryptographic concepts to enable the security features of their WLAN.


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Keys derived from the pass-phrase provide relatively low levels of security, especially with keys generated form short passwords, since they are subject to dictionary attack. Use of the key hash is recommended only where it is impractical to make use of a stronger form of user authentication. A key generated from a pass-phrase of less than about 20 characters is unlikely to deter attacks.

The pass-phrase mapping defined in this subclause uses the PBKDF2 as defined in IETF RFC 2898 [B34] section 5.2.

*PSK* = PBKDF2(*passPhrase*, *ssid*, 4096, 256/8)

The following apply:

— passPhrase is a sequence of between 8 and 63 ASCII-encoded characters. The limit of 63 comes from the need to distinguish between a pass-phrase and a PSK displayed as 64 hexadecimal characters.

— Each character in the pass-phrase has an encoding in the range 32 to 126 (decimal).

— *ssid* is the SSID of the ESS or IBSS where this pass-phrase is in use, encoded as an octet string used in the Beacon and Probe Response frames for the ESS or IBSS.

— 4096 is the number of times the pass-phrase is hashed.

— 256 is the number of bits output by the pass-phrase mapping.

### J.4.2 Test vectors

```
Test case 1
passPhrase = "password"(#6283)
ssid = { 'I', 'E', 'E', 'E' }
PSK = f42c6fc52df0ebef9ebb4b90b38a5f90 2e83fe1b135a70e23aed762e9710a12e

Test case 2
passPhrase = "ThisIsAPassword"(#6283)
ssid = { 'T', 'h', 'i', 's', 'I', 's', 'A', 'S', 'S', 'I', 'D' }
PSK = 0dc0d6eb90555ed6419756b9a15ec3e3 209b63df707dd508d14581f8982721af

Test case 3
passPhrase = "aaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaa"(#6283)
ssid = {'Z','Z','Z','Z', 'Z','Z','Z','Z', 'Z','Z','Z','Z', 'Z','Z','Z','Z',
             'Z','Z','Z','Z', 'Z','Z','Z','Z', 'Z','Z','Z','Z', 'Z','Z','Z','Z'}
PSK = becb93866bb8c3832cb777c2f559807c 8c59afcb6eae734885001300a981cc62
```

Note that the passPhrase does not have a terminating null.

## J.5 Suggestions for random number generation

### J.5.1 General

In order to properly implement cryptographic protocols, every platform needs the ability to generate cryptographic-quality random numbers. IETF RFC 4086 explains the notion of cryptographic-quality random numbers and provides advice on ways to harvest suitable randomness. It recommends sampling multiple sources, each of which contains some randomness, and by passing the complete set of samples through a PRF. By following this advice, an implementation can usually collect enough randomness to distill into a seed for a PRNG whose output is unpredictable.

This clause suggests two sample techniques that can be combined with the other recommendations of IETF RFC 4086 to harvest randomness. The first method is a software solution that can be implemented on most

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hardware; the second is a hardware-assisted solution. These solutions are expository only, to demonstrate that it is feasible to harvest randomness on any IEEE 802.11 platform. They are not mutually exclusive, and they do not preclude the use of other sources of randomness when available, such as a noisy diode in a power circuit; in this case, the more the merrier. As many sources of randomness as possible should be gathered into a buffer, and then hashed, to obtain a seed for the PRNG.

### J.5.2 Software sampling

Due to the nature of clock circuits in modern electronics, there is some lack of correlation between two clocks in two different pieces of equipment, even when high-quality crystals are used—crystal clocks are subject to jitter, noise, drift, and frequency mismatch. This randomness might be as little as the placement of the clock waveform edges. Even if one entity were to attempt to synchronize itself to another entity's clock, the correlation cannot be perfect due to noise and uncertainties of the synchronization.

Two clock circuits in the same piece of equipment might synchronize in frequency, but again the correlation is not perfect due to the noise and jitter of the circuits.

The randomness between the two clocks might not be much per sample—a tenth of a bit or less—but enough samples might be collected to gather enough randomness to form a seed.

A device can use software methods to take advantage of this lack of synchronization, to collect randomness from different sources. As an example, an AP might measure the frame arrival times on Ethernet wireless ports. There is always some amount of traffic on modern Ethernets: ARPs, DHCP requests, NetBIOS advertisements, etc. The sample algorithm in this subclause uses this traffic. In the example, an AP obtains randomness from the available traffic. If Ethernet traffic is available, the AP utilizes that for a source of randomness. Otherwise, it waits for the first association and creates traffic from which it can obtain randomness.

The clocks used to time the frames should be the highest resolution available, preferably 1 ms resolution or better. The clock used to time frame arrival should not be related to the clock used for frame serialization.

```
Initialize result to empty array
LoopCounter = 0
Wait until Ethernet traffic or association
Repeat until global key counter "random enough" or 32 times {
    result = PRF-256(0, "Init Counter",
    (#144)Local MAC Address || Time || result || LoopCounter)
    LoopCounter++
    Repeat 32 times {
        If Ethernet traffic available then {
            Take least significant octet of the timestamp when Ethernet packet is received
            Concatenate this octet onto result
        } else {
            Start 4-way handshake; after receipt of message 2, deauthenticate
            Take least significant octet of the timestamp of when message 1 is sent
            Take least significant octet of the timestamp of when message 2 is received
            Take the least significant octet of RSSI from message 2
            Take SNonce from message 2
            Concatenate the sent time, received time, RSSI and SNonce octets onto result
        }
```


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}
}
Global key counter = result = PRF-256(0, "Init Counter",
(#144)Local MAC Address || Time || result || LoopCounter)

NOTE—The Time is set to 0 if it is not available.

### J.5.3 Hardware-assisted solution

The sample implementation in this subclause uses hardware ring oscillators to generate randomness, as depicted in Figure J-1 (Randomness generating circuit).

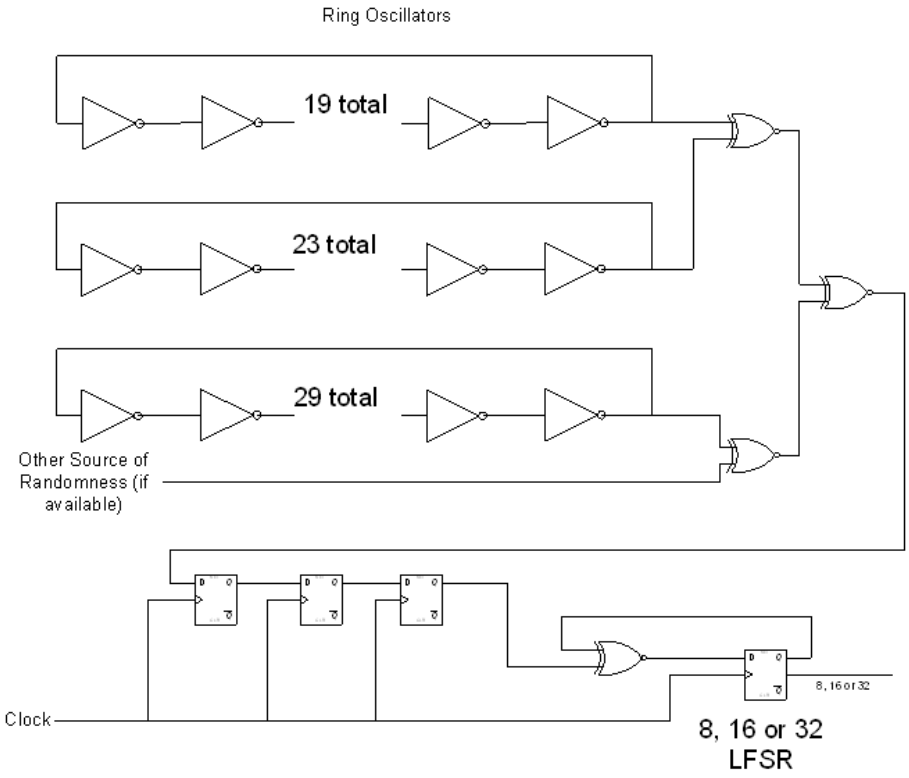


**Figure J-1—Randomness generating circuit**

The circuit in Figure J-1 (Randomness generating circuit) generates randomness. The clock input should be about the same frequency as the ring oscillator's natural frequencies. The LFSR should be chosen to be one that is maximal length. Sample LFSRs can be found in Arazi [B4].

The three ring oscillators should be isolated from each other as much as possible to avoid harmonic locking between them. In addition, the three ring oscillators should not be near any other clock circuitry within the system to avoid these ring oscillators locking to system clocks. The oscillators should be tested to verify that their output is not correlated.

The output of the LFSR is read by software and concatenated until enough randomness is collected. As a rule of thumb, reading from the LFSR 8 to 16 times the number of bits as the desired number of random bits is sufficient.

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```
Initialize result to empty array
Repeat 1024 times {
    Read LFSR
    result = result | LFSR
    Wait a time period
}
Global key counter = PRF-256(0, "Init Counter", result)
```

## J.6 Additional test vectors

### J.6.1 Notation

In the examples that follow in J.6 (Additional test vectors), frames are represented as a stream of octets, each octet in hexadecimal notation, sometimes with text annotation. The order of transmission for octets is left to right, top to bottom. For example, consider the following representation of a frame in Table J-3 (Notation example).

**Table J-3—Notation example**

| | |
|---|---|
| Description #1 | 00 01 02 03 04 05 |
| Description #2 | 06 07 08 |

The frame consists of 9 octets, represented in hexadecimal notation as “00”, “01”, ..., “08”. The octet represented by “00” is transmitted first, and the octet represented by “08” is transmitted last. Similar tables are used for other purposes, such as describing a cryptographic operation(#3056).

### J.6.2 TKIP test vector

An example of a TKIP MSDU is provided in Table J-4 (Sample TKIP parameters) and Table J-5 (Sample plaintext and cipher text MPDUs, using parameter from Table J-4 (Sample TKIP parameters)). The key and PN are used to create the IV, Phase1, and Phase2 keys.

**Table J-4—Sample TKIP parameters**

| | |
|---|---|
| Source MAC Address | 02 03 04 05 06 07 |
| Destination MAC Address | 02 03 04 05 06 08 |
| Key | 12 34 56 78 90 12 34 56 78 90 12 34 56 78 90 12<br>34 56 78 90 12 34 56 78 90 12 34 56 78 90 12 34 |
| PN | 0x000000000001 |
| IV | 00 20 01 20 00 00 00 00 |


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**Table J-4—Sample TKIP parameters *(continued)***

| | |
|---|---|
| Phase1 | bb 58 07 1f 9e 93 b4 38 25 4b |
| Phase2 | 00 20 01 4c fe 67 be d2 7c 86 7b 1b f8 02 8b 1c |

**Table J-5—Sample plaintext and cipher text MPDUs, using parameter from Table J-4 (Sample TKIP parameters)**

| | |
|---|---|
| Plaintext MPDU with TKIP MIC | 08 42 2c 00 02 03 04 05 06 08 02 03 04 05 06 07<br>02 03 04 05 06 07 d0 02 00 20 01 20 00 00 00 00<br>aa aa 03 00 00 00 08 00 45 00 00 54 00 00 40 00<br>40 01 a5 55 c0 a8 0a 02 c0 a8 0a 01 08 00 3a b0<br>00 00 00 00 cd 4c 05 00 00 00 00 00 08 09 0a 0b<br>0c 0d 0e 0f 10 11 12 13 14 15 16 17 18 19 1a 1b<br>1c 1d 1e 1f 20 21 22 23 24 25 26 27 28 29 2a 2b<br>2c 2d 2e 2f 30 31 32 33 34 35 36 37 68 81 a3 f3<br>d6 48 d0 3c |
| Encrypted MPDU with MIC and ICV | 08 42 2c 00 02 03 04 05 06 08 02 03 04 05 06 07<br>02 03 04 05 06 07 d0 02 00 20 01 20 00 00 00 00<br>c0 0e 14 fc e7 cf ab c7 75 47 e6 66 e5 7c 0d ac<br>70 4a 1e 35 8a 88 c1 1c 8e 2e 28 2e 38 01 02 7a<br>46 56 05 5e e9 3e 9c 25 47 02 e9 73 58 05 dd b5<br>76 9b a7 3f 1e bb 56 e8 44 ef 91 22 85 d3 dd 6e<br>54 1e 82 38 73 55 8a db a0 79 06 8a bd 7f 7f 50<br>95 96 75 ac c4 b4 de 9a a9 9c 05 f2 89 a7 c5 2f<br>ee 5b fc 14 f6 f8 e5 f8 |

### J.6.3 CCMP test vectors

```
==== CCMP-128 PV0 test vector ====

-- MPDU fields

Version  = 0
Type     = 2   SubType  = 0  Data
ToDS     = 0   FromDS   = 0
MoreFrag = 0   Retry    = 1
PwrMgt   = 0   moreData = 0
Encrypt  = 1
Order    = 0
Duration = 11459
A1 = 0f-d2-e1-28-a5-7c    DA
A2 = 50-30-f1-84-44-08    SA
A3 = ab-ae-a5-b8-fc-ba    BSSID
SC = 0x3380
seqNum = 824 (0x0338)  fraqNum = 0 (0x00)
Algorithm = AES_CCM
Key ID = 0

TK = c9 7c 1f 67 ce 37 11 85  51 4a 8a 19 f2 bd d5 2f

PN = 199027030681356  (0xB5039776E70C)

(#7183)MAC Header = 08 48 c3 2c 0f d2 e1 28 a5 7c 50 30 f1 84 44 08 ab ae a5 b8 fc
             ba 80 33
```

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(#7183)Muted MAC Header = 08 40 0f d2 e1 28 a5 7c 50 30 f1 84 44 08 ab ae a5 b8 fc ba 00 00

CCMP Header = 0c e7 00 20 76 97 03 b5

CCM Nonce = 00 50 30 f1 84 44 08 b5  03 97 76 e7 0c

Plaintext Data = f8 ba 1a 55 d0 2f 85 ae 96 7b b6 2f b6 cd a8 eb 7e 78 a0 50

CCM MIC = 78 45 ce 0b 16 f9 76 23

-- Encrypted MPDU with FCS

08 48 c3 2c 0f d2 e1 28 a5 7c 50 30 f1 84 44 08 ab ae a5 b8 fc ba 80 33 0c e7 00 20 76 97 03 b5 f3 d0 a2 fe 9a 3d bf 23 42 a6 43 e4 32 46 e8 0c 3c 04 d0 19 78 45 ce 0b 16 f9 76 23 1d 99 f0 66

==== CCMP-128 PV1 test vectors ====

BSSID: a2:ae:a5:b8:fc:ba

DA: 02:d2:e1:28:a5:7c

SA: 52:30:f1:84:44:08

Association ID: 7

Base PN: 123 (0x0000007b)

SC = 0x3380 (FragNum=0 SeqNum=824)

TID = 3

Key ID: 0

TK - hexdump(len=16): c9 7c 1f 67 ce 37 11 85 51 4a 8a 19 f2 bd d5 2f

PN = SC||BPN

PN (PN0..PN5) - hexdump(len=8): 80 33 7b 00 00 00 00 00

PV1 test vector #1:
Header compression used and A3 was previously stored at the receiver

FC=0x0061 (PV=1 Type=0 PTID/Subtype=3 From_DS=0 More_Fragments=0 Power_Management=0 More_Data=0 Protected_Frame=0 End_of_SP=0 Relayed_Frame=0 Ack_Policy=0)

A1=a2:ae:a5:b8:fc:ba

A2=07 00 (SID: AID=7 A3_Present=0 A4_Present=0 A-MSDU=0); corresponds to 52:30:f1:84:44:08 in uncompressed header

Sequence Control: 80 33 (FN=0 SN=824)

A3 not present; corresponds to 02:d2:e1:28:a5:7c in uncompressed header


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A4 not present

Plaintext Frame Header - hexdump(len=12): 61 00 a2 ae a5 b8 fc ba 07 00 80 33

Plaintext Frame Body - hexdump(len=20): f8 ba 1a 55 d0 2f 85 ae 96 7b b6 2f b6 cd a8 eb 7e 78 a0 50

CCMP AAD - hexdump(len=22): 61 10 a2 ae a5 b8 fc ba 52 30 f1 84 44 08 00 00 02 d2 e1 28 a5 7c

(#1774)CCM Nonce - hexdump(len=13): 23 52 30 f1 84 44 08 00 00 00 7b 33 80

CCM B_0 - hexdump(len=16): 59 23 52 30 f1 84 44 08 00 00 00 7b 33 80 00 14

CCM T - hexdump(len=8): 54 a0 f5 a5 58 c3 8b 98

CCM U - hexdump(len=8): f8 ca bc a8 6d ff 2c f8

CCMP encrypted - hexdump(len=20): 4c 53 53 ce ea fa 0d 5a 04 52 49 66 04 86 e1 68 41 59 e9 42

Encrypted Frame Header - hexdump(len=12): 61 10 a2 ae a5 b8 fc ba 07 00 80 33

Encrypted Frame Frame Body - hexdump(len=28): 4c 53 53 ce ea fa 0d 5a 04 52 49 66 04 86 e1 68 41 59 e9 42 f8 ca bc a8 6d ff 2c f8

Encrypted Frame FCS - hexdump(len=4): 9e 3d 21 65

PV1 test vector #2:
Header compression used and A3 was not previously stored at the receiver

FC=0x0061 (PV=1 Type=0 PTID/Subtype=3 From_DS=0 More_Fragments=0 Power_Management=0 More_Data=0 Protected_Frame=0 End_of_SP=0 Relayed_Frame=0 Ack_Policy=0)

A1=a2:ae:a5:b8:fc:ba

A2=07 20 (SID: AID=7 A3_Present=1 A4_Present=0 A-MSDU=0); corresponds to 52:30:f1:84:44:08 in uncompressed header

Sequence Control: 80 33 (FN=0 SN=824)

A3=02:d2:e1:28:a5:7c

A4 not present

Plaintext Frame Header - hexdump(len=18): 61 00 a2 ae a5 b8 fc ba 07 20 80 33 02 d2 e1 28 a5 7c

Plaintext Frame Body - hexdump(len=20): f8 ba 1a 55 d0 2f 85 ae 96 7b b6 2f b6 cd a8 eb 7e 78 a0 50

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CCMP AAD - hexdump(len=22): 61 10 a2 ae a5 b8 fc ba 52 30 f1 84 44 08 00 00 02 d2 e1 28 a5 7c

(#1774)CCM Nonce - hexdump(len=13): 23 52 30 f1 84 44 08 00 00 00 7b 33 80

CCM B_0 - hexdump(len=16): 59 23 52 30 f1 84 44 08 00 00 00 7b 33 80 00 14

CCM T - hexdump(len=8): 54 a0 f5 a5 58 c3 8b 98

CCM U - hexdump(len=8): f8 ca bc a8 6d ff 2c f8

CCMP encrypted - hexdump(len=20): 4c 53 53 ce ea fa 0d 5a 04 52 49 66 04 86 e1 68 41 59 e9 42

Encrypted Frame Header - hexdump(len=18): 61 10 a2 ae a5 b8 fc ba 07 20 80 33 02 d2 e1 28 a5 7c

Encrypted Frame Frame Body - hexdump(len=28): 4c 53 53 ce ea fa 0d 5a 04 52 49 66 04 86 e1 68 41 59 e9 42 f8 ca bc a8 6d ff 2c f8

Encrypted Frame FCS - hexdump(len=4): aa 07 71 93

PV1 test vector #3:
Type 3 frame from SA to DA(=BSSID) (i.e., no separate DA in this example)

FC=0x006d (PV=1 Type=3 PTID/Subtype=3 From_DS=0 More_Fragments=0 Power_Management=0 More_Data=0 Protected_Frame=0 End_of_SP=0 Relayed_Frame=0 Ack_Policy=0)

A1=a2:ae:a5:b8:fc:ba

A2=52:30:f1:84:44:08

Sequence Control: 80 33 (FN=0 SN=824)

A3 not present; corresponds to 02:d2:e1:28:a5:7c in uncompressed header

A4 not present

Plaintext Frame Header - hexdump(len=16): 6d 00 a2 ae a5 b8 fc ba 52 30 f1 84 44 08 80 33

Plaintext Frame Body - hexdump(len=20): f8 ba 1a 55 d0 2f 85 ae 96 7b b6 2f b6 cd a8 eb 7e 78 a0 50

CCMP AAD - hexdump(len=22): 6d 10 a2 ae a5 b8 fc ba 52 30 f1 84 44 08 00 00 02 d2 e1 28 a5 7c

(#1774)CCM Nonce - hexdump(len=13): 23 52 30 f1 84 44 08 00 00 00 7b 33 80
CCM B_0 - hexdump(len=16): 59 23 52 30 f1 84 44 08 00 00 00 7b 33 80 00 14

CCM T - hexdump(len=8): 76 b9 1f 36 2a 0c e0 e8


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```
CCM U - hexdump(len=8): da d3 56 3b 1f 30 47 88

CCMP encrypted - hexdump(len=20): 4c 53 53 ce ea fa 0d 5a 04 52 49 66 04 86 e1 68
41 59 e9 42

Encrypted Frame Header - hexdump(len=16): 6d 10 a2 ae a5 b8 fc ba 52 30 f1 84 44
08 80 33

Encrypted Frame Frame Body - hexdump(len=28): 4c 53 53 ce ea fa 0d 5a 04 52 49 66
04 86 e1 68 41 59 e9 42 da d3 56 3b 1f 30 47 88

Encrypted Frame FCS - hexdump(len=4): ff a5 82 36


==== CCMP-256 test vector ====

TK: c9 7c 1f 67 ce 37 11 85 51 4a 8a 19 f2 bd d5 2f 00 01 02 03 04 05 06 07 08 09
             0a 0b 0c 0d 0e 0f

PN: b5 03 97 76 e7 0c

(#7183)MAC Header: 08 48 c3 2c 0f d2 e1 28 a5 7c 50 30 f1 84 44 08 ab ae a5 b8 fc
             ba 80 33

CCMP-256 AAD: 08 40 0f d2 e1 28 a5 7c 50 30 f1 84 44 08 ab ae a5 b8 fc ba 00 00

(#1774)CCM Nonce: 00 50 30 f1 84 44 08 b5 03 97 76 e7 0c

Plaintext Data: f8 ba 1a 55 d0 2f 85 ae 96 7b b6 2f b6 cd a8 eb 7e 78 a0 50

CCMP-256 encrypted: 6d 15 5d 88 32 66 82 56 d6 a9 2b 78 e1 1d 8e 54 49 5d d1 74

Encrypted MPDU (without FCS): 08 48 c3 2c 0f d2 e1 28 a5 7c 50 30 f1 84 44 08 ab
             ae a5 b8 fc ba 80 33 0c e7 00 20 76 97 03 b5 6d 15 5d 88 32 66 82 56
             d6 a9 2b 78 e1 1d 8e 54 49 5d d1 74 80 aa 56 c9 49 2e 88 2b 97 64 2f
             80 d5 0f e9 7b

FCS: 29 c2 06 69
```

### J.6.4 PRF test vectors

A set of test vectors are provided for each size of PRF function used in this subclause. See Table J-6 (RSN PRF Test Vector 1) to Table J-9 (RSN PRF Test Vector 4). The inputs to the PRF function are strings for key, prefix, and data. The length can be any multiple of 8, but the values 192, 256, 384, and 512 are used in this subclause. The test vectors were taken from IETF RFC 2202 [B25] with additional vectors added to test larger key and data sizes.

**Table J-6—RSN PRF Test Vector 1**

| | |
|---|---|
| Test_case | 1 |
| Key | 0b 0b 0b 0b 0b 0b 0b 0b 0b 0b 0b 0b 0b 0b 0b 0b 0b 0b 0b 0b |
| Prefix | "prefix" |
| Data | "Hi There" |

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**Table J-6—RSN PRF Test Vector 1 *(continued)***

| | |
|---|---|
| Length | 192 |
| PRF-192 | bc d4 c6 50 b3 0b 96 84  95 18 29 e0 d7 5f 9d 54<br>b8 62 17 5e d9 f0 06 06 |

**Table J-7—RSN PRF Test Vector 2**

| | |
|---|---|
| Test_case | 2 |
| Key | 'Jefe' |
| Prefix | "prefix-2" |
| Data | "what do ya want for nothing?" |
| Length | 256 |
| PRF-256 | 47 c4 90 8e 30 c9 47 52  1a d2 0b e9 05 34 50 ec<br>be a2 3d 3a a6 04 b7 73  26 d8 b3 82 5f f7 47 5c |

**Table J-8—RSN PRF Test Vector 3**

| | |
|---|---|
| Test_case | 3 |
| Key | aa aa aa aa aa aa aa aa aa aa aa aa aa aa aa aa aa aa aa aa<br>aa aa aa aa aa aa aa aa aa aa aa aa aa aa aa aa aa aa aa aa<br>aa aa aa aa aa aa aa aa aa aa aa aa aa aa aa aa aa aa aa aa<br>aa aa aa aa aa aa aa aa aa aa aa aa aa aa aa aa aa aa |
| Prefix | "prefix-3" |
| Data | "Test Using Larger Than Block-Size Key - Hash Key First" |
| Length | 384 |
| PRF-384 | 0a b6 c3 3c cf 70 d0 d7  36 f4 b0 4c 8a 73 73 25<br>55 11 ab c5 07 37 13 16  3b d0 b8 c9 ee b7 e1 95<br>6f a0 66 82 0a 73 dd ee  3f 6d 3b d4 07 e0 68 2a |

**Table J-9—RSN PRF Test Vector 4**

| | |
|---|---|
| Test_case | 4 |
| Key | 0b 0b 0b 0b 0b 0b 0b 0b 0b 0b 0b 0b 0b 0b 0b 0b 0b 0b 0b 0b |
| Prefix | "prefix-4" |
| Data | "Hi There Again" |


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**Table J-9—RSN PRF Test Vector 4 *(continued)***

| | |
|---|---|
| Length | 512 |
| PRF-512 | 24 8c fb c5 32 ab 38 ff a4 83 c8 a2 e4 0b f1 70<br>eb 54 2a 2e 09 16 d7 bf 6d 97 da 2c 4c 5c a8 77<br>73 6c 53 a6 5b 03 fa 4b 37 45 ce 76 13 f6 ad 68<br>e0 e4 a7 98 b7 cf 69 1c 96 17 6f d6 34 a5 9a 49 |

## J.7 Key hierarchy test vectors for pairwise keys

### J.7.1 General

The test vectors in this subclause provide an example of PTK derivation for both CCMP-128 and TKIP.

Pairwise keys are derived from the PMK, AA, SPA, SNonce, and ANonce. The values in Table J-10 (Sample values for pairwise key derivations) are used as input to the pairwise key derivation test vectors.

**Table J-10—Sample values for pairwise key derivations**

| | |
|---|---|
| PMK | 0d c0 d6 eb 90 55 5e d6 41 97 56 b9 a1 5e c3 e3<br>20 9b 63 df 70 7d d5 08 d1 45 81 f8 98 27 21 af |
| AA | a0 a1 a1 a3 a4 a5 |
| SPA | b0 b1 b2 b3 b4 b5 |
| SNonce | c0 c1 c2 c3 c4 c5 c6 c7 c8 c9 d0 d1 d2 d3 d4 d5<br>d6 d7 d8 d9 da db dc dd de df e0 e1 e2 e3 e4 e5 |
| ANonce | e0 e1 e2 e3 e4 e5 e6 e7 e8 e9 f0 f1 f2 f3 f4 f5<br>f6 f7 f8 f9 fa fb fc fd fe ff 00 01 02 03 04 05 |

### J.7.2 CCMP-128 pairwise key derivation

Using the values from Table J-10 (Sample values for pairwise key derivations) for PMK, AA, SPA, SNonce, and ANonce, the key derivation process for CCMP generates a temporal key as shown in Table J-11 (Sample derived CCMP-128 temporal key (TK)).

**Table J-11—Sample derived CCMP-128 temporal key (TK)**

| | |
|---|---|
| TK | b2 36 0c 79 e9 71 0f dd 58 be a9 3d ea f0 65 99 |

### J.7.3 TKIP pairwise key derivation

Using the values from Table J-10 (Sample values for pairwise key derivations) for PMK, AA, SPA, SNonce, and ANonce, the key derivation process for TKIP generates the values shown in Table J-12 (Sample derived PTK).

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**Table J-12—Sample derived PTK**

| | |
|---|---|
| (#3742)(#4063)PTK-KCK | 37 9f 98 52 d0 19 92 36 b9 4e 40 7c e4 c0 0e c8 |
| (#4063)PTK-KEK | 47 c9 ed c0 1c 2c 6e 5b 49 10 ca dd fb 3e 51 a7 |
| TK | b2 36 0c 79 e9 71 0f dd 58 be a9 3d ea f0 65 99<br>db 98 0a fb c2 9c 15 28 55 74 0a 6c e5 ae 38 27 |
| Authenticator Tx MIC_key | db 98 0a fb c2 9c 15 28 |
| Supplicant Tx MIC_key | 55 74 0a 6c e5 ae 38 27 |

## J.8 Test vectors for AES-128-CMAC

Test vectors for AES-128-CMAC are in Annex D.1 of NIST Special Publication 800-38B.

## J.9 Management frame protection test vectors

### J.9.1 BIP with broadcast Deauthentication frame

Unprotected broadcast Deauthentication frame (without FCS):
c0 00 00 00 ff ff ff ff ff ff 02 00 00 00 00 00 02 00 00 00 00 00 09 00 02 00

FC=c0 00
DUR=00 00
DA=ff ff ff ff ff ff
SA=02 00 00 00 00 00
BSSID=02 00 00 00 00 00
SEQ=09 00
Reason Code: 02 00

IGTK: 4e a9 54 3e 09 cf 2b 1e ca 66 ff c5 8b de cb cf

BIP-CMAC-128 AAD (FC || A1 || A2 || A3): c0 00 ff ff ff ff ff ff 02 00 00 00 00 00 02 00 00 00 00 00

Management Frame Body: 02 00

MME (with MIC=0): 4c 10 04 00 04 00 00 00 00 00 00 00 00 00 00 00 00

AES-128-CMAC(AAD || Management Frame Body || MME): 48 df bf a7 b8 27 88 72

Protected broadcast Deauthentication frame (without FCS):

c0 00 00 00 ff ff ff ff ff ff 02 00 00 00 00 00 02 00 00 00 00 00 09 00 02 00 4c 10 04 00 04 00 00
00 00 00 48 df bf a7 b8 27 88 72

FC=c0 00 (note: Protected flag is _not_ set)
DUR=00 00
DA=ff ff ff ff ff ff
SA=02 00 00 00 00 00


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BSSID=02 00 00 00 00 00
SEQ=09 00
Reason Code: 02 00

MME: 4c 10 04 00 04 00 00 00 00 00 48 df bf a7 b8 27 88 72

(Key ID = 04 00 (= 4), Seq# = 04 00 00 00 00 00, MIC = 48 df bf a7 b8 27 88 72)

==== BIP-GMAC-128 with broadcast Deauthentication frame ====

Unprotected broadcast Deauthentication frame (without FCS):

c0 00 00 00 ff ff ff ff ff ff 02 00 00 00 00 00 02 00 00 00 00 00 09 00 02 00

FC=c0 00

DUR=00 00

DA=ff ff ff ff ff ff

SA=02 00 00 00 00 00

BSSID=02 00 00 00 00 00

SEQ=09 00

Reason Code: 00 20

IGTK: 4e a9 54 3e 09 cf 2b 1e ca 66 ff c5 8b de cb cf

IPN: 04 00 00 00 00 00

BIP-GMAC AAD (FC || A1 || A2 || A3): c0 00 ff ff ff ff ff ff 02 00 00 00 00 00 02 00 00 00 00 00

Management Frame Body: 02 00

BIP-GMAC IV: 02 00 00 00 00 00 00 00 00 00 00 04

BIP-GMAC MME MIC: 3e d8 62 fb 0f 33 38 dd 33 86 c8 97 e2 ed 05 3d

Protected MPDU (without FCS):

c0 00 00 00 ff ff ff ff ff ff 02 00 00 00 00 00 02 00 00 00 00 00 09 00 02 00 4c 18 04 00 04 00 00 00 00 00
3e d8 62 fb 0f 33 38 dd 33 86 c8 97 e2 ed 05 3d

==== BIP-GMAC-256 with broadcast Deauthentication frame ====

Unprotected broadcast Deauthentication frame (without FCS):

c0 00 00 00 ff ff ff ff ff ff 02 00 00 00 00 00 02 00 00 00 00 00 09 00 02 00

FC=c0 00

DUR=00 00

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DA=ff ff ff ff ff ff

SA=02 00 00 00 00 00

BSSID=02 00 00 00 00 00

SEQ=09 00

Reason Code: 00 20

IGTK: 4e a9 54 3e 09 cf 2b 1e ca 66 ff c5 8b de cb cf 00 01 02 03 04 05 06 07 08 09 0a 0b 0c 0d 0e 0f

IPN: 04 00 00 00 00 00

BIP-GMAC AAD (FC || A1 || A2 || A3): c0 00 ff ff ff ff ff ff 02 00 00 00 00 00 02 00 00 00 00 00

Management Frame Body: 02 00

BIP-GMAC IV: 02 00 00 00 00 00 00 00 00 00 00 04

BIP-GMAC MME MIC: 23 be 59 dc c7 02 2e e3 83 62 7e bb 10 17 dd fc

Protected MPDU (without FCS):

c0 00 00 00 ff ff ff ff ff ff 02 00 00 00 00 00 02 00 00 00 00 00 09 00 02 00 4c 18 04 00 04 00 00 00 00 00 23 be 59 dc c7 02 2e e3 83 62 7e bb 10 17 dd fc

### J.9.2 BIP with S1G Beacon Frames(#6054)

==== S1G Beacon frame with BIP-CMAC-128, no optional header fields, S1G Beacon Compatibility element in body ====

Unprotected S1G Beacon frame (without FCS): 1c 40 00 00 02 00 00 00 00 00 00 00 00 00 d5 08 80 00 00 00 12 34 56 78

BIGTK: 4e a9 54 3e 09 cf 2b 1e ca 66 ff c5 8b de cb cf

BIPN: 04 00 00 00 00 00

S1G BIP-CMAC-128 AAD|Body(masked): 1c 40 02 00 00 00 00 00 00 d5 08 80 00 00 00 00 00 00 00 4c 10 07 00 04 00 00 00 00 00 00 00 00 00 00 00 00

S1G BIP-CMAC-128 MIC: 6b f6 47 29 3f 14 5b bc

Protected MPDU (without FCS): 1c 40 00 00 02 00 00 00 00 00 00 00 00 00 d5 08 80 00 00 00 12 34 56 78 4c 10 07 00 04 00 00 00 00 00 6b f6 47 29 3f 14 5b bc

==== S1G Beacon frame with BIP-CMAC-128, all optional header fields, no body elements ====

Unprotected S1G Beacon frame (without FCS): 1c 47 00 00 02 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00

BIGTK: 4e a9 54 3e 09 cf 2b 1e ca 66 ff c5 8b de cb cf


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BIPN: 04 00 00 00 00 00

S1G BIP-CMAC-128 AAD|Body(masked): 1c 47 02 00 00 00 00 00 00 00 00 00 00 00 00 00 4c 10 06 00 04 00 00 00 00 00 00 00 00 00 00 00 00

S1G BIP-CMAC-128 MIC: 3c 58 b6 bd 3b da 56 c3

Protected MPDU (without FCS): 1c 47 00 00 02 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 4c 10 06 00 04 00 00 00 00 00 3c 58 b6 bd 3b da 56 c3

==== S1G Beacon frame with BIP-CMAC-128 using BCE, no optional header fields, S1G Beacon Compatibility element in body ====

Unprotected S1G Beacon frame (without FCS): 1c 40 00 00 02 00 00 00 00 00 00 00 00 00 d5 08 80 00 00 00 12 34 56 78

BIGTK: 4e a9 54 3e 09 cf 2b 1e ca 66 ff c5 8b de cb cf

BIPN: 04 00 00 00 00 00

S1G BIP-CMAC-128 AAD|Body(masked): 1c 40 02 00 00 00 00 00 04 00 00 00 00 00 d5 08 80 00 00 00 00 00 00 00 8c 08 00 00 00 00 00 00 00 00

S1G BIP-CMAC-128 MIC: bf d5 09 15 39 04 ef 3c

Protected MPDU (without FCS): 1c 40 00 00 02 00 00 00 00 00 00 00 00 00 d5 08 80 00 00 00 12 34 56 78 8c 08 bf d5 09 15 39 04 ef 3c

==== S1G Beacon frame with BIP-CMAC-128 using BCE, all optional header fields, no body elements ====

Unprotected S1G Beacon frame (without FCS): 1c 47 00 00 02 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00

BIGTK: 4e a9 54 3e 09 cf 2b 1e ca 66 ff c5 8b de cb cf

BIPN: 04 00 00 00 00 00

S1G BIP-CMAC-128 AAD|Body(masked): 1c 47 02 00 00 00 00 00 00 00 00 00 00 00 00 00 04 00 00 00 00 00 8c 08 00 00 00 00 00 00 00 00

S1G BIP-CMAC-128 MIC: c1 1e d2 f4 23 34 40 15

Protected MPDU (without FCS): 1c 47 00 00 02 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 8c 08 c1 1e d2 f4 23 34 40 15

==== S1G Beacon frame with BIP-GMAC-128, no optional header fields, S1G Beacon Compatibility element in body ====

Unprotected S1G Beacon frame (without FCS): 1c 40 00 00 02 00 00 00 00 00 00 00 00 00 d5 08 00 00 00 00 12 34 56 78

BIGTK: 4e a9 54 3e 09 cf 2b 1e ca 66 ff c5 8b de cb cf

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BIPN: 04 00 00 00 00 00

S1G BIP-GMAC-128 AAD|Body(masked): 1c 40 02 00 00 00 00 00 00 d5 08 00 00 00 00 00 00 00 00 4c 18 06 00 04 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00

S1G BIP-GMAC-128 Nonce: 02 00 00 00 00 00 00 00 00 00 00 04

S1G BIP-GMAC-128 MIC: a5 b2 42 c1 c1 1e ab 10 c5 a4 e8 b9 53 66 19 38

Protected MPDU (without FCS): 1c 40 00 00 02 00 00 00 00 00 00 00 00 00 00 d5 08 00 00 00 00 12 34 56 78 4c 18 06 00 04 00 00 00 00 00 a5 b2 42 c1 c1 1e ab 10 c5 a4 e8 b9 53 66 19 38

==== S1G Beacon frame with BIP-GMAC-128, all optional header fields, no body elements ====

Unprotected S1G Beacon frame (without FCS): 1c 47 00 00 02 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00

BIGTK: 4e a9 54 3e 09 cf 2b 1e ca 66 ff c5 8b de cb cf

BIPN: 04 00 00 00 00 00

S1G BIP-GMAC-128 AAD|Body(masked): 1c 47 02 00 00 00 00 00 00 00 00 00 00 00 00 00 4c 18 07 00 04 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00

S1G BIP-GMAC-128 Nonce: 02 00 00 00 00 00 00 00 00 00 00 04

S1G BIP-GMAC-128 MIC: 39 d0 0c c2 ee d7 4c 2a b7 41 cc f8 08 9b 5b 08

Protected MPDU (without FCS): 1c 47 00 00 02 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 4c 18 07 00 04 00 00 00 00 00 39 d0 0c c2 ee d7 4c 2a b7 41 cc f8 08 9b 5b 08

==== S1G Beacon frame with BIP-GMAC-128 using BCE, no optional header fields, S1G Beacon Compatibility element in body ====

Unprotected S1G Beacon frame (without FCS): 1c 40 00 00 02 00 00 00 00 00 00 00 00 00 d5 08 00 00 00 00 12 34 56 78

BIGTK: 4e a9 54 3e 09 cf 2b 1e ca 66 ff c5 8b de cb cf

BIPN: 04 00 00 00 00 00

S1G BIP-GMAC-128 AAD|Body(masked): 1c 40 02 00 00 00 00 00 00 04 00 00 00 00 00 d5 08 00 00 00 00 00 00 00 00 8c 10 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00

S1G BIP-GMAC-128 Nonce: 02 00 00 00 00 00 00 00 00 00 00 04

S1G BIP-GMAC-128 MIC: a2 5b 7e 67 76 f0 11 57 a4 fb 4a 2d 66 d0 17 66

Protected MPDU (without FCS): 1c 40 00 00 02 00 00 00 00 00 00 00 00 00 d5 08 00 00 00 00 12 34 56 78 8c 10 a2 5b 7e 67 76 f0 11 57 a4 fb 4a 2d 66 d0 17 66

==== S1G Beacon frame with BIP-GMAC-128 using BCE, all optional header fields, no body elements ====


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Unprotected S1G Beacon frame (without FCS): 1c 47 00 00 02 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00

BIGTK: 4e a9 54 3e 09 cf 2b 1e ca 66 ff c5 8b de cb cf

BIPN: 04 00 00 00 00 00

S1G BIP-GMAC-128 AAD|Body(masked): 1c 47 02 00 00 00 00 00 00 00 00 00 00 00 00 00 04 00 00 00 00 00 8c 10 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00

S1G BIP-GMAC-128 Nonce: 02 00 00 00 00 00 00 00 00 00 00 04

S1G BIP-GMAC-128 MIC: 86 dd b6 c0 56 21 30 9d 3e bd 25 96 67 5b dd c3

Protected MPDU (without FCS): 1c 47 00 00 02 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 8c 10 86 dd b6 c0 56 21 30 9d 3e bd 25 96 67 5b dd c3

==== S1G Beacon frame with BIP-GMAC-256, no optional header fields, S1G Beacon Compatibility element in body ====

Unprotected S1G Beacon frame (without FCS): 1c 40 00 00 02 00 00 00 00 00 00 00 00 00 d5 08 80 00 00 00 12 34 56 78

BIGTK: 4e a9 54 3e 09 cf 2b 1e ca 66 ff c5 8b de cb cf 00 01 02 03 04 05 06 07 08 09 0a 0b 0c 0d 0e 0f

BIPN: 04 00 00 00 00 00

S1G BIP-GMAC-256 AAD|Body(masked): 1c 40 02 00 00 00 00 00 00 d5 08 80 00 00 00 00 00 00 00 00 4c 18 07 00 04 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00

S1G BIP-GMAC-256 Nonce: 02 00 00 00 00 00 00 00 00 00 00 04

S1G BIP-GMAC-256 MIC: 33 a2 6f c6 7e bf fd a0 ac 9b 29 aa 70 da 3f 51

Protected MPDU (without FCS): 1c 40 00 00 02 00 00 00 00 00 00 00 00 00 d5 08 80 00 00 00 12 34 56 78 4c 18 07 00 04 00 00 00 00 00 33 a2 6f c6 7e bf fd a0 ac 9b 29 aa 70 da 3f 51

==== S1G Beacon frame with BIP-GMAC-256, all optional header fields, no body elements ====

Unprotected S1G Beacon frame (without FCS): 1c 47 00 00 02 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00

BIGTK: 4e a9 54 3e 09 cf 2b 1e ca 66 ff c5 8b de cb cf 00 01 02 03 04 05 06 07 08 09 0a 0b 0c 0d 0e 0f

BIPN: 04 00 00 00 00 00

S1G BIP-GMAC-256 AAD|Body(masked): 1c 47 02 00 00 00 00 00 00 00 00 00 00 00 00 00 4c 18 06 00 04 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00

S1G BIP-GMAC-256 Nonce: 02 00 00 00 00 00 00 00 00 00 00 04

S1G BIP-GMAC-256 MIC: 0a 5f a0 f4 71 df 73 9e 61 4d cf 5d bb 36 f9 65

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Protected MPDU (without FCS): 1c 47 00 00 02 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 4c 18 06 00 04 00 00 00 00 00 0a 5f a0 f4 71 df 73 9e 61 4d cf 5d bb 36 f9 65

==== S1G Beacon frame with BIP-GMAC-256 using BCE, no optional header fields, S1G Beacon Compatibility element in body ====

Unprotected S1G Beacon frame (without FCS): 1c 40 00 00 02 00 00 00 00 00 00 00 00 00 d5 08 80 00 00 00 12 34 56 78

BIGTK: 4e a9 54 3e 09 cf 2b 1e ca 66 ff c5 8b de cb cf 00 01 02 03 04 05 06 07 08 09 0a 0b 0c 0d 0e 0f

BIPN: 04 00 00 00 00 00

S1G BIP-GMAC-256 AAD|Body(masked): 1c 40 02 00 00 00 00 00 04 00 00 00 00 00 d5 08 80 00 00 00 00 00 00 00 8c 10 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00

S1G BIP-GMAC-256 Nonce: 02 00 00 00 00 00 00 00 00 00 00 04

S1G BIP-GMAC-256 MIC: f8 76 22 80 3d 9c 22 8a cb 3c 55 8a 33 2e 94 13

Protected MPDU (without FCS): 1c 40 00 00 02 00 00 00 00 00 00 00 00 00 d5 08 80 00 00 00 12 34 56 78 8c 10 f8 76 22 80 3d 9c 22 8a cb 3c 55 8a 33 2e 94 13

==== S1G Beacon frame with BIP-GMAC-256 using BCE, all optional header fields, no body elements ====

Unprotected S1G Beacon frame (without FCS): 1c 47 00 00 02 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00

BIGTK: 4e a9 54 3e 09 cf 2b 1e ca 66 ff c5 8b de cb cf 00 01 02 03 04 05 06 07 08 09 0a 0b 0c 0d 0e 0f

BIPN: 04 00 00 00 00 00

S1G BIP-GMAC-256 AAD|Body(masked): 1c 47 02 00 00 00 00 00 00 00 00 00 00 00 00 00 00 04 00 00 00 00 00 8c 10 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00

S1G BIP-GMAC-256 Nonce: 02 00 00 00 00 00 00 00 00 00 00 04

S1G BIP-GMAC-256 MIC: 3c 80 49 be 8c 23 34 1f 5c 2f 9c d6 03 e3 7a 5b

Protected MPDU (without FCS): 1c 47 00 00 02 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 8c 10 3c 80 49 be 8c 23 34 1f 5c 2f 9c d6 03 e3 7a 5b

### J.9.3 CCMP-128 with individually addressed Deauthentication frame

Plaintext individually addressed Deauthentication frame (without FCS):
c0 00 00 00 02 00 00 00 01 00 02 00 00 00 00 00 02 00 00 00 00 00 60 00 02 00

FC=c0 00
DUR=00 00
DA=02 00 00 00 01 00
SA=02 00 00 00 00 00
BSSID=02 00 00 00 00 00


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SEQ=60 00
Reason Code: 02 00

CCMP-128 TK: 66 ed 21 04 2f 9f 26 d7 11 57 06 e4 04 14 cf 2e

CCM flags: 59 (Adata: 1, M: 011, L: 001)
Nonce = Nonce Flags || A2 || PN
= 10 (Management)
02 00 00 00 00 00
00 00 00 00 00 01
(#1609)l(m) = 00 02 (see IETF RFC 3610)

AAD = FC || A1 || A2 || A3 || SC || A4 || QC
= c0 40 02 00 00 00 01 00 02 00 00 00 00 00 02 00 00 00 00 00 00 00

AAD blocks:
00 16 c0 40 02 00 00 00 01 00 02 00 00 00 00 00
02 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00

Encrypted Deauthentication frame (without FCS):
c0 40 00 00 02 00 00 00 01 00 02 00 00 00 00 00 02 00 00 00 00 00 60 00 01 00 00 20 00 00 00 00
1d 07 ca fd 04 09 bb 8b af ef

FC=c0 40 (note: Protected bit set)
DUR=00 00
DA=02 00 00 00 01 00
SA=02 00 00 00 00 00
BSSID=02 00 00 00 00 00
SEQ=60 00
CCMP Header: 01 00 00 20 00 00 00 00 (PN=1, ExtIV=1)
Encrypted Data: 1d 07

MIC: ca fd 04 09 bb 8b af ef

## J.10 SAE test vector

group: 19
password: mekmitasdigoat
local MAC address: 4d:3f:2f:ff:e3:87
peer's MAC address: a5:d8:aa:95:8e:3c

H(addrs, mekmitasdigoat | 1):
a9025368 ef78f7d6 5e8d4d55 6f0d1d0d 758f2f7f 1e116eb1 d11307a7 e8a9621a

candidate x value:
b8e89a72 5c57f18e 8f68a7f7 2613e15f 1c904938 c38800ef a01f1306 f5e454b5

H(addrs, mekmitasdigoat | 2):
954bbbf8 923284e4 ca164e3a f0b9520c e53aa35b e39020e9 ccb23aff 86df2226

candidate x value:
da6eb7b0 6a1ac562 4974f90a fdd6a8e9 d5722634 cf987c34 defc91a9 874e5658
.

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.
.
H(addrs, mekmitasdigoat | 40):
cde7b81e b539c87a f5bf1be2 402d315c 45ad4c3d b06c9c56 b7f8b7da ae5e5842

candidate x value:
2e12a1d6 15647963 fd7aa4a9 05fd51b6 f49a902f d917ef8f 0ff20010 2699ecdb

PWE (x,y):
da6eb7b0 6a1ac562 4974f90a fdd6a8e9 d5722634 cf987c34 defc91a9 874e5658
f4fefd13 0bd5be08 fe68af3e 4a290272 ec065fd3 671f3c25 bf8ec419 ddc9b822

local private value:
992465fd 3daa3c60 aa6565b7 f62a2a7f 2e12dd12 f198faf4 fbed89d7 ff1ace94

local mask value:
9507a90f 777a044d 6a0830b9 1ea3d5dd 70bece44 e1acffb8 6983b5e1 bf9fb322

local commit:
13002e2c 0f0db524 40ad146d 967114ce 005ce1ea b0aa2c2e 5c2871b7 74f6c257
5c65d5ad 9e008297 07aa36ba 8b859738 fc961d08 243505f4 7c035376 d7ac4bc8
d7b95083 bf43827d 0fc31ed7 78dd3671 fd21a46d 1091d64b 6f9a1e12 72621325
dbe1

peer’s private value:
bedfd9e4 da33a468 7778c0e2 b9b878c7 bae6d595 79e6b6e6 e0a392e8 547259f5

peer’s mask value:
9a3bbd0d 5f4c14dd 988f8804 fb97db73 6920fd9b 651f7b9a 5d13a5d2 887c1d7f

peer’s commit:
1300591b 96f3397f b9451008 48e7b550 543b6720 d88337ee 93fc49fd 6df7e08b
5223e71b 9bb048d3 873f2055 6953a96c 91536fd8 ee6ca9b4 a68a148b 056a909b
e03e83ae 208f60f8 ef553785 8074db06 68703239 9862999b 511e0a15 52a5fea3
17c2

k:
189f666f 3181b4a1 701c2bf7 d34d644e 66b5a104 acb99adf 25f3d48b 878c081f

keyseed:
06900d37 677ed6c1 03ea1386 d753b56b e74dc3a7 e5fe9652 8e580521 daad121a

(#3742)SAE-KCK:
1e733f6d 9bd53256 28730433 8831b09a 39406d12 1017073a 5c30db36 f36cb81a

PMK:
4e4dfab1 a2dd8ac1 a91790f9 53faaa45 2ae5c687 3ab75b63 605ba663 f8a7fe59

PMKID:
8747a600 eea3f9f2 2475df58 ca1e5498

Hash-to-element method of PT/PWE generation(#331-Ed1)

group 19


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SSID: byteme
identifier: psk4internet
password: mekmitasdigoat
MAC address 1: 00:09:5b:66:ec:1e
MAC address 2: 00:0b:6b:d9:02:46

---

calculating PT for group 19

salt:
62797465 6d65

ikm:
6d656b6d 69746173 6469676f 61747073 6b34696e 7465726e 6574

prk:
3bd53fe9 223dc028 0fbfce17 d7a35640 64e20f48 c6ec7224 6ce367b5 569a22af

info:
53414520 48617368 20746f20 456c656d 656e7420 75312050 31

okm:
a5044469 ab16f25b 6abf1e0e 37a36b56 f50be733 69053df8 db87989a 6b66fd1a
491f1cda cbd07931 620f8300 8ffc0ecc

SSWU(u1):
---

u1:
dc941bc3 c6a2b494 8b6c61d5 5590ecb1 f0c51c4b 1bebaff6 77e59369 8d5a53c6

m = z^2 × u^4 + z × u^2:
7f655b40 2e73946f 02101f64 a56dc14e 691d8808 689c6cc5 4a3347c7 ad082e2d

t = 1/m:
f07ea718 98e90f41 1064aa04 0469609d 2246579b 1b986ffc 0958f26a ecdb2dcf

(– b/a) × (1 + t):
a07c2607 64a13445 ff8cd97c 5acc644e 7119bde5 1bad4258 3eed6f41 09639e6b

b/(z × a):
a528bd86 96bdaf99 6c65b982 d94959d3 146fe6a0 20693090 bdba1313 2375f224

m != 0, so x1 = (– b/a) × (1+t)
x1:
a07c2607 64a13445 ff8cd97c 5acc644e 7119bde5 1bad4258 3eed6f41 09639e6b

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gx1:
b21f71a7 645b281a c384ae40 9d4d56dc 919134fb c11ac0ac a3c4c0d6 8607d8b0

x2:
bd07b38a 812ed2cc 8472cdca 4beee58a bd55f40b 17216097 bc2b547d a12a692e

gx2:
8d8ba5d5 6b6fea0b 7087af73 0bb1fca5 092ba140 d0d7777a f9f07c26 815794fb

gx1 is a quadratic residue
gx2 is not a quadratic residue
point P1...
P1.x:
a07c2607 64a13445 ff8cd97c 5acc644e 7119bde5 1bad4258 3eed6f41 09639e6b

P1.y:
3bdc8df0 d3233793 6c74df60 4933a454 142251c5 3c576c03 51b28dea f9428d7e

---
salt:
62797465 6d65

ikm:
6d656b6d 69746173 6469676f 61747073 6b34696e 7465726e 6574

prk:
3bd53fe9 223dc028 0fbfce17 d7a35640 64e20f48 c6ec7224 6ce367b5 569a22af

info:
53414520 48617368 20746f20 456c656d 656e7420 75322050 32

okm:
9b4e0d5b 1879f253 c5319615 099b05ae c5b06fa5 e788bcfd 1e9ea60d 33436927
190814c3 22a62585 c93c577b baa3d307

SSWU(u2):
---

u2:
1b8375a5 18bc2139 6ad6a65e 5597e0bf 80d793b6 d66e2534 a6e7dfe3 ee22616f

m = z^2 × u^4 + z × u^2:
5b17c6b0 531ae0ab 1a346116 7f2c309e 731fe072 aa5043e0 307d71dd fc0983be

t = 1/m:
8c7200be e794cc45 f7d1c0a1 4843b641 40366f7e 42e6fbd3 49b92320 4ebe4615

(– b/a) × (1 + t):


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```
72cd2a96 7a837fea 5051f013 3db46227 775ba09f 7b6dfb99 ae7a8ef2 2c7d34a0
```

b/(z × a):

```
a528bd86 96bdaf99 6c65b982 d94959d3 146fe6a0 20693090 bdba1313 2375f224
```

m != 0, so x1 = (– b/a) × (1+t)

x1:

```
72cd2a96 7a837fea 5051f013 3db46227 775ba09f 7b6dfb99 ae7a8ef2 2c7d34a0
```

gx1:

```
ad50cf4c 878e2a40 a3f9bc5a 85137fef 7ff5887a 2d46a23e 3a534f99 543fa53d
```

x2:

```
e7c2d3f3 580f1c04 5c7e5f06 8fcfc03d 2a7dcd32 bb42166f 95ff5c04 04109782
```

gx2:

```
7578d68b d9c60233 508ab8a1 90313ae4 d0215f41 d1a3646f be639434 a8710d55
```

gx1 is a quadratic residue

gx2 is not a quadratic residue

point P2...

P2.x:

```
72cd2a96 7a837fea 5051f013 3db46227 775ba09f 7b6dfb99 ae7a8ef2 2c7d34a0
```

P2.y:

```
864390d7 97d352b3 68d311af 515bde11 6fe54459 fec867ee 18a8a161 9ca3ff59
```

```
------------------------------------
```

PT = P1 + P2:

x:

```
b6e38c98 750c684b 5d17c3d8 c9a4100b 39931279 187ca6cc ed5f37ef 46ddfa97
```

y:

```
5687e972 e50f73e3 898861e7 edad21be a7d5f622 df88243b b804920a e8e647fa
```

```
------------------------------------
```

val:

```
bb7f9cac 5aa8b72c 02b5daac c2771abe 74e72604 612295ec a2ce1836 3ae9a927
```

PWE = val × PT:

x:

```
c93049b9 e64000f8 48201649 e999f2b5 c22dea69 b5632c9d f4d633b8 aa1f6c1e
```

y:

```
73634e94 b53d82e7 383a8d25 8199d9dc 1a5ee826 9d060382 ccbf33e6 14ff59a0
```

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# J.11 GCMP

## J.11.1 GCMP test vectors

```
==== GCMP-128 test vector #1 ====
Plaintext: The plaintext is a sequence of 0s made up to 256 octets.
  —   Input data (Plaintext): 256 octets
      —   1: 0x00000000000000000000000000000000
      —   2: 0x00000000000000000000000000000000
      —   3: 0x00000000000000000000000000000000
      —   4: 0x00000000000000000000000000000000
      —   5: 0x00000000000000000000000000000000
      —   6: 0x00000000000000000000000000000000
      —   7: 0x00000000000000000000000000000000
      —   8: 0x00000000000000000000000000000000
      —   9: 0x00000000000000000000000000000000
      —   10: 0x00000000000000000000000000000000
      —   11: 0x00000000000000000000000000000000
      —   12: 0x00000000000000000000000000000000
      —   13: 0x00000000000000000000000000000000
      —   14: 0x00000000000000000000000000000000
      —   15: 0x00000000000000000000000000000000
      —   16: 0x00000000000000000000000000000000
  —   Key: 16 octets
      —   0xAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
  —   AAD: 22 octets
      —   0x2002000000000000FFFFFFFFFFFFFFFFFFFFFFFF0000
          —   Frame Control (FC): 2 octets, 0x0220
          —   Address 1 (A1): 6 octets, 0x000000000000
          —   Address 2 (A2): 6 octets, 0xFFFFFFFFFFFF
          —   BSSID: 6 octets, 0xFFFFFFFFFFFF
          —   Sequence Control (SC): 2 octets, 0x0000
  —   GCM nonce: 12 octets
      —   0xFFFFFFFFFFFF000000000001
          —   A2: 6 octets, 0xFFFFFFFFFFFF
          —   PN: 6 octets, 0x000000000001
  —   Output data (Cipher text): 256 octets
      —   1: 0x5F5578C18F137AD279BF3F2B24C7BD8F
      —   2: 0x277A1BE6770DA1D98B70C6D28AE01C55
      —   3: 0x9ECBA6A01DB067C5A27E4DB08CDADC77
      —   4: 0x52AD637EAF0A18ED13FBAA143BAFEF18
      —   5: 0xF8FBCE4C65E86BD02A87B601B7EAB93F
      —   6: 0x2BBC874C8A710580F502341A6A533931
      —   7: 0x43DE4C9EC6A286F125718378AEDC84EB
      —   8: 0xA2B30F5C28BB5D75C6B025466D0651C7
      —   9: 0x22DC71151F212D6887828A0382E9288A
      —   10: 0x7F43D52B7D25086157646954BB43B57E
      —   11: 0xA587A025F40CE74511E4DD2285B40BA3
      —   12: 0xF3B96262CBC28C6AA7BE443E7B41E1EB
      —   13: 0xFF524857A6816897750115B0231AB7C2
      —   14: 0x8472C06DD0B49BE9F369A8C39CCD0DB7
      —   15: 0x983510E1AE8F05D77545E0235CDBD612
      —   16: 0xF3150754CEE5CE6A1225D99525026F74
  —   MIC (Tag): 16 octets
      —   0x80CB0662EA71ABFD9F04C7F872F58090
==== GCMP-128 test vector #2 (CCMP test vector format) ====
```


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```
//Changed Plaintext, Key, AAD and Nonce

// MPDU fields

Version = 0
Type    = 2  SubType = 8  QoS Data
ToDS    = 0  FromDS  = 0
MoreFrag= 0  Retry   = 1
PwrMgt  = 0  MoreData= 0
Encrypt = 1
Order   = 0
Duration= 11 (40 Octets(MCS1) + SIFS + Ack(MCS1))
A1 = 0f-d2-e1-28-a5-7cDA
A2 = 50-30-f1-84-44-08SA
A3 = 50-30-f1-84-44-08BSSID
SC = 0x3380
seqNum = 824 (0x0338)fragNum = 0 (0x00)
QoSControl = 0x0003
TID = 3
Algorithm = AES-GCM
Key ID = 0

TK = c9 7c 1f 67 ce 37 11 85 51 4a 8a 19 f2 bd d5 2f

PN = 590010592008 (0x00895F5F2B08)

(#7183)MAC Header = 88 48 0b 00 0f d2 e1 28 a5 7c 50 30 f1 84 44 08 50 30 f1 84 44
08 80 33 03 00

(#7183)Muted MAC Header = 88 40 0f d2 e1 28 a5 7c 50 30 f1 84 44 08 50 30 f1 84 44
08 00 00 03 00

GCMP Header = 08 2b 00 20 5f 5f 89 00

GCM Nonce = 50 30 f1 84 44 08 00 89 5f 5f 2b 08

Plaintext Data = 00 01 02 03 04 05 06 07 08 09 0a 0b 0c 0d 0e 0f 10 11 12 13
             14 15 16 17 18 19 1a 1b 1c 1d 1e 1f 20 21 22 23 24 25 26 27

Encrypted Data = 60 e9 70 0c c4 d4 0a c6 d2 88 b2 01 c3 8f 5b f0 8b 80 74 42
             64 0a 15 96 e5 db da d4 1d 1f 36 23 f4 5d 7a 12 db 7a fb 23

GCM MIC = de f6 19 c2 a3 74 b6 df 66 ff a5 3b 6c 69 d7 9e

-- Encrypted MPDU with FCS
88 48 0b 00 0f d2 e1 28 a5 7c 50 30 f1 84 44 08 50 30 f1 84 44 08 80 33 03 00 08
2b 00 20 5f 5f 89 00 60 e9 70 0c c4 d4 0a c6 d2 88 b2 01 c3 8f 5b f0 8b 80 74 42
64 0a 15 96 e5 db da d4 1d 1f 36 23 f4 5d 7a 12 db 7a fb 23 de f6 19 c2 a3 74 b6
df 66 ff a5 3b 6c 69 d7 9e bf ee e9 53

==== GCMP-256 test vector ====

TK= c9 7c 1f 67 ce 37 11 85 51 4a 8a 19 f2 bd d5 2f 00 01 02 03 04 05 06 07 08 09
0a 0b 0c 0d 0e 0f

PN= 00 89 5f 5f 2b 08

(#7183)MAC Header= 88 48 0b 00 0f d2 e1 28 a5 7c 50 30 f1 84 44 08 50 30 f1 84 44
08 80 33 03 00
```

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```
GCMP AAD= 88 40 0f d2 e1 28 a5 7c 50 30 f1 84 44 08 50 30 f1 84 44 08 00 00 03 00

(#1774)GCM Nonce= 50 30 f1 84 44 08 00 89 5f 5f 2b 08

Plaintext Data= 00 01 02 03 04 05 06 07 08 09 0a 0b 0c 0d 0e 0f 10 11 12 13 14 15
16 17 18 19 1a 1b 1c 1d 1e 1f 20 21 22 23 24 25 26 27

GCMP MIC= 11 43 16 85 90 95 47 3d 5b 1b d5 96 b3 de a3 bf

Encrypted Data= 65 83 43 c8 b1 44 47 d9 21 1d ef d4 6a d8 9c 71 0c 6f c3 33 33 23
6e 39 97 b9 17 6a 5a 8b e7 79 b2 12 66 55 5e 70 ad 79

Encrypted MPDU (without FCS)=
88 48 0b 00 0f d2 e1 28 a5 7c 50 30 f1 84 44 08 50 30 f1 84 44 08 80 33 03 00 08
2b 00 20 5f 5f 89 00 65 83 43 c8 b1 44 47 d9 21 1d ef d4 6a d8 9c 71 0c 6f c3 33
33 23 6e 39 97 b9 17 6a 5a 8b e7 79 b2 12 66 55 5e 70 ad 79 11 43 16 85 90 95 47
3d 5b 1b d5 96 b3 de a3 bf

FCS= cf 16 ed 59
```

### J.11.2 Example of encryption C code

```
// GCMP code
#include <stdio.h>

#define USE_VECTOR_1       // Use test vector #1 as GCMP input
// #define USE_VECTOR_2    // Use test vector #2 as GCMP input

// Prototype
int tcSubWord(int x);
int tcSubByte(int x);
void tcAESfunc(int StartofRound[4], int RoundKey[44]);
void tcKeyExpansion(int x[4], int RoundKey[44]);
void tcAdjustText(int move, int data[4]);
int tcMixColumns(int x);
int tcMultEight(int x, int y);
void tcMultGF(int x[4], int y[4], int Zout[4]);

int main(void)
{
       // Function parameter
       int i, j, temp[4];
       int Nr = 16;        // 256 octet * 8 bit / 128 bit

       // Input for main
       int ENCDEC=1;
       // Indication of Encryption and Decryption: 1 Enc 0 Dec

#ifdef USE_VECTOR_1
       // Input for GCMP test vector #1

       // Key for system 128-bit
       int Key[4]={0xaaaaaaaa, 0xaaaaaaaa, 0xaaaaaaaa, 0xaaaaaaaa};

       // Initialization Vector 96-bit + 1 (32-bit)
       int IV[4]={0xffffffff, 0xffff0000, 0x00000001, 0x00000001};
       // Additional Authenticated Data
```


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```
        int AAD[2][4]={{0x20020000, 0x00000000, 0xffffffff, 0xffffffff},
                       {0xffffffff, 0x00000000, 0x00000000, 0x00000000}};
                                    // FC, A1=0s, A2=Fs, A3=Fs
        // Length of AAD and Cipher Text
        int LENAC[4]={0x00000000, 0x000000b0, 0x00000000, 0x00000800};
#endif // USE_VECTOR_1


#ifdef USE_VECTOR_2
        // Input for GCMP test vector #2 (see also plaintext input below)
        // Key for system 128-bit
        int Key[4]={0xc97c1f67, 0xce371185, 0x514a8a19, 0xf2bdd52f};
        // Initialization Vector 96-bit + 1 (32-bit)
        int IV[4]={0x5030f184, 0x44080089, 0x5f5f2b08, 0x00000001};
        // 88 40 0f d2 e1 28 a5 7c 50 30 f1 84 44 08 50 30 f1 84 44 08 00 00 03 00
        // Additional Authenticated Data
        int AAD[2][4]={{0x88400fd2, 0xe128a57c, 0x5030f184, 0x44085030},
               {0xf1844408, 0x00000300, 0x00000000, 0x00000000}};
               // FC, A1=0f-d2-e1-28-a5-7c,
               // A2=50-30-f1-84-44-08, A3=50-30-f1-84-44-08
        // Length of AAD and Cipher Text
        int LENAC[4]={0x00000000, 0x000000c0, 0x00000000, 0x00000140};
#endif // USE_VECTOR_2

        int TextIn[16][4];

        // AES parameter
        // Round Keys, Generated by Input Keys and use for AES
        int RoundKey[44];
        // Input/output of AES function
        int StartofRound[4];
        // HASH output, AES function with 0s input
        int HASH[4];
        // First output of AES function with Y0 input,
        // which uses for generating Tag
        int EKY0[4];
        // Output Text, which is either Cipher/Plaintext.
        // Length should much with TextIn
        int TextOut[16][4];

        // GF parameter
        int MultIn[4];      // Input of Multiplication
        int Tag[4] = {0, 0, 0, 0};// Tag output

        // Processing Parameter
        int p_flag = 1;     // Indication of end of process
        int LengthTxt[2];   // Block length of text that is Plain/Cipher Text
        int TxtRemain;      // The last block of text, range is between 0 to 127
        int Txt_flag = 0;   // Indication of last text is not 128-bit

        // ===== Main Process =====
        // Generate 1500 Octets '0' Text
        for (i=0;i<Nr;i++) {
               for (j=0;j<4;j++) {
                      TextIn[i][j] = 0;
               }
        }

        #ifdef USE_VECTOR_1
```

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```
            // Plaintext for GCMP test vector #1
            // Not necessary as data is all 0s
      #endif // USE_VECTOR_1

      #ifdef USE_VECTOR_2
            // Plaintext for GCMP test vector #2
            TextIn[0][0] = 0x00010203;
            TextIn[0][1] = 0x04050607;
            TextIn[0][2] = 0x08090a0b;
            TextIn[0][3] = 0x0c0d0e0f;
            TextIn[1][0] = 0x10111213;
            TextIn[1][1] = 0x14151617;
            TextIn[1][2] = 0x18191a1b;
            TextIn[1][3] = 0x1c1d1e1f;
            TextIn[2][0] = 0x20212223;
            TextIn[2][1] = 0x24252627;
      #endif // USE_VECTOR_2

      // Generate Round Key
      tcKeyExpansion(Key, RoundKey);

      // Count 128-bit Text block size
      // Check input text size is multiply by 128-bit or not
      // Calculate the text length of last block
      LengthTxt[0] = LENAC[2] >> 7;
      if ((LENAC[3] & 0x0000007f) == 0) {
            LengthTxt[1] = LENAC[3] >> 7;
      }
      else {
            LengthTxt[1] = (LENAC[3] >> 7) + 1;
            TxtRemain = LENAC[3] & 0x0000007F;
            Txt_flag = 1;
      }

      // Generate HASH, which uses for GF(2^128) function
      // AES function with 0s input
      for (i=0;i<4;i++) {
            StartofRound[i] = 0;
      }
      tcAESfunc(StartofRound, RoundKey);
      for (i=0;i<4;i++) {
            HASH[i] = StartofRound[i];
      }
      // GF 2^128 with AAD
      for (i=0;i<2;i++) {
            for (j=0;j<4;j++) {
                  MultIn[j] = AAD[i][j] ^ Tag[j];
            }
            tcMultGF(HASH, MultIn, Tag);
      }

      // Generate Encryption Key and Tag
      // AES function with Yi input to generate Encryption Keys
      // First output for which Y0 input is used for generating Tag
      i = 0;
      while (p_flag) {
            // Set IV as a Input of AES
            for (j=0;j<4;j++) {
                  StartofRound[j] = IV[j];
```


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```
}
// AES function
tcAESfunc(StartofRound, RoundKey);
printf("AES Number %02d is %08x %08x %08x %08x\n", i,
       StartofRound[0], StartofRound[1],
       StartofRound[2], StartofRound[3]);
// Increment IV by '1'
IV[3] = IV[3] + 1;
// Set EKY0 for Tag
if (i == 0) {
       for (j=0;j<4;j++) {
              EKY0[j] = StartofRound[j];
       }
}
// XOR Input Text and Encryption Keys
// Check the last Block of processing
else if (LengthTxt[1] == 0) {
       if (LengthTxt[0] == 0) {
              p_flag = 0;
              for (j=0;j<4;j++) {
                     TextOut[i-1][j] = TextIn[i-1][j] ^
                                          StartofRound[j];
              }
              // Adjust the length textout
              for (j=0;j<4;j++) {
                     temp[j] = TextOut[i-1][j];
              }
              if (Txt_flag == 1) {
                     tcAdjustText(TxtRemain, temp);
              }
              for (j=0;j<4;j++) {
                     TextOut[i-1][j] = temp[j];
              }
              // XOR with last text and former Tag
              for (j=0;j<4;j++) {
                     if (ENCDEC == 1) {
                            MultIn[j] = TextOut[i-1][j] ^ Tag[j];
                     }
                     else {
                            MultIn[j] = TextIn[i-1][j] ^ Tag[j];
                     }
              }
              tcMultGF(HASH, MultIn, Tag);
       }
       else {
              LengthTxt[0]--;
              LengthTxt[1]--;
              for (j=0;j<4;j++) {
                     TextOut[i-1][j] = TextIn[i-1][j] ^
                                          StartofRound[j];
                     if (ENCDEC == 1) {
                            MultIn[j] = TextOut[i-1][j] ^ Tag[j];
                     }
                     else {
                            MultIn[j] = TextIn[i-1][j] ^ Tag[j];
                     }
              }
              tcMultGF(HASH, MultIn, Tag);
       }
```

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```
                }
                else {
                        for (j=0;j<4;j++) {
                                TextOut[i-1][j] = TextIn[i-1][j] ^ StartofRound[j];
                                if (ENCDEC == 1) {
                                        MultIn[j] = TextOut[i-1][j] ^ Tag[j];
                                }
                                else {
                                        MultIn[j] = TextIn[i-1][j] ^ Tag[j];
                                }
                        }
                        tcMultGF(HASH, MultIn, Tag);
                }
                i++;
                LengthTxt[1]--;
        }
        // Generate Tag
        // 1. XOR with LENAC and Tag
        for (j=0;j<4;j++) {
                MultIn[j] = LENAC[j] ^ Tag[j];
        }
        // 2. GF(2^128)
        tcMultGF(HASH, MultIn, Tag);
        // 3. XOR with EKY0 and Tag
        for (j=0;j<4;j++) {
                Tag[j] = EKY0[j] ^ Tag[j];
        }
        // Display
        for (i=0;i<Nr;i++) {
                printf("Text Output %d is %08x %08x %08x %08x\n", i,
                        TextOut[i][0], TextOut[i][1], TextOut[i][2], TextOut[i][3]);
        }
        printf("Tag is %08x %08x %08x %08x\n", Tag[0], Tag[1], Tag[2], Tag[3]);

        return 0;
}

// AES function with 128-bit Key length
void tcAESfunc(int StartofRound[4], int RoundKey[44])
{
        int i;
        int Nr = 10;
        int AfterSubBytes[4];
        int AfterShiftRows[4];
        int AfterMixColumns[4];

        // XOR Input and Round Key
        StartofRound[0] = StartofRound[0] ^ RoundKey[0];
        StartofRound[1] = StartofRound[1] ^ RoundKey[1];
        StartofRound[2] = StartofRound[2] ^ RoundKey[2];
        StartofRound[3] = StartofRound[3] ^ RoundKey[3];

        for (i=0;i<Nr-1;i++) {
                // Sub Bytes
                AfterSubBytes[0] = tcSubWord(StartofRound[0]);
                AfterSubBytes[1] = tcSubWord(StartofRound[1]);
                AfterSubBytes[2] = tcSubWord(StartofRound[2]);
                AfterSubBytes[3] = tcSubWord(StartofRound[3]);
                // Shift Rows
```


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```
                AfterShiftRows[0] = (AfterSubBytes[0] & 0xFF000000) ^
                                    (AfterSubBytes[1] & 0x00FF0000) ^
                                    (AfterSubBytes[2] & 0x0000FF00) ^
                                    (AfterSubBytes[3] & 0x000000FF);
                AfterShiftRows[1] = (AfterSubBytes[1] & 0xFF000000) ^
                                    (AfterSubBytes[2] & 0x00FF0000) ^
                                    (AfterSubBytes[3] & 0x0000FF00) ^
                                    (AfterSubBytes[0] & 0x000000FF);
                AfterShiftRows[2] = (AfterSubBytes[2] & 0xFF000000) ^
                                    (AfterSubBytes[3] & 0x00FF0000) ^
                                    (AfterSubBytes[0] & 0x0000FF00) ^
                                    (AfterSubBytes[1] & 0x000000FF);
                AfterShiftRows[3] = (AfterSubBytes[3] & 0xFF000000) ^
                                    (AfterSubBytes[0] & 0x00FF0000) ^
                                    (AfterSubBytes[1] & 0x0000FF00) ^
                                    (AfterSubBytes[2] & 0x000000FF);
                // Mix Columns
                AfterMixColumns[0] = tcMixColumns(AfterShiftRows[0]);
                AfterMixColumns[1] = tcMixColumns(AfterShiftRows[1]);
                AfterMixColumns[2] = tcMixColumns(AfterShiftRows[2]);
                AfterMixColumns[3] = tcMixColumns(AfterShiftRows[3]);
                // XOR with Round Key
                StartofRound[0] = AfterMixColumns[0] ^ RoundKey[(i*4)+4];
                StartofRound[1] = AfterMixColumns[1] ^ RoundKey[(i*4)+5];
                StartofRound[2] = AfterMixColumns[2] ^ RoundKey[(i*4)+6];
                StartofRound[3] = AfterMixColumns[3] ^ RoundKey[(i*4)+7];
        }
        // Last Round
        // Sub Bytes
        AfterSubBytes[0] = tcSubWord(StartofRound[0]);
        AfterSubBytes[1] = tcSubWord(StartofRound[1]);
        AfterSubBytes[2] = tcSubWord(StartofRound[2]);
        AfterSubBytes[3] = tcSubWord(StartofRound[3]);
        // Shift Rows
        AfterShiftRows[0] = (AfterSubBytes[0] & 0xFF000000) ^ (AfterSubBytes[1] &
0x00FF0000) ^ (AfterSubBytes[2] & 0x0000FF00) ^ (AfterSubBytes[3] & 0x000000FF);
        AfterShiftRows[1] = (AfterSubBytes[1] & 0xFF000000) ^ (AfterSubBytes[2] &
0x00FF0000) ^ (AfterSubBytes[3] & 0x0000FF00) ^ (AfterSubBytes[0] & 0x000000FF);
        AfterShiftRows[2] = (AfterSubBytes[2] & 0xFF000000) ^
                            (AfterSubBytes[3] & 0x00FF0000) ^
                            (AfterSubBytes[0] & 0x0000FF00) ^
                            (AfterSubBytes[1] & 0x000000FF);
        AfterShiftRows[3] = (AfterSubBytes[3] & 0xFF000000) ^
                            (AfterSubBytes[0] & 0x00FF0000) ^
                            (AfterSubBytes[1] & 0x0000FF00) ^
                            (AfterSubBytes[2] & 0x000000FF);
        // XOR with Round Key
        StartofRound[0] = AfterShiftRows[0] ^ RoundKey[40];
        StartofRound[1] = AfterShiftRows[1] ^ RoundKey[41];
        StartofRound[2] = AfterShiftRows[2] ^ RoundKey[42];
        StartofRound[3] = AfterShiftRows[3] ^ RoundKey[43];
}

// Key Expansion function used for AES
void tcKeyExpansion(int x[4], int RoundKey[44])
{
        int i;

        int AfterRotWord;
```

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```
        int AfterSubWord;
        int AfterXorWithRcon;
        int Rcon[10] = {0x01000000, 0x02000000, 0x04000000, 0x08000000,
                            0x10000000, 0x20000000, 0x40000000, 0x80000000,
                            0x1b000000, 0x36000000};

        // Generate first Round Key from Input Key
        for (i=0;i<4;i++) {
              RoundKey[i] = x[i];
        }
        // Generate other Round Key
        for (i=4;i<44;i++) {
              if (i%4 == 0) {
                    AfterRotWord = (RoundKey[i-1] << 8) ^
                                        ((RoundKey[i-1] >> 24) & 0x000000FF);
                    AfterSubWord = tcSubWord(AfterRotWord);
                    AfterXorWithRcon = AfterSubWord ^ Rcon[i/4-1];
                    RoundKey[i] = RoundKey[i-4] ^ AfterXorWithRcon;
              }
              else {
                    RoundKey[i] = RoundKey[i-4] ^ RoundKey[i-1];
              }
        }
}

// Adjust the Plain/Cipher Text Size if it is not multiply by 128-bit
void tcAdjustText(int move, int data[4])
{
        int i;
        // Move to MSB -> LSB
        i = 128 - move;
        while (i) {
              data[3] = ((data[3] >> 1) & 0x7FFFFFFF) ^
                            ((data[2] << 31) & 0x80000000);
              data[2] = ((data[2] >> 1) & 0x7FFFFFFF) ^
                            ((data[1] << 31) & 0x80000000);
              data[1] = ((data[1] >> 1) & 0x7FFFFFFF) ^
                            ((data[0] << 31) & 0x80000000);
              data[0] = (data[0] >> 1) & 0x7FFFFFFF;
              i--;
        }
        // Move to LSB -> MSB
        i = 128 - move;
        while (i) {
              data[0] = ((data[0] << 1) & 0xFFFFFFFE) ^
                            ((data[1] >> 31) & 0x00000001);
              data[1] = ((data[1] << 1) & 0xFFFFFFFE) ^
                            ((data[2] >> 31) & 0x00000001);
              data[2] = ((data[2] << 1) & 0xFFFFFFFE) ^
                            ((data[3] >> 31) & 0x00000001);
              data[3] = (data[3] << 1) & 0xFFFFFFFE;
              i--;
        }
}

// 32-bit SubByte function
int tcSubWord(int x)
{
        int r = 0;
```



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```
        int i;
        int temp;
        for (i=0;i<4;i++) {
              temp = (x >> i*8) & 0xFF;
              r = r ^ tcSubByte(temp) << i*8;
        }
        return r;
}

// S-Box Lookup Table
int tcSubByte(int x)
{
        int r;
        switch(x) {
              case 0x00 : r = 0x63; break;
              case 0x01 : r = 0x7c; break;
              case 0x02 : r = 0x77; break;
              case 0x03 : r = 0x7b; break;
              case 0x04 : r = 0xf2; break;
              case 0x05 : r = 0x6b; break;
              case 0x06 : r = 0x6f; break;
              case 0x07 : r = 0xc5; break;
              case 0x08 : r = 0x30; break;
              case 0x09 : r = 0x01; break;
              case 0x0A : r = 0x67; break;
              case 0x0B : r = 0x2b; break;
              case 0x0C : r = 0xfe; break;
              case 0x0D : r = 0xd7; break;
              case 0x0E : r = 0xab; break;
              case 0x0F : r = 0x76; break;
              case 0x10 : r = 0xca; break;
              case 0x11 : r = 0x82; break;
              case 0x12 : r = 0xc9; break;
              case 0x13 : r = 0x7d; break;
              case 0x14 : r = 0xfa; break;
              case 0x15 : r = 0x59; break;
              case 0x16 : r = 0x47; break;
              case 0x17 : r = 0xf0; break;
              case 0x18 : r = 0xad; break;
              case 0x19 : r = 0xd4; break;
              case 0x1A : r = 0xa2; break;
              case 0x1B : r = 0xaf; break;
              case 0x1C : r = 0x9c; break;
              case 0x1D : r = 0xa4; break;
              case 0x1E : r = 0x72; break;
              case 0x1F : r = 0xc0; break;
              case 0x20 : r = 0xb7; break;
              case 0x21 : r = 0xfd; break;
              case 0x22 : r = 0x93; break;
              case 0x23 : r = 0x26; break;
              case 0x24 : r = 0x36; break;
              case 0x25 : r = 0x3f; break;
              case 0x26 : r = 0xf7; break;
              case 0x27 : r = 0xcc; break;
              case 0x28 : r = 0x34; break;
              case 0x29 : r = 0xa5; break;
              case 0x2A : r = 0xe5; break;
              case 0x2B : r = 0xf1; break;
              case 0x2C : r = 0x71; break;
```

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```
case 0x2D : r = 0xd8; break;
case 0x2E : r = 0x31; break;
case 0x2F : r = 0x15; break;
case 0x30 : r = 0x04; break;
case 0x31 : r = 0xc7; break;
case 0x32 : r = 0x23; break;
case 0x33 : r = 0xc3; break;
case 0x34 : r = 0x18; break;
case 0x35 : r = 0x96; break;
case 0x36 : r = 0x05; break;
case 0x37 : r = 0x9a; break;
case 0x38 : r = 0x07; break;
case 0x39 : r = 0x12; break;
case 0x3A : r = 0x80; break;
case 0x3B : r = 0xe2; break;
case 0x3C : r = 0xeb; break;
case 0x3D : r = 0x27; break;
case 0x3E : r = 0xb2; break;
case 0x3F : r = 0x75; break;
case 0x40 : r = 0x09; break;
case 0x41 : r = 0x83; break;
case 0x42 : r = 0x2c; break;
case 0x43 : r = 0x1a; break;
case 0x44 : r = 0x1b; break;
case 0x45 : r = 0x6e; break;
case 0x46 : r = 0x5a; break;
case 0x47 : r = 0xa0; break;
case 0x48 : r = 0x52; break;
case 0x49 : r = 0x3b; break;
case 0x4A : r = 0xd6; break;
case 0x4B : r = 0xb3; break;
case 0x4C : r = 0x29; break;
case 0x4D : r = 0xe3; break;
case 0x4E : r = 0x2f; break;
case 0x4F : r = 0x84; break;
case 0x50 : r = 0x53; break;
case 0x51 : r = 0xd1; break;
case 0x52 : r = 0x00; break;
case 0x53 : r = 0xed; break;
case 0x54 : r = 0x20; break;
case 0x55 : r = 0xfc; break;
case 0x56 : r = 0xb1; break;
case 0x57 : r = 0x5b; break;
case 0x58 : r = 0x6a; break;
case 0x59 : r = 0xcb; break;
case 0x5A : r = 0xbe; break;
case 0x5B : r = 0x39; break;
case 0x5C : r = 0x4a; break;
case 0x5D : r = 0x4c; break;
case 0x5E : r = 0x58; break;
case 0x5F : r = 0xcf; break;
case 0x60 : r = 0xd0; break;
case 0x61 : r = 0xef; break;
case 0x62 : r = 0xaa; break;
case 0x63 : r = 0xfb; break;
case 0x64 : r = 0x43; break;
case 0x65 : r = 0x4d; break;
case 0x66 : r = 0x33; break;
case 0x67 : r = 0x85; break;
```


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```
case 0x68 : r = 0x45; break;
case 0x69 : r = 0xf9; break;
case 0x6A : r = 0x02; break;
case 0x6B : r = 0x7f; break;
case 0x6C : r = 0x50; break;
case 0x6D : r = 0x3c; break;
case 0x6E : r = 0x9f; break;
case 0x6F : r = 0xa8; break;
case 0x70 : r = 0x51; break;
case 0x71 : r = 0xa3; break;
case 0x72 : r = 0x40; break;
case 0x73 : r = 0x8f; break;
case 0x74 : r = 0x92; break;
case 0x75 : r = 0x9d; break;
case 0x76 : r = 0x38; break;
case 0x77 : r = 0xf5; break;
case 0x78 : r = 0xbc; break;
case 0x79 : r = 0xb6; break;
case 0x7A : r = 0xda; break;
case 0x7B : r = 0x21; break;
case 0x7C : r = 0x10; break;
case 0x7D : r = 0xff; break;
case 0x7E : r = 0xf3; break;
case 0x7F : r = 0xd2; break;
case 0x80 : r = 0xcd; break;
case 0x81 : r = 0x0c; break;
case 0x82 : r = 0x13; break;
case 0x83 : r = 0xec; break;
case 0x84 : r = 0x5f; break;
case 0x85 : r = 0x97; break;
case 0x86 : r = 0x44; break;
case 0x87 : r = 0x17; break;
case 0x88 : r = 0xc4; break;
case 0x89 : r = 0xa7; break;
case 0x8A : r = 0x7e; break;
case 0x8B : r = 0x3d; break;
case 0x8C : r = 0x64; break;
case 0x8D : r = 0x5d; break;
case 0x8E : r = 0x19; break;
case 0x8F : r = 0x73; break;
case 0x90 : r = 0x60; break;
case 0x91 : r = 0x81; break;
case 0x92 : r = 0x4f; break;
case 0x93 : r = 0xdc; break;
case 0x94 : r = 0x22; break;
case 0x95 : r = 0x2a; break;
case 0x96 : r = 0x90; break;
case 0x97 : r = 0x88; break;
case 0x98 : r = 0x46; break;
case 0x99 : r = 0xee; break;
case 0x9A : r = 0xb8; break;
case 0x9B : r = 0x14; break;
case 0x9C : r = 0xde; break;
case 0x9D : r = 0x5e; break;
case 0x9E : r = 0x0b; break;
case 0x9F : r = 0xdb; break;
case 0xA0 : r = 0xe0; break;
case 0xA1 : r = 0x32; break;
case 0xA2 : r = 0x3a; break;
```

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```
case 0xA3 : r = 0x0a; break;
case 0xA4 : r = 0x49; break;
case 0xA5 : r = 0x06; break;
case 0xA6 : r = 0x24; break;
case 0xA7 : r = 0x5c; break;
case 0xA8 : r = 0xc2; break;
case 0xA9 : r = 0xd3; break;
case 0xAA : r = 0xac; break;
case 0xAB : r = 0x62; break;
case 0xAC : r = 0x91; break;
case 0xAD : r = 0x95; break;
case 0xAE : r = 0xe4; break;
case 0xAF : r = 0x79; break;
case 0xB0 : r = 0xe7; break;
case 0xB1 : r = 0xc8; break;
case 0xB2 : r = 0x37; break;
case 0xB3 : r = 0x6d; break;
case 0xB4 : r = 0x8d; break;
case 0xB5 : r = 0xd5; break;
case 0xB6 : r = 0x4e; break;
case 0xB7 : r = 0xa9; break;
case 0xB8 : r = 0x6c; break;
case 0xB9 : r = 0x56; break;
case 0xBA : r = 0xf4; break;
case 0xBB : r = 0xea; break;
case 0xBC : r = 0x65; break;
case 0xBD : r = 0x7a; break;
case 0xBE : r = 0xae; break;
case 0xBF : r = 0x08; break;
case 0xC0 : r = 0xba; break;
case 0xC1 : r = 0x78; break;
case 0xC2 : r = 0x25; break;
case 0xC3 : r = 0x2e; break;
case 0xC4 : r = 0x1c; break;
case 0xC5 : r = 0xa6; break;
case 0xC6 : r = 0xb4; break;
case 0xC7 : r = 0xc6; break;
case 0xC8 : r = 0xe8; break;
case 0xC9 : r = 0xdd; break;
case 0xCA : r = 0x74; break;
case 0xCB : r = 0x1f; break;
case 0xCC : r = 0x4b; break;
case 0xCD : r = 0xbd; break;
case 0xCE : r = 0x8b; break;
case 0xCF : r = 0x8a; break;
case 0xD0 : r = 0x70; break;
case 0xD1 : r = 0x3e; break;
case 0xD2 : r = 0xb5; break;
case 0xD3 : r = 0x66; break;
case 0xD4 : r = 0x48; break;
case 0xD5 : r = 0x03; break;
case 0xD6 : r = 0xf6; break;
case 0xD7 : r = 0x0e; break;
case 0xD8 : r = 0x61; break;
case 0xD9 : r = 0x35; break;
case 0xDA : r = 0x57; break;
case 0xDB : r = 0xb9; break;
case 0xDC : r = 0x86; break;
case 0xDD : r = 0xc1; break;
```



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```
                case 0xDE : r = 0x1d; break;
                case 0xDF : r = 0x9e; break;
                case 0xE0 : r = 0xe1; break;
                case 0xE1 : r = 0xf8; break;
                case 0xE2 : r = 0x98; break;
                case 0xE3 : r = 0x11; break;
                case 0xE4 : r = 0x69; break;
                case 0xE5 : r = 0xd9; break;
                case 0xE6 : r = 0x8e; break;
                case 0xE7 : r = 0x94; break;
                case 0xE8 : r = 0x9b; break;
                case 0xE9 : r = 0x1e; break;
                case 0xEA : r = 0x87; break;
                case 0xEB : r = 0xe9; break;
                case 0xEC : r = 0xce; break;
                case 0xED : r = 0x55; break;
                case 0xEE : r = 0x28; break;
                case 0xEF : r = 0xdf; break;
                case 0xF0 : r = 0x8c; break;
                case 0xF1 : r = 0xa1; break;
                case 0xF2 : r = 0x89; break;
                case 0xF3 : r = 0x0d; break;
                case 0xF4 : r = 0xbf; break;
                case 0xF5 : r = 0xe6; break;
                case 0xF6 : r = 0x42; break;
                case 0xF7 : r = 0x68; break;
                case 0xF8 : r = 0x41; break;
                case 0xF9 : r = 0x99; break;
                case 0xFA : r = 0x2d; break;
                case 0xFB : r = 0x0f; break;
                case 0xFC : r = 0xb0; break;
                case 0xFD : r = 0x54; break;
                case 0xFE : r = 0xbb; break;
                case 0xFF : r = 0x16; break;
                default : r = 0x00; printf("S-BOX Error!!"); break;
        }
        return r;
}

// MixColumns function for AES
int tcMixColumns(int x)
{
        int r;
        int s0, s1, s2, s3;
        s0 = (tcMultEight(0x02,(x>>24) & 0xFF))^
                (tcMultEight(0x03,(x>>16) & 0xFF))^ ((x>>8) & 0xFF)^ (x & 0xFF);
        s1 = ((x>>24) & 0xFF)^ (tcMultEight(0x02,(x>>16) & 0xFF))^
                (tcMultEight(0x03,(x>>8) & 0xFF))^ (x & 0xFF);
        s2 = ((x>>24) & 0xFF)^ ((x>>16) & 0xFF)^
                (tcMultEight(0x02,(x>>8) & 0xFF))^ (tcMultEight(0x03,x & 0xFF));
        s3 = (tcMultEight(0x03,(x>>24) & 0xFF))^
                ((x>>16) & 0xFF)^ ((x>>8) & 0xFF)^ (tcMultEight(0x02,x & 0xFF));

        r = ((s0<<24) & 0xFF000000) ^
        ((s1<<16) & 0x00FF0000) ^ ((s2<<8) & 0x0000FF00) ^ (s3 & 0x000000FF);
        return r;
}

// Multiplication in GF(2^8)
```

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```
int tcMultEight(int x, int y)
{
	int r = 0x1b;
	int i, z = 0;
	int y_flag = 0;
	for (i=0;i<8;i++) {
		if (((x >> i) & 1) == 1) {
			z = z ^ y;
		}
		if (((y >> 7) & 1) == 1) {
			y_flag = 1;
		}
		y = (y << 1) & 0xFF;
		if (y_flag == 1) {
			y = y ^ r;
		}
		y_flag = 0;
	}
	return z;
}

// Multiplication in GF(2^128)
void tcMultGF(int x[4], int y[4], int Zout[4])
{
	int i,j,k=0;
	int r[4] = {0xe1000000, 0x00000000, 0x00000000, 0x00000000};
	int z[4] = {0x00000000, 0x00000000, 0x00000000, 0x00000000};
	int V[4];
	for (i=0;i<4;i++) {
		V[i] = x[i];
	}
	for (i=0;i<4;i++) {
		for (j=0;j<32;j++) {
			if (((y[i]>>(31-j)) & 1) == 1) {
				for (k=0;k<4;k++) {
					z[k] = z[k] ^ V[k];
				}
			}
			if ((V[3] & 1) == 0) {
				V[3] = ((V[3] >> 1) & 0x7fffffff) ^
					((V[2] << 31) & 0x80000000);
				V[2] = ((V[2] >> 1) & 0x7fffffff) ^
					((V[1] << 31) & 0x80000000);
				V[1] = ((V[1] >> 1) & 0x7fffffff) ^
					((V[0] << 31) & 0x80000000);
				V[0] = ((V[0] >> 1) & 0x7fffffff);
			}
			else {
				V[3] = ((V[3] >> 1) & 0x7fffffff) ^
					((V[2] << 31) & 0x80000000);
				V[2] = ((V[2] >> 1) & 0x7fffffff) ^
					((V[1] << 31) & 0x80000000);
				V[1] = ((V[1] >> 1) & 0x7fffffff) ^
					((V[0] << 31) & 0x80000000);
				V[0] = ((V[0] >> 1) & 0x7fffffff);
				for (k=0;k<4;k++) {
					V[k] = V[k] ^ r[k];
				}
			}
```


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```
                }
        }
        for (i=0;i<4;i++) {
                Zout[i] = z[i];
        }
}
```

## J.12 PASN Test Vectors(11az)

The Diffie-Hellman exchange to establish a shared secret used in key derivation for PASN and FILS with PFS is a well known algorithm. See IETF RFC 5903 [B48] for test vectors when using ECP groups. Only the x-coordinate of the result of scalar multiplication of a private key with the received public key is used as the shared secret.

Sample PTKSA derivation with PASN Authentication

KCK || TK || KDK = KDF-HASH-NNN (PMK, “PASN PTK Derivation”, SPA || BSSID || DHss)

| | |
|---|---|
| Hash: | SHA-256 |
| NNN: | 640 |
| PMK: | de f4 3e 55 67 e0 1c a6 64 92 65 f1 9a 29 0e ef<br>f8 bd 88 8f 6c 1d 9c c9 d1 0f 04 bd 37 8f 3c ad |
| SPA: | 00 90 4c 01 c1 07 |
| BSSID: | c0 ff d4 a8 db c1 |
| DHss: | Sample using NIST P256 (Group 19)<br>f8 7b 20 8e 7e d2 b7 37 af db c2 e1 3e ae 78 da<br>30 01 23 d4 d8 4b a8 b0 ea fe 90 c4 8c df 1f 93 |
| KCK: | 7b b8 21 ac 0a a5 90 9d d6 54 a5 60 65 ad 7c 77<br>eb 88 9c be 29 05 bb f0 5a bb 1e ea c8 8b a3 06 |
| TK: | 67 3e ab 46 b8 32 d5 a8 0c bc 02 43 01 6e 20 7e |
| KDK: | 2d 0f 0e 82 c7 0d d2 6b 79 06 1a 46 81 e8 db b2<br>ea 83 be a3 99 84 4b d5 89 4e b3 20 f6 9d 7d d6 |

## J.13 KDK Test Vectors when PASN authentication is not used(11az)

KCK || KEK || TK || KDK = KDF-Hash-Length(PMK, “Pairwise key expansion”, Min(AA, SPA) || Max(AA, SPA) || Min(ANonce, SNonce) || Max(ANonce, SNonce)

| | |
|---|---|
| Hash: | SHA-256 |
| Length: | 640 |
| PMK: | de f4 3e 55 67 e0 1c a6 64 92 65 f1 9a 29 0e ef<br>f8 bd 88 8f 6c 1d 9c c9 d1 0f 04 bd 37 8f 3c ad |
| AA: | c0 ff d4 a8 db c1 |
| SPA: | 00 90 4c 01 c1 07 |
| ANonce: | be 7a 1c a2 84 34 7b 5b d6 7d bd 2d fd b4 d9 9f<br>1a fa e0 b8 8b a1 8e 00 87 18 41 7e 4b 27 ef 5f |

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SNonce: 40 4b 01 2f fb 43 ed 0f b4 3e a1 f2 87 c9 1f 25
06 d2 1b 4a 92 d7 4b 5e a5 0c 94 33 50 ce 86 71

KCK: cd 7b 9e 75 55 36 2d f0 b6 35 68 48 4a 81 12 f5

KEK: 99 ca d3 58 8d a0 f1 e6 3f d1 90 19 10 39 bb 4b

TK: 9e 2e 93 77 e7 53 2e 73 7a 1b c2 50 fe 19 4a 03

KDK: 6c 7f b9 7c eb 55 b0 1a cf f0 0f 07 09 42 bd f5
29 1f eb 4b ee 38 e0 36 5b 25 a2 50 bb 2a c9 ff

## J.14 LTF Sequence Generation Test Vectors(11az)

As defined in 11.21.6.3.4 (Negotiation for secure HE-LTF in the TB and non-TB ranging measurement exchange), Secure-LTF-Key-Seed is derived from KDK as follows:

Secure-LTF-Key-Seed = HMAC-Hash(KDK, "Secure (#8005)LTF key seed")

Hash: SHA-256

KDK: 6c 7f b9 7c eb 55 b0 1a cf f0 0f 07 09 42 bd f5
29 1f eb 4b ee 38 e0 36 5b 25 a2 50 bb 2a c9 ff

Secure-LTF-Key-Seed: 07 60 6f 7b 0d 98 ca 03 ec 2d 61 e1 7c 6b df d3
0e 2f 20 30 e3 47 02 22 55 1a 05 ec 55 d1 35 b9

SAC || ista-ltf-key || rsta-ltf-key = KDF-Hash-Length(Secure-LTF-Key-Seed, "Secure (#8005)LTF Expansion", Secure-LTF-Counter)

Hash: SHA-256

Length: 272 (bits)

Secure-LTF-Key-Seed: 07 60 6f 7b 0d 98 ca 03 ec 2d 61 e1 7c 6b df d3
0e 2f 20 30 e3 47 02 22 55 1a 05 ec 55 d1 35 b9

Secure-LTF-Counter: 0x000000000100

SAC: 23 cf

ista-ltf-key: d2 a8 a2 b7 6c 3c 29 2d 81 e1 82 a4 69 fd e8 3c

rsta-ltf-key: 65 02 7a 83 8d 58 59 3c 57 b9 41 6f 17 24 e6 c4

Transmitter MAC address: 00 10 18 32 76 54

LTF octet stream generator inputs and outputs(#7093)(#8003):


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| Octet | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **LTF_KEY** | d2 | a8 | a2 | b7 | 6c | 3c | 29 | 2d | 81 | e1 | 82 | a4 | 69 | fd | e8 | 3c |
| **LTF_IV** | 00 | 10 | 18 | 32 | 76 | 54 | 00 | 00 | 00 | 00 | 01 | 00 | 00 | 00 | 00 | 00 |
| **AES counter [0]** | 00 | 10 | 18 | 32 | 76 | 54 | 00 | 00 | 00 | 00 | 01 | 00 | 00 | 00 | 00 | 00 |
| **Output block [0]** | $M_{0,15}$ | $M_{0,14}$ | $M_{0,13}$ | $M_{0,12}$ | $M_{0,11}$ | $M_{0,10}$ | $M_{0,9}$ | $M_{0,8}$ | $M_{0,7}$ | $M_{0,6}$ | $M_{0,5}$ | $M_{0,4}$ | $M_{0,3}$ | $M_{0,2}$ | $M_{0,1}$ | $M_{0,0}$ |
| | aa | f6 | 2c | 30 | 6b | cd | 8a | 5d | 89 | 80 | 8b | 03 | 8e | da | 43 | f1 |
| | (I,Q)= (2,5) | (I,Q)= (3,3) | (I,Q)= (1,5) | (I,Q)= (0,3) | (I,Q)= (6,5) | (I,Q)= (5,4) | (I,Q)= (2,4) | (I,Q)= (5,6) | (I,Q)= (4,4) | k=1 | k=1 | k=0 | k=1 | k=3 | k=2 | k=7 |
| **AES counter [1]** | 00 | 10 | 18 | 32 | 76 | 54 | 00 | 00 | 00 | 00 | 01 | 00 | 00 | 00 | 00 | 01 |
| **Output block [1]** | $M_{1,15}$ | $M_{1,14}$ | $M_{1,13}$ | $M_{1,12}$ | $M_{1,11}$ | $M_{1,10}$ | $M_{1,9}$ | $M_{1,8}$ | $M_{1,7}$ | $M_{1,6}$ | $M_{1,5}$ | $M_{1,4}$ | $M_{1,3}$ | $M_{1,2}$ | $M_{1,1}$ | $M_{1,0}$ |
| | 54 | 15 | f0 | 5c | 7f | c7 | ee | f5 | 9b | c4 | 58 | d2 | f4 | 6b | 5b | 5a |
| | (I,Q)= (1,2) | (I,Q)= (5,2) | (I,Q)= (0,3) | (I,Q)= (1,6) | (I,Q)= (7,7) | (I,Q)= (7,0) | (I,Q)= (3,5) | (I,Q)= (5,3) | (I,Q)= (6,6) | (I,Q)= (1,0) | (I,Q)= (0,6) | (I,Q)= (2,2) | (I,Q)= (1,3) | (I,Q)= (6,5) | (I,Q)= (6,6) | (I,Q)= (2,6) |

**…**

**(I, Q) = input index for 64-QAM octet, I = input bits (B0 B1 B2), Q = input bits (B3 B4 B5) defined in Table 17-18 (64-QAM encoding table).**
**The integer k is defined in Equation (27-131) that is used to construct the pseudo random phase rotation.**

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# Annex K

(informative)

# TSPECs and Admission control

## K.1 Example use of TSPEC for admission control

Admission control, in general, depends on vendors' implementations of schedulers, available channel capacity, link conditions, retransmission limits, and the scheduling requirements of a given TSPEC. However, for any given channel capacity, link conditions, and retransmission limits, some TSPEC constructions might be categorically rejected because a scheduler cannot create a meaningful schedule for that TSPEC. There needs to be, for example, be a minimum number of specified fields in the TSPEC in order for the admission control mechanism to create a valid TSPEC. Table K-1 (Admissible TSPECs) below lists the valid TSPEC fields that need to be present for all admission control algorithms to admit a TSPEC. This represents a set of necessary parameters in order for TSPEC to be admitted; it is not sufficient in and of itself to guarantee TSPEC admittance, which depends upon channel conditions and other factors. Such TSPECs are said to be *admissible*. In the table, S means specified, X means unspecified, and Opt means "optional."

**Table K-1—Admissible TSPECs**

| TSPEC parameter | Continuous time QoS traffic (HCCA) | Controlled-access CBR traffic (HCCA) | Bursty traffic (HCCA) | Contention based traffic (EDCA) |
|---|---|---|---|---|
| Nominal MSDU Size | S | S | X | S |
| Minimum Service Interval | S | Nominal MSDU size/mean data rate, if specified (VoIP typically uses this) | S<br>Usually set to 0 or a small number (e.g., 1) | X |
| Maximum Service Interval | S | Same as Minimum SI | S | Opt<br>(Used to indicate aggregation limit) |
| Inactivity Interval | Always specified | | | X |
| Suspension Interval | Opt | | | |
| Minimum Data Rate | Specified if peak data rate is specified | Equal to mean data rate | X | Specified if peak data rate is specified |
| Mean Data Rate | S | S | Opt | S |
| Burst Size | X | X | S | Opt |
| Minimum PHY Rate | Always specified | | | |
| Peak Data Rate | Opt<br>Should be specified if Minimum Data Rate is specified | Equal to Mean Data Rate | Opt | Opt<br>Should be specified if Minimum Data Rate is specified |


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**Table K-1—Admissible TSPECs *(continued)***

| TSPEC parameter | Continuous time QoS traffic (HCCA) | Controlled-access CBR traffic (HCCA) | Bursty traffic (HCCA) | Contention based traffic (EDCA) |
|---|---|---|---|---|
| Delay Bound | S | S | Opt | Opt |
| Surplus Bandwidth Allow-ance | Is specified if the delay bound is present | | | S |
| Medium Time | (not specified by non-AP STA; only an output from the HC) | | | |

## K.2 Recommendation for implementation of contention based admission control

### K.2.1 Use of ACM (admission control mandatory) subfield

It is recommended that admission control not be required for the access categories AC_BE and AC_BK. The ACM subfield for these categories should be set to 0. The announced EDCA parameters and the EDCA parameters used by the AP should account for unadmitted traffic in these ACs.

When dot11SSPNInterfaceActivated is true, it is recommended that any STA authenticated through an SSPN interface use admission control to access categories AC_VO and AC_VI to produce network utilization consistent with the policy imposed by the SSPN for admission. The announced EDCA parameters and the EDCA parameters used by the AP should further account for any unadmitted traffic in AC_VO and AC_VI that might be reserved for users of a particular SSPN.

### K.2.2 Deriving medium time

An AP should use the following procedure to derive the value of the Medium Time field in its ADDTS Response frame.

There are two requirements to consider: 1) the traffic requirements of the application, and 2) the expected error performance of the medium.

The application requirements are captured by the following TSPEC fields: Nominal MSDU Size and Mean Data Rate. Note that the Nominal MSDU Size field is the nominal A-MSDU size, where A-MSDU aggregation is employed.

The medium requirements are captured by the following TSPEC fields: Surplus Bandwidth Allowance and Minimum PHY Rate.

The following formula describes how Medium Time, in units of 32 μs periods per second, can be calculated:

$$\text{Medium Time} = \left\lceil \frac{\text{Surplus Bandwidth Allowance} \times \text{Packets Per Second} \times \text{Frame Exchange Time}}{0\text{x}2000 \times 32} \right\rceil$$

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where

a) if A-MPDU aggregation is not employed (i.e., TS Info Ack Policy = 00 (Normal Acknowledgment)):

$$\text{Packets Per Second} = \left\lceil \frac{\text{Mean Data Size}}{8 \times \text{Nominal MSDU Size}} \right\rceil$$

Frame Exchange Time =
duration (Nominal MPDU Size, Minimum PHY Rate)
+ SIFS
+ duration (Ack Size, Ack Rate)

Nominal MPDU Size =
MAC Header Size
+ Nominal MSDU Size
+ Security Encapsulation Size
+ FCS Size

b) if A-MPDU aggregation is employed (i.e., TS Info Ack Policy = 11 (Block Ack)):

$$\text{Packets Per Second} = \left\lceil \frac{\text{Mean Data Rate}}{8 \times \text{Nominal MSDU Size} \times \text{Nominal MSDUAggregation}} \right\rceil$$

Frame Exchange Time =
duration (Nominal A-MPDU Size, Minimum PHY Rate)
+ SIFS
+ duration (BlockAck Size, BlockAck Rate)

Nominal A-MPDU Size =
Nominal MSDU Aggregation
× Nominal A-MPDU Subframe Size
– Padding Size

Nominal A-MPDU Subframe Size =
MPDU Delimiter Size
+ MAC Header Size
+ Nominal MSDU Size
+ Security Encapsulation Size
+ FCS Size
+ Padding Size

Padding Size =
3
– (MAC Header Size
+ Nominal MSDU Size
+ Security Encapsulation Size
+ 3)
mod 4

and where

Sizes are in octets; Rates are in b/s; durations and Times are in μs; Surplus Bandwidth Allowance is the unsigned integer value passed

MAC Header Size = 26

MPDU Delimiter Size = 4


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Security Encapsulation Size = 16 (CCMP), 20 (GCMP and TKIP), (#3056)or 0 (open system)
Ack Size = 14
BlockAck Size = 32
FCS Size = 4
SIFSIFS = 10 when operating in the 2.4 GHz band, 16 when operating in the 5 GHz band, 3 when operating in the 60 GHz band
Ack/BlockAck Rate is the rate used for the Ack/BlockAck frame, given the Minimum PHY Rate, subject to the corresponding multirate rules
duration () is the PLME-TXTIME primitive defined in 6.7.5 (PLME-TXTIME.request) and 6.7.6 (PLME-TXTIME.confirm) that returns the duration of a PPDU based on the PSDU size and the PHY data rate and PHY employed, e.g., 16.3.4 (HR/DSSS TXTIME calculation), 17.4.3 (OFDM TXTIME calculation), 18.5.3.2 (ERP-OFDM TXTIME calculations), 19.4.3 (TXTIME calculation), and 20.11.3 (TXTIME calculation)

Notes:

— Division does not truncate.

— Any signal extension is included, even for the (#14)signal extension following the PPDU containing the acknowledgment frame which ends the frame exchange.

— If protection frames are used, then they are included in the Frame Exchange Time too. Each frame contributes an additional term:

Frame Exchange Time +=
duration (Protection Frame Size, Protection Frame Rate)
+ SIFS

where
RTS Protection Frame Size = 20
CTS Protection Frame Size = 14
Protection Frame Rate is the rate used for the protection frame, given the Minimum PHY Rate, subject to the corresponding multirate and protection rules

An AP assumes that a STA will use CTS-to-self protection if an ERP element directs use of protection.

— The assumption is made that HT Control headers and beamforming frames are not normally used and so their contribution to Medium Time is negligible.

— The Nominal A-MPDU Subframe Size can be increased by the AP where necessary to account for the Minimum MPDU Start Spacing. For example, if the Minimum PHY Rate is 65 Mb/s and the Minimum MPDU Start Spacing is 16 µs then the minimum Nominal A-MPDU Subframe Size is 132 octets (including 2 octets of pad).

— A STA might request TSPEC fields that would result in violation of other applicable constraints such as the receiver's maximum A-MSDU or A-MPDU size, any maximum PPDU duration, or, for uplink or bidirectional TSPECs, any nonzero TXOP limit. An AP receiving such a request is likely to reject it. An AP might also reject requests that cannot be satisfied for reasons that the STA is not always aware of, such as, for uplink or bidirectional TSPECs, the AP's maximum Block Ack Buffer Size.

— Where A-MPDU aggregation is employed, (#3251)HT-immediate block ack is assumed.

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# K.3 Guidelines and reference design for sample scheduler and admission control unit

## K.3.1 Guidelines for deriving service schedule parameters

The HC establishes the SI for each admitted TS for a STA to derive the aggregate minimum SI contained in the STA's service schedule. The SI for each TS is equal to the maximum SI contained in the TSPEC, if it exists; otherwise, it is the nominal MSDU size divided by the mean data rate. The SI contained in the service schedule is equal to the smallest SI for any TSPEC.

The HC can use an aggregate "token bucket specification" to police a STA's admitted flows. The HC derives the aggregate mean data rate and aggregate burst size to establish the aggregate token bucket specification. The aggregate mean data rate is equal to the sum of the mean data rates of all of the STA's admitted TSs. The aggregate burst size is equal to the sum of the burst size of all of the STA's admitted TSs. An aggregate token bucket is initialized with the aggregate burst size. Tokens are added to the token bucket at the aggregate mean data rate. Alternatively the method of summing TSPECs for statistical multiplexing, as described in T.2.3 (Calculation of potential traffic self), can be used.

When dot11SSPNInterfaceActivated is true, the HC polices all traffic flows from a non-AP STA authenticated against the maximum authorized data rates stored in the dot11InterworkingTable. Each SSPN-authenticated STA is given a maximum bandwidth allowance by the SSPN for each access category as well as scheduled access. The AP polices the SSPN-authenticated STA traffic flows to the maximum bandwidth allowance provided by the SSPN.

## K.3.2 Reference design for sample scheduler and admission control unit

### K.3.2.1 General

This subclause provides the guidelines for the design of a simple scheduler and admission control unit (the unit that administers admission policy in the HC's SME) that meet the minimum performance requirements as specified in 10.23.4.3 (Controlled-access admission control). The scheduler and admission control unit use the minimum set of mandatory TSPEC fields as specified in 10.23.4.3 (Controlled-access admission control).

### K.3.2.2 Sample scheduler

This subclause includes the reference design for a sample scheduler. This scheduler uses the mandatory set of TSPEC fields to generate a schedule: Mean Data Rate, Nominal MSDU Size, and Maximum Service Interval or Delay Bound. If both Maximum Service Interval and Delay Bound parameters are specified in the TSPEC, the scheduler uses the Maximum Service Interval parameter for the calculation of the schedule.

The schedule generated by the scheduler satisfies the requirements specified in 10.23.4.3 (Controlled-access admission control). The schedule for an admitted stream is calculated in two steps. The first step is the calculation of the scheduled SI. In the second step, the TXOP duration for a given SI is calculated for the stream.

The calculation of the scheduled service interval is done as follows: First, the scheduler calculates the minimum of all maximum SIs for all admitted streams. Let this minimum be *m*. Second, the scheduler chooses a number lower than *m* that is a submultiple of the beacon interval. This value is the scheduled SI for all STAs with admitted streams. See Figure K-1 (Schedule for stream from STA i).


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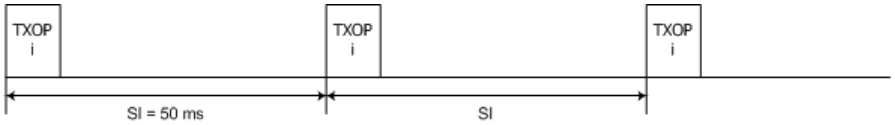


**Figure K-1—Schedule for stream from STA *i***

For the calculation of the TXOP duration for an admitted stream, the scheduler uses the following parameters: Mean Data Rate and Nominal MSDU Size; and from the negotiated TSPEC, the Scheduled Service Interval calculated above, Physical Transmission Rate, Maximum Allowable Size of MSDU, and Overhead. The Physical Transmission Rate is the minimum PHY rate negotiated in the TSPEC. If the minimum PHY rate is not committed in the ADDTS Response frame, the scheduler can use the observed PHY rate as the Physical Transmission Rate. The Overhead includes IFSs, Ack frames and QoS CF-Poll frames. For simplicity, details for the Overhead calculation are omitted in this description. The TXOP duration is calculated as follows: First, the scheduler calculates the number of MSDUs that can arrive at the Mean Data Rate during the SI:

$$N_i = \left\lceil \frac{SI \times \rho_i}{L_i} \right\rceil$$

where

| | |
|---|---|
| $SI$ | is the Scheduled Service Interval |
| $\rho$ | is the Mean Data Rate |
| $L$ | is the Nominal MSDU Size |

Then the scheduler calculates the TXOP duration as the maximum of

— Time to transmit $N_i$ frames at $R_i$ and

— Time to transmit one maximum size MSDU at $R_i$ (plus overhead):

$$TXOP_i = max(\frac{N_i \times L_i}{R_i} + O, \frac{M}{R_i} + O)$$

where

| | |
|---|---|
| $R$ | is the Physical Transmission Rate |
| $M$ | is the maximum possible size of MSDU |
| $O$ | is the Overhead in time units |

An example is shown in Figure K-1 (Schedule for stream from STA i). Stream from STA *i* is admitted. The beacon interval is 100 ms and the maximum SI for the stream is 60 ms. The scheduler calculates a scheduled SI ($SI$) equal to 50 ms using the steps explained above is this annex.

The same process is repeated continuously while the maximum SI for the admitted stream is larger than the current SI. An example is shown in Figure K-2 (Schedule for streams from STAs i to k).

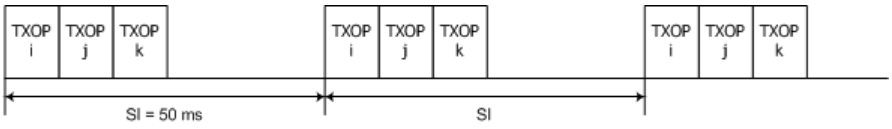


**Figure K-2—Schedule for streams from STAs *i* to *k***

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If a new stream is admitted with a maximum SI smaller than the current SI, the scheduler needs to change the current SI to a smaller number than the maximum SI of the newly admitted stream. Therefore, the TXOP duration for the current admitted streams needs also to be recalculated with the new SI.

If a stream is dropped, the scheduler might use the time available to resume contention. The scheduler might also choose to move the TXOPs for the STAs following the STA dropped to use the unused time. An example is shown in Figure K-3 (Reallocation of TXOPs when a stream is dropped), when the stream for STA *j* is removed. However, this option might require the announcement of a new schedule to all STAs.

**Figure K-3—Reallocation of TXOPs when a stream is dropped**

Different modifications can be implemented to improve the performance of the minimum scheduler. For example, a scheduler might generate different scheduled SIs ($SI$) for different STAs, and/or a scheduler might consider accommodating retransmissions while allocating TXOP durations.

### K.3.2.3 Admission control unit

This subclause describes a reference design for an admission control unit (ACU) that administers admission of TS. The ACU uses the same set of parameters that the scheduler uses in K.3.2.2 (Sample scheduler).

When a new stream requests admission, the admission control process is done in three steps. First, the ACU calculates the number of MSDUs that arrive at the mean data rate during the scheduled SI. The scheduled SI ($SI$) is the one that the scheduler calculates for the stream as specified in K.3.2.2 (Sample scheduler). For the calculation of the number of MSDUs, the ACU uses the equation for $N_i$ shown in K.3.2.2 (Sample scheduler). Second, the ACU calculates the TXOP duration that needs to be allocated for the stream. The ACU uses the equation for $TXOP_i$ shown in K.3.2.2 (Sample scheduler). Finally, the ACU determines that the stream can be admitted when the following inequality is satisfied:

$$\frac{TXOP_{k+1}}{SI} + \sum_{i=1}^{k} \frac{TXOP_i}{SI} \leq \frac{T - T_{EDCA}}{T}$$

where

| | |
|---|---|
| $k$ | is the number of existing streams |
| $k + 1$ | is used as index for the newly arriving stream |
| $T$ | indicates the beacon interval |
| $T_{EDCA}$ | is the time used for EDCA traffic |

Subclause 10.23.3.3 (HCCA TXOP structure and timing) requires that the ACU complies with the dot11CAPlimit, i.e., the scheduler does not allocate TXOPs that exceed dot11CAPlimit. The ACU might also consider additional time to allow for retransmissions.

The ACU allows admitted streams to have an allocated access to the channel. Any modification can be implemented for the design of the ACU. For example, UP-based ACU is possible by examining the UP field in TSPEC to decide whether to admit, retain, or drop a stream. If the UP is not specified, a default value of 0 is used. If a higher UP stream needs to be serviced, an ACU might drop lower UP streams.


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# K.4 TSPEC construction

## K.4.1 General

TSPECs are constructed at the SME from application requirements supplied via the SME and with information specific to the MAC(#6268). However, in this subclause a description is given of how and where certain parameters can be chosen. The following parameters typically arise from the application: Nominal MSDU Size, Maximum MSDU Size, Minimum Service Interval, Maximum Service Interval, Inactivity Interval, Minimum Data Rate, Mean Data Rate, Burst Size, Peak Data Rate, and Delay Bound. The following parameters are generated locally within the MAC: Minimum PHY Rate and Surplus Bandwidth Allowance, although the Maximum Service Interval and Minimum Service Intervals can be generated within the MLME as well. This subclause describes how the parameters that are typically generated within the MAC can be derived.

Note that a TSPEC can also be generated autonomously by the MAC without any initiation by the SME. However, if a TSPEC is generated subsequently by the SME, the TSPEC generated autonomously by the MAC might be overridden (see 11.4.4.5 (TS renegotiation)).

Typically, TSPEC fields not determined by the application are built upon the assumption that the following exist:

— A probability $p$ of not transmitting the frame (because it would have exceeded its delay bound)
— An MSDU length (which can be considered fixed for constant-bit-rate applications)
— Application throughput and delay requirements
— A channel model of error, in particular a channel error probability for the (fixed) frame length
— Possibly country-specific limits on TXOP limits

## K.4.2 Surplus Bandwidth Allocation

Typically, it can be assumed that the scheduler would attempt to schedule TXOPs distributed throughout a small multiple of beacon intervals (if not a single beacon interval). In addition, TXOP limits would typically be chosen to be as short as possible (within the constraints of the minimum PHY rate, ack policy, and so forth), consistent with the goal of maximizing throughput. In other words, because of overhead, not to mention the requirements for transmitting a single Poll frame, MPDU, and possibly Ack frame, the TXOPs need to be at least of a certain duration.

The channel model implies an error ratio and an assumption about dependency (joint probability distribution of channel errors sequentially, i.e., burst error probabilities).

For example, if the channel causes errors independently from frame to frame and the error probability is the same for all frames of the same length at all times, this channel would be said to be an independent, identically distributed error channel. (#4218)Let $N_p$ be the minimum number of retries required to maintain the probability of (#3683)abandoning the transmission of the frame to be no more than $p$, and let $p_e$ be the probability of the frame not being transmitted successfully in a given frame exchange (i.e., either the Data frame or the Ack frame associated with it is in error).

The probability of any given packet being (#3683)abandoned in such a channel after $N_p$ retries is given by(#3683)

$$p_{\text{ignore}} = (p_e)^{N_p + 1}$$

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For example, in such a channel, if $p_e$ = 0.1 and(#3683) $p_{\text{ignore}} = 10^{-8}$, then up to seven retries within the delay bound are required, and the scheduler should consider these retransmissions in the cumulative TXOP allocations.

The Surplus Bandwidth Allowance (SBA) parameter causes the requesting STA to be allocated a minimum amount of excess time by the scheduler so that the application (#3683)abandoned packet rates are bounded.

The probability of not successfully transmitting *k* packets is given by the cumulative distribution function of the Binomial Distribution.

The binomial probability mass function is

$$b(k, n, p) = \frac{n!}{k!(n-k)!} p^k (1-p)^{n-k}$$

where

*n* is the number of trials
*p* is the probability of success for each trial.

The binomial cumulative distribution function is

$$B(k, n, p) = \sum_{y=0}^{n} b(y, n, p)$$

Assuming a certain packet error ratio (PER), $P_e$, the number of extra packets, *N,* that are required in order to have a probability, $P_{ns}$, of not successfully transmitting *S* packets is given:

$$B(S, S+N, 1-P_e) = \sum_{y=0}^{n} b(y, S+N, 1-P_e)$$

Then

$$SBA = (S+N)/S$$

Now, if just one packet is lost, then the lost packet ratio, $L_{PR}$, is $L_{PR} = 1/(S+N)$

The condition where $P_{ns} < L_{PR}$ represents a practical point for determining the value of *N*.

Medium Time used for EDCA Admission Control is based upon one second periods and HCCA Medium time, used to aggregate TSPECs (see T.2.3 (Calculation of potential traffic self)) also uses the one second period. Hence, for each application, *S* is the number of packets that are desired to be sent in each one second period.

For example, consider a voice application:

PER, $P_e = 0.1$ or probability of success is $1 - P_e = 0.9$

Number of packets per second, $S = 50$

Probability of not having 50 successful packets, $P_{ns} = 0.87\%$ for $N = 13$


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Lost packet ratio for 1 lost packet, $L_{PR}$ = 1.59%

$SBA$ = 1.26

Take the example of a video stream at 380 packets per second (about 4 Mb/s):

Number of packets per second, $S$ = 380

Probability of not having 380 successful packets, $P_{ns}$ = 0.2% for $N$ = 64

Lost packet ratio for 1 lost packet, $L_{PR}$ = 0.23%

$SBA$ = 1.168

It can be seen that the value for SBA varies with $S$, the number of required packets per second.

A reasonable estimate for $SBA$ is given by

$$SBA = -0.033 \ln(S) + 1.37$$

Table K-2 (SBA vs Packets/s) is a table of $SBA$ for various values of $S$, and the $SBA$ estimate derived by using the formula above.

**Table K-2—SBA *vs* Packets/s**

| ***S* Packets/s** | ***SBA*** | **Estimated *SBA*** |
|---|---|---|
| 50 | 1.26 | 1.241 |
| 95 | 1.221 | 1.220 |
| 190 | 1.189 | 1.197 |
| 285 | 1.179 | 1.183 |
| 380 | 1.168 | 1.174 |
| 475 | 1.164 | 1.167 |
| 570 | 1.160 | 1.161 |
| 665 | 1.156 | 1.156 |
| 760 | 1.154 | 1.151 |
| 855 | 1.151 | 1.147 |
| 950 | 1.151 | 1.144 |
| 1900 | 1.139 | 1.121 |

The values for $SBA$ as shown in Table K-2 (SBA vs Packets/s) are based upon a one second time period and hence are what should be used in the (#3320)TSPEC for EDCA Admission Control. The value used in an HCCA TSPEC might be different.(M118)

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In an HCCA TSPEC the *SBA* relates the overhead required in each scheduled period. A voice stream, for example, sends only one packet every 20 ms. Obviously an *SBA* of 1.26 is meaningless as it does not allow even one retry. To allow just one retry, the minimum *SBA* is 2.0. Similarly for a video example of 6 packets per schedule period, to allow at least one retry would require an *SBA* of (6+1)/6 = 1.167.

Hence, for an HCCA TSPEC:

Calculate packets per SI:

$$PPSI = \frac{R_m}{S_n \times 8 \times SI}$$

where

$R_m$ is the mean data rate (b/s)

$S_n$ is the nominal MDSU size (octets)

*SI* is the service interval (seconds)

Then Minimum HCCA $SBA = \text{MAX}\left(SBA, \frac{PPSI + 1}{PPSI}\right)$.

Table K-3 (HCCA SBA for video streams) shows the recommended SBA values for HCCA TSPECs for various video streams.

**Table K-3—HCCA SBA for video streams**

| Video, Mb/s | Pkts per SI | Min HCCA SBA | SBA, (1 s) | HCCA SBA |
|---|---|---|---|---|
| 1 | 1 | 2.000 | 1.221 | 2.000 |
| 2 | 3 | 1.333 | 1.189 | 1.333 |
| 3 | 4 | 1.250 | 1.179 | 1.250 |
| 4 | 6 | 1.167 | 1.168 | 1.168 |
| 5 | 7 | 1.143 | 1.164 | 1.164 |
| 6 | 9 | 1.111 | 1.160 | 1.160 |
| 7 | 10 | 1.100 | 1.156 | 1.156 |
| 8 | 12 | 1.083 | 1.154 | 1.154 |
| 9 | 13 | 1.077 | 1.151 | 1.151 |
| 10 | 15 | 1.067 | 1.151 | 1.151 |
| 20 | 30 | 1.033 | 1.139 | 1.139 |

In summary, the suggested value for SBA is derived as follows:

— Calculate packets/s , *PPS*

$$PPS = \frac{R_m}{S_n \times 8}$$



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where

$R_m$ is the mean data rate (b/s)

$S_n$ is the nominal MDSU size (octets)

NOTE—Nominal MSDU = MDSU or A-MSDU

— Calculate *SBA*

$$SBA = -0.033 \ln(PPS) + 1.37$$(#315)

EDCA Admission Control TSPEC and Medium Time calculation uses SBA.

For HCCA TSPEC:

— Calculate packets per SI, PPSI

$$PPSI = \frac{R_m}{S_n \times 8 \times SI}$$

where

$R_m$ is the mean data rate (b/s)

$S_n$ is the nominal MDSU size (octets)

$SI$ is the service interval (seconds)

— HCCA $SBA = \text{MAX}\left(SBA, \frac{PPSI + 1}{PPSI}\right)$

HCCA Medium Time uses SBA in place of HCCA SBA, if different.

## K.4.3 Minimum and Maximum Service Interval

### K.4.3.1 Scheduled traffic

The HC uses the Maximum Service Interval for the calculation of the schedule.

The value of the Minimum Service Interval is an indication that the traffic is CBR or VBR.

For CBR traffic the minimum and maximum Service Intervals should be set to the same value. For example, most voice traffic requires a minimum and maximum service interval value of 20 ms.

In the case of VBR traffic, such as video, Minimum Service Interval should be set to 0 and the Maximum Service Interval set to the service interval required by the application, e.g., to correspond to the codec that is to be used For example, Maximum Service Interval is set to 16 ms for many real time video applications.

### K.4.3.2 Use of Maximum Service Interval with Aggregation of Packets

Aggregation of MPDUs or MSDUs introduces delay to the packets, but the use of aggregated packets is to be encouraged because of the increased efficiency. In the case of scheduled traffic, the aggregation of packets is such that the number of MSDUs that are aggregated into a single packet (A-MSDU or A-MPDU) does not exceed the scheduling service interval. Consider the following example:

— Video packet = 1316 B (7 × 188 MPEG2-TS)

— Nominal MSDU Size = 1364 (octets)

— Mean Data Rate = 4 Mb/s

— Maximum Service Interval = 16 ms

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$$\text{Nominal MSDUs per SI} = \left\lfloor \frac{4 \times 10^6}{1364 \times 8} \right\rfloor = 3$$

Hence, to comply with the 16 ms SI, the limit for aggregation is 3, (an A-MSDU of 3 MSDUs, or an A-MPDU consisting of 3 MSDUs).

In the case of EDCA Admission Control, where regular scheduling is not used, the value of the Maximum Service Interval is used to indicate the limit of aggregation of nominal MSDUs and the acceptable latency between packets. Using aggregation reduces the Medium Time and Used Time required.

For example, assuming a minimum PHY Rate of 39 Mb/s for the example used above, the accurate Medium Time returned by the AP would be 13 783 µs. If the AP assumed that A-MPDUs were to be used, then the accurate Medium Time would be 11 681 µs, a 15% reduction. Hence, an AP could 'force' a STA to use aggregation, or alternatively could assume aggregation when it is considering the total traffic as part of its admittance policy.

The Nominal MSDU Size is the size of the MSDU or A-MSDU belonging to the TS.

Consider another example:

- Video packet = 1316 B (7 × 188 MPEG2-TS)
- Nominal MSDU Size = 4137 (A-MSDU of 3 MSDUs)
- Mean Data Rate = 10 Mb/s
- Maximum Service Interval = 16 ms

$$\text{Nominal MSDUs per SI} = \left\lfloor \frac{10 \times 10^6}{4137 \times 8} \right\rfloor = 4$$

Hence, further aggregation is possible and an A-MPDU consisting of 4 A-MSDUs could be sent and still comply with the latency or SI requirement.

Note that the TSPEC is invalid if the Nominal MSDUs per Maximum Service Interval is less than 1.

### K.4.4 Minimum, Mean, and Peak Data Rate

In an HCCA TSPEC, for CBR traffic the Minimum, Mean and Maximum Data Rate fields should contain the same value but it is allowable to just specify the Mean Data Rate noting that the Minimum and Maximum Service Intervals are the same.

In an EDCA TSPEC, for CBR traffic the Minimum, Mean and Maximum Data Rate fields should contain the same value but it is allowable to just specify the Mean Data Rate.

For VBR traffic it is desirable to populate the Minimum, Mean and Peak data rate fields.

If a TSPEC has the Minimum Data Rate ($R_{min}$) and Peak Data Rate ($R_{max}$) fields populated, then the standard deviation of that stream, σ, can be estimated as follows:

$$\sigma = 0.25(R_{max} - R_{min})$$


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If a TSPEC has the Mean Data Rate ($R_{mean}$) and Peak Data Rate fields populated, then the standard deviation of that stream, σ, can be estimated as follows:

$$\sigma = 0.5(R_{max} - R_{mean})$$

If there are *n* streams, the values of the mean μ and standard deviation σ, of the total stream traffic should be calculated using:

$$\mu = \sum \mu_n$$

$$\sigma_{tot} = \sqrt{\sum \sigma_n^2}$$

This is of particular use to EDCA admission control policy. When summing streams for EDCA Admission Control, the EDCA Overhead Factor needs to be taken into account; see T.2.7 (EDCA Overhead Factor).

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# Annex L

(informative)

# Examples and sample code for encoding a TIM Partial Virtual Bitmap

## L.1 Introduction

The purpose of this annex is to show an examples of encoding a Partial Virtual Bitmap field of the TIM element, as described in 9.4.2.5 (TIM element). Sample C code is provided in L.3 (Sample C code).

## L.2 Examples

The following examples help clarify the use of TIM values, both with and without the multiple BSSID capability for non-S1G STAs, with multiple BSSID Capability for S1G STAs as well as the use of the encoding modes of Block Bitmap, Single AID, OLB, ADE, Inverse Bitmap + Block Bitmap, Inverse Bitmap + Single AID, Inverse Bitmap + OLB and Inverse Bitmap + ADE of TIM element for S1G STAs.

The first example is one in which there are no group addressed MSDUs buffered in the AP but there is traffic for two STAs queued in the AP. STAs with AID 2 and AID 7 have data buffered in the AP. Figure L-1 (Partial Virtual Bitmap example #1(#7219)) shows the values of the Bitmap Control and Partial Virtual Bitmap fields that would be part of the TIM element for this example.

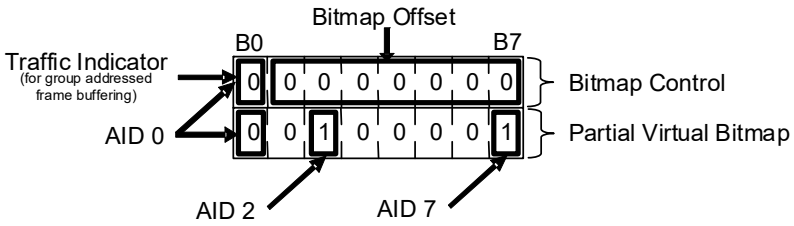


**Figure L-1—Partial Virtual Bitmap example #1(#7219)**

The next example is one in which group addressed MSDUs are buffered in the AP as well as traffic for STAs. The DTIM Count field in the TIM element equals 0. STAs with AID 2, AID 7, AID 22 and AID 24 have data buffered in the AP. Figure L-2 (Partial Virtual Bitmap example #2) shows the values of the Bitmap Control and Partial Virtual Bitmap fields.

Another example is one in which group addressed MSDUs are buffered in the AP as well as traffic for STAs. The DTIM Count field in the TIM element equals 0. Only the node with AID 24 has data buffered in the AP. In this example, the Bitmap Offset is used to start the Partial Virtual Bitmap at the third octet. Figure L-3 (Partial Virtual Bitmap example #3) shows the values of the Bitmap Control and Partial Virtual Bitmap fields.


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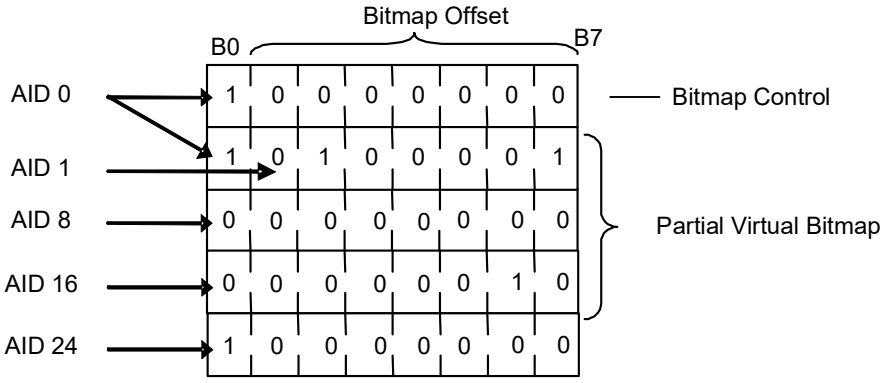


**Figure L-2—Partial Virtual Bitmap example #2**

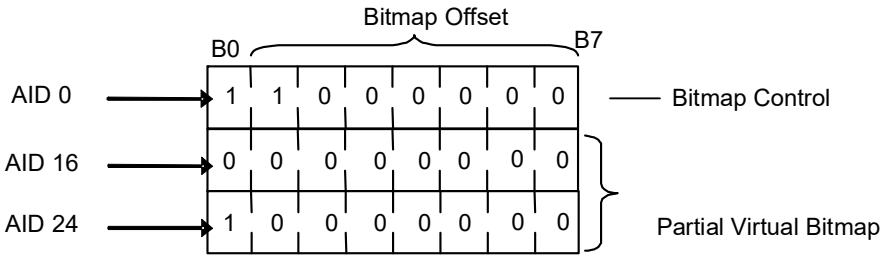


**Figure L-3—Partial Virtual Bitmap example #3**

The three examples listed above describe the construction of the Partial Virtual Bitmap when multiple BSSID operation is not supported. The following three examples demonstrate how to construct the Partial Virtual Bitmap, when multiple BSSID operation is supported.

The first example showing multiple BSSID operation is one in which there are eight BSSIDs and the lowest possible AID that can be assigned to any STA in this example is 8. There are no group addressed frames buffered in the AP for any of the eight BSSIDs. However, STAs with AID 9 and AID 11 have an individually addressed frames buffered in the AP. Figure L-4 (Partial Virtual Bitmap example #4, Method A and Method B(#7219)) shows the values of the Bitmap Control and Partial Virtual Bitmap fields that would be part of the TIM element for this example when either Method A or Method B is used. It is noted that Method B reduces to Method A in this example.

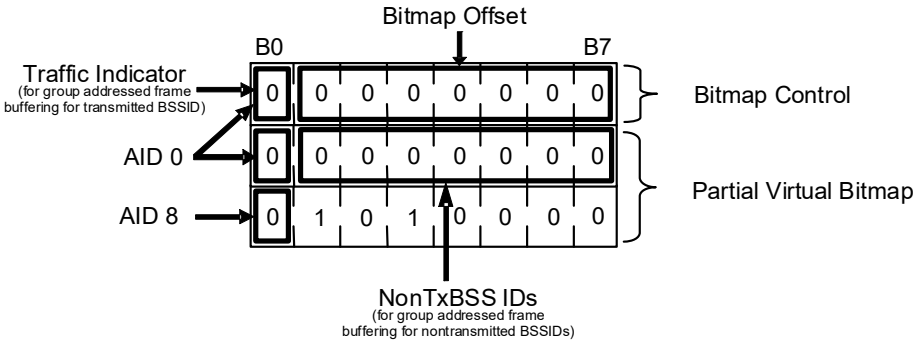


**Figure L-4—Partial Virtual Bitmap example #4, Method A and Method B(#7219)**

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In the next example, there are eight BSSIDs and the lowest possible AID that can be assigned to any STA in this example is 8. There are group addressed frames buffered at the AP for the transmitted BSSID, and the DTIM Count field in the TIM element of the transmitted BSSID is 0. The nontransmitted BSSID with BSSID Index 3 also has the DTIM Count field set to 0 and has buffered group addressed frames. All other nontransmitted BSSIDs have no buffered group addressed frames. In addition, STAs with AID 12, AID 17, AID 22 and AID 24 have data buffered at the AP. Figure L-5 (Partial Virtual Bitmap example #5, Method A or Method B(#7219)(#8132)) shows the values of the Bitmap Control and Partial Virtual Bitmap fields that would be part of the TIM element for this example when either Method A or Method B is used. It is noted that Method B reduces to Method A in this example.

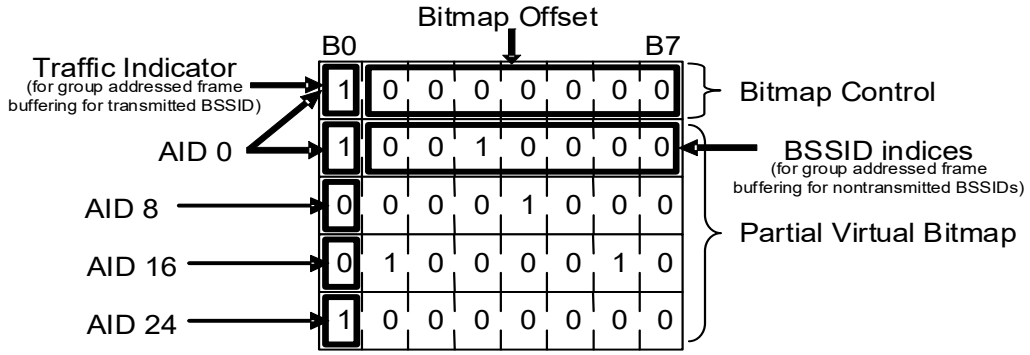


**Figure L-5—Partial Virtual Bitmap example #5, Method A or Method B(#7219)(#8132)**

In the third example, there are sixteen BSSIDs and the lowest possible AID that can be assigned to any STA is 16 ($n$=4, see 9.4.2.5 (TIM element). There are no group addressed frames buffered at the AP for the transmitted BSSID, and the DTIM Count field in the TIM element of the transmitted BSSID is 0. The nontransmitted BSSID Index 3 also has the DTIM Count field set to 0 and has group addressed frames buffered at the AP. All other nontransmitted BSSIDs have no buffered group addressed frames. In addition, the STA with AID 39 has individually addressed frames buffered at the AP. Figure L-6 (Partial Virtual Bitmap example #6, Method A(#7219)(#8132)) and Figure L-7 (Partial Virtual Bitmap example #6, Method B(#7219)(#8132)) show the values of the Bitmap Control and Partial Virtual Bitmap fields that would be part of the TIM element for this example when Method A ($N2$=4, see 9.4.2.5 (TIM element)) and Method B ($N0$=2, $N1$=4, $N2$=4, see 9.4.2.5 (TIM element)) are used, respectively.

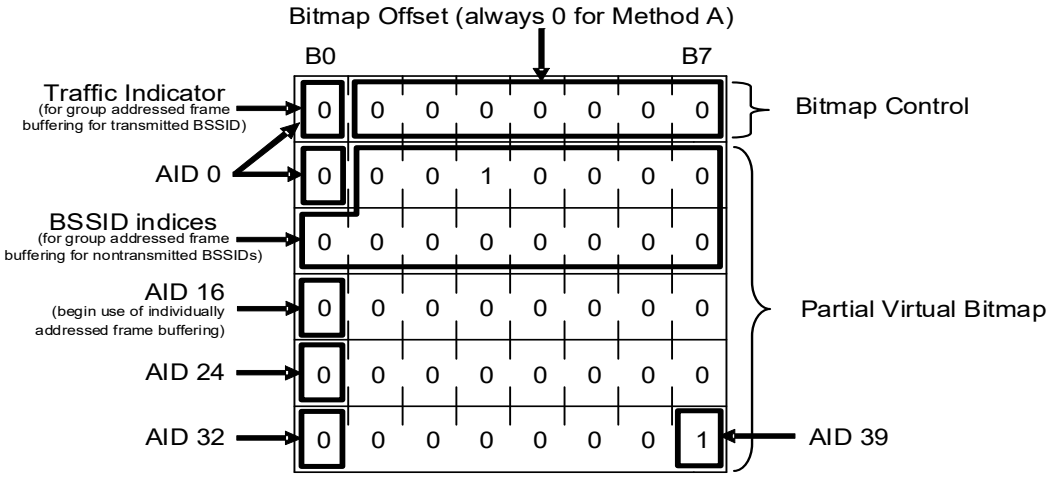


**Figure L-6—Partial Virtual Bitmap example #6, Method A(#7219)(#8132)**


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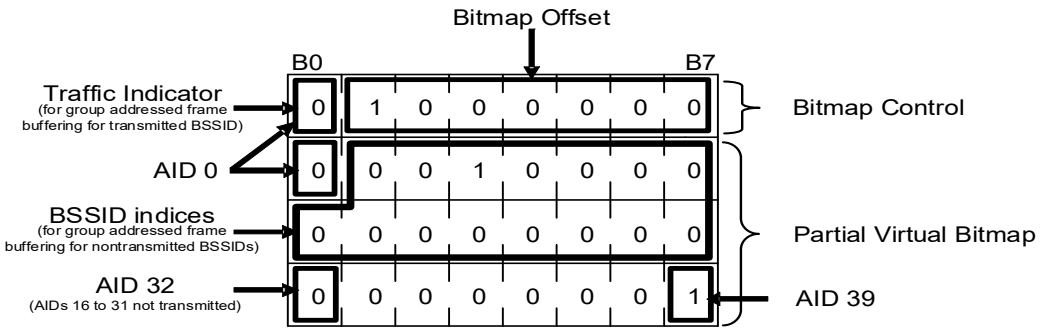


**Figure L-7—Partial Virtual Bitmap example #6, Method B(#7219)(#8132)**

The examples listed above describe the construction of the TIM Virtual Bitmap for non-S1G STAs. The following eight examples demonstrate how to construct the TIM element for S1G STAs.

The first example is one in which group addressed MSDUs are buffered in the AP as well as traffic for S1G STAs. The TIM element uses the encoding mode of Block Bitmap. The DTIM Count field in the TIM element equals 0. The (#7218)Traffic Indicator field is 1, the Page Slice Number field in the TIM element is 0 and the Page Index field is 0. The STAs with AID 1, AID 6, AID 21 and AID 23 have data buffered in the AP. Figure L-8 (Partial Virtual Bitmap example #7 for S1G STAs, Block Bitmap mode(#7218)) shows the values of the Bitmap Control and Partial Virtual Bitmap fields. The Partial Virtual Bitmap field consists of only one encoded block in which the Block Control field is 0 and the Block Offset field is 0. The Encoded Information Block field in the Partial Virtual Bitmap field consists of Block Bitmap field with the value of 3 and two Subblock fields with the value of 66 and 160, respectively.

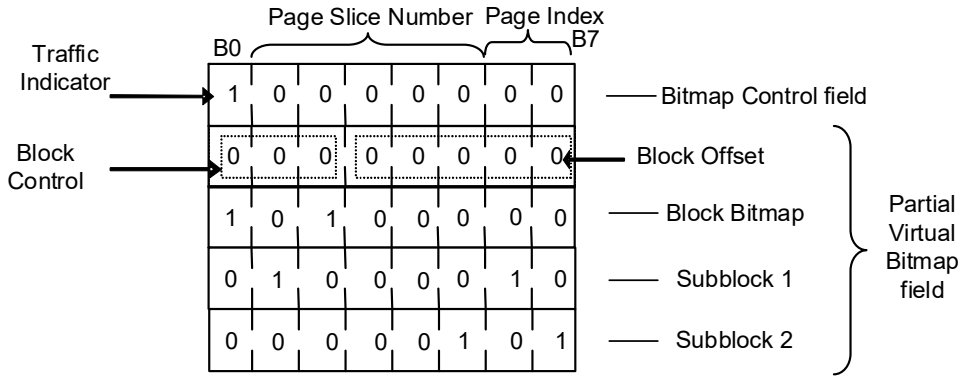


**Figure L-8—Partial Virtual Bitmap example #7 for S1G STAs, Block Bitmap mode(#7218)**

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The second example is one in which group addressed MSDUs are buffered in the AP as well as traffic for S1G STAs. The TIM element uses Single AID mode. The DTIM Count field in the TIM element equals 0. The (#7218)Traffic Indicator field is 1, the Page Slice Number field in the TIM element is 0 and the Page Index field is 0. Only the STA with AID 31 has data buffered in the AP. Figure L-9 (Partial Virtual Bitmap example #8 for S1G STAs, Single AID mode(#7218)) shows the values of the Bitmap Control and Partial Virtual Bitmap fields. The Partial Virtual Bitmap field consists of only one encoded block in which the Block Control field is 1 and the Block Offset field is 0. The Encoded Information Block field in the Partial Virtual Bitmap field consists of one Single AID field with the value of 31.

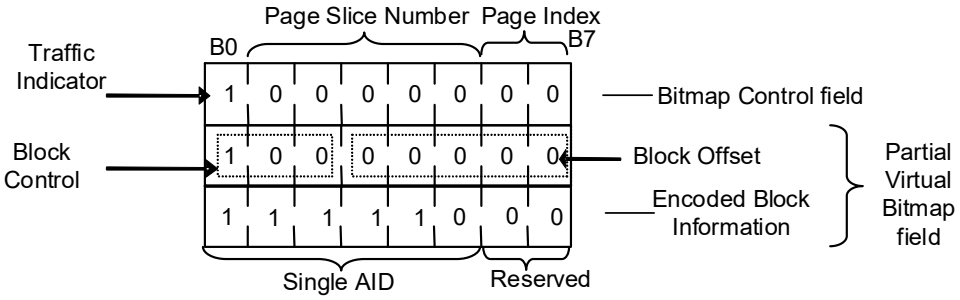


**Figure L-9—Partial Virtual Bitmap example #8 for S1G STAs, Single AID mode(#7218)**

The third example is one in which group addressed MSDUs are buffered in the AP as well as traffic for S1G STAs. The TIM element uses OLB mode. The DTIM Count field in the TIM element equals 0. The (#7218)Traffic Indicator field is 1, the Page Slice Number field in the TIM element is 0 and the Page Index field is 0. The STAs with AID 1, AID 6, AID 13, AID 15, AID 17, AID 22, AID 29, AID 31, (#6042)AID 33, AID 38, AID 45, AID 47, AID 49, AID 54, AID 61, AID 63, AID 65, and AID 70 have data buffered in the AP. Figure L-10 (Partial Virtual Bitmap example #9 for S1G STAs, OLB mode(#7218)) shows the values of the Bitmap Control and Partial Virtual Bitmap fields. The Partial Virtual Bitmap field consists of only one encoded block in which the Block Control field is 2 and the Block Offset field is 0. The Encoded Information Block field in the Partial Virtual Bitmap field consists of one Length field with the value of 9 and nine Subblock fields with the value of 66, 160, 66, 160, 66, 160, 66, 160, and 66, respectively.

The fourth example is one in which group addressed MSDUs are buffered in the AP as well as traffic for S1G STAs. The TIM element uses ADE mode. The DTIM Count field in the TIM element equals 0. The (#7218)Traffic Indicator field is 1, the Page Slice Number field in the TIM element is 0 and the Page Index field is 0. The STAs with AID 1, AID 6, AID 21 and AID 23 have data buffered in the AP. Figure L-11 (Partial Virtual Bitmap example #7 for S1G STAs, ADE mode(#6043)(#7218)) shows the values of the Bitmap Control and Partial Virtual Bitmap fields. The Partial Virtual Bitmap field consists of only one encoded block in which the Block Control field value is 3 and the Block Offset field value is 0. The Encoded Information Block field in the Partial Virtual Bitmap field consists of only one ADE Block in which the EWL field is 4 and the Length field is 2. Four differential AID values (ΔAID), i.e., 1, 5, 15, and 2 are encoded in the Encoded Information Block that has zero padding bits.


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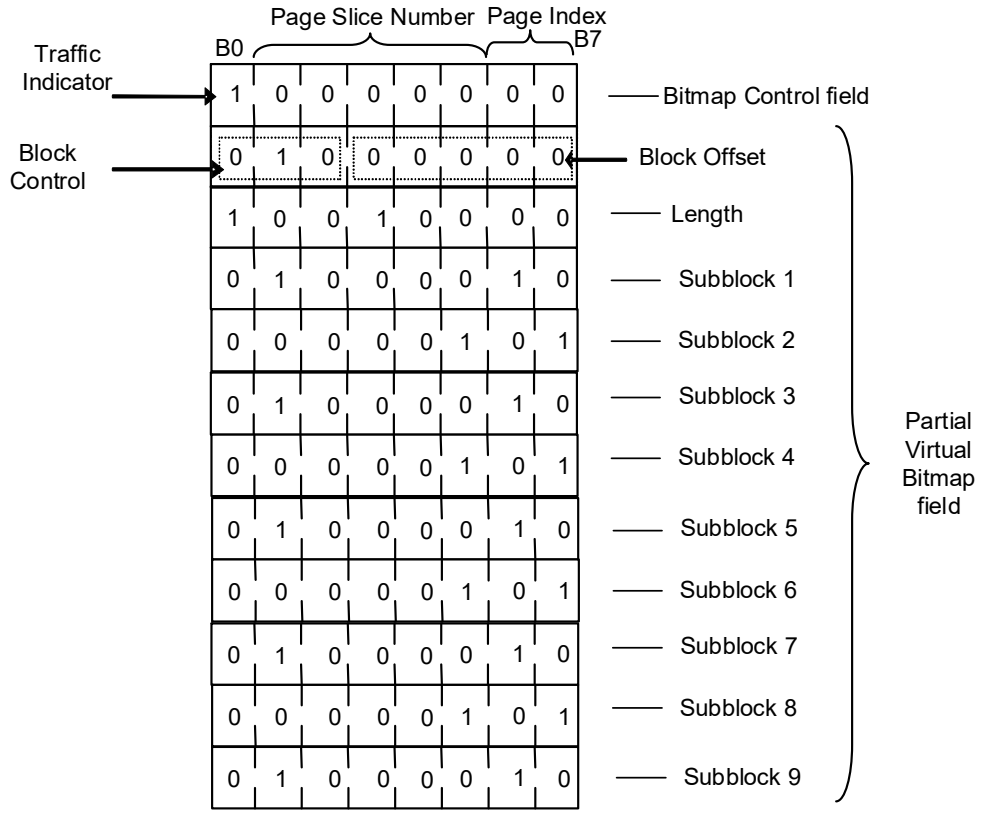


**Figure L-10—Partial Virtual Bitmap example #9 for S1G STAs, OLB mode(#7218)**

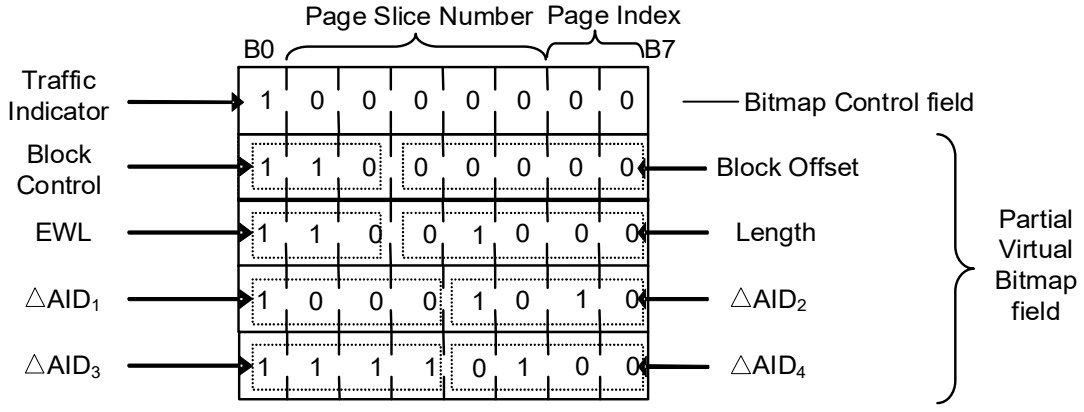


**Figure L-11—Partial Virtual Bitmap example #7 for S1G STAs, ADE mode(#6043)(#7218)**

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The fifth example is one in which group addressed MSDUs are buffered in the AP as well as traffic for S1G STAs. The TIM element uses the encoding mode of Inverse Bitmap + Block Bitmap. The DTIM Count field in the TIM element equals 0. The (#7218)Traffic Indicator field is 1, the Page Slice Number field in the TIM element is 0 and the Page Index field is 0. All the STAs with the AID value smaller than 64 except AID 1, AID 6, AID 21 and AID 23 have data buffered in the AP. Figure L-12 (Partial Virtual Bitmap example #10 for S1G STAs, Inverse Bitmap + Block Bitmap mode(#7218)) shows the values of the Bitmap Control and Partial Virtual Bitmap fields. The Partial Virtual Bitmap field consists of only one Encoded Block in which the Block Control field is 4 and the Block Offset field is 0. The Encoded Information Block field in the Partial Virtual Bitmap field consists of Block Bitmap field with (#6044)the value of 5 and two Subblock fields with the value of 66 and 160, respectively.

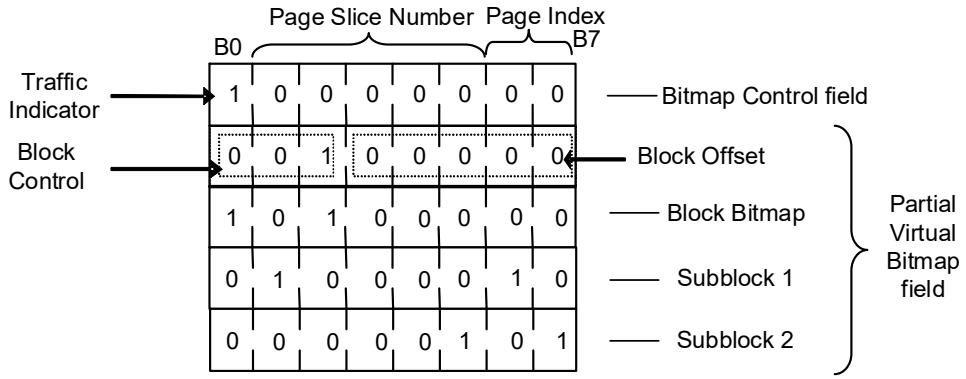


**Figure L-12—Partial Virtual Bitmap example #10 for S1G STAs, Inverse Bitmap + Block Bitmap mode(#7218)**

The sixth example is one in which group addressed MSDUs are buffered in the AP as well as traffic for S1G STAs. The TIM element uses the encoding mode of Inverse Bitmap + Single AID. The DTIM Count field in the TIM element equals 0. The (#7218)Traffic Indicator field is 1, the Page Slice Number field in the TIM element is 0 and the Page Index field is 0. All the STAs with the AID value smaller than 64 except AID 31 have data buffered in the AP. Figure L-13 (Partial Virtual Bitmap example #11 for S1G STAs, Inverse Bitmap + Single AID mode(#7218)) shows the values of the Bitmap Control and Partial Virtual Bitmap fields. The Partial Virtual Bitmap field consists of only one Encoded Block in which the Block Control field


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is 5 and the Block Offset field is 0. The Encoded Information Block field in the Partial Virtual Bitmap field consists of one Single AID field with the value of 31.

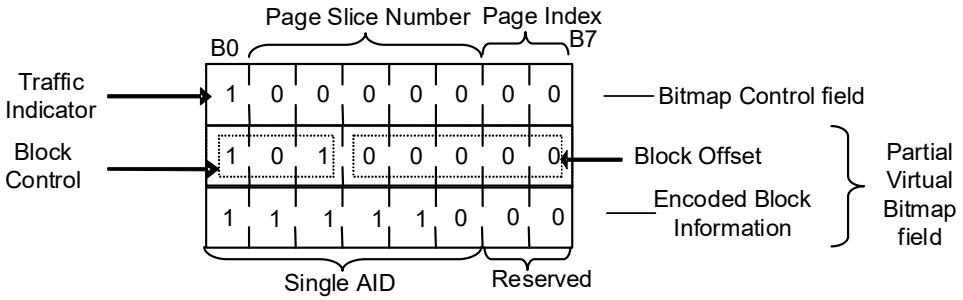


**Figure L-13—Partial Virtual Bitmap example #11 for S1G STAs, Inverse Bitmap + Single AID mode(#7218)**

The seventh example is one in which group addressed MSDUs are buffered in the AP as well as traffic for S1G STAs. The TIM element uses the encoding mode of Inverse Bitmap + OLB. The DTIM Count field in the TIM element equals 0. The (#7218)Traffic Indicator field is 1, the Page Slice Number field in the TIM element is 0 and the Page Index field is 0. All the STAs with the AID value smaller than 128 except AID 1, AID 6, AID 13, AID 15, AID 17, (#6045)AID 22, AID 29, AID 31, AID 33, AID 38, AID 45, AID 47, AID 49, AID 54, AID 61, AID 63, AID 65, and AID 70 have data buffered in the AP. Figure L-14 (Partial Virtual Bitmap example #12 for S1G STAs, Inverse Bitmap + OLB mode(#6045)(#7218)) shows the values of the Bitmap Control and Partial Virtual Bitmap fields. The Partial Virtual Bitmap field consists of only one Encoded Block in which the Block Control field is 6 and the Block Offset field is 0. The Encoded Information Block field in the Partial Virtual Bitmap field consists of one Length field with the value of 9 and nine Subblock fields with the value of 66, 160, 66, 160, 66, 160, 66, 160, and 66, respectively.

The eighth example is one in which group addressed MSDUs are buffered in the AP as well as traffic for S1G STAs. The TIM element uses the encoding mode of Inverse Bitmap + ADE. The DTIM Count field in the TIM element equals 0. The (#7218)Traffic Indicator field is 1, the Page Slice Number field in the TIM element is 0 and the Page Index field is 0. All the STAs with the AID value smaller than 64 except AID 1, AID 6, AID 21 and AID 23 have data buffered in the AP. Figure L-15 (Partial Virtual Bitmap example #10 for S1G STAs, Inverse Bitmap + ADE mode(#6046)(#7218)) shows the values of the Bitmap Control and Partial Virtual Bitmap fields. The Partial Virtual Bitmap field consists of only one Encoded Block in which the Block Control field value is 7 and the Block Offset field value is 0. The Encoded Information Block field in the Partial Virtual Bitmap field consists of only one ADE Block in which the EWL field is 4 and the

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Length field is 2. Four differential AID values (ΔAID), i.e., 1, 5, 15, and 2 are encoded in the Encoded Information Block that has zero padding bits.

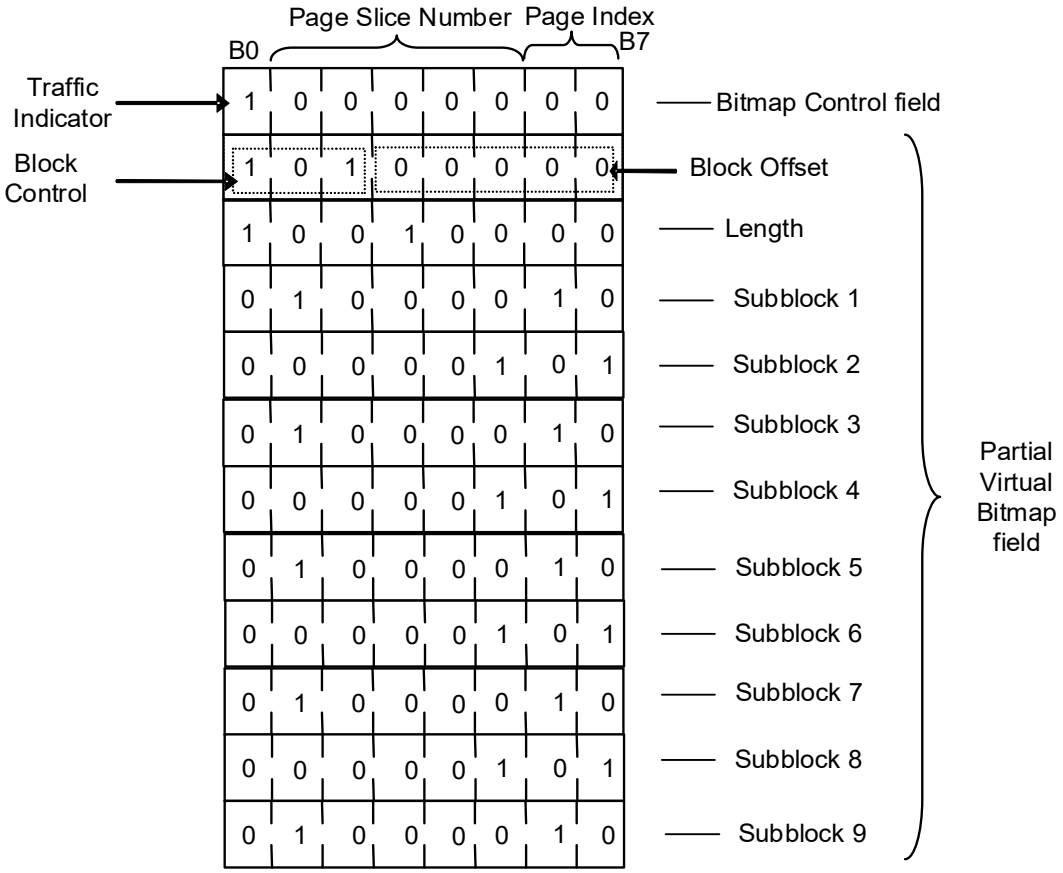


**Figure L-14—Partial Virtual Bitmap example #12 for S1G STAs, Inverse Bitmap + OLB mode(#6045)(#7218)**

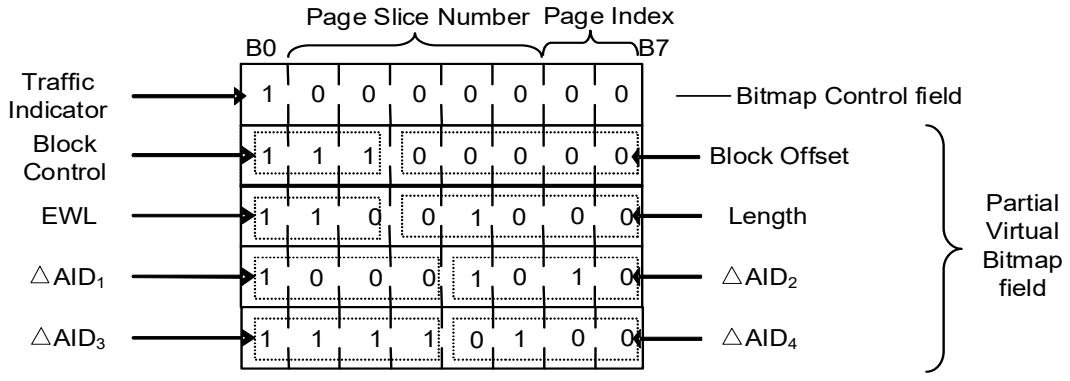


**Figure L-15—Partial Virtual Bitmap example #10 for S1G STAs, Inverse Bitmap + ADE mode(#6046)(#7218)**



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## L.3 Sample C code

The following C source code illustrates how to construct the Partial Virtual Bitmap. Because this is an illustration, no efficiency or appropriateness for actual implementation is implied.

```
#include <stdio.h>
#include <limits.h>

#define ADD_TIM_BIT     0
#define REMOVE_TIM_BIT  1

#define TIM_ELEMENT_ID  5
#define TIM_BASE_SIZE   3       /* size of TIM fields */

#define AID_SIZE        2008    /* valid AIDs are numBssids thru 2007 */
#define VBM_SIZE        251     /* size of VBM array = 2008/8 = 251 */
#define MAX_BSSIDS      128     /* maximum possible number of BSSIDs in a
multiple BSSID set is a power of 2 */

typedef unsigned char UINT8;
typedef unsigned short int UINT16;

struct _tim
    {
    UINT8 Element_id;
    UINT8 IELength;
    UINT8 DtimCount;
    UINT8 DtimPeriod;
    UINT8 BitMapControl;
    UINT8 PartialVirtualBitMap [VBM_SIZE];
    };

UINT8 virtualBitMap [VBM_SIZE];

UINT8 mcast_pending [MAX_BSSIDS] = {0};
UINT8 dtimCount [MAX_BSSIDS] = {0};
UINT8 dtimPeriod [MAX_BSSIDS] = {5};

void
Build_TIM (struct _tim *Tim, char TIM_method, UINT16 numBssids)
    {
    UINT8 octetIndex = 0;
    UINT8 octetIndex0 = 0;
    UINT8 octetIndex1 = 0;
    UINT8 offset = 0;
    UINT8 lengthOfPartialVirtualBitMap = 0;
    UINT8 bcast_octet = 0;
    UINT8 bcast_bit = 0;
    UINT8 max_bcast_octetIndex = 0;
    UINT16 bssidIndex = 0;
    UINT16 N2 = 0;

    /* Compute the largest octet_index for bcast indication */
    max_bcast_octetIndex = (numBssids - 1) / 8;

    /* Initialize PartialVirtualBitMap */
    for (octetIndex = 0;  octetIndex < VBM_SIZE;  octetIndex++)
        Tim->PartialVirtualBitMap [octetIndex] = 0;
    octetIndex = 0;
    if (numBssids == 1)
        {
        /* Find the first nonzero octet in the Partial Virtual Bitmap */
        for (octetIndex = 0;  ((virtualBitMap [octetIndex] == 0) &&
                                (octetIndex < VBM_SIZE));
             octetIndex++)
            /* empty */ ;
        if (octetIndex < VBM_SIZE)
            offset = octetIndex & 0xFE;

        /* Find the last nonzero octet in the Partial Virtual Bitmap */
```

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```
        for (octetIndex = (VBM_SIZE - 1);  ((virtualBitMap [octetIndex] == 0) &&
                                            (octetIndex > 0));
             octetIndex--)
            /* empty */ ;
        lengthOfPartialVirtualBitMap = octetIndex - offset + 1;
        Tim->IELength = lengthOfPartialVirtualBitMap + TIM_BASE_SIZE;
        Tim->BitMapControl = offset;

        /* Copy the virtual Bitmap octets that are nonzero */
        /* Note: A NULL virtualBitMap still adds(M118) a single octet of 0 */
        for (octetIndex = 0;
             octetIndex < lengthOfPartialVirtualBitMap;  octetIndex++)
            Tim->PartialVirtualBitMap [octetIndex] =
                    virtualBitMap [offset + octetIndex];
        }
    if (numBssids > 1)
        {
        /* Update the broadcast/multicast bits, when numBssids > 1 */
        for (bssidIndex = 1;  bssidIndex < numBssids;  bssidIndex++)
            {
            bcast_octet = (bssidIndex >> 3) & 0xff;
            bcast_bit = 0x01 << (bssidIndex & 0x07);
            if (mcast_pending [bssidIndex])
                virtualBitMap [bcast_octet] |= bcast_bit;
            else
                virtualBitMap [bcast_octet] &= ~bcast_bit;
            }
        for (octetIndex0 = 0;
             (octetIndex0 < VBM_SIZE) && (virtualBitMap [octetIndex0] == 0);
             octetIndex0++)
            /* empty */ ;

        /* Partial virtual bitmap (PVB) contains neither bcast nor
             buffered ucast traffic, PVB is a single all-0 octet */
        if (octetIndex0 == VBM_SIZE)
            {
            lengthOfPartialVirtualBitMap = 1;
            offset = 0;
            Tim->IELength = lengthOfPartialVirtualBitMap + TIM_BASE_SIZE;
            Tim->BitMapControl = offset;
            Tim->PartialVirtualBitMap [0] = virtualBitMap [0];
            }
        for (octetIndex1 = (max_bcast_octetIndex + 1);
             ((octetIndex1 < VBM_SIZE) && (virtualBitMap [octetIndex1] == 0));
             octetIndex1++)
            /* empty */ ;

        /* PVB only contains bcast indication, no buffered ucast traffic */
        if ((octetIndex1 == VBM_SIZE) && (octetIndex0 < VBM_SIZE))
            {
            lengthOfPartialVirtualBitMap = max_bcast_octetIndex + 1;
            offset = 0;
            Tim->IELength = lengthOfPartialVirtualBitMap + TIM_BASE_SIZE;
            Tim->BitMapControl = offset;
            for (octetIndex = 0;
                    octetIndex < (max_bcast_octetIndex + 1);
                    octetIndex++)
                /* empty */ ;
            Tim->PartialVirtualBitMap [octetIndex] =
                    virtualBitMap [octetIndex];
            }

       /* PVB contains ucast indication with or without buffered bcast traffic */
        for (octetIndex = 0;
             octetIndex < (max_bcast_octetIndex + 1);
             octetIndex++)
            Tim->PartialVirtualBitMap [octetIndex] = virtualBitMap [octetIndex];
        if ((octetIndex1 < VBM_SIZE) && (octetIndex0 < VBM_SIZE))
            {
            if (TIM_method == 'A')
                {
                offset = 0;
```



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```
                    for (octetIndex = (VBM_SIZE - 1);
                         (virtualBitMap [octetIndex] == 0) &&
                        (octetIndex > (max_bcast_octetIndex + 1));
                         octetIndex--)
                        /* empty */ ;
                    N2 = octetIndex;
                    lengthOfPartialVirtualBitMap = N2 - offset + 1;
                    for (octetIndex = (max_bcast_octetIndex + 1);
                        (octetIndex <= N2);  octetIndex++)
                        Tim->PartialVirtualBitMap [octetIndex] =
                              virtualBitMap [octetIndex];
                    Tim->IELength = lengthOfPartialVirtualBitMap + TIM_BASE_SIZE;
                    Tim->BitMapControl = offset;
                    }
                if (TIM_method == 'B')
                    {
                    offset = octetIndex1 - (max_bcast_octetIndex + 1);
                    offset = offset & 0xFE;
                    /* The result of (max_bcast_octetIndex + 1) + offset is equal
          to N1 that is described in 9.4.2.5 (TIM element) for the TIM element. */
                    for (octetIndex = (VBM_SIZE - 1);
                         ((virtualBitMap [octetIndex] == 0) &&
                         (octetIndex > (max_bcast_octetIndex + 1)));
                         octetIndex--)
                        /* empty */ ;
                    N2 = octetIndex;
                    lengthOfPartialVirtualBitMap = N2 - offset + 1;
                    for (octetIndex = (max_bcast_octetIndex + 1);
                         octetIndex <= (lengthOfPartialVirtualBitMap - 1);
                         octetIndex++)
                        Tim->PartialVirtualBitMap [octetIndex] =
                              virtualBitMap [offset + octetIndex];
                    Tim->IELength = lengthOfPartialVirtualBitMap + TIM_BASE_SIZE;
                    Tim->BitMapControl = offset;
                    }
                }
            }
        Tim->Element_id = TIM_ELEMENT_ID;
        Tim->DtimCount = dtimCount [0];
        Tim->DtimPeriod = dtimPeriod [0];

        /* Update broadcast/ multicast indication bit for transmitted
           BSSID if necessary */
        if ((Tim->DtimCount == 0) && mcast_pending [0])
            Tim->BitMapControl |= 0x01;
        }

    void
    Update_VirtualBitMap (UINT16 station_id, UINT8 Action)
        {
        UINT16 aid = station_id;
        UINT8 aid_octet;
        UINT8 aid_bit;

        if ((aid > 0) && (aid < AID_SIZE))
            {
            /* Get AID position in the Partial Virtual Bitmap. */
            aid_octet = (aid >> 3) & 0xff;
            aid_bit = 0x01 << (aid & 0x07);
            if (Action == REMOVE_TIM_BIT)
                virtualBitMap [aid_octet] &= ~aid_bit;
            else
                virtualBitMap [aid_octet] |= aid_bit;
            }
        }

    int
    main (void)
        {
        struct _tim Tim;
        UINT8 ExampleCase;
        UINT16 count = 0;
```

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```
char TIM_method;
UINT16 numBssids = 1;

/* The value of ExampleCase depends on the test case,
   allowed values are 1 to 22 */
ExampleCase = 1;

/* The value of TIM_method depends on the method to use,
   allowed values are 'A' and 'B' */
TIM_method = 'A';

switch (ExampleCase)
    {
    /* Nine examples with numBssids = 1,
         no difference between Method A and B */
    case 1:
        mcast_pending [0] = 0;
        Update_VirtualBitMap (2, ADD_TIM_BIT);
        Update_VirtualBitMap (7, ADD_TIM_BIT);
        break;
    case 2:
        mcast_pending [0] = 1;
        Update_VirtualBitMap (2, ADD_TIM_BIT);
        Update_VirtualBitMap (7, ADD_TIM_BIT);
        Update_VirtualBitMap (22, ADD_TIM_BIT);
        Update_VirtualBitMap (24, ADD_TIM_BIT);
        break;
    case 3:
        mcast_pending [0] = 1;
        Update_VirtualBitMap (24, ADD_TIM_BIT);
        break;
    case 4:
        mcast_pending [0] = 0;
        Update_VirtualBitMap (3, ADD_TIM_BIT);
        Update_VirtualBitMap (37, ADD_TIM_BIT);
        Update_VirtualBitMap (43, ADD_TIM_BIT);
        break;
    case 5:
        mcast_pending [0] = 0;
        Update_VirtualBitMap (35, ADD_TIM_BIT);
        break;
    case 6:
        mcast_pending [0] = 0;
        Update_VirtualBitMap (43, ADD_TIM_BIT);
        break;
    case 7:
        mcast_pending [0] = 0;
        Update_VirtualBitMap (35, ADD_TIM_BIT);
        Update_VirtualBitMap (35, REMOVE_TIM_BIT);
        break;
    case 8:
        mcast_pending [0] = 1;
        Update_VirtualBitMap (13, ADD_TIM_BIT);
        Update_VirtualBitMap (43, ADD_TIM_BIT);
        Update_VirtualBitMap (63, ADD_TIM_BIT);
        Update_VirtualBitMap (73, ADD_TIM_BIT);
        break;
    case 9:
        mcast_pending [0] = 1;
        Update_VirtualBitMap (2007, ADD_TIM_BIT);
        break;


    /* Thirteen examples with numBssids > 1, TIM_method = 'A' or 'B' */
    case 10:
        numBssids = 8;
        Update_VirtualBitMap (9, ADD_TIM_BIT);
        Update_VirtualBitMap (11, ADD_TIM_BIT);
        break;
    case 11:
        numBssids = 8;
        mcast_pending [0] = 1;
```


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```
            mcast_pending [3] = 1;
            Update_VirtualBitMap (12, ADD_TIM_BIT);
            Update_VirtualBitMap (17, ADD_TIM_BIT);
            Update_VirtualBitMap (22, ADD_TIM_BIT);
            Update_VirtualBitMap (24, ADD_TIM_BIT);
            break;
        case 12:
            numBssids = 16;
            mcast_pending [3] = 1;
            Update_VirtualBitMap (39, ADD_TIM_BIT);
            break;
        case 13:
            numBssids = 8;
            mcast_pending [5] = 1;
            mcast_pending [7] = 1;
            Update_VirtualBitMap (23, ADD_TIM_BIT);
            break;
        case 14:
            numBssids = 8;
            mcast_pending [2] = 1;
            mcast_pending [7] = 1;
            Update_VirtualBitMap (10, ADD_TIM_BIT);
            break;
        case 15:
            numBssids = 15;
            mcast_pending [5] = 1;
            mcast_pending [7] = 1;
            Update_VirtualBitMap (2007, ADD_TIM_BIT);
            break;
        case 16:
            numBssids = 15;
            mcast_pending [5] = 1;
            mcast_pending [7] = 1;
            Update_VirtualBitMap (1997, ADD_TIM_BIT);
            Update_VirtualBitMap (1999, ADD_TIM_BIT);
            break;
        case 17:
            numBssids = 32;
            for (count = 0;  count < numBssids;  count += 2)
                mcast_pending [count] = 1;
            Update_VirtualBitMap (32, ADD_TIM_BIT);
            Update_VirtualBitMap (33, ADD_TIM_BIT);
            Update_VirtualBitMap (39, ADD_TIM_BIT);
            break;
        case 18:
            numBssids = 14;
            mcast_pending [5] = 1;
            mcast_pending [7] = 1;
            break;
        case 19:
            numBssids = 14;
            mcast_pending [0] = 1;
            mcast_pending [12] = 1;
            break;
        case 20:
            numBssids = 15;
            Update_VirtualBitMap (38, ADD_TIM_BIT);
            break;
        case 21:
            numBssids = 15;
            mcast_pending [0] = 1;
            Update_VirtualBitMap (44, ADD_TIM_BIT);
            break;
        case 22:
            numBssids = 16;
            break;
        default:
            break;
        }
    Build_TIM (&Tim, TIM_method, numBssids);

    printf ("\nCase = %d, method %c.\n", ExampleCase, TIM_method);
```

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```
    printf ("numBssids = %d.\n", numBssids);
    printf ("Element_id = %d.\n", Tim.Element_id);
    printf ("IELength = %d.\n", Tim.IELength);
    printf ("DtimCount = %d.\n", Tim.DtimCount);
    printf ("DtimPeriod = %d.\n", Tim.DtimPeriod);
    printf ("BitMapControl = 0x%02X\n", Tim.BitMapControl);
    if (Tim.IELength - TIM_BASE_SIZE > 0)
        {
        int octetIndex;

        for (octetIndex = 0;
             octetIndex < Tim.IELength - TIM_BASE_SIZE;
             octetIndex++)
            printf ("PartialVirtualBitMap [%d] = 0x%02X\n", octetIndex,
                    Tim.PartialVirtualBitMap [octetIndex]);
        }
    return 0;
    }
/* The End. */
```


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# Annex M

(informative)

# EPD and LPD headers and the integration function

## M.1 Introduction

The purposes of this informative annex are to (1) guide the implementer of a non-GLK WLAN system that includes a portal that integrates the WLAN systems with a wired LAN, (2) clarify EPD and LPD headers including the case of A-MSDU subframes, and (3) clarify where and how EPD to LPD and LPD to EPD conversions are required.

As specified in IEEE Std 802, EPD encoding always starts with a Length/Type field that is either a 2-octet length or a 2-octet EtherType(#2186) while LPD encoding always starts with an LSAP octet. There is no indication in a Data frame as to whether EPD or LPD MSDU encoding is in use. A receiving STA uses the rules in 5.1.4 (MSDU format) to determine the encoding of MSDUs it receives.

## M.2 Integration function header conversions

Table M-1 (EPD and LPD MSDU headers) illustrates EPD and LPD protocol header encodings. The encoding used within the DS is unspecified. If the DS has a portal, that portal provides the integration function. The integration function converts between the encoding used within the DS and that used in the non-IEEE-802.11 network with which the portal is connecting the DS. If the DS uses LPD and the portal connects to a network that uses EPD, for example (#6014)IEEE Std 802.3-2022, the integration function converts MSDUs exiting the DS from LPD to EPD format and those entering the DS from EPD to LPD.

Conversion between LPD and EPD might also be required at any GLK STA unless the GLK STA joins(M118) only BSSs limited to EPD STAs. If the GLK STA might receive or transmit Data frames containing LPD MSDUs, it converts them to or from the EPD MSDUs required by the Internal Sublayer Service SAPs provided by GLK STAs.

Conversion between LPD and EPD is discussed in 5.1.4 (MSDU format) and IEEE Std 802.1AC-2016.

## M.3 A-MSDU subframes

The formats of A-MSDU subframes are shown in 9.3.2.2 (Aggregate MSDU (A-MSDU) format), specifically in Figure 9-122 (A-MSDU structure), Figure 9-123 (Basic A-MSDU subframe structure when not in a mesh Data frame(#462)), and Figure 9-124 (Basic A-MSDU subframe structure when in a mesh Data frame(#462)(#419)). These formats apply as shown regardless of whether the MSDU is EPD or LPD encoded.

When the MSDU is EPD encoded, it always starts with a 2-octet Length/Type field as shown in Table M-1 (EPD and LPD MSDU headers). Thus, in the case where that field is a length (indicated by its value considered as an unsigned field being less than 0x05DC) and the MSDU appears in an A-MSDU subframe, there are(M118) two sequential length fields or, (#419)in the mesh Data frame case, two length fields separated only by the Mesh Control field. Figure M-1 (EPD BPDU subframe), Figure M-2 (EPD VLAN tagged IPv4 subframe), and Figure M-3 (EPD VLAN tagged IS-IS subframe) show (#279)Basic A-MSDU subframes containing an EPD encoded BPDU, an EPD encoded VLAN tagged IPv4 packet, and an EPD encoded VLAN tagged IS-IS PDU respectively. In those figures, the arrowed line from each Length field goes to a curly bracket covering the data whose Length is in that length field.

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When parsing an MSDU, if the default LPD encoding is being used, the MSDU starts with an LSAP; if EPD encoding is being used, the MSDU starts with a Length/Type field. Subclause 5.1.4 (MSDU format) specifies which encoding is used.

**Table M-1—EPD and LPD MSDU headers**

| Protocol | EPD MSDU Header | LPD MSDU Header |
|---|---|---|
| BPDU | length[a]-42-42-03 | 42-42-03 |
| IPv4 | 08-00 | AA-AA-03-00-00-00-08-00 |
| IPv6 | 86-DD | AA-AA-03-00-00-00-86-DD |
| IP ARP | 08-06 | AA-AA-03-00-00-00-08-06 |
| IS-IS | length[a]-FE-FE-03 | FE-FE-03 |
| C-VLAN[b] tagged IPv4 | 81-00-xy-zw-08-00 | AA-AA-03-00-00-00-81-00-xy-zw-08-00 |
| S-VLAN[c] and C-VLAN[b] tagged IPv6 | 88-A8-st-uv-81-00-xy-zw-86-DD | AA-AA-03-00-00-00-88-A8-st-uv-81-00-xy-zw-86-DD |

[a] A 2-octet, big-endian, unsigned integer length in octets.
[b] Assuming C-VLAN ID xy-zw.
[c] Assuming S-VLAN ID st-uv.

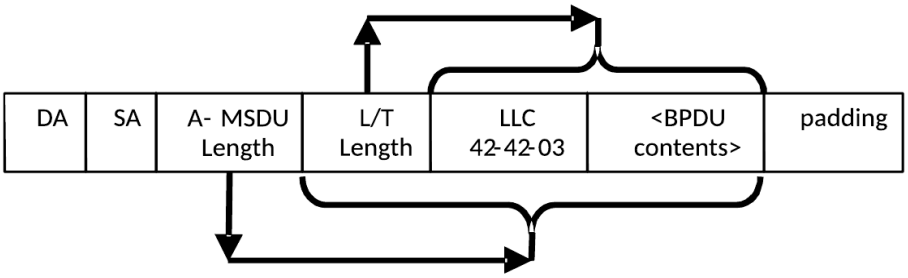


**Figure M-1—EPD BPDU subframe**

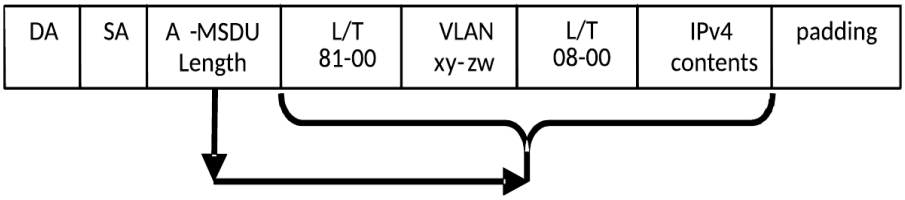


**Figure M-2—EPD VLAN tagged IPv4 subframe**


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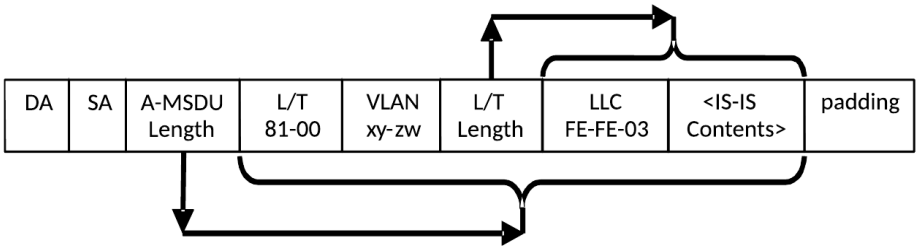


**Figure M-3—EPD VLAN tagged IS-IS subframe**

## M.4 Integration service versus bridging

There are a number of differences between the IEEE 802.11 integration service and the service provided by an IEEE 802.1 bridge. In the IEEE 802.11 non-GLK architecture a portal provides the minimum connectivity between an IEEE 802.11 WLAN and a non-IEEE-802.11 LAN. Requiring an (#74)IEEE 802.1Q bridge in order to be compliant with IEEE Std 802.11 would unnecessarily render some implementations noncompliant.

The most important distinction is that a portal has only one "port" (in the sense of IEEE Std 802.1Q(#75), for example) through which it accesses the DS. This renders it unnecessary to update bridging tables inside a portal each time a STA changes its association status. In other words, the details of distributing MSDUs inside the non-GLK IEEE 802.11 WLAN need not be exposed to the portal.

Another difference is that the DS is not an IEEE 802 LAN (although it carries IEEE 802 LLC SDUs). Requiring that the DS implements all behaviors of an IEEE 802 LAN places an undue burden on the architecture.

Finally, it is an explicit intent of this standard to permit transparent integration of an IEEE 802.11 WLAN into another non-IEEE-802.11 LAN, including passing bridge PDUs through a portal. While an implementer might wish to attach an (#76)IEEE 802.1Q bridge to the portal (note that the non-IEEE-802.11 LAN interface on the bridge need not be any particular type of LAN), it is not an architectural requirement of this standard to do so.

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# Annex N

(informative)

# AP functional description

## N.1 Introduction

This informative annex seeks to clarify the AP functional description; however, it does not provide information or clarification for GLK APs. At times there is some confusion surrounding the term *AP* and the relation of that term to the AP functions and common implementations of AP devices. The core IEEE 802.11 conceptual definitions that surround the AP (refer to Clause 4 (General description)) are abstract (and can sometimes cause confusion), but Clause 4 (General description) definitions are crafted to be flexible and hence serve to allow the adaptation and extension of this standard in a wide variety of ways.

In this annex a wireless local area network (WLAN) system is a system that includes the distribution system (DS), access point (AP), and portal entities. It is also the logical location of distribution and integration service functions of an extended service set (ESS). A WLAN system contains an optional portal and one or more APs in addition to the DS.

## N.2 Terminology

An enhanced description of these access entities begins with clarification of several terms.

This standard defines an entity called a *STA*. STAs can operate in different modes. The possible operational modes of a STA are:

a) Infrastructure mobile STAs
b) Independent mobile STAs
c) Access control mode STAs
d) Mesh STAs

The mobile STAs are the STA entities that are ordinarily moving around, but might also be in a fixed location. The mobile adjective prefix often helps in visualizing the type of STA under discussion.

Infrastructure mobile STAs operate in an infrastructure BSS, i.e., they are the users of an AP. Devices that incorporate an infrastructure mobile STA are referred to in this annex by the term mobile unit. A mobile unit device might consist of just a mobile STA implementation, but also likely includes an SME and a client. The exact configuration of the mobile unit it is not relevant to the descriptions in this annex.

Independent mobile STAs operate in an IBSS. Independent mobile STAs form autonomous networks that do not require an AP.

A STA can also form an integral part of an AP. To do so, the STA operates in access control mode. This type of STA is called an *access control mode STA* (ACM_STA).

The primary function of an AP is to provide the mobile units with access to the DS, as shown in the Unified Modeling Language (UML) use case diagram in Figure N-1 (Very high level UML use case diagram for the AP). Complete UML specifications can be found in Rumbaugh et al. [B67]. The UML diagram shows a system boundary box containing a single use case (ellipse). Entities that are outside the system boundary


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box are shown as stick people. These external entities represent the actors (formal term), or users, of the system. Since the actors are outside the system boundary, their internal behavior is not described (i.e., it is out of scope for the current view). Instead, references to the external entities are limited to descriptions of their interactions with, and expectations of, the system, which is accomplished by describing the use cases and scenarios (i.e., functions) of the system and later (in Figure N-4 (High-level UML entity diagram for the WLAN system)) a decomposition of the entities (objects and behaviors) within the system that provide that functionality. The use case diagram employs connecting lines to indicate relationships between the various artifacts present in the diagram. Relationship lines lacking arrows on both ends indicate that there is a bidirectional relationship between the artifacts.

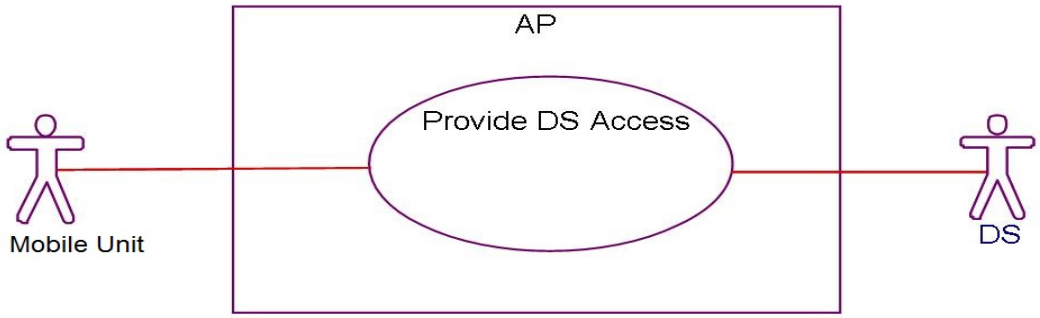


**Figure N-1—Very high level UML use case diagram for the AP**

The DS enables communication between mobile units and the construction of collections of APs. To enable communication between mobile units and a non-IEEE-802.11 LAN entity requires the presence of a (logical) portal from the DS to the non-IEEE-802.11 LAN.

Often the functions of an AP (which includes an ACM_STA), a DS, and a portal, are combined into a single device, referred to in this annex as an *access unit* (AU). While reference to that basic implementation is commonplace, it is helpful to discuss the abstract case: a WLAN system. The WLAN system includes the DS, an optional portal, APs, and the AP's STAs. It is also the logical location of distribution and integration service functions of an ESS. An infrastructure WLAN system contains one or more APs and zero or one portals in addition to the DS.

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The primary function of a WLAN system is to provide the mobile units with access to the non-IEEE-802.11 LAN, as shown in Figure N-2 (Very high level UML use case diagram for the WLAN system). A secondary function is to provide the mobile units with access to each other.

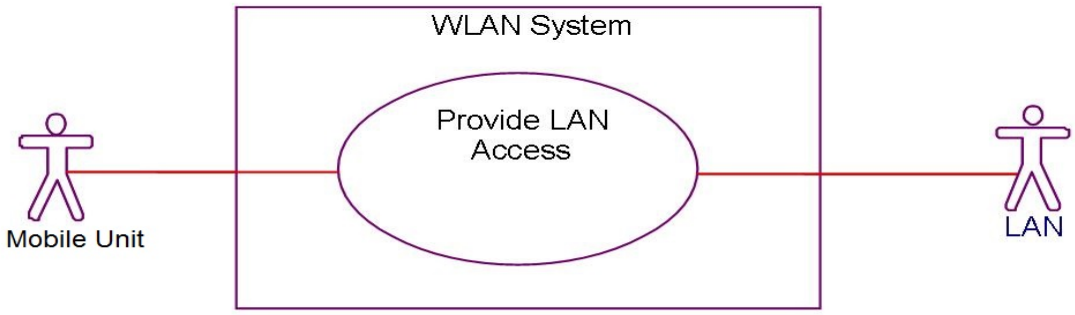


**Figure N-2—Very high level UML use case diagram for the WLAN system**

The primary functions of the WLAN system can be further characterized as follows:

a) Provide non-IEEE-802.11 LAN access.
   1) Includes mobile unit validation.
   2) Includes moving data between the mobile units and the non-IEEE-802.11 LAN.
      i) Uses a special data movement function called *filtering data*.

b) Configure the system.

Those high-level use cases of the WLAN system are shown in the UML use case diagram in Figure N-3 (High-level UML use case diagram for the WLAN system). The UML diagram shows multiple use cases with two types of relationships between those use cases: include and generalization. The include relationship "includes" functionality in one use case that is described by another use case. The "provide LAN Access" use case includes the functionality of the "Validate mobile unit" use case. The generalization relationship indicates that one use case is a more general form of another use case. The relationship line with a hollow triangle at the end indicates that the "Move Data" use case is a more generalized form of the "Filter Data" use case. Or, equivalently, "Filter Data" is a more specialized form of "Move Data." The constraint artifact


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(in the lower left corner of the diagram) requires the WLAN system and the mobile units to be set to the same SSID.

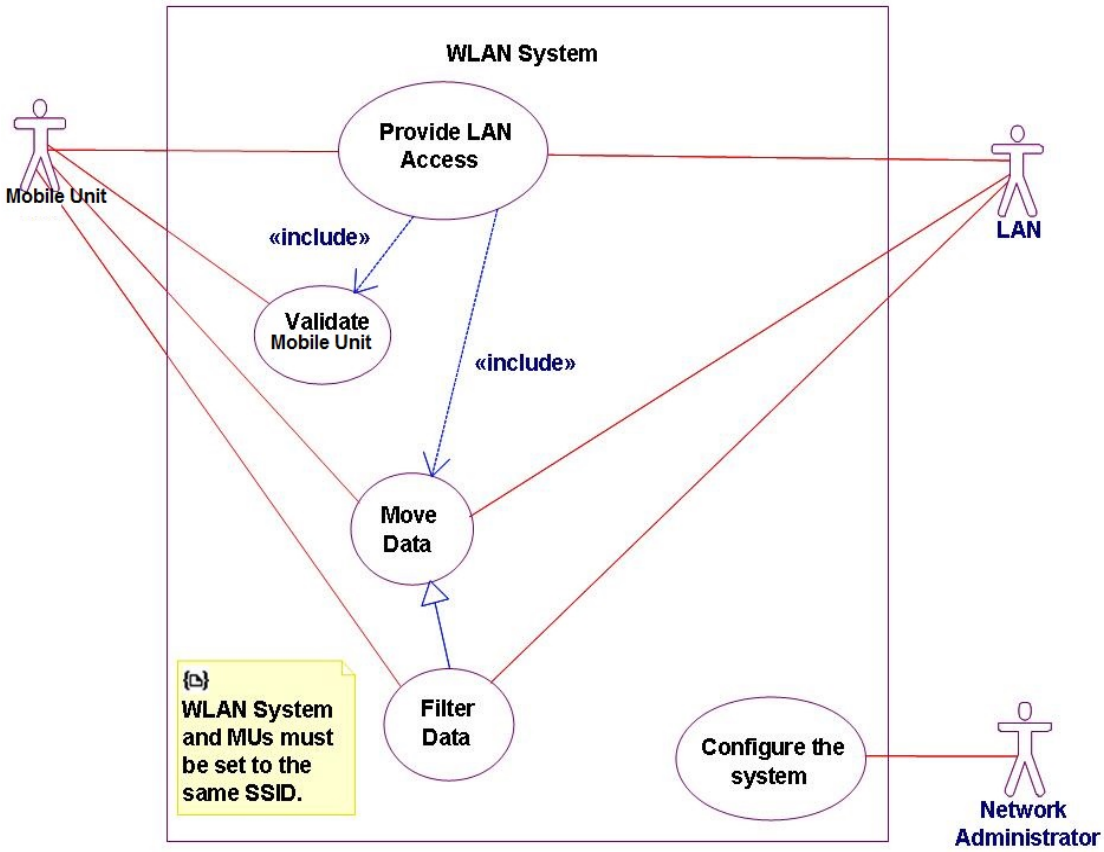


**Figure N-3—High-level UML use case diagram for the WLAN system**

The primary functions of the WLAN system, depicted in the UML object model diagram in Figure N-4 (High-level UML entity diagram for the WLAN system), are provided by the AP, and DS entities, the latter via the DSSs. The portal is merely a conceptual link from the DS to the non-IEEE-802.11 LAN. The UML object model diagram shows a package containing a set of object classes. References to the actors (external entities) are limited to descriptions of their interactions with, and expectations of, the object classes, which is accomplished by describing the attributes and behaviors of the class entities. The object model diagram uses connecting lines to indicate interfaces (called *associations* in UML terminology) between the various artifacts present in the diagram. UML association lines lacking arrows on both ends indicate that there is a bidirectional interface between the artifacts. The UML association lines are annotated with multiplicity counts to indicate the how many entities might fill the position at that end of the association.

Figure N-4 (High-level UML entity diagram for the WLAN system) also shows the relationships between the WLAN system entities. There exists a bidirectional association between zero or more [0..*] mobile units and a single (given) ACM_STA. The solid diamond terminated line indicates that there is a composition relationship between the ACM_STA and the AP, i.e., the AP is composed of (or always has an) ACM_STA. Hence there is a one-to-one mapping between APs and ACM_STAs. This composition and one-to-one relationship can also be drawn as shown in Figure N-5 (AP UML composition diagram (alternate syntax)). These two forms are equivalent. There are one or more [1..*] APs connected to a single DS. The DS in turn connects to zero or one [0..1] portals. The portal connects to a single non-IEEE-802.11 LAN.

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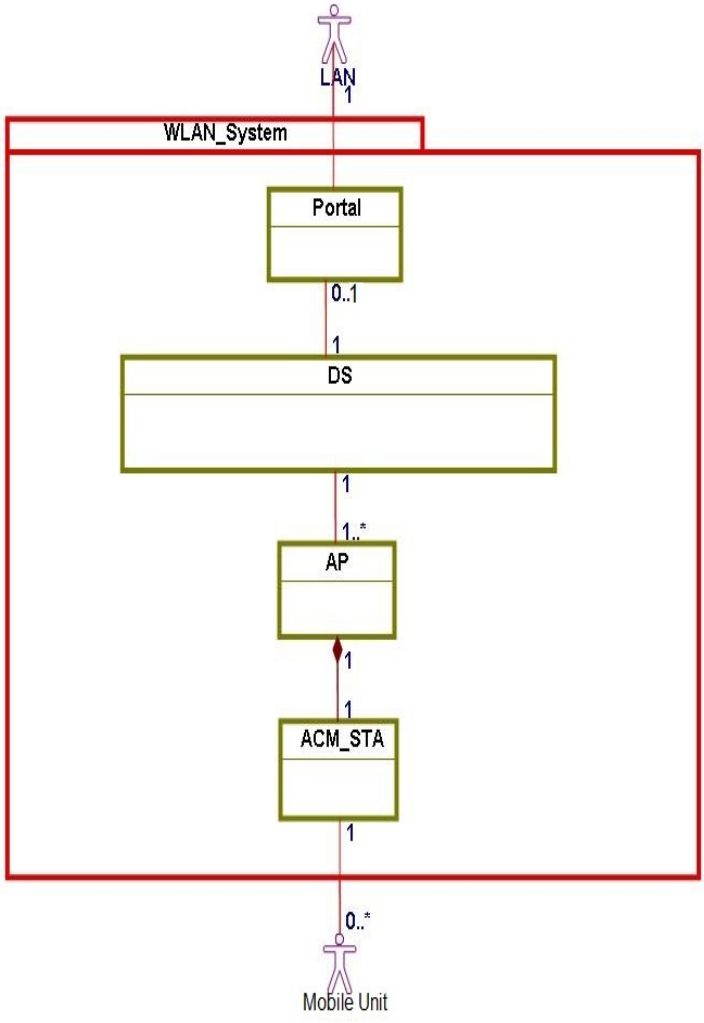


**Figure N-4—High-level UML entity diagram for the WLAN system**

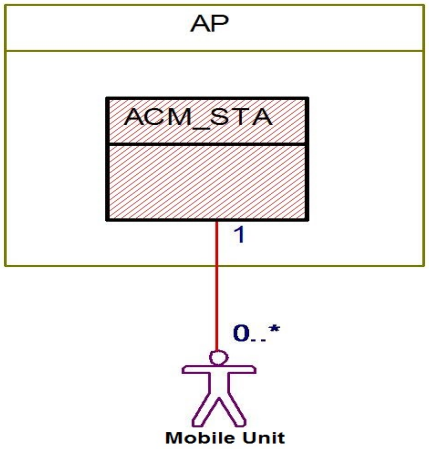


**Figure N-5—AP UML composition diagram (alternate syntax)**


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## N.3 Primary ACM_STA functions

The primary functions of an ACM_STA are as follows:

a) Instantiate the infrastructure BSS.
b) Move data between the mobile units and the AP.

Instantiating the infrastructure BSS consists of advertising the BSS and defining timing for the entire BSS (i.e., infrastructure mode TSF). Advertising the BSS includes creating an infrastructure mode Beacon frame, transmitting that Beacon frame, and replying to mobile unit probe requests with corresponding probe response transmissions. Beacon frames and probe responses provide a way for the mobile units to find, join with the ACM_STA, and (subsequently) associate with the AP. This includes, for example, the AP providing channel, regulatory, and country information to the mobile units.

Moving data between the mobile units and the AP consists of translating between MSDUs and MPDUs, buffering data, and transmitting/receiving MPDUs via an IEEE 802.11 PHY.

## N.4 Primary AP functions

The primary functions of an AP are as follows:

a) Provide DS access for the mobile units.
    1) Includes mobile unit validation and extends (in some cases) to notifying the DS.
    2) Includes moving data between the mobile units and the DS.
        i) Uses a special data movement function called *data filtering*.
b) Configure the AP (both the AP itself and the included ACM_STA).

Those high-level use cases of the AP are shown in the UML use case diagram in Figure N-6 (High-level UML use case diagram for the AP). The UML extend relationship “extends” a use case with optional functions provided by another use case that are applied only in some scenarios. In Figure N-6 (High-level UML use case diagram for the AP), the “Notify the DS” use case extends the “Validate mobile unit” use case in some scenarios.

The AP provides DS access for the mobile units, including validating the mobile units (e.g., via STA and/or client authentication) and providing access and admission control (e.g., via the association process). An AP is literally a point of access to the DS (and, by extension, to the non-IEEE-802.11 LAN beyond). Upon validating a mobile unit, the AP updates the DS mapping of the mobile unit to the AP. DS mapping updates can, for example, be based on (re)association requests (received from the ACM_STA) or aging of inactive links (based on session timers). An AP might also receive access control updates directly from other APs, via a protocol outside the scope of this standard, in the form of inter-AP notifications of mobile unit association events and transitions. In this way, mobile unit validation and subsequent changes in mobile unit access control lead to adjustments in how data are allowed to move through the AP (i.e., between the mobile units and the DS).

Providing DS access for the mobile units also includes moving data between the mobile units and the DS, which is accomplished by moving MSDUs between the ACM_STA and the DS (bidirectionally).

The moving data function includes “filtering data.” The filtering data function controls which MSDUs (if any) are moved between the DS and the mobile units. For example, filtering of data to and from a particular mobile unit is adjusted based on the various stages of validation of that mobile unit.

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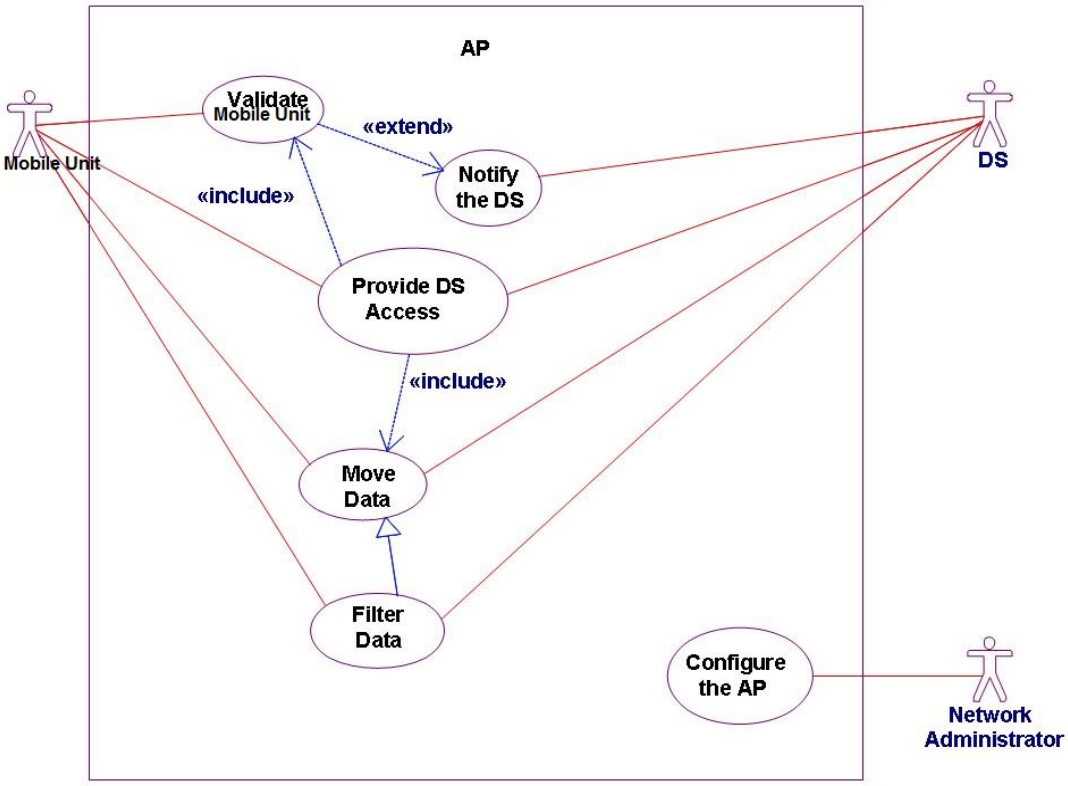


**Figure N-6—High-level UML use case diagram for the AP**

The AP also provides a function for configuration. Configuring the AP includes configuring the AP itself as well as the included ACM_STA. For example, configuration might include setting the local values of the SSID, PHY channel, beacon interval, and so on.

## N.5 Primary DS functions

The primary functions of the DS (i.e., the DSSs) are as follows:

a) Map mobile unit to AP (for DS-to-mobile unit traffic delivery).
b) Move data.

The DS's mobile unit-to-AP map determines which AP is to be used for a given mobile unit's data delivery. This function includes mapping update adjustments, which are based on notification from the APs, of changes in mobile unit access control.

Moving data consists of moving MSDUs among the APs (including returning MSDUs to the source AP for mobile unit-to-mobile unit communications) and between the APs and the portal.

## N.6 Primary portal function

The primary function of a portal is as follows:

a) Move data with a special data movement function called *data transformation*.


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Moving data consists of moving MSDUs between the DS and the external non-IEEE-802.11 LAN. Moving data through the portal transforms the MSDUs using the integration function. The integration function translates external non-IEEE-802.11-LAN MSDUs to and from IEEE 802.11 MSDUs using, for example, the procedures defined in Annex M.

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# Annex O

(informative)

# Additional HT, VHT, and S1G information

## O.1 HT, VHT, and S1G waveform generator tool

As an informative extension to this standard, waveform generator tools have been written to model the PHY transmission process described in Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification), Clause 18 (Extended Rate PHY (ERP) specification), Clause 19 (High Throughput (HT) PHY specification(#2297)), Clause 21 (Very high throughput (VHT) PHY specification), and Clause 23 (Sub 1 GHz (S1G) PHY specification(#4095)).

The waveform generator can be downloaded from the public IEEE 802.11 document website. The waveform generator code that includes Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification), Clause 18 (Extended Rate PHY (ERP) specification), and Clause 19 (High Throughput (HT) PHY specification(#2297)) is contained in document 11-06/1715, and the waveform generator description is contained in document 11-06/1714 (HT code). A description of the waveform generator that includes Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification), Clause 19 (High Throughput (HT) PHY specification(#2297)), and Clause 21 (Very high throughput (VHT) PHY specification) and the waveform generator code itself is contained in document 11-11/0517 (VHT code). A description of the waveform generator that includes Clause 23 (Sub 1 GHz (S1G) PHY specification(#4095)) and the waveform generator code itself is contained in document 11-14/0631 (S1G code).

The purpose of these tools is to promote common understanding of complex PHY algorithms, facilitate device interoperability by providing reference test vectors, and assist researchers in industry and academia to develop next generation wireless solutions.

The code is written in the MATLAB computing language and can be configured to generate test vectors for most PHY configurations, defined by this standard. Instructions on how to configure and run the tools are specified in the referenced documents.

A command line interface and graphic user interface (GUI) exist to configure the HT code tool. For consistency with this standard, the configuration interface is made very similar to the TXVECTOR parameters defined in 19.2.2 (TXVECTOR and RXVECTOR parameters).

A command line interface is used to configure the VHT code tool. For consistency with this standard, the configuration interface is made very similar to the TXVECTOR parameters defined in 21.2.2 (TXVECTOR and RXVECTOR parameters).

A GUI exists to configure the S1G code tool.

The HT and VHT waveform generator tool produces test vectors for all transmitter blocks, defined in Figure 19-2 (Transmitter block diagram 1) and Figure 19-3 (Transmitter block diagram 2), generating reference samples in both frequency and time domains. Outputs of the tool are time domain samples for all transmitting chains.#


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The S1G waveform generator tool produces test vectors for transmitter blocks that support 1 MHz and 2 MHz channel widths, defined in 23.3.3 (Transmitter block diagram), generating reference samples in both frequency and time domains. Outputs of the tool are time domain samples for 1 and 2 spatial streams.

NOTE—In the case of a nonaggregated packet the S1G waveform generator tool does not correctly set the signal field length subfield to indicate the packet duration in number of octets in the PSDU.

## O.2 A-MPDU deaggregation

This subclause contains a description of the deaggregation process. Other implementations are also possible.

The receiver checks the MPDU delimiter for validity based on the CRC. It can also check that the length indicated is within the value of the LENGTH parameter indicated in RXVECTOR.

If the MPDU delimiter is valid, the MPDU is extracted from the A-MPDU. The next MPDU delimiter is expected at the first multiple of 4 octets immediately after the current MPDU. This process is continued until the end of the PPDU is reached.

If the MPDU delimiter is not valid, the deaggregation process skips forward 4 octets and checks to see whether the new location contains a valid MPDU delimiter. It continues searching until either a valid delimiter is found or the end of the PSDU is reached based on the value of the LENGTH parameter indicated in the RXVECTOR.[59]

An A-MPDU parsing (deaggregation) algorithm is expressed (as a C programming language snippet) in Figure O-1 (A-MPDU parsing).

[59] This procedure occasionally wrongly interprets a random bit-pattern as a valid delimiter. When this happens, the MAC attempts to interpret a random MPDU. The MAC discards it with a high probability based on a check of the FCS field.

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```
void Parse_A_MPDU (int length)
{
  int offset = 0; /* Octet offset from start of PSDU */
  while (offset+4 < length)
  {
    if (valid_MPDU_delimiter(offset) &&
        get_MPDU_length(offset) <= (length -(offset+4)))
    { /* Valid delimiter */

      /* Receive the MPDU */
      Receive_MPDU(offset+4, get_MPDU_length(offset));

      /* advance by MPDU length rounded up to a multiple of 4 */
      offset += 4 + 4*((get_MPDU_length(offset)+3)/4);
    }
    else /* Invalid delimiter */
    {
      /* Advance 4 octets and try again */
      offset += 4;
    }
  }
}
```

NOTE 1—This algorithm is not optimized for efficiency.

NOTE 2—The delimiter signature can be used to reduce the amount of computation required while scanning for a valid delimiter. In this case, the receiver tests each possible delimiter for a matching Delimiter Signature field. Only when a match is discovered does it then check the CRC.

**Figure O-1—A-MPDU parsing**



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## O.3 Example of RD frame exchanges(#109)

Figure O-2 (Example of RD frame exchanges showing response burst(#109)) shows an example of the operation of the RD rules, defined in 10.29 (Reverse direction protocol).

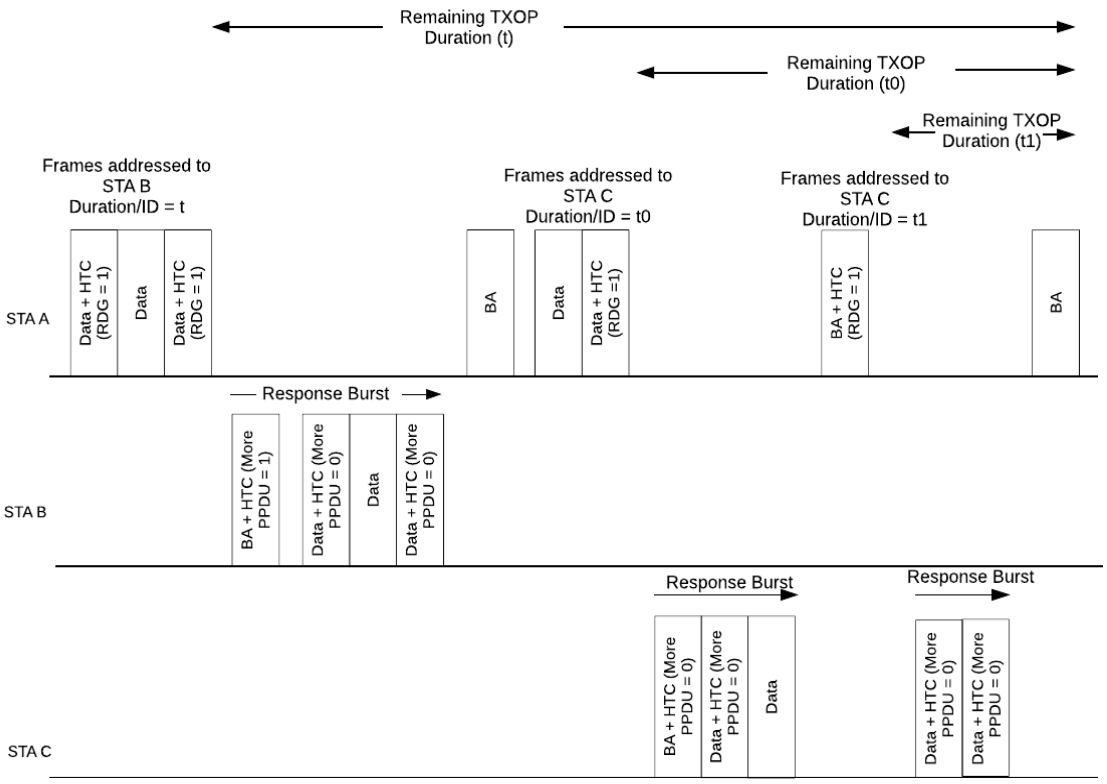


**Figure O-2—Example of RD frame exchanges showing response burst(#109)**

The following is a summary of Figure O-2 (Example of RD frame exchanges showing response burst(#109)):

a) STA A (acting as RD initiator) transmits a PPDU containing MPDUs addressed to STA B (acting as RD responder). The ack policy of the QoS Data frames in this PPDU is Implicit BAR. One or more MPDUs within this PPDU include an HT Control field with the RDG/More PPDU subfield set to 1, indicating an RDG. The Duration/ID field of MPDUs within the PPDU contains the remaining duration of the TXOP, t μs.

b) STA B (the RD responder) responds with the transmission of a +HTC BlockAck frame in which the RDG/More PPDU subfield is set to 1, indicating that another PPDU will follow a SIFS or RIFS after the end of the PPDU containing the BlockAck frame.

c) STA B transmits a PPDU (the second PPDU of an RD response burst) to STA A, with Implicit BAR ack policy for its QoS Data frames and containing one or more +HTC MPDUs in which the RDG/ More PPDU subfield is set to 0, indicating that this is the last PPDU in the response burst.

d) STA A (the RD initiator) regains control of the TXOP and transmits a BlockAck frame addressed to STA B to acknowledge the MPDUs transmitted by STA B in the RD response burst.

e) STA A (the RD initiator) transmits a PPDU containing MPDUs addressed to STA C (acting as RD responder). The ack policy of the QoS Data frames in this PPDU is Implicit BAR. This PPDU includes one or more +HTC MPDUs in which the RDG/More PPDU subfield is set to 1, indicating

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an RDG. The Duration/ID field of MPDUs in the PPDU contains the remaining duration of the TXOP, t0 μs.

f) STA C (the RD responder) transmits a PPDU to STA A, containing one or more +HTC MPDUs with the RDG/More PPDU subfield set to 0, indicating that this is the last PPDU in the response burst. This PPDU contains a BlockAck frame that is a response to the implicit block ack request of the previous PPDU, plus QoS Data frames with Implicit BAR ack policy.

g) STA A (the RD initiator) regains control of the TXOP and transmits a BlockAck frame to STA C that acknowledges the MPDUs transmitted by STA C. This PPDU contains one or more +HTC MPDUs with the RDG/More PPDU subfield set to 1, indicating an RDG. The Duration/ID field of MPDUs in the PPDU contains the remaining duration of the TXOP, t1 μs.

h) STA C (the RD responder) transmits a PPDU to STA A, containing QoS data +HTC MPDUs with Implicit BAR ack policy and the RDG/More PPDU subfield set to 0. This is the only PPDU in the RD response burst.

i) STA A transmits a BlockAck frame to STA C that acknowledges the MPDUs transmitted by STA C in the RD response burst.

## O.4 Illustration of determination of NDP addresses

Determination of NDP SA and DA are illustrated in Figure O-3 (Determination of NDP source and destination for unidirectional NDP sequences) and Figure O-4 (Determination of NDP source and destination for bidirectional NDP sequence).

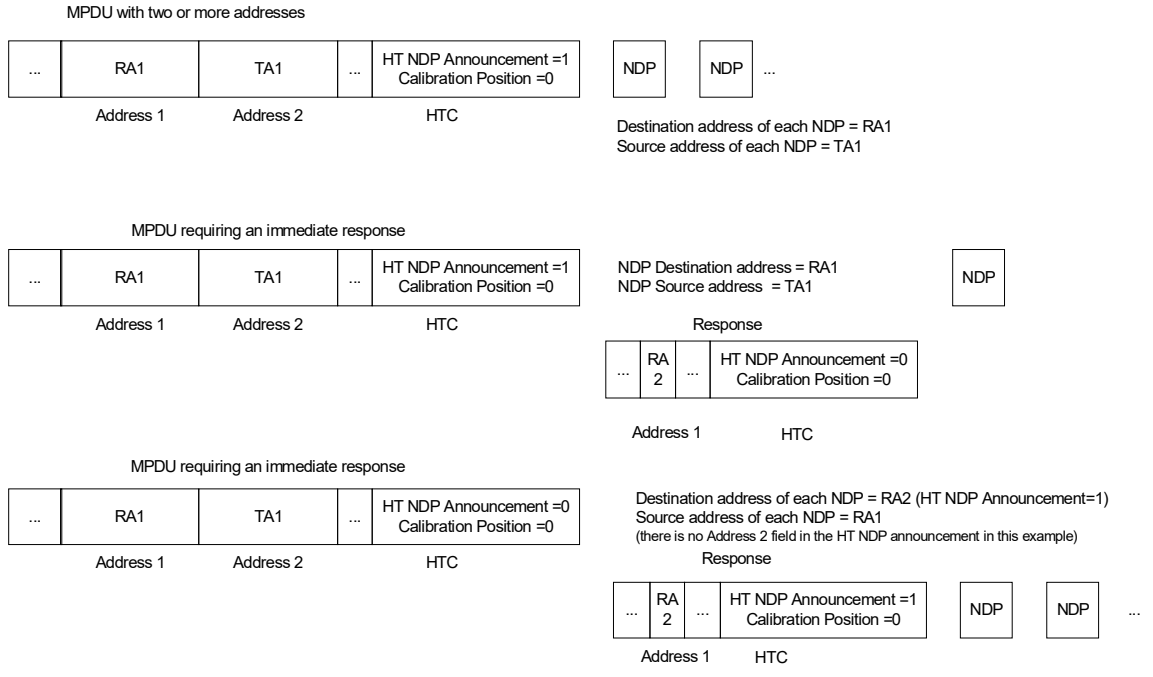


**Figure O-3—Determination of NDP source and destination for unidirectional NDP sequences**



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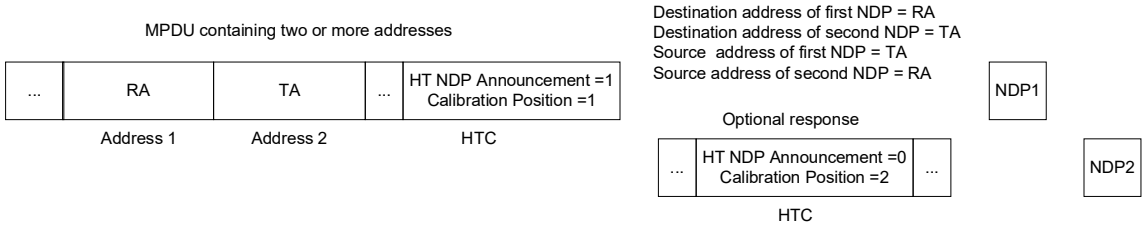


**Figure O-4—Determination of NDP source and destination for bidirectional NDP sequence**

## O.5 20/40 MHz BSS establishment and maintenance

### O.5.1 Signaling 20/40 MHz BSS capability and operation

A BSS that occupies 40 MHz of bandwidth and that is administered by an HT AP is called a *20/40 MHz BSS*.

An HT AP that has dot11FortyMHzOperationImplemented equal to true sets the Supported Channel Width Set subfield of the HT Capabilities element to a nonzero value. The AP might also operate a 20/40 MHz BSS. The Supported Channel Width Set subfield of the HT Capabilities element that is transmitted by the AP indicates the possible operating mode of the BSS and of the AP, but the value in this field is not an indication of the current BSS bandwidth of either the AP or the BSS.

An HT AP signals the operating width of the BSS through the Secondary Channel offset field of the HT Operation element. A nonzero value in this field indicates that a secondary channel exists; in other words, the BSS is a 20/40 MHz BSS. A value of 0 in this field indicates that the BSS is operating as a 20 MHz BSS.

An HT AP that has dot11FortyMHzOperationActivated equal to true sets its STA Channel Width field of the HT Operation element to (#4203)1.

### O.5.2 Establishing a 20/40 MHz BSS

Before starting a 20/40 MHz BSS, a 40MC HT AP is required by the rules defined in 11.15.5 (Scanning requirements for 40MC HT STA 2G4) to examine the channels of the current regulatory domain to determine whether the operation of a 20/40 MHz BSS might unfairly interfere with the operation of existing 20 MHz BSSs. The AP (or some of its associated HT STAs) is required to scan all of the channels of the current regulatory domain in order to ascertain the operating channels of any existing 20 MHz BSSs and 20/40 MHz BSSs. This type of scanning is called *OBSS scanning*. The particulars of OBSS scanning are controlled by the following:

- dot11FortyMHzOptionImplemented
- dot112040BSSCoexistenceManagementSupport
- dot11FortyMHzIntolerant
- dot11BSSWidthTriggerScanInterval
- dot11BSSWidthChannelTransitionDelayFactor
- dot11OBSSScanPassiveDwell
- dot11OBSSScanActiveDwell
- dot11OBSSScanPassiveTotalPerChannel
- dot11OBSSScanActiveTotalPerChannel
- dot11OBSSScanActivityThreshold

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Specific values for these MIB attributes are provided to set minimum scan times for passive scanning of each channel, and a separate minimum time is provided for active scanning of each channel. A total minimum amount of scanning per channel is required before a determination can be made to allow the operation of a 20/40 MHz BSS.

The rules that are applied when determining whether a 20/40 MHz BSS can be established are intended to avoid a full or partial overlap of the secondary channel of the 20/40 MHz BSS with an existing primary channel of either a 20 MHz BSS or a 20/40 MHz BSS. The lack of partially overlapping channels in the 5 GHz band allows these rules to be written as recommendations, while in the 2.4 GHz band, they are requirements.

An additional constraint on establishing a 20/40 MHz BSS includes the allowance for any IEEE 802.11 device to explicitly prohibit the operation of the 40 MHz operating channel width due to other considerations. For example, if an IEEE 802.15.1™ WPAN device is operating in the area, that device is likely to be unable to communicate successfully with a paired receiver if the number of available IEEE 802.15.1 WPAN channels falls below a given threshold. Operation of a 20/40 MHz BSS in the 2.4 GHz band can contribute to the reduction of the number of available IEEE 802.15.1 WPAN channels, possibly pushing the available channels below that threshold.

To promote sharing of the spectrum resource under such circumstances, it might be desirable to prohibit the operation of a 20/40 MHz BSS. As such, the 20/40 BSS coexistence mechanism allows a STA to transmit Management frames containing a value of 1 for the Forty MHz Intolerant field. (dot11FortyMHzIntolerant determines the setting of the value of the Forty MHz Intolerant field in transmitted frames, and the setting of the value of the MIB attribute is beyond the scope of this standard.) Receivers of such frames on any channel in the band are not allowed to establish a 20/40 MHz BSS anywhere in the band for a duration of dot11BSSWidthChannelTransitionDelayFactor × dot11BSSWidth-TriggerScanInterval seconds. To effect this requirement, monitoring STAs and APs maintain a countdown timer to indicate that a prohibition is in force. The countdown timer is reloaded with the value dot11BSSWidthChannelTransitionDelayFactor × dot11BSSWidthTriggerScanInterval seconds each time that the STA or AP observes a Management frame containing a value of 1 for the Forty MHz Intolerant field. STAs communicate changes in their countdown counter (i.e., transitions between a zero value and a nonzero value) to their associated AP through the 20 MHz BSS Width Request field of the 20/40 BSS Coexistence Management frame.

### O.5.3 Monitoring channels for other BSS operation

Some of the STAs that are associated with a 20/40 MHz BSS perform monitoring so that the conditions which allowed the establishment of the 20/40 MHz BSS do not change to conditions that would disallow the existence of the 20/40 MHz BSS.

Monitoring STAs keep a local record of channels that are in use by other BSSs. STAs that receive Beacon frames determine the primary channel by examining the DSSS Parameter Set element. Secondary channel existence and channel information are determined by examining the Secondary Channel Offset field of the 20/40 BSS Coexistence element. Monitoring STAs also record receptions of frames that contain a value of 1 for the Forty MHz Intolerant field. Any changes to the local record that would create a prohibition against 20/40 MHz BSS operation are immediately reported to the associated AP through the transmission of a 20/40 BSS Coexistence Management frame (i.e., with the 20 MHz BSS Width Request field set to 1). The reception of a 20 MHz BSS Width Request field equal to 1 at the AP causes the AP to switch the BSS to 20 MHz operation immediately.

Any change of a channel in use that had not previously been in use is also reported immediately within a 20/40 BSS Coexistence Management frame. The AP examines the new in-use channel information to determine whether any changes in BSS width operation are required (i.e., to see if any changes have


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occurred that indicate an overlap of the secondary channel). If a change to 20 MHz BSS operation is required, the change occurs immediately.

Conditions that prevent the operation of a 20/40 MHz BSS might be transient. If the number of channels in use is reduced or all STA signaling 40 MHz intolerance leave the area, an AP might choose to revert to 20/40 MHz operation, if allowed to do so. However, the conditions that allow 20/40 MHz BSS operation have to persist for a period of dot11BSSWidthChannelTransitionDelayFactor × dot11BSSWidthTriggerScanInterval seconds before a STA can signal that the conditions have changed, and the same period of time has elapsed before an AP can resume 20/40 MHz BSS operation.

STAs that do not monitor channels through OBSS scanning and do not report any channel information or received Forty MHz Intolerant field information to their associated AP are listed here:

— Non-HT STAs
— HT STAs that are exempt from scanning as specified in 11.15.6 (Exemption from OBSS scanning)
— HT APs, once the 20/40 MHz BSS is established
— HT STAs that are associated with an AP whose BSS is operating on a channel that is not in the 2.4 GHz band
— HT STAs that are associated with an HT AP that is not a 40MC HT AP (as indicated by a value of 0 in the Supported Channel Width Set subfield of the HT Capabilities element)

All other HT STAs that are associated with a a 40MC HT AP whose BSS is operating on a channel in the 2.4 GHz band monitor channels through OBSS scanning and report any channel information or received Forty MHz Intolerant field information to their associated AP.

All MIB attributes that are employed by the 20/40 BSS Coexistence mechanism are maintained by the AP, which has the ability to provide updates to the MIB attribute values to the associated STA by transmitting an OBSS Scan Parameters element.

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# Annex P

(informative)

# Location and Time Difference accuracy test

## P.1 Location via Time Difference of arrival

The location of a device might be determined using multiple methods, including:

- Signal strength at different sensors
- Time of flight between the device and different sensors
- Time difference of arrival between the device and pairs of sensors

A typical implementation of the time difference of arrival method requires that the sensors are co-channel, have synchronized clocks, and receive the same transmission from the device. The sensor's time of arrival measurements are shared, and the device location is determined via multilateration, i.e., each pair of sensor measurements provides a time difference of arrival measurement that represents a hyperbola in 2D space of most likely candidate locations, and the overlap of the multiple hyperbola from multiple pairs of sensors leads to the location estimate. The single time of departure is not relevant in this typical multilateration implementation as it is canceled out when time differences of arrival are computed.

When the sensors are on different channels, such as APs in a typical multichannel deployment, the device transmits on each channel and thus with multiple times of departure. In this environment it is necessary for the device to advertise each time of departure so that it can be subtracted from the times of arrivals measured by sensors on different channels. Furthermore, the device's clock frequency typically does not match the clock frequency of the synchronized sensors, and so the device should transmit on the same channel multiple widely spaced times in order for the sensors to estimate the device's clock frequency relative to themselves and to be able to suitably scale the device's advertised times of departure.

An example transmission sequence comprises frames transmitted on channels 1, 6, 11, 1 at 2.4 GHz. From this, the device's clock frequency can be determined relative to the synchronized APs on channel 1, and all APs on channels 1, 6, and 11 can measure a time of arrival. These four transmissions enable a single location calculation. The Time of Departure Accuracy test in P.2 (Time Difference of departure accuracy test) is designed to measure errors within such a transmission sequence that would degrade a multichannel time difference of arrival location scheme.

## P.2 Time Difference of departure accuracy test

The Time Difference of Departure accuracy test is an informative description of how time difference of departure accuracy can be measured for any parameterizable PHY waveform. This accuracy test does not apply when the Time of Departure timestamps are exclusively used for timing measurement (see 11.21.5 (Timing measurement procedure)).

The Time Difference of Departure accuracy test is parameterized by the following test parameters:

- TIME_OF_DEPARTURE($j,i$), $1 \le j \le 500$, $1 \le i \le I$ (scalar entries)
- MULTICHANNEL_SAMPLING_RATE (scalar)
- FIRST_TRANSITION_FIELD($j,i$), $1 \le j \le 500$, $1 \le i \le I$ (waveform entries)
- SECOND_TRANSITION_FIELD($j,i$), $1 \le j \le 500$, $1 \le i \le I$ (waveform entries)


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— TRAINING_FIELD($j,i$), $1 \le j \le 500$, $1 \le i \le I$ (waveform entries)
— TIME_OF_DEPARTURE_ACCURACY_TEST_THRESH (scalar)

TIME_OF_DEPARTURE(j,i) is exposed externally through the TOD Timestamp field in the Time of Departure subelement in Location Track Notification frames.

The Time Difference of Departure accuracy test is performed as follows or in an equivalent or more accurate manner.

The Time Difference of Departure accuracy test is performed by instrumentation capable of converting signals transmitted on one or more channels into a stream of complex samples at $f_s$ sample/s or more, with sufficient accuracy in terms of I/Q arm amplitude and phase balance, dc offsets, phase noise, etc, and at a fixed delay from the transmitter. The minimum sampling rate is MULTICHANNEL_SAMPLING_RATE expressed in sample/s. A possible embodiment of such a setup is converting the signal to a low IF frequency with a cabled microwave synthesizer, sampling the signal with a digital oscilloscope and decomposing it digitally into quadrature components. The sampled signal is processed in a manner similar to an actual time of arrival processor, according to the following steps:

a) Repeat steps b) to j) indexed by $j = 1, \ldots, 500$
b) Repeat steps c) to i) indexed by $i = 1, \ldots, I$
c) Start of frame is detected.
d) Channel number, coarse and fine frequency offsets are estimated.
e) The packet is derotated according to estimated frequency offsets.
f) The transition from FIRST_TRANSITION_FIELD($j,i$) to SECOND_TRANSITION_FIELD($j,i$) is detected; and fine timing (with one sample resolution) is established.
g) The TRAINING_FIELD($j,i$) of the derotated signal is upsampled to meet the TIME_OF_DEPARTURE_ACCURACY_TEST_THRESH requirement. For example, a TIME_OF_DEPARTURE_ACCURACY_TEST_THRESH of 1 ns requires upsampling of at least 1 GHz.
h) The up-sampled signal is cross-correlated with a reference waveform of the TRAINING_FIELD($j,i$)
i) The measured time of departure $x_{j,i}$ is determined from the time of the peak of the magnitude of the cross-correlation.

NOTE 1—The time of the peak of the magnitude of the cross-correlation is actually a time of arrival measurement that equals the time of departure up to a fixed delay. Since the fixed delay is removed within step j), the fixed need not be known or explicitly compensated for.

j) Having repeated steps c) to i) $I$ times, the ($j,i$)th time of departure error $e_{j,i}$ is calculated as TIME_OF_DEPARTURE($j,i$) minus the synchronized time of departure. Defining (#515)$x_j = [x_{j,1}, \ldots, x_{j,I}]^T$ as the $I$ measured times of departure, $y$ = [TIME_OF_DEPARTURE($j$,1), … TIME_OF_DEPARTURE($j,I$)]$^T$, $e_j = [e_{j,1}, e_{j,I}]^T$ are the $I$ time of departure errors and $X_j = [1_{I\times 1}, x_j]$, where $1_{I\times 1}$ is an $I \times 1$ matrix of 1s, then the relative clock intercept, $rci_j$, and slope, $rcs_j$, between device and instrumentation are determined as the linear least squares line of best fit: i.e., $[rci_j, rcs_j]^T = (X_j^T X_j)^{-1} X_j^T y^j$. With these definitions and calculations, the synchronized time of departure $s_j$ = (#515)$[s_{j,1}, \ldots, s_{j,I}]^T$ equals $rcs_j \times x_j + rci_j \times 1_{I\times 1}$, and so the $I$ time of departure errors equal $e_j = y_j - s_j$.
k) Having repeated steps b) to j) 500 times, there are $500 \times I$ values of the time of departure errors $e = [e_{1,1}, e_{500,I}]$
l) The Time Difference of Departure accuracy test is passed if both of the following conditions are met:

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1) The RMS value of *e* is less than aTxPHYTxStartRMS.
2) aTxPHYTxStartRMS is less than TIME_OF_DEPARTURE_ACCURACY_TEST_THRESH, where the units of *e*, aTxPHYTxStartRMS, and TIME_OF_DEPARTURE_ACCURACY_TEST_THRESH are properly accounted for.

NOTE 2—One possible implementation of a time of departure measurement system is a free-running oscillator clocking (a) the digital-to-analog converter(s) used to transmit the packet, (b) a 32-bit continuously counting counter, and (c) a hardware finite state machine such that PHY-TXSTART.request primitive causes a transition within the finite state machine that in turn causes frame transmission at the DACs a fixed number of cycles later; where the time of departure is recorded as the value of the counter at that transition minus aTxPHYTxStartRFDelay (using TIME_OF_DEPARTURE_ClockRate), where aTxPHYTxStartRFDelay can vary by channel. In this implementation, the principal source of time of departure error is short-term oscillator imperfection (e.g., phase noise) and RF group delay variation across channels uncompensated by aTxPHYTxStartRFDelay.

NOTE 3—One ns of time of departure error corresponds to approximately 0.3 m of distance error, so high location accuracy depends upon a tight time of departure standard deviation.

## P.3 Differential Distance Computation using FTM frames(#7223)

In Figure P-1 (Parameters recorded by Observing STA when monitoring FTM frames(#7223)(M13)) the Observing STA is able to listen to the FTM frame(#7223) exchange between the Sending and Receiving STAs. The time of flight of a line of sight transmission between the Sending and Receiving STAs is denoted as *T*. At the Observing STA, the time of arrival (TOA) of message M and its Ack frame are respectively $t_{c1}$ and $t_{c2}$. At the Sending STA, the time of departure (TOD) of message M and the TOA of its Ack frame are $t_1$ and $t_4$ respectively.

The differential distance between the Observing STA and each of the Sending and Receiving STAs, denoted as $D_{SR}$, is defined as:(11bd)

$$D_{SR} = c \times (T_{SO} - T_{RO}) \quad \text{(P-1)}$$

where

$c$ is speed of the light.
$T_{SO}$ is the time of flight between the Sending STA and the Observing STA
$T_{RO}$ is the time of flight between the Receiving STA and the Observing STA

$D_{SR}$ can now be computed as:(11bd)

$$D_{SR} = c \times (t_{c1} - t_{c2} - T - (t_1 - t_4)) \quad \text{(P-2)}$$

An Observing STA can use the TOA and the time stamps ($t_1$ and $t_4$) received in the following messages in the message exchange to refine its computation of the differential distance to the Sending and Receiving STAs.

In Figure P-1 (Parameters recorded by Observing STA when monitoring FTM frames(#7223)(M13)) the Receiving and Sending STAs can be APs. The APs can learn about neighboring APs that support the FTM procedure and an AP can initiate an FTM message exchange on a periodic basis (e.g., the beacon interval or a multiple of the beacon interval) with its neighbor APs. Monitoring and receiving these messages can enable Observing STAs to estimate their differential distance with the AP pairs. An Observing STA that is able to determine its differential distance to at least three pairs of Sending and Receiving STAs can determine its location using the principle of hyperbolic navigation. An Observing STA can potentially determine its location by monitoring the FTM frames(#7223) of a single AP (Sending STA) if there are three or more neighbor APs of the Sending STA that support FTM.


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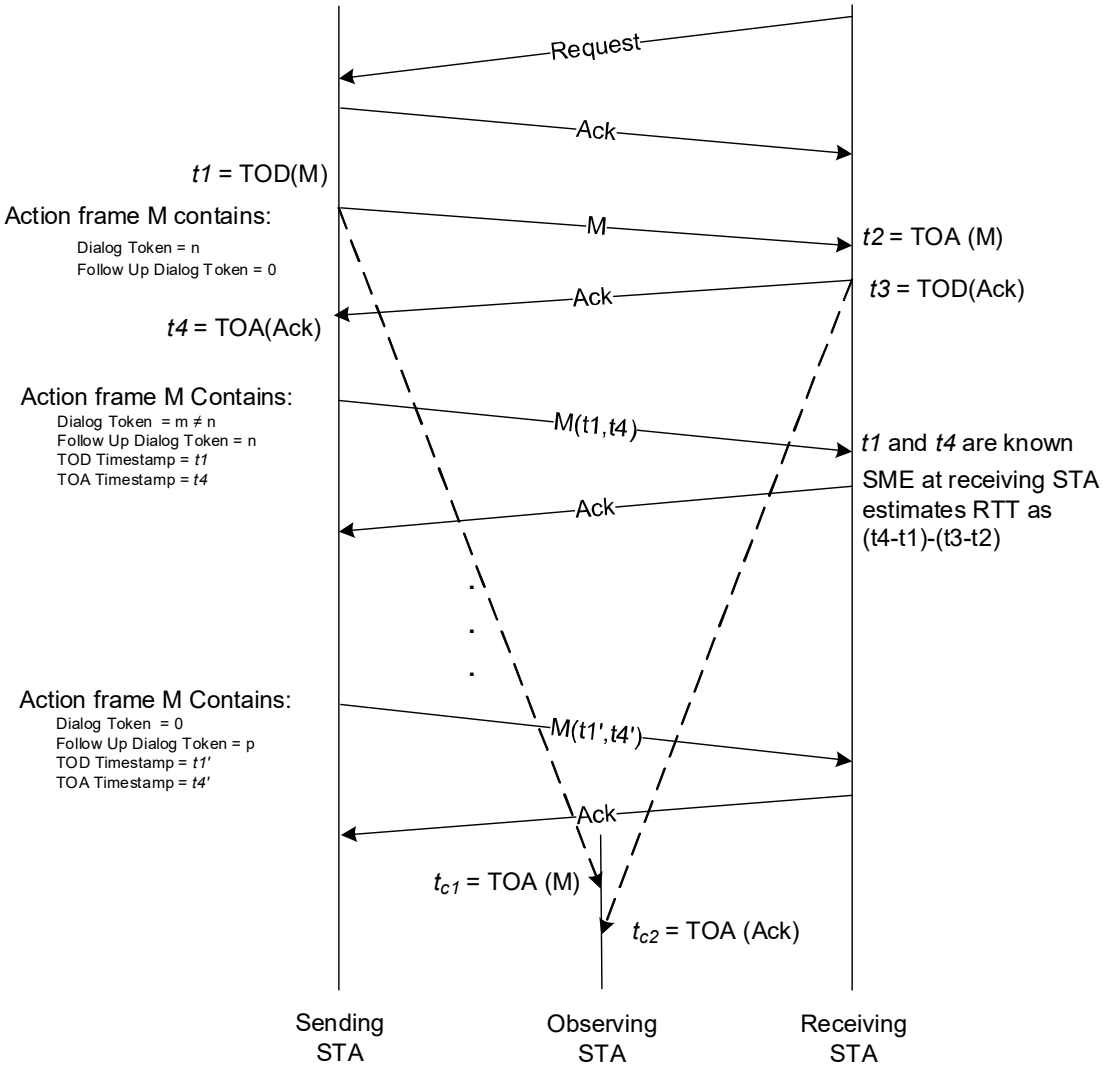


**Figure P-1—Parameters recorded by Observing STA when monitoring FTM frames(#7223)(M13)**

(11bd)In Figure P-2 (Parameters recorded by PSTA when monitoring non-TB ranging measurement exchange(11bd)) the observing or passive STA (PSTA) that supports NGV non-TB ranging is able to listen to the NGV non-TB ranging measurement exchange between (#7140)an initiating STA (ISTA) and a responding STA (RSTA). The time of flight of a line of sight transmission between the ISTA and RSTA is denoted as $T$.At the PSTA, the TOAs of the I2R NDP and the R2I NDP are respectively $t_{c1}$ and $t_{c2}$. At the ISTA, the TOD of the I2R NDP and the TOA of the R2I NDP are $t_1$ and $t_4$, respectively. $D_{SR}$ can now be computed according to Equation (P-2). The PSTA might obtain $t_1$ and $t_4$ by receiving the I2R LMR frame or by higher layer information exchange.

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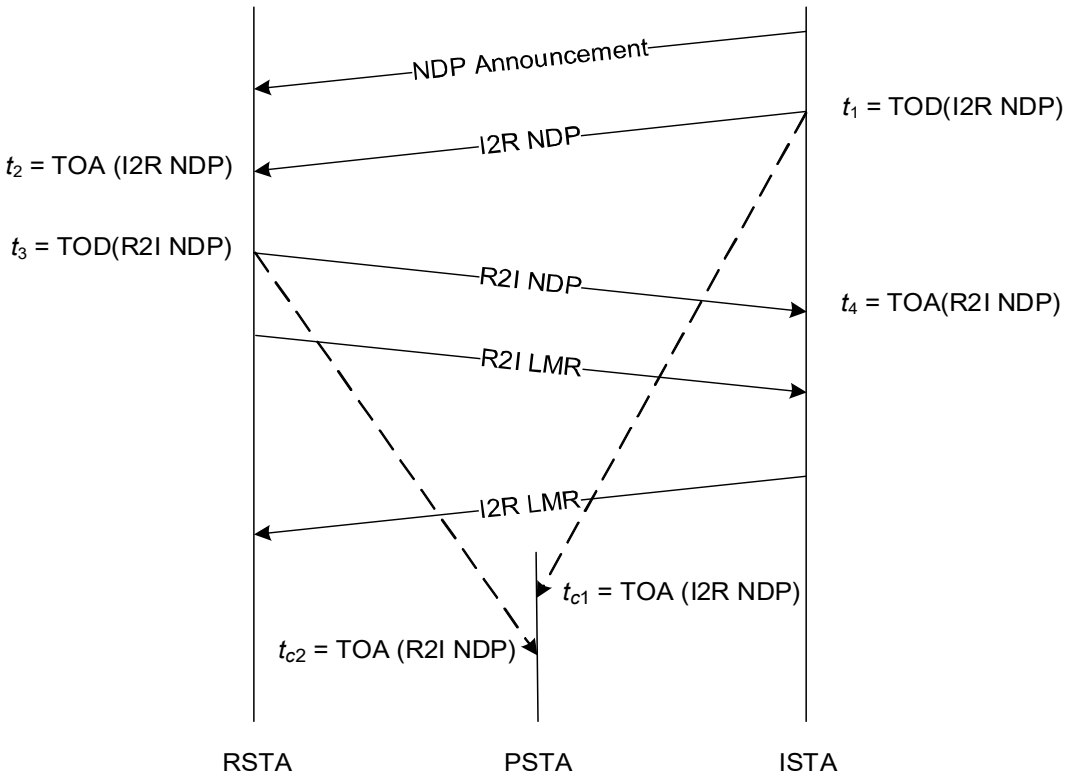


**Figure P-2—Parameters recorded by PSTA when monitoring non-TB ranging measurement exchange(11bd)**


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# Annex Q

(informative)

# Example use of the Destination URI for Event and Diagnostic Reports

## Q.1 Destination URI payload

An example of the payload used to transmit Event and Diagnostic reports shown in Table Q-1 (Destination URI payload). The protocol used to transport the Destination URI payload is beyond the scope of this standard. An example use of the Destination URI is given in Q.2 (Use of HTTP (or HTTPS) for Destination URI of Event and Diagnostic Reports).

**Table Q-1—Destination URI payload**

| Size (octets) | Information |
|---|---|
| 6 | BSSID |
| 6 | Reporting STA Address |
| variable | Event or Diagnostic Report frame contents |

## Q.2 Use of HTTP (or HTTPS) for Destination URI of Event and Diagnostic Reports

Under certain conditions a non-AP STA might need to send Event and Diagnostic reports to an AP using the Destination URI advertised by the AP in the request frame. A suitable higher layer protocol that could be used to transport the Event or Diagnostic report is HTTP or HTTPS.

For example, consider the following:

1) IT is investigating a WLAN coverage problem and uses a non-AP STA with a WLAN and Ethernet adapters to collect some additional information.
2) The non-AP STA with MAC 00-ff-fd-00-00-01 has received a request for a Diagnostic report from AP 00-ff-fe-00-00-10 and is in fringe coverage. The non-AP STA has an Ethernet adapter that is connected.
3) The AP includes an Alternate Destination URI of http://www.myserver.mycompany.com in the Diagnostic Report frame.
4) The non-AP STA loses WLAN connectivity while trying to transmit a Diagnostic Report frame to the AP and the non-AP STA's SME determines that it can use the Alternate Destination URI to send the Diagnostic Report frame using the Ethernet link.
5) The non-AP STA POSTs the Diagnostic report as follows:
   POST /wnm/msg/00-ff-fd-00-00-01/msg1 HTTP/1.1
   Host: http://www.myserver.mycompany.com
   Content-Type: application/octet-stream
   Content-Encoding-Type: base64
   Content-Length: i (length of data as specified in Figure 9-1268 (Diagnostic Report frame Action field format) in 9.6.13.5 (Diagnostic Report frame format))
   <encoded data = 00 ff fe 00 00 10 00 ff fd 00 00 01 …>

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In the HTTPS case, the non-AP STA would need to be provisioned with credentials to establish the TLS connection prior to posting the message over HTTP. The HTTP post would work as described previously.


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# Annex R

(informative)

# Interworking with external networks

## R.1 General

The purpose of this informative annex is to describe and clarify the support for interworking with external networks including the support for network discovery and selection, QoS mapping, SSPN interface, and emergency services and to provide some background information and recommended practices.

## R.2 Network discovery and selection

### R.2.1 General

Interworking service provides features to support the network discovery and selection process a STA uses to choose the network with which to associate. GAS provides a non-AP STA access to an advertisement server (e.g., an IEEE 802.21 Information Server(#580)), which can provide a rich set of information to aid the network discovery and selection process. In addition, interworking service provides lightweight features that also facilitate this process. The following subclauses describe several use cases illustrating how these features can be used to aid in network discovery and selection:

- **Airport:** A traveling (#6062)businessperson needs to connect via an airport hotspot to their enterprise network to download email and information from the customer database.
- **Shopping:** A shopper visits a shopping mall and wants to use a smartphone to discover items on sale.
- **Sales meeting:** A salesperson(#3246) visiting a customer accesses (#6062)their guest network.
- **Museum:** A visitor to a museum uses a smartphone to obtain virtual docent service.
- **Emergency call:** A traveler needs to make an emergency call while in another country.
- **Emergency alert:** A traveler, having enabled the display of emergency alerts, arrives at a new destination.

### R.2.2 Airport

A traveling (#6062)businessperson arrives for the first time at an airport having a WLAN. This user wants to download email onto their laptop utilizing the airport's hotspot, a chargeable network. Once associated, the user needs to connect via VPN connection back to their company's servers to access email and information from the customer database. This is performed as follows:

a) The laptop's non-AP STA performs an active scan by transmitting a Probe Request frame containing the wildcard SSID and an Interworking element with Access Network Type subfield set to "Chargeable Public Network." In response, it receives Probe Response frames from several of the airport's APs, in the immediate neighborhood, for the SSID "Narita Hotspot."

b) The Probe Response frame received by the laptop indicated the following capabilities:

   1) Extended Capabilities element indicates: AP provides interworking service.

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2) Interworking element indicates: venue group = 1 (Assembly) and venue type = 3 (passenger terminal), Internet = 1 (Internet access available), ASRA = 1 (there is an additional step required for network access).
3) Advertisement Protocol element including the Advertisement Protocol ID field set to MIS Information Service.
4) Roaming Consortium element present containing an OI for "Hotspot Roaming International."
5) There is no RSNE present in the received Beacon frame.

c) Since the laptop's SME does not recognize the Roaming Consortium OI, it invokes the GAS protocol to query the network's IEEE 802.21 information service. The IEEE 802.21 Information Server's response indicates the roaming partners for "Narita Hotspot" and the laptop have security credentials for one of them.

d) Since the AP indicated ASRA = 1, the SME again invokes the GAS protocol to retrieve the Network Authentication Type ANQP-element. The response indicates that https redirection is in use and provides the (#7224)redirect URL of hotspot.narita.co.jp. Note that this is helpful since some networks use conditional redirection—that is, access to a walled garden is provided for free, but a subscription fee is required to access the Internet.

e) (#93)In large federations (where multiple venues may allow for multiple sources of identities) using Roaming Consortium OI, the multi-to-multi relationship makes it difficult for the STA to understand which credentials from which members of the consortium are actually accepted by the venue. Beyond posing restrictions on the source of credentials, the venue may also mandate a level of robustness for these credentials. The credentials may then only be accepted if the entity providing them has validated the user identity reliably. When validation is light, credentials that have been in existence for a long time may be seen as more reliable than credentials that were created very recently. Last, the venue may have legal requirements to receive a contactable identity for each user. Since the AP has advertised a Roaming Consortium OI, the laptop SME invokes the GAS protocol to retrieve the Credential Types ANQP-element:

1) The AP response indicates, in the Credential Types ANQP-element, two Credential Types subfields, the first indicating Category Group = 12, Category Type = 1 (Service Provider), Validation = 2 (email, SMS, Government ID or Government issued credentials), Lifetime = 0 (account has been in existence for any duration) and Privacy Indicator = 1 (contactable identity required), the second indicating Category Group = 12, Category Type = 2 (Cloud or Social Media Provider), Validation = 4 (Government ID or Government issued credentials), Lifetime = 4 (account has been in existence for one year or more) and Privacy Indicator = 1 (contactable identity required).
2) The laptop now knows which credentials types are accepted.

f) (#93)Venues accepting several types of credentials may have agreements to provide different level of service for different types of users. These levels of services are usually agreed upon at a large scale (e.g., all members of a federation), and thus use a common naming convention (Gold, Silver, Bronze). Since the AP has advertised a Roaming Consortium OI and support for Service Level Agreement information, the laptop SME invokes the GAS protocol to retrieve the Service Level Agreement ANQP-element. The AP response indicates: First Settlement Indicator = 1 (free services), First SLA Indicator = 1 (Bronze), Second Settlement Indicator = 2 (paid services), Second SLA Indicator = 2 (Silver). The laptop can then select, from the profiles with accepted credentials, those that also accept the SLA offered by the venue.

g) Since the laptop's SME now knows it should be able to successfully authenticate with the network, the STA associates with(#1427) the AP.

h) The following operations are then carried out by higher layers operating within the laptop:

1) The laptop's SME autonomously launches an http client and provides to it the URL of hotspot.narita.co.jp, which provides the proper security credentials to the network and thereby successfully authenticates it to the network.


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2) The VPN client is autonomously launched and a secure session to the user's corporate network is established. Then the user launches the email application to download email and other required information.

### R.2.3 Shopping

A shopper visits a shopping mall and wants to use a smartphone to discover items on sale. In this mall, the mall's IT department is providing WLAN facilities for all of the stores in the mall; therefore, there is only one SSID for shoppers (i.e., there is not a different SSID for each store in the mall). The user arrives at the mall and taps an icon on the screen to put the smartphone in "shopping mode." The smartphone's shopping application causes the non-AP STA to carry out the following steps:

a) The smartphone's non-AP STA performs an active scan by transmitting a Probe Request frame containing the wildcard SSID and an Interworking element with Access Network Type subfield set to "Free Public Network." In response, it receives Probe Response frames from several of the mall's APs, but only one SSID is provided, which is "Silicon Valley Mall." The mall's APs did not transmit Probe Response frames for the SSIDs "Engineering," "Deliveries," and "Janitorial" since their access network type is "Private network."

b) The Probe Response frame received by the smartphone indicated the following capabilities:

1) Extended Capabilities element indicates: AP provides interworking service.

2) Interworking element indicates: venue group = 6 (mercantile) and venue type = 4 (shopping mall), Internet = 0 (unspecified).

3) RSNE indicates: IEEE 802.1X authentication.

c) Since the AP indicated Interworking service is available, the smartphone's non-AP STA uses the MLME-GAS.request primitive to invoke GAS to request the Capability List ANQP-element (see 9.4.5.3 (Capability List ANQP-element)). In the Capability List ANQP-element, the AP has indicated (#1606)support for the Venue Name, Domain Name, and Excluded NAI Realm ANQP-elements.(#93) Subsequent to receipt of the Capability List ANQP-element, the non-AP STA invokes the MLME-GAS.request primitive to retrieve the other (#93)lists.

d) Next, the non-AP STA's Supplicant(#1441)(#1380) searches the received domain name(#1405) list to determine whether it has any stored credentials for these domains.

e) (#93)In some cases, the venue may also not accept credentials from competing entities. Therefore, the non-AP STA's Supplicant(#1441)(#1380) also searches the list of excluded NAI realms to determine which realm credentials are not accepted. The non-AP STA discards the credentials that match elements of the excluded NAI realm list returned by the AP. If the non-AP STA finds accepted credentials,

1) The smartphone autonomously associates with(#1427) the "Silicon Valley Mall Shopping" SSID and displays the following information:

i) Venue name: Silicon Valley Mall, 1234 Main Street, Rownhams, CA 98765-1234

ii) SSID: Silicon Valley Mall

iii) Venue type: Shopping Mall

2) The Supplicant(#1441)(#1380) autonomously provides the security credentials for the selected domain.

f) Higher layer protocols then download discount coupons being offered for items on sale.

### R.2.4 Sales meeting

A salesperson(#3246) travels across town to a meeting at ACME Manufacturing. While there, this user needs to send email to get a document from engineering. The user requests (#4182)WLAN guest access via their laptop's UI to search for guest networks.(#3246) The laptop performs the following steps:

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a) The laptop's non-AP STA performs an active scan by transmitting a Probe Request frame containing the wildcard SSID and an Interworking element with Access Network Type subfield set to "Private Network with Guest Access." In response, it receives Probe Response frames from several of ACME Manufacturing's APs, but only one SSID is provided, which is "Guest." ACME Manufacturing's APs did not transmit Probe Responses for the SSIDs "Engineering" and "Finance" since their access network type is "Private network."

b) The Probe Response frame received by the laptop indicated the following capabilities:

   1) Extended Capabilities element indicates: AP provides interworking service.

   2) Interworking element indicates: Internet is available, venue group = 2 (Business) and venue type = 8 (Research and Development Facility).

   3) RSNE indicates: IEEE 802.1X authentication with CCMP-128 pairwise, group data cipher suites, and group management cipher suite.(#6020)

c) Since the AP indicated interworking service is available, the laptop's non-AP STA uses the MLME-GAS.request primitive to invoke GAS to request the Capability List ANQP-element (see 9.4.5.3 (Capability List ANQP-element)). In the Capability List ANQP-element, the AP has indicated (#1607)support for the Venue Name ANQP-element. Upon receipt of the Capability List ANQP-element, the non-AP STA again invokes the MLME-GAS.request primitive to retrieve the venue name.

d) The laptop's UI displays the following information and automatically associates with(#1427) the network:

   1) SSID: Guest (Type: Private network with Guest access)

   2) Venue name: ACME Manufacturing, 1234 Main Street, Rownhams, CA 98765-1234

   3) Venue type: Research and Development Facility

   4) Internet is available

e) Upon prompt, the user enters the username and password supplied by (#6062)their point of contact from ACME Manufacturing and is then able to send and receive email.

### R.2.5 Museum

A visitor enters a museum that is advertising virtual docent service (audio tracks describing each of the major exhibits). The visitor taps an icon on a smartphone and requests it to search for free networks. The smartphone then carries out the following:

a) The smartphone's non-AP STA performs an active scan by transmitting a Probe Request frame containing the wildcard SSID and an Interworking element with Access Network Type subfield set to "Free Public Network." In response, it receives Probe Response frames from several of the museum's APs, but only one SSID is provided, which is "Visitors." The museum's APs did not transmit Probe Response frames for the SSID "Maintenance" since its access network type is "Private network."

b) The Probe Response frame received by the smartphone indicated the following capabilities:

   1) Extended Capabilities element indicates: AP provides interworking service.

   2) Interworking element indicates: venue group = 1 (assembly), venue type = 9 (museum), and ASRA = 0 (no additional steps are required for access).

c) Since the AP indicated interworking service is available, the smartphone's non-AP STA uses the MLME-GAS.request primitive to invoke GAS to request the Capability List ANQP-element (see 9.4.5.3 (Capability List ANQP-element)). In the Capability List ANQP-element, the AP has indicated (#1607)support for the Venue Name ANQP-element. Upon receipt of the Capability List ANQP-element, the non-AP STA again invokes the MLME-GAS.request primitive to retrieve the venue name.


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d) The smartphone's UI displays the following information, asking the user whether they wish to connect to the network:
   1) Venue name: Museum of Modern Art (MOMA)
   2) SSID: Visitors
   3) Venue type: Museum
   4) No authentication required

e) The user taps the "Connect" icon on the smartphone's display. Note that the smartphone's non-AP STA knows that the network uses Open System authentication since there is no RSNE present in the beacon and ASRA = 0.

### R.2.6 Emergency call

A traveler needs to make an emergency call while in another country. The traveler might not be aware of the emergency call numbers that are used in that country. Being in this new location for the first time, the traveler is not aware of which local access points provide access for emergency calling. (Note that emergency calling requires higher layer application(s) that are outside the scope of this standard.) This is performed as follows:

a) The traveler's non-AP STA performs an active scan by transmitting a Probe Request frame containing the wildcard SSID and an Interworking element. (If the non-AP STA is already associated with an AP that has indicated support for emergency service in its beacon, the probe request would not be necessary.)

b) In response, it receives Probe Response frames from one or more APs indicating support for emergency service in the Access Network Options field of the Interworking element.
   1) Extended Capabilities element indicates: AP provides interworking service.
   2) Emergency services reachability is indicated by the ESR and UESA fields in the Access Network Options field in the Interworking element.
   3) A dedicated emergency services network is indicated by the Access Network Type field in the Interworking element.

c) The traveler's non-AP STA then requests the Emergency Call Number ANQP-element with a GAS Initial Request frame.

d) The GAS Initial Response frame from the AP provides the Emergency Call Number, for example the sequence of digits "911" or an emergency service URN label, URI pair "urn:service:sos.fire, tel:112;sip:+15555551002@fire.com" (IETF RFC 5031 [B46]).

e) This information is passed to the higher layer application in the traveler's non-AP STA.

f) The traveler's non-AP STA then associates with the AP.

g) The traveler's non-AP STA then places the emergency call, (#1776)with an Expedited Bandwidth Request element in an ADDTS Request frame to provide priority to the emergency call.

### R.2.7 Emergency alert

A traveler has enabled the display of emergency alerts on a wireless device (non-AP STA) by appropriately setting the higher layer emergency alert application on the device. The traveler arrives at a new destination and turns on the device. The device, when switched on, will perform a search and then associate with an AP to which the traveler has a subscription or associate with an open AP (if the traveler has enabled the device to do that). During the steps leading up to association, the device, when it becomes aware of an emergency alert, will obtain and display it. The emergency alert will likely be obtained from the AP that has the service to which the traveler has subscribed, but the device might also obtain the emergency alert from other APs, if an AP to which the traveler has a subscription is not available. This is performed as follows:

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a) The traveler's non-AP STA performs an active scan by transmitting a Probe Request frame containing the wildcard SSID. If it is associated with an AP, it checks the beacon.

b) In response, it receives Probe Response frames from one or more APs, which it checks (or, alternately, checks the beacon) for the subscription and also whether the Emergency Alert element indicates that there are emergency alert message(s).

c) If there are one or more emergency alert messages to be downloaded, the Emergency Alert Identifier element provides an Alert Identifier Hash value.

d) The device uses the hash of each of the available emergency message(s) to determine whether that message has already been received or whether it is a new message that needs to be downloaded.

e) If there are one or more emergency alert messages to be downloaded, the device forms the EAS Message URI by concatenating the Emergency Alert URI with the hexadecimal numerals of the Alert Identifier Hash, using the specified method.

f) Should the device be unassociated with an AP when it determines that a new emergency alert is available, it retrieves the EAS message using either GAS procedures with the Advertisement Protocol ID field set to the value for EAS. If the device is associated with the AP, it retrieves the EAS message using either GAS procedures with the Advertisement Protocol ID field set to the value for EAS or, for example, using HTTP.

## R.3 QoS mapping guidelines for interworking with external networks

### R.3.1 General

The EDCA and HCCA mechanism defined in 10.23 (HCF) provide QoS control at the MAC sublayer(#6268). However, the QoS control parameters used by the EDCA and HCCA cannot match directly with other QoS control parameters of the interworked external networks, e.g., SSPN. For example, the SSPN could have different metrics for defining the QoS levels. Destination Network 1 (DN1) and DN2 can use DSCP values differently, (#274)in which case STA1 and STA2 would require different QoS mapping information. Therefore, mapping from these external QoS control parameters to the QoS parameters of this standard is necessary.

The QoS parameters mapping can be used for both uplink and downlink data transmission:

— For uplink: at the non-AP STA, external QoS parameters are mapped to IEEE 802.11 QoS parameters, e.g., DSCP to IEEE 802.11 User Priority and in turn to EDCA ACs. This mapping helps the non-AP STA to construct correct QoS requests to the AP, e.g., the ADDTS Request frame and to transmit frames at the correct priority.

— For downlink: at the AP, DSCP values are mapped to EDCA UPs. Optionally, the non-AP STA can use TSPEC and TCLAS elements in an ADDTS Request frame to set up a traffic stream in the BSS. In this method, the User Priority is specified in the TCLAS element. The policy used by the AP to choose a specific method to map frames to user priorities is outside the scope of this standard.

Different external networks can use different DSCP sets for the same services as described in R.3.3. For example, a 3GPP network can use different code points from that of an enterprise network. The QoS Map distribution mechanism defined in 11.22.9 (Interworking procedures: support for QoS mapping from external networks) provides means to communicate to the STA's mapping information from the network. The mapping of the DSCP to 3GPP Traffic Class is available in GSMA IR.34 v4.6 [B13] (similar to that of GSMA IREG34). See TR 21.905 [B1] for definition of general packet radio service (GPRS) roaming exchange. Enterprise networks use mapping based on application classes defined in IETF RFC 4594 and their mapping to IEEE 802.11 UPs defined in IETF RFC 8325. Mapping between DSCP and UP can be done using Exception fields or by range. The use of DSCP Exception fields maps(M118) a DSCP to a UP.


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Mapping by range requires(M118) the setting of DSCP ranges as per the format defined in 9.4.2.93 (QoS Map element).

### R.3.2 Determination of the mapping for a STA

The QoS mapping to be applied depends upon the network the non-AP STA is accessing. In an interworking IEEE 802.11 infrastructure setting, (#7116)the APs can serve non-AP STAs from different SSPNs on different BSSIDs. As such, these STAs are separated into different BSSs. Figure R-1 (Interworking IEEE 802.11 infrastructure supporting multiple SSPNs(#8231)) presents an example of the scenario (#7116)of an AP using authentication, authorization, and accounting (AAA). In Figure R-1 (Interworking IEEE 802.11 infrastructure supporting multiple SSPNs(#8231)), AAA Server 1 controls access to DN-1 and AAA Server 2 controls access to DN-2.

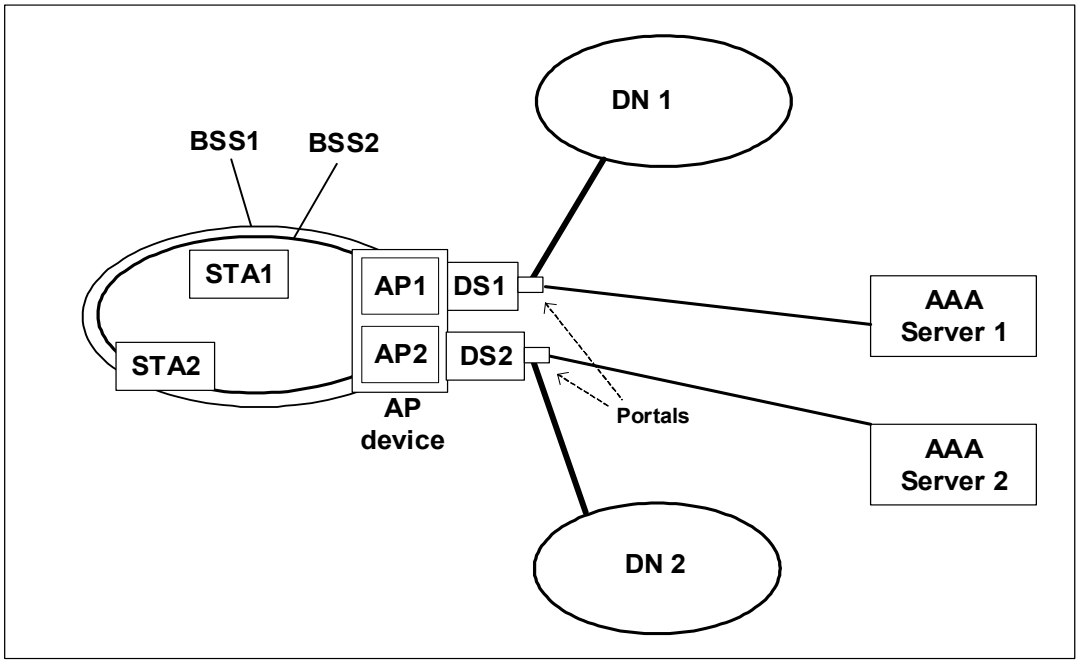


**Figure R-1—Interworking IEEE 802.11 infrastructure supporting multiple SSPNs(#8231)**

### R.3.3 QoS mapping and GLK

General links connect through a STA to an IEEE 802.1AC(#77) Internal Sublayer Service instance.

NOTE —Suggested default UPs differ from IEEE 802.1Q suggested default priorities. For example, in IEEE Std 802.11, priority 2 is lower than priority 0 while in IEEE Std 802.1Q it is higher.(#79)

The priority provided to the MS SAP by the GLK Convergence Function is the UP for the IEEE 802.11 MSDU being transmitted. As provided in IEEE Std 802.1AC-2016, the GLK Convergence Function derives this UP from the priority code point associated with the frame inside the IEEE 802.1Q bridge. A suggested mapping is given in Table R-1 (Suggested default priority code point to UP mapping). The GLK Convergence Function might be configured to provide other mappings.

When an MSDU received over the WM is passed up to the corresponding GLK Convergence Function, the UP passed up is mapped to an IEEE 802.1Q Priority Code Point. A suggested mapping is shown in Table R-2 (Suggested default UP to priority code point mapping).

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**Table R-1—Suggested default priority code point to UP mapping**

| Priority code point | UP |
|---|---|
| 7 | 7 |
| 6 | 6 |
| 5 | 5 |
| 4 | 4 |
| 3 | 3 |
| 2 | 3 |
| 0 | 0 |
| 1 | 1 |

**Table R-2—Suggested default UP to priority code point mapping**

| UP | Priority code point |
|---|---|
| 7 | 7 |
| 6 | 6 |
| 5 | 5 |
| 4 | 4 |
| 3 | 3 |
| 0 | 0 |
| 2 | 1 |
| 1 | 1 |

## R.4 Interworking and SSPN interface support

### R.4.1 General

The interworking service architecture defines the scope of the SSPN interface. This interface is provided by the IEEE 802.11 MAC to support the interworking service. In an interworking scenario, the IEEE 802.11 infrastructure is operating in infrastructure mode.

Figure R-2 (Basic architecture of the interworking service) shows an example implementation of the control aspect of the Interworking Interface. As shown in the figure, the Interworking Interface consists of two parts: the generic SSPN Interface between the AP and the AAA Client; and the AAA Interface between the AAA Client and the corresponding AAA Server in the SSPN. Depending on the implementation the AAA Client can be (#2210)colocated with the AP or stand alone serving as a proxy or translation agent between the SSPN Interface and AAA Interface. The AAA Interface serves as a transparent carrier of the SSPN interface.

The possible interactions over the SSPN interface are defined in 11.22.5 (Interworking procedures: interactions with SSPN). The information transferred over the SSPN Interface is defined in R.4.2 (SSPN


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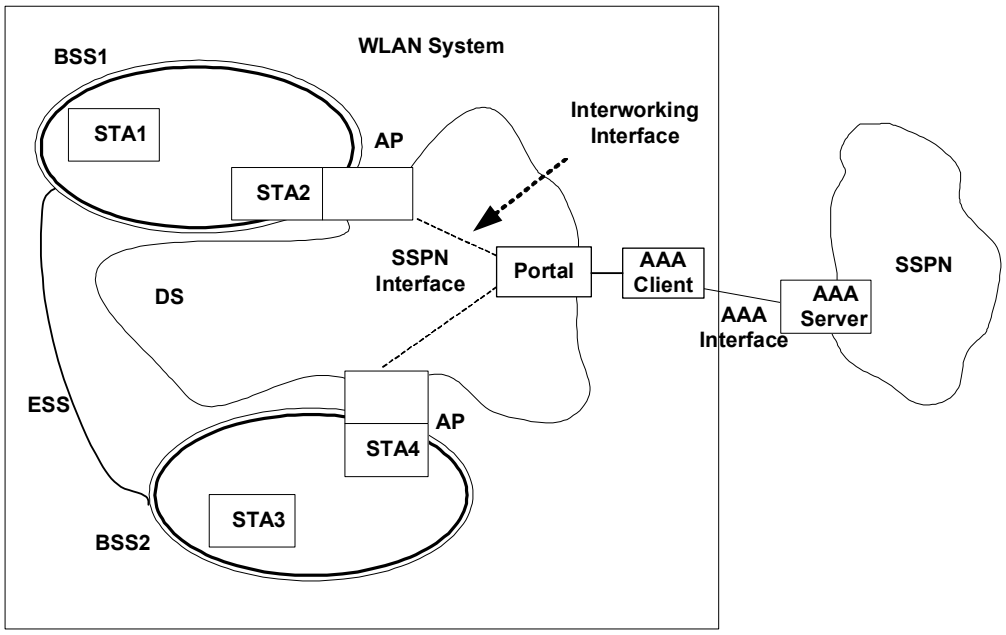


**Figure R-2—Basic architecture of the interworking service**

interface parameters). This interface results in parameters being set in the dot11InterworkingTable. The AP's SME thereafter uses these parameters to permit or deny, as appropriate, services to non-AP STAs.

## R.4.2 SSPN interface parameters

### R.4.2.1 General

The parameters for each associated non-AP STA defined in this clause cross the SSPN Interface, i.e., between AP and AAA Client as shown in Table R-3 (SSPN Interface information or permission parameters).

**Table R-3—SSPN Interface information or permission parameters**

| Information or permission name | From AN to SSPN | From SSPN to AN | Per non-AP STA entry |
|---|---|---|---|
| Non-AP STA MAC | + | | + |
| Non-AP STA User ID | + | + | + |

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**Table R-3—SSPN Interface information or permission parameters**

| Information or permission name | From AN to SSPN | From SSPN to AN | Per non-AP STA entry |
|---|---|---|---|
| Non-AP STA Interworking Capability | + | | + |
| Link Layer Encryption Method | + | | + |
| Authorized Priority | | + | + |
| Authorized Rate | | + | + |
| Authorized Delay | | + | + |
| Authorized Service Access Type | | + | + |
| Authorized Service Access Information | | + | + |
| Non-AP STA Transmission Count | + | | + |
| Non-AP STA Location Information | + | | + |
| Non-AP STA State Information | + | | + |

The SSPN Interface parameters are stored in the AP with corresponding MIB attributes as defined in Annex C, and are used by the Interworking Service Management function in the SME. The MIB attributes themselves, which are used by the AP SME, are read only.

### R.4.2.2 Non-AP STA MAC

This parameter is the MAC address of the non-AP STA accessing the interworking service through the AP. It can be requested by the external network, e.g., a 3GPP network, for fraud prevention. The non-AP STA MAC address is normally available through MLME SAP, e.g., MLME-ASSOCIATE.indication primitive, and should be forwarded by the AS to the AAA Server entity in the SSPN through the AAA Interface.

The following is used:

— dot11NonAPStationMacAddress

### R.4.2.3 Non-AP STA User ID

This parameter contains the subscriber information of the non-AP STA for the interworking service. It is provided by the non-AP STA through the RSNA establishment process to the AAA Server; in turn, the AAA Server provides it back to the AP via the SSPN interface. It is in the form of an NAI, i.e., it contains both the user's identity and its SSP information.

NOTE—The reason the AAA Server provides the user identity back to the AP is that some EAP methods use encrypted tunnels to maintain confidentiality of the user and thus the AP might not otherwise be able to learn the user's identity.

The following is used:

— dot11NonAPStationUserIdentity

### R.4.2.4 Non-AP STA Interworking Capability

This parameter is derived from the non-AP STA's Extended Capabilities element, which is included in (Re)Association Request frames.The AP SME obtains this information from the MLME SAP, e.g., MLME-ASSOCIATE.indication primitive. This information needs to be passed over the SSPN interface since the service authorization decisions can depend on the non-AP STA capabilities.

The following is used:


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— dot11NonAPStationInterworkingCapability

### R.4.2.5 Link Layer Encryption Method

This parameter indicates the link layer encryption method selected during the RSNA establishment process for protecting the pairwise communication between the non-AP STA and the AP. The cipher suite format of this parameter is drawn from the RSNE defined in 9.4.2.23 (RSNE). The AP obtains this information about the STA via the MLME SAP.

In the interworking service, the SSPN also participates in the selection of the cipher suite selection, as described in 11.22.5. Therefore, the link layer encryption method selected will meet or exceed the security requirement of the SSPN.

NOTE—In interworking, the SSPN can require visibility and configurability of the STA access.

With this information available to the SSPN, the operator would be able to have better control, e.g., barring access to IEEE 802.11 networks if null encryption is used. This is also related to the operator network's configuration, e.g., if preauthentication should be supported.

The following is used:

— dot11NonAPStationUnicastCipherSuite

### R.4.2.6 Authorized Priority

This parameter is used for admission control and user priority policing at the AP. It is based on the Infrastructure Authorization Information delivered from the SSPN during the AAA procedure. The Authorized Priority specifies the authorized User Priorities that the non-AP STA is allowed to use during the Interworking access. It also specifies whether the non-AP STA can use HCCA.

For EDCA operation, the following is used:

— dot11NonAPStationAuthAccessCategories after mapping the priority according to Table 10-1 (UP-to-AC mappings(#68)).

For HCCA operation, the following is used:

— dot11NonAPStationAuthHCCAHEMM

### R.4.2.7 Authorized Maximum Rate

This parameter is used for admission control decisions or policing actions at the AP. It is based on the Infrastructure Authorization Information delivered from the SSPN during the AAA procedure. For EDCA operation, this parameter contains a list of four MaxRate values indicating the maximum rate allowed for each of the access categories. For HCCA operation, there is one MaxRate value. Each of the MaxRate values is (#1161)an unsigned integer in kb/s. An additional value provides the maximum rate at which a non-AP STA can source group addressed frames.

The following are used:

— dot11NonAPStationAuthMaxVoiceRate,

— dot11NonAPStationAuthMaxVideoRate,

— dot11NonAPStationAuthMaxBestEffortRate,

— dot11NonAPStationAuthMaxBackgroundRate,

— dot11NonAPStationAuthMaxHCCAHEMMRate

— dot11NonAPStationAuthMaxSourceMulticastRate.

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### R.4.2.8 Authorized Service Access Type

This per-non-AP STA parameter indicates the access type allowed for the non-AP STA based on the SSPN decision. The AP uses(M118) this information for authorization requests from the STA, e.g., allow or disallow direct link operation and group addressed services. The parameter uses truth values to indicate the service type authorized.

The following is used:

— dot11NonAPStationAuthMaxSourceMulticastRate is to authorize a non-AP STA to source group addressed stream(s) to toward the network

### R.4.2.9 Authorized Delay

This parameter is used for admission control decisions at the AP. It is based on the Infrastructure Authorization Information delivered from the SSPN during the AAA procedure. This parameter is used only for HCCA operation, and contains one value. An AP should deliver frames to a non-AP STA within the time period specified in this attribute. Furthermore, when a non-AP STA requests admission control, the requested delay is approved only if it is greater than or equal to the value stored in the corresponding parameter. Each parameter is an unsigned integer that measures delay in units of microseconds.

The following is used:

— dot11NonAPStationAuthHCCAHEMMDelay

### R.4.2.10 Authorized Service Access Information

This parameter contains the relevant information for the AP to enforce the authorized service access type indicated in the Authorized Service Access Type parameter. The Authorized Service Access parameters provide the VLAN assignment (VLAN ID and VLAN Name) to which frames to or from the non-AP STA are bridged.

The following are used:

— dot11NonAPStationVLANId

— dot11NonAPStationVLANName

### R.4.2.11 Non-AP STA Transmission Count

This parameter indicates the count of the data traffic transmitted to and received from a non-AP STA. Such information would be used by the on-line charging and accounting function, especially for the IEEE 802.11 WLAN local service, where the data traffic does not necessarily go through the SSPN network. In such cases, Layer 3 accounting/charging information is not reliable since addresses could be spoofed. Layer 2 would be a better place to collect such information since due to the cryptographic security association that exists between the non-AP STA and AP.

The following are used:

— dot11NonAPStationVoiceMSDUCount,

— dot11NonAPStationVideoMSDUCount,

— dot11NonAPStation-BestEffortMSDUCount,

— dot11NonAPStationBackgroundMSDUCount,

— dot11NonAPStationHCCAHEMMMSDUCount,

— dot11NonAPStationMulticastMSDUCount,

— dot11NonAPStationVoiceOctetCount,


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- dot11NonAPStationVideoOctetCount,
- dot11NonAPStationBestEffortOctetCount,
- dot11NonAPStationBackgroundOctetCount,
- dot11NonAPStationHCCAHEMMOctetCount,
- dot11NonAPStationMulticastOctetCount

#### R.4.2.12 Non-AP STA Location Information

This parameter provides information about the STA's location to the SSPN. It is required by the SSPN applying location based service control. In the IEEE 802.11 network, the non-AP STA location is approximated using the AP's location information. This parameter includes two type of formats, Geospatial and Civic Location.

The following are used:

- dot11APLCITable,
- dot11APCivicLocationTable

#### R.4.2.13 Non-AP STA State Information

This parameter indicates whether the power management mode of the non-AP STA is either active mode or PS mode.

The following MIB attribute is used:

- dot11NonAPStationPowerManagementMode

## R.5 Interworking with external networks and emergency call support

### R.5.1 General

Emergency services define the IEEE 802.11 functionality to support an emergency call (e.g., E911) service as part of an overall multi-layer solution, specifically capability advertisement and access to emergency services by STAs not having proper security credentials. "Multi-layer" indicates that emergency services will be provided by protocols developed in part by other standards bodies; see IETF RFC 7406 [B52], 3GPP TS 23.167 [B3], and 3GPP TS 22.067 [B2]. Three features of interworking with external networks support emergency call services.

The first feature is a mechanism for a non-AP STA to signal to an AP that a call is an emergency call. This is useful in the case where the access category to be used to carry the emergency call traffic (typically AC_VO) is configured for mandatory admission control. If the WLAN is congested, then the AP can deny the TSPEC request for bandwidth to carry the call. However, if the AP is able to determine that the call is an emergency call, then it can invoke other options to admit the TSPEC request.

The second and third features provide the means for a client without proper security credentials to be able to place an emergency call. The second feature makes use of the Interworking element, which can be included in Association Request frames in order to bypass the IEEE 802.1X port at an AP for unauthenticated access to emergency services. This is described further in R.5.5 (Access to emergency services in an RSN). The third feature makes use of an SSID configured for Open Authentication to provide emergency services and is described in R.5.3 (System aspects for emergency call support).

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The STA has the burden to confirm the availability of emergency services from the IEEE 802.11 network, including that the network is authorized for emergency services. The time it takes for a client to find an authorized emergency services network is related to the speed of forward progress the authorized network can make over the air with the STA, relative to all of the other networks (attackers as well), and is inversely related to the number of false advertisements. A STA can confirm the availability of emergency services by observing the value of the access network type, ESR and UESA fields in the Interworking element of any received Beacon or Probe Response frame.

## R.5.2 Background on emergency call support over IEEE 802.11 infrastructure

Special handling for emergency service calls is required over IEEE Std 802.11. To use a public hotspot a user will go typically through an authentication process (e.g., EAP-based, or http/https redirect or DNS redirection) before being able to use it for emergency calls.

There is a need to support these emergency services both when the user has a relationship with the IEEE 802.11 network (credentials to access the network) and when it does not have any relationship with the IEEE 802.11 network.

The former case requires no changes to the authentication process—the user, having already been authenticated to and associated with the WLAN, simply dials the emergency number thereby placing the call.

In the latter case, the non-AP STA will be able to gain access to the network without using security credentials and make an emergency call.

Another difficulty is that once the user gains access to the network, there is no mechanism to prioritize their emergency traffic in the IEEE 802.11 MAC over that of other users, even with IEEE 802.11 QoS capability.

Supporting emergency services, such as E911 calling, requires a multi-layer solution with support at various protocol layers. Apart from MAC-level access and support for transfer of data between non-AP STA and AP with appropriate QoS at layer 2, there is a clear need, above this layer, to set up the call, conduct call control and management, and use an appropriate audio codec.

One specific example is when a user arrives in a new country and needs to make an emergency call in a public hotspot where there is no prior relationship with the available WLAN or WLAN hotspot operator.

NOTE—The callback feature, if required in a regulatory domain, is dealt with at a higher layer.

## R.5.3 System aspects for emergency call support

An IEEE 802.11 infrastructure by itself cannot ensure that all factors are compatible for an emergency service call to actually take place. The client device might have to register with a call manager (SIP agent or some other signaling endpoint) for the call to be placed successfully. Different signaling systems such as SIP, H.323, etc., can be deployed for supporting emergency service calling. Higher layers can also verify an emergency service call is being placed so that appropriate level of resources can be granted to the emergency call. Voice endpoints (e.g., non-AP STAs) can use different codecs such as G.711, AMR, and iLBC. All these functionalities are outside the scope of this standard.

IEEE Std 802.11 can provide priority for emergency traffic both for the initial call establishment and during an ongoing emergency call, which assumes advertisement of this functionality supported in the BSS.

This subclause describes general design assumptions to support emergency services with IEEE Std 802.11:


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a) It is assumed that there is a higher layer (above IEEE 802.11 Layer 2) protocol (or protocol suite) for making emergency calls or using any other emergency services.

b) In order to make the emergency call procedure work properly, the non-AP STA has the following responsibilities:

   1) Recognize the user's request to make an emergency call.

   2) Select an AP that supports QoS and (#1776)expedited bandwidth request capability.

   3) Non-AP STA will associate with the AP if it is not already done so. In an RSN, if the user does not have valid authentication credentials for network access then non-AP STA can bypass the RSN that will provide access to the network to make emergency calls.

   4) If location information is required in a particular regulatory domain, request location information from the WLAN. If the STA cannot determine its own location by its own means, then Location information should be obtained from the network prior to initiating the emergency call request. There are two methods a non-AP STA can use to obtain location services from the IEEE 802.11 network:

      i) If the non-AP STA can use location information in geospatial format (i.e., latitude, longitude and altitude), then the LCI report procedures (11.10.9.6 (LCI report (Location configuration information report))) can be used to obtain this information. The AP advertises its capability for the LCI report procedures by setting the LCI Measurement Capability Enabled field to 1 in the RM Enabled Capabilities field in the RM Enabled Capabilities element, and the non-AP STA transmits an LCI request to the AP.

         NOTE—The non-AP STA can receive an LCI report with the incapable field set. According to the procedures in 11.10.9.6 (LCI report (Location configuration information report)), the non-AP STA can resubmit an LCI request with a location subject of "remote." If the AP still responds with incapable, then location services are not available from the AP via the LCI report procedures.

      ii) If the non-AP STA requires location information in Civic or geospatial formats, then an AP's wireless network management capability can be used. In this case, an AP advertises its ability to provide its location in Civic or geospatial format by setting the Civic Location or Geospatial Location field in the Extended Capabilities element to 1 respectively in the Beacon frame. A non-AP STA can also request its location using the procedures in 11.22.7 (Interworking procedures: emergency alert system (EAS) support). An AP that advertises its ability to provide its location in civic or geospatial format does not return an "incapable" response if a requesting STA requests the "remote" location.

   5) Selects one of possibly several SSPNs advertising support for emergency services and VoIP service.

c) There are two methods described in this annex by which a user lacking security credentials can gain access to the network. The method selected in any particular deployment is at the discretion of the IEEE 802.11 infrastructure provider, SSPN or system administrator as appropriate. The AP and non-AP STA should permit users lacking security credentials to gain access to a network using one of two methods:

   1) Using an emergency services association (see 9.4.2.90 (Interworking element)) in a BSS configured for RSNA. Using this type of association means the AP and non-AP STA exchanges(M118) unprotected frames for emergency service access only during the lifetime of the association. In this situation, cryptographic keys are not exchanged, the IEEE 802.1X (#1909)Uncontrolled Port is bypassed without invoking the IEEE 802.1X state machine. Since protection is used for authenticated STAs, their traffic is protected.

   2) Using an SSID configured for Open System authentication. Network elements necessary to complete an emergency call are reachable via this SSID. How to reach these network elements (e.g., a call manager) and which protocol to use (e.g., SIP) are outside the scope of this standard.

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d) The AP can separate the backhaul of emergency services traffic from other traffic, typically via a dedicated VLAN.

To ease burden of implementation on the network side, some basic means should exist to allow easy filtering, routing and basic access control of "regular" BSS traffic and emergency-type BSS traffic. This can be assisted by the downloading of emergency call number information, as described in 9.4.5.5 (Emergency Call Number ANQP-element).

## R.5.4 Description of the Expedited Bandwidth Request element

For access categories configured for mandatory admission control, a non-AP STA requests bandwidth using a TSPEC element in an ADDTS Request frame. The TSPEC Request includes parameters describing the characteristics of the traffic stream, but no information on the use of the traffic stream. (#1776)The Expedited Bandwidth Request element describes the "use" of a traffic stream. To use this element, it is the responsibility of the station to transmit this element in response to certain call signaling messages. How this is done is outside the scope for the interworking service. (#1776)The following bandwidth uses are provided in the Expedited Bandwidth Request element:

— Emergency call, defined in NENA 08-002 [B65]
— Public first responder (e.g., fire department)
— Private first responder (e.g., enterprise security guard)
— Multi-level precedence and preemption (MLPP)

MLPP services are provided by other voice networking technologies such as 3GPP (see 3GPP TS 22.067 [B2]), H.323 (see ITU-T Recommendation H460.14 [B62]) and other proprietary signaling protocols. MLPP is used as a subscription service to provide differentiated levels of consumer service; it is also used by military organizations so that commanding officers will not get a network busy signal.

If the AP is provided additional information regarding the nature of the Traffic Stream, it can invoke additional policy that can be configured on the AP to accept the TSPEC request when it would be otherwise denied. Policy configured at AP defines how bandwidth is allocated. Specification of these policies is outside the scope of interworking with external networks. Policy examples include the following:

— No action
— Preemptive action: delete a TS of lower priority if necessary to make room for new TS
— Use capacity allocated for nonvoice services if priority is above a certain value (assuming TSPEC is for AC_VO)
— Interpret MLPP codes as defined 3GPP specification
— Interpret MLPP codes as defined in proprietary specification

## R.5.5 Access to emergency services in an RSN

If an infrastructure BSS requires authentication and encryption with RSN, a non-AP STA placing an emergency call associates and authenticate to the network by using an emergency services association (see 9.4.2.90 (Interworking element)). If the non-AP STA has user credentials that allow it to use a particular network, the non-AP STA can use its credentials to authenticate to the SSPN through the IEEE 802.11 infrastructure.

When a mesh STA has an emergency services association, and it receives a Mesh Peering Open frame that includes the Interworking element, with ASRA bit equal to 1 and UESA bit equal to 0, and the Authenticated Mesh Peering Exchange element (see 9.4.2.116 (Authenticated Mesh Peering Exchange element)) it allows access to emergency services. If the mesh STA has user credentials that allow the


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accessing mesh STA to use the mesh network, the mesh STA can use its credentials to authenticate with the accessing mesh peer.

In order to use an emergency services association in an infrastructure BSS, a STA lacking security credentials can associate with a BSS in which emergency services are accessible by including an Interworking element with the UESA field set to 1 in a (Re)Association Request frame. An AP receiving this type of (re)association request recognizes this as a request for unauthenticated emergency access. The AP can look up the VLAN ID to use with a AAA Server, or it can have an emergency services VLAN configured. The STA can either have, policies configured locally for quality-of-service parameters and network access restrictions, or it can look them up through external policy servers. When a mesh STA has an emergency services association, and it receives a Mesh Peering Open frame, from a mesh STA lacking security credentials, that includes the Interworking element, with ASRA bit equal to 1 and UESA bit equal to 1, and the Mesh Peering Management element (see 9.4.2.100 (Mesh Peering Management element)) it allows access to emergency services.

When an emergency services association is used, an infrastructure BSS or an MBSS should be designed to restrict access to emergency services only (or alternatively prioritize the emergency services to the highest level of access). Methods of such restriction are beyond the scope of this standard, but can include an isolated VLAN for emergency services, filtering rules in the AP or network entity (e.g., router) in an external network to limit network access to only network elements involved in emergency calls, and per-session bandwidth control to place an upper limit on resource utilization.

## R.6 Peer information

Peer information allows TDLS peer STAs to discover their capabilities. An example of peer information could be expressed in an XML format as follows:

```
<Peer information>
        <mode> tdls </mode>

        <wireless info>
                <MAC(#1558) address> 00-01-02-03-04-05 </MAC(#1558) address>
                <bssid> 00-0a-0b-0c-0d-0e </bssid>
        </wireless info>

        < network info>
                < DHCP> No</DHCP>
                < IP address>192.168.2.1 </IP address>
                < Subnet> 255.255.255.0 </subnet>
                <Hostname> myphone </Hostname>
        </network info>
</Peer information>
```

The minimum required peer information for TDLS is contained in “wireless info.” The “MAC(#1558) address” field contains the MAC address of the transmitting STA and the “bssid” identifies the BSS in which the STA is a member. The “network info” could optionally be used to aid the peer devices in establishing a TDLS direct link(#2152).

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## R.7 Calculating Estimated Throughput

In response to an MLME-ESTIMATED-THROUGHPUT.request primitive, ESP STAs can determine values for EstimatedThroughputInbound and EstimatedThroughputOutbound for each AC of a current or potential link to another STA using Equation (R-1):

$$EstimatedThroughput = \frac{EST_{AirtimeFractionDir} \times MPDU_{pPPDU} \times A\_MSDU\_B \times 8}{(CWmin/2 + AIFSN[AC]) \times aSlotTime + 2 \times SIFS + BA\_PPDU_{Dur} + PPDU_{Dur} + OtherOverhead_{Dur}} \quad \text{(R-1)}$$

where

*EstimatedThroughput* is in b/s and is calculated separately for inbound and outbound transmissions for this link

$PPDU_{Dur}$ is the expected duration of a single PPDU, in seconds

$EST_{AirtimeFractionDir}$ is dimensionless. It is the estimated portion of air time that is available for inbound or outbound transmissions for this link when calculating EstimatedThroughput for inbound and outbound directions, respectively. The value of this parameter is based on the value of the Estimated Inbound Air Time Fraction or Estimated Outbound Air Time Fraction subfield, respectively, of the Estimated Service Parameters Inbound element or Estimated Service Parameters Outbound element, respectively, received from the STA with the MAC address that matches the PeerSTAAddress(#144) in the MLME-ESTIMATED-THROUGHPUT.request primitive, using a method that is beyond the scope of this standard

*AIFSN[AC]* is calculated according to 10.23.2.4 (Obtaining an EDCA TXOP) where the AC value corresponds to the AC of the Data frames

$BA\_PPDU_{Dur}$ is the expected duration of a PPDU containing a BA using the rate indicated for a BA response to an MPDU using the rate of DataRate as determined according to 10.6.6 (Rate selection for Control frames)

$OtherOverhead_{Dur}$ is in seconds. It is a term that includes airtime that is needed for additional overhead per Data PPDU, which is not already account for in the existing terms in the denominator of Equation (R-1), such as an optionally present RTS/CTS exchange and its accompanying, appropriate interframe space and collision and PER losses

$\min(x,y)$ is the minimum of $x$ and $y$

$\max(x,y)$ is the maximum of $x$ and $y$

$MPDU_{pPPDU} = \min(BA\_WIN\_Size, \max(1, MPDU\_pA\_MPDU))$

$BA\_WIN\_Size = \min(BA\_WIN\_Size_{TX}, BA\_WIN\_Size_{RX})$

$BA\_WIN\_Size_{TX}$ is the expected block ack window size of the transmitter of the PPDUs containing MPDUs with the Type field equal to Data

$BA\_WIN\_Size_{RX}$ is the expected block ack window size of the receiver of the PPDUs containing MPDUs with the Type field equal to Data

*MPDU_pA_MPDU* is dimensionless, and is calculated as shown in Equation (R-2)

$$MPDU\_pA\_MPDU = \min\left(\left\lfloor \frac{PPDUR}{MPDU_{SS}} \right\rfloor, \left\lfloor \frac{PPDUR \times DataRate}{(MAC_{Hdr} + A\_MSDU\_B + 4 + (4 - (MAC_{Hdr} + A\_MSDU\_B) \bmod 4)) \times 8} \right\rfloor\right) \quad \text{(R-2)}$$

$PPDUR = DPDUR - PHDUR$

*PPDUR* *is the PPDU payload duration, in seconds*

*DPDUR* is the Data PPDU duration target of the transmitter of the PPDUs containing MPDUs with the Type subfield equal to Data, in seconds. For calculations of inbound Estimated Throughput, the value of this variable is equal to the time indicated in the Data PPDU Duration Target subfield of the Estimated Service Parameters Inbound element (see 9.4.2.172 (Estimated Service Parameters


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Inbound element)). For calculations of outbound Estimated Throughput, the value of this variable is determined by the STA performing the calculation using a method that is beyond the scope of this standard. A value of 5430 μs is recommended for such calculations

*PHDUR* is the PHY header duration, estimated based on the expected PPDU format of the PPDUs containing MPDUs with the Type subfield equal to Data, in seconds

$MPDU_{SS}$ is the minimum MPDU start spacing of the receiver of the PPDUs containing MPDUs with the Type subfield equal to Data, in seconds

$MAC_{Hdr}$ is the number of octets of MAC header information for an A-MSDU

$A\_MSDU\_B = \min(A\_MSDU\_B_{TX}, A\_MSDU\_B_{RX})$

$A\_MSDU\_B_{TX}$ is a number of octets which is equal to the maximum A-MSDU size of the transmitter of the PPDUs containing MPDUs with the Type subfield equal to Data if the MPDUs are expected to contain A-MSDUs. If the MPDUs are not expected to contain A-MSDUs, then the value is a number of octets equal to the AverageMSDUSizeInbound or AverageMSDUSizeOutbound, respectively, depending on whether the EstimatedThroughput being calculated is inbound or outbound

$A\_MSDU\_B_{RX}$ is a number of octets which is equal to the maximum A-MSDU size of the receiver of the PPDUs containing MPDUs with the Type subfield equal to Data if the MPDUs are expected to contain A-MSDUs. If the MPDUs are not expected to contain A-MSDUs, then the value is a number of octets equal to the AverageMSDUSizeInbound or AverageMSDUSizeOutbound, respectively, depending on whether the EstimatedThroughput being calculated is inbound or outbound

$$PPDU_{Dur} = \left\lceil \frac{(MAC_{Hdr} + A\_MSDU\_B) \times MPDU_{pPPDU} \times 8}{DataRate \times DSYM_{DUR}} \right\rceil \times DSYM_{DUR} + PHDUR \quad \text{(R-3)}$$

$DSYM_{DUR}$ is the duration of one PPDU payload symbol for the expected PHY format of the PPDUs containing MPDUs with the Type subfield equal to Data, in seconds. If multiple symbol durations are possible, then the shortest symbol duration is assumed

*DataRate* is calculated using equation Equation (R-4), in b/s(#315)

$$DataRate = \min(\log2(1 + SNR\_tone), MaxBitsPerSc) \times \frac{NSS\_max \times Ntone}{DSYM_{DUR}} \quad \text{(R-4)}$$

where

$$SNR\_tone = 10^{\frac{RSSI + P_{adjust}}{10}}$$

*RSSI* is the RSSI of Beacon or Probe Response frames received from the STA with the MAC address that matches the (#145)PeerSTAAddress in the MLME-ESTIMATED-THROUGHPUT.request primitive, in dBm

*P_adjust* is the implementation specific power adjustment parameter used to convert RSSI into SNR, as well as take into account potential transmit power differences between Beacon/Probe Response frames to Data frames and between STAs for which the estimation is being performed, in dBm

*NSS_max* is the maximum number of spatial streams allowed in the link based on the capabilities of the two STAs

*Ntone* is N_SD × N_Seg if the expected PPDU format is VHT, and N_SD otherwise, where N_SD is defined as number of subcarriers in Table 17-19 (Major parameters of the OFDM PHY) for non-HT format, NSD in Table 19-6 (Timing-

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related constants) for HT format and NSD in Table 21-5 (Timing-related constants) for VHT format. If multiple channel bandwidths are available, the N_SD of the widest possible TXVECTOR CH_BANDWIDTH allowed between the two STAs based on capabilities is assumed.

$$MaxBitsPerSc = \begin{cases} \frac{40}{6}, \text{ if 256-QAM 5/6 modulation is allowed in the link} \\ 6, \text{ if 256-QAM 3/4 modulation is allowed in the link} \\ \quad \text{but 256-QAM 5/6 modulation is not} \\ 5, \text{ otherwise} \end{cases}$$

NOTE 1—The equations above do not account for signal extension.

NOTE 2 —The STA can adjust the value of $EST_{AirtimeFractiondir}$ based on knowledge about whether it is currently competing for airtime with the targeted BSS and would no longer do so if the STA joins that BSS.



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# Annex S

(informative)

# Mesh BSS operation

## S.1 Clarification of mesh Data frame format

A mesh Data frame consists of MAC header, frame body, and the FCS. The fields in the MAC header are described in 9.2.3 (General frame format).

In a mesh Data frame containing a single MSDU, the Mesh Control field is placed immediately before the Data (PDU) in the encrypted portion of the frame body. The Data (PDU) comprises the LLC/SNAP headers and the higher layer data. This is shown in the example frame format for a CCMP-128-encrypted mesh Data frame containing a single MSDU in Figure S-1 (Format of a CCMP-128-encrypted mesh Data frame containing a single MSDU).

When the mesh Data frame is fragmented, only the first fragment contains the Mesh Control field.

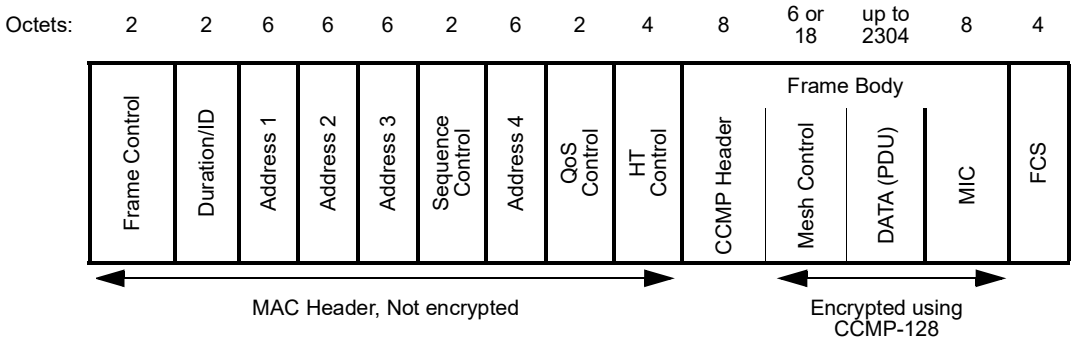


**Figure S-1—Format of a CCMP-128-encrypted mesh Data frame containing a single MSDU**

NOTE—A DMG STA does not send mesh Data frames, and all other STAs have a maximum MSDU size of 2304 octets (see Table 9-34 (Maximum data unit sizes and durations(#1327)(#4013))).

## S.2 Operational considerations for interworking

No special action is required to support formation of the IEEE 802.1Q(#80) spanning tree. Spanning tree control messages are typically delivered to bridges in group addressed frames. These messages are Data frames from the point of view of the mesh BSS.

## S.3 Power save parameters selection

### S.3.1 General

Power save mechanisms enable mesh STA operation in doze state. In doze state a mesh STA might set the transceivers off. The power save mechanism might adjust the mesh power management mode of a mesh

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STA for various reasons that are beyond the scope of the standard, including but not limited to traffic load or scanning and network maintenance needs.

This annex specifies recommendations on how a mesh STA selects mesh power management modes based on traffic load, recommendations on how to do scanning in mesh BSSs that might contain mesh STAs in light or deep sleep mode, and recommended default values for power save related parameters.

### S.3.2 Selecting the mesh power management mode based on traffic load

A mesh STA might adjust its mesh power management mode based on the traffic load or the QoS requirements of the forwarded traffic. If a mesh STA has high traffic load or if a mesh STA is congested, the mesh STA should operate in active mode on the corresponding mesh peering to reduce delays or overhead that might be created by the operation in light or deep sleep mode.

A mesh STA might consider staying in active mode for all peer mesh STAs, even if only a single link is congested. When mesh STA operates in active mode, the mesh STA might receive frames at any time and mesh peer service periods might be triggered on demand, as in case of an AP that receives a trigger frame at times controlled by a non-AP STA.

If traffic load is moderate or low and best effort data is transmitted, a mesh STA might consider staying in light sleep mode for all or some mesh peerings. The mesh STA in light sleep mode for a mesh peering receives beacons from the peer mesh STA with periodic indication of buffered traffic.

If traffic load is low or no traffic is transmitted, a mesh STA might consider staying in deep sleep mode for a mesh peering. The mesh STA does not need to transition to awake state(#6038) to receive a beacon from the peer mesh STA to which it is in deep sleep mode.

The mesh STA might use deep sleep mode to control the number of times it enters the awake state to receive Beacon frame from a peer mesh STA. If the mesh STA is in deep sleep mode for all of its mesh peering, the mesh STA needs only to remain in awake state during its own beacon transmission and mesh awake window.

The mesh STA that forwards real time traffic (AC3 or AC2 with EDCA) should be in active mode for the corresponding link. A mesh STA forwarding real time traffic with EDCA might stay in light or deep sleep mode for the corresponding link, if the mesh STA is capable of initiating mesh peer service periods frequently and the other forwarding peer mesh STAs are in active mode. Poor handling of the mesh power management modes might result to delays and inappropriate QoS of the forwarded MSDUs.

### S.3.3 Scanning of mesh BSSs

A mesh BSS might have mesh STAs that alternate awake state and doze state. With active scanning only devices in awake state at the transmission time of Probe Request frame might be found. However, with passive scanning also mesh STAs in light or deep sleep mode for a mesh peering can be found.

Since mesh STAs in light or deep sleep mode might transmit beacons at long intervals, a mesh STA seeking for candidate mesh STAs for a new mesh peerings should perform passive scanning relatively for a longer time compared to passive scanning in BSS infrastructure mode. Mesh STAs in light or deep sleep mode with long DTIM interval might not be discovered with short scanning durations. Mesh STAs that operate in light or deep sleep mode for a mesh peering might use a short DTIM interval, if they intend to establish new mesh peerings.


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### S.3.4 Default parameters

Table S-1 (Default parameters for mesh STAs that intend to operate in light or deep sleep mode for mesh peerings) shows the recommended default values for power save related parameters for mesh STAs.

**Table S-1—Default parameters for mesh STAs that intend to operate in light or deep sleep mode for mesh peerings**

| | For moderate power save | For aggressive power save |
|---|---|---|
| Beacon period | 200 TU | 800 TU |
| DTIM Period | 4 | 1 |
| Mesh awake window | 10 TU | 10 TU |

A mesh STA that is eager to conserve power and likely to remain in deep sleep mode with most of the mesh peerings should utilize the value from aggressive power save parameters.

Although mesh STAs might utilize individual parameters regardless of the parameters used by neighbor mesh STAs or peer mesh STAs, each implementer should recognize balance between the power save efficiency and delay in the service initiation.

### S.3.5 MSDU forwarding in an MBSS containing mesh STAs in light or deep sleep mode

The battery powered mesh STAs should avoid forwarding MSDUs, to avoid power consumption and possible additional delays and inefficiencies that power save mechanisms might cause. If a light or deep sleep mode mesh STA forwards MSDUs, it should select its mesh power management mode based on the traffic load and the traffic type as described in S.3.2 (Selecting the mesh power management mode based on traffic load).

A mesh STA might save power by selecting the light or deep sleep mode for a mesh peering as follows:

— A mesh STA that is “mains powered” might apply light or deep sleep mode if it does not have MSDUs to forward

— A mesh STA that is “battery powered” might freely use all mesh power management modes

Mesh STAs that are in light or deep sleep mode for a mesh peering might degrade the corresponding link metric value. The use of worse metric values reduces the probability of a link being used for MSDU forwarding. If the mesh STA will operate in active mode for the link in forwarding path, it should apply the link metric value without degradation.

### S.3.6 Synchronization maintenance of mesh STAs in deep sleep mode

A mesh STA in deep sleep mode for a mesh peering might not receive Beacon frames from the corresponding peer mesh STA, but the mesh STA is required to maintain synchronization with the neighbor peer mesh STAs. Neighbor offset synchronization method imposes the maintenance of TSF offset values between neighbor peer mesh STAs, which generally requires the reception of Beacon frame or Probe Response frame. The simplest way to maintain the synchronization is that the mesh STA in deep sleep mode for a mesh peering listens to the corresponding peer mesh STA’s Beacon frame for certain periods and check the TSF offset value.

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## S.4 SIV key wrapping test vector

This test vector is from the appendix of IETF RFC 5297.

```
Input:
-----
Key:
        fffefdfc fbfaf9f8 f7f6f5f4 f3f2f1f0
        f0f1f2f3 f4f5f6f7 f8f9fafb fcfdfeff

Associated Data (ad):
        10111213 14151617 18191a1b 1c1d1e1f
        20212223 24252627

Plaintext:
        11223344 55667788 99aabbcc ddee

S2V-CMAC-AES
------------
CMAC(zero):
        0e04dfaf c1efbf04 01405828 59bf073a

double():
        1c09bf5f 83df7e08 0280b050 b37e0e74

CMAC(ad):
        f1f922b7 f5193ce6 4ff80cb4 7d93f23b

xor:
        edf09de8 76c642ee 4d78bce4 ceedfc4f

double():
        dbe13bd0 ed8c85dc 9af179c9 9ddbf819

pad:
        11223344 55667788 99aabbcc ddee8000

xor:
        cac30894 b8eaf254 035bc205 40357819

CMAC(final):
        85632d07 c6e8f37f 950acd32 0a2ecc93

CTR-AES
-------
CTR:
        85632d07 c6e8f37f 150acd32 0a2ecc93

E(K,CTR):
        51e218d2 c5a2ab8c 4345c4a6 23b2f08f

cipher text:
        40c02b96 90c4dc04 daef7f6a fe5c
```



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```
output
------
IV || C:
        85632d07 c6e8f37f 950acd32 0a2ecc93
        40c02b96 90c4dc04 daef7f6a fe5c
```

## S.5 Airtime link metric usage example

The airtime cost constants (Table 14-4 (Airtime cost constants for airtime link metric and high PHY rate airtime link metric)) and estimates of the average data rate and frame error rate will vary from one implementation and configuration of the IEEE 802.11 PHY and MAC to the other. While no mechanism is defined to measure the average data rate and the frame error rate, numeric values are not expected to exhibit large variations in amplitude over the lifetime of a path. Unstable measurements might cause path selection instabilities.

An example of an airtime link metric is provided to illustrate how it might be calculated.

Assume a DSSS PHY with an average data rate of 1 Mb/s to a given neighbor and a frame size of 8192 bits.

The overhead O for the Data frame comprises the PHY preamble (144 μs) and the PHY header (48 μs). The payload Bit is 8192 bits at an r of 1 Mb/s, or 8192 μs. The data transmission time is therefore 8416 μs. Other transmission times for different frame types are calculated in the same way (based on their size, rate, and overhead).

If RTS/CTS is used, the data transmission time (including PHY preamble and header) is 8416 μs, the RTS transmission time (including PHY preamble and header) is 352 μs, the CTS frame transmission time (including PHY preamble and header) is 304 μs, the Ack frame transmission time (including PHY preamble and header) is 304 μs and the interframe spacing overhead is 390 μs. The total time, including overhead, is 9766 μs.

This airtime and overhead value is converted to units of 0.01 TU (10.24 μs), i.e., 953.71 (rounded to 954).

If the frame error rate to the neighbor is 0%, the metric is 954. If the frame error rate is 80%, the metric is 4769 [i.e., Round(953.71/(1–0.8))](#382).

## S.6 Link metric report example

When HWMP is activated as the active path selection protocol in a mesh BSS, the link metric of a link is determined by a STA that received a PREQ frame or RANN frame over the link. To establish a reliable mesh path, it is desirable that the link metric value is calculated considering the bidirectional link quality, particularly because HWMP generates a single mesh path for bidirectional transmissions. Link metric reporting is used to collect a link metric value calculated by the peer STA, so that STA can determine the bidirectional quality of a link.

The following procedure explains one example practice of link metric calculation using link metric reporting, when HWMP is activated.

a) The STA monitors the MCS of Data frames transmitted to a peer STA and calculates the averaged metric value $M_{TX}$ of the link toward the peer STA. The STA updates $M_{TX}$ when it transmits a Data frame to the peer STA. If the STA has not transmitted Data frames to the peer STA recently, $M_{TX}$ might be approximated from the strength of the signal (RSSI) received from the peer STA.

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NOTE—The mechanism by which the RSSI is obtained is outside the scope of this standard.(#1375)

b) The STA transmits Mesh Link Metric Report frames containing the metric value $M_{TX}$ to the peer STA.

c) When the STA receives a Mesh Link Metric Report frame from the peer STA, it stores the reported metric value as $M_{RX}$ of the link. If the STA has not received a Mesh Link Metric Report frame recently, the STA might invalidate $M_{RX}$.

d) When the STA is in need of the link metric value of the link, i.e., it received an HWMP Mesh Path Selection frame to determine an active mesh path, it calculates the link metric for the path selection $M_{PATH}$ using the following equation:

$$M_{PATH} = \alpha \times M_{TX} + (1 - \alpha) \times M_{RX}$$

where $\alpha$ is the ratio of the outgoing traffic on the link versus total traffic on the link. If this ratio is unknown, it is set to 0.5. If $M_{RX}$ is invalidated, it is set to 1.0.

# S.7 Generation of proactive PREP elements in the proactive PREQ mechanism of HWMP

## S.7.1 General

In the proactive PREQ mechanism of HWMP, the generation of a proactive PREP element in response to a proactive PREQ element depends on the value of the Proactive PREP subfield in the received proactive PREQ element (see 14.11.4.2 (Proactive PREQ mechanism)). Furthermore, if the Proactive PREP subfield is 0, the mesh STA might respond with the proactive PREP element in case it needs a bidirectional path between the root mesh STA and itself. This is usually the case if the mesh STA has data to be sent to the root mesh STA. This clause provides a unified mechanism that controls the generation of proactive PREP elements in the proactive PREQ mechanism of HWMP.

A proactive PREQ element is defined by all of the following:

— The Target Address is set to all 1s, and

— The TO subfield in the Per Target Flags field is 1.

## S.7.2 Additions to forwarding information

The forwarding information to a root mesh STA contains two additional Boolean information fields. The Proactive PREP field indicates whether the mesh STA will generate a proactive PREP element to the root mesh STA in response to a proactive PREQ element (Proactive PREP = 1) or not (Proactive PREP = 0). The Proactive PREP Sent field indicates whether the mesh STA has sent a proactive PREP element to the root mesh STA (Proactive PREP Sent = 1) or not (Proactive PREP Sent = 0). Both fields are initialized with 0.

## S.7.3 Actions when sending Data frames as source mesh STA

If a mesh STA receives proactive PREQ elements with the Proactive PREP subfield set to 0, the recipient mesh STA sends a proactive PREP element before sending a Data frame as source mesh STA only if the mesh STA has data to send to the root mesh STA, which requires establishing a bidirectional path with the root mesh STA and the field Proactive PREP Sent of the forwarding information to the root mesh STA is not set (=0).


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If the mesh STA sends a Data frame as source mesh STA to the root mesh STA, the mesh STA sets the field Proactive PREP of the forwarding information to 1.

### S.7.4 Actions on receipt of a proactive PREQ element

If the mesh STA receives a proactive PREQ element, the field Proactive PREP Sent of the forwarding information to the root mesh STA is set to 0. If the field Proactive PREP of the forwarding information to the root mesh STA is 1, the mesh STA generates a proactive PREP element to the root mesh STA (see 14.11.10.3 (Conditions for generating and sending a PREP element) Case D), sets the field Proactive PREP of the forwarding information to 0, and sets the field Proactive PREP Sent of the forwarding information to 1.

If the Proactive PREP subfield of the Flags field of the received proactive PREQ element is 1, the mesh STA sets the field Proactive PREP of the forwarding information to the root mesh STA to 1.

### S.7.5 Generation of proactive PREP elements

A mesh STA will generate a proactive PREP element according to 14.11.10.3 (Conditions for generating and sending a PREP element) Case D if one of the following applies:

— [The mesh STA has received a proactive PREQ element] AND [in the forwarding information to the root mesh STA of the proactive PREQ element, field Proactive PREP is set to 1 AND field Proactive PREP Sent is set to 0].

— [The mesh STA has data to send to the root mesh STA, which requires establishing a bidirectional path with the root mesh STA] AND [the field Proactive PREP Sent of the forwarding information to the root mesh STA is not set (=0)].

If the mesh STA generates a proactive PREP to the root mesh STA, the field Proactive PREP Sent of the forwarding information is set to 1 and the field Proactive PREP of the forwarding information is set to 0.

## S.8 Generation of PREQ elements in proactive RANN mechanism of HWMP

### S.8.1 General

In the proactive RANN mechanism of HWMP, the generation of a PREQ element for root path confirmation in response to a RANN element depends on the path metric from the mesh STA to the root mesh STA as computed by the RANN element propagation. However, the RANN mechanism does not set up the necessary forwarding information. This is done with individually addressed PREQ elements. This clause provides further details to the generation of individually addressed PREQ elements in the proactive RANN mechanism of HWMP.

An individually addressed PREQ element is defined by the following:

— The Addressing Mode subfield in the Flags field is 1 (individually addressed).

### S.8.2 Additions to forwarding information

The forwarding information to a root mesh STA contains an additional address field. The RANN element Sender Address field contains the MAC address of the neighbor peer mesh STA that has sent the RANN element with the best metric.

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### S.8.3 Actions when sending Data frames as source mesh STA

If the mesh STA sends a Data frame as source mesh STA to the root mesh STA, the mesh STA uses the forwarding information to the root mesh STA. The RANN element Sender Address is not used for forwarding mesh Data frames to the root mesh STA.

### S.8.4 Actions on receipt of proactive RANN element

If the mesh STA receives a proactive RANN element, the field RANN element Sender Address of the forwarding information to the root mesh STA is set to the sender of the RANN element if the metric to the root mesh STA is better than the path metric of the existing mesh path in the forwarding information.

In this case, the mesh STA generates an individually addressed PREQ element to the root mesh STA; see 14.11.10.3 (Conditions for generating and sending a PREP element) Case D. This individually addressed PREQ element is not sent according to the general forwarding information. Instead, it is sent to the neighbor peer mesh STA indicated in the RANN element Sender Address field.

Since all mesh STAs between the mesh STA and the root mesh STA have already a value in the RANN element Sender Address field, the individually address PREQ element will eventually reach the root mesh STA. Since the TO subfield in the Per Target Flags field is 1, only the root mesh STA will generate a PREQ element as reply to the individually addressed PREQ element.

The individually addressed PREQ elements will set up forwarding information (that can be used for forwarding mesh Data frames) from the root mesh STA toward the mesh STA that initiated the root path confirmation in all intermediate mesh STAs according to the normal HWMP procedures.

Note, since the PREQ element is sent in an individually addressed frame, every sender of the individually addressed PREQ element will be able to determine whether the next mesh STA toward the root mesh STA has received the PREQ element.

The root mesh STA will generate a PREP element according to the normal HWMP procedures; see 14.11.10.3 (Conditions for generating and sending a PREP element) Case A.

### S.8.5 Actions on receipt of a PREP element

The PREP element generated by the root mesh STA will be forwarded on the mesh path from the root mesh STA to the mesh STA as set up by the individually addressed PREQ element. The PREP element will be propagated and will eventually reach the mesh STA. The PREP element will set up forwarding information (that can be used for forwarding mesh Data frames) toward the root mesh STA in the mesh STA that initiated the root path confirmation and in all intermediate mesh STAs on this path according to the normal HWMP procedures.

After establishing the forwarding information (mesh path) toward the root mesh STA, the path to the root mesh STA is updated to the better one.

Note that since the PREP element is sent in an individually addressed frame, every sender of the PREP element will be able to determine whether the next mesh STA has received the PREP element.


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# Annex T

(informative)

## Overlapping BSS (OBSS) management

## T.1 Introduction

When two or more BSSs overlap, the available bandwidth is shared and hence reduced for each BSS. The basic access mechanism, such as DCF, is able to work across OBSSs. Similarly, if EDCA is used, the OBSS might be considered a larger network, and access to the WM is basically shared according to the EDCA access mechanism. Note that for both DCF and EDCA overlapping networks, the sharing is affected by the relative traffic; and if more than two APs are sharing, the problem of "neighbor capture" might occur. The neighbor capture effect might occur when a BSS is in the middle of two other BSSs that are hidden from each other, where it might suffer a disproportionate degradation in throughput, relative to the total traffic in all three BSSs. A particular problem arises when there is some expectation of QoS. If EDCA admission control is in use, then it can be used to regulate the QoS traffic on its own BSS, but it might not take into account the EDCA admitted traffic on an OBSS. The result is that the QoS is compromised if each BSS admits traffic up to its local maximum. Similarly a BSS using HCCA might schedule traffic in its own BSS, to "guarantee" a service, but, if not controlled, this might suppress overlapping EDCA admission control BSS. Furthermore, if two HCCA BSSs overlap and they do not coordinate their scheduled TXOPs, then a degradation of QoS might result. (11ax)An HE BSS advertises BSS color information, which is a value in the range 1 to 63 that identifies the BSS. Based on the BSS color information, a receiving STA can make decisions on whether to access the medium while there is ongoing transmission on the medium or go to doze state until the end of the received PPDU or update the NAV. The features described in this annex have been introduced in order to allow a degree of management for OBSSs and for mitigation of the basic problems outlined above.

## T.2 QLoad Report element

### T.2.1 General

The fields and their uses in the QLoad Report element are as follows:

- Potential Traffic Self field value represents the potential QoS traffic load that this AP is expecting and is provided as an indication to other APs that might be considering selecting the same channel and for sharing when an OBSS situation occurs. The Potential Traffic Self field also includes the peak number of AC_VO and AC_VI EDCA streams.
- Allocated Traffic Self field value represents the total QoS traffic and the numbers of AC_VI and AC_VO streams that are active at that time. This field is provided to enable an on-demand sharing scheme. It might be used by the other APs in OBSSs to determine if the AP has either overallocated in a proportional sharing scheme or is using an on-demand sharing scheme.
- Allocated Traffic Shared field contains the sum of the Allocated Traffic Self field values for OBSSs and is used to protect an AP from the neighbor capture effect where an AP that has neighbors that are hidden from each other. It indicates to other APs in OBSSs if this AP has either overallocated in a proportional sharing scheme, or might be using an on-demand sharing scheme.
- EDCA Access Factor field value represents the total QoS traffic bandwidth requirement for all of the APs in OBSSs and is used to indicate potential overallocation. It also enables a proportional sharing scheme. The Potential Traffic Self fields from QLoad Report elements of nearby co-channel

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APs are used for estimating the overhead bandwidth required due to EDCA contention and is used in the determination of the EDCA Access Factor.

— HCCA Peak field value represents the total peak HCCA TXOP requirement for the BSS and is provided so that other overlapping APs can determine whether the AP has overallocated.

— HCCA Access Factor field contains the sum of all of the HCCA Peak field values in all of the QLoad Reports of all of the overlapping APs, including its own. This value is used when HCCA APs are sharing as defined in 11.26.2 (QLoad Report element).

— Overlap field value is the number of other APs that are on the same channel and from which Beacon frames are being regularly received. It might be used to aid the channel selection process.

### T.2.2 Calculating medium time

This annex uses the function defined in Equation (T-1) for calculating and estimating medium times in both ACM and non-ACM QoS modes:

$$\text{mediumTime}(s,d,m,p) = s \times pps \times MPDUExchangeTime \quad \text{(T-1)}$$

where

$$pps = \left\lceil \frac{d}{8 \times m} \right\rceil \quad \text{(T-2)}$$

$$MPDUExchangeTime = \text{duration}(m,p) + SIFS + \text{duration}(14,p) \quad \text{(T-3)}$$

duration() is the PLME-TXTIME primitive that returns the duration of a frame based on its payload size and the PHY data rate employed.

$s$, $d$, $m$ and $p$ are parameters that are passed in to the mediumTime function

(Also see the definition of MPDUExchangeTime in 10.23.4.2.3 (Procedure at non-AP STAs).)

### T.2.3 Calculation of potential traffic self

The Potential Traffic Self field value represents the sum of all of the streams derived from all of the potential EDCA admission control and HCCA QoS traffic. The individual TSPEC elements provided by the non-AP STAs are used by the AP to calculate mean, maximum, and minimum values for

— Medium time, (#1162)in units of 32 μs/s, in the case of EDCA admission control

— HCCA medium time, in the case of HCCA; where HCCA medium time is the TXOP time scheduled by the (#1162)HC converted to units of 32 μs/s, by dividing the scheduled TXOP time by the SI that the HC has allocated

The AP maintains a <mean, standard deviation, AC_VO, AC_VI> tuple that contains the maximum values from Allocated Traffic Self field. The values of this tuple are calculated using

a) The mean and standard deviation from the Allocated Traffic Self field that had the largest value of the Mean subfield

b) The AC_VO Streams subfield from the Allocated Traffic Self field that had the largest value

c) The AC_VI Streams subfield from the Allocated Traffic Self field that had the largest value

This <mean, standard deviation, AC_VO, AC_VI> tuple is calculated over fixed, consecutive seven-day periods and is reset at the start of each new period. If, at any time, any of the maximum values in the tuple are greater than those in the corresponding subfields of the Potential Traffic Self field, then those fields in the Potential Traffic Self field are set to the value(s) in the tuple. If the AP refuses an ADDTS request due to


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a perceived overallocation (for example, step b) 4) in the proportional sharing scheme described in T.4.2.2 (Proportional sharing scheme)), then the AP adds the TSPEC values of the rejected request to the tuple.

At the end of each seven-day period, if any of the maximum values in the tuple are less than those in the corresponding subfields of the Potential Traffic Self field, then those subfields in the Potential Traffic Self fields are set to the value(s) in the tuple.

NOTE—It is not required that the start and end of the seven-day periods be synchronized across OBSSs. After the first seven-day period, each AP advertises its correct potential load irrespective of its start time.

TSPECs provide for mean, maximum, and minimum bit rate values, which allow for statistical multiplexing of streams. The result of summing multiple streams is a composite stream, which should be reported in the Potential Traffic Self field. The summing of streams to produce a composite stream is achieved by using the mean and standard deviation of each stream.

The mean (MEAN), maximum (MAX), and minimum (MIN) values of the medium time or HCCA medium time should be calculated using the values provided in the individual TSPECs, as follows:

For a TSPEC for stream, *i*, is:

$$MIN_i = \text{mediumTime}(\textit{Surplus Bandwidth Allowance, Nominal MSDU Size, Minimum Data Rate, Minimum PHY Rate}) \quad \text{(T-4)}$$

$$MEAN_i = \text{mediumTime}(\textit{Surplus Bandwidth Allowance, Nominal MSDU Size, Mean Data Rate, Minimum PHY Rate}) \quad \text{(T-5)}$$

$$MAX_i = \text{mediumTime}(\textit{Surplus Bandwidth Allowance, Nominal MSDU Size, Peak Data Rate, Minimum PHY Rate}) \quad \text{(T-6)}$$

$$\mu_i = MEAN_i \quad \text{(T-7)}$$

If the Minimum Data Rate and Peak Data Rate fields were provided in the TSPEC element, σ is:

$$\sigma_i = 0.25(MAX_i - MIN_i) \quad \text{(T-8)}$$

Else if the Peak Data Rate field was provided in the TSPEC element, σ is:

$$\sigma_i = \frac{MAX_i - MEAN_i}{2} \quad \text{(T-9)}$$

Otherwise:

$$\sigma_i = 0 \quad \text{(T-10)}$$

When the non-AP STA does not have any active TSPECs, the AP should monitor the mean and maximum frame reception and transmission rates for AC_VI and AC_VO (for example, by regular sampling of changes to dot11QosMPDUsReceivedCount and dot11QosTransmittedFrameCount of each AC) to calculate the potential load information as follows:

For a QoS traffic capability, the mean value, $\mu$, is:

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$\mu_0$ = mediumTime(dot11DefaultSurplusBandwidthAllowance/100,
dot11STAStatisticsAverageMSDUSizeVideo,
*MAXt[VI],*dot11STAStatisticsAverageBitrateVideo) (T-11)

$\mu_1$ = mediumTime(dot11DefaultSurplusBandwidthAllowance/100,
dot11STAStatisticsAverageMSDUSizeVoice,
MAXt[VO],
dot11STAStatisticsAverageBitrateVoice) (T-12)

and the standard deviation, $\sigma$, is:

$\sigma_0 = 0$ (T-13)

$\sigma_1 = 0$ (T-14)

The values reported in the Potential Traffic Self field represent the composite stream of all of the individual streams of all associated STAs, and this composite stream should be calculated as follows:

Potential traffic self mean is:

$\mu_{tot} = \Sigma\mu_i$ (T-15)

Potential traffic self standard deviation:

$\sigma_{tot} = \sqrt{\sum \sigma_i^2}$ (T-16)

### T.2.4 Calculation of allocated traffic self

The Allocated Traffic Self field value represents the total BSS load of all streams that the AP has allocated at any one time and the number of AC_VI and AC_VO streams that make up that total. The AP should calculate the mean and standard deviation using the Minimum Data Rate, Mean Data Rate, and Peak Data Rate fields of admitted TSPECs and to recalculate the Allocated Traffic Self field value as each TS is added or deleted. The values of the Mean and Standard Deviation subfields placed in the Allocated Traffic Self field for *i* allocated streams should be calculated using Equation (T-17) to Equation (T-24).

$MIN_i$ = mediumTime(*Surplus Bandwidth Allowance, Nominal MSDU Size,*
*Minimum Data Rate, Minimum PHY Rate*) (T-17)

$MEAN_i$ = mediumTime(*Surplus Bandwidth Allowance, Nominal MSDU Size,*
*Mean Data Rate, Minimum PHY Rate*) (T-18)

$MAX_i$ = mediumTime(Surplus Bandwidth Allowance, Nominal MSDU Size,
*Peak Data Rate, Minimum PHY Rate*) (T-19)

If $TSPEC_i$ has the Minimum Data Rate and Peak Data Rate fields populated, $\sigma$ is:

$\sigma_i = 0.25(MAX_i - MIN_i)$ (T-20)

Else if $TSPEC_i$ has the Mean Data Rate and Peak Data Rate fields populated, $\sigma$ is:

$\sigma_i = \frac{MAX_i - MEAN_i}{2}$ (T-21)


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Otherwise:

$$\sigma_i = 0 \quad \text{(T-22)}$$

$$\text{Mean} = \Sigma\mu_i \quad \text{(T-23)}$$

$$\text{Standard deviation} = \sqrt{\sum \sigma_i^2} \quad \text{(T-24)}$$

When admission control is not used, the AP should monitor the mean and maximum frame reception and transmission rates for AC_VI and AC_VO (for example, by regular sampling of changes to dot11QosMPDUsReceivedCount and dot11QosTransmittedFrameCount of each AC). The MAX, MEAN, and standard deviation (STDEV) at time $t$ for access category AC are as given in Equation (T-25), Equation (T-26), and Equation (T-27).

$$MEAN_i = o\ (\text{duration}(s, b) + \text{SIFS} + \text{duration}(14,b))\ p_t \quad \text{(T-25)}$$

$MAX_t$ is the maximum value of $MEAN_t$ since MLME-START.confirm

$$STDEV_t = \frac{MAX_t - MEAN_t}{2} \quad \text{(T-26)}$$

where

$$p_t = \frac{d}{dt}(dot11QosMPDUsReceivedCount[AC] + dot11QosTransmittedFrameCount[AC] - dot11QosFrameDuplicateCount[AC]) \quad \text{(T-27)}$$

$o$ = dot11DefaultSurplusBandwidthAllowance

$s$ = dot11STAStatisticsAverageMSDUSizeVideo

$b$ = dot11STAStatisticsAverageBitrateVideo

duration() is the PLME-TXTIME primitive that returns the duration of a packet based on its payload size and the PHY data rate employed

NOTE—The differentiation above calculates the frames per second for the given AC.

## T.2.5 Calculation of allocated traffic shared

The Allocated Traffic Shared field value is the sum of the values expressed in the Allocated Traffic Self fields of all APs in OBSSs, including in its own Allocated Traffic Self field. The values of the mean $\mu$ and standard deviation $\sigma$, placed in the Allocated Traffic Shared field, for $n$ OBSSs should be calculated using Equation (T-28) and Equation (T-29).

$$\mu = \Sigma\mu_n \quad \text{(T-28)}$$

$$\sigma = \sqrt{\sum \sigma_n^2} \quad \text{(T-29)}$$

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## T.2.6 Calculation of EDCA Access Factor

The EDCA Access Factor is the total traffic requirement for all of the OBSSs. The value of EDCA Access Factor might be greater than 1. The EDCA Access Factor should be calculated from the addition of all of the Potential Traffic Self fields of the APs that are overlapping as follows:

First calculate the overlap traffic for all of the APs in OBSSs. Each AP notes the reported Potential Traffic Self fields for every OBSS, including the AP's own Potential Traffic Self field, and calculates the maximum traffic of the composite stream, using Equation (T-30), Equation (T-31), and Equation (T-32).

$$\text{Overlap traffic} = \mu_{tot} + 2\,\sigma_{tot} \tag{T-30}$$

where, for $i$ Potential Traffic Self fields

$$\mu_{tot} = \Sigma\mu_i \tag{T-31}$$

$$\sigma_{tot} = \sqrt{\sum \sigma_i^{\,2}} \tag{T-32}$$

(#1163)This overlap traffic value is in units of 32 µs/s.

The following procedure should be used to calculate the EDCA Access Factor:

a) Sum the AC_VI and AC_VO priority streams reported in the Potential Traffic Self fields of its own QLoad report and all of the QLoad reports of APs in OBSSs, and determine the EDCA Overhead Factor as recommended in T.2.7 (EDCA Overhead Factor).

b) Multiply the overlap traffic and the resulting EDCA Overhead Factor together. This value represents the total overlap traffic requirement for the OBSSs (#1164)in units of 32 µs/s.

c) Convert the total overlap traffic to a fraction (seconds per second) by multiplying by $32 \times 10^{-6}$.

d) Round the resulting fraction value rounded down to a multiple of 1/64.

For example, if the total overlap traffic is 74 268 (32 µs/s), this is 2.376 576 (seconds/second). Now 2.376 576 × 64 = 152.1 rounded to 152. Hence, the EDCA Access Factor octet, in this case, would be 1001100 (152 in decimal, representing the fraction 152/64).

## T.2.7 EDCA Overhead Factor

The Potential Traffic Self field also includes the number of AC_VI and AC_VO streams that make up the composite stream. The recommended calculation for medium time for an admitted EDCA is given in K.2.2 (Deriving medium time). This value includes the duration of the packet plus SIFS and Ack frame times. The medium time, therefore, does not include the access time. For example, for a single stream, between each transmitted packet, there is a time period due to SIFS, AIFSN, and contention window, and for two or more streams, there is also the time when each packet is delayed while another packet is being transmitted. Hence, in order to calculate the total time or bandwidth required to service multiple EDCA streams, an overhead is present.

A fixed value of 1.34 should be used for EDCA Overhead Factor. The value of the EDCA Overhead Factor is dependent upon many factors, including

— Number and mix of streams, voice and video
— Mixture of PHY rates and PHYs
— Mixture of streams' data rates
— Use and mix of aggregated MSDUs
— Choice of EDCA parameters including different settings in OBSSs


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Based on a range of simulations, the value of EDCA Overhead Factor is normally in the range 1.26 to 1.43. These simulations, however, were not exhaustive and did not include the effects of hidden nodes and non-IEEE 802.11 interference.

### T.2.8 Calculation of HCCA Access Factor

The HCCA Access Factor should be calculated as follows:

a) Sum the HCCA Peak field values in all of the QLoad reports of all of the APs in OBSSs, including its own.

b) Convert the total peak traffic to a fraction (seconds per second) by multiplying by $32 \times 10^{-6}$.

c) Round the resulting fraction value to the nearest 1/64 and enter the result into the HCCA Access Factor field.

For example, if the total overlap traffic is 74 268 (32 μs/s), this is 2.376 576 (seconds/second). Now 2.376 576 × 64 = 152.1 rounded to 152. Hence, the HCCA Access Factor octet, in this case, would be 152 (representing the fraction 152/64).

## T.3 Channel selection using QLoad report

### T.3.1 General

In addition to the channel selection described below, it is advised that other factors such as traffic from IBSSs, energy from non-IEEE-802.11 systems, and device constraints on the AP or STAs anticipated within the BSS be considered, and regulatory constraints need to be complied with.

The most effective mitigation to OBSS is for an AP to operate on channels that are free or that are occupied by another AP that is not fully loaded with QoS traffic. In the absence of a centralized channel assignment algorithm, an AP should use the Overlap and Potential Traffic Self fields of the QLoad Report element as part of its channel selection procedure. An AP might use the Overlap field and Potential Traffic Self field information when deciding the best channel to select. If there are sufficient channels for an AP to find a channel with no other APs within range, then an AP is advised to select one of them.

When selecting a channel, the AP should scan to see whether there is a free channel taking account of BSS channel width and channel spacing. If a free channel is not available, then it is advised to select channels that have the least number of QoS APs present. There might be more than one channel with the same number of QoS APs present. At this point, the AP is advised to select, in turn, the candidate channels and send a QLoad Request frame to each AP on that channel. The AP is advised to examine the Overlap and Potential Traffic Self fields of the QLoad Report element to make its final selection.

### T.3.2 AP with admission control mandatory

If no “empty” channels are available, then an AP with the ACM (admission control mandatory) bit in the EDCA Parameter Set element set for AC_VI or AC_VO should implement a channel selection procedure to share with one or more APs, in the following preference order:

a) Non-QoS AP where the EDCA Parameter Set element is not present in the Beacon frame

b) QoS AP with the ACM subfield set for AC_VI or AC_VO and with an indication of support for QLoad reporting (i.e., the QLoad Report field equal to 1 in the Extended Capabilities element)

c) QoS AP with an HC and with an indication of support for QLoad reporting (i.e., the QLoad Report field equal to 1 in the Extended Capabilities element)

d) QoS AP with an HC and with no indication of support for QLoad reporting

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e) QoS AP with the ACM subfield set for AC_VI or AC_VO and with no indication of support for QLoad reporting

f) QoS AP where the EDCA Parameter Set element is present in the Beacon frame and the ACM subfield is not set for AC_VI or AC_VO

### T.3.3 AP with an HC

If no "empty" channels are available, then an AP with an HC should implement a channel selection procedure to share with one or more APs, in the following preference order:

a) Non-QoS AP where the EDCA Parameter Set element is not present in the Beacon frame

b) QoS AP where the EDCA Parameter Set element is present in the Beacon frame and the ACM subfield is not set for AC_VI or AC_VO

c) QoS AP with the ACM subfield set for AC_VI or AC_VO and with an indication of support for QLoad reporting (i.e., the QLoad Report field equal to 1 in the Extended Capabilities element)

d) QoS AP with an HC and with an indication of support for QLoad reporting (i.e., the QLoad Report field equal to 1 in the Extended Capabilities element)

e) QoS AP with the ACM subfield set for AC_VI or AC_VO and with no indication of support for QLoad reporting

f) QoS AP with an HC and with no indication of support for QLoad reporting

### T.3.4 Channel selection procedures

Channel selection should be performed as follows:

a) Create a list of the available channels. Typically this is the list of channels allowed by regulation in the operating regulatory domain; however, this list might be modified by management policy (e.g., removing overlapping channels, avoiding radar detect channels).

b) Create an array for each available channel that allows the recording of the QoS AP count, ACM subfield count, HC count, overlap count, and potential load for that channel.

c) Step through the list of available channels, listening for beacons for at least dot11OBSSScanPassiveTotalPerChannel TUs per channel.

d) Upon completion of the scan of a channel, process the beacons received on that channel, filtered to the set of unique BSSIDs:

   1) Using the capabilities signaled in the beacon, modify the QoS AP count, ACM subfield count, HC count, overlap count, and potential load of the channel array for the primary channel indicated in the received beacon.

   2) If the AP is using a channel bandwidth that is greater than the channel spacing (e.g., when using the 2.4 GHz band or when the overlapping AP allows 40 MHz HT PPDUs in its BSS), also update the channel array for channels that are affected by this OBSS. For example, a beacon received on channel 2 indicating a 20 MHz BSS also affects channels 1, 3, and 4.

e) Upon completion of scanning all of the channels, the AP has information on the number of APs and the potential load of each channel, including co-channel BSSs.

f) If the channel array indicates that there are channels with no other APs, one of these "empty" channels should be chosen randomly.

g) Otherwise, create a list of candidate channels by selecting only the channels with the lowest number of QoS APs. For example, if the channel scan procedure indicated that there were two QoS APs on channel 3, three QoS APs on channel 6, and two QoS APs on channel 11, the list of candidate channels would contain 3 and 11.


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1) If this list contains one or more channels with non-QoS APs, then filter the list for the least number of APs.
2) If this list contains more than one channel, one of these channels should be chosen randomly.

h) If this list contains more than one channel and the AP has been configured to set the ACM subfield for AC_VI or AC_VO:
1) Filter the list for the minimum count of QoS AP where the EDCA Parameter Set element is present in the Beacon frame and the ACM subfield is not set for AC_VI or AC_VO.
2) If this list contains more than one channel, filter the list for the minimum count of QoS AP with the ACM subfield set for AC_VI or AC_VO and with no indication of support for QLoad reporting.
3) If this list contains more than one channel, filter the list for the minimum count of QoS AP with an HC and with no indication of support for QLoad reporting.
4) If this list contains more than one channel, filter the list for the minimum count of QoS AP with an HC and with an indication of support for QLoad reporting (i.e., the QLoad Report field equal to 1 in the Extended Capabilities element).
5) If this list contains more than one channel, filter the list for the minimum count of QoS AP with the ACM subfield set for AC_VI or AC_VO and with an indication of support for QLoad reporting (i.e., the QLoad Report field equal to 1 in the Extended Capabilities element).

i) If this list contains more than one channel and the AP has an HC:
1) Filter the list for the minimum count of QoS AP with an HC and with no indication of support for QLoad reporting.
2) If this list contains more than one channel, filter the list for the minimum count of QoS AP with the ACM subfield set for AC_VI or AC_VO and with no indication of support for QLoad reporting.
3) If this list contains more than one channel, filter the list for the minimum count of QoS AP with an HC and with an indication of support for QLoad reporting (i.e., the QLoad Report field equal to 1 in the Extended Capabilities element).
4) If this list contains more than one channel, filter the list for the minimum count of QoS AP with the ACM subfield set for AC_VI or AC_VO and with an indication of support for QLoad reporting (i.e., the QLoad Report field equal to 1 in the Extended Capabilities element).
5) If this list contains more than one channel, filter the list for the minimum count of QoS AP where the EDCA Parameter Set element is present in the Beacon frame and the ACM subfield is not set for AC_VI or AC_VO.

j) If this list contains more than one channel, filter the list to the set of channels with the minimum overlap count.

k) If this list contains more than one channel, filter the list to the set of channels with the minimum potential load.

l) From the remaining channels in this list, randomly choose one of these channels.

## T.4 Sharing in an OBSS situation

### T.4.1 General

If the EDCA Access Factor is greater than one, then there is a potential overallocation of the WM. APs should avoid overallocation in the channel selection process, but if overallocation exists, then a sharing scheme should be used to provide each AP with a fair share of the bandwidth, but more importantly, so that any already admitted or scheduled QoS streams are not impaired by the addition of streams from any OBSS.

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The EDCA Access Factor, HCCA Access Factor, and Potential Traffic Self fields in the QLoad Report element are provided to enable sharing schemes to be used.

The sharing scheme also protects an AP from the neighbor capture effect where it has neighbors that are hidden from each other. A major objective of an OBSS sharing scheme is that if a QoS stream is allocated or scheduled, then it is not compromised by the addition of further streams from any OBSS that would cause the medium to be overallocated. This objective is achieved if the APs in OBSSs cooperate.

## T.4.2 Sharing schemes

### T.4.2.1 General

Two sharing schemes are suggested: proportional sharing and on-demand sharing. In each sharing scheme, the purpose is to keep the total allocated traffic to a value where overallocation does not occur. The absolute maximum allocation is 1 s/s (100%). In the following descriptions of the two suggested sharing schemes, this value is referred to as the *maximum allocation value (MAV)*. It is suggested that in order to provide some protection to non-QoS traffic, each AP select a value for MAV:

$$MAV = (M + 1)/(M + N + 1) \text{ s/s} \quad \text{(T-33)}$$

where

$M$ is the number of overlapping APs that are robust AV streaming STAs

$N$ is the number of overlapping APs that are not robust AV streaming STAs

There is no requirement that each AP select the same MAV.

### T.4.2.2 Proportional sharing scheme

The proportional sharing scheme described in this subclause is an example of a static sharing policy, as described in Table 9-288 (Sharing Policy definitions) and 11.26.2.2 (Calculating field values).

When using the proportional sharing scheme, the AP examines the sum of the EDCA Access Factors and HCCA Access Factors in the QLoad reports from each OBSS, including its own Qload report, and determines the maximum. This maximum value is termed the *combined access factor*. If the maximum value from the combined access factor is less than or equal to MAV, the AP is advised to allocate only up to its advertised potential traffic self traffic. If the maximum value from the combined access factor is greater than MAV, then the AP is advised to allocate only up to a value of its potential traffic self divided by the combined access factor, multiplied by MAV.

In the proportional sharing scheme, before an AP allocates a new medium time or schedules a new TXOP in response to an ADDTS Request frame, it checks that this addition does not exceed its sharing limit, as follows:

a) If the EDCA Access Factor is less than or equal to MAV, then the AP allocates up to its advertised potential traffic self, with the composite stream (MAX traffic) calculated as shown in Equation (T-34).

$$\text{MAX traffic} = \mu_{tot} + 2\,\sigma_{tot} \quad \text{(T-34)}$$

b) If the EDCA Access Factor is greater than MAV, the AP carries out the following:

1) Calculate the peak traffic value of the potential traffic self using Equation (T-35).

$$Peak = \mu_{tot} + 2\,\sigma_{tot} \quad \text{(T-35)}$$


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2) Divide this value by the combined access factor and multiply by MAV. This value is termed the *maximum allowable potential traffic self traffic*.
3) Calculate the resulting value of the allocated traffic self if the new TSPEC is accepted, as explained in T.2.4, and then calculate the resulting peak value using Equation (T-36).

$$Peak = \mu_{tot} + 2\,\sigma_{tot} \quad \text{(T-36)}$$

4) If the resulting peak value, calculated in step 3), is greater than the maximum allowable potential traffic self traffic, then the AP is advised to reject the ADDTS Request frame.
5) If the resulting peak value, calculated in step 3), is less than the maximum allowable potential traffic self traffic and the ADDTS Request frame is set for EDCA admission, then the AP is advised to accept the request.
6) The AP then checks that it is possible to schedule TXOPs using the HCCA TXOP advertisement as described in 11.26.3.

If the new stream is allocated, then the AP updates the appropriate fields in its QLoad Report element.

### T.4.2.3 On-demand sharing scheme

The on-demand sharing scheme described in this subclause is an example of a dynamic sharing policy, as described in Table 9-288 (Sharing Policy definitions) and 11.26.2.2 (Calculating field values).

The on-demand sharing scheme is as follows:

a) Before allocating a new stream, the AP examines the Allocated Traffic Shared field values in the QLoad reports from each OBSS, including its own Qload report, and selects the maximum Allocated Traffic Shared field value that has the highest peak value, using Equation (T-37).

$$Peak = \mu_{tot} + 2\,\sigma_{tot} \quad \text{(T-37)}$$

The AP also notes the number of AC_VI and AC_VO streams in this maximum Allocated Traffic Shared field.

b) The AP adds the requested new stream (*new*) to the selected maximum Allocated Traffic Shared field value (*max*) determined in step a), using Equation (T-38) and Equation (T-39).

$$\mu = \mu_{new} + Peak \quad \text{(T-38)}$$

$$\sigma = \sqrt{\sigma_{new}^2 + \sigma_{max}^2} \quad \text{(T-39)}$$

c) The AP then calculates the peak value for the new composite stream calculated in step b), using Equation (T-40).

$$Peak = \mu + 2\sigma \quad \text{(T-40)}$$

d) Using the values of the AC_VI and AC_VO streams noted in step a), plus the stream represented by the new stream, the AP determines the new EDCA Access Factor and then the combined access factor, as described in T.4.2.2 (Proportional sharing scheme).
e) Multiply the peak value calculated in step c) by the EDCA Access Factor, determined in step d). This value is the new peak traffic requirement.
f) If this peak traffic requirement value calculated in step e) is greater than MAV, then the AP is advised to refuse to allocate the new stream.
g) If the peak value calculated in step e) is less than or equal to MAV and the new allocation is for an EDCA admission ADDTS, then the AP allocates that new traffic.

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h) If the peak value calculated in step d) is less than or equal to MAV and the new allocation is for an HCCA ADDTS, the AP checks that it is possible to schedule TXOPs using the HCCA TXOP advertisement as described in 11.26.3 (HCCA TXOP negotiation).

If the new stream is allocated, then the AP updates the appropriate fields in its QLoad Report element.

The Allocated Traffic Self field in the QLoad Report element of a particular AP can be used by other APs as an indication of whether an AP has overallocated or is using an on-demand sharing scheme.

If, using either the proportional or on-demand sharing schemes, an AP determines that the acceptance of a TSPEC would exceed the available allocation, or if a non-AP STA has a TSPEC refused, the non-AP STA could always request a new TSPEC that represents a lower medium time or TXOP. This request might be used, for example, where the non-AP STA or AP has the ability to send a more compressed stream.

An AP might choose to use the on-demand sharing scheme until the maximum value of any access factor field in the QLoad Report elements from each OBSS reaches MAV. Once this condition has occurred, the AP could then use the proportional sharing for subsequent ADDTS requests.

## T.5 Mitigating consequences of OBSS sharing in presence of noncollaborating devices

The performance of the channel selection and HCAA TXOP negotiation procedures described in this annex and 11.26 (Procedures to manage OBSS) might become degraded by the presence of devices that willfully or accidentally behave in an uncooperative manner.

It is suggested that implementations use additional heuristics (e.g., a history of collaboration, traffic monitoring, device configuration, or a combination of such) to assess the accuracy of the information they receive from neighboring APs in order to determine an appropriate collaboration strategy.

An AP that maintains historical information of collaboration results with its neighboring APs could use this information to control its collaboration behavior. For example, an AP might choose to share a channel with an AP that had a history of successful collaboration. In another example, an AP might choose to avoid transmissions only during the HCCA TXOPs of neighboring APs with which it has a history of successful HCCA TXOP negotiation.

When using HCCA TXOP negotiation, it is suggested that an AP perform some monitoring of the channel to assess whether the HCCA AP with which it is collaborating is using its advertised HCCA TXOPs. If the monitoring AP does not detect HCCA traffic during these advertised HCCA TXOPs, such a lack of traffic might indicate that the neighboring AP is willfully or accidentally behaving in an uncooperative manner by advertising HCCA TXOPs that it is not using, possibly as a method to suppress traffic in neighboring BSSs. The monitoring AP might wish to ignore the HCCA TXOP advertisements from APs that do not appear to be collaborating.

Some of the OBSS procedures use unauthenticated Beacon frames and Public Action frames, which are susceptible to impersonation. If unauthenticated Beacon frames and Public Action frames are used, an AP might suffer a denial of service attack by another device impersonating the AP. This denial of service attack, due to the actions of the impersonating device, might cause neighboring APs to falsely ascertain the AP is not collaborating.

An AP could enable protected HCCA TXOP negotiation and protected QLoad reporting to provide protection against impersonation. The AP PeerKey protocol is used in the generation of the PMK to prove that an AP has the private key that corresponds to its public key. Impersonation of protected HCCA TXOP


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negotiation and protected QLoad report management from an AP is prevented while the AP maintains possession of this private key and this private key is not possessed by any other devices.

## T.6 BSS color and spatial reuse(11ax)

The BSS color is an identifier of the BSS and is used to assist a receiving STA in identifying the BSS from which a PPDU originates so that the STA can follow the channel access rules to perform spatial reuse. The objective of spatial reuse operation is to allow the medium to be used more often between OBSSs in dense deployment scenarios by the early identification of signals from OBSSs and interference management. See 26.10 (HE spatial reuse operation(#2389)).

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# Annex U

(informative)

## Functions of the centralized coordination service root (CCSR)

Via unspecified means over the DS, a centralized coordination service root (CCSR) performs the following functions:

- Allows APs to enroll or unenroll from the CCSS.
- Provides a directory service, wherein the CCSR responds to a directory service request that includes a MAC address with an indication of whether the MAC address is an S-AP within the CCSS.
- Configures the beacon interval, ClusterMaxMem, Beacon SP duration, TXSS offset, TXSS CBAP duration, and TXSS CBAP MaxMem (see 10.39.2.2 (Centralized AP or PCP cluster formation)) of each S-AP.
- Aligns the rate of increment of TSFs of S-APs within the CCSS.
- Configures the individual TSF offsets of each S-AP in order to minimize the temporal, spatial, and frequency overlap of BHIs of the BSSs in the same CCSS.
- Provides to each S-AP the cluster time offset availability information from nearby co-channel S-APs.
- Configures each S-AP with certain medium access policies for its centralized AP or PCP cluster (see 10.39.3.4 (Centralized AP or PCP cluster MAC requirements)). The CCSR is permitted to configure different S-APs with different medium access policies.
- Configures each S-AP with a list of one or more channels in an operating class that the S-AP is excluded from operating upon and that the S-AP advertises via the (#3311)channel usage procedures (see 11.21.15 (Channel usage procedures)). The excluded channels are available to STAs that are operating in the area covered by the ECAPC, yet are not within the ECAPC.


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# Annex V

(informative)

# Informative procedures for DMG STAs(#124)

## V.1 TSPEC aggregation for BMG BSSs(#124)

Examples of TSPEC aggregation include, but are not limited to, the following:

— Traffic streams between DMG STA A and DMG STA B, having an access policy of SPCA, even if they flow in opposite directions, sharing an SP allocation created with DMG STA A as Source AID and DMG STA B as Destination AID.

— Traffic streams between DMG STA A and other DMG STAs, having an access policy of EDCA, even if they flow in opposite directions (some having DMG STA A as source and some having DMG STA A as destination), sharing a CBAP allocation created with DMG STA A as Source AID and broadcast Destination AID.

Figure V-1 (Example of TSPEC aggregation (SPCA and EDCA access policies)) and Figure V-2 (Example of TSPEC aggregation (SPCA, EDCA, and SEMM access policies)) show examples of TSPEC aggregation in a DMG BSS. Note that TSPEC 3 in Figure V-1 (Example of TSPEC aggregation (SPCA and EDCA access policies)) (for both SPCA and EDCA cases) can flow only through an RD grant.

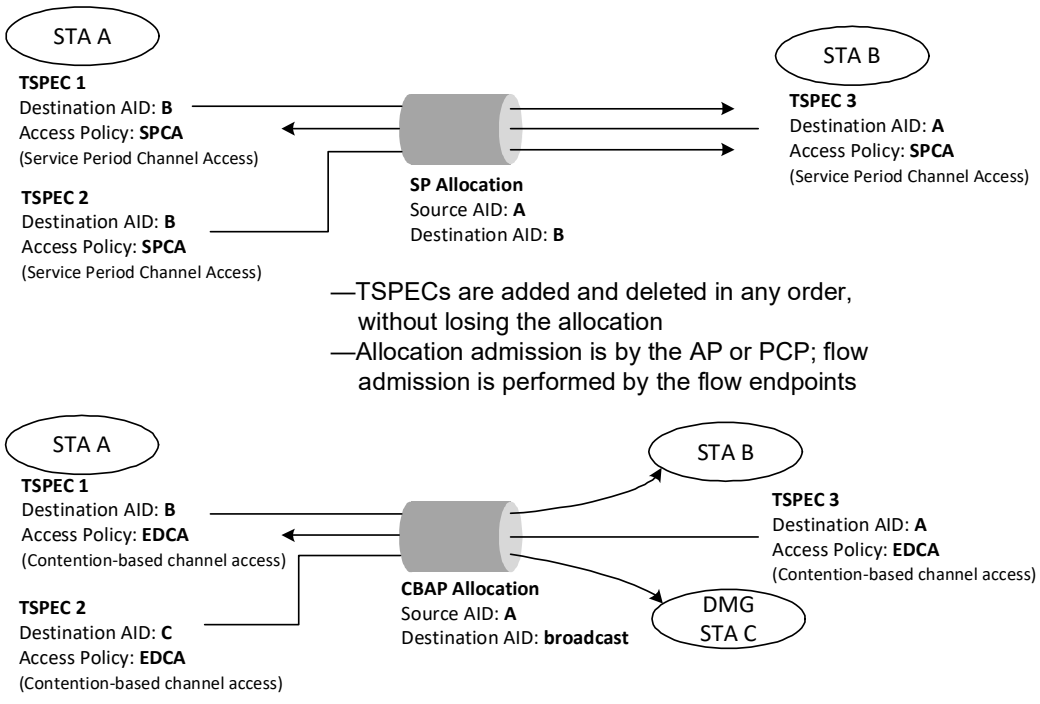


**Figure V-1—Example of TSPEC aggregation (SPCA and EDCA access policies)**

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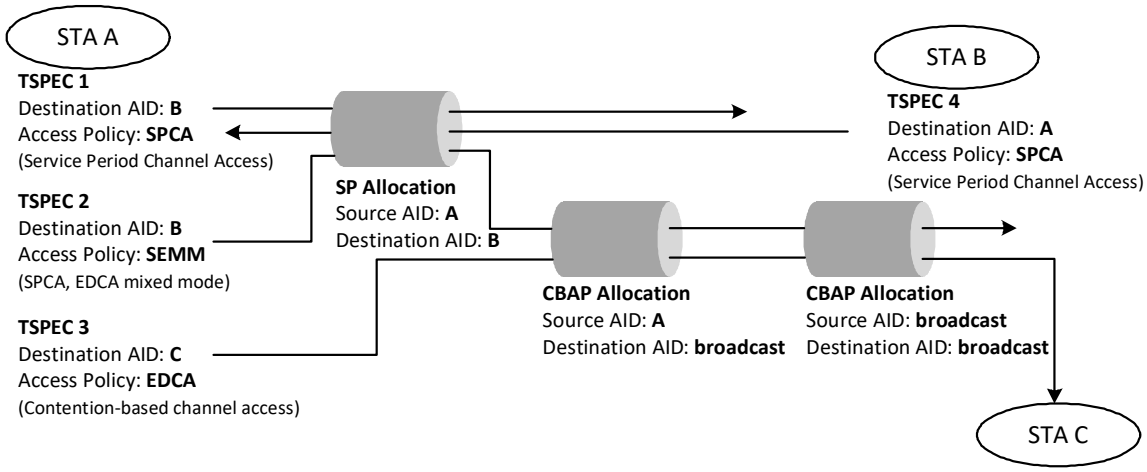


**Figure V-2—Example of TSPEC aggregation (SPCA, EDCA, and SEMM access policies)**

## V.2 Backoff procedure for DMG STAs(#124)

Figure V-4 (Backoff procedure for DMG STAs(#124)) describes the backoff procedure for DMG STAs for the example topology shown in Figure V-3 (Example topology of NAV setting in DMG STAs(#124)).

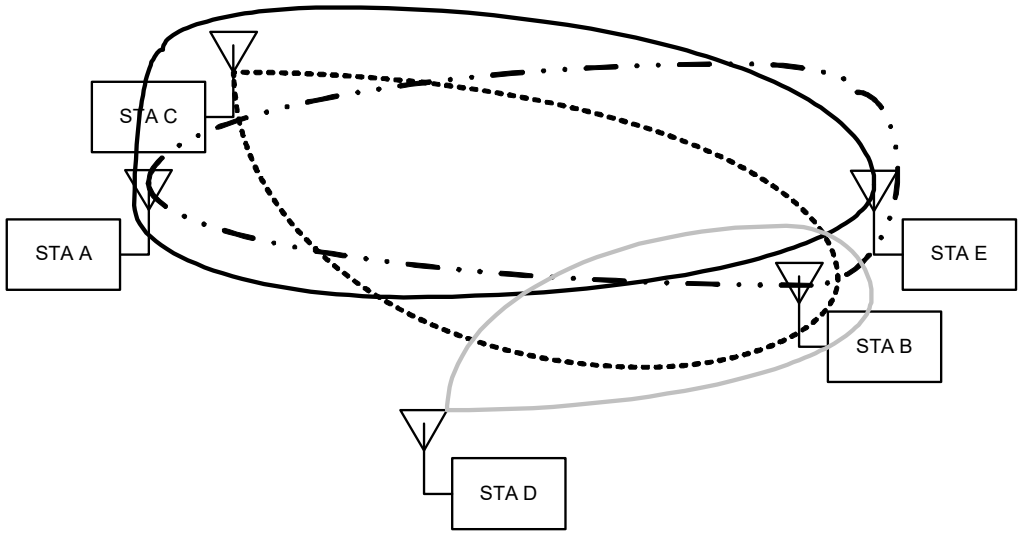


**Figure V-3—Example topology of NAV setting in DMG STAs(#124)**

At the time that STA A starts transmitting a frame to STA E and STA E starts receiving the frame, the antennas of both stations are directed to the peer, i.e., the transmitting antennas of STA A are directed to STA E and the receiving antennas of STA E are directed to STA A. At this point, STA B, STA C, and STA D are not involved in any frame exchange; therefore, they are in receiving state and happen to have the configuration of their receiving antenna arrays set to a quasi-omni antenna pattern to be ready to receive frames from any STA.


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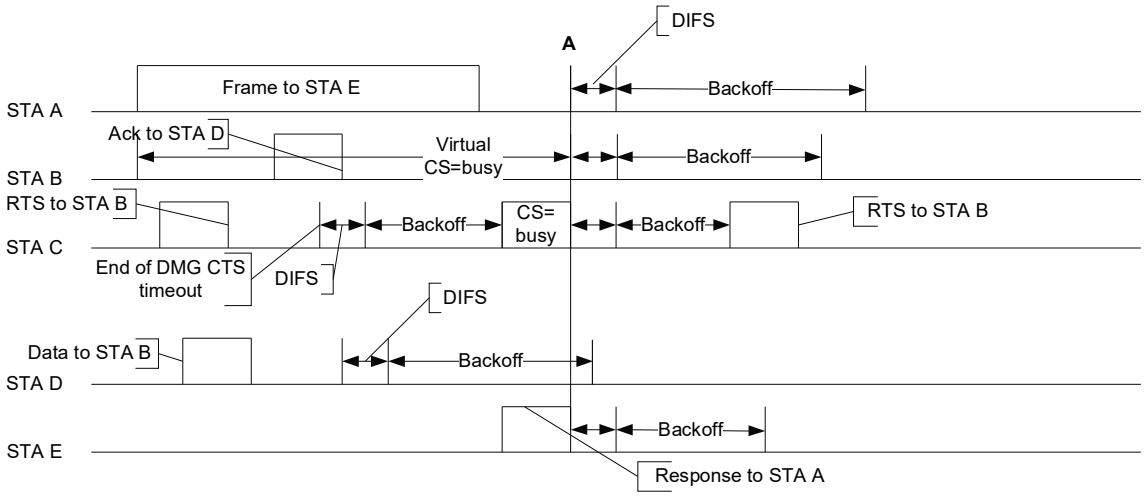


**Figure V-4—Backoff procedure for DMG STAs(#124)**

STA B receives the frame transmitted by STA A (to STA E), and CS (physical and virtual) in STA B indicates a busy medium during the exchange between STA A and STA E.

STA D is not able to receive the frame transmitted by STA A or the response transmitted by STA E; hence CS in STA D indicates IDLE for the duration of the exchange between STA A and STA E.

The physical CS function of STA C indicates a medium busy condition when it receives the response sent by STA E, but indicates an idle medium condition during the transmission from STA A.

STA A and STA E (which are directly involved in the frame exchange), STA B (which received the frame sent by STA A), and STA C (which received the response sent by STA E) are synchronized at point A, where the transaction between STA A and STA E completes.

Since STA D cannot hear the directional transmissions from either STA A or STA C, its physical CS indicates an idle medium condition for the duration of the frame exchange, enabling a frame exchange with STA B at the same time as the frame exchange between STA A and STA E. This is an example of SPSH.

Because STA C is unaware of the transmission of the frame from STA A to STA E, STA C transmits an RTS to STA B. But STA C does not receive a DMG CTS from STA B since the CS at STA B is busy when STA B receives the RTS from the STA C. This causes STA C to retry the RTS transmission following the expiration of a backoff count, which occurs after the completion of the exchange between STA A and STA E.

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# Annex W

(informative)

# Informative procedures for CDMG STAs

## W.1 Selection of candidate SPs for spatial sharing

An AP or PCP uses the SSW Report element (9.4.2.221 (SSW Report element)) to construct a beamforming training table. Based on the beamforming training table, the AP or PCP selects a pair of existing SP and candidate SP to perform spatial sharing according to the procedures described in 11.32 (MMSL cluster operation).

Each entry of the beamforming training table has three items: source AID, destination AID, and the best sector for transmitting from source STA to destination STA. The AP or PCP stores the beamforming training results between any pair of STAs among its BSS. If a source STA and a destination STA have not performed beamforming training, the best sector item is typically given a default sector number.

The select condition is that any source STA involved in an existing SP does not employ the same transmit sector with the one that it employs to communicate with any other STA involved in a candidate SP, and vice versa. If a pair of existing SP and candidate SP satisfies the above condition, the AP or PCP schedules the existing SP and the candidate SP time-overlapping with each other for spatial sharing.

For the same existing SP, if more than one candidate SP satisfy the above condition, the AP or PCP selects the SP with the largest number of difference between any two of transmit sectors employed by a source STA to communicate with its destination STA and with any other STA involved in the other SP.

## W.2 N-phase beamforming codebook for CDMG STAs

### W.2.1 General

This annex puts forward a method for *N*-phase beamforming codebook design, which is applicable to CDMG STAs only. The codebook cannot only be used in the multi-beam switching system, but also be applied to 1-D (one-dimensional) uniform linear phased antenna array and 2-D (two-dimensional) uniform phased antenna array. The STA can simply choose this beamforming codebook for directional transmission during communication.

### W.2.2 1-D (one-dimensional) antenna array

As to the 1-D uniform linear antenna array, all antenna array elements linearly distribute with the interval of λ/2 while λ denotes the carrier's wavelength. The beam codebook is a data matrix **W,** and each element of **W** defines the corresponding antenna array element's weights. For phased antenna array, the weights define the phase misalignment, so the element $w_{m,k}$ of **W** satisfies $|w_{m,k}|=1$. Equation (W-1) gives an example of a beam codebook matrix, among which $M$ denotes the number of antenna elements and $K$ denotes the numbers of beam patterns. Each column of the codebook matrix specifies a certain beam pattern, and all columns cover the whole space together. The columns of **W** number from 0.


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$$\boldsymbol{W}_{M\times K} = \begin{bmatrix} 1 & j & \cdots & 1 \\ 1 & j & \cdots & j \\ \cdots & \cdots & \cdots & \cdots \\ 1 & j & \cdots & 1 \end{bmatrix}_{M\times K} \quad \text{(W-1)}$$

Figure W-1 (An arrange mode of 1-D uniform linear antenna array) shows an arrange mode of 1-D uniform linear antenna array.

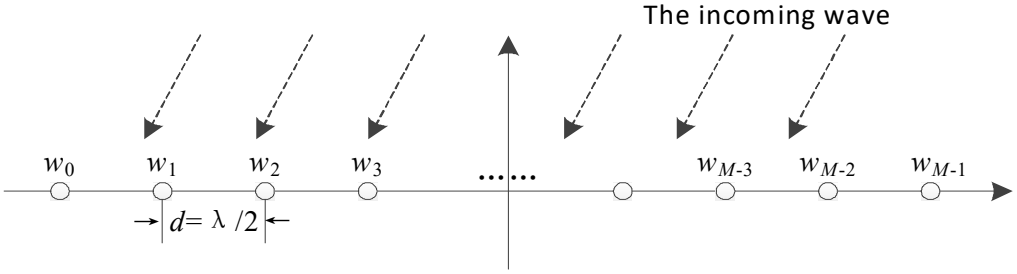


**Figure W-1—An arrange mode of 1-D uniform linear antenna array**

*N*-phase beam codebook is shown in Equation (W-2). The matrix's element of line *m* and column *k* denotes the antenna weight for the *m*-th antenna element of the *k*-th beam. *K* is the number of beams, and *M* is the number of antenna elements. The function fix(*x*) returns the biggest integer that is less than or equal to *x*. *N* denotes the number of discrete phases, and the size of *N* is free while each beam gain's loss generated by the codebook is smaller with the increase of *N*. Generally, *N* satisfies $N \geq 4$ (i.e., at least 2 bit discrete phases) to obtain the beam codebook's performance gain. Meanwhile, *N* also satisfies $N \leq 2M$ for no more performance gain is acquired when $N>2M$.

$$W(m,k) = e^{j\frac{2\pi}{N}\mathrm{fix}\left(\frac{m\times \mathrm{mod}(k+K/2,K)}{K/N}\right)} \quad \text{(W-2)}$$

$$m = 0, 1, \ldots, M-1;\ k = 0, 1, \ldots$$

Figure W-2 (Beam patterns generated by the codebook) shows the codebook's beam patterns when $m$=8 and $k$=16. Figure W-2 (Beam patterns generated by the codebook)(a) shows the beam patterns when $N$=4, and Figure W-2 (Beam patterns generated by the codebook)(b) shows the beam patterns when $N$=16.

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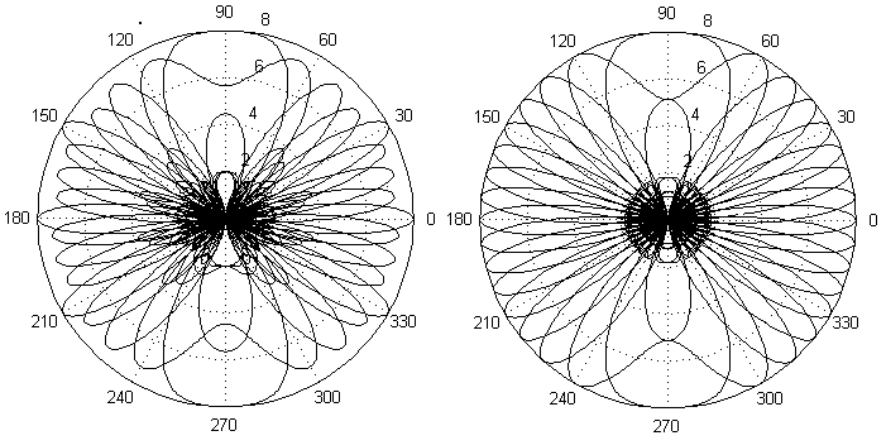


**Figure W-2—Beam patterns generated by the codebook**

### W.2.3 2-D (two-dimensional) antenna array

A beam of 2-D linear antenna array is made up of two mutually perpendicular 1-D uniform linear antenna arrays. Figure W-3 (An arrange mode of 2-D uniform linear antenna array) shows an arrange mode of 2-D uniform linear antenna array. The antenna elements are arranged in the mutually perpendicular directions of $x$ and $z$, and the antenna elements' number in the direction of $x$ is $M_x$ with the spacing of $d_x$ while the antenna elements' number in the direction of $z$ is $M_z$ with the spacing of $d_z$.

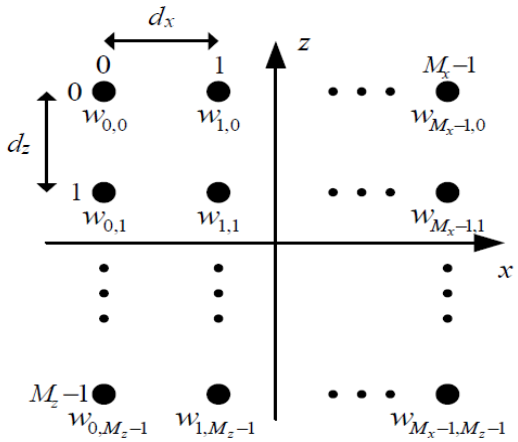


**Figure W-3—An arrange mode of 2-D uniform linear antenna array**

Each beam pattern of 2-D antenna array is actually superposition of two beam patterns of 1-D antenna array. The weights of antenna elements of 2-D antenna array should be calculated as follows:

$$w_{m_x, m_z} = w_{m_x} w_{m_z};\ m_x = 0, 1, \ldots, M_x, m_z = 0, 1, \ldots, M_z \quad \text{(W-3)}$$

Among which $w_{m_x}$ and $w_{m_z}$ separately stands for the beam weights of $x$ and $z$.


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## W.3 Beam tracking and switching for enhanced beam tracking mechanism

This annex puts forward a method of beam tracking and switching for a CDMG STA pair supporting enhanced beam tracking mechanism to combat link blockage and antenna rotation. After enhanced beam tracking is requested, the e-TRN subfields are transmitted in the end of the PHY frame.

The CDMG STA pair measure the receive signal powers corresponding to the training beam links, including the current transmission link, the neighboring beam links and the current alternative beam link.

The signal power attenuation induced by the link blockage is calculated as the difference value of the power obtained by originally optimal beam link minus maximum power obtained by current transmission and its neighboring beam links. If the signal power attenuation induced by the link blockage is larger than a blockage attenuation threshold, or the power obtained by alternative beam link is larger than the maximum power obtained by current transmission and its neighboring beam links, the link blockage is declared.

If antenna rotation is considered, the signal power attenuation induced by the antenna rotation is calculated as the difference value of maximum power of the current transmission and its neighboring beam links minus the power of the current transmission beam link. If the signal power attenuation induced by the antenna rotation is larger than a predefined rotation attenuation threshold, the antenna rotation is declared, and the rotation compensation angle for the subsequent transmission and alternative beam links is calculated as the difference value of the azimuth of the neighboring beam link that has the maximum signal power minus the azimuth of current transmission beam link.

Finally, according to the switching declaration results and the rotation compensation angle, STAs can switch to the AWV, i.e., azimuth, of the updated alternative beam link to combat link blockage and antenna rotation. Specifically, if the link blockage is declared, the azimuth of the subsequent transmission beam link is to become the azimuth of the current alternative beam link plus the rotation compensation angle, and the azimuth of subsequent alternative beam link is to become the azimuth of the current transmission beam link plus the rotation compensation angle; otherwise, the azimuths of subsequent transmission and alternative beam links are to become their current azimuths plus the rotation compensation angle, respectively.

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# Annex X

(informative)

# Link rate considerations

Default values for the link cost determination variables whose names start with “dot11GLKLinkRate” are provided in Annex C. In adjusting the values of these variables, the following considerations are recommended:

— For applications such as bulk data transfer, in which the long-term bandwidth is of primary concern, it is recommended that dot11GLKLinkRateWavg be set near the top of its range while dot11GLKLinkRateWgeo and dot11GLKLinkRateWmin are set low, perhaps to 0. It might also be reasonable to increase some combination of dot11GLKLinkRateSamples and dot11GLKLinkRateWindowSize and decrease dot11GLKLinkRateHysteresis from their default values.

— For time critical applications requiring good performance on short bursts of transmissions, it is recommended that dot11GLKLinkRateWmin be set near the top of its range while dot11GLKLinkRateWavg and dot11GLKLinkRateWgeo be set low, perhaps to 0. It might also be reasonable to decrease dot11GLKLinkRateWindowSize and/or increase dot11GLKLinkRateHysteresis from their default values to make the cost more responsive. dot11GLKLinkRateSamples × dot11GLKLinkRateWindowSize will determine how quickly $R_{composite}$ can spring back from one or more samples of low or 0 effective data bandwidth.

— For general applications that are not time critical but require reasonable performance, for example, messages related to human interaction or the like, it is recommended that dot11GLKLinkRateWgeo weight dominate and dot11GLKLinkRateWmin and dot11GLKLinkRateWavg are set low, perhaps to 0. In this case, it is also recommended that dot11GLKLinkRateSamples × dot11GLKLinkRateWindowSize not exceed typical human response expectations, perhaps 1 s or 2 s.


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# Annex Y

(informative)

# Preassociation discovery (PAD) additional information

## Y.1 Preassociation discovery usage models

The preassociation discovery (PAD) and service information procedures (see 11.23 (Preassociation discovery (PAD) procedures)) support several ways of obtaining service information. The following subclauses describe two methods: background search and immediate search.

## Y.2 Background search

Applications that run in the background on the STA (e.g., automatically receiving sales coupons within messages transmitted from a BSS for which a user has previously signed up) might not require immediate discovery results to be presented to the user. It may be appropriate to prevent non-AP and non-PCP STAs, running such background applications, from performing a solicited PAD procedure.

Solicited PAD has the potential to introduce network congestion, and it is recommended that STAs limit the use of solicited PAD to cases requiring an active search for services. In those cases, it is more effective to perform an unsolicited PAD search, in which an AP or PCP advertises multiple services known to the SIR, while non-AP and non-PCP STAs need respond only if there is a matched service.

The SIR can advertise services through an AP or PCP, using the Service Hash element, and advertise remaining services, using the Service Hint element, in the Beacon or DMG Beacon frame. Alternatively, the SIR can advertise all of the services through an AP or PCP, using either the Service Hash or Service Hint element, in the Beacon or DMG Beacon. Upon receiving a Beacon or DMG Beacon frame, the SIC in a non-AP and non-PCP STA processes the Service Hash and Service Hint elements to verify if there are any potential matching services. Figure Y-1 (Example of a frame exchange for background search with Service Hint matching) and Figure Y-2 (Example of frame exchange for background search with matching Service Hash element) show two cases where there is a matching service hint.

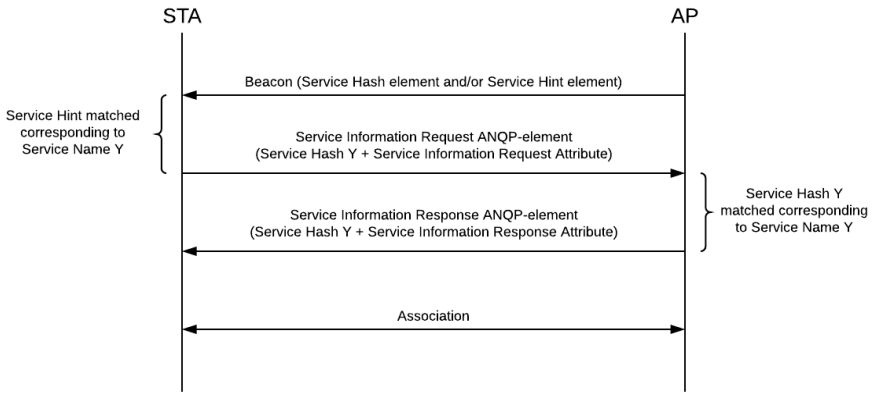


**Figure Y-1—Example of a frame exchange for background search with Service Hint matching**

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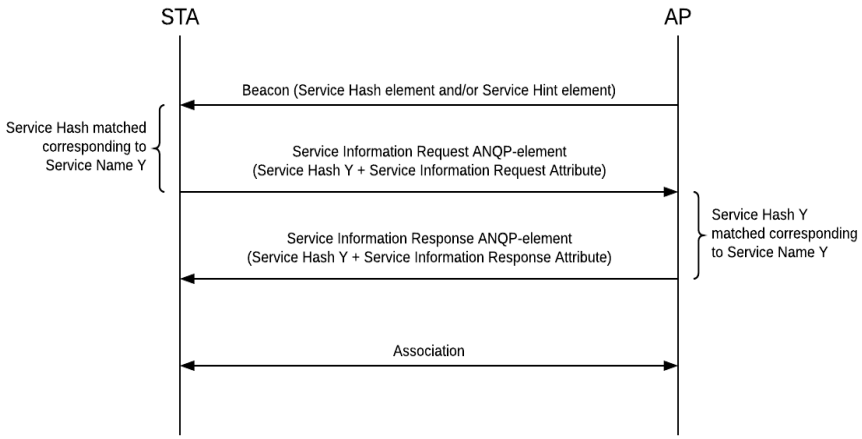


**Figure Y-2—Example of frame exchange for background search with matching Service Hash element**

If the probability of false positives as indicated in the False Positive Probability Range field of the Service Hint element is considered relatively high by the SIC in the non-AP and non-PCP STA (see Figure Y-1 (Example of a frame exchange for background search with Service Hint matching)), the SIC can send, through the non-AP and non-PCP STA, a Service Information Request ANQP-element containing Service Information. The SIR then responds, through an AP or PCP, with a Service Information Response ANQP-element containing the Service Information Response Attribute subfield. This subfield contains information about the service(s) that was requested. Following these service information exchanges, the non-AP and non-PCP STA might associate to the AP or PCP.

If the probability of false positive as indicated in False Positive Probability Range field of the Service Hint element is considered relatively low by the SIC in the non-AP and non-PCP STA, the SIC might choose the AP or PCP as a candidate BSS. The SIC might send a Service Information Request ANQP-element to confirm if a service is reachable through the AP or PCP as shown in Figure Y-1 (Example of a frame exchange for background search with Service Hint matching). Based on the results of either of these steps, the SIC in the non-AP and non-PCP STA might request association with the BSS.

In a scenario where there is a matching service hash, the non-AP and non-PCP STA can send a Service Information Request ANQP-element containing a Service Information Request Attribute to the AP or PCP to obtain more information about the service from the SIR as shown in Figure Y-2 (Example of frame exchange for background search with matching Service Hash element). The SIR responds to the ANQP request, through the AP or PCP, with a Service Information Response ANQP-element containing the Service Information Response Attribute subfield. Following these service message exchanges, the non-AP and non-PCP STA might associate with the AP or PCP. Alternatively, the non-AP and non-PCP STA might choose to associate based on the matching Service Hash element.

## Y.3 Immediate search

Applications that are initiated by users on the STA (e.g., a user is looking for a fast movie download service provided by a BSS) require immediate discovery results to be presented to the STA or a user so that network selection can be performed by either a STA or the user to obtain the desired service.

Figure Y-3 (Example of frame exchange for immediate search) shows a non-AP and non-PCP STA performing a solicited PAD procedure, whereby the non-AP and non-PCP STA sends a Service Information


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Request ANQP-element to query specific services immediately after user initiation of the service/ application. The SIR responds through an AP or PCP with a Service Information Response ANQP-element accordingly if there is a matched service.

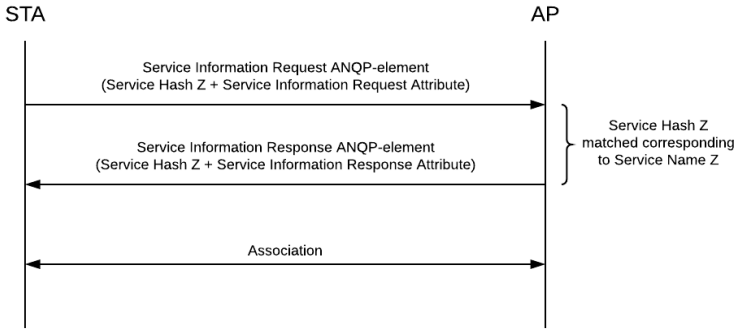


**Figure Y-3—Example of frame exchange for immediate search**

Following these service message exchanges, the SIC in the non-AP and non-PCP STA can make an informed decision about choosing to associate to the AP or PCP.

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# Annex Z(11ax)

(informative)

# HE-SIG-B content examples

## Z.1 General

This annex provides a number of examples to illustrate the content of HE-SIG-B content channels.

HE-SIG-B content channels are padded to the same length and to an OFDM symbol boundary as defined in 27.3.11.8.5 (Encoding and modulation). For illustration simplicity, the examples do not include the complete padding bits but only pad to make the two HE-SIG-B content channels equal in length and an integer number of 4 bits. All the padding bits in the examples are set to 0.

In the examples, the binary sequence of each HE-SIG-B field is in transmission order. For the entire content of each HE-SIG-B content channel, the binary sequences are converted to hexadecimal listed in transmission order as pairs of hexadecimal digits, where the first bit transmitted is the LSB of the first transmitted octet and is the LSB of the second hexadecimal digit.

## Z.2 Example 1

An example of the HE-SIG-B field with resource allocation signaling for an 80 MHz HE MU PPDU is shown in Table Z-1 (Resource allocation signaling example 1(11ax)).

**Table Z-1—Resource allocation signaling example 1(11ax)**

| RU | 484-tone RU 1 | 26-tone RU 19 (center 26-tone RU) | 242-tone RU 3 | 242-tone RU 4 |
|---|---|---|---|---|
| SS0 | STA-ID 1441, HE-MCS 10, LDPC | STA-ID 1443, HE-MCS 3, BCC, 1SS, no beamforming, no DCM | STA-ID 1444, HE-MCS 4, BCC, 2SS, Tx beamforming | STA-ID 1445, HE-MCS 8, BCC |
| SS1 | | | | STA-ID 1446, HE-MCS 7, BCC |
| SS2 | STA-ID 1442, HE-MCS 9, LDPC | | N/A | STA-ID 1447, HE-MCS 6, BCC |
| SS3 | | | | STA-ID 1448, HE-MCS 5, BCC |


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The AP performs a dynamic split of the User fields for the two MU-MIMO STAs on 484-tone RU 1, with two User fields assigned to HE-SIG-B content channel 1 and none to HE-SIG-B content channel 2, to avoid a disparity in the number of User fields between content channels (see NOTE 1 in 27.3.11.8.3 (Common field)). The User field for STAs 1441, 1442, 1443, and 1444 are in HE-SIG-B content channel 1 while User field for STAs 1445, 1446, 1447, and 1448 are in HE-SIG-B content channel 2. The content of the entire HE-SIG-B field for this example is shown in Table Z-2 (HE-SIG-B field content for example 1(11ax)).

**Table Z-2—HE-SIG-B field content for example 1(11ax)**

| | HE-SIG-B content channel 1 | | HE-SIG-B content channel 2 | |
|---|---|---|---|---|
| Common field | 10010011 00000011 1 1111 000000 | | 01001110 11000011 1 1100 000000 | |
| User fields | STA 1441 | 10000101101 0010 0101 0 1 | STA 1445 | 10100101101 0000 0001 0 0 |
| | STA 1442 | 01000101101 0010 1001 0 1 | STA 1446 | 01100101101 0000 1110 0 0 |
| | CRC & tail | 0011 000000 | CRC & tail | 1101 000000 |
| | STA 1444 | 00100101101 100 1 0010 0 0 | STA 1447 | 11100101101 0000 0110 0 0 |
| | STA 1443 | 11000101101 000 0 1100 0 0 | STA 1448 | 00010101101 0000 1010 0 0 |
| | CRC & tail | 1000 000000 | CRC & tail | 1001 000000 |
| | Padding | 0 | Padding | 0 |
| HE-SIG-B field content in binary, organized as octets (LSB first) | 10010011 00000011 11111000 00010000 10110100 10010101 01000101 10100101 00101001 10000000 01001011 01100100 10001100 01011010 00011000 01000000 0000 | | 01001110 11000011 11100000 00010100 10110100 00000100 01100101 10100001 11000110 10000001 11001011 01000001 10000001 01011010 00010100 01001000 0000 | |
| HE-SIG-B field content in binary, organized as octets (MSB first within each octet) | 11001001 11000000 00011111 00001000 00101101 10101001 10100010 10100101 10010100 00000001 11010010 00100110 00110001 01011010 00011000 00000010 0000 | | 01110010 11000011 00000111 00101000 00101101 00100000 10100110 10000101 01100011 10000001 11010011 10000010 10000001 01011010 00101000 00010010 0000 | |
| HE-SIG-B field content in hexadecimal, organized as octets | c9 c0 1f 08 2d a9 a2 a5 94 01 d2 26 31 5a 18 02 00 | | 72 c3 07 28 2d 20 a6 85 63 81 d3 82 81 5a 28 12 00 | |

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## Z.3 Example 2

An example of the HE-SIG-B field with full-bandwidth MU-MIMO resource allocation for more than 1 user in an 80 MHz HE MU PPDU is shown in Table Z-3 (Resource allocation signaling example 2(11ax)).

**Table Z-3—Resource allocation signaling example 2(11ax)**

| RU | 996-tone RU 1 |
|---|---|
| SS0 | STA-ID 1449, HE-MCS 6, LDPC |
| SS1 | |
| SS2 | STA-ID 1450, HE-MCS 7, LDPC |
| SS3 | STA-ID 1451, HE-MCS 8, LDPC |

In this example, the HE-SIG-B Compression field in the HE-SIG-A field is set to 1, and the Common field is not present in either HE-SIG-B content channel. The User field for STA 1449 and STA 1450 is in HE-SIG-B content channel 1, and the User field for STA 1451 is in HE-SIG-B content channel 2. The content of the HE-SIG-B field in this example is shown in Table Z-4 (HE-SIG-B field content for example 2(11ax)).

**Table Z-4—HE-SIG-B field content for example 2(11ax)**

| | HE-SIG-B content channel 1 | | HE-SIG-B content channel 2 | |
|---|---|---|---|---|
| User fields | STA 1449 | 10010101101 1000 0110 0 1 | STA 1451 | 11010101101 1000 0001 0 1 |
| | STA 1450 | 01010101101 1000 1110 0 1 | CRC & tail | 0101 000000 |
| | CRC & tail | 0011 000000 | Padding | 00000000000000000000 |
| HE-SIG-B field content in binary, organized as octets (LSB first) | 10010101 10110000 11001010 10101101 10001110 01001100 0000 | | 11010101 10110000 00101010 10000000 00000000 00000000 0000 | |
| HE-SIG-B field content in binary, organized as octets (MSB first within each octet) | 10101001 00001101 01010011 10110101 01110001 00110010 0000 | | 10101011 00001101 01010100 00000001 00000000 00000000 0000 | |
| HE-SIG-B field content in hexadecimal, organized as octets | a9 0d 53 b5 71 32 00 | | ab 0d 54 01 00 00 00 | |



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## Z.4 Example 3

An example of the HE-SIG-B field with signaling for a full-bandwidth single-user resource allocation in an 80 MHz HE MU PPDU is shown in Table Z-5 (Resource allocation signaling example 3(11ax)).

**Table Z-5—Resource allocation signaling example 3(11ax)**

| RU | 996-tone RU 1 |
|---|---|
| SS0 | STA-ID 1452, HE-MCS 8, LDPC, 2SS, Tx beamforming |
| SS1 | |

In this example, the HE-SIG-B Compression field in the HE-SIG-A field is set to 0, and the resource allocation is signaled as an OFDMA transmission with one user. The User field for STA 1452 is in HE-SIG-B content channel 1, and no User field is present in HE-SIG-B content channel 2. The content of the HE-SIG-B field is shown in Table Z-6 (HE-SIG-B field content for example 3(11ax)).

**Table Z-6—HE-SIG-B field content for example 3(11ax)**

| | HE-SIG-B content channel 1 | | HE-SIG-B content channel 2 | |
|---|---|---|---|---|
| Common field | 00001011 11001110 0 1011 000000 | | 11001110 11001110 0 1110 000000 | |
| User fields | STA 1452 | 00110101101 100 1 0001 0 1 | Padding | 00000000000000000000 0000000000 00 |
| | CRC & tail | 1100 000000 | | |
| | Padding | 00 | | |
| HE-SIG-B field content in binary, organized as octets (LSB first) | 00001011 11001110 01011000 00000110 10110110 01000101 11000000 0000 | | 11001110 11001110 01110000 00000000 00000000 00000000 00000000 0000 | |
| HE-SIG-B field content in binary, organized as octets (MSB first within each octet) | 11010000 01110011 00011010 01100000 01101101 10100010 00000011 0000 | | 01110011 01110011 00001110 00000000 00000000 00000000 00000000 0000 | |
| HE-SIG-B field content in hexadecimal, organized as octets | d0 73 1a 60 6d a2 03 00 | | 73 73 0e 00 00 00 00 00 | |

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## Z.5 Example 4

In the following example there is an 80 MHz or wider PPDU with the lowest 484-tone RU containing two users, and there are multiple other unlisted users, which are variously split across the two HE-SIG-B content channels (e.g., because their RU sizes are up to 242 tones). For the two users in the 484-tone RU, Table Z-7 (RU Allocation subfields for different dynamic splits of User fields for the example of two MU-MIMO users in the lowest 484-tone RU of an 80 MHz or wider PPDU(11ax)) shows various dynamic split options that can be used to reduce the disparity in the number of User fields across the HE-SIG-B content channels (see NOTE 1 in 27.3.11.8.3 (Common field)). The example shows just the associated RU Allocation subfields (i.e., a fragment of the HE-SIG-B field), which might be sent in one of three ways.

**Table Z-7—RU Allocation subfields for different dynamic splits of User fields for the example of two MU-MIMO users in the lowest 484-tone RU of an 80 MHz or wider PPDU(11ax)**

| Dynamic split option | First RU Allocation subfield of HE-SIG-B content channel 1 | Number of User fields contributed to HE SIG-B content channel 1 | First RU Allocation subfield of HE SIG-B content channel 2 | Number of User fields contributed to HE SIG-B content channel 2 |
|---|---|---|---|---|
| Both User fields signaled in HE-SIG-B content channel 1 | MSB first: 11001001<br>LSB first: 10010011 | 2 | MSB first: 01110010<br>LSB first: 01001110 | 0 |
| Both User fields signaled in HE-SIG-B content channel 2 | MSB first: 01110010<br>LSB first: 01001110 | 0 | MSB first: 11001001<br>LSB first: 10010011 | 2 |
| One User field per HE-SIG-B content channel | MSB first: 11001000<br>LSB first: 00010011 | 1 | MSB first: 11001000<br>LSB first: 00010011 | 1 |


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# Annex AA(11ax)

(informative)

# Multiple BSSID configuration examples

## AA.1 Introduction

This annex provides examples showing the relationship between profile periodicity (indicated by the Full Set Rx Periodicity field in the Multiple BSSID Configuration element) and the DTIM interval (DTIM Period field in the Multiple BSSID-Index element) for a multiple BSSID set as described in 11.1.3.8.3 (Discovery of a nontransmitted BSSID profile(11ax)). The examples provide guidance on how an AP might organize the advertisement of nontransmitted BSSID profiles in its Beacon frames if it cannot fit all the profiles in a single Beacon frame (i.e., partial list of profiles) it is advertising. By having the DTIM interval for a nontransmitted BSSID a multiple of the profile periodicity, the profile for that BSSID would always appear in its DTIM beacon. This helps an associated non-AP STA save power as it is able to receive any updates to the profile when it wakes to receive the DTIM beacon.

## AA.2 Examples

In the following examples, a BSSID with BSSID-index I, DTIM count of X, and DTIM period of Y is represented as [I] X/Y. A profile appears in every $p^{th}$ Beacon frame; where p is the value carried in the Full Set Rx Periodicity field. Each set of profiles appearing in a Beacon frame amongst the p Beacon frames is identified as set A to set P. In the following examples, a nontransmitted BSSID is considered as active if the AP corresponding to that BSSID has set up a BSS and the information of the BSSID is carried in a Beacon frame of the AP corresponding to the transmitted BSSID in the set. When an AP is advertising a partial list of profiles, the information (#1217)might not be carried in every Beacon frame (see 11.1.3.8.3 (Discovery of a nontransmitted BSSID profile(11ax))). For simplicity, the examples show that the BSSIDs are activated in contiguous order of BSSID-index and appear in the same order in a Beacon frame. In practice, an AP can activate BSSIDs in any order and include a certain BSSID profile in a Beacon frame based on size.

The first example illustrates the case where MaxBSSID Indicator ($n$) is set to 4 and there are 11 active nontransmitted BSSIDs in a multiple BSSID set. The AP is able to fit up to 3 nontransmitted BSSID profiles in each beacon, and the Full Set Rx Periodicity field is set to 4. Figure AA-1 (Example of partial list of profiles with a profile periodicity of 4(11ax)) shows the configuration for DTIM count and DTIM period of each BSSID in this set. With the DTIM period being a multiple of profile periodicity, the AP is able to include a nontransmitted BSSID in its DTIM beacon.


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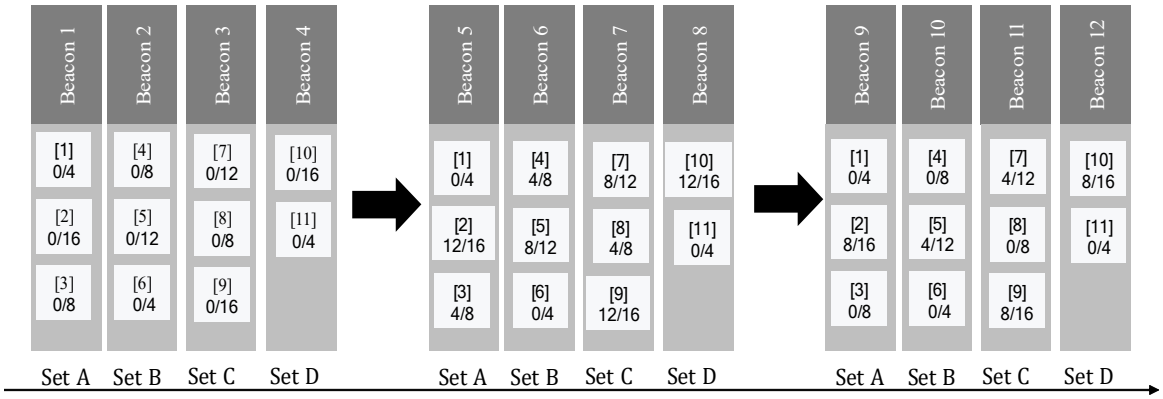


**Figure AA-1—Example of partial list of profiles with a profile periodicity of 4(11ax)**

The next example considers the case where MaxBSSID Indicator (n) is set to 4 and there are 15 active nontransmitted BSSID in a multiple BSSID set. In this example, the AP's Beacon frame is able to fit up to 6 nontransmitted BSSID profiles; therefore, the profile periodicity for the set has a value equal to 3. Figure AA-2 (Example of partial list of profiles with a profile periodicity of 3(11ax)) shows the configuration for DTIM count and DTIM period of each BSSID in this set. A BSSID profile would be included every third Beacon frame. In addition, since the DTIM interval is a multiple of profile periodicity, it would appear in the DTIM beacon of each profile.

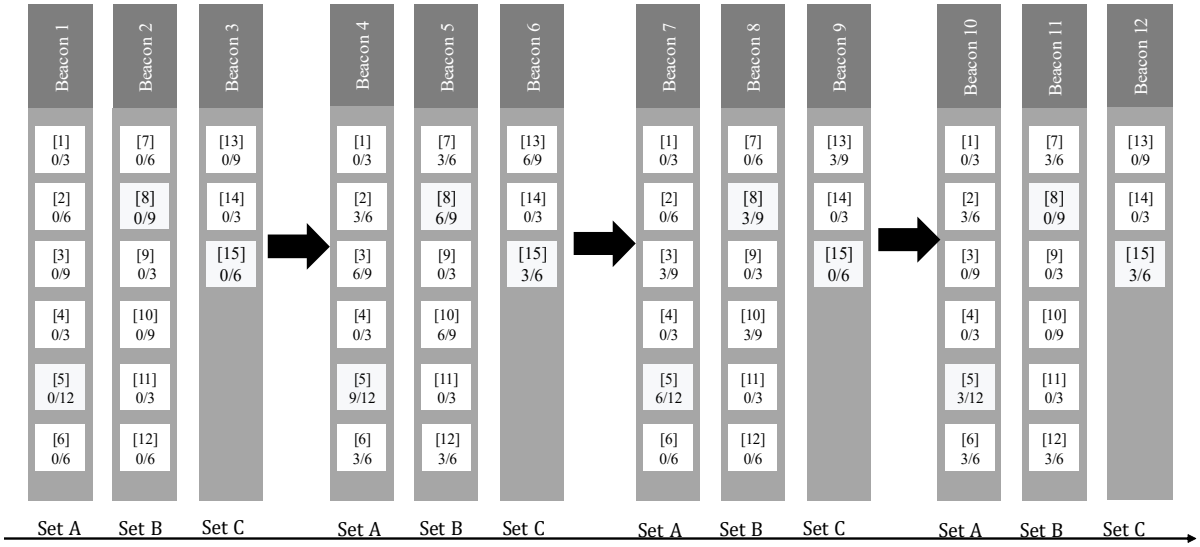


**Figure AA-2—Example of partial list of profiles with a profile periodicity of 3(11ax)**

The next example considers the case where a BSSID is deactivated and the corresponding AP disassociates the entire BSS. In this case, there are 15 nontransmitted BSSIDs that are active, and one of the BSSID in set B (BSSID-Index = 10 with DTIM period = 9) is turned off at some point. Figure AA-3 (Example of a

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BSSID being deactivated(11ax)) illustrates this case. Once deactivated, this BSSID is no longer included in the Beacon frame. No other BSSIDs in set B or other sets are affected.

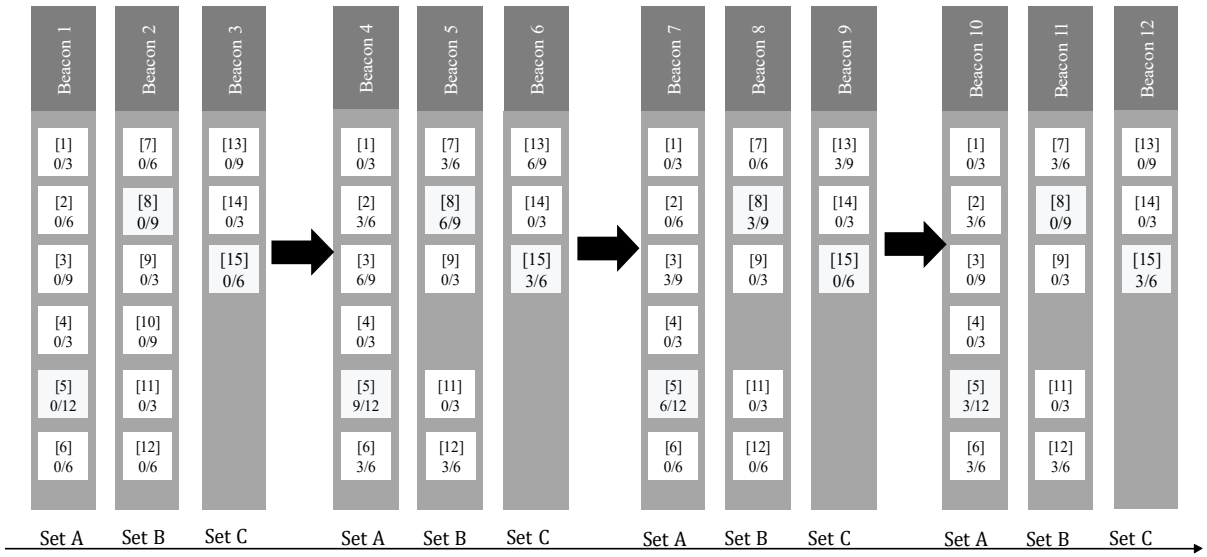


**Figure AA-3—Example of a BSSID being deactivated(11ax)**

The next example considers the case where a BSSID that was not active earlier is activated. In this case, there are 14 nontransmitted BSSIDs that are active, and a new BSSID (BSSID-Index = 15 with DTIM period = 6) is activated at some point. The AP is able to fit it as part of set C. Figure AA-4 (Example of a BSSID being activated(11ax)) illustrates this case. This BSSID is included in the next set of beacons and is advertised as part of set C. When the BSSID is included in a Beacon frame for the first time, it is started with DTIM count set to 0. With the DTIM Period being a multiple of profile periodicity, the AP can ensure that the profile appears in its DTIM beacon.

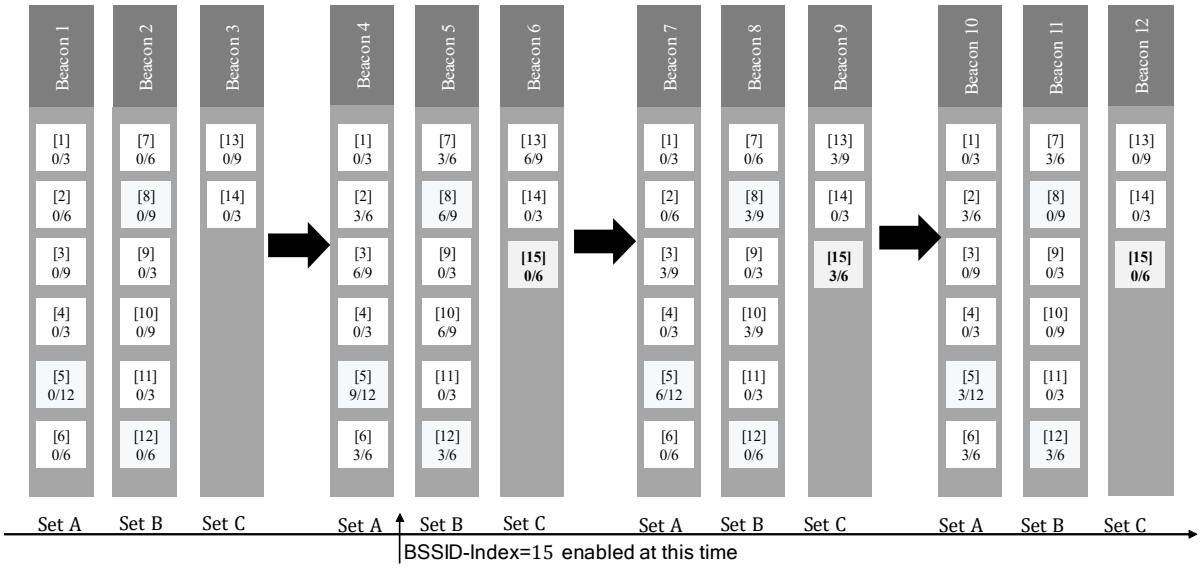


**Figure AA-4—Example of a BSSID being activated(11ax)**

The next example considers the case where the DTIM period for a BSSID is updated. In this case, the DTIM period for a BSSID (BSSID-Index = 12) is changed from 6 to 15. This change would be indicated during a


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DTIM beacon for that profile. This ensures(M118) that STAs associated with that profile are able to receive the update. After the change, when the BSSID is included in a Beacon frame for the first time, it starts with DTIM count set to 0. With the new DTIM period (of 15) being a multiple of profile periodicity (of 3), the profile will appear in its DTIM beacon. Figure AA-5 (Example of DTIM period being changed for a particular BSSID(11ax)) shows the configuration for DTIM count and DTIM period of each BSSID in this set.

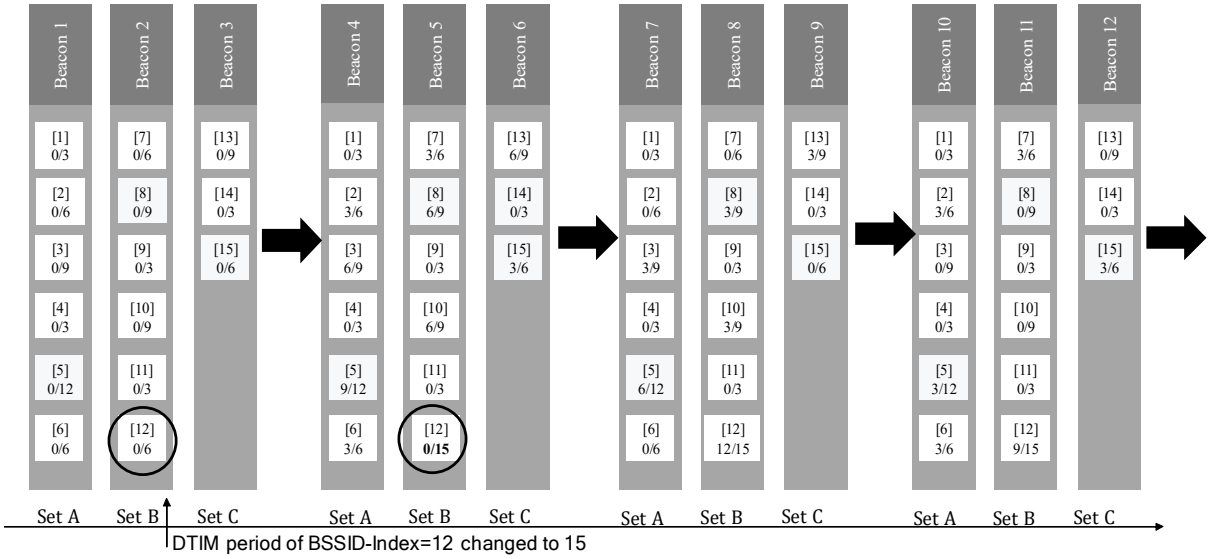


**Figure AA-5—Example of DTIM period being changed for a particular BSSID(11ax)**

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# Annex AB(11ay)

(informative)

## Radar implementation using the DMG PHY and EDMG PHY

A radar is used to estimate the relative position and velocity of a target object with respect to the radar by transmitting a signal from a transmitting antenna and measuring the time and direction in which one or more reflections of the signal arrive at a receiving antenna. Given their directional propagation characteristics, the DMG PHY and EDMG PHY can be used to implement radar functionality.

To implement radar functionality, a STA (non-EDMG STA or EDMG STA) can transmit a PPDU and measure the time it takes and direction from which reflections arrive at the STA. Any type of PPDU can be used by the STA as long as the following conditions are met:

— The PPDU is a valid EDMG or DMG PPDU constructed according to the EDMG or DMG PHY specification, respectively

— The STA follows all corresponding medium access rules to transmit the PPDU.

— The TA field and RA field of the frame in the PPDU are set to the MAC address of the transmitting STA.

— For a Short SSW PPDU, the source AID field and Destination AID field of the PPDU are set to the same value.

By using the approach described in this Annex to implement radar function, coexistence with DMG and EDMG transmissions on the same channel is achieved due to the use of IEEE 802.11 EDCA medium access rules and DMG or EDMG PPDUs, which allow other STAs to determine the duration of a transmission. The addressing rules described above enhance coexistence by reducing the probability that a STA gets confused by radar transmissions. When radars follow these rules, the throughput of a DMG or an EDMG STA operating in the vicinity of the radar transmissions can increase due to reduced collisions with such transmissions.

Examples of transmissions that can be used to realize radar functionality include the following:

— A STA may transmit an SSW frame with both the RA field and the TA field set to the MAC address of the transmitting STA to implement radar functionality. In this case, the TXVECTOR parameter TRN_LEN, if the frame is transmitted with the DMG PHY, or the EDMG_TRN_LEN, if the frame is transmitted with the EDMG PHY, may be set to a nonzero value.

— A non-PCP and non-AP EDMG STA may transmit a Short SSW PPDU with both the TXVECTOR parameter SSW_SOURCE_AID and SSW_DESTINATION_AID set to the AID of the transmitting STA to implement radar functionality.

— An EDMG PCP STA or an EDMG AP STA may transmit a Short SSW PPDU with both the TXVECTOR parameter SSW_SOURCE_AID and SSW_DESTINATION_AID set to the BSS AID of the transmitting STA to implement radar functionality.


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# Annex AC(11ba)

(informative)

## Examples of WUR OOK Symbol Design and CSD Design using MC-OOK modulation(#4370)(#4055)

Subclauses 30.3.4.1 (WUR Basic PPDU waveform generation for WUR-Sync field and WUR-Data field with WUR HDR), 30.3.4.2 (WUR Basic PPDU waveform generation for WUR-Data field with WUR LDR), and 30.3.4.3 (WUR FDMA PPDU WUR-Data field waveform generation) provides a description of how the 2 µs duration (#4370)(#4055)WUR OOK and 4 µs duration (#4370)(#4055)(#7174)WUR OOK On and Off symbols might be constructed using MC-OOK modulation(#4370)(#4055) but does not provide the actual frequency domain sequences for those symbols. This annex provides example sequences for the construction of these symbols using MC-OOK modulation.(#4370)(#4055)

Table AC-1 (Example Values for the Sequence $S^{HDR}$ used for the Construction of the 2 µs duration WUR OOK On symbol(#7174)(11ba) using MC-OOK modulation(#4370)(#4055)) provides example sequences for the construction of the 2 µs duration (#4370)(#4055)(#7174)WUR OOK On symbol using MC-OOK modulation.

**Table AC-1—Example Values for the Sequence $S^{HDR}$ used for the Construction of the 2 µs duration WUR OOK On symbol(#7174)(11ba) using MC-OOK modulation(#4370)(#4055)**

| Index | Sequence $S^{HDR}$ |
|---|---|
| Example 1 | $\frac{\{1, 0, -3, 0, -3, 0, 0, 0, -3, 0, -3, 0, 1\}}{\sqrt{6.333}}$ |
| Example 2 | $\frac{\{3 + 7j, 0, 1 + 15j, 0, -5 + 13j, 0, 0, 0, 13 - 5j, 0, -15 - 1j, 0, 7 + 3j\}}{\sqrt{159.333}}$ |
| Example 3 | $\frac{\{3 + 5j, 0, -7 + 5j, 0, -7 - 5j, 0, 0, 0, -5 + 1j, 0, 7 + 7j, 0, 5 - 5j\}}{\sqrt{80.8}}$ |
| NOTE—For all three examples, the scaling factors are chosen so that the (#4370)(#4055)(#7174)WUR OOK On symbol is normalized to have the same power as the other examples. | |

Example 1 in Table AC-1 (Example Values for the Sequence $S^{HDR}$ used for the Construction of the 2 µs duration WUR OOK On symbol(#7174)(11ba) using MC-OOK modulation(#4370)(#4055)) is evaluated under a number of channel conditions and shows consistent good performance in both multipath fading and additive white Gaussian noise channels. This sequence also has low PAPR for a single channel transmission. (#4370)(#4055)The WUR OOK symbols generated using this sequence meet the correlation test in 30.3.12.5 (Correlation test on (#4370)(#4055)WUR OOK symbols).

Example 2 in Table AC-1 (Example Values for the Sequence $S^{HDR}$ used for the Construction of the 2 µs duration WUR OOK On symbol(#7174)(11ba) using MC-OOK modulation(#4370)(#4055)) is designed to provide good performance in commonly found propagation conditions, including the additive white Gaussian noise channel. This (#4370)(#4055)(#7174)WUR OOK On symbol has nearly constant envelope



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and power distributed over the full bandwidth. Therefore, it might be transmitted with an output power higher than during the L-STF, L-LTF and L-SIG. The sequence meets the correlation test in 30.3.12.5 (Correlation test on (#4370)(#4055)WUR OOK symbols).

Example 3 in Table AC-1 (Example Values for the Sequence $S^{HDR}$ used for the Construction of the 2 µs duration WUR OOK On symbol(#7174)(11ba) using MC-OOK modulation(#4370)(#4055)) is found to provide good performance through exhaustive search among the OFDM symbols with BPSK modulation. This sequence is optimized for good tradeoff between multipath fading channel performance and PAPR. (#4370)(#4055)The WUR OOK symbols generated using this sequence meet the correlation test in 30.3.12.5 (Correlation test on (#4370)(#4055)WUR OOK symbols).

Table AC-2 (Example Values for the Sequence $S^{LDR}$ used for the Construction of the 4 µs duration WUR OOK On symbol(#7174)(11ba) using MC-OOK modulation(#4370)(#4055)) provides example sequences for the construction of the 4 µs duration (#7174)MC-OOK On symbol.

**Table AC-2—Example Values for the Sequence $S^{LDR}$ used for the Construction of the 4 µs duration WUR OOK On symbol(#7174)(11ba) using MC-OOK modulation(#4370)(#4055)**

| Index | Sequence $S^{LDR}$ |
|---|---|
| Example 1 | $\{-1, 1, 1, 1, -1, 1, 0, -1, -1, -1, 1, -1, -1\}$ |
| Example 2 | $\frac{\{1+j, -1+j, -1+j, 1+j, -1+j, 1-j, 0, 1+j, 1+j, 1-j, 1+j, -1-j, -1+j\}}{\sqrt{2}}$ |
| Example 3 | $\frac{\{-1+j, 1+j, -1+j, 1+j, -1-j, 1-j, 0, 1-j, 1+j, -1-j, -1-j, 1+j, 1+j\}}{\sqrt{2}}$ |
| NOTE—For Example 2 and Example 3, the scaling factors are chosen so that the (#7174)MC-OOK On symbol is normalized to have the same power as the other examples. | |

Example 1 in Table AC-2 (Example Values for the Sequence $S^{LDR}$ used for the Construction of the 4 µs duration WUR OOK On symbol(#7174)(11ba) using MC-OOK modulation(#4370)(#4055)) is evaluated under a number of channel conditions and shows consistent good performance in both multipath fading and additive white Gaussian noise channels. (#4370)(#4055)The WUR OOK symbols generated using this sequence meet the correlation test in 30.3.12.5 (Correlation test on (#4370)(#4055)WUR OOK symbols).

Example 2 in Table AC-2 (Example Values for the Sequence $S^{LDR}$ used for the Construction of the 4 µs duration WUR OOK On symbol(#7174)(11ba) using MC-OOK modulation(#4370)(#4055)) is designed to provide good performance in commonly found propagation conditions, including the additive white Gaussian noise channel. This (#4370)(#4055)(#7174)WUR OOK On symbol has a nearly constant envelope and has power distributed over the full bandwidth. Therefore, it might be transmitted with an output power higher than during the L-STF, L-LTF and L-SIG. (#4370)(#4055)The WUR OOK symbols generated using this sequence meet the correlation test in 30.3.12.5 (Correlation test on (#4370)(#4055)WUR OOK symbols).

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(#3210)Example 3 in Table AC-2 (Example Values for the Sequence $S^{LDR}$ used for the Construction of the 4 µs duration WUR OOK On symbol(#7174)(11ba) using MC-OOK modulation(#4370)(#4055)) is found to provide good performance through exhaustive search among the OFDM symbols with BPSK modulation. This sequence is optimized for good tradeoff between multipath fading channel performance and PAPR. (#4370)(#4055)The WUR OOK symbols generated using this sequence meet the correlation test in 30.3.12.5 (Correlation test on (#4370)(#4055)WUR OOK symbols).

For the WUR-Sync field and the HDR WUR-Data field, which are both constructed from 2 µs duration (#4370)(#4055)WUR OOK symbols, Table AC-3 (Recommended CSD values for the WUR-Sync field and WUR-Data field with WUR HDR(11ba) using MC-OOK modulation(#4370)(#4055)) provides recommended CSD values $T_{CS}^{HDR}$ for one to eight transmit antennas, for each of the three recommended (#4370)(#4055)WUR OOK symbols from Table AC-1 (Example Values for the Sequence $S^{HDR}$ used for the Construction of the 2 µs duration WUR OOK On symbol(#7174)(11ba) using MC-OOK modulation(#4370)(#4055)).

**Table AC-3—Recommended CSD values for the WUR-Sync field and WUR-Data field with WUR HDR(11ba) using MC-OOK modulation(#4370)(#4055)**

| Example Sequence | Number of Transmit Chains | CSD Values (ns) |
|---|---|---|
| Example 1 | 1 | [0] |
| | 2 | [0, –600] |
| | 3 | [0, –600, –1100] |
| | 4 | [0, –600, –1100, –1350] |
| | 5 | [0, –600, –1100, –1350, –350] |
| | 6 | [0, –600, –1100, –1350, –350, –850] |
| | 7 | [0, –600, –1100, –1350, –350, –850, –600] |
| | 8 | [0, –600, –1100, –1350, –350, –850, –600, –1350] |


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**Table AC-3—Recommended CSD values for the WUR-Sync field and WUR-Data field with WUR HDR(11ba) using MC-OOK modulation(#4370)(#4055)**

| Example Sequence | Number of Transmit Chains | CSD Values (ns) |
|---|---|---|
| Example 2 | 1 | [0] |
| | 2 | [0, –100] |
| | 3 | [0, –850, –100] |
| | 4 | [0, –1100, –600, –100] |
| | 5 | [0, –1200, –850, –450, –100] |
| | 6 | [0, –1300, –1000, –700, –400, –100] |
| | 7 | [0, –1350, –1100, –850, –600, –350, –100] |
| | 8 | [0, –1400, –1150, –950, –750, –550, –300, –100] |
| Example 3 | 1 | [0] |
| | 2 | [0, –100] |
| | 3 | [0, –850, –100] |
| | 4 | [0, –1100, –600, –100] |
| | 5 | [0, –1200, –850, –450, –100] |
| | 6 | [0, –1300, –1000, –700, –400, –100] |
| | 7 | [0, –1350, –1100, –850, –600, –350, –100] |
| | 8 | [0, –1400, –1150, –950, –750, –550, –300, –100] |

For the LDR WUR-Data field, which is constructed from 4 µs duration (#4370)(#4055)WUR OOK symbols, Table AC-4 (Recommended CSD values for the WUR-Data field with WUR LDR using MC-OOK modulation(#4370)(11ba)) provides recommended CSD values $T_{CS}^{LDR}$ for one to eight transmit antennas, for each of the three recommended (#4370)(#4055)WUR OOK symbols from(#3210) Table AC-2 (Example Values for the Sequence $S^{LDR}$ used for the Construction of the 4 µs duration WUR OOK On symbol(#7174)(11ba) using MC-OOK modulation(#4370)(#4055)).

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**Table AC-4—Recommended CSD values for the WUR-Data field with WUR LDR using MC-OOK modulation(#4370)(11ba)**

| Example Sequence | Number of Transmit Chains | CSD Values (ns) |
|---|---|---|
| Example 1 | 1 | [0] |
| | 2 | [0, –1200] |
| | 3 | [0, –1200, –2200] |
| | 4 | [0, –1200, –2200, –2700] |
| | 5 | [0, –1200, –2200, –2700, –700] |
| | 6 | [0, –1200, –2200, –2700, –700, –1700] |
| | 7 | [0, –1200, –2200, –2700, –700, –1700, –1200] |
| | 8 | [0, –1200, –2200, –2700, –700, –1700, –1200, –2700] |
| Example 2 | 1 | [0] |
| | 2 | [0, –200] |
| | 3 | [0, –1700, –200] |
| | 4 | [0, –2200, –1200, –200] |
| | 5 | [0, –2450, –1700, –950, –200] |
| | 6 | [0, –2600, –2000, –1400, –800, –200] |
| | 7 | [0, –2700, –2200, –1700, –1200, –700, –200] |
| | 8 | [0, –2750, –2350, –1900, –1500, –1050, –650, –200] |
| Example 3 | 1 | [0] |
| | 2 | [0, –200] |
| | 3 | [0, –1700, –200] |
| | 4 | [0, –2200, –1200, –200] |
| | 5 | [0, –2450, –1700, –950, –200] |
| | 6 | [0, –2600, –2000, –1400, –800, –200] |
| | 7 | [0, –2700, –2200, –1700, –1200, –700, –200] |
| | 8 | [0, –2750, –2350, –1900, –1500, –1050, –650, –200] |


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# Annex AD(11az)

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## Phase shift feedback calculation

Assume there is a single Tx and Rx RF chain between (#7141)the initiating STA (ISTA) and responding STA (RSTA) and denote the frequency domain channel estimation of I2R NDP and R2I NDP as a column vector $h = [h_1,h_2,\ldots,h_N]^{\mathrm{T}}$ and $N$ is the number of subcarriers, then the corresponding phase shift might be calculated from Equation (AD-1).

$$PS = -\frac{\mathrm{angle}(h_0^{\mathrm{H}} h_K)}{2\pi K \Delta_{F,\,\text{HE-LTF}}} + t_{\text{HE-LTF, DFT boundary}} - T_{\text{GI, HE-LTF}} - T_{\text{HE-STF}} - T_{\text{Pre-HE portion}} \quad \text{(AD-1)}$$

where

| | |
|---|---|
| $h_0$ | is $[h_1,h_2,\ldots,h_{N-K}]^{\mathrm{T}}$ |
| $h_K$ | is $[h_{K+1},h_{K+2},\ldots,h_N]^{\mathrm{T}}$ |
| $(\ldots)^{\mathrm{T}}$ | denotes the transpose of a vector |
| $(\ldots)^{\mathrm{H}}$ | represents the Hermitian transpose of a vector |
| angle(…) | is the phase angle of a complex number |
| $K$ | is implementation specific |
| $\Delta_{F,\,\text{HE-LTF}}$ | is the frequency subcarrier spacing for the HE-LTF field |
| $t_{\text{HE-LTF, DFT boundary}}$ | is the timing boundary of the DFT window for the HE-LTF symbol expressed in the receiver's local clock |
| $T_{\text{GI, HE-LTF}}$ | is the guard interval duration for the HE-LTF portion |
| $T_{\text{HE-STF}}$ | is the HE-STF field duration in Ranging NDP or TB Ranging NDP |
| $T_{\text{Pre-HE portion}}$ | is the duration of the pre-HE portion in the preamble of a Ranging NDP or TB Ranging NDP |

Channel estimates might be filtered for noise reduction and ranging accuracy improvement before they are applied in Equation (AD-1).

When the ISTA and RSTA have multiple Tx and Rx chains, the frequency domain channel estimation vector between the *i*th Tx spatial stream and *j*th Rx antenna is denoted as $h_{i,j} = [h_{i,j,1},h_{i,j,2},\ldots,h_{i,j,N}]^{\mathrm{T}}$, and the phase shift is calculated from Equation (AD-2).

$$PS = -\frac{\mathrm{angle}\left(\sum_i \sum_j h_{i,j,0}^{\mathrm{H}} h_{i,j,K}\right)}{2\pi K \Delta_{F,\,\text{HE-LTF}}} + t_{\text{HE-LTF, DFT boundary}} - T_{\text{GI, HE-LTF}} - T_{\text{HE-STF}} - T_{\text{Pre-HE portion}} \quad \text{(AD-2)}$$

where

| | |
|---|---|
| $h_{\mathrm{i,j,0}}$ | is $[h_{i,j,1},h_{i,j,2},\ldots,h_{i,j,N-K}]^{\mathrm{T}}$ |
| $h_{i,j,K}$ | is $[h_{i,j,K+1},h_{i,j,K+2},\ldots,h_{i,j,N}]^{\mathrm{T}}$ |



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# Annex AE(11az)

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## SIR-based attack detection

The presence of an attack signal will cause the receiver SINR to drop. Given a measured noise floor, the SINR can be mapped to a signal to interference ratio (SIR). In this annex, an analysis is shown to illustrate the impact of an attack signal on the SIR drop.

Assume that an attacker observes the Secure HE-LTF symbol for a duration of $T_{ob}$, referred to as the observation period; see Figure AE-1 (Attacking secure HE-LTF symbols(11az)). The attacker can use these observations to generate an attack signal over the duration $T_c$, referred to as the computation period. Finally, the attacker will transmit the attack signal during the attack period, $T_a$, to create a false first path of arrival that has an earlier arrival time than the true first path of arrival.

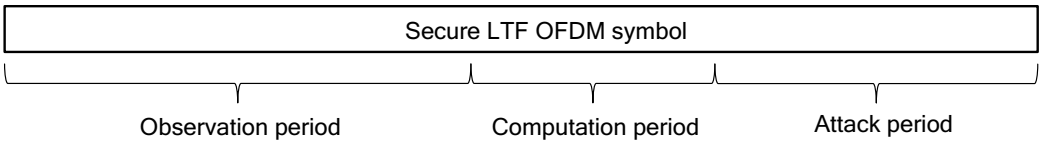


**Figure AE-1—Attacking secure HE-LTF symbols(11az)**

A side effect of creating the false first path of arrival is that the attacker will also generate interference at the intended receiver. If we assume that the attack signal has a correlation of ρ with the true Secure HE-LTF signal and creates a false first path of arrival with a relative power level of *FFP* (dB), then the signal-to-interference ratio (SIR) that is seen by the intended receiver will be:

$$SIR(\text{dB}) = -FFP(\text{dB}) + 10\log_{10}(\rho^2 T_a) - 10\log_{10}(1 - \rho^2 T_a)$$

When an attack signal is present, the interference introduced by the attack signal will lead to an SIR drop and the value will depend on the relative power level of *FFP*, correlation, and attack period.

For example, if *FFP* = –10 dB, then the expected SIR levels for different values of ρ and $T_a$ are shown in Figure AE-2 (Received SIR after attack(11az)).

From this figure, we see that as the correlation of the attack signal decreases or the attack duration decreases, the SIR will drop even further.

Therefore, the presence of an attack signal can be detected by looking for drops in the SIR over a single, or multiple, HE-LTF repetitions. The exact details of the algorithm are left to the implementer.


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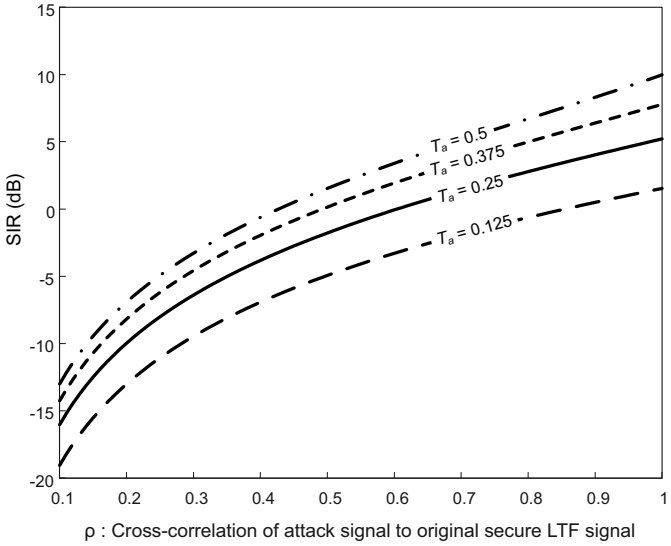


**Figure AE-2—Received SIR after attack(11az)**

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